GERDA Commissioning

July 2010 - April 2011

Björn Lehnert for the GERDA-Collaboration

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Varenna 03/08/2011

1. Status of data taking in the GERDA experiment

2. The struggle with unforeseen difficulties

Not included:

- $0\nu\beta\beta$
- General GERDA setup

Neutrino-less Double Beta Decay

Phase I

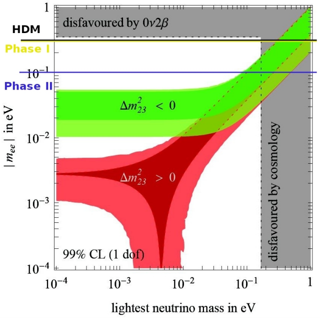
- Exposure: 15 $\mathrm{kg \cdot yr}$
- BI: $10^{-2}\,\mathrm{cts/(kg \cdot yr \cdot keV)}$
- $T_{1/2}$: $3 \cdot 10^{25}$ yr
- $|m_{ee}|$: 300 meV

- Goal: Test HDM claim
  $T^{0\nu}_{1/2} = 2.23^{+0.44}_{-0.31} \cdot 10^{25}$ yr

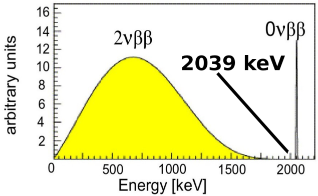
Phase II

- Exposure: 100 $\mathrm{kg \cdot yr}$
- BI: $10^{-3}\,\mathrm{cts/(kg \cdot yr \cdot keV)}$
- $T_{1/2}$: $2 \cdot 10^{26}$ yr
- $|m_{ee}|$: 90 meV

Effective Majorana neutrino mass



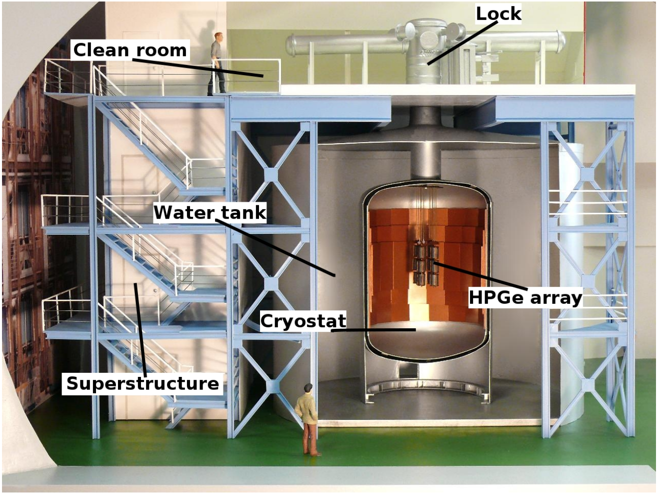
Expected spectrum of double beta decay



The GERDA Idea

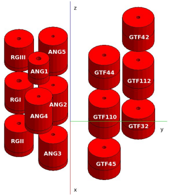
Novel idea: Operate naked HPGe detectors in liquid argon (LAr)

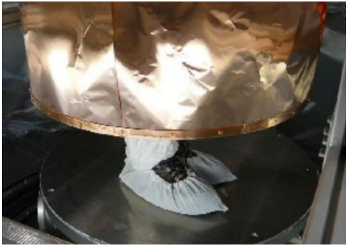
- Serving as cooling
- Serving as shielding
- Possible to implement as active veto

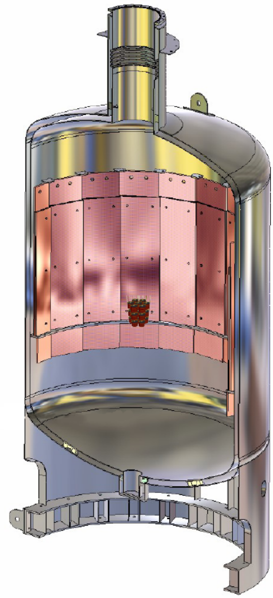


Inside the Cryostat

- 89 t liquid argon
- Detector array
- Radon shroud to prevent convection

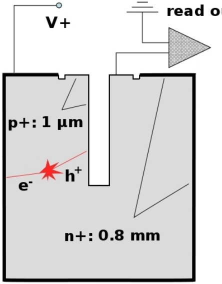






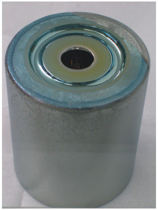
High Purity Germanium Detectors - HPGe

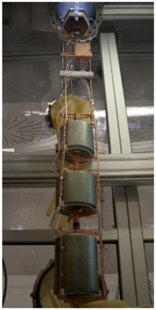
p-type coaxial germanium detectors



Commissioning string:

3 detectors, 7.6 kg



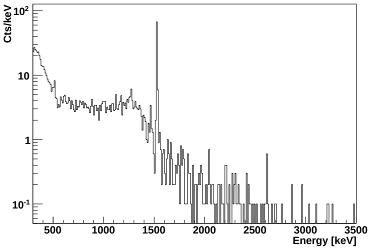


- Thick dead layer outside
- Thin dead layer inside

- High voltage outside
- Read out inside

The First Data

Measured background spectrum
91.7 d exposure July-Nov 2010



Decay chain:

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

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

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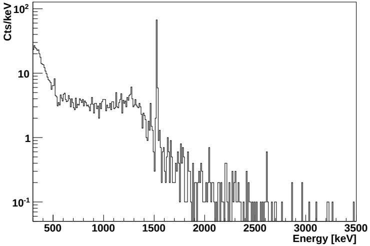
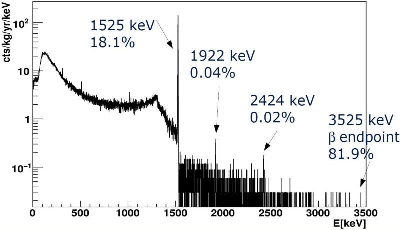


Simulated spectrum (homogeneous distribution)



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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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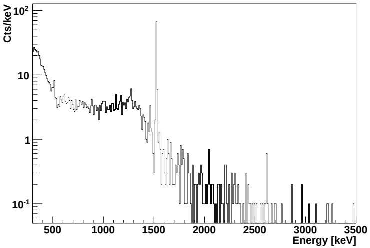

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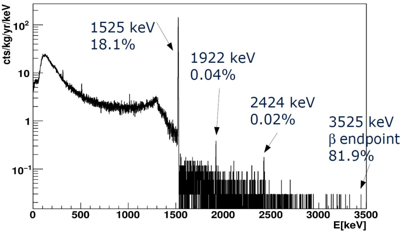

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0.094 cts/(kg · d)

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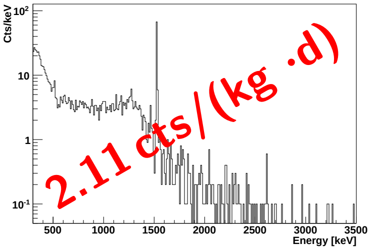

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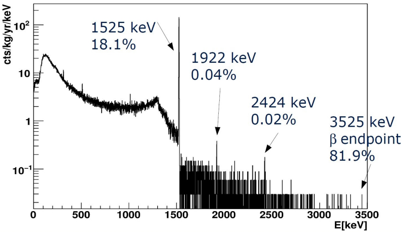

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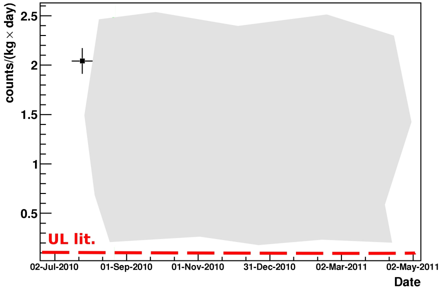
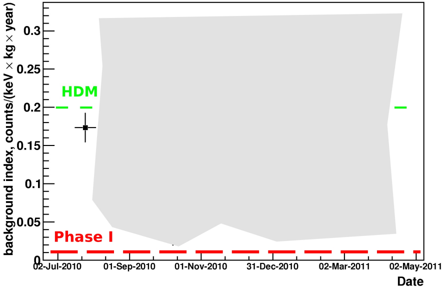
Factor 20 difference! Why does MC not agree with data?



Observables:

^{42}K 1524 keV
peak count
[cts/(kg · day)]



Background Index
±200 keV
[cts/(kg · keV · yr)]

Assumption 1: Charge collection

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

Approach 1:

Installation of the mini-shroud

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

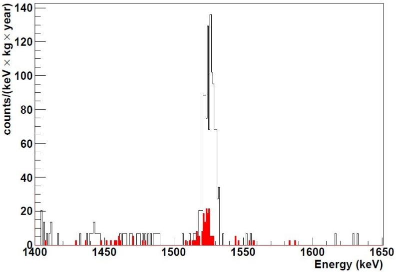
Exp runs with different E-field configurations

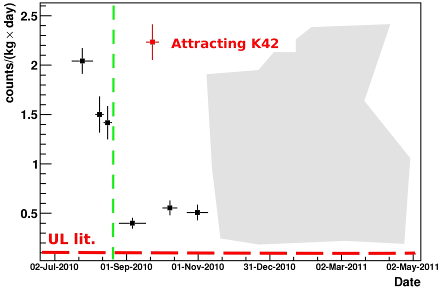
Results

- Mini-shroud installation reduced peak count rate by factor 4..5
- Charge collection can be seen

Same conditions but different E-field

Black: -700 V, red: +400 V on mini-shroud





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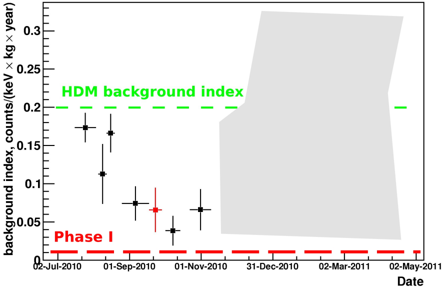
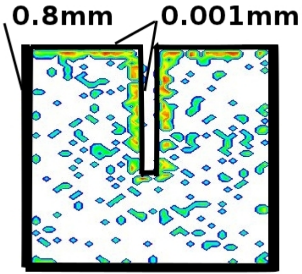
^{42}K 1524 keV peak count [cts/(kg · day)]



Background Index ±200 keV [cts/(kg · keV · yr)]

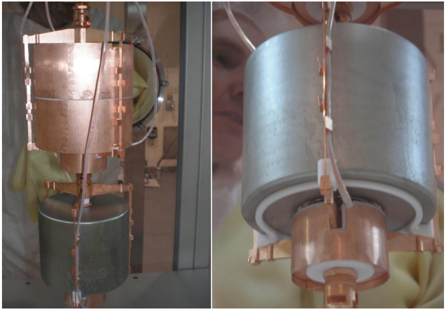
Assumption 2: β-penetration

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



Approach 2:

- Detector encapsulated
- Bore hole capping



Result

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

Approach 3: Reversing bias

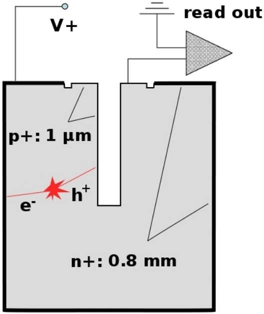
Field free configuration

- HV on the inside
- Outside grounded

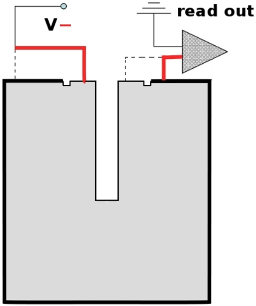
Result

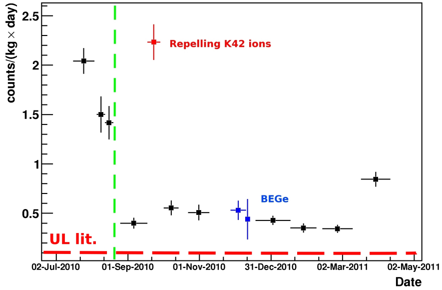
- Ongoing investigation
- Energy resolution decreases
- Last run: Removing of mini shroud

Normal operation

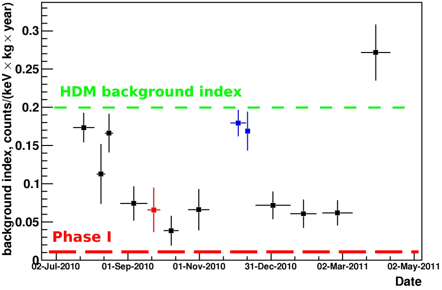


Reverse bias

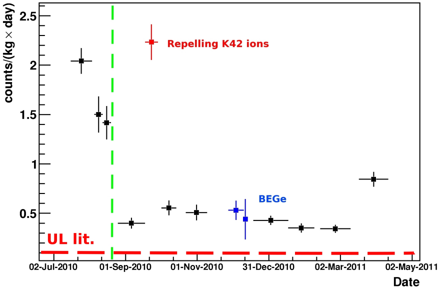


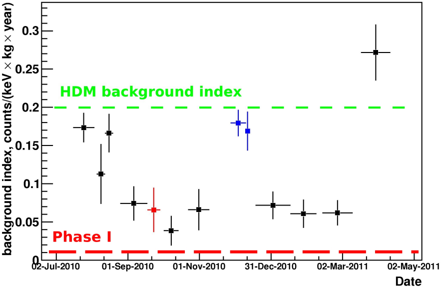


counts/(kg × day)
Repelling K42 ions
BEGe
UL lit.
Date



background index, counts/(keV × kg × year)
HDM background index
Phase I
Date





Conclusions:

- Start data taking July 2010
- Larger than expected $^{42}\mathrm{K}$ background
- Charge collection of $^{42}\mathrm{K}$ confirmed
- Different approaches countering $^{42}\mathrm{K}$:
  - Mini shroud
  - Encapsulation
  - Reversed bias
- $^{42}\mathrm{K}$ still under investigation
- BI larger than expected but below HDM

Outlook:

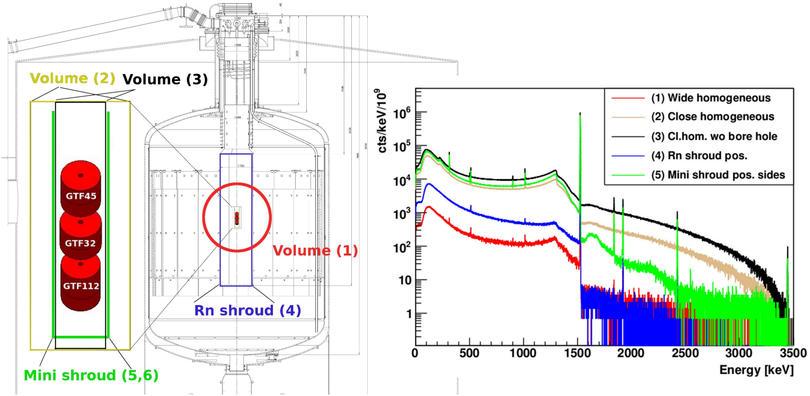
- Data taking started with enriched detectors
- BI Improvements expected
- LAr instrumentation considered

Stay tuned for upcoming results

Backup

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