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Study of EAS neutron component temporal structure

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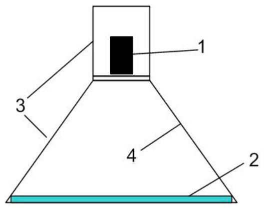
EAS neutron component carries information about the primary cosmic ray flux as well as about parameters of hadronic interactions at ultra high energy. We present here the data obtained with NEUTRON array, which is a prototype of a novel type EAS array PRISMA [1]. The prototype consists of 5 large area scintillator detectors (0.75 m^2 each) placed in the corners and in the center of 5 m side square. The scintillator based on $ZnS(Ag)+^6LiF$ is shaped as a thin layer of grains covered with thin plastic transparent film.

The detectors are used for measuring both the neutron and the electron component and for triggering as well. It is shown that recorded thermal neutron delay distribution can be fitted with double exponential function, thus confirming the existence of two EAS neutron sources: solid matter near the detector (local neutrons) and the air above the detector (atmospheric neutrons).

Detector



1 - PMT-200;
2 - scintillator $ZnS(Ag)+^6LiF$
3 – light shielding box
4 – light reflecting surface

Thermal neutron recording efficiency of such scintillator is equal to about 20 %.

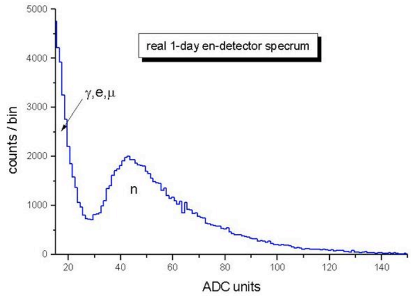
The area of scintillator – 0.75 m^2.

We use a compound of inorganic scintillator ZnS (Ag) and LiF, enriched to 90 % with ^6Li isotope.

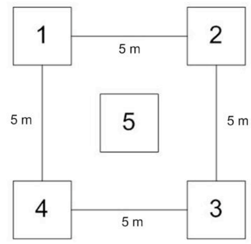
$$^6Li + n = ^3H + \alpha + 4.8\ MeV$$

Average thickness of the recording layer is ~ 30 mg/cm^2.

Spectrum measured from one detector



The array layout



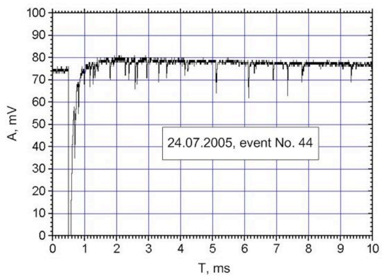
As a monitoring information, every 5 min we store the counting rates of neutrons in each detector as well as counting rates of their discriminators, outdoor air temperature, absolute humidity and atmospheric pressure. Moreover, once a day we store all accumulated pulse height spectra.

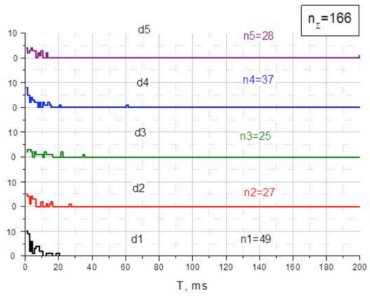
Results of measurements

During the 2009 – 2010 the array was running both under the EAS recording program, and under the variation program [2]. In this work we present preliminary results obtained under the EAS program.

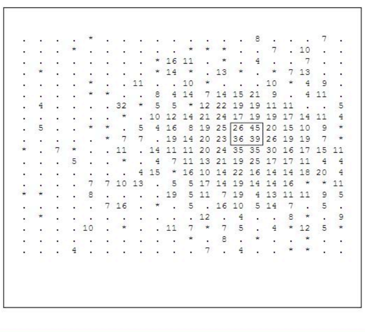
An example of the event with the maximal recorded number of neutrons N = 166 in 5 detectors is presented below. Unfortunately, insufficient ADC dynamic range at the moment has not allowed us to measure N_e in the event (all 5 ADC were saturated). Nevertheless, comparing the density map of the recorded neutrons in 5 detectors with a similar map obtained with the simulation of the PRISMA experiment, we can estimate the energy of the event as $E_0 \approx 15$ PeV.

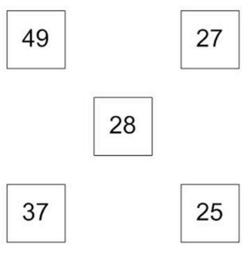
The oscillogram of a most powerful event (EAS):



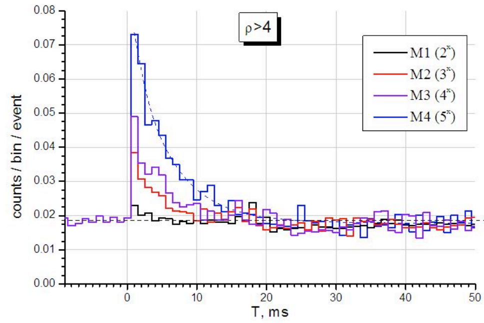


An example of an artificial EAS originated from a proton with energy of 15 PeV, obtained using CORSIKA (version 6.501), for the central array of 400 en-detectors of the PRISMA is plotted below. Figures show number of neutrons in the detectors. The rectangle in the centre shows one cell of the array (size of 5 x 5 m^2) with the number of neutrons close to recorded in the most powerful event in the NEUTRON array.



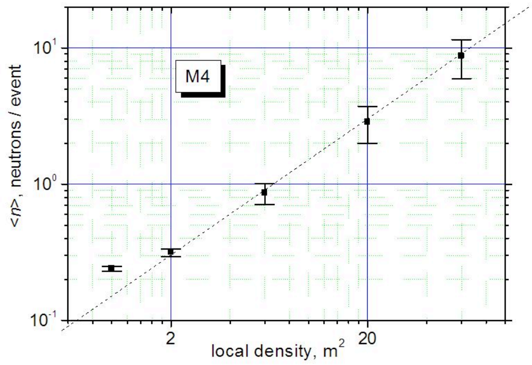


Time distributions of recorded neutrons for EAS of different size, selected by various triggers (M1 – M4), corresponding to different multiplicity of the detector coincidence from 2 to 5. Dashed curve: double experimental fit.



These distributions are in a good agreement with that obtained earlier on «Multicom prototype» [3] if one takes into account that the conditions of two experiments are essentially different.

Dependence of mean number of recorded neutrons per event as a function of the discrimination level of the threshold A in each detector for the case of 5-fold coincidence (M4 trigger) is presented in the figure.



An interesting feature could be noticed: for $A > 2$ relativistic particles in the detector, the mean number of recorded neutrons $<n>$ is proportional to A. It means that in a first approximation $<n>$ is proportional to local density of EAS particles at observation level.

Conclusion

Preliminary experimental results obtained on the NEUTRON array confirmed good performances of the method of EAS studying and possibility of use of the same detectors for recording both neutron (hadronic) and electronic component. R&D works and natural tests on this prototype will result in the PRISMA project development. Time "thickness" of EAS in thermal neutrons is as large as ~10-20 ms and that is approximately 10^6 times wider than that in the charged particles. Linear dependence of the number of neutrons registered by the installation on local density of EAS charged particles at observation level is observed at density above ~ 2 particles/m^2.

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[1] Yu.V. Stenkin./On the PRISMA project. // Nucl. Phys. B (Proc. Suppl.), v. 196, 2009, p. 293-296.
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[3] Yu. V. Sten'kin, V. V. Alekseenko, D. M. Gromushkin et al. How Does the EAS Look Like in Thermal Neutrons? // Bulletin of the Russian Academy of Sciences: Physics, 2009, Vol. 73, No. 5, pp. 609–611.