MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

GERDA

Status of GERDA Phase II experiment aimed for the $0\nu\beta\beta$ decay search.

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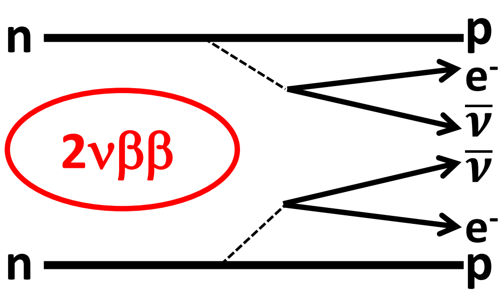
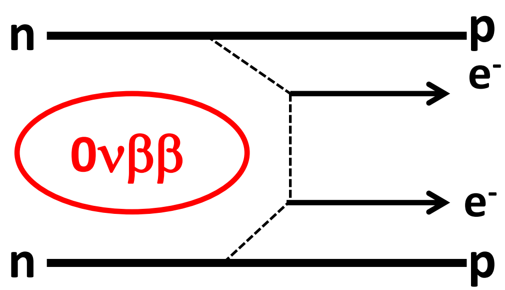
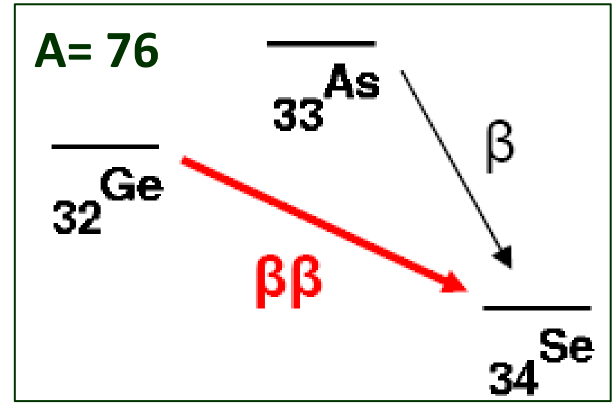
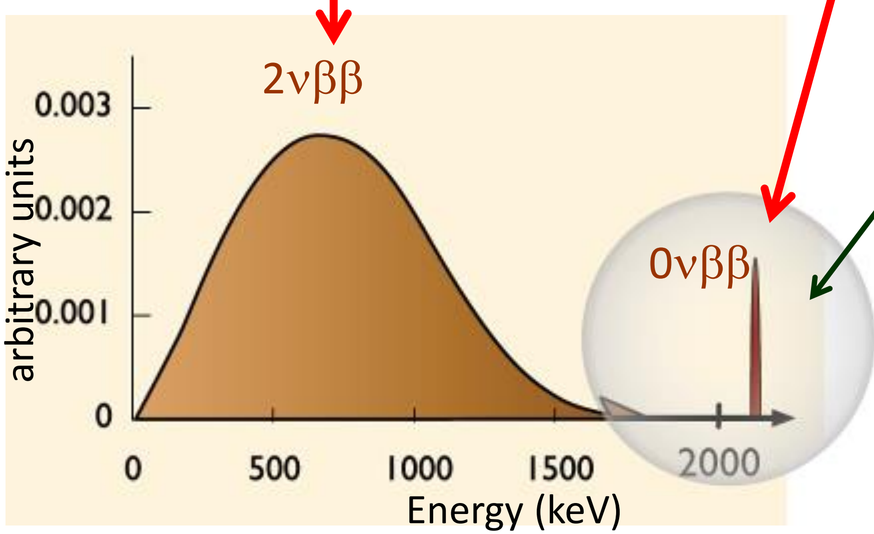
Motivation

Search for the neutrinoless double beta (0νββ) decay is a good way to search for the physics beyond the Standard Model. The observation of such a decay would prove that lepton number is not conserved.









Region of interest (ROI) of 0νββ

Searching for 0νββ helps to understand:

- Nature of ν (Dirac or Majorana)
- Neutrino mass scale
- Neutrino hierarchy
- Some fields in particle physics including cosmology

^{76}Ge 0νββ decay

The GERDA experiment is a low background experiment aimed to search for ^{76}Ge 0νββ decay.

Experimental sensitivity:

If background << 1

$$T_{1/2}^{0\nu} \propto \varepsilon \cdot a \cdot M \cdot t$$

If background >> 1

$$T_{1/2}^{0\nu} \propto \varepsilon \cdot a \cdot \sqrt{\frac{M \cdot t}{\Delta E \cdot BI}}$$

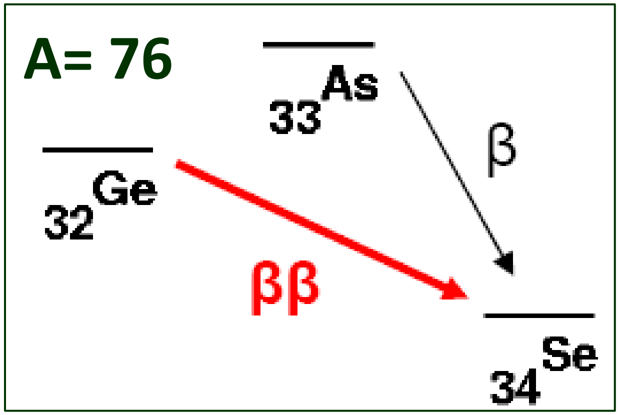
ε Efficiency

$M \cdot t$ Mass·Time = Exposure

a Abundance

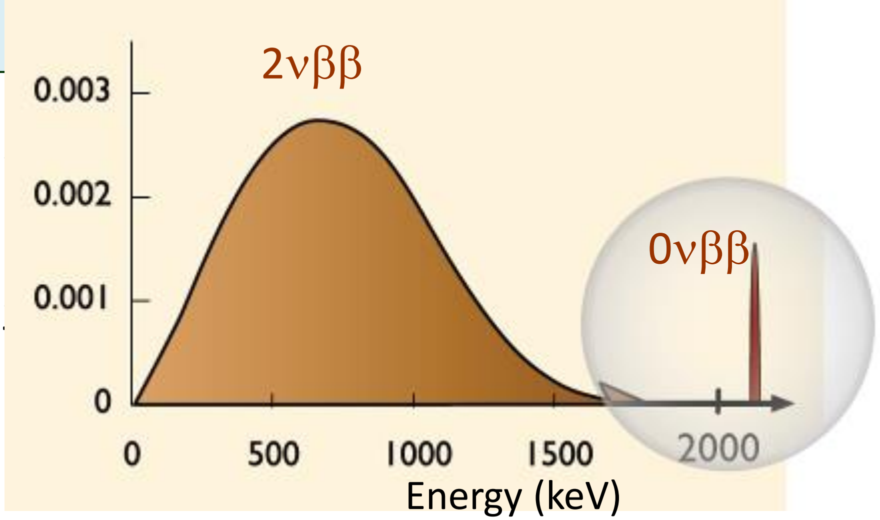
ΔE Energy resolution

BI Background Index



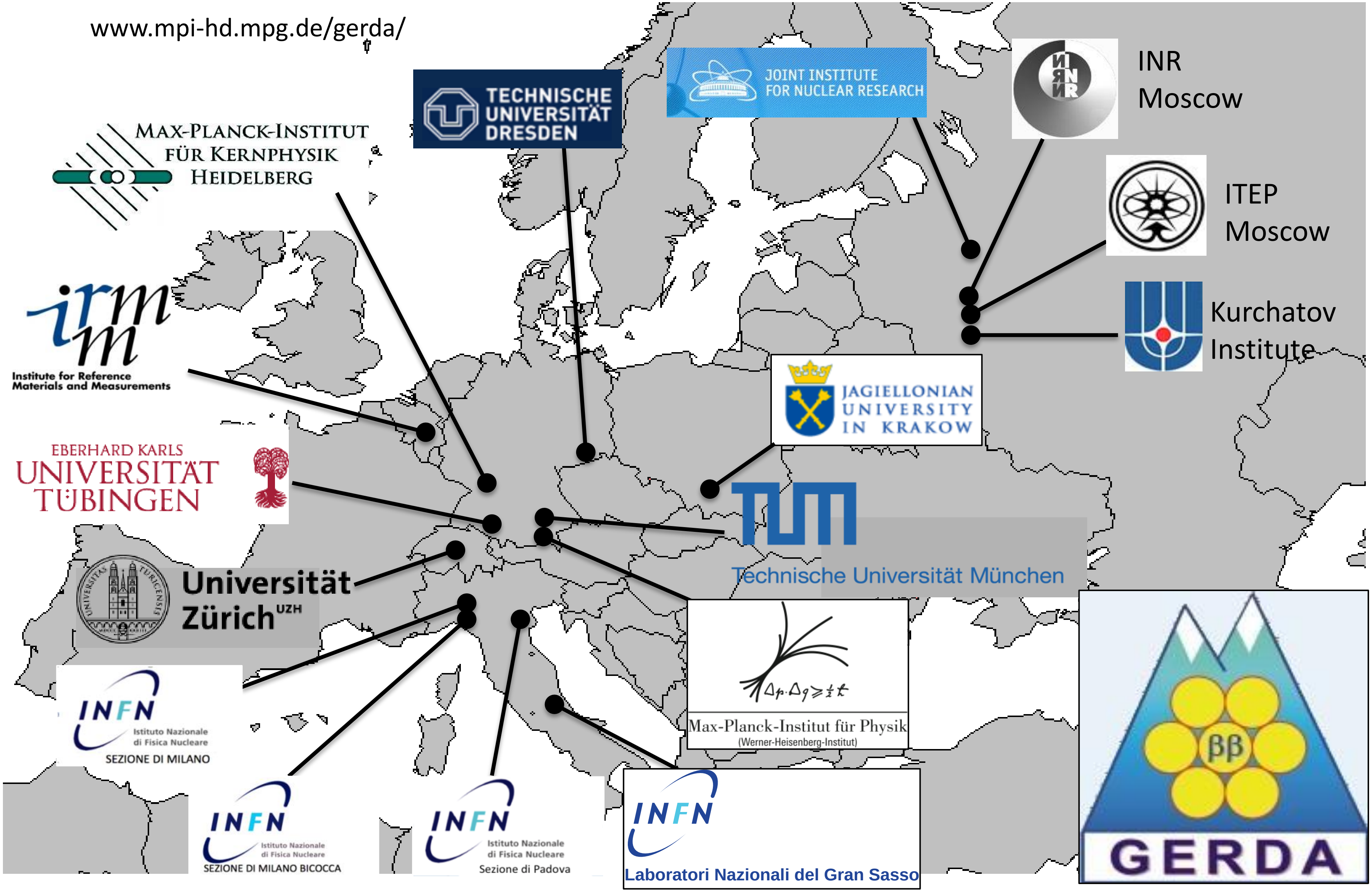
Search with enriched HPGe detectors enriched with ^{76}Ge:

- Detector = source
- Very good detector's energy resolution: better than 0.2%
- Intrinsically pure material



GERDA collaboration

www.mpi-hd.mpg.de/gerda/



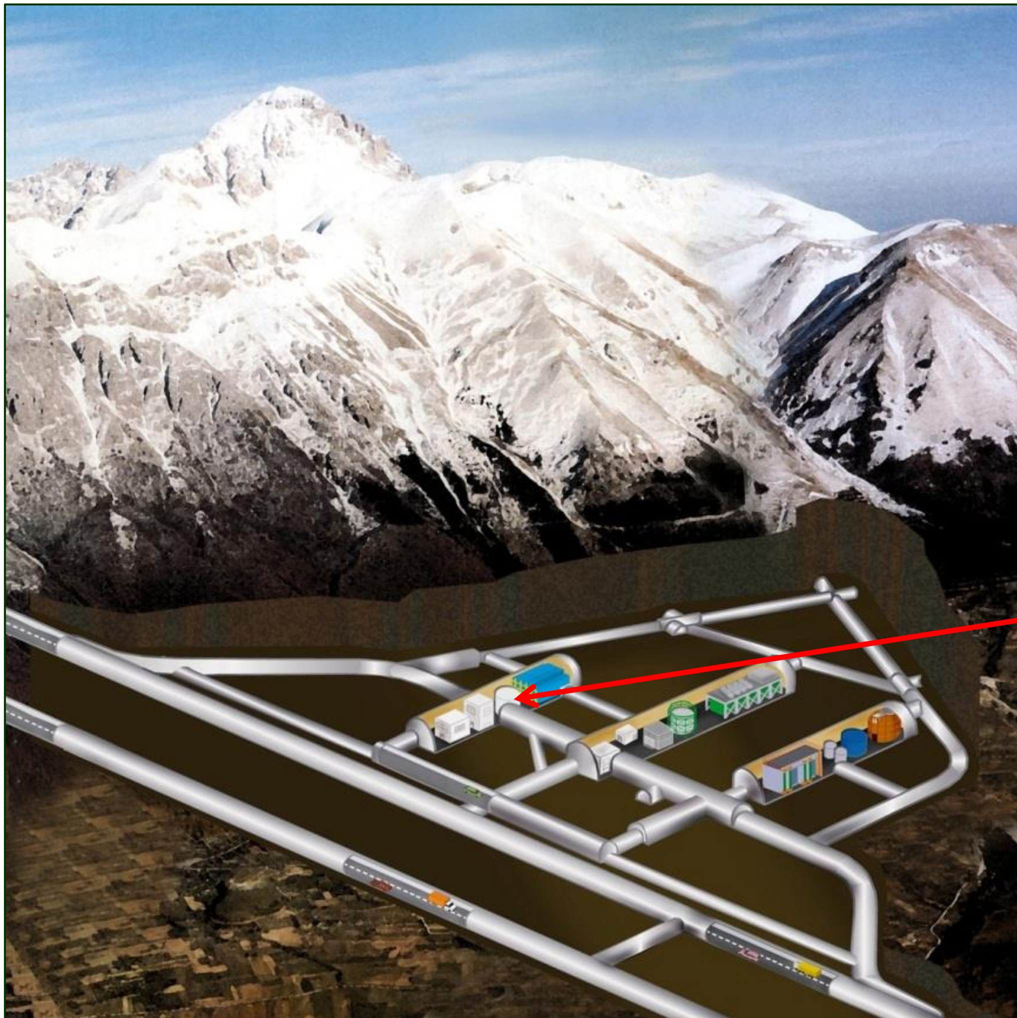
GERDA collaboration

GERDA collaboration meeting in Heidelberg, 2014

16 institutions, 132 members

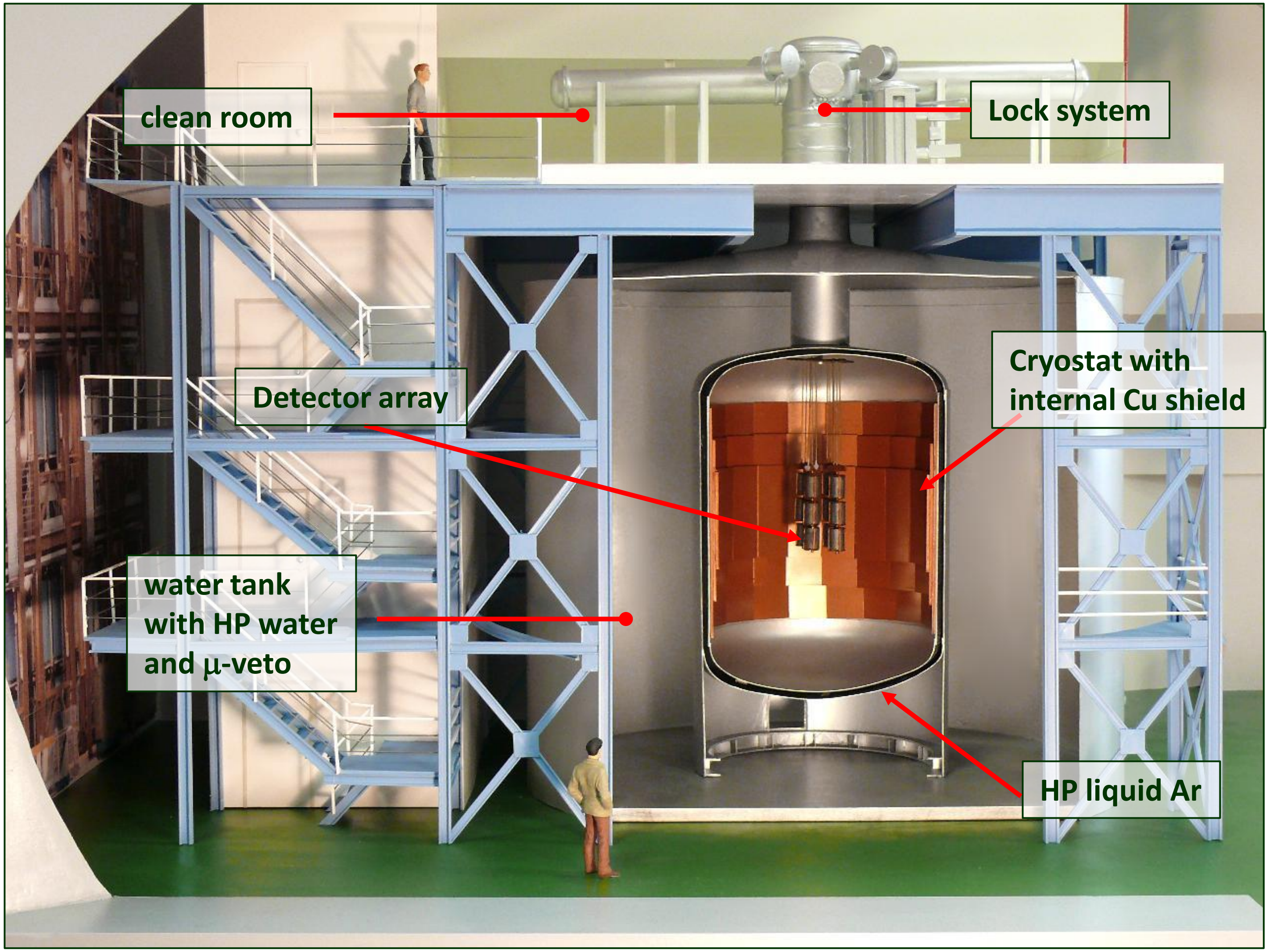
Background reduction

GERDA experiment located at LNGS underground laboratory of INFN (Italy). The rock overburden is equivalent to 3500 m.w.e. This allows to reduce μ (~ 10^6 times) and neutron flux induced by cosmic radiation.



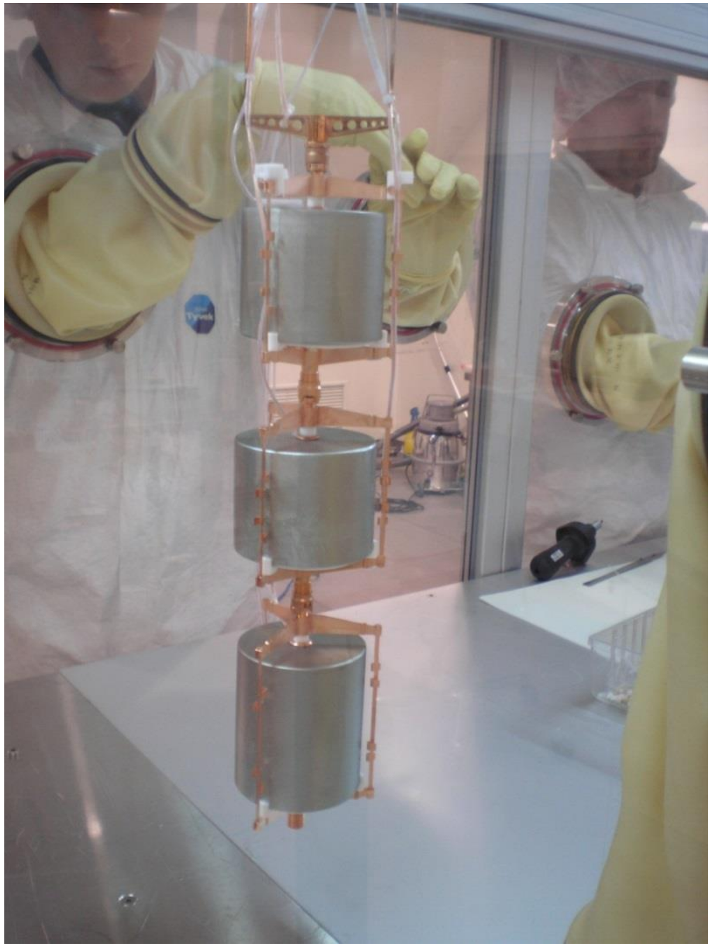
Scheme of GERDA experiment

Bare germanium detectors enriched by ^{76}Ge, submerged into the high-purity liquid argon (LAr), are used in GERDA experiment.

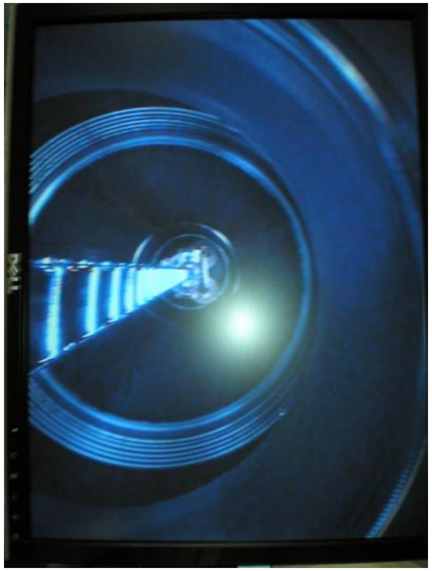


General concept

Bare Ge detectors allows to decrease background from the surrounding materials, liquid argon shields from the radiation and cools down the Ge detectors.

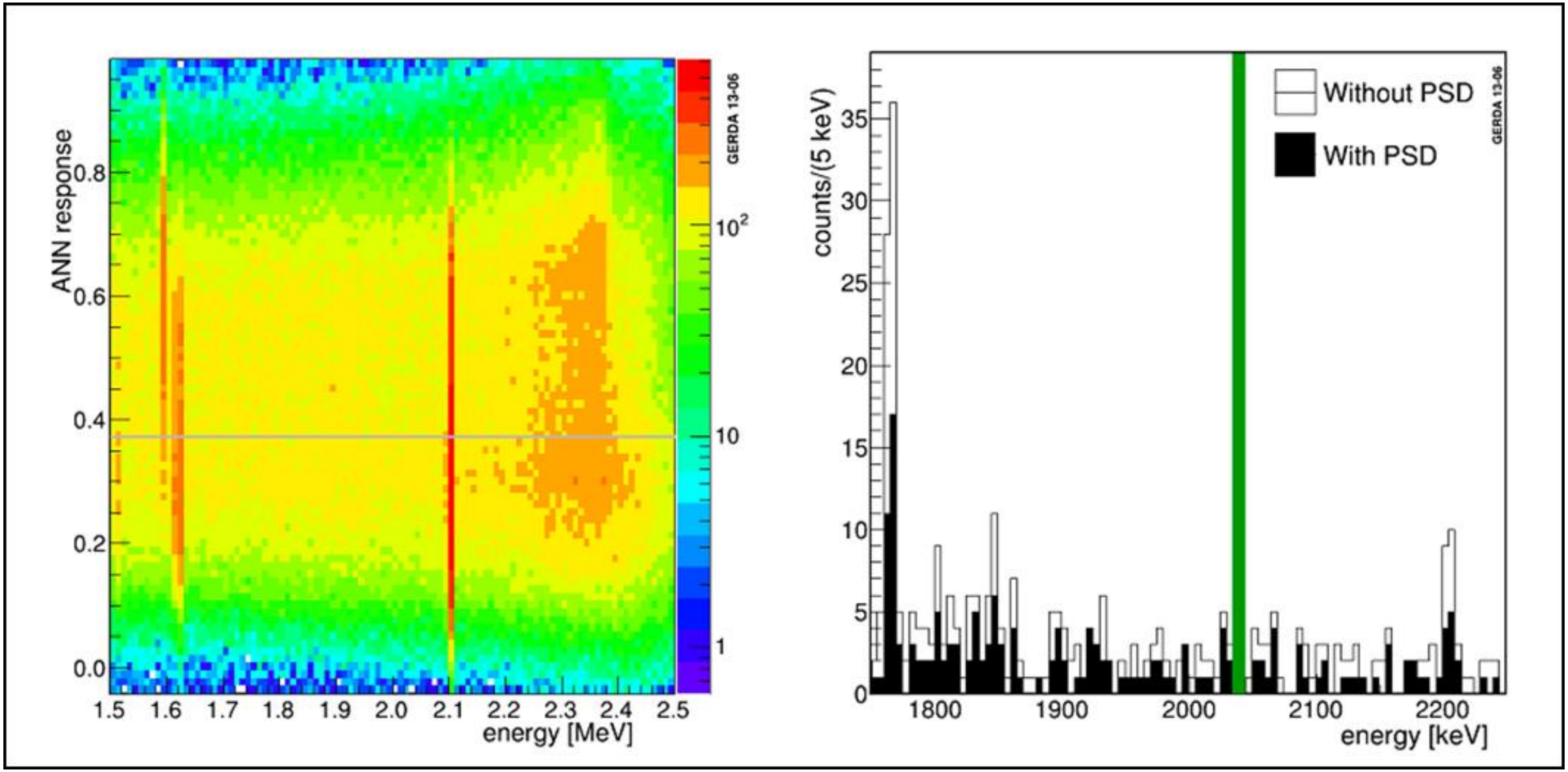


~ 80 g Cu,
~ 10 g PTFE,
~ 1 g Si per detector
(in Phase I)

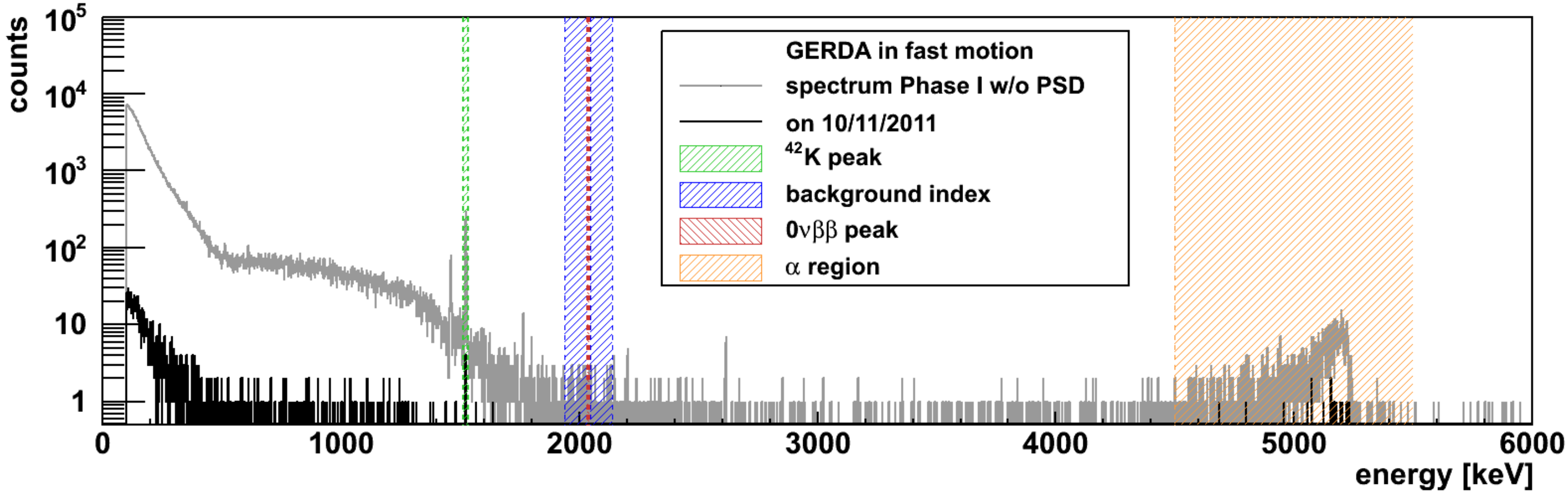


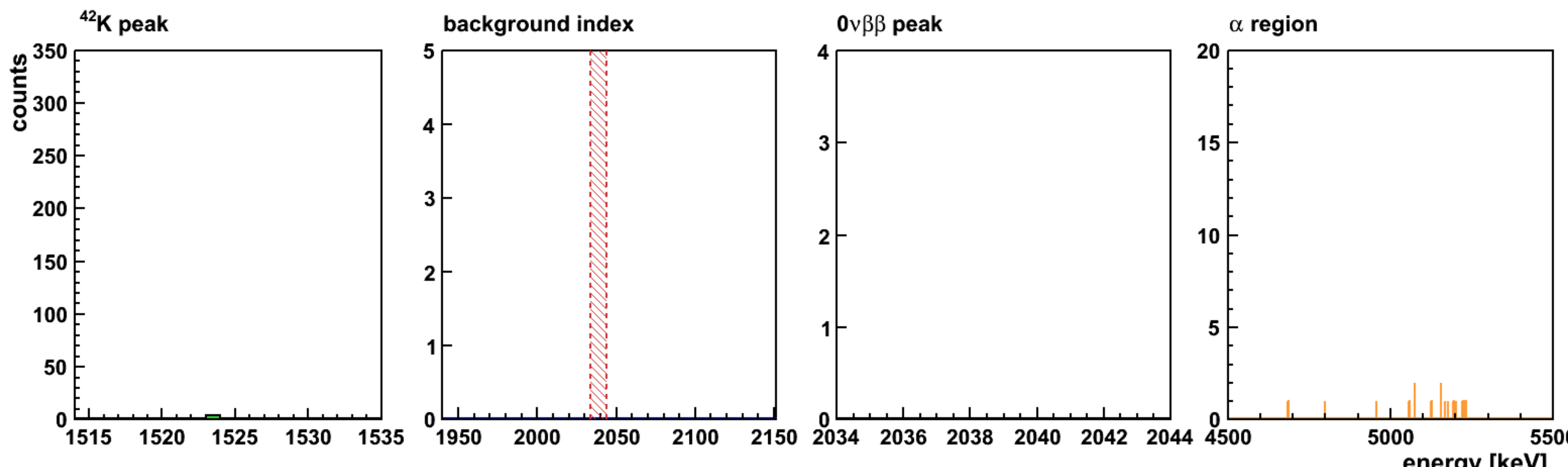
GERDA Phase I

- Achieved Background Index (BI) for semi-coaxial detectors is **0.018(2) cts/(keV·kg·yr).**
- BI after pulse shape discrimination: **0.011(2) cts/(keV·kg·yr).**
- About **one order of magnitude better** than in previous experiments with HPGe detectors.



GERDA Phase I

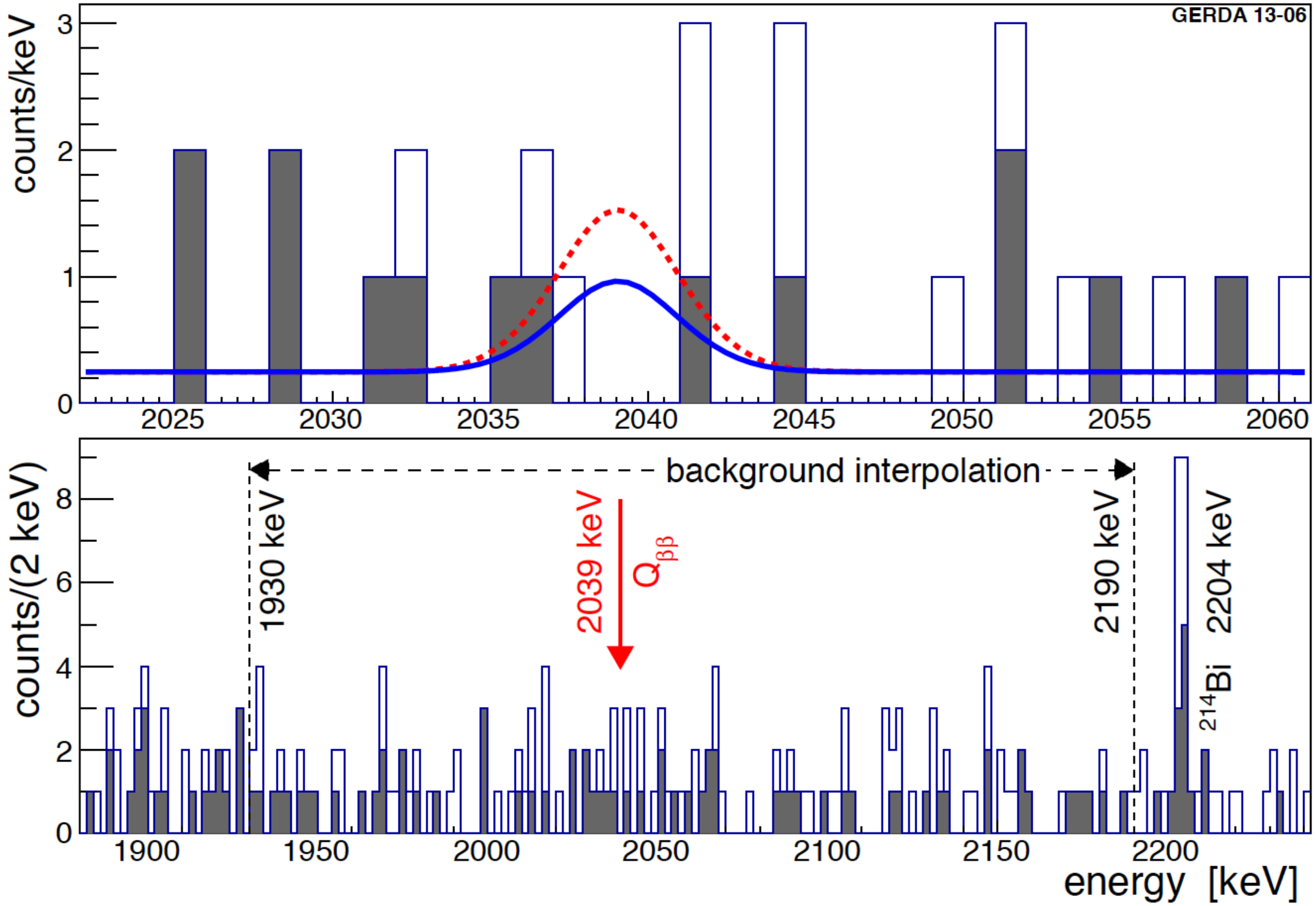




- **8 enriched Coaxial detectors:** working mass 14.6 kg. Average FWHM at $Q_{\beta\beta}$: ΔE = 4.8 keV
- **Natural Ge:** 3.0 kg.
- **5 enriched BEGe:** working mass 3.0 kg (for test Phase II concept): ΔE = 3.2 keV

GERDA Phase I results

Energy spectrum from all enriched Ge detectors with and without the PSD selection.



GERDA: 90% lower limit ($T_{1/2}^{0\nu}$) [Phys. Rev. Lett. 111 (2013) 122503]

Claim: $T_{1/2}^{0\nu} = 1.19\times10^{25}$ (Phys. Lett. B 586 198 (2004))

Total exposure is **21.6 kg·yr.**

All analysis parameters were fixed before unblinding.

No event remain within $Q_{bb}\pm\sigma$ after PSD cut.

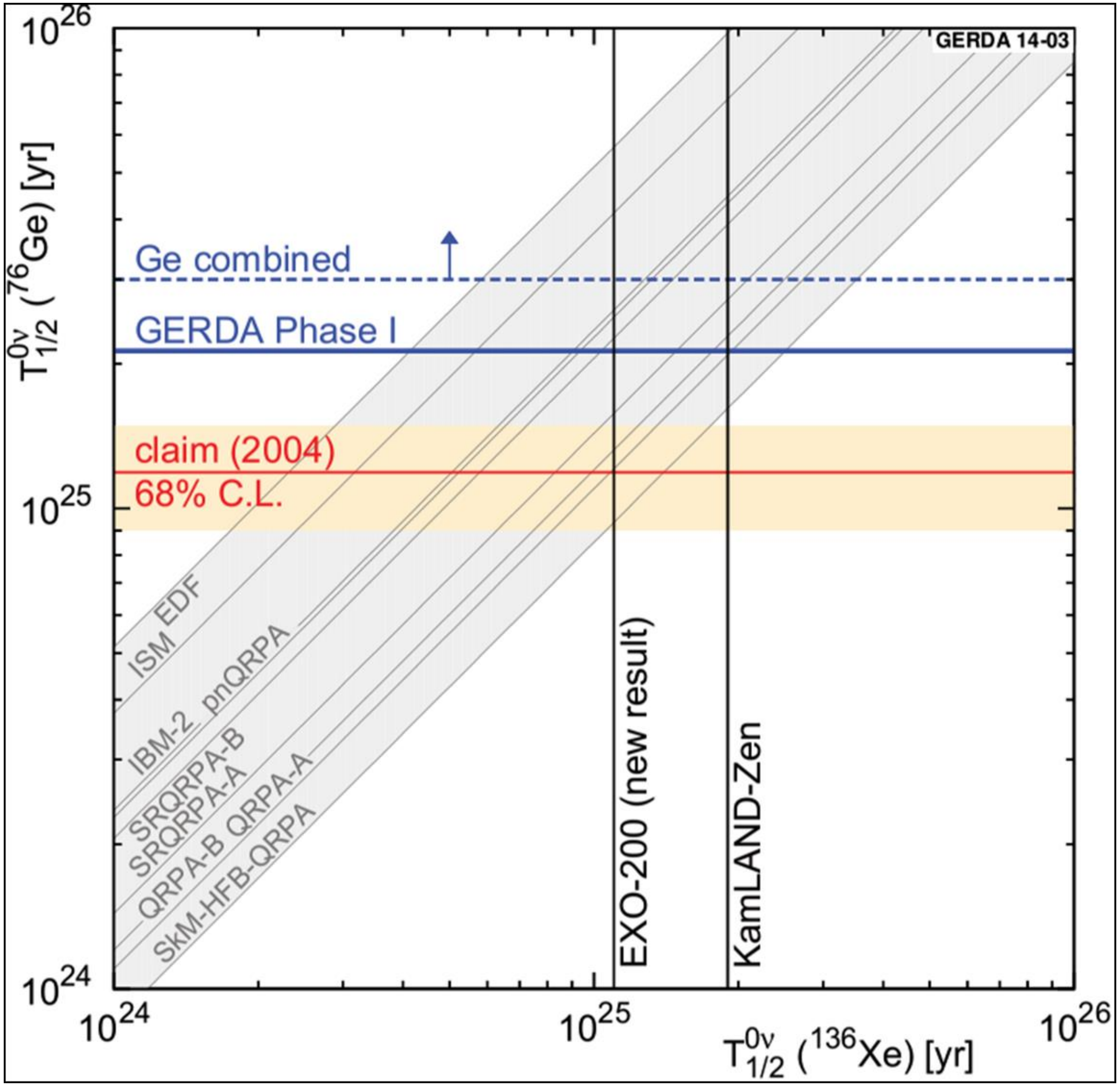
The **"claim"** of a signal for $0\nu\beta\beta$ decay of ^{76}Ge is **ruled out** by GERDA with **99%** probability.

The limit on the half-life of $0\nu\beta\beta$ decay is:

$$T_{1/2}^{0\nu} > 2.1\cdot10^{25}\ yr$$

GERDA Phase I results

90% C.L. on $T_{1/2}$ for ^{76}Ge and ^{136}Xe compared with the signal claim.



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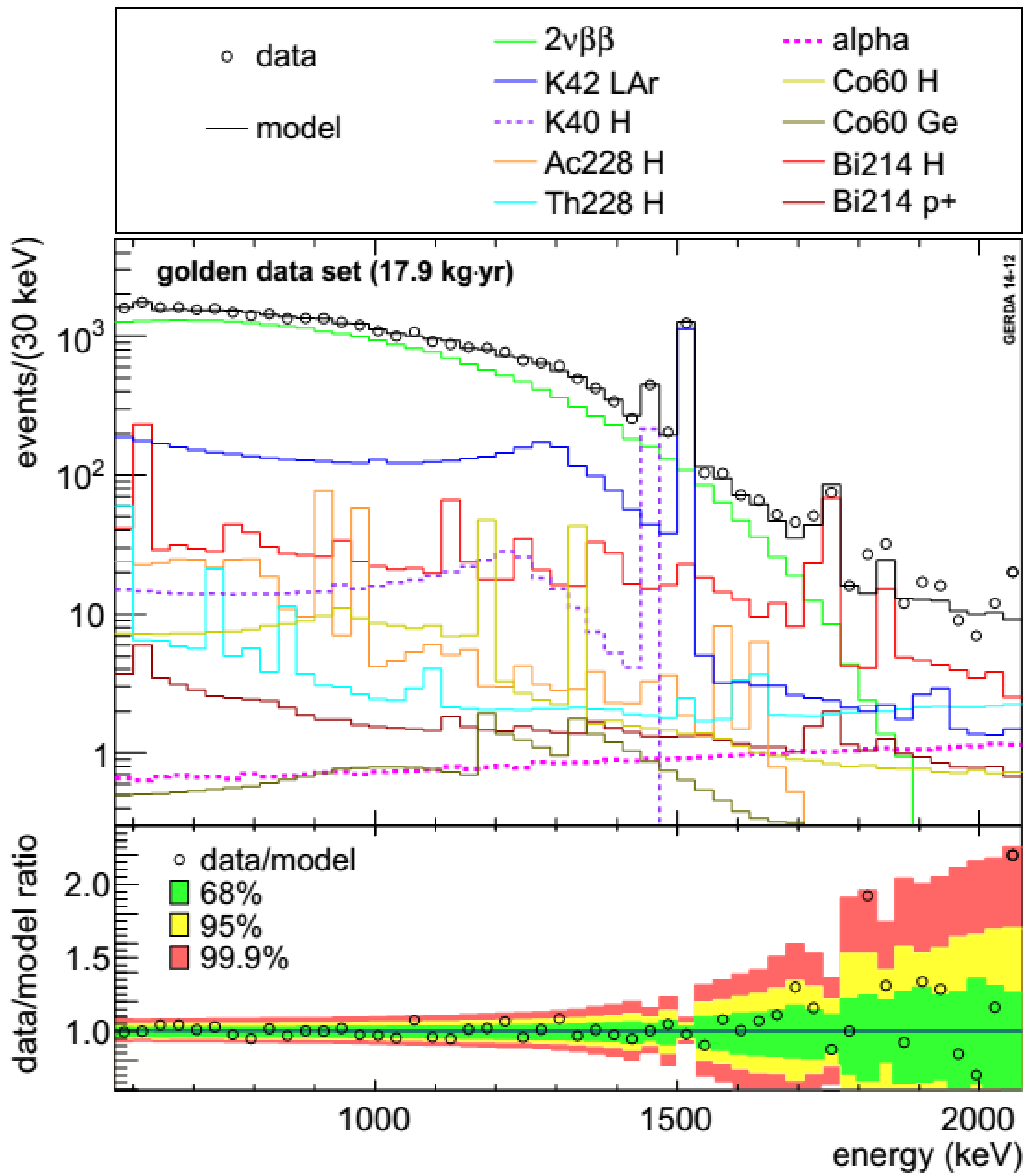
The limit on the half-life of $0\nu\beta\beta$ decay is:

$$T^{0\nu}_{1/2} > 2.1 \cdot 10^{25} \ yr$$

Other GERDA Phase I results



Analysis of 2νββ spectrum gives:

$$T_{1/2}^{2\nu} = \left(1.93 \pm 0.10\right) \cdot 10^{21}\ yr$$

Experimental results for the limits on $T^{0\nu\chi}_{1/2}$ of ^{76}Ge for the Majoron models

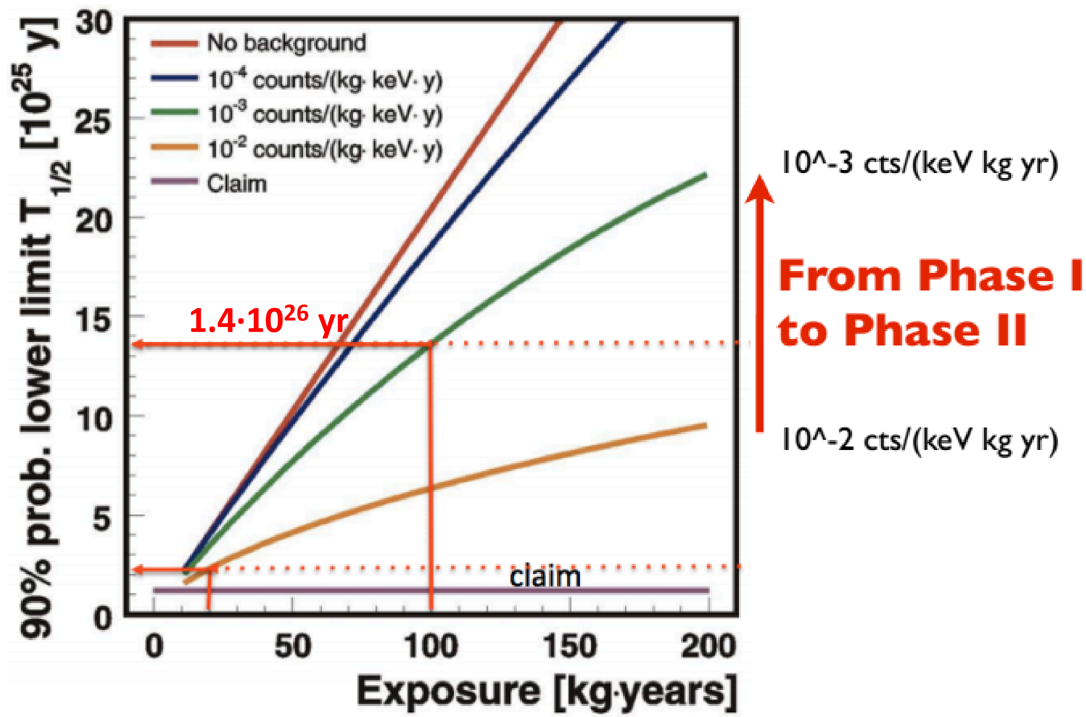
Model	n	Mode	Goldstone boson	L	$T_{1/2}^{0\nu\chi}$ [10^{23}yr]
IB	1	χ	no	0	> 4.2
IC	1	χ	yes	0	> 4.2
ID	3	$\chi\chi$	no	0	> 0.8
IE	3	$\chi\chi$	yes	0	> 0.8
IF	2	χ	bulk field	0	> 1.8
IIB	1	χ	no	-2	> 4.2
IIC	3	χ	yes	-2	> 0.8
IID	3	$\chi\chi$	no	-1	> 0.8
IIE	7	$\chi\chi$	yes	-1	> 0.3
IIF	3	χ	gauge boson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

see more in arXiv:1501.02345

From Phase I to Phase II

$$T_{1/2}^{0\nu} \propto \varepsilon \cdot a \cdot M \cdot t$$

$$T_{1/2}^{0\nu} \propto \varepsilon \cdot a \cdot \sqrt{\frac{M \cdot t}{\Delta E \cdot BI}}$$

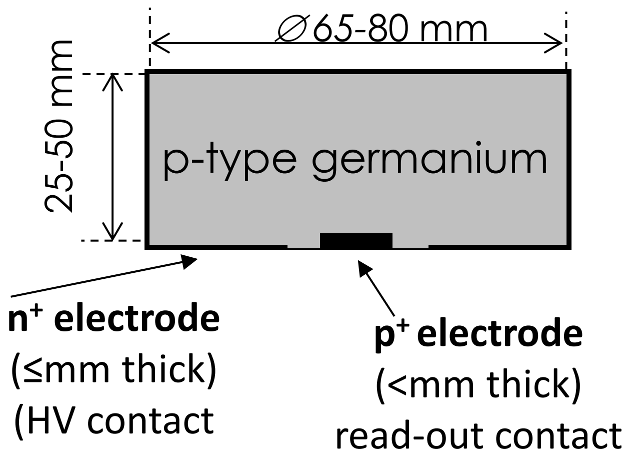


- Increase mass: additional 30 new BEGe detectors with total mass of ~ 20 kg.
- Exposure: 20 kg yr → 100 kg yr (within 3 years).
- Reduce background: (from $\mathbf{10^{-2}}$ cts/(keV kg yr) → $\mathbf{10^{-3}}$ cts/(keV kg yr)):
  - ✓ Power Pulse Shape Discrimination (PSD) of new BEGe detectors.
  - ✓ LAr light scintillation veto.
  - ✓ Cleaner materials.

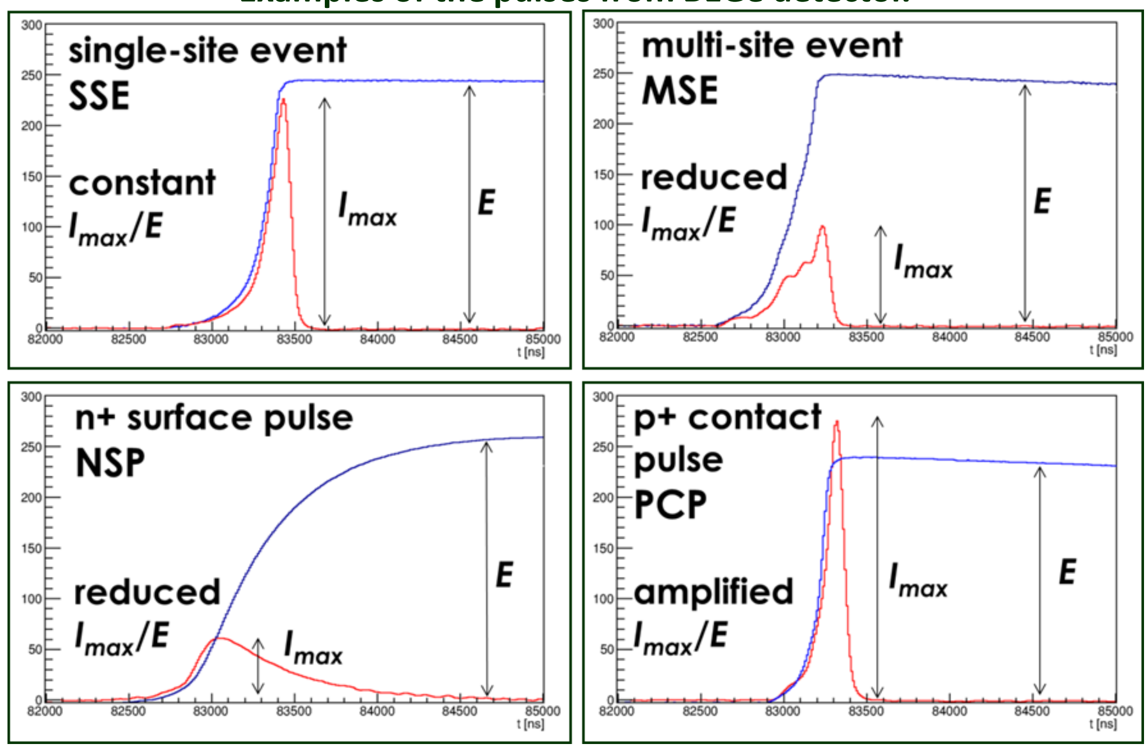
GERDA Phase II preparations

New BEGe detectors for GERDA Phase II:

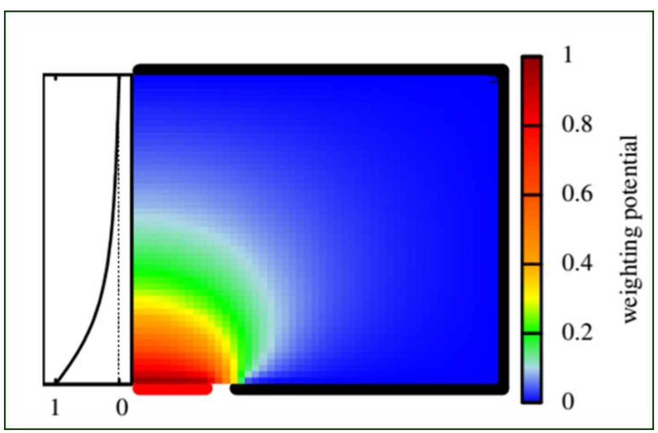
- Better energy resolution (FWHM up to 1.6 keV@1.3MeV in a vacuum cryostat).
- Powerful PSD.
- Holders with lower intrinsic radioactivity.



Examples of the pulses from BEGe detector.

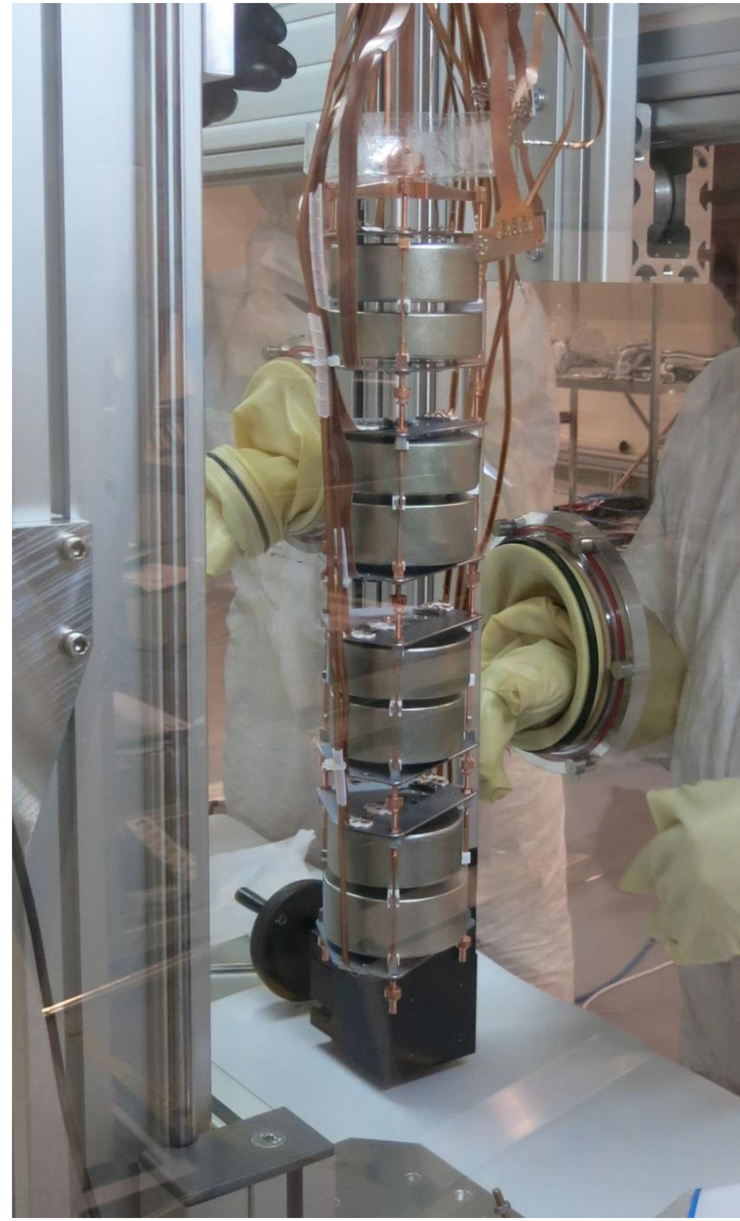


Simulation of E-field in BEGe



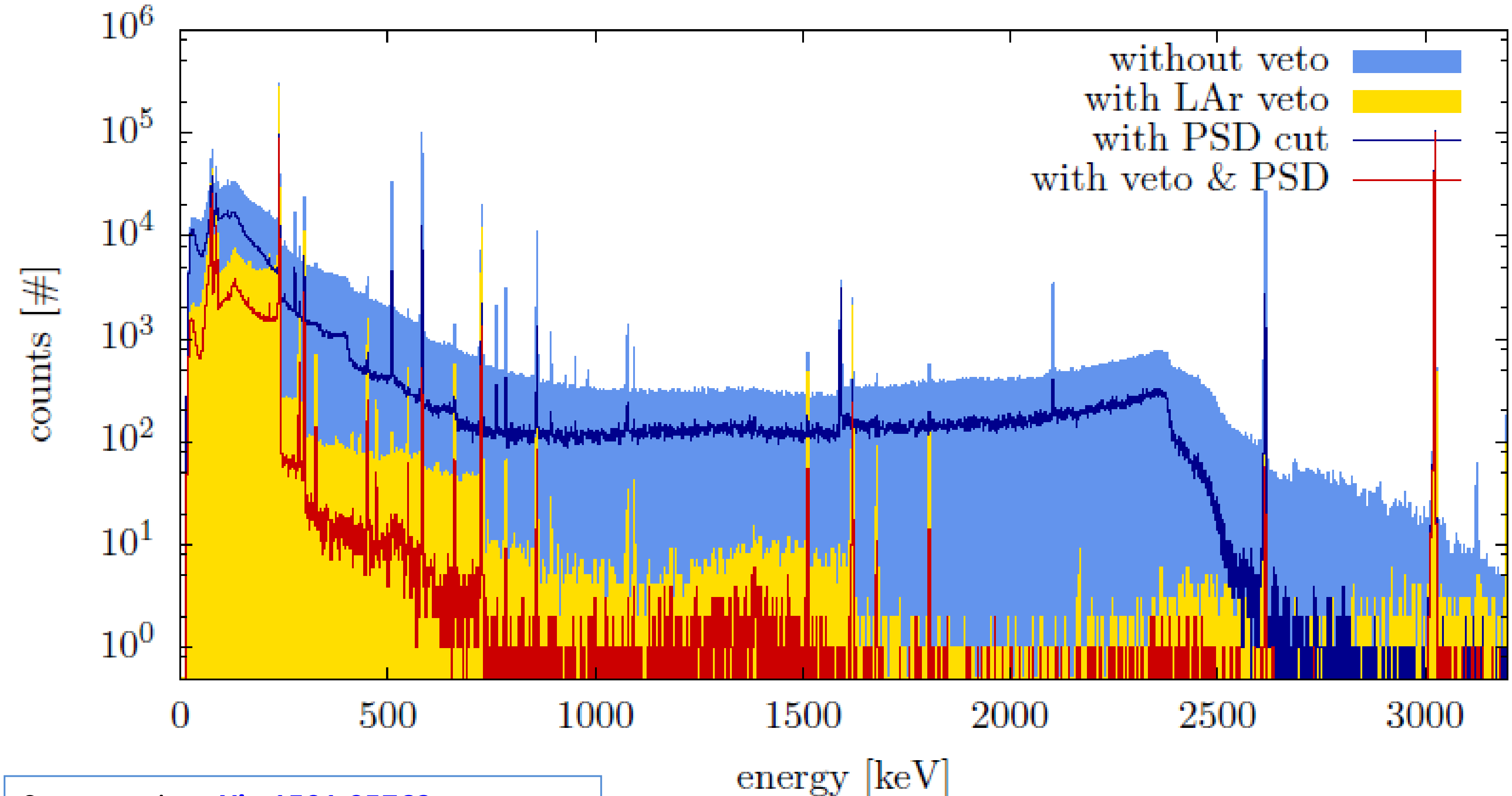
All detectors prepared and ready for installation in GERDA. More information in talk of V.Wagner **T 10.4.**

GERDA Phase II preparations



LAr light instrumentation

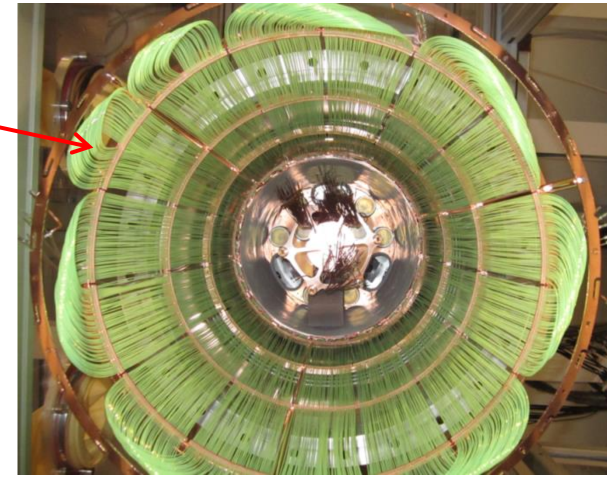
Measurements with BEGe detector inside LArGe test facility show very good suppression of background. For ^{228}Th inner source the suppression factor > 5000 has been obtained after applying LAr veto and PSD (but for other sources it can be lower for example for external ^{226}Ra it is only factor 18). That is why to reach goal of Phase II background index of < 10^{-3} cts/(keV·kg·yr) light scintillation veto will be implemented in GERDA experiment.



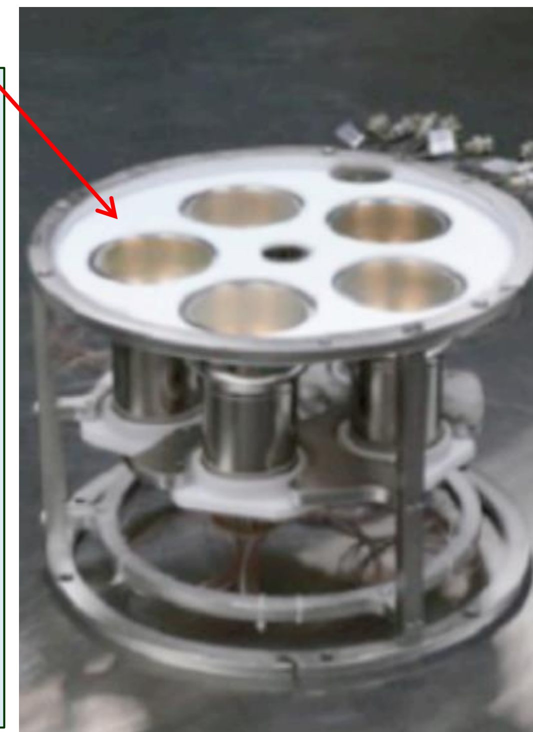
See more in [arXiv:1501.05762]

LAr light instrumentation

SiPM & fibers readout

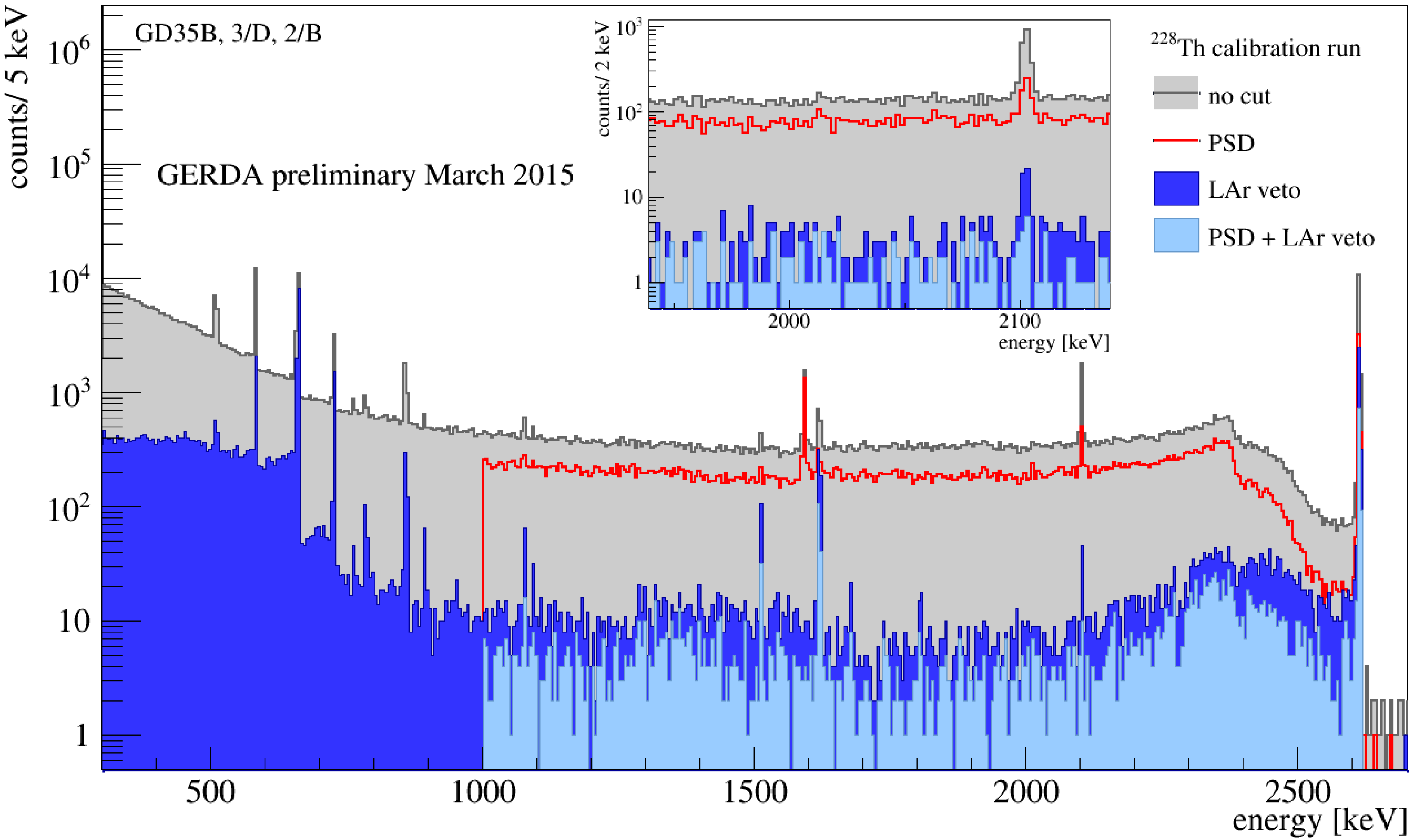


PMTs readout



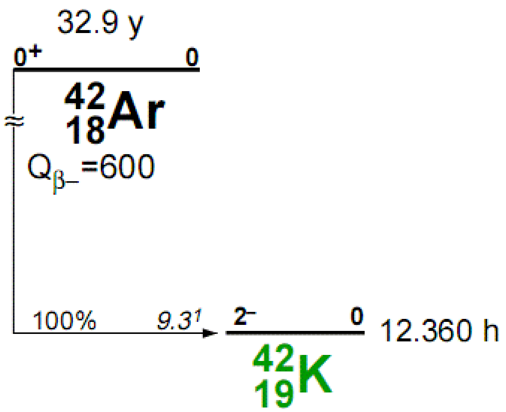
LAr light instrumentation was developed and successfully installed in GERDA. More information in talk of A.Wegmann **T 10.5** and B.Schneider **T 28.2** (light attenuation)

First commissioning tests

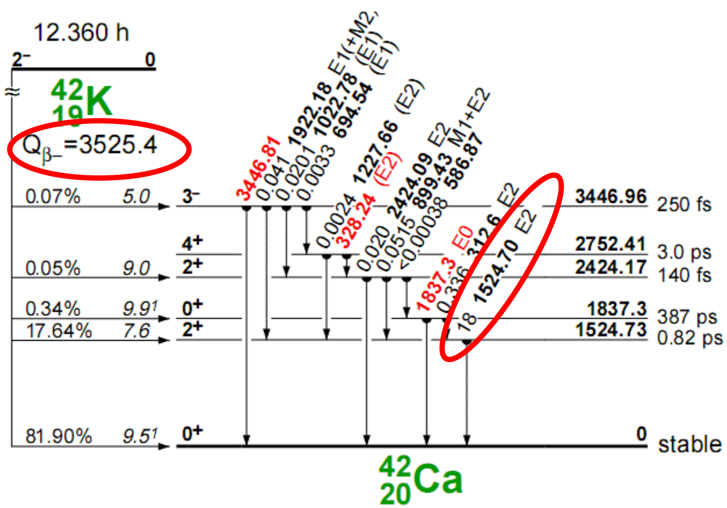


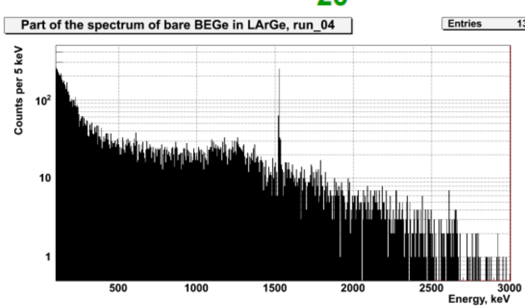
Spectrum taken in the commissioning run of GERDA Phase II. More details in following talks: **T 10.4** and **T 10.5.**

^{42}Ar background mitigation

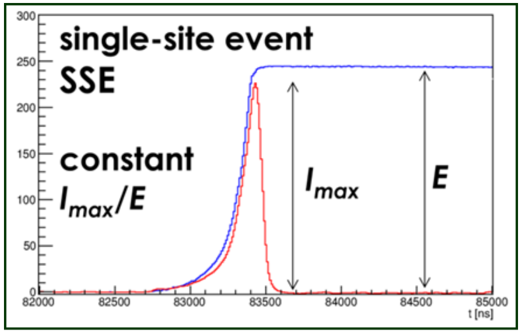


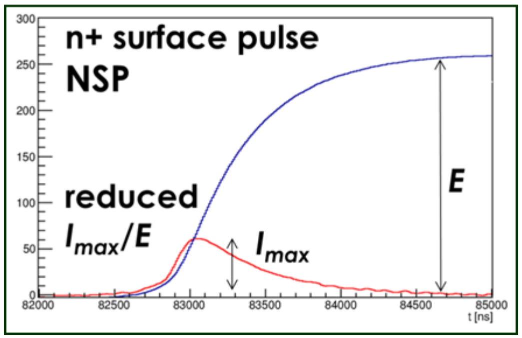
In GERDA Phase I for suppression of ^{42}Ar background copper "mini-shroud" is used.
For GERDA Phase II such device will block the scintillation light -> new device was developed: nylon mini-shroud covered with wavelength shifter.

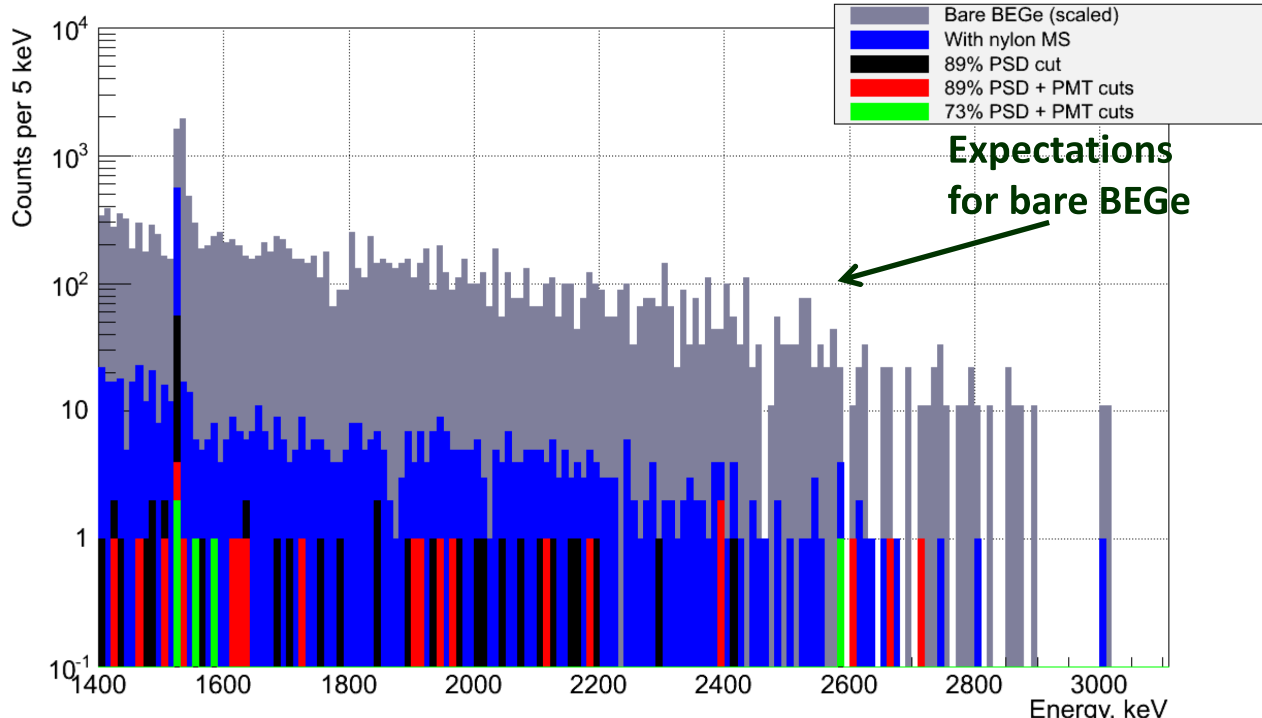




^{42}Ar background mitigation







In measurements in LArGe accumulated statistics is equivalent approximately to ~ 17 kg·yr in natural argon.

It was shown that with NMS+PSD+PMT suppression it is possible to dramatically decrease ^{42}K background: suppression more than factor of 1000 was demonstrated.

Conclusion

- GERDA Phase I data taking was successfully performed.
- Obtained limit on the half-life of the $0\nu\beta\beta$ decay is $2.1 \cdot 10^{21}$ yr.
- Signal from the previous claim disfavoured by GERDA with
- 99% probability.
- Installation of the GERDA Phase II is ongoing.
- First results of background suppression by LAr scintillation veto are promising.
- More data are coming….
- Listen more about GERDA: T10.4, T10.5, T 26.8, T28.1, T28.2, T28.7.

Back up slides

LArGe test facility

LArGe low background test facility has been created in order to study the possibility to suppress background by using anticoincidence with liquid Ar scintillation signal detected by PMTs. It was shown that liquid scintillation veto can efficiently suppress the background.