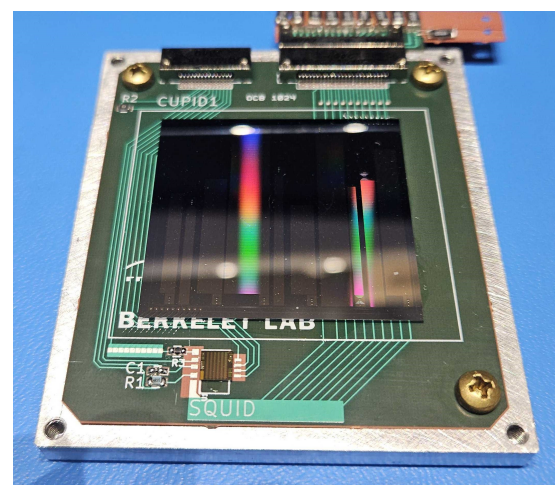
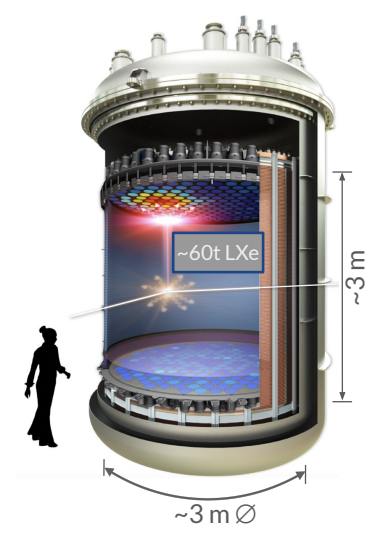
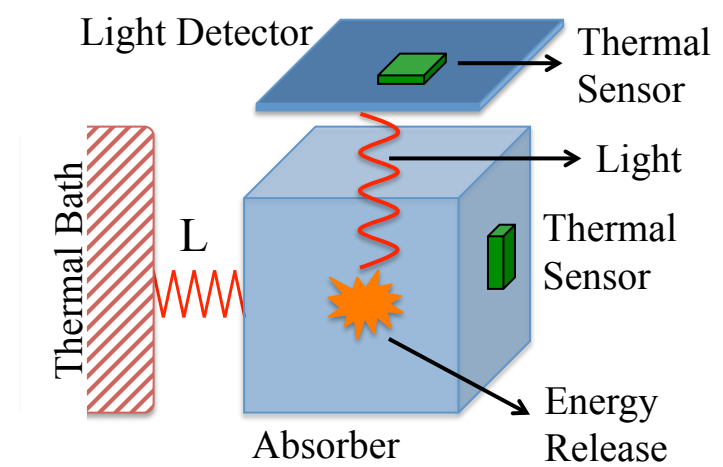
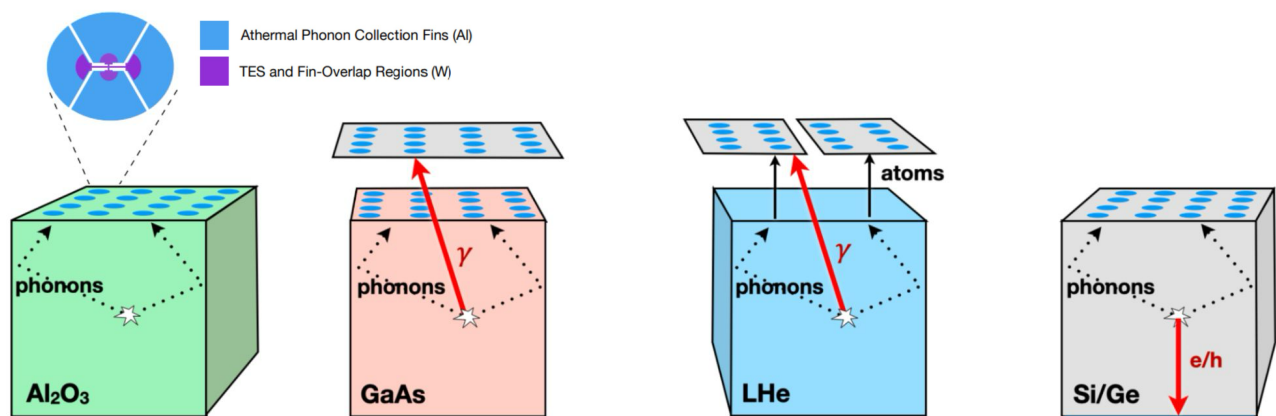


HEP-NP Synergies in Low-Background, Cryogenic Experiments

Yury Kolomensky
UC Berkeley/LBNL

May 22, 2026



Hitoshi's Message

HEP vs. NP

- We share the same unit system among all physics subareas

$$\hbar = c = 1$$

- I hope we can work together for the advancement of science as a whole

Complementary Measures

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$$c = 1$$

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(low energies)

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(low energies)

$$\hbar c = 0.2 \text{ GeV} \cdot \text{fm}$$

(high energies)

Synergies in Cryogenic Low Background Experiments

Synergies in Cryogenic Low Background Experiments

- HEP
 - Profound question: nature of dark matter
 - Direct detection technologies: liquid noble gas TPCs, bolometers, HPGe detectors
 - What determines sensitivity: energy threshold, backgrounds, exposure
 - Underground labs
 - Scales of projects: O(\$1M)-O(\$100M)

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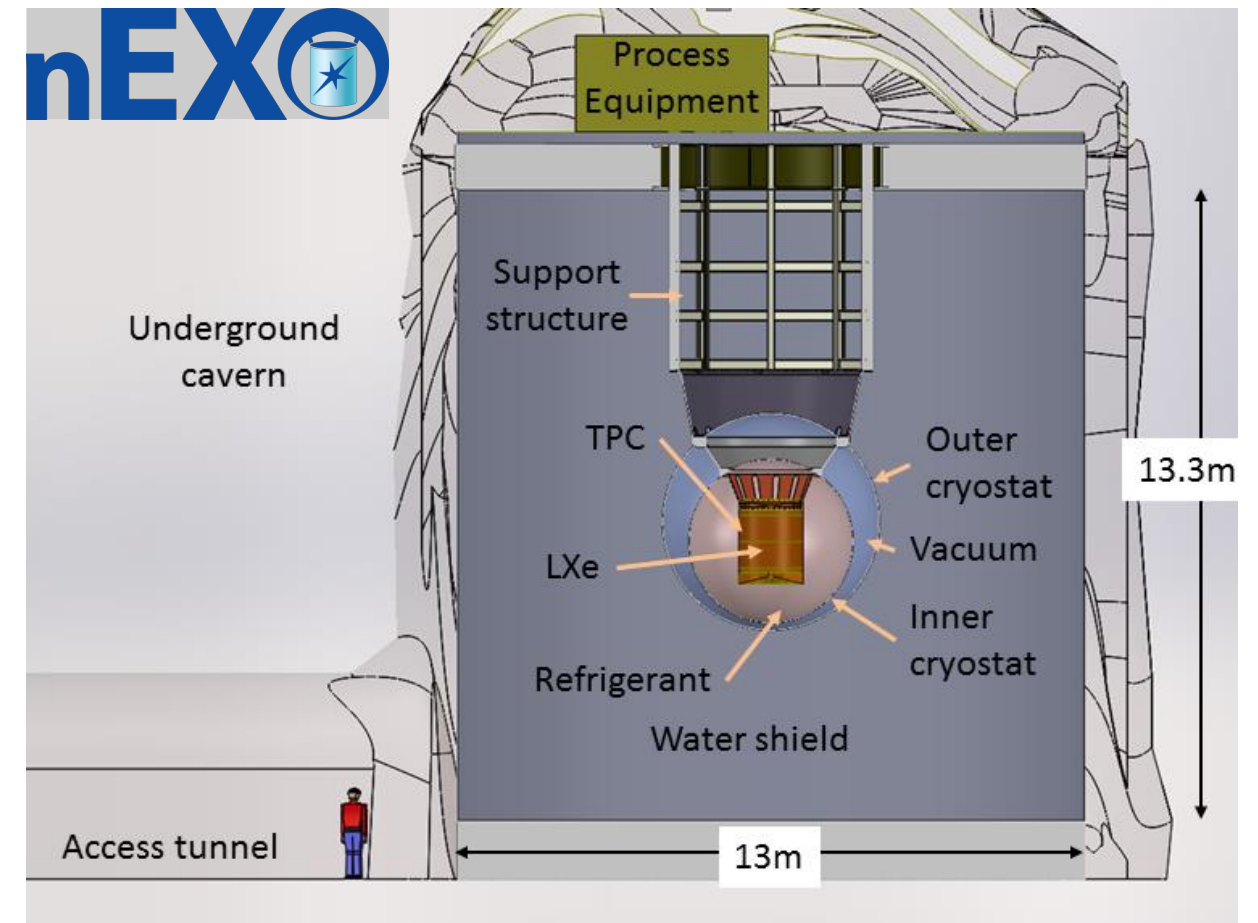
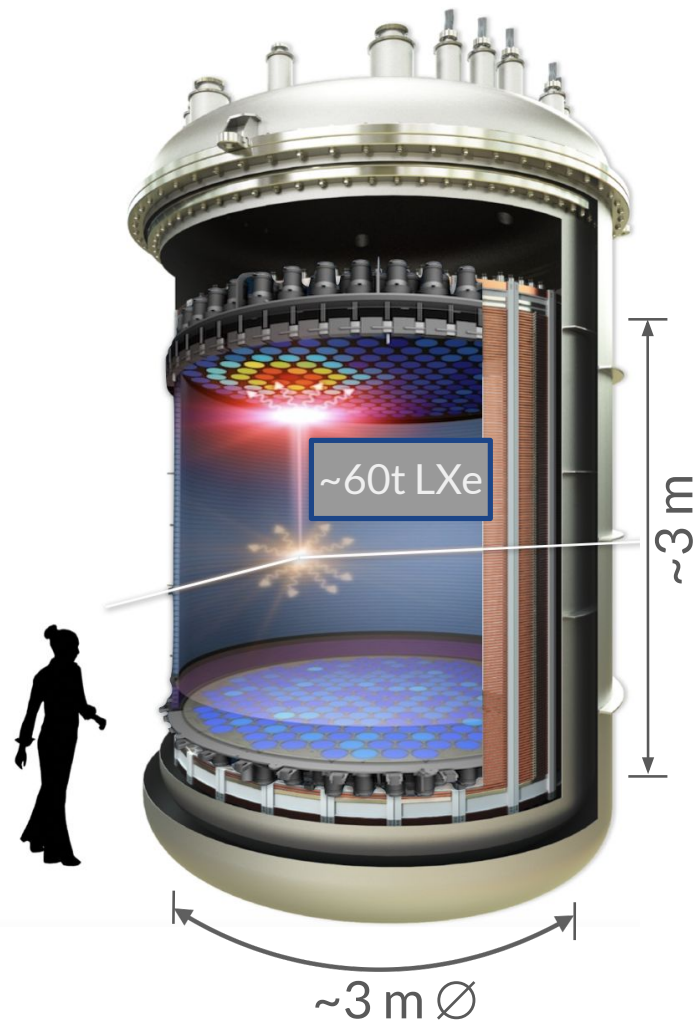
- What determines sensitivity: energy resolution, backgrounds, exposure

- Underground labs

- Scales of projects: O(\$1M)-O(\$100M)

In Europe, both science topics fall under the umbrella of “astroparticle physics”

Liquid Xenon Detectors



Common issues: availability of Xe, material selection, background rejection, TPC design, readout

Different optimization: low thresholds (DM) vs 2.5 MeV ($0\nu\beta\beta$); ^{136}Xe vs $^{\text{nat}}\text{Xe}$

→ Collaborations joining forces to pursue both science goals

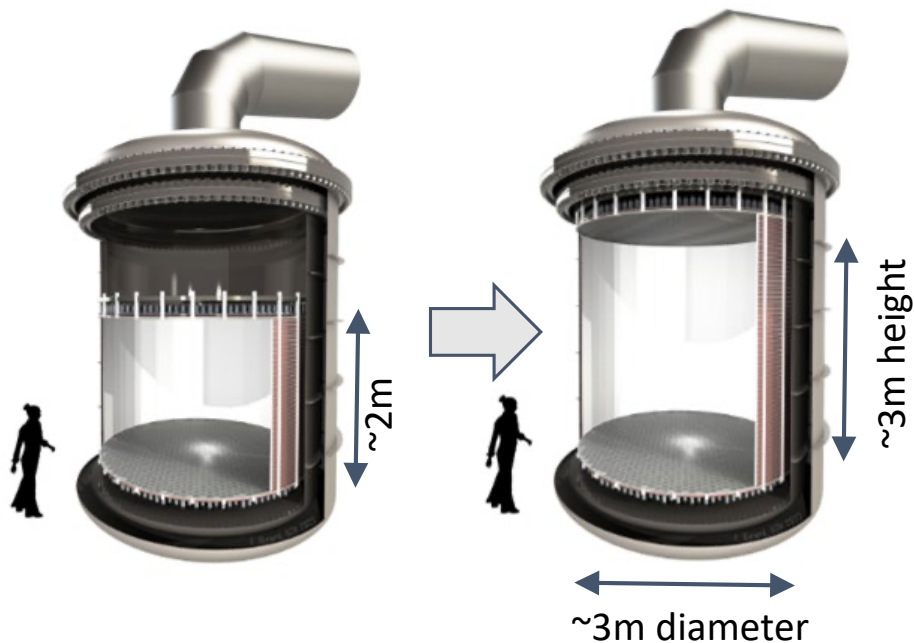
$0\nu\beta\beta$ in LXe Dark Matter Detectors



TPC with large $^{\text{nat}}\text{Xe}$ target for direct dark matter search, offers position reconstruction, calorimetry and low background

⇒ **High sensitivity to $0\nu\beta\beta$ -decay**

Xenon acquisition supports staged approach with



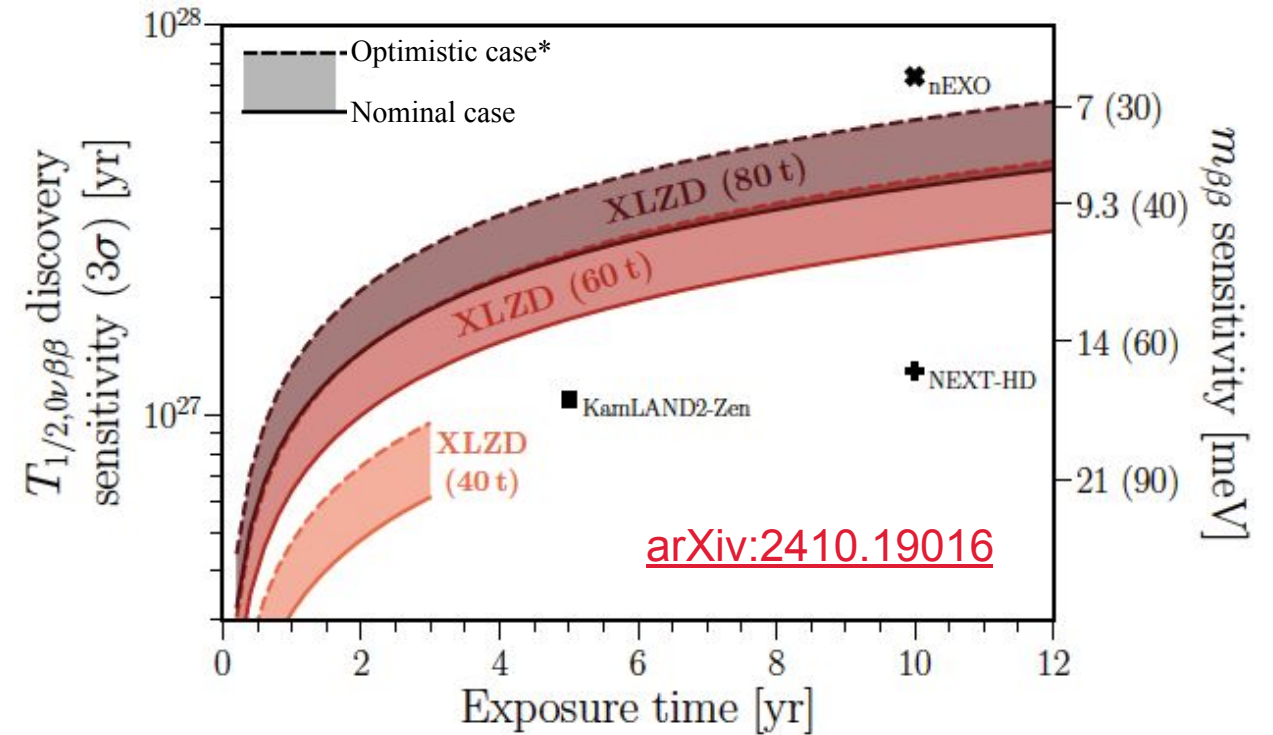
early science phase

40t TPC, < 5yr operation, shallow TPC design

main science phase

(60t TPC, > 10yr operation, optimized 1:1 aspect ratio)

+ **80t option in tall TPC**, depending on Xe market



Projection bands cover a baseline scenario (lower bounds) based on state-of-the-art DM LXe-TPC performance to more progressive assumptions on backgrounds (upper bounds).

Proof of Principle

Projected sensitivity of the LUX-ZEPLIN experiment to the two-neutrino and neutrinoless double β decays of ^{134}Xe

[D. S. Akerib](#)^{1,2}, [A. K. Al Musalhi](#)³, [S. K. Alsum](#)⁴, [C. S. Amarasinghe](#)⁵, [A. Ames](#)^{1,2}, [T. J. Anderson](#)^{1,2}, [N. Angelides](#)⁶, [H. M. Araújo](#)⁷, [J. E. Armstrong](#)⁸ *et al.* (The LUX-ZEPLIN Collaboration)

[Show more](#) ▾

Phys. Rev. C **104**, 065501 – Published 10 December, 2021

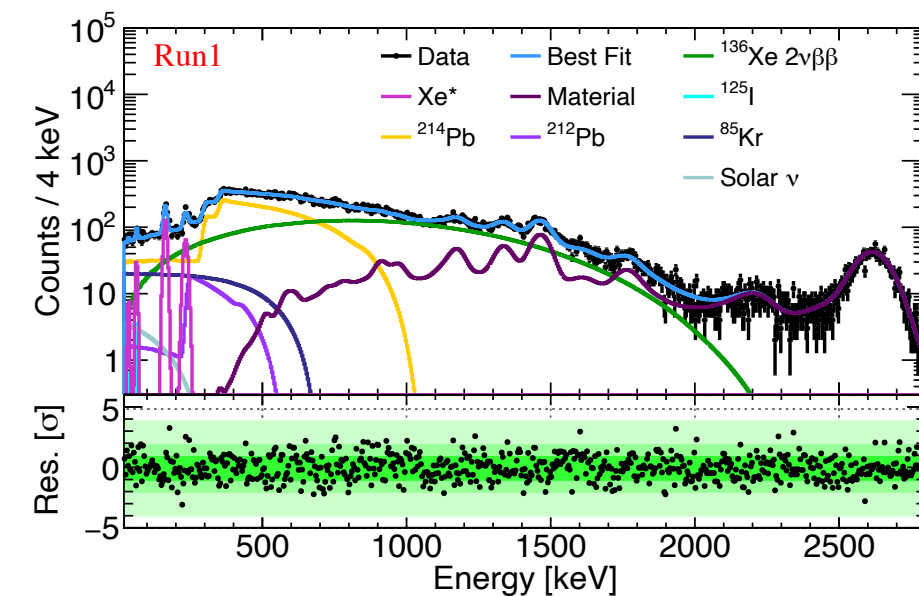
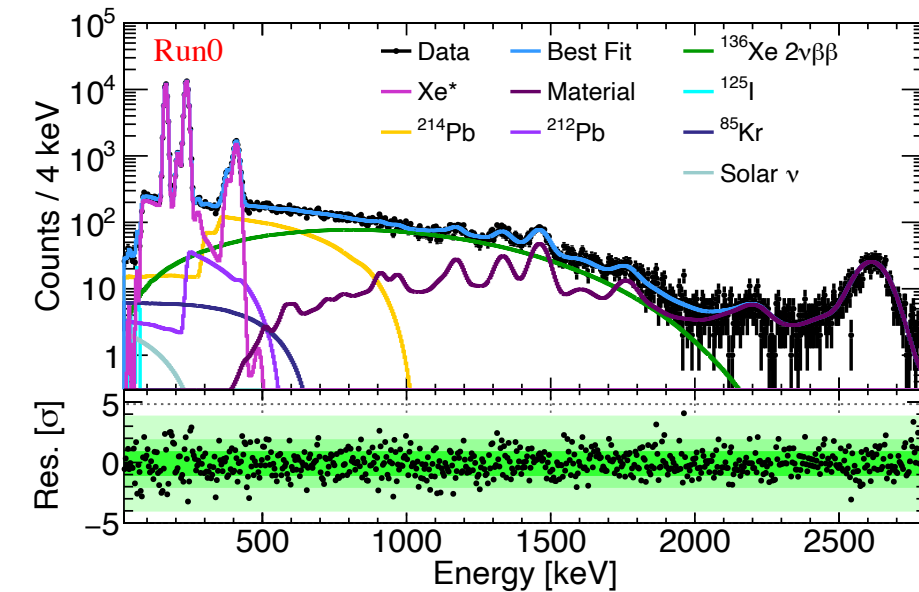
Precise ^{136}Xe Double Beta Decay Measurement in PandaX-4T with Implications on the Nuclear Matrix Elements and Majorons

[Zhe Yuan](#)², [Zihao Bo](#)³, [Wei Chen](#)³, [Xun Chen](#)^{1,4,5}, [Yunhua Chen](#)^{6,5}, [Chen Cheng](#)⁷, [Xiangyi Cui](#)¹, [Manna Deng](#)⁸, [Yingjie Fan](#)⁹ *et al.* (PandaX Collaboration)

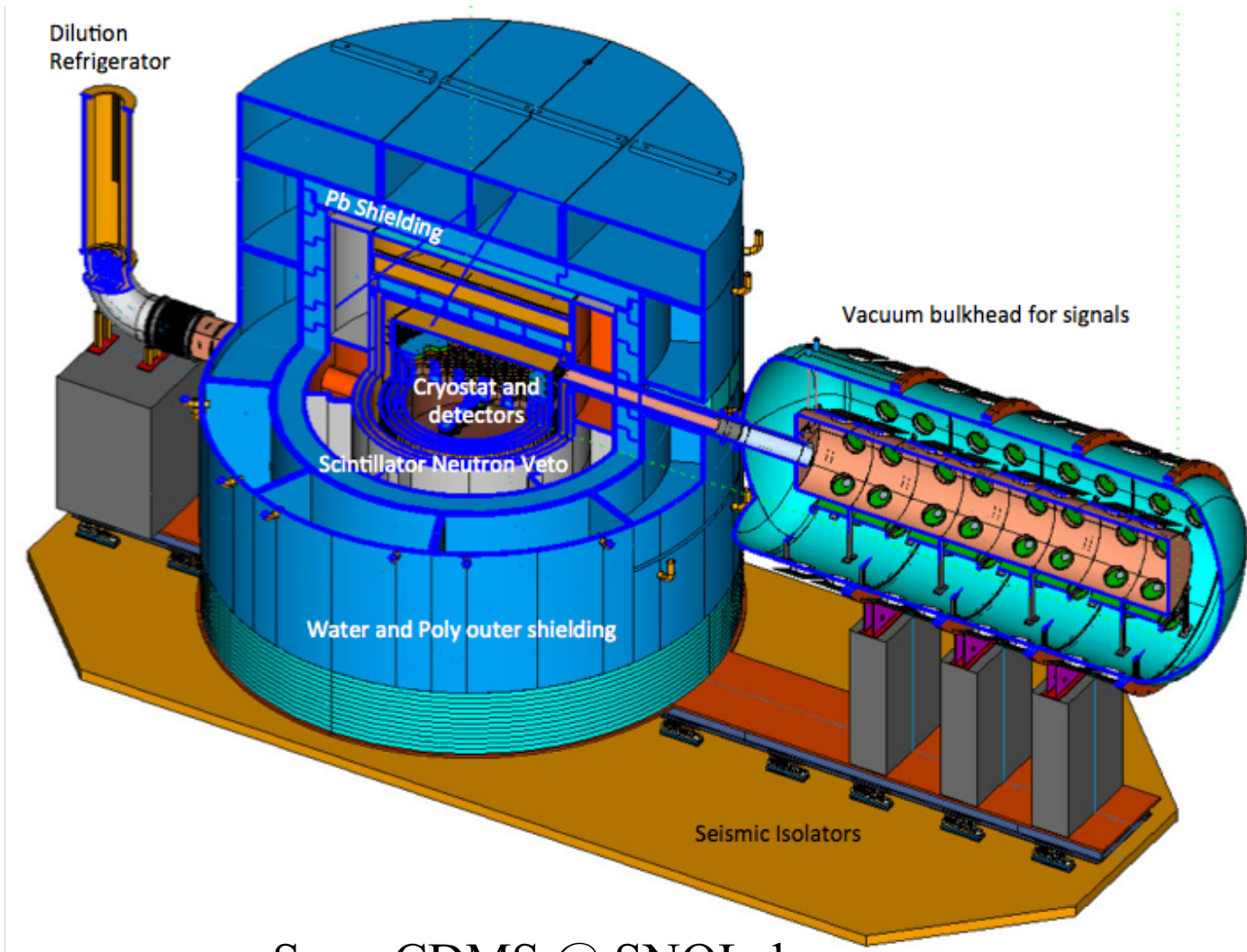
[Show more](#) ▾

Phys. Rev. Lett. **136**, 162501 – Published 21 April, 2026

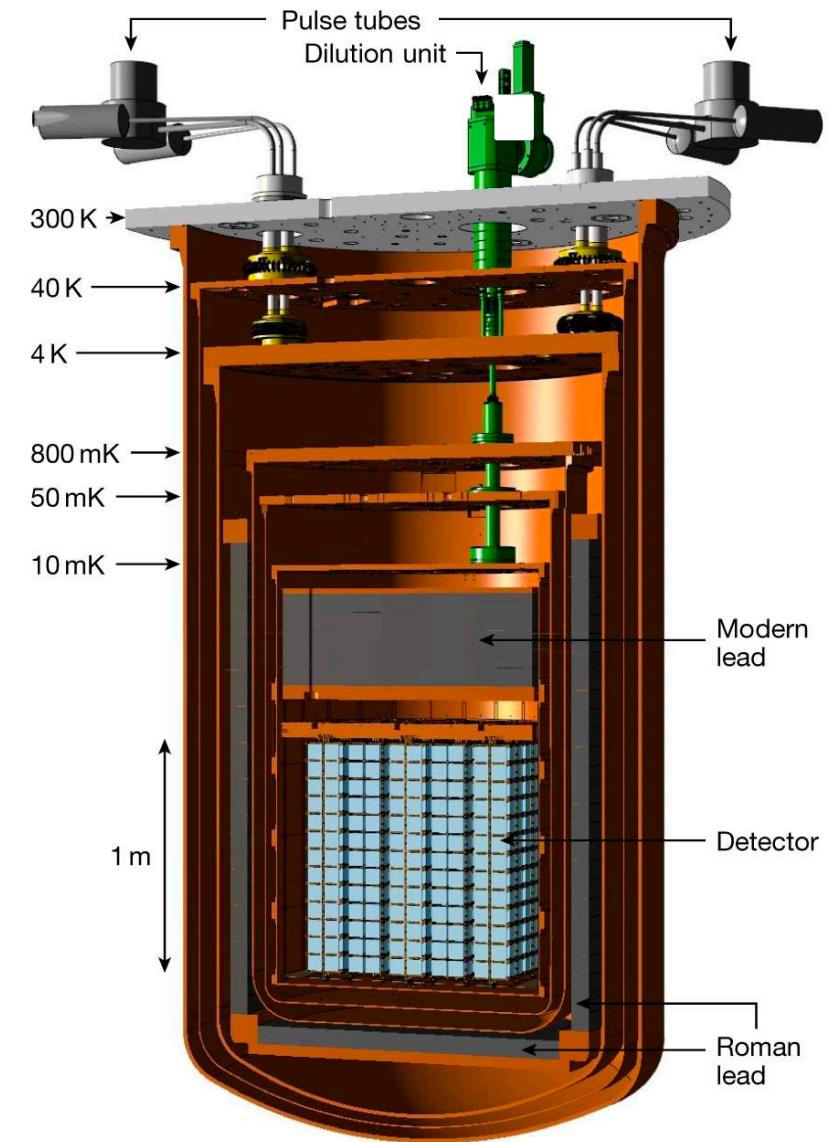
PandaX-4T



Cryogenic Calorimeters (Bolometers)



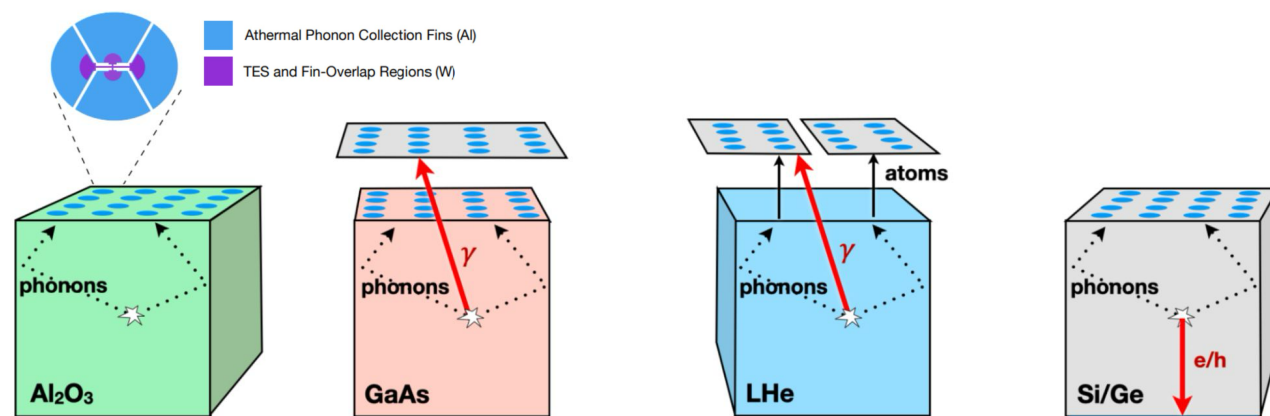
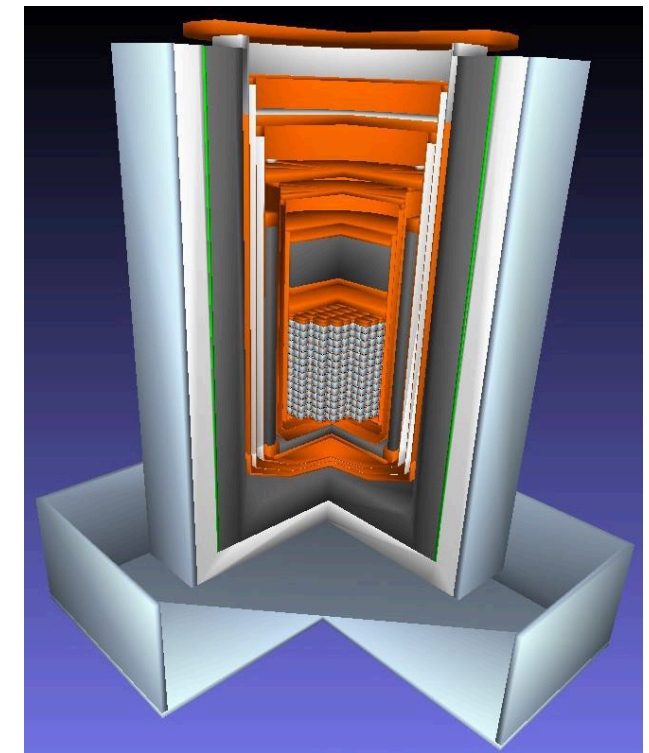
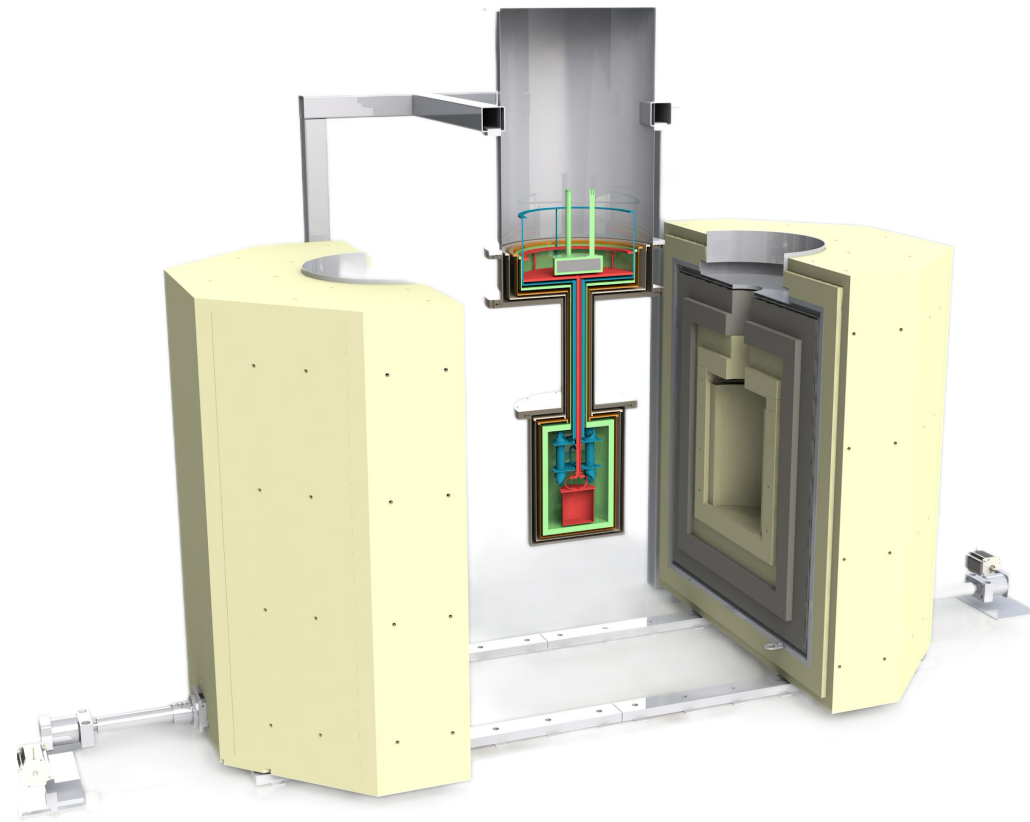
SuperCDMS @ SNOLab



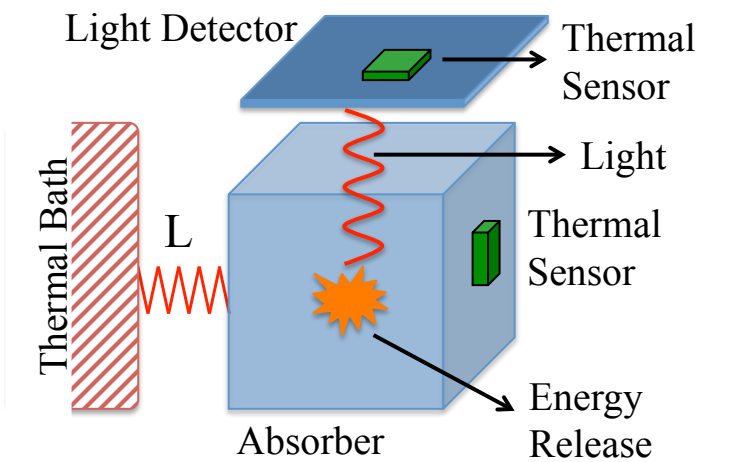
Dell'Oro S. et al., *Cryogenics* 102, 9, (2019)
<https://doi.org/10.1016/j.cryogenics.2019.06.011>
 Adams D. et al. (CUORE collaboration), *Prog.Part.Nucl.Phys.* 122 (2022) 103902,
<https://doi.org/10.1016/j.pnpnp.2021.103902>

CUORE @ LNGS

Cryogenic Calorimeters (Bolometers)



TESSERACT @ LSM

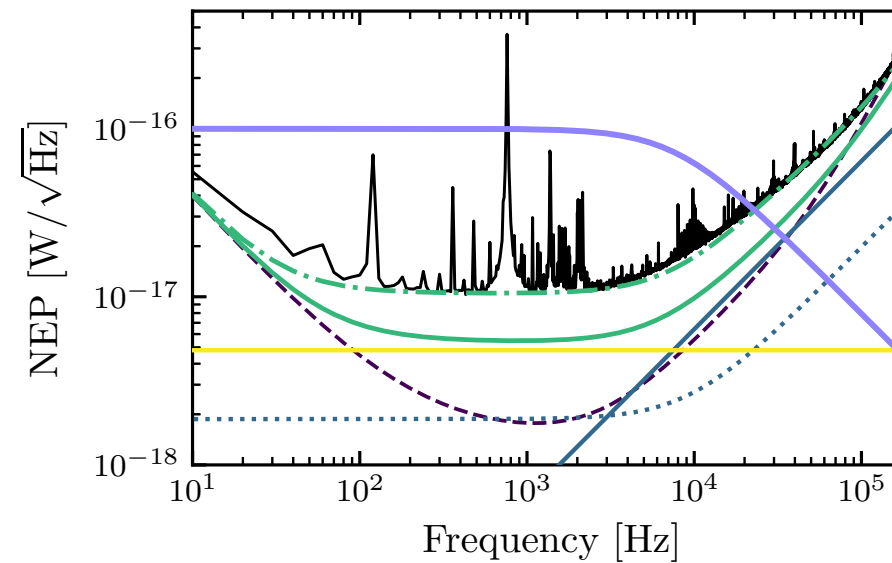
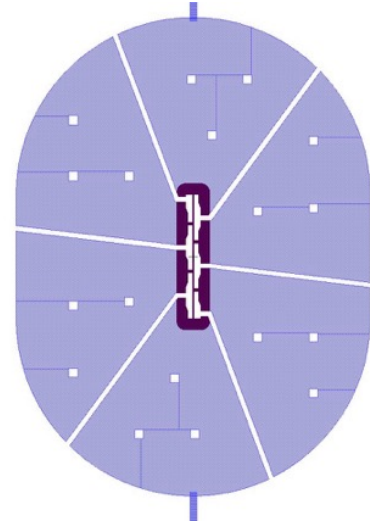


CUPID @ LNGS

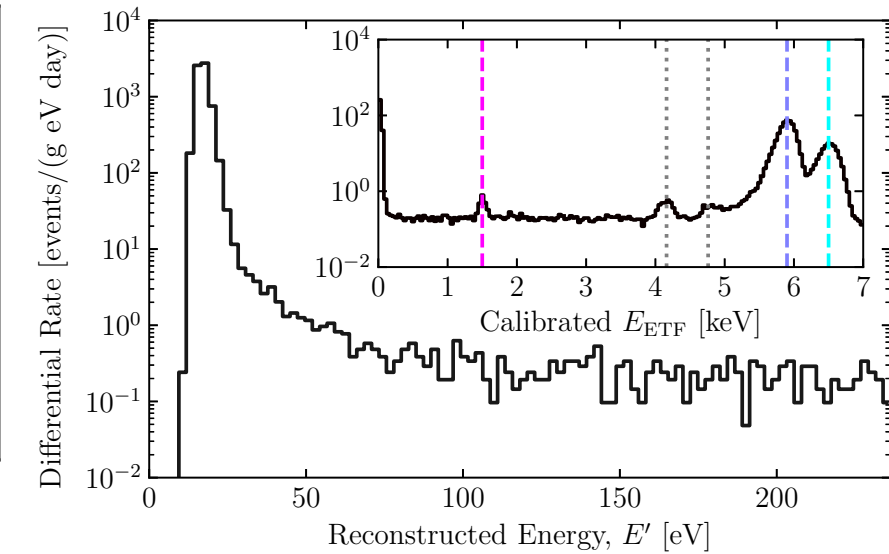
Synergies between HEP and NP

- Common features
 - ❑ Large mK cryogenic installations: thermal design, mechanical design, IR suppression
 - ❑ Sensitivity to vibrations, radioactive and non-ionizing backgrounds
 - ❑ Backgrounds: material screening and selection, radiopurity
 - ❑ Superconducting sensors, microfabrication techniques, cabling, interconnects
 - ❑ Cryogenic electronics: superconducting (SQUIDs) and semiconductor (HEMTs, CMOS)
 - ❑ Room-temperature electronics, multiplexed readout
 - ❑ Data processing pipelines
- Next-generation projects are agile, modest in size, fit very well in the “small scale project” initiatives
 - ❑ E.g. TESSERACT, CUPID
 - ❑ Generic R&D efforts for next-next generation fit very well into KA25 portfolio

Examples of Joint Development



C.W. Fink et al. (CPD Collaboration), APL **118**, 022601 (2021)

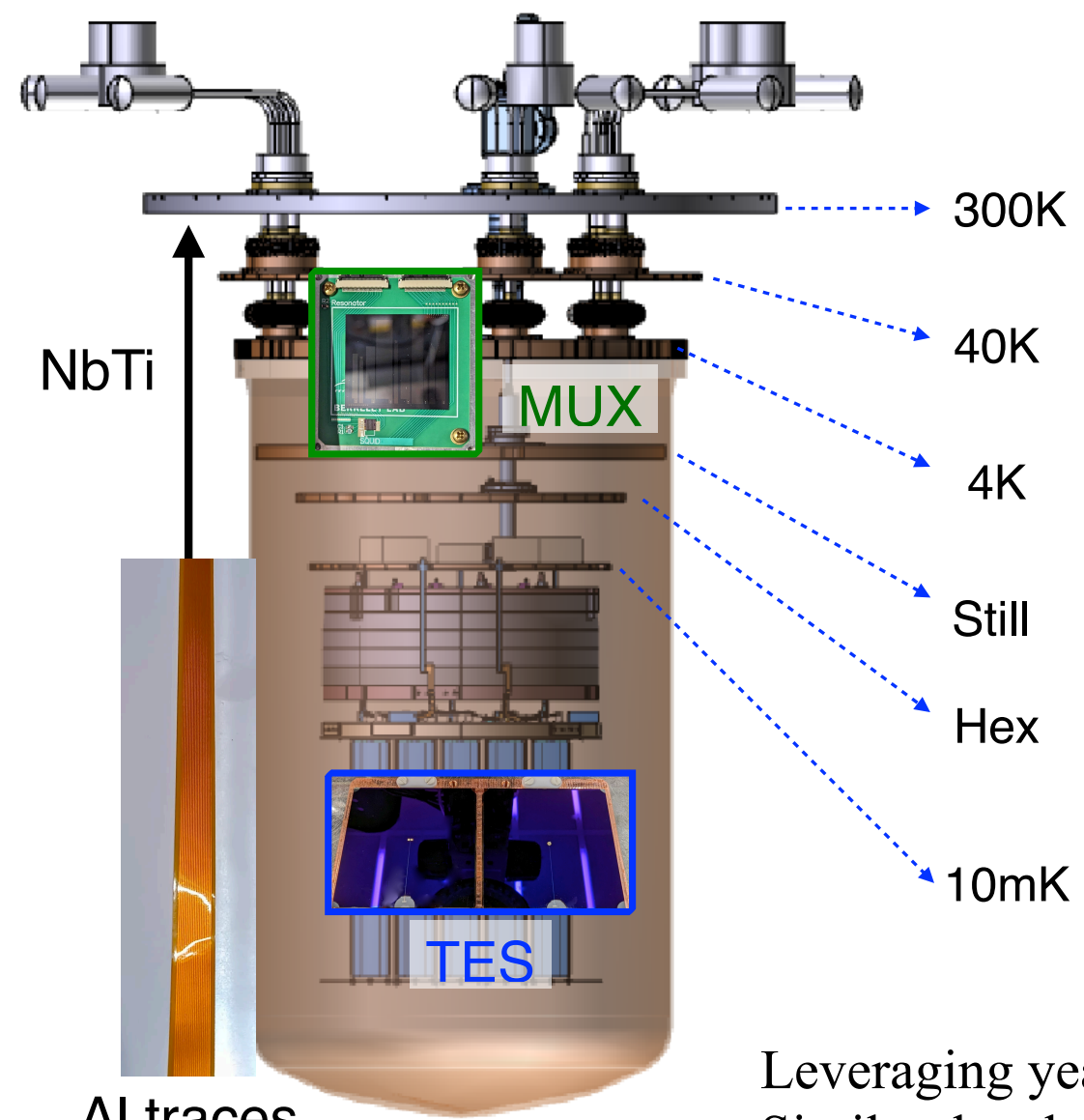


I. Alkhatib et al. (SuperCDMS Collaboration), PRL **127**, 061801 (2021)

- Cryogenic Photon Detector developed by CUPID and SuperCDMS groups
 - Ballistic phonon readout (QET)
 - Best (at the time) baseline energy resolution $\sigma_E = 3.9 \pm 0.4$ eV
 - Time jitter $\sigma_t = 2.3 \mu\text{s}$
- TESSERACT sensors have since exceeded this performance

Examples of Joint Development

Frequency-domain multiplexing of TES sensors

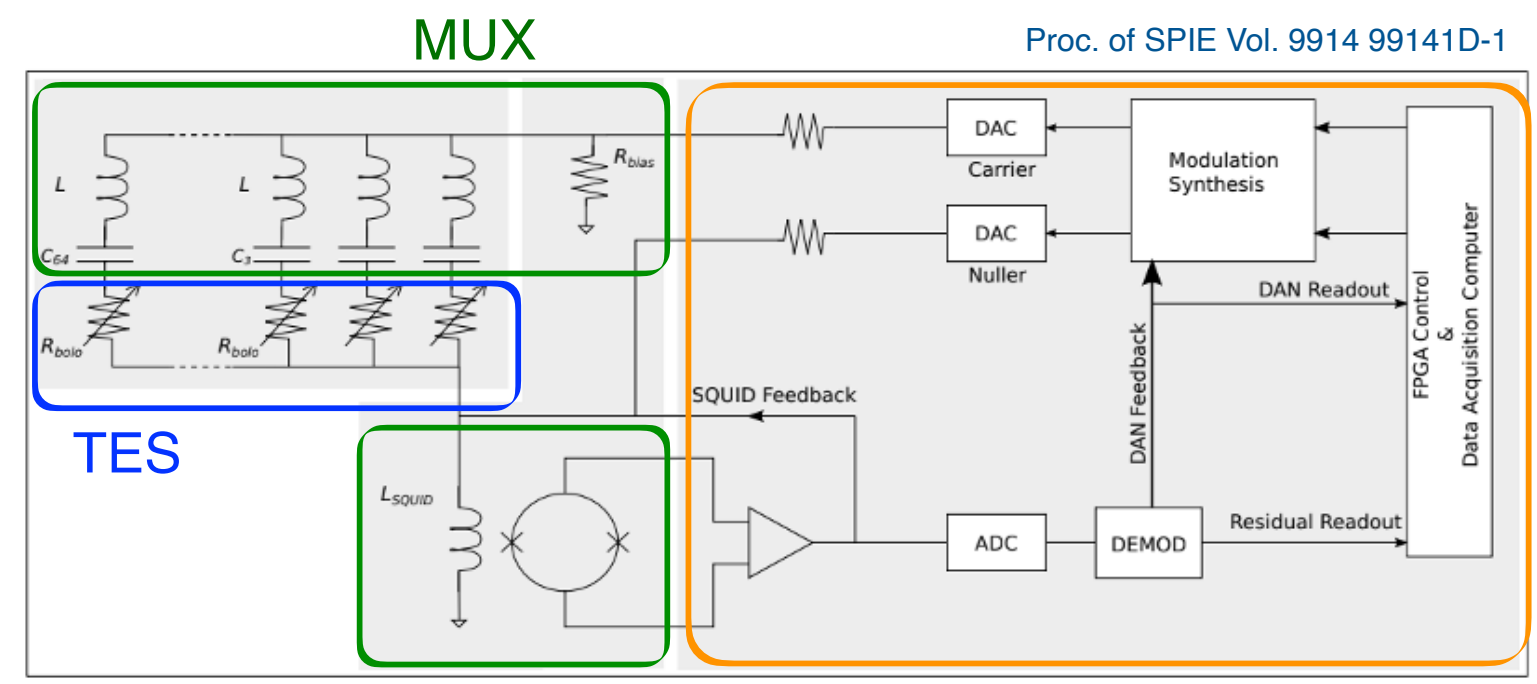


Al traces on Kapton

Leveraging years of experience for CMB
 Similar developments with μ MUX, MKIDs, ...
 Applications for $0\nu\beta\beta$, CE ν NS, neutrino mass, ...

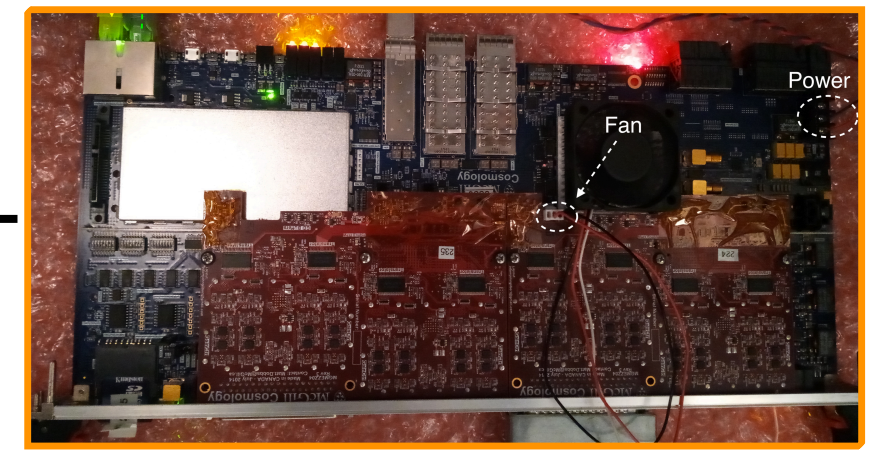
ANL, UCB, LBNL, McGill, VT, MIT

Proc. of SPIE Vol. 9914 99141D-1



Integrated board at Room T~300 K

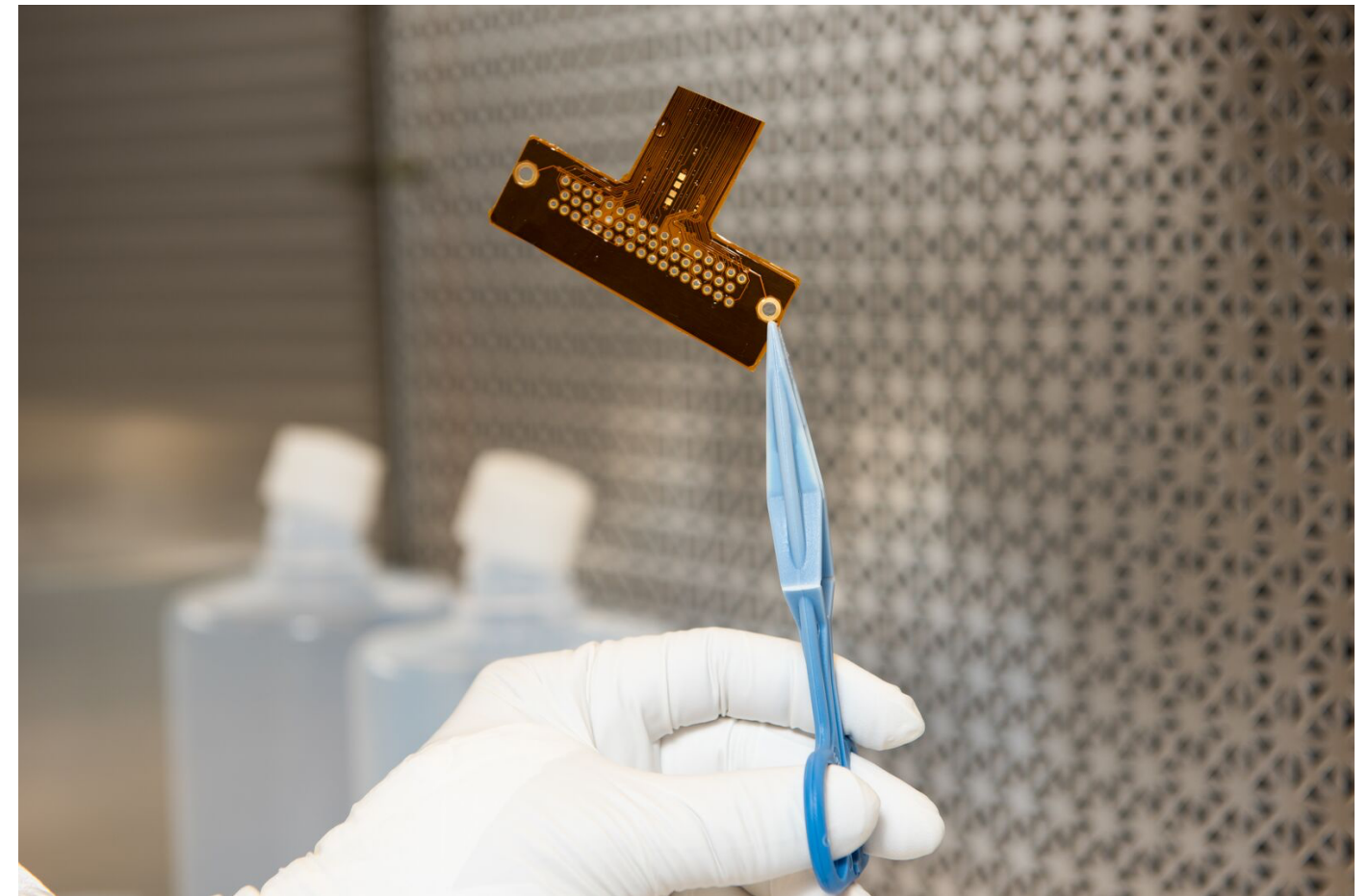
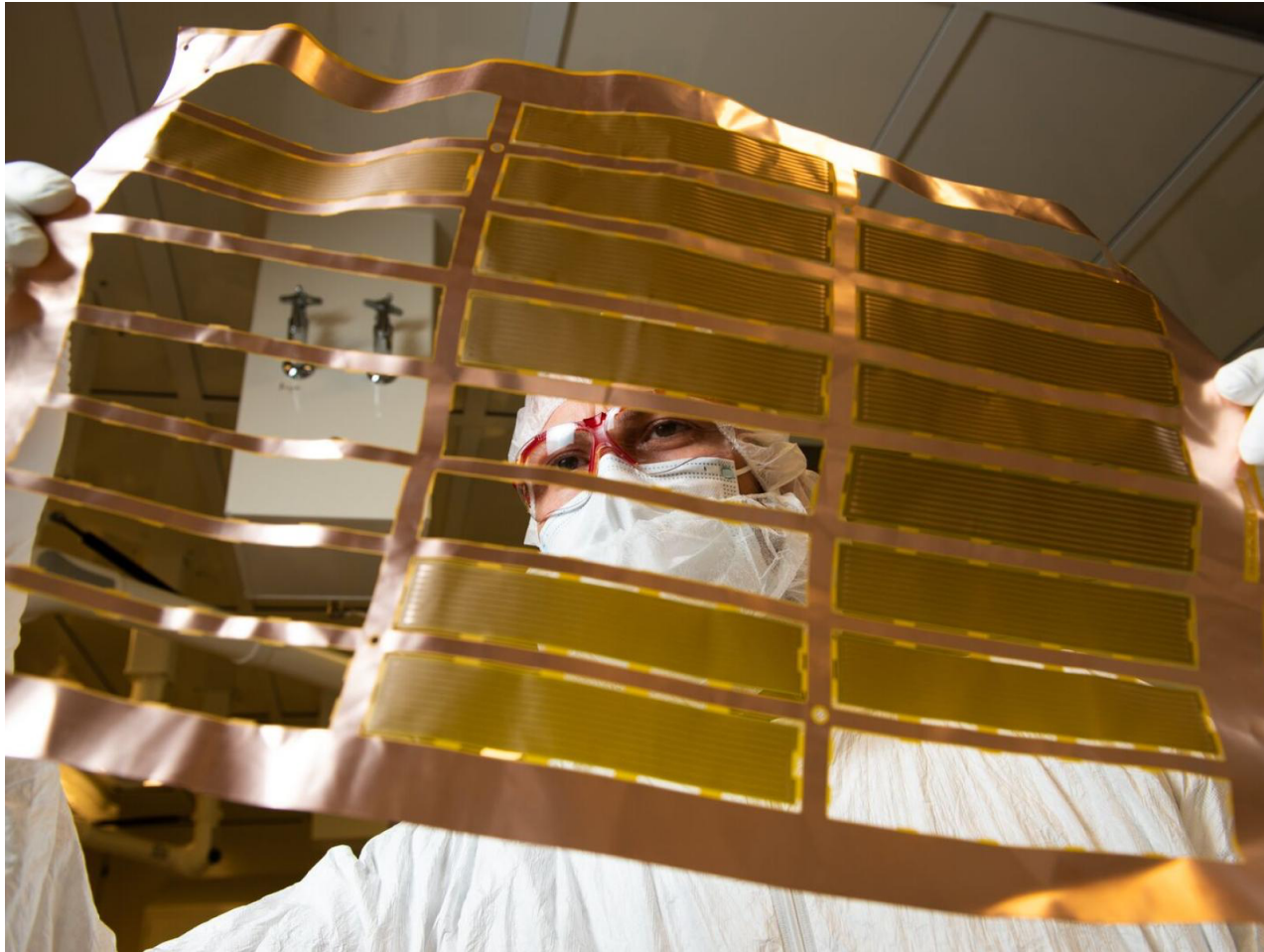
Ethernet



C. Capelli, DNP-2023

Examples of Joint Development

National lab — industry partnership to develop low-radioactivity cables: PNNL and QFlex



Credit: PNNL

Examples of Joint Development



radiopurity.org



documentation

GitHub

about

search

advanced
search

insert

update

Query Assistant

1 Bq U-238/kg	=	81 ppb U	(81 x 10 ⁻⁹ gU/g)
1 Bq Th-232/kg	=	246 ppb Th	(246 x 10 ⁻⁹ gTh/g)
1 Bq K-40/kg	=	32300 ppb K	(32300 x 10 ⁻⁶ gK/g)
1 Bq U-235/kg	=	1.76 ppm U	(1.76 x 10 ⁻⁶ gU/g)

Common Challenges

- Advances in sensitivity require advancement in instrumentation
 - Many novel ideas worth pursuing. Complementarity with microelectronics, QIS initiatives, SBIR
- Advances in sensitivity require scale and investment
 - From medium sized projects (CMB-S4, LEGEND) to agile R&D efforts (TESSERACT, CUPID) to small-scale demonstrators
- Advances in sensitivity require stable long-term operations
 - Perfect application of AI/ML → complementarity with detector & accelerator operations
- Advances in sensitivity require trained scientific workforce
 - Common skillsets, but competing with industry, especially QIS and AI/ML will remain a challenge

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