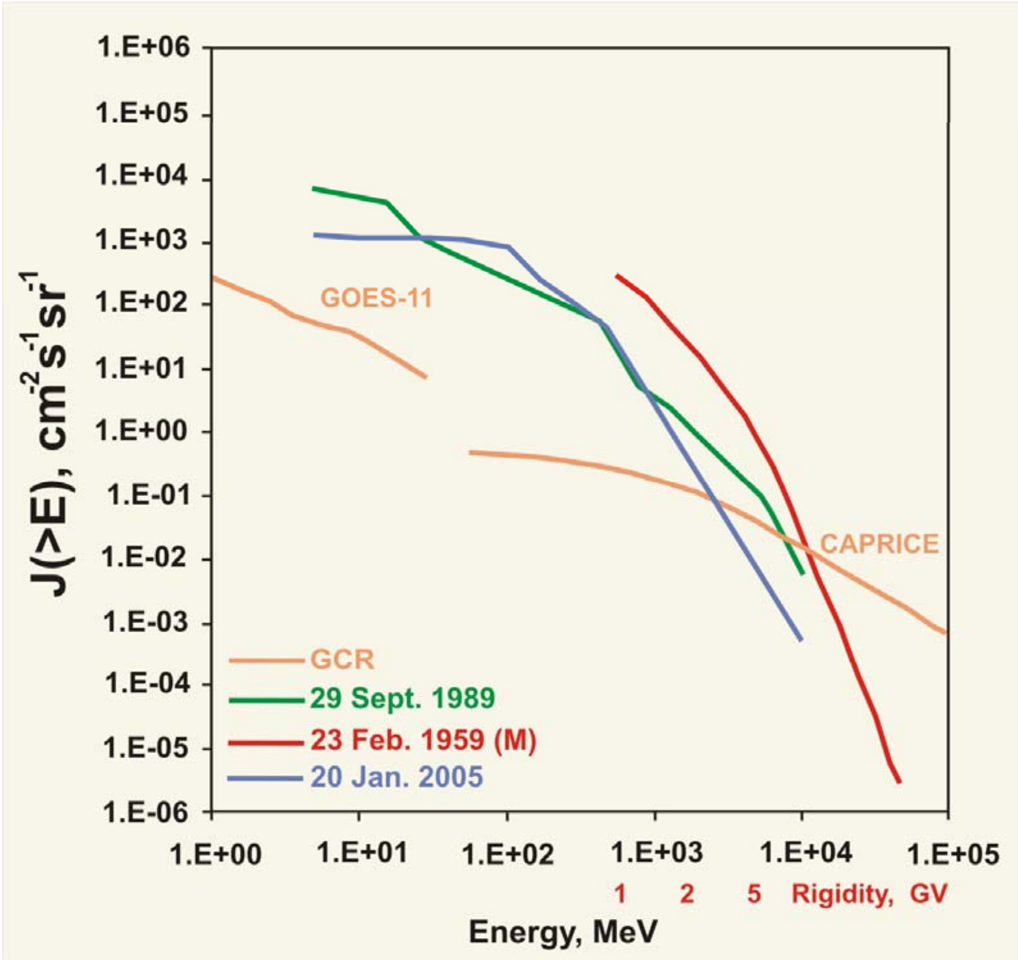
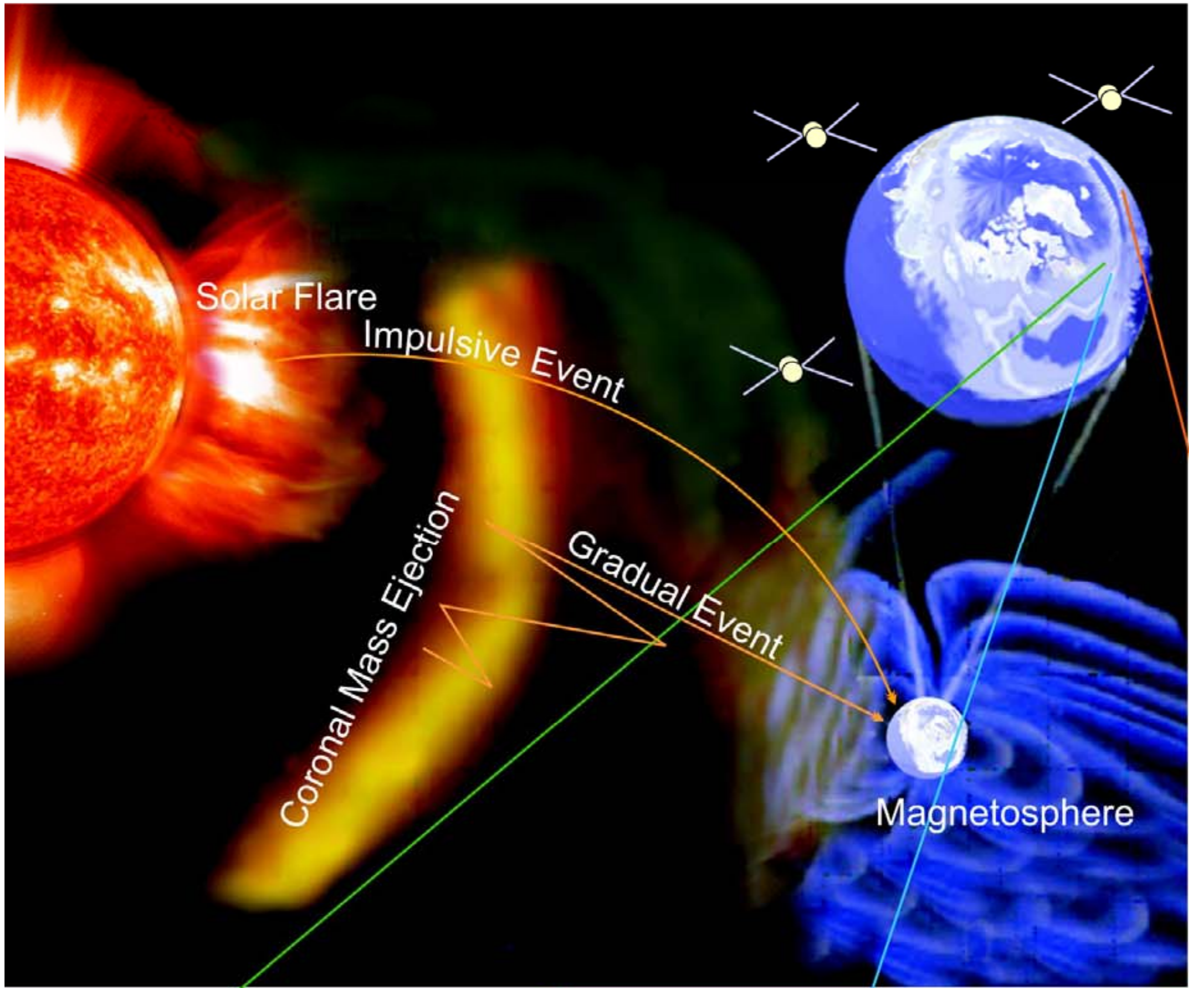
A middle to low latitude particle detector network for Space Weather Research

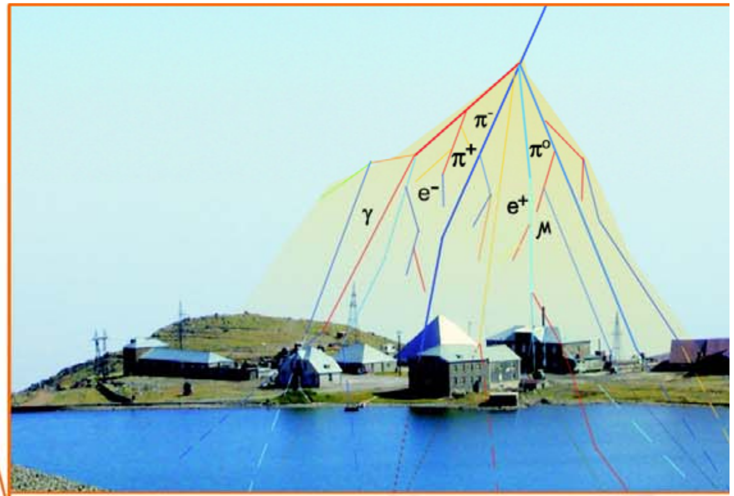
A.Chilingarian

Cosmic Ray Division, Alikhanyan Physics Institute,Yerevan,
ASEC and ANI collaborations

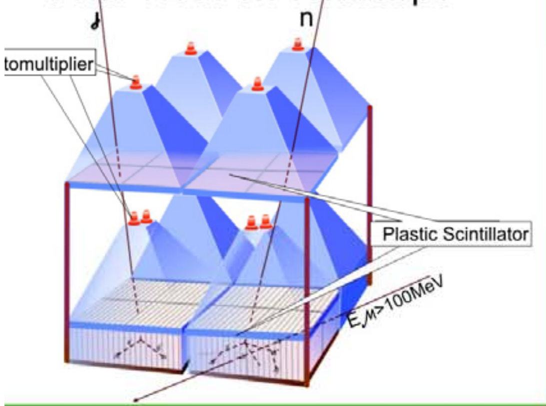
Galactic and Solar Cosmic Rays



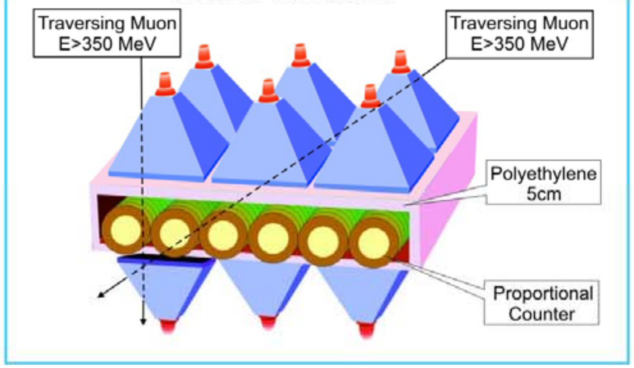




Solar-Neutron Telescope

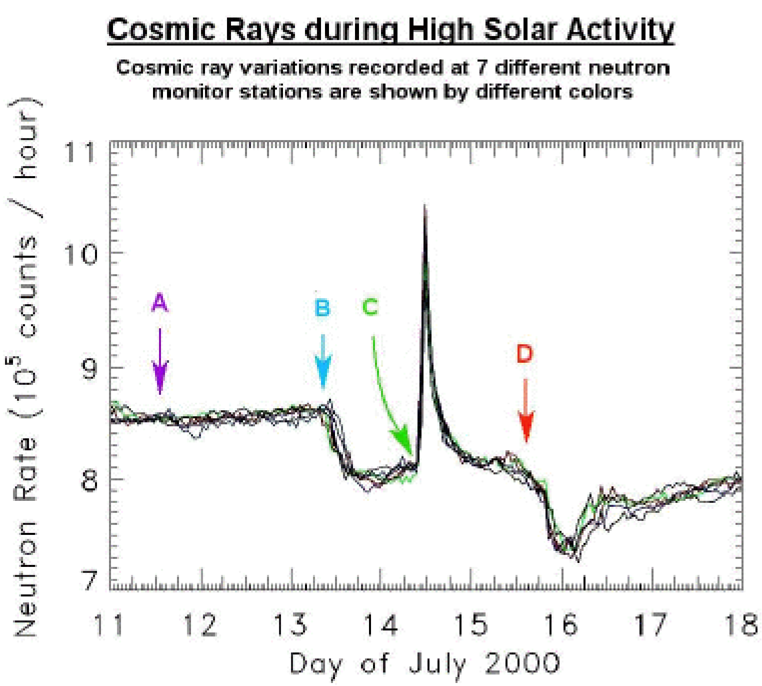


Nor-Amberd Multidirectional Muon Monitor



High energy cosmic rays open a window for the exploration of the d
and forceful processes in the far-corners of the universe. The A
Space-Environmental Center (ASEC) of the Cosmic Ray Division in Ar
http://crdlx5.yerphi.am, conducts research in the field of Galactic Cosmi
and Solar Physics. The two research stations, at 3200m and 2000m el
on Mt. Aragats, are equipped with modern scientific detectors and instr
which allow the scientists to make new discoveries in high energy astrop
The ASEC explores the activity of our own star, the Sun, and is dev
Space Weather forecasting and early warning systems and technique
strategic geographic coordinates of the ASEC research stations and the
based particle detector systems developed by the ASEC scientists, c
with data from detectors in space and on the ground, will allow the intern
community to develop a reliable and global Space Weather forecasting
to protect astronauts and satellites in space and power grids on the grou

GLE at High and Low Latitudes

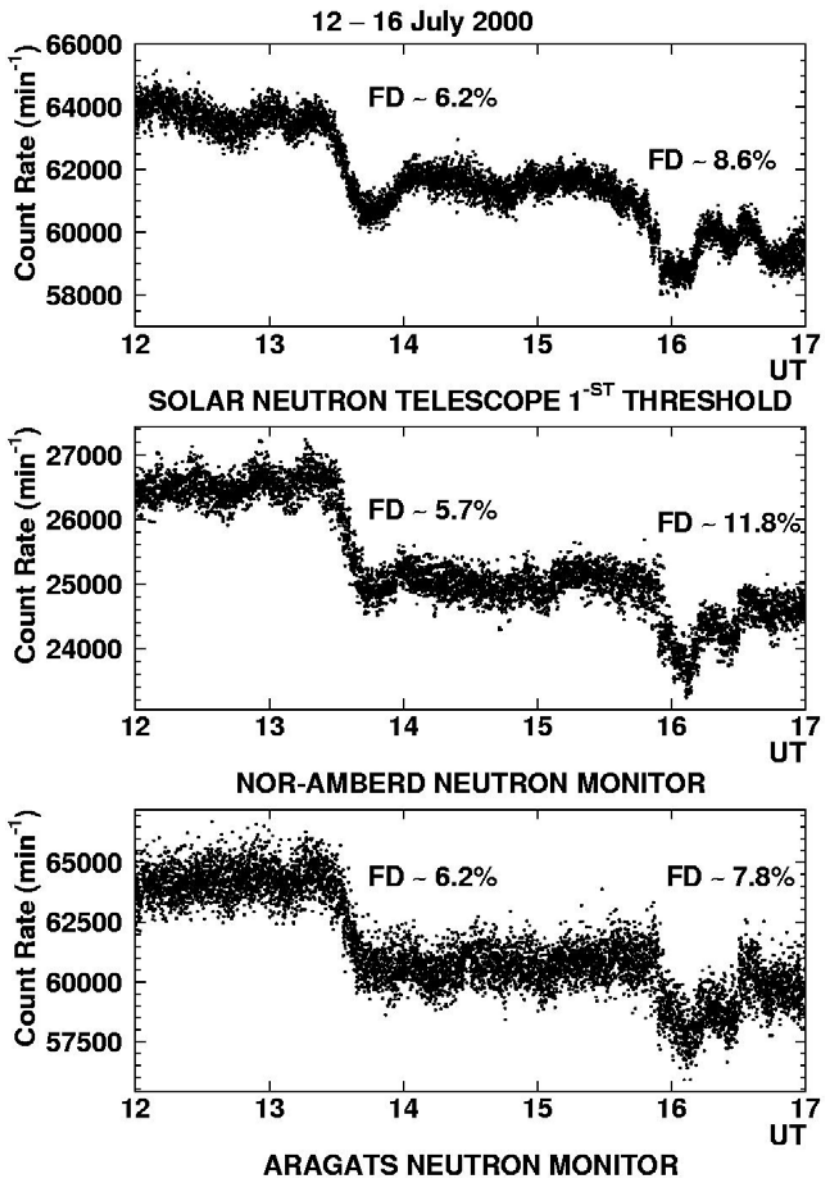


A: First coronal mass ejection (CME) at Sun.

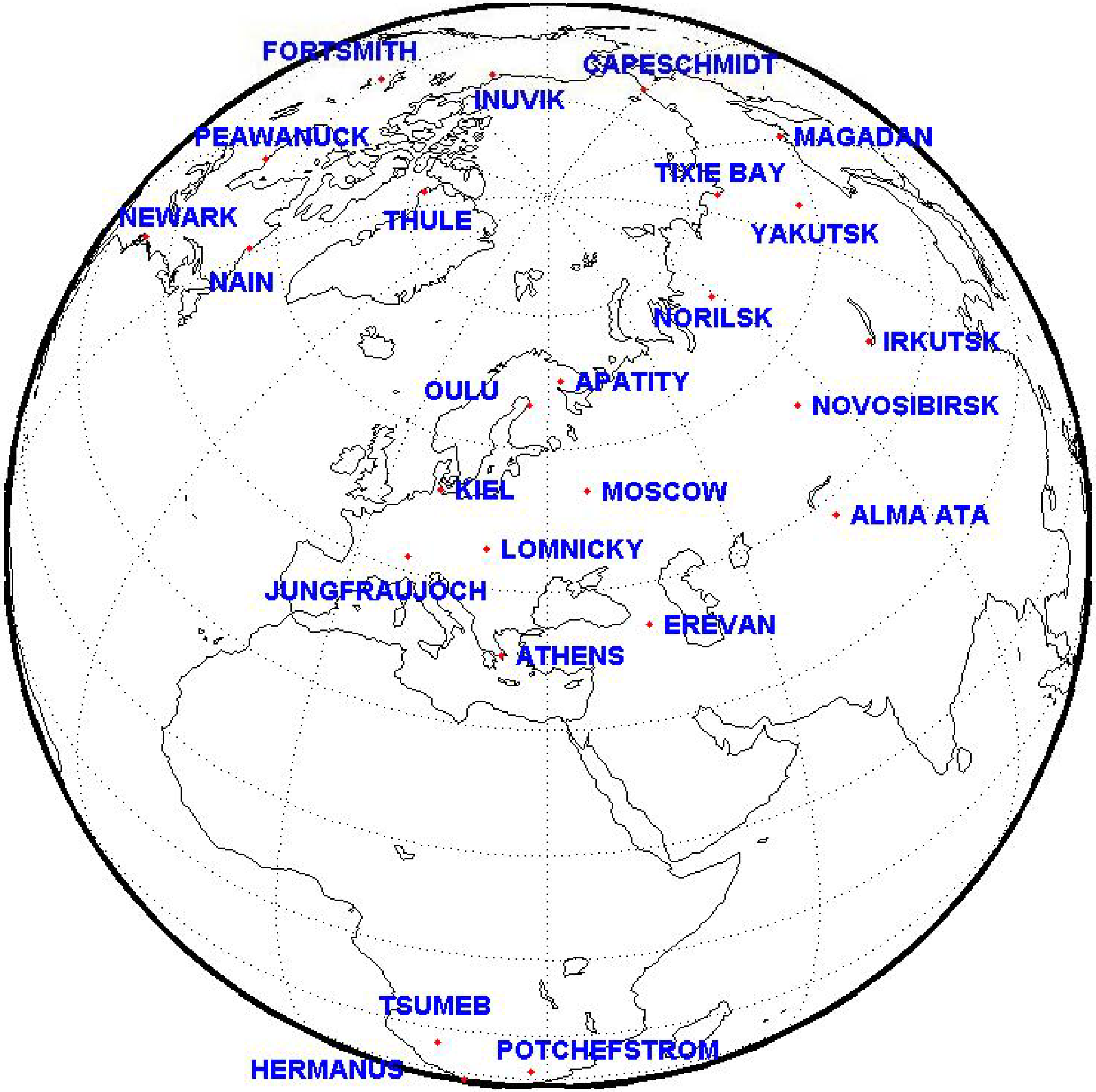
B: First CME arrives at Earth. Cosmic rays decrease suddenly — a "Forbush decrease."

C: Second CME at Sun. This one accelerates high energy particles that reach Earth minutes later. The sudden increase recorded by the neutron monitor is a "ground level enhancement."

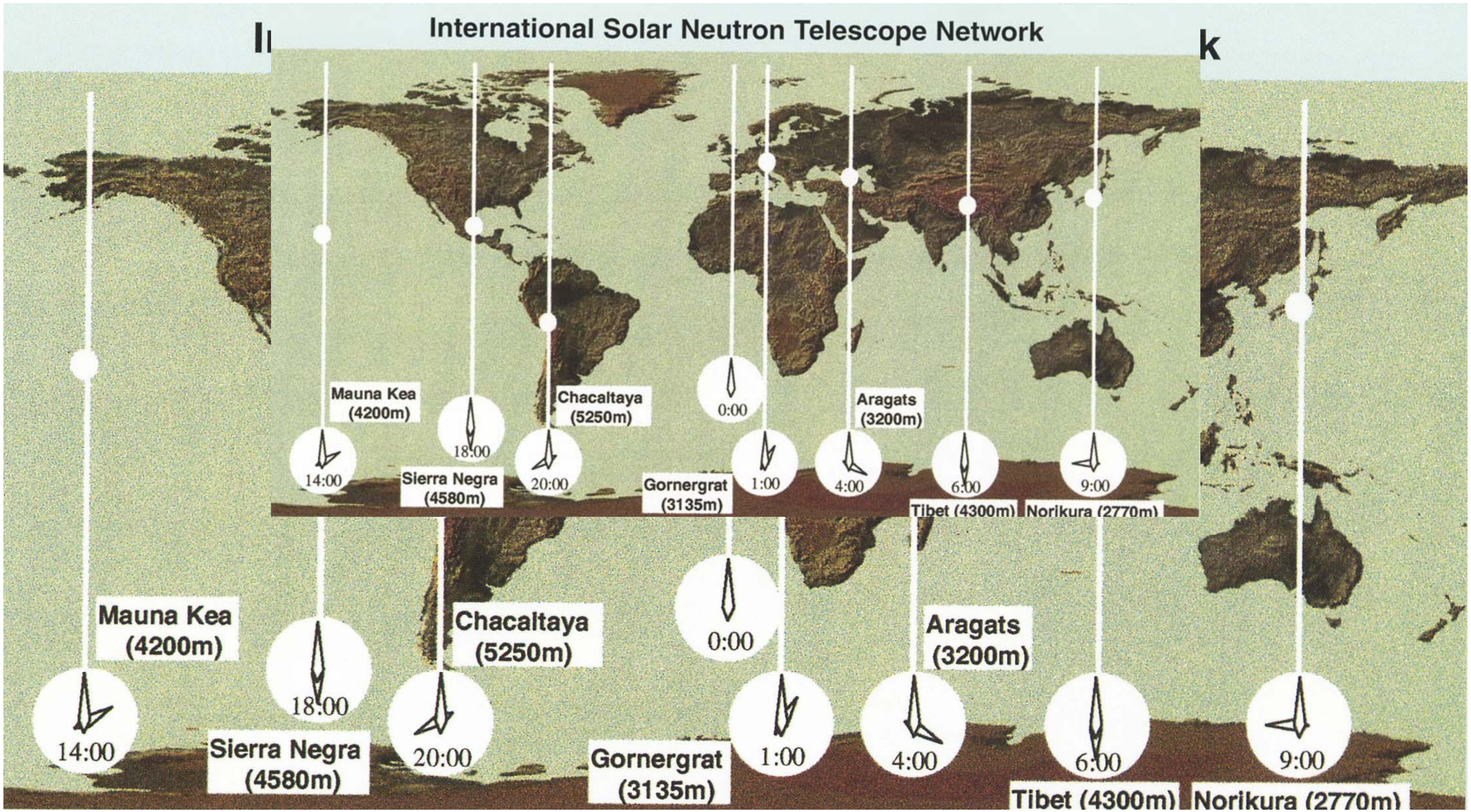
D: Second CME arrives at Earth. Cosmic rays decrease again. This CME produces the largest geomagnetic storm in 10 years. Aurora observed as far south as Georgia.



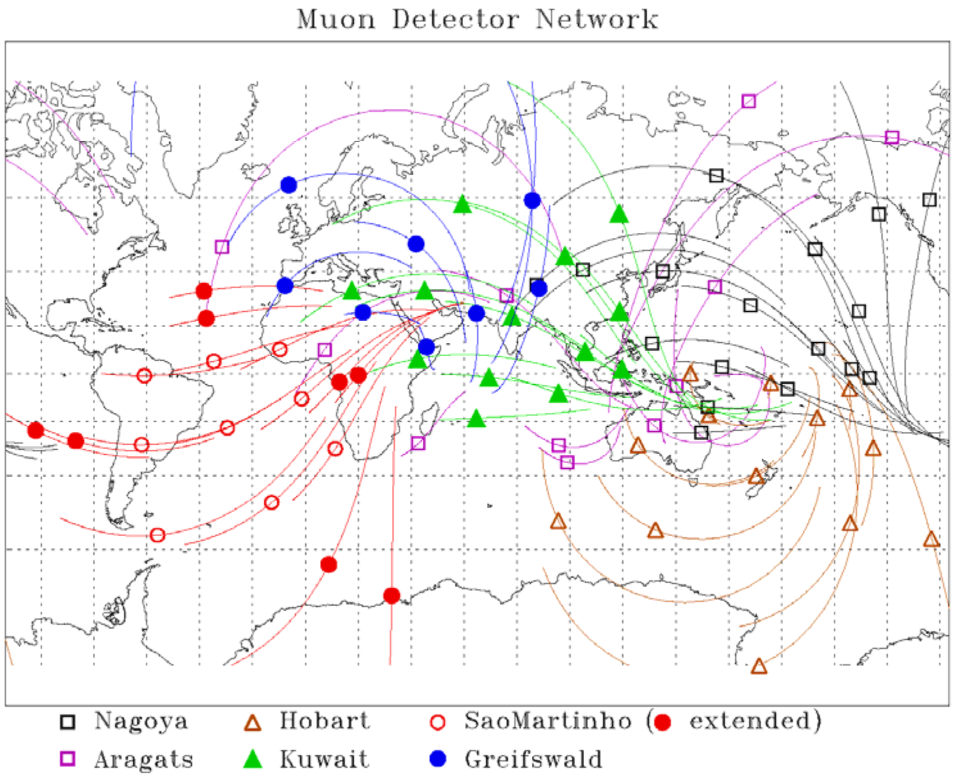
Neutron Monitors World-Wide Network

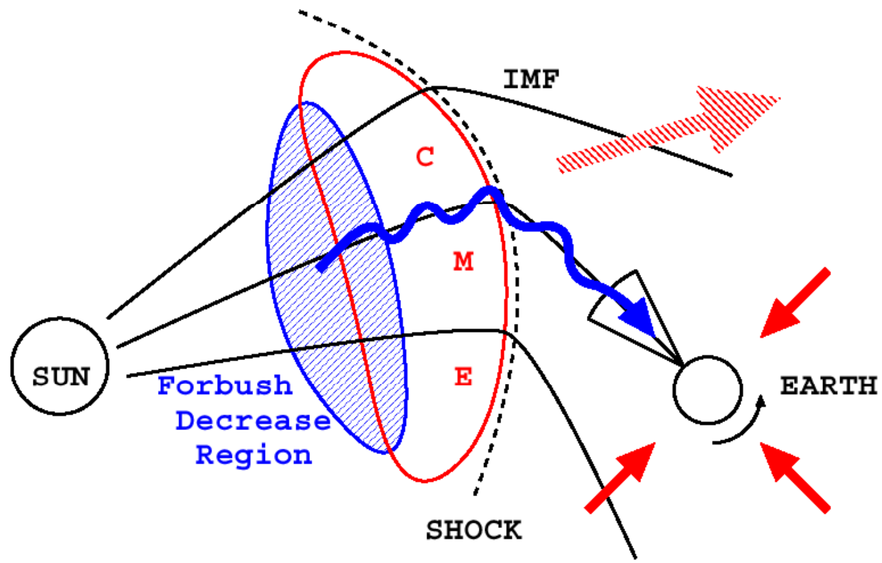


Worldwide network of neutron detectors



World-wide Networks of Particle Detectors





A CME propagating away from the Sun with a shock ahead of it affects the pre-existing population of galactic cosmic rays in a number of ways. Most well known is the Forbush decrease, a region of suppressed cosmic ray density located downstream of a CME shock. Some particles from this region of suppressed density leak into the upstream region and, traveling nearly at the speed of light, they race ahead of the approaching shock and are observed as precursory loss-cone anisotropy far into the upstream region. Loss-cones are typically observed 4-8 hours ahead of shock arrival for shocks associated with major geomagnetic storms (Munakata et al., JGR, 105, 2000).

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
SNT-4channels +	3200	4 (60cm thick)	120, 200, 300, 500	1998	$5.2\times 10^{4*}$
veto		4 (5cm thick)	7		1.2×10^5
NAMMM	2000	5 + 5	7 ; 350***	2002	7.0×10^4
AMMM	3200	45	5000	2002	$1.3 \times 10^{5**}$
MAKET-ANI	3200	6	7	1996	1.5×10^5

*Count rate for the first threshold; near vertical charged particles are excluded

**Total count rate of 45 muon detectors from 150 (100 to be put in operation in 2006)

*** First number – energy threshold for the upper detector, second number – bottom detector.

Solar Extreme Events: Fundamental Science and applied Aspects (SEE - 2005)

International Symposium
Nor Amberd, Armenia
26 - 30 September 2005

Topics

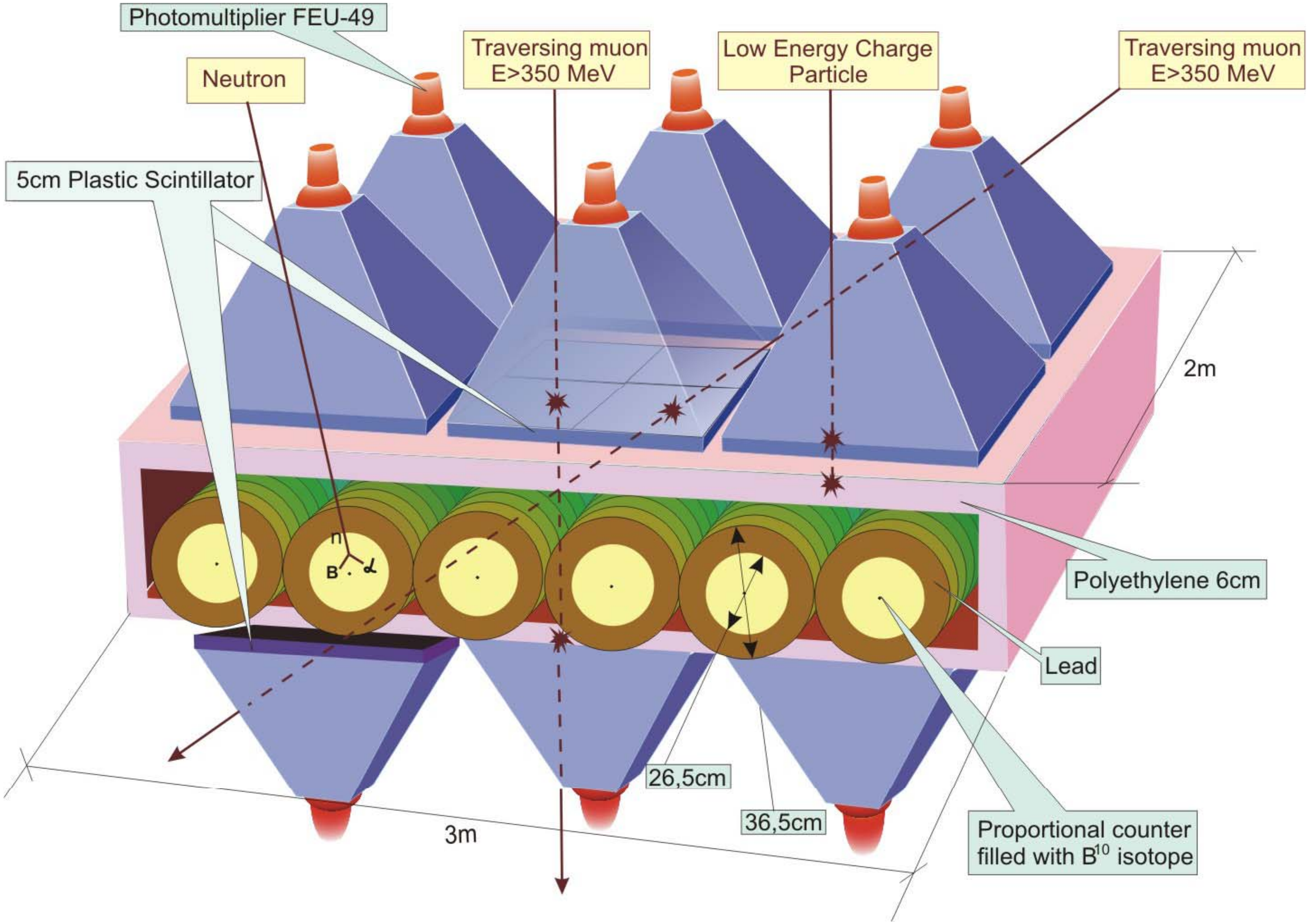
- Energetic processes on the Sun during the extreme events
- Propagation of the solar energetic particles and interplanetary CMEs
- Magnetospheric response to the solar extreme events
- Methodologies of forecasting of space weather conditions Effects of Space Weather on technology infrastructure and human environment

Co-sponsored by COSPAR, ISTC, NFSAT, YerPHI, WEB - limited, SCACRD

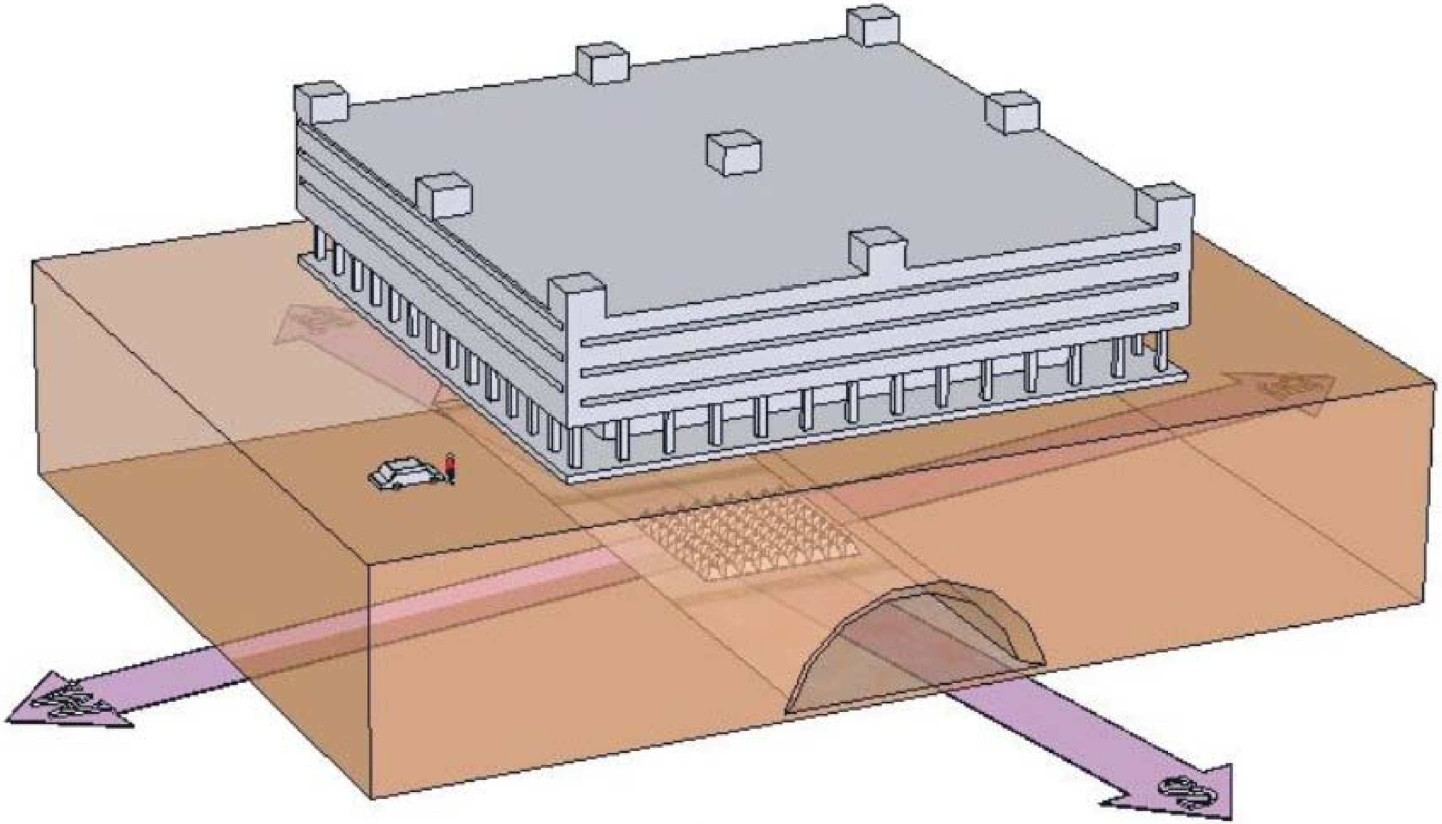
International Advisory Committee

Galina Bazilevskaya, lebedev institute, Russian Academy of Science
Karen Buniatov, ISTC, Moscow
Ashot Chilingarian, Alichanyan Physics Institute, Armenia (Co-chairman)
Ioannis A. Daglis, Institute for Space Applications, National Observatory of Athens, Greece
Lev Dorman, Israel Cosmic Ray Center and Emilio Segre' Observatory, Israel
Murray Dryer, Geophysical institute, University of Alaska, USA
Erwin O. Flueckiger, Physikalisches Institute, University of Bern, Switzerland
Terry G. Forbes, University of New Hampshire, USA
Karel Kudela, Institute of Experimental Physics, Slovakia
Joseph M. Kunches, NOAA Space Environment Center, USA
Jean Lilensten,Laboratory of Planetology, Grenoble, France
Kazuoki Munakata, Shinshu University, Japan
Yasushi Muraki, Kioto University, Japan
Michail Panasyuk, Moscow State University, Russia (Co-chairman)
Vahe' Petrosian, Stanford University, USA
Igor Veselovsky, Moscow State University, Russia
Yuri Yermolaev, Space Reseearch Institute, Russian Academy of Science

Nor Amberd Multidirectional Muon Monitor

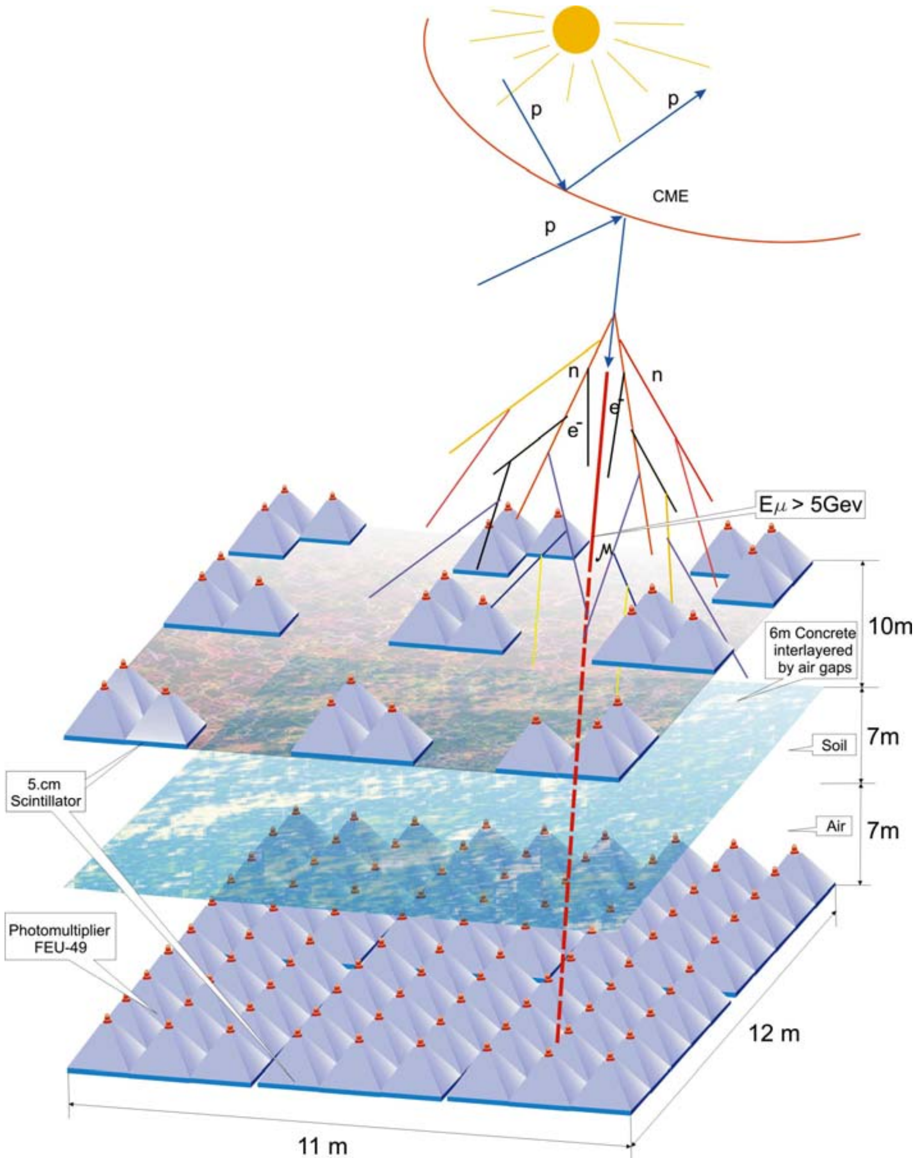


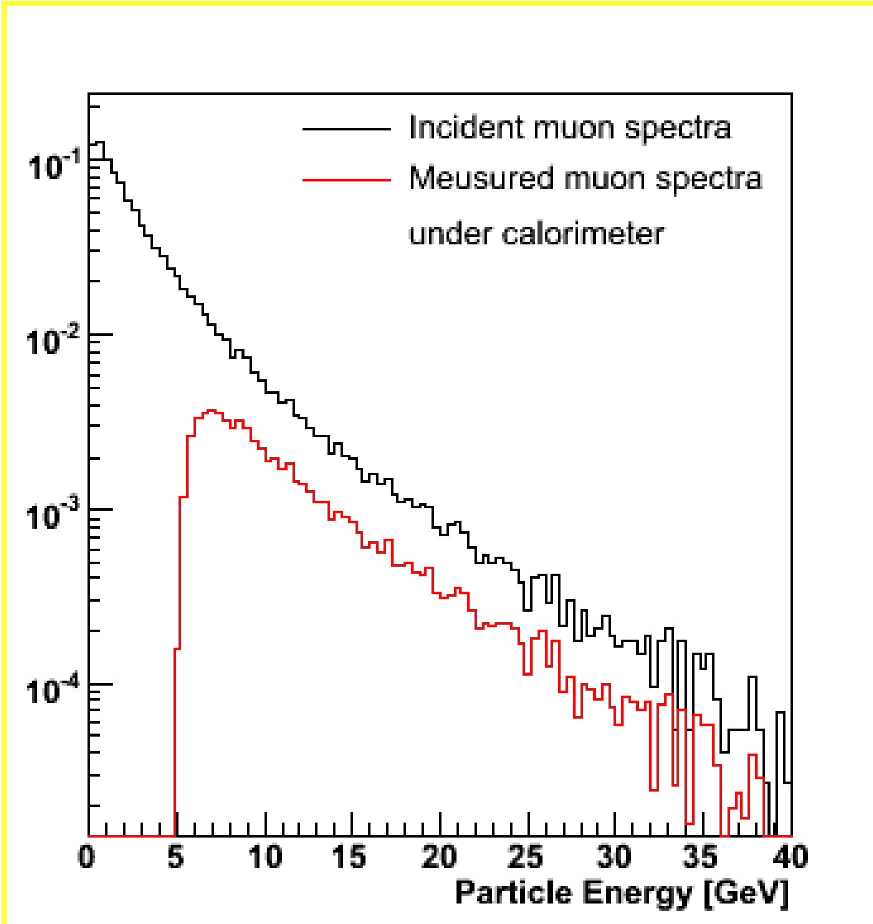
Aragats Multidirectional Muon Monitor (AMMM)



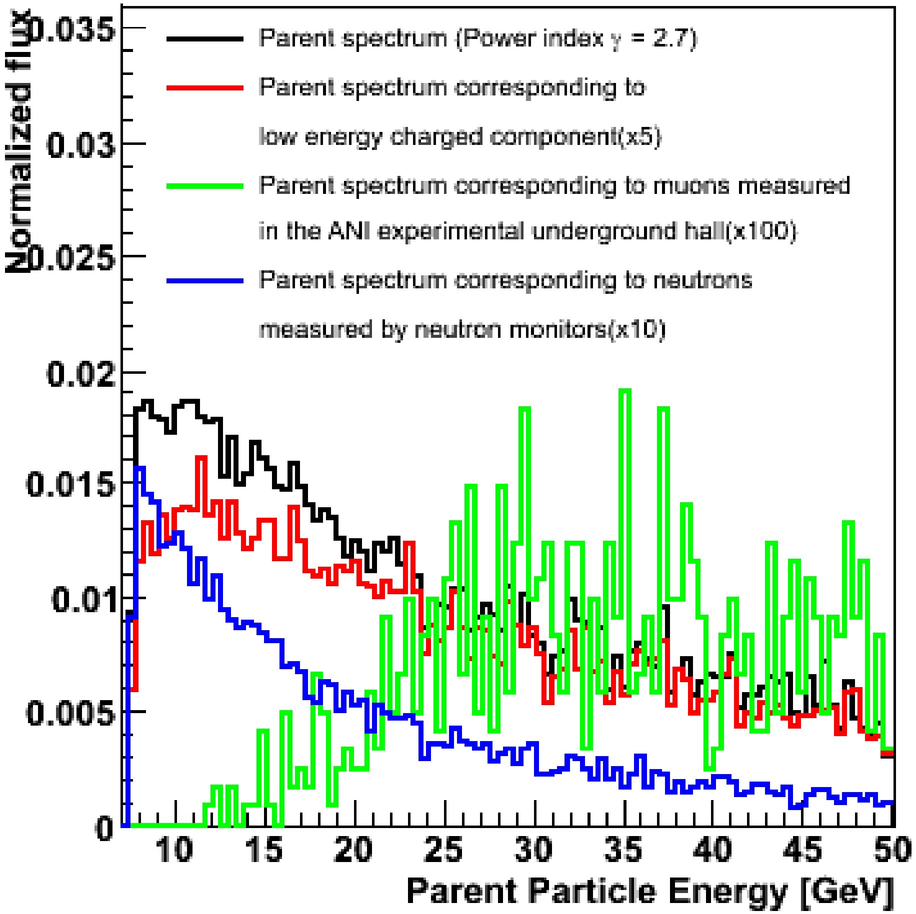
AMMM

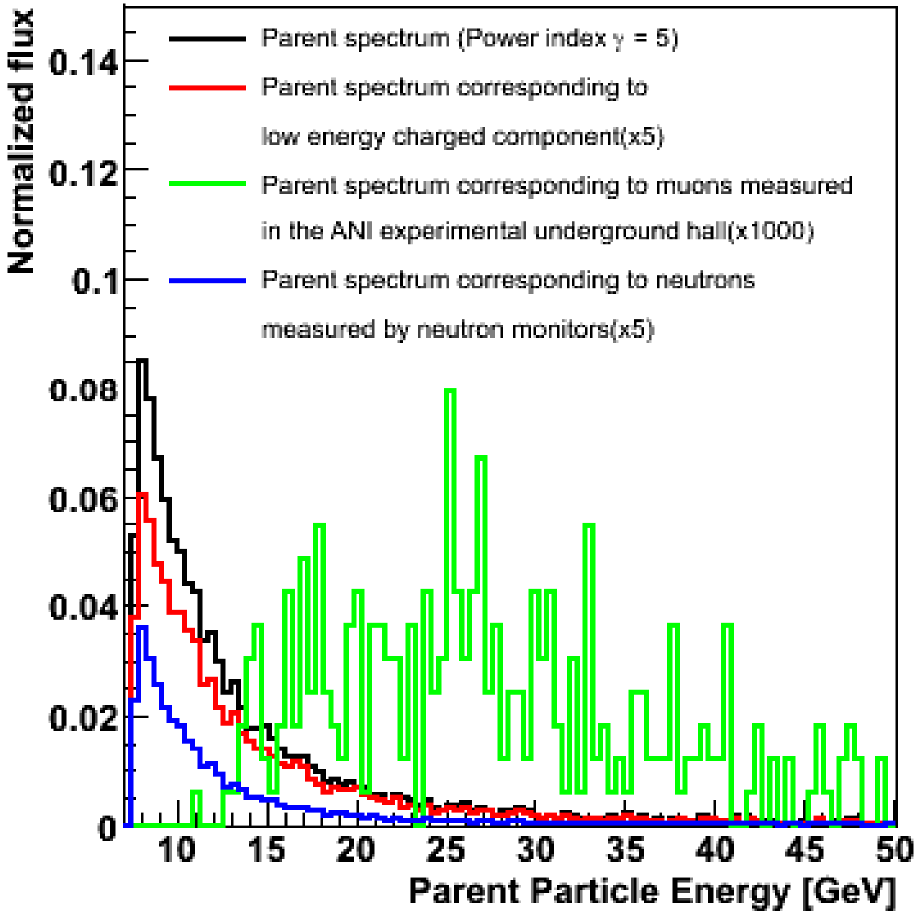
Aragats Multidirectional Muon Monitor (AMMM)



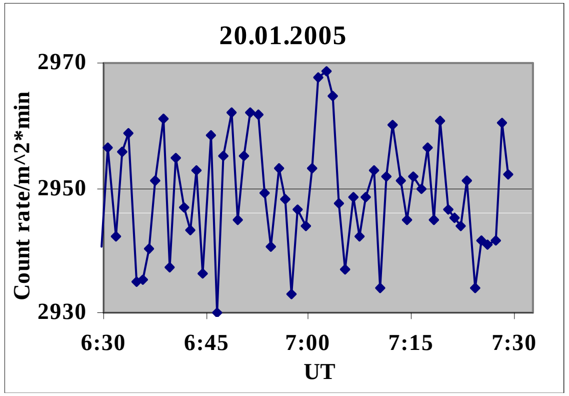


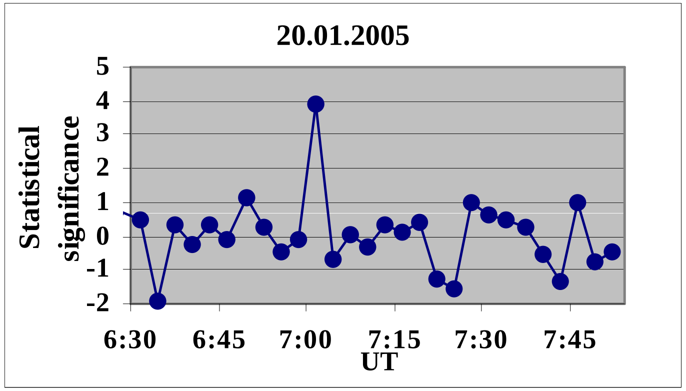
Energy range of Aragats Monitors



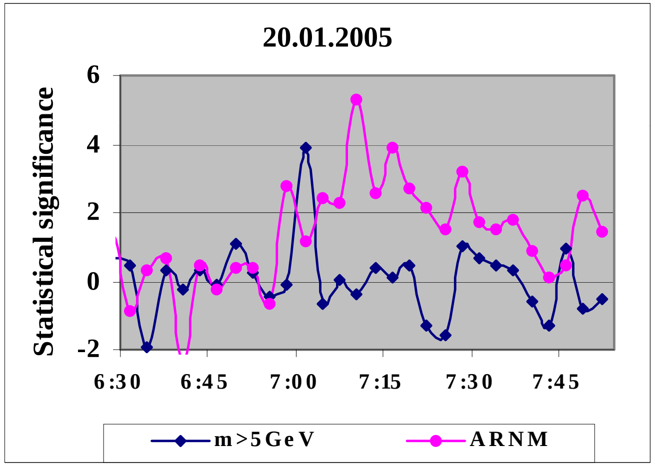


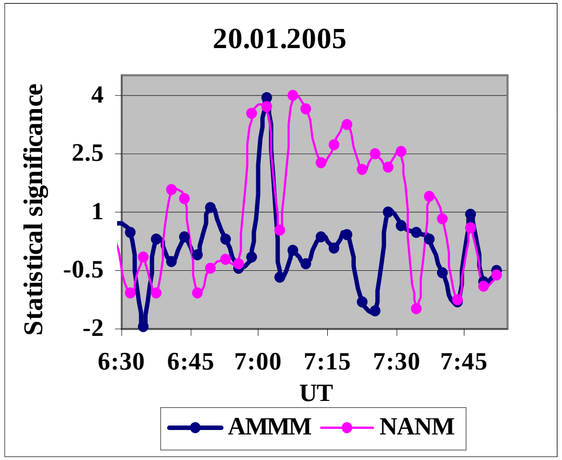
AMMM Detection of GLE 20 January 2005

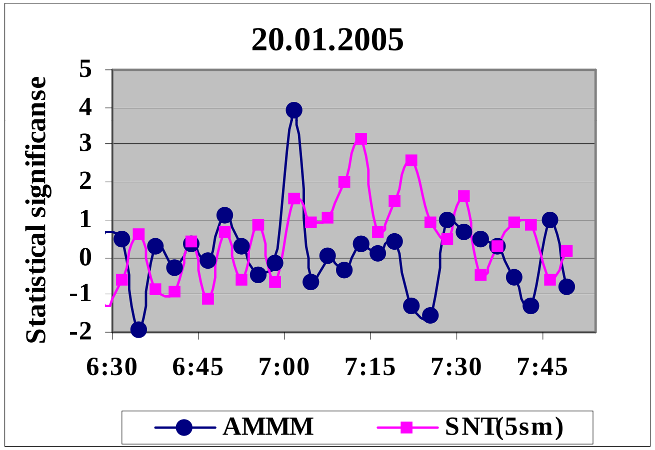


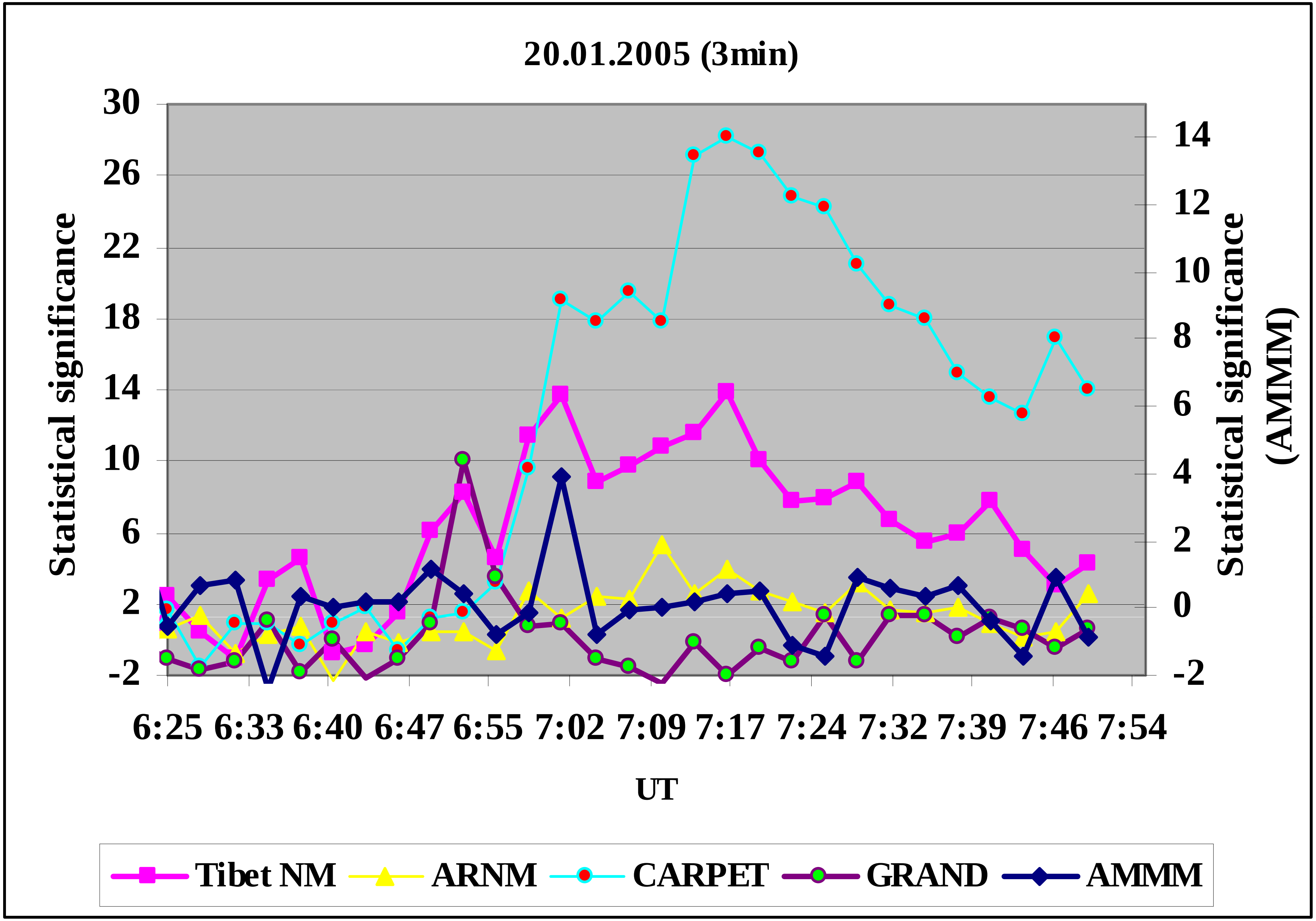


The additional signal at 7:02-7:04 UT equals 2354 (0.644%) If we adopt the Poisson standard 0.164%, significance = 3.93σ



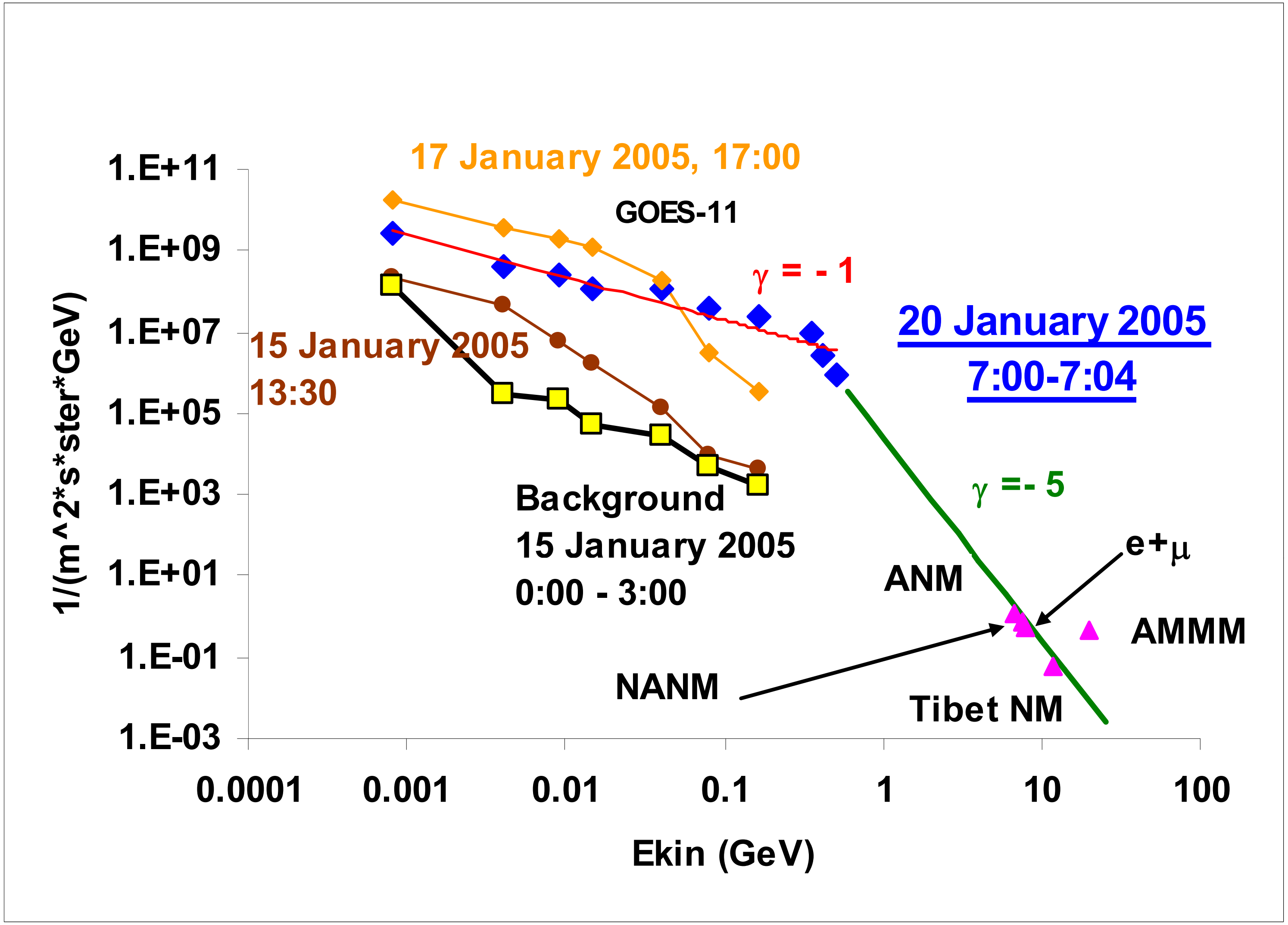




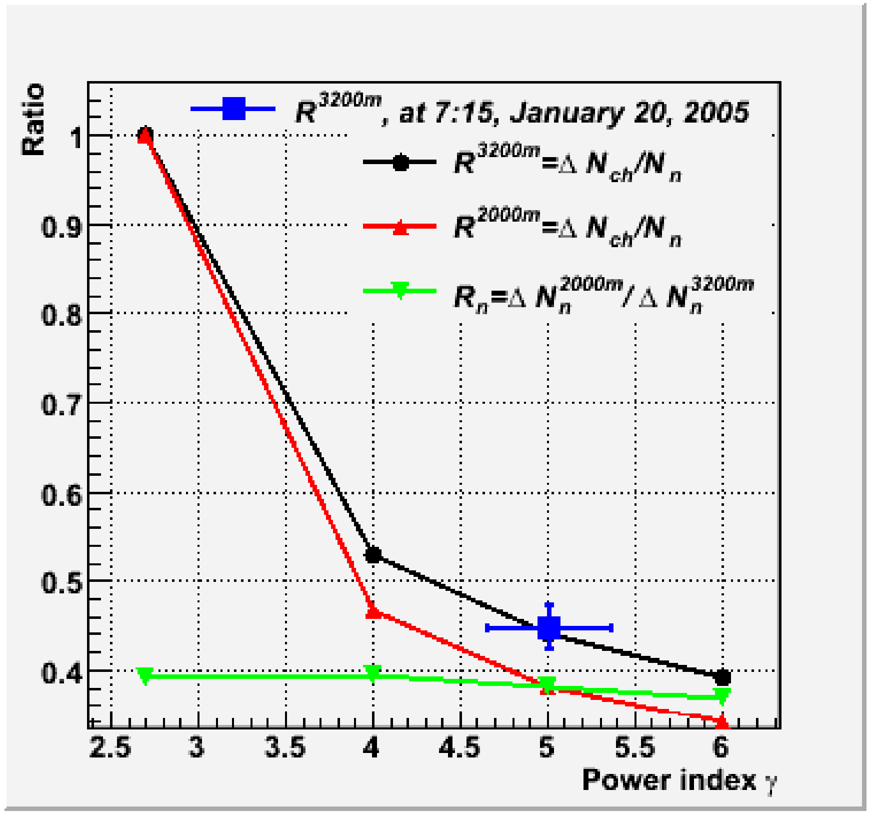


20.01.2005 (3min)
Statistical significance
Statistical significance (AMMM)
30
26
22
18
14
10
6
2
-2
14
12
10
8
6
4
2
0
-2
6:25 6:33 6:40 6:47 6:55 7:02 7:09 7:17 7:24 7:32 7:39 7:46 7:54
UT
Tibet NM
ARNM
CARPET
GRAND
AMMM

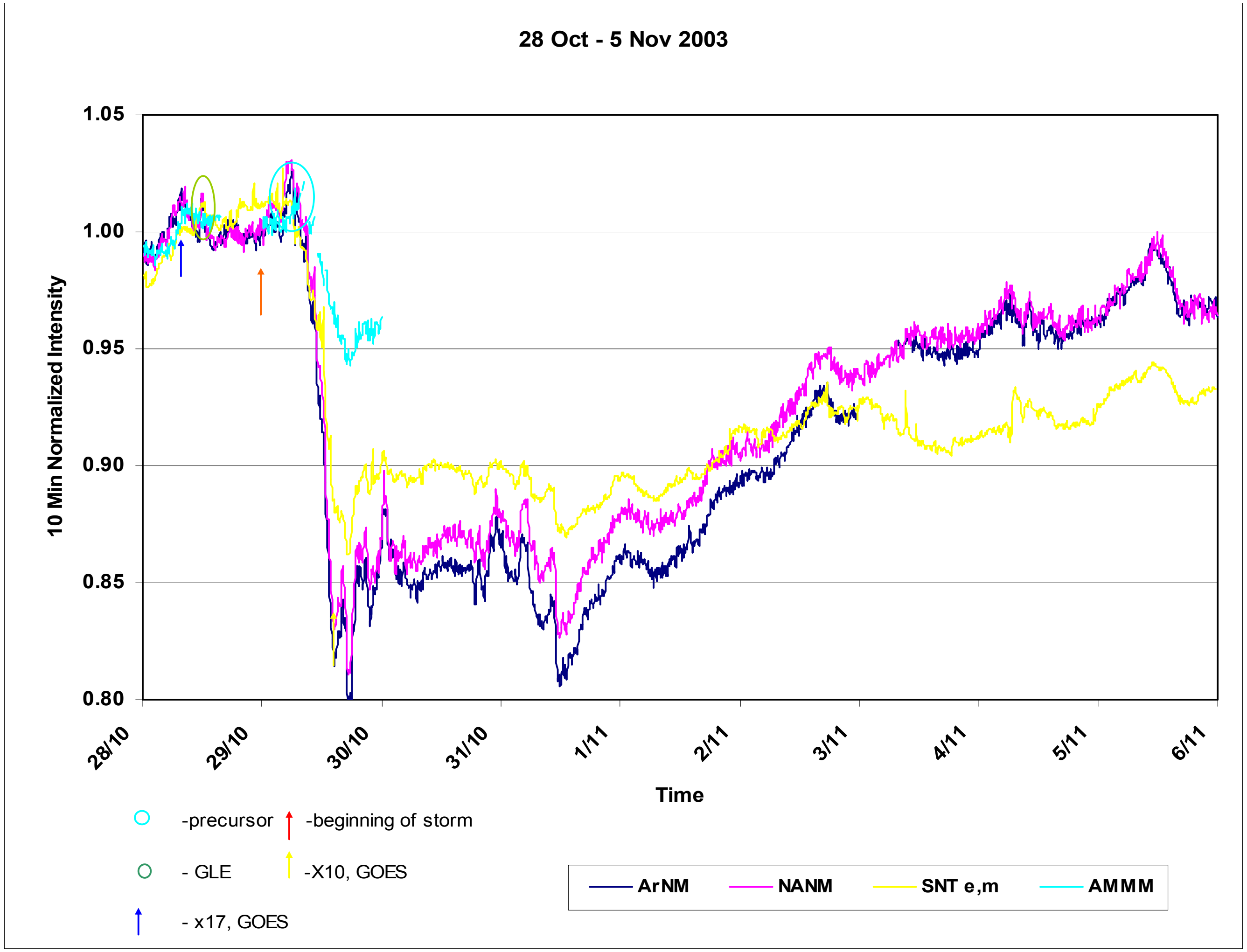
Highest Energies of 20 January GLE



Estimation of the Energy Spectra Power Index



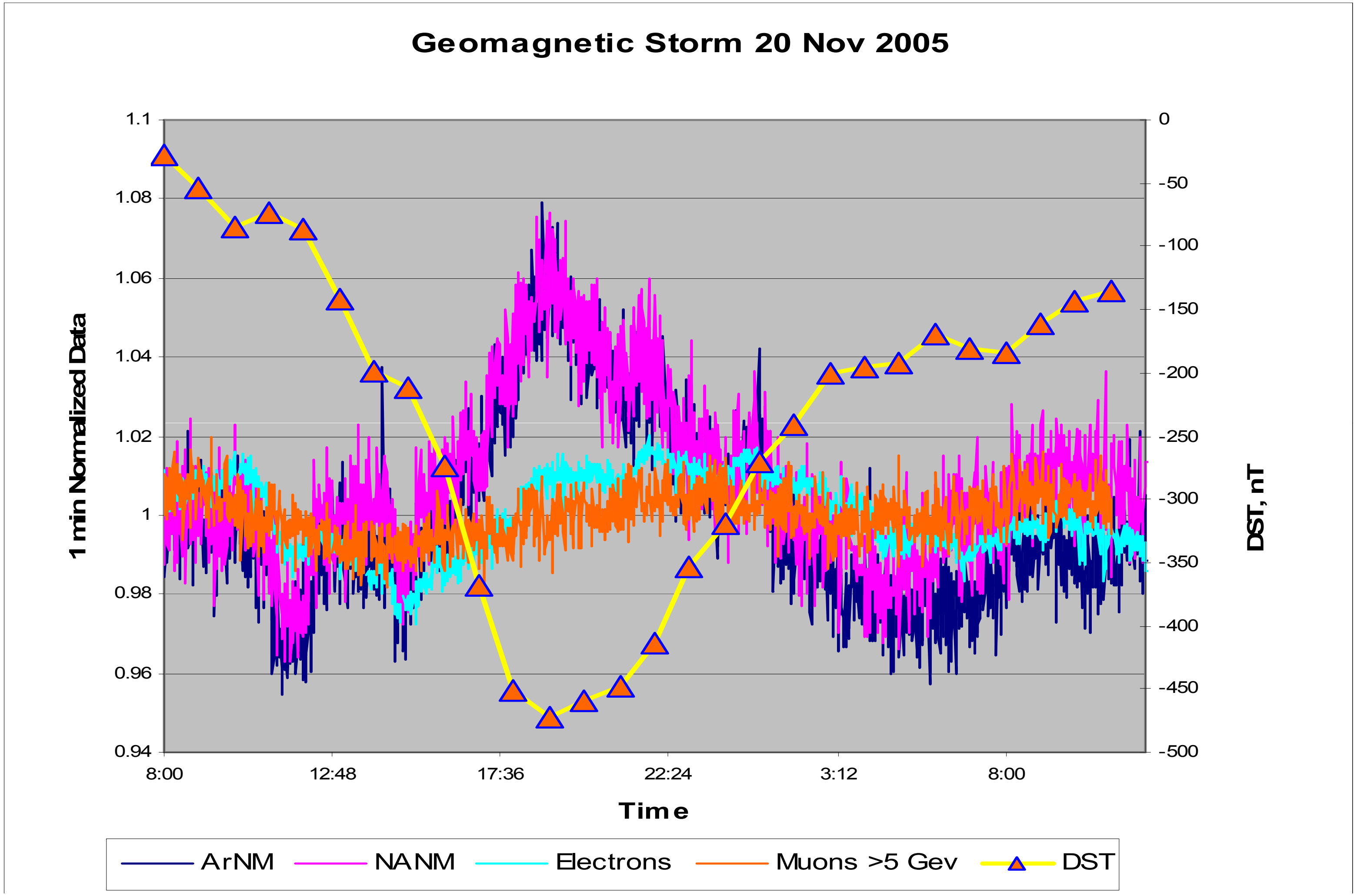
Famous “Halloween” events of 2003, detected in electron & muon and neutron fluxes by ASEC monitors at different altitudes



Correlation Matrix of ASEC monitors for 29 October 2003 (6:09 – 14:39), Fd

	ANM	NANM	AMMM	SNTe,μ	SNT thr1	SNT thr2	SNT thr 3	SNT thr4
ANM	**1**	1,00	0,97	0,99	0,99	0,97	0,95	0,98
NANM	**1,00**	**1**	0,97	0,99	0,99	0,97	0,95	0,98
AMMM	0,97	0,97	**1**	0,97	0,97	0,95	0,93	0,95
SNTe,μ	0,99	0,99	0,97	**1**	1,00	0,99	0,97	0,99
SNT thr1	0,99	0,99	0,97	1,00	**1**	0,99	0,96	0,99
SNT thr2	0,97	0,97	0,95	0,99	0,99	**1**	0,99	0,99
SNT thr3	0,95	0,95	0,93	0,97	0,96	0,99	**1**	0,97
SNT thr4	0,98	0,98	0,95	0,99	0,99	0,99	0,97	**1**

Geomagnetic Disturbance of 20 November



Correlation Matrix of ASEC monitors for 20-21 November 2003 г. (14:50 – 19:10), Geomagnetic Storm

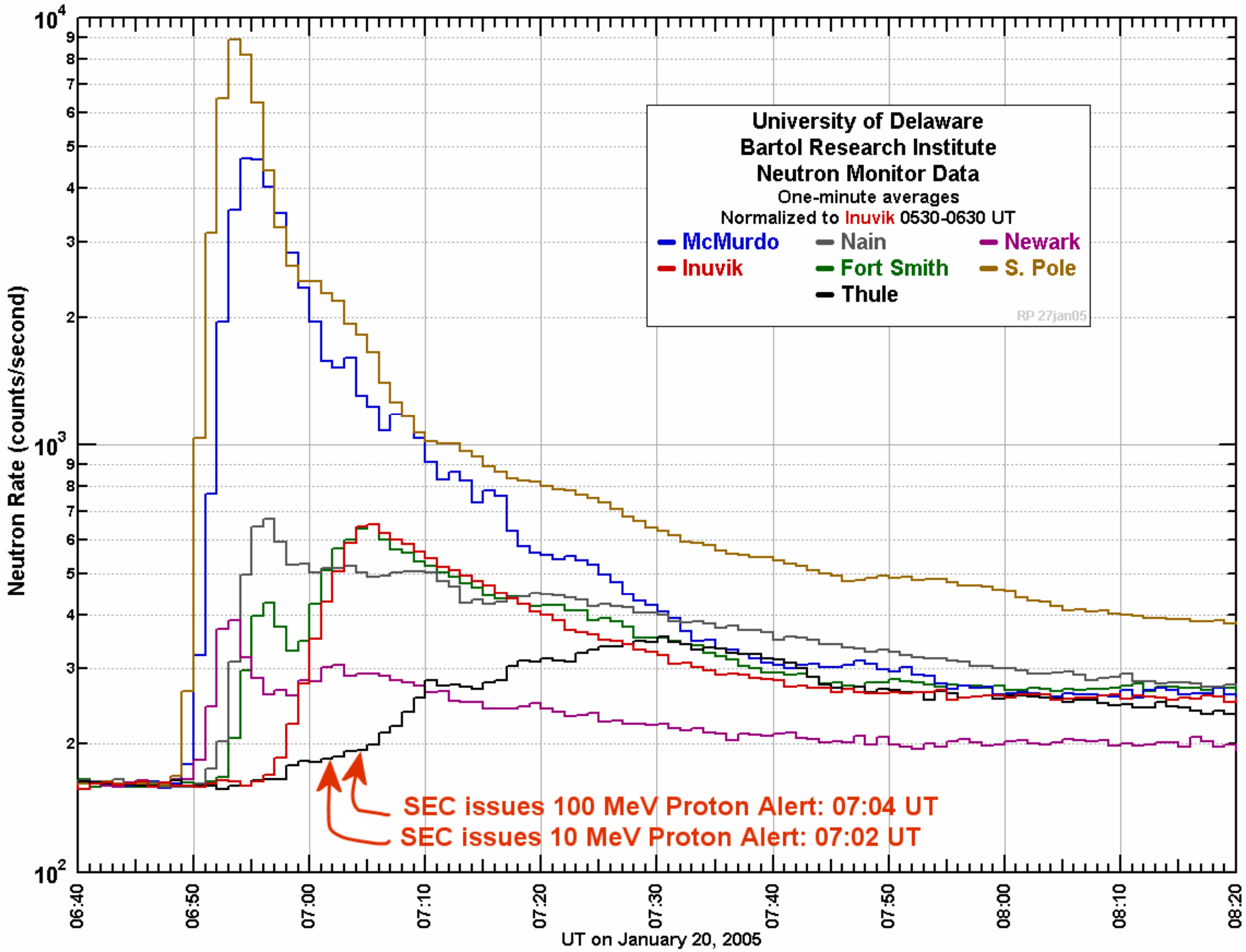
	ArNM	NANM	AMMM	SNTe,m	Thr0	Thr1	Thr2	Thr3	Thr4
ArNM	1.00								
NANM	0.90	1.00							
AMMM	0.29	0.23	1.00						
SNTe,m	0.90	0.88	0.23	1.00					
Thr0	0.91	0.88	0.26	0.91	1.00				
Thr1	0.83	0.82	0.28	0.83	0.88	1.00			
Thr2	0.78	0.78	0.23	0.80	0.81	0.80	1.00		
Thr3	0.65	0.65	0.14	0.65	0.64	0.67	0.76	1.00	
Thr4	0.43	0.43	0.05	0.42	0.43	0.46	0.47	0.62	1.00

GLE of 23-rd cycle detected by ANM

Table 2 GLE of 23-rd cycle detected by the Aragats Neutron Monitor

1	2	3	4	5
Date and Order No. of GLE	Flare Importance	GLE start at ASEC, in UT	Estimates of Significance %	$I(E_p>10MeV) > 100/cm^2.s.sr.$ S2 Onset, UT*
02-05-1998 56	X1.1	**13:47**	2.3 (3.2σ)	**15:25**
06-05-1998 57	X2.7	**8:08**	2.4 (3.4σ)	**9:15**
15-04-2001 60	X14.4	**13:53**	2.5 (3.6σ)	**14:25**
26-12-2001 63	M7.1	**5:52**	2.4 (3.4σ)	**6:35**

Neutron Monitors Can Provide the Earliest Alert of a Solar Energetic Particle Event



- In the January 20, 2005 GLE, the earliest neutron monitor onset preceded the earliest Proton Alert issued by the Space Environment Center **by 14 minutes.**

Courtesy John Bieber

Solar Ions Identification

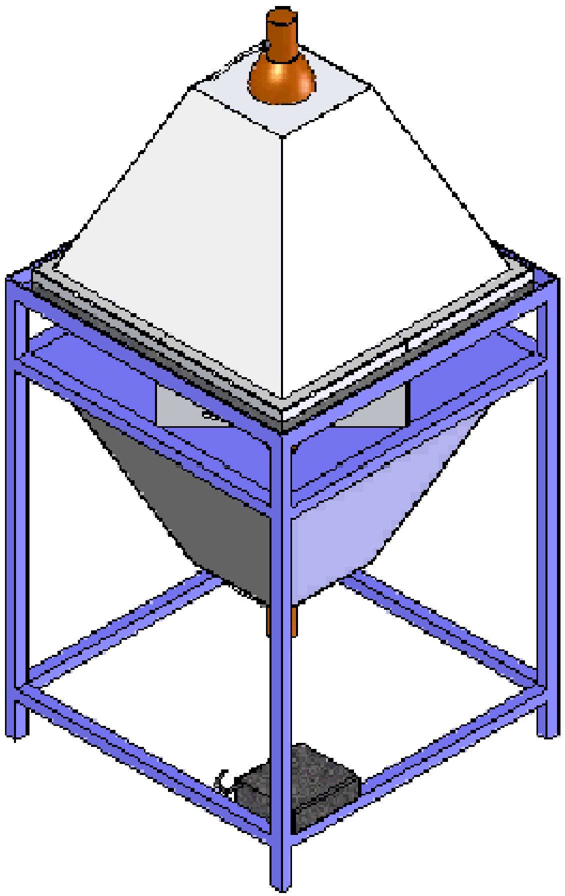
Table 1 Correlations between fluxes of different components initiated by GCR protons with rigidities 7.5<R< 20GV.

proton	e, μ	μ (>350 M3V)	μ (>5GeV)	n
e, μ	1.00	0.40	0.32	-0.21
μ (>350 MeV)	0.45	1.00	0.70	-0.37
μ (5GeV)	0.32	0.70	1.00	-0.24
n	-0.21	-0.37	-0.24	1.00

Table 2 Correlations between fluxes of different components initiated by GCR iron nuclei with rigidities 7.5<R< 20GV.

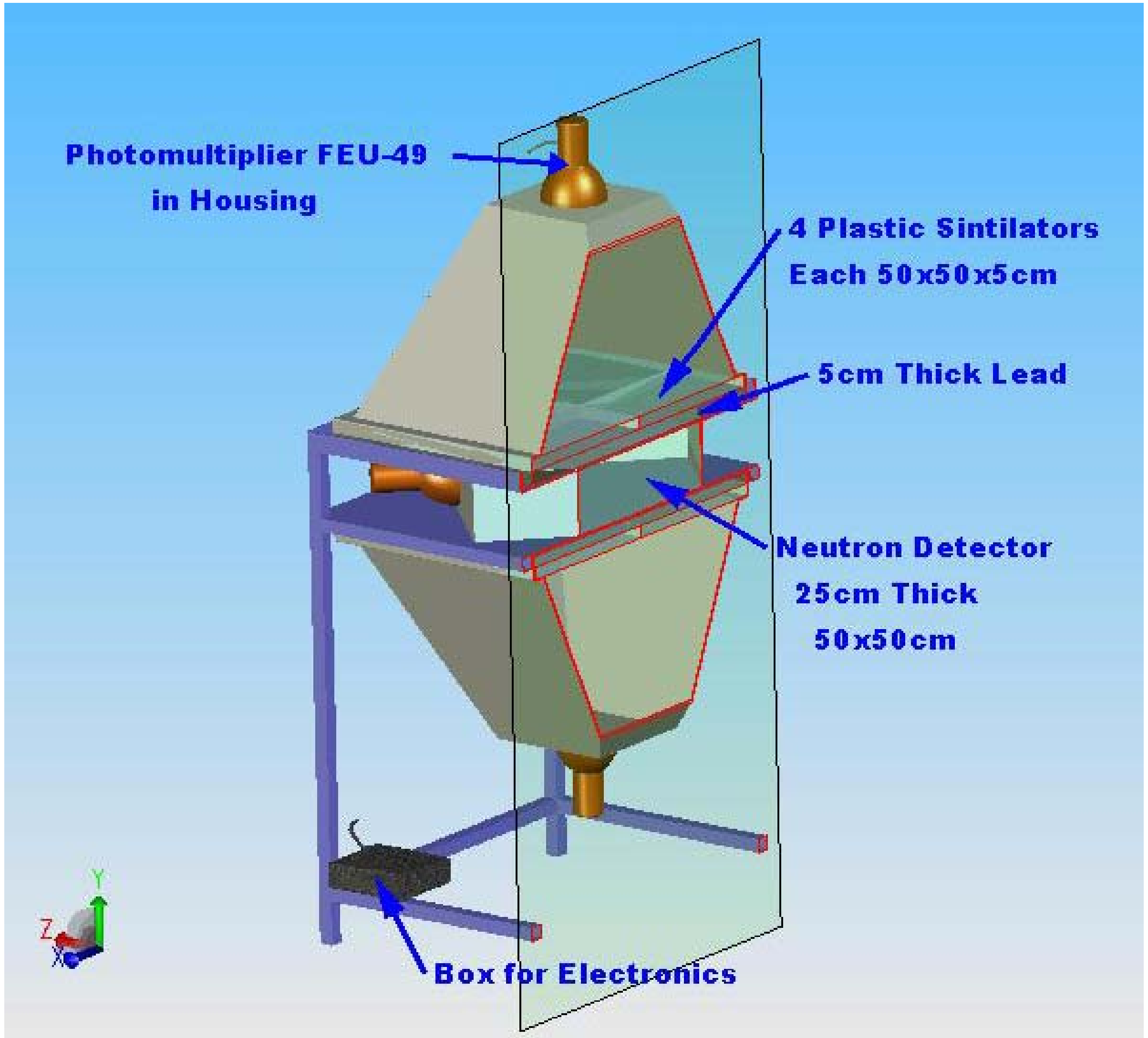
proton	e, μ	μ (>350 M3V)	μ (>5GeV)	n
e, μ	1.00	0.73	0.60	0.35
μ (>350 MeV)	0.73	1.00	0.82	0.28
μ (5GeV)	0.60	0.82	1.00	0.24
n	0.35	0.28	0.24	1.00

Space Environmental Viewing and Analysis Network (SEVAN)



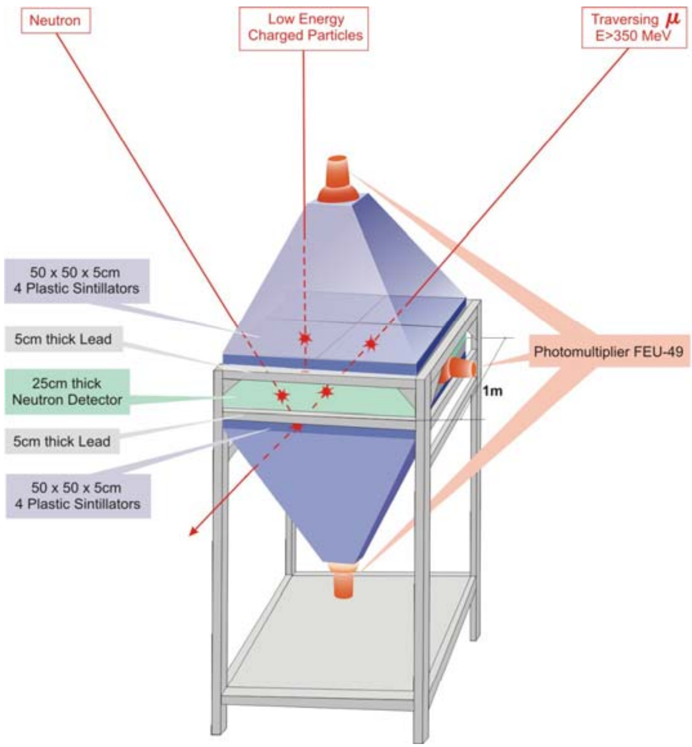
Assem with karkas

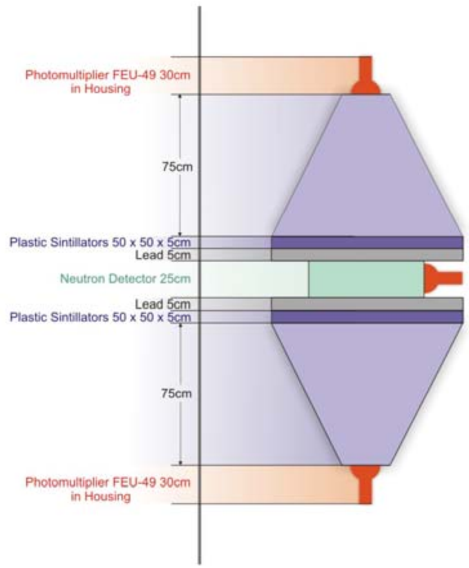
Sevan Detector



Space Environment Viewing and Analysis Network (SEVAN)

Modular Particle Monitor for Neutral and Charged CR fluxes





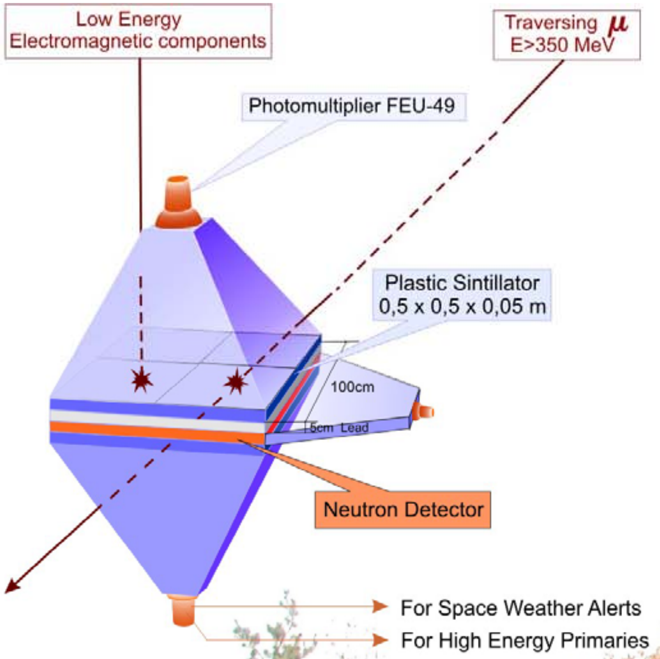
SPONSOR Provides:
8 scintillator slabs each of 50 x 50 x 5 cm;
2 photomultipliers;
Electronics board with counters, discriminators, optional temperature and pressure sensors and PC interface;
High voltage units for the photomultiplier;
DAQ, analysis and WEB software;
Access to DVIN data bases;
Training of students;
Documentation

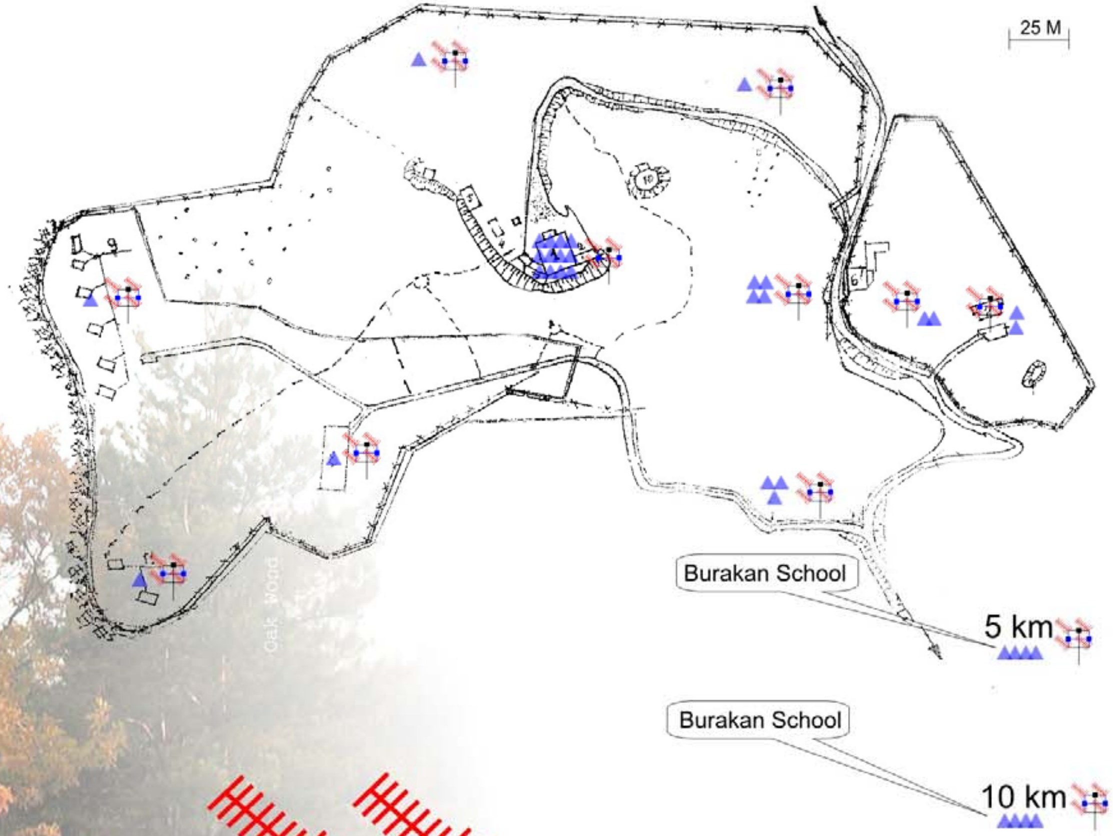
RECIPIENT Provides:

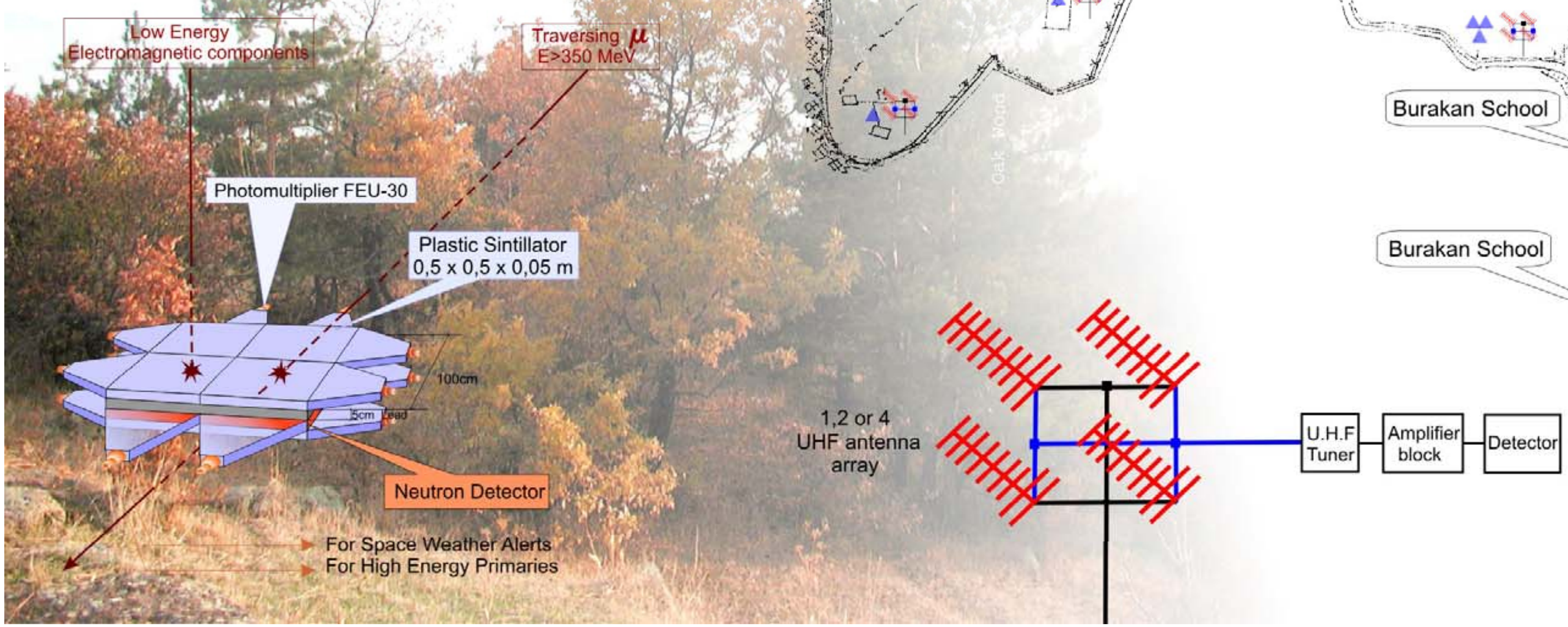
1. Mechanical parts, including lead.
2. Purchase computer with GPS;
3. Uninterruptible electricity and Internet access;
4. Transportation of equipment from Yerevan;
5. Cover travel and stay expenses of sponsor experts (if necessary).

Installed Detectors

Aragats International Cosmic Ray Center Nor - Amberd Detector for Space Weather and High Energy Astrophysics Studies







SEVAN Count Rates

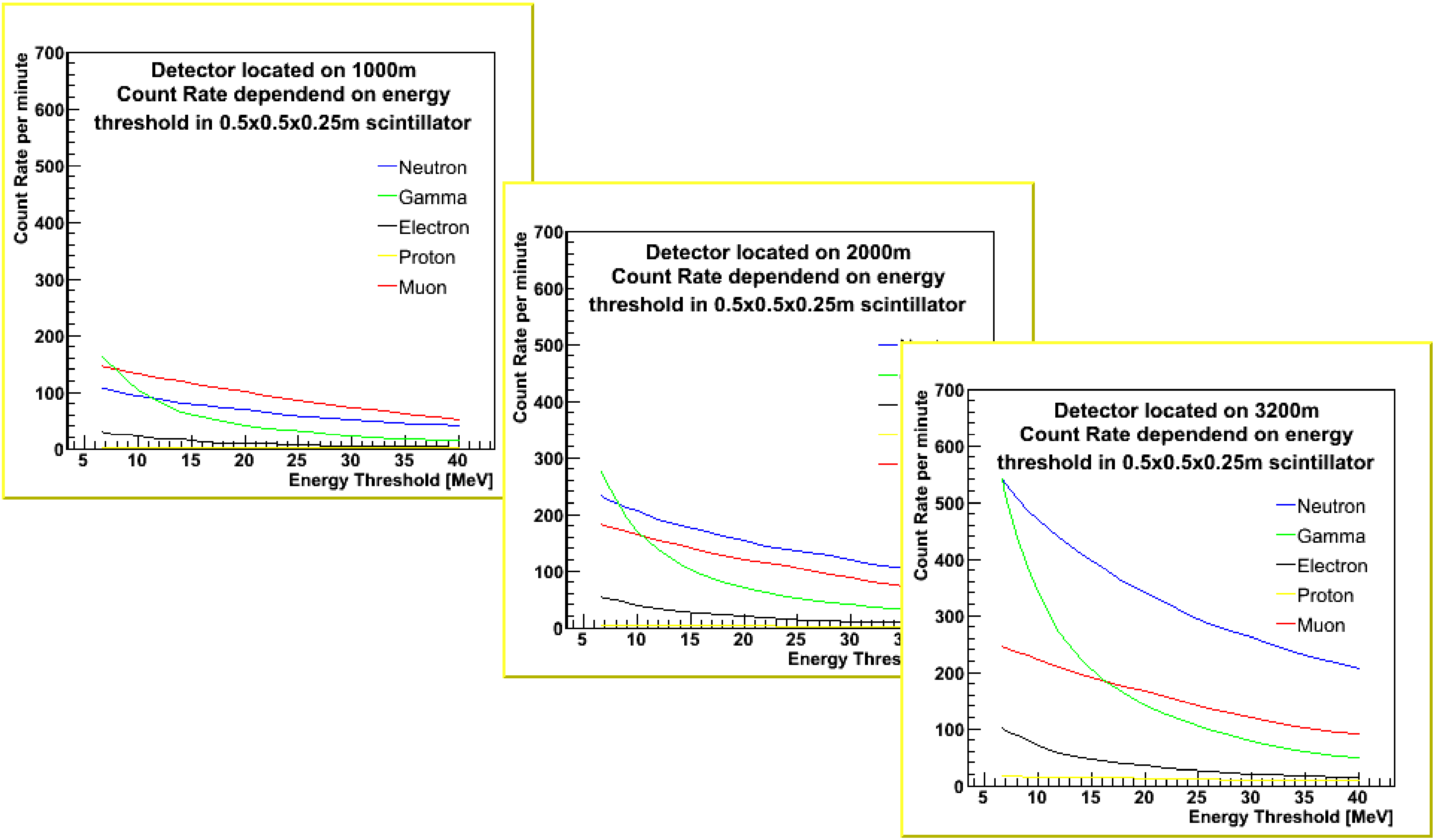
Per Minute

	All	Electrons	Muons	Gamma	Neutrons	Protons
0 m	10078	1583	7959	383	53	95
1000 m	13033	2472	9619	572	154	209
2000 m	17583	3986	11670	1038	333	544
3200 m	26766	7696	14959	2002	787	1297

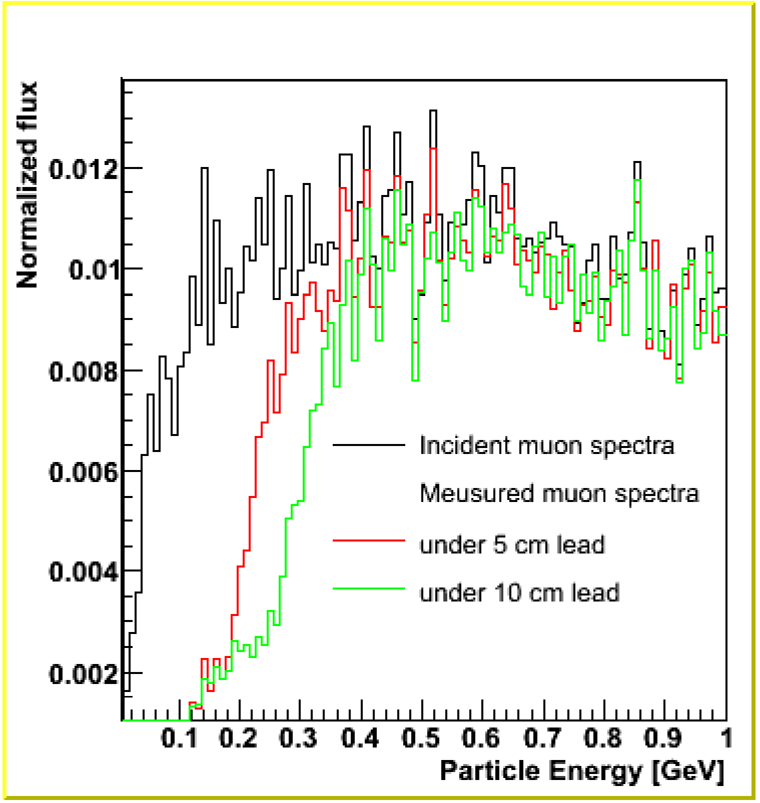
Per Second

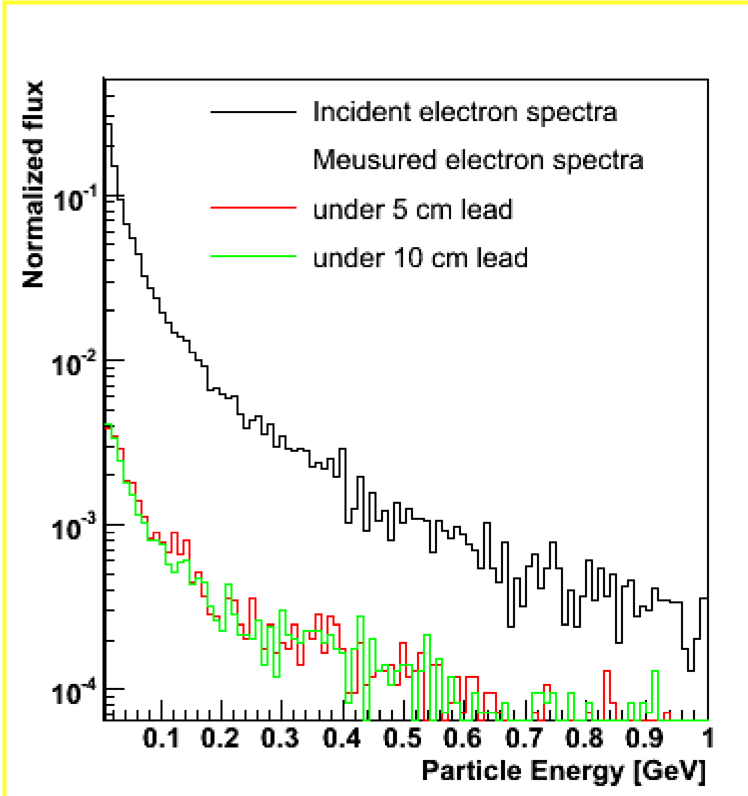
	All	Electrons	Muons	Gamma	Neutrons	Protons
0 m	168	26	133	6	1	2
1000 m	217	41	160	10	3	3
2000 m	293	66	195	17	6	9
3200 m	446	128	249	33	13	22

Expected Count Rates at Different Altitudes

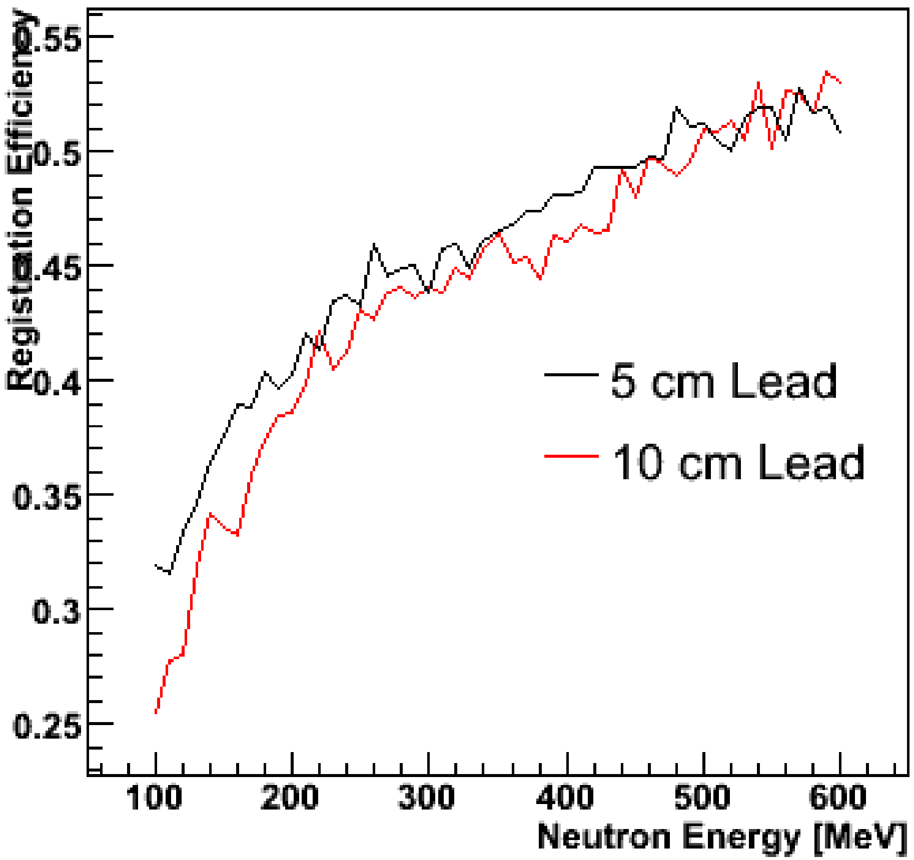


Electron and Muon Fluxes under Lead Filter

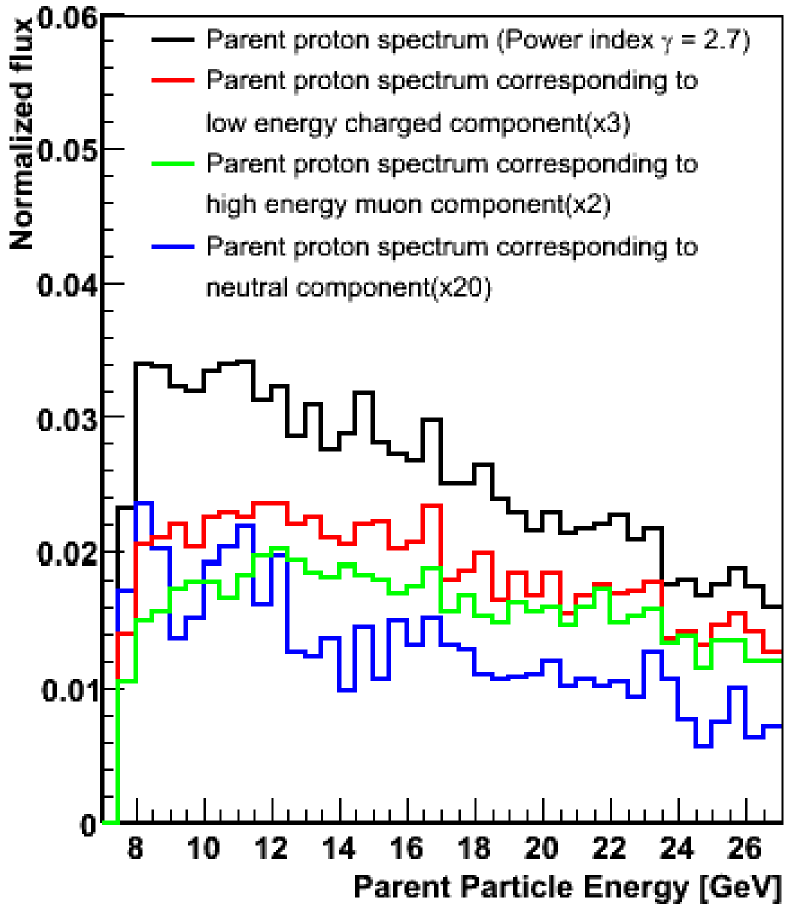


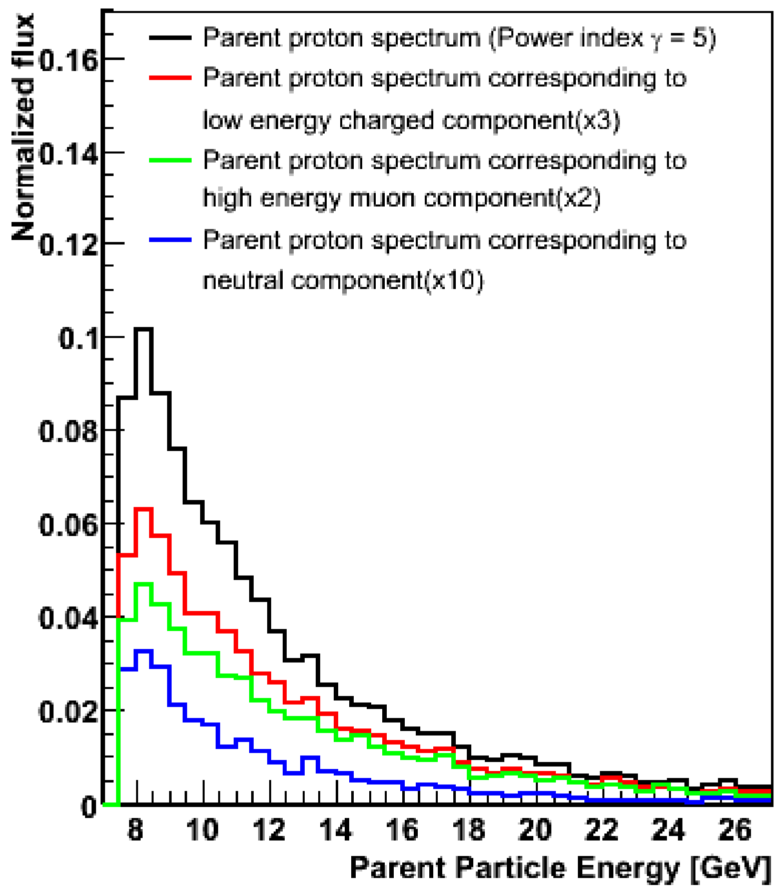


Efficiency of Neutron Detection



SEVAN Response to GCR and SCR





Conclusions

- Investigations of the highest energy solar cosmic rays are very difficult problem, requiring large surfaces of the particle detectors at middle and low latitudes. For the energy spectra estimation detection of the various neutral and charged secondary particles are necessary.
- As the benefit of variety information from different type particle detectors are both the basic knowledge on the universal processes of particle acceleration and warnings on the Space Weather severe conditions. The second is of huge importance taking into account results of the newest model of solar activity (Dikpati, 2006), claiming ~50% enhancement of solar activity in 24-th cycle comparing with 22 and 23 cycles.