Status of the GERDA Experiment

Oliver Schulz
for the GERDA collaboration

MAX-PLANCK-GESELLSCHAFT

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

GERDA

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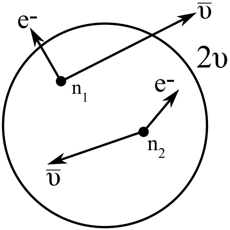
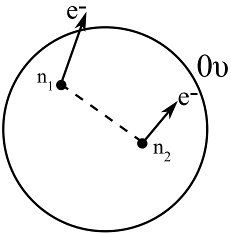
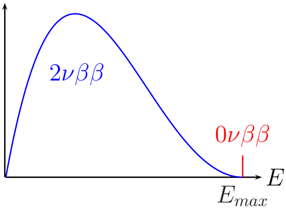
IPA2012, May 13, 2013

$0\nu\beta\beta$-Decay

- Single β-decay not allowed for some isotopes, only double β-decay
- If ν is a Majorana Particle ($\nu = \bar{\nu}$), $0\nu\beta\beta$-decay must exist







$$\left(T^{0\nu}_{1/2}\right)^{-1} = G(Q,Z)\,\left|M_{\mathrm{nucl}}\right|^2 \langle m_{ee}\rangle^2$$

- Study of $0\nu\beta\beta$-decay can
  - Discover lepton-number violation
  - Determine nature of ν (Majorana or Dirac).
  - Give information about absolute Neutrino mass / hierarchy?

The Gerda Experiment

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  - Limit: $T_{1/2} > 1.9 \cdot 10^{25} y$ at 90% conf. HdM and IGEX
  - Claim: $T_{1/2} = 1.2 \cdot 10^{25} y$ Klapdor-Kleingrothaus et al., PL B586 (2004) 198

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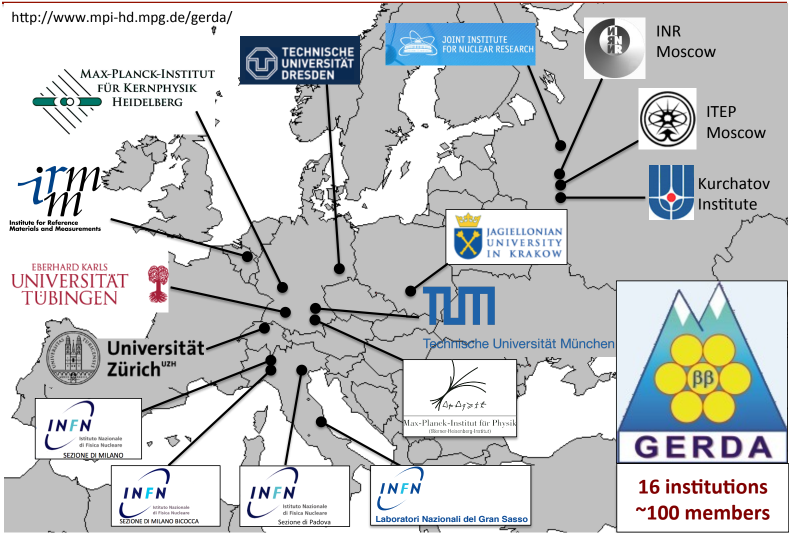
- Ultra-low background setup, located underground at LNGS
- Currently running in Phase-I, designed to test Klapdor claim
- Phase-II will go beyond: Increased total detector mass, even lower background

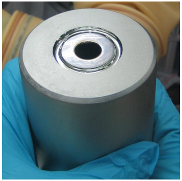
The GERDA Collaboration



Why use ^{76}Ge?

Advantages:

- Source = Detector
- Production of enriched detectors up to 86% well established (though expensive)



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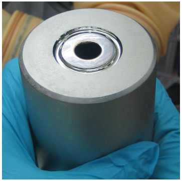
- Intrinsically pure



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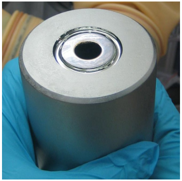

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- For all $0\nu\beta\beta$experiments:
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  - Radio-pure setup, carefully select and screen all materials

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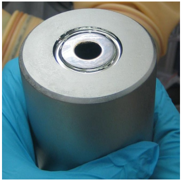

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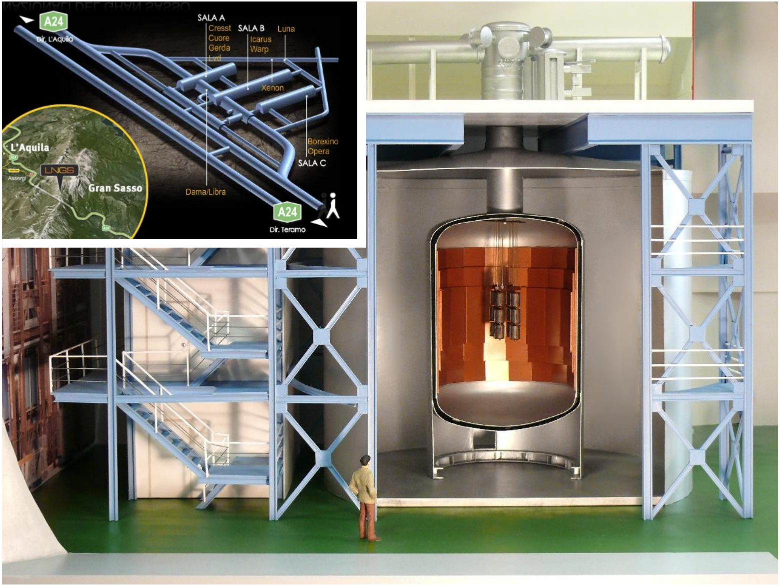
  - Must be well shielded from cosmics and external radiation
  - Radio-pure setup, carefully select and screen all materials
- Detector operation under cryogenic conditions
- Cosmic activation of detector material ($\rightarrow$ ^{60}Co and ^{68}Ge)

The Gerda Setup



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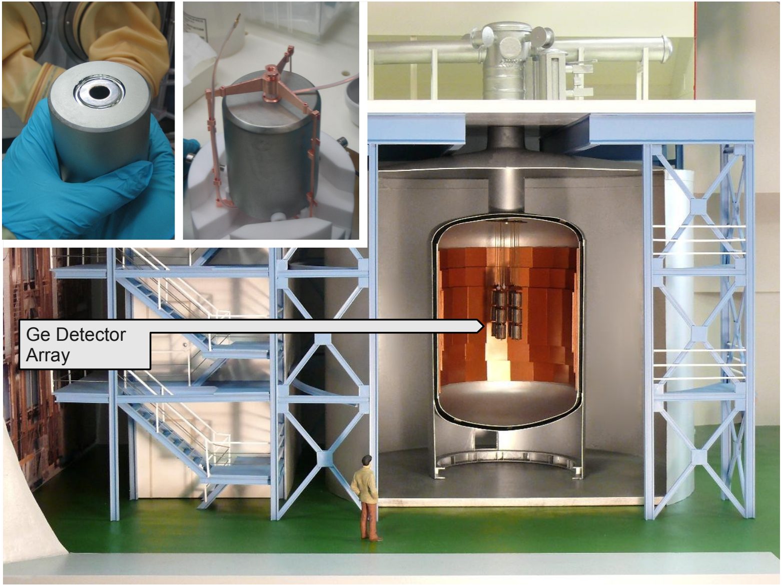

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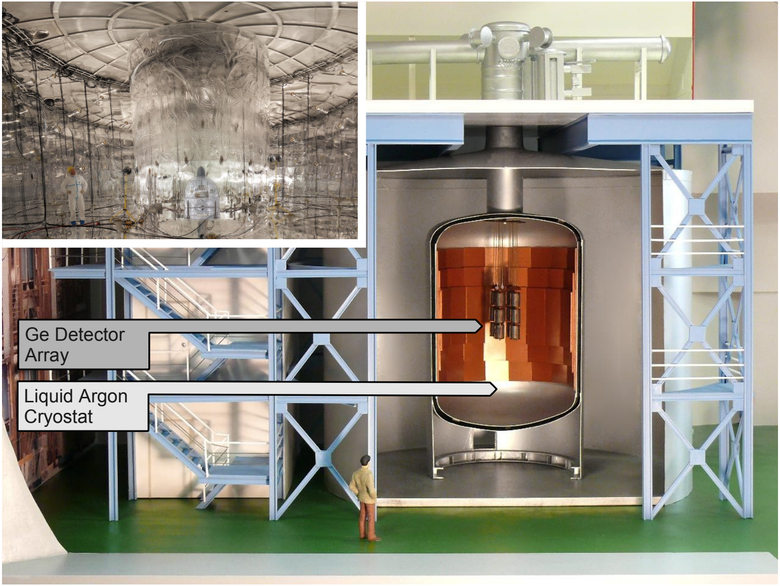
The Gerda Setup



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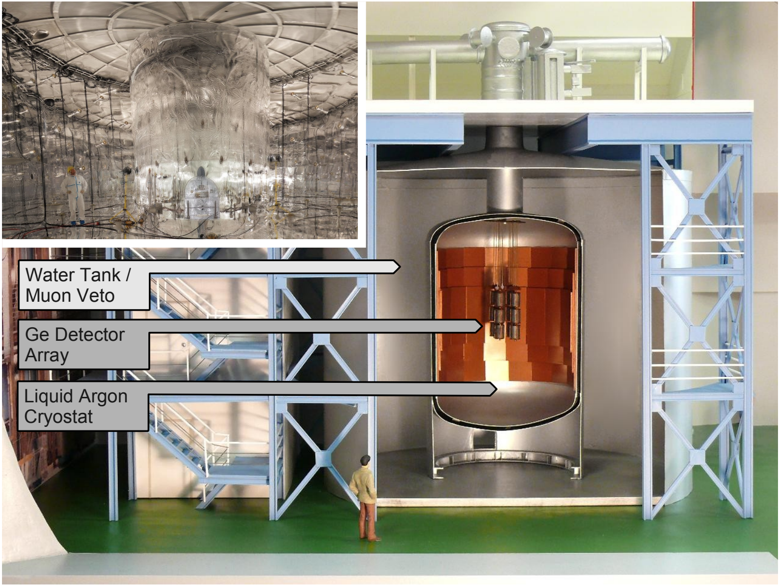

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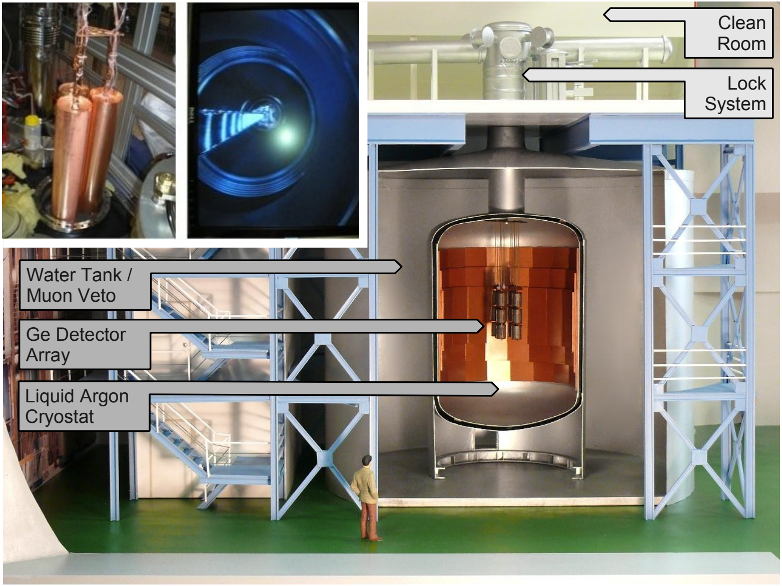

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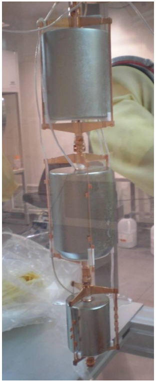
Gerda Phase-I Detectors



- 8 enriched coaxial detectors from HdM and IGEX (17.7 kg)
- 1 non-enriched coaxial detector (3.0 kg)

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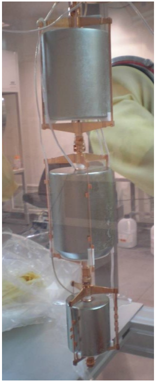

- 8 enriched coaxial detectors from HdM and IGEX (17.7 kg)
- 1 non-enriched coaxial detector (3.0 kg)
- Since Spring 2012: 5 enriched Phase-II BeGe detectors (3.6 kg)

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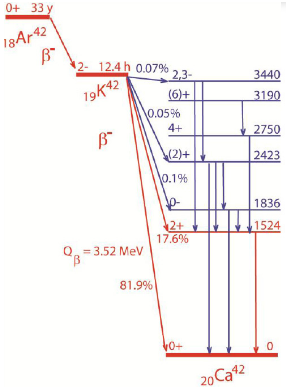
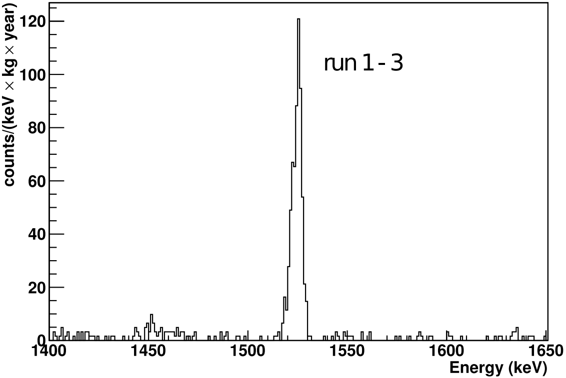
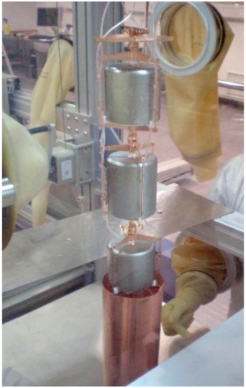
An Unexpected Background

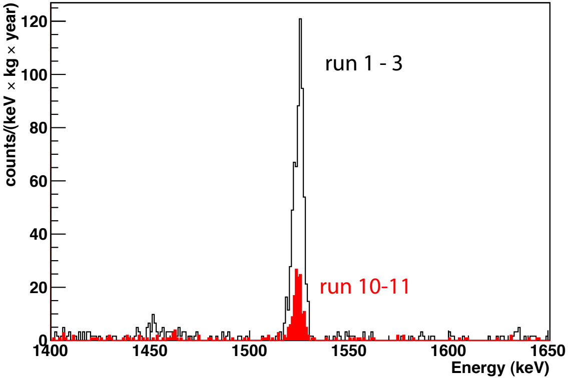




- Observed background 10 × higher than expected

An Unexpected Background





- Observed background 10 × higher than expected
- $^{42}\mathrm{Ar} \rightarrow {}^{42}\mathrm{K}$, charged $^{42}\mathrm{K}$ drift in E-field of detectors and decay there
- Copper mini-shrouds shield detector strings

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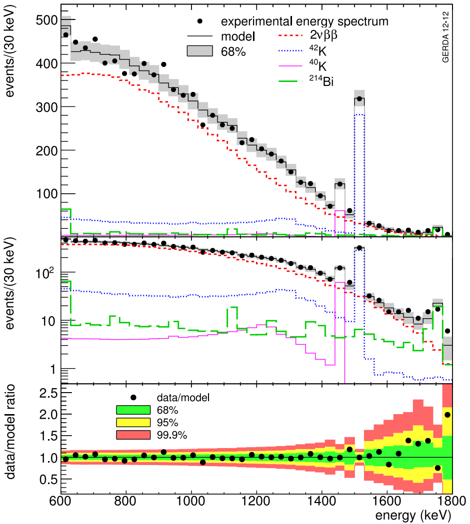
Measurement of $^{76}\mathrm{Ge}\ 2\nu\beta\beta$ Half-Life



$$T_{1/2}^{2\nu} = \left(1.84^{+0.09}_{-0.08\ \mathrm{fit}}\ {}^{+0.11}_{-0.06\ \mathrm{syst}}\right) \times 10^{21}\mathrm{yr} = \left(1.84^{+0.14}_{-0.10}\right) \times 10^{21}\mathrm{yr}$$

J. Phys. G: Nucl. Part. Phys. 40 (2013) 035110

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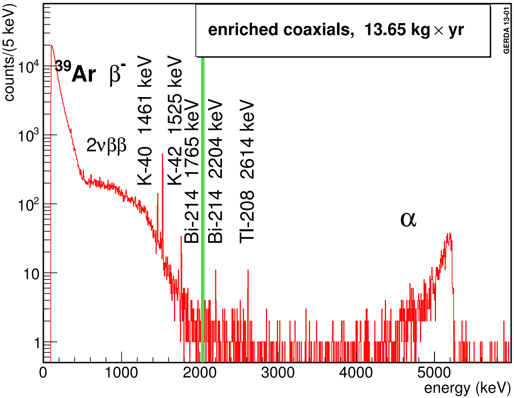
Phase-I Background



No contribution at $Q_{\beta\beta}$:
^{39}Ar (Q_β = 565 keV), **^{40}K**, **^{228}Ac**

Contribution at $Q_{\beta\beta}$:

- **^{42}K** (^{42}Ar) → Q_β = 3.5 MeV, E_γ = 2.4 MeV
- **^{214}Bi** (^{238}U) → Q_β = 3.3 MeV, E_γ = 2.1, 2.2, 2.4 MeV
- **^{208}Tl** (^{232}Th) → E_γ = 2.6 MeV
- **^{60}Co** → Q_β = 2.8 MeV
- **α-induced events** (from isotopes in ^{238}U chain)

- Blinded window: 40 keV around $Q_{\beta\beta} = 2039$ keV
- Achieved background index: 0.02 cts/(keV kg yr) in ROI: 10 × better than HdM and IGEX

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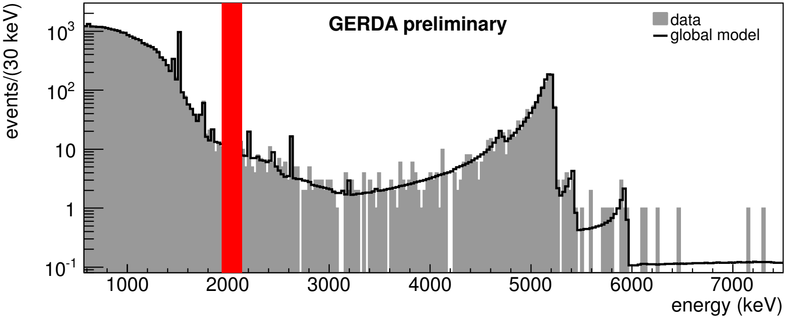
Background Model



- Have reached good understanding of background
- Strong indications about location of α-induced events
- No details here - paper with detailed background decomposition coming soon

End of Phase-I and Unblinding

- Exposure target of 20 kg y reached
- Dataset for $0\nu\beta\beta$-Analysis (almost) frozen:
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  Nov. 9 2011 to Apr. 15 2013, Live time of 456.15 days
- Unblinding in June, publication shortly after
- Data taking will continue for a short while
- Decommissioning of Phase-I setup in June,
  followed by maintenance and inspections of setup

Gerda Phase-II Upgrade

- After Phase-I decommissioning, installation of Phase-II
- 30 new BeGe-type HPGe detectors, additional mass of 20 kg
- Phase-I coaxial detectors (18 kg) will be re-used in Phase-II

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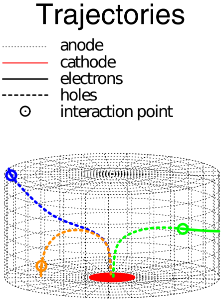
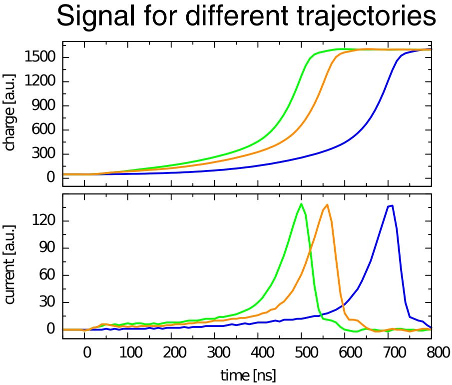
- New background target: 0.001 cts/(keV kg yr)
- Liquid-Argon instrumentation
  $\rightarrow$ active veto around detectors

BeGe Detectors for Phase-II





- BeGe: Broad-Energy Germanium Detector (Canberra)
- No bore-hole, small contact:
  - Small capacitance, higher energy resolution
  - Strong weighting field

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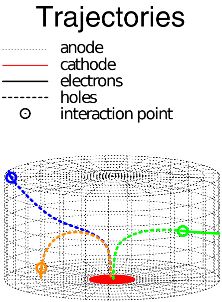

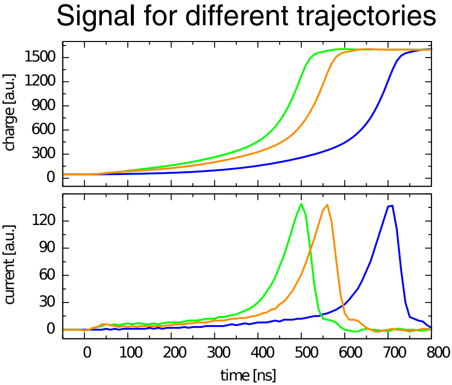

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Event Topology with BeGe Detectors

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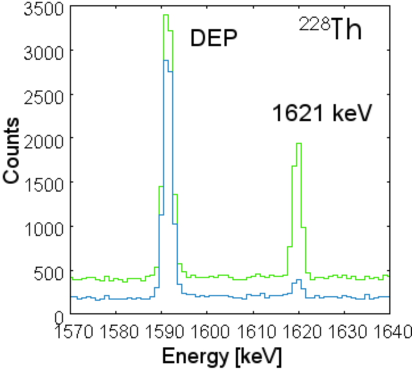

D. Budjas et al., JINST 4P10007 (2009)

green: before PSA, blue: after PSA

- Double-escape peak (DEP): Mostly single-site events (simulates $0\nu\beta\beta$-decay)
- $^{212}\mathrm{Bi}$ γ-line at $1621\mathrm{keV}$: Mostly multi-site events (simulates γ-background)

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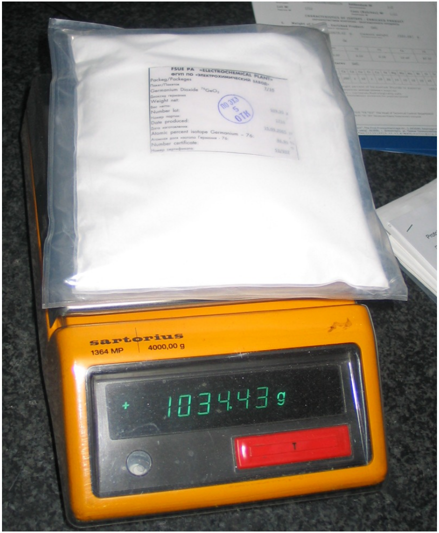
BeGe Detector Production



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[JINST 8 P04018]

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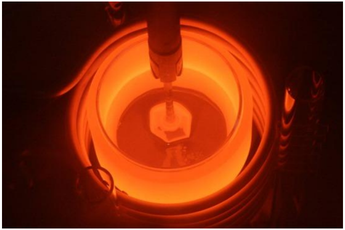

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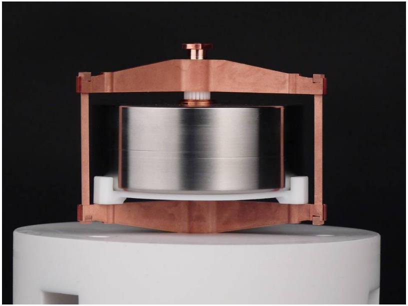

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- All Ge transport in shielded shipping container (Water plus Steel shield)

[JINST 8 P04018]

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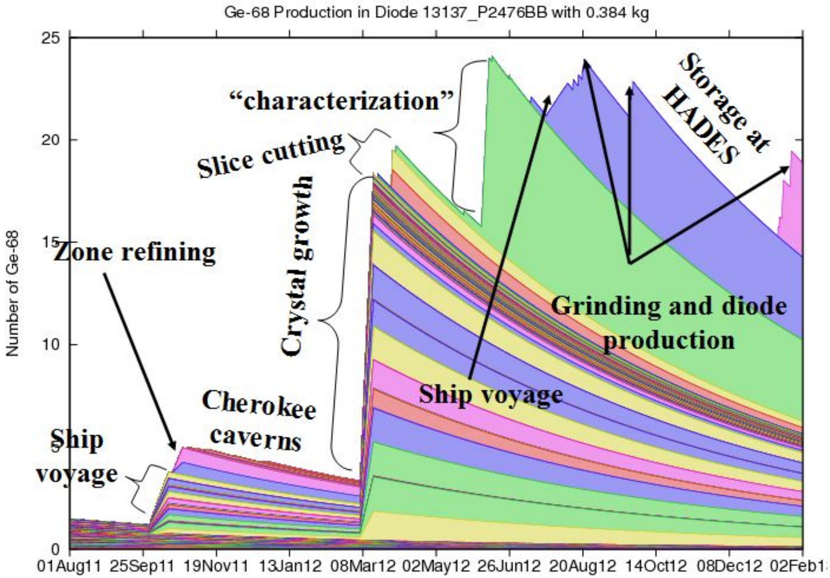
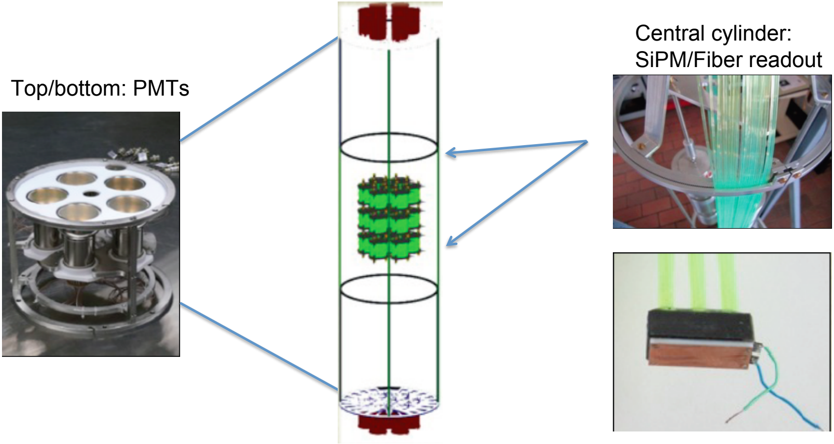
^{68}Ge Activation During Production

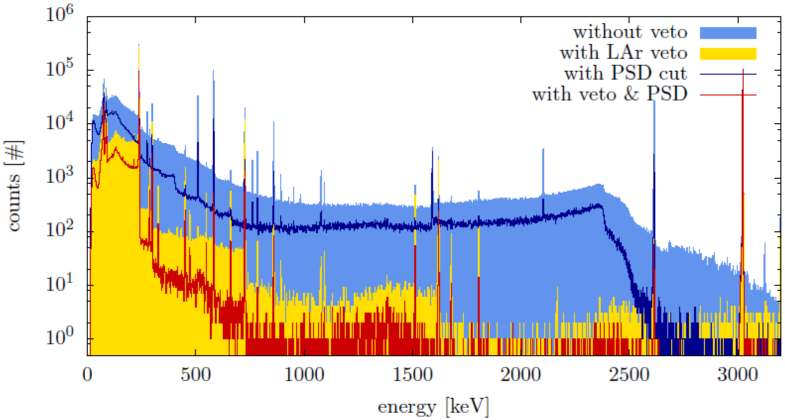


LAr Instrumentation, Design



- Liquid Argon scintillates - untapped potential
- Instrument LAr volume around detectors as BG veto

LAr Instrumentation, BG Reduction



[M. Heisel, PhD thesis]

- Effective background reduction, esp. for γ

Conclusions and Outlook

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- Full background decomposition to be published soon
- Unblinding of $0\nu\beta\beta$-ROI in June - Analysis will be ready
- Phase-II will add 20 kg of detector mass
  with new detector technology for background suppression
- Instrumentation of liquid argon around detectors
  will help to reach new background target:
  10^{-3} cts/(keV kg yr)

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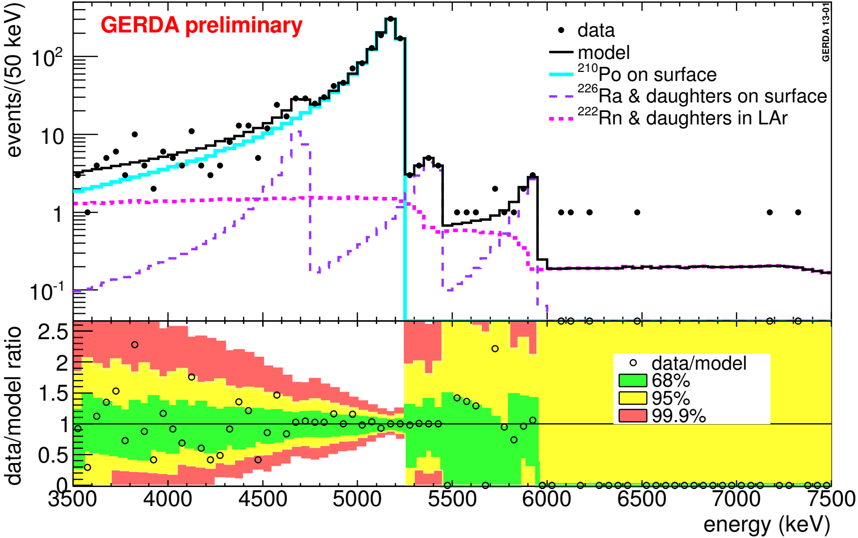
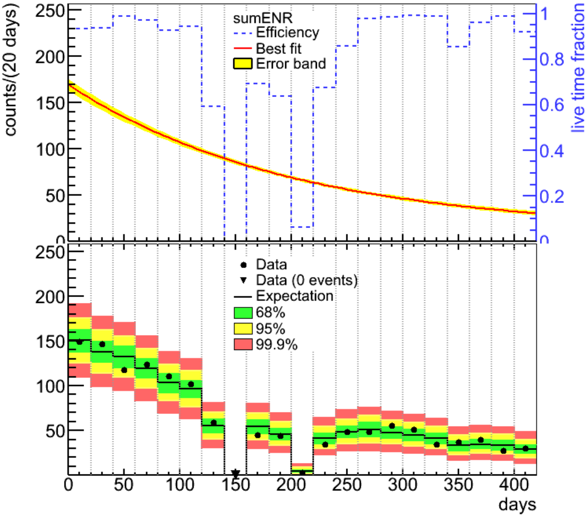
Appendix

Alpha-Background Model

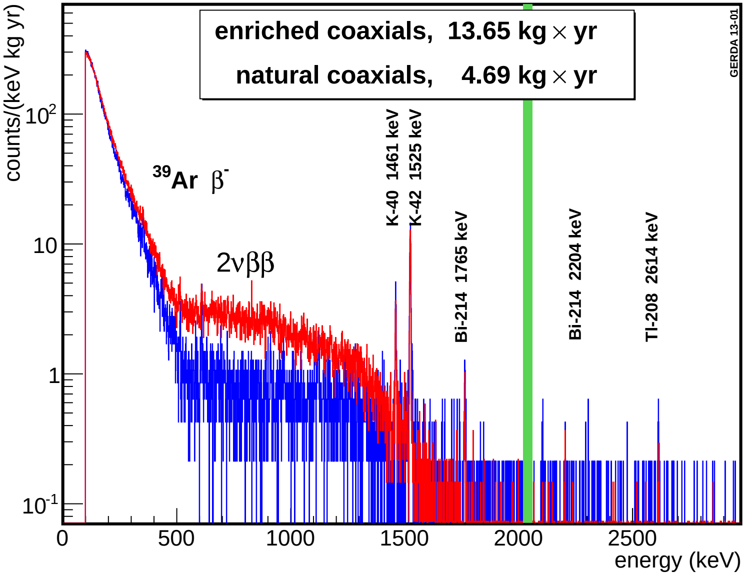


Exponential Decay of ^{210}Po Background

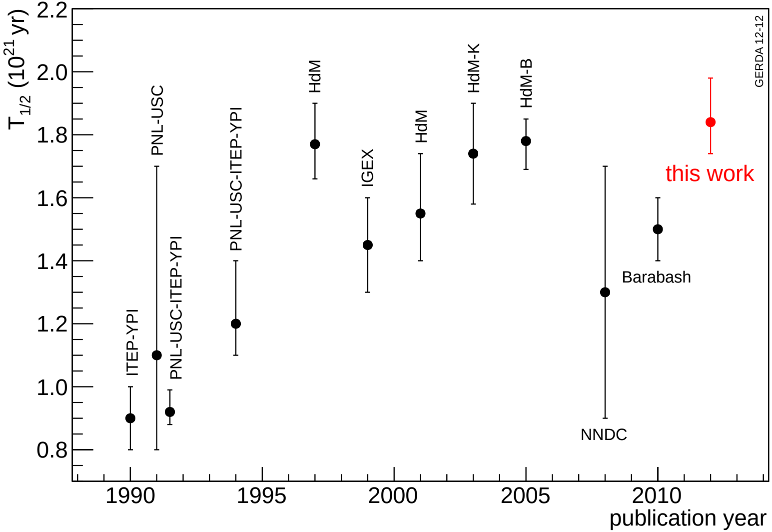


$T_{1/2} = 138.4 \pm 0.2\mathrm{d}$ fits perfectly

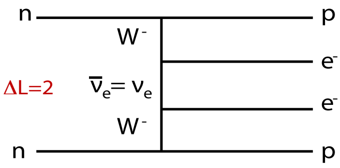
Enriched vs. Non-Enriched Detectors



$2\nu\beta\beta$-Decay Publication History



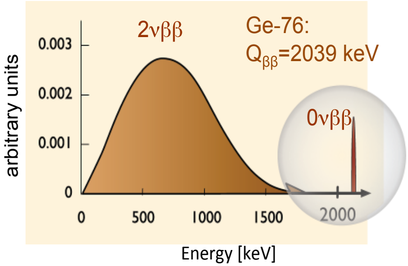
GERDA physics goals

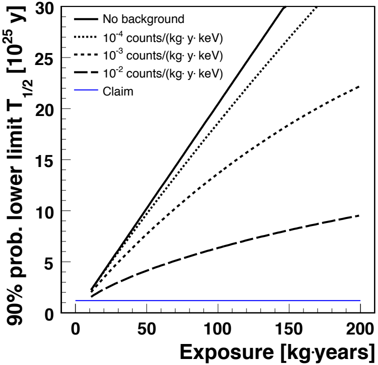


0νββ driven by exchange of light Majorana neutrinos

Phase	I	II
Exposure [kg ·yr]	15	100
Bg [counts/(keV·kg·yr)]	10^{-2}	10^{-3}
Upper limit $m_{\beta\beta}$ [eV]	0.23-0.39	0.09-0.15

A. Smolnikov, P. Grabmayr PRC 81 028502(2010)





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