

Coincidence measurements for GERDA Phase II

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Some open questions we try to shed light on

- What is the mass of the neutrinos?
- Normal or inverted neutrino mass hierarchy?
- Are neutrinos Majorana or Dirac particles?
- Which physics beyond the Standard Model?



Some open questions we try to shed light on

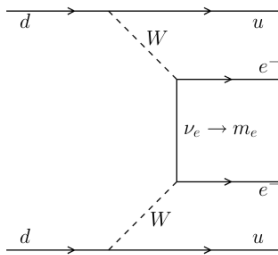
- What is the mass of the neutrinos?
- Normal or inverted neutrino mass hierarchy?
- Are neutrinos Majorana or Dirac particles?
- Which physics beyond the Standard Model?

Search for the $0\nu\beta\beta$ decay

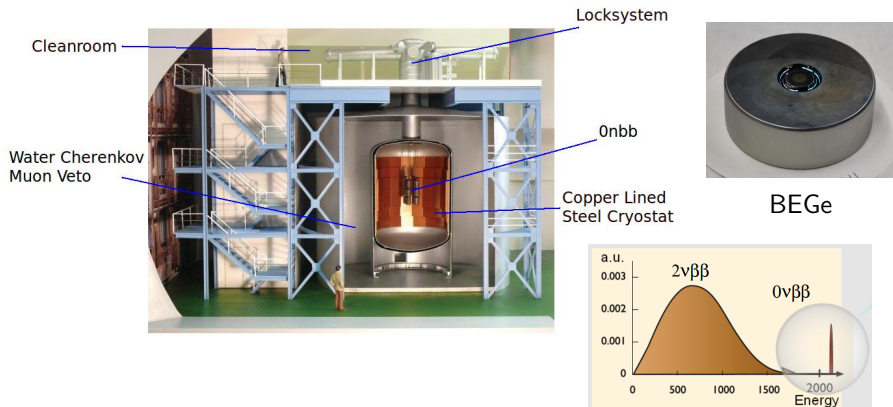
$$\mathcal{N}(A,Z) \rightarrow \mathcal{N}(A,Z+2) + 2e^- \quad (\mathcal{H}/2\nu_e)$$

- Lepton number violating $\Delta L = 2$

⇒ Physics beyond the standard model



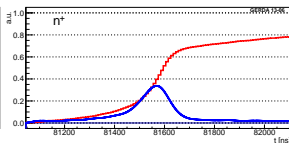
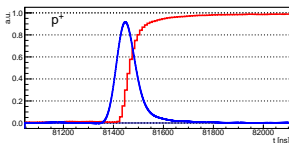
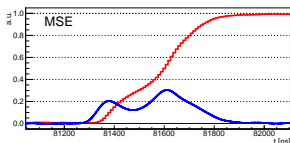
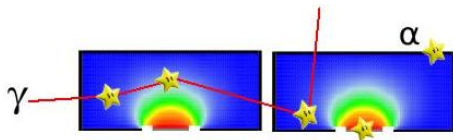
The GERDA experiment



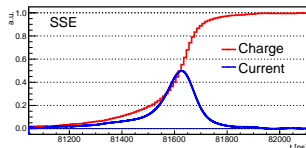
Phase I $T_{1/2}^{0\nu\beta\beta} > 2.1 \cdot 10^{25}$ yr 90% C.L. (med. sens. $T_{1/2}^{0\nu\beta\beta} > 2.4 \cdot 10^{25}$ yr)

Phase II 30 new detectors + **improve background rejection**

Pulse shape analysis to reduce background

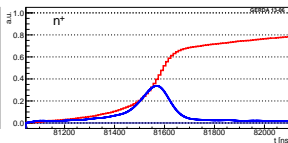
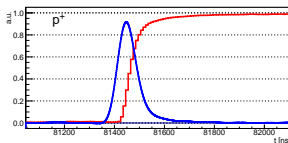
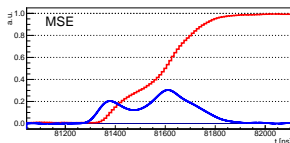
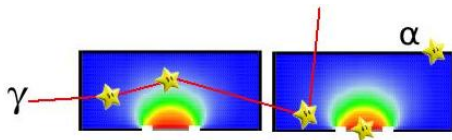


background



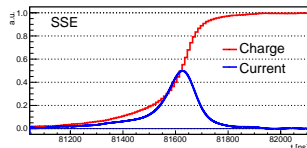
signal

Pulse shape analysis to reduce background



background

- Recognize and reject background events
- We want to know how signal like events look like in the detector



signal

Single compton events with coincidence measurements

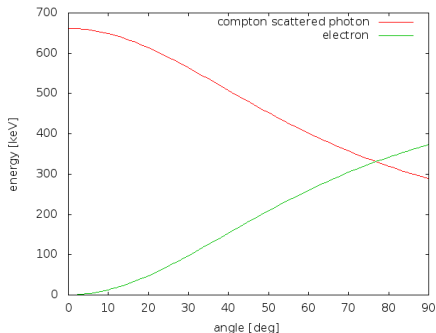
Energy compton scattered photon

$$E'_\nu = E_\nu \left(1 + \frac{E_\nu}{m_e c^2} (1 - \cos \Theta) \right)^{-1}$$

Energy electron

$$E_e = E_\nu - E'_\nu$$

661 keV γ s from a ^{137}Cs source

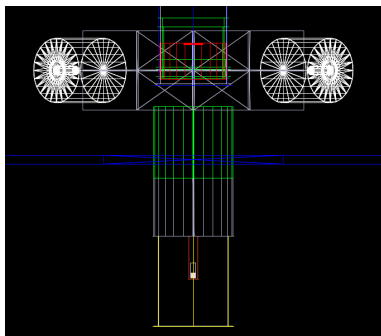
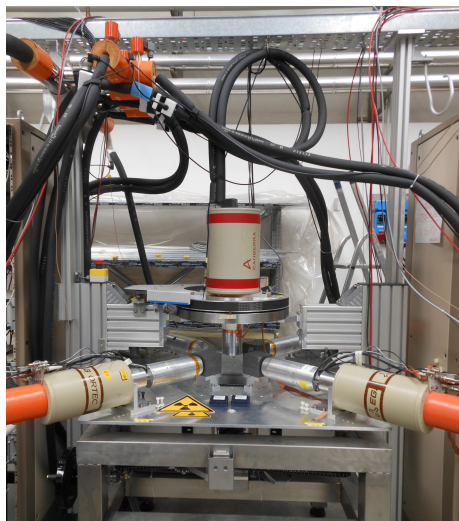


- Coincidence measurements
- Depending on the observation angle cut on energy to select single compton events
- ⇒ Parameters A/E, rise-time etc.
- ⇒ Neural network, pulse shape library

LEGO... LEgnaro Germanium Observatory



LEGO @ Laboratori Nazionali di Legnaro



MC geometry

⇐ Automatic filling every 14 h

Remote control

(on calliope)

Update Configure Log Messages

stop start

No. of Events: 0 File Name: Digi Event Display >>

Digitizer Run Status on undefined

DAQ is **STOPPED** 0.0000 Hz Ch. 0 Samples

Started on Thu, 19 Jun at 17:27:54 Collected 0 events out of 0 Ch. 1 0

Stopped on Thu, 19 Jun at 17:27:54 Logged into File unknown Ch. 2 Buffers

Ch. 3 0

Digitizer Configuration Handling (on calliope)

Enable	Threshold	Edge	Offset
<input type="checkbox"/> Ch. 0	0x 1f5e	Falling	0x 8000
<input type="checkbox"/> Ch. 1	0x 2026	Falling	0x 8000
<input type="checkbox"/> Ch. 2	0x 24cc	Falling	0x 8000
<input checked="" type="checkbox"/> Ch. 3	0x 1fcc	Falling	0x 8000

DAQ Parameters

Samples: 128 us

Buffers: 327

PostTrigger: 50 %

Coincidence: 1 channels

Trigger Source

Ch. 0 Software

Ch. 1 at 10 Hz

Ch. 2

Ch. 3 External

Output Trigger

Ch. 0 Software

Ch. 1 Daq Trigger

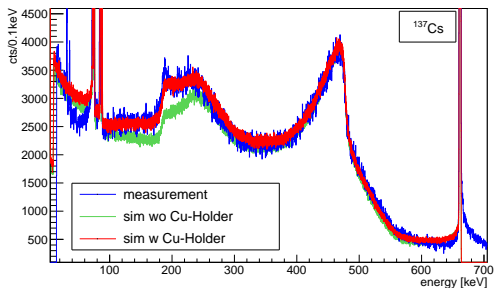
Ch. 2

Ch. 3

Get Configuration Load Configuration

Everything is remote controllable

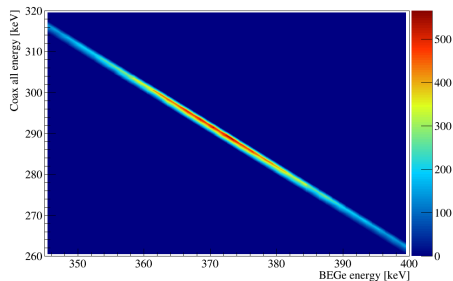
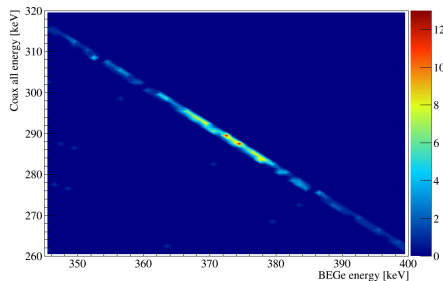
Tuning the MC simulations



^{137}Cs Spectrum

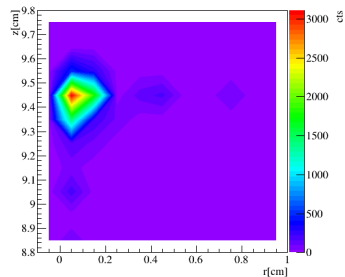
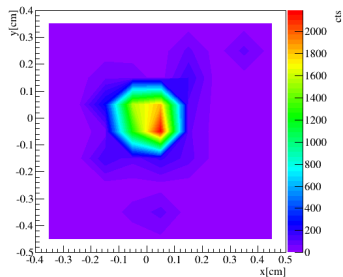
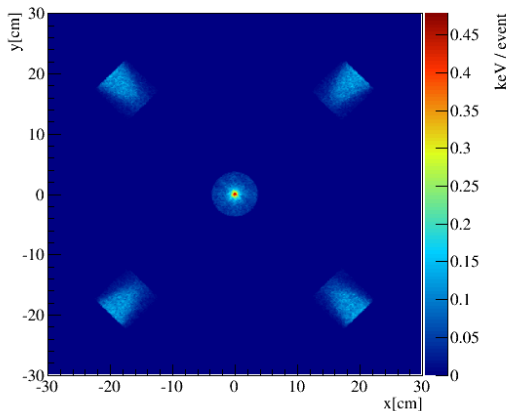
- Comparison of uncollimated measurement and simulation
- Adding copper holder improves accordance

Collimated simulation

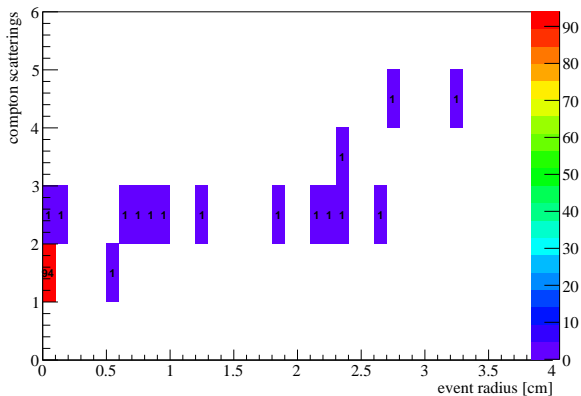


- Coaxial detectors collimated to 1 mm (left) and 10 mm (right)

Confinement of the events



Signal and Background events



- About 85% are single compton events

Rate... Events where are thou?

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- Events
- ✓ right energy
- ✓ confined in roughly $3 \times 3 \times 3$ mm region
- ✓ roughly 85% are single compton events

Rate... Events where are thou?

- Events
 - ✓ right energy
 - ✓ confined in roughly 3x3x3 mm region
 - ✓ roughly 85% are single compton events
- Event rate is on the order of $1 \text{ MBq}^{-1} \text{ d}^{-1}$

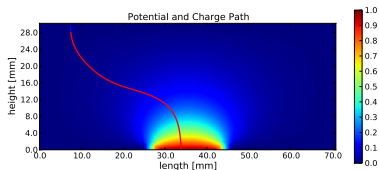
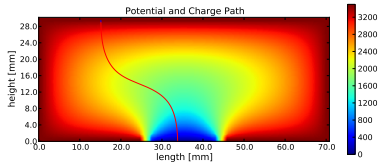
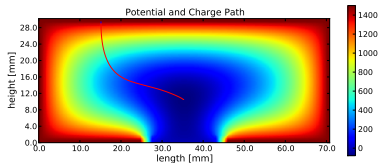
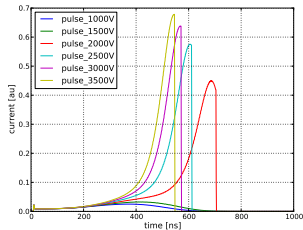
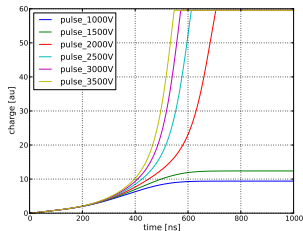
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- Event rate is on the order of $1 \text{ MBq}^{-1} \text{ d}^{-1}$
- We can use a 740 MBq ^{137}Cs source

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 - ✓ confined in roughly 3x3x3 mm region
 - ✓ roughly 85% are single compton events
- Event rate is on the order of $1 \text{ MBq}^{-1} \text{ d}^{-1}$
- We can use a 740 MBq ^{137}Cs source
- ! Careful
- ! Single rate cannot be too high \Rightarrow pile-up
- ! We cannot handle the source ourselves and need additional shielding

Pulse shape simulations using adl3

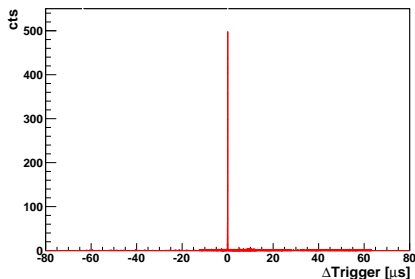


Summary

- Background suppression with PSA is essential for Gerda Phase II
- Coincidence measurements to learn how Single Site events look like
- LEGO has been set up and is ready to go
- Compare with PS simulations
- Build a new method to do PSA and cross check other methods

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Δ trigger of a ^{22}Na measurement

Thanks for your attention!

