LEGEND-200 first physics results

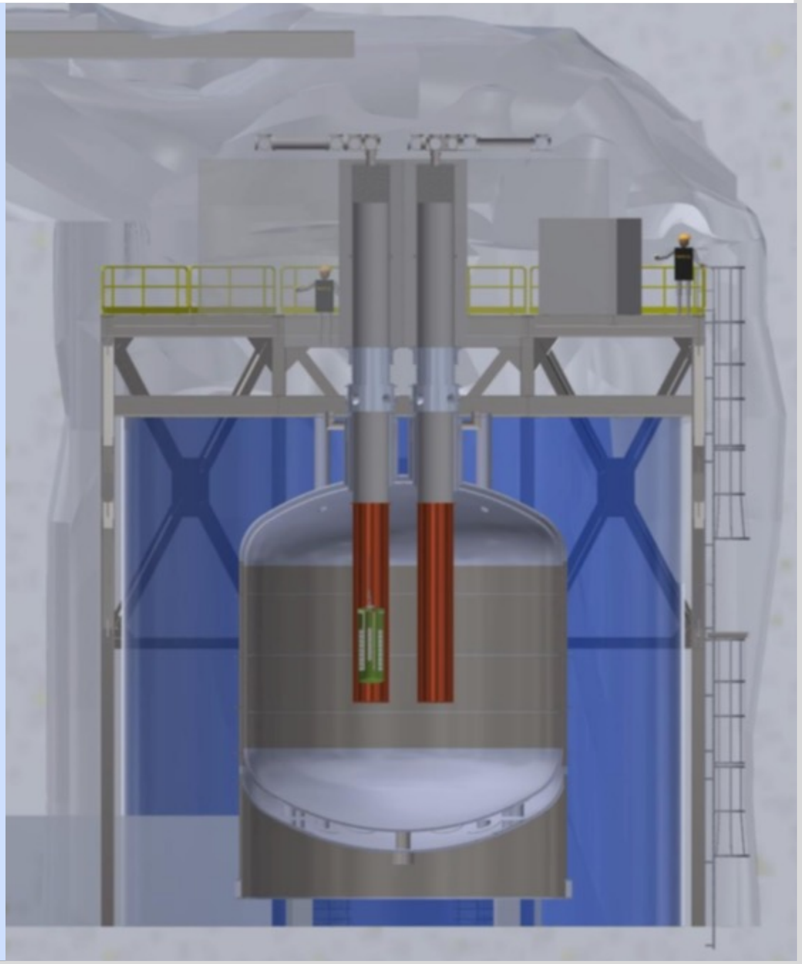
LEGEND

Large Enriched
Germanium Experiment
for Neutrinoless ββ Decay

George Marshall
on behalf of the LEGEND Collaboration

8th–11th April 2024

IOP Joint APP, HEPP and NP Annual Conference

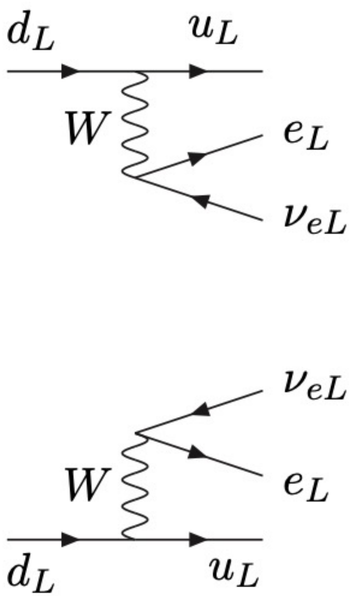


UCL

Motivation

- We know from oscillation experiments that neutrinos have mass but what is the mechanism?
- Neutrinoless double beta decay (0vbb) would show that neutrinos are their own antiparticle (Majorana)
- Additionally it would be evidence of Lepton Number violation
- Purely matter creating process

E.Kh. Akhmedov. Neutrino physics arXiv:0001264

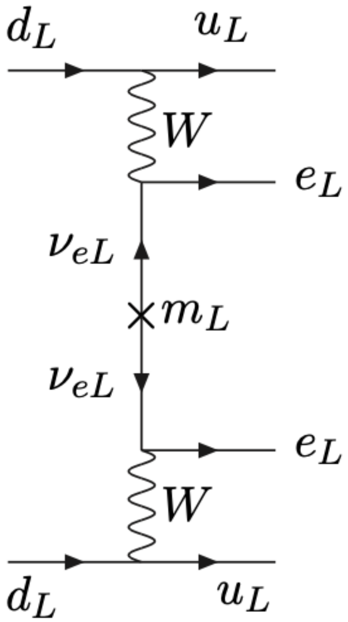


2νββ

$\sim 10^{21} yrs$

in Ge

arXiv 0202264



$> 2.3 \times 10^{26} yrs$

(KamLAND-ZEN)

arXiv 2203.02139

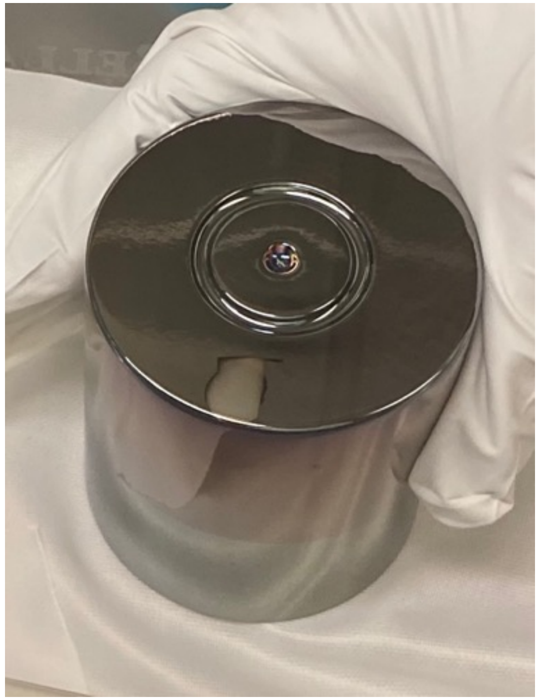
$> 1.8 \times 10^{26} yrs$

GERDA

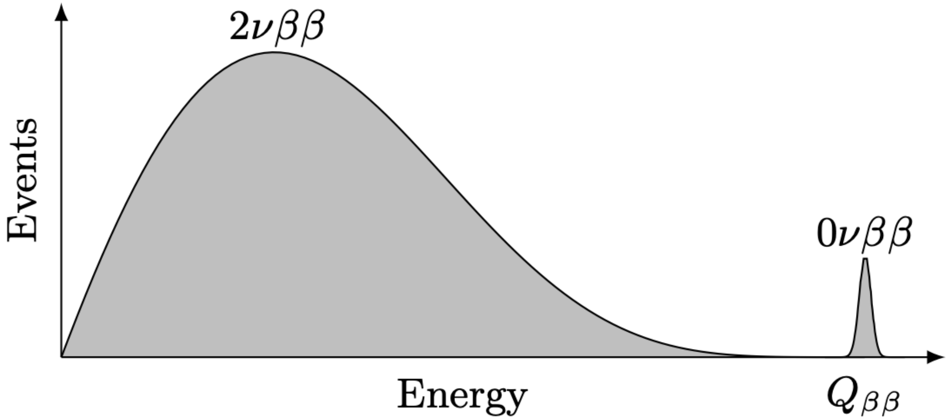
Phys. Rev. Lett. **125**, 252502

Why Germanium?

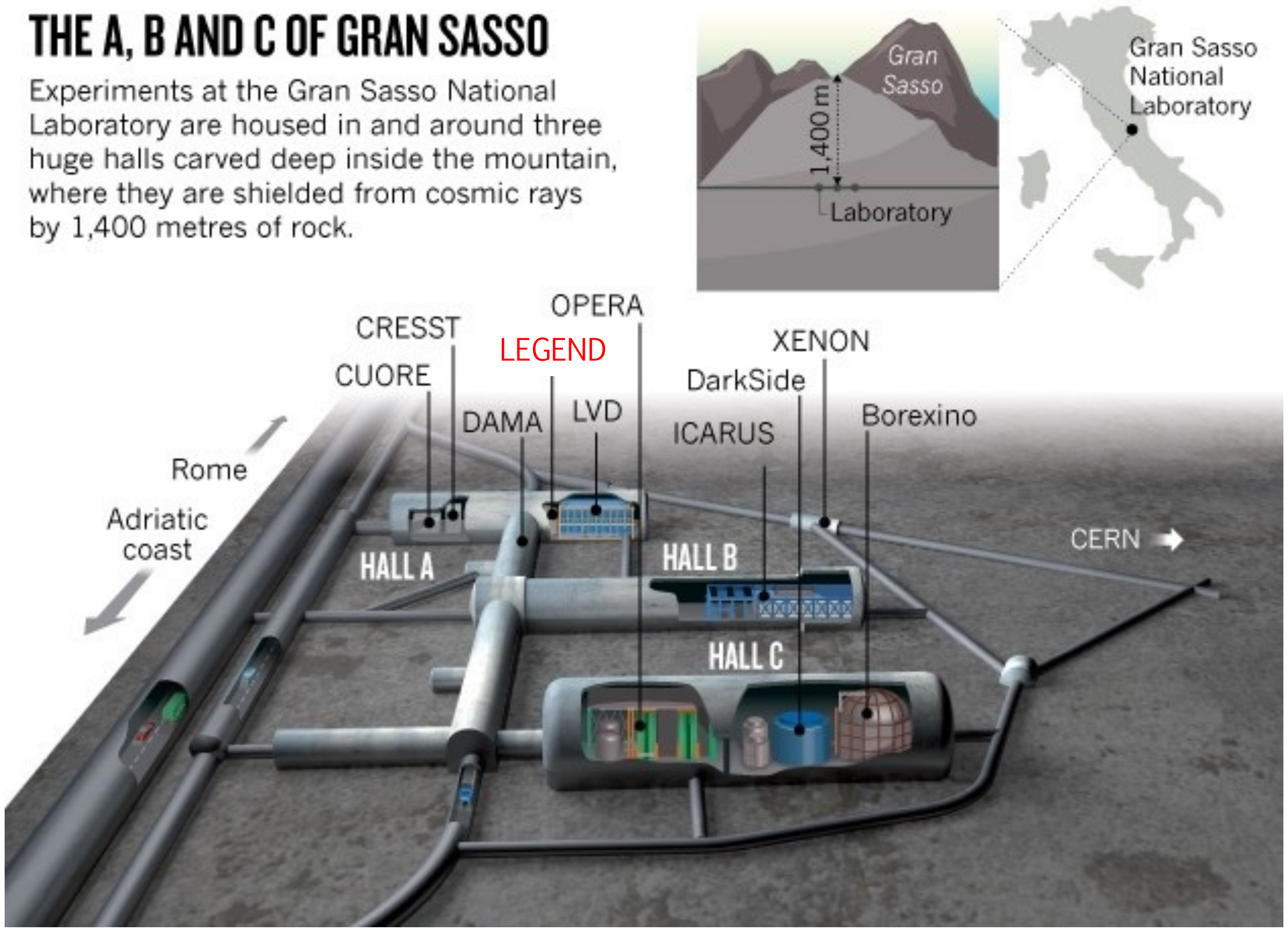
$$^{76}\text{Ge} \longrightarrow {}^{76}\text{Se} + 2e^-$$



- Q-value of 2039 keV
- Source = detector -> high detection efficiency
- Excellent energy resolution
- Low intrinsic background
- High density -> point like events
- Can be enriched to >90% in isotope of interest ^{76}Ge



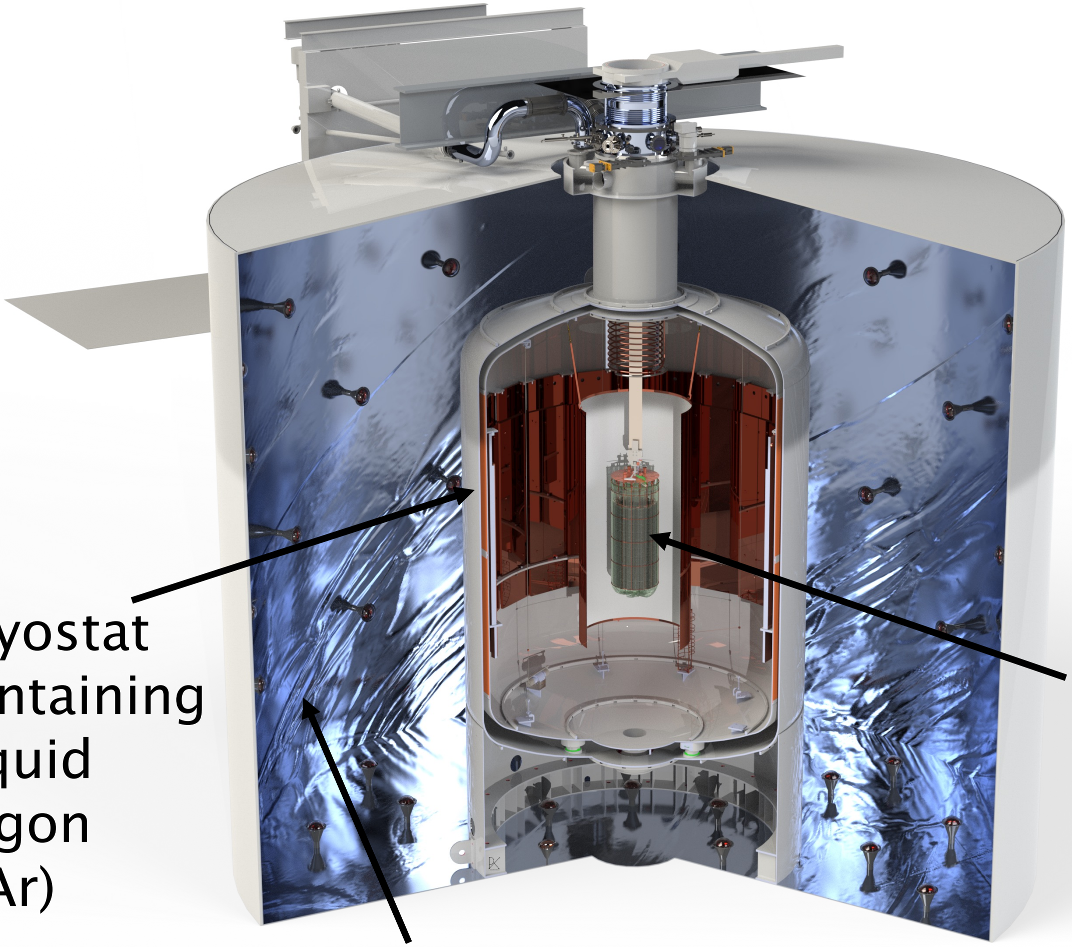
LEGEND-200 – Location



- Located in Hall A at Gran Sasso, Italy
- Reusing the Gerda infrastructure
- 3600 m.w.e. depth to reduce cosmic flux

Nosengo, N. Gran Sasso: Chamber of physics. *Nature* **485**, 435–438 (2012). https://doi.org/10.1038/485435a

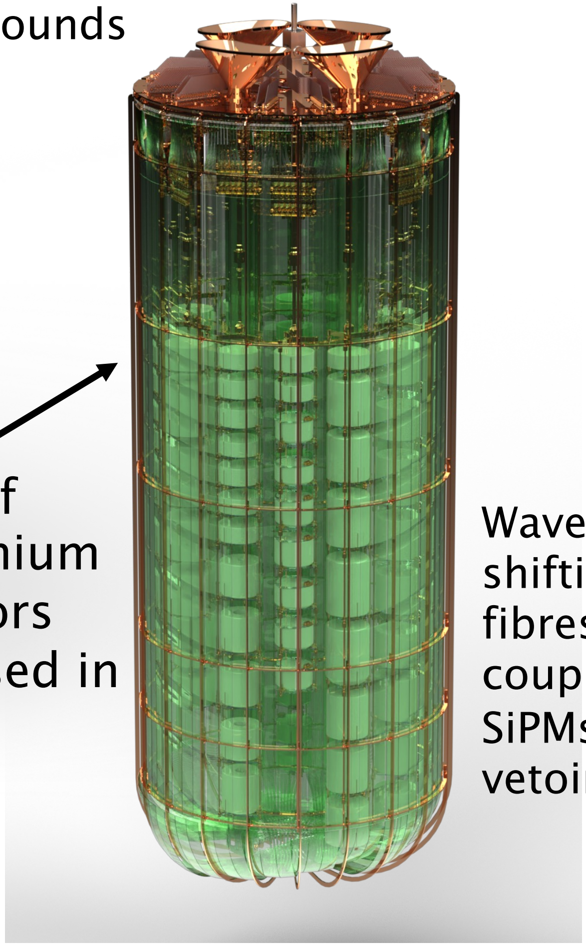
LEGEND-200 – Design



Cryostat containing Liquid Argon (LAr)

Water Tank instrumented with PMTs for muon veto

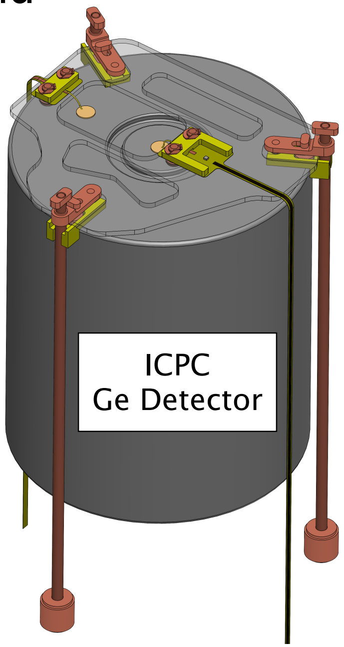
Electronics located at top of array to minimise backgrounds



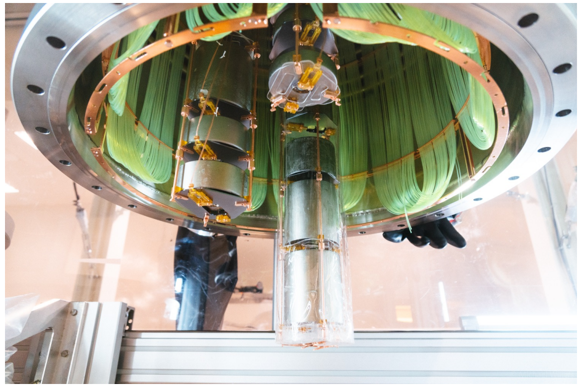
Array of Germanium Detectors organised in strings

Wavelength shifting fibres coupled to SiPMs for LAr vetoing

Solid State TPC, use event topology reconstruction to flag background



Integration and Commissioning



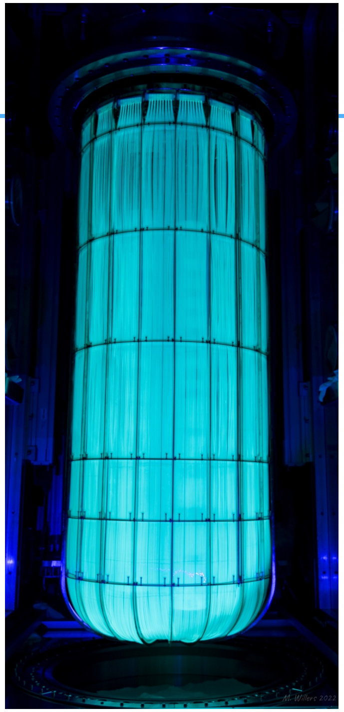
Post Gerda Test

2020

Electronics and DAQ tests

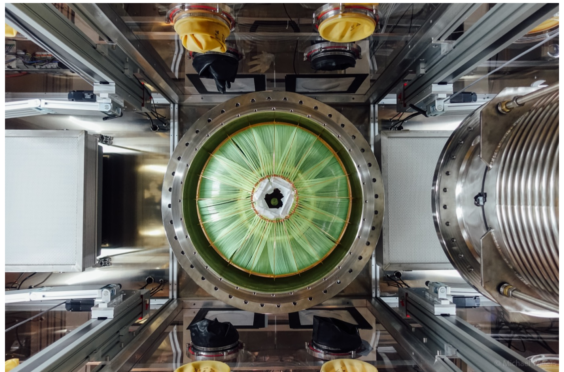
Installation of mechanics and glove box

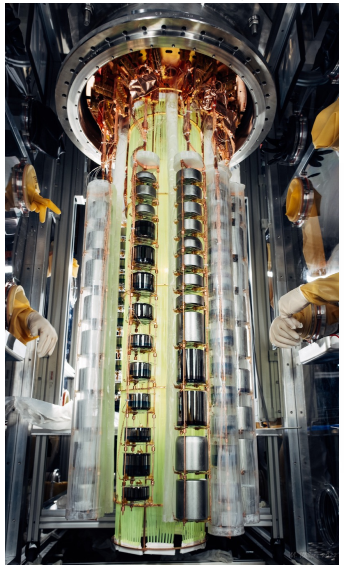
2021



2022

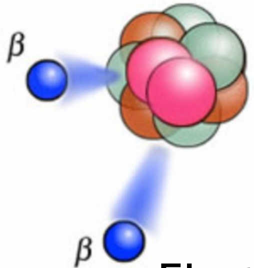
LAr instrumentation commissioning





2023

Installation of available Ge detectors



?

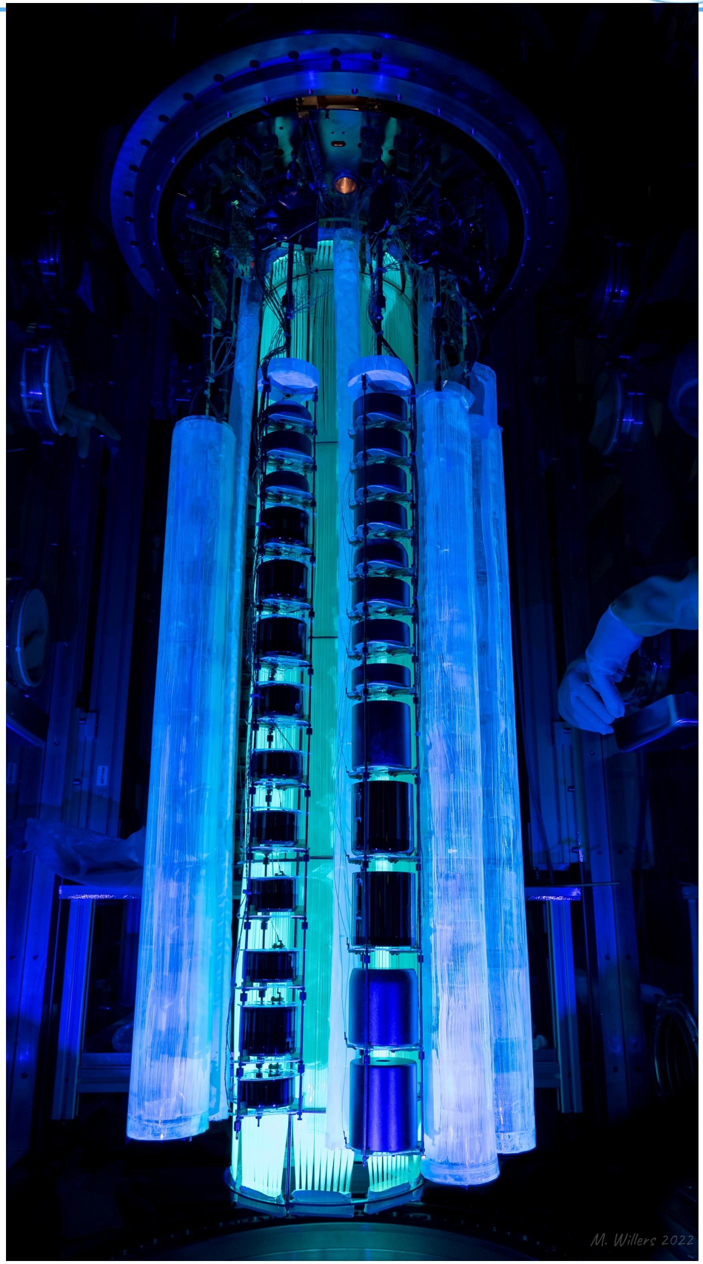
First Unblinding

2024

Status

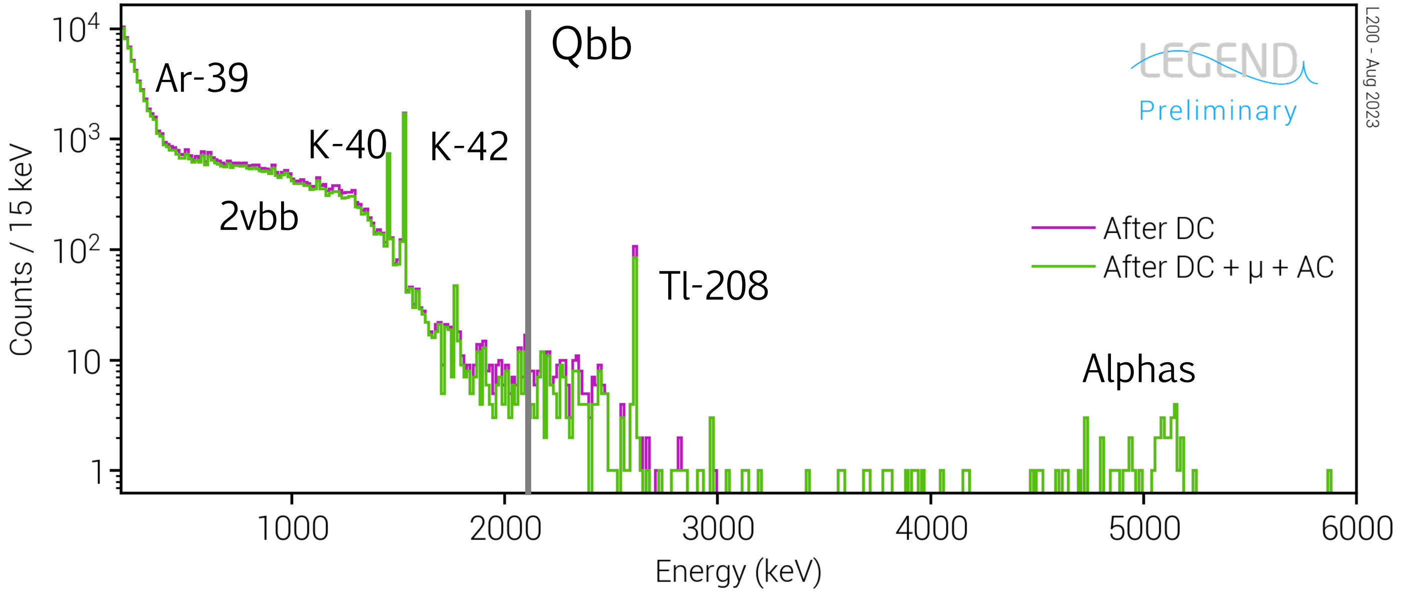
- 142kg of detectors deployed
- 130kg operational
- Analysed first 10 kg.yr of exposure

- Expect first unblinding of ~80kg.yrs this year
- Array completion planned for summer, increase mass to ~200kg

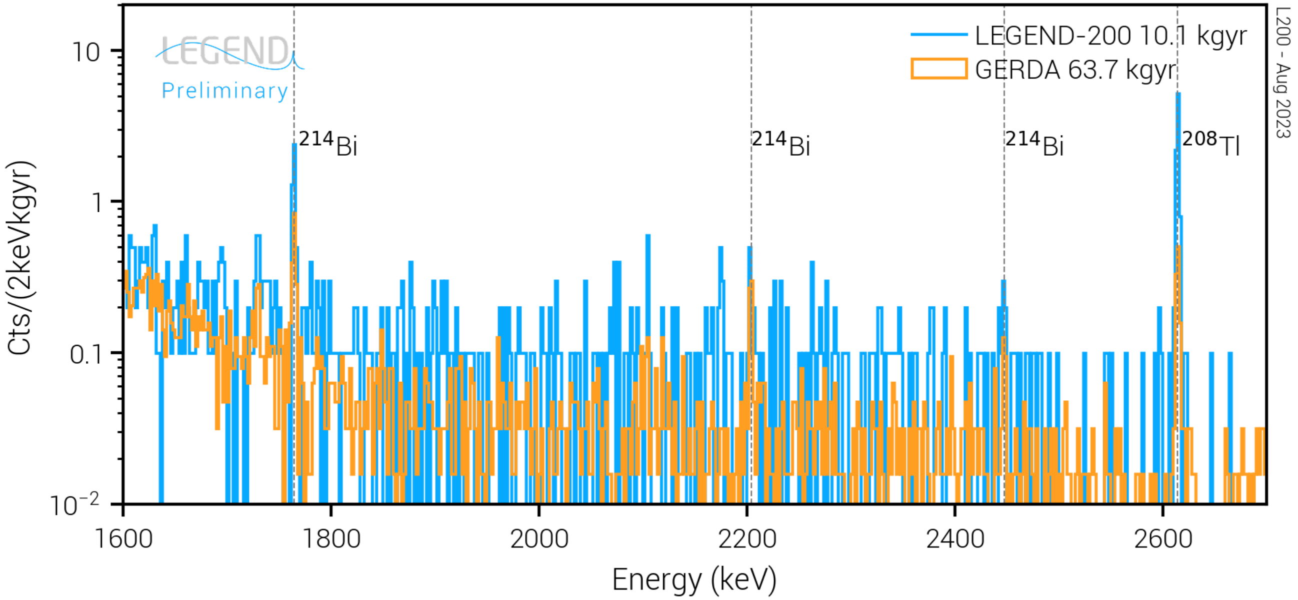


Spectrum before analysis cuts

- Apply:
  - Data cleaning cuts
  - Muon veto cut
  - Detector anti-coincidence cut

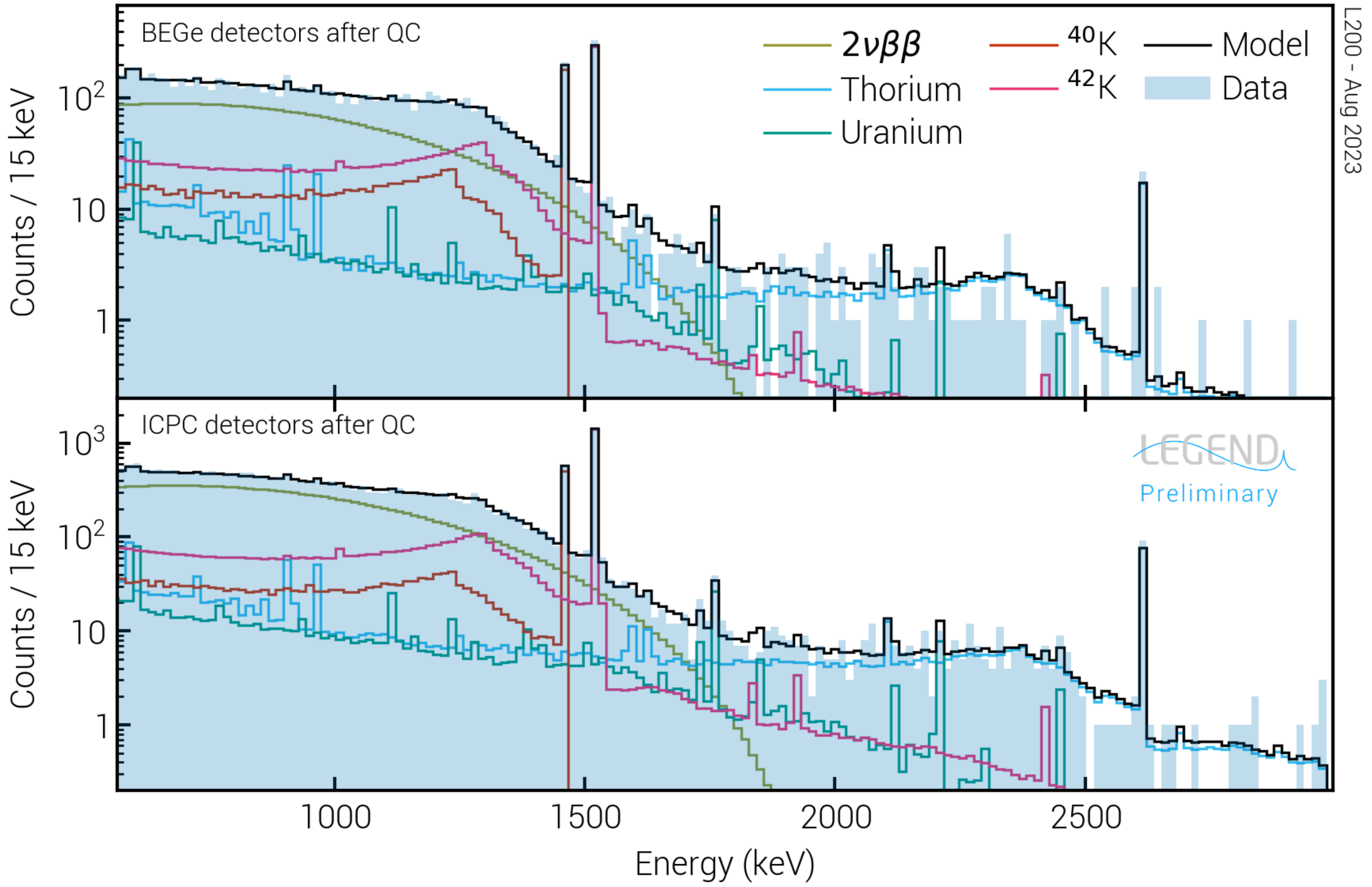


Before analysis cuts (Golden dataset)



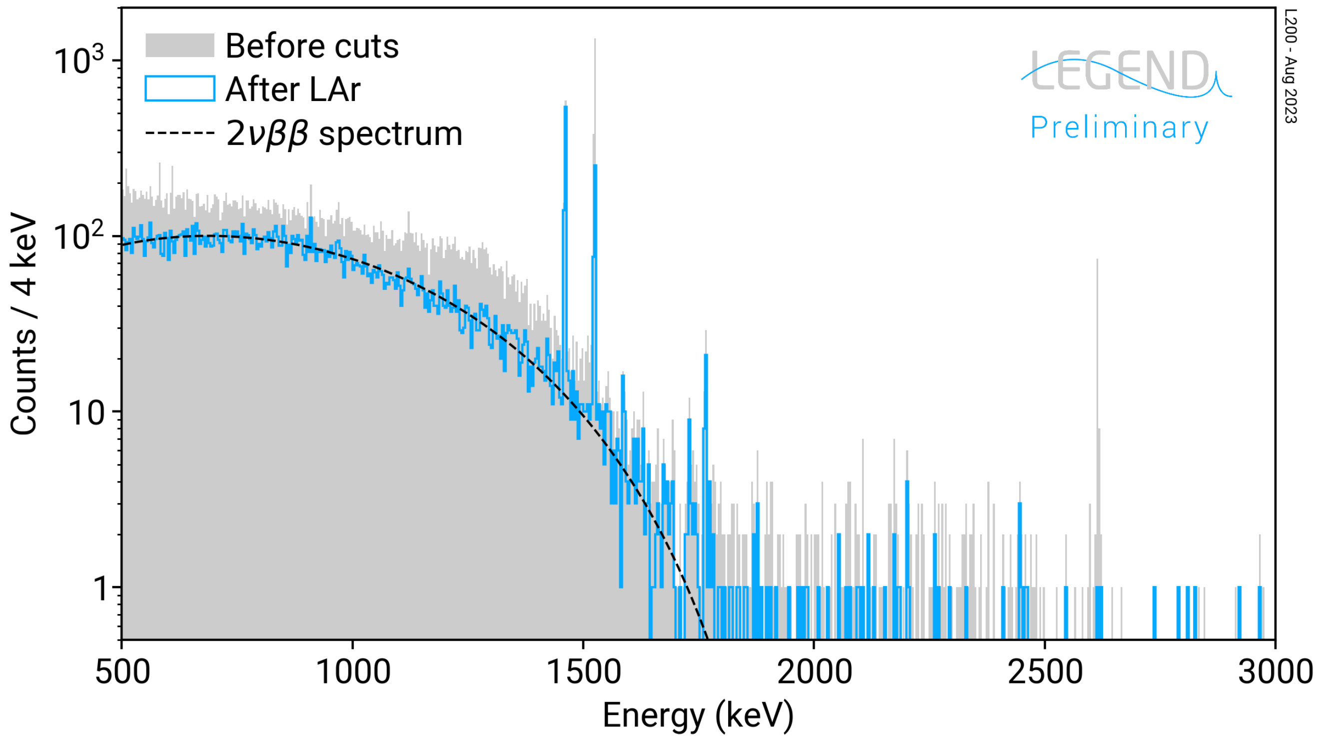
Background Model – WIP

- Background is well described by expected contributions at current statistics
- Major focus of work in last year working up to unblinding

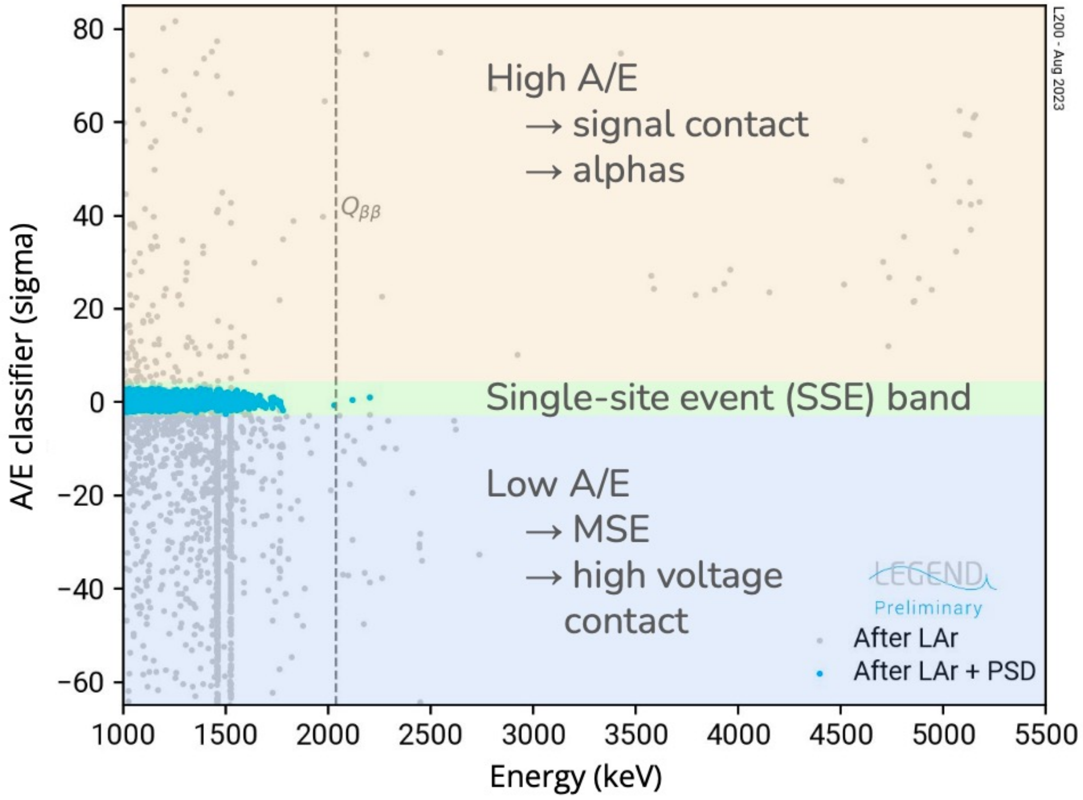


Analysis Cuts

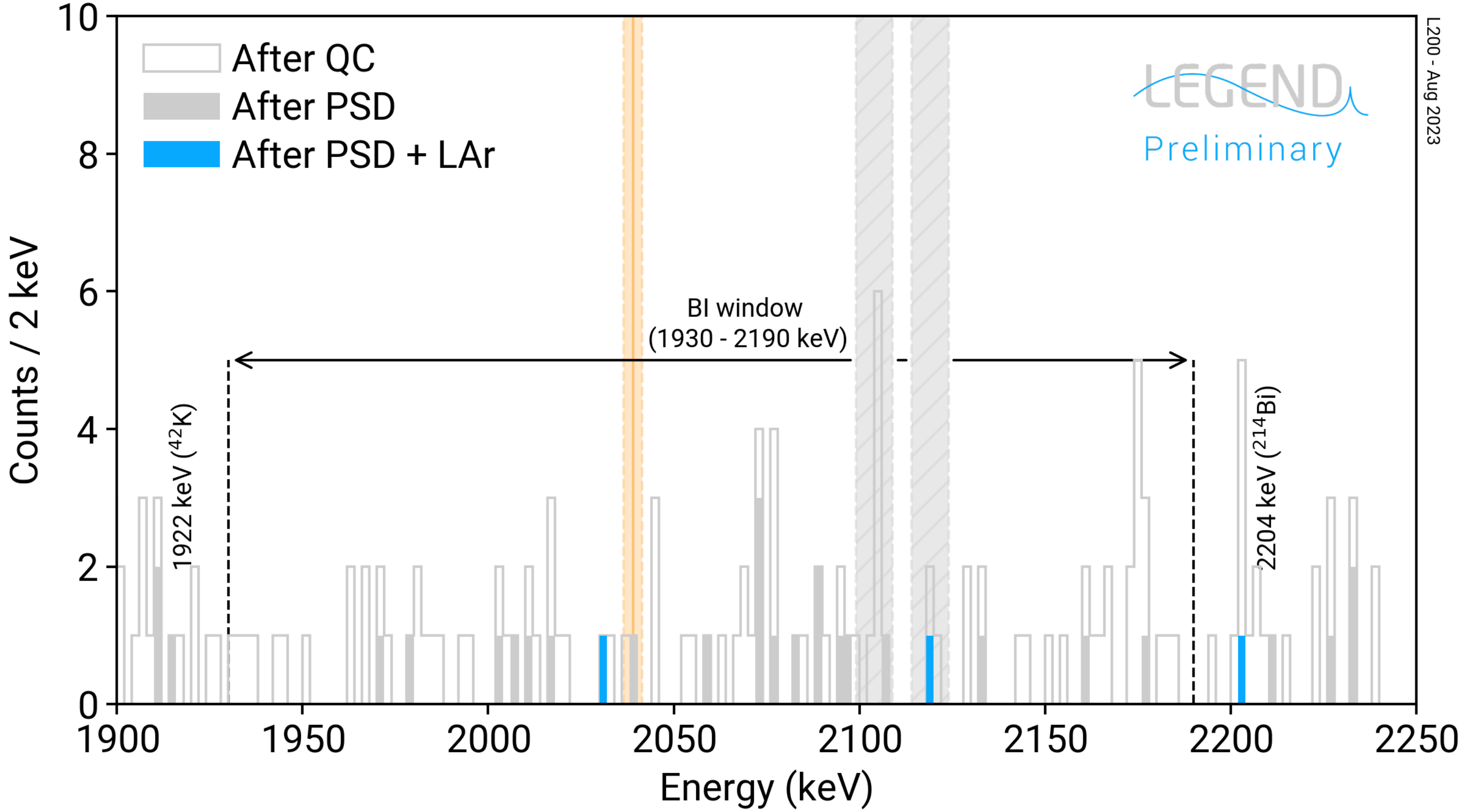
Liquid Argon Veto



Pulse Shape Discrimination



Results from first 10 kg.yrs



- BI compatible with LEGEND-200 goal of 2 x 10-4 cts/(keV kg yr)
- Expect 0.48 cts
- Probability to observe counts > 0 ~ 38%

	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] x 10^{-4}	5.2 [3.9,6.8] x 10^{-4}

Summary

- Neutrinoless double beta decay would show neutrinos are Majorana and show that lepton number is violated
- LEGEND is searching for this process using germanium diodes
- No unexpected background components
- First unblinding and 0vbb result this year

LEGEND mission: "The collaboration aims to develop a phased, ^{76}Ge based double-beta decay experimental program with **discovery potential** at a half-life beyond 10^{28} years, using existing resources as appropriate to expedite physics results."

Univ. New Mexico
L'Aquila University and INFN
Lab. Naz. Gran Sasso
University Texas, Austin
Lawrence Berkeley Natl. Lab.
University California, Berkeley
Leibniz Inst. Crystal Growth
Indiana University
Comenius University
Simon Fraser University

University of North Carolina
University of South Carolina
Tennessee Tech University
University of Warwick
Jagiellonian University
Technical University Dresden
Joint Inst. Nucl. Res.
Duke University
Polytechnical University of Milan

Triangle Univ. Nuclear. Lab.
Joint Research Centre, Geel
Max Planck Institute, Heidelberg
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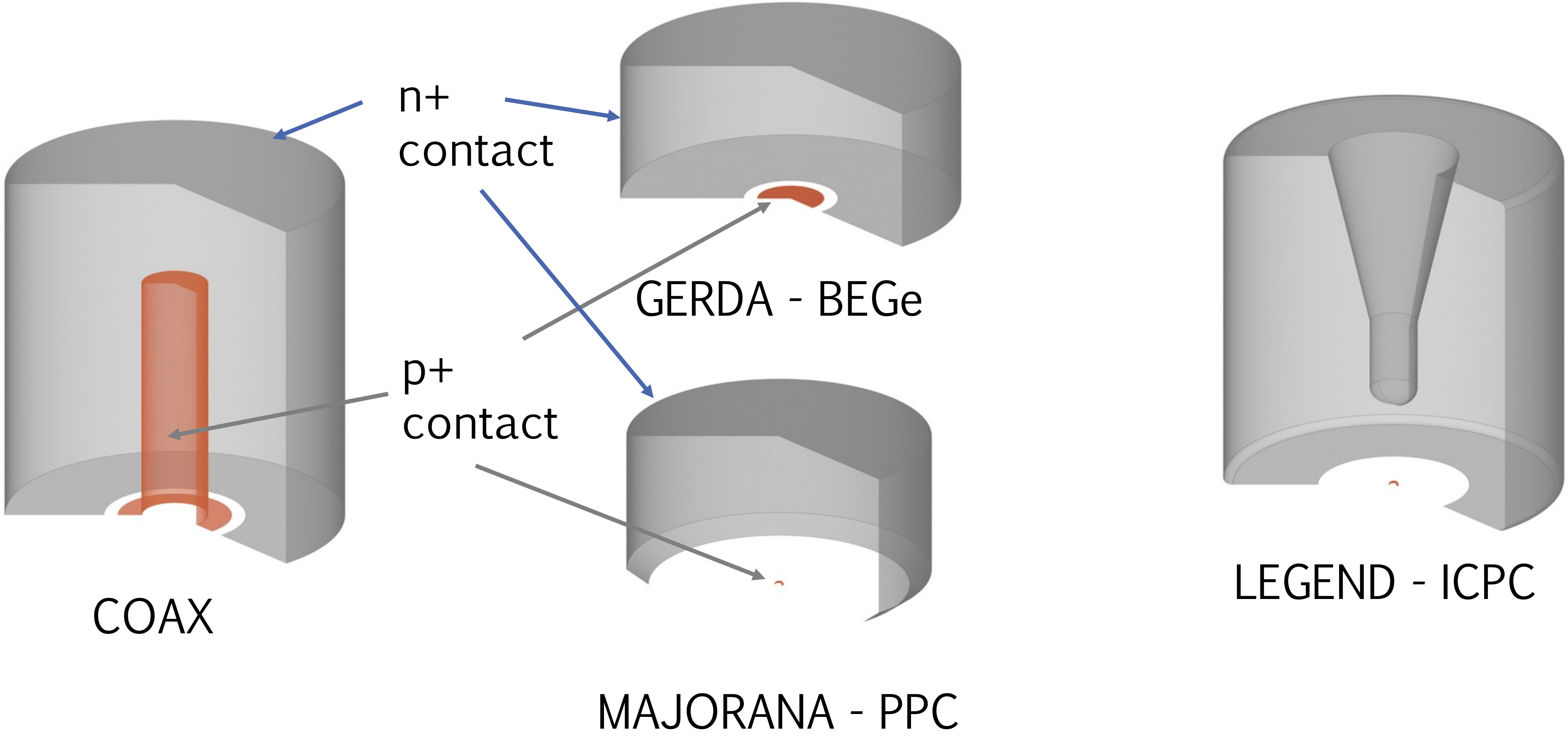
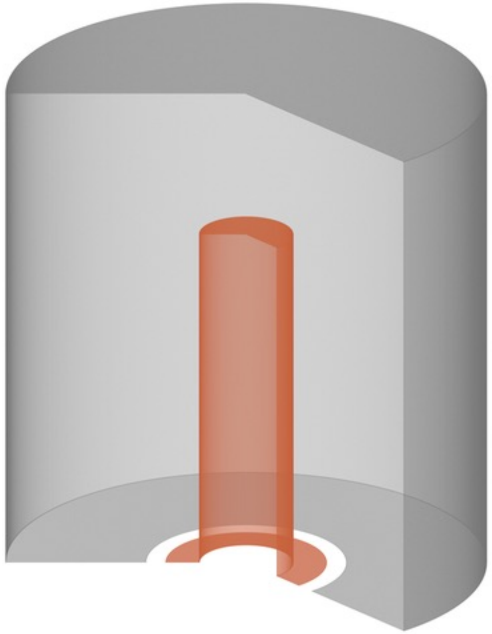
South Dakota School Mines Tech.
University Washington
University Tübingen
University South Dakota
Williams College
University Zurich
University of Regina

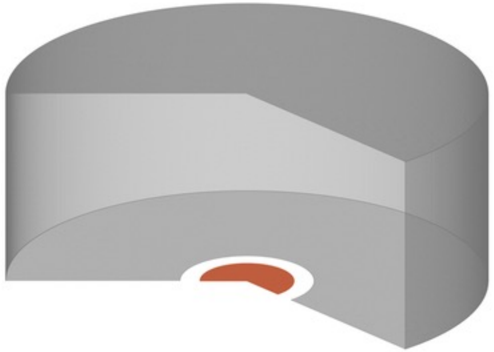
Detectors


n+
contact
p+
contact
GERDA - BEGe
COAX
MAJORANA - PPC
LEGEND - ICPC

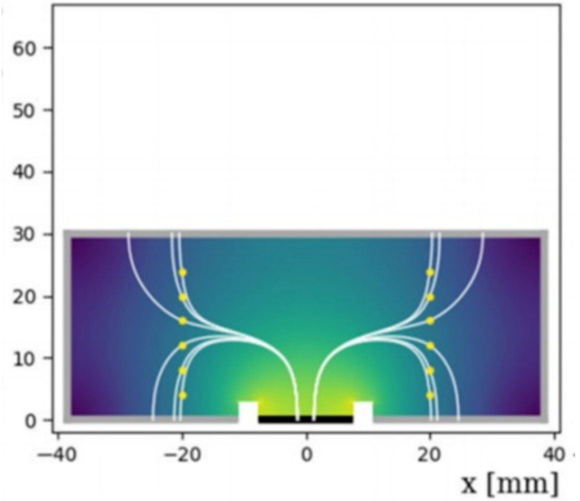
Detectors

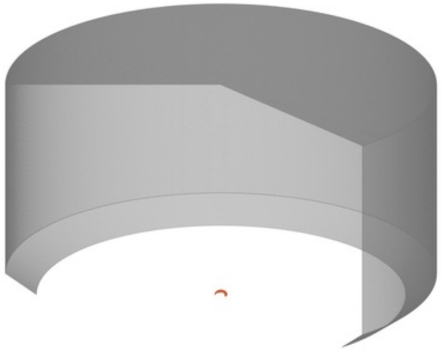


COAX

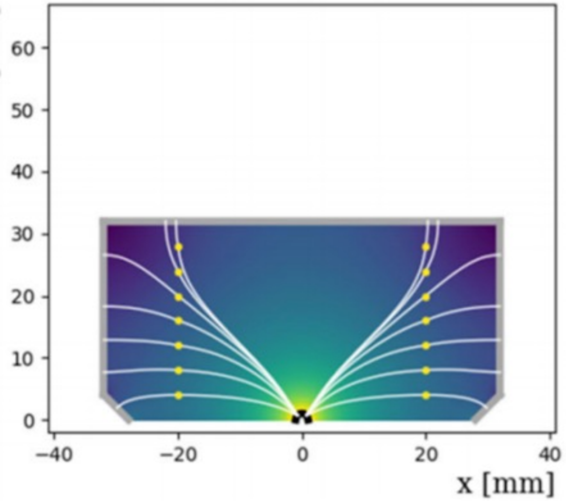


GERDA - BEGe

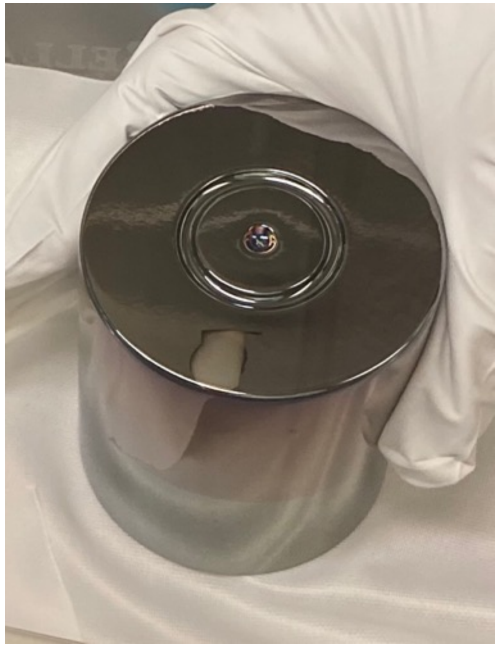


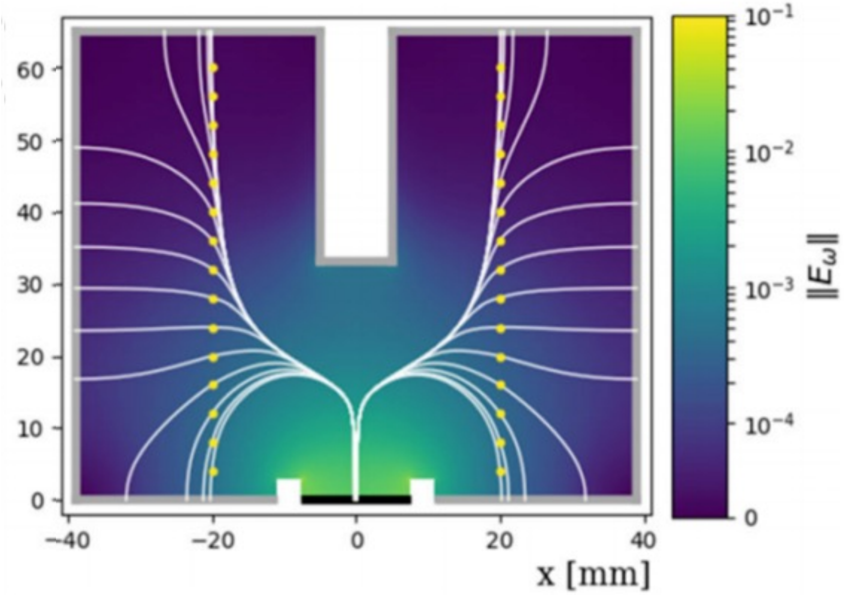


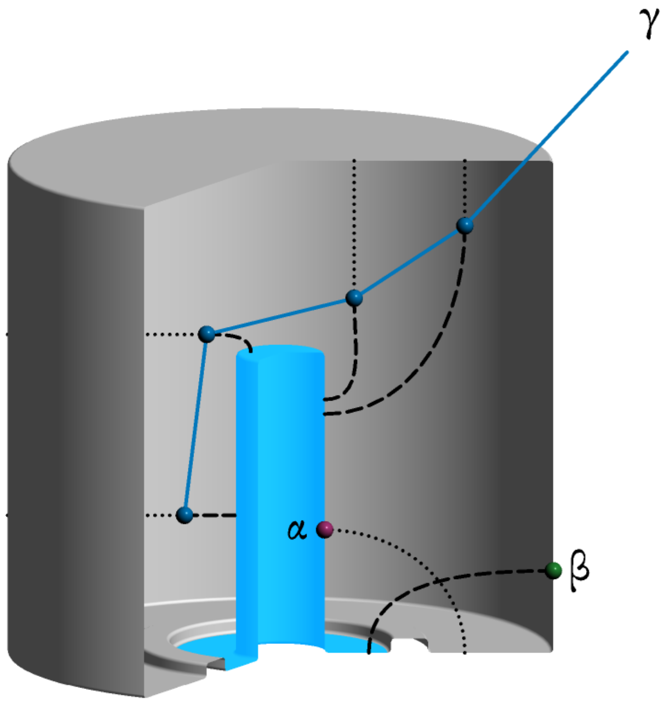
MAJORANA - PPC



Detectors



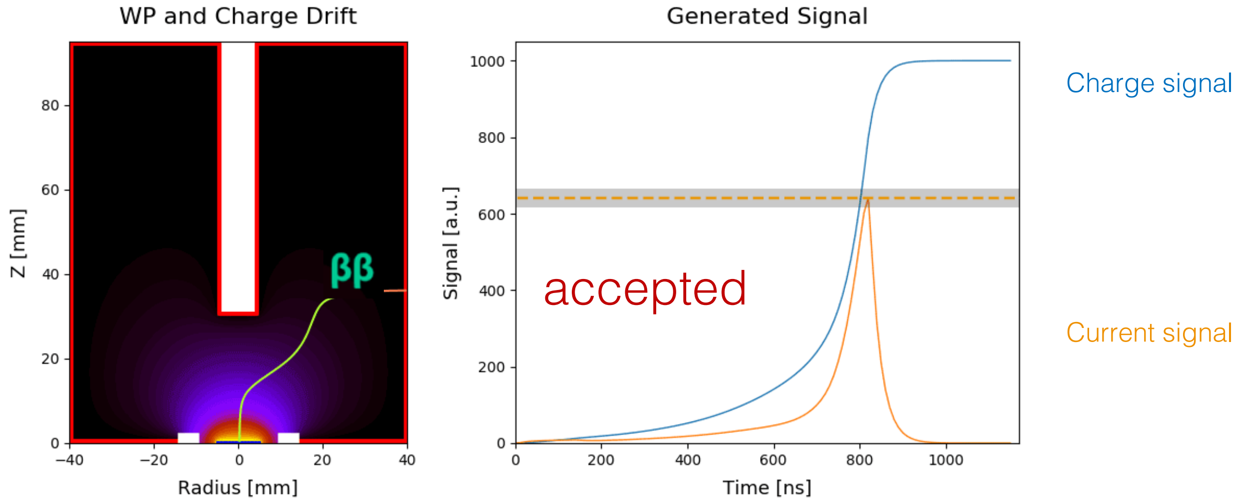




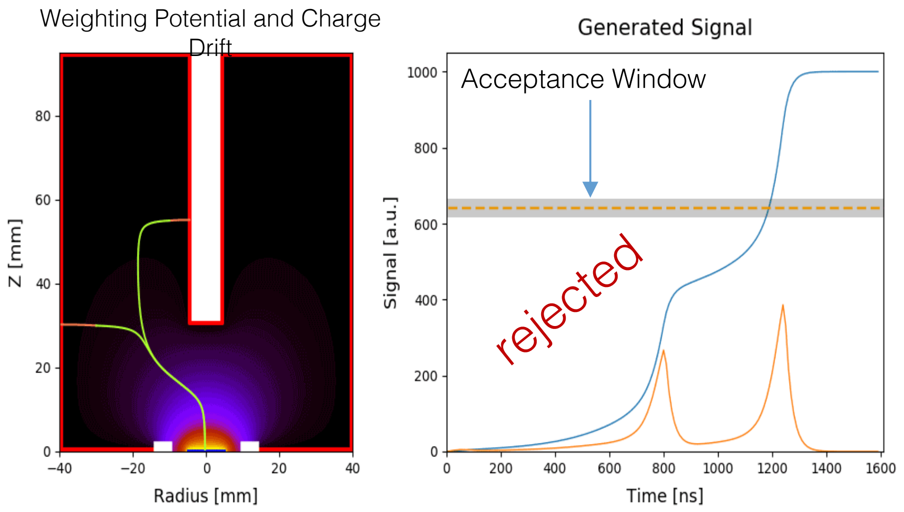
LEGEND - ICPC

Pulse Shape Analysis

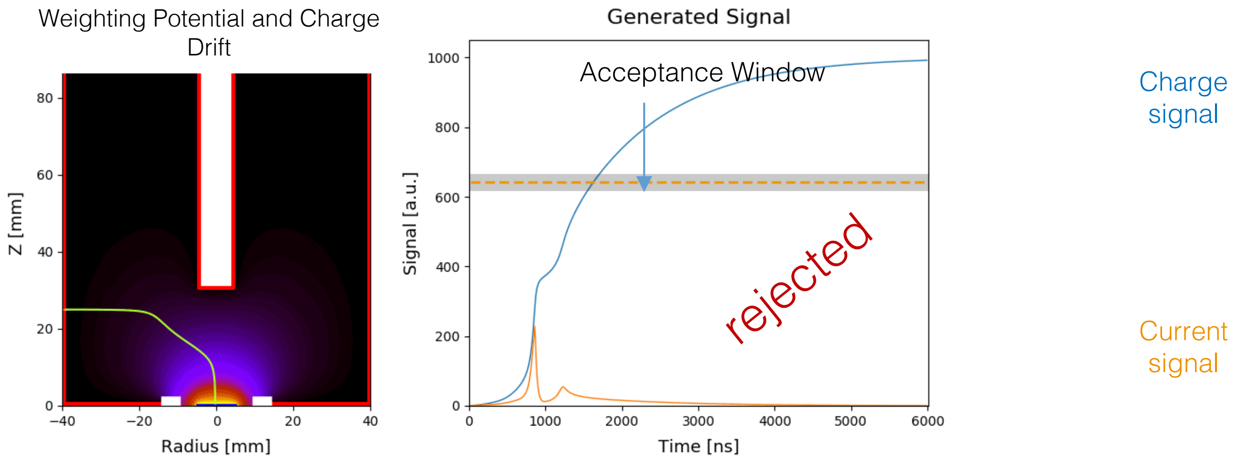
0νββ signal candidate (single-site)



γ-background (multi-site)



Surface–β–background ^{42}K (^{42}Ar) on n+ contact



α-background on p+ contact