Surface Particle Detectors in Space Weather research and forecast

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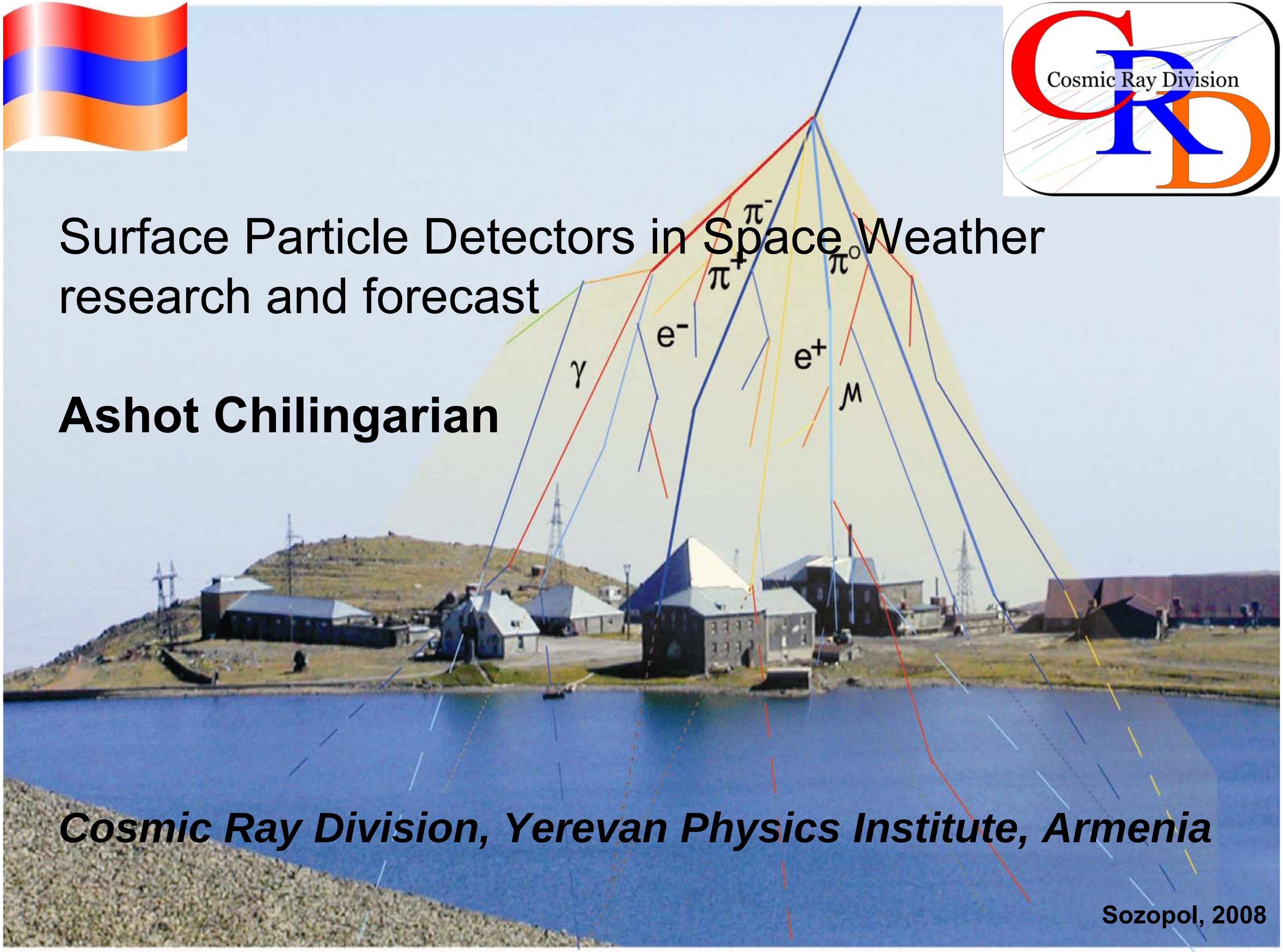
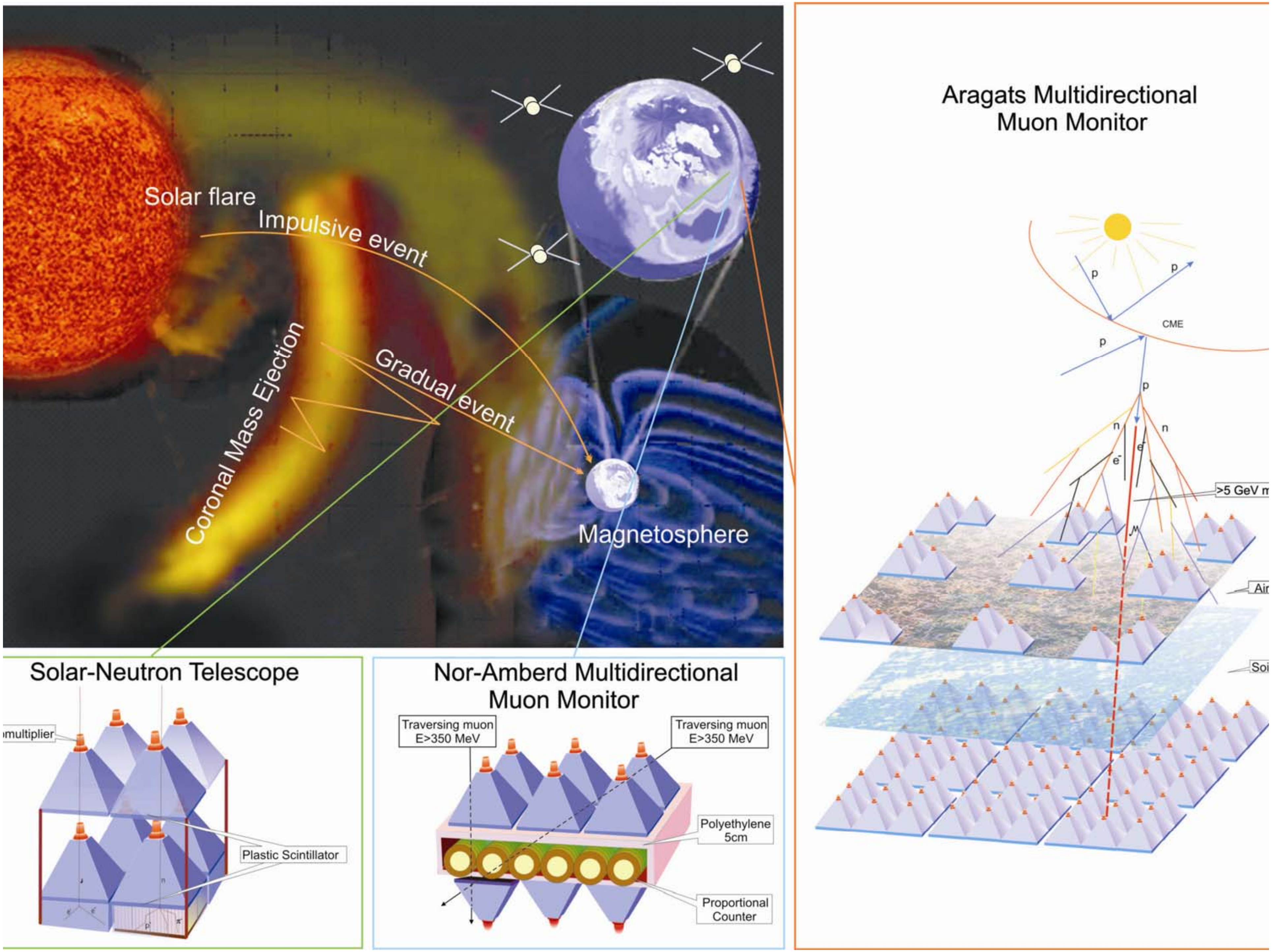
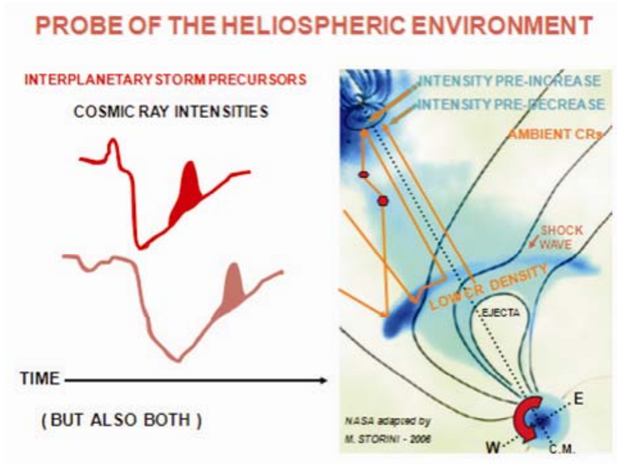


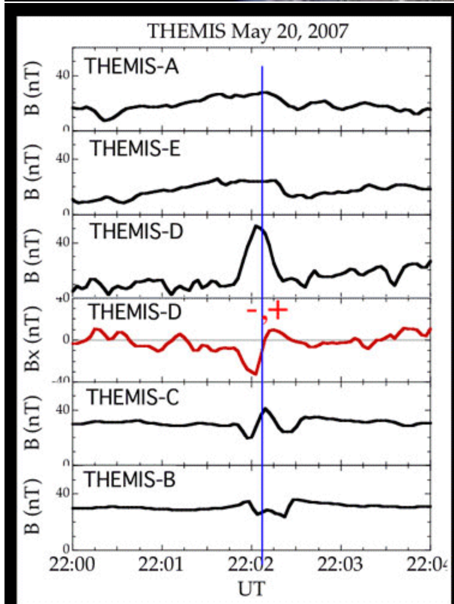
Sozopol, 2008

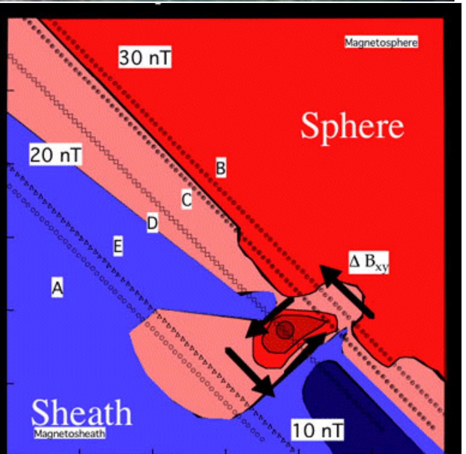


Solar flare
Impulsive event
Coronal Mass Ejection
Gradual event
Magnetosphere
Solar-Neutron Telescope
multiplier
Plastic Scintillator
Nor-Amberd Multidirectional Muon Monitor
Traversing muon E>350 MeV
Traversing muon E>350 MeV
Polyethylene 5cm
Proportional Counter
Aragats Multidirectional Muon Monitor
CME
>5 GeV
Air
Soi

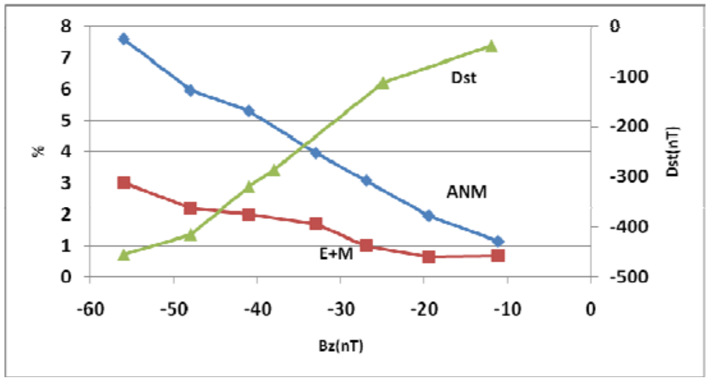
A magnetic map of a magnetospheric "rope" observed in cross-section by the THEMIS satellites on May 20, 2007 – **collisionless transport!**





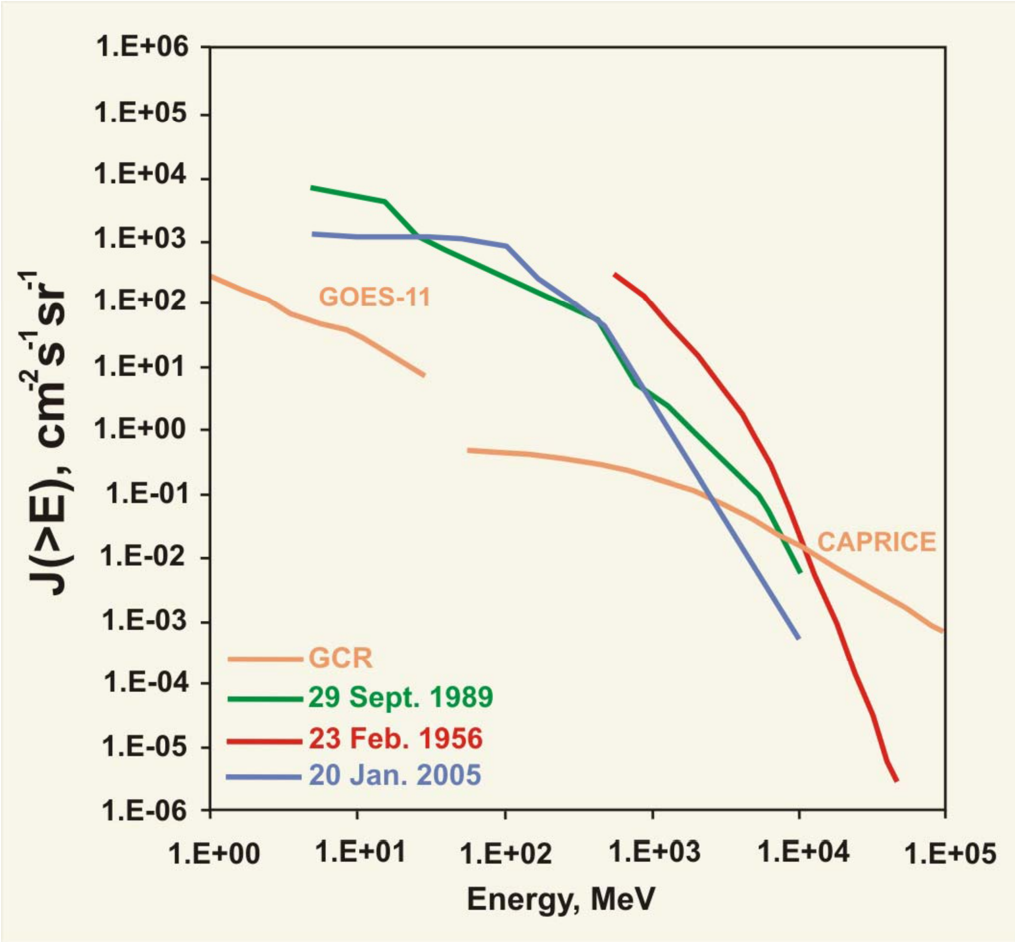


Five THEMIS spacecraft were used to construct cross-sections indicating a flux rope detached from the magnetosphere



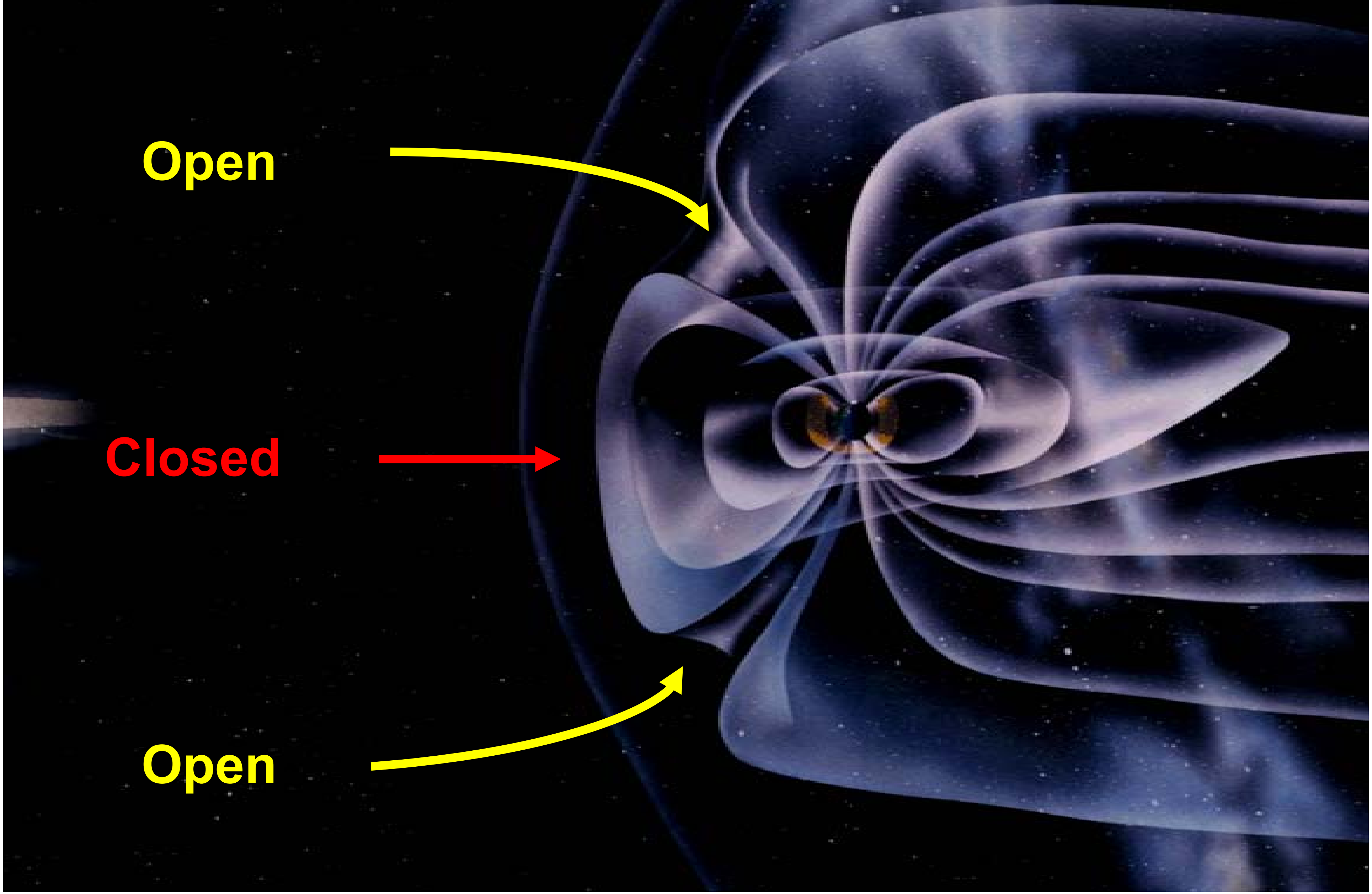
R^2(ANM,Bz)=0.992, R^2(E+M,Bz)=0.942, R^2(Dst,Bz)=0.978, multiple R^2=0.995

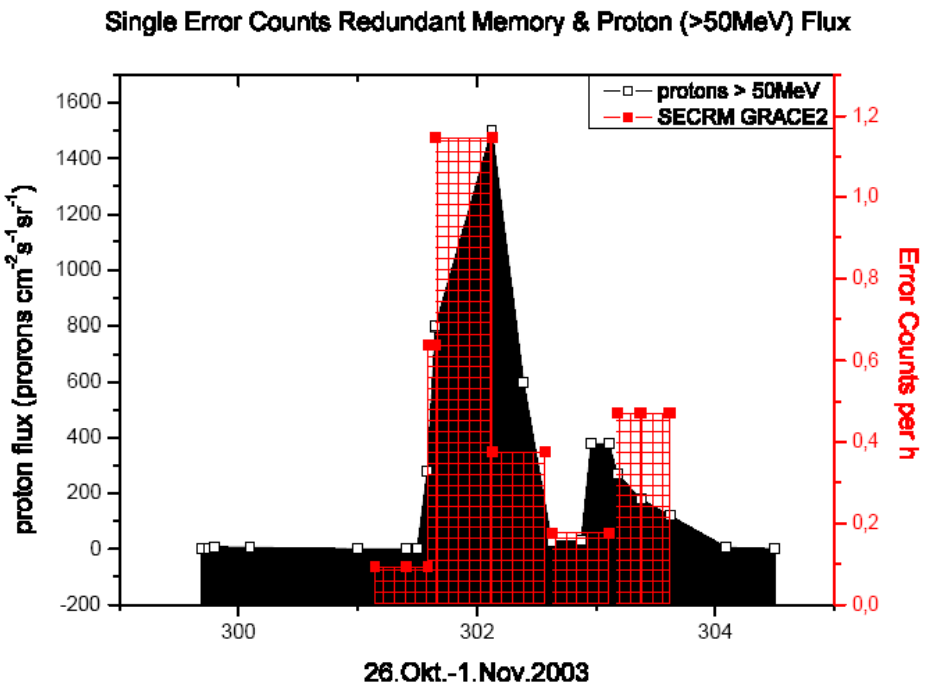
Galactic and Solar Cosmic Rays

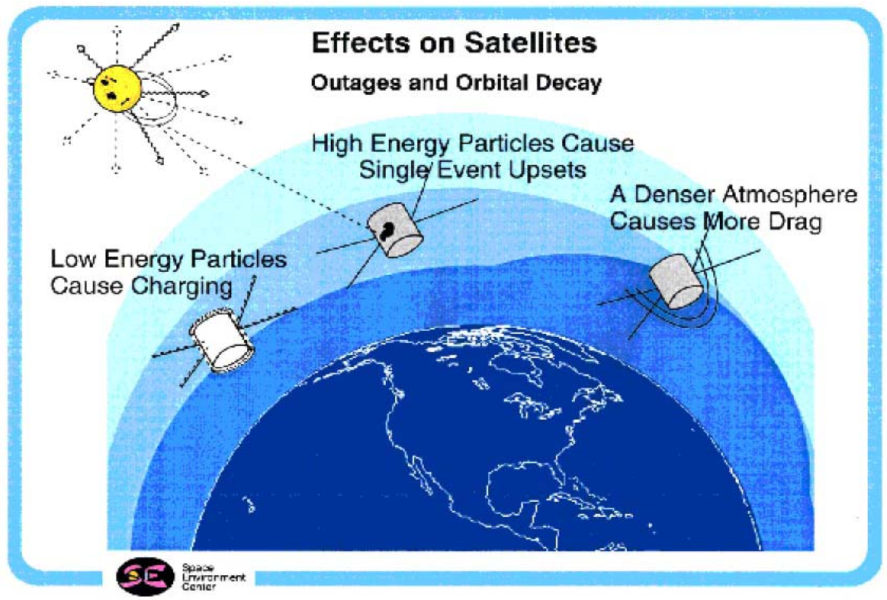


After 10 GeV the intensity of GCR become increasingly higher comparing with ever detected SCR

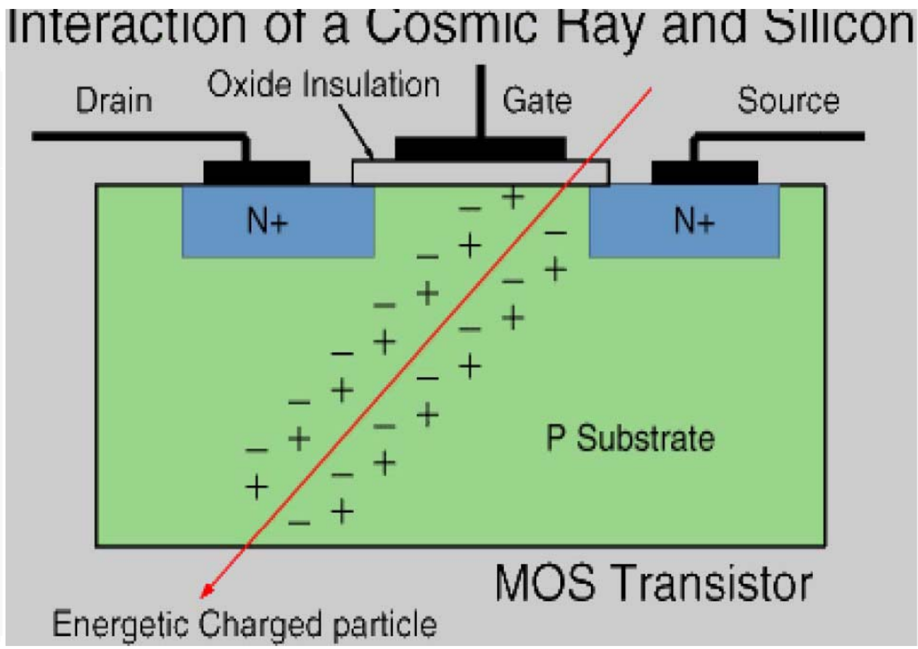
Cosmic Ray Access



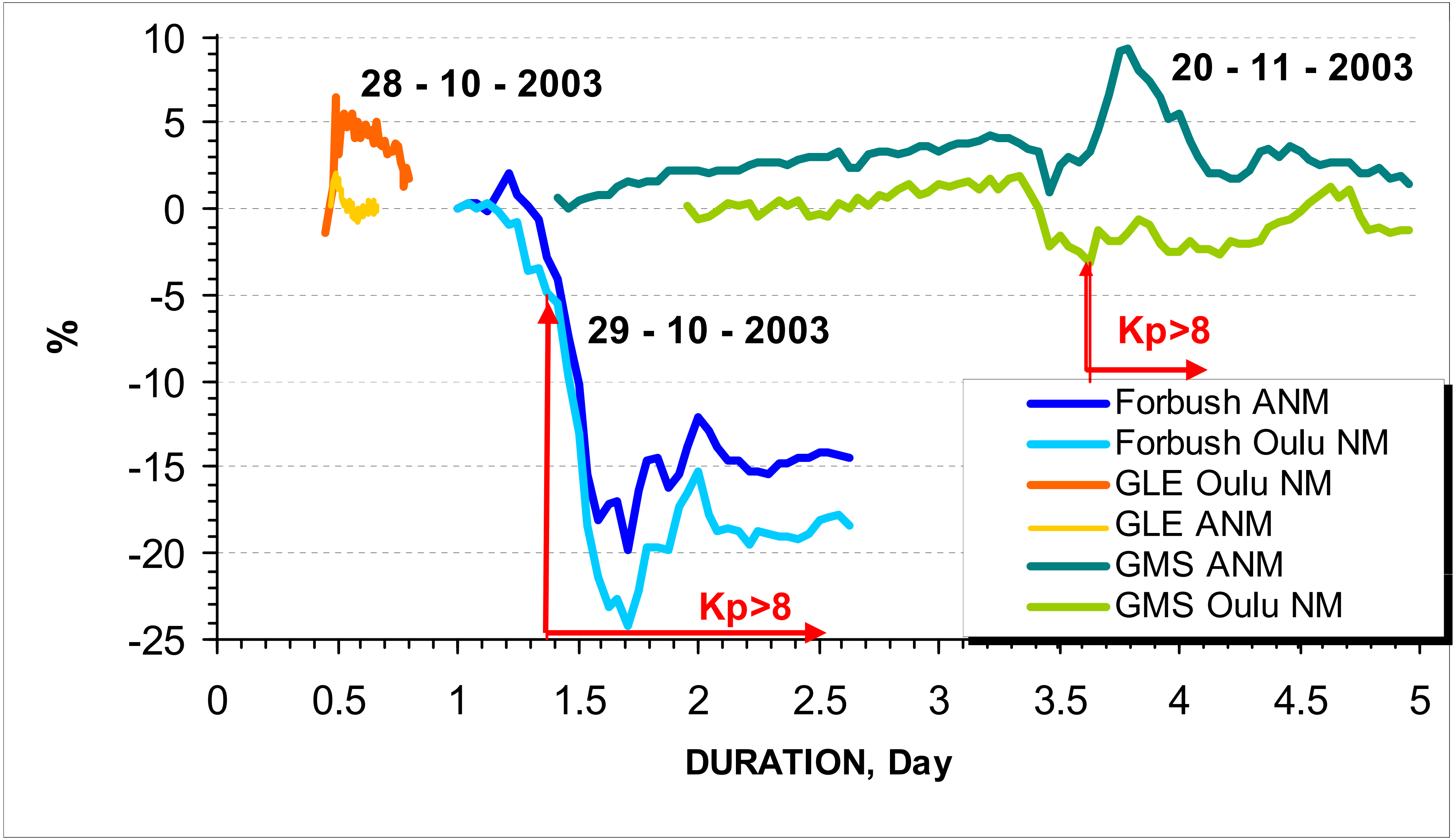

Single Error Counts Redundant Memory & Proton (>50MeV) Flux
protons > 50MeV
SECRM GRACE2
proton flux (protons $cm^{-2}s^{-1}sr^{-1}$)
Error Counts per h
1600
1400
1200
1000
800
600
400
200
0
-200
1,2
1,0
0,8
0,6
0,4
0,2
0,0
300
302
304
26.Okt.-1.Nov.2003


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

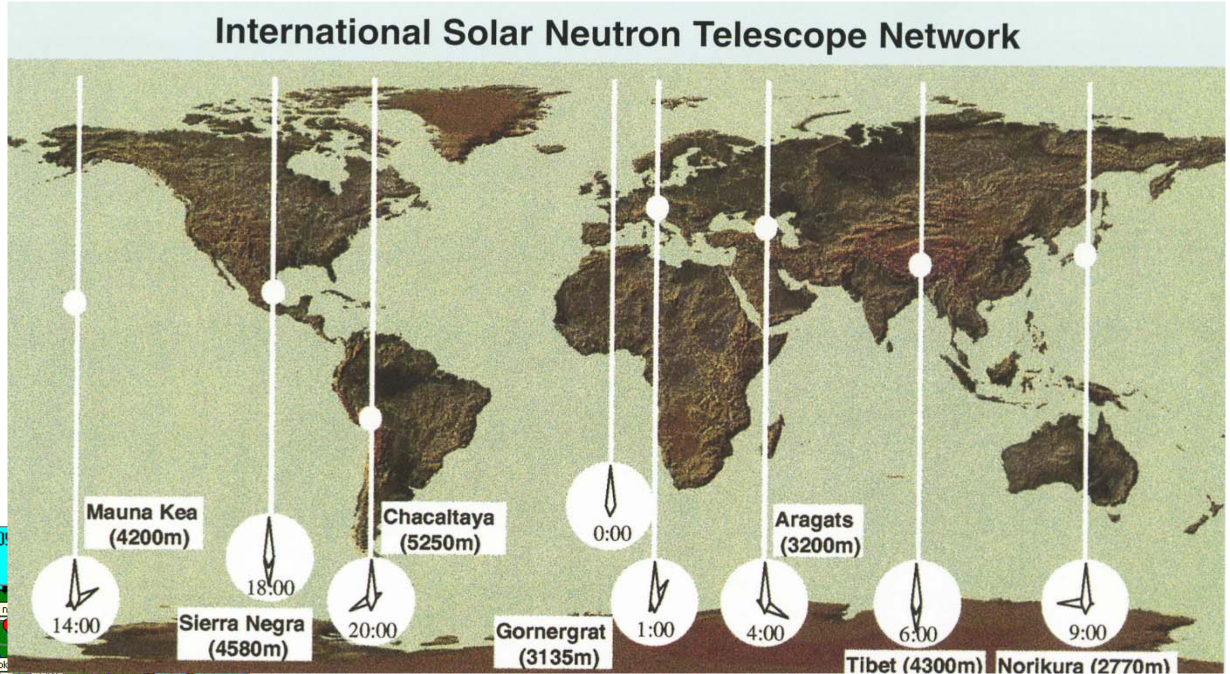

PJM Public Service
Step Up Transformer
Severe internal damage caused by the space storm of 13 March, 1989.


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

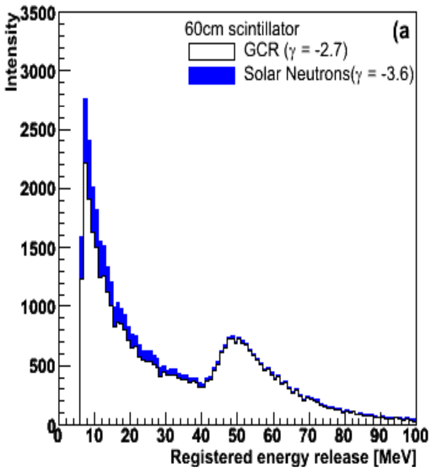
Solar Modulations Effects

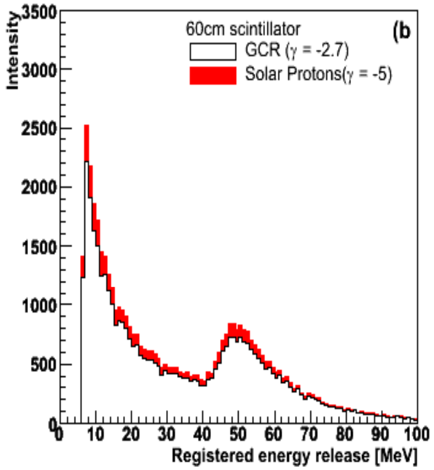


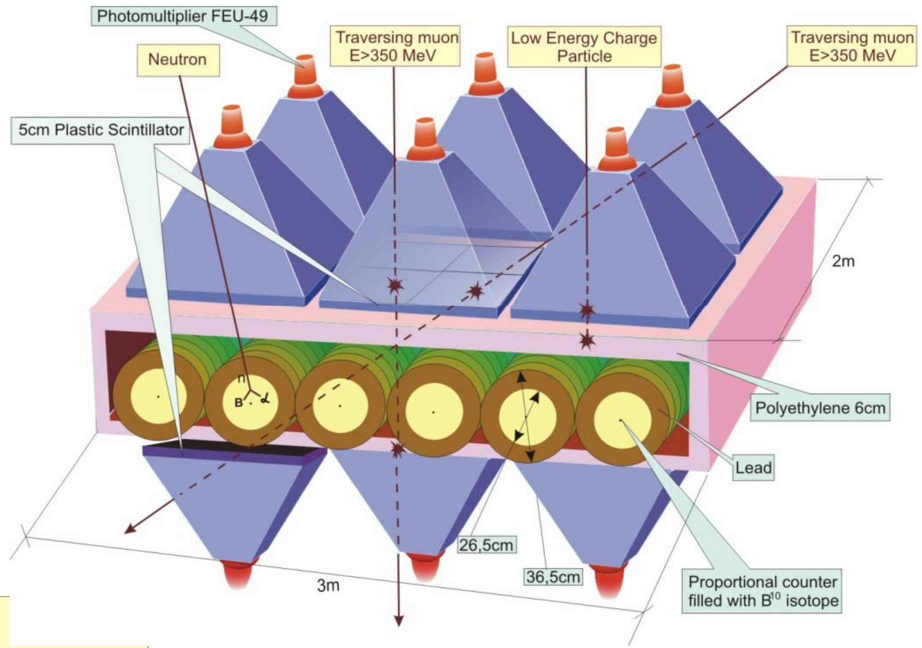
World-wide Particle Detector Networks



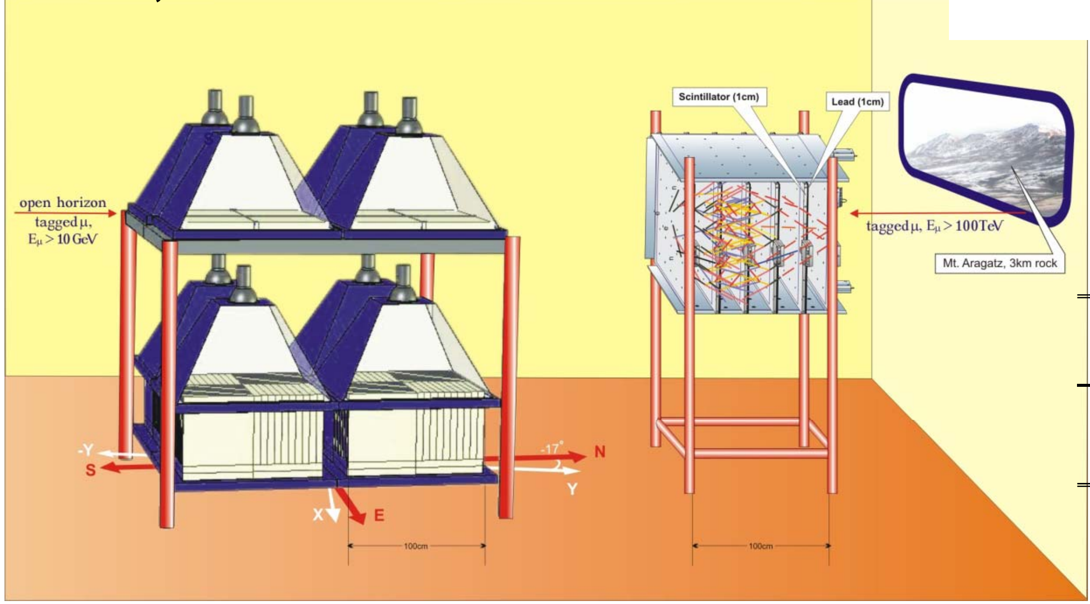
Particle Detectors Operated at Aragats Space Environmental Center





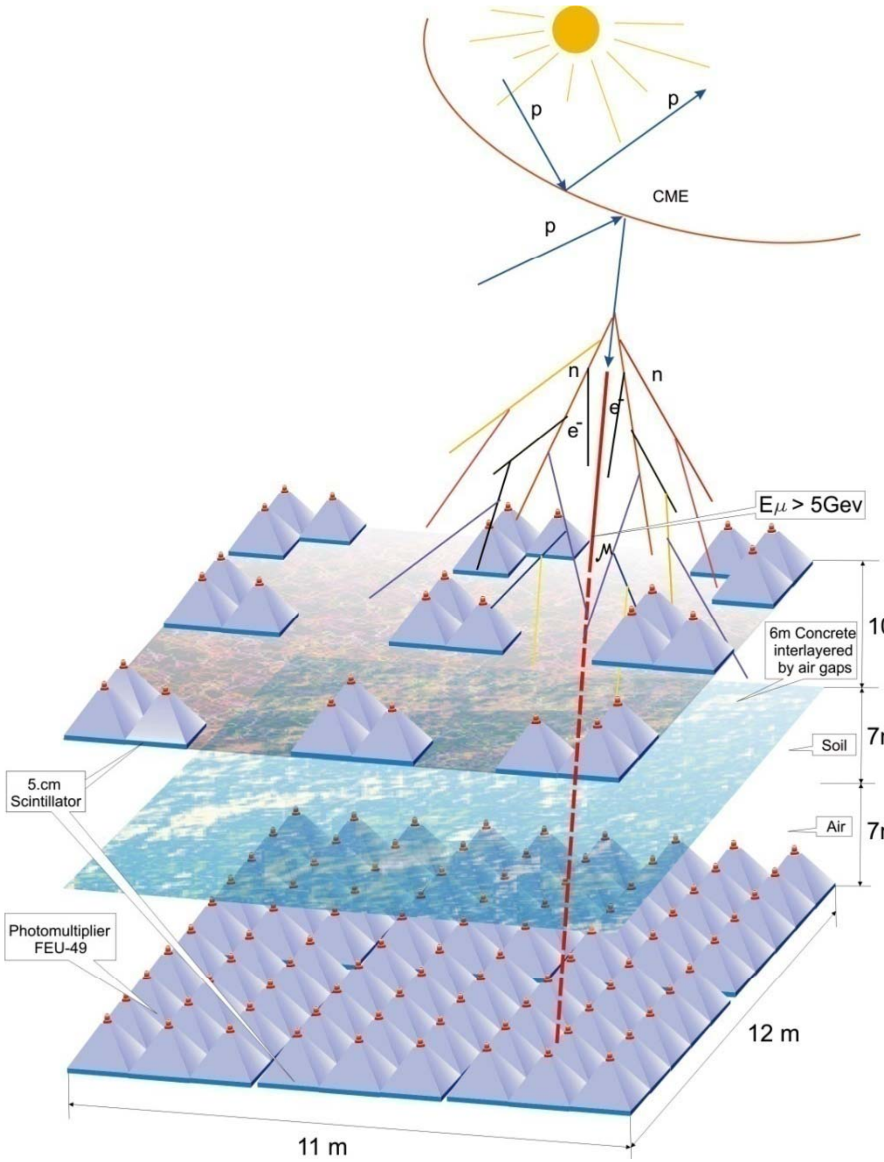


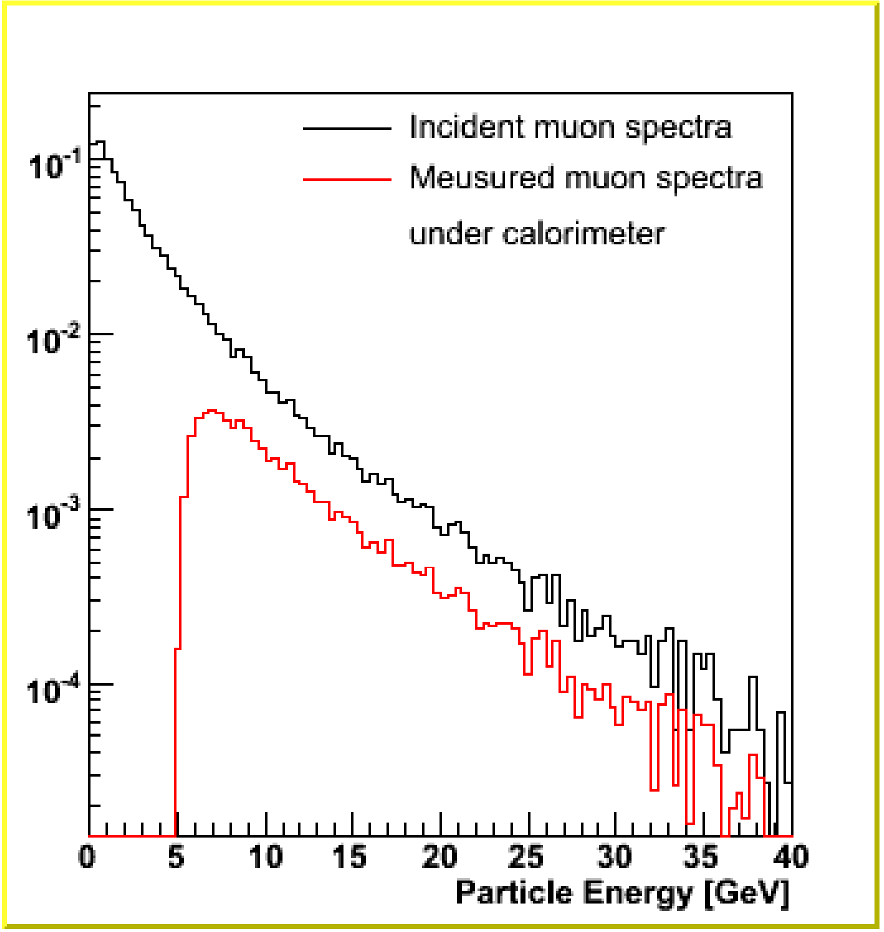
Registered energy deposit corresponding to GCR, Solar Protons and Solar Neutrons.



Detector layer	Solar Protons	Solar Neutrons
Upper 5cm scintillator	4.8σ	2.6σ
Middle 25 cm scintillator	1.7σ	6.4σ

Aragats Multidirectional Muon Monitor (AMMM)

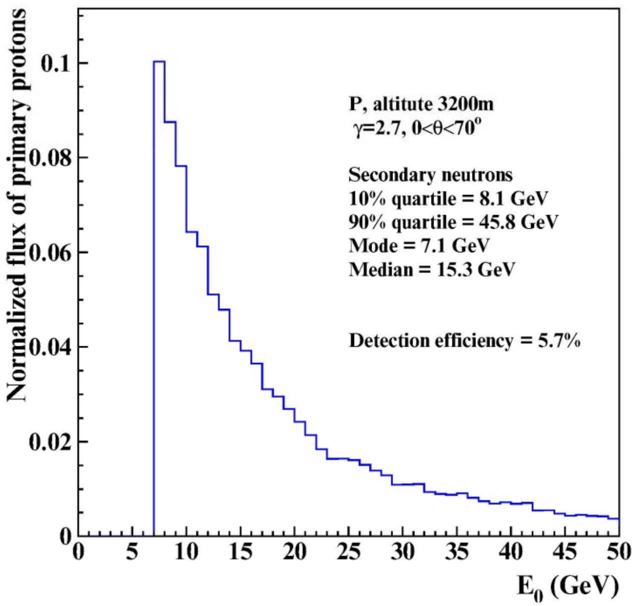


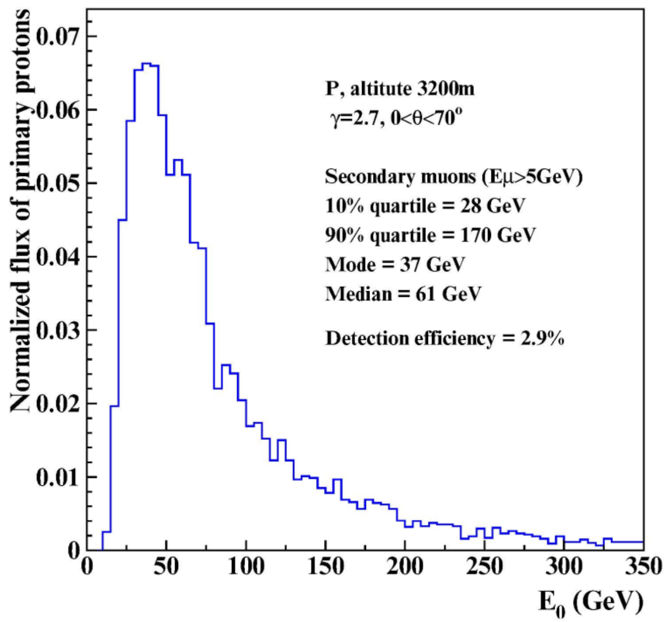


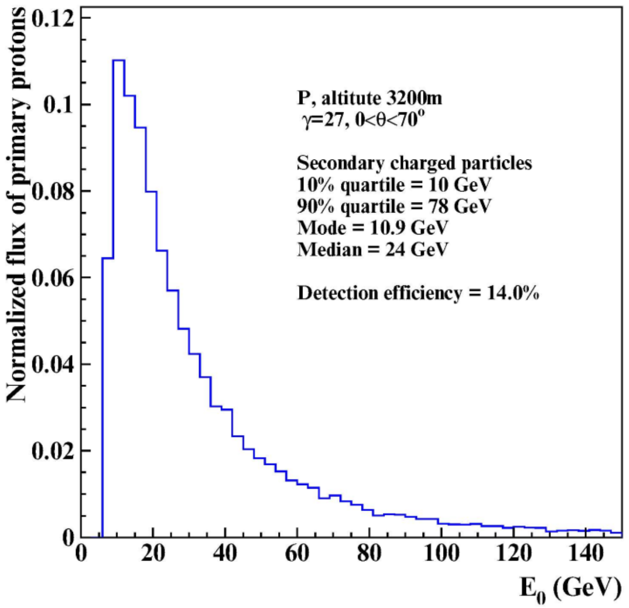
Barometric Coefficient of ASEC Monitors

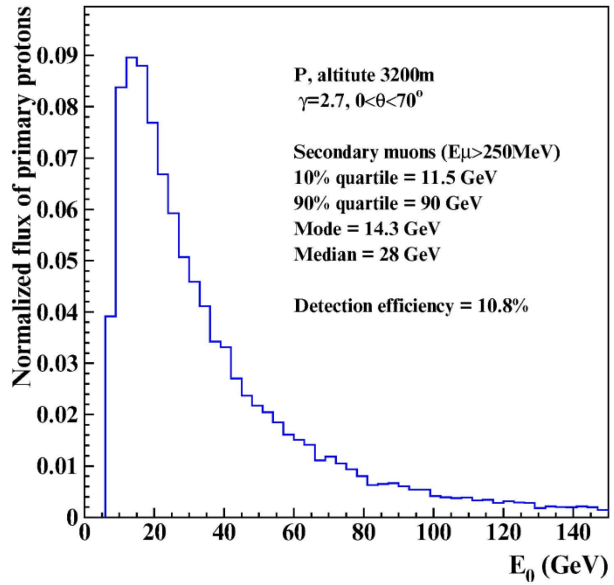
MONITORS	BAROMETRIC COEFFICIENT	ERROR	CORRELATION COEFFICIENT
Nor Amberd neutron monitor 0.4us	-0.695 %/mb	± 0.0133	0.997
Nor Amberd neutron monitor 250us	-0.678 %/mb	± 0.0127	0.997
Nor Amberd neutron monitor 1250us	-0.670 %/mb	± 0.0216	0.995
Aragats neutron monitor 0.4us	-0.730 %/mb	±0.0185	0.997
Aragats neutron monitor 250us	-0.713%/mb	±0.0183	0.997
Aragats neutron monitor 1250us	-0.688%/ mb	±0.0182	0.996
Nor Amberd multidirectional muon monitor(1) (upper layer)	-0.324%/mb	±0.012	0.992
Nor Amberd multidirectional muon monitor(1) (lower layer)	-0.223%/mb	±0.0135	0.987
Nor Amberd multidirectional muon monitor(2) (upper layer)	-0.323%/mb	±0.0136	0.991
Nor Amberd multidirectional muon monitor(2) (lower layer)	-0.225%/mb	±0.0135	0.987
Aragats underground muon monitor E>5 Gev	-0.08%/mb	±7.57E-05	0.924

Energy distribution of the GCR protons initiated various secondaries at 3200 m altitude

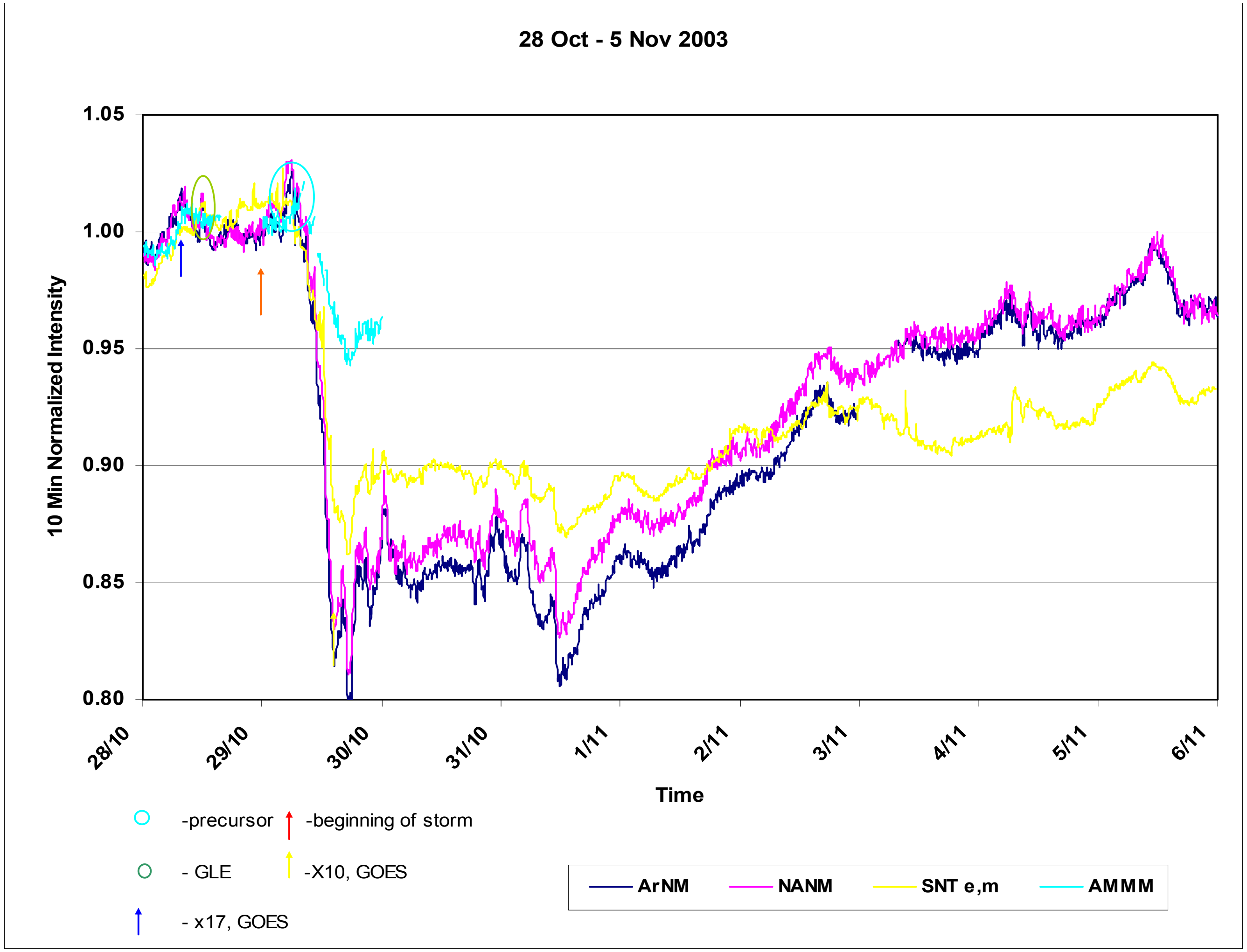








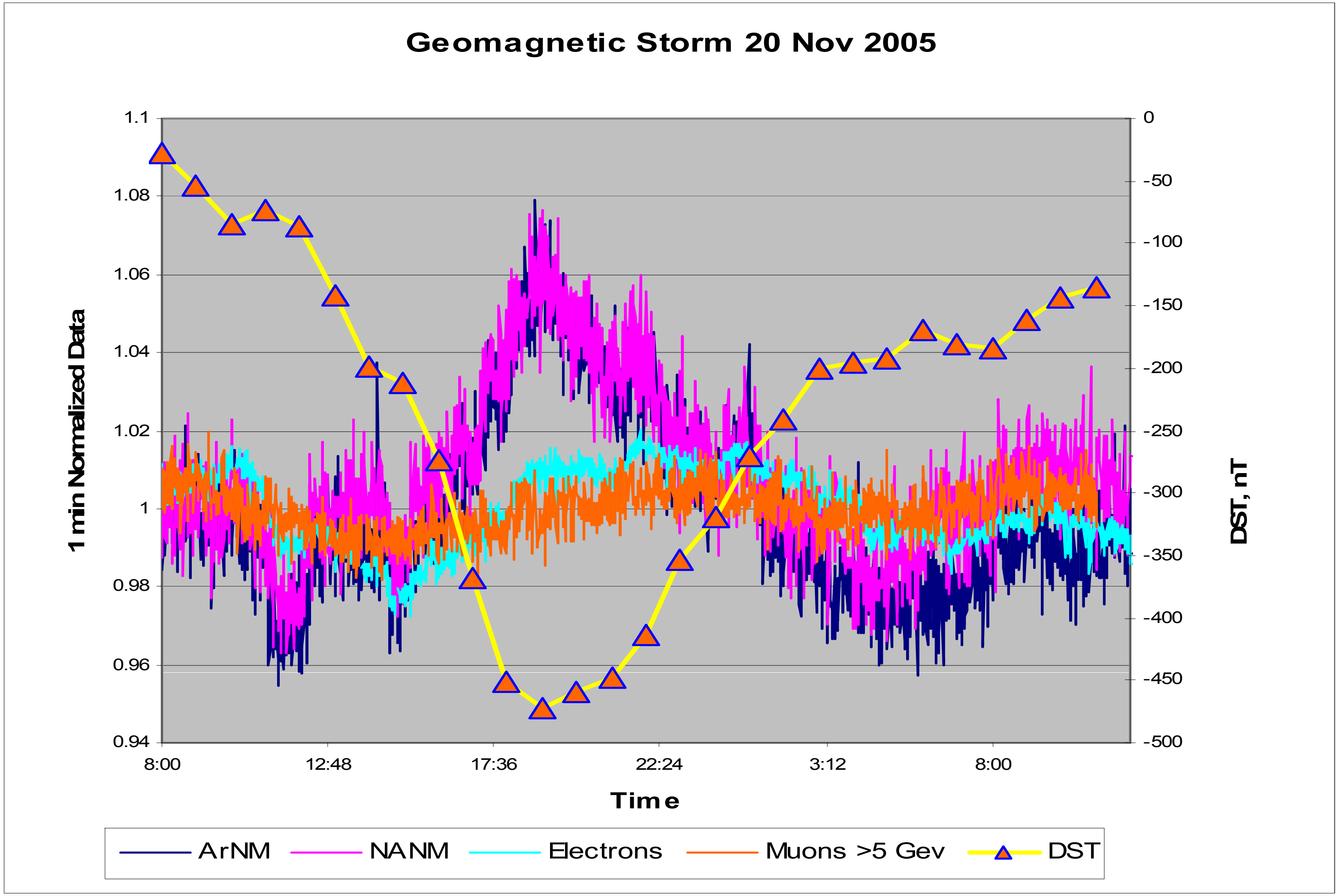
Famous “Halloween” events of 2003, detected in electron & muon and neutron fluxes by ASEC monitors at different altitudes



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 2003



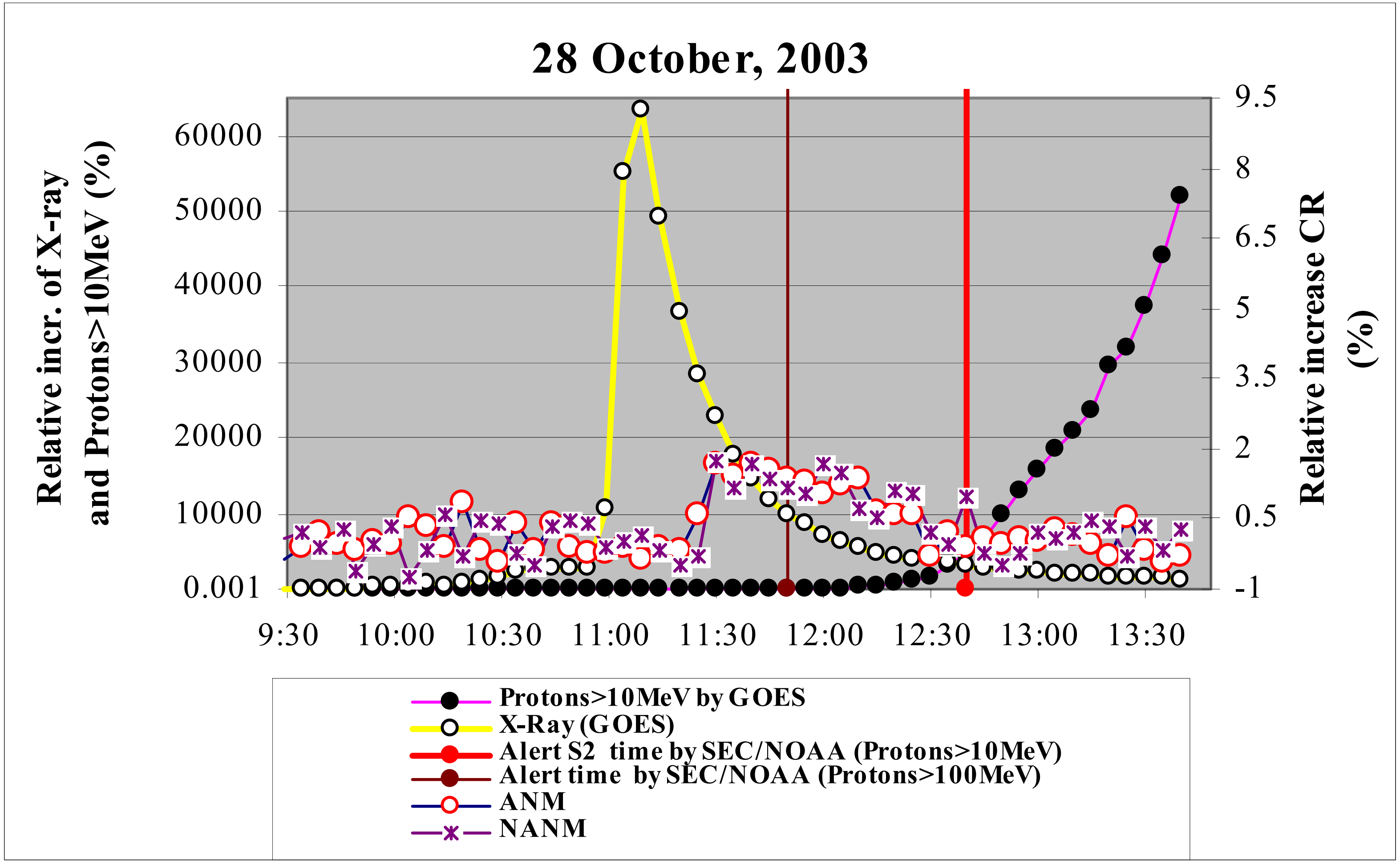
Correlation Matrix of ASEC monitors for 20-21 November 2003 г. (14:50 – 19:10), Geomagnetic Storm

	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

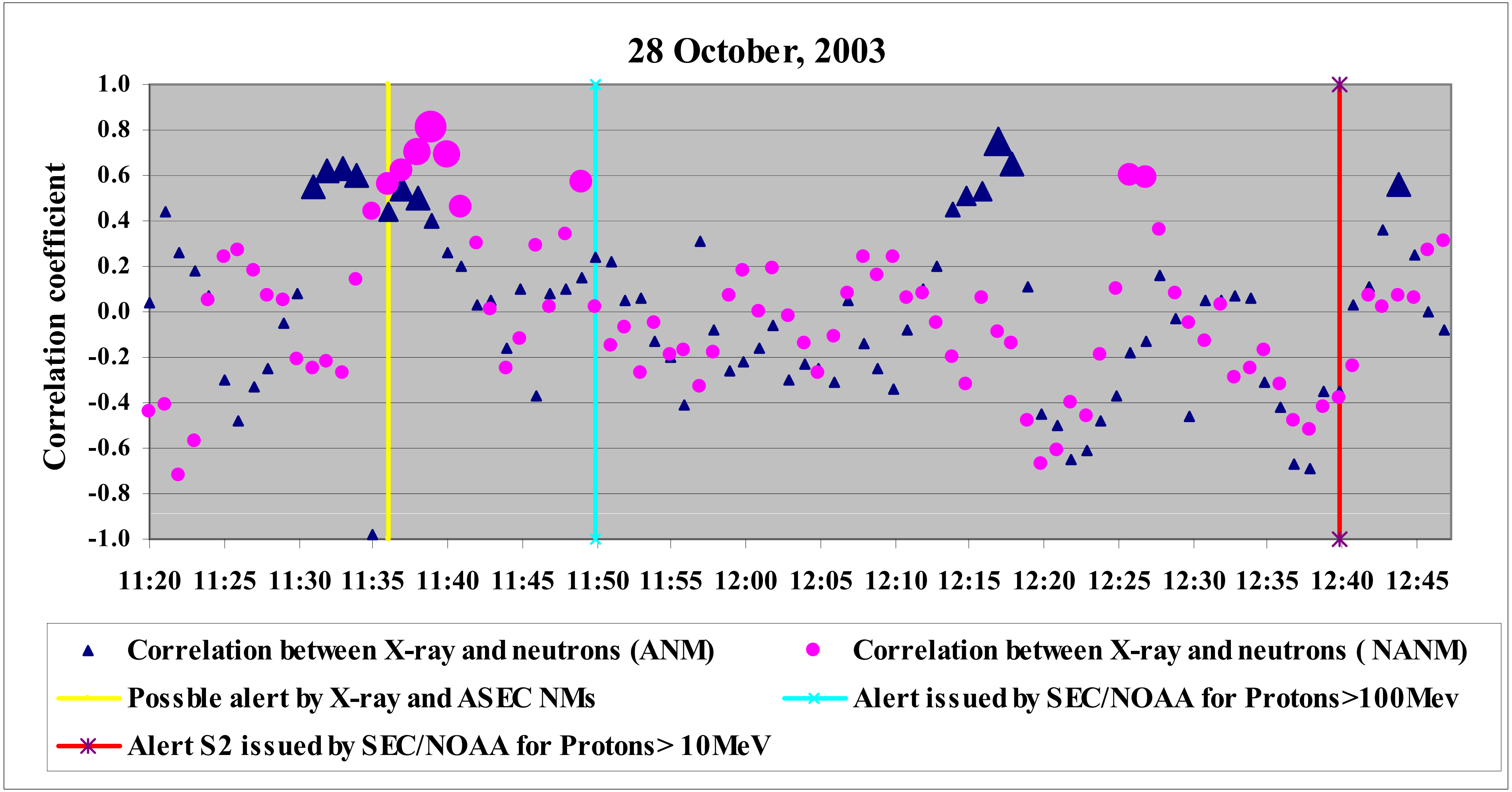
Additional possibilities of measuring multiple secondary fluxes

- Enlarge statistical accuracy of detection different solar modulation effects;
- Probing different populations of primary CR, from 1 GeV up to 50 GV;
- Reconstructing SCR spectra and spectral “knees”;
- Classification of primary particles: “neutron” or “proton” SEP events;
- Correlation matrices between different fluxes;
- Statistical analysis of the Fd and GMS events: understanding physics of IMCE interactions with magnetosphere;
- Space Weather forecasting, to be tested by extensive data base of ASEC monitors operation during 23 cycle.

Radiation from 28 October 2003 X14.4 flare (flux maximum at 11:10). SEC/NOAA alerts on 100 MeV protons at 11:50 and S2 alert for 10 MeV protons at12:40. Enhancement of the ANM and NANM) reaches ~1.7% at ~11:35.



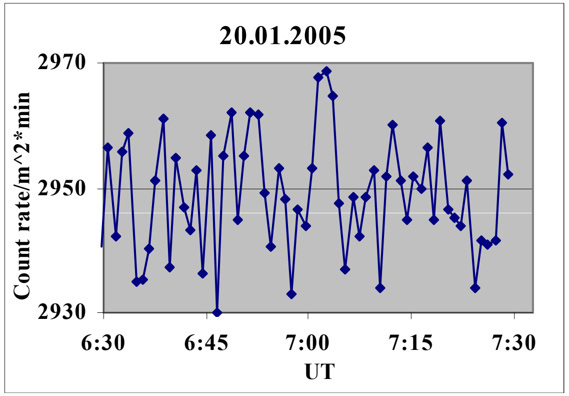
Pattern of correlations between neutron flux and X-ray flux. Correlations are calculated with 1-minute count rates, by memorizing the X-ray 10 minute peak and moving 10 minute intervals of surface particle detector count rates.

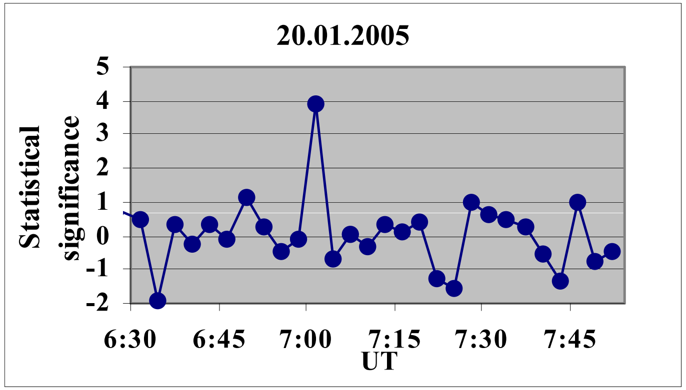


GLE of 23rd cycle detected by the ASEC particle monitors

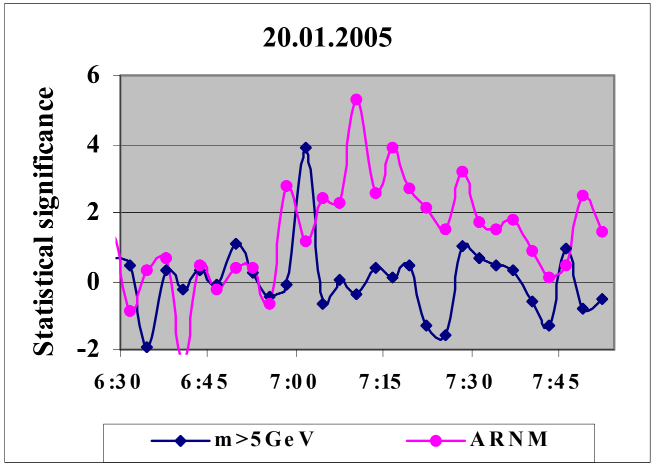
GLE number and date	X-Ray Flare	ASEC Monitor	GLE onset	time	σ	time	σ	Time of S2 Alert by SEC/NOAA
GLE 60	X14.4	ANM	13:55	14:00	3.8	14:30	5.3	14:25
4/15/2001		NANM	13:55	14:00	3.5	14:30	4.1	
GLE 65	X17	ANM	11:25	11:45	4.6	12:10	4	12:40
10/28/2003		NANM	11:30	11:35	3.5	12:05	3.6	
GLE 69	X7	ANM	6:55	7:10	5.6			7:01
1/20/2005		NANM	6:55	7:00	4.5			

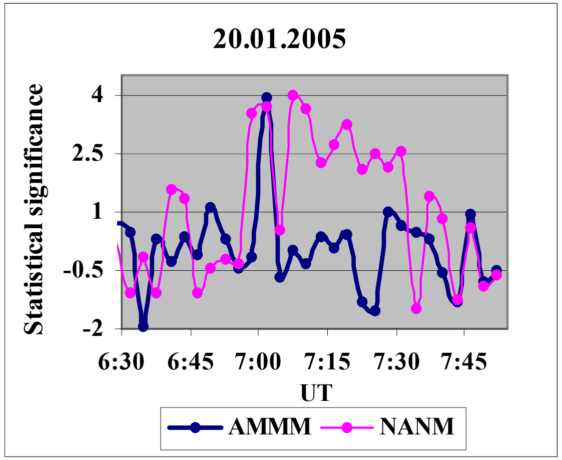
AMMM Detection of GLE 20 January 2005

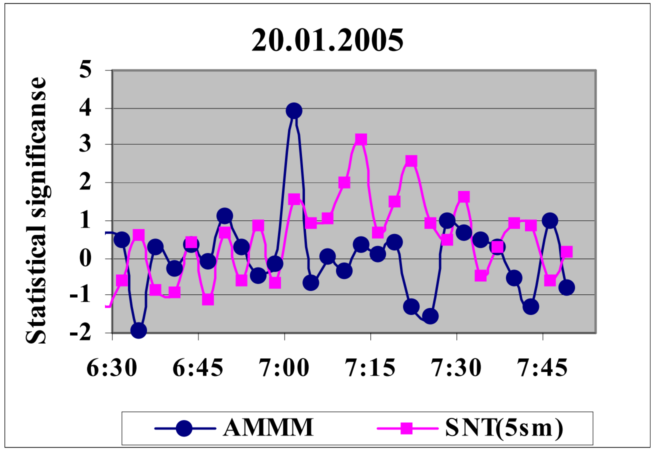


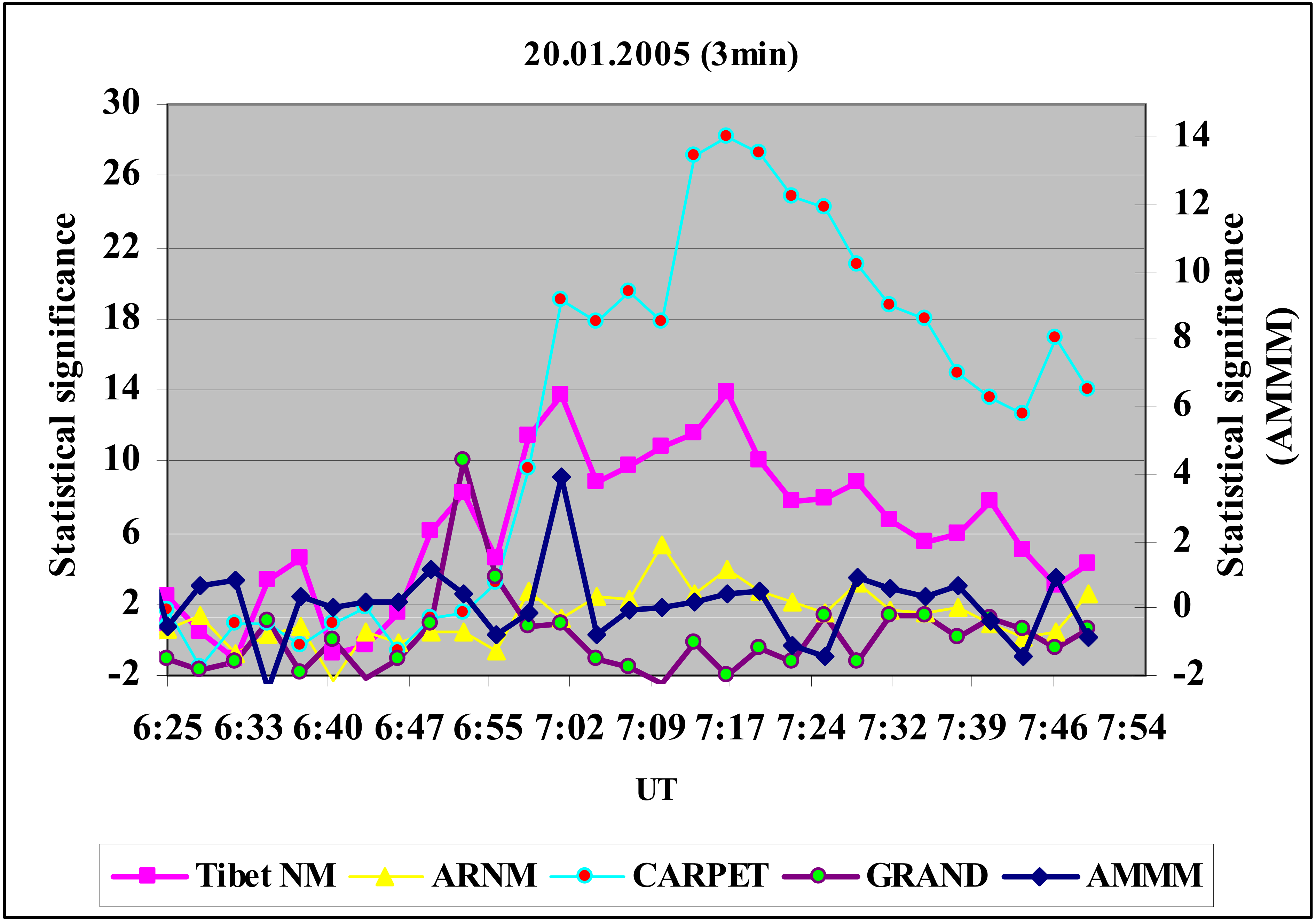


The additional signal at 7:02-7:04 UT equals 2354 (0.644%) If we adopt the Poisson SD~ 0.164%, significance = 3.93σ

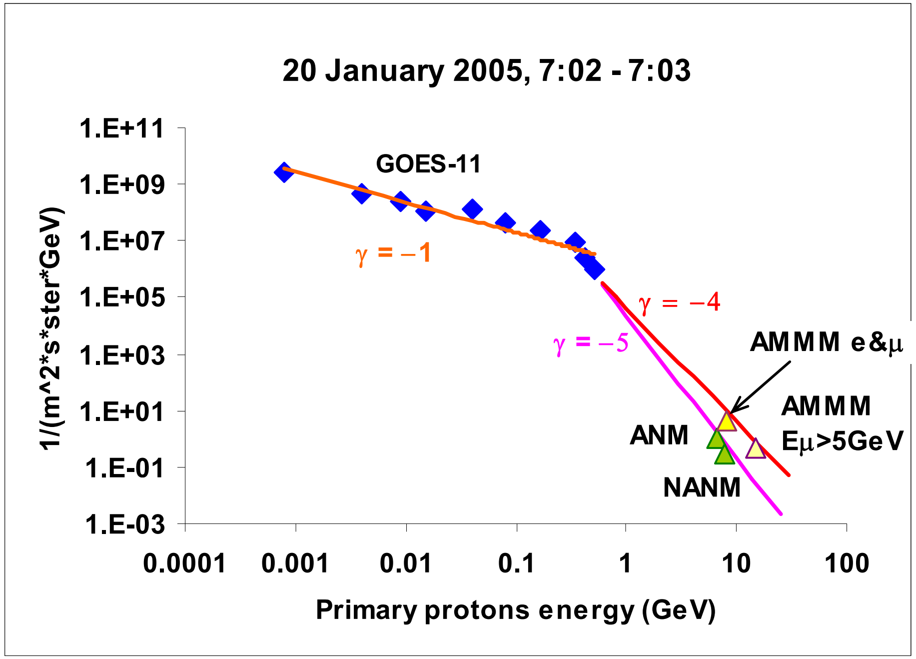


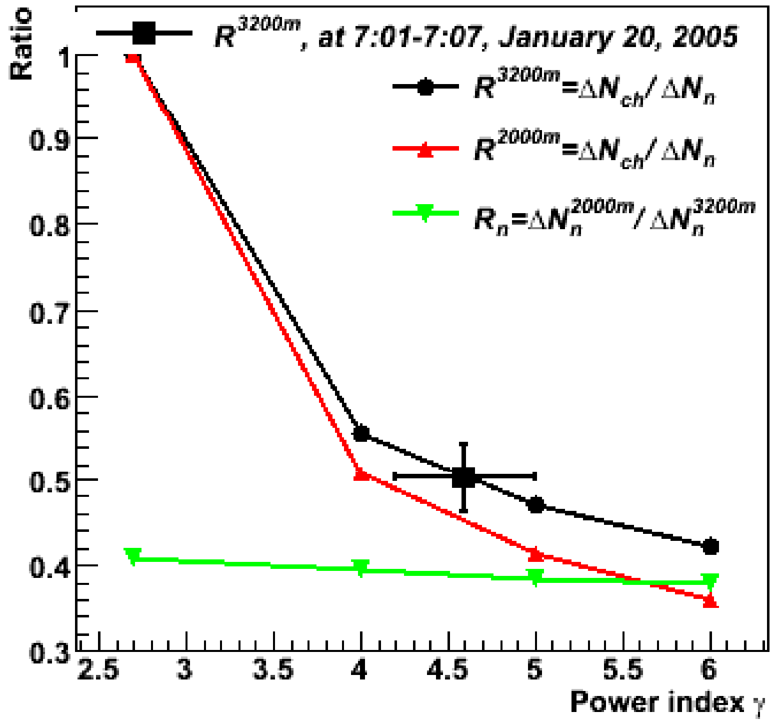





20.01.2005 (3min)
Statistical significance
Statistical significance (AMMM)
30
26
22
18
14
10
6
2
-2
14
12
10
8
6
4
2
0
-2
6:25
6:33
6:40
6:47
6:55
7:02
7:09
7:17
7:24
7:32
7:39
7:46
7:54
UT
Tibet NM
ARNM
CARPET
GRAND
AMMM

Energy Spectrum of the GLE from 20 January 2005

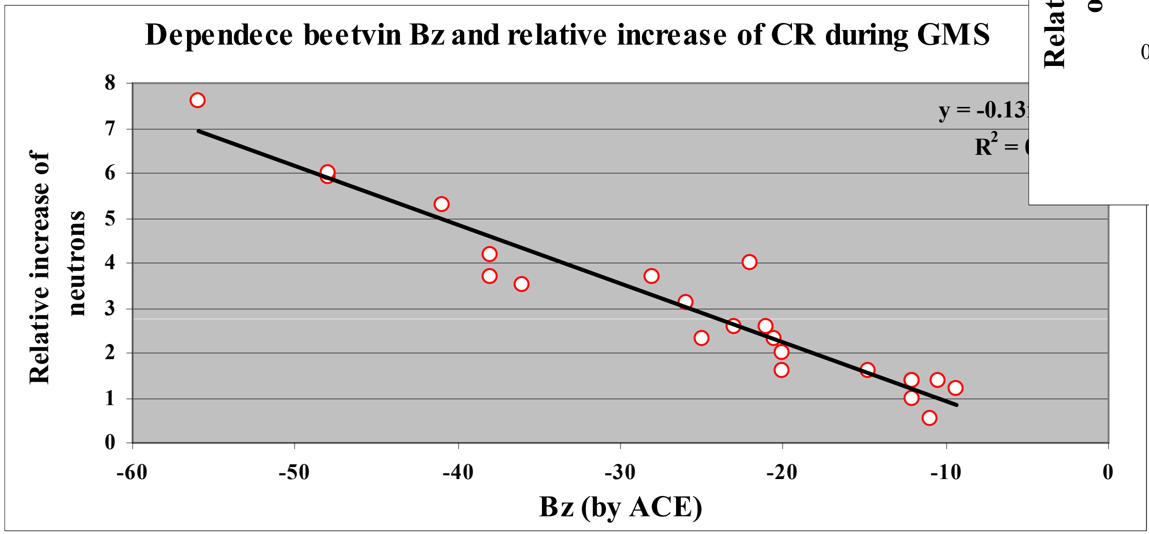


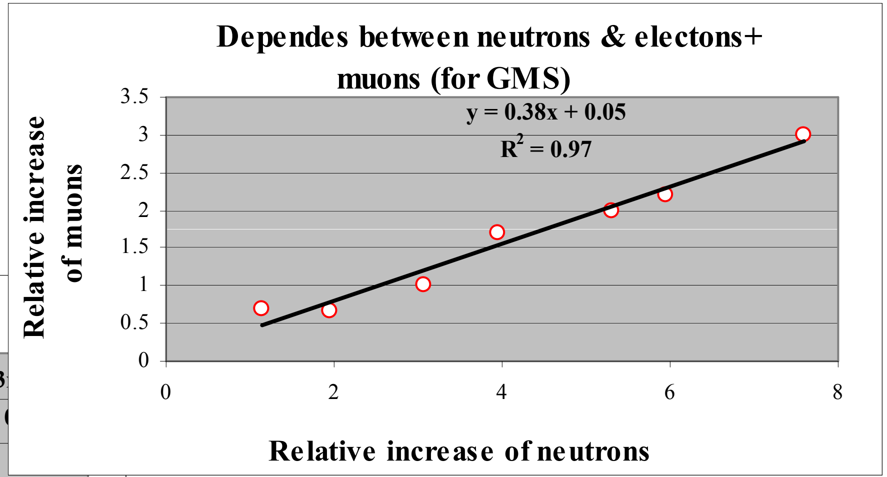


N.Kh. Bostanjyan , A.A. Chilingarian, V.S. Eganov, G.G. Karapetyan, **On the production of highest energy solar protons on 20 January 2005,** Advances in Space Research 39 (2007) 1456–1459

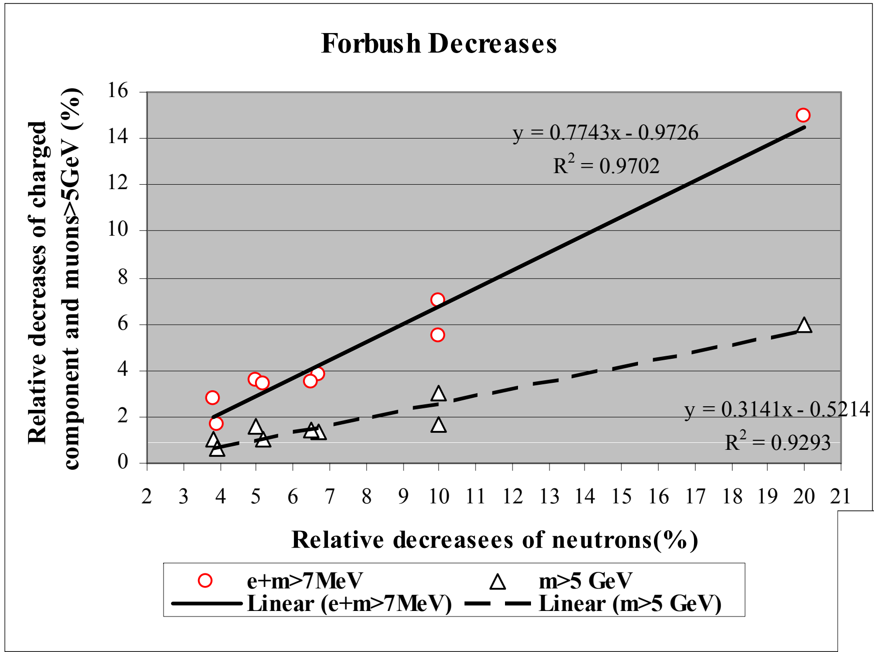
A.A.Chilingarian, A.E.Reimers, **Particle detectors in Solar Physics and Space Weather research**, Astroparticle Physics 27 (2007) 465–472

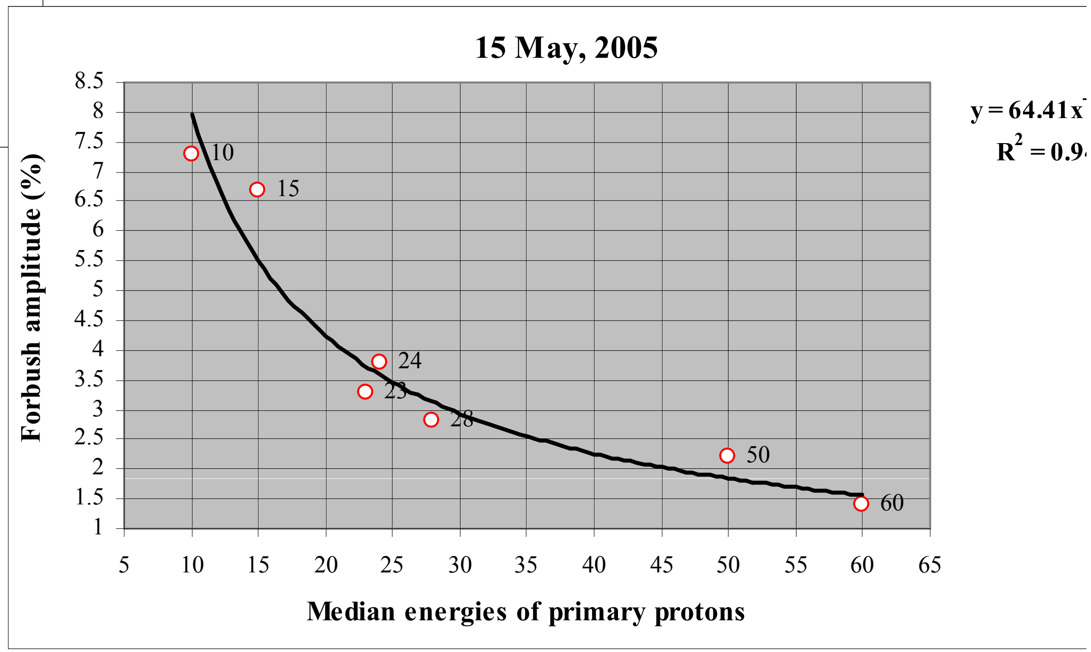
Relation between relative increase of charged and neutral components and B_z.





Relative decreases of the charged CR compared with neutron decreases

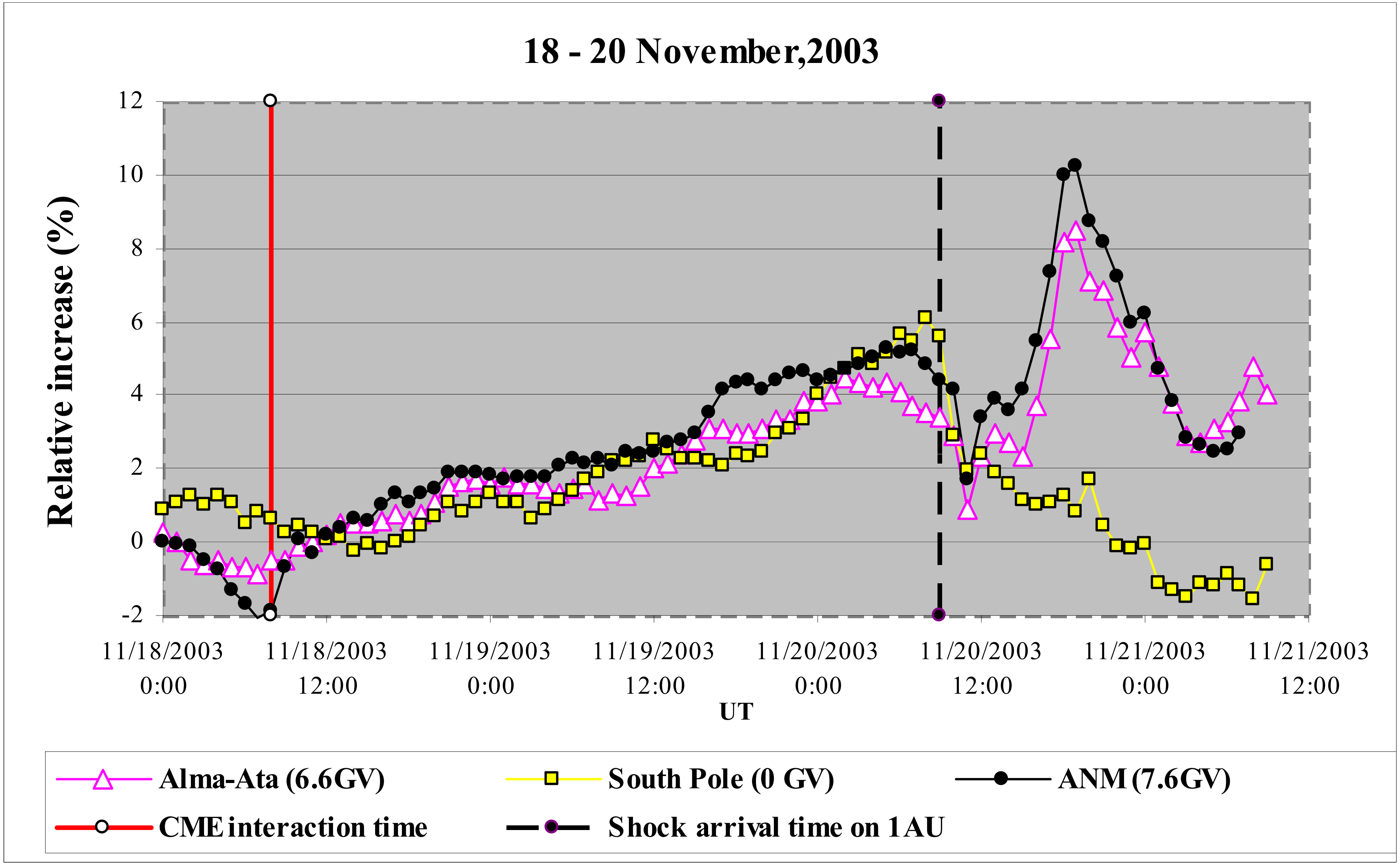




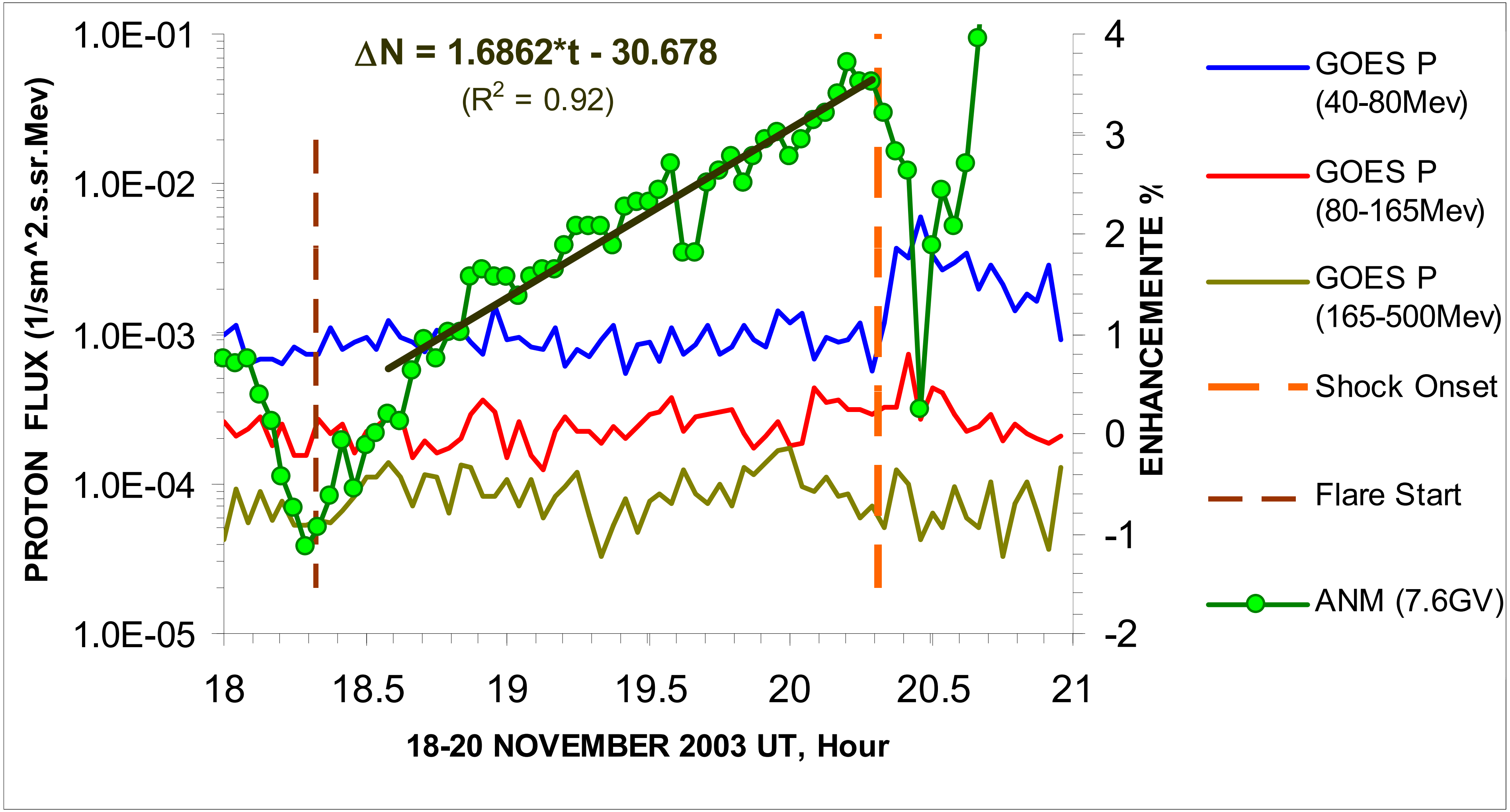
Parameters of the fast CMEs unleashed at 18 November 2003 from ASR 501 and 508

Date	Time UT	Heliocoorditas	Angular depth (^{0})	CME velocity км/sec	Kinetic Energy erg
18-10-2003	11:30	S16E08	360	2459	$1.3 \cdot 10^{33}$
18-11-2003	**8:06**	**N01E19**	**>104**	**1223**	$\mathbf{1.3 \cdot 10^{32}}$
18-11-2003	**8:50**	**N02E18**	**360**	**1660**	$\mathbf{3.3 \cdot 10^{32}}$
18-11-2003	9:50	S13E89	>197	1824	$3.6 \cdot 10^{32}$

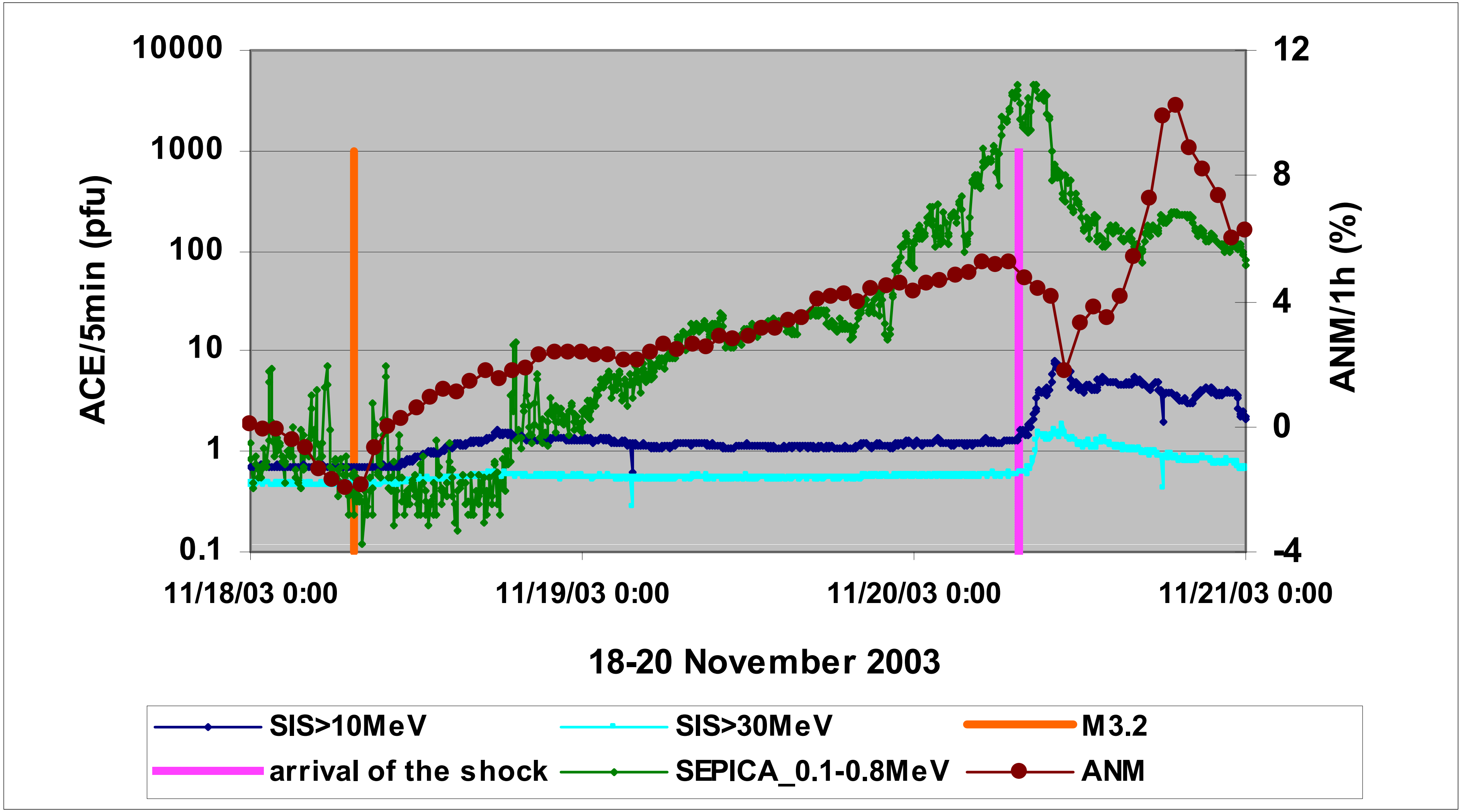
Time history of count rate enhancements of high and middle latitude Neutron Monitors.



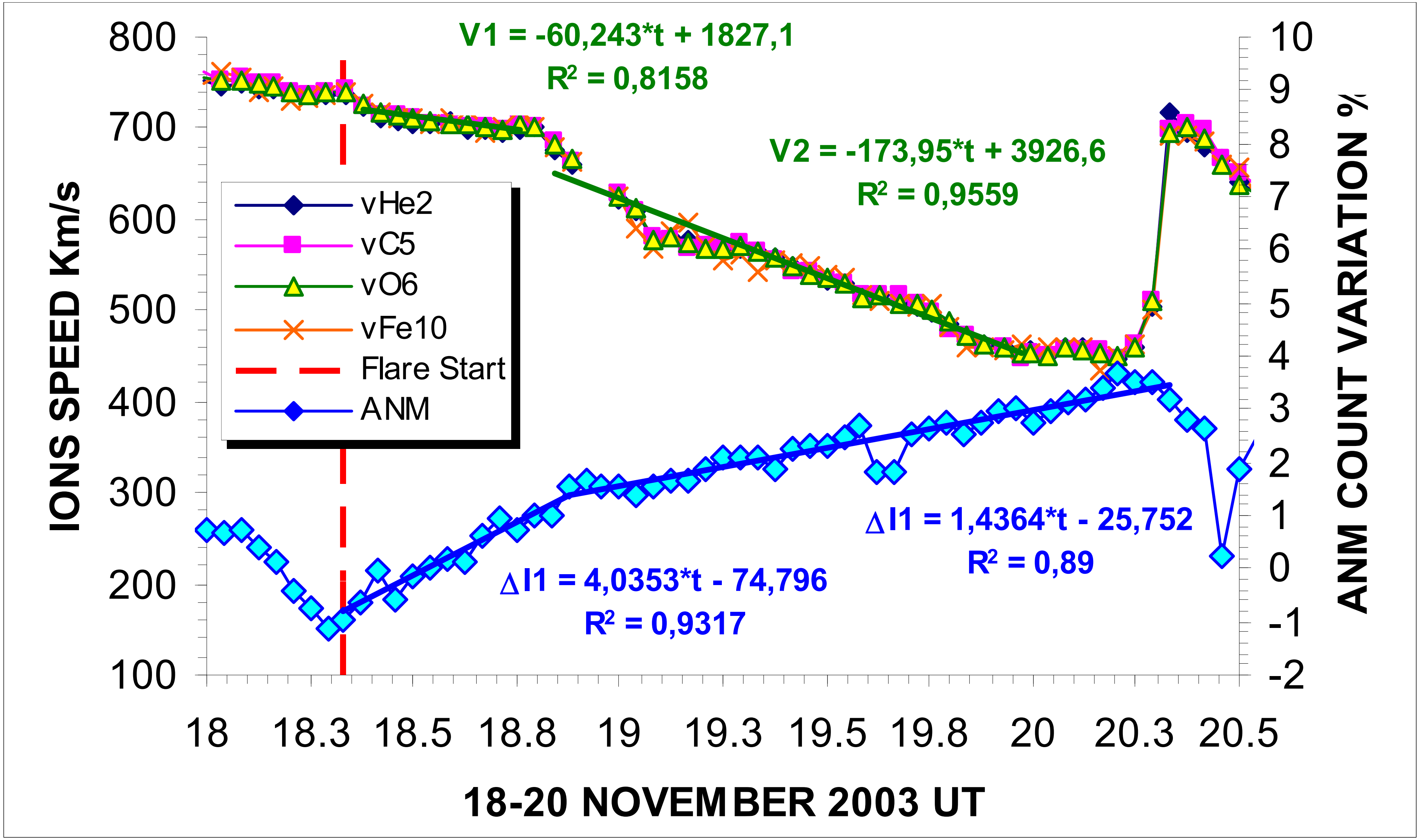
Time history of count rate enhancements ANM and GOES MeV proton detector channels.



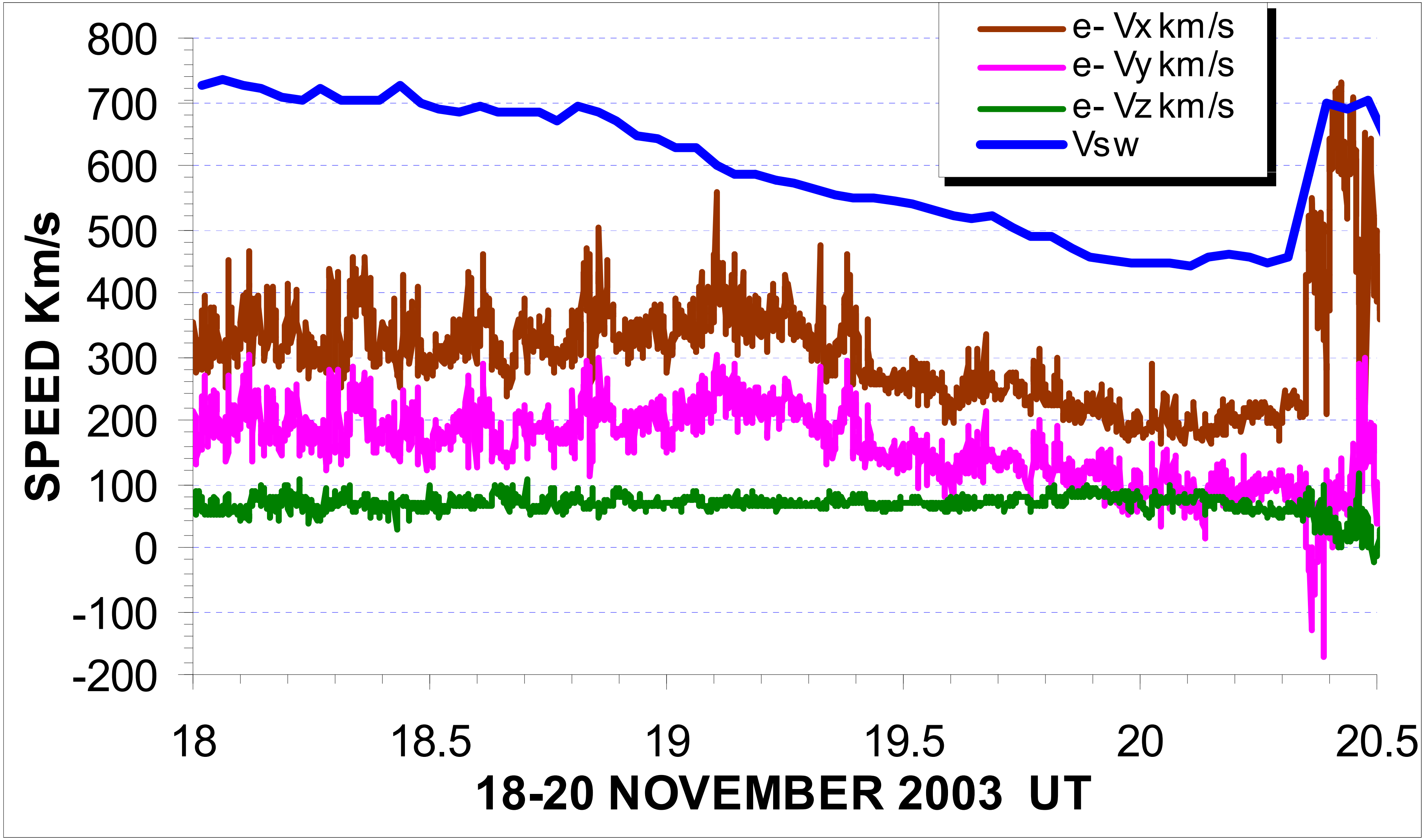
ICME modulation effects in KeV; MeV; and GeV particle fluxes



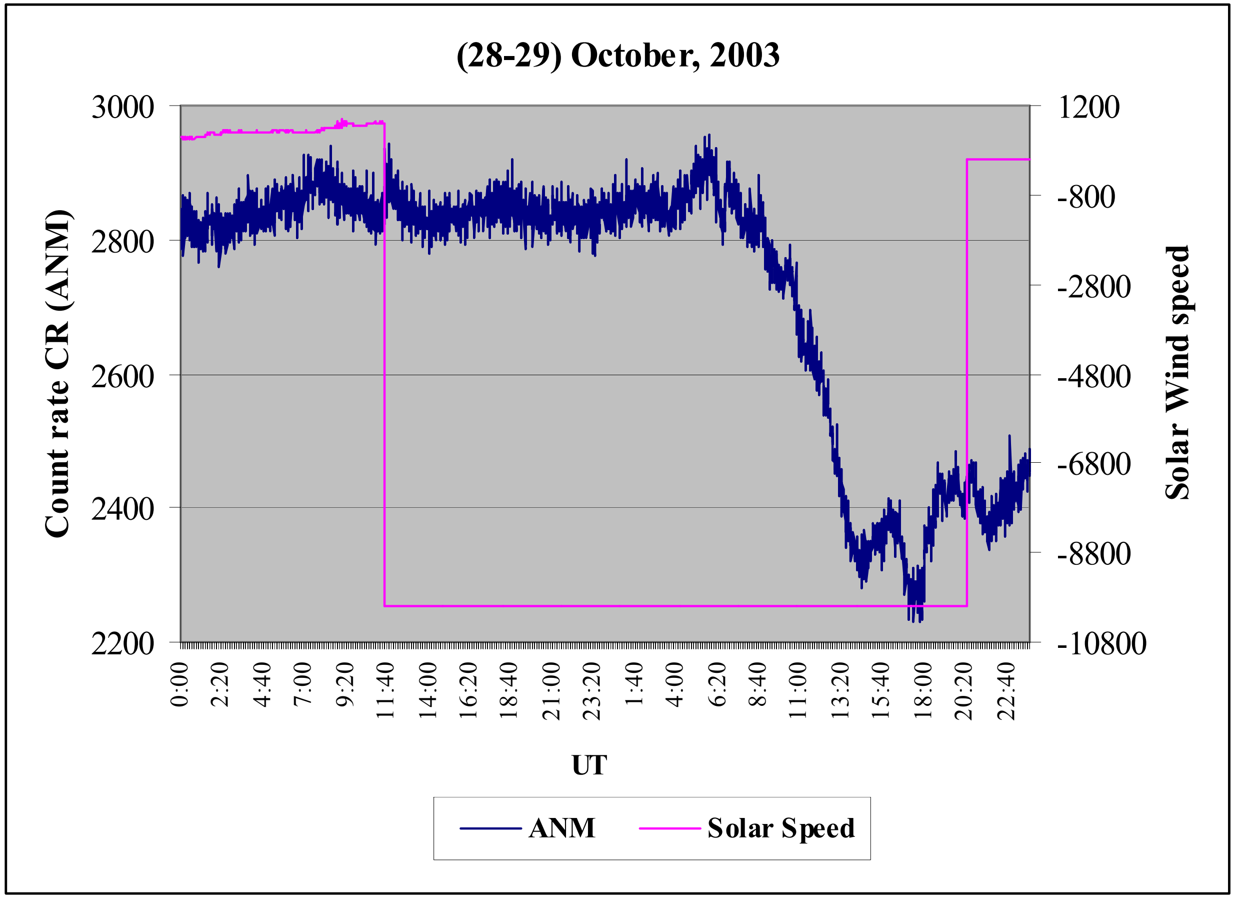
ICME modulation effects on the Solar Wind speed and GeV particles flux



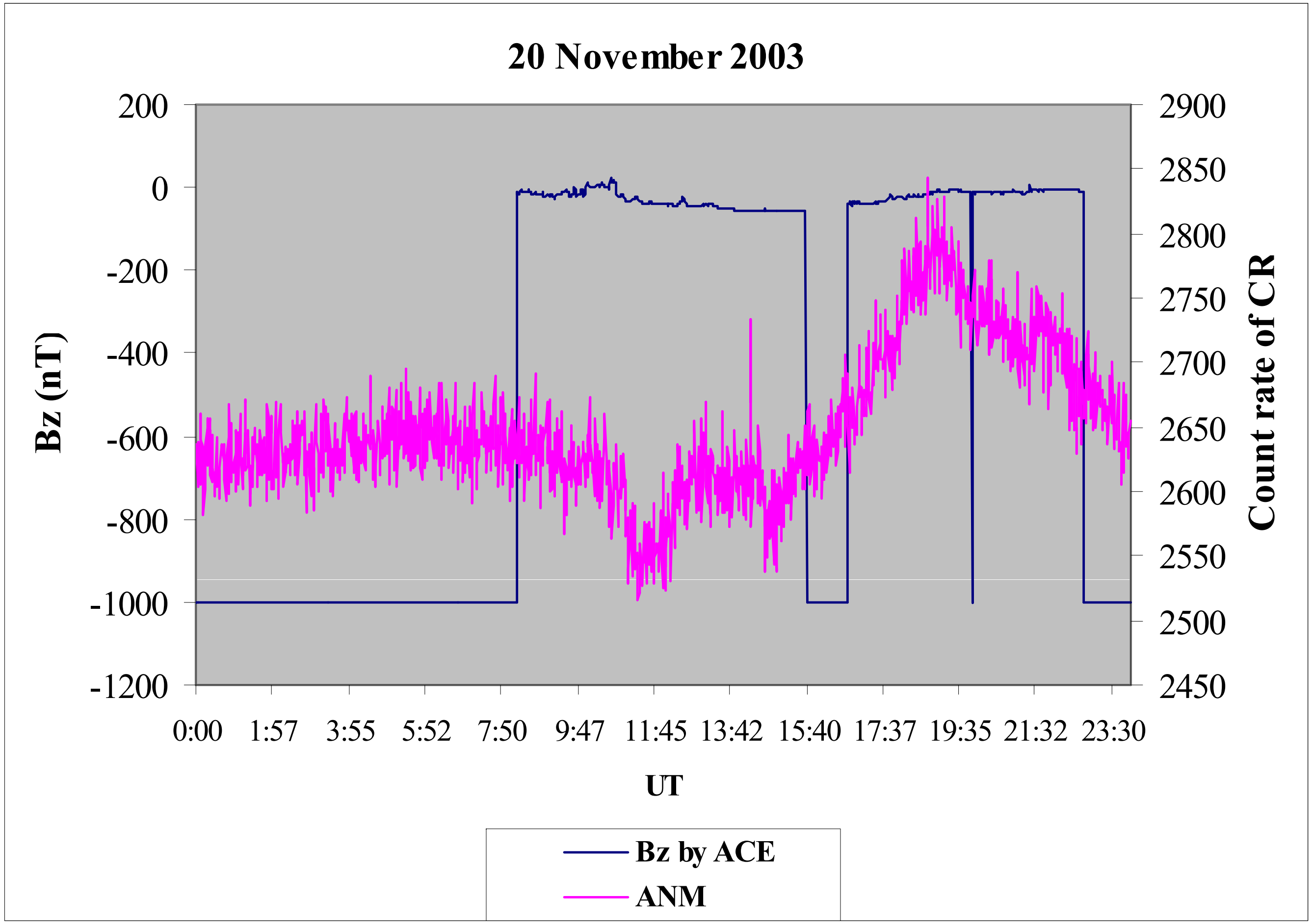
ICME modulation effect on Solar Wind and electron velocities



Failure of the ACESWEPAM solar wind detector on board of the ACE space station during extreme solar event of 28 October 2003. In contrast the ASEC monitors is registering the ground level enhancement at 28 October and largest detected Intensity decrease (~20%) at 29 October.

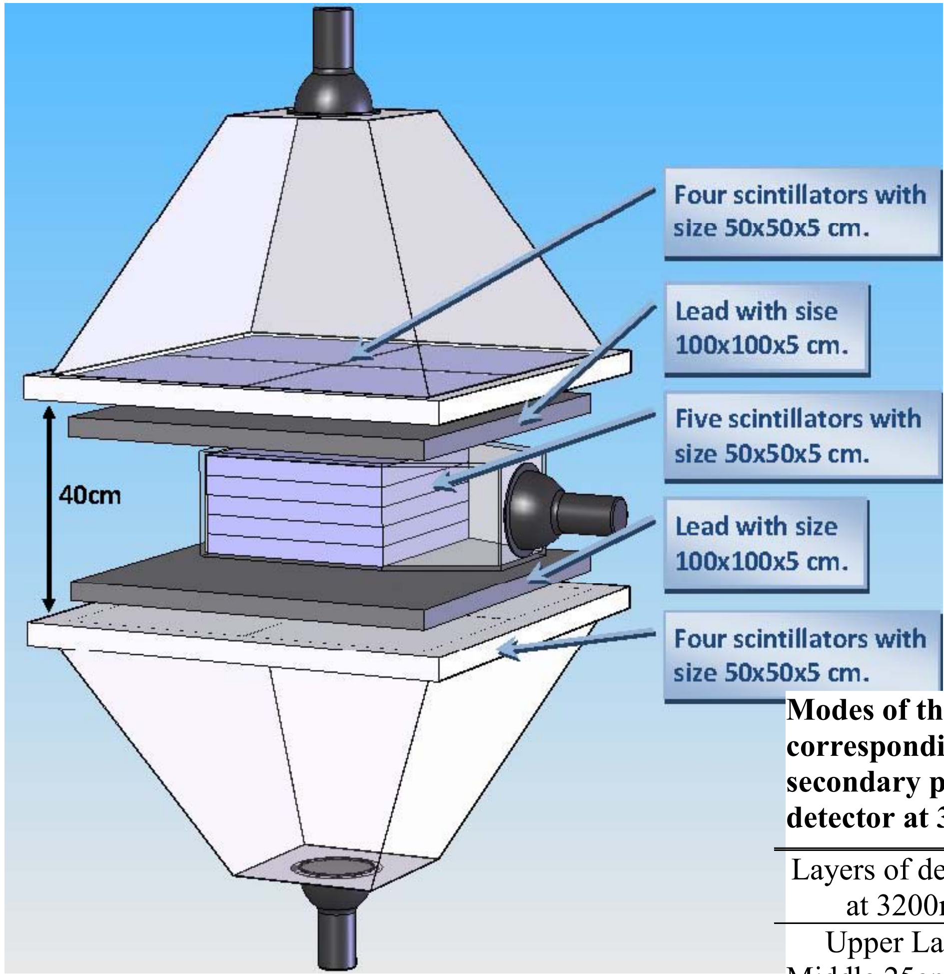


Failure of the Magnetometer on board of the ACE space station during extreme geomagnetic storm of 20 November 2003 (The measurement of the B_z component of the interplanetary magnetic field is disabled as well as of other parameters of the ICME) . In contrast the Aragats Neutron monitor is registering the huge increase of count rate due to effective decreasing of the geomagnetic cutoff energy at Aragats latitude.



Hybrid Particle Detectors for the Space Environmental Viewing and Analysis Network (SEVAN)

111 ; 101– traversal of high energy muon;
010 – traversal of the neutral particle;
100 – traversal of low energy charged particle.
110 – traversal of higher energy charged particle stopped in the second lead absorber.
001 – registration of the inclined charged particles.



Modes of the GCR Energy spectra corresponding to the different species of secondary particles registered by SEVAN detector at 3200m above sea level.

Layers of detector at 3200m	Mode of the parent "GCR" Energy spectrum [GeV]
Upper Layer	11.5
Middle 25cm layer	8.5
Down Layer	14.5

Information, detector charts, agreements in:
http://crdlx5.yerphi.am/index.php?Page=/IHY-CRD/SEVAN/&Title=SEVAN

Post stamp on CRD Participation in IHY 2007

Forecasting of Radiation and Geomagnetic Storms by networks of particle detectors (FORGES-2008)

September 29-October 3, 2008 • Nor Amberd, Armenia

OVERVIEW

The focus of the International Astroparticle Physics Symposium: Forecasting of Radiation and Geomagnetic Storms by Networks of Particle Detectors (FORGES-2008) will be to examine the state and the future possibilities of networks of particle detectors distributed at different latitudes, longitudes and altitudes measuring changing fluxes of neutral and charged particles to forewarn on coming severe radiation and geomagnetic storms.

SPONSORS

- Yerevan Physics Institute (YerPhI)
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- Support Committee for Armenia's Cosmic Ray Division (SCACRD)
- Committee on Space Research (COSPAR)

PROGRAM OUTLINE

1. Physics of Interplanetary Coronal Mass Ejections (ICME), their propagation in the interplanetary space and interaction with cosmic rays and magnetosphere; modulation effects posed on the galactic cosmic rays; classification of Geomagnetic Storms (GMSs).
2. Characteristics of ground-based networks of particle detectors; experimental methods of measuring count rates and energies of secondary cosmic rays; efficiency of detecting various species of secondary cosmic rays. Networks monitoring main geophysical parameters.
3. Mathematical methods of the prediction; feature selection; Bayesian and Neural Network models of interpolation and extrapolation; multivariate regression methods.
4. Training of SEVAN (Space Environmental Viewing and Analysis Network) host groups.

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