The Calibration System for the GERDA Experiment

Francis Froborg

University of Zurich

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University of Zurich

Outline

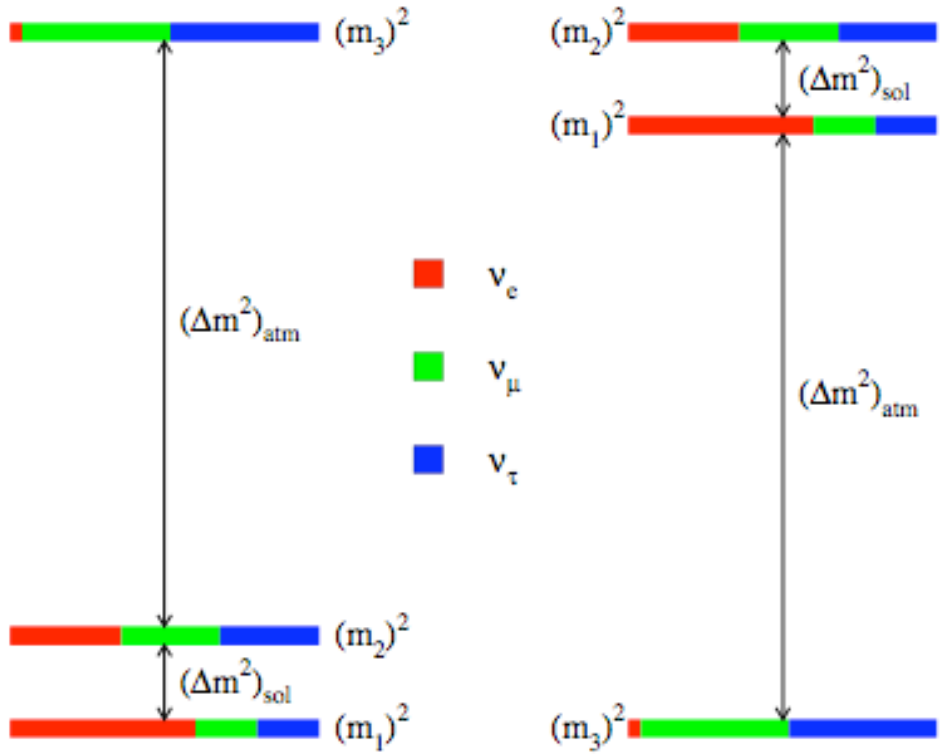
Status

We know

- Neutrinos have a mass
- Mass difference between eigenstates

The 3 big questions

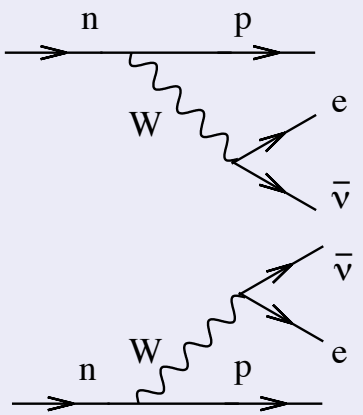
- Absolute mass scale
- Mass hierarchy
- Majorana vs. Dirac



Double Beta Decay

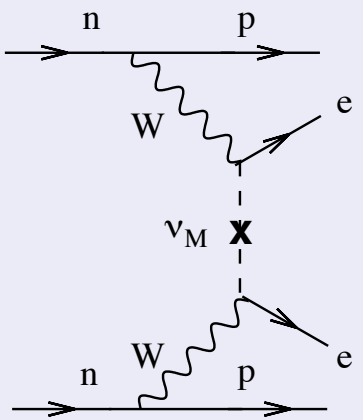
$2\nu\beta\beta$

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



$0\nu\beta\beta$

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



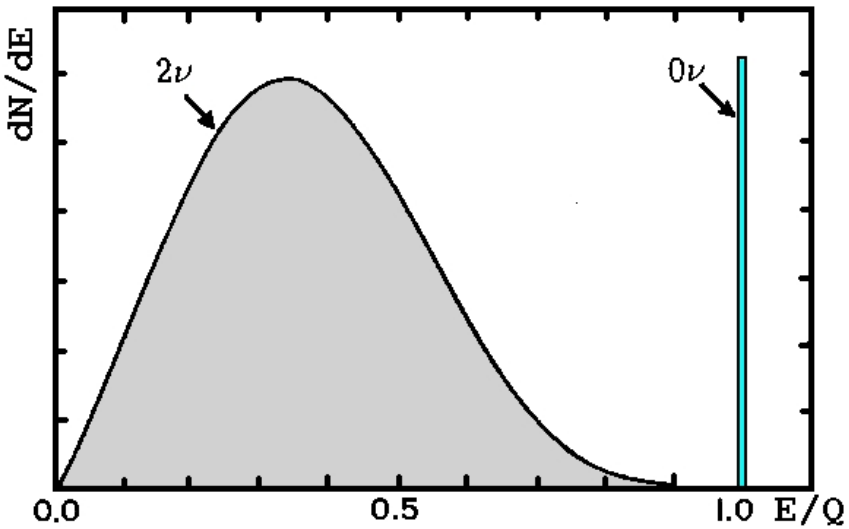
Signature

Measuring the energy of both electrons

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

$$Q = E_{e1} + E_{e2} - 2m_e$$

- Background reduction essential because of small half lives
- Schechter & Valle (1982): Measuring $0\nu\beta\beta \Rightarrow \nu$ Majorana particle



Heidelberg-Moscow Experiment

The Claim

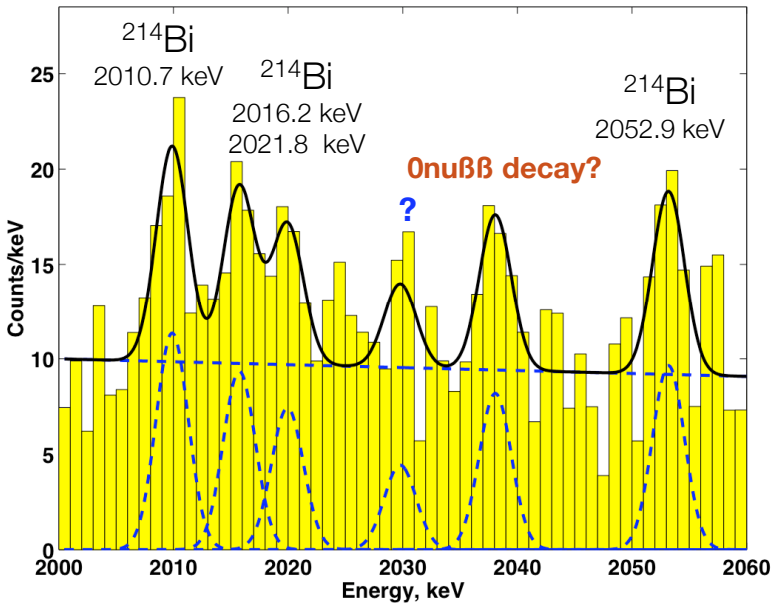
- 5 HPGe crystals with 71.7 kg y
- Peak at Q value:

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

- 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)

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

Phase I

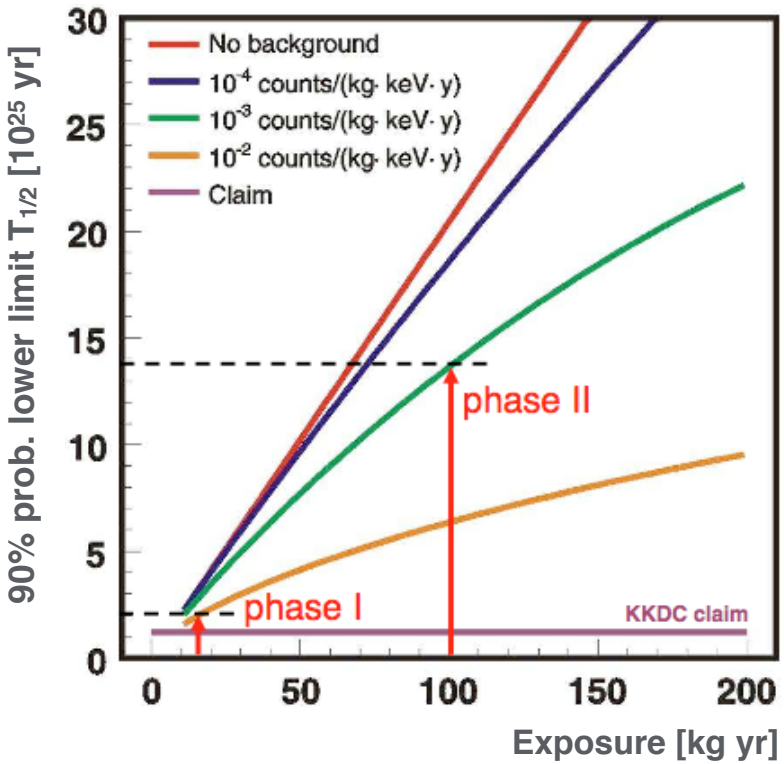
- 8 Hd-Mo & IGEX crystals (15 kg y)
- Background goal: 10^{-2} cts/kg/keV/y

$$\Rightarrow \quad T^{0\nu}_{1/2} > 2.0 \times 10^{25}\,\text{y}$$
$$\langle m_{\beta\beta} \rangle < 0.33\,\text{eV}$$

Phase II

- Phase I + 14 new crystals (100 kg y)
- Background goal: 10^{-3} cts/kg/keV/y

$$\Rightarrow \quad T^{0\nu}_{1/2} > 14 \times 10^{25}\,\text{y}$$
$$\langle m_{\beta\beta} \rangle < 0.13\,\text{eV}$$



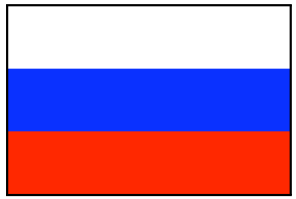
The Collaboration

ITALY
INFN LNGS, Assergi
Univ. di Milano Biocca e INFN
Univ, di Padova e INFN

GERMANY
MPI Heidelberg
MPI München
TU Dresden
Universität Tübingen

BELGIUM
IRMM, Geel

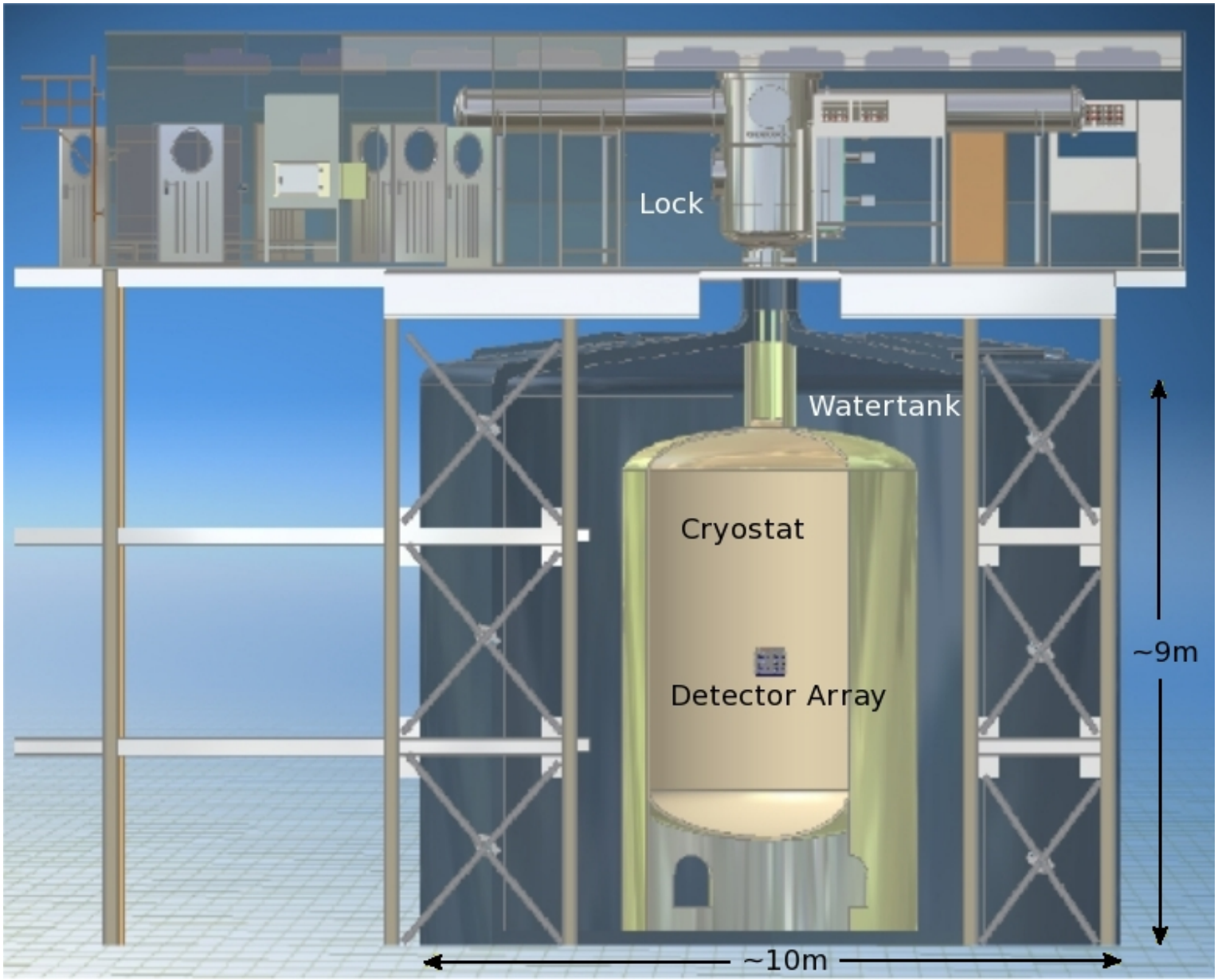
RUSSIA
INR, Moscow
ITEP Physics, Moscow
Kurchatov Institute, Moscow
JINR Dubna



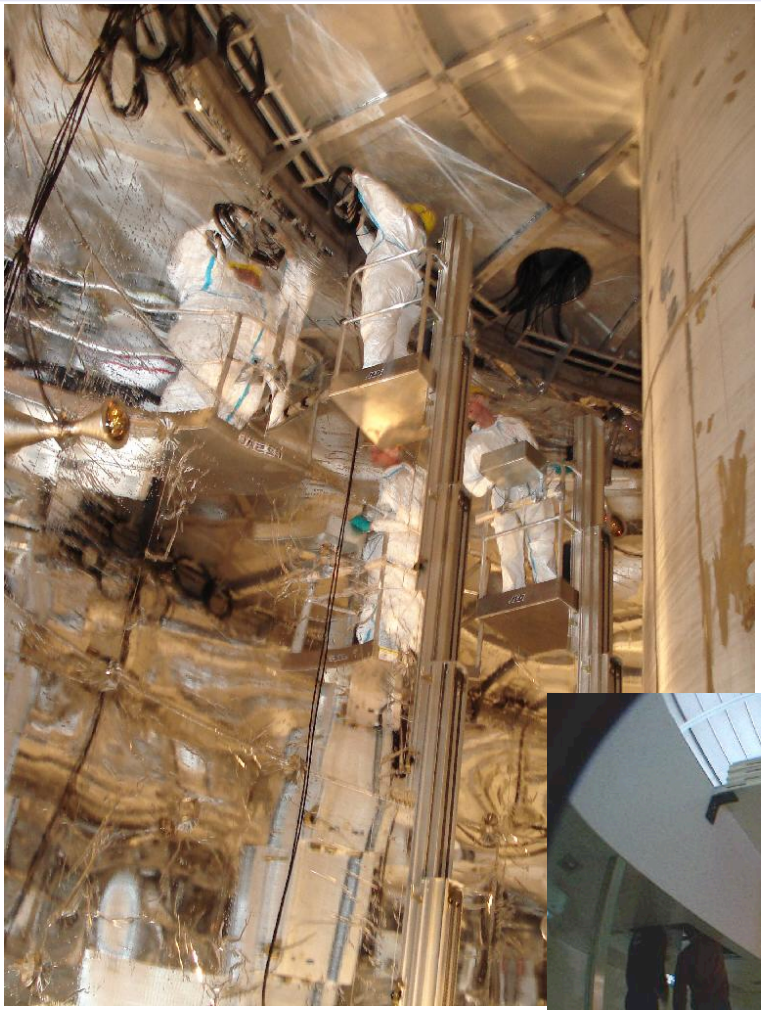
POLAND
Jagiellonian University, Cracow

SWITZERLAND
University of Zurich

Overview



Status of the Experiment



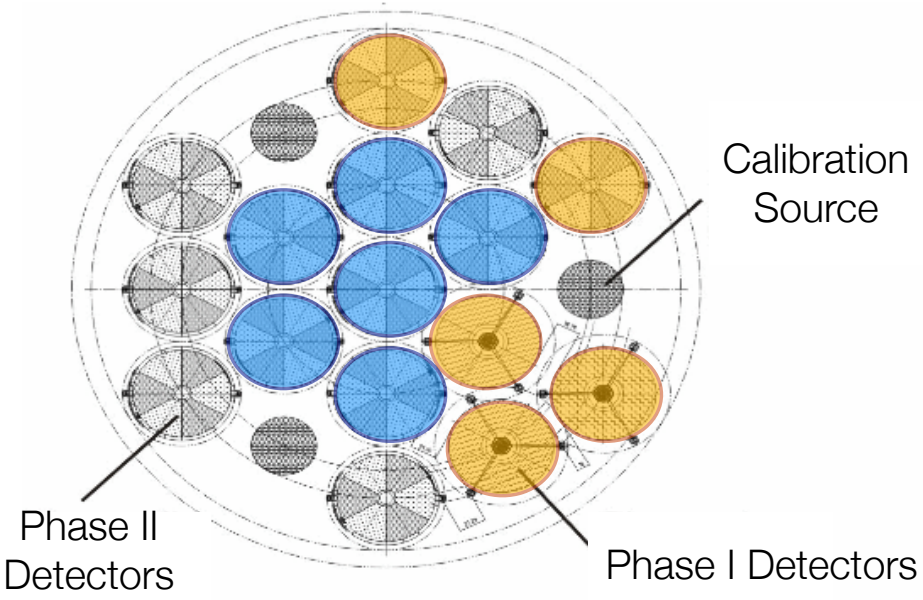
The Calibration System

Boundary Conditions

- Fixed positions of the sources
- Maximum radius $\sim$ 4cm
- Minimum weight $\sim$ 3kg
- Parking position in the lock of the detector

Goals

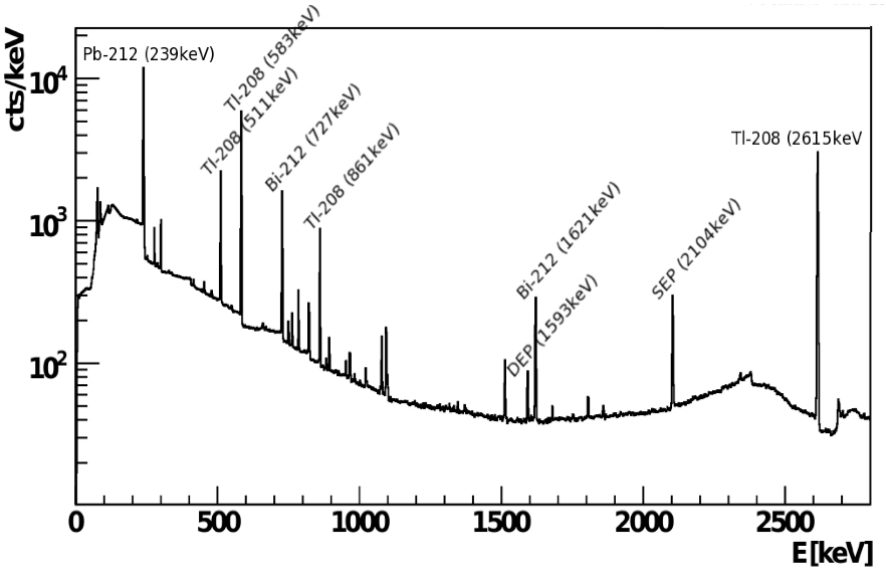
- Type and strength of calibration sources
- Absorber material and geometry
- Efficiency of energy deposition in each detector
- Efficiency of pulse shape analysis



Type of Source

Requirements

- Enough lines up to $\sim$ 3000keV for energy calibration
- Line close to Q-value at $E = 2039$keV
- Double escape peak for pulse shape calibration
- Half life of 1.5 years or longer



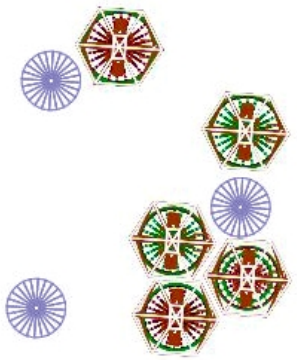
Tests

Monte Carlos of ^{56}Co, ^{238}U, ^{152}Eu, ^{228}Th

z Position

- Position non-trivial due to different detector sizes
  $\Rightarrow$ MCS with different z positions
- Analysis of statistics in
  - single escape peak $\longrightarrow$ close to Q-value
  - double escape peak $\longrightarrow$ PSA

  for each single detector
- Optimization of overall statistics as well as events in detector(s) with worst statistics



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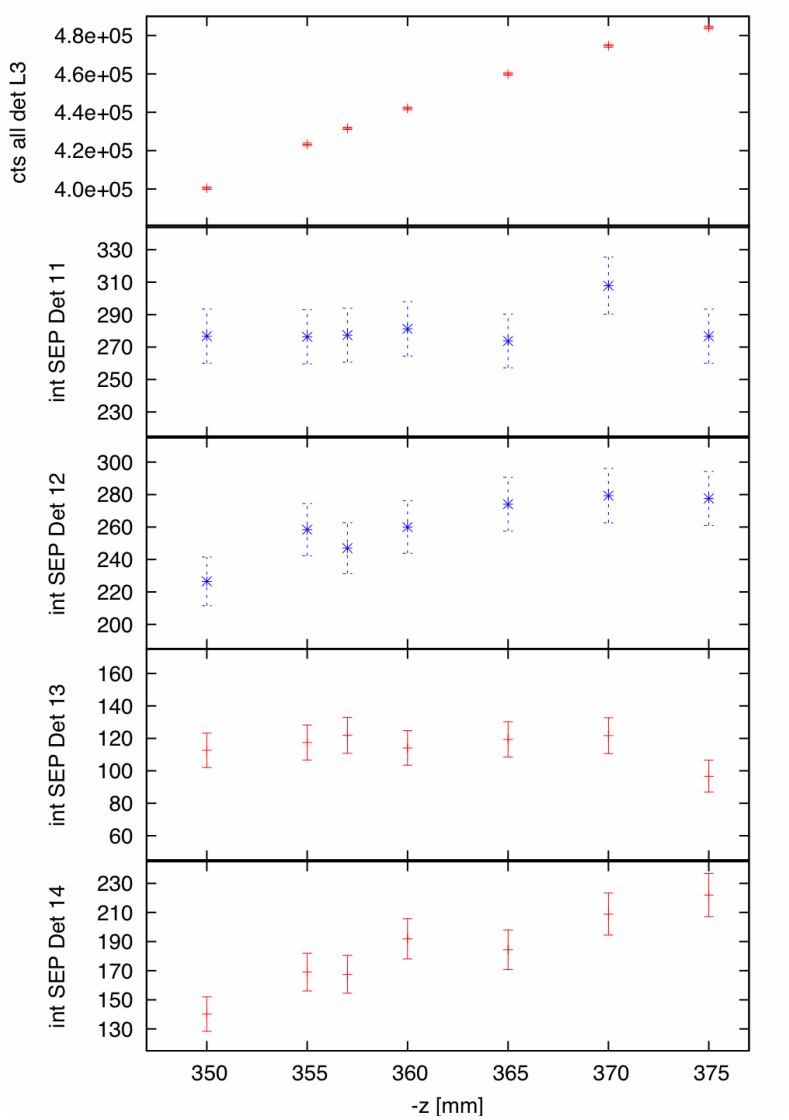
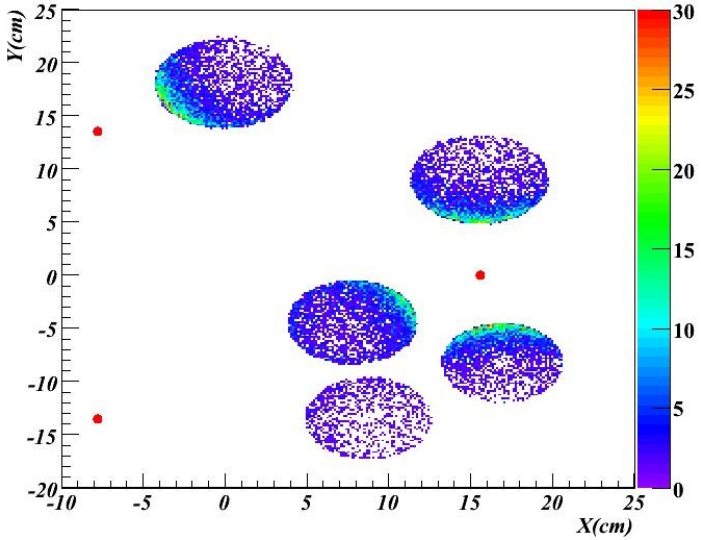


Minimum Source Strength

Investigating statistics in DEP und SEP

- Peak:Backgrd in SEP sufficient for energy calibration
- Peak:Backgrd in DEP problematic for pulse shape calibration
- Investigations ongoing how to improve DEP statistics



	15×10^7	12×10^7	9×10^7	6×10^7	3×10^7
# Events	2721	2160	1637	1073	547
SEP	4.4	4.5	4.4	4.5	4.5
DEP	2.0	2.0	1.9	2.0	2.1
DEP 2σ	2.9	2.9	2.8	2.8	3.0

9×10^7 decays sufficient

$\Rightarrow$ 3 Sources with $A = 20$kBq and runtime of 25 min per layer

Mockup

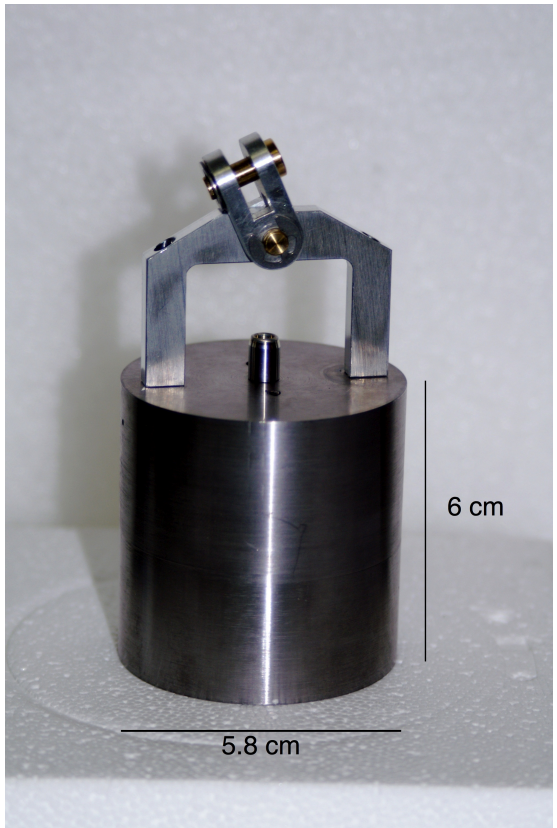
Absorber

- Requirements: High density, high radio purity, machinable
- Screenig of W, Densimet, Ta
- Ta lowest radioactivity, no α-n reactions in material

Mockup

- 20 thermal cycles with LN
- 2 slow immersion tests

$\Rightarrow$ No problems so far!



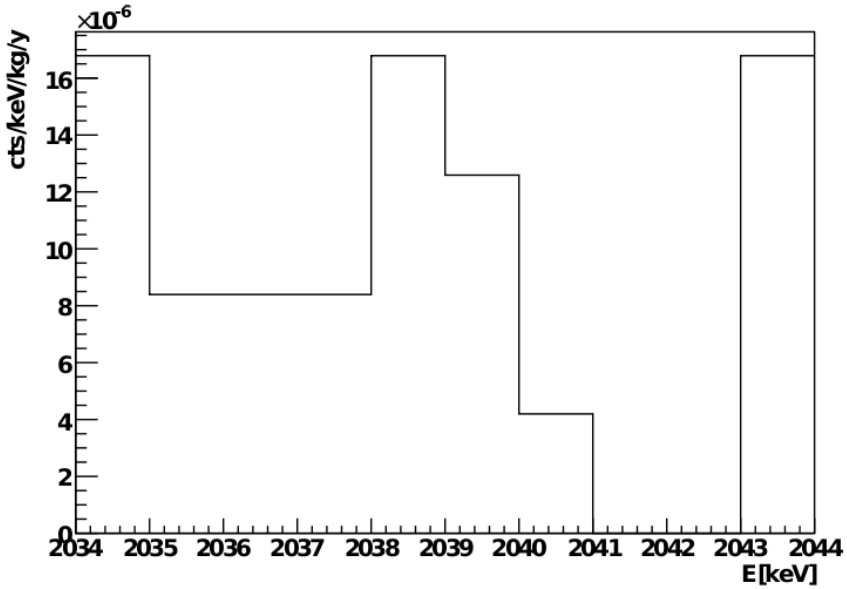
γ Background

Analytical Estimate

- Linear attenuation: $\phi = \phi_0 e^{-d/l}$
- LAr: $d = 280\text{cm}$, $l = 20.69\text{cm}$
- Tantalum: $d = 6\text{cm}$, $l = 1.48\text{cm}$

Monte Carlo Simulation

- Get spectrum in region of interest
- Naked source
- Activity scaled according linear attenuation

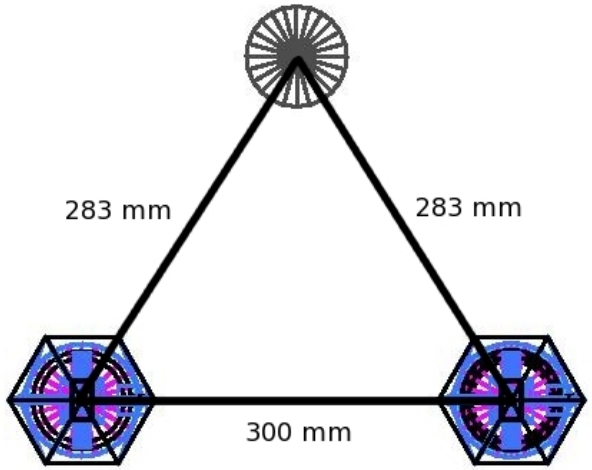


Background for 3 sources with $A = 20\text{kBq}$ in region of interest

$$B(\text{cts/kg/keV/y}) = 1.1 \pm 0.6(\text{stat.})\, 10^{-4}\,\text{cts}$$

Commissioning Lock

- Delay of final lock
- New geometry
  - Just one source
  - Larger distances between source and detectors



Final	12×10^7	9×10^7	6×10^7	3×10^7	3×10^7	CLock
# Events	2160	1637	1073	547	118	# Events
SEP	4.5	4.4	4.5	4.5	3.8	SEP

First Results

Significantly lower statistics in detectors (Factor $\sim$ 4.5)
$\Rightarrow$ Stronger source and/or longer run needed

Outlook

Delay due to earthquake on April 6 in L'Aquila

	Phase I	Phase II
June 2009	Clean room and lock	Tests for crystal pulling (IKZ, Berlin)
November 2009	**Start taking data**	Natural Ge test detectors
June 2010	Final lock	
February		Crystal growing of enriched Ge
June 2010		^{76}Ge detectors (Canberra)
November 2010		**Start taking data**

Summary

GERDA

- Potential to answer all 3 important questions in ν physics
- Start taking data $\sim$ Nov 2009

Status of Calibration System

- Phase I: Three ^{228}Th sources with $A = 20$kBq
- γ background $B(\text{cts/kg/keV/y}) = 1.1 \pm 0.6(\text{stat.})\, 10^{-4}$ cts
- Further investigations for pulse shape calibration needed
- Further investigations for comm lock needed
- Mockup tests successful so far