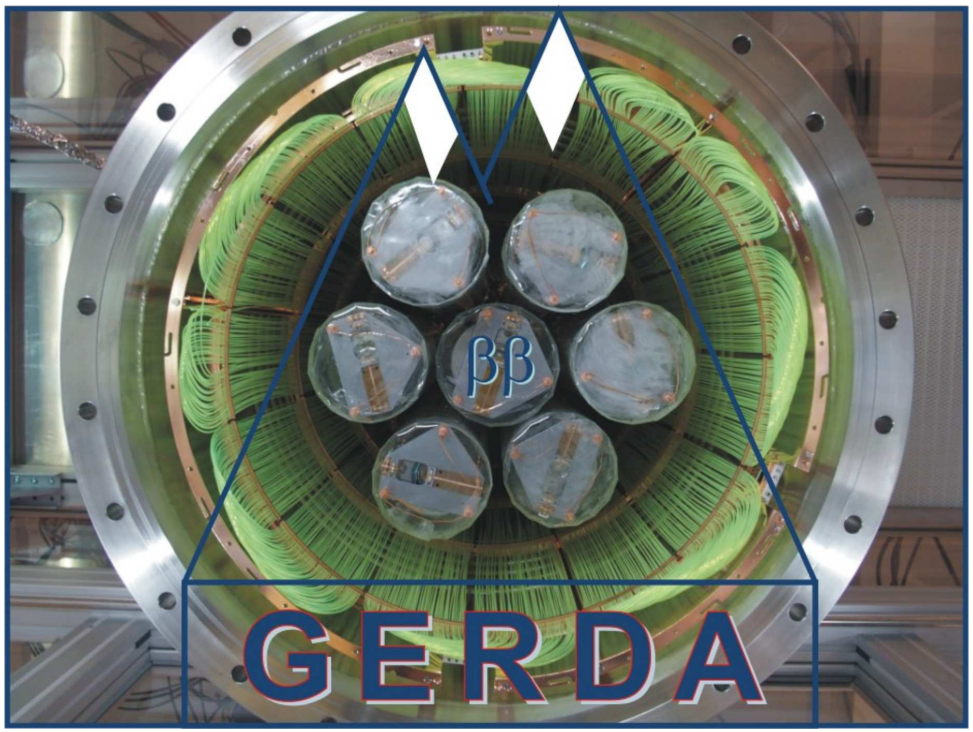
University of Zurich[UZH]

Physik-Institut

Background free search for $0\nu\beta\beta$ decay with GERDA

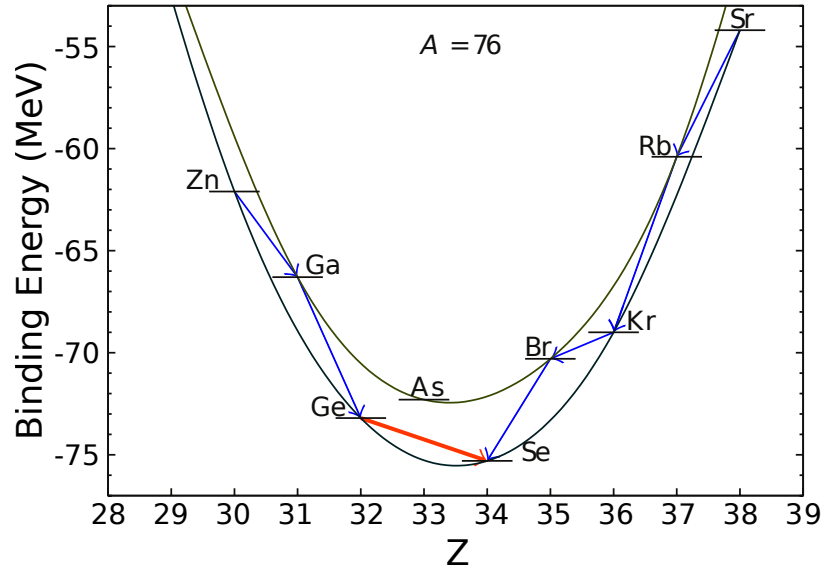
Roman Hiller for the GERDA collaboration

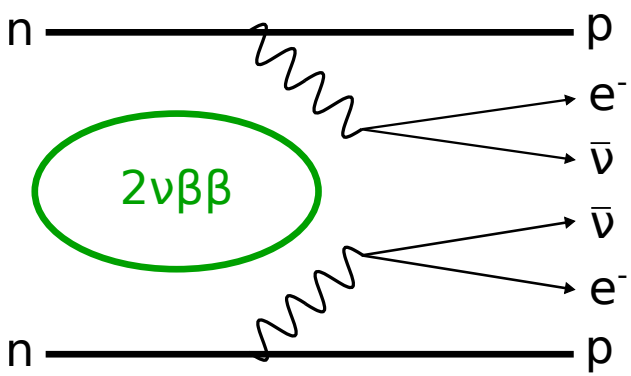


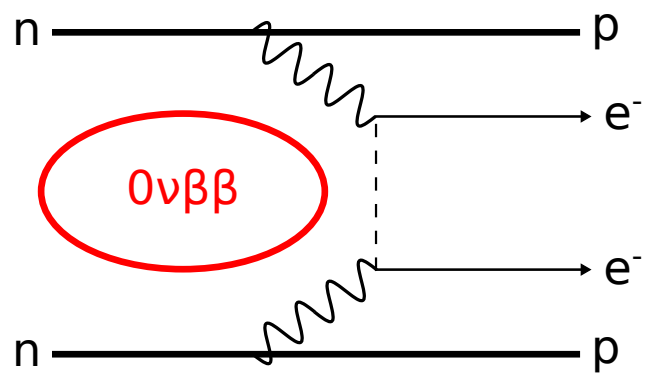
$0\nu\beta\beta$ Motivation

- Hypoth. process in even-even nuclei, e.g., (Z, N)$\rightarrow$(Z+2, N) + 2e$^-$
- Relation to $2\nu\beta\beta$ (Ge: $T_{1/2} = 1.926 \pm 0.095 \times 10^{21}$ yr)

  Eur. Phys. J. C 75 (2015) 416
- Theory: Dirac vs. Majorana fermion
- Lepton number violation
- Potentially sensitive to other ν properties



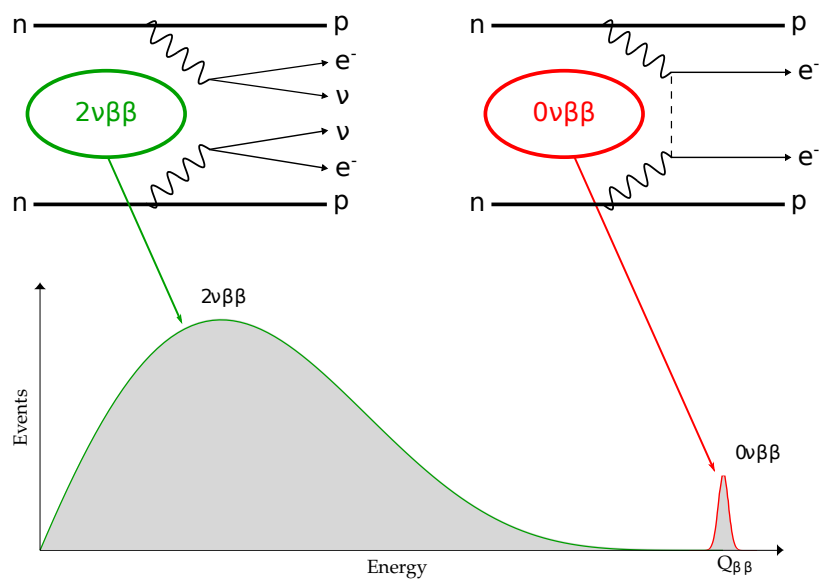




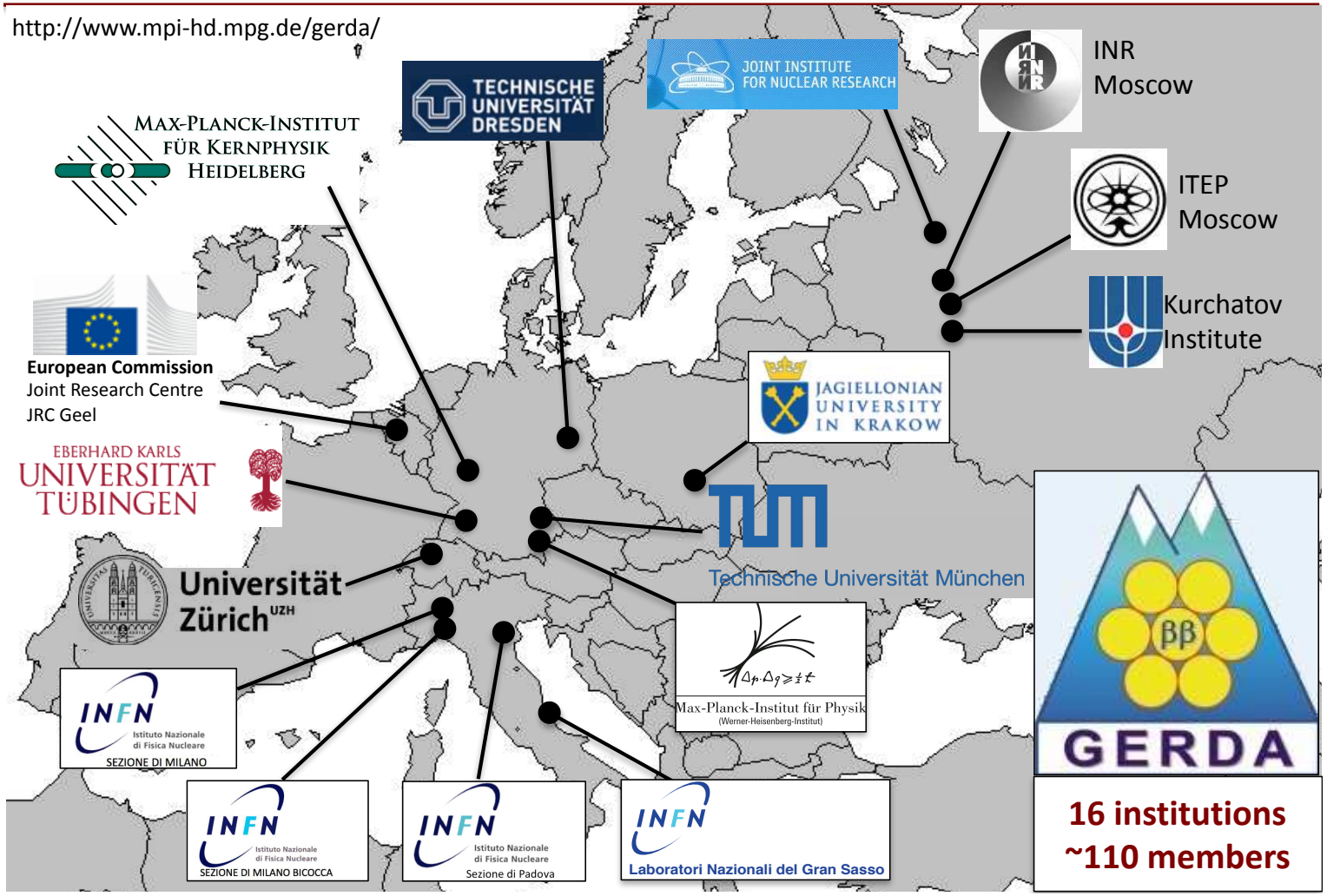
$0\nu\beta\beta$ Detection

- $0\nu\beta\beta$ signature = peak at $Q_{\beta\beta}$ in e^- spectrum
- $\mathcal{O}(10)$ experimentally interesting isotopes
- No clear favorite ($G|M|^2$ ~const.) $T_{1/2}^{-1} = G|M|^2 \left|\sum_{i=1}^{3} m_i U_{ei}\right|^2$
  G phase space integral, M nuclear matrix element
- Sensitivity $\sim$ abundance·efficiency·$\sqrt{\frac{\text{exposure}}{BI \cdot \Delta E}}$
  BI=background index, ΔE= energy resolution
- advatages of Ge: ΔE, detector tech. (BI, efficiency), enrichment

isotope	nat. ab.	$Q_{\beta\beta}$ (keV)
^{48}Ca	0.2%	4263
^{76}Ge	7.6%	2039
^{82}Se	9.2%	2998
^{96}Zr	2.8%	3348
^{100}Mo	9.6%	3035
^{116}Cd	7.6%	2813
^{130}Te	34.1%	2527
^{136}Xe	8.9%	2459
^{150}Nd	5.6%	3371

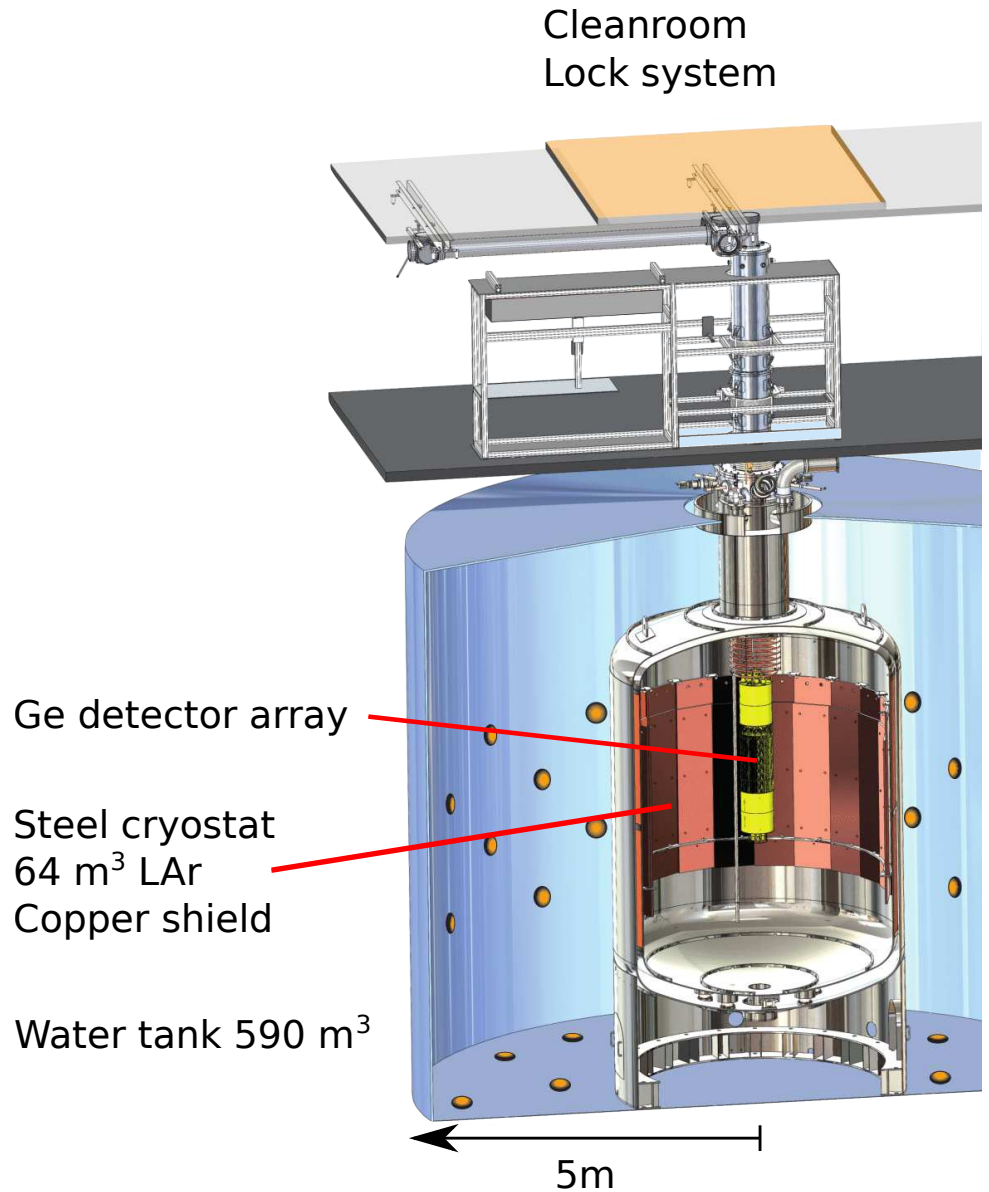


The GERDA Collaboration



GERDA concept

- Enriched ^{76}Ge detectors
- Cryostat /w liquid argon
- Innermost active shielding via LAr scintillation
- Wavelength shifting + PMT, SiPM
- Passive shielding
- WCD as μ veto

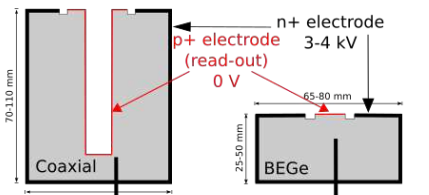


GERDA experiment

- LNGS, Italy, 3500 m.w.e., Muons $10^6 \rightarrow$1 per m^2 h
- Coaxial and BEGe type detectors
- 36 kg total Ge mass

Goals:

- BI$\sim 10^{-3}$ $\frac{\mathrm{cts}}{\mathrm{keV\ kg\ yr}}$
- 100 kg yr exposure $\rightarrow$ sensitivity $\sim 10^{26}$yr
- Demonstrate LAr veto concept



Eur. Phys. J. C 73 (2013) 2330

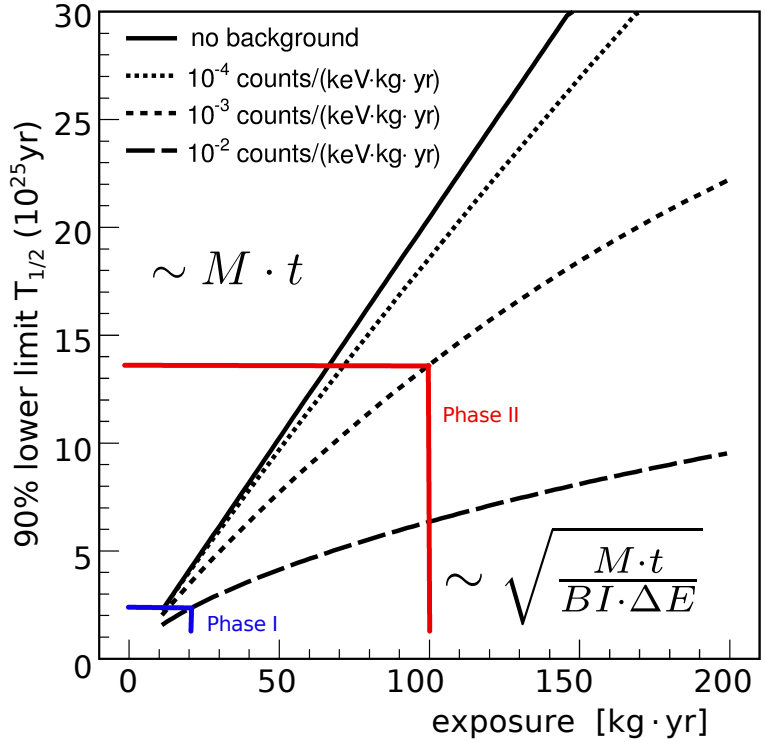
Phases of GERDA

Phase I (2011-2013):

- Completed with 21 kg yr exposure
- 18 kg refurbished HdM+IGEX detectors
- Only passive LAr shield
- BI$\sim$0.01 $\frac{\mathrm{cts}}{\mathrm{keV\ kg\ yr}}$

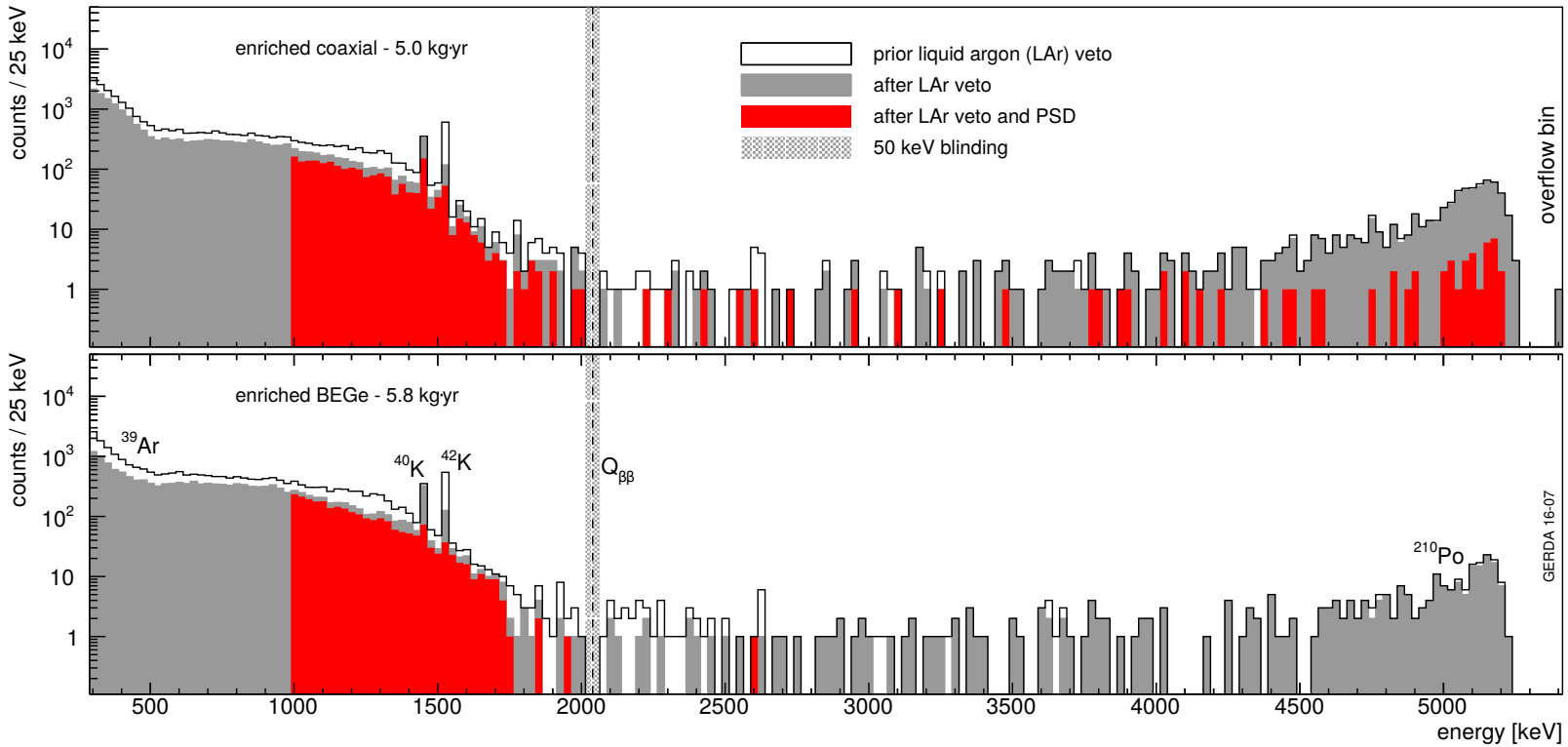
Phase II (Dec 2015-present):

- Add BEGe detectors (20 kg)
- Readout LAr
- BI$\sim$0.001 $\frac{\mathrm{cts}}{\mathrm{keV\ kg\ yr}}$
- Events at 2039$\pm$25 keV blinded
- Unblinding when certain exposure milestones reached after finalizing cuts



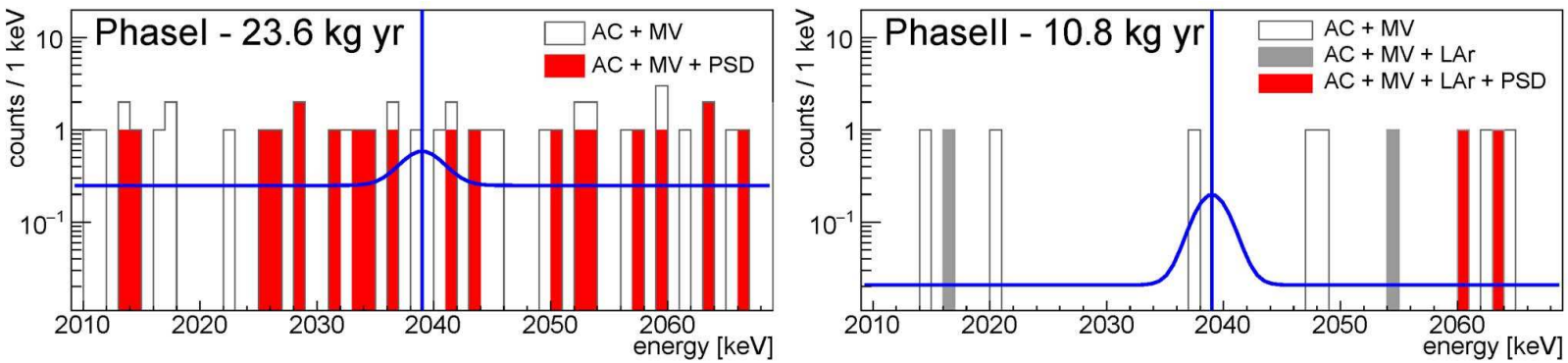
Phase IIa (Dec. 2015 - June 2016)

- First data release Phase IIa, Dec. 2015 - June 2016
- 10.8 kg yr Phase II exposure



Phase IIa

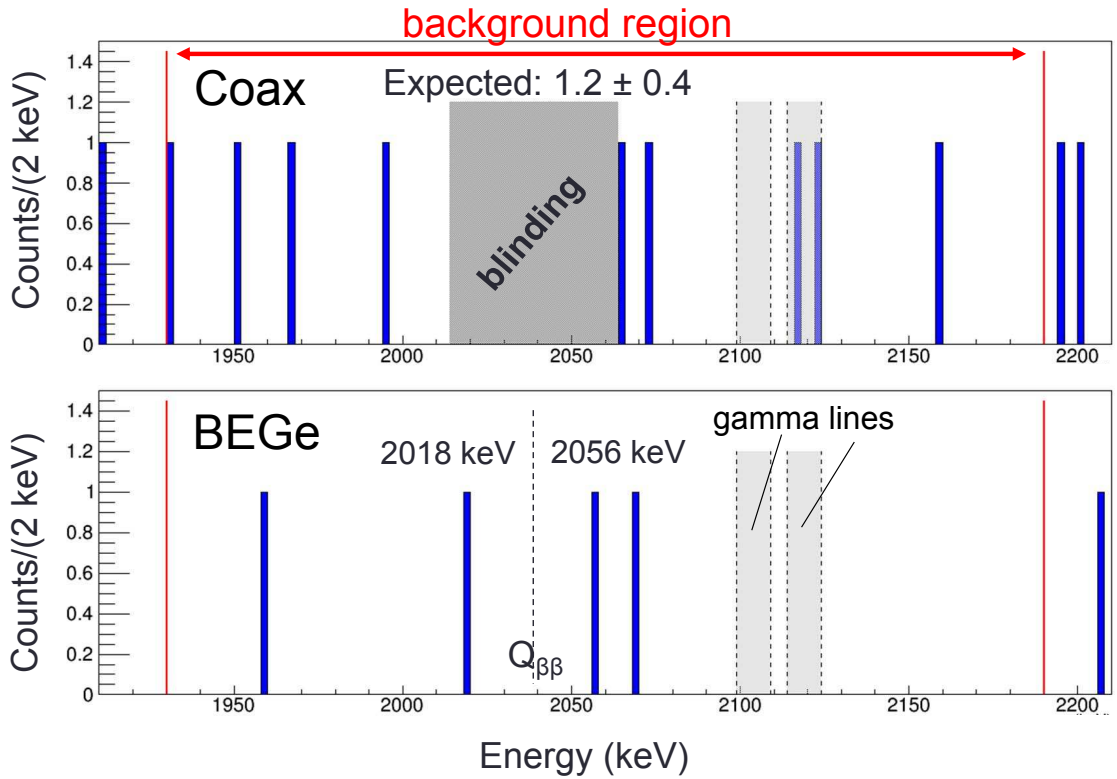
- Published in Nature 544 (2017) 47
  $T_{1/2} > 5.3 \cdot 10^{25}$ yr@90% CL (median sensitivity $4.0 \cdot 10^{25}$ yr)
  $BI_{Coax} = 3.5^{+2.1}_{-1.5} \cdot 10^{-3}$ cts/(keV kg yr), FWHM 4.2 keV
  $BI_{BEGe} = 0.7^{+1.1}_{-0.5} \cdot 10^{-3}$ cts/(keV kg yr), FWHM 3.0 keV
- Expected background < 1 cts for full design exposure



Phase IIb (June 2017)

Unblinding at collab. meeting in Krakow June 2017:

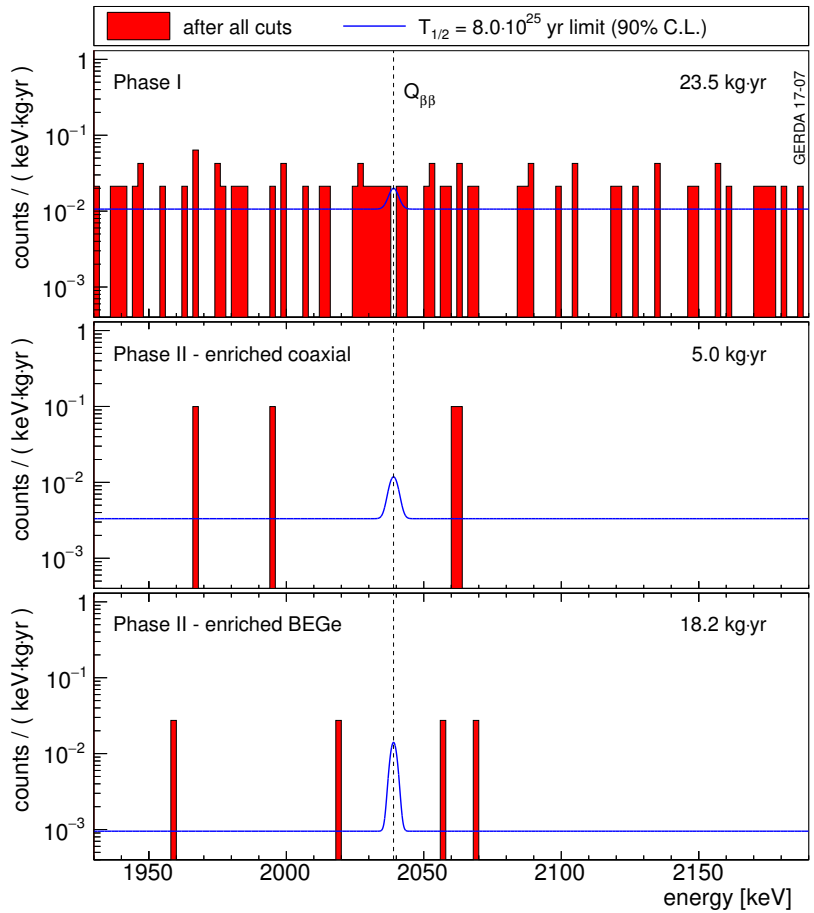
- Unblinded an additional 12.4 kg yr of BEGe data (for 18.2 kg yr total)
- Left 11.2 kg yr of new Coax data blind (16.2 kg yr total): background from groove events can probably be further suppressed
- $BI_{Coax} = 2.7^{+1.0}_{-0.0} \cdot 10^{-3}$ cts/(keV kg yr)
  $BI_{BEGe} = 1.0^{+0.6}_{-0.4} \cdot 10^{-3}$ cts/(keV kg yr)



ROI statistical analysis (preliminary)

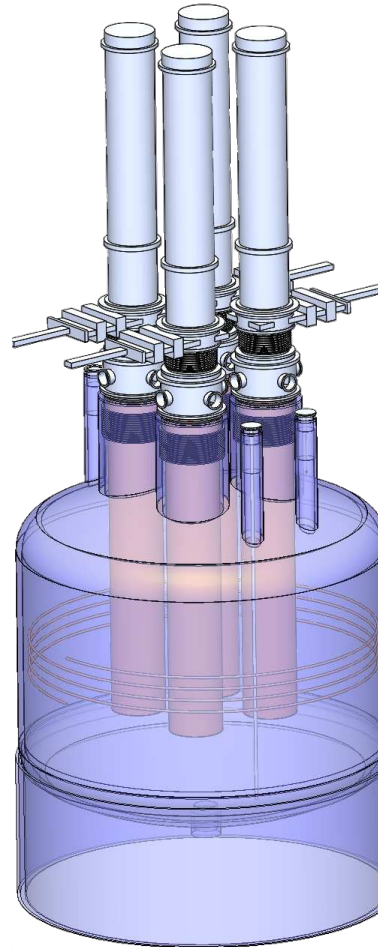
Combined unbinned maximum likelihood fit of all data sets of GERDA (PI and PII)

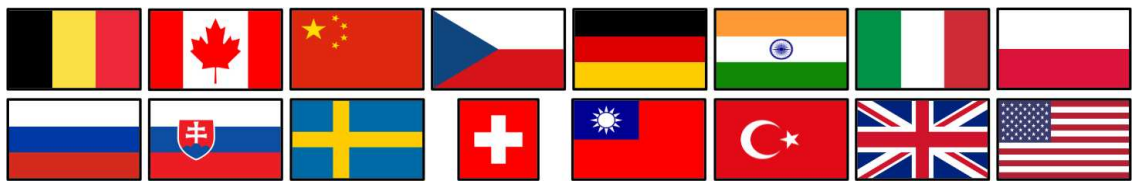
- **Frequentist**:
  Details on method: Agostini et al., Nature 544, 47-52, 2017
  - Best fit $N_{0\nu} = 0$
  - $T_{1/2} > 8.0 \cdot 10^{25}$ yr @ 90% CL
  - Median sensitivity (limit) $5.8 \cdot 10^{25}$ yr
- **Bayesian**:
  Flat prior on $1/T_{1/2}$ between 0 and 10^{-24} yr
  - $T_{1/2} > 5.1 \cdot 10^{25}$ yr @ 90% CI
  - Median sensitivity $4.5 \cdot 10^{25}$ yr



LEGEND

- Large Enriched Germanium Experiment for Neutrinoless $\beta\beta$ Decay
- Collaboration formed October 2016 (GERDA, Majorana, others)
- 1ṫ scale experiment to reach 10^{28} yr sensitivity ($10^{-5}\,\frac{\mathrm{cts}}{\mathrm{keV\,kg\,yr}}$)
- First 200 kg stage at LNGS ∼2020





216 members, 48 institutions, 16 countries

Conclusion

- GERDA Phase II accumulated 34 kg yr exposure over the last 1.5 yr
- Confirmed background level at $Q_{\beta\beta}$ 2.7 (Coax) and 1.0 (BEGe) [10^{-3}cts/keV kg yr]
- "Background free" (<1 cts in 1 FWHM) up to design exposure of 100 kg yr
- $T_{1/2} > 8.0 \cdot 10^{25}$ yr @ 90% CL
- Projected sensitivity 10^{26} yr (limit) mid-2018