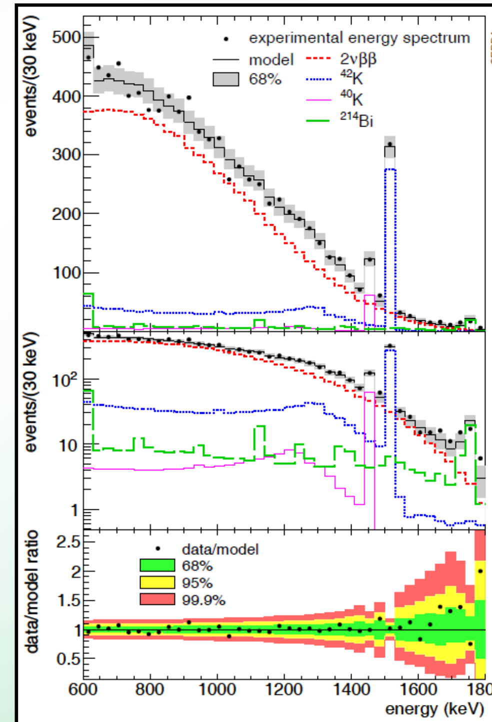
GERDA status report



OUTLINE:

- **Motivation: Neutrinoless Double Beta Decay**
- **Phase I data taking**
- **Hardware preparations for phase II**
- **Active background rejection in GERDA**
- **New detectors for GERDA phase II**

GERDA group at MPI für Physik:

Postdocs:	Fabiana Cossavella, Oliver Schulz Chris O'Shaugnessy (until Oct. 2012)
PhD students:	Heng-Ye Liao, Neslihan Becerici-Schmidt, Oleksander Volynets (until Sept. 2012),
Diploma student:	Aaron Michel
Engineers/Technicians:	Hans Seitz, Franz Stelzer (until April 2012) Margus Härk (Jul. – Nov. 2012)
Group leader GERDA:	Béla Majorovits
Director:	Allen Caldwell

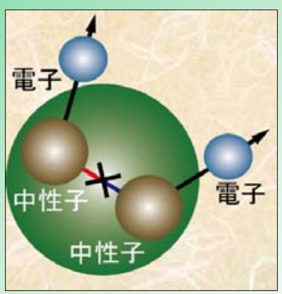
Many thanks to the technical departments!

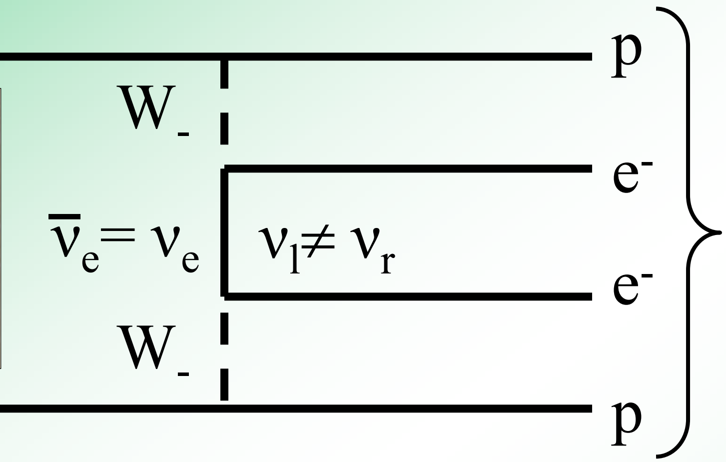
Especially to: T. Haubold, R. Sedlmayer, D. Wamsler A. Wimmer, G. Winkelmüller, S. Vogt

Motivation: Neutrinoless Double Beta Decay

Unknowns about Neutrinos:

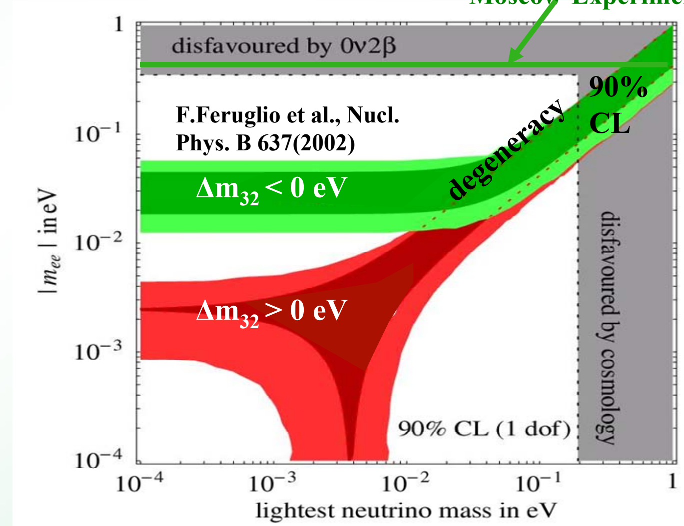
- Nature of the Neutrino (Dirac - Majorna?)
- Absolute mass scale? Inverted/normal hierarchy?
- CP phases?





LEPTON NUMBER VIOLATION!

Evidence from Heidelberg-Moscow-Experiment



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

If neutrinoless double beta-decay is observed:

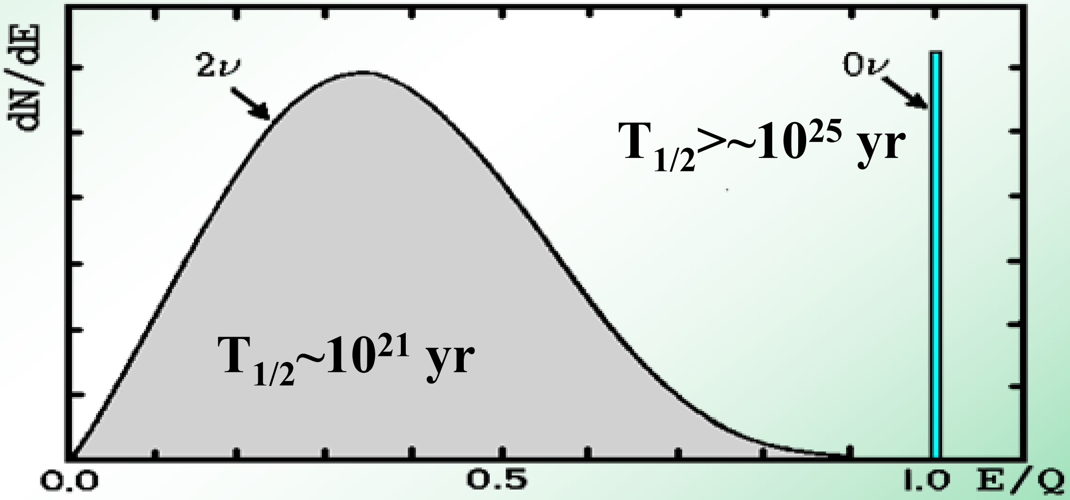
→Lepton number violating process!

→Neutrino has Majorana character!

Detection principle:

Use Detector made of double beta emitting material:

HP^{76}Ge detector



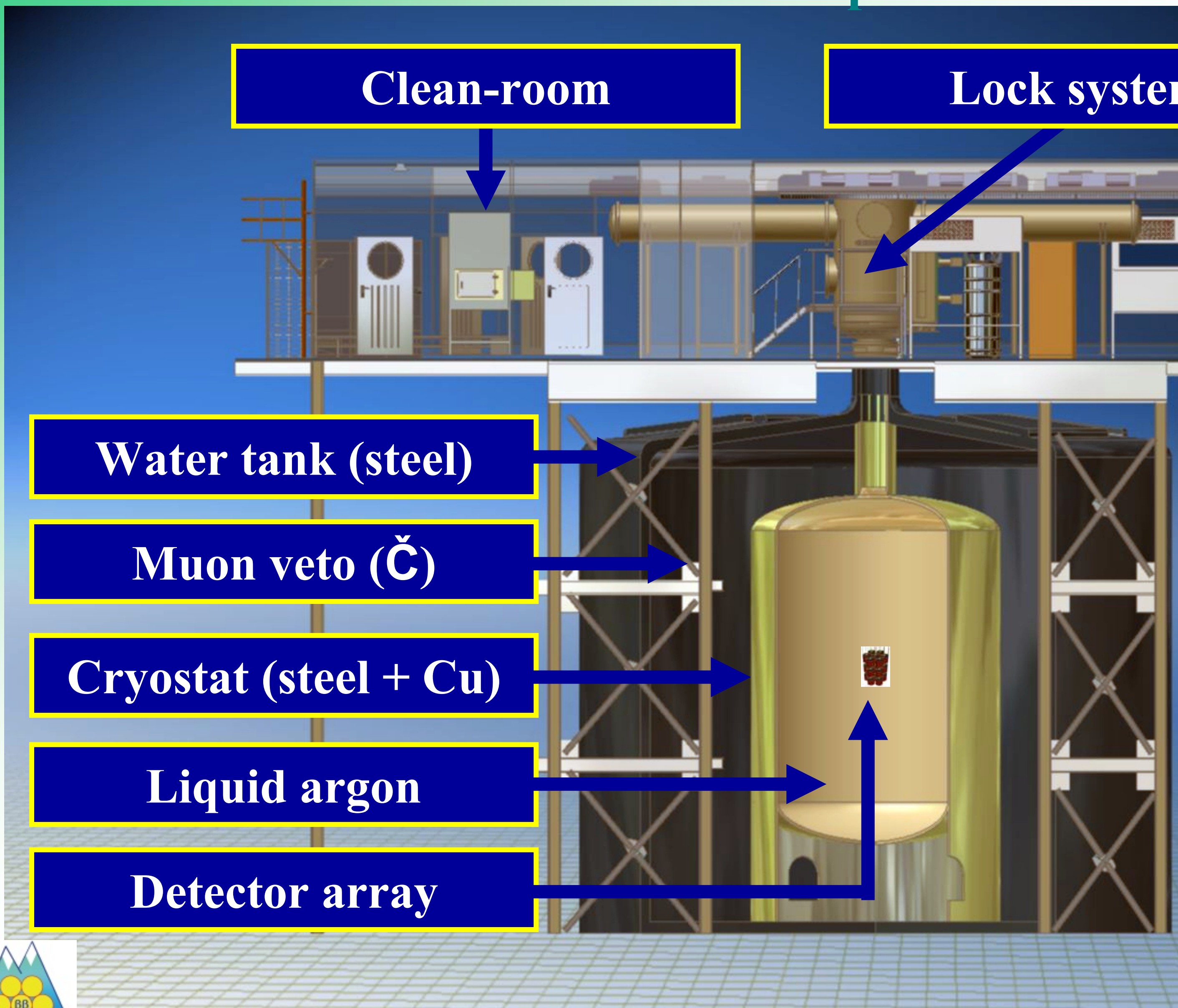
Signature: Sharp peak at Q-value of the decay (2039 *keV* for ^{76}Ge)

- **High detection efficiency (source = detector)**
- **Very good energy resolution (0.2% at RoI)**
- **Intrinsically very pure → very low background**

The GERDA Collaboration

Institute for Reference Materials and Measurements, Geel, Belgium
Max-Planck-Institut für Kernphysik, Heidelberg, Germany
Max-Planck-Institut für Physik (Werner-Heisenberg-Insititut), München, Germany
Physikalisches Institut, Universität Tübingen, Germany
Institut für Kern- und Teilchenphysik, Universität Dresden, Germany
Dipartimento di Fisica dell'Univeristá; di Padova e INFN Padova, Padova, Italy
INFN Laboratori Nazionali del Gran Sasso, Assergi, Italy
Universitá; di Milano Bicocca e INFN Milano, Milano, Italy
Jagiellonian University, Cracow, Poland
Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia
Institute for Theoretical and Experimental Physics, Moscow, Russia
Joint Institute for Nuclear Research, Dubna, Russia
Russian Research Center Kurchatov Institute, Moscow, Russia
University Zurich, Switzerland

The GERDA Experiment



Phase I:

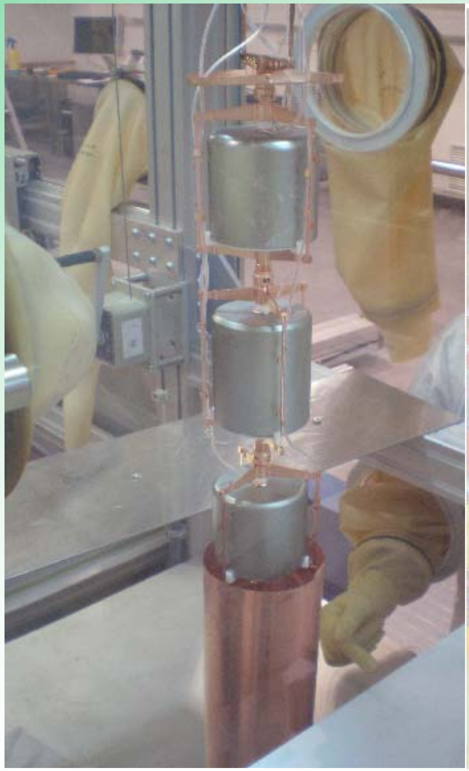
Use HdMo and IGEX detectors (18kg)

Phase II:

Use additional detectors made from 37.5kg enriched material

The GERDA Experiment

Finished infrastructure in 2009
First data taking started in May 2010
Deployed all enriched detectors in Nov. 2011

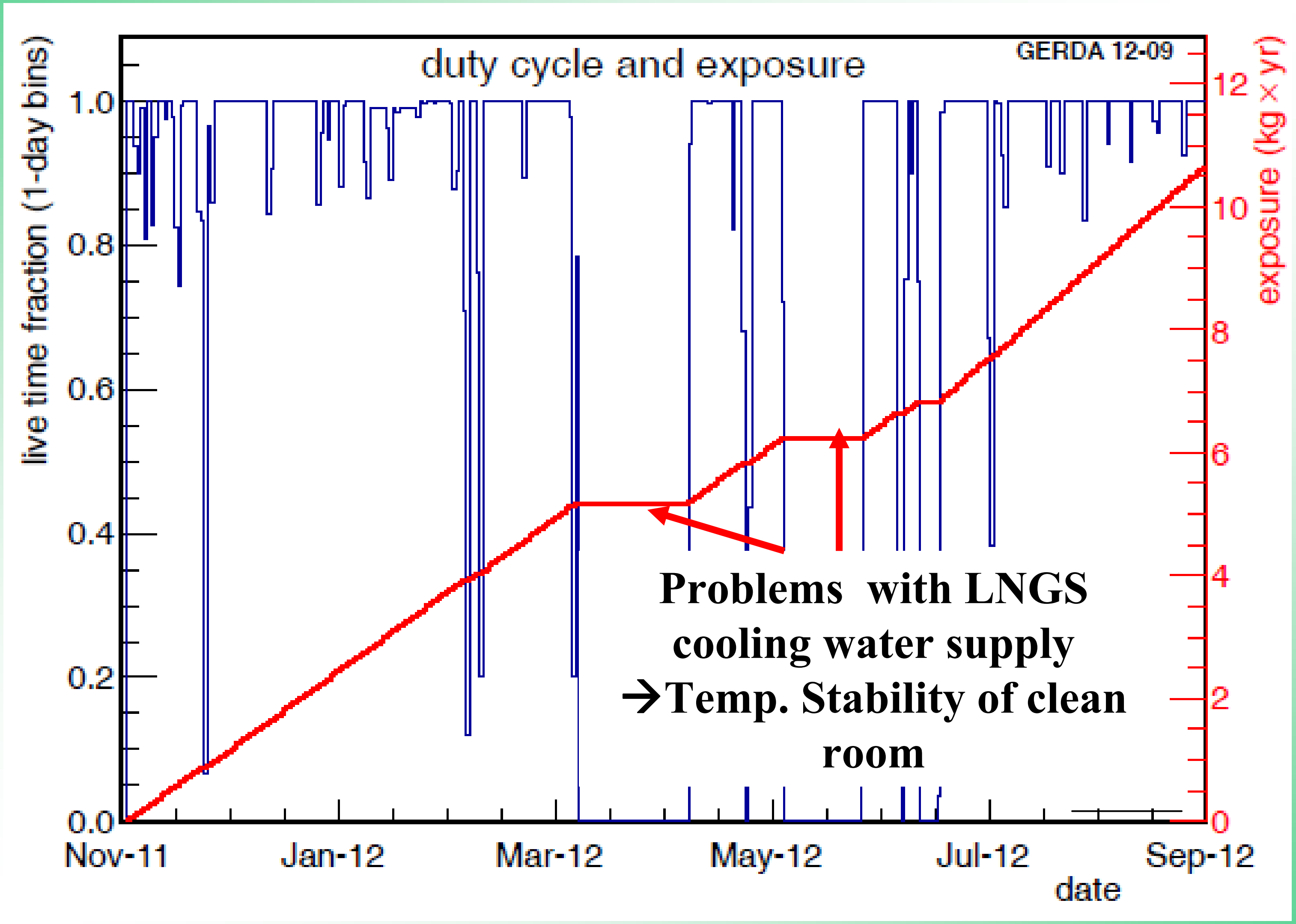


detector	total mass (g)	active mass (g)	^{76}Ge isotopic abundance (%)
ANG2	2833	2468±121±89	86.6±2.5
ANG3	2391	2070±118±77	88.3±2.6
ANG4	2372	2136±116±79	86.3±1.3
ANG5	2746	2281±109±82	85.6±1.3
RG1	2110	1908±109±72	85.5±2.0
RG2	2166	1800±99±65	85.5±2.0

Two detectors switched off due to leakage current.

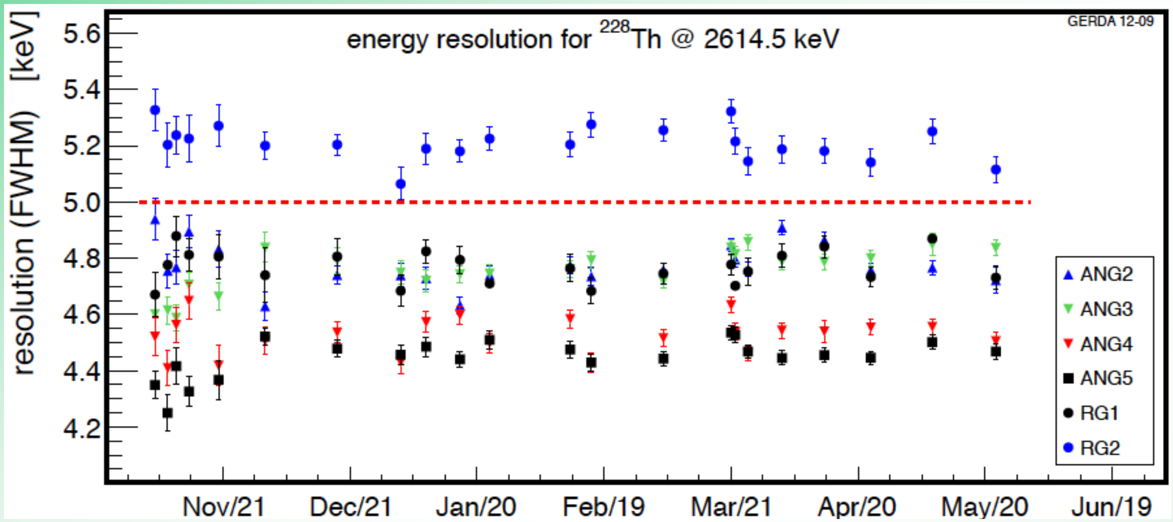
→ Total detector mass: 14.6 kg

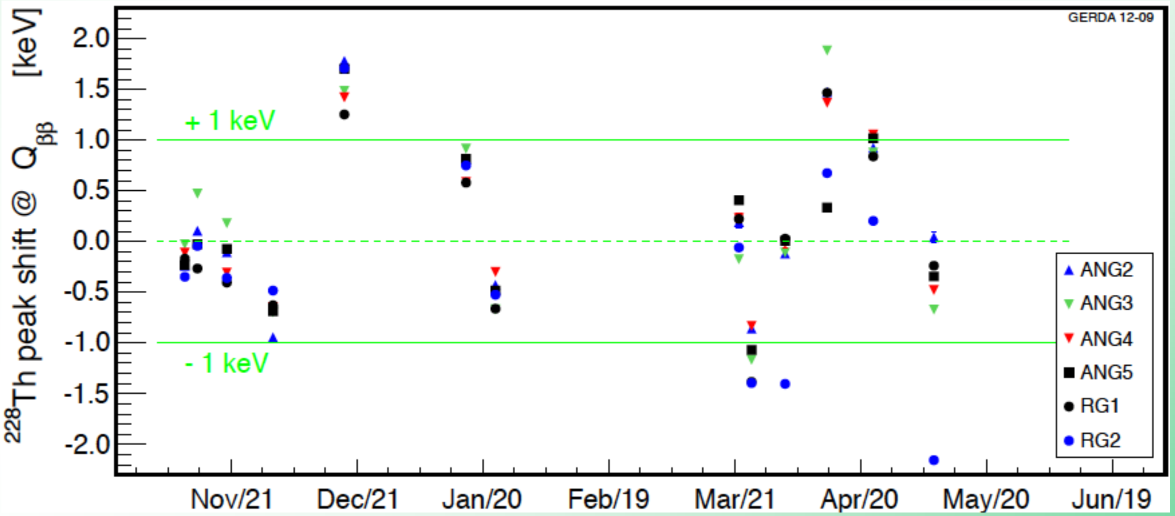
Duty Cycles and Exposure



Exposure now: ca. 12.5 kg y

Stability of detector performance:

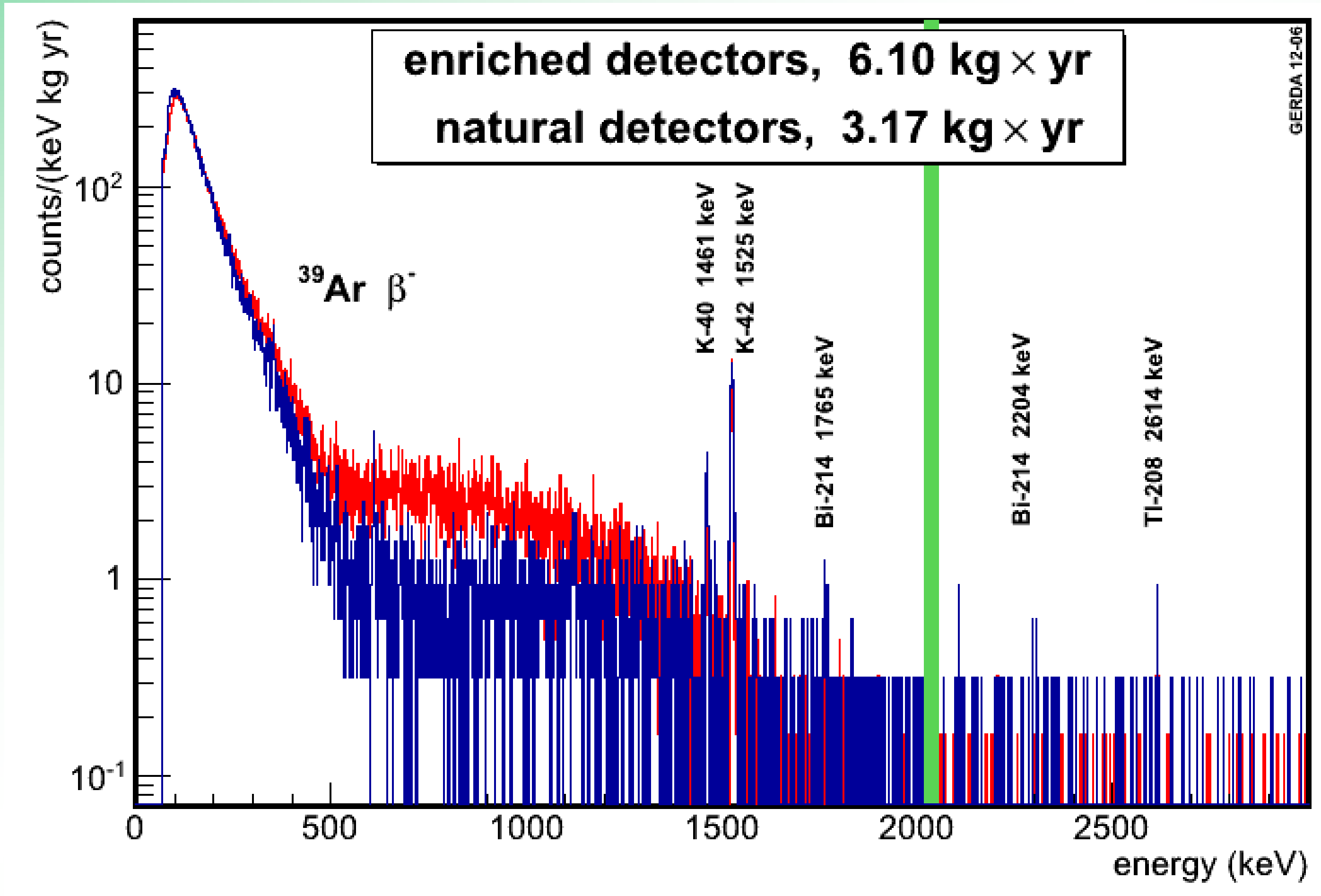




Energy resolution and calibration are stable since months

Background in GERDA:

Background data for enriched detectors (red) and control detectors with natural germanium abundance (blue):



Background in GERDA:

Count rates in observed gamma lines:

isotope	energy [keV]	^{nat}Ge (3.17 kg·yr) tot/bck [cts]	^{nat}Ge (3.17 kg·yr) rate [cts/(kg·yr)]	^{enr}Ge (6.10 kg·yr) tot/bck [cts]	^{enr}Ge (6.10 kg·yr) rate [cts/(kg·yr)]	HdM (71.7 kg·yr) rate [cts/(kg·yr)]
^{40}K	1460.8	85 / 15	$21.7^{+3.4}_{-3.0}$	125 / 42	$13.5^{+2.2}_{-2.1}$	181 ± 2
^{60}Co	1173.2	43 / 38	< 5.8	182 / 152	$4.8^{+2.8}_{-2.8}$	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	$5.1^{+2.8}_{-2.9}$	294 / 303	< 5.8	29.8 ± 1.6
	968.9	64 / 42	$6.9^{+3.2}_{-3.2}$	247 / 230	$2.7^{+2.8}_{-2.5}$	17.6 ± 1.1
^{208}Tl	583.2	56 / 51	< 6.5	333 / 327	< 7.6	36 ± 3
	2614.5	9 / 2	$2.1^{+1.1}_{-1.1}$	10 / 0	$1.5^{+0.6}_{-0.5}$	16.5 ± 0.5
^{214}Pb	352	740 / 630	$34.1^{+12.4}_{-11.0}$	1770 / 1688	$12.5^{+9.5}_{-7.7}$	138.7 ± 4.8
^{214}Bi	609.3	99 / 51	$15.1^{+3.9}_{-3.9}$	351 / 311	$6.8^{+3.7}_{-4.1}$	105 ± 1
	1120.3	71 / 44	$8.4^{+3.5}_{-3.3}$	194 / 186	< 6.1	26.9 ± 1.2
	1764.5	23 / 5	$5.4^{+1.9}_{-1.5}$	24 / 1	$3.6^{+0.9}_{-0.8}$	30.7 ± 0.7
	2204.2	5 / 2	$0.8^{+0.8}_{-0.7}$	6 / 3	$0.4^{+0.4}_{-0.4}$	8.1 ± 0.5

→ All background components reduced by factor >~10 with respect to HdM

Background in GERDA:

experiment diode environment	diodes	ΔE (keV)	exposure (kg·yr)	background index 10^{-2}cts/(keV·kg·yr)
IGEX [1]				
vacuum, Cu enclosed	enr	2000-2500	4.7	26
HdM [2]				
vacuum, Cu enclosed	enr	2000-2100	56.7	16
GERDA commissioning				
LAr	nat	1839-2239	0.6	18±3
LAr, Cu mini-shroud	nat	1839-2239	2.6	5.9±0.7
dto	enr	1839-2239	0.7	$4.3^{+1.4}_{-1.2}$
GERDA Phase I				
LAr, Cu mini-shroud	nat	1839-2239*	1.2	$3.5^{+1.0}_{-0.9}$
LAr (diodes AC-coupled)	nat	1839-2239*	1.9	$6.0^{+1.0}_{-0.9}$
LAr, Cu mini-shroud	enr	1939-2139*	6.1	$2.0^{+0.6}_{-0.4}$

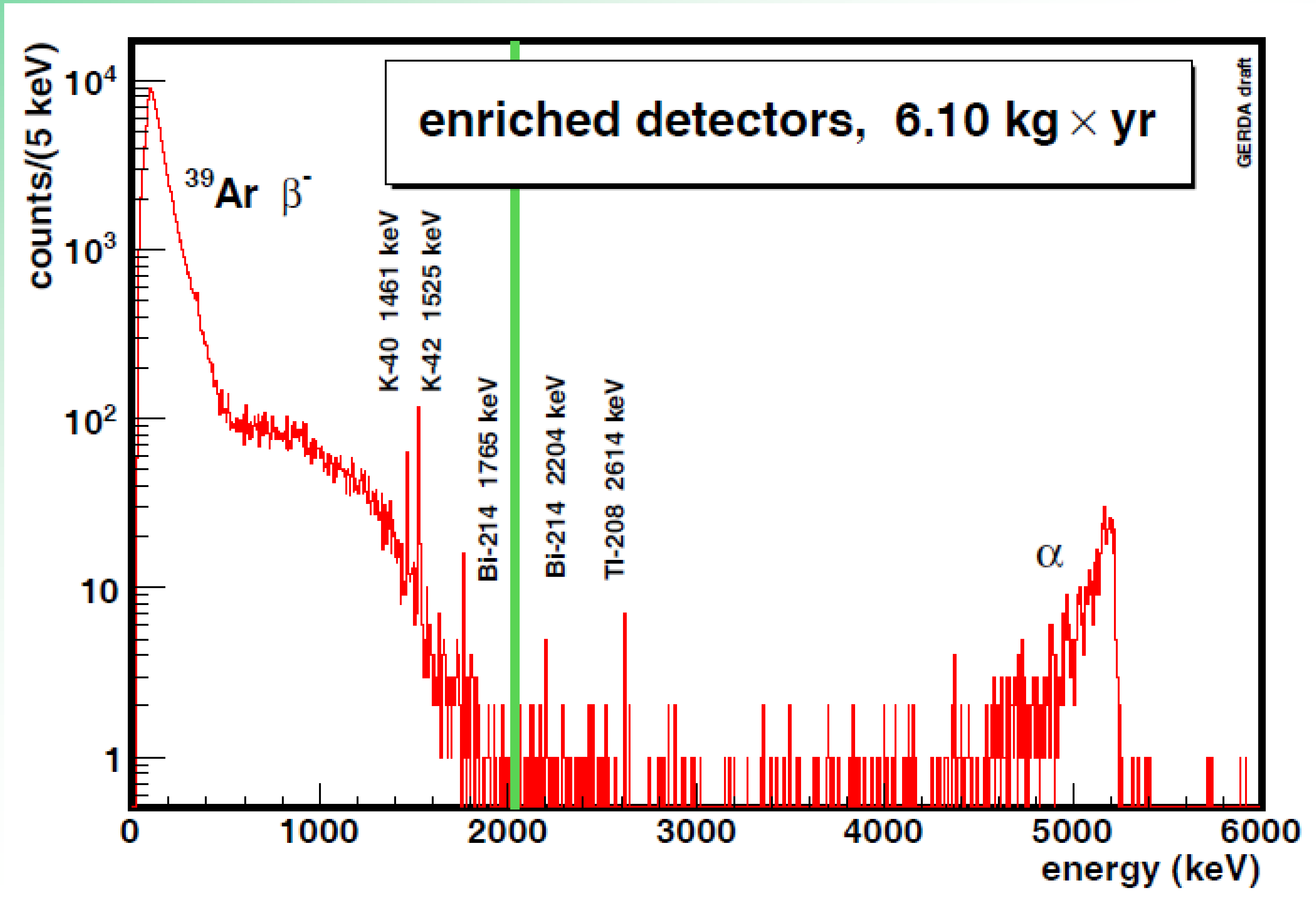
⋆) excluding the blinded region of $Q_{\beta\beta}$±20 keV

Background index in energy RoI for enriched detectors:
$(2.0^{+0.6}_{-0.4}) \cdot 10^{-2}$ cts/(kg yr keV)
(all stable runs, no PSA)

GERDA technical publication submitted to EPJ A

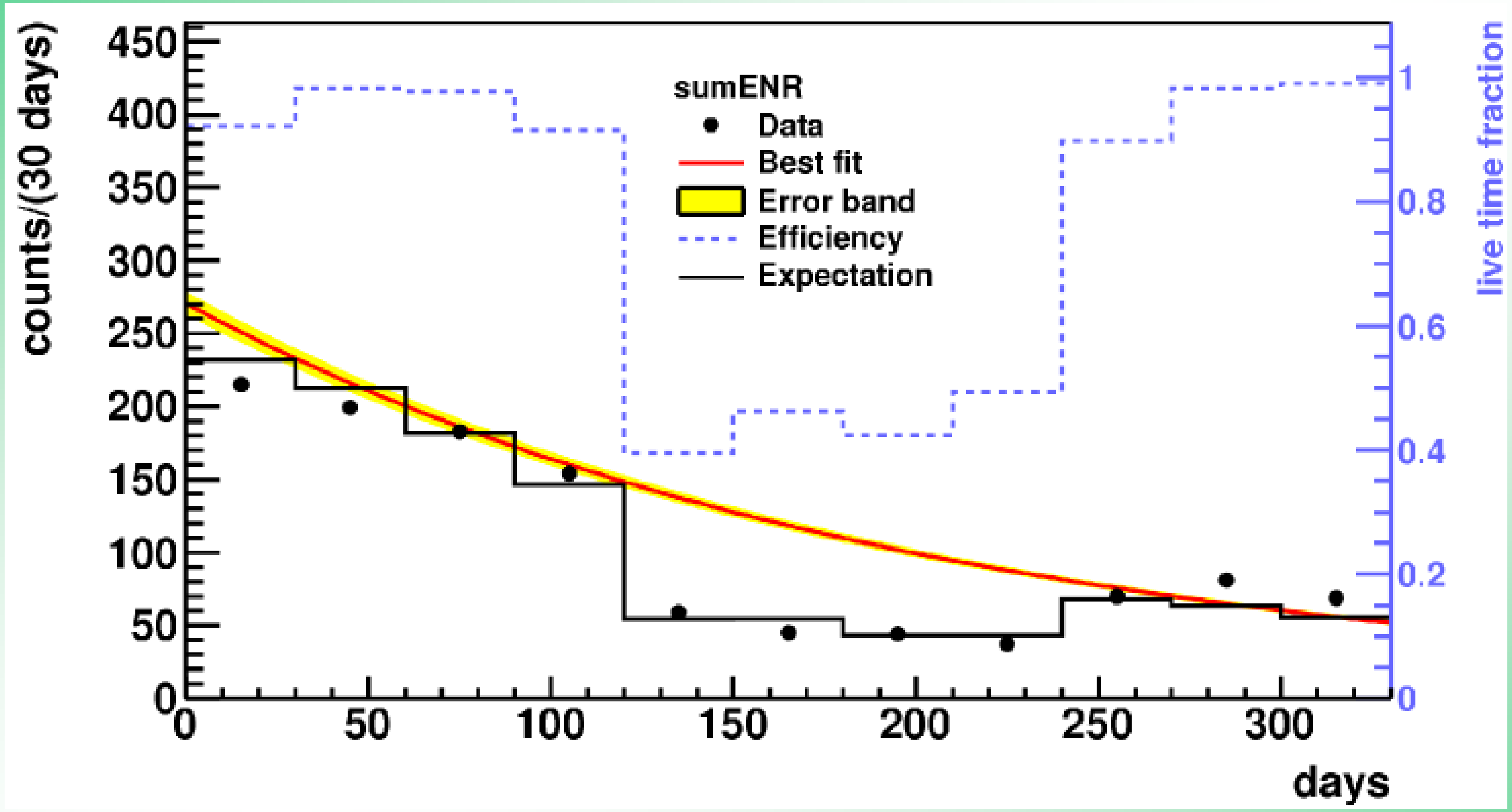
Background in GERDA:

High energy spectrum reveals alpha contamination on detector surface



Peak at 5.2 MeV on detector surface
Contamination different for each detector
→ Surface treatment

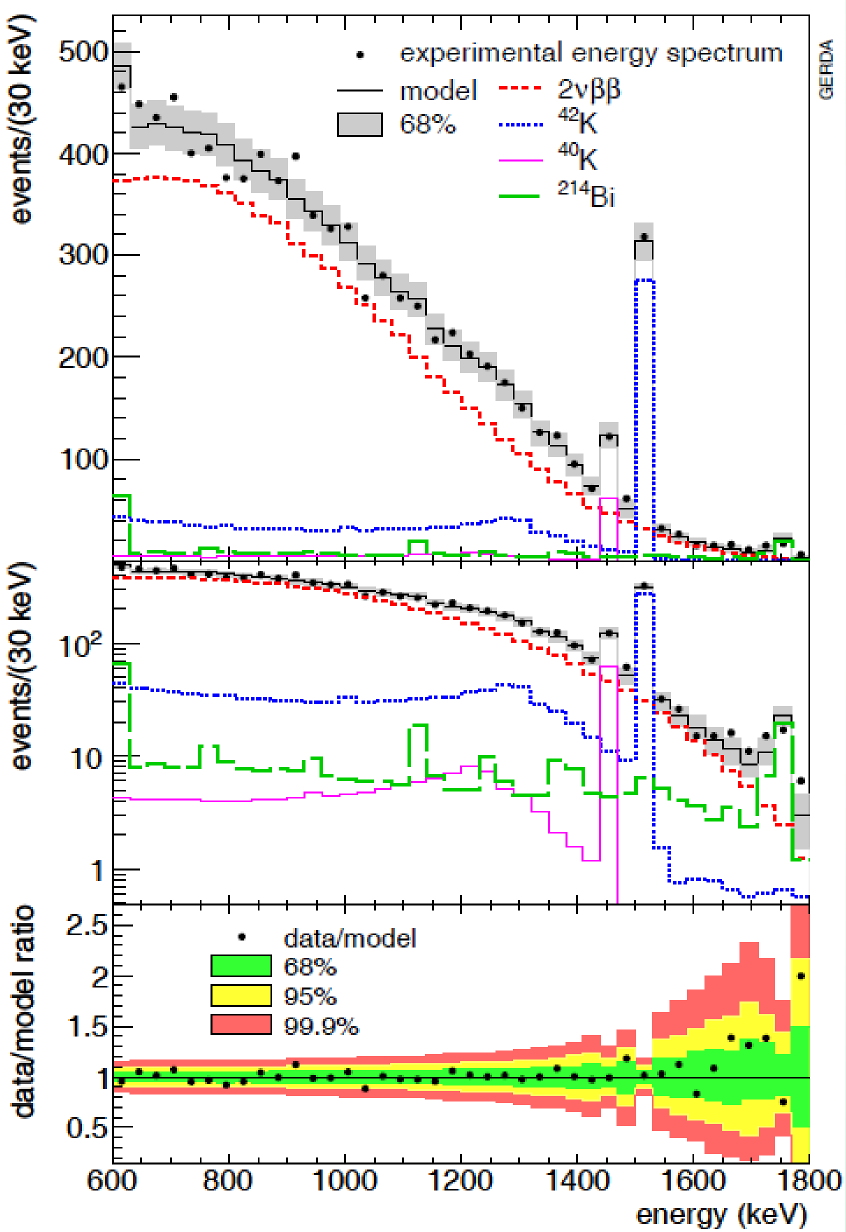
Background in GERDA:



Event rate in 5.2 MeV peak as function of time is consistent with decay of ^{210}Po ($T_{1/2}$=138 days) on detector surface

Simulations suggest: Tail of α-peak at energy ROI contributes ~5% to background

New measurement of 2νββ half life:



Signal to background ratio increased by factor of ~10 with respect to Heidelberg-Moscow experiment

Dominant background components between 600 keV and 1600 keV:

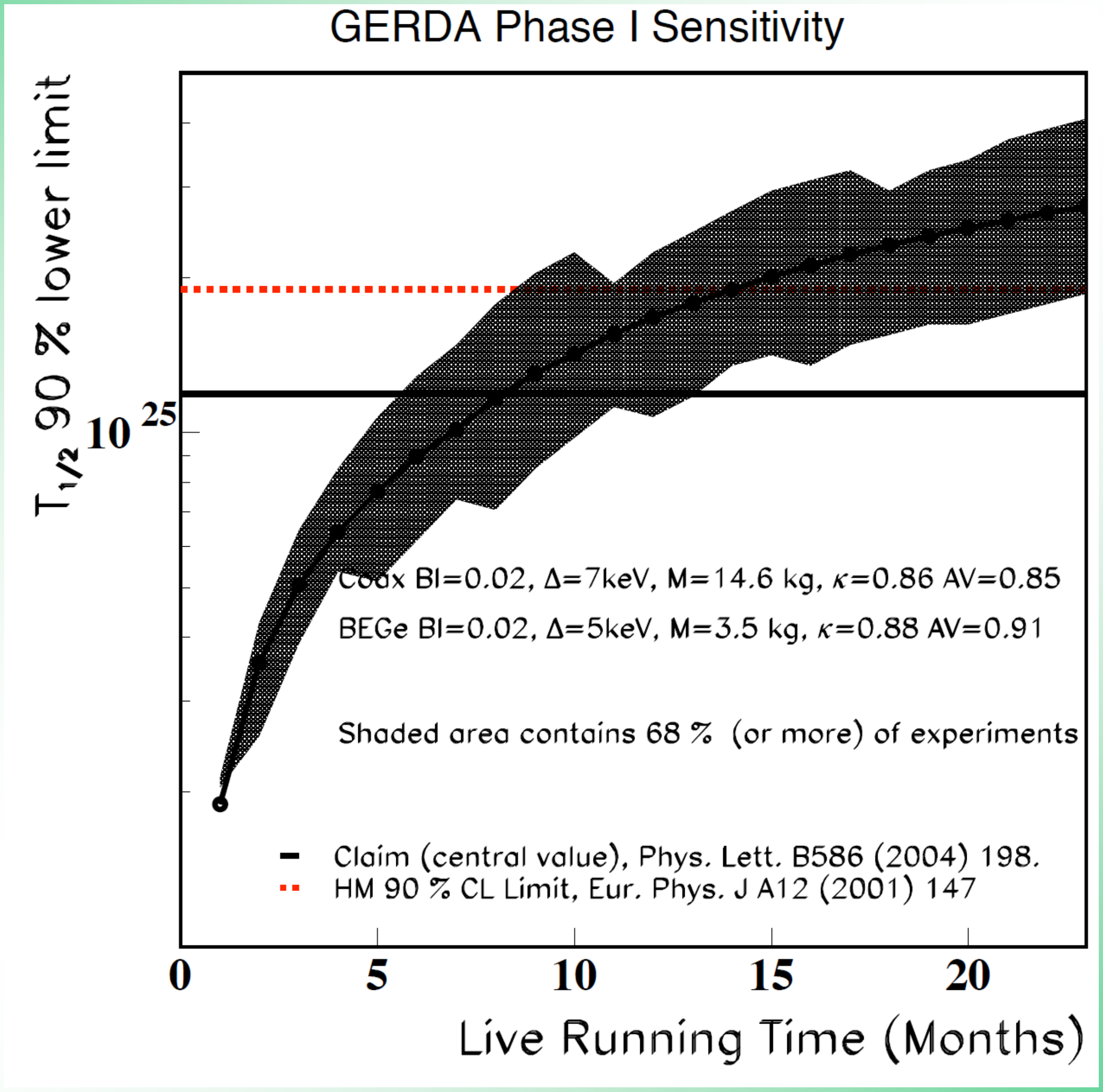
^{40}K, ^{42}K, ^{214}Bi, ^{228}Th

$$T_{1/2} = (1.84^{+0.14}_{-0.10}) \cdot 10^{21}\ \text{yr}$$

submitted for publication in J. Phys. G. arXiv:1212.3210

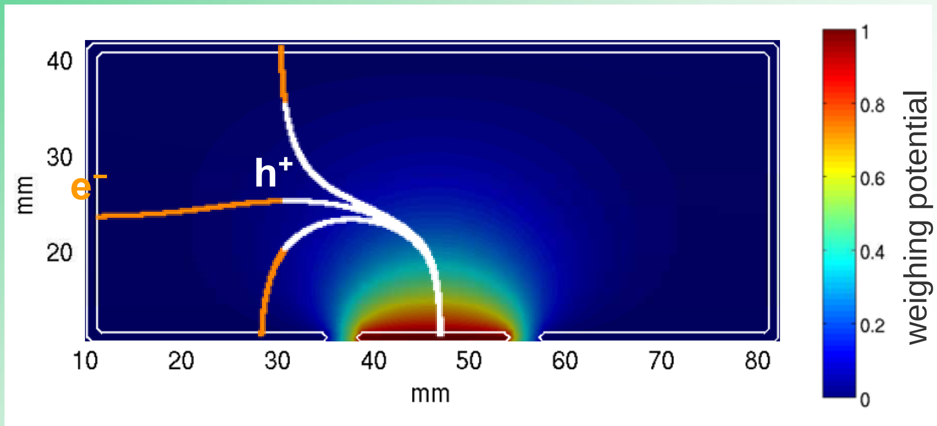
Background decomposition is focus of PhD thesis of N. Becerici-Schmidt
Investigation of PSA by ANN done by F. Cossavella & O. Volynets

GERDA phase I sensitivity curve:



Detectors for phase II:

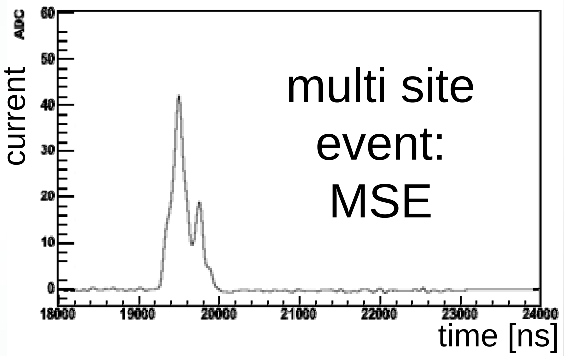
BEGe detectors for improved background recognition



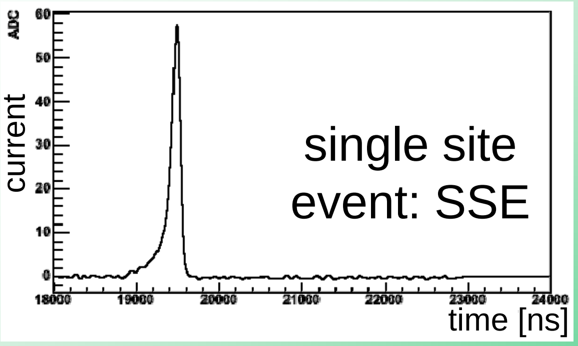
→ Very pronounced pulse shape structures for individual energy deposits

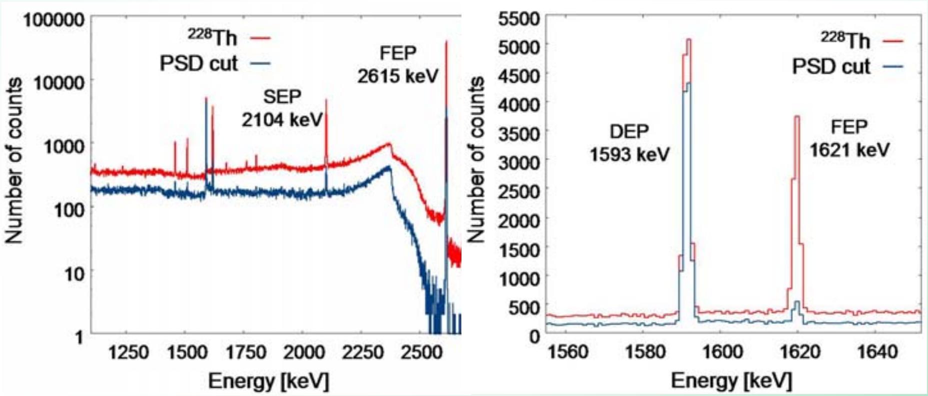
→ Improved multi site recognition efficiency by A/E parameter

Background like event:



Signal like event:



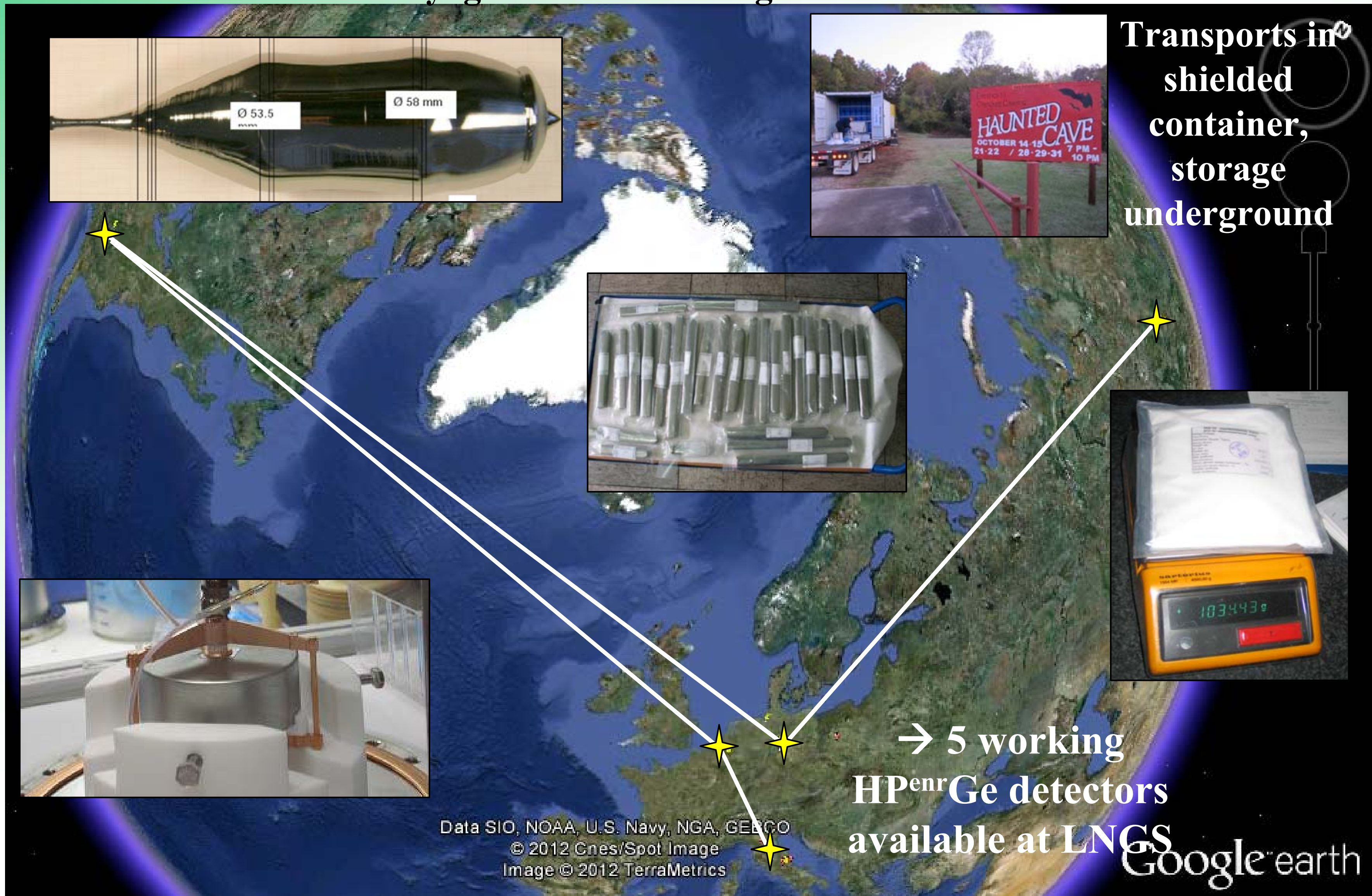


D. Budjas et al., JINST 4 P10007 (2009)

→ **Significant background reduction possible dependent on and position of contamination**

Logistics of detector production:

The voyage of the enriched germanium



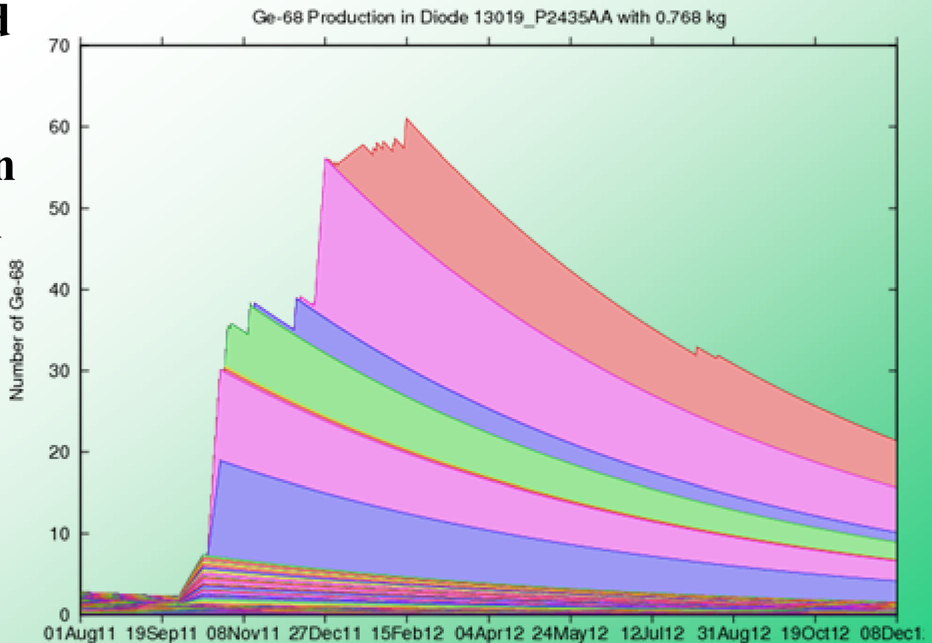
Transports in shielded container, storage underground

→ 5 working HP^{enr}Ge detectors available at LNGS

Logistics of detector production:

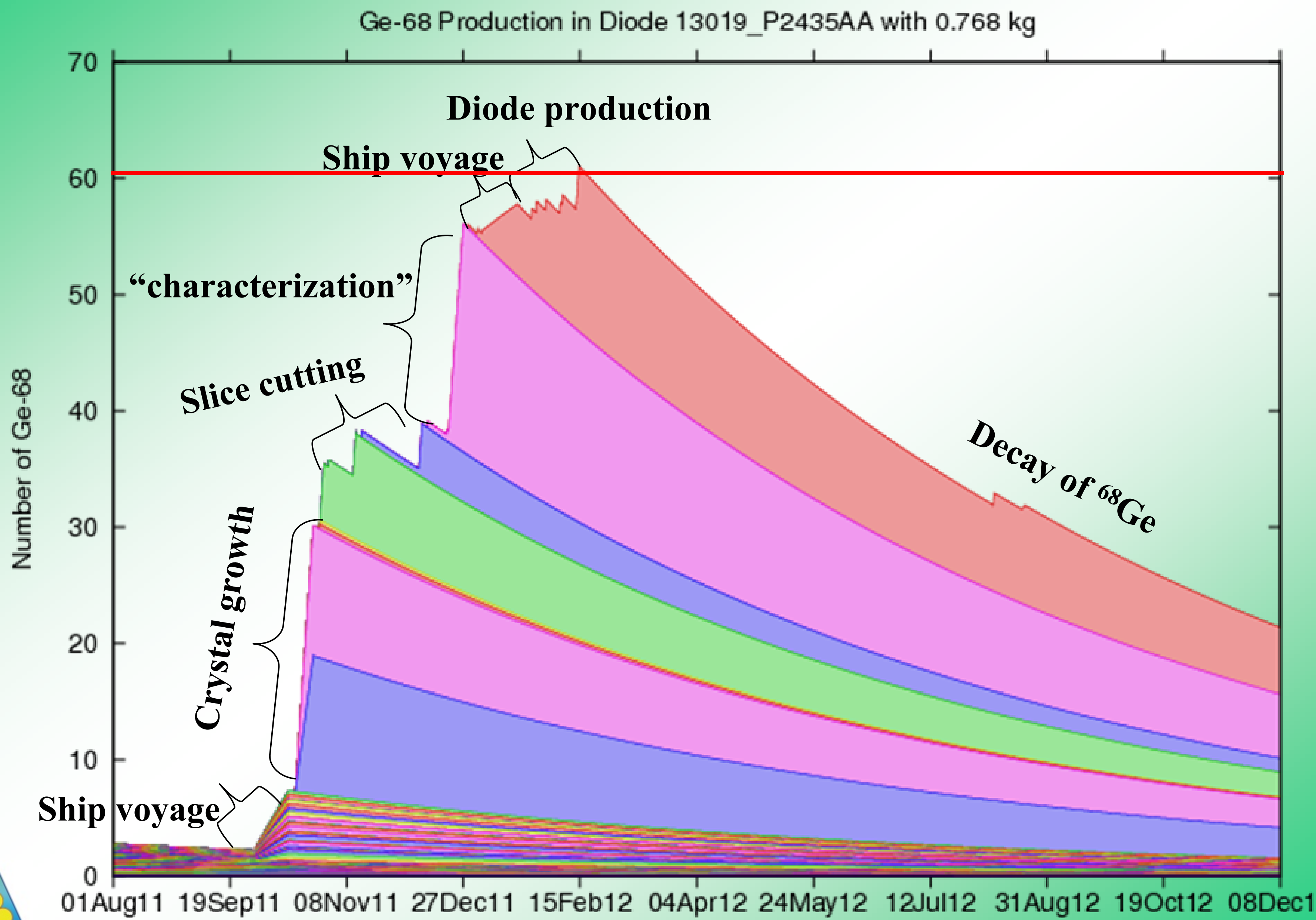
Tracking of exposure to above ground cosmic rays:

Prediction of background contribution due to cosmogenic activation for each detector available



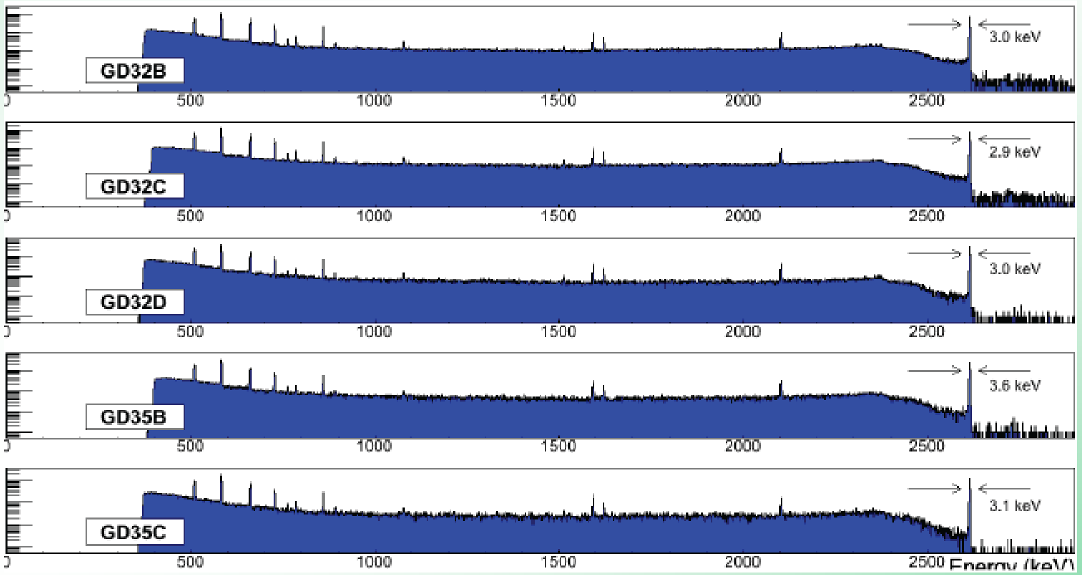
Logistics has been organized and controlled by Ch. O'Shaughnessy

Investigation of shielding powers of container materials done for diploma thesis of A. Michel


Ge-68 Production in Diode 13019_P2435AA with 0.768 kg
Number of Ge-68
0
10
20
30
40
50
60
70
01Aug11
19Sep11
08Nov11
27Dec11
15Feb12
04Apr12
24May12
12Jul12
31Aug12
19Oct12
Diode production
Ship voyage
"characterization"
Slice cutting
Crystal growth
Ship voyage
Decay of 68Ge

Phase II detectors in GERDA:

5 BEGes deployed into GERDA cryostat in Sept. 2012



3.6 kg of additional enriched detector material in GERDA

Significantly better energy resolution

Improved background recognition efficiency

Presently in learning phase

Investigation of PSA properties subject of PhD thesis of H.Y. Liao

Phase II detectors in GERDA:

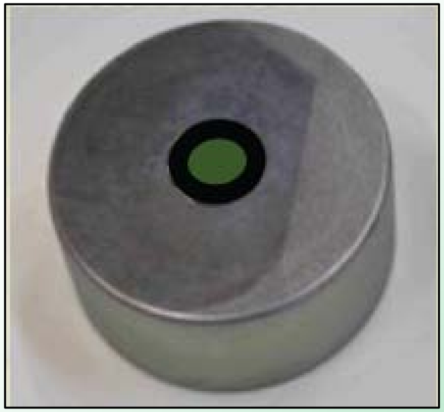
Produced 30 BEGes with total mass 20.8 kg

Presently 29 of 30 working within specifications

Energy resolution < 3.0keV at 2.6 MeV

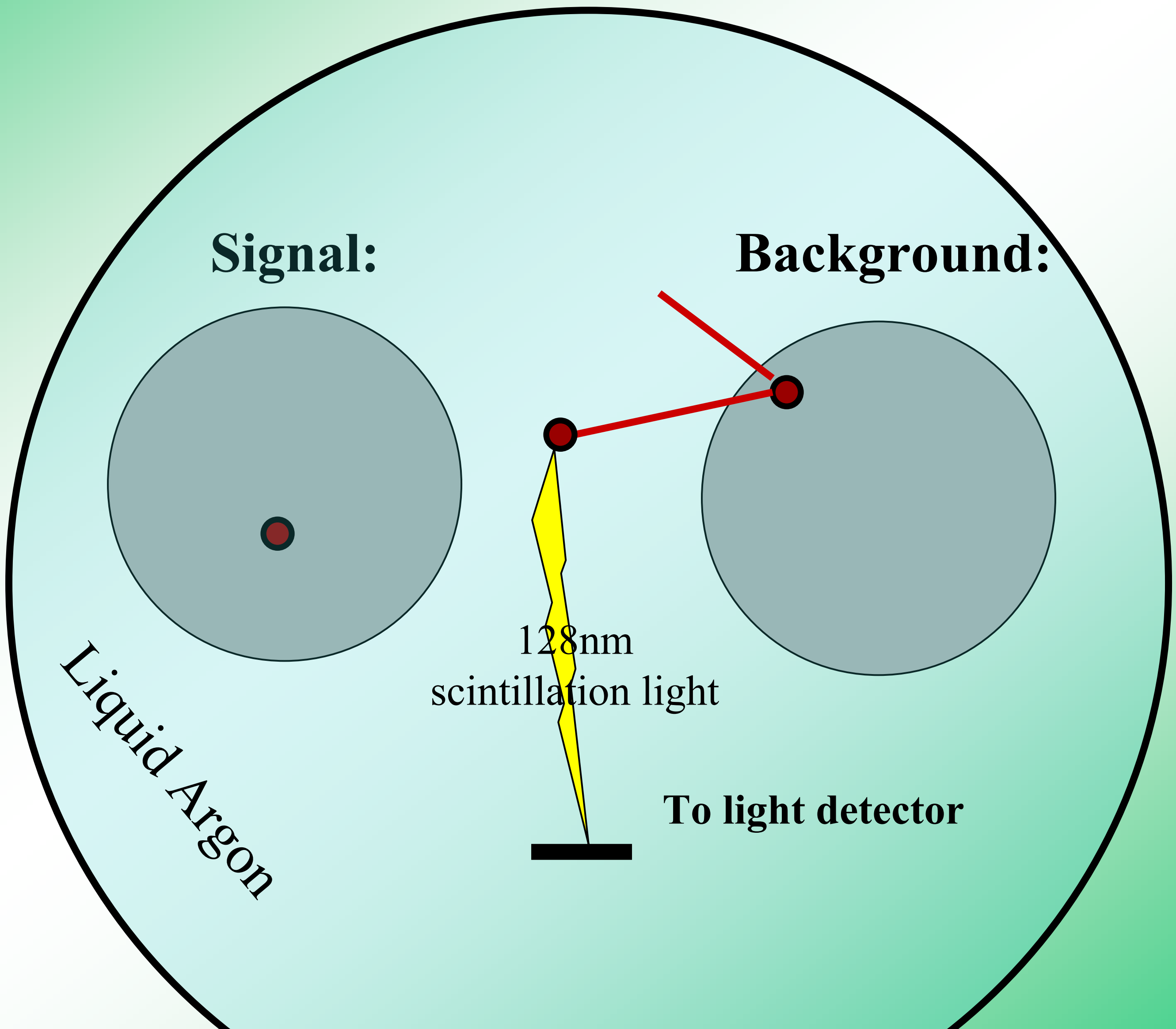
Characterization being presently performed at HADES Site in Belgium

Measurement	Equipment
Leakage Current	Continuously / USB loggers
HV Scans	Co60 Source (fixed)
Energy Resolution	Co60 Source (fixed)
Stability	Co60 Source (fixed)
Surface Scans	Am241 (scanning)
Dead Layer / Active Volume	**Am241, Ba133, Co60, Th228 (fixed)**
Pulse Shape Properties	**Am241 (scanning) / Th228 (fixed)**



GERDA LAr instrumentation:

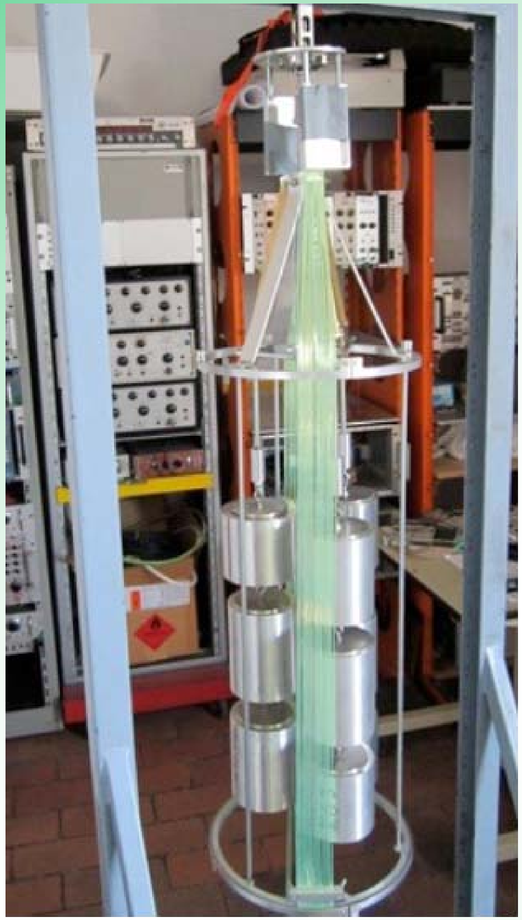
Background rejection by detection of LAr scintillation light



GERDA LAr instrumentation:

Background rejection by detection of LAr scintillation light

Two solutions (supported by MC with light tracking):



SiPMs connected to fibres

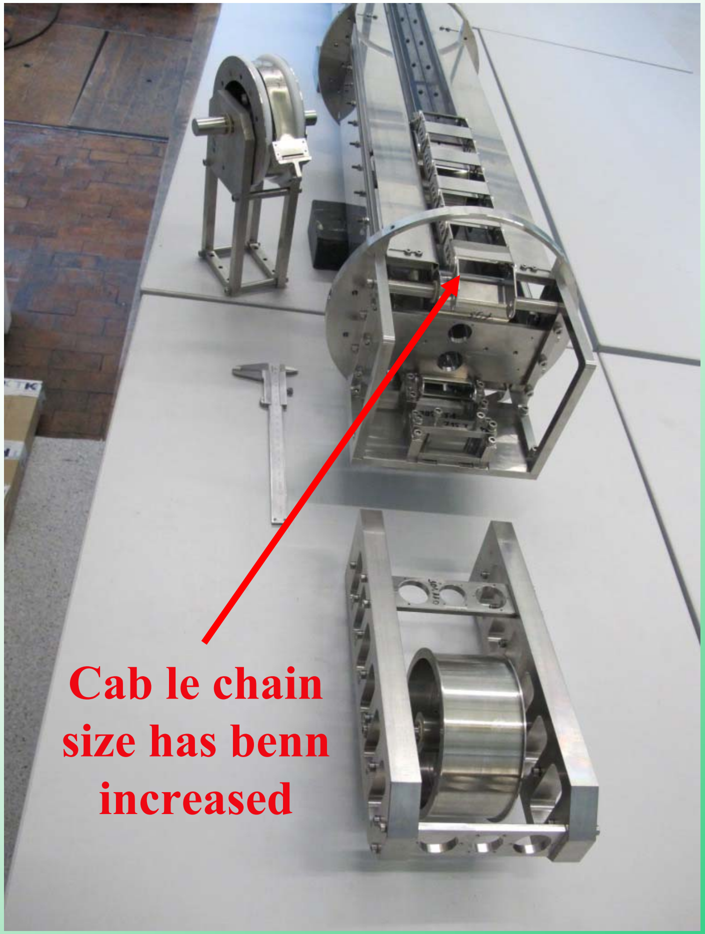
Low background PMTs → **Combine designs**

simulations suggest: reduction of background to 0.001 cts/(kg yr kev) realistic

Phase II Hardware:

Infrastructure for phase II upgrade on the way:

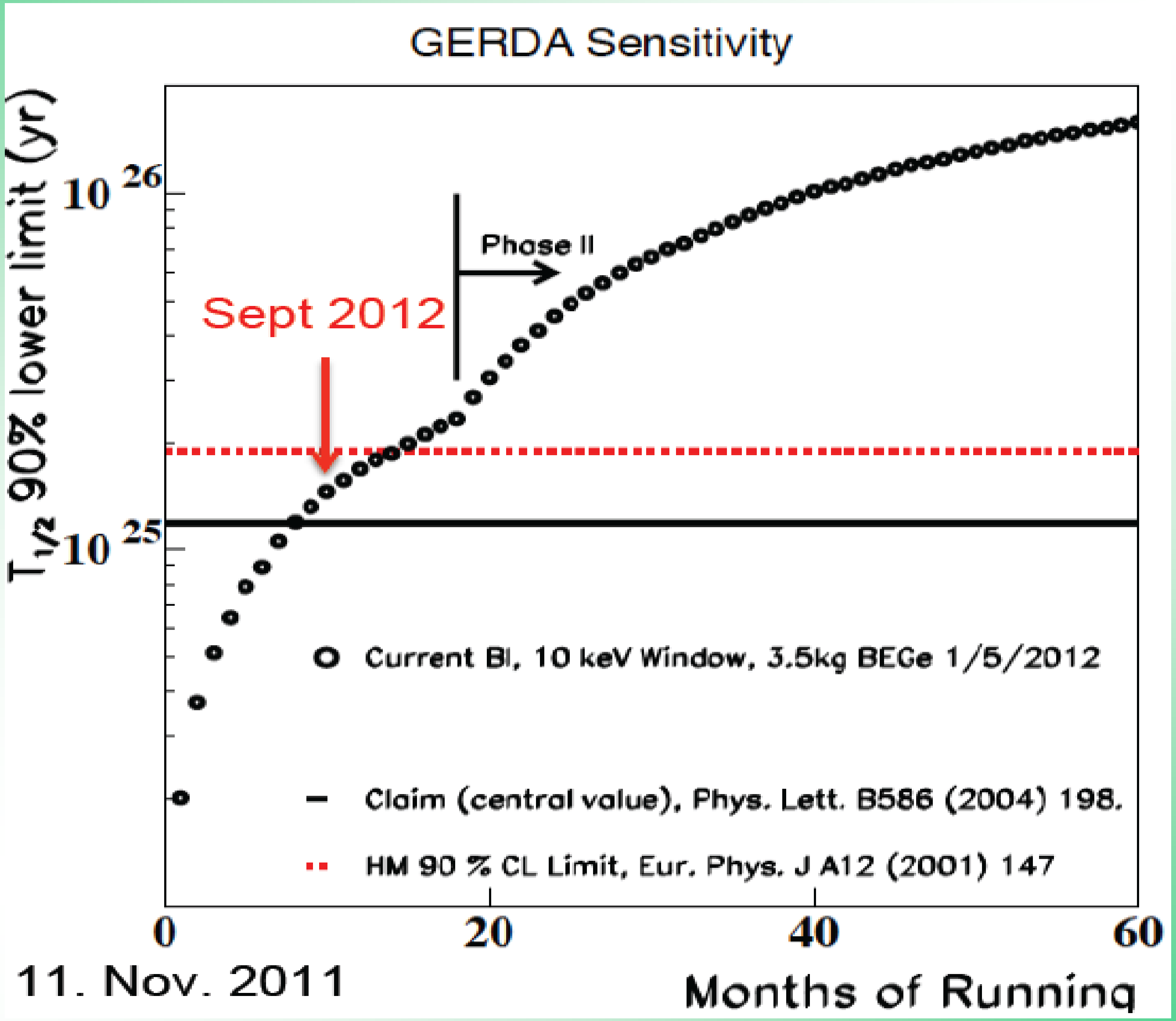
Inner mechanics partly available



Infrastructure for phase II upgrade on the way:
Lock cylinder available
Inner mechanics partly machined
New holder structures being produced and tested
LAr readout being constructed

→ Upgrade scheduled for 2013

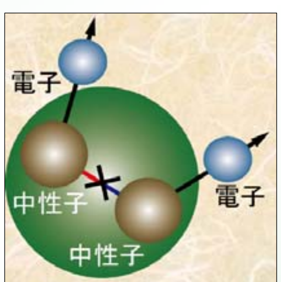
Phase II Sensitivity:



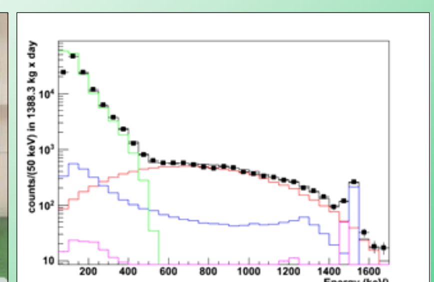
Sensitivity calculations and plots by A. Caldwell

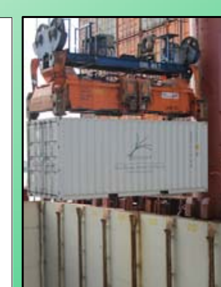
SUMMARY:

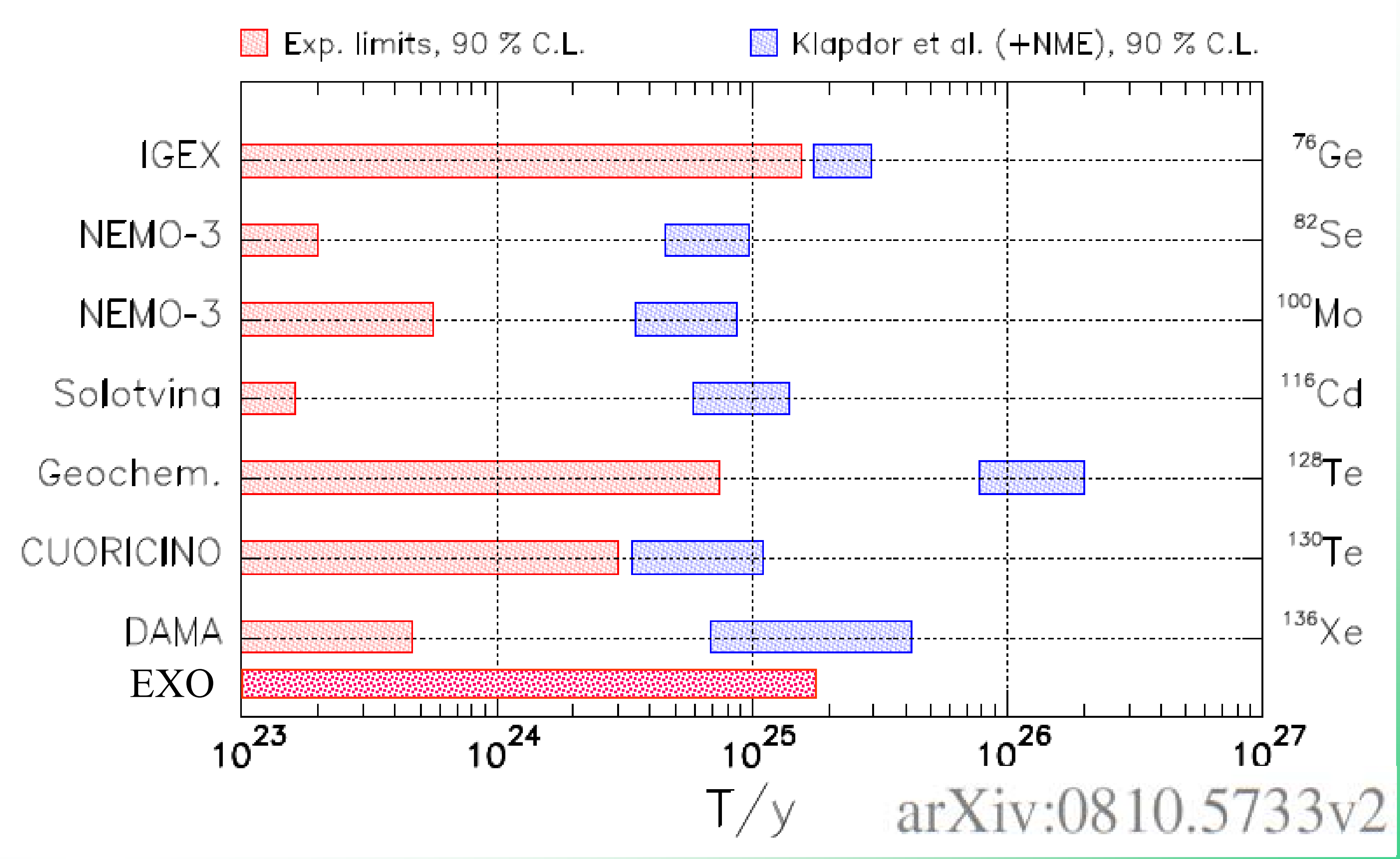
- We do not understand Neutrinos yet
- 0νββ-decay might help
- GERDA phase I background is close to design goal
- GERDA phase II: more mass with „intelligent detectors“
- 29 of 30 BEGes are available
- GERDA PhaseII hardware upgrade planned for next year

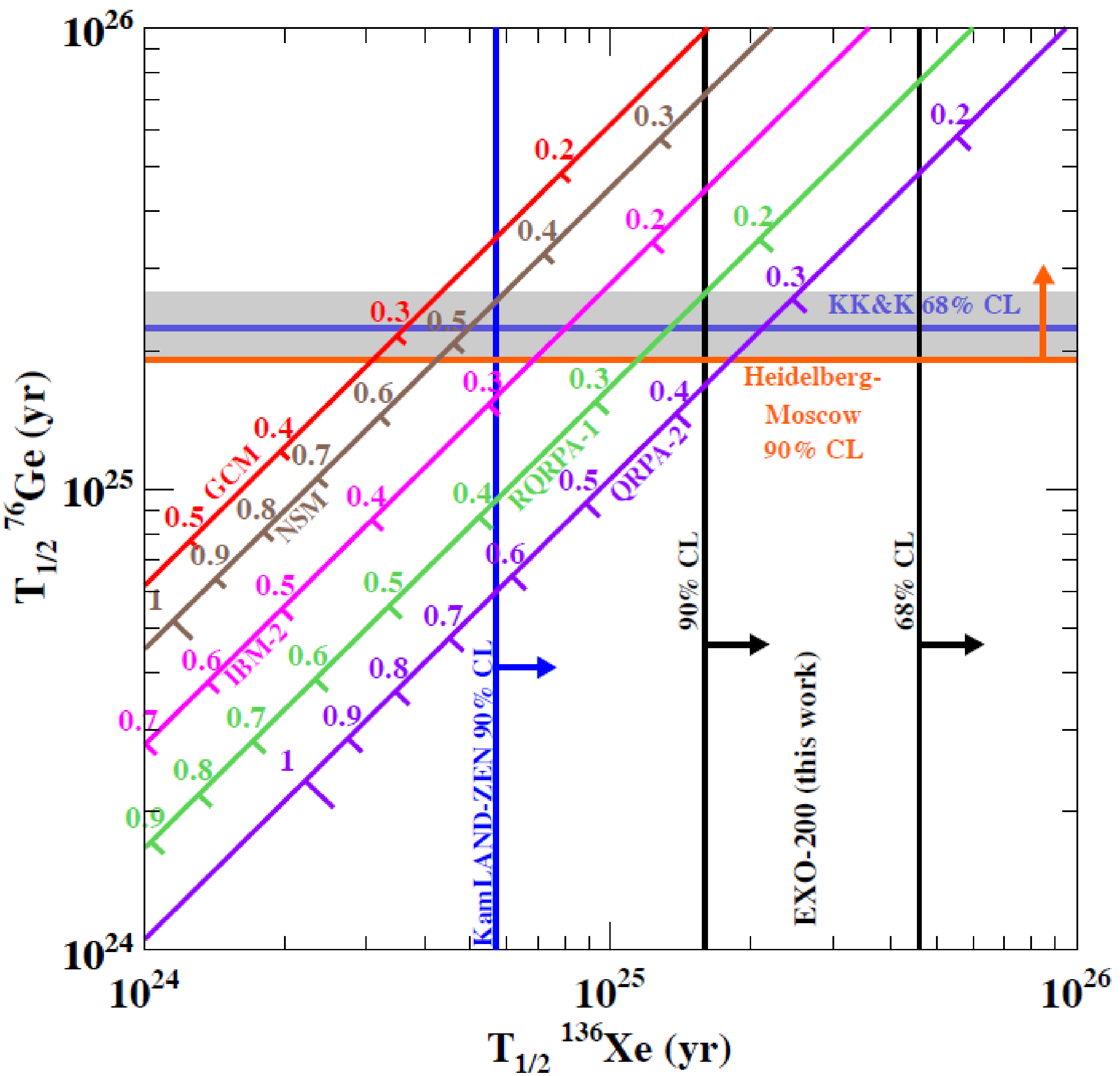






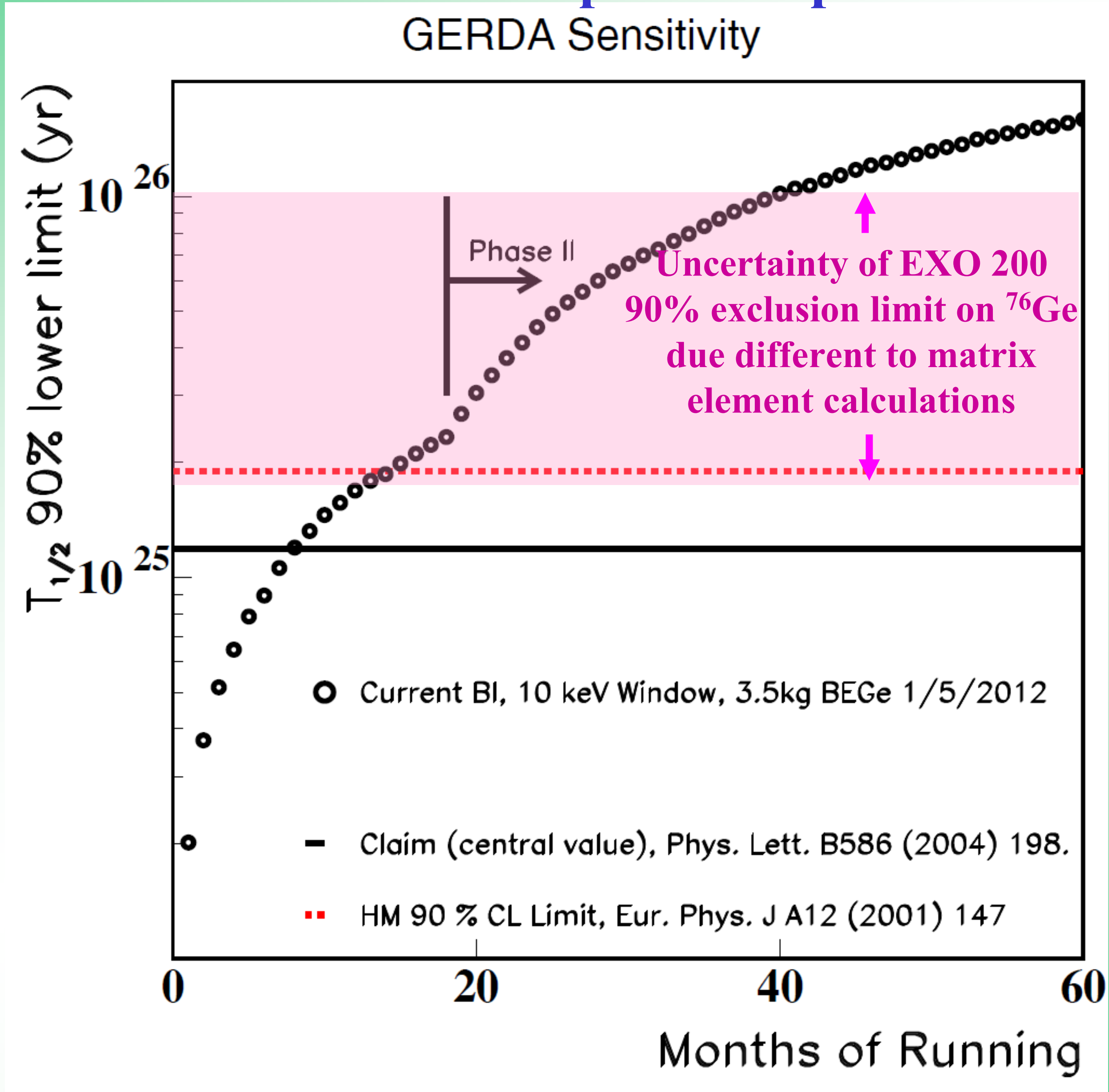



Exp. limits, 90 % C.L.
Klapdor et al. (+NME), 90 % C.L.
IGEX
NEMO-3
NEMO-3
Solotvina
Geochem.
CUORICINO
DAMA
EXO
76Ge
82Se
100Mo
116Cd
128Te
130Te
136Xe
10^23
10^24
10^25
10^26
10^27
T/y
arXiv:0810.5733v2



10^{26}
10^{25}
10^{24}
$T_{1/2}$ ^{76}Ge (yr)
$T_{1/2}$ ^{136}Xe (yr)
GCM
NSM
IBM-2
RQRPA-1
QRPA-2
KK&K 68% CL
Heidelberg-Moscow 90% CL
KamLAND-ZEN 90% CL
90% CL
68% CL
EXO-200 (this work)

GERDA : Status and plans for phase II

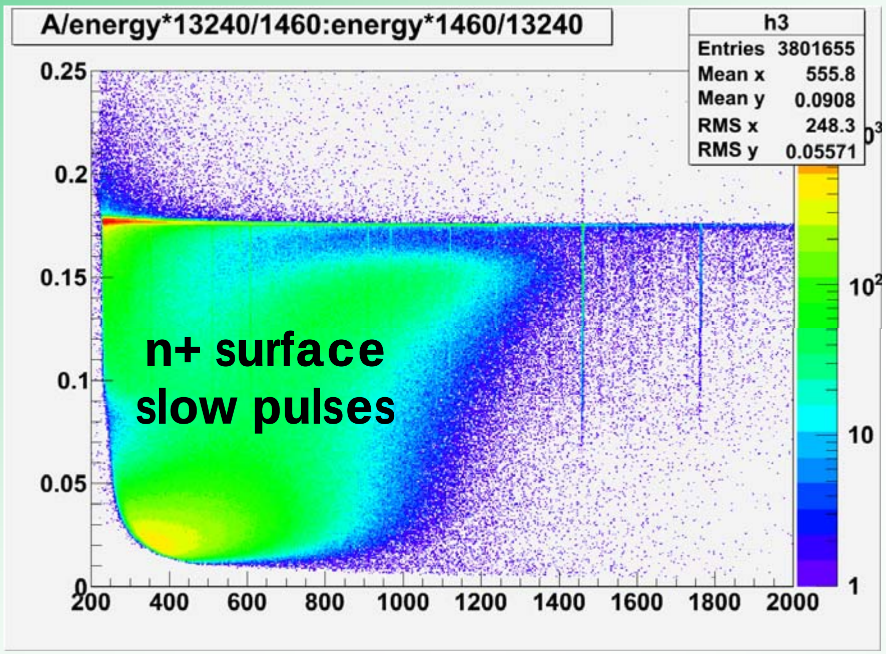


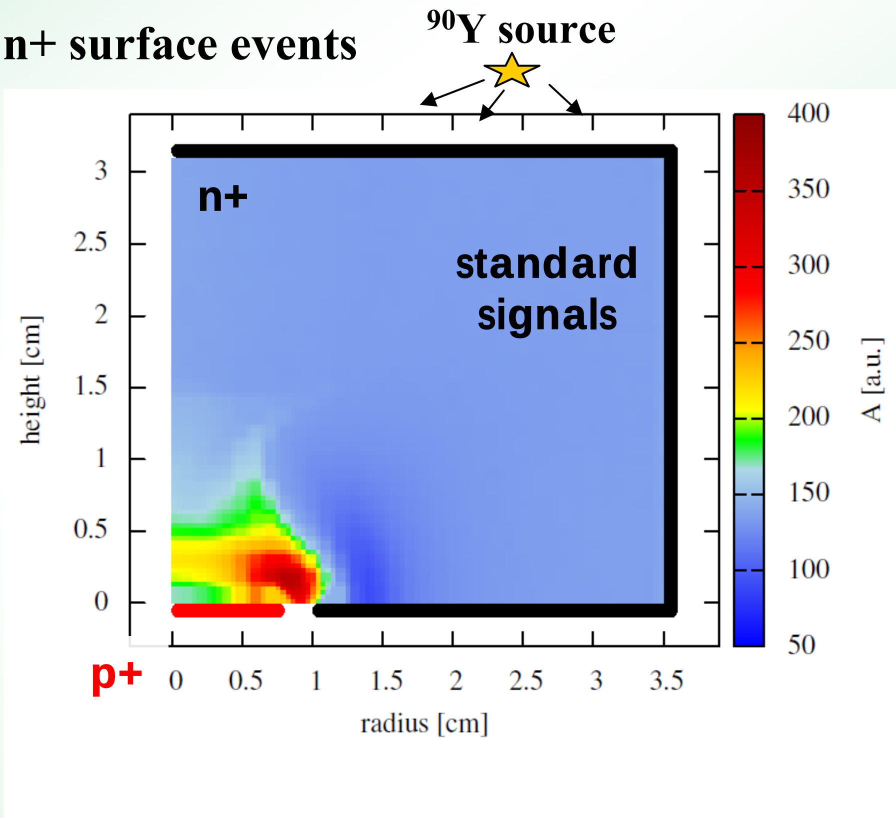
Plans for phase II: new detectors

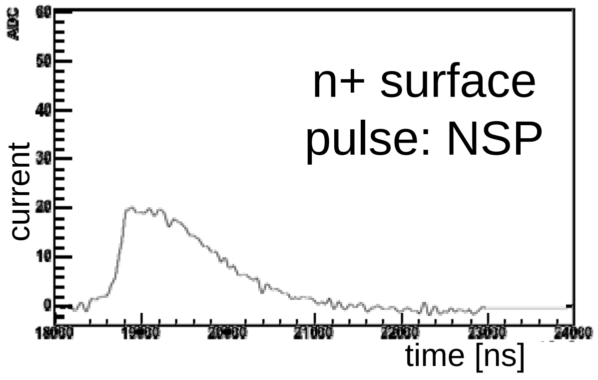
Background recognition powers of BEGes

Identify surface events:

Data taken with ^{90}Y β-source → n+ surface events







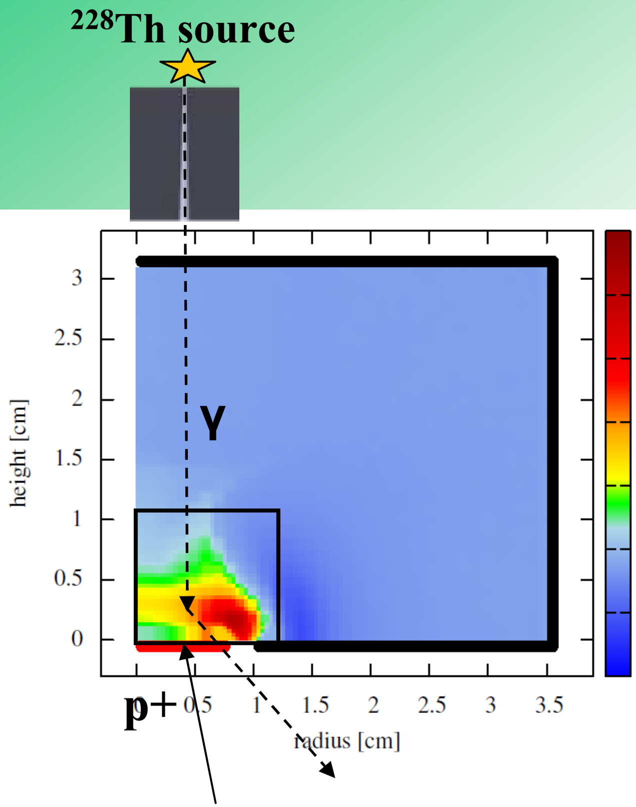
→**Low E-fields in "partially" dead layer**

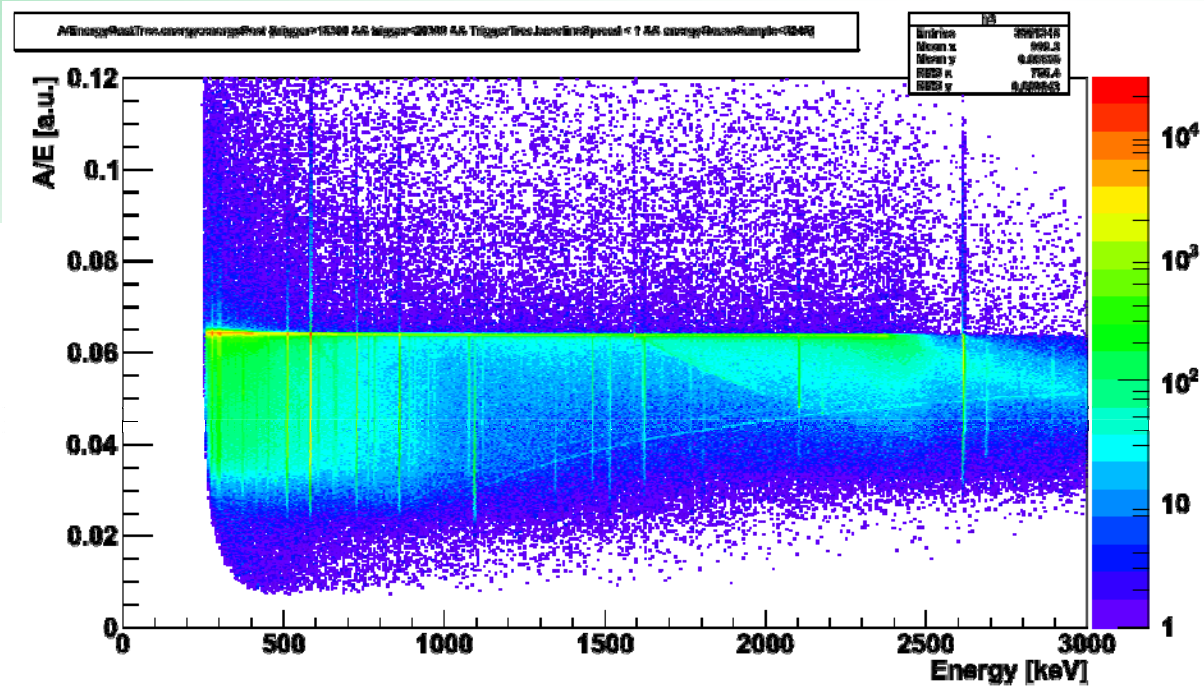
→**Slow pulses**

→**Decrease A/E parameter**

Plans for phase II: new detectors

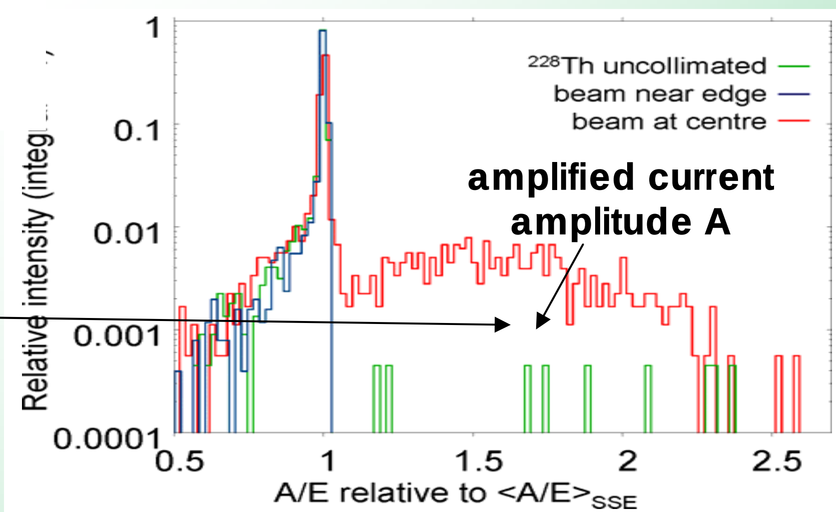
Background recognition powers of BEGes





At p+ contact also e$^-$ are "visible"

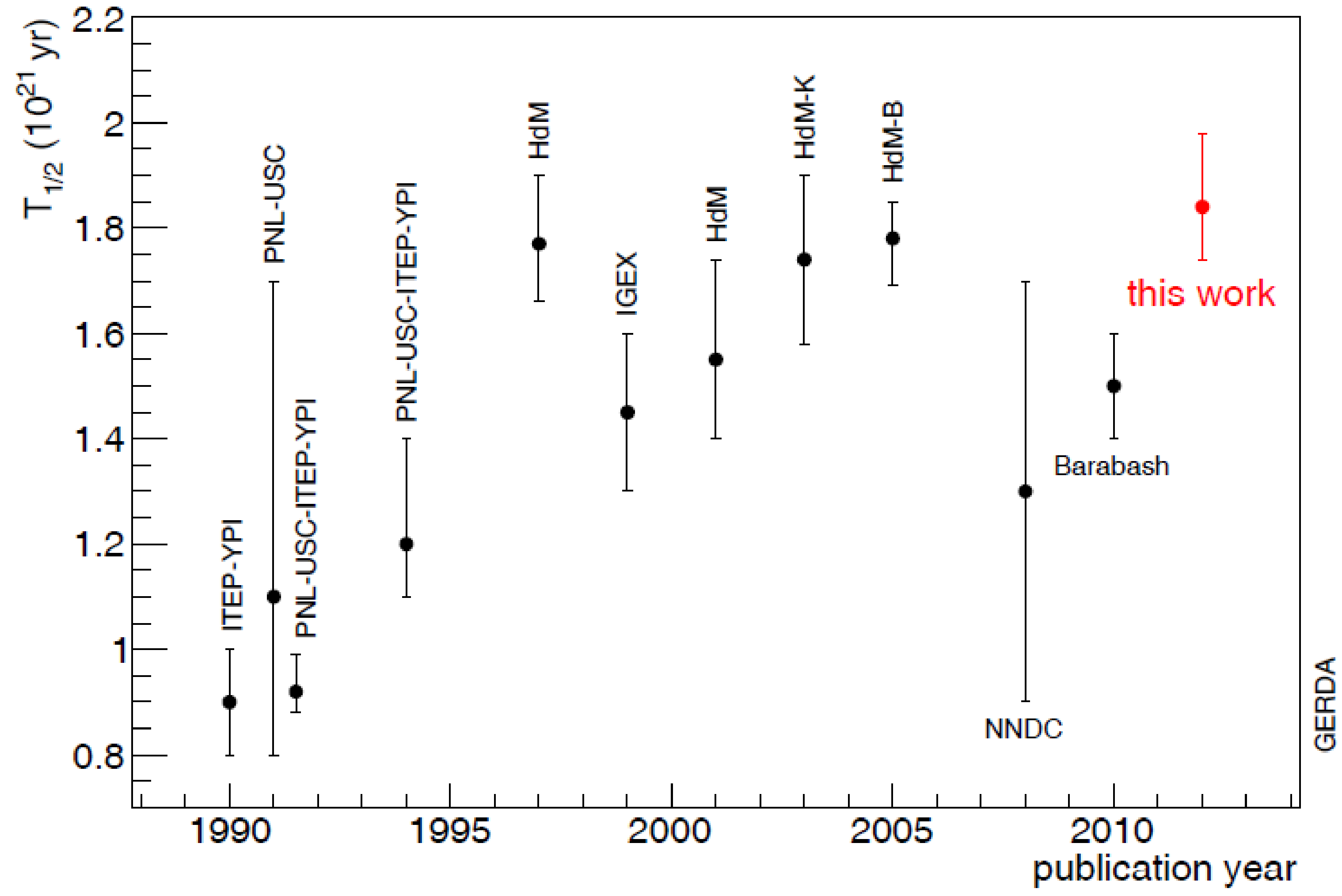
→ A_{max}/E is increased

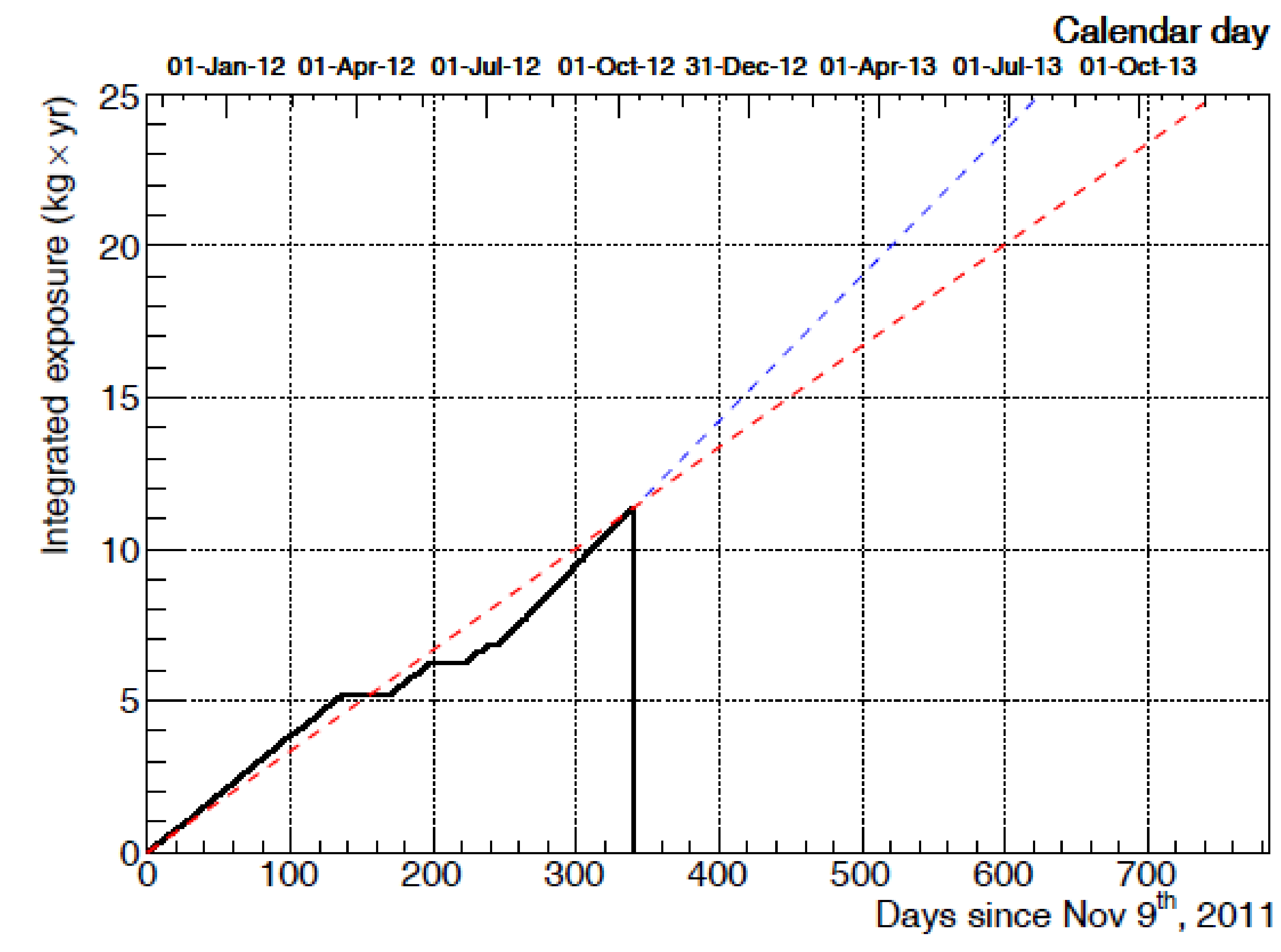


M. Agostini et al., JINST 6 P03005 (2011)

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

New measurement of 2vbb half life:




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