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Extensive Air Showers Detected by Aragats Neutron Monitor

A. Badalyan, A. Chilingarian, G. Hovsepyan, A. Grigoryan, Y. Khanikyants, A. Manukyan, D. Pokhsraryan and S. Soghomonyan

Yerevan Physics Institute, Armenia

Abstract. Extensive Air Shower (EAS) duration as registered by the surface particle detectors does not exceed a few tens of nanosecond. However, Neutron monitors containing plenty of absorbing matter can respond to EAS core traversal during 1 ~ms by registering secondary slow neutrons born by EAS hadrons in the soil, walls of buildings and in the matter of detector itself. Thus, the time distribution of the pulses from the proportional counters of the neutron monitor after EAS propagation extends to ~1 ms, ~5 orders of magnitude larger than the EAS passing time. The Aragats Neutron Monitor (ArNM) has a special option for the EAS core detection. In general, the dead time of NM is ~1 ms that provides the one-to-one relation of incident hadrons and detector counts. The pulses generated by the neutrons possibly entering the proportional chamber after the first one will be neglected. In ArNM, we use several "electronic" dead times, and with the shortest one, 400 ns, the detector counts all pulses that enter the proportional chambers. If ArNM one-second time series corresponding to the shortest dead time contain much more signals (a neutron burst) than with 1-ms dead time, then we conclude that the EAS core hits the detector.

We assume that he distribution of registered burst multiplicities is proportional to the energy of the primary particle. The primary cosmic ray energy spectrum was obtained by the frequency analysis through the counting frequencies of the multiplicities of different magnitudes and relating them to the integral energy spectrum measured by the MAKET array at the same place several years ago.

1. INTRODUCTION

Cosmic Ray (CR) flux incident on terrestrial atmosphere consists mostly of protons and heavier stripped nuclei accelerated at numerous galactic and extragalactic sites. The most exciting questions associated with cosmic rays is the observation of a particular accelerating source and exploring the acceleration mechanism. Due to the bending in the magnetic fields, charged particles loose information about the parent sites during long travel and arrived highly isotropic to the solar system. Thus, cosmic rays cannot map the sites where they born, therefore, only integrated information from all sources are available from measurements of cosmic ray fluxes near Earth and on the Earth's surface. Energy spectra of the primary particles with energies larger than 100 TeV can be studied only by surface detectors registering numerous secondary cosmic rays (SCR) belonging to the Extensive Air Showers (EASs) developed in the interaction of primaries with atmosphere atoms. The information on the acceleration mechanisms of CR is covered in the shape of the energy spectra of the different species of SCR measured by the particle detectors located on the earth's surface. Usually, the rather sparse arrays of plastic scintillators overviewed by photomultipliers are used for registration of the shower particles. When trigger conditions are fulfilled (EAS generate predefined particle density or more in the predefined number of scintillators or more) signals from all scintillators are stored and used for estimation of the lateral distribution and then, by integrating it, – the shower size, i.e. the total number of electrons in the shower. The relation of shower size to primary energy (conditioned on primary type) was established by simulations of EAS with sophisticated Monte-Carlo codes. The energy spectrum of different SCR species follows a power law dN/dE ~ Eγ over many orders of magnitude. The spectrum recovered by the electron content of EAS steepens at energies around 4-5 PeV from a spectral index $\gamma \approx -2.7$ to $\gamma \approx -3.1$. This feature is commonly called the knee and its explanation is generally believed to be a cornerstone in understanding the origin of cosmic rays, providing answers to one of the key questions of astroparticle physics (Horandel, 2004).

Large fluctuations of the EAS development in the terrestrial atmosphere along with uncertainties of the extrapolation of strong interaction models to yet unexplored with manmade accelerators energy domain make the unfolding (solving the inverse problem) of the measured CR spectrum extremely difficult. However, implementation of the nonparametric multivariate methodology (Chilingarian, 1989), allows the event-by-event-analysis of EAS data (Chilingarian et al., 1991) using Bayesian and Neural Network models. At each stage of the analysis, we estimate the value of the information content of the variables used for EAS classification and energy estimation and restrict the complexity of the physical inference according to this value. The MAKET-ANI experiment (Chilingarian et. al., 2004) is located at 3200 m. above sea level on Mt. Aragats, In Armenia; the quality of reconstruction of the EAS size and shape (shower age) are good enough and we can use these 2 parameters for the EAS classification. The distinctive information contained in distributions of these parameters allows us to classify the EAS with high accuracy into two distinct groups: initiated by "light" or "”heavy" nucleolus. In the KASCDE experiment (Antoni et al., 2002), where the muon content of the EAS is measured in addition to shower electron size, it is possible to classify showers into 3 categories adding also the "intermediate" class.

The differences in the spectra slope before and after the knee for different mass groups of the primary cosmic ray flux is the key feature for the solving of the knee origin problem. The available world data confirms the existence of very sharp knee for the CR light component. Energy spectra of KASCADE (Vardanyan et.al., 1999) and MAKET-ANI (Chilingarian, et.al. 2004) experiments are in good agreement in terms of intensities, the shape of the spectra, and spectral indices, Fig.1. HEGRA spectrum (Arqueros et.al.,2000), obtained with completely different experimental methodic, also prove steepening of the light mass group spectra and shift of the knee position to the lower values of primary energy comparing with all-particle spectra, Figure 1.

In Figure 2 we show the energy spectra unfolded by the neural classification methodology (Chilingarian, 1994, 1995). More than million EASs detected in 1999-2004 have been carefully examined and rummage-sale for the estimation of energy spectra of light and heavy nuclei. The efficiency of extensive air shower core selection around geometrical center of the array was >95% for EASs generated by primary particles with energy ≥ 5x1014 eV. The compact array with well calibrated detectors turned out to be very well suited for the energy and composition measurements at the "knee" of the cosmic ray spectrum.

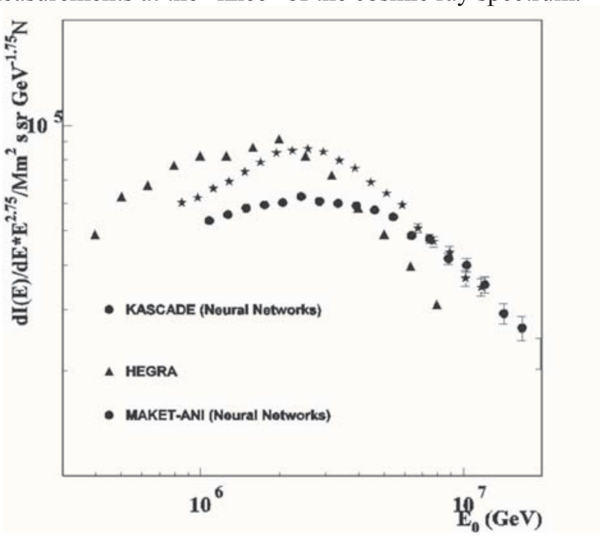

Figure 1. Light nuclei group spectra (Arqueros et.al.,2000, Vardanyan et.al., 1999, Chilingarian et.al., 2004)

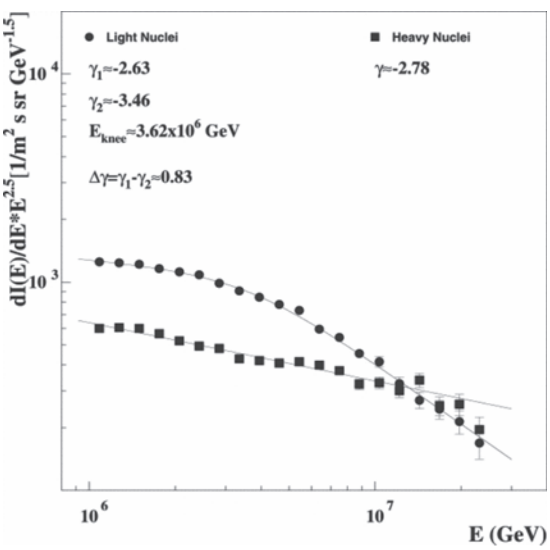

Figure 2 Energy spectra of light and heavy nuclei obtained by neural classification and energy estimation. The EAS characteristics used are shower size and shape (age parameter).

The physical inference from MAKET data can be summarized as follows:

1. The estimated energy spectrum of the light mass group of nuclei shows a sharp knee: $\Delta\gamma \sim 0.9$, compared to ~0.3 for the all-particle energy spectra.
2. The energy spectrum of the heavy mass group of cosmic rays shows no break in the energy interval of 10^{15} - $2x10^{16}$ eV.
3. The MAKET results on the rigidity-dependent position of the knee confirm the Super Novae Remnants (SNRs) as a most probable source of galactic cosmic rays and Fermi-type acceleration as the mechanism of hadron acceleration.

In (Anglietta et al., 2004), the light mass group was isolated using information on the EAS electrons and TeV In (Anglietta et al., 2004), the light mass group was isolated using information on the EAS electrons and TeV muons. Obtained knee position at Ek ≈ 4 ·1015 eV and difference of the slopes after and before the knee for light component equals to $\gamma 2 - \gamma 1 = 0.7\pm0.3$, as compared with all charged particles spectra $\gamma 2 - \gamma 1 = 0.4\pm0.1$ again can be interpreted in the standard framework of the rigidity-dependent acceleration. Conclusive evidence from KASCADE experiment has been reached on the knee being caused by light primaries mostly. Furthermore, the data are in agreement with a rigidity scaling of the knee position giving support to an astrophysical origin by either maximum confinement energy or diffusion/drift models of propagation (Kampert et al., 2004).

Thus, the origin of Galactic cosmic rays can be supernovae shock waves as they can explain the intensity of the CRintensity at least up to 1015 eV. Direct evidence of shock acceleration in SN shells can be deduced from joint detection of young SNRs in X and γ-rays. To prove that the young supernovae remnant RX J1713.7-3946 is a very efficient proton accelerator Uchiyama et al., (2007) include in the analysis information on broadband X-ray spectra (from 0.4 to 40 KeV) measured by the Suzaku satellite (Takahashi et al., 2008) and - on high energy γ-ray spectra (extending over 10 TeV) measured by HESS Atmospheric Cherenkov Telescope (ACT) (Aharonyan et al., 2007). They exclude the inverse Compton origin of detected high-energy γ-quanta, and taking into account the Tev–KeV correlations validate the hadronic model of detected γ -rays. Thus, the joint analysis of X-ray maps from Chandra and X-ray spectra from Suzaku satellites with high energy γ -ray spectra measured by HESS ACT provide a very strong argument for the acceleration of protons and nuclei with energies 1 PeV and beyond in young SNR shells. The SNR origin of galactic CR has been recently confirmed by the observations of AGILE (Giuliani et.al. 2013) and FERMI satellites (Ackermann et. al., 2013).

As we mention above, inferring the energy and type of the primary particle from the EAS measurements is a very hard task requiring a priori model of the energy spectrum and chemical composition. In modern experiments, a multivariate approach, based on the simultaneous detection of as much as possible EAS observables and their correlation is used to infer the features of the cosmic ray spectrum (Antony et al., 2002, Chilingarian et al., 2007). Hadronic component of EAS carry important information for multi-parameter correlation analysis and can significantly improve the reliability of CR classification and energy estimation. Recently, instead of very expensive hadron calorimeter, an alternative approach for incorporation hadronic information was proposed (Bartoli et al., 2016). Instead of hadrons, it was proposed to measure neutron content of EAS. Evaporation neutrons are generated abundantly by EAS hadrons, up to 2 orders of magnitude more than parent hadrons. The energy distribution of hadrons in EAS exhibits a very slow dependence on the primary energy; on the other hand, the total number of evaporation neutrons is expected to be proportional to the total number of high-energy hadrons reaching the observation level. A large fraction of the evaporation neutrons thermalized, so that recording thermal neutrons can be exploited to reconstruct the hadron content in the shower. Measurement of the neutron bursts correlated with EAS with neutron monitors or/and a new EN-detector, made of a mixture of the inorganic scintillator ZnS(Ag) with 6LiF, (Stenkin, 2008) looks very promising for measurements carried out at mountain altitude.

At Aragats research station of Yerevan Physics Institute (3200 m asl) variety of particle detectors are in operation (see details in Chilingarian et al., 2005, Chilingarian et. al. 2016) including 2 Neutron monitors 18NM64 and ~ 300 m2 of scintillation detectors. The purpose of this paper is to use these detectors for the detection of EAS neutron content, and - for scrutinizing possibilities of primary CR energy estimation by the registered neutron multiplicities.

2. INSTRUMENTATION

The Aragats neutron monitor (ArNM) consists of eighteen cylindrical proportional counters of CHM-15 type (length 200 cm, diameter 15 cm) filled with BF3 gas enriched with B10 isotope and grouped in three sections containing six tubes each (in Figure 3 we show one section of it - 6NM64). The proportional chambers are surrounded by 5 cm of lead (producer) and 2 cm of polyethylene (moderator). The cross section of lead producer above each section has a surface of $6m^2$ and the total surface of three sections is $18m^2$. The atmospheric hadrons produce secondary neutrons in nuclear reactions in lead; then the neutrons get thermalized in a moderator, enter the sensitive volume of the counter, and in interactions with boron gas born Li7 and the α particle. The α particle accelerates in the high electrical field inside the chamber and generates enough ionization to be detected by the data acquisition electronics. High- energy hadrons generate a large number of secondary neutrons entering the lead producer, and, if we want to count all pulses initiated by the incident hadrons, we have to keep the dead time of the NM very low (the ArNM has a minimal dead time of 0.4 μs). If we want to count incident hadrons only (a one-to-one relation between count rate and hadron flux) we have to keep the dead time as long as the whole secondary neutron collecting time (~1250 μs) to avoid double counting.

The Aragats Muon detector (Figure 4) consists of three vertically stacked plastic scintillators with an area of $1m^2$. The top 3cm thick scintillator is covered by 7.5cm of the lead filter; the middle 1cm thick scintillator is covered by 1.5cm of the lead filter and by ~ 60 cm thick rubber layer (carbon); the bottom 1cm thick scintillator is covered by the 6cm thick lead filter. The energy thresholds to detect muons in three stacked scintillators are ~170 MeV, ~220 MeV and ~350 MeV accordingly. DAQ electronics provides registration of 50 ms time series of all scintillators. ArNM and Muon detectors are located at a distance of ~ 6m from each other in the MAKET experimental hall. The close location of these detectors allows joint detection of large EASs. Outdoors is located the STAND1 detector comprised of three layers of 1-cm-thick, $1m^2$ area molded plastic scintillators and 3 cm thick plastic scintillator of the same type fabricated by the High Energy Physics Institute, Serpukhov, Russian Federation. The light from the scintillator through optical spectrum-shifter fibers is reradiated to the long- wavelength region and passed to the photomultiplier FEU-115M. The maximum of luminescence is emitted at the 420-nm wavelength, the luminescence time being about 2.3 ns.

The heart of the Data acquisition system (DAQ) is NI-myRIO board (see Figure 5). The output pulses from the 7-channel discriminator board are fed to the FPGA of the myRIO board where the logic of event identifying, pulses counting and GPS time stamping is implemented. The 8-th channel is reserved for the synchronization pulse (the trigger) from any of particle detectors. We use for triggering one of ArNM channels (second or 8-th proportional counter); the “EAS” trigger was generated when 1-second count rate exceeds the mean count rate by 4 standard deviations. The output of the proportional counters (Figure 3) and one of the Muon detector scintillators (Figure 4) were directly connected to the digital oscilloscope (2 channel picoscope 5244B with 25MS/s sampling rate) with 60 cm long RG58 coaxial cable. Data capture length can be chosen from 1 second, including 200 ms pre-trigger and 800 ms post-trigger time with sample interval 40 ns, or, for instance, 10 ms with the sample interval of 0.4 ns.

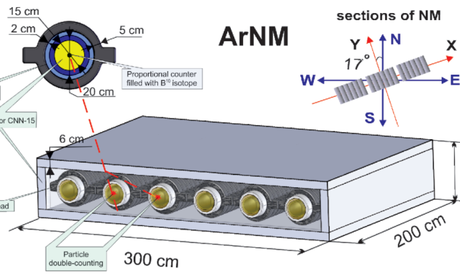

Figure 3. Layout of Aragats Neutron Monitor (ArNM)

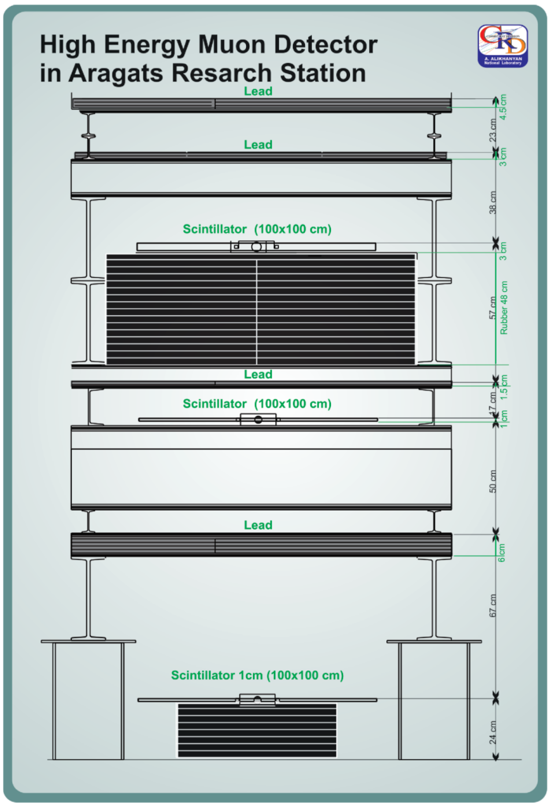

Figure 4. The “muon” stacked detector with large amount of lead and rubber between 3 scintillators

The special file generated by digital oscilloscope at any trigger, time series of particle detector count rates, current electrostatic field strength and service information (status of myRio, time delays, number of satellites used) are transferred to the mySQL database at CRD headquarters in Yerevan. All information is available via ADEI multivariate visualization code by link http://adei.crd.yerphi.am; explanations are located in the WiKi section.

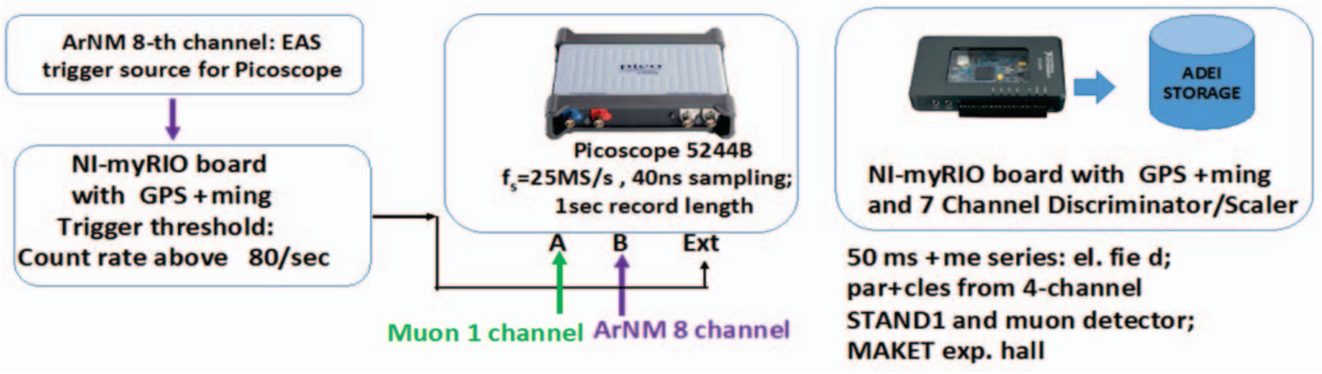

Figure 5. Schematic view of the fast DAQ for the EAS core detection. The particle pulses from first scintillator of Muon detector and 8-th (or second) counter of ArNM are registered and stored when 1-second count rate of ArNM proportional counter exceeds mean count rate by 4σ. The DAQ is continuously registered 50 ms time series of all STAND1 and muon detector channels and electrostatic field as well.

3. THE CORES OF EXTENSIVE AIR SHOWERS DETECTED BY ARAGATS NEUTRON MONITOR AND MUON DETECTOR EAS

Yu. Stenkin suggested slow neutron registration for the EAS studies (Stenkin et. al., 2008). The EAS duration as registered by the surface particle detectors does not exceed a few tens of nanosecond. However, Neutron monitors containing plenty of absorbing matter can respond to EAS core traversal during ~1 ms by registering secondary slow neutrons born by EAS hadrons in the soil, walls of buildings and in the matter of detector itself. Thus, the time distribution of the pulses from the proportional counters of the neutron monitor after EAS propagation extends to ~1 ms, ~5 orders of magnitude larger than the EAS passing time. In the Neutron monitor's 5 cm lead producer the EAS hadrons can generate many hundreds of neutrons and in the polyethylene moderator they slow down to thermal energies before entering the proportional counters. Due to multiple scattering in the absorber and moderator, the time distribution of the secondary neutrons became significantly broader. Thus, the time distribution of the pulses from the proportional counters of the neutron monitor after EAS core propagation extends to ~ 1 ms (Balabin et al., 2011). The measurements on Tien-Shan demonstrated that EASs with energy greater than 10 PeV with axes in 3-10 meters from NM could produce multiplicities above 1000 (Antonova et al., 2002). This, very high number of recorded neutrons are caused by the groups of high-energy hadrons hitting the NM (Stenkin and Vald´es-Galicia, 2002).

The Aragats neutron monitor (Figure 3) has a special option for the EAS core detection. Usually, the dead time of NM is set to 1.25 ms for the one-to-one relation of incident hadrons to detector counts. Thus, all neutrons entering the proportional chamber after the first one are neglected; it is expected that during 1.25 ms all delayed secondary thermalized neutrons will enter proportional chamber or will be absorbed in the moderator. In ArNM we use several "electronic" dead times, which artificially block the output of the proportional counter for predefined time span. The shortest one dead time 400 nsec, can count almost all output pulses. Thus, if ArNM with the shortest dead time registers much more pulses than with ~ 1ms dead time it means that the EAS core is hitting the detector. Within 1 ms, if we assume very large (continuous) pulse train, 2500 pulses can be count. Sure, only extremely energetic EASs (producing numerous hadrons) hitting NM can yield such a large multiplicity.

In Figure 6 we demonstrate 1-second time series of the second (first section) proportional counter of ArNM. On November 26 at 04:08:05 UT the second proportional counter registered neutron burst above trigger level (multiplicity >100) and a file from the digital oscilloscope with detector pulses shown on the nanosecond scale was stored. In Figure 6 we see the peak corresponding to the shortest dead time of 0.4 μs; the time series of 250 μs and 1250 μs demonstrate no peaks.

In Figure 7 we show time series of 7 operating channels of the ArNM.

Only 2 proportional counters belonging to the first section of ArNM (namely the third and forth) close to the second one demonstrate peaks in 1-sec time series. Accordingly, we can conclude, that EAS core hits the ground near first section of ArNM producing plenty of secondary neutrons, which registered by the proportional counters.

In Tab. 1 we show the mean values, variances and peak values of 1-second time series registered by ArNM at 04:08:20 – 04:08:20. Only in the first section of ArNM we see large enhancements (counters 2, 3, 4). In the second section (counter 8) and in the third section (counters 13, 14, and 18) we see no enhancements. Thus we can relate measured enhancements in 3 close channels of ArNM to high-energy hadron(s) from the EAS core.

Table 1. ArNM registration of the neutron burst

N of Proportional	Mean	σ	Maximum
ArNM #2	41.3	11.	107
ArNM #3	63.0	12.	116
ArNM #4	38.5	9.4	81 (4.48σ)
ArNM #8	30.7	6.4	46 (2.38σ)
ArNM #13	22.1	5.3	35 (2.43σ)
ArNM #14	25.8	6.2	39 (2.12σ)
ArNM #18	18.5	4.3	29 (2.4σ)

In Figure 8 we show the pulses from ArNM counter and from plastic scintillator of Muon detector with different time zooming. In the Fig.8a we show the initial full-scale (1 sec) pulse shapes. On the upper line, we can see several charged particle registrations by the plastic scintillator of Muon detector. The muons are entering the muon detector randomly according to the mean count rate of high-energy muons on 3200 m altitude ~ 500/m2s. In the time series below we see the multiple detections of slow neutrons entering the sensitive volume of the proportional counter of ArNM. The time distribution of the pulses from the proportional counters of the neutron monitor after EAS core propagation extends several hundreds of μs as we can see in Figure 8b. Plastic scintillator's response to EAS passage is only one pulse. We assume that the first very wide pulse in Figure 8c corresponds to the EAS core passage when a lot of slow neutrons enter the counter simultaneously; following subsequent pulses – are correspond to the delayed neutrons.

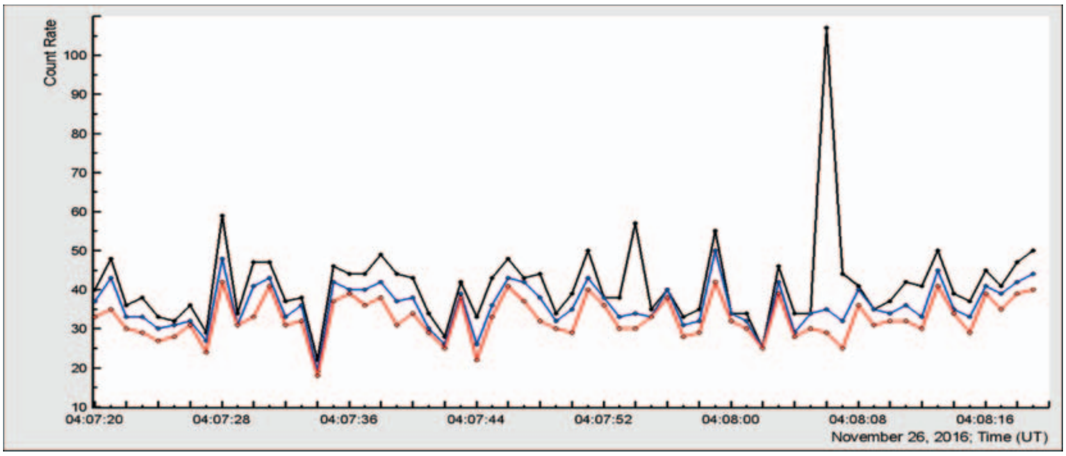

Figure 6. Time series of ArNM second proportional counter corresponding to 3 dead times. Only with shortest dead time of 0.4 μs DAQ electronics registered a large neutron burst.

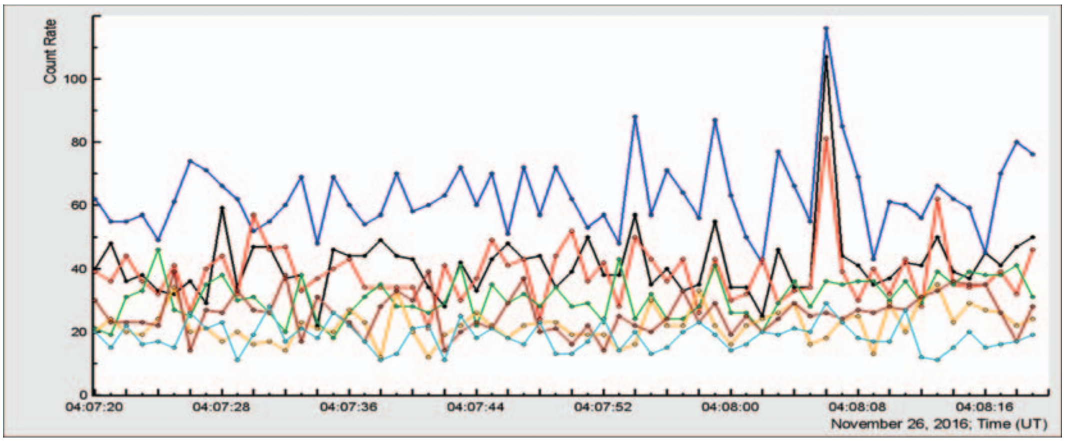

Figure 7. Neutron burst detected by the ArNM with dead time 0.4 μs. Only counters from the first section (2,3,4) demonstrate peaks.

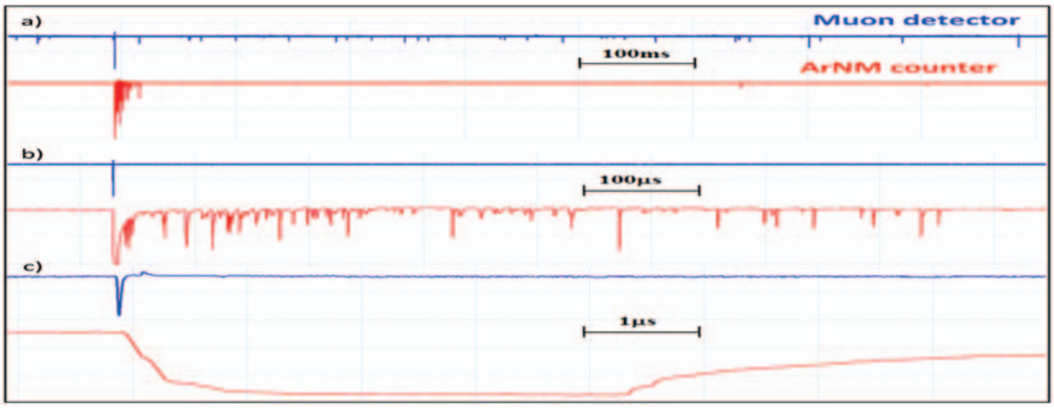

Figure 8. Particle detector output waveforms corresponding to different time zooming scales

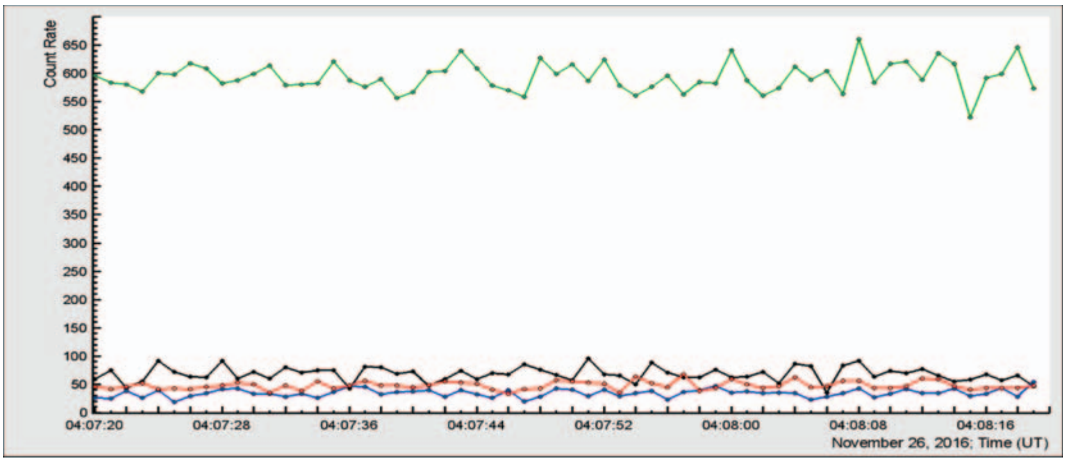

Figure 9. 1-sec time series of 3 scintillators of Muon detector and 3 cm thick outdoor scintillator of STAND1 detector.

In Figure 9 we show 1-second time series of plastic scintillators located under thick layer of lead (Muon detector) and 3-cm thick 1 m^2 area plastic scintillator located outdoors. No one of them demonstrate any enhancement. EAS do not induce any charged particles even in thick lead; whole thousands of EAS particles are passing scintillators in few tens of nanosecond generating only one pulse in DAQ electronics.

4. ON THE POSSIBILITY OF RECOVERY OF PRIMARY CR ENERGY SPECTRUM WITH ARNM

In (Stenkin and Valdés-Galicia, 2002) the dependence of neutron burst multiplicity on primary proton and iron nuclei energy was calculated. They found that this dependence can be fitted by a power law with an index ~ 1.3 for protons, and ~1.6 for iron nuclei (hadrons were counted inside ~1 m around EAS axes). They also found that majority of the neutron bursts are produced by a single hadron. Very high burst multiplicities (>1000), caused by groups of hadrons are very rare: 1-2 per year that coincides with our observations. Such a large multiplicities occurred in all 3 sections of NM, so can be easily distinguished and treated separately. The primary CR energy spectrum was obtained by the frequency analysis of measured multiplicity distribution measured by several proportional counters. The multiplicity spectrum was related to the integral energy spectrum measured by the MAKET array at the same place 10 years ago (see the introduction section and Chilingarian et al., 2004).

MAKET array is a rather compact array comparing with other EAS detectors (the core selection area is only ~10,000 m^2) and was aimed to measure EASs with energies around the "knee" feature of energy spectra, (4-5) PeV. Thus, we can use measured by MAKET array integral spectrum (Figure 10) for the normalization (establish a relation between multiplicity and primary energy) of measured multiplicity distributions (Figure 11).

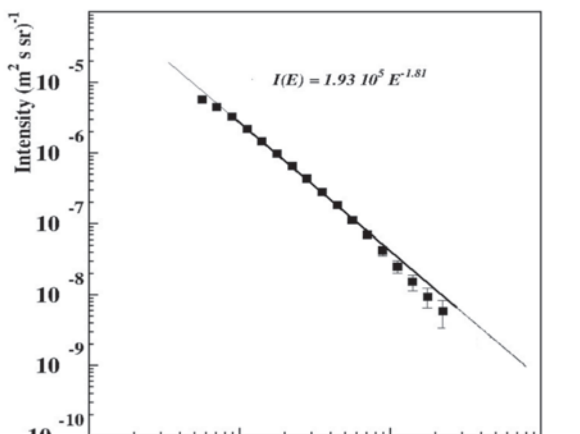

Figure 10. The integral energy spectrum of all particles measured by the MAKET-ANI surface array.

The MAKET-ANI experiment has taken data with exposition time of ~1.46 · 10^8 s. The total number of the registered shower events was ~1.2 · 10^7. A smaller sample of the data ~7.2 · 10^5 (near the vertical EAS, $\theta <= 30^O$) was used for recovering energy spectra. Thus, we proceed from energy spectrum of primary cosmic rays measured by MAKET array:

$I\ (E) = aE^{-\gamma}$ (Figure 10) and distribution of ArNM proportional counter burst multiplicity:

$J\ (E) = bE^{-\beta}$ (Figure 11), where E – is energy of primary CR, γ – spectral index of primary flux and β – fitted slope of the burst multiplicity distribution. Under our assumption of selecting the EASs those core hit the array (area 10,000 m^2 and the ArNM (18^2) we can normalize the multiplicity distribution by the energy spectra measured by MAKER array to tune the arbitrary scale of burst multiplicity distribution to primary energy scale. We can do it simply by equalizing maximal frequencies, i.e. assuming that maximal intensities of both distributions correspond to the one and the same energy of primary particle:

$$I_{max}\ (E_0) = J_{max}\ (E_0).$$

In this way we readily obtain integral energy spectra using different proportional counters of ArNM (see Table 2). Fitted power index β can be checked by equalizing frequencies for 2 arbitrary frequencies: $aE_1^{-\gamma} = bE_2^{-\beta}$ and $aE_3^{-\gamma} = bE_4^{-\beta}$.

Table 2. Recovered energy spectra from ArNM proportional counters (numerical values obtained from the fits shown in Figure 11)

$I_1=178.5E^{-1.39}$	$I_2=5884E^{-1.64}$
$I_3=779.3E^{-1.52}$	$I_4=5873E^{-1.64}$
$I_8=2606E^{-1.589}$	$I_{11}=130.6E^{-1.369}$

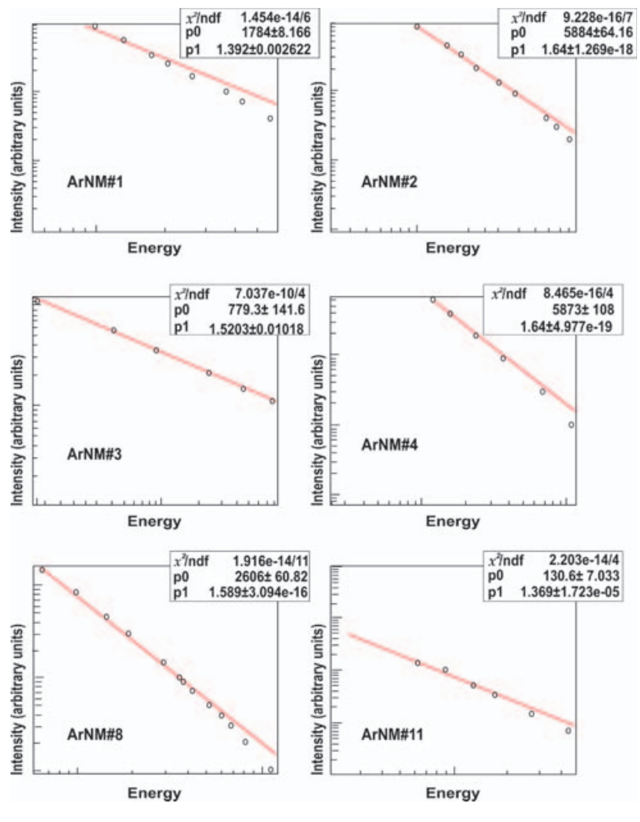

Figure 11. Multiplicity distributions of ArNM proportional counters channels (1,2,3,4,8,11) measured in time span of 1 July 2014 - 1 June 2015.

CONCLUSION

We demonstrate that by measuring the distribution of the bursts multiplicities in NM we can estimate the integral energy spectrum of the primary CR. Obtained multiplicity distribution (Table 2) are in good agreement with previously published estimates (Stenkin and Valdés-Galicia, 2002). The developed fast electronics techniques could be successfully used in the EAS core studies. Nanosecond accuracy detection of EAS core particle by neutron monitor and scintillation detectors located nearby can reveal fine structure of EAS core.

However, NM is a rather small detector with an area not exceeding 18 m2 and cannot collect enough shower axes for a reliable spectrum recovering. The temporal accuracy of the boron filled proportional counters is rather low and they saturated at high multiplicities (Stenkin et al., 2008). Therefore, NM proportional counters are not suitable for large area EAS experiments.

Bartolli et al.,(2016) suggest using EN-detectors (Stenkin, 2008) for the EAS hadron measurements. The detection of thermal neutrons of EAS by means of proposed quite simple devices deployed over a large area on mountain altitudes is an attractive and a cost effective tool opening a new opportunity to EAS research. Instead of an expensive and complicated hadronic calorimeter, one can spread a number of thermal neutron scintillator detectors over a large area to obtain information on hadrons of EAS.

In this concern, we suggest Aragats research station equipped with advanced technical and scientific infrastructure as a possible site for a new surface array. It is possible to locate EN scintillator within each of ~ 300 housings of plastic scintillators equipped with photomultipliers and high voltage supplies belonging to the finishing it's duty GAMMA array.

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