The GERDA Experiment: Status and Results

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for the GERDA collaboration

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GERDA

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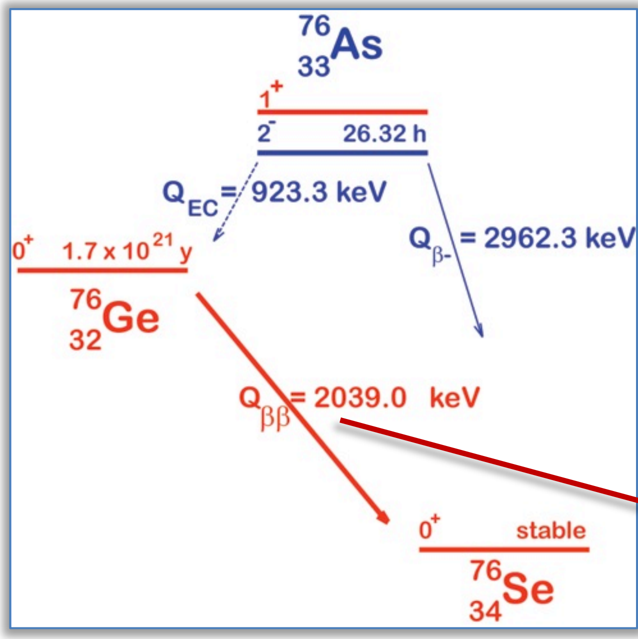
~ 100 members
19 institutions
6 countries

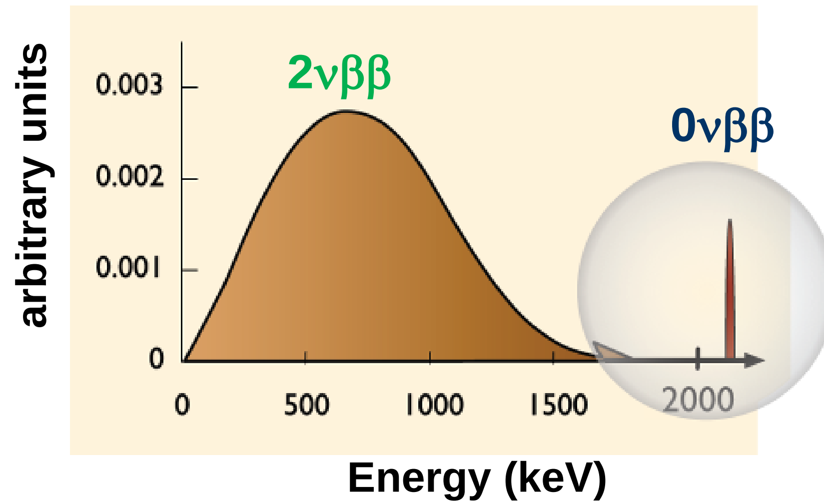
Outline

1. The GERDA experiment
   - short introduction
2. Status of Phase I
   - installation
   - measurements & preliminary results
3. Perspectives for Phase II
   - the detectors
   - R&D

Physics of the GERDA Experiment

Search for the half-life of the 0νββ–decay of ^{76}Ge





2νββ: $(A,Z) \rightarrow (A,Z+2) + 2e^- + 2\bar{\nu}_e$

0νββ: $(A,Z) \rightarrow (A,Z+2) + 2e^-$

Majorana nature of neutrino
Physics beyond SM
Absolute mass scale

- Hierarchy: degenerate, inverted or normal
- (effective) neutrino mass

Best limits on 0ν®®–decay used ^{76}Ge (86%) (IGEX & Heidelberg-Moscow):

$T_{1/2}$> 1.9 ×10^{25}y (90%CL)

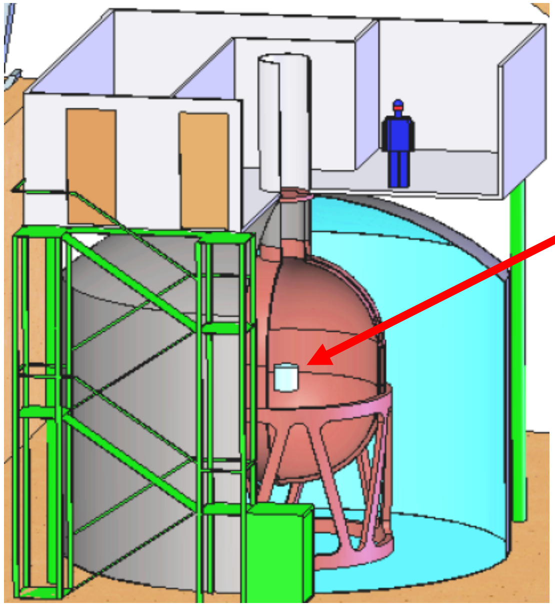
(@ 6σ claim for evidence)

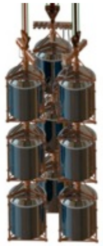
Sensitivity of the GERDA Experiment

$$T_{1/2}^{0\nu}(y) > \frac{\log 2 \cdot N_A}{k_{CL}} \cdot \frac{\varepsilon \cdot k_{enr}}{A} \cdot \sqrt{\frac{M \cdot t}{B \cdot \Delta E}}$$

- well established enrichment technique (reasonable cost for > 80%)
  $\Rightarrow$ enrichment k_{enr} = 86% ^{76}Ge
- established detector technologies
  $\Rightarrow$ large total mass M (expandable)
- very good energy resolution:
  $\Rightarrow$ small ΔE ~ 2-3 keV
- very good detection efficiency because detectors are made of source material
  $\Rightarrow$ ε ~ 1
- detector-grade semiconductors are high-purity materials (low background)
  $\Rightarrow$ small direct contribution to the background index B

Optimize the parameters





- Bare Ge-diodes array in LAr

+

- Shield: high-purity LAr/H_2O

Background Sources in GERDA

Source	B [10^{-3} cts/(keV kg yr)]
Ext. γ from ^{208}Tl (^{232}Th)	<<1
Ext. neutrons	<0.05
Ext. muons (veto)	<0.03
Int. ^{68}Ge ($t_{1/2}$= 270 d)	**12**
Int. ^{60}Co ($t_{1/2}$= 5.27 y)	**2.5**
^{222}Rn in LAr	<0.2
^{208}Tl, ^{238}U in holder	<1
Surface contamination	<0.6

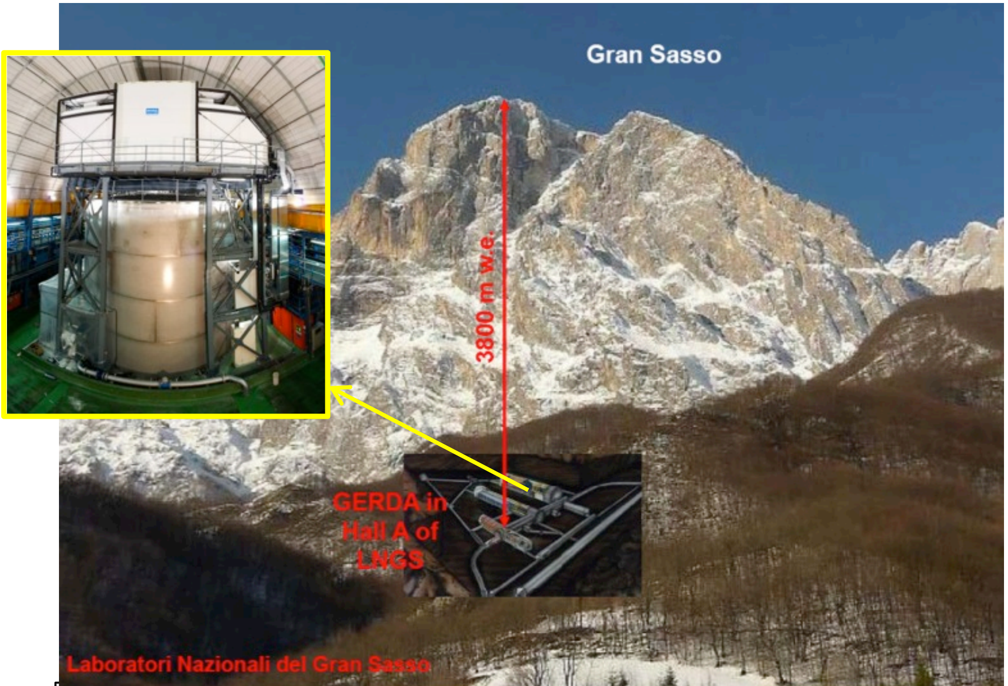
Muon veto

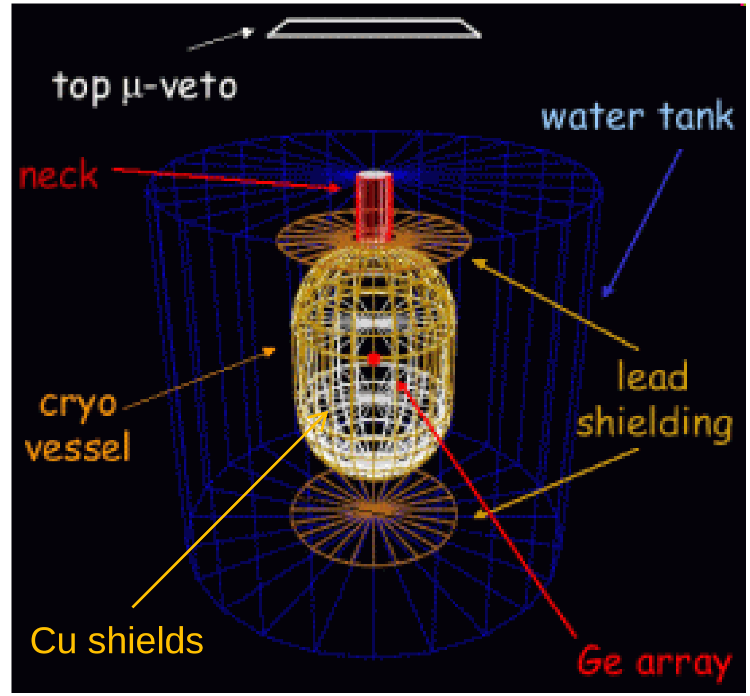
180 days exposure after enrichment + 180 days underground storage

30 days exposure after crystal growing

Target values: Phase I: B < 10^{-2} cts/(keV· kg· yr)
Phase II: B < 10^{-3} cts/(keV· kg· yr)

Background Reduction in GERDA





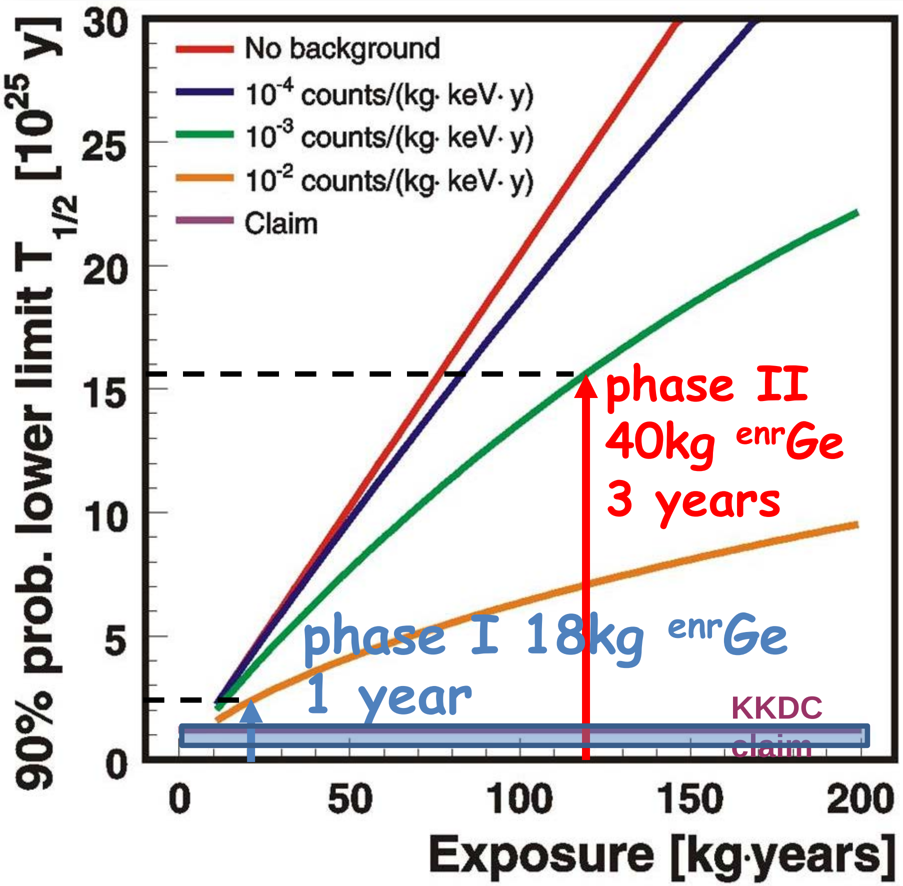
Suppression of μ-flux > 10^6

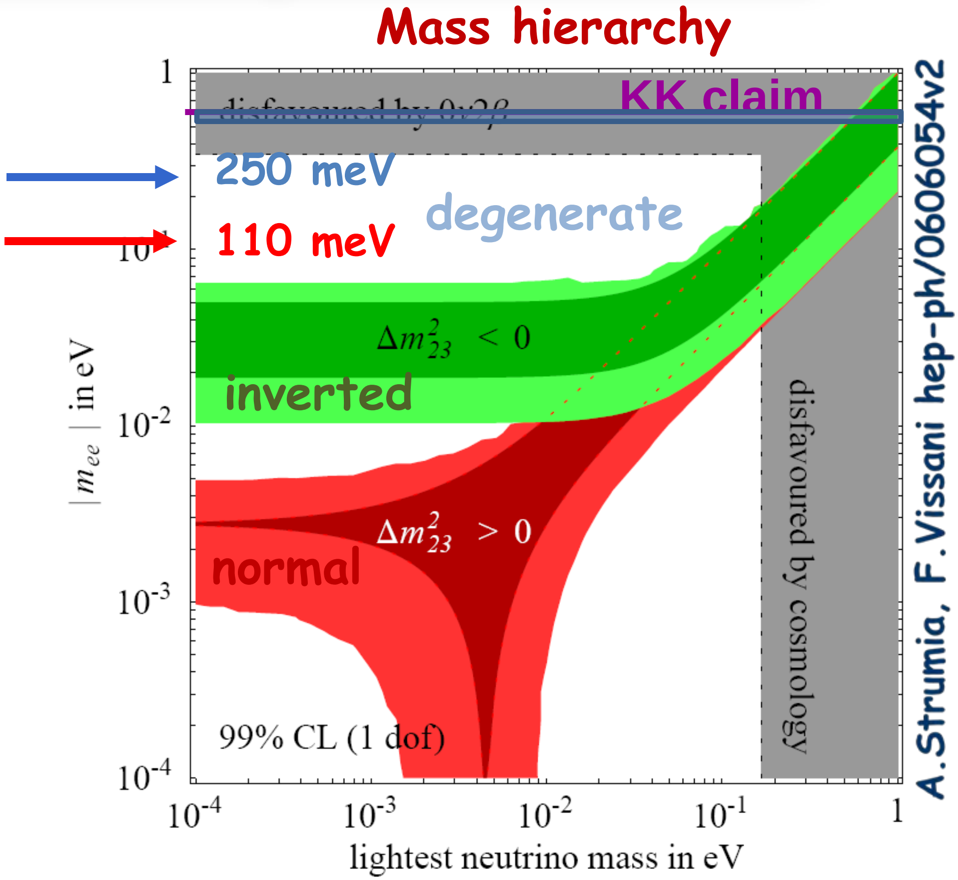
Background reduction methods

- Underground laboratory
- Material cleaning
- Passive shield (Cu&Pb&LAr)
- Muon veto

- Pulse shape analysis vs. detector segmentation
- Detector anti-coincidence
- R&D: LAr scintillation

Phases of the GERDA Experiment

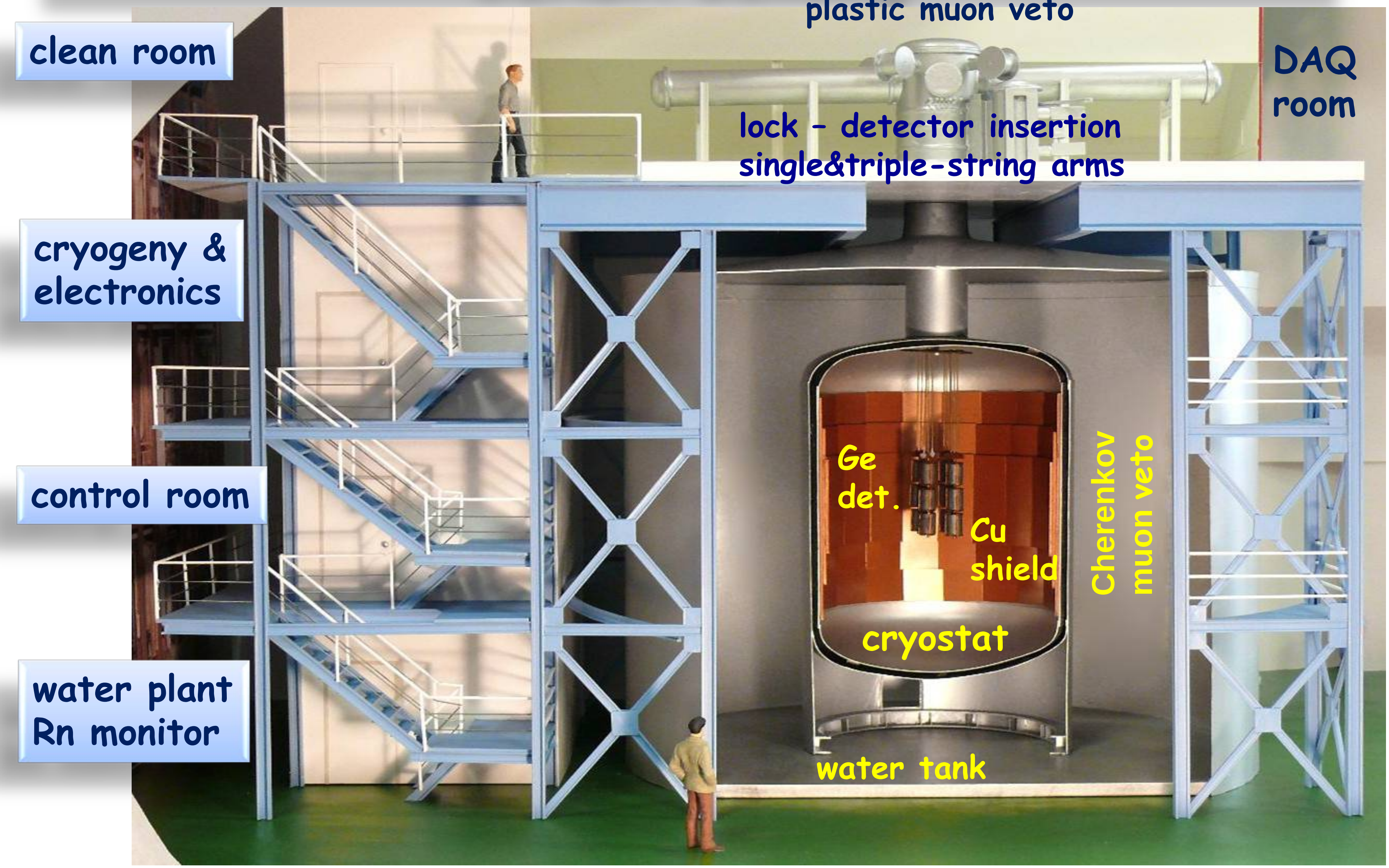




GERDA Phase I – after 1 year able to verify the KK claim

Phase III (GERDA+Majorana) – 1 ton exp. → ~50 meV

GERDA Building



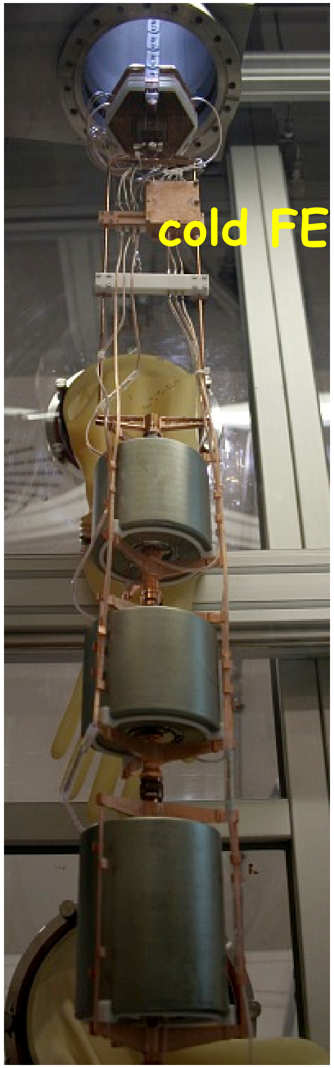
Mounting of GERDA 2008-2010

Commissioning with ^{nat}Ge Det.

- Summer/autumn 2009: integration test of phase I detectors, FE, lock, DAQ, LAr dewar

- Apr/May 2010: Installation of single-string lock in the GERDA cleanroom
- May 2010: Deployment of FE & detector mock-up, followed by first deployment of a of non-enriched det.
- June 2010: Water tank filling

- June 2010: Commissioning run with 3 ^{nat}Ge detectors
- cooling cycles
- grounding problems
- characterization runs with Th source
- optimizing energy reconstruction algorithms from digital data
- long-term background measurement
- **long-term stability of naked Ge detectors operated in LAr/LN_2 experimentally proved**



GERDA – Start of Phase I

Inauguration – November 2011

Phase I Detectors

Detector	Total mass (g)	HV (V)
ANG 1	958	3500
ANG 2	2833	4000
ANG 3	2391	3000
ANG 4	2372	3000
ANG 5	2746	1800
RG 1	2110	4500
RG 2	2166	4000
RG 3	2087	3500
GTF 32	2321	3200
GTF 42	2467	3000
GTF 44	2465	3500
GTF 45	2332	1500
GTF 110	3046	3000
GTF 112	2965	2500
Prototype	1560	3000

- 8 ^{enr}Ge (HdM&IGEX) + 6 ^{nat}Ge (GTF) p-type coaxial Ge detector refurbished

- ^{enr}Ge mass:1-3 kg (total 17.9 kg)
- C_{det} = 30–40 pF
- deployed in strings of 3 dets.
- mounted in low-mass Cu holders
- HV contact: on Li surface by pressure
- readout contact: in borehole spring-loaded
- all the detectors have been tested naked in LAr and perform well (I-V & R < 3 keV @ 1.332 MeV).

Deployment of Phase I Detectors

low-mass Cu holder

October 2011

1 & 3 string arms

1 string

2 ^{nat}Ge detectors 4.65 kg

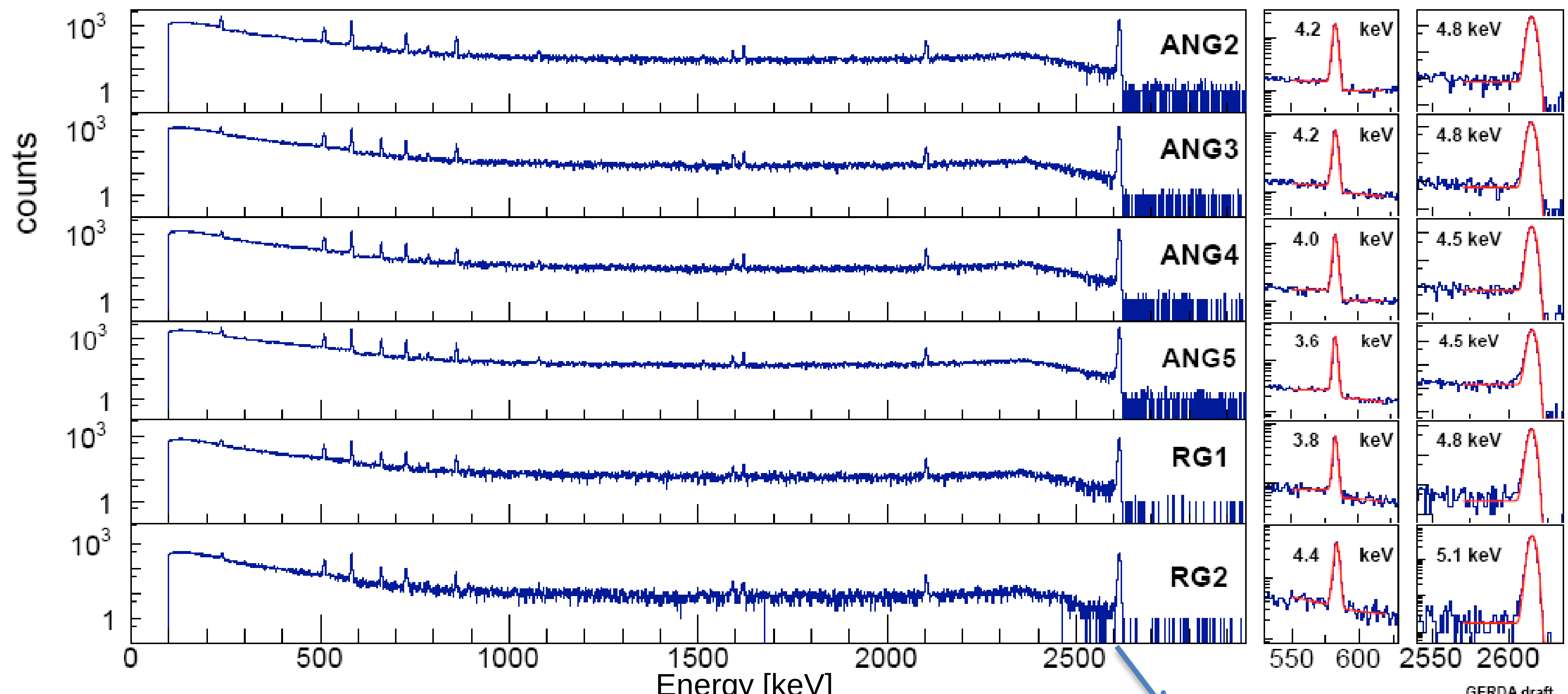
3 strings

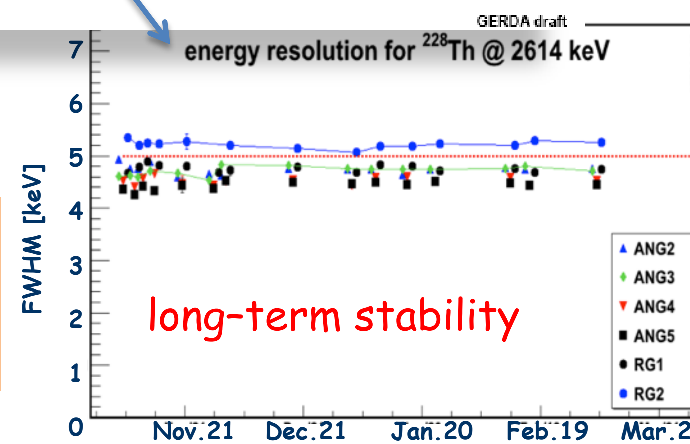
8 ^{enr}Ge detectors 17.66 kg

1 ^{nat}Ge detectors 2.96 kg

Status of Phase I Detectors

Calibration with Th source





2 ^{enr}Ge with high leakage current

eliminated from physics analysis

total effective ^{enr}Ge mass = 14.63 kg

Status of Phase I Data Taking

Nov. 2011 – May 2012

Live time = 152.49 days

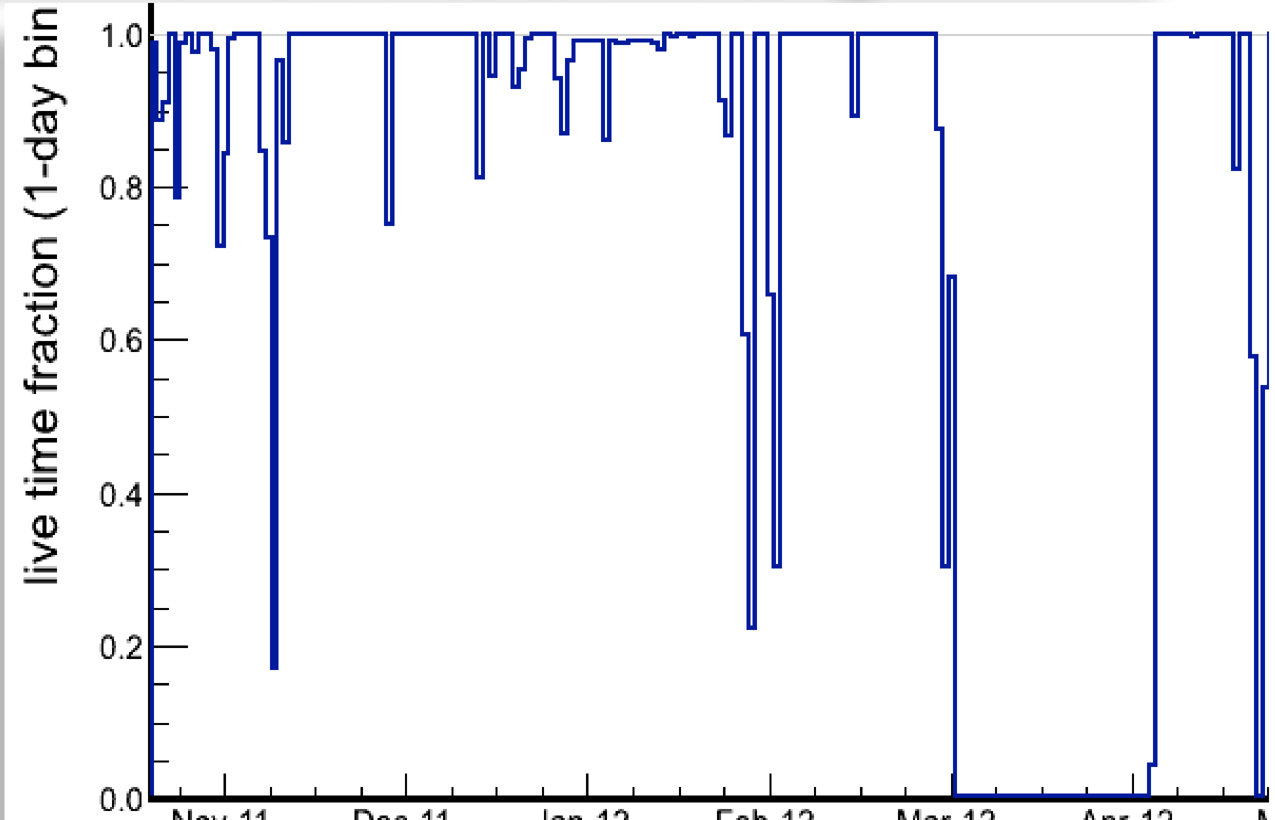
Duty cycle = 78.3%

^{enr}Ge mass

14.63 kg

^{nat}Ge mass

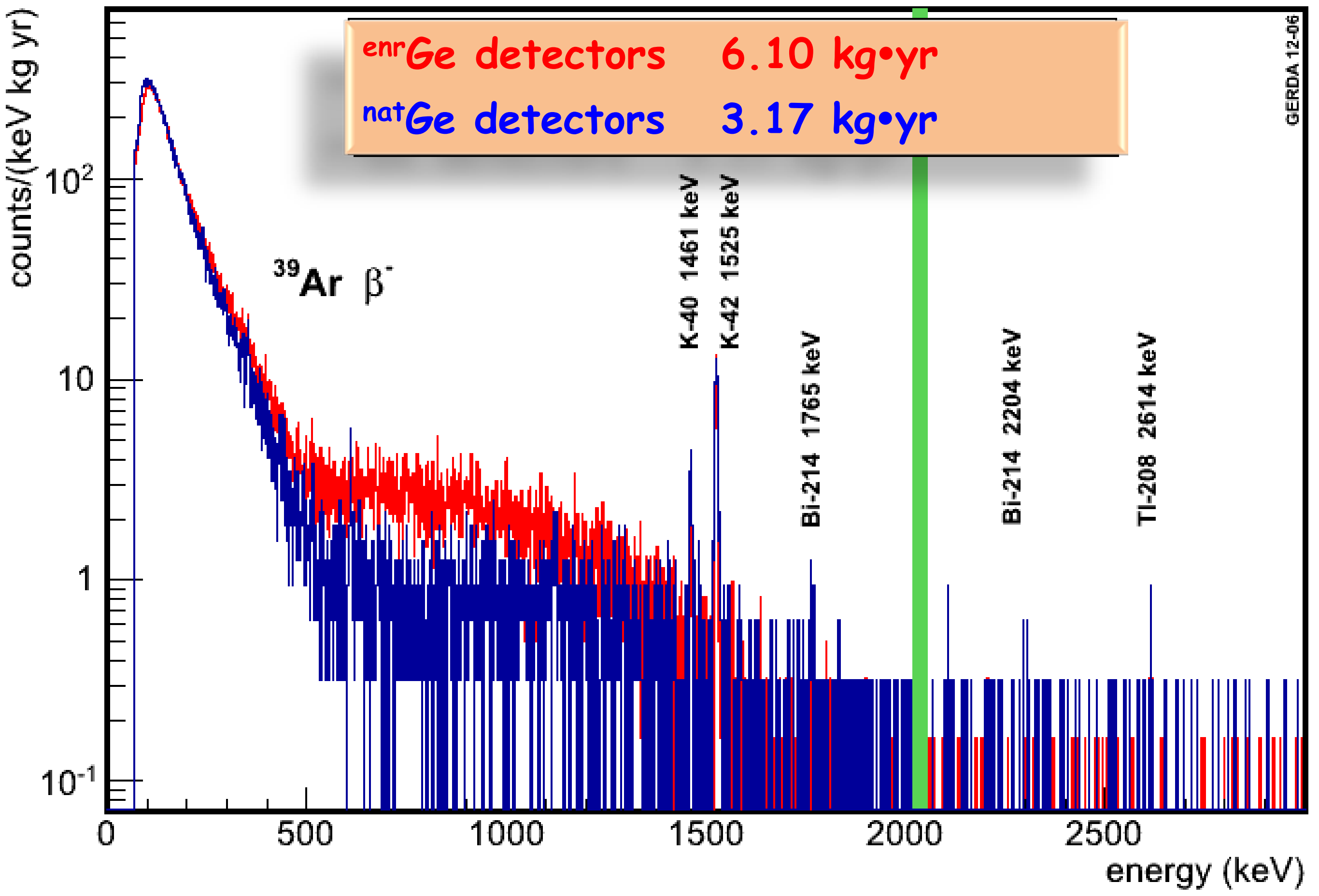
7.59 kg



6.10 kg•yr (^{enr}Ge) and 3.17 kg•yr (^{nat}Ge)

Since Jan. 2012 – events with energy between 2019 and 2059 are filtered out ('blinded') from the analysis

Data from Phase I Detectors

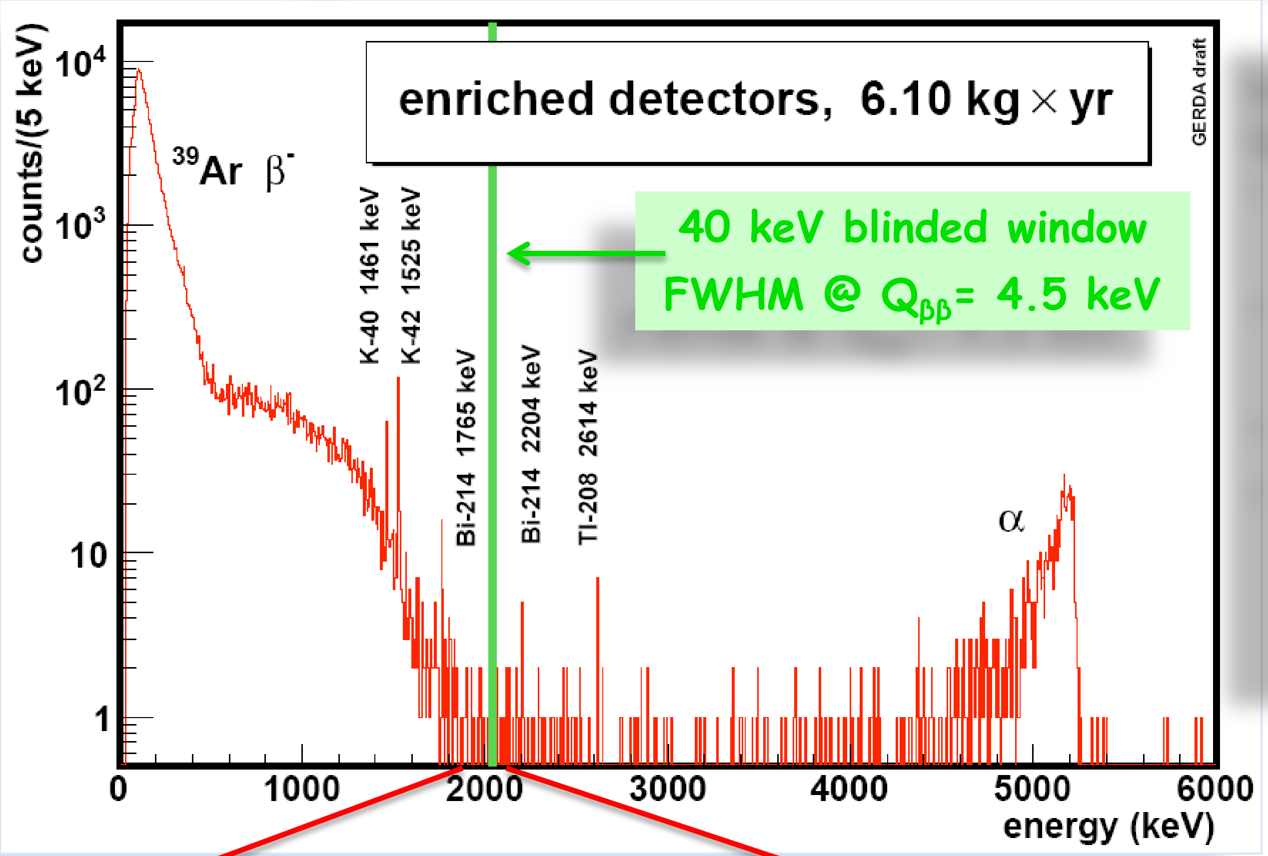


Background in GERDA Phase I

isotope	energy [keV]	^{nat}Ge–dets (3.2 kg·y) tot/bck [cnt]	^{nat}Ge–dets (3.2 kg·y) rate [cnt/(kg·y)]	^{enr}Ge–dets (6.1 kg·y) tot/bck [cnt]	^{enr}Ge–dets (6.1 kg·y) rate [cnt/(kg·y)]	HdM rate [cnt/(kg·y)]
^{40}K	1460.8	85 / 15	$21.7^{+3.9}_{-3.1}$	125 / 42	$13.5^{+2.5}_{-2.2}$	181 ± 2
^{60}Co	1173.2	43 / 38	< 5.8	182 / 152	$5.1^{+3.1}_{-3.1}$	55 ± 1
	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
^{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
^{214}Pb	352	740 / 630	$34.6^{+15.2}_{-12.4}$	1770 / 1688	$13.2^{+11.5}_{-7.9}$	138.7 ± 4.8
^{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
	2204.2	5 / 2	$0.8^{+0.9}_{-0.7}$	6 / 3	$0.4^{+0.4}_{-0.4}$	8.1 ± 0.5

Important reduction as compared to the HdM experiment

Background Index of GERDA Phase I



background contrib. @ $Q_{\beta\beta}$

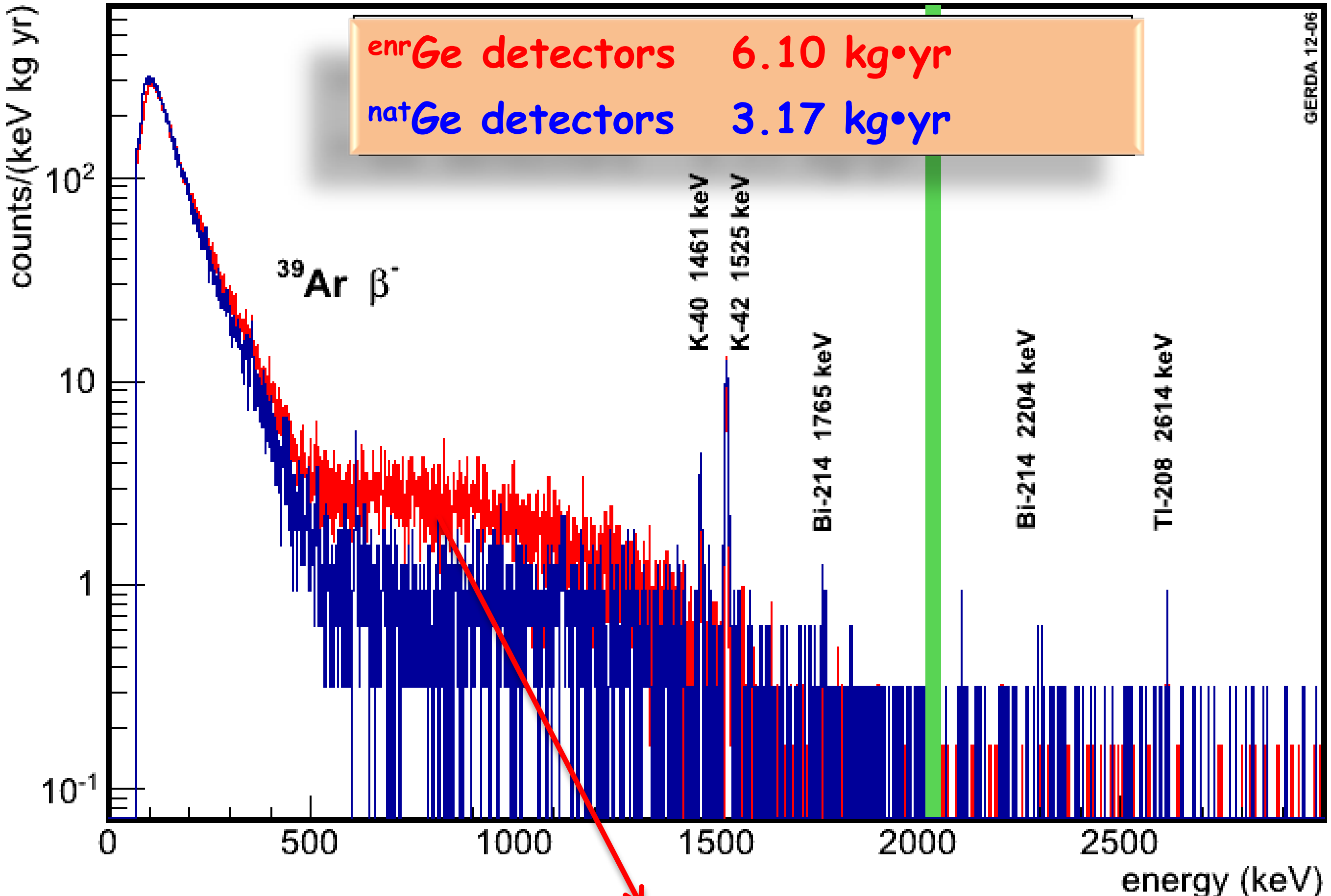
- γ rays from ^{214}Bi and ^{208}Tl
- degraded α from ^{210}Po
- β from ^{42}K
- internal contaminations such as ^{60}Co

Background index in a 200 keV window (- 40 keV blinded) centered on $Q_{\beta\beta}$ =

0.020 + 0.006 – 0.004 counts/(keV•kg•yr)

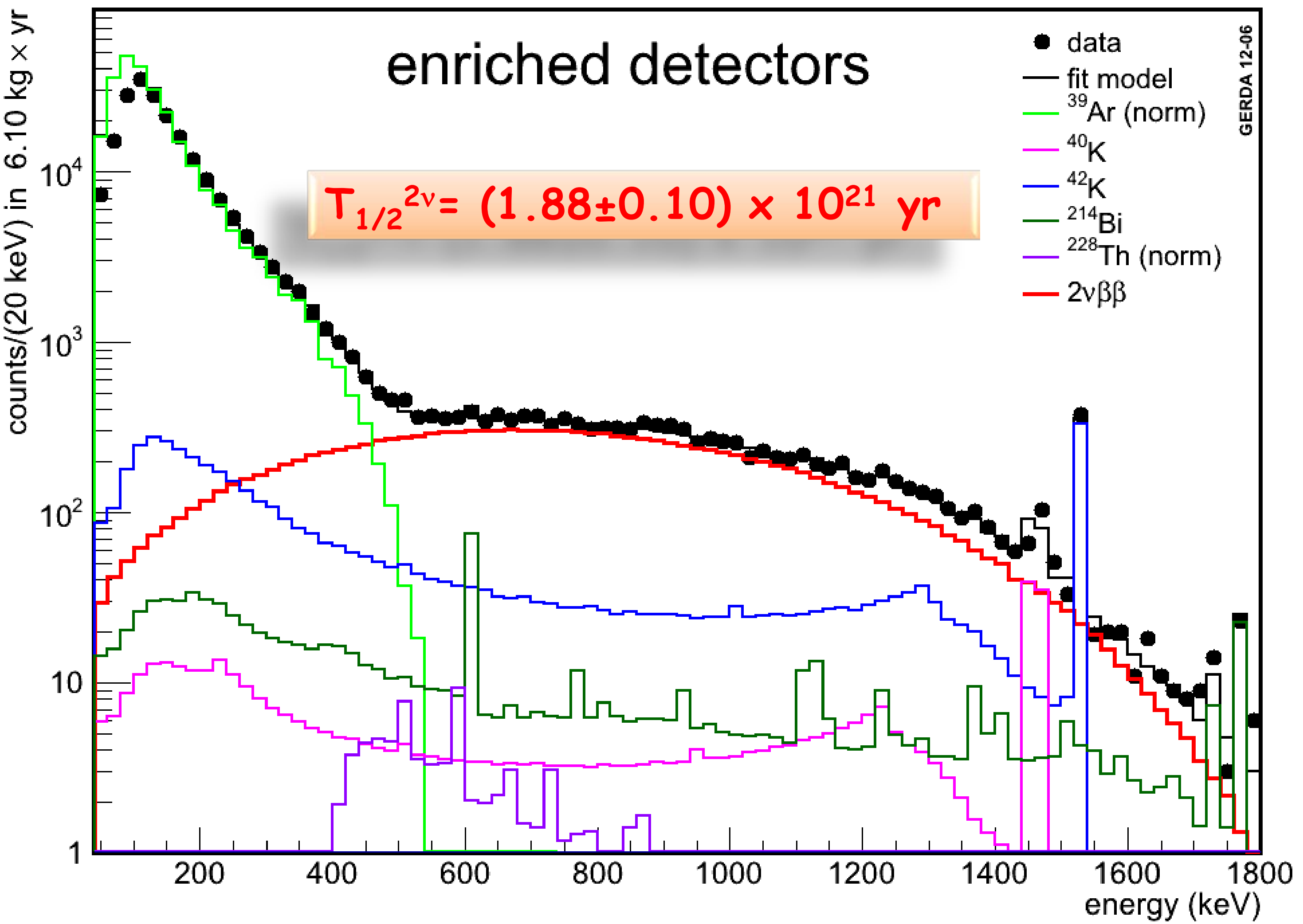
No PSA applied yet !

2νββ Decay of ^{76}Ge

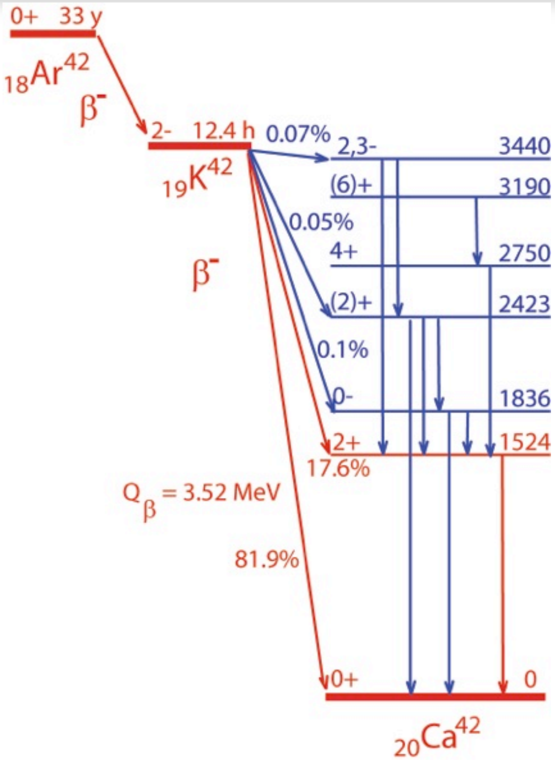


Excess counts in ^{enr}Ge related to 2νββ decay

Preliminary Half-Life of $2\nu\beta\beta$ Decay of ^{76}Ge



^{42}Ar Background

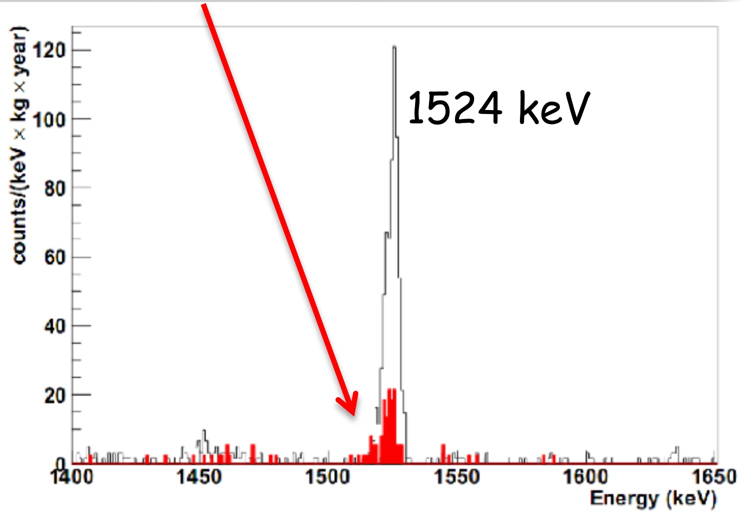


A.S.Barabash,
Proc. Int. Workshop on Technique and Application of Xenon Detectors 2002
^{42}Ar/Ar = 3 x 10^{-21} g/g
< 41 μBq/kg 90% CL

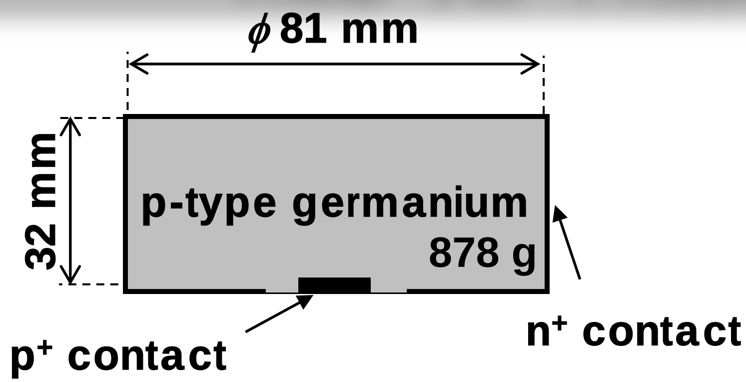
Consistent measurements in LArGe and GERDA setups yield
93.0 ± 6.4 μBq/kg
Preliminary result !

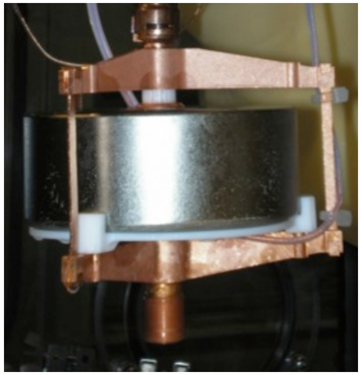
mini-shround around the detectors
- E-field free environment around detectors
- avoid convection effects

reduces the effect



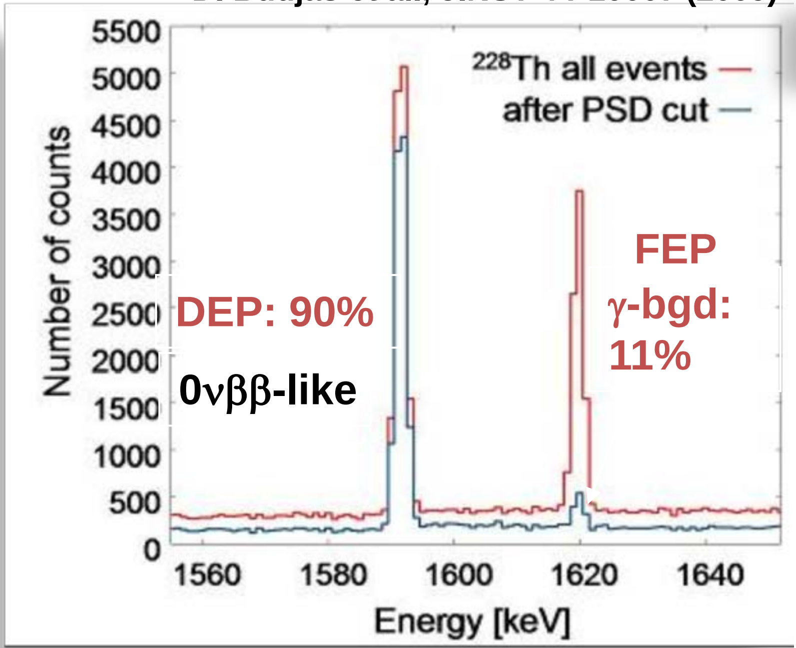
R&D for Phase II Detectors





BEGe type detectors were chosen for the Phase II of the GERDA experiment

D. Budjas et al., JINST 4 P10007 (2009)



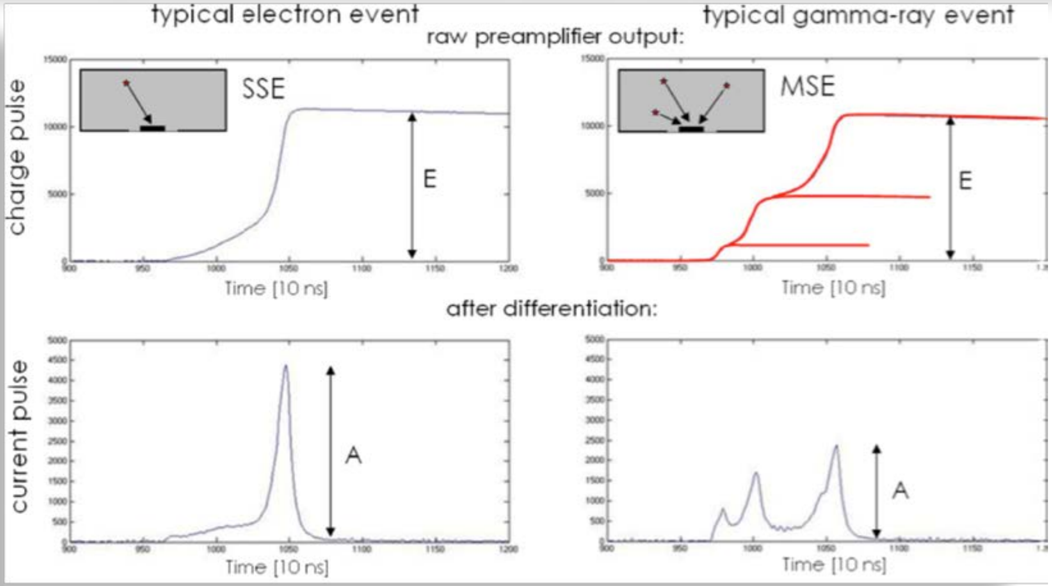
>26 detectors (>20 kg ^{enr}Ge) to be built

June – 5 ^{enr}BEGe deployed on the 1-string arm

⟶ total 18.1 kg ^{enr}Ge

- good energy resolution and noise characteristics
- excellent discrimination capability of between SSE and MSE based on PSD analysis

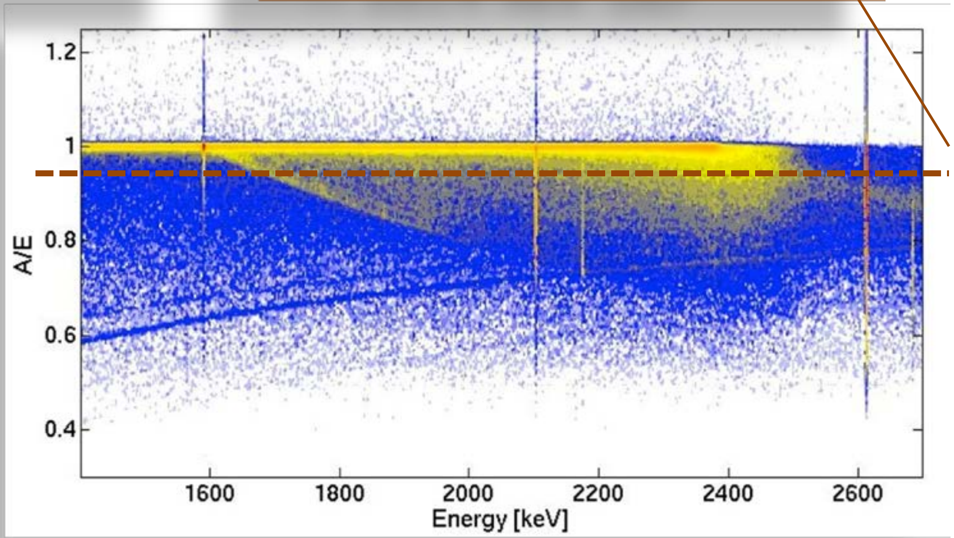
Discrimination based on A/E Parameter



A = maximal current signal amplitude

E = energy of the event

PSD cut – 90% of the ^{208}Tl 2614 keV DEP



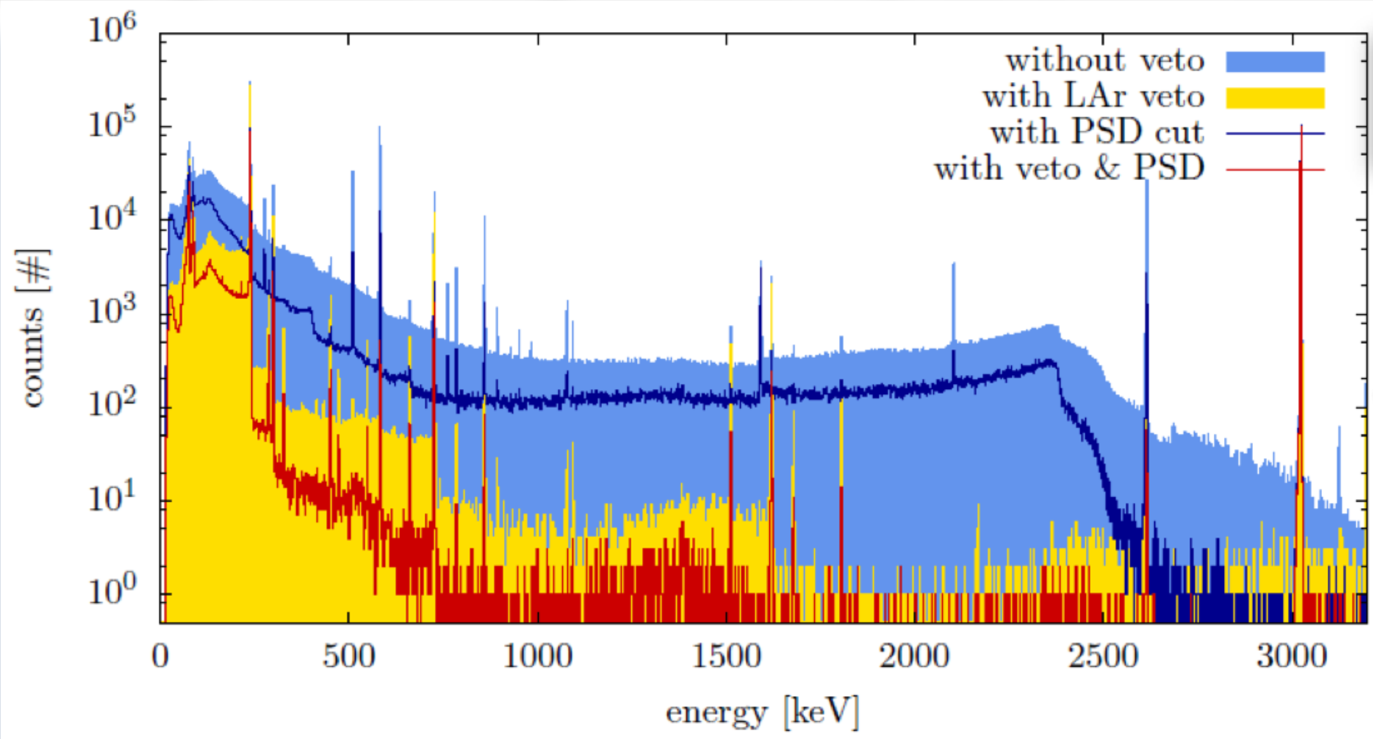
A/E for SSE is independent of the energy and the interaction location inside the crystal volume

A/E for MSE is smaller

See talk by A.D.Ferella

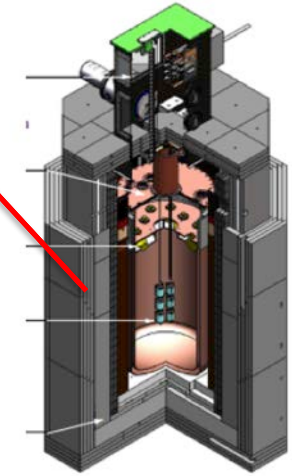
D. Budjas et al., JINST 4 P10007 (2009)
M. Agostini et al., JINST 6 P03005 (2011)

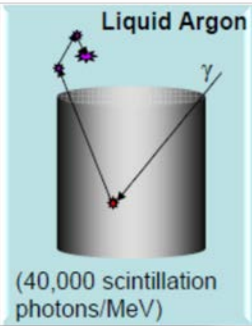
Background Rejection by LAr - R&D Phase II



LAr scint. light read-out

LArGe PMT read-out





- importance of the LAr veto for the reduction of the γ-ray backg.
- Simulations confirm possibility to reach B.I. of 10^{-3} counts/(kg keV yr)

See talk by B.Lehnert

GERDA read-out

- SiPMs connected to fibers
- Low background PMTs

Summary

Phase I

- GERDA Phase I started in November 2011 with 14.63 kg of ^{enr}Ge
- Phase I background index of 10^{-2} counts/(keV kg yr) is attainable when PSA applied
- Half-life of the $2\nu\beta\beta$ decay of ^{76}Ge measured with a remarkable signal-to-noise ratio
- Accurate determination of the ^{42}Ar contaminant concentration
- Minimized ^{42}Ar background through the use of polarized mini-shrouds
- 5 $^{enr}BEGe$ added to Phase I to increase ^{enr}Ge mass to 18.1 kg

Summary

Phase II

- Phase II ^{enr}BEGe detectors are under production (> 20 kg)

- Phase II R&D for LAr scintillation light read-out is going on

- Phase II background index 10^{-3} counts/(keV kg yr) with LAr veto

- Phase I expected to be completed by early 2013; start of Phase II