# The GERDA experiment.
# Status and results of data taking.

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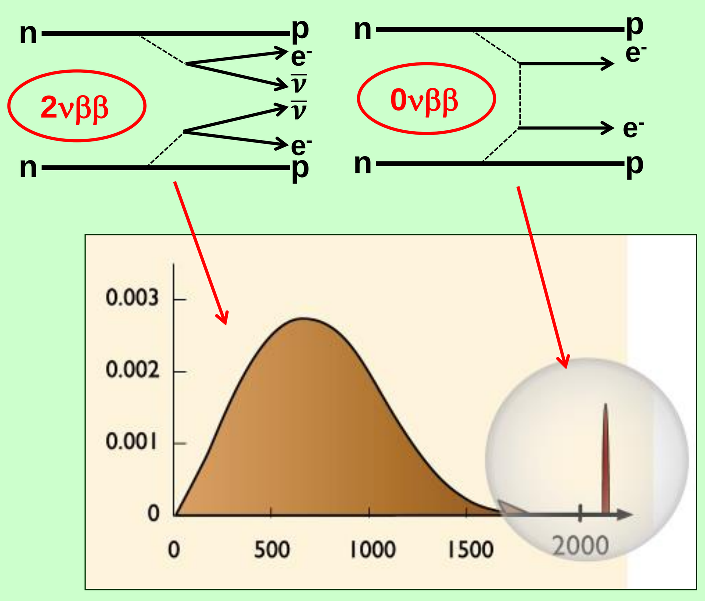
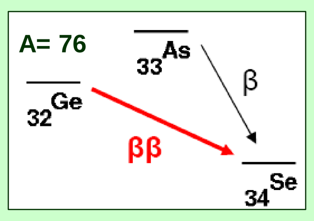
## Introduction

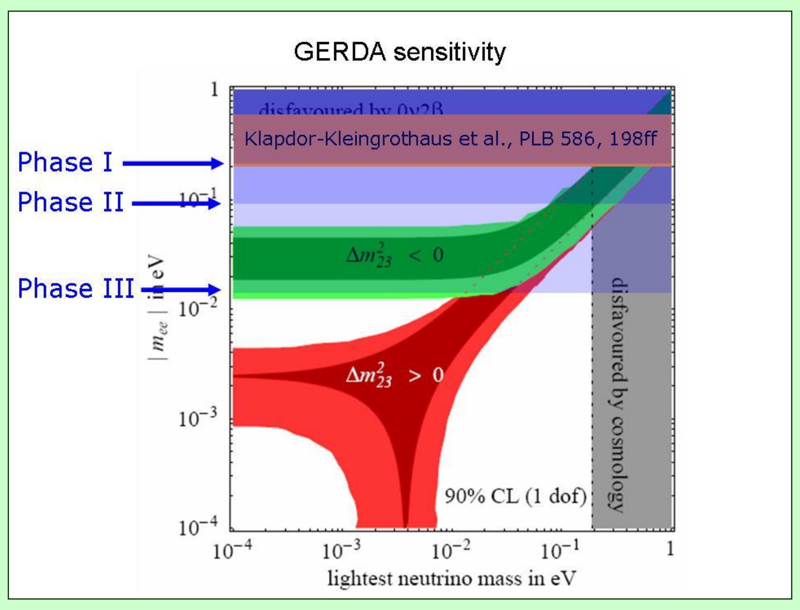
The study of neutrinoless double beta (0νββ) decay is a powerful approach to investigate fundamental properties of neutrinos.




Searching for the 0νββ decay helps to understand:
- Nature of ν (Dirac or Majorana)
- Neutrino mass scale
- Neutrino hierarchy

Part of H-M Collaboration, claimed evidence for 0νββ decay observation with the best fit $T_{1/2} = 1.19 \times 10^{25}$ yr [1].

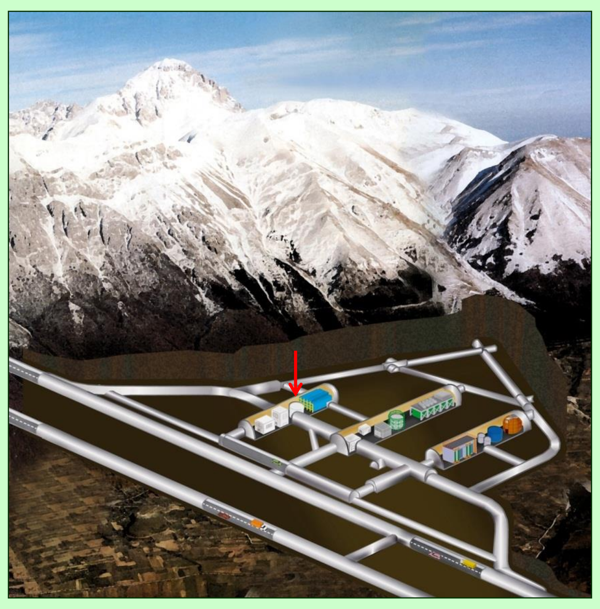



The GERDA experiment (GERmanium Detector Array [2]) is a low background experiment aims to search for the 0νββ decay of $^{76}$Ge. The aim of GERDA is to test the claim of discovery by part of Heidelberg-Moscow Collaboration, and, in a second phase, to achieve much better sensitivity than recent experiments.

**Phase I:** Deployed 8 existing enriched detectors (18 kg total), 3 natural HPGe detectors (in total 7.6 kg of natural Ge) and 5 enriched BEGe (3.6 kg from 7/07/2012)

**Phase II:** In addition new enriched BEGe detectors with total mass of about 20 kg will be incorporated together with liquid argon (LAr) scintillation veto.

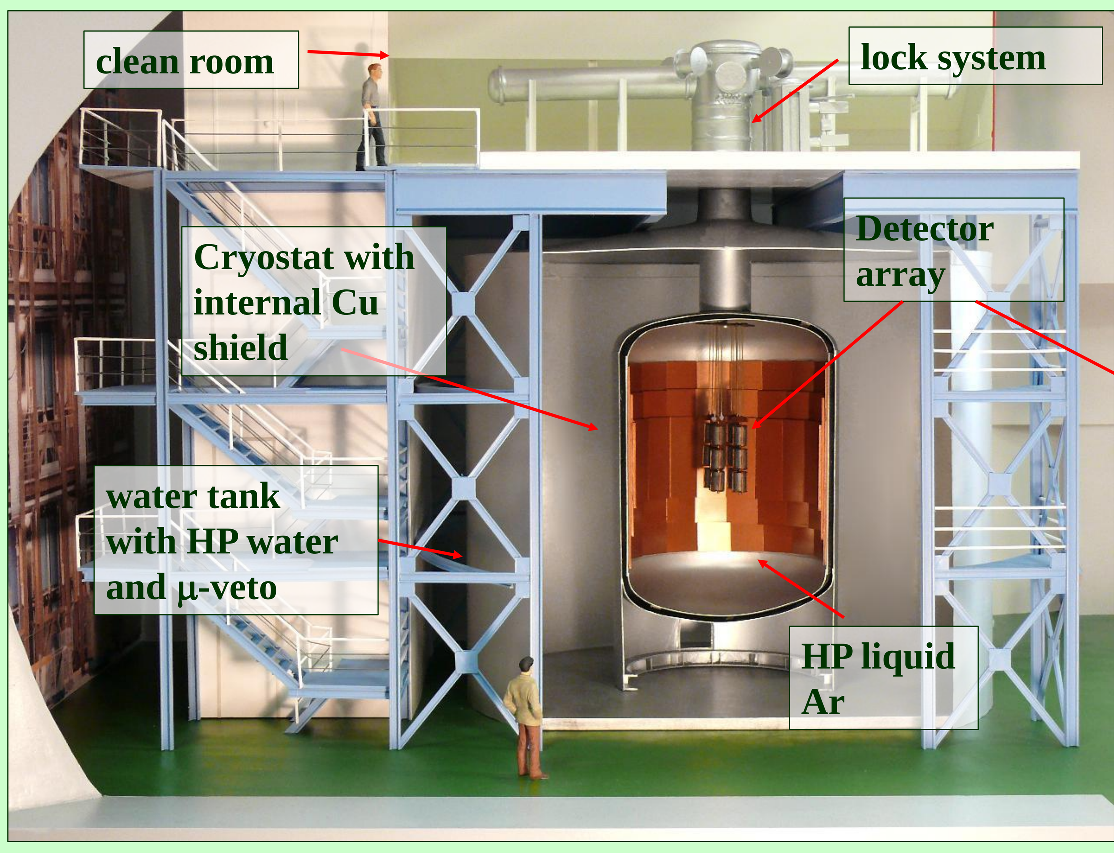
## Experimental setup



GERDA experiment located at LNGS underground laboratory (Italy). The rock overburden is equivalent to 3500 m.w.e.

GERDA background reduced by:
- Usage of bare HPGe detectors, enriched by 86% of $^{76}$Ge, low mass radioactive pure holders.
- Germanium detectors deployed in a cryostat with 64 m$^3$ LAr, which shields from the radiation and cools them down.
- Steel tank containing 590 m$^3$ ultrapure water equipped with Cerenkov μ-veto.
- Proper material selection and avoiding irradiation of the detectors.
- Anti-coincidence between different detectors is used during the analysis.
- Location in LNGS reduces μ flux (in ~ 10$^6$ times) and neutron flux induced by cosmic radiation.

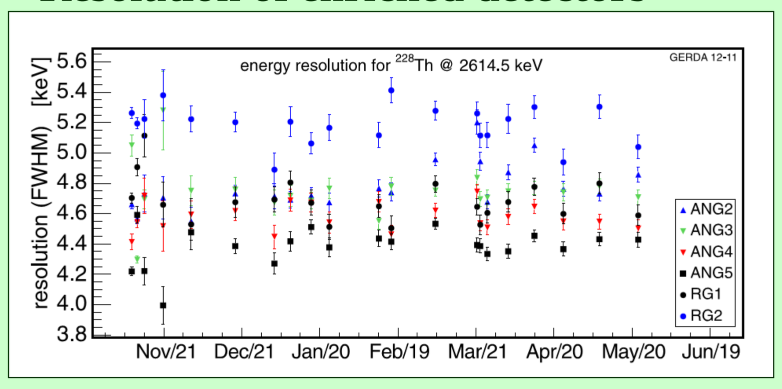
**Artistic view of GERDA Phase I setup**




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

## Results and discussion

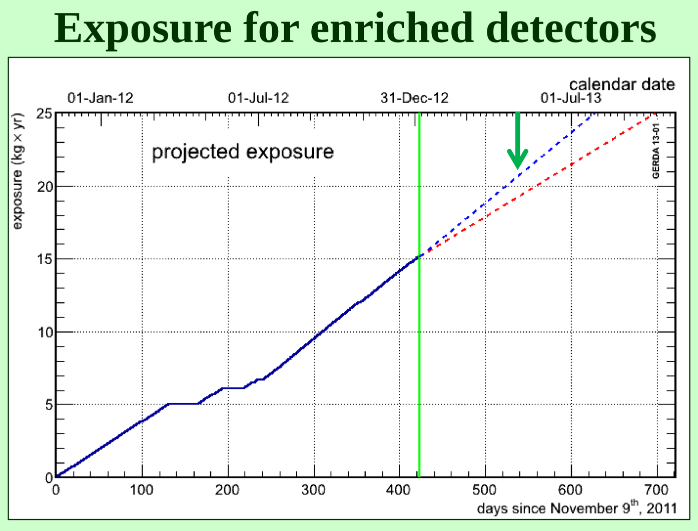
**Resolution of enriched detectors**



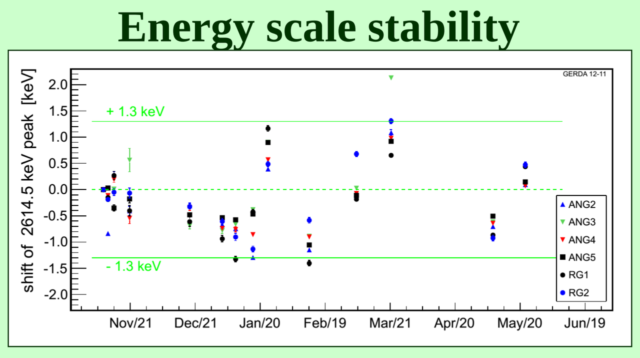
9/11/2011: Start Phase I in GERDA. 8 detectors HPGe coaxial detectors made from material enriched in $^{76}$Ge + 3 detectors from natural Ge were deployed. Resolution 4.2-5.3 keV at 2.6 MeV (FWHM) has been obtained. 6 enriched detectors used for analysis.

Accumulated exposure up to 02/05/2013:
Enriched coaxial: 18.6 kg·yr
Natural: 6.05 kg·yr
Enriched BEGe: 2.27 kg·yr

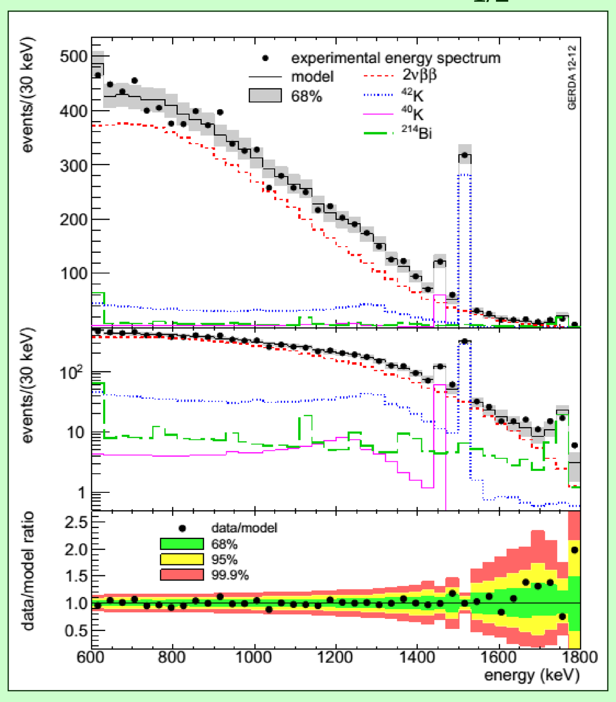
**Exposure for enriched detectors**

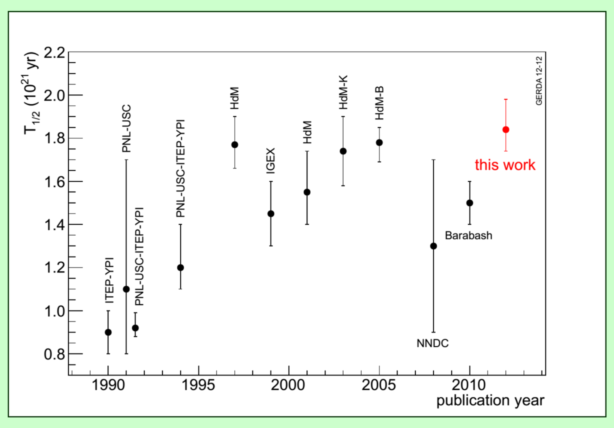



**Energy scale stability**



**Measurements of $T^{2\nu}_{1/2}$ [3]**






From analysis of first 126 days of data taking obtained half-life of the 2νββ decay:

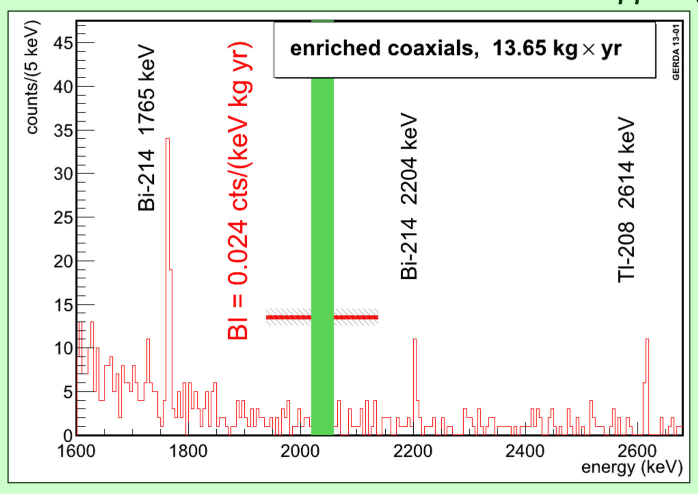
$$T^{2\nu}_{1/2} = (1.84^{+0.09}_{-0.08\,\mathrm{fit}}\ {}^{+0.11}_{-0.06\,\mathrm{syst}}) \cdot 10^{21}\ \mathrm{yr}$$

Data blinded between 2019 keV and 2059 keV. Background index (BI) is about 10 times lower than in previous experiments with $^{76}$Ge [2].

**Comparison with the previous experiments**

| experiment<br>diode environment | diodes | ΔE (keV) | exposure (kg yr) | background index $10^{-2}$ cts/(keV kg yr) |
|---|---|---|---|---|
| IGEX [30–33] | | | | |
| vacuum, Cu enclosed | enr | 2000–2500 | 4.7 | 26 |
| HdM [62] | | | | |
| vacuum, Cu enclosed | enr | 2000–2100 | 56.7 | 16 |
| GERDA commissioning | | | | |
| LAr | nat | 1839–2239 | 0.6 | $18 \pm 3$ |
| LAr, Cu mini-shroud | nat | 1839–2239 | 2.6 | $5.9 \pm 0.7$ |
| ditto | 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 | $2.0^{+0.6}_{-0.4}$ |

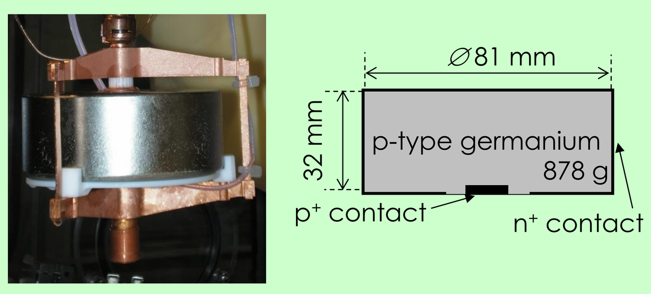
**Part of energy spectrum near $Q_{\beta\beta}$**




BI for coaxial detectors in $Q_{\beta\beta}\pm$ 100 keV energy region is 0.024 cts/(keV·kg·yr). Excluding higher background short period in July 2012: **0.017 ± 0.003 cts/(keV·kg·yr).**

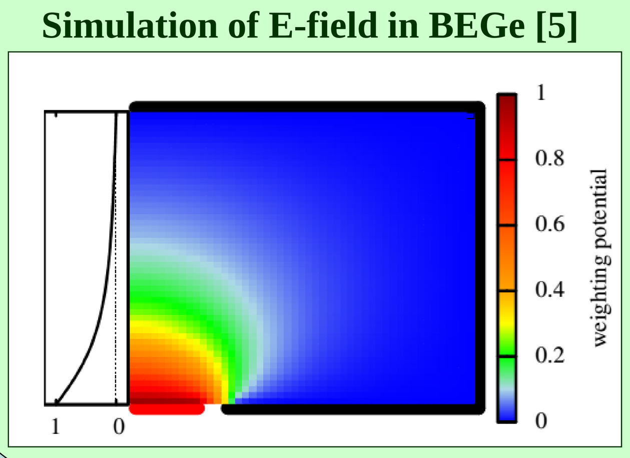
**Blinded region will be open in June 2013!**

## Phase II preparations



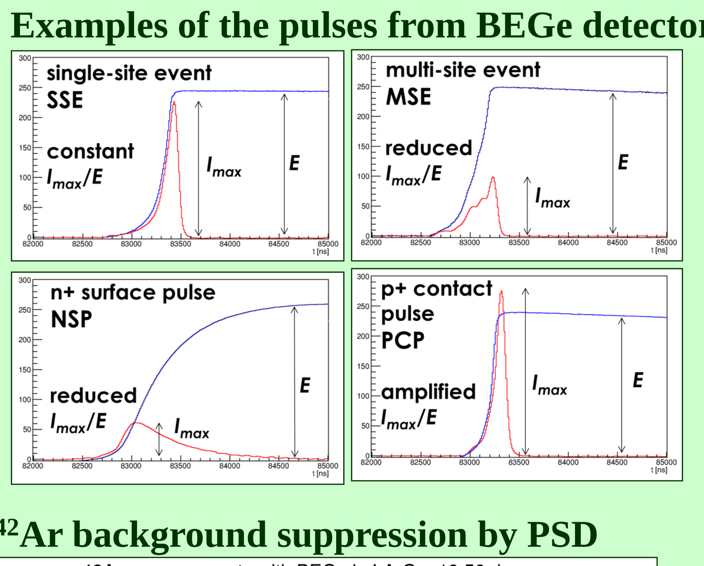

BEGe: new HPGe detectors for GERDA Phase II:
- Better energy resolution.
- Powerful pulse shape discrimination (PSD) [4].

**Simulation of E-field in BEGe [5]**

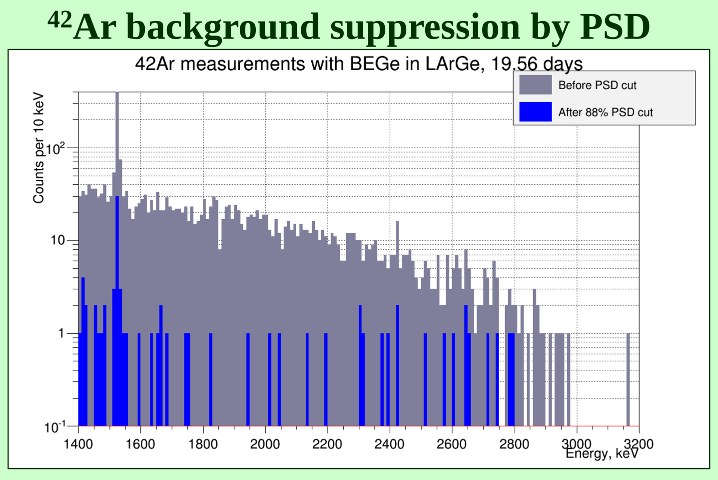


Pulse shape analysis of the BEGe detectors is a powerful tool to reject background events like multi-side events and surface events.

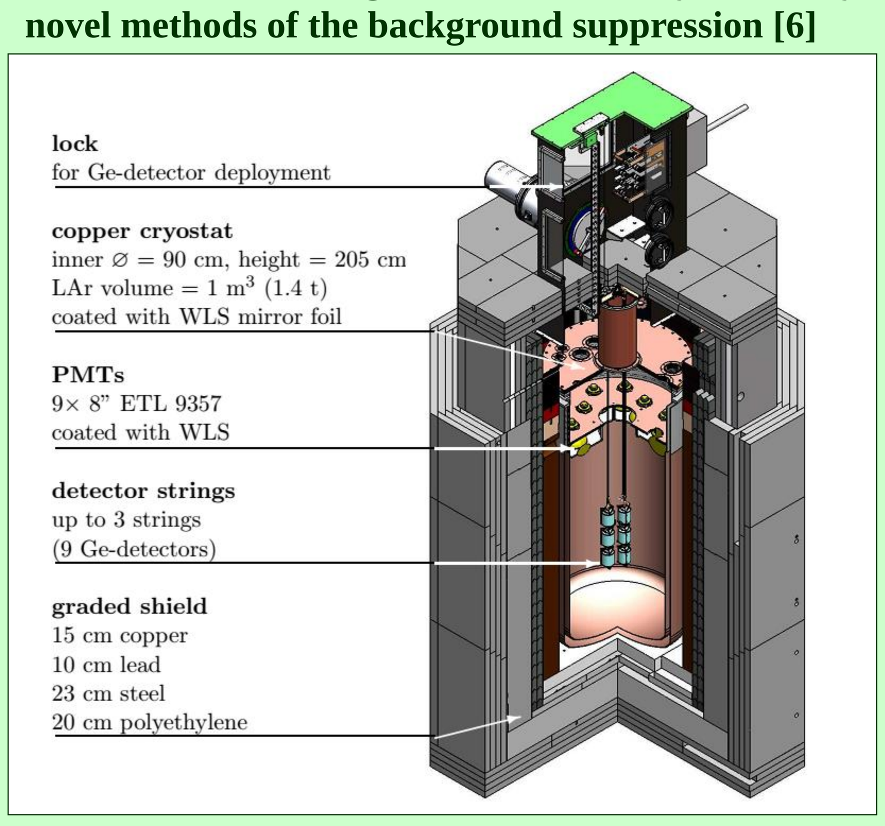
**Examples of the pulses from BEGe detector**




**$^{42}$Ar background suppression by PSD**



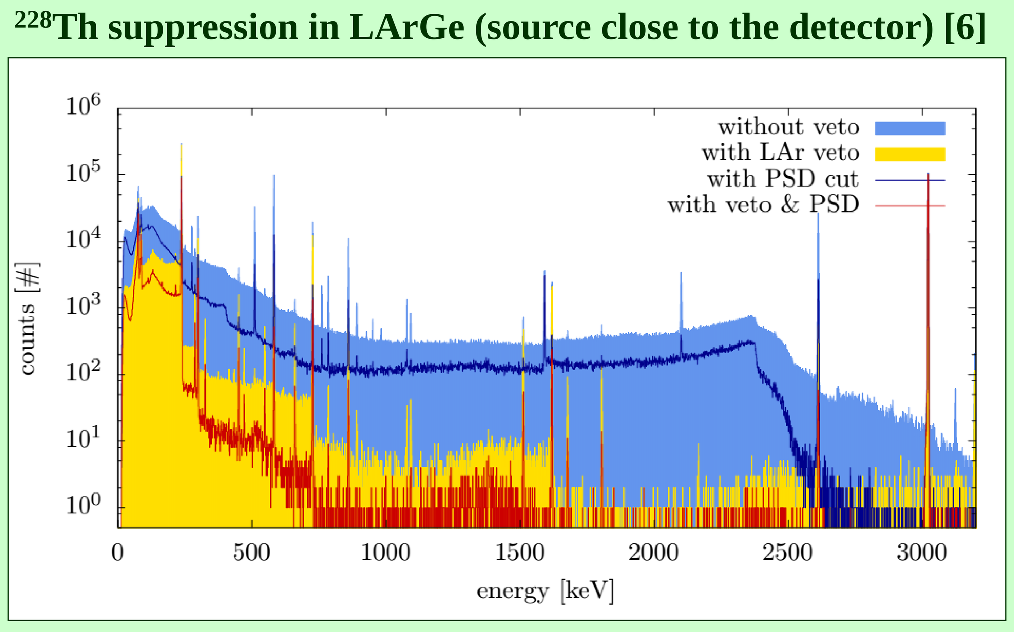
**LArGe – low background test facility to study novel methods of the background suppression [6]**




It was demonstrated in LArGe that LAr scintillation veto can considerably reduce lot of the backgrounds, dangerous for GERDA. That is why in GERDA Phase II LAr scintillation veto together with new BEGe detectors will be implemented.

- Currently about 20 kg of enriched BEGe detectors has been produced and tested in vacuum cryostat in Hades.
- 5 of enriched BEGe have been already tested in GERDA. Average resolution of them in Phase I configuration is 3.08 keV.
- Installation of the GERDA Phase II will start in June 2013.

**$^{228}$Th suppression in LArGe (source close to the detector) [6]**




**References:**
[1] H.V. Klapdor-Kleingrothaus et al., Phys. Lett. B586, 198 (2004)
[2] H.-K.Ackermann et al., Eur. Phys. J. C 73 (2013) 2330.
[3] M.Agostini et al., J. Phys. G: Nucl. Part. Phys. 40 (2013) 035110.
[4] D. Budjas et al., JINST 4 (2009) P10007.
[5] M. Agostini et al., J. of Instrumentation (JINST), 6 (2011) P03005.
[6] M. Heisel, PhD thesis, 335 (2011).