Search for the neutrinoless ββ decay in ^{76}Ge with the GERDA experiment

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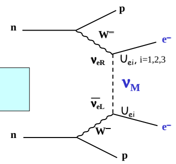
The Gerda 0ν2β experiment

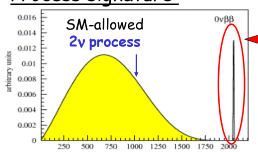
Neutrinoless ββ decay: (A,Z) → (A,Z+2) + 2e$^-$



Forbidden in the Standard Model: violates of two units the lepton number conservation

only possible if neutrino is a **massive Majorana particle**

Process signature:



Sum of the electrons kinetic energies

Single line at $Q_{\beta\beta}$ = 2039 keV

Experimental sensitivity:

$$T_{1/2}^{0\nu}(y) > 4.3 \cdot 10^{24}\, \varepsilon a \sqrt{\frac{mt}{BR}} \quad (90\%\ CL)$$

ε = detection efficiency,
a = ββ isotope fraction → enrichment
m = mass of detector (kg), t = measurement time (y)
B = background index in cts/(keV kg y),
R = energy resolution at $Q_{\beta\beta}$ (keV)

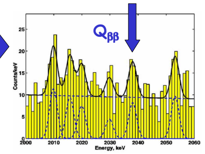
The **GERmanium Detector Array** experiment (GERDA) will look for 0ν2β decay in ^{76}Ge using HP-Ge detectors **enriched in ^{76}Ge** at the Gran Sasso underground laboratory (Italy)

0ν2β decay of ^{76}Ge

Claim for the observation of 0ν2β decay of ^{76}Ge based on the data of the Heidelberg-Moscow (HM) experiment at Gran Sasso

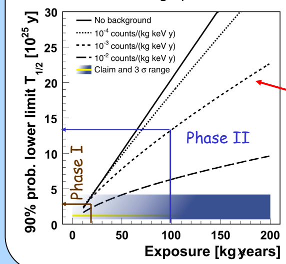
$T_{1/2}$ = (0.69 – 4.2) $\cdot 10^{25}$ y (3σ)

71 kg · y , B = 0.2 c/keV kg y



Klapdor-K. et al, Phys.Lett. B586(2004)198

No positive indication from the IGEX experiment
8.8 kg · y , B = 0.2 c/keV kg y



GERDA first goal: confirm or reject the claim

Goal background for GERDA: **10^{-3} counts/(keV kg y)**

100 kg·y exposure **background-free**

Phased approach:

Phase I: existing detectors from HM and IGEX, establish background reduction

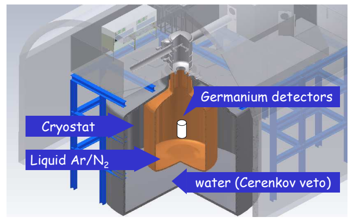
Phase II: new detectors

GERDA concept

Idea to reduce the background down to **10^{-3} counts/keV kg y**: shield against external γ operating naked Ge crystals suspended in high radiopurity liquid nitrogen or argon (also cooling medium)

same concept of Genius and GEM

Design: graded shielding. Inner **liquid N/Ar shielding** + external **water buffer**



Water: additional γ shielding, neutron shielding, Cerenkov muon veto

No high-Z material surrounding the detectors

Background from external γ rays can be reduced below 10^{-3} counts/keV kg y

Additional background reduction from: material selection (expecially for parts close to detectors), detector anti-coincidence and segmentation, pulse shape analysis (0ν2β = localized energy deposition)

Phase I detectors

Eight enriched detectors (= 18 kg) from the former HdM and IGEX experiments have been **underground for more than ten years** → internal cosmogenic background reduced. A procedure for the removal from their actual cryostat, re-contacting and mounting inside LN bath while keeping their radiopurity quality has been developed.

Phase I Detectors Array

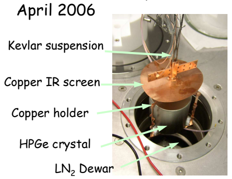
Using Ge-Ge **coincidences** to suppress bkg

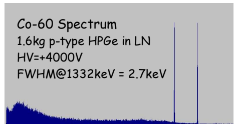
Only 50 g of selected clean material around each detector (conventional Cu cryostat ~ 3-4 kg)

IGEX detectors RG1-3

Heidelberg-Moscow detectors ANG1-5

Test of prototype HPGe detector assembly in LNGS April 2006





Phase II detectors

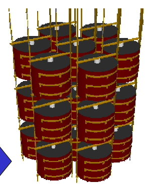
Custom-made detectors: true-coaxial n-type **prototype**

Already procured **37 kg of Ge enriched at 86% in ^{76}Ge** (Krasnoyarsk, Russia) for the production of the new crystals. Material stored underground to prevent cosmogenic activation

Designed a **suspension system** such that a minimum of material is used → under test

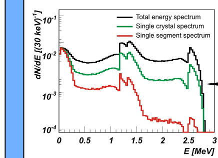
Crystals will be **segmented** (e.g. 18-fold, 6-fold in the azimuth angle φ, 3-fold in the height z) → **each segment read out separately**

Detectors placed in **hexagonal pattern** in strings of **three detectors each**



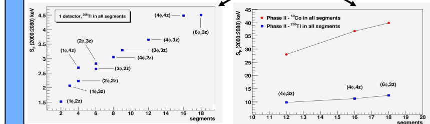
Background rejection with segmentation

Detector segmentation in phase II is a powerful background rejection tool



Background rejection due to crystal and segment **anti-coincidence** for ^{60}Co in germanium

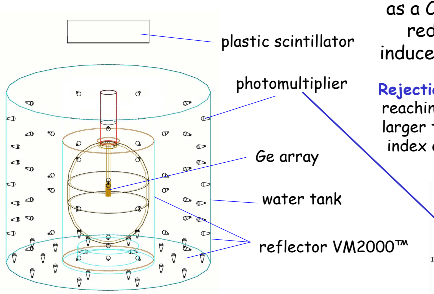
Study of background rejection for **several segmentation options**



Source	Crystals AC	Segments (6φ x 3z)
Muons	27	80
^{68}Ge in Ge	2.5	18
^{60}Co in Ge	3.2	39
^{60}Co in holder	6.7	157
^{208}Tl in Ge	2.6	13
^{208}Tl in holder	2.2	5

Suppression Factor @ $Q_{\beta\beta}$ due to anticoincidence between crystals and/or segments

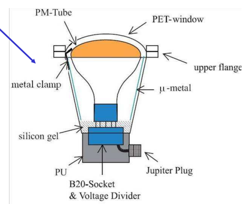
Cerenkov muon veto



80-100 8" PMTs mounted on the walls of the water tank. The walls of the cryostat and of the water tank are covered with **VM2000™ light-reflecting foils**

The water tank is operated as a Cerenkov muon veto, to reduce the background induced by **cosmic ray muons**

Rejection efficiency for muon events reaching the detector array must be larger than **90%** to get a background index of **10^{-4} counts/(keV kg y)** → **feasible**



Front-end electronics

To reduce background: **minimize mass** of component close to crystals → integrated front end.

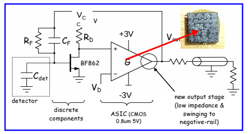
Two ASIC CMOS circuits under development and test

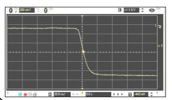
0.8 μm 5V CMOS single or differential ended preamp with: external input stage (JFET) or integrated input FET, external feedback components

Negative output voltage swing: ~ 2.4 V
Energy sensitivity (C_F = 0.15 pF) : ~ 185 mV/MeV after 50 Ω termination
Input dynamic range: ~ 6.5 MeV
Minimum ENC (C_{det}= 15pF) : 112 e$^-$ at t_{shap}=10μs
Total power consumption: ~ 25 mW
Rise time: ~ 15 ns driving 10m cable

ASIC CMOS preamplifier in LN bath

Tested circuit structure: external BF862 JFET + 0.8μm 5V CMOS single-ended preamplifier

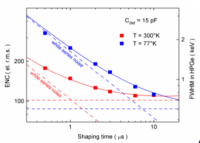




Acquired output signal driving a 50 Ω coaxial cable of ~ 10 m

First measurement results at T=77°K
(C_F = 0.15pF, R_F= 1GΩ, C_{det} = 15pF)

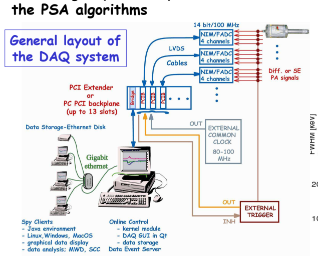
Comparison between noise measured at room temperature (T=300°K) and in LN (T=77°K)

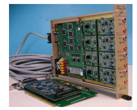


Digital DAQ system

- **pulse shape analysis** to reduce the background produced by **multi-site events**
- digital filters can improve **detector response** when signals are affected by **microphonics and/or high ripple**
- detector test and characterization
- building of **pulse shape databases for the PSA algorithms**

General layout of the DAQ system





Input Signals: SE or Diff.

Signal conditioning boards
Gain – jumpers
Offset – front panel screw
Signal polarity
Antialiasing (< 40 MHz)

PCI Boards/FPGA 32/64 bit

ADC boards 100 MHz/14 bit
ANALOG DEVICES AD6645

The digital sampling system

Results with a low-noise planar Ge detector