Experimental Determination of the Cerium Betaspectrum

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Content

- Apparatus as used by Nils Haag
- Possible customizations
- Open Questions
- Conclusion

Original application of the Detector module

Measurement of the of the Antineutrino Spectrum of the Fission Products of ^{238}U

- Important for neutrino oscillation experiments (*Double Chooz*)
- Accuracy of $\sim 10\,\%$ at energies of $\sim 4\,\mathrm{MeV}$

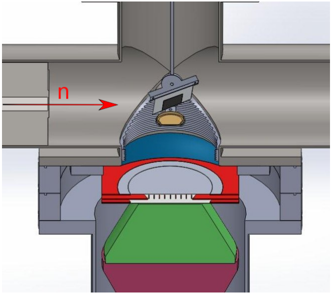
Thesis is finished

- Well known setup
- Detector response well understood down to 1 MeV
- Thesis at: http://nbn-resolving.de/urn/resolver.pl?urn:nbn:de:bvb:91-diss-20131017-1171187-0-3

The detector

Detector setup

- Spectroscopic module of plastic scintillator and photomultiplier
- Multiwire Chamber for suppression of gamma-induced events



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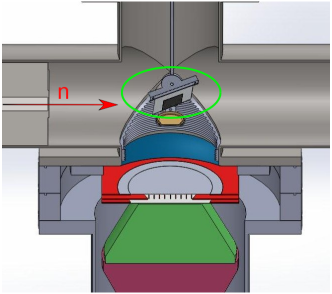

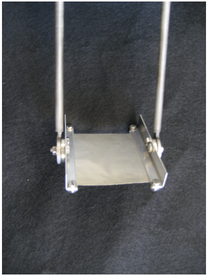

- **Target** from natural uranium:

  99.3 % ^{238}U
  0.7 % ^{235}U

- 25 μm thickness
- Between Ni foils

The detector

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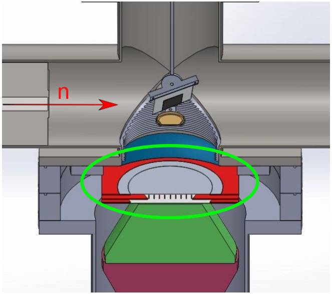
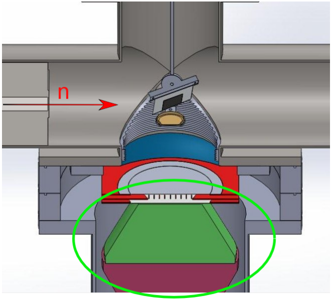


- **MWC**:
  γ- suppression
- 25 Au-coated W-wires
- Counting gas: CF_4

The detector

Detector setup

- Spectroscopic module of plastic scintillator and photomultiplier
- Multiwire Chamber for suppression of gamma-induced events



- **Scintillator** and **PM** for β-spectroscopy
- 6.5 cm thick plastic scintillator (13 MeV)
- Truncated cone for optimal electron detection

The ^{238}U experiment - the experimental setup

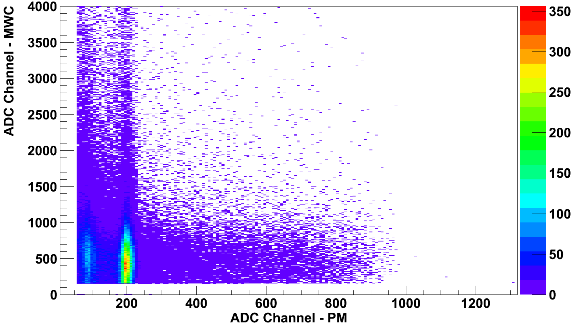
The ^{238}U experiment - the experimental setup

Detector Performance

The coincidence

Coincidence matrix

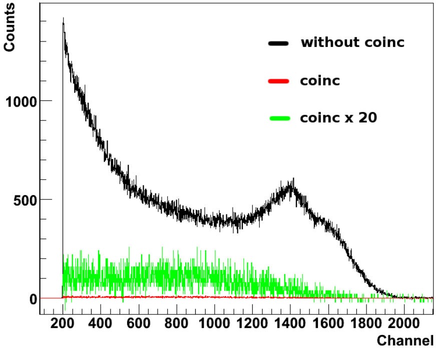
- Assign PM and MWC signal event-by-event
- Possibility to introduce offline cuts
- Time resolved: Check for time dependencies (nothing unexpected observed)



Detector performance: γ-suppression

Coincidence between PM and MWC

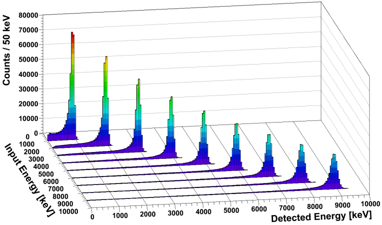
- ^{60}Co source outside detector pot
- Without coincidence: Compton-edges of γ-lines
- Coincidence: Background suppression of $\gtrsim 99.5\,\%$



Detector performance: Response function

Monoenergetic β line is affected by:

- Energy deposition in material between target and detectors
- Backscattering and bremsstrahlungs losses at scintillator
- Scattering off the detector housing
- Gaussian broadening: photon statistics in spectroscopic module



- Simulations cross-checked with Bi-calibration measurements

Detector performance: Energy calibration

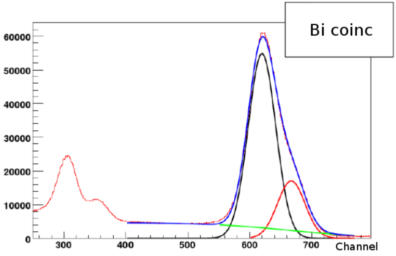
Energy calibration

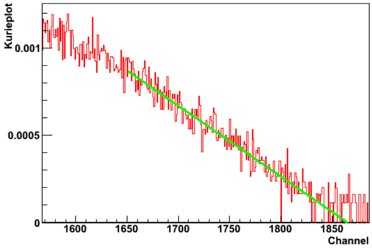
^{207}Bi: Lines of internal conversion at 1 MeV

^{116}In β-decay: Q-value at 3.3 MeV

^{38}Cl β-decay: Q-value at 4.9 MeV

- Spectroscopic module: FWHM: 8 % at 1 MeV





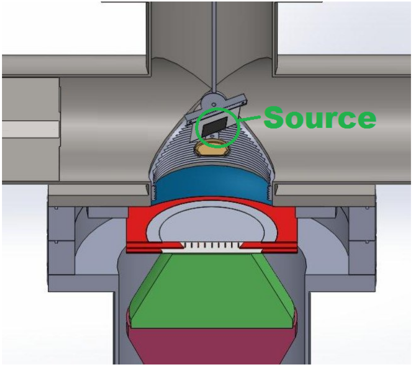
Conclusion: Performance

- Energy resolution: 8 % FWHM
- Gamma-suppression: better than 99.5 %
- Solid angle of detector with standard target foil: 2 - 4 %
- Detector stable over weeks
- Maximal trigger rate of MWC:
  - Tested up to 500 Hz in the U238 experiment
  - Tests necessary to verify if higher count rates are possible
  - Necessary trigger rate and time of measurement depend on bin-width desired ⇒ What is the requested bin-width?
- Adjustment of target position necessary, maybe another target-containment has to be build

Experiment well suited for the measurement of the Cr/Pr source

Modifications for the Cerium source

Original Source position



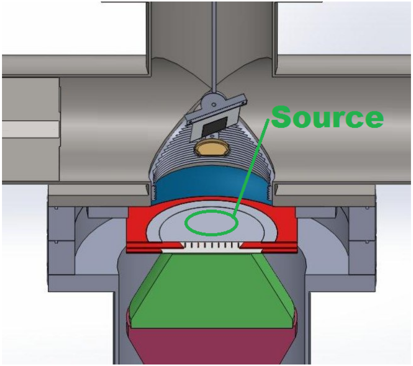
Pros

- Setup designed for this position
- Diameter of the MWC optimized for this position
- No adjustment of the setup needed

Cons

- High activity needed $>10\,\text{kBq}$
- Measurements possible to $\simeq$ 300 keV (more simulations needed)
- $\simeq$ 50 keV absorbance for 1 MeV electrons
- detector response at low energies not known

Lower Source position



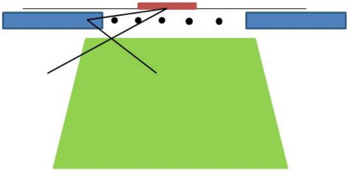
Pros

- Low activity of $\simeq 1\,\text{kBq}$ enough
- Less energy absorbance

Cons

- Probability for partly contained events higher
- Possible scattering in the MWC mounting
- Detector response not well known
- Lower energy threshold not known

Lower Source position



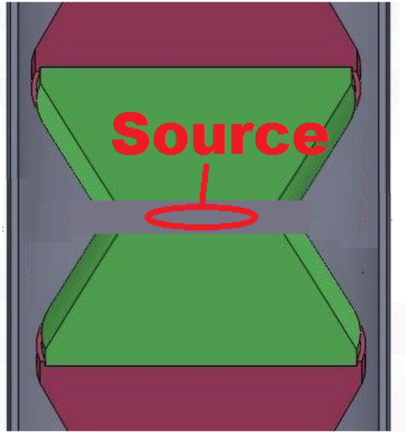
Pros

- Low activity of $\simeq 1\,\mathrm{kBq}$ enough
- Less energy absorbance

Cons

- Probability for partly contained events higher
- Possible scattering in the MWC mounting
- Detector response not well known
- Lower energy threshold not known

Second Plastic Scintillator



Pros

- No absorbance
- Activity of 0.1-1 kBq enough
- Best detector response

Cons

- No gamma discrimination → cerium spectrum not measurable
- calibration just possible with compton edges
- calibration sources have to be on a substrate
- Ready in several month

Overview different setups

original source position

- $\gtrsim$10 kBq needed
- threshold $\simeq$300-500 keV (absorbance)

lower source position

- $\simeq$1 kBq needed
- threshold $\simeq$300-500 keV (absorbance)

two scintillator setup

- 0.1-1 kBq
- threshold $\lesssim$300 keV

$\rightarrow$ two scintillator setup preferred

Calibration

Possible Calibration Sources

- ^{90}Sr-source endpoint at 2.3 MeV
- ^{207}Bi monoenergetic line at 1 MeV
- ^{144}Pr endpoint at 3 MeV

$\rightarrow$ no calibration sources at low energies. Any ideas?
$\rightarrow$ calibration for two scintillator setup must be very thin. Possible at Saclay?

Current Status

- Scintillator module is running again and tested with a ^{207}Bi and ^{90}Sr sources
- Workshop finished the last parts for the MWC this week
- New simulations are in preparation

To Do for original setup

- Test electronics and detector performance (3 - 4 weeks)
- Perform experiment (2 - 3 weeks)
- Setup detector simulations (mainly exist) and perform data analysis (2 - 4 weeks)

- Let's add 1 month due to unexpected problems

Experiment may then be finished within 3 month.

To Do for two scintillator setup

- design and order second scintillator
- order second pmt
- adjust the simulation

$\rightarrow$ probably ready in summer

Open Questions

- Sample geometry
- Sample activity
- Calibration sources

Proposed Approach

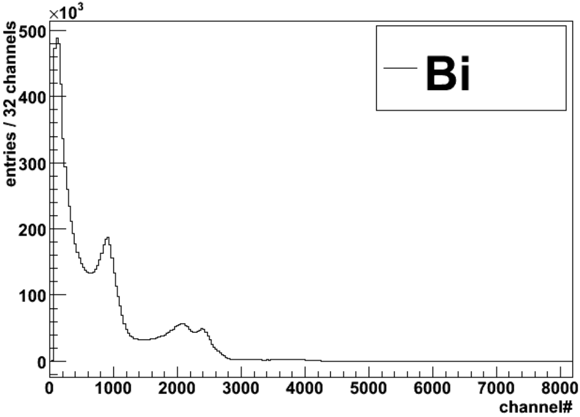
- Measure the sample with the current setup as soon as possible, as it needs a high activity
- Measure again with a two scintillator setup and cross check the results

Conclusion

- Setup well known and tested
- Ready to measure in the near future
- Two measurements preferred
- Well suited for the Ce source

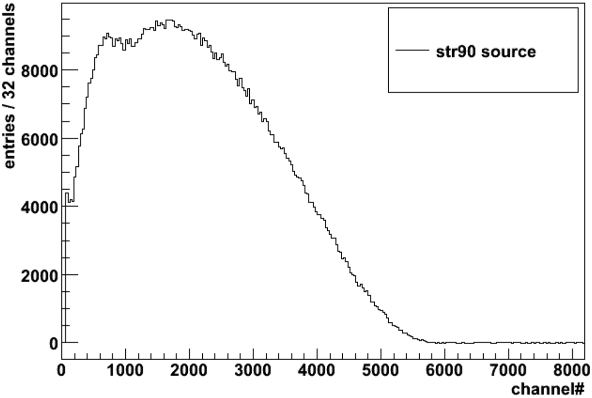
Backup

Bi source



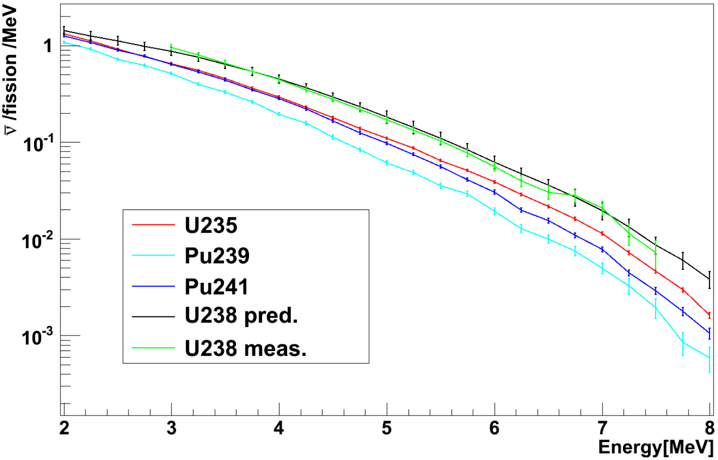
×10³
entries / 32 channels
500
400
300
200
100
0
0
1000
2000
3000
4000
5000
6000
7000
8000
channel#
Bi

Str source



entries / 32 channels
8000
6000
4000
2000
0
0
1000
2000
3000
4000
5000
6000
7000
8000
channel#
str90 source

Reactor $\bar{\nu}_e$ spectra now complete



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