Data analysis and simulations for GERDA

Doktorandentag 2012

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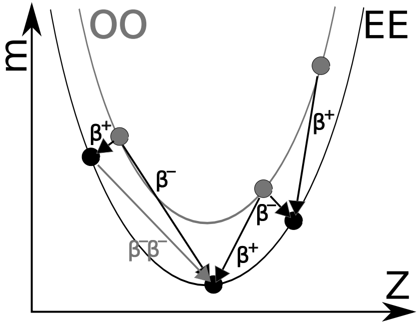
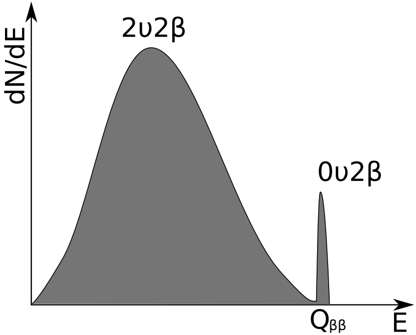
The Double Beta Decay



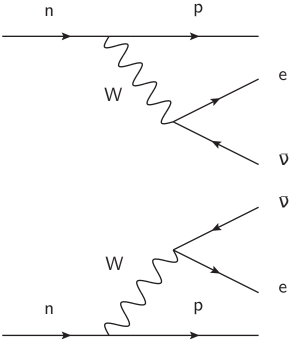
Energy scheme for the double decay



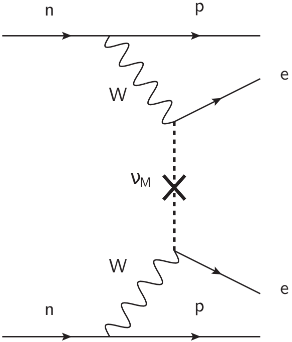
$2\nu 2\beta$ *and* $0\nu 2\beta$ *theoretical spectra*

Two neutrino double beta decay ($2\nu 2\beta$)

- Visible if single beta decay energetically forbidden;
- Experimental signature: continuum from 0 to the Q-value.
- Measured in some dozen of isotopes, halflives $> 10^{18}$ years.



$2\nu2\beta$ decay



$0\nu2\beta$ decay

Neutrinoless double beta decay ($0\nu2\beta$)

- Forbidden by the Standard Model, violates the lepton number conservation.
- Possible only if neutrinos are Majorana particles, i.e. $\nu = \bar{\nu}$
- Signature: spectral peak at the Q-value.
- Halflives $> 10^{23}$ years.

The GERDA experiment

- GERDA = **Ger**manium **D**etector **A**rray
- Goal: search for $0\nu2\beta$ decay in $^{76}\mathrm{Ge}$.
- Strategy: enriched germanium crystals as both source and detector.

- Located at the Gran Sasso Laboratory under 3800 meter of water equivalent
- Multi-layered shield: water tank, copper, Liquid Argon (LAr)
- Ge detectors immersed naked in LAr

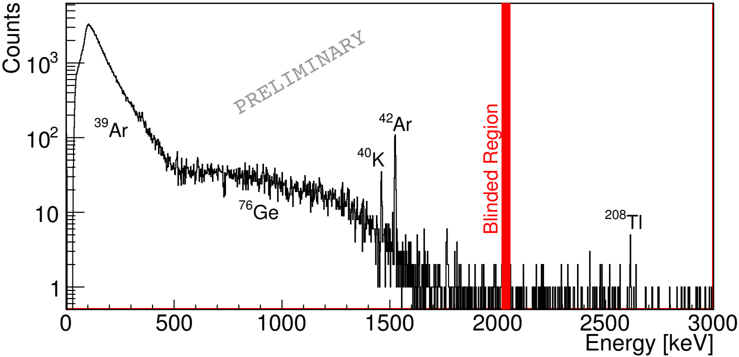
GERDA Phase I

- 18 kg of Ge detectors previously used in other experiments
- Background Index (BI) 10^{-2} counts/(keV $\cdot$ kg $\cdot$ yr)
- Sensitivity: $\langle m_{\beta\beta} \rangle \leq 0.23 - 0.39$ eV;
- $\mathrm{T}_{1/2}^{0\nu 2\beta} \geq 2 \cdot 10^{25}$ yr

$$\left(T_{1/2}^{0\nu 2\beta} \right)^{-1} = F |M|^2 \langle m_{\beta\beta} \rangle^2$$

GERDA Phase II

- Add $20 - 25$ kg of new generation Broad Energy Germanium detectors (BEGe);
- BI $\simeq 10^{-3}$ counts/(keV $\cdot$ kg $\cdot$ yr);
- $100\ \mathrm{kg} \cdot \mathrm{yr}$ exposure;
- Sensitivity: $\langle m_{\beta\beta} \rangle \leq 0.09 - 0.15$ eV;
- $\mathrm{T}_{1/2}^{0\nu 2\beta} \geq 1.5 \cdot 10^{26}$ yr.



Experimental spectrum taken by GERDA in the first 7 months of Phase I

First results of GERDA

- 9 $\mathrm{kg} \cdot \mathrm{yr}$ exposure (since November 2011);
- BI $= 2 \cdot 10^{-2}$ $\mathrm{counts}/(\mathrm{kev} \cdot \mathrm{kg} \cdot \mathrm{yr})$;
- BI improvable with application of Pulse Shape Discrimination;
- Energy spectrum blinded in the [2019 – 2059] keV;
- $\mathrm{T}_{1/2}^{2\nu2\beta} = 1.88 \pm 0.10 \cdot 10^{21}$ years (PRELIMINARY)

Analysis of calibration data

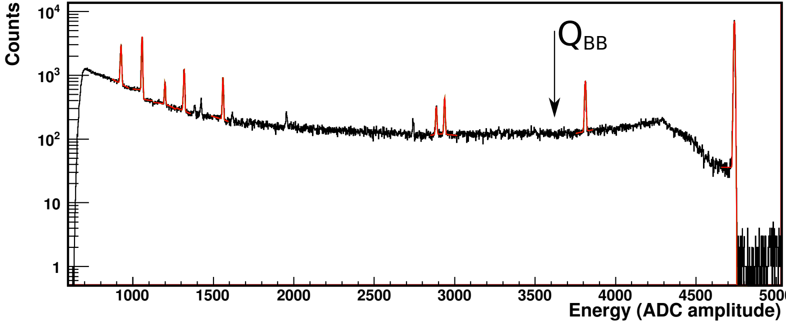
- Problem: complex experiment $\rightarrow$ possible instabilities (long cables, temperature variations, ...)
- Solution: pulser monitoring + bi-weekly calibrations with $^{228}\mathrm{Th}$ source

Calibration procedure in GERDA

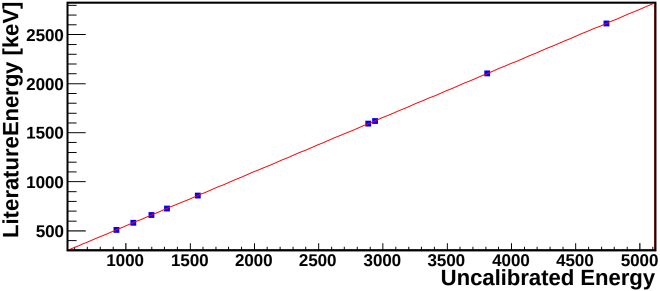
- 3 calibration sources lowered from above to the vicinity of the detectors
- $2-3$ hour exposure
- Calibration run taken after each modification in the setup or any hint of instability given by the pulser
- Need to perform the data analysis as soon as possible not to lose physics data!

Calibration script

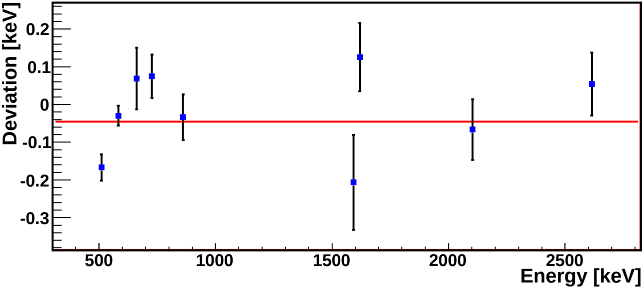
- Fully automatic script was developed to analyze the calibration data
- Output: calibration curves, resolution curves, parameters for quality cuts
- Calibration parameters also used to study stability properties



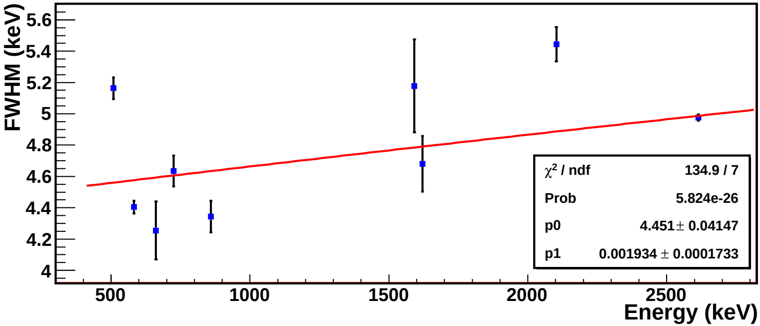
Uncalibrated spectrum recorded using ^{228}Th sources.



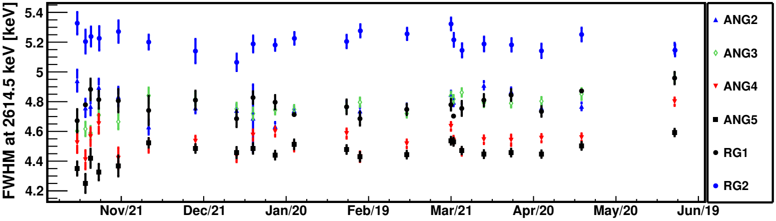
Calibration curve extracted from a ^{228}Th spectrum



Residuals of the peaks from a 2^{nd} degree polinomial

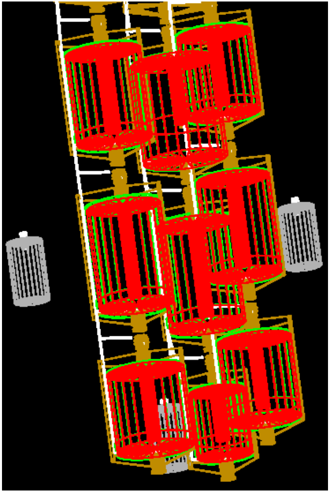


Resolution as function of energy



Resolution as function of time for all the GERDA detectors

Simulations of calibrations



Aim of simulations

- Cross check the Majorana-GERDA simulation framework (MAGE)
- Estimate detector positions in GERDA
- Estimate ratio of Single Site Events (SSE) vs Multi Site Events (MSE) for Pulse Shape Analysis
- Estimate thickness of detector deadlayers
- Estimate best sources configuration for Phase II

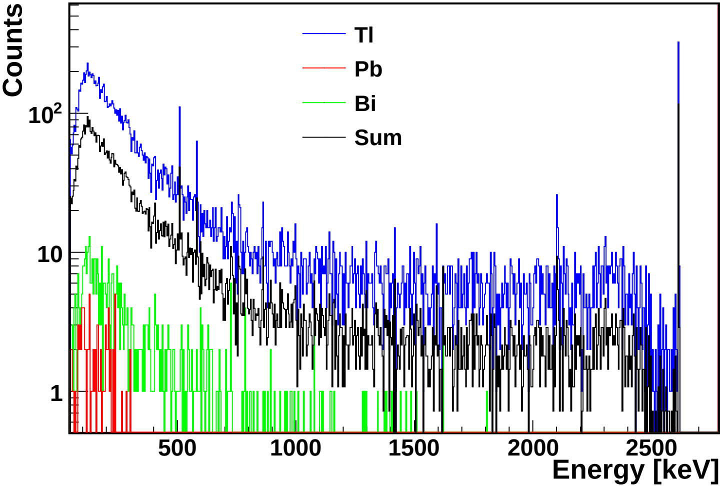
MC

- Simulate only gamma emitters of Thorium chain: $^{212}\mathrm{Pb}$, $^{212}\mathrm{Bi}$, $^{208}\mathrm{Tl}$
- Simulate 10^7 events for each isotope
- Merge simulated spectra according to the branching ratios
- Smear simulated spectra according to detector energy resolution

Data

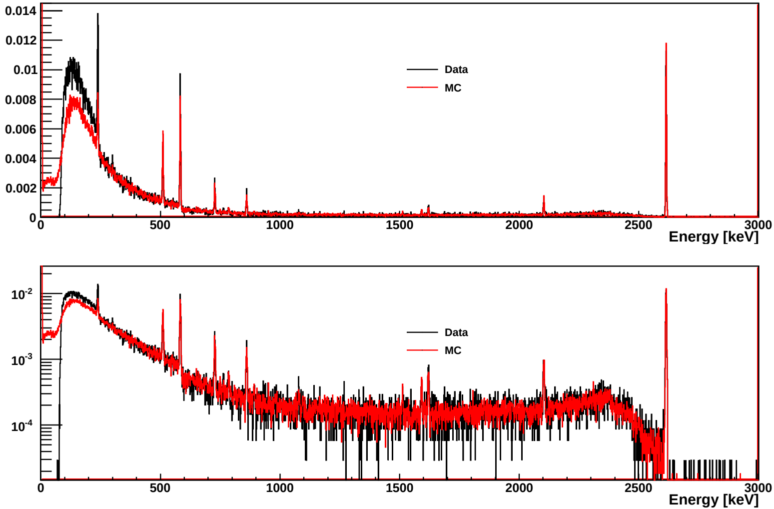
- Use calibration data taken only with one of the three sources
- Select data taken when the sources are not moving

Sum of simulated spectra

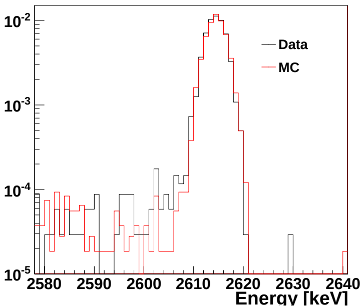


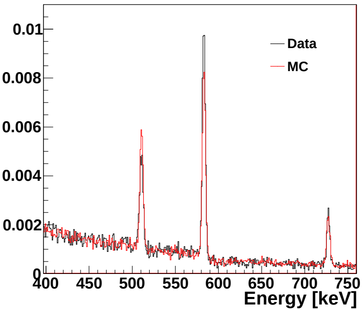
Spectra of all the simulated isotopes of the ^{228}Th chain and their weighted sum

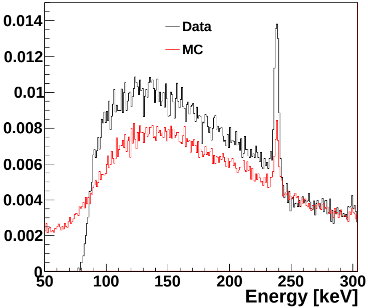
Comparison of data and MC



Experimental and simulated calibration spectra normalized in the $100 - 3000$ keV region.

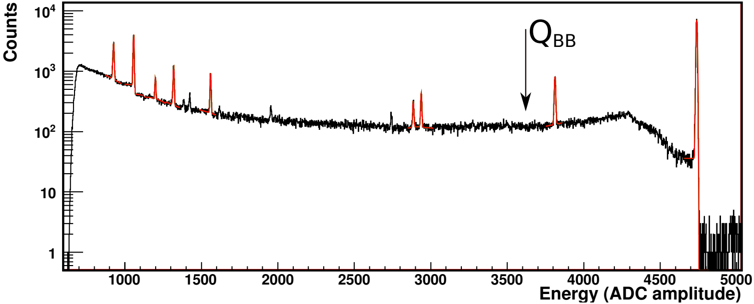


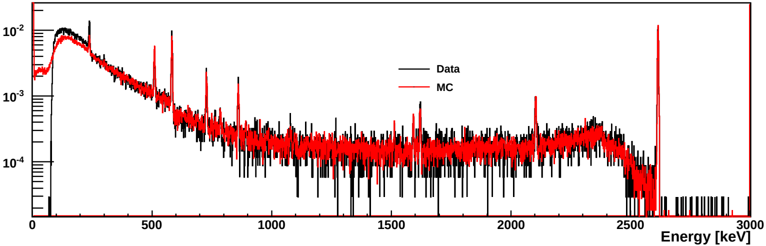




- Good agreement above 300 keV
- Disagreement at low energy → Deadlayer effect? Further investigation needed...

conclusion


Counts
10^4
10^3
10^2
10
1
Q_{BB}
1000
1500
2000
2500
3000
3500
4000
4500
5000
Energy (ADC amplitude)


10^{-2}
10^{-3}
10^{-4}
Data
MC
0
500
1000
1500
2000
2500
3000
Energy [keV]