A.Chilingarian

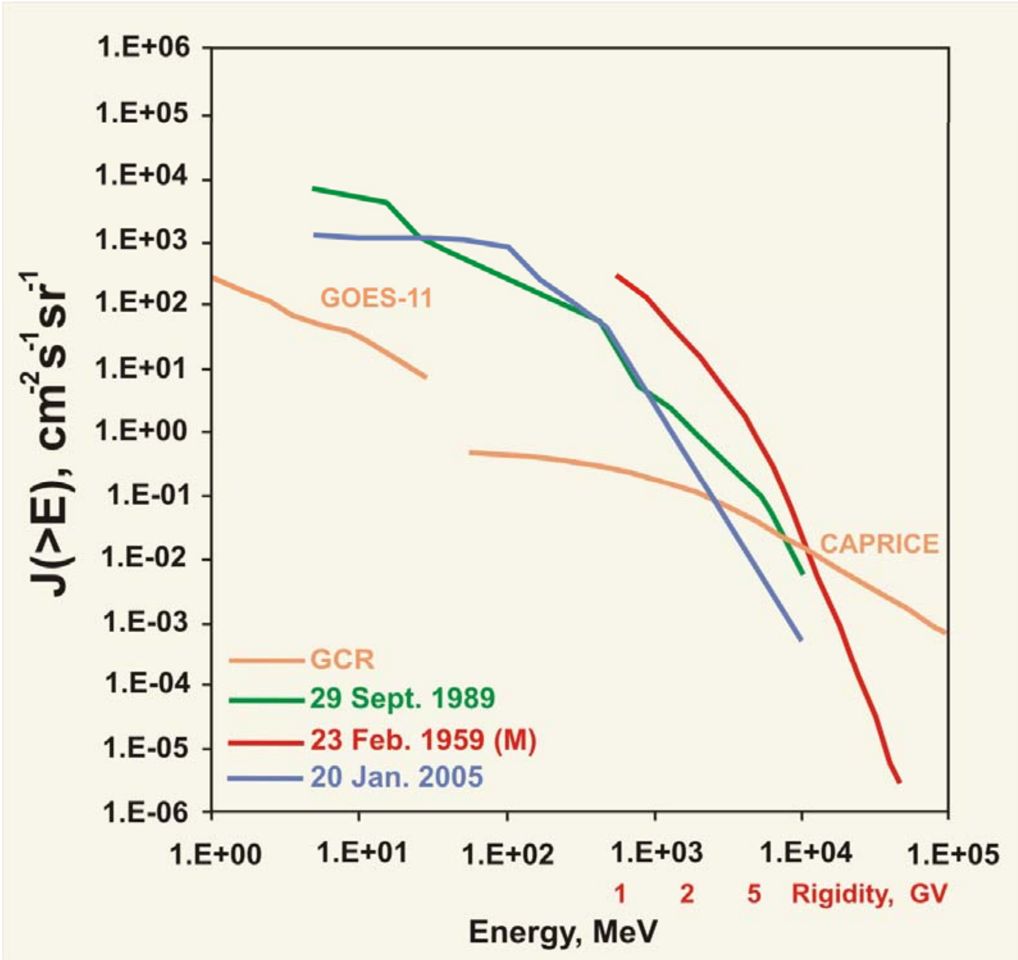
Particle detectors networks for the Fundamental Physics, Space Weather and Education

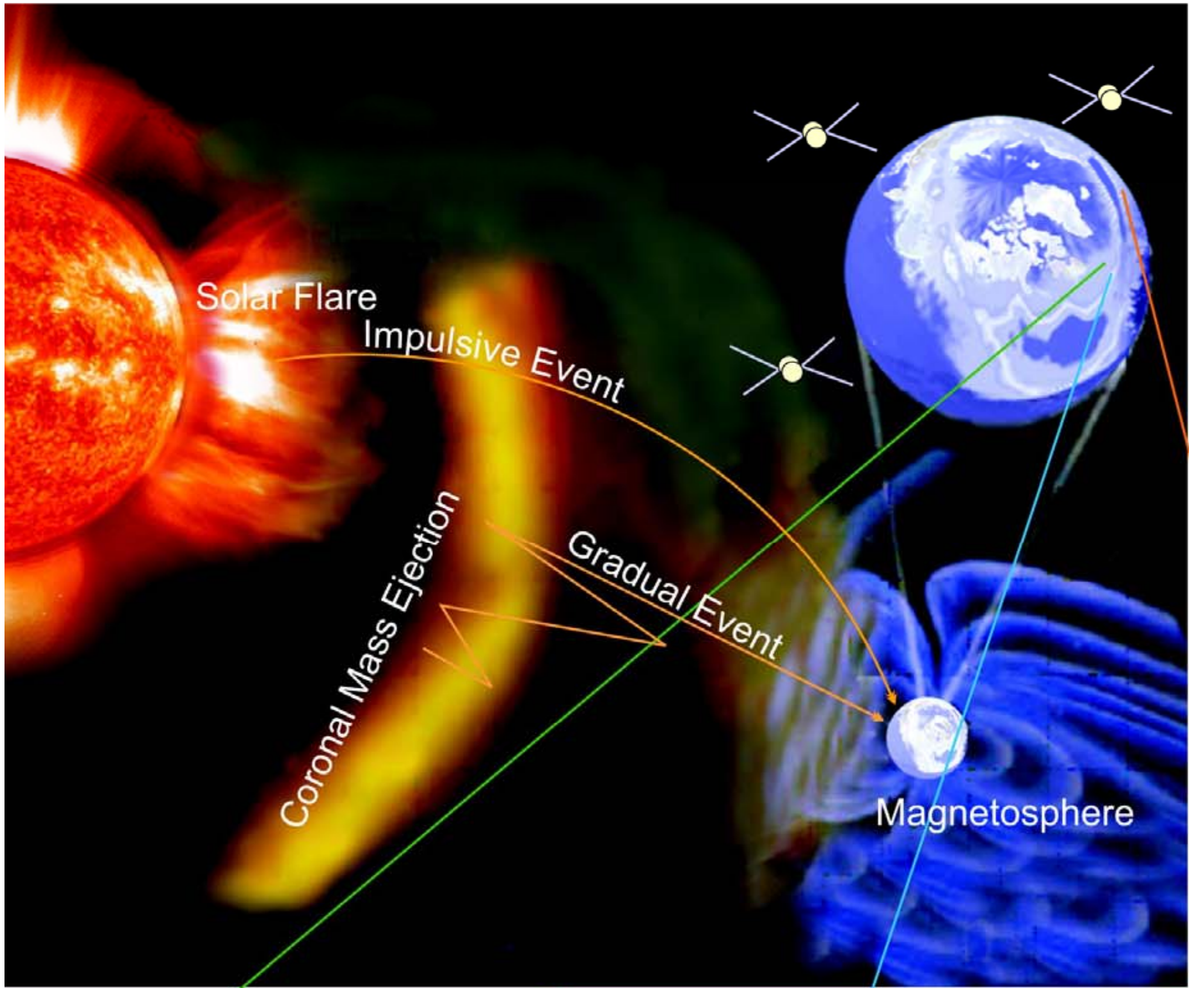
Cosmic Ray Division, Alikhanyan Physics Institute,Yerevan, Armenia
ASEC and ANI collaborations

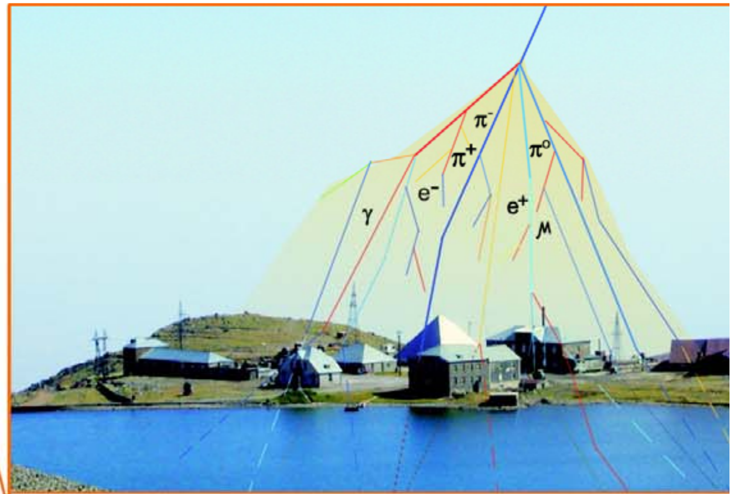
Space Education

- Involvement of students in the experimental studies is of crucial importance. It is necessary to select a topic interesting from scientific point of view and simple enough to allow students understand and participate in all stages of experiment from measurements via data analysis to physical inference. Also the results of experiment should be apparent and allow on-line analysis and interpretation. Very important is to connect the physical inference not only with progress of the fundamental science, but also with applied problems, and, if possible, with real life problems.
- In my report I'll try to prove that networks of particle detector designed and commissioned in Cosmic Ray Division of Alikhanyan Physics Institute fulfilled these requirements.
- Detailed information on our experience with students of Physical Department of Yerevan State University is contained in 3 posters: New Particle Detector for Space Weather Research; Simple Detectors for Educational Studies; Data Visualization Interactive Network
- Last 5 years we have more than 150 students and 40 diploma and master thesis.

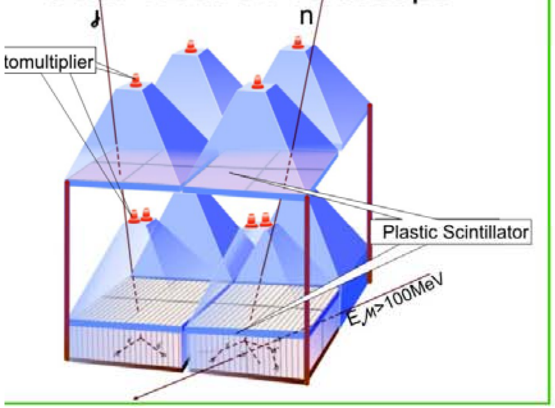
Galactic and Solar Cosmic Rays



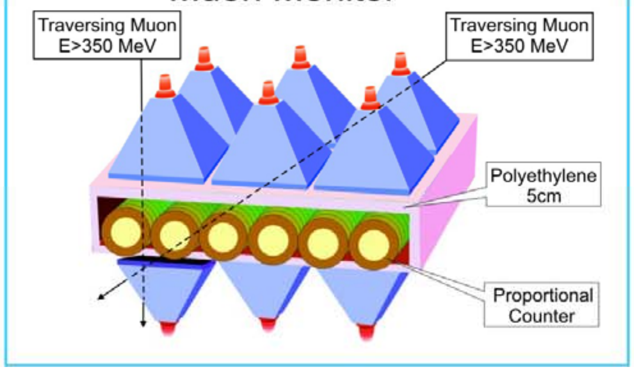




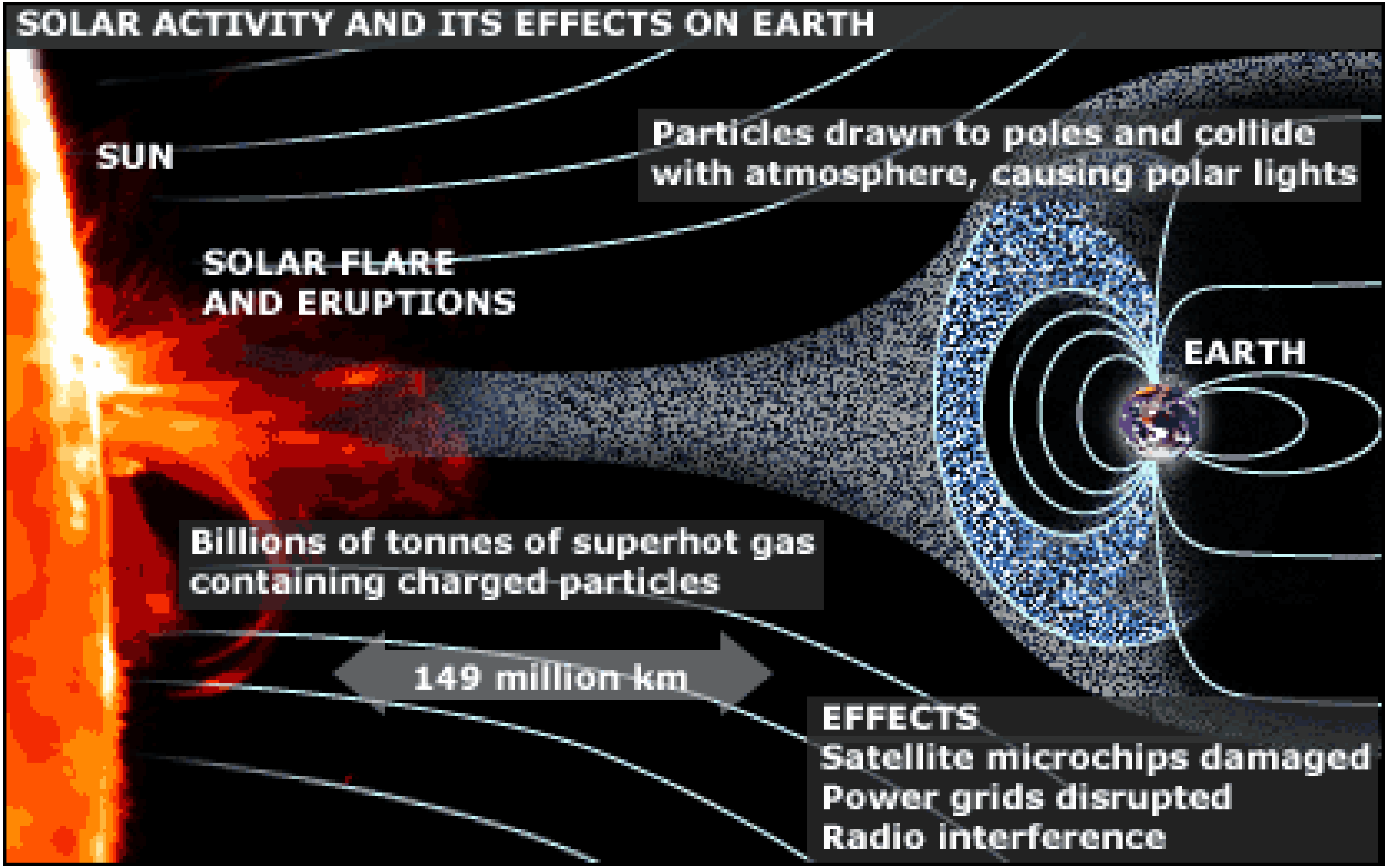
Solar-Neutron Telescope

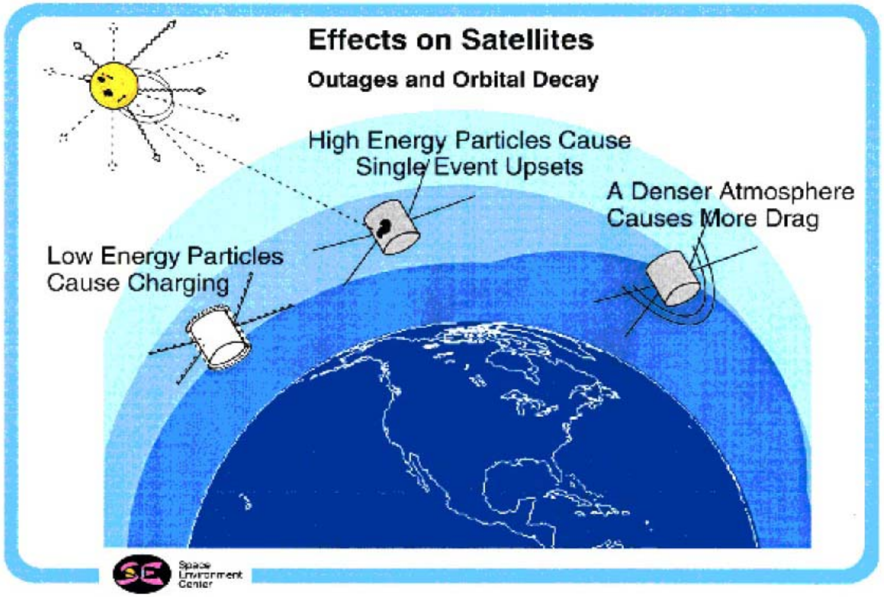


Nor-Amberd Multidirectional Muon Monitor

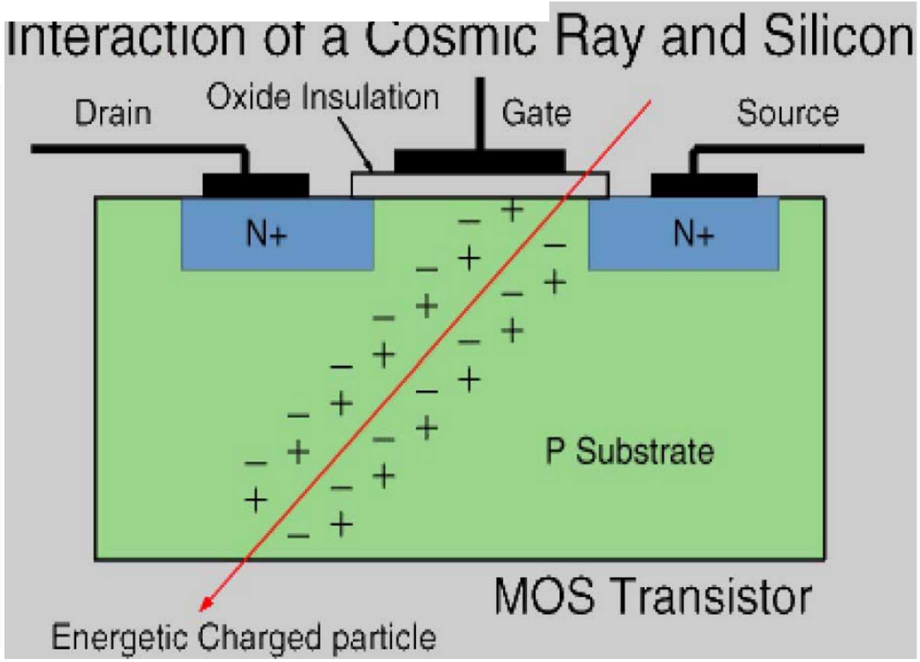


High energy cosmic rays open a window for the exploration of the d
and forceful processes in the far-corners of the universe. The A
Space-Environmental Center (ASEC) of the Cosmic Ray Division in Ar
http://crdlx5.yerphi.am, conducts research in the field of Galactic Cosmi
and Solar Physics. The two research stations, at 3200m and 2000m el
on Mt. Aragats, are equipped with modern scientific detectors and instru
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


SOLAR ACTIVITY AND ITS EFFECTS ON EARTH
SUN
Particles drawn to poles and collide with atmosphere, causing polar lights
SOLAR FLARE AND ERUPTIONS
EARTH
Billions of tonnes of superhot gas containing charged particles
149 million km
EFFECTS
Satellite microchips damaged
Power grids disrupted
Radio interference


Effects on Satellites
Outages and Orbital Decay
High Energy Particles Cause Single Event Upsets
A Denser Atmosphere Causes More Drag
Low Energy Particles Cause Charging
Space Environment Center


PJM Public Service
Step Up Transformer
Severe internal damage caused by the space storm of 13 March, 1989.


Interaction of a Cosmic Ray and Silicon
Drain
Oxide Insulation
Gate
Source
N+
N+
P Substrate
MOS Transistor
Energetic Charged particle

Space Weather can effect everyday lives

- Solar events occur at a magnitude of violent force and energy that equals the power of a billion hydrogen bombs, fortunately people on the ground are not at risk from solar storms, protected by the magnetosphere and atmosphere, but…
- space Storm Causes Power Outages, a power grid in Canada was tripped by a 1989 storm, and electricity to the entire province of Quebec was lost for about 9 hours;
- airline passenger can experience as much radiation as 10 chest X-rays elevated doses of radiation can be experienced on high-altitude flights, caused airlines to reroute commercial flights;
- radio communications were disrupted, at least two key U.S. communications satellites were disabled by solar weather in the late 1990s, causing failures in personal pagers, television broadcast and some airline traffic communications;
- increase the probability of latent cancer formation in the astronaut/space traveler cohort.

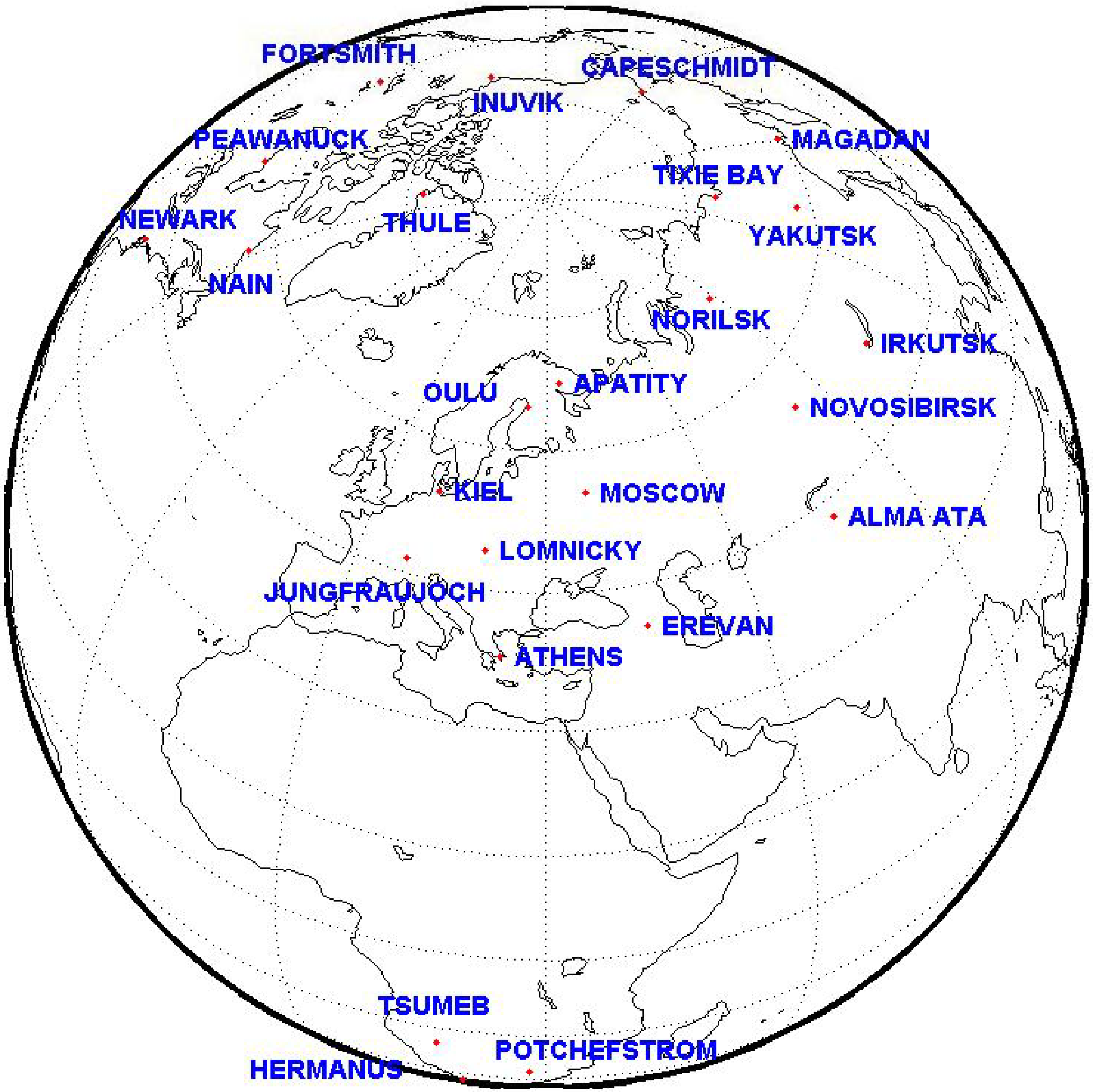
Protective actions after Space Weather Alert

- Satellite operators put satellites to sleep. They rotated some so vulnerable solar panels were better protected, and made arrangements to switch signals to backup satellites if necessary;
- elevated doses of radiation can be experienced on high-altitude flights, caused airlines to reroute commercial flights
- Astronauts should retreat to the most well-protected module

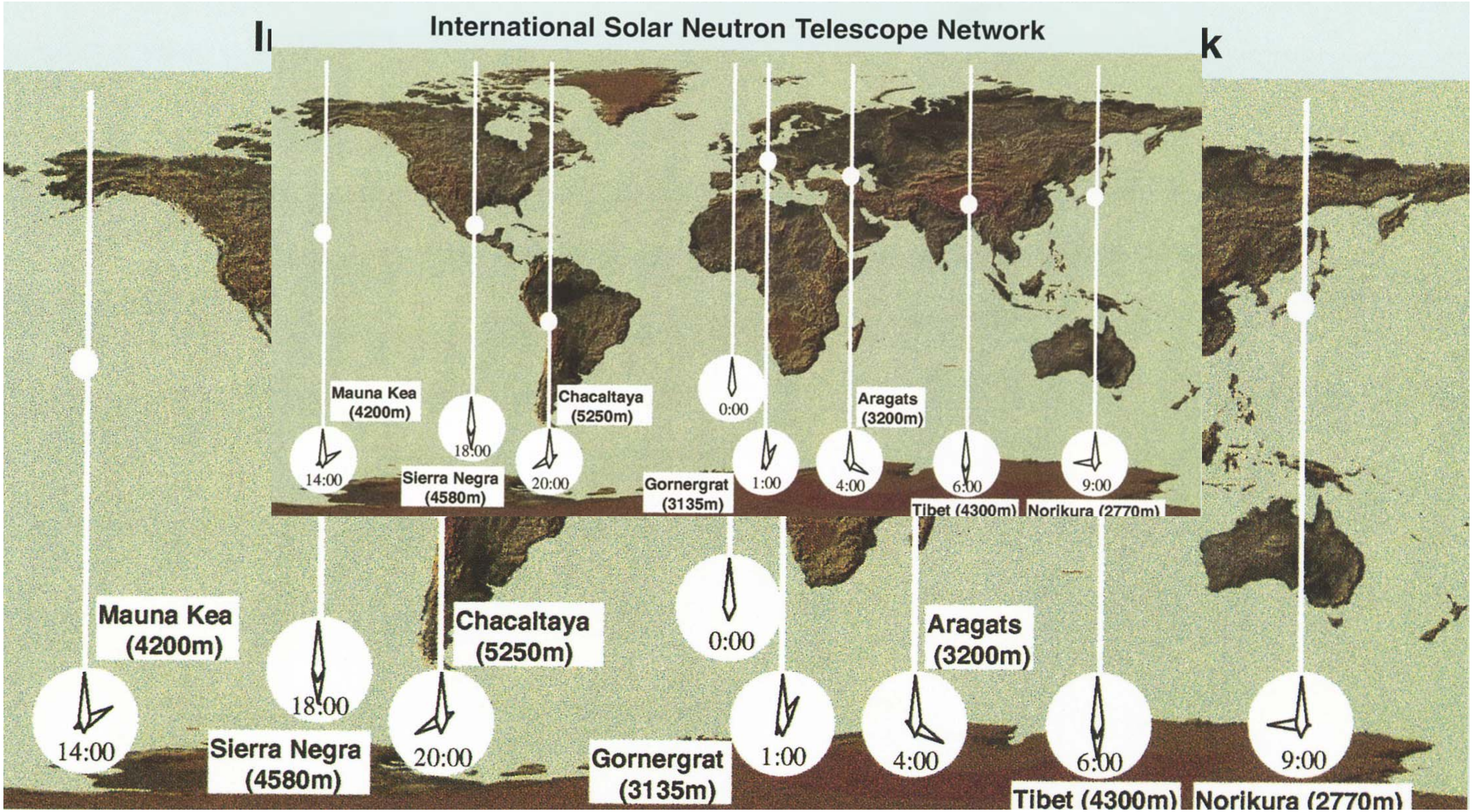
Surface Monitoring of the Secondary Cosmic Ray Fluxes

- Put a satellite closer to the Sun to predict a space storm's magnetic field earlier, but…
- Some instruments aboard SOHO were shut down during powerful flares to prevent damage. Others are operating at reduced capacity;
- Some devices produce less-than-perfect images because they get covered with "snow" that represents the charged particles streaming out from the Sun;
- Most energetic particles detected by surface monitors brings information about upcoming storms 10 hours prior shock arrival.

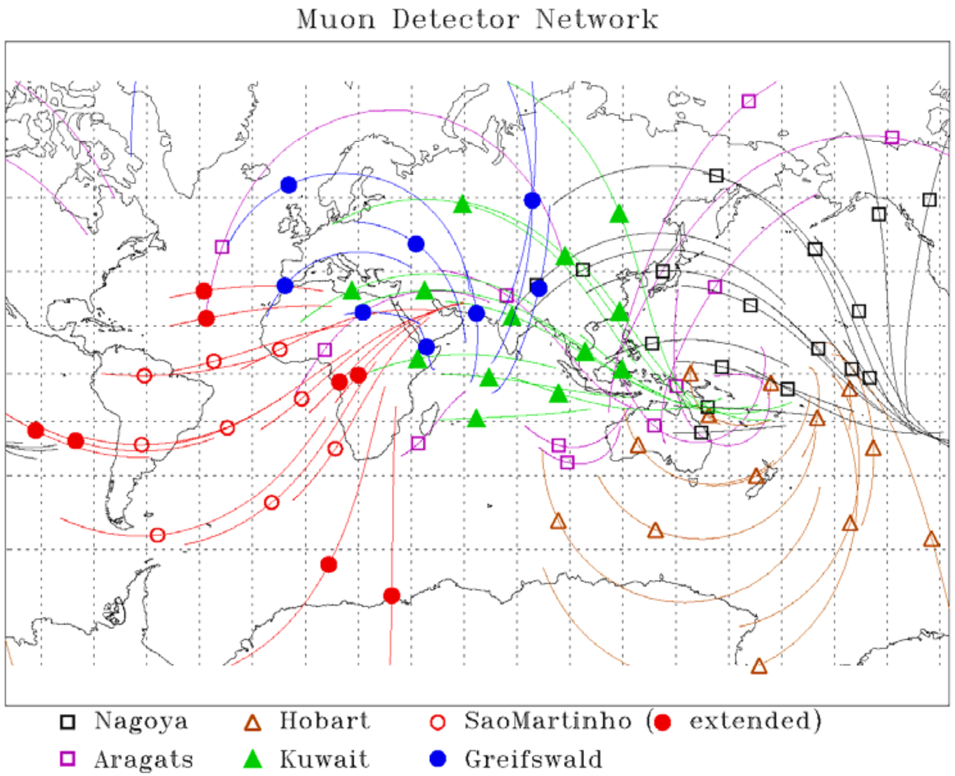
Neutron Monitors World-Wide Network

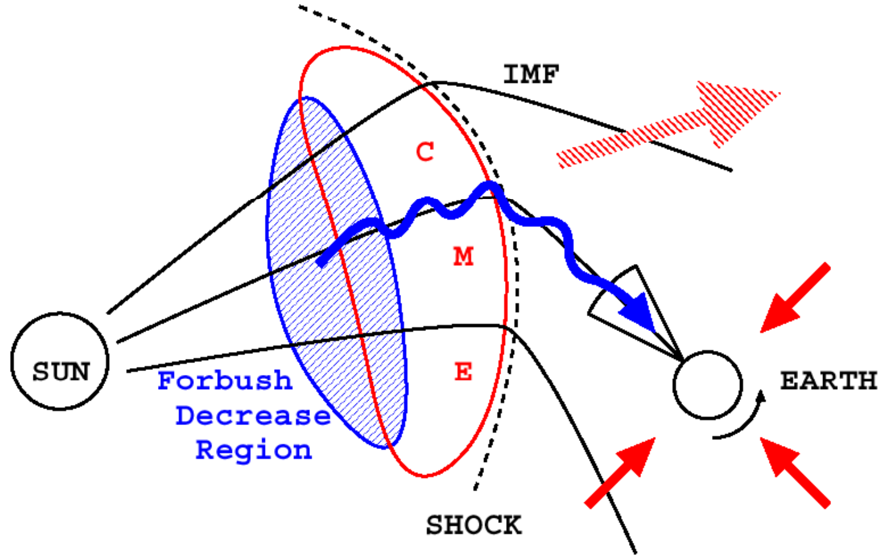


Worldwide network of neutron detectors



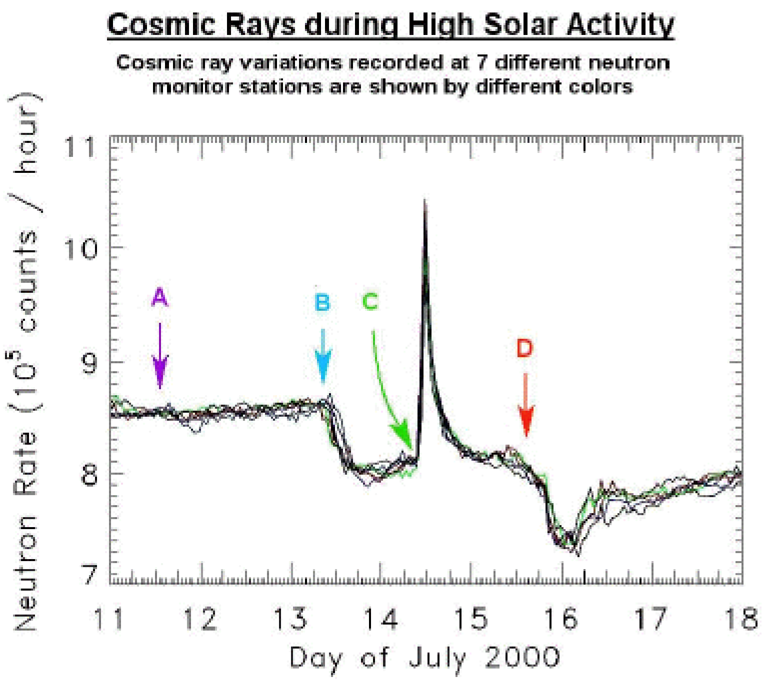
World-wide Networks of Particle Detectors





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).

GLE at High and Low Latitudes

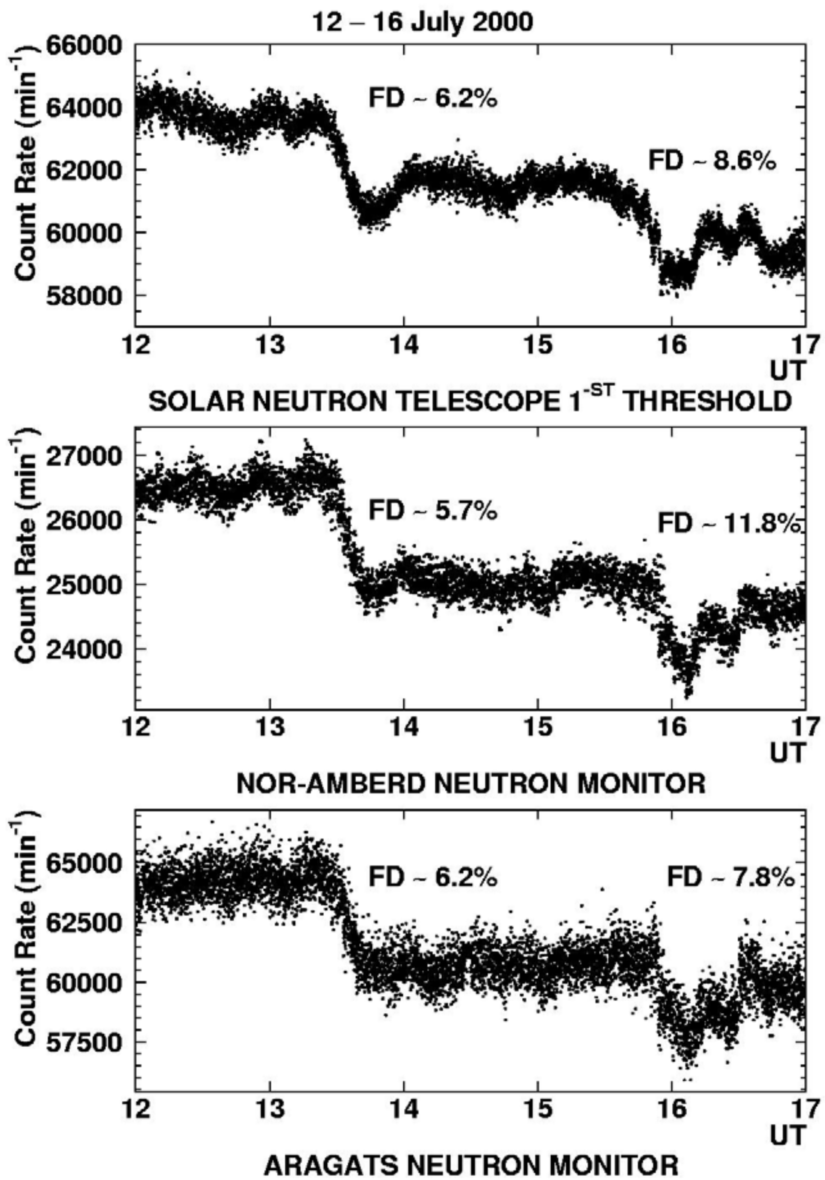


A: First coronal mass ejection (CME) at Sun.

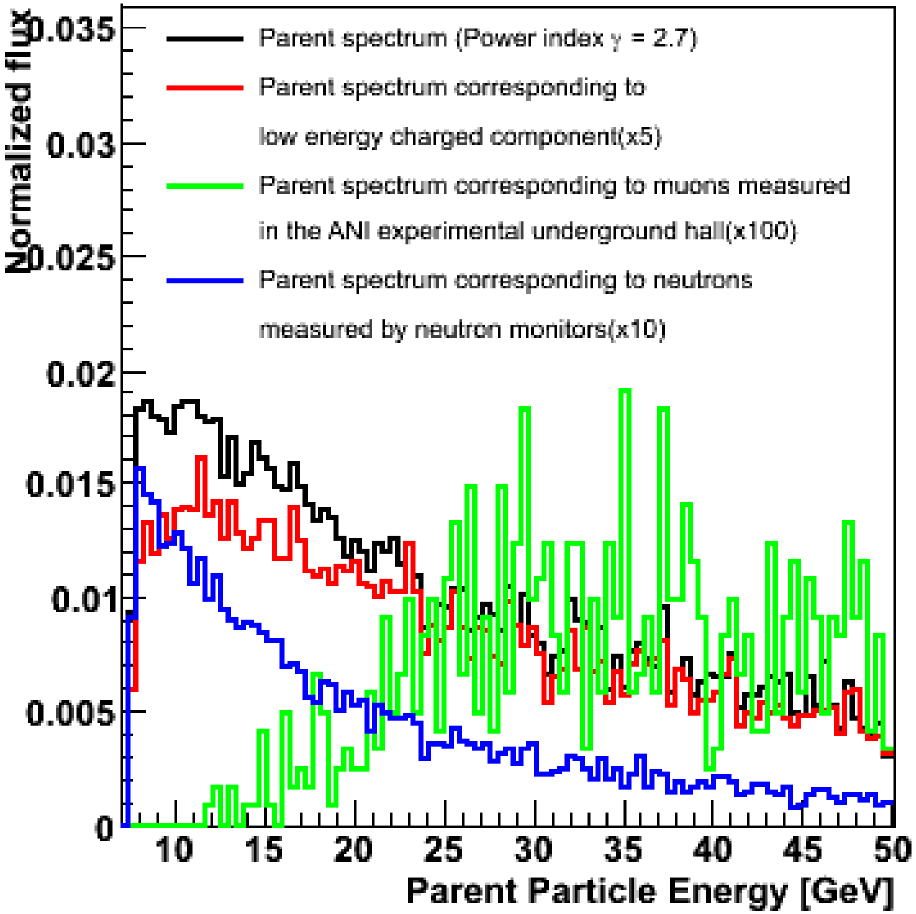
B: First CME arrives at Earth. Cosmic rays decrease suddenly — a "Forbush decrease."

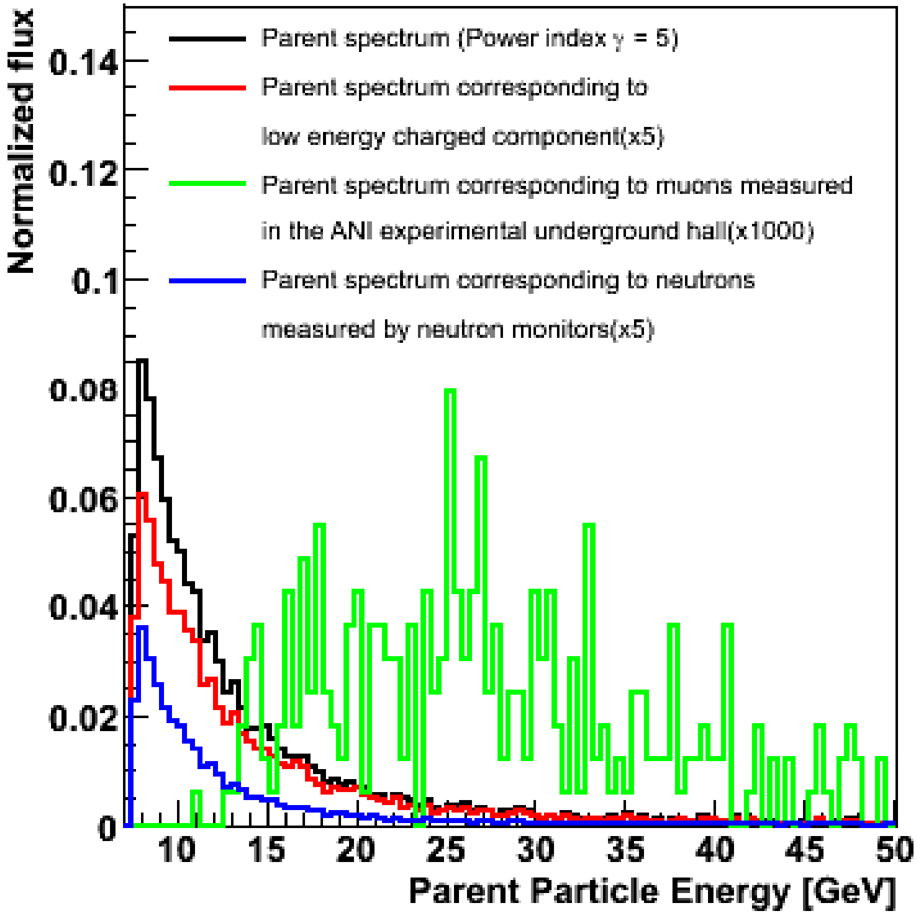
C: Second CME at Sun. This one accelerates high energy particles that reach Earth minutes later. The sudden increase recorded by the neutron monitor is a "ground level enhancement."

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.

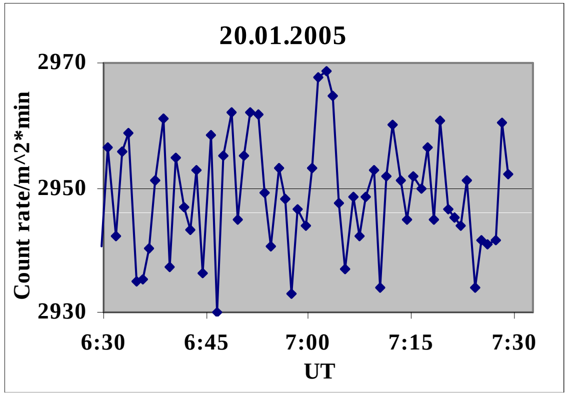


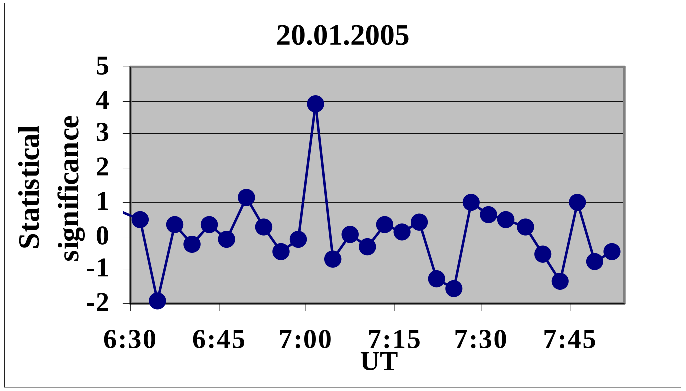
Energy range of Aragats Monitors



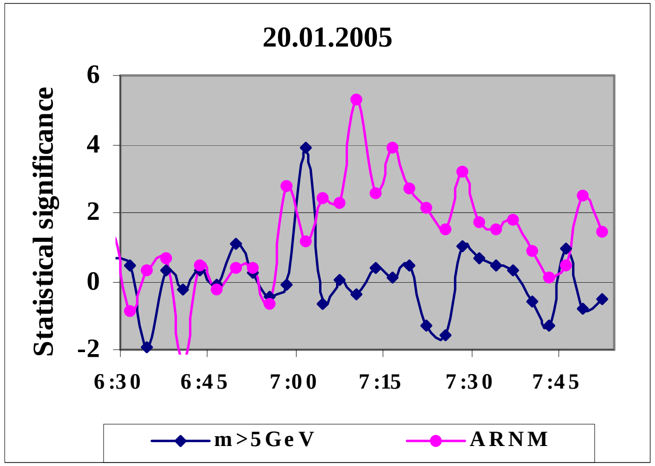


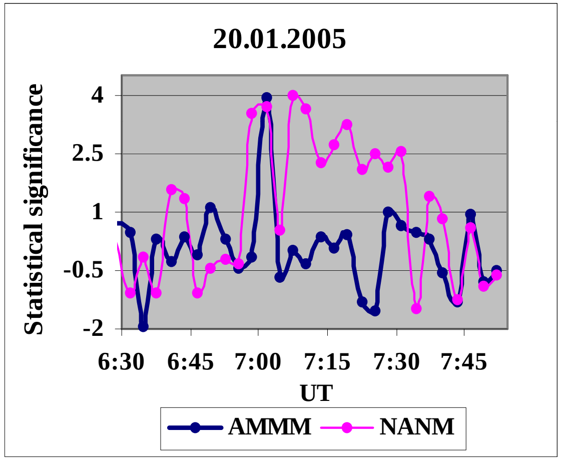
AMMM Detection of GLE 20 January 2005

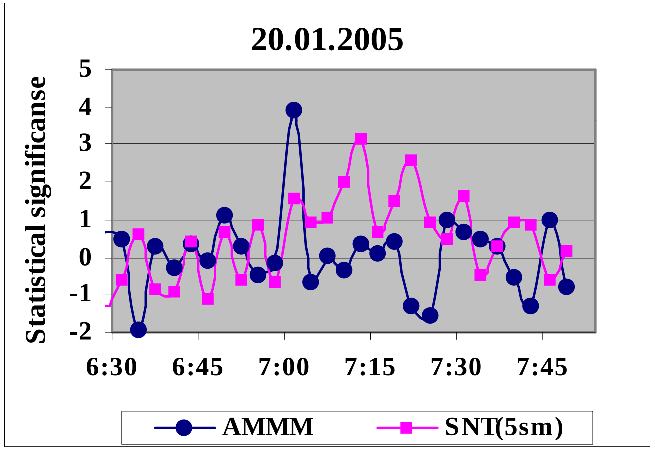


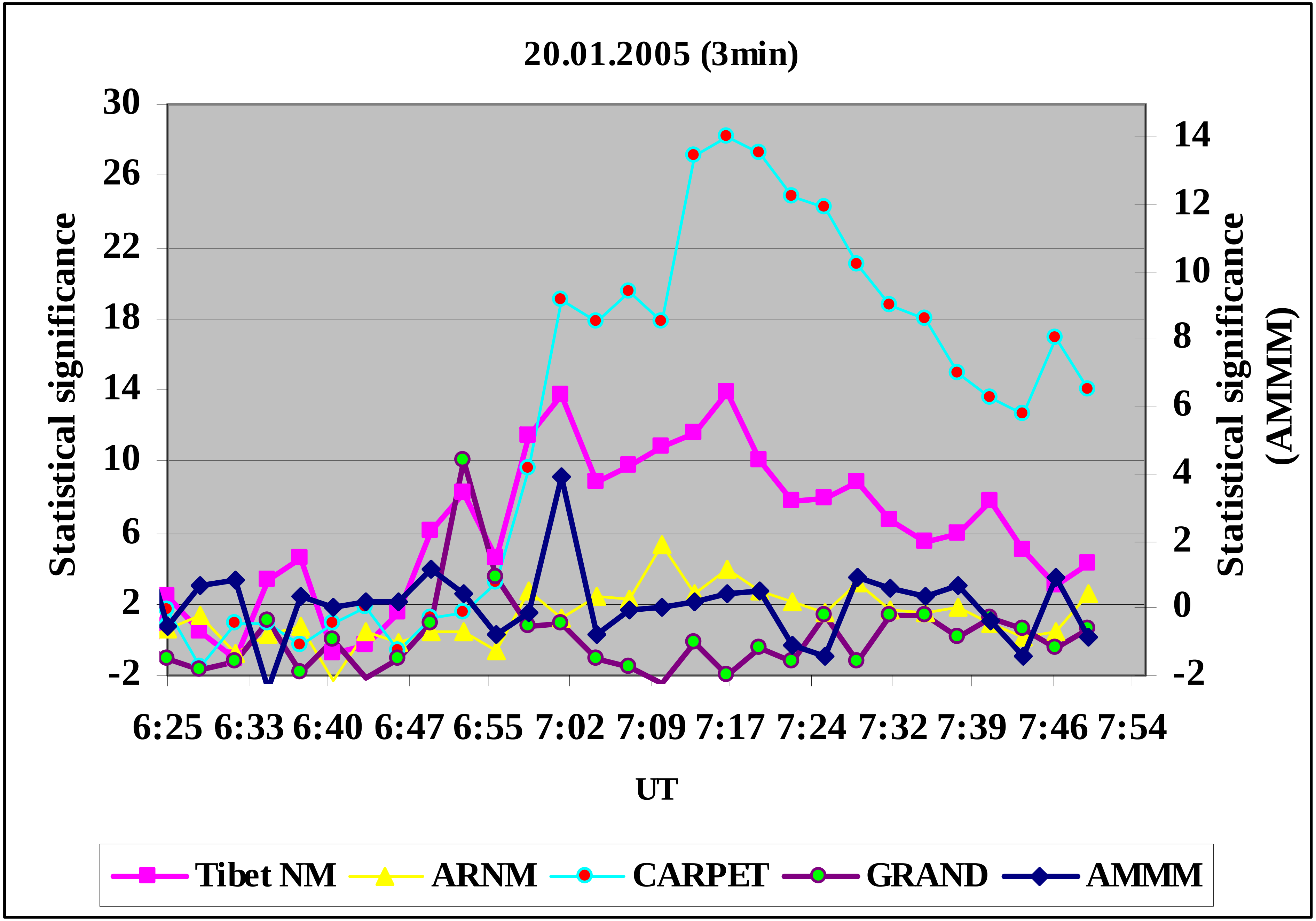


The additional signal at 7:02-7:04 UT equals 2354 (0.644%) If we adopt the Poisson standard 0.164%, significance = 3.93σ

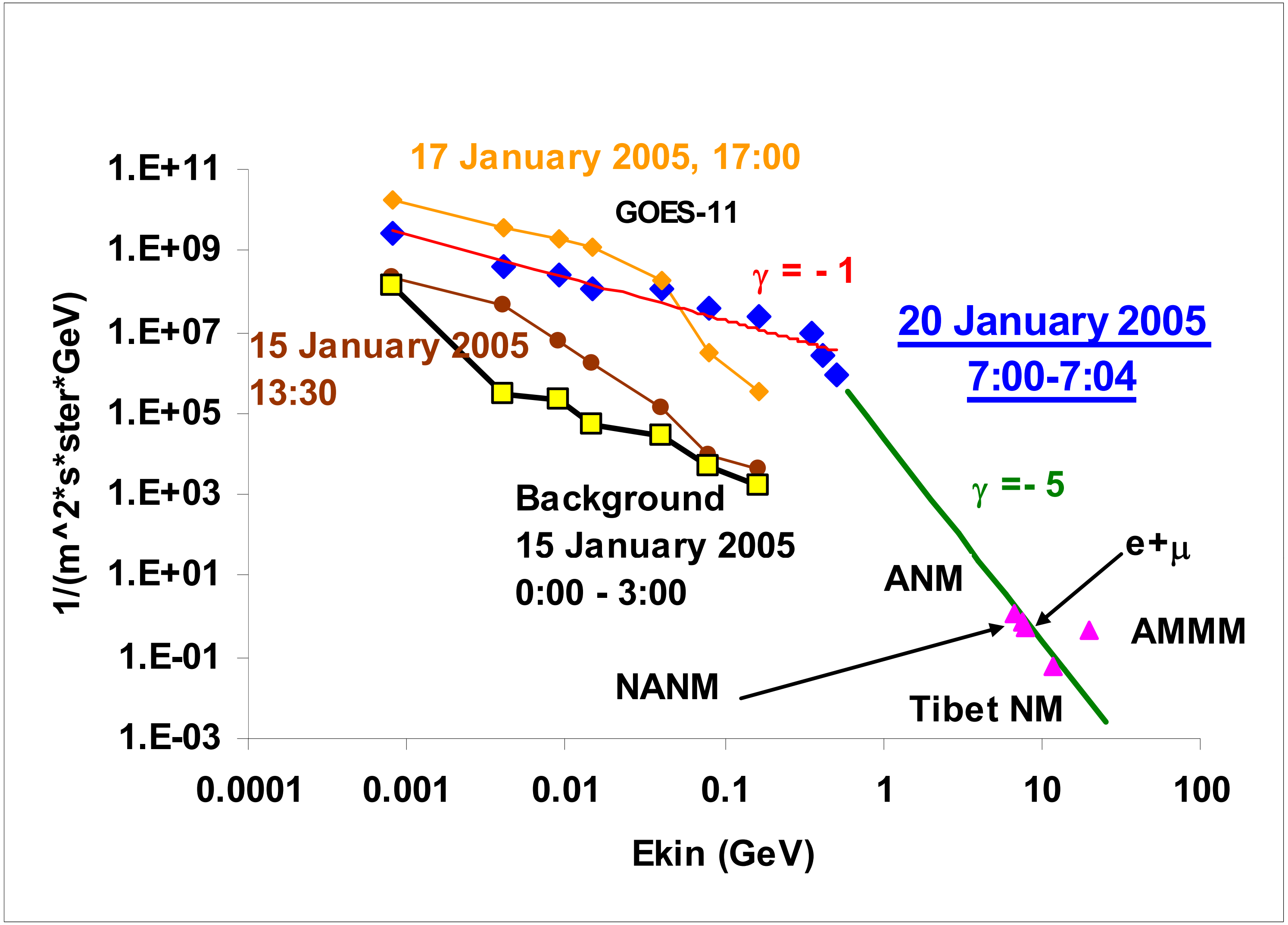




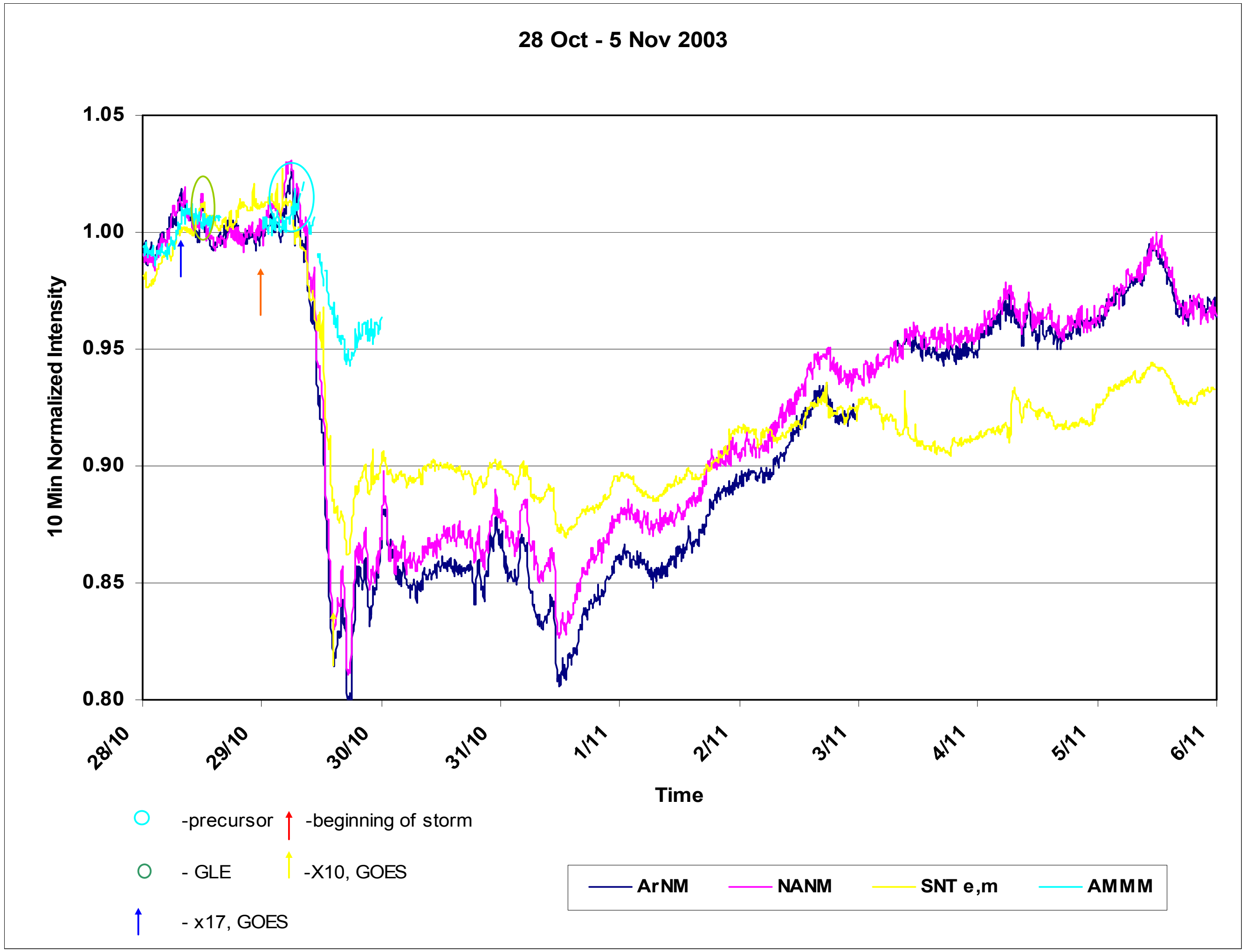



20.01.2005 (3min)
Statistical significance
Statistical significance (AMMM)
30
26
22
18
14
10
6
2
-2
14
12
10
8
6
4
2
0
-2
6:25 6:33 6:40 6:47 6:55 7:02 7:09 7:17 7:24 7:32 7:39 7:46 7:54
UT
Tibet NM
ARNM
CARPET
GRAND
AMMM

Highest Energies of 20 January GLE



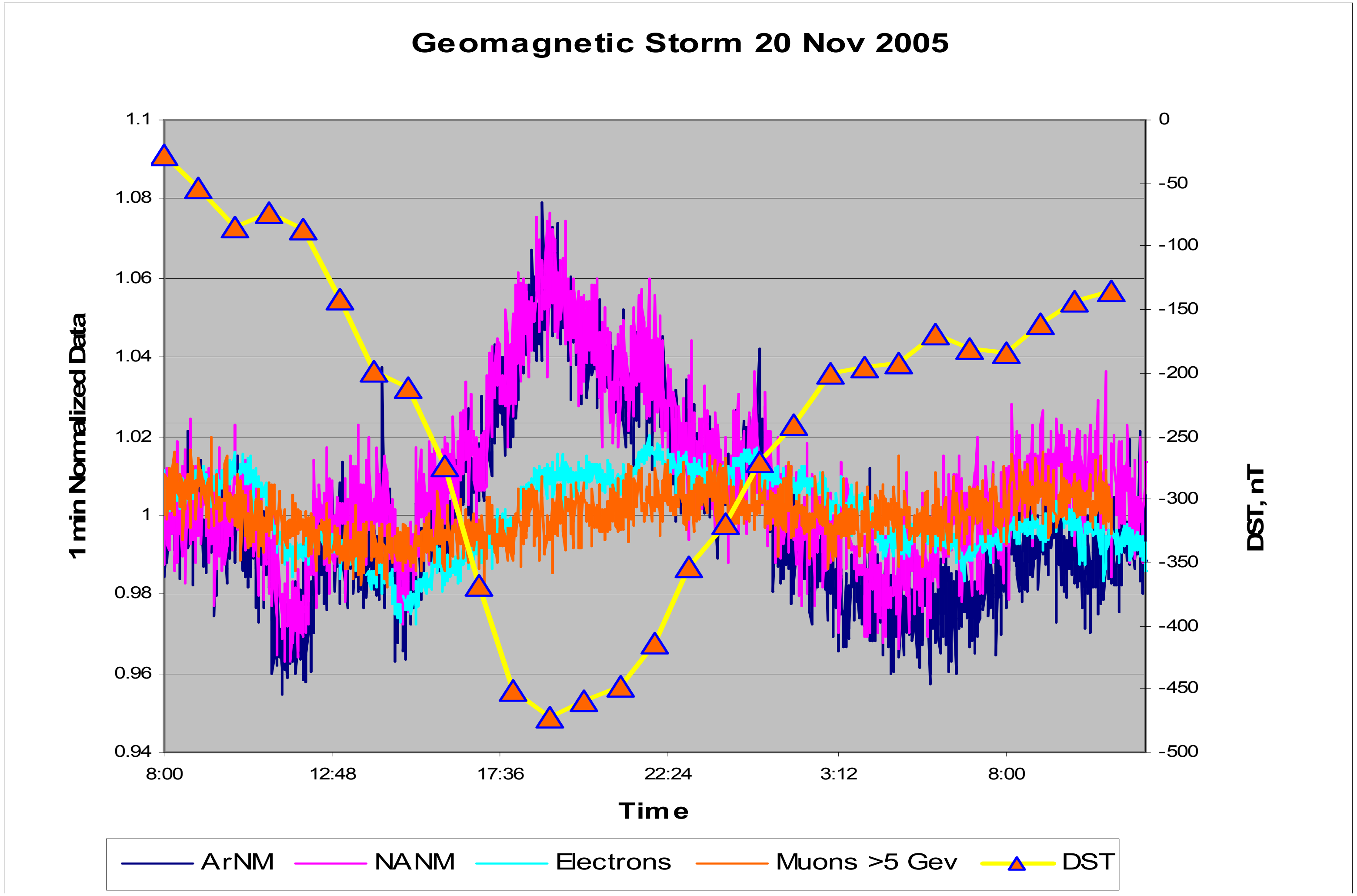
Famous "Halloween" events of 2003, detected in electron & muon and neutron fluxes by ASEC monitors at different altitudes



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**

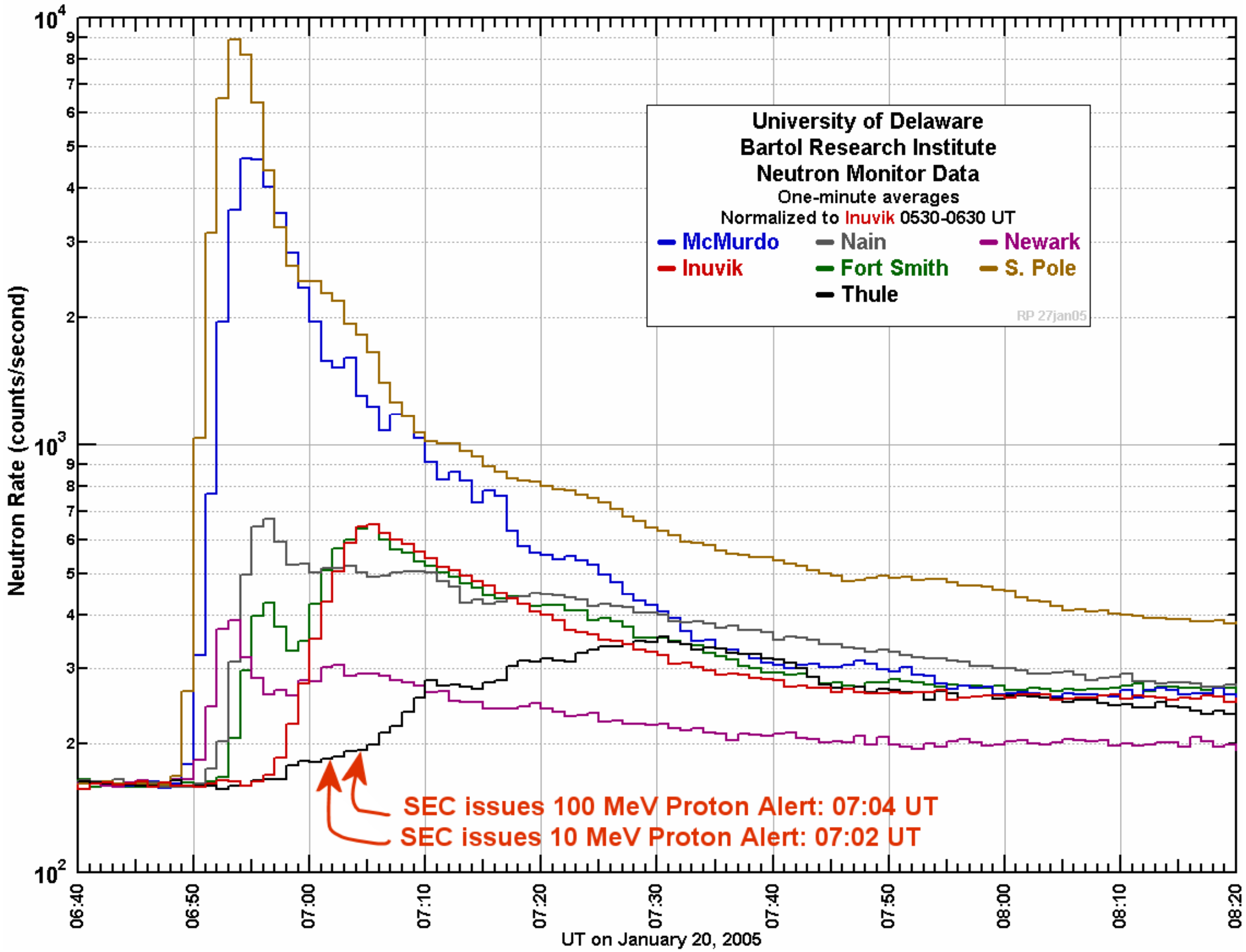
Geomagnetic Disturbance of 20 November



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

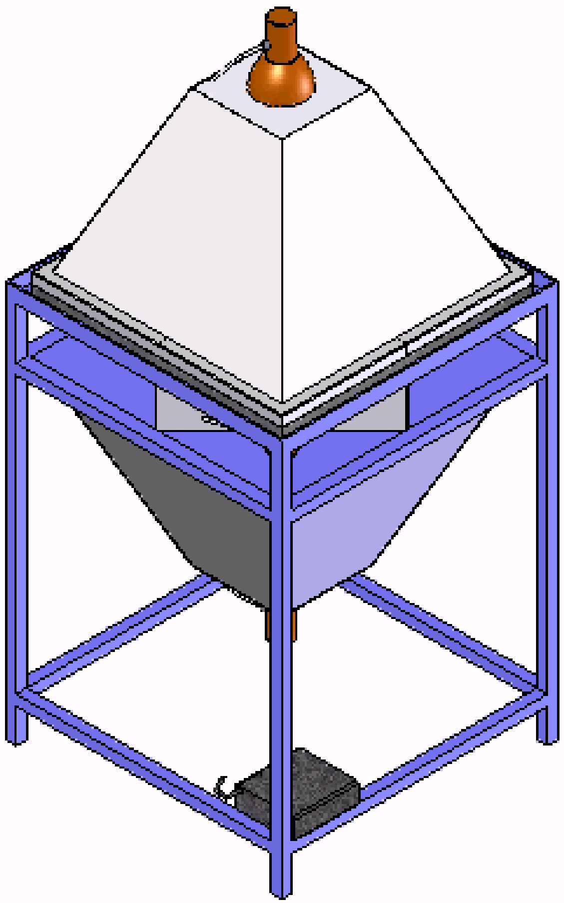
Neutron Monitors Can Provide the Earliest Alert of a Solar Energetic Particle Event



- 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.**

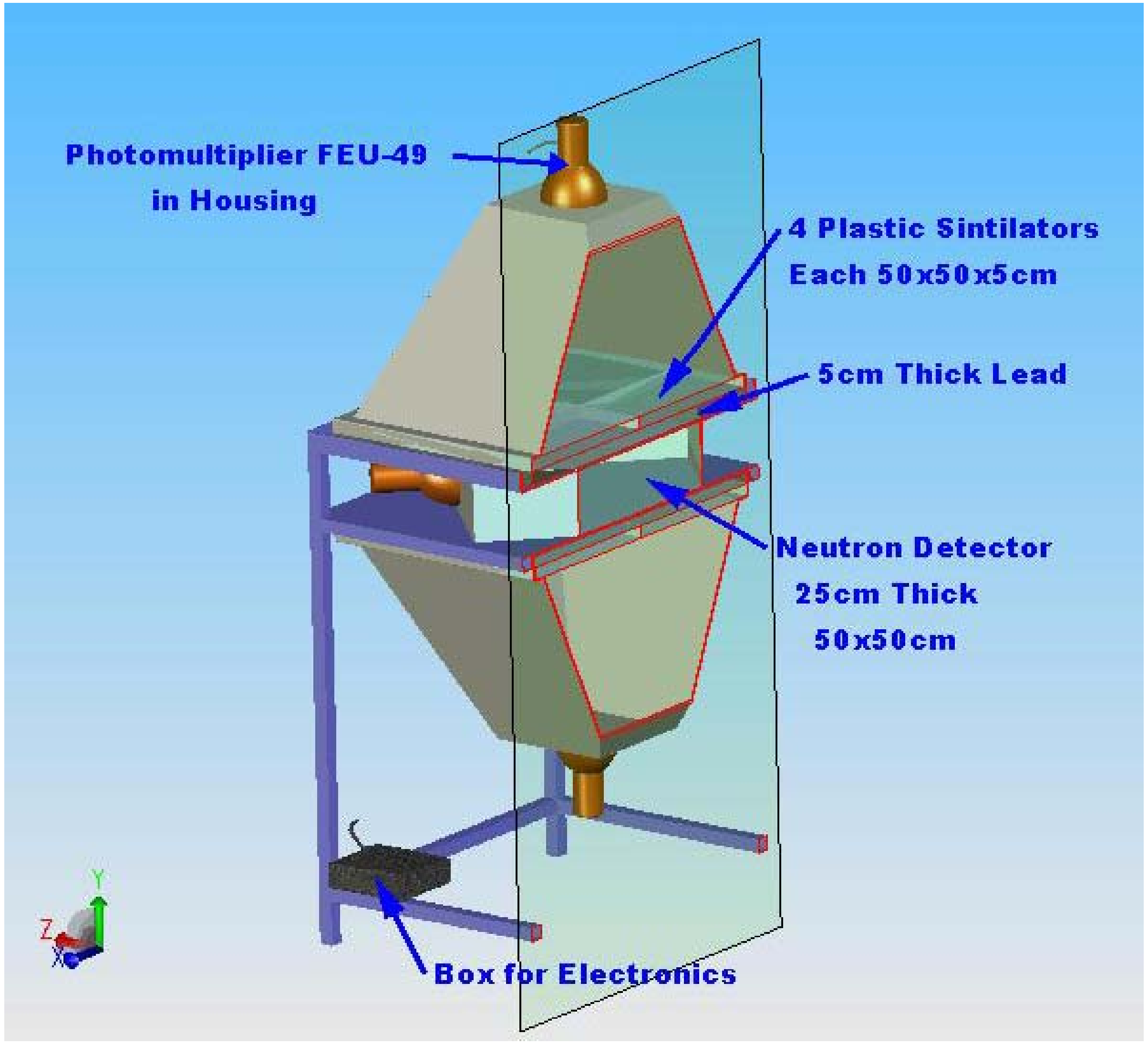
Courtesy John Bieber

Space Environmental Viewing and Analysis Network (SEVAN)



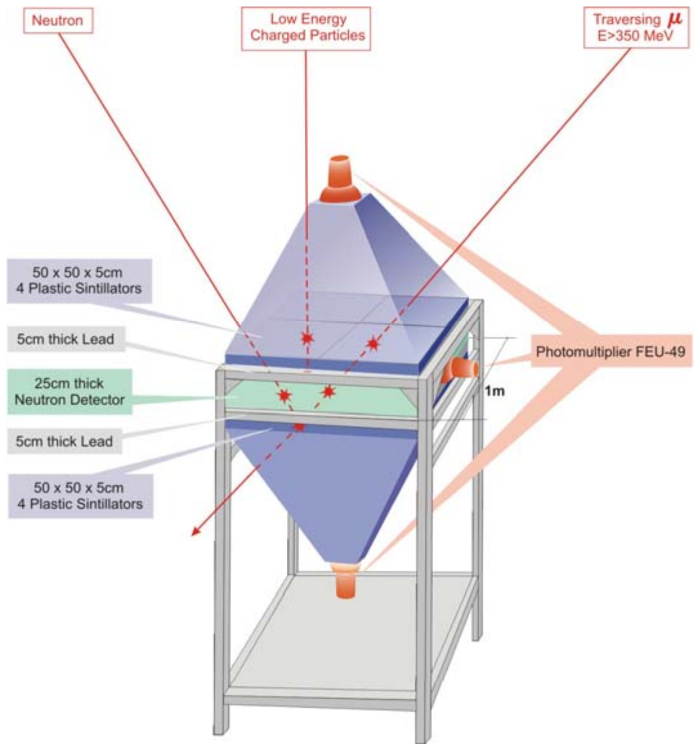
Assem with karkas

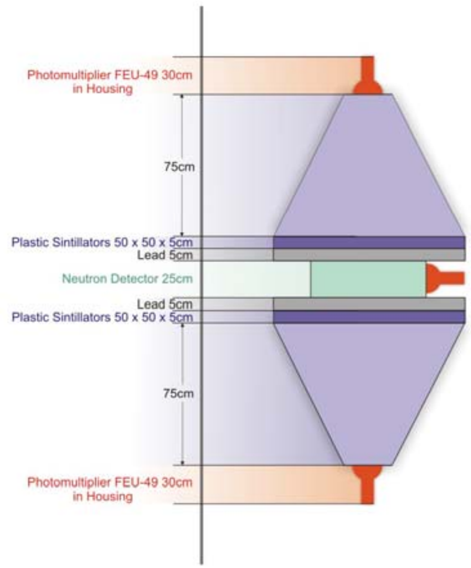
Sevan Detector



Space Environment Viewing and Analysis Network (SEVAN)

Modular Particle Monitor for Neutral and Charged CR fluxes





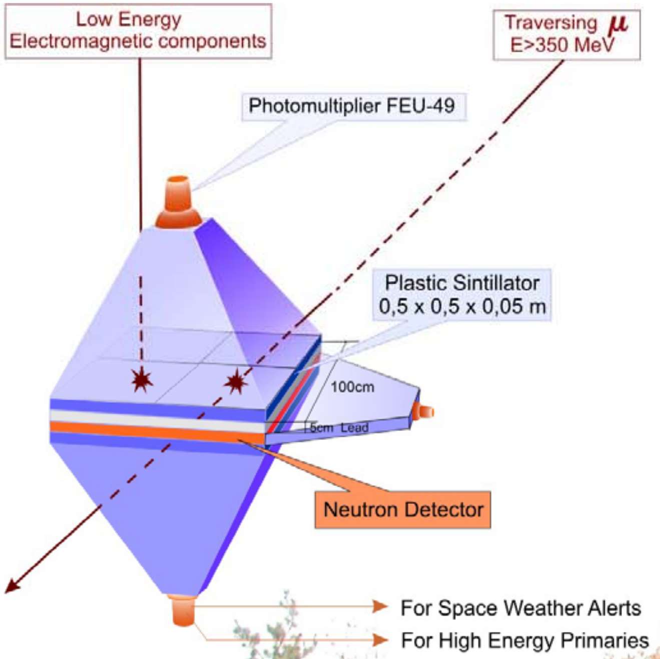
SPONSOR Provides:
8 scintillator slabs each of 50 x 50 x 5 cm;
2 photomultipliers;
Electronics board with counters, discriminators, optional temperature and pressure sensors and PC interface;
High voltage units for the photomultiplier;
DAQ, analysis and WEB software;
Access to DVIN data bases;
Training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

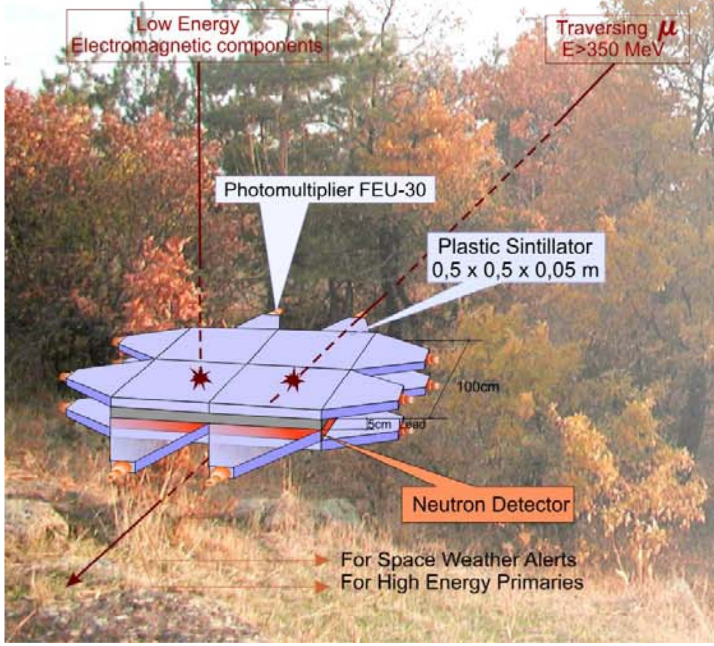
RECIPIENT Provides:

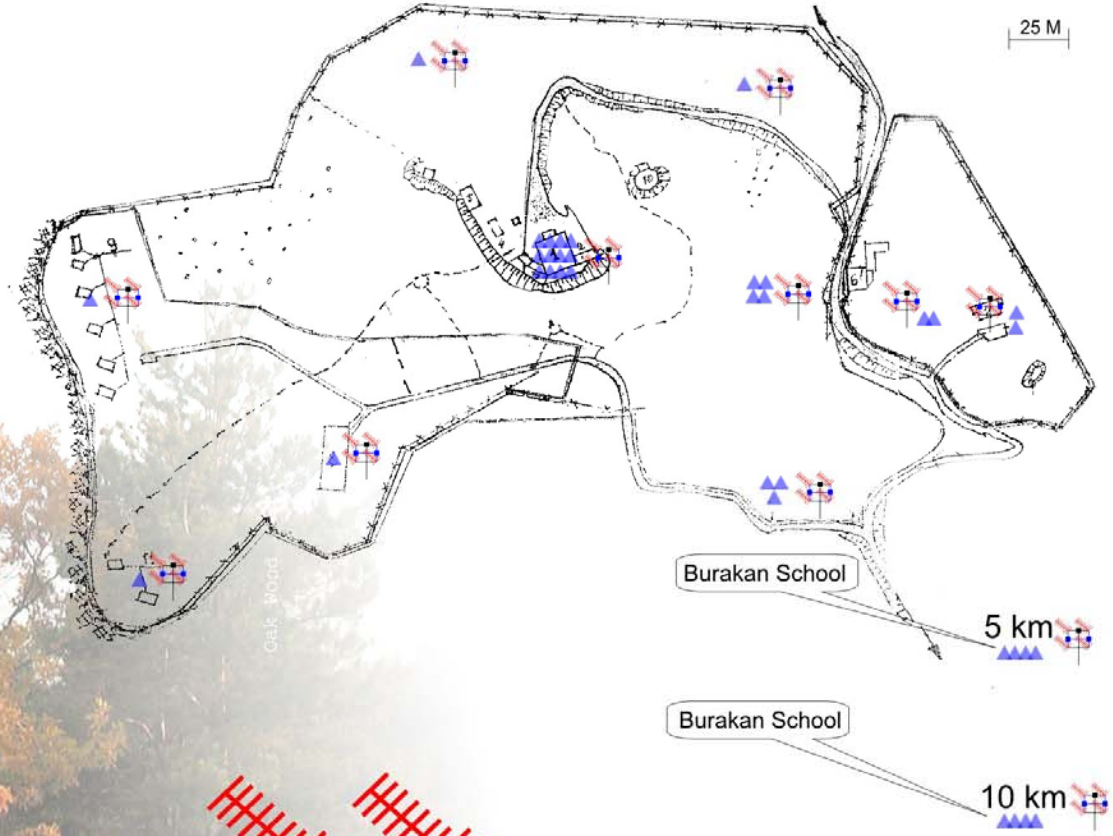
1. Mechanical parts, including lead.
2. Purchase computer with GPS;
3. Uninterruptible electricity and Internet access;
4. Transportation of equipment from Yerevan;
5. Cover travel and stay expenses of sponsor experts (if necessary).

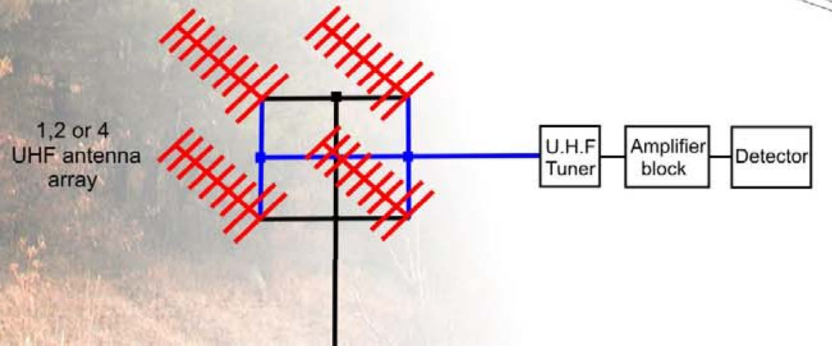
Installed Detectors

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









SEVAN Count Rates

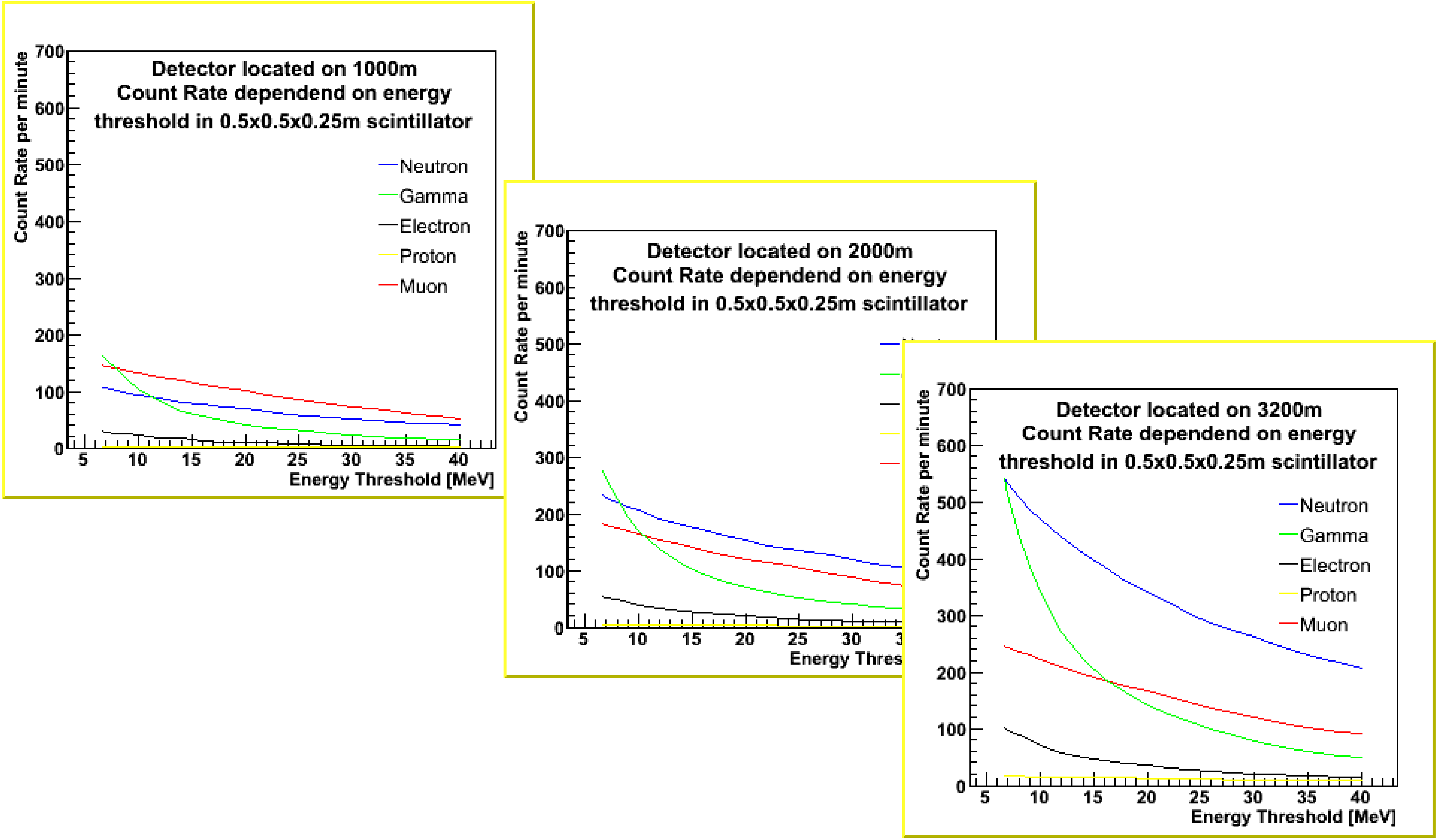
Per Minute

	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

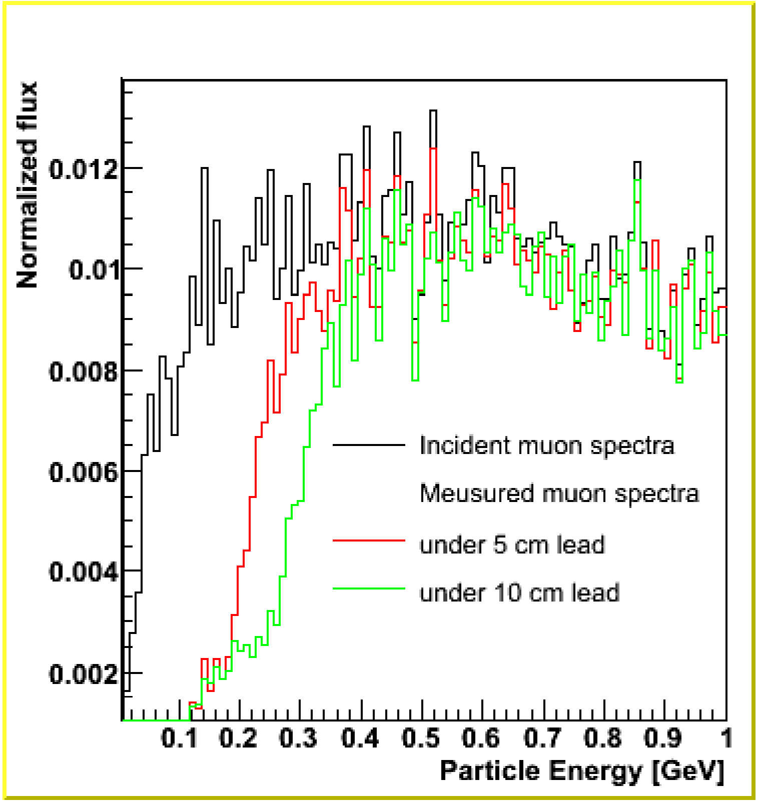
Per Second

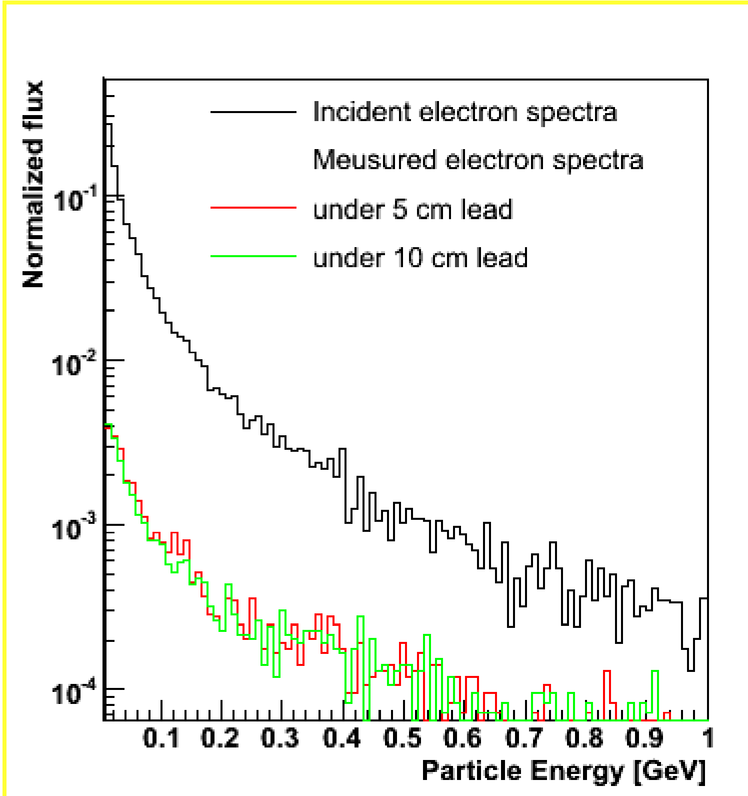
	All	Electrons	Muons	Gamma	Neutrons	Protons
0 m	168	26	133	6	1	2
1000 m	217	41	160	10	3	3
2000 m	293	66	195	17	6	9
3200 m	446	128	249	33	13	22

Expected Count Rates at Different Altitudes

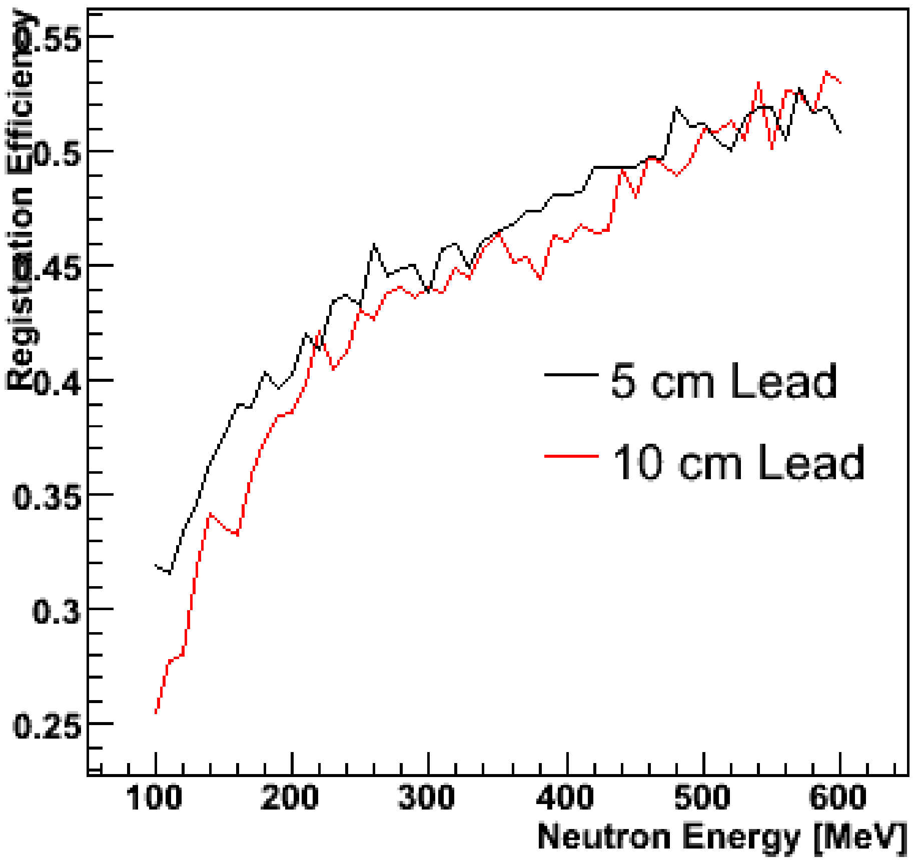


Electron and Muon Fluxes under Lead Filter

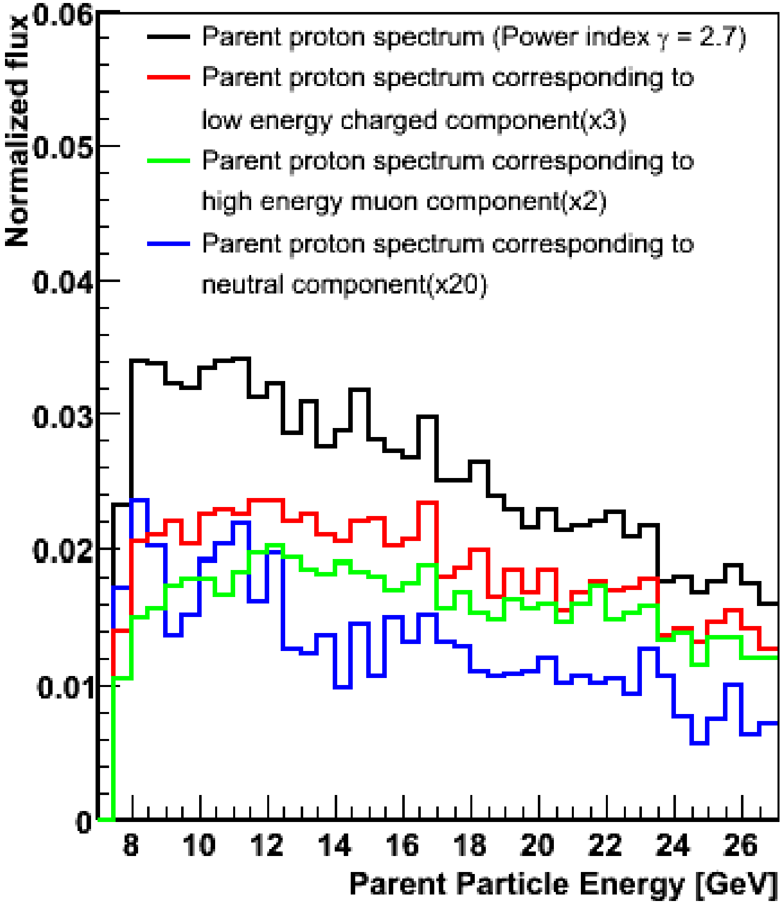


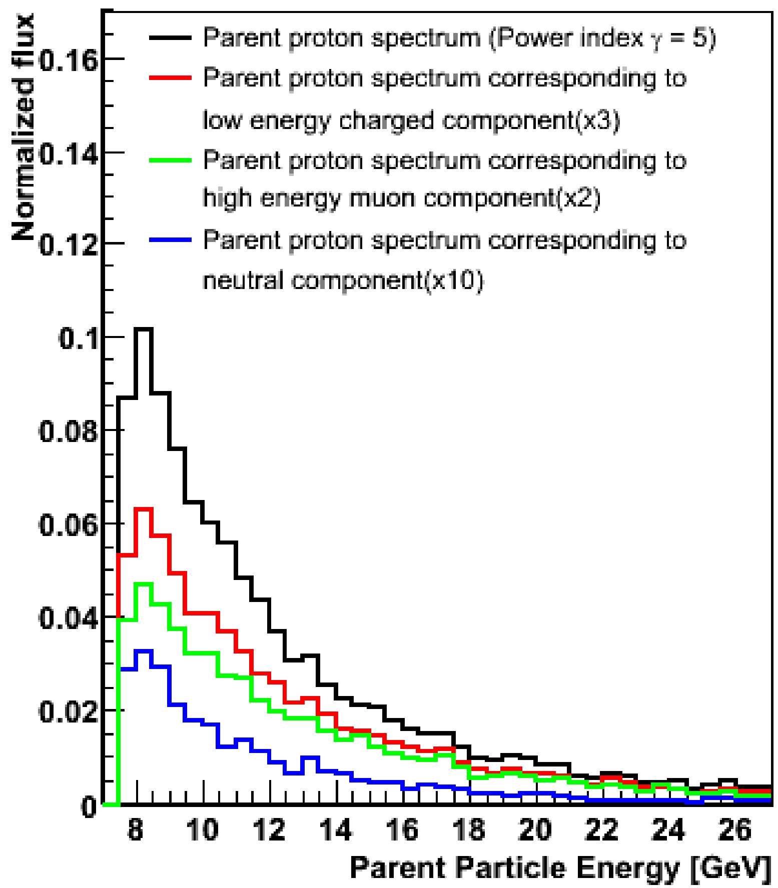


Efficiency of Neutron Detection



SEVAN Response to GCR and SCR





Conclusions

- Particle detector is measuring count rate (number of hits per minute) of secondary cosmic rays. Simple microcontroller driven electronics, allows to measure separately fluxes of neutrons, low energy charged component (mostly electrons and muons) and high energy muons. From scientific point of view it is advanced research, measuring in much more details the characteristics of global geophysical parameters, comparing with existent networks of particle detectors;
- Basic physics is extremely interesting and up-to-date. By measuring neutral and charges species of secondary fluxes it is possible to reconstruct primary flux of cosmic rays incident on the terrestrial atmosphere (mostly protons for energies up to several tens of GeV). Changes of the primary flux are controlled by the sun activity and reflect major solar events: flares, acceleration of particles, coronal mass ejections. Physics of Solar flares is one of fastest developing fields of high energy astrophysics both from theoretical and experimental points of view. The universal processes of particle acceleration by stellar objects and shocks are one of main unsolved problems vital for understanding the Universe and our nearest star gives us excellent possibility to study these processes *in vitru*. Space Weather is another aspect of solar “modulation”: many space and surface technologies are affected by the consequences of violent solar explosions.
- Solar modulation effects usually are lasting not more than 2 weeks, the time group of spots are traveling via visible solar disc. The effects of solar modulations are reflected in the noticeable changes of the count rates of particle detectors. For the data analysis we prepare simple and powerful platform allowing remote on-line data analysis. Revealing and enumerating the peaks, estimating significances decreases and increases of count rates, estimating correlations between charged and neutral fluxes and many other operations are feasible via our DVIN3 software. Students using measurements of the their own detector will get experience in the statistical procedures necessary for the physical inference.
- Solar modulation effects and physical characteristics and analysis of the major solar events are possible only by joining data from space-born and surface particle and radiation detectors. Students will participate in data exchange and joint analysis within several scientific networks, thus understanding that communicating the results of own research is obligatory part of global scientific process.