^{42}K background mitigation for GERDA Phase II

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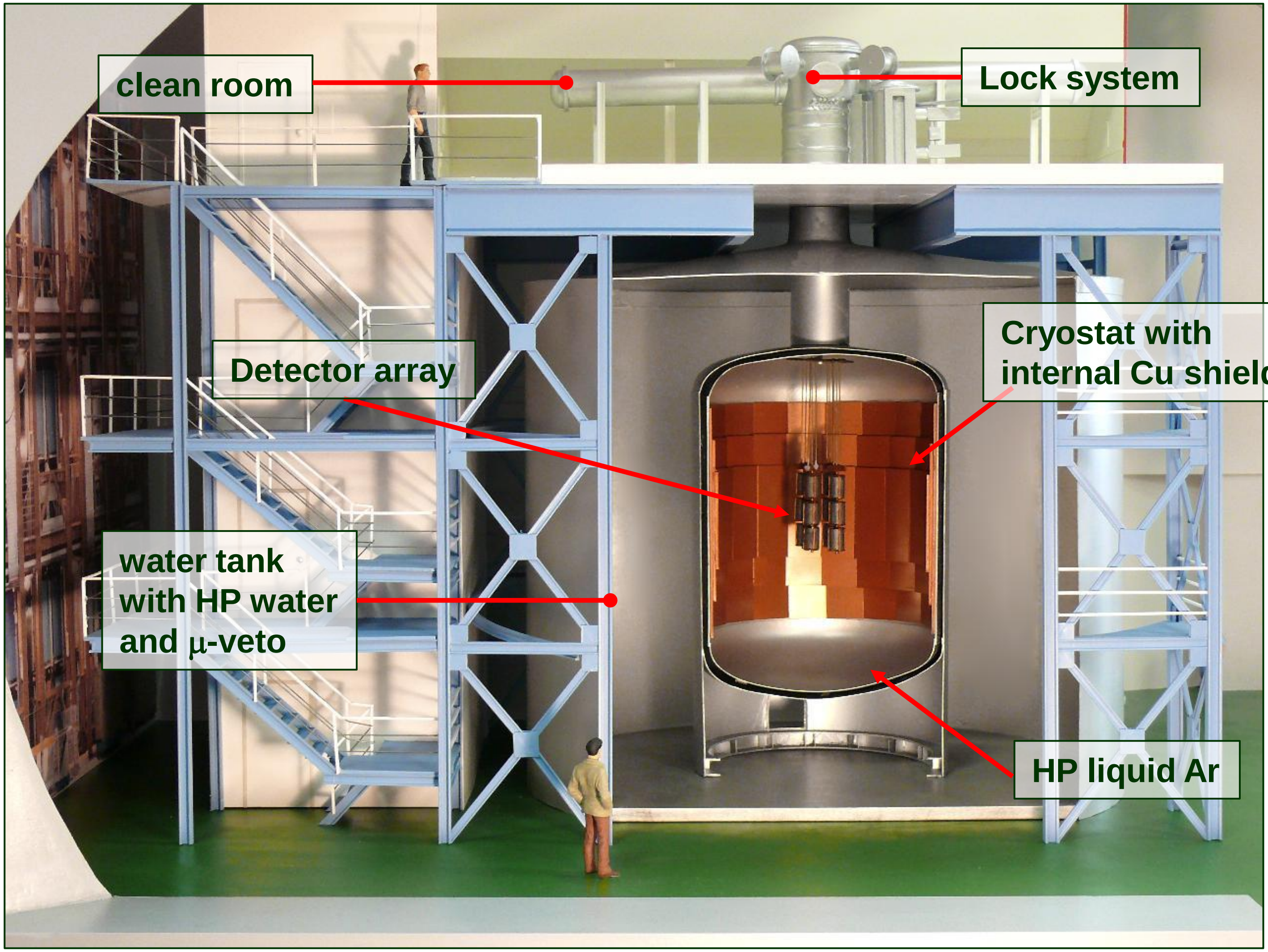
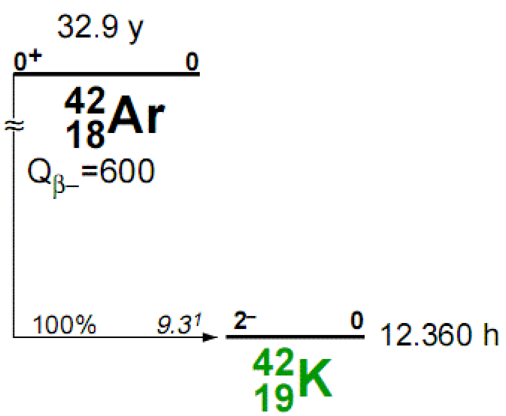
GERDA experiment

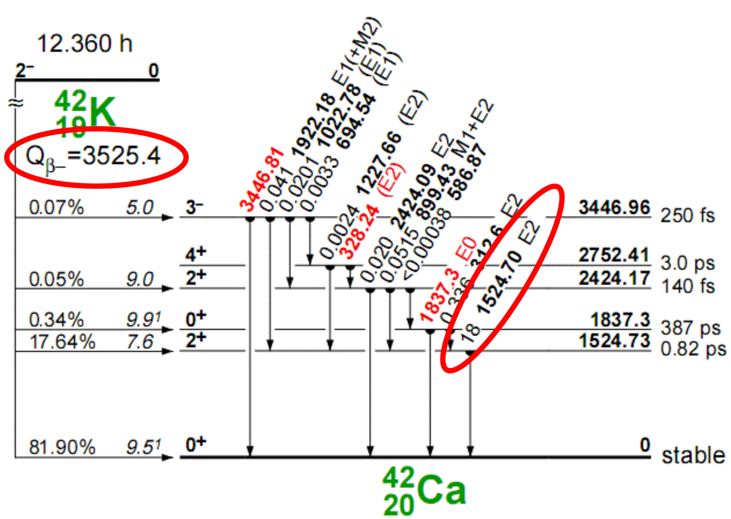
In GERDA experiment bare germanium detectors enriched by ^{76}Ge are submerged into the high-purity liquid argon. This allows to decrease background from the surrounding materials, liquid argon shields from the radiation and cools down the Ge detectors.

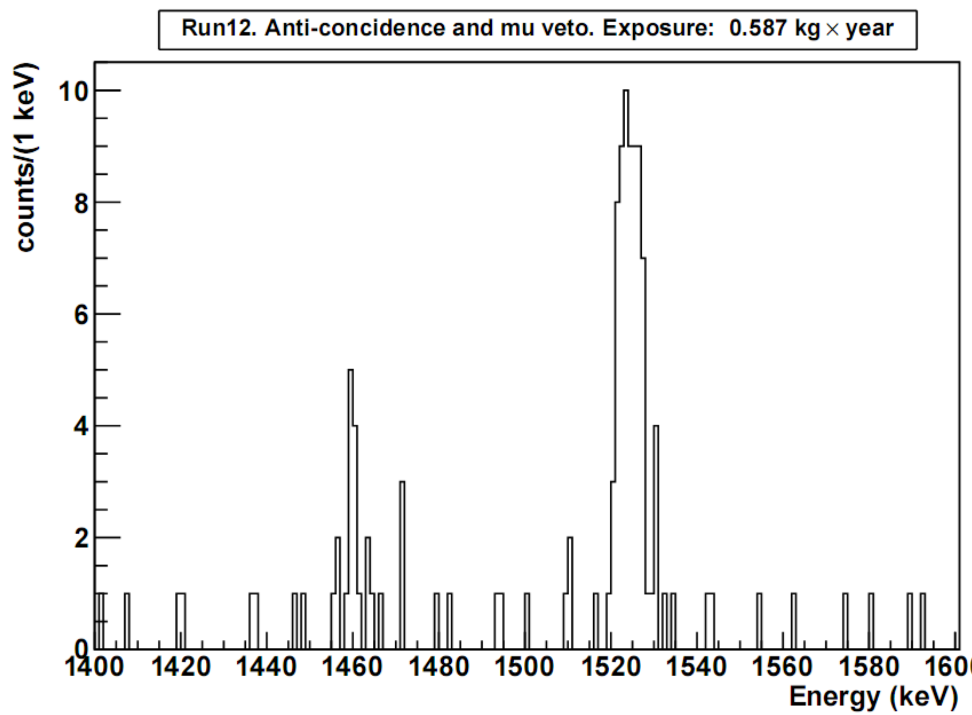


Unexpected ^{42}Ar background

Already during first commissioning runs in GERDA 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 we expected from the previous limit (< 30 μBq/kg)[Bar02].
During our investigations we understood the origin of an increase of the background and we able to suppress it.

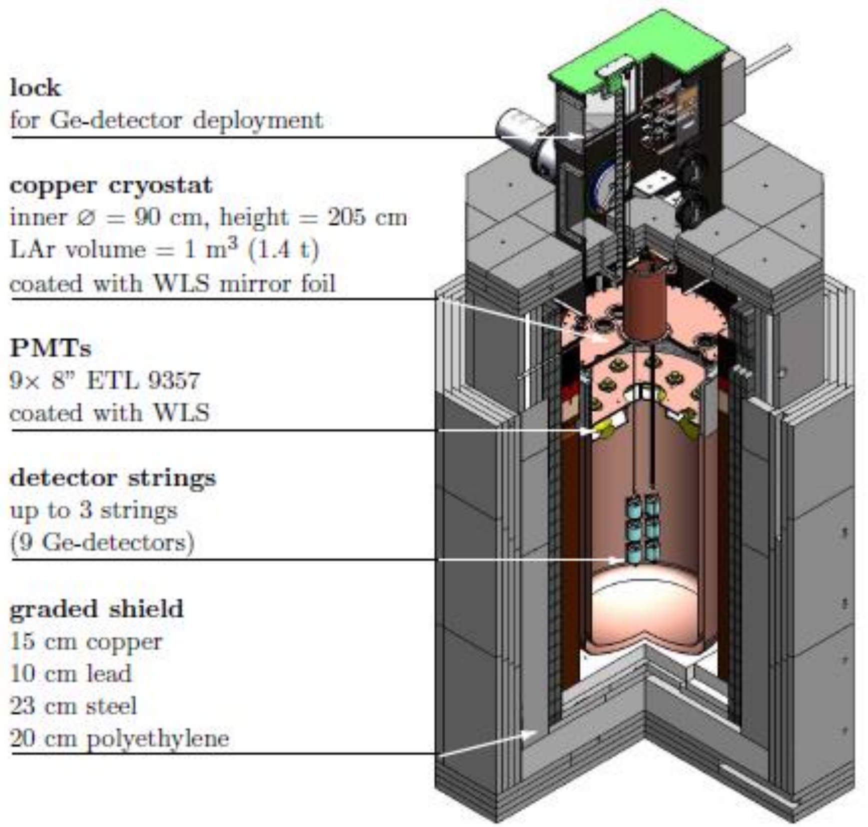






LArGe test facility

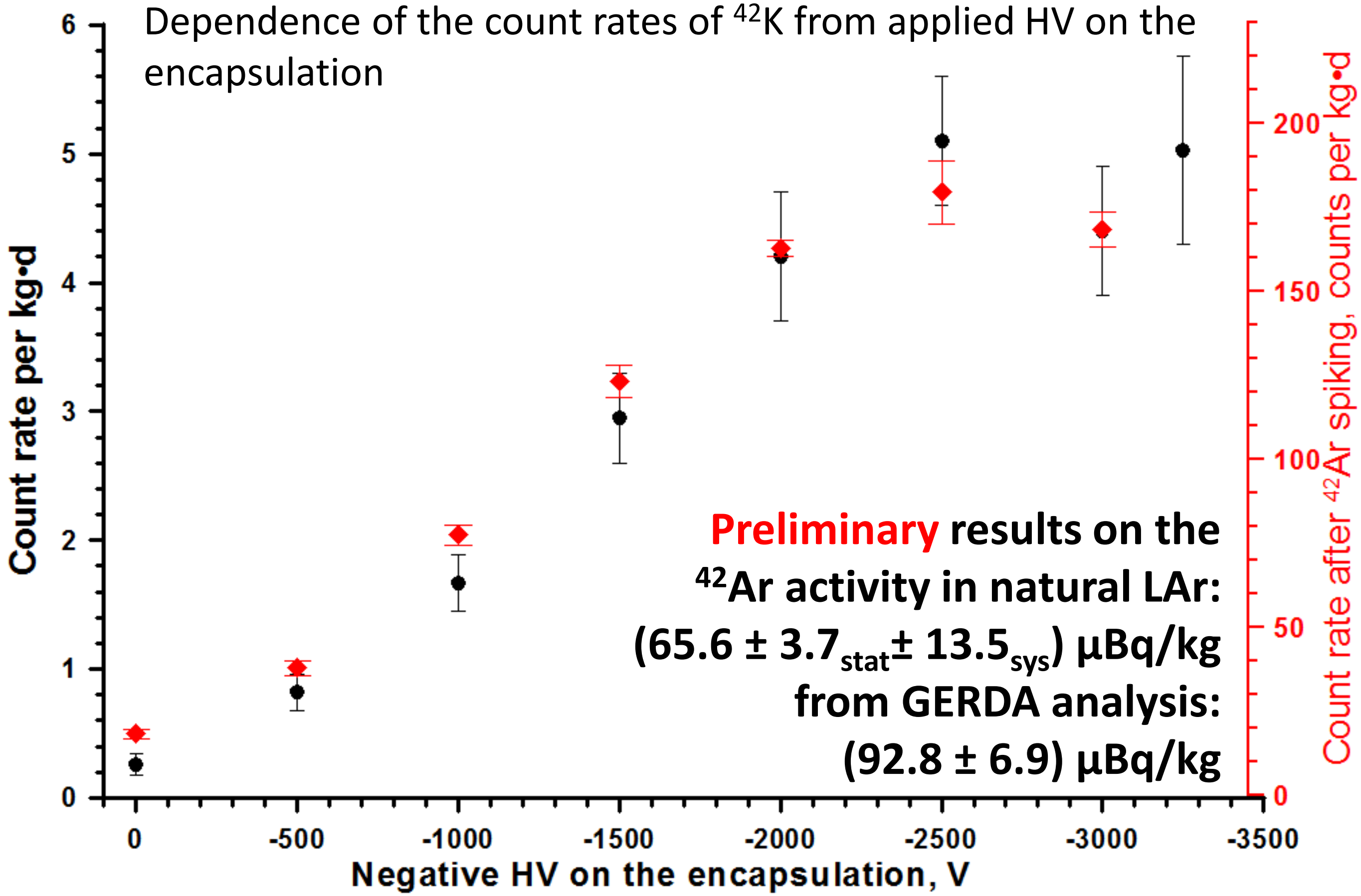
Investigations of ^{42}Ar background behavior have been performed in LArGe, a low background test facility. LArGe was created in order to study the possibility to suppress backgrounds by using anticoincidence with liquid Ar scintillation signal detected by PMTs.

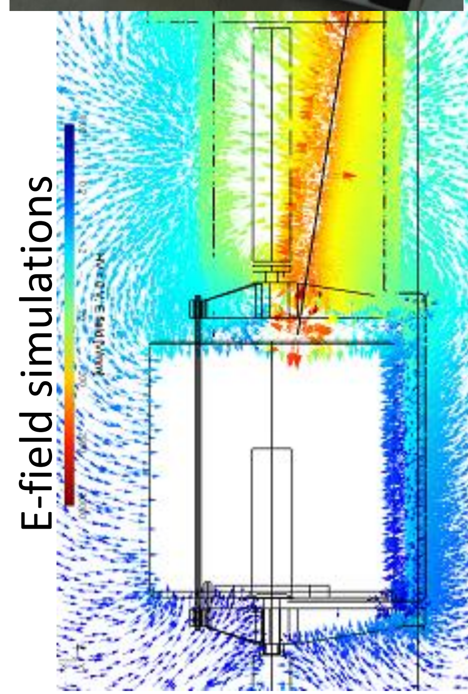


For detail investigation of the collection processes of ^{42}K and for direct estimation of the activity of ^{42}Ar well-known amount of the activity of ^{42}Ar has been introduced into the LArGe volume.

^{42}K collection by encapsulated detector

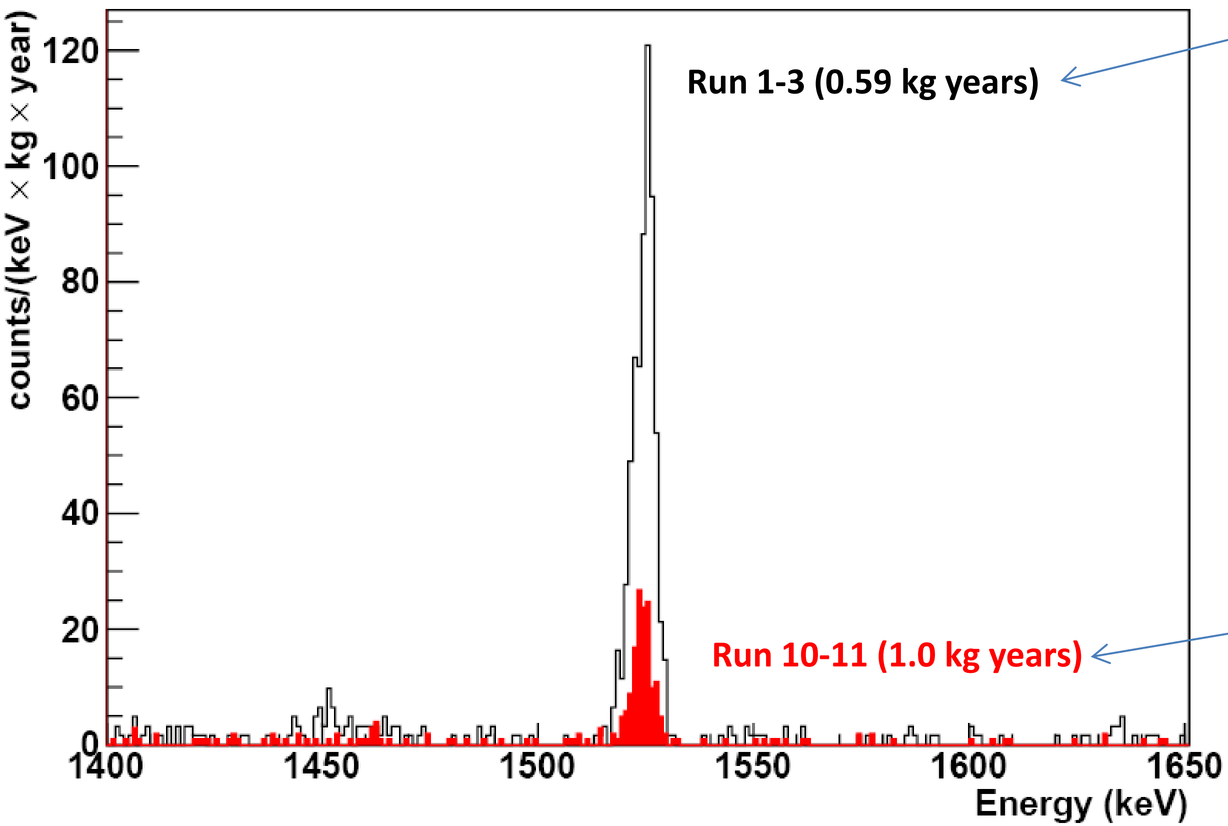
Measurements with a germanium detector have been performed in LArGe for investigation of the collection processes of ^{42}K. The detector was fully **encapsulated** by a PTFE/Cu/PTFE sandwich. It is possible to apply positive/negative HV on the encapsulation and study of collection ^{42}K ions by electric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

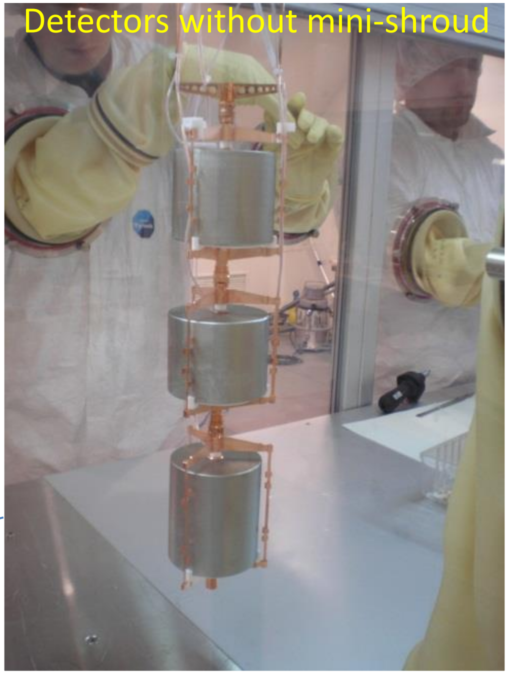




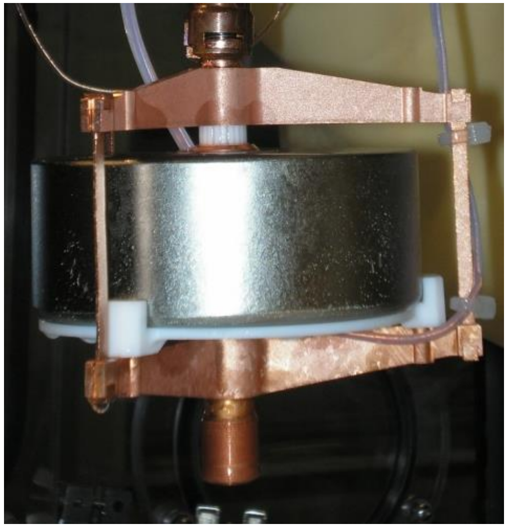
Mini-shroud

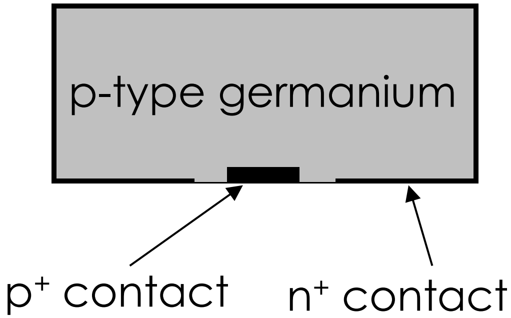
To suppress ^{42}K background in GERDA Phase I we used copper mini-shroud that cover detector from all sides allowing to suppress ^{42}K background. Its contribution estimated to be about **3×10^{-3} cts/(keV·kg·yr)** near ROI of $0\nu\beta\beta$.
However for the GERDA Phase II background requirements are higher: All backgrounds should be **< 1×10^{-3} cts/(keV·kg·yr).**





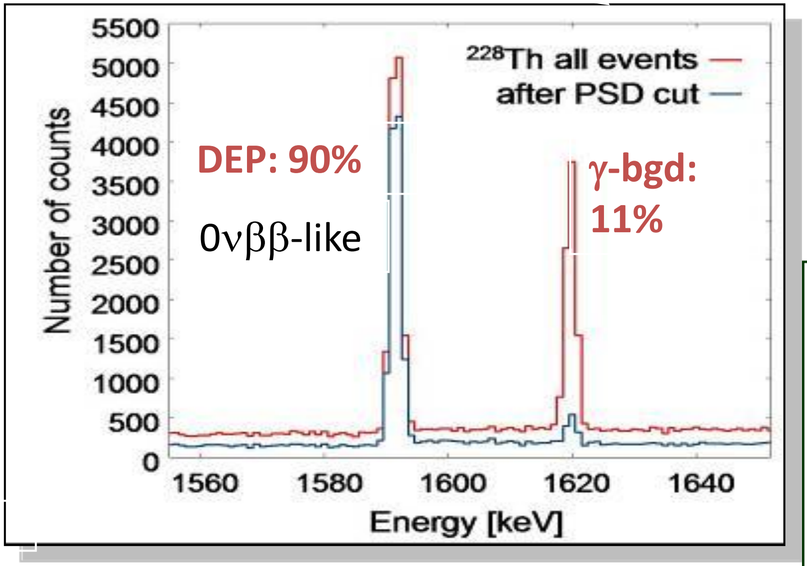
GERDA phase II: BEGe detectors



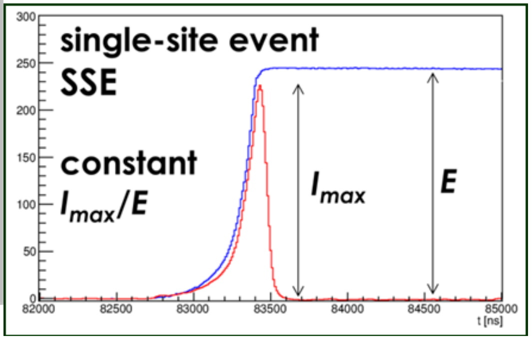


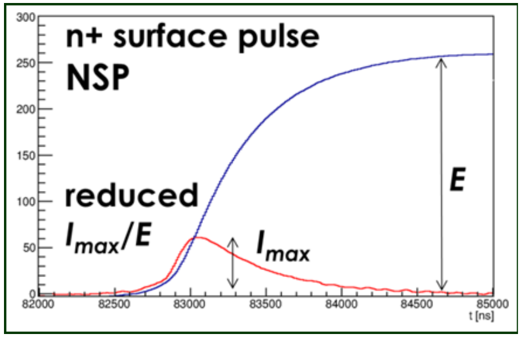
- Very good energy resolution: up to **1.6 keV** (FWHM @ 1.33 MeV in a vacuum cryostat).
- Powerful PSD which allow not only efficiently suppress multi-side effect (dominated background from gamma), but also distinguish surface events.
- Dead layer of newly produced BEGe detectors is much smaller: -> smaller absorption of surface electrons -> higher ^{42}K background -> higher suppression needed

Powerful Pulse Shape Discrimination (PSD)



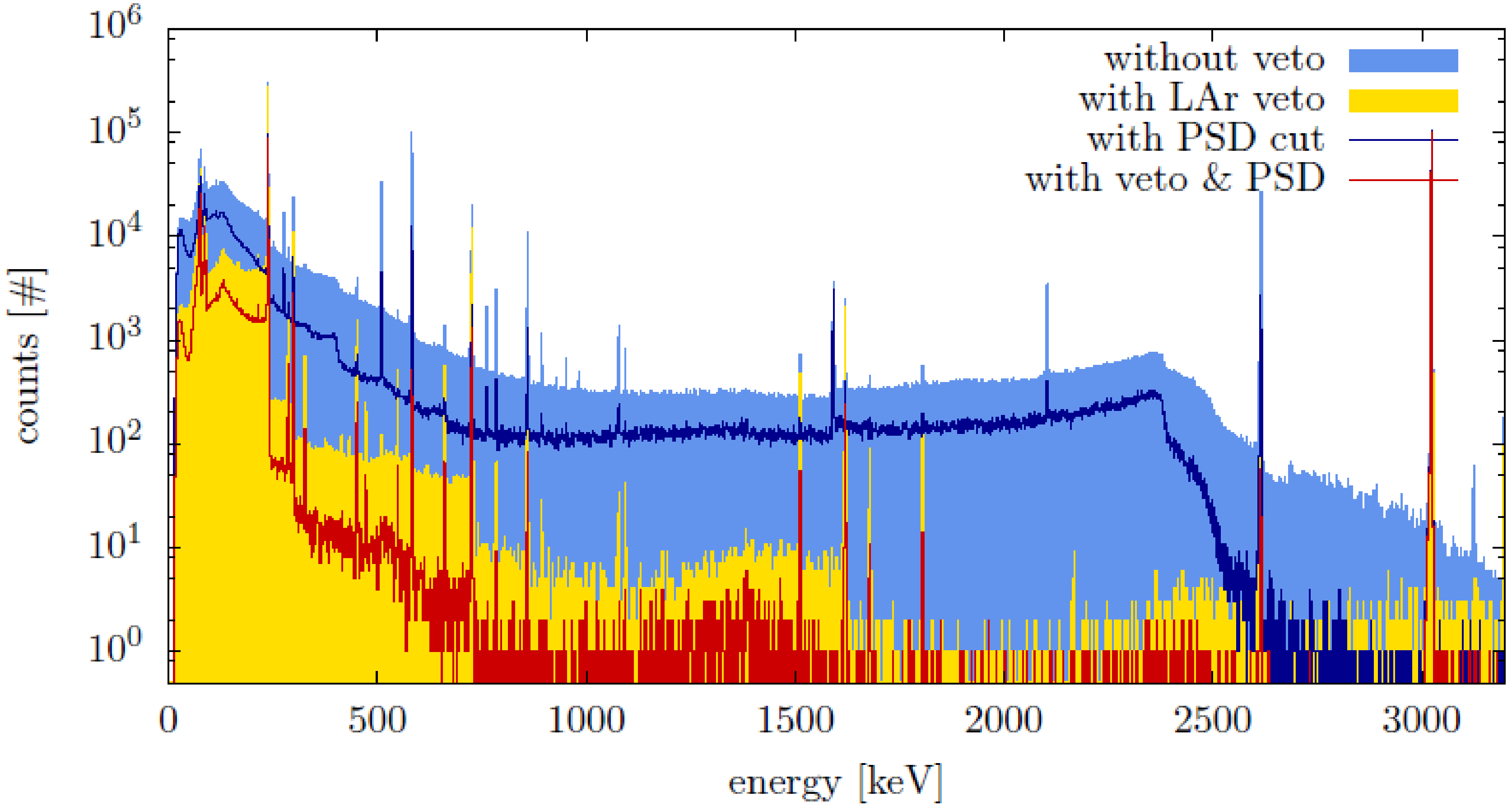
PSD of events from the surface of the detector





GERDA phase II: light instrumentation

Light scintillation veto will be implemented in GERDA Phase II setup.



But usage of copper mini-shroud will decrease efficiency of scintillation veto dramatically. So another configuration should be used instead of copper mini-shroud .

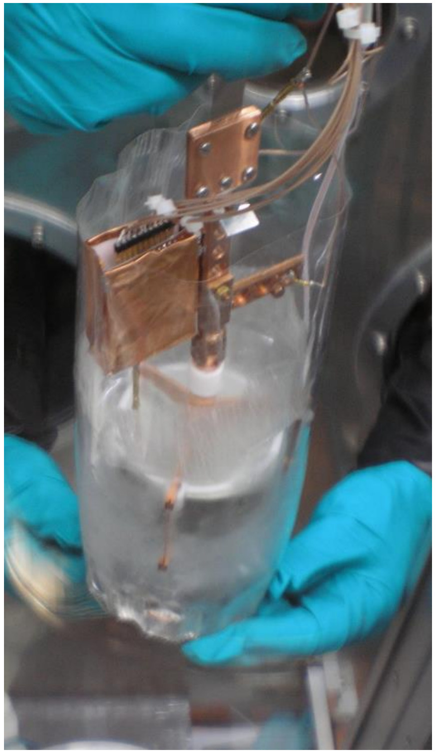
Coated nylon mini-shroud

To suppress ^{42}K background in GERDA Phase II we will use nylon mini-shroud (NMS) instead of copper foil. It is the same nylon that was used for inner balloon of Borexino experiment. Such mini-shroud creates a barrier which prevent collection of ^{42}K towards to the detector without changes of the e-field configuration around the detector.
For scintillation light detection we coated it with wavelength shifter (WLS).

Already first investigations showed that:

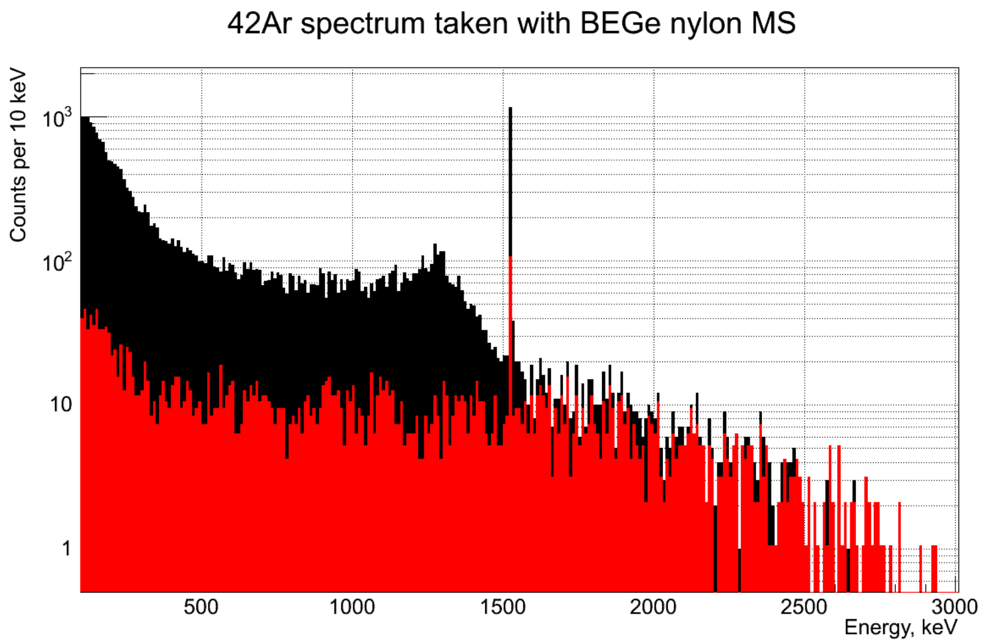
- NMS has good mechanical strength even at cryogenic temperatures.
- It is very radioactively clean.
- Shift and transport light which can be detected by PMTs.

To check suppression of ^{42}K background by NMS and properties of the scintillation veto we tested NMS in LArGe test facility.



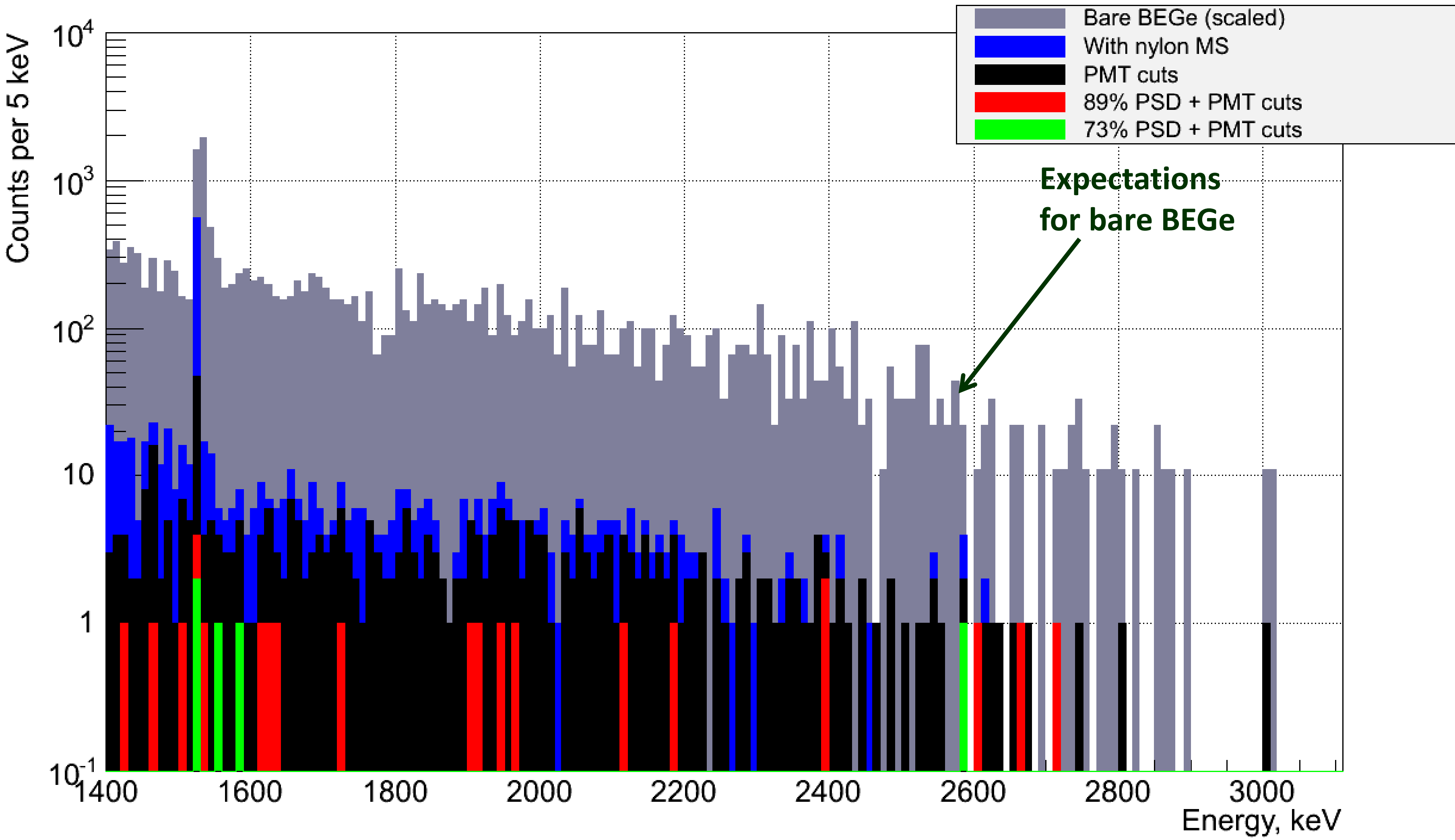
PMT veto acceptances

Energy region, keV	PMT veto acceptance, bare BEGe	PMT veto acceptance, BEGe with NMS
1510-1540 (gamma line)	0.32(3)	**0.100(14)**
1540-3000 (beta region)	0.70(4)	**0.63(5)**
1839-2239 (ROI)	0.78(8)	**0.67(8)**



No deterioration of PMT scintillation veto were seen in respect with bare BEGe detector. Moreover **significantly better suppression of 1.5 MeV gamma line is observed.**
An increase of scintillation veto efficiency can be explained by the fact that shifted light is less absorbed in a liquid argon than unshifted.

Suppression by NMS+PSD+PMT veto



Activity of spiked ^{42}Ar is about 200 times higher than natural, so accumulated statistics is equivalent approximately to ~ 17 kg·yr in natural argon.

Expectations for BI

Experimental conditions	Number of counts in measurements with spiked ^{42}Ar in 400 keV ROI of $0\nu\beta\beta$ for 32 days	Expected background index in GERDA from ^{42}K in 400 keV ROI of $0\nu\beta\beta$ 10^{-3}cts/(keV·kg·yr)
Bare BEGe (scaled)	3700	290-800*
NMS	220	20-56
NMS + 89% PSD + PMT	3	0.28-0.76
NMS + 73% PSD + PMT	0	<(0.2-0.6) [90% C.L.]

Preliminary!

* Estimation based on the measurements in LArGe and GERDA

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 two times higher than the previous limit (<43 µBq/kg from V.D. Ashitkov, A.S. Barabash, et al. 2003).
- It was shown that with NMS+PSD+PMT suppression it is possible to dramatically decrease ^{42}K background: from initial 3700 counts no events survived after application all the cuts.
- Estimations based on this experimental data demonstrated that ^{42}K background can be suppressed at the level below GERDA Phase II requirements: $<10^{-3}$cts/(keV·kg·yr).