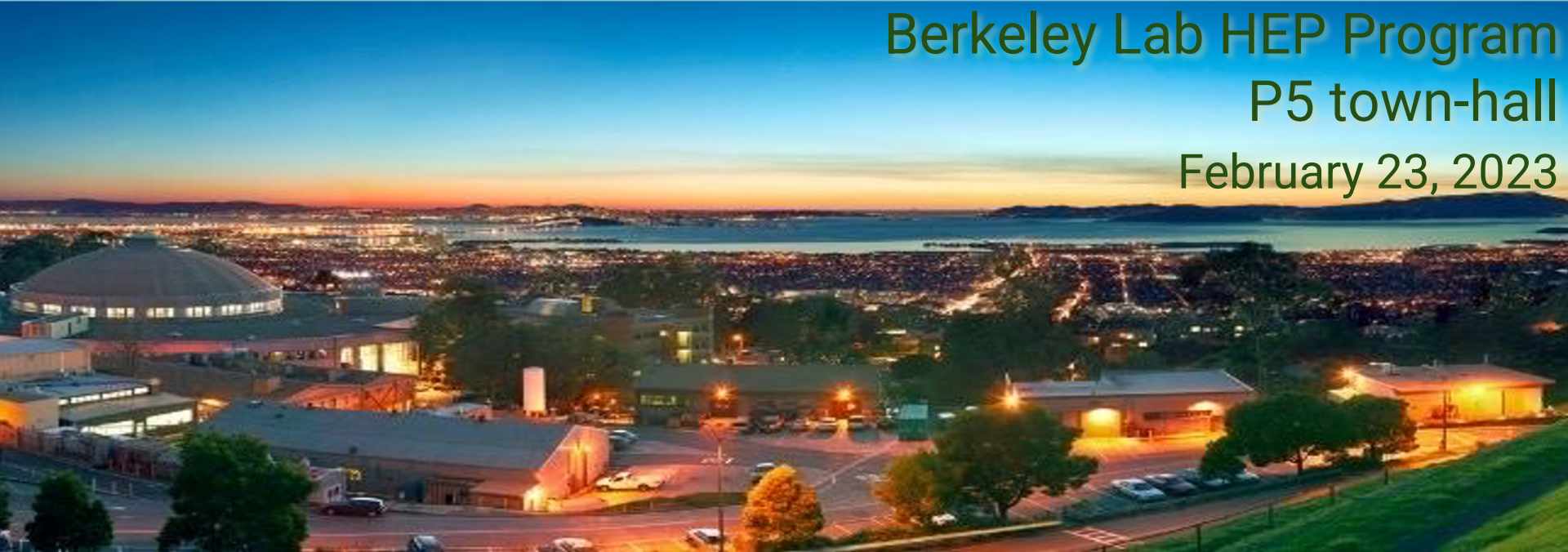


PHYSICAL SCIENCES AREA

Berkeley Lab HEP Program
P5 town-hall
February 23, 2023




BERKELEY LAB



U.S. DEPARTMENT OF
ENERGY

Office of
Science

Berkeley Lab HEP Program Snapshot

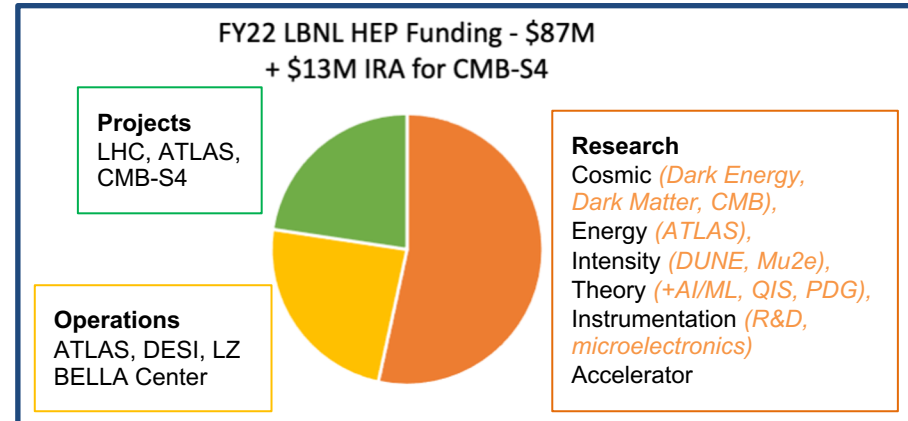
- LBNL is a large (>\$1B) multi-purpose DOE lab
 - HEP at LBNL at the core of two divisions: Physics and Accelerator Technology and Applied Physics, ~250 employees in all
 - Award winning staff – 9 Nobel prizes in physics
 - Fully matrixed Engineering division
 - Strong connections with
 - NERSC, ESNNet, Computing Sciences Area
 - Materials Science, Molecular Foundry
 - Nearby UC Berkeley, many joint faculty and students
-  **UCB/LBL theory group:** world-leading center for theoretical work on elementary particle phenomenology



Accelerator Division
Cameron Geddes

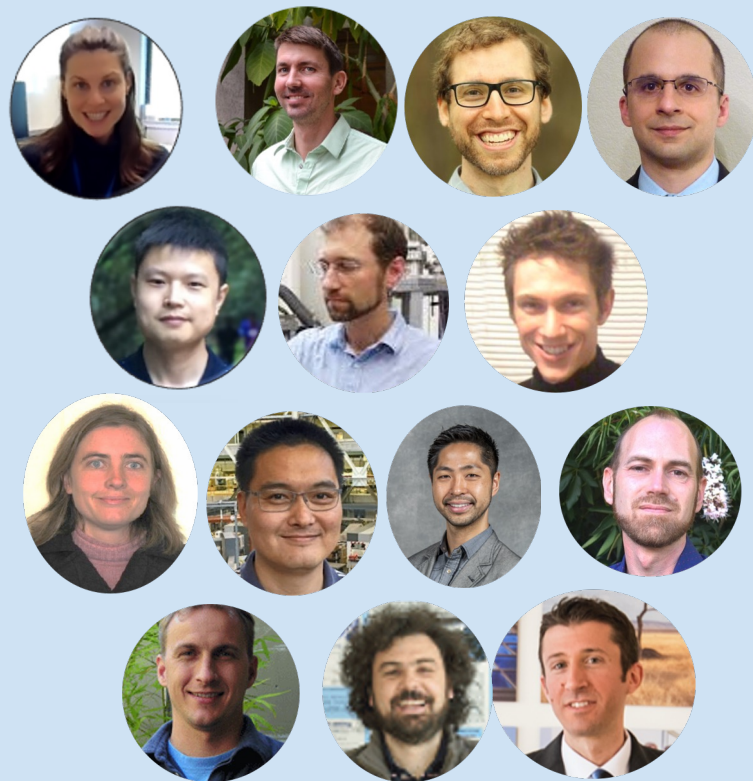


Physics Division
Nathalie Palanque-Delabrouille



Outstanding Young Scientists – Our Most Important Asset

- 14 recent DOE HEP + BES Accelerator Early Career Awards
- 3 of past 9 recipients of the APS Primakoff Award for early career physicists



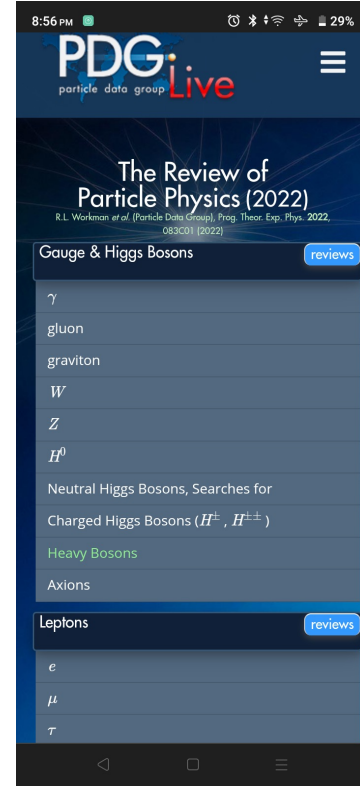
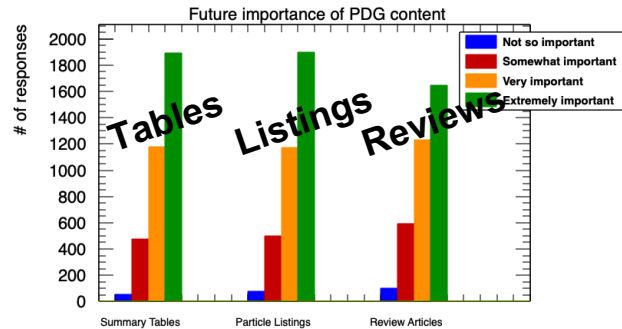
IDEA: Inclusion, Diversity, Equity and Accountability

- **IDEA@Berkeley Lab:** Fostering a diverse workforce – diverse in experiences, perspectives, and backgrounds – and a culture of inclusion are key to attracting and engaging the brightest minds and advancing our record of scientific excellence and groundbreaking innovations
- **Physical Sciences Area Mentoring Program**
 - Launched in 2021, expanded in 2022 to include admin, technical staff
 - 50 to 70 Mentor/Mentee pairings every year
- **Division activities:** Quarknet, US Particle Accelerator School, SAGE, Snowmass white paper, IDEA events & seminars, APS divisional IDEA groups



Serving the community: the Particle Data Group

- **PDG is a science legend**, recognized by SC as an authoritative data resource
 - In the process to make PDG data **machine-readable**
- **PDG is vital** to HEP community & related areas (particles, cosmology, astroparticle physics) but more largely too (academia)
 - For researchers
 - For students
 - For teaching and outreach
- **PDG user survey** (2022) demonstrates **extremely strong interest** from community in all of PDG's content



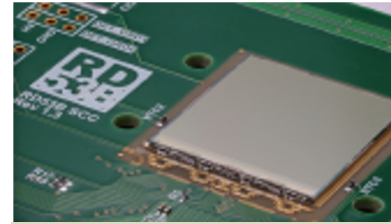
Energy Frontier: Collider projects and accelerators

ATLAS

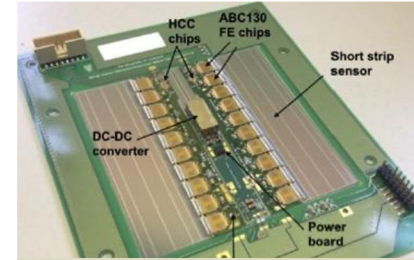
- Higgs physics, precision measurements, BSM physics
- Benefits from growing AI/ML cross-cutting activity

HL-LHC

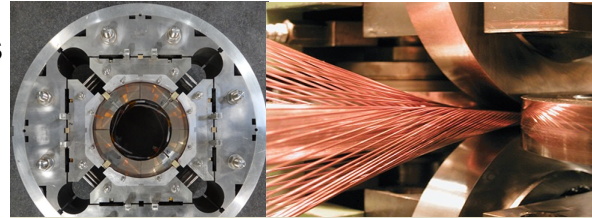
- Detector upgrade: Lead roles on all three WBS of ITk tracker
 - Pixels: Leadership role in ASIC development
 - Strips: Selected stave concept originated & demonstrated at LBNL
 - Global Mechanics: Lead design & construction of carbon-fiber structures (first carbon shells recently delivered)
- Accelerator Upgrade Project: HL-LHC magnets
 - Lead cable assembly and magnet facility
 - Drives increased luminosity for future runs



Leadership: pixel readout



LBNL design: Silicon Strip



Precision assembly, state of art cabling

Energy Frontier: Collider projects and accelerators

Accelerator modeling program – Exascale and SciDAC

- GordonBell Prize for WarpX; Post-Exascale funding critical for sustainability

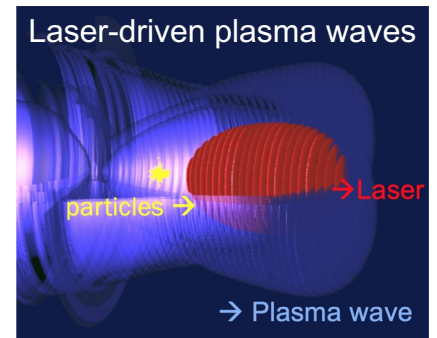
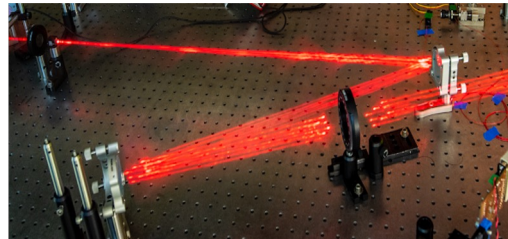
Lead lab for US Magnet Development Program

- High-temperature superconducting and hybrid magnets towards $\geq 20\text{T}$
- Key to **future circular colliders**, as well as light sources, fusion etc.

Bella center

- Laser plasma acceleration (towards 10 TeV/parton scale)
- kBella \rightarrow kHz regime for future colliders
- Mid-scale project

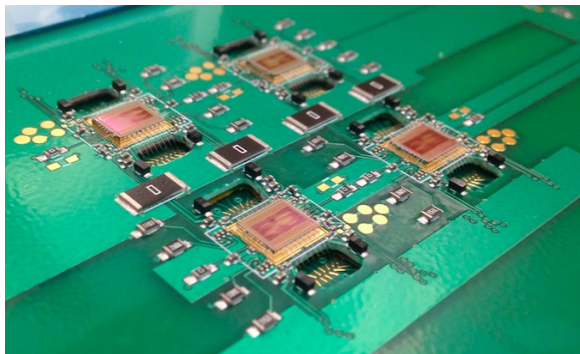
kHz laser technology for colliders
kBELLA & fiber combination



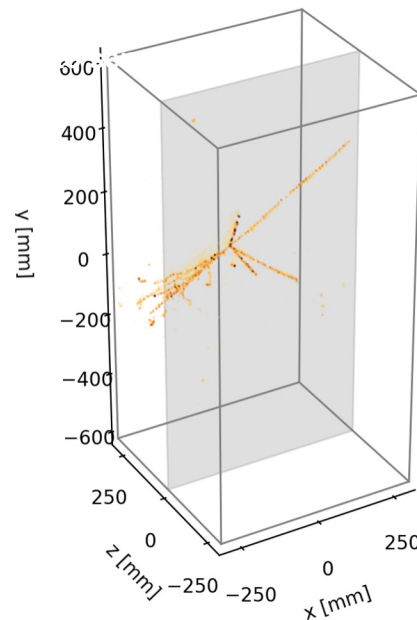
Contributions to the Intensity Frontier

DUNE

- Leadership on Far Detector #1 and #2 Vertical Drift read-out electronics
- Leadership of Near Detector LAr TPC (ND-LAr)
 - Successful demonstration of ton-scale demonstrator modules with >80k LArPix readout channels; LArPix was designed, fabricated & demonstrated at LBNL
 - Coordinating production of 4 modules for ArgonCube 2x2 demonstrator to be operated in NuMI neutrino beam



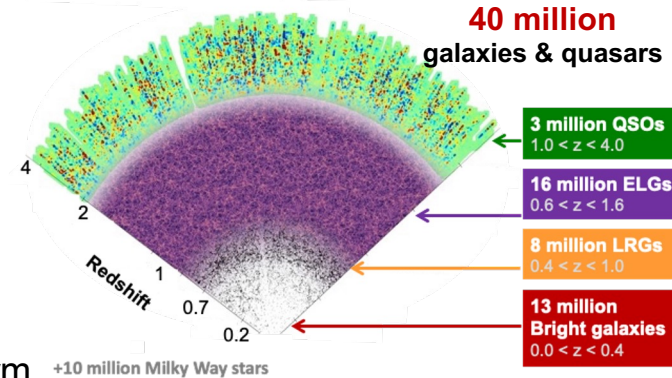
Cryogenic
pixelated
readout ASIC
(LArPix)



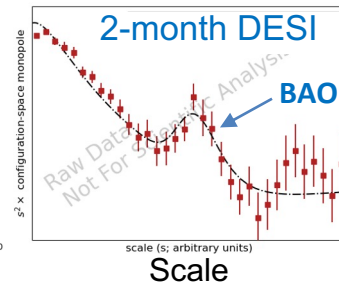
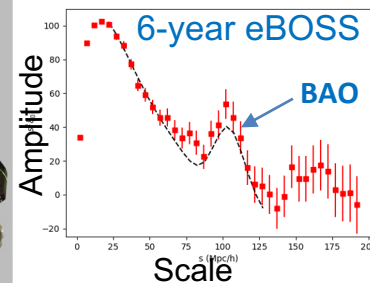
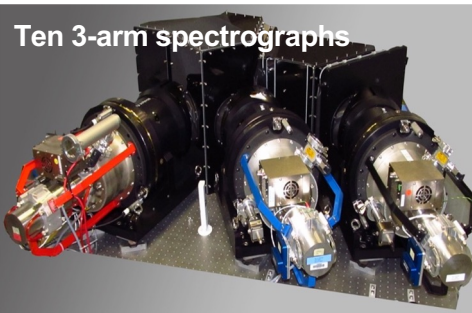
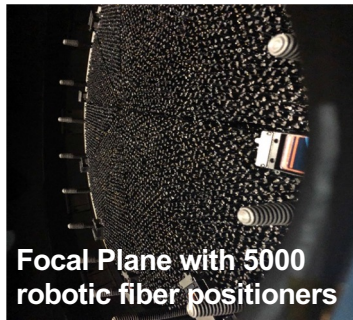
Cosmic Ray
Shower imaged
with LArPix

DESI: Dark Energy Spectroscopic Instrument

- Largest-ever 3D map of the Universe from 40M sources, charting the Universe **expansion history** over 12 billion years to study **Dark Energy**
- DESI received the **DOE Project Management Excellence Award** (delivery **on schedule and under budget**)
- **Led by LBNL**, collaboration of over 1000 scientists from 70 institutions
- First Stage IV Dark Energy experiment taking data
- Preparing near-term DESI-II to address early dark energy, and long-term Stage-5 spectroscopic instrument to probe inflation & primordial features

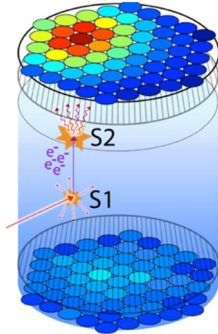
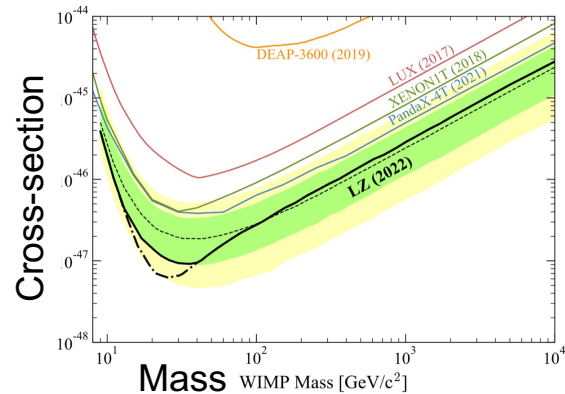
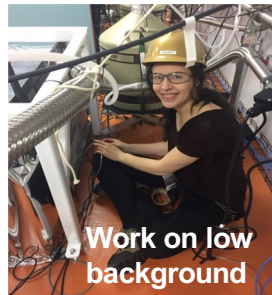
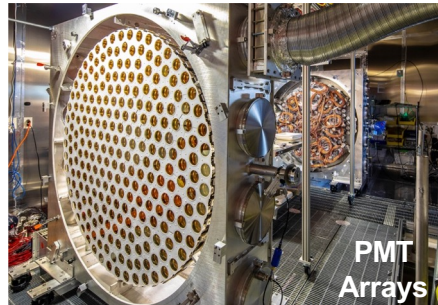
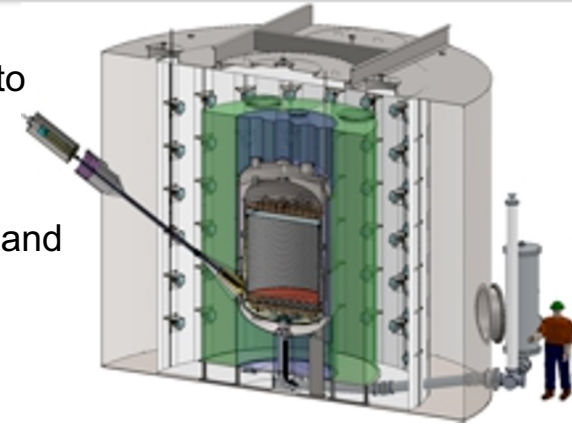


Kitt Peak Observatory
NSF's Mayall telescope



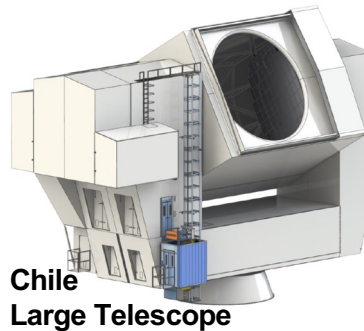
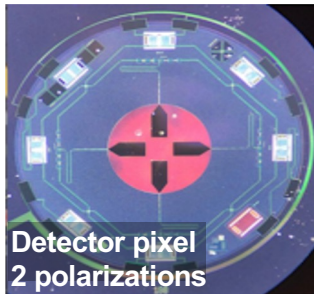
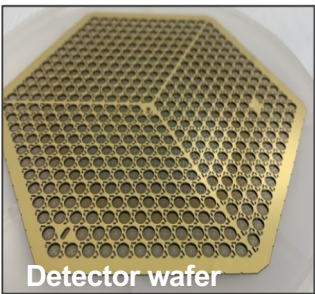
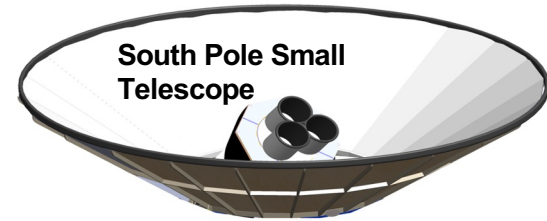
LZ: Dark Matter Experiment

- LZ: 10 tonnes of liquid xenon viewed by sensitive light and charge sensors to detect minute energy deposits from **Dark Matter**
- Located 1 mile underground at the Sanford Underground Research Facility
- **Led by LBNL**, over 250 collaborators from 37 institutions; delivered on time and budget despite pandemic
- First data run yielded world-leading constraints on WIMPS
- Year-long Science Run 2 in progress



CMB-S4 experiment

- CMB-S4 will measure the relic radiation from the **early Universe** to characterize the content and evolution of the Universe
- Array of small & large telescopes with ~ 500,000 superconducting microwave detectors, deployed in Chile and the South Pole
- **LBNL is lead lab** of CMB-S4, with >400 collaborators from >100 institutions
- Recommended by the HEPAP 2014 P5 report, very strong endorsement from Astro2020 and snowmass 2022 - Planned as a joint DOE/NSF project
- Growing interest from foreign partners



AI/ML and QIS Initiatives

- Cross-cutting Physical Sciences AI/ML group
 - HEP-specific but project-independent team of experts to complement project-specific experts
- QIS initiative integrates Physics and ATAP expertise, connections to Quantum System Accelerator center
 - Quantum sensor development, quantum computing, networking, qubits and controls
 - Leverages related programs with ASCR and FES

QuantISED Quest



Low-mass Dark Matter;
Detect single phonon at 0 dark count;
Solving QCD on quantum computers

Quantum fields



Table-top gravity

Skipper CCD QuantISED



Single photo-electron
read-out

QIS Alpha



Best-measured
constant



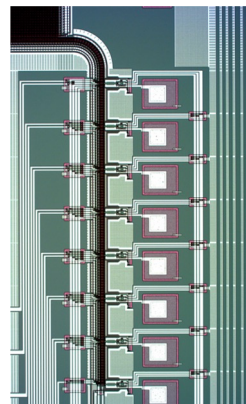
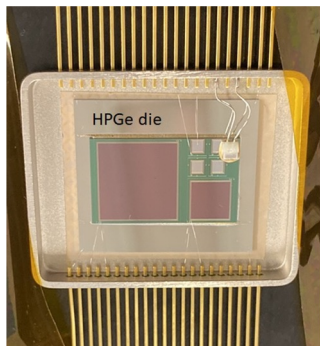
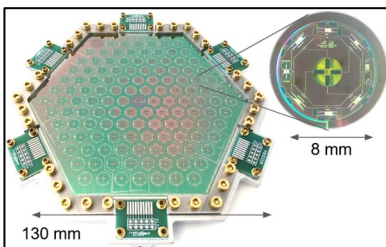
Advanced Qubit controls



LBL: a long tradition of innovation

Cosmic Frontier

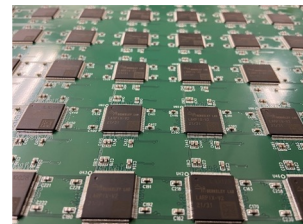
Ge CCDs, skipper CCDs
CMB polarization detectors



Technology transfer to industry

Intensity Frontier

Pixellated readout for DUNE
Hydra I/O to bypass chip failure
Beam physics for high intensity



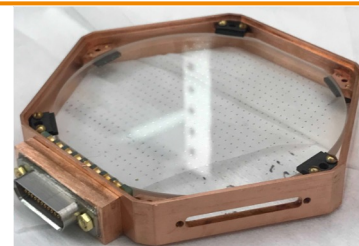
Energy Frontier

HL-LHC ATLAS & AUP upgrade
Magnets and accelerators
RD53 pixel readout chip
R&D on 28 nm for next generation



QIS

Quantum sensing
Qubit control



Summary

- **LBNL HEP leads a broad program of discovery science to address the most compelling questions in fundamental physics**
 - Across the Energy, Intensity, Theory and Cosmic frontiers; significant AI/ML and QIS efforts
 - Strengths in advanced accelerators, superconducting magnets, detectors, electronics, computing
 - HEP benefits from the scientifically rich environment and resources at LBNL
 - Outstanding staff, training the next generation
- **We are advancing the next generation of experiments**
 - All our projects benefit from our matrixed engineering division and our historical stewardship in HEP-wide instrumentation & theory
 - Strong contributions to ATLAS and DUNE, with unique and enabling contributions
 - Leading DESI and LZ: P5 experiments in Dark Energy and Dark Matter, both taking data
 - Leading CMB-S4: CD-0, working with NSF and DOE to define the path to CD-1
 - Extending the reach of colliders via superconducting magnets, exascale simulation and controls
 - BELLA: leading in plasma accelerators towards future collider, kBELLA shovel ready