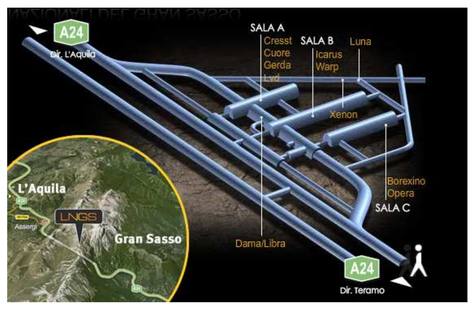
Preparations for GERDA Phase II Updates

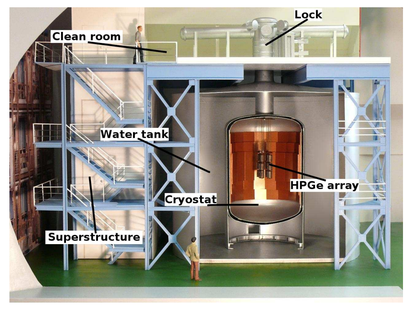
GRADUIERTEN KOLLEG Masse-Spektrum-Symmetrie

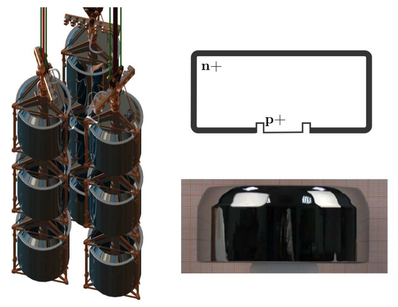
TECHNISCHE UNIVERSITÄT DRESDEN

Introduction

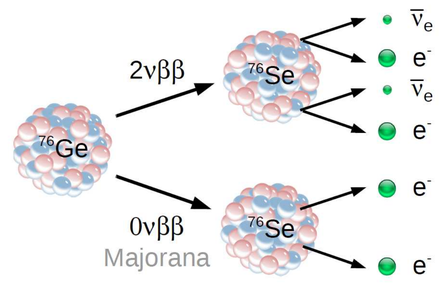


The Laboratori Nazionali del Gran Sasso (LNGS), in a highway tunnes in the Abruzzo mountains, have an overburden of about 3800 m w.e.





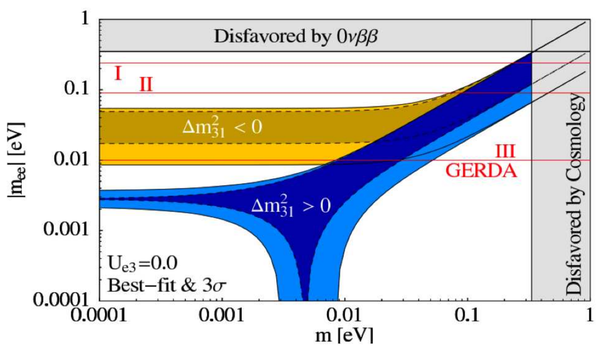
The GERDA setup with its main components, the detector array and a BEGe detector

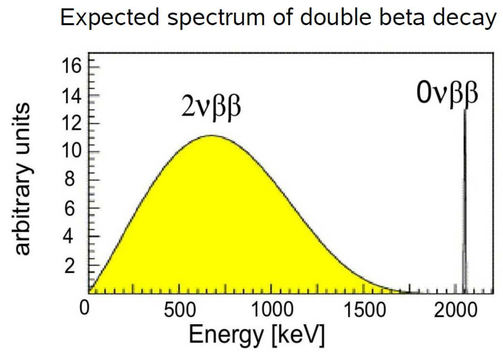


Double beta decay in $^{76}\mathrm{Ge}$ with two neutrinos (top) and without neutrinos (bottom)

The Physics

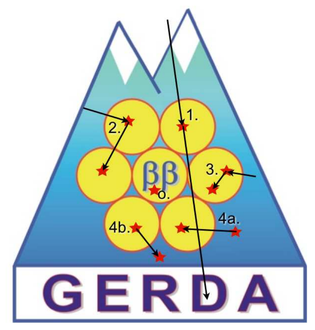
Neutrino less double beta decay ($0\nu\beta\beta$) experiments are the only approach to determine the possible Majorana nature of neutrinos. Subsequently, one can also determine the effective Majorana neutrino mass $|m_{ee}| = \left|\sum_i m_i U_{ei}^2\right|$ and identify the mass hierarchy structure assuming a light neutrino propagator.





The experimental signature of the well known $2\nu\beta\beta$ decay is a continuous $\beta\beta$-spectrum whereas the signature for the $0\nu\beta\beta$ decay is a peak at the Q-value of 2039 keV for $^{76}\mathrm{Ge}$. The sensitivity of $0\nu\beta\beta$ experiments is mainly determined by target exposure and radioactive background reduction.

There is a pending claim of discovery of $0\nu\beta\beta$ by a subset of the HDM collaboration. Phase I of GERDA aims at testing the claim within this year. Phase II aims at probing down to 90 meV with two major detector upgrades: 30 additional Broad Energy Germanium Detectors (BEGe) and a liquid argon (LAr) scintillation veto.



0: Signal: $0\nu\beta\beta$ single site event

1: Background from outside: Water Cherenkov muon veto

2: Background hitting multiple detectors: Detector array coincidence

3: Background hitting multiple times the same detector: Pulse shape discrimination

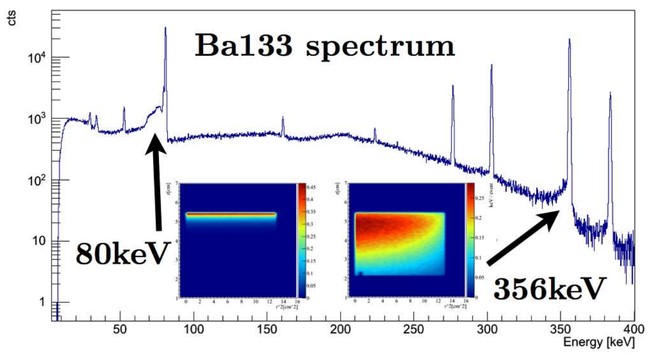
4a: Background from the LAr: LAr scintillation veto

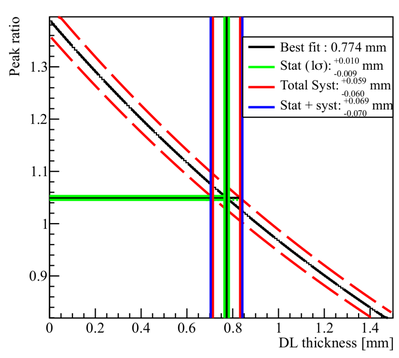
4b: Background scattering into the LAr: LAr scintillation veto

GERDA uses various background rejection techniques to reach a background level of $10^{-3}\,\mathrm{cts}/(\mathrm{kg}\cdot\mathrm{yr}\cdot\mathrm{keV})$ for Phase II. Major improvements compared to Phase I are enhanced pulse shape discrimination with BEGe detectors and additional background rejection with the new LAr instrumentation.

Topic: Active Volume Determination of Phase II BEGe

The new BEGe detectors for Phase II are fully characterized prior to deployment in GERDA which is performed in the HADES facility at SCK·CEN, Belgium. An important parameter for all GERDA analysis is the active volume (AV) determination of the new detectors which is part of this PhD thesis.

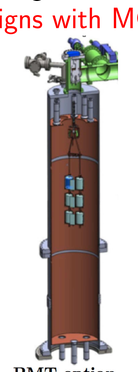




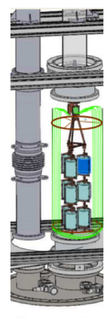
The AV is determined via multiple γ-probes which are compared to MC simulations altering the thickness of the dead layer. Those probes measure the total volume ($^{60}\mathrm{Co}$), the top dead layer $^{241}\mathrm{Am}$, $^{133}\mathrm{Ba}$ or raster scan the top and the side surfaces of the detectors ($^{241}\mathrm{Am}$) in order to yield a coherent picture of the individual very distinct detectors.

Topic: MC Study of LAr Instrumentation Designs

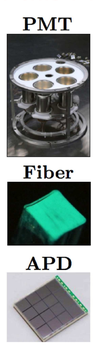
There are three design options for the instrumentation of the LAr in GERDA: PMT design, light guiding fiber design and direct detection APD design. The comparison and optimization of these designs with MC simulations is part of this PhD thesis.

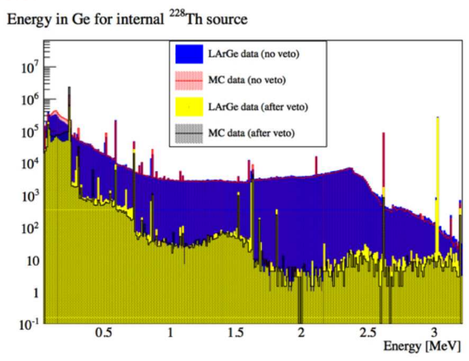


PMT option



Fiber option





The possibility to successfully veto prominent backgrounds has been proven in the GERDA R&D facility LArGe. The implementation of the LAr veto designs and tuning of the MC has been performed last year and results are in very good agreement between MC and experimental data. After the subsequent design comparison resulted in no clear favorite, a combination of design techniques is now considered.

Selected Talks

- GERDA Meeting, Dresden, 2010: MC Simulations of $^{42}\mathrm{K}$ Decay
- DPG, Karlsruhe, 2010: $^{42}\mathrm{Ar}/^{42}\mathrm{K}$ Background in the GERDA Experiment
- GERDA Meeting, LNGS, 2010: MC Simulations of $^{42}\mathrm{K}$ - Update
- ISAPP, Varenna, 2011: GERDA Commissioning July 2010 - April 2011
- Graduate School, Berlin, 2011: Neutrinoless Double Beta Decay for Particle Physicists
- GERDA Meeting, Zuerich, 2011: New Limit on the radiative $0\nu\mathrm{ECEC}$ Decay of $^{36}\mathrm{Ar}$
- Invited seminar talk, Hamburg, 2012: The GERDA Experiment
- Graduate School, Krippen, 2012: Application of Feldman and Cousins
- DPG, Mainz, 2012: MC Benchmarks for LAr Instrumentation in GERDA
- GERDA Meeting, Munich, 2012: Search for Excited State Transitions in $^{76}\mathrm{Ge}$
- GERDA-Majorana Meeting, Munich, 2012: Dead Layer Modeling and BEGe's in MaGe
- EUNPC, Bukarest, 2012: A Liquid Argon Scintillation Veto for the GERDA Experiment
- GERDA Meeting, LNGS, 2012: Dead Layer and Active Volume Determination
- HAP Workshop, Bad Liebenfels, 2012: Acceptance Tests of Enriched BEGe Detectors for GERDA

Publications

- B. Lehnert and K. Zuber, Phys. Lett. B 705, 47 (2011), A first search of excited states double beta and double electron capture decays of $^{110}\mathrm{Pd}$ and $^{102}\mathrm{Pd}$
- B. Lehnert, Proceedings of ISAPP, Commissioning of the GERDA Experiment
- GERDA Coll., arXiv:1212.3210, Measurement of the half-life of the two-neutrino double beta decay of Ge-76 with the Gerda experiment
- GERDA Coll., arXiv:1212.4067, The GERDA experiment for the search of $0\nu\beta\beta$ decay in $^{76}\mathrm{Ge}$

B. Lehnert et. al, arXiv:1212.5120, New Half-life Limits on Double Beta Decays of $^{110}\mathrm{Pd}$ and $^{102}\mathrm{Pd}$ into Excited States

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