Veto signal consideration for the muon induced single neutron background in the DANSS experiment

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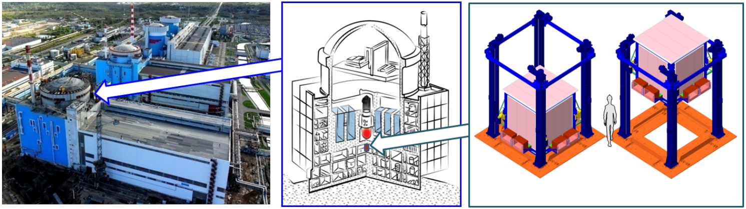
Plan

Description of the experiment

VetoHitChecker
- Lead
- Copper

Results

Description of the experiment

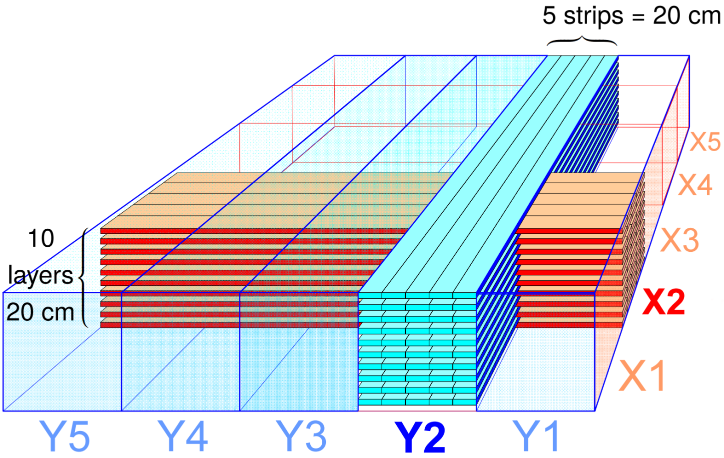


Description of the experiment

$$\overline{\nu}_e + \mathrm{p} = \mathrm{n} + \mathrm{e}^+$$

- Prompt signal: the positron deposits its energy within a short range of few cm and then annihilates emitting two 511 keV photons at 180°
- Delayed signal: the neutron is captured by $^{157}\mathrm{Gd}$ or $^{155}\mathrm{Gd}$ with a very high cross-section after moderation in 1-3 cm of the plastic scintillator
- The time difference between the prompt and the delayed signal is in the tens of microseconds range
- For reactor neutrino energy of the positron produced is to a good precision equal to that of the original neutrino energy with the subtraction of the reaction threshold energy of 1.804 MeV

Description of the experiment



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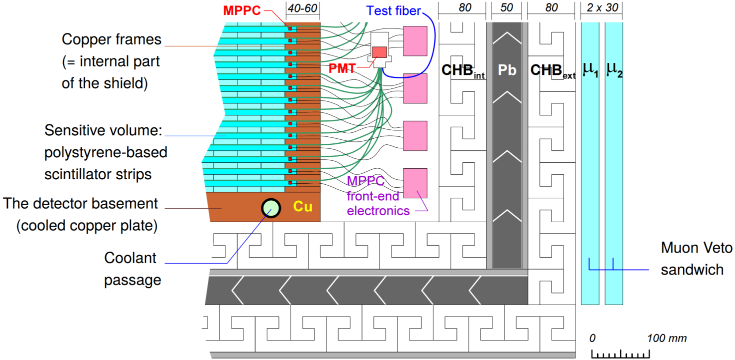
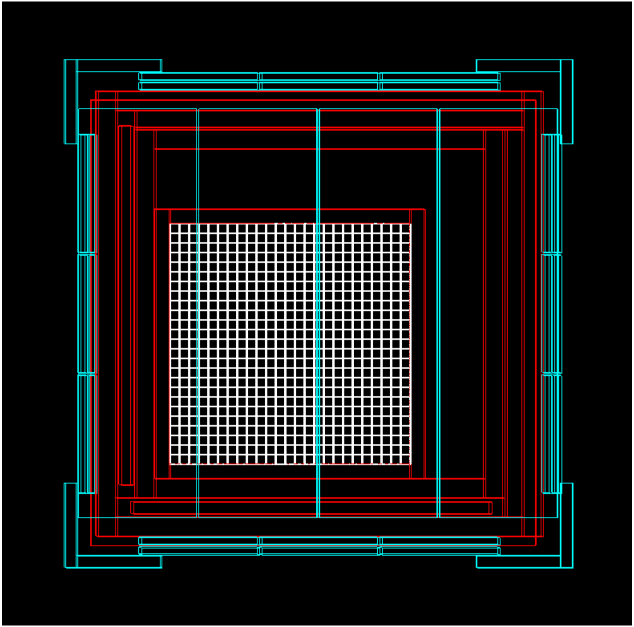


Description of the experiment

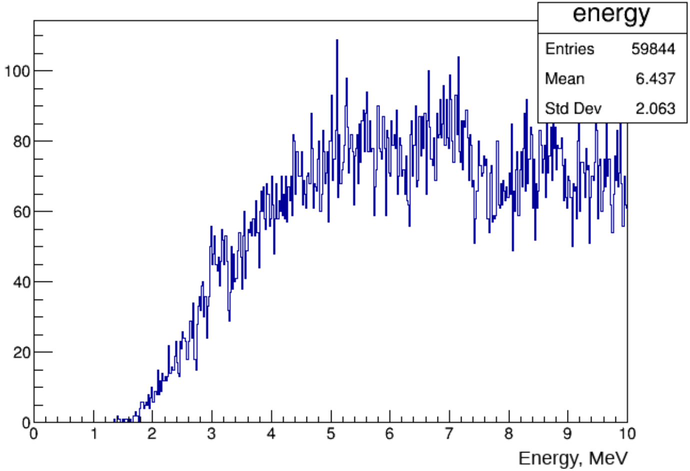


Background mechanism

- low energy neutrons are captured by borated polyethylene contained in passive shielding
- muons generate fast neutrons in materials of passive shielding (copper, lead)
- fast neutron gives recoil proton during thermalisation (prompt signal-like event) and is captured by $^{157}\mathrm{Gd}$ or $^{155}\mathrm{Gd}$ (delayed signal-like event)

Need to estimate neutron background from cosmic muons

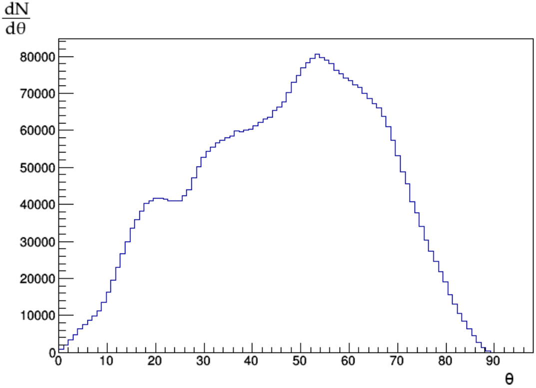
What are fast neutrons?



Muon spectrum

Energy spectrum is equivalent to the cosmic muon spectrum taking into account 50 m.w.e. suppression

$$\theta = arccos(-DirZ) \cdot \frac{180^o}{\pi}$$

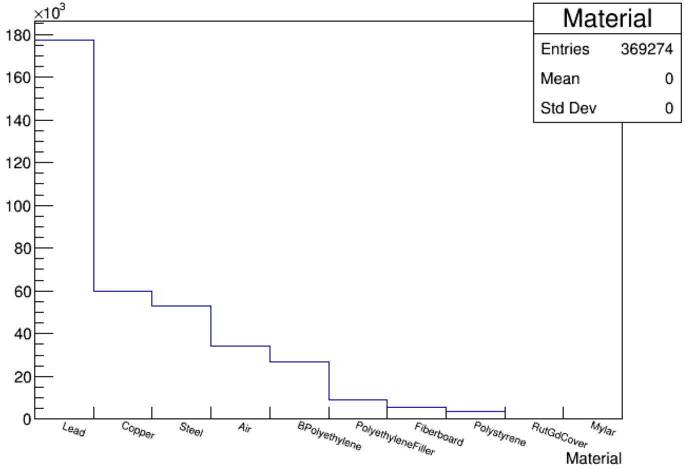


TODO

- simulated 38 days of real time to analyze the neutron spectrum from muons in lead, copper and steel
- obtained distribution of energy, points of birth and direction of neutron motion
- taking into account the obtained distributions, sources of single neutrons were created in Geant4
- statistics for each source was collected
- the analysis of the number of signal-like events was conducted

A signal event is an event in which capture by $^{157}\mathrm{Gd}$ or $^{155}\mathrm{Gd}$ happened and the primary PMT signal is more than 1 MeV

Material, single neutrons



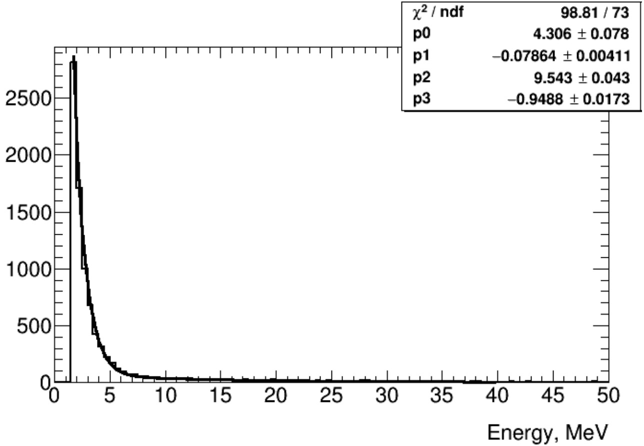
Time estimation

- $6.6 \cdot 10^8$ muons equals to 10 days of real time
- $2.5 \cdot 10^9$ muons was really generated
- was simulated $\frac{2.5 \cdot 10^9 \cdot 10}{6.6 \cdot 10^8} \approx 38$ days
-
  - 170000 ± 400 single neutrons in lead
  - 60000 ± 250 – in copper
  - 50000 ± 200 – in steel
  - 34000 ± 1801 – in air
  - 25000 ± 150 – in borated polyethylene
-
  - 3 neutrons per minute in lead
  - 1 – in copper
  - 0.9 – in steel
  - 0.6 – in air
  - 0.45 – in borated polyethylene

Energy distribution

Lead; one of the side planes

Fit: $e^{p_0+p_1\cdot x} + e^{p_2+p_3\cdot x}$

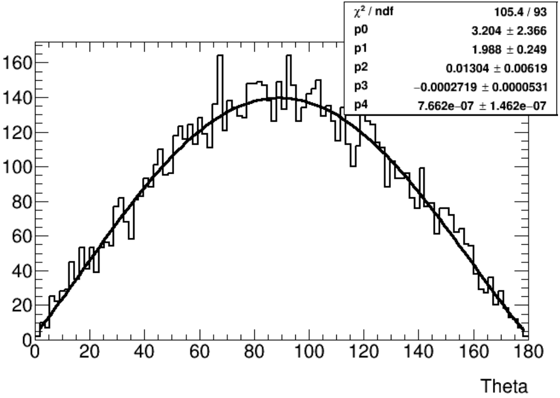


Theta distribution

Lead; one of the side planes

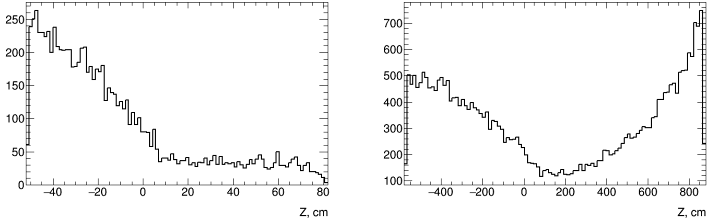
Fit: $p_4 \cdot x^4 + p_3 \cdot x^3 + p_2 \cdot x^2 + p_1 \cdot x + p_0$

$$\theta = arccos(-DirZ) \cdot \frac{180^o}{\pi}$$



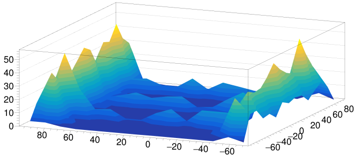
Examples of point of birth distribution

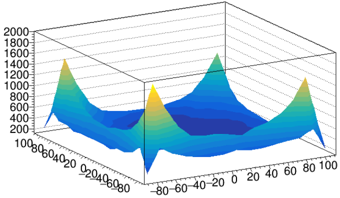
Lead; side planes



Examples of point of birth distribution

Lead; up and down planes
XY plane

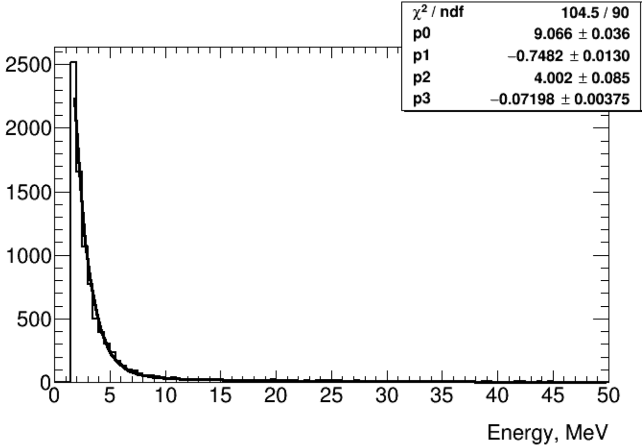




Energy distribution

Copper; one of the side planes

Fit: $e^{p_0+p_1\cdot x}+e^{p_2+p_3\cdot x}$

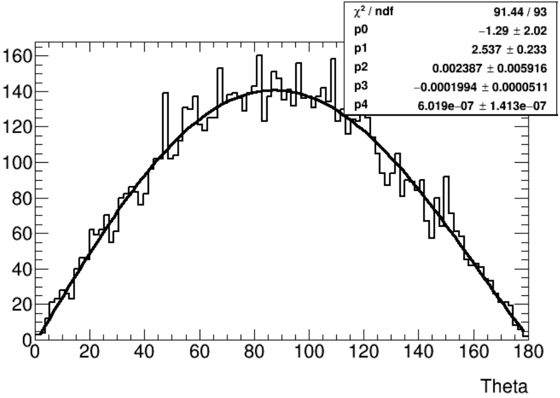


Theta distribution

Copper; one of the side planes

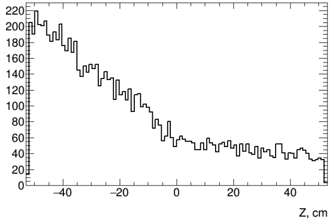
Fit: $p_4 \cdot x^4 + p_3 \cdot x^3 + p_2 \cdot x^2 + p_1 \cdot x + p_0$

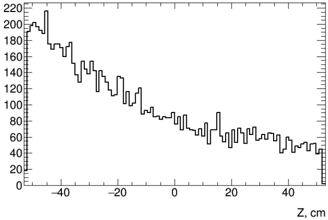
$$\theta = arccos(-DirZ) \cdot \frac{180^o}{\pi}$$



Examples of point of birth distribution

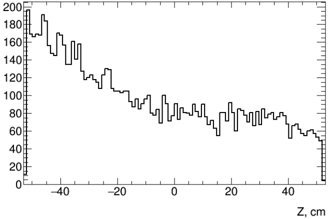
Copper; side planes
XY plane

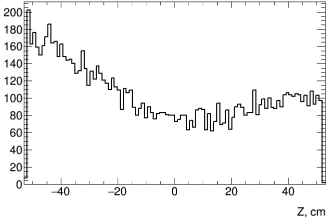




Examples of point of birth distribution

Copper; side planes
XY plane





Results

Lead

3 neutrons per minute
4% can give a signal
0.12 signal-like events/min

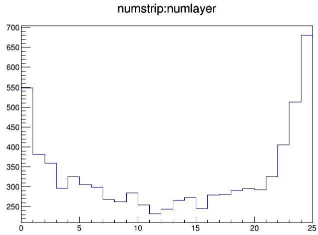
Copper

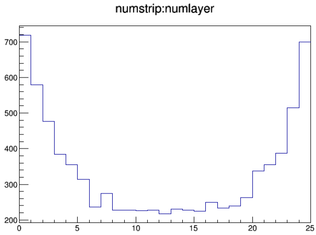
1 neutron per minute
0.15% can give a signal
0.15 signal-like events/min

A signal event is an event in which capture by $^{157}\mathrm{Gd}$ or $^{155}\mathrm{Gd}$ happened and the primary PMT signal is more than 1 MeV

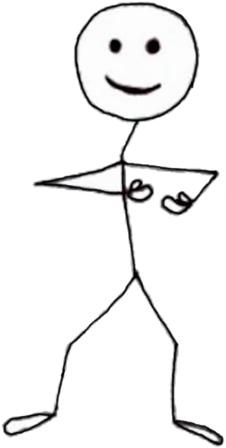
Signal in the detector

Copper, ID of the strip with maximum energy deposit





This is
my
thank you
DANSS



Back slides

Literature

Alekseev I. et al. (2018)
DANSS Neutrino Spectrometer: Detector Calibration, Response Stability, and Light Yield
Physics of Particles and Nuclei Letters T. 15. № 3. C. 272–283.

Alekseev I. et al. (2017)
Detector of the reactor AntiNeutrino based on Solid-state plastic Scintillator (DANSS). Status and first results
J. Phys. Conf. Ser. T. 798. № 1. C. 012152.

Alekseev I. et al. (2016)
DANSS: Detector of the reactor AntiNeutrino based on Solid Scintillator
J. Instrum. T. 11. № 11. C. 012006.

PhysicsList

Electromagnetic processes

EmStandardPhysics_option4 — a set of models of electromagnetic processes selected from standard and low-energy packages, adapted to low-energy physics (about MeV).

Hadron processes

QGSP_BERT_HP — gives good data for particles with energies greater than 1 GeV (necessary when simulating cosmic muons) and gives greater accuracy for events with energy less than 20 MeV which are important for this experiment

Other processes

The decay processes of unstable particles and the process of capture of negative muons are included