Investigation and development of the suppression methods of the ^{42}K background in LArGe

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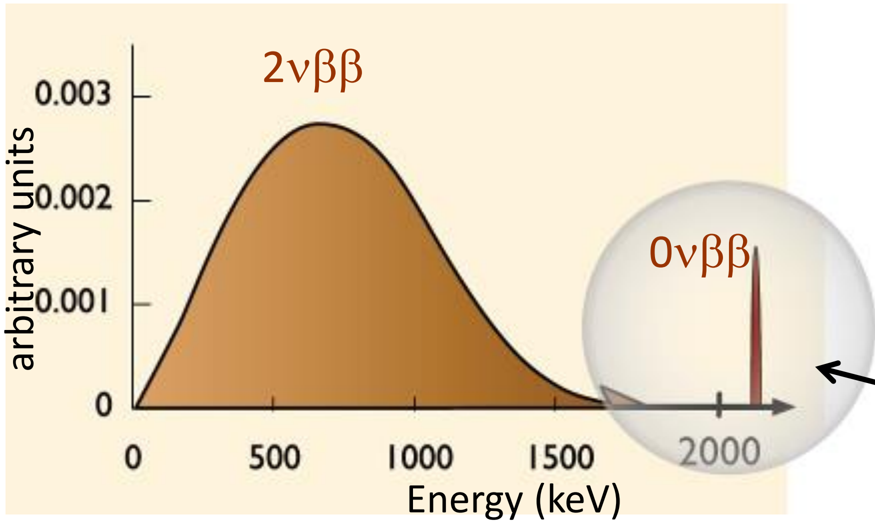
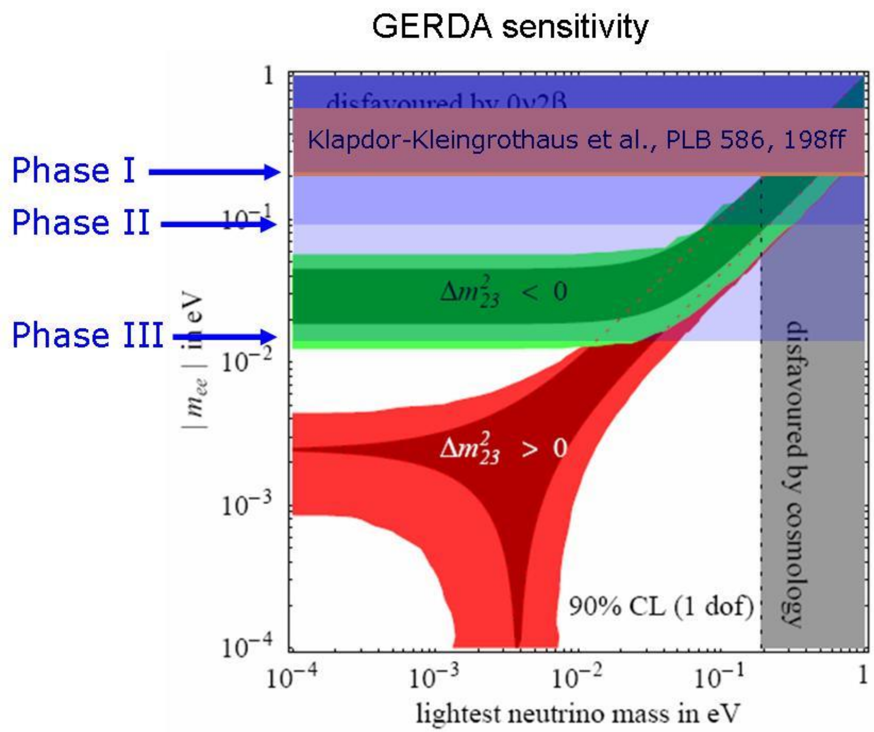
Motivation



The main goal of the GERDA experiment is searching for neutrinoless double beta decay of ^{76}Ge. **Background level** is one of the most important factors for the successful experiment.



$$T^{0\nu}_{1/2} \propto \langle m_{\beta\beta}\rangle^{-2} \propto const \sqrt{\frac{M \times t}{\Delta E \times B}}$$

M Mass

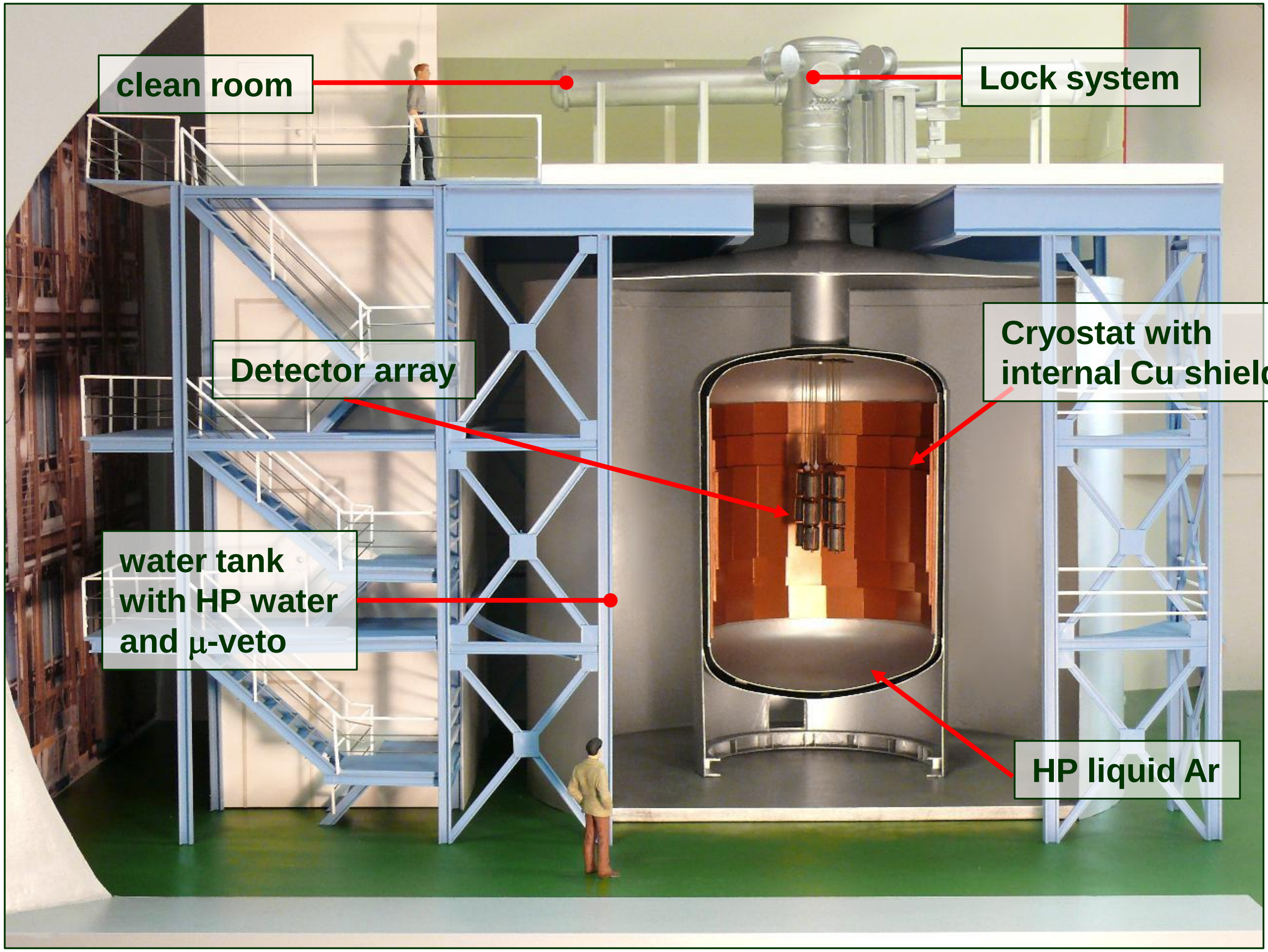
t Time

B Background rate

ΔE Energy resolution

GERDA experiment

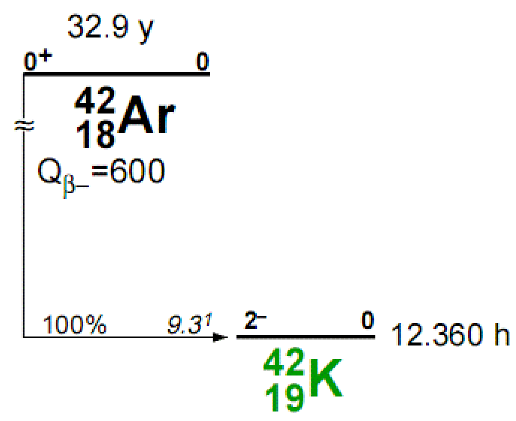
Bare germanium detectors enriched by ^{76}Ge, submerged into the high-purity liquid argon, are used in GERDA experiment. This allows to decrease background from the surrounding materials, liquid argon shields from the radiation and cools down the Ge detectors.

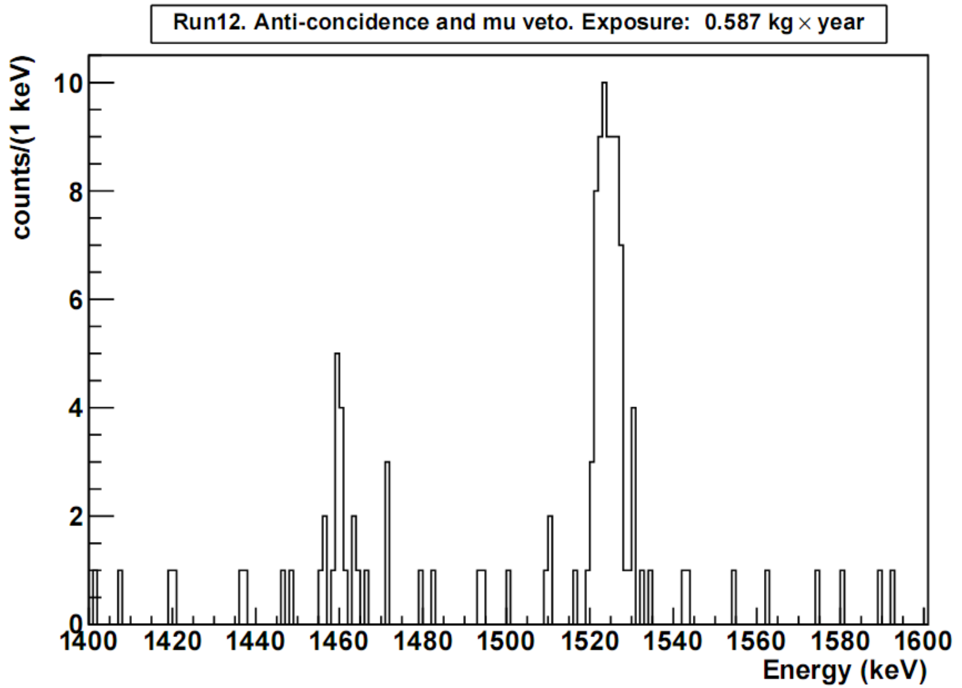


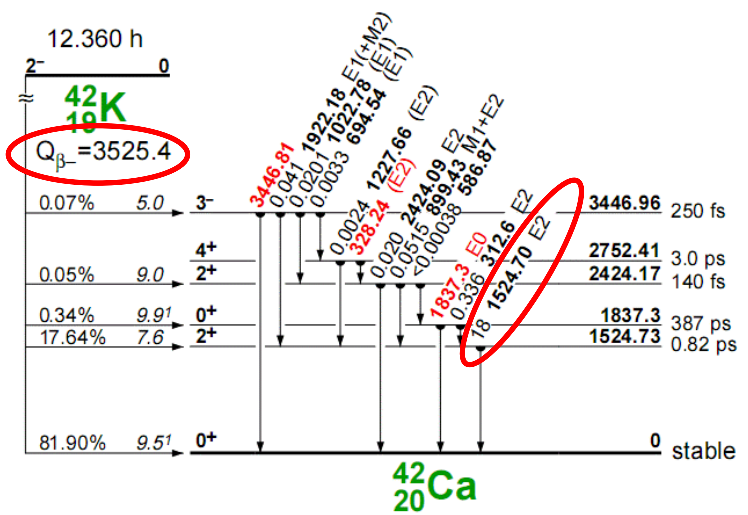
See more in GERDA review talks:
M.Heisel [HK 43.2]
M.Agostini [T 103.1]

Unexpected ^{42}Ar background

In the **proposal of GERDA** for estimation of the ^{42}Ar activity in liquid Ar in GERDA cryostat, the **limit < 30 μBq/kg** [Barabash et al., 2002] has been taken into account.
Already during first commissioning runs with non-enriched detectors it was found that the intensity of 1525 keV peak from ^{42}K (daughter of ^{42}Ar) **at least is 10 times higher** than expected from the limit [Bar02]. It will be shown later that we are able to decrease it by preventing of collection of ^{42}K ions by electric field of the detector.

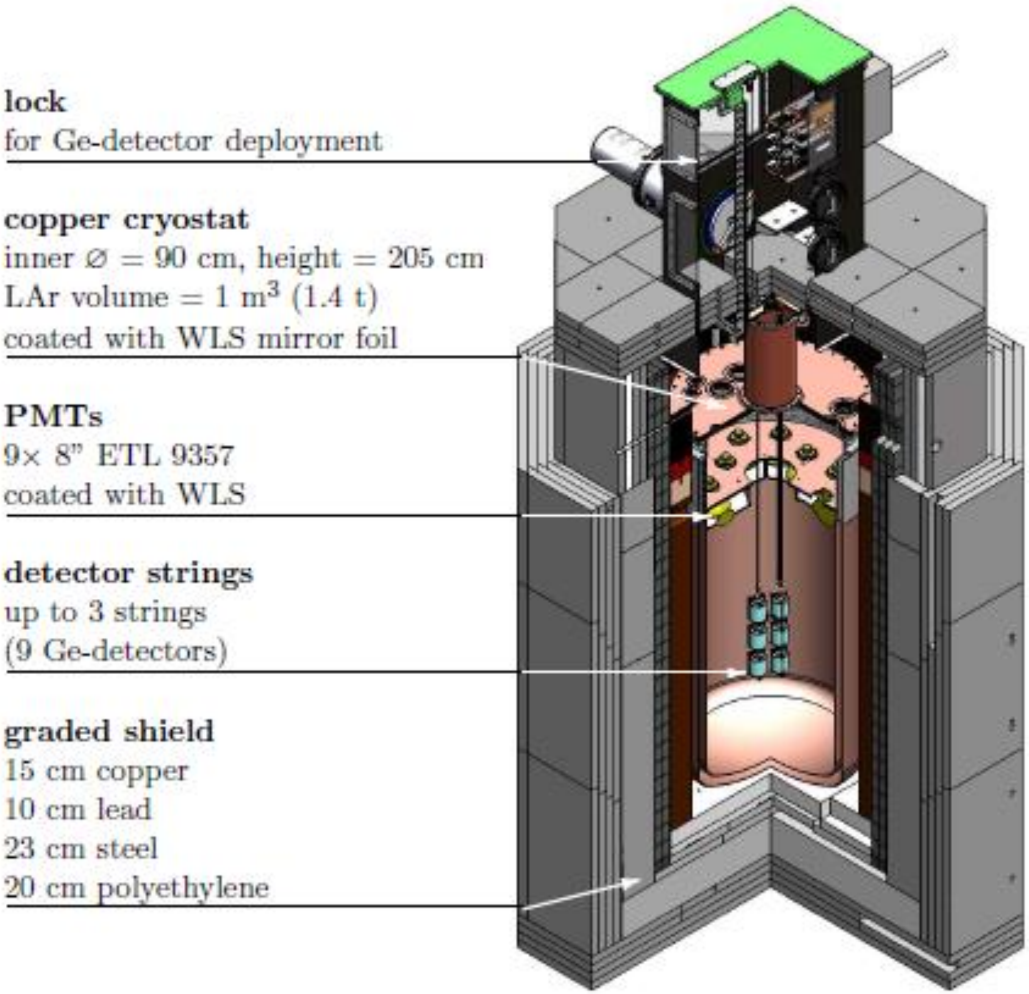






LArGe test facility

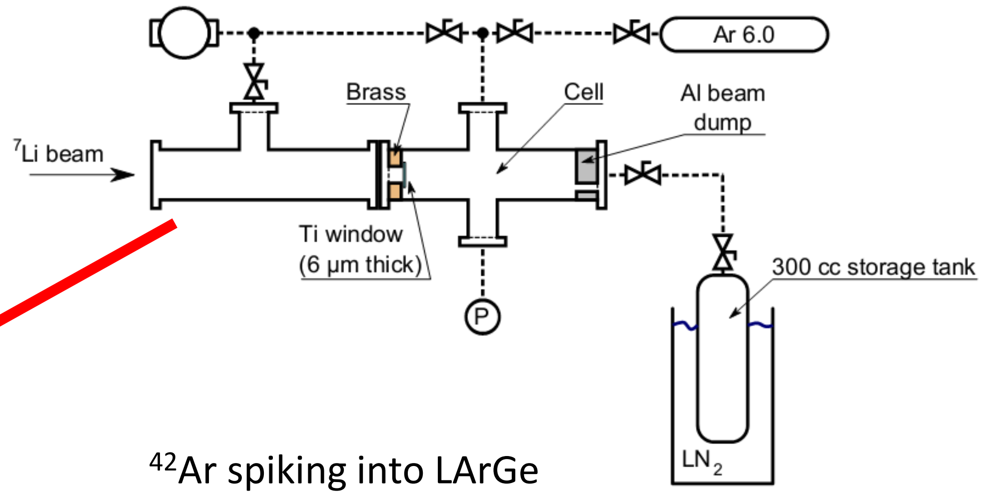
Investigations of ^{42}Ar background behavior have been performed in LArGe low background test facility. LArGe has been created in order to study the possibility to suppress background by using anticoincidence with liquid Ar scintillation signal detected by PMTs.

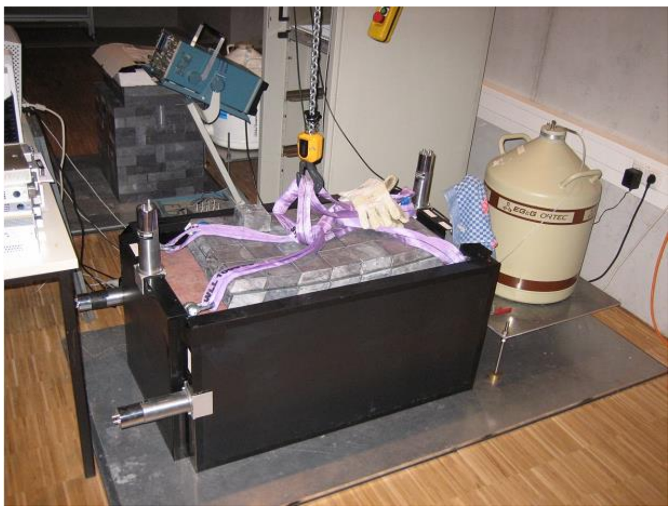


^{42}Ar source production & spiking

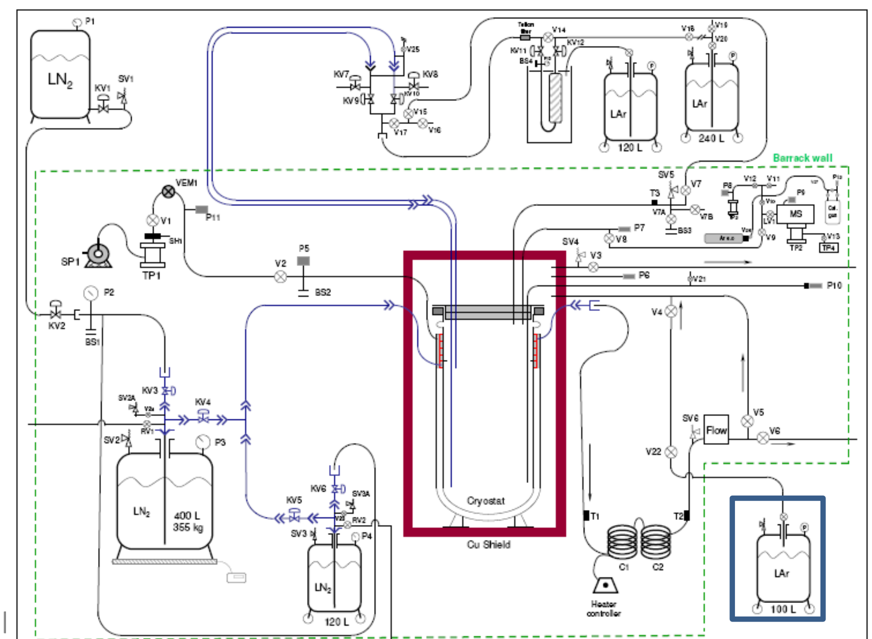
For detail investigation of the collection processes of ^{42}K and for direct estimation of the activity of ^{42}Ar well-known amount of the activity of ^{42}Ar has been introduced into the LArGe volume.

^{42}Ar production at MLL Garching by TUM from ^{40}Ar via (^{7}Li, α p)





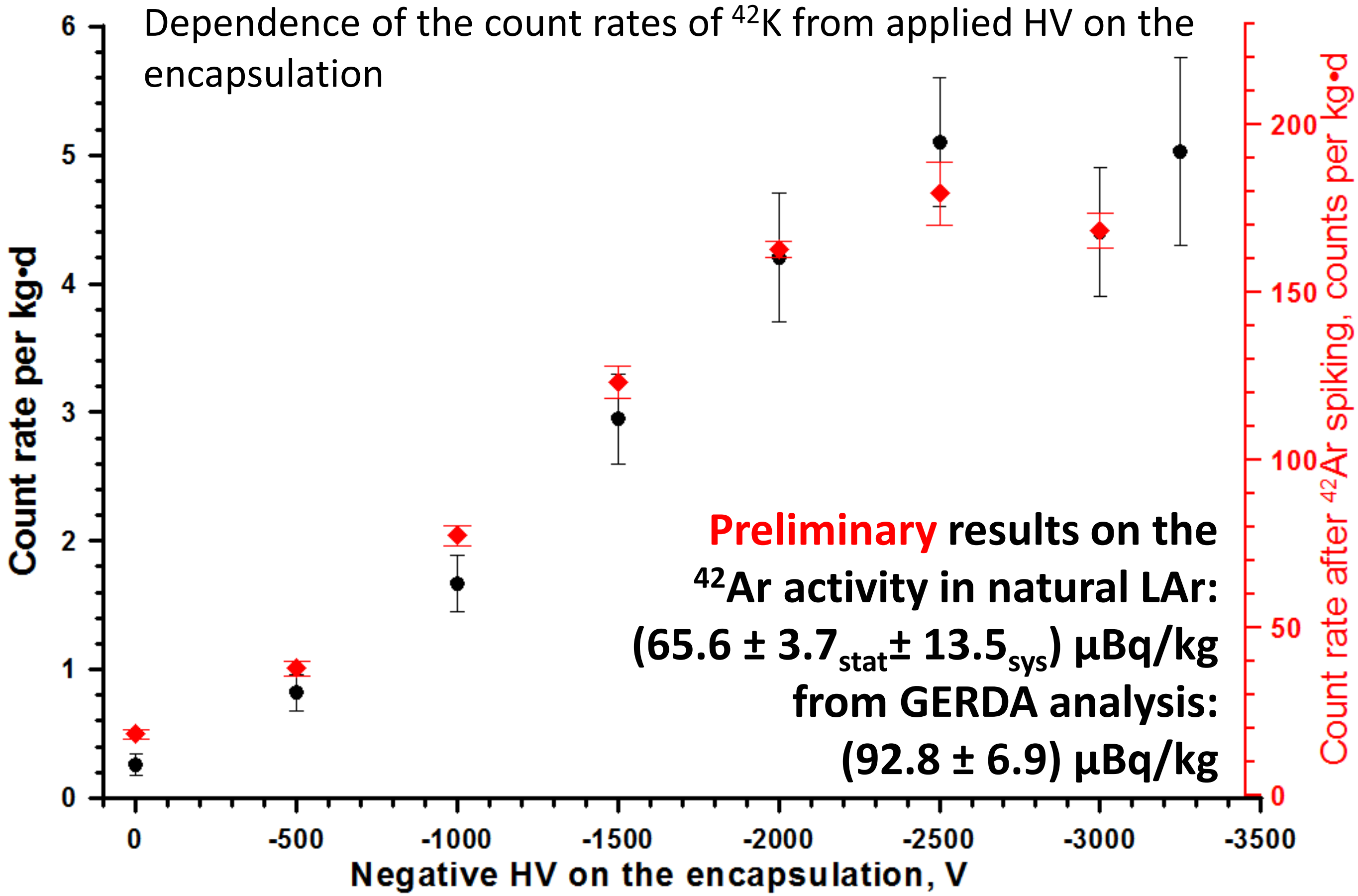
^{42}Ar spiking into LArGe

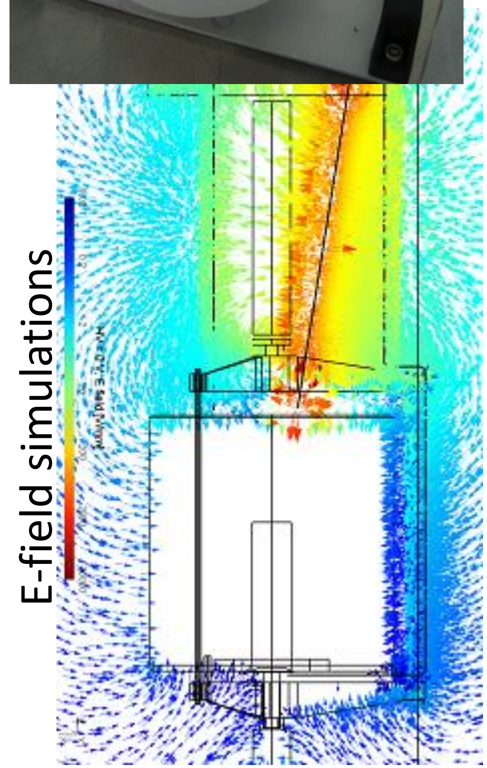


Screening at Garching and LNGS.
Estimated activity of ^{42}Ar is
First source: **5.18±0.91 Bq**
Second source: **79 Bq**

^{42}K collection by encapsulated detector

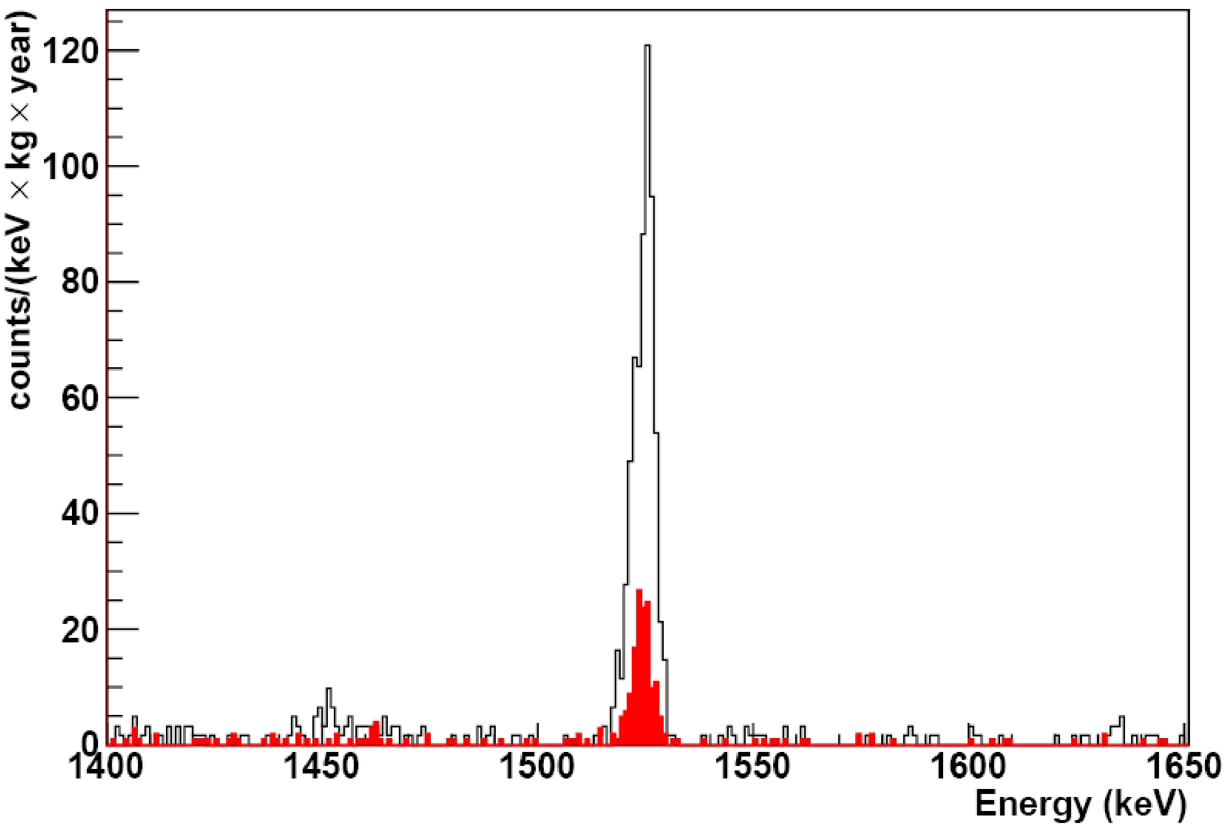
Measurements with a germanium detector have been performed in LArGe for investigation of the collection processes of ^{42}K. The detector was fully **encapsulated** by a PTFE/Cu/PTFE sandwich. It is possible to apply positive/negative HV on the encapsulation and study of collection ^{42}K ions by electric field.

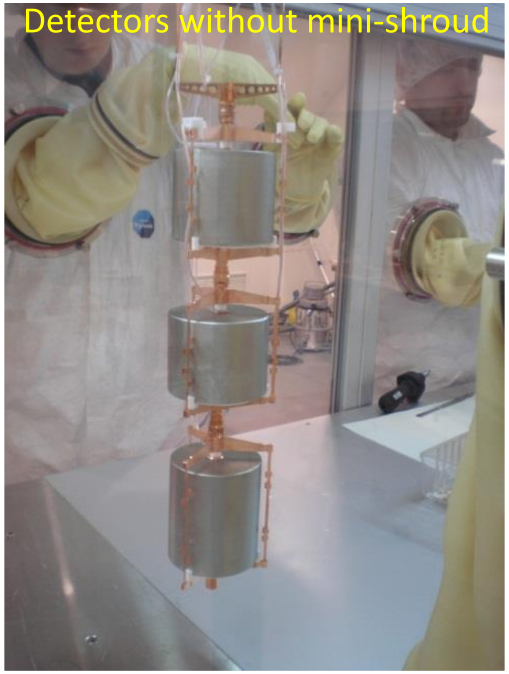




Mini-shroud

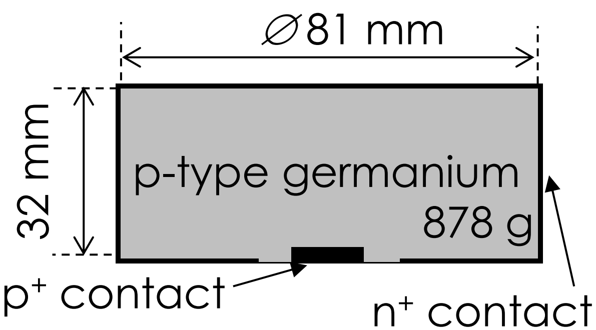
Intensity of ^{42}K peak in GERDA is significantly higher than with “E-field free” configuration. ^{42}K background contribution from analysis of the GERDA Phase I data estimated to be about **3 x 10^{-3} cts/(keV·kg·yr)** near ROI of $0\nu\beta\beta$. However for the GERDA Phase II background requirements are higher: All backgrounds should be **< 1 x 10^{-3} cts/(keV·kg·yr).**

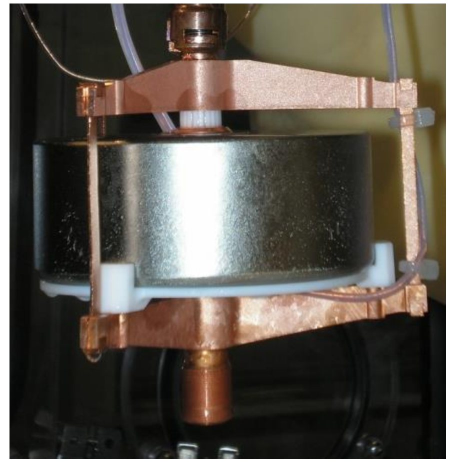




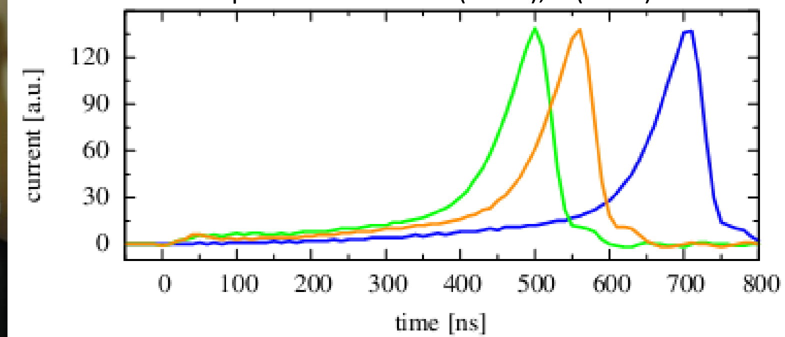
GERDA phase II: BEGe detectors

Example of BEGe detector:
FWHM @ 1.33 MeV 1.59 keV



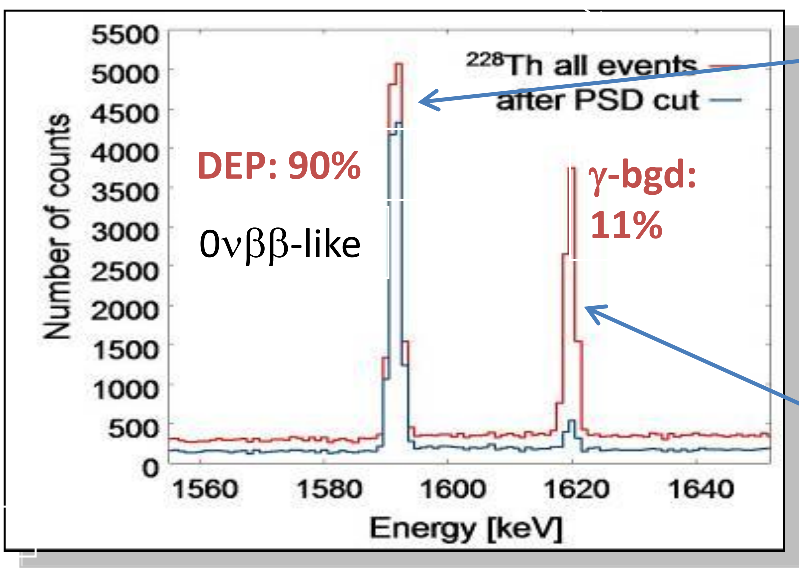


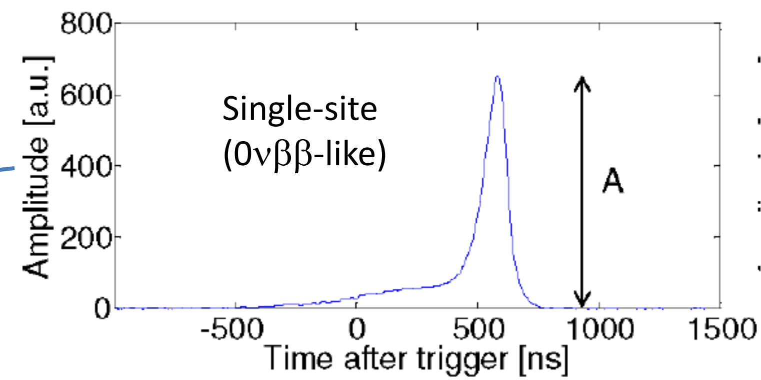
Simulated pulses taken from (JINST), 6 (2011) P03005

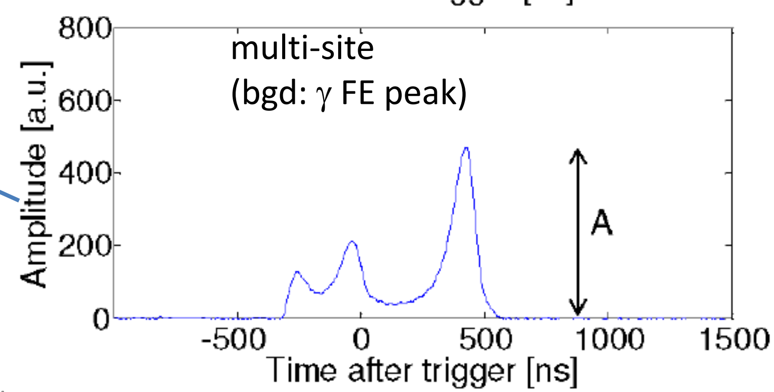


See more in talk of A.Lazzaro [HK 66.6]

Powerful Pulse Shape Discrimination (PSD)!

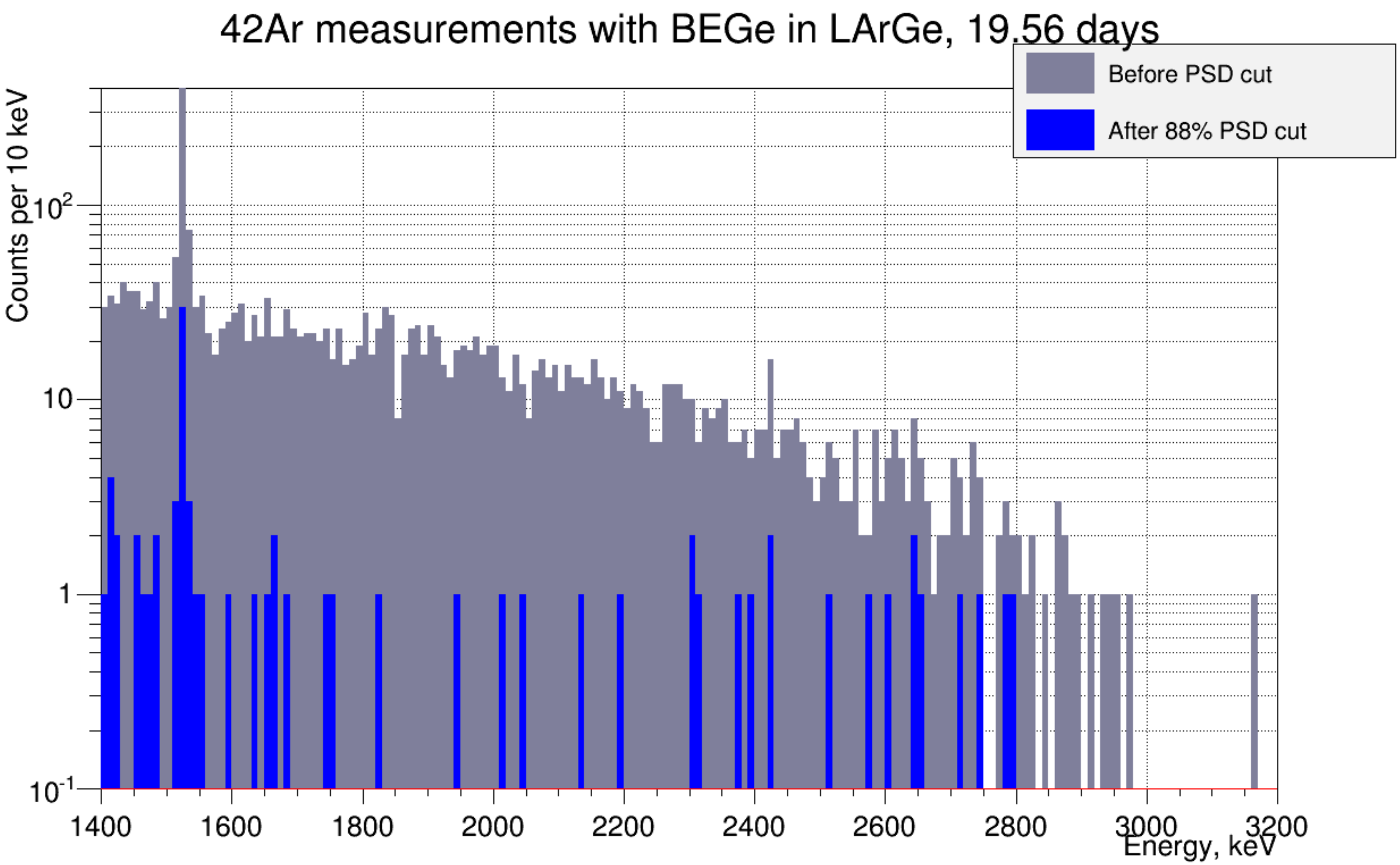






Suppression by PSD

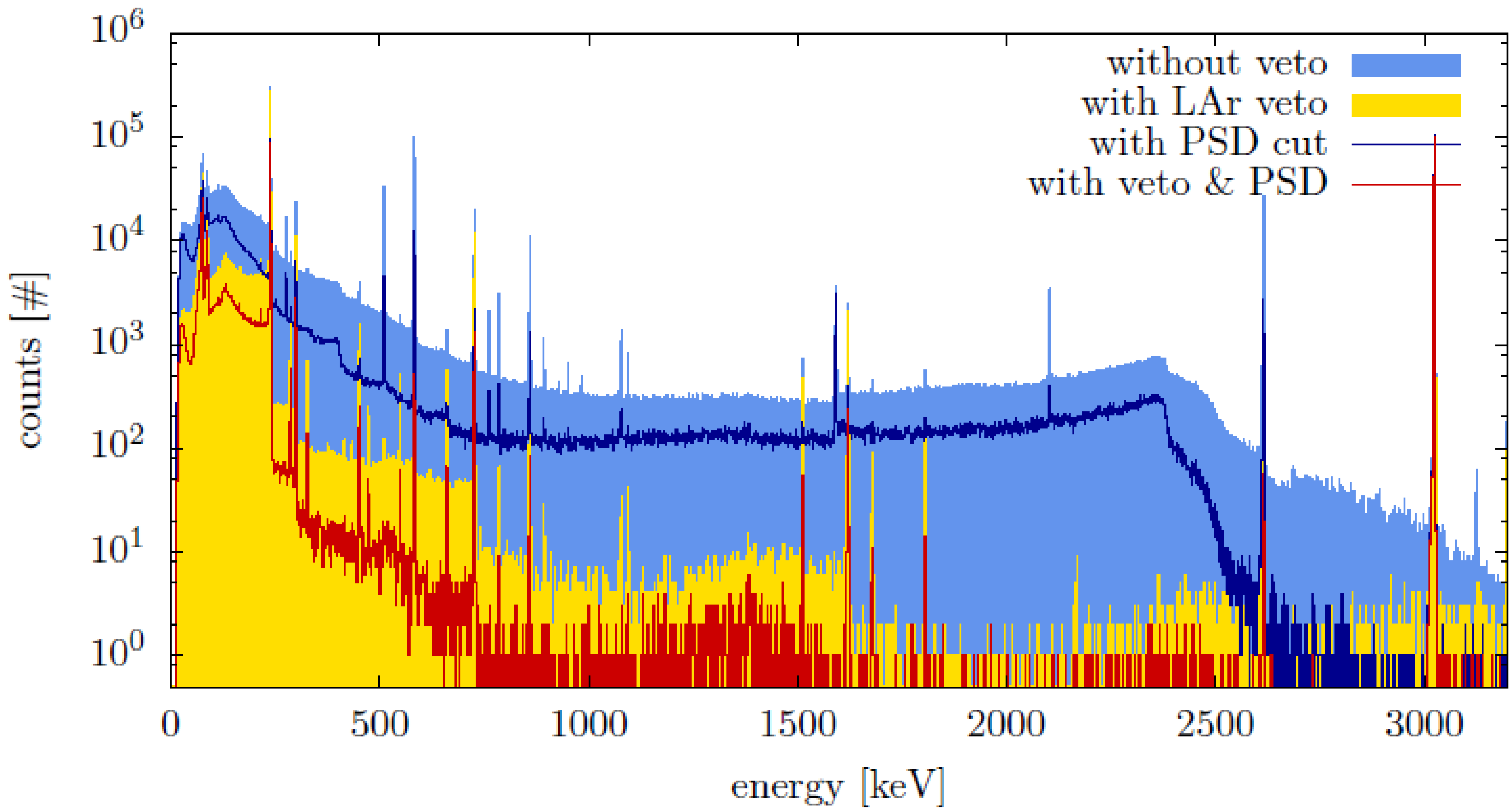
PSD method allows efficiently suppress also background coming from ^{42}K. Such type of the events usually deposit energy near n+ contact -> different shape (“slow pulses”).



Number events from ^{42}K in 400 keV near $0\nu\beta\beta$ which survive PSD cut are < **1%** [90% C.L.].

GERDA phase II: light instrumentation

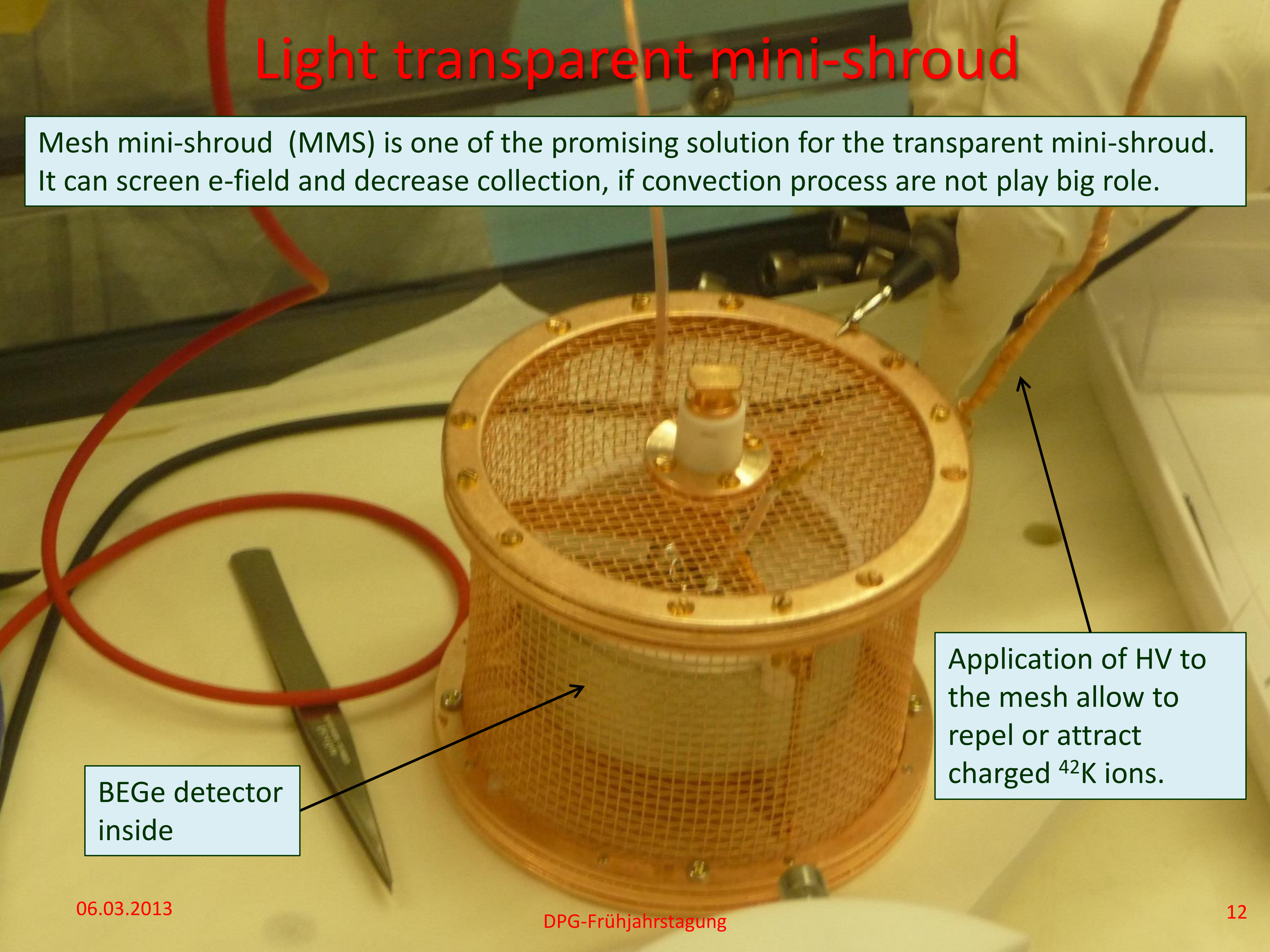
Measurements with LArGe shows very good suppression of the background. For internal ^{228}Th calibration suppression factor together with PSD up to 5000 in ROI has been obtained.



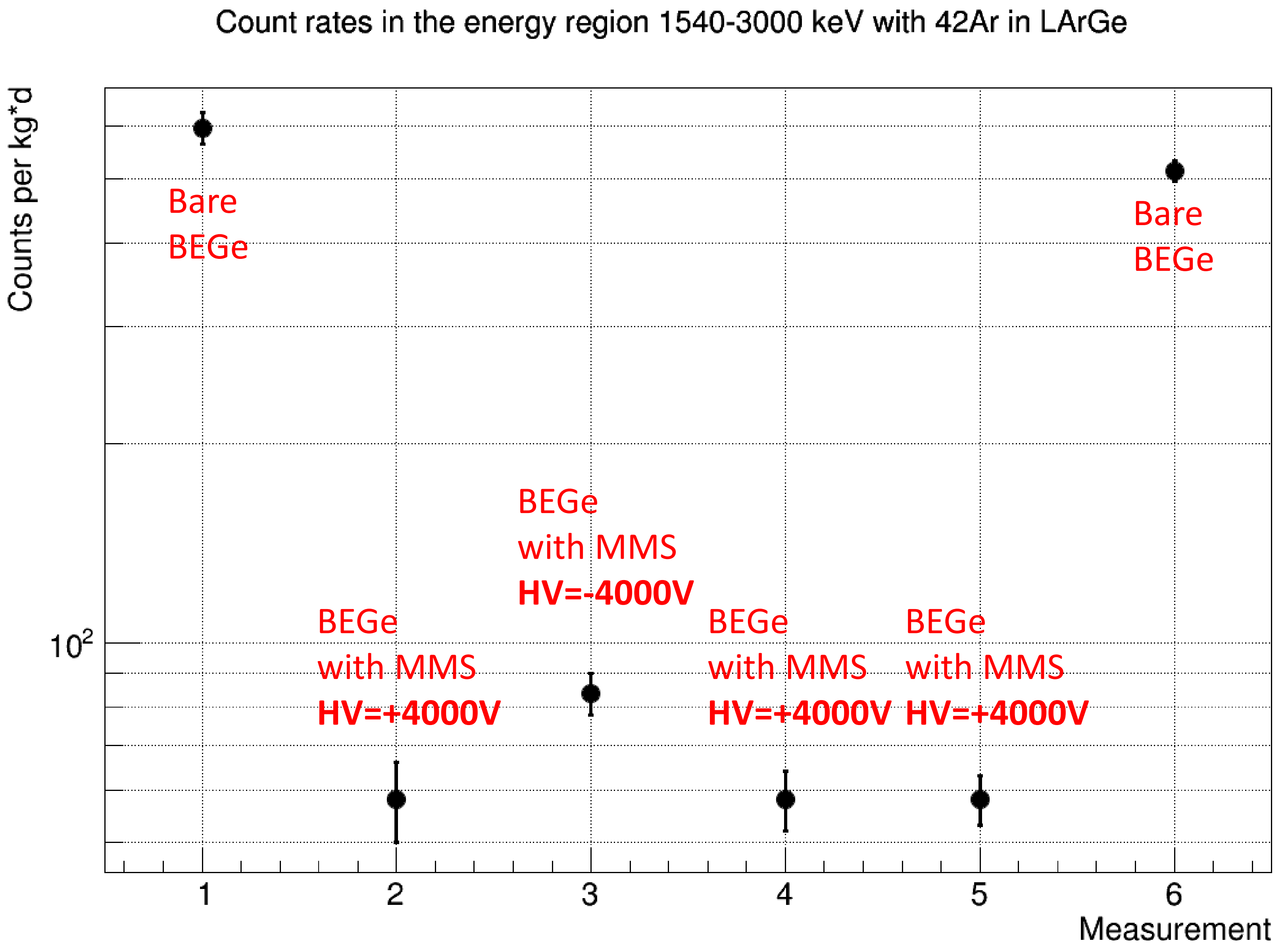
But usage of mini-shroud decrease efficiency of scintillation veto. In case of worse PSD performance ^{42}K background can be dangerous for GERDA Phase II.

Light transparent mini-shroud

Mesh mini-shroud (MMS) is one of the promising solution for the transparent mini-shroud.
It can screen e-field and decrease collection, if convection process are not play big role.

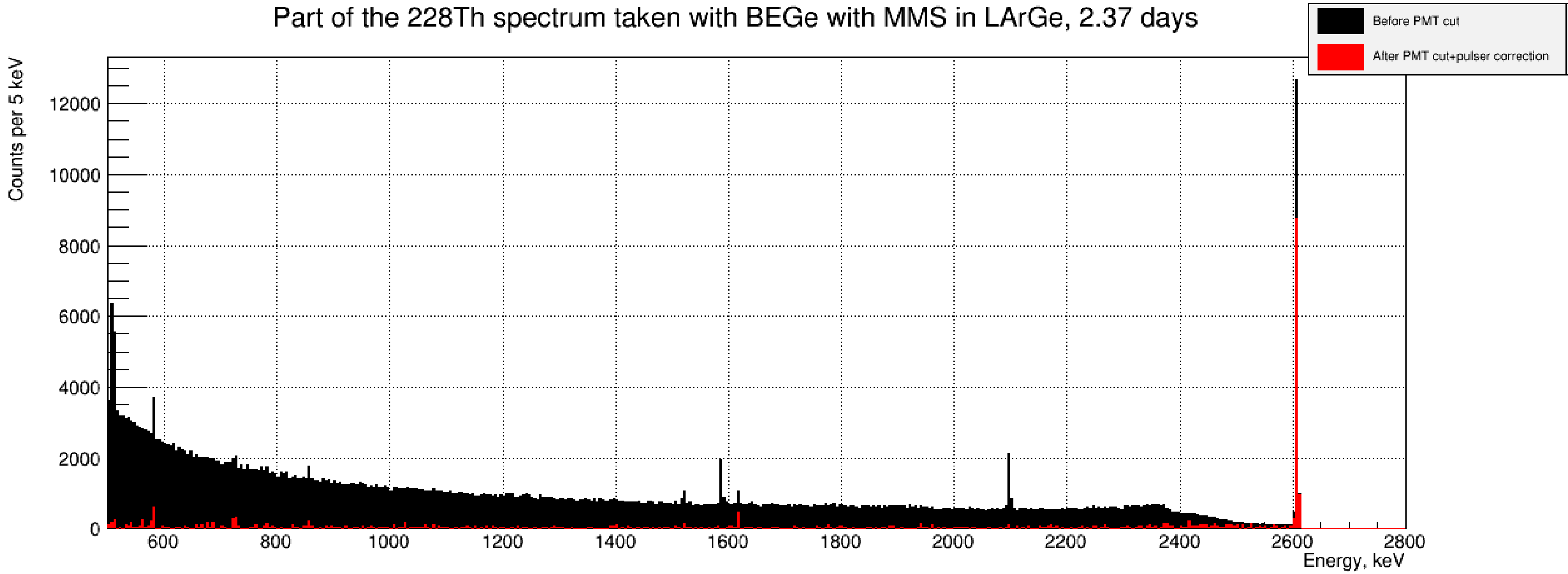


Results from LArGe measurements



Suppression factor **about 10** after applying HV =±4000V on the mesh!

PMT veto suppression



Suppression of the external ^{228}Th background by PMT veto		
Energy region, keV	PMT veto acceptance, **bare BEGe**	PMT veto acceptance, **BEGe with mesh MS**
$0\nu\beta\beta \pm 50$ keV	**0.040(5)**	**0.030(10)**
$0\nu\beta\beta \pm 100$ keV	**0.0385(26)**	**0.045(6)**
2605-2625 (FEP)	**0.756(19)**	**0.71(4)**

Coated nylon mini-shroud

Drift of ^{42}K ions can be prevented by putting around the detector foil which did not interfere with detection of the scintillation light in liquid argon. One of the promising candidate is nylon coated with TPB+PS wavelength shifter nylon foil.

Advantages of such solution:

- Probably better suppression in case if convection play important role.
- Good mechanical strength
- Can be produced very clean.
- Insulator: safer to work in closer distance to the detector.
- Shifted light will less absorbed in LAr -> better veto efficiency.

Currently is testing in LArGe!

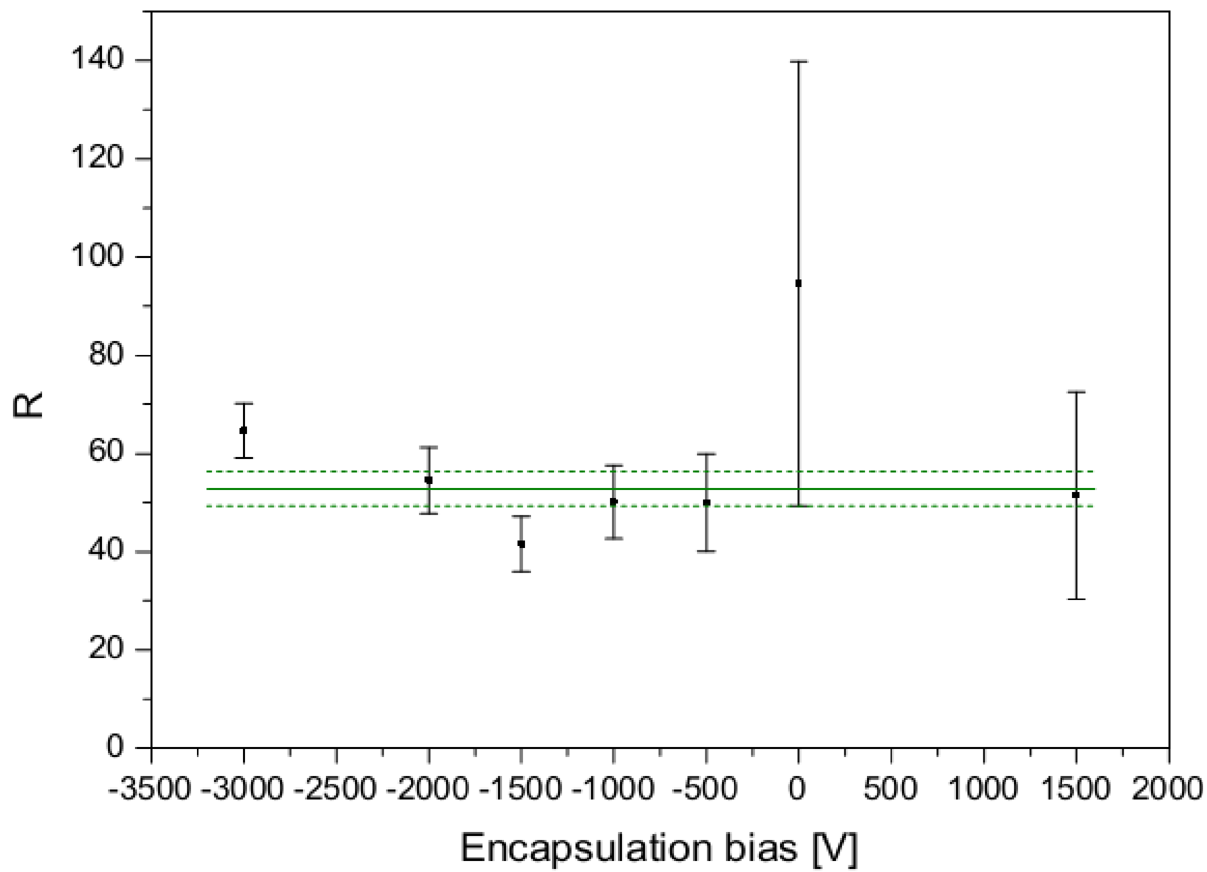
Conclusion

- Investigations of the background caused by ^{42}Ar has been performed in the low-background test facility LArGe.
- Comparison between count rates for the natural and spiked Ar gives an estimations of ^{42}Ar concentration in natural LAr. Preliminary estimation of the activity is $(65.6 \pm 3.7_{stat} \pm 13.5_{sys})$ µBq/kg from LArGe measurements and (92.8 ± 6.9) µBq/kg from GERDA measurements. It is about 2 times higher than the previous limit (<43 µBq/kg from V.D. Ashitkov, A.S. Barabash, et al. 2003).
- It was proven that PSD is an effective method to suppress background from ^{42}K for GERDA Phase2. Obtained acceptances after applying 88% PSD cut in 400 keV near $0\nu\beta\beta$ was better than 1 % [90% c.l.].
- Development of the transparent mini-shroud is ongoing. First results have been obtained. Copper mesh mini-shroud allows to suppress ^{42}K background in about 10 times, keeping similar suppression of PMT veto.
- All this information indicates that ^{42}K background can be suppressed at the level below GERDA Phase II requirements.

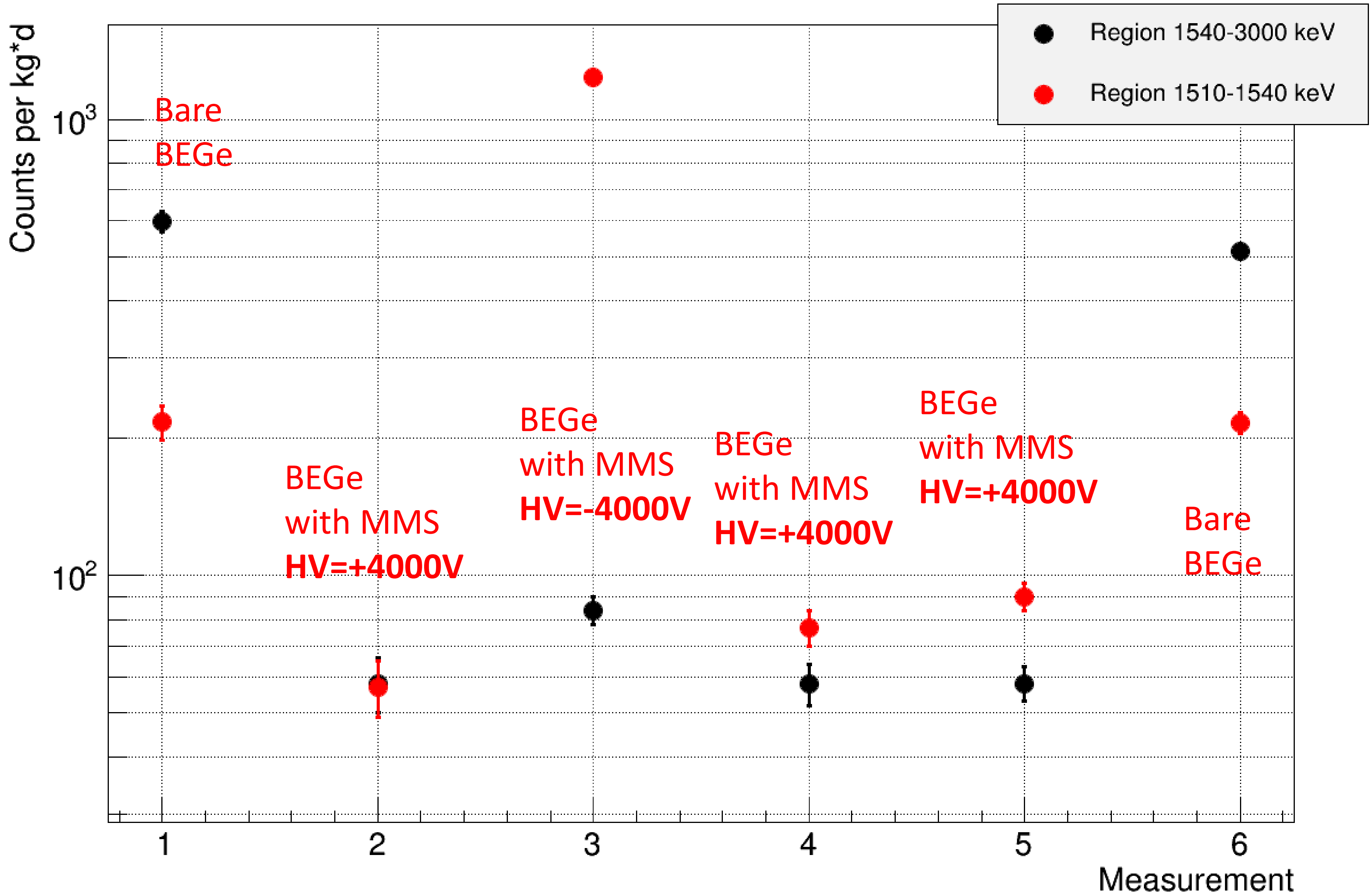
Back up slides

Preliminary estimations of the activity of ^{42}Ar

With well-known activity at different HV biasing of the encapsulation it is possible estimate to directly the abundance of ^{42}Ar in natural LAr using ratio of the count rates. Assuming that there is no significant influence of the collection properties of ^{42}K in LAr after dissolving it inside LArGe, we can estimate concentration of ^{42}Ar. Average value of the activity is **($65.6 \pm 3.7_{stat} \pm 13.5_{sys}$) µBq/kg.** Additional studies of the systematics which can be introduced via influence on the ^{42}K collection from LAr properties is required.



Results from LArGe measurements



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