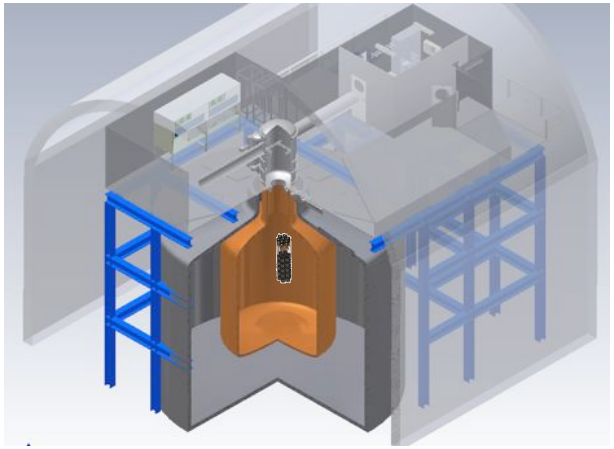
GERDA - the GERmanium Detector Array

A search for neutrinoless double beta decay



- Detection principle
- Technical realization
- R&D: Prototype detectors
- Conclusions

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on behalf of the GERDA collaboration

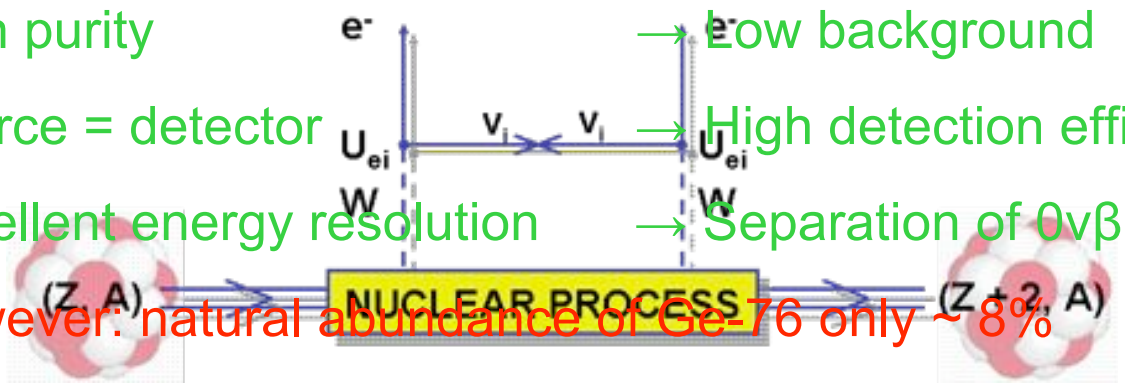
Neutrinos and Dark Matter in Nuclear Physics, Paris, 09/2006

Detection Principle

- 0νββ is a O(2) weak process / rare nuclear transition (if it exists)
- Need for detection:
  - Large amount of source material
  - Low background environment
  - High detection efficiency

Background identification and reduction is essential as everything else is fixed

- Germanium Ge-76 is one candidate for 0νββ:
  - High purity → Low background
  - Source = detector → High detection efficiency (~95%)
  - Excellent energy resolution → Separation of 0νββ / 2νββ
  - However: natural abundance of Ge-76 only ~ 8%



→ Need enrichment as background scales with total mass

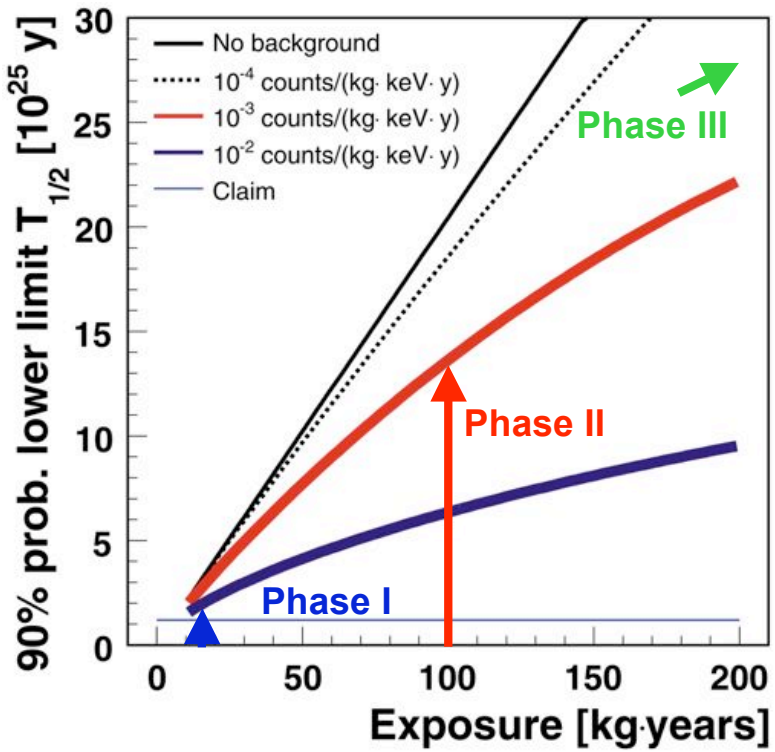
Goals / Strategy

- **Status of Ge-76 experiments:**
  - Lower limits on half-life from HdM and IGEX experiments
  - Claim based on data of HdM experiment: $T_{1/2} = 1.2 \cdot 10^{25}$ y
  - Background index ~ 10^{-1} counts/(kg·keV·y) at $Q_{\beta\beta}$
- **Goals:**
  - Run the experiment quasi background free

    (Aim at a background index of 10^{-3} counts/(kg·keV·y) at $Q_{\beta\beta}$)
  - Verify/reject recent claim
  - Extend current limits
- **Strategy:** Operate germanium crystals directly in cryo-liquid

  → Minimize material close to detectors, use as coolant and shield

Physics Reach



Phased approach:

- Phase I: ~ 15 kg enriched Ge
  verify/reject recent claim
- Phase II: add. ~ 20 kg enriched Ge
- Phase III: O(1) ton experiment
  world-wide collaboration
  with Majorana (LoI)

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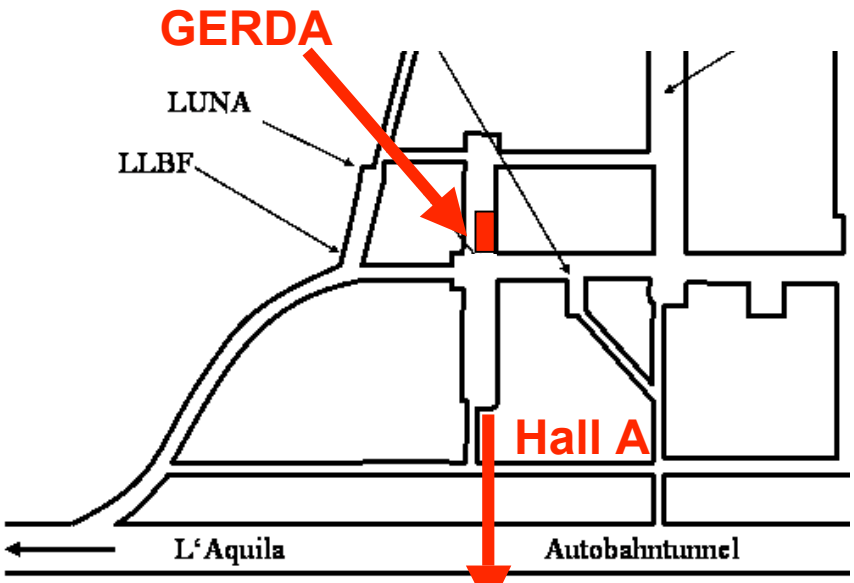
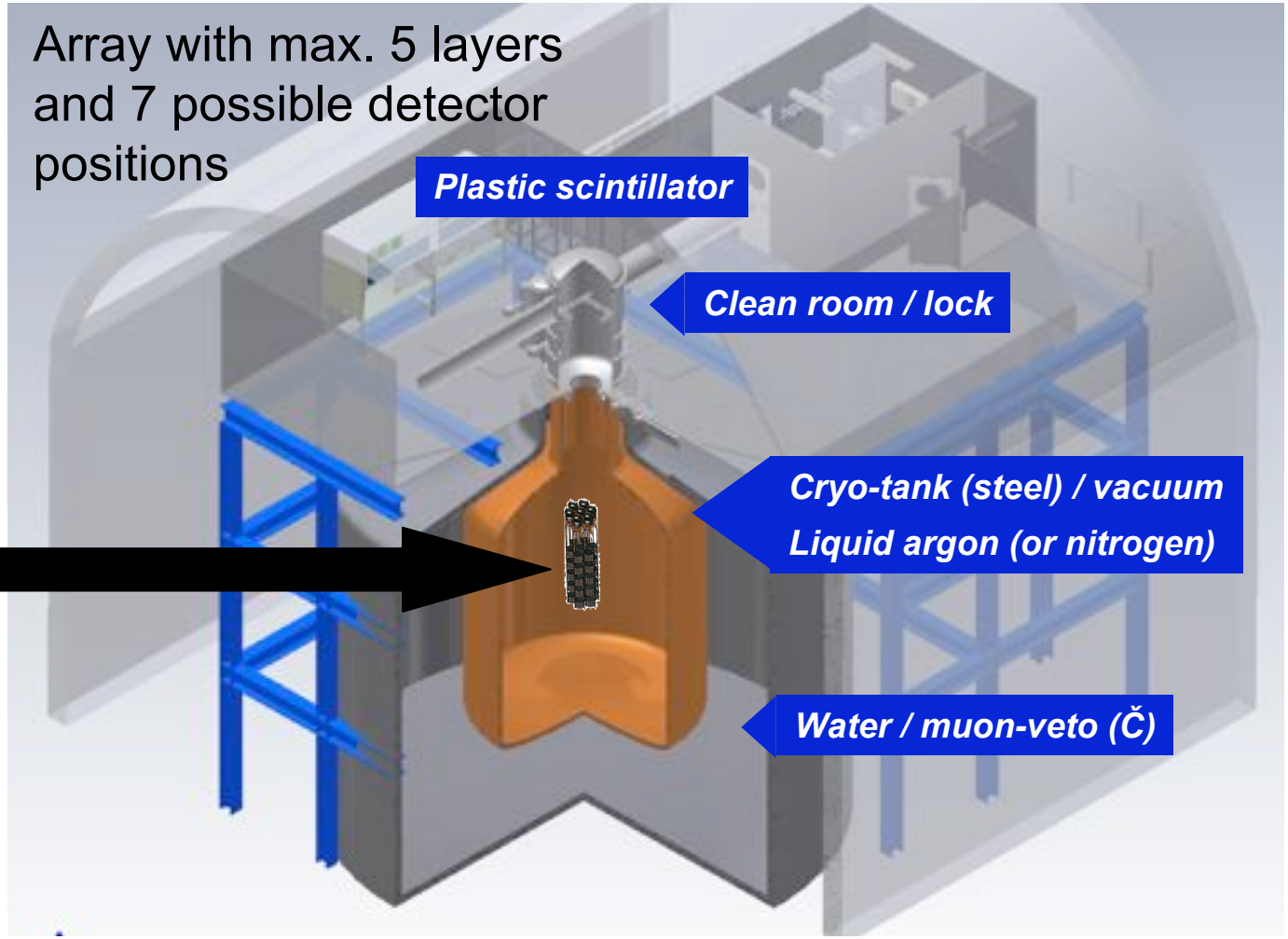
Exposure [kg·years]	Background [counts/(kg·keV·y)]	Limit $T_{1/2}$ [y]	Limit $\langle m_{\beta\beta}\rangle$[1] [meV]
15 (Phase I)	10^{-2}	$>2\cdot10^{25}$	<500
100 (Phase II)	10^{-3}	$>1.4\cdot10^{26}$	<200

Location



- GERDA is approved by the INFN Gran Sasso National Laboratory (LNGS), Italy
- Overburden of 1 400 m rock (3 800 m.w.e.)
- Installation currently under preparation (Hall A)

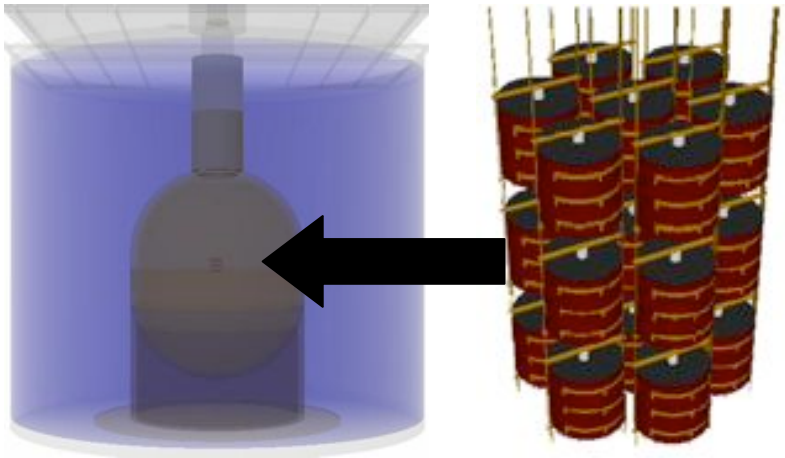
Technical Realization

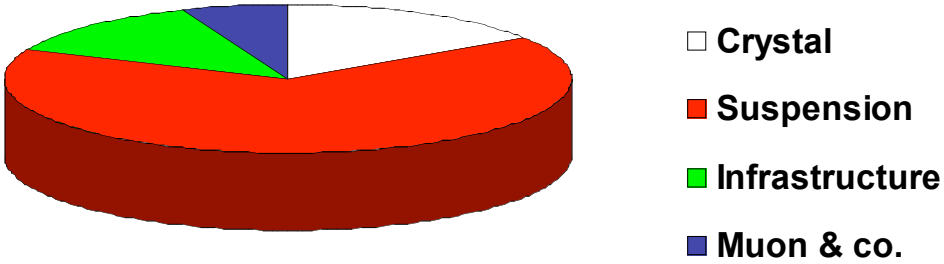


Background Expectation

- Shared GEANT4 Monte Carlo package MaGe (Majorana-GERDA)
- Detailed simulation of geometries and physics processes
- Background index calculated based on material screening results

Part	Background index [10^{-4} counts/(kg·keV·y)]
Crystal	5
Holder (copper)	4
Holder (Teflon)	8
Cabling	6
Electronics	3
Infrastructure	4
Muon, neutron & co.	2
GERDA	32



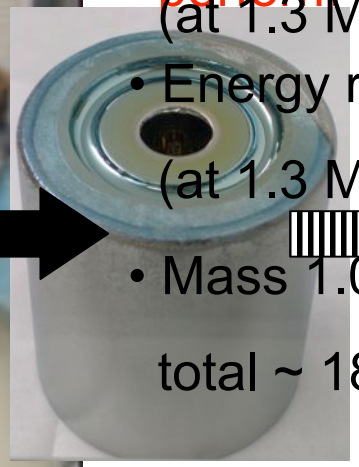


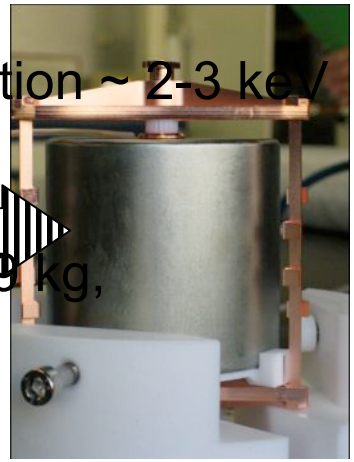
- Substantial lower background with improved suspension design
- No pulse shape analysis yet

Phase I Detectors

- Phase I: Use detectors from HdM and IGEX experiments (stored at LNGS)
- Need to be refurbished and mounted

- Prototype detector (nat. Ge) tested in liquid N_2
- All detectors were tested and perform well
- Energy resolution ~ 2.2 keV (at 1.3 MeV)
- Energy resolution ~ 2-3 keV (at 1.3 MeV)
- Mass 1.0 – 2.9 kg, total ~ 18 kg





Phase II Detectors

- September 05: 37.5 kg germanium enriched in Ge-76 ~ 88%
- April 06: Delivery to Germany, stored underground
- Next steps: Purification, crystal pulling, detector manufacturing

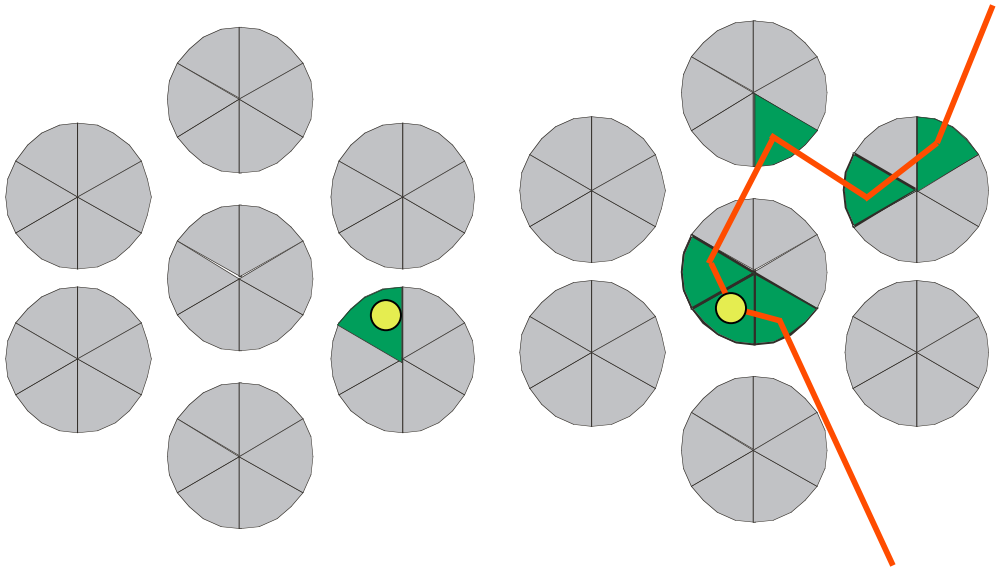
R&D: Segmented Detectors

- Germanium detectors can be segmented

  → Identify multiply Compton-scattered photons by coincidences

  → Reduction factors between 1 and 2 orders of magnitude

Signal: ***Background (^{60}Co):***

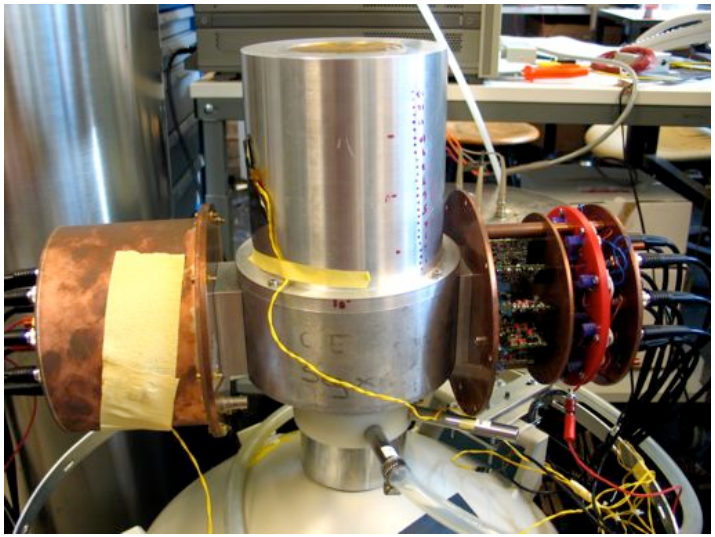


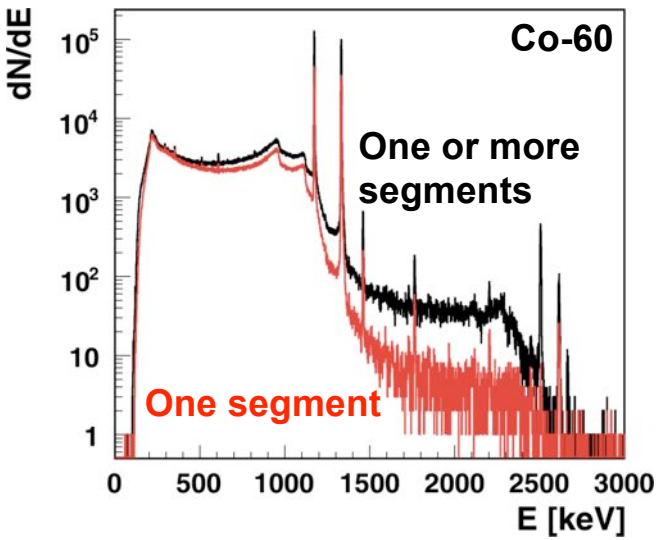
Source	Reduction
^{208}Tl (in Ge)	13
^{60}Co (in Ge)	38
^{68}Ge (in Ge)	18
^{210}Pb (α on Ge surface)	1
^{208}Tl (in holder)	5
^{60}Co (in holder)	157
^{208}Tl (in cable)	5

Reduction factors estimated using a GEANT4 Monte Carlo simulation

R&D: Phase II Prototype Detector

- Phase II prototype detector currently under study
  - 6-fold segmentation in φ, 3-fold segmentation in z
  - N-type crystal operated in test-cryostat
- Plan: Mount holder and submerge into cryo-liquid





More results from MPI Munich test stands → Poster session

Conclusions

- GERDA will search for 0νββ-decay of Ge-76
- Strategy: operation of bare Ge detectors in cryo-liquid

  → Background index of 10^{-3} counts/(kg·keV·y)
- Phased approach (~15 kg → ~35 kg enriched germanium)
- Aimed sensitivity ~ $T_{1/2} > 1.4 \cdot 10^{26}$ years (90% prob.) with 100 kg·years
- Approved by LNGS, construction prepared, construction will soon get under way
- Lot's of R&D being performed

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