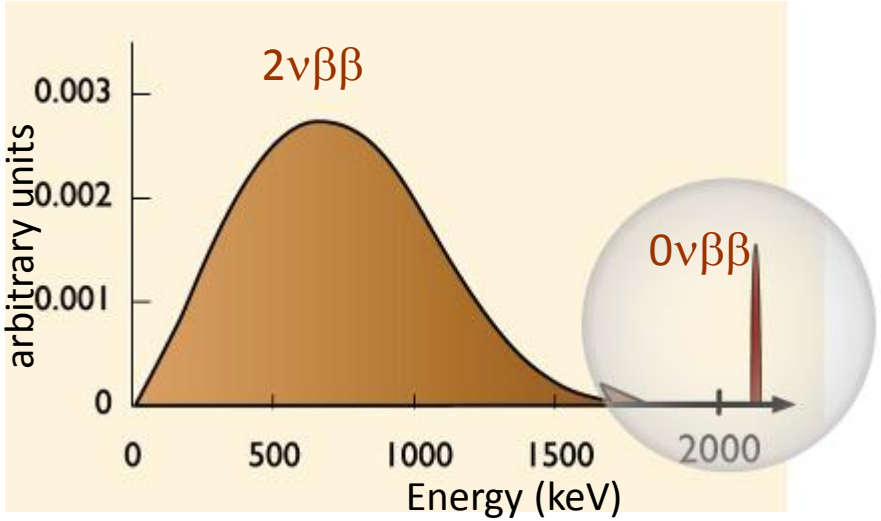
Investigations of the ^{42}Ar background in the LArGe test facility for the GERDA experiment

A.V. Lubashevskiy
on behalf of GERDA collaboration,
Max-Planck-Institut für Kernphysik,
Heidelberg

Motivation

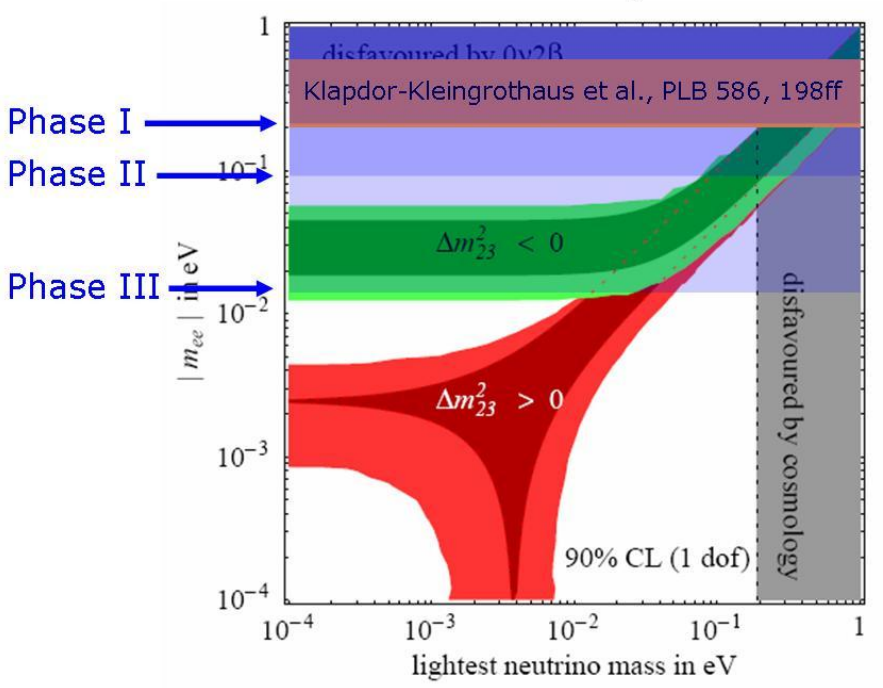


The main goal of the GERDA experiment is searching for neutrinoless double beta decay of ^{76}Ge. Background level is one of the most important factors for the successful experiment.
Phase1: expected BI ~ 0.01 counts / (kg · y · keV)
Phase2: expected BI ~ 1 counts / (ton · y ·keV)

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

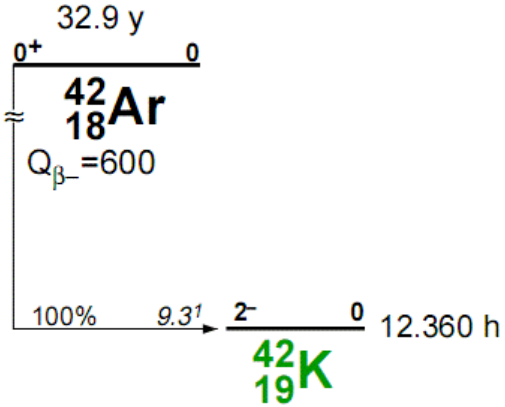
M Mass
t Time
B Background rate
ΔE Energy resolution

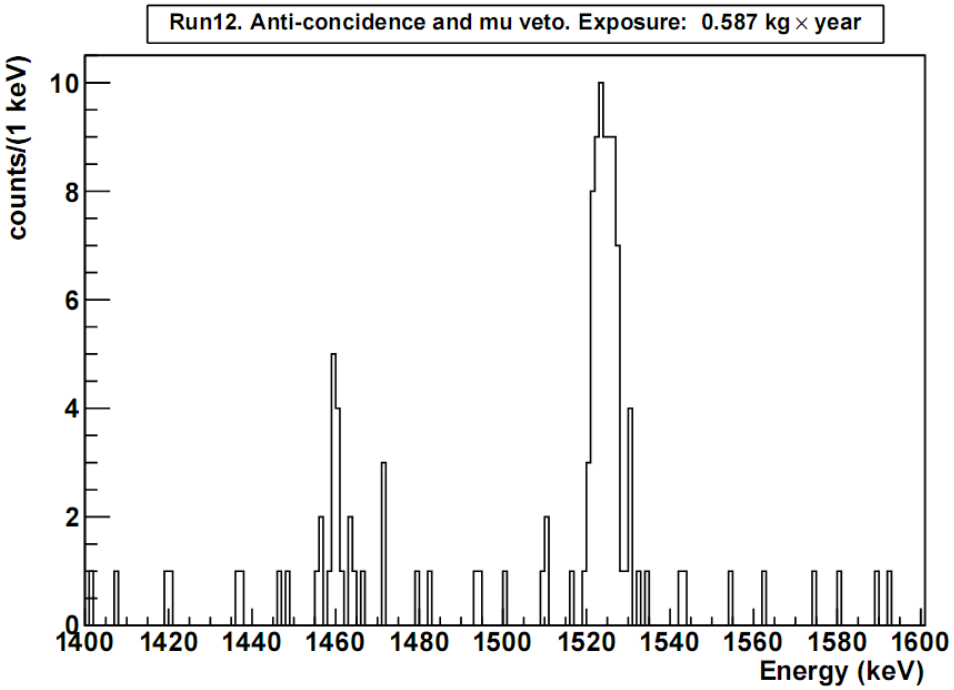
GERDA sensitivity

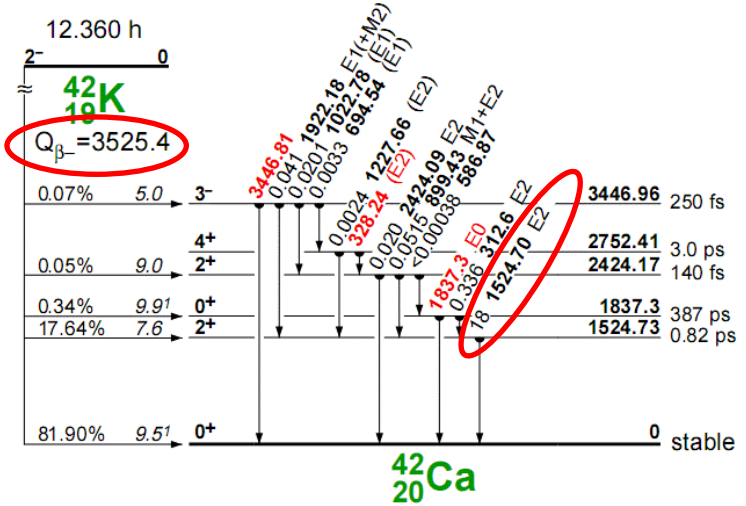


Unexpected ^{42}Ar background

In the **proposal of GERDA** for estimation of the ^{42}Ar concentration in liquid Ar in GERDA cryostat, the **limit of ^{42}Ar/^{nat}Ar < 3·10^{-21}** [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 removing electric field)
Possible explanation: ^{42}K ion collection on the surface by E-field?

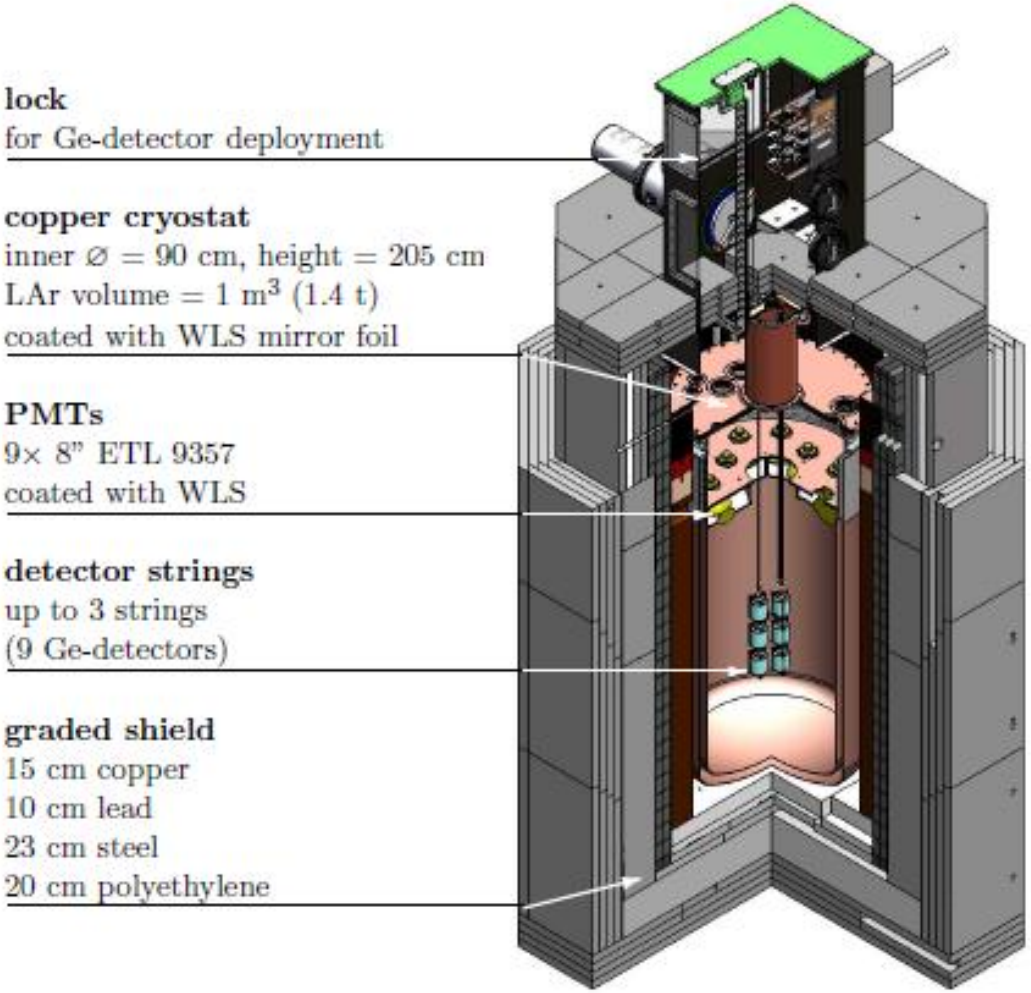






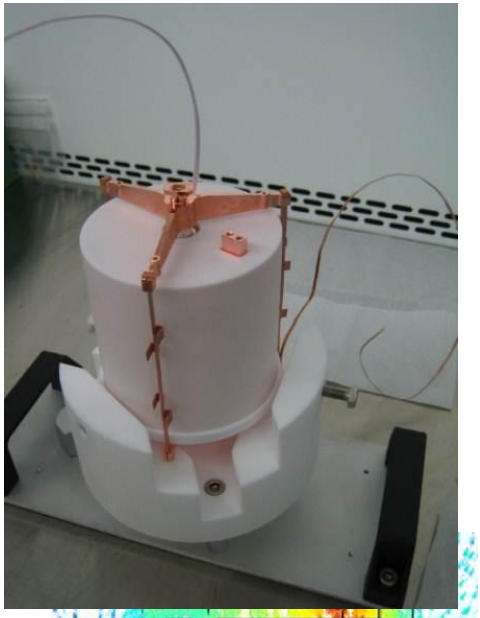
LArGe test facility

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

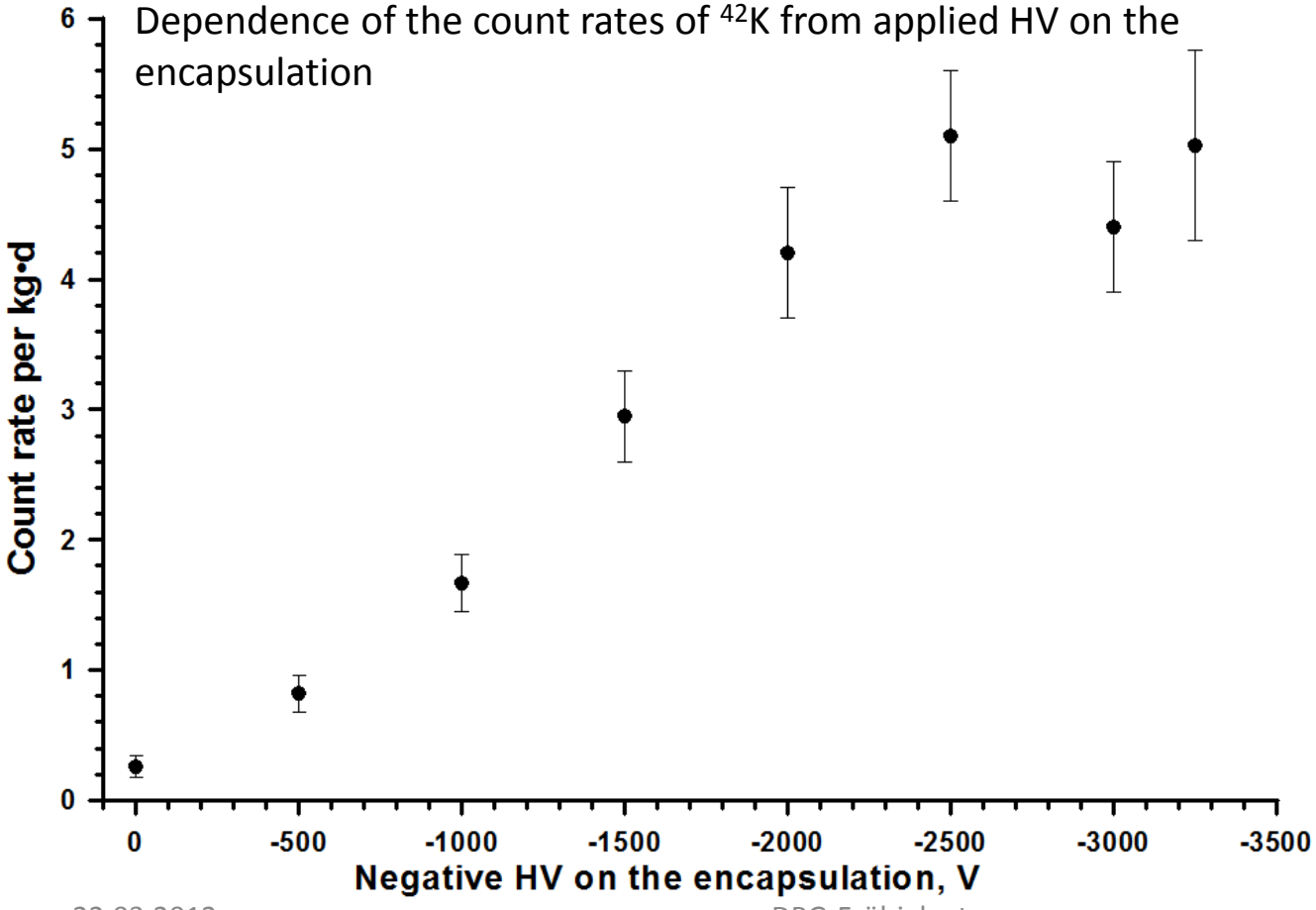


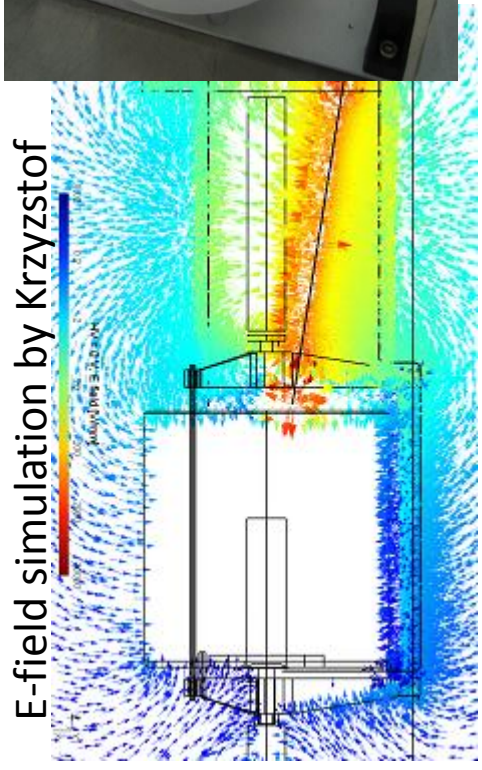
^{42}K collection by encapsulated detector

Measurements with a germanium detector have been performed in LArGe (in a "quasi background" mode) for investigation of the collection processes of ^{42}K. The detector was fully **encapsulated** by a PTFE/Cu/PTFE sandwich.



Dependence of the count rates of ^{42}K from applied HV on the encapsulation



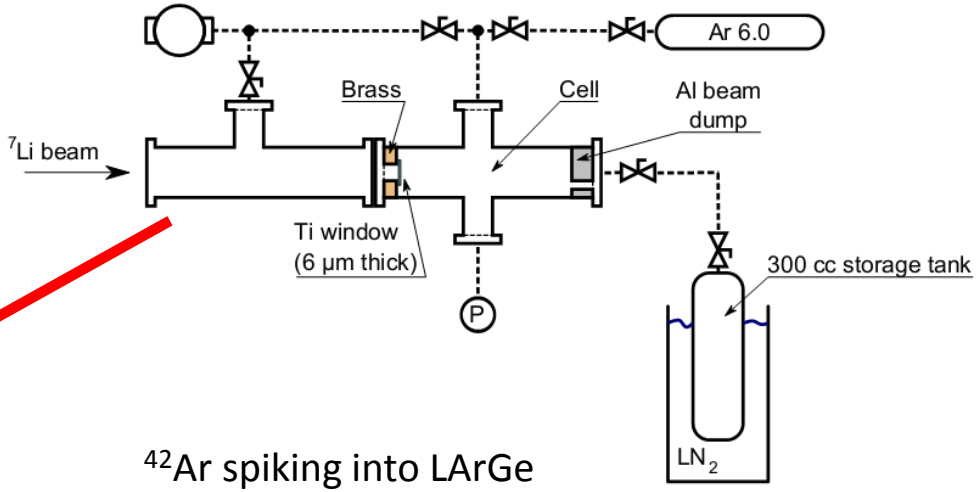


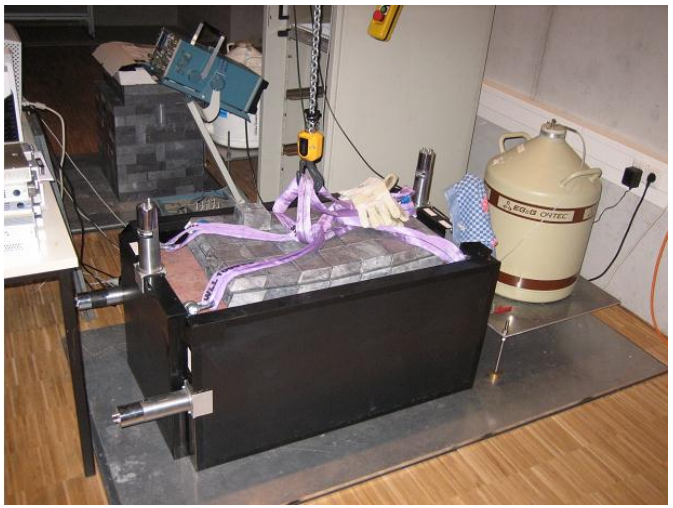
E-field simulation by Krzyzstof

^{42}Ar source production & spiking

For further 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.

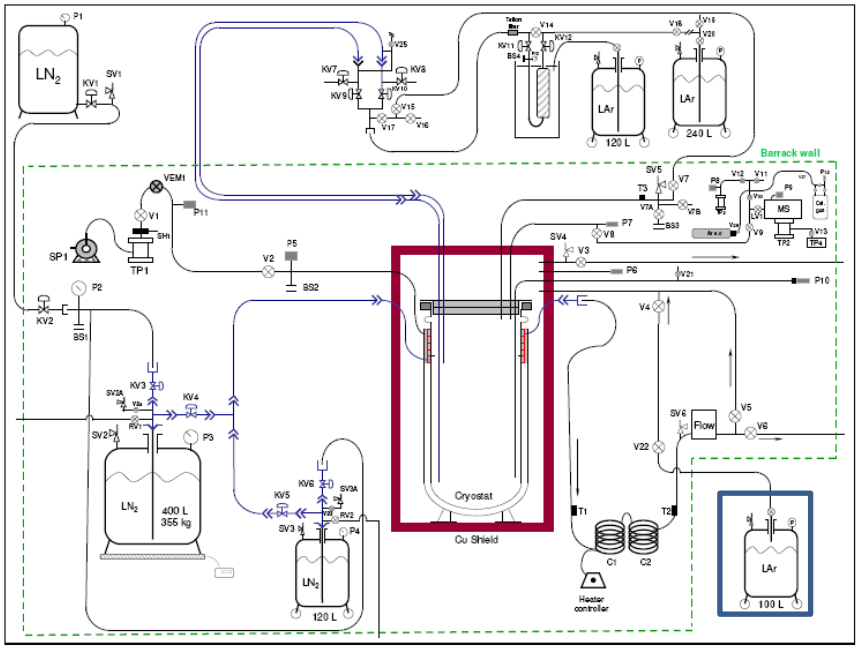
^{42}Ar production at MLL Garching by TUM from ^{40}Ar via (^{7}Li, α p)





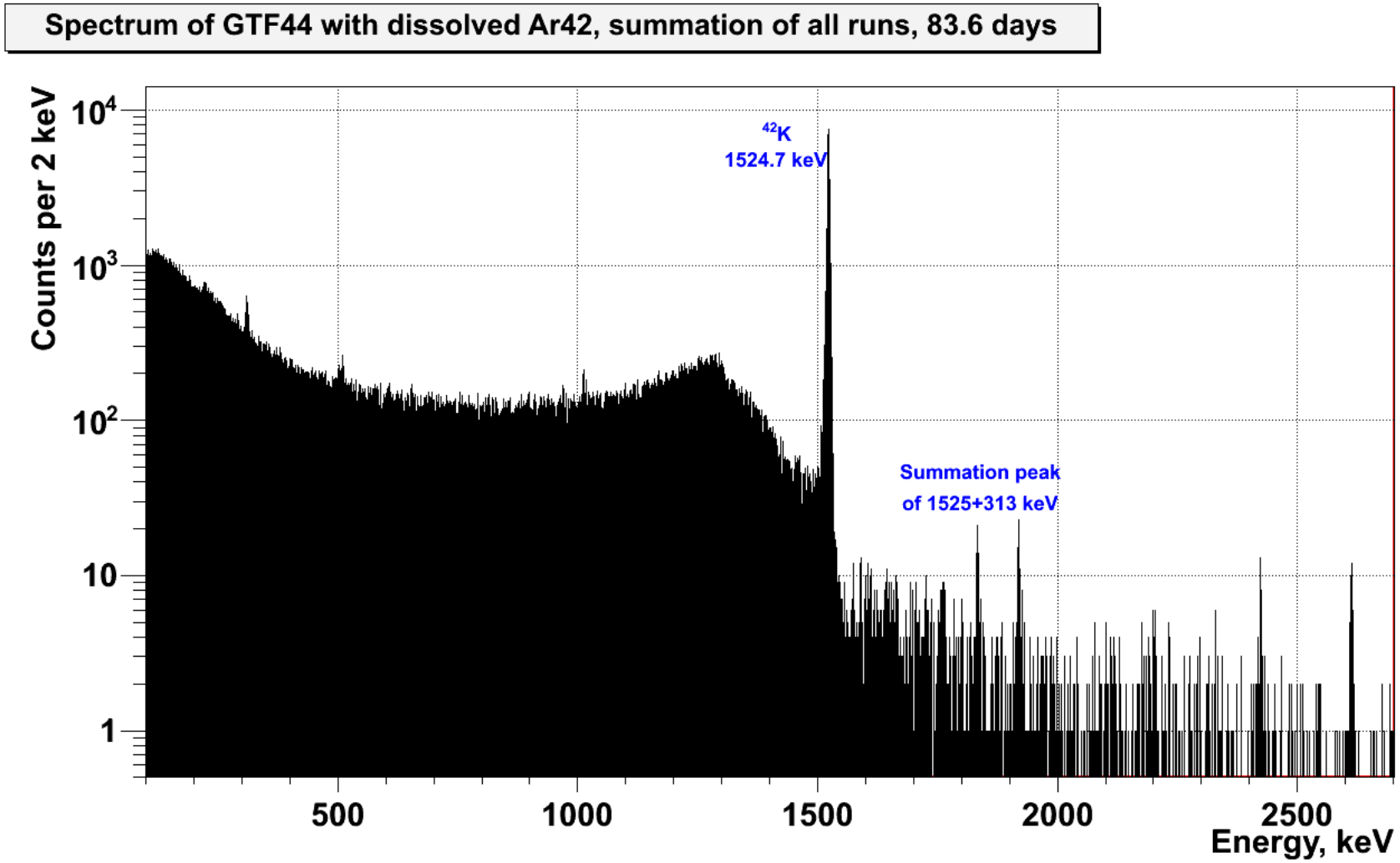
Screening at Garching and LNGS.
Estimated activity of ^{42}Ar is
5.18±0.91 Bq

^{42}Ar spiking into LArGe



^{42}K spectrum

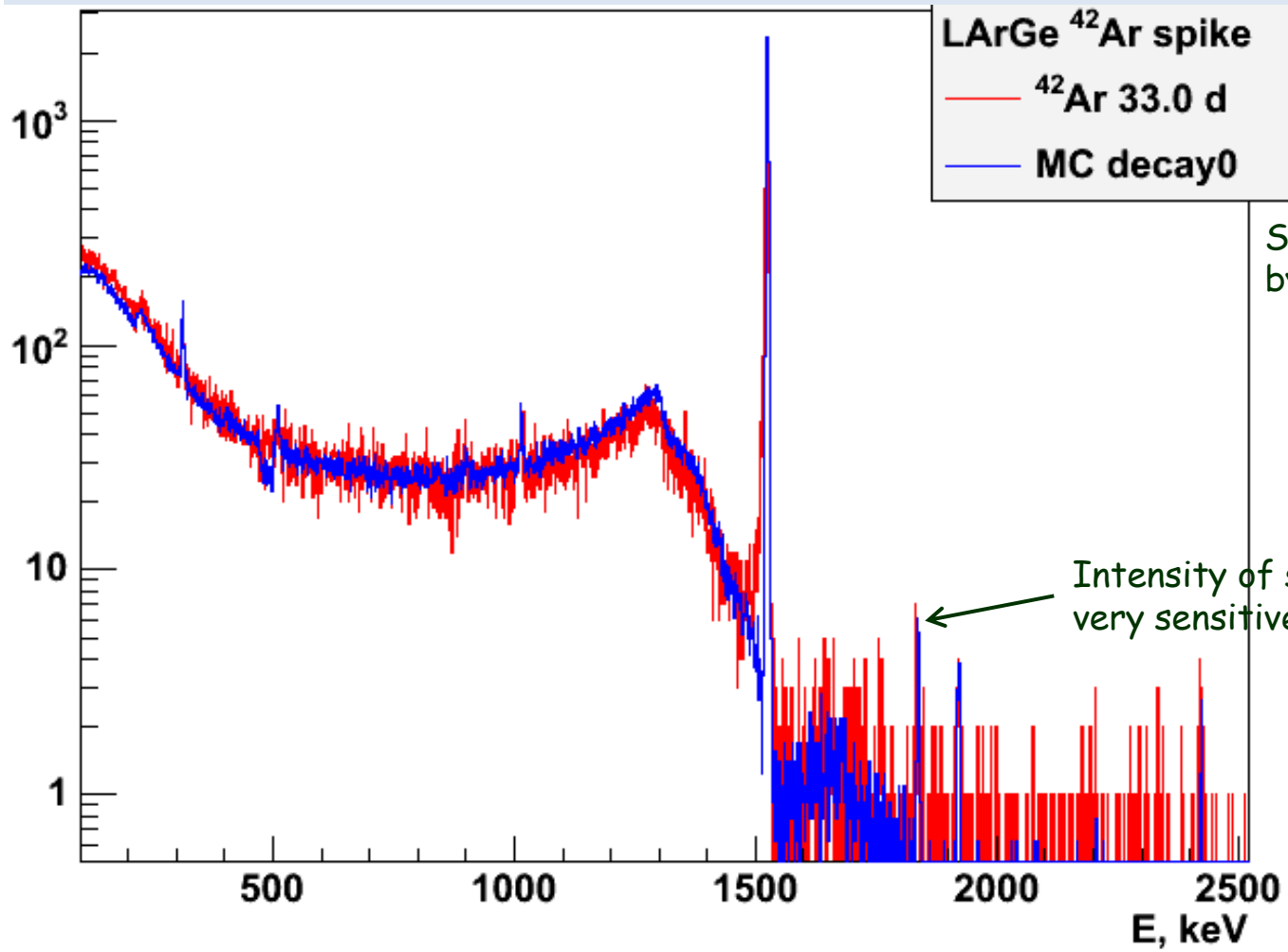
After dissolving of ^{42}Ar into LArGe count rates under the peak increased by about factor of 40 with respect to the measurements with natural Ar.



^{42}K location

Comparison between simulation and experiment gives an important information about ^{42}K location. At least a big fraction of ^{42}K ions should be located near detector to explain experimental data.

Experiment data and simulation (uniformly distributed on the surface)

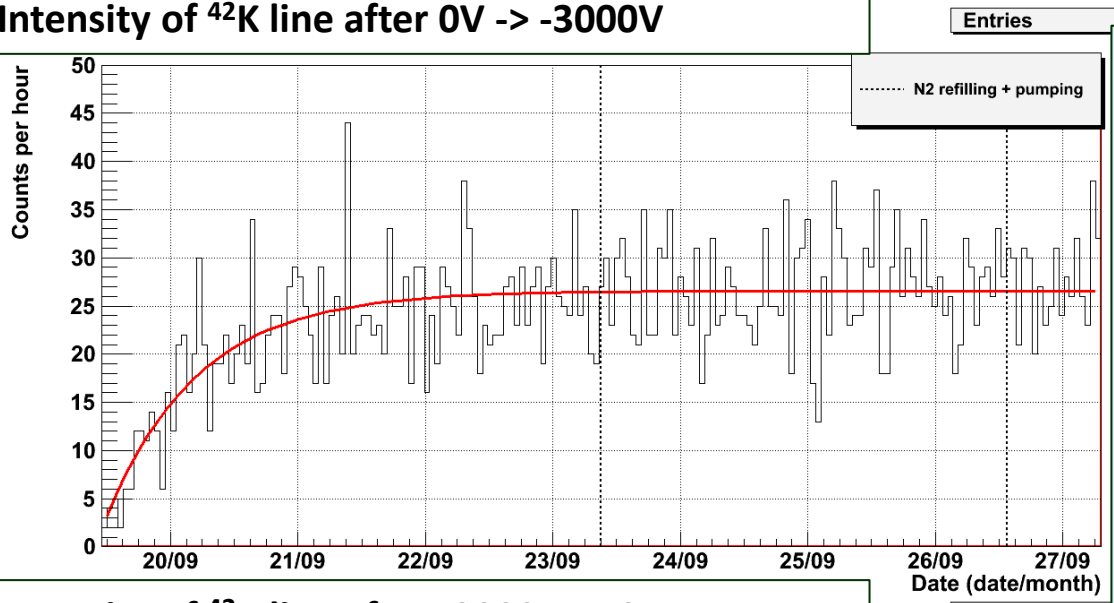


Simulation performed by Alexander Klimenko

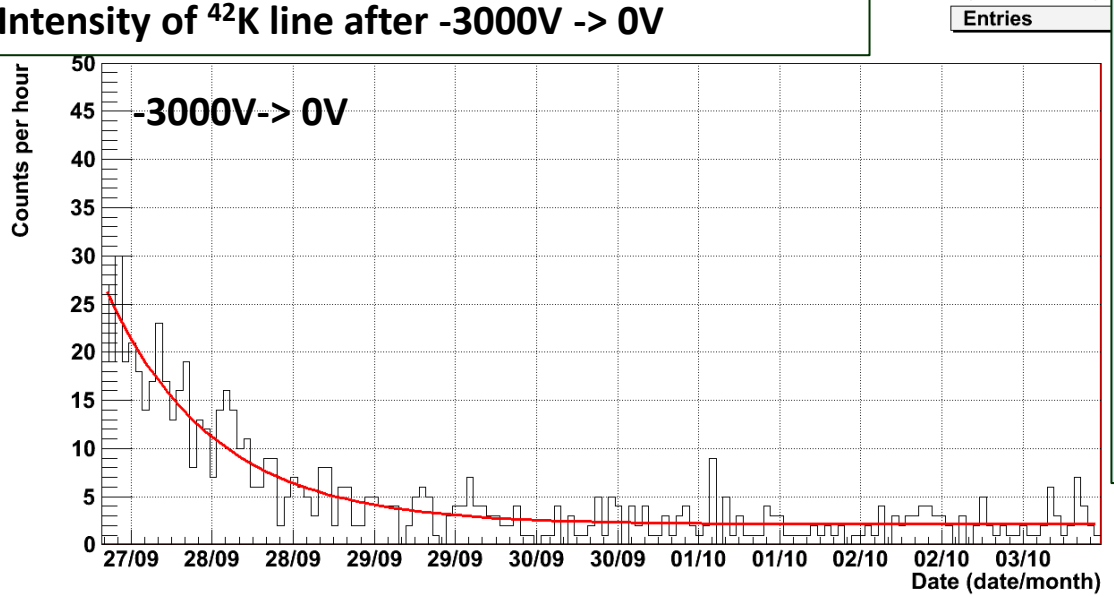
Intensity of summation peak is very sensitive for source location

^{42}K collection

Intensity of ^{42}K line after 0V -> -3000V



Intensity of ^{42}K line after -3000V -> 0V



The measured time constant for the ^{42}K accumulation towards the encapsulation after switching the encapsulation bias voltage from 0V to -3000V follows an exponential transient with

$T_{1/2}$= 11.4(13) hours.

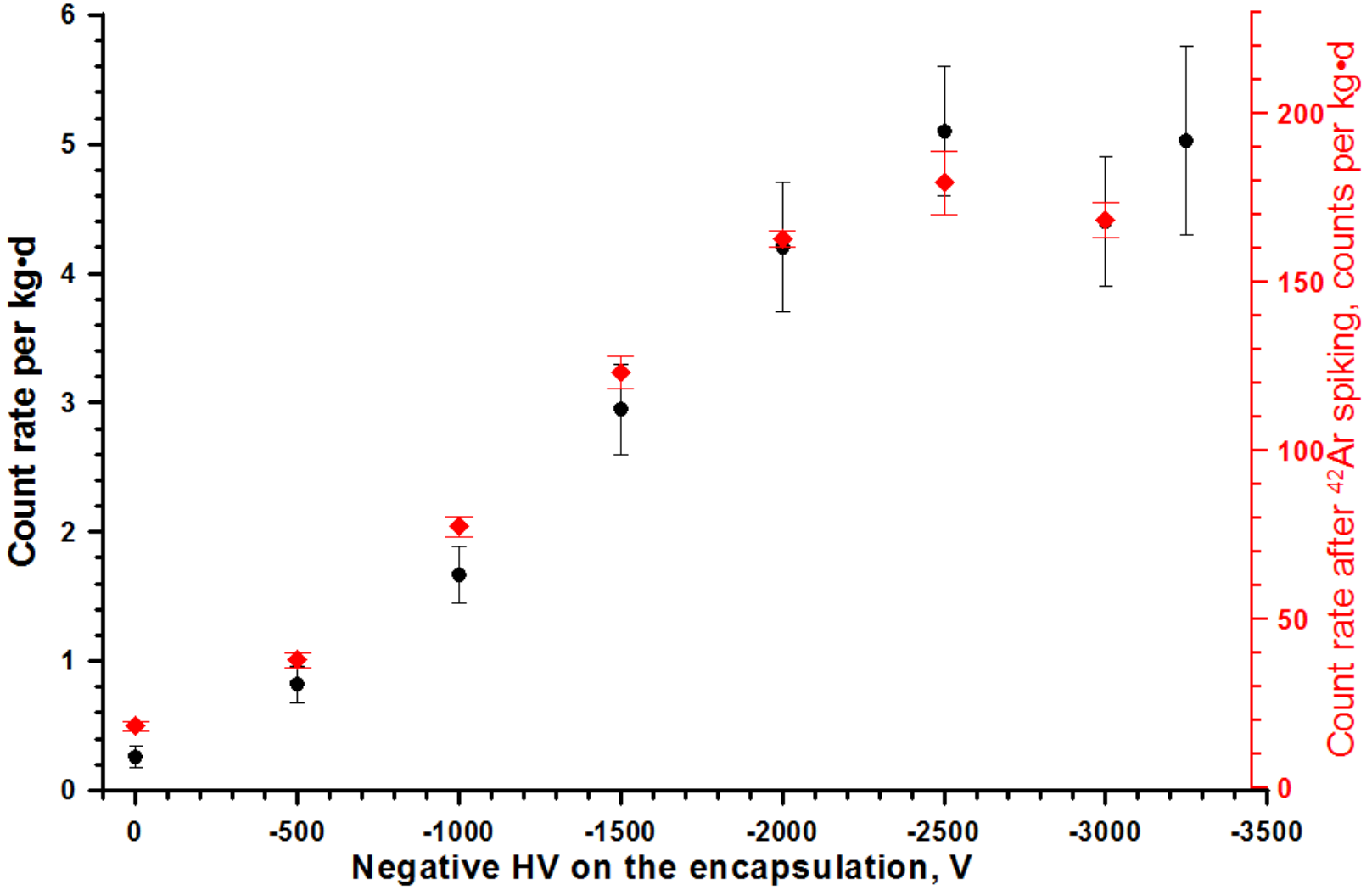
^{42}K ions attracted by the encapsulation are sticking to the PTFE surface (or alternatively stay close by in case of absence of convection) after switching the bias voltage from -3000 V to 0 V. The measured half-life of

$T_{1/2}$ = 11.1(10) hours

is in agreement with the nuclear half-life of ^{42}K (12.36 hours)

Dependence of ^{42}K count rate

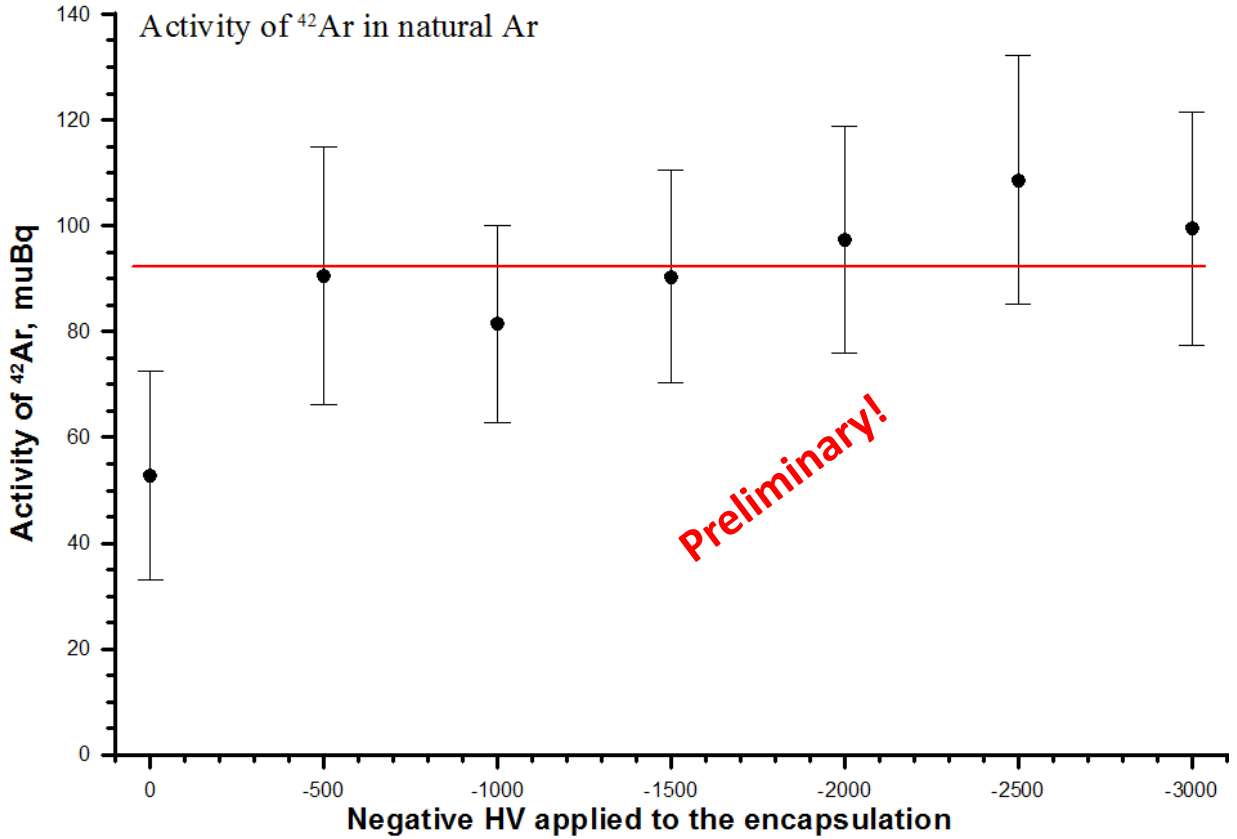
Intensity of ^{42}K line shows similar behavior depending on the applied negative HV both for the natural and spiked Ar cases.



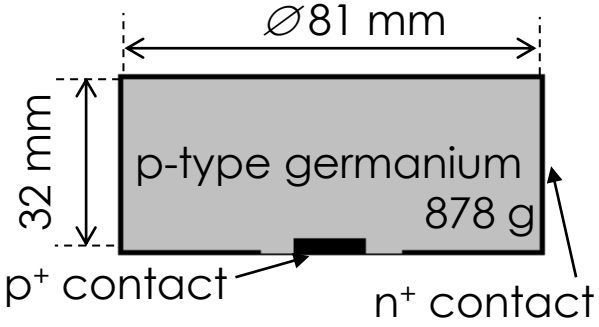
Preliminary estimations of the activity of ^{42}Ar

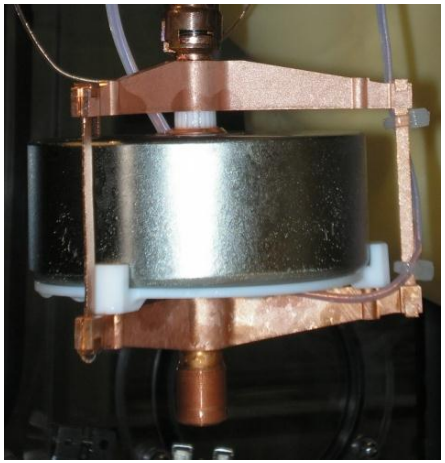
With well-known activity at different HV biasing of the encapsulation it is possible estimate to directly the abundance of ^{42}Ar in natural LAr using ratio of the count rates. Assuming that there is no significant influence of the collection properties of ^{42}K in LAr after dissolving it inside LArGe, we can estimate concentration of ^{42}Ar. Average value of the activity is **94.5±4.7(stat)±17.5(system) μBq/kg.** This corresponds to ^{42}Ar concentration: $^{42}Ar/^{nat}Ar = 9.3 \cdot 10^{-21}$.

Preliminary! Additional studies of the systematics which can be introduced via influence on the ^{42}K collection from LAr properties is required.

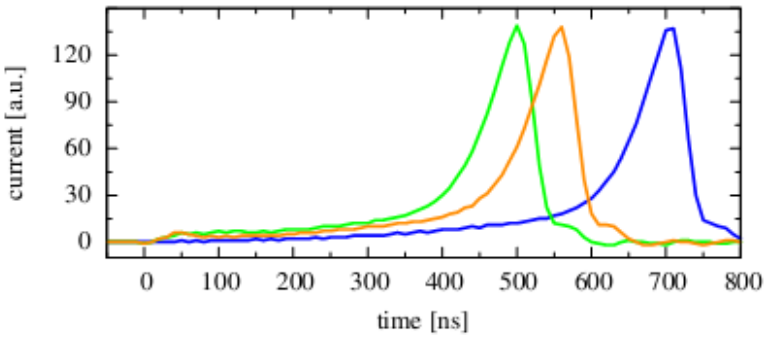


GERDA phase II detectors: BEGe

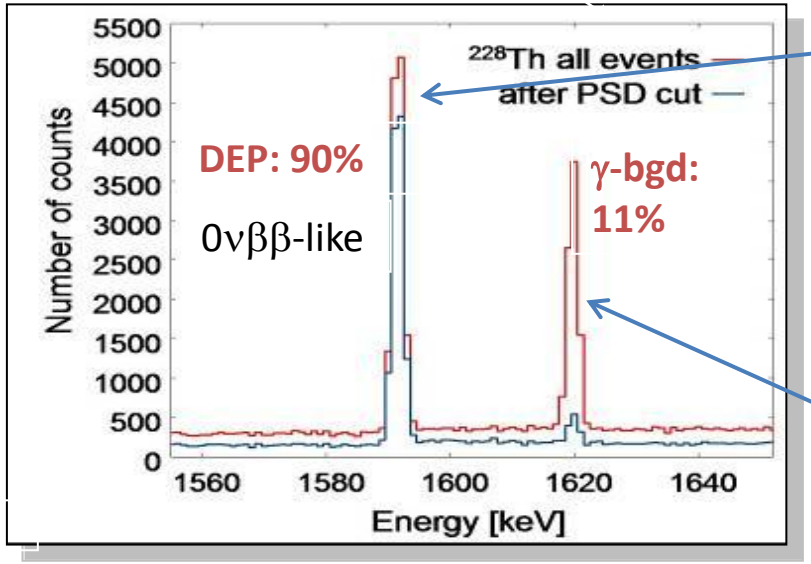


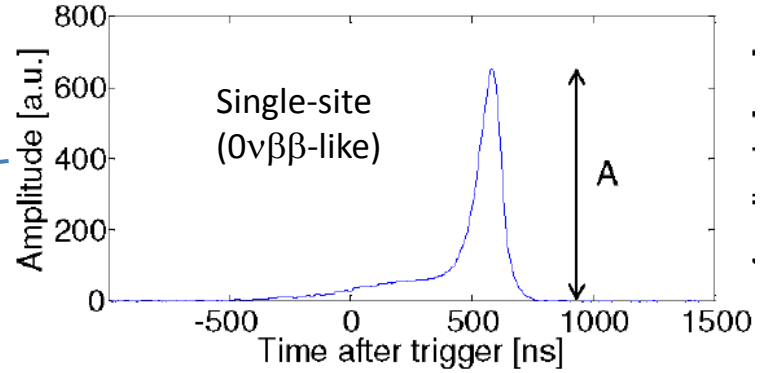


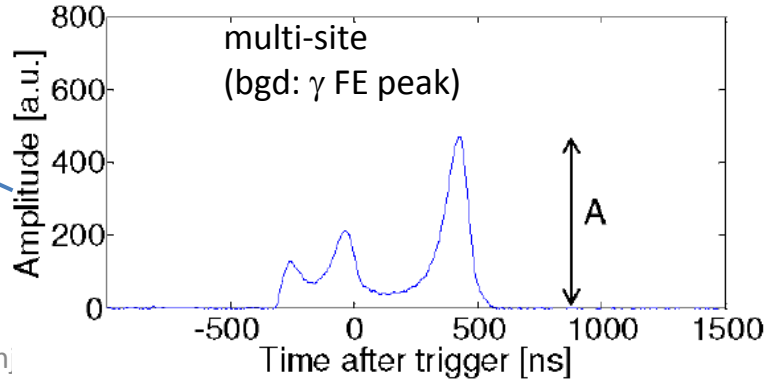
Simulation by Matteo Agostini



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



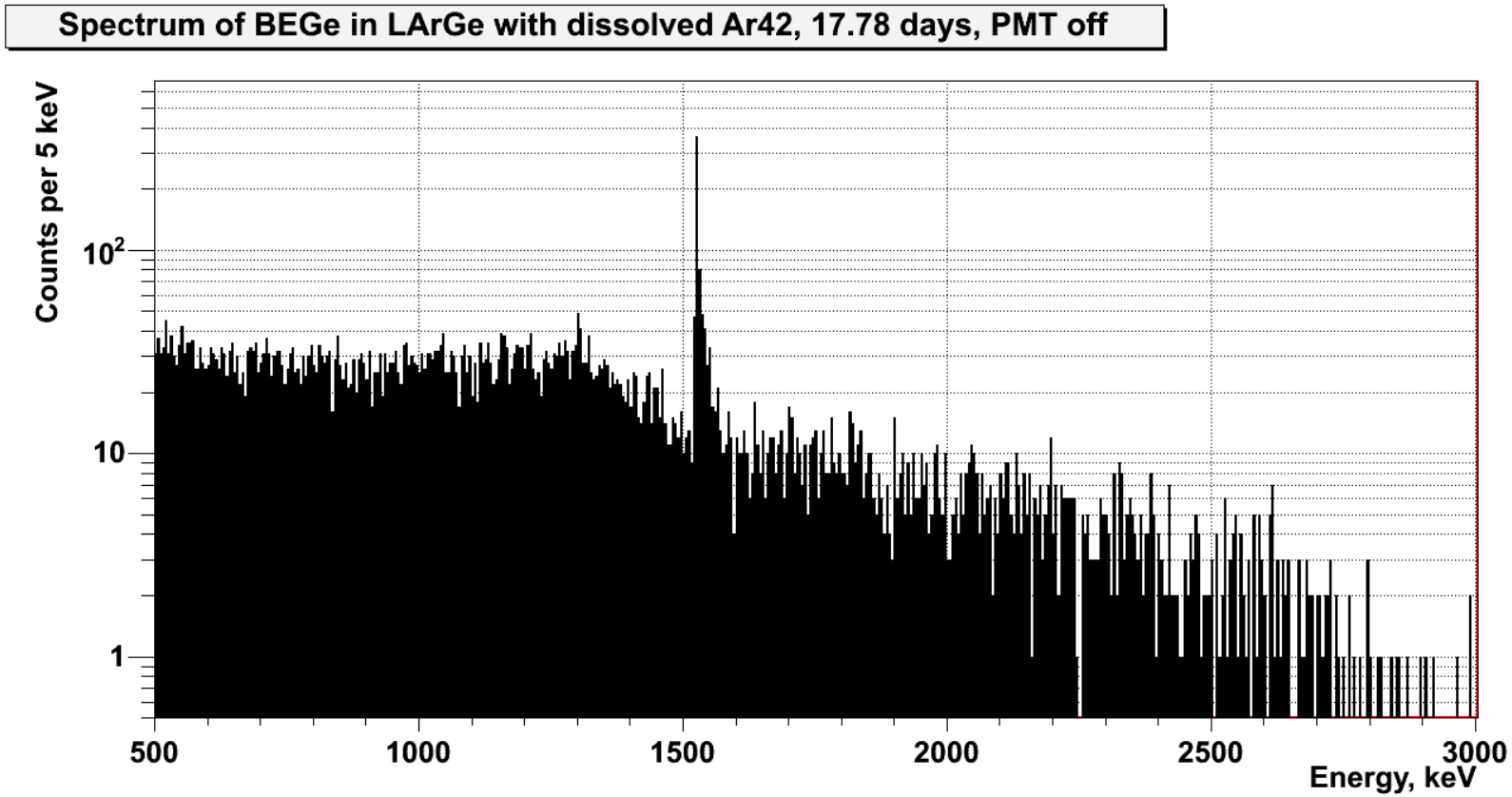




Measurements with BEGe in LArGe

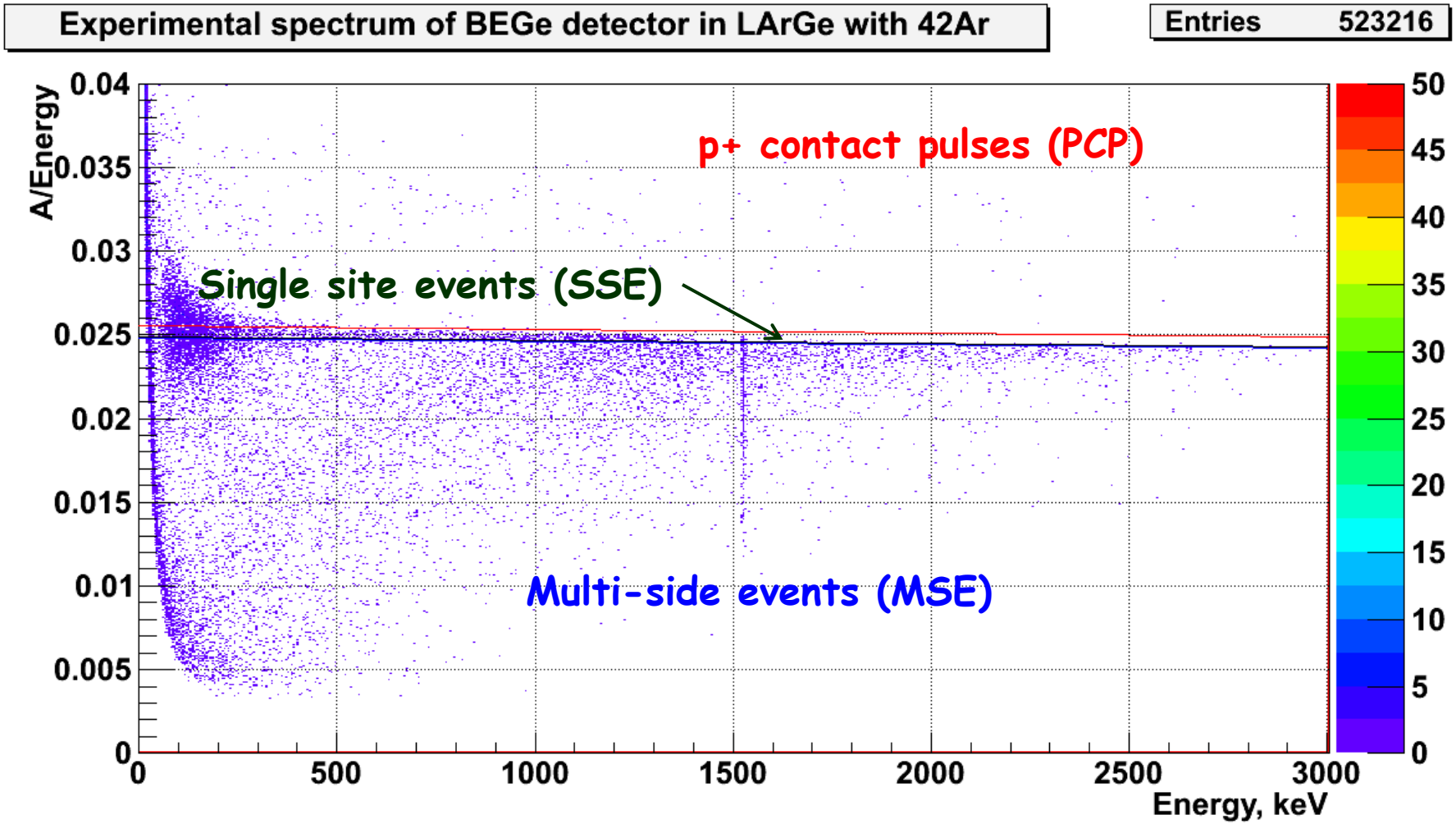
Measurements with a naked depleted BEGe inside LAr which contain spiked ^{42}Ar can give important information about intensity, ^{42}K spectrum shape and suppression efficiency of such background by PSD and PMT veto. It was found that a lot of detected events from ^{42}K is in the high energy part of the spectrum (near ROI).

Field free configuration and/or powerful PSD discrimination is required to achieve background required by GERDA Phase II.



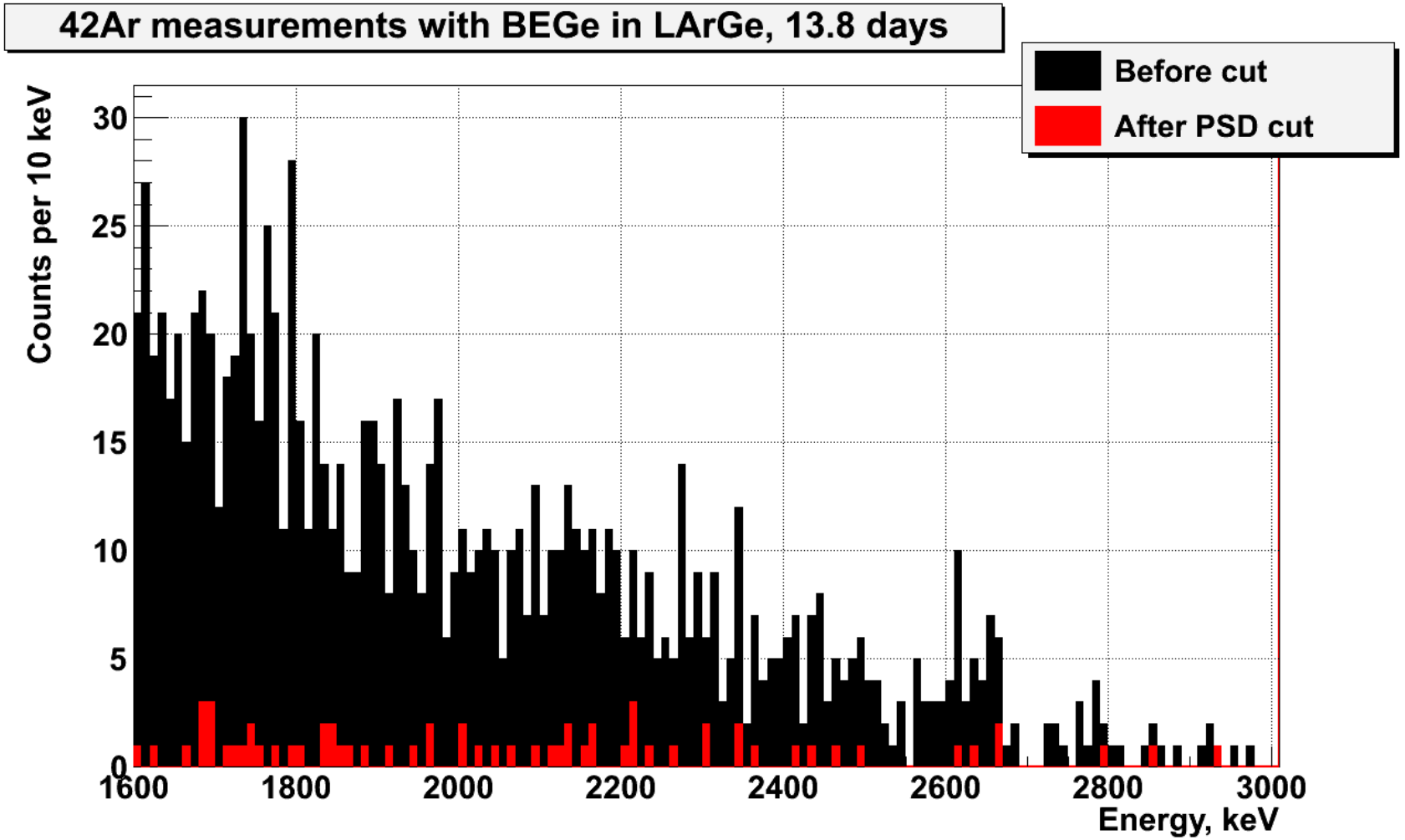
Suppression of the ^{42}Ar by PSD

We can dramatically suppress background beta events of ^{42}K applying PSD cut obtained from ^{228}Th calibration .



Suppression of the ^{42}Ar by PSD

Only 5% of events survive within ROI of 0νββ after applying the PSD cut.
We found that stability and noise conditions are very important for good PSD.



Conclusion

- Investigations of the background caused by ^{42}Ar has been performed in the low-background test facility LArGe.
- The measured time constant for the ^{42}K collection is 11.4(13) hours.
- After switching bias of encapsulation from -3000 to 0 ^{42}K stays near the encapsulation. Time constant is 11.1(10) hours.
- Comparison between experiment and simulation indicates that at least a big fraction of ^{42}K is located on the surface of the encapsulation.
- 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 94.5±4.7(stat)±17.5(system) μBq/kg.
- To achieve the background required for GERDA Phase 2 field free configuration and/or improvement of PSD is needed.
- It was proven that PSD is an effective method to suppress background from ^{42}K for GERDA Phase2. Suppression factor in ROI of $0\nu\beta\beta$ obtained for the BEGe detector in these measurements is about 20.

Back up slides

LArGe test facility

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