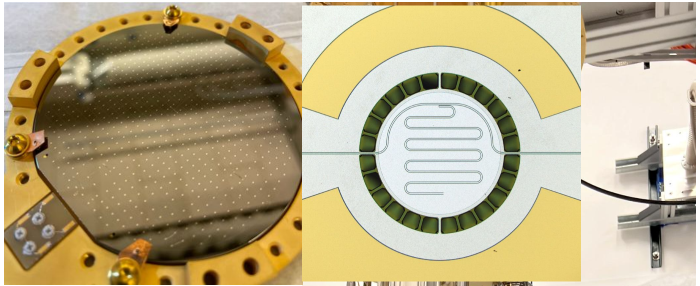
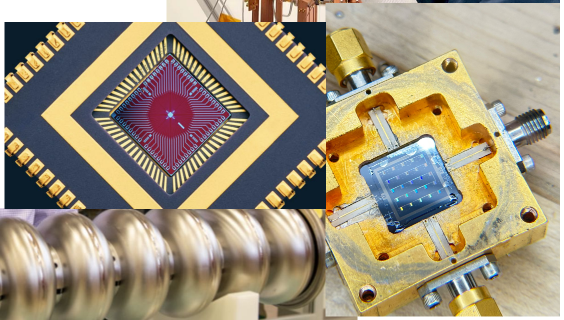
Welcome to

CPAD RDC8
Quantum & Superconducting Detectors

Rakshya Khatiwada & Aritoki Suzuki
11/06/2023






Who are we?

CPAD R&D Coordination (RDC) groups

Brings together the CPAD community in a more persistent way than the annual workshops alone, to coordinate R&D efforts and to forge collaboration.

RDC	Topic	Coordinators
1	Noble Element Detectors	Jonathan Asaadi, Carmen Carmona
2	Photodetectors	Shiva Abbaszadeh, Flavio Cavanna
3	Solid State Tracking	Sally Seidel, Tony Affolder
4	Readout and ASICs	Angelo Dragone, Mitch Newcomer
5	Trigger and DAQ	Jinlong Zhang, (TBN)
6	Gaseous Detectors	Prakhar Garg, Sven Vahsen
7	Low-Background Detectors (incl. CCDs)	Noah Kurinsky, Guillermo Fernandez-Moroni
8	Quantum and superconducting Detectors	Aritoki Suzuki, Rakshya Khatiwada
9	Calorimetry	Marina Artuso, Minfang Yeh
10	Detector Mechanics	Andy Jung, Eric Anderssen
11	Fast Timing	Gabriele Giacomini, Matt Wetstein

Our Goal

1. Foster a collaborative, supportive, and coordinated environment for new ideas, blue sky efforts, and non-project specific R&D

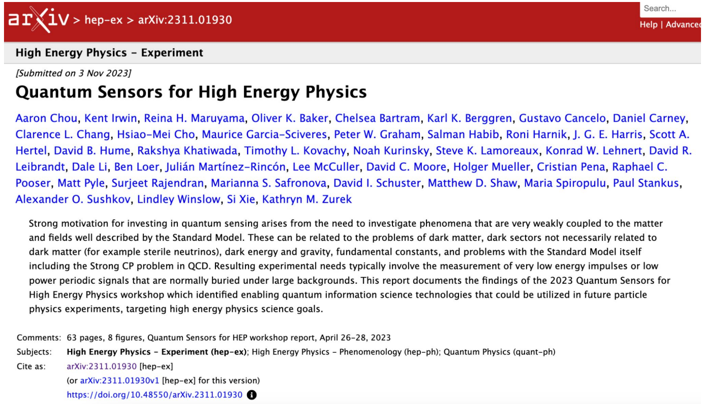
2. Provide a platform to link together facilities, expertise and people to tackle technology challenges across HEP/NP

3. Facilitate new funding mechanism for R&D through development of work packages and proposals

RDC-8 Sub-Groups

- One of the largest CPAD RDCs
  - We base collaboration and R&D ideas from **Basic Research Needs (BRN)** and particularly, **QIS for HEP workshop, 2023**.

Report arXiv:2311.01930


arXiv > hep-ex > arXiv:2311.01930

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High Energy Physics – Experiment

[Submitted on 3 Nov 2023]

Quantum Sensors for High Energy Physics

Aaron Chou, Kent Irwin, Reina H. Maruyama, Oliver K. Baker, Chelsea Bartram, Karl K. Berggren, Gustavo Cancelo, Daniel Carney, Clarence L. Chang, Hsiao-Mei Cho, Maurice Garcia-Sciveres, Peter W. Graham, Salman Habib, Roni Harnik, J. G. E. Harris, Scott A. Hertel, David B. Hume, Rakshya Khatiwada, Timothy L. Kovachy, Noah Kurinsky, Steve K. Lamoreaux, Konrad W. Lehnert, David R. Leibrandt, Dale Li, Ben Loer, Julián Martínez-Rincón, Lee McCuller, David C. Moore, Holger Mueller, Cristian Pena, Raphael C. Pooser, Matt Pyle, Surjeet Rajendran, Marianna S. Safronova, David I. Schuster, Matthew D. Shaw, Maria Spiropulu, Paul Stankus, Alexander O. Sushkov, Lindley Winslow, Si Xie, Kathryn M. Zurek

Strong motivation for investing in quantum sensing arises from the need to investigate phenomena that are very weakly coupled to the matter and fields well described by the Standard Model. These can be related to the problems of dark matter, dark sectors not necessarily related to dark matter (for example sterile neutrinos), dark energy and gravity, fundamental constants, and problems with the Standard Model itself including the Strong CP problem in QCD. Resulting experimental needs typically involve the measurement of very low energy impulses or low power periodic signals that are normally buried under large backgrounds. This report documents the findings of the 2023 Quantum Sensors for High Energy Physics workshop which identified enabling quantum information science technologies that could be utilized in future particle physics experiments, targeting high energy physics science goals.

Comments: 63 pages, 8 figures, Quantum Sensors for HEP workshop report, April 26-28, 2023

Subjects: **High Energy Physics – Experiment (hep-ex)**; High Energy Physics – Phenomenology (hep-ph); Quantum Physics (quant-ph)

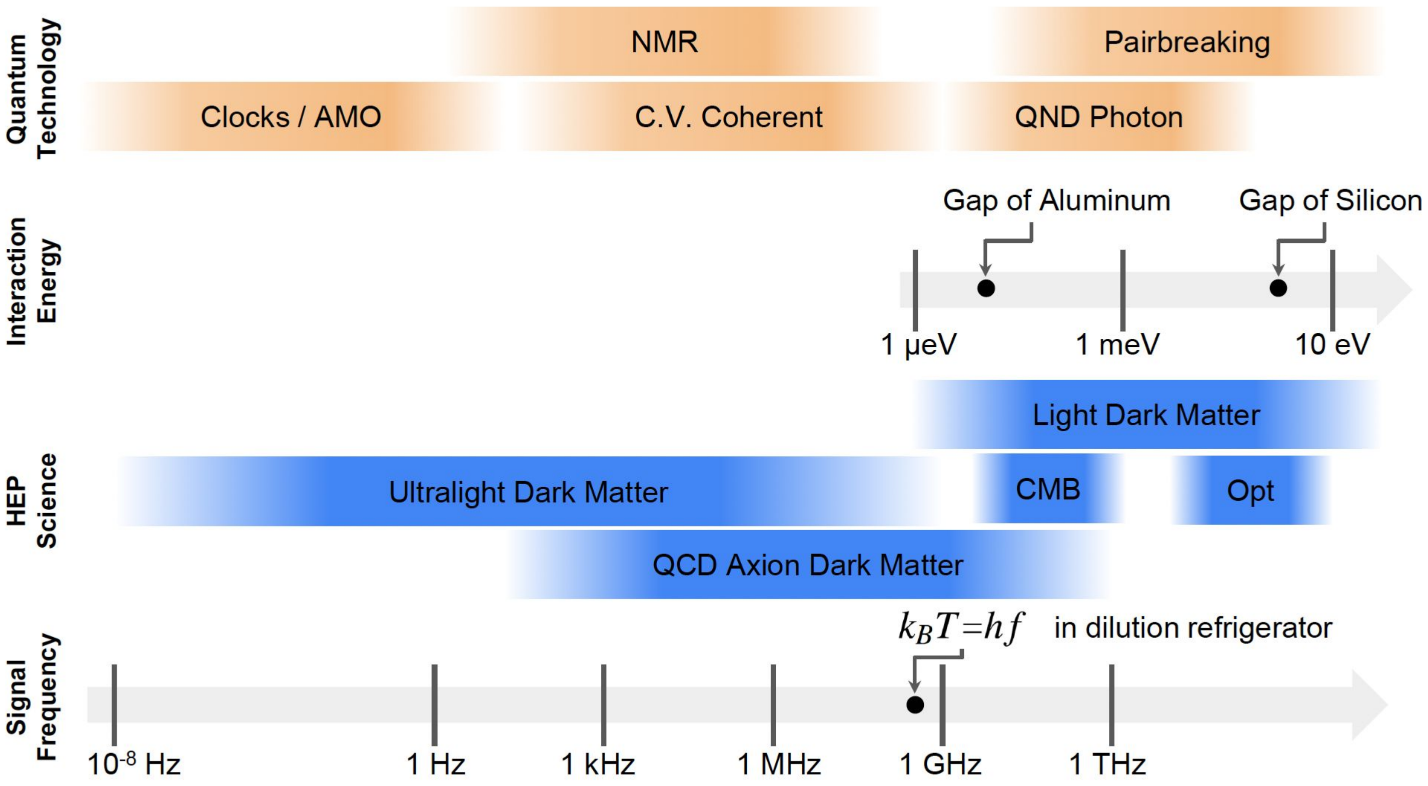
Cite as: arXiv:2311.01930 [hep-ex]

(or arXiv:2311.01930v1 [hep-ex] for this version)

https://doi.org/10.48550/arXiv.2311.01930

1) **Pairbreaking sensors**:
   MKIDs, TESes, SNSPDs, QCDs, SC Qubits and variants etc.
2) **Coherent wave sensors:**
   JPA, TWPA, KIPA, Squeezed state receivers, microwave to optical transducers, SRF cavities, rf quantum upconverters, mechanical tuning of cavities, etc.
3) **AMO (interferometry, NMR, Optomechanical) clocks sensors:**
   Neutral atoms, trapped ions, magnetometers, spin precession, optomechanical devices, optical-RF-magnetic levitation, cantilevers etc. entangled probes that beat SQL with optical readout etc.
4) **Novel materials & Theory:**
   Quantum and metamaterials, Low bandgap materials (Dirac, Weyl, Sapphire), High T_c materials, spin liquids, NV centers etc. New theories/ideas that can be tested with detectors, specific technology model building etc.

Science Drivers and Energy Scale



Source: QIS for HEP report arXiv:2311.01930

RDC8 Activities

Formed in the summer 2023

First meeting - August 31

- Introduction to CPAD RDCs

Community Survey - September

- Collected info on interests, collaboration ideas, necessary and available resources/facilities
- Solicited for subgroup leads
- Work package ideas

Second meeting - October 18

- Survey results shared
- Subgroup organizations refined
- Subgroup leads identified

Future (next year): Develop work packages, make it available to the community

Please bring up suggestions for future activities during our scheduled discussion !

CPAD Survey Results

Focused on interests, collaboration ideas, necessary and available resources

RDC8 representative Institutions

DOE Labs (22 responses)

- Argonne National Laboratory
- Fermilab
- Los Alamos
- Livermore
- LBNL
- Pacific Northwest National Laboratory
- Sandia National Laboratories
- SLAC

National Labs (6 responses)

- Jet Propulsion Laboratory
- NIST

University (11 responses)

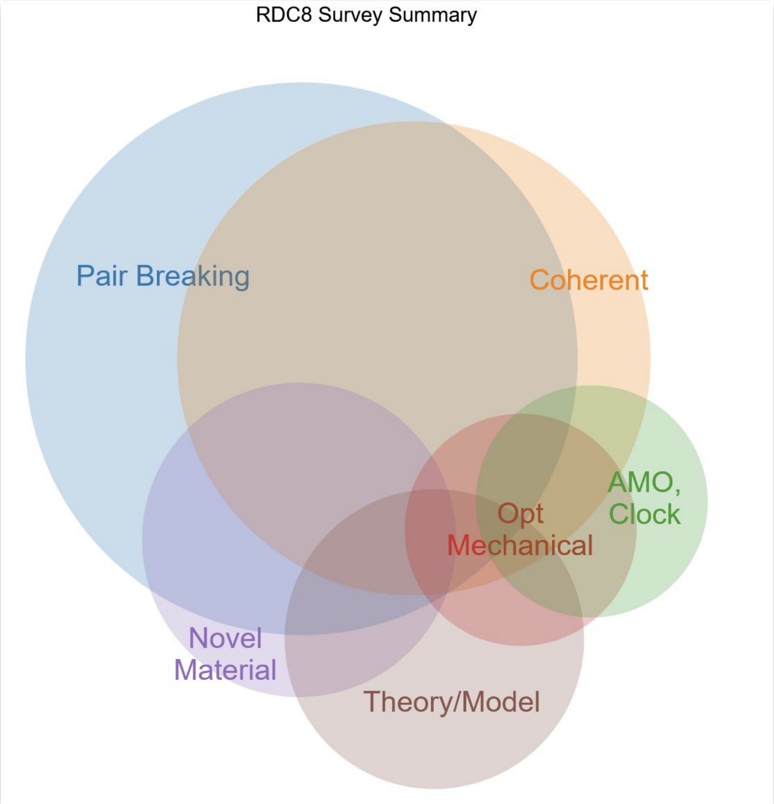
- Boston University
- Caltech
- Cornell
- UC Santa Barbara
- University of Chicago
- University of Delaware
- University of Florida
- University of Oklahoma

Non-US University (2 responses)

- Humboldt University Berlin
- The University of Western Australia

Responses from both labs and universities as well as from international institutions

RDC8 Interests



Sample size: 42

Pair breaking : 34

Coherent : 25

AMO, Clock : 6
Opt Mech : 6

Novel Material : 11
Theory : 10

Other : 1

A lot of interest in **pair breaking and coherent groups**.
Good overlaps between groups as well

Synergy with other RDCs

Sample size: 31/42 (multiple answers possible)

1. Noble Element Detector : 3
2. Photodetectors : 21
3. Solid State Tracking : 2
4. Readout and ASICs : 13
5. Trigger and DAQ : 3
6. Gaseous Detectors : 0
7. Low Background Detectors : 21
8. This RDC
9. Calorimetry : 3
10. Detector Mechanics : 3
11. Fast Timing : 6

We have synergy with almost every other RDCs. Three RDCs stood out

We have a combined session with RDC 7 on Thursday

CPAD workshop organization and time table (Nov 7 ~ Nov 10)

Meeting notes: https://docs.google.com/document/d/129Olig_V0OTugSFRCaFVPf3QEk9fxQJhXqhy2nHNWLk/edit?usp=sharing

Tuesday: RDC8 Session #1

- Open/Intro (Rakshya/Toki)
- Pair breaking subgroup intro (Clarence Chang/Matt Shaw)
- Coherent subgroup intro (Silvia Zorzetti/Gianpaolo Carosi)

Wednesday: RDC8 Session #2

- ECFA DRDq (Mike Doser)
- AMO,clock, NMR subgroup intro (Swati Singh)
- Novel Material & Theory subgroup intro (Sinead Griffin)

Wednesday: RDC8 Session #3

- 8 contributed talks

Thursday: RDC8

- 6 contributed talks

Thursday: RDC8 Session #4

- 4 contributed talks
- 1.0 hour Work package discussion

Thursday: RDC7+8 Low Backgrounds in Quantum Sensors

- 3 contributed talks
- 1.0 hour Work package discussion

Friday: RDC8 Session #5

- 6 contributed talks

Discussions!!

Suggested topics for discussion

1. How can we collect/share information beyond survey?
2. Did the subgroup summary capture all of your interest/activities? If not, what are those?
3. What are common challenges we can tackle?
4. What should be the content/structure of work packages?
5. Suggestions on activities and how to efficiently hold discussions about work packages?

Supplementary Slides

Pair Breaking

Number of Interests: 34

Sub-group lead(s)
- Clarence Chang (Argonne), Matt Shaw (JPL)

Summary of topics
- Superconducting detector development (MKID, TES, SNSPD, Qubit / Quantum Capacitance), Readout electronics (Frequency-domain multiplexing, Cryogenic Electronics, ASIC development, High-density interconnects), New approaches to detector calibrations and backgrounds
  Science Targets
- Dark Matter (wave and particle), cosmology, collider physics (ultra-fast timing, radiation hardness), neutrino physics.

Existing Collaborations
- SQMS, BREAD, SPICE/HERALD, TESSERACT, RICOCHET, SuperCDMS, SPT

Facility needs
- Nanofabrication, cryogenic testing, calibration and backgrounds

Ideas for work packages
- Scalable CMB Detector Arrays (Beyond CMB-S4). Low-threshold, large-area SNSPDs, Phonon-mediated MKIDs, Ultra-low-threshold TES, Qubit-based THz and mm-wave photon counting, quantum-limited parametric amplifiers.

Coherent

Number of Interests: 25

Sub-group lead(s)

- Gianpaolo Carosi (LLNL), Silvia Zorzetti (FNAL)

Summary of topics

- Precision measurements, axions (haloscopes, light shining through wall), dark matter, detection of keV mass, frequency converters, weak signals detection, wave-like DM

Science Targets

- DM, axion detection

Existing Collaborations

- ADMX, ORGAN, MAGIS-100, SQMS, BREAD
- Nat. Labs: SLAC, ANL, Fermilab, LBNL

Facility needs

- Dilution refrigerators, underground cryogenic facilities, cleanrooms, device fabrication, nanofabs, test and production facilities for superconducting devices.

Ideas for work packages

- Phonon physics, qubit-based detection, low noise amplifiers (low-frequency SQUID, JPAs), digital electronics, optomechanical systems, low dark counts single-photon detectors, microelectronics and ASICs, quantum entanglement and sensors networks