Search for the $^{77(m)}$Ge Production with GERDA Data and Implications for LEGEND-1000

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TAUP VIENNA 2023

Gran Sasso

atmospheric muon

to L'Aquilla

to Teramo

Laboratori Nazionali del Gran Sasso (LNGS) *Note: Much creative freedom was used in designing this LNGS layout.*

to L'Aquilla

Highway tunnel

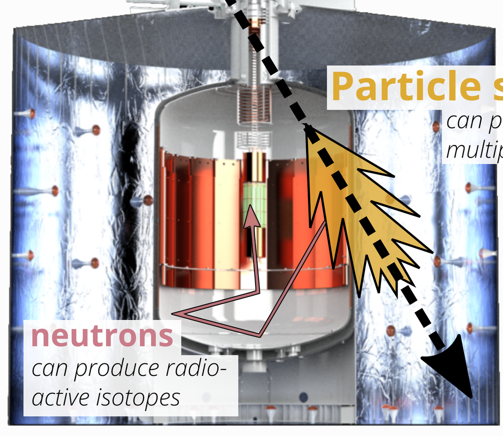
to Teramo

The Background

GERDA experiment

search for neutrinoless double beta (0νββ) decay of ^{76}Ge [1]

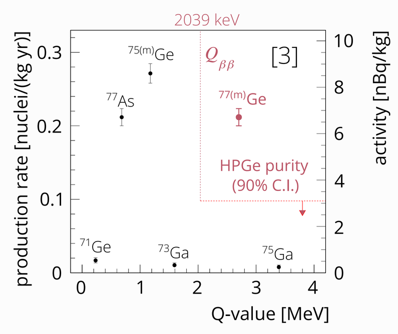
Completed data taking: 2019 [2]
Final exposure: 103.7 kg × yr
$T_{1/2}^{0\nu\beta\beta}$ >1.8 × 10^{26} yr (90% CL)
Precurser to LEGEND

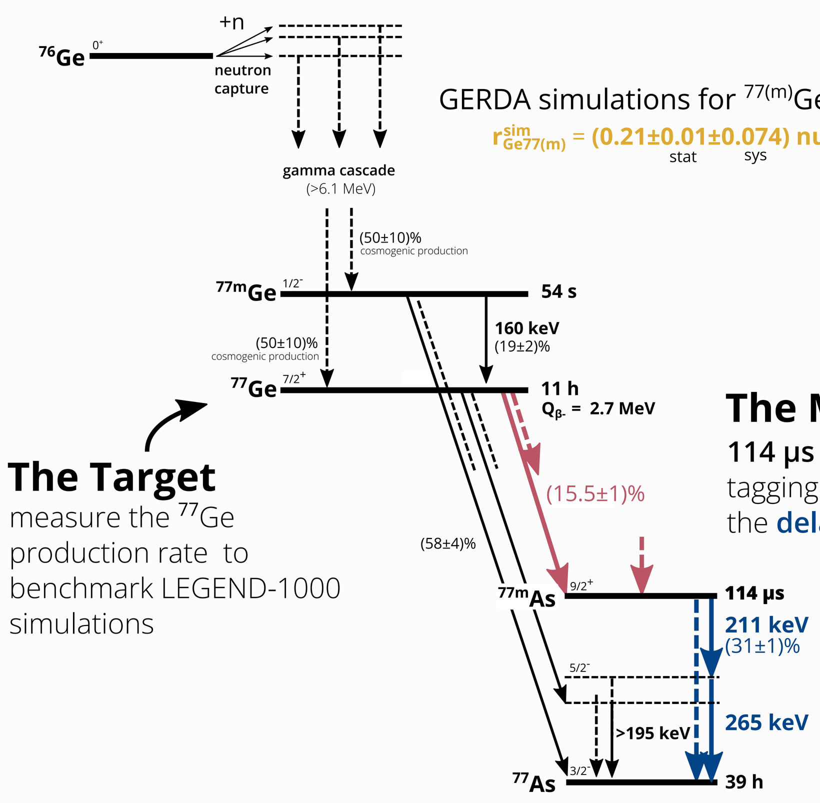


The Background

$^{77(m)}$Ge (^{77}Ge and ^{77m}Ge)

- decay with $T_{1/2}$ of 11h or 54s
- $Q_\beta(^{77(m)}Ge)$ > $Q_{\beta\beta}(^{76}Ge)$
- background for 0νββ decay search [3]





GERDA simulations for $^{77(m)}$Ge production rate:
$r^{sim}_{Ge77(m)}$ = (0.21±0.01$_{stat}$±0.074$_{sys}$) nuc/kg/yr

The Target

measure the ^{77}Ge production rate to benchmark LEGEND-1000 simulations

The Method

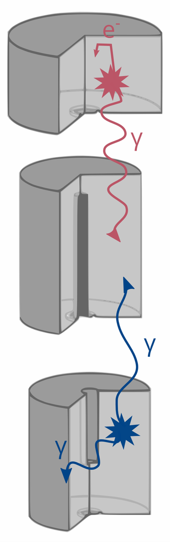
114 μs delayed coincidence (DC) tagging of the **prompt β-decay** and the **delayed de-excitation**

Hall A

The Search

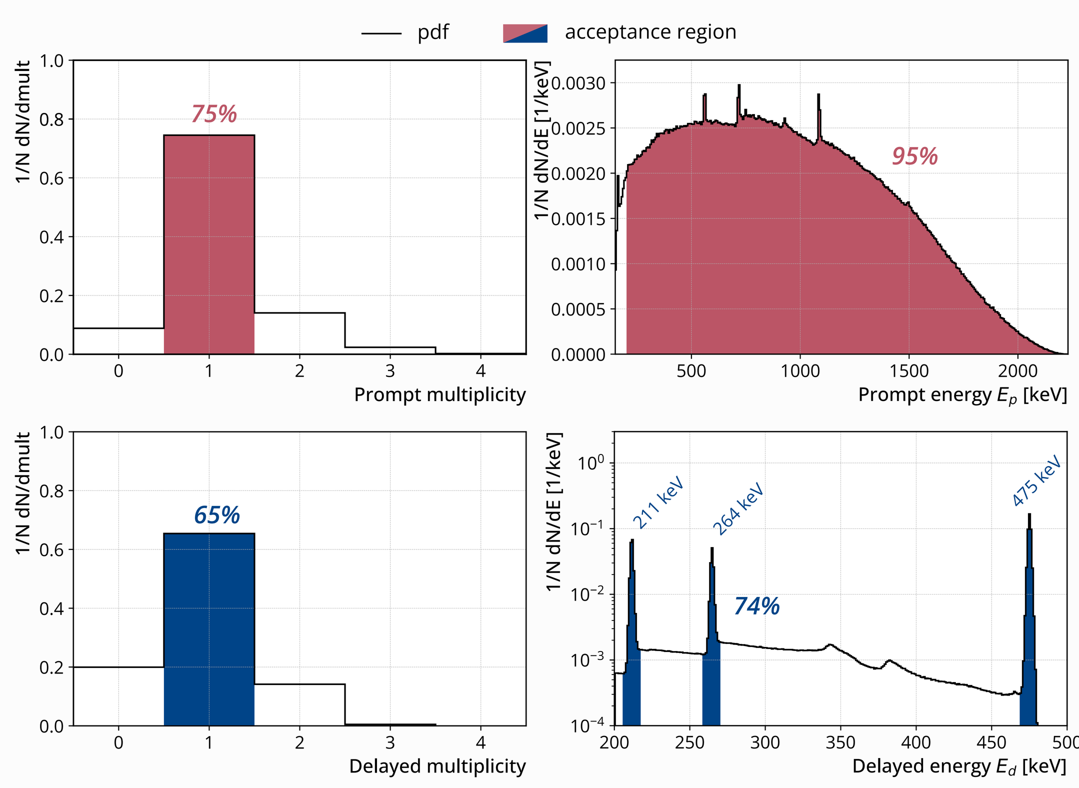
The energy and multiplicity selection

based on Geant4 simulation



multiplicity:
number of HPGe detectors with energy deposition

Energy:
total energy deposited inside the sensitive region of one HPGe detector

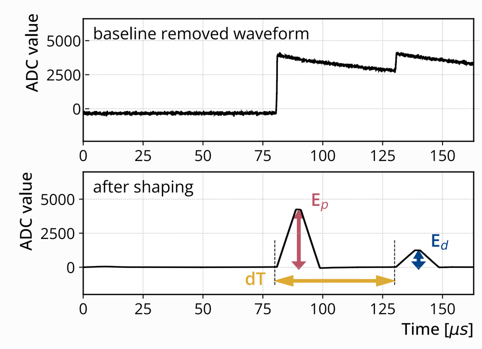


combined prompt and delayed energy and multiplicity selection efficiency:

ε_{Em} = 34.4%

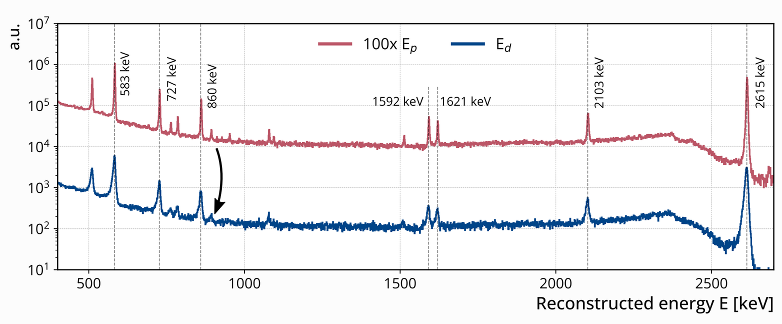
The event reconstruction and selection:

new digital signal processor to extract energies and time differences:



pile-up from calibration data as cross-check:

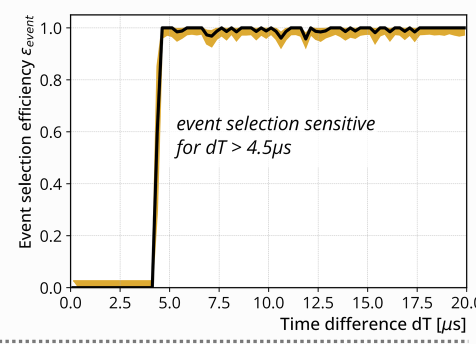
resolution larger and slight shift in energy (bias)



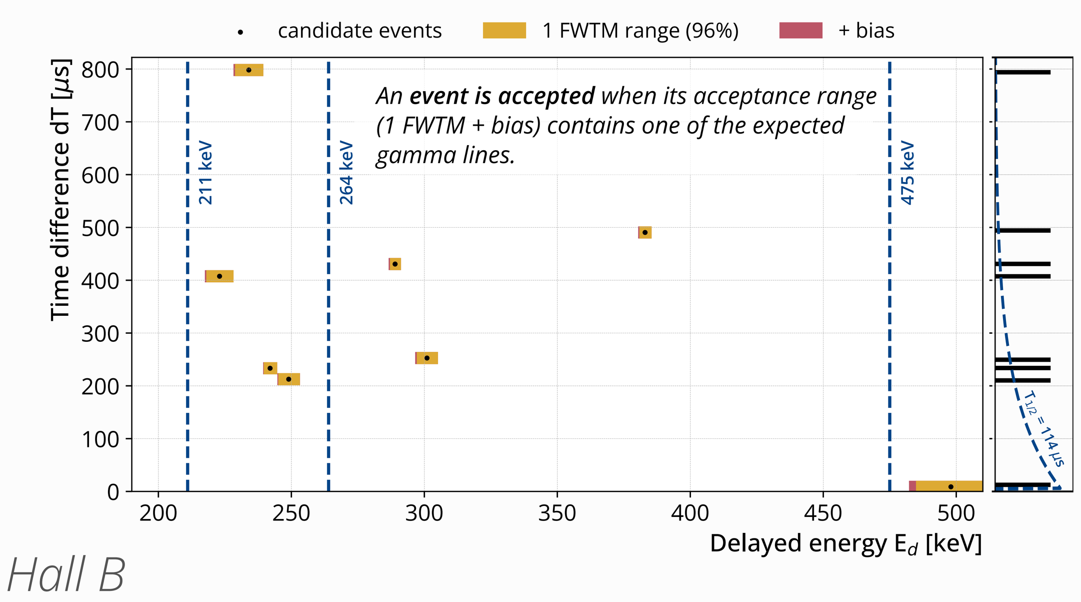
generated pile-up pulses:

- uncertainty and bias in E_d on an event by event basis
- event selection efficiency:

ε_{event} = 94.9%



The Candidate Events



N_{obs} = 0 cts
N_b = $N_{random\text{-}coincidence}$ = 0.04 cts

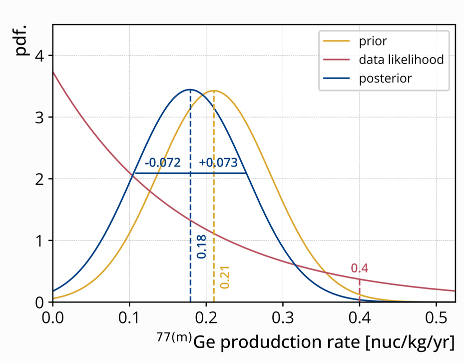
All ^{77}Ge are produced in-situ (Feldman-Cousins N_{sig} < 2.4 cts (90%CL))

r_{Ge77} = N_{sig} / (ε_{Em} × ε_{event} × (31±1)% × 103.7 kg × yr)
< 0.235 nuc/kg/yr (90%CL)

Majority of $^{77(m)}$Ge is produced via cosmogenic activation:

$r_{Ge77(m)}$ = r_{Ge77} / ((50±10)% + (1 - (50±10)%) × (19±2)%)
< 0.40 nuc/kg/yr (90%CL)
The 90% CL is 1.9x the MC production rate.

The Update



Bayesian update of the simulated production rate $r_{Ge77(m)}$. In ***relative terms***, the original values are scaled by:

$0.85^{+0.35}_{-0.34}$

We can use this value to update estimates for LEGEND.

Hall B

The Implications

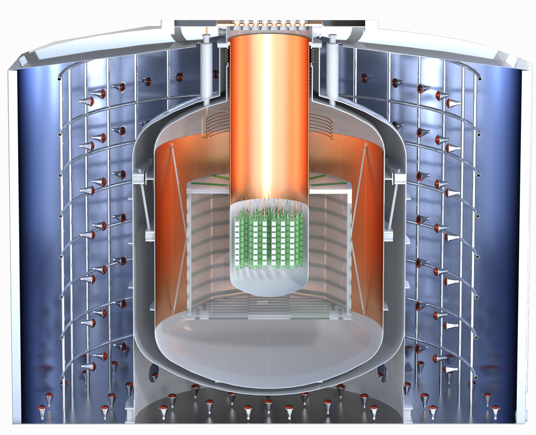
LEGEND-200

Target exposure: 1 ton × yr
0νββ discovery sensitivity: 10^{27} yr
Background index goal:
BI_{goal} < 2 ×10^{-4} cts/keV/kg/yr
Location: LNGS
Start of data taking: 2023

With one year of lifetime, we doubled the combined sensitivity of the ^{77}Ge production rate and an observation might be possible. Conversely, in the absence of a signal, the limit scales linearly.

Stay tuned for next years results!

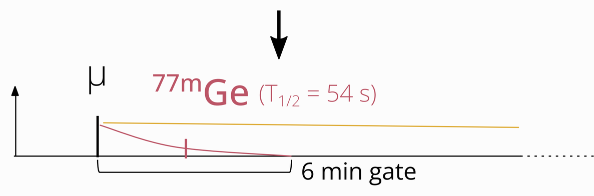
LEGEND-1000 @ LNGS



Target exposure: 10 ton × yr [4]
0νββ discovery sensitivity: 1.3 × 10^{28} yr
Background index goal:
BI_{goal} <10^{-5} cts/keV/kg/yr

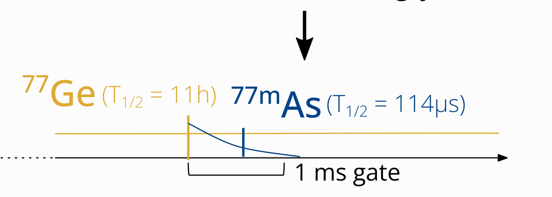
Without additional suppression, the cosmogenic background contribution is [5]

1.2 × 10^{-5} cts/keV/kg/yr > BI_{goal}



After applying the *(μ,^{77m}Ge) delayed coincidence* cut:

1.0 × 10^{-6} cts/keV/kg/yr



After scaling with $0.85^{+0.35}_{-0.34}$ and the use of the *(^{77}Ge,^{77m}As) delayed coincidence* cut, we can reduce the BI to:

$4.0^{+3.0}_{-2.9}$ × 10^{-7} cts/keV/kg/yr (4% BI_{goal})
LEGEND-1000 can fully realize its science objectives at LNGS.

Hall C

[1] GERDA Collaboration, Eur. Phys. J. C 78, 388 (2018)
[2] GERDA Collaboration, Phys. Rev. Lett. 125, 252502 (2020)
[3] C. Wiesinger et al., Eur. Phys. J. C (2018) 78:597
[4] LEGEND-1000 pCDR (https://legend-exp.org/science/publications)
[5] Michele Morella, Moritz Neuberger, 598 Poster Neutrino 2022 [10.5281/zenodo.6804443]