The upgraded low-background germanium counting facility Gator for high-sensitivity ɣ-ray spectrometry

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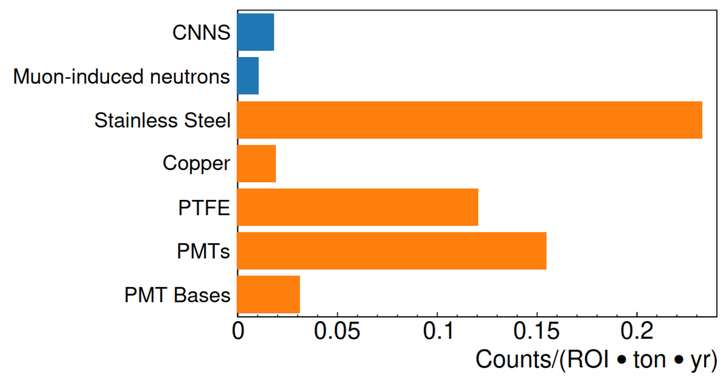
Motivation

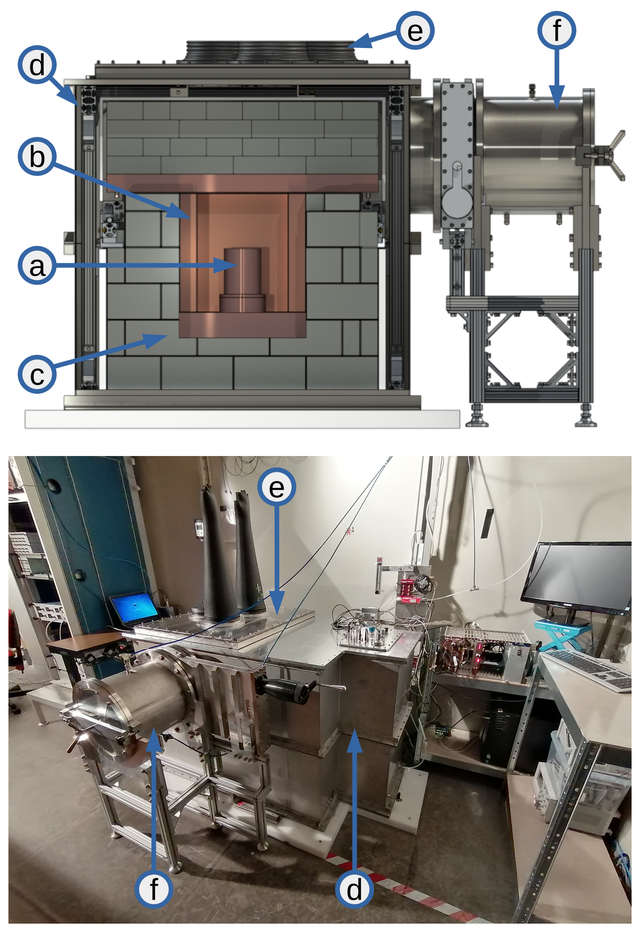
- Requirement of low backgrounds in rare event searches such as dark matter (e.g. XENONnT) and neutrinoless double beta decay (e.g. GERDA) experiments
- Germanium spectroscopy offers a non-destructive, high resolution screening method for material radioactivity quantification for these experiments
- Selection of radiopure detector materials and precise background simulations based on radioassay results

Nuclear recoil backgrounds in XENON1T from materials (orange), predicted from screening measurements, and external sources (blue) [3].



The Upgraded Gator Facility

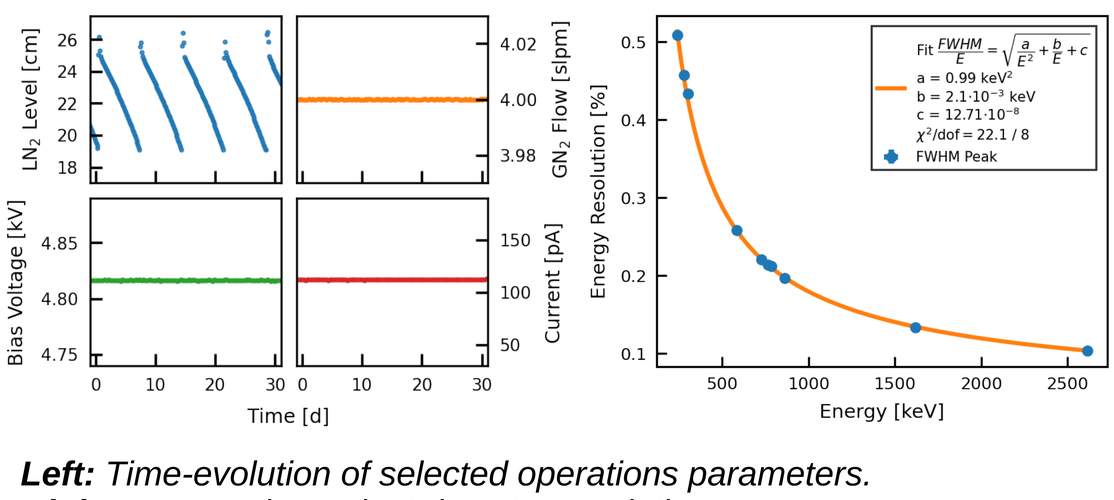
- Located at the Gran Sasso underground laboratory in Italy (LNGS) at a depth of 3600 m water equivalent
- P-type coaxial high-purity germanium (HPGe) detector with 2.2 kg sensitive mass, enclosed in an ultra-low activity, oxygen-free copper cryostat and cooled with liquid nitrogen via a copper coldfinger
- Several layers of passive shielding material:
  - 5 - 7 cm oxygen-free high-conductivity (OFHC) copper
  - 5 cm inner (3 Bq/kg) + 15 cm outer (75 Bq/kg) lead
  - 5 cm polyethylene for ambient neutron mitigation
- Continuous purge of airtight stainless steel enclosure with gaseous nitrogen for radon suppression
- Sample pre-purging with nitrogen in load-lock chamber and subsequent loading using glove ports with access to the entire sample chamber volume (25×25×33 cm^3)



***(a)** HPGe crystal inside Cu cryostat, **(b)** OFHC Cu cavity, **(c)** lead shield, **(d)** airtight enclosure, **(e)** glove ports, **(f)** sample load lock*

Detector Performance

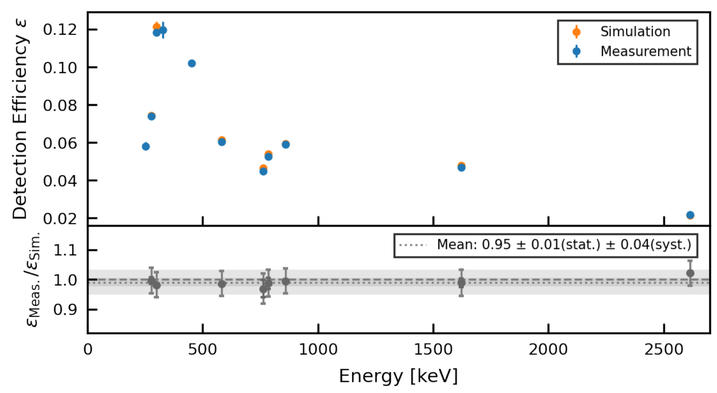
- Integrated background count rate of (82.0±0.7) $d^{-1}kg^{-1}$ [1] in the energy region 100-2700 keV (as compared to value from 2010: (102.8±0.7) $d^{-1}kg^{-1}$ [2])
- Typical sensitivities of < a few mBq/kg for exposures of 1-3 weeks and tens of kg sample mass (a few µBq/kg for radiopure samples and longer exposure)
- Regular calibrations of the detector with radioactive point- and extended sources (FWHM at 1332 keV: (2.03 ± 0.04) keV)
- Remote monitoring of operations parameters to ensure detector stability and data quality



***Left:** Time-evolution of selected operations parameters.*
***Right:** Energy-dependent detector resolution.*

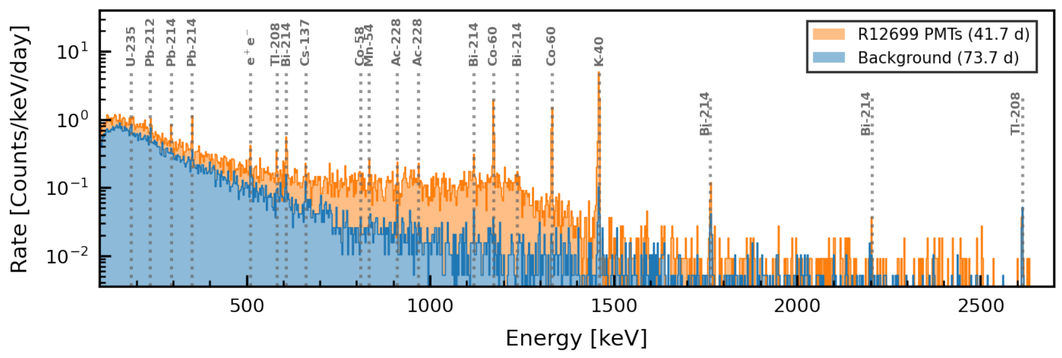
Simulations & Analysis

- Geant4 Monte Carlo simulations for detection efficiency ε determination



Verification of the detection efficiency simulations with a calibrated Th-228 point source.

- Activities from counting method using background- and Compton-subtracted counts around the most prominent lines, with detection limits according to [4]



Measured energy spectrum of sample photosensors (orange) as compared to the background (blue). Prominent isotopes are labeled.

References:

[1] G. R. Araujo et al., “The upgraded low-background germanium counting facility Gator for high-sensitivity ɣ-ray spectrometry”, arXiv:2204.12478 (2022)
[2] L. Baudis et al., “Gator: a low-background counting facility at the Gran Sasso Underground Laboratory”, JINST 6:08 (2011)
[3] E. Aprile et al., “Material radioassay and selection for the XENON1T dark matter experiment”, Eur. Phys. J. C 77:890 (2017)
[4] C. Hurtgen et al., “Revisiting currie – how low can you go?”, Applied Radiation and Isotopes 53:45 (2000)