Double beta decay of ⁷⁶Ge into excited states of ⁷⁶Se in GERDA

Birgit Schneider and Thomas Wester on behalf of the GERDA collaboration
Institute of nuclear and particle physics, TU Dresden, Germany

Double beta decay

- The neutrino accompanied double beta decay (2νββ) is an allowed process in the Standard Model, but it is only observable if the single β decay is forbidden, e.g. for ⁷⁶Ge. If the neutrino is its own antiparticle, a so-called Majorana particle, a double beta decay without neutrino emission, 0νββ, is possible. This process violates the lepton number conservation by two. If light Majorana neutrino exchange is the dominant process, the investigation of the 0νββ decay can constrain the effective Majorana neutrino mass mν, because it is connected with the half life T½ of the decay via a phase space factor G and a nuclear matrix element M. 0νββ cannot only decay into the ground state of ⁷⁶Se, but also into excited states (e.g.). The investigation of 2νββ into e.e. helps to constrain the nuclear matrix elements M⁰ and M²e, which are numerically different but rely on similar assumptions.

The GERDA experiment

- GERDA stands for Germanium Detector Array and is an experiment searching for 0νββ in ⁷⁶Ge. It uses germanium detectors which are enriched in ⁷⁶Ge and are operated bare in liquid argon (LAr), which serves both as a coolant and a shield for external radiation. For Phase II of GERDA it is planned to reach an exposure of 100kg yr with a background index of 10⁴cts/(keV·yr).

- GERDA Phase II operates 40 detectors in 7 strings in a close geometry. The granularity of the detector array is optimally suited to study ββ decays into excited states. While the two electrons of the ββ decay remain in the source detector, the de-excitation gammas can escape it and deposit energy in another detector. Thus the search for ββ decays into excited states is done investigating multiplicity 2 events.

MC signal signature from excited states

- The expected signal signatures are produced with MC simulations with 10⁷ decays per detector. The decay particles are generated such that the angular correlation between the gamma rays is taken into account. Only so called multiplicity 2 events are shown in the 2D plots, where the energy deposition in two detectors are plotted versus each other.

The full energy deposition of the de-excitation gamma rays can be seen as horizontal and vertical lines. The diagonal lines are caused by gamma rays that share their full energy between two detectors. The ββ energy is not detected in some of these cases due to decays in the inactive volume of a detector or in detectors excluded from the analysis.

The region of interest (ROI) includes the horizontal and vertical lines, where one energy deposition is equivalent to a de-excitation gamma energy. Along these lines lies the continuous beta spectrum of the ββ decay superimposed with the gamma spectrum of partial energy depositions. In the 0ν mode 17% of the simulated decays produce multiplicity 2 events, while 2% lie in the ROI. This corresponds to an efficiency increase of a factor of 2.5 to 3 for all investigated decay modes compared to Phase I of GERDA due to a more efficiently arranged detector setup.

Background estimation with MC simulation

- The background for the search for decays into e.e. is estimated with the background model of GERDA Phase II, but only multiplicity 2 events are taken into account. Background components taken into account are selected according to screening results of each part of the detector array and the surrounding materials. The dominant background for this analysis originates from ⁷⁶K (50%) and ⁷⁶Ge (20%).

Preliminary results of GERDA Phase II data

- Spectrum of multiplicity 2 events accumulated for 35kg yr exposure in GERDA Phase II before all cuts. The diagonal lines from ⁷⁶K and ⁷⁶Ge are rejected, which leaves only ⁷⁶K and ⁷⁶Ge events with partial energy deposition as the main background.

- Comparison of experimental limits and theoretical half life predictions for the 0ν mode. With the current sensitivity of > 3.7 · 10²⁷yr some of the older predictions can be ruled out. It is expected that with the sensitivity increase by the energy of Phase II of GERDA the more recent half life predictions can be probed.