Status of the GERDA experiment

Fabiana Cossavella for the GERDA collaboration

Max-Planck Institut für Physik, München

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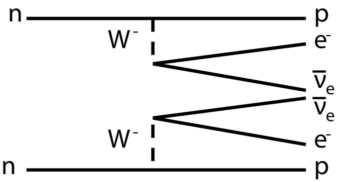
Outline

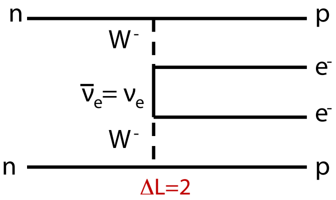
- Introduction
- the GERDA experiment: construction and status
- background measurements in GERDA
- conclusions

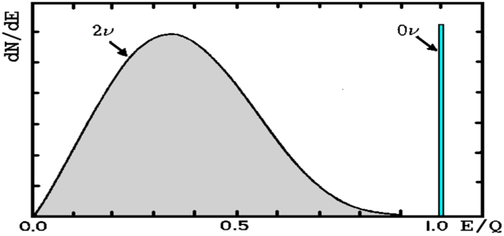
Search for $0\nu\beta\beta$ *decay*

Neutrino accompanied Double-Beta Decay:



Neutrinoless Double-Beta Decay:

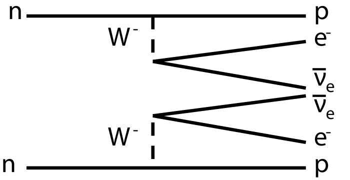




Signature: Sharp peak at Q-value of the decay (2039 keV for ^{76}Ge)

Search for $0\nu\beta\beta$ *decay*

Neutrino accompanied Double-Beta Decay:



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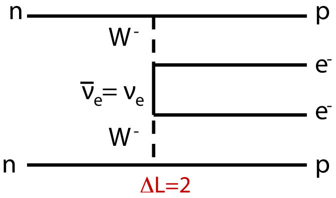


If neutrino-less double beta-decay is observed:

- neutrino is a Majorana particle
- information on absolute mass scale

$$1/\tau = G(Q,Z) \; |M_{nucl}|^2 \; \langle m_{ee} \rangle^2$$

0νββ Decay rate | Phase space factor | Matrix element | Effective Majorana Neutrino mass

$$\langle \mathbf{m_{ee}} \rangle = \left| \sum_i |\mathbf{U_{ei}}|^2 \mathbf{e}^{i\beta_i} \mathbf{m_i} \right|$$

The experimental challenge

about 30 isotopes available, but:

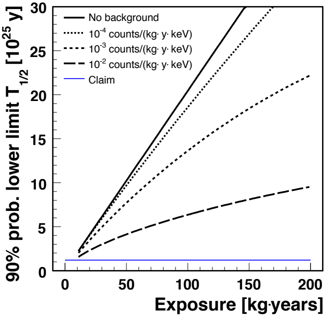
$$\text{sensitivity on } T_{1/2} \propto \epsilon \cdot A \cdot \sqrt{\frac{M \cdot T}{b \cdot \Delta E}}$$

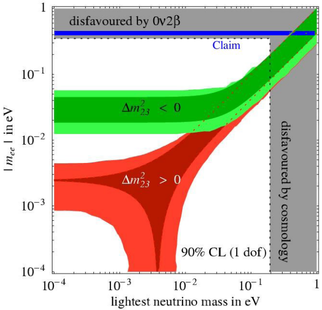
ϵ	detection efficiency	$\sim$ 85% if detector=source
A	isotopic abundance	high natural i.a. or enrichment!
M	active target mass	increase mass
T	measuring time	
b	background rate (cts/(keV kg yr))	minimize & select radio-pure material
ΔE	energy resolution	use high resolution spectroscopy

Experimental approach: improve exposure (M·T) and resolution, reduce background.

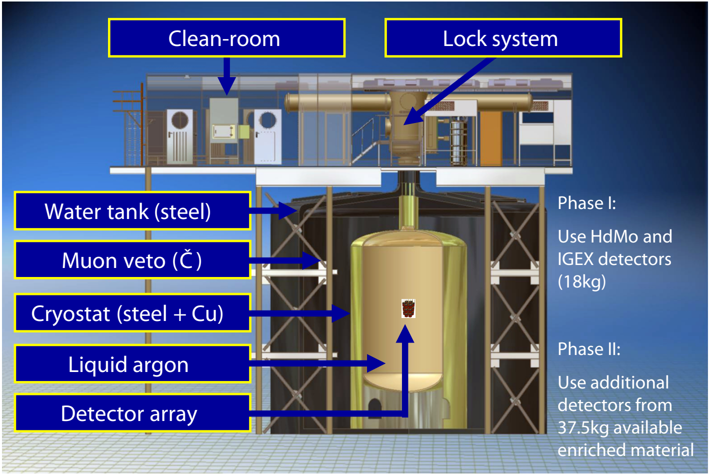
GERDA physics goals

Phase	I	II	Ton Scale
Exposure [kg ·yr]	15	100	>1000
Bg [counts/kg ·keV ·yr]	10^{-2}	10^{-3}	10^{-4}
Upper limit $m_{\beta\beta}$ [eV]	0.23-0.39	0.09-0.15	~ 0.05
A. Smolnikov, P. Grabmayr			Merge
PRC 81 028502(2010)			with Majorana





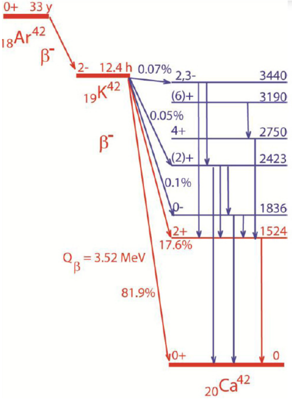
The GERmanium Detector Array

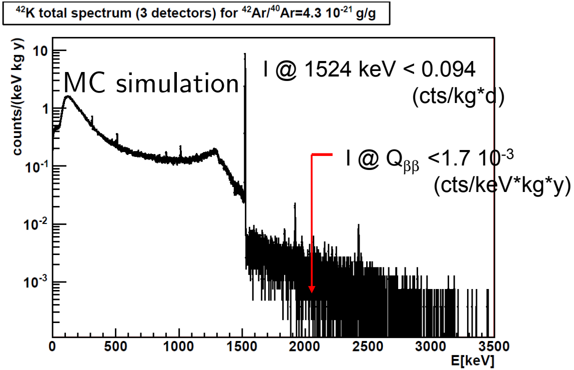


@ LNGS: suppression of μ-flux $> 10^6$

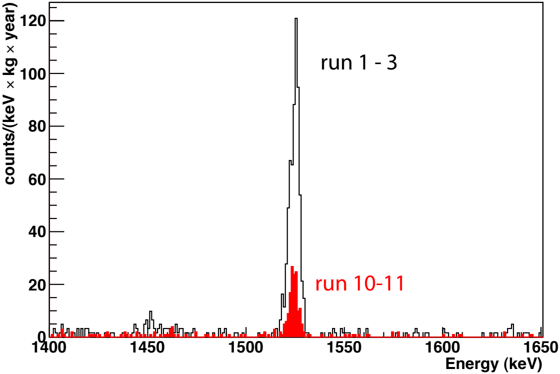
Commissioning runs (2010) : the ^{42}Ar

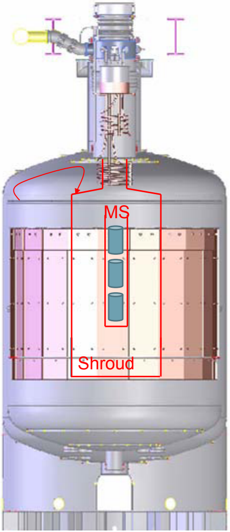
- production: ^{40}Ar(α,2p)^{42}Ar reaction in atmosphere and fall-out from atmospheric nuclear explosion





GERDA background with mini-shroud





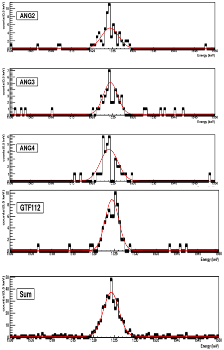
Observed : $I_{\mathrm{measured}} > 10\ I_{\mathrm{expected}}$

Tested different electric field configuration by biasing shroud and mini-shroud

Determination of ^{42}Ar activity

previously: $< 41\ \mu$Bq/kg (90% CL) A.S. Barabash (2002)

GERDA:
Measurement in best ‘E-field free’ configuration & comparison MC



1525 keV

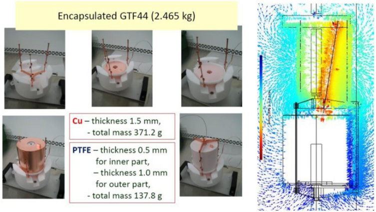
enriched

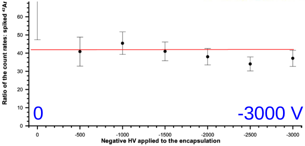
natural

sum

A_{spec} = (92.8 ± 5.2 ± 4.5) μBq/kg

LArGe:
LAr spiked with known amount of ^{42}Ar & measurements at different HV



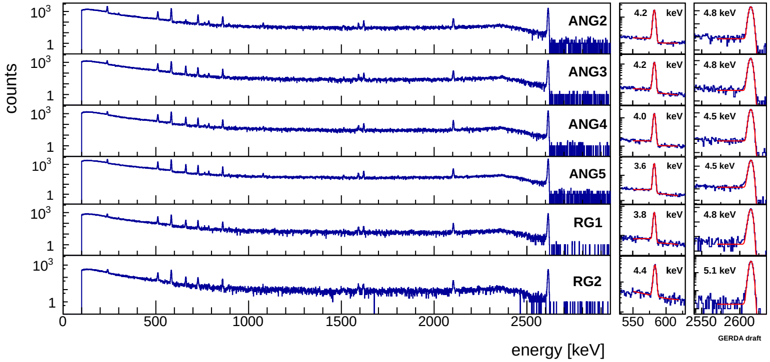


A_{ratio} = (94.5 ± 4.7 ± 17.5) μBq/kg

GERDA measurement: $(93.0 \pm 6.4)\ \mu$Bq/kg stat.+syst.

Current status

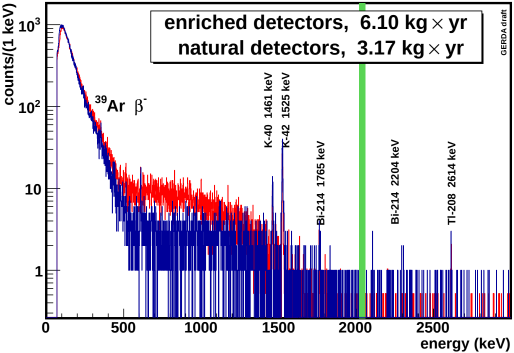
phase I started in November 2011:



- 6 working ^{enr}Ge detectors: 14.63 kg
- 3 ^{nat}Ge detectors: 7.6 kg
- resolution, FWHM: 4.5 keV at 2.6 MeV (mass weighted average)

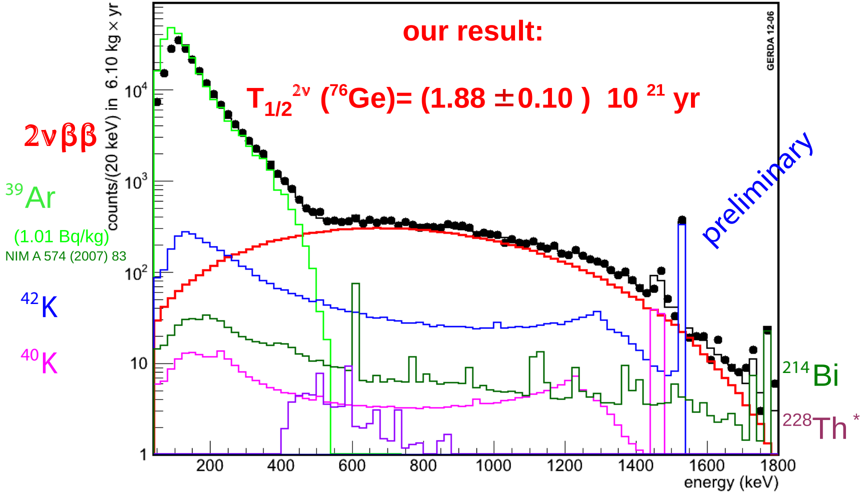
Current status

- low background: few γ lines
- duty cycle 92.6% without run 31 (data quality problems)
- overall duty cycle 78.3%
- since January 2012: blinding at $(Q_{\beta\beta} \pm 20)$ keV
- unblinding when sufficient exposure is reached
- establish analysis procedures to be employed on $0\nu\beta\beta$ data after unblinding



^{nat}Ge, 3.17 kg y ^{enr}Ge, 6.10 kg y

Current results: $2\nu\beta\beta$ spectrum



Current results: $2\nu\beta\beta$ spectrum

- 600 keV - 1800 keV
- $2\nu\beta\beta$ of ^{76}Ge homogeneously distributed in the detectors
- ^{42}K unifor. distributed in LAr
- ^{40}K, ^{214}Bi in detector holders
- binned max. likelihood approach
- free parameters:
  - active mass, enrichment: x6 detectors
  - integral rates of ^{40}K, ^{42}K, ^{214}Bi: x6 detectors
  - $T_{1/2}^{2\nu}$

Current results: $2\nu\beta\beta$ spectrum

authors	data	half live $T_{1/2}^{2\nu\beta\beta}$ $[10^{21}$ yr]
IGEX collaboration [1]	IGEX	1.45 ± 0.20
HDM collaboration [2]	HDM	$1.55 \pm 0.01(\text{stat})\ ^{+0.19}_{-0.15}(\text{syst})$
C. Dörr and H.V. Klapdor-Kleingrothaus [3]	HDM	$1.74 \pm 0.01(\text{stat})\ ^{+0.18}_{-0.16}(\text{syst})$
A.M. Bakalyarov *et al.* [4]	HDM	$1.78 \pm 0.01(\text{stat})\ ^{+0.07}_{-0.09}(\text{syst})$
A.S. Barabash, compilation [5]	weighted average	1.50 ± 0.10
GERDA with ~1/10 statistics of HDM	run 25-30	1.88 ± 0.10

stat+syst in quadr.
PRELIMINARY

[1] A. Morales, Nucl. Phys. B. Proc. Suppl. **77** (1999) 335
J. Morales and A. Morales, Nucl.Phys. B Proc.Suppl. **114**

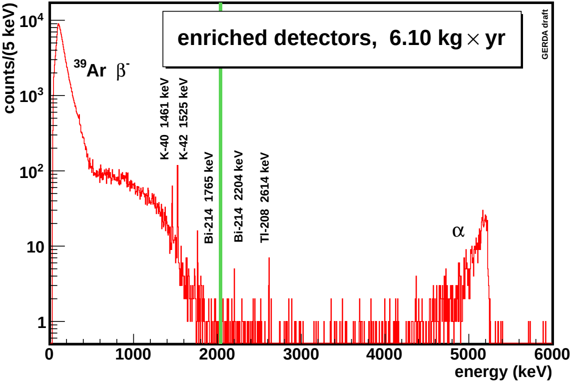
[2] H.V. Klapdor-Kleingrothaus *et al.*, Eur. Phys. J. A **12** (2001) 147, (2003) 141

[3] C. Dörr and H.V. Klapdor-Kleingrothaus, Nucl. Inst. Meth. A **513** (2003) 596

[4] A.M. Bakalyarov *et al.*, Phys. Part. Nucl. Lett. **2** (2005) 77

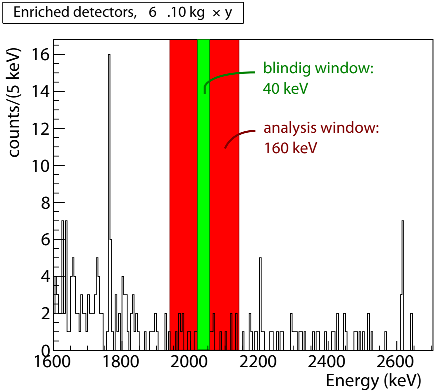
[5] A.S. Barabash, Phys. Rev. C, **81** (2010) 035501

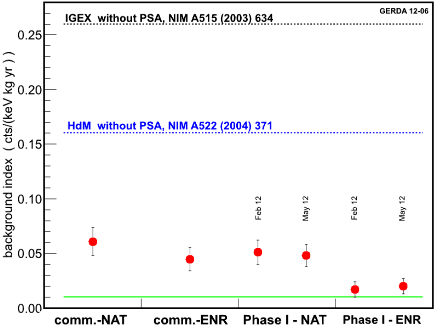
Current results: alpha contribution



- Alpha candidate occur events with varying frequency for each detector suggesting a surface contamination mostly on two detectors

Current results: background index





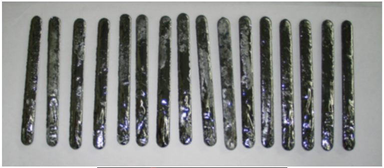
current background index (NO PSA): $0.020^{+0.006}_{-0.004}$ cts/(keV kg yr)

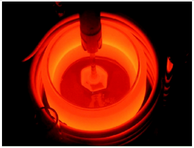
I @ 1764 keV and @ 2615 keV: factor of 10 lower than in HdM

Ge-Procurement and Detector fabrication for Phase II

complete production chain tested with depleted Ge:

- 2009: 37.5 kg GeO2 produced by ECP, Zelengorsk, Russia
- 2010: Reduction and zone refinement, PPM Metals GmbH, Rammelsberg, Germany
- 2011: Transport to Oak Ridge, United States
- 2011-12: Crystal pulling and cutting, Canberra, Oak Ridge
- 2012: Diode fabrication & testing, Canberra, Geel, Belgium.





GERDA Phase II

- Detector Production Status
  - crystals pulling completed: 9 crystals
  - 7 diodes produced: resolution of 1.7 keV @ 1.3 MeV in vacuum cryostat
  - 5 diodes being prepared for insertion in phase-I
- Improve sensitivity:
  - increase mass: 26+ enriched diodes expected by Fall 2012
  - BEGe detectors: good pulse shape discrimination
  - LAr readout to further suppress background
- complete Phase I and start Phase II in early 2013

Conclusions

- GERDA aims to determine $T^{0\nu}_{1/2}$ of ^{76}Ge via an innovative approach: concept working!
- from 1.11.2011 until 21.05.2012 GERDA has accumulated 6.10 kg·yr $^{\mathrm{enr}}$Ge exposure
- blinded ROI: 2019 keV to 2059 keV
- the current BI is $0.020 + 0.006 - 0.004$ cts/(keV kg y)
- determined ^{42}Ar activity: (93.0 ± 6.4) μBq/kg (preliminary)
- preliminary $T^{2\nu}_{1/2} = (1.88 \pm 0.10) \cdot 10^{21}$ yr (stat+syst)
- preparation for Phase II in progress

backups

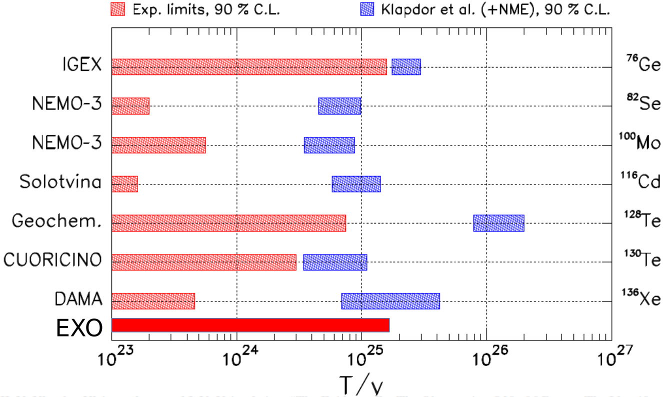
		^{nat}Ge–dets (3.2 kg·y)		^{enr}Ge–dets (6.1 kg·y)		HdM	ratio
isotope	energy [keV]	tot/bck [cnt]	rate [cnt/(kg·y)]	tot/bck [cnt]	rate [cnt/(kg·y)]	rate [cnt/(kg·y)]	HdM/enr
^{40}K	1460.8	85 / 15	$21.7^{+3.9}_{-3.1}$	125 / 42	$13.5^{+2.5}_{-2.2}$	181 ± 2	13
^{60}Co	1173.2	43 / 38	< 5.8	182 / 152	$5.1^{+3.1}_{-3.1}$	55 ± 1	11
	1332.3	31 / 33	< 3.8	93 / 101	< 3.1	51 ± 1	
^{137}Cs	661.6	46 / 62	< 3.2	335 / 348	< 5.9	282 ± 2	> 47
^{228}Ac	910.8	54 / 38	$5.0^{+3.0}_{-3.0}$	294 / 303	< 11.1	29.8 ± 1.6	
	968.9	64 / 42	$6.7^{+3.8}_{-3.1}$	247 / 230	< 15.2	17.6 ± 1.1	
^{208}Tl	583.1	56 / 51	< 6.5	333 / 327	< 7.6	36 ± 3	
	2614.5	9 / 2	$2.1^{+1.2}_{-1.0}$	10 / 0	$1.5^{+0.7}_{-0.5}$	16.5 ± 0.5	11
^{214}Pb	352	740 / 630	$34.6^{+15.2}_{-12.4}$	1770 / 1688	$13.2^{+11.5}_{-7.9}$	138.7 ± 4.8	11
^{214}Bi	609.3	99 / 51	$14.8^{+4.9}_{-3.5}$	351 / 311	$6.2^{+4.7}_{-4.0}$	105 ± 1	
	1120.3	71 / 44	$8.4^{+3.8}_{-3.4}$	194 / 186	< 6.1	26.9 ± 1.2	
	1764.5	23 / 5	$5.5^{+2.0}_{-1.6}$	24 / 1	$3.6^{+0.9}_{-0.9}$	30.7 ± 0.7	~ 10
	2204.2	5 / 2	$0.8^{+0.9}_{-0.7}$	6 / 3	$0.4^{+0.4}_{-0.4}$	8.1 ± 0.5	

backups

Comparison of upper limits (90 % C.L.) with claim [16] for QRPA NME

A.Faessler, G.L. Fogli, E. Lisi, V. Rodin, A.M. Rotunno, F. Simkovic, PhysRevD.79.053001
arXiv:0810.5733v2

(EXO result included by 'hand')



[16] H. V. Klapdor-Kleingrothaus and I. V. Krivosheina, "The Evidence For The Observation Of $0\nu\beta\beta$ Decay: The Identification Of $0\nu\beta\beta$ Events From The Full Spectra," Mod. Phys. Lett. A **21**, 1547 (2006).

backups

mini-shroud: 60 μm Cu foil