Status of the GERDA experiment

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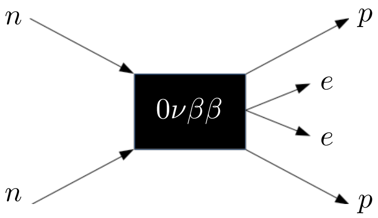
5 June 2018

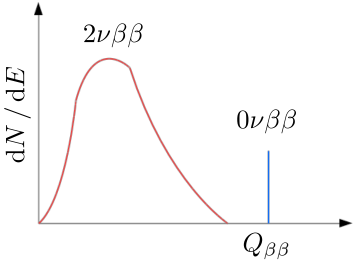
Detecting neutrinoless double-beta decay ($0\nu\beta\beta$)

- Can explain mass of neutrino with small Majorana mass component
- Hypothetical lepton number violating process: $0\nu\beta\beta$
- Signature in calorimeters would be monoenergetic line, $Q_{\beta\beta}$, in energy spectrum of emitted electrons
- Sensitivity to half-life of decay:

$$T_{1/2}^{0\nu} \propto \epsilon \sqrt{\frac{Mt}{BI \cdot \Delta E}}$$

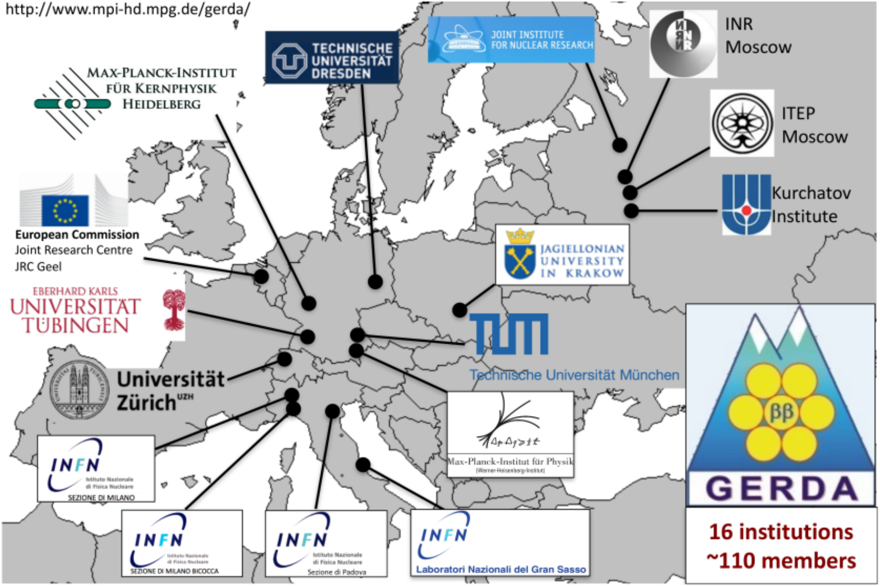
where ϵ: efficiency; Mt: exposure; BI: background events per kg·yr·keV; ΔE: resolution





Summed electron energy

GERDA collaboration

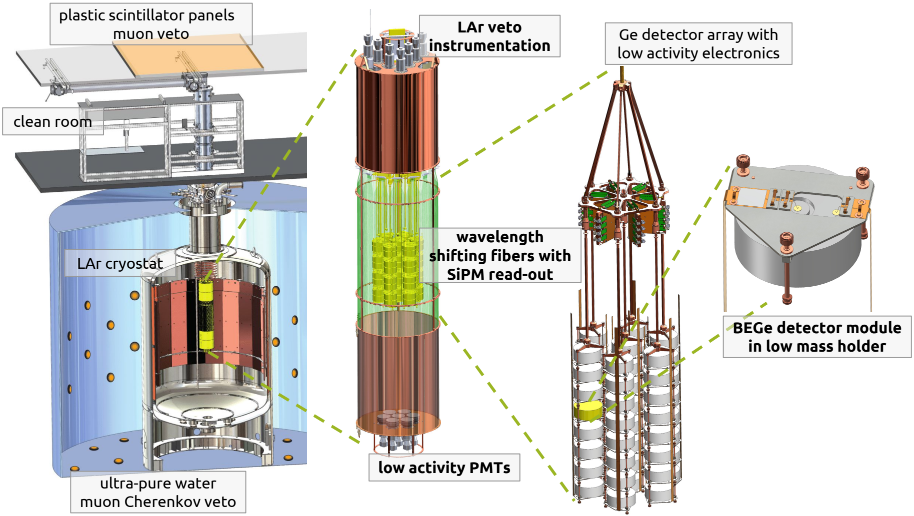


16 institutions
~110 members

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

- GERDA searches for $0\nu\beta\beta$ of ^{76}Ge at LNGS
- $Q_{\beta\beta} = 2039\,\text{keV}$
- Diodes isotopically enriched up to 88%, act as both source and detector
- Ge detectors have high intrinsic purity, excellent energy resolution

GERDA experiment



Detector types

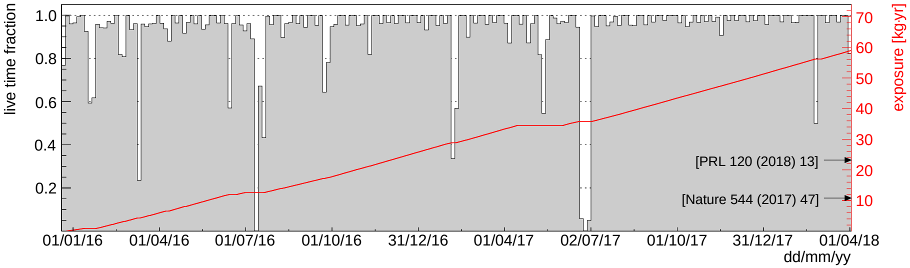
Semi-coaxial Ge detector (Coax)

- 7 enriched detectors
- 3 non-enriched detectors
- Total enriched mass 15.6 kg

Broad Energy Ge detector (BEGe)

- 30 enriched detectors
- Superior pulse shape discrimination (PSD), energy resolution
- Total mass 20.0 kg

Data taking



Phase II data taking since December 2015

June 2016: 10.8 kg· yr

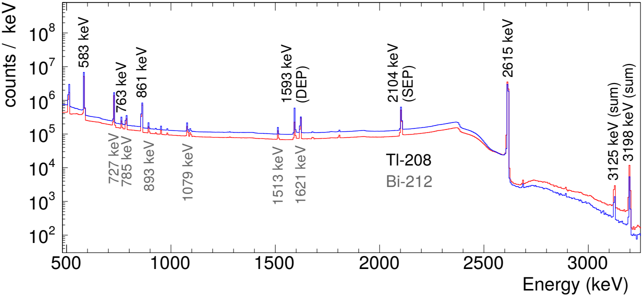
- Published in **Nature 554 (2017)**

June 2017: 23.2 kg· yr

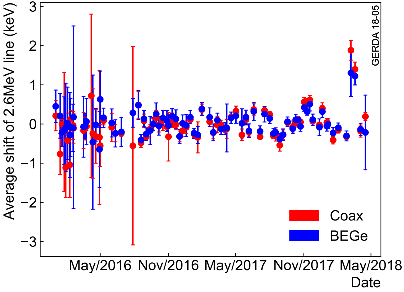
- Published in **PRL 120 (2018)**

June 2018 (this presentation): 58.9 kg· yr

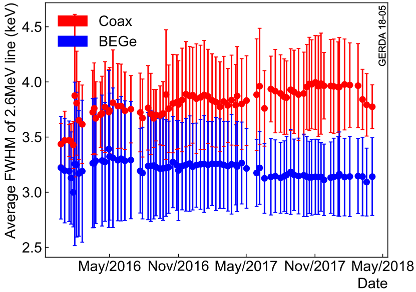
Energy scale

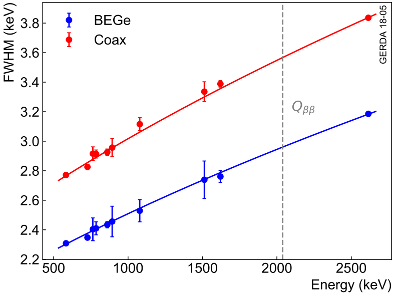


- Energy scale calibrated by exposure to low-neutron ^{228}Th sources ea. 7-10 days
- Stability monitored via 2.6 MeV ^{208}Tl line



Resolution





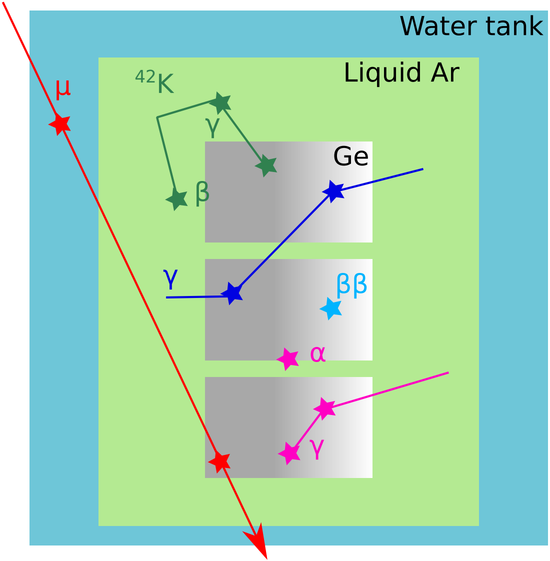
- Resolution at $Q_{\beta\beta}$ determined per dataset, weighting individual detectors

$$\mathrm{FWHM}^2 = \frac{1}{\epsilon}\Sigma_i \epsilon_i \mathrm{FWHM}_i^2$$

sum over detectors, ϵ is exposure

Resolution at $Q_{\beta\beta}$:
Coax: 3.6(1) keV
BEGe: 3.0(1) keV

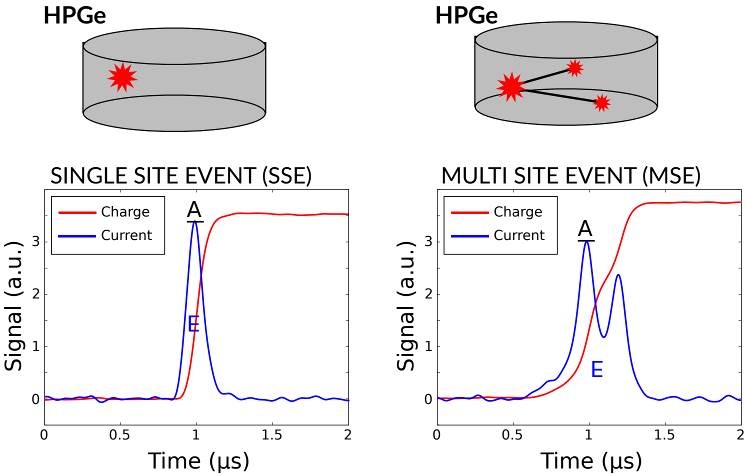
Background reduction techniques



- Signal! Single-site event
- Cherenkov water veto for muons
- LAr scintillation veto for γ, β
- Detector anti-coincidence cut
- Pulse shape discrimination (PSD) for multi-site and surface α events

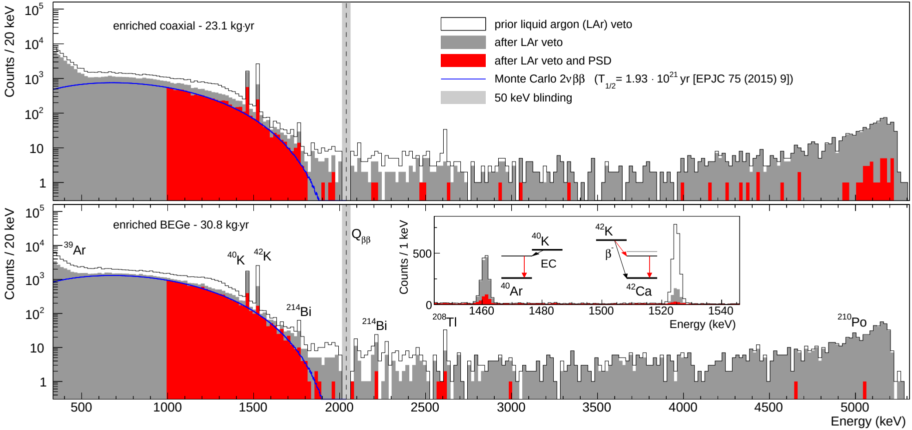
Pulse shape discrimination

- Reject multi-site events by pulse shape differences



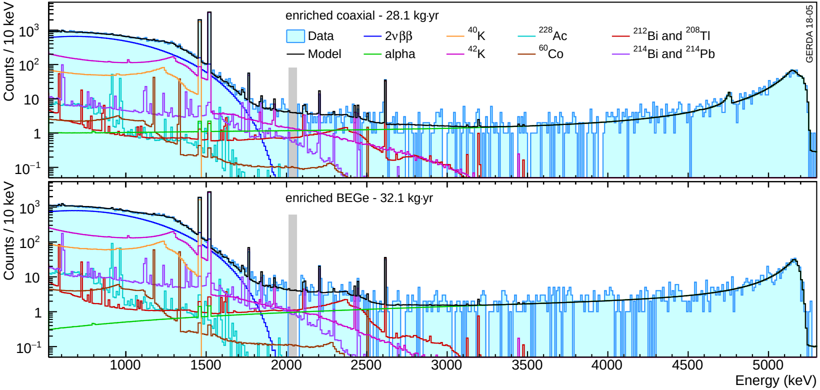
- BEGe: cut on ratio of current amplitude (A) to energy (E)
- Coax: artificial neural network

Physics spectrum



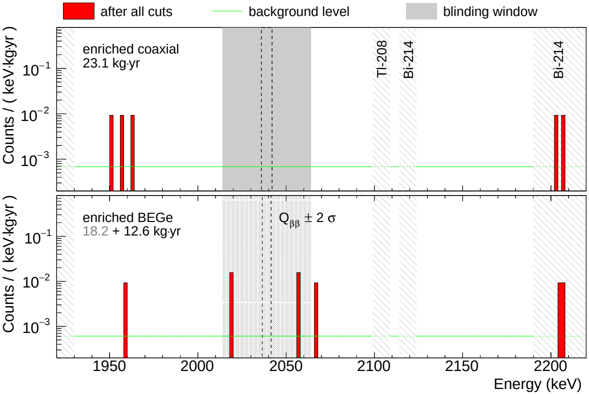
- After muon veto, detector anti-coincidence cuts
- Remaining features: ^{39}Ar β, ^{40}K, ^{42}K, α

Background model



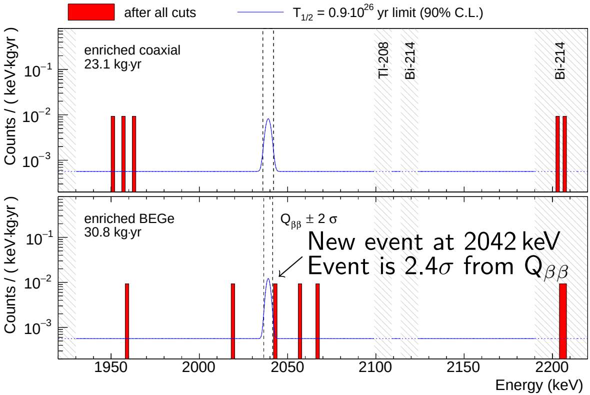
- Fitted using screening measurements as priors
- Low energy region dominated by $2\nu\beta\beta$ continuum
- Predicted flat background in $Q_{\beta\beta}$ region

Background index



- Background index determined in region 1930-2190 keV, excluding two known γ lines and $Q_{\beta\beta}\pm 5$ keV
- Background index at $Q_{\beta\beta}$:
  Coax: $0.6^{+0.4}_{-0.3} \cdot 10^{-3}$ cts/(keV·kg· yr)
  BEGe: $0.6^{+0.4}_{-0.3} \cdot 10^{-3}$ cts/(keV·kg· yr)
- Sensitivity is not limited by background, but by exposure

Unblinded spectrum



Frequentist

- Sensitivity for limit setting: $1.08 \cdot 10^{26}$ yr (90% C.L.)
- Best fit: no signal
- $T^{0\nu}_{1/2} > 0.91 \cdot 10^{26}$ yr (90% C.L.)

Bayesian

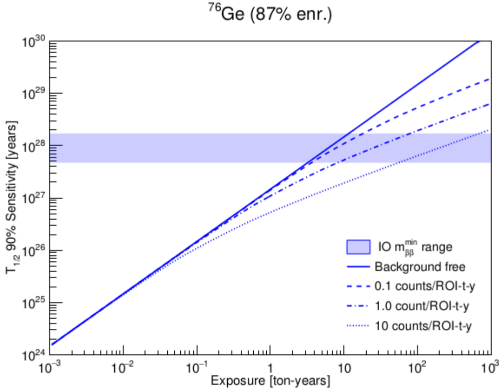
- Sensitivity for limit setting: $0.82 \cdot 10^{26}$ yr (90% C.I.)
- Best fit: background only
- $T^{0\nu}_{1/2} > 0.76 \cdot 10^{26}$ yr (90% C.I.)

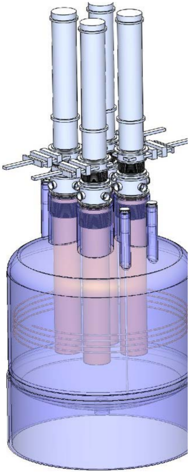
GERDA upgrade

- Upgrade April-May 2018
- 5 new enriched inverted-coaxial-type detectors (9.5 kg)
    - Similar PSD, resolution as BEGe detectors
    - Larger mass
- New fibre shroud → increase in veto efficiency
- Lower activity cables
- JFET exchange (improved reliability)
- Detector holder modification

LEGEND (Large Enriched Germanium Experiment for Neutrinoless $\beta\beta$ Decay)

- Majorana and GERDA collaborations join (among others)
- Aim for discovery potential above 10^{27} yr
- Phased approach, 200 kg $\rightarrow$ 1 t Ge





Conclusion

- GERDA continues to operate smoothly
- Nearly (21.6+)60 kg· yr collected (c.f. aim of 100 kg· yr)
- New limit: $T^{0\nu}_{1/2} > 0.91 \cdot 10^{26}$ yr (90% C.L.)
- World's best sensitivity $> 1 \cdot 10^{26}$ yr
- Upgrade will improve final sensitivity of GERDA

C. R. is funded by the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 674896.