The XXV International Conference on Neutrino Physics and Astrophysics June 3-9 2012 Kyoto, Japan

Results from GERDA

Kyoto June 6, 2012

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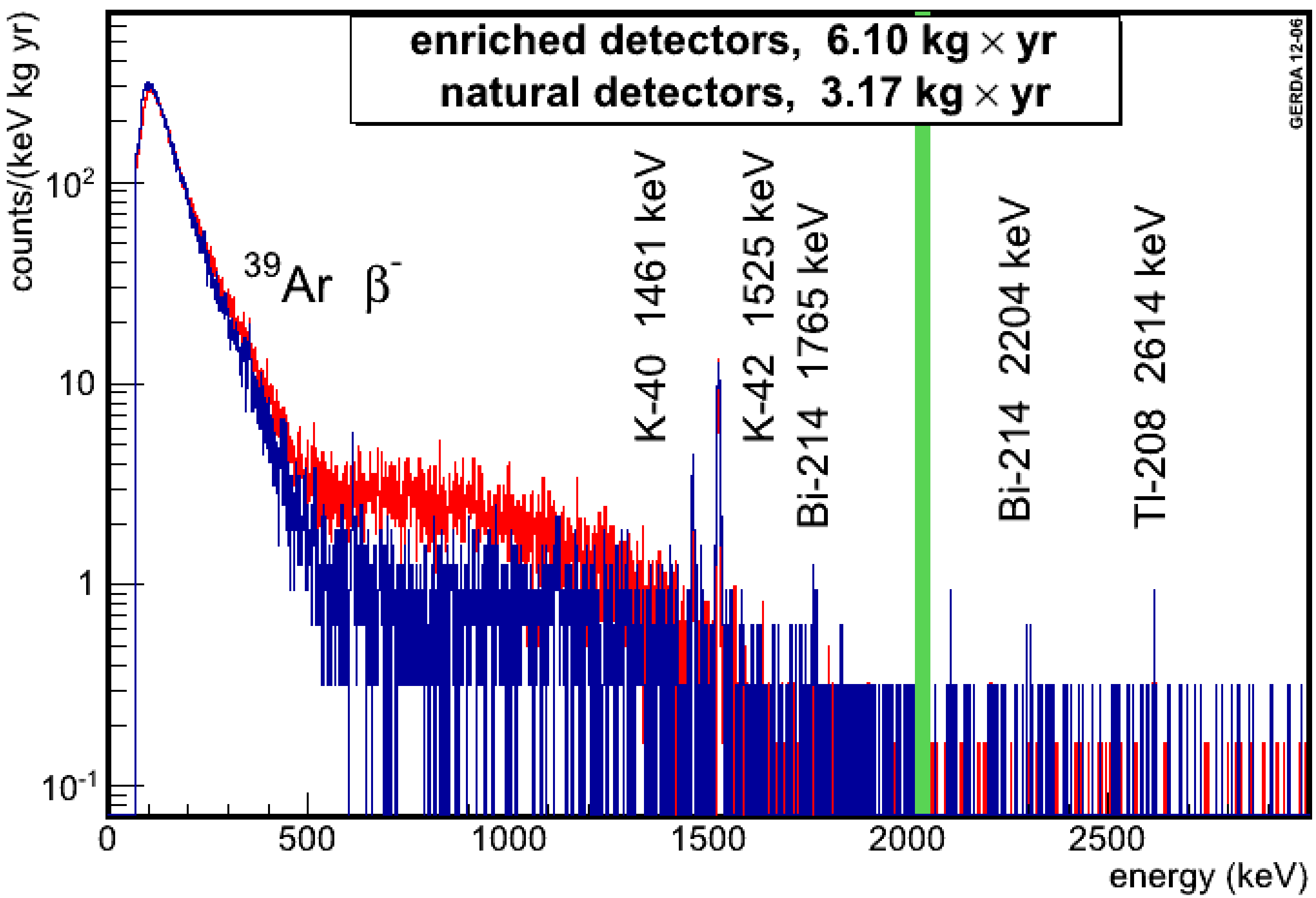
for the GERDA Collaboration

the energy spectra in GERDA

difference in shapes for natural and enriched diodes (7 % vs. 86 % ^{76}Ge)

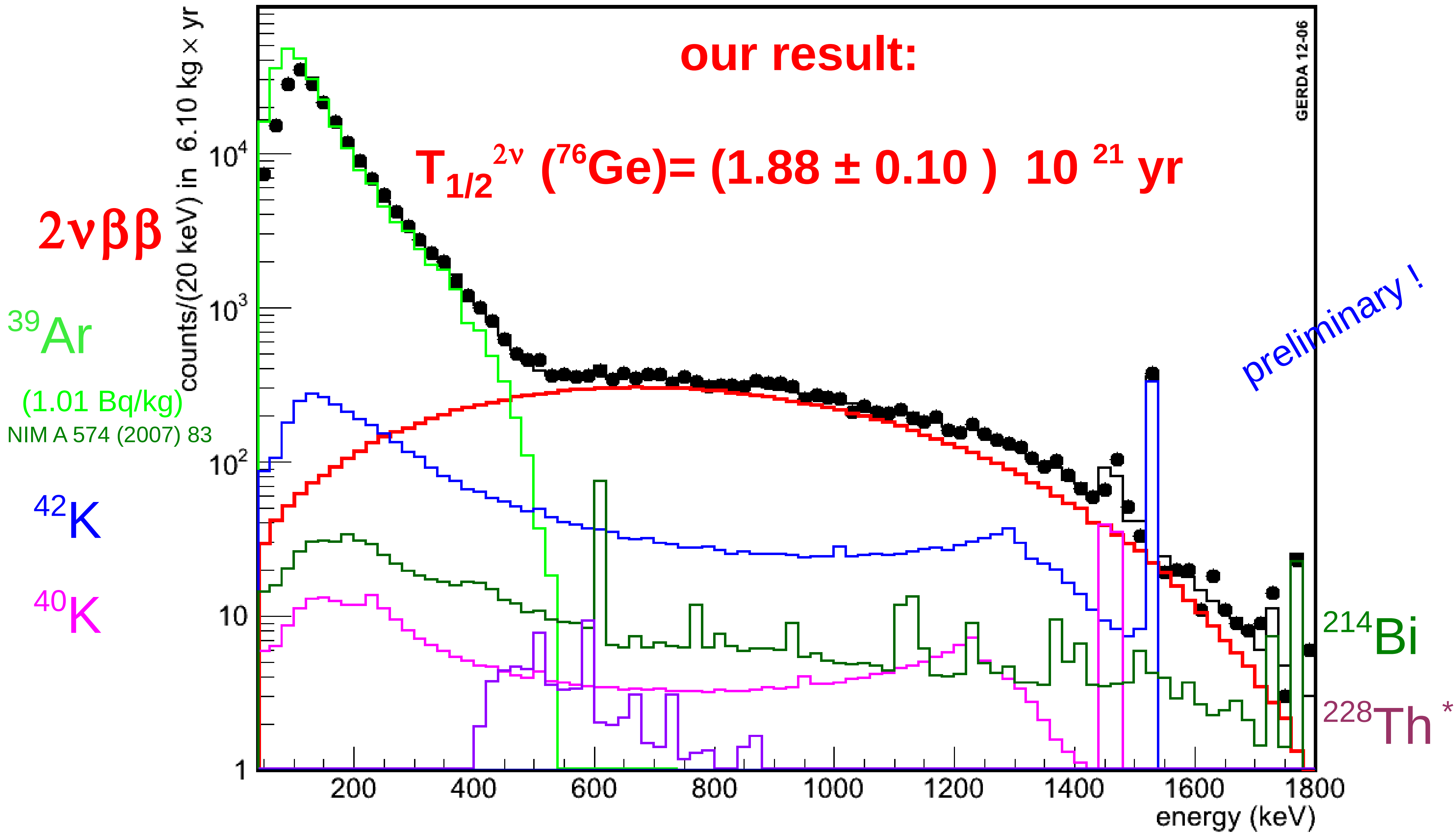
low background, few γ lines ⇒ more precise $T_{1/2}^{2\nu}$

no PSA, blinding @ $Q_{\beta\beta}$ = 2039 keV



summed electron energy spectrum in GERDA

exposure : 6.1 kg yr



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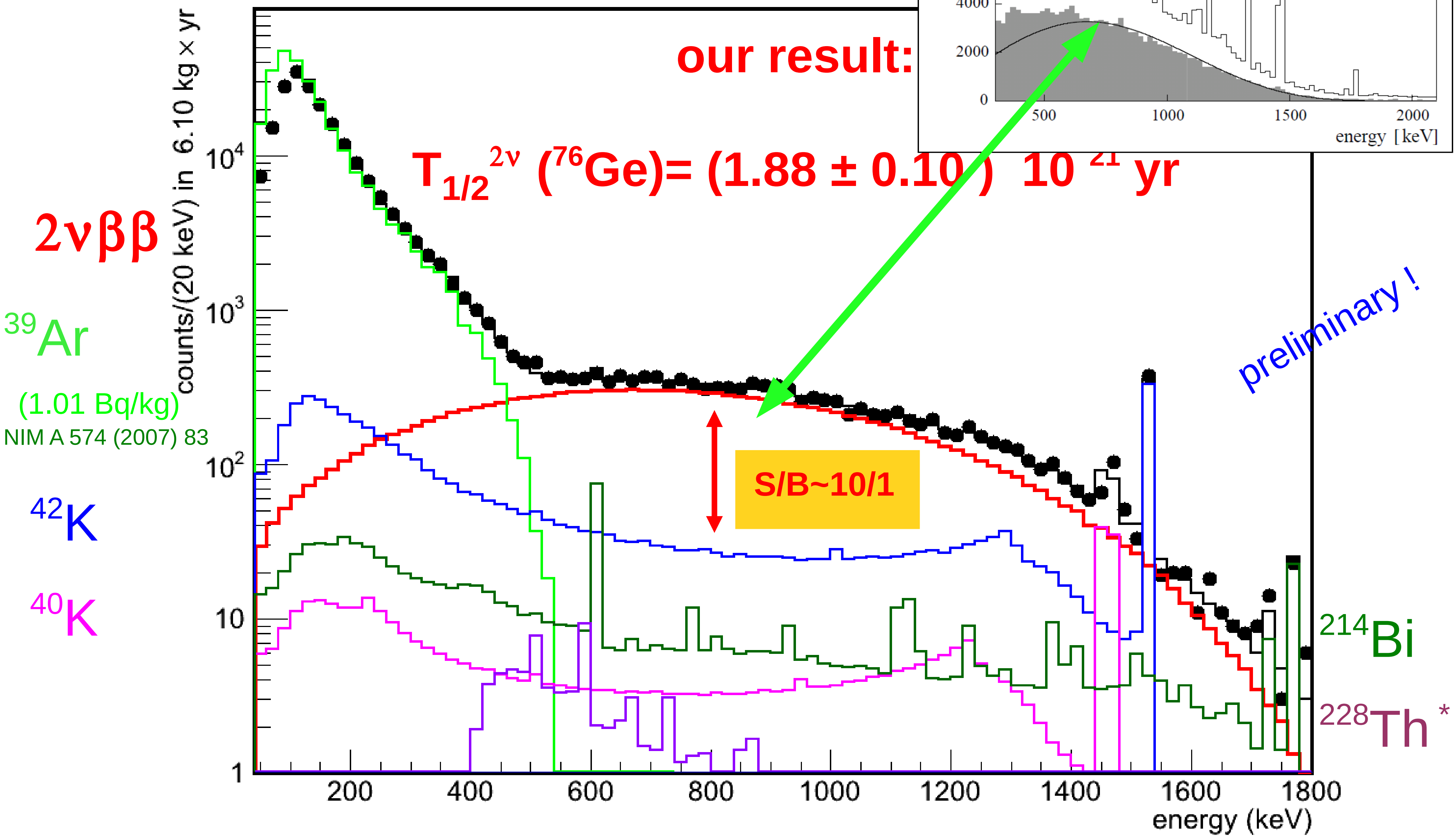
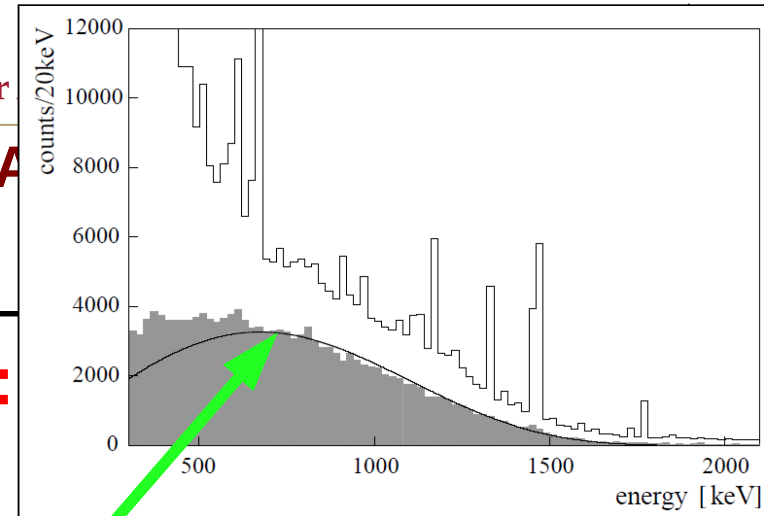




the search for the $0\nu\beta\beta$ decay in ^{76}Ge

concept: diodes enriched in ^{76}Ge on strings in liquid argon (Lar) @ LNGS

we learn from the summed electron spectrum:

- ^{76}Ge — active mass, $T_{1/2}^{2\nu}$
- LAr: — ^{39}Ar and ^{42}Ar (^{42}K)
- background: — γ, α, μ, n
- systematics: — linearity, stability (calibrations)

blinding 2019 – 2059 keV

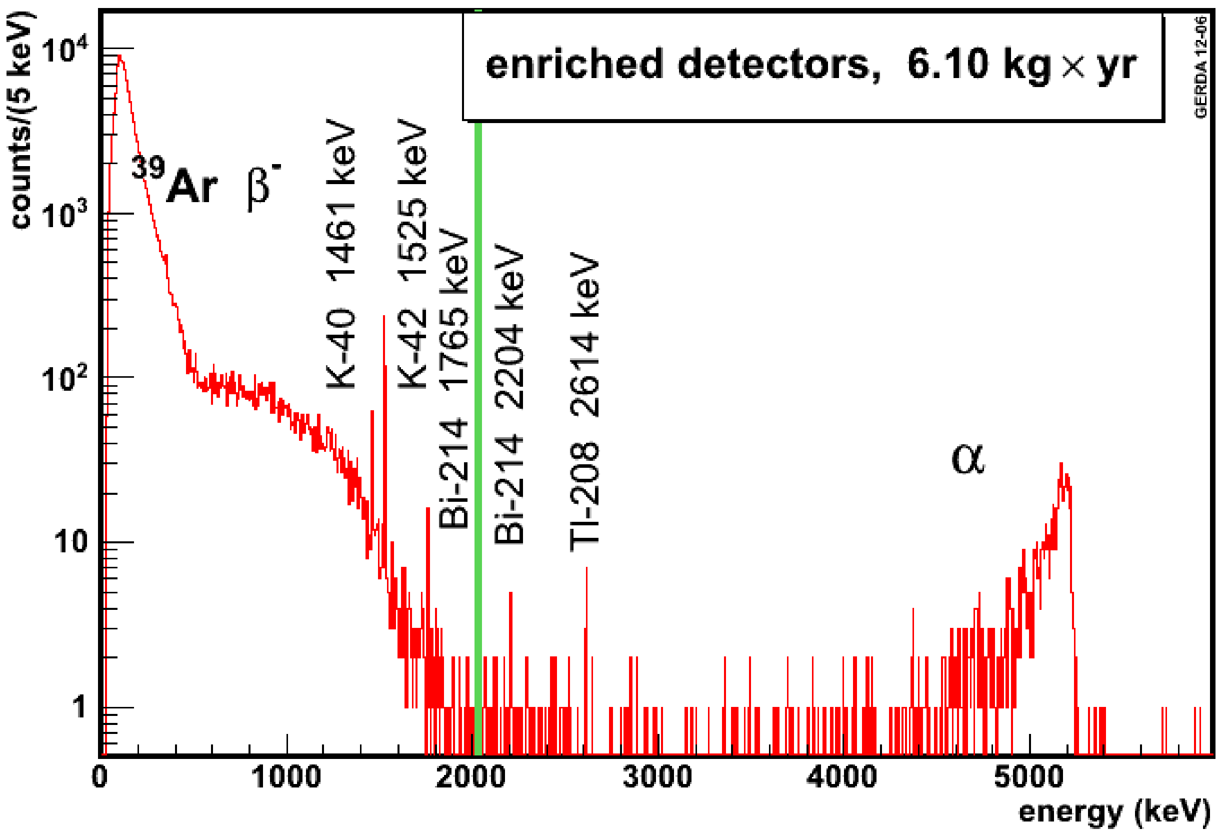
statistics: enriched 6.10 kg yr

1.11.2011 – 21.5.2012

establish analysis procedures to be employed on $0\nu\beta\beta$ data after unblinding

outline:

1) Phase I
2) Phase II (starting early 2013)



the GERDA Collaboration

~ 100 members
19 institutions
6 countries

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[b]) Institute of Physics, Ja
[c]) Institut für Kern- und Teilchenphysik
[d]) Joint Institute for
[e]) Institute for Reference Ma
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[h]) INFN Mila
[i]) Dipartimento di Fisica, Università d
[j]) Institute for Nuclear Research of t
[k]) Institute for Theoretical a
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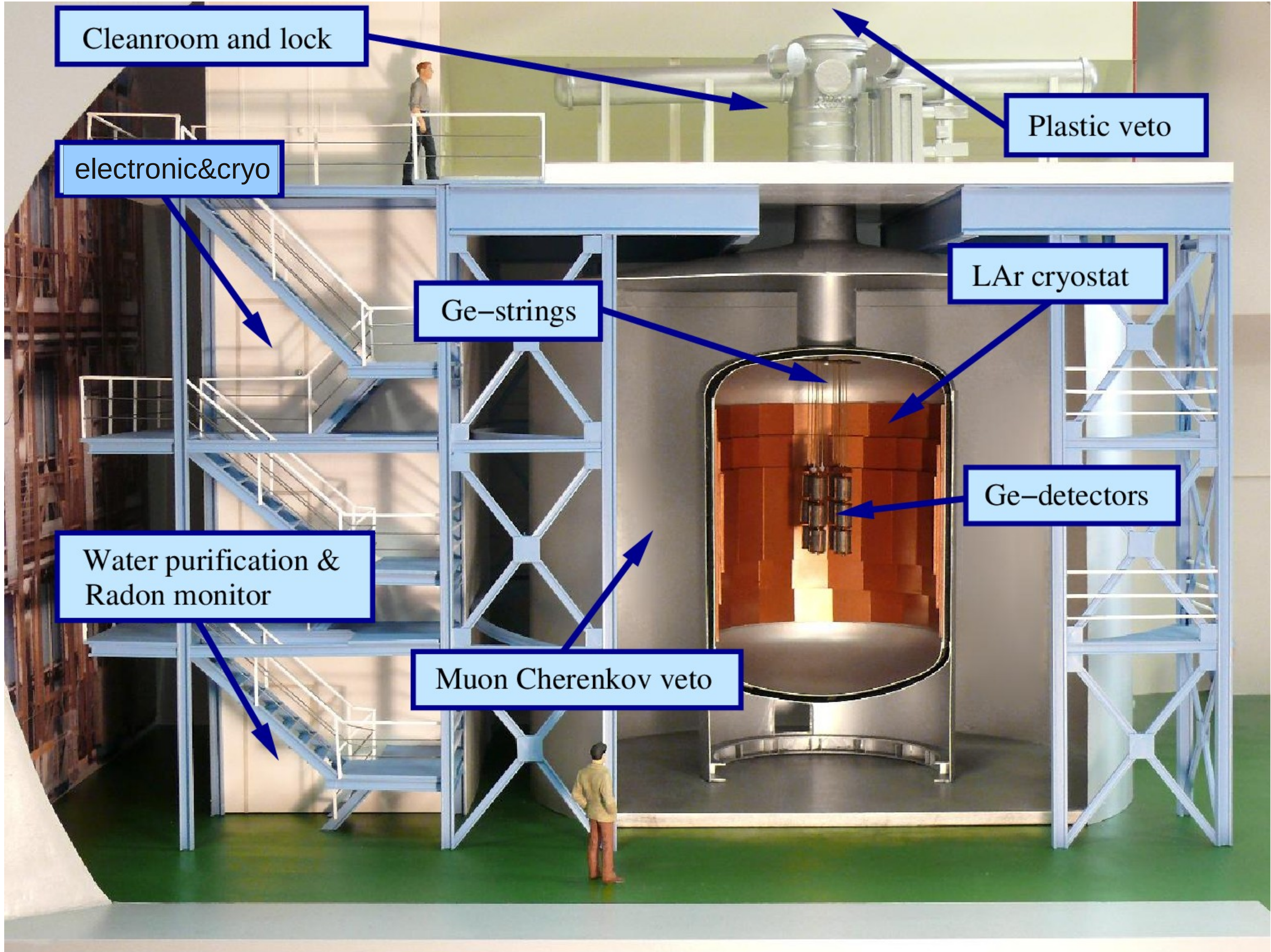
[o]) Dipartimento di Fisica e Astro
[p]) INFN
[q]) Shanghai Jiaoto
[r]) Physikalisches Institut, Eberhard
[s]) Physik Institut der Un


Cleanroom and lock
Plastic veto
electronic&cryo
LAr cryostat
Ge−strings
Ge−detectors
Water purification &
Radon monitor
Muon Cherenkov veto

construction

2008 -- 2010

Hall A of LNGS

inauguration Nov. 2011

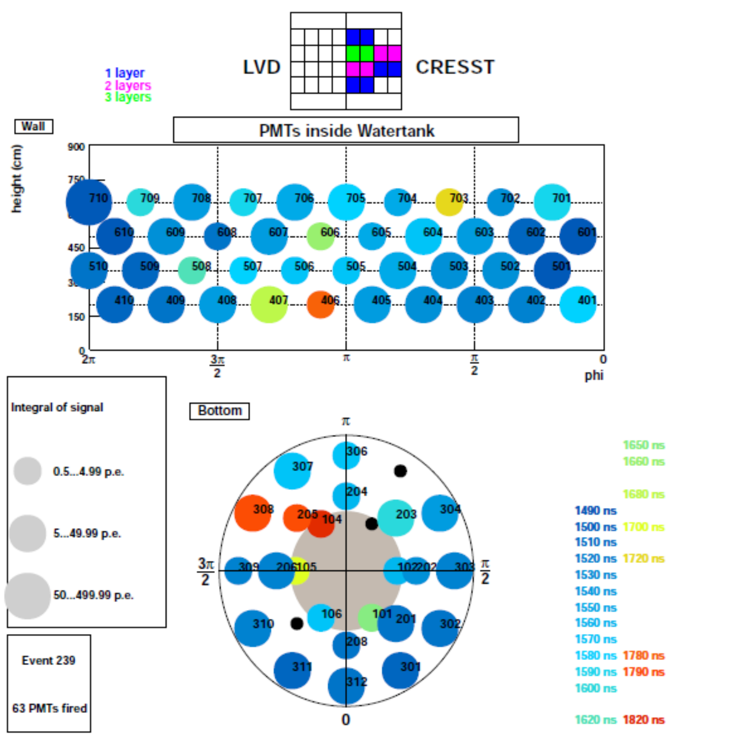
the muon veto

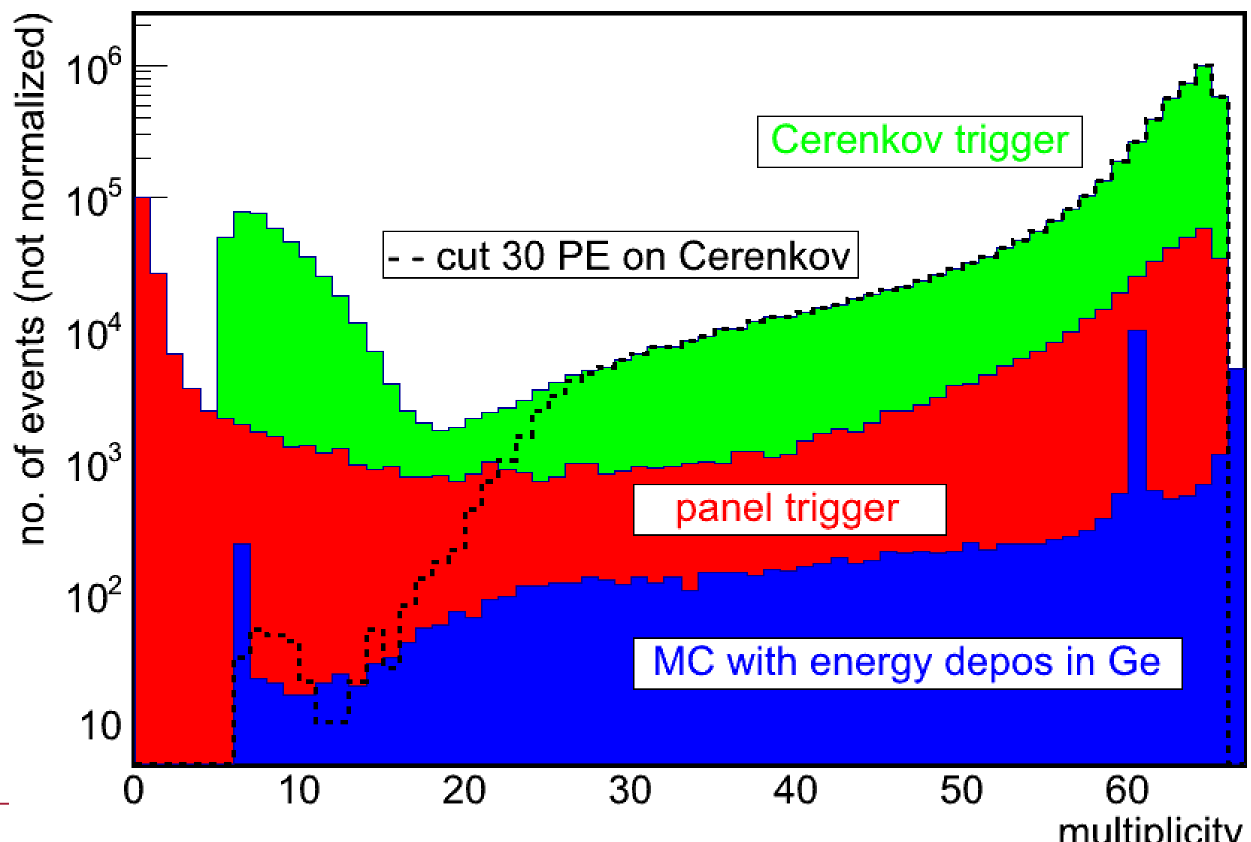
66 PMT (8") Cerenkov in the water tank
32 plastic panels with fibre/PMT readout

μ – Ge timing resolution < 70 ns (decay of cosmogenic isotopes)

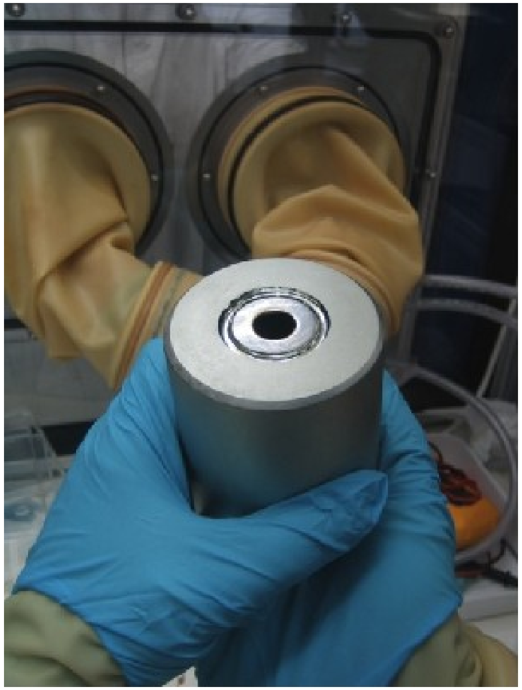
overall detection efficiency: (97.2 ± 0.3) % $BI_{\mu} < 2 \cdot 10^{-4}$ cts/(keV kg yr)
efficiency with energy depos. in Ge : (99.6 ± 0.4) %

poster by K. Freund (58-1)





installation of GERDA Phase I detectors

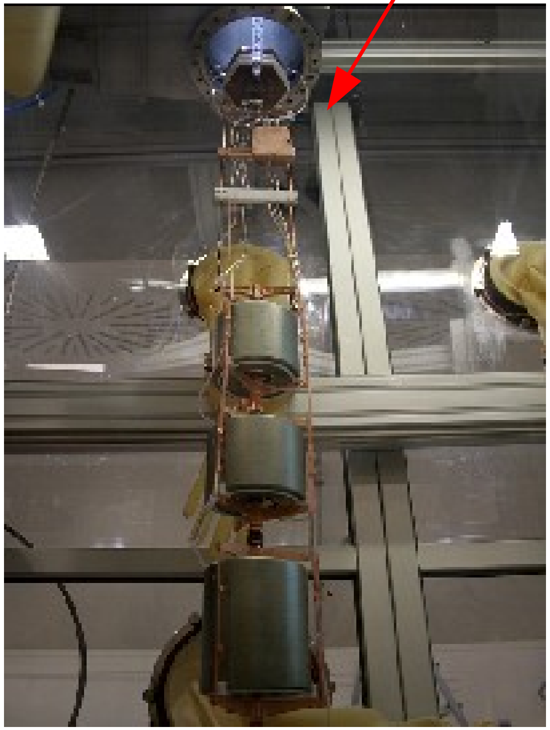


refurbished by Canberra

low mass holder

3 diodes arranged on 1 string,

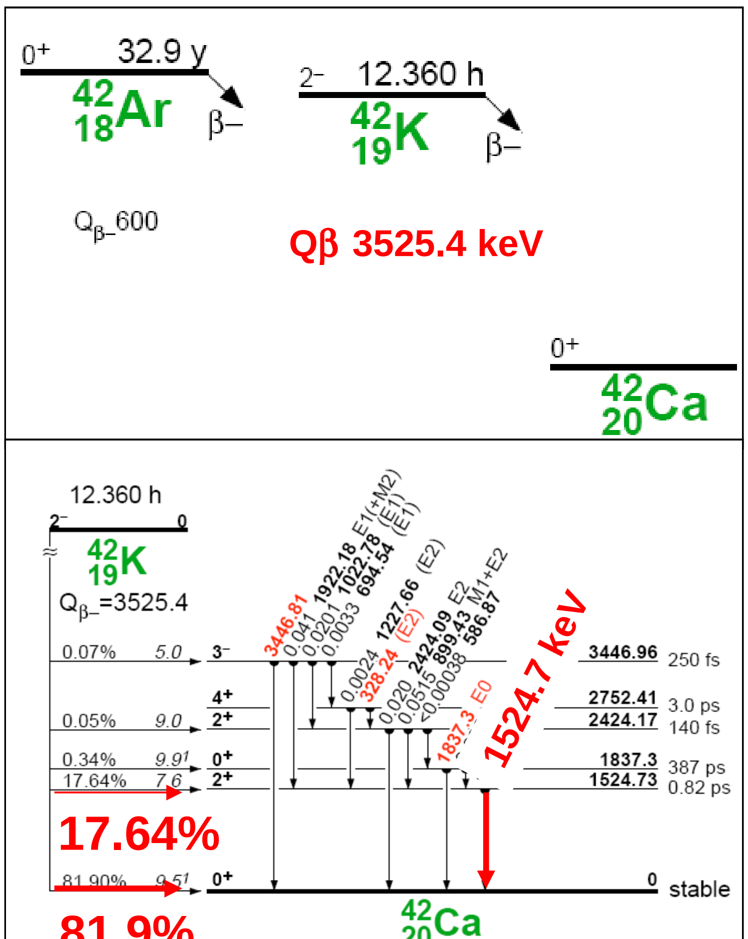
inclusive cold FE

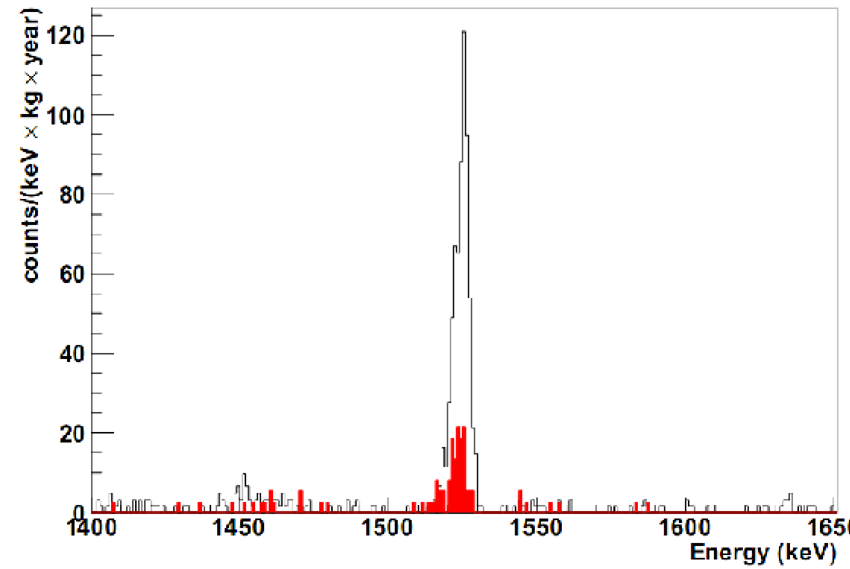


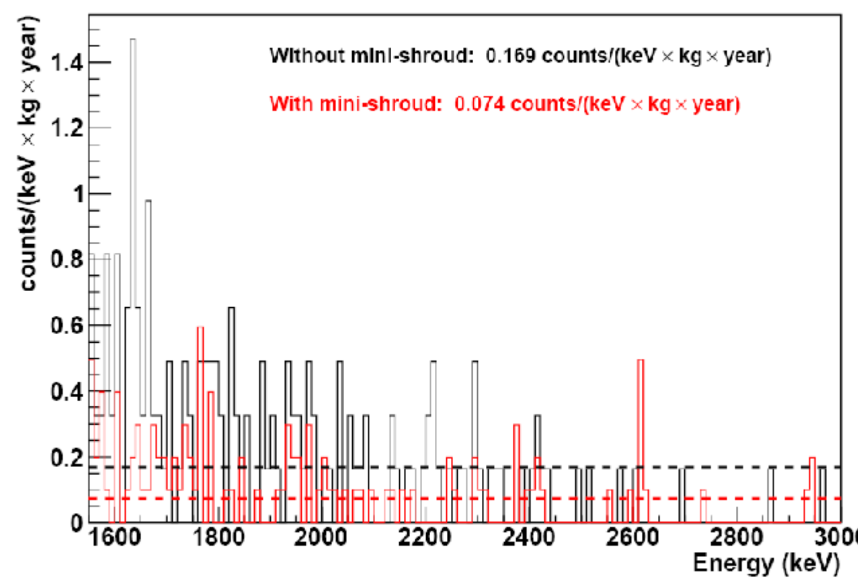
reason for mini-shroud: ^{42}K, resp. ^{42}Ar

Barabash: ^{42}Ar < 3*10^{-21} g/g ; used for proposal
< 41 µBq/kg 90% CL

however: collection of ions through E-field from HV







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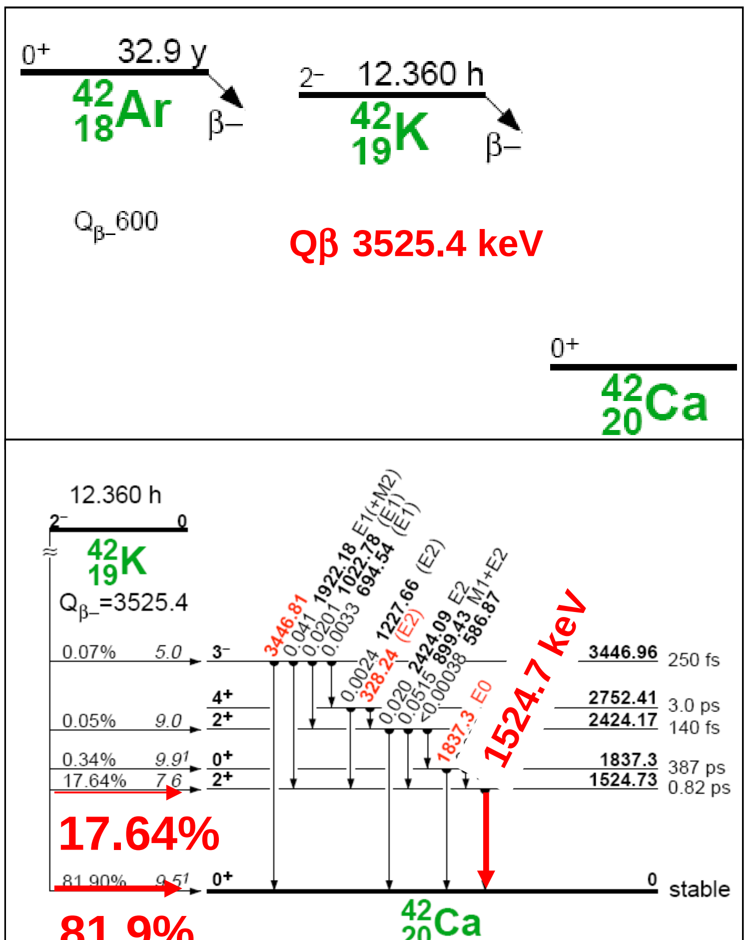
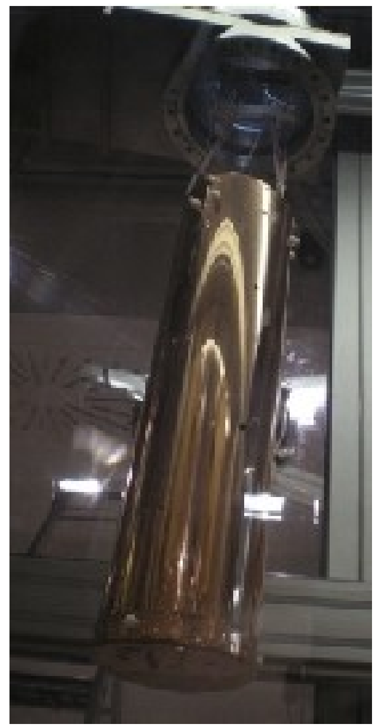
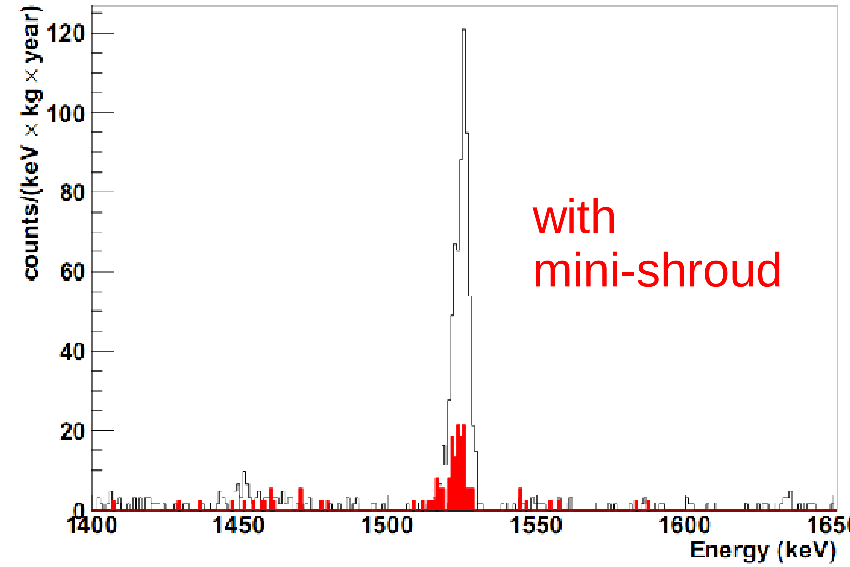
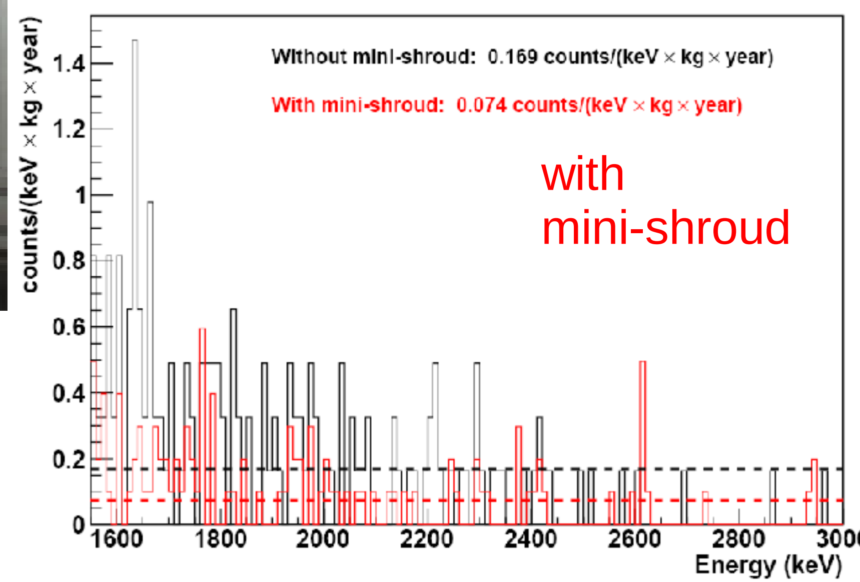




thickness:
60 μm Cu

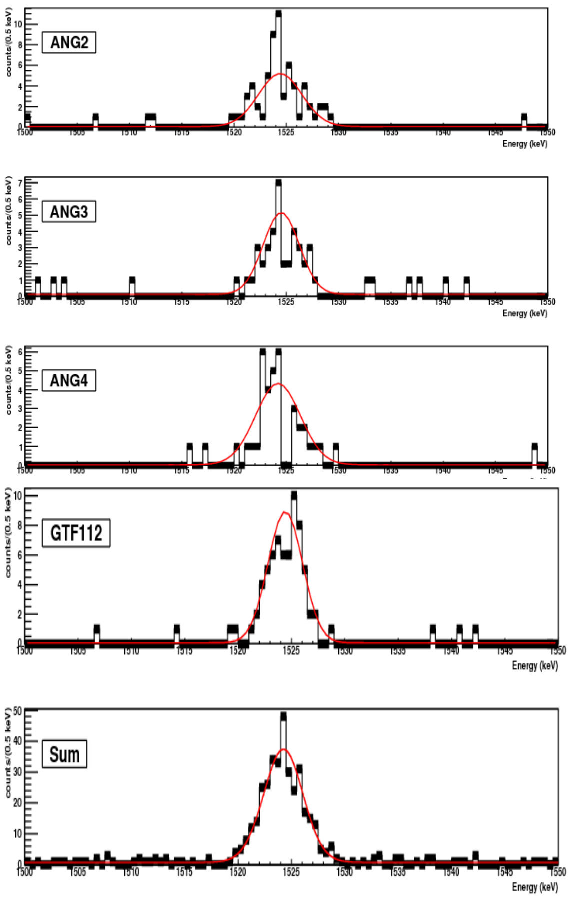




determination of ^{42}Ar concentration

previously: < 41 µBq/kg 90% CL

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



1525 keV

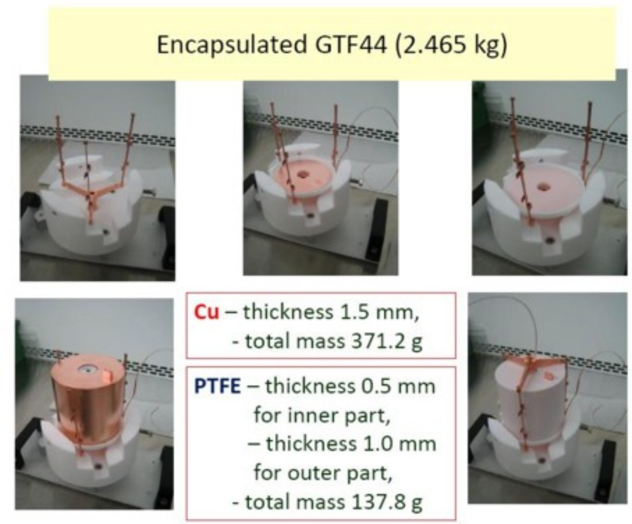
enriched

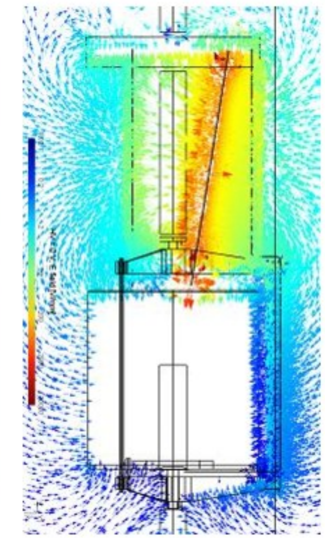
natural

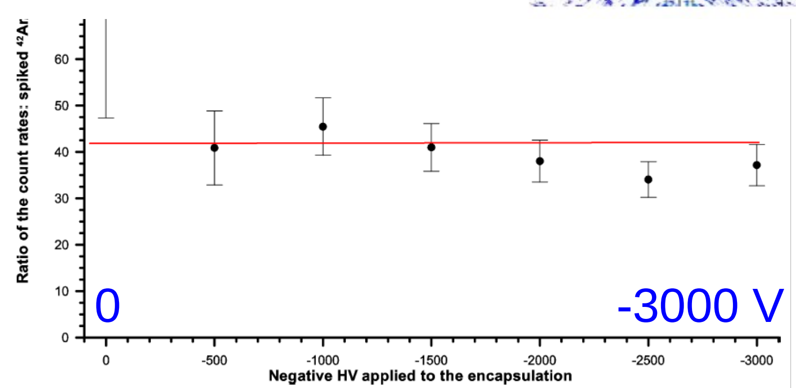
sum

A_{spec} = (92.8 ± 5.2 ± 4.5) µBq/kg

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





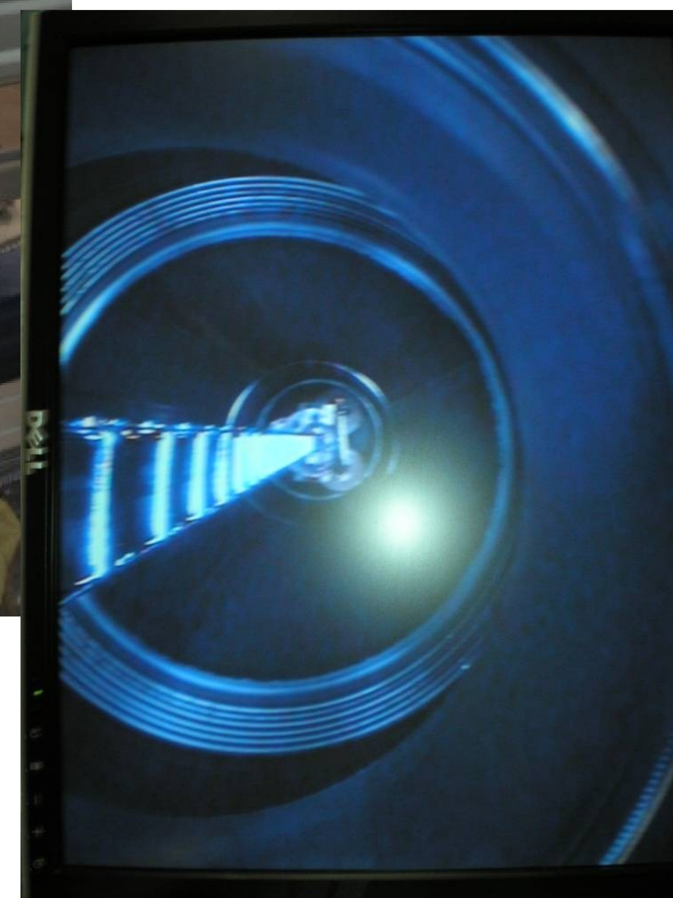


A_{ratio} = (94.5 ± 4.7 ± 17.5) µBq/kg

our measurement: A = (93.0 ± 6.4) µBq/kg stat.+syst.

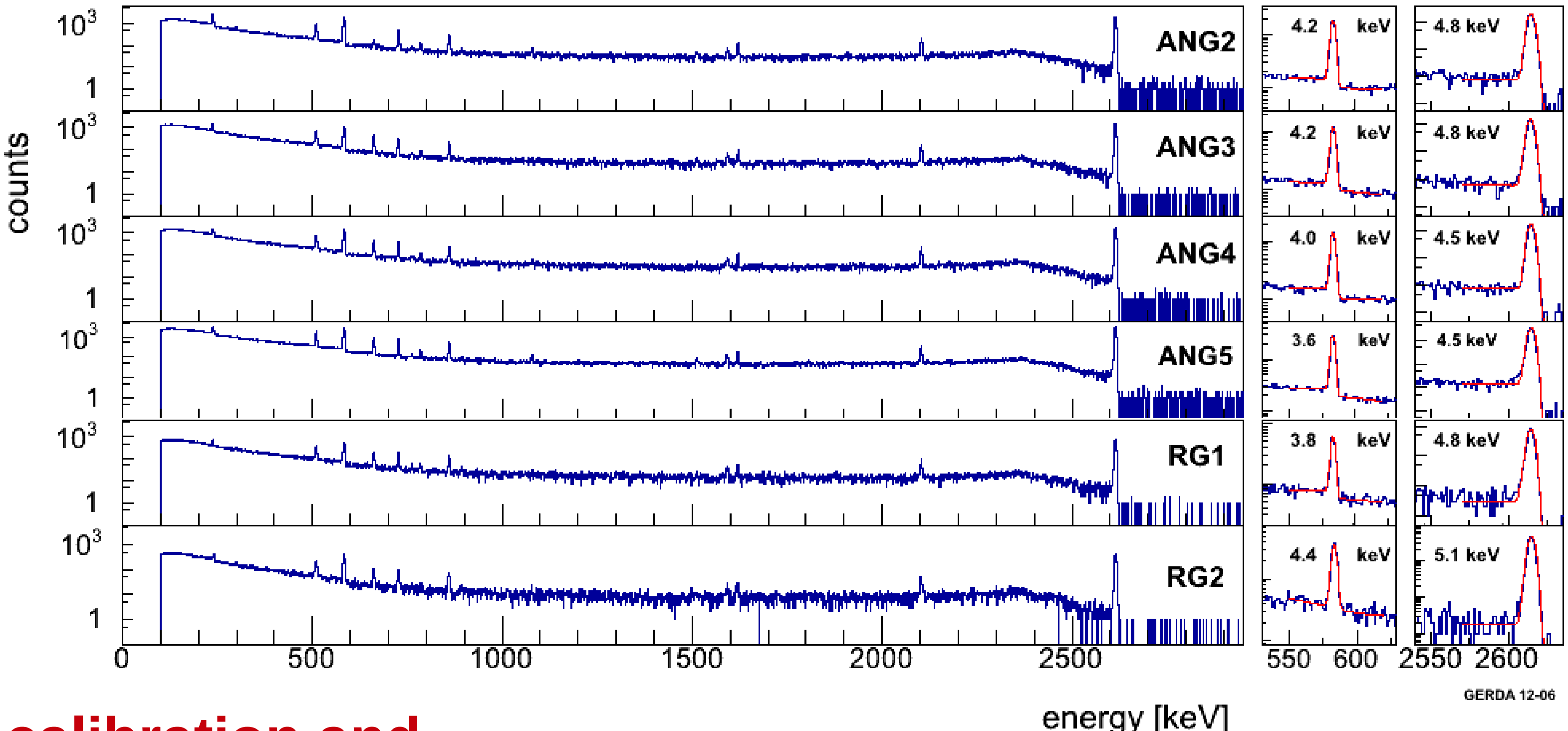
inserted of 1 & 3 string arm:
total of 8 enriched + 3 natural diodes in October 2011



2 enriched detectors had problems from the very beginning, removed from physics analysis:

6 enriched detectors with 14.6 kg total mass
3 natural detectors with 7.6 kg total mass



calibration and

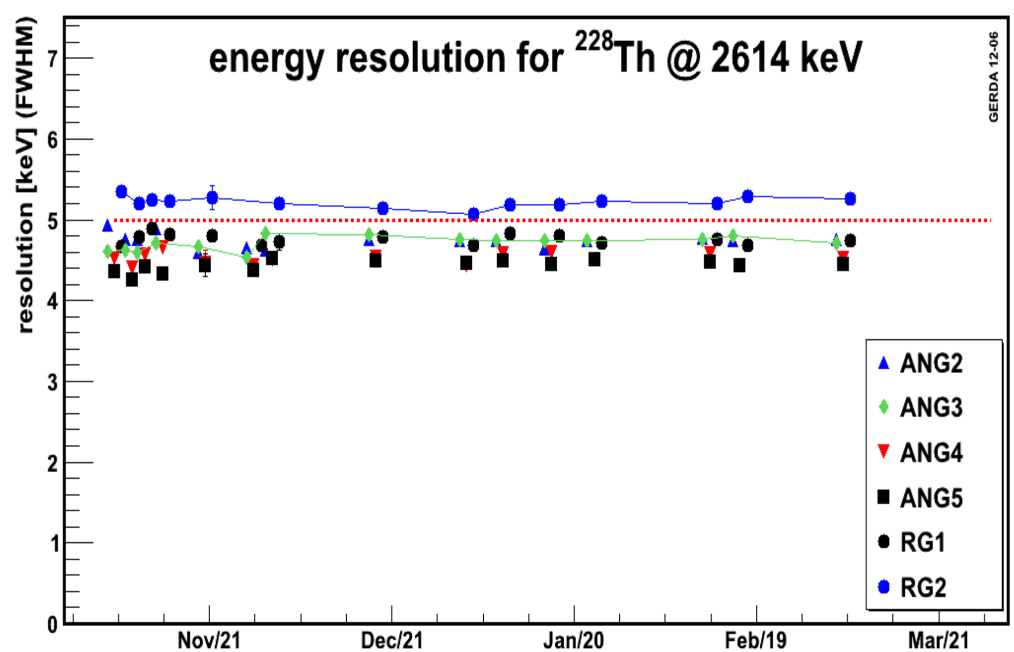
long term stability

4.5 to 5.1 keV (FWHM) at 2614 keV

@ $Q_{\beta\beta}$ = 2039 keV:

4.5 keV resolution (FWHM)

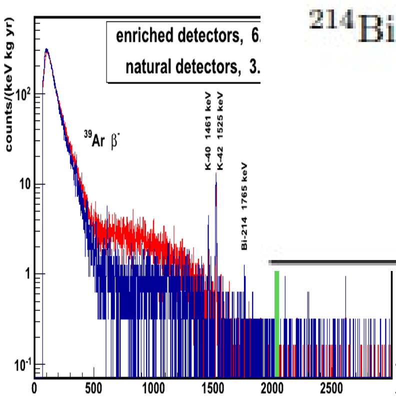
mass weighted average



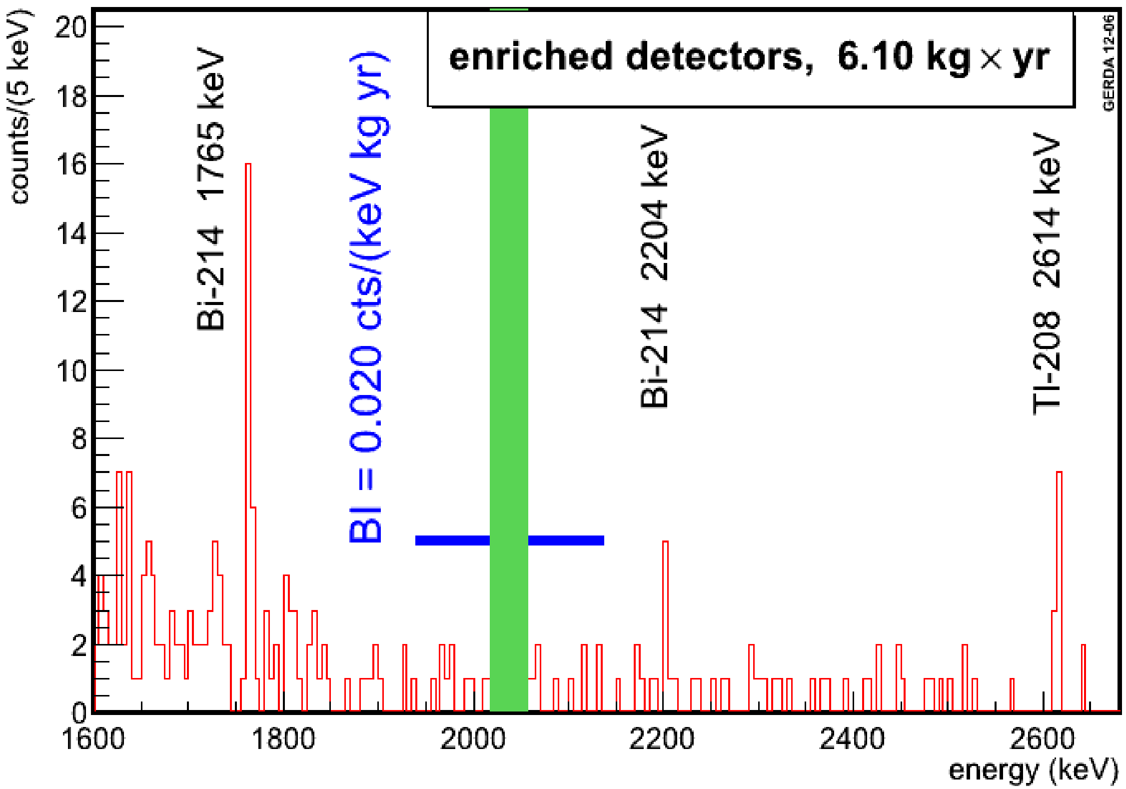
The GERDA background

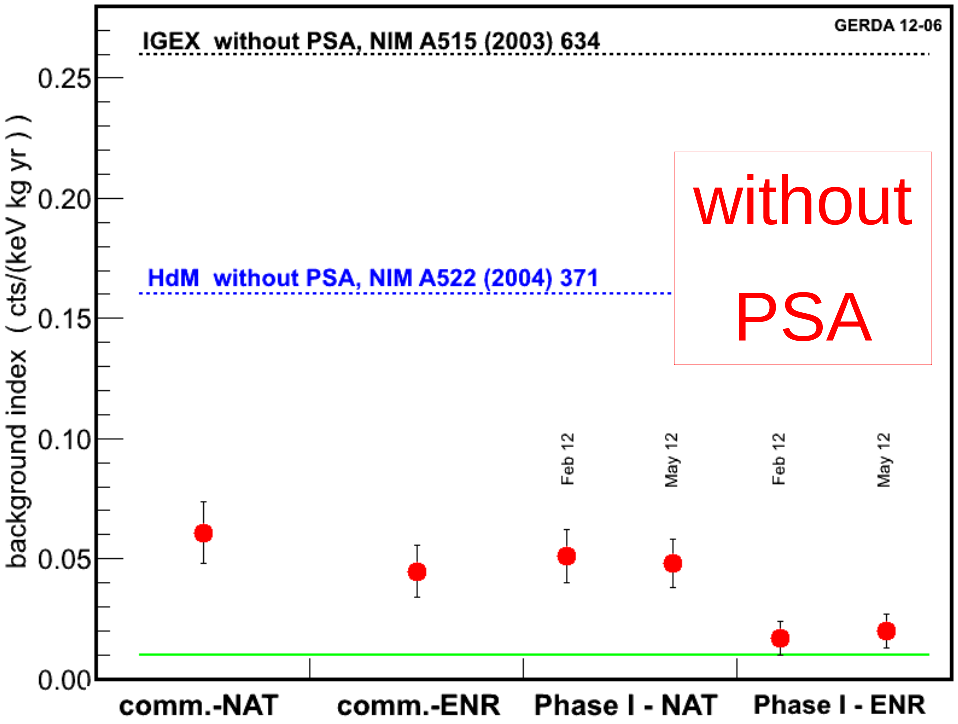
intensities of γ lines are sizeably reduced compared to HdM

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)]	ratio 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	



The GERDA background index (BI)





window: 200 – 40 = 160 keV

BI = 0.020 +0.006 -0.004 cts/ (keV kg yr) [68% coverage]

duty factor: usually 95% ;
one run not used for physics analysis because of temperature instabilities (overall duty cycle 80%)

The $T_{1/2}^{2\nu}$ prelimenary values from fit to data from 6 enriched diodes

binned max. likelihood approach:

free parameters: (active mass,enrichment,detect.eff., $^{40,42}K$, ^{214}Bi, $^{228}Th^{*}$)$_{6det}$, $T_{1/2}^{2\nu}$

600 – 1800 keV range

* normalized

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+sys added in quadrature

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

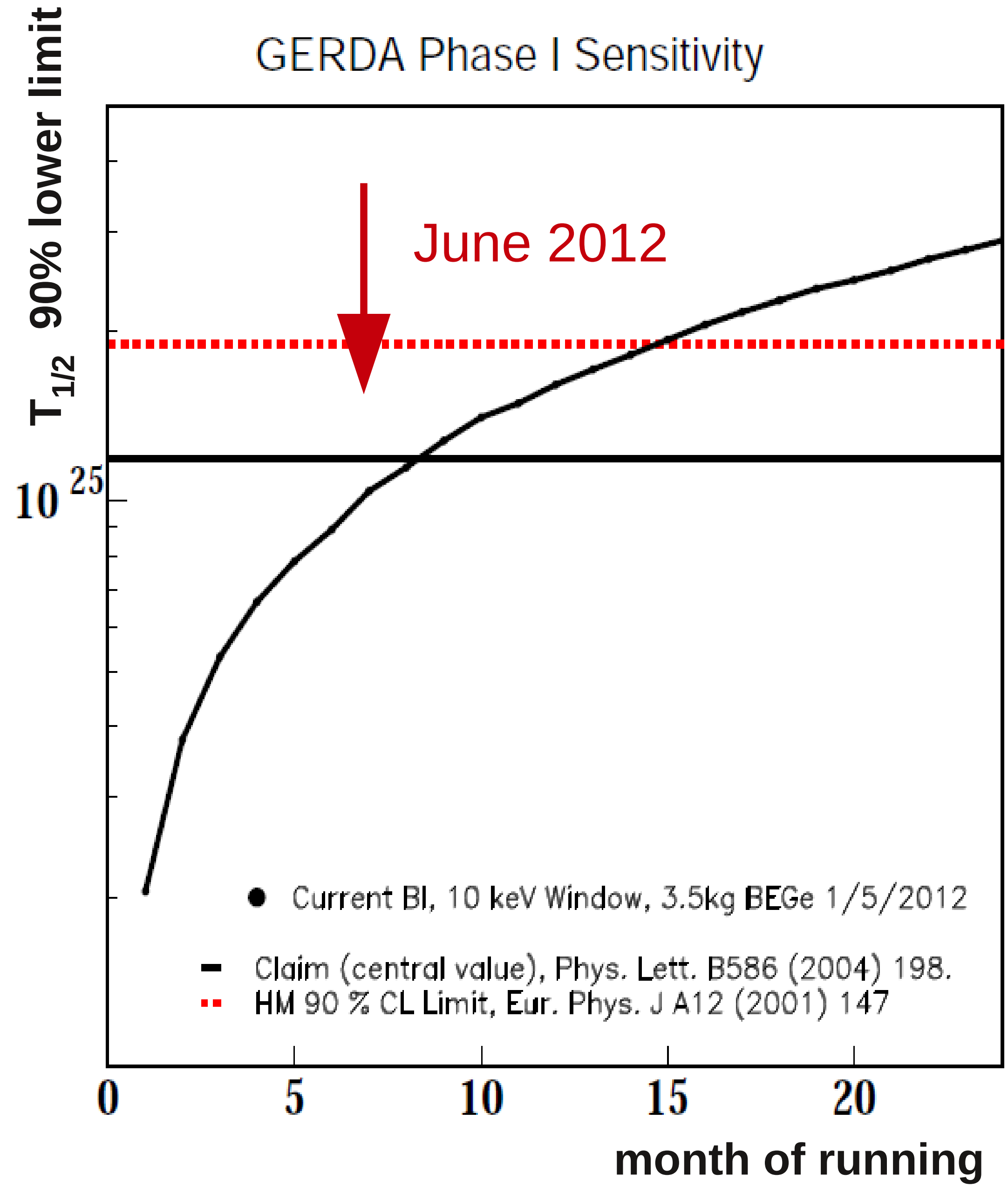
[4] A.M. Bakalyarov *et al.*, Phys. Part. Nucl. Lett. **2** (2005) 77

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

The future

➪ June/July: deploy 5 Phase II enriched BEGe in 1 string arm

14,6 kg Phase I + 3,5 kg Phase II to improve exposure ➪➪➪



➪ prepare Phase II

crystal pulling completed
9 crystals pulled

26+ enr. diodes (20+ kg)

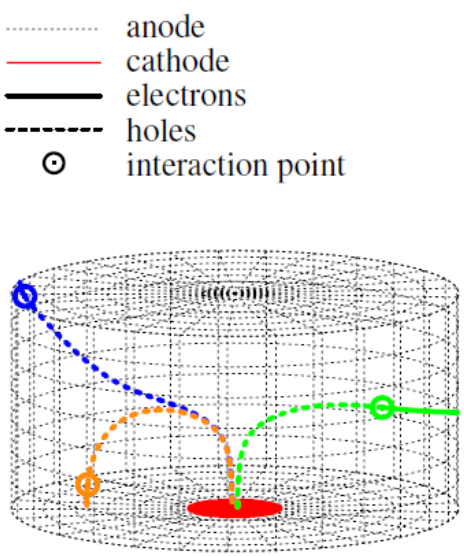
7 tested 1.7 keV (FWHM) @ 1.3MeV

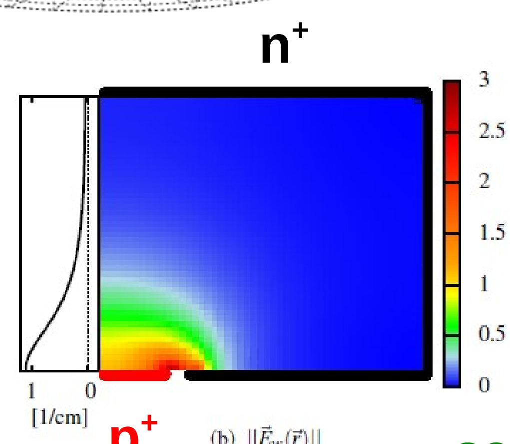
➪ goal: BI = 10^{-3} cts/ (keV kg yr)

1) thickwindow BEGe with advanced PSA performance
2) detect LAr scintillation light as active veto

posters by D. Budjas (60-3)
M. Heisel (59-2)

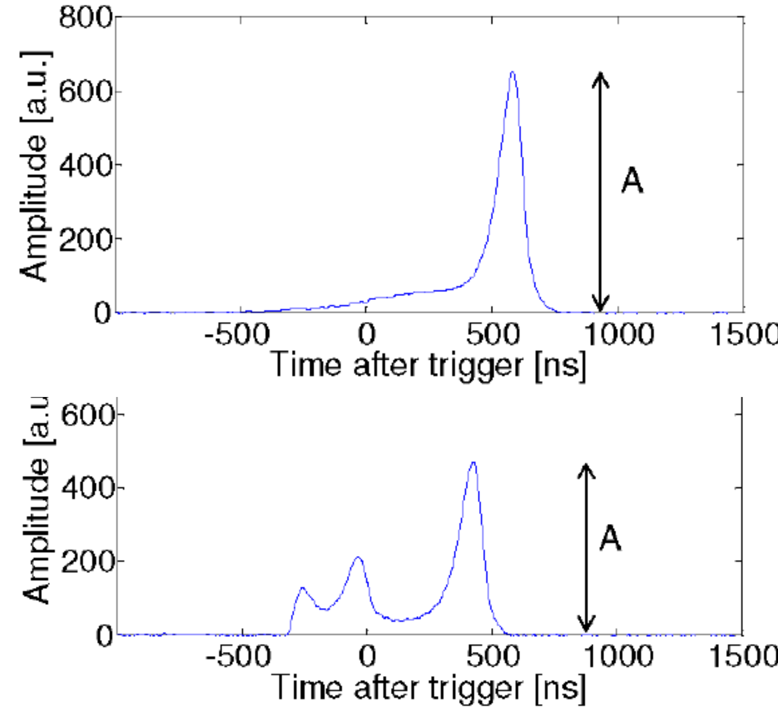
Phase II : new BEGe (thick window) detectors

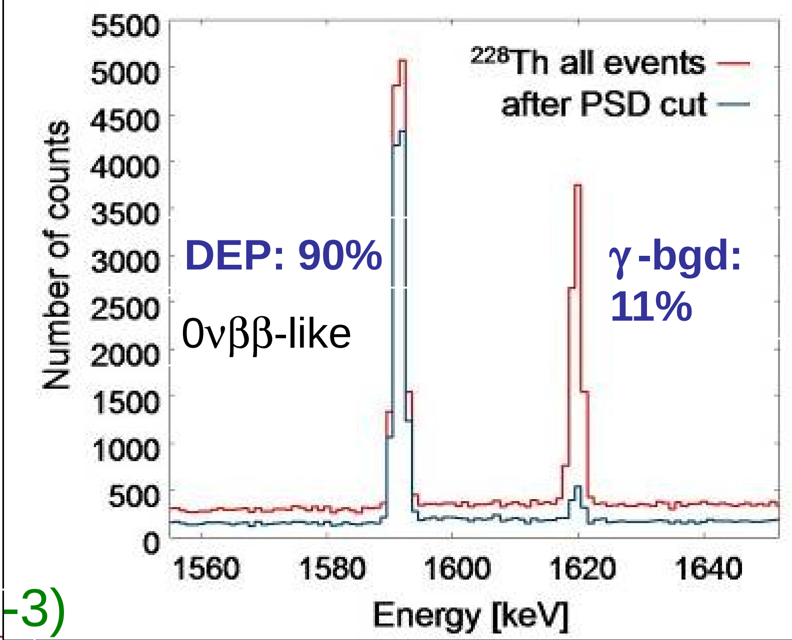




Signal shape provides clear topology for event-by-event signal ID / bgd discrimination:

- **SSE/MSE** discrimination
- **Surface** events:
  - n^+ slow pulses
  - p^+: 'amplified' current pulses

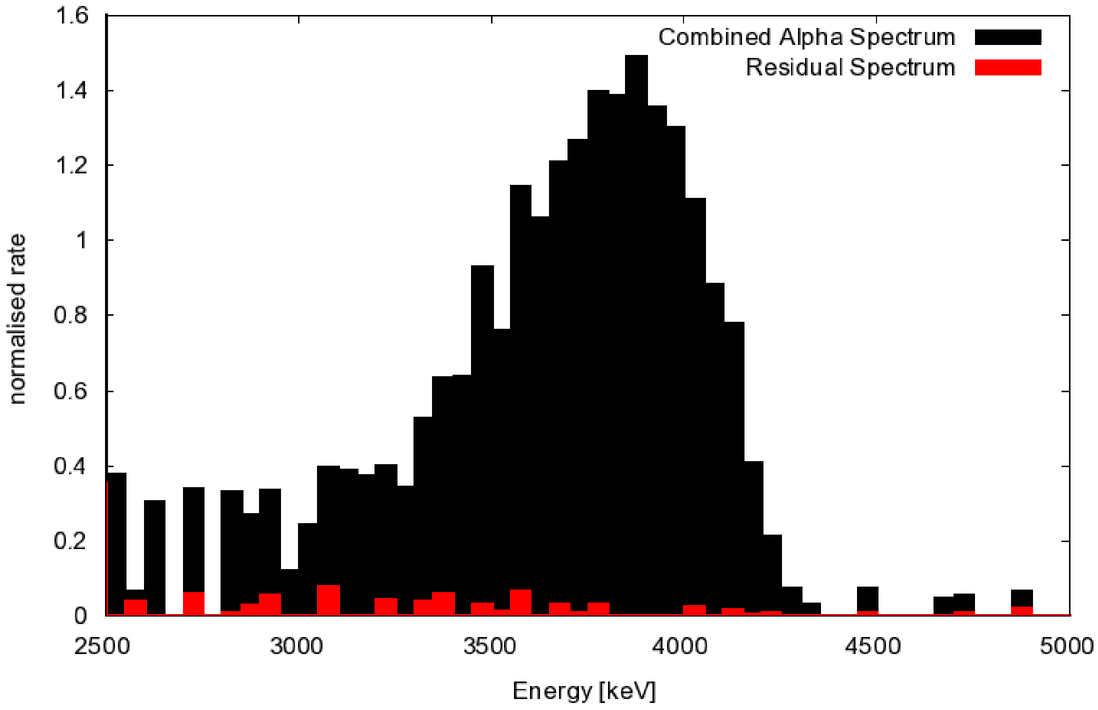




see poster by D. Budjas (60-3)

suppression of surface events

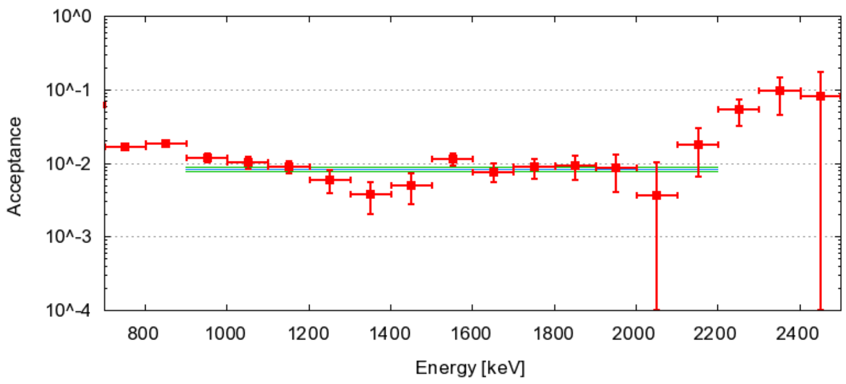
p^+ contact pulses measured with a ^{241}Am α source



p^+ contact pulses cut tuned to 90% survival of $0\nu\beta\beta$–like event

see poster by D. Budjas (60-3)

n^+ surface events measured with ^{90}Sr and ^{106}Ru β sources



β n^+ surface event PSD rejection power demonstrated stable in region 1 - 2 MeV

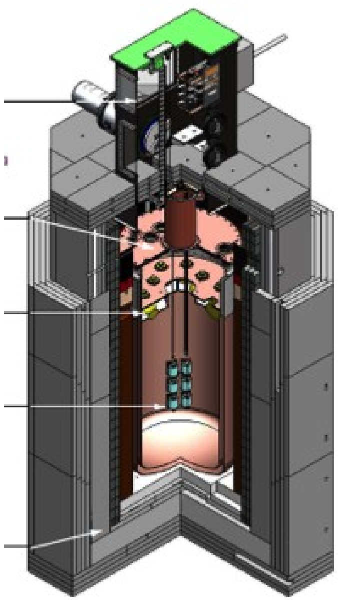
MC cut set to 20% survival of γ-like events and 0.1% survival of β-like events

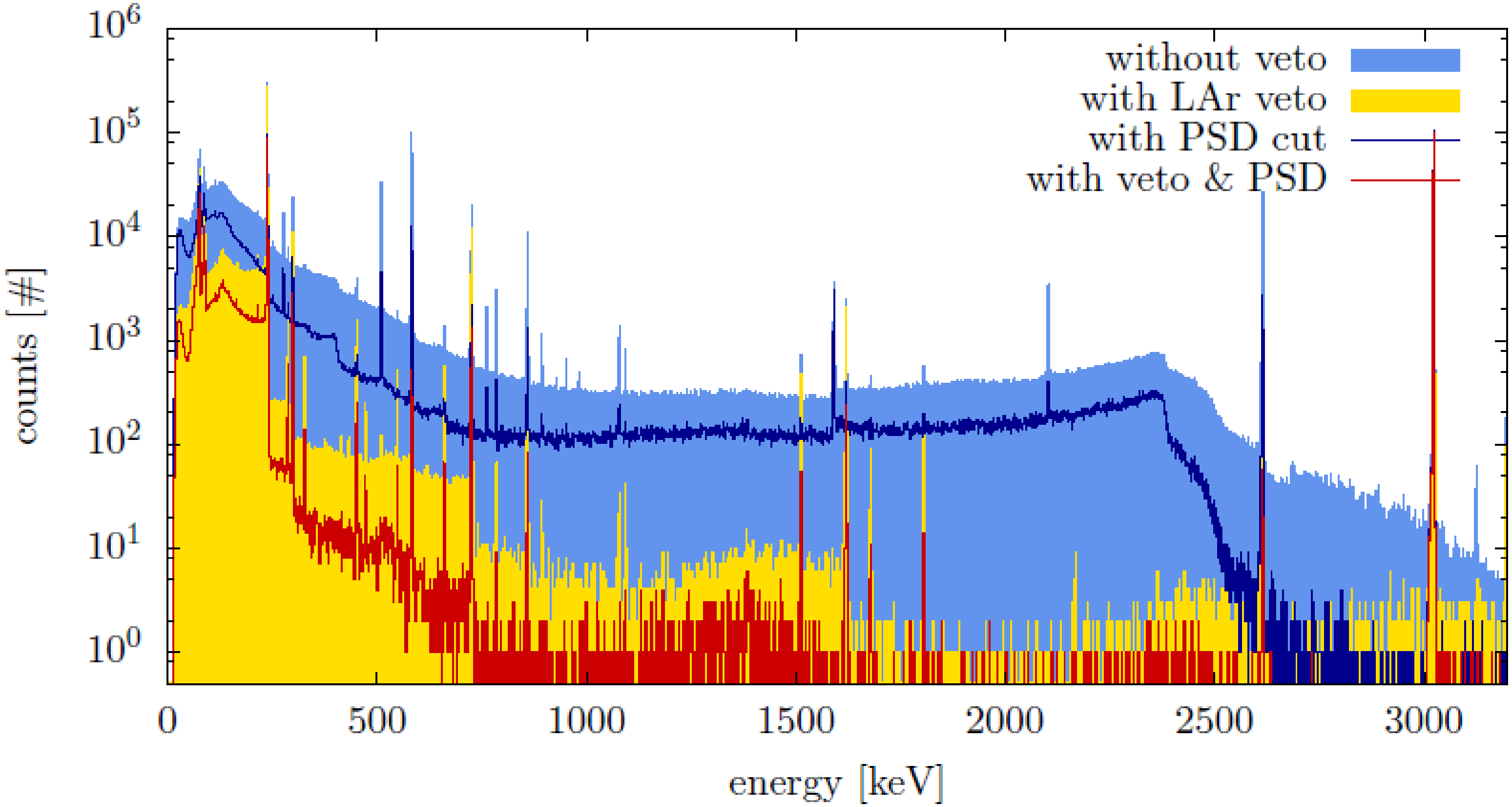
good quantitative agreement of simulated suppression with measurement

LAr instrumentation R&D

LArGe test facility

PMT read out of
LAr scintillation



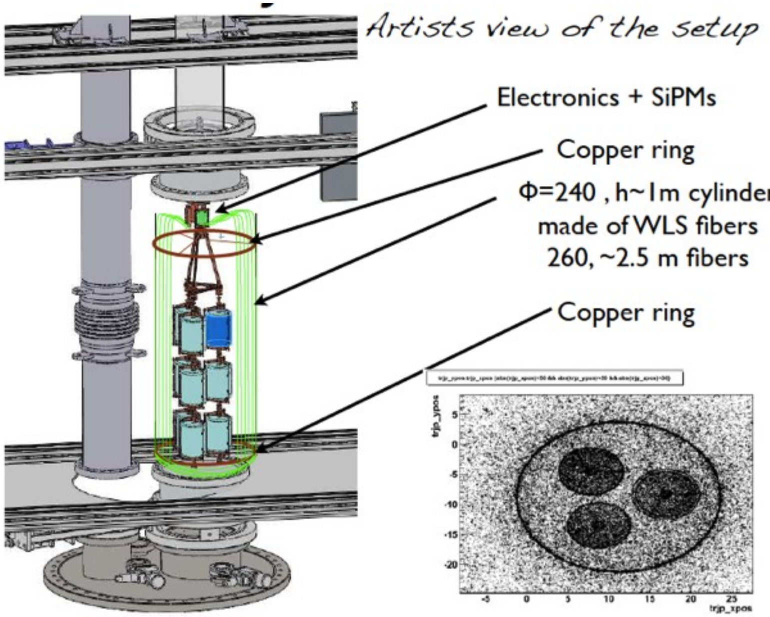


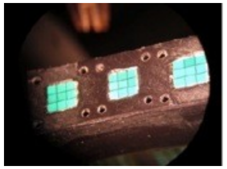
Operation of Phase II detector prototype in LArGe:
Measured suppression factor at $Q_{\beta\beta}$: **~0.5·10^4** for a ^{228}Th calibration source
Also: successful read out scintillation light with fibers coupled to SiPMs

LAr instrumentation

PMT read out

fibre read out





- 3rd option: R&D on large area avalanche photodiodes or UV sensitive SiPMs on custom low activity substrates has started
- MC campaign to compare competing options ongoing
- Hardware for PMT and fiber options available & prototype/test setup construction started

see poster by M. Heisel (59-2)

summary

GERDA : searching for the $0\nu\beta\beta$ decay in ^{76}Ge

concept works : diodes enriched in ^{76}Ge on strings in liquid argon (Lar) @ LNGS

- GERDA is running and taking data
- statistics: 1.11.2011 – 21.5.2012 (^{enr}Ge exposure 6.10 kg yr)
- systematics: blinding 2019 – 2059 keV
- background index (BI) : 0.020 +0.006 -0.004 cts/(keV kg yr) [68% coverage]

- LAr: ^{42}Ar (^{42}K) activity determined: (93.0 ± 6.4) μBq/kg
- ^{76}Ge $T_{1/2}^{2\nu}$ = (1.88 ± 0.10) 10^{21} yr

all results are preliminary !!!

- preparations for Phase II progressing well:

  increase in mass by add. ~20kg (26+ BEGe) & BI = 10^{-3} cts/(keV kg yr)

  9 crystals pulled – milestone completed successfully !!

complete Phase I and start Phase II in early 2013