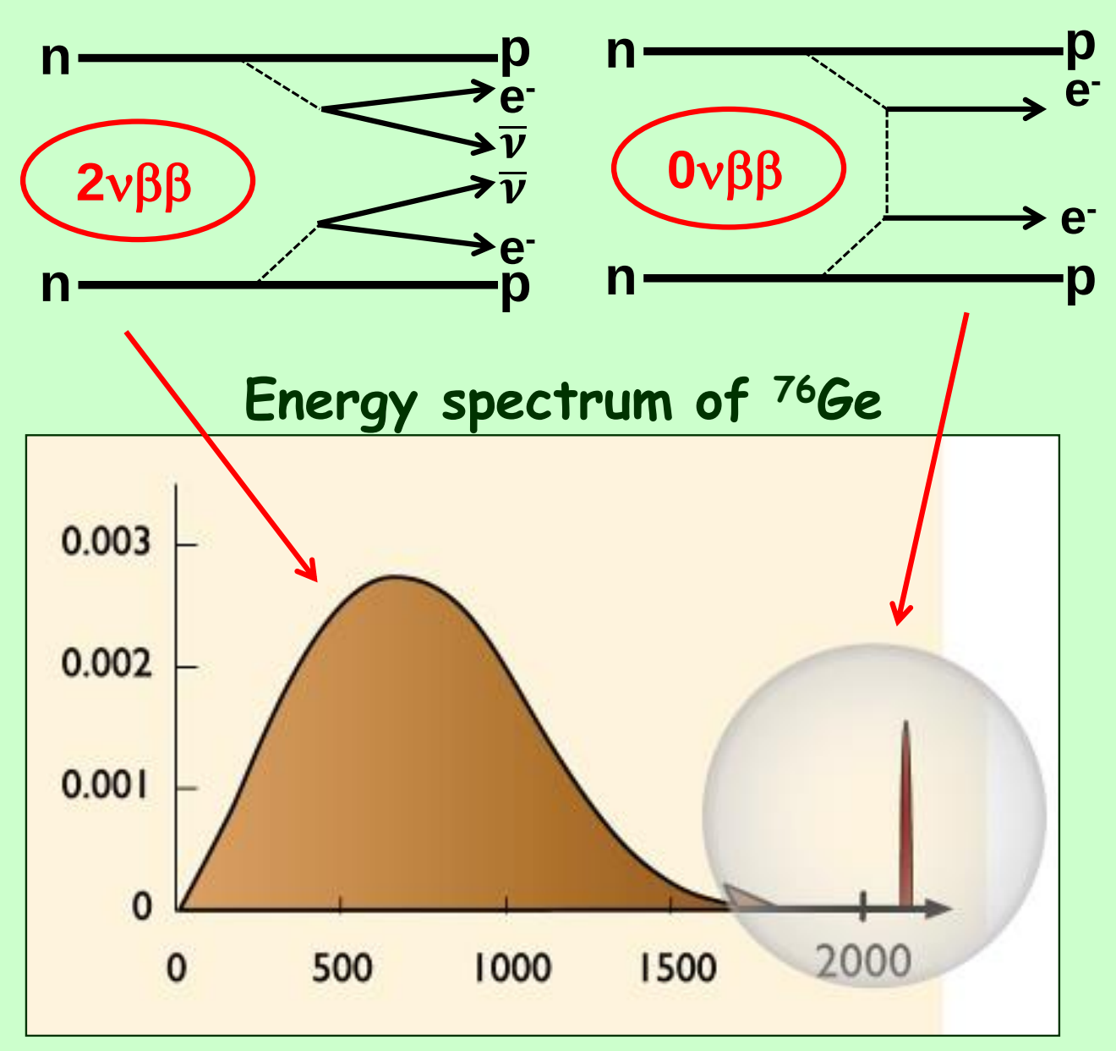
Results and perspectives of the GERDA experiment

A. Lubashevskiy for the GERDA collaboration
Max-Planck-Institut für Kernphysik, Heidelberg

Introduction

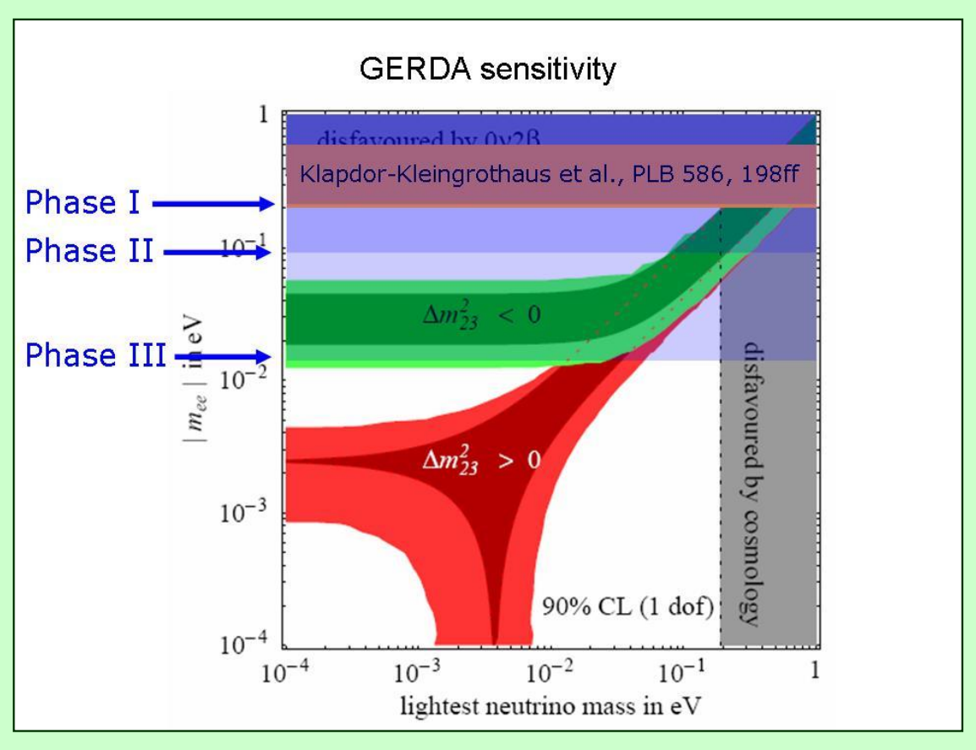
The study of neutrinoless double beta ($0\nu\beta\beta$) decay is a powerful approach to investigate fundamental properties of neutrinos.



Q_{bb}= 2039 keV

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

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



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

GERDA 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.

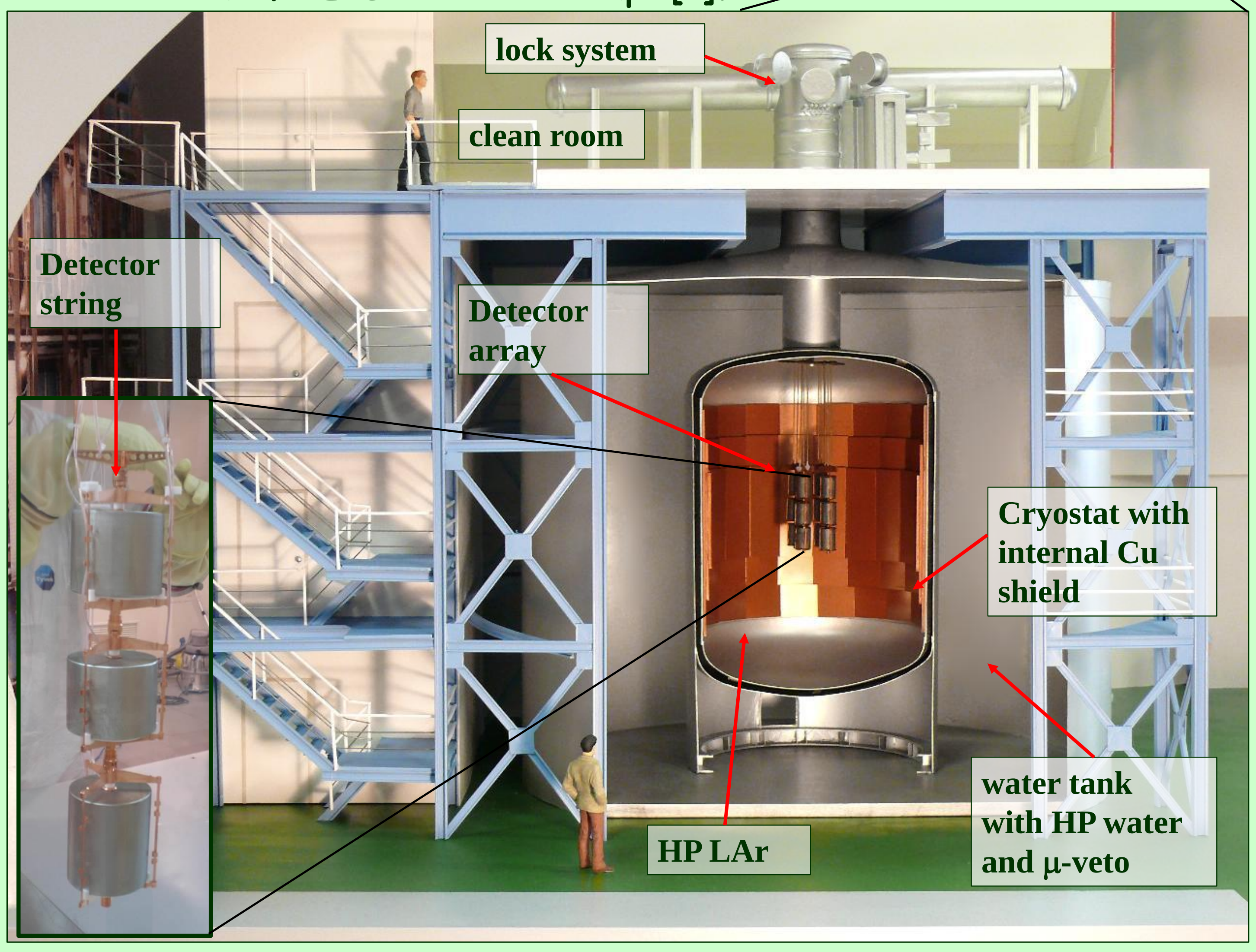
Experimental setup

GERDA background reduced by:

- Usage of bare HPGe detectors, enriched to 86% in ^{76}Ge.
- Low mass radiopure holders of the detectors.
- Germanium detectors deployed in a cryostat with 64 m^3 LAr which shields from radiation and cools them down.
- Stainless 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.
- Pulse shape discrimination (PSD) techniques.

LNGS underground laboratory (Italy). Location in LNGS reduces μ flux (by ~ 10^6 times) and neutron flux induced by cosmic radiation.

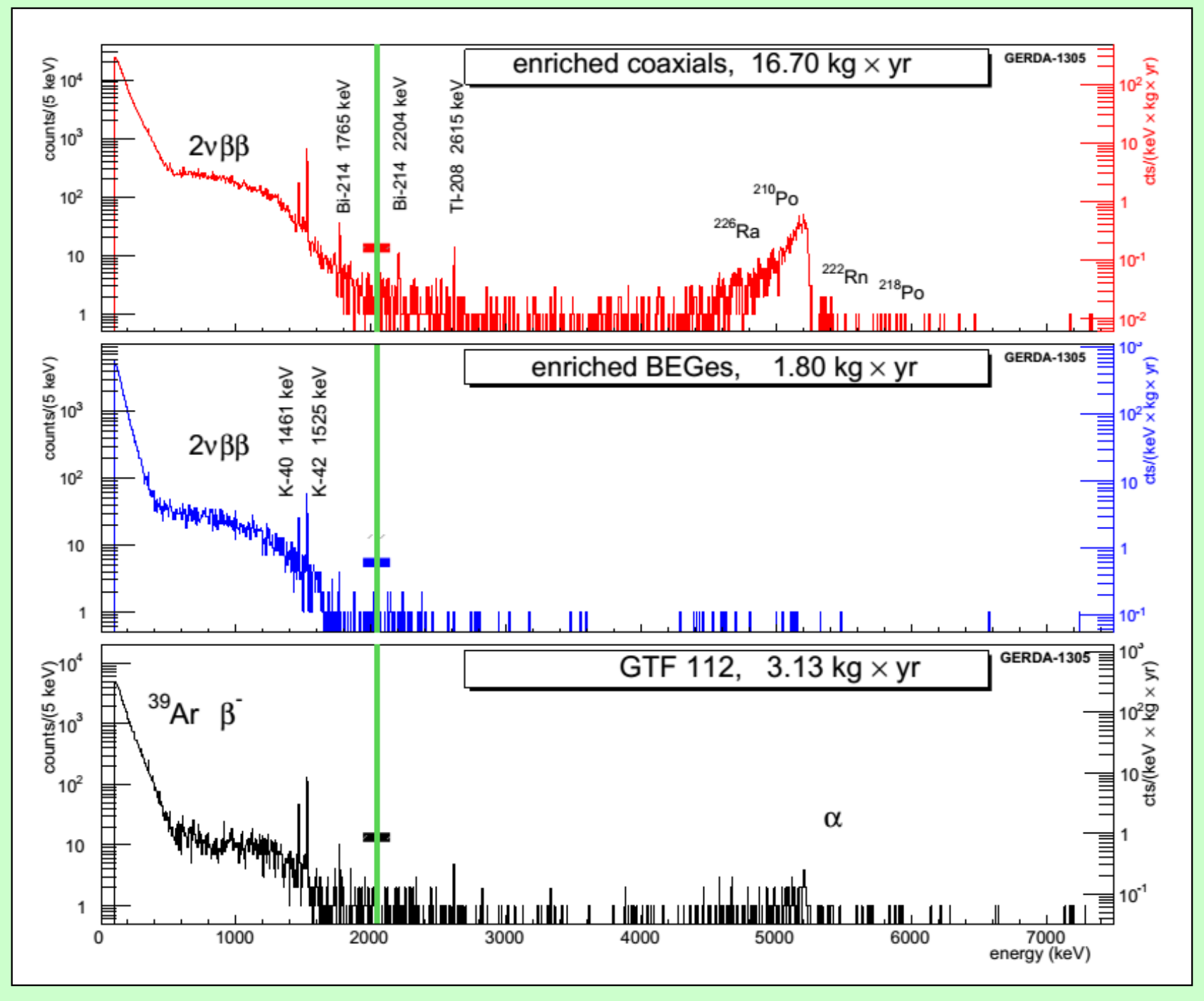
Artistic view of GERDA Phase I setup [1].



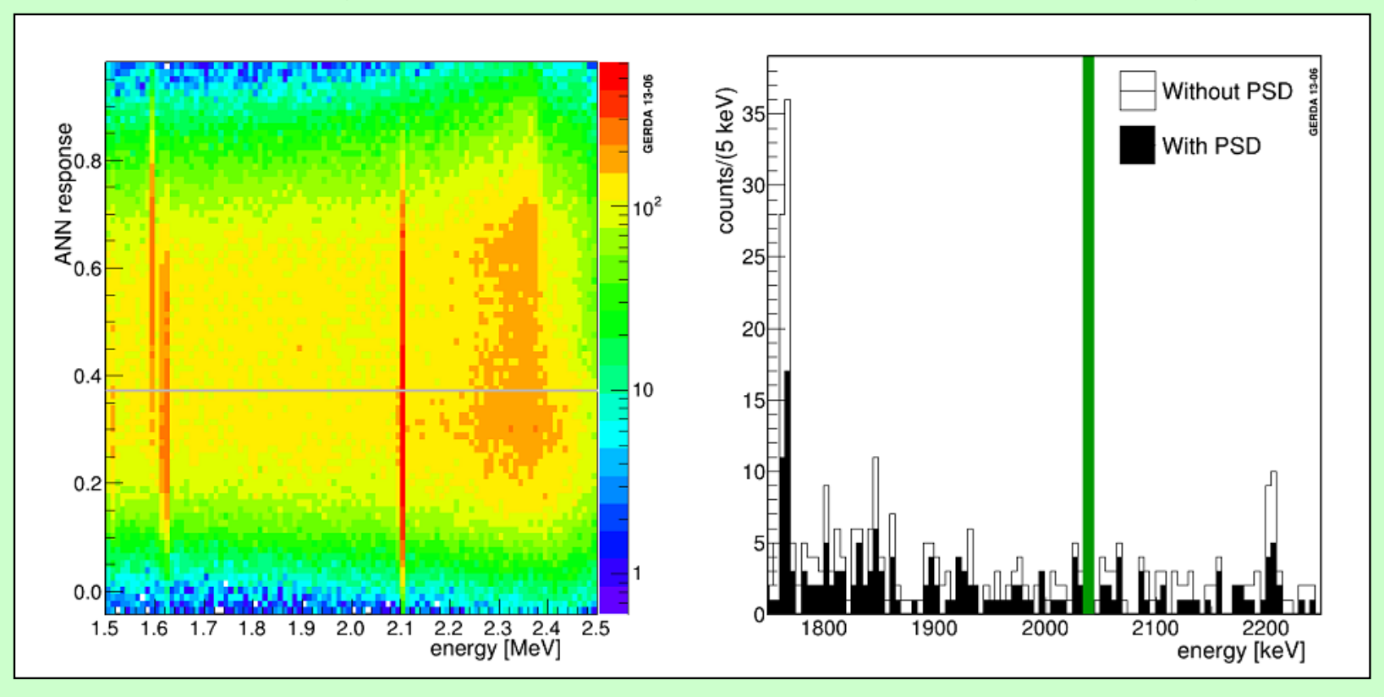
Phase I results

- Data taking (Nov 2011 - May 2013).
- The exposure-averaged resolution of semi-coaxial detectors is 4.8 keV.
- Blinded data between 2019 keV and 2059 keV.

Spectra from detectors of GERDA Phase I.



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



Response of the PSD analysis versus energy for events from ^{228}Th calibrations.

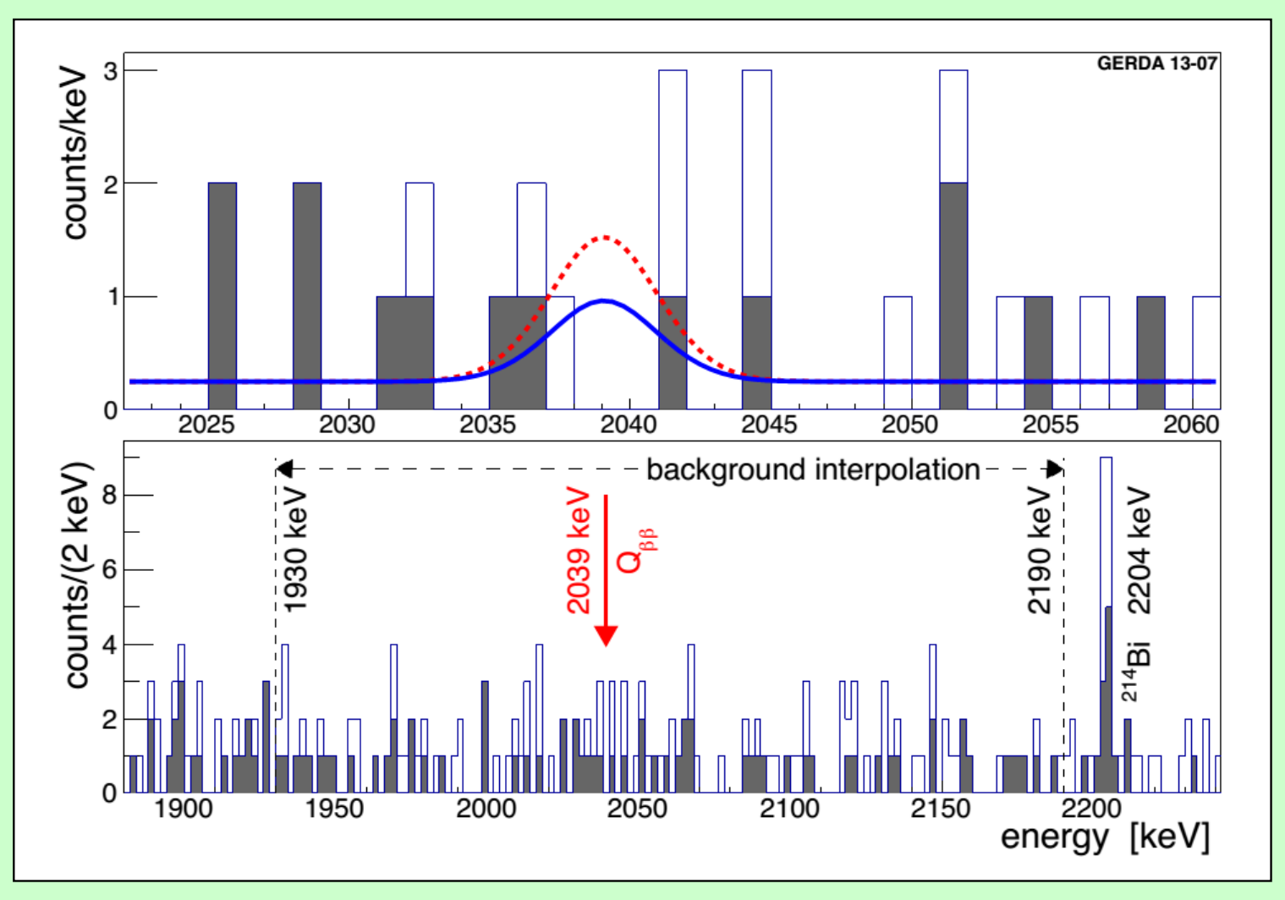
Energy spectrum from semi-coaxial detectors before and after the PSD selection.

Analysis of $2\nu\beta\beta$ spectrum gives [2]:

$$T^{2\nu}_{1/2} = \left(1.84 \pm^{0.14}_{0.10}\right) \cdot 10^{21}\ yr$$

- 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 [3] of a signal for $0\nu\beta\beta$ decay of ^{76}Ge is **ruled out** by GERDA with **99%** probability.

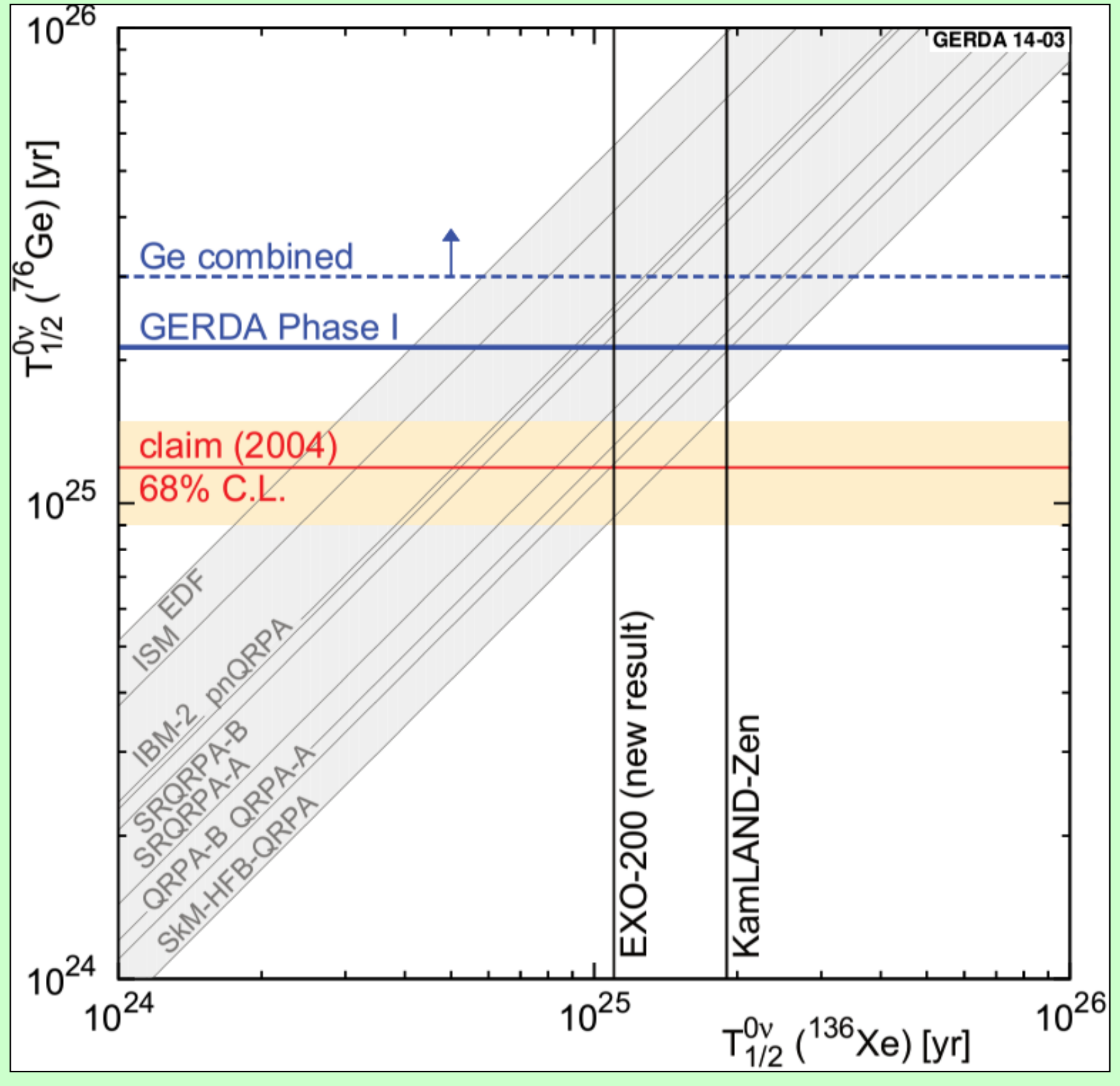
Energy spectrum from all enriched Ge detectors with and without the PSD selection.



The limit on the half-life of $0\nu\beta\beta$ decay is [4]:

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

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

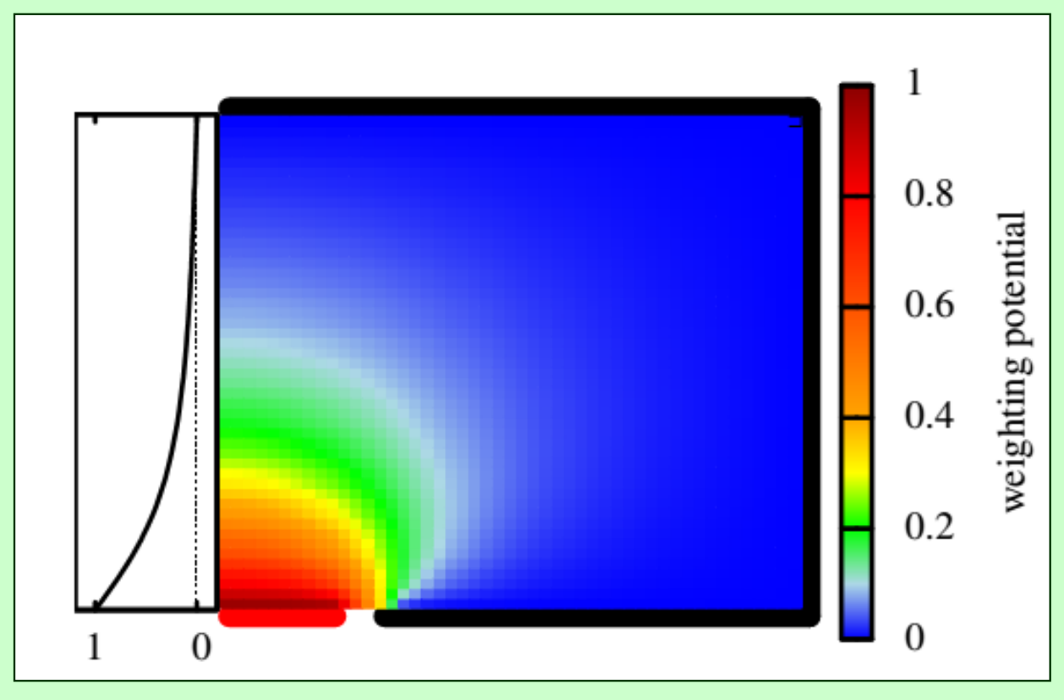


Phase II preparations

New BEGe detectors for GERDA Phase II:

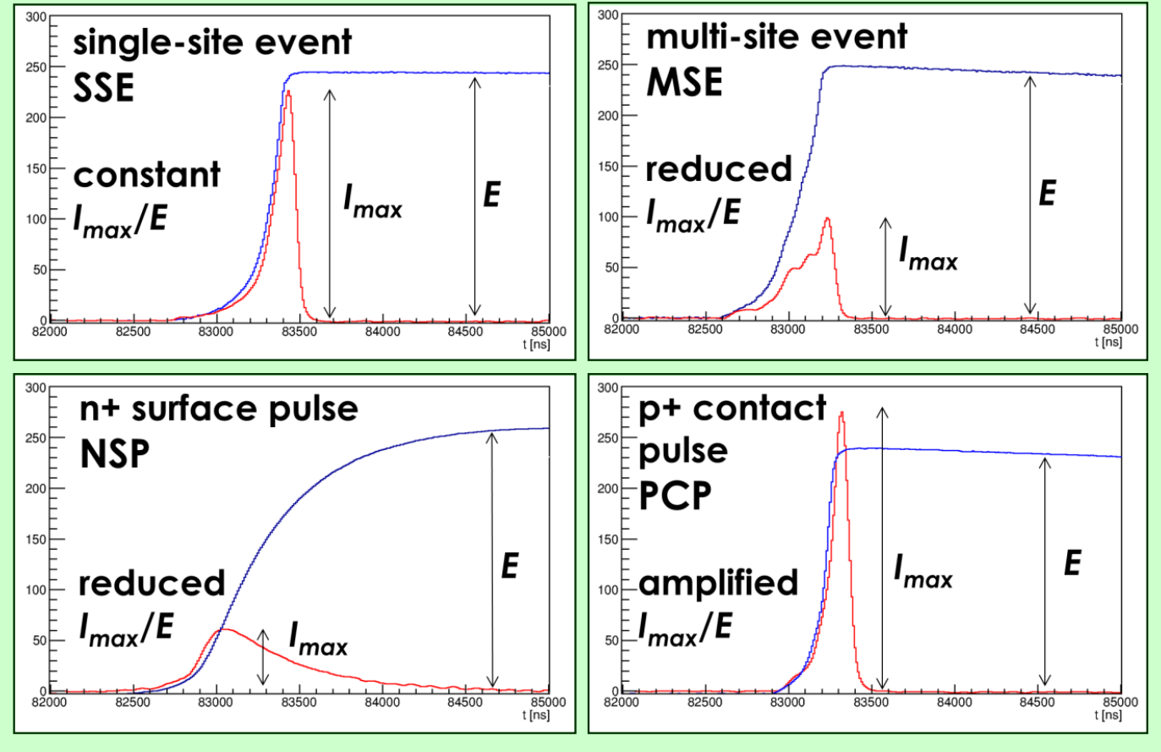
- Better energy resolution (FWHM up to 1.6 keV@1.3MeV in a vacuum cryostat).
- Powerful pulse shape discrimination [5].
- Holders with lower intrinsic radioactivity.

Simulation of E-field in BEGe [6].

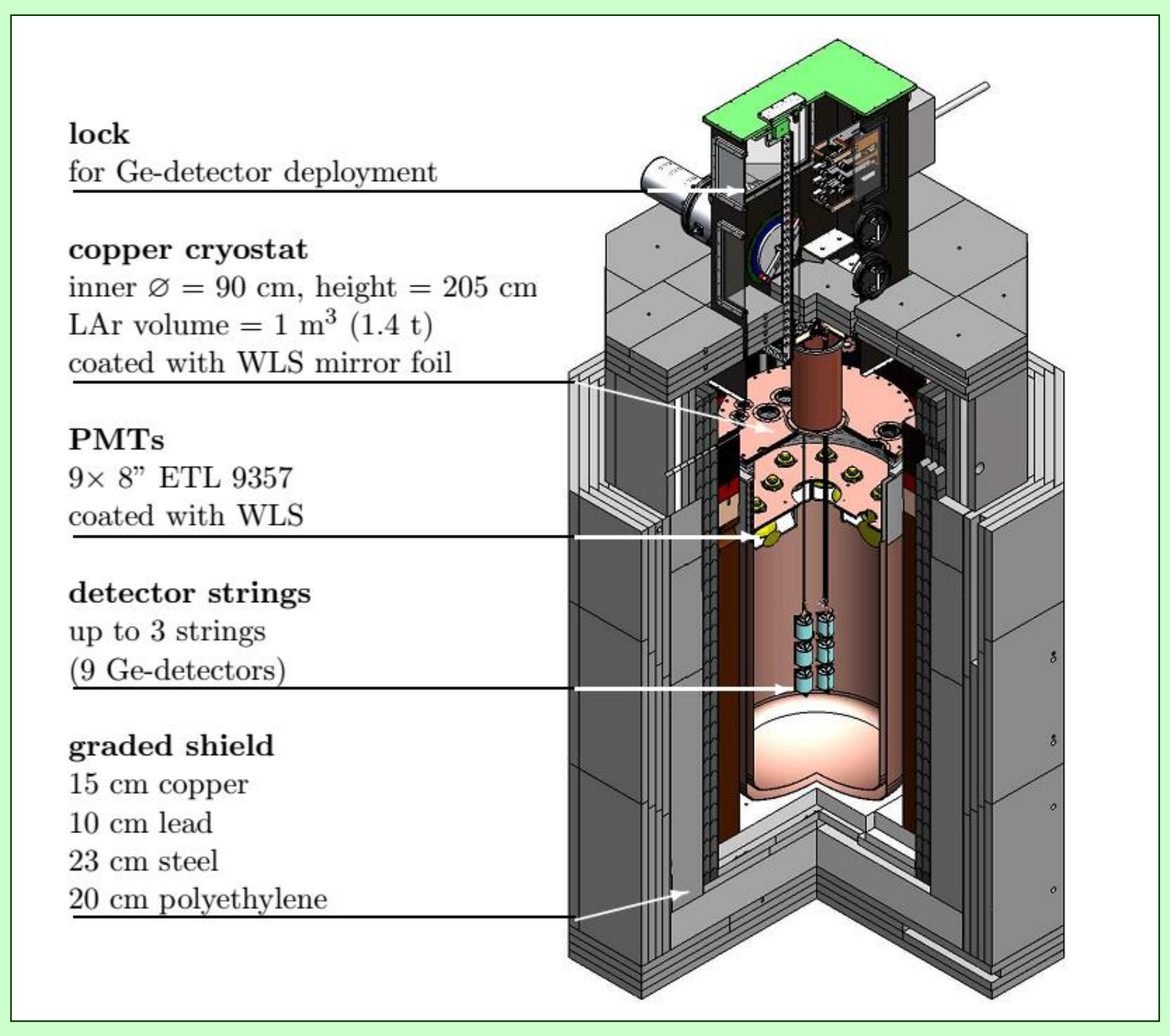


Pulse shape analysis of the BEGe detectors is a powerful tool to reject background events like multi-side events and surface events.

Examples of the pulses from BEGe detector.



LArGe – low background test facility to study of novel methods of the background suppression [7].



lock
for Ge-detector deployment

copper cryostat
inner ∅ = 90 cm, height = 205 cm
LAr volume = 1 m^3 (1.4 t)
coated with WLS mirror foil

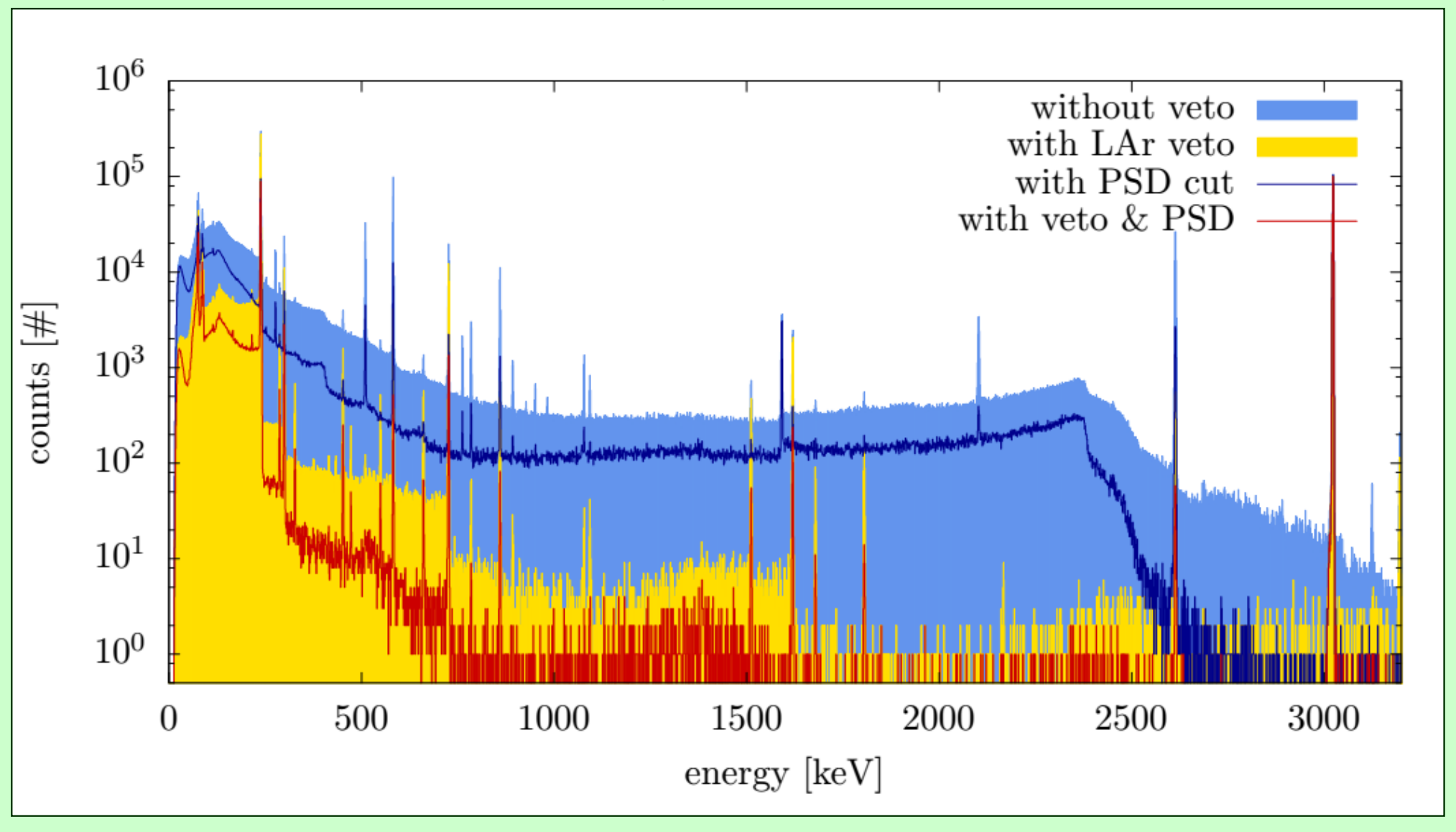
PMTs
9× 8" ETL 9357
coated with WLS

detector strings
up to 3 strings
(9 Ge-detectors)

graded shield
15 cm copper
10 cm lead
23 cm steel
20 cm polyethylene

A LAr scintillation veto was tested in low background test facility LArGe. It was demonstrated that it is efficient tool for suppressing backgrounds. LAr scintillation veto will be installed for GERDA Phase II.

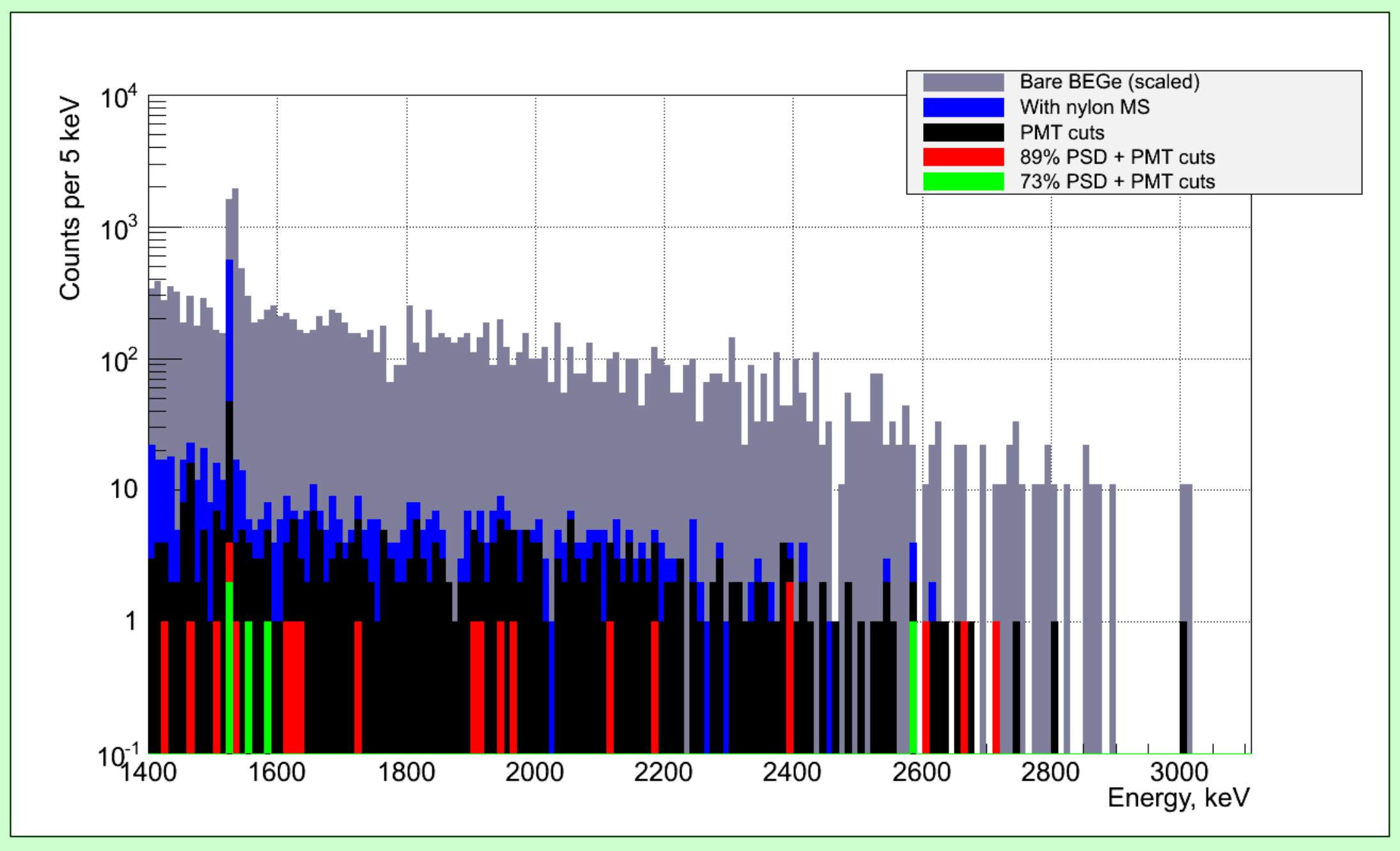
The internal ^{228}Th spectrum taken in LArGe.



Background coming from ^{42}Ar is considered to be one of the most dangerous for GERDA Phase II experiment. Its daughter, ^{42}K is the beta decay emitter with endpoint of 3.5 MeV. It can increase the background in the region of interest of $0\nu\beta\beta$ decay of the GERDA experiment by decaying on the surface of the detector. Our measurements with spiked ^{42}Ar in LArGe demonstrated that PSD is an efficient tool for suppression of surface events coming from ^{42}K. For preventing ^{42}K collection by electric field towards to the detector a nylon mini-shroud (NMS) covered with wavelength shifter will be installed. Our investigations showed that with NMS and PSD it is possible to suppress ^{42}K background by more than three order of magnitudes in comparison with bare BEGe detectors. This allows to decrease the BI below GERDA Phase II requirements.

NMS in a ultraviolet light.

The ^{42}K spectrum taken in LArGe with bare BEGe surrounded by NMS.



The start of Phase II in GERDA is planned for this year

References:
[1] GERDA collaboration, Eur. Phys. J. C 73 (2013) 2330.
[2] GERDA collaboration, J. Phys. G: Nucl. Part. Phys. 40 (2013) 035110.
[3] H.V. Klapdor-Kleingrothaus et al., Phys. Lett. B586, 198 (2004)
[4] GERDA collaboration, Phys. Rev. Lett 111 (2013) 122503
[5] D. Budjas et al., JINST 4 (2009) P10007.
[6] M. Agostini et al., JINST 6 (2011) P03005.
[7] M. Agostini et al., J. Phys.: Conf. Ser. 375 042009 (2012).