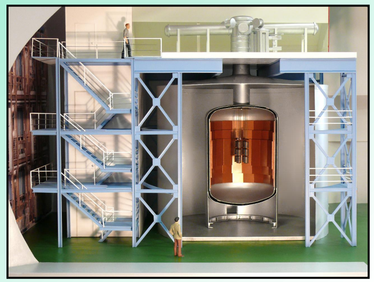
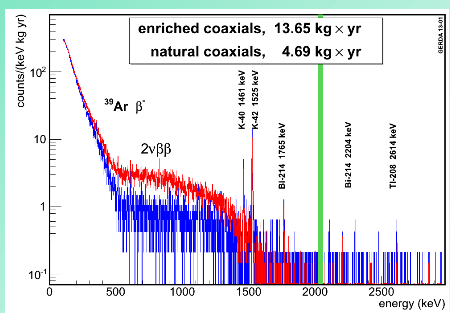
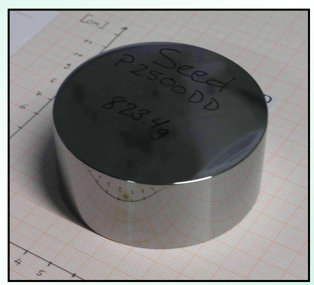
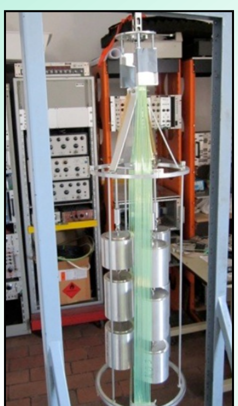
Search for neutrinoless double beta decay with GERDA: Status report









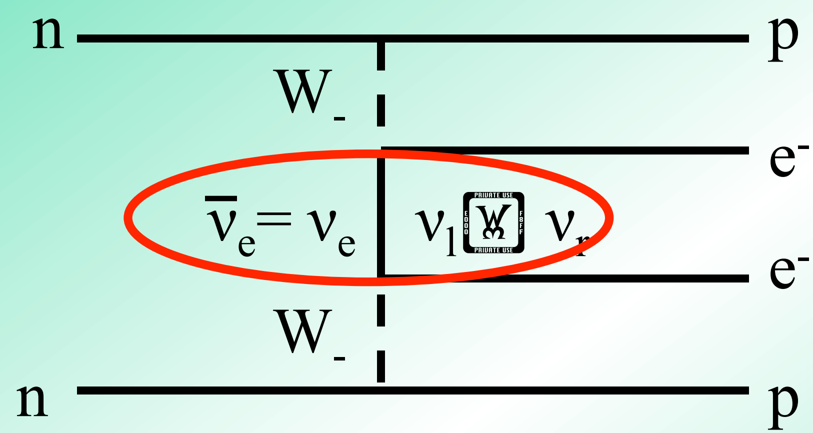
O U T L I N E

- A very short introduction
- Phase I Data taking
- Phase I background decomposition
- Phase II detectors
- Phase II hardware preparations

Béla Majorovits for the GERDA collaboration
Max-Planck-Institut für Physik, München, Germany

A very short introduction: 0νββ-decay

0νββ-decay:



Neutrinoless mode of double beta-decay only possible if:

- Neutrino has Majorana character
- Helicity flip can occur in the vertex

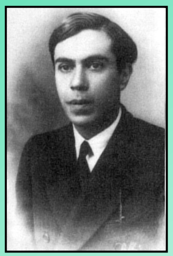
Effective Majorana neutrino mass contributes to 0νββ-decay rate:

$$1/\tau = G(Q^5,Z)\,|M_{nucl}|^2\,\langle m_{\nu}\rangle^2$$

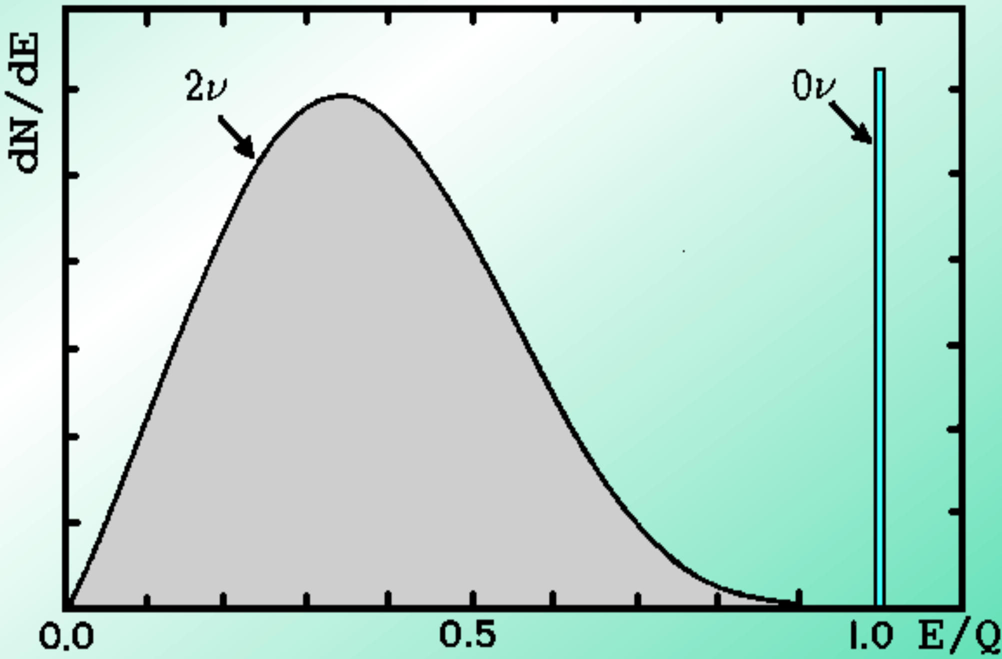
0νββ decay-rate | Phase space-factor | Matrix element | Effective Majorana Neutrino mass

A v ery short introduction: 0νββ-decay

Observation of 0νββ decay:



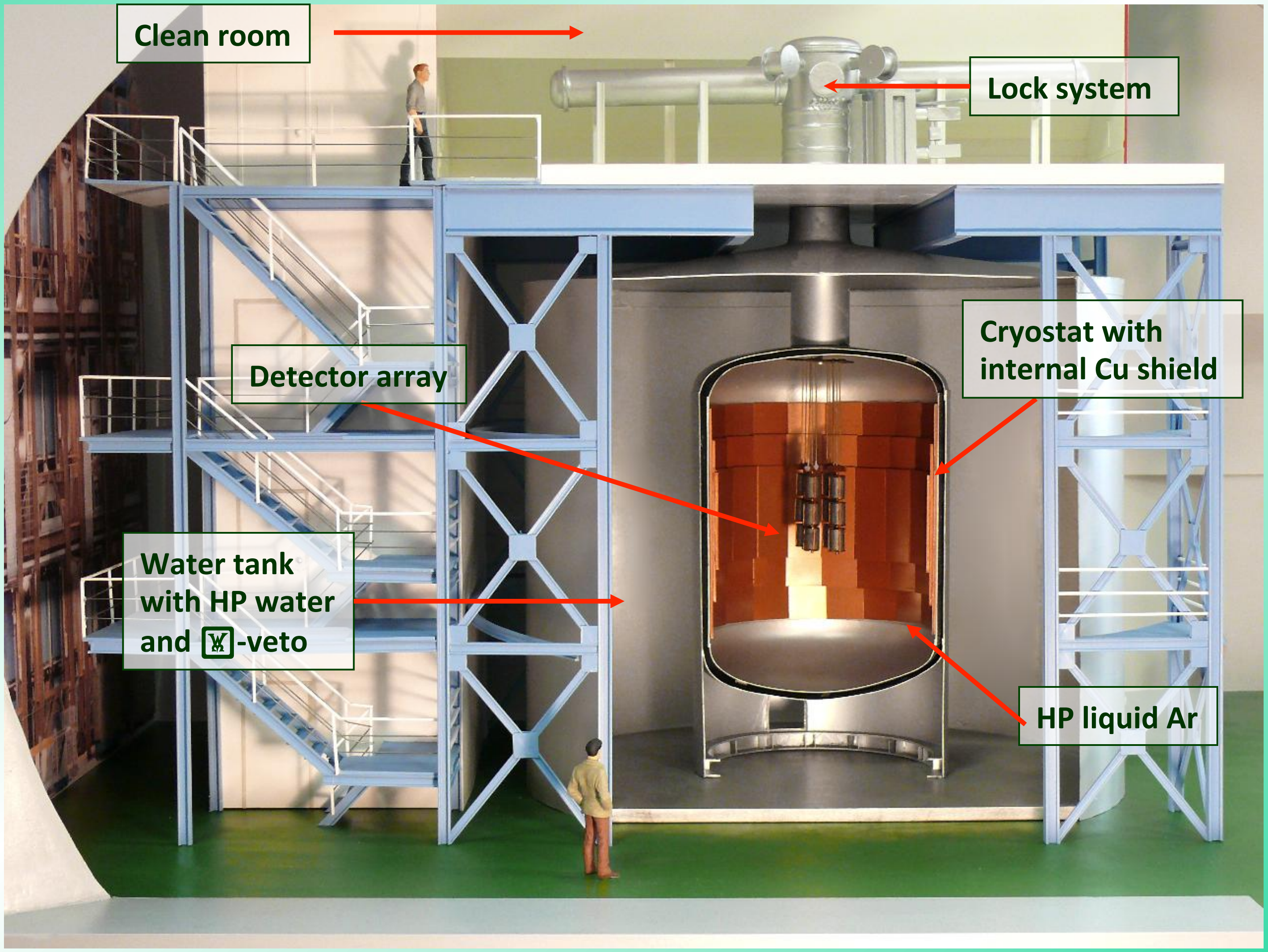
- Lepton number violation!
- Neutrino must have Majorana nature!
- Determination of absolute mass scale?
- Mass hierarchy of Neutrinos?
- Information on CP violating phases?



CP violating Majorana phases could be responsible for Baryogenesis via Leptogenesis

A very short introduction: GERDA

Operate „naked“ HPGe detectors directly in ultra pure cryoliquid (G. Heusser, 1995)



A very short introduction: GERDA

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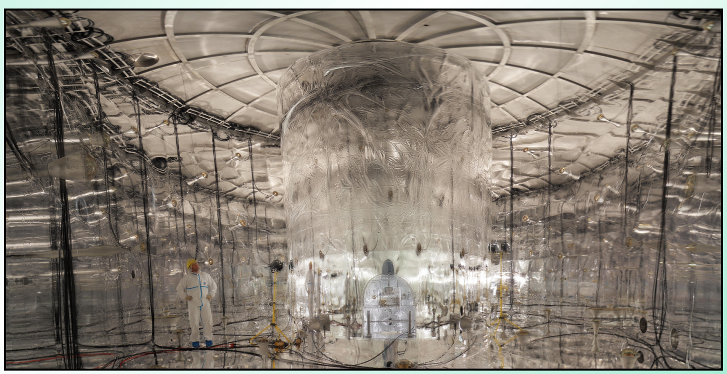
DOI 10.1140/epjc/s10052-013-2330-0

THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Experimental Physics

The GERDA experiment for the search of $0\nu\beta\beta$ decay in ^{76}Ge

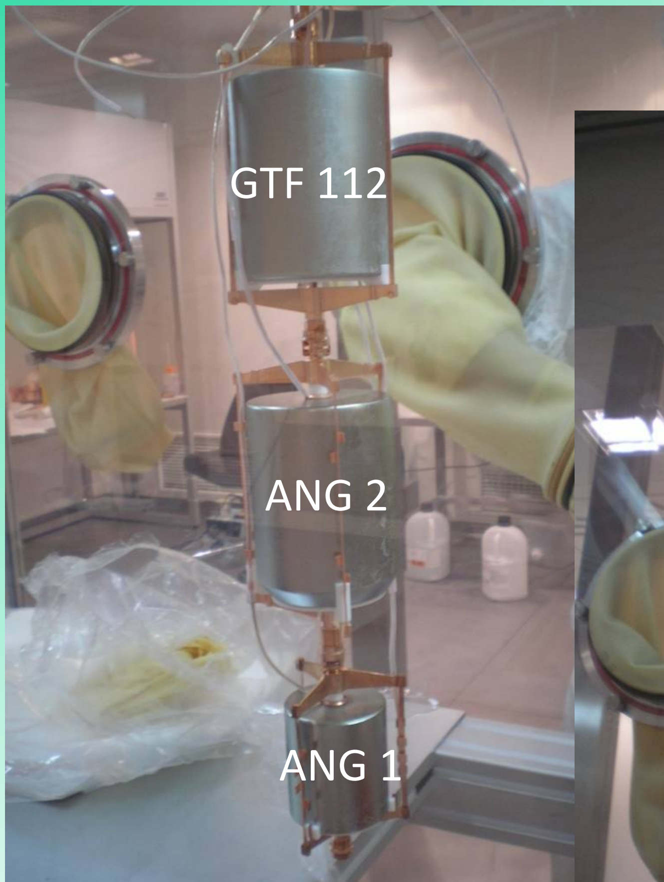


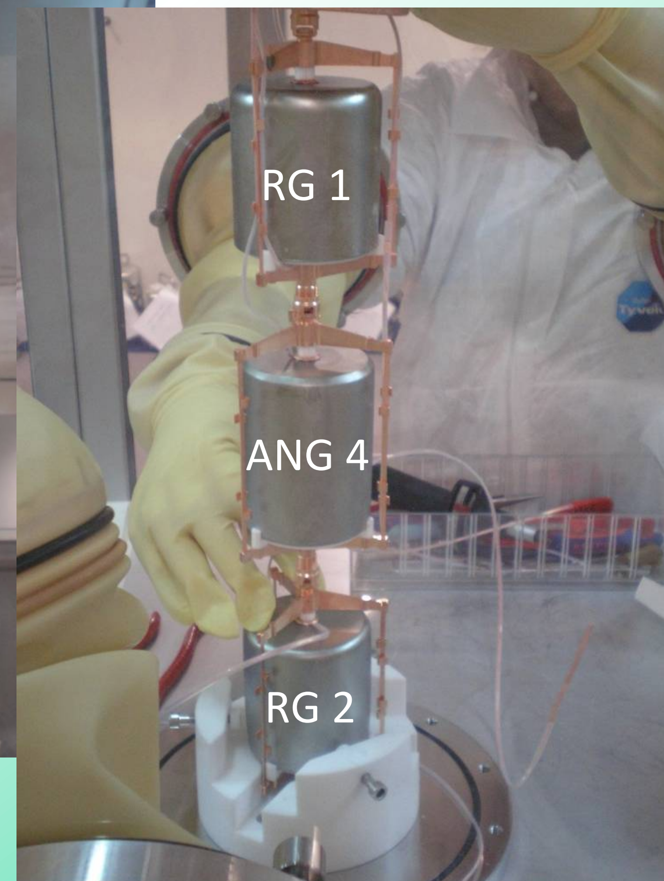
Phase I: reach BI 0.01 cts/(keV kg yr) → $T_{1/2}$ sensitivity: $2*10^{25}$ yr (test KK claim)

Phase II: reach BI 0.001 cts/(keV kg yr) → $T_{1/2}$ sensitivity: ~ 10^{26} yr

A very short introduction: GERDA

Installation of phase I detectors :

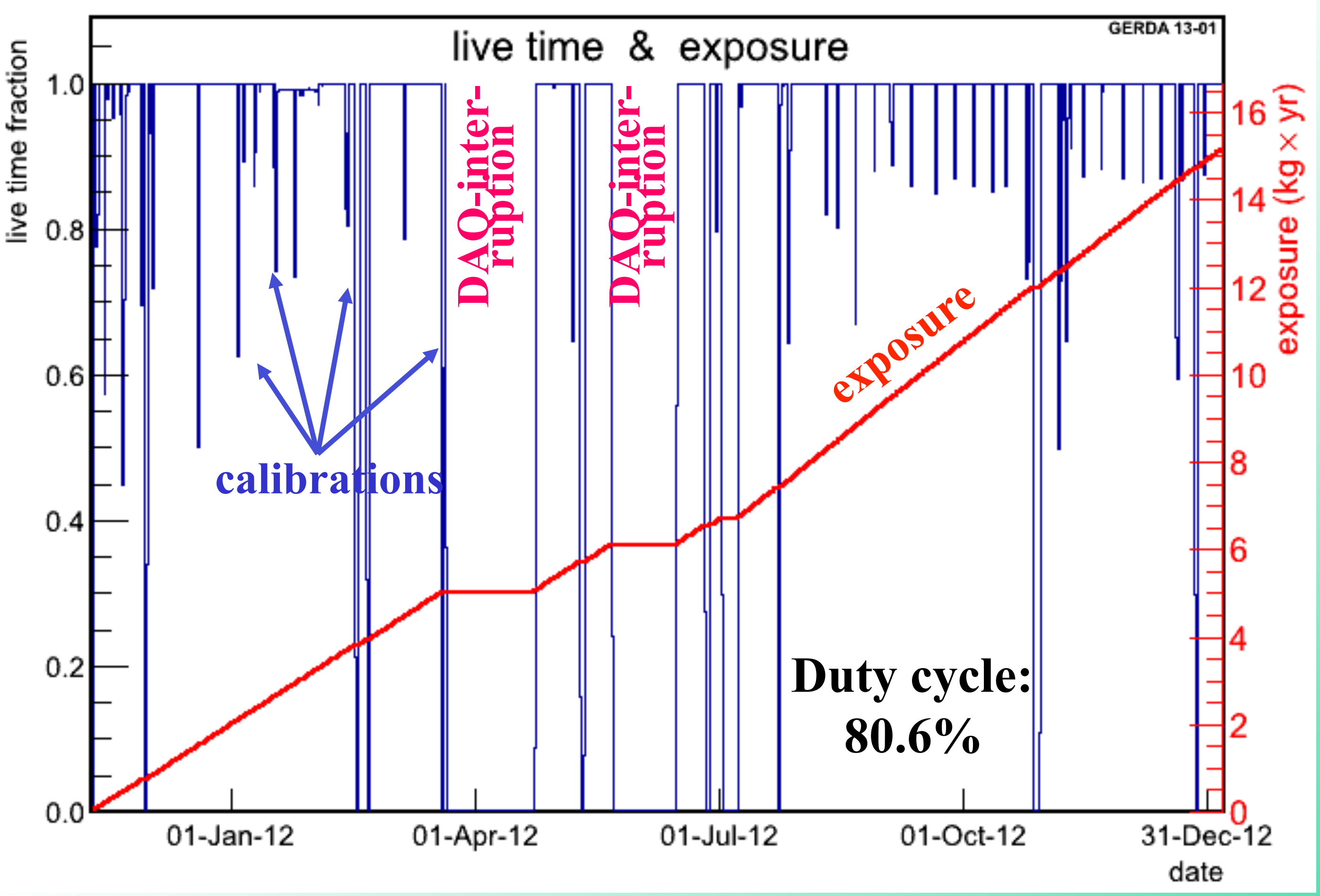




Deployed all phase I detectors in Nov. 2011 together with one natural HPGe detector

Phase I data taking

Live time & duty cycle 9th of Nov – 5th of Jan 2013



Phase I data taking

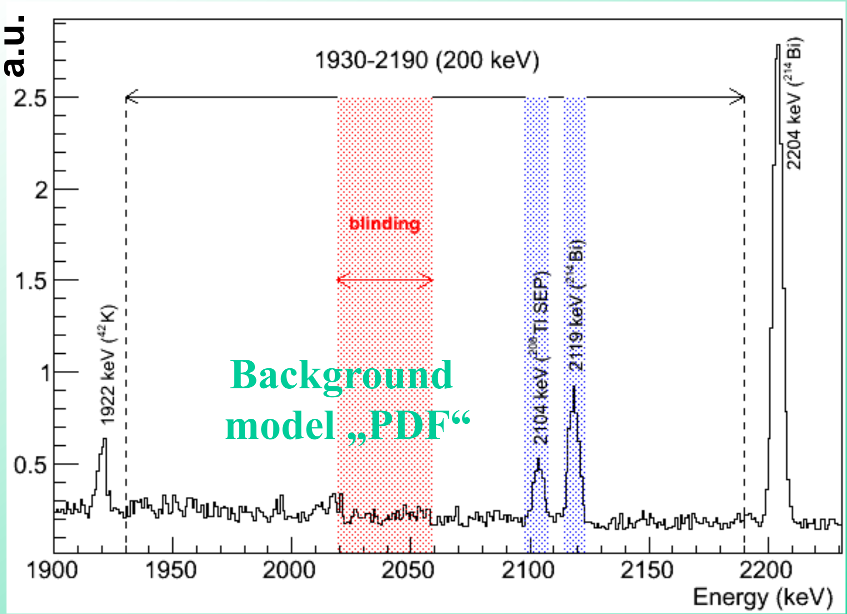
Total exposure and BIs until 15th Apr. 2013:

Time stamp of first event: Wed Nov 9 17:50:20 2011

Time stamp of last event: Mon Apr 15 00:52:16 2013

(Live time: 456.15 days,
after recovery of some data from unstable runs)

Dataset	Exposure [kg yr]	Cnts in 200keV window	BI [cts/(keV kg yr)]
golden	16.721	58	0.017±0.002
silver	1.304	17	0.065 ±0.016
BEGe *	2.287	21	0.046 ±0.010
All enr	20.312	96	0.024 ±0.002
Nat	5.910	52	0.044 ±0.006

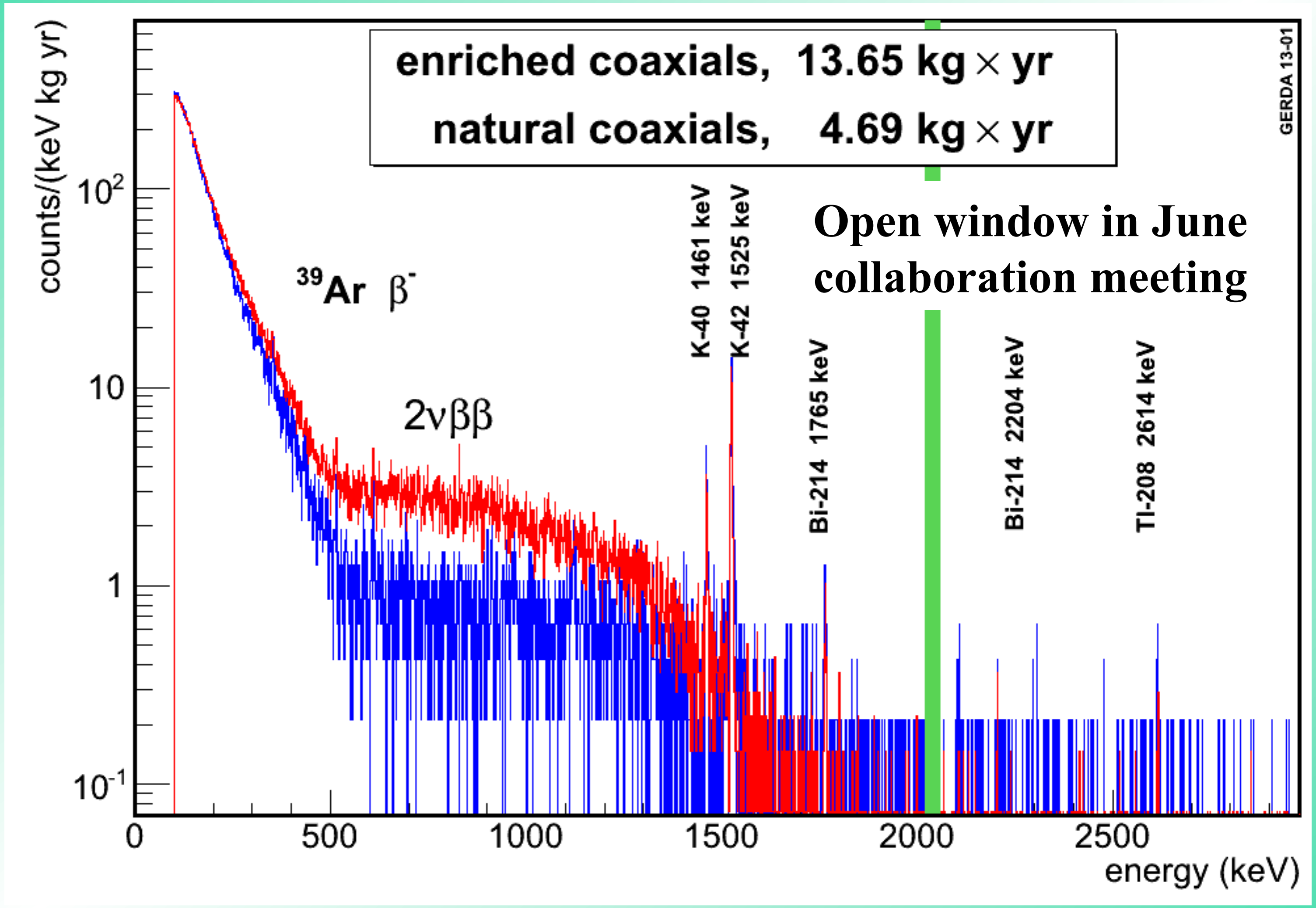


* no PSA applied

Exposure with Phase I detectors: 20.00 kg*yr on April 8th 2013

Phase I data taking

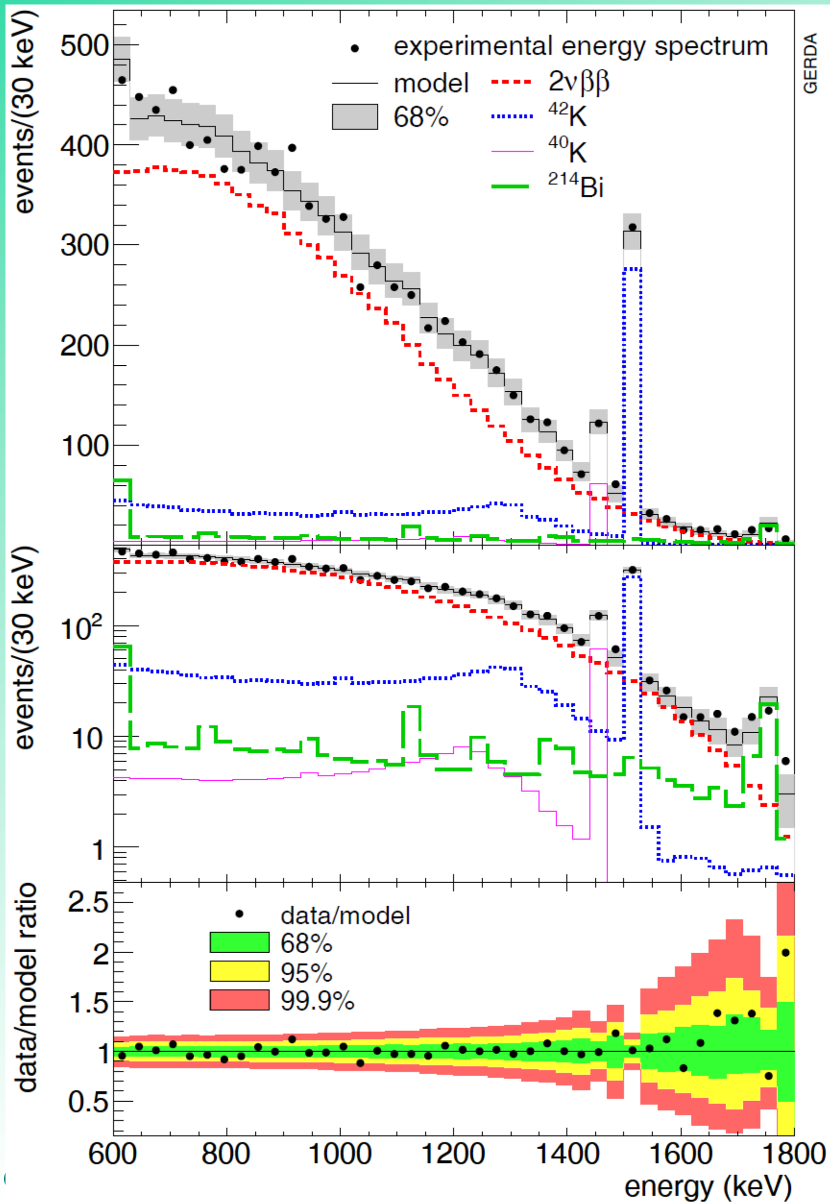
Natural vs. Enriched detectors:



GERDA phase I background improved by order of mag. wrt earlier experiments.

Phase I data taking

New measurement of $^{2\nu}T_{1/2}$ (^{76}Ge) published:

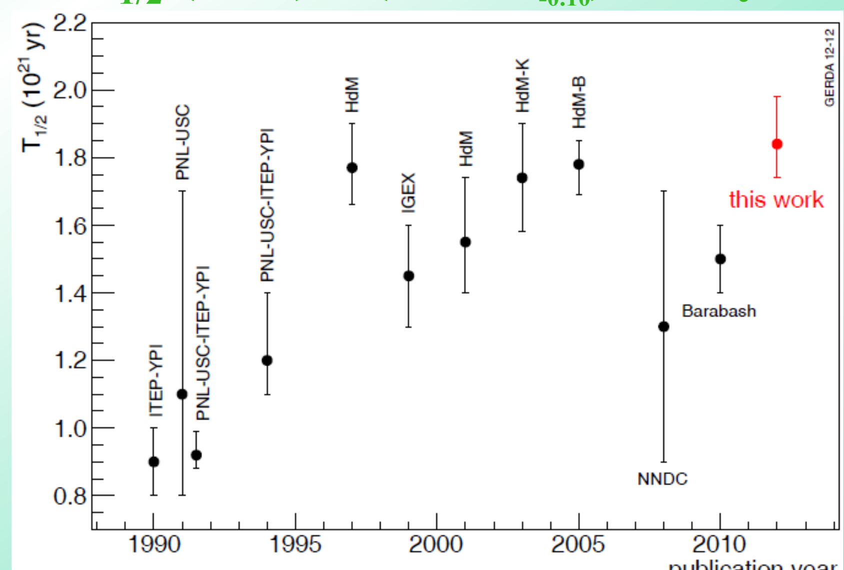


IOP Publishing Journal of Physics G: Nuclear and Particle Physics
J. Phys. G: Nucl. Part. Phys. 40 (2013) 035110 (13pp) doi:10.1088/0954-3899/40/3/035110

Measurement of the half-life of the two-neutrino double beta decay of ^{76}Ge with the GERDA experiment

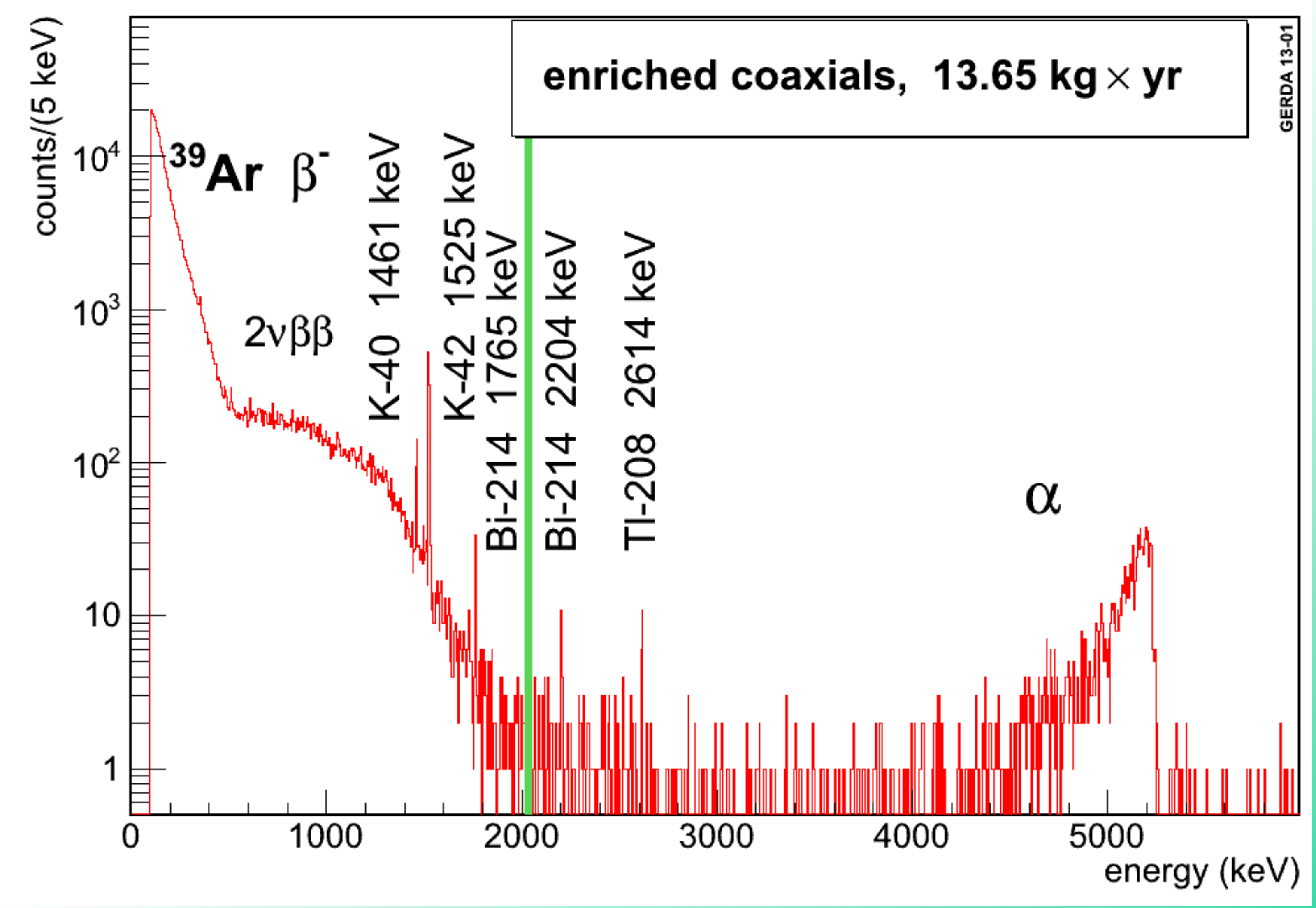
Signal to background ratio > 4 : 1

$$^{2\nu}T_{1/2} (^{76}Ge) = (1.84^{+0.14}_{-0.10}) \cdot 10^{21} yr$$

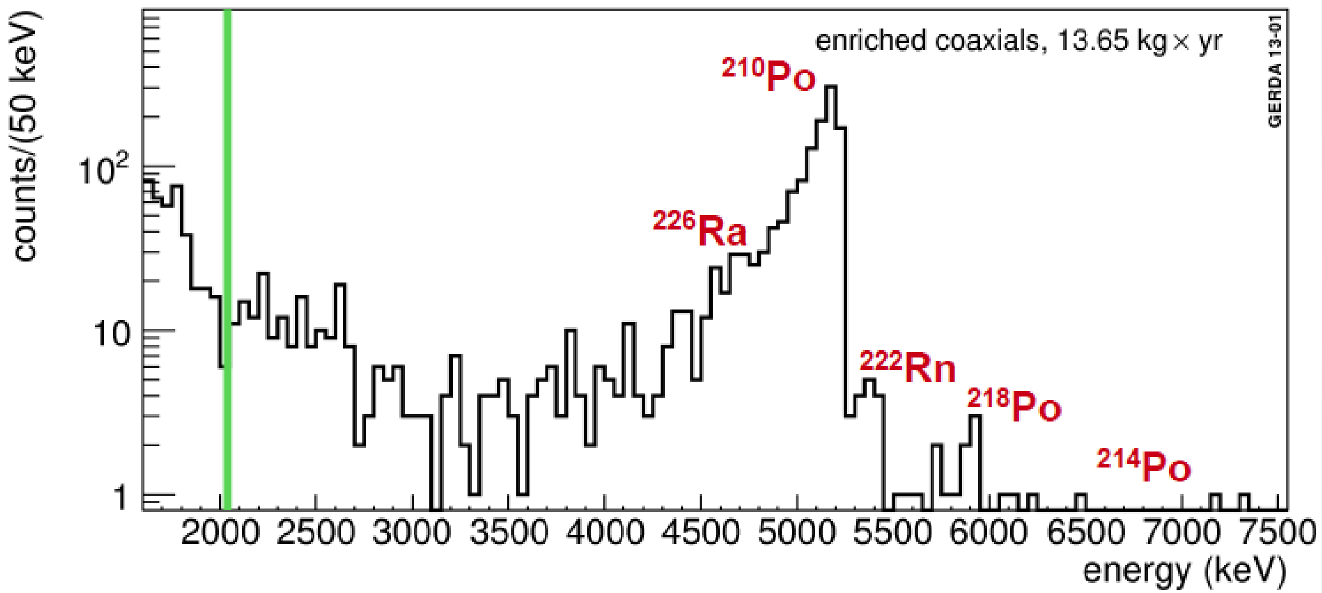


LAB Talk of J. Phys. G Feb. 2013 issue:
http://iopscience.iop.org/0954-3899/labtalk-article/52398

Phase I background decomposition:



Phase I background decomposition:



^{226}Ra (E_α = 4.8 MeV, $T_{1/2}$ = 1600 y)

^{222}Rn (E_α = 5.5 MeV, $T_{1/2}$ = 3.8 d)

^{218}Po (E_α = 6.0 MeV, $T_{1/2}$ = 183 s)

^{214}Pb ($T_{1/2}$ = 0.45 h)

^{214}Bi ($T_{1/2}$ = 0.33 h)

^{214}Po (E_α = 7.7 MeV, $T_{1/2}$ = 164 μs)

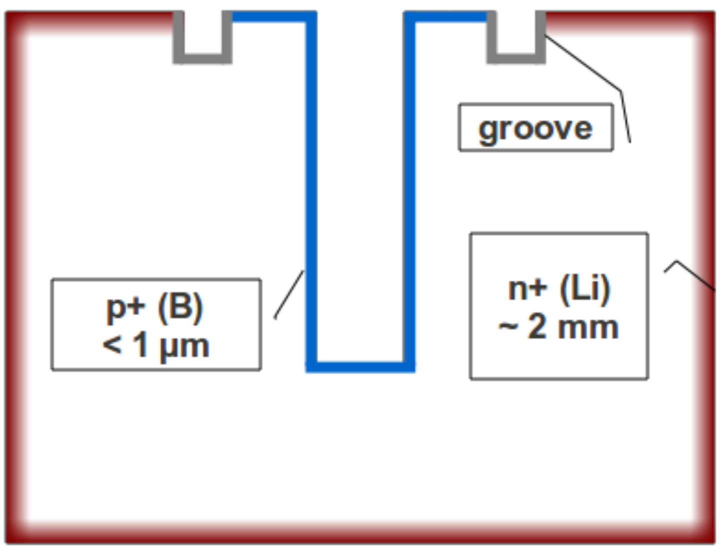
---

^{210}Pb ($T_{1/2}$ = 22.3 y)

^{210}Bi ($T_{1/2}$ = 5.01 d)

^{210}Po (E_α = 5.3 MeV, $T_{1/2}$ = 138.4 d)

^{206}Pb (stable)

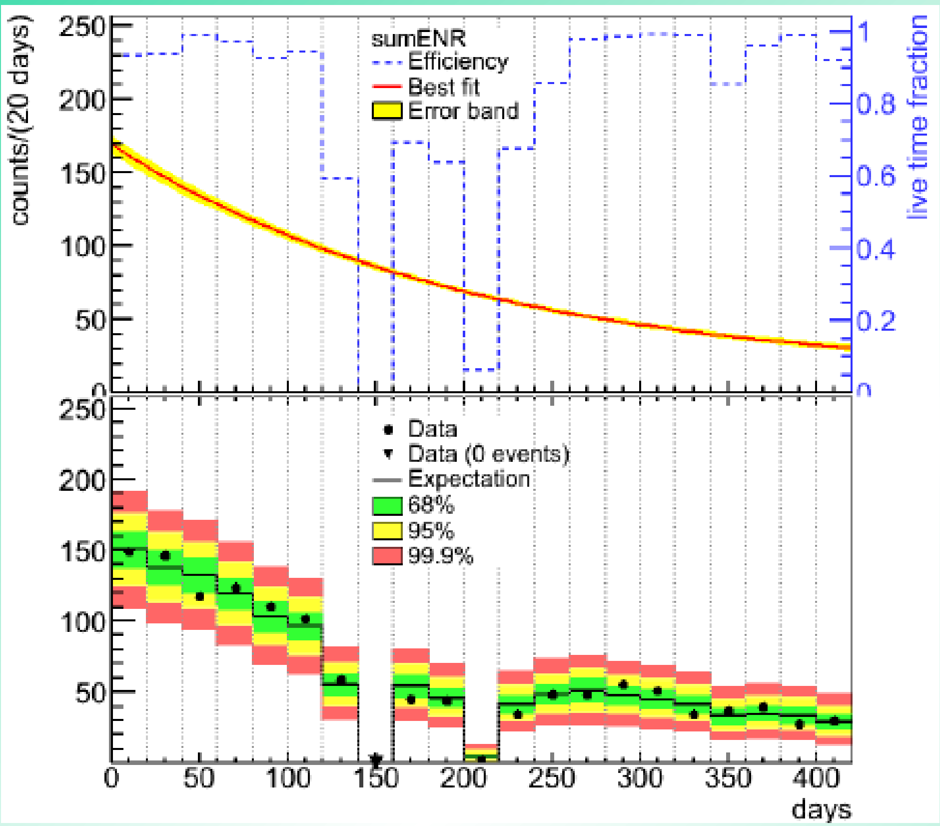


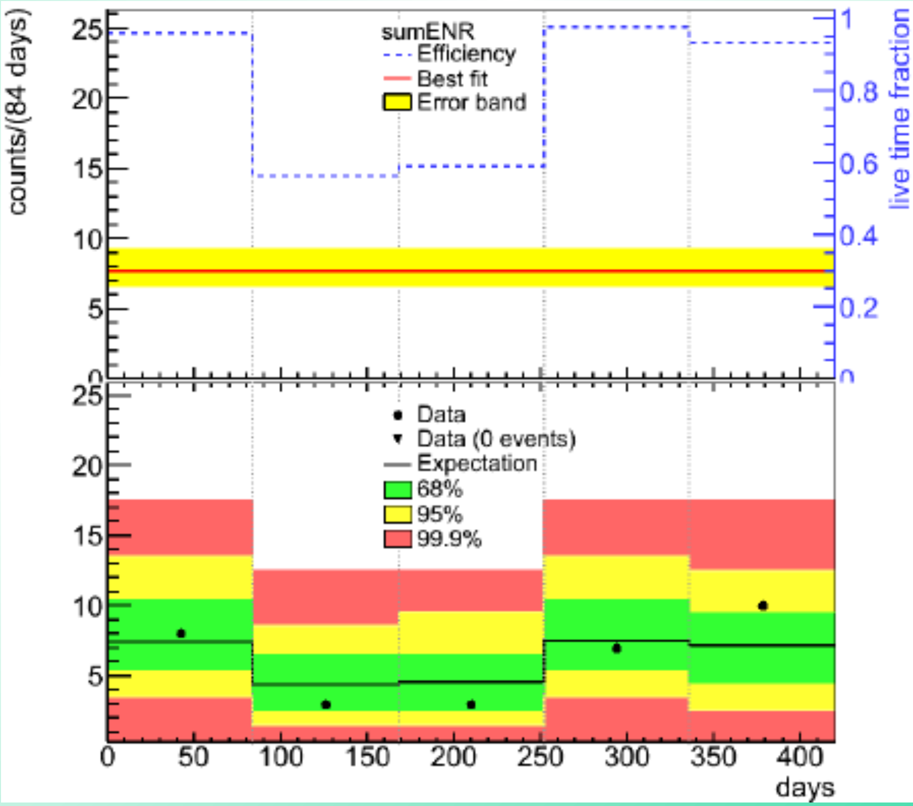
Range of 4 MeV – 9 MeV α:
→ 14 μm – 41 μm in Ge
→34 μm – 113 μm in LAr

Possible origin of α-induced events:
→Separate ^{226}Ra and ^{210}Po contaminations on thin dead layer (thinDL) surfaces.

Phase I background decomposition:

Count rate in 5.3 MeV peak and E>5.3 MeV as fct. of time:



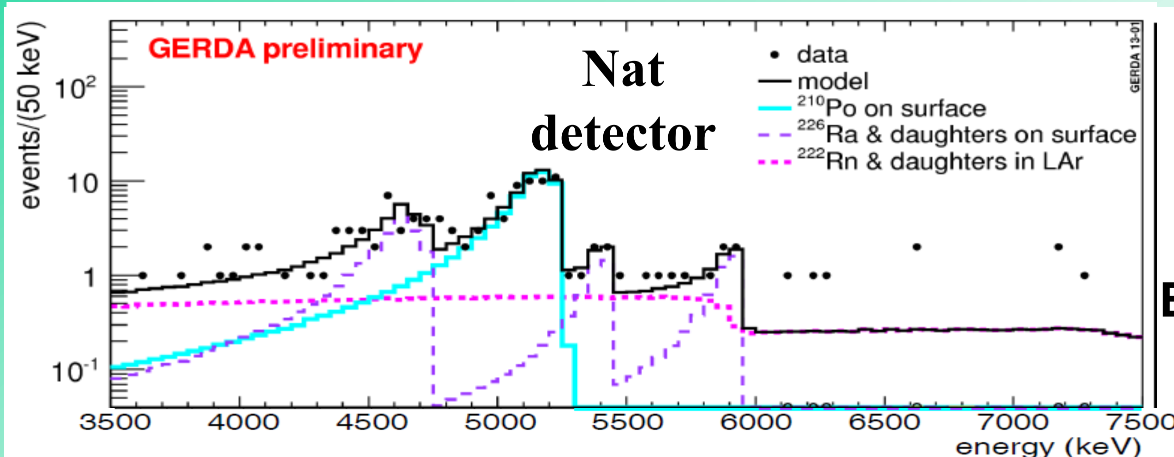


→^{210}Po contamination of p+ surface ($T_{1/2}$ = 138 days)

→^{226}Ra contamination on and close to p+ surface

Phase I background decomposition:

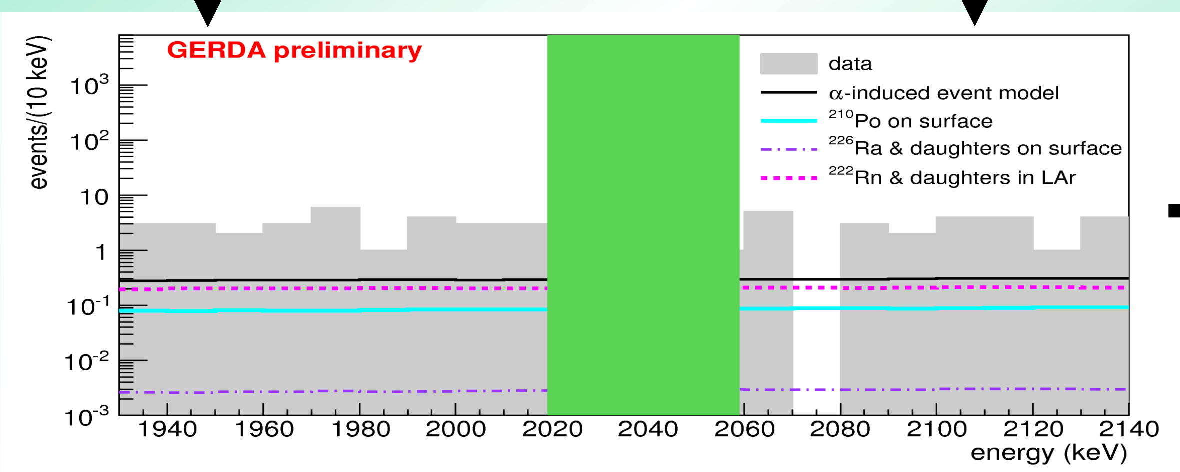
Background decomposition:



α-peaks are crucial for understanding background in RoI (contributions from ^{226}Ra decay chain)

Binned maximum likelihood fit
Fit window: 3500 – 7500 keV
p-value: 0.7

Extrapolation to RoI

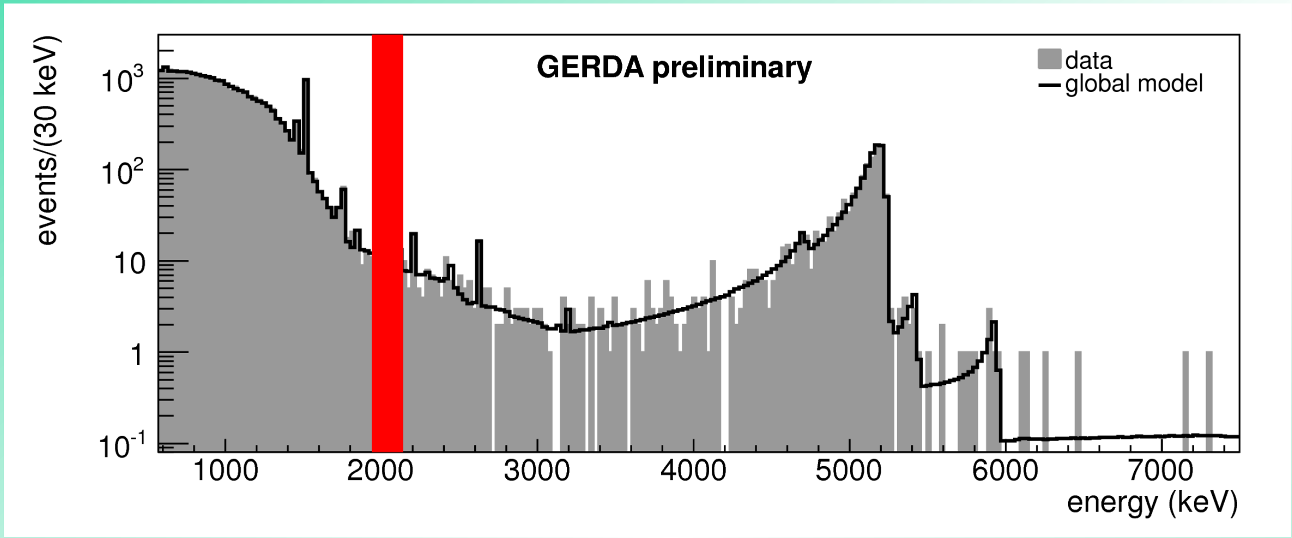


data: 49 events in RoI

α-model: $4.55^{+1.25}_{-0.95}$ events

~ 9% contribution from α - tails

Phase I background decomposition:



Binned maximum posterior fit to the sum enrGe coax spectrum in (570 – 7500) keV window

Background components considered:
^{42}K, ^{40}K, ^{214}Bi (from ^{222}Rn & ^{226}Ra chains), ^{228}Ac & ^{228}Th (β- / γ-induced events)

and α-induced event model

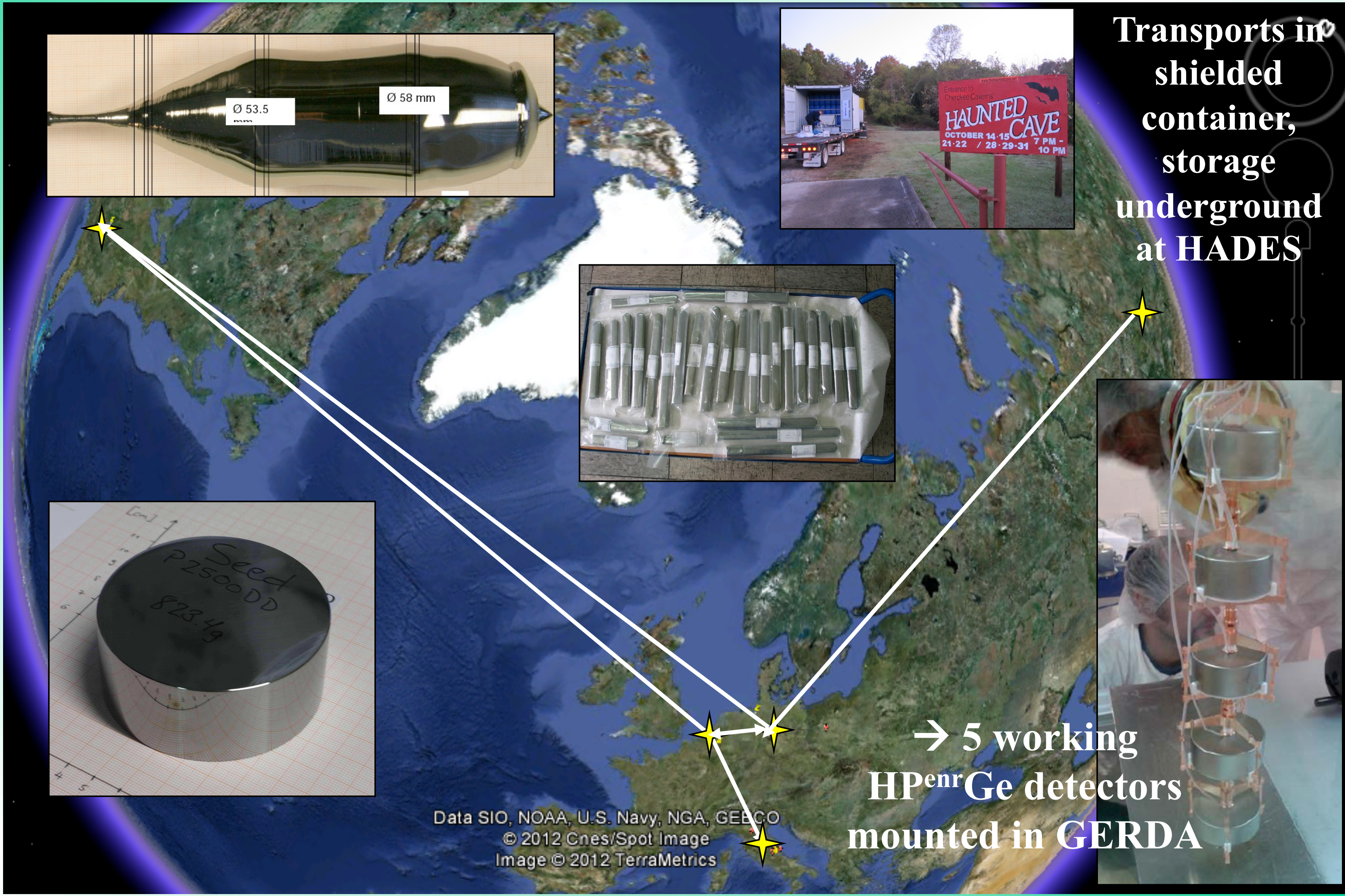
p-value of the fit: 0.3

Prediction for BI consistent with interpolation of Bkg

→0νββ analysis independent from background model!

Phase II detectors

The voyage of the enriched germanium



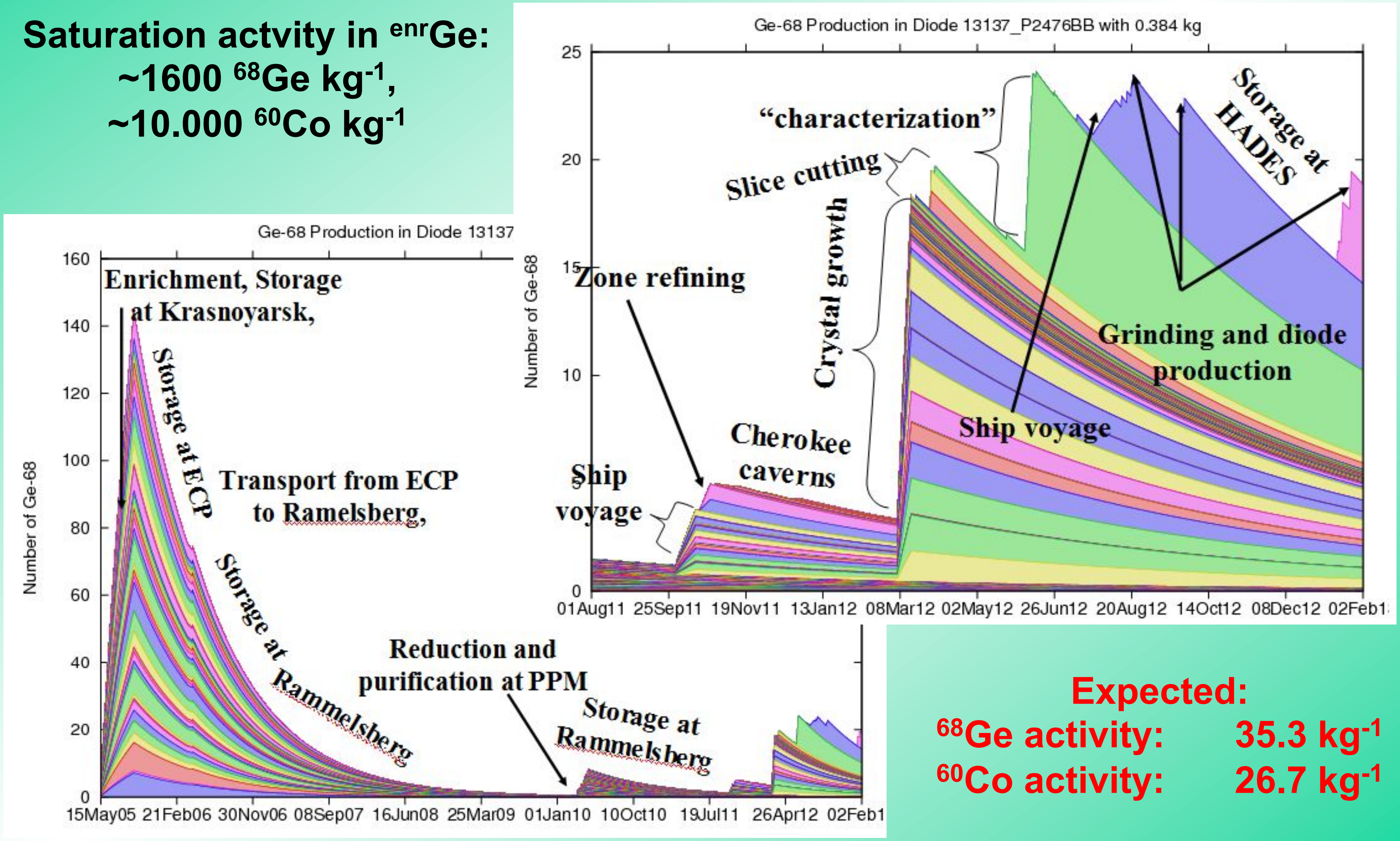
Transports in shielded container, storage underground at HADES

→ 5 working $HP^{enr}Ge$ detectors mounted in GERDA

Phase II detectors

Monitoring of exposure to cosmic rays: Production history

Saturation actvity in ^{enr}Ge:
~1600 ^{68}Ge kg^{-1},
~10.000 ^{60}Co kg^{-1}

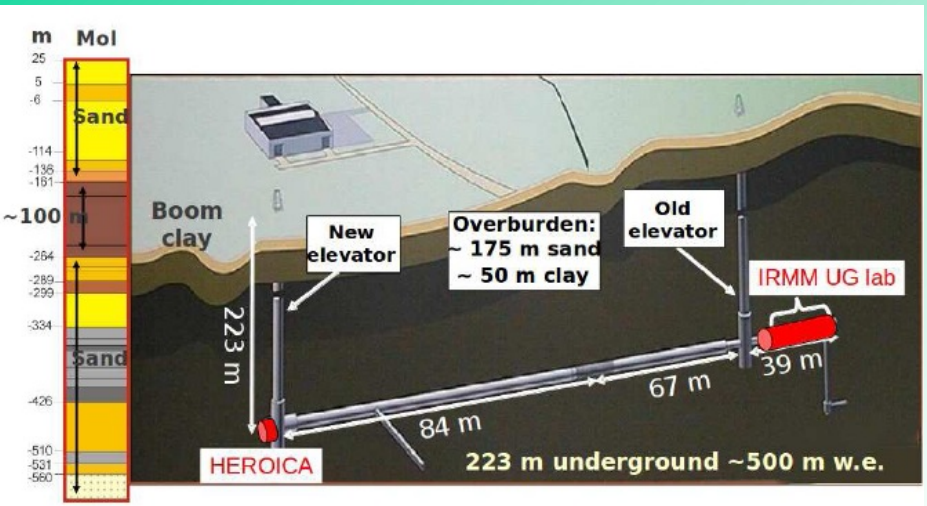


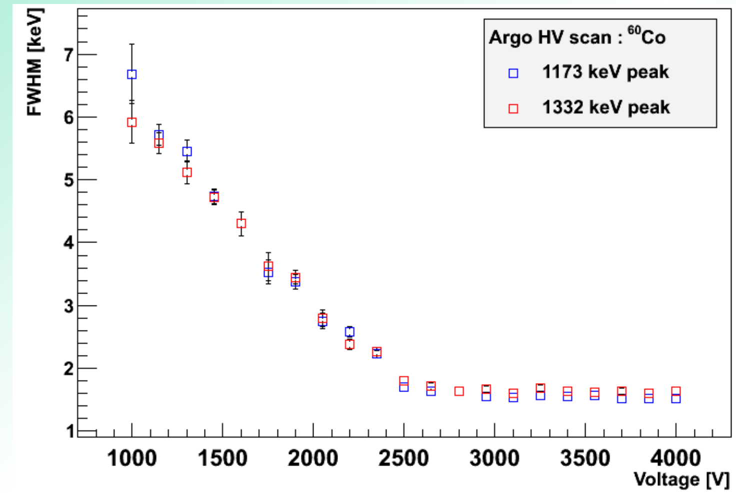
Expected:

^{68}Ge activity: 35.3 kg^{-1}

^{60}Co activity: 26.7 kg^{-1}

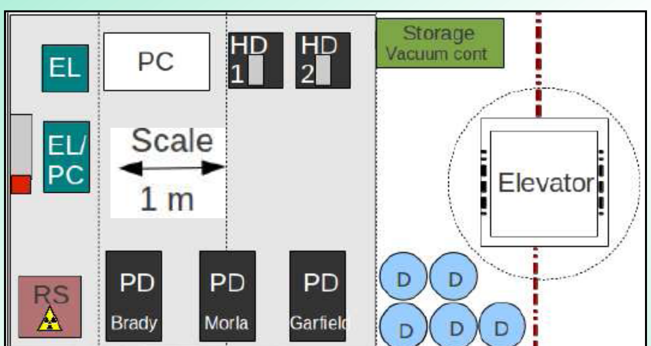
Phase II detectors



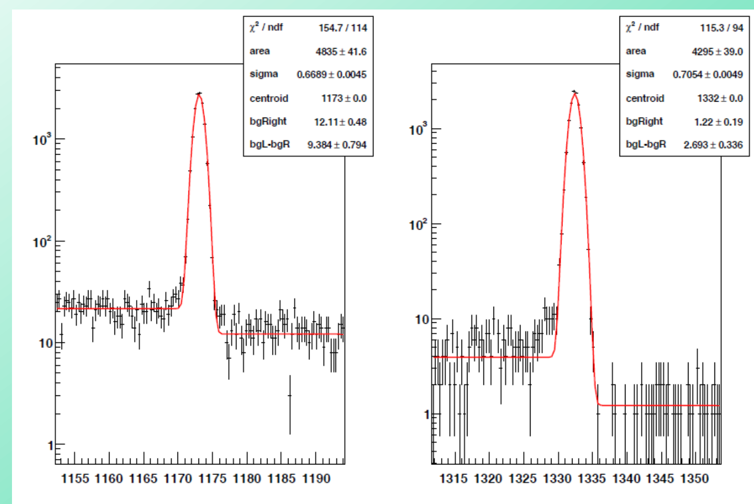


HEROICA team:
Measured main operational paramters, active volumes, dead layers and pulse shape parameters for all 30 BEGe detectors

All 30 detectors according to specifications: Bias voltage < 5000kV, E-resolution @ 1.3MeV (FWHM) < 1.9 keV (0.14%)

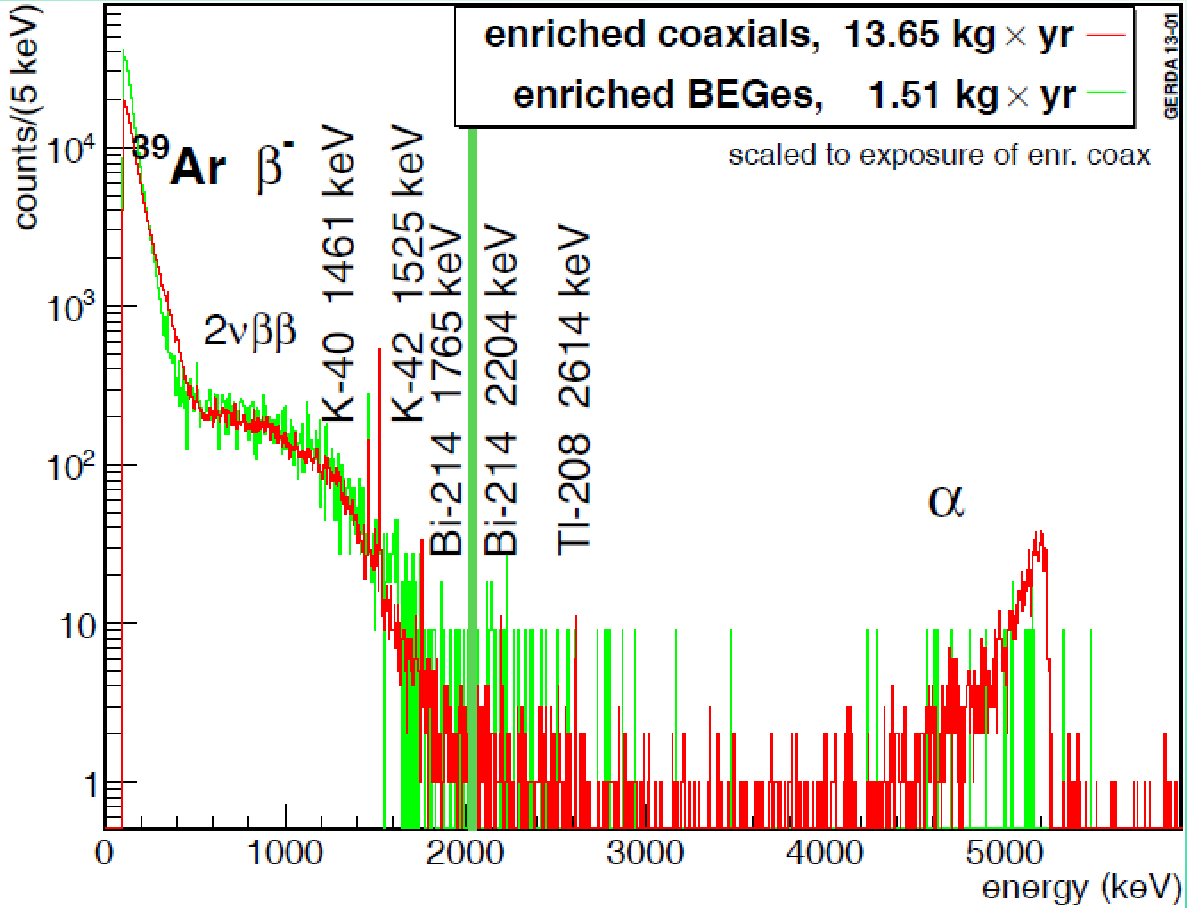


PD: Automatic scanning table (PaDova)
HD: Static tables (HeiDelberg)
S: Security gate
D: Queue of cryostats with diodes to be screened
RS: Save with radioactive sources
EL: Electronics for DAQ



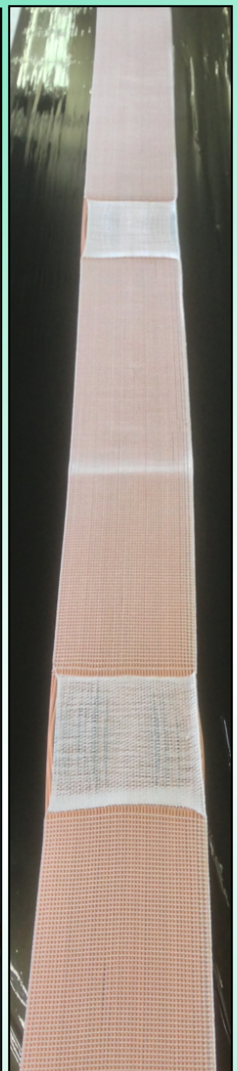
Phase II detectors

Background of enriched coax and BEGe detectors:



BEGe BI: (0.046±0.010) cts/(keV kg yr)
Without pulse shape analysis and LAr veto used

Phase II hardware preparations



Mounting of new GERDA phase II infrastructure ongoing

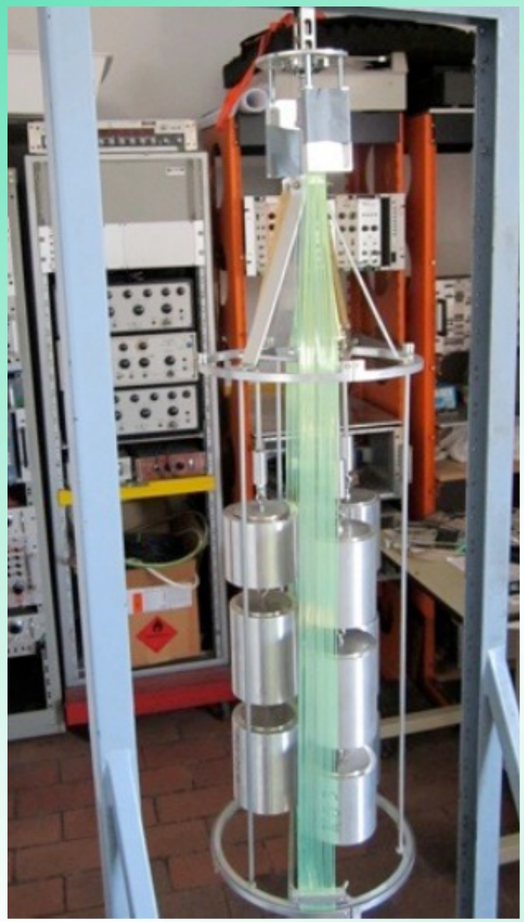
Cable bands for new lock being produced, partly ready

Upgrade of GERDA infrastructure planned for summer 2013

Phase II hardware preparations

Background rejection by detection of LAr scintillation light

“hybrid solution” (supported by MC with light tracking):



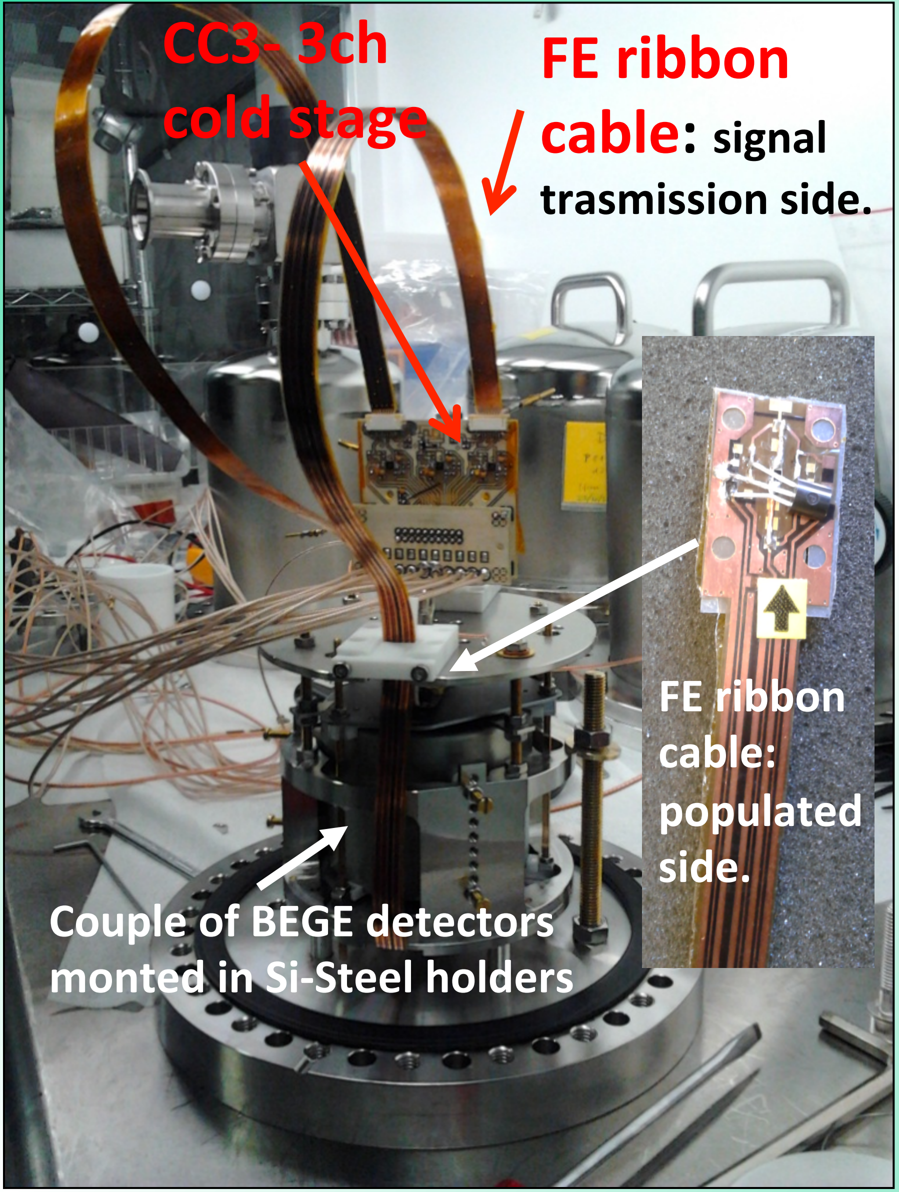
SiPMs connected to fibres

Low background PMTs

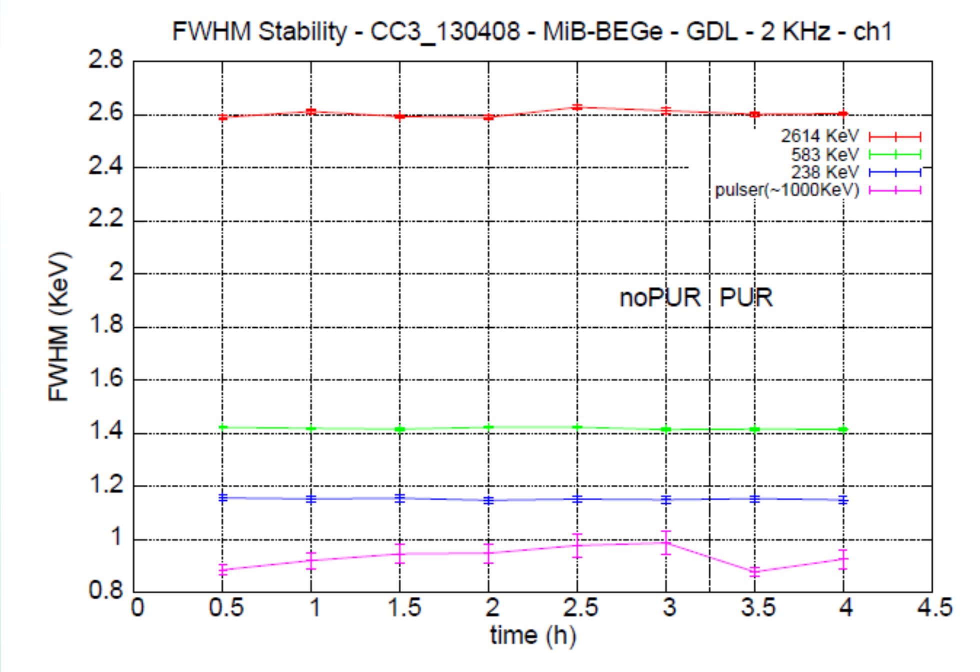
simulations show: reduction of background to 0.001 cts/(keV kg yr) seems realistic

Phase II hardware preparations

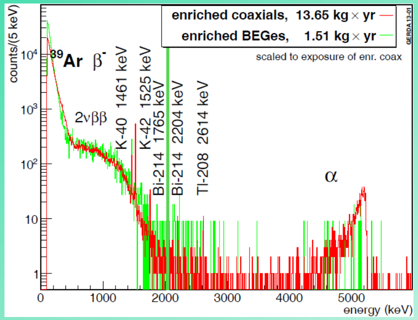
Integration test with two BEGes and new very front end electronics:

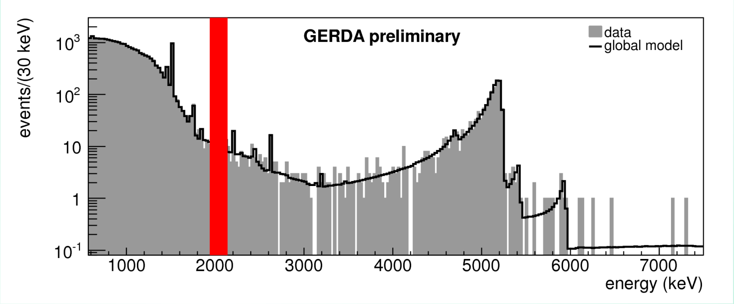


Spectra taken in LAr:
Long term stability seems ok
Energy res. good: ~2.6 keV @ 2.6 MeV
PSA: 1.1% A/E (FWHM)

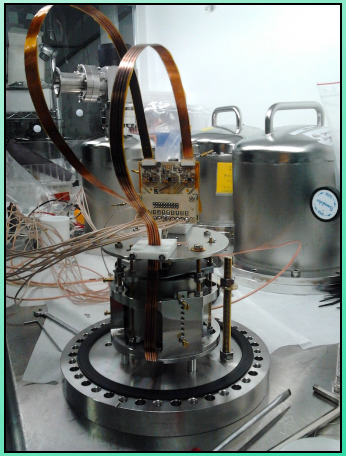


CONCLUSIONS:



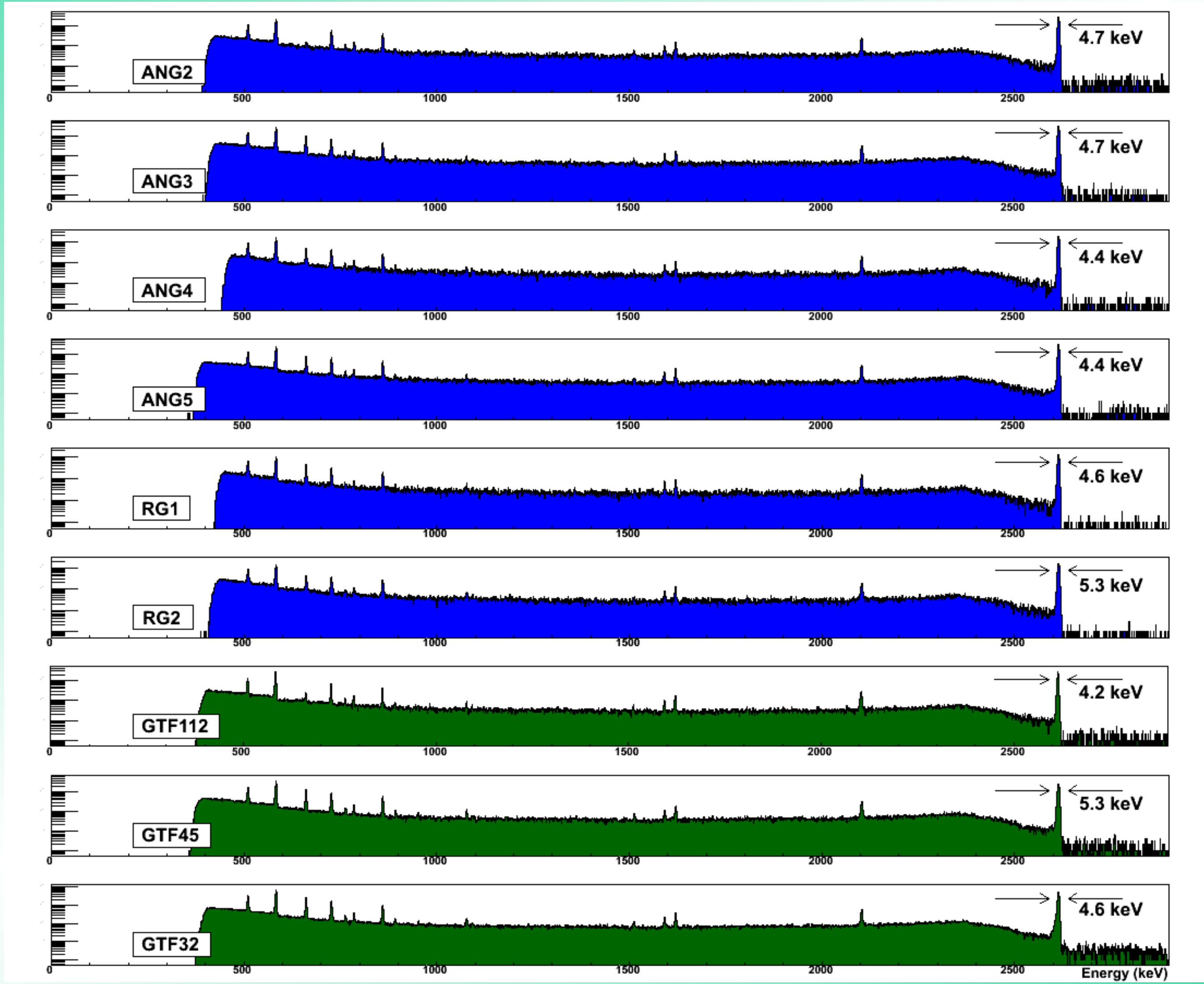


- Phase I design exposure 20 kg yr reached beginning of April
- Background index of golden data set close to design goal
- Prediction for BI in blinded window is „stable“
- Unblinding of RoI in June
- All 30 BEGe detectors available and characterized
- Five BEGes taking data since July 2012
- Hardware for GERDA phase II in preparation
- Transition to Phase II will start in July



GERDA : Status of phase I

Energy calibration of all detectors:



ANG1 and RG3 are NOT included

GERDA : Status of phase I

Comparison of backgrounds lines in HdMo and GERDA experiments

isotope	energy [keV]	^{nat}Ge (3.17 kg yr)		^{enr}Ge (6.10 kg yr)		HDM (71.7 kg yr)
		tot/bck [cts]	rate [cts/(kg yr)]	tot/bck [cts]	rate [cts/(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

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