Unraveling the neutrino nature with the GERDA experiment

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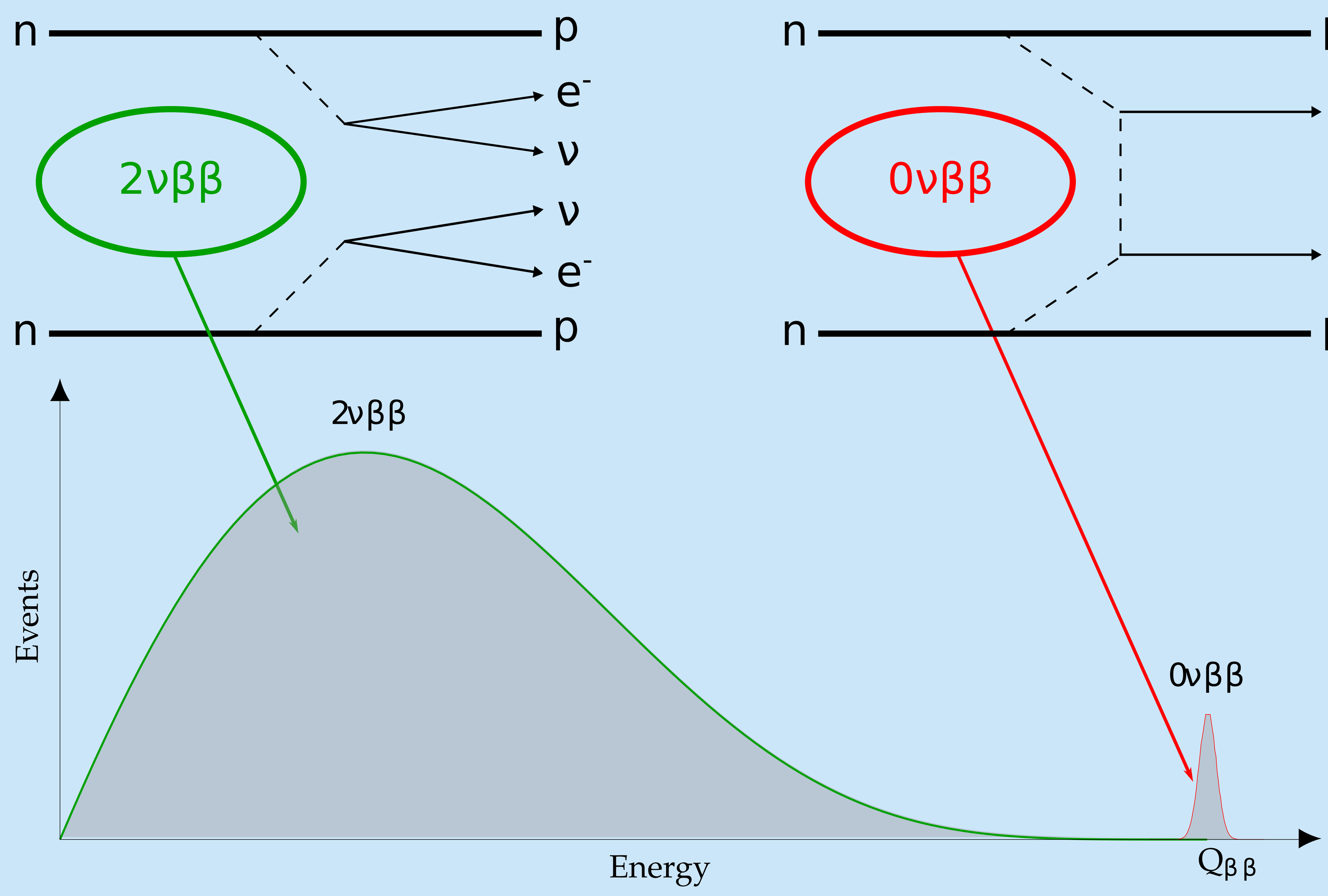
GERDA

Double beta decay ($2\nu\beta\beta$)

- Standard Model process, two simultaneous β decays: $^{76}Ge \rightarrow {}^{76}Se + 2e^- + 2\nu_e$
- Broad electron energy distribution
- Observed in 12 isotopes, life times 10^{18}-10^{24} yr

Neutrinoless double beta decay ($0\nu\beta\beta$)

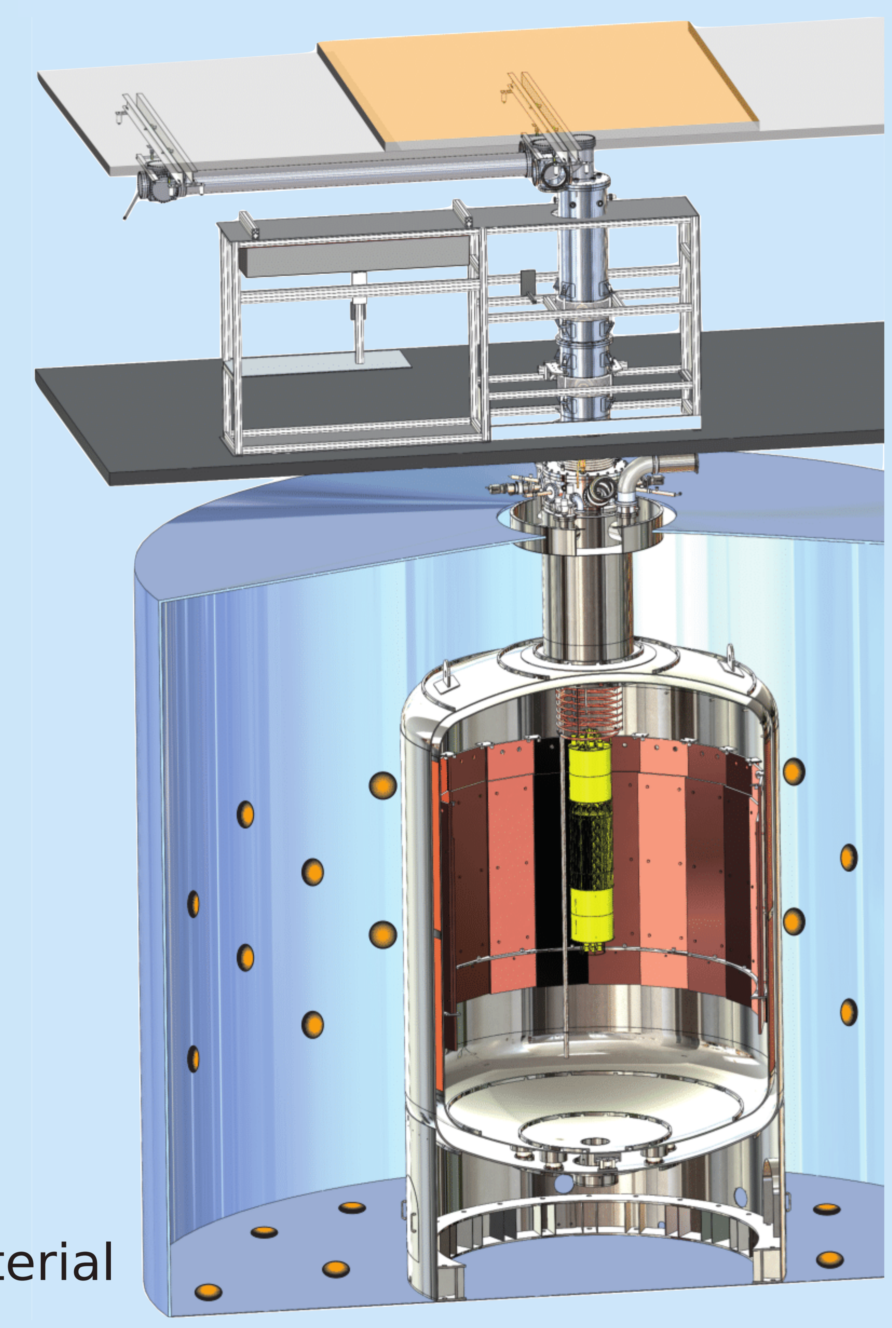
- Hypothetical non-standard model process, e.g. $^{76}Ge \rightarrow {}^{76}Se + 2e^-$
- Lepton number violation ΔL=2
- Neutrino nature, mass scale, hierarchy
- Peaked electron energy spectrum at $Q_{\beta\beta}$ (in ^{76}Ge at 2039 keV)

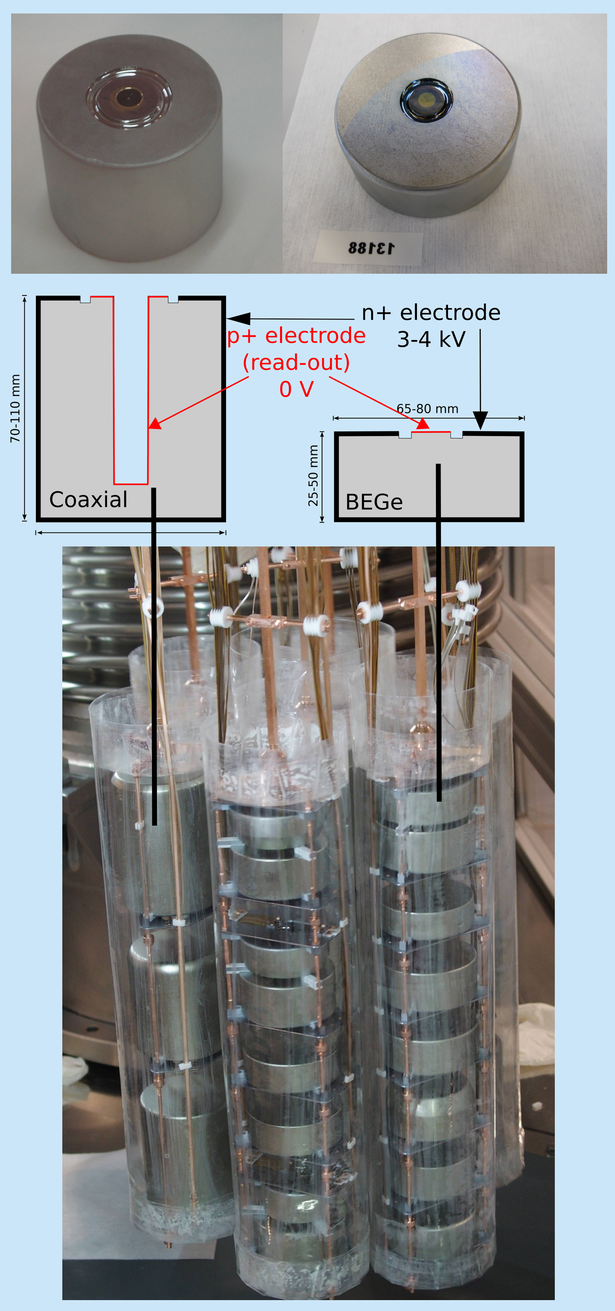


Above: Processes and signatures of double beta decay (left) and neutrinoless double beta decay (right)

The GERDA experiment

- GERmanium Detector Array [1]
- Germanium diodes (detector and source)
- Liquid argon veto (LAr)
- Passive copper shielding
- Water-Cherenkov detector for active shielding
- Low background environment:
  - Underground lab (LNGS)
  - Clean room access
  - Material selection
  - High intrinsic purity detector material





Above Left: Sketch of the GERDA experiment. The Ge detectors are contained within multiple layers of active and passive shielding.
Right: Picture of the Ge detectors. Two different types are used in GERDA, coaxial (upper left) and BEGe (upper right).

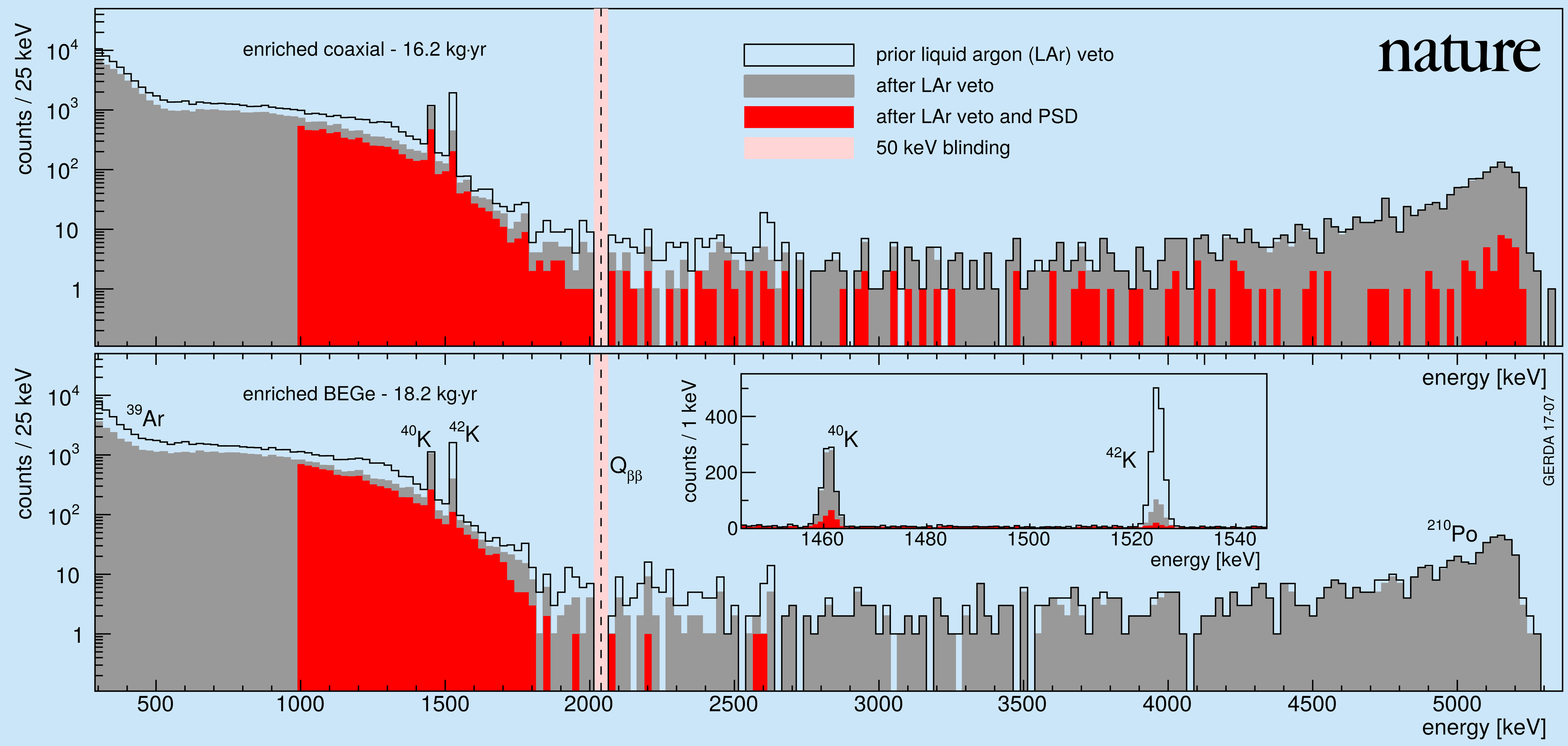
Germanium detectors

- Enriched 86% ^{76}Ge
- Inversely biased diodes
- 40 kg total mass
- energy resolution ~3 keV at $Q_{\beta\beta}$

Laboratori Nazionali del Gran Sasso (LNGS)

- Underground laboratory in Italy
- 1400 m below Gran Sasso massive
- 3500 m water equivalent shield against cosmic rays

Below: Energy spectrum of GERDA with various known backgrounds and analysis region indicated. After all background rejection cuts, the red spectrum remains.



Phase II $0\nu\beta\beta$ search [2]

- Started Dec. 2016
- Design 100 kg yr (~3 yr) July 2017: 34.4 kg yr
- Background free regime: Expect < 1 background event in 3 yr runtime
- Current world's best $0\nu\beta\beta$ half-life limit for ^{76}Ge:

$$T_{1/2} > 8 \times 10^{25}\ \text{yr}$$

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References

[1] K. H. Ackermann et al., The GERDA experiment for the search of neutrinoless double betadecay in ^{76}Ge, Eur. Phys. J. C73 no. 3, 2330, 2013.

[2] M. Agostini et al., Background free search for neutrinoless double beta decay with GERDA Phase II, Nature 544, 47–52, 2017.