

# LEGEND-200: A first glance at the background in physics data

LEGEND

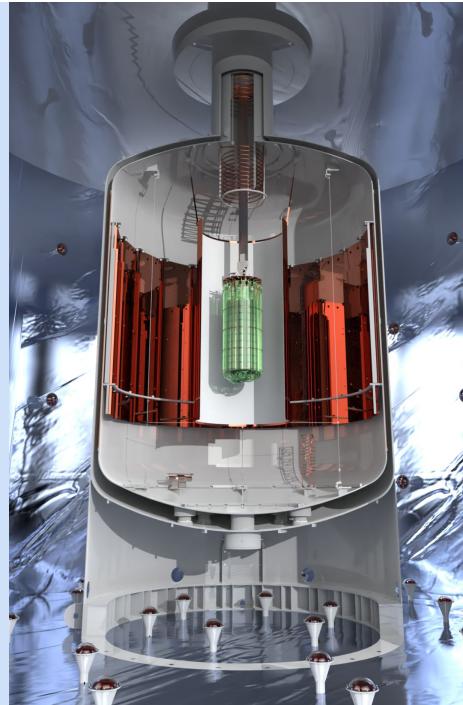
Katharina von Sturm

[vonsturm@pd.infn.it](mailto:vonsturm@pd.infn.it)

Uni & INFN Padova  
MPIK Heidelberg

on behalf of the LEGEND Collaboration

Large Enriched  
Germanium Experiment  
for Neutrinoless  $\beta\beta$  Decay



29. August 2023

XVIII International Conference on Topics in  
Astroparticle and Underground Physics (TAUP2023)

# First LEGEND-200 Background Data

LEGEND

Take a look at

- Background before and after LAr and PSD cuts
- Compare with GERDA

Dataset: BEGe & ICPC

- Directly comparable with GERDA
- Mono-parametric PSD
- No blinding applied

Exp (kg yr)	BEGe	ICPC
10.1	2.1	8.0

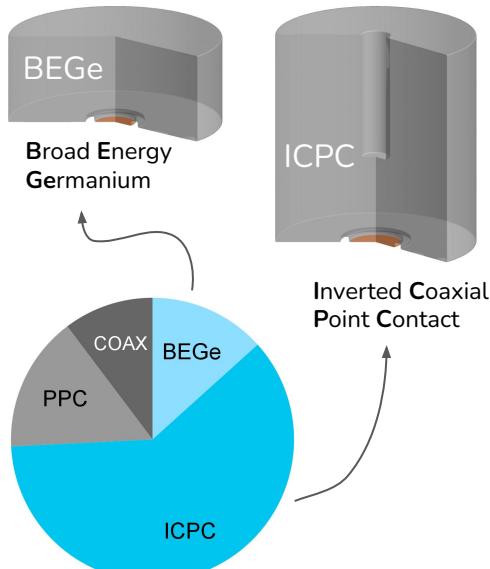
commissioning

March  
2023

physics data  
taking

LAr - Liquid Argon  
PSD - Pulse Shape Discrimination

point-contact detector  
types already operated in  
GERDA



POSTER: L-200 detectors (V. Biancacci)  
POSTER: L-200 DAQ and Calibration (B. Bos)



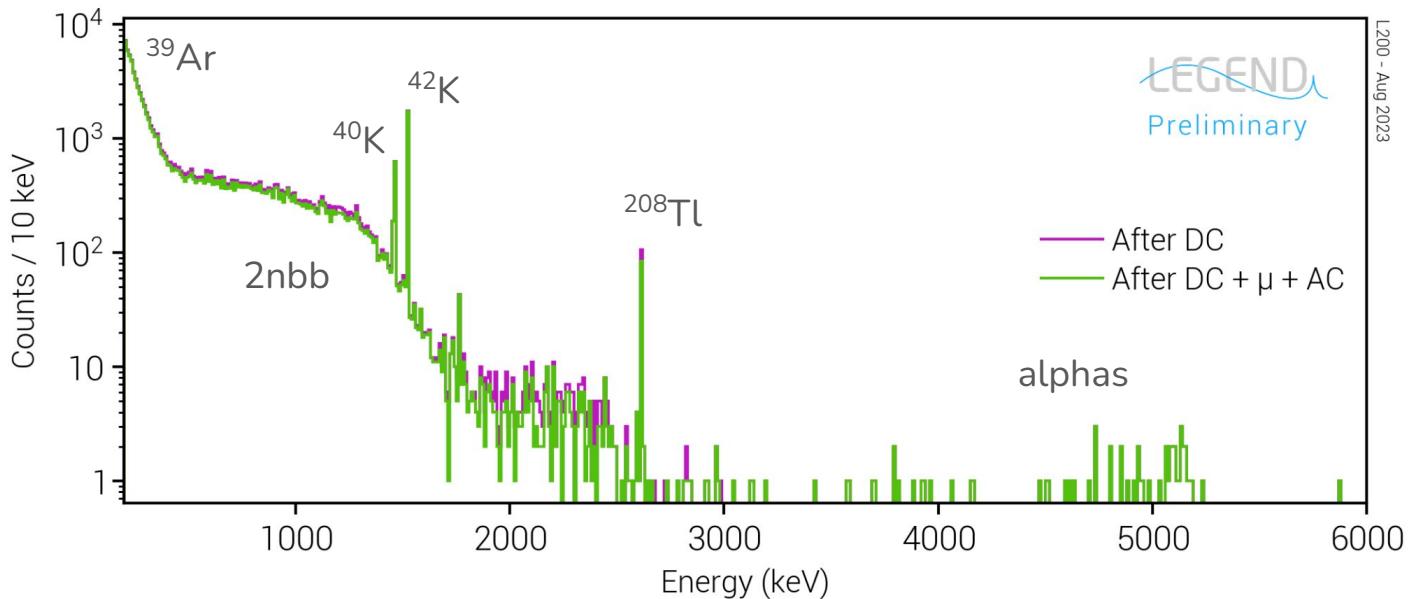
10 strings - 142 kg - 101 detectors

# Quality Cuts

- Data cleaning (DC)
- Muon veto ( $\mu$ )
- Ge-detector anti-coincidence (AC)

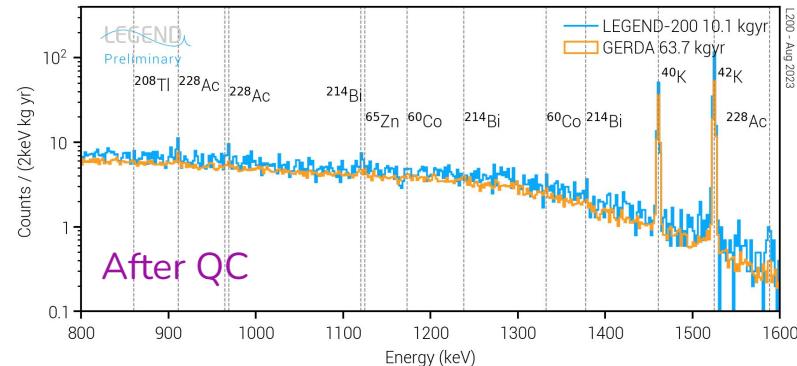
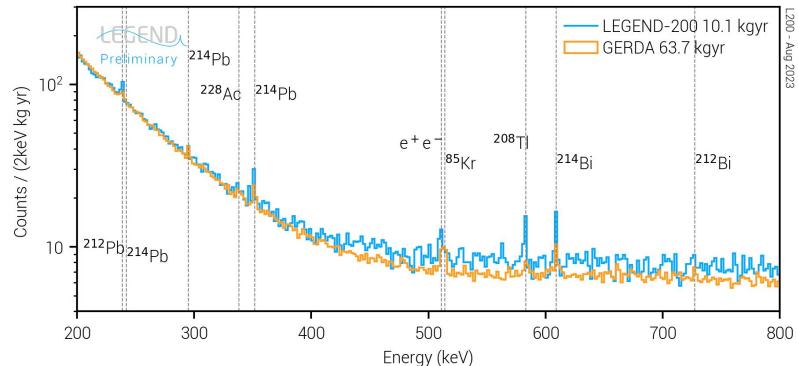
In the following:

- After DC +  $\mu$  + AC  $\rightarrow$  After QC

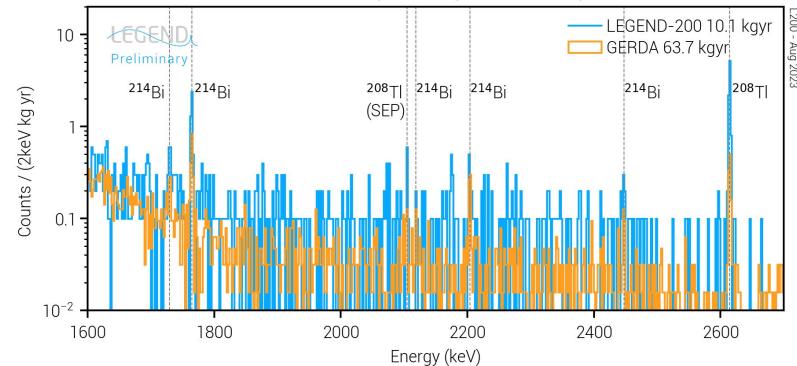


# Background - After QC

LEGEND



- No unexpected background components
  - $^{238}\text{U}$  &  $^{232}\text{Th}$  decay chains,  $^{40}\text{K}$ ,  $^{42}\text{K}$
- Improved peak to Compton ratio
  - Reduces Compton continuum background
  - Higher detection efficiency due to larger mass detectors
- Higher rate from  $^{208}\text{Tl}$  compared to GERDA
  - Expected -> more construction material
- Similar spectral shape



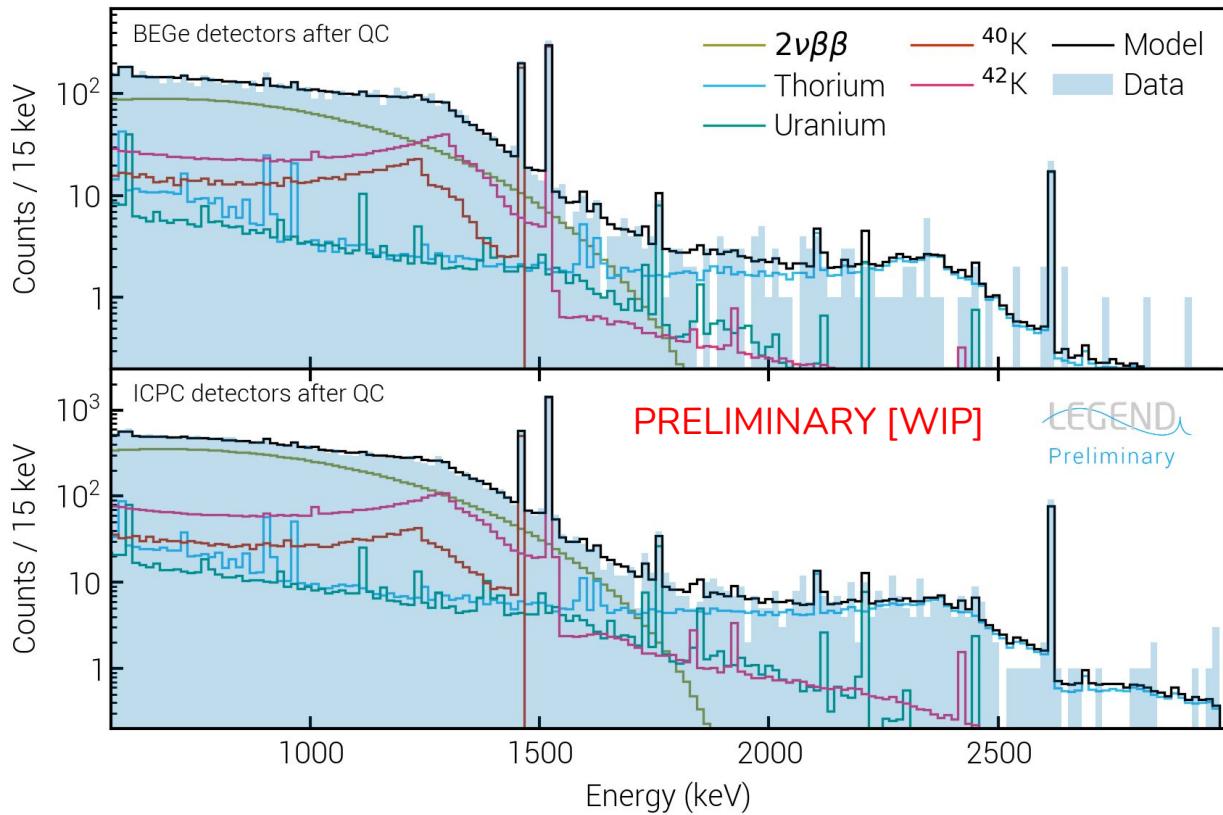
LEGEND vs. GERDA BEGe+ICPC

# Background decomposition - After QC

[WIP]

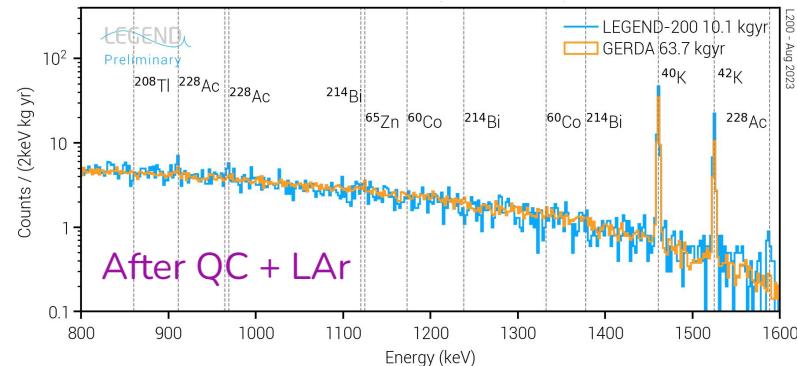
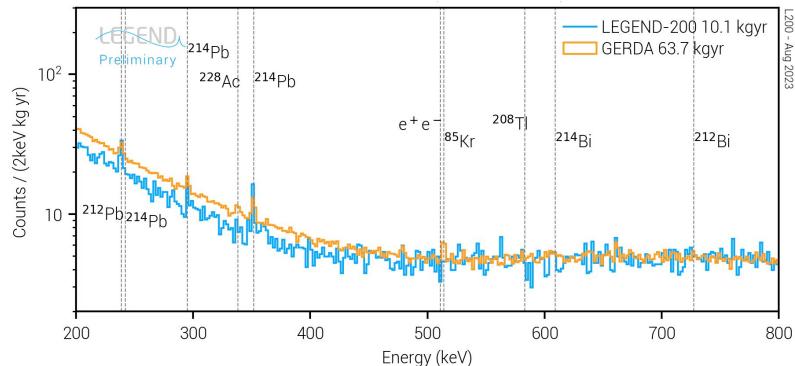
Decomposition before analysis cuts

- Well described by expected contributions with current statistics

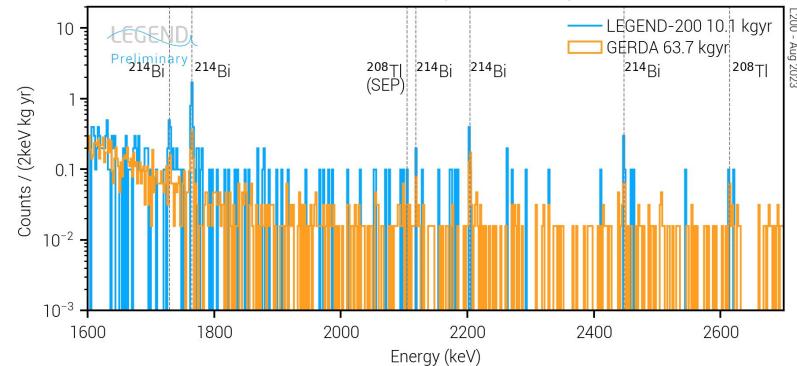


# Background - After QC + LAr AC

LEGEND



- Some gamma lines “vanish” & Compton continuum suppressed
- LAr instrumentation
  - Improved background suppression higher light yield & less shadowing
  - More self-vetoing material: LAr instr. fibers & PEN plates

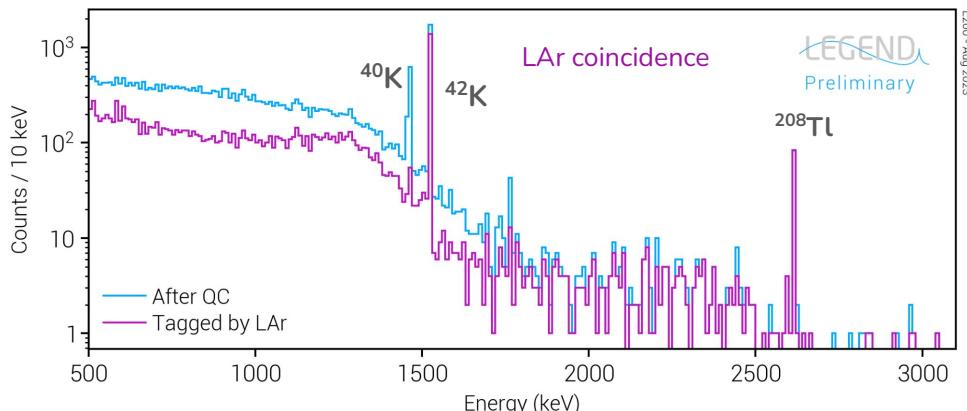
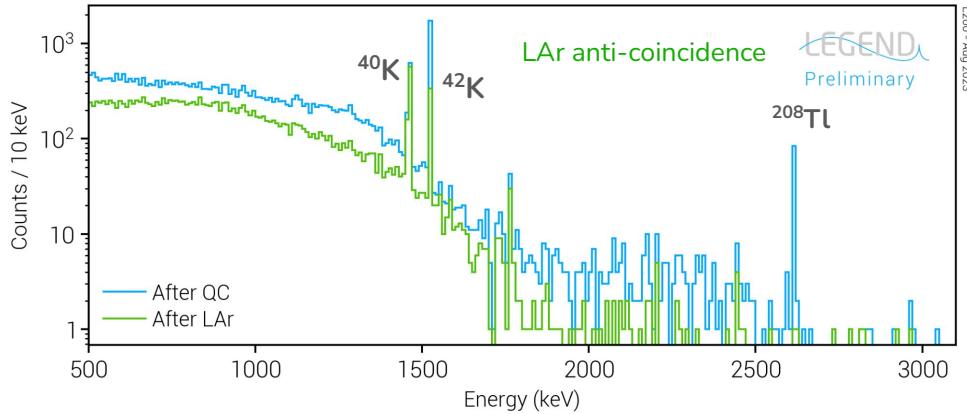
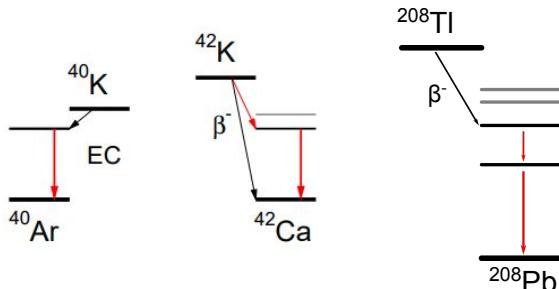


LEGEND vs. GERDA BEGe+ICPC

# LAr instrumentation - (Anti-)Coincidence

LEGEND

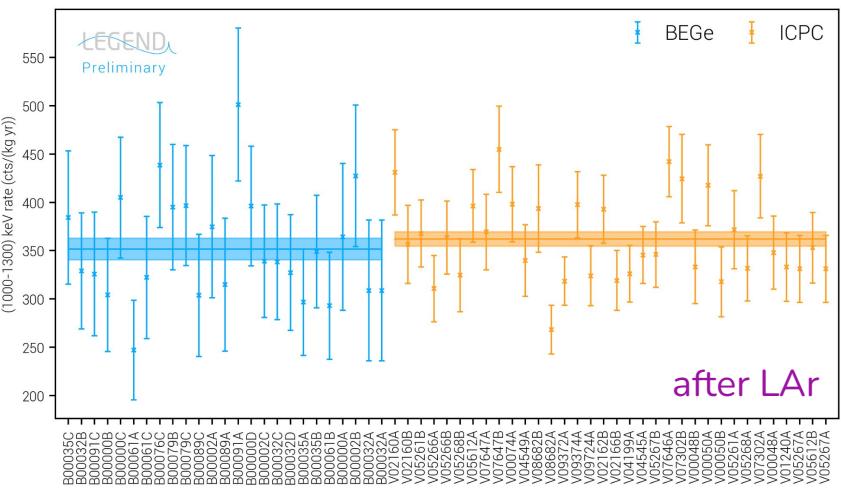
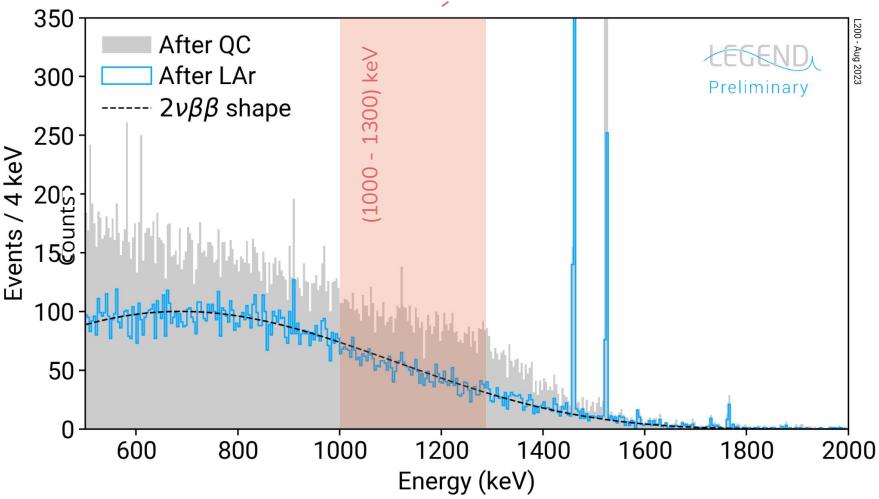
- Suppression depends on decay location and specifics
- LAr instrumentation is working as expected
  - $^{40}\text{K}$ -line barely suppressed
  - $^{42}\text{K}$  strongly suppressed
  - $^{208}\text{TL}$  strongly suppression
- Compton continuum stronger suppressed than gamma lines



# $2\nu\beta\beta$ shape and uniformity - After QC + LAr AC

LEGEND

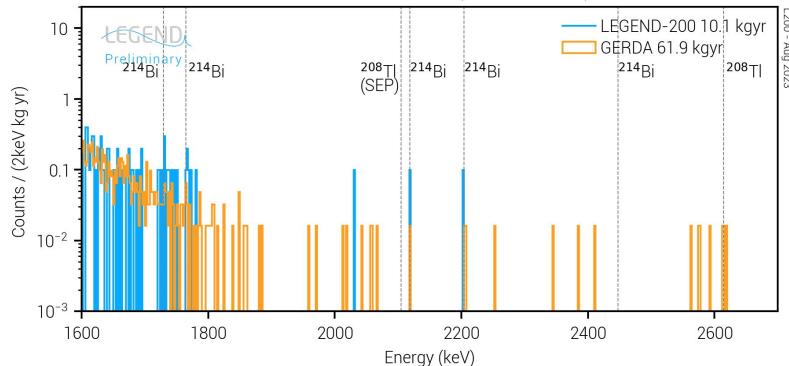
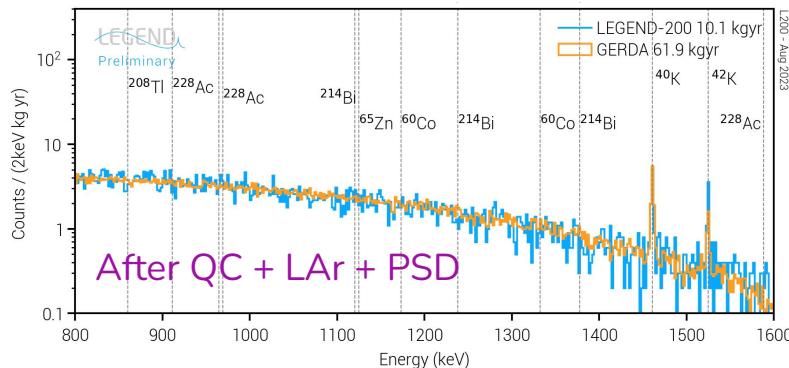
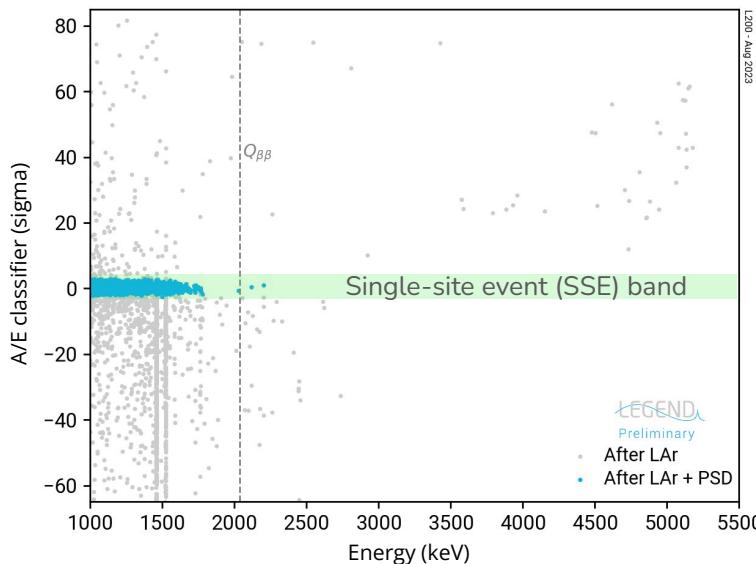
- Spectral shape compatible with 2nbb after LAr instrumentation anti-coincidence (LAr AC)
- $^{40}\text{K}$  &  $^{42}\text{K}$  Compton edges vanish
- Uniform rate / detector in (1000 - 1300) keV
  - Normalized to detector specific exposure
  - BEGe/ICPC different containment eff.
- After LAr AC: Medium energy region dominated by 2nbb



# Background - After QC + LAr AC + PSD

LEGEND

- PSD cuts multi-site and alpha events effectively
- More powerful due to higher MSE probability in larger ICPC detectors
- PSD suppression in physics data depends on actual background composition and location

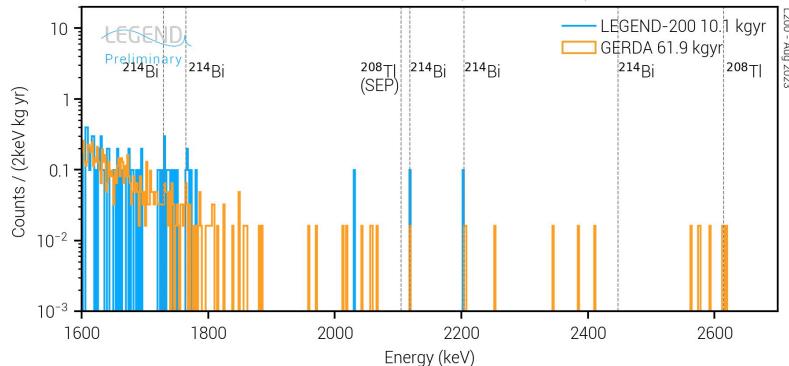
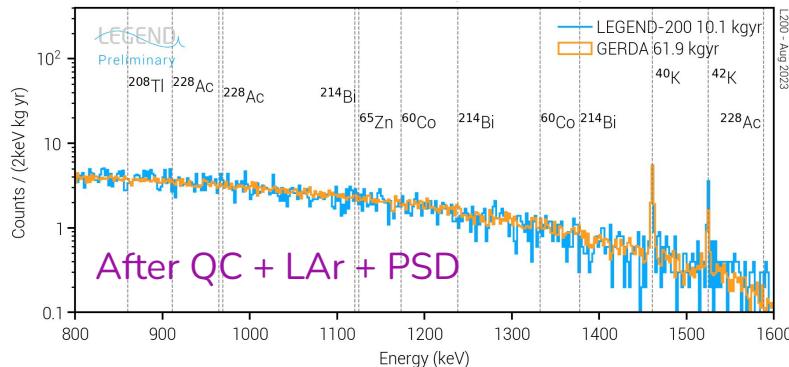
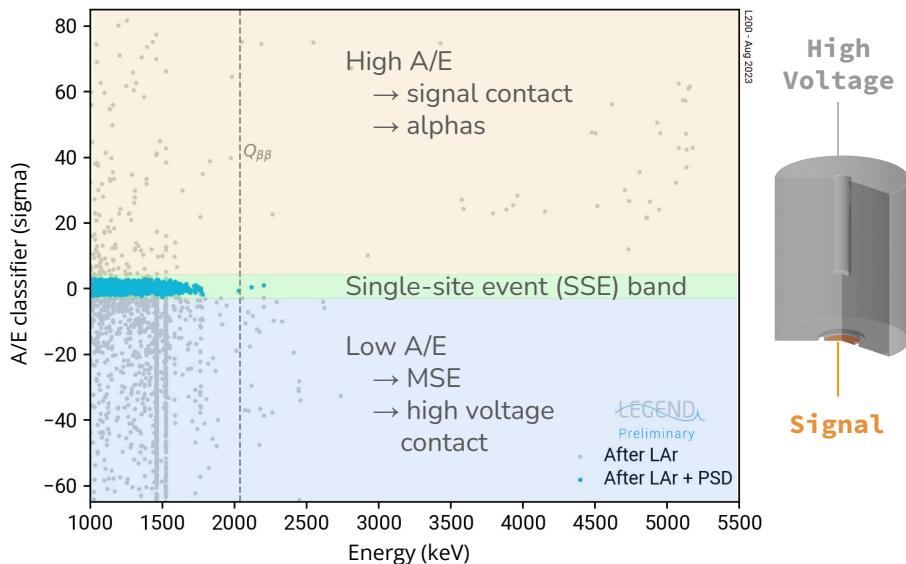


LEGEND vs. GERDA BEGe+ICPC

# Background - After QC + LAr AC + PSD

LEGEND

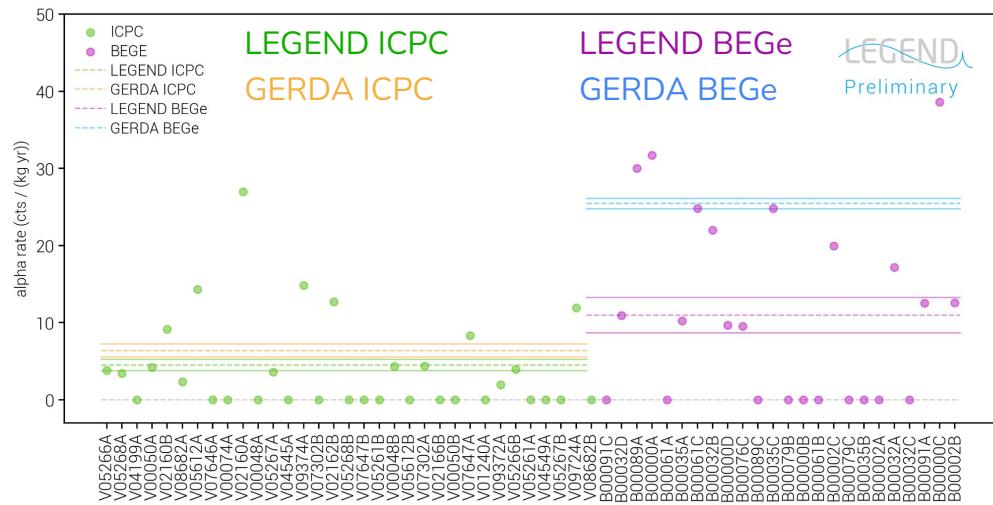
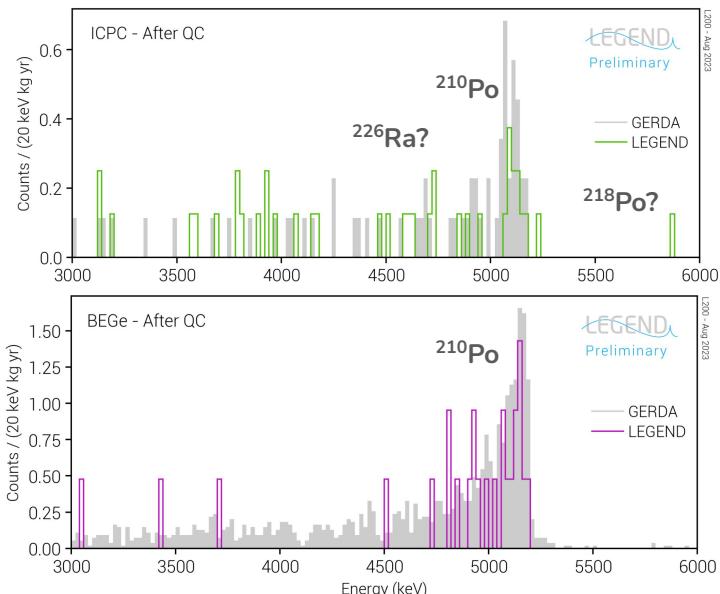
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LEGEND vs. GERDA BEGe+ICPC

# High energy alpha region

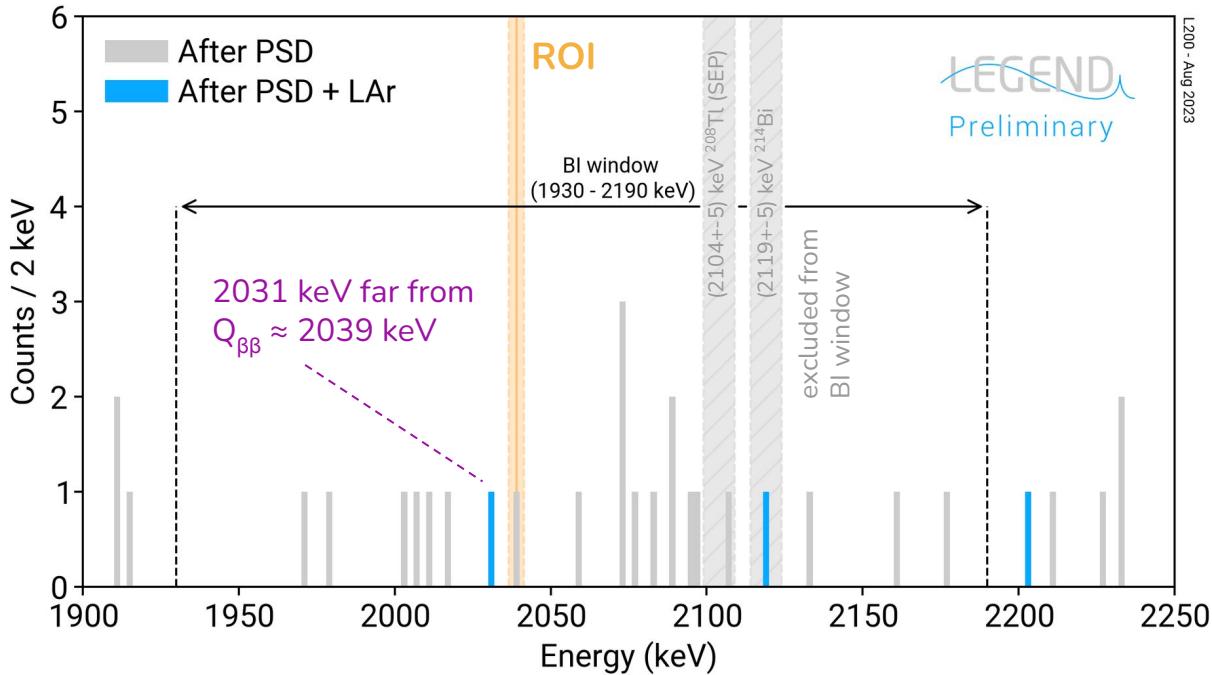
- High energy events are compatible with  $^{210}\text{Po}$ 
  - Can not distinguish  $^{210}\text{Po}$  ( $T_{1/2} \sim 138\text{d}$ ) from  $^{210}\text{Pb}$  ( $T_{1/2} \sim 22.3\text{yr}$ ) supported  $^{210}\text{Po}$  yet
- Weak evidence for  $^{226}\text{Ra}$  and  $^{222}\text{Rn}$  &  $^{218}\text{Po}$  &  $^{214}\text{Po}$  chain
- Less alphas/kg in ICPC
  - smaller contact surface to volume ratio
- Less alphas in LEGEND compared to GERDA
  - successful detector handling procedures



# Background Index

LEGEND

- First 10.1 kg yr of LEGEND-200 data
- ICPC & BEGe
- LAr accepted
- PSD accepted

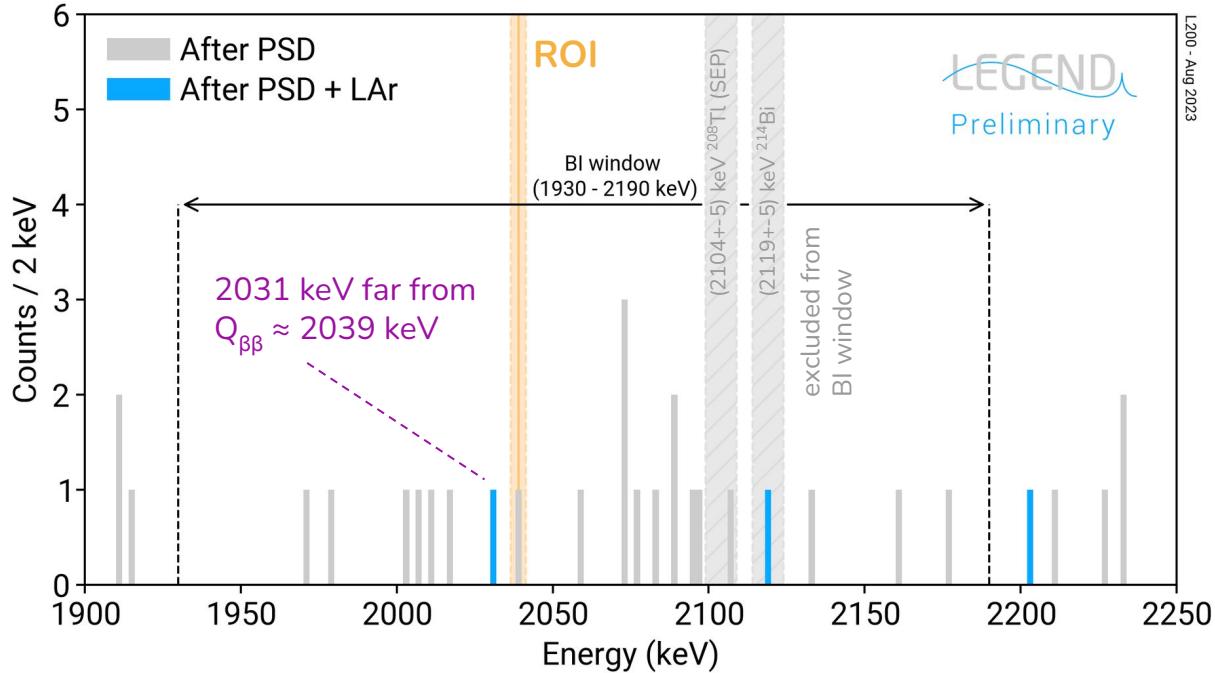


# Background Index

- First 10.1 kg yr of LEGEND-200 data
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- PSD accepted

- BI is compatible with LEGEND-200 goal  
 $2 \times 10^{-4} \text{ cts}/(\text{keV kg yr})$
- Expect 0.48 cts
- Probability to observe  
 $\# \text{cts} > 0 \sim 38\%$

window 240 keV & exposure 10.1 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	$4.1 [1.5, 11.4] \times 10^{-4}$	$5.2 [3.9, 6.8] \times 10^{-4}$

- **Background in first LEGEND-200 physics data**

- No unexpected background components
- Detailed background decomposition [WIP]
- LAr instrumentation and PSD work as expected
  - ✓ Suppression in physics data depends on realized background composition and location
- Less alpha events compared to GERDA
  - ✓ Successful detector handling procedures
- Background in the ROI after analysis cuts:
  - ✓ Evaluated on first 10.1 kg yr of physics data compatible with LEGEND-200 goal



## LEGEND Collaboration

- ~ 300 members
- 55 institutions
- 12 countries

<https://legend-exp.org>



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**Thank you for your attention!**

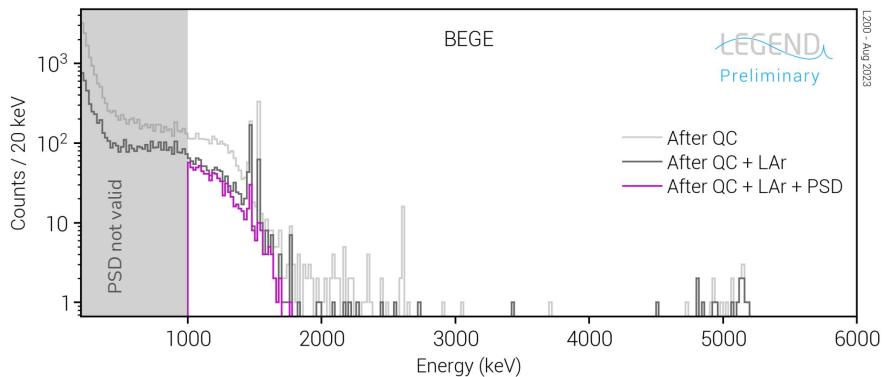
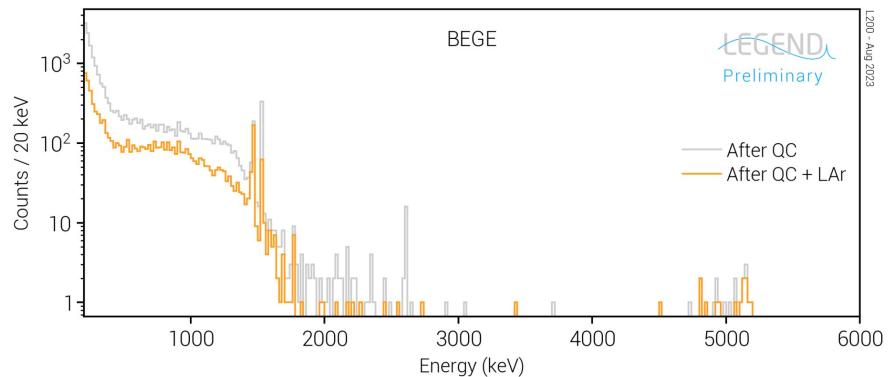
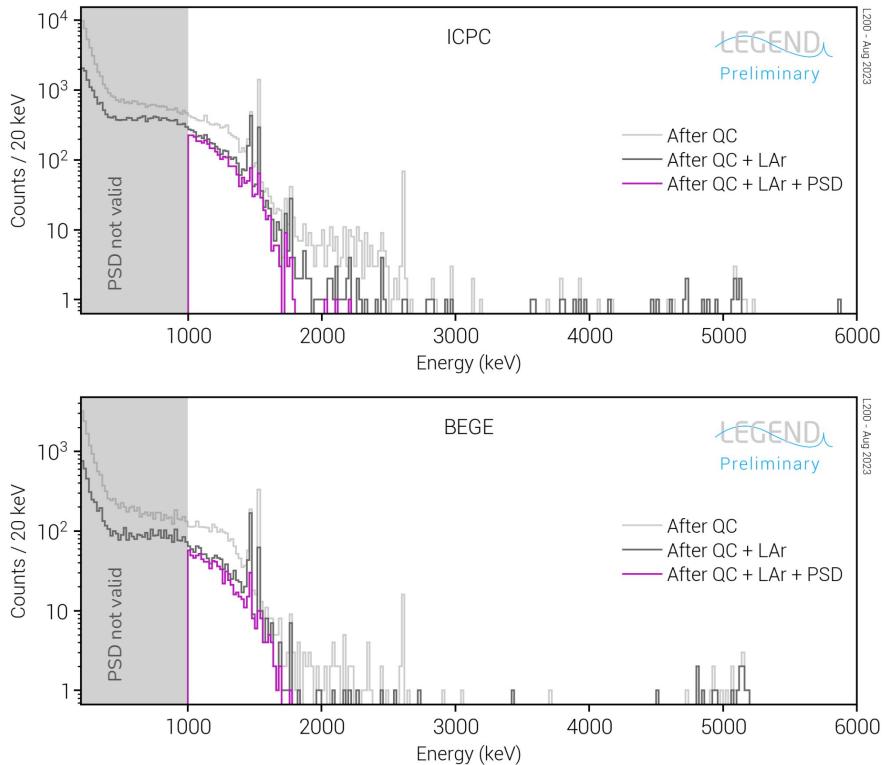
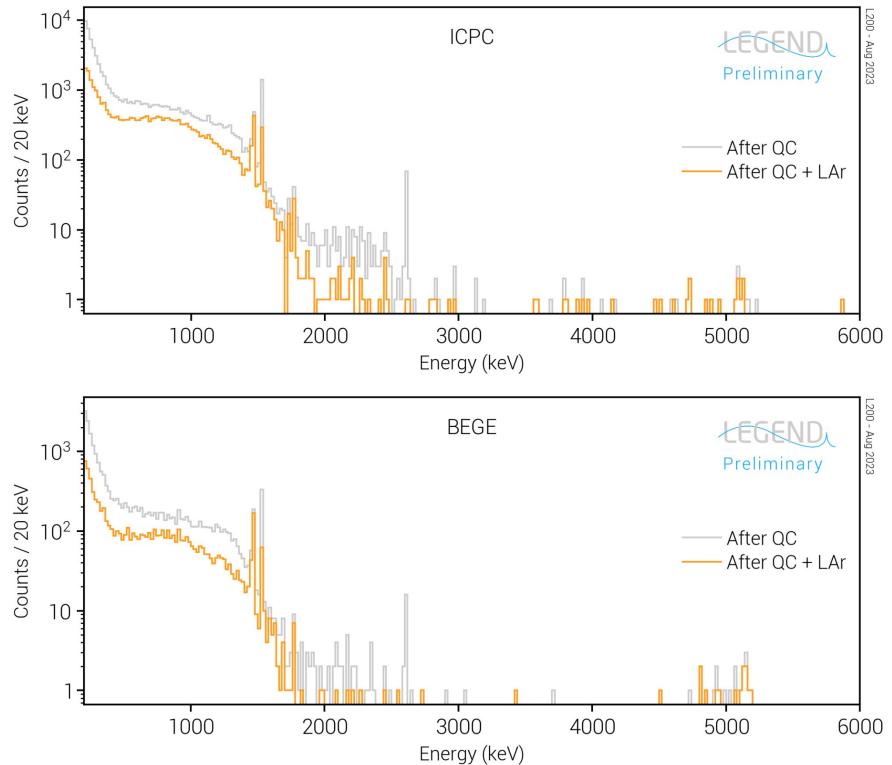
LEGEND-1000: V. Guiseppe (Tomorrow Wed. 14:45 Audimax)



- Background modeling for LEGEND-200 (Rushabh Gala)
- LEGEND-200 Data Acquisition, Monitoring and Calibration (Brady Bos)
- $^{76}\text{Ge}$  Detectors of LEGEND experiment: Production, Characterization, Performance (Valentina Biancacci)
- The LEGEND-200 Liquid Argon Instrumentation: From a simple veto to a full-fledged detector (Rosanna Deckert)
- Muon Veto of the LEGEND experiment (Gina Grünauer)
- Searching for Beyond-Standard-Model Physics with LEGEND-1000 (Samuel Watkins)
- Neutron Veto Instrumentation for LEGEND-1000 at LNGS (Michele Morella)
- Constraining the  $^{77(m)}\text{Ge}$  Production with GERDA Data and Implications for LEGEND-1000 (Moritz Neuberger)

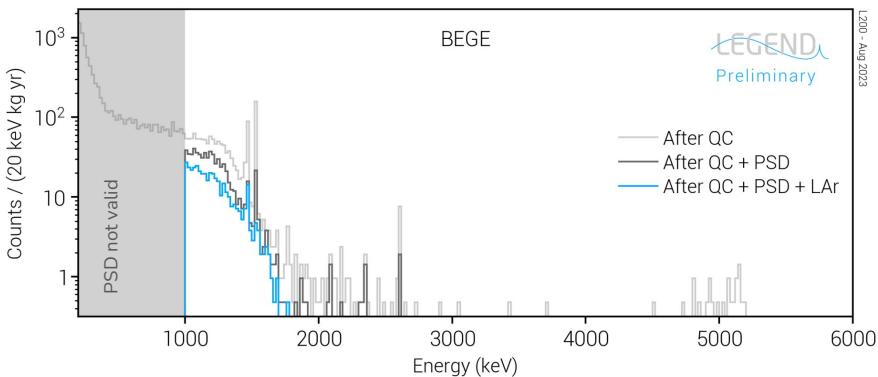
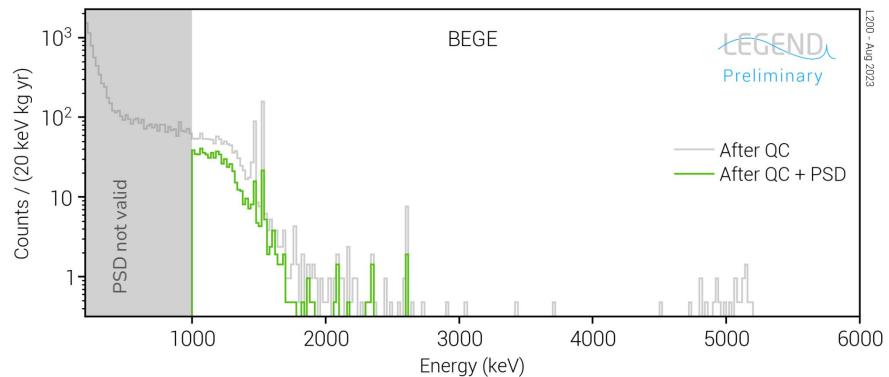
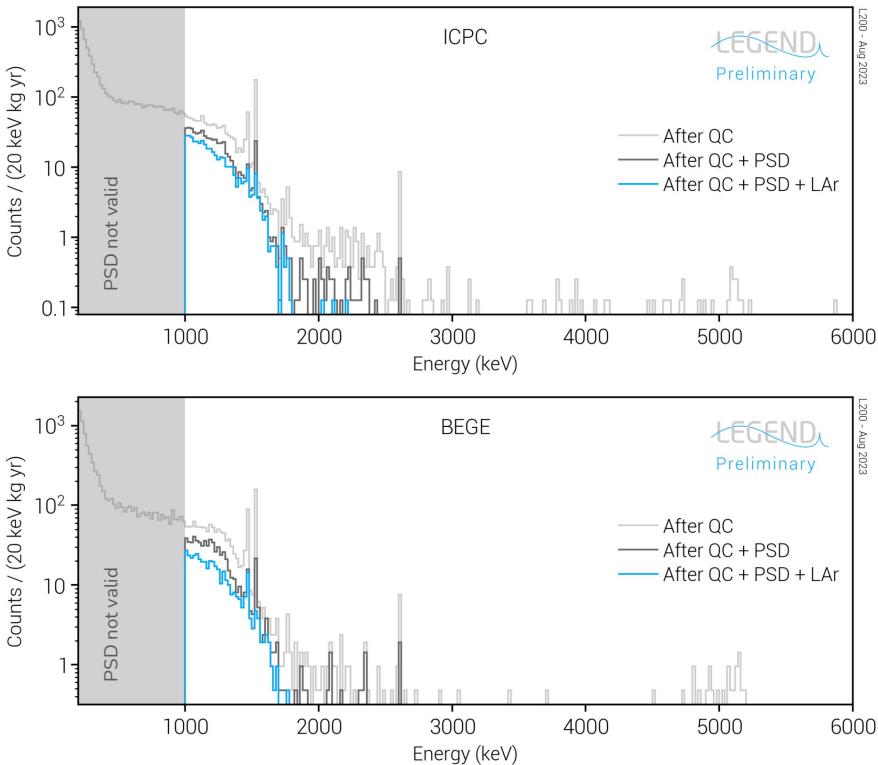
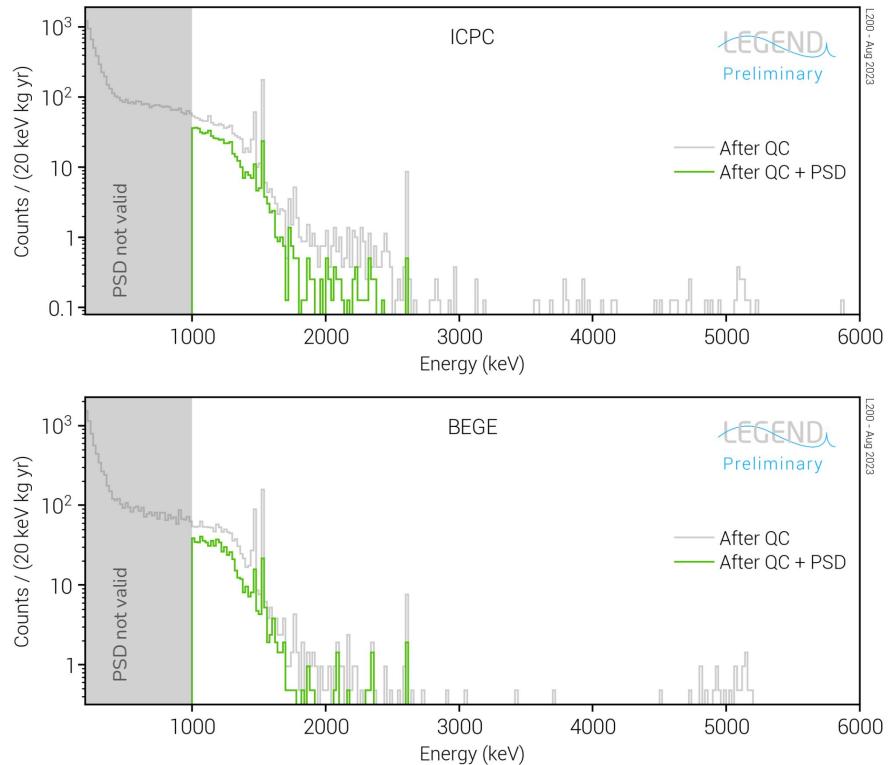
# Backup - Spectra ICPC & BEGe separate - LAr first

LEGEND



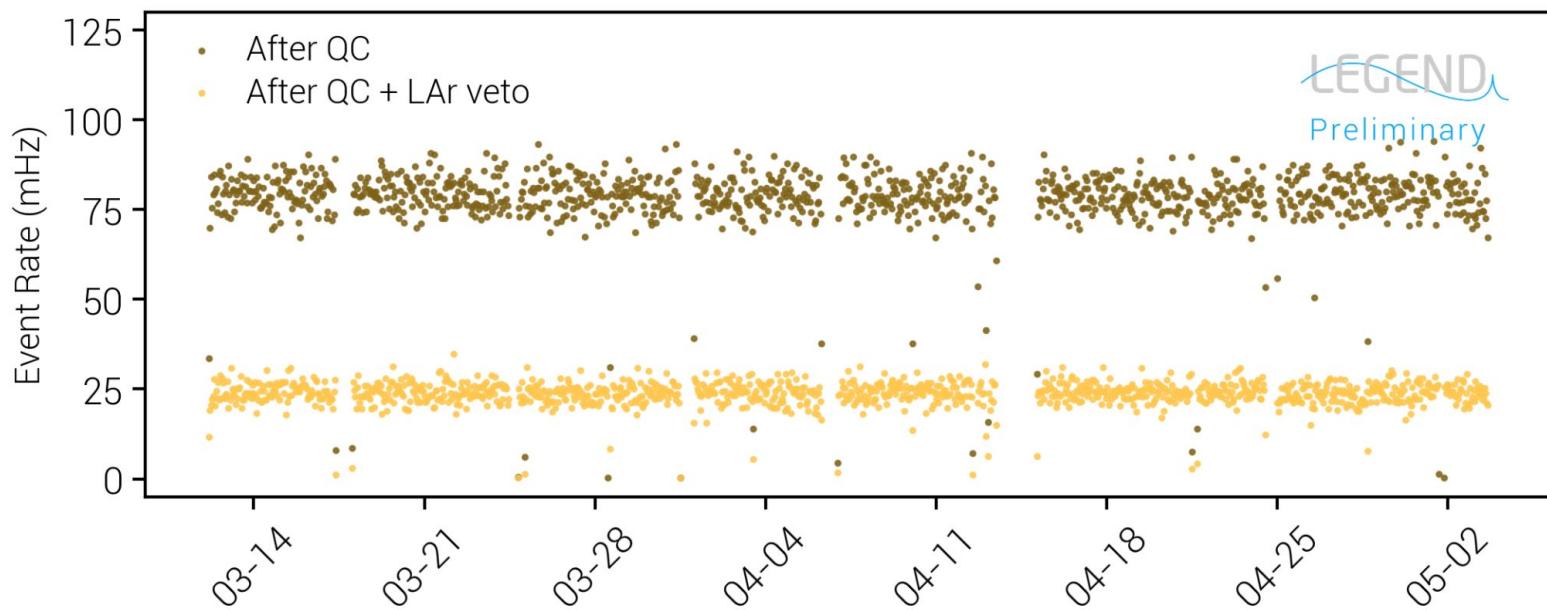
# Backup - Spectra ICPC & BEGe separate - PSD first

LEGEND



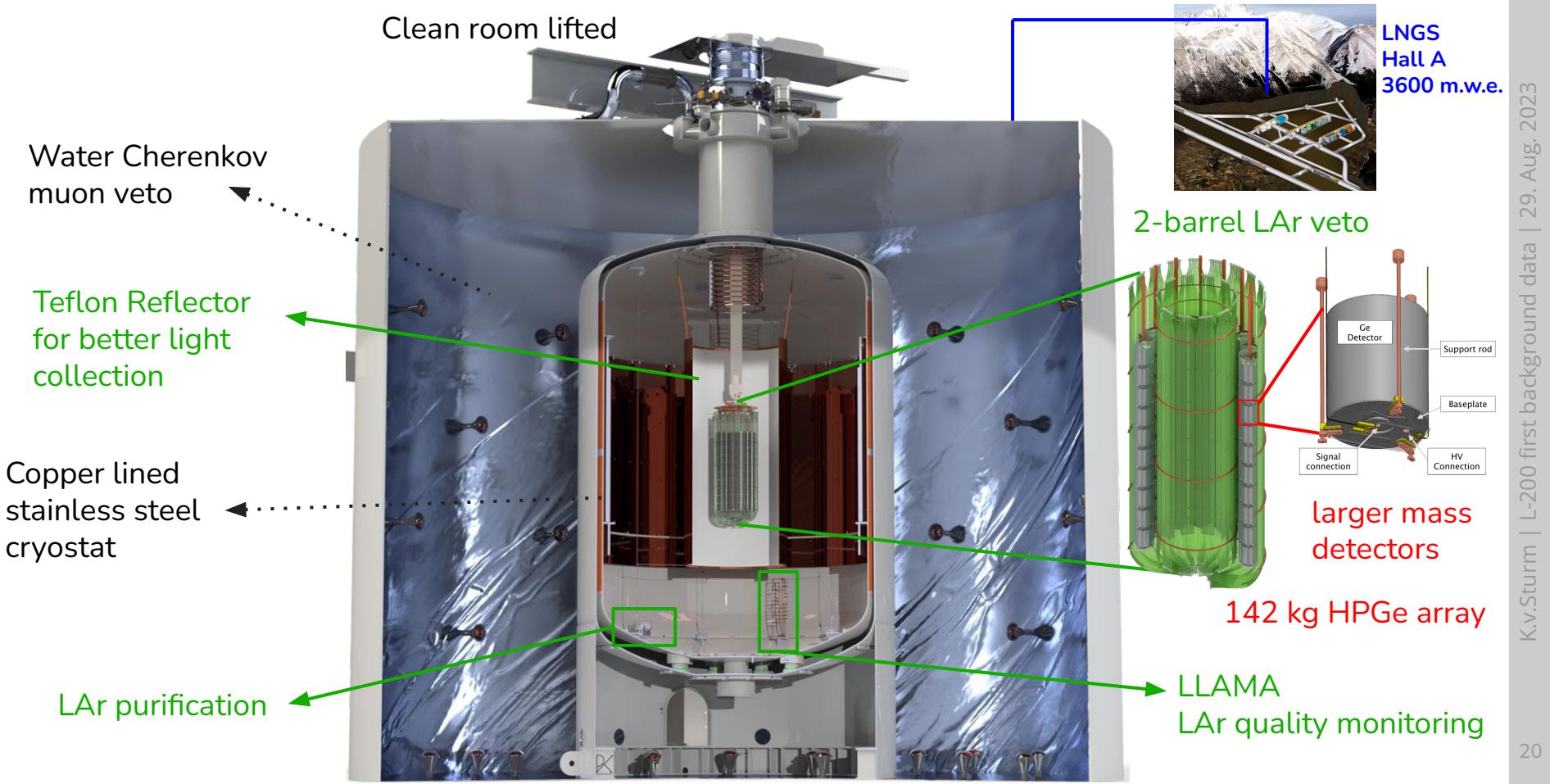
# Backup - Event rate

- Uniform germanium event rate after QC
- No event “bursts”
- No evident “hot-spots” in the array



# Backup - Full Setup

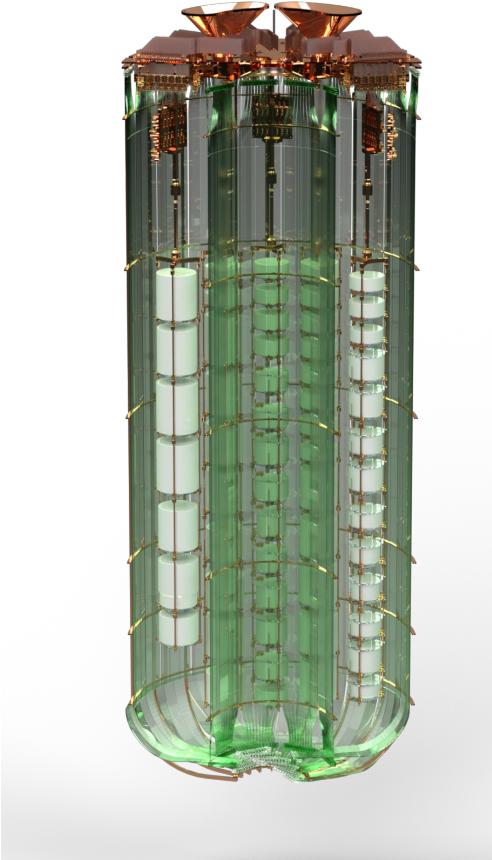
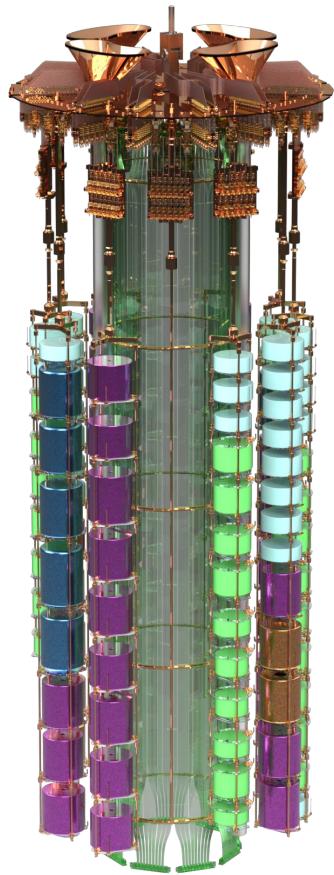
LEGEND

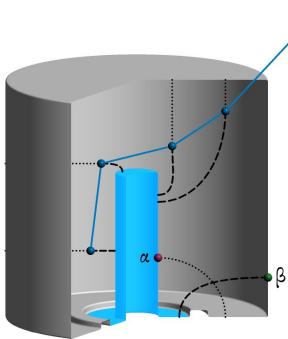


# Backup - Array as built



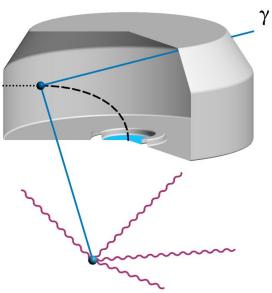
installed: 101 detectors - 142 kg - 10 strings  
working: 89 detectors - 130 kg





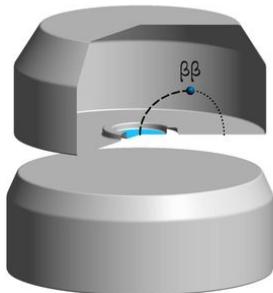
## Pulse Shape Discrimination (PSD)

- scattered multi-site events (MSE)
- surface events



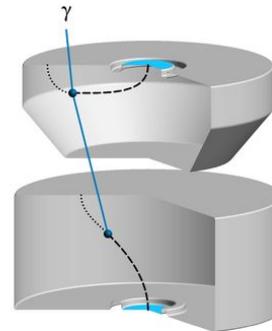
## LAr anti-coincidence

- intrinsic backgrounds
- Ge cosmogenics



## Single-site event topology (SSE)

- $2\nu\beta\beta$
- $0\nu\beta\beta$



## Detector multiplicity

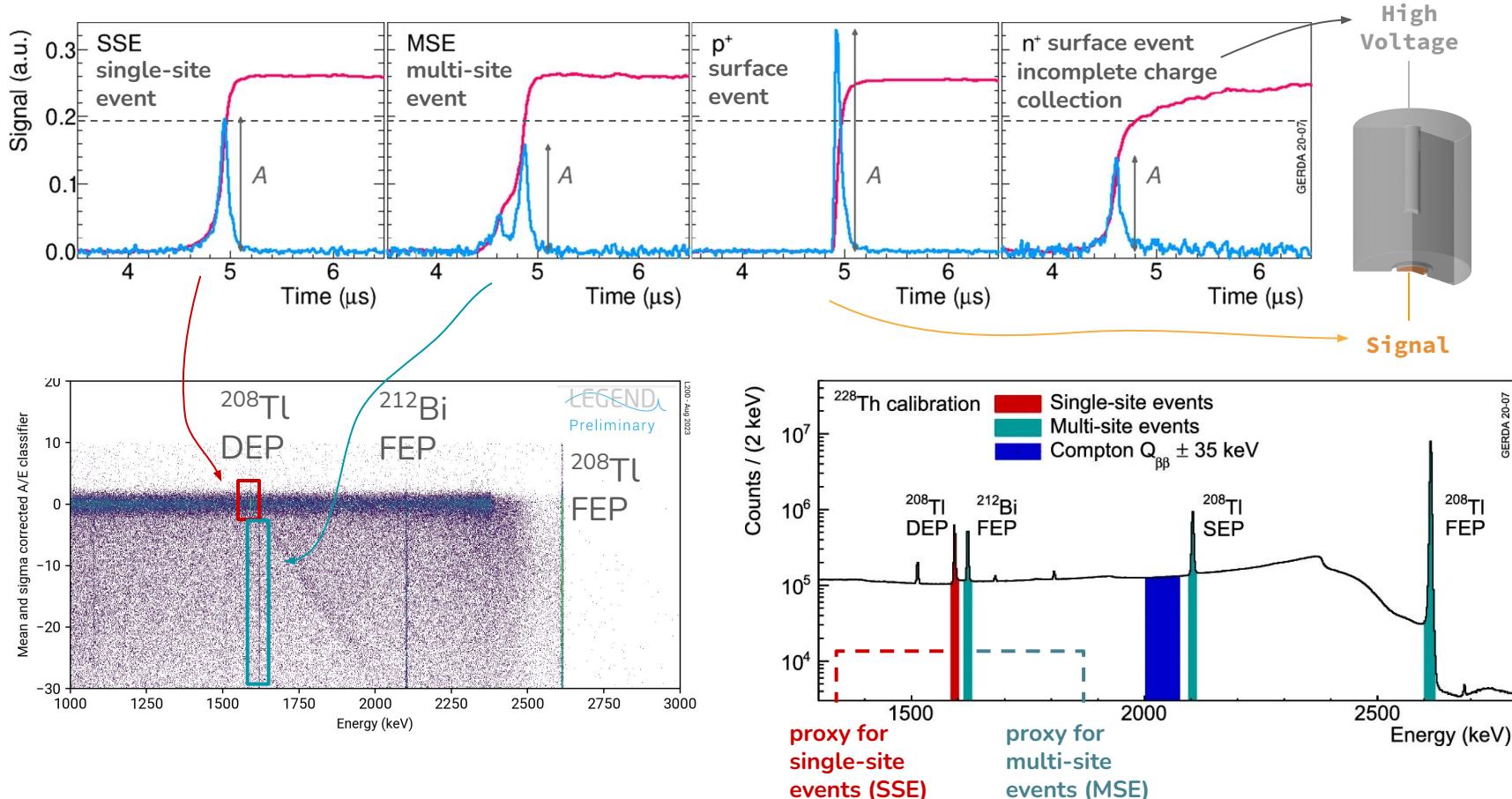
- scattered events

## Water Cherenkov anti-coincidence

- muons

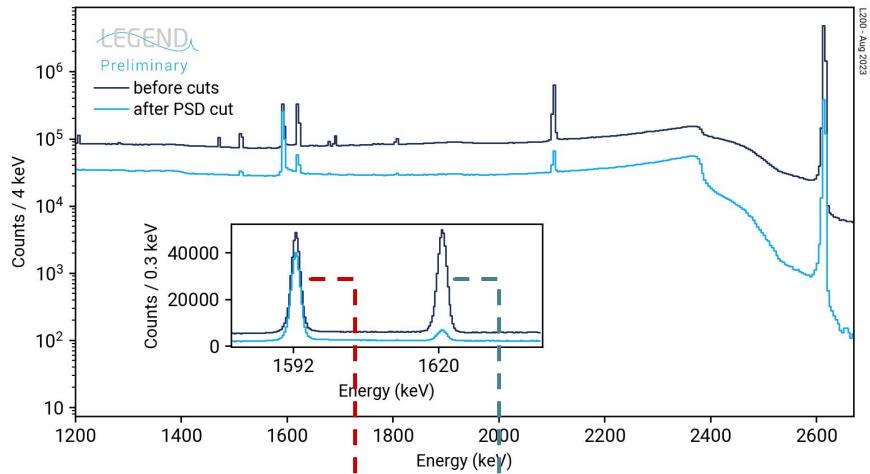
# Backup - PSD explained

LEGEND

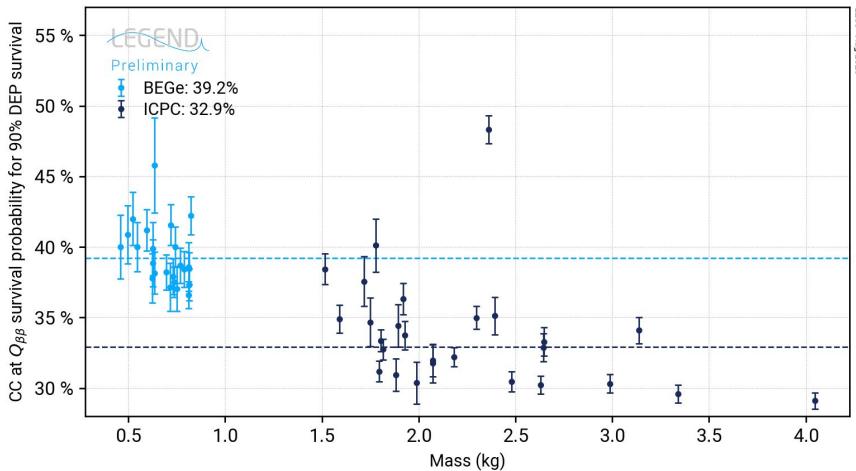


# Backup - PSD in LEGEND-200 calibrations

LEGEND

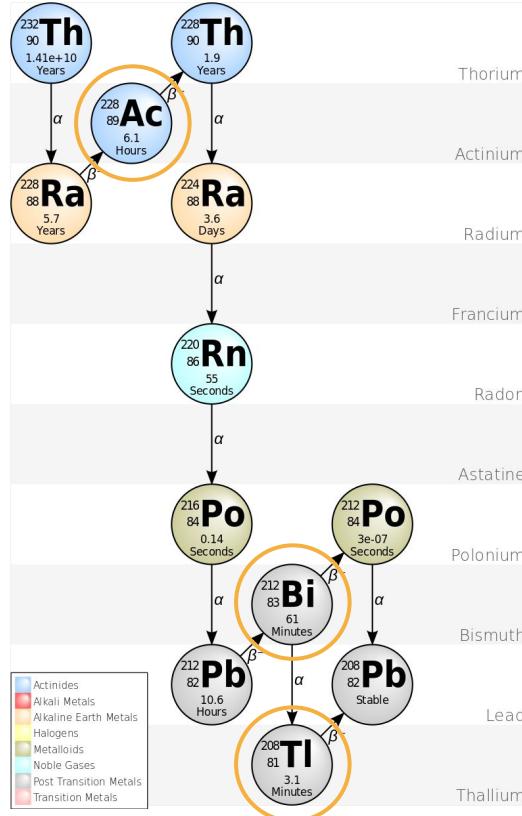


$^{208}\text{TL}$   
DEP      proxy for  
single-site  
events (SSE)      proxy for  
multi-site  
events (MSE)       $^{212}\text{Bi}$   
FEP

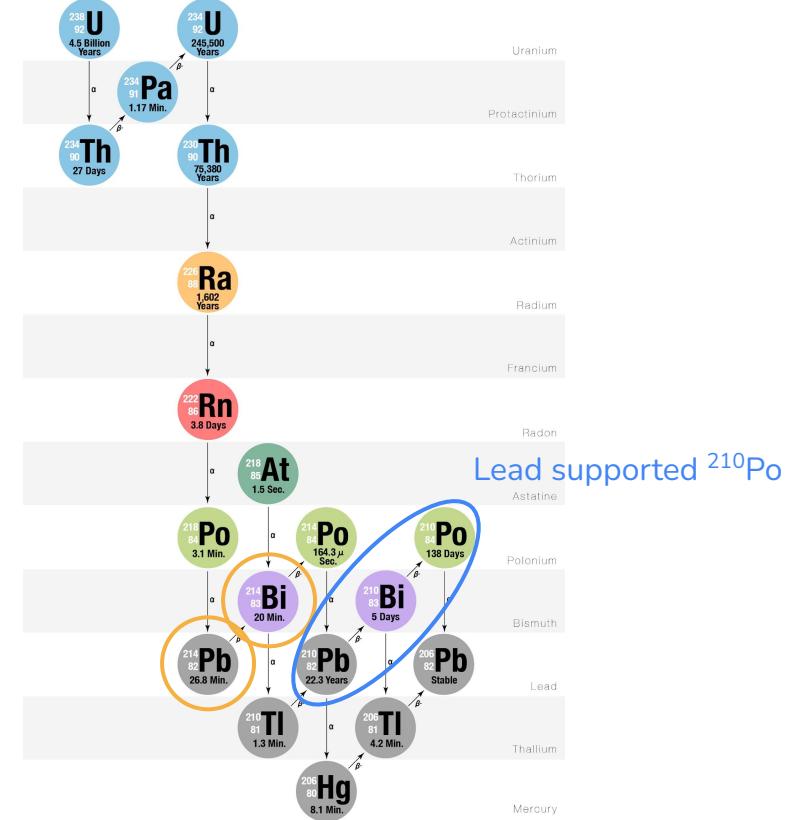


# Backup - Decay chains

LEGEND



Relevant isotopes from  
U & Th decay chains



# Backup - GERDA Background Model - After QC

LEGEND

