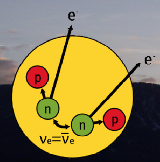


GERDA – Germanium Detector Array

searching for the

Neutrinoless Double Beta Decay

GERDA @ LNGS

0νββ-decay detection principles

To detect **0νββ-decay** one needs

- A *source* or generator of the decays. In case of GERDA it is the ^{76}Ge
  - ➢ A Phase I GERDA detector (~ 2 kg) contains ~10^{25} Atoms or 22 Moles of ^{76}Ge candidates for the decay.
  - ➢ If the half-life of 0νββ-decay is 10^{25} years one expects ~1 decay per year and per detector.
- A *detector* with adequate performances in terms of energy resolution, i.e. accuracy in measuring the energy, and radiopurity.

In GERDA the source of the decays and the detector are the same physical devices: they are *special* germanium detectors, as they are made of ^{enr}Ge , i.e. germanium enriched up to 86% in the ^{76}Ge *isotope*†.

An environmental physic laboratory (top) where 3 germanium detectors are enclosed in their lead shields. An unshielded germanium detector (bottom) with the dewar for liquid nitrogen or liquid argon.

- Germanium detectors are commercial devices, widely adopted in environmental physics services to evaluate quantitatively the concentration of radioactive *isotopes*† by measuring with high accuracy the energy and the intensity of the *γ–rays*†† *emitted by environmental or biological samples*.

† Isotope: an atom of the same chemical element, having a different number of neutrons . The number of neutrons = A – Z, varies in different isotopes of the same chemical element. The number that appears top left of the element symbol is the mass number.

†† γ-ray: a photon emitted by the nucleus during or immediately after its decay

0νββ-decay detection challenges: *ultra-low background techniques*

Radioactivity and Radiopurity

- Any material contains radioactive *isotopes*† in extremely variable concentrations ranging from 100 ppm (10^{-4}) or more to ppt (10^{-12}) or less.
- The radioactive *isotopes*† present on earth have either natural origin (from nucleosynthesis or cosmogenic) as ^{238}U, ^{235}U, ^{232}Th, ^{40}K, ^{7}Be, ^{42}Ar, ^{60}Co or anthropogenic origin (fallout) as ^{137}Cs, ^{131}I, ^{85}Kr, ^{133}Xe and others.
- Radioactivity is measured in Bequerel units (Bq) i.e. number of disintegrations per second.
- There is no general rule to know which material has high or low radiopurity; it depends mainly on the raw material and the production process.

Typically

- Rocks, soils, indoor air, the human being, agricultural fertilizers, ceramics etc. are all quite radioactive:
  ~ 10 -100 Bq/kg
- Copper, Teflon, Polyethylene, cryogenic liquids are highly radiopure

- A long R&D work is behind each part of the GERDA setup design and realization, to preserve a high radiopurity.

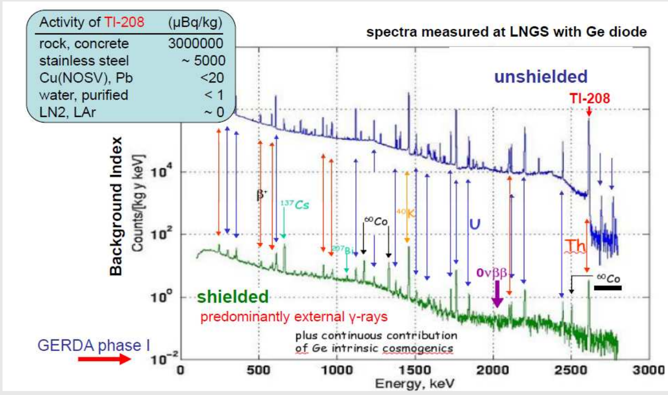
Techniques

- A germanium detector is a large diode (~1 kg mass or larger) that once polarized inversely, is fully depleted from charge carriers.
- Following a ^{76}Ge 0νββ-decay in the detector a charge pulse of ~100 *femtoCoulomb** (fC), or a current pulse of ~1 μA is produced.
- To fully deplete the diode from charges, and detect such a small amount of charge, the Ge detectors must be operated at cryogenic temperatures: in GERDA it is liquid argon.

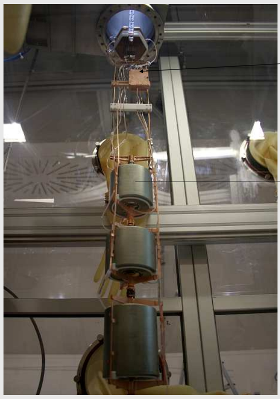
* femtoCoulomb: 10^{-15} Coulomb

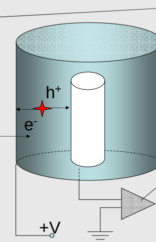
γ-ray spectra measured at LNGS with a Ge detector mounted in a standard cryostat:

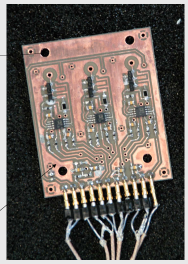
- In the blue spectrum the activity of the rock & concrete is dominating.
- In the green one the detector is highly shielded; the environmental activity is still present even if highly reduced, and the activity of the materials constituting the Ge detector is visible.
- The level of radioactivity of 10^{-2} cts/(kg y keV) needed to perform the GERDA experiment in Phase I is also reported by the red arrow.
- The cosmic rays (CR) impinging a detector in a non underground lab (~1 per second), will prohibit to observe any rare event: underground the CR flux is reduced by a factor ~ one million (10^6). Moreover only a fraction of the CR hard component (muons) survives; the residual muons crossing the detectors are tagged, as they first cross the water of the external shield (see devoted poster)



Ge detector operational principle: The e⁻,h+ pairs produced by a particle releasing its energy in the detector are drifted by the biasing electric field towards the electrode where they are collected and injected into an amplifier, that produces a impulsive signal (pulse).







One GERDA detector string (left), the model of a coaxial germanium detector (middle), and the cryogenic, low noise, high radiopurity amplifier (right) developed to read out the GERDA detectors; the latter is placed at the top of the detector string.