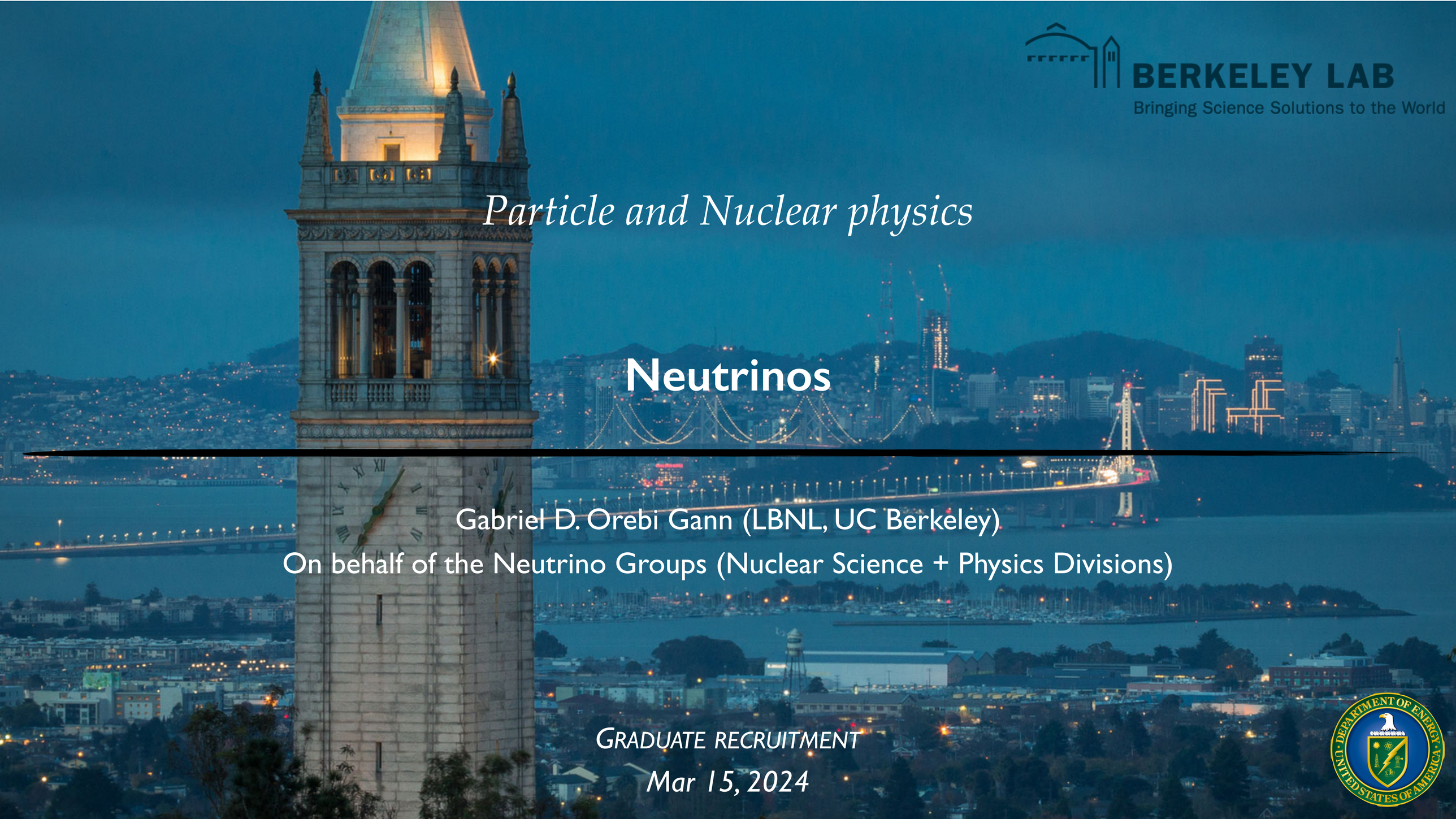


BERKELEY LAB
Bringing Science Solutions to the World

Particle and Nuclear physics

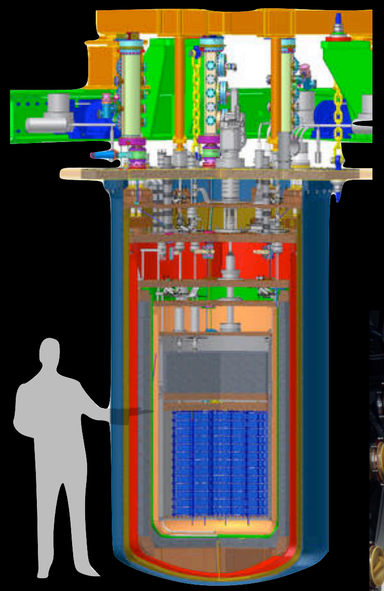
Neutrinos

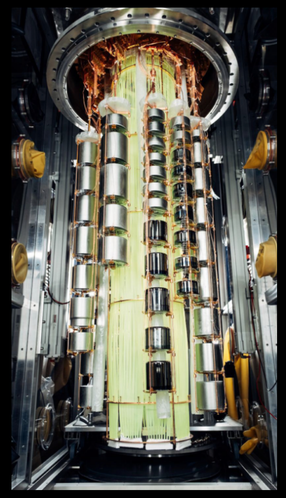
Gabriel D. Orebi Gann (LBNL, UC Berkeley)
On behalf of the Neutrino Groups (Nuclear Science + Physics Divisions)

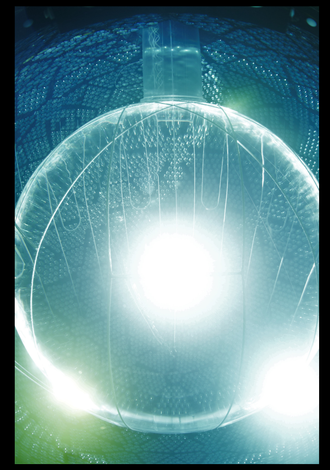
GRADUATE RECRUITMENT

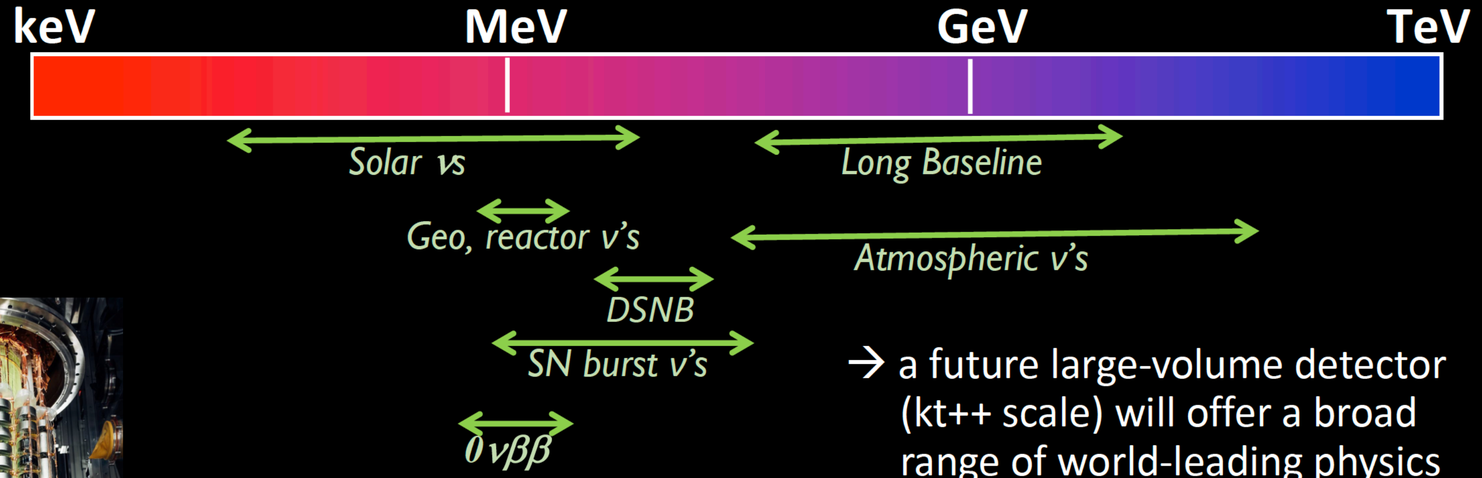
Mar 15, 2024

Lepton physics at Berkeley

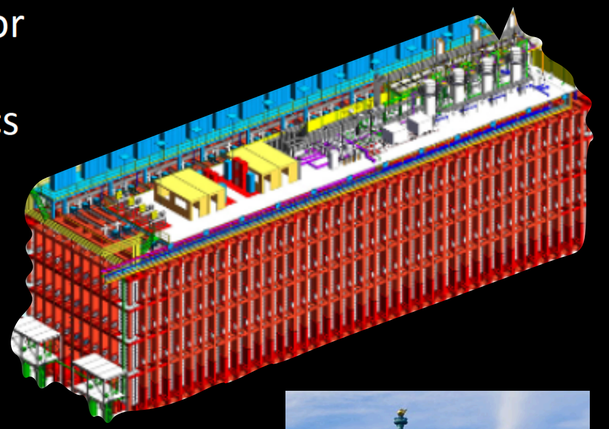




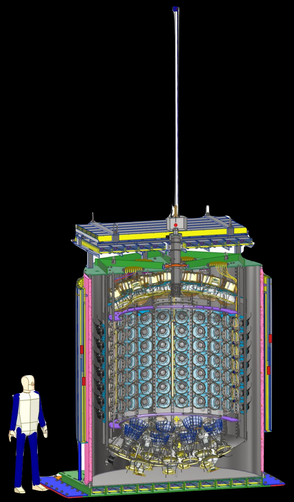


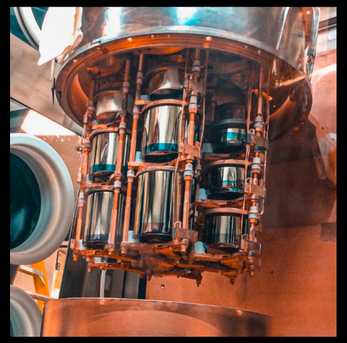


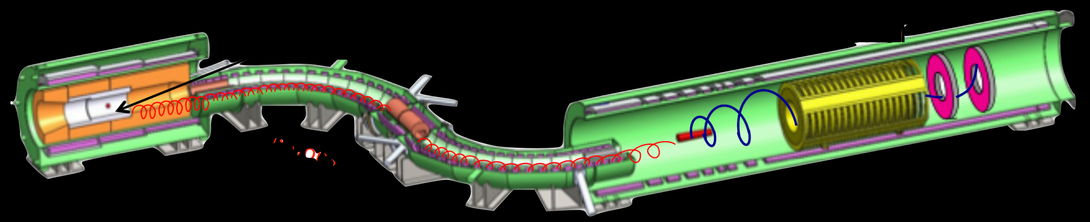
→ a future large-volume detector (kt++ scale) will offer a broad range of world-leading physics

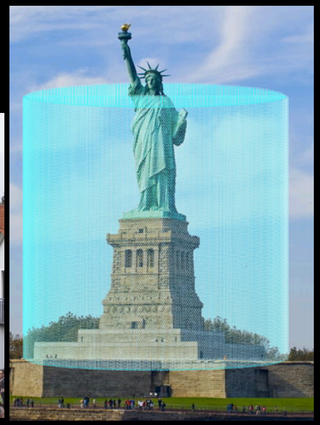


- Spans from very low to very high energy
- From bench-top to 10s of ktons
- Mu2E, DUNE, LEGEND, Katrin, CUORE/ CUPID, SNO+, Theia, Eos







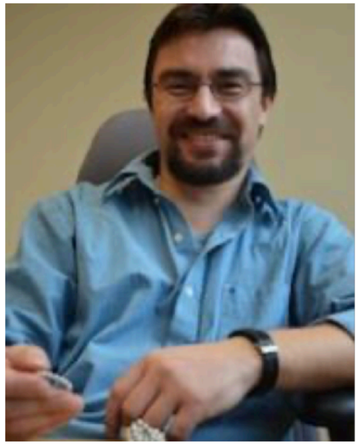


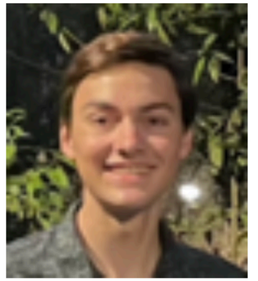
Mu2e: lepton flavour violation

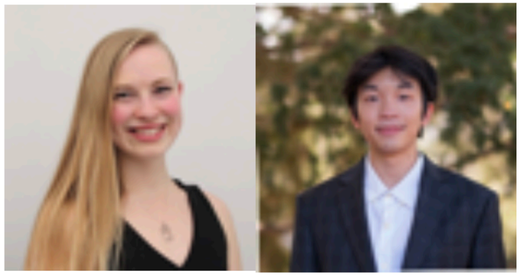
contact ygkolomensky@berkeley.edu, dave_brown@lbl.gov, or RBonventre@lbl.gov for details

The Berkeley Mu2e group

- (LBNL) Dave Brown, Richie Bonventre, Ed Callaghan
- (UCB) Yury Kolomensky, Vivek Singh, Nick Cutsail, Jason Guo, Hien Nguyen, Talia Saarinen, Johan Vonk



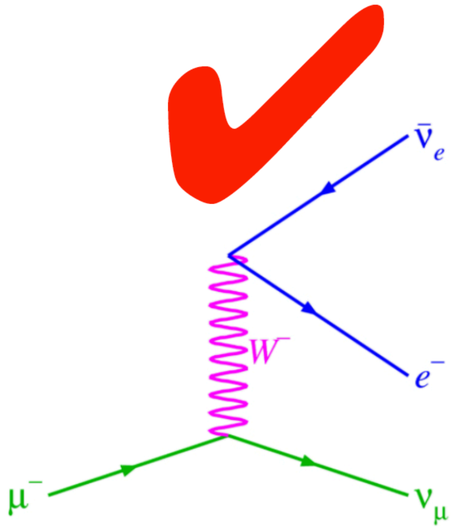




The Mu2e experiment

Probing lepton flavour violation with 10^{17} muons

10^4 sensitivity improvement over the previous experiment



Why are there 3 generations? Why are lepton flavors conserved?

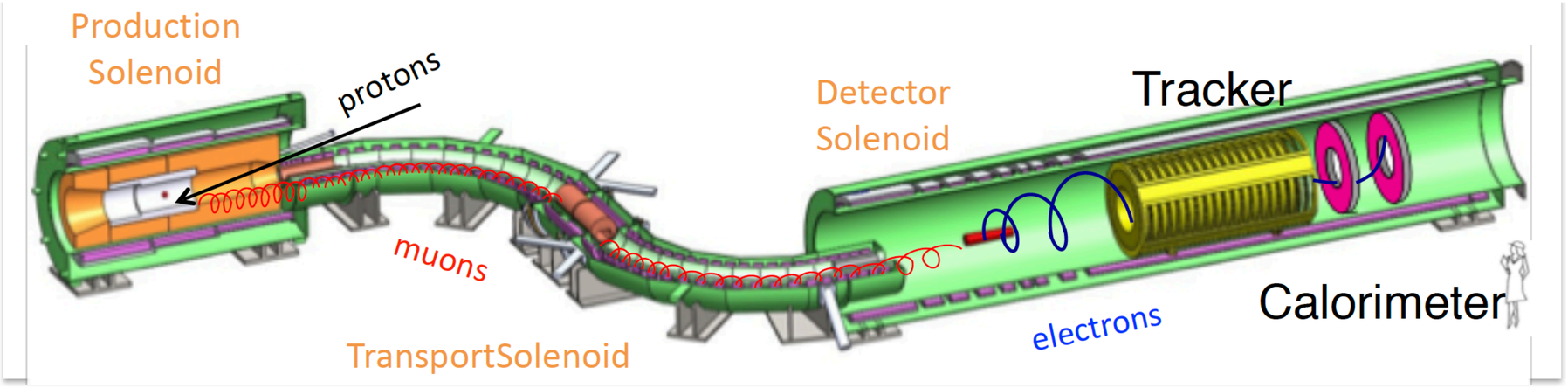
Lepton flavor violation in muon→electron conversion

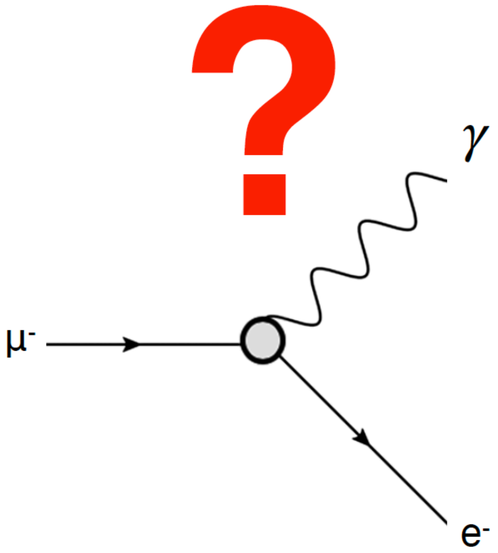
Fully funded experiment at FermiLab, slated to operate in ~2026

Technical and science development at Berkeley focused on precision tracking

+ developments of novel detection techniques for a Mu2e upgrade

Opportunities for 1-2 students

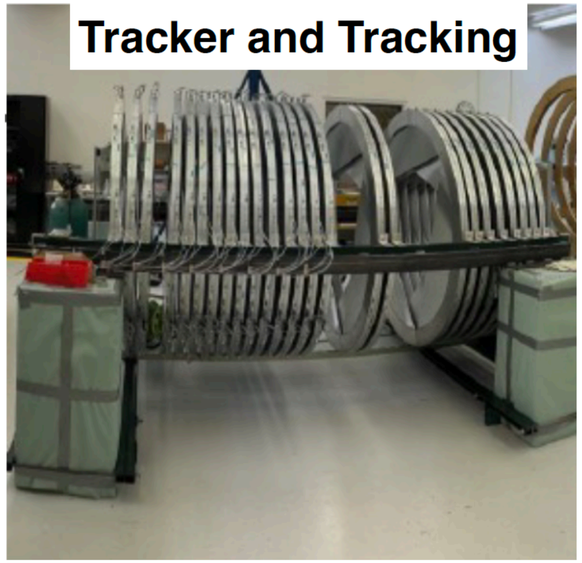


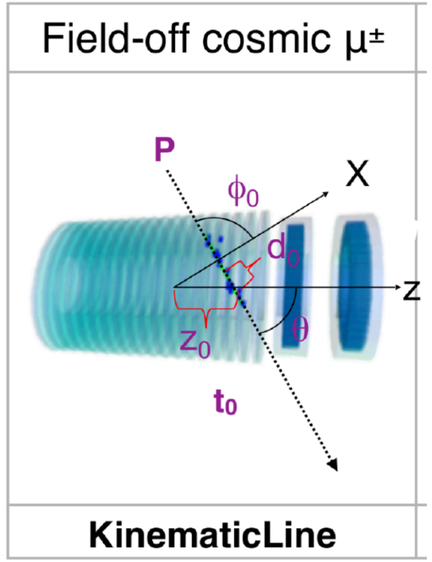


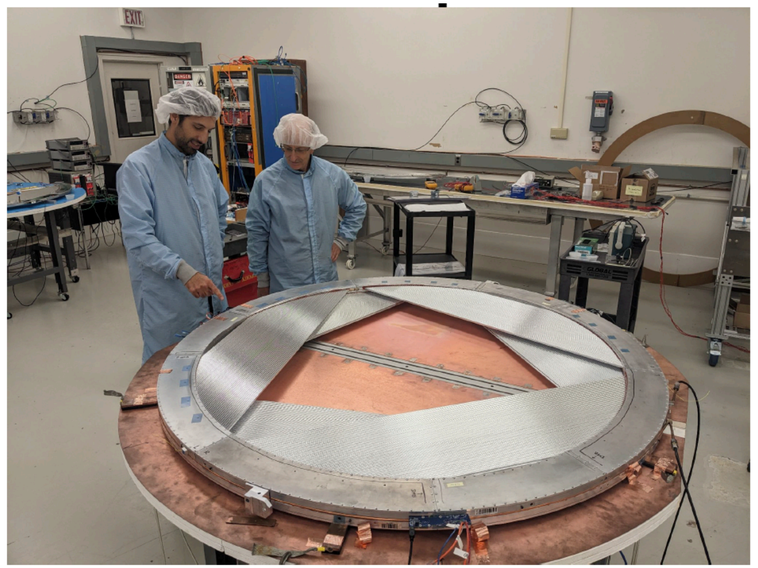
Mu2e status

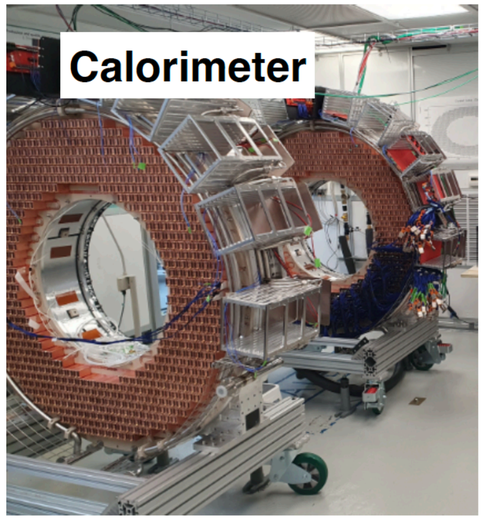
Mu2e construction is 80% complete

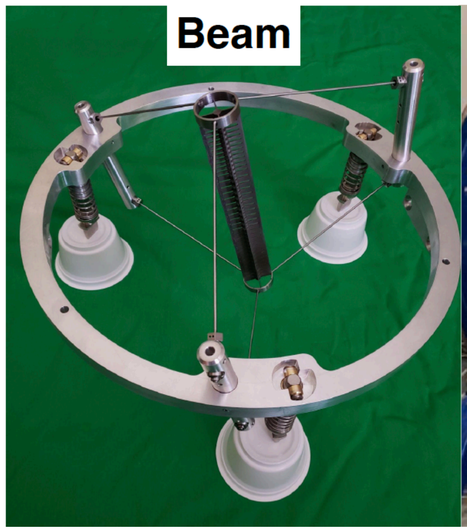
Cosmic ray commissioning starts ***this year***

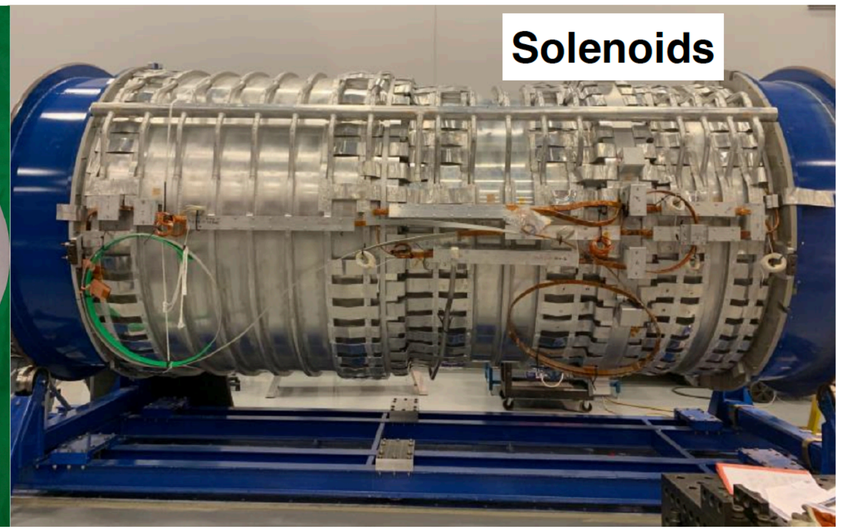












DUNE: long-baseline neutrinos

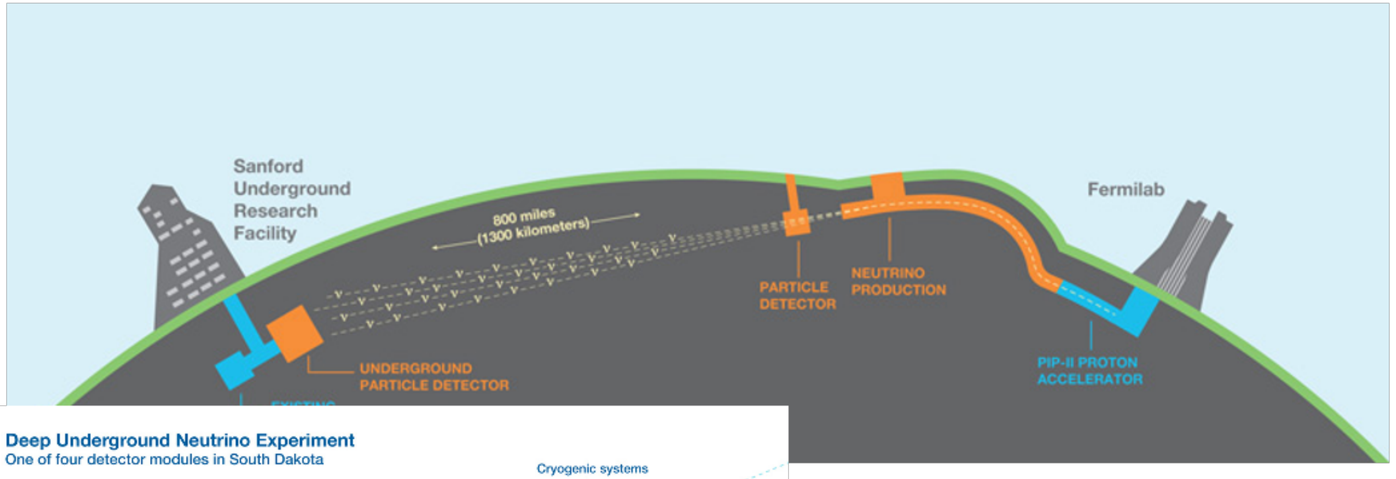
contact Daniel Dwyer <dadwyer@lbl.gov>, Callum Wilkinson <cwilkinson@lbl.gov> for details

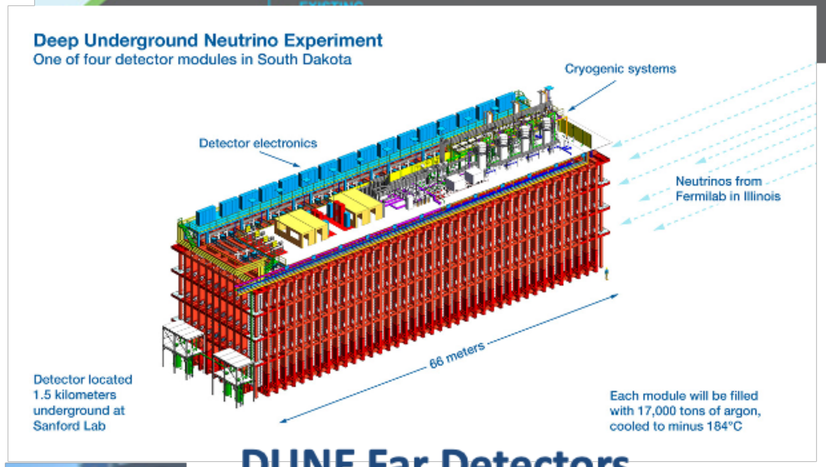
Neutrinos in the LBL Physics Division

Our Research:

The Deep Underground Neutrino Experiment (DUNE):

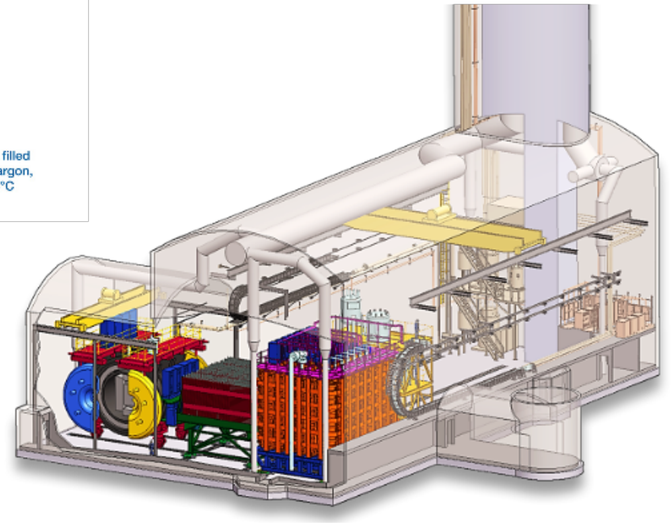
- Do neutrinos behave the same as antineutrinos?
- What is the mass spectrum of neutrinos?
- What can we learn from Supernova neutrinos?
- Experiment construction has begun





DUNE Far Detectors

DUNE Near Detectors



Our Team:

Dan Dwyer

Cheng-Ju Lin

Callum Wilkinson

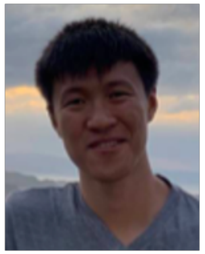
Kam-Biu Luk

Herb Steiner

Cynthia McNulty

Kevin Wood

Matt Kramer



Roger Huang

Jaafar Chakrani

Stephen Greenberg

Neutrinos in the LBL Physics Division

Current Activities:

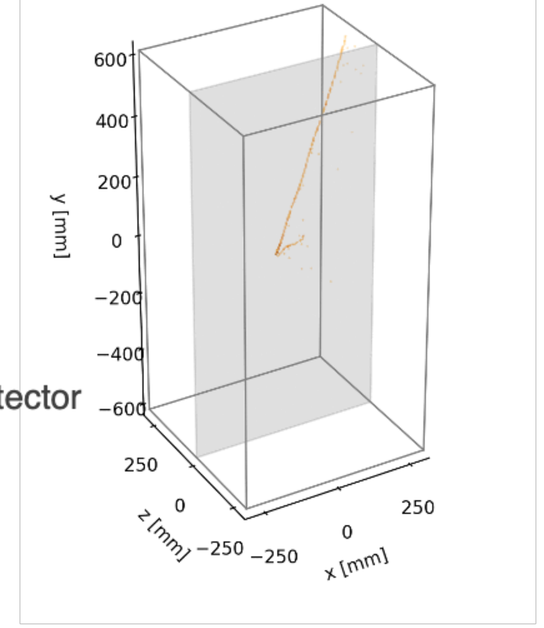
- **Detector R&D**
  - Developing novel 3D pixel readout of large liquid argon detectors
  - Design and testing of custom integrated circuits for particle detectors
  - Exploring scalable pixelated photon detection

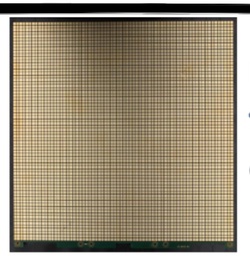
- **DUNE Near Detector design and prototyping**
  - Design of the Liquid Argon Time-projection Chamber (LArTPC) Near Detector
  - Small-scale prototyping of detector designs
  - Operation of a multi-ton prototype in a neutrino beam

- **Far Detector electronics**
  - Production and testing of electronics for the DUNE Far Detectors

- **Neutrino Oscillation physics**
  - Development of GPU-accelerated simulation techniques
  - Exploration of native 3D signal analysis techniques
  - Applications of Machine Learning in neutrino physics
  - Studies of the physics potential of DUNE

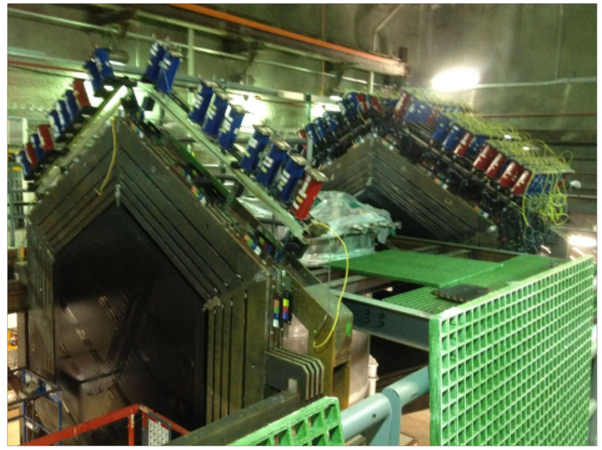
Cosmic rays imaged in 3D using recent prototype LArTPC



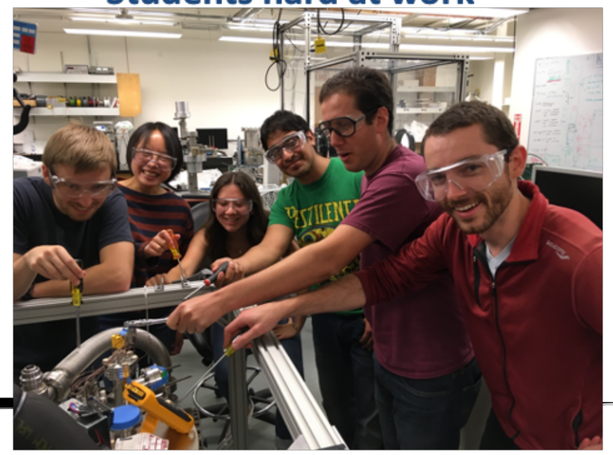


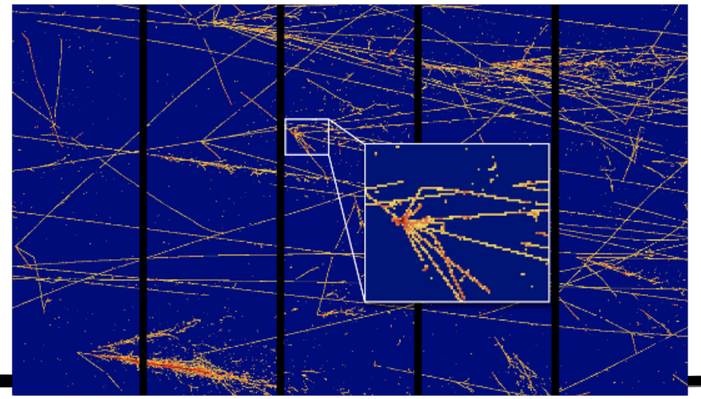
Prototype pixel tile with 6,400 channels

Multi-ton Detector in Neutrino Beam



Students hard at work





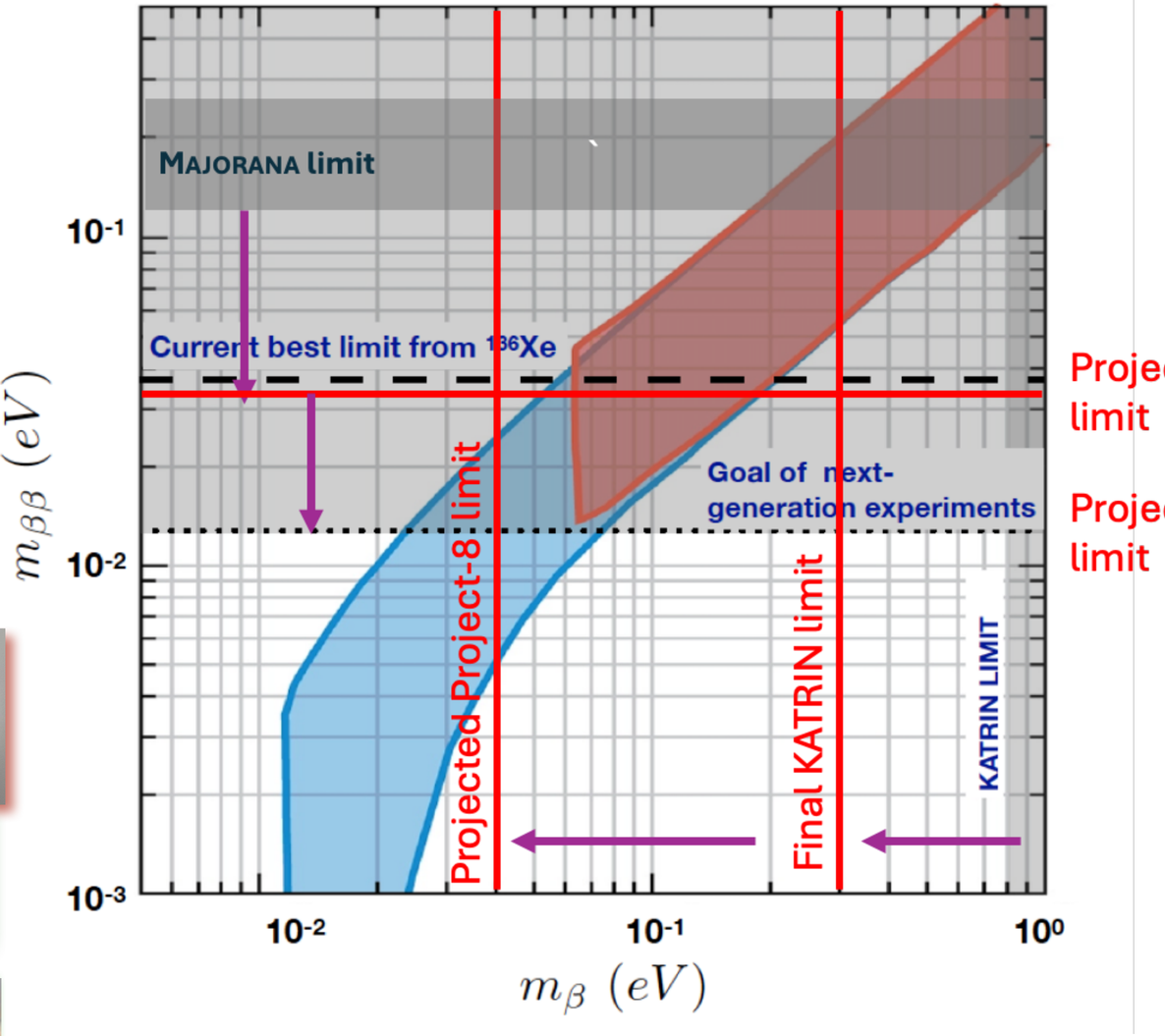
GPU-accelerated neutrino detector simulation

LEGEND and Katrin: neutrino mass and nature

contact Alan Poon <awpoon@lbl.gov> for details

Physics of the M(ajorana)L(EGEND)K(ATRIN) group

First row:
Gabriela Rodrigues Araujo (Visiting PhD student from Zürich)
Alan Poon (Group leader)
Phoebe Andromeda (BSc student from Oregon State)
Ann-Kathrin Schütz (Postdoc)
Lisa Schlüter (Postdoc)
Second row:
Yannick Müller (Visiting PhD student from Zürich)
Steve Eberly + Falcor (Undergrad student + assistant)
Yuen-dat Chan (retired)
Alexey Drobizhev (research scientist)*
Marco Turqueti (electronics engineer, ENG)
Third row:
Lucas Brouwer (Staff Scientist, ATAP)
Björn Lehnert (project scientist)
Rebecca Carney (research engineer, ENG)*
Amanda Krieger (ASIC designer)
*denotes former postdoc of the group who became a career staff at the Lab



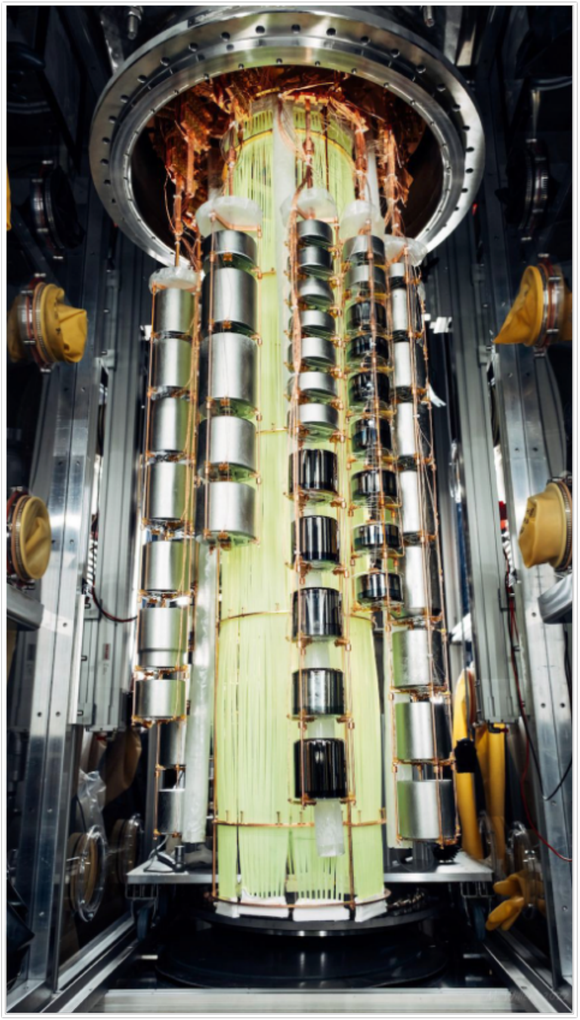
Projected LEGEND-200 limit

Projected LEGEND-1000 limit

M(ajorana)L(EGEND)K(ATRIN) group projects

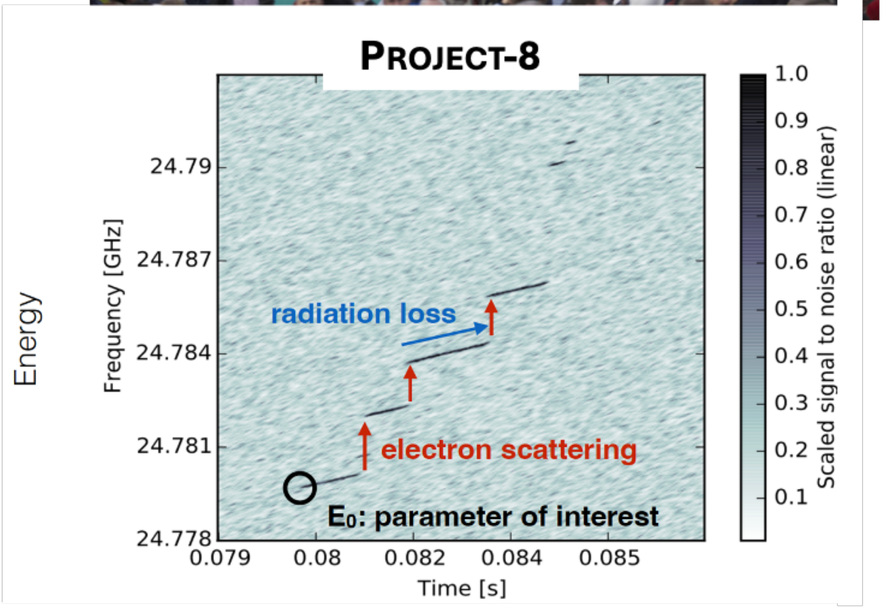
MAJORANA DEMONSTRATOR

LEGEND-200



KATRIN

PROJECT-8



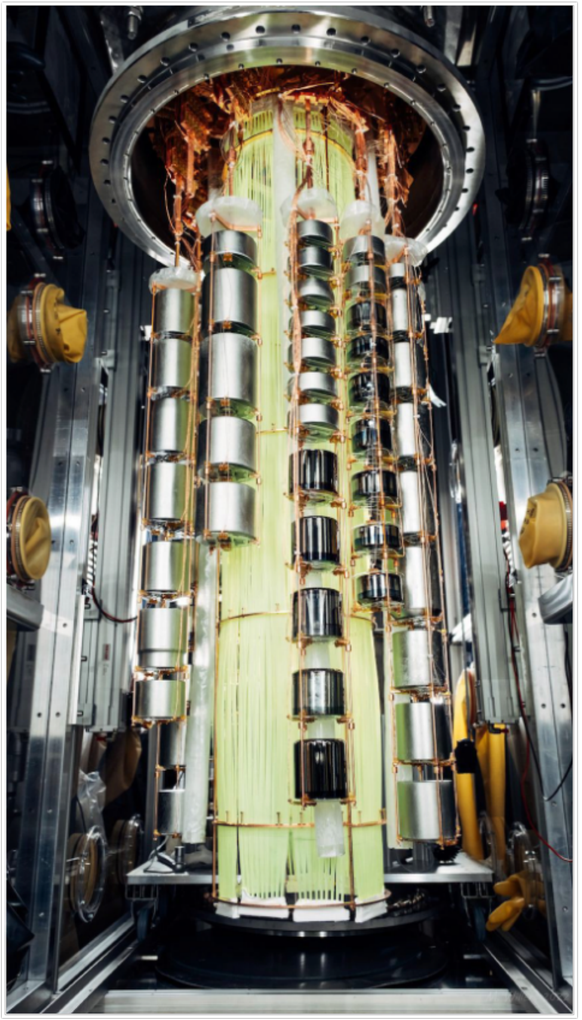
M(ajorana)L(EGEND)K(ATRIN) group projects

MAJORANA DEMONSTRATOR

- Completed
- Built best-of-class electronics (best energy resolution, lowest threshold) that also enabled other BSM Physics beyond 0νββ (e.g. solar axion)

LEGEND-200

- Production data-taking in progress
- Designed and built electronics (improved energy resolution over MAJORANA DEMONSTRATOR)
- Designing an ASIC for LEGEND-1000. DOE funding review (CD-1) for LEGEND-1000 in June



KATRIN

- Will complete production data-taking at the end of 2025.
- Focus on Bayesian analysis of the tritium beta decay spectrum using HPC Perlmutter at NERSC
- Developing multimodal algorithms (including ML methods) to enable an efficient Bayesian analysis with uncertainty quantification

PROJECT-8

- Developing an R&D effort to read out Cyclotron Radiation Emission Spectroscopy (CRES) signal from tritium β-decay electrons in a resonant cavity.
- Developing a graphene field-effect transistor for sensitive magnetometry

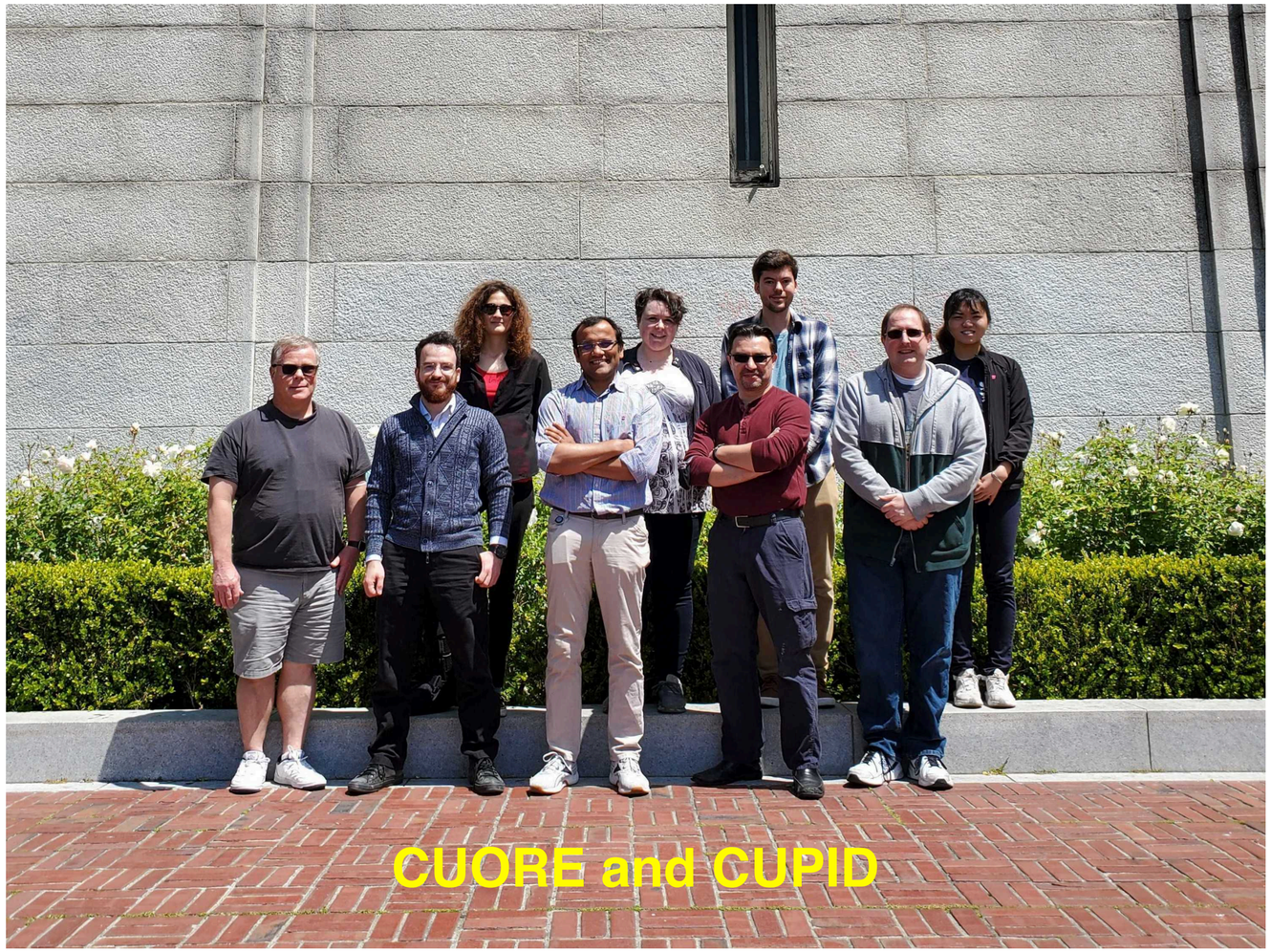
Contact: Alan Poon (awpoon@lbl.gov)

CUORE / CUPID & MOLLER: Fundamental symmetries

contact Yury Kolomensky <ygkolomensky@berkeley.edu> for details

Tests of Fundamental Symmetries

Kolomensky group: CUORE, CUPID, MOLLER (& Mu2e, see previous)

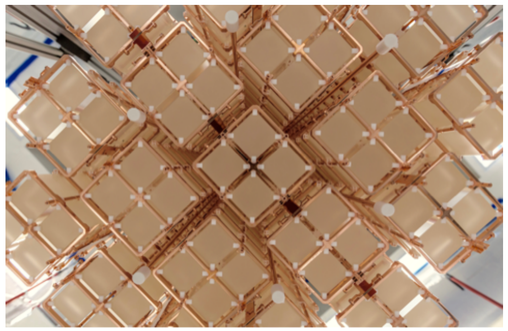


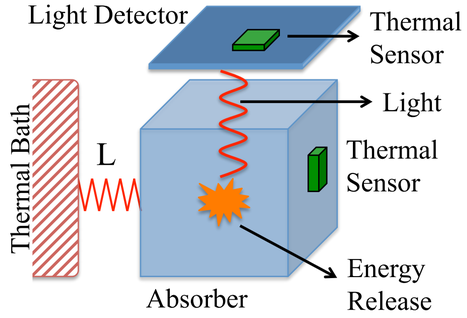
MOLLER

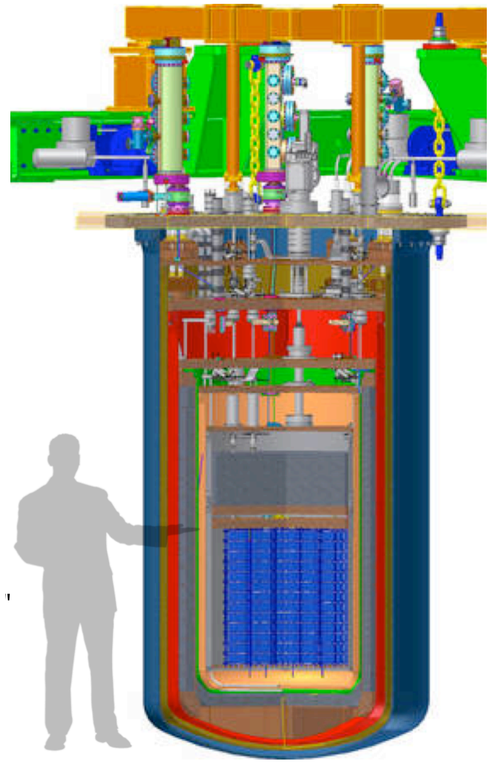
+ very many undergrads

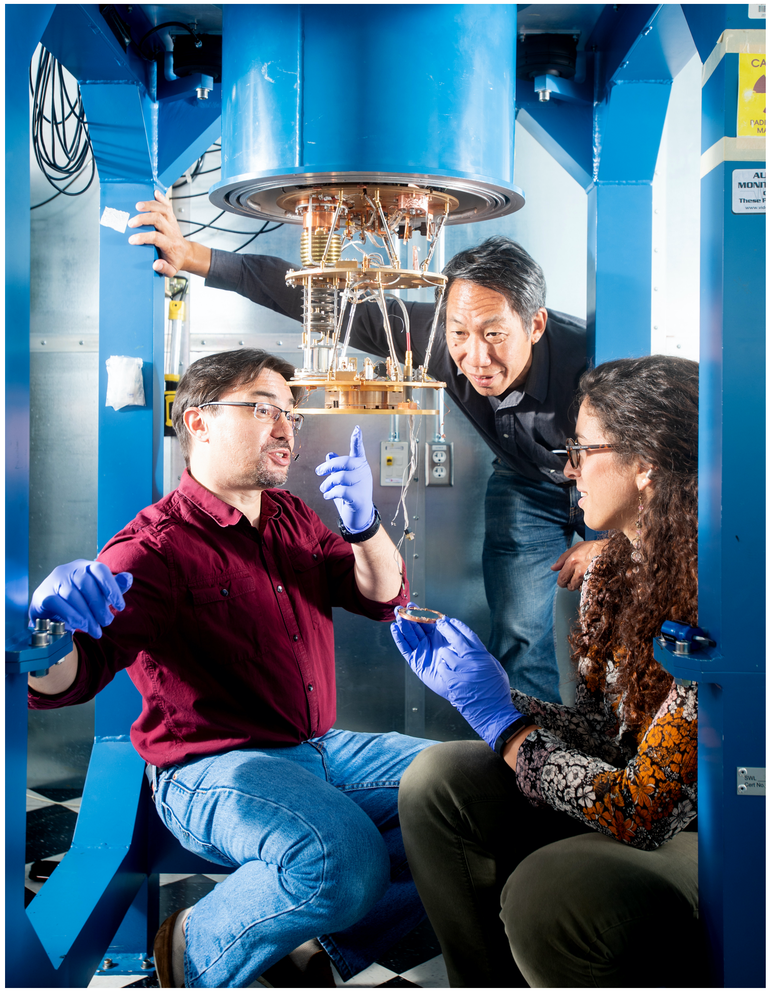
CUORE & CUPID

- Neutrinoless double-beta decay (Lepton Number Violation) at Gran Sasso Underground Lab in Italy
- CUORE: one of the most sensitive running experiments. Data taking to 2025-2027
- CUPID: upgrade with x10 better sensitivity, to start construction soon
- Technical and science leadership at Berkeley
- Large group at UCB and LBNL
- Opportunities for 1-2 students



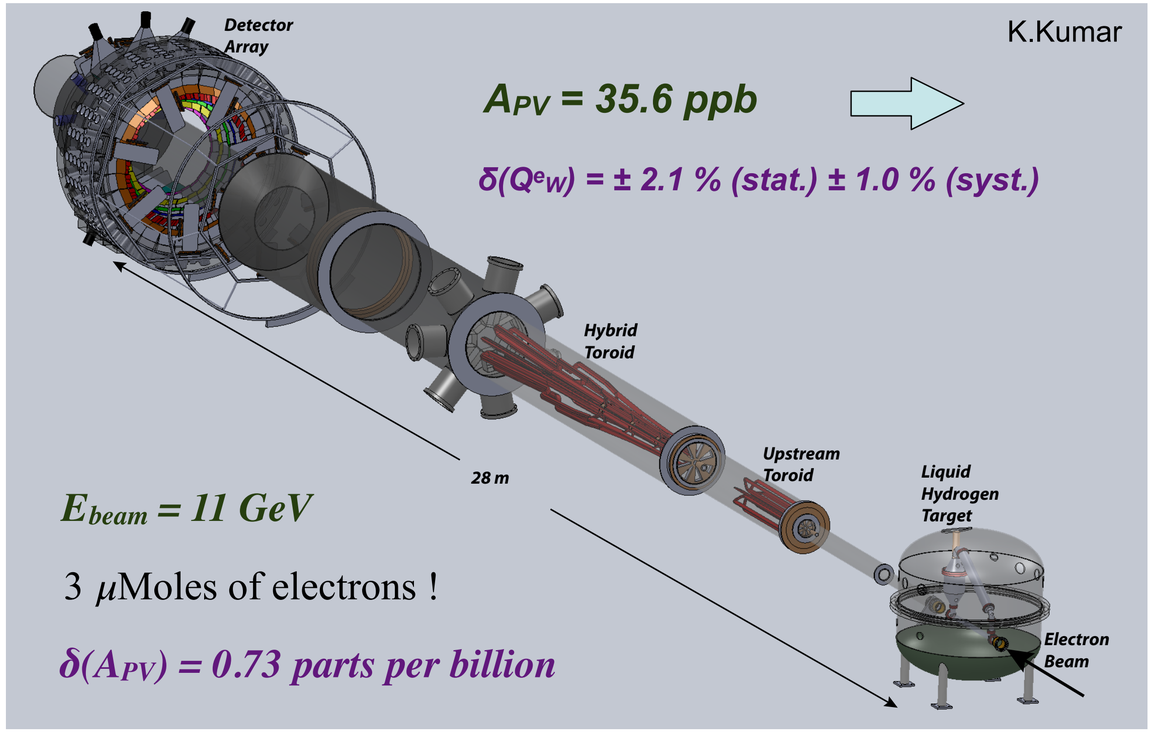






MOLLER

- Parity violation in e-e- scattering: MOLLER at Jefferson Lab
- Look for new physics at TeV scales by probing weak interactions with exquisite precision
- Under construction: physics run in 2025-2026
- Technical and science developments at Berkeley
- Opportunity for 1 student



SNO+, EOS & THEIA: neutrino properties and rare-event searches

contact Gabriel Orebi Gann <gabrielog@berkeley.edu> for details

“Underground physics” @ Berkeley

Group

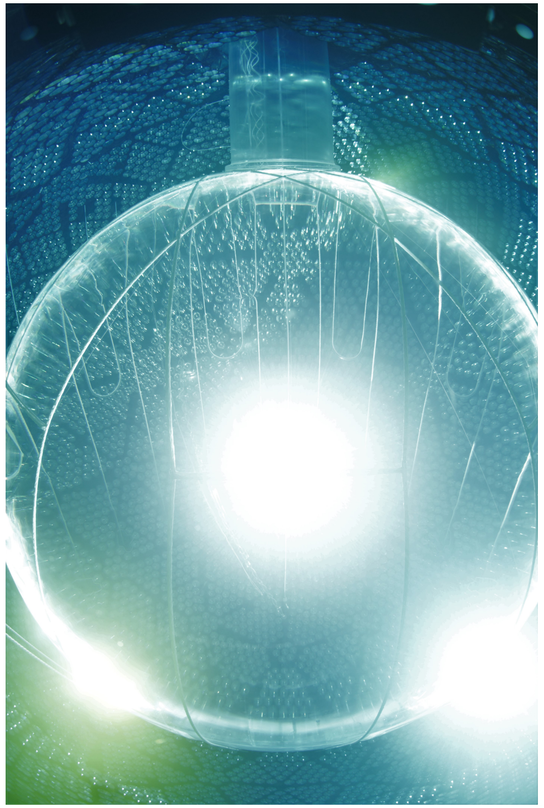
- PI: Gabriel D. Orebi Gann
- Project scientist & post docs: Tanner Kaptanoglu, Logan Lebanowski, Leon Pickard
- Grad students: Max Smiley, Martina Hebert
- Lab assistants: Sawyer Kaplan, Ashley Rincon
- Undergrads: Joseph Koplowitz, Hong-Joo Ryoo











SNO+

- Multi-purpose scintillator experiment
- Deepest, largest operating scintillator detector in the world
- Solar neutrinos, reactor neutrinos, geo neutrinos, supernova neutrinos, ND
- Neutrinoless double beta decay
- Berkeley leadership of multiple working groups: solar neutrino, nucleon decay
- Lead roles in physics results, published in PRL, Phys. Rev. D (lead author, lead analysts, backgrounds, coordination)

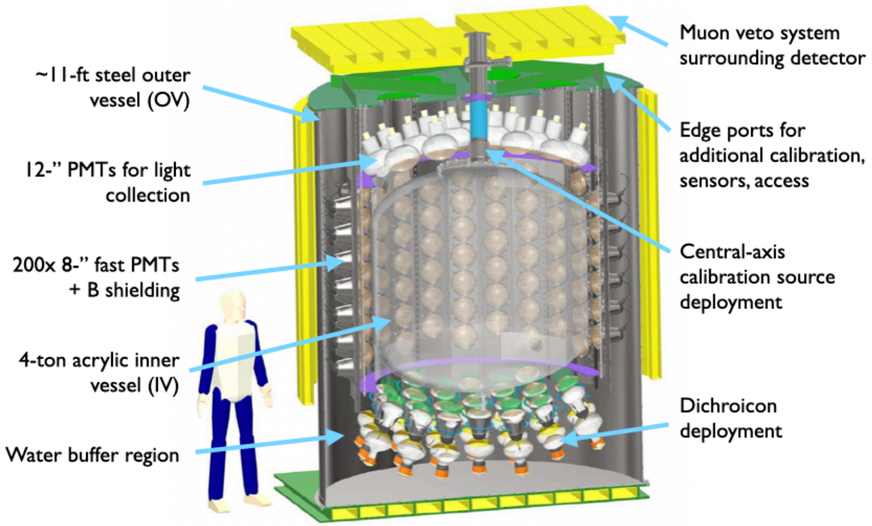
Recent papers:

arXiv:2309.06341 (accepted to PRD)
Phys.Rev.Lett. 130 (2023) 9, 091801
Phys. Rev. D 105, 112012 (2022)
JINST 16 P10021 (2021)
JINST 16 P05009 (2021)
Phys. Rev. D 102, 062006 (2020)
Phys. Rev. C 102, 014002 (2020)
Phys. Rev. D 100, 112005 (2019)
Phys. Rev. D 99, 112007 (2019)
Phys. Rev. D 99, 032008 (2019)
Phys. Rev. D 99, 012012 (2019)
Phys. Rev. D 99, 032013 (2019)
Phys. Rev. D 98, 112013 (2018)

“Underground physics” @ Berkeley

Eos

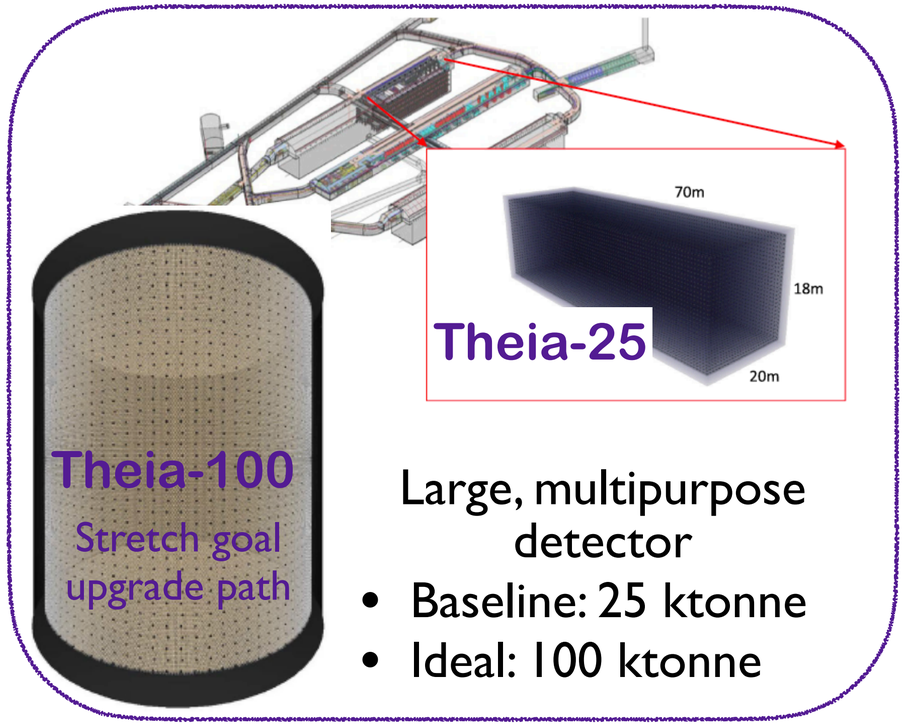
- Flexible testbed to demonstrate impact of novel technology
- Particle detection using hybrid Cherenkov + scintillation signatures
- Validate models to support performance predictions for next-gen experiments



Designed for flexible upgrade paths & to be redeployed at a neutrino source → demonstrate viability of future applications

Theia

- Long-baseline sensitivity (CPV) comparable to a LAr DUNE module
- Complementary supernova sensitivity (primarily anti-ν, fast response: trigger)
- + broad (new!) additional physics program
- Broad physics program: nucleon decay, solar, geo, beyond-ton-scale 0νββ



Large, multipurpose detector

- Baseline: 25 ktonne
- Ideal: 100 ktonne

THEIA: An advanced optical neutrino detector Eur. Phys. J. C 80, 416 (2020)

Inner vessel and detector array translated to the outer vessel