Low Radioactivity Techniques 2013

Low-Background Gamma-Ray Spectrometry in the Garching Underground Laboratory

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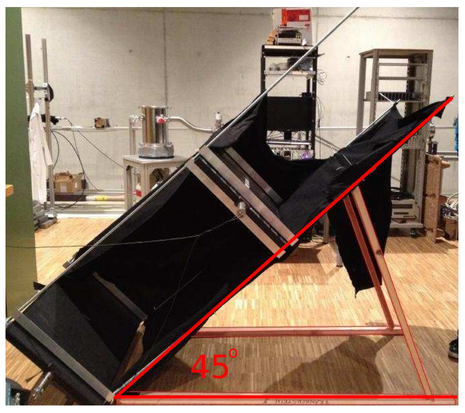
The Garching Underground Laboratory and its Shielding Profile

Underground Lab

- Shallow depth: $\sim$10 m.w.e.
- 2 screening stations (**GEM** [1,2] and **LoAx** [6]) mainly used for material preselection
- Measured Radon content in lab air: $\sim$10 Bq/m^3
- Located close to the Research Reactor FRM II

⇒ *Possibility to carry out Neutron Activation Analyses with very short time delay [1]*



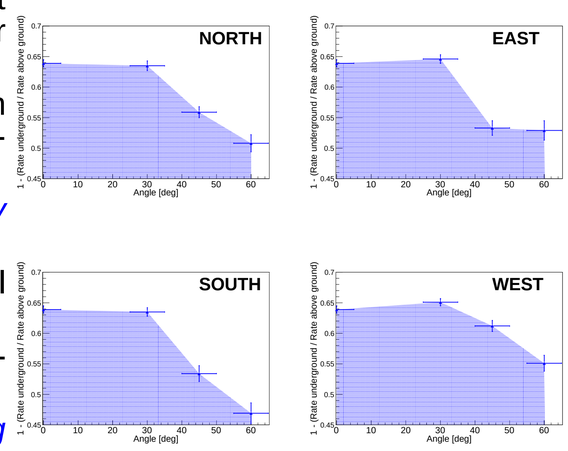
Muon Flux Measurement

- Coincidence Measurement with two plastic scintillator panels
- Comparison of the total muon rate above ground and underground

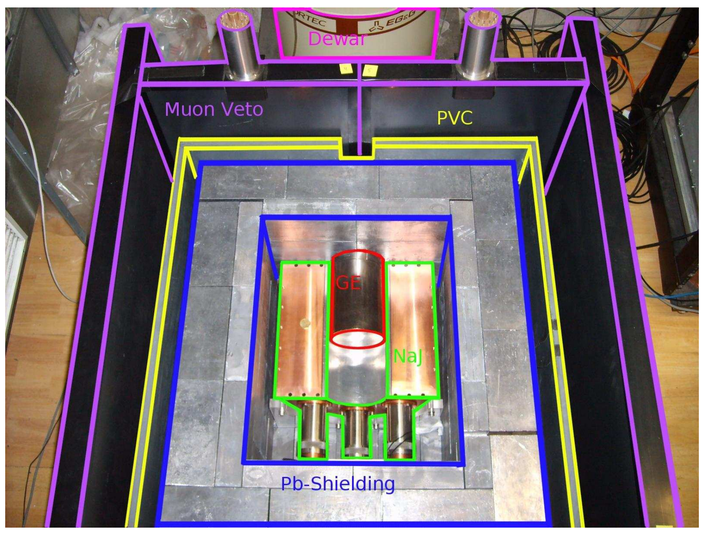
⇒ *Integral muon flux reduced by factor of 2.6 [3,4]*

- Investigation of the 4 cardinal directions
- Measurements under an inclination of 0°, 30°, 45°, 60°

⇒ *Investigation of the shielding profile of the underground lab*



GEM Detector Setup



Germanium Detector

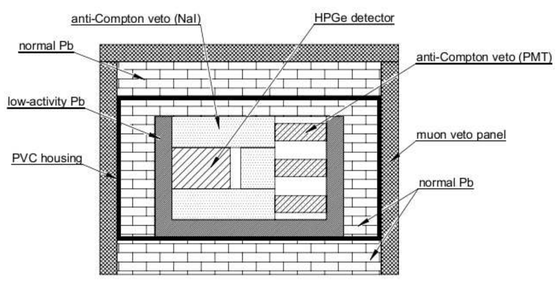
- HPGe detector with 150.5% relative counting efficiency
- Entrance window: 1.5 mm Mg
- Measured resolution: 955 eV at 122 keV (^{57}Co), 1.764 keV at 1.33 MeV (^{60}Co) [2]

Anti-Compton Veto

- Tl-doped sodium iodide scintillation crystals; Copper housed
- Read-out by six 2" and one 3" PMTs
- Entrance window: 0.8 mm ultrapure aluminium

Passive and Active Shielding

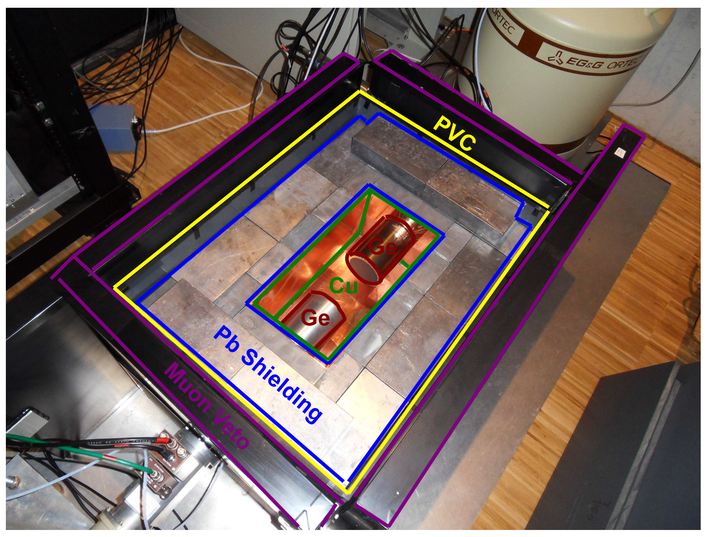
- 5 cm of low-activity lead ($\lesssim$5 Bq/kg ^{210}Pb)
- 10 cm normal lead
- Nitrogen-flushed air-tight PVC box
- Six plastic scintillator panels as active muon veto on top and all sides

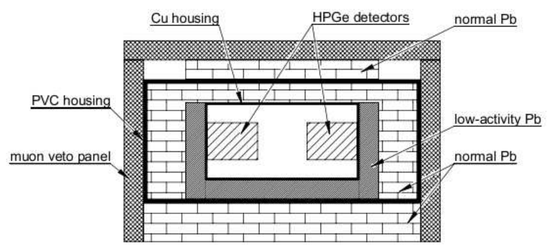


LoAx Detector Setup

Germanium Detectors

- Two HPGe detectors in face-to-face geometry
- Active mass / volume:
  - 620 g / 118 cm^3 (LoAx1)
  - 594 g / 113 cm^3 (LoAx2)
- Entrance window of both detectors: $\sim$1 mm carbon fiber
- Measured resolution [6]:
  - LoAx1: 1.05 keV at 122 keV (^{57}Co), 1.82 keV at 1.33 MeV (^{60}Co)
  - LoAx2: 0.89 keV at 122 keV (^{57}Co), 2.12 keV at 1.33 MeV (^{60}Co)

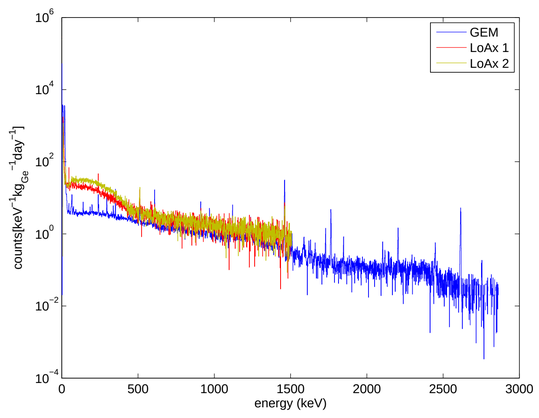




Passive and Active Shielding

- 5 mm of copper
- 5 cm of low-activity lead ($\lesssim$5 Bq/kg ^{210}Pb)
- 10 cm normal lead
- Nitrogen-flushed air-tight PVC box
- Seven plastic scintillator panels as active muon veto on top and all sides

Background Spectra, Integral Count Rates and Gamma Lines



Integral Count Rates

- Measured with full active and passive shieldings:
  - **GEM:** 10250±26 cts/day (40-2700 keV)
  - **LoAx1:** 5258±27 cts/day (20-1500 keV)
  - **LoAx2:** 6876±31 cts/day (20-1500 keV)

Gamma Lines in the Background

- **GEM:** many lines from U/Th-chain and ^{40}K that originate from materials in anti-Compton veto
- **LoAx1/2:** only few lines from ^{210}Pb, ^{212}Pb, ^{40}K from surrounding shielding

Detector		GEM	LoAx1	LoAx2	Heisel et al. [5]
Isotope	Energy (keV)	Activity (cts/day)			
^{238}U chain:					
^{234}Th	63.3	< 67.3	< 45.5	< 36.7	-
^{234m}Pa	1001.0	< 22.0	< 7.0	< 9.5	-
214Bi	609.3	97.1 ± 3.8	< 11.6	< 13.8	< 1.9
^{210}Pb	46.5	20.1 ± 3.3	35.6 ± 4.8	10.9 ± 4.9	-
^{232}Th chain:					
^{208}Tl	583.1	35.7 ± 3.0	< 15.9	< 13.0	-
	2614.5	63.7 ± 2.1	-	-	< 1.3
other:					
^{137}Cs	661.7	< 25.0	< 9.6	< 8.6	-
^{60}Co	1332.5	< 9.9	< 4.0	< 7.6	< 2.1
^{40}K	1460.8	300.5 ± 4.7	10.5 ± 1.8	10.5 ± 1.9	1.45 ± 0.80
β^+	511	51.2 ± 3.7	11.0 ± 2.5	14.5 ± 3.6	-

Detector Efficiency Monte-Carlo Simulation and its Calibration

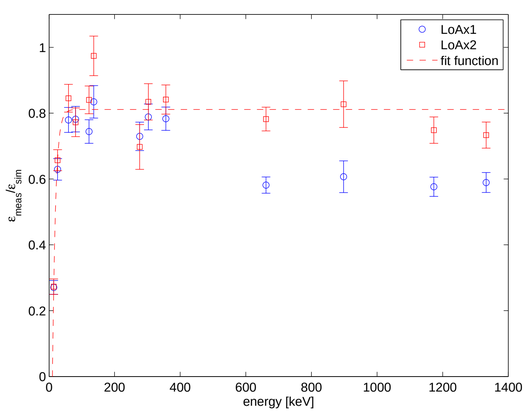


Figure 1: Efficiency ratio $\epsilon_{meas}/\epsilon_{sim}$ for the two LoAx germanium detectors including the empirical fit function for the LoAx2 data. For screening measurements only gamma lines above 45 keV are used.

Monte-Carlo Simulation

- Geant4 simulation of full detector setup
- Physics List: standard EM physics
- Decay cascades simulated with Radioactive Decay Module

Efficiency Calibration

- Detector efficiency determined with radioactive sources of well known and low activities: ^{241}Am, ^{133}Ba, ^{57}Co, ^{60}Co, ^{137}Cs, ^{22}Na, and ^{88}Y
- Different source positions within the setup
- Ratio $\epsilon_{meas}/\epsilon_{sim} < 1$ and constant for large energies, decrease for small energies

⇒ *Additional dead layer that is not implemented in simulation*

⇒ *Efficiency ratio fitted with* $\frac{\varepsilon_{meas}}{\varepsilon_{sim}} = a_0 - e^{a_1 \cdot E + a_2}$

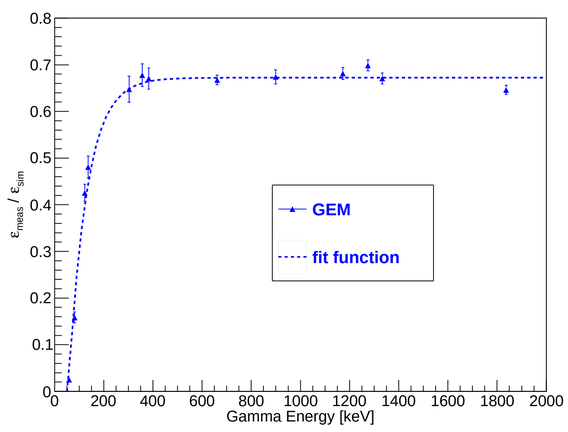


Figure 2: Efficiency ratio $\epsilon_{meas}/\epsilon_{sim}$ for the GEM detector including the empirical fit function [1]. For screening measurements only gamma lines above 230 keV are used.

References

[1] M. Hofmann, Ph.D. thesis, TU München (2012)

[2] M. Hofmann, Diploma thesis, TU München (2007)

[3] B. Heiss, Bachelor thesis, TU München (2012)

[4] R. Burkhardt, Bachelor thesis, TU München (2012)

[5] M. Heisel, et al., arXiv: 0812.0768v1 [physics.ins-det] (2008)

[6] C. Wiesinger, Bachelor thesis, TU München (2012)