Study of Reconstruction Precision of Double Beta Decay Vertex for SuperNEMO Demonstrator

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2.6.2017, Prague, MEDEX’17 meeting
Presentation plan

• SuperNEMO and Falaise
• Precision of vertex resolution
• RMS and FWHM method
• Results
• Conclusions
SuperNEMO and Falaise
SuperNEMO experiment

- Modular geometry (20 modules)
- Planned start: 2017
- Placed in LSM (Modane, FRA)
- Studied isotope: $^{82}$Se

- 7 kg of isotope (100+ kg*)
- $0\nu\beta\beta$: $T_{1/2} > 6 \times 10^{24}$ yr ($10^{26}$ yr*).
- Limit $m_{\beta\beta}$: 0.2-0.4 eV (0.04-0.11 eV*).

* Full SuperNEMO design = 20 modules
Photos of SuperNEMO demonstrator

Tracker

Calorimeter wall

Clean tent from outside
Falaise

- Software package developed by SuperNEMO software group
- Based on Geant4
- `flsimulate`, `flreconstruct`, `flvisualize`
- `simulation` -> `mock calibration` -> `user module`

- Includes full geometry of module
Precision of vertex reconstruction
CAT & filtration criteria

- **CAT** (Cellular Automaton Tracker) is a **reconstruction algorithm** for electron tracks for SuperNEMO.
- In optimal case there are **two** electron **tracks**, each with one **vertex on foil** and one **vertex on calorimeter**.
- In simulated set of events we look only for „**nicely looking events“**.
- What are **my criteria** for „nice looking event“?
  - **2 calorimeter hits**
  - **2 associated calorimeter hits**
  - **2 foil vertices**
  - **2 reconstructed particles**
  - **2 negatively charged particles**
- Only if event fulfilled **all of the criteria** it was **kept** by pre-filter.
- In case of 2νββ only roughly 10,4 % of events are kept.
SuperNEMO module coordinate system
Description of the problem

\[ \Delta y = y_1 - y_2 \]

(\[ \Delta z = z_1 - z_2 \])
Δy and Δz values

- Main interest of my work is the **precision of foil vertex** reconstruction by CAT.
- In ideal case vertices **should be at the same point, they are not** (experimental uncertainties).
- Δy and Δz values were calculated for every event after pre-filtration.
- They form **two statistical sets** with some distribution and standard deviation.

![Graph showing precision in y direction in bin (1250, 250)](image)

- Precision in y direction bin (1250, 250)
  - **y**: 1250, 250
  - **Entries**: 99167
  - **Mean**: 0.07434
  - **RMS**: 30.24

- **Real vertex**
  - Δy = y1 - y2 (Δz = z1 - z2)

- 1 cm
RMS and FWHM method
Methodology

- "RMS" \( (\sqrt{<\Delta y^2> - <\Delta y>^2}) \) of this distribution = "RMS precision"
- Condition: \(|\Delta y|, |\Delta z| < 300 \text{ mm}\)

- Fitting and extraction of FWHM = "FWHM precision"

- Aim was to study precision **in dependence on electron energy and magnetic field**.
- Before calculation of precision of \( \Delta y \) and \( \Delta z \) I categorized events into **2D bins** depending on **energy of individual electrons**.
- I calculated both precisions (RMS and FWHM) for every bin.
- **Upper limit** on single electron energy was chosen to 1500 keV.
- I used two types of binning 3x3 and 10x10.

- Values for magnetic field were chosen as follows: 0G, 5G, 10G, 15G, 20G, 25G, 30G, 60G.
- I generated **2.4x10^7 events** of \( 2\nu\beta \) of \(^{82}\text{Se}\) with Falaise for **each data set** of different value of magnetic field.
3x3-binning results
RMS precision in y-direction

RMS precision in z-direction

Number of events per bin for y

FWHM precision in y-direction

FWHM precision in z-direction

0 G

Precision [mm]
5 G

Precision [mm]
RMS precision in y-direction

RMS precision in z-direction

Number of events per bin for

10 G

Precision [mm]
RMS precision in y-direction

RMS precision in z-direction

Number of events per bin for y

FWHM precision in y-direction

FWHM precision in z-direction

15 G

Precision [mm]
RMS precision in y-direction

RMS precision in z-direction

Number of events per bin for y

FWHM precision in y-direction

FWHM precision in z-direction

20 G

Precision [mm]
RMS precision in y-direction

RMS precision in z-direction

Number of events per bin for y

FWHM precision in y-direction

FWHM precision in z-direction

25 G

Precision [mm]
RMS precision in y-direction

RMS precision in z-direction

Number of events per bin for y

FWHM precision in y-direction

FWHM precision in z-direction

30 G

Precision [mm]
RMS precision in y-direction

RMS precision in z-direction

Number of events per bin for y

FWHM precision in y-direction

FWHM precision in z-direction

60 G

Precision [mm]
10x10-binning results
RMS precision in y-direction

RMS precision in z-direction

Number of events per bin for y

FWHM precision in y-direction

FWHM precision in z-direction

0 G

Precision [mm]
5 G
Precision [mm]
RMS precision in y-direction

RMS precision in z-direction

Number of events per bin for y

FWHM precision in y-direction

FWHM precision in z-direction

10 G

Precision [mm]
RMS precision in y-direction

RMS precision in z-direction

Number of events per bin for y

15 G

Precision [mm]
RMS precision in y-direction

RMS precision in z-direction

Number of events per bin for y

FWHM precision in y-direction

FWHM precision in z-direction

20 G

Precision [mm]
25 G

Precision [mm]
RMS precision in y-direction

RMS precision in z-direction

Number of events per bin for y

FWHM precision in y-direction

FWHM precision in z-direction

60 G

Precision [mm]
Precision is **worse** for lower energies.

Precision is the best in the region of 15G – 25G.
RMS is sensitive to limits of $\Delta y$ ($\Delta z$)!

RMS precision is in general worse than FWHM precision.

Precision [mm]
e$^{-}$ energies [keV]
RMS = 30.24 mm

RMS = 26.4 mm

RMS = 21.75 mm

RMS = 15.98 mm
Conclusions

- The best invariant method to evaluate precision is *fitting*.
- The precision using **FWHM** method is changing *negligibly with magnetic field*.
- **RMS** method can be used in case **upper and lower limit** is given.
- RMS From **0G to 20G** precision **get better** and **towards 60G** it **drops** again.
- Future work: To study dependence on the angle between electrons.
Thanks for attention!
Backup
Gauss vs. Lorentz

- Fitting is not so dependent on the distribution tails as RMS.
- **Lorentzian fit** seems to describe datasets more suitably.
- FWHM = 2\(\gamma\) => FWHM precision.

\[ f(x) = \frac{A}{x^2 + \gamma^2} \]
Red bins – small statistics – fit is imprecise

Error bins in FWHM method

10 G
Electron scattering in source foil

Source foil (~200 μm)

Decay vertex

Main calo wall