SEARCHING FOR THE NEUTRINOLESS DOUBLE BETA DECAY WITH GERDA



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on behalf of the GERDA Collaboration



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### Looking for <sup>76</sup>Ge decay with GERDA

**GERmanium Detector Array** (INFN-LNGS, Italy) searches for 0v2β decay in <sup>76</sup>Ge using HPGe detectors enriched in <sup>76</sup>Ge

<u>Design strategy</u>: **«zero background» regime** for the entire exposure (100 kg yr)





 $Q_{\beta\beta}$ -value = **2039 keV** in <sup>76</sup>Ge Energy resolution <4 keV FWHM  $\rightarrow$  important for discovery

## **GERDA: the Collaboration**



## **GERDA: the concept**

Eur. Phys. J. C 73 (2013) 2330 Nature 544 (2017) 47 Phys Rev Lett 128 (2018) 13 Science 365 (2019) 1445



### **GERDA: the concept**



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### **GERDA: the concept**



# **GERDA** history and Ge detectors



### **Background reduction tools**



**Point-like (single-site)** energy deposition inside one HP-Ge diode

**Multi-site** energy deposition inside HP-Ge diode (Compton scattering), or **surface** events

- Anti-coincidence with the muon veto
- Anti-coincidence between detectors (cuts multi-site)
- Active veto using LAr scintillation



- Anti-coincidence with the muon veto
- Anti-coincidence between detectors (cuts multi-site)
- Active veto using LAr scintillation
- Pulse shape discrimination (PSD)
  - MSE within one detector and surface events
  - Very efficient for the BEGe and inverted coaxial detectors
    - Accept >90% of SSE, while rejecting 90% of MSE and surface events
  - Less efficient with semi-coaxial detectors, but still doable (acc: 90%/ suppr: 50%)

Eur. Phys. J. C 73 (2013) 2583 Science 365 (2019) 1445

#### Data taking

#### Science 365 (2019) 1445

- Data taking completed in Dec 2019!
  - Target exposure of 100 kg yr achieved
  - 58.9 kg yr already analyzed for 0vββ decay, rest to be unblinded soon



- Energy scale & resolution
  - Offline, using optimized ZAC filter on traces (digitized at 25 MHz) [EPJ C 75, 255]
  - Stability monitored online with test pulses, 0.05 Hz
  - Energy scale and resolution profile derived from weekly <sup>228</sup>Th calibrations

Energy resolution @ $Q_{\beta\beta}$ 

Coax: 4.2(1) keV BEGe: 2.7(1) keV InvCoax: 2.9(1) keV

#### **GERDA** spectra: active veto



• Most prominent features > 500 keV:  $2\nu\beta\beta$ ,  $^{42}$ K and  $^{40}$ K  $\gamma$ -rays,  $\alpha$ 

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## GERDA spectra: active veto and PSD



- Most prominent features > 500 keV:  $2\nu\beta\beta$ ,  $^{42}K$  and  $^{40}K\gamma$ -rays,  $\alpha$
- PSD clears completely the  $\alpha$  region
- LAr and PSD complementary
- Final background at  $Q_{\beta\beta}$  O(10<sup>-3</sup> cts/(keV kg yr))

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# 0vββ analysis

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	Exposure (kg⋅yr)		cien
Phase I	23.5	Nature 544	ce 3
Phase II – coax1	5.0	(2017) 47	35 (2
Phase II – coax2	23.1		019
Phase II - BeGe	30.8		) 144
8 <mark>2.4 kg yr</mark>			5



#### Combined unbinned maximum likelihood fit

- Frequentist: test statistics and method after Cowan et al., EPJC 71 (2011) 1554
- Bayesian: flat prior on 1/T<sub>1/2</sub> between 0 and 10<sup>-24</sup> yr<sup>-1</sup>
- Systematic uncertainties folded as pull terms or by Monte Carlo Nature 544 (2017) 47

• Frequentist:

Best fit:  $N^{0v} = 0$ 

T<sub>1/2</sub> > 0.9 10<sup>26</sup> yr @ 90% CL m<sub>ββ</sub> < (100 - 230)meV

MC **Median sensitivity** (no signal):

**1.1 10<sup>26</sup> yr** (for 90% C.L.) 65% chance to have a better limit than what actually seen

# Post-upgrade background

#### C. Wiesinger, Talk at TAUP2019

- Background after the «minor upgrade» of 2018 is comparable with the previous Phase II performance
  - Background of the new Inv Coax detectors also very good
- Globally in Phase II: (5.6<sup>+2.1</sup>-1.7)10<sup>-4</sup> cts/(keV kg yr)
  - <u>Design goal</u>: 10·10<sup>-4</sup> cts/(keV kg yr)
- Data blinded for 0vββ analysis



# Conclusions

#### GERDA Phase II completed the data taking

- Met design goals in exposure (> 100 kg yr) and in background level (< 10<sup>-3</sup> cts/(keV kg yr))
- Lowest background (~10x) in ROI wrt other isotopes
- First experiment to surpass 10<sup>26</sup> yr in median sensitivity
- About 40 kg yr blinded data, to be unblinded shortly
  - Expect sensitivity ~1.3 · 10<sup>26</sup> yr
- Tested inverted coaxial detectors
- LEGEND is ready to take over infrastructure
  - first stage ~200kg
  - start taking data with LEGEND-200 in 2021

