CALIBRATION SYSTEM FOR GERDA

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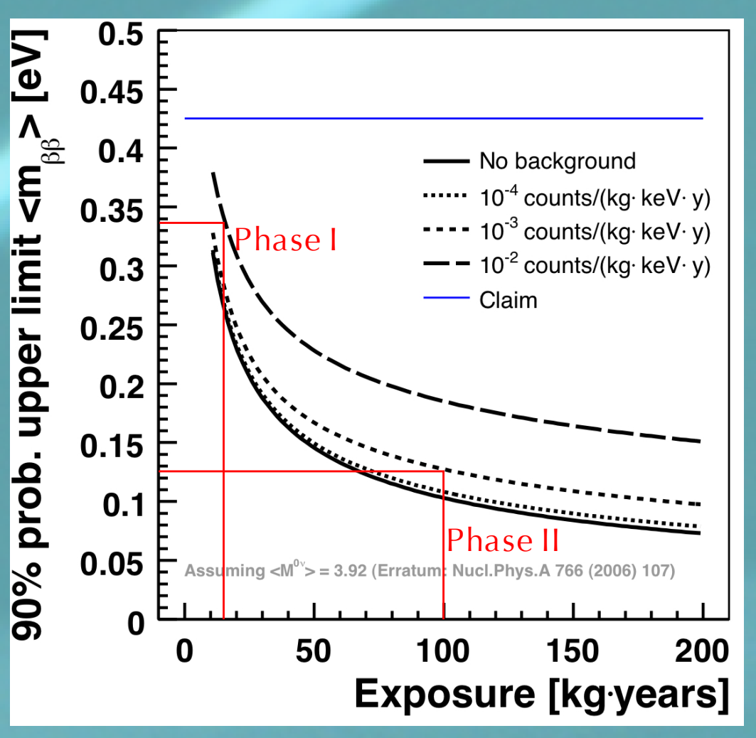
GERDA

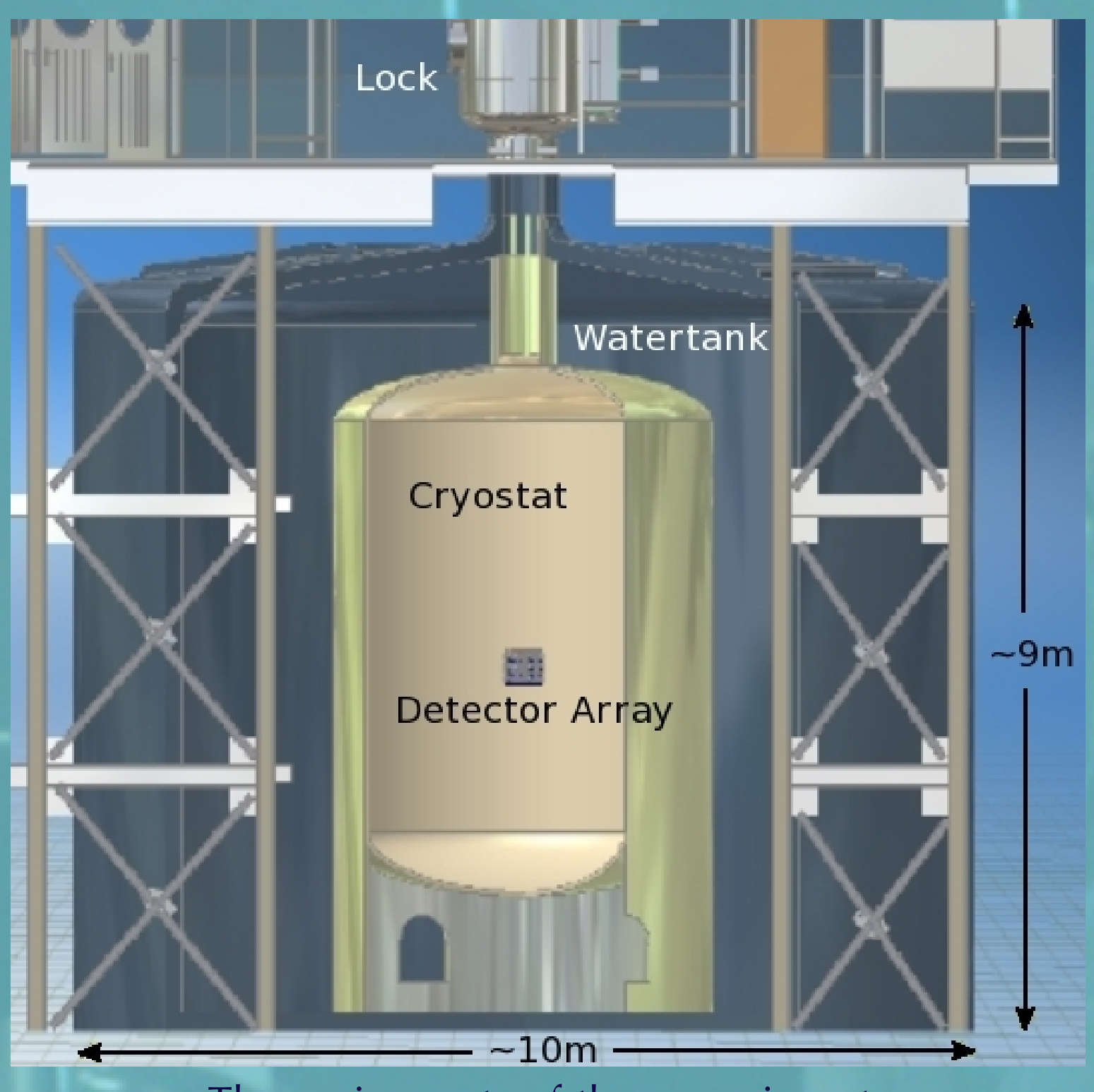
The GERmanium Detector Array (GERDA) uses naked germanium detectors enriched up to 86% in Ge-76 placed in liquid argon to measure the neutrinoless double beta decay. The experiment is forseen to proceed in two phases:

- Phase I uses 8 modified Hd-Mo and IGEX crystals reaching a mass of 17.9 kg of Ge-76, a background level of 0.01 cts/(kg keV y) and a sensitivity for the effective neutrino mass down to $m_\nu < 0.34$ eV.
- Phase II uses the Phase I detectors together with new crystals specially developed for GERDA reaching a mass of 40 kg of Ge-76, a background of 0.001 cts/(kg keV y) and a sensitivity for the effective neutrino mass down to $m_\nu < 0.13$eV.

GERDA is located at the Gran Sasso laboratory in Italy 1500 m underground. Construction is under way and we plan to start taking data in the fall of this year.



The detectable effective neutrino masses as a function of the detector mass and the background level. The red lines mark GERDA Phase I and II, the blue line the claim of the Heidelberg-Moscow experiment.



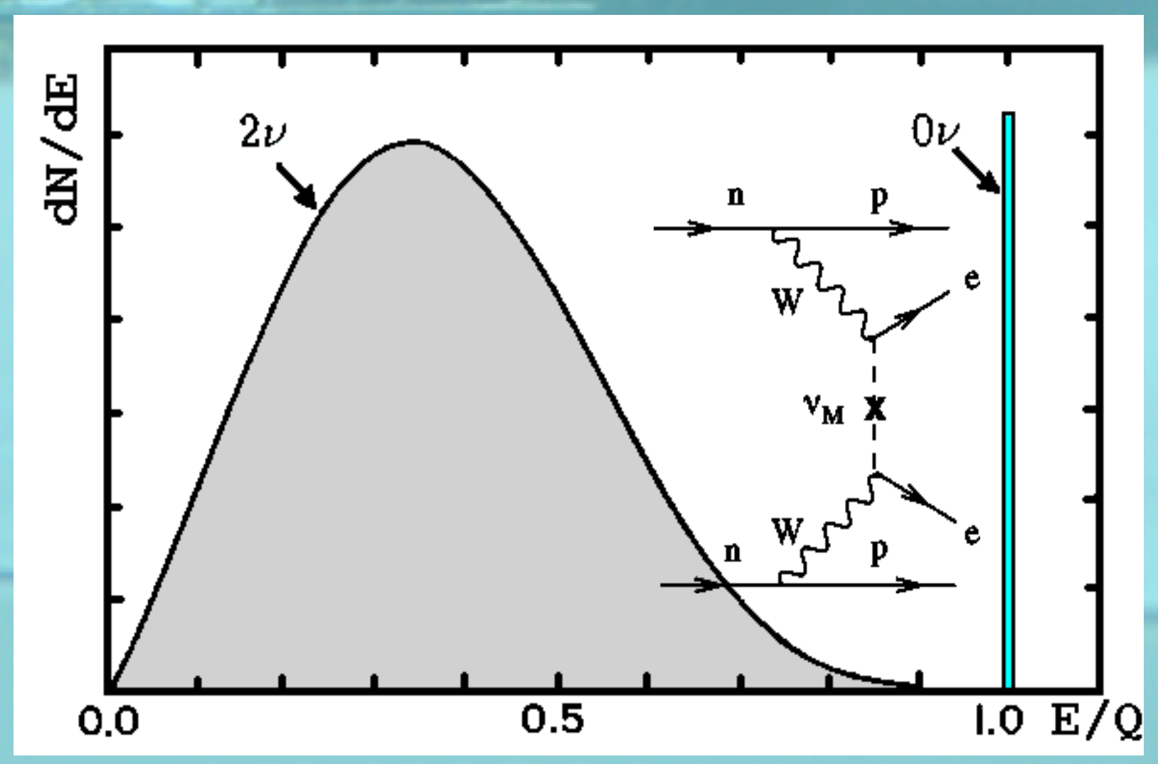
The major parts of the experiment.

NEUTRINOLESS DOUBLE BETA DECAY

The three most important questions in neutrino physics are

- Are neutrinos Dirac or Majorana particles?
- What is their absolute mass scale?
- What is their mass hierarchy?

One way to probe all three questions is using the neutrinoless double beta decay. In double beta decay, two neutrons decay simultaneously into two protons by emitting two electrons and two electron antineutrinos (2nbb).



The electron spectrum for the 2nbb (continuum) as well as the 0nbb (peak) decay together with the Feynman diagram for the 0nbb decay.

If the neutrino is a Majorana particle, and therefore its own antiparticle, it is possible that both neutrinos annihilate and just the two electrons are emitted (0nbb).

To detect the double beta decay, the energy spectrum of the electrons is measured. In the 2nbb decay, the neutrinos carry away some of the available energy which results in a continuous spectrum, while in the 0nbb decay the electron spectrum peaks at the maximum available energy (Q-value). The decay rate is correlated to the neutrino mass.

The 2nbb decay has been measured for around ten different nuclei.

A subgroup of the Heidelberg-Moscow experiment lead by Prof. Klapdor-Kleingrothaus has claimed the observation of the 0nbb. The results are controversial and need to be verified in a dedicated experiment.

CALIBRATION SYSTEM

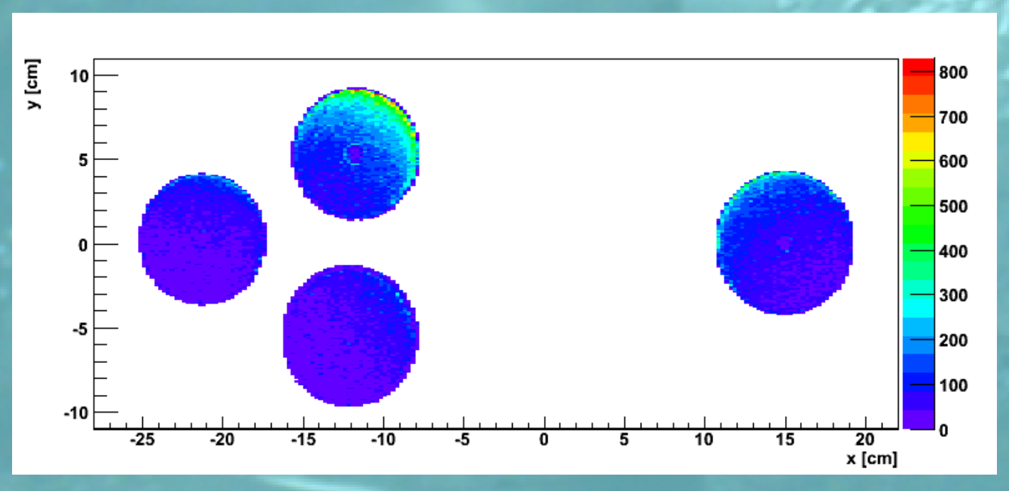
The goal of the calibration system is to determine the energy scale of every single detector as well as the pulse shape of singe-site and multi-site events. We will therefore use the photon emission of a radioactive source. Due to technical conditions we have the following restrictions:

- Fixed positions for the calibration sources
- Parking position in the lock of the experiment
- Minimum weight of around 3 kg
- Maximum radius of 2.9cm (P I) or 4cm (P II)

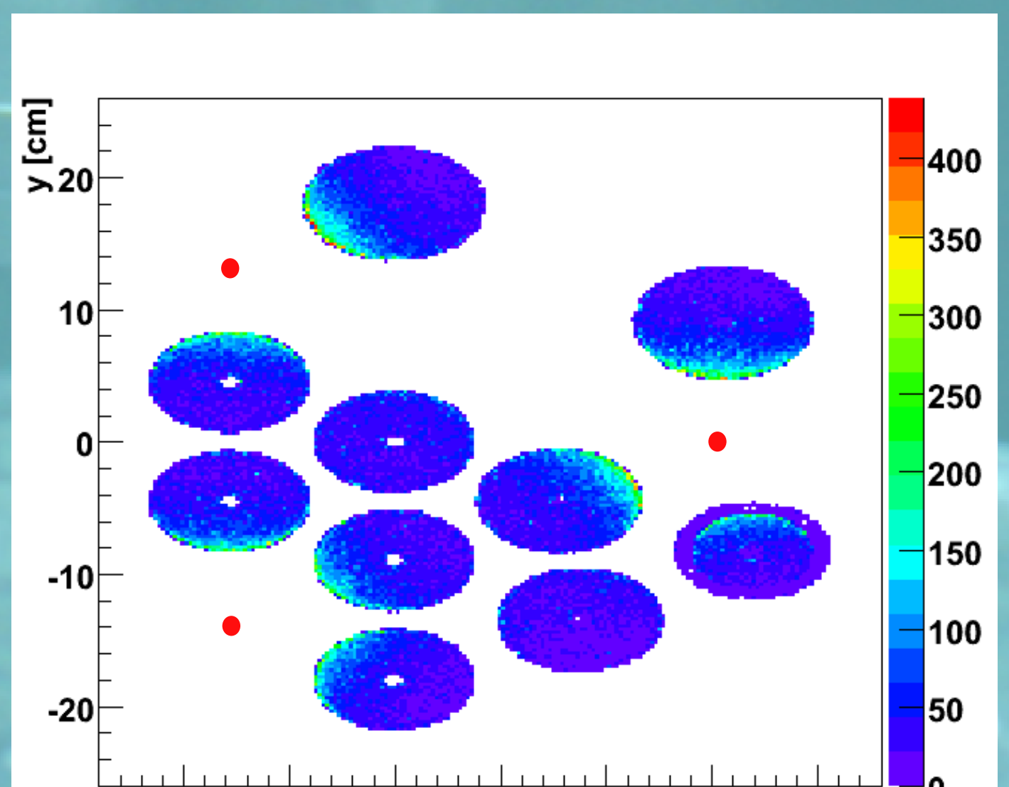
To successfully calibrate the energy scale as well as the pulse shape we have the following requirements for the calibration source:

- A γ line close to the Q-value of Ge-76 which is at 2039 keV
- Sufficient lines up to around 3000 keV
- Significant sample of single-site events

We use Monte Carlo simulations to investigate the different system parameters. We find that Th-228 fulfills all requirements. The source is placed on top of an absorber to shield the radiation in the parking position and prevent background events during the measurements.



Phase I geometry: Up to four detector strings plus one calibration source which is placed above this plot. Color coded are the number of events which shows e.g. the self shielding effect of the detectors.



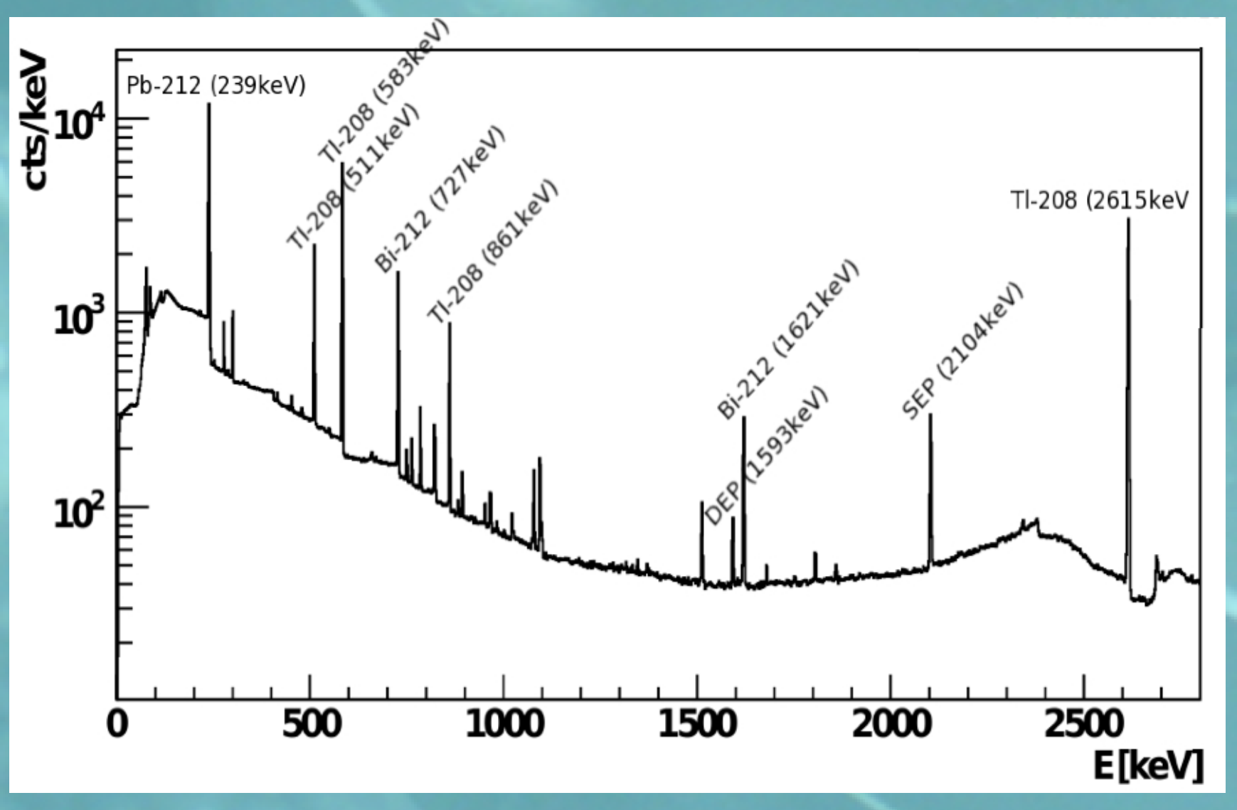
Phase II geometry: Three calibration sources (red dots), five detector strings with Phase I detectors plus 5 strings of detectors especially designed for GERDA Phase II. Color coded are the number of events which shows e.g. the self shielding effect of the detectors.

SOURCE STRENGTH

The radio activity of the calibration source should be as low as possible to minimize background events from the source in the parking position. However, we need sufficient events in each detector to be able to calibrate these. The two most important peaks are:

- Single escape peak from the Tl-208 line with an energy of 2104 keV: This line is closest to the Q-value and therefore most important for the energy calibration.
- Double escape peak from the Tl-208 line: This line provides a good sample of single-site events and is therefore most important for the pulse shape calibration.

On both peaks we fit a Gaussian function above a linear background to get the number of events in the peak as well as the error on the peak postition. We used these quantaties and the detector with the lowest statistics to determine the required minimum number of decays. Using this number we calculated the minimum source strength as a function of the time needed for a calibration run.



The first results for Phase I lead to a total activity of about 100 kBq at a run time of 1.5 hours. The exact values are still under discussion.

The Th-228 spectrum. Marked are the strongest lines we will use for the energy calibration as well as the double escape peak we need for the pulse shape calibration.

BACKGROUND

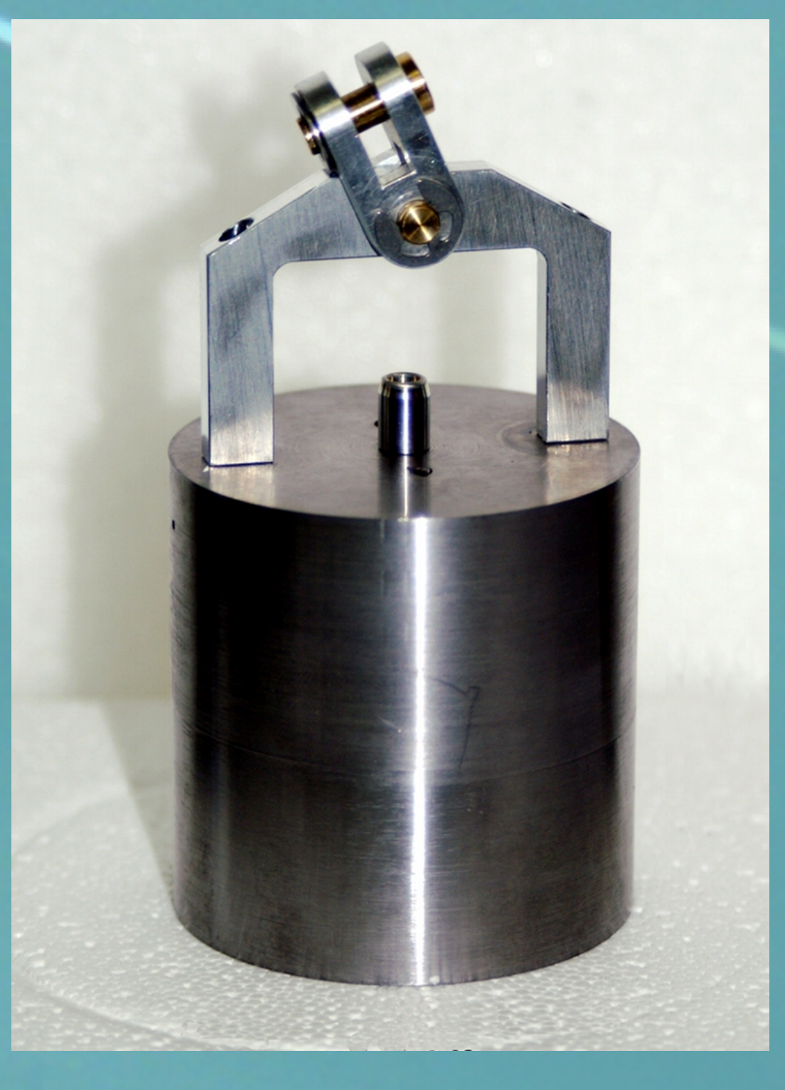
The calibration system must suppress the background contribution from the calibration source(s) in the parking position as much as possible. We used a combination of analytical calculations and Monte Carlo simulations to estimate the background with three different absorber materials.

The following list shows the gamma background contribution in the region of interest for all three tested absorber materials (cylinders with a height of 6 cm respectively) as well as the attenuation of the liquid argon itself (350 cm). The values are normalized to a source activity of 1 kBq.

- LAr: B = 9.23×10^{-5}cts/(kg keV y)
- LAr+Cu: B = 1.35×10^{-5}cts/(kg keV y)
- LAr+W: B = 8.29×10^{-7}cts/(kg keV y)
- LAr+Ta: B = 1.57×10^{-6}cts/(kg keV y)

These values are well below the GERDA background goals even with source activities up to 200 kBq.

SYSTEM PROTOTYPE



The system prototype consists of the calibration source, the absorber, and the connection to the lowering system. The absorber is made of tantalum because of its high density and radio purity: Our screening showed a radioactivity of less than 50mBq.

The capsule for the calibration source is made of stainless steel; the connection to the lowering system of stainless steel as well as copper. All three materials have different thermal expansion coefficients. To unproblematic operation of the system for the complete experiment we performed 20 thermal cycles and two slow immersion tests with liquid nitrogen. These tests went well so the system is ready for the actual experiment when the final source activity is decided.