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Study of EAS neutron component temporal structure

D. M. Gromushkin[1], **A. A. Petrukhin**[1], **Yu. V. Stenkin**[2], **and I. I. Yashin**[1]

[1]National Research Nuclear University MEPhI, Moscow 115409, Russia
[2]Institute for Nuclear Research of RAS, Moscow 117312, Russia

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Abstract. The neutron component of Extensive Air Showers (EAS) carries information about the primary cosmic ray flux as well as about parameters of hadronic interactions at ultra-high energies. We present here the data obtained with the "Neutron" array which is a prototype of a novel type EAS array PRISMA (Stenkin, 2009). The prototype consists of 5 large area scintillator detectors (0.75 m^2 each) placed in the corners and in the center of 5 m side square. The scintillator consisting of an alloy of ZnS(Ag) and ^{6}LiF is shaped as a thin layer of grains covered with thin transparent plastic film.

1 Introduction

For the purpose of experimental check of a novel technique proposed for EAS studying (the PRISMA project), one array cell prototype (the "Neutron" array) has been deployed in the NEVOD experimental complex (MEPhI, Moscow). The "Neutron" array consists of five large area thin scintillator detectors (EN-detectors), capable to record two main EAS components: hadronic and electromagnetic ones. Hadronic component is the main EAS component forming its structure and therefore measurement of the EAS hadronic component is very promising because it could allow one to reconstruct primary cosmic ray energy and mass most adequately, but it was never measured before by a large area detector array. We could emphasise that central detector array of the PRISMA project will be as large as 10^4 m^2 and can be enlarged later without any problem. This will allow us to measure EAS size spectrum in hadrons through thermal neutrons and to use this component for primary cosmic ray mass composition measurement.

Correspondence to: D. M. Gromushkin
(dmgromushkin@mephi.ru)

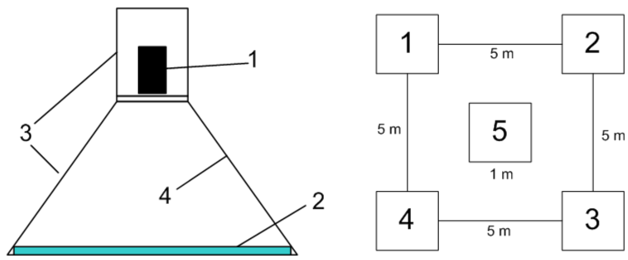

Fig. 1. An individual detector of the "Neutron" array (left): 1 - photomultiplier FEU-200; 2 - scintillator ZnS(Ag) $+^6$LiF; 3 - light shielding box; 4 - reflecting surface. Right: layout of the array (top view).

2 The experiment

The EN-detector looks like a usual detector for EAS study where plastic scintillator is replaced with a thin layer of inorganic scintillator (Fig. 1, left). The scintillator is a granulated alloy of ZnS(Ag) and ^{6}LiF. The average scintillator thickness is only 30 mg cm^{-2} that makes it almost insensitive to single charged particle passage. At the same time, the scintillator is sensitive to a coherent passage of charged particles (EAS case). The large cross section for neutron capture in $^6\mathrm{Li}(n,\alpha)^3\mathrm{H}+4.78$ MeV reaction and a high, nearly point-like, energy deposit make this scintillator very effective for recording heavy particles (and thermal neutrons as well) even in thin layers. The scintillator produces about 160 000 photons per neutron capture.

The experimental setup consists of five detectors (see Fig. 1, right) with 0.75 m^2 scintillator area each, located in the center and in the corners of the square with 5 m side on the upper floor of the experimental building ($\sim$10.5 m above the ground level). The PMTs anode signals are digitized by means of a standard ADC installed into industrial PC. The trigger (M1) is produced by a coincidence of two of five

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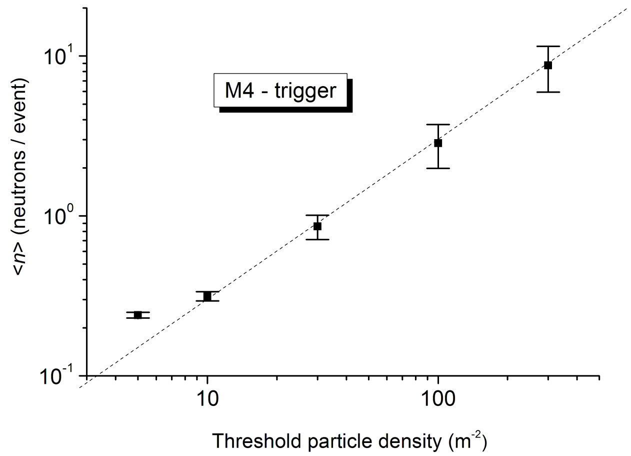

Fig. 2. The mean number of recorded neutrons per event as a function of the threshold charged particle density for the case of 5-fold coincidences (M4 trigger).

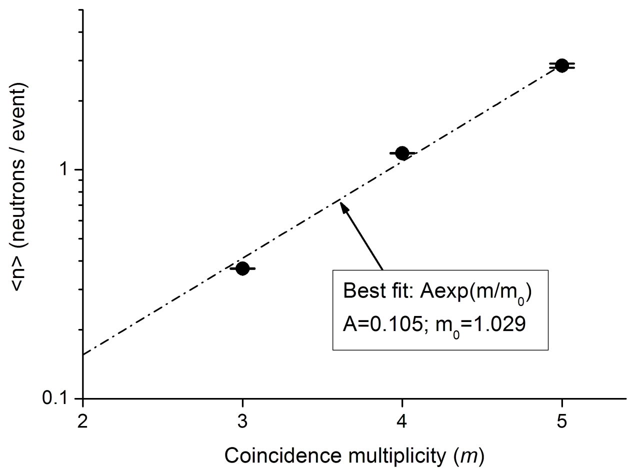

Fig. 3. Mean number of neutrons per event recorded at different detector coincidence multiplicities.

detectors with a threshold $A = 5$ relativistic particles within $2\,\mu$s time gate. Variation of the threshold was applied in the off-line data analysis to study correlations between the number of recorded neutrons and the parameter A, which is in fact proportional to the local density of charged particles. Additionally, off-line triggers M2, M3 and M4 corresponding to coincidences of 3, 4 and 5 detectors (of 5) were formed. Every 5 min a program trigger M0 was formed to monitor the background level of random coincidences. The neutrons were recorded within a time window of 200 ms starting after the EAS trigger in 1 ms steps. Energy deposit spectra of each detector and their counting rates were continuously monitored using the method described earlier (Gromushkin et al., 2009).

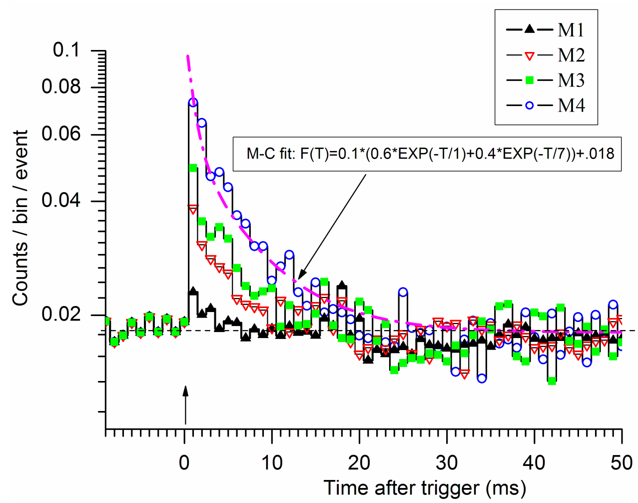

Fig. 4. Recorded and simulated neutron time distributions for different EAS triggers. M1 – M4 correspond to 2-, 3-, 4-, and 5-fold coincidences.

3 Experimental results

During 2009 – 2010, preliminary results on EAS thermal neutron flux temporal structure, correlations between the recorded neutron number and local density of EAS charged particles were obtained. The latter dependence is presented in Fig. 2 where the mean number of recorded neutrons per event is shown as a function of the threshold level A (expressed in particles per m^2) in each detector for the case of 5-fold coincidence (M4 trigger). As one can see, at sufficiently high density this relation can be fitted by a linear function. It means that in our case the quantity of recorded neutrons in a first approximation is proportional to the local particle density at the observation point.

Figure 3 shows the mean number of neutrons per event recorded at different detector coincidence multiplicity (for triggers M2 – M4). It is seen that for multiplicities $m \geq 3$ the recorded number of neutrons rises with m exponentially.

In Fig. 4, we plotted the time distributions of recorded neutrons for events induced by EAS, selected for various triggers (M1 - M4) corresponding to coincidence multiplicity of hit detectors from 2 to 5. Measured EAS time profile in thermal neutron component is consistent with our previous results (Stenkin et al., 2009) as well as with the experiment simulation made using the CORSIKA code (dashed-dotted curve in the figure).

4 Conclusions

Preliminary experimental results obtained on the “Neutron” array confirmed a good performance of the new method of EAS investigations and possibility to use the same detectors for recording both neutron (hadronic) and electronic components. Time “thickness” of EAS in thermal neutrons is as large as $\sim 10\,\text{ms}$ and it is approximately 10^6 times wider than that in the charged particles. Linear dependence of the number of recorded neutrons on local density of EAS charged particles at observation level at density above $\sim 10\,\text{particles/m}^2$ is observed. Now R&D (Research and Development) studies are being continued, and in the near future the extension of the array up to 16, and then up to 36 EN-detectors is planned. This research and natural tests will result in a final design of the PRISMA project.

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References

Gromushkin, D. M., Petrukhin, A. A., Stenkin, Yu. V., et al.: Thermal neutron flux detection near the Earths surface, Bull. RAS: Physics, 73, 407 – 409, 2009.

Stenkin, Yu. V.: On the PRISMA project, Nucl. Phys. B (Proc. Suppl.), 196, 293 – 296, 2009.

Stenkin, Yu. V., Alekseenko, V. V., Gromushkin, D. M., et al.: How does the EAS look like in thermal neutrons? Bull. RAS: Physics, 73, 609 – 611, 2009.