Status of the GERDA experiment

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on behalf of the
GERDA collaboration

Outline

- Introduction and motivation
- Goals and design of GERDA
- Main hardware components of GERDA:
  - Cryostat and water tank
  - Cleanroom and lock system
  - GERDA detector laboratory (GDL)
- Status of subprojects:
  - Detector preparation for phase I
  - Development of phase II detectors
  - Further running R&D programs
- Schedule and summary

The GERDA collaboration

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~70 physicists
13 institutions
6 countries

GERDA – A quick overview

- Next generation ^{76}Ge double beta decay experiment at Gran Sasso
- Significant reduction of background around $Q_{\beta\beta}$ to $\leq 10^{-3}$ cts/(kg·keV·y)
- Contamination in previous experiments mainly in cryostat / diode holder

  $\rightarrow$ Bare diodes in cryogenic liquid (LAr)
- Cryogenic liquids have very high radiopurity

Why Germanium?

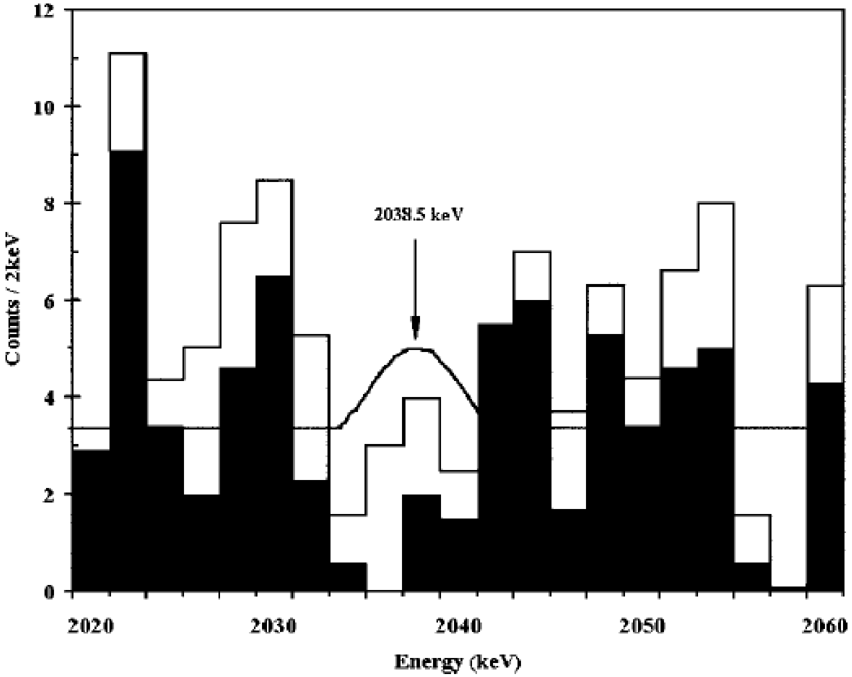
- Enrichment of ^{76}Ge possible (natural abundance: 7.4%)
- Germanium semiconductor diodes
  - source = detector
  - excellent energy resolution
  - ultrapure material (monocrystal)
- long experience in low-level Germanium spectrometry

Previous ^{76}Ge 0νββ experiments

IGEX experiment:

C. Aalseth et al., Phys. Rev. D 65, 092007.

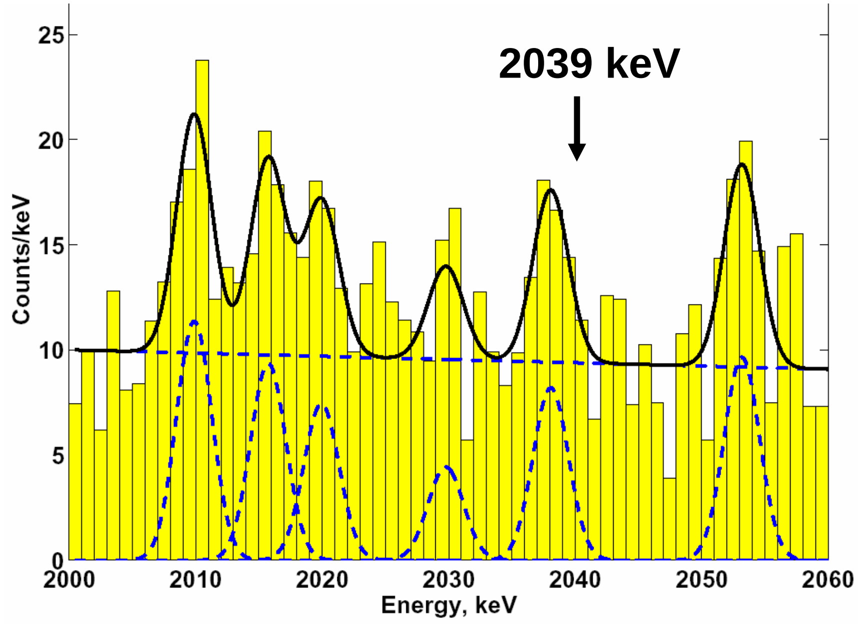
$T_{1/2} > 1.6\ 10^{25}$ y (90% C.L.)



Heidelberg-Moscow experiment:

H.V.Klapdor-Kleingrothaus et al., Phys.Lett. B586 (2004) 198.

$T_{1/2} = (0.7 - 4.2) \cdot 10^{25}$ y (3σ range)

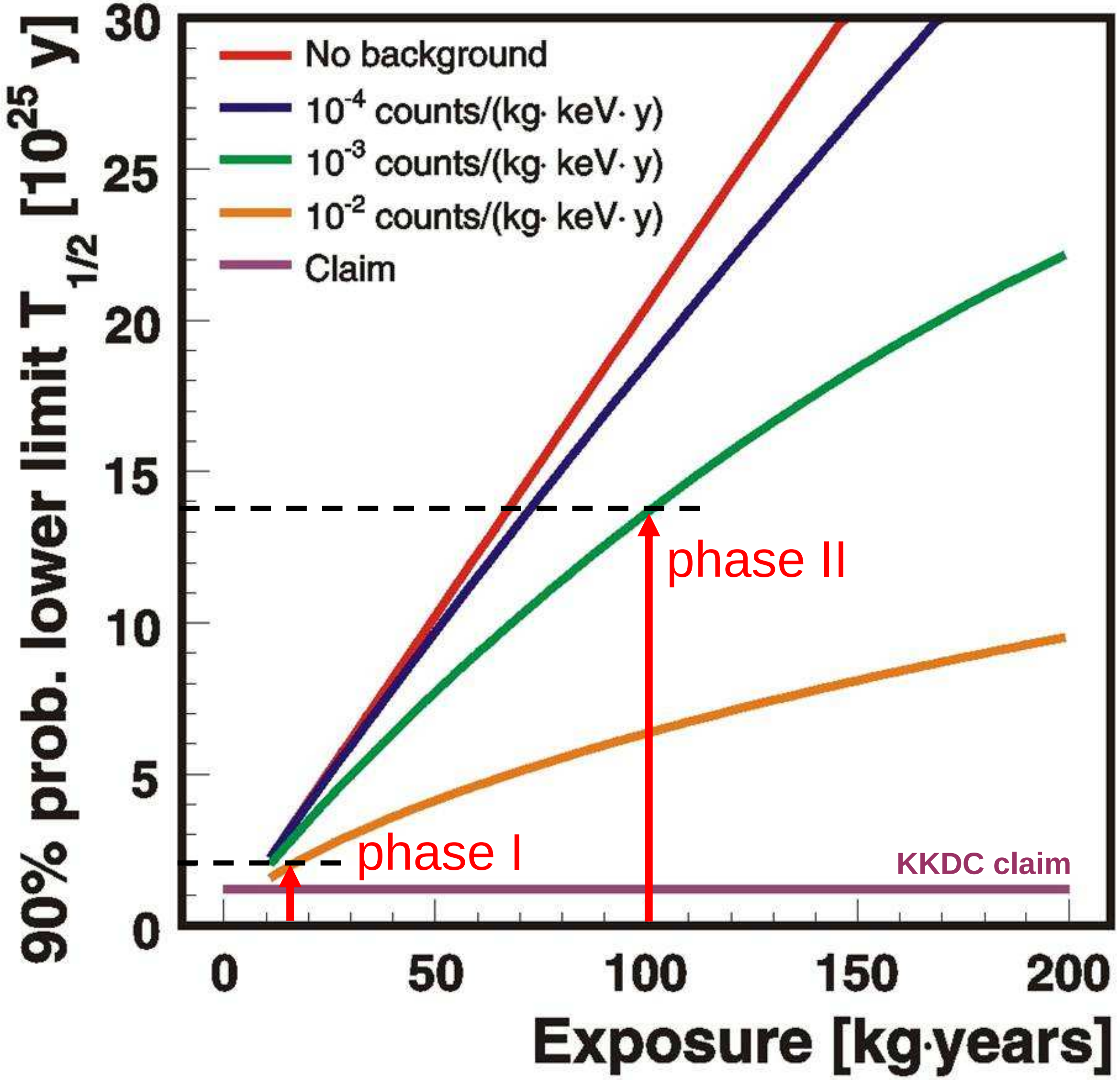


Scrutinize claim with same & different isotopes!

Phases of GERDA

- Phase I:
  - Use of existing ^{76}Ge-diodes from Heidelberg-Moscow and IGEX-experiments
  - 17.9 kg enriched diodes $\Rightarrow$ ~15 kg ^{76}Ge
  - Background-free probe of KKDC evidence
- Phase II:
  - Adding new segmented diodes (total: ~40 kg ^{76}Ge)
  - Demonstration of bkg-level <1 count/(kg·keV·y)
- If KKDC-evidence not confirmed:
  - Goal: O(1 ton) experiment in worldwide collaboration (cooperation with Majorana)

GERDA sensitivity

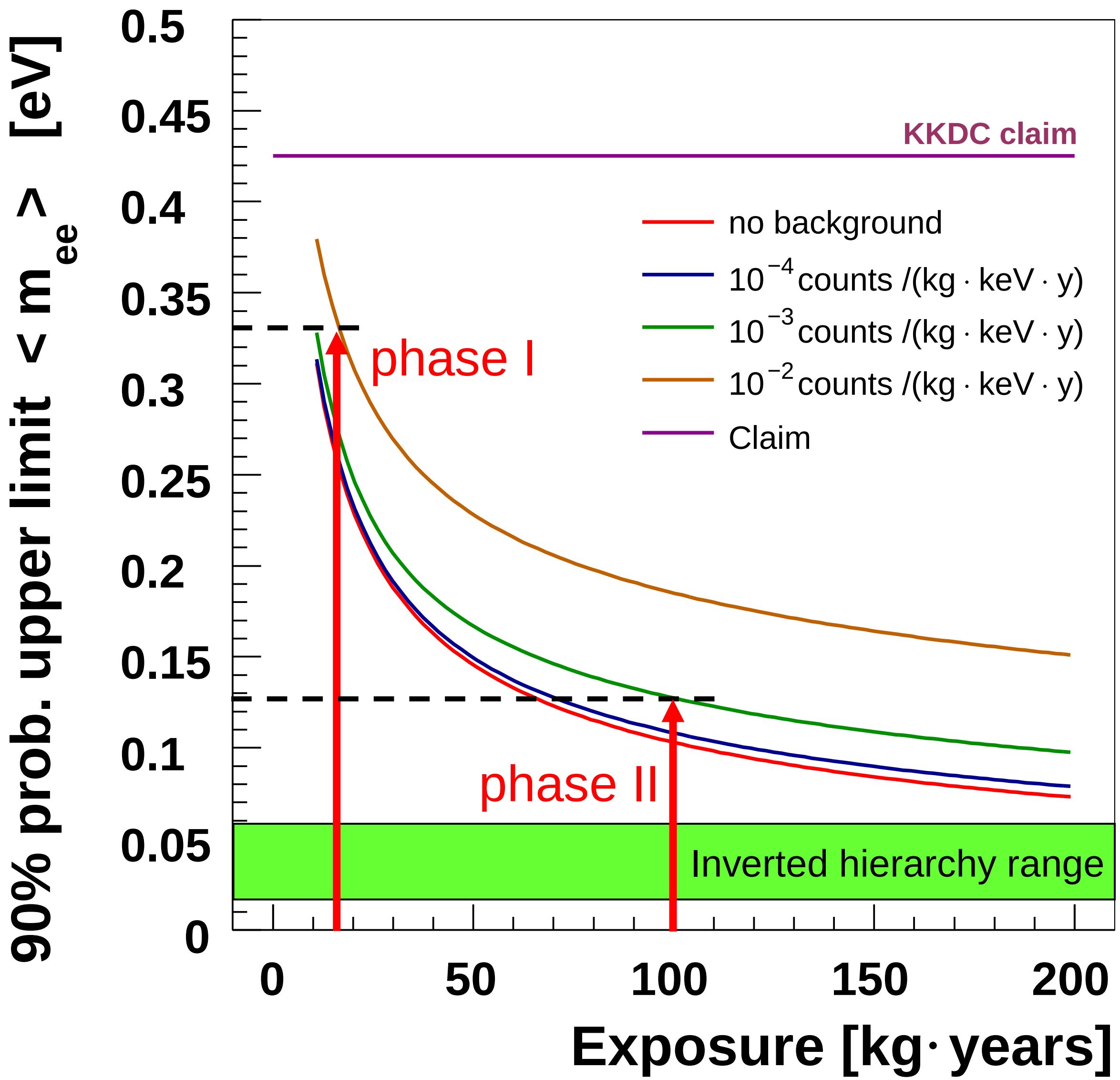


assumed energy resolution:

$\Delta E = 4$ keV

Background reduction!!!

GERDA sensitivity

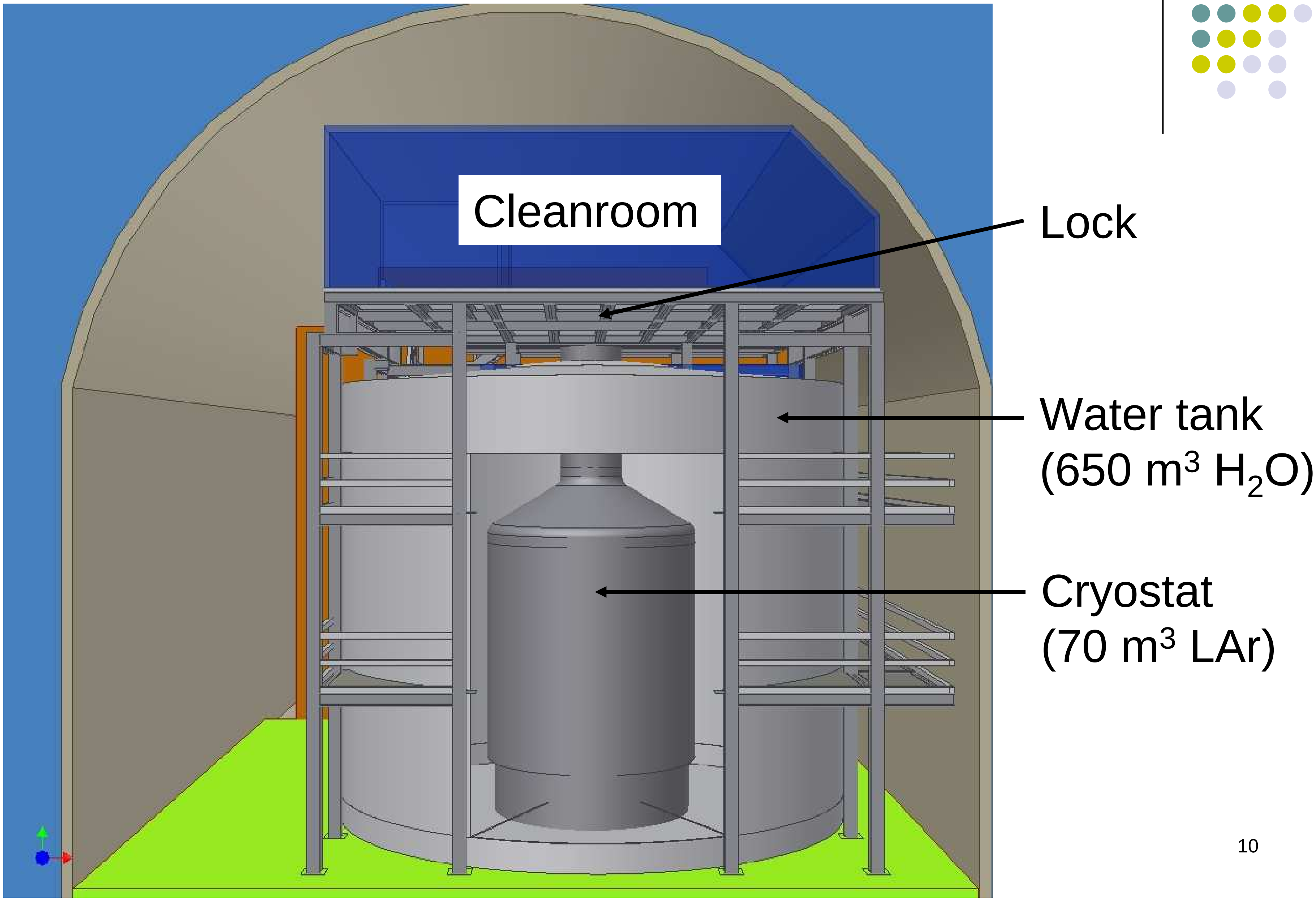


using $\langle M^{0\nu} \rangle = 3.92$

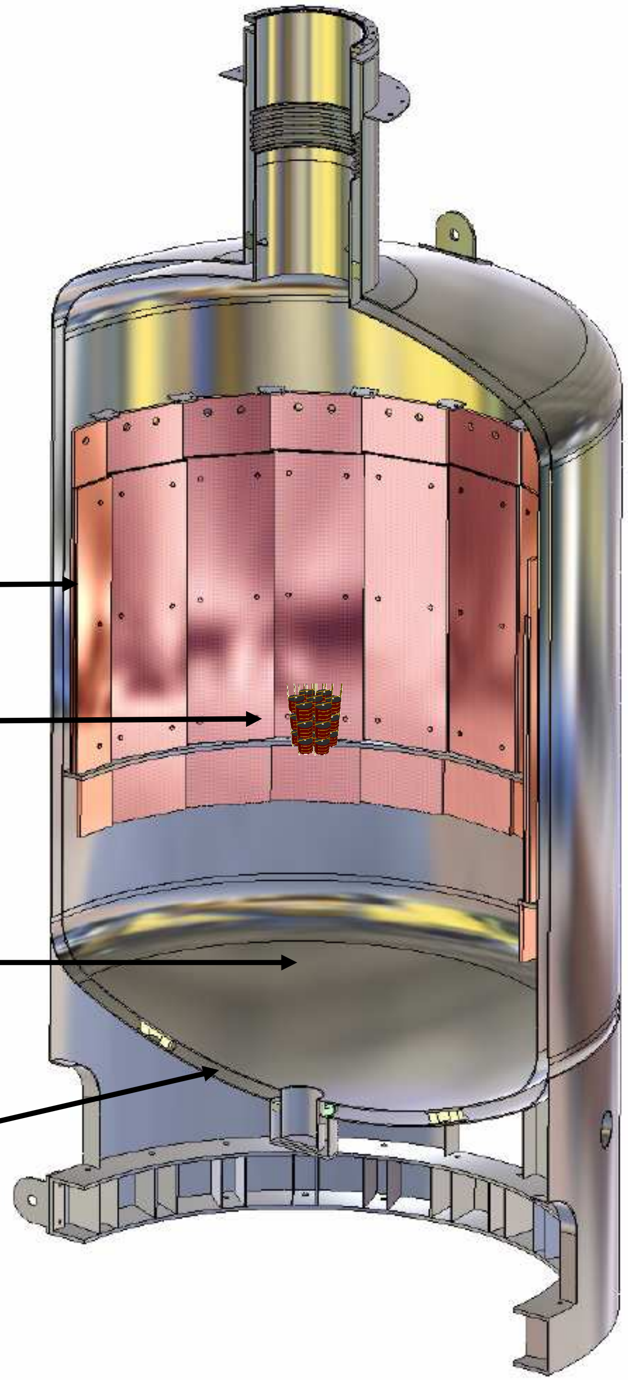
V.A. Rodin at al., Nucl. Phys. A 366 (2006) 107-131

Erratum:
Nucl. Phys. A 793 (2007) 213-215

GERDA design



GERDA design



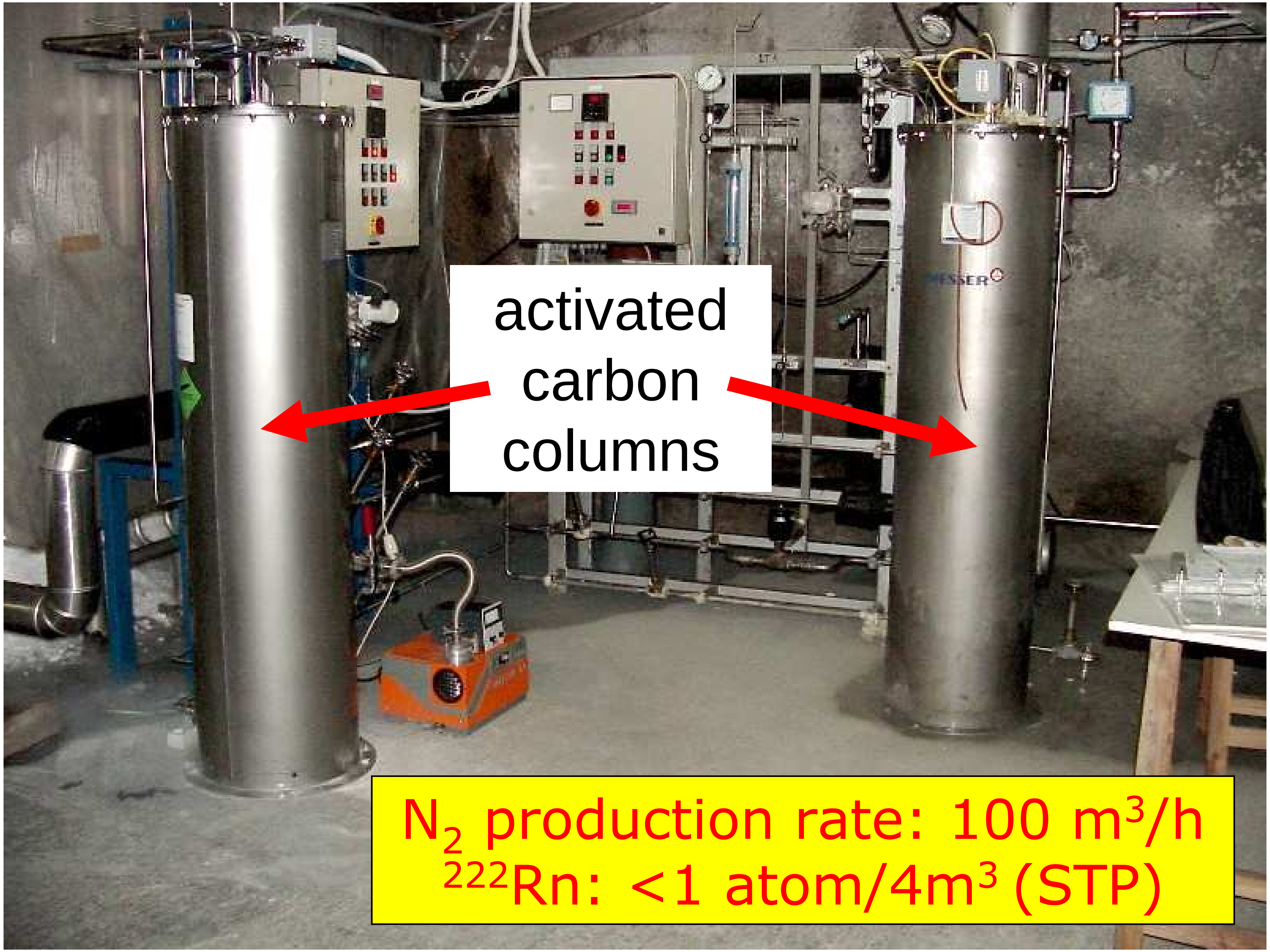
Additional inner copper shield

Germanium-detectors

Liquid argon

Vacuum-insulated double wall stainless steel cryostat

Gas purification for BOREXINO



Argon purification from ^{222}Rn

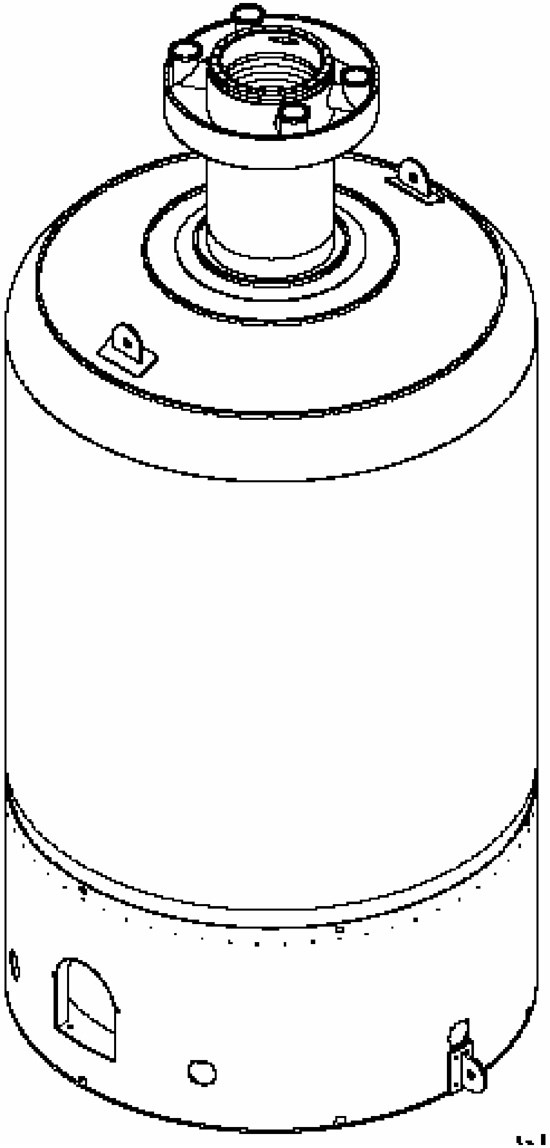
- Same principle as N_2 purification
- Initial ^{222}Rn conc. in Ar higher than in N_2
- In gas phase achieved:

^{222}Rn in Ar: <1 atom/4m^3 (STP)

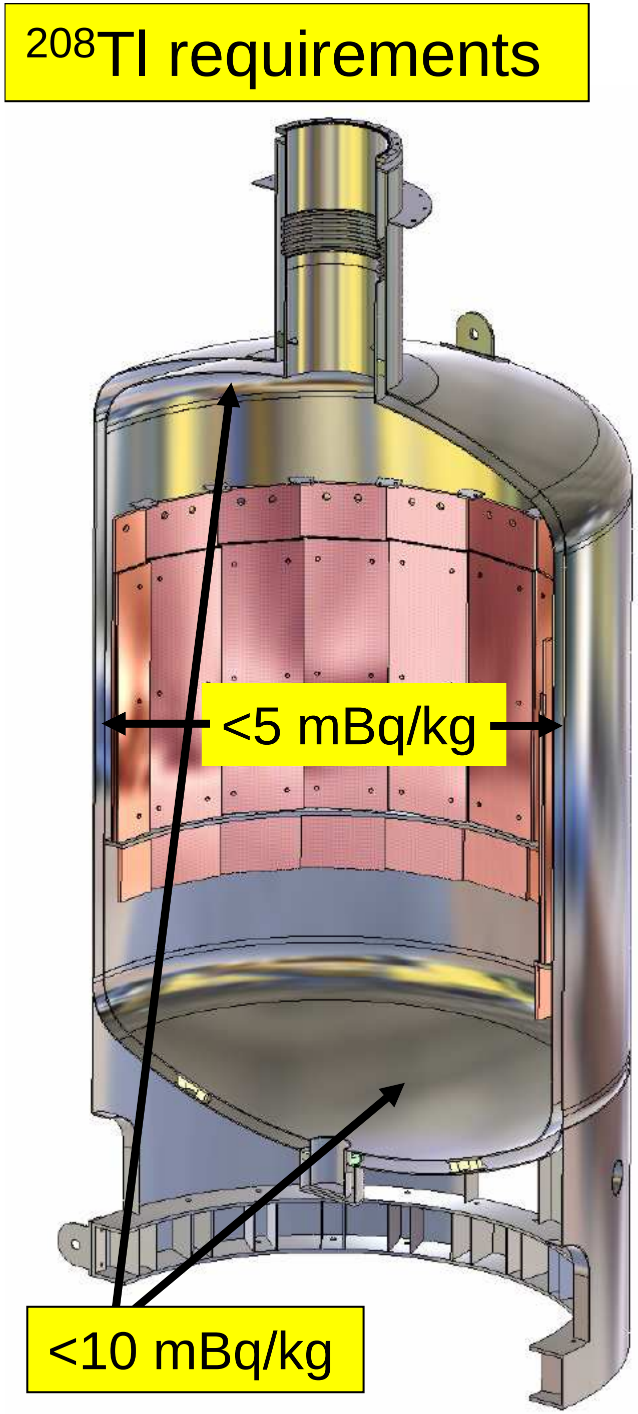
- Even sufficient for GERDA phase III
- Purification works also in liquid phase (efficiency lower $\Rightarrow$ more activated carbon)

G. Zuzel: “Low-level techniques applied in the experiments looking for rare events”, Wed. 12.09, Solar neutrinos & low background techniques

Stainless steel (SS) cryostat



- Ordered in Dec. 2006
- 4 vessel heads produced
- Welding certification in progress
- Delivery: Beginning of 2008



Radioactivity of the SS cryostat

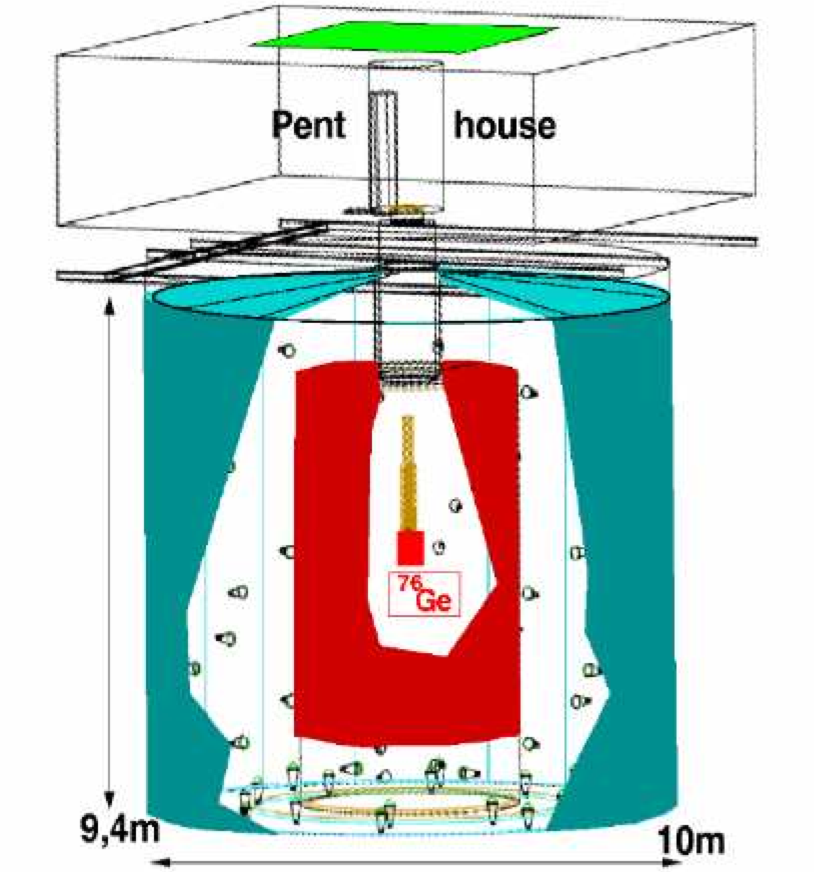
- SS contains U/Th/K-contaminations (and ^{60}Co)
- Most dangerous: ^{208}Tl (^{214}Bi)
- LAr (higher density than LN_2)
- ^{208}Tl requirements of stainless steel (SS 1.4571) for
  - Vessel heads: <10 mBq/kg
  - Cylindrical part: <5 mBq/kg

Screening results of stainless steel samples (SS 1.4571)

No.	Specific activity [mBq/kg]				
	^{228}Th	^{226}Ra	^{40}K	^{60}Co	
1 D	5.1 ± 1.0	2.9 ± 1.0	< 3.9	6.5 ± 0.5	vessel heads
2 G	< 0.27	< 0.35	< 1.1	13.0 ± 0.6	vessel heads
3 D	1.1 ± 0.4	< 0.84	< 3.3	15.1 ± 0.5	vessel heads
4 D	< 2.6	< 2.2	< 6.2	14.4 ± 1.0	vessel heads
5 D	< 1.1	< 1.2	< 2.8	11.6 ± 0.5	vessel heads
6 D	< 0.8	< 0.6	< 1.7	16.7 ± 0.4	cylindrical part
7 G	< 0.20	< 1.3	< 2.8	45.5 ± 2.1	cylindrical part
8 G	< 0.11	< 0.24	< 0.93	14.0 ± 0.1	cylindrical part
9 G	< 0.41	< 0.74	< 1.1	13.8 ± 0.7	cylindrical part
10 G	< 1.0	< 1.3	< 6.8	17.1 ± 0.7	cylindrical part
11 G	1.5 ± 0.2	1.0 ± 0.6	< 0.81	18.3 ± 0.7	cylindrical part

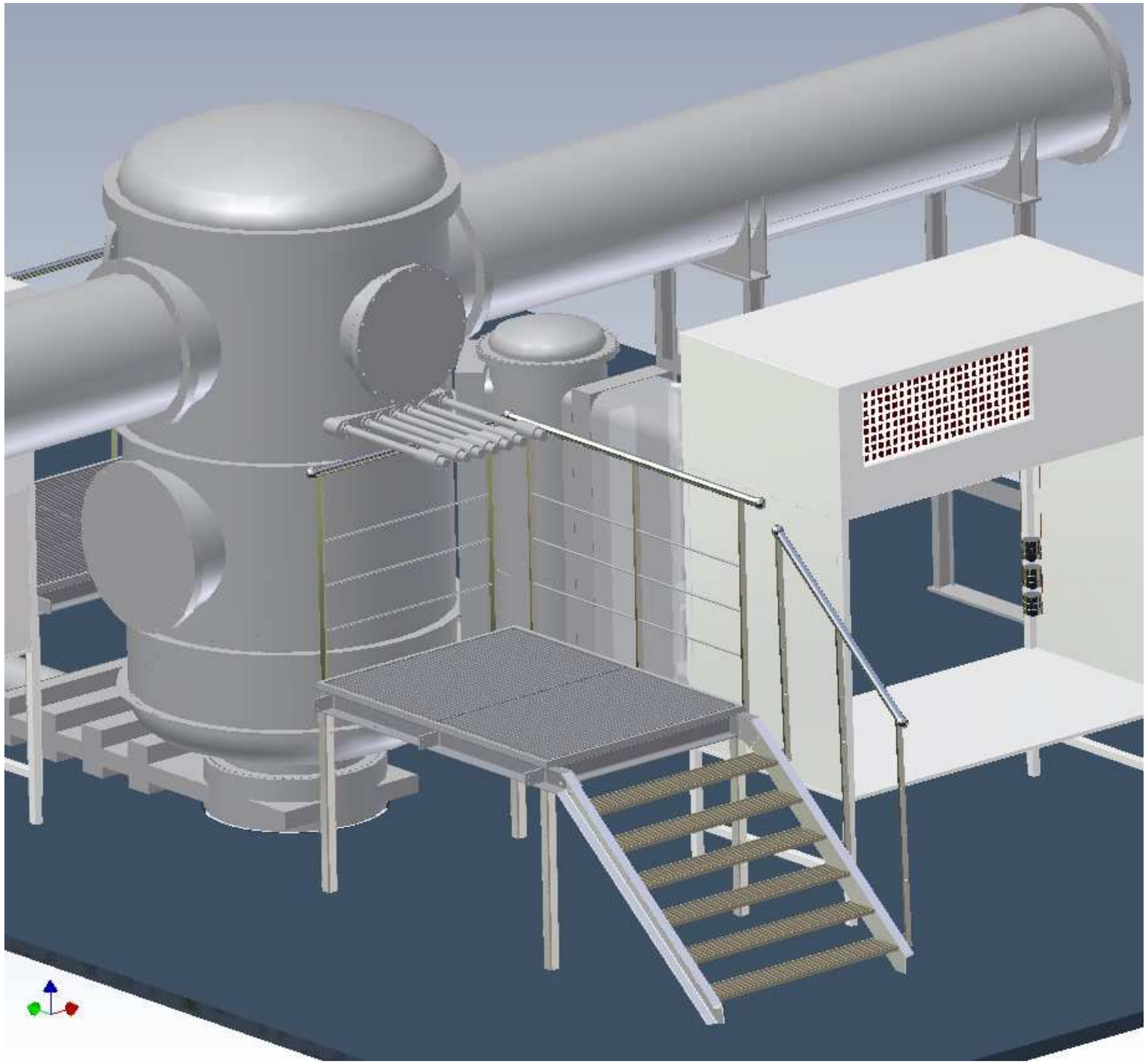
Water tank and muon veto

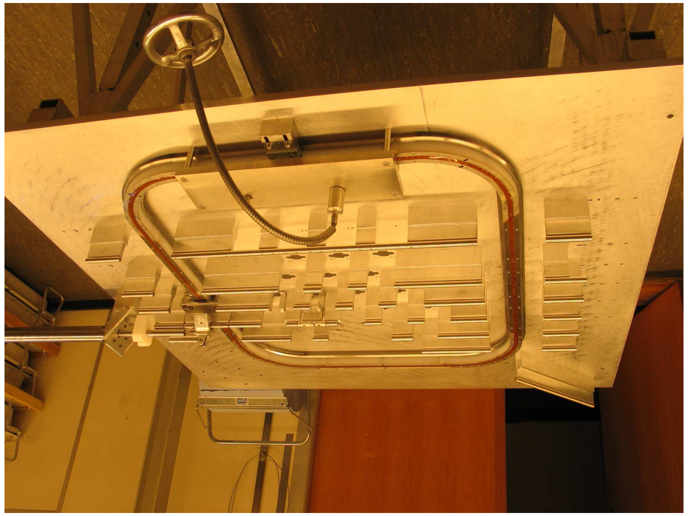
- Passive shield (reduces amount of LAr)
- Filled with ultrapure water
- Equipped with 66 PMTs: Cherenkov detector
- Plastic scintillator on top
- Construction has started (bottom plate installation)

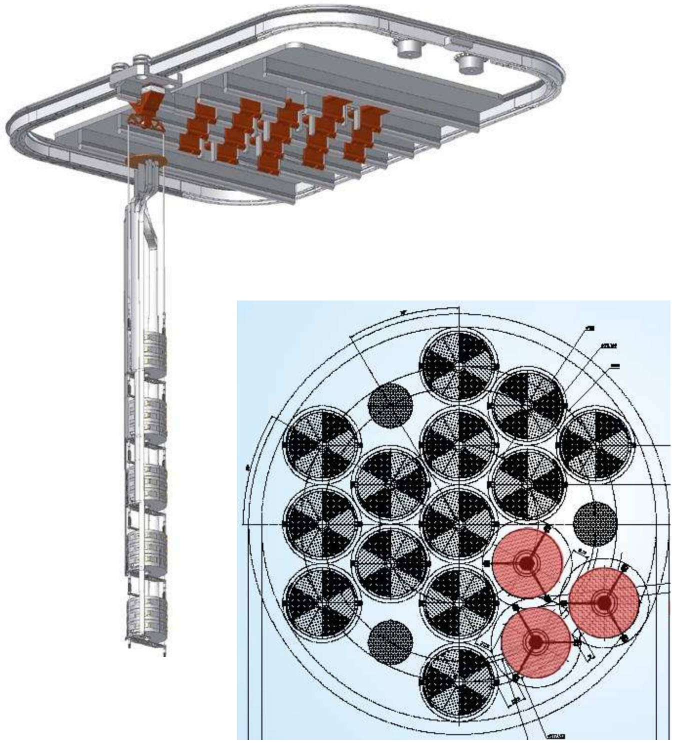


Cleanroom on top of water vessel

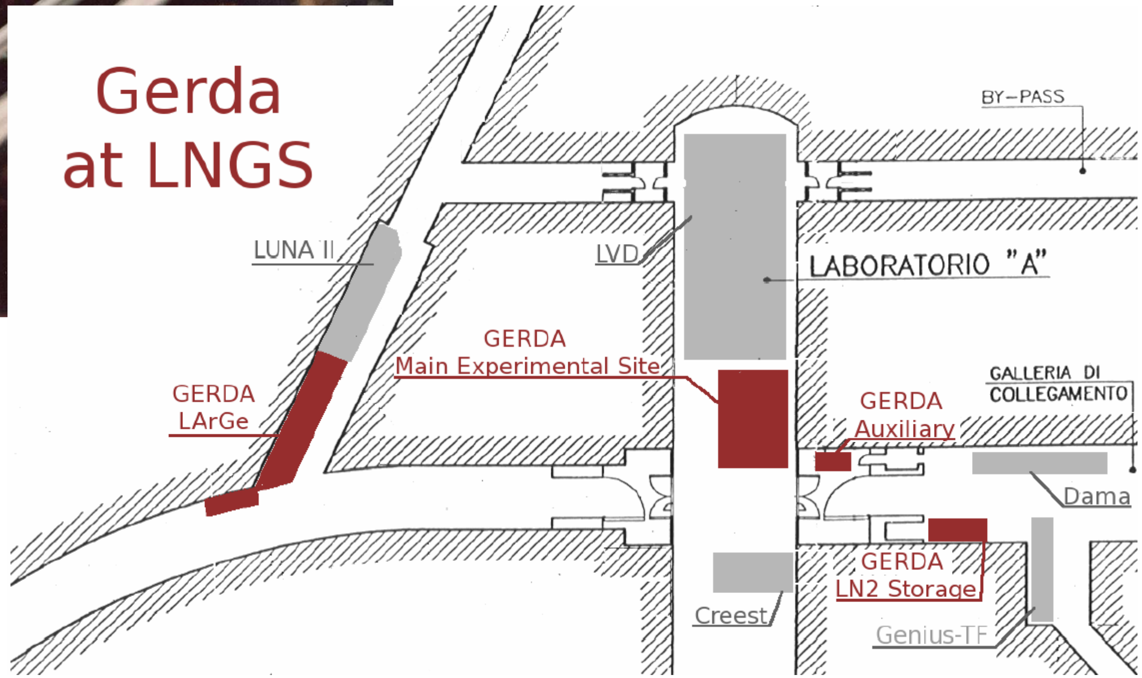
The lock system







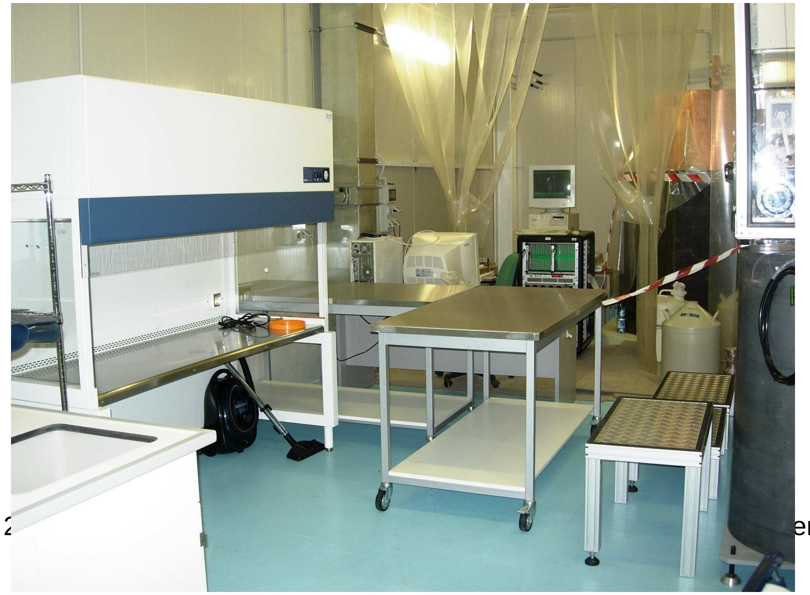
GERDA site at Gran Sasso



Construction in hall A started

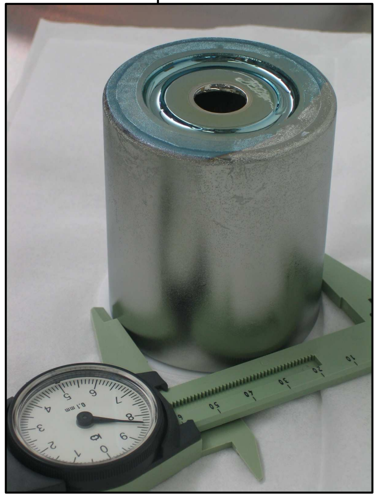
Water tank bottom plate (August 2007)

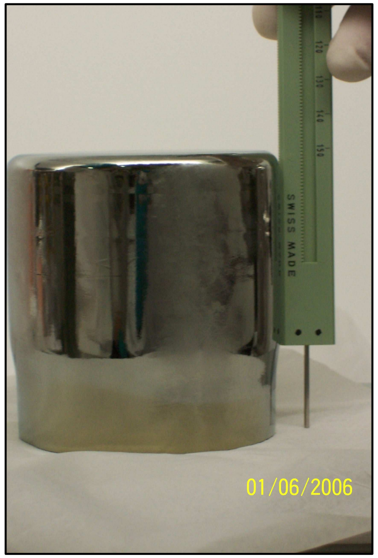
GERDA detector lab (GDL) at Gran Sasso



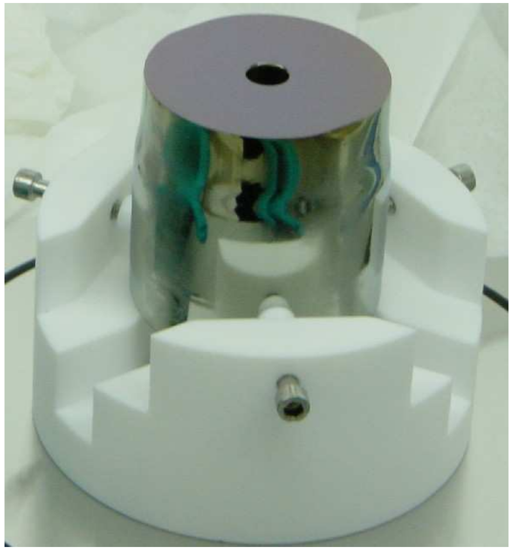
Enriched diodes for phase I

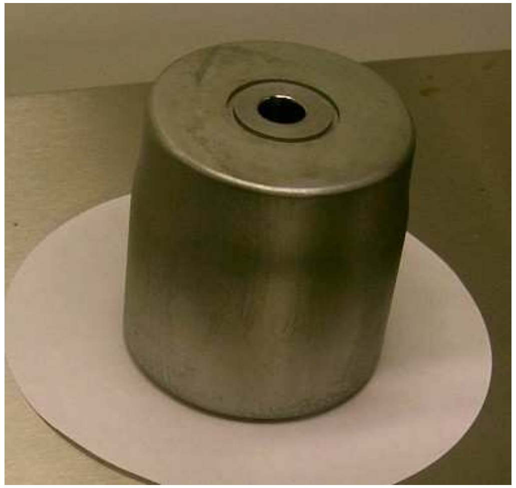
- In 2006 3 IGEX diodes and 5 HdM diodes were removed from their cryostats
- Dimensions were measured
- Construction of dedicated low-mass holder for each diode





Reprocessing of enriched and non-enriched diodes for phase I

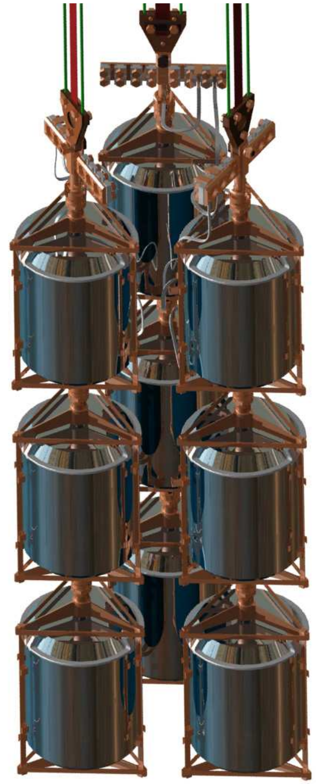


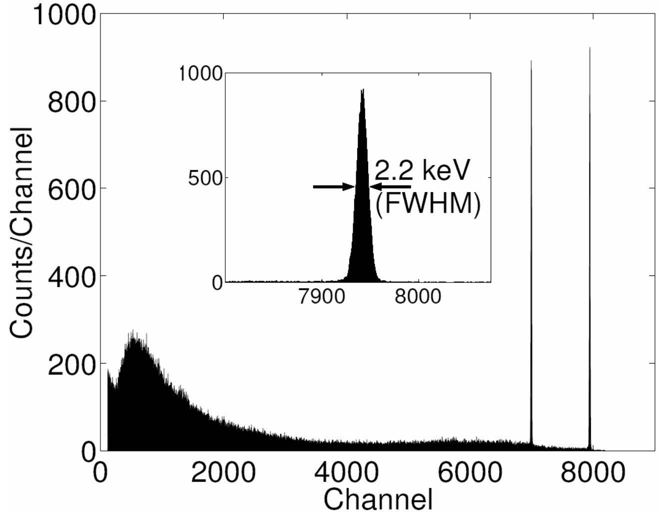


- Different design of Hd-Moscow and IGEX diodes
- Reprocessing of all diodes at manufacturer
- Underground storage in between
- 17.9 kg enriched and 15 kg non-enriched crystals under processing

Phase I prototype testing

- Low mass detector holder developed and tested
- Definition of detector handling protocol
- Optimization of thermal cyclings
  - >40 warming and cooling cycles carried out
  - Passivation layer only refurbished twice





Same performance in LN_2/LAr

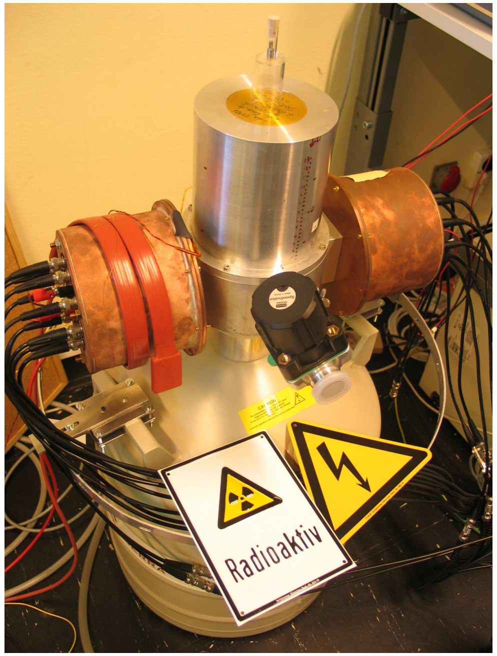
Phase I prototype testing

- Study of leakage current (LC) with respect to
  - Detector handling procedure
  - Irradiation with γ-sources
- Prototype detector continuously operated in LAr under varying irradiation conditions since Feb 07
- Present LC similar to initial value (few tens of pA)

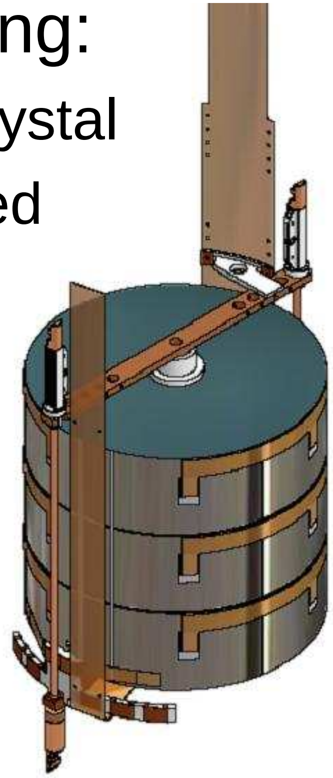
GERDA phase II

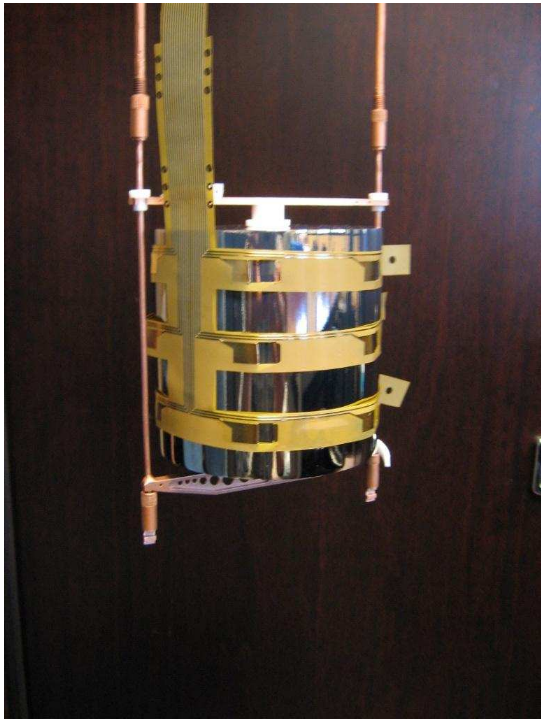
- September 2005: 37.5 kg ^{enr}Ge produced
  - ~87% ^{76}Ge enrichment
  - in form of GeO_2
  - Chemical purity: 99.95 % (not yet sufficient)
- Underground storage until further processing steps are defined
- Investigation of different options for crystal pulling

Development of true-axial segmented detectors

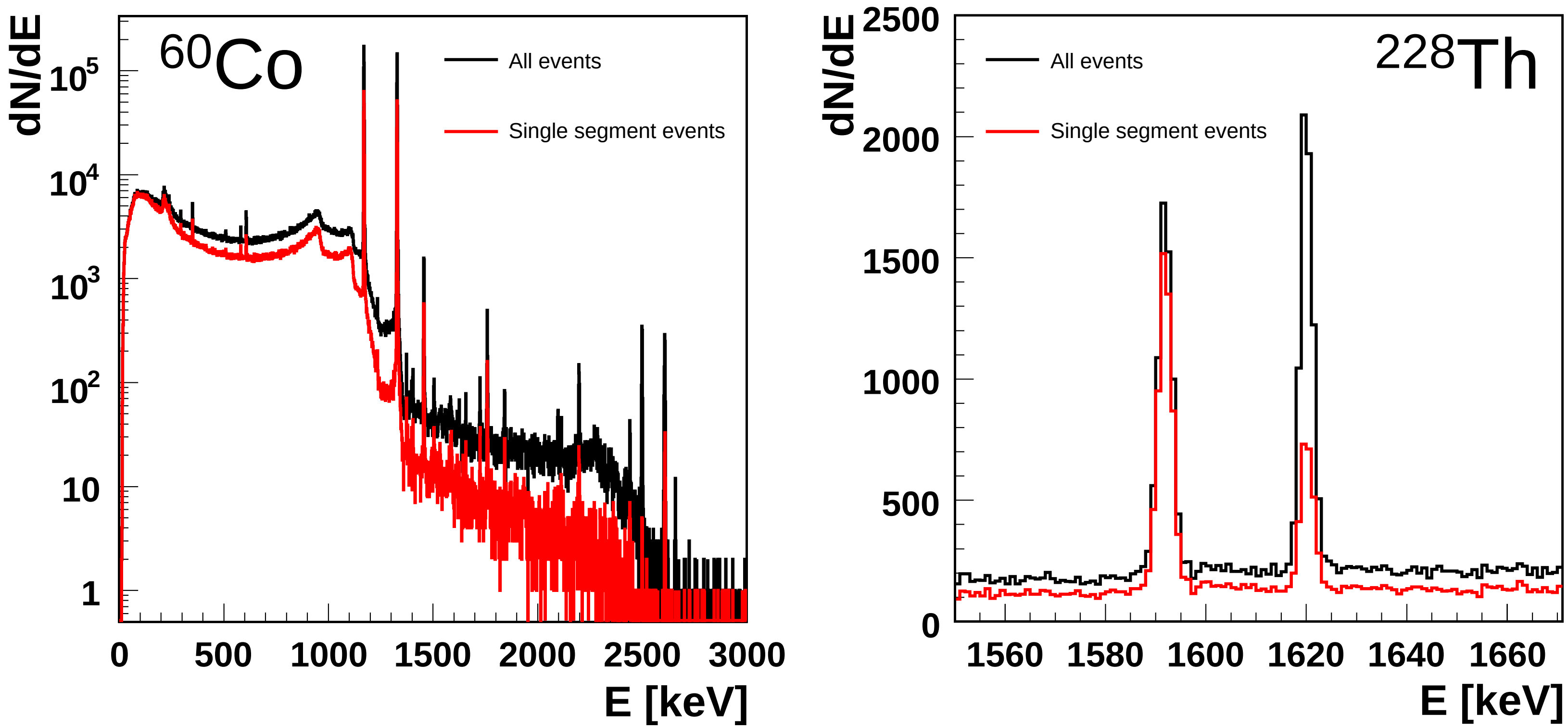


- $\beta\beta$-decay is single-site event, γ-background mostly multi-site event
  $\Rightarrow$ Discrimination by segmentation
- Available detectors for testing:
  - 6-fold ϕ–segmented p-type crystal
  - two 18-fold (6ϕ, 3z) segmented detectors (n- and p-type)
- 18-fold n-type preferred:
  - Segmentation easier
  - Thin outside dead layer
    $\Rightarrow$ little loss of active mass



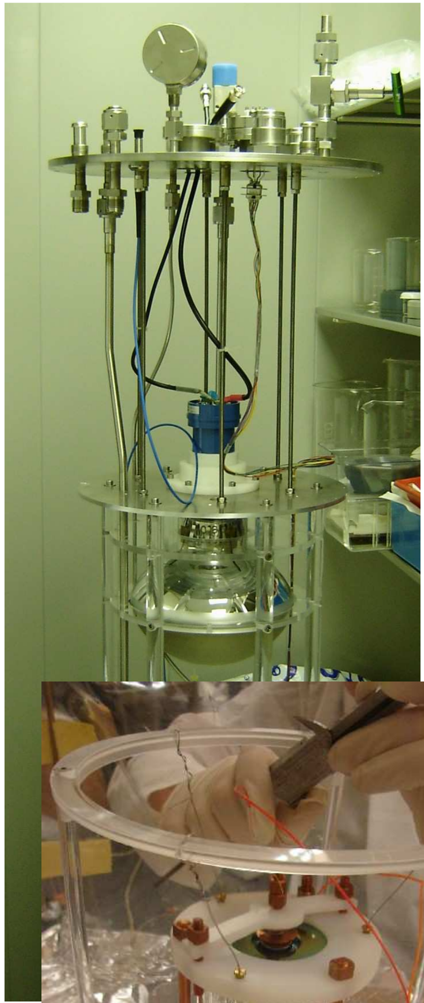


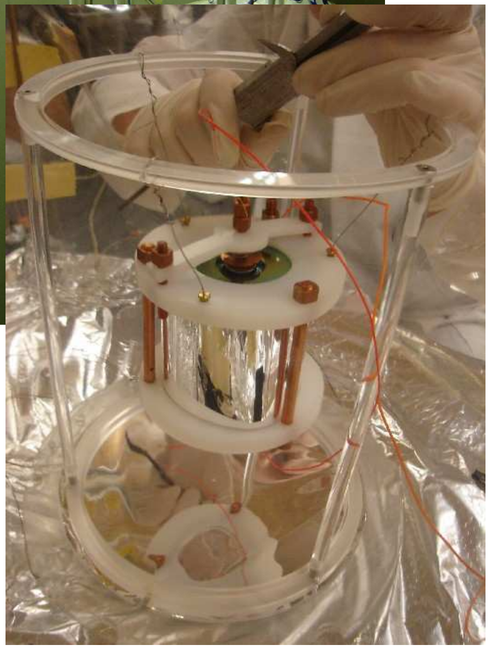
Results obtained with 18-fold segmented n-type detector



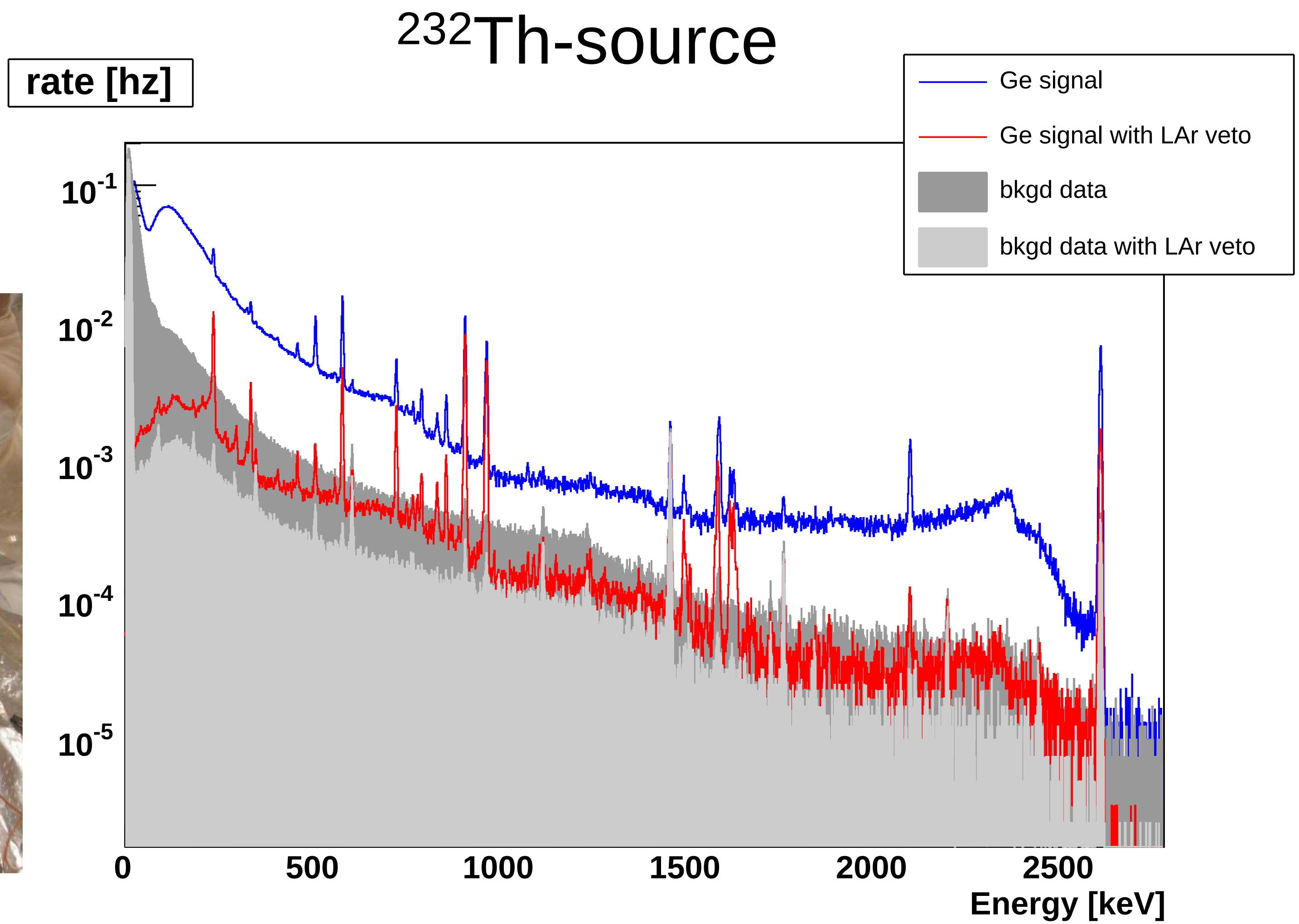
- Suppression of events from external ^{60}Co and ^{228}Th source (10 cm distance).

Background reduction by LAr-scintillation





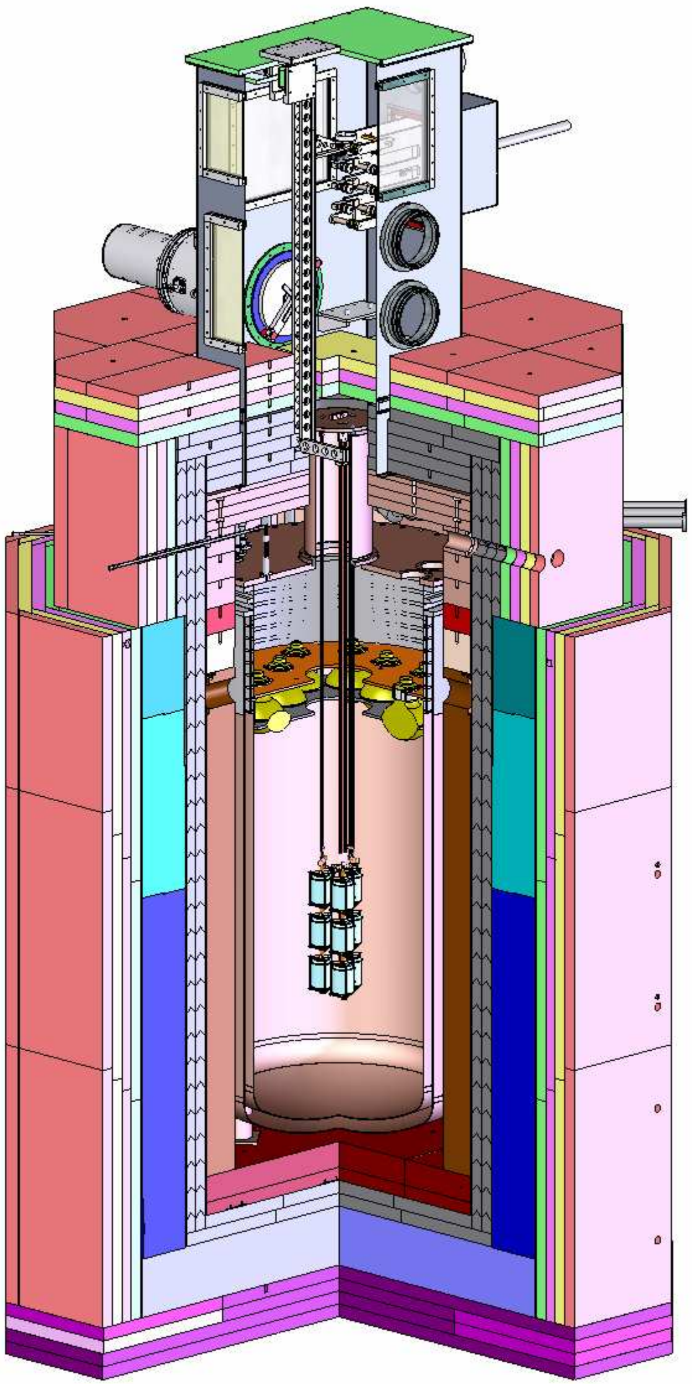
September 14, 2007



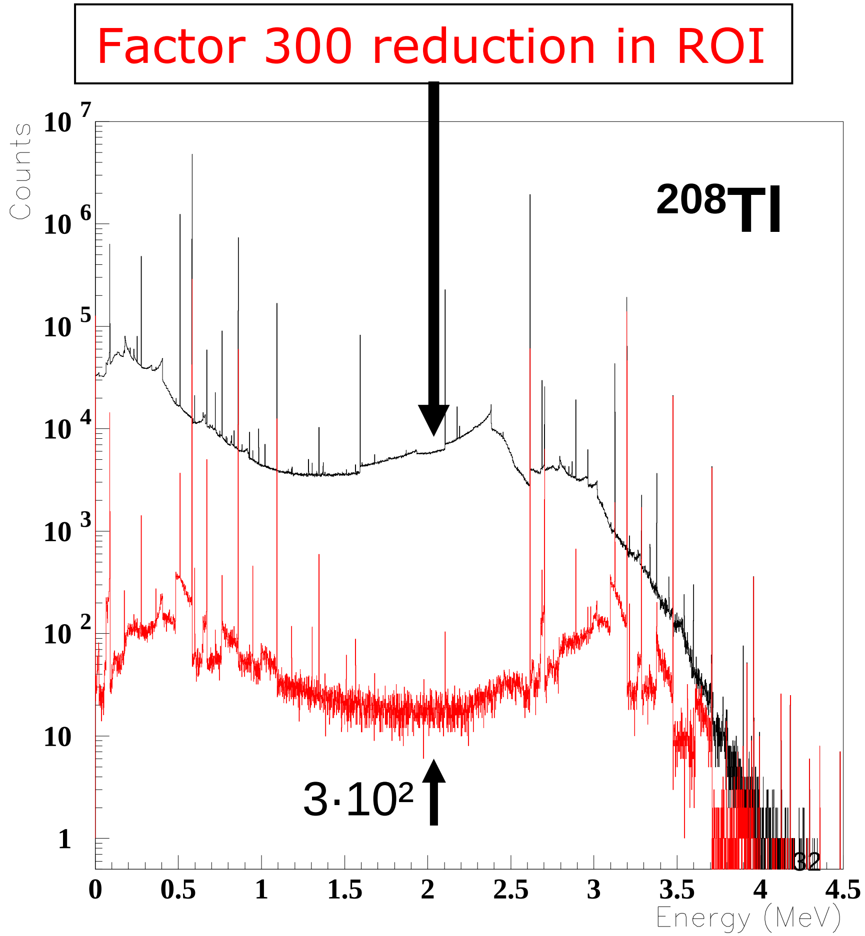
Liquid argon scintillation – Work in progress

- Increase of photo-electron yield:
  - by fluor coating (1100 pe/MeV achieved)
  - by Xe doping
- Characterization of α, β, γ and neutron interactions by pulse shape analysis
- Preparation for LArGe in GDL @ Gran Sasso:
  - Study of LAr scintillation in ultralow-background environment
  - operational beginning of 2008

LArGe in GDL @ Gran Sasso



MC example: Background suppression for contaminations located in detector support

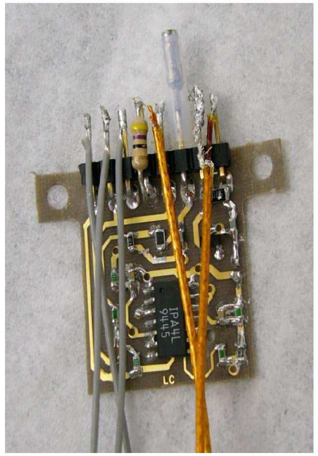


mgen, TAU

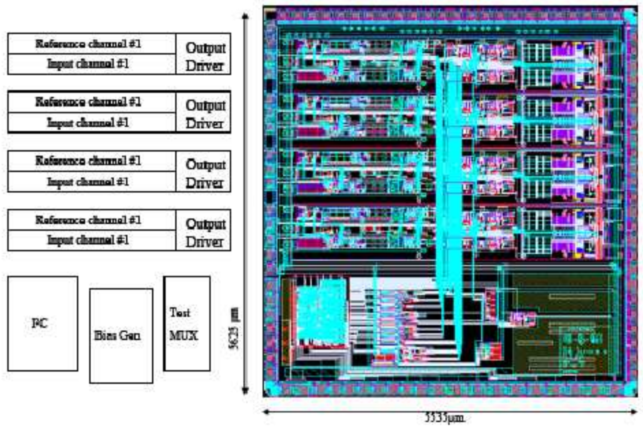
LArGe @ Gran Sasso

Front-end electronics

- Requirements:
    - Low noise, low radioactivity, low power consumption, operational at 87 K
- Monolithic JFET semi-integrated CSA currently used for prototype testing

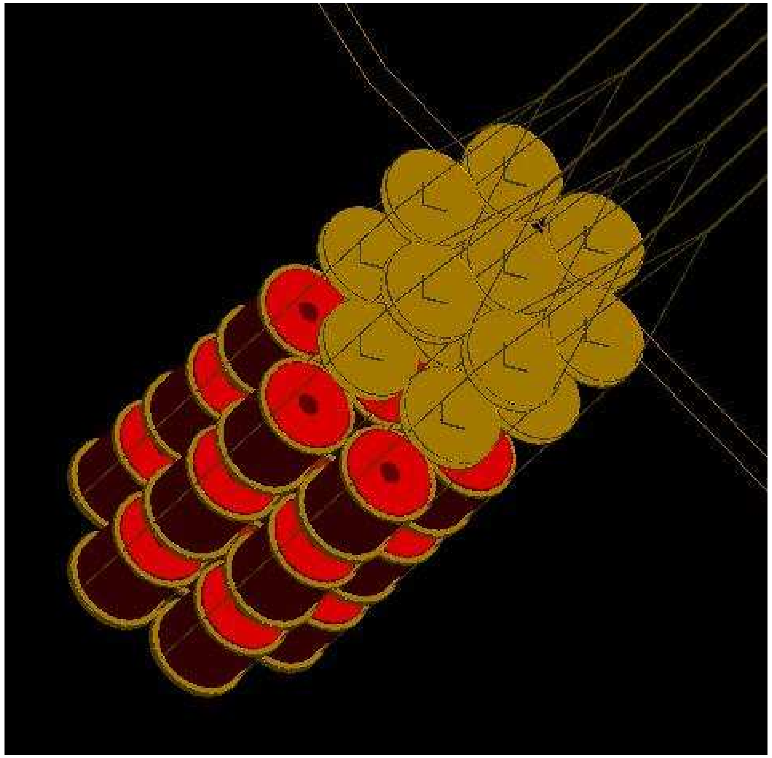


- 2 R&D programs for ASIC CMOS chips
- Characterization and testing ongoing

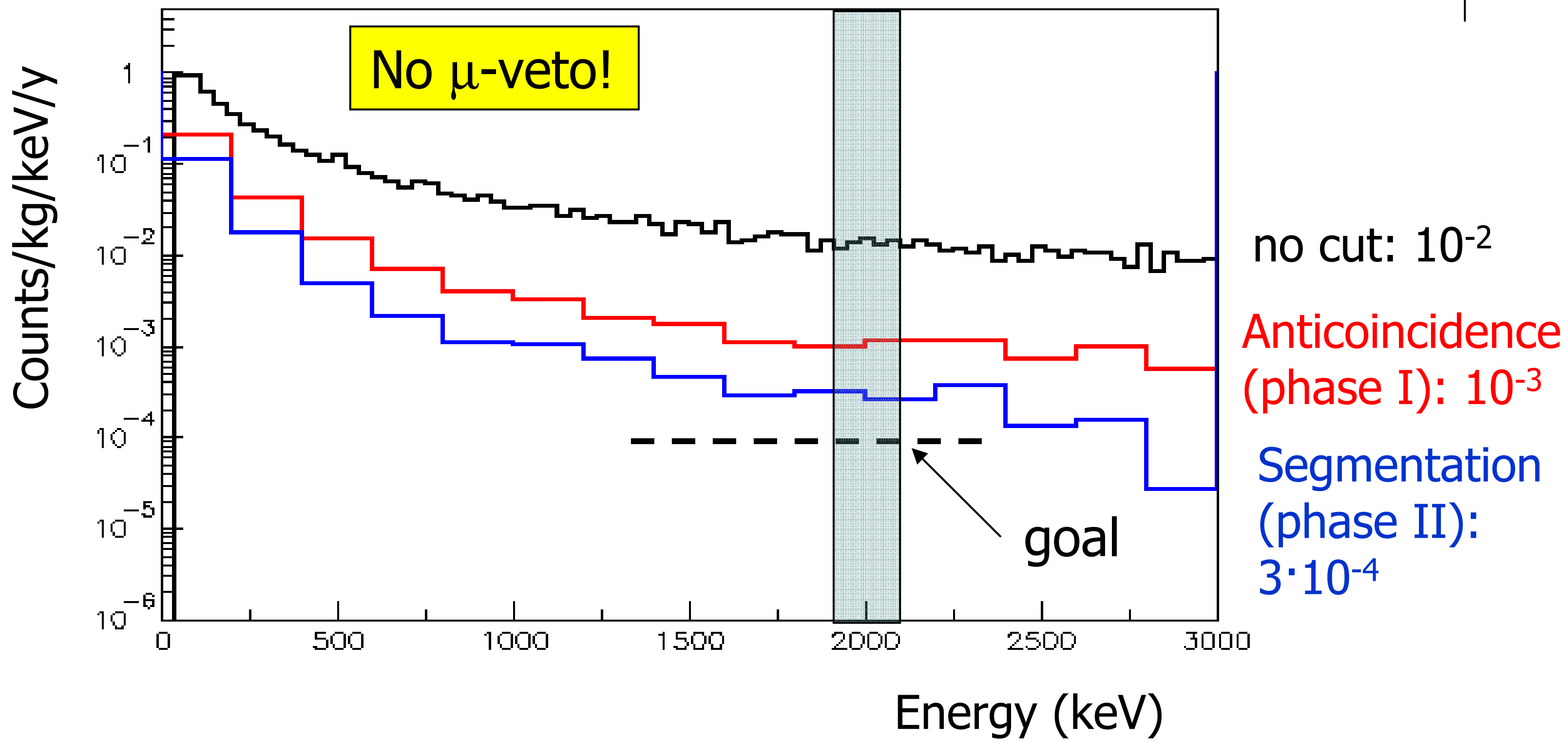


Monte Carlo Simulations

- Joint Gerda/Majorana code “MaGe” based on GEANT4
- Extensive physics validation program (most test setups are implemented).



Muon-induced background I: Prompt background



- 75% effective muon-veto is sufficient to achieve 10^{-4} counts/kg/keV/y

Muon-induced background II: Delayed background

	Background in LAr [cts/(kg·keV·y)]
$^{77,77m}Ge$	$1.1 \cdot 10^{-4}$
Others	$5 \cdot 10^{-5}$

- ^{77}Ge produced from ^{76}Ge by n-capture.
- Significant reduction possible by delayed coincidence cut (muon, γ-rays, β-decay).

Schedule

- June 2007: GERDA safety concept officially approved by Gran Sasso
- Water tank installation started → continued after cryostat delivery beginning of 2008
- Next: Construction of lab building, platform, cleanroom and lock (~1 year)
- Meanwhile: Prototype and enriched detector testing is going on
- Commissioning of GERDA ~14 months after cryostat delivery

Summary

- The challenge:
  - Reduction of background by ~2 orders of magnitude wih respect to previous ^{76}Ge experiments ⇒ Using bare diodes
- The status:
  - Construction of cryostat and water-tank started
  - Good understanding of bare detector handling
  - Reprocessing of existing enriched diodes almost finished
  - New ^{76}Ge for phase II available
  - Different new background reduction strategies for phase II and beyond under investigation
- The future:
  - Start data taking in 2009