Time variation of the neutron background rate measured in the Gran Sasso Underground Laboratory

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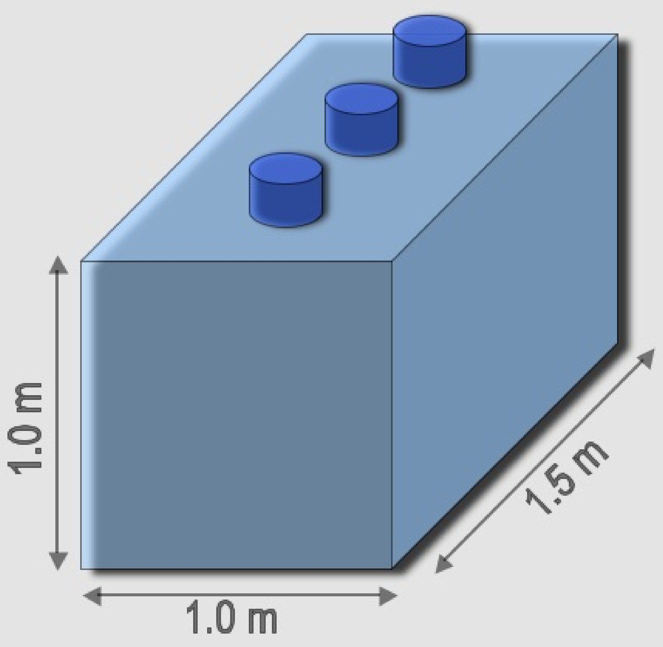
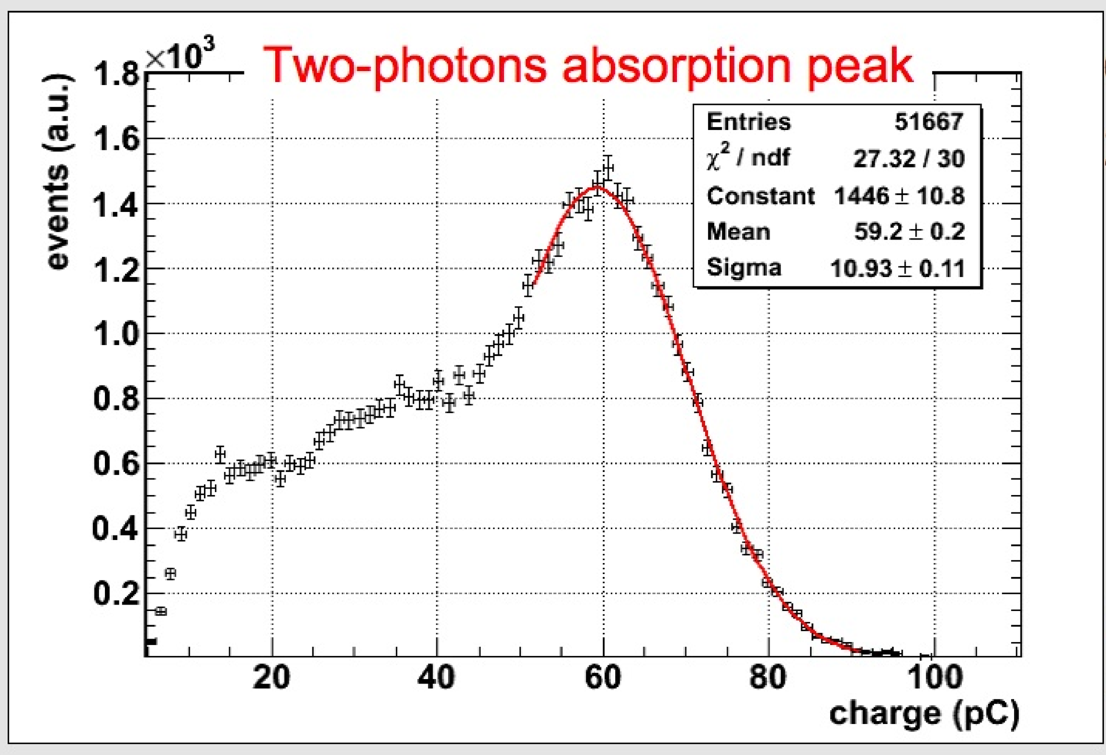
Detector and Electronics



- ✓ 1.2 ton Gd-loaded Liquid Scintillator contained in a parallelepiped box (1.5 m^3 volume) made of stainless steel sheet (5 mm thick).
- ✓ 3 PMTs (5 inch diameter), PHOTONIS XP3550b, gain ~10^6, QE ~20%.
- ✓ VME Waveform Digitizer CAEN V1724:
  - Bandwidth: 40 MHz
  - Sampling Frequency: 100 MS/s
  - Vertical Depth: 14 bit
  - Input Range: 2.25 V_{pp}
- ✓ VME crate controller with USB interface for connection to PC

Energy calibration

^{60}Co source placed in the middle of the counter



^{60}**Co** decay emitting 2 γ-rays of energy: **1.173 MeV** and **1.332 MeV**

Calibration: **23.6 ± 0.7 pC MeV^{-1}**

Experimental Method

• *Expected signal from n-Gd capture*

The advantage of using a Gd-loaded scintillator is that Gd has a huge absorption cross section for thermal neutrons: σ_{abs} = 49700 ±125 barn.

The response of this detector to neutrons has been widely investigated[(1)] through the use of a ^{252}Cf source and a MC simulation.

Captures on Gd originate γ cascades of total energy ~8 MeV (while captures on H are followed by the emission of a 2.2 MeV γ-ray). This characteristic allows us to disentangle the neutron component from the whole background.

• *Data Taking*

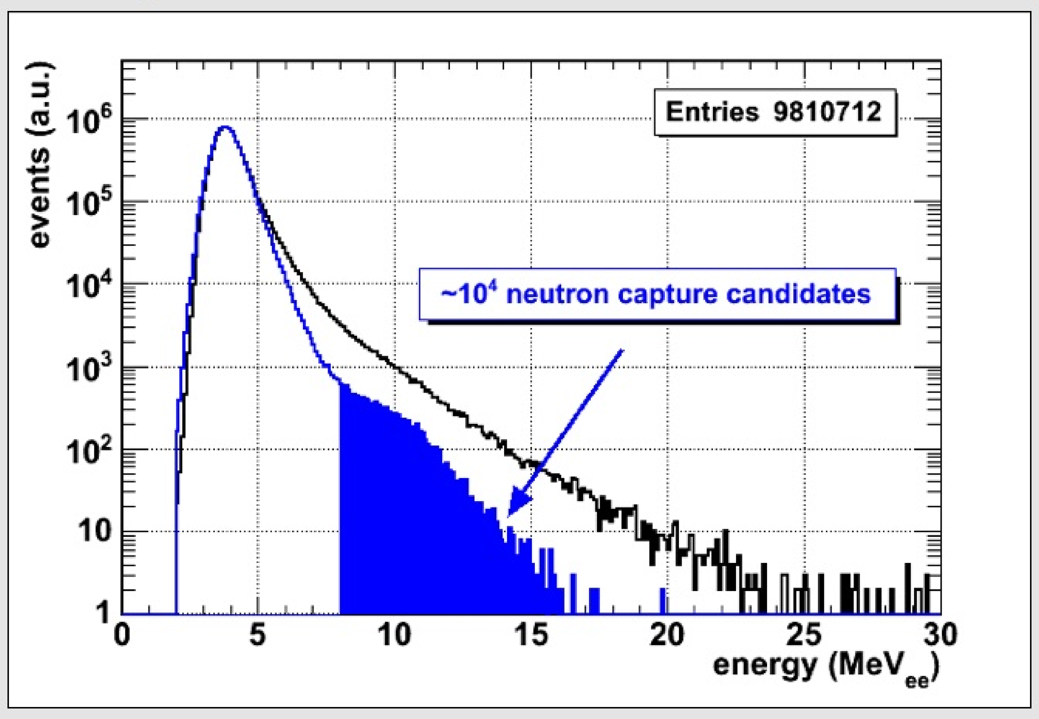
To trigger an event we request a 3-fold coincidence among the signals of the 3 PMTs of the detector. The trigger threshold is set to have about 50% of efficiency at 3 MeV. When the trigger condition is satisfied we store the pulse corresponding to the trigger itself together with any pulses, with energy greater than ~1 MeV, occurring in a time window of [-300μs, +300μs] around the trigger.

The idea is that a fraction of the trigger pulses are due to neutron captures, a fraction of the pulses occurring before the trigger should be proton recoil due to fast neutrons impinging the detector and the pulses occurring after the trigger can be used for the background estimation.

(1) *I R Barabanov et al 2010 JINST **5** P04001*

Observed Energy Spectrum

Energy spectrum of the pulses satisfying the trigger condition.
The spectrum has been obtained integrating the data collected since March 2011, until august 2011 for a total live-time of about ~140 days.



The **black curve** represent the average energy seen by the three PMTs event by event.
The **blue curve** has been obtained from the black one, but in this case we use the spread in the number of photons detected by the 3 PMTs to correct the events in which the energy has been overestimated for geometrical reason.

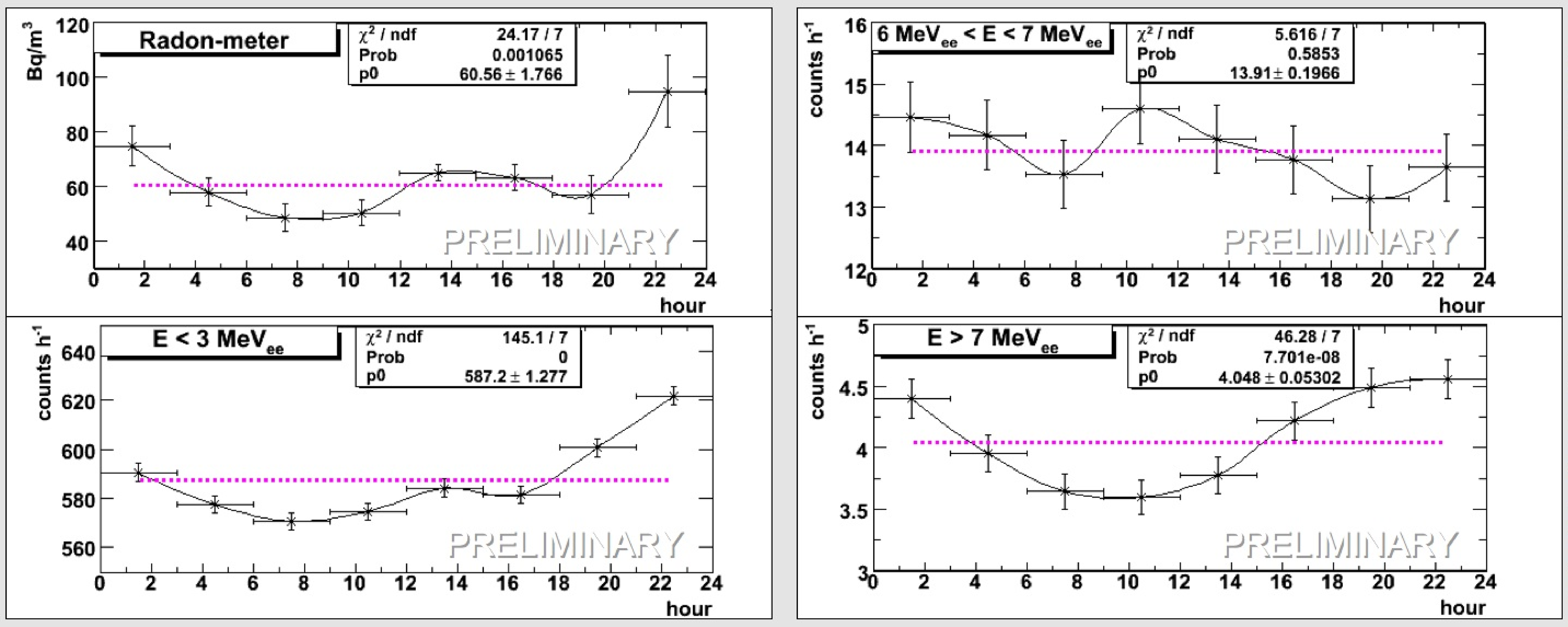
The excess of events with energy greater than ~8 MeV is likely due to neutrons captured by Gd. It is remarkable that they emerge from the background only when the energy is calculated taking into account the geometrical properties of the detector.

Average counting rate on a daily time-base

It is known that the ^{222}Rn concentration in the Gran Sasso Underground Laboratory varies periodically during the day[(2)]. Here we show the average daily counting rate of the detector at different energies, obtained overlapping 20 days of continuous data taking, comparing it with the data of a Radon-meter located very close to the detector.

The radon concentration is well correlated to the counting rate of the detector in the energy range up to 3 MeV.

In fact, the detector is sensitive to the γ-ray emitted by the decay of the radon daughters whose energy exceed the threshold level because of the energy smearing.



The counting rate of the events with energy between 6 and 7 MeV exhibit a flat distribution during the 24 hours, proofing that the contribution due to radon is negligible in this energy range.

At higher energies (>7MeV), where neutron captures are present, the counting rate shows a modulation.
A possible explanation is that we are observing the variability of those neutrons induced by radon through (α,n) reaction.

(2) 2010 J. Phys. Conf. Ser. 203 012091

Summary

We set-up a detector with the aim of investigating the neutron background at LNGS. In this work we presented the data obtained after about 140 days of data-taking, in which we collected about 10^4 neutrons candidate. In about 2% of them the capture signal is preceded by a signal compatible with that of a proton recoil (accidental coincidences already subtracted). With the help of a MC simulation, under development, we may evaluate the neutron flux and reconstruct the energy spectrum for neutrons with energy greater than ~3 MeV (quenching effect taken into account).
We found a daily modulation of the neutron rate that could be explained by radon variations. To date the detector is still taking data to look for modulation of longer period.