Commissioning of GERDA

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Heidelberg

GERDA collaboration

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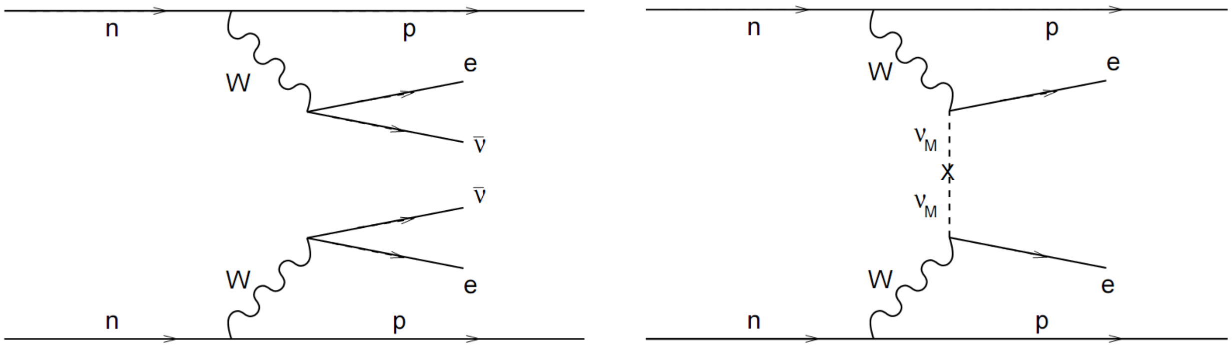
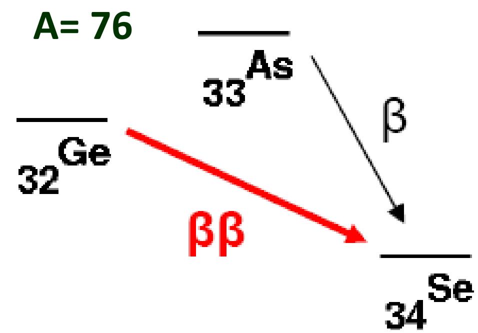
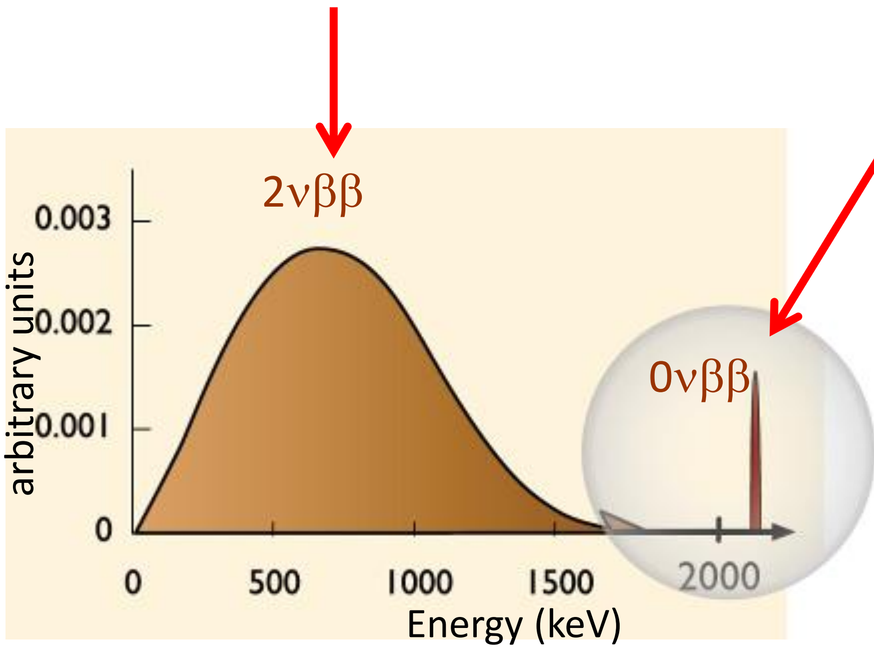
The **GER**manium **D**etector **A**rray (GERDA) Collaboration:
~ 100 physisists
19 institutes
7 countries

Motivation

The GERDA experiment is an ultra-low background experiment aimed to search for ^{76}Ge $0\nu\beta\beta$ decay.





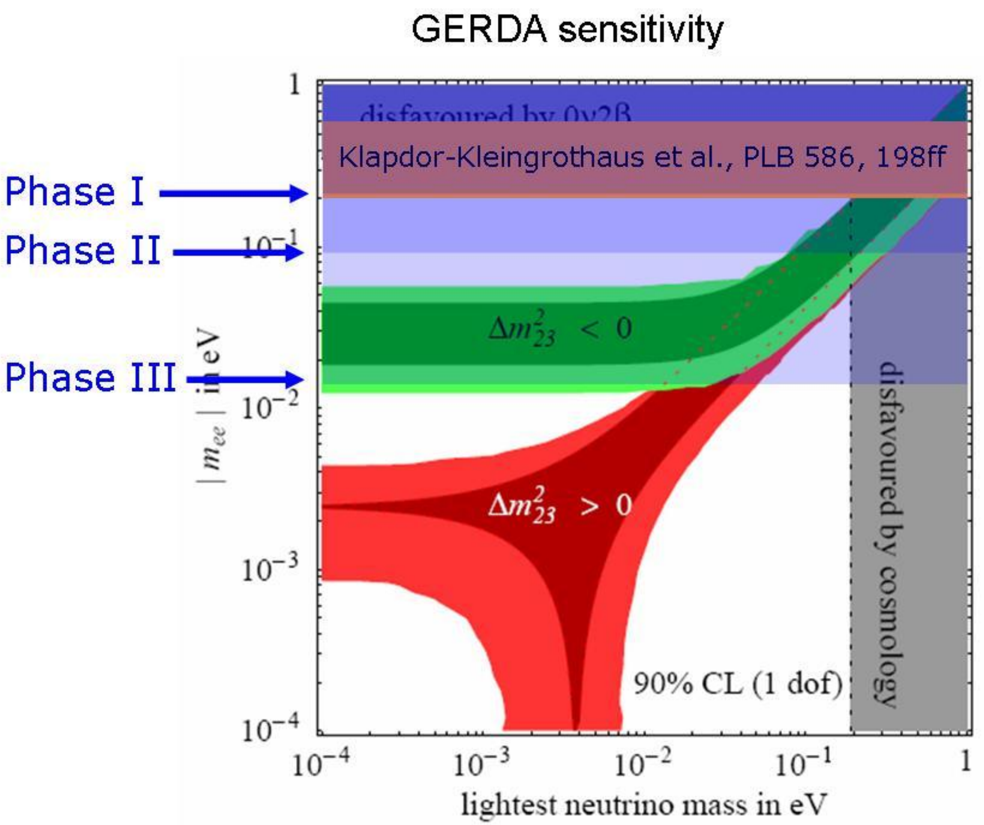


Searching for $0\nu\beta\beta$ helps to understand:

- Nature of ν (Dirac or Majorana)
- Neutrino mass scale
- Neutrino hierarchy

Motivation

Best limits on (0νββ)-decay half-life **$1.9{\cdot}10^{25}$ y** and **$1.6{\cdot}10^{25}$ y**, correspond to **$|m_{ee}| < 0.3 - 1.1$ eV**, have been obtained with HPGe detectors in the previous experiments **Heidelberg-Moscow & IGEX** with using Enriched Germanium (86% in ^{76}Ge, Q_{bb}=2038,5 keV)



Part of H-M Collaboration, claimed evidence for 0νββ observation with the best fit

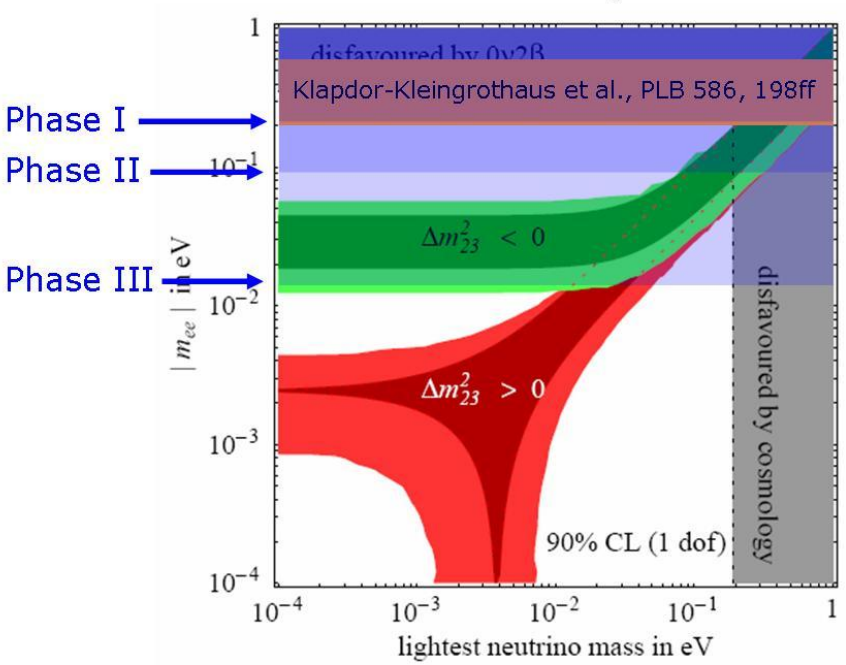
$T_{1/2}$ = $1.2{\times}10^{25}$ *y*, | *m_{ee}* | = 0.44 eV

H.V. Klapdor-Kleingrothaus, et.al, NIM A 522 (2004)

The main goal of the GERDA experiment is searching for neutrinoless double beta decay of ^{76}Ge. Within 1 year of data taking with considerable reduction of background GERDA will able to check claim of H-M experiment.

Phases of GERDA

GERDA sensitivity



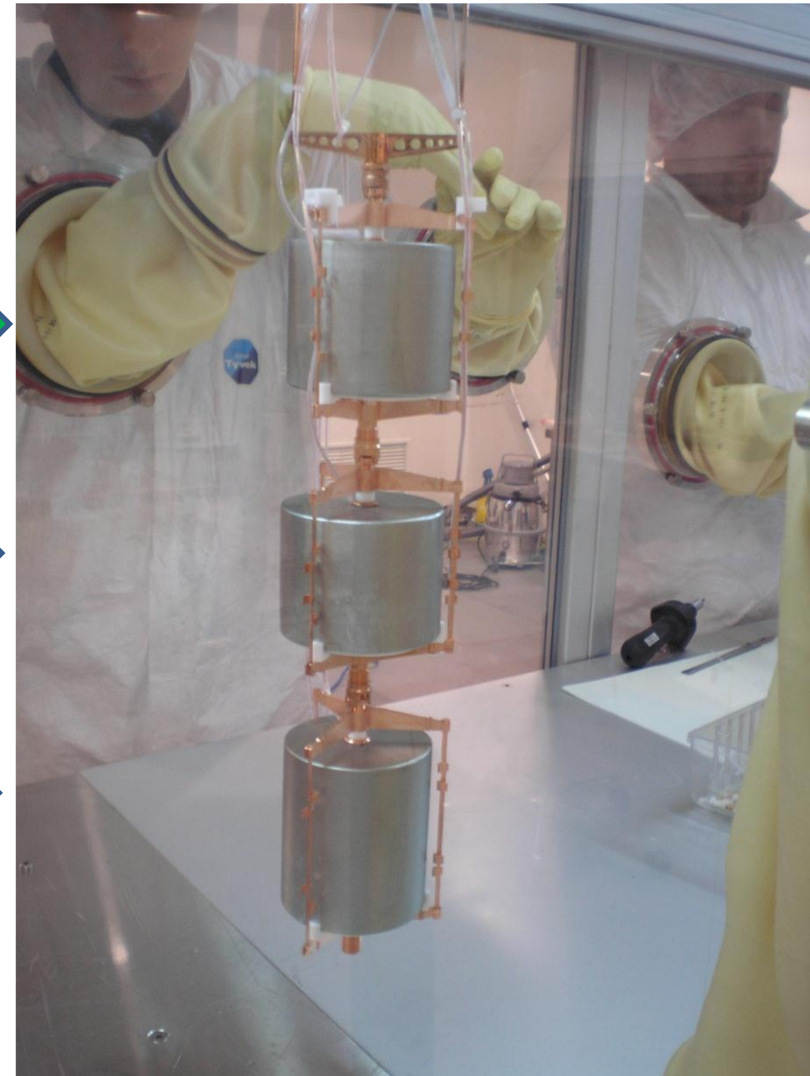
Three phases of GERDA experiment has been proposed:

- **Phase I:** 8 existing enriched detectors (18 kg of ^{76}Ge total) from the previous Heidelberg-Moscow and IGEX experiments, and 6 natural HPGe detectors (in total 15 kg of natural Ge) from the Genius Test-Facility will be deployed. Expected BI ~ 0.01 counts (kg · keV · year)
- **Phase II**: BEGe detectors (>20 kg of ^{76}Ge). In total: 40 kg of ^{76}Ge + 15 kg of natural Ge. In addition several detectors from depleted of ^{76}Ge material will be incorporated too. Expected BI ~ 1 counts (ton · keV · year)
- **Phase III:** Depending on the results of phase II possible GERDA-MAJORANA collaboration aimed to cover inverted hierarchy. Planned BI ~ 0.1 counts (ton · keV · year)

General concept

In IGEX and H-M experiments it was shown that main part of the detector's background is due to radioactive contamination of surrounding materials (including copper cryostat).

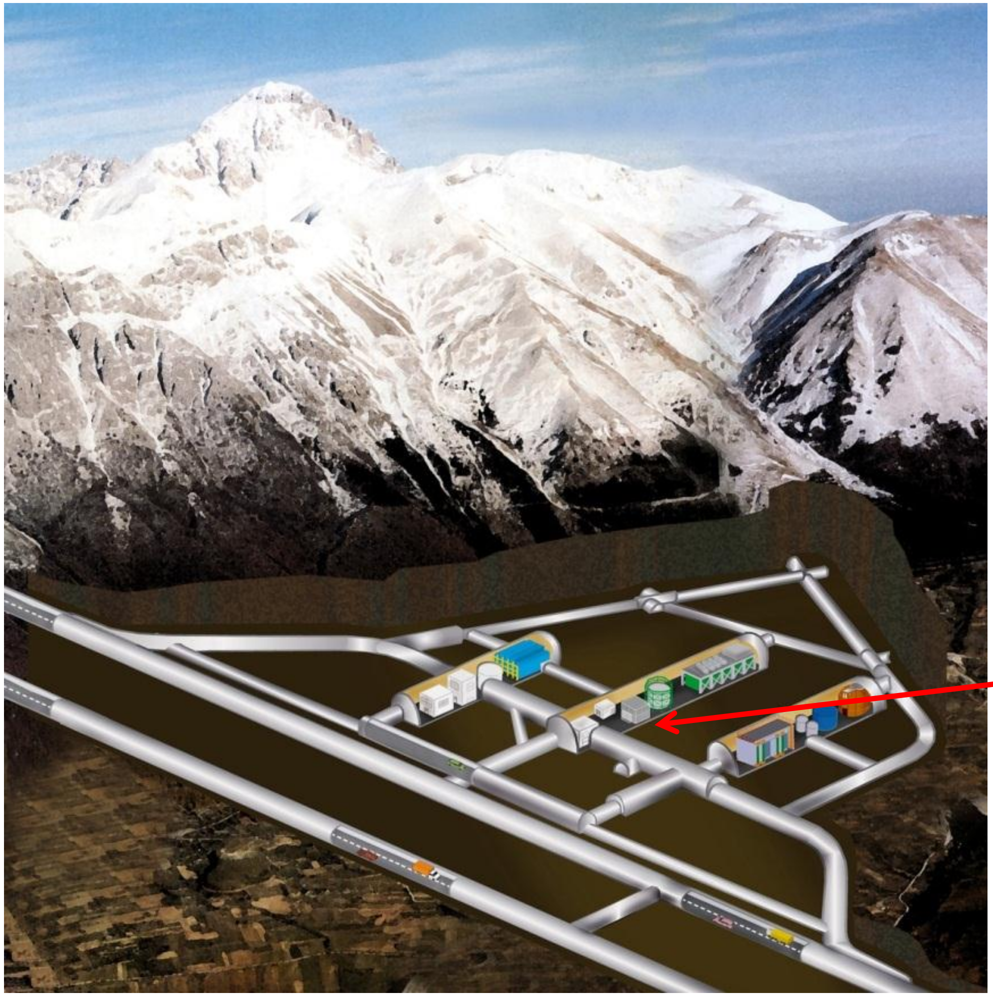
So, in GERDA we use "naked" Ge detectors submerged into the High-Purity liquid Ar which shields from the radiation and cools down the Ge detectors.



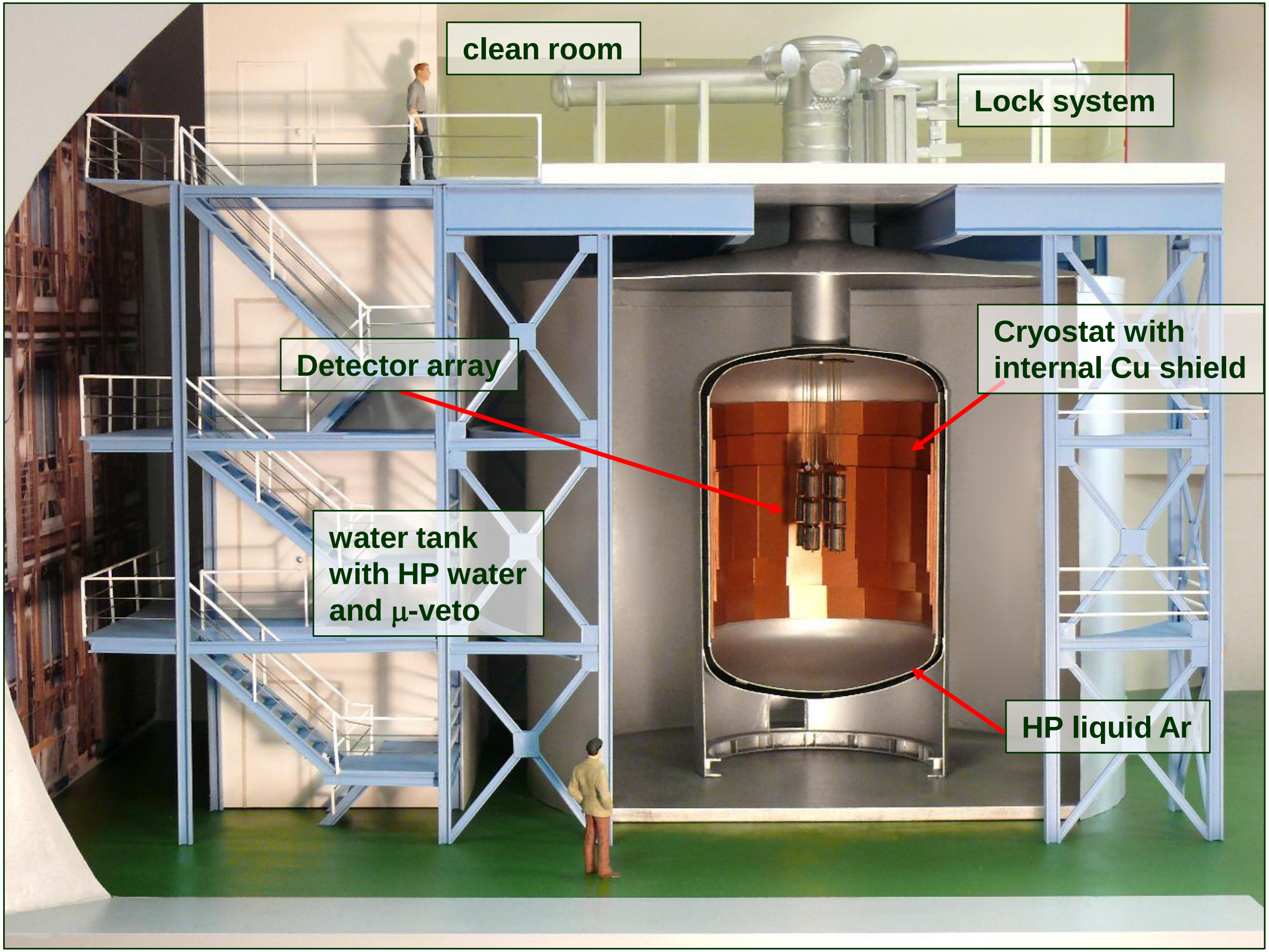
30g Cu, 6.3g PTFE, 1g Si per detector

Background reduction

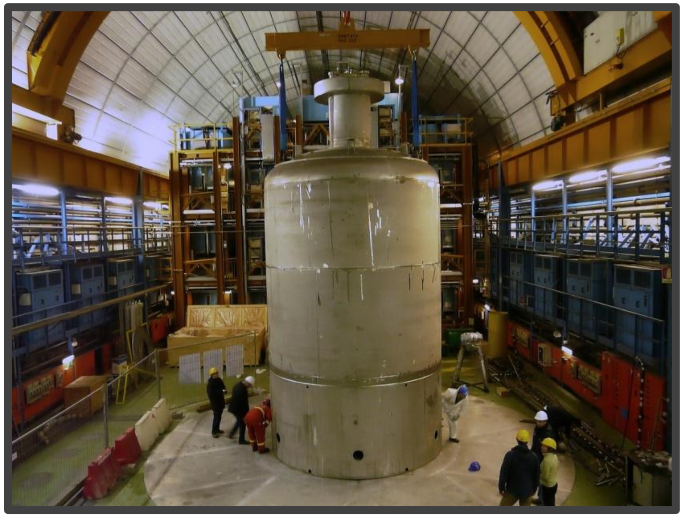
GERDA experiment located at LNGS underground laboratory (Italy). The rock overburden is equivalent to 3400 m.w.e. This allows to reduce μ (~ 10^6 times) and neutron flux induced by cosmic radiation.



Scheme of GERDA



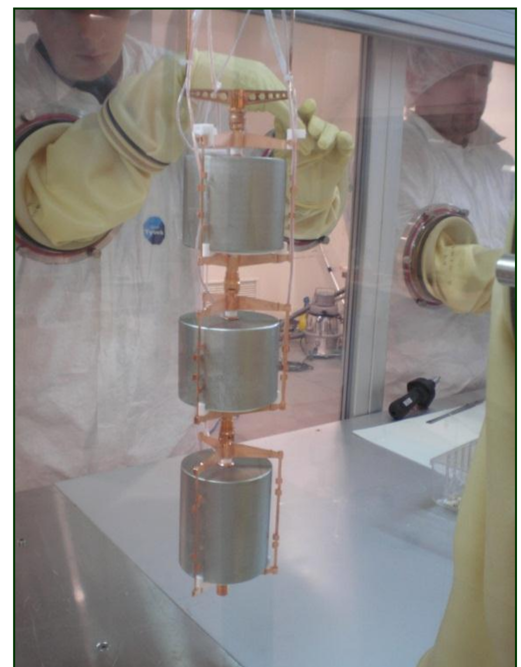
Stages of installation process


Stages of installation process

History of installation:

- 12.09 cryostat has been filled with liquid Ar.
- 05.10 first submerging of the non-enriched detector into the liquid Ar.
- 06.10 start commissioning with non-enriched detectors in GERDA.

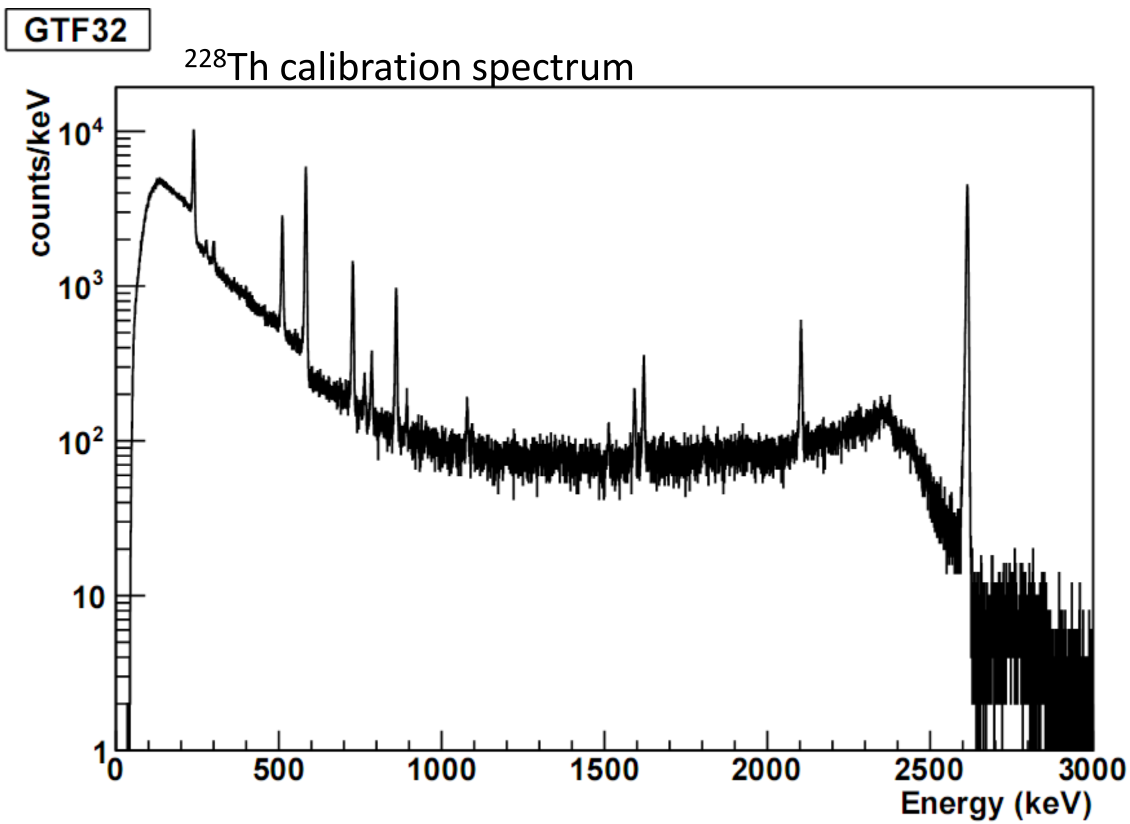


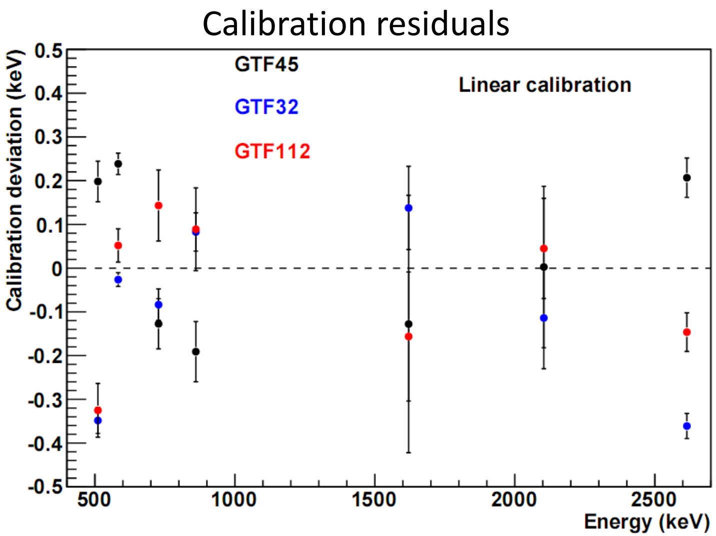
Calibration measurements

Since June 2010 commissioning of GERDA has been started. Non-enriched detectors has been used. Detectors work stable in liquid Ar.

Energy resolution of Phase I detectors is 3.6 - 6 keV (FWHM at 2.6 MeV) depending on the configuration of the detector and surrounding.

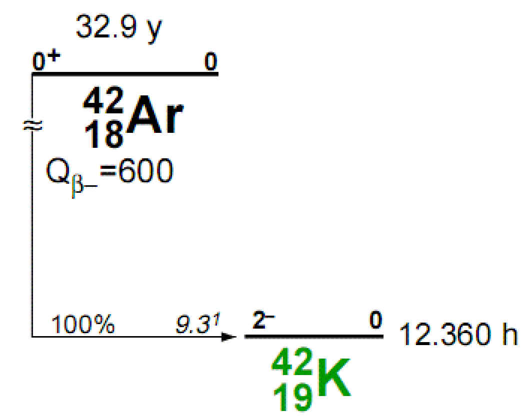
Energy resolution of Phase II detector (BEGe) is 2.8 keV (FWHM at 2.6 MeV).

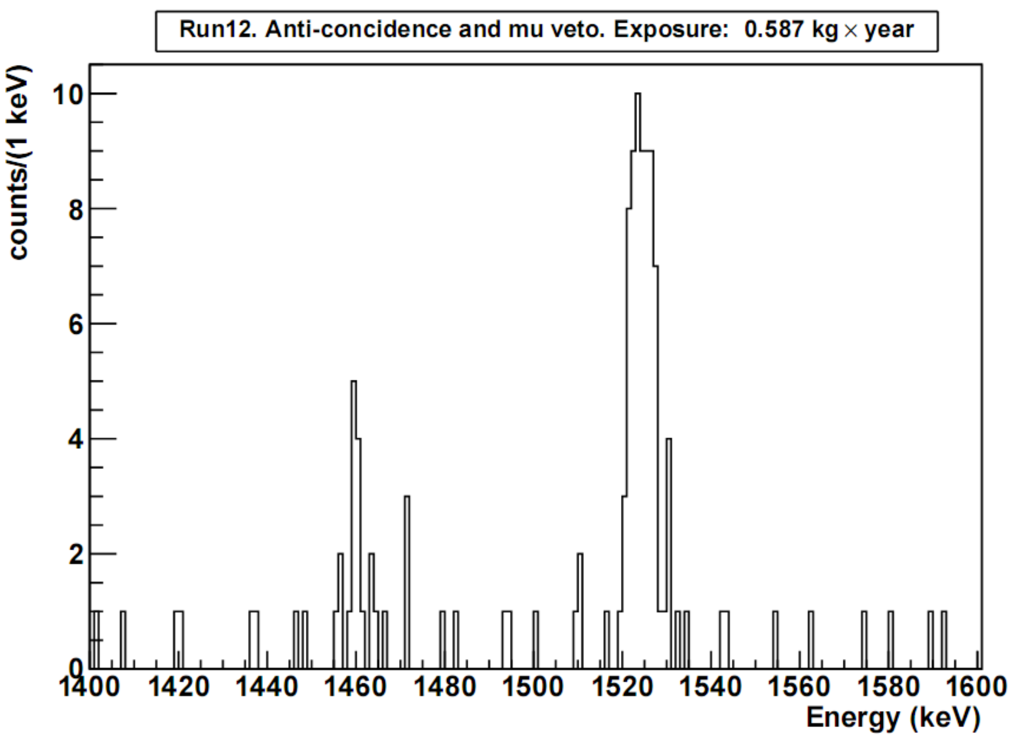


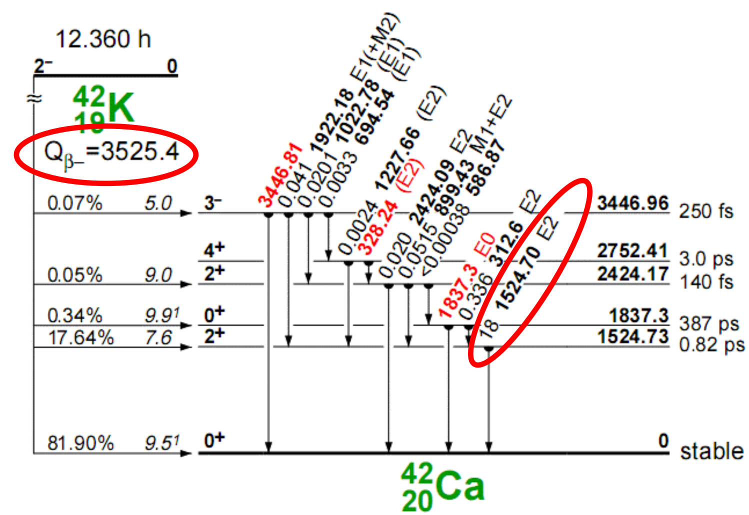


Unexpected ^{42}Ar background

In proposal of GERDA for estimation of the ^{42}Ar concentration, it was taken a limit of $^{42}Ar/^{nat}Ar < 3\cdot10^{-21}$ [Barabash et al., 2002]. After deposition of the detector into GERDA we found that intensity of 1525 keV peak from ^{42}K (daughter of ^{42}Ar) at least 10 times more than expected from limit [Bar02]. Beta decay of ^{42}K near detector could increase a background for $0\nu\beta\beta$ search. Incorrect limit or ^{42}K ion collection on the surface?



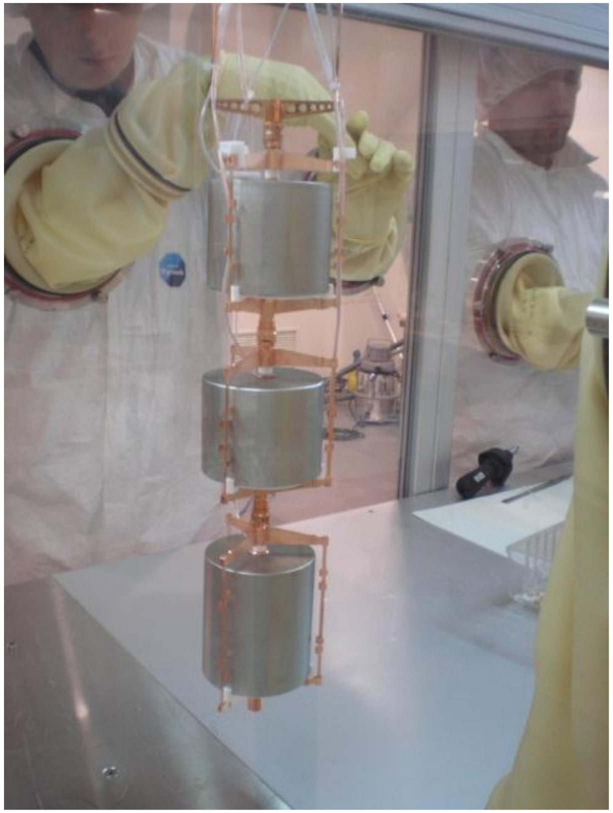




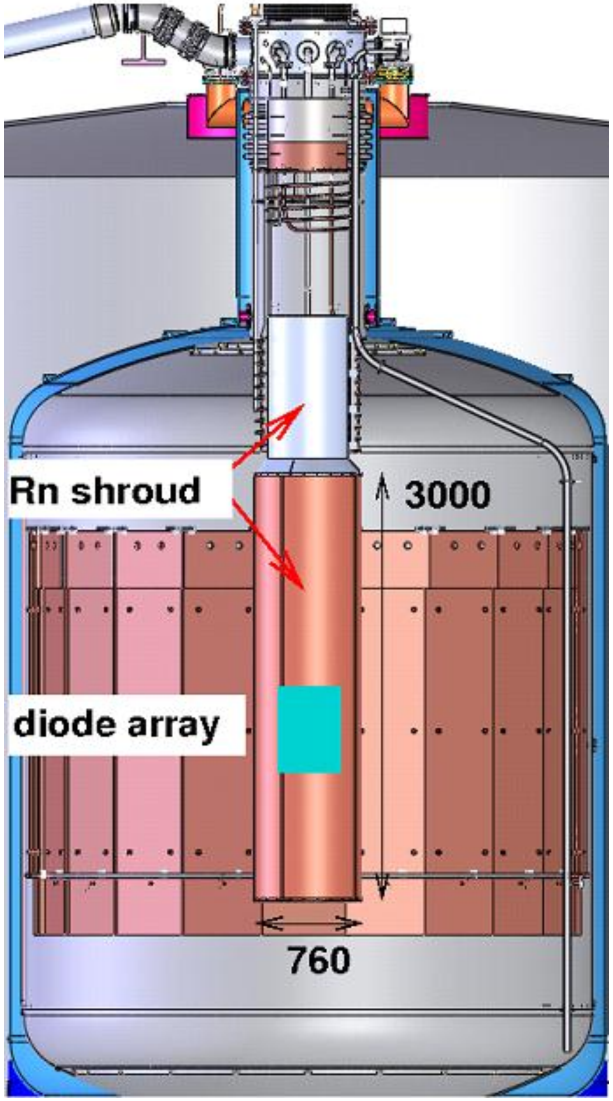
Creating the field to drift ^{42}K ions

If positive or negative ions of ^{42}K are drifting in the liquid Ar they could be attracted by the E-field of the detectors or another electrodes. To check this different electrical fields have been organized by using shroud and mini-shroud.

Detectors without mini-shroud



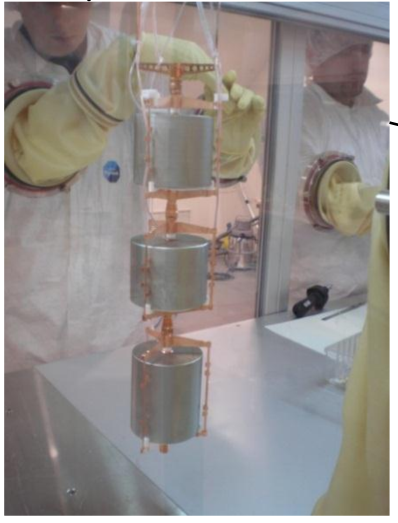
Detectors with mini-shroud



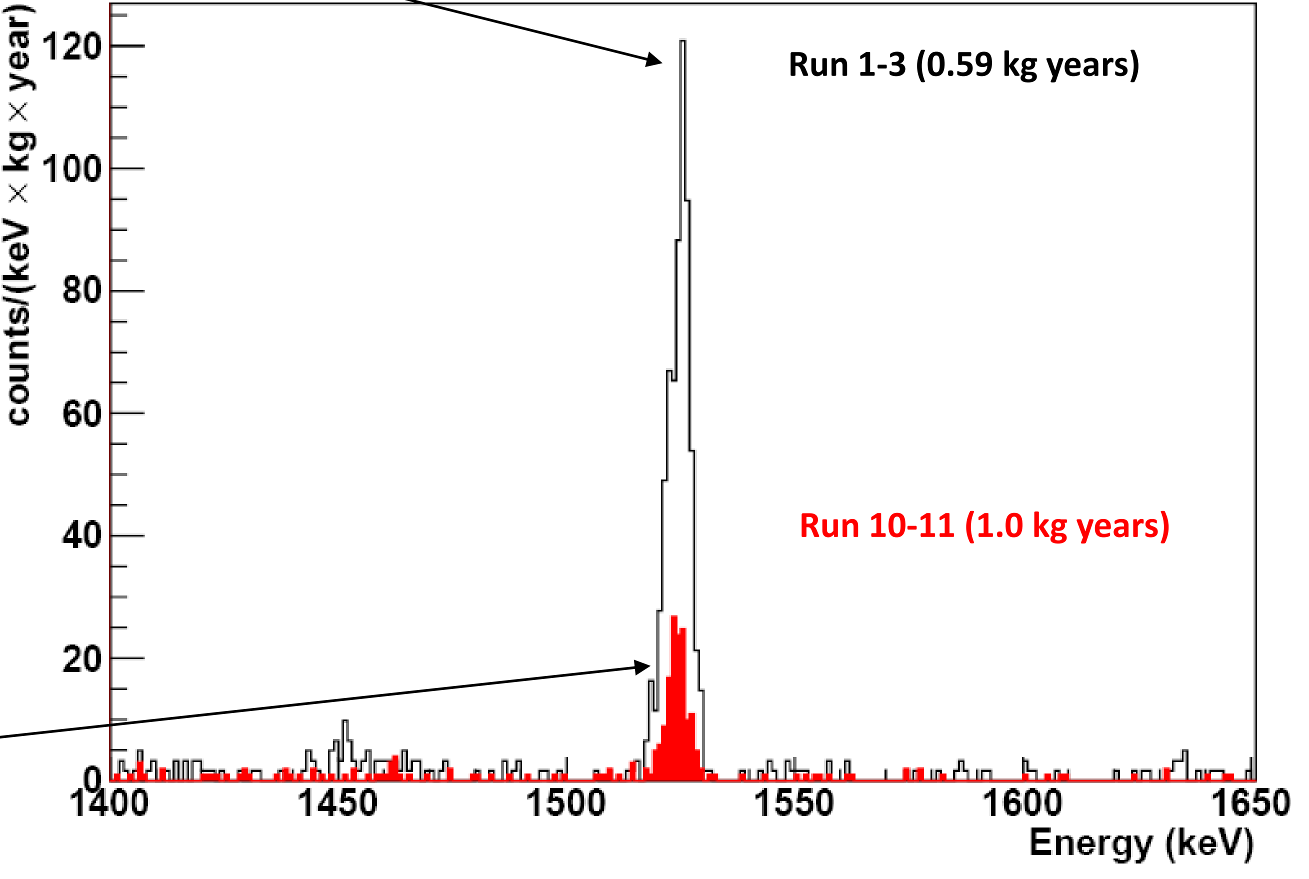
Rate of ^{42}K

It was found that initial intensity of ^{42}K peak is significantly higher than with "E-field free" configuration.

w/o mini-shroud

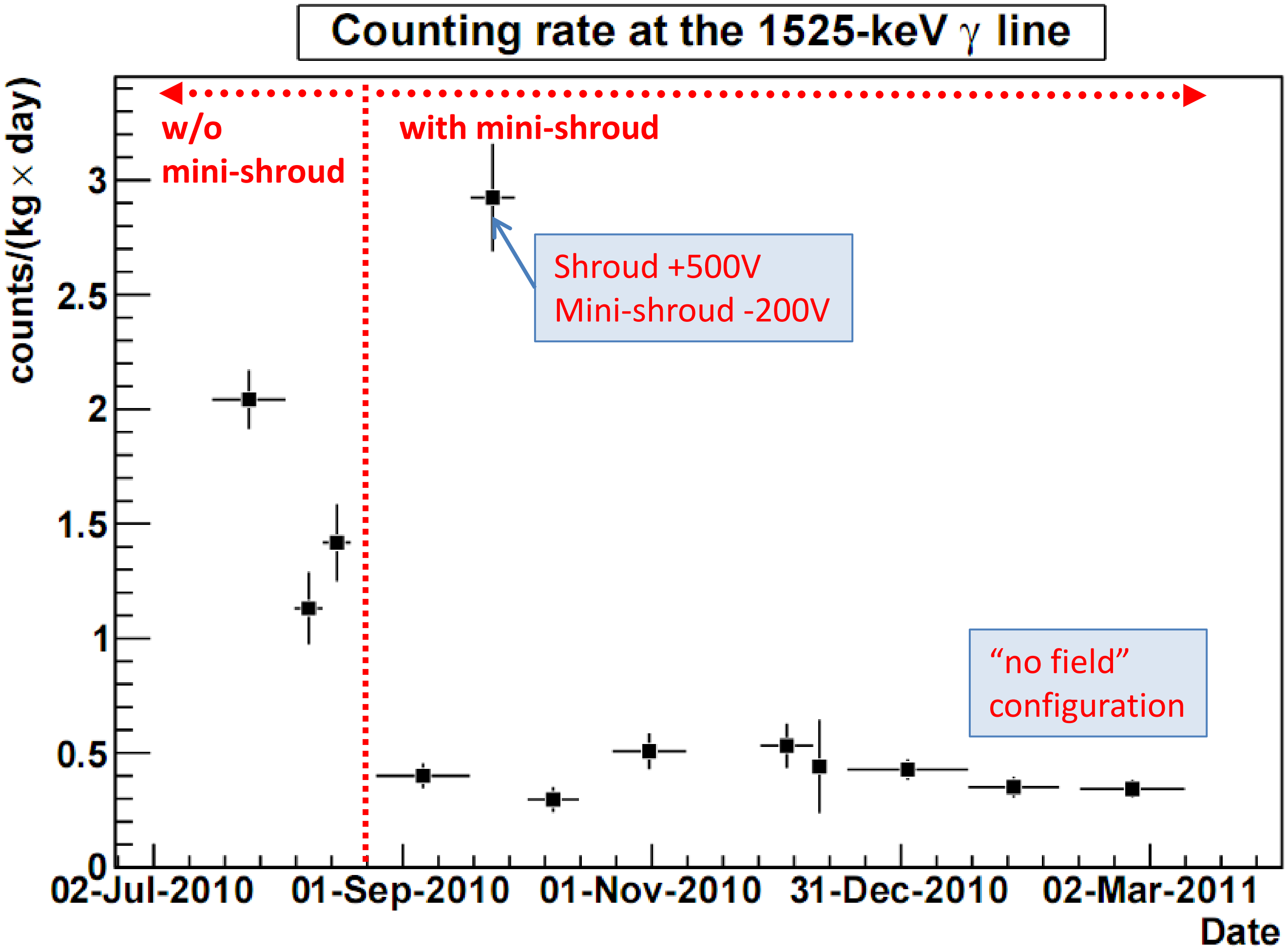


mini-shroud



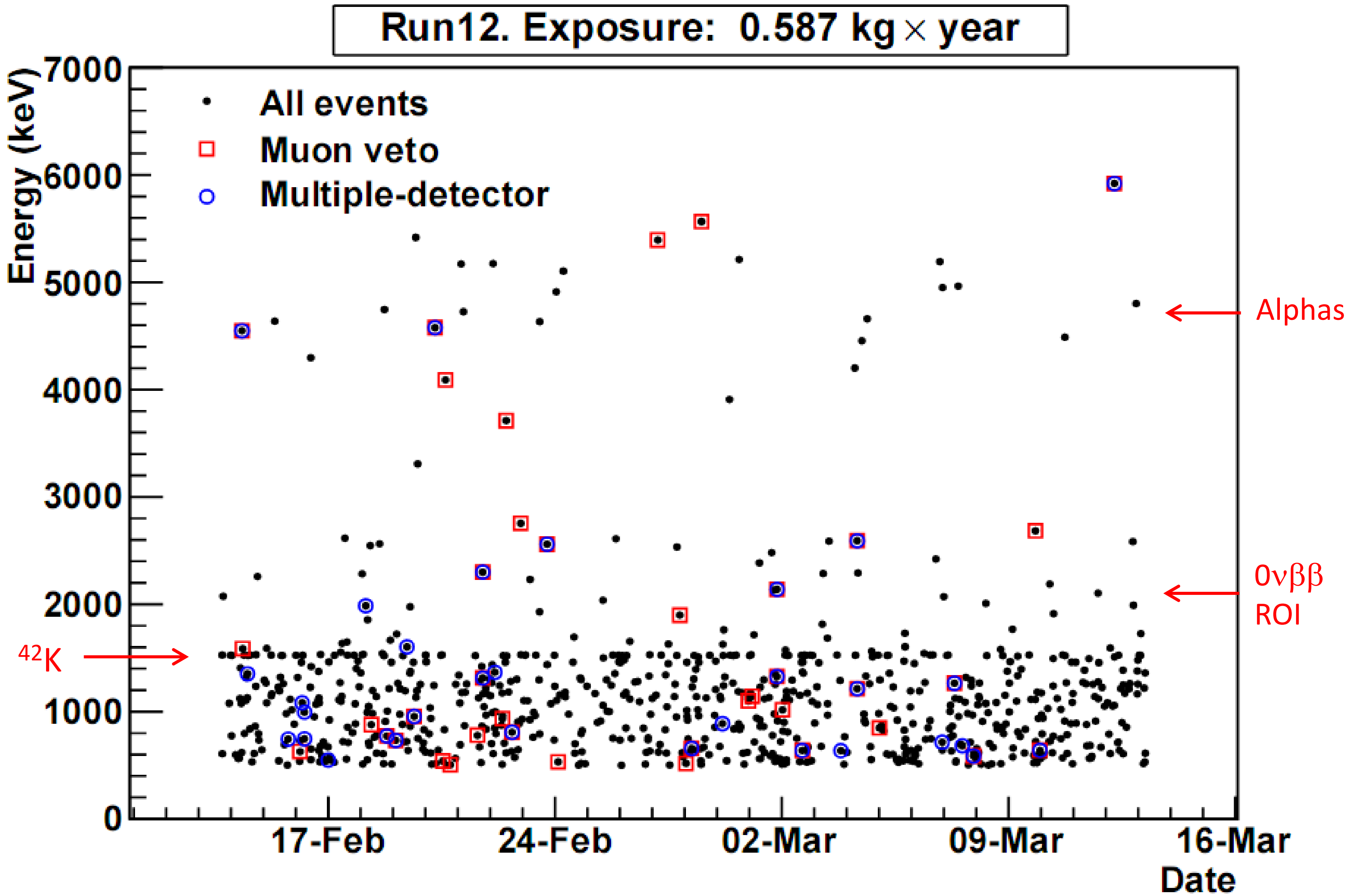
Rate of ^{42}K

Since June 2010 12 commissioning runs with different electric field configuration has been performed. Count rate of the 1525 keV peak from ^{42}K decay changes almost in 10 times depending on different E-field near the detector.



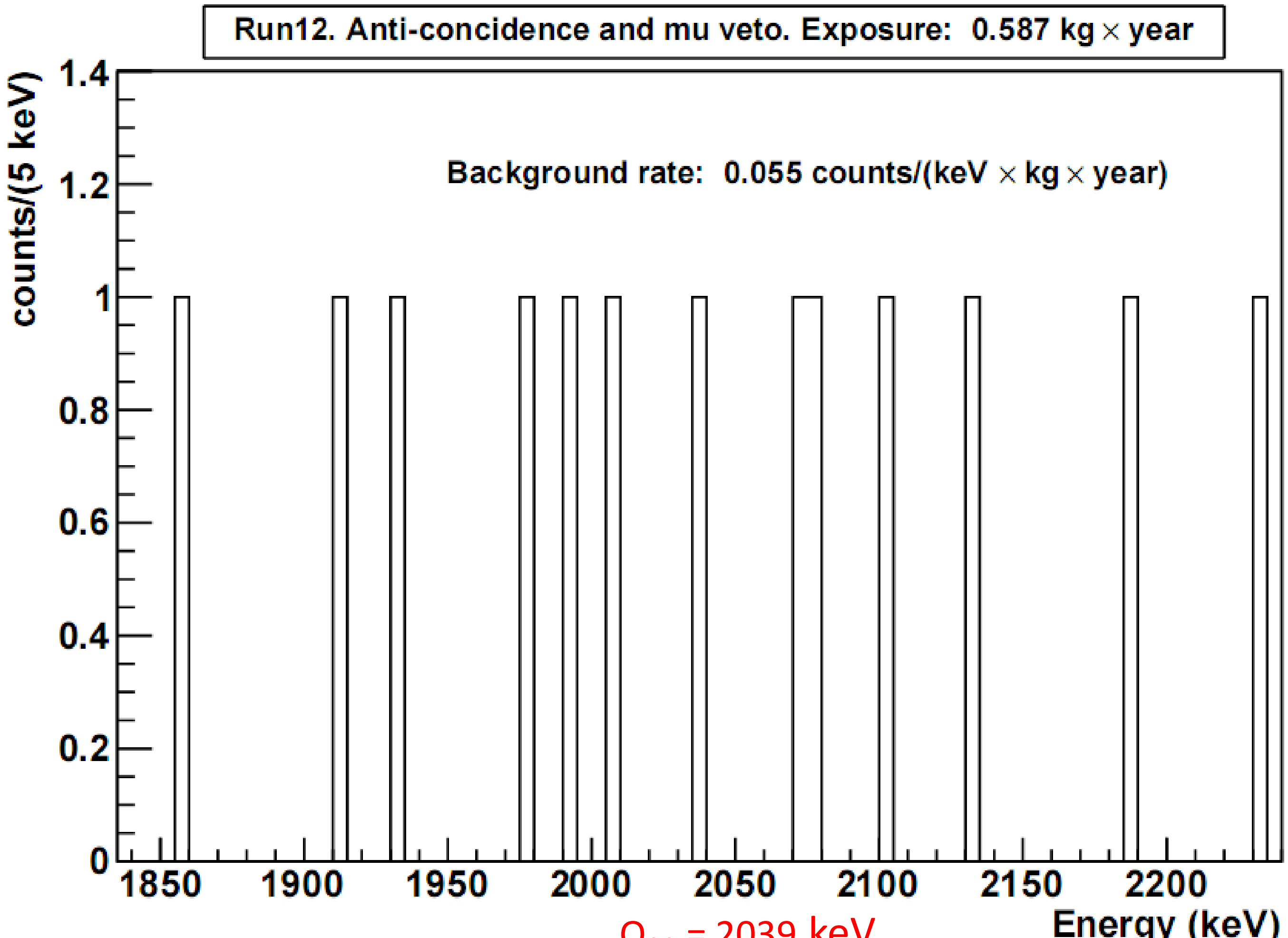
Also ^{42}K "problem" was investigated in LArGe low-background test facility. With no field configuration ^{42}K rate is 0.050±0.023. So we have possibilities for further suppression of background from ^{42}K in GERDA.

Background vs. time



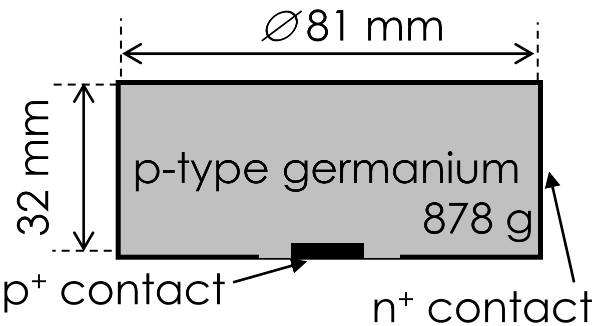
Background index in ROI for run12

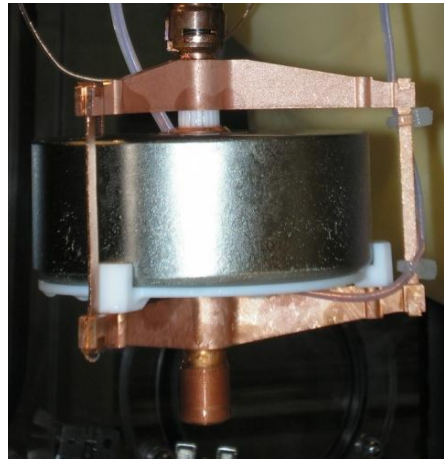
Background index is significantly lower than in previous experiments but still higher than Phase I proposal (0.01 counts/(keV·kg·year)). Next steps: runs in field free configuration and with **enriched** germanium detectors with **low** cosmogenic activation.

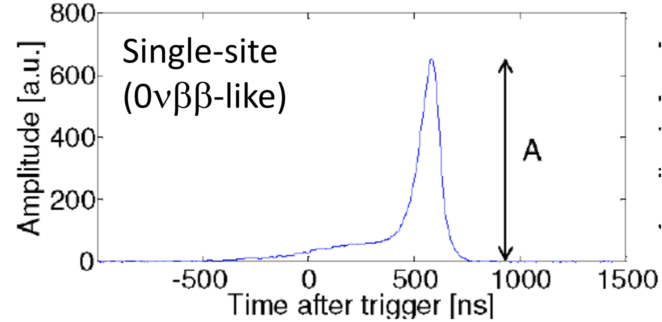


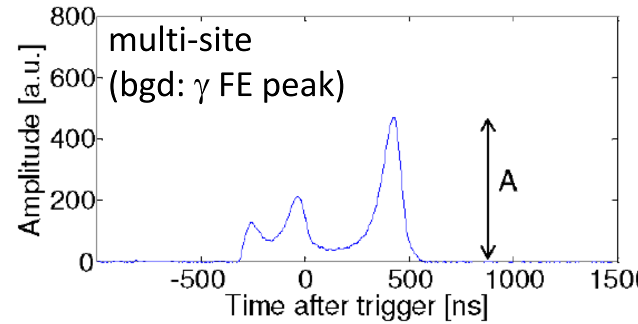
$Q_{\beta\beta}$ = 2039 keV

Phase II detectors BEGe

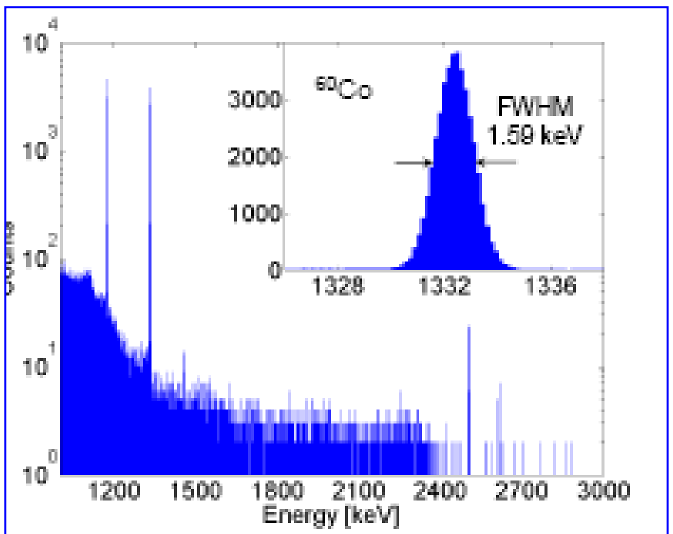


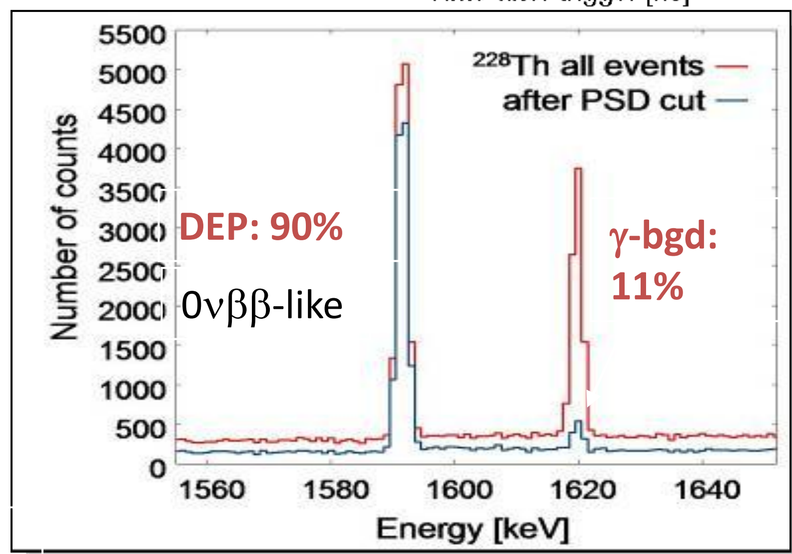






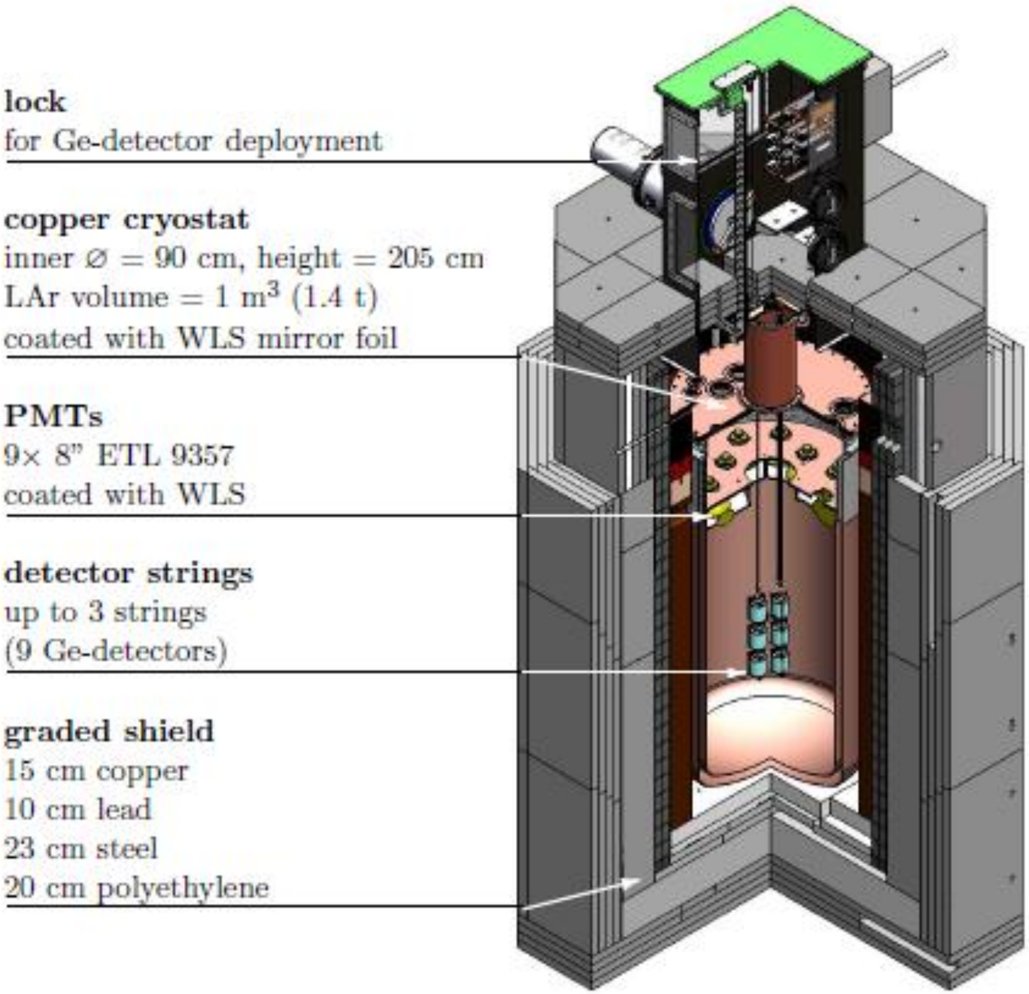
FWHM @ 59.5 keV	0.49 keV
FWHM @ 1.33 MeV	1.59 keV





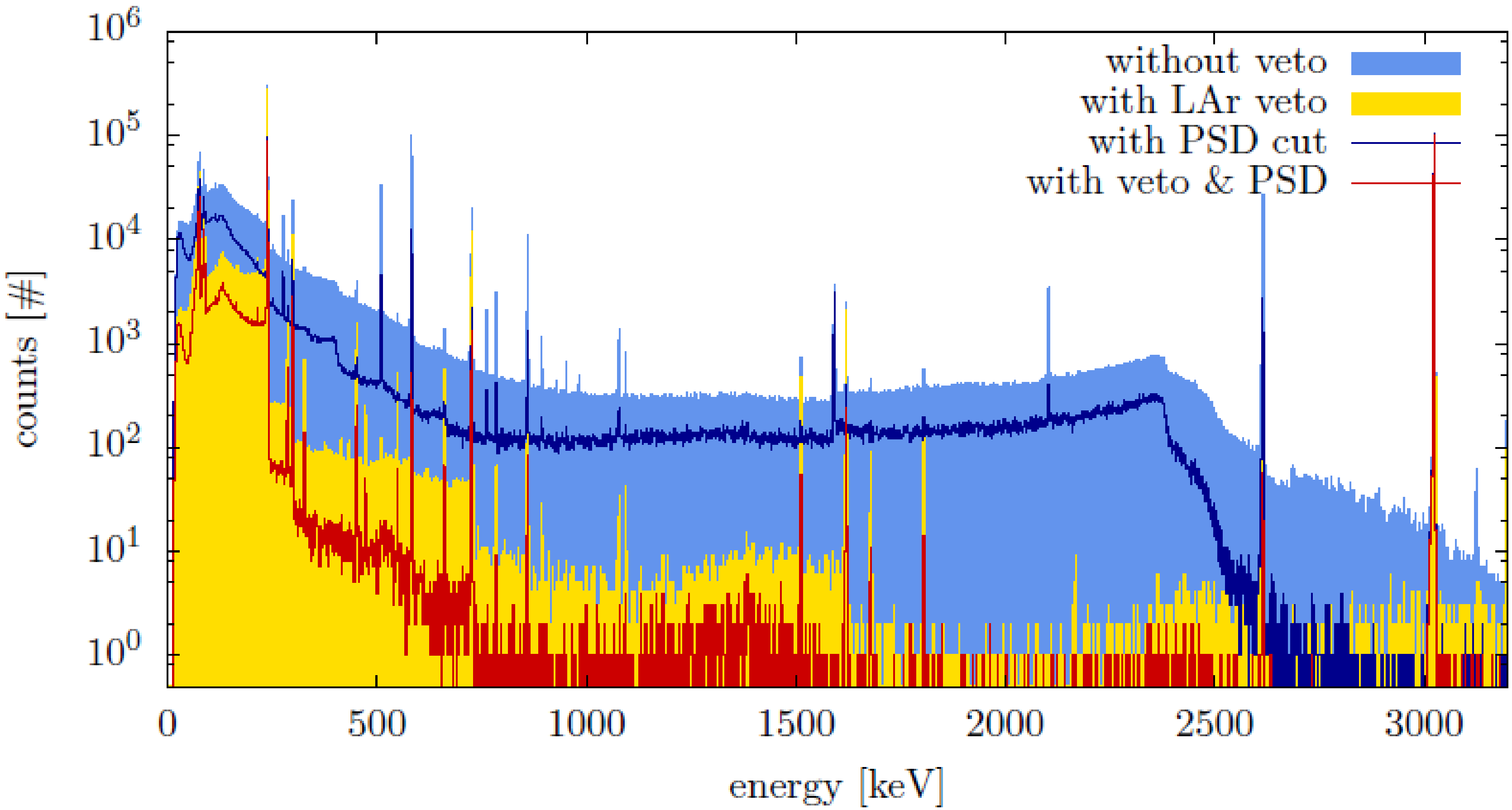
LArGe test facility

LArGe is a low background test facility, which has been created in order to investigate possibility to suppress background by using anticoincidence with liquid Ar scintilation signal detected by PMTs.



LArGe test facility

Measurements with BEGe detector inside LArGe show very good suppression of background. As an example, for ^{228}Th inner source the suppression factor > 5000 has been obtained after applying LAr VETO and PSD.

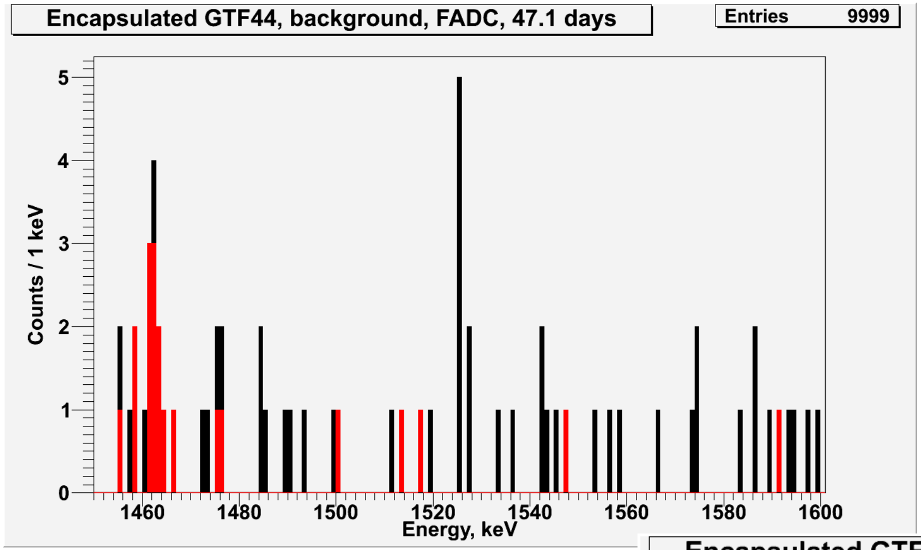


Conclusion

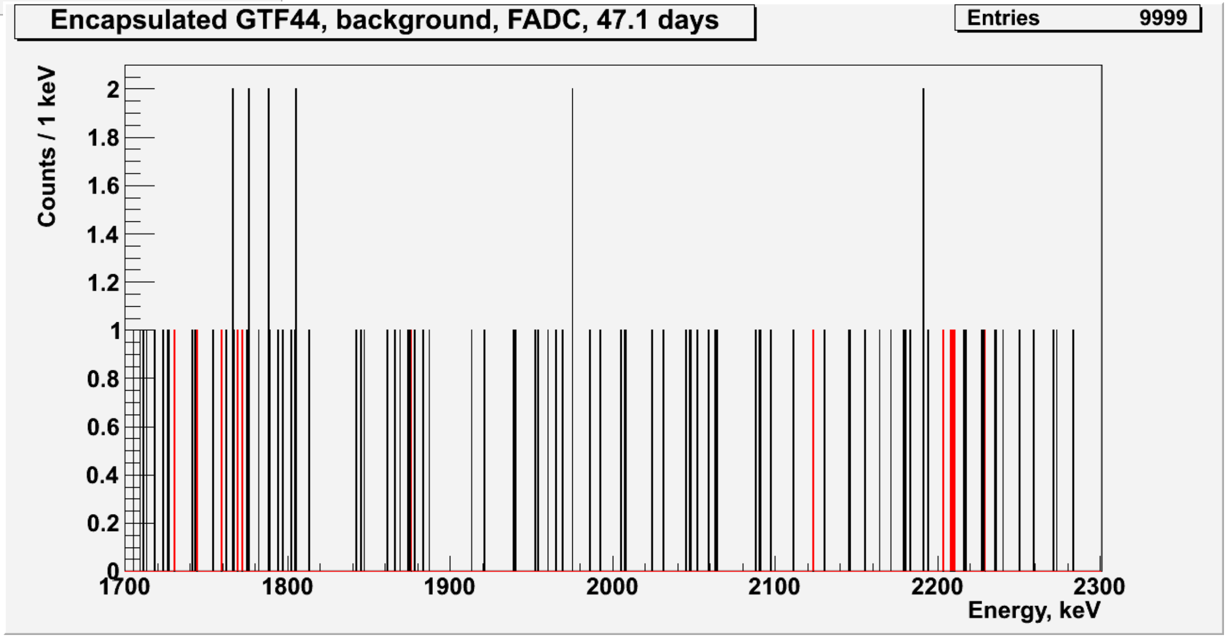
- GERDA experimental setup has been installed and working stable. Commissioning runs with non-enriched germanium detectors has been started.
- Background rate of ^{42}K is different with different field configuration and could be suppressed.
- BI in ROI of $0\nu\beta\beta$ is 0.05 counts /(keV·kg·year), it is significantly better than in predecessor experiments.
- Possibilities of further suppression of the background have been developed (BEGe and LArGe).
- Enriched detectors will be deployed into the GERDA detector soon.

Back up slides

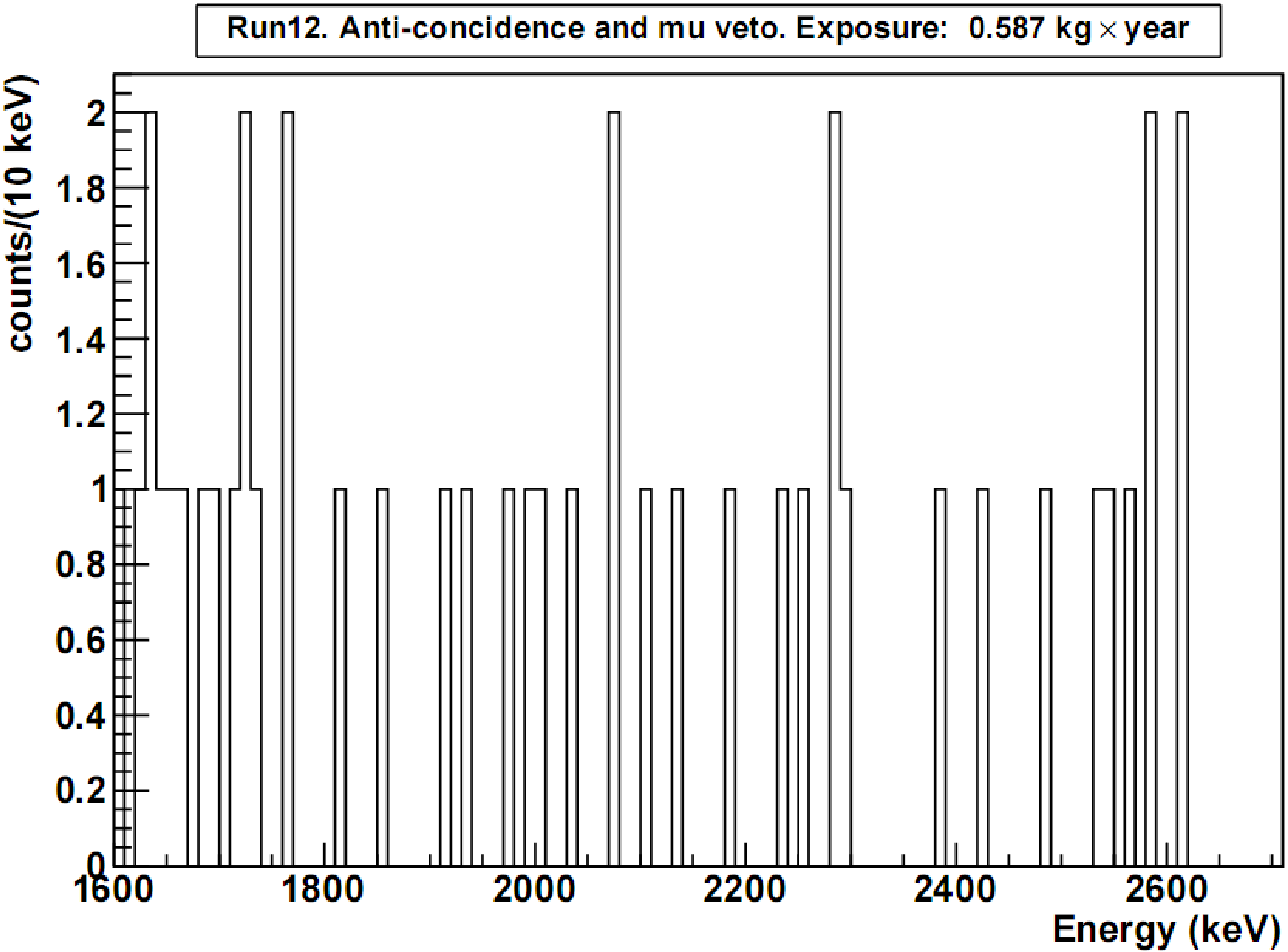
LArGe test facility



Estimated ^{42}Ar concentration is $(2.1 \pm 1.9) \cdot 10^{-21}$ [90% c.l.].

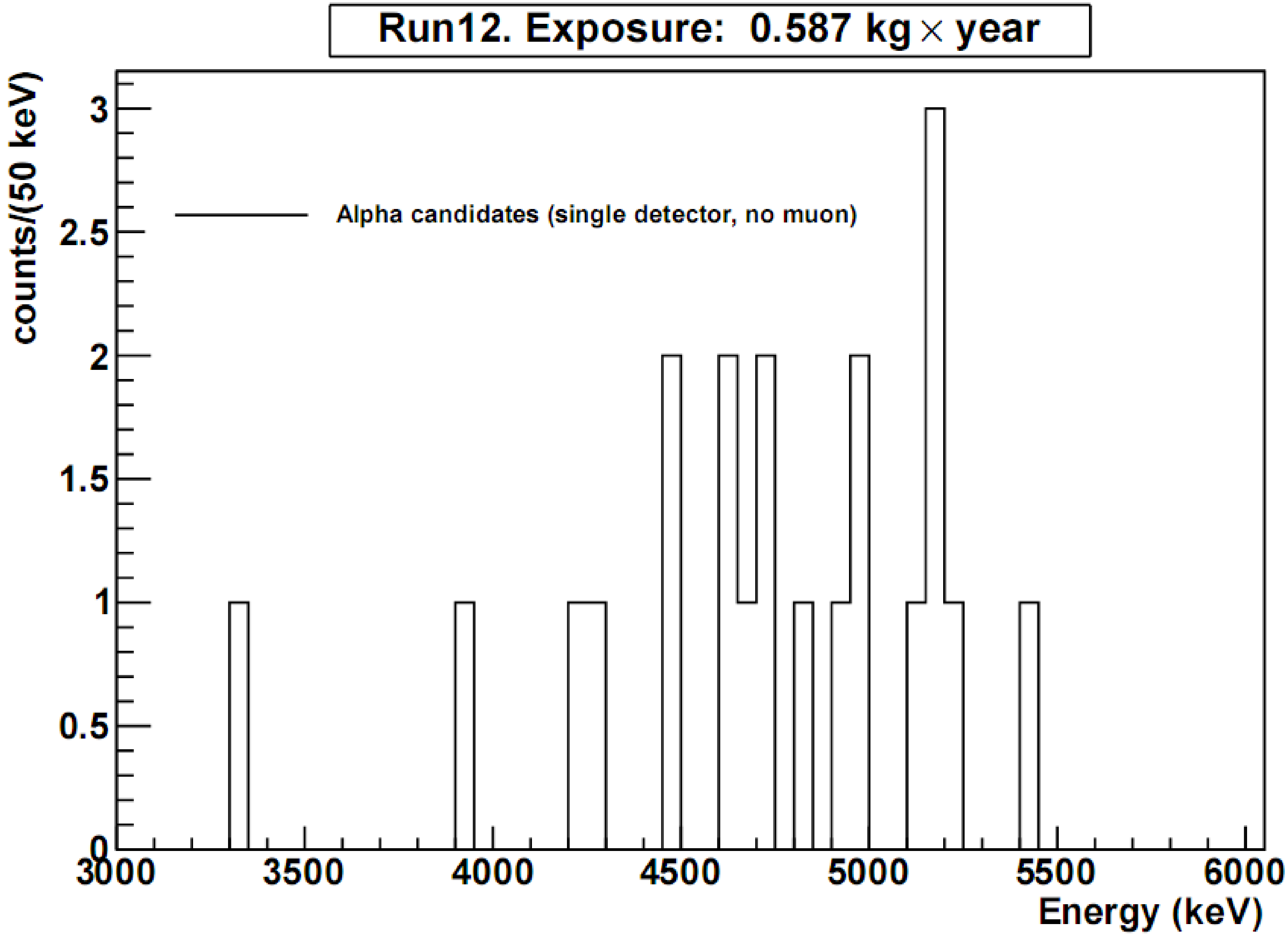


GERDA



Run12. Anti-concidence and mu veto. Exposure: 0.587 kg × year
counts/(10 keV)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1600
1800
2000
2200
2400
2600
Energy (keV)

GERDA



Run12. Exposure: 0.587 kg × year
Alpha candidates (single detector, no muon)
counts/(50 keV)
3
2.5
2
1.5
1
0.5
0
3000
3500
4000
4500
5000
5500
6000
Energy (keV)

DBD and some values

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

$0\nu\beta\beta$ Decay rate	Phase space factor	Matrix element	Effective Majorana Neutrino mass

$$T_{1/2} \propto M_{nucl}\; a\; \varepsilon \sqrt{\frac{m\,t}{b\,\delta E}}$$

Simplest explanation for observations by 3-neutrino flavor mixing

Neutrino Mixings

Weakly interacting and mass eigenstates are independant basis

$$\begin{bmatrix} |\nu_e\rangle \\ |\nu_\mu\rangle \\ |\nu_\tau\rangle \end{bmatrix} = \begin{bmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{bmatrix} \begin{bmatrix} |m_1\rangle \\ |m_2\rangle \\ |m_3\rangle \end{bmatrix}$$

$$U_{\nu i} = \begin{bmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta_{13}} \\ -s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta_{13}} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta_{13}} & s_{23}c_{13} \\ s_{12}c_{23} - c_{12}c_{23}s_{13}e^{i\delta_{13}} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta_{13}} & c_{23}c_{13} \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & e^{i\frac{\alpha_{21}}{2}} & 0 \\ 0 & 0 & e^{i\frac{\alpha_{31}}{2}} \end{bmatrix}$$

Activity of Tl-208, **mBq/kg**:

Rock, concrete	~ 3000
Stainless steel	< 5
Cu(OFHC)	< 0.02
Water purified	< 0.001
LAr	~ 0

H-M

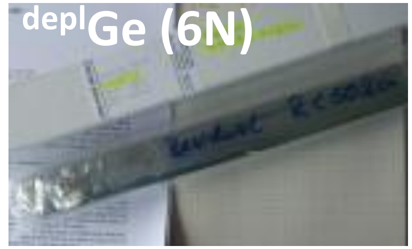
11.5 kg of enriched Ge detectors
71.7 kg yrs of data
0.11 Counts/(kg keV y) around 2040 keV
$T_{1/2} \geq 1.9 * 10^{25}$ years (90% C.L.) Eur. Phys. J.A 12 (2001)147.

Background: 0.16 counts/(keV kg year)
O. Chkvorets, Diss. Univ. Heidelberg, 2008

IGEX

6.8 kg of enriched Ge detectors
8.5 kg yrs of data
0.17 Counts/(kg keV y) around 2040 keV
$T_{1/2} \geq 1.6 * 10^{25}$ years (90% C.L.) Aalseth et al., Phys.Rev.D 65 (2002)092007

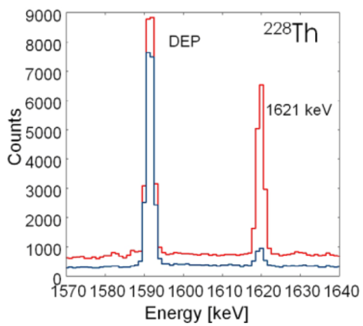
Production of BEGe detectors from ^{enr}Ge for GERDA Phase II



Crystal pulling

Full production chain tested with isotopic depleted germanium

crystal slice



After successful test of production production chain with ^{depl}Ge:

- **37.5 kg of 86% ^{enr}Ge** (in form of GeO2) purified to **35.4 kg (94%) of 6N** (+ 1.1 kg tail = 97%);
- crystal pulling and detector fabrication under preparation