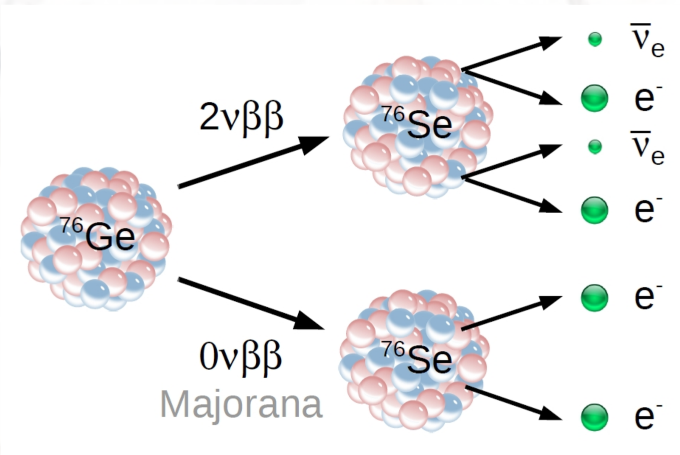
Search for neutrinoless double beta decay with the GERDA experiment

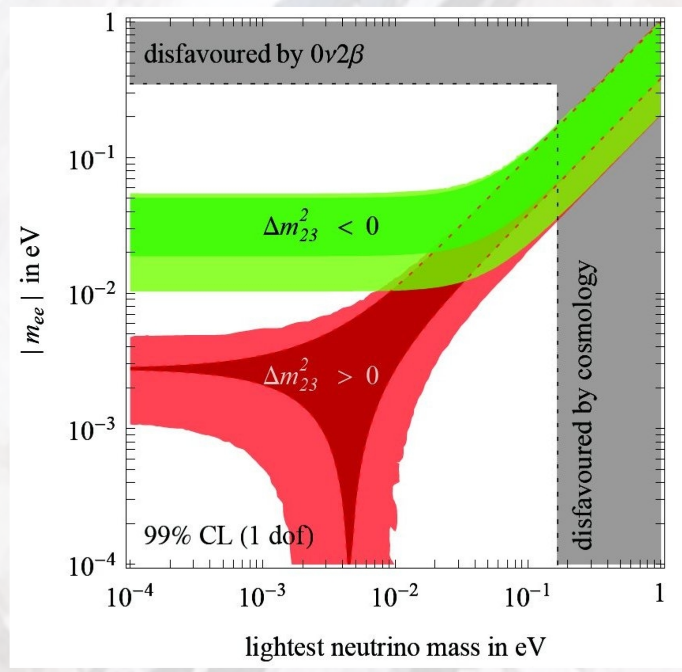
Neslihan Becerici-Schmidt for the GERDA Collaboration
Max-Planck-Institut für Physik



Double beta decay (2νββ) is an allowed second order weak process **observed** in a number of even-even nuclei with half-lives on the order of 10^{20} years and beyond. It can be seen as two simultaneous β-decays in a nuclei for which a β-decay is forbidden or strongly suppressed: $m(Z,A) < m(Z+1,A)$ & $m(Z,A) > m(Z+2,A)$

The neutrinoless mode of double beta decay - a neutron decays under the emission of a right-handed $\bar{\nu}_e$ and it is absorbed at the second vertex as a left-handed ν_e - can occur if the **neutrinos are their own anti-particles, i.e., Majorana particles.**

$$(Z,A) \rightarrow (Z+1,A) + e + \bar{\nu}_e,$$
$$(Z+1,A) + \nu_e \rightarrow (Z+2,A) + e$$

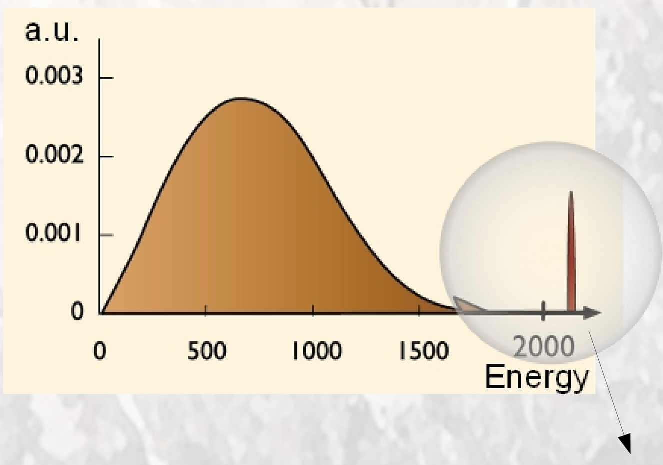


Neutrinoless double beta decay (0νββ) violates total lepton number conservation by two units and is forbidden in the Standard Model of particle physics. Discovery of 0νββ decay would reveal the Majorana nature of neutrinos. The effective Majorana neutrino mass, $|m_{ee}|$, can be determined from the measured half-life of the decay.

→ **Absolute neutrino mass scale can be determined**
→ **Neutrino mass hierarchy can be probed**

$$[T_{1/2}]^{-1} = F^{0\nu} \cdot |M^{0\nu}|^2 \cdot |m_{ee}|^2$$
$$|m_{ee}| = |\sum_i U_{ei}^2 m_i|$$

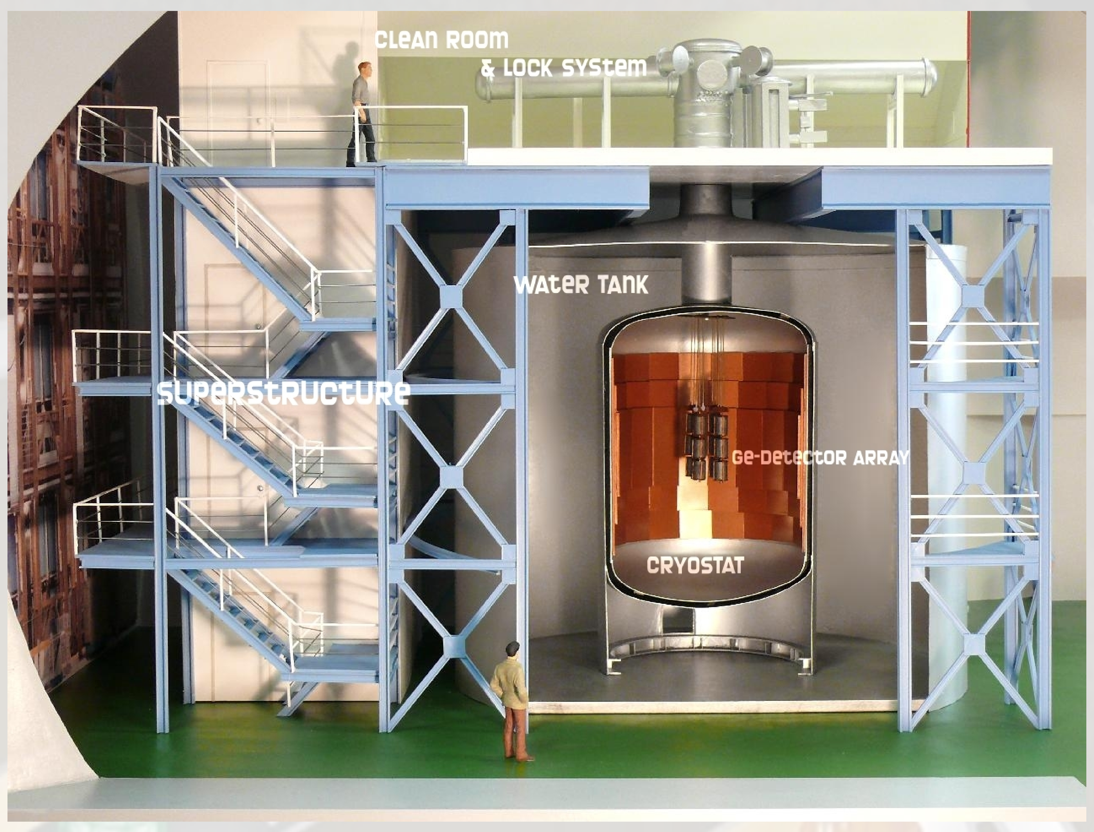
$F^{0\nu}$: phase space factor
$M^{0\nu}$: nuclear matrix element



$Q_{\beta\beta}(^{76}Ge)$ = 2039 keV

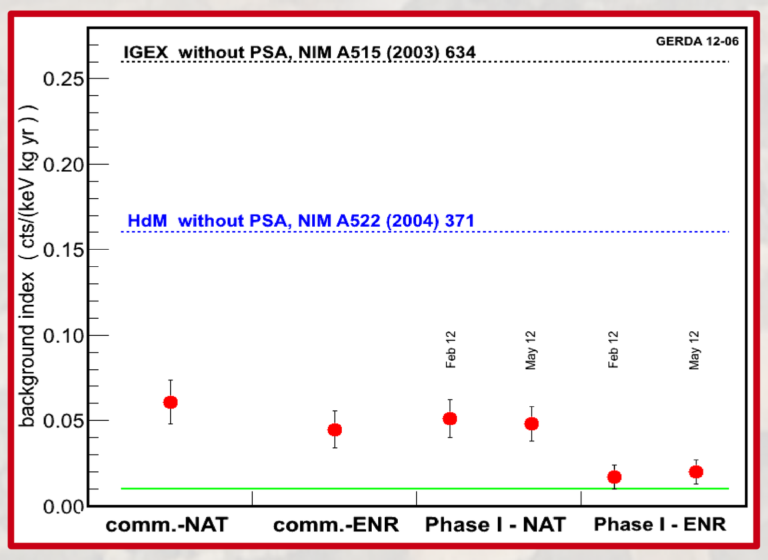
The experimental signature of 0νββ decay is a peak at the total energy emitted in the decay. The current limits on the half-life of 0νββ decay are on the order of 10^{25} years. Such a low rate makes the detection very challenging. The experiments searching for 0νββ decay are build in deep underground laboratories to be far from the cosmic rays, which is just the first step on a long journey to achieve the necessary **low-background environment**.

The GERDA - GERmanium Detector Array - experiment searches for the 0νββ decay in the isotope ^{76}Ge. High purity Ge diodes with excellent energy resolution are used as source and detector at the same time, which results in a very high detection efficiency. The detector material is enriched in ^{76}Ge from the natural abundance of 7.83% to ~86% to increase the target mass. The experiment is located **@ the LNGS** underground laboratory under the Italian Apennines. 1.4 km of rock overburden reduce the cosmic ray induced muon (neutron) flux by a factor of 10^6 (10^3) compared to the surface. The Germanium detector array is placed at the center of the experiment and is shielded against external radiation gradually. Detectors are submerged directly into liquid argon (LAr) contained in a steel cryostat 4 m in diameter. The LAr serves as a cooling medium for the operation of the detectors and as a shielding material simultaneously. A tank filled with ultra-pure water surrounds the LAr cryostat and is instrumented with PMTs to act as active muon veto. A minimal amount of material is used for the infrastructure in the direct vicinity of the detectors. All used material have been screened beforehand to achieve an ultra-pure environment.

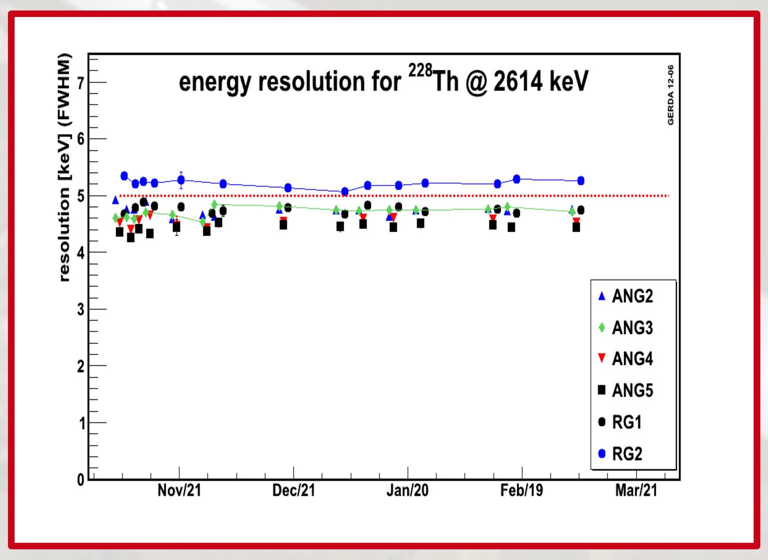


In GERDA Phase-I enriched detectors from the HDM and IGEX experiments and natural detectors from the GENIUS test facility have been deployed. The goal of Phase-I is to achieve an order of magnitude lower background index, **BI=0.01 cts/(keV kg yr)**, compared to previous HPGe experiments and to test the claim ($T_{1/2}$=1.2·10^{25} yr or $<m_{ee}>$ = 300-530 meV) by part of the HDM collaboration [ref]. **For GERDA Phase-II** newly developed enriched BEGe detectors will be deployed. These detectors show an improved background discrimination with PSA methods. The detector production is already in an advanced level. Additional background reduction is planned to be achieved by LAr instrumentation, by detection of coincident LAr scintillation light to discriminate background events scattering into LAr. The goal for Phase-II is an improvement of BI by an order of magnitude. With 100 kg·yr of exposure sensitivty to 0νββ decay half lives of 1.6·10^{26} yr can be reached.

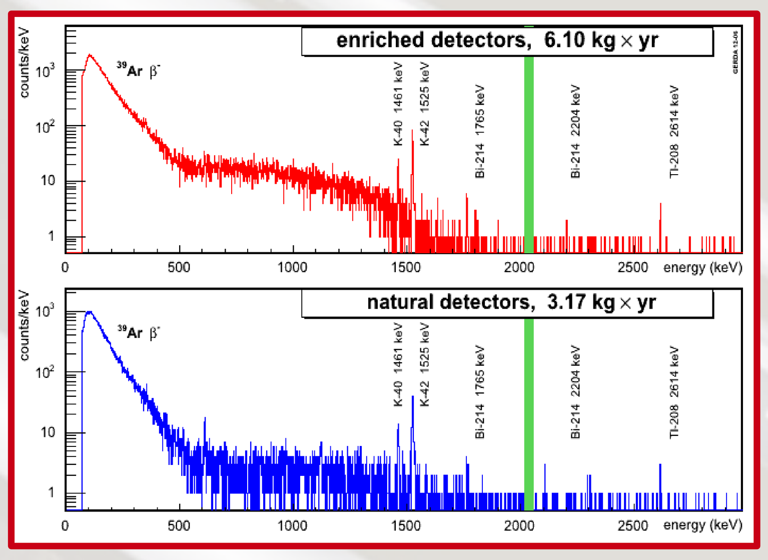
Results from GERDA Phase-I after 152.49 days of physics data-taking with 14.63 kg enriched (86% ^{76}Ge) and 7.59 kg natural (7% ^{76}Ge) HPGe detectors:



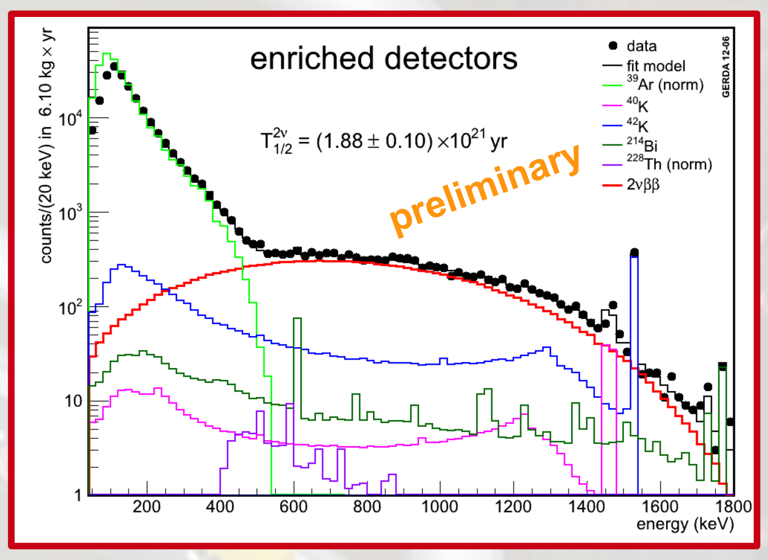
BI = 0.020 $^{+0.006}_{-0.004}$ cts/(keV kg yr) [68% coverage] (without PSA)



Calibration data every ~2 weeks: long term stability.



GERDA energy spectrum: Blinding @ $Q_{\beta\beta}$ ± 20 keV window.



Most precise measurement of the half-life of ^{76}Ge 2νββ-decay.