Status of the GERDA experiment

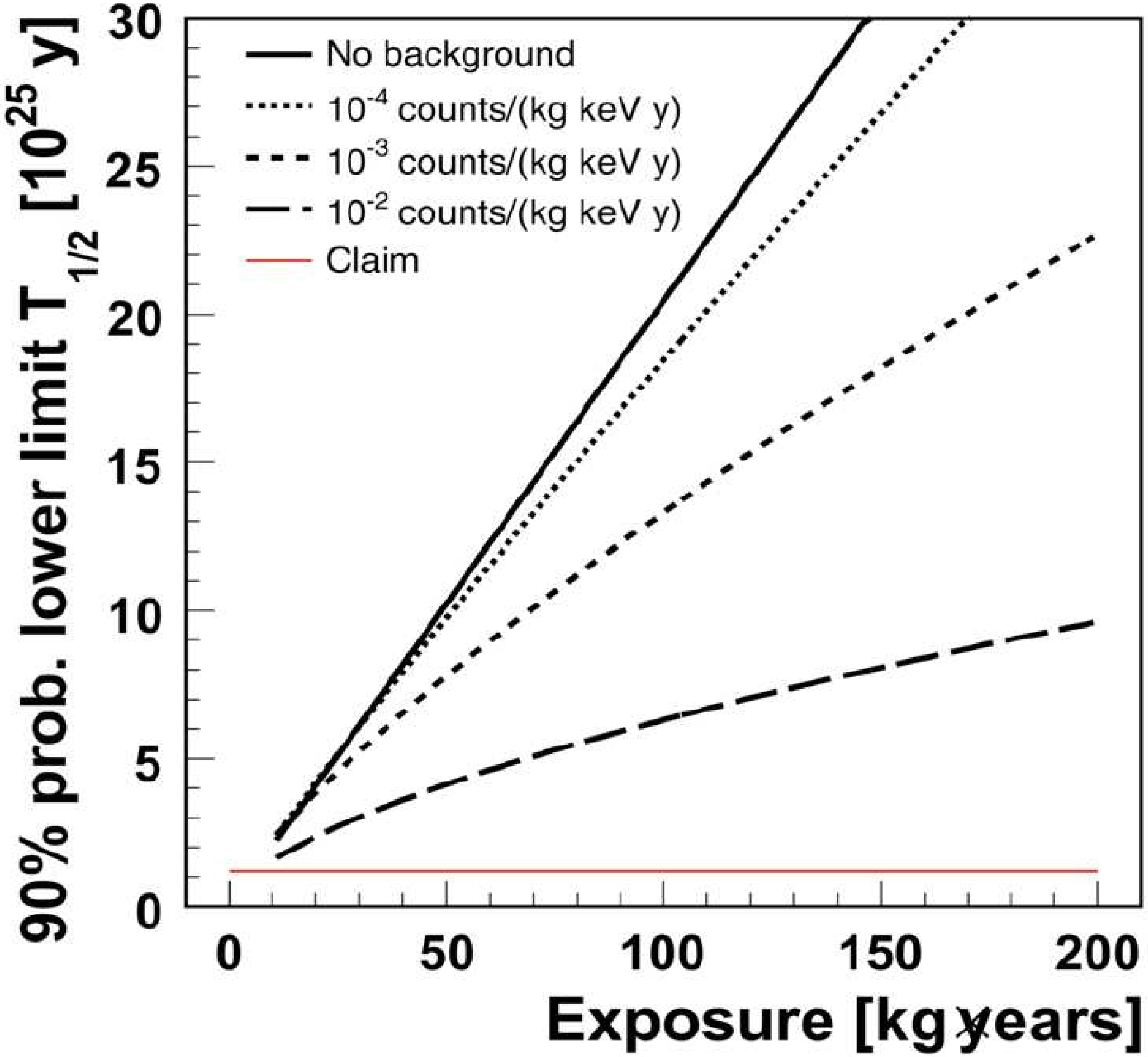
Hardy Simgen

Max-Planck-Institute
for Nuclear Physics
Heidelberg

The GERDA experiment

- Next generation ^{76}Ge double beta decay experiment at Gran Sasso.
- Basic idea: Operation of bare ^{76}Ge diodes in ultrapure cryogenic liquid (LN_2 or LAr).
- Phase I: Using available ^{76}Ge diodes from HdM and IGEX.
- Phase II: Add new (segmented) ^{76}Ge diodes.
- Phase III: O(500 kg) experiment.

GERDA sensitivity



assumed energy resolution:

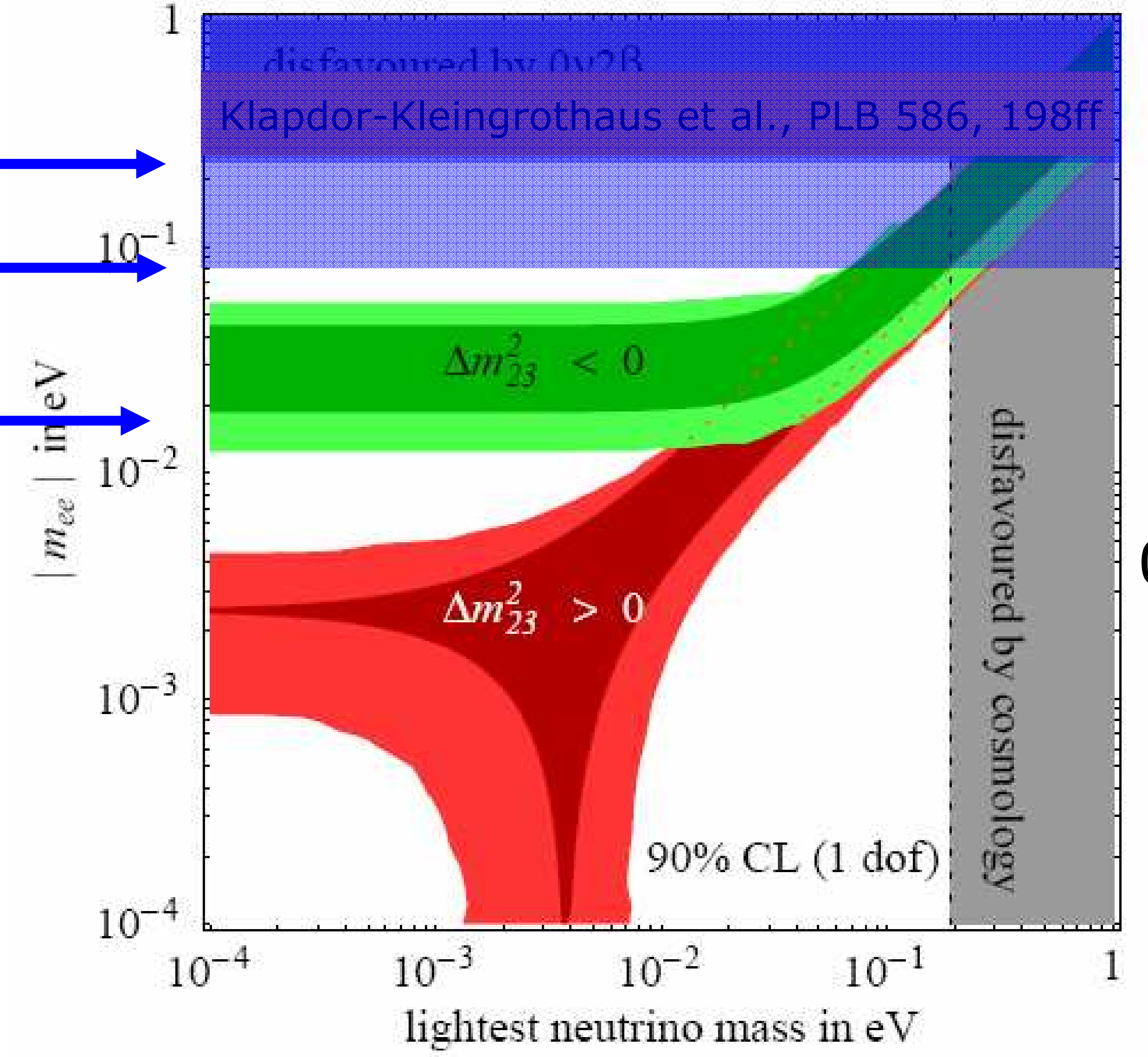
ΔE=4keV

Phases of GERDA

Phase I

Phase II

Phase III



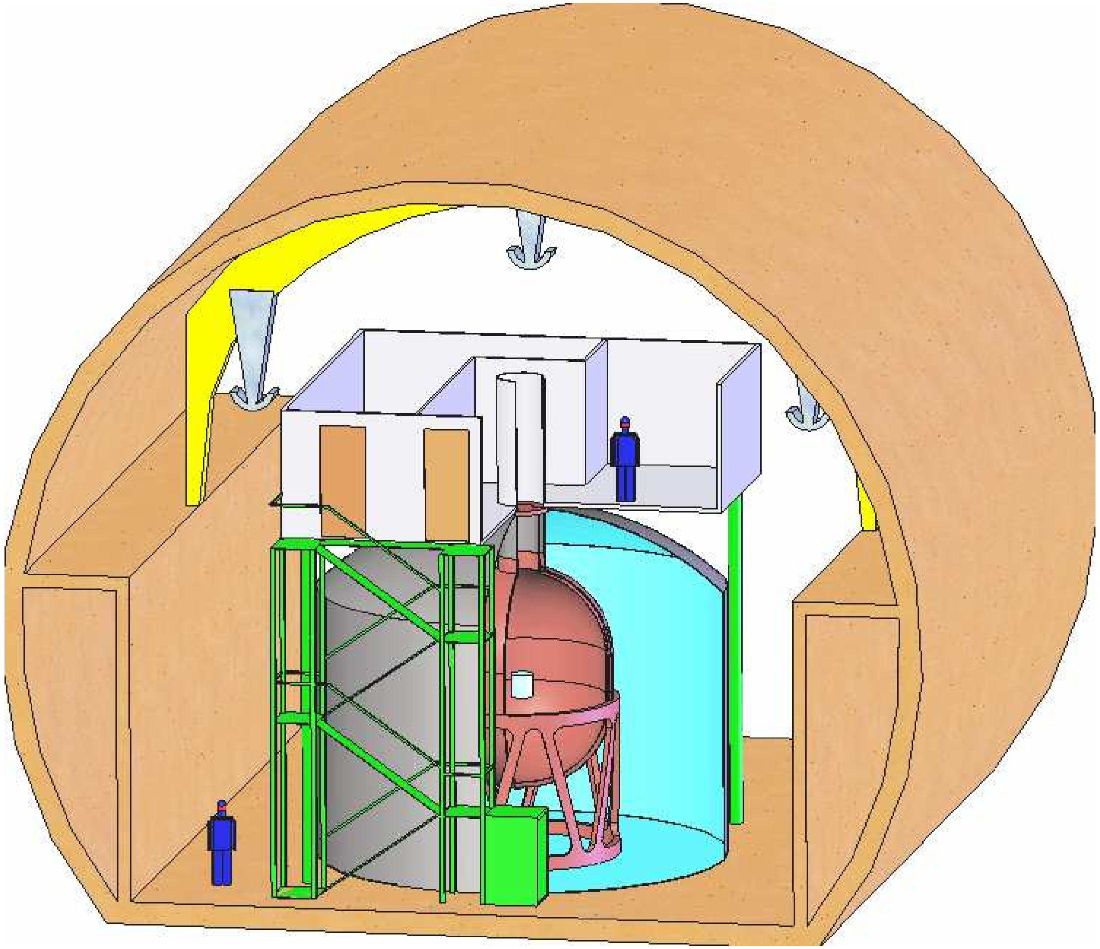
Feruglio
Strumia
Vissani

NPB 659

(hep-ph/
0201291)

Original GERDA design

- Cryogenic liquid in vacuum insulated Cu cryostat (Radiopurity!)
- Water as (cheap) passive shield against gammas and neutrons and as active Cherenkov muon veto system.
- 3rd wall required.



The cryostat issue

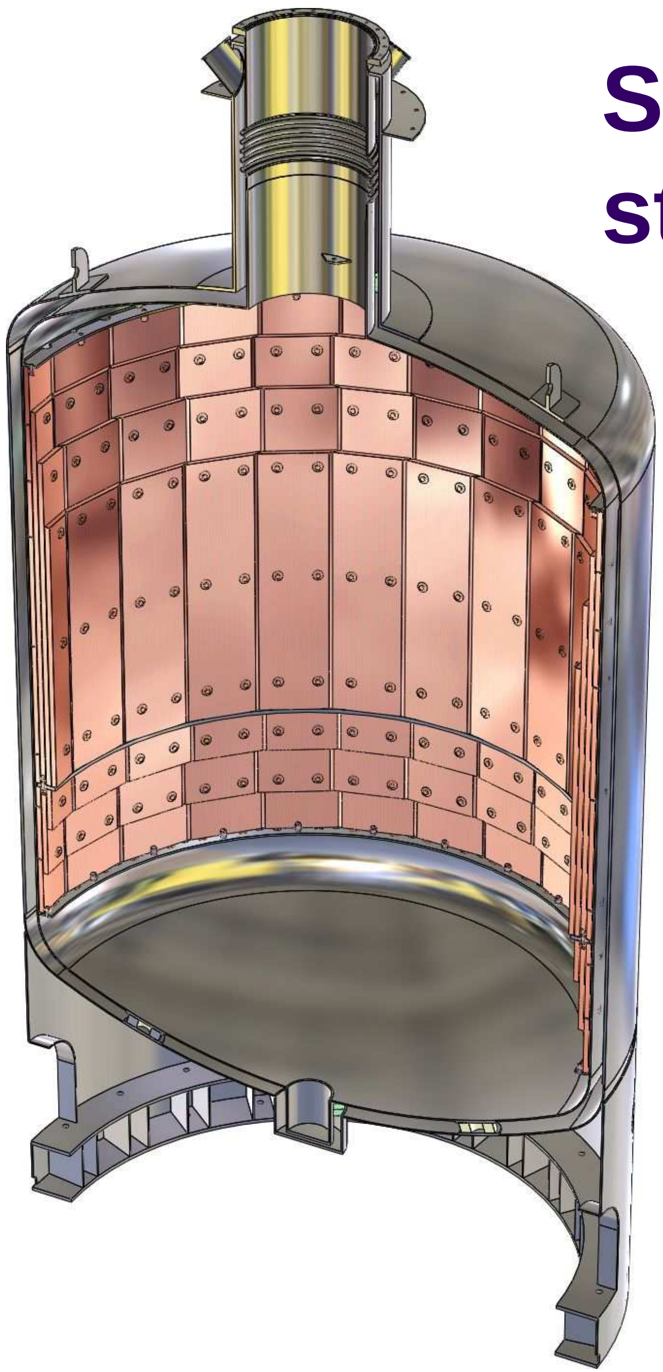
- Sep 2004: Feasibility study for Cu cryostat.
  - 300 k€ welding cost estimate.
- 3rd wall required by Gran Sasso for safety.
- Feb 2006:
  - Quote for welding >1 M€.
  - Copper prize increased from 3k$/ton to 5k$/ton.

  $\Rightarrow$ Total cost beyond budget.
- May 2006: Decision for fall-back solution:

  Stainless steel cryostat.

Implications of the new cryostat design

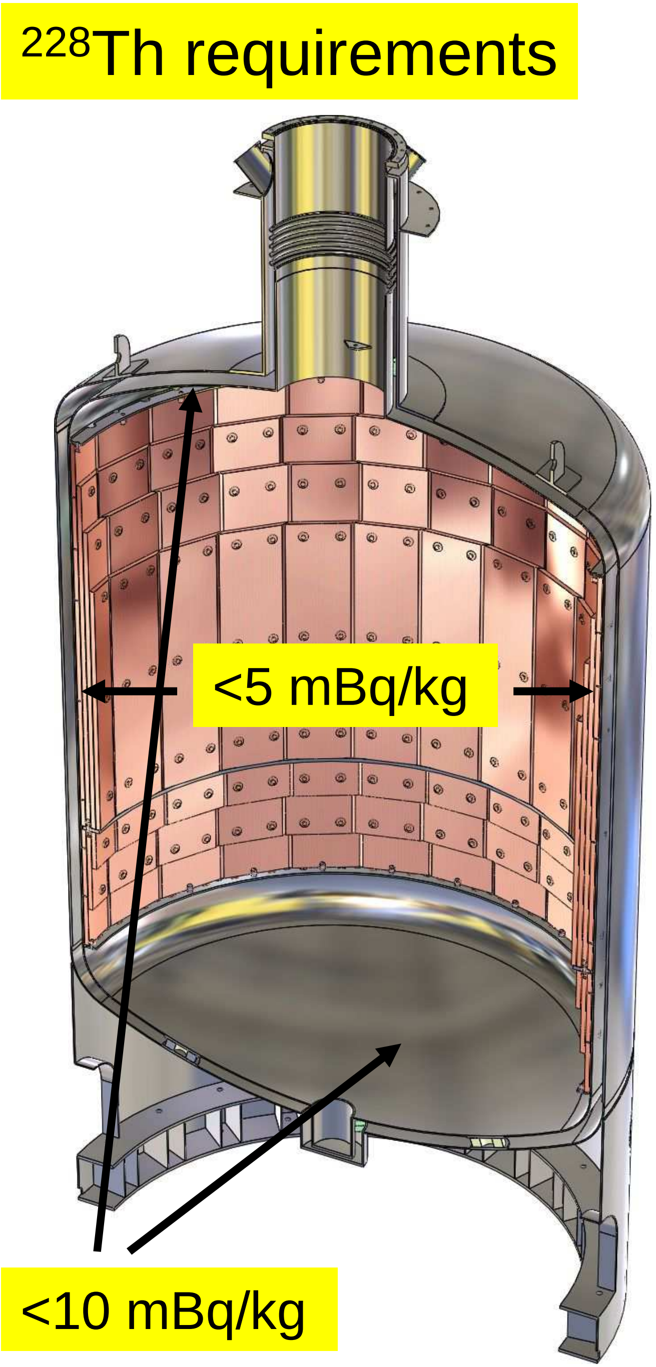
- U/Th concentrations in stainless steel usually ≥100 times higher than in copper ⇒ More internal shield required.
  - Liquid argon instead of liquid nitrogen.
  - Additional internal copper shield.
- Amount of required copper determined by radiopurity of stainless steel.
- Investigations of neutron background.



Status of the stainless steel cryostat

- Decision for SS cryostat taken on May, 29th 2006.
- Tendering started in August
- Risk analysis performed: Design of cryostat is accepted by Gran Sasso.
- No 3rd wall, only hermetic plastic skin.
- Contract was signed recently.

Stainless steel radiopurity

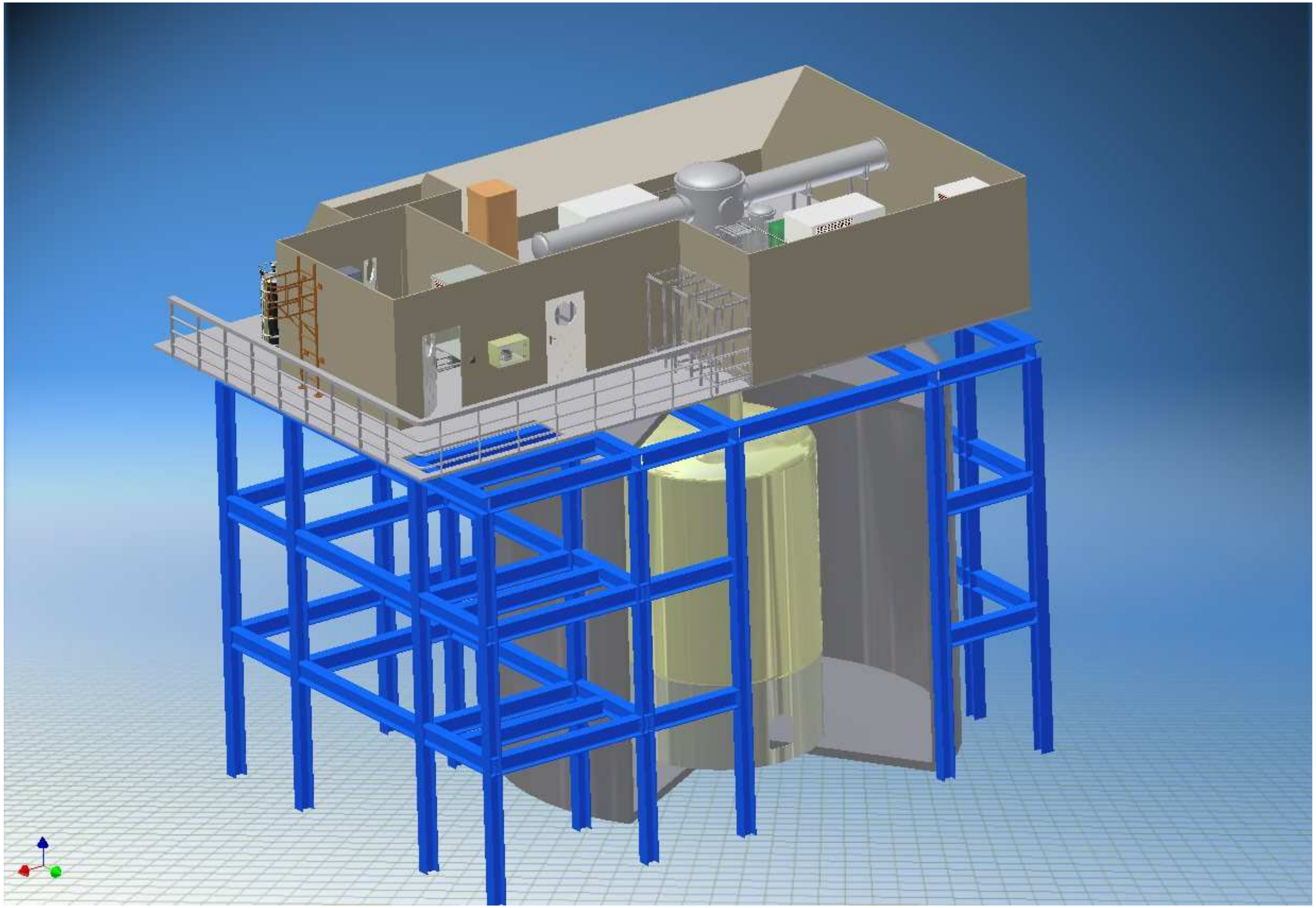


- Requirements seemed realistic from past experience.
- 10 stainless steel batches screened (SS 1.4571):
  - ^{228}Th activities lower than expected.
  - Best result: <0.1 mBq/kg.
  - All samples (except one) for mantle <1 mBq/kg.

Water tank and muon detector

- Water tank contract has been signed.
- Construction will be interrupted for cryostat mounting.
- Tank will be equipped with 66 PMTs (6 of them in extra water volume below cryostat).
- Well-tested Borexino design applied for PMT encapsulation.
- 95% muon veto efficiency predicted.
- Additional plastic scintillators above water tank.

Infrastructure on top of the platform



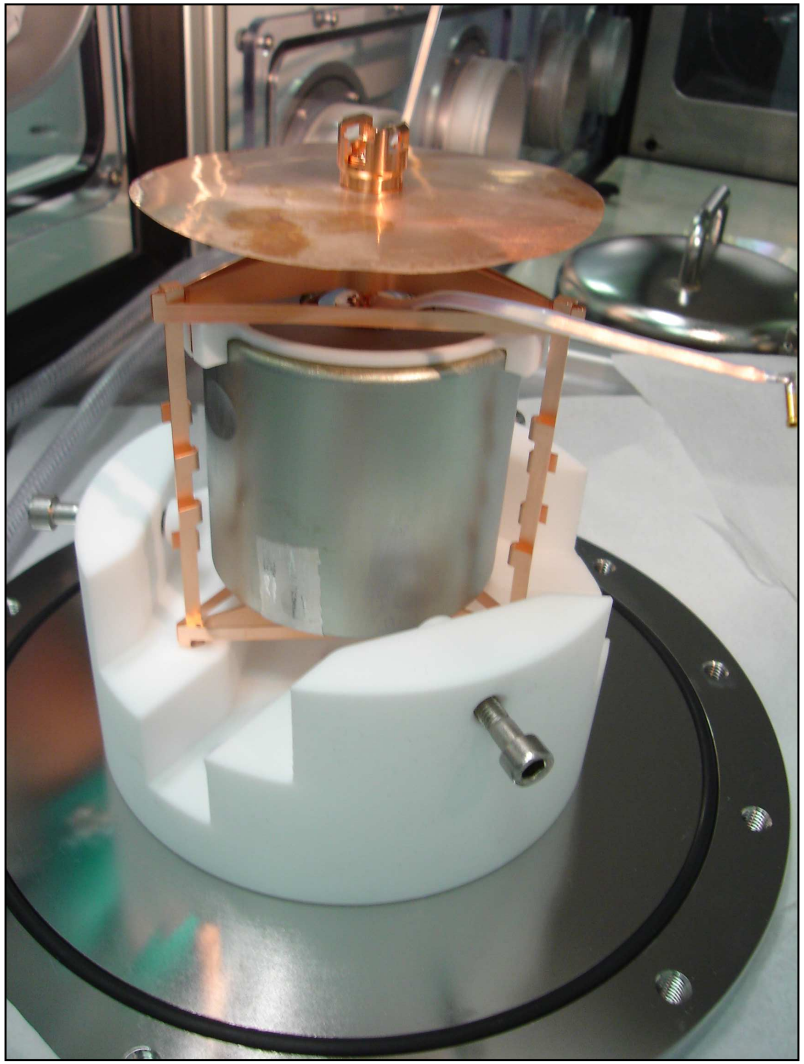
Infrastructure on top of the platform

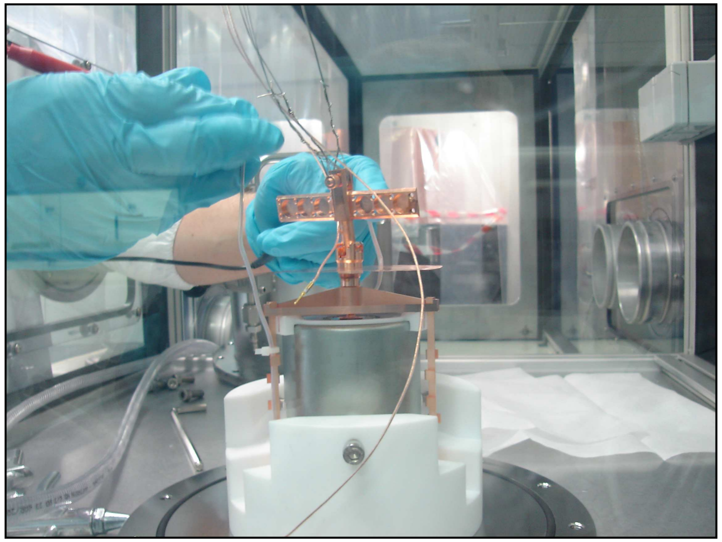
- Clean-room ready for tendering.
- Technical solutions for lock and internal loading systems available.
- Magnetic arms for mechanical transfer into inner lock.
- Rail system currently prototyped.
- ^{222}Rn emanation and γ-screening tests of used materials ongoing.

Underground detector laboratory at Gran Sasso




Operation of a bare prototype detector in LAr



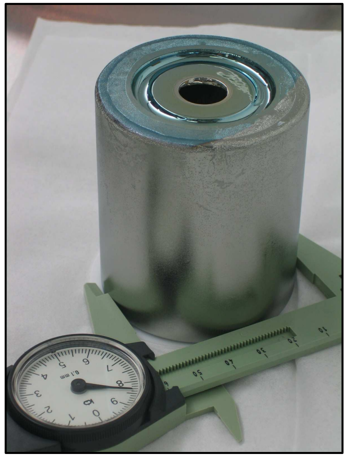


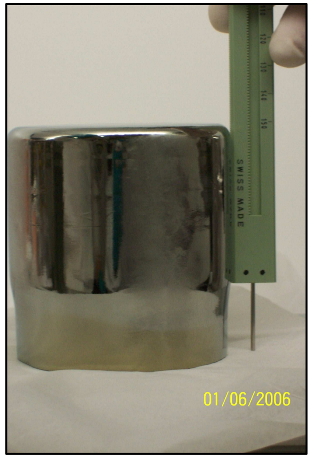
- More than 10 cooling and warming cycles performed.
- Leakage current increased only at the end.
- Fixed after reprocessing
- Stable operation for 2 month.

Phase I detectors at Gran Sasso (from HdM and IGEX)

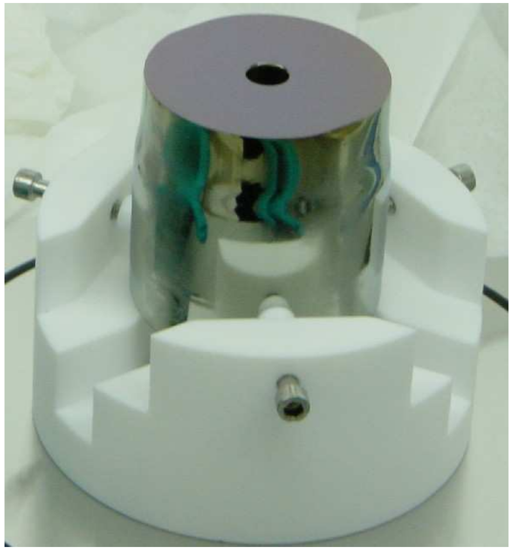
Phase I detectors

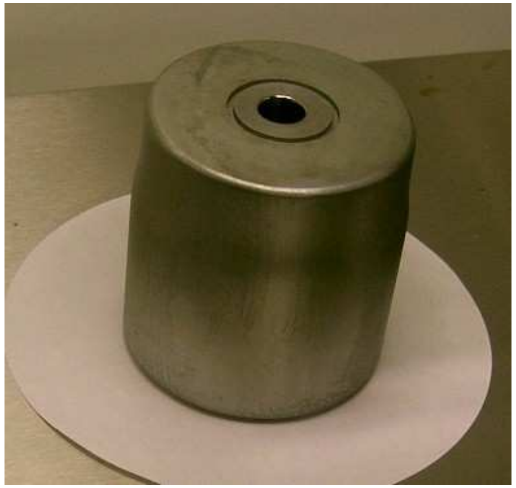
- All 3 IGEX diodes and 1 HdM diode were removed from their cryostats.
- Dimensions were measured.
- Construction of dedicated low-mass holder for each diode.





Refurbishment of phase I detectors





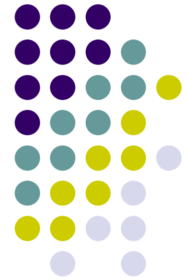
- Different design of HdM and IGEX diodes (Ortec- and Canberra-style).
- Only 1 design (Canberra-style) preferable: Allows to fix possible future difficulties in most time-efficient way.
- All IGEX diodes will be refurbished.
- Causes loss of ~1% of ^{76}Ge mass.
- Also 1 HdM diode refurbished which showed poor performance.

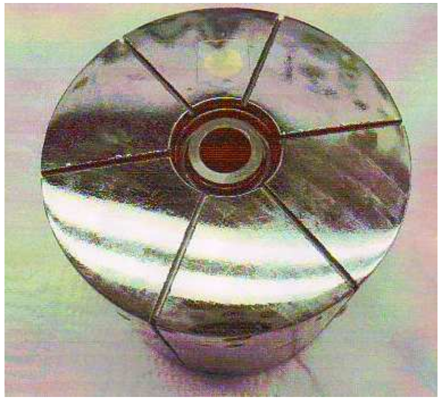
GERDA phase II

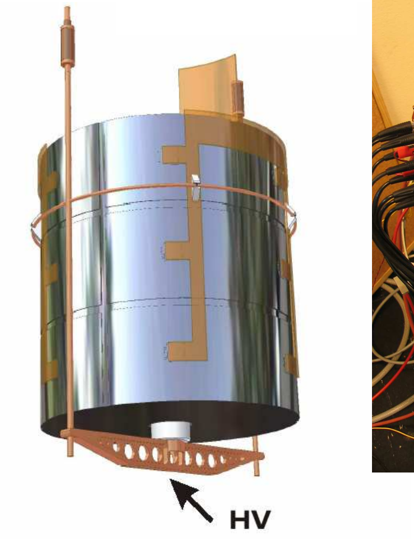
- New segmented ^{76}Ge detectors will be added.
- 37.5 kg of ^{76}Ge produced in Sep. 2005
  - 87% enrichment
  - chemical form: GeO_2
  - chemical purity: 99.95 % (not yet sufficient)
- Stored underground until decision on further processing steps.
- Investigation of different options for crystal pulling.

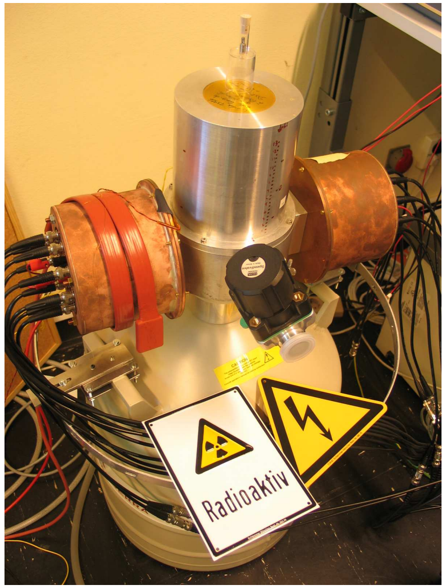
Development of true-axial segmented detectors

- ββ-decay is single-site event, γ-background mostly multi-site event ⇒ Discrimination by segmentation.
- Available detectors for testing:
  - 6-fold ϕ–segmented p-type crystal.
  - 18-fold (6ϕ, 3z) segmented n-type detector.
- 18-fold n-type preferred:
  - Segmentation easier.
  - More regular electrical fields.

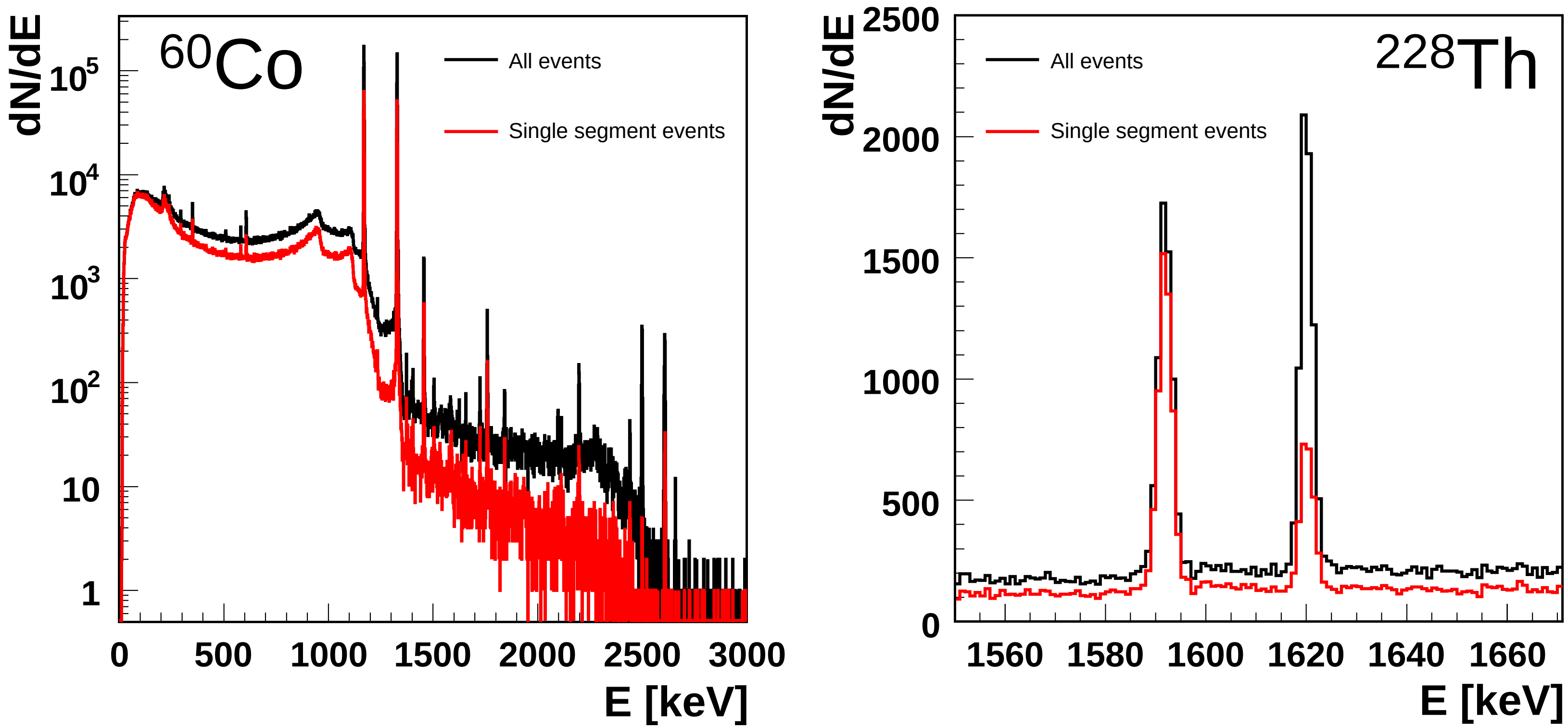








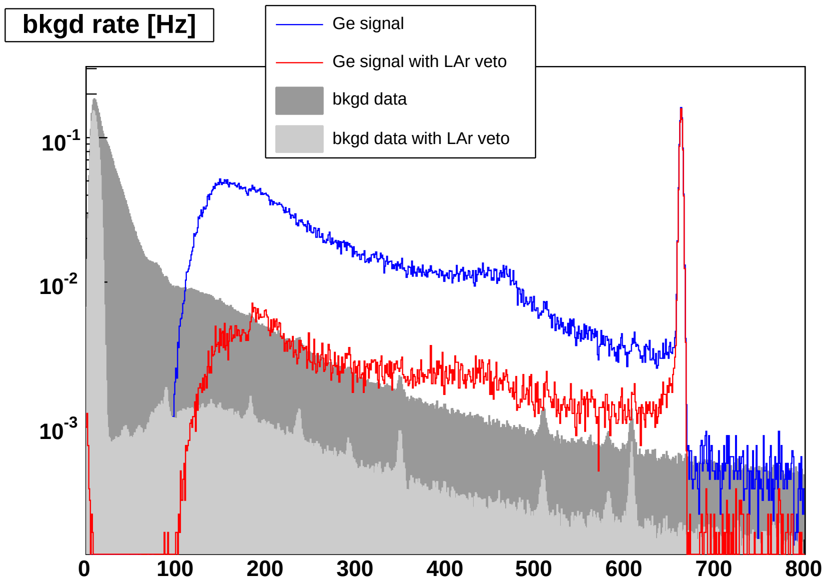
Results obtained with 18-fold segmented n-type detector



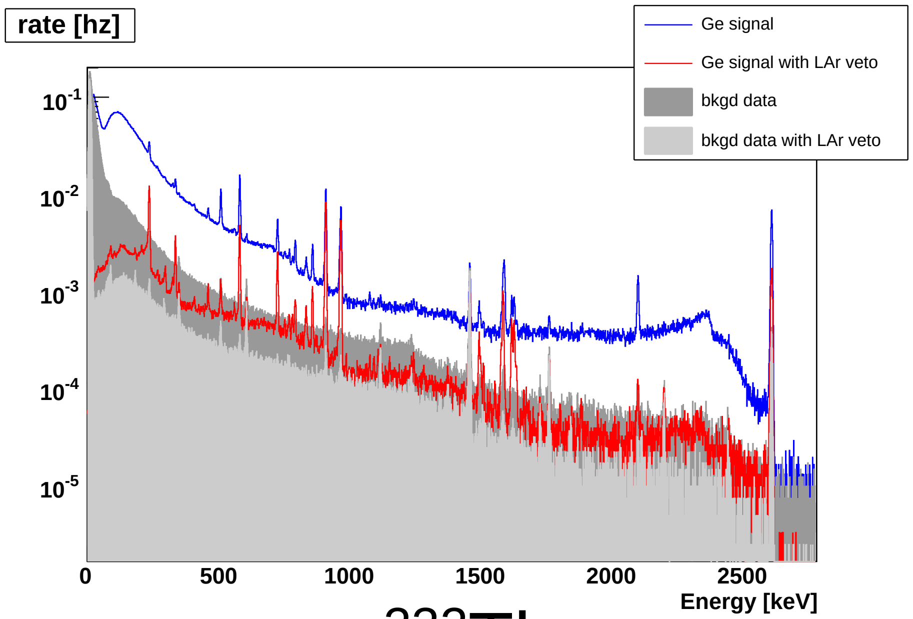
- Suppression of events from external ^{60}Co and ^{228}Th source (10 cm distance).

Background suppression by liquid argon scintillation

- (407 ± 10) pe's/MeV for γ-energy achieved in small (20 liters) Heidelberg test setup.
- Obtainable reduction factor limited by LAr volume.



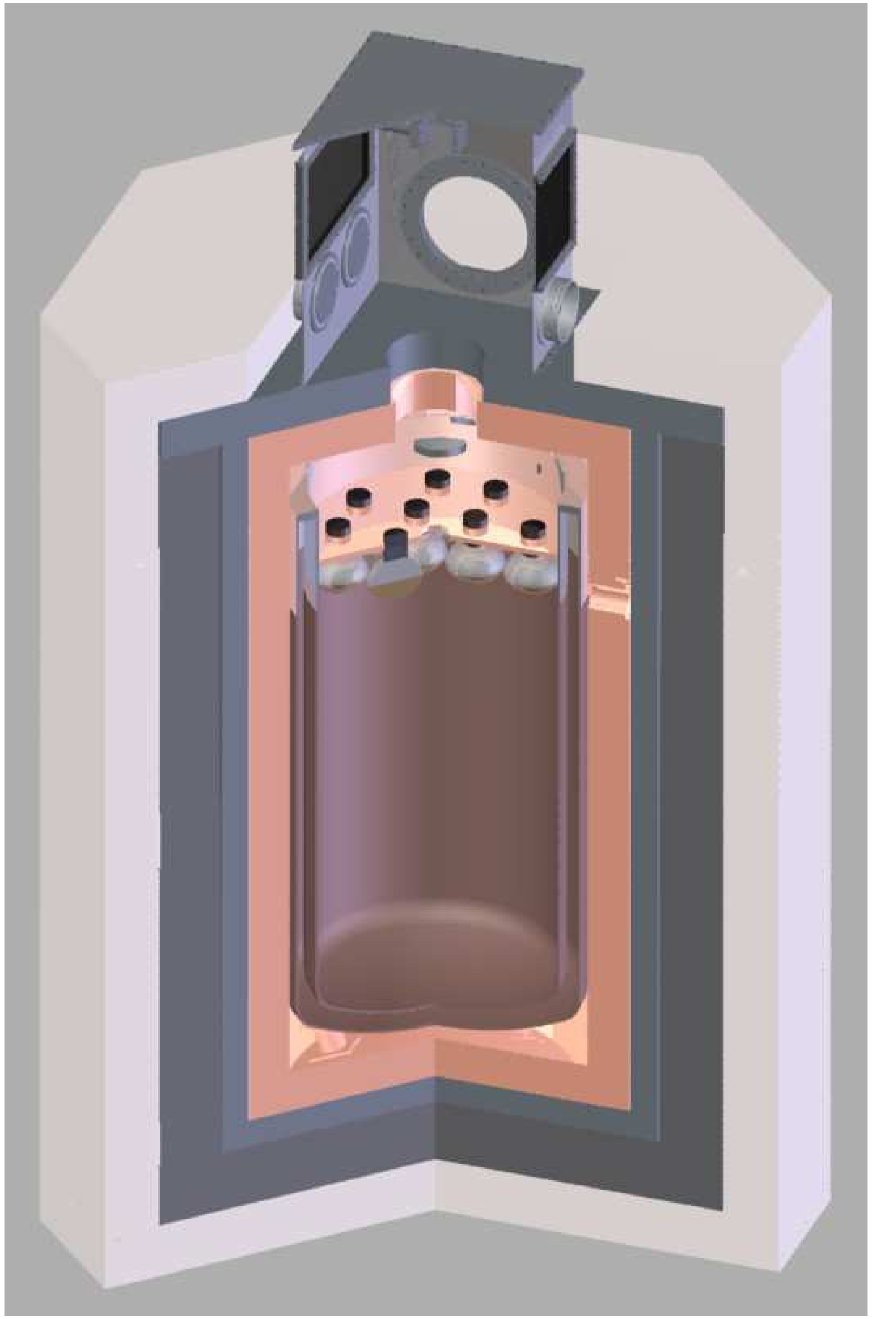
^{137}Cs



^{232}Th

Liquid argon scintillation – Work in progress

- Increase of photo-electron yield:
  - by fluor coating (1100 pe/MeV achieved).
  - by Xe doping (just started).
- Characterization of α, β, γ and neutron interactions by pulse shape analysis.
- Preparation for LArGe @ Gran Sasso:
  - Study of LAr scintillation in ultralow-background environment.
  - operational in 2007.

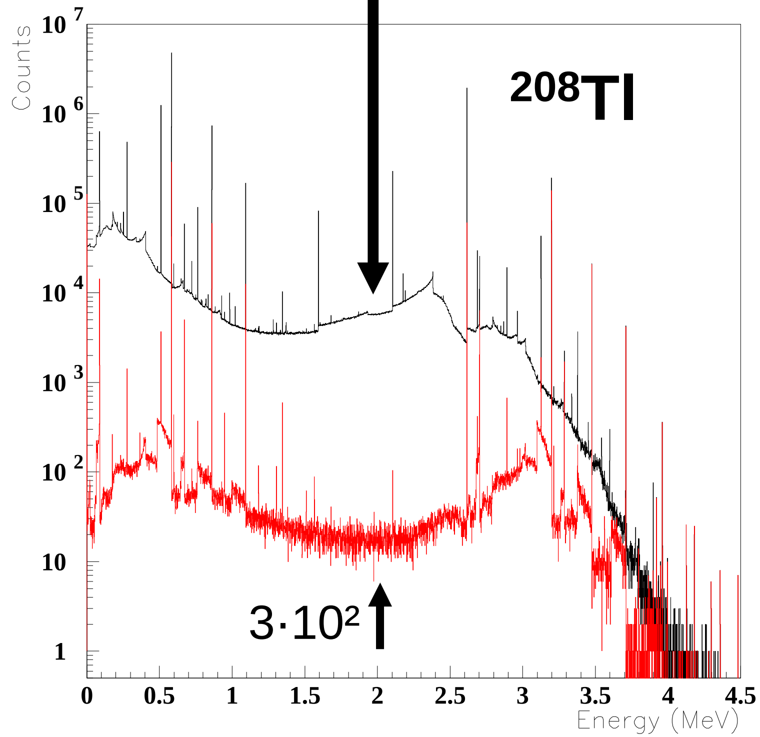


LArGe @ Gran Sasso

MC Example:

Background suppression for contaminations located in detector support

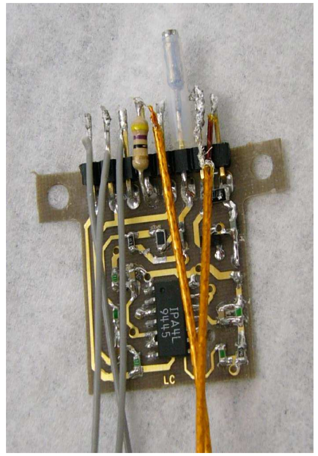
Factor 300 reduction in ROI



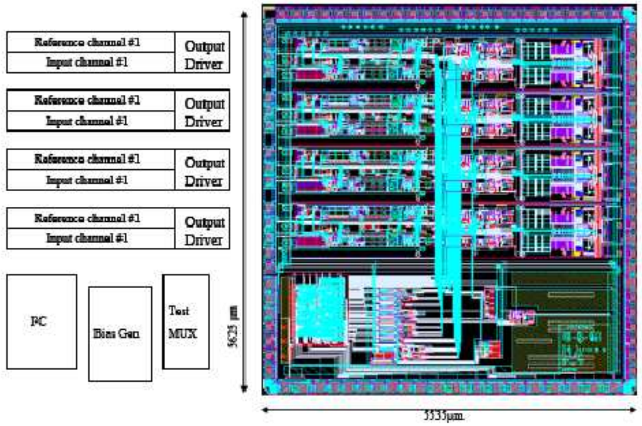
LArGe @ Gran Sasso

Front-end electronics

- Requirements:
  - Low noise, low radioactivity, low power consumption, operational at 87 K.



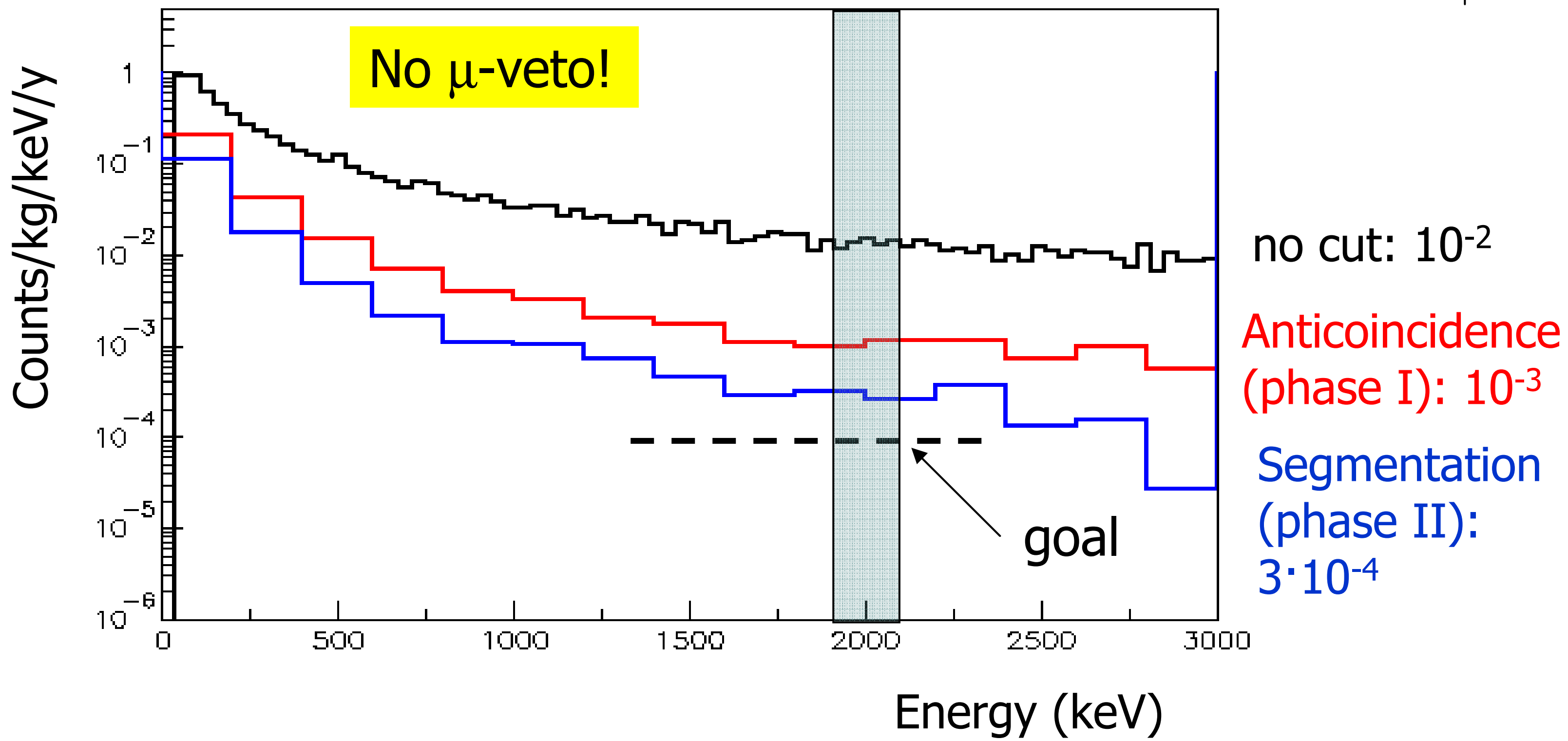
- Monolithic JFET semi-integrated CSA currently used for prototype testing.
- 2 R&D programs for ASIC CMOS chips.
- Characterization and testing ongoing.



Monte Carlo simulations

- Joint Gerda/Majorana simulation package MaGe based on GEANT4.
- Extensive physics validation program (most test setups are implemented).
- Used for design studies:
  - Tolerable amount of material.
  - Distribution of muon veto PMTs.
- Study of cosmogenic activation.

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

- Concrete basement of GERDA site completed.
- Next: Mounting of water tank base plate.
- Middle of 2007: Delivery of cryostat.
- Afterwards:
  - Completion of the water tank.
  - Construction of GERDA building.
  - Construction of clean-room and lock.
- Goal: Start of Ge detector commissioning by summer 2008.

Summary

- Switch of cryostat design carried out quickly.
- Decision for liquid argon taken.
- Refurbishment of enriched diodes ongoing.
- Handling of bare diodes extensively tested.
- Successful operation of segmented detectors.
- Some open questions about crystal growing for phase II crystals.
- Installation at Gran Sasso will start soon.