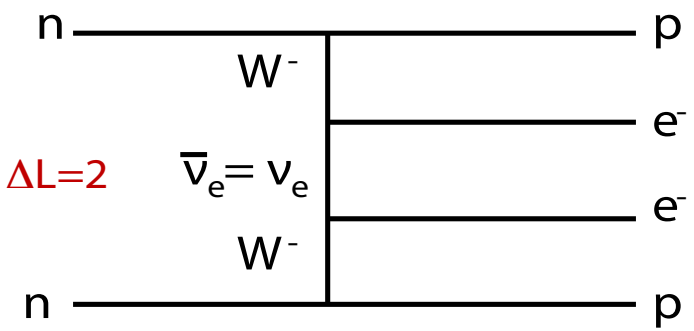
Status of the GERDA experiment

Fabiana Cossavella for the GERDA collaboration

Max-Planck Institut für Physik, München

16 October 2012

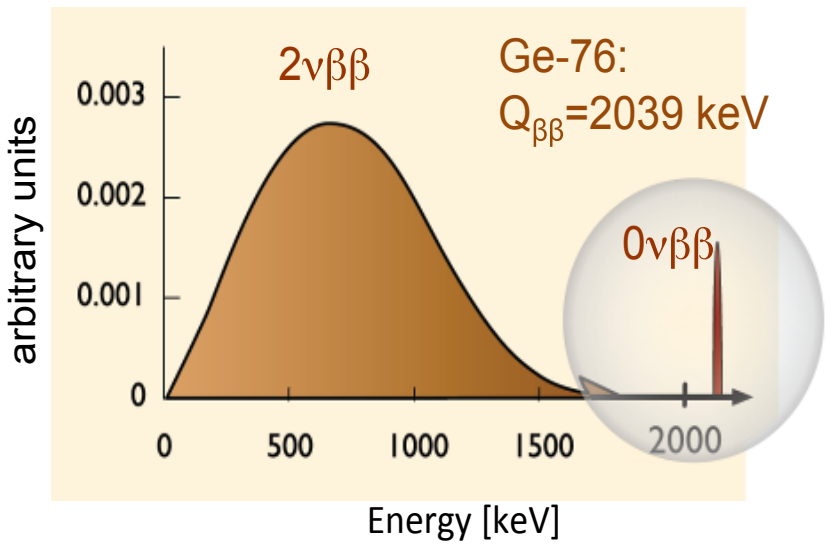
GERDA physics goals

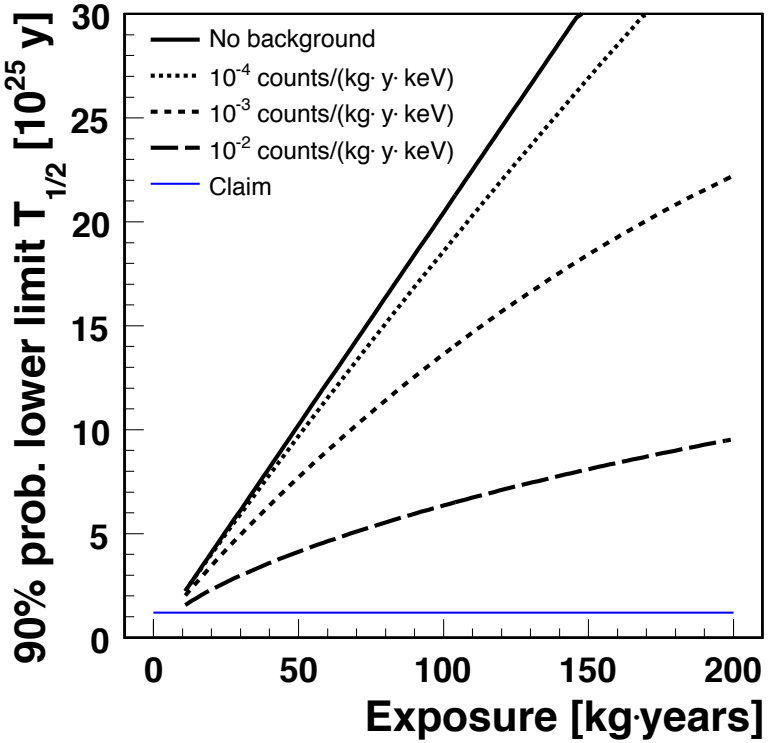


0νββ driven by exchange of light Majorana neutrinos

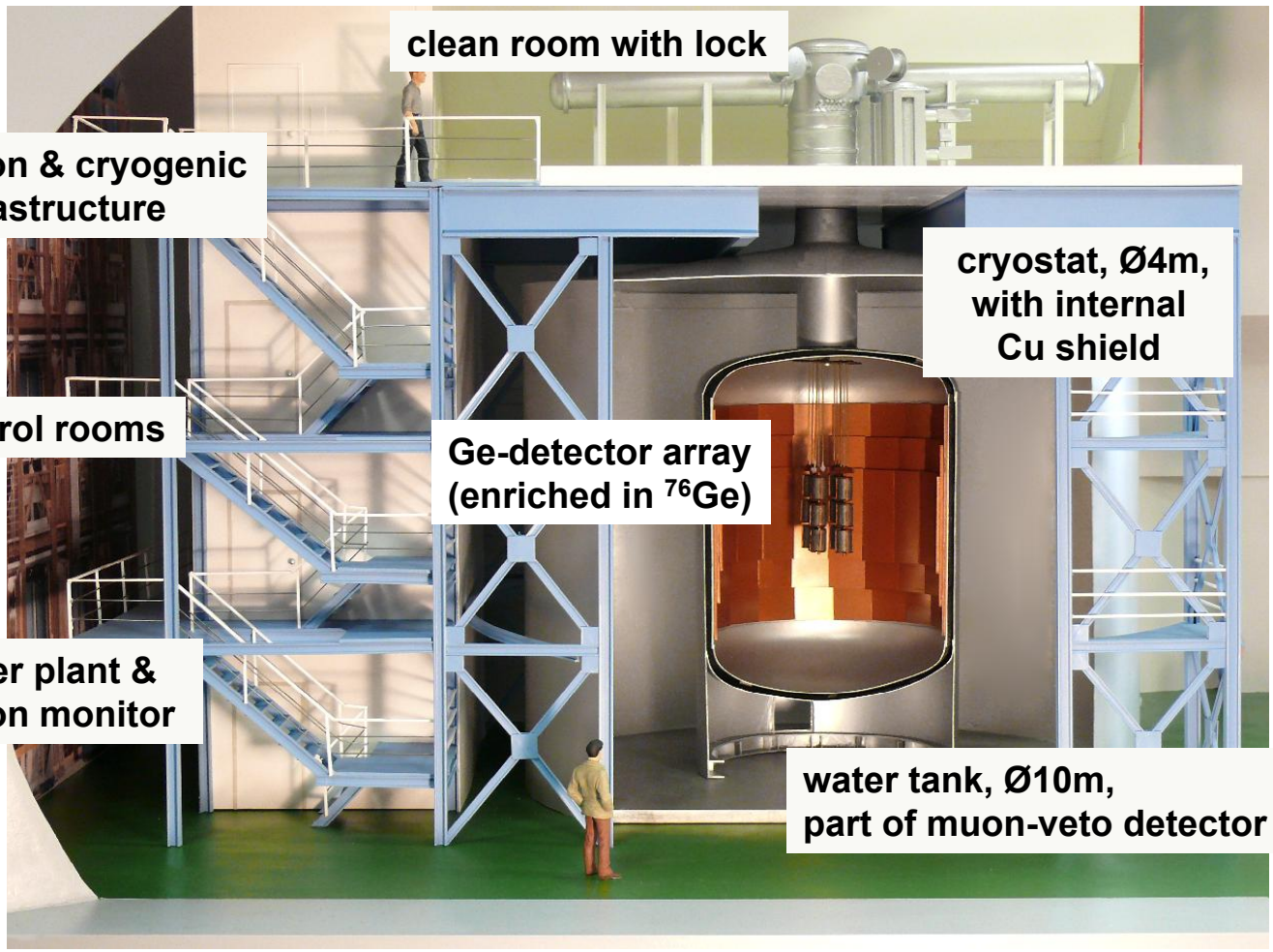
Phase	I	II
Exposure [kg ·yr]	15	100
Bg [counts/(keV·kg·yr)]	10^{-2}	10^{-3}
Upper limit $m_{\beta\beta}$ [eV]	0.23-0.39	0.09-0.15

A. Smolnikov, P. Grabmayr PRC 81 028502(2010)





The GERmanium Detector Array



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

Phase I: 3-string assembly

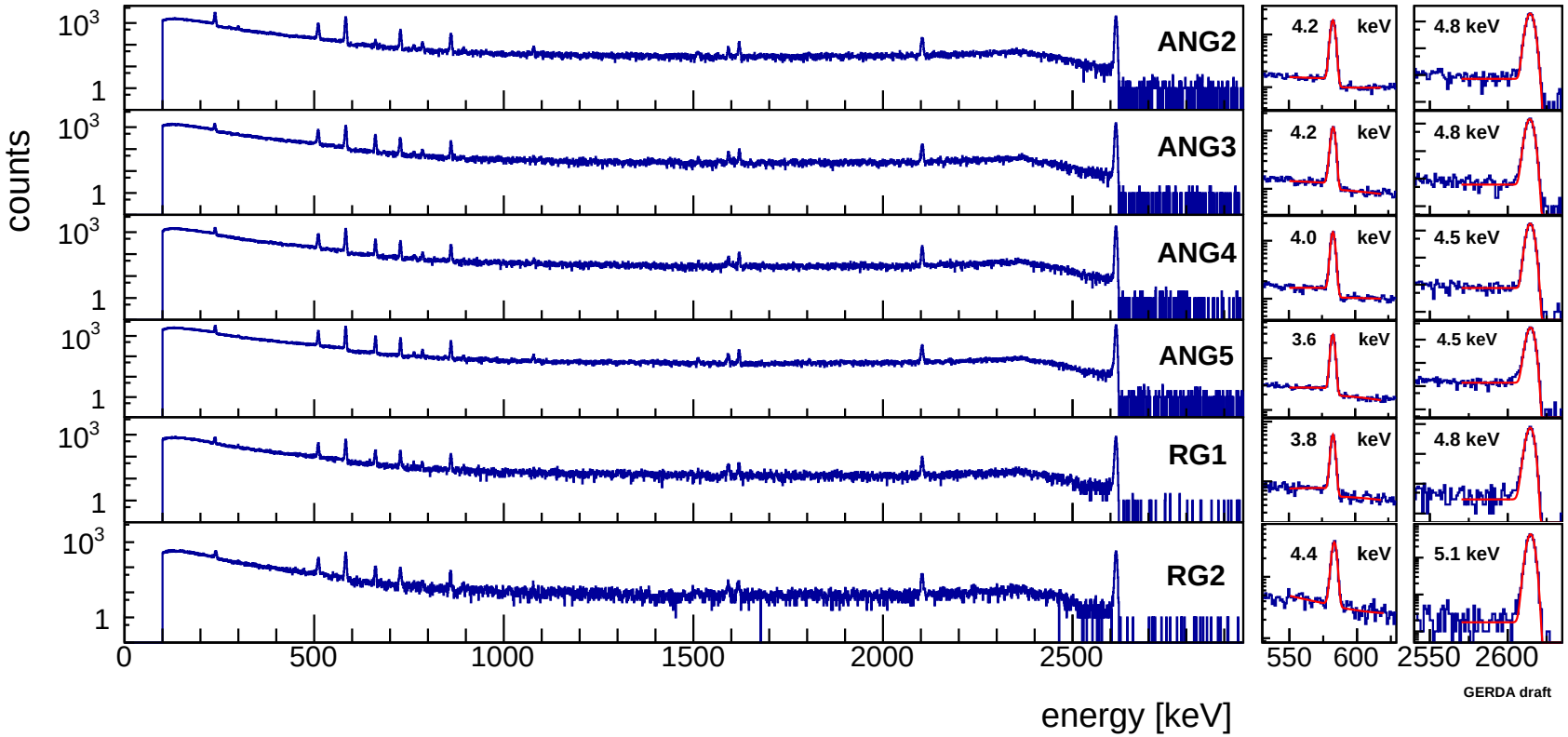
phase I started in November 2011



- 8 refurbished enriched diodes from HdM and IGEX
- 86% isotopically enriched in ^{76}Ge
- 1 $^{\mathrm{nat}}$Ge detectors
- 2 diodes shut off due to high leakage current

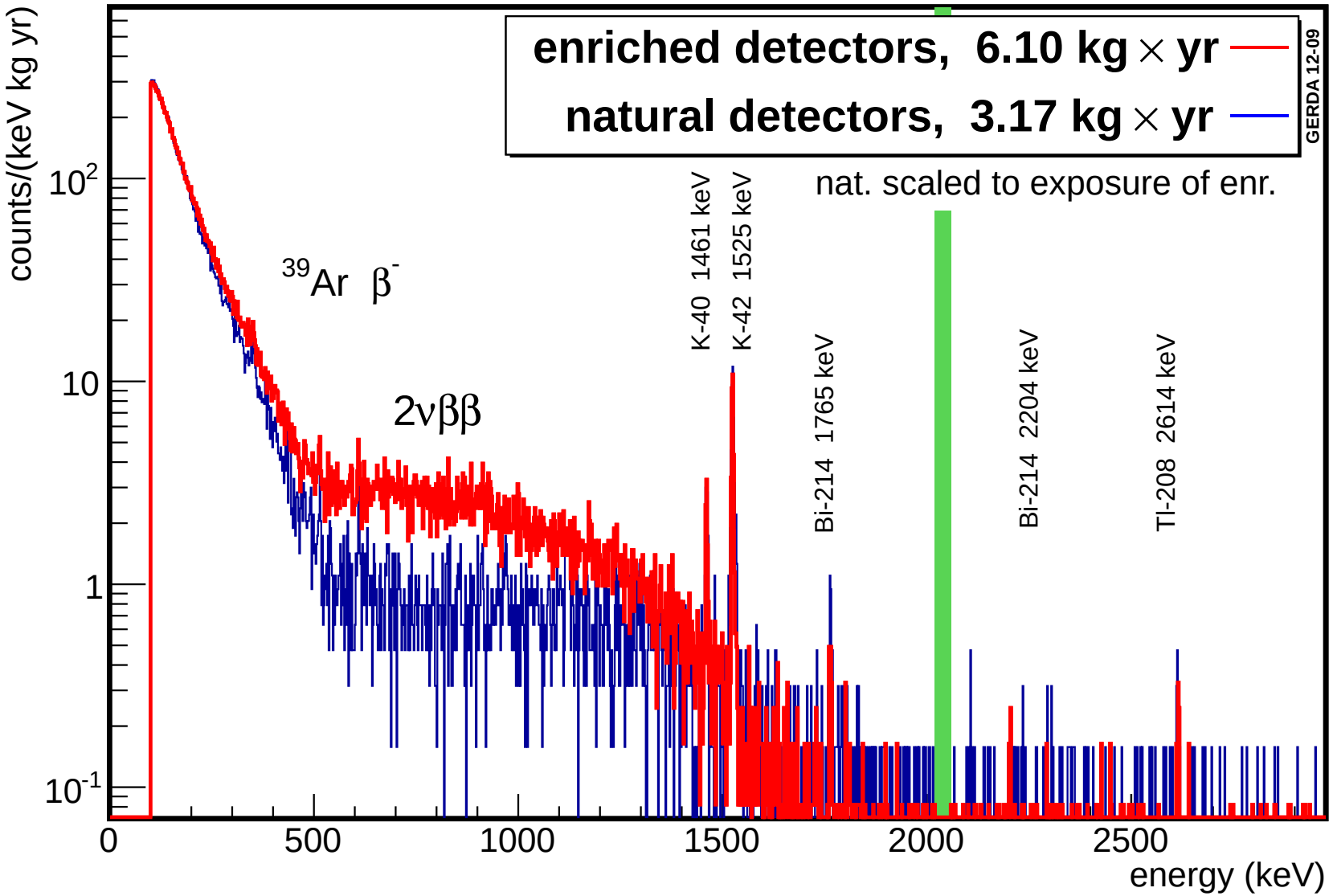
total (enriched) mass of working phase I detectors: 14.6 kg

Phase I: 3-string assembly

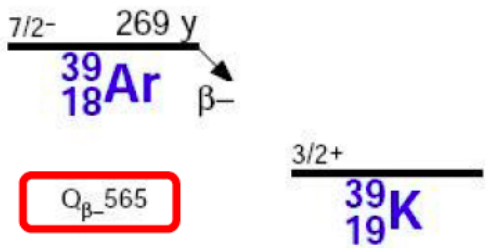


- ^{228}Th calibration every one to two weeks
- resolution, FWHM: 4.5 keV at $Q_{\beta\beta}$ (mass weighted average)

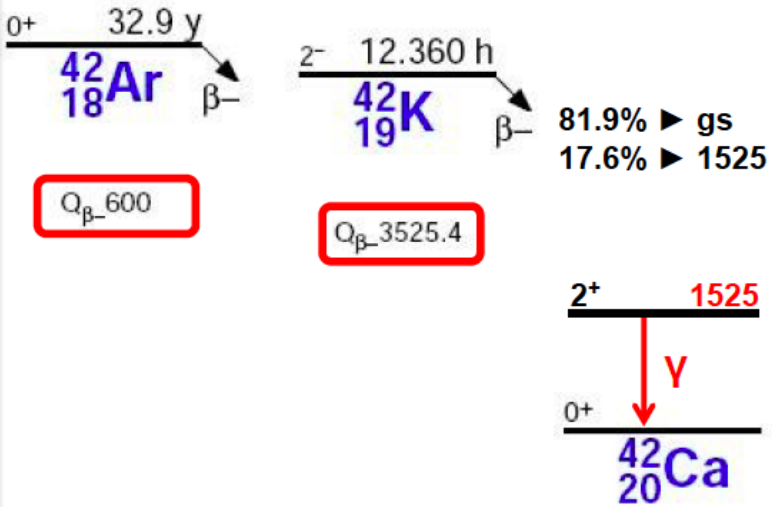
Preliminary results



Preliminary results



Published activity of (1.01±0.08) Bq/kg (Benetti et al., NIM A574 (2007) 83) fully compatible with our data



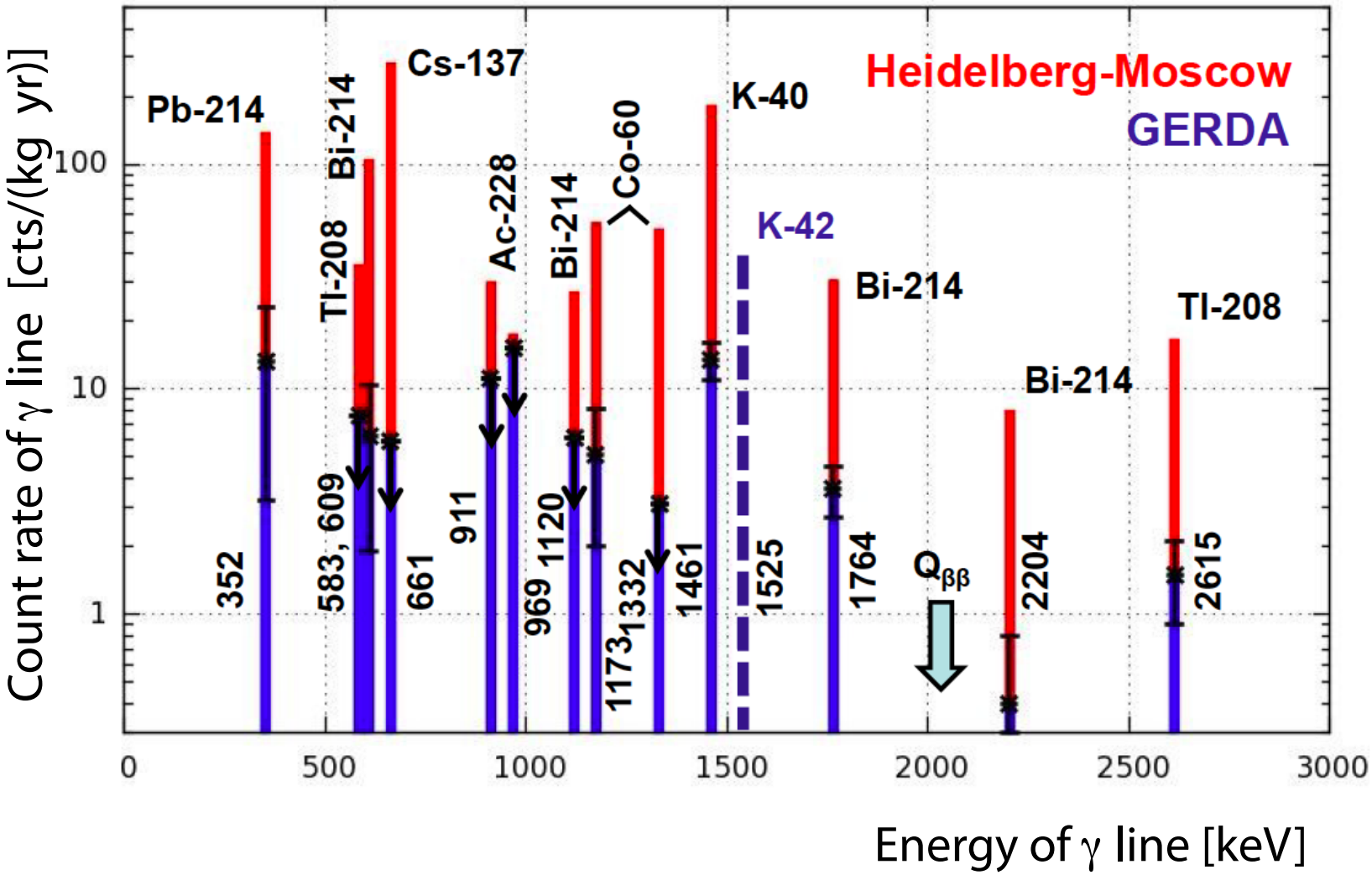
Limit <41 µBq/kg (90% CL) (Ashtikov et al., arXiv:nucl-ex/0309001) NOT compatible with our data

Intensity of 1525 keV line in E-field free setup indicates Ar-42 activity to be more than twice the value of avove limit

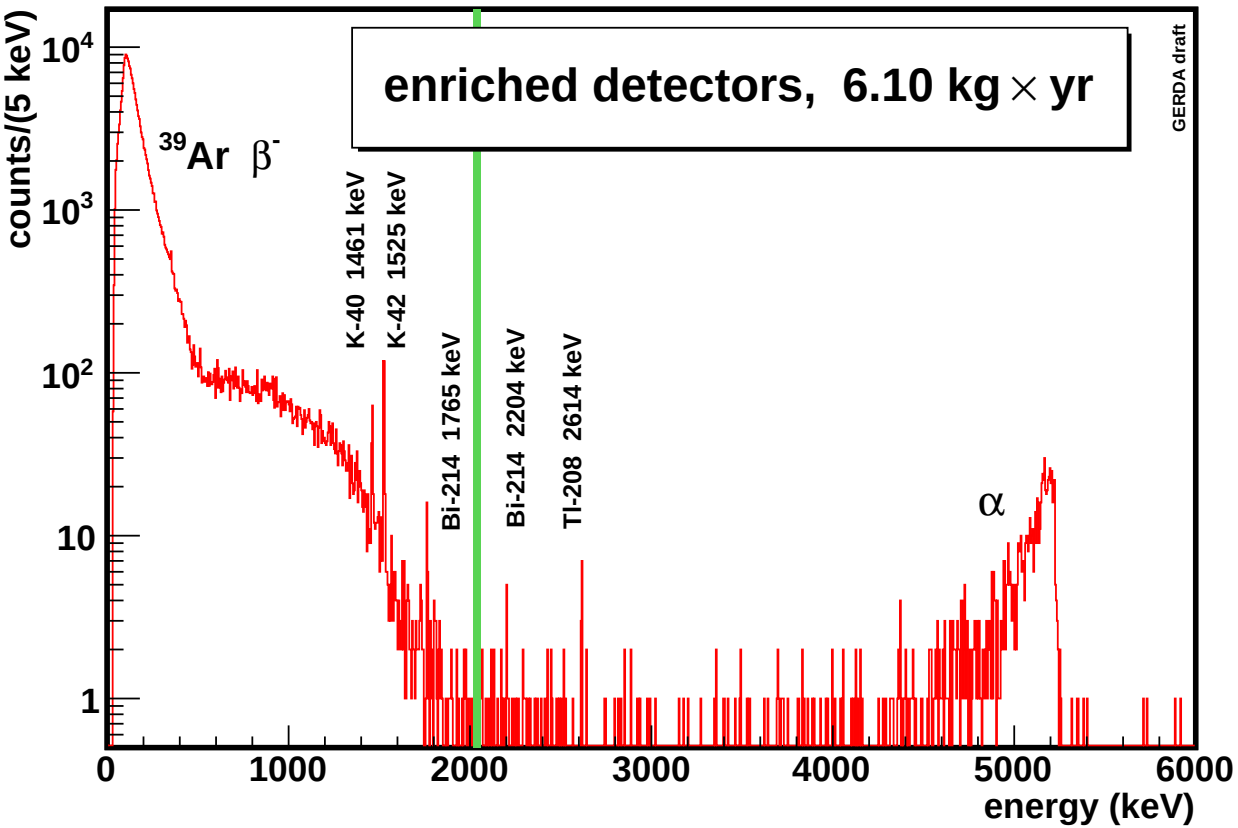
Evidence that charge K-42 ions drift in electic field of Ge-diodes. Minishroud as shield against E-field

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

Preliminary results

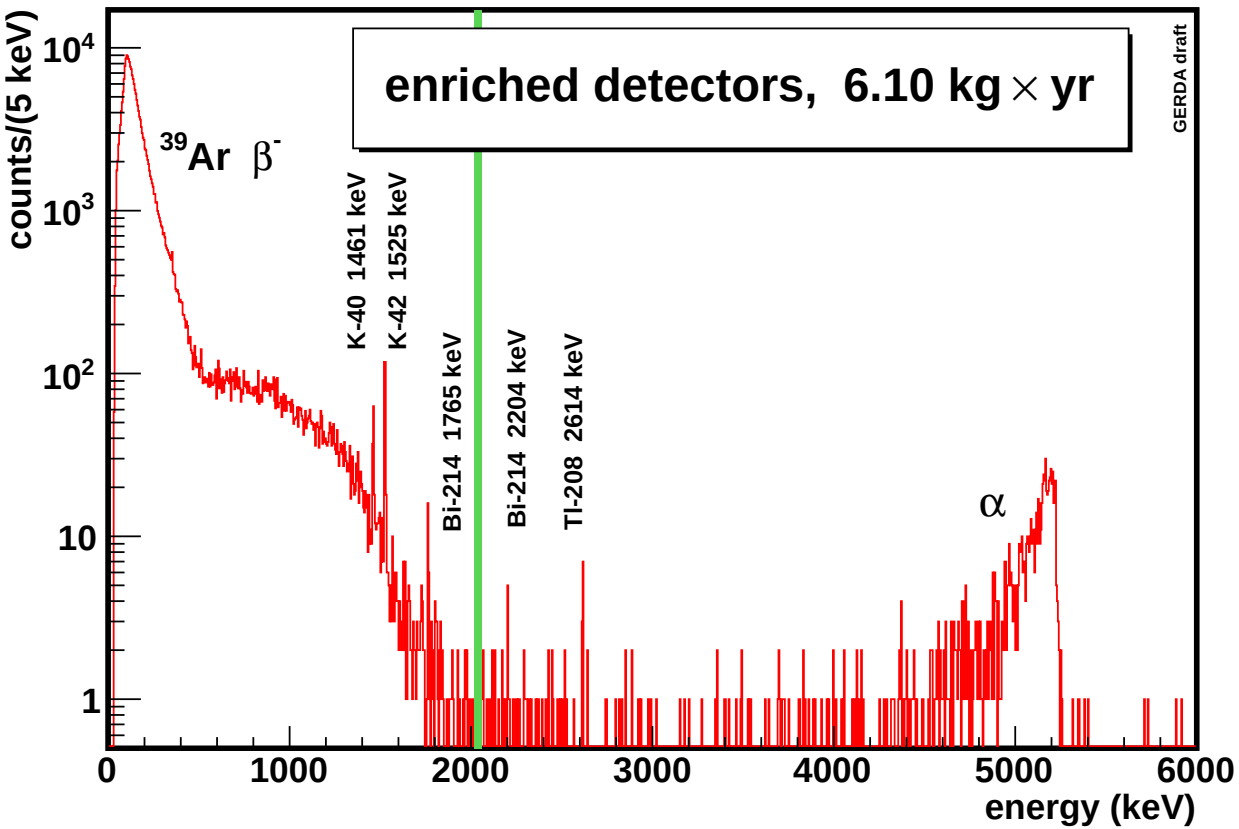


Preliminary results



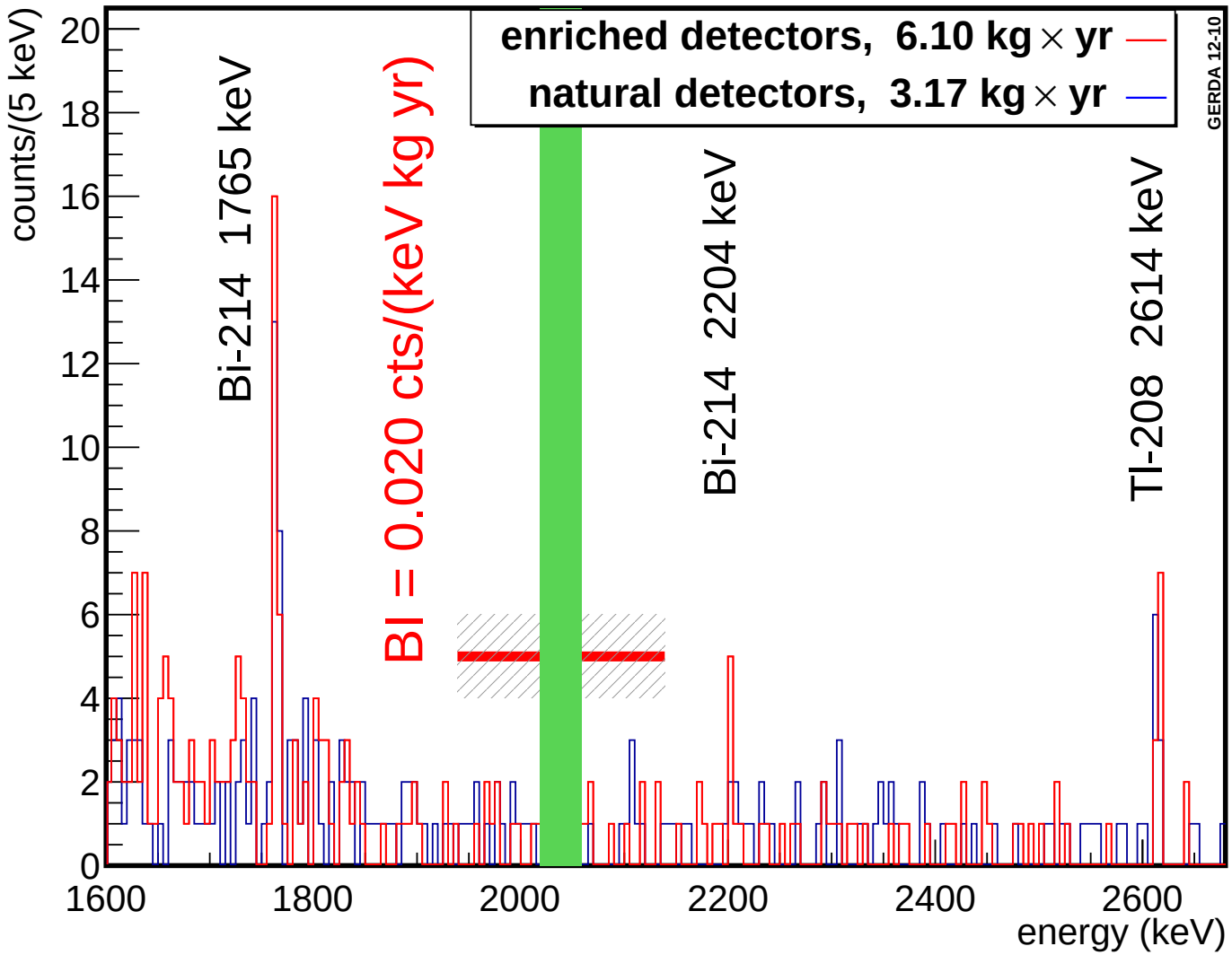
- Alpha candidate event rates different for individual detectors, suggesting a surface contamination mostly on two detectors

Preliminary results

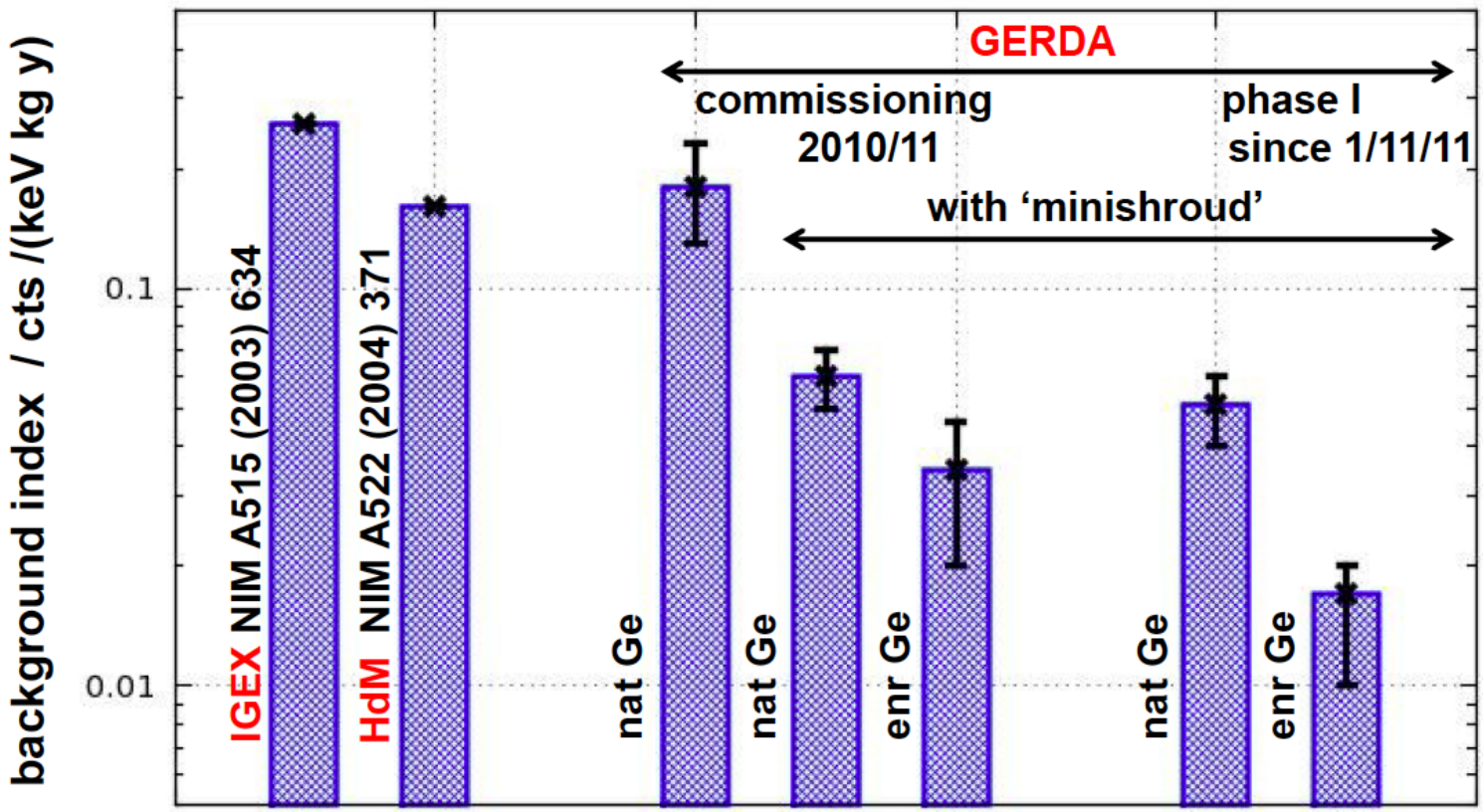


- Monte Carlo studies suggest ^{210}Po decays on the p+ contact/groove surface

Preliminary results

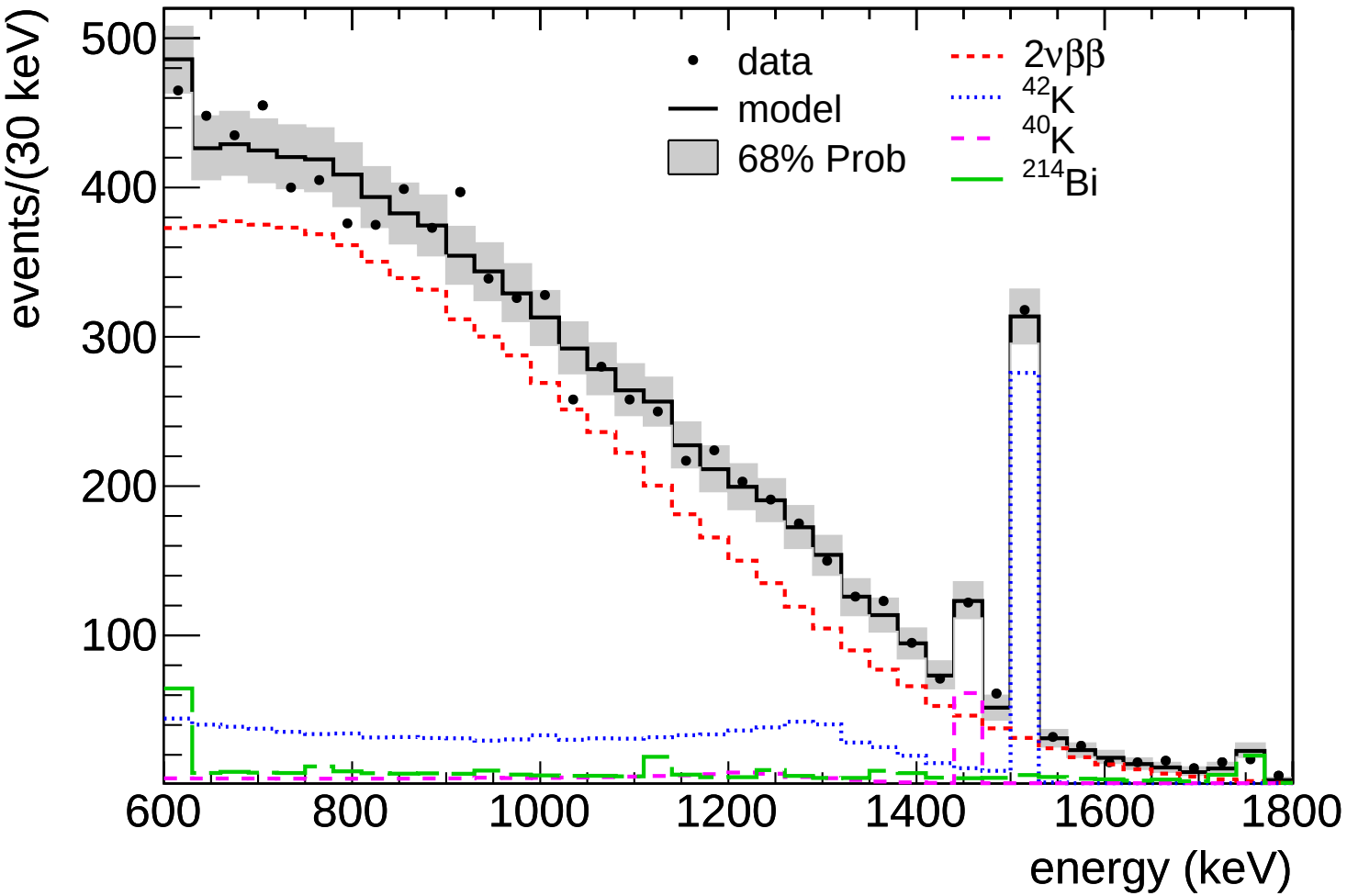


Preliminary results



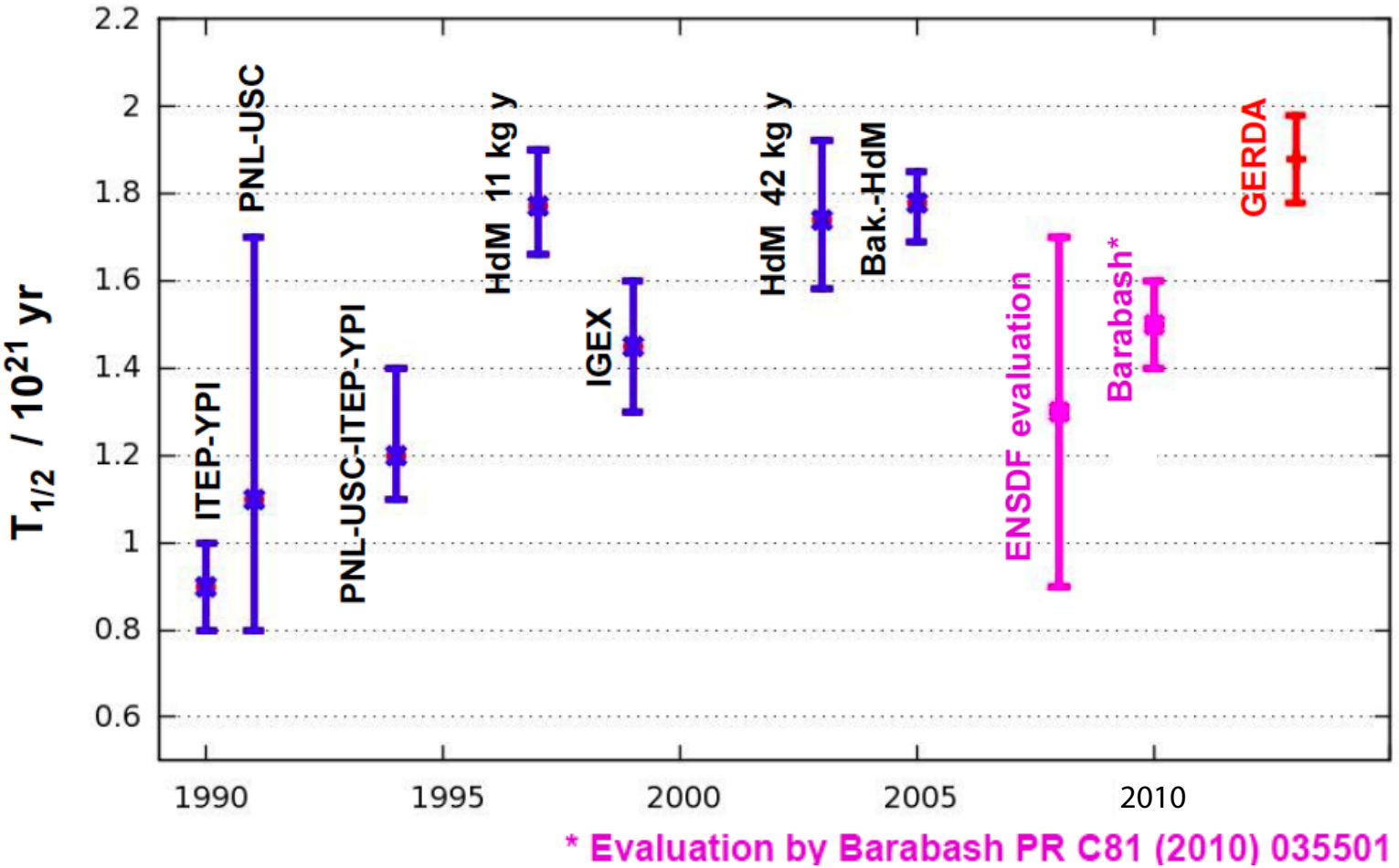
GERDA/HdM BI ratio about 1/10

Preliminary results



$$T^{2\nu}_{1/2} = (1.88 \pm 0.10) \cdot 10^{21} \text{ yr } (5.04 \text{ kg·yr})$$

Preliminary results



Current status

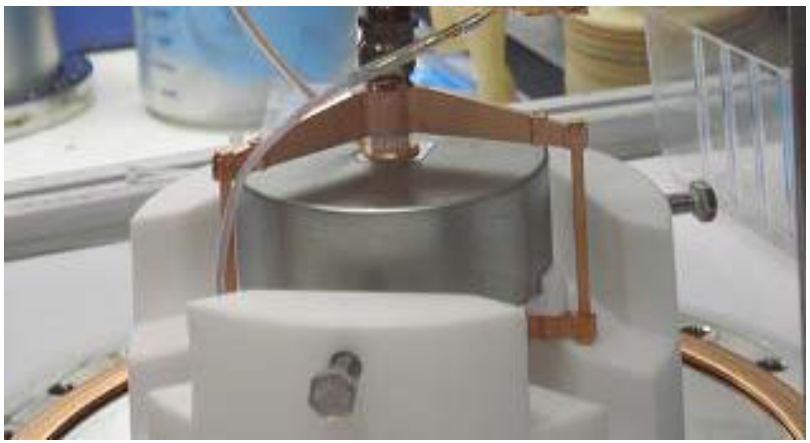
Phase I

- approximatively 10 kg yr of data acquired until September 2012
- GERDA Phase I completion expected in spring 2013: unblinding and physics analysis
- $T_{1/2}$ (90% C.L.) $> 1.9 \cdot 10^{25}$ yr (assuming no $0\nu\beta\beta$ signal and current BI)

Phase II

- reduce background by factor > 10 with respect to phase I
- increase mass: up to additional 30 enriched BEGe detectors (20 kg)
- liquid argon veto instrumentation
- construction of new lock system and development of phase II front end electronic ongoing

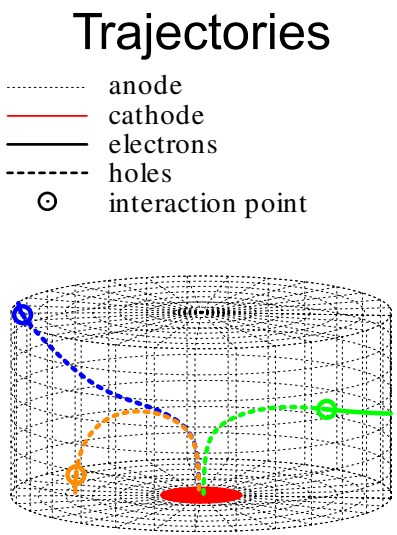
Phase II detectors

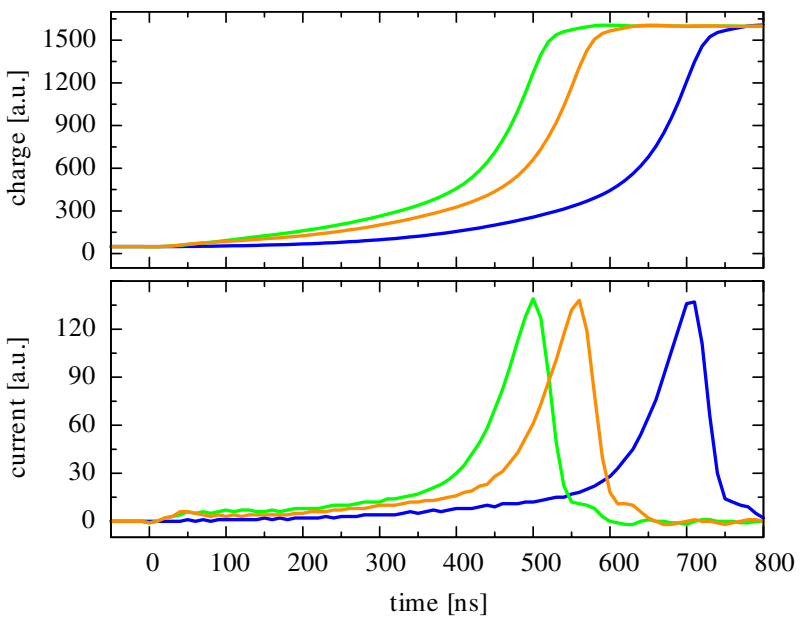


Broad-Energy GErmanium (BEGe) detector

- Low capacitance → high energy resolution: 1.6 keV @ 1.332 MeV
- good pulse shape discrimination:

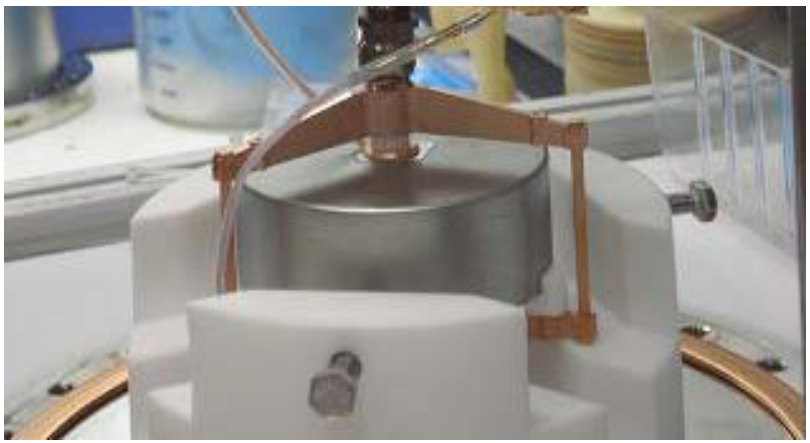
Signal for different trajectories





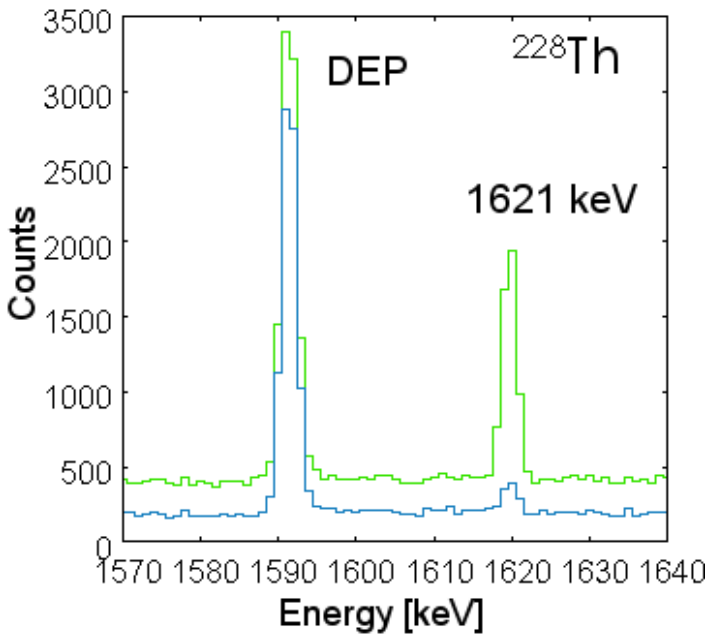
M. Agostini et al., JINST 6P03005 (2011)

Phase II detectors



Broad-Energy GErmanium (BEGe) detector

- Low capacitance $\rightarrow$ high energy resolution: 1.6 keV @ 1.332 MeV
- good pulse shape discrimination:



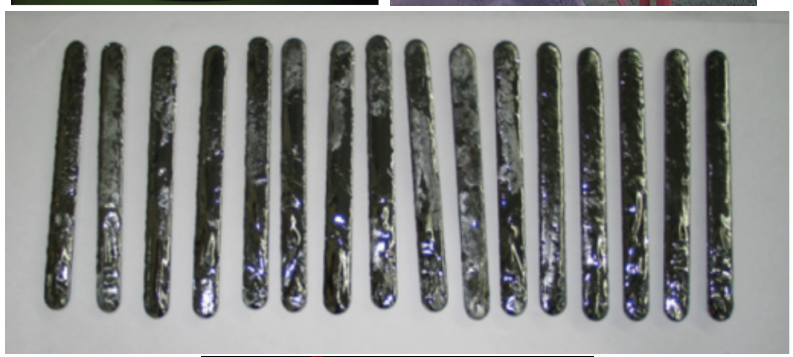
D. Budjas et al., JINST 4P10007 (2009)

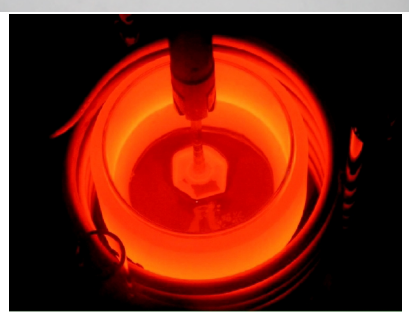
- PSA accepting 90% of ^{208}Tl DEP (SSE $\rightarrow 0\nu\beta\beta$-like)
- about 10% survival of the ^{212}Bi γ-line (mainly MSE)

Ge-Procurement and Detector fabrication for Phase II

complete production chain tested with depleted Ge:

- 2005: 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.



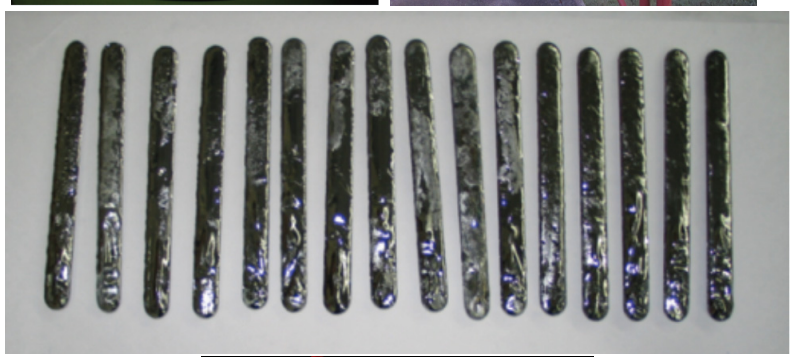


Ge-Procurement and Detector fabrication for Phase II

complete production chain tested with depleted Ge:

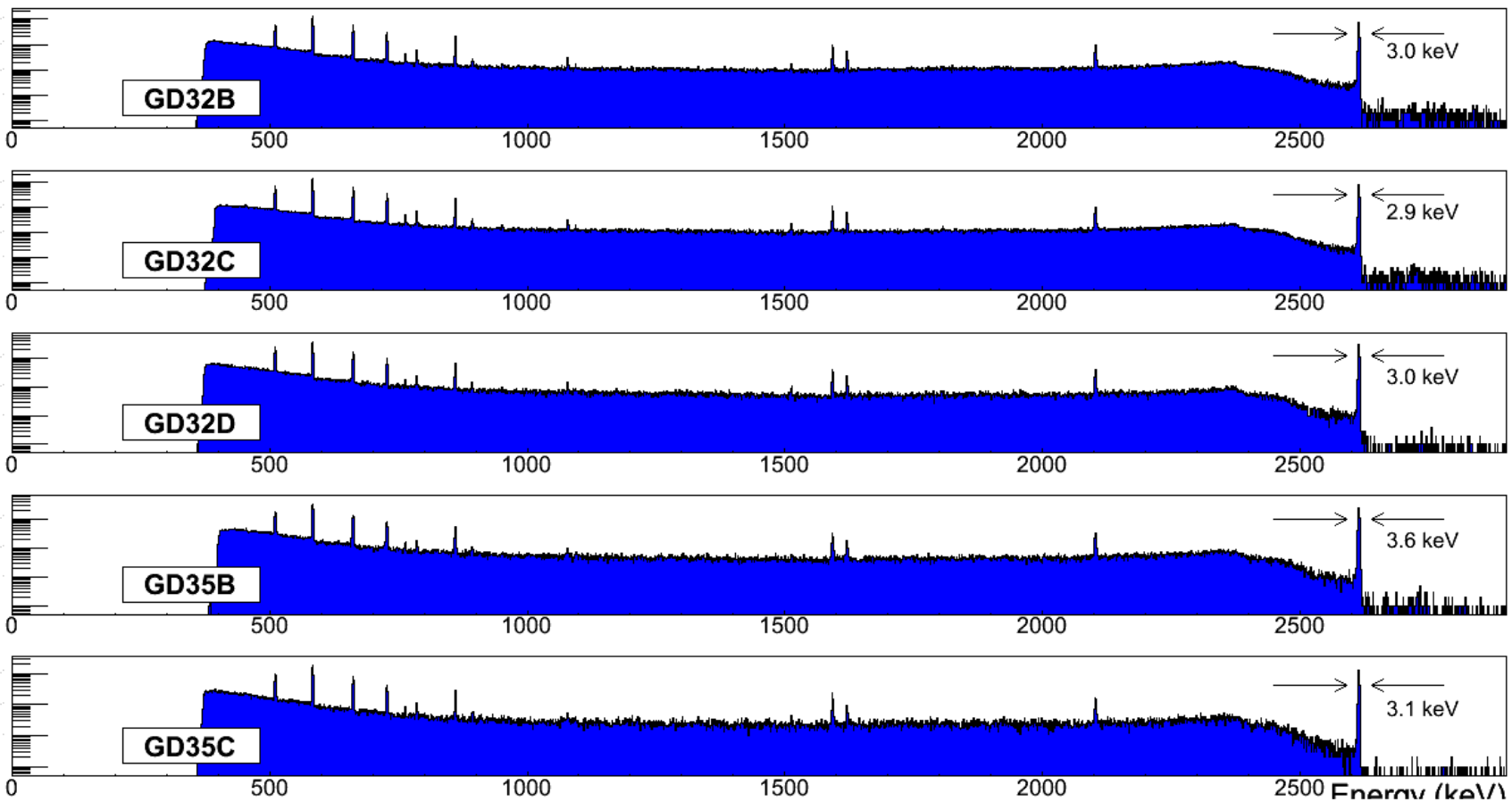
Detector Production Status:

- crystals pulling completed: 30 crystal slices (20.5 kg)
- 28 diodes produced
- End of 2012: up to 30 phase II detectors available
- up to 15 kg residual $^{\mathrm{enr}}$Ge material: needs chemical purification

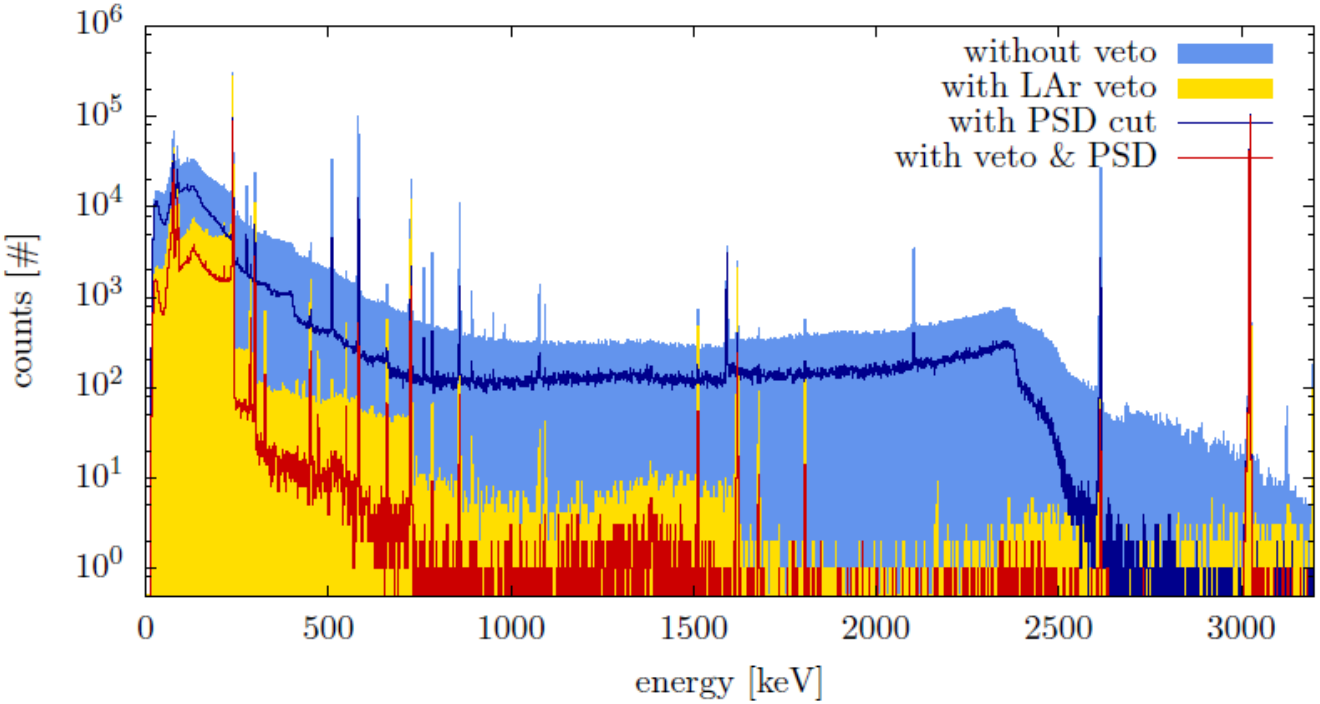


GERDA Phase II

June 2012: 5 $^{\mathrm{enr}}$BEGe deployed in GERDA



Liquid Argon instrumentation



[M.Heisel, PhD thesis]

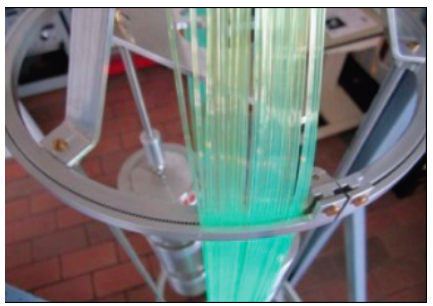
Operation of Phase II detector prototype in LArGE:

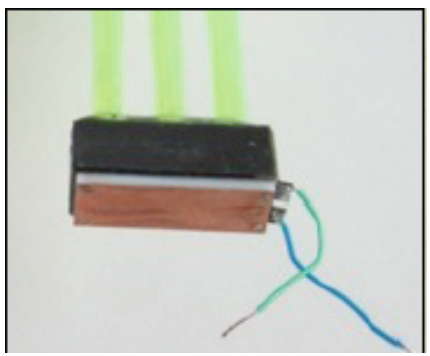
- measured suppression factor at $Q_{\beta\beta}$, e.g. $\approx 1.2 \cdot 10^3$ for a ^{228}Th calibration source close-by detectors
- successful scintillation light read out with fibers couples to SiPMs

Liquid Argon instrumentation

Top/bottom: PMTs

Central cylinder:
SiPM/Fiber readout





Also R&D on large area avalanche photodiodes and UV sensitive SiPMs to detect ligth inside mini-shroud

Conclusions

- GERDA aims to determine $T^{0\nu}_{1/2}$ of ^{76}Ge via an innovative approach: concept working!
- Phase I started in November 2011: $\approx$ 10 kg yr exposure reached
- blinded ROI: ($Q_{\beta\beta} \pm 20$ keV)
- expected sensitivity: $T_{1/2}(90\ \%\ \text{C.L.}) > 1.9 \cdot 10^{25}$ yr (assuming current BI and 20 kg yr exposure)

Preliminary results

5.04 kg yr exposure:

- $T^{2\nu}_{1/2} = (1.88 \pm 0.10) \cdot 10^{21}$ yr
- ^{42}Ar activity: (93.0 ± 6.4) μBq/kg
  ($>$ factor 2 larger than 90 % published limit)

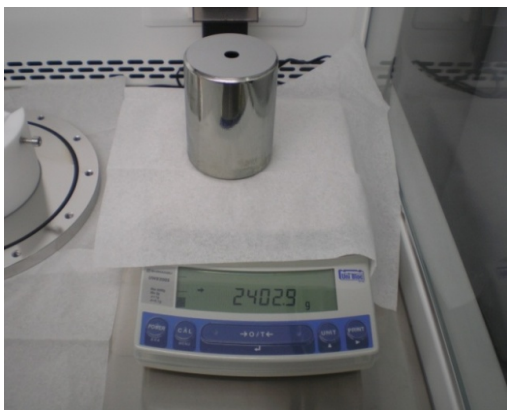
6.1 kg yr exposure:

- BI $\approx$ 0.02 counts/(keV kg yr) w/o pulse shape analysis

Phase II

- $\approx$ 20 kg new enriched diodes produced by end of 2012
- installation of LAr scintillation veto
- goal: BI $\leq$ 0.001 counts/(kev kg yr) $\rightarrow$ $T_{1/2} > 1.5 \cdot 10^{26}$ yr

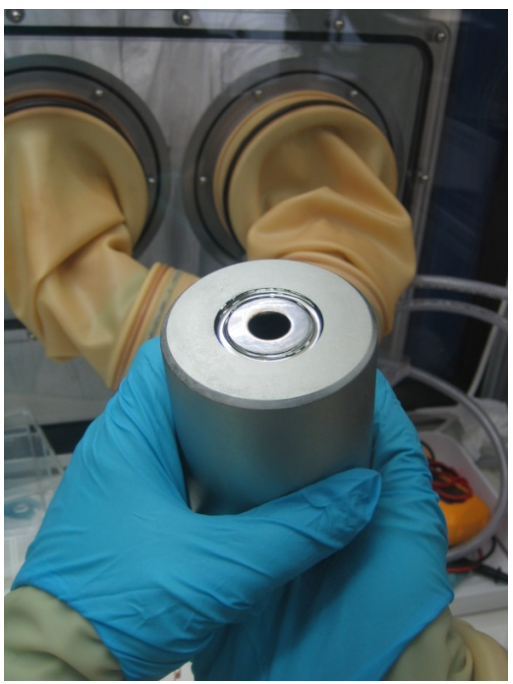
backups



- All diodes reprocessed and optimized for LAr
- Well tested procedure for detector handling
- Long term stability in LAr established
- Energy resolution in LAr: ~2.5 keV (FWHM) @1.3 MeV

<u>8 diodes (from HdM, IGEX):</u>

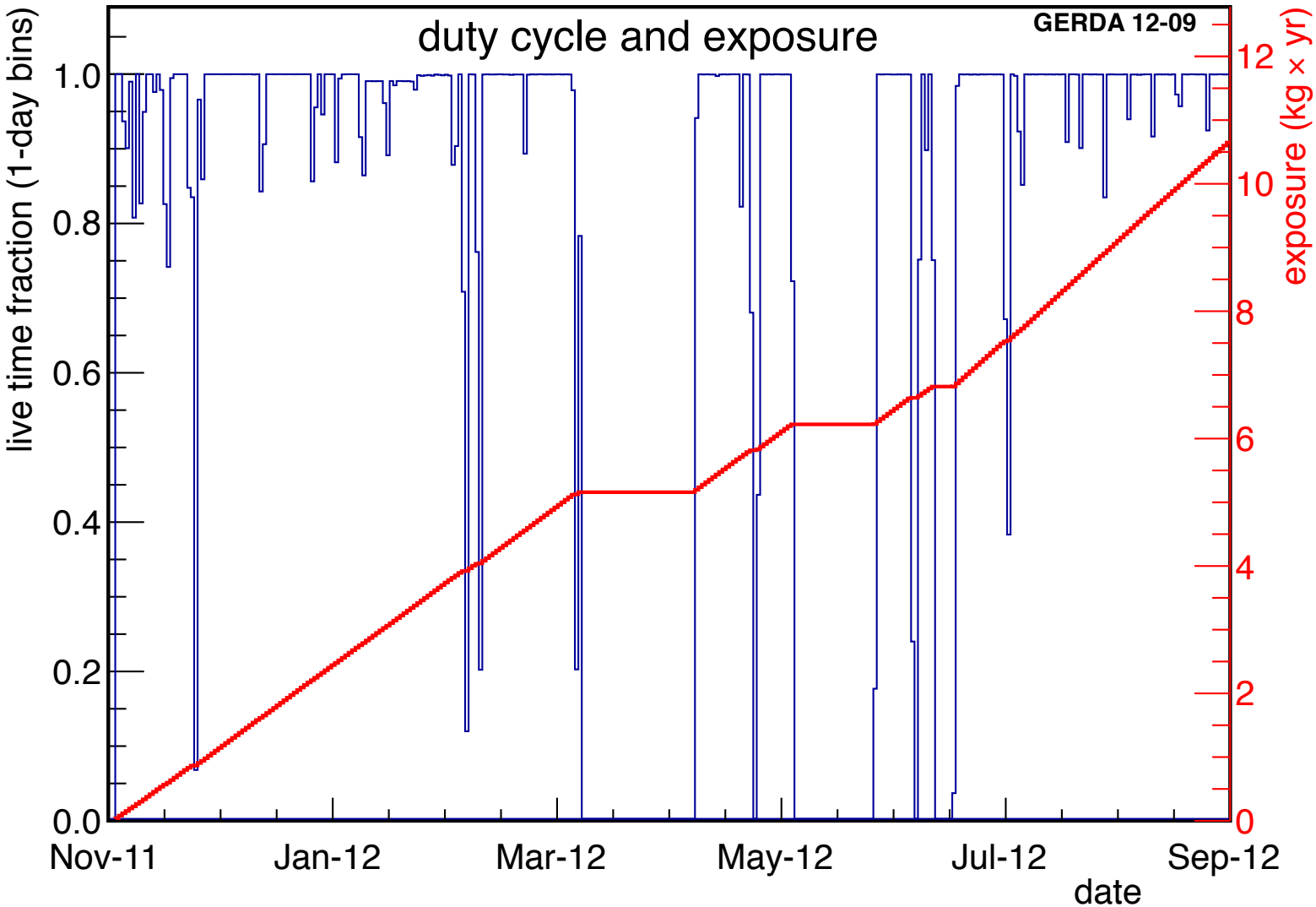
- Enriched 86% in ^{76}Ge
- Total mass 17.66 kg



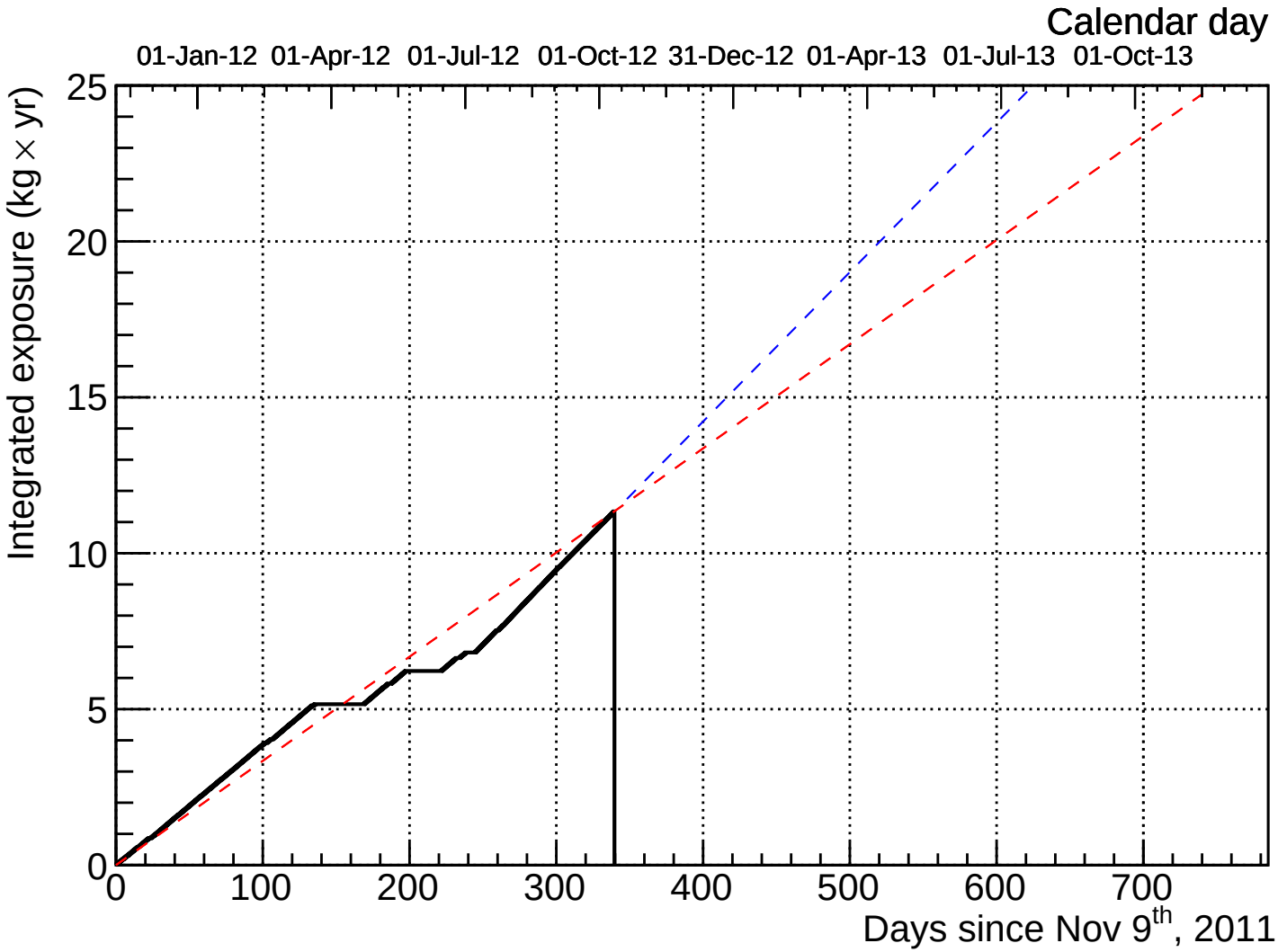
<u>6 diodes from Genius-TF:</u>

- ^{nat}Ge
- Total mass: 15.60 kg

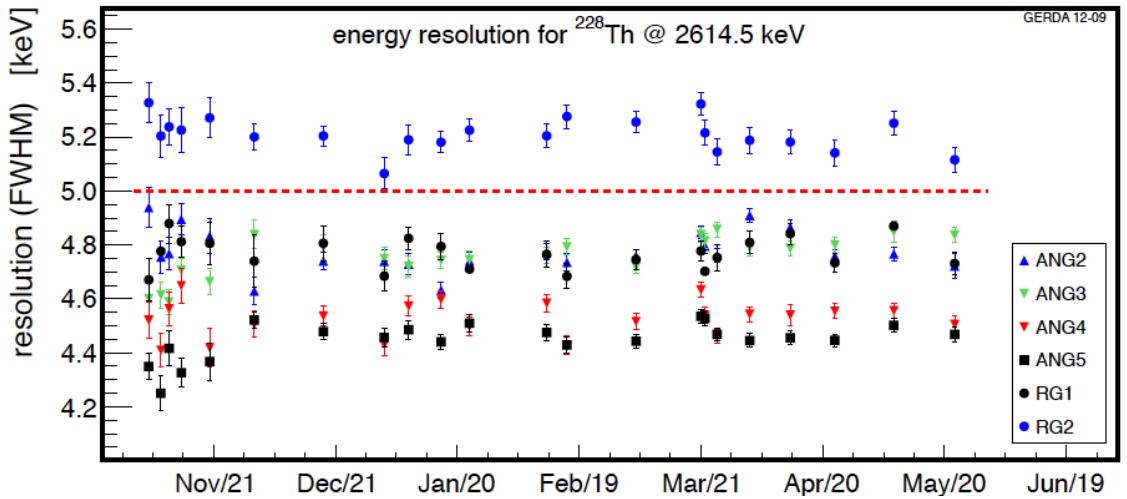
backups

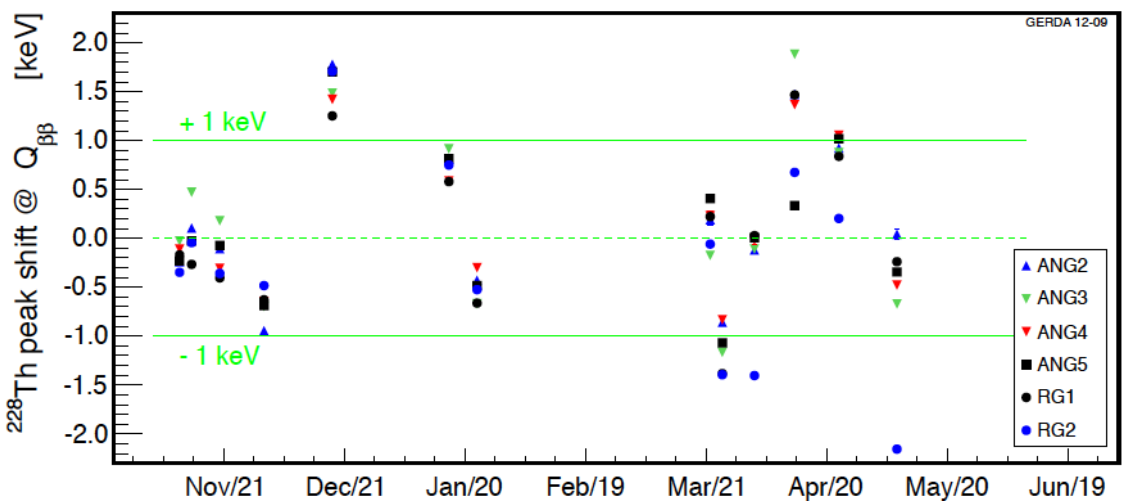

duty cycle and exposure
GERDA 12-09
live time fraction (1-day bins)
exposure (kg × yr)
1.0
0.8
0.6
0.4
0.2
0.0
12
10
8
6
4
2
0
Nov-11
Jan-12
Mar-12
May-12
Jul-12
Sep-12
date

backups

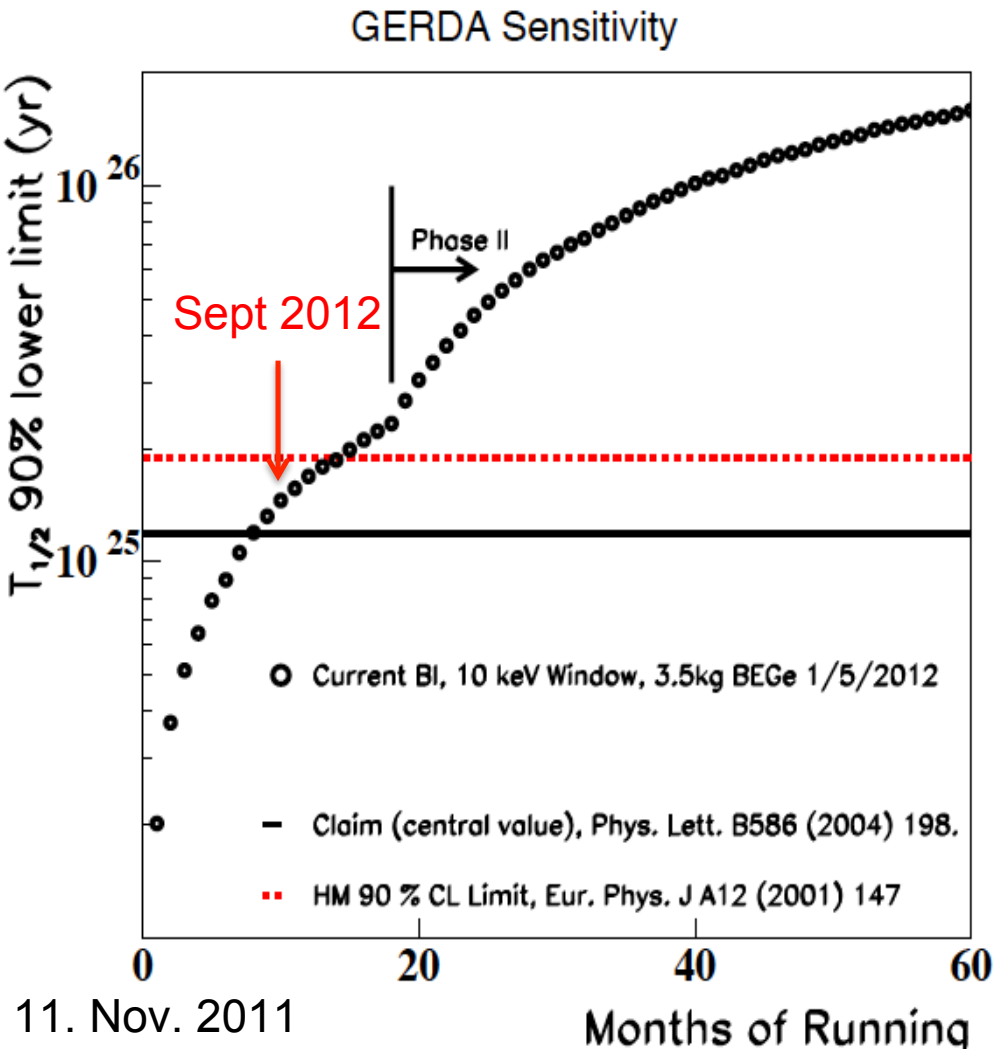

Calendar day
01-Jan-12
01-Apr-12
01-Jul-12
01-Oct-12
31-Dec-12
01-Apr-13
01-Jul-13
01-Oct-13
Integrated exposure (kg × yr)
0
5
10
15
20
25
0
100
200
300
400
500
600
700
Days since Nov 9th, 2011

backups


energy resolution for ^{228}Th @ 2614.5 keV
GERDA 12-09
resolution (FWHM) [keV]
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
Nov/21
Dec/21
Jan/20
Feb/19
Mar/21
Apr/20
May/20
Jun/19
ANG2
ANG3
ANG4
ANG5
RG1
RG2


GERDA 12-09
^{228}Th peak shift @ $Q_{\beta\beta}$ [keV]
+ 1 keV
- 1 keV
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
Nov/21
Dec/21
Jan/20
Feb/19
Mar/21
Apr/20
May/20
Jun/19
ANG2
ANG3
ANG4
ANG5
RG1
RG2

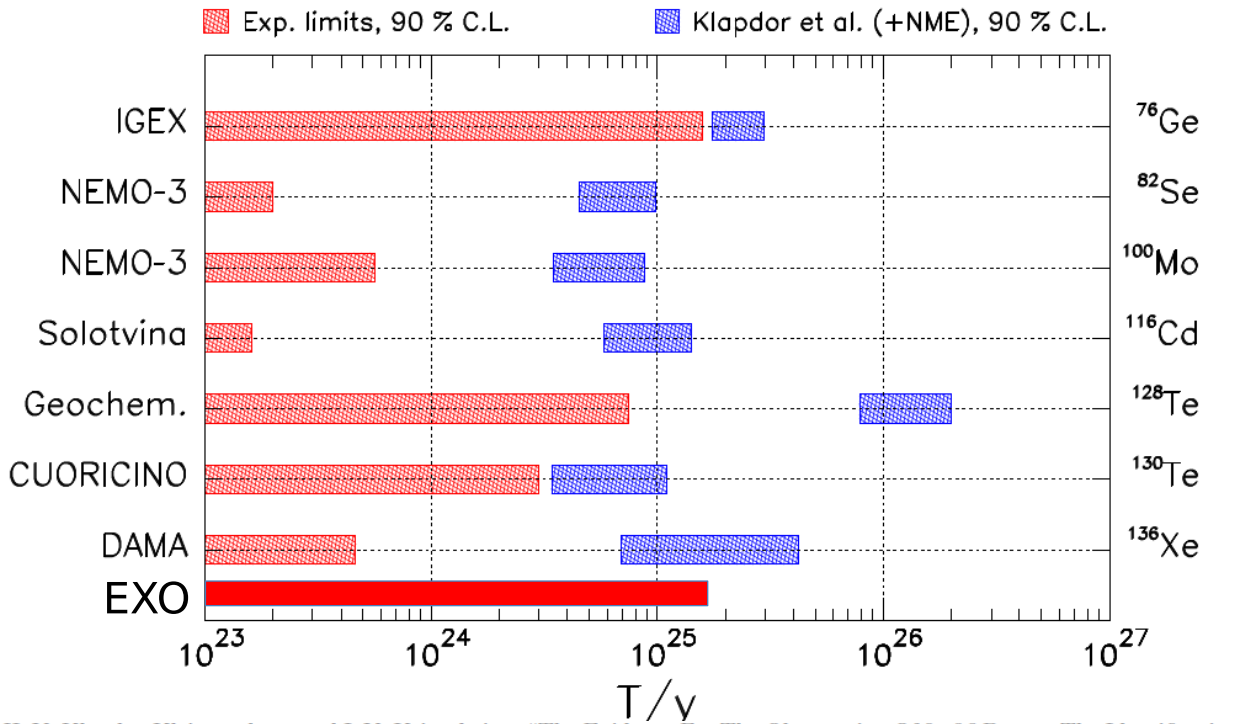
backups


GERDA Sensitivity
$T_{1/2}$ 90% lower limit (yr)
10^{26}
10^{25}
Phase II
Sept 2012
Current BI, 10 keV Window, 3.5kg BEGe 1/5/2012
Claim (central value), Phys. Lett. B586 (2004) 198.
HM 90 % CL Limit, Eur. Phys. J A12 (2001) 147
0
20
40
60
11. Nov. 2011
Months of Running

backups

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

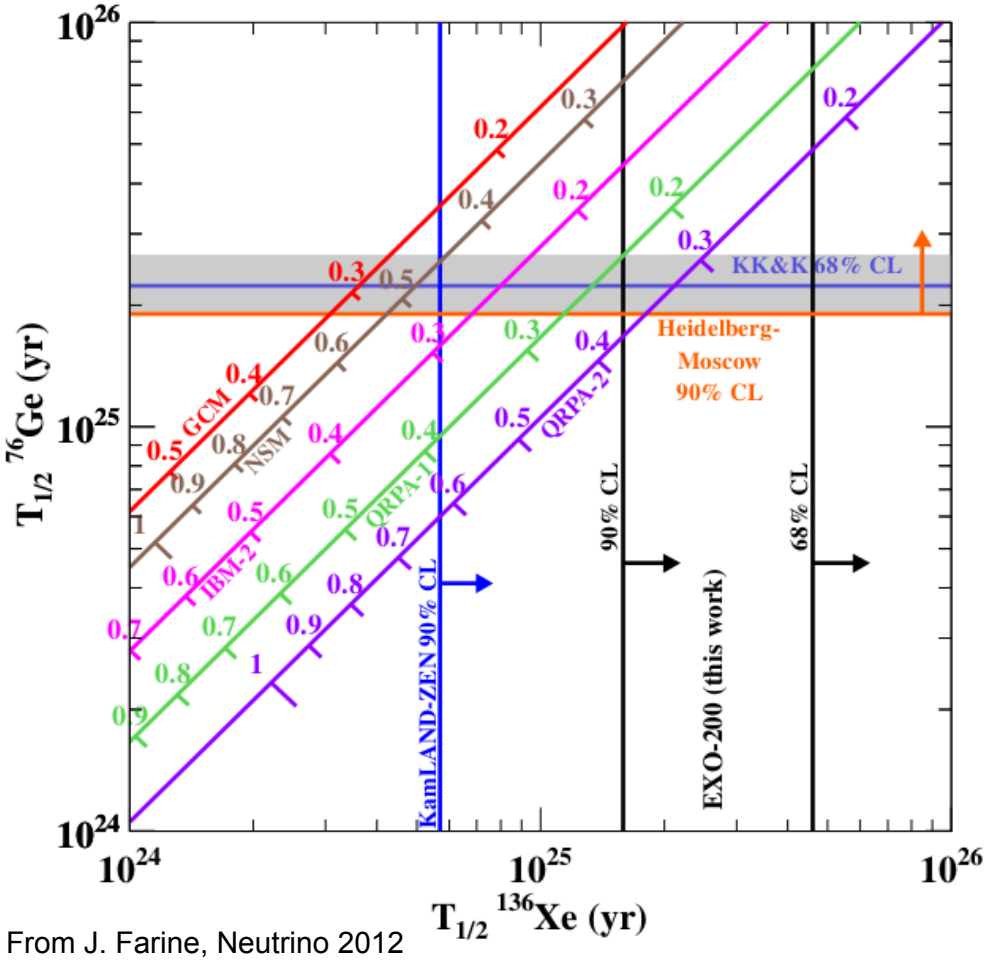
A.Faessler, G.L. Fogli, E. Lisi, V. Rodin, A.M. Rotunno, F. Simkovic, PhysRevD.79.053001
arXiv:0810.5733v2 (EXO result included by 'hand')



[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

Limits on $T_{½}^{0\nu\beta\beta}$ and $\langle m_{\beta\beta} \rangle$



From J. Farine, Neutrino 2012

90% C.L. limit compared with Recent ^{136}Xe constraints (KamLAND-ZEN) >2.5 factor improvement.

Tension with discovery claim in Ge.

KamLAND-Zen Collaboration
Phys. Rev. C 85 (2012) 045504]
[H.V. Klapdor-Kleingrothaus et al.
Eur. Phys. J. A12 (2001) 147]
[H.V. Klapdor-Kleingrothaus and I.V. Krivosheina
Mod. Phys. Lett., A21 (2006) 1547]

backups

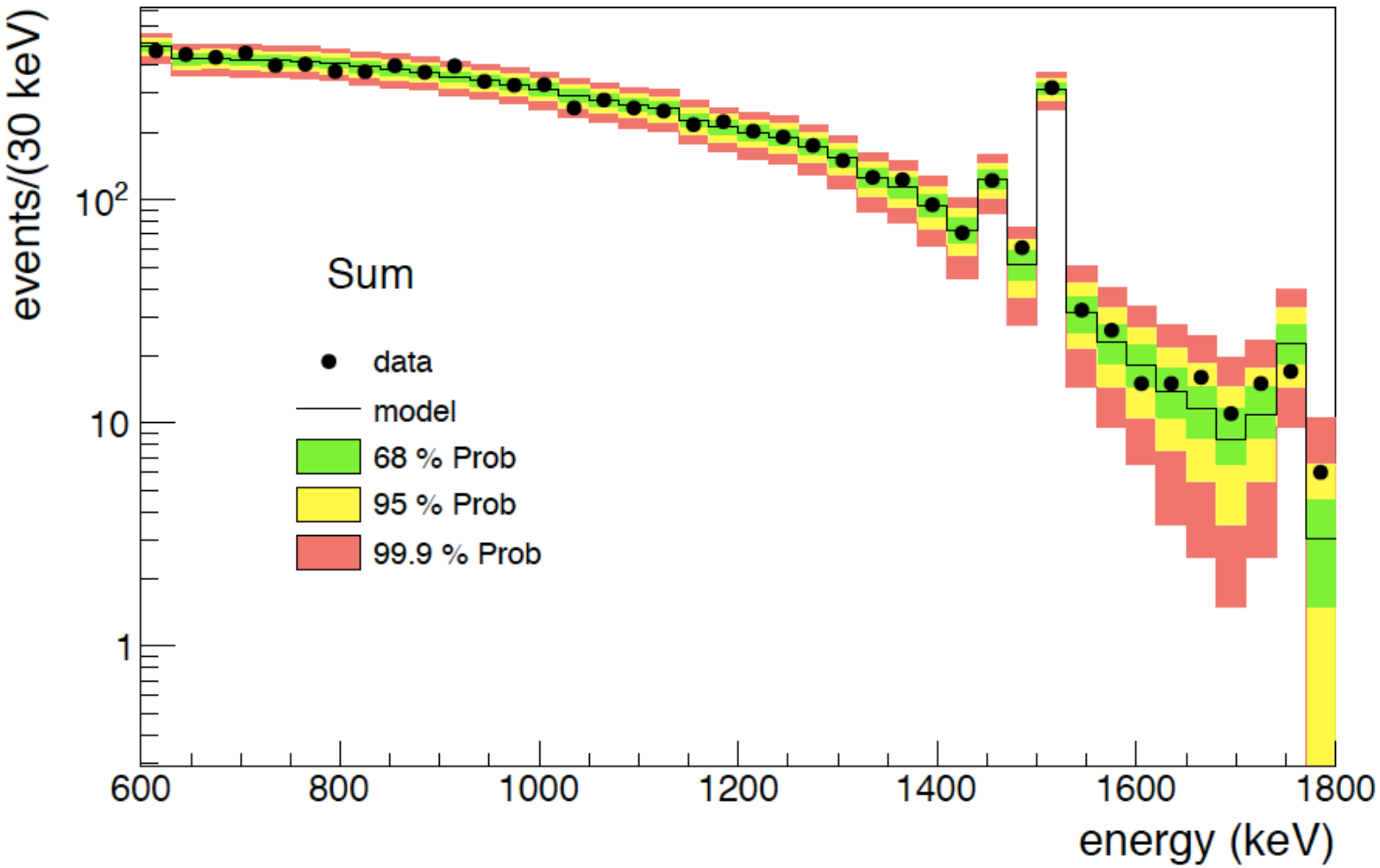
Table 2 Bayesian posterior probabilities $p(\bar{H})$ using EXO-200 data for the hypothesis that the $0\nu\beta\beta$ signal of Heidelberg-Moscow is correct. Probabilities are given for different matrix element calculations and for the $\pm 1\sigma$ and $\pm 2\sigma$ energy windows.

method	expected signal events	$p(\bar{H})$ in %	expected signal events	$p(\bar{H})$ in %
	in $\pm 1\sigma$ window		in $\pm 2\sigma$ window	
QRPA max	4.4 ± 1.1	4	6.1 ± 1.5	6
QRPA min	2.8 ± 0.7	11	3.9 ± 0.9	16
ISM	10.6 ± 2.5	0.1	14.8 ± 3.5	0.2
GCM	14.3 ± 3.4	0.03	19.9 ± 4.8	0.05
pnQRPA	6.3 ± 1.5	1	8.8 ± 2.1	2
IBM	6.1 ± 1.5	1	8.6 ± 2.1	2

N.B. comparison with HdM claim (28±6.86) cts in 71.7 kg yr

B. Schwingenheuer, Annalen der Physik, August 22, 2012

backups


events/(30 keV)
10^2
10
1
Sum
data
model
68 % Prob
95 % Prob
99.9 % Prob
600
800
1000
1200
1400
1600
1800
energy (keV)