The Calibration System for the GERDA Experiment

Francis Froborg

Universität Zürich

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Universität Zürich

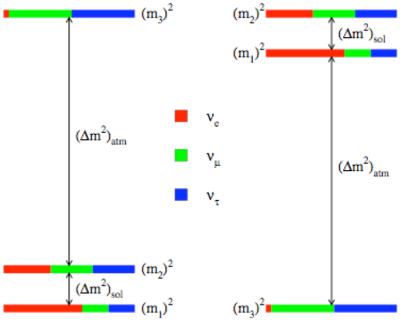
Status

We know

- Neutrinos have a mass
- Mass difference between eigenstates

The 3 big questions

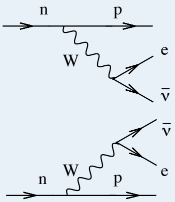
- Absolute mass scale
- Mass hierarchy
- Majorana vs. Dirac



Double Beta Decay

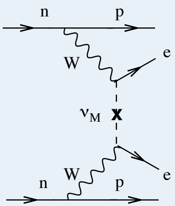
$2\nu\beta\beta$

- $(Z, A) \rightarrow (Z+2, A) + 2e^- + 2\bar{\nu}_e$
- $\Delta L = 0$
- $\left|T_{1/2}^{2\nu}\right|^{-1} = G^{2\nu}(Q_{\beta\beta}, Z)\,|M_{2\nu}|^2 \sim \left|10^{20}\ \mathrm{y}\right|^{-1}$



$0\nu\beta\beta$

- $(Z, A) \rightarrow (Z+2, A) + 2e^-$
- $\Delta L = 2$
- $\left|T_{1/2}^{0\nu}\right|^{-1} = G^{0\nu}(Q_{\beta\beta}, Z)\,|M_{0\nu}|^2\,\langle m_{\beta\beta}^2\rangle \sim \left|10^{25}\ \mathrm{y}\right|^{-1}$
- $\langle m_{\beta\beta}\rangle = \left|\sum_i U_{ei}^2\ m_i\right|$



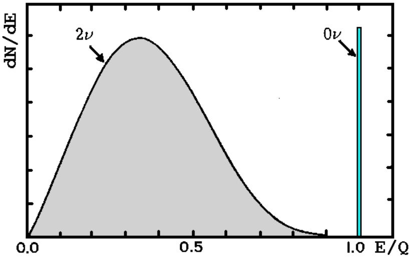
Signature

Measuring the energy of both electrons

- $2\nu\beta\beta$: Continuous energy spectrum
- $0\nu\beta\beta$: Sharp peak at Q value of decay

$$Q = E_{\text{mother}} - E_{\text{daugther}} - 2m_e$$

- Schechter & Valle (1982): Measuring $0\nu\beta\beta \Rightarrow \nu$ Majorana particle



Heidelberg-Moscow Experiment

The Claim

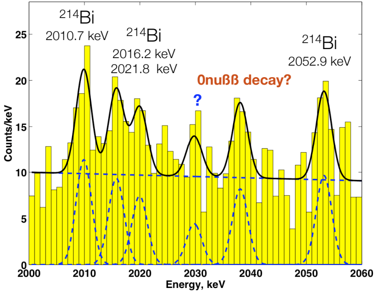
- 5 HPGe crystals with 71.7 kg y
- Peak at Q value:

$$T_{1/2}^{0\nu} = 1.2 \times 10^{25} y \qquad (4\sigma)$$
$$\langle m_{\beta\beta} \rangle = 0.44\,\text{eV}$$

- Problem: Confidence depends on background model and energy region selected for analysis

$\Rightarrow$ New experiments with higher sensitivity needed

H.V.Klapdor-Kleingrothaus et al., Phys. Lett. B 586 (2004) 198



The GERmanium Detector Array (GERDA)

Overview

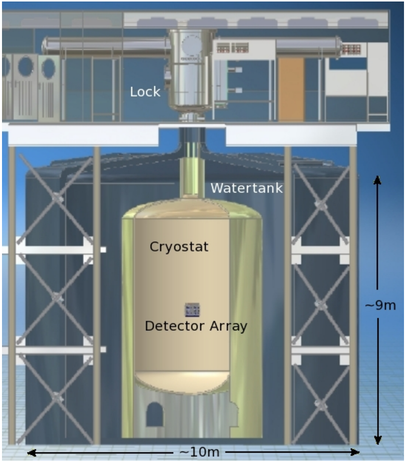
Naked High purity ^{76}Ge crystals placed in LAr

Phase I goals

Exposure	15 kg y
Background	10^{-2} cts/(keV kg y)
Half-life	$T_{1/2} > 2.2 \times 10^{25}$ s
Majorana mass	$m_{ee} < 0.27$ eV

Phase II goals

Exposure	100 kg y
Background	10^{-3} cts/(keV kg y)
Half-life	$T_{1/2} > 15 \times 10^{25}$ s
Majorana mass	$m_{ee} < 0.11$ eV



GERDA

Status of the Experiment

The Calibration System

Phase I

Goals

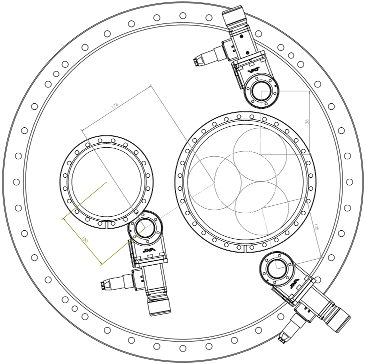
- Calibrate energy scale & pulse shapes
- Monitor stability of corresponding parameters
- Low background

Boundary Conditions

- Fixed xy positions of the sources
- Maximum diameter of < 4 cm
- Park position in the lock of the detector

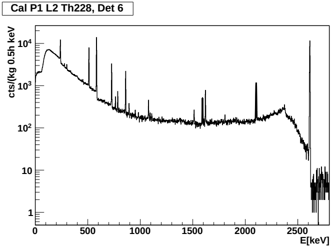
Parameters

- Type, strength and z position of sources
- Shielding material and geometry for parking position



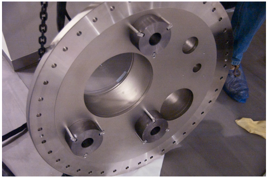
The Source

^{228}Th	Enough lines, long half life, double escape peak
Activity	3 sources with 20 kBq
z Position	One calibration run per detector layer
Time	0.5h per layer



Design

- Source shield in parking position by a Tantalum absorber (cylinder and ring)
- Manual lowering system
- System succesfully tested at LNGS in Jan 2010
- Upgrade on motorized lowering system in progress



γ Background

Linear Attenuation

- Take flux of sources in 1 year
- Flux reduction because detector covers just small area but source radiates isotropically
- γ with highest energies have 2.6 MeV (36%) and 2.1 MeV (64%)
- Calculate linear attenuation of 250 cm of LAr and 6 cm of Ta absorber

Monte Carlo Simulation

- Photon beam downwards 1m above detector array
- Rescale hits in ROI to flux calculated above

Result for 3 20kBq sources

$B(2.6) = 2.008 \times 10^{-5}$ cts/(keV kg y) $B(2.1) = 0.054 \times 10^{-5}$ cts/(keV kg y)

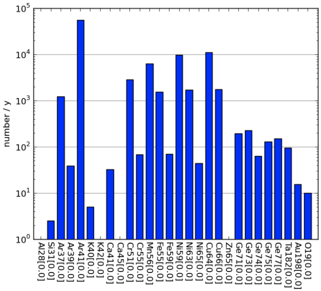
$$B = 2.062 \times 10^{-5} \text{ cts/(keV kg y)}$$

Neutron Background

(α-n) Background

- MCS to estimate background contribution
- Neutron flux measured for specially produced source (see talk by M. Tarka)

$$B \sim 6 \times 10^{-4} \text{ cts/(keV kg y)}$$



Activated Isotopes

- MCS to get isotopes activated by neutrons during calibration and in parking position
- Estimate background contribution

Analysis

- Each calibration run produces ∼400 GB of data
- Extract parameters for energy calibration as well as pulse shapes
- Convert raw data into MGDO objects containing also the parameters in an easy accesible form for further analysis
- Store information also in a database
- Web based visualization of parameters showing also stability over time

Summary

- 3 ^{228}Th sources with 20kBq used for calibration
- Sources shielded in their parking position by 6cm of Tantalum
- Background from sources in parking position on an acceptable level
- System for Phase I ready
- Upgrade for lowering system in progress
- Analysis software in progress