^{42}Ar/^{42}K Background in the GERDA Experiment

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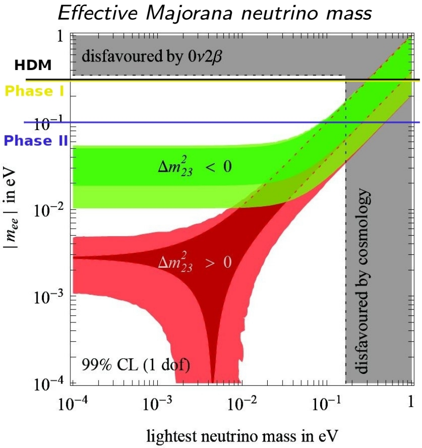
Neutrinoless Double Beta Decay

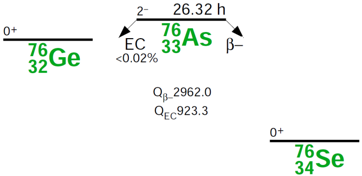
$$(Z, A) \to (Z+2, A) + 2e^-$$

$$\left(T_{1/2}^{0\nu}\right)^{-1} = G^{0\nu} \cdot |\mathcal{M}^{0\nu}|^2 \cdot |m_{ee}|^2$$



(Strumia et al. arXiv:hep-ph/0606054)

GERDA



$$Q = 2039\,\mathrm{keV}$$

Phase I

- Exposure: $15\,\mathrm{kg \cdot yr}$
- Background index (BI): $10^{-2}\,\mathrm{cts/(kg \cdot yr \cdot keV)}$
- Goal: Test HDM claim $T_{1/2}^{0\nu} = 2.23^{+0.44}_{-0.31} \cdot 10^{25}$ yr

(Klapdor-Kleingrothaus et al. Eur Phys J A12 147)

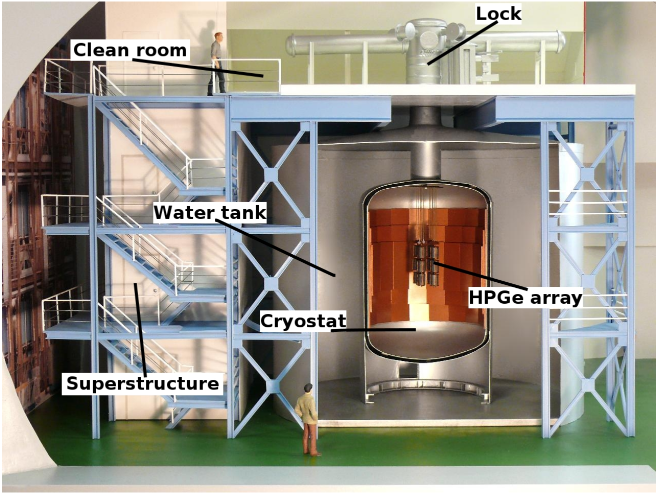
Phase II

- Exposure: $100\,\mathrm{kg \cdot yr}$
- BI: $10^{-3}\,\mathrm{cts/(kg \cdot yr \cdot keV)}$

The GERDA Idea

Novel idea: Operate HPGe detectors naked in liquid Argon

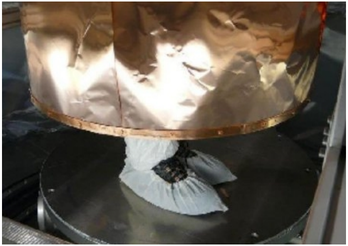
- Serving as cooling
- Serving as shielding
- Possible to implement as active veto

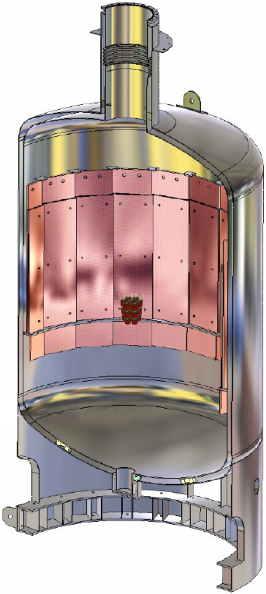


The Cryostat

- Two walls of stainless steel
- 16 t copper as shielding
- 89 t liquid argon

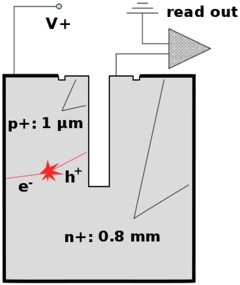
- Radon shroud to prevent convection

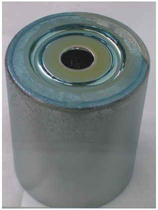




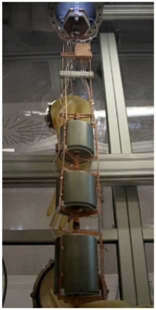
High Purity Germanium Detectors - HPGe

p-type coaxial germanium detectors





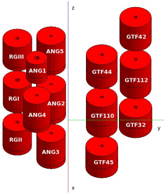
Test string



Phase I - recycled detectors

- 6 natural detectors (GENIUS)
- 5 enriched detectors (HDM)
- 3 enriched detectors (IGEX)

Phase I array

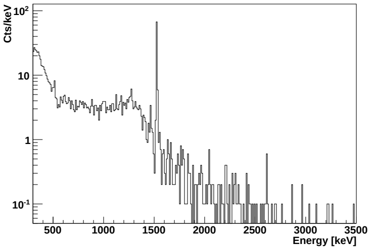


Phase II - new detectors

- BEGe's (Matteo Agostini T108.3)

The First Data

Measured background spectrum
91.7 d exposure July-Nov 2010



Decay chain:

$^{42}\mathrm{Ar} \rightarrow ^{42}\mathrm{K} \rightarrow ^{42}\mathrm{Ca}$

$^{42}\mathrm{Ar}$: $Q = 599$ keV, $T_{1/2} = 32.9$ yr
$^{42}\mathrm{K}$: $Q = 3525.4$ keV, $T_{1/2} = 12.36$ h

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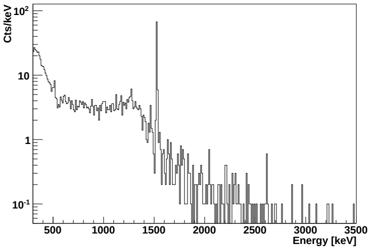
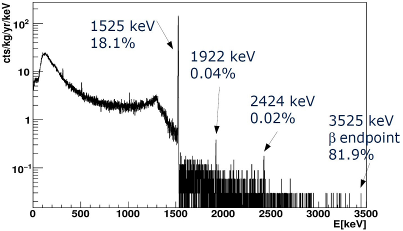


Simulated spectrum (homogeneous distribution)



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$^{42}\mathrm{Ar}$ production:

$^{\mathrm{nat}}\mathrm{Ar} > 99\,\%\ {}^{40}\mathrm{Ar}$ and $0.934\,\%_{\mathrm{vol}}$ in air

Cosmic α's: $^{40}\mathrm{Ar}(\alpha,2p)^{42}\mathrm{Ar}$

Nuclear explosions:
$^{40}\mathrm{Ar}(n,\gamma)^{41}\mathrm{Ar}(n,\gamma)^{42}\mathrm{Ar}$

Exp limit: (Ashitkov et al. arXiv:nucl-ex/0309001)
$^{42}\mathrm{Ar}/^{\mathrm{nat}}\mathrm{Ar} < 4.3 \cdot 10^{-21}$ g/g (90 % CL)

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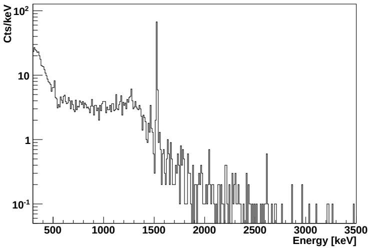

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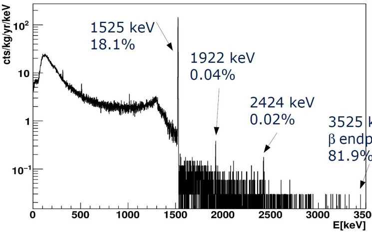

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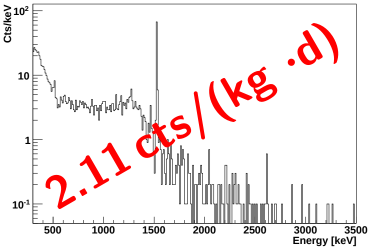

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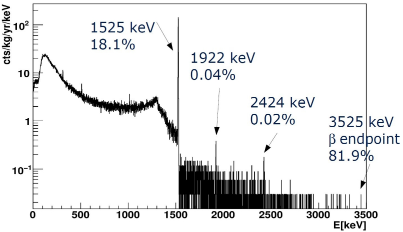

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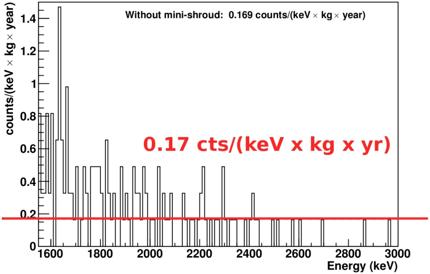
Question 1: Why does data not agree with MC (hom, exp limit)

Background Index at $Q_{\beta\beta}$ (2039 keV)

First data around $Q_{\beta\beta}$ (28.5 d exposure)



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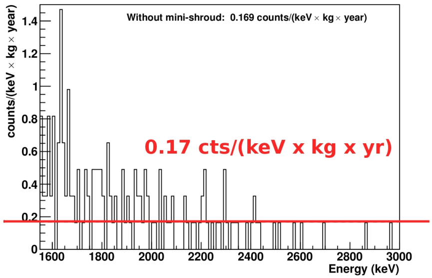

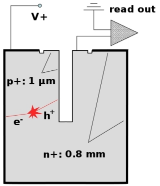

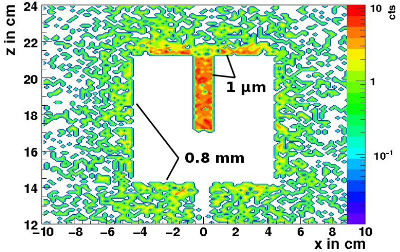

Position of ^{42}K decays with E-deposition in detector (MC for homogeneous distribution)

^{42}K contributions:

- 2424 keV γ-line (0.02 %)
- β with 3525 keV endpoint (81.9 %)

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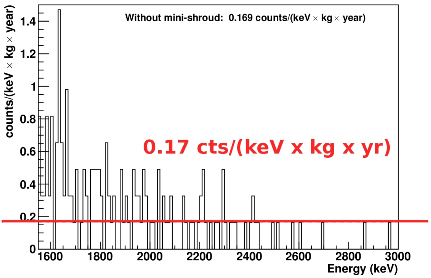

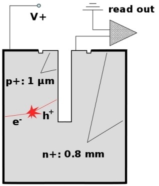

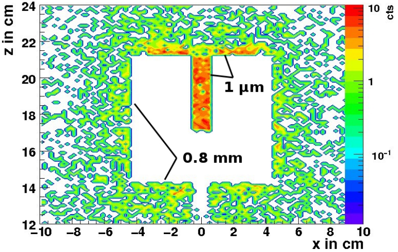

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- 2424 keV γ-line (0.02 %)
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Question 2: Where is the background coming from? ^{42}K?

Answering Question 1 - Inhomogeneous $^{42}\mathrm{K}$ distribution?

Assumption

Charge collection

- $^{42}\mathrm{Ar} \rightarrow {}^{42}\mathrm{K}^{\pm}$
- $^{42}\mathrm{K}$ ions get attracted by detector HV

Approach:

Installation of the mini-shroud

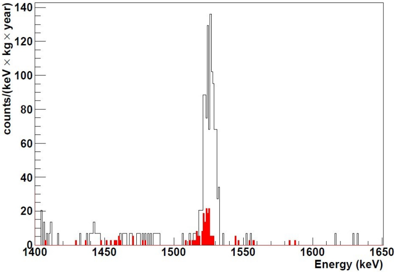
- Close field lines
- Restrict LAr volume / Prevent drift
- Repel ions from detectors

Exp runs with different E-field configurations

Results

- Mini-shroud installation reduced peak count rate by factor 4..5
- Charge collection can be seen
- Indication on + and − charged $^{42}\mathrm{K}$ ions

Same conditions but different E-field
Black: -700 V, red: +400 V on mini-shroud



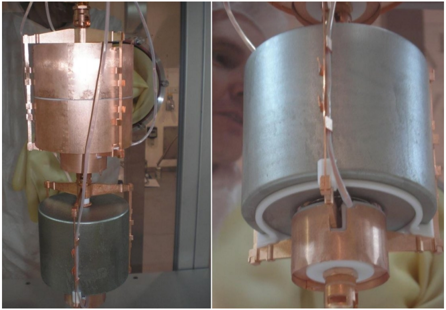
Answering Question 2: Is the Background coming from ^{42}K?

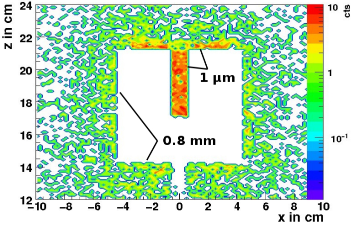
Assumption

- Counts around $Q_{\beta\beta}$ come from ^{42}K β's penetrating dead layer

Approach

- Detector encapsulated
- Bore hole capping





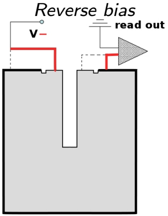
Result

- Count rate at $Q_{\beta\beta}$ mainly insensitive to encapsulation
- BI is not dominated by ^{42}K

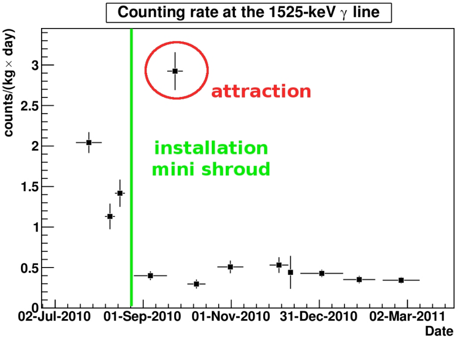
Current Situation

Field free configuration

HV on the inside
Outside grounded



Evolution of $^{42}\mathrm{K}$ peak counts



Current background index:
$0.055 \pm 0.015\,\mathrm{cts/(kg \cdot yr \cdot keV)}$ (68 % CL for 0.59 kg · yr):

Conclusions for $^{42}\mathrm{K}$

Major experimental effort of the collaboration in the last 6 months

- Installation of mini-shroud and investigation of charge collection
- Investigation of detector encapsulating
- Parallel investigation with LArGe (R&D setup)

Question 1: Discrepancy between data and MC

- Charge collection can be seen
- Explains some of the discrepancy

Question 2: High background at $Q_{\beta\beta}$

- $^{42}\mathrm{K}$ is not the dominating background contribution around $Q_{\beta\beta}$
- Present BI: 6 times higher than the goal for Phase I
- GERDA BI already two times better than in previous $^{76}\mathrm{Ge}$ experiments

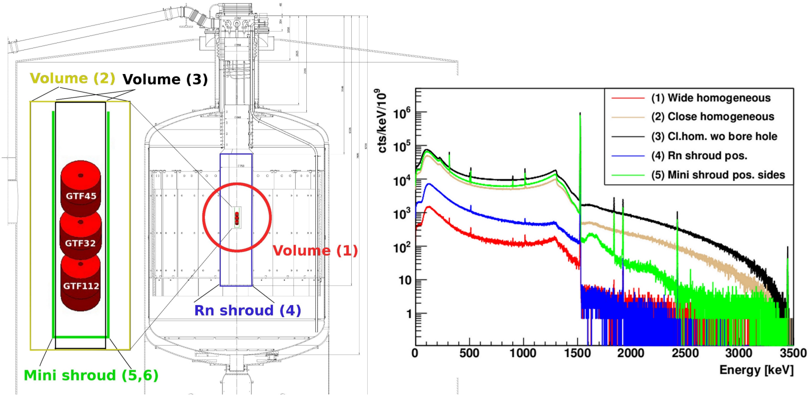
- Investigations ongoing - all results preliminary

Thanks for the attention.

Backup

Bonus Question - Is Charge Collection the Reason for the High BI?

MC simulations in different volumes and at different positions



None of the MC scenarios can explain consistently

- the peak count
- the background index

Problem: MC simulations very dependent on precision of dead layer implementation

BI Evolution