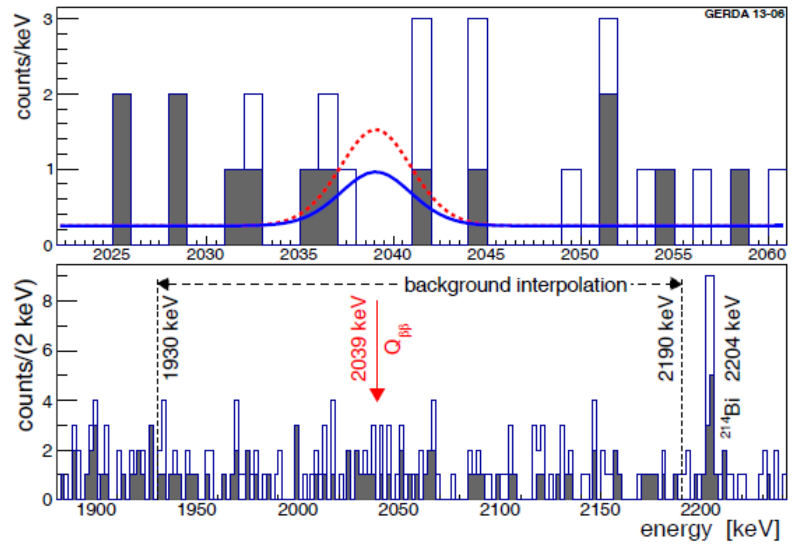
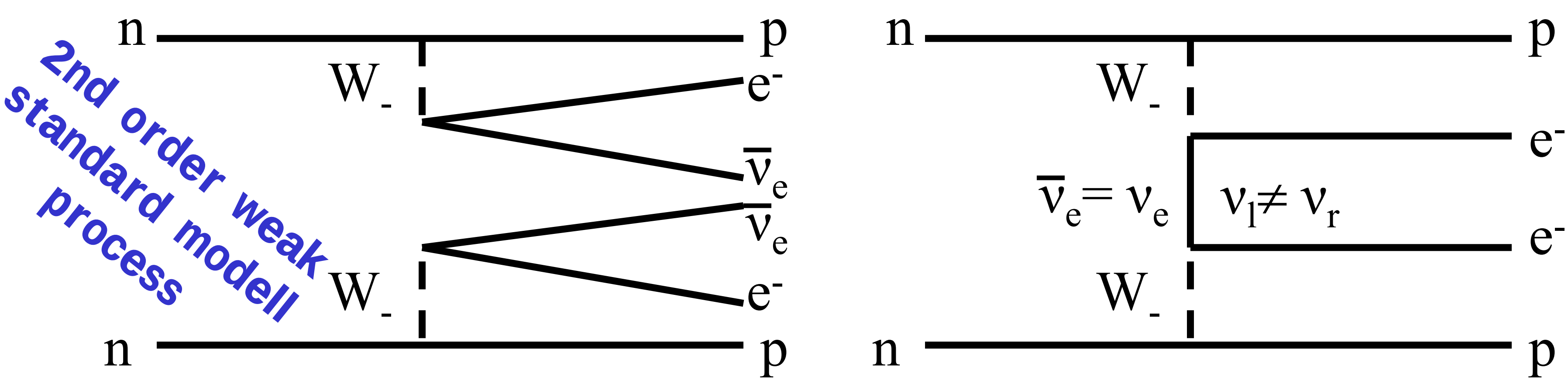
Results and perspectives of the GERDA experiment



- Why and how to search for 0νββ-decay
- The GERDA experiment
- GERDA Phase I results & background model
- GERDA Phase II status & projection

Why and how to search for 0νββ decay

2νββ-decay: **0νββ-decay:**



Neutrinoless mode of double beta-decay only possible if:

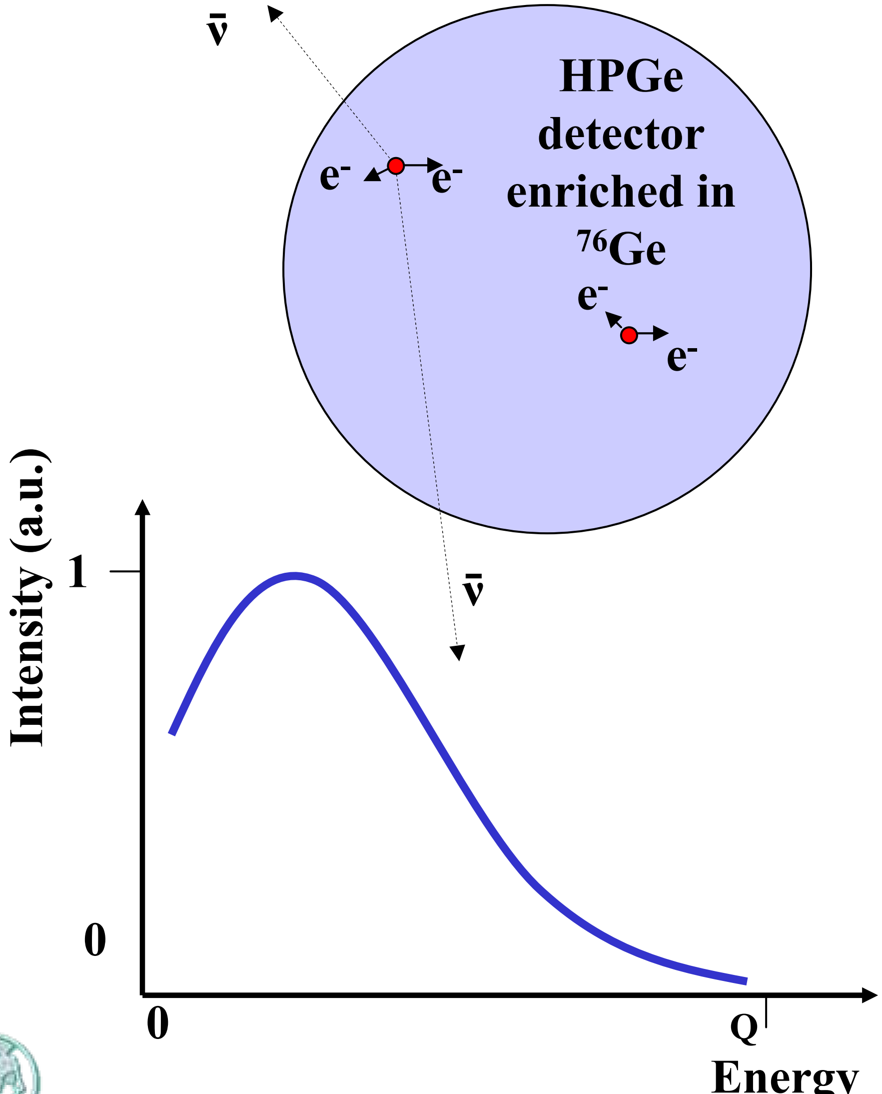
- **Neutrino has Majorana character**
- **Helicity flip can occur in the vertex**

Contribution to 0νββ-decay rate by effective Majorana neutrino mass:

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

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

Why and how to search for 0νββ decay



Observation of 0νββ decay would prove:

- Lepton number violation ΔL=2
- Majorana character of neutrino

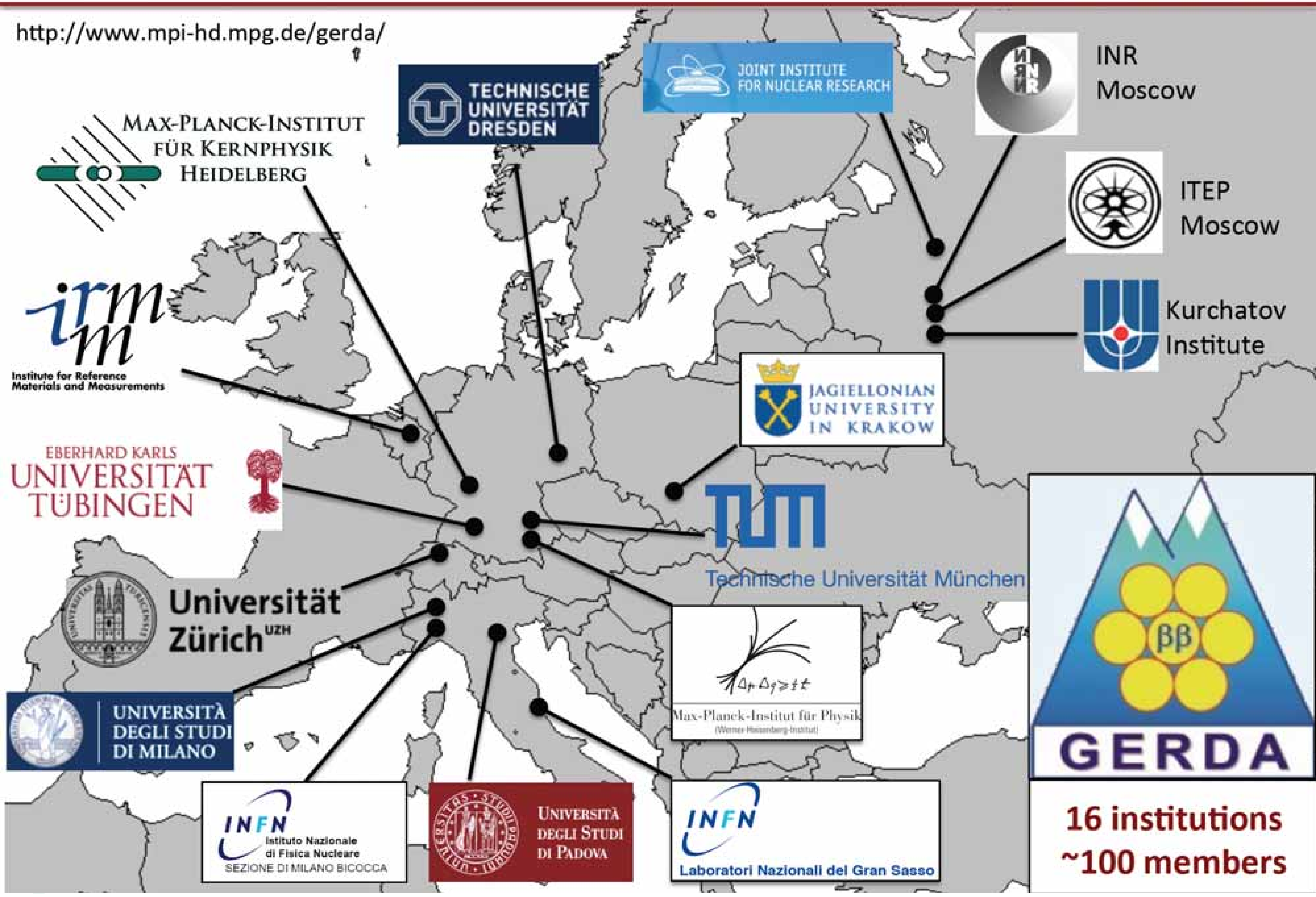
0νββ decay is motivated by:

- Baryogenesis via Leptogenesis
- Majorana Neutrino masses
- See Saw Mechanism: Smallness of neutrino masses
- Any Lepton number violating BSM process

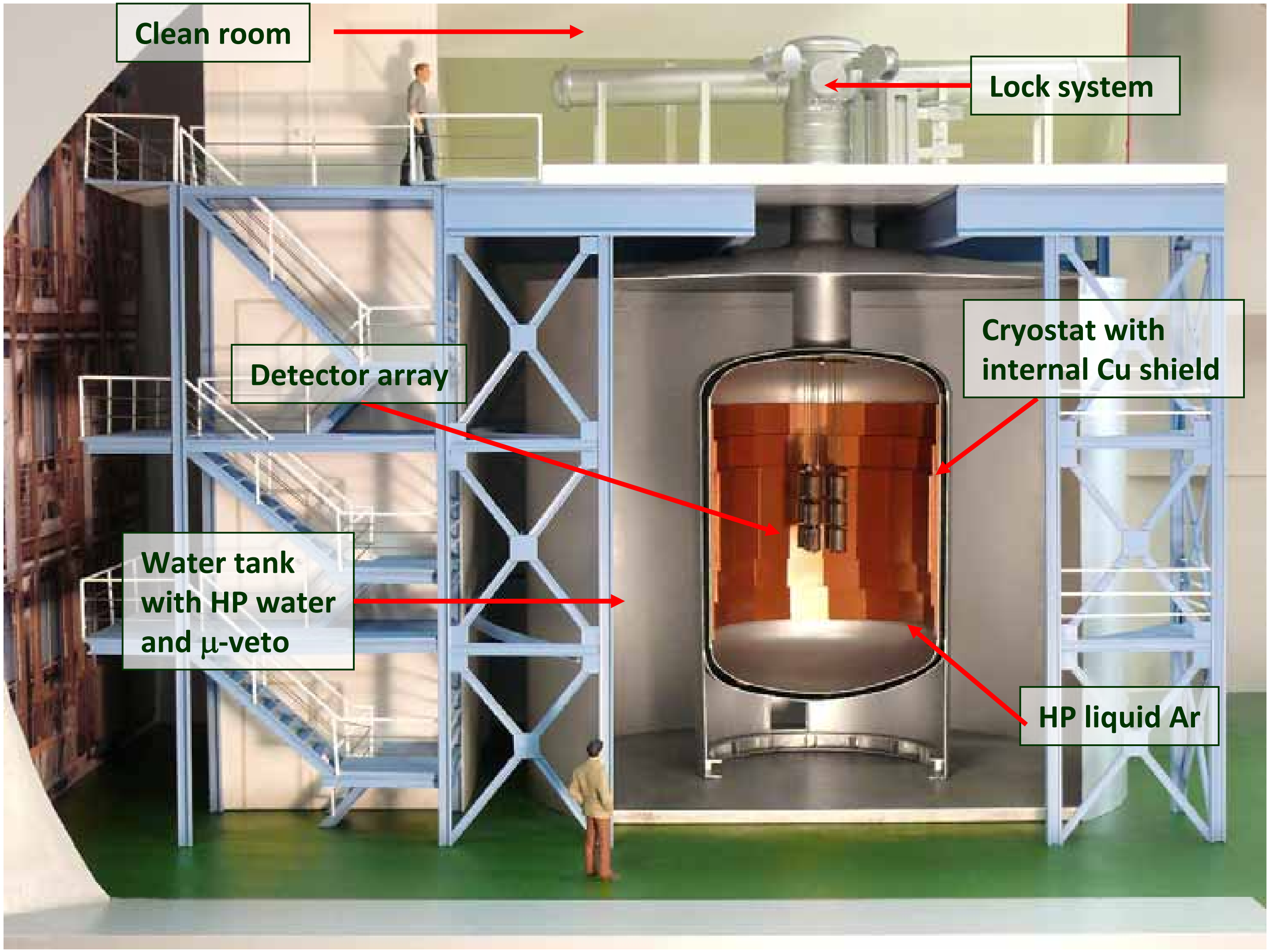
No (observable) 0νββ decay is expected if:

- ν is a pure Dirac particle
- CP violating Majorana phases add up destructively
- $\langle m_{ee} \rangle < 1$ meV $[T_{1/2} > 10^{31}$ yr$]$

The GERDA Collaboration



The GERDA experiment



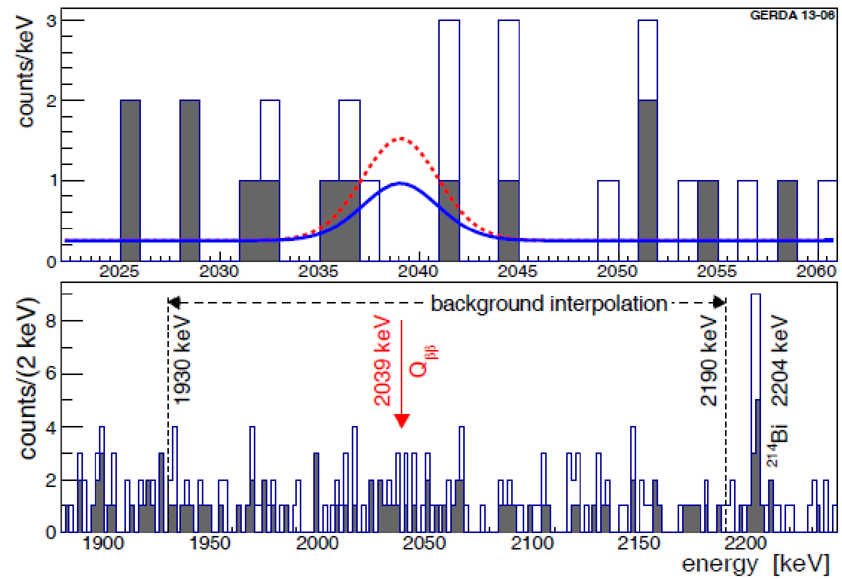
Idea: use bare HPGe detectors in ultra pure cryogenic liquid:

[G. Heusser, Annu. Rev. Nucl. Part. Sci. 45(1995) 543]

GERDA Phase I results

Phase I data taking:
Nov. 2011 to May 2013

14.6 kg coaxial detectors
3.0 kg BEGe detectors
→ 21.6 kg yr exposure

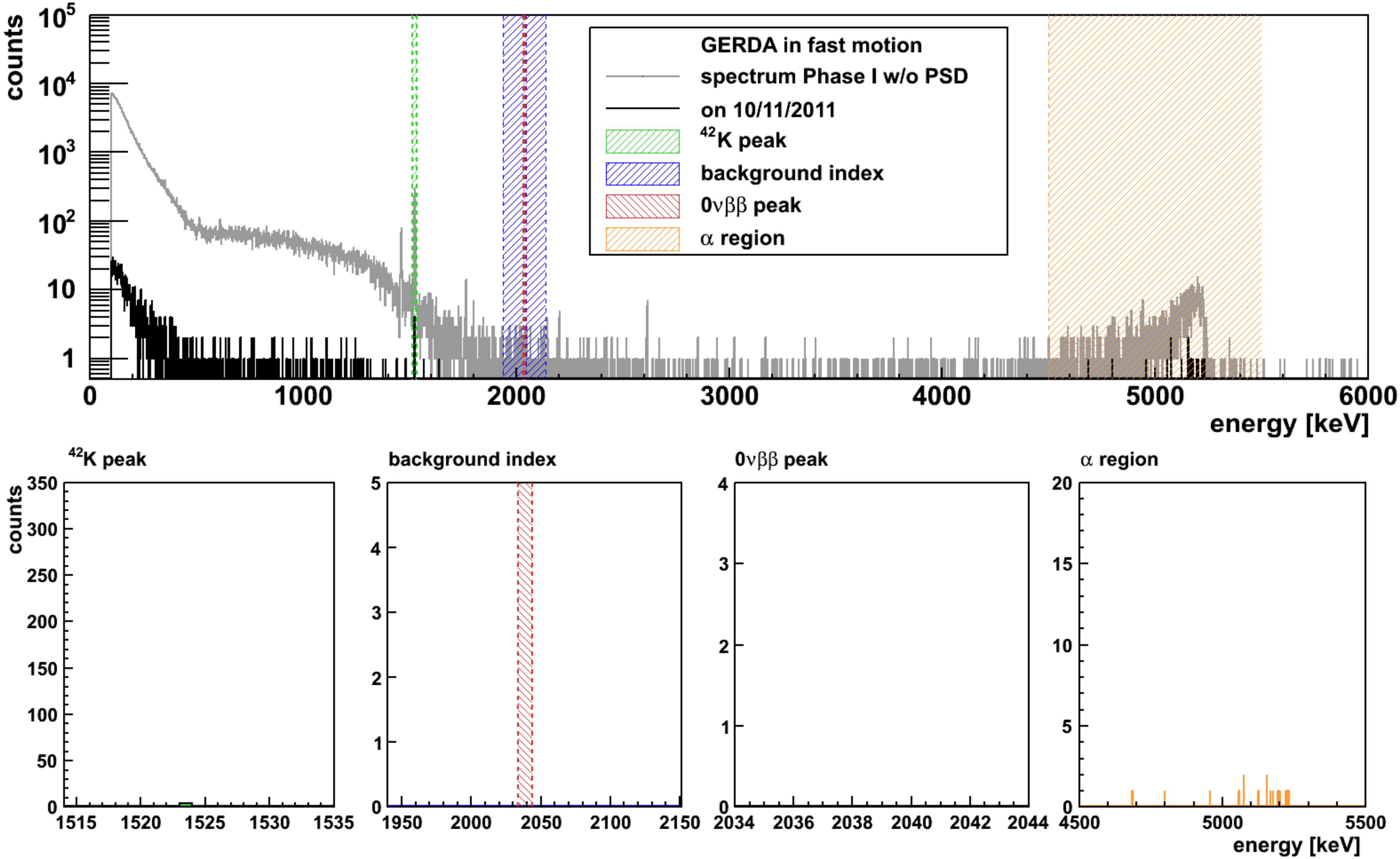


PRL 111 (2013) 122503
[arXiv:1307.4720]

→ $T_{1/2}(0\nu\beta\beta) > 2.1\ 10^{25}$ yr (90% C.L.) frequ. analysis

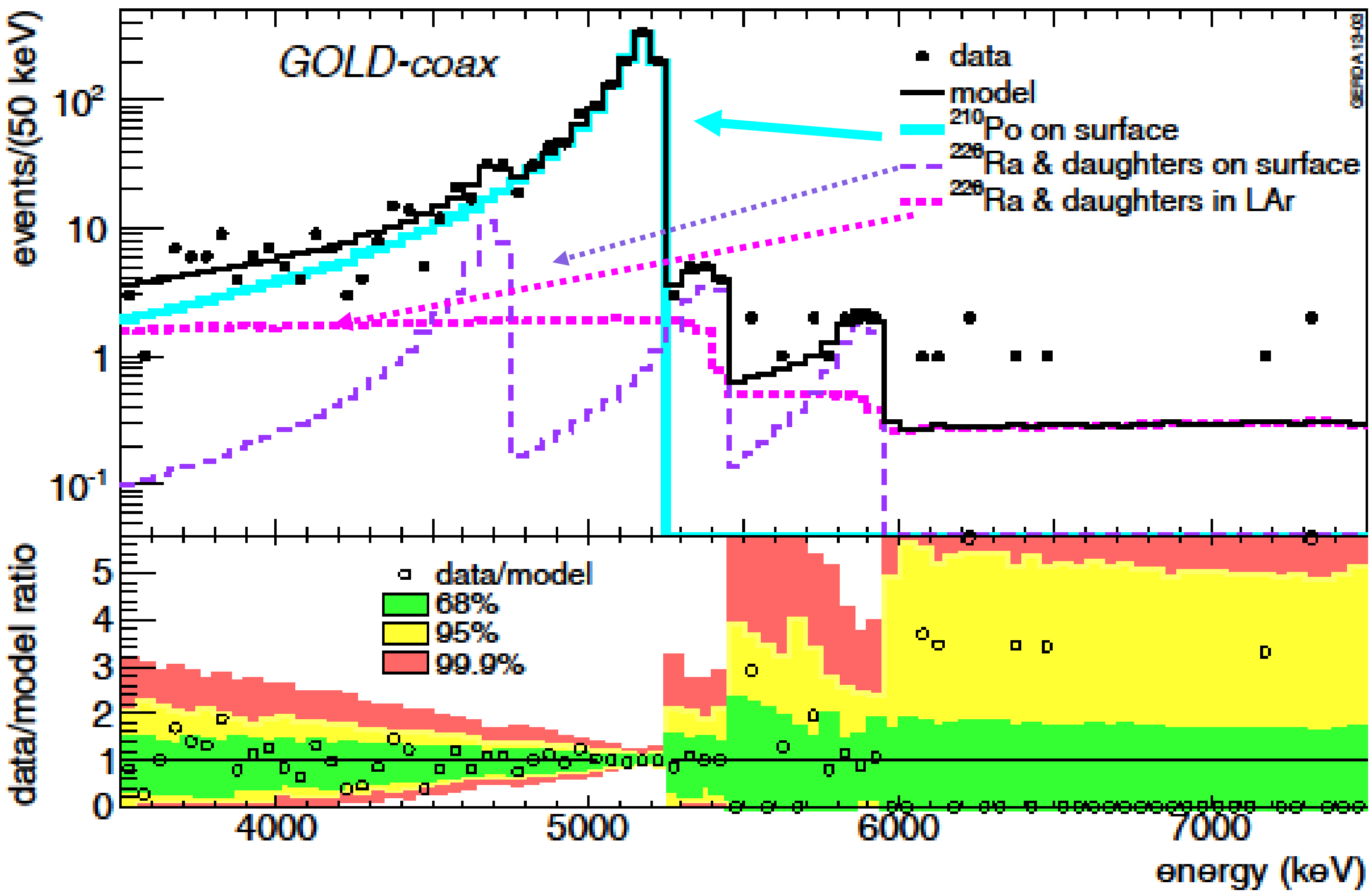
median sensitivity: $T_{1/2}(0\nu\beta\beta) > 2.4\ 10^{25}$ yr

GERDA Phase I results



GERDA Phase I background model

background decomposition of the high energy spectrum

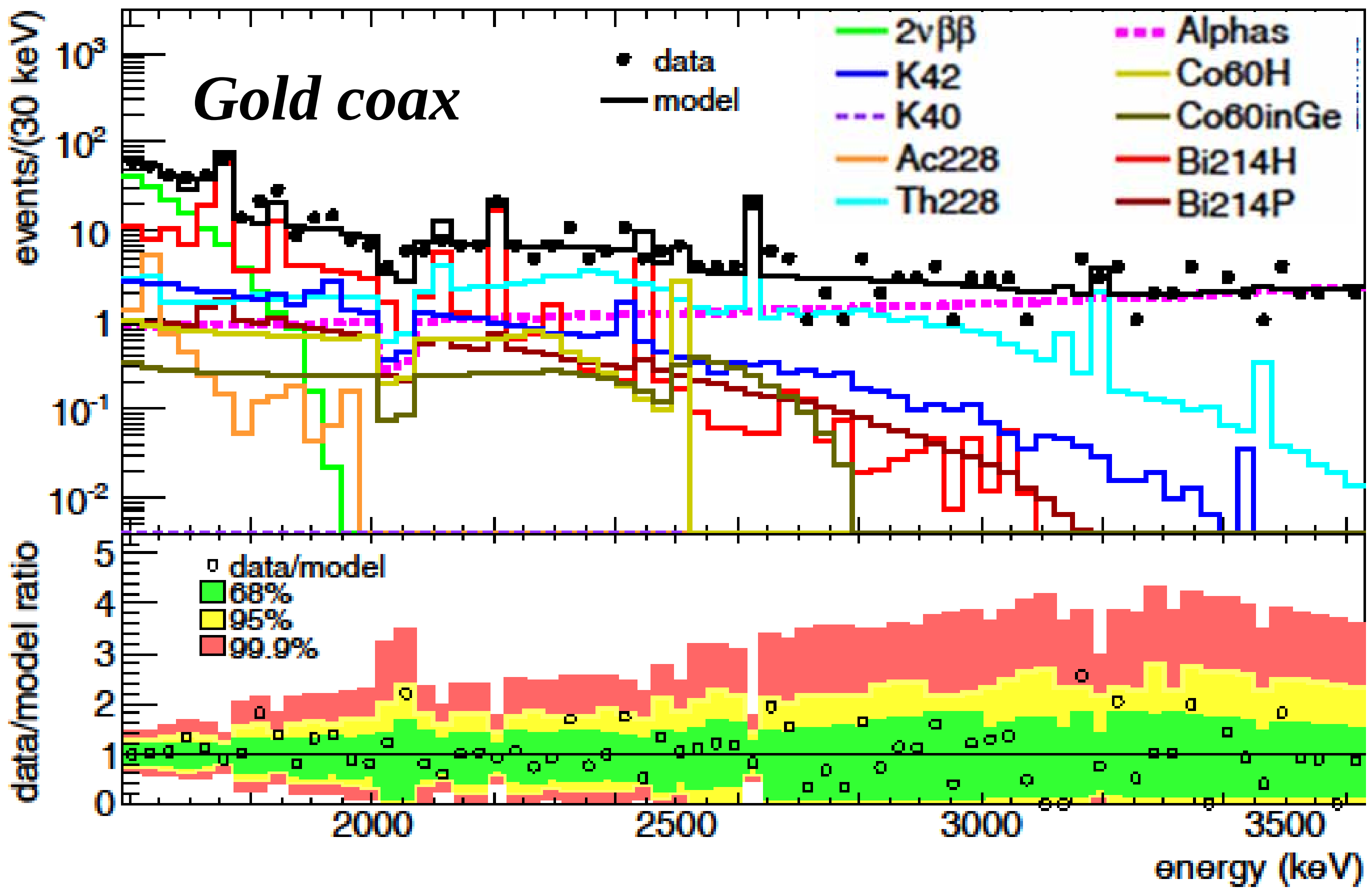


→ contribution from ^{226}Ra in LAr main α-component in RoI

preliminary analysis: 0 events with complete sub chain detected

→internal A(^{226}Ra, ^{228}Th, ^{227}Ac) ≲ 4nBq/kg

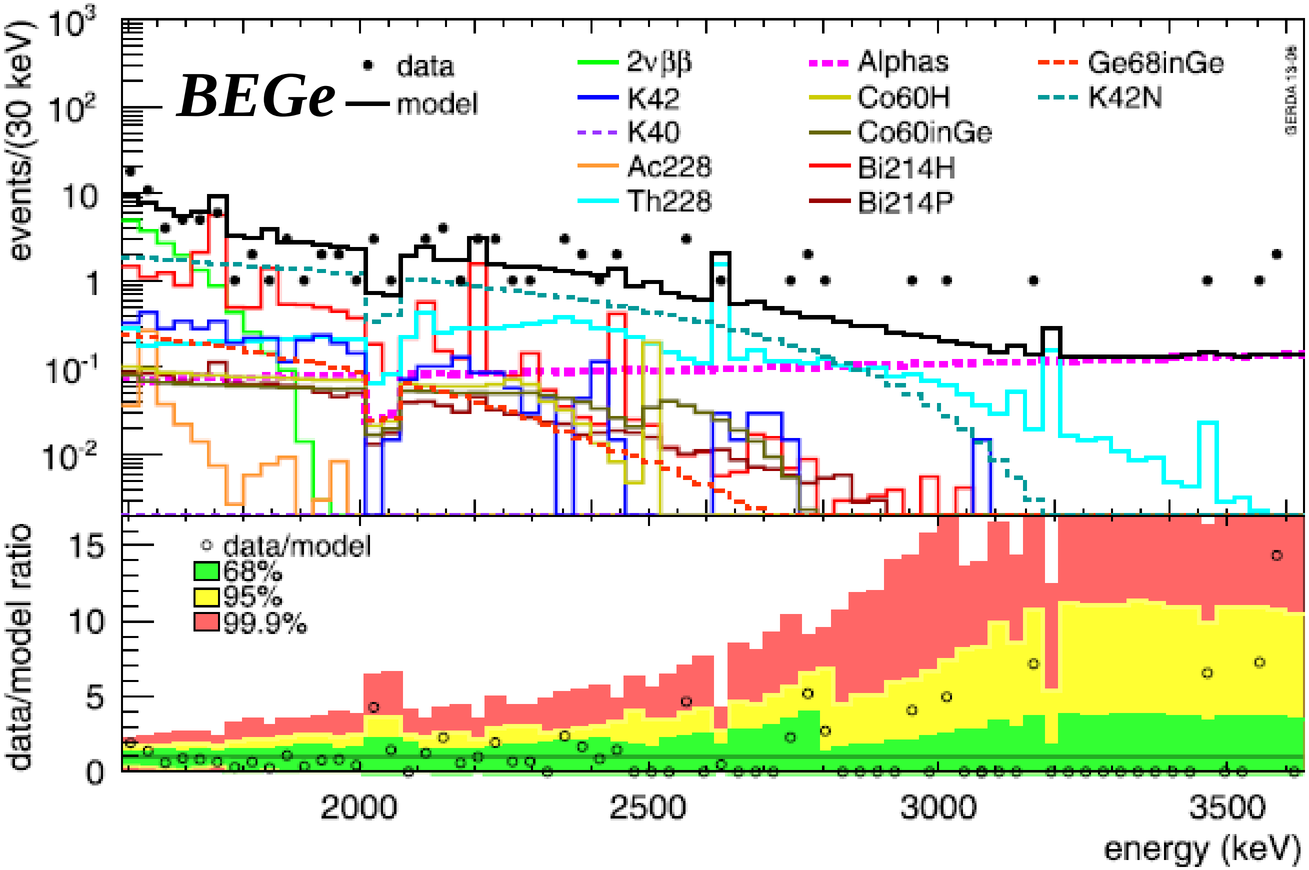
GERDA Phase I background model



minimum model:
close components only describe background well!
^{42}K, ^{60}Co, ^{214}Bi, ^{228}Th, alphas

Eur. Phys. J. C (2014) 74:2764 arXiv:1306.5084

GERDA Phase I background model



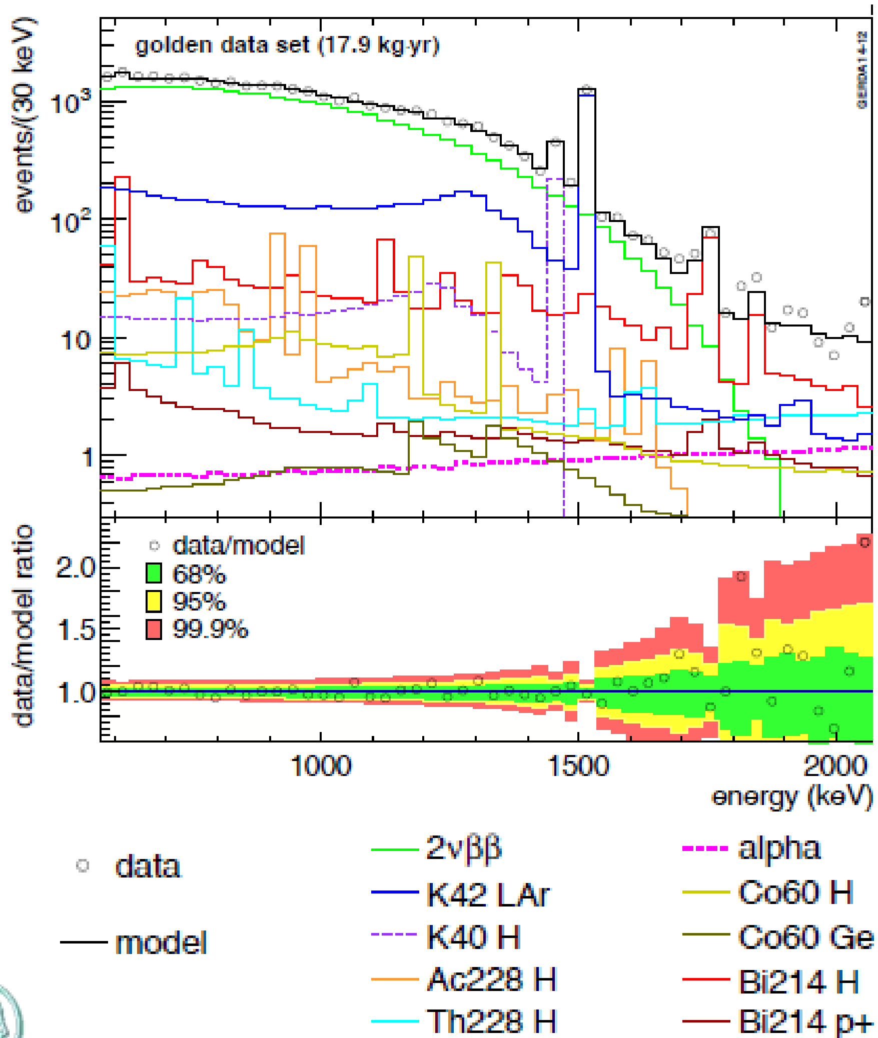
^{42}K dominates BEGe spectrum in RoI

close components only describe background well!
^{42}K, ^{60}Co, ^{214}Bi, ^{228}Th, alphas

Eur. Phys. J. C (2014) 74:2764 arXiv:1306.5084

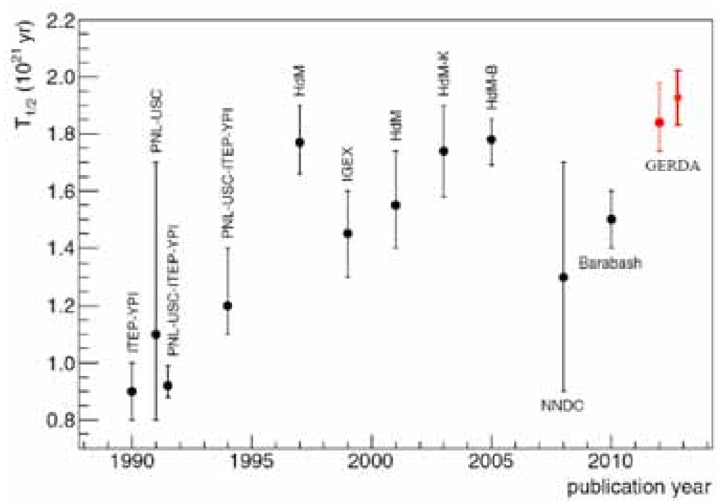
GERDA Phase I background model

2νββ half lifes derived from for different models and data sets



Model	$\mathcal{E}$ [kg yr]	$T^{2\nu}_{1/2} \times 10^{21}$ yr
GOLD-coax minimum	15.40	$1.92^{+0.02}_{-0.04}$
GOLD-coax maximum	15.40	$1.92^{+0.04}_{-0.03}$
GOLD-nat minimum	3.13	$1.74^{+0.48}_{-0.24}$
SUM-BEGe	1.80	$1.96^{+0.13}_{-0.05}$
Analysis in Ref. [20]	5.04	$1.84^{+0.09}_{-0.08}\,_{fit}\,^{+0.11}_{-0.10}\,_{syst}$

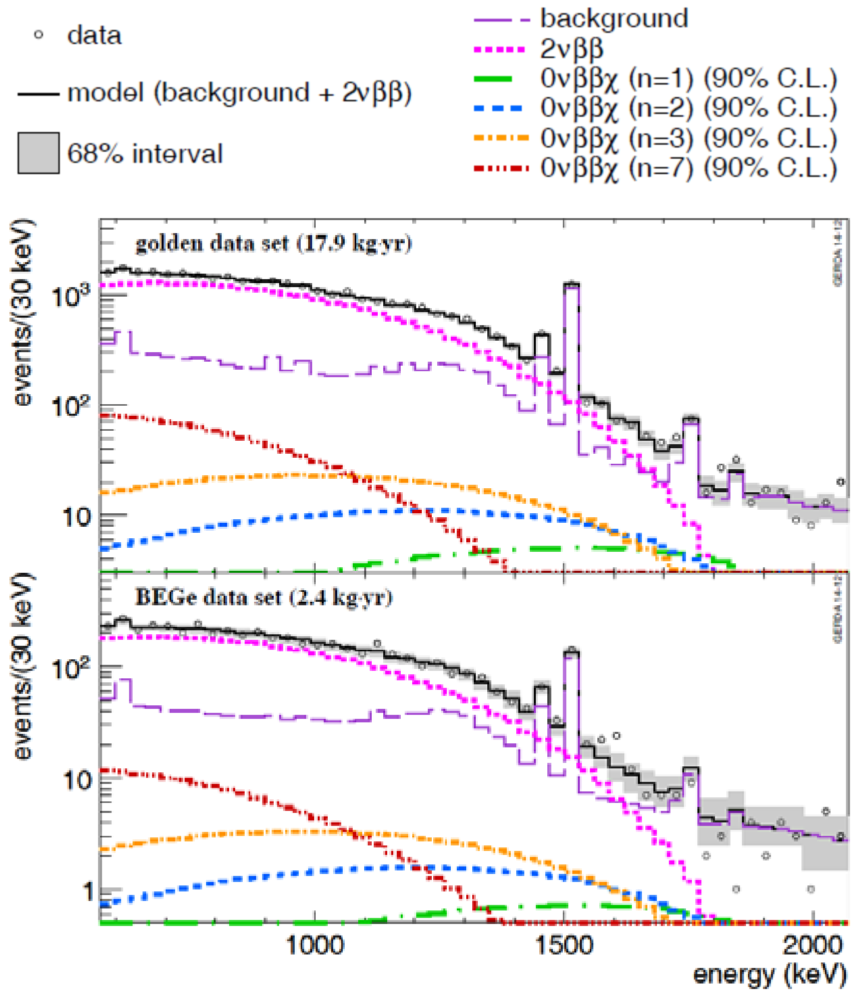
$$T^{2\nu}_{1/2} = (1.926\,^{+0.025}_{-0.022}\,(\text{stat})\ \pm 0.092\,(\text{syst}))\cdot 10^{21}\ \text{yr}$$



arXiv:1501.02345

GERDA Phase I results

2vββ decay of ^{76}Ge with the emission of Majoron(s)



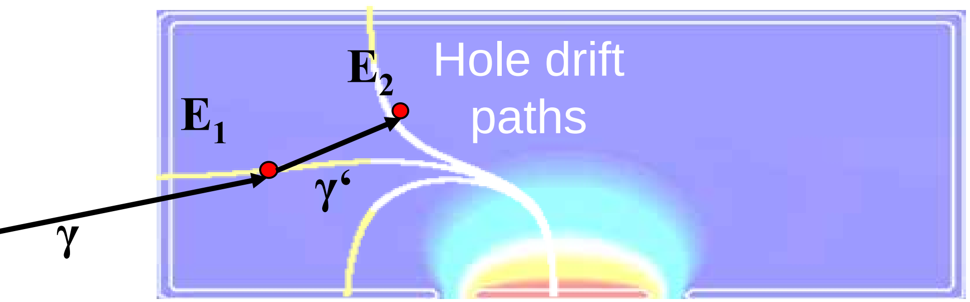
Model	n	Mode	Goldstone boson	L	$T_{1/2}^{0\nu\chi}$ [10^{23}yr]
IB	1	χ	no	0	> 4.2
IC	1	χ	yes	0	> 4.2
ID	3	$\chi\chi$	no	0	> 0.8
IE	3	$\chi\chi$	yes	0	> 0.8
IF	2	χ	bulk field	0	> 1.8
IIB	1	χ	no	-2	> 4.2
IIC	3	χ	yes	-2	> 0.8
IID	3	$\chi\chi$	no	-1	> 0.8
IIE	7	$\chi\chi$	yes	-1	> 0.3
IIF	3	χ	gauge boson	-2	> 0.8

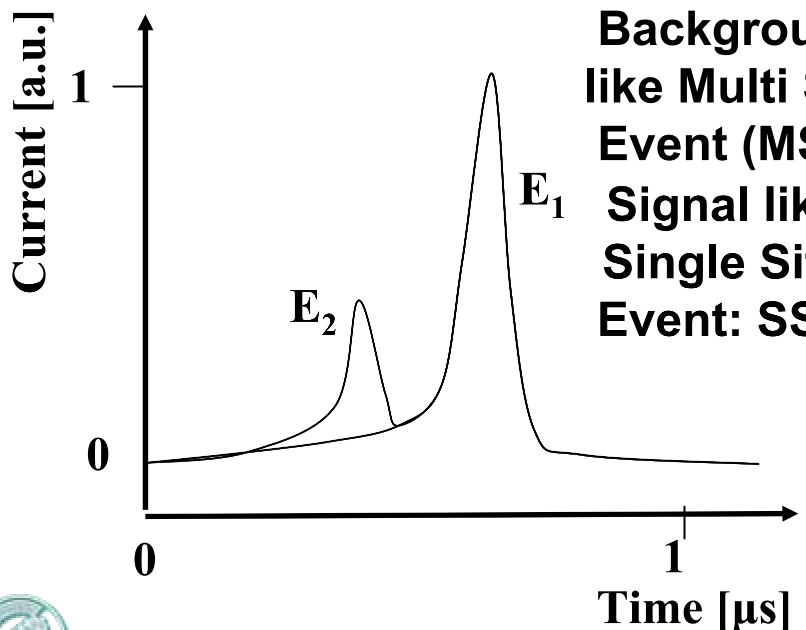
Most stringent limits (^{76}Ge)
***n*=1 & *n*=3 → improved by a factor 6**
for *n*=7 → improved by a factor 5
for *n*=2 → reported for the first time

arXiv:1501.02345

GERDA Phase II:

Additional 20kg BEGe detectors with point like contact:

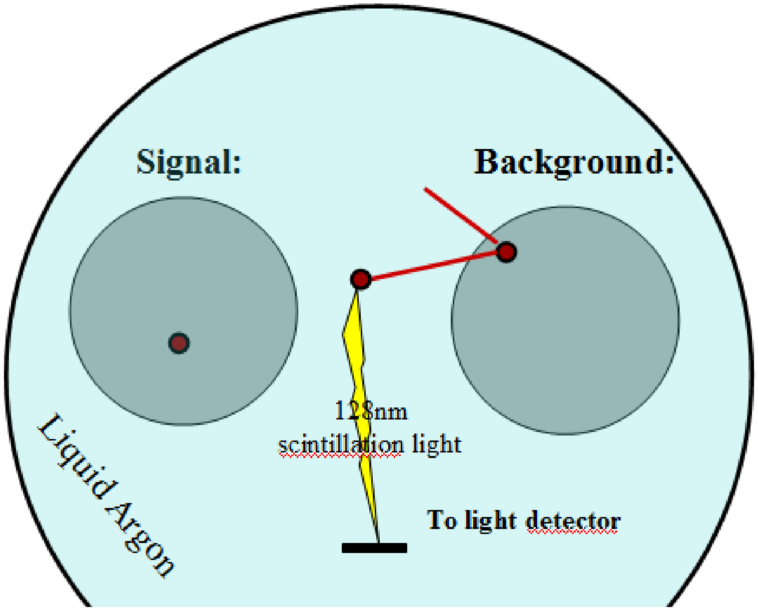




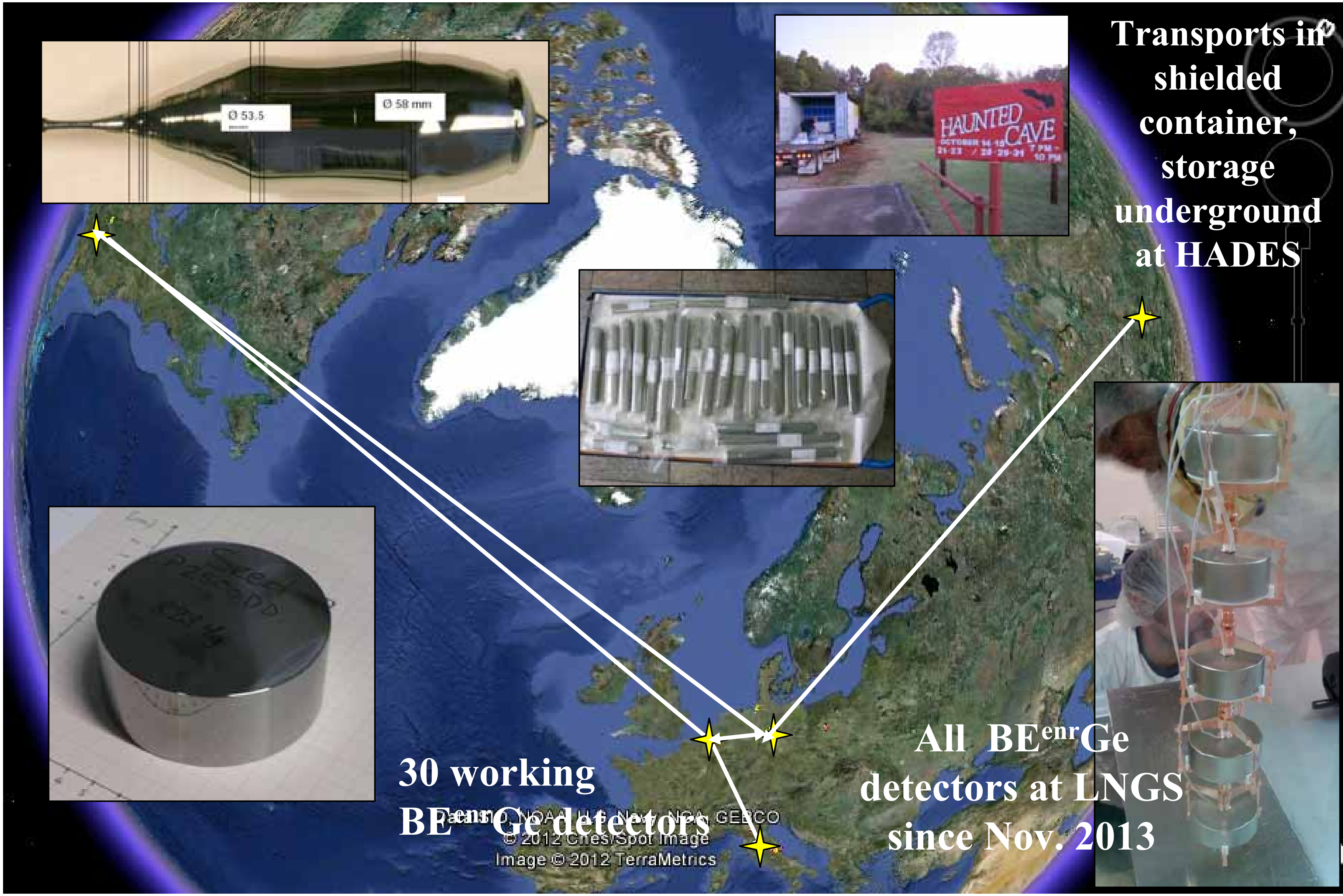
Background like Multi Site Event (MSE)

Signal like Single Site Event: SSE

Use LAr veto:



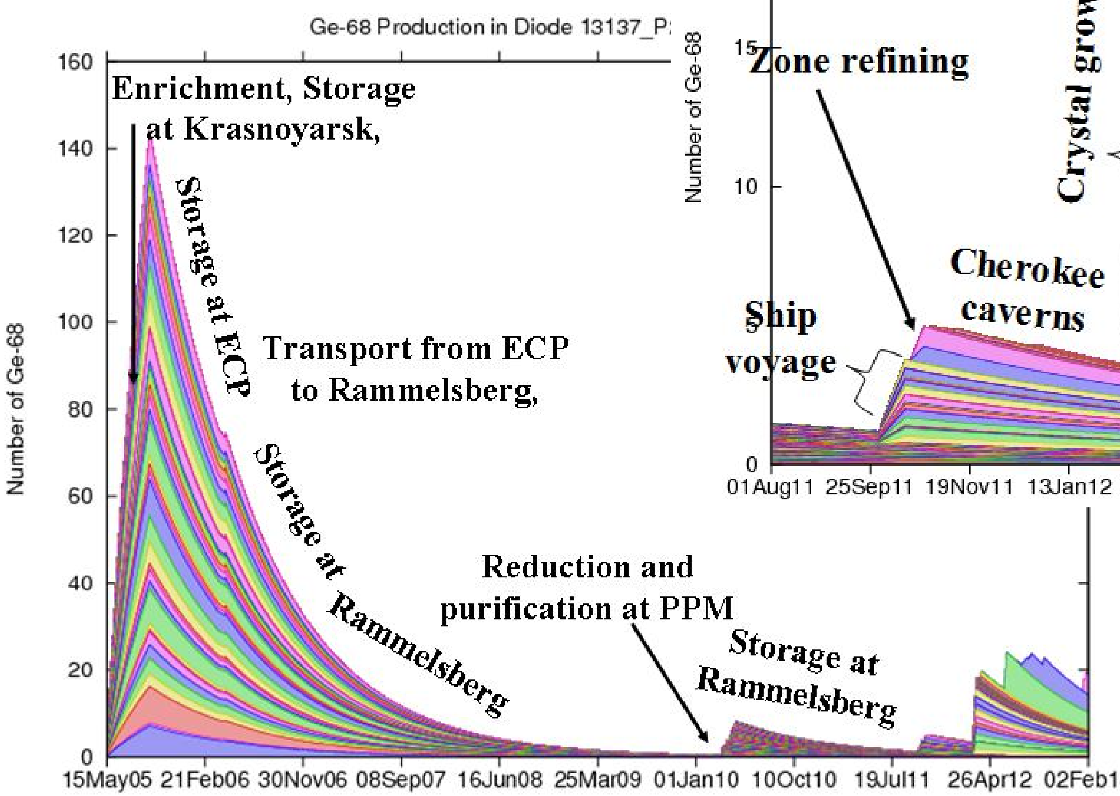
GERDA Phase II status

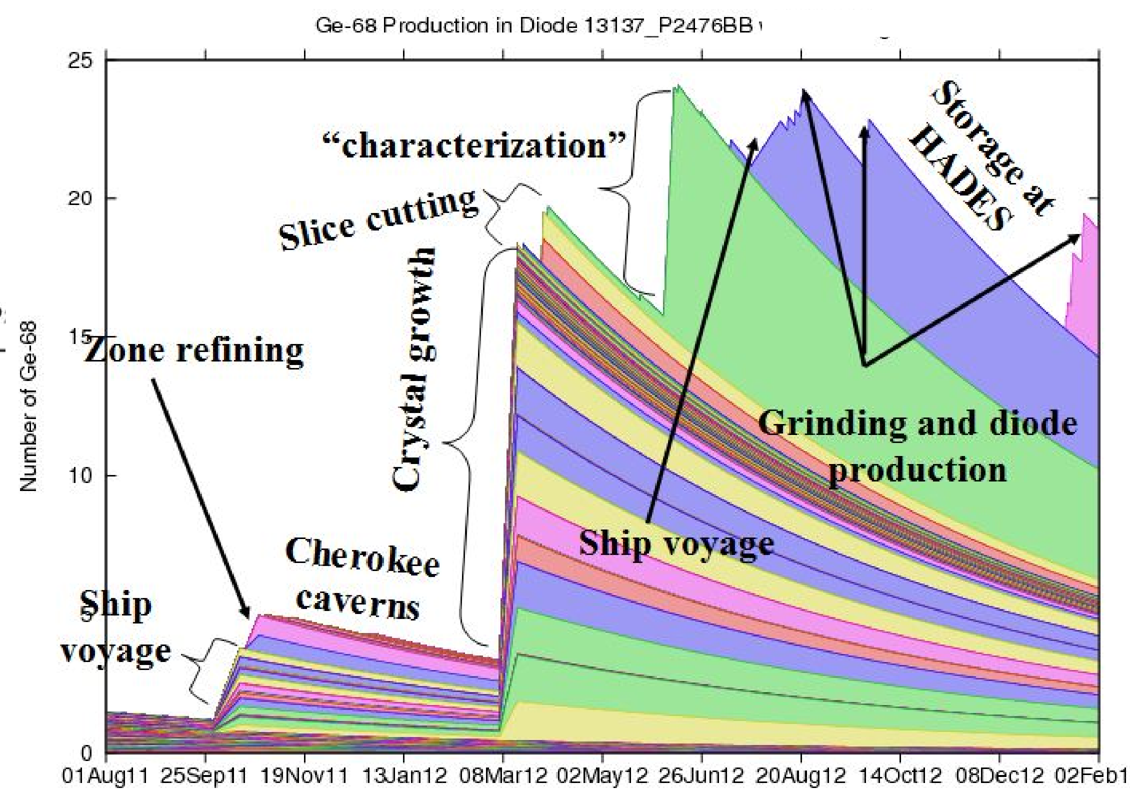


GERDA Phase II status

BEGe production history: shielded whenever possible

saturation concentration in ^{enr}Ge @ sea level: ~1600 ^{68}Ge kg^{-1}, ~10.000 ^{60}Co kg^{-1}



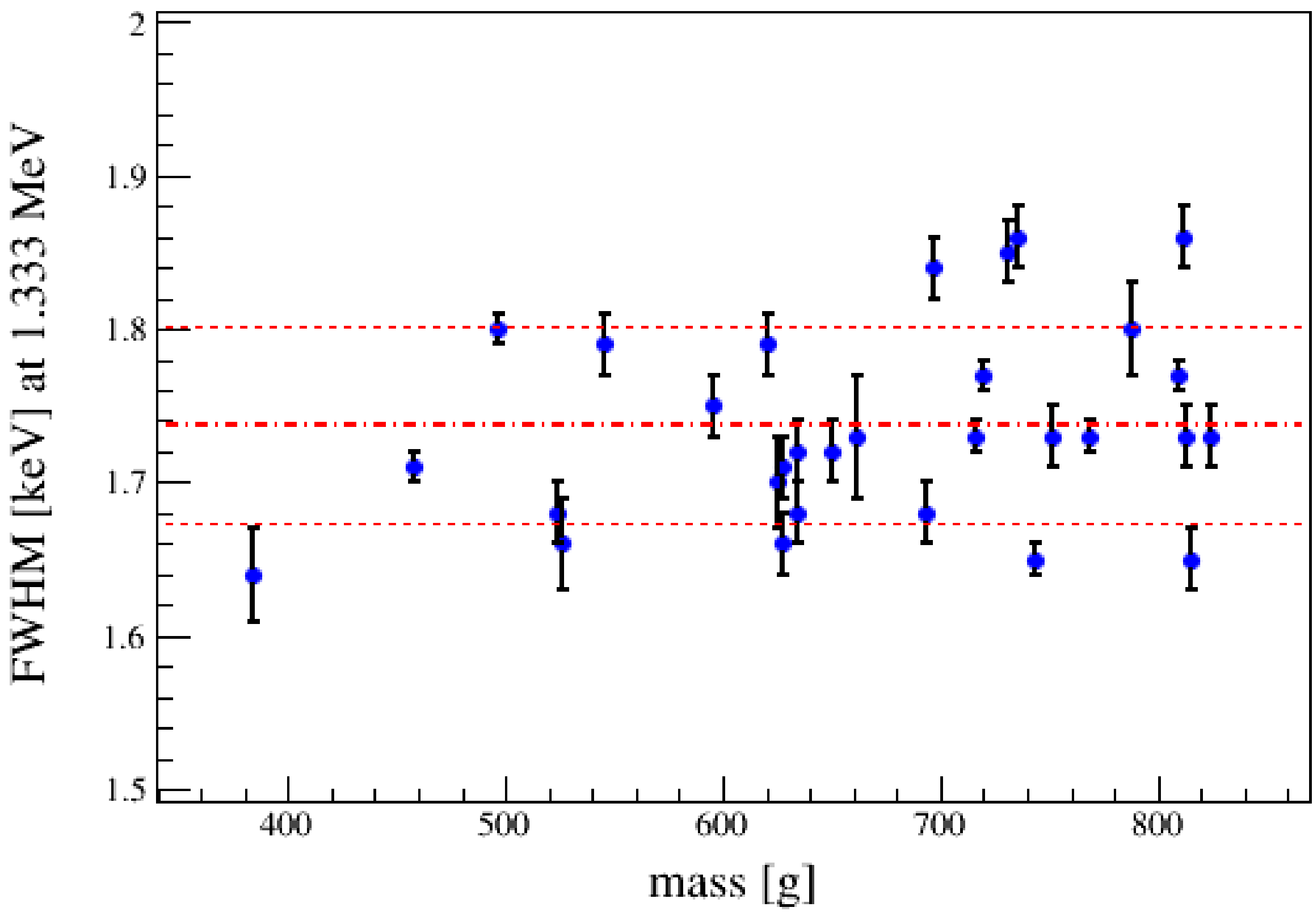


expected (June 2014):
^{68}Ge concentration:13.9 kg^{-1}
^{60}Co concentration:23.7 kg^{-1}

GERDA Phase II status

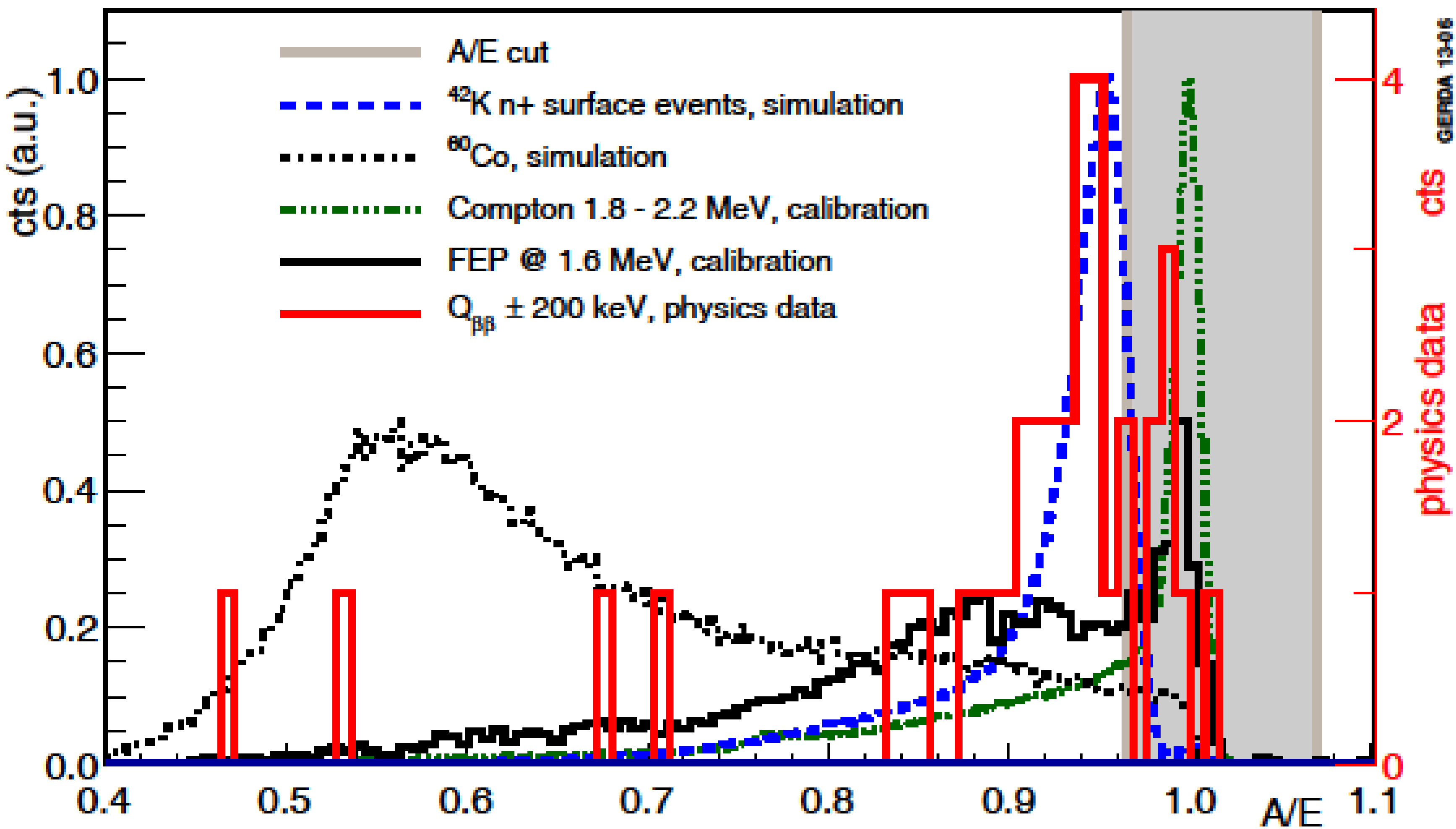
Production and characterization of BEGes

Energy resolution of GERDA BEGe detectors in vacuum cryostat



GERDA Phase II status

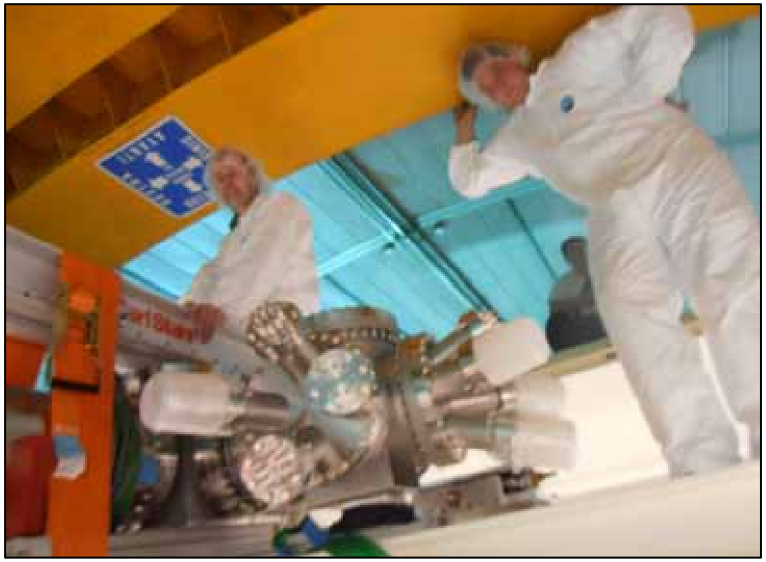
BEGe PSD: Comparison between expected and observed A/E distributions:



GERDA Phase II status

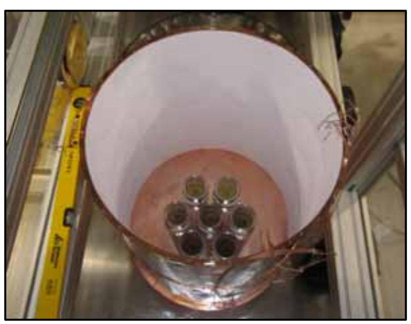
mounting support and lock at LNGS



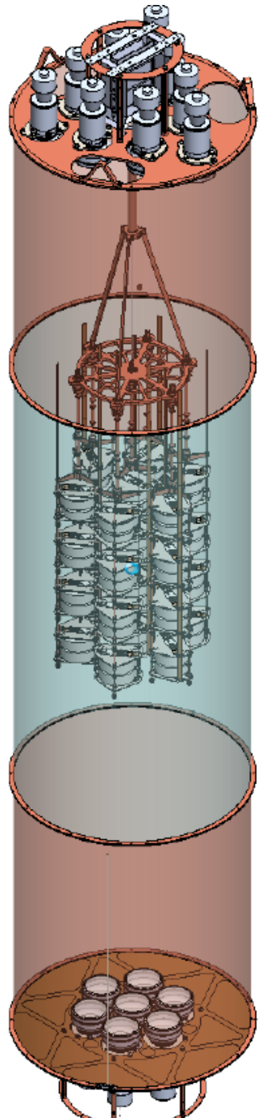
GERDA Phase II status

Copper shroud lined with reflecting TPB coated Tetratex



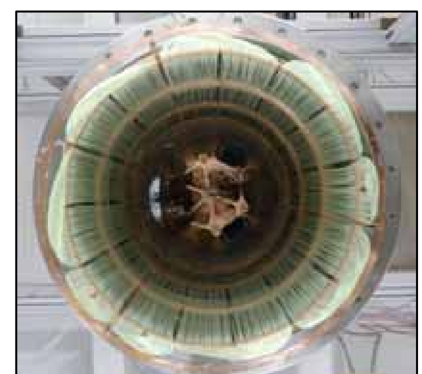
7 bottom 3” PMTs

GERmanium Detector Array



9 top 3” PMTs

TPB coated fiber shroud with SiPMs



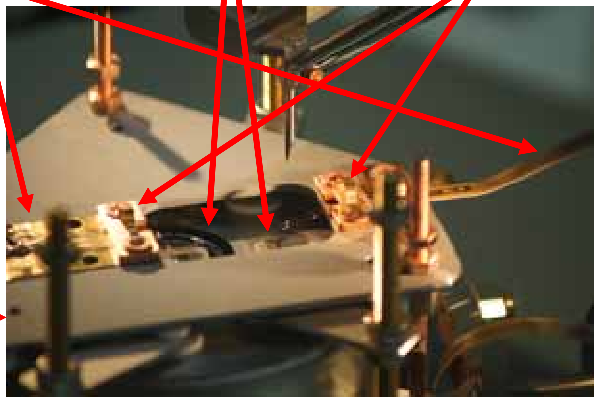
GERDA Phase II status

CuFLon cables

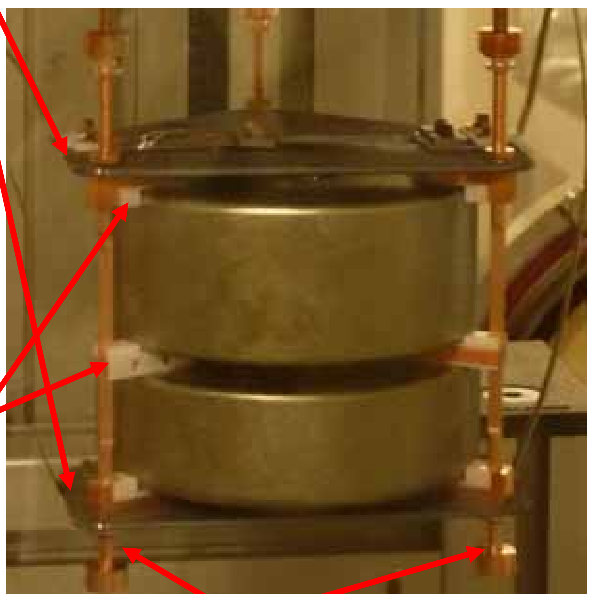
bonded contacts

CuSn6 clamps

Si plates

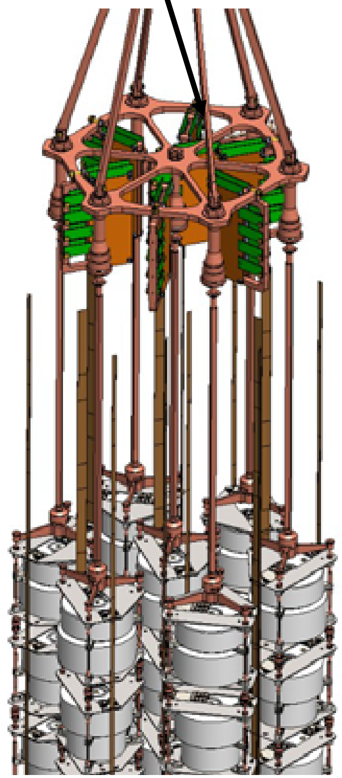


PTFE spacers



Cu support

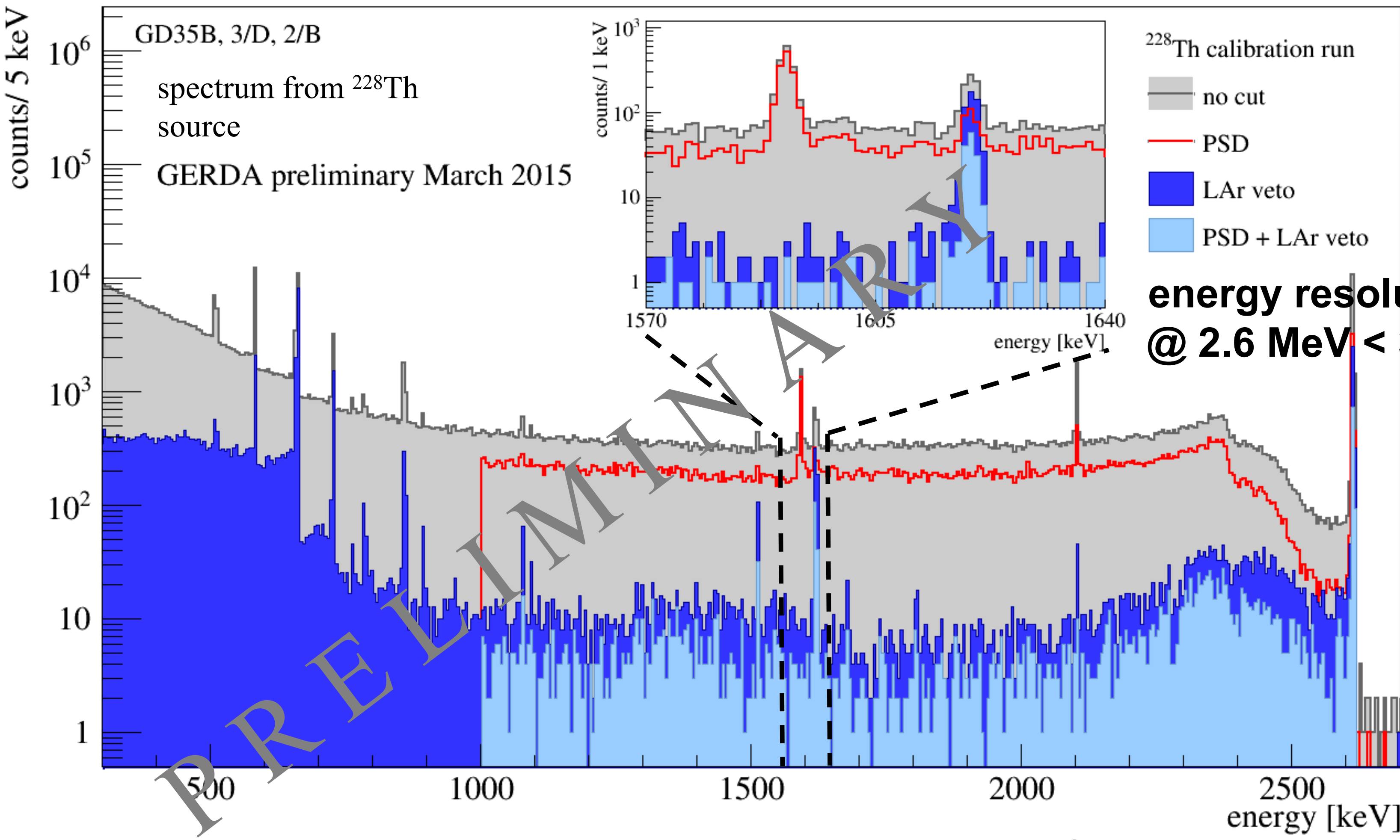
CC3 cryogenic preamps



pilot string

with nylon mini-shroud

GERDA Phase II status



energy resolution @ 2.6 MeV < 3 keV

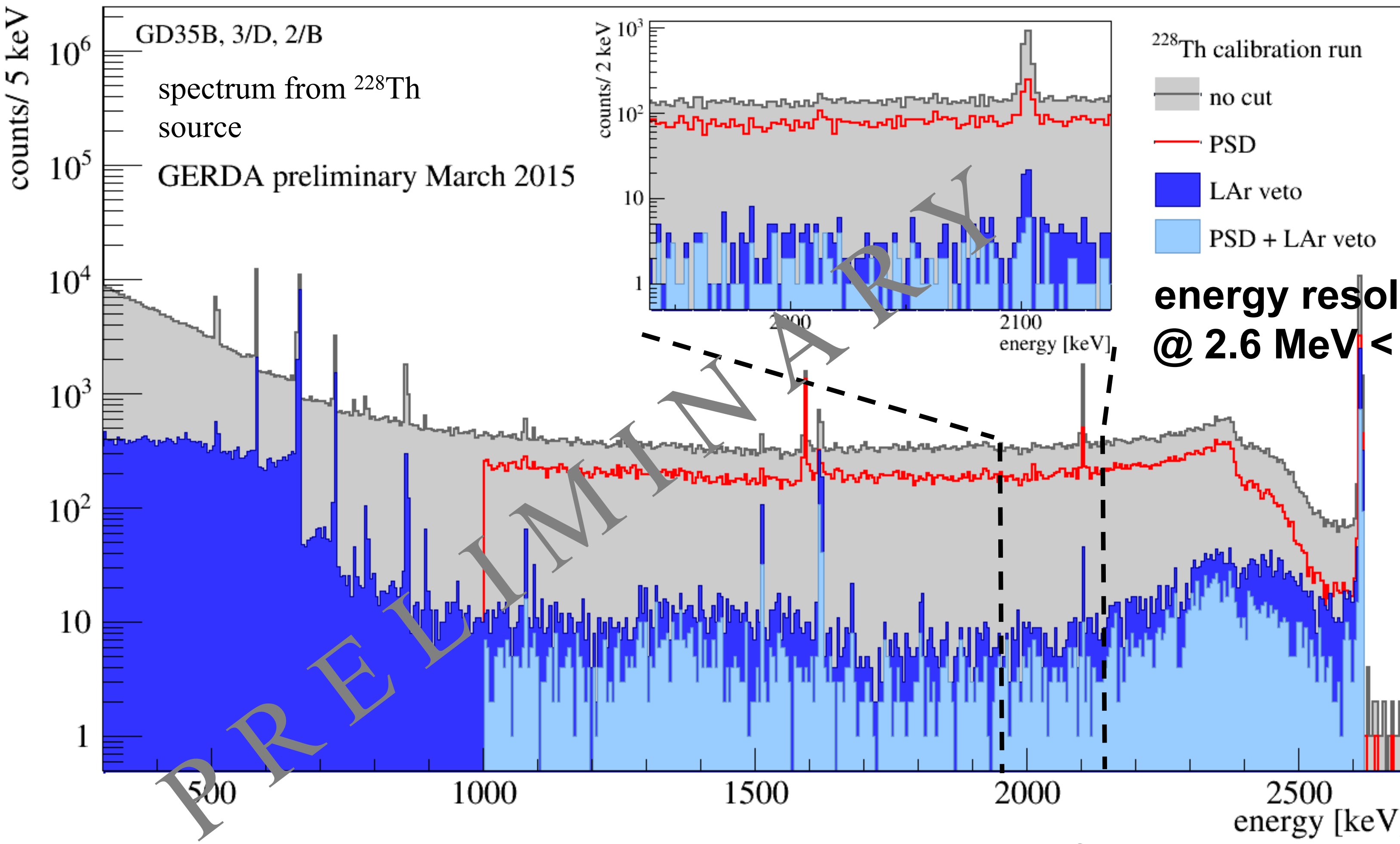
15 hours data - 3 BEGe det. (2 depleted, 1 enriched) 15 PMTs and 7 SiPM fibre modules

supression factor

LAr veto + BEGe PSD: ~ 100

with 7 of 15 fibre modules operational (now all modules operational)

GERDA Phase II status



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LAr veto + BEGe PSD: ~ 100

with 7 of 15 fibre modules operational (now all modules operational)

GERDA Phase II

Main background components expected after PSD & LAr veto:

^{42}K in LAr ~ 0.9 · 10^{-3} counts/(kg yr keV)

mini shroud & PSD essential!

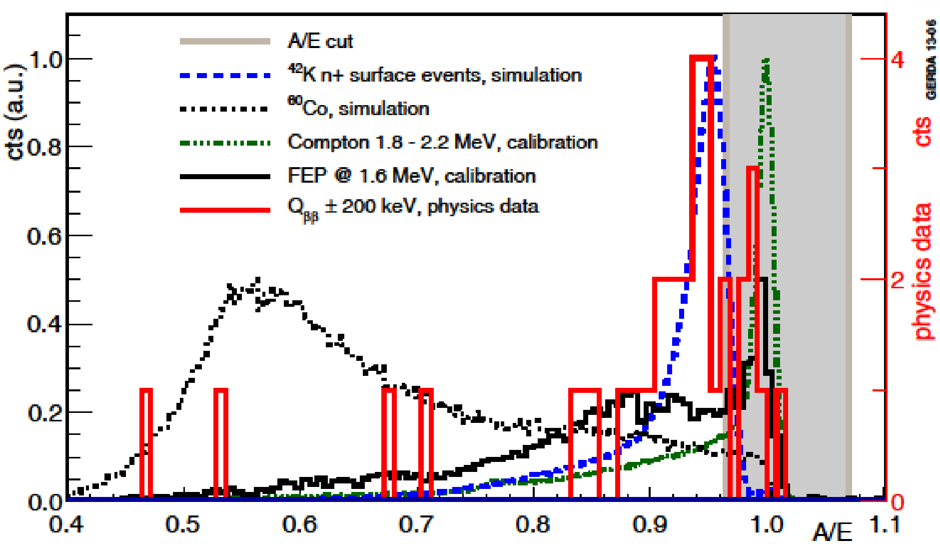
^{214}Bi in close surrounding ~ 0.2 · 10^{-3} counts/(kg yr keV)

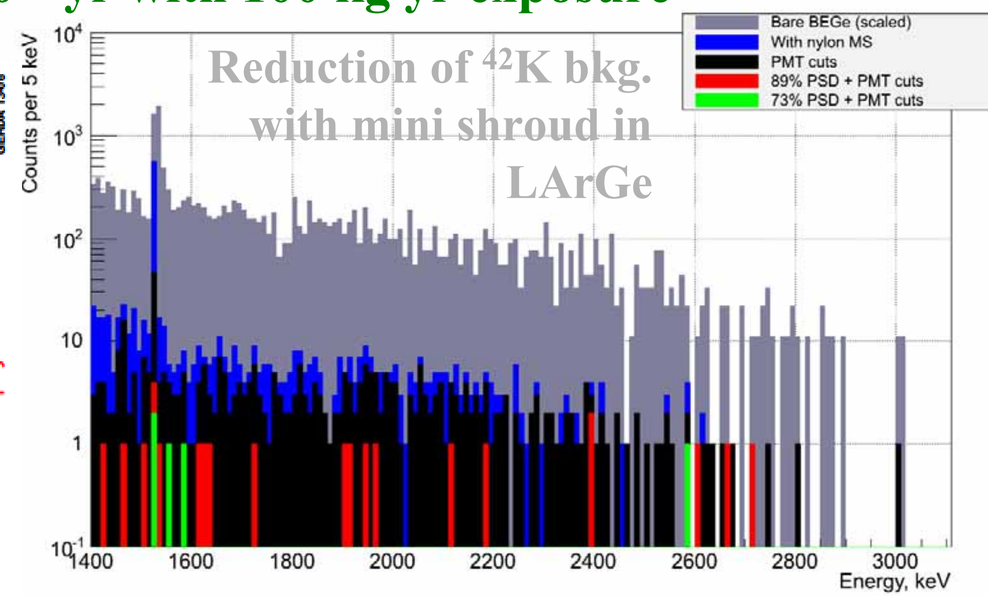
→ LAr veto & transp. mini shroud!

FE electronics & support ~ 0.1 · 10^{-3} counts/(kg yr keV)

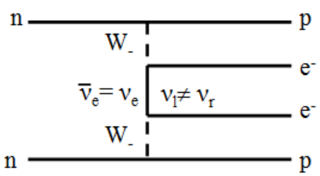
→Total expected BI ~ 10^{-3} (Cts/kg yr keV)

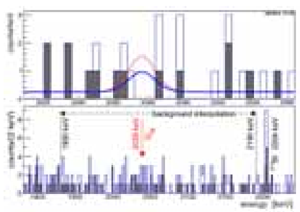
→ sensitivity: $^{0\nu\beta\beta}T_{1/2}(^{76}Ge) \sim 2\cdot10^{26}$ yr with 100 kg·yr exposure



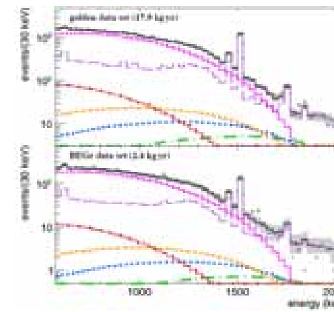


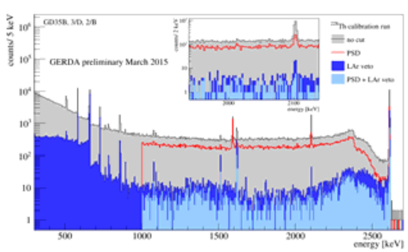
CONCLUSIONS:



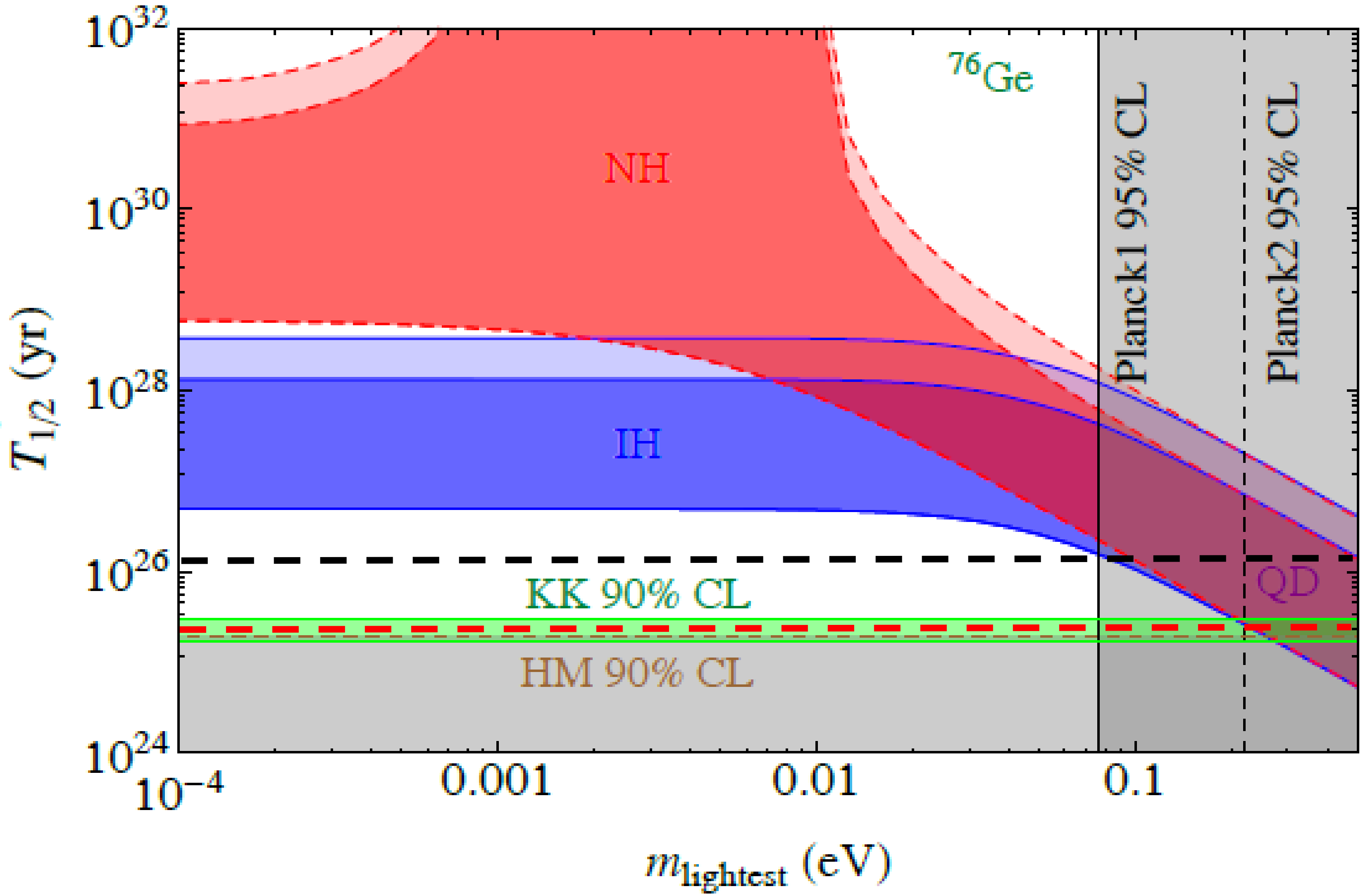


- $0\nu\beta\beta$ decay is important probe of BSM physics
- GERDA Phase I:
  best (^{76}Ge) limits on $0\nu\beta\beta(\chi)$
- background dominated by close by contaminations
- GERDA phase II infrastructure in place
- LAr veto works!
- GERDA Phase II will start commissioning soon
- GERDA Phase II reach: $^{0\nu}T_{1/2}$~10^{26} years



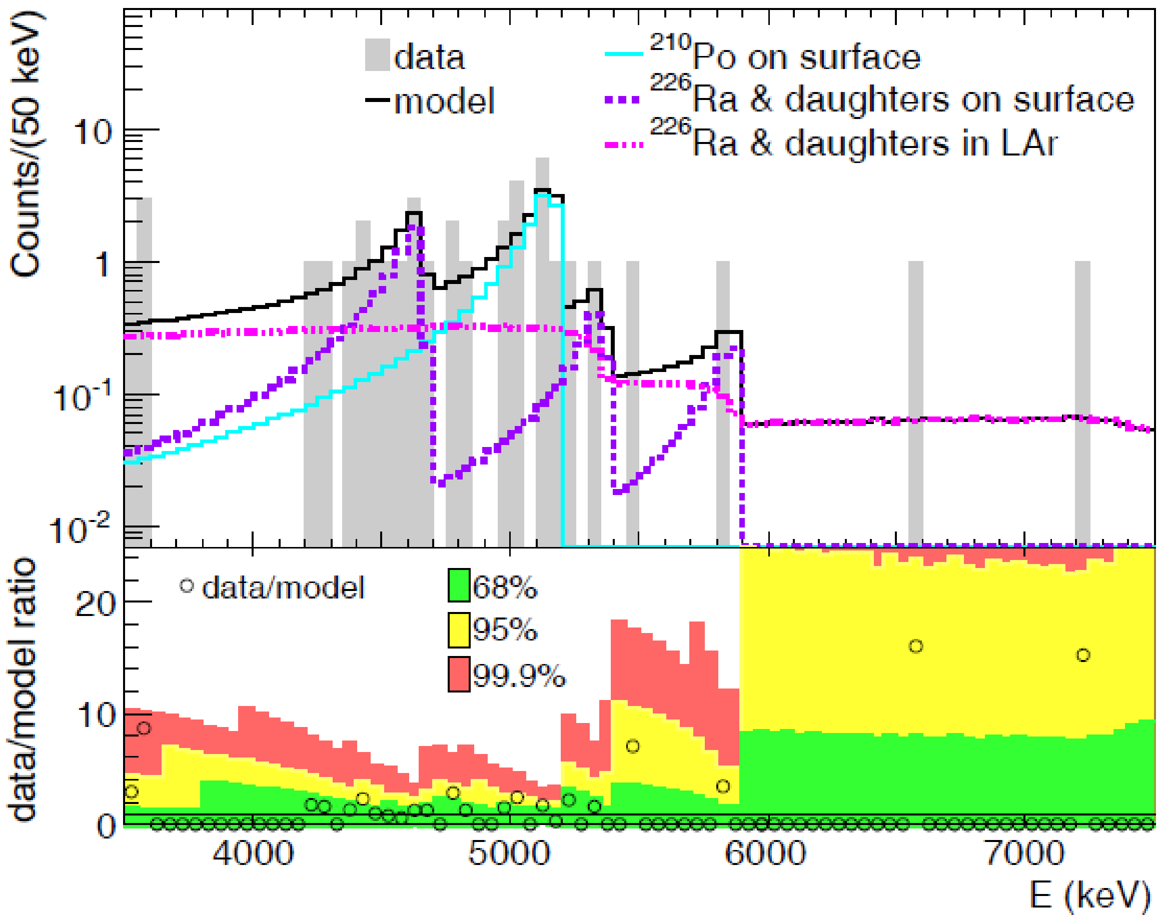


GERDA Phase II goal



GERDA Phase I background model

background decomposition of the high energy spectrum



α-component detector specific. Structures in BEGe spectra less pronounced