Highly Sensitive Gamma-Spectrometers of GERDA for Material Screening

part 1.

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on behalf of the material screening task group of
GERDA collaboration

Overview

1. **Introduction to the GERDA experiment**
   Requirements on the material selection for GERDA.

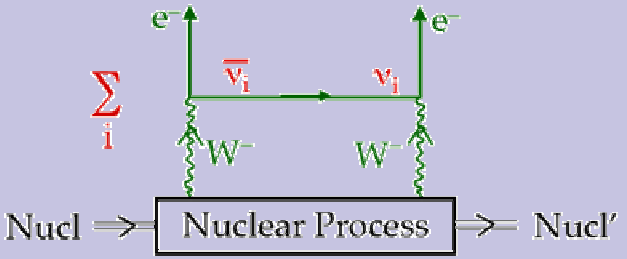
2. **High-sensitivity material screening laboratories of GERDA**
   Overview of laboratories using germanium gamma-ray spectrometry to select materials for GERDA.

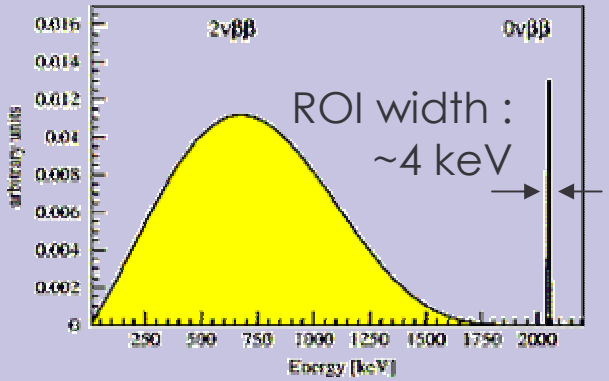
3. **Measurement results highlights**

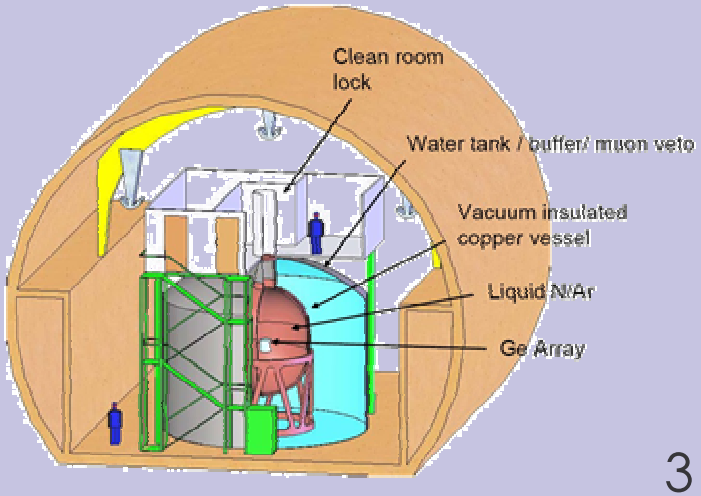
4. **Accuracy of the measurement evaluation**
   Intercomparison of the evaluation precision in different laboratories.

Background of GERDA

- GERDA experiment aims to search for half-life of 0νββ decay of ^{76}Ge
- present lower limit : $t_{1/2}>1.9\cdot10^{25}$ y
  background in peak region : 0,17 cts/(keV.kg.y)
- goal : reach $t_{1/2}$ sensitivity of
  $3\cdot10^{25}$ y in Phase 1 of GERDA
  (15 kg of Ge and 1 year data taking)
  $2\cdot10^{26}$ y in Phase 2 of GERDA
  (35 kg of Ge and 3 year data taking)
- required background (peak region) :
  $<10^{-2}$ cts/(keV.kg.y) for Phase 1
  $<10^{-3}$ cts/(keV.kg.y) for Phase 2
- in total <0,5 background events in ROI

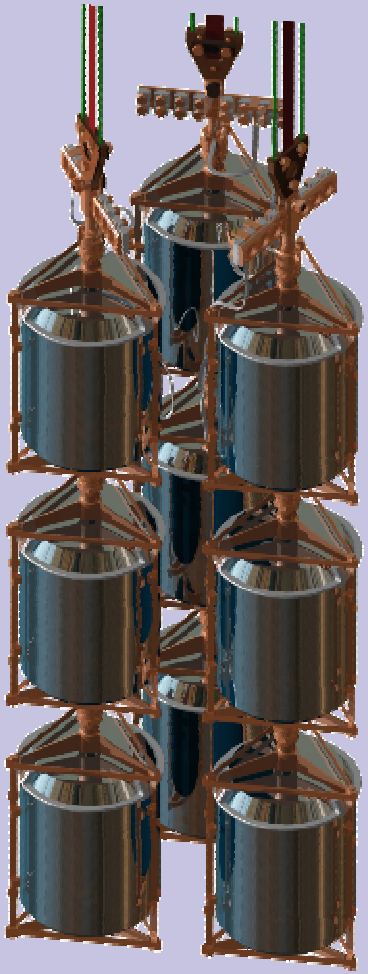






The material screening challenge

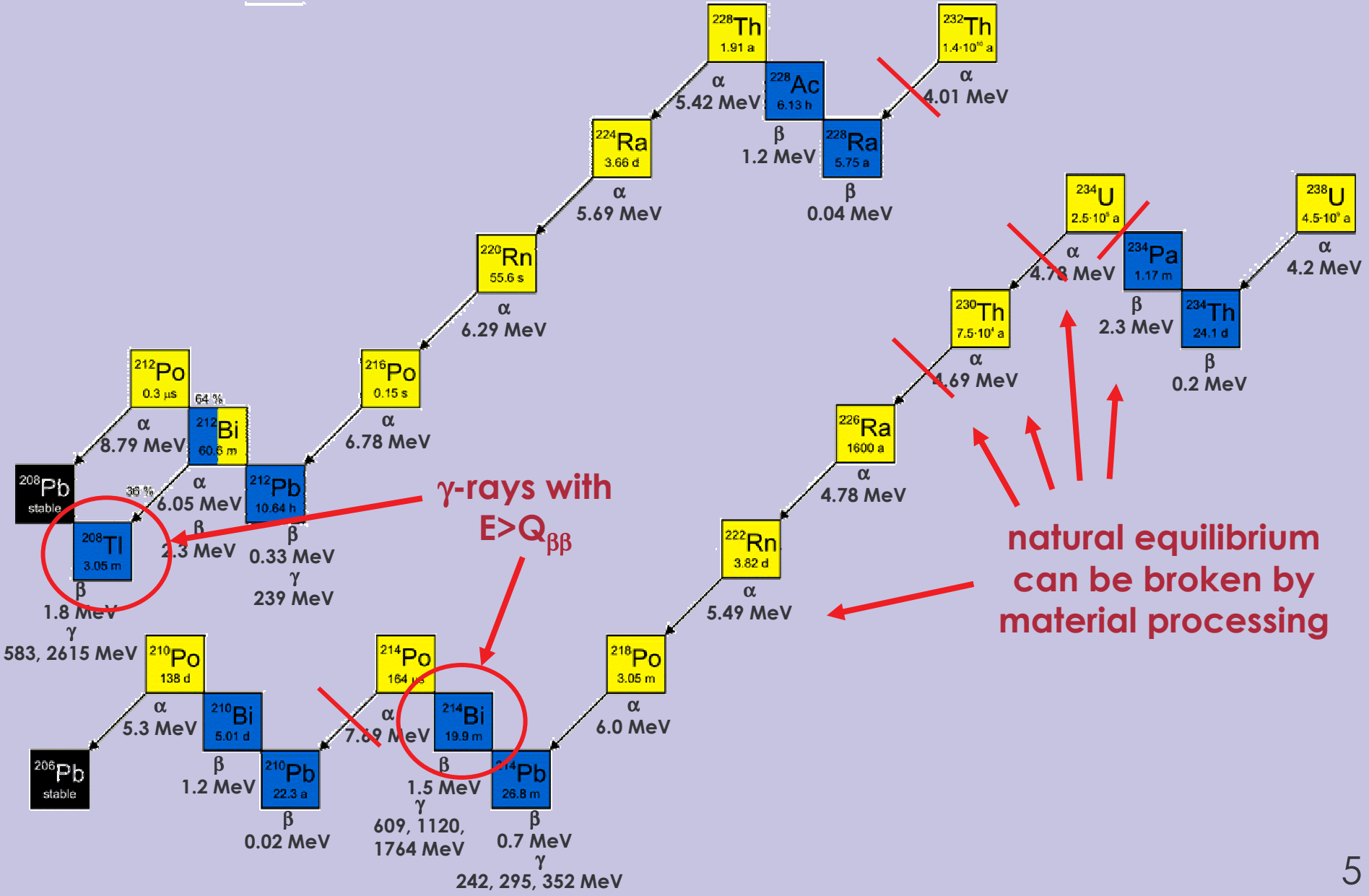
- required radiopurity of materials
  (close to the detectors) :
  ~10μBq/kg to ~mBq/kg
- this means concentrations of
  ^{232}Th on the level of ~2.5 to ~250·10^{-12} g/g and
  ^{238}U on the level of ~0.8 to ~80·10^{-12} g/g



Material screening techniques :

- α and β spectrometers (surface contaminations)
- Neutron activation analysis (only for some isotopes)
- Mass spectrometry (Ar and Kr in gases)
- ICP-MS (metal element contaminations)
- High sensitivity proportional gas counters
  (for Rn emanation and concentration in gases)
- Gamma-ray spectrometry (Ge-detectors)

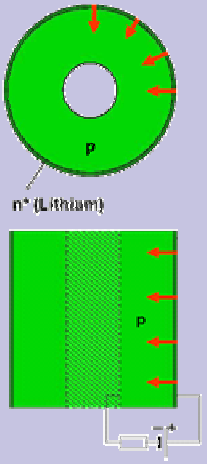
The material screening challenge



Gamma-ray spectrometry

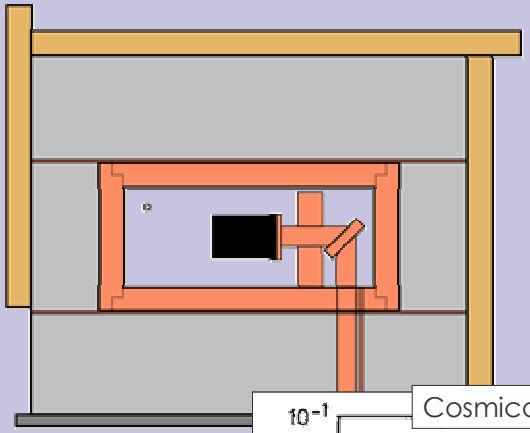
Ge detectors :

- very good resolution : ~2-3 keV
- very good detection efficiency (high Z material)



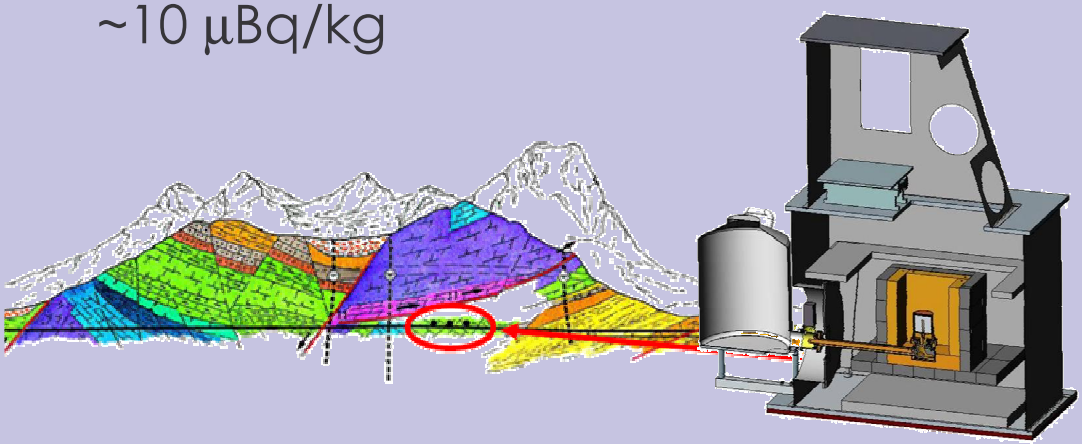
Reaching excellent sensitivity :

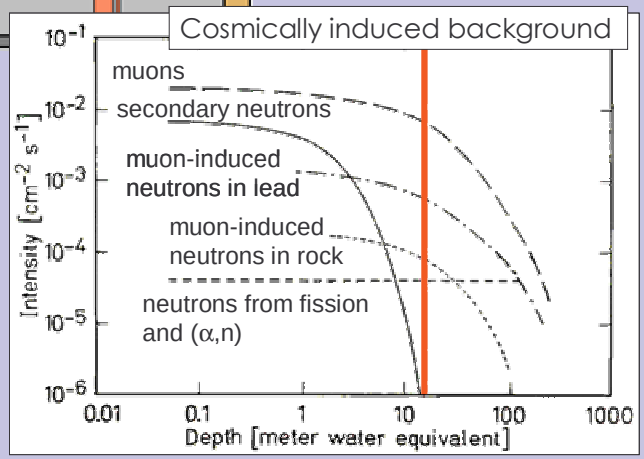
1. Reduction of background
2. Long measurement times
3. Large-mass samples



GeMPI in LNGS, Gran Sasso :

~10 μBq/kg



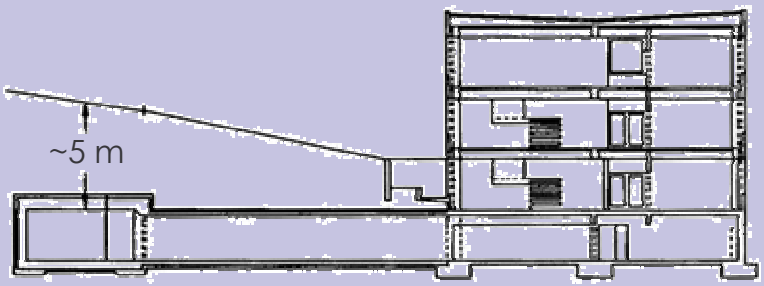


Material screening laboratories of GERDA

1. Max-Planck-Institut für Kernphysik, Heidelberg, Germany
2. INFN Laboratori Nazionali del Gran Sasso, Assergi, Italy
3. Institute for Reference Materials and Measurements, Geel, Belgium
4. Joint Institute for Nuclear Research, Dubna, Russia
5. Baksan Neutrino Observatory of INR RAS, Baksan, Russia

Max-Planck-Institut für Kernphysik

- laboratory location : 15 m w.e. under ground

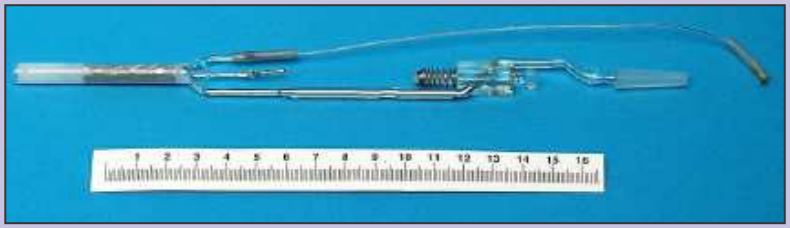


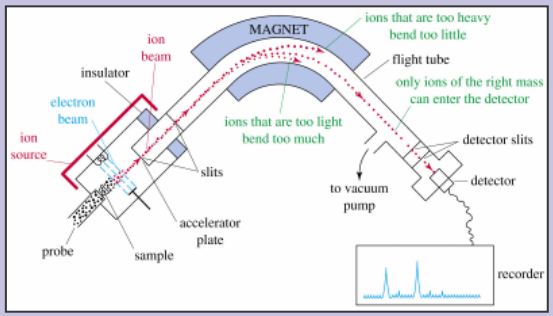
Detectors used for material screening :

- 3 low-background Ge detectors
- used for large samples, preliminary selection
- lower sensitivity due to shallow depth

Other measurement techniques :

- Rn concentration and emanation measurements with proportional counters
- Noble gas mass-spectrometry





Laboratori Nazionali del Gran Sasso

- located at a depth of 3800 m w.e.
  (μ flux reduced by factor of ~10^6)

Available detectors :

- 10 Ge detectors for low-level gamma-ray measurements, including GeMPI 1, 2 and 3
- used for high sensitivity measurements

NAA, mass spectrometry and proportional gas counters are also used at LNGS for material screening

Institute for Reference Materials and Measurements

- location underground : 500 m w.e.
- in HADES underground facility in Geel, Belgium

Detectors :

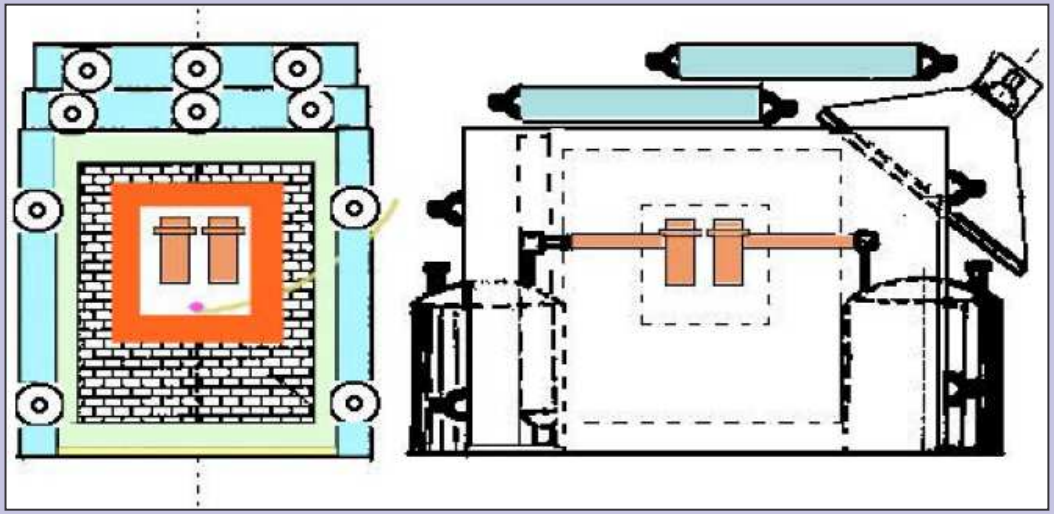
- several low-background Ge detectors, including one planar diode, n-type and p-type coaxial detectors, all with Pb/Cu shielding and nitrogen flushed chambers
- useful for small sized samples due to limited detector chambers

Baksan Neutrino Observatory

- material screening facility located at 660 m w.e.
- Deep Underground Low Background Laboratory located at 4900 m w.e.

Detectors :

- IGEX/Baksan HPGe Set Up with up to 4 crystals located in 1 m concrete/dunite/steel shield and an additional 40 cm Cu/Pb/PE shield with liquid scintillator muon veto and nitrogen flushing
- additional NaI gamma-spectrometer
- new Ge spectrometer will be installed at 4900 m w.e. this year



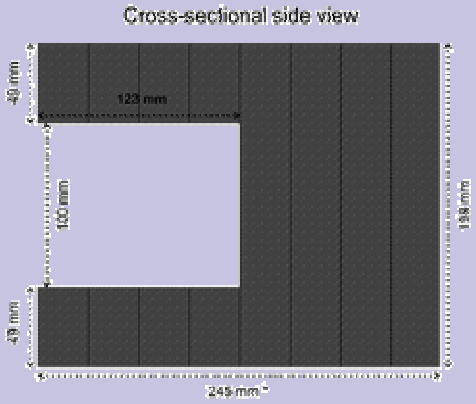
Laboratories overview

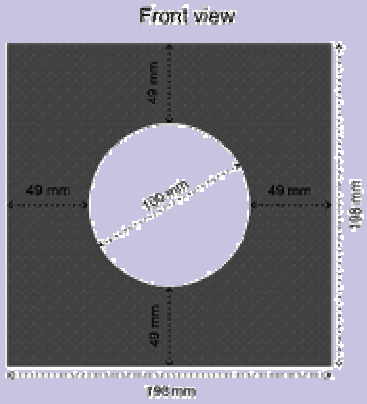
Institute	Depth	Detectors	Most sensitive detector	
			Active mass	Background (40-2700) keV
MPIK	15 m w.e.	3 p-type Ge with active and passive shields	0.84 kg	1280 cts/d
LNGS	3800 m w.e.	10 p-type Ge with passive shields	2.15 kg	65 cts/d
IRMM	500 m w.e.	1 p-type and 2 n-type Ge with passive shields	1.34 kg	349 cts/d
JINR	surface	n-type Ge with passive shield	1.36 kg	$2.55 \cdot 10^5$ cts/d
BNO	660 m w.e.	4 n-type Ge with active and passive shield	4 x 1 kg	~250 cts/d

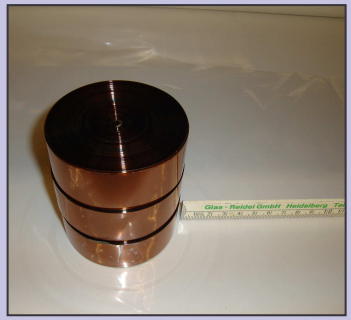
Selected results of material screening

Specific activities in [mBq/kg]

Sample	^{228}Th	^{226}Ra	^{40}K	^{210}Pb
Copper	≤ 0.012	≤ 0.016	≤ 0.088	-
Lead DowRun	≤ 0.022	≤ 0.029	0.044 ± 0.014	27000 ± 4000
Ancient lead	≤ 0.072	≤ 0.045	≤ 0.27	≤ 1300
Teflon	0.023 ± 0.015	0.021 ± 0.009	0.54 ± 0.11	-
Kapton cable	≤ 4	9 ± 6	130 ± 60	-





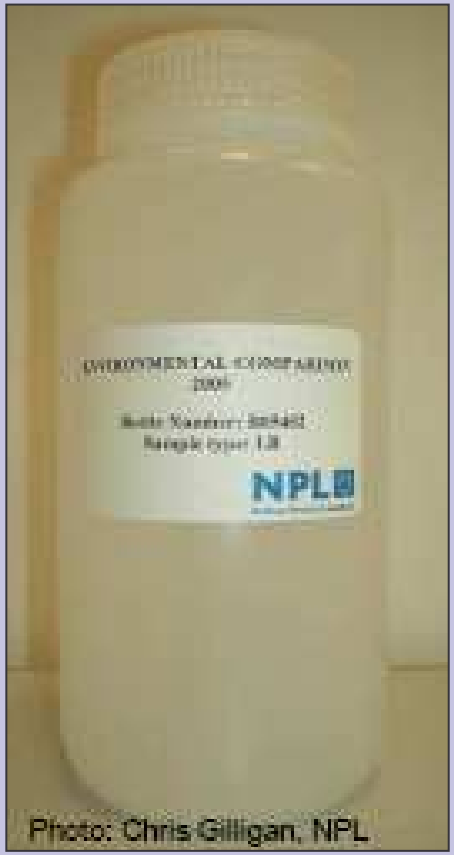


Stainless steel batches for GERDA cryostat

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
2 G	< 0.27	< 0.35	< 1.1	13.0 ± 0.6
3 D	1.1 ± 0.4	< 0.84	< 3.3	15.1 ± 0.5
4 D	< 2.6	< 2.2	< 6.2	14.4 ± 1.0
5 D	< 1.1	< 1.2	< 2.8	11.6 ± 0.5
6 D	< 0.8	< 0.6	< 1.7	16.7 ± 0.4
7 G	< 0.20	< 1.3	< 2.8	45.5 ± 2.1
8 G	< 0.11	< 0.24	< 0.93	14.0 ± 0.1
9 G	< 0.41	< 0.74	< 1.1	13.8 ± 0.7
10 G	< 1.0	< 1.3	< 6.8	17.1 ± 0.7
11 G	1.5 ± 0.2	1.0 ± 0.6	< 0.81	18.3 ± 0.7

A comparison of GERDA laboratories

- aim : to check the reliability of material screening performed by the laboratories
- all laboratories measured the same sample : liquid solution containing 10 γ-emitting radionuclides with ~Bq/kg activities
- the content was not revealed before the submission of results



This intercomparison was based on the Environmental Radioactivity Comparison Exercise 2005, organized by NPL, UK.

NPL report : A.V.Harms et al., DQL-RN 015, June 2006 ISSN 1744-0629

A comparison of GERDA laboratories

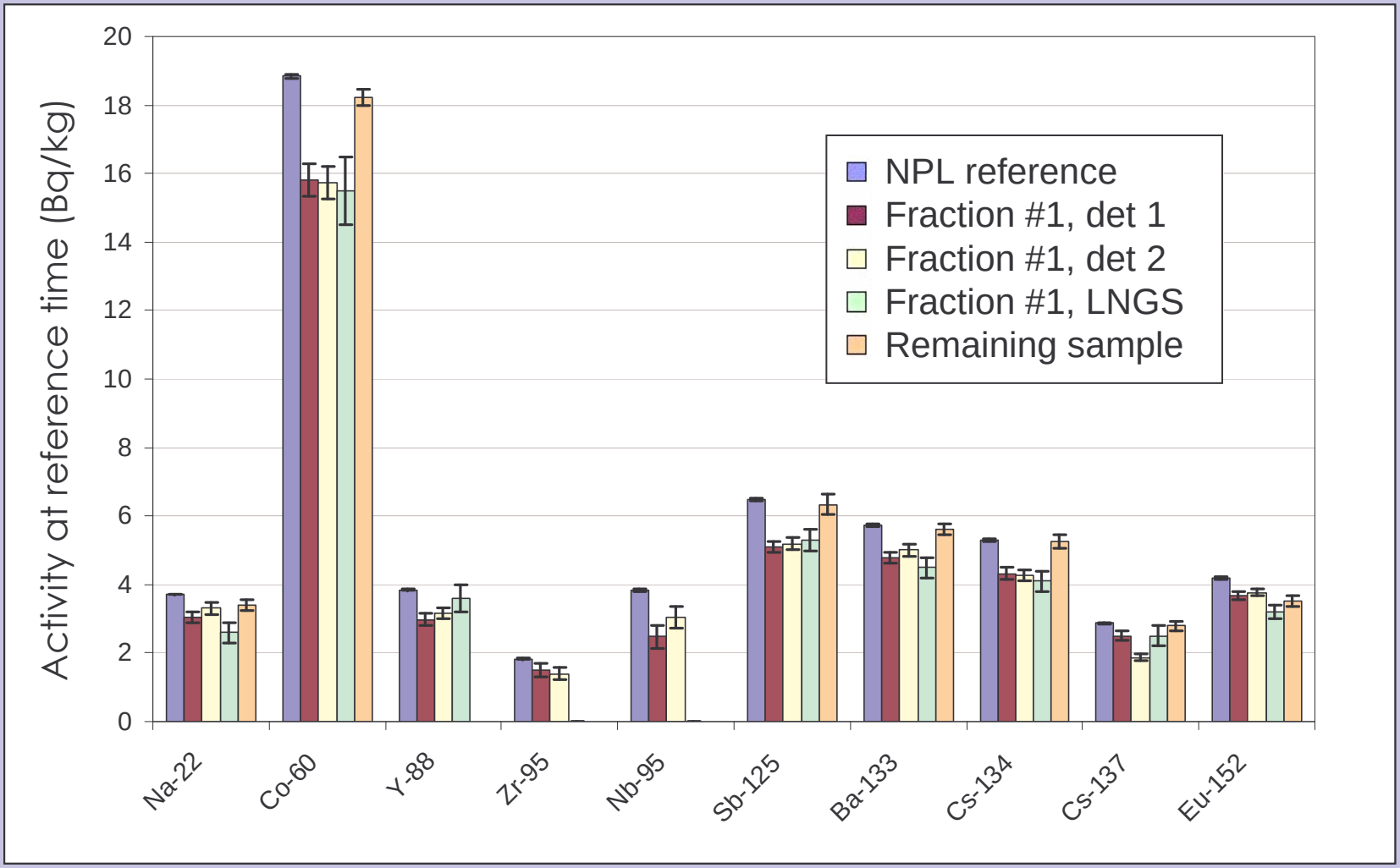
- all laboratories identified correctly the radioactive content of the sample and no false identifications occurred

Results (mean deviations from the reference value) :

- MPIK Heidelberg : -19.2% ± 6.5%
- LNGS Gran Sasso : -2.0% ± 6.8%
- IRMM Geel : 1.7% ± 1.6%
- JINR Dubna : -19.9% ± 3.5%
- BNO Baksan : -17.6% ± 3.4%

The discrepances found in the results of this comparison were thoroughly investigated and support our effort to increase the precision of our measurements evaluation.

Additional investigation



Conclusions

Gamma spectrometry is the most direct material screening method relevant for critical backgrounds of the GERDA experiment.

The GERDA collaboration has several low-level laboratories available, which provide :

- reliable material selection
- sufficient capacity to screen all construction materials
- ultra high sensitivity levels, fulfilling the requirements of GERDA and reaching the world's best sensitivity

Thank you for your attention

The GERDA Collaboration :

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3. Max-Planck-Institut für Kernphysik, Heidelberg, Germany
4. Jagiellonian University, Krakow, Poland
5. Università di Milano Bicocca e INFN Milano, Milano, Italy
6. Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia
7. Institute for Theoretical and Experimental Physics, Moscow, Russia
8. Russian Research Center Kurchatov Institute, Moscow, Russia
9. Max-Planck-Institut für Physik, München, Germany
10. Dipartimento di Fisica dell'Università di Padova e INFN Padova, Padova, Italy
11. Physikalisches Institut, Universität Tübingen, Germany
12. Institute for Reference Materials and Measurements, Geel, Belgium