The Science of SLAC

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SLAC NATIONAL ACCELERATOR LABORATORY

Stanford University | U.S. DEPARTMENT OF ENERGY

SLAC scientific impact over the next decade

LABORATORY GOALS

Be the world leader in X-ray and ultrafast science and in our selected areas of accelerator science and high energy physics

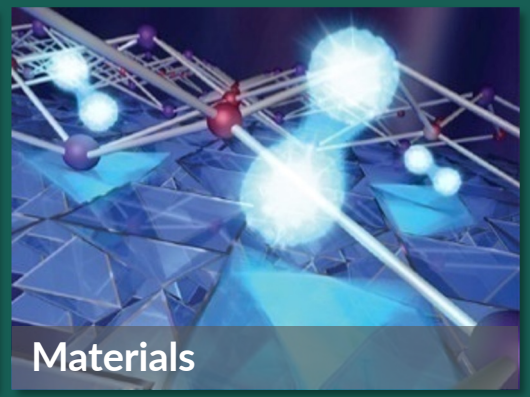
Expand and increase our impact in DOE-SC mission areas by leveraging our world-leading core capabilities and expertise

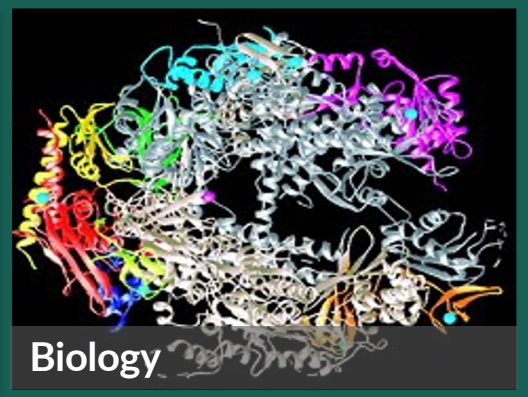
Broaden and strengthen our impact across critical national needs by using our position within Stanford and Silicon Valley

Be the "best-in-class" DOE Laboratory for safe, efficient and innovative operations that align with and enable our research mission

Beyond HEP, SLAC's unique facilities enable scientific discoveries and help solve national challenges


Chemistry


Materials


Biology


Fusion


Environmental Sciences

Boosting LCLS power and capacity with LCLS-II & LCLS-II-HE keeps the U.S. in the lead for Free Electron Lasers into 2030s

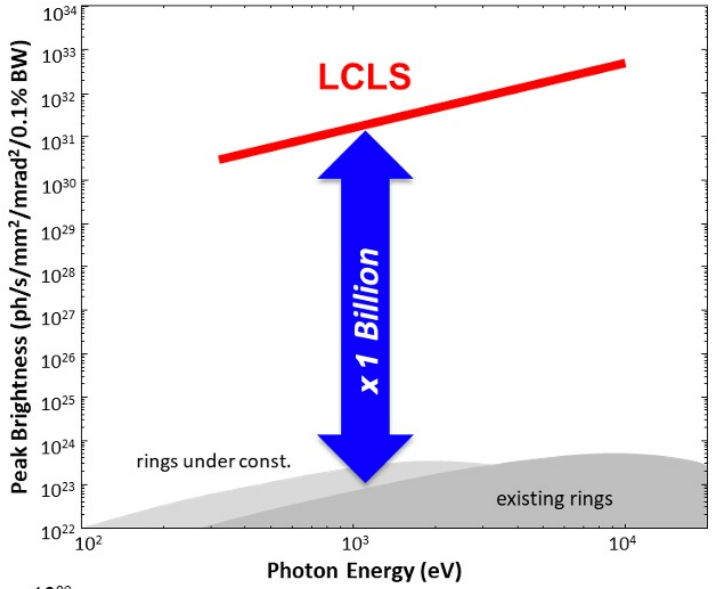
- New superconducting linear accelerator will create **nearly continuous X-ray laser beam** and work in parallel with existing copper linac
- Beam will be **10,000 times brighter** and **1,000 times more powerful**
- ~50% of total LCLS-II cost spent in **other national labs** using their core competencies

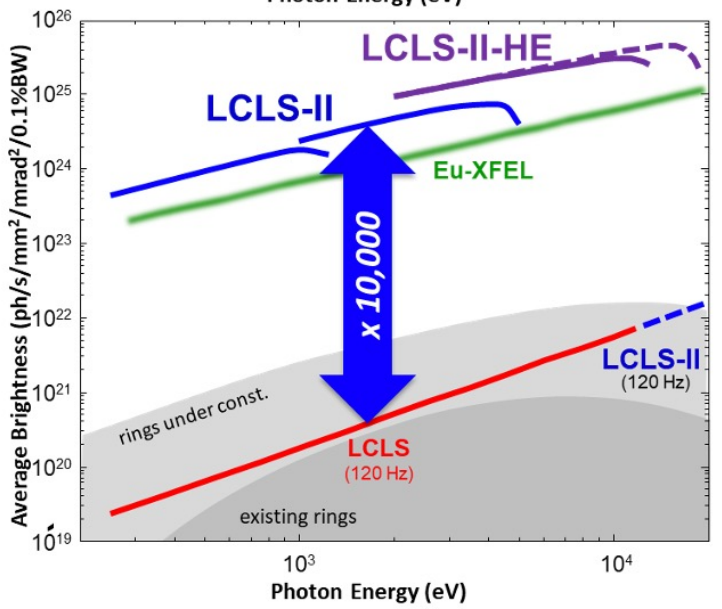
Fermilab

Argonne NATIONAL LABORATORY

Jefferson Lab

BERKELEY LAB

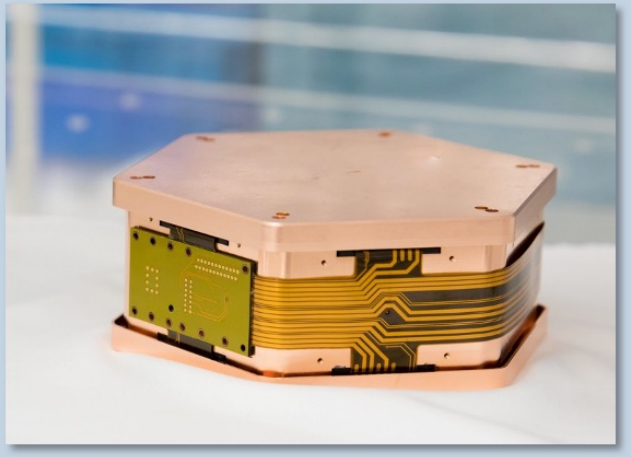




SLAC

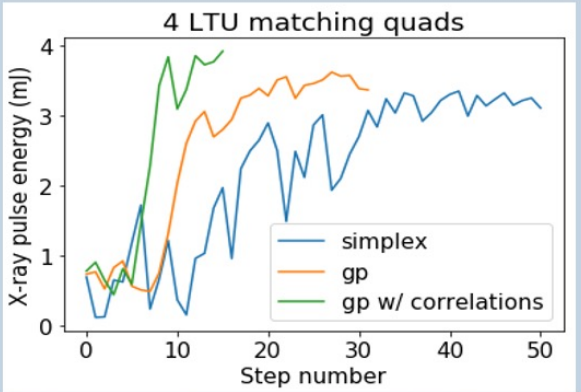
Develop world-leading sensors, detectors and machine learning to advance X-ray science, high energy physics and computing

Superconducting (SC) Quantum Sensors



Developing sophisticated electronics (transition-edge sensors and SC quantum interference devices) for energy sensitive experiments in high energy physics and quantum information science

Machine Learning for Big Data



10x speed up tuning LCLS

Launching a new lab-wide machine learning initiative to address the rapidly developing, unprecedented big data needs from our facilities, particularly LCLS-II, -HE

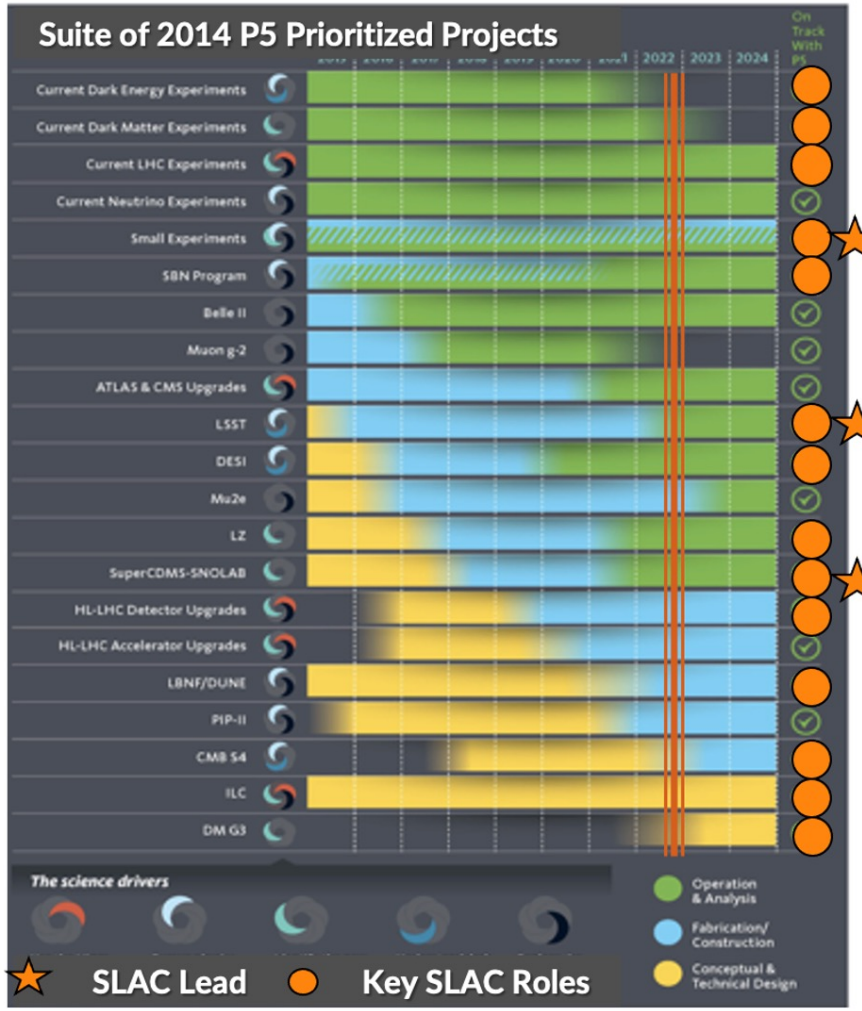
Specialized Microchips

Designing application-specific integrated circuits (ASICs) for cutting-edge scientific research and applications, such as self-driving cars

SLAC has key leadership across the national HEP program

HEP ecosystem vital to success of P5 program

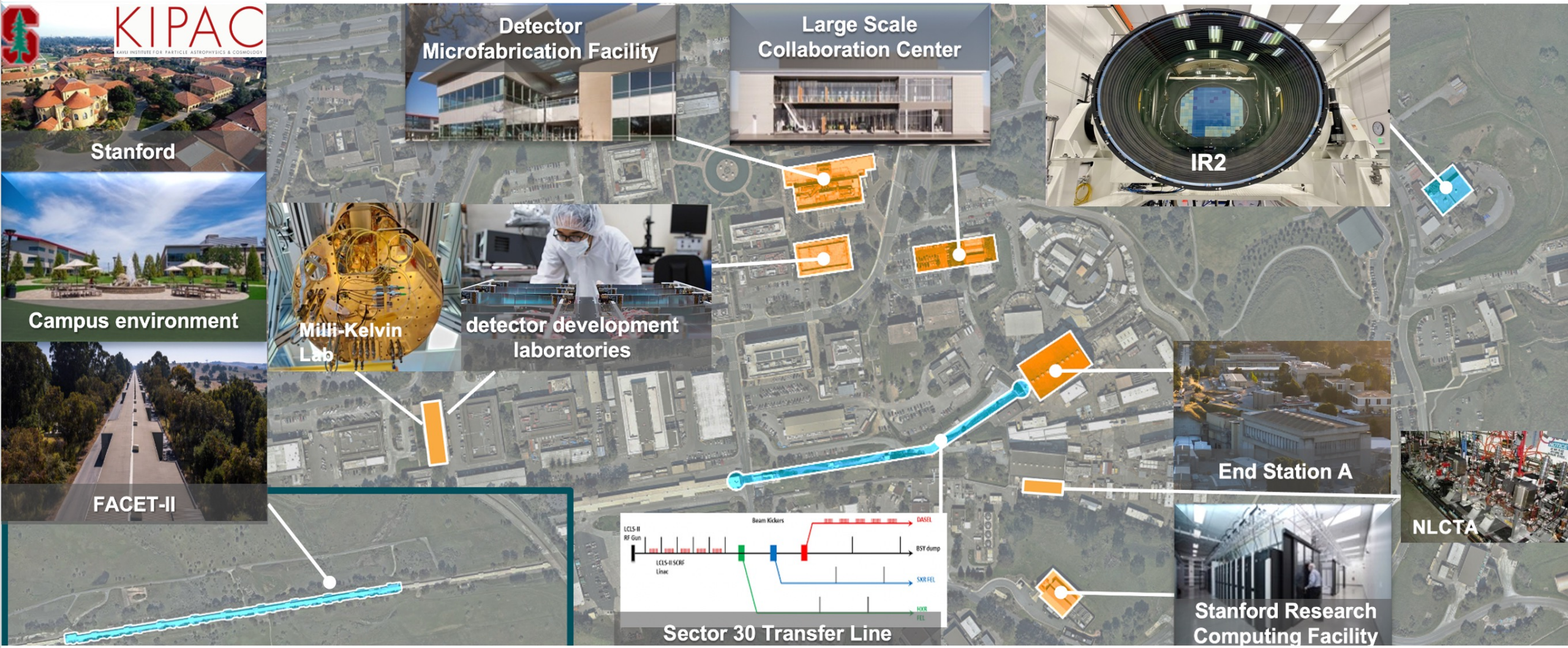
- Advantage of multiple strengths across the system
- Diverse expertise & creativity
- Diagonalized core capabilities
- SLAC leadership of mid- & small-scale unique impactful experiments
- SLAC plays crucial role in broad set of P5 projects and leads design of innovative new concepts



SLAC HEP main developments since P5

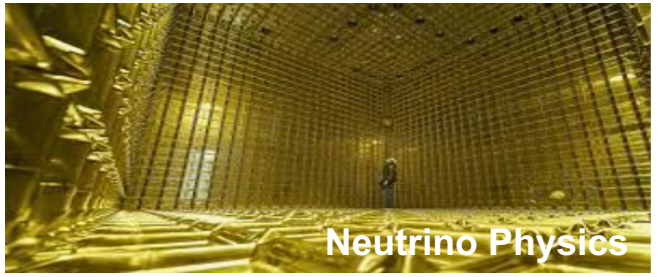
- Investment in new Neutrino and Dark Matter programs
- Design of innovative new concepts and instrumentation
- Initiated leading AI/ML and QIS programs
- Invested in the Detector Microfabrication Facility
- Increased diversity of our workforce

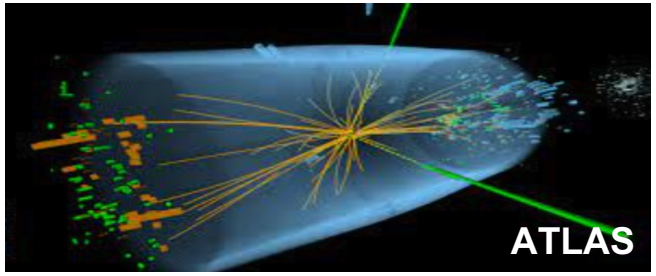
Broad ecosystem of HEP activities across the lab

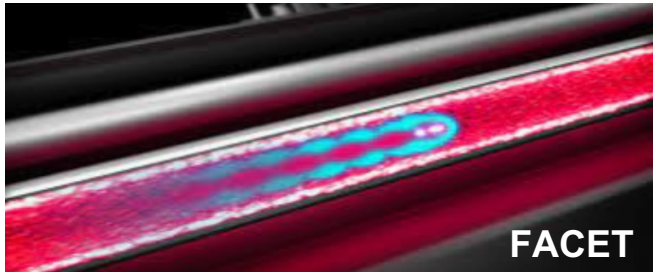


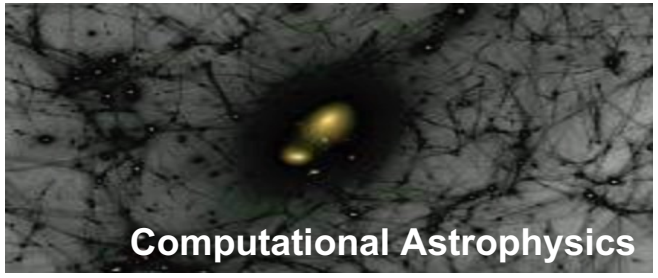
We benefit from integration of capabilities and facilities at SLAC and Stanford

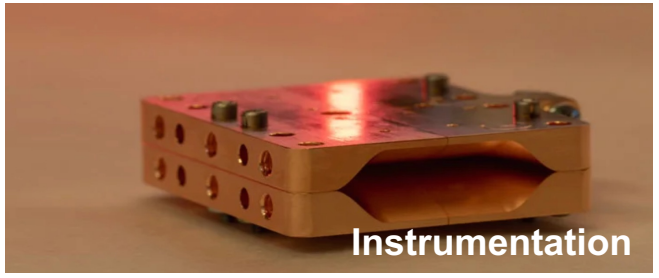
SLAC HEP physics program at a glance

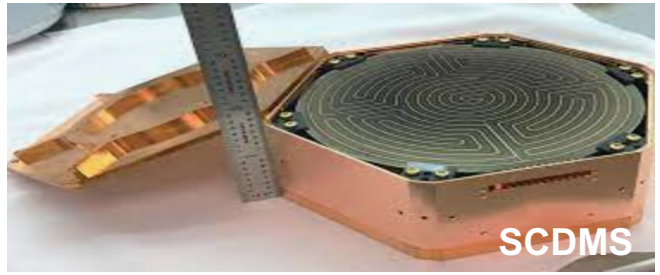






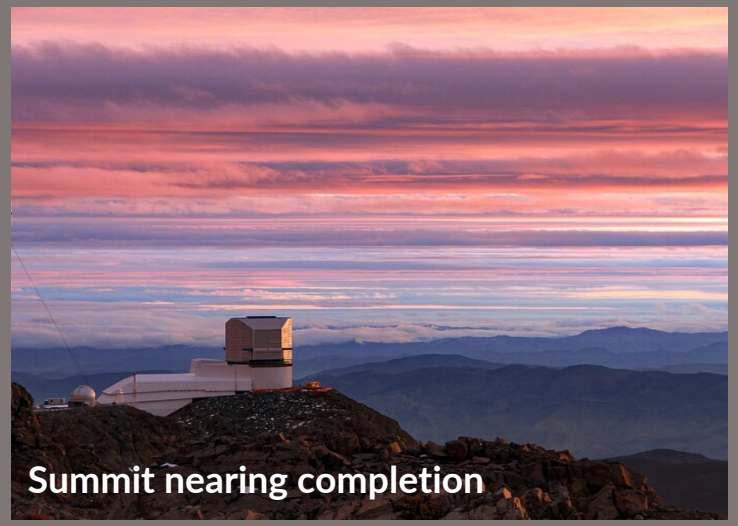


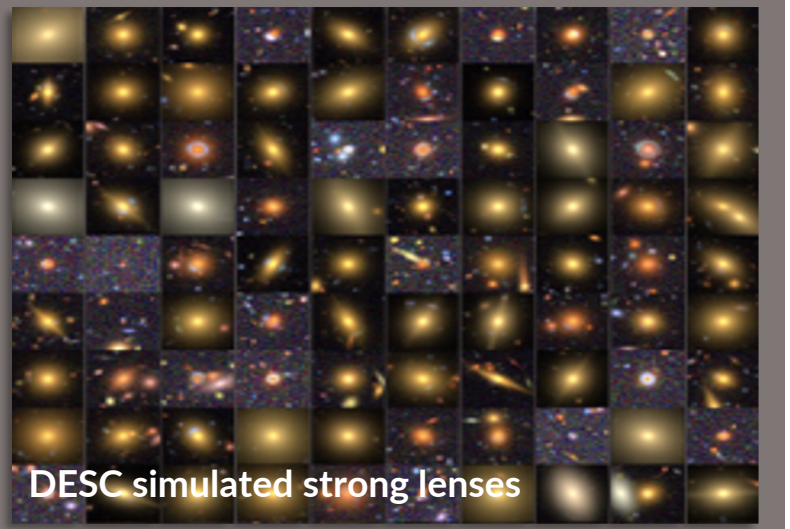




Vera C. Rubin Observatory is preparing for first light!

Will perform the 10-year Legacy Survey of Space & Time (LSST)


Summit nearing completion

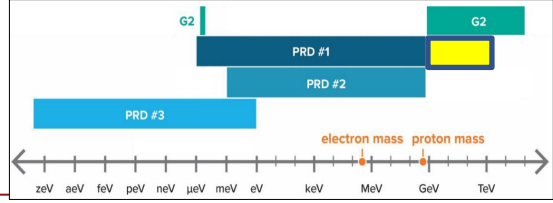

DESC simulated strong lenses

- Will record deep images of 20 billion galaxies to observe the nature of dark energy
- **SLAC-built LSST Camera, CD-4 completed in Fall 2021**
- Camera commissioning almost completed
- Careful planning to ship camera to Chile in Fall 2023

- **Partnering with NSF NOIRLab to manage Rubin Operations**
- **SLAC is hosting U.S. Data Facility – stood up and operational**
- Primary LSST archive, prompt data processing, alert production, and annual data release
- **Host for the Dark Energy Science Collaboration**

SLAC

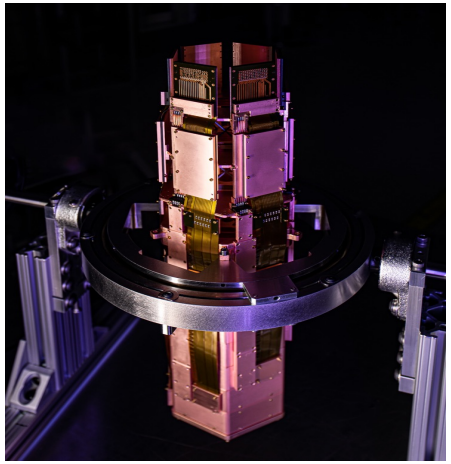
Leading Dark Matter searches for WIMPS



sCDMS completed CD-4 and transitioned to installation & ops!

Search for Weakly Interacting Massive Particles in 0.5-10 GeV mass range

- SLAC-led project back on track with early CD-4 completed March 2023
- Commissioning, installation & integration part of operations – beginning now at SNO-Lab
- Computing to be performed at SLAC shared data facility

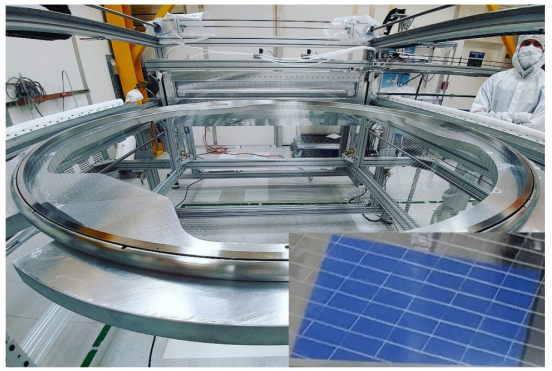


Detector towers are constructed, tested, and stored.

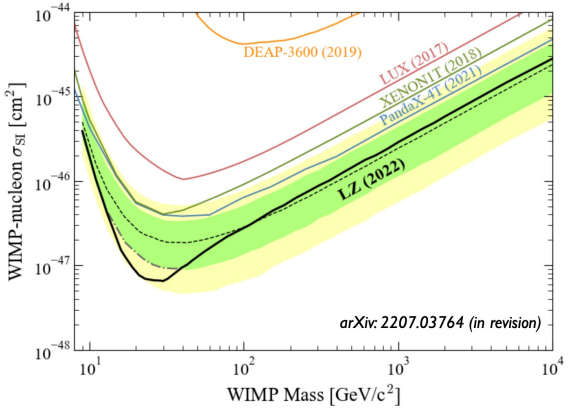
LZ science underway with SLAC leadership

Search for Weakly Interacting Massive Particles in 10-1000 GeV mass range

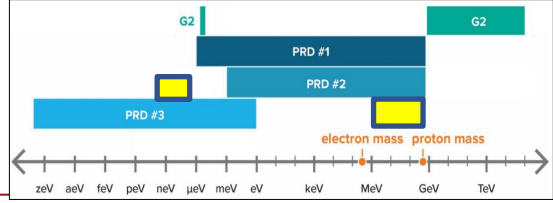
- Kr removal/xenon purification: 10.3 tonnes purified and delivered to SURF. Science requirements exceeded
- SLAC scientist leads detector commissioning & calibration
- SLAC Scientist leads effort for data movement, prompt processing , and data/sim production at NERSC
- Data taking on-going. Combined engineering/WIMP search paper led by SLAC Scientist



Custom HV grids



Leading Dark Matter exploration beyond WIMPS



Light Dark Matter Experiment (DMNI program)

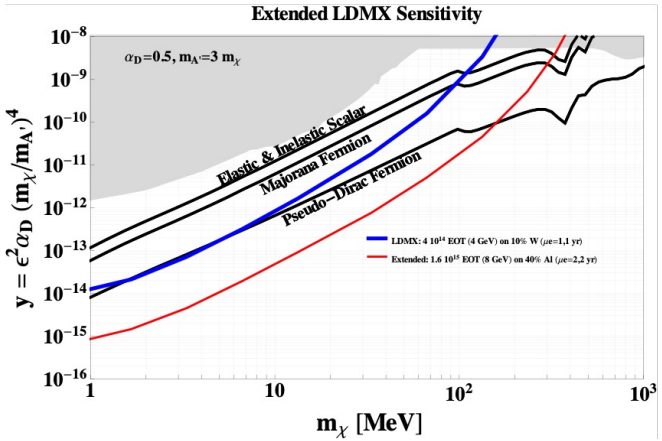
Accelerator based search for sub-GeV thermal relic DM

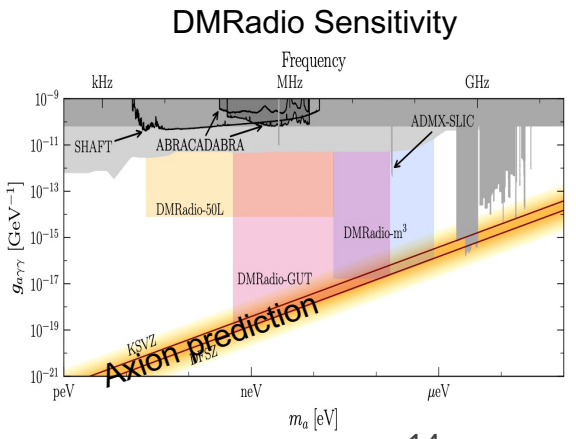
- Planned to run at LESA facility using S30XL beamline with 4(8) GeV LCLS-II(HE) drive beam
- Utilizes detector technologies already developed for other experiments: HPS (tracker), CMS(ECal), Mu2e(HCal)
- Development of detector design and "small project" plan funded as a Dark Matter New Initiative starting in Q2 FY20
- Awaits design review process: Ready for construction now! construction ~2.5 years
- With only weeks of data, LDMX will become the most sensitive probe of sub-GeV thermal relics
- Will also probe lepton-nucleon cross sections relevant for DUNE

Dark Matter Radio (DMNI Program)

QIS based search for Axions and Axion-like particles

- QIS "LC circuit" tuned to axion wave-like frequency
- Development of magnet design and "small project" plan funded as a Dark Matter New Initiative starting in Q2 FY20
- Development of QIS sensor funded under QuantISED
- Ready for construction at any minute….





DUNE NEAR DETECTOR

DUNE will pursue the next milestones in neutrino oscillations

- CP Violation? Mass ordering? Three-flavor mixing?

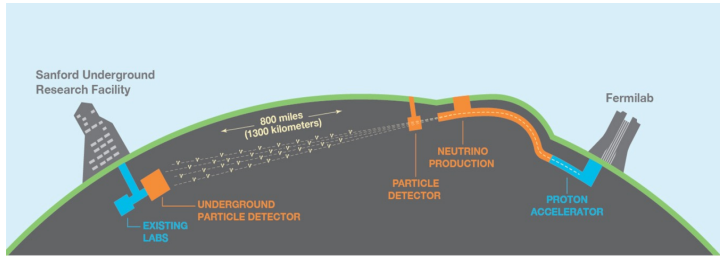
  with MW-class beams and multi-kton LArTPC far detectors

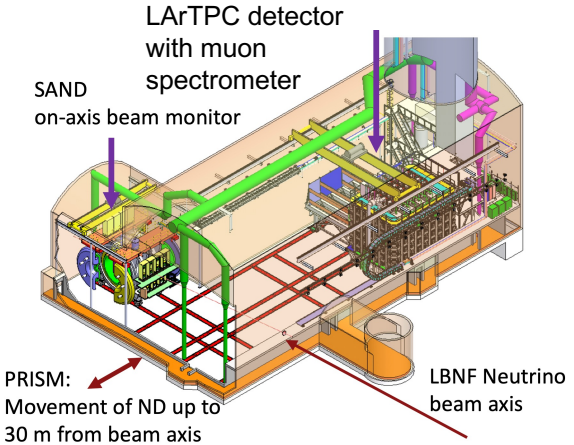
- control and reduction of systematics uncertainties will be critical

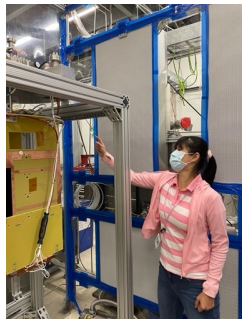
The Near Detector is the means to control large uncertainties in the neutrino flux, interaction model, and detector response

SLAC leadership for DUNE ND subproject:

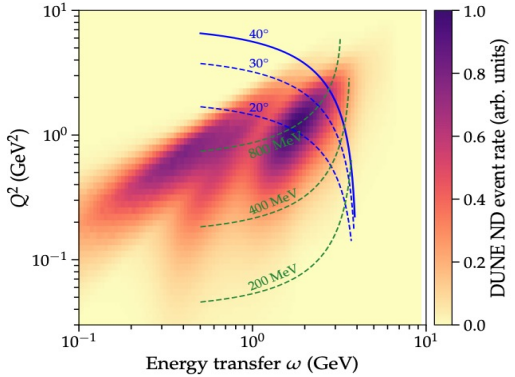
- Management:
  - H. A. Tanaka (Tech. Coordinator)
  - L2 managers responsible for Muon Spectrometer and PRISM movement system
- Design/Development contributions (supported by PD/LDRD):
  - Mechanical design of novel modular LArTPCs optimized for high-rate environment
  - Low-cost/profile electric field structures
- Deliverables:
  - Field structures for 35 LArTPC modules
  - Design of moveable services for ND systems







SLARChetto:
SLAC LAr detector development platform



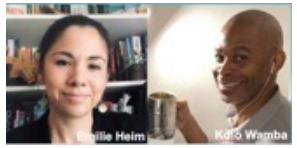
LDMX Lepton - Nucleon cross section measurements overlap DUNE ND kinematic region

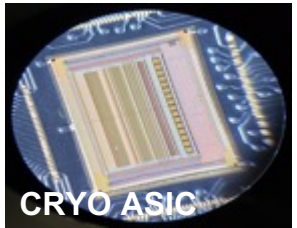
Key Roles in Large International Collaborations

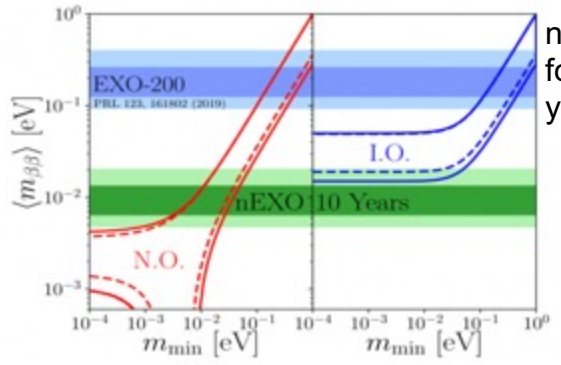
nEXO

Neutrinoless Double Beta Decay experiment to determine if neutrino is its own anti-particle

- 5-ton enriched liquid ^{136}Xe Time Projection Chamber
- Lauren Thompson is Deputy Project Manager
- Responsible for Commissioning (L1), Charge readout electronics (L2), Radio Assay (L2 & L3), Simulations (L3)
- Faculty search underway for Senior Science Lead
- Emilie Heim and Kolo Wamba of Skyline Community College work with SLAC as recipients of NP grant to broaden and diversity DOE nuclear physics program







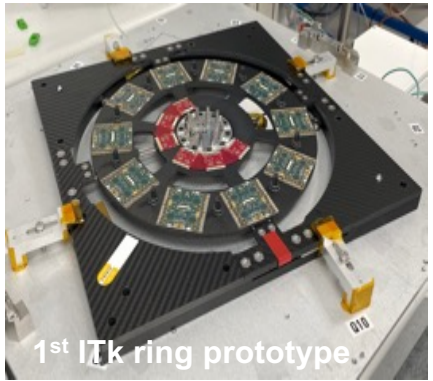
nEXO sensitivity for half-life of 10^{28} yrs

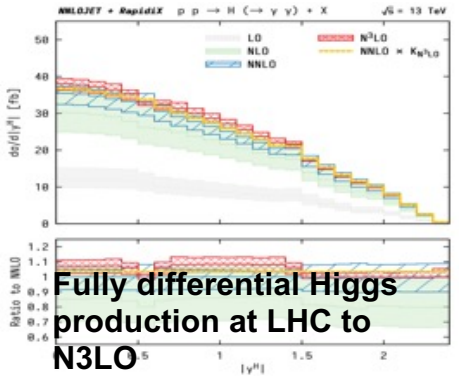
ATLAS High-Luminosity Detector Upgrade

Large Hadron Collider High-Luminosity upgrade to accumulate ~4 ab^{-1}

ATLAS experiment will undergo extensive upgrade

- P. Grenier is U.S. ATLAS pixel lead (L2)
- Responsible for assembly of inner tracker pixel detector (L2 & L3s)
- Focus on Di-Higgs, Higgs coupling measurements, search for new Higgs Bosons, and ML
- Strong connection to theory group



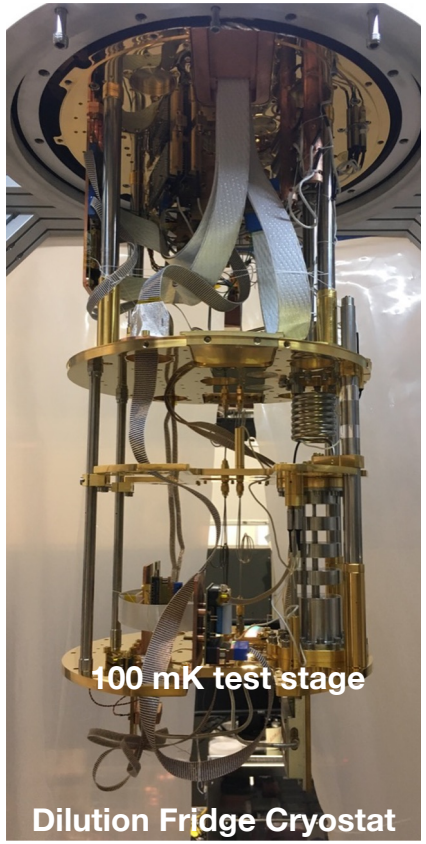


Fully differential Higgs production at LHC to N3LO

Cosmic Microwave Background

CMB-S4

A DOE-NSF joint project to build 21 CMB telescopes at the South Pole and in Chile incorporating ~550,000 superconducting detectors to study inflation



Dilution Fridge Cryostat

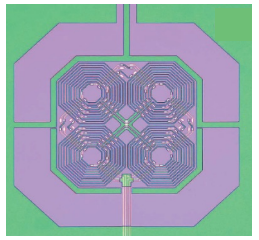
- SLAC is the center for Detector Readout and DAQ/Controls for the experiment, may host Module Assembly and Test Site and will fabricate wafers
- Utilizes SLAC's detector and electronics expertise
- Built and operating the experiment's first cryogenic detector readout prototyping and test system with complete readout string
- SLAC lead on inflation search analysis working group
- CMB correlation studies with Rubin data

Detector Microfabrication Facility

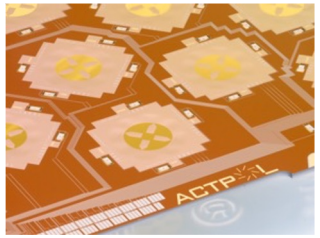
A quantum factory for superconducting devices for CMB, X-ray, QIS and Dark Matter

- 5500 sq.ft. clean room in Arrillaga Science Center
- Beneficial occupancy in August 2022
- Tool research & specification concluded for all ~50 tools with procurement in various stages
- Operations to fully start 2024

CMB SQUID Amplifiers

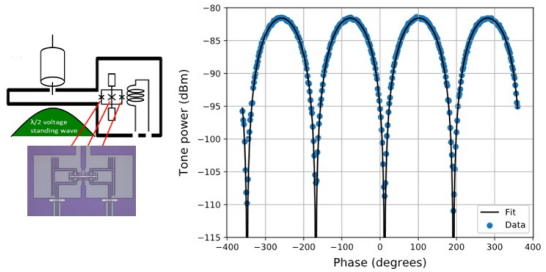


CMB TES detectors



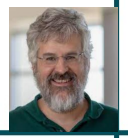
Detector Microfabrication Facility

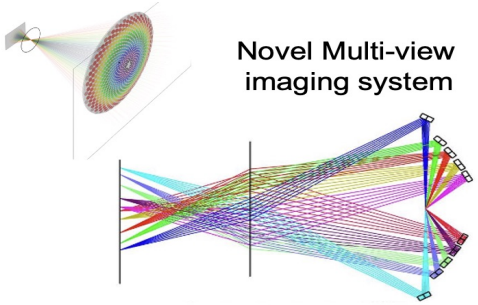
Quantum Information Science for HEP



Next Generation Quantum Sensing

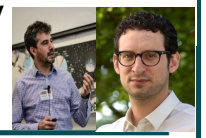
Quantum metrology of EM modes at low frequencies





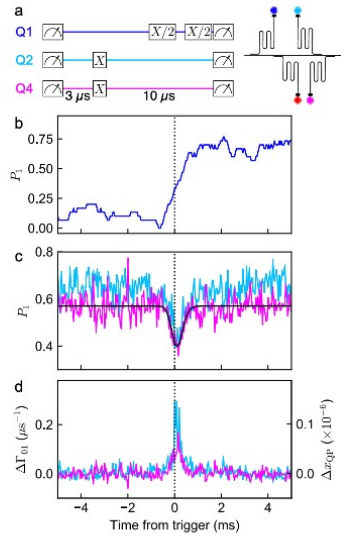
MAGIS-100

Developed diagnostic imaging system for cold atom interferometry

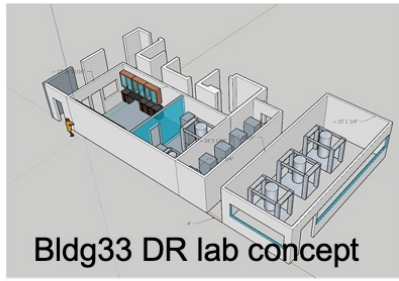


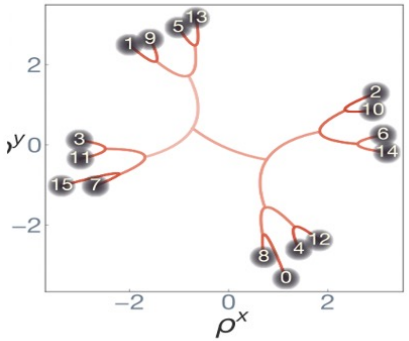
QIS-based Dark Matter Detection

Single charge and single phonon detector and readout R&D for meV-scale particle detection, based on superconducting qubits



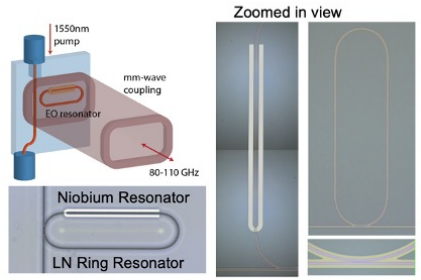
Characterization of correlation errors in superconducting qubits, *Nature 594 (2021)*





Quantum Simulations

Tree-like bulk geometry emerges from measured spin correlations



Quantum Transduction

Link microwave frequency quantum devices with optical quantum networks and solid-state platforms

Planning for the next decade

Future program interests, pending P5 report

DUNE Phase II

- More capable Near Detector

Dark Matter Generation 3 WIMP Search

- ~80 Ton Liquid Xe TPC in collaboration with Europe

Dark Energy Stage-5 spectroscopic survey

- Extensions to Rubin

Suite of DMNI small experiments

e^+e^- Higgs Factory

- FCC-ee, ILC, CLIC, C^3 accelerator contributions

Detector R&D

- Coordinated across US with SLAC involvement

Advanced Accelerator R&D

- FACET & C^3

SLAC initiated program!

SAGE: Empowering young women through science

SLAC

As a consortium of national laboratories and a sponsor, we are committed to guiding high school students TO CAREERS at DOE

Fermilab

OAK RIDGE National Laboratory

SLAC NATIONAL ACCELERATOR LABORATORY

Lawrence Livermore National Laboratory

BERKELEY LAB Bringing Science Solutions to the World

NATIONAL ENERGY TECHNOLOGY LABORATORY

Los Alamos NATIONAL LABORATORY

Accomplishments

- 100% of college-age SAGE participants are enrolled in college
- 94% are pursuing a STEM major
- 100% of the program participants have been women

GORDON AND BETTY MOORE FOUNDATION

SAGE Mission

Grow and diversify the DOE national laboratory workforce by encouraging young women with a passion for discovery and innovation to explore the opportunities in science and engineering and join the national laboratory workforce

SAGE Camp Goals

- Diverse socio-economic background
- Create the feeling of awe
- Develop professional skills
- Show impact of science and engineering on our communities and the world
- Grow SAGE community
- Imagine themselves as scientists and engineers

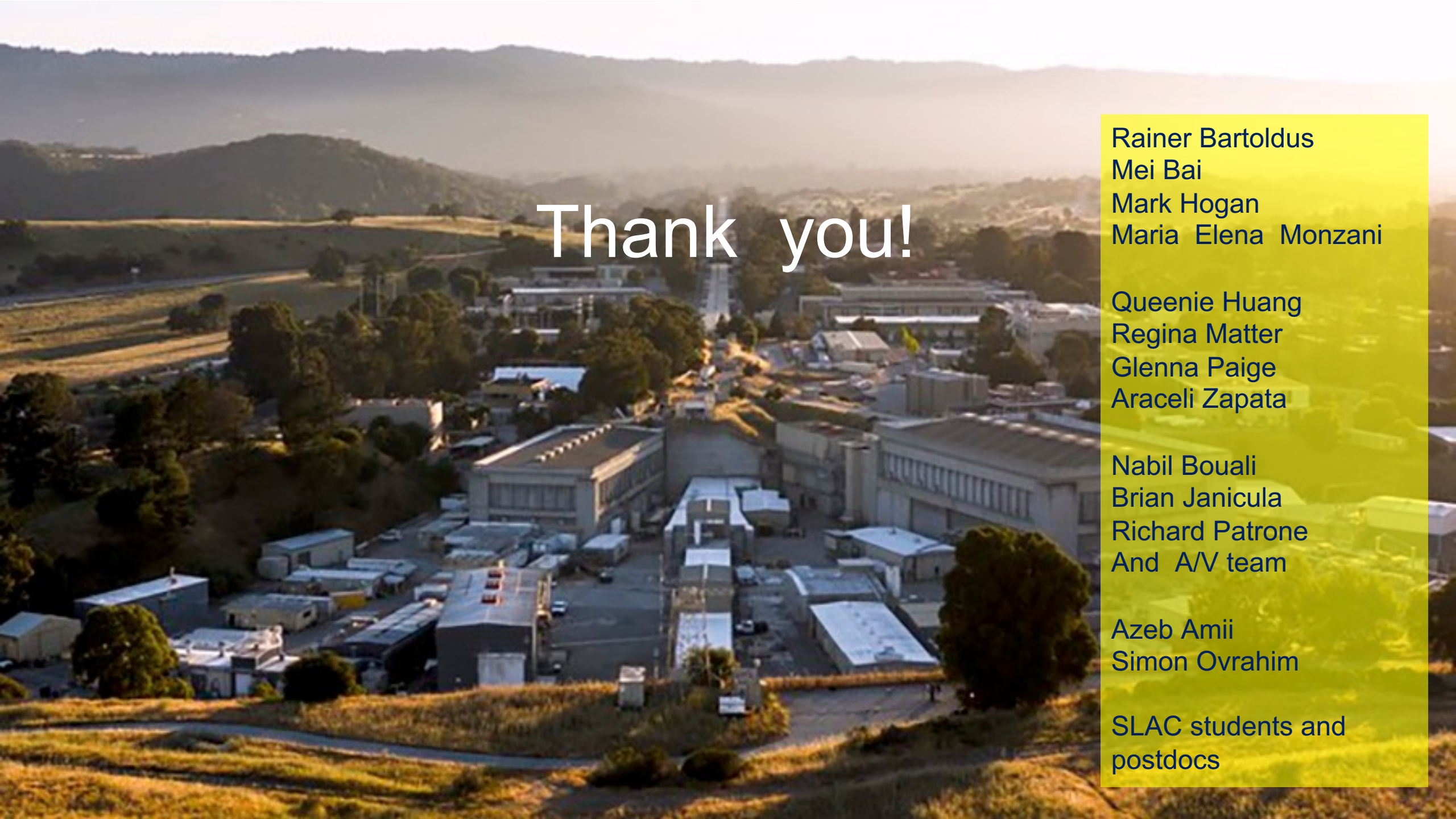
Metrics

- Evaluate impact by tracking students for 5 years
- Use data to improve program
- Optimize return on investment

Investment in the commitment, development, and engagement of historically underrepresented groups significantly improves diversity and equity in STEM professions

SLAC HEP

- Strives for excellence in scientific research
- Plays key roles in National program with strengths across the 2014 P5 Science Drivers
- Key roles in defining future domestic and global HEP program
- Strong connections across programs
- Leverages the strengths of a multi-purpose laboratory
- Leverages connection with Stanford University
- Provides support to the HEP community through lab partnerships and university engagement
- Community service is a SLAC hallmark
- Strong track record in training of young scientists & engineers
- Strong commitment to Diversity, Equity, and Inclusion


Thank you!
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