

## PHYSICAL SCIENCES AREA

Berkeley Lab HEP Program  
Natalie Roe, Associate Lab Director for Physical Sciences  
Snowmass Community Meeting, July 24, 2022



**BERKELEY LAB**

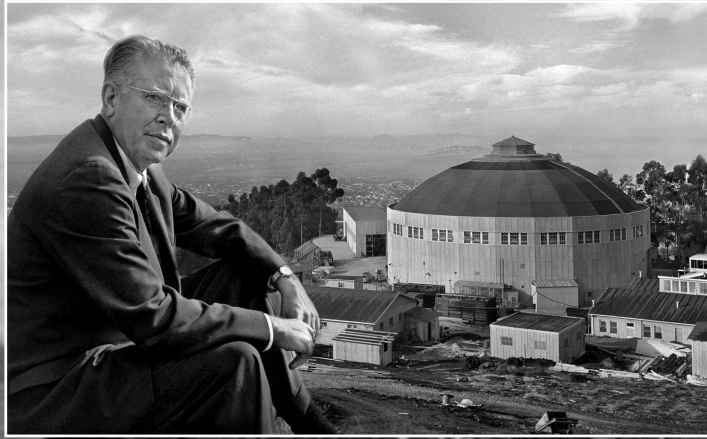


U.S. DEPARTMENT OF  
**ENERGY**

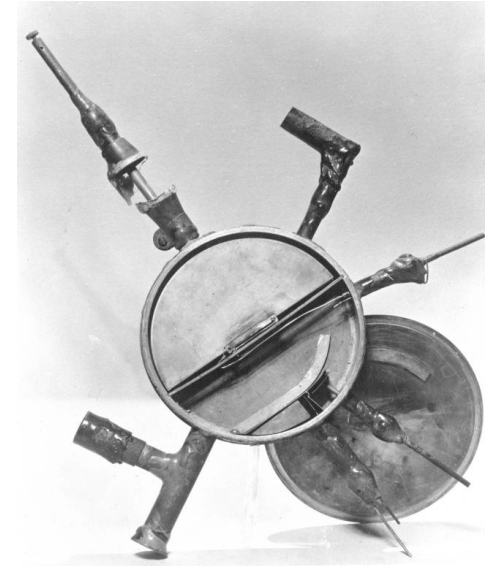
Office of  
Science



# Berkeley Lab was founded in 1931 on two pillars: the cyclotron and team science



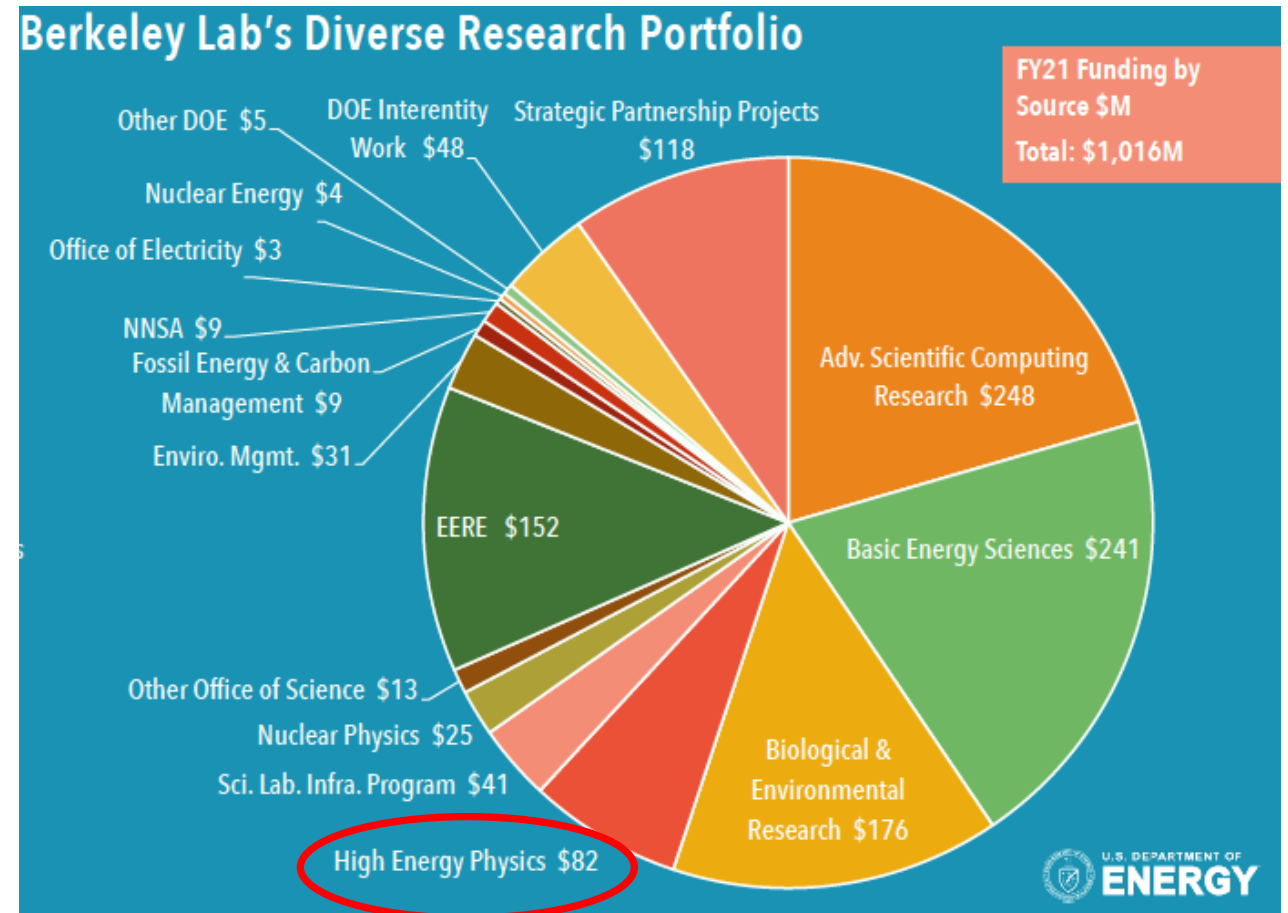
E. O. Lawrence and the  
184" cyclotron (circa 1940).



The small seed from  
which Big Science grew.

# Today, Berkeley Lab is a diverse multipurpose DOE Lab

- Total FY21 funding \$1.016B, ~3700 FTE
- 5 Major User facilities with ~14K users
  - NERSC/ESNet
  - Advanced Light Source => ALS-U
  - Molecular Foundry
  - Joint Genome Institute
- The Berkeley HEP program benefits from multiple local connections
  - Engineering Division
  - Nuclear Science Division
  - Computing Sciences Area/NERSC
  - Materials Science Division/Molecular Foundry
  - Quantum System Accelerator (QSA)
  - UC Berkeley faculty and students, who are deeply embedded in our program
  - Synergies with ASCR, BES, FES, NP, NNSA...



# Berkeley Lab HEP Program Overview

- Two Divisions
  - Physics and Accelerator Technology and Applied Physics
- Leading programs in
  - Energy Frontier – ATLAS group
  - Cosmic Frontier – Lead lab for DESI, LZ, CMB-S4
  - Superconducting Magnets – Lead lab for the US Magnet Development Program
  - Advanced Accelerators – BELLA center for laser plasma acceleration
- Tradition of Innovation in Accelerators, Detectors and Readout
  - TPC, Silicon vertex detectors and readout, Red-sensitive CCDs, Skipper CCDs, LArPix (DUNE), Quantised Quest program in QIS sensors and Qbit readout, Accelerator sources and control systems, Muon cooling, High power lasers...
- Cross-cutting AI/ML group and QuantISed program in QIS
- Home of the Particle Data Group



Physics Division  
Nathalie Palanque-Delabrouille



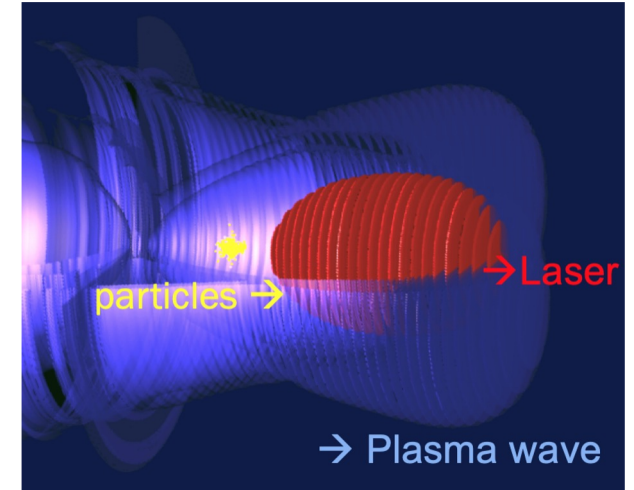
Accelerator Technology and  
Applied Physics Division  
Cameron Geddes



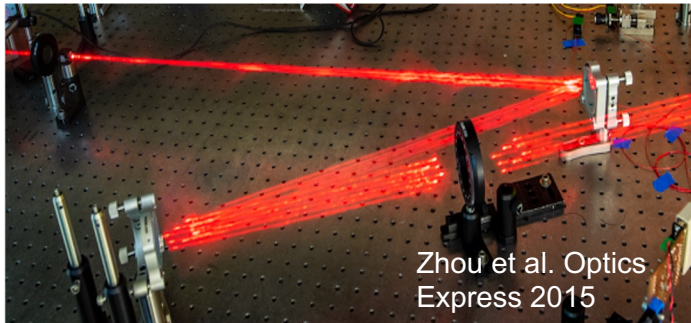
# BELLA Center for Laser-Plasma Based Accelerators

- World leading program: 8 GeV energy electrons in just 20 cm
  - would require 100's of m using conventional acceleration techniques
  - competing with \$B scale investments overseas in laser, plasma technologies
- New BELLA 2nd beamline will enable “staging” to higher energies
- Future O(10TeV) collider parameter concepts via ITF and e+e- forum
- Next step: kBELLA will extend to kHz rep rates needed for **future colliders**
  - leverages cross-federal applications: ARDAP, BES, NNSA, FES, DoD...

Laser driven plasma wave

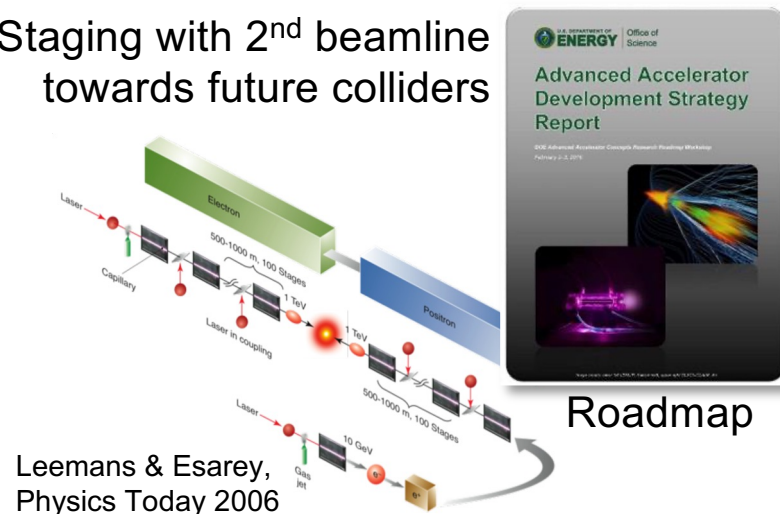


kHz laser technology for colliders  
kBELLA & fiber combination

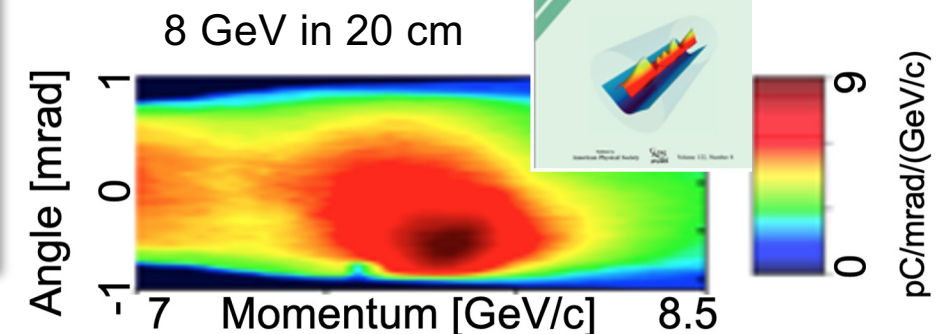


Zhou et al. Optics Express 2015

Staging with 2<sup>nd</sup> beamline  
towards future colliders



Roadmap

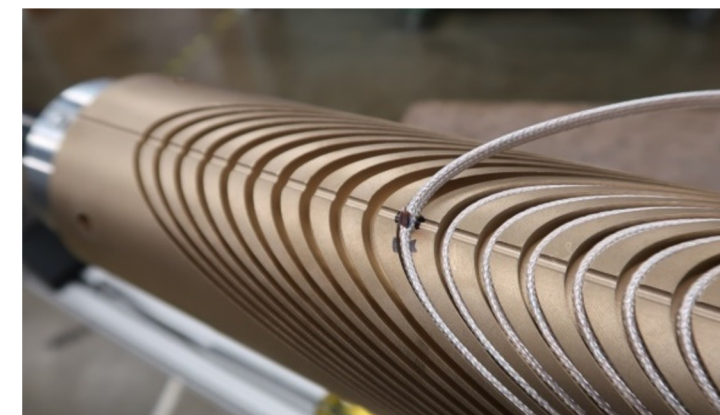


Gonsalves et al., Phys. Rev. Lett. 2019

# LBNL Leads the US Magnet Development Program (US MDP)

- US MDP develops next generation superconducting magnets
  - key to **future circular colliders**, as well as light sources, fusion etc.
- Also playing key roles in High Lumi-LHC Accelerator Upgrade Program for magnet cabling and assembly, to drive increased luminosity
- Exascale accelerator modeling and state of the art active feedback controls and sources enable **intensity & energy frontier accelerators**

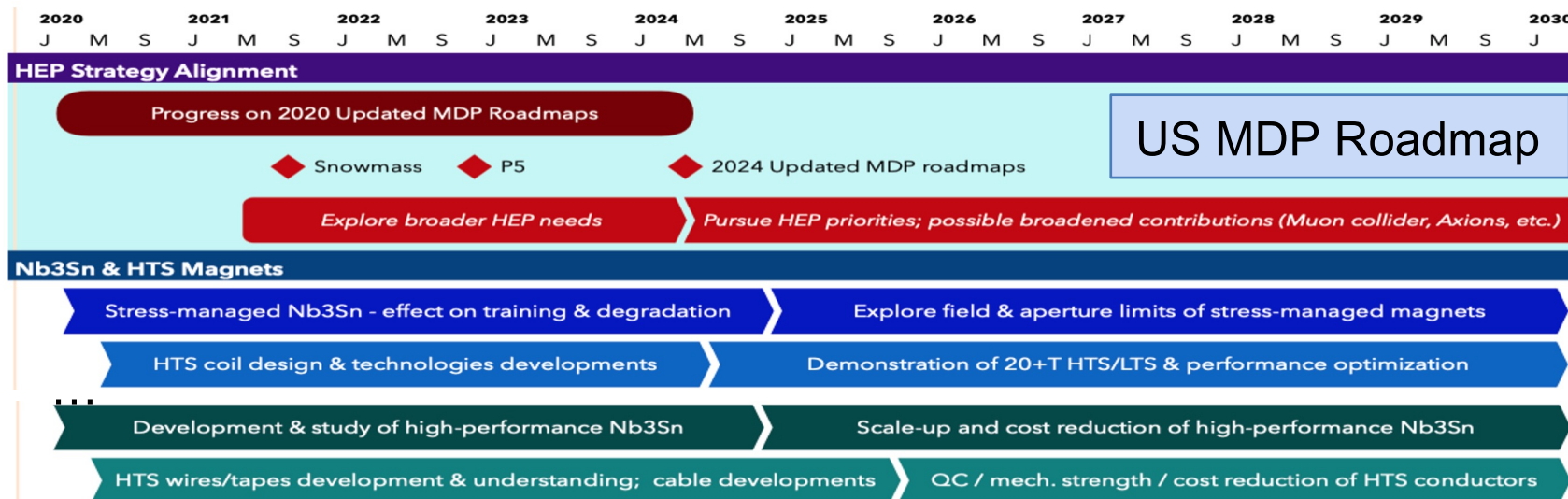
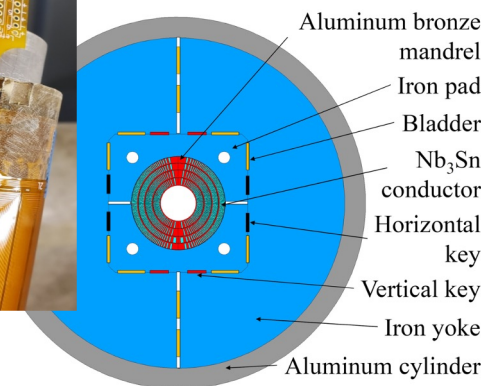
Stress management for high field



High temperature  
superconductor  
inserts



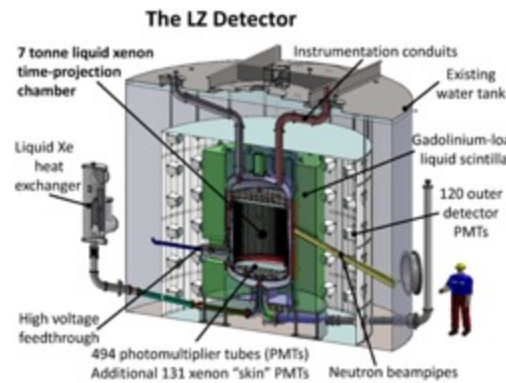
Towards full  
scale new magnets



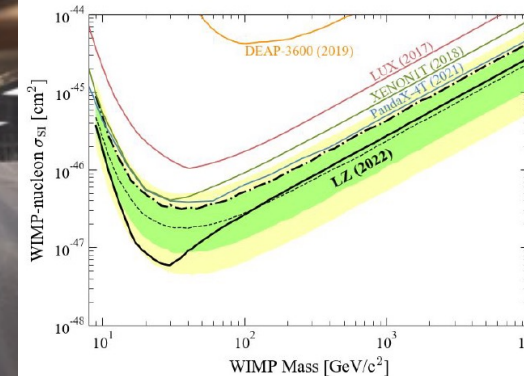


# COSMIC FRONTIER @ Berkeley – Leading DM, DE and CMB projects

**LZ: 20x increased sensitivity to dark matter**

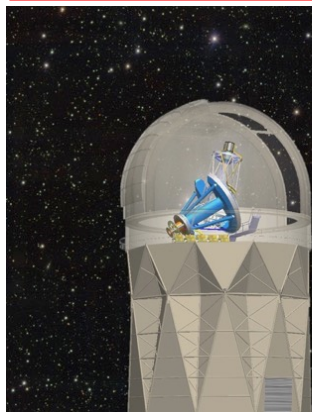


Outer Cryostat tested and being installed at SURF

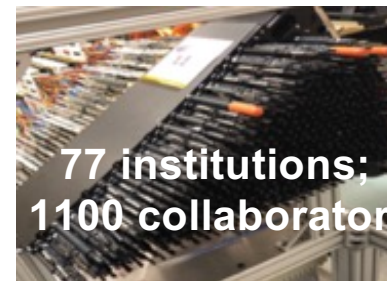


**CD-4 awarded in September 2020; First data with world leading results just released!**

**DESI: 20x increased precision in dark energy, + large scale structure and neutrino masses**

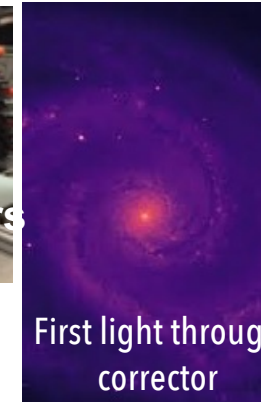


12-ton corrector installed on the Mayall telescope

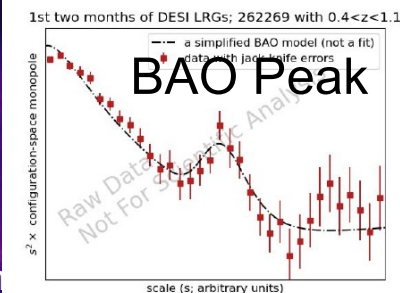


77 institutions; 1100 collaborators

Final production petal, with fiber positioners



First light through corrector



**CD-4 awarded in May 2020; 14 million redshifts observed, more than all previous surveys!**

**CMB-S4: most sensitive map of the early Universe**



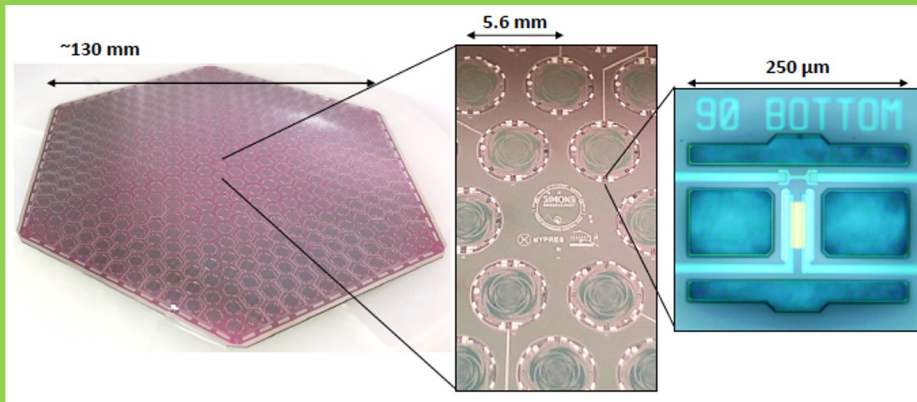
CMB-S4 will comprise an array of 18 telescopes with 500,000 superconducting microwave detectors located in Chile and the South Pole

62 institutions; >300 collaborators

**CD-0 awarded in 2019; LBNL selected as lead lab in August 2020**

# Innovations in Instrumentation: ATLAS, DUNE, PIP-II and R&D

Superconducting transition edge detectors for **CMB** and **Dark Matter** experiments;  
Technology transfer to industry under SBIR program

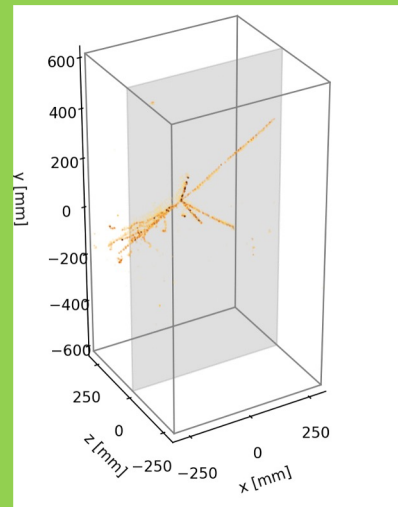


LArPix ASIC  
bonded to sensor

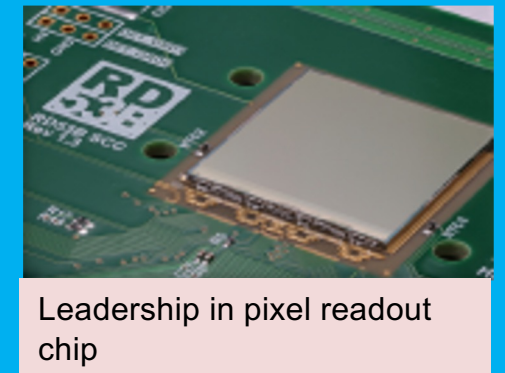
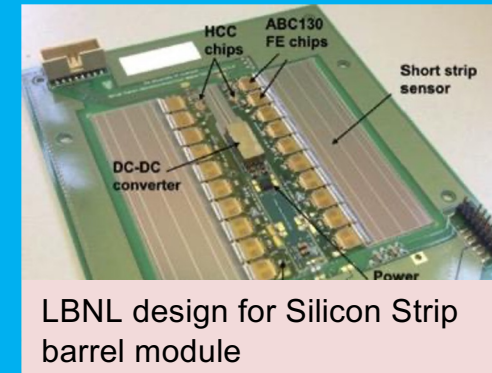


Cryogenic  
pixelated  
readout ASIC  
(LArPix)  
for **DUNE**

Cosmic Ray  
Shower imaged  
with LArPix



Silicon Strip and Pixel detectors for the **ATLAS**  
experiment at CERN



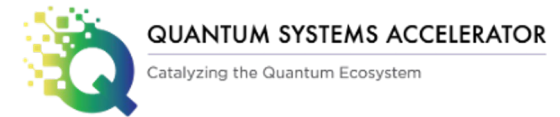
Scalable controls to extend **accelerators**  
(**PIP-II**, others) and superconducting qubits  
by ATAP for AQT



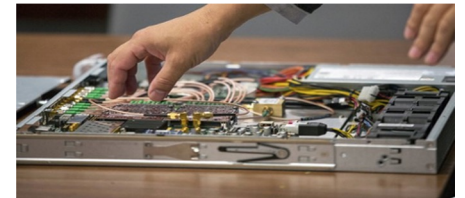


# QIS Initiatives: Partnerships

- QIS initiative integrates Physics and ATAP expertise, connections to QSA center
  - Quantum sensor development, quantum computing, qubits and controls
  - Subawards to/from other labs and universities



Advanced Qubit controls



## QuantISED Quest



Low-mass Dark Matter;  
single phonon detection  
with zero dark count

## Quantum fields



Table-top gravity

## Skipper CCDs QuantISED

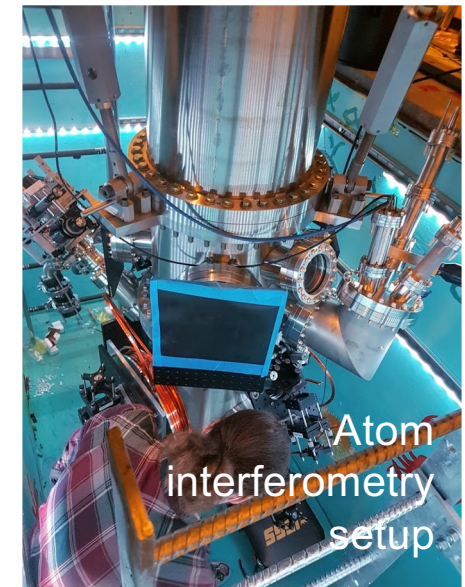


Single photo-electron  
read-out

## QIS Alpha



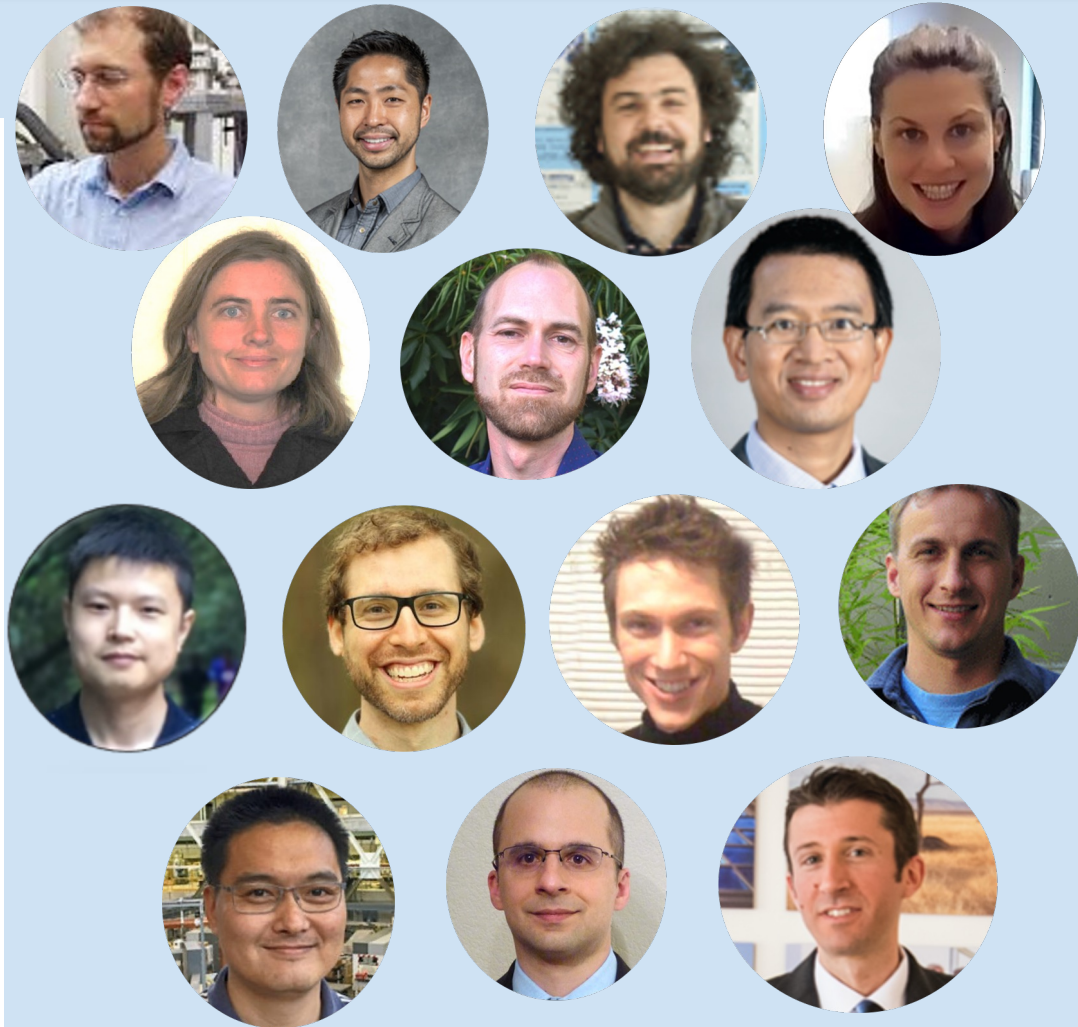
Best-measured  
constant



Atom  
interferometry  
setup

# Outstanding Young Scientists – Our Most Important Asset

- 14 recent DOE HEP + BES Early Career Awards =>
- 3 of past 9 recipients of the APS Primakoff Award for early career physicists
- L'Oreal Award for US Woman Scientist in 2021
- European Physical Society Award 2021 for outstanding young particle physicist
- American Phys. Soc. Div. Beams outstanding dissertation 2021






# 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 – 50 Mentor/Mentee pairings, who meet monthly for a year
  - Expanded in 2022 to include admin, technical staff – 67 Mentor/Mentee pairings
- Division activities: Quarknet, US Particle Accelerator School, SAGE, Snowmass paper
- Divisional and Area committees, strong participation in professional societies' & reports
- Participation in and executive sponsorship of LBNL Employee Resource Groups
- **Snowmass: CEF participation and climate of field white paper**



# Snowmass @ Berkeley Lab

- Snowmass @ LBNL by the numbers:
  - 26 Berkeley scientists contributed to Snowmass organization 
  - 90 Berkeley scientists co-authored at least 1 Snowmass white paper, total of 104 white papers
  - 2 local workshops organized by the Snowmass LBNL cross-cutting steering committee to foster cross-cutting dialog
  - 3 Snowmass workshops co-organized/co-hosted by LBNL: “Software and Computing for Small HEP Experiments”, “MultiHEP 2020”, “Advanced accelerators”
- Snowmass topics of special interest at LBNL:
  - CMB-S4: Confirm 2014 P5 Report recommendation
  - DESI-2 as a bridge towards a Stage 5 Spectroscopic Survey candidate (MegaMapper)
  - G3 Dark Matter experiment – “Dig deep”, eg XLZD
  - DMNI – “Prospect wide”, eg TESSERACT, LZ upgrades
  - Long-lived particle detection at HL-LHC (eg CODEX)
  - AI/ML to discover new physics at HL-LHC
  - kBELLA and future laser plasma wave linear accelerators
  - Advanced magnets & systems to support future circular colliders and muon collider
  - Muon collide detector and reconstruction algorithms

Coordination role	Persons
Snowmass Steering Group	1
Frontier Conveners	3
Topical Group Conveners	11
Focused-groups conveners	5
Frontier liaisons	6
Total unique scientists	26



# Summary

- LBNL HEP program of discovery science aims to address the most compelling questions in fundamental physics
  - Across the Energy, Intensity and Cosmic frontiers; significant AI/ML and QIS efforts
  - Strengths in advanced accelerators, superconducting magnets, detectors, electronics
  - Outstanding staff, training the next generation
- Team Science is still alive and well at Berkeley – we have strong collaborations with our sister national labs and with universities in all our programs
- We benefit from many resources in the LBNL multi-disciplinary environment
- We aim to forge connections with other DOE SC offices: ASCR, BES, FS, NP
- Berkeley is strongly engaged and supports the Snowmass process towards the next generation of exciting HEP projects