CPAD Workshop 2023

Tuesday, 7 November 2023 - Friday, 10 November 2023

SLAC

Book of Abstracts

Contents

RDC9 / 2

Beam Test of the First Prototype of SiPM-on-Tile Calorimeter Insert for the EIC Using 4 GeV Positrons at Jefferson Laboratory

Author: Miguel Arratia[1]

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I will present the design and initial test beam results for a high-granularity calorimeter "insert" intended for the EIC. This design leverages SiPM-on-tile technology and introduces innovative features such as the use of 3D-printed frames to minimize optical crosstalk, as well as an ASIC-away-of-SiPM strategy to optimize spatial efficiency and reduce cooling requirements. We built a 40-channel prototype and evaluated it using a 4 GeV positron beam at JLab. The observed energy spectra and shower shapes aligned well with our simulations, thereby validating our design and construction approaches. These findings represent the first application of SiPM-on-tile technology in EIC detectors and offer valuable insights for the development of other subsystems.

These results are presented in https://arxiv.org/abs/2309.00818.

Early Career:

Yes

RDC9 / 3

Leveraging Staggered Tessellation for Enhanced Spatial Resolution in High-Granularity Calorimeters

Authors: Miguel Arratia[1]; Sean Preins[1]

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We present results of a novel design for high-granularity calorimeters, incorporating multi-layered, staggered tessellations to enhance position resolution. Moreover, we introduce HEXPLIT, a sub-cell re-weighting algorithm tailored to harness staggered designs, resulting in additional performance improvements. By combining our proposed staggered design with HEXPLIT, we achieve an approximately twofold enhancement in position resolution for neutrons across a wide energy range, as compared to unstaggered designs. These findings hold the potential to elevate particle-flow performance across various forthcoming facilities. This talk is based on results presented in https://arxiv.org/abs/2308.06939

Early Career:

Yes

RDC9 / 4

Studies of time resolution, light yield, and crosstalk using SiPM-on-tile calorimetry for the future Electron-Ion Collider

Author: Miguel Rodriguez[1]

Co-authors: Miguel Arratia [2]; JiaJun Huang [2]

[1] *UC Riverside*

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We recently proposed a high-granularity calorimeter insert for the EIC, which uses plastic scintillator tiles read out by silicon photomultipliers. In this talk, we present findings that characterize its fundamental components through measurements of light yield, optical crosstalk, and timing resolutions. These measurements were conducted using cosmic rays, an LED, and a beta source. We also compared two methods for optically isolating cells: one using "megatiles" with grooved boundaries between cells, and another using a 3D-printed plastic frame to host individual cells. Our results indicate that the 3D-printed frame effectively eliminates optical crosstalk and simplifies the assembly process. This presentation is based on results published in JINST 18 (2023) 05, P05045.

Early Career:

Yes

RDC3+4+11 / 5

Investigation of low gain avalanche detectors exposed to proton fluences beyond $10^{15}\ n_{eq}cm^{-2}$

Authors: Jiahe Si[1]; Josef Sorenson[1]; Martin Hoeferkamp[1]; Sally Seidel[1]; Gregor Kramberger[2]

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Low gain avalanche detectors (LGADs) promise excellent timing resolution, which can mitigate misassignment of vertices associated with pileup at the High Luminosity LHC and other future hadron colliders. The most highly irradiated LGADs will be subject to $2.5 \times 10^{15}\ n_{eq}cm^{-2}$ of hadronic fluence during HL-LHC operation; their timing performance must tolerate this. Hamamatsu Photonics K.K. and Fondazione Bruno Kessler LGADs have been irradiated with 400 and 500 MeV protons respectively in several steps up to $1.5 \times 10^{15}\ n_{eq}cm^{-2}$. Measurements of the acceptor removal constants of the gain layers, evolution of the timing resolution and charge collection with damage, and inter-channel isolation characteristics, for a variety of design options, are presented here.

Early Career:

No

RDC 7+8 / 6

Correlated and Uncorrelated Backgrounds and Noise Sources in Athermal Phonon Detectors and Other Low Temperature Detectors

Author: Roger Romani[1]

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The performance of a variety of superconducting detectors including athermal phonon detectors and qubits is limited by spurious energy depositions, which create background events, noise, and otherwise degrade device performance. In athermal phonon detectors, at high event energies, these energy depositions appear as the zero charge component of the "Low Energy Excess." At lower event energies, these events contribute to excess shot noise in TESs and the "quasiparticle poisoning" problem in qubits. Here, we present evidence that these phenomena are linked, and that a single mechanism or set of mechanisms is responsible for observations over a wide range of energy scales. We show that the rate of these energy depositions scales similarly with time over a wide range of energies, and that the events are both phonon and non-phonon mediated. The slow relaxation of stress in detector materials is discussed as a likely source of these events. Resolving these excesses will be key to improving next generation light dark matter searches and developing advanced high energy resolution superconducting detectors.

Early Career:

Yes

RDC9 / 8

Light yield non-proportionality of LYSO scintillators to gamma rays and measurement of the Birks-Onsager quenching parameters.

Author: Francesco Nozzoli[1]

Co-authors: Luigi Ernesto Ghezzer [2]; Riccardo Nicolaidis [3]

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Lutetium-yttrium oxyorthosilicate (LYSO) is a high density, rugged/radiation tolerant, fast scintillator. For this reason LYSO crystal scintillators are used or planned in many High Energy Particle experiments (as e.g., KLOE-2, srEDM, COMET, CMS Barrel Timing Layer) in medical diagnostic devices (PET, TAC, CT) and in current and planned astroparticle physics space calorimeters (as e.g., HEPD-01, HEPD-02, NUSES, Crystal-Eye, HERD, ALADInO, AMS-100).
On the other hand, a relatively strong light quenching phenomena was observed in LYSO scintillators when irradiated with highly ionizing particles. The current uncertainties in the modeling and in the measurement of quenching parameters for LYSO could affect the capability of a precise determination of shower energy in LYSO-based hadronic calorimeters planned for future space experiments.
In this work, the scintillation response of a Ce-doped LYSO crystal is investigated with several radioactive sources in the INFN-TIFPA laboratory and a non-proportionality of the light yield for sub-MeV gamma rays is measured. The effect of the scintillation quenching of relatively slow electron recoils produced by low-energy gamma rays in the LYSO scintillator is evaluated with a dedicated GEANT4 simulation to describe the measured light yield non-proportionality.

In the framework of the Birks-Onsager model, the quenching parameters for low-energy electron recoils are inferred. The comparison with the previous measurements of LYSO quenching parameters, using nuclei at particle beam from proton to Argon, is a powerful test for the underlying quenching theory, that appears to be valid for different particles in a wide kinetic energy range from several GeV nuclei down to few keV electrons.

Early Career:

No

RDC6 / 9

Spark protection system for sPHENIX TPC GEMs

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sPHENIX is a new detector experiment currently under commissioning at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Lab (BNL). The Time Projection Chamber (TPC) uses stacks of 4 Gas Electron Multipliers (GEMs) as a gain stage in its 72 modules. Under certain conditions the high voltage across a GEM can cause an uncontrolled discharge. To study and mitigate the effects of sparks in the TPC GEMs, an online spark monitoring system was created. If the spark monitoring system detects a spark, voltages will be adjusted to allow the gas to settle and prevent further sparks. GEM modules use a capacitor between the bottom GEM and ground to remove charges which are collected on the bottom of the GEM. A resistor was placed between a capacitor and the ground, the voltage across this resistor is monitored for spark signals. Various resistor and capacitor values were tested to optimise this pick off. To get the signal into a form that can reliably be digitised, electronics were developed to take an absolute value of the signal and then integrate. This results in a mono-polar pulse with a length of a few microseconds. The spark monitoring system has 72 channels with 10MSPS ADC per channel, uses two thresholds, one for hardware trigger and one for triggering the system to lower the HV. Machine learning methods are used to understand the nature of the background and the sparks.

Early Career:

No

RDC5 / 11

Machine learning based developments for LHC level-1 triggers

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Machine learning based developments made for the level-1 trigger of the CMS experiment at LHC, both for Run-3 and HL-LHC eras will be presented. Unsupervised anomaly detection models are

used in CICADA and AXOL1TL implementations using high-level synthesis on Xilinx Virtex-7 based boards for Run-3 running at full LHC clock rate digesting every bunch crossing within level-1 trigger latency budget. Models for both pattern recognition in level-1 trigger and anomaly detection based triggers planned for the HL-LHC era in larger FPGAs will also be described. The hardware characteristics, the firmware strategies and ML model adaptation to FPGA-environment will be discussed.

Early Career:

Plenary / **13**

Novel Quantum Materials and Sensing for Low Energy Event Detection

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With the advancement in low-threshold detector technology over the last decade, the HEP community has increasingly been able to probe for new physics at low energies. Specifically, looking for beyond the standard model physics via distortions of the low energy CEνNS spectrum, searching for low mass dark matter, and single counting of THz photons. However, measuring particle interactions via electronic and phonon signals using traditional semiconducting based technologies like Si and Ge is quickly reaching a limit in its fundamental sensitivity.

Orders of magnitude in sensitivity and new physics reach can be made by exploring quantum materials as detector targets which are well kinetically matched to various physical processes. In this talk I will discuss the motivation and physics behind a variety of proposed detectors based on novel materials. I will present preliminary results and progress being made by the LANL LDRD funded SPLENDOR Experiment to search for sub-MeV fermionic and eV scale bosonic dark matter, using novel narrow bandgap semiconductors synthesized at LANL with bandgaps on the order of 1-100 meV. Additionally I will also show preliminary data demonstrating how these devices could be promising for high-energy high-rate gamma spectroscopy.

Early Career:

Yes

RDC9 / **14**

Low-Dose TOF-PET Based on Surface Electron Production in Dielectric Laminar MCPs

Author: Kepler Domurat-Sousa[1]

Co-authors: Cameron Poe [1]; Henry Frisch [1]; Bernhard Adams [2]; Camden Ertley [3]; Neal Sullivan [4]

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We present simulations of whole-body low-dose time-of-flight positron emission tomo\-graphy (TOF-PET) based on laminar microchannel plates (LMCP$^{\text{TM}}$) packaged into High-Resolution Gamma Multiplier Tubes (HGMTs$^{\text{TM}}$) [1]. 511 keV gamma rays interact in the LMCP via the photoelectric and Compton effects to create an electron through surface direction conversion [2], eliminating the scintillator and photodetector sub-systems in PET scanners. The absence of a photocathode allows assembly of large arrays at atmospheric pressure and less stringent vacuum requirements. The laminae surfaces are micro-patterned to form channels, which can then be functionalized to support secondary electron emission in the manner of conventional MCPs.

We have simulated surface direct conversion using modifications to the TOPAS Ge\-ant4-based tool kit. A 20 $\times$ 20 $\times$ 2.54 cm^3 LMCP composed of 150-micron thick lead-glass laminae is predicted to have a $\geq$ 30% conversion efficiency to a primary electron that penetrates an interior wall of a pore. The subsequent secondary electron shower is largely confined to one pore and can provide high space and time resolutions.

TOPAS simulations of the Derenzo and XCAT-brain phantoms are presented with dose reductions of factors of 100 and 1000 from literature benchmarks. New applications of PET at orders of magnitude lower radiation dose include routine screening for early detection of pathologies and the use in previously unserved patient populations.

[1] K. Domurat-Sousa, C. Poe, H. J. Frisch, B. W. Adams, C. Ertley, N. Sullivan; *Low-Dose TOF-PET Based on Surface Electron Production in Dielectric Laminar MCPs*; To be published in Nucl. Instr. and Meth. A, arXiv:2307.02708.

[2] K. Domurat-Sousa, C. Poe, H. J. Frisch, B. W. Adams, C. Ertley, N. Sullivan; *Surface Direct Conversion of 511 keV Gamma Rays in Large-Area Laminated Multichannel-Plate Electron Multipliers*; Nucl. Instr. and Meth. A, v. 1055, Oct. 2023, 168538.

Early Career:

No

RDC2 / 15

Constructing Microchannel Plates from Thin Patterned Laminae

Author: Kepler Domurat-Sousa[1]

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We have proposed a method of construction and simulated the performance in TOPAS [1] of large-area microchannel plates (MCPs) assembled by stacking thin, patterned laminae on edge to form laminar microchannel plates (LMCPs$^{\text{TM}}$) [2]. The laminae are first patterned with channels of arbitrary shape and size so that when stacked, they form pores as in a traditional MCP. The laminae are typically coated with resistive and secondary-emitting materials to support electron multiplication in the pores, and since they are coated before stacking, methods other than atomic layer deposition (ALD), such as chemical vapor deposition (CVD), can be used. Functionalization of the

pores is completed before stacking, introducing additional parameters for controlling the shower development, for example, non-uniform resistivity and customized voltage differences between strike surfaces along the pore. Unique slab geometries are also possible: The LMCP can be non-planar, allowing curved surfaces in both lateral dimensions. The laminar construction creates the possibility of incorporating structural elements in the LMCP for modular assembly in large-area arrays.

The LMCP construction allows for the use of substrates optimized for the direct conversion of various incoming particles to electrons in the bulk. For example, LMCPs built from thin laminae of high atomic number (high-Z) material, like lead glass, can be used in gamma ray detection via surface direct conversion. TOPAS simulations predict an efficiency for conversion of 511 keV gamma rays of $\geq$ 30% for a 2.54 cm-thick lead-glass LMCP. Large arrays of LMCPs would provide high resolution space and time measurements in searches for kaon and rare η decays and in shower-max detectors at the LHC and EIC. Since conversion happens in the bulk, a photocathode is not necessary, allowing assembly at atmospheric pressure and packages with reduced vacuum requirements.

[1] B. Faddegon, J. Ramos-Mendez, J. Schuemann, J. Shin, J. Perl, H. Paganetti, *The TOPAS tool for particle simulation, a Monte Carlo simulation tool for physics, biology and clinical research*, Eur. J. Med. Phys. 72 (2020) 114-121.

[2] K. Domurat-Sousa, C. Poe, H. J. Frisch, B. W. Adams, C. Ertley, N. Sullivan; *Surface Direct Conversion of 511 keV Gamma Rays in Large-Area Laminated Multichannel-Plate Electron Multipliers*; Nucl. Instr. and Meth. A, v. 1055, Oct. 2023, 168538.

Early Career:

No

Poster Session / **16**

A User-Friendly, Highly-Extendable Geant4 Wrapper for Process-Based Detector Development

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The development of new detector technologies requires high-accuracy simulations of the fundamental underlying processes with simple, transparent tools that newcomers can rapidly learn. TOPAS [1] fully satisfies these requirements as a well-documented, extendable wrapper for Geant4. We have used TOPAS to simulate and develop two photodetector designs: a whole-body time-of-flight positron emission tomography (TOF-PET) scanner using a low atomic number (low-Z) scintillator [2] and a laminar microchannel plate (LMCP$^{\mathrm{TM}}$) utilizing surface direct conversion of a gamma ray to an electron, eliminating the scintillator and photodetector subsystems [3].

In TOPAS, a user can easily define basic detector geometries, generate particle sources with arbitrary energy spectra, render state-of-the-art phantoms, and modify the underlying software to track a particle's history in a medium, including position and 4-momentum. In simulating the low-Z scanner, we used the pre-built cylinder geometry components in TOPAS to model a Derenzo phantom. The whole-body XCAT phantom is easily simulated using a native TOPAS interface. We set tissue activities using volumetric sources with discrete energy spectra, thus accurately modeling the positron energy spectrum of fluorodeoxyglucose (FDG). TOPAS' default phasespace scorer can only record particle energy and position when a trajectory crosses a geometric boundary but does not natively record these data within a medium. However, TOPAS allows users to extend the underlying Geant4 code, which we exploit to record particle data throughout a volume to record Compton scatter locations.

While TOPAS was originally created as a tool for the medical community, we were able to use it to simulate the LMCP by extending the software to support arbitrary electric fields and by using the native phasespace scoring to generate secondary electrons in the LMCP pores. By modifying the existing code for non-uniform magnetic fields in Opera-3d format, we were able to render non-uniform electric fields generated by Ansys. To simulate secondary emission, we have TOPAS write particle data to a phasespace file, and then use a C program to read the file and generate secondary electrons as input for a next-iteration TOPAS run. This allows us to follow the first few generations of secondaries in the electron shower that largely determine the time jitter.

[1] B. Faddegon, J. Ramos-Mendez, J. Schuemann, J. Shin, J. Perl, H. Paganetti, *The TOPAS tool for particle simulation, a Monte Carlo simulation tool for physics, biology and clinical research*, Eur. J. Med. Phys. 72 (2020) 114-121.

[2] K. Domurat-Sousa, C. Poe; *Methods for simulating TOF-PET in TOPAS using a low-Z medium*; Nucl. Instr. and Meth. A, Sep. 2023, 168675.

[3] K. Domurat-Sousa, C. Poe, H. J. Frisch, B. W. Adams, C. Ertley, N. Sullivan; *Surface Direct Conversion of 511 keV Gamma Rays in Large-Area Laminated Multichannel-Plate Electron Multipliers*; Nucl. Instr. and Meth. A, v. 1055, Oct. 2023, 168538.

Early Career:

No

RDC7 / **17**

nEXO Low Background Techniques

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The nEXO experiment developing a neutrinoless double beta decay search in liquid xenon enriched in ^{136}Xe. nEXO is being designed to have extremely low background near the $Q^{0\nu\beta\beta}$ value (2457 keV) to maximize its sensitivity to this rare decay. Many assay techniques are used to find the lowest background materials possible for nEXOs construction including underground Ge, NAA, ICP-MS, Rn counting ESCs, and others. This talk will summarize the nEXO radioactive background control program and these techniques.

Early Career:

Yes

RDC11 / **18**

Design of a 40 GS/sec 10 mw/Channel Waveform Sampling ASIC in 65 nm CMOS

Authors: Eric Oberla[1]; Evan Angelico[2]; Hector Rico-Aniles[3]; Henry Frisch[1]; Jinseo Park[1]; Nathaniel Pastika[4]; Paul Rubinov[5]; Richmond Yeung[1]; Troy England[4]

[1] *University of Chicago*

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[3] *North Central College*

[4] *Fermi National Accelerator Laboratory*

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The development of large-area MCP-based particle detectors with time resolutions of 5 ps or less [1] would allow substantive advances in particle identification at particle colliders such as the LHC and EIC, high precision mass reconstruction in searches for rare K and η decays, and a reduction by orders-of-magnitude of the radiation dose in positron-emission tomography [2, 3]. We describe a preliminary design for a 16-channel 40 GS/sec waveform sampling ASIC in the TSMC 65 nm process with the goal of achieving 1 ps resolution at 10 mW power per
channel. The buffer depth of each channel is 256 samples, corresponding to a recording window of 6.4 ns, long compared to a pulse from an MCP-based photomultiplier. In parallel for each channel, a 5 GS/sec 1024-deep sampling records a longer window of 204.8 ns for identifying pile-up and the temporal context for unusual signals. Recording of the data for each channel is triggered by a 10 ps resolution fast constant fraction discriminator [4] capable of multiple triggering during the window of the slow buffer. The sampling switches are implemented as 2.5V nMOSFETs controlled by 1.2V shift registers in order to achieve a large dynamic range, low leakage, and high bandwidth. Stored data is exported to be digitized by an external ADC at 10 bits or better. Specifications on operational parameters include a 4 GHz analog bandwidth and a deadtime of 20 microseconds, corresponding to a 50 kHz readout rate, determined by the choice of the external ADC. The current status will be presented.

[1] K. Inami, N. Kishimoto, Y. Enari, M. Nagamine, and T.
Ohshima; A 5-ps Tof-counter with an MCP-PMT; Nucl. Instr. Meth. A560, p.303, 2006

[2] P.~Lecoq, C.~Morel and J.~Prior, Case for setting up a 10ps challenge: A step toward reconstruction-less TOF-PET, Nuovo Cim. C (2020) no.1, 2 doi:10.1393/ncc/i2020-20002-y

[3] K. Domurat-Sousa, C. Poe, H. J. Frisch, B. W. Adams, C. Ertley, N. Sullivan; Low-Dose TOF-PET Based on Surface Electron Production in Dielectric Laminar MCPs; To be published in Nucl. Instr. and Meth. A, arXiv:2307.02708.

[4] Si Xie, Artur Apresyan, Ryan Heller, Christopher Madrid, Irene Dutta, Aram Hayrapetyan, Sergey Los, Cristián Peña, Tom Zimmerman,
Design and performance of the Fermilab Constant Fraction Discriminator ASIC, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment,
Volume 1056, 2023, 168655, ISSN 0168-9002

Early Career:

Yes

RDC1 / 19

CrystaLiZe: Pushing Dark Matter Detection to the Limit with Solid Xenon

Author: Scott Kravitz[1]

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We present the crystalline xenon time projection chamber (TPC), a promising novel technology for next-generation dark matter searches. Initial tests have established that it maintains many of the benefits of the liquid xenon TPC while also effectively excluding radon, the dominant background in currently-running xenon dark matter experiments such as LZ. This offers the potential for greatly improved sensitivity to dark matter through a crystal xenon upgrade to an existing experiment. This talk will discuss instrumental performance, comparison with respect to liquid phase detectors, and plans for establishing its scalability.

Early Career:

Yes

RDC1 / 20

The Capabilities of the Liquid Xenon Proportional Scintillator Counter for Low-energy Event Detection

Author: Jianyang Qi[None]

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The Liquid Xenon Proportional Scintillation Counter (LXePSC) is a single-phase liquid xenon detector capable of producing electroluminescence directly in the liquid phase. In doing so, we are able to disregard the extraction efficiency, as seen in dual phase LXeTPCs, and simplify the detector design and operation by not needing to maintain a liquid-gas interface. In this talk, we will present our recently published results, which include the detection of low-energy electronic recoils down to ~1 keV, as well as evidence of single-electron signals from photo-induced electron emission of cathode surfaces. Furthermore, we will present preliminary results of our recent run, which includes a potential for nuclear and electronic recoil discrimination using the LXePSC, and an improved energy calibration using activated xenon lines.

Early Career:

Yes

RDC2 / 21

APEX: Scale up photon detectors for large detector area coverage

Author: Wei Shi[1]

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In this talk, we propose a detector concept called APEX (Aluminum Profiles with Embedded X-arapucas) for large LArTPC detectors by instrumenting large-area X-arapuca photon detectors on the entire LArTPC field cage. The photon detectors will cover four sides of a typical cuboid LArTPC volume like the DUNE VD module excluding the two anode planes, with a covered area of up to

2500m^2. The PoF (power over fiber) and SoF (signal over finer) technologies developed and successfully demonstrated in DUNE VD make such a design possible and promising. Despite this, the scaling up of the X-arapuca detectors to thousands of square meters as well as integrating with the LArTPC field cage structure poses many challenges to mechanics and electronics.

One particular challenge is understanding how the instrumented PD modules interplay with the LArTPC E field. To address this, we perform a material charge-up test in a tabletop TPC system at the surface environment to understand the evolution of the LArTPC E field. Further tests in an underground environment are also planned to understand the charge-up behavior due to the limited available charges. The PoF and SoF require multiple optical fibers to supply detector power and read out signals. The routing of hundreds-of-kilometers-long fibers inside and outside aluminum field cage profiles without affecting the E field requires new profile and field cage designs. The large area detector also puts higher requirements on detector production speed. While the production of large wavelength shifting plates is possible, the current production of dichroic filters based on glass substrates is slow. Each unit filter takes hours to coat and the produced unit sizes are small. Large-area dichroic coating with physical vapor deposition and atomic layer deposition technologies are both aggressively pursued to address the issue. Large-scale production of the pTerphenyl coating for first wavelength shifting of the LAr scintillation light with an industrialized light source is actively investigated.

The scaling up of the photon detectors also drastically increases the number of readout channels. This brings challenges to the power consumption of cold electronics and signal readout bandwidth. In response to these challenges, we proposed a new design of PoF that can supply the high SiPM bias for many PD modules sitting on equipotential FC profiles. This solution will mitigate both power consumption challenges and noise problems. A wavelength-division multiplexing solution in combination with a novel ring resonator modulation technology that offers hundreds of GB/s readout ability is proposed to address the bandwidth problem. The signal amplification and digitization with in-house designed ASICs are also proposed to reduce the cost and power consumption.

At the end of the talk, I will also go through prototype plans and relevant physics studies. The APEX detector concept will be extremely useful for the next generation long baseline neutrino experiment DUNE which requires 40 kilotons of LAr fiducial mass to achieve its main physics goal specified in the 2014 P5 report. To complete the fiducial mass, the DUNE phase 2 program requires two more far detector modules. The APEX concept proposed in this talk increases detector coverage area fraction up to 75% and will enable DUNE with improved event reconstruction, energy resolution, background rejection, and expansion of its physics reach to the MeV energy region. More importantly, our proposal can be combined with most of the proposed phase 2 VD LArTPC technologies.

Early Career:

Yes

RDC8 / **22**

Searching for axions and dark photons with superconducting nanowire single photon detectors (SNSPDs) in the BREAD experiment

Authors: Boris Korzh[1]; Christina Wang[None]; Cristian Pena[2]; Maris Spiropulu[3]; Si Xie[4]

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The BREAD(Broadband Reflector Experiment for Axion Detection) experiment searches for axions and wave-like dark matter using a novel dish resonator which allows to utilize state-of-the-art high-field solenoidal magnets. The axion target mass extends from ~□eV to eV, this large mass range makes it difficult to scale traditional resonator setups to the required volume. However, metallic surfaces in a high magnetic field dark matter axions can convert to photons regardless of axion mass. These photons can then be focused by a parabolic focusing reflector onto a low noise single photon counting detector. One of the single photon counting detectors that can be used for the BREAD experiment is superconducting nanowire single photon detectors (SNSPDs) that are sensitive to 0.1 to 1 eV axions and dark photons, due to its sensitivity to 1-10um photons.

In this talk, we present the progress towards a first stage dark photon pilot experiment with a focus on SNSPDs. We show the progress on characterizing the SNSPDs for the pilot experiment and outline the sensitivity estimates for BREAD with SNSPDs and other single photon counting detectors.

Early Career:

Yes

RDC7 / **23**

An ICP-MS based monitoring methodology to inform dust radioactive backgrounds on detector materials

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Rigorous radioactive background constraints are necessary for rare-event search experiments to meet their sensitivity goals. Underground facilities provide ideal attenuation of cosmic radiation, shielding materials around the detectors are used to mitigate backgrounds from soil, and extensive radioassay campaigns are performed to source the most radiopure materials. To reduce the impact of particulate deposition on material surfaces, detectors are assembled and operated in cleanroom facilities. Even so, dust particulate fallout on rare-event detector materials remains a concerning source of radioactive backgrounds. Within the low-background community, much effort is being invested to investigate, inform, and mitigate dust backgrounds. Fallout models and assumed dust composition are typically employed to estimate the impact of dust particulate on low-background detectors. In this work, fallout rates of radionuclides and stable isotopes of interest from dust particulate are directly determined at key locations of the SNOLAB underground facility using an ICP-MS based methodology. Results demonstrate the method as a valuable tool to assess the impact of laboratory activities to material backgrounds from dust particulate fallout and to evaluate mitigation procedures.

Early Career:

Yes

RDC4 / **24**

Design, Testing, and Applications of the Fermilab CFD Readout ASIC

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We present the design and performance of the Fermilab CFD ASIC (FCFD) developed for front-end readout of detectors with fast signals such as LGAD. The FCFD includes a specially designed discriminator that makes its response robust against amplitude variations of the signal. The application of the CFD directly in the readout ASIC promises to be more reliable and reduces the need for complicated and potentially time-dependent calibrations of precision timing detectors during their operation. We present measured performance of the FCFD for input signals generated by internal charge injection, LGAD signals from an infrared laser, and LGAD signals from minimum-ionizing particles. We show that the mean time response is stable for a wide range of signal amplitudes and that the time resolution contributed by the ASIC is less than 10 ps for signals of charge above 20 fC. We will also discuss other potential applications in quantum sensors such as superconducting nanowire detectors.

Early Career:

Yes

RDC1 / 25

Characterization of Delayed Ionization Backgrounds in the LZ Experiment

Author: Eli Mizrachi[1]

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Dual-phase noble liquid time projection chambers (TPCs) are known to experience delayed ionization backgrounds which persist for at least a second after an ionization event occurs. Their rate has been observed by some experiments to exhibit a characteristic power law in time, but the cause is not yet understood. This work presents an analysis of delayed ionization backgrounds from different regions of the LZ TPC. The dependence of these backgrounds on various detector conditions is discussed, revealing features which may have been overlooked by previous studies.

Early Career:

No

RDC1 / 26

Calibration Systems of the Multi-Tonne Scale Xenon Detector in LZ

Author: Qing Xia[1]

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The LUX-ZEPLIN (LZ) experiment utilizes 7 tonnes of active liquid xenon to search for dark matter at the Sanford Underground Research Facility (SURF) in Lead, South Dakota, USA. The core of the LZ detector is a dual-phase xenon time projection chamber, primarily designed for detecting Weakly Interacting Massive Particles (WIMPs). In this talk, I will discuss the novel features and performance of the LZ calibration systems, which played a crucial role in enabling LZ's world-leading WIMP search results and will facilitate its broad scientific program in the future. The description of the LZ calibration systems presented in this talk will be a valuable reference for future calibration efforts in direct dark matter search experiments.

Early Career:

Yes

Poster Session / 27

Overview and Status of the SPLENDOR Experiment

Author: Samuel Watkins[1]

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The SPLENDOR (Search for Particles of Light Dark Matter with Narrow-gap Semiconductors) experiment is a search for light dark matter via the electron-recoil interaction channel, taking advantage of novel single-crystal narrow-bandgap (order 10-100 meV) semiconductors. Synthesized within the collaboration, the properties of these designer materials imply low dark counts when operated as ionization detectors at cryogenic temperatures. Using a readout scheme based on low-noise cryogenic high electron mobility transistors (HEMTs), the experiment is on track to achieve O(1) electron-hole pair resolution. This provides an excellent opportunity to probe new light dark matter parameter space: down to sub-MeV masses for fermionic dark matter and sub-eV masses for bosonic dark matter. This poster will review the multidisciplinary R&D behind SPLENDOR, discuss the current status of the experiment, and present projected sensitivities for planned dark matter searches operated both above- and below-ground.

This work was supported by the U.S. Department of Energy through the Los Alamos National Laboratory. Los Alamos National Laboratory is operated by Triad National Security, LLC, for the National Nuclear Security Administration of U.S. Department of Energy (Contract No. 89233218CNA000001). Research presented in this presentation was supported by the Laboratory Directed Research and Development program of Los Alamos National Laboratory under project number 20220135DR.

Early Career:

Yes

RDC3 / 28

Use of CVD Diamond Sensors in Extreme Environments and Applications

Author: Mohammad Nizam[1]

Co-authors: Bruce Schumm [2]; Bryce Jacobson [3]; C. Grace [4]; C. Rowling [5]; D. Kim [6]; D. Stuart [7]; D. Zhu [3]; E. Gonzalez [8]; E. Potter [8]; Eric Prebys [9]; Eric Ryan [8]; F. Martinez-McKinney [8]; I. S. Torecilla [3]; J. Bohon [4]; John Smedley [3]; M. Kennedy [8]; M. Wilder [8]; N. Nagel [8]; P. Freeman [7]; Rene Padilla [8]; S. Kachiguine [8]; Simone Mazza ; T. Prakash [4]

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The Advanced Accelerator Diagnostic (AAD) collaboration, which is a consortium of University-of-California affiliated institutions and the SLAC National Accelerator Laboratory, is exploring the use of electronic-grade diamond sensors for diagnostic applications that push the limits of the capability of the sensors and their applications. Results from TCAD simulation of charge collection efficiency of diamond sensors as a function of the deposited density of charge carriers are presented and are benchmarked against data obtained from irradiating diamond sensors with intense X-Ray laser pulses from the XPP beamline at SLAC's LCLS. Results are presented on the lateral diffusion of charge carriers within the diamond sensor, which provides a limit on the position sensitivity of diamond sensors. Real-time results from a radiation damage study of diamond sensors are presented during an exposure to a 67.5 MeV proton beam that reached a fluence of 4x10^16 protons per cm^2. Finally, work towards the development of a diamond-sensor-based detection system capable of readout bandwidth in excess of 5 GHz is presented.

Early Career:

Yes

Poster Session / 29

The beam test of the lead tungstate calorimeter prototype with SiPM readout at Jefferson Lab

Authors: Vladimir Berdnikov[1]; Fernando Barbosa[1]; Alexander Somov[1]

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The lead tungstate crystals (PbWO4) are a well-known radiator material for precise homogeneous electromagnetic calorimetry. In nuclear physics experiments, the typical way to read out the crystals is using conventional photomultiplier tubes (PMTs). In the case of the presence of a magnetic field, such a method has some complications and requires a passive PMT shielding design. The recent development of Silicon Photomultipliers (SiPMs) with small pixel pitch sizes and relatively small noise levels opens an opportunity avenue to use such a device as an alternative to conventional PMTs. The SiPM readout method may be beneficial for future nuclear physics and collider experiments. We are presenting the beam test results of the calorimeter prototype instrumented with SiPM readout performed at Jefferson Lab. The SiPM readout performance was compared with PMT readout measured at the same experimental conditions. The prototype was successfully tested using beam of photons

in the energy range between 3 GeV and 11 GeV in experimental Hall D. The detector performance was also studied using a secondary beam of positrons provided by Hall D pair spectrometer.

Early Career:

Yes

RDC8 / 30

In-situ System Noise Measurement for Axion Haloscopes with JPAs

Author: Michaela Guzzetti[1]

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The Axion Dark Matter eXperiment (ADMX) is one of the world's leading direct detection experiments searching for an elusive dark matter particle candidate known as the axion. The axion's origin lies in the realm of particle physics, initially coming into existence as a solution to the strong CP problem. Since its inception however, physicists have been interested in it not only for its ability to solve this mystery, but also for its characteristics that make the axion a compelling cold dark matter candidate. One of two benchmark models, designated as DFSZ, has been of particular interest due to its compatibility with GUT, however it has notably weak axion-photon couplings making it difficult to detect. To date, the ADMX collaboration has excluded axion-photon couplings predicted by the KSVZ (DFSZ) model for the axion between 2.66-4.2 μeV (2.66-3.3 μeV & 3.9-4.1 μeV). This feat was accomplished by making use of a dilution refrigerator to reduce thermal noise, as well as the application of low-noise quantum electronics to minimize receiver noise. Namely, we utilize a superconducting Josephson Parametric Amplifier (JPA) as our first stage amplifier, which requires sufficient understanding of the noise in our receiver chain. In this talk, I will discuss the procedure for calibrating system noise in an axion haloscope, with a particular focus on the experimental set up used in our most recent data taking run. I will speak to the different types of measurements taken, the noise models used, as well as the operation and performance of our JPA.

Early Career:

Yes

RDC4 / 31

Exploration of Resource-efficient Implementations of ML Models Targeting eFPGAs

Author: Jyothisraj Johnson[1]

Co-authors: Billy Boxer [2]; Carl Grace [3]; Tarun Prakash [3]

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Implementing machine learning (ML) models in hardware has received considerable interest over the last several years from the physics community. The Python packages, hls4ml and conifer, has enabled porting models trained using Python ML libraries to register transfer level (RTL) code. Most of the attention, thus far, has been focused on porting ML models to commercial FPGAs or synthesized blocks on ASICs. With the latter, a (physical) area-optimized implementation of a ML model can be integrated on-chip. The reduction in area generally results in reduced costs for chip fabrication. The usual trade-off with an ASIC implementation is the inability to update model architecture post-synthesis. However, updating of biases/weights has been demonstrated at an additional area cost with techniques such as distributed I2C networks. Regardless, recent developments in open-source embedded FPGA (eFPGA) frameworks now provide an alternate and more flexible pathway for implementing ML models in hardware: customized eFPGA fabrics, which can also be integrated as part of an overall chip design. In general, the decision between an ASIC or eFPGA ML implementation will depend on the target application. We explored the design parameter space for eFPGA implementations of fully connected neural network (fc-NN) and boosted decision tree (BDT) models using the classification task of neutron/gamma identification, with a specific focus on resource efficiency. We used training data from an AmBe sealed source incident on a plastic scintillator read out by SiPMs. We studied relevant input features, the required bit-resolution, sampling rate and trade-offs in hyperparameters for both ML models while tracking resource usage and neutron efficiency at a gamma leakage of 10^-3. The results of the study will be used in the specification of an eFPGA fabric, which will be integrated as part of a 130 nm test chip next year.

Early Career:

Yes

RDC11 / **32**

LAPPD Based TOF system at Fermilab Test Beam Facility

Author: Nathaniel Pastika[1]

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To meet the demands of modern detector designs, a new time of flight (TOF) detector based on Large Area Picosecond Photo Detectors (LAPPD) is being developed for the Fermilab Test Beam Facility (FTBF). An array of LAPPDs will be deployed in combination with a multichannel 10 Gsps DAQ based on the PSEC4 ASIC. Timing synchronization over long distance will be achieved using a White Rabbit timing system. Results from the pilot system, demonstrating 19 ps TOF resolution, will be shared along with the upcoming plans for the deployment of a 50 m baseline TOF system allowing pion/kaon separation up to ~30 GeV.

Early Career:

No

RDC9 / **33**

Progresses of Inorganic Scintillators for Future HEP Calorimeters

Author: Ren-Yuan Zhu[1]

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Future HEP calorimeters at the energy and intensity frontiers present stringent challenges to inorganic scintillators in radiation tolerance, ultrafast time response and low cost. We will report recent progresses in radiation hard, ultrafast, and cost-effective inorganic scintillators. Examples are LYSO:Ce crystals and LuAG:Ce ceramics for an ultracompact, radiation resistant shashlik sampling calorimeter RADiCAL, BaF_2:Y crystals and Lu_2O_3:Yb ceramics for time of flight as well as Mu2e-II ultrafast BaF_2:Y calorimeter, and novel high density glasses, such as ABS, AFO and DSB, for a homogeneous hadron calorimeter (HHCAL) concept for CalVision. Applications in Gigahertz hard X-ray imaging and Multi-Probe Radiography will also be discussed.

Early Career:

Poster Session / 34

Why would you put a flashlight in a dark matter detector?

Authors: Hao Chen[1]; Peter Sorensen[1]; Qing Xia[2]; Ryan Gibbons[3]; Scott Haselschwardt[1]

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Silicon photomultipliers (SiPMs) are an appealing photosensor technology for next generation dark matter detectors, including XLZD and potential upgrades to LZ. The energy threshold of these experiments is driven in part by the ability to distinguish actual few-photon scintillation events from accidental coincidence events caused by photodetector dark counts. The avalanche process inside a SiPM produces excess photons which can escape the originating pixel and be detected by other pixels. If the excess photon is detected by a pixel in a different device, the process is referred to as external optical crosstalk. We have measured the effects of external optical crosstalk in a dual-phase liquid xenon TPC. In contrast to previous work, we find that the effect is significant and problematic. It causes the gain calibration of the scintillator to be strongly dependent on the bias voltage of the SiPMs. It further increases the rate of accidental coincidence. Depending on the photosensitive area, external optical crosstalk coincidences can dominate over dark count accidental coincidences.

Early Career:

No

RDC5 / 36

hls4ml: deploying deep learning on FPGAs for L1 trigger and Data Acquisition

Author: Mia Liu[None]

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Machine learning is becoming ubiquitous across HEP. There is great potential to improve trigger and DAQ performance, and potentially in other real-time controls applications. However, the exploration of such techniques within the field in low latency/power FPGAs has just begun. We present

hls4ml, a user-friendly software, based on High-Level Synthesis (HLS), designed to deploy network architectures on FPGAs. As a case study, we use hls4ml for boosted-jet tagging with deep networks at the LHC. We map out resource usage and latency versus network architectures, to identify the typical problem complexity that hls4ml could deal with. We discuss current applications in HEP experiments and future applications. We also report on recent progress in the past year on newer neural network architectures such as binary and ternary networks, large convolutional neural networks, support for QONNX, graph neural networks and transformer neural network types.

Early Career:

Yes

RDC2 / **37**

Quality Assurance and Quality Control of the 25 m^2 SiPM production for the Darkside-20k dark matter experiment

Author: Giacomo Gallina[1]

Co-author: Paolo Organtini [1]

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Liquid Argon Time Projection Chambers (TPC) are promising detectors for dark matter search due to their response uniformity, scalability to large target masses, and suitability for extremely low background operations. The DarkSide-20k experiment is a new dark matter detector under construction at Istituto Nazionale di Fisica Nucleare (INFN) Laboratori Nazionali del Gran Sasso (LNGS) that aims to push the sensitivity for Weakly Interacting Massive Particles (WIMP) detection into the neutrino fog. The core of the apparatus is a dual-phase TPC, serving both as WIMP target and detector, filled and surrounded by low-radioactivity Underground Argon (UAr). Fondazione Bruno Kessler (FBK) NUV-HD Cryo Silicon Photomultipliers (SiPM)s have been selected as the photon sensors of choice to instrument the two 25 m^2 Optical Planes and the two veto detectors of the experiment. This talk focuses on the Quality Assurance and Quality Control (QA/QC) of the production wafers made with FBK~NUV-HD-Cryo SiPMs manufactured by LFoundry s.r.l. (Avezzano, AQ, Italy). Several SiPMs characteristics such as breakdown voltage, leakage current in the pre-breakdown region, quenching resistor and correlated noise are measured at the wafer level, at 77~K, with a custom design probe station. Overall up to September 2023 we tested 207 of the 1400 production wafers. The wafer yield is measured to be 94.3 ± 2.3~\% being not only in-spec but actually exceeding the 80\% expected by the original DarkSide-20k production plan.

Early Career:

Yes

RDC3+4+11 / **38**

3D Integrated Sensing Solutions

Authors: Ariel Schwartzman[1]; Arthur Carpenter[2]; Artur Apresyan[None]; Bojan Markovic[1]; Christopher Kenney[1]; Davide Braga[3]; Farah Fahim[3]; Julie Segal[1]; Lorenzo Rota[1]; Ron Lipton[3]

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We will present the proposed research project to develop 3D-integrated sensors using advanced manufacturing capability for novel sensors, heterogeneously integrated with energy efficient readout circuits. The lack of precision timing in particle tracking detectors and the absence of low power, high throughput communications solutions to read them out limits progress in multiple fields of fundamental science. The aim of the project is to develop technology to enable large-scale particle detectors with 3D-integrated ASIC designs to simultaneously achieve 10 μm position resolution and 10 ps precision timing, with low-power consumption and high throughput rates. This research program leverages the unique combination of facilities and cross-disciplinary expertise of scientists and engineers at SLAC, FNAL, and LLNL and industrial partners.

Early Career:

No

RDC3+4+11 / 39

First survey of centimeter-scale AC-LGAD strip sensors with a 120 GeV proton beam

Authors: Alessandro Tricoli[1]; Artur Apresyan[None]; Christopher Madrid[2]; Claudio San Martín[3]; Cristian Pena[4]; Gabriele Giacomini[5]; Ohannes Koseyan[6]; Rene Rios[3]; Ryan Heller[7]; Sergey Los[8]; Shirsendu Nanda[9]; Si Xie[10]; Wei Chen[1]; William Brooks[3]; Zhenyu Ye[11]

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We present the results with large-area AC-LGAD strip sensors, using the Fermilab Test Beam Facility and sensors manufactured by the Brookhaven National Laboratory. Sensors of this type are envisioned for applications that require large-area precision 4D tracking coverage with economical channel counts, including timing layers for the Electron Ion Collider (EIC), and space-based particle experiments. A survey of sensor designs is presented, with the aim of optimizing the electrode geometry for spatial resolution and timing performance. Several design considerations are discussed towards maintaining desirable signal characteristics with increasingly larger electrodes. The resolutions obtained with several prototypes are presented, reaching simultaneous 18 μm and 32 ps resolutions.

Early Career:

No

RDC1 / 41

Lowering the threshold of dual-phase LArTPCs

Author: Shawn Westerdale[1]

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Dual-phase LArTPCs have demonstrated the capability of achieving sub-keV thresholds in the electron-counting S2-only channel, making them powerful tools for light dark matter searches, measuring coherent elastic neutrino-nucleus scattering at nuclear reactors, and other low-energy applications. However, efforts to study the lowest accessible energies in these detectors are complicated by spurious electron (SE) signals that dominate the lowest energies. In this presentation, we will discuss observations of SEs in the DarkSide-50 LArTPC, along with potential interpretations that can inform R&D needs and the design of future detectors. We will also discuss the prospect of doping LAr to enhance its ionization yield, along with R&D needs to deploy such technology in a future detector.

Early Career:

No

RDC4 / 42

Frequency Multiplexing of Cryogenic Sensors for the Ricochet Experiment

Author: Wouter Van De Pontseele[1]

Co-authors: Jiatong Yang [2]; Patrick Harrington [2]; Shawn Henderson [3]; Steve Weber [4]; William Oliver [2]; Joseph Formaggio [2]; Zeeshan Ahmed [3]

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Readout of low-intensity microwave signals over a wide bandwidth has become increasingly important for fundamental science. The high frequency allows high information transfer, which is ideal for multiplexing detectors and reducing low-frequency noise.

One specific experiment in need of frequency multiplexing is Ricochet. Ricochet aims to measure coherent neutrino scattering to search for new fundamental physics. It consists of superconducting crystals that function as bolometers and are read out using transition-edge sensors.

We designed, fabricated and characterised devices for frequency multiplexing in 6 and 18-channel configurations with Lincoln Laboratory. The signals inductively couple into RF SQUIDS that modulate the resonant frequency of aluminium resonators. These high-Q resonators connect to a single RF feedline, simplifying cabling and reducing heat loads. The low-frequency signals are recovered

using SLAC Microresonator Radio Frequency (SMuRF) electronics for read-out of frequency-division-multiplexed cryogenic sensors.

Early Career:

Yes

RDC1 / 43

Experimental search for the Migdal Effect in a compact liquid xenon TPC

Author: Brian Lenardo[1]

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Direct dark matter searches have reported dramatically increased sensitivity to sub-GeV parameter space by taking into account the "Migdal Effect", a predicted inelastic process in which a neutral particle scattering with a nucleus results in the ejection of a bound electron from the recoiling atom. However, the Migdal Effect has never been experimentally observed, and should be confirmed and characterized before a potential dark matter signal in this channel can be reliably discovered. In this talk, we report on a dedicated experimental campaign to search for the Migdal Effect using neutron scattering in a small liquid xenon detector at Lawrence Livermore National Laboratory. Scattered neutrons are detected by a ring of liquid scintillator detectors at fixed angle, providing a high-statistics sample of 7+/-1.5 keV nuclear recoils in the liquid xenon. We search for nuclear recoil events with an electronic recoil component consistent with atomic excitation from the Migdal Effect. We find no evidence for a signal consistent with predictions, and discuss possible explanations for this discrepancy. Our results, while inconclusive, provide important input into future experimental studies of the Migdal Effect.

Early Career:

Yes

RDC1 / 44

Studies of Xenon-Doped Argon with the CHILLAX Experiment

Authors: Eli Mizrachi[1]; Ethan Bernard[2]; James Kingston[3]; Jingke Xu[4]; Teal Pershing[2]

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Xenon and argon are widely used target media for low cross-section experiments including neutrino physics and dark matter searches. Xenon-doping of dual phase argon time projection chambers

(TPCs) at the O(1%) level may substantially improve detector sensitivity. However, the large temperature discrepancy between the argon and xenon phase transition points can cause instabilities in a xenon-doped argon detector such as unwanted xenon distillation. The CHILLAX experiment at LLNL is investigating the challenges and benefits of xenon-doping of argon. We discuss the results of various stability experiments conducted within CHILLAX, which have thus far culminated in housing liquid argon doped with 2.35% xenon mole fraction with excellent stability. We also discuss recent work aiming to quantify the scintillation, ionization, and electroluminescence performance of argon from xenon-doping.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory (LLNL) under Contract DE-AC52-07NA27344.

Early Career:

Yes

RDC1 + RDC4: Session #1 / 45

Testing of CRYO ASIC for the nEXO Experiment

Author: Zepeng Li[1]

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nEXO is a next-generation liquid xenon experiment to search for the neutrino-less double beta decay of ^{136}Xe, with a lifetime sensitivity goal of greater than 10^{28} years. The experiment will use an array of charge tiles composed of crossed metal strips to record ionization electrons. An in-xenon cryogenic application-specific integrated circuit (ASIC) named CRYO ASIC has been designed by SLAC for amplification, digitization and multiplexing of the charge signals. The CRYO ASIC mounted on an auxiliary board is characterized in a test stand comprised of a chamber filled with liuquid xenon to mimic the nEXO experiment. This work presents the results of CRYO ASIC tests in a liquid xenon environment.

Early Career:

Yes

RDC1 / 47

Status and Development of nEXO's Charge Readout System

Author: Glenn Richardson[1]

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The nEXO detector, a 5-tonne liquid xenon time projection chamber enriched to 90% in Xe-136, will search for the hypothetical decay process known as neutrinoless double beta decay with a half-life sensitivity > 10^{28} years. As part of this search, the nEXO collaboration is developing a radiopure charge readout system which will help reach nEXO's sub-percent energy resolution goal and its requirement for positional reconstruction and topological discrimination. In this talk I will outline nEXO's design for the charge readout system, which consists of an array of fused silica tiles with

a specially designed electrode pattern, as well as share results from prototype tiles and readout electronics.

Early Career:

No

RDC7 / 48

A cryogenic witness detector for low-energy neutron backgrounds

Author: Anthony Villano[1]

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My group is developing a prototype liquid 3He-based scintillation detector with a TES readout to precisely measure neutron fluxes in low-background experiments. Until now, efforts to determine neutron backgrounds focus around simulations of the neutron environment without experimental comparison. The high sensitivity to low-energy neutrons provided by the 3He(n,p) process makes our prototype more sensitive to neutrons than typical dark matter or neutrino-less double-beta experiments. Furthermore the prototype is suitable for operation in a cryogenic environment similar to those used for many low-background efforts. I will discuss the prototype effort and seek feedback from the community on design and physics issues.

Early Career:

Yes

RDC7 / 49

Ultra-low Background Flexible Cables

Author: Isaac Arnquist[1]

Co-authors: Maria Laura di Vacri [2]; Nicole Rocco [2]; Richard Saldanha [2]; Tyler Schlieder [2]

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Readout cables for signal sensors are a necessary component of rare event searches for neutrinoless double beta decay and particle-like dark matter. While possessing unique mechanical and electrical properties, polyimide-based flexible cables can be a significant contributor to the total detector background, due to their relatively high content of natural radionuclides. Contaminations of U-238 and Th-232 in commercially available flexible cables have been measured in the milliBq/kg range, making them incompatible with the stringent radiopurity levels required for next-generation rare event detectors.

In previous work, we have demonstrated the possibility of obtaining low-background (microBq/kg) copper-polyimide laminates which serve as the starting material for flexible cable manufacturing.

However, we have found that even when starting with low-background laminates, the cable manufacturing process results in finished flexible cables with high (milliBq/kg) levels of radioactivity.

In this work, each step of the flexible cable manufacturing process was systematically investigated as a potential vector of radioactive impurities using inductively coupled plasma mass spectrometry. Through the investigation of process modifications, the development of cleaning procedures, and surveys of alternative materials, we have demonstrated that the radioactivity content from U-238 and Th-232 can be reduced to microBq/kg levels, roughly 250× lower than previously achievable. We will discuss our key findings, report the current best levels of radiopurity achieved, and discuss plans for making ultra-low background flexible cables commercially available.

Early Career:

Yes

RDC7 / 50

Progress and Plans for the TESSERACT Project

Author: Michael Williams[1]

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The TESSERACT collaboration will search for dark matter particles below the proton mass through interactions with two types of novel, ultra-sensitive detectors, These detectors, SPICE & HeRALD, aim to provide leading sensitivities to low mass dark matter candidates. The HeRALD experiment will use superfluid He4 as a target material, which is an ideal kinematic match for dark matter nuclear recoils. SPICE will use different polar crystals with background discrimination to be sensitive to dark photons. Both detectors will be read out by Transition Edge Sensors (TES) that are sensitive to phonon, roton, and light signals from LHe and crystal phonons and photons. In this talk I will be discussing the current R&D progress on SPICE and HeRALD and preliminary simulations of the eventual underground detector.

Early Career:

Yes

RDC4 / 51

Towards 4D tracking: 28nm sub-10ps TDC ASIC design and characterization setup

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4D trackers with ~10ps timing will be transformative at future collider experiments. Timing is crucial for reducing the combinatorial challenge of track reconstruction at extremely high pileup densities, it offers completely new handles to detect and trigger on long-lived particles (LLP), expands the reach to search for new phenomena, and enables particle-ID capabilities at low transverse momentum. At the Muon Collider, the timing information will be essential for reduction of the beam-induced background (BIB).
As one of the critical blocks necessary to enable 4D operation in trackers, we developed a 4-channel sub-10ps Time-to-Digital Converter (TDC) ASIC in the 28nm CMOS technology node. The developed TDC is based on a novel 2D Vernier ring-oscillator structure with embedded sliding-scale technique for conversion linearity improvement that will simplify calibration of the TDCs, especially useful in high-channel count implementations such as 4D trackers.
The core of the TDC architecture is composed of differential voltage-controlled delay cells set at 50ps propagation delay and assembled in a 4-cell ring-oscillator with enable/disable function with programmable starting state. The ring-oscillator, enabled with a START trigger, coupled with a counter and a series of flip-flops that sample the oscillator's state at a STOP-trigger, can perform time-interval quantization with 50ps time-steps and a range of 1.6ns. The feature of having the oscillator starting condition programmable, coupled with pseudo-random selection of the starting point at each measurement cycle, performs the sliding-scale function thus improving the conversion linearity beyond the limits set by mismatches between the delay cells of the ring-oscillator. To reach a sub-10ps resolution, the 50ps time-step of the previous structure is interpolated by a factor of 8 using a second ring-oscillator with delay cells set to 56.25ps propagation delay and enabled by a second STOP signal. Each step of the first ring-oscillator is sampled in correspondence of both rising and falling edges of the second ring-oscillator by a 2D array of flip-flops. This 2D Vernier structure reaches a resolution equal to the difference of propagation delays of cells in the two oscillators, i.e. 6.25ps. Compared to a traditional Vernier TDC, the 2D configuration allows faster conversion times and easily extendable measurement range. Both ring-oscillators implement the programmable starting state, i.e. sliding-scale, thus improving the linearity of the overall conversion.
The ASIC is composed of 4 measurement channels, each receiving one common START and two STOP signals (one common to all channels and one channel specific), simultaneously performing a 6.25ps and a 50ps measurements of the two time-intervals, for example a time-of-arrival (TOA) and a time-over-threshold (TOT) measurement. The 1.6ns measurement range of the prototype can easily be extended to match experiment requirements in future iterations by simple addition of a flip-flop to the counter. The TDC core area is 45µm x 20µm, conversion time after receiving the time-interval is less than 2ns, and average power consumption is 18.4µW for 10% occupancy and 2.9µW for 1% occupancy.
The ASIC design, test setup development and performance, and ASIC characterization challenges will be presented at the workshop.

Early Career:

No

Poster Session / 52

The Quantum Capacitor Detector –counting single photons in the far-infrared

Authors: Pierre Echternach[1]; Aaron Chou[2]; Andrew Beyer[1]; Sven van Berkel[1]; Charles Bradford[1]; Matthew Shaw[1]

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The Quantum Capacitance Detector (QCD) is a high-sensitivity direct detector under development for low background applications such as far-infrared spectroscopy from a cold space telescope. The QCD has demonstrated an optically-measured noise equivalent power of 2x10-20 W·Hz-1/2 at 1.5 THz, making it among the most sensitive far-infrared (IR) detectors systems ever demonstrated. It has demonstrated the ability to count single far-infrared photons in single pixel and large array formats. As such, The QCD is an excellent candidate as the detector of choice for applications such as search for hidden sector dark matter and dark energy radiation. A brief overview of the operating principle and current status will be given.

Early Career:

RDC4 / 53

Developments of Reconfigurable Digital Logic in the ASIC using 130nm and 28nm CMOS

Author: Larry Ruckman[1]

Co-authors: Aseem Gupta [1]; Hyunjoon Kim [1]; Lorenzo Rota [1]

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With the push for future high-energy physics detectors to move more processing to the edge in an effort to reduce data volumes at the earliest possible stage, the ability to use programmable digital logic further up the digital signal processing chain becomes increasingly important. While embedded Field-Programmable Gate Arrays (eFPGAs) built into Application-Specific Integrated Circuits (ASICs) are nothing new, these frameworks were neither free nor open source. In recent years, several popular FPGA architectures have aged beyond 20 years, which means that the original patents have expired. In 2021, the University of Manchester initiated a project called FABulous, which is an open-source eFPGA Framework.
FABulous has demonstrated eFPGA designs in 180nm CMOS and 130nm CMOS at the University of Manchester. In 2022, SLAC demonstrated an eFPGA design using FABulous framework in a 130nm CMOS Multi-Process Wafer (MPW). For 2023, our team taped out a 28nm CMOS MPW in July 2023 and expects to receive the ASIC back in November 2023. The goal of using 28nm is to determine what programmable logic area density can be achieved while using HVT devices for radiation hardening. This 28nm eFPGA design will utilize the SLAC Ultimate Gateway Operational Interface (SUGOI), which is a lightweight 8B10B-based serial protocol for register access, to load the eFPGA bitstream. The Pretty Good Protocol Version 4 (PGPv4), which is a 64B66B-based serial protocol designed for Trigger Data Acquisition (TDAQ) systems, will be used to move data in and out of the eFPGA.
We will present the performance of our 130nm design, the Post-PnR simulation results for our 28nm design, and a comparison between the two designs at this workshop.

Early Career:

No

RDC8 / 54

First Detection of 120 GeV Protons with SNSPDs

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SNSPDs are well established as an ultra-fast and highly efficient single photon detector technology. Typical sensor properties, such as small pixel size, low power, and low material thickness, make

these sensitive detectors ideal for tracking particle detector applications. Cases where only modest detector areas are needed are prime candidates for this new particle detection technology. One example is a forward ion detector at the Electron Ion Collider which would detect high energy ions scattered at very small angles relative to the beam. We report the first detection of 120 GeV protons using SNSPDs of various sizes as first step in demonstrating the feasibility of such a detector system at the EIC. We also discuss other future applications of SNSPD particle detectors in nuclear and particle experiments and future R&D plans.

*This work has been supported by the U.S. Department of Energy, Office of Science, Offices of Nuclear Physics, under contract number DE-AC02-06CH11357 and the U.S. Department of Energy, Office of Science under the Microelectronics Co-Design Research Project "Hybrid Cryogenic Detector Architectures for Sensing and Edge Computing enabled by new Fabrication Processes"(LAB 21-2491).

Early Career:

Yes

RDC6 / 56

Status and Future Developments of Micro-pattern Gas Detectors for low-energy nuclear physics applications at FRIB

Author: Marco Cortesi[1]

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Rare isotope (RI) beams facilities are now critical tools for nuclear physics. The Facility for Rare Isotope Beams (FRIB), located on the campus of Michigan State University, is a world-class facility for the study of RIs using the in-flight fragmentation method. The unprecedented potential discovery of a modern rare isotope beam facility, such as FRIB, can only be realized by implementing state-of-the-art experimental equipment capable of studying these isotopes at a high beam rate and high performance.
Originally developed for high-energy physics (HEP), implementation of MPGD technology as gas avalanche readouts has expanded to other fields, including nuclear physics, astrophysics, neutrino physics, material science, neutron detection, and medical imaging. MPGDs offer great flexibility and allow geometry and performance to be tailored to specific working conditions and requirements. The requirements of a typical low-energy nuclear physics experiment (LENP) with RI beam are generally very different from HEP fixed-target experiments, so that substantial efforts and resources are necessary to develop MPGD architectures optimized for LENP environments.
In this work, we will describe our latest results and progress obtained with novel gas avalanche concepts designed to target applications at the Facility for Rare Isotope Beam (FRIB). In particular, we will describe recent progress in the development of Multi-layer THGEM (M-THGEM) structures, for application in active-target TPC readout, as well as tracking at the focal-plane of high-rigidity spectrometers. This also includes a recent performance evaluation of the Multi-mesh THGEM in terms of gas gain and ion backflow suppression.
Further, we present a measurement of the secondary scintillation yield produced in multi-layer Thick Gas Electron Multipliers (M-THGEMs) in low-pressure (20-100 Torr) Tetrafluoropropane gas (CF4), which is of particular importance for the design of the next generation of optical-readout Time Projection Chamber (TPC) operated at low-pressure CF4. Potential applications include experimental nuclear physics with rare isotope beams or direct detection of dark matter based on the Migdal effect approach.

Acknowledgement: This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics and user resources of the Facility for Rare Isotope Beams (FRIB) Operations, which is a DOE Office of Science User Facility under Award Number DE-SC0023633.

Early Career:

Yes

RDC8 / **57**

Development of Superconducting Qubit-Based Sensors for meV Scale Detectors

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The increasing maturity of superconducting qubits over the past few decades has allowed the field of superconducting quantum computing to flourish. In parallel, advances in detector technology which have built on this wave of qubit fabrication expertise have shown that this same technology can be applied to energy sensing at the THz (meV) scale, opening up a new regime of sensing leveraging the single quasiparticle sensitivity of qubit-derived structures. In this talk I will give a brief overview of the interesting HEP physics that can be done at the meV scale and talk about two recent sensor designs we have developed based on superconducting qubits.

The development of single electron-sensitive charge amplifiers is of interested to a wide array of experiments in HEP and beyond. To date, this sensitivity has only been achieved using fabrication techniques limited to specific detector substrates, e.g. Skipper CCDs (Si) and SuperCDMS HVeV (Si, Ge). I will give an overview of a recently funded project between LANL and SLAC to build a single electron-sensitive charge amplifier that will be compatible with any solid-state detector target. This will be achieved using Cooper pair box electrometers based on charge qubits, which can be externally coupled to a large variety of detector target materials. Additionally I will discuss an athermal-phonon sensitive qubit sensor which leverages quasiparticle trapping and amplification, based on the transmon architecture. I will detail our initial designs, quasiparticle trapping model, and R&D plan which will allow these sensors to achieve sensitivity to single meV phonons. Both of these sensor designs have the potential to have profound impacts on the direct detection of sub-MeV dark matter.

Early Career:

Yes

RDC2 / **58**

Investigation for pixel-based accelerated aging of Large Area Picosecond Photodetectors

Author: Iakovos Tzoka[1]

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Micro-channel plate photo-multiplier tubes (MCP-PMTs) have become ubiquitous and are widely considered potential candidates for next-generation high-energy physics experiments due to their picosecond timing resolution, ability to operate in strong magnetic fields, and low noise rates. A key factor determining the applicability of MCP-PMTs is their lifetime, mainly when used in high-event rate experiments. We have developed a novel aging method to investigate the performance degradation of an MCP-PMT in an accelerated manner. The accelerated aging method involves exposing a localized region of the MCP-PMT to photons at a high repetition rate. This pixel-based method was inspired by earlier results showing that damage to the photocathode of the MCP-PMT occurs primarily at the site of light exposure and that the surrounding region undergoes minimal damage. One advantage of the pixel-based method is that it allows the dynamics of photo-cathode damage to be studied at multiple locations within the same MCP-PMT under different operating conditions. In this work, we use the pixel-based accelerated lifetime test to investigate the aging behavior of a 20 cm x 20 cm Large Area Picosecond Photo Detector (LAPPD) manufactured by INCOM Inc. at multiple locations within the same device under different operating conditions. We compare the aging behavior of the MCP-PMT obtained from the first-lifetime test conducted under high gain conditions to the lifetime obtained at a different gain. Through this work, we aim to correlate the lifetime of the MCP-PMT and the rate of ion feedback, which is a function of the gain of each MCP and voltage across each MCP, and which can also vary from point to point across a large area 400 cm^2 MCP. The tests were made possible by the uniqueness of the LAPPD design, which allows independent control of the gain of the chevron-stacked MCPs. We will further discuss the implications of our results for optimizing the operating conditions of the detector when used in high-event rate experiments.
Keywords: Electron multipliers (vacuum), LAPPD, Micro-channel plate photo-multipliers tubes, Photoemission, Time-of-Flight.

Early Career:

Yes

RDC2 / 59

New results on thin entrance window LGAD's

Author: Julie Segal[1]

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There has been increasing progress in using Low Gain Avalanche Detectors (LGADs) for HEP applications to obtain improved signal-to-noise ratio and temporal resolution compared to PIN diode arrays. However, the lack of a thin entrance window is a limiting factor for deploying LGADs in some applications. For instance, UV light from noble liquid scintillation, low-energy electrons in reaction microscopes, ion products from nuclear fusion, and soft x-rays for heliophysics all require thin entrance window sensors. In 2020 IEEE NSS/MIC we proposed a novel thin entrance window LGAD device concept. We have now produced the first wafer run. We will describe the design and simulation of the new device, as well as test results. Bench test measurements on single-pixel test

structures show gain of 7 for shallow absorption. We are currently bump-bonding proto-type size arrays to SLAC ASICs for full functional test.

Early Career:

RDC9 / 61

RADiCAL: Ultra-compact, Radiation-hard, Fast-timing EM Calorimetry

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To address the challenges of providing high performance calorimetry in future hadron collider experiments under conditions of high luminosity and high radiation, we are conducting R&D on advanced calorimetry techniques suitable for such operation, based on scintillation and wavelength-shifting technologies and photosensor (SiPM and SiPM-like) technology. In particular, we are focusing our attention on ultra-compact radiation hard EM calorimeters, based on modular structures (RADiCAL modules) consisting of alternating layers of very dense absorber and scintillating plates, read out via radiation hard wavelength shifting (WLS) solid fiber or capillary elements to photosensors positioned either proximately or remotely, depending upon their radiation tolerance. RADiCAL modules provide the capability to measure simultaneously and with high precision the position, energy and timing of EM showers. This paper will provide preliminary results from recent beam tests of a RADiCAL module in electron beams over the energy range 25 GeV < E < 150 GeV.

Early Career:

Yes

RDC4 / 63

SiGe integrated chip readout for fast timing

Authors: Bruce Schumm[1]; Gabriel Saffier-Ewing[2]; Jennifer Ott[3]; Simone Mazza[None]; Zachary Galloway[2]

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Advances in timing detector technology require new specialized readout electronics. Applications demand high rep rates, below 10 ps time of arrival resolution and, low power. A possible path to achieve O(10 ps) time resolution is an integrated chip using Silicon Germanium (SiGe) technology. Using DoE SBIR funding, Anadyne, Inc. in collaboration with UC Santa Cruz has developed a prototype SiGe front end readout chip optimized for low power and timing resolution (0.6 mW/channel, 10 ps of timing resolution for 8 fC). In this contribution the ASIC performance simulation and the results from the first prototype run will be shown.

Early Career:

RDC3+4+11 / 64

A high-granularity timing active target for the PIONEER experiment

Authors: Bruce Schumm[1]; Gabriele Giacomini[2]; Jennifer Ott[3]; Mohammad Nizam[4]; Simone Mazza[None]

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PIONEER is a next-generation experiment to measure the charged-pion branching ratio to electrons vs. muons and the pion beta decay with an order of magnitude improvement in precision. A high-granularity active target (ATAR) is being designed to provide detailed 4D tracking information, allowing the separation of the energy deposits of the pion decay products in both position and time. The chosen technology for the ATAR is Low Gain Avalanche Detectors (LGAD). These are thin silicon detectors with moderate internal signal amplification. Several technologies still under development are being evaluated to achieve a ~100% active region, such as AC-coupled LGADs (AC-LGADs) and Trench Insulated LGADs (TI-LGADs). Since a range of deposited charge from Minimum Ionizing Particle (MIP, few 10s of KeV) from positrons to several MeV from the stopping pions/muons is expected, the detection and separation of close-by hits in such a wide dynamic range will be the main challenge. Furthermore, the compactness and the requirement of low inactive material of the ATAR present challenges for the readout system, forcing the amplification chip and digitization to be positioned away from the active region. In the contribution, a brief introduction to the LGAD active target idea for PIONEER and for general applications will be made. Results from a BNL sensor production of 200um and 120um devices with double-sided readout will be presented.

Early Career:

Yes

RDC3+4+11 / 65

Development of AC-LGADs for near-future Higgs factories and nuclear physics experiments

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Low Gain Avalanche Detectors (LGADs) are characterized by an extremely good time resolution (down to 17ps), a fast rise time (~500ps) and a very high repetition rate (~1ns full charge collection). For the application of this technology to near future experiments such as e+e- Higgs factories, EPIC, or smaller experiments (e.g., the PIONEER experiment), the first issue to be addressed is the intrinsic low granularity of LGADs and the large power consumption of readout chips for precise timing. AC-coupled LGADs, where the readout metal is AC-couple through an insulating oxide layer, could solve both issues at the same time thanks to the 100% fill factor and charge-sharing capabilities. Charge sharing between electrodes allows a hit position resolution well below the pitch/sqrt(12) of standard pixel detectors. At the same time, it relaxes the channel density and power consumption requirement of readout chips. Extensive characterization of AC-LGAD devices will be shown in this contribution, with both laser TCT and probe station (IV/CV). The sensors from a variety of manufacturers had variations of the following parameters: readout dimensions: strip/pad metal contact size (length, width), pitch, sensor production details: N+ layer resistivity, dielectric specs (thickness, value of permittivity), bulk thickness, doping of the gain layer. The initial data suggest that the length of the strip plays a dominant role in determining the distance the pick-up extends. On the other hand, the N+ layer resistivity influences the strength of the picked-up signal. Our study compares the effect of all parameters listed above, including a comparison of different manufacturers.

Early Career:

Yes

RDC1+2+7 / 67

Scintillating Bubble Chamber (SBC) preparations for first calibration run.

Author: Thomas Whitis[1]

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The Scintillating Bubble Chamber (SBC) Collaboration is developing noble liquid bubble chambers for the detection of sub-keV nuclear recoils, enabling both high-exposure GeV-scale dark matter searches and CEvNS measurements using reactor neutrinos. A 10-kg liquid argon bubble chamber is currently under construction at Fermilab in order to calibrate the nuclear recoil threshold in argon down to sub-keV levels. We have recently completed an engineering run, testing the cooling system and pressure control systems of the detector using liquid argon alone, and are now preparing the internal bubble chamber for the first calibration run that will take place in the MINOS tunnel at Fermilab. I'll be giving an update on the status of the detector construction, the results of our engineering run, and plans for the first calibration run at Fermilab.

Early Career:

Yes

Plenary / 68

The Fermilab and Illinois Express Quantum Networks —Synergies with HEP Science

Author: Cristián Peña[1]

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We present the latest developments of the Fermilab and Illinois Express Quantum Networks experiments. These operating quantum networks, with deployed infrastructure spanning the Chicagoland metropolitan area and connecting Fermilab and Argonne National Labs, spanning more than 50 km, have achieve record quantum teleportation and entanglement swapping fidelities using time-bin photonics qubits with the existing fiber optics infrastructure. We will discuss a program to increase the information rate and distances as well as to realize more complex protocols and how the existing network infrastructure including the classical backbone with a record timing synchronization below 3 ps can enable distributed sensing experiments with HEP applications.

Early Career:

Yes

RDC1+2+7 / 69

Towards Low Energy Threshold and Large Area Superconducting Nanowire Single Photon Detectors for HEP Science

Authors: Boris Korzh[1]; Christina Wang[None]; Cristián Peña[2]; Jamie Luskin[3]; Matthew Shaw[4]; Si Xie[5]

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We present the latest results in superconducting nanowire single photon detectors (SNSPDs) towards large active ares at the 1×1 mm^2 level and beyond. These large active areas sensors are key to enable HEP experiment looking for axion dark matter candidates in proposed experiments such as BREAD. We will present the initial characterization of these devices and show in depth characterization of the dark count rate of these new devices and its dependence on operating temperature. The dark count rate is a key detector parameter for expected low-signal experiments such as those searching for dark matter and special care has been put to develop a characterization system at Fermilab to extensively characterize these devices. We will discuss possibilities for enabling SNSPDs with lower energy threshold and further area scalability by using frequency domain multiplexing readout schemes. These developments have a unique physics case towards detecting axion masses below the in the 0.01 - 1 eV range which currently remains largely unexplored.

Early Career:

Yes

RDC7 / 70

Update on the status of the SENSEI Dark Matter Experiment

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I will present an update on the SENSEI dark matter experiment and I will highlight any RnD collaboration opportunities we envision as possible.

Early Career:

Yes

RDC2 / 71

Light collection and simulation for nEXO

Author: Molly Watts[1]

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nEXO is a next-generation 5-tonne liquid xenon time projection chamber that will search for neutrinoless double beta decay ($0\nu\beta\beta$) of ^{136}Xe with a projected half-life sensitivity of 1.35x10^{28} years in 10 years of livetime. To achieve this sensitivity, the design goal of nEXO is $\leq$1% energy resolution at the $Q_{\beta\beta}$ endpoint value of 2.458 MeV. To reach this desired energy resolution, we require optimizing the collection of ionization electrons and scintillation photons resulting from energy deposits in liquid xenon. For light collection, nEXO will employ Silicon Photo-Multipliers (SiPMs) positioned around its barrel to detect 175 nm scintillation light of liquid xenon. In this talk I will describe current efforts of the collaboration to characterize candidate SiPMs for nEXO and simulate the light detection performance for the full detector.

Early Career:

RDC1 + RDC4: Session #1 / 72

Q-Pix: ASIC Development and First Prototypes for Pixelated Charge Readout

Author: Kevin Keefe[1]

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The Q-Pix concept (arXiv: 1809.10213) is a continuously integrating low-power charge-sensitive amplifier (CSA) viewed by a Schmitt trigger. When the trigger threshold is met, the comparator initiates a 'reset' transition and returns the CSA circuitry to a stable baseline. This is the elementary Charge-Integrate / Reset (CIR) circuit. The instance of reset time is captured in a 32-bit clock value register, buffers the cycle and then begins again. What is exploited in this new architecture is the time difference between one clock capture and the next sequential capture, called the Reset Time Difference (RTD). The RTD measures the time to integrate a predefined integrated quantum of charge (Q). Waveforms are reconstructed without differentiation and an event is characterized by the sequence of RTDs. This technique easily distinguishes the background RTDs due to 39Ar decays (which also provide an automatic absolute charge calibration) and signal RTD sequences due to ionizing tracks. Q-Pix offers the ability to extract all track information providing very detailed track profiles and also utilizes a dynamically established network for DAQ for exceptional resilience against single point failures. This talk will present the status of the Q-Pix analog and digital ASICs, introduce results from first prototypes, and discuss future planned tests.

Early Career:

Yes

RDC5 / 73

An Open Source General Purpose DMA Engine For DAQ Systems

Authors: Benjamin Reese[1]; Larry Ruckman[1]; Ryan Herbst[1]

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We present a description of a high-performance direct memory access (DMA) engine and kernel driver for data acquisition systems. The DMA engine is designed to support multiple incoming interleaved data channels simultaneously. The kernel driver enables multiple user-space clients to access the DMA engine for receiving or transmitting data, with the ability to create a memory map in the user space to the underlying DMA buffers to minimize the number of data copies required during data recitation or transmission. The DMA engine and kernel driver combination have been deployed in multiple data acquisition systems, including on PCI-Express cards, Xilinx ZYNQ SOC devices, and the Xilinx RFSOC platform, with the platform fully utilizing the bandwidth of the host PCI-Express bus.

Early Career:

No

Poster Session / 74

Underlying physics properties for identifying 511 keV gammas in high-Z crystal PET

Author: Kepler Domurat-Sousa[1]

Co-authors: Cameron Poe [1]; Eric Spieglan [2]; Patrick La Riviere [3]; Henry Frisch [1]; Allison Squires [4]

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Due to the need to correctly determine the first interaction location of each of the two gamma rays to measure the line-of-response, Positron Emission Tomography (PET) scanner sensitivity changes rapidly with small changes in the efficiency at 511 keV. Current PET scanner designs use high atomic number (high-Z) scintillating crystals to detect photoelectric interactions in the detector. Due to photoelectric interactions having a lower cross-section than Compton scattering at 511 keV for high-Z materials, large losses in detector sensitivity occur. This loss in sensitivity can be countered by the inclusion of Compton scattering in the detection of the gamma rays.

Determination of the first scatter in a chain of Compton scatters requires precise measurement of the geometry of the scatter chain, requiring uncertainty in scattering locations to be substantially smaller than the distance between scatters. In typical high-Z detectors the crystal segmentation is on the same scale as the distance between scatters, making determination of the first scatter so difficult it is typically not done. TOPAS simulations show that sensitivity for lines-of-response can be increased by a factor of 3 with the inclusion of Compton scatters.

Early Career:

Poster Session / 75

Progress on a SiPM for readout of the fast component of BaF2 scintillation light

Author: David Hitlin[1]

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We report on the status of the development of a SiPM incorporating an internal filter that has high sensitivity to the fast component (<0.6ns) of BaF2 scintillation light at 220nm, and substantial suppression of the slow component (650ns) at 300nm.

Early Career:

RDC9 / 76

Minimum Requirements for a low-Z-medium detector for low-dose high-resolution TOF-PET

Author: Kepler Domurat-Sousa[1]

Co-authors: Cameron Poe [2]; Maya McDaniel [3]; Eric Spieglan [4]; Joao Shida [5]; Evan Angelico [6]; Bernhard Adams [7]; Patrick La Riviere [8]; Henry Frisch [2]; Allison Squires [3]

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Two major drawbacks to time-of-flight positron emission tomography (TOF-PET) are low spatial resolution and high radioactive dose to the patient, both of which result from limitations in detection technology rather than fundamental physics. To address these, a new type of TOF-PET detector employing low-atomic number (low-Z) scintillation media recording Compton scattering locations and energies in the detector has been proposed [1]. Here we present a preliminary comparison of the low-Z detector performance to conventional TOF-PET using high-Z scintillation crystals, and the minimum technical requirements for such a system. We have performed a simulation study using a customized TOPAS simulation [2] to evaluate the potential of a proposed low-Z detection medium, linear alkylbenzene (LAB) doped with a switchable molecular recorder. By quantifying contributions and tradeoffs for energy, spatial, and timing resolution of the low-Z detector, we show that a reasonable combination of detector specifications improves the TOF-PET sensitivity by more than 5x, with comparable or better spatial resolution and 40-50% enhanced contrast-to-noise as compared to state-of-the-art photoelectric based high-Z TOF-PET. These improvements enable imaging of a brain phantom simulated at less than 1% of a standard radiotracer dose. This would enable expanded access and new clinical applications for TOF-PET.

Early Career:

RDC4 / 77

CRYO ASIC: A System-on-Chip (SoC) for Charge Readout in the nEXO Experiment

Author: Aldo Pena Perez[1]

Co-authors: Angelo Dragone ; Aseem Gupta ; Benjamin Reese ; Bojan Markovic ; Brian Lenardo ; Dionisio Doering ; Evan Angelico ; Hugo Hernandez ; Liang Yang ; Lorenzo Rota ; Mark Convery ; Sander Breur ; Zepeng Li

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CRYO ASIC plays a vital role as the charge readout component in the nEXO experiment. Its primary purpose is to process signals from sensors situated within the liquid xenon chamber, facilitating the study of phenomena such as neutrinoless double-beta (0νββ) decay and other rare events. Featuring a compact system-on-chip (SoC) architecture in a small 7mm x 9mm form factor, its primary functions involve signal preamplification, channel multiplexing and waveform digitization, enabling it to convert analog data generated by interactions within the liquid xenon detector into a digital format suitable for in-depth analysis. Designed to operate reliably under the extreme cryogenic temperatures of nEXO, preliminary assessments conducted at ~165K indicate that the CRYO ASIC, presently in its R&D prototype phase, is steadily approaching compliance with nEXO's stringent requirements.

This talk provides a comprehensive overview of the CRYO ASIC's architecture, describing design choices made to align with the experiment's demands. Furthermore, it outlines key specifications and encompasses future design implementations to reach its final version. A dedicated bench setup developed at SLAC is also described for initial chip characterization at cryogenic temperatures. Results from two ASICs operating efficiently at ~165K will be presented, demonstrating how these findings mitigate early-stage critical design risks within the nEXO project.

Early Career:

No

RDC1+2+7 / 78

Advancing Particle Research: Multimodal Pixel Detectors with Integrated Tracking and Photodetection

Author: Michael Rooks[1]

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In the realm of particle physics, the quest for ever more precise and efficient detection methods is an ongoing pursuit. A cutting-edge technology, Liquid Argon Time Projection Chamber (LArTPC), is poised to revolutionize the field by introducing a paradigm-shifting pixelated approach to enhance neutrino detection experiments.

Traditionally, LArTPCs have relied on wire-based projective readout technologies, which, while effective, pose construction challenges and require continuous readout systems. Furthermore, the complexity of reconstructing complex neutrino interaction topologies using wire-based readouts has pushed the boundaries of current methodologies.

In response to these challenges, the exploration of true 3D pixel-based schemes has gained significant momentum. However, this transition to pixelated charge readout presents a unique obstacle - the detection of scintillation light. Unlike wire planes, pixel planes are opaque to light, necessitating novel solutions.

A groundbreaking proposal involves coating the dielectric surface of pixels with a specialized photoconductor designed to respond to vacuum ultraviolet (VUV) light incident on its surface, effectively transforming the pixel into an integrated tracking/photodetector. In this presentation, I unveil the results of early research and development efforts toward realizing this integrated tracking/photodetector for pixel based LArTPCs.

By seamlessly combining charge and direct VUV light detection capabilities in a true multimodal pixel, this technology promises to be a game-changer, offering unparalleled precision and versatility in the study of elusive neutrinos. Join me on this journey as I unveil the future of neutrino detection, with a proposed small-scale demonstrator LArTPC serving as a strategic stride toward a paradigm-shifting pixelated technology poised at the forefront of scientific innovation.

Early Career:

Yes

RDC8 / 79

Versatility of superconducting Hafnium for transition edge sensor bolometers.

Author: Kaja Rotermund[1]

Co-authors: Aritoki Suzuki [1]; Daniel Yohannes [2]; Robin Cantor [3]; John Vivalda [2]; Asa Chambal-Jacobs [2]

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Several current and next generation cosmic microwave background (CMB) polarimetry experiments employ transition edge sensor (TES) bolometers whose operating temperature is ~100 milli-Kelvin, requiring a critical temperature (Tc) around 170 milli-Kelvin. Aluminum Manganese (AlMn) has been successfully used as the superconducting metal by several groups for CMB experiments. However, achieving a repeatable and stable Tc requires careful thermal management that puts bounds on fabrication processes. We studied an alternative superconducting metal –Hafnium (Hf) is an attractive alternative as its bulk Tc is well matched to our needs and can also be deposited as a thin film as demonstrated by the microwave kinetic inductance detector (MKID) community. One critical differentiation between past Hf MKID fabrication processes and our own, is our use of a heated sputter deposition that enables us to finely tune the Tc to our desired target. Furthermore, the Tc remains robust against subsequent exposure to heat as long as the initial deposition temperature is not exceeded. As the deposition temperatures are high (ranging from 300℃ - 550℃, depending on the desired Tc), there is ample thermal budget for continued fabrication processes while maintaining a stable Tc. Additionally, by using an interdigitated geometry we are able to precisely design the normal resistance of the TES to anywhere between 1 Ohm and 10 milli-Ohm, making these TESs compatible with CMB experiments that use both time-domain as well as frequency-domain and microwave multiplexing readout systems. We present our findings of a Hf based TES bolometer designed for CMB experiments.

Early Career:

Yes

Poster Session / 80

High-performance Dichroic Filters Development for Large-Scale Neutrino Detector

Author: Yichen Li[1]

Co-authors: Milind Diwan [2]; Yimin Hu [3]; Feng Niu [3]; Xin Qian [1]; Chao Zhang [1]; Steve Lu [1]

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High performance dichroic filters (DFs) are key photon wavelength sorting devices for Cherenkov and scintillation light in water- and scintillator-based neutrino detectors. Future detectors such as THEIA and DUNE will require large-area DFs at a low cost and with improved transmissivity and reflective properties. DFs are traditionally manufactured by various physical vapor deposition (PVD) techniques such as ion beam sputtering, electron beam and thermal evaporators with ion assistance. However they all have been subject to intrinsic drawbacks of poor large area uniformity, especially on curved surface, poor thickness control and high cost associated with vacuum technology and thickness monitoring tools. Atomic layer deposition (ALD) on the other hand has been well established for precise thickness control, excellent large area uniformity and conformity for coatings on complex surfaces, and low growth temperatures. Therefore it is well suited for optical coatings on large area glass tiles or temperature sensitive plastics, and on curved surfaces of Winston cones. In addition, a wide range of high quality dielectric materials (oxides, nitrides, fluorides, carbides, etc.) with high, medium and low refractive indexes are available by ALD, most of which can be deposited in a single ALD chamber thus complexity and production cost can be reduced. These merits provide an excellent solution to manufacturing various bandpass DFs requiring tight specs for multiple dielectric layer coatings and precise wavelength positioning and steepness. Other advantages of ALD coatings include defect free thus low optical loss, and super moisture/environmental resistance. Special ALD tools for handling large areas up to meter size, and multiple wafers up to hundreds/hour were demonstrated commercially. We present a cost effective DF development with ALD coating techniques for neutrino detector with a potential path for commercialization in collaboration with Raytum Photonics. The DFs with ALD coatings have been produced and is scheduled for the detector performance test in liquid argon at BNL.

Early Career:

No

RDC4 / 81

Rapid Firmware/Software Development with SLAC's Open-Source Tools: SURF, RUCKUS, and ROGUE

Authors: Benjamin Reese[1]; Larry Ruckman[1]; Ryan Herbst[1]

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SLAC Instrumentation has developed a set of open-source tools that provide an extensible firmware library (SURF), coupled with a robust build system (RUCKUS), and a power hardware abstraction and readout layer (ROGUE) which, when combined, support rapid firmware/software development. This package is gaining traction in the community, with partner labs utilizing and improving the open-source repository.

The SLAC Ultimate RTL Framework (SURF) is a firmware framework that provides the building blocks commonly used in all firmware designs. It is a substantial VHDL library, built upon more than 10 years of development. It is extensively used in AMD/Xilinx FPGAs and custom digital ASIC designs. The framework comprises VHDL-based intellectual properties (IPs) for commonly implemented modules. It has been widely adopted by numerous experiments and applications. SURF is open source and published on GitHub.

Ruckus is our common build system for ASIC digital logic and FPGA firmware. This build system is a hybrid of Makefile and TCL scripts. Ruckus is not a replacement for the synthesis tools but rather a

wrapper on top of them. Ruckus helps with repeatable synthesis project creation and configuration. Ruckus supports Xilinx Vivado for FPGA firmware and Synopsys Design Compiler for digital ASIC synthesis.

Rogue is our modular mixed Python/C++ software platform, named Rogue, that allows for both powerful and user-friendly interaction with firmware and hardware modules. Rogue enables the integration of Python and C++ plug-in modules into its data flow and register manager layers, facilitating ease of development and high-performance data processing. Rogue is not simply a wrapped C++ platform but a carefully architected platform that allows for the tight integration of C++ and Python. Its core C++ classes can be subclassed in Python with a common set of pluggable interfaces, enabling true mixed development. Rogue is deployed as a set of C++ and Python libraries that can integrate with third-party C++ and Python software, allowing for maximum flexibility when integrating into larger systems.

Early Career:

No

RDC5 / 82

HLS In A DAQ Environment

Author: J.J. Russell[1]

Co-authors: Larry Ruckman [1]; Ryan Herbst [1]

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The use of High-Level Synthesis Languages (HLS) instead of VHDL or Verilog for FPGA code development is no longer a novelty. HLS allows for greater abstraction, enabling the handling of increasingly complex problems. The rapid prototyping and exploration of various ideas made possible by HLS would be respectively impossible and too time-consuming when using an FPGA hardware language. HLS has proven to be especially useful in the real-time environment of embedded Data Acquisition (DAQ) systems, helping FPGAs become omnipresent, providing highly coveted low-latency, high throughput, and deterministic behavior.

A particularly valuable and potent combination is HLS coupled with C++ meta-programming techniques. This offers two advantages: a) many operations and concepts can be accomplished at compile time, and b) the development of generic frameworks where data types, array sizes, and even algorithmic choices are selected at compile time. This leverages the strengths of FPGAs, where specifying as much as possible at compile-time results in both performance and resource usage advantages, while simultaneously allowing the code to be flexible and adaptive.

Two cases that illustrate these techniques in HLS are presented. Arithmetic Probability Encoding is a data compression method previously used in the protoDUNE project, which will be adapted for nEXO, a neutrinoless double-beta decay experiment. In Mathusla, a proposed experiment for searching for long-lived particles (LLP) emanating from CMS at CERN, HLS is being used to develop a complex trigger. This involves employing 100 FPGAs for local track-finding and then aggregating the found tracks into a central FPGA to locate a possible vertex of the decaying LLP. All of these tasks must adhere to a 2.5-microsecond time budget.

Early Career:

No

RDC9 / 83

Eos: A Ton-Scale Hybrid Neutrino Detector

Author: Adam Baldoni[1]

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Hybrid neutrino detectors utilize both Cherenkov and scintillation light to detect neutrino events, combining the lower energy threshold of pure scintillator detectors and enhanced direction resolution of water detectors. The benefits of hybrid detectors provide for advancements in fundamental physics goals as well as in applications such as nuclear nonproliferation. Experiments with small benchtop hybrid detectors have shown success in Cherenkov/scintillation separation, but a ton-scale test of hybrid detector technologies is needed to extrapolate the performance to larger hybrid detectors like the planned Theia detector with a fiducial volume of tens of kT. Eos is a detector with an approximately 4-ton target fiducial volume under construction at UC Berkeley and Lawrence Berkeley National Laboratory. The detector, featuring fast photomultiplier tubes (900 ps transit time spread), a novel water-based liquid scintillator (WbLS) target, and a first large-scale test of spectral sorting, will provide a test-bed for emerging technologies required for hybrid detectors. Furthermore, Eos will deploy calibration sources to verify the optical models of WbLS and other liquid scintillators with slow light emission, to enable an extrapolation to kT-scale detectors. This input will support the development of advanced techniques for reconstructing event energy, position, and direction in hybrid detectors significantly. After achieving these goals, Eos can be moved near a nuclear reactor or in a particle test-beam to demonstrate neutrino event reconstruction or detailed event characterization with these novel detection technologies.

Early Career:

Yes

RDC4 / 87

CMS High Granularity Calorimeter ECON-D ASIC overview and radiation testing results

Author: Grace Cummings[1]

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The Compact Muon Solenoid (CMS) Experiment's High Granularity Calorimeter (HGCAL) upgrade replaces the CMS electromagnetic and hadronic endcap calorimeters in preparation for the high-rate and high-radiation environment of the High Luminosity LHC. To effectively use the over 6 million channels of this highly-segmented "imaging"calorimeter, CMS is pioneering very front-end data compression with the Endcap Concentrator (ECON) ASICs –the ECON-T for the trigger path and the ECON-D for the data path. These 65 nm CMOS ASICs are radiation tolerant (200 Mrad) and low-power (< 2.5 mW/channel). In June 2023, we received the first full-functionality prototype of the data path concentrator ASIC, the ECON-D-P1. This talk will present an overview of the ECON-D-P1, summarize functionality and system testing, and present results from both Total Ionizing Dose (TID) and Single Event Effect (SEE) testing campaigns completed in summer 2023, validating the ECON-D radiation tolerant performance.

Early Career:

Yes

Poster Session / 88

Two-stage Cryogenic Charge Amplifier for Semiconductor Dark Matter Detectors

Author: Arran Phipps[1]

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Effective searches for sub-GeV particle dark matter require sensitivity to recoil energies below ~1 eV. The SPLENDOR (Search for Particles of Light dark mattEr with Narrow-gap semiconDuctORs) collaboration aims to detect MeV-scale dark matter through the use of novel narrow-gap semiconductor materials coupled to extreme low noise charge amplifiers. In this talk, I describe the design and performance of a two-stage cryogenic charge amplifier built upon CryoHEMTs - commercial HEMTs (high electron mobility transistors) specifically designed for deep cryogenic charge readout. A base temperature source-follower stage is first used to buffer the charge signal, mitigating the effects of cabling/stray capacitance. The buffered signal is then amplified at T=4K and read out using standard room temperature electronics. The amplifier's expected charge resolution is a few electrons, resulting in sub-eV energy resolution when coupled to a suitable narrow gap material.

Early Career:

Yes

RDC3+4+11 / 89

Design of the NAPA Prototypes Towards Large Area Sensors for Future e+e- Colliders

Authors: Alexandre Habib[1]; Jim Brau[2]; Martin Breidenbach[1]; Lorenzo Rota[1]; Caterina Vernieri[1]; Angelo Dragone[1]

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The detectors at future e+e- linear colliders will need unprecedented precision on Higgs physics measurements. These ambitious physics goals translate into very challenging detector requirements on tracking and calorimetry. Monolithic Active Pixel Sensor (MAPS) technology offers small dead area, thin sensors, and small pixels over large areas,
Future e+e- Colliders require fast detectors with O(ns) timing tagging. This is feasible at the cost of a relatively high-power consumption that would not be compatible with cooling large areas with gas. Today some commercial imaging technologies offer the possibility of producing large, stitched sensors (with a rectangle area ~30 cm × 10 cm). Such large sensors are very interesting from a physics point of view, but they are very challenging from an engineering point of view.
A first MAPS prototype 'NAPA-p1'was designed by SLAC in CMOS Imaging 65 nm technology. The prototype has dimensions of 1.5 mm × 1.5 mm with a pixel pitch of 25 µm. This work benefits from our collaboration with CERN, capitalizing on the improved sensor's performance after a decade of optimizations. This prototype will set the baseline for the sensor and the electronics performance which will serve future developments.

The pixel is designed with auto-calibration schemes, thus avoiding the per-pixel threshold trimming. The power consumption is kept to a minimum of 720 nW/pixel, which will be scaled down by a factor or 100 or more for low duty cycle e+e- machines.
The simulations results of NAPA-p1 show a time resolution is 350 ps-rms and an equivalent noise charge (ENC) of 12 e-rms which are compatible with the target specifications.
NAPA-p1 is fabricated and the chip characterization has begun. Characterization results will be available soon.
In a parallel effort, a second prototype 'NAPA-p2'is being currently designed to tackle large area challenges. The key features of 'NAPA-2'are reduced power density, power pulsing, and good tolerance to ohmic voltage drops across a large column of 500 pixels. A discussion will be presented about the design strategies to allow the scalability of this design into a large-area stitched sensor of 20 cm × 5 cm, with specifications compatible with future e+e- colliders.

Early Career:

Yes

RDC1+2+7 / 90

Fast Single-Quantum Measurement with a Multi-Amplifier Sensing Charge-Coupled Device

Authors: Agustin Lapi[1]; Alex Drlica-Wagner[2]; Ana Martina Botti[3]; Blas Junior Irigoyen Gimenez[4]; Brenda Aurea Cervantes Vergara[2]; CLAUDIO CHAVEZ[2]; Edgard Marrufo Villalpando[5]; Fernando Chierchie[6]; Guillermo Fernandez Moroni[2]; Javier Tiffenberg[2]; Juan Estrada[2]; Kenneth Lin[7]; Miguel Sofo Haro[8]; Sho Uemura[2]; Stephen Holland[9]

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Non-destructive readout capability of the Skipper Charge Coupled Device (CCD) has been proven to be a powerful technique to reduce the noise limitation of conventional silicon devices even to levels that allow single-photon or single-electron counting. The noise reduction is achieved by spending extra time taking several measurements of the same pixel charge. This extra time has been a limitation for the broader use of the technology in particle physics and astronomy applications beyond its successful use for dark matter searches.
In this talk, I will present recent results of a novel sensor architecture that uses multiple non-destructive floating-gate amplifiers to achieve sub-electron readout noise in a thick, fully-depleted silicon detector as a solution to the readout time limitation with an order of magnitude increase in readout speed.
This Multi-Amplifier Sensing Charge-Coupled Device (MAS-CCD) can perform multiple independent charge measurements with each amplifier. These measurements from the multiple amplifiers can then be combined to reduce the readout noise without the penalty of the extra readout time of the repetitive sampling scheme of the Skipper CCD.
The readout speed of this detector scales roughly linearly with the number of amplifiers without requiring segmentation of the active area. We will show the results obtained for sensors with 8 and 16 amplifiers per readout stage. The noise reduction capability of the new technique will be demonstrated emphasizing the ability to resolve individual quanta, low energy particle detection, optical

properties, and the ability to combine measurements across amplifiers to reduce readout noise.
The unprecedented low noise and fast readout of the MAS-CCD have been already identified as a candidate technology for the next large spectroscopic survey of galaxies, it provides a faster sensor alternative for background reduction in single-electron energy depositions searches from dark matter and other dark sector candidates and provides a suitable solution for fast readout in high-precision and quantum imaging systems.

Early Career:

Yes

RDC3 / 91

The mystery of "Cold Noise" in the ATLAS ITk strip detector

Author: Ian Dyckes[1]

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In preparation for the High Luminosity LHC, the ATLAS Experiment is constructing a new Inner Tracker (ITk) composed of silicon pixel and silicon strip detectors. After multiple years of prototyping, the ITk strips project entered the pre-production phase in late-2021. However, in early 2022, clusters of strips exceeding the noise specification were observed when operating modules at cold temperatures. This observation of "Cold Noise"interrupted pre-production and initiated an extensive investigation into the cause and potential mitigation strategies. This talk will summarize our current understanding of the Cold Noise mechanism, highlighting the most insightful studies from this year-long investigation.

Early Career:

Yes

RDC5 / 92

Empowering AI Implementation: The Versatile SLAC Neural Network Library (SNL) for FPGA, eFPGA , ASIC

Authors: Abhilasha Dave[1]; Angelo Dragone[1]; Dionisio Doering[1]; J.J. Russell[1]; Larry Ruckman[1]; Ryan Coffee[1]; Ryan Herbst[1]

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This paper presents the SLAC Neural Network Library (SNL), a specialized set of extensible libraries designed in High-Level Synthesis (HLS) for deploying machine learning structures on Field Programmable Gate Arrays (FPGAs), eFPGAs and ASICs. Positioned at the edge of the data chain, SNL aims to create a high-performance, low-latency FPGA implementation for AI inference engines. Utilizing the Xilinx's High-Level Synthesis (HLS) framework, SNL offers an API modeled after the widely used Keras interface to TensorFlow. The primary objective of SNL is to deliver a high-performance, low-latency FPGA implementation of an AI inference engine capable of handling moderately sized networks. SNL allows for dynamic reloading of weights and biases without

re-synthesis, enhancing adaptability, and facilitating experimentation. Moreover, SNL supports a modular approach, enabling the implementation of novel and custom ML layers for FPGAs and ASICs. The framework facilitates a standard interface for storing weights and biases, such as HDF5. SNL not only demonstrates its capability to attain higher data throughput but also contributes to meeting experiment-specific latency constraints.

Early Career:

RDC4 / **93**

Front-end neural network filtering implemented in a silicon pixel detector

Authors: Aaron Young[1]; Alice Bean[2]; Benjamin Parpillon[3]; Chinar Syal[3]; Corrinne Mills[4]; Dahai Wen[5]; Douglas Berry[3]; Farah Fahim[3]; Gauri Pradhan[3]; Giuseppe Di Guglielmo[3]; James Hirschauer[3]; Jennet Dickinson[3]; Jieun Yoo[4]; Karri Folan Di Petrillo[6]; Lindsey Gray[3]; Manuel Blanco Valentin[7]; Mark Neubauer[8]; Morris Swartz[5]; Nhan Tran[None]; Petar Maksimovic[5]; Ron Lipton[3]; Shruti Kulkarni[1]

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Next-generation silicon pixel detectors with fine granularity will allow for precise measurements of particle tracks in both space and time. This will result in unprecedented data rates which will exceed those anticipated at the HL-LHC. A reduction in the size of pixel data must be applied at the collision rate of 40MHz in order to fully exploit the pixel detector information of every proton-proton interaction for physics analysis. Using the shape of charge clusters deposited in arrays of small pixels, the transverse momentum (p_T) of the traversing particle can be extracted by on-ASIC locally customized neural networks. This talk will discuss both deep neural network (DNN) and spiking neural network (SNN) algorithms for filtering pixel data based on p_T, as well as the relative benefits for physics and for efficient implementation within the strict power and area constraints of a readout ASIC.

Early Career:

No

Plenary / **94**

Probing sub-GeV dark matter with superfluid helium

Authors: TESSERACT Collaboration[None]; Vetri Velan[1]

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The Helium Roton Apparatus for Light Dark Matter (HeRALD) experiment will use superfluid 4He to probe unexplored dark matter parameter space. Superfluid helium has several advantages: good kinematic matching to light dark matter candidates, ballistic quasiparticle propagation, scalability, and multiple signal channels for electronic vs. nuclear recoil discrimination. I will discuss recent progress by the TESSERACT collaboration to develop this technology, including work done at LBNL, UC Berkeley, and UMass Amherst. I will focus on detector development and instrumentation.

Early Career:

Yes

RDC4 / 96

3D Heterogeneous Integration Multi-Project Wafer

Authors: Farah Fahim[1]; James Hoff[1]

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Corresponding Authors: farah@fnal.gov, jimhoff@fnal.gov

Fermilab is organizing a 3D Heterogeneous Integration Multi-Project Wafer (3DHI-MPW) run to meet the current advanced packaging needs of scientific instrumentation as well as to further the state-of-the-art in advanced packaging for small-volume users.

Our goals are to:
1. Leverage high density face-to-face/face-to-back wafer bonding for current and future projects
2. Start the first of many community-organized, regularly-scheduled 3DHI-MPW runs in order to:
1. Develop the 3DHI low-volume prototyping community, and
2. Create a 3DHI-MPW fabrication methodology analogous to the 2D VLSI MPW fabrication methodology currently enjoyed by the HEP community.
3. Advance and standardize industry-wide TSVs, (including)
1. Define and develop open standards to facilitate 3D integration of diverse heterogenous wafers from multiple foundries

Early Career:

Poster Session / 97

Radiopurity.org Materials Database Development

Author: Chris Jackson[1]

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The radiopurity.org database has proven to be a valuable resource for the low background physics community as a tool to track and share assay results. This talk will describe recent collaborative efforts between the Pacific Northwest National Laboratory and SNOLAB to modernize the database for the community. Improvements to the search utility and data upload methods will be discussed. Installations to support individual physics collaborations (for example DUNE) and assay facilities will be described, as well as ongoing plans to develop and support the database.

Early Career:

No

RDC7 / 98

Radon Emanation at Cryogenic Temperatures

Author: Chris Jackson[1]

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Radon is a key problem for many low-background experiments and emanation assays are essential tools to select detector materials and characterize these events. Emanation in cryogenic liquids will be important for coming neutrino and dark matter experiments where both temperature and surface properties will determine the radon level. In this talk a radon emanation bench, taking advantage of ultralow background proportional counters, will be introduced. Work to construct a cryogenic liquid version of this system will be outlined as well as a new simulation tool to model radon emanation in liquid argon.

Early Career:

No

RDC1 + RDC4: Session #1 / 99

LightPix: Scalable digital readout for cryogenic SiPM applications

Author: Stephen Greenberg[1]

Co-authors: Brooke Russell [2]; Carl Grace [2]; Dan Dwyer

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LightPix is an Application Specific Integrated Circuit (ASIC) geared towards highly scalable cryogenic SiPM readout. LightPix is manufactured in 180-nm Bulk CMOS, and provides 64 individual channels each with amplification, a self-triggering TDC with O(ns) precision, and digital readout. Each ASIC dissipates <200 μW per channel, and is scalable to >1000 channels per signal cable, allowing for large area coverage and high channel density in cryogenic environments. LightPix also features multi-channel hit-coincidence logic to deal with high dark count rates, enabling applications beyond cryogenic detectors. We present several directions of current and future R&D, including results of operation of LightPix-based cosmic ray telescope in liquid Argon, as well as progress towards deployment of LightPix for joint charge-light readout in a pixelated LArTPC. Prospects of LightPix for use in future large scale experiments are discussed.

Early Career:

Yes

Poster Session / 100

A novel approach to purification in small-scale noble liquid systems

Author: Stephen Greenberg[1]

Co-authors: Andrew Lambert [2]; Brooke Russell [2]; Dan Dwyer [2]; Kevin Wood [2]

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The inert-behavior, high nuclear mass, and scintillating properties of liquid Argon and Xenon make them attractive for use in a variety of sensitive experiments. However, great care must be taken to remove electronegative impurities which reduce light yield from scintillation, and degrade the resolution of ionization-charge imaging. An external purification circuit is generally beyond the of smaller systems devoted to detector R&D, where instead various creative pumping approaches have been developed. We present progress towards the development of a novel, mechanically inactive, submerged pump and purification system for liquid Argon developed at Lawrence Berkeley National Laboratory. This system is low noise, low power, pressure safe, low cost, and achieves nearly continuous O(liters/min) flow rates using only a resistive heater as the primary energy input.

Early Career:

Yes

RDC2 / 101

Advances in Large Area MCP-PMTs

Author: Alexey Lyashenko[1]

Co-authors: Mark A. Popecki [1]; Michael J. Minot [1]; Michael R. Foley [1]; Stephen Clarke [1]; Derrick Mensah [1]; Melvin Aviles [1]; Stefan Cwik [1]; Cole J. Hamel [1]; Michael E. Stochaj [1]

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Large Area Picosecond Photo-Detectors (LAPPDs) produced by Incom Inc. are the world's largest commercially-available planar-geometry photodetectors based on microchannel plates (ALD-GCA-MCPs). It features a chevron pair of "next generation"large area MCPs produced by applying resistive and emissive Atomic Layer Deposition (ALD) coatings to borosilicate glass capillary array (GCA) substrates encapsulated in a borosilicate glass or a ceramic hermetic package. These are available with 10 or 20 µm pore diameters.

A VUV-grade fused silica entry window of the detector is coated with a high sensitivity semitransparent bi-alkali photocathode with roughly 20 cm X 20 cm detection area.

Signals are read out via a capacitively coupled resistive anode. The "baseline"devices have demonstrated electron gains of 1E7, low dark noise rates (<1000 Hz/cm2), single photoelectron (PE) timing resolution less than 50 picoseconds RMS (electronics-limited), and single photoelectron spatial resolution under 1mm RMS (also electronics-limited), high (25% - 30%) QE uniform bi-alkali photocathodes.

Incom Inc. has recently started manufacturing a smaller format, 10 cm X 10 cm High Rate Picosecond Photo-Detector (HRPPD). In addition to all of the LAPPD attractive features, HRPPD has a fully

active area with no window support spacers (structural supports). It is equipped with new 10 μm pore MCPs and a highly pixelated anode with either capacitively of directly coupled readout to provide sub-mm spatial resolution. In comparison with LAPPDs, HRPPD prototypes demonstrated similar gain and dark rates but higher spatial resolution.

Measurements with LAPPDs and now HRPPDs operating in strong magnetic fields have been performed. Stable high gain LAPPD and HRPPD operation was demonstrated at magnetic field strength of up to 2 T.

LAPPDs and HRPPDs are good candidates for neutrino experiments, HEP experiments, neutrinoless double-beta decay experiments, medical and nuclear non-proliferation applications. Currently, customized HRPPDs with a pixelated direct readout are being developed to be employed in pf-RICH modules of ePIC detector in EIC.

We report on the recent progress in the production and development of the LAPPDs and HRPPDs. Ongoing efforts on development of wide temperature range MCPs and red-enhanced photocathodes, extending sensor lifetime and enlarging sensor active area will also be discussed.

Early Career:

Yes

RDC2 / **102**

Improving the performance of amorphous selenium photodetectors by alloying for indirect X-ray imaging

Authors: Kaitlin Hellier[1]; Molly McGrath[1]; Shiva Abbaszadeh[1]

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Amorphous selenium (a-Se) is a well-studied photoconductor utilized in both direct and indirect X-ray detection, with applications in medical, industrial, materials, and high-energy imaging; recent studies also highlight its potential for particle detection with noble elements. Amorphous Se exhibits many ideal properties for photodetection, with excellent conversion efficiency from the vacuum ultraviolet (VUV) through blue wavelengths at reasonable fields (40 V/μm), low leakage currents, and low-cost large-area fabrication capabilities. Its ability to achieve impact ionization at low fields (<70 V/μm) offers potential for low-photon detection with high signal. However, a-Se suffers from low hole and electron mobilities, and its bandgap of 2.1 eV limits its applications in green to near infrared (NIR) detection, which is important for high-yield, high-resolution scintillators.

Studies of alloying a-Se with Group IV and VI elements have long been performed to improve the material properties. However, until recently, it was thought that these alloys instead lead to detrimental impacts in transport and, therefore, detector performance. In this work, we will review our studies of alloying a-Se with Ge and Te, demonstrating that improvements can be found when conditions are optimized, such as alloy content, applied field, and device architecture. We will discuss how the physics of the material plays a role in the device performance and outline paths towards even greater improvements and the potential for alloyed a-Se in future detector applications.

Early Career:

Yes

Poster Session / **103**

The TOPAS Tool for Particle Simulation

Author: Joseph Perl[1]

[1] *SLAC*

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TOPAS lets users model any sort of radiation therapy or medical imaging apparatus in three dimensions by combining a set of pre-built geometry components. Users can then send any form of fundamental particle through this setup, from x-rays and electrons to protons and heavy ions. Users can easily import patient models, animal models or phantoms through DICOM and other formats and see where the particles travel. TOPAS users can score Energy, Dose, Fluence, RBE, Time of Flight, etc. to various formats: csv, binary, nTuple, phase space, or DICOM dose files, and can also directly calculate DVH or perform output modeling for TCP or NTCP. TOPAS also allows users to make almost any parameter vary over time, hence we speak of TOPAS as not just 3D but 4D. TOPAS has been widely accepted, currently in use by over 2500 users at 638 institutions in 68 countries.
While the primary use of TOPAS has been for studies in medical physics, its unparalleled combination of flexibility and ease of use make it an excellent tool for developers of any form of apparatus where Monte Carlo particle tracking is useful including any form of imaging detector. Indeed, at the core of TOPAS is the same Geant4 Simulation Toolkit used by the majority of HEP detector developers worldwide. I will show the general capabilities of TOPAS, present a quick overview of how the user builds their TOPAS simulation, and show some examples of how it has been used for a wide variety of research projects. TOPAS is freely available to all users both as a pre-built executable and as open source code.
TOPAS is further described in the open-access manuscript: Perl J, Shin J, Schumann J, Faddegon B, Paganetti H. TOPAS: an innovative proton Monte Carlo platform for research and clinical applications. Med Phys. 2012 Nov; 39(11):6818-37. (View in: PubMed). This manuscript has has been cited 888 times in Google Scholar. Further details can be found a https://www.topasmc.org/

Early Career:

Poster Session / 104

Testing and characterization of the RD53 ATLAS pixel production readout ASIC (ITkPixV2) for HL-LHC

Authors: Maria Mironova[1]; Maurice Garcia-Sciveres[2]; Timon Heim[3]

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The Phase-2 upgrades of ATLAS and CMS for the High-Luminosity LHC (HL-LHC), require a new tracker with robust readout electronics capable of withstanding extreme radiation (1 Grad), a high hit rate (3 GHz/cm2), and a high data rate readout (5 Gb/s). In a joint effort between ATLAS and CMS, pixel detector readout chips have been designed by the RD53 collaboration in 65 nm CMOS technology. Based on a half-sized demonstrator (RD53A), two chip variants were designed for ATLAS and CMS, respectively. The ATLAS pre-production readout chip, ITkPixV1, was characterized in detail, and informed by the results, the final ATLAS pixel readout chip, ITkPixV2, has been designed, submitted, and the first wafers were received in July 2023. This contribution provides an overview of the characterization measurements performed on the ITkPixV2 chip so far, focusing on bench-top testing of chip functionality, and first results of X-ray irradiation studies to assess the radiation tolerance of the chip.

Early Career:

RDC9 / 105

Simulated Performance of the SiD Digital ECal Based on Monolithic Active Pixel Sensors

Authors: Martin Breidenbach[1]; James Brau[2]; Caterina Vernieri[1]; Alexandre Habib[1]; Lorenzo Rota[1]

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The SiD Collaboration has had a long interest in the potential for improved granularity in the tracker and ECal; a study of MAPS in the SiD ECal was described in the 2013 ILC TDR . Work is progressing on the MAPS application in an upgraded SiD design, both for the ECal and tracking. A prototyping design effort is underway for a common SiD tracker/ECal design based on stitched reticles to achieve 5 x 25 cm^2 sensors with 25 x 100 (or 50) $micron^2$ pixels for a linear collider application (C^3 or ILC). Application of large area MAPS in these systems would eliminate delicate and expensive bump-bonding, provide possibilities for better timing, and should be significantly cheaper due to being a more conventional CMOS foundry process. The small pixels significantly improve shower separation. Simulation studies confirm previous results, indicating electromagnetic energy resolution based on digital hit cluster counting provides better performance than the SiD TDR analog design based on 13 mm^2 pixels. Furthermore, the two-particle separation in the ECal is excellent down to the millimeter scale. Geant4 simulation results with optimized analysis based on machine learning will be presented demonstrating optimization of these expectations.

Early Career:

RDC3+4+11 / 106

Integrated CMOS sensor r&d for future colliders

Authors: Artur Apresyan[None]; Corrinne Mills[1]; Farah Fahim[2]; Karri Folan Di Petrillo[3]; Maral Alyari[2]; Matthew Jones[4]; Mia Liu[4]; Nicola Bachetta[2]; Petra Merkel[2]; Ron Lipton[2]

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We will present a program to establish the first development and manufacturing of HEP-specific sensors monolithically integrated into a standard CMOS process using a US-based foundry. In collaboration with several US universities the project aims to develop Monolithic Active Pixel Sensors (MAPS) designs implemented in the 90 nm technology node, including simple test structures and multi-pixel arrays, and monolithic CMOS sensors with readout integrated circuits, perform detailed characterization of the detector prototypes and quantify their performance for HEP applications.

Early Career:

No

RDC7 / 107

Transition-edge sensors with multiplexing readout for the CUPID experiment.

Author: Vivek Singh[1]

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CUPID is a proposed next-generation experiment that will search for neutrinoless double-β (0νββ) decay in ^{100}Mo using ~1600 $Li_2{}^{100}MoO_4$ scintillating crystals operated as low-temperature calorimeters close to ~10mK. It will leverage the crystal's energy loss mechanism to tag particle type by simultaneously measuring the thermal and scintillation signals. We will use an auxiliary low-temperature calorimeter to detect light with high photon collection efficiency. The light detectors must have a very low energy threshold $\mathcal{O}$(100eV) and good timing resolution < 1 ms to tag α background and 2νββ pile-up events in the region of interest, and are crucial to reach the CUPID background goal of <1E-4 counts/(keV.kg.yr) for its baseline design. In this talk, I will briefly discuss the R&D status of a future upgrade using a novel Iridium/Platinum bilayer superconducting transition-edge-sensor (TES) on a large area dielectric wafer (Si/Ge), acting as light-detectors. CUPID is under development at the 250 kg level but is already looking to the next stage with 1 ton of ^{100}Mo (CUPID-1T). Scaling the next generation of crystalline detectors to the ton size requires ten thousand channels or more; efforts to decrease this wire density using frequency-division multiplexing are ongoing. These efforts still require technical solutions to demonstrate performance at operating temperature; systems must also adhere to stringent noise, crosstalk, and radiopurity constraints. I will discuss our efforts toward these technical solutions.

Early Career:

Yes

RDC1 / 109

Measuring the transverse diffusion of electrons in noble gasses: A laboratory-scale demonstration of the physics capabilities of Q-Pix.

Authors: N. Hoch[1]; O. Seidel[2]

Co-authors: K. Keefe [2]; A. B. Enriquez [2]; I. Parmaksiz [2]; A. D. McDonald [2]; V. A. Chirayath [2]; H. Mahdy [2]; M. Rooks [2]; J. B. R. Battat [1]; J. Asaadi [2]

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We report measurements of the transverse diffusion parameters of electrons through P10 gas (90% Ar, 10% CH4) in a laboratory-scale time projection chamber (TPC) using a novel pixelated signal capture and digitization method. The method, Q-Pix, consists of a precision switched integrating trans-impedance amplifier whose output is compared to a threshold voltage by a comparator. The comparator sends a 'reset'signal that discharges the integrating capacitor when the output of the integrator reaches the preset threshold. The time difference between the successive resets, the reset time difference (RTD), is inversely proportional to the current at the pixel, and the number of resets is directly proportional to the total charge collected at the pixel, enabling a pixel-based readout of the ionization signals using either the RTDs or the number of resets. Here, the constant of proportionality, depending on the voltage threshold and the value of the integrating capacitor, represents the minimum charge required for a single reset. We used a 16-channel Q-Pix readout fabricated using commercial off-the-shelf components and coupled them to 16 concentric anode rings to measure the spatial extension of the electron swarm that reaches the anode after drifting through an electric field of $\sim$ 500V/cm in P10. The macroscopic electron swarm is produced at the Au photocathode using pulsed VUV photons. We obtained a reasonable fit to the swarm diffusion profiles extracted from the pixelated anode plane at various operating pressures ($\sim$ 250 Torr - 2200 Torr). Our results demonstrate that a Q-Pix readout can successfully reconstruct geometric properties of ionization events in a TPC.

Early Career:

Yes

RDC4 / **110**

RFSoC-based Readout and Characterization Platform Development at SLAC

Author: Chao Liu[1]

Co-authors: Chelsea Bartram [1]; Larry Ruckman [1]; Lili Ma [2]; Noah Kurinsky [1]; Ryan Herbst [1]; Shawn Henderson [1]; Zeeshan Ahmed [1]

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RF system-on-chip (RFSoC) devices have been widely used for instrumentation development at SLAC for various physics experiments hosted by SLAC and other collaborators worldwide. To leverage the integrated RF data converters and the large amount of programmable logic resources in RFSoC, a new RFSoC-based readout for superconducting detectors of microwave SQUID multiplexers (μmux) or microwave kinetic inductance detectors (MKIDs) for Cosmic Microwave Background (CMB) experiments is under development. We are also developing readout and control platforms using RFSoC devices for axion dark matter detection experiments, one employing cavity-based receiver and another using quantum device-based sensors targeting meV-Scale energy sensitivity. The platforms can also be transformed to be used as digital backend for radio astronomy receivers based on heterodyne methods in C band and X band. In this presentation, we summarize the latest development efforts and characterization results for the platform for those experiments.

For the readout of μmux and quantum device-based DM detection experiment, we applied the direct RF sampling technique instead of using the heterodyne method. The direct RF sampling method significantly simplifies the RF circuit and reduces the cost of the readout system. The performance of direct RF sampling in different configurations has comprehensively evaluated for the application, and it demonstrated the desired spurious free dynamic range (SFDR) and inter-modulation distortion (IMD) with the optimum settings. The direct RF sampling data converters and data paths have been integrated with the SLAC Microresonator RF (SMuRF) firmware. The initial single frequency DAC to ADC loopback test shows approximately -110 dBc/Hz of phase noise at 30 kHz offset from the carrier frequency in 4-6 GHz and that it 10 dB lower than SMuRF electronics. The RFSoC based readout has been connected to a resonator array designed for Simons Observatory in a cryostat at SLAC and we are performing debugging and testing tasks now.

For the characterization and readout platform for cavity-based haloscope for axion search experiments, a spectrum analyzer with approximately 80 Hz spectra resolution in 5 MHz bandwidth at a configurable center frequency and the integration time up to 200s. The spectrum analyzer will be extended to a custom network analyzer with a synthetic axion generator to be used as a complete

solution for alignment and data collection for axion search. We are in the process of characterizing the performance of our spectrum analyzer with the latest RFSoC DFE device.

To make the systems more accessible researchers, engineers, and students, we use a Jupyter notebook front end to perform the test and document the test procedure. The backend is powered by SLACs SURF firmware framework, with the software interface powered by the Rogue software environment. The full system configuration and test procedure can be realized in a single notebook, including network setup, firmware configuration, data recording, data analysis and visualization. Therefore, users can easily reproduce the test or readout flow and implement custom data processing in the same scripts. We are open to collaborations to improve the platform's tool flow, portability, processing library and overall user experience for science communities.

Early Career:

RDC4 / 111

Pebbles: paving the way toward 4D Pixel detectors in 28nm CMOS

Author: Timon Heim[1]

Co-authors: Amanda Krieger [2]; Carl Grace [2]; Maurice Garcia-Sciveres [3]; Zhicai Zhang [2]

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Detectors at future colliders will rely on the ability to perform 4D tracking with O(10ps) resolution. As a stepping stone towards these future detectors we have developed a prototype ASIC, Pebbles, that contains the Big Rock analog front-end and embedded testing circuits. The Big Rock front-end aims to achieve 50ps timing resolution while maintaining all other requirements from the current generation RD53 Pixel readout chips (50um x 50um pitch, 1000e threshold, 5uW per pixel, 50fF input capacitance). This kind of pixel front-end could serve as an interesting stepping stone towards future 4D trackers, as it could be deployed during the potential replacement of innermost layers of the ATLAS ITk Pixel detector. We will present the analog-front and test bed architecture design and the summarize the bench top test results from the prototype ASIC.

Early Career:

Yes

Poster Session / 112

System tests for prototypes of the ATLAS ITK pixel detector

Author: Zhi Zheng[1]

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The current ATLAS Inner detector will be replaced with a new all silicon Inner Tracker (ITK) to cope with the high density environment during High Luminosity LHC (HL-LHC). The innermost part of the ITK will comprise a state-of-the-art pixel detector. This pixel detector is built upon lightweight

carbon structures in the shape of rings and staves, which host the pixel modules. Designing proper system tests on these loaded supports is very crucial in building the detector fulfilling the requirements. Prototypes of these supports, employing the RD53A readout chip, have been fabricated and subjected to system-level studies and development of final qualification procedures. Preliminary system tests have been designed and conducted to assess aspects which are essential for detector operation, like thermal performance with CO_2 cooling, serial power, grounding, shielding, system monitoring, and the overall performance of the multi-module detector systems. This contribution outlines the ongoing testing on these loaded supports and provides insights into some of the system test outcome which in return will help improving the test procedures.

Early Career:

Yes

RDC8 / 113

Towards Quantum Charge Parity Detectors with meV Resolution for Astroparticle Applications

Author: Karthik Ramanathan[1]

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Next generation rare-event searches, for example in looking for "sub-GeV" particle dark matter, require new tools and techniques with much improved sensitivity. In particular, the constrained kinematic space of potential interactions suggests that collective excitations like phonons may be the only signature of very low mass dark matter candidates. One promising technology to study these are qubit derived superconducting charge-parity sensors. These detection schemes include Quantum Capacitance Detectors (QCDs) and Offset-Charge Sensitive (OCS) devices, and the former have been demonstrated in previous literature as excellent far-IR photon counters with NEP of <1E-20 W/√Hz. We seek to extend the applicability of these techniques by directly coupling the sensors to interaction induced athermal phonons generated within a crystalline silicon substrate. Such a scheme will enable the literal counting of O(100) ueV quasiparticle quanta (broken Cooper-pair electrons) within a superconducting absorber, as produced by single meV phonons. In this presentation, we will discuss progress towards demonstrating a charge-parity detector design, and lay out a roadmap for demonstrating eV and subsequently lower energy resolution in future iterations.

Early Career:

Yes

RDC8 / 115

Accelerating dark matter axion searches with quantum measurement and cavity innovation with HAYSTAC Experiment:

Author: Xiran Bai[1]

[1] *Yale University*

Corresponding Author: xiran.bai@yale.edu

The HAYSTAC Collaboration is actively searching for axion cold dark matter using a resonant microwave cavity and quantum squeezed state receiver. With axion mass and coupling strength unknown, a crucial metric is the scanning rate across their parameter space. Recent advancements in squeezed state receivers have doubled the scanning rate. This talk will discuss HAYSTAC's current instrumentation and future plans to explore higher axion masses.

Early Career:

Yes

RDC3+4+11 / **116**

MAPS R&D for tracking and calorimetry at future e+e- colliders

Author: Caterina Vernieri[1]

Co-authors: Alexandre Habib [1]; Angelo Dragone [1]; Christopher Kenney [1]; Christos Bakalis [1]; James Brau [2]; Julie Segal [1]; Lorenzo Rota [1]; Martin Breidenbach [1]; Mirella Vassilev [1]

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SLAC National Accelerator Laboratory has led developed MAPS in several technologies, both for high-energy physics applications and foras well as ultra-fast photon science. SLAC is now leading a collaborative effort to develop MAPS for future colliders, with a strong synergy with the CERN DRD 7.6 project. SLAC has participated withengaged with international efforts led by CERN and ALICE in the 65 nm development with a and submission of a pixel sensor prototype in the ER1 run (within the CERN WP1.2 collaboration) and is contributing effort to the ALICE ITS3 testing team.
Simulation efforts are ongoing to inform the final requirements for the ASIC., currently, SLAC is investigating challenges of wafer-scale designs optimized for detectors at future e+e- machines, focusing in particular on the silicon tracker and calorimetry. This is a general challenge for MAPS application at any of the future Higgs Factories. This effort will help identify the risks that wafer-scale MAPS pose at system-level, particularly power transmission to the sensors, power distribution on the sensor, data paths on the sensor, and power pulsing, all with the goal of retiringto retire the high-risk technological challenges of such developments.

Early Career:

Yes

RDC6 / **117**

First Light from the MIGDAL experiment: Results from Commissioning Data Using Fast Neutrons

Author: Elizabeth Tilly[1]

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A number of experiments searching for dark matter have invoked the Migdal effect to improve their mass sensitivity to Weakly Interacting Massive particles by over an order of magnitude without this application of the effect having ever been experimentally validated. In light of this, the Migdal in Galactic Dark mAtter expLoration (MIGDAL) experiment aims to make the first direct and unambiguous observation of the Migdal effect from fast neutron scattering.

This experiment uses an Optical Time Projection Chamber equipped with a stack of two glass-GEMs operating in 50-Torr CF4 gas, with light and charge readout provided by a CMOS camera, a photomultiplier tube, and a 120 Indium-Tin-Oxide strip anode. The signals from these enable precise three-dimensional reconstruction of ionization tracks that form the characteristic Migdal V-shape topology, namely a nuclear and electron recoil sharing an interaction vertex.

In this talk, I will present preliminary results from the experiment's commissioning using the D-D generator at the Rutherford Appleton Laboratory's Neutron Irradiation Laboratory for Electronics (NILE).

Early Career:

No

RDC11 / 118

Synchrotron light source X-ray detection with Low-Gain Avalanche Diodes

Authors: Abraham Seiden[1]; Bruce Schumm[2]; D Yerdea[3]; F. Martinez-McKinney[4]; Gabriele Giacomini[5]; Guilherme Tomio Saito[6]; Hartmut Sadrozinski[7]; Jennifer Ott[1]; Marco Lisboa Leite[6]; Maurício Moralles[8]; Mohammad Nizam[9]; N Nagel[3]; N Yoho[3]; T Kirkes[3]; Wei Chen[10]; Yuzhan Zhao[11]

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Low Gain Avalanche Diodes (LGADs) represent the state-of-art technology in fast timing measurement for charged minimum ionizing particles (MIPs). LGADs are initially developed for future Timing Detectors in the ATLAS and CMS experiments at the High-Luminosity LHC. One of LGADs' key features is the gradient-doped multiplication layer providing intrinsic gain. The intrinsic gain enables the detection of low energy X-rays with good energy resolution and precise timing capabilities. We extensively tested LGADs from HPK and BNL with varying thicknesses ranging from 20μm to 50μm at room temperature. These tests utilized X-ray energies from 5 keV to 70 keV at the Stanford Synchrotron Radiation Lightsource (SSRL) with 10ps pulsed X-ray bunches separated by 2ns interval. In this contribution, we will show that LGADs has better energy sensitivity and timing resolution for low energy X-ray than PiN devices under finely-tuned operational conditions. Moreover,

we will demonstrate the high frame-rate capability of LGADs (with at least 500MHz). Additionally, we investigated the gain suppression effect resulting from point-like large charge deposition along with the aid of TCAD simulation. Lastly, we made a crude attempt to assess the feasibility of reliable Compton scattering detection with LGADs, which aim to employ LGADs as pass-through beam monitoring device for high-energy X-ray beams using Compton interaction.

Early Career:

Yes

Poster Session / 119

Testbeam measurements with ALICE MAPS prototype

Author: Mirella Vassilev[1]

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In light of upgrades such as the High Luminosity LHC (HL-LHC) and proposals for future collider experiments, continued development of particle tracking technology is crucial. Monolithic Active Pixel Sensors (MAPS) are established vertex detectors, which combine the readout electronics and sensitive volume in one sensor, providing excellent spatial resolution, while maintaining a low power consumption and material budget. The Digital Pixel Test Structure (DPTS) is a MAPS prototype for the inner tracker of the ALICE experiment (ITS3) manufactured in the Tower Partners Semiconductor Co. 65 nm process for their upgrade for the HL-LHC. It is important to characterize the DPTS performance, in particular their radiation tolerance, given their estimated yearly radiation exposure of up to 10 kGy and 10^{13} 1 MeV neq cm^{-2}.

Here, we will present the results of a 2022 testbeam at CERN PS. DPTS sensors were irradiated to various levels up to 100 kGy and 10^{15} 1 MeV neq cm^{-2} and characterized in a 10 GeV/c positive hadron beam. The detection efficiency and spatial resolution were measured for each chip. It is shown that all the chips can be operated at 99% efficiency and with a spatial resolution of around 4.3 µm. The demonstrated performance and radiation hardness of the DPTS sensor makes the 65 nm technology a viable candidate not only for the ALICE inner tracker, but also a technology with potential applications, such as future e+e- colliders.

Early Career:

RDC6 / 120

NEXT-CRAB-0: a high pressure gaseous xenon time projection chamber with a direct VUV camera based readout

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The research and development (R&D) efforts to detect neutrinoless beta decay have made significant progress in recent years. One of the R&D directions involves the use of high-pressure gas xenon

detectors, like those employed by the NEXT experiment. In this approach, a fast optical camera is utilized to convert the tracking information into digital form. The NEXT-CRAB (Camera Readout and Barium Tagging) is a prototype detector that records event topology in an electroluminescent xenon gas TPC via a VUV image-intensified camera. Our system has been characterized using alpha particles, which are decay products of Po-210. We have compared these results with simulation. Additionally, we have observed particle tracks of high-energy betas from Bi-214 and cosmic muons. In this presentation, we will present these findings.

Early Career:

No

RDC8 / **121**

Low Tc Thin Film Superconducting Detectors

Author: Clarence Chang[1]

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A number of applications, including neutrino studies and the search for dark matter, require detectors with lower thresholds and increased sensitivity. Superconducting detectors like Transition Edge Sensors (TES), Microwave Kinetic Inductance Detectors (MKID), and Josephson Junctions are attractive candidate technologies where the use of low Tc materials could enable them to address theses needs. I will present an overview of some ongoing work at Argonne National Lab for developing low Tc thin films, integrating them into new detector technologies such as athermal and bolometric TES detectors, and discuss future potential for other classes of devices.

Early Career:

RDC3+4+11 / **122**

InAs/GaAs Quantum Dot Scintillator for 4D Tracking Applications

Author: Tushar Mahajan[1]

Co-authors: Allan Minns [1]; Vadim Tokranov [1]; Michael Yakimov [1]; Michael Hedges [2]; Pavel Murat [3]; Serge Oktyabrsky [1]

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An InAs/GaAs quantum dot (QD) detector is a novel GaAs semiconductor-based scintillation detector utilizing artificial luminescent centers - epitaxial InAs QDs, combined with a monolithically integrated photodiode (PD) to collect the QD emission. To assess its feasibility for future tracking applications, we compare the parameters of this detector against a perspective Si Low Gain Avalanche Detector (LGAD) projected to have ~10 ps and 10 μm "4D resolution". Parameters of 25 μm thick QD scintillators with a 3 μm thick integrated PD are extracted from experimental studies supported by GEANT4 simulations. These parameters are compared to an LGAD sensor simulated using Weightfield2. For a QD luminescence decay time of 300 ps, the break-even point for 10 ps time resolution

between this detector and LGAD falls within a thickness range of 20 to 50 μm, where the Ramo current in silicon becomes comparable to the peak optical flux produced by the QDs. Fast and efficient optical collection of deposited energy is the enabling factor for the fast risetime of the scintillator. The QD detector parameters were obtained from the response to 60 keV and 122 keV gamma photons. The collected charge exceeds 90 photoelectrons per keV of the deposited energy, which contained a small contribution from direct ionization in the PD. The material's radiation resistance has been tested with 1 MeV H^+ fluxes of up to 10^{14} cm^{-2}. This enhanced radiation resistance is shown to result from the improved electron confinement in the QDs when higher barriers of wider bandgap semiconductor, AlGaAs instead of GaAs is used.

Early Career:

No

RDC9 / 123

The Optimal use of Segmentation for Sampling Calorimeters

Authors: Aaron Angerami[1]; Anshuman Sinha[1]; Benjamin Nachman[2]; Bishnu Karki[3]; Fernando Torales Acosta[2]; Kenneth Barish[3]; Miguel Arratia[3]; Piyush Karande[1]; Ryan Milton[3]; Sebastian Moran[3]

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We present a study on the impact of detector granularity on machine-learning-based energy regression for high-granularity sampling calorimeters. As a case study, we simulate the response of a detector similar to the forward calorimeter system intended for use in the ePIC detector, which will operate at the upcoming Electron-Ion Collider. Models using DeepSets and graph neural networks are trained on the simulated calorimeter showers, represented as point clouds. We train several models on detector simulations with different numbers of longitudinal sections to investigate the impact of increased longitudinal information on the model performance, defined in this work as energy scale and resolution for single-particle showers. We then train models on varied levels of calorimeter cell information, to further investigate the impact of longitudinal granularity, as well as the impact of transverse cell information on machine-learning-based energy regression. These results provide a valuable benchmark for ongoing EIC detector optimizations and may also inform future studies involving high-granularity calorimeters in other experiments.

Early Career:

Yes

RDC1 + RDC4: Session #1 / 124

GAMPix: A Novel Charge Readout Architecture for Enhanced Spatial and Energy Resolution in TPCs

Authors: Aldo Pena Perez[1]; Angelo Dragone[1]; Bahrudin Trbalic[1]; Dan Douglass[None]; Henry Purcell[None]; Hirohisa Tanaka[1]; Lorenzo Rota[1]; Mark Convery[1]; Miriam Moore[1]; Steffen Luitz[1]; Tom Shutt[1]; Yun-Tse Tsai[1]

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We introduce GAMPix (Grid-Activated Multi-scale Pixel readout), a novel charge readout system for TPCs, that is designed to enhance the accuracy of electron track reconstruction to the sub-millimeter level, while also ensuring high energy reconstruction accuracy with a low power consumption. The GAMPix system operates using coarse wire grids paired with pixel planes. The signal generated from the induction wire plane activates the pixel plane and the analog front end of a new, rapidly power-cycled ASIC. Our initial analysis indicates that GAMPix fulfills the stringent demands for GammaTPC, a proposed MeV gamma ray detector instrument concept relying on LArTPC technology. Beyond this, GAMPix showcases significant promise for broader applications, including use in the DUNE Phase 2 and similar cutting-edge experiments.

Early Career:

Yes

RDC1+2+7 / 125

Scintillating Bubble Chambers for Rare Event Searches

Author: Ben Broerman[1]

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The Scintillating Bubble Chamber (SBC) collaboration will combine the well-established liquid argon and bubble chamber technologies to search for GeV-scale dark matter and the coherent elastic neutrino-nucleus scattering from MeV reactor antineutrinos. SBC detectors benefit from the excellent electron-recoil insensitivity inherent in bubble chambers with the addition of energy reconstruction provided from the scintillation signal. The targeted nuclear recoil threshold of 100 eV is made possible by the high level of superheat attainable in noble liquids while remaining electron-recoil insensitive. Two functionally-identical, 10 kg detectors are being built. SBC-LAr10, under construction at Fermilab, will be used for engineering and calibration studies and a potential measurement of the coherent elastic neutrino-nucleus scattering on argon. A low-background version, SBC-SNOLAB, for the dark matter search will be operated at SNOLAB. An overview of scintillating liquid-noble bubble chambers and the physics potential of SBC-SNOLAB and SBC-LAr10 will be presented.

Early Career:

Yes

RDC1 + RDC4: Session #1 / 126

The LArPix Pixelated Charge Readout System for Liquid Argon TPCs

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The LArPix charge readout system is designed to provide native 3D readout of ionization charge signals in liquid argon time projection chambers (LArTPCs) in a way that is scalable to instrument large volumes. The system is compatible with large-scale commercial fabrication techniques, which enables low-cost quick-turn production. At the heart of the system is the low-power, cryo-compatible, 64-channel LArPix ASIC responsible for reading out analog signals sensed by millimeter-sized pixel pads on large-format anode tiles. The digitization and readout of signals on the pixels is self-triggered with a tunable threshold for the analog voltage on the pixel, which allows for manageable data rates for detectors with O(100K) channels and above depending on the level of activity in the detector. The 2x2 demonstrator is the largest LArPix-based detector to date, contains over 300K pixel channels, and is currently being installed in Fermilab's NuMI beamline where it will image neutrino interaction in the GeV energy regime. This talk will provide an overview of the LArPix system design and its implementation in the 2x2 demonstrator.

Early Career:

Yes

RDC4 / 127

CryoCMOS modelling and PDK development for GF 22 FDX

Authors: Davide Braga[1]; Olivia Seidel[1]

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Cryogenic Process Design Kits (PDKs) are an indispensable tool in the design of complex integrated circuits across a wide spectrum of applications, from noble element detectors to Quantum Information Science, Superconducting Nanowire Single Photon Detectors (SNSPDs), and precision atomic clocks. The development of PDK-compatible SPICE models is a complex endeavor requiring test structures, measurements, models and fitting. We will present the cryogenic modeling and development of a cryo-PDK for a 22nm FDSOI CMOS process for operation at 3.8 Kelvin.

Early Career:

No

Poster Session / 129

ATLAS ITk Pixel Module Electrical Quality Control

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The High-Luminosity Large Hadron Collider (HL-LHC) is set to commence operations in 2029 and will reach unprecedented peak instantaneous luminosity values, resulting in 200 proton-proton interactions per bunch crossing. To cope with this challenging environment, the ATLAS Inner Detector will be replaced by an all-silicon system, the Inner Tracker (ITk). The inner most part of the ITk will consist of a pixel detector, constructed from about 10,000 pixel modules for a combined active area of 13 m^2. Each of these pixel modules will undergo a rigorous electrical quality control (QC) testing procedure to ensure that they meet the required electrical specifications for optimal performance in the final detector.

Ensuring the uniformity and consistency of electrical tests across 25 different testing sites and several testing stages is of utmost importance. This talk will present the module electrical QC procedure and the specially designed tools aimed at addressing this challenge.

Early Career:

Yes

RDC4 / 130

Front-end Application Specific Integrated Circuits (ASICs) in 65 nm CMOS for Charge and Light Readout

Author: Prashansa Mukim[1]

Co-authors: Chao Zhang [1]; Dominik Gorni [1]; Gabriella Carini [1]; Grzegorz Deptuch [1]; Hucheng Chen [1]; Jay Hyun Jo [1]; Lingyun Ke [1]; Sergio Rescia [1]; Shanshan Gao [1]; Soumyajit Mandal [1]; Steven Kettel [1]; Xin Qian [1]

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In this talk, we present the progress on development of CMOS-based front-end application-specific integrated circuits (ASICs) for charge and light readout undertaken at Brookhaven National Laboratory. This design evolves from the LArASIC chip manufactured in 0.18 µm, that has been selected for charge readout in the liquid argon time protection chamber (LArTPC) in the phase I of DUNE. LArASIC is the first component in a 3-ASIC readout chain, realizing amplification with transformation of charge to a pulse-shaped voltage waveform. DUNE explores neutrino oscillations, interactions and transformations and is carried out at liquid argon temperatures (i.e., 87 K). The efforts aim at translation and introduction of the required modifications of the legacy design to a scaled CMOS technology, i.e., 65 nm, that can be used in future experiments. The front-end ASIC is designed to have two amplification stages with a programmable gain followed by a 5^{th} order semi-gaussian filter for pulse shaping, suitable to operate at cryogenic temperatures, while it also suits testing at room temperature. We will discuss the design choices we make for the 65 nm chip that enable readout with variable pulse peaking times in the long, i.e., 0.5-2 µs, and short 10 ns-100 ns range within a power budget of 10 mW with an ENC less than 500 electrons RMS with the input capacitance on the order of tens to hundreds of pico farads. Along with exploiting the benefits of transistor scaling and improved transistor f_T to achieve the above-mentioned goals, we make use of I^2C based programmability to create a more robust and flexible design. The targets for this development are such as light/charge readout in Far Detector (FD) 3/4 in phase II of DUNE, silicon based active target and LXe calorimeter in PIONEER, light readout in nEXO, etc.

Early Career:

Yes

Poster Session / 131

A scalable scientific detector platform (SSDP)

Author: Michael Farrier[1]

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As X-ray micro-CT applications drive development of the next generation of detectors to offer larger and variable fields of view combined with micron scale pixel resolution and high conversion efficiency, a scalable hybrid X-ray detector technology is under development. Direct hybrid X-ray detectors using amorphous Selenium (a-Se) deposited on 3T CMOS readout ASICs have been demonstrated with pixel sizes less than 7µm. Using reticle stitching methodologies available at CMOS foundries, readout ASIC's may be seamlessly patterned to create multiple sizes of die up to and including a die size that fits within a 200mm wafer (~ 90mm x 90mm FOV). To create larger FOV X-ray panel detectors using CMOS Readout ASIC technology, detector tiles (CMOS die + a-Se) are formed and physically aligned and closely butted together on a common substrate. Three side tileable ROIC tile designs may be constructed to enable 2 x N tile X-ray panel sizes.

There is a need in for high resolution X-ray imagery to be performed on increasingly large sample sizes, up to and including, mammographic and chest X-ray fields of view. It has been a challenge to obtain both large field of view combined with micron scale pixel pitch at affordable cost from commercially available detector sources. This work will combine the advantages of global shutter 4T pixel design (reduced motion blur in CT imaging), micron scale sampling resolution (phase contrast enhancement) variable die size reticle stitching, high frame rate, and 2 x N detector tile panel assembly, plus modular camera electronics design, to enable a detector platform that is scalable to meet the application and target size. The platform will be configured such that the modular camera electronics can accommodate 1 to 2N detector tiles using a common I/O bus and camera operational software. Development of a-Se deposition and patterning technology over large area die with 100 µm to 200 µm thickness and low defect density, will be required.

Once the development is completed, the scalable direct X-ray detector platform will enable researchers to scale up their imaging benches by adding detector tiles while using the modular camera electronics base. Researchers will not be forced to purchase expensive new X-ray cameras to accommodate changes of the experimental configuration and target size. This work will enable cost effective configuration of X-ray still imaging, dynamic imaging (fluoroscopic), and XCT applications.

Early Career:

Poster Session / 133

Backgrounds and decoherence due to energy accumulation and releases in materials

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The hypothesis of energy accumulation and release in materials allow an explanation for excess background events and noise spectra in different detectors and provides a general framework to analyze and deal with such phenomena: one needs to look at what states or defect can carry excess energy, how they can be produced in materials, how they interact, and how their production or interaction can be suppressed, or how these states can be quenched. We discuss the application of this approach to superconducting devices, with an emphasis on the backgrounds and noise at the smallest size and energy scale in superconducting nanowire single-photon detectors and superconducting qubits, and make predictions for new phenomenology to be present.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-PRES-855100

Early Career:

No

Poster Session / 134

Quantum micromachines and IR bioluminescence

Author: Sergey Pereverzev[1]

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Interactions of states storing excess energy in a system with energy flow can lead to avalanche energy releases (Self-Organized Criticality scenario), to correlations in energy releases in luminescence, electron emission, and other complex dynamics. While processes of uncontrolled releases of stored energy led to quantum errors and decoherence in quantum computers, these processes and correlations are regarded as essential for understanding live system functioning and live origin. There were no tools to look at these states and interactions inside live cells directly, but progress in detector technologies is making it possible. A multi-pixel array of Superconducting Nanowire Single Photon Detectors installed in the focal plane of a cooled IR grid monochromator is capable of detecting and time-stamping with resolution in ps scale all IR photons emitted by an object of live cell size in the wavelength region 1-30 μm. Here, "ALL" means random thermal background radiation emission and IR cell bio-luminescence, either self-(chemo-) luminescence accompanying cell biochemical processes or induced luminescence caused by intentional excitation of biomolecules with pulsed IR light source with controlled spectrum. Analyzing spectral and time patterns in the induced luminescence spectrum can provide real-time information on biochemical changes- i.e., functional imaging of live cells. Self-luminescence accompanying about 108 biochemical reactions per second in the living cell can be detectable. Detectors' time resolution and energy sensitivity are expected to improve, as well as capabilities in computer learning for time and spectral pattern analysis techniques for the "Big Data." IR emission of live samples can be coupled to a cryogenic monochromator and detector system with IR fibers, so the whole design can be compact and mass-produced for use in biomedical laboratories or can be installed on an unmanned mission to look for chemical and dynamical signatures of microbial life on other planets.
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-PRES-855094

Early Career:

No

RDC4 / 135

An input buffer for PSEC5 –a waveform sampling ASIC –in 65nm CMOS Technology with a 5GHz analog bandwidth

Authors: Richmond Yeung[1]; Henry Frisch[2]; Jinseo Park[1]; Eric Oberla[1]; Evan Angelico[3]; Hector Rico-Aniles[4]; Nathaniel Pastika[5]; Paul Rubinov[6]; Troy England[7]

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PSEC4 [1] has been utilized for waveform sampling in the PhD theses of E. Angelico[2] and E. Oberla[3] ,the Fermilab Test Beam, and the Accelerator Neutrino Neutron Interaction Experiment. PSEC5 aims to improve on its predecessor by raising the number of channels from 6 to 16, the sampling rate from 10 GSa/s to 40 GSa/s, and most importantly, achieving a timing resolution of 1 picosecond.

A buffer of high input and impedance and low output impedance is required to prevent any loading and disruption to the signal source, while driving the waveform to subsequent stages with minimal loss in signal quality.

We present an input buffer of said ASIC in the TSMC 65nm process, which provides an analog bandwidth of 5GHz, unitary gain, a significant DC offset to prevent a cutoff at 0V, and no AC phase difference using 2.5V nMOSFETs. The described input buffer is situated at the front end of the ASIC, feeding into three followers of a similar design. We will also discuss the larger scheme of the front end signal transmission.

We have simulated the buffer with a capacitive load of itself under a three times multiplier in order to account for the capacitance of the followers succeeding the input buffer using Cadence® Virtuoso® System Design Platform.

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1
[3] Eric Oberla; Charged Particle Tracking in an Optical Time Projection Chamber; Doctoral Dissertation, Department of Physics, University of Chicago

Early Career:

Yes

RDC4 / 137

Readout IC R&D for future Phase III High Luminosity Upgrade of the LHC

Author: Benjamin Parpillon[None]

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We introduce an Application Specific Integrated Circuit (ASIC) readout integrated circuit (ROIC) prototype designed using the CMOS 28 nm bulk process. This chip serves as a smart pixel concept

test chip for the Phase III high luminosity upgrade of the large Hadron collider.
Our design demonstrates a synchronous 40MSPS analog-to-digital converter (ADC) at the frontend, enabling data conversion within a single bunch crossing.
The prototype contains a 32x16 pixel matrix. Each pixel measuring 25×25 μm² and fully integrated with a charge-sensitive preamplifier with leakage current compensation and three auto-zero comparators for a 2-bit flash-type ADC. The power consumption is approximately 4 μW per pixel for an equivalent noise charge of 90 electrons at the output of all the hit comparators across the ROIC allowing an in-time threshold of approximatively 450 electrons.

Early Career:

No

RDC8 / 138

Optical Strain Sensing for Particle Detection

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Optomechanical strain sensing provides attractive opportunities for novel particle detection schemes, as well as studying stress-induced (i.e. non-radiogenic) phonon bursts, which have been demonstrated to limit the coherence times of superconducting qubits and are a suspected culprit in the low energy excesses observed by many dark matter direct detection experiments. We are investigating SiN microring optical resonator strain sensors, developed at Purdue University, for applications in fundamental particle sensing and QIS. These sensors can be embedded in the substrate upon which superconducting qubits are patterned, providing a handle to distinguish decoherence events of radiogenic origin from those due to crystal stress. In a similar way, these sensors can be operated in conjunction with superconducting detectors (e.g., MKIDs, TES) to enable multi-channel readout of particle interactions in the device substrate or serve as anticoincidence detectors, which may be required to identify low-energy interactions from dark matter particles down to the fermionic thermal relic mass limit of a few keV. Such sensors can potentially be used to directly observe resonant scattering processes of gamma rays (and perhaps neutrinos) where no detectable quanta are produced in the target, via the microscopic stress induced by the momentum transfer to the (fixed-in-place) crystal lattice as a whole. These strain sensors have so far found application in photonics and communications, but have yet to be adopted for HEP uses, where they can provide unique capabilities in the search for dark matter as well as understanding and improving the coherence times of superconducting qubits.

Early Career:

Yes

Poster Session / 139

The Detector Microfabrication Facility at SLAC for quantum and superconducting sensors

Author: Zeeshan Ahmed[1]

Co-authors: Hsiao-Mei Cho [1]; Dale Li [1]; Kent Irwin [1]; Paul Welander [1]

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We present plans for SLAC's Detector Microfabrication Facility (DMF), a dedicated 5,500 sq. ft. foundry for the R&D and at-scale production of quantum and superconducting sensors and devices with high purity, complexity, yield, and reproducibility. In addition to a specialized toolset on 150mm wafers, the DMF also includes necessary capabilities for post-fabrication metrology, room-temperature and cryogenic characterization, as well as validation of functionality and performance of devices produced at the DMF. The facility is envisioned to support DOE mission science by enabling collaborative research across universities, labs and industry in quantum information science and fundamental physics. The DMF staff will commission the toolset and begin process development in 2024. We expect to invite R&D projects and science collaborations from the community to take advantage of the DMF starting 2025.

Early Career:

Yes

Poster Session / 140

Instrumentation for Resolving Nuclear Recoils in Argon Based TPCs

Authors: Alexander Antonakis[1]; David Caratelli[1]

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Novel detection methods for nuclear recoil (NR) imaging have the potential to allow one to resolve weak signatures from Coherent Elastic Neutrino Nucleus Scattering (CEνNS) as a method to probe an exciting frontier of attractive new physics. CEνNS is postulated to be a critical background to future dark matter (DM) searches and measurements of these interactions in LAr targets may serve as a way to explore fundamental properties of neutrinos, lepton unitarity, sterile neutrino candidates, and the existence of new mediator particles. In this poster, we present our work at the University of California, Santa Barbara in the development of low threshold detectors using LArCADe anode geometries as well as nuclear recoil tracking in argon gas. LArCADe is a project being pursued jointly with colleagues at Fermilab aimed at increasing the scope of single-phase LArTPCs to be sensitive to nuclear recoil ionization signatures by means of charge amplification devices. In principle, this is achieved by using anodes with tip-like structures to create electric field amplification in highly localized regions. We present Monte Carlo predictions of stable charge amplification in LAr using this method with a microphysics simulation of electron transport in LAr across a range of anode configurations. The second component of our poster is an exploration of our abilities to resolve O(10-100) μm tracks originating from O(10-100s) keV sources with a GAr TPC. We will present details and available simulation studies of a potential apparatus that uses GEM-based readout electronics.

Early Career:

No

RDC2 / 141

Photon-Counting CCDs for Future Spectroscopic Surveys

Authors: Kenneth Lin[1]; Julien Guy[2]; Armin Karcher[2]; Stephen Holland[2]; Peter Nugent[3]

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The next generation of ground and space-based cosmic surveys in the optical to near-IR regime require extremely sensitive, virtually noiseless detectors that are capable of counting single-photon or single-electron events. Skipper charge-coupled devices (CCDs) offer the ability to achieve deeply sub-electron read noise by exploiting the technique of non-destructive readout to independently measure the charge in each pixel repeatedly to reduce noise to desired levels, while preserving the well-established characteristics of fully-depleted, backside-illuminated silicon CCDs including excellent low-light sensitivity, high quantum efficiency, and uniformity. However, the limiting factor for astronomical applications is the prohibitive read time that scales with the number of measurements per pixel. The Multi-Amplifier Sensing (MAS) CCD architecture evolved from the Skipper CCD to address this readout time penalty by allowing charge to be measured by a series of Skipper amplifiers interspersed along the serial register. This capability reduces the readout time by a factor of the number of amplifiers in the chain compared to a Skipper CCD for the same number of samples per pixel and equivalent noise level. We will present an overview of the MAS CCD and their role in the upgrade to the ongoing DESI massive spectroscopy survey and in the R&D of next generation surveys that builds on the success of the CCDs employed in the Dark Energy Camera and DESI. We will discuss the promising preliminary experimental efforts on instrumenting and testing the first MAS CCDs currently underway at LBNL and Fermilab. Finally, we will highlight science cases in the broader context of astrophysics that MAS CCDs would enable, from capturing faint transients to direct imaging and spectroscopy of Earth-like extrasolar planets.

Early Career:

RDC8 / 142

First Results from the GigaBREAD Experiment

Authors: Gabriel Hoshino[1]; Stefan Knirck[2]

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We will discuss the first results from the GigaBREAD experiment. GigaBREAD is a 10.7-12.5 GHz search for dark photons which completed its first round of data taking during the summer of 2023. GigaBREAD is a pilot experiment which is the first to implement the novel BREAD reflector geometry. The BREAD reflector is designed to enhance a dark photon or axion-like particle signal by focusing microwaves (or optical photons) to an antenna/sensor at the focal spot of the reflector. GigaBREAD couples a BREAD reflector to a custom microwave coaxial horn antenna to search for dark photon and axion-like particles in the gigahertz regime. A signal is received at the horn antenna and passes through an amplifier chain to an FPGA DAQ board which performs a real-time FFT and allows for efficient integration of small signals due to its low dead-time. Additionally, we discuss plans to search for axion-like particles in the same frequency range by placing the GigaBREAD detector in a 3 T magnet at Argonne National Laboratory.

Early Career:

Yes

Plenary / **143**

Skipper CCD-in-CMOS active pixel sensor: status and first characterization results

Authors: Adam Quinn[1]; Agustin Lapi[2]; Aseem Gupta[3]; Benjamin Parpillon[1]; Davide Braga[1]; Lorenzo Rota[3]; Miguel Sofo Haro[4]; Fabricio Alcade[4]

Co-authors: Angelo Dragone [3]; Farah Fahim [1]; Guillermo Fernandez Moroni [1]; Juan Estrada [1]

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The Skipper CCD-in-CMOS image sensor integrates the non-destructive readout capability of skipper Charge Coupled Devices (CCDs) with a high conversion gain pinned photodiode on a CMOS imaging process, while taking advantage of in-pixel signal processing.
We will present the first results of the testing of the first prototype ASIC, fabricated in a commercial 180nm CMOS processes, which integrates a pixel matrix as well as individual test structures. Individual pixels in the test structures of the fabricated devices were instrumented to characterize their charge transfer capability and to study their operation in low readout noise conditions. We were able to operate the pixel in single carrier counting mode with deep sub-electron noise to measure charge packets collected by the photodiode when exposed to low illumination levels. Additionally, we will also report on the status of the custom 65nm ASICs prototypes being developed to achieve high speed, sub-electron noise readout.

Early Career:

Yes

RDC4 / **144**

Scalable SNSPD cryogenic readout

Authors: Adam Quinn[1]; Boris Korzh[2]; Davide Braga[1]; Emanuel Knehr[2]; Farah Fahim[1]; Jeff Fredenburg[1]; Karl Berggren[3]; Kyle Woodworth[1]; Matteo Castellani[3]; Matthew Shaw[4]; Owen Medeiros[3]; Reed Foster[3]; Sangbaek Lee[5]; Whitney Armstrong[5]

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The HYDRA Microelectronics Codesign collaboration is developing scalable superconducting nanowire sensors (SNSPD) and cryogenic readout combining superconducting nanocryotrons and cryoCMOS ASICs operating at 4K.
We will present the status of the development of superconducting nanowire devices and circuit architectures, scalable high-density interconnect architecture for large-format SNSPD arrays at the 1 Kelvin stage, and a 32-channel 22nm cryoCMOS ASIC prototype for control and readout with ultrafast timing (10s ps).

Early Career:

RDC7 / 145

Energy dissipation and phonon kinematics simulation in qubits with G4CMP

Author: Israel Hernandez[1]

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In order to utilize qubits as particle detectors, understanding energy dissipation in qubit substrate (Silicon and Sapphire) through electron-hole pair generation and phonon kinematics is essential. These mechanisms are strongly associated with correlated errors in qubit chips, as observed in cosmic muon and gamma ray absorption events reported recently. We present our work on phonon kinematics simulation and the expected decoherence time of the simulated Silicon qubit chip using G4CMP. Furthermore, the scattering of sub-Mev Dark Matter (for scalar and vector mediators) can produce optical phonon excitations with sub-eV energy in Sapphire. In the second half of the talk, we also present our attempt to better understand energy dissipation in Sapphire with phonon caustics and kinematics simulation.

Early Career:

No

RDC11 / 146

Precision Timing Using Composite Microchannel Plates

Author: Eric Spieglan[None]

Co-authors: Camden Ertley [1]; Cameron Poe [2]; Henry Frisch [2]; Kepler Domurat-Sousa [3]

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We propose a technique to use composite microchannel plate detectors to measure the arrival time of particles. The resistive and electron multiplying functions of a microchannel plate can be constructed by thin coatings on many insulating substrates. Suitable substrates could produce the initial electrons for multiplication in situ. Such composite microchannel plates produced without fiber

drawing could function as both absorbing and amplifying elements in a detector system. We identify requirements in the detector to achieve 1 psec time resolution by this method.

Early Career:

RDC1 / 148

Hydrogen doping in liquid xenon TPCs (HydroX) at SLAC

Author: Drew Ames[1]

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Liquid xenon time projection chambers (TPCs) are leading the search for particle dark matter with mass greater than 5 GeV. HydroX is a proposed upgrade to enhance their sensitivity to masses as low as 10s of MeV, by doping the xenon with a light element such as hydrogen. The dopant nucleus provides a better kinematic match for lighter particles, but its presence may interfere with signal generation in xenon. This talk will give an overview of the HydroX test system at SLAC, which aims to study the production of light signals in xenon-hydrogen gas mixtures. Construction is nearly complete on the system, which includes a TPC instrumented with 32 PMTs, a test vessel for material compatibility studies, and a hydrogen-compatible gas circulation and recovery system.

Early Career:

Yes

Poster Session / 149

R&D program for Doped Liquid Argon TPCs

Author: Fernanda Psihas[None]

Co-author: Hannah LeMoine

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LArTPCs are the technology of choice for current and future neutrino experiments. This technology provides sensitivity to GeV signals like accelerator neutrinos down to the 10s of MeV, covering part of the supernova neutrino spectrum. Expanding the reach of LArTPCs to the 1-10 MeV range would substantially enhance the flagship analyses of experiments like DUNE, while enabling low-energy analyses.

We outline the R&D pathway for Ar + Xe + photosensitive dopants, whose introduction into the LAr, has the potential to substantially enhance ionization yields of LAr detectors. This scalable R&D program will demonstrate the feasibility and impacts of introducing doped LAr into current and future neutrino detectors at the kTon scale.

Early Career:

Yes

RDC4 / 150

From ETROC to VTROC (Vertically integrated Timing ReadOut)

Author: Tiehui Ted Liu[1]

[1] *Fermilab*

Corresponding Author: thliu@fnal.gov

The Endcap Timing ReadOut Chip (ETROC) is designed to process LGAD signals with time resolution down to about 40-50ps per hit, to reach 30-35ps per track with two detector layers. The ETROC2 is the first full size (16x16) prototype design and is fully compatible with the final chip specifications in terms of functionality. The ETROC2 has been extensively tested recently. In this talk, the testing results of the ETROC2 will be presented first, including performance study using charge injection, laser and beam, as well as TID testing and wafer probe testing to study the yield. In addition, future challenges of precision position and timing ASIC design will be discussed, based on what we have learned from the ETROC development, and how the challenges could be addressed in the VTROC, Vertically integrated Timing ReadOut chip (funded as SBIR phase 2) for precision position and timing detector R&D.

Early Career:

No

RDC7 / 151

Dark sector searches with skipper-CCDs: current status and future ideas

Author: Brenda Aurea Cervantes Vergara[1]

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Skipper-CCDs, with their electron-counting capability, are among the leading technologies in the exploration of the dark sector, with g-size experiments imposing stringent limits on dark sector - standard model particle interactions. In this talk, I will summarize the current status of Oscura, the first massive (10 kg) skipper-CCD array aiming to search for sub-GeV dark matter. I will also discuss the capability of this technology to explore the dark sector at accelerator facilities, particularly showing sensitivities to beam-produced millicharged particles. Finally, I will discuss future ideas to enhance dark sector searches, including the development of fast readout sensors with single electron resolution.

Early Career:

Yes

RDC7 / 152

Nuclear recoil calibration for rare event searches

Author: Jingke Xu[1]

Co-authors: Phil Barbeau [2]; Ziqing Hong [3]

[1] *Lawrence Livermore National Laboratory*

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Detection of nuclear recoil events plays a central role in dark matter and neutrino scatter experiments. Precise nuclear recoil calibration data allow the responses of these detectors to be characterized and enable in situ evaluation of an experiment's sensitivity to anticipated signals. Using a few examples, we discuss the main experimental factors that are critical for accurate nuclear recoil calibrations, investigate mitigation strategies for different backgrounds and biases, and discuss how the presentation of calibration results can facilitate comparison between experiments.
Prepared by LLNL under Contract DE-AC52-07NA27344 (LLNL release number LLNL-ABS-855092).

Early Career:

Yes

Poster Session / 153

Status of ADRIANO2 R&D in T1604 Collaboration

Authors: Corrado Gatto[1]; T1604 Collaboration[2]

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A novel high-granularity, dual-readout calorimetric technique (ADRIANO2) is under development as part of the research program of the T1604 Collaboration[1]. The building block of such a calorimeter comprises a pair of optically isolated, small tiles made of scintillating plastic and lead glass. The prompt Cerenkov light from the glass can be exploited to perform high resolution time measurements while the high granularity provides good resolution of the spatial components of the shower. Dual-readout compensation and particle flow techniques applied to the plastic and lead glass sections should provide excellent energy resolution as well as PID particle identification, making ADRIANO2 a 6D detector suited for High Energy as well as High Intensity experiments.
Several prototypes have been built and tested at the Fermilab Test Beam Facility. A report on the ADRIANO2 project, current and future R&D plans by T1604 Collaboration, and the results of ongoing data analyses will be presented.

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References
1. http://www-ppd.fnal.gov/FTBF/TSW/PDF/T1604_mou_signed.pdf (2019)

Early Career:

Poster Session / 154

TinyTPC - A test stand for photosensitive dopants

Author: Hannah LeMoine[None]

Co-author: Fernanda Psihas

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LArTPCs are designed to explore signals with energies as low as 10s of MeV. To improve the LArTPC's energy resolution at the MeV range, photosensitive dopants may be used. These dopants convert light to charge and have the potential to increase ionization yields. We built a LArPix test stand, TinyTPC, to demonstrate this technology and study potential enhancements for next generation LArTPCs. We plan to compare TinyTPC's energy resolution with and without dopants for radioactive sources and determine optimal doping strategies. This presentation will describe the status and progress of the TinyTPC test stand and analysis.

Early Career:

Yes

Poster Session / 155

Maximizing Filtration Efficiency for Gadolinium Sulfate Retention in Water-Based Liquids Scintillators

Author: DeAngelo wooley[1]

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In this study, we used a state of the art filtration machine to refine the filtration process for water-based liquids scintillators (WBLS). Our primary objective was to optimize the retention of gadolinium sulfate while concurrently eliminating optical contaminants. Through meticulous experimentation, we determined the precise filter size crucial for preserving the integrity of gadolinium sulfate within the WBLS.

Encouraged by these promising results, we extended our investigation to a larger scale, employing a robust 30-ton filtration machine. This expansion aims to validate and replicate the success achieved with the smaller scale apparatus. Preliminary findings suggest that the filtration efficiency demonstrated in the original setup can be successfully scaled up, opening avenues for large scale experimental setups.

This breakthrough not only ensures the reliable retention of the target substance but also elevates the purity of WBLS by effectively removing micellar contaminants. Our research contributes not only to the advancement of filtration technology but also holds significant implications for experiments that wish to use WBLS.

Early Career:

No

RDC5 / 156

Yet Another Rapid Readout - For ATLAS Inner Tracker during HL-LHC

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The Inner Pixel Tracker (ITkPix) is the most important subdetector in ATLAS for tracking and vertexing of the charged particles produced in the collisions. Being closest to the beam pipe, it also has the highest flux of particles traversing through the material per unit area at any given time. During HL-LHC, the number of particle interactions in every bunch crossing will increase manifolds. Hence, there will be a need for an efficient readout software which can cope with receiving hit data from the Front-Ends (FEs) and to support FE-specific calibrations at MHz frequencies. At LBNL, we have designed such a software, known as Yet Another Rapid Readout (YARR), which is in fact a very flexible implementation for various FE types and supports various hardware platforms where an FPGA is interfaced via a PCIe link. With YARR, we can perform readout of a single chip for smaller scale developments to actually reading out multiple modules to simulate a more realistic detector-like scenario. We have a test-stand with the ITkPix v1.1 modules with the FELIX hardware, where we are carrying out testing and developments for the ATLAS community, which will be later used for actual operations such as the system tests and data-taking.

Early Career:

Yes

RDC4 / 158

Emerging approaches for a flexible and energy-efficient readout

Author: Prafull Purohit[1]

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In a standard active pixel sensor, every pixel records brightness information which is sent out to the acquisition system through some sort of readout mechanism. Depending on the experiment requirements, a readout mechanism ranging from a completely serial readout to a completely parallel readout has been proposed by the research community. Like every other circuit design, each readout mechanism has an associated tradeoff in terms of power, performance, or area (PPA). In this review, we will introduce some of the readout approaches and present a comparison of emerging approaches for a flexible and energy-efficient readout.

Early Career:

Yes

RDC7 / 159

Non-linear kinetic inductance devices for dark matter searches

Author: Ritoban Basu Thakur[1]

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Non-linear kinetic inductance (NLKI) enables engineering sensitive devices that operate at the quantum limit. This talk will cover kinetic inductance traveling wave parametric amplifiers (KI-TWPAs) and spectrometers being developed at JPL and Caltech. With relation to KI-TWPAs we will also showcase a hidden photon search experiment QUantum LImited PHotons In the Dark Experiment (QUALIPHIDE) and outline the plans for expanding to wider mass ranges. Finally, we will briefly review a new class of superconducting spectrometers, e.g. the superconducting on-chip fourier transform spectrometer (SOFTS), and their potential for dark matter searches.

Early Career:

Yes

Plenary / 160

2023 DPF Instrumentation Award

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"For their experimental proof and subsequent characterization of radio emission from high-energy particle cascades, the Askaryan Effect, which has been used in searches for the highest energy astrophysical (PeV and EeV) neutrinos. They have utilized the lunar regolith, Antarctic ice sheet, salt and other dielectrics as detector materials. In addition, they have studied the radio signatures of magnetic emission from the highest energy cosmic rays. And finally, for development of calorimeters and timing planes for future high energy physics collider detectors utilizing the Askaryan effect."

Plenary / 161

2023 DPF Instrumentation Early Career Award

Corresponding Author: dadwyer@lbl.gov

"For his work on 3D pixelated readout technology for liquid argon time projection chambers (LArPix). This low power, low noise custom ASIC with dynamic i/O, capable of running in liquid argon, has helped open the field to advanced systems on chips. Such technologies underpin the modular DUNE ND-LAr near detector which will need to make precise measurements in a high flux environment with event pileup for the ultimate measurements of neutrino oscillations and CP violation in the neutrino sector."

Plenary / 162

2023 DPF Instrumentation Awards

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https://cpad-dpf.org/?page_id=750

Plenary / 163

2023 GIRA Awards

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https://cpad-dpf.org/?page_id=750#temporaryId12

Plenary / 164

A Qubit Inspired Ion Sensor for Barium Tagging in Neutrinoless Double-Beta Decay Searches

Plenary / 165

Development of Quantum Optomechanical Sensors for Dark Matter and Sterile Neutrino Searches

Plenary / 166

First Definitive Demonstration of Electron Counting in Three Dimensions

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Early Career:

RDC3+4+11 / 167

Investigating the impact of 4D tracking in ATLAS beyond Run 4

Authors: Ariel Schwartzman[1]; Lorenzo Santi[2]; Valentina Cairo[1]

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The Inner Detector of the ATLAS Experiment will be upgraded to a full-silicon Inner Tracker (ITk) to cope with the extreme conditions of the High-Luminosity phase of the Large Hadron Collider, currently foreseen to start with Run 4 towards 2029. In order to address the challenge of pileup in the forward region of ITk, a High Granularity Timing Detector (HGTD) will provide time track measurements with a precision of 30ps for tracks with pseudo-rapidity larger than 2.4. Due to the high radiation dose in proximity of the interaction point, the two innermost pixel layers of the ITk are designed to be replaced after 2000 fb−1. This represents a unique opportunity to bring in technological innovation and fully exploit the potential of HL-LHC by including fast- timing through 4-dimensional (4D) tracking in the ATLAS barrel region, enabling full hermitic coverage when combined with the HGTD. In this contribution, we will demonstrate how the availability of a timestamp for the tracks in the central ATLAS region allows to significantly enhance the physics potential and discovery reach beyond what can be achieved with the HGTD alone.

Early Career:

No

Poster Session / 168

Cryo-CMOS at SLAC: Present and Future

Author: Aldo Pena Perez[1]

Co-authors: Gunther Haller ; Liang Yang ; Lorenzo Rota ; Mark Convery ; Sander Breur ; Shawn Henderson ; Tom Shutt ; Zeeshan Ahmed

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SLAC is pursuing a central role in advancing cryogenic-CMOS development across a spectrum of High-Energy Physics (HEP) experiments. These endeavors encompass diverse domains, including neutrino science through projects like DUNE and nEXO, as well as investigations in quantum computing and Cosmic Frontier research efforts. The latter involves Cosmic Microwave Background surveys, searches for axions or light dark matter, gamma-ray detection in space, and exploration of gravitational wave observatories. Presently, the readout of cryogenic sensors and detectors utilized in these experiments encounters challenges stemming from the segregation of readout electronics, conventionally designed for higher operating temperatures. This necessitates extensive cabling and introduces limitations on analog readout bandwidth, hindering scalability for experiments with large channel counts. Cryogenic ASICs offer a remedy, facilitating cost-effective sensor multiplexing schemes, supplying low-noise amplification along with waveform digitization, and delivering lower noise currents and voltages for sensitive circuits. The appeal of cryogenic ASICs lies in their potential to simplify complexity, reduce costs, and enhance performance margins for ambitious scientific undertakings across the HEP landscape.

This work will showcase a brief overview of SLAC's commitment to advancing specialized cryo-CMOS electronics aimed to support these experiments. We explore their applications in liquid-argon (LAr) and liquid-xenon (LXe) detectors, featuring System-on-Chip (SoC) implementations like CRYO ASIC for nEXO and ongoing endeavors in GAMPix. The latter is a high-granularity charge readout system designed for a LAr-based Gamma-ray detection instrument and holds the potential for application in future DUNE modules 3rd and 4th. Expanding into the realm of High-Energy Physics (HEP) applications, particularly in the extreme cold environments encountered in projects like CMB-S4, we will outline the significant challenges posed by this project. Additionally, we will provide insights into our recent R&D initiative program, dedicated to the development of cutting-edge cryo-CMOS circuit techniques. The program leverages the state-of-the-art 22nm FDSOI ultra-low-power,

rad-hard technology, capable of reliable operation down to 4K as the primary technology node. Furthermore, this R&D initiative will serve as the foundation and risk mitigation strategy for the future development of SoC ASICs tailored explicitly for cryogenic experiments and will also yield valuable advantages for forthcoming liquid noble gas experiments.

Early Career:

No

RDC8 / 169

Cryogenic Crystal Phonon Detectors for meV-keV Signals

Author: James Ryan[1]

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Experiments employing transition-edge sensors (TESs) coupled to crystals for athermal phonon detection are a major part of the worldwide effort to detect dark matter. Such detectors can provide the highest sensitivity to meV to keV-scale signals from a variety of dark matter candidates, including axion-like particles, dark sector dark matter, and WIMPs. We review the current status of the detectors used by the SuperCDMS SNOLAB experiment. We then describe advances in several areas aimed at meV-scale excitations, including carbon-based detector fabrication, SQUID-based TES readout, and work to move to RF-based readout, including KIDs and SQUATs.

Early Career:

Yes

RDC8 / 170

Sapphire substrate qubit-based detector for light dark matter search

Author: Kester Anyang[1]

Co-authors: Rakshya Khatiwada ; Ryan Linehan

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Harnessing sub-eV energy excitations from light dark matter interaction with a target material is one of the challenges in exploring promising novel materials for dark matter searches. In polar materials like sapphire, dark matter interaction can excite sub-eV optical phonon modes. Furthermore, the anisotropy of sapphire crystal could provide a signature of daily modulation of the dark matter scattering rate, making it a promising target material. We plan to utilize superconducting qubits on a sapphire substrate to take advantage of the excitation of phonons, which scatter and further down-convert to lower-energy phonons. A good fraction of these phonons are expected to reach the qubit superconductor on the substrate and break Cooper pairs. Such a process can cause qubit decoherence, which can be measured using standard qubit readout protocol. In this talk, we describe our ongoing attempt to build such a prototype detector.

Early Career:

No

RDC8 / 171

Novel Light Field Imaging for the MAGIS-100 Experiment

Authors: Ariel Schwartzman[1]; Jason Hogan[2]; Michael Kagan[1]; Murtaza Safdari[1]; Sanha Cheong[3]; Sean Gasiorowski[1]

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Long-baseline atom interferometry presents an exciting opportunity for DOE to develop a new program of research in quantum atomic sensors for ultralight dark matter and mid-band gravitational waves. The development and science exploitation of long-baseline atomic experiments promises an ambitious long-term research program at the intersection of the energy, cosmic, and quantum information frontiers, complementing the physics potential of colliders and other dark matter experiments. Scaling existing atom interferometers to terrestrial 100m and kilometer-scale and space experiments will require investment over the next 10 years to support design studies for the next generation of experiments and to develop the core technologies required to achieve the science goals. National Laboratories will be critical to achieve this scale. The MAGIS-100 experiment, now under construction at Fermilab, will be the first large-scale quantum sensor of its kind in the US. This contribution will present a high-level introduction to MAGIS-100 and focus on the design of a novel tomographic imaging system: a Super-aperture 3-Dimensional (3D) light-field imaging device. The system is designed to maximize the total light collection by capturing a larger solid angle of light than a conventional lens with equivalent depth of field. This is achieved by populating a plane of virtual objects using mirrors and fully utilizing the available field of view and depth of field.

Early Career:

RDC8 / 173

Ultralight Axion Dark Matter Search using Optical Quantum Sensors

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An optical quantum sensor (OQS) based on lasers and alkali-metal atoms is currently the most sensitive ambient-temperature magnetometer. Because of high sensitivity and operation in a broad frequency range, the OQS can be used in axion dark matter search with an inductor-capacitor (LC) circuit at kHz and MHz frequencies. In this talk, we will present our recent activities on OQS-based axion dark matter search at Los Alamos National Laboratory. Our search targets an extremely weak axion-induced oscillating magnetic field in the presence of a static magnetic field. We investigate the sensitivity of an LC circuit-OQS axion detector to ultralight axion dark matter that could be potentially reached by an OQS performing close to the fundamental quantum noise levels of 10 aT. We

anticipate that such an experiment could probe benchmark quantum chromodynamics (QCD) axion models in an unexplored mass range near 10 neV.

Early Career:

No

RDC7 / 174

Scintillating Crystals for Directional Detection of Sub-GeV Dark Matter

Author: Daniel Baxter[1]

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The only unambiguous way to detect dark matter (DM) scattering in a direct detection experiment is with a detector capable of distinguishing the direction of the incident particles. Even without event-by-event directionality, such a detector can use the daily modulation (or lack thereof) of measured rates to detect (or set strong limits on) DM-electron scattering, even over otherwise-limiting backgrounds. To be sensitive to sub-GeV DM scattering, an experiment needs to maintain directional sensitivity down to eV-energies. Organic scintillating crystals, such as trans-Stilbene, offer great promise as sub-GeV directional DM detectors. The scintillation light from these crystals can be measured using optically-sensitive Skipper CCDs, potentially launching a new application for the technology. I present a proposal for a modular, segmented array of crystals that can be read out using such Skipper CCDs that has the potential to push past otherwise-limiting excess backgrounds and unambiguously observe DM scattering using directionality.

Early Career:

Yes

RDC 7+8 / 175

Energy and charge accumulation and release in xenon and argon dual-phase detectors

Author: Sergey Pereverzev[1]

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Xe and Ar dual-phase detectors cannot detect nuclear recoils with energies below 200 eV because of the limitations of ionization processes. Still, the number of excitations and defects in these detectors, which can store energy and produce delayed or excess background electron and photon emission, is lower than in solid-state sensors. Combined with larger mass, this can provide superior sensitivity of dual-phase detectors to nuclear recoil in the 200-2000 eV energy range. We discuss differences in backgrounds observed in detectors with different designs and possible microscopic energy and charge release mechanisms. Uncontrolled accumulation of unextracted electrons on liquid-gas interphase can lead to instabilities of the charged liquid surface in the electric field, delayed electron emission events, and changes in electron extraction efficiency. Different experiments indicate trapping and delayed release of electrons in bulk liquid by yet unidentified mechanism. We discuss design changes and R&D required to decouple, investigate, and suppress these mechanisms. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-PRES-855099Xe and Ar dual-phase detectors cannot detect nuclear recoils with energies below 200 eV because of the limitations of ionization processes. Still, the number of excitations and defects in these detectors, which can store energy and produce delayed or excess background electron and photon emission, is lower than in solid-state sensors. Combined with larger mass, this can provide superior sensitivity of dual-phase detectors to nuclear recoil in the 200-2000 eV energy range. We discuss differences in backgrounds observed in detectors with different designs and possible microscopic energy and charge release mechanisms. Uncontrolled accumulation of unextracted electrons on liquid-gas interphase can lead to instabilities of the charged liquid surface in the electric field, delayed electron emission events, and changes in electron extraction efficiency. Different experiments indicate trapping and delayed release of electrons in bulk liquid by yet unidentified mechanism. We discuss design changes and R&D required to decouple, investigate, and suppress these mechanisms. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-PRES-855099

Early Career:

No

RDC3+4+11 / 176

AstroPix: Low Power CMOS Detectors

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AstroPix is a high-voltage CMOS monolithic silicon detector that was designed for space-based applications, specifically gamma-ray trackers. It targets low power operation in a relatively low occupancy environment with minimal dead material. These traits are synergistic with an imaging calorimeter as well and AstroPix will be the silicon technology in the Electron Ion Collier barrel electromagnetic calorimeter covering approximately 100 square meters. Characterization and performance results will be shown.

Early Career:

Yes

RDC8 / 177

Quantum Capacitance Detectors for Ultralight Dark Matter searches.

Author: Jialin Yu[1]

Co-authors: Aaron Chou [2]; David Harrison [3]; Pierre Echternach [4]; Rakshya Khatiwada [5]; Robert Mcdermott [3]

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QCDs, which are based on a charge qubit design, are the most sensitive far-infrared detectors in 1.5 THz regime. Apart from their current application in space telescopes for infrared spectroscopy, they have single-photon sensitivity that can be utilized to look for ultralight Dark Matter at the meV scale. This talk will give an overview of our work to characterize a QCD detector using a weak photon source. Furthermore, we will discuss readout and optimization of these detectors to reduce the current dark count rate of 100 Hz, with the goal of reaching sensitivities needed for ultralight Dark Matter detection.

Early Career:

RDC4 / 178

Advanced time-division transition-edge sensor readout development for CMB-S4

Author: Shawn Henderson[1]

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The next generation CMB-S4 survey aims to map the Cosmic Microwave Background (CMB) with unparalleled sensitivity in order to measure and constrain a vast range of fundamental physics including inflation, exotic light relics, and dark energy. To meet its sensitivity goals, the experiment requires fielding about 500,000 photon-noise limited superconducting transition edge sensors (TES) in cryogenic receivers in a diverse set of large and small aperture telescopes. In order to reduce cost, integration complexity, and thermal load on the lowest temperature stages of the cryogenic receivers, the transition edge sensors must be multiplexed using low temperature superconducting quantum interference device (SQUID)-based electronics. Incorporating recent advancements in low temperature SQUID multiplexer technology, we are developing a new SQUID-based time-division multiplexing system for the CMB-S4 project targeting a number of improvements including higher bandwidth and multiplexing factor, lower wire count per sensor, and lower readout noise. These improvements aim in particular to overcome the bandwidth limitations of prior implementations in order to enable higher multiplexing factors and lower total wire counts. We report on the design, characterization, early performance of the first realization of this new cryogenic readout architecture and present our plans for further optimization and development for the CMB-S4 project. The new readout technologies we are developing for CMB-S4 have wide potential applicability to other high energy physics (HEP) efforts.

Early Career:

Yes

Plenary / 179

Thin film particle tracking detectors

Author: Sungjoon Kim[1]

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Thin film technology such as chemical vapor deposition and atomic layer deposition can deposit a variety of materials with high precision over large areas. Thin film detectors incorporate semiconducting materials for the sensing layer and also potentially electronic elements into a monolithic design. Fabrication of thin film detectors is possible on large, flexible substrates which can scale to cover large areas (>100m2) of detectors. These detectors have the potential to build upon their unique properties and offer advantages such as faster response times, operation without cooling, radiation hardness, and less dead detector material. To explore this possibility, three promising semiconductors were chosen from the list of candidates and tracking detectors were fabricated with single crystal materials: indium phosphide, cadmium zinc telluride, and diamond. The resulting detectors were tested in-lab using radiation sources, as well as the high-energy proton beam (120 GeV) from the Fermilab test beam facility. Of the fabricated detectors, the indium phosphide detector showed very fast response time of ~ 250 picoseconds and a pulse amplitude of ~50 mV under room temperature operation.

Early Career:

Yes

RDC9 / 180

The LFHCAL forward hadronic calorimeter for the EPIC detector at the EIC

Author: Oskar Hartbrich[1]

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The Electron Ion Collider (EIC) is the next Nuclear Physics flagship experiment to be constructed at Brookhaven National Lab over the next decade. The EPIC detector will be the first experiment at the EIC dedicated to detailed studies of nuclear structure in electron-proton and electron-ion collisions.

The ambitious physics program of the EIC requires a high performance hadronic calorimetry system in the hadron-going "forward"region. Accurate jet measurements are crucial to reconstruct the full 3D nucleon tomography and to study the gluon saturation region. The main goal of the Longitudinally segmented forward HCal (LFHCAL) is measuring the energies of jets and distinguishing between overlapping jet depositions to high accuracy in the jet energy range up to 120 GeV.

LFHCal is designed as a plastic scintillator-steel sandwich calorimeter. The plastic scintillator is transversely segmented into 5x5 cm2 tiles. Each tile is directly coupled to a silicon photomultiplier. The electrical signals of all photomultipliers are routed out of the LFHCAL to be digitized by external readout electronics based on the H2GCROC3 developed for the CMS HGCAL project.

This talk will present the current status of the LFHCAL for the EPIC experiment including results from SiPM characterization measurements and scintillator light yield comparisons from lab measurements as well as initial results from a first small-scale testbeam prototype operated at CERN PS and SPS in the fall 2023.

Early Career:

No

RDC6 / 181

Machine Learning for Improved Analyses of High Resolution Gaseous Detector Data

Author: Jeffrey Schueler[1]

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Advances in computer vision techniques over the past decade have enabled high performance, real-time analyses of 2D and 3D images, opening up the possibility of not only classification and regression tasks, but also more complicated tasks like object detection, key point detection, and semantic segmentation of image data. In this talk, we detail examples of machine learning techniques applied to data from micro-patterned gaseous detectors (MGPDs) for (1) improving particle identification, (2) improving low-energy angular resolution and directional head/tail performance in prototypes for the proposed CYGNUS experiment, and (3) improving signal efficiencies in the rare event search for the Migdal effect. The deep learning algorithms discussed here can, in principle, be applied to both 2D and 3D images, and are thus suitable both for gas TPCs with optical readout or charge readout.

Early Career:

Yes

Poster Session / 182

Warm Electronics for Time Division Multiplexed (TDM) SQUID readout of CMB-S4

Authors: Benjamin Reese[1]; David Goldfinger[1]; Gunther Haller[1]; Leonid Sapozhnikov[1]; Ryan Herbst[1]; Shawn Henderson[1]; Zeeshan Ahmed[1]

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We present the new warm electronics for Time Division Multiplexed (TDM) readout of the CMB-S4 microwave background telescopes. The system consists of "Row Address"and "Column Readout" boards which can be grouped together in modular fashion for readout of each detector wafer. Each Row Address board is capable of addressing 32 signals used for flux-activated switches. Each Column Readout board provides bias, feedback and readout for 8 columns of Superconducting Quantum Interference Device (SQUID) amplifiers operating at 100 mK and 4 K temperature stages. It also provides bias for the 100-mK Transition Edge Sensors (TES) being amplified by each SQUID. Firmware

on the module implements a servo loop to bias the SQUIDS at the optimum operating point. A timing distribution and communications loop between all boards in a group allows one board to coordinate timing between all boards in the group, and multiplexing readout data to the back-end DAQ system. The first prototypes have been developed and are fully functional and have been connected to a cryogenic readout chain at SLAC for testing and analysis.

Early Career:

RDC7 / 183

Studying Correlated Charge Fluctuations in Superconducting Qubits in a Low-Background Underground Facility

Author: Hannah Magoon[1]

Co-authors: Daniel Baxter [2]; Daniel Bowring [2]; Enectalí Figueroa-Feliciano [3]; Grace Bratrud [3]; Grace Wagner [2]; Jialin Yu [4]; Kester Anyang [4]; Samantha Lewis [5]

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Abstract: The search for increasingly low-mass (sub-GeV) dark matter motivates the development of detectors with sub-eV energy thresholds. Quantum sensors such as superconducting qubits have demonstrated great promise in this regime. Particle interactions in the substrate of these devices can generate phonons and liberate charge carriers. Propagation of these events can induce a spatially-correlated response across multiple qubits. In this talk, we will discuss preliminary studies involving an array of weakly charge-sensitive qubits being operated in NEXUS, a low-background facility located 100 meters (225 m.w.e) underground at Fermilab. Here, we map correlated charge fluctuations in the presence of various radiation sources and shielding configurations. We will use this suite of measurements to quantify the effects of potential backgrounds and to inform the design of robust detector schemes and test facilities.

Early Career:

No

Poster Session / 184

Future detector readout

Author: Alexander Paramonov[1]

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Evolution of the ATLAS detector readout is driven by the rapid development of COTS network and computing systems. The Front-End Link eXchange (FELIX) system takes advantage of the new COTs components to reduce complexity and life-cycle effort. FELIX is an interface between the trigger and detector electronics and commodity switched networks for the ATLAS experiment at CERN. This rapid improvement in commodity computing enables triggerless readout of the future experiments that maximizes their discovery potential. On-detector data processing and availability of radiation-hard and cryogenic-capable fast data links will be key to enabling the triggerless readout. In this talk we will discuss link technologies, on-detector data processing, and where to find the balance.

Early Career:

No

RDC8 / **185**

Quantum-Enhanced Telescopy for HEP Science

Author: Paul Stankus[1]

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Astronomical measurements, particularly using optical interferometers, can be improved – in some cases greatly so – through the new application of quantum devices such as quantum memories, single-photon sources, quantum repeaters, quantum teleportation, and more. We will review recent work in this field, a.k.a. "quantum telescopy" and show how quantum-linked optical arrays can directly address HEP science drivers for the Cosmic Frontier through distance ladder measurements, GR tests, and even observation of gravitational wavew. This will lead into discussion of new technological needs.

Early Career:

No

RDC5 / **186**

An In-Network Event Builder for the Mu2e TDAQ System

Authors: Sean Cummings[1]; Hyunsuk Bang[1]; Nishanth Shyamkumar[1]; Michael H L S Wang[2]; James B Kowalkowski[2]; Ryan Rivera[2]; Nik Sultana[1]

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The muon campus program at Fermilab includes the Mu2e experiment that will search for a charged-lepton flavor violating processes where a negative muon converts into an electron in the field of an aluminum nucleus, improving by four orders of magnitude the search sensitivity reached so far.

The Trigger and Data Acquisition System (TDAQ) of the Mu2e projects consists of commercial, off-the-shelf (COTS) servers that receive digitized data from the read-out controllers (ROC) over a custom optical links protocol through a commercial PCIe FPGA card, which then conducts real-time event building over a commodity Ethernet network.

This talk describes the first hardware prototype of an in-network program that is applied to DAQ real-time event building networking. This program executes on a commodity programmable Ethernet switch that interconnects the commercial PCIe FPGA card (i.e., the Data Transfer Controller).

This prototype is being built to explore performance and programmability features that exceed the original Mu2e design specification, to study the use of programmable network hardware for use in future HEP experiments.

Early Career:

Yes

RDC7 / 187

Cryogenic optical beam steering for calibration of superconducting sensors

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A major obstacle in the search for detection of meV-scale rare events is demonstrating sufficiently low energy detection thresholds in order to detect recoils from light dark matter particles. Many detector concepts have been proposed to achieve this goal, which often include novel detector target media or sensor technology. A universal challenge in understanding the signals from these new detectors is characterization of detector response near the detection threshold, as the calibration methods available at low energies are very limited. We have developed a method of cryogenic optical beam steering that can be used to generate O(μs) pulses of small numbers of photons over the energy range of 0.1-5 eV and deliver them to any location on the surface of a superconducting device with time and energy features comparable to expected signals. This allows for robust calibration of any photon-sensitive detector , enabling exploration of a variety of science targets including position sensitivity of detector configurations, phonon transport in materials, and the effect of quasiparticle poisoning on detector operation. In this talk, I will review the operating principles of optical beam steering, present current results from both the pulse creation and pulse delivery systems, and discuss the implementation of this technology for various sensors such as KIDs and qubits.

Early Career:

Yes

RDC3 / 188

Studies of InP as a sensor material for tracking system based on thin film technology

Authors: Anirudha Sumant[1]; Anthony Affolder[2]; Dennis Sperlich[3]; Earl Russell Almazan[4]; Ian Dyckes[5]; Jason Nielsen[6]; Jennifer Ott[7]; Jessica Metcalfe[1]; Luise Poley[8]; Manoj Jadhav[1]; Mike Hance[6]; Sungjoon Kim[9]; Vitaliy Fadeyev[10]

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We are exploring the properties of different sensor materials to enable large-scale low-mass tracking detectors for future colliders and other applications. For this purpose, we are targeting materials amendable to fast and economical fabrication methods, for example Indium Phosphide (InP). First devices have been fabricated in different electrode geometries on single-crystal 350 μm thick InP:Fe wafers. In this contribution we present results on fundamental device characterization tests using a variety of methods: IV, CV, response to red laser stimulus (waveform response and spatial scans), response to beta particles from Sr-90 source, area uniformity assessment with focused X-ray beams.

We find the InP material to feature a very fast response, due to the high electron mobility. It is larger than in silicon by about a factor of 4. The timing resolution of about 35 ps was achieved without any special bulk modification techniques. A channel response within 5x5 pad array was characterized. High charge collection was achieved. The area scans with focused X-rays showed a typically uniform response within the electrode area. Several additional features are under investigation, and a set of devices has been irradiated for the radiation tolerance assessment. The compilation of the results supports the initial goal of exploring this material with mass-manufacturing fabrication techniques as the next step.

Early Career:

Yes

RDC1+2+7 / 189

Novel Applications of Superconducting Nanowire Detectors in Nuclear Physics

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We report ongoing efforts in developing superconducting nanowire single photon detectors (SNSPDs) for nuclear and particle physics applications. SNSPDs offer unique set of capabilities which are well suited for accelerator facilities with significant cryogenic infrastructure to support operation of superconducting magnets. We will give an overview of targeted applications which leverage new modes of instrumentation at the Electron-Ion Collider and Jefferson Lab. We will report on a new liquid helium active target concept under development for high luminosity fixed target experiments at Jefferson Lab in Hall-C and the SoLID detector.

Early Career:

Yes

RDC6 / 190

High-resolution gas TPCs for next-generation intensity frontier tracking

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In the next decade, intensity frontier experiments will require tracking systems that are robust against high event and background rates while maintaining excellent tracking performance. I will discuss the first conceptual design of a tracking system for a hypothetical future experiment–imagined as an upgrade of or successor to Belle II–built around a gas time projection chamber with high-resolution readout. At sufficiently high event rates continuous readout is mandatory, necessitating charge amplification and readout that is continuous and ungated, without degrading track parameter measurement resolution. This capability is achievable using existing–but still quite young and underutilized–integrated grid technology

Early Career:

RDC4 / 191

Design Updates for HPSoC: A very high Channel Density Waveform Digitizer with sub-10ps resolution

Authors: Abraham Seiden[1]; Bruce Schumm[2]; Hartmut Sadrozinski[3]; Isar Mostafanezhad[4]; Jennifer Ott[1]; Simone Mazza[None]

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We present the architectural design, prototype fabrication and and first results for the High Pitch digitizer System-on-Chip (HPSoC). The HPSoC is a high channel density and scalable waveform digitization ASIC with an embedded interface to advanced high-speed sensor arrays such as e.g. AC-LGADs. The chip is being fabricated in 65nm technology and targets the following features: picosecond-level timing resolution; 10 Gs/s waveform digitization rate to allow pulse shape discrimination; moderate data buffering (256 samples/chnl); autonomous chip triggering, readout control, calibration and storage virtualization; on-chip feature extraction and multi-channel data fusion.

Early Career:

Yes

RDC9 / 192

Water-based Liquid Scintillator 30-ton Demonstration and Calorimetry Application

Authors: Richard Rosero[1]; Sasmit Gokhale[1]; Minfang Yeh[1]

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The water-based liquid scintillator (WbLS) has many potential applications in nuclear and particle physics and other rare-event detections. The WbLS, as the primary detector target, allows simple detector design, minimum chemical hazard, and adjustable scintillation light yield. In addition, the separation of scintillation and Cherenkov events enables directional reconstruction and enhances low energy efficiency. WbLS also provides a new approach loading inorganic metallic ions from aqueous solution directly into the organic scintillator liquid to enhance detector sensitivity and expand physics reach for a wide range of particle interactions with adequate photon yield and high optical transparency. This talk will report on the feasibility development, in terms of formulation, characterization, and production, of kiloton-scale WbLS deployment via the study of a 30-ton Demonstrator at BNL. The use of WbLS as a highly pixelated, imaging detector to deduce event topology enhancing particle identification for calorimetry application will also be discussed. This research was funded by Brookhaven National Laboratory LDRD 12-033 and by U.S. Department of Energy Grant No. DE-SC0012704.

Early Career:

RDC1 / 193

Multiple Argon Experiments (MArEX) at n_TOF

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Liquid argon has become the primary detector material in many neutrino and dark matter experiments like DUNE, SBND, ICARUS, MicroBooNE, and DarkSide. In particular, multi-kiloton experiments like the Deep Underground Neutrino Experiment (DUNE) have stringent requirements for systematic uncertainties on the energy scale and resolution. Neutron production from neutrino interaction brings a large uncertainty on neutrino energy reconstruction. Calibrations to achieve these requirements also face a hurdle as the DUNE far detector is located 1.5 km underground. One of the proposed calibration systems is the Pulsed Neutron Source (PNS) system which utilizes neutrons traveling long distances in liquid argon to calibrate the enormous DUNE far detector volume.

Thus it is of utmost importance to understand neutron propagation and capture in liquid argon. In recent times, the ACED and the ARTIE experiments at LANSCE have taken steps to precisely measure the neutron capture cross section at eV energies and total cross section in the 20-70 keV region respectively. Through the Multiple Argon Experiments (MArEX) initiative, we endeavor to perform accurate measurements for the transmission and capture reaction channels for neutron interactions in liquid argon at the n_TOF facility in CERN.

The first tests for the feasibility of transmission measurements have been performed recently at n_TOF and in this presentation, I will present some preliminary results from this test run.

Early Career:

No

RDC3+4+11 / 194

The Development of Silicon Carbide Low Gain Avalanche Detector

Authors: Ben Sekely[1]; Carl Haber[2]; Greg Allion[1]; John Muth[1]; Philip Barletta[1]; Sam Turkington[1]; Spyridon Pavlidis[1]; Stephen Holland[2]; Tao Yang[2]; Yashas Satapathy[1]

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High-energy and high-luminosity collision experiments on the future collider demand higher radiation resistance and time resolution detectors due to events pile-up. Silicon Low-gain avalanche detectors (LGADs) with excellent time resolution have been identified for use in collider experiments, such as ATLAS and CMS experiments. However, due to the inherent properties of silicon material, the operating voltage and temperature requirements for irradiated Si LGADs are even more demanding. Especially in environments with irradiation fluences exceeding $10^{16} n_{eq}/cm^2$ and under general detector operating conditions, there is a need to explore new solutions.
In comparison to silicon, silicon carbide (SiC) offers lower intrinsic carrier concentration, faster carrier saturation drift velocity, higher breakdown electric field, and greater theoretical radiation resistance. This makes it a promising candidate for applications in collider experiments.
In recent years, with the increasing demand for commercial silicon carbide power devices, related silicon carbide processing technologies have rapidly advanced. This has made it possible to fabricate multi-layer epitaxial structures of silicon carbide devices, such as SiC LGAD. However, the fabrication of SiC LGAD also imposes additional requirements on the processing technology, such as ultra-low-doped silicon carbide epitaxial layers, precise control of epitaxial layer doping concentration and thickness, and small bevel angle termination etching. We will report on the latest developments in SiC LGAD conducted by Lawrence Berkeley National Laboratory(LBNL) and North Carolina State University (NCSU).

Early Career:

RDC8 / 195

KID-based phonon-mediated (KIPM) detectors

Author: Osmond Wen[1]

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KID-based phonon-mediated (KIPM) detectors have two features that make them attractive for dark matter searches and CEvNS studies: 1) the massive multiplexability of KIDs enables the position

resolution necessary for nuclear recoil discrimination; and 2) a variety of amplifier-based and KID-specific improvements chart an attainable path forward to sub-eV energy resolution. We report on the progress of two different KIPM detector architectures optimized for each of these goals. Architecture 1: a 9-gram 80-KID KIPM detector demonstrates clear dependence of pulse shape on KID location relative to event position. Furthermore, the non-uniformity in the amplifier-limited energy resolution among the KIDs in this device is amenable to improved RF engineering, which will be necessary to obtain sub-eV amplifier-limited resolution on energy absorbed in each KID. Architecture 2: a 1-gram, single-KID KIPM detector has shown a resolution of 2.5eV on energy absorbed in the KID (albeit with low phonon collection efficiency). Future devices that recover the 10%-level efficiency seen in earlier devices could then achieve eV-scale resolutions. Finally, we will present the result of a KIPM detector whose readout was amplified by a kinetic inductance traveling wave amplifier to achieve few-quanta noise and 5x improvement in amplifier-limited resolution.

Early Career:

No

RDC2 / 196

Analog optical signal transmission for HEP experiments

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A critical element in all high-energy physics experiments is the signal transmission from the active elements to the data acquisition system. It is especially challenging in large volume detectors based on noble liquids that are extensively being used for dark matter and neutrino detection.

The topics of this contribution is the optical signal transmission of the signals acquired with silicon photomultipliers, which is able to satisfy many stringent experimental requirements. It is RF-noise immune and operates in cryogenic liquids and in high-electric fields.
This transmission system is based on commercially available electronics components and customized Fabry-Perot laser diodes.
I will talk about encountered challenges, breakthrough, and advances from the original concept of this system up to final validation tests, demonstrating progressive developments.

Early Career:

Yes

RDC2 / 197

VUV light collection enhancement with metasurface lenses

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Vacuum-ultraviolet (VUV) light has applications in many areas of fundamental research and technology, including high-energy physics (HEP) experiments and especially those based on scintillation of

noble elements (xenon and argon).
There are persistent challenges associated with the detection of the VUV photons in particle detectors, e.g. strong absorption by structural materials and low detection efficiency of the photosensors. Metasurfaces are relatively novel nano-fabricated devices which offer unprecedented control of light with a wide field of view and diffraction-limited focusing.
This contribution will present the first linear metasurface lens operating in the VUV spectral range with the measured diffraction efficiencies above 50%.
The design and fabrication processes will be described in detail, as well as the characterization measurements, and possible applications in the HEP experiments will be discussed.

Early Career:

Yes

RDC6 / 198

sPHENIX TPC in the 2023 commissioning run

Author: Evgeny Shulga[1]

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The sPHENIX experiment at RHIC was fully assembled and started its first commissioning run in the summer of 2023. This experiment will further investigate the microscopic nature of sQGP through precision measurements of jet, upsilon, and open heavy flavor probes over a broad pT range. The Time Projection Chamber (TPC) is one of the main tracking detectors in the sPHENIX detector. It is designed for operation in a 1.4 T magnetic field and high luminosity collisions to provide a rapidity coverage of $|\eta|<1.1$ and over the full azimuth.
Amplification in the TPC is provided by the quadruple-GEM stack. The signals are collected with zigzag patterned readout pads, and processed with the SAMPA ASIC. The stability of the GEM performance is controlled with the fast trip protection system. Two laser systems are tested and installed to calibrate the static and dynamic distortions.
In this talk, we will present the highlights of the first months of operation of sPHENIX TPC in the commissioning run.

Early Career:

Yes

RDC8 / 199

R&D for Use of Superconducting Qubits as Dark Matter Detectors

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Developments over the last decade have pushed the search for particle dark matter (DM) to new frontiers, including the keV-scale lower mass limit for thermally-produced DM. Galactic DM at this mass is kinematically matched with the energy needed to break a Cooper pair in common superconductors (~meV). Quantum sensors such as superconducting qubits are sensitive to these broken Cooper pairs, and can potentially be exploited as low-threshold detectors for particle-like DM scattering. The Quantum Science Center group at Fermilab exploring the use of qubit-based detectors for particle detection in the LOUD surface dilution fridge facility. This talk will discuss recent R&D efforts to understand qubit response to energy depositions through a combination of measurements in LOUD and low-energy G4CMP simulations of our superconducting qubit chips.

Early Career:

Yes

RDC8 / **200**

Thermal Kinetic Inductance Detectors for millimeter wave cosmology

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We are currently developing thermal kinetic inductance detectors (TKIDs) for CMB observations and millimeter wave spectroscopy. TKIDs use the temperature dependance of a KID-like high Q resonator as a drop in replacement to TESes, granting bolometric arrays the ease of KID-like readout. We will report on the laboratory performance of an array of antenna coupled KIDs designed for CMB observations at the South Pole. We will also report on early stage work developing lower Tc high resistivity TKIDs that would operated background limited under the lower loading environments of space CMB observatories or the narrow bandwidths typical of millimeter wave spectrometers.

Early Career:

No

RDC9 / **201**

Dual-readout calorimetry with homogenous crystals

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The Calvision project seeks to develop high resolution calorimetry for a future lepton collider with state-of-the-art performance for both electromagnetic (EM) and hadronic signatures using the dual-readout technique. We seek to improve the hadronic energy resolution of homogenous scintillating-crystal calorimeters through the measurement and separation of the scintillation and Cherenkov

light in hadronic showers. The research program considers materials, sensors, light-collection techniques, readout, raw-signal analysis, and reconstruction algorithms to improve the data collected at a Higgs factory. This talk will briefly introduce the goals of the research program and review some of the initial measurements from our first test beam efforts aimed at studying the collection of Cherenkov and scintillation signals in homogenous crystals applicable to an EM layer with dual-readout capability.

Early Career:

No

RDC6 / **202**

A Gaseous Argon-Based Near Detector to Enhance the Physics Capabilities of DUNE

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DUNE aims to measure CP violation in the leptonic sector, observe supernova burst neutrinos, and detect rare processes such as proton decay. To achieve these goals, DUNE will use a highly capable suite of near detectors. The DUNE Near Detector complex for Phase II includes ND-GAr, a magnetized high-pressure gaseous-argon TPC (HPgTPC) surrounded by a calorimeter. Due to the low detection threshold of HPgTPC, ND-GAr will be able to constrain one of the least understood sources of uncertainty in the oscillation analysis: nuclear effects in argon at the neutrino interaction vertex. Ongoing R&D efforts for HPgTPC will be discussed.

Early Career:

Yes

RDC8 / **203**

Superconducting Parametric Amplifiers

Author: Kyle Woodworth[1]

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Parametric amplifiers continue to be vital components in solid state quantum readout at cryogenic temperatures. Various flavors of parametric amplifiers are carving their place in a number of different readout architectures. Josephson junction (JJ) based amplifiers are the natural progression when these readout architectures are at deep cryogenic temperatures. Josephson traveling wave parametric amplifiers (JTWPA) and Josephson parametric amplifiers (JPA) are the two main contenders of JJ based amplifiers. These types are further divided into current pumped and flux pumped operating modes. Current pumped designs require a directional coupler at the input to combine the signal tone

with the pump tone. Whereas a flux pump designs mutually couples the pump tone over the entire amplifier as the signal tone travels through it. JTWPAs have a wider bandwidth than their JPA counterparts. The JTWPA acts as a non-linear transmission line which requires dispersion engineering. The JPAs are narrowband amplifiers, but can be tuned to a desired frequency.

We have designed flux pumped JTWPA and JPA devices with MIT-LL's SFQ5ee process. The JTWPA was designed to operates from 4-12 GHz at 6dB of power gain. Our JPA's are designed to operate at 7.5 GHz with 20db of power gain. We will report on the design while we prepare for packaging and testing ahead of the prototype delivery in November of 2023.

Early Career:

No

RDC 7+8 / 205

Investigation of the low energy excess in SuperCDMS HVeV detectors and its potential subtraction for enhanced dark matter sensitivity

Author: Osmond Wen[1]

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A variety of detectors across many different rare event search experiments have reported a rising sub-keV low energy excess (LEE) in the spectra of both total substrate energy deposits eV_t and ionization-producing energy deposits eV_{ee}. It has been hypothesized that non-ionizing substrate events such as stress-induced events from crystal or film relaxation could be a possible source of the low energy excess in eV_t. The spectrum of these non-ionizing events has been termed 0QLEE. SuperCDMS High Voltage (HV) detectors are a type of phonon-mediated detector that is sensitive to eV_{ee} by way of Neganov-Trofimov-Luke phonon production from voltage-driven charge drift; as phonon-mediated detectors, they are also sensitive to the non-ionizing components of the eV_t spectrum. The most recent deployment of a prototype HV-style detector called HVeV saw greatly decreased rates of the ionizing low energy excess in comparison to previous runs. At these lower rates, measurement of the 0QLEE contribution to the HVeV phonon spectrum at high voltage may now be possible via *in situ* operation of the detector at zero voltage. I will present on this technique as well as the expected gain in sensitivity from subtracting the 0QLEE background in search of charge-producing dark matter.

Early Career:

No

Poster Session / 206

Investigating e- Light Yield in Scintillating Media

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An understanding of the electron light yield of organic scintillators is important for a variety of high energy physics (HEP) applications, from neutrino studies to the detection of exotic matter.

However, measurements of the electron light yield in organic scintillators are scarce, and there is a general misunderstanding that the electron light yield is linear above 40 keV. This misconception often results in poor light output calibration, biasing organic scintillator ionization quenching studies and response simulations. No theoretical model can predict the response of ions in organic scintillators, particularly at low energies, possibly due in part to poor treatment of the contribution of secondary electrons to the light output. Given the widespread use of organic scintillators in dark matter, antineutrino studies, and other HEP applications, accurate light calibration and understanding of the response to nuclear recoils is needed. The goal of this work is to establish a platform for measuring the light output of scintillating media as a function of electron energy in collaboration with Lawrence Berkeley National Laboratory (LBNL). To this end, simulations have been conducted to design and optimize an experimental setup to measure the electron light yield over a broad energy range using an array of organic scintillators and Compton scattering kinematics. It is expected that this investigation will help to adjudicate controversial measurements in literature while also providing the community with new low energy electron light yield data for a wide range of scintillating media including new classes of scintillators such as organic glasses, triple-mode plastic scintillators, and water-based liquid scintillators.

Early Career:

RDC6 / **209**

Digital RPC Gas Calorimetry for future colliders

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University of Iowa, ANL, together through CALICE collaboration developed the Digital Calorimeter. The detector uses RPCs as active media and is read out with 1 x 1 cm 2 pads and digital (1-bit) resolution. Our group has the necessary expertise to develop alternative RPC gases, a gas recycling facility and HV system up to 8 kV. We will also develop low resistivity glass with the optimum resistivity to allow larger counting rates but still have the desirable RPC performance.

Early Career:

No

RDC3 / **210**

LIGHTWEIGHT EMBEDDING AND INTERCONNECTION OF FLEXIBLE ULTRA-THIN SILICON DETECTORS

Author: Mathieu Benoit[1]

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Silicon sensors play a crucial role in High-Energy and Nuclear Physics (HEP & NP) experiments, providing high-precision position and timing measurements for traversing particles. Their utilization is essential for
achieving the physics program goals of most ongoing and future NP and HEP
experiments. In the future of nuclear and particle physics research, it is imperative to instrument large areas with silicon sensors to enable a comprehensive 4-dimensional reconstruction of particles and their decay products, encompassing position and time.
In order to overcome the fragility of modern paper-thin silicon pixel detectors, like the ALICE ITS3 MAPS sensors, that are fabricated in deep submicron CMOS processes, we propose the development of a lightweight embedding process into thin polymer foils. This process will provide mechanical stability as well as electrical connections for power and data transfer into and out of the embedded sensor assembly while fully maintaining the flexibility of the thinned silicon. As such, this will ultimately enable the large-scale application of ultra-thin large-area silicon sensor technologies. Moreover, such highly resistant and low-power embedded sensors have broad applications in biomedical, environmental, and material science fields, as well as in ongoing and future low-energy experiments.

Early Career:

No

RDC4 / 211

Machine-Learning-Based Regression for Edge Data Reduction of Small Pixel, High-Bandwidth Silicon Detectors

Authors: Aaron Young[1]; Alice Bean[2]; Mathieu Benoit[3]; Shruti Kulkarni[1]

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Based on deep-sub-micron CMOS processes, modern silicon pixel detectors exhibit large arrays of fine-pitch pixels. They are designed to provide
unprecedented precise information on particle detection, encoded in pixel addresses, energy, and Time-of-Arrival, and provide a large bandwidth for reading out this information. Information on the initiating particle interaction is determined from data analysis by clustering pixel hits in geometrical and temporal patterns to calculate the time and position of the interaction in the detector. Modern data analysis methods, based on machine learning and neural networks,can be exploited to perform data stream reduction in such detectors at a high rate, at the edge of the detector, contributing to the reduction in services in future detectors, the reduction of the bandwidth required for extraction of the data from the detector and to minimizing data storage need for experiments.
We propose the development of a Spiking Neural Network (SNN) for the
clustering and fitting of small-pixel, large-area, high-bandwidth silicon detector data stream. In this approach, an FPGA-based SNN is employed to perform the aggregation of pixels in a particle detection event, and the regression calculation necessary to reconstruct the timing and spatial information of the interaction. The SNN will be trained using Allpix2 simulation data and experimental data from test beams using a high-precision tracking telescope. We propose to use the Timepix4 technology or similar high bandwidth ASIC for experimental validation of the method.

Early Career:

No

RDC7 / 212

Characteristic Sensitivity and Dark Count Rate of a Low Tc Ir-Pt Bilayer Infared TES

Author: Maggie Reed[1]

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In recent years, Transition Edge Sensors (TES) have been developed and used in a variety of experiments, such as low-energy Dark Matter (DM) searches, high sensitivity astroparticle measurements, and quantum information devices. For ultra-sensitive light DM direct detection and infrared photon sensing, TES with low superconducting transition temperatures (Tc) and low dark counts are required. TES superconducting film material can strongly impact calorimeter response, and Tungsten has traditionally been the film of choice for these appli- cations. However, reproducibility with Tungsten films has always been less than ideal. In this talk, we present the measured sensitivity and dynamical charac- teristics of a low Tc Iridium-Platinum (Ir-Pt) bilayer infrared TES. Our results indicate that Ir-Pt TES are promising new low energy DM search devices with sub-eV energy resolution and reliable, precise Tc control. This sub-eV device could also be used in future optical haloscope dark photon searches and other low threshold dark count experiments.

Early Career:

Yes

RDC3 / 213

Introduction to RDC3

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RDC3+4+11 / 215

Discussion of Commonalities (MAPs)

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RDC3+4+11 / 216

Discussion of Commonalities (Timing)

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RDC6 / 217

Compact TPC with TimePix Readout as a PID and tracking device

Author: Prakhar Garg[1]

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In this presentation, we will present a TimePix readout-based Time Projection Chamber as one of the options for the Particle Identification (PID) and to aid the tracking capabilities. TimePix based readout opens an interesting possibility to perform PID via cluster counting with high separation power for pion, kaon, and proton identification. The added benefit of using this device is the smaller track length requirement as compared to the conventional dE/dx methods for PID and the capability to reconstruct the decay topologies. Further the momentum resolution is expected to improve significantly because of the large number of space points with such a device.

Early Career:

Yes

RDC6 / 218

Gaseous Detector R&D aimed at Recoil Imaging

Authors: James Battat[1]; Majd Ghrear[2]; Hima Korandla[2]; Michael Litke[2]; Dinesh Loomba[3]; Jeffrey Schueler[3]; Thomas Thorpe[4]; Elizabeth Tilly[3]; Sven Vahsen[2]

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Directional detectors of low-energy nuclear and electronic recoils would enable unique dark matter searches and neutrino experiments. I will introduce the motivation and the CYGNUS proposal to build a large-scale detector of this type, and review R&D on gaseous detectors that achieve directionality by reconstructing the detailed topology of recoils in gas. If time allows, I will also comment briefly on broader impacts and other applications of the detectors being developed.

Early Career:

No

RDC4 / 219

DC-DC Converters Using New Materials and Architectures

Author: Adrian Nikolica[1]

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Future detector systems will require miniaturized, low mass, low electromagnetic interference (EMI), magnetic field tolerant, and radiation tolerant power converters. One approach is to use on-chip or on-module DC-DC converters. These converters typically use inductors as an energy storage element, which can by physically large compared to the electronics they power, and require EMI and magnetic shielding. Inductors can be difficult to miniaturize and integrate on-chip while maintaining high efficiencies. Switched capacitor (SC) offer an alternative for on-chip DC-DC converters, but can suffer from low efficiencies because of bottom-plate leakages, and generally have fixed voltage conversion ratios. Piezoelectric resonators (PRs) show promise for a new class of resonant DC-DC converters. PRs have been demonstrated to work in buck and boost configurations for a large range of power output. PRs can be miniaturized while maintaining high quality (Q) factors and thus realize high efficiencies, and are low EMI. We present work at the University of Pennsylvania on PR converters, and propose investigation into opportunities in PR converters and alternative inductor-less converter designs.

Early Career:

No

RDC4 / 220

Introduction: RDC4 and work planning

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ASIC and Electronics Workforce Development

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RDC4 / 225

Kicking our Veto Addiction: Accelerating Edge Computing for Tailored Lossy Compression

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Work packages planning

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Cold Electronics: Progress and Potential

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DRD7 Perspective on R&D for ASIC and Electronics

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Work Packages Planing

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Work Packages Planning

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Opening Remarks

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Including a welcome to SLAC from new director John Serrao

Plenary / 232

Introduction to CPAD and RDCs

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Plenary / 233

Overview of DRDs in Europe

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Plenary / 234

Detector Challenges for Future Colliders

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Early Career:

Plenary / 235

Quantum Devices for HEP

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Detectors for DUNE Phase 2

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Perspective from DRD2

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RDC 7+8 / 239

Roundtable Discussion: Synergies Between Low-Background Detectors and Quantum Sensing

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RDC2 / 240

75-Progress on a SiPM for readout of the fast component of BaF2 scintillation light

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RDC6 / 241

Overview and Status of DRD1 in Europe

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I will report on the formation of the new DRD1 detector R&D collaboration (focused on gaseous detectors) in Europe.

Early Career:

No

Plenary / 242

SiPM for the Tile Calorimeter Insert

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RDC8 / 243

RDC8 coordination effort summary

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Early Career:

RDC8 / 244

RDC8 pair-breaking detectors summary

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RDC8 / 245

RDC8 coherent wave detectors summary

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ECFA Detector R&D roadmap for Quantum Sensing summary

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Detector R&D roadmap for Quantum Sensing (DRDq) summary

Early Career:

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RDC8 work packages discussion

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RDC5 / 248

Introduction to RDC5

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Early Career:

RDC5 / 249

Discussion

RDC5 / 250

Future detector readout

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Evolution of the ATLAS detector readout is driven by the rapid development of COTS network and computing systems. The Front-End Link eXchange (FELIX) system takes advantage of the new COTs components to reduce complexity and life-cycle effort. FELIX is an interface between the trigger and detector electronics and commodity switched networks for the ATLAS experiment at CERN. This rapid improvement in commodity computing enables triggerless readout of the future experiments that maximizes their discovery potential. On-detector data processing and availability of radiation-hard and cryogenic-capable fast data links will be key to enabling the triggerless readout. In this talk we will discuss link technologies, on-detector data processing, and where to find the balance.

RDC8 / 251

AMO, NMR, Interferometry, clock detectors RDC8 subgroup

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Early Career:

RDC8 / 252

Novel Material/Theory and Modeling RDC8 subgroup

Early Career:

RDC6 / 253

MPGD as tracker for EIC

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(on behalf of EIC-eRD108 MPGD consortium)
Excellent tracking over large kinematic acceptance is one of the most important requirement for EIC Physics program. The proposed MPGD trackers in EIC will cover both central and forward rapidity regions to provide additional space point to complement Si hits needed for pattern recognition along with nominal timing resolution for background rejection. This talk will focus on current MPGD configuration in EPIC along with various R&D activities to develop low channel, low radiation length and good spatial resolution MPGD tracker which can be used either as an upgrade for EPIC or as main tracker in possible second detector in EIC.

Early Career:

Yes

RDC10 + System Integration / 254

Detector R&D Towards a 10 TeV Muon Collider

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Merged with #10 titled “Towards the Muon Collider Detectors”

RDC10 + System Integration / 255

The DUNE FD2 Photon Detection System: Implementing novel concept of signal over fiber and power over fiber transmission

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RDC10 + System Integration / 256

Energy Frontier Tracking Detector Mechanics R&D at Argonne National Laboratory

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RDC10 + System Integration / 257

A 1:100 Scale Pathfinder for the The OSCURA Experiment

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RDC10 + System Integration / 258

Multifunctional Composite Sensor Support Structure with Integrated Cooling

Co-authors: Andy Jung [1]; Eduardo Barocio Vaca [2]; Sushrut Karmarkar [2]; Sushrut Karmarkar [2]

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Early Career:

RDC10 + System Integration / 259

RDC10 Mechanics & Cooling: Directions and Goals

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RDC8 / 260

Microwave kinetic inductance detector development for the SPT-3G+ camera on the South Pole Telescope

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SPT-3G+ is the planned next-generation camera for the South Pole Telescope (SPT). Building on three generations of increasingly sensitive SPT cameras, SPT-3G+ will observe the mm/sub-mm sky at 220, 285, and 345 GHz, beyond the peak of the cosmic microwave background (CMB) blackbody spectrum. Consisting of 34,000 monochroic microwave kinetic inductance detectors (MKIDs)

across seven wafers, SPT-3G+ will provide a high-frequency, high sensitivity complement to the existing SPT-3G dataset.SPT-3G+ will target cosmological observables such as the kinematic Sunyaev-Zel'dovich (kSZ) effect, placing new constraints on the timing and duration of reionization, and the recombination-era Rayleigh scattering of the CMB, a new probe of cosmic expansion and ionization history. It will also enable the detection of new high-redshift dusty star-forming galaxies, extend the SPT cluster search to higher redshift, characterize astrophysical foregrounds, such as the cosmic infrared background, on small angular scales, and extend SPT astrophysical transient observations into the sub-mm band. I will present a brief overview of the SPT-3G+ instrument, followed by a more detailed discussion of the SPT-3G+ detectors. I will show updated SPT-3G+ pixel designs at all three observation frequencies along with an overview of array fabrication efforts at both the University of Chicago and Argonne National Laboratory. Finally, I will show test results from recent prototype wafers and describe upcoming plans for fabrication and testing as we move further along the path toward full deployment-sized arrays.

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Millimeter-wave Superconducting Spectrometers for Next-Generation Cosmology

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The most compelling open questions in cosmology – understanding the nature of inflation, dark energy, dark matter, and light relativistic species – require cosmic surveys over extremely large volumes. The emerging technique of millimeter-wave line intensity mapping (LIM) has the potential to measure large-scale structure at distances far greater than the next generation of optical surveys. But while pathfinder instruments are now demonstrating the technique, they lack the sensitivity to constrain cosmology. Next-generation LIM experiments with orders of magnitude more sensitivity will require large-format arrays of on-chip superconducting mm-wave spectrometers. I will discuss the technical advances needed for these detectors to achieve their potential, including novel spectrometer architectures, R&D in superconducting materials, and advanced microwave readout technologies. I will also outline the path towards deploying these detectors at scale in a staged series of LIM experiments, including the SPT-SLIM pathfinder deploying next year and an eventual upgrade to the future SPT-3G+.

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Improving light coupling into instruments with integrated photonic and low temperature sensors

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Superconducting Nanowire Single Photon Detectors for Dark Matter Detection and HEP

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Superconducting nanowire single photon detectors (SNSPDs) are the most advanced sensors available for time-resolved single photon counting from the ultraviolet to the infrared. We will discuss

recent advances in SNSPD technology, including demonstration of dark count rates below 1e-5 cps, scaling to large-format arrays (up to 400 kpix), single-photon sensitivity at wavelengths as long as 29 μm, ultra-high time resolution (as short as 3ps FWHM at visible wavelengths), and ultra-high count rates (1.5 Gcps). We will discuss the prospects for extending these performance metrics even further, and discuss potential applications of SNSPD technology in HEP, including dark matter detection.

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LuSEE Night Electronics Design

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LuSEE-Night is a project to investigate the feasibility of measuring the fundamental physics processes occurring during the cosmic Dark Ages using instrumentation on the lunar surface. The "Dark Ages" refers to the cosmic era between the last scattering of the cosmic microwave background (CMB) and the time when the first stars and galaxies formed. Only cold, non-luminous hydrogen gas existed during this epoch. The experimental Dark Ages program is based on observations of the hyperfine 21-cm transition of neutral hydrogen, seen against the backlight of the CMB. The global (sky-averaged) spectrum of the redshifted 21cm line is sensitive to the temperature and ionization state of the hydrogen gas and provides a tomographic probe of the thermal history of the early universe. The highly redshifted frequency range between 4 and 40 MHz is particularly of interest. Because of strong terrestrial RFI and ionospheric distortions, this signal cannot be observed from the Earth or from Earth orbit. The detector will therefore be stationed on the lunar surface, on the radio-quiet far side facing away from Earth. To avoid interference from solar RF emissions, cosmology observations will take place during the lunar night.
The LuSEE-Night instrument is a radio frequency spectrometer consisting of a set of antennas, analog and digital signal processing electronics, and the necessary mechanical, thermal, communications, and power delivery hardware to support reliable operation on the lunar surface. Together, the antenna and preamplifier electronics are designed to be sky-noise limited over the 1 - 50 MHz band. Each antenna's output is processed by a signal chain having analog amplification and filtering, and Nyquist-rate digitization. The four channels of digitized data are fed to an FPGA-based "software-defined radio" signal processor that computes auto- and cross-correlation spectra and stores data in nonvolatile memory. The overview of the LuSEE Night electronics design is reported.

Early Career:

RDC5 / 265

Rogue: Back-End Integration and Future Developments

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Rogue is an open-source, C++/python, hybrid architecture platform that facilitates the communication with firmware and hardware modules. It uses low level C++ interfaces for performant data movement, asynchronous messaging and high-speed register access. A high level python interface is used to easily define and organize device nodes in a hierarchical tree structure. Both layers are extensible via plug-ins, allowing for users to easily develop high-performing solutions. Rogue's extensibility coupled with the flexibility of its libraries, allows it to be easily integrated into the data acquisition pipelines of larger systems.

Rogue has been successfully integrated into several existing data acquisition back-ends including the CEBAF Online Data Acquisition (CODA), EUDAQ and the Observatory Control System (OCS).

Ongoing developments continue to improve Rogue's capabilities as a stand-alone data acquisition framework providing high performance data processing and monitoring all controlled by a central run control. This work will review the back-end integration details and future developments aimed at enhancing Rogue's stand-alone capabilities.

Early Career:

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Portable Acceleration of CMS Mini-AOD Production with Coprocessors as a Service

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Computing demands for large scientific experiments, such as the CMS experiment at CERN, will increase dramatically in the next decades.To complement the future performance increases of software running on CPUs, both in online TDAQ systems and offline data processing, explorations of coprocessor usage hold great potential and interest. We explore the novel approach of Services for Optimized Network Inference on Coprocessors (SONIC) and study the deployment of this as-a-Service approach in large-scale data processing. In this setup, the main CMS Mini-AOD creation workflow is executed on CPUs, while several machine learning (ML) inference tasks are offloaded onto (remote) coprocessors, such as GPUs. With experiments performed at Google Cloud and the Purdue Tier-2 computing center, we demonstrate the ML algorithm acceleration individually and the throughput improvement for the entire workflow. We also show the generalizability of the approach, demonstrating deployment on CPUs without performance decrease. SONIC enables high coprocessor usage with portability to different hardware types enabled. This is the first demonstration of a realistic CMS workflow with co-processors as-a-service computing paradigm. Future plans and challenges will also be discussed.

Early Career:

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RDC1 Coordination Discussion

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RDC1 Work package Planning Session

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RDC1 + RDC4 Coordination Discussion

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Viewpoint of the RDCs from the DOE Program Manager for Detectors

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Topics for roundtable discussion

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Early Career:

Plenary / **272**

Workshop Summary and Next Steps

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