Low-background radioactivity counting at the most sensitive HPGe detector in Germany

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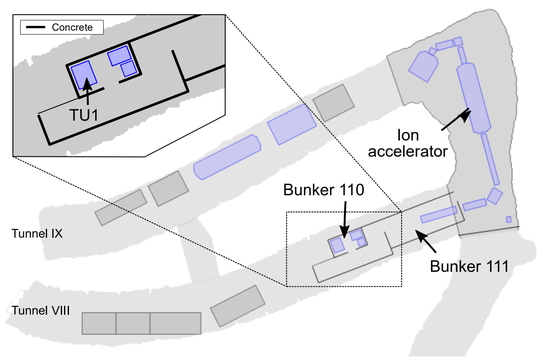
Abstract

A new ultra low-level counting setup has been installed in the shallow-underground laboratory Felsenkeller in Dresden, Germany. It includes a high-purity germanium detector (HPGe) of 163% relative efficiency within passive and active shields. The passive shield consists of 45 m rock overburden (140 meters water equivalent), 40 cm of low-activity concrete, and a lead and copper castle enclosed by an anti-radon box. The passive shielding alone is found to reduce the background rate to rates comparable to other shallow-underground laboratories. An additional active veto is given by five large plastic scintillation panels surrounding the setup. It further reduces the background rate by more than one order of magnitude down to 116(1) $kg^{-1}d^{-1}$ in an energy interval of [40 keV; 2700 keV]. This low background rate is unprecedented for shallow-underground laboratories and close to deep underground laboratories.

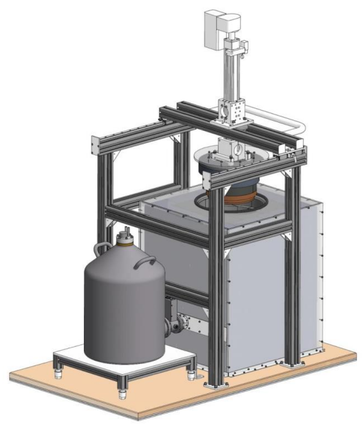
The location and the setup

The Felsenkeller underground laboratory



- New shallow-underground laboratory for nuclear astrophysics and physics of rare decays
- Located in Dresden (Germany)
- 45m of rock overburden (140 m.w.e.)
- Also hosts 5 MV Pelletron

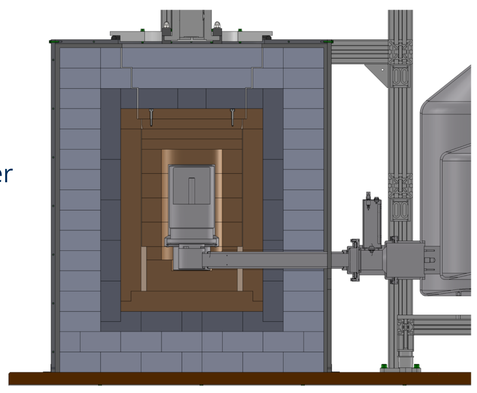
The TU1 detector & its passive shielding



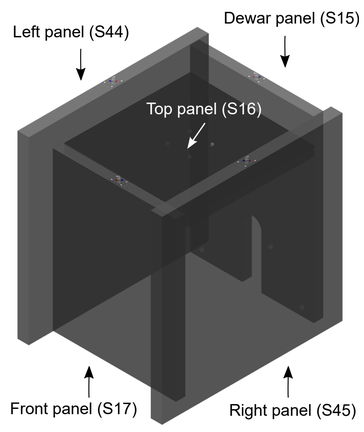
- HPGe with 574 cm^3 and 163% relative efficiency
- p-type with E_{min} = 22 keV

Passive Shielding:

- Low-activity concrete bunker
- Anti-radon box
- 10 cm low activity lead with 21(2) Bq/kg in ^{210}Pb
- 5 cm low activity lead with 2.5(1) Bq/kg in ^{210}Pb
- 10 cm OFRP copper

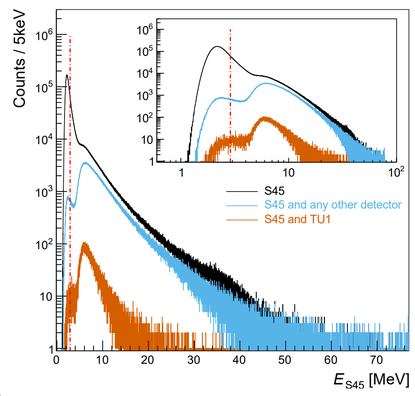


The active shielding



- Five scintillation panels of polyvinyltoluene
- Surrounding the passive shielding
- Purpose is to veto events induced by cosmic muons
- Muons induce larger pulse height than photons

Coincidences between the active shielding and TU1



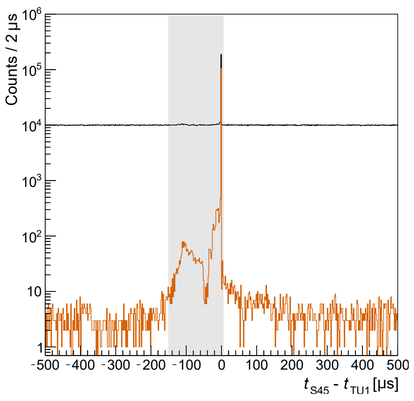
Signals in panels need to have a threshold energy and maximum time difference to a signal in TU1 in order to act as veto signal.

Energy spectra of the panels

- Low energetic bump is due to photons (not needed for veto)
- High energetic bump is due to muons (needed for veto)

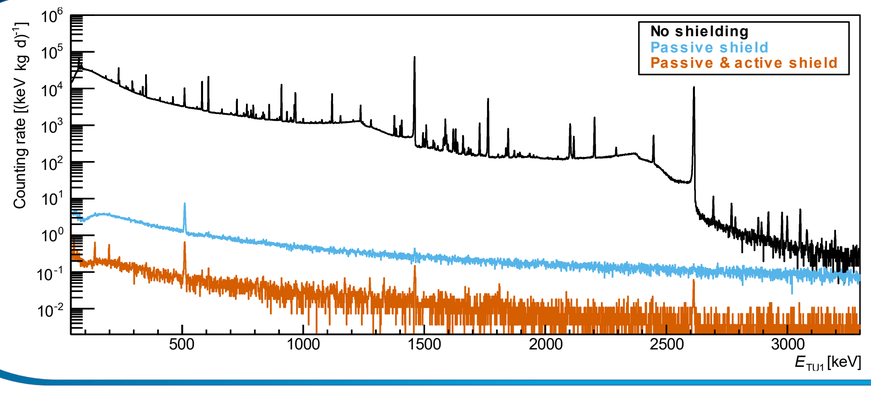
Timing between panels & TU1

- Clear coincidence signals within timing of [-150µs,5µs]



Results

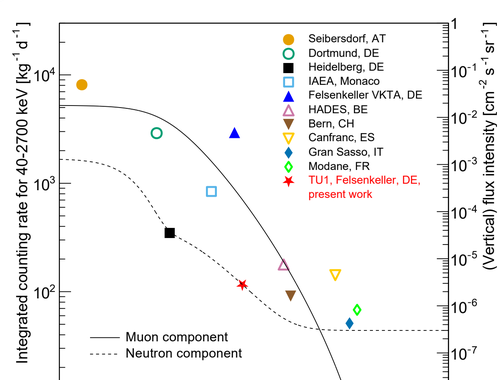
The background counting rate of TU1



Counting rate within [40 keV, 2700 keV]:

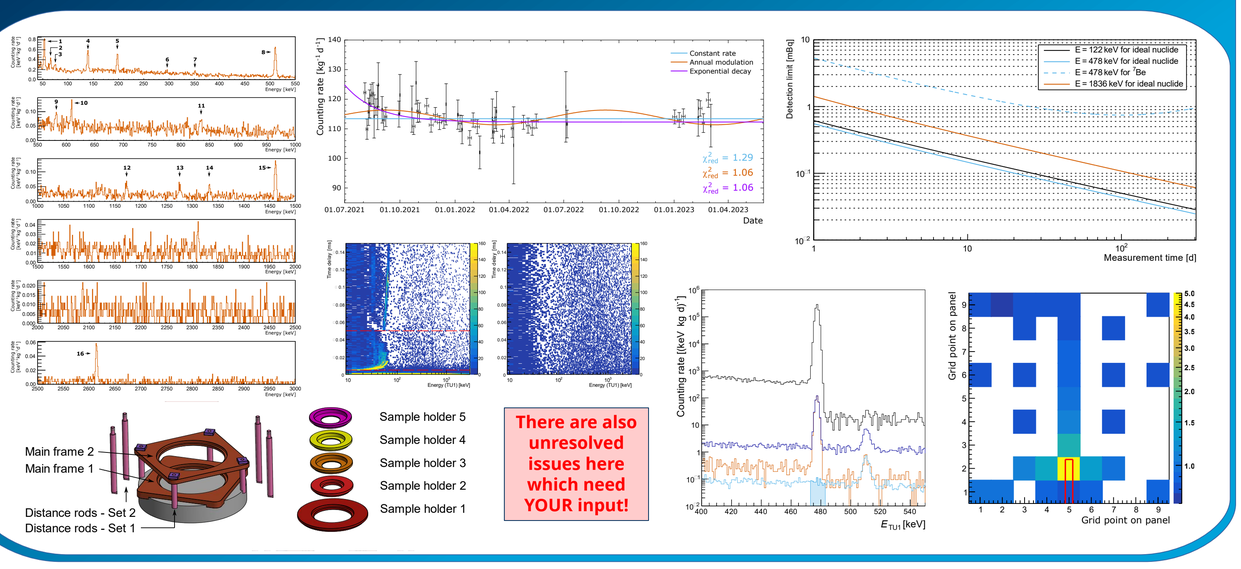
- **Without shielding: R = 8603400 $kg^{-1}d^{-1}$**
- **With passive shield: R = 1982 $kg^{-1}d^{-1}$**
- **Final shielding: R = 116 $kg^{-1}d^{-1}$**

Comparison to other underground HPGes



- Unprecedented counting rates for non-deep underground laboratories
- Most sensitive HPGe detector in Germany and among the most sensitive devices for measuring radioactivity worldwide

Let's also discuss additional material!!



Take-home message

The new ultra low-level counting setup in the shallow-underground laboratory Felsenkeller in Dresden (Germany) is among the most sensitive devices to measure radioactivity worldwide. Activities below 100 µBq are measurable within 20 d of data taking when using samples with negligible intrinsic contamination.

This setup is of great interest for nuclear astrophysics, as well as dark matter and double beta experiments. Furthermore, it is highly suitable for investigations of samples with low activities in general or radio nuclides with comparatively long half lives and/or low natural abundances.

Main institutions involved:

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Recent publication on this topic:

S. Turkat, D. Bemmerer, A. Boeltzig, et al. "A new ultra low-level HPGe activity counting setup in the Felsenkeller shallow-underground laboratory."

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