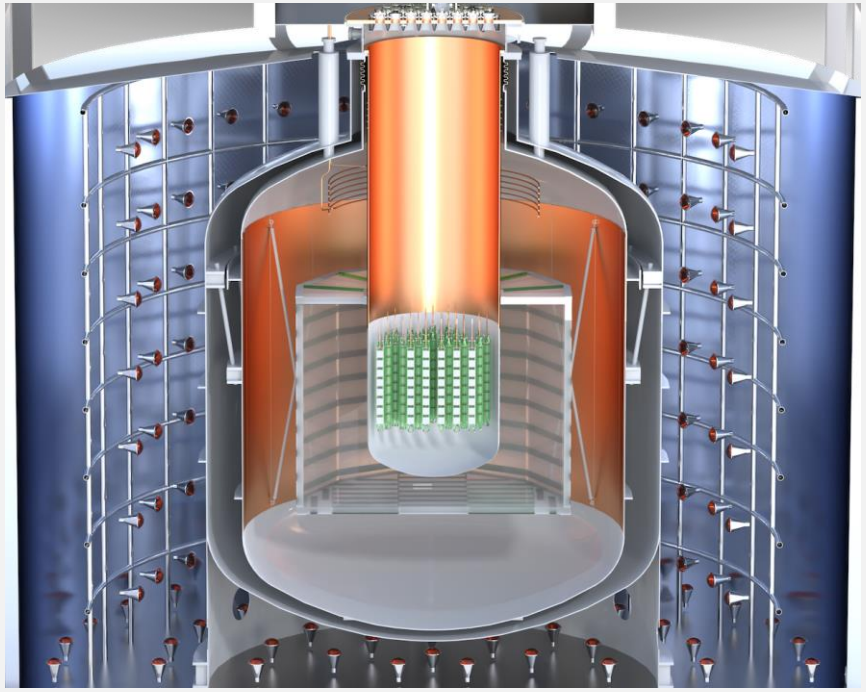
LEGEND-200: first physics data and analysis

LEGEND
Large Enriched Germanium Experiment for Neutrinoless ββ Decay



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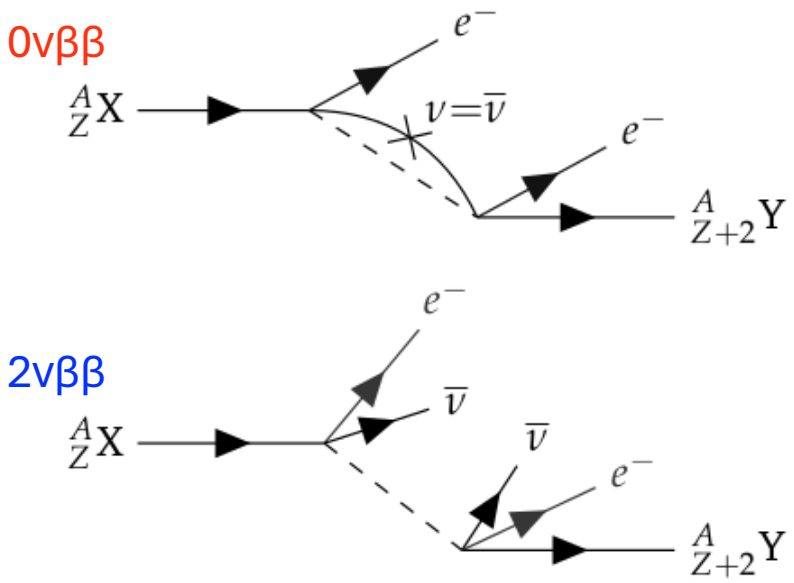
ROMA TRE
UNIVERSITÀ DEGLI STUDI

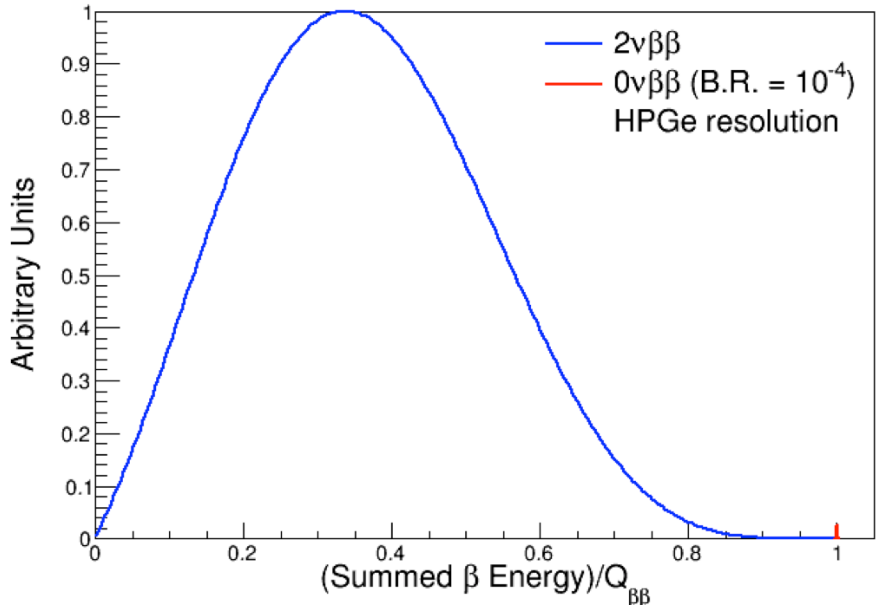
since 1966 Rencontres de Moriond

INFN
Istituto Nazionale di Fisica Nucleare
SEZIONE DI ROMA TRE

Neutrinoless double-beta decay (0νββ)

- Hypothetical rare decay mode
- Available in several isotopes
- Experimentally viable method to probe the Majorana/Dirac nature of the neutrino

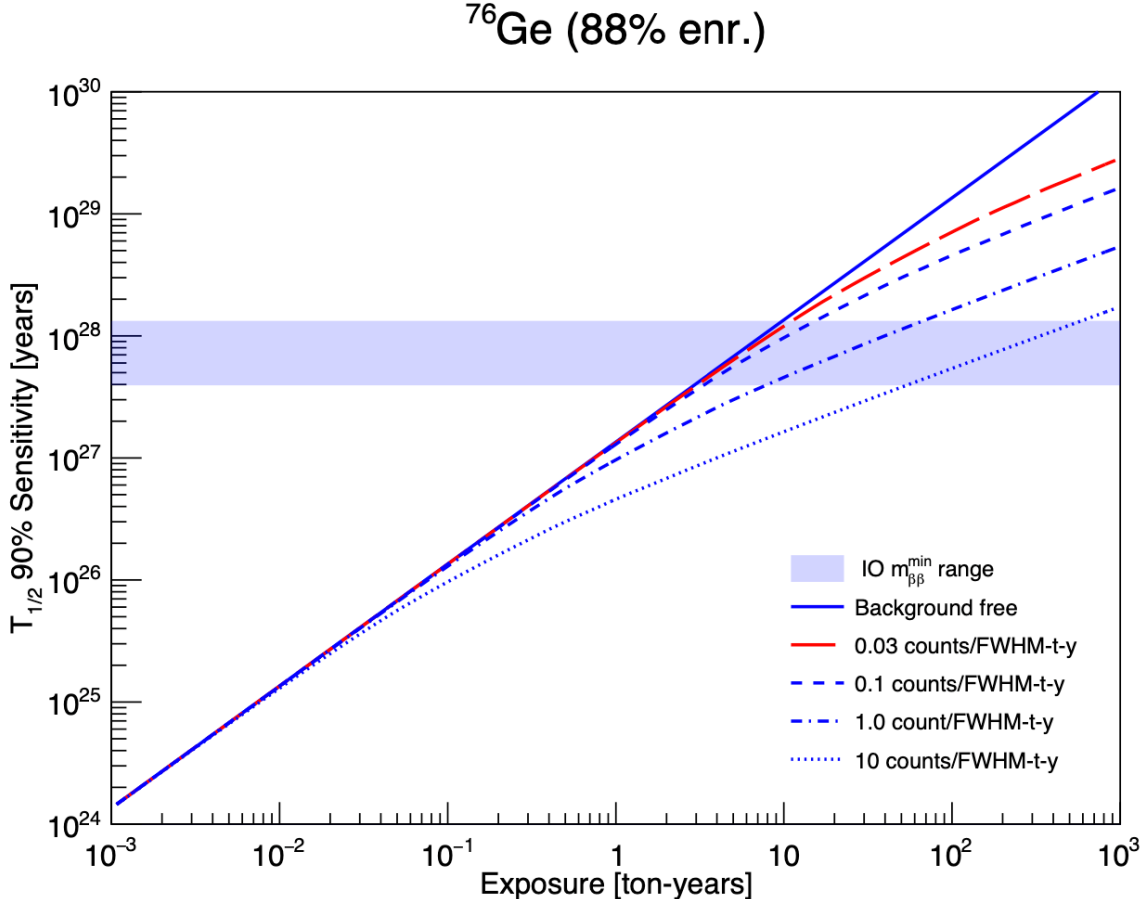




LEGEND

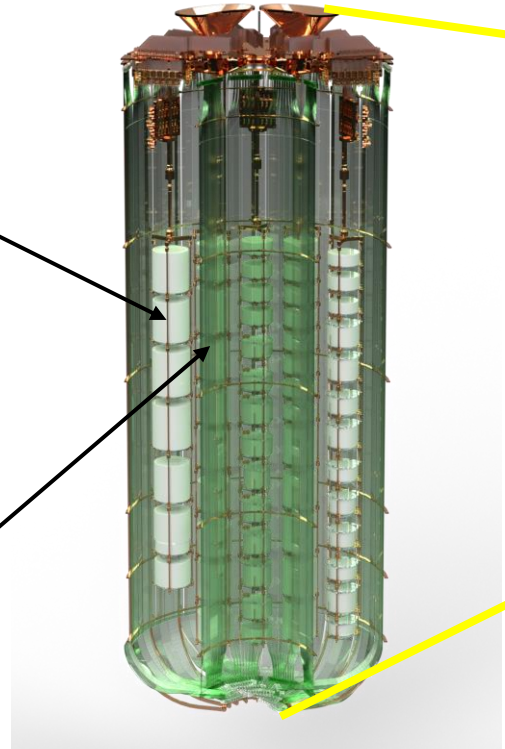
The LEGEND (Large Enriched Germanium Experiment for Neutrinoless Double-beta decay) project searches for neutrinoless double-beta decay in ^{76}Ge, with goals to establish a discovery sensitivity for a half-life of this nucleus beyond 10^{28} years.

- Dual-phase program: LEGEND-200 (operational) and LEGEND-1000 (planned)
- For ^{76}Ge, $T_{1/2} > 10^{28}$ for 0νββ corresponds to a neutrino effective mass measurement of $m_{eff} \approx 18$ meV
- With sufficiently low background, LEGEND will ultimately cover the parameter space for Majorana neutrinos in the inverted hierarchy mass ordering



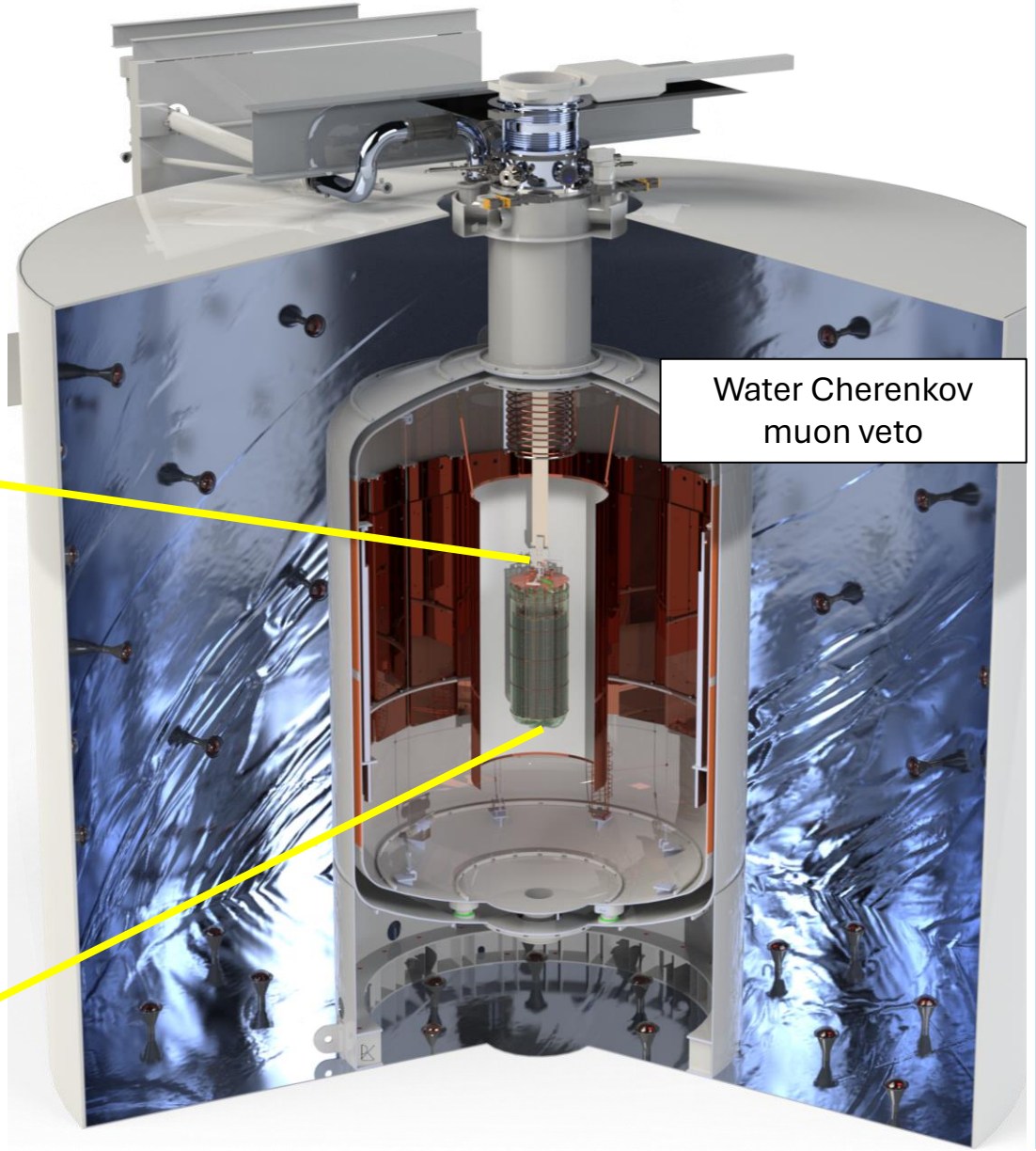
LEGEND-200

- Initial phase of the project
- Currently operational at LNGS in Italy with ~140 kg of Ge detectors enriched in ^{76}Ge
  - Will have 200 kg operational - upgrade planned for later this year
- Multiple detector systems allow event classification/background rejection



Ge detector array in vertical “string” structure

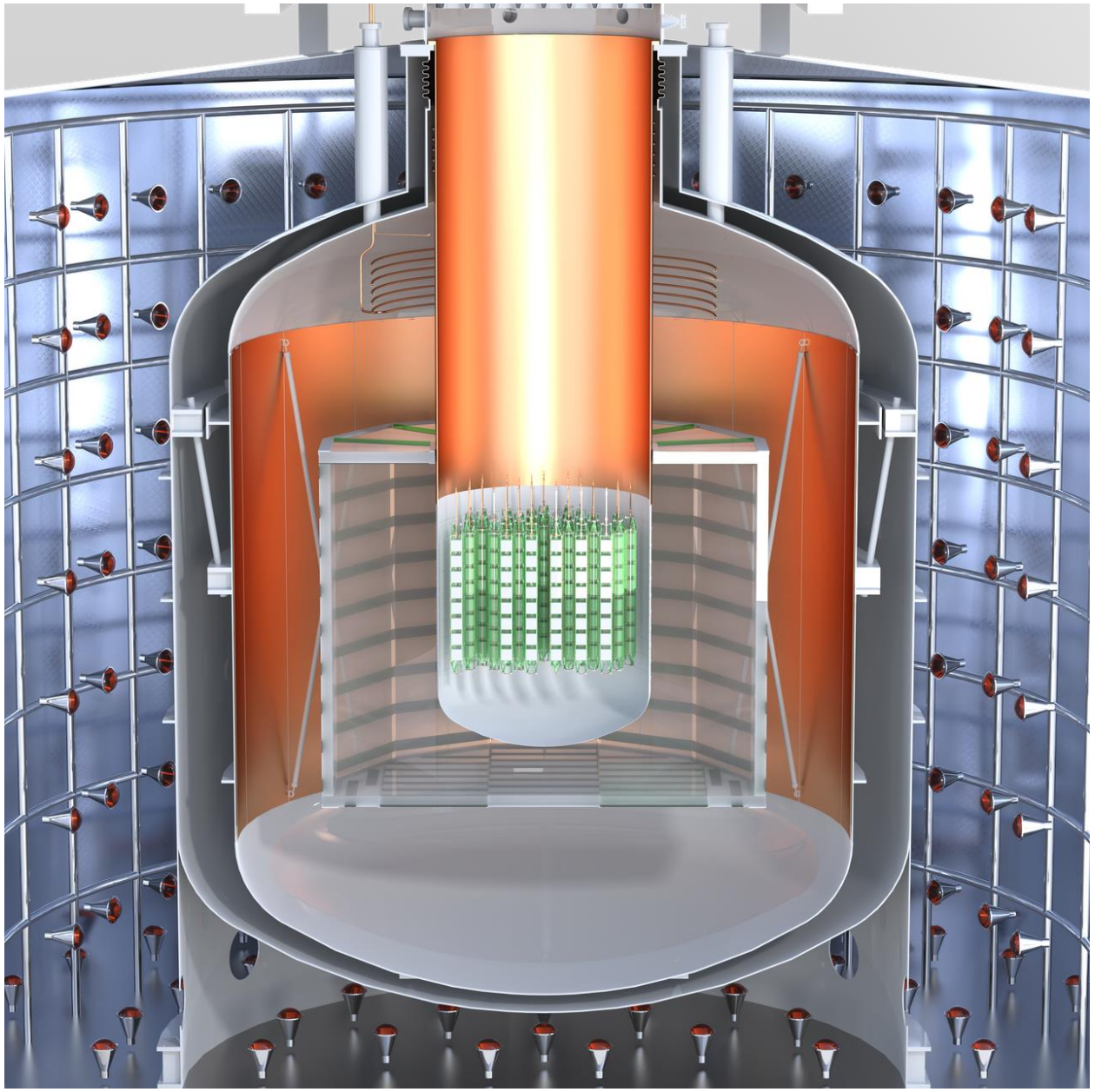
Fiber shroud (green) scintillation detectors



Water Cherenkov muon veto

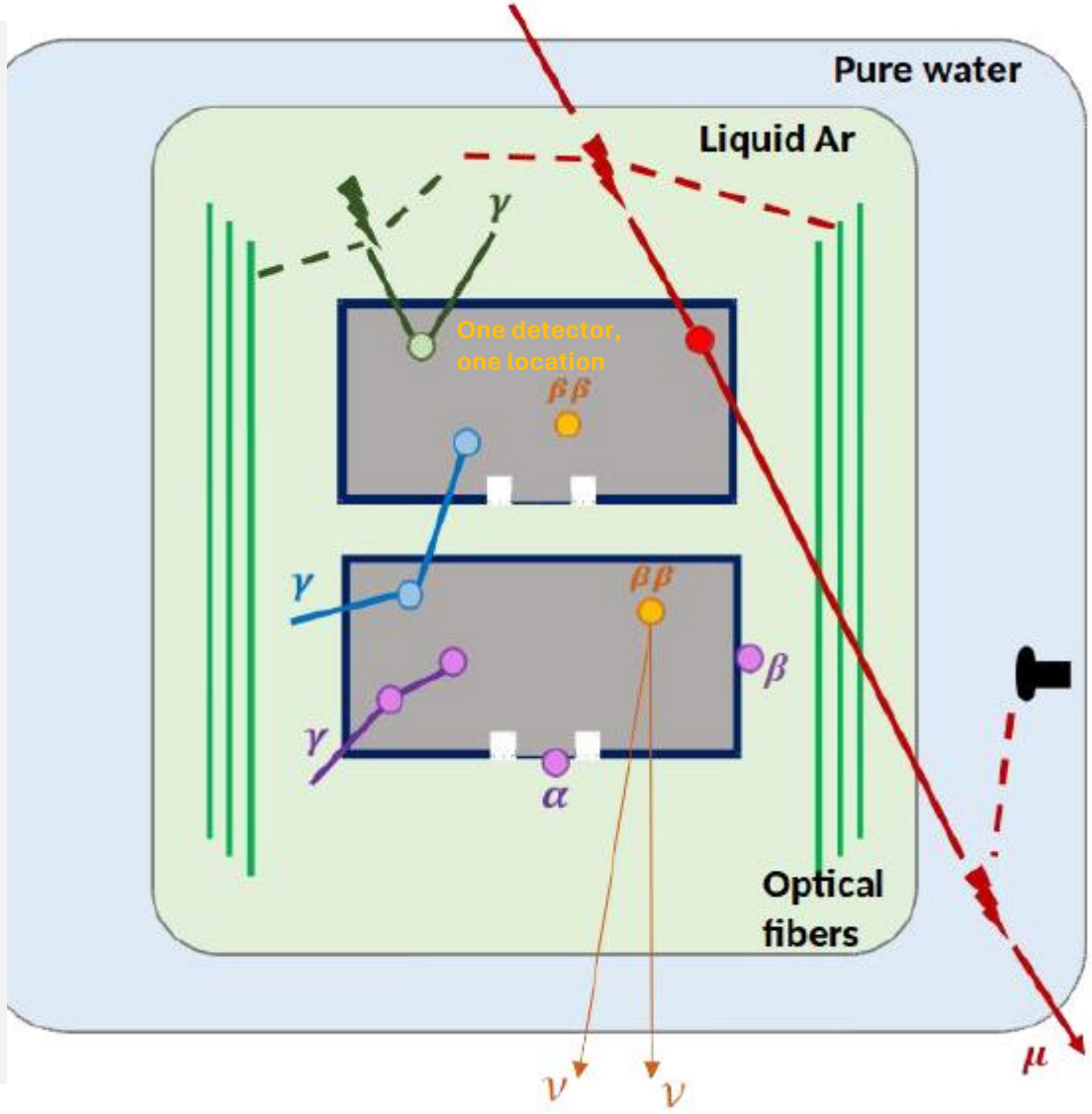
LEGEND-1000

- Next-generation 0νββ detection system
- Location TBD
- Expected to have 1000 kg of detectors operational in the final configuration
- Widespread improvements and lessons learned from LEGEND-200 aim to reduce background x20 compared to LEGEND-200
- In a very active R&D phase, overall design is subject to modification



Background rejection

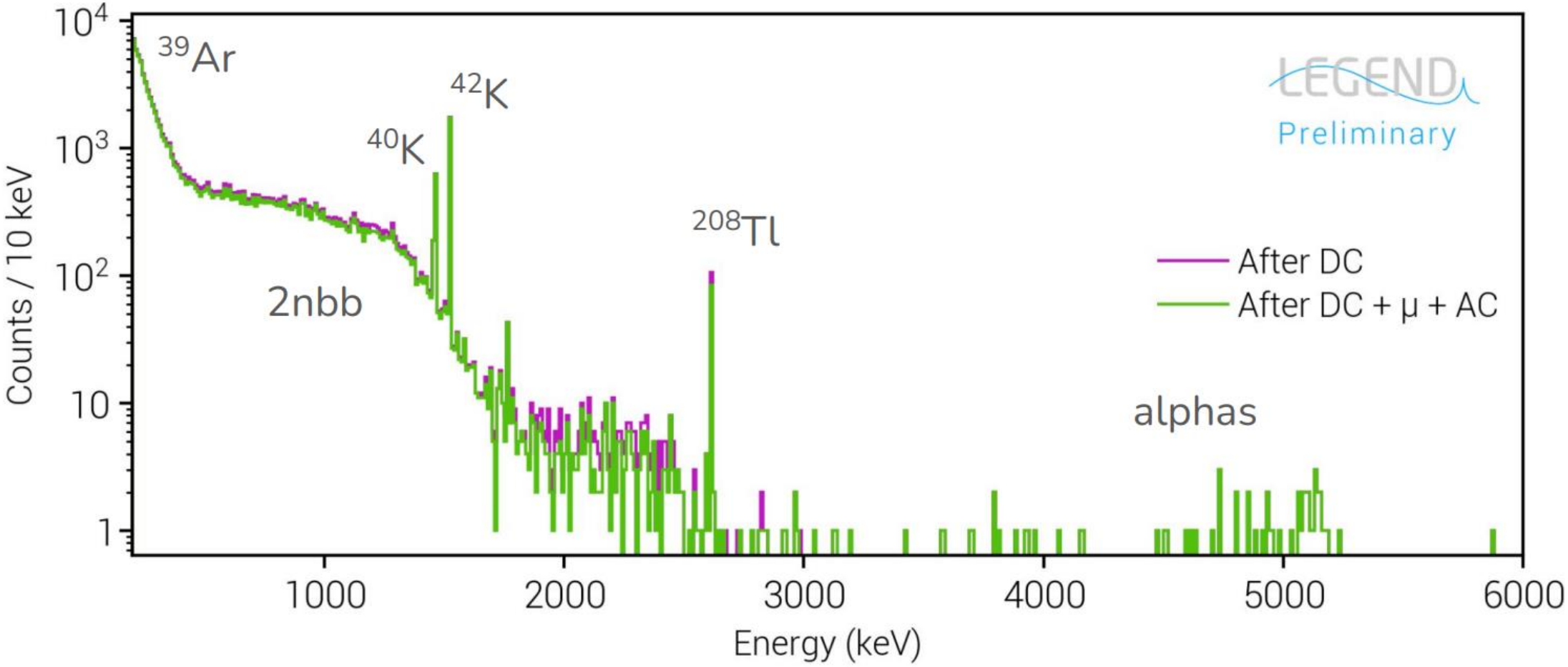
- Cosmogenic muons are rejected by the water Cerenkov veto (and pretty much every other rejection method)
- External gammas (mostly from radioimpurities in construction materials) are rejected based on the event type:
  - Energy deposition in the scintillating Liquid Argon (LAr): rejection by the fiber shroud (LAr cut)
  - Energy deposited in multiple detectors: rejected by the Anti-Coincidence cut (AC cut)
  - Energy scattered throughout a detector: rejected by Pulse Shape Discrimination (PSD cut)
- Surface events, like external alphas and betas, are rejected by pulse shape discrimination (PSD cut) as well



Quality cut

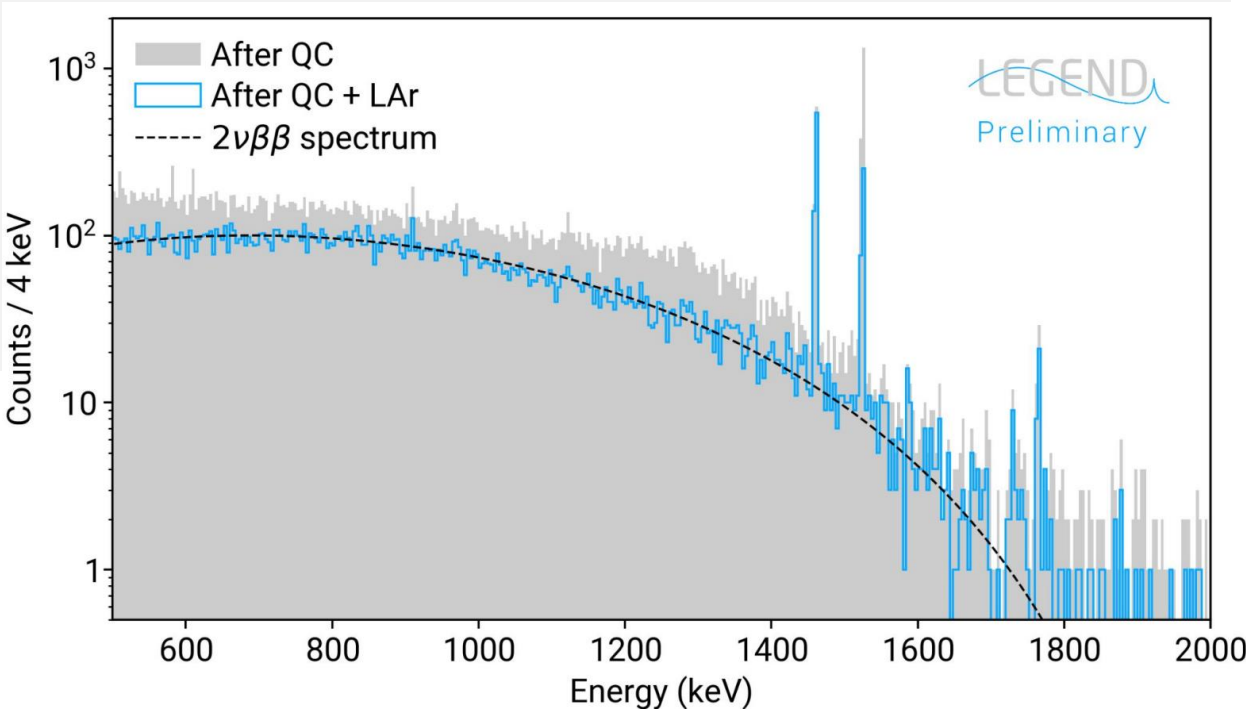
- The muon veto, AC, and Data Cleaning (DC) cuts are simpler and are bundled together into the "quality cut" (QC)

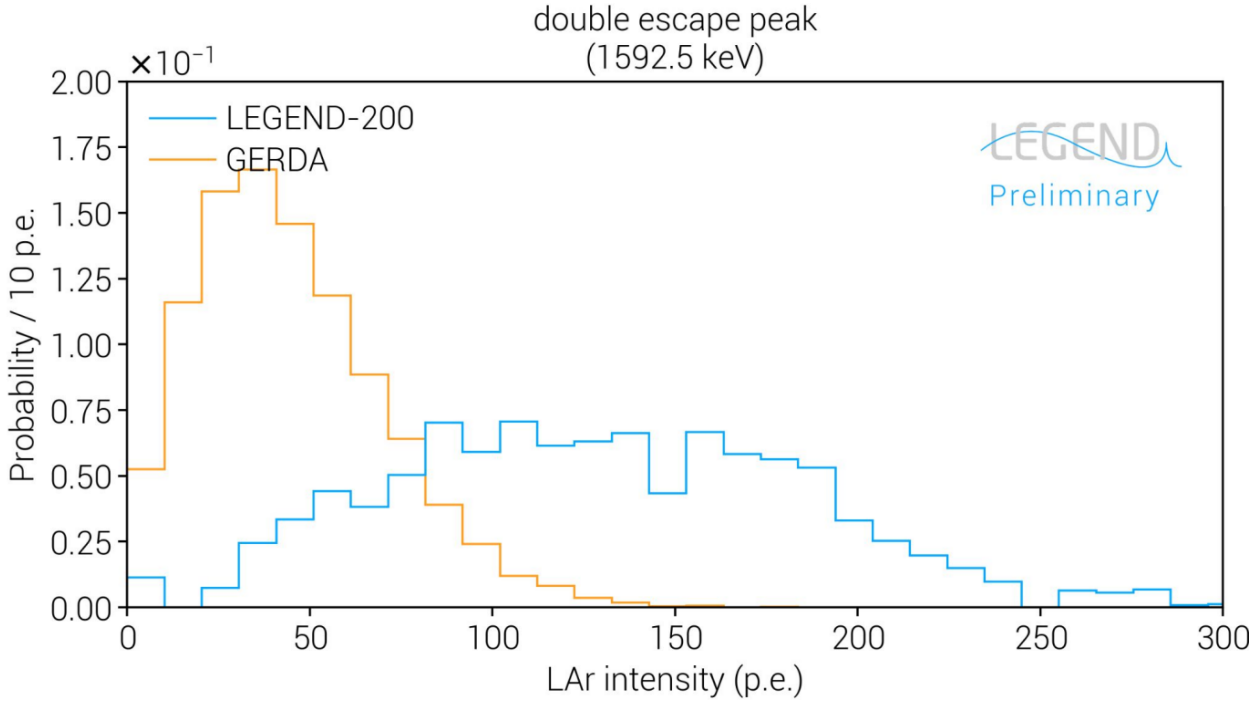
Data cleaning = removing pulser, empty, and saturated events

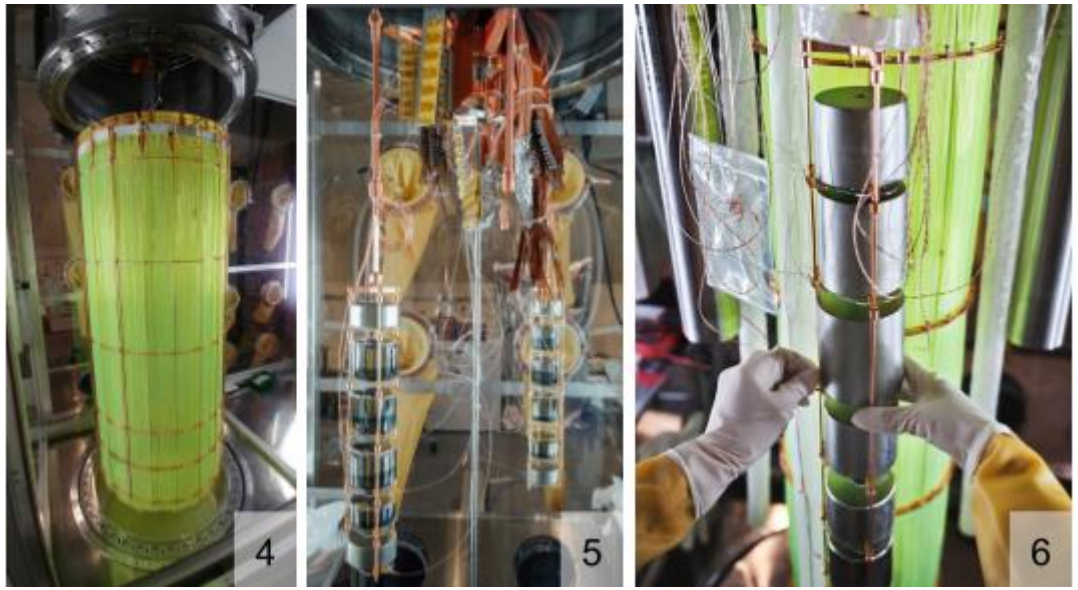


LAr cut

- Improved light collection instrumentation in LEGEND-200 allows for increased photo-electron signal compared to GERDA



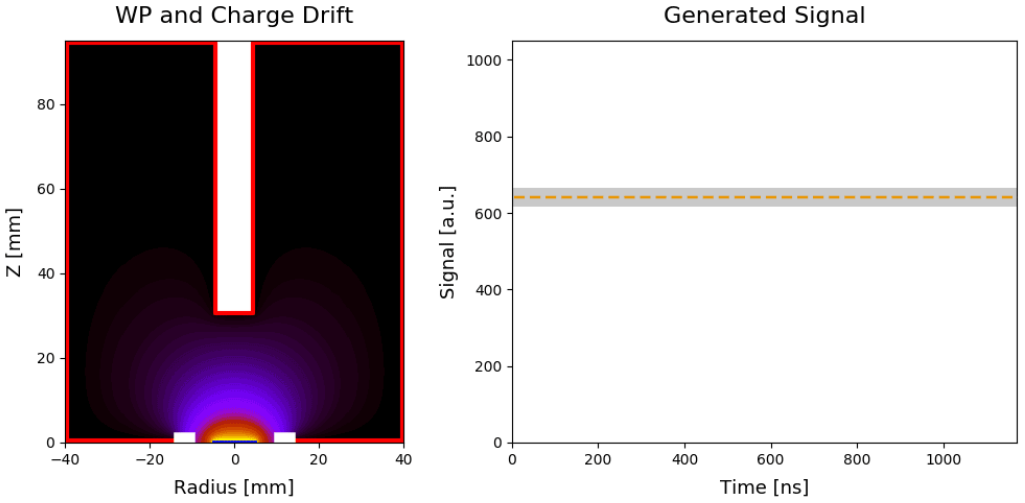


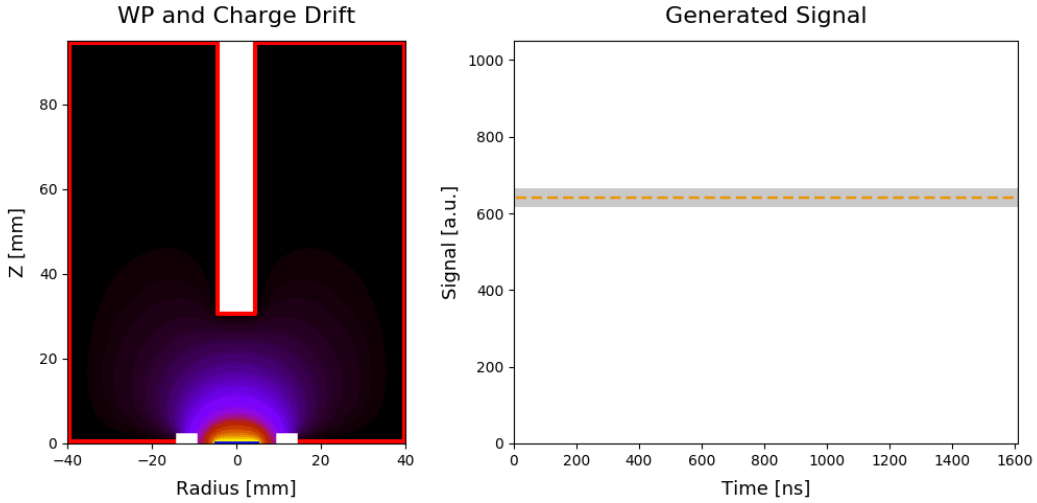


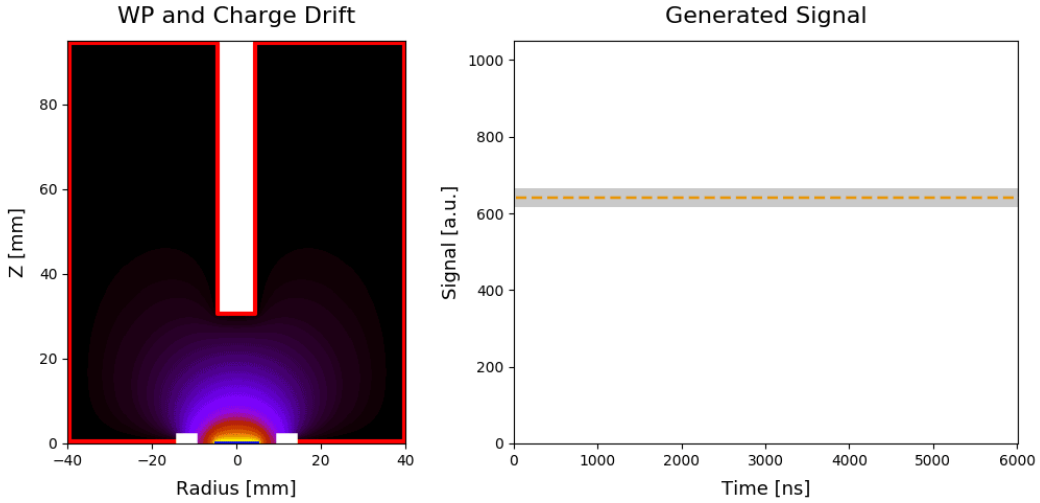
PSD cuts

Pulse-shape discrimination classifies events in the germanium detectors based on the characteristics of the generated signal

0νββ (or 2νββ)-like signal

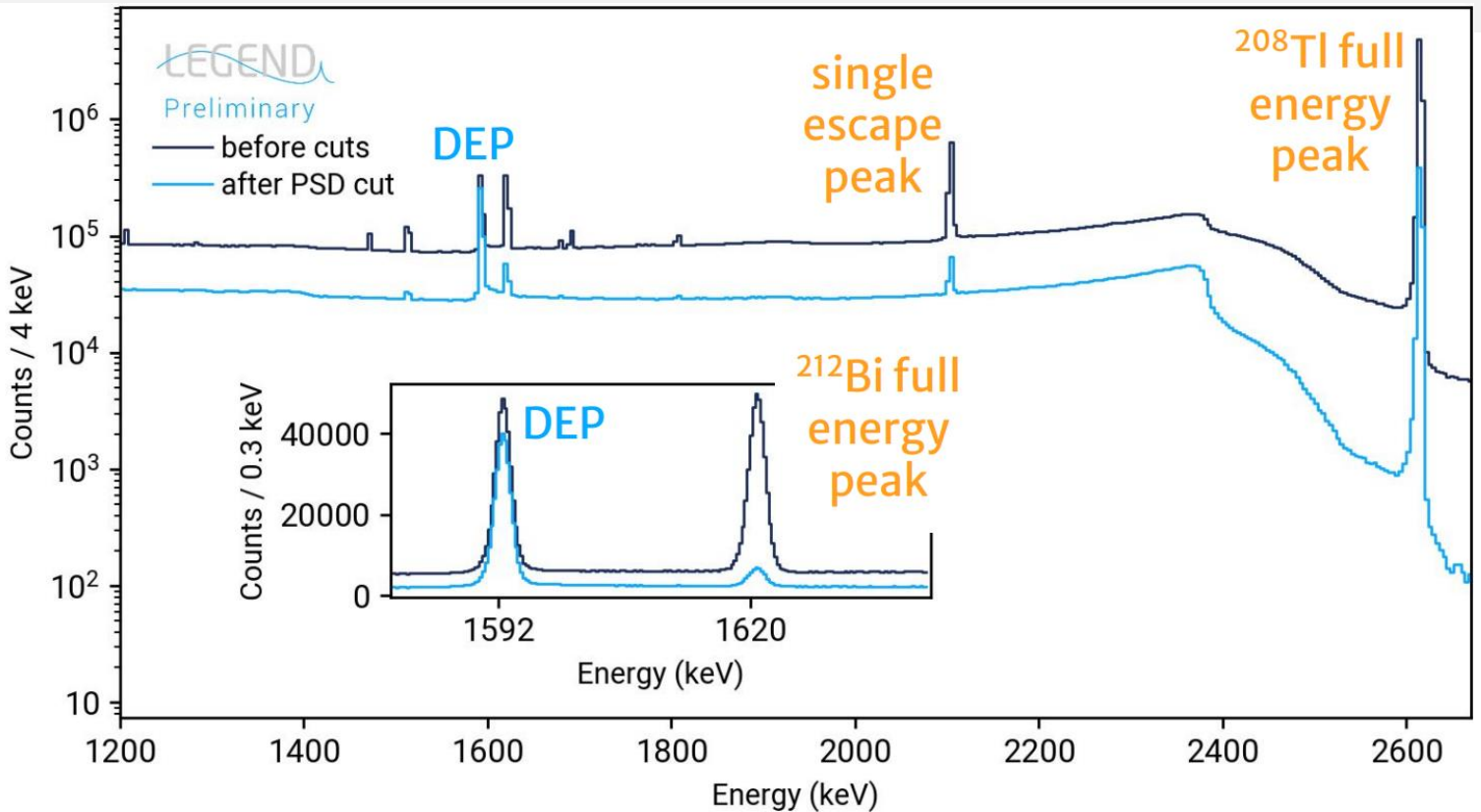






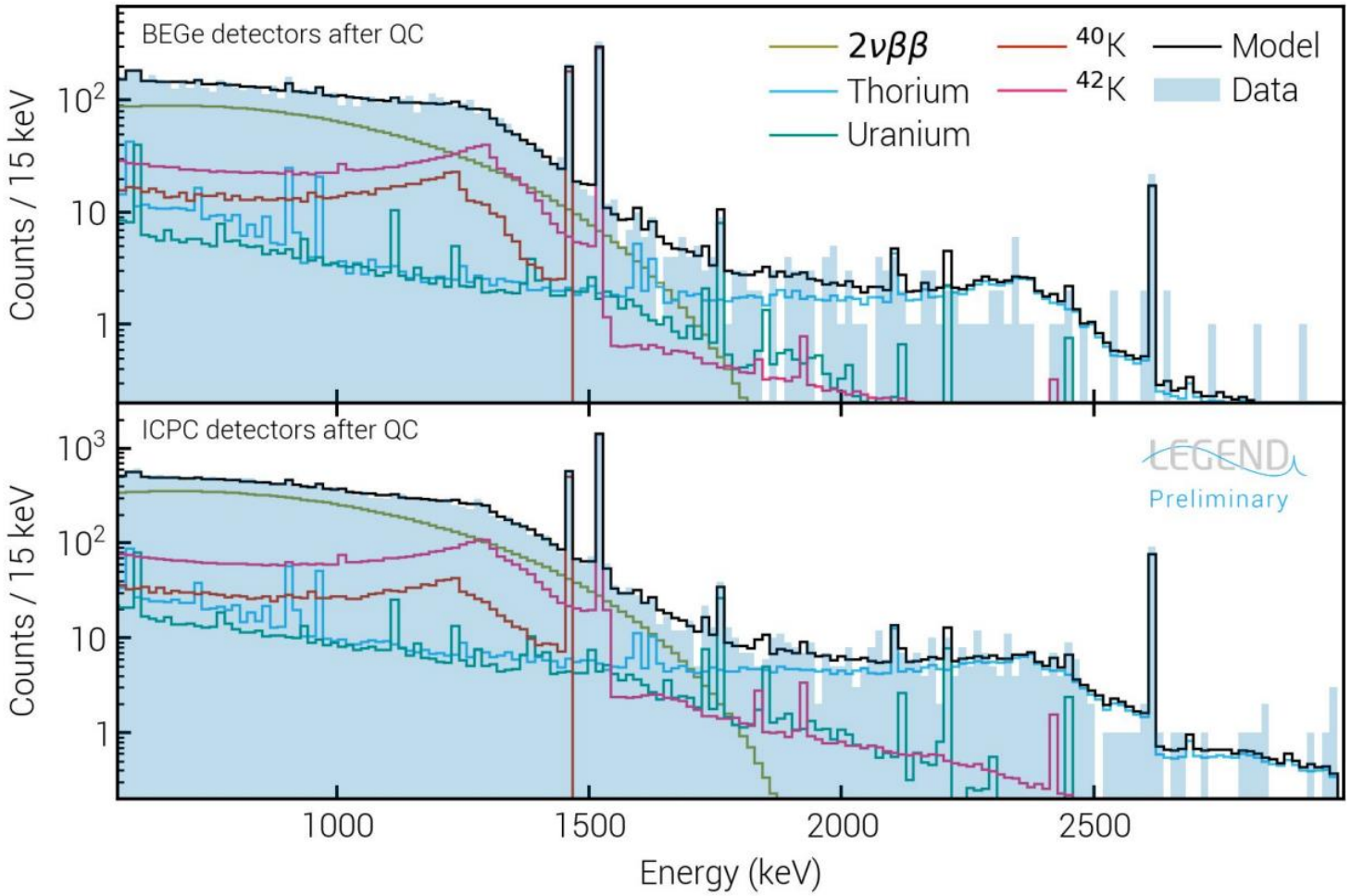
Optimizing the PSD cut

- Calibrations with ^{208}Tl decays are used to determine efficiencies of the multi-site PSD cut
  - 2614 keV full-energy peak (strongest gamma line) is multi-site
  - 2113 keV "single-escape" peak is multi-site
  - 1592 keV "double-escape" peak is single-site
  - Cut parameters are tuned to accept 90% of events in the 1592 keV peak, and exhibit good rejection of the other multi-site peaks



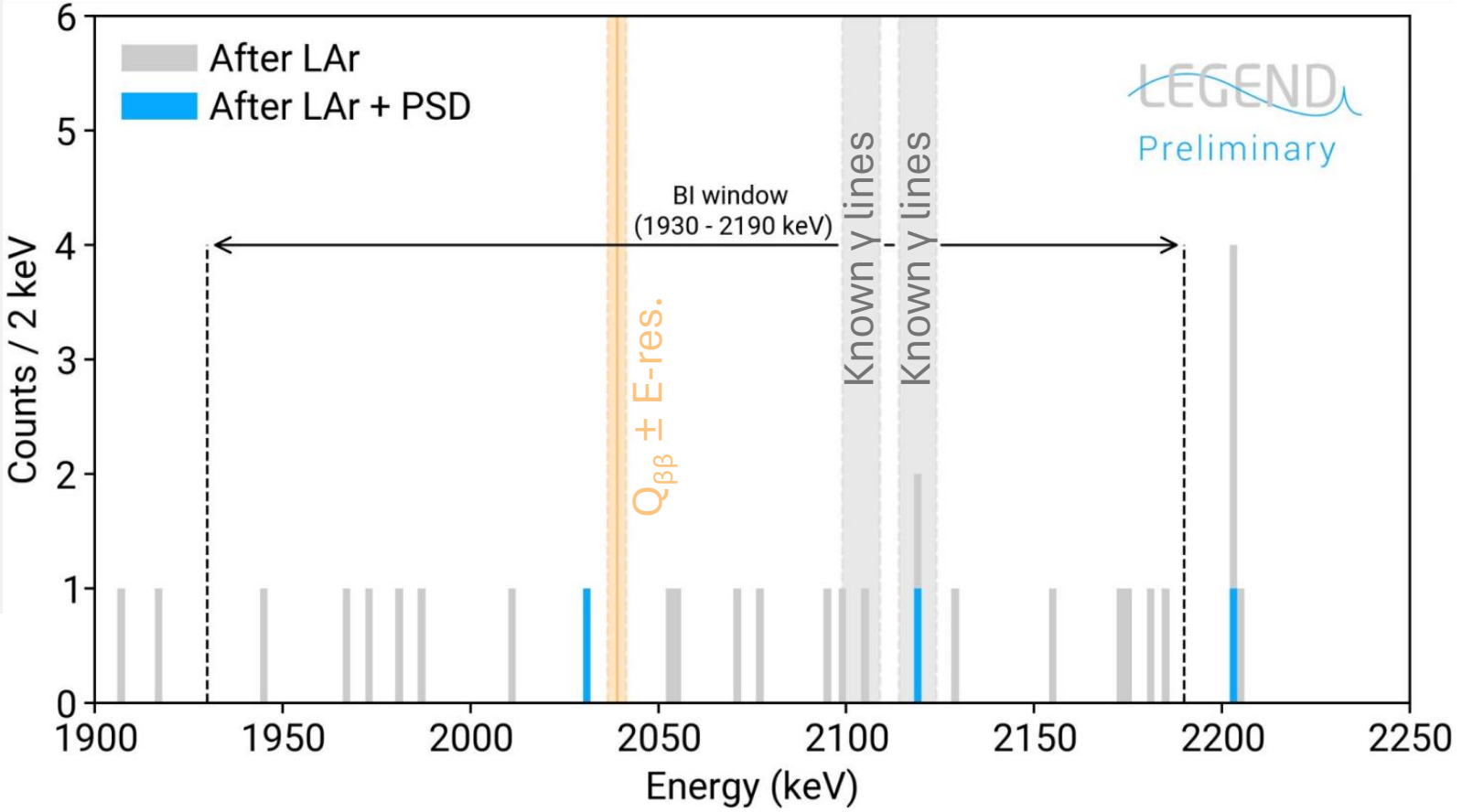
LEGEND-200 first data set

- 10.1 kg·yr of exposure
  - LEGEND-200 goal is up to 1000 kg·yr of exposure
- All the "usual suspects" identified in the model for the data
- Low exposure means high uncertainties -> will improve greatly over time



LEGEND-200 first background index near $Q_{0\nu\beta\beta}$

- 1 event passing all cuts
- $= 4.1^{+7.3}_{-2.6} \times 10^{-4}$ cts/(keV kg yr)
- For LEGEND-200's target background of 2×10^{-4}, dataset is compatible (0.48 expected events, 1 observed)



Conclusion

- LEGEND is currently operational with LEGEND-200, 142/200 kg of detector mass inside
  - Full operation is expected to begin later this year after an upgrade
- Analysis techniques from the previous GERDA and MAJORANA DEMONSTRATOR experiments are being modified and applied to LEGEND data, with new analysis techniques in active development
- With a small initial data set, we were able to test our PSD routines and model the background data which has been collected with some moderate uncertainties
- Next major update is expected for release later this year

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