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Particle detectors in solar physics and space weather research

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Abstract

The use of large area particle detectors, which can only be accommodated on the Earth's surface, is vital for measuring the low fluxes of high energy particles accelerated in the vicinity of the Sun. The mystery of particle acceleration in the Universe cannot be explored without the understanding of solar particle accelerators. The energy spectra of highest energy solar particles, as measured by the surface detectors, will shed light on these universal processes of high-energy particle acceleration at numerous galactic and extragalactic sites.

Detected at Earth, energetic particles also can provide extremely cost-effective information on the key characteristics of the interplanetary disturbances. Because cosmic rays are fast this information travels rapidly and can be useful for space weather forecasting. Taking into account that only very few of a great number of solar flares and coronal mass ejections (CME) produce intensive ion fluxes, the so-called solar energetic particle events, it is not only critical to alert clients about the arrival of the most severe radiation storms, but also to minimize the number of false alarms against events which are not severe enough to cause damage.

Using examples of extreme solar events from the 23rd solar cycle, we present experimental results and analysis of the sensitivity of the secondary cosmic ray flux, registered at middle latitudes to the various parameters of the solar particle "beams" incident on the Earth's atmosphere.

Keywords: Cosmic rays; Space weather; Particle detectors; Solar physics

1. Introduction

The sun influences Earth in different ways by emissions of electromagnetic radiation, plasma and high-energy particles and ions. Although the entire energy of the high-energy particles comprises very small fraction of the visible light energy, nonetheless the study of these particles gives clues about fundamental and universal processes of particle acceleration, and provides timely information about the consequences of the huge solar explosions affecting the near-Earth environment, space born and surface technologies, i.e. so-called space weather issues [25].

During billions of years of its evolution, the Earth was bombarded by the protons and fully stripped ions accelerated in the Galaxy during tremendous explosions of the supernovae and by other exotic stellar sources. This flux was changed during the passage of the sun through the four galactic arms during its path around the center of Galaxy and, may be, was affected several times by huge explosions of nearby stars. Nonetheless, on the shorter time scales the GeV galactic cosmic ray flux is rather stable. In turn, our nearest star – the sun is a tremendously variable object, capable of changing radiation and particle flux intensities by 3–4 orders of magnitude in the span of a few minutes. Because of the sun's closeness, the effects of the changing fluxes have major influence on Earth, including climate, safety and other issues (see for example, [7,15]).

The influence of sun on the near-Earth radiation environments can be described as modulation of the stable galactic cosmic ray "background" by the sun activity. The sun "modulates" the low energy Galactic Cosmic Rays (GCR) in several ways. The most energetic flaring process

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in the solar system releases up to 10^{33} erg of energy during few minutes. Along with broad-band electromagnetic radiation, the explosive flaring process usually results in ejection of huge amounts of solar plasma and in acceleration of the copious electrons and ions. Particles can be generated either directly in the coronal flare site with subsequent escape into interplanetary space, or they can be accelerated in CME associated shocks that propagate through corona and interplanetary space [3]. These particles, along with neutrons, produced by the accelerated protons and ions in collisions with dense solar plasma, constitute the so-called, solar cosmic rays (SCR). If energetic enough, reaching the Earth they initiate secondary elementary particles in the terrestrial atmosphere. Low energy SCR (up to ~1 GeV/nucleon) are effectively registered by the particle spectrometers on board of space stations (SOHO, ACE) and satellites (GOES, CORONAS). Highest energy particles generate showers capable of reaching the Earth surface and being detected by the surface particle detectors.

Only few of the SEP events (usually not more than a dozen during solar activity cycle of ~11 years) can be detected by surface particle detectors. Such events cause the so-called ground level enhancement (GLE). The latitudinal dependence of the geomagnetic field provides the possibility to use the dispersed world-wide network of the neutron monitors (NM, [28]) as a spectrometer registering GCR in the energy range from 0.5 to ~10 GeV. The spectra of GCR can be approximated by the power law $-\mathrm{d}J_{\mathrm{p}}/\mathrm{d}E\ (\mathrm{GCR}) \sim E^{\gamma}$, $\gamma \sim -2.7$. SCR flux at GeV energies usually is very weak ($\gamma > -6$), only at some events, such as in 1956, 20 January, 2005, the spectra of SCR is considerably "hard": $\gamma \sim -4$ to -5 at highest energies.

Surface particle detectors measure the number of the secondary particles incident on the detector surface in a fixed time span. These measurements (usually not more detailed as 1-min time series) are the basis for the physical inference on the solar modulation effects. There is absolutely no possibility to distinguish SCR and GCR on event-by-event basis. The solar modulation effects are detected as non-random changes in the time series. And, if at high latitudes, where secondary particles are produced by abundant low energy SCR, modulation effects can reach 1000% and more, at low latitudes the enhancements due to SCR is very small, usually not more than 1–2%. If we take into account that for energies greater than 10 GeV the intensity of the GCR becomes increasingly higher than the intensity of the largest known SEP events (see Fig. 1), we confront a very complicated problem of detecting a small signal of the SCR against the huge "background" of the GCR. Low statistics experiments often demonstrate fake peaks with high significances. Some remedies to avoid erroneous inference on existence of signal are discussed in [12].

Existing networks of particle detectors are unable to reliably research SCR of highest energies (>10 GeV); therefore we still can not determine the maximal energy $E_{\max}$ of solar accelerators. The common adopted opinions put $E_{\max}$ at ~20 GeV, although several underground muon detectors report incident solar ion energies above 100 GeV (see review in [27]).

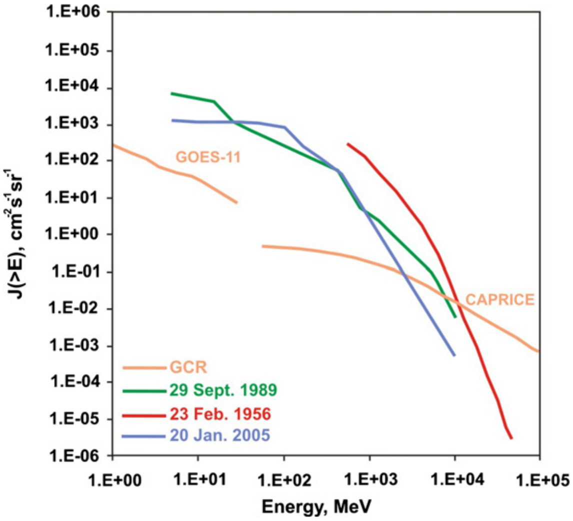

Fig. 1. Galactic and solar cosmic rays.

The direct measurement of highest energy cosmic rays by space-born spectrometers or balloons is not feasible yet due to payload and time-of-flight limitations. Therefore, recently some large surface detectors intended to register GCR with energies higher that 10^5–10^6 GeV (in the region of the so-called all particle energy spectra "knee" region) are used for detecting SCR [9,10,21,30]. The experimental technique used for these detectors i.e. registration of the extensive air showers (EAS) is very similar to the techniques used for detection of SCR. The difference is that PeV particles generate millions and millions of secondary particles in the atmosphere, large portion of which reach the Earth's surface (in contrast, only a few particles generated by SCR can reach the Earth's surface). To detect and measure the energy (and type) of PeV particles, hundred square meters of detectors are used. Detectors are triggered by the special conditions, rejecting low energy particles. By established methods of parallel data acquisition systems (DAQ), it is possible to simultaneously register time series of the secondary particles incident on each of EAS detectors. In this way, due to large sizes of EAS detectors, the signal-to-noise ratio is significantly enlarged and the unexplored energy region of >10 GeV becomes attainable for research. For example, in [39] the use of the L3 [1] detector at the CERN electron–positron collider, LEP, was proposed for the measurement of SCR with energies up to 40 GeV.

However, in addition to relevant experimental techniques we need also the particle "beams" from the sun, hard enough to provide sufficient intensities in the GeV region. The solar extreme events (SEE), which occurred in October 2003, and especially in January 2005, provided such "beams" and, fortunately, the secondary neutrons and muons were detected by several EAS arrays. Obtained experimental information from large particle detector arrays proves possibility of measuring SCR spectra up to 20–30 GeV [21,17,6].

Other solar modulation effects also influence the intensity of the cosmic rays in the vicinity of Earth.

The solar wind "blows out" lowest energy GCR from the solar system, thus changing the GCR flux intensity. Huge magnetized plasma clouds and shocks initiated by coronal mass ejections travel in the interplanetary space with velocities up to 2000 km/s (so-called interplanetary coronal mass ejection (ICME) and disturb the interplanetary magnetic field (IMF)). In turn these disturbances introduce anisotropy in the GCR flux in vicinity of Earth, forming depletion and enhancement regions manifested themselves as anisotropic distribution of GCR.

Time series of intensities of high-energy particles can provide highly cost-effective information on the key characteristics of the interplanetary disturbances (ICMEs). Because cosmic rays are fast and have large scattering mean free paths in the solar wind, this information travels rapidly and may prove useful for space weather forecasting [23]. Size and occurrence of southward B_z in an ICME are correlated with the modulation effects ICME poses on the ambient population of the galactic cosmic rays during its propagation up to 1 AU. In statistical study [22] the relation of CR variability/anisotropy with the geospace disturbances was investigated. It was demonstrated that the parameters of changing CR time series are potentially useful for the geomagnetic activity forecasts. Of course, the direct detection of the energetic storm particles (ESP) by the EPAM instrument on board the ACE space station [20] also alerts hours prior to the approaching interplanetary shock and plasma cloud [2].

Upon arrival at the magnetosphere, the overall depletion of the GCR triggered by the interplanetary shock and plasma cloud, manifest itself as a decrease in the secondary cosmic rays detected by the networks of particle detectors on the Earth's surface. The relative decrease of the count rate at the particle monitors is well pronounced at high latitudes. Due to low magnetic cutoff rigidity at high latitudes the primary protons and ions, responsible for the greater part of count rate, have considerably low energy ($\sim$1 GeV) and are strongly depleted by the disturbances of the IMF. The count rates of the particle monitors at middle to low latitudes are formed by the primaries with energies much higher >5 GeV. Therefore, the relative depletion of higher energies, and consequently depletion of the count rates of low latitude monitors will be less compared to high latitude particle monitors.

Visa-verse geomagnetic storms, appearing as sudden change of the Earth's magnetic field can magnify the relative change of the count rates of middle and low latitude particle detectors, without any corresponding notable alteration in the count rates of the high latitude detectors. If the magnetic field of ICME is directed southwards, it reduces the cutoff rigidity. Therefore, GCRs of lower energies, usually effectively declined by the magnetosphere, penetrate the atmosphere and generate additional secondary particles, thus enlarging the count rate of the monitors located at middle and low latitudes. At high latitudes, cutoff rigidity is very low and the count rates of particle detectors are determined mostly by the attenuation of the cascades in the atmosphere and the decrease of the cutoff rigidity does not significantly magnify the number of secondary particles reaching the detectors at high latitudes.

Because the flux of high-energy ions is weak, and because the most violent particle events are usually highly anisotropic, a network of large area particle detectors, located at low latitudes and high mountain altitudes, is necessary for the reliable detection of these particles. The information about primary ion type and energy is mostly smeared during particles successive interactions with the atmospheric nuclei. Thus, only coherent measurement of all secondary fluxes (neutrons, muons, and electrons), along with their correlations, can help to make unambiguous forecasts and estimates of the energy spectra of the dangerous flux that follows. Hybrid particle detectors of Aragats Space Environmental Center [11] measuring both charged and neutral components of secondary cosmic rays provide good coverage of solar extremely events (SEE) of the 23rd solar cycle. First results of the physical analysis of these events are presented in this paper.

The structure of the paper is as following:

In the second section we give brief description of the particle detectors measuring neutral and charged fluxes of secondary cosmic rays.

In the third section the spectra of the primary protons responsible for the detected fluxes by ASEC monitors are derived from simulations of-nucleic–electromagnetic cascades in the atmosphere followed by the detector response function calculation.

The fourth section presents the largest GLE of the satellite era, which occurred on 20 January, 2005, along with a new technique to derive the spectral index of the SCR at highest energies.

2. Networks of particle detectors

Solar modulation effects in general are not global, i.e. their influences do not uniformly and isotropically affect the Earth as a whole. Therefore, a network of particle detectors is necessary for providing coverage of the whole Earth, as much as possible – as many latitudes and longitudes as possible. The best coverage up until now has been provided by the network of neutron monitor instruments located at $\sim$50 locations, some of which are taking data for $\sim$50 years [32].

Charged particles travel and reach the Earth by way of the "best magnetic connection paths", which is not a straight line between their birthplace and the Earth. The solar neutrons on the other hand, not influenced by solar and interplanetary magnetic fields, reach Earth directly from their place of birth on the solar disc. The special network aimed at detecting very rare neutron events from the

Table 1
Characteristics of the ASEC monitors

Detector	Altitude (m)	Surface (m^2)	Threshold(s) (MeV)	Operation	Count rate (min^{-1})
NANM (18NM64)	2000	18	50	1996	2.7×10^4
ANM (18NM64)	3200	18	50	2000	6.1×10^4
ASNT-8 channels	3200	4 (60 cm thick)	85, 172, 256, 382	1998	5.2×10^{4}[a]
		4 (5 cm thick)	7		1.2×10^5
NAMMM 24 channels	2000	10 – upper	7, 250[b]	2006	7.0×10^4
		10 – down			
AMMM	3200	100	5000	2002	3×10^5
MAKET-ANI 6 channels	3200	6	7	1996	1.5×10^5

[a] Count rate for the first threshold; near vertical charged particles are excluded.

[b] First number – energy threshold for the upper detector, second number – down detector.

Sun includes seven particle detectors on high mountains around the world [34].

The muon detector network [29] (Japan, USA, Brazil, Australia) recently was enlarged by adding new facilities located in Kuwait. Each of the mentioned world-wide networks of particle detectors are intended to measure only one type of secondary particles generated by the primary GCR or SCR. To overcome several limitations on the physical inference, specially for the primaries of highest energies, additional networks are needed to complement these two.

The large variety of solar modulation effects and the stringent limitations of space and surface based facilities require new ideas for developing experimental techniques for measuring the changing fluxes of all the secondary particles. New type of particle detectors with enhanced flexibility to precisely and simultaneously measure changing fluxes of different secondary particles with different energy thresholds will be a key to better understanding of the sun. Establishing a new world-wide network of such detectors, at low to mid latitudes will give the possibility to measure solar proton and ion energy spectra up to 50 GeV, as well as, provide cost-effective possibilities for space weather research [36,14].

The energy distributions of the primary protons which give rise to charged and neutral particles as secondaries in the atmosphere are shifted from each other. Thus, by measuring fluxes of different particles with various energy thresholds, we can estimate the energy spectra of the highest energy solar ions. To do this we have to understand the detector response function on different particles. For each of the detector channels, we have to determine the efficiency and purity of the detected particles (neutrons, protons, mesons, electrons, muons, gammas). We use the GEANT3 [8] and CORSIKA [19] simulation codes for modeling the traversal of particles in the detector and atmosphere respectively.

The Aragats Space Environmental Center (ASEC) provides monitoring of different species of secondary cosmic rays and consists of two high altitude research stations on Mt. Aragats in Armenia. Geographic coordinates: 40°30′N, 44°10′E, cutoff rigidity: ~7.6 GV. The characteristics of the main ASEC particle detectors are depicted in Table 1 (Detailed description of the ASEC monitors is published in the [11]). Data from all ASEC monitors is available on-line from http://crdlx5.yerphi.am/DVIN3/.

The Data Visualisation Interactive Network for the Aragats Space-environmental Center (DVIN for ASEC) provides wide possibilities to display physical inference from the multiple time-series of particle fluxes. DVIN enables sending warnings and alerts to users, gives opportunity to remote groups to share the process of analyzing and exchanging data analysis methods and schemes, preparing joint publications, and maintaining networks of particle detectors [18].

Starting from 1996 we have been developing various detectors, to measure fluxes of different components of secondary cosmic rays at the Aragats research stations of Alikhanian Physics Institute in Armenia. In 1996 we restarted our first detector – the Nor Amberd Neutron Monitor 18NM64 (2000 m a.s.l.). A similar detector was commissioned and started to take data at the Aragats research station (3200 m a.s.l.) in 2000. Solar Neutron Telescope (SNT) is in operation at the Aragats station since 1997, as part of the world-wide network coordinated by the Solar-Terrestrial laboratory of the Nagoya University [34]. In addition to the primary goal of detecting the direct neutron flux from the Sun, the SNT also has the possibility to detect charged fluxes (mostly muons and electrons) and roughly measure the direction of the incident muons. Another monitoring system is based on the scintillation detectors of the extensive air shower (EAS) surface arrays, MAKET-ANI and GAMMA, located on Mt. Aragats at 3200 m a.s.l. Charged component monitoring system on Nor Amberd research station started operation in 2002. Data acquisition (DAQ) system was modernized in 2005. Flexible microcontroller based electronics is designed to support the combined neutron–muon detector system and utilize the correlated information from cosmic ray secondary fluxes, including measurement of the environmental parameters (temperature, pressure, magnetic field). Microcontroller based DAQ systems and high precision time synchronization of the remote installations via global positioning system (GPS) receivers are crucial ingredients of the new facilities on Mt. Aragats.

Simultaneous detection of variations in low energy charged particles, neutron, and high-energy muon fluxes by the ASEC monitors will provide new possibilities for investigating the transient solar events and will allow us to classify Geoeffective events according to their physical nature and magnitude.

3. Determination of the probable energies of primary protons responsible for the secondary fluxes measured by ASEC particle detectors

The world-wide network of neutron monitors located at different latitudes act as a distributed magnetic spectrometer, measuring primary rigidities from 1 to ~10 GV [33]. The current knowledge about solar particles of highest energies is limited by the maximum detectable momentum of this "spectrometer" and by the scarcity of data from solar cosmic rays of highest energies. Furthermore, due to very weak fluxes of GeV particles and vast background of GCR, the energy region of 5–10 GeV is also very poorly investigated by the low latitude NM and there are not many attempts to obtain energy spectra of SCR above 5 GeV in any detail. Usually the energy spectra well above satellite energies are shown in the figures by wide shaded areas or extrapolated dotted lines because of the uncertainty in measurement techniques.

Thus, it is vitally important to acquire data on the SCR above 5 GeV to better define this range of the spectrum. The network of muon monitors is not yet well developed, and moreover extremely rare GLE events initiated by SCR with energies above 5 GeV are very anisotropic. Therefore, for the estimating of the energy spectra of SCR above 5 GeV, it is crucial to perform multiple measurements at the same location. ASEC monitors provide excellent possibilities for the research of highest energy SCR by measuring muon and neutron content of secondary cosmic rays at the same latitude and two altitudes (in 2007 we plan to add additional particle detectors located at 1000 m a.s.l. to complement those already existing at the research stations at 2000 and 3200 m a.s.l.).

To outline the energy range of the primary particles, which can be investigated by the ASEC monitors, we perform simulation of the cascade development initiated by primary protons by the CORSIKA code [19] along with the detectors response simulation with the GEANT3 code [8]. The primary proton spectra was adopted from [5]. The details of the simulations are available from [35].

In Fig. 2 we present the spectra "selected" by different ASEC monitors from proton spectrum incident on the terrestrial atmosphere. Each ASEC detector registers secondary particles, corresponding to parent protons with different energy spectra. As we can see from Fig. 2, if protons just above rigidity cutoff of 7.6 GV effectively generate neutrons detected at 3200 m, the most probable energy of the low energy charged particles "parents" is above 10 GeV. Muons (5 GeV) are effectively generated by the primary protons with energies of 25–30 GeV.

For the SCR, we have to consider much softer energy spectra of primaries compared to the GCR. In Fig. 3 we assume power index of $\gamma = -4$ and, as we can expect, the most probable energies of the "parent" protons are shifted to the lower values. Mode of the distribution of the low energy component is shifted to ~8–9 GeV, and of 5 GeV muons to 20–30 GeV. Nonetheless, ASEC monitors provide several independent measurements of the secondary particle fluxes corresponding to the primary energies of up to ~25 GeV. We measure fluxes of neutrons and low energy charged particles with neutron monitors and plastic scintillators at 2000 and 3200 m a.s.l. and −5 GeV muons by scintillators located under 14 m of concrete and soil (detailed description of the ASEC detectors is given in [11]). Newly installed Advanced Data Acquisition System (ADAS; [13]) enables a number of software controlled

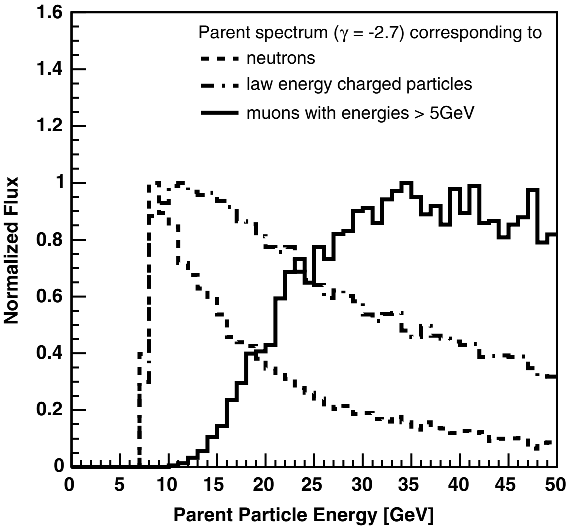

Fig. 2. Simulation of the "Parent" energy spectra of secondary particles initiated by the GCR (spectral slop equals −2.7), "selected" by the ASEC monitors at 3200 m.

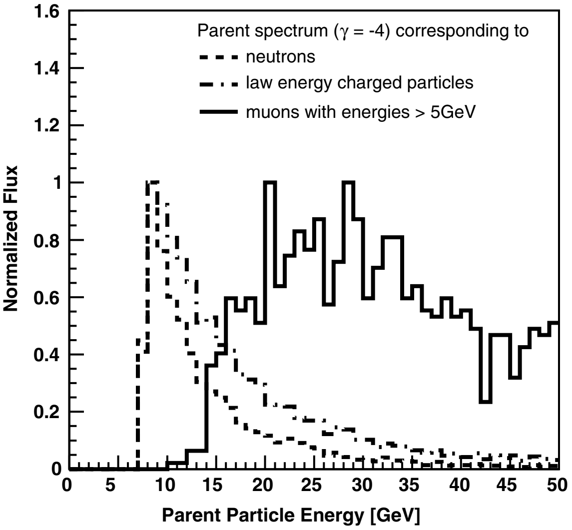

Fig. 3. Simulation of the "Parent" energy spectra of secondary particles initiated by the SCR (spectral slop equals −4), "selected" by the ASEC monitors at 3200 m.

triggers, thus selecting secondary cosmic rays of specific energies coming from a range of directions.

The highest energy detector is, of course, AMMM, with probable primary energy of ~20–30 GeV for the SCR and rather large detecting surface (44 m^2, to be enlarged to 100 m^2 in 2007).

4. Highest energy particles detected on 20 January, 2005

On 20 January, 2005, during the recovery phase of the Forbush decrease a long lasting X-ray burst occurred near the west limb of the Sun (helio-coordinates: 14N, 67W). The start of X7.1 solar flare was at 06:36 and maximum of the X-ray flux at 7:01. The fastest (relative to X-ray start time) SEP/GLE event of 23-cycle was detected by space-born and surface particle detectors few minutes after the flare onset. The start of GLE was placed at 6:48; the maximal amplitude of 5000% recorded by NM at the South Pole is the largest increase ever recorded by neutron monitors. The event was highly anisotropic [4,37,38] and the hardest of the 23rd solar cycle.

As we can see in the Fig. 4 on 20 January, 2005, ASEC monitors detected significant excess of count rates at 7:00–8:00 UT. From 7:02 to 7:05 UT, AMMM detected a peak with significance $\sim 4\sigma$. It was the first time that we detected a significant enhancement of the >5 GeV muons coinciding with the GLE detected by the world-wide networks of neutron monitors. Detailed statistical analysis of the peak [6] proves the non-random nature of the detected enhancement. This short enhancement (denoted in Fig. 4 by the solid curve with open circles) at 7:02–7:05 exactly coincides in time with peaks from Tibet NM [31], Tibet SNT [40] and Baksan array [21]. The solid line in Fig. 4 denotes the time series of the low energy charged component and the dashed line indicates the Aragats neutron Monitor time series.

Although peak signal from the other ASEC monitors do not coincide in time with the 5 GeV muons flux peak, and low energy charged particles (mostly electrons and muons) peak, they also demonstrate enhancement at 7:02–7:05, thus providing possibility to extend the energy spectrum measured by the proton channels of GOES 11 satellite up to 20 GeV (presented in Fig. 5). The differential energy spectra of the SCR protons at 7:02–7:05 UT measured by the space-born spectrometers and surface particle detectors covers more than three orders of magnitude from 10 MeV to 20 GeV and demonstrates very sharp "turn-over" at 700–800 MeV.

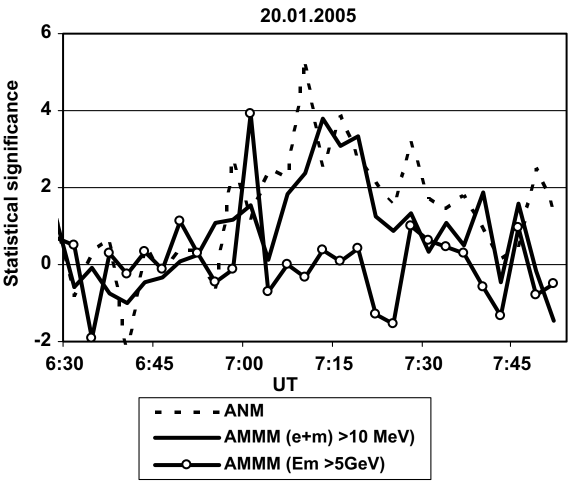

Fig. 4. Detection of the GLE from 20 January, 2005 by ASEC monitors.

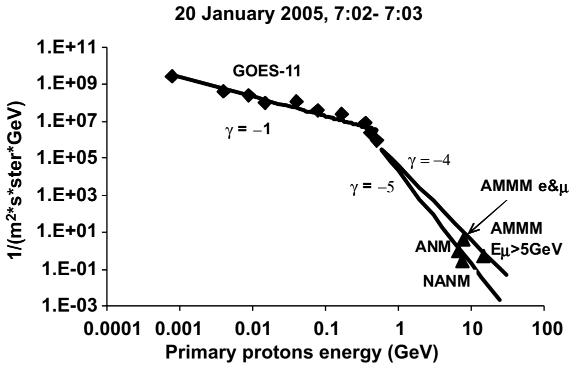

Fig. 5. Differential energy spectra of the SCR protons 20 January, 2005.

The energy spectrum remains very hard up to ~800 MeV (with power index ~−1) and prolongs till tens of GeV with power index ~−4 to −5. This signifies that acceleration at GeV energies probably have a different nature than at MeV energies.

Neutrons detected by the ASEC neutron monitors (ANM and NANM) and low energy charged particles have "parent" primary protons with energies slightly greater than cutoff rigidity threshold (see Fig. 3). The most probable proton energy corresponding to the measured 5 GeV muon flux, as we can see from the same Fig. 3 is in the region 20–25 GeV. Note that the reconstructed differential spectra of AMMM is between the lines corresponding to index of $\gamma = -4$ and -5. It is consistent with most spectra estimates reported at the 29th ICRC at Puna, India [31,37]. The uncertainty in the spectral index reflects the methodical difficulties of estimation of differential spectrum at such high energies.

The estimated energy spectra index of $\gamma = -4$ to -5 at highest energies is a very good indicator of upcoming abundant SCR protons and ions with energies 50–100 MeV, extremely dangerous for the astronauts and high over-polar flights, as well as for satellite electronics.

Another way to estimate the index of power law exploits the different attenuation of the secondary fluxes depending on altitude. Estimation of the energy spectra index using data from NM located at same latitude, but different altitudes was suggested by [26]. Recently same methodology was used for the determinations of the radiation dozes received on-board of airplanes during solar particle events [24]. We use this technique for estimation of the spectral index of the 20 January GLE from the data of the Aragats and Nor Amberd NM [35].

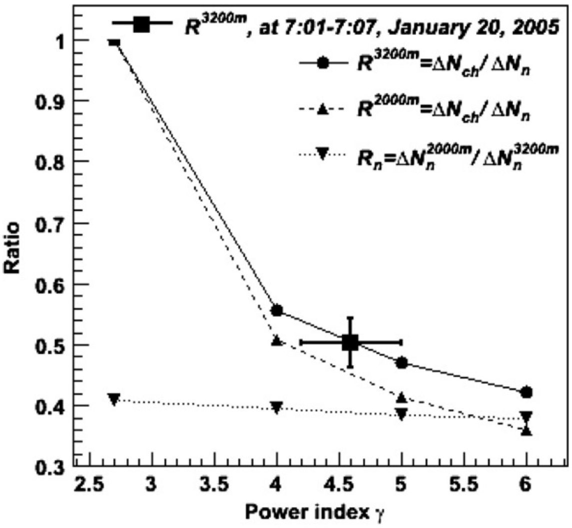

Fig. 6. Estimation of the energy spectra index by comparing different secondary fluxes measured at same the location.

Proceeding from detected fluxes at Aragats, we check if using the ratio of the enhancements of the flux of different secondaries (for example neutrons and low energy charged particles) it is possible to estimate the power law index. As one can see from Fig. 6, indeed the ratio of the neutral-to-charge flux is more sensitive to the power index compared with neutron flux ratio measured at different altitudes.

The estimate of the spectral index obtained by the proposed parameter R^{3200}, as one can see in Fig. 6, coincides within statistical error bars, with the most probable value of the index obtained by the direct method (see Fig. 5). However, to achieve reasonable statistical accuracy we integrate fluxes of neutrons and low energy charged particles over 7 min starting from 7:00. In Fig. 4 we see very fast changing pattern of secondary fluxes, therefore, the estimate based on the R^{3200} parameter is too smeared and can only be used for detectors with large surfaces and/or for very strong fluxes of solar particles.

5. Conclusions

Investigation of the highest energy solar cosmic rays is a very difficult problem, requiring large surfaces of the particle detectors located at middle and low latitudes. Detection of the neutral and charged secondary particles is necessary for the estimation of the energy spectra. Measurements of the energy spectra of primary particles up to several tens of GeV will significantly enlarge the basic knowledge on the universal processes of particle acceleration at the Sun and in the Universe and give good perspectives for the timely warnings on Space Weather severe conditions.

Enhancements in the AMMM count rates indicate higher solar ion energies, and, consequently hard spectra of the GLE in progress. Of course, not all GLEs will have ions with energies of tens of GeV, but ones having such energies are of utmost hazard and should be reported as soon as possible to satellite operators. To detect very weak fluxes of highest energy solar ions we enlarge the surface of 5 GeV muon detectors at Aragats up to 100 m^2, to achieve the relative accuracy of signal detection of 0.16% (for 1-min time series).

Gradual increasing of NM count rates before the sudden commencement of the Geomagnetic storm is usually detected by the particle detectors located at high latitudes. The pattern of the steady enhancements of count rates of all middle latitude monitors will provide firm basis for the on-line warning service.

Alerts on the upcoming radiation and geomagnetic storms are of huge importance taking into account planned manned flights to the Moon and Mars and the overall enhancement of space activity of our civilization. In 2006 the sun reached the minimum of activity and a new solar cycle started. The newest model of the migration of the solar spots [16] predicts ~50% enhancement of solar activity in the new 24th cycle as compared with 22nd and 23rd cycles. Therefore, we need timely and reliable information on the state of radiation environments in the interplanetary space and correct models of the major solar energetic events in progress. The information about highest energies is necessary to test such models and to obtain overall knowledge on the particle acceleration in flares and by fast shock waves.

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