

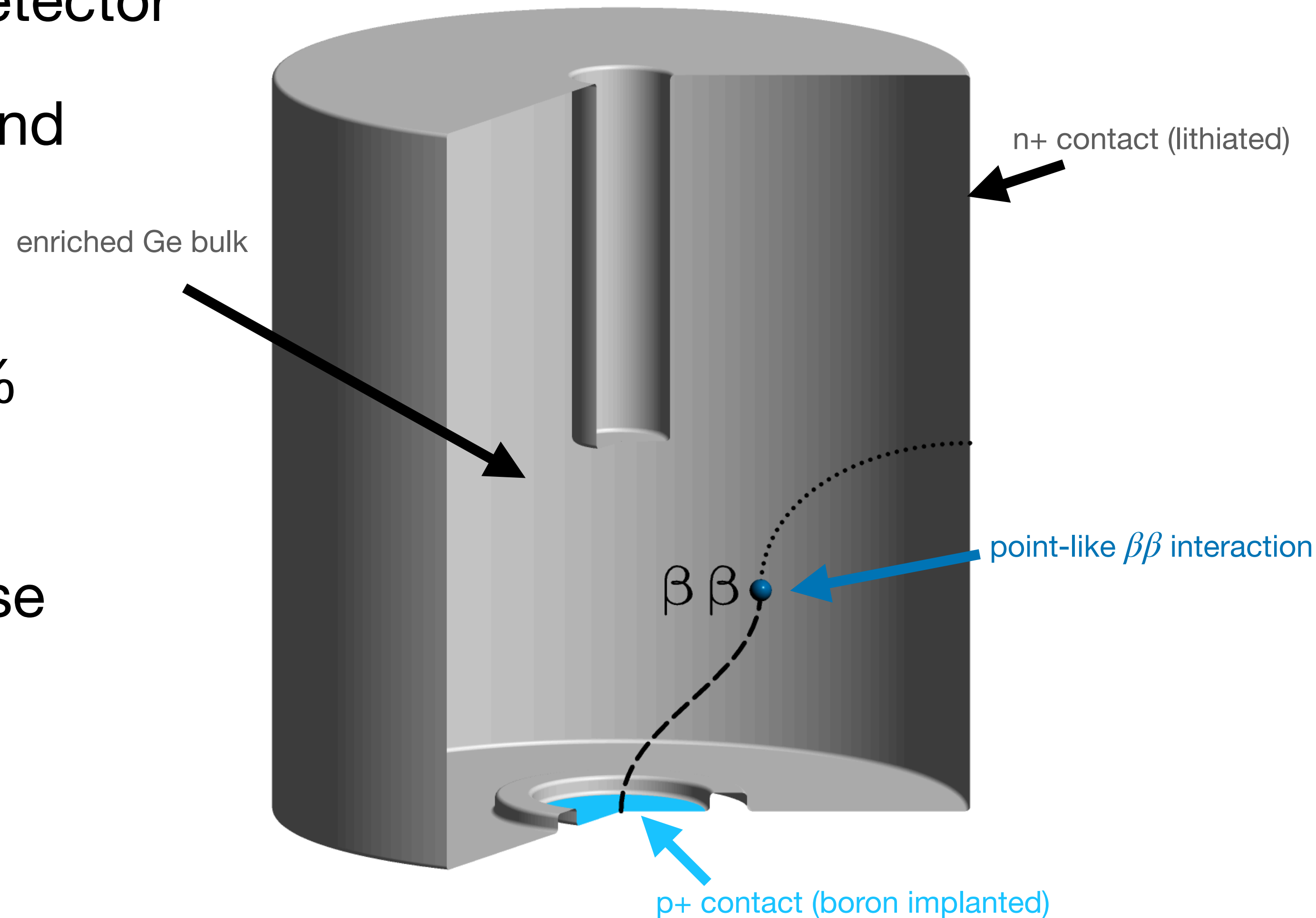
The LEGEND Experiment for Neutrinoless Double Beta Decay

Samuel L. Watkins, on behalf of the LEGEND collaboration
Director's Postdoctoral Fellow, Los Alamos National Laboratory
September 12, 2023



Searching for $0\nu\beta\beta$ with Germanium

- Simultaneous source of $\beta\beta$ and detector
- High purity, low intrinsic background
- Isotope enrichment ($\sim 90\%$ ^{76}Ge)
- Excellent energy resolution ($\sim 0.1\%$ FWHM at $Q_{\beta\beta}$)
- Topological Discrimination via pulse shape analysis



LEGEND Collaboration

LEGEND

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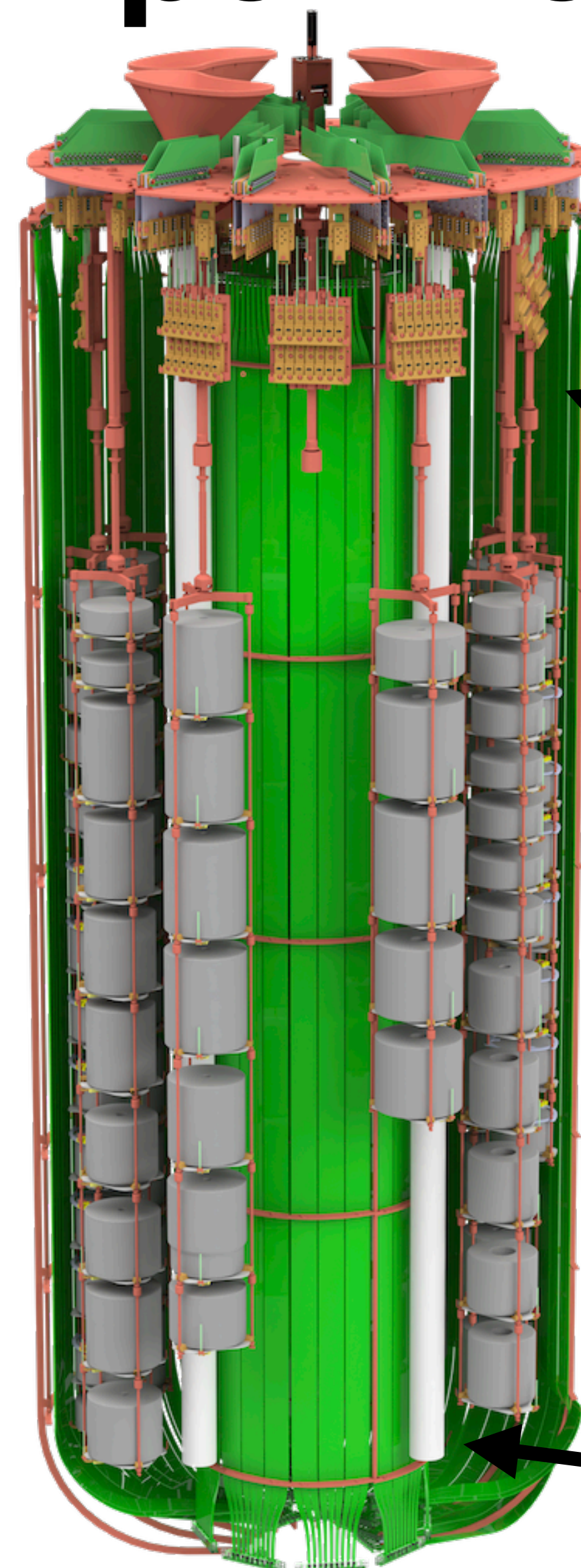
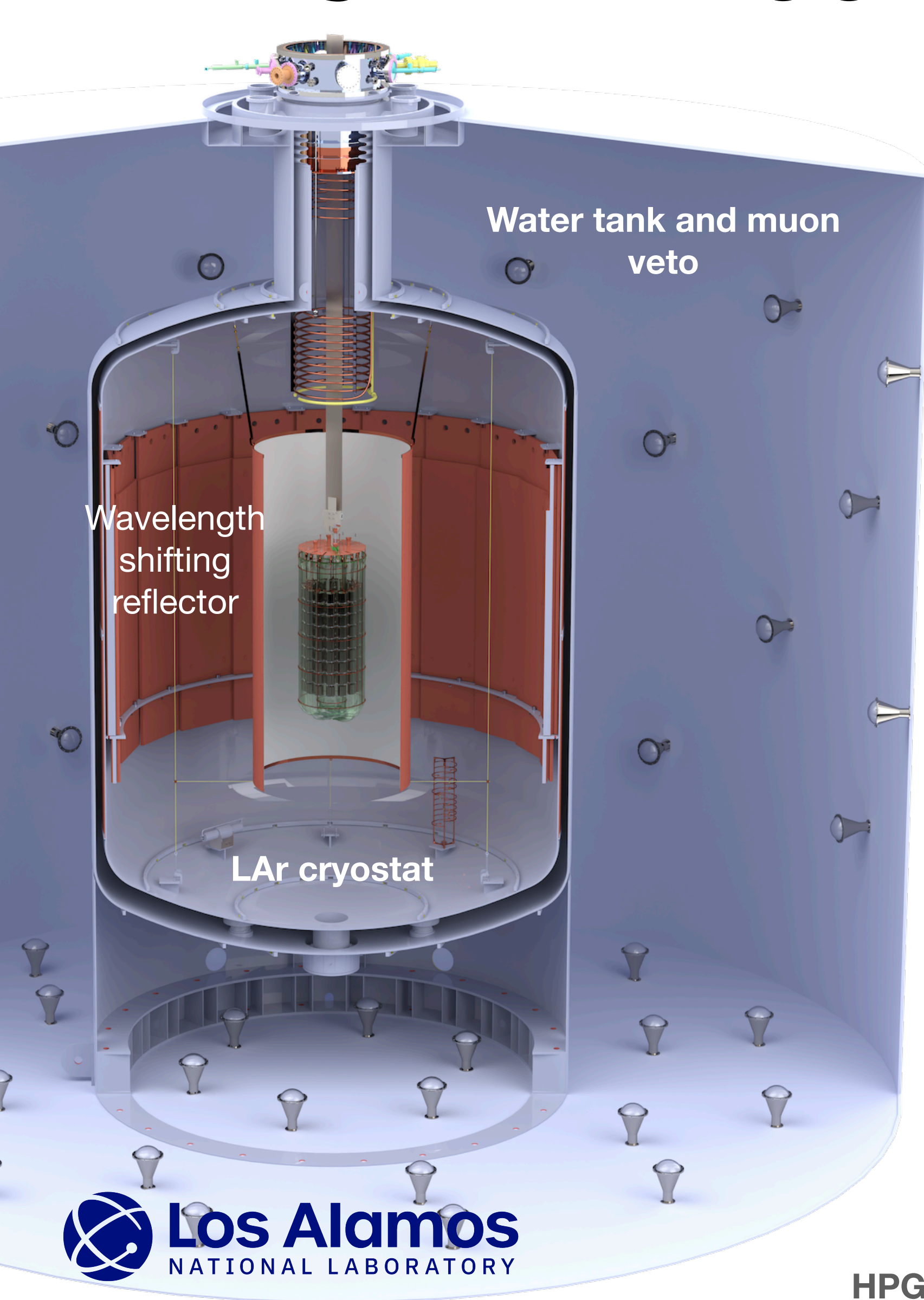


+



+ more!

LEGEND-200 Experiment

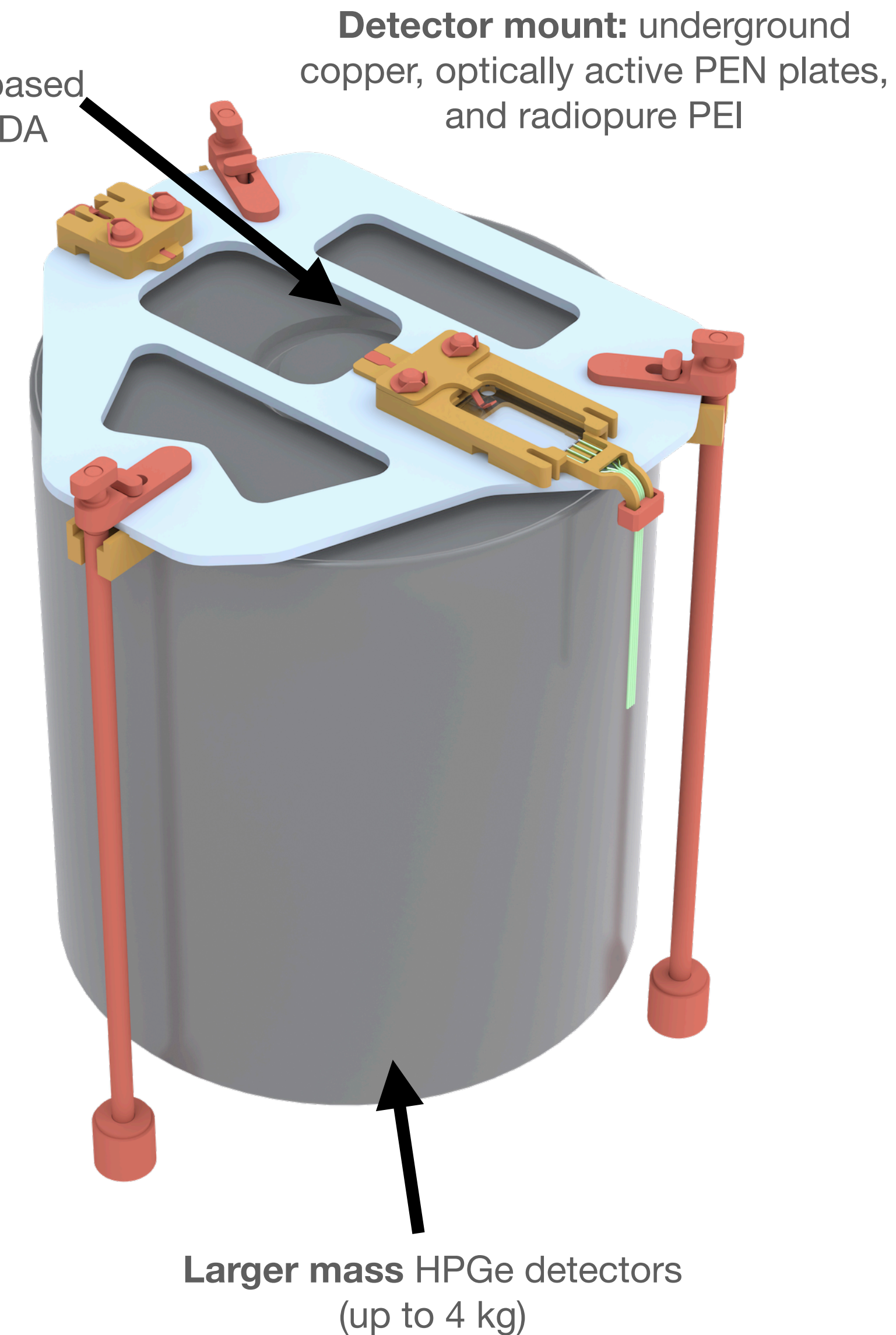


HPGe readout electronics: based on MJD front-end and GERDA charge amplifier

Liquid Ar instrumentation: fiber barrels read by SiPMs at top and bottom

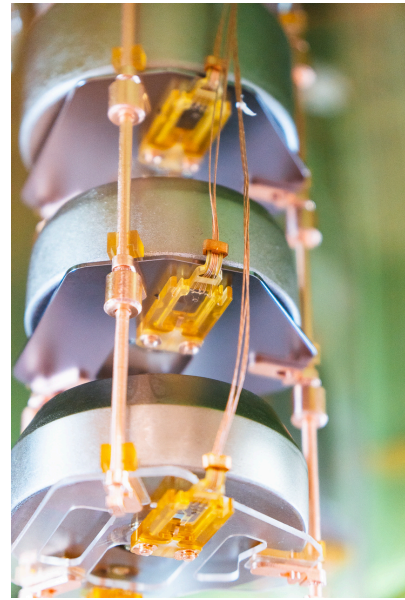
Source funnels for calibration

HPGe detector array and LAr instrumentation

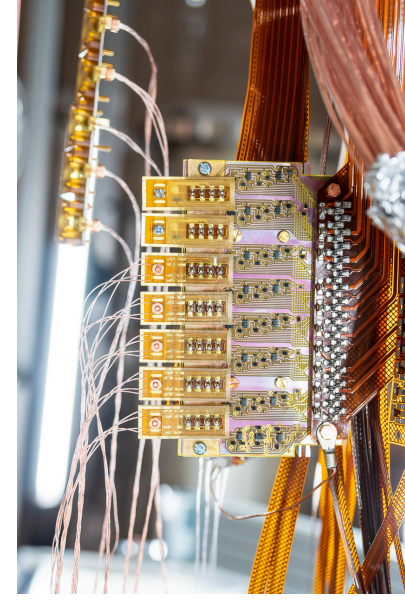


Larger mass HPGe detectors (up to 4 kg)

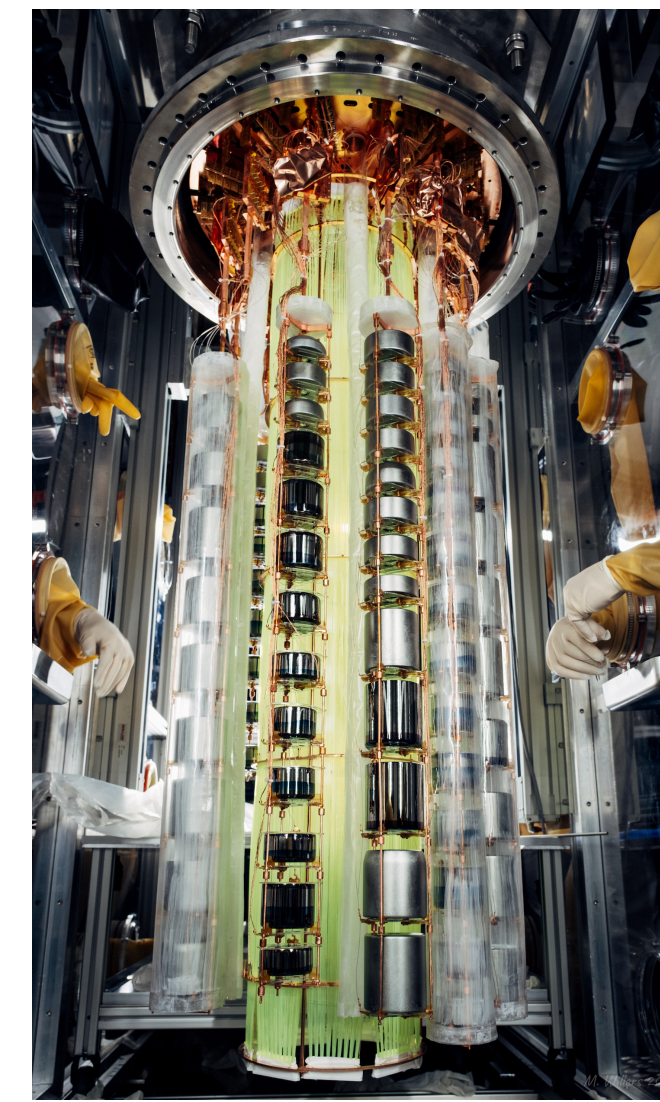
Integration & Commissioning



Post-GERDA Test



Electronics & DAQ test,
Mechanics & glovebox installation



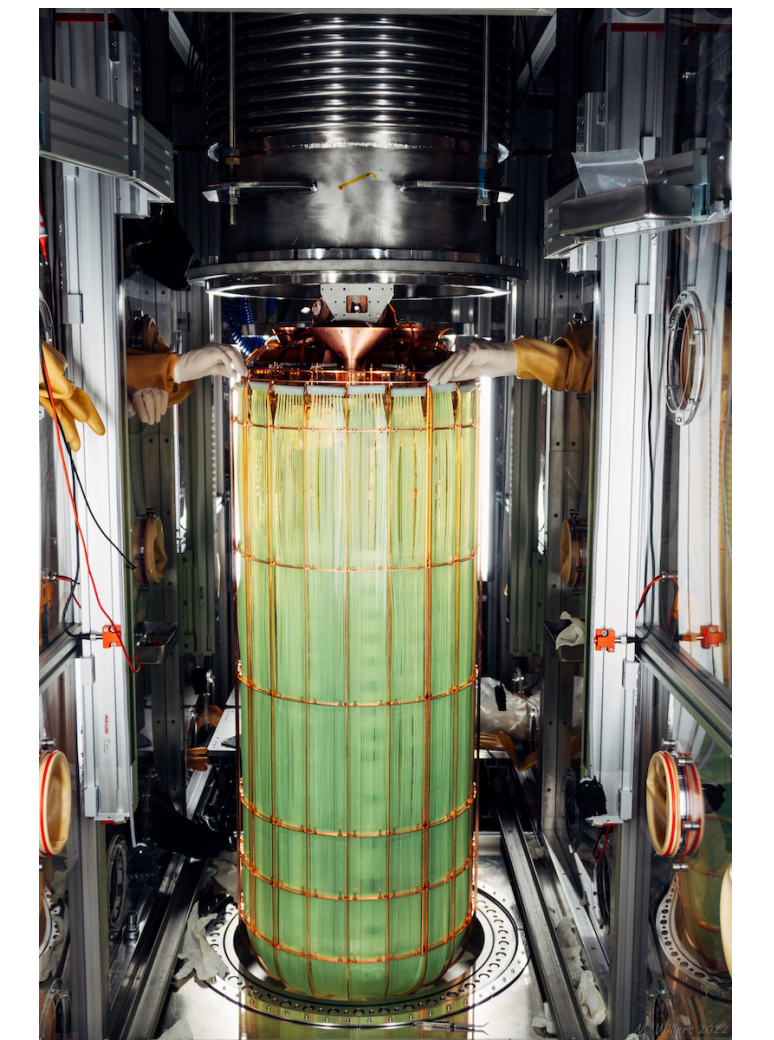
142kg installation and commissioning



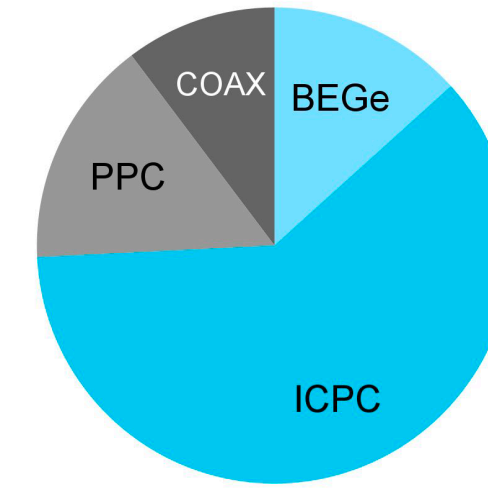
Upgrade of cryostat infrastructure

Electronics & LAr instrumentation commissioning

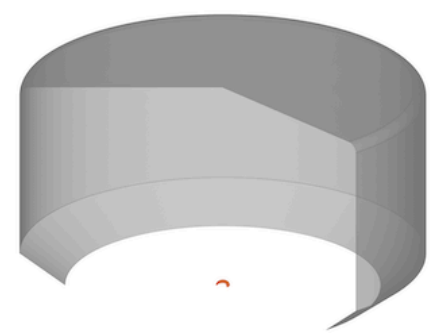
Physics data taking



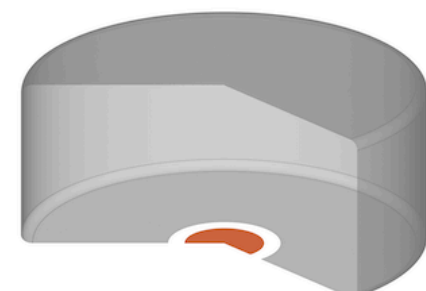
Status of Detector Array



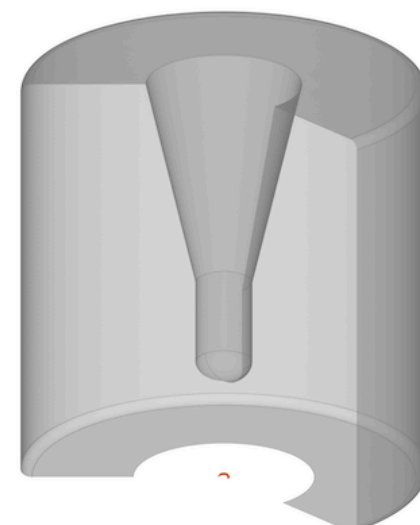
- October 2022:
 - Successful installation of 142kg of HPGe detectors
 - 101 detectors in 10 strings, 130kg operational
 - Focus on analysis of ICPC and BEGe detectors
- Next Steps:
 - Continue data taking, evaluate backgrounds, complete array in early 2024



PPC (MJD)



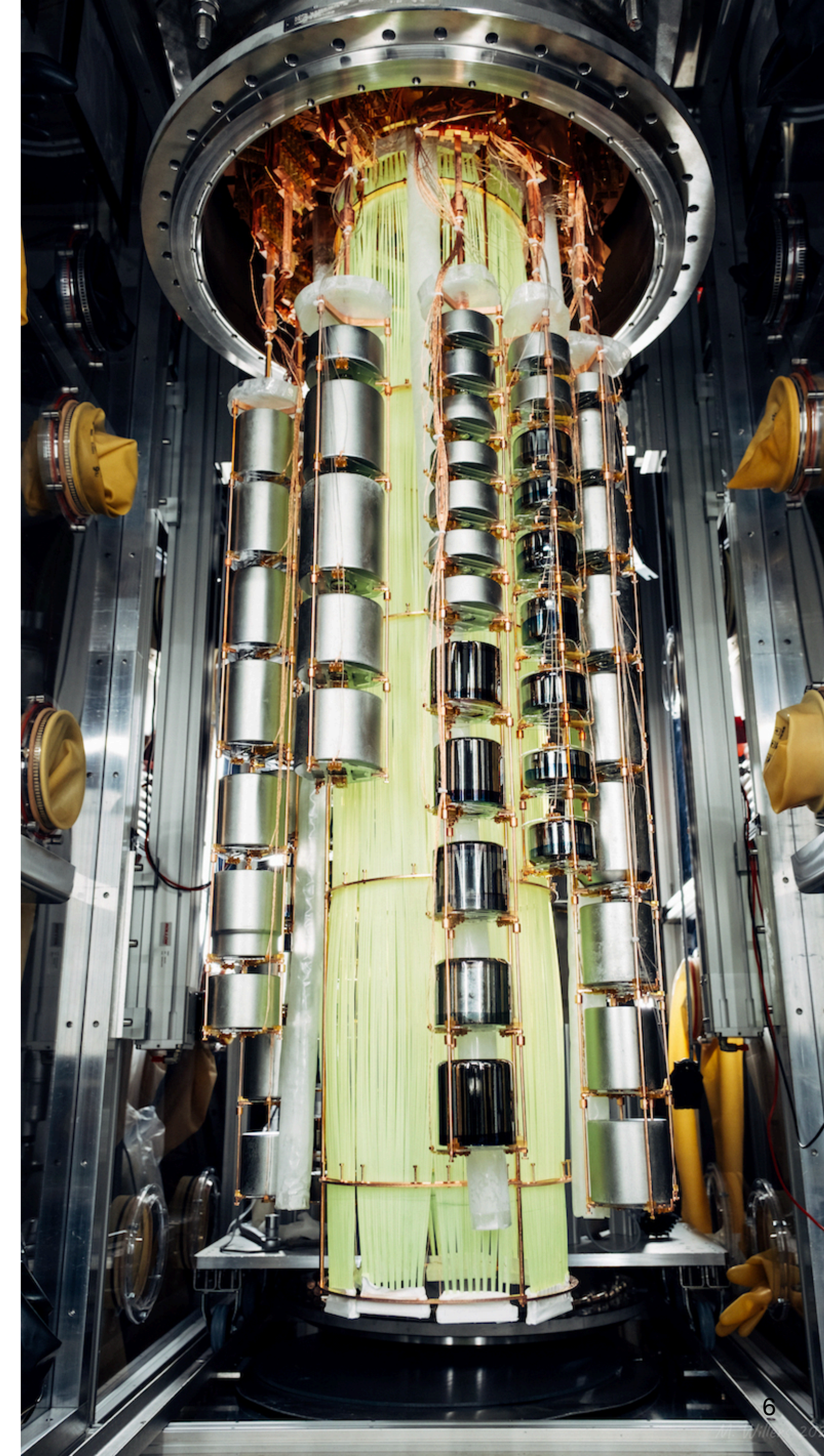
BEGe (GERDA)



ICPC (LEGEND)

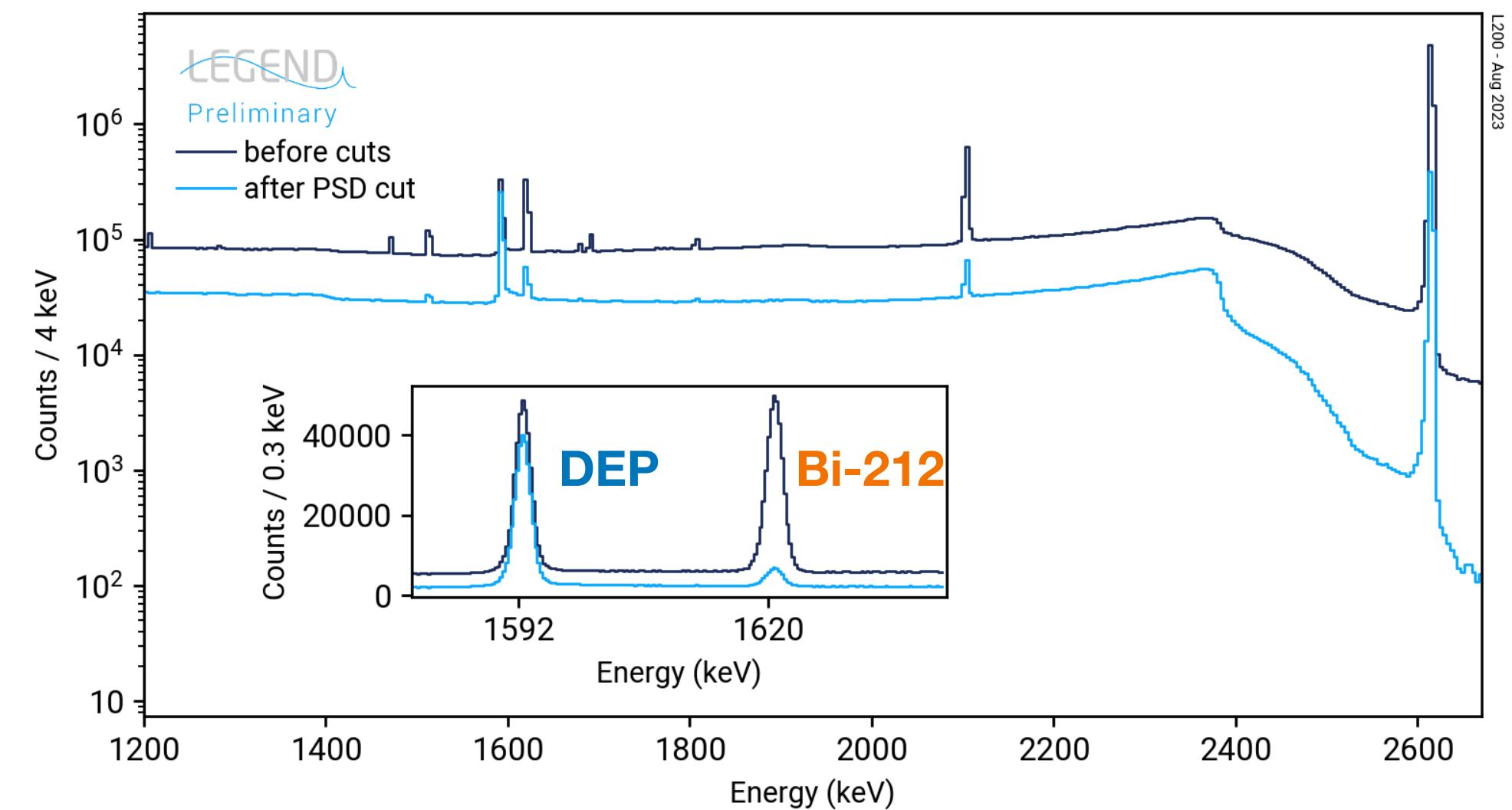
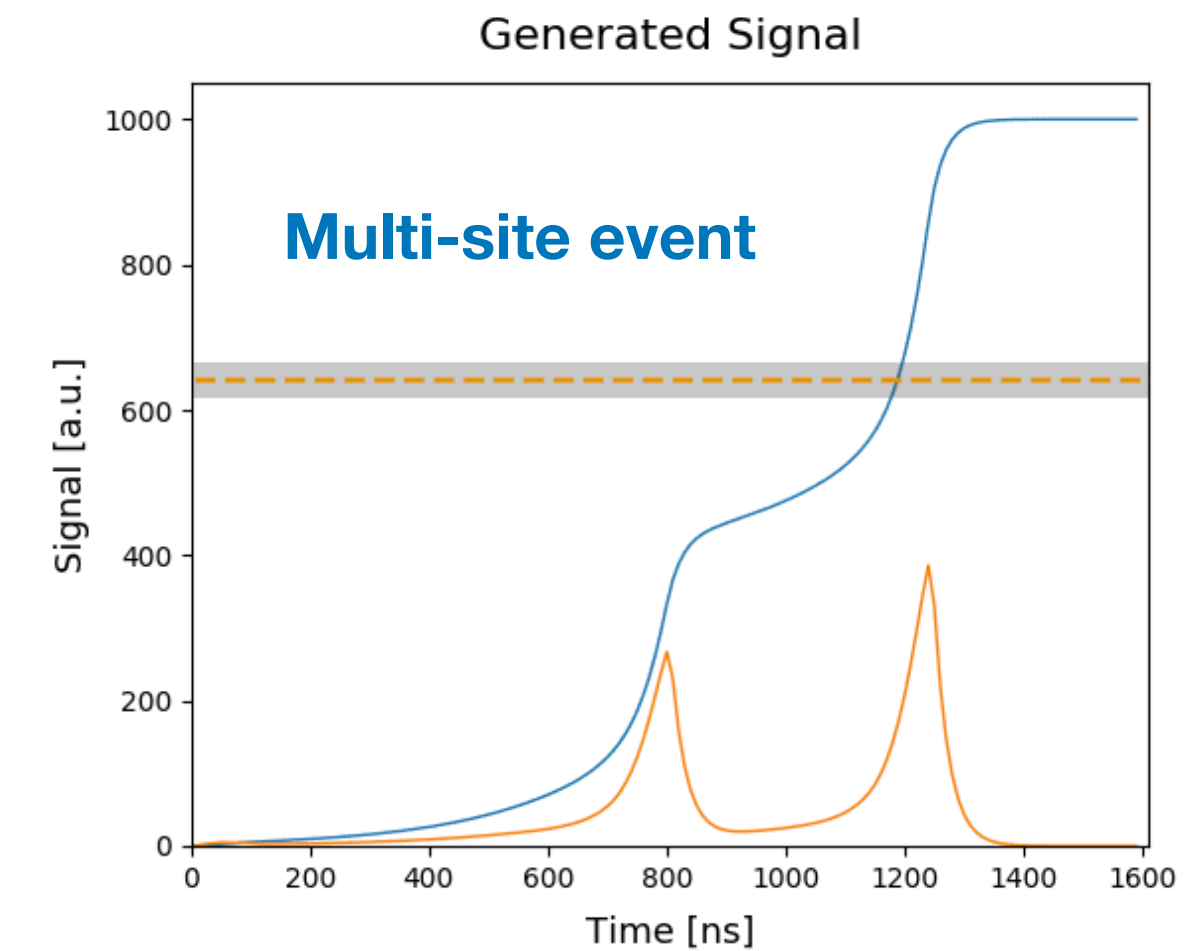
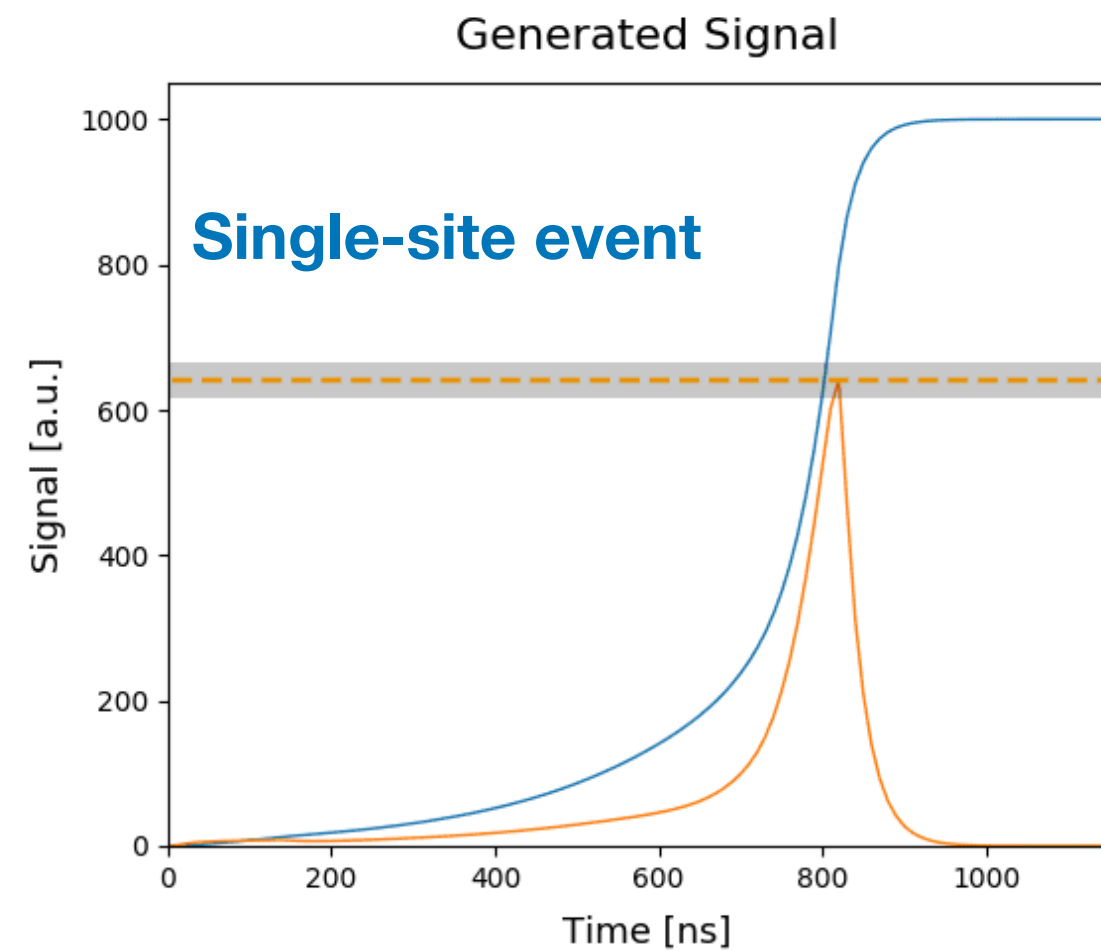
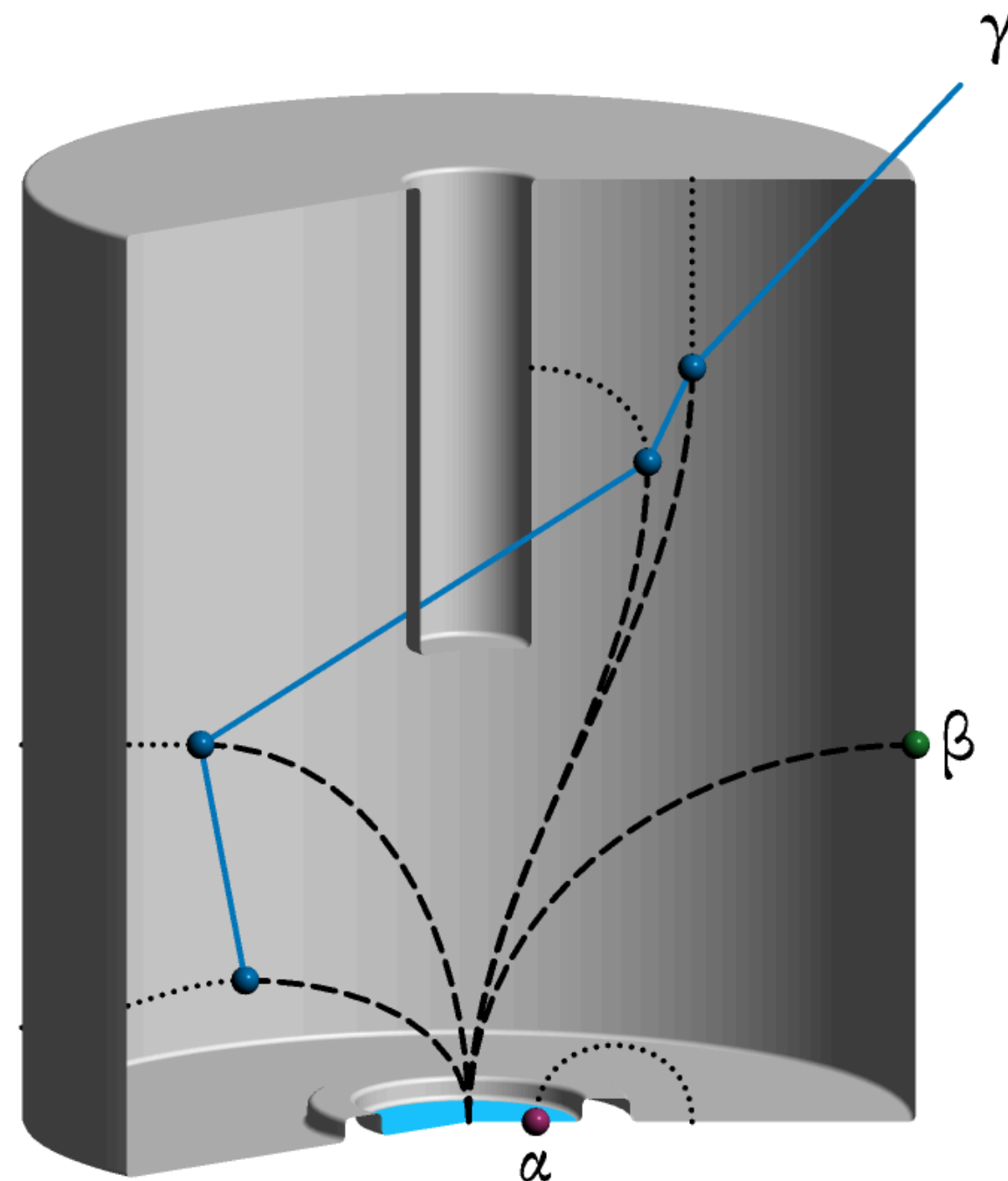


Coax (GERDA)



Pulse Shape Discrimination

- Based on A/E parameter
- PSD tuned to 90% survival at DEP
- Excellent rejection of multi-site events

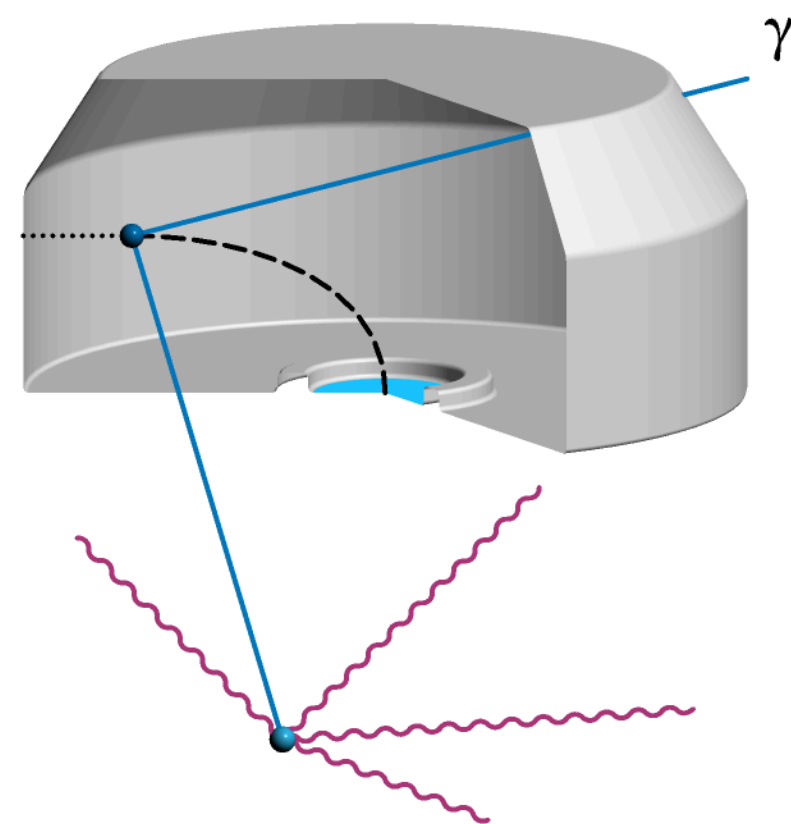
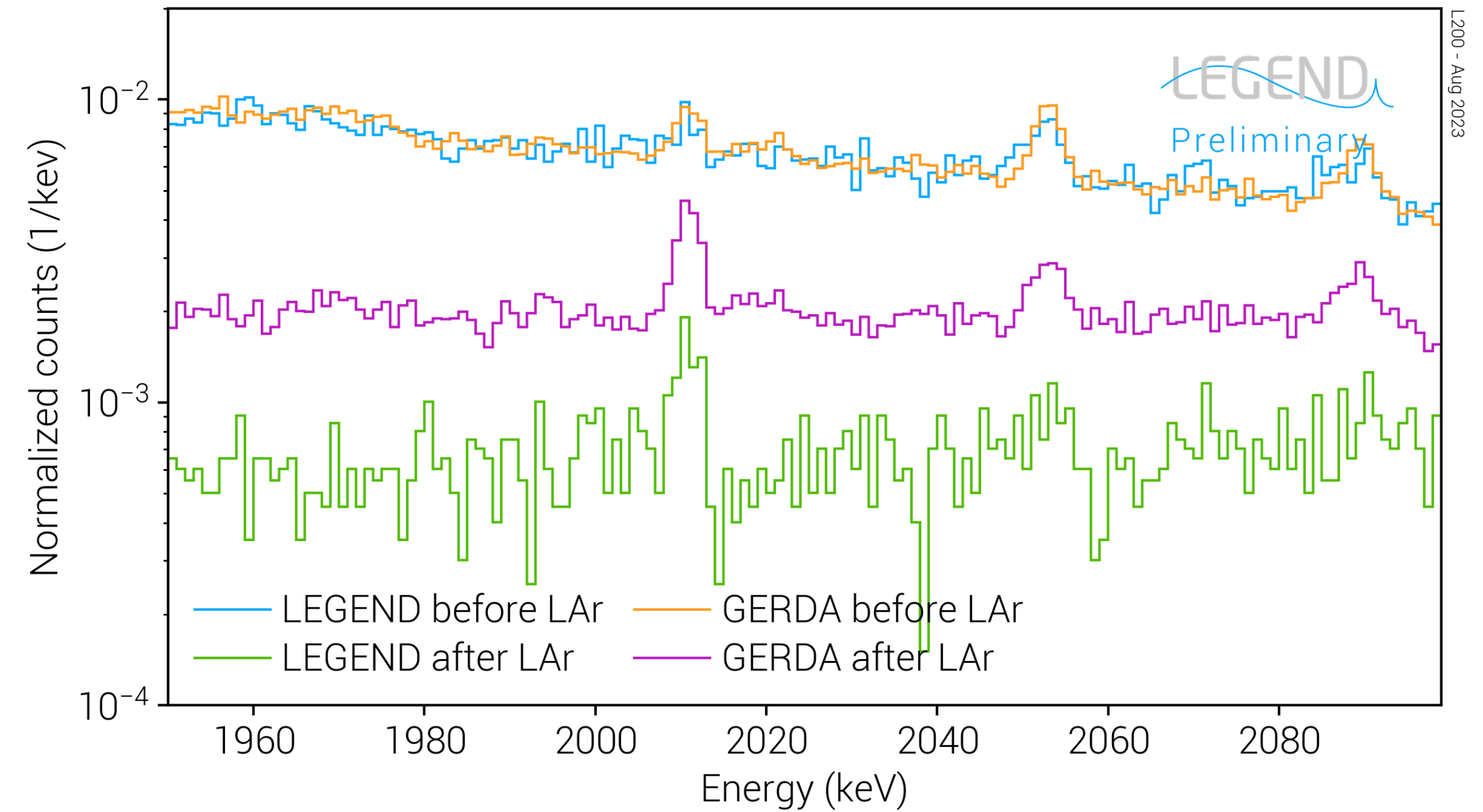
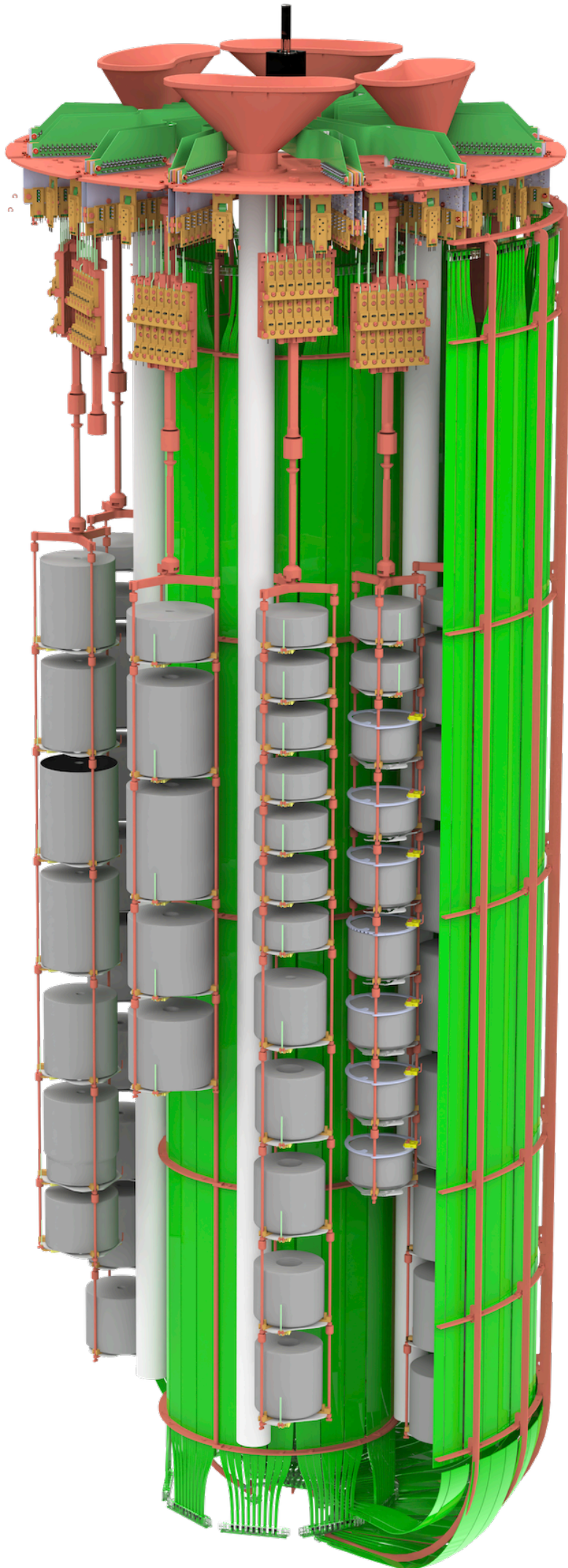


Proxy for single-site events

Proxy for multi-site events

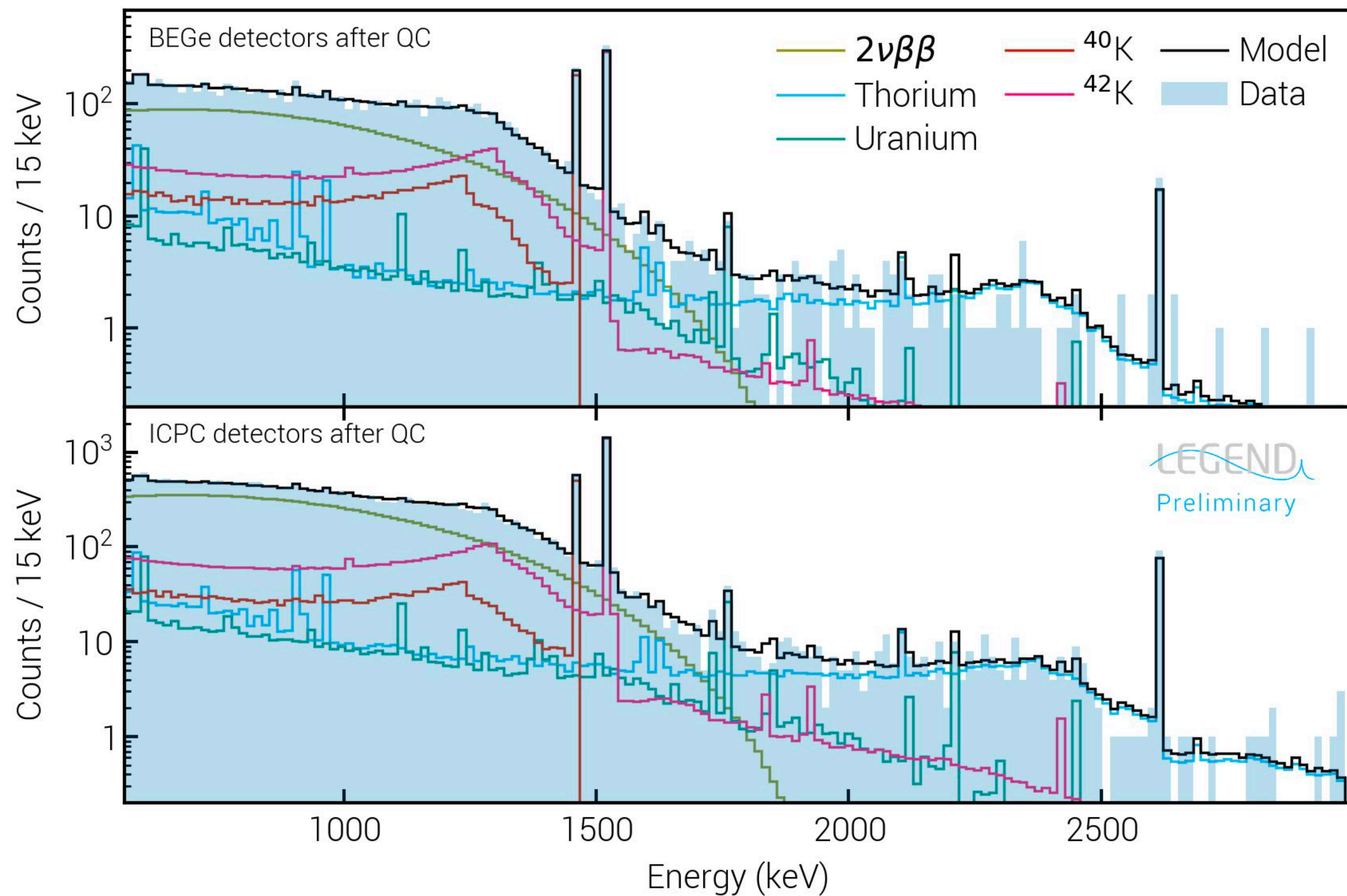
LAr Instrumentation

- Improved SiPM readout
- Improved geometry
- Optical active PEN
- Improved wavelength-shifting fiber coating

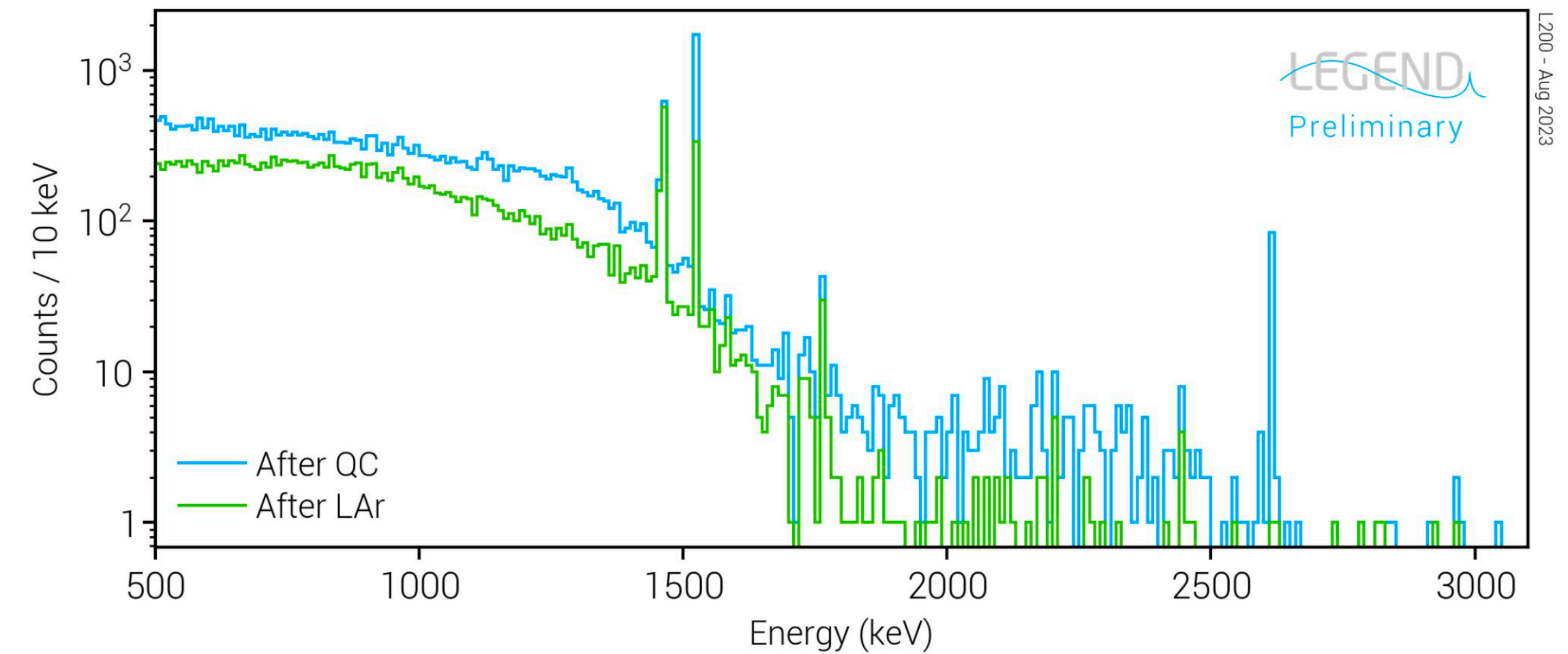


- Improved light yield by a factor of ~ 3
- Better background suppression!

Background Suppression with Quality Cuts



L200 - Aug 2023



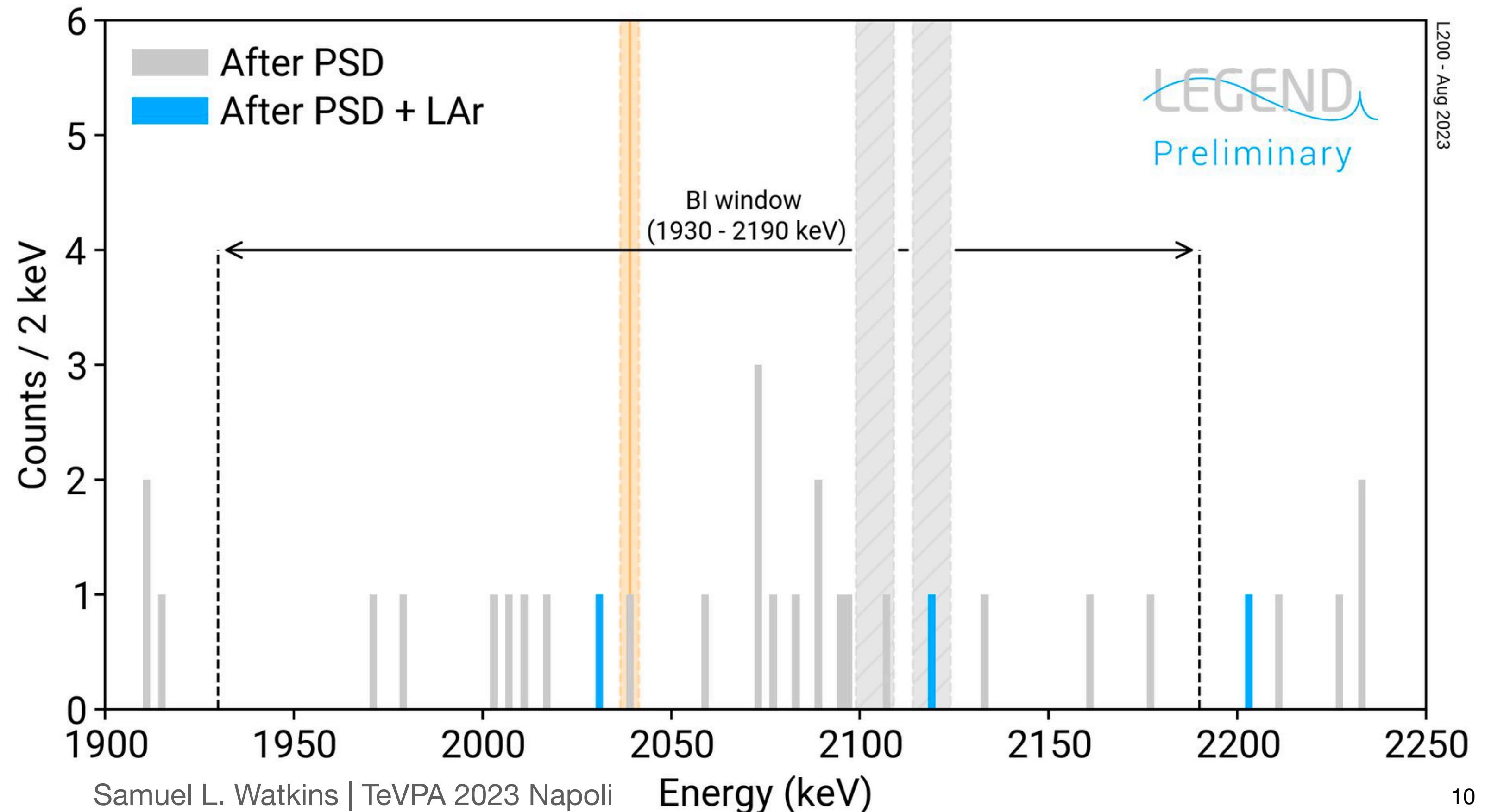
L200 - Aug 2023

- Background suppression is driven by
 - PSD-based data cleaning
 - Ge anti-coincidence
 - Muon veto
 - LAr instrumentation

Background Index at $Q_{\beta\beta}$

- First **10.1 kg yr** of LEGEND-200 data with ICPC and BEGe
- BI is **compatible** with LEGEND-200 goal of: 2×10^{-4} cts/(keV kg yr)

	LEGEND-200 BI 68% CL (cts/keV/kg/yr)	GERDA Phase II unblinded BI 68% CL (cts/keV/kg/yr)
After LAr & PSD	$4.1 [1.5,11.4] \times 10^{-4}$	$5.2 [3.9,6.8] \times 10^{-4}$

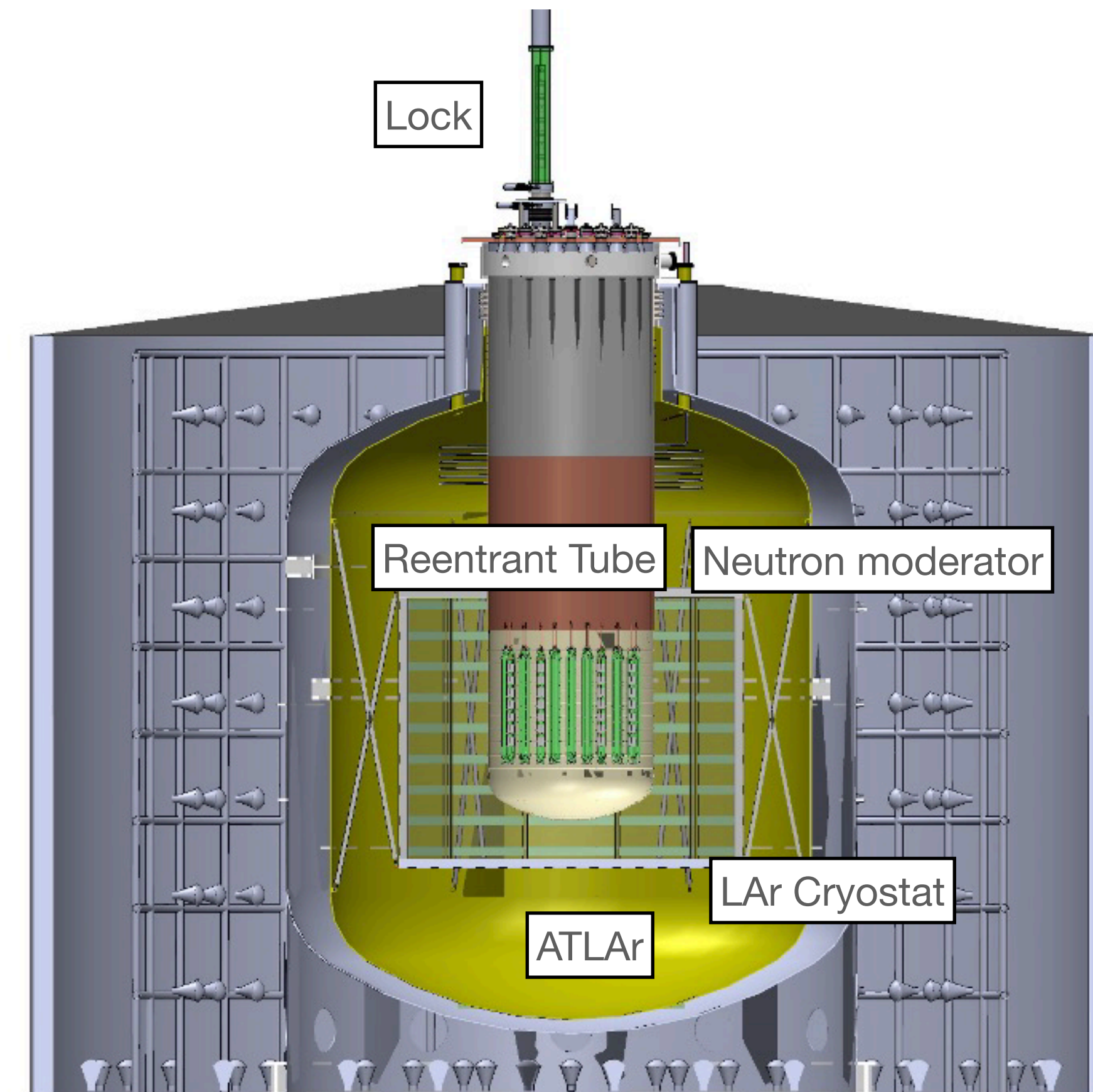
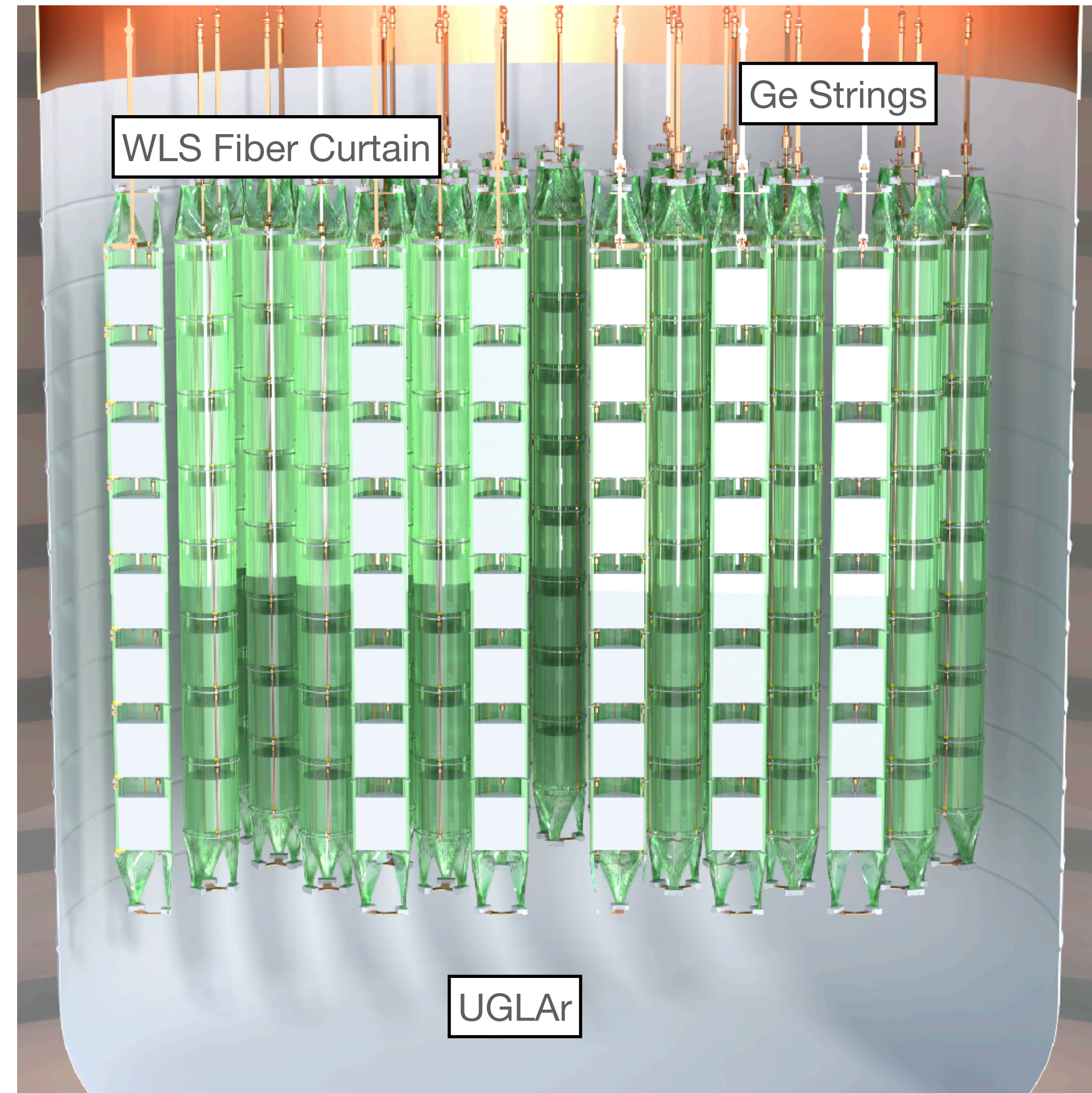
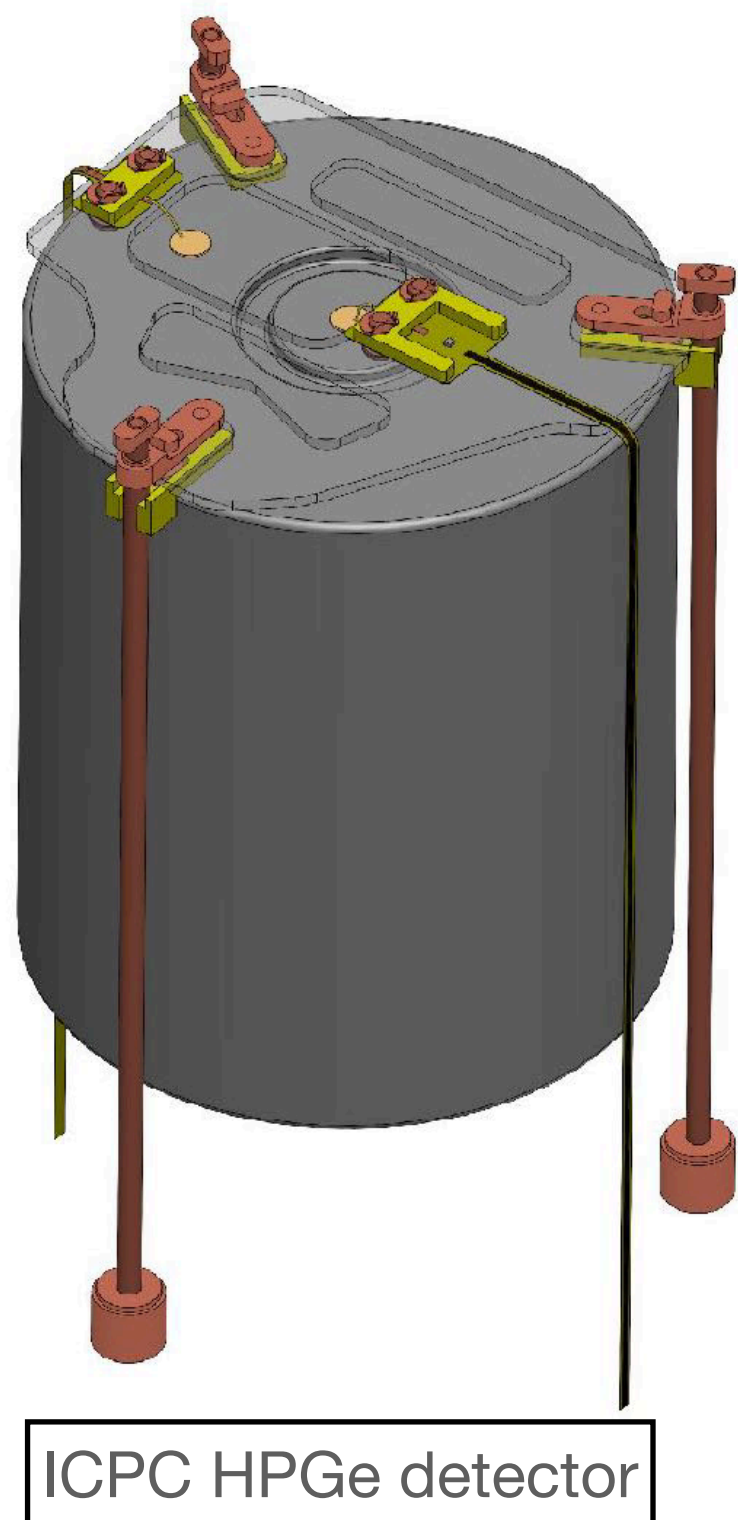


Looking Forward: LEGEND-1000

ICPC: Inverted-Coaxial Point Contact
 WLS: Wavelength-shifting
 UGLAr: Underground Liquid Ar
 ATLaR: Atmospheric Liquid Ar

336 detectors of 3 kg avg. mass

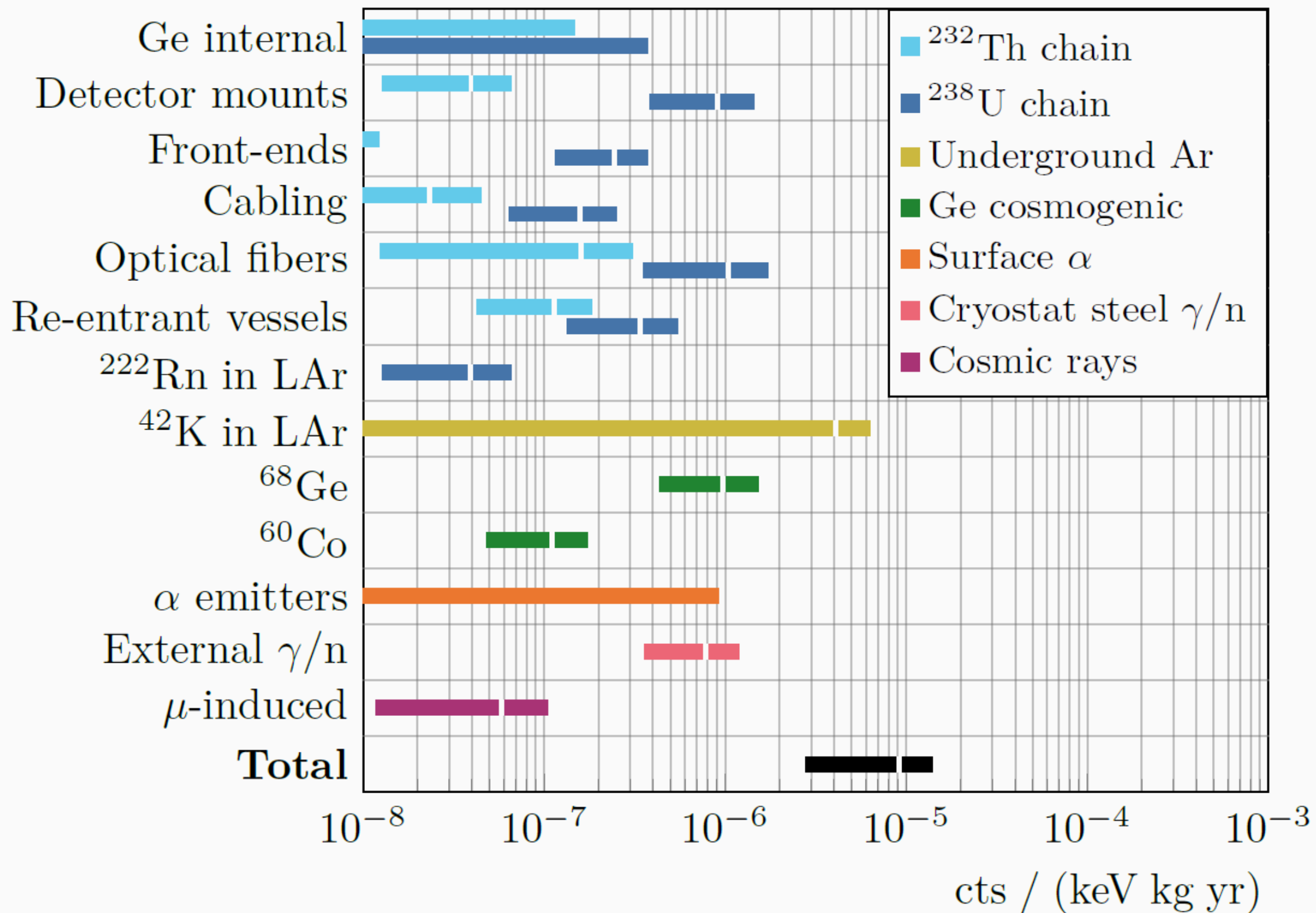
Detector strings can be individually installed:
 Early data as detectors are produced



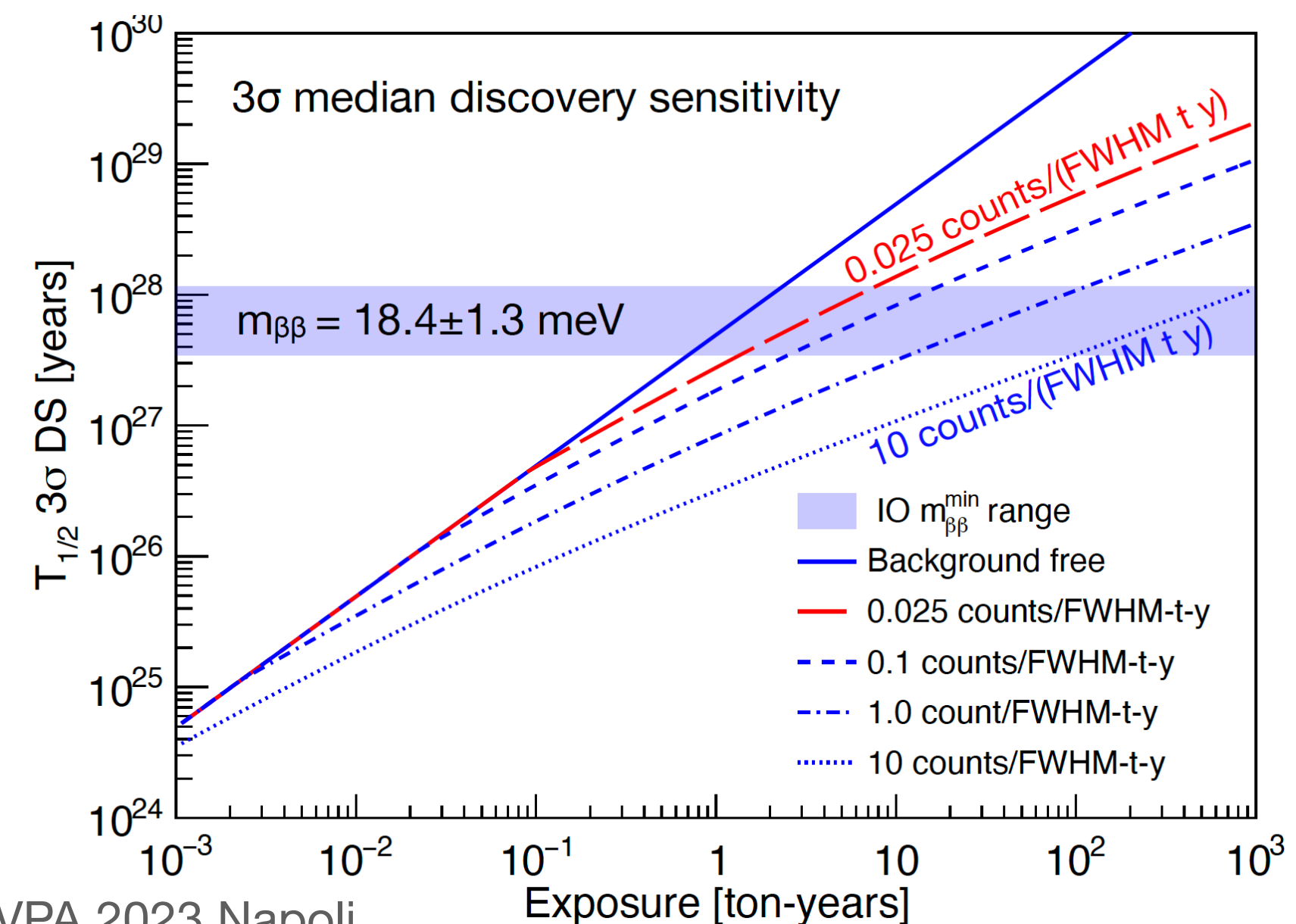
Reference design accommodates siting in
 LNGS Hall C or the SNOLAB Crypt

Background Index

- Projected background index after all cuts:
 - $< 10^{-5}$ cts/(keV kg yr)
- Background model is being refined
 - Updated layout and spacing
 - New material radiopurity assays
 - Additional detail of internal components



LEGEND-1000 pre-CDR: [arXiv:2107.11462](https://arxiv.org/abs/2107.11462)



Summary & Outlook

- LEGEND-200
 - Successful commissioning
 - Currently running and taking physics data
 - More detectors to be installed in 2024
- LEGEND-1000



- Optimized for quasi-background free search for $0\nu\beta\beta$

- Low-risk path to meeting background goal

- Design allows for an unambiguous discovery of $0\nu\beta\beta$ at $T_{1/2} = 10^{28}$ yr

