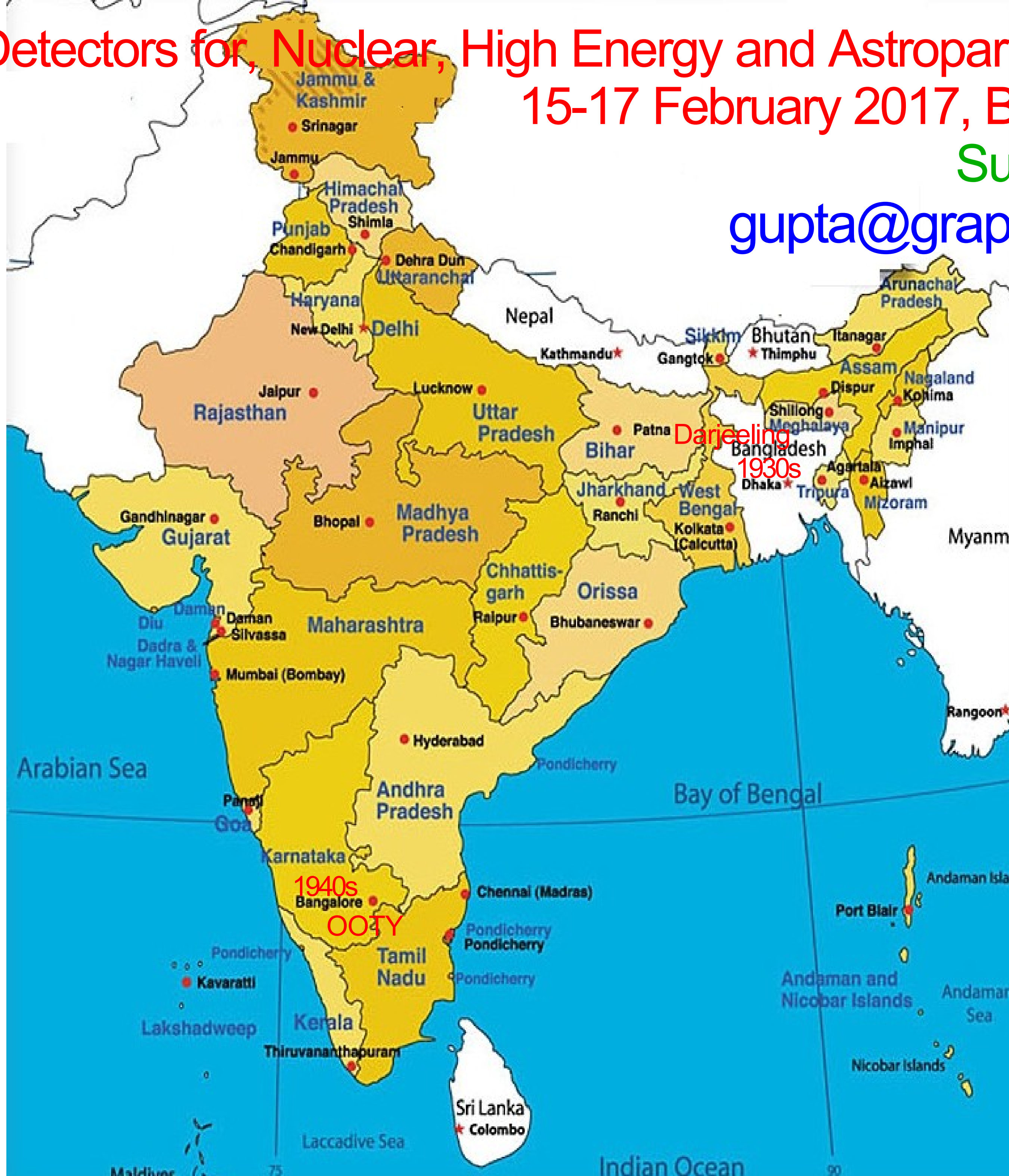
Advanced Detectors for, Nuclear, High Energy and Astroparticle Physics

15-17 February 2017, Bose Institute

Sunil K. Gupta

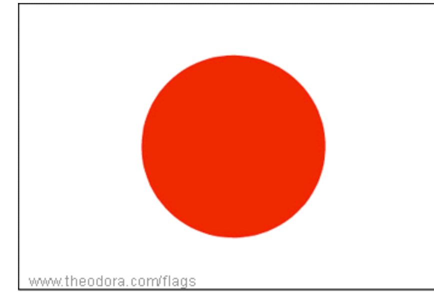
gupta@grapes.tifr.res.in



GRAPES-3 Observatory: A sensitive probe in high-energy Astroparticle physics.

(Gamma Ray Astronomy at Pev EnergieS Phase-3)

ADNHEAP, Bose Inst. 16 February 2017



1. Tata Institute of Fundamental Research, Mumbai, India
2. Osaka City University, Osaka, Japan
3. Aichi Institute of Technology, Aichi, Japan
4. J.C. Bose Institute, Kolkata, India
5. Indian Institute of Science & Edu. Res. Pune, India
6. Chubu University, Kasugai, Aichi, Japan
7. Hiroshima City University, Hiroshima, Japan
8. Aligarh Muslim University, Aligarh, India
9. Indian Institute of Technology, Kanpur, India
10. North Bengal University, Siliguri, India
11. Vishwakarma Inst. of Information Tech. Pune, India
12. Kochi University, Kochi, Japan
13. BITS Pilani, Hyderabad, India
14. Utkal University, Bhubaneshwar, India

S.K. Gupta, K.P. Arunbabu, S.R. Dugad, B. Hariharan, I. Mazumdar, P.K. Mohanty, P.K. Nayak, P. Jagadeesan, A. Jain, S.D. Morris, P.S. Rakshe K. Ramesh, B.S. Rao, L.V. Reddy, Y. Hayashi, S. Kawakami, H. Kojima, S.K. Ghosh, S. Raha, P Subramanian, A. Oshima, S. Shibata, K. Tanaka, S. Ahmad, P.K. Jain, A. Bhadra, R.K. Dey, C.S. Garde, T. Nakamura, R. Nigam, D.P. Mahapatra, S. Mahapatra

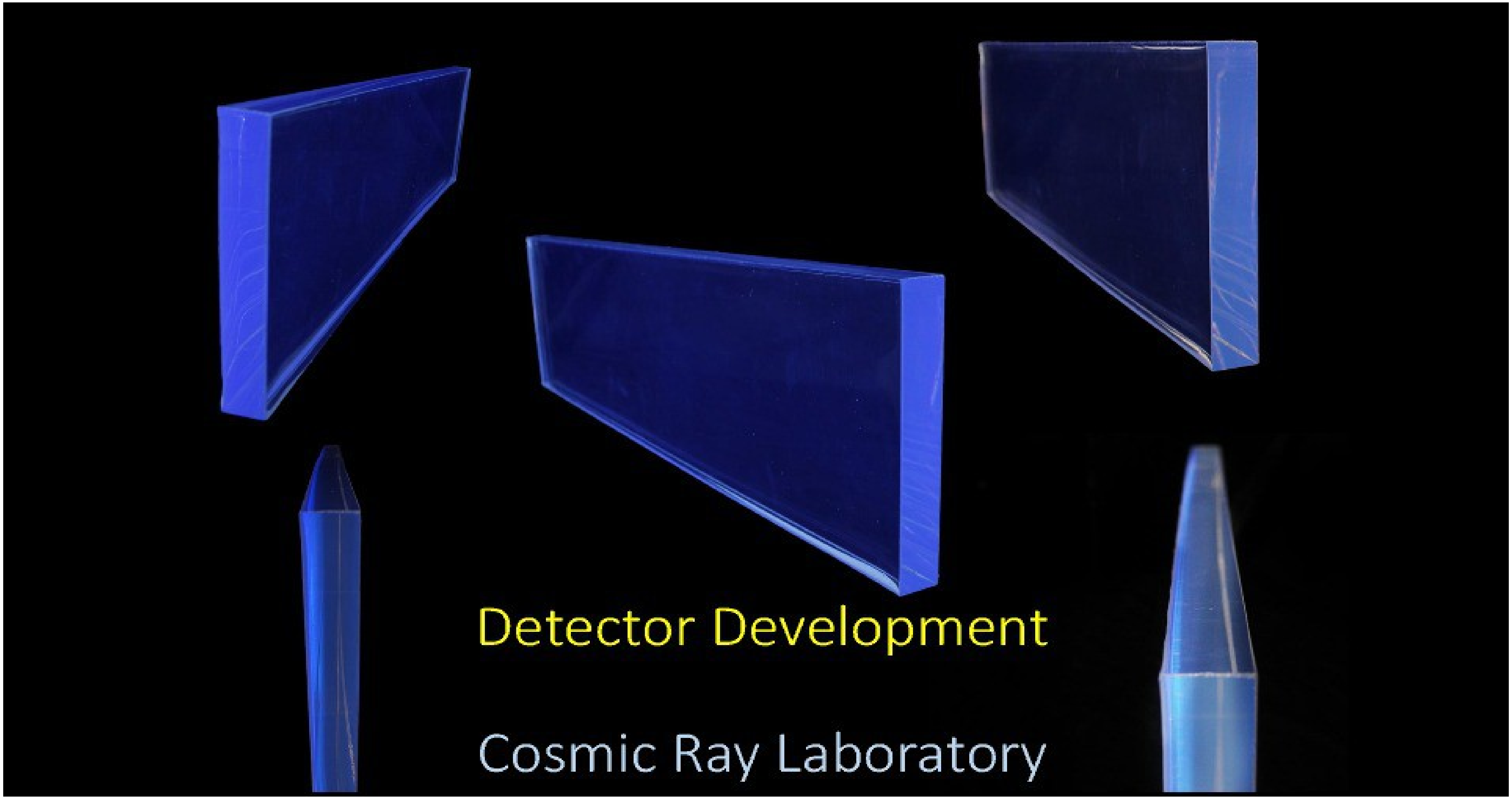
400 Plastic Scintillator detectors (1 m^2 area)

560 m^2 muon telescope (E_μ=1 GeV) (11.4N, 76.7E)

3712 Proportional Counters (6m x 0.1m x 0.1m)

E = 10^{14} eV ~20000 particles over ~1000 m^2

In-house technology development for Fabrication of various detectors



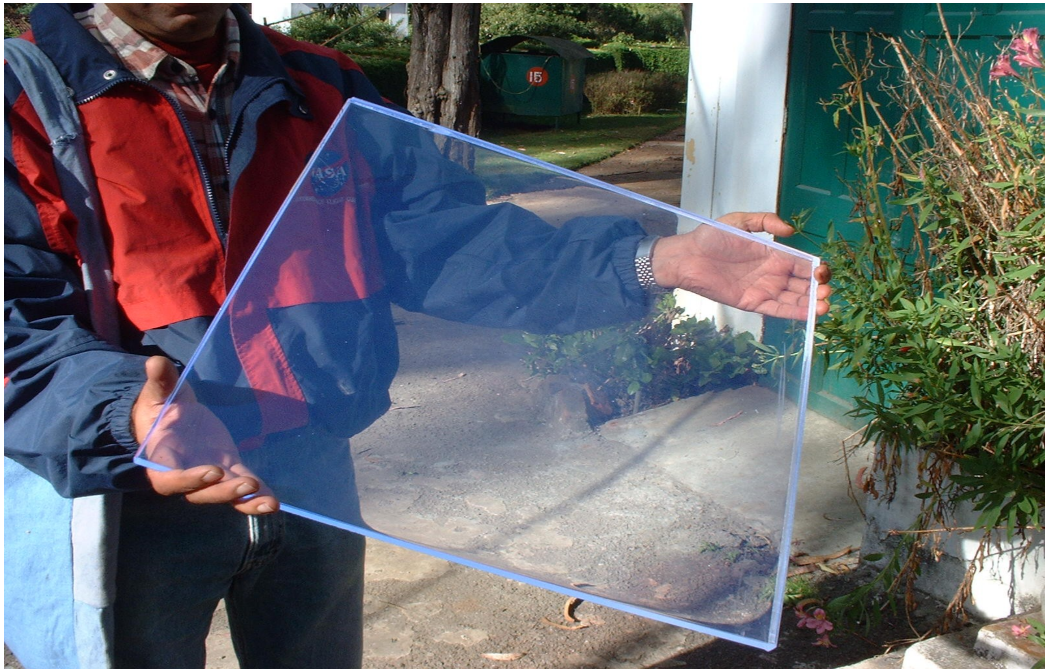
Plastic Scintillator development:

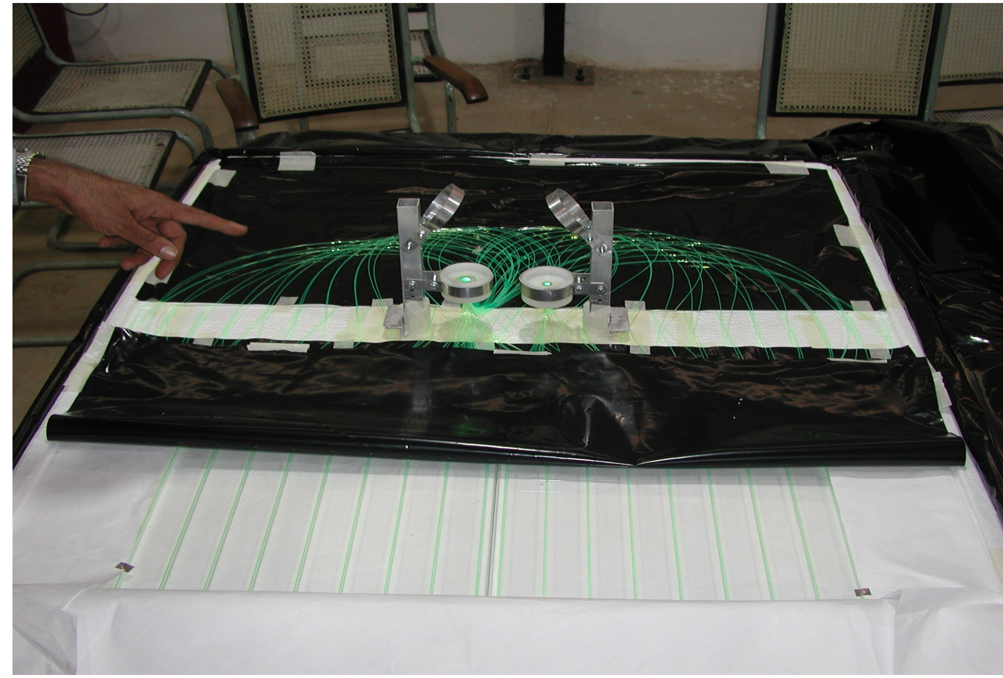
Decay Time= 1.6 ns Light Output = 85% Bicron (54% anthracene)

Timing 25% faster Atten. Length $\lambda = 100$cm Cost ~fraction of Bicron

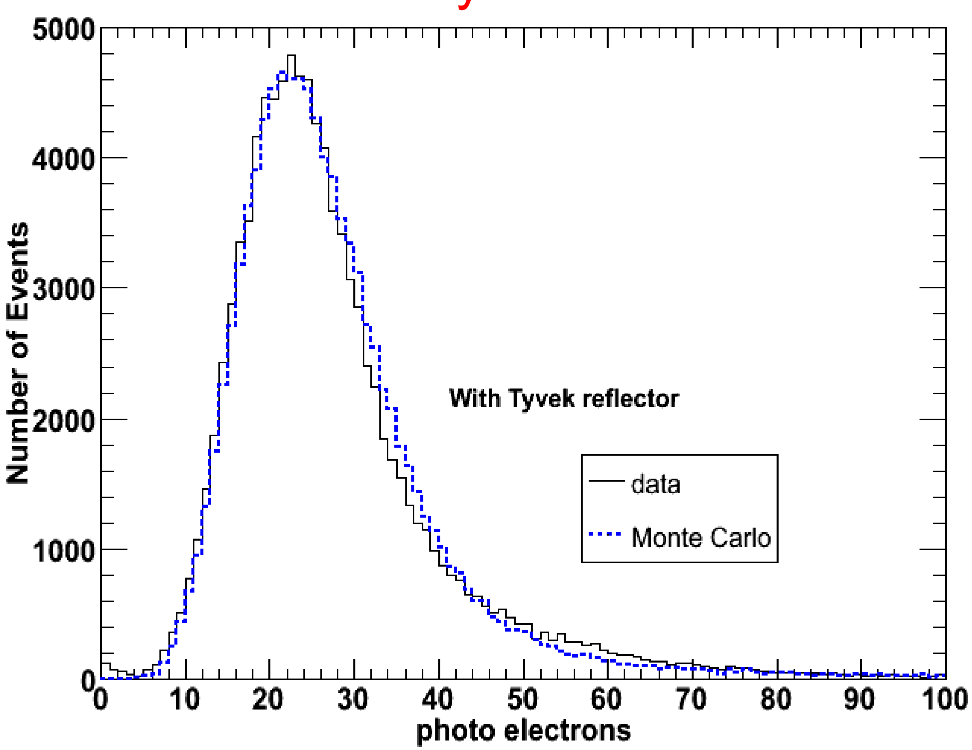
Max Size 100cmX100cm Total > 2000

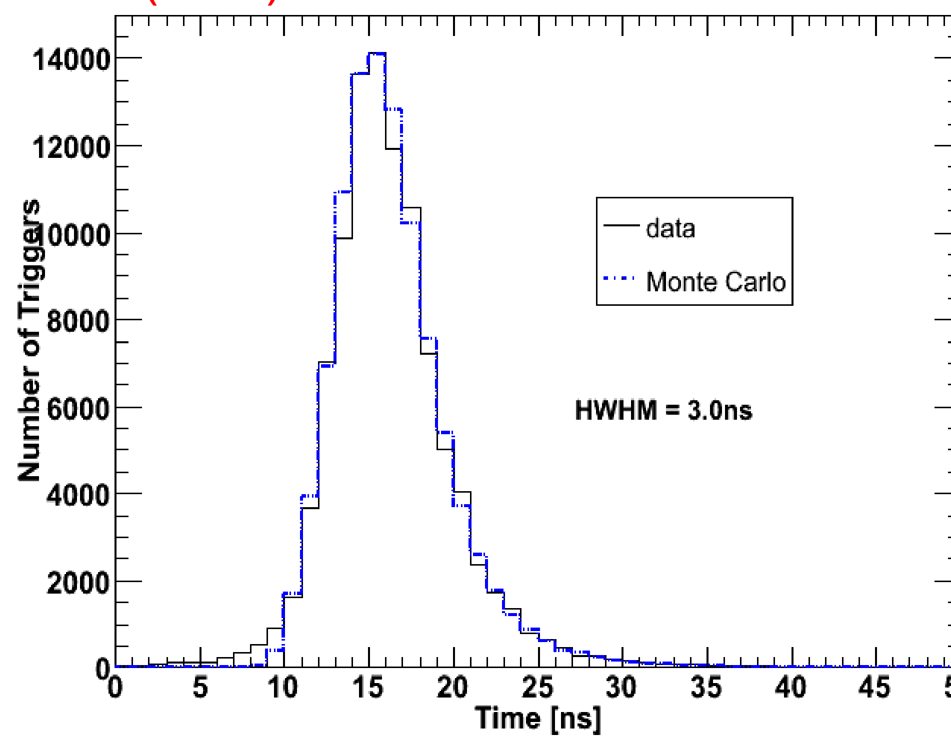
CERN, Osaka, IUAC Delhi, Bose, VECC, DEI Agra, BARC, ECIL, Utkal, BITS(H), IOP, ...



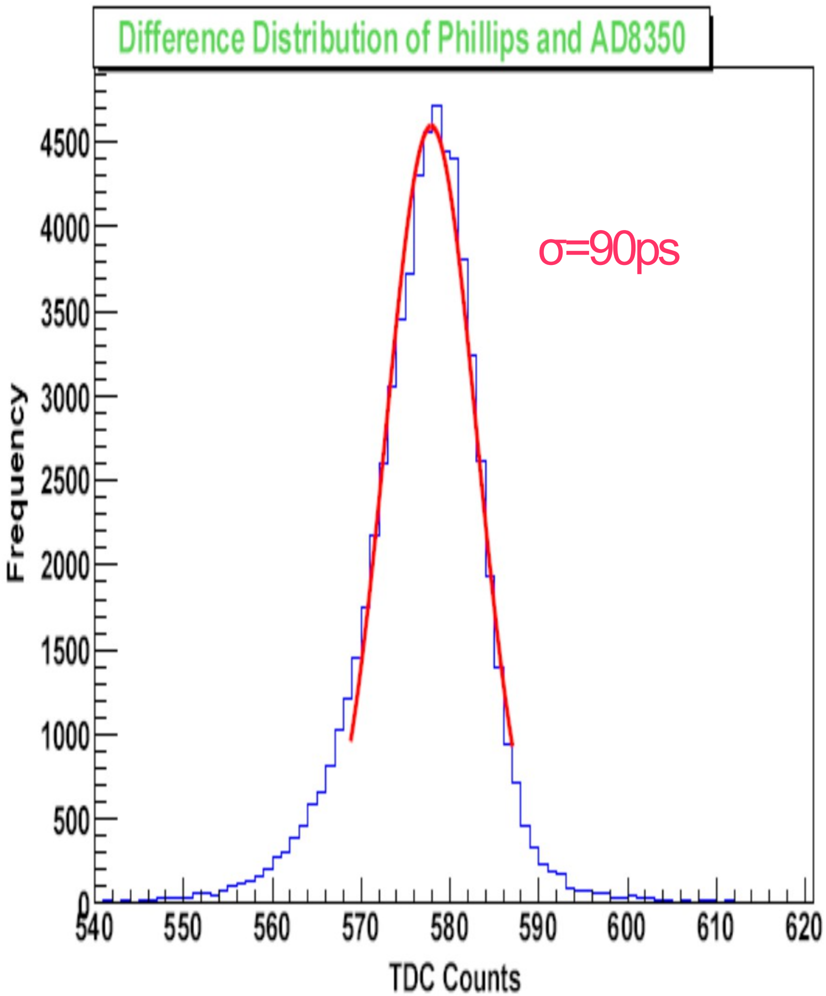


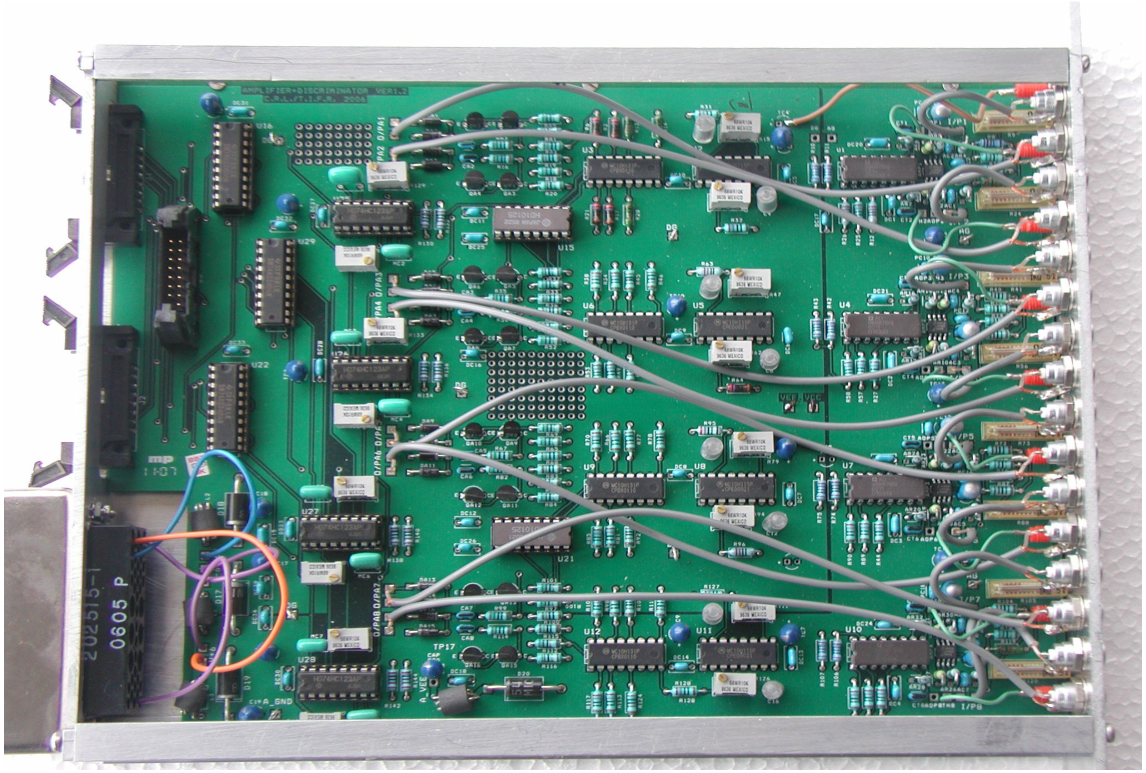
P.K. Mohanty et al. Rev. Sci. Instr. **83** 043301 (2012)





Amplifier-Discriminator response using muons





HPTDC (Stop Watch)

32-channels τ=100 ps Range: 50 μs

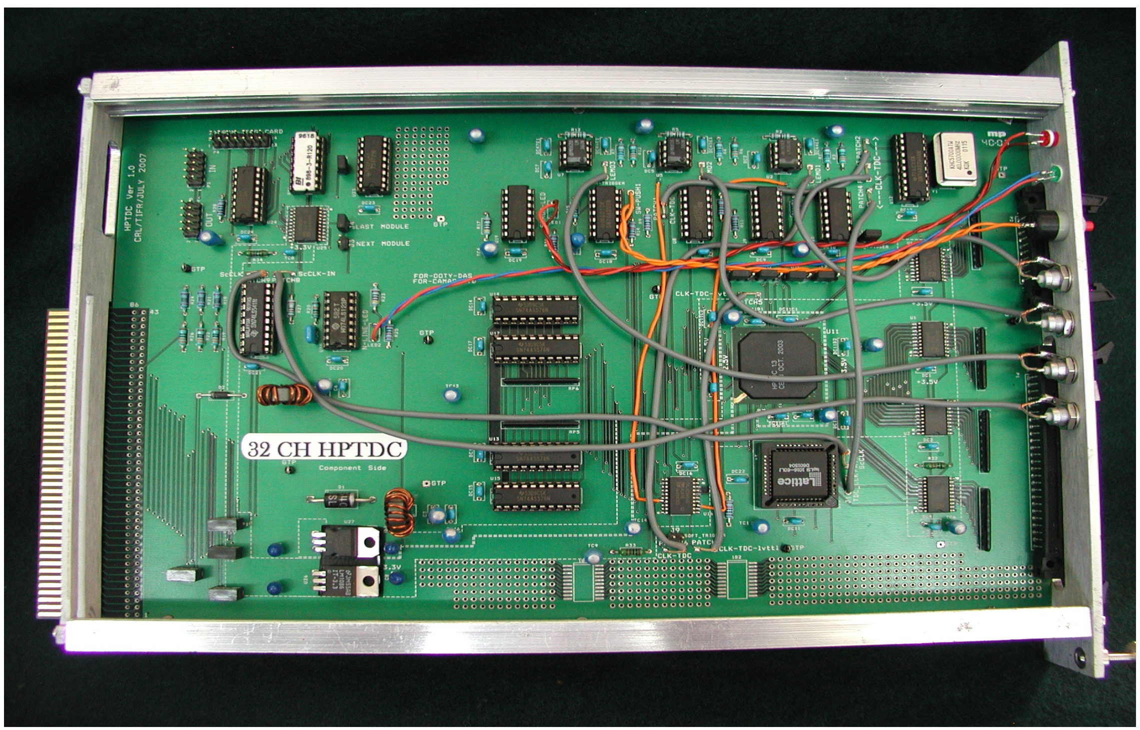
Multi-hit capability

Trigger mode (no delay)

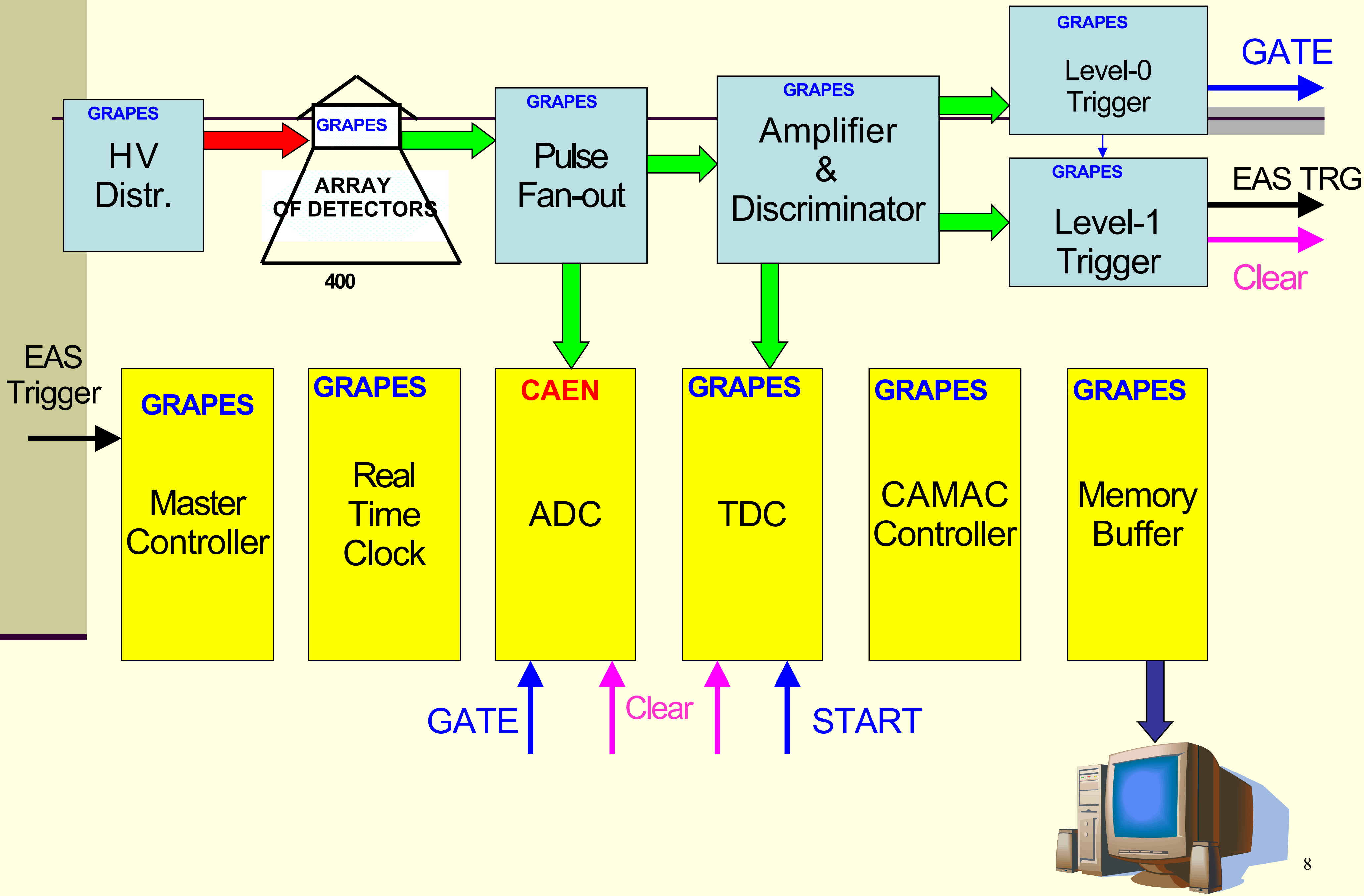
Novel method measuring TDC-Zero

S.K. Gupta et al. Experimental Astronomy

DOI: 10.1007/s10686-012-9320-3(2012)

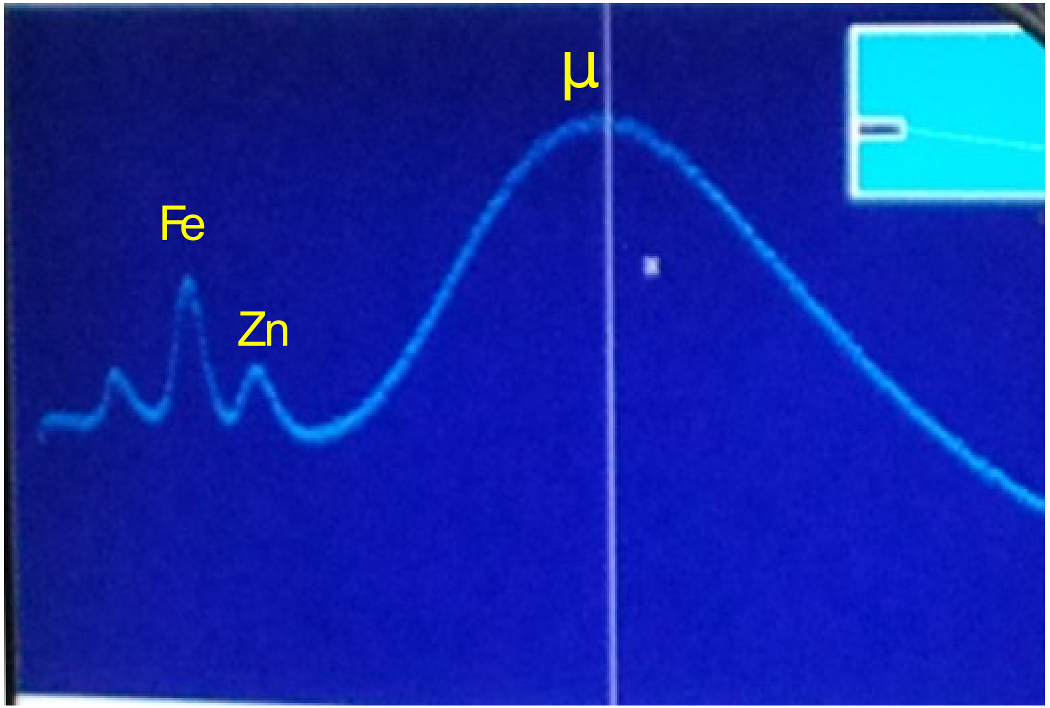


EAS Scintillator DAQ



Proportional Counter (PRC) Fabrication

2270 PRCs fabricated 58% of required 3780 PRCs




19 February 2016


22 November 2016

27 January 2017

GRAPES-3 Cluster

Nodes : 40 (Initial phase)

Total Jobs : 1280

Total Memory : 1280 GB

Storage at nodes: 600 TB

Storage at server : 60 TB

Optical network: 10 Gbps

Forced air cooling, 1.2KW removes 25KW of heat

37th Rocks Cluster Rank

VIIT, Pune and GRAPES-3 joint R&D activity

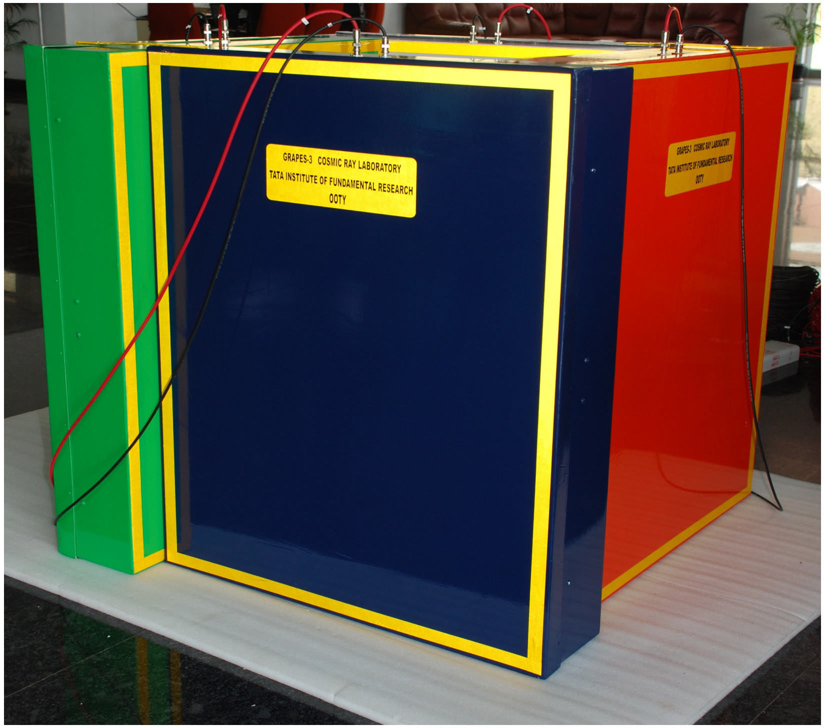
Hardware project examples:
(1) 64 channel FPGA based scalar with Ethernet
(2) 64 channel pulse-width analysis with USB
(3) Monitoring 1000 channels of HV using Ethernet
(4) Programmable power supply (100 V)
(5) Multiple solar panel power regulation & control

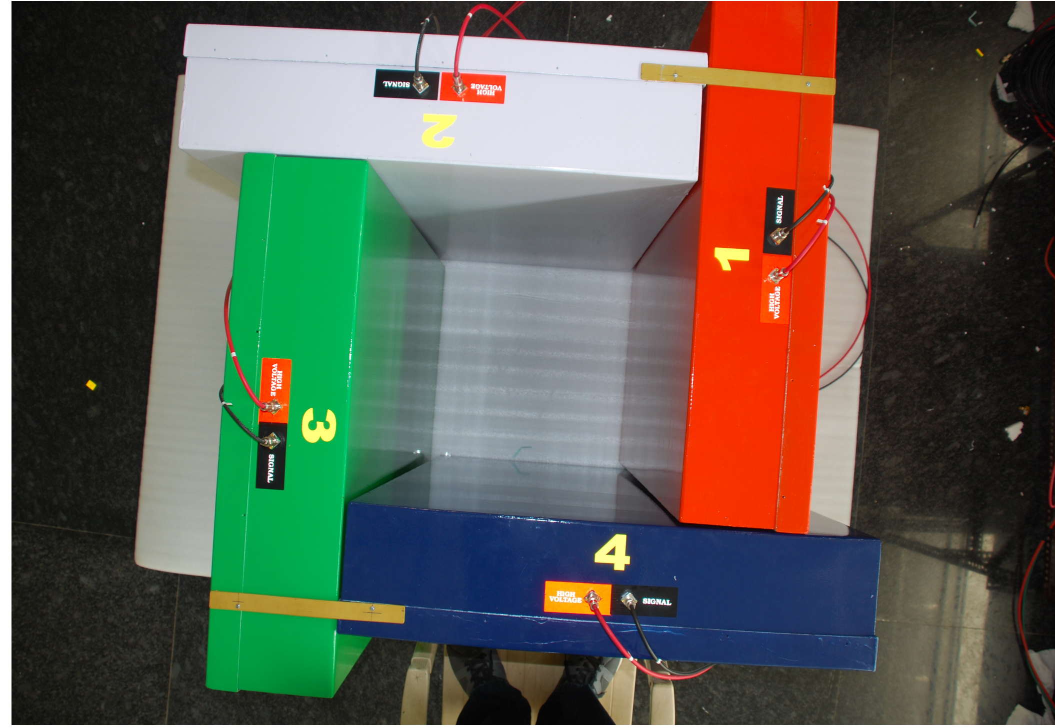
Software project examples:
(6) Web-tools for remote processing of data including dynamic plots
(7) Web-based database management of calibration and other data
(8) Web-based monitoring of experiment
(9) Inventory management of detector components

Participation during 2010-2016:

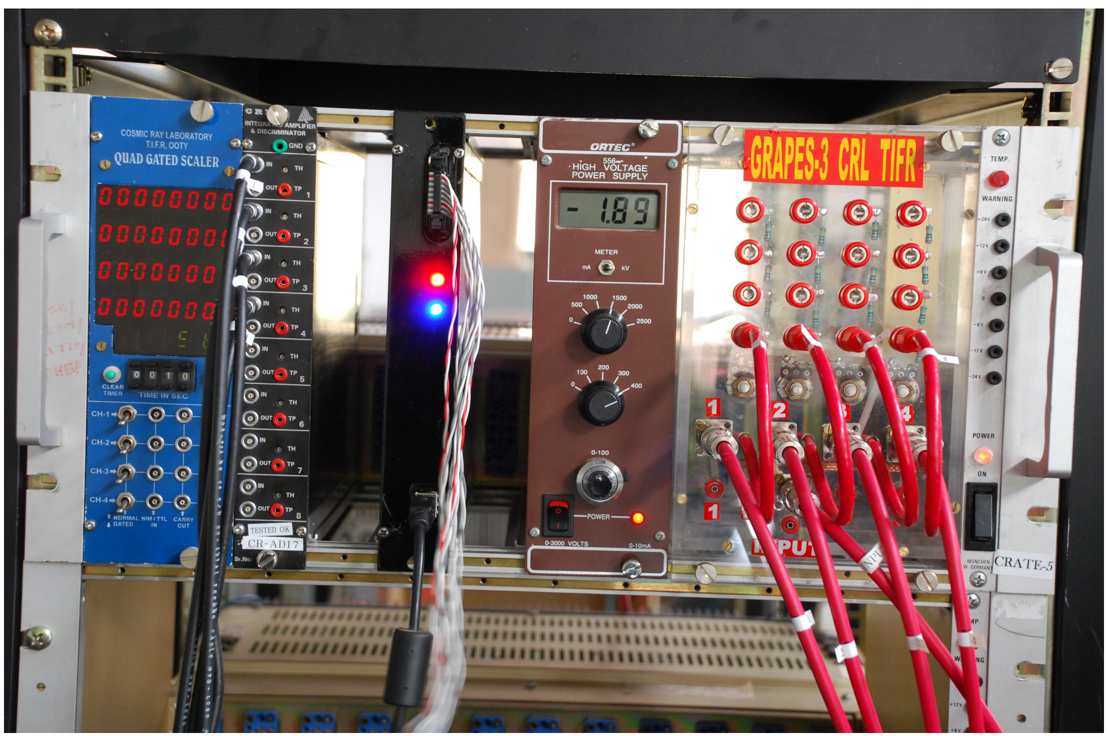
VIIT faculty	10
GRAPES-3 members	10
BE Final students	77
Projects	28
(20 Hardware + 8 Software)	

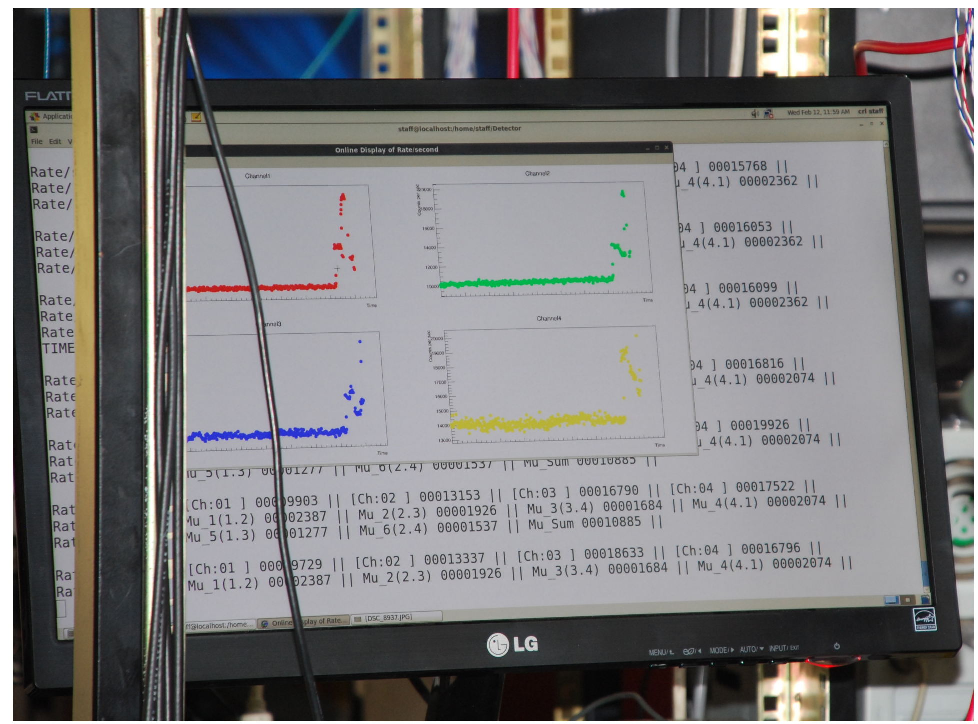
GRAPES-3 projects	= 28 (72%)	Students = 77 (73%)
Rest TIFR projects	= 11 (28%)	Students = 28 (23%)
Total projects	= 39	Students = 105





GRAPES-3 Radiation Monitor for RPG BARC

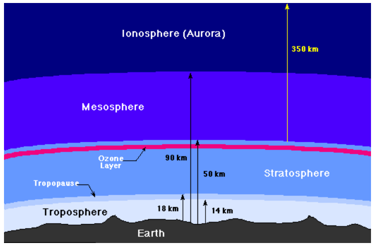




Objective: Universe at high energies

Acceleration, propagation of high energy particles,
Extreme conditions may require new physics ...

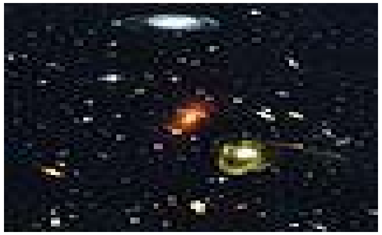
1. Acceleration in atmospheric electric field
   Energy ~100 MeV Scale ~10^5-10^6 cm



2. Solar flares, Coronal Mass Ejections
   Energy ~10 GeV Scale ~10^{11}-10^{13} cm

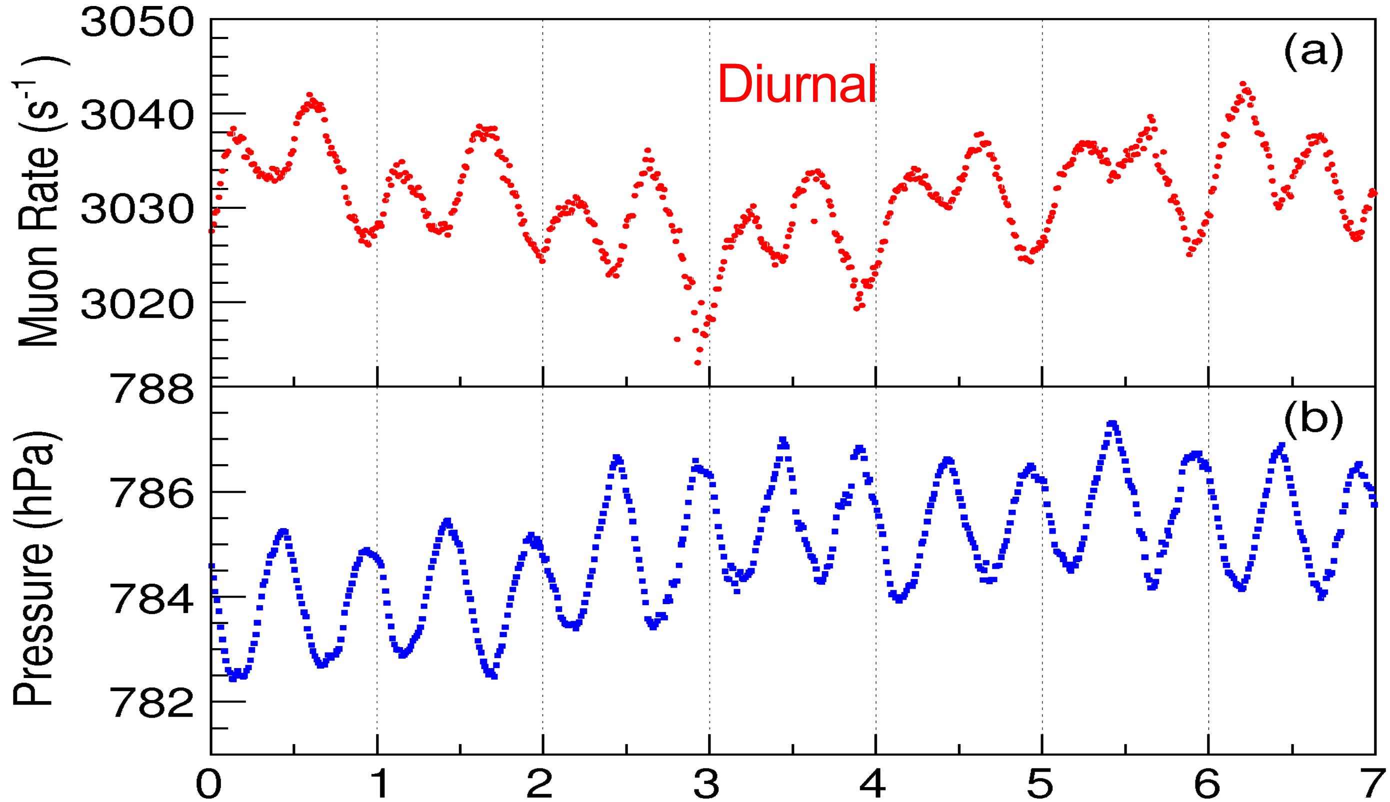
3. Galactic Cosmic Rays at “ Knee ”
   Energy ~1 PeV Scale ~10^{21}-10^{23} cm

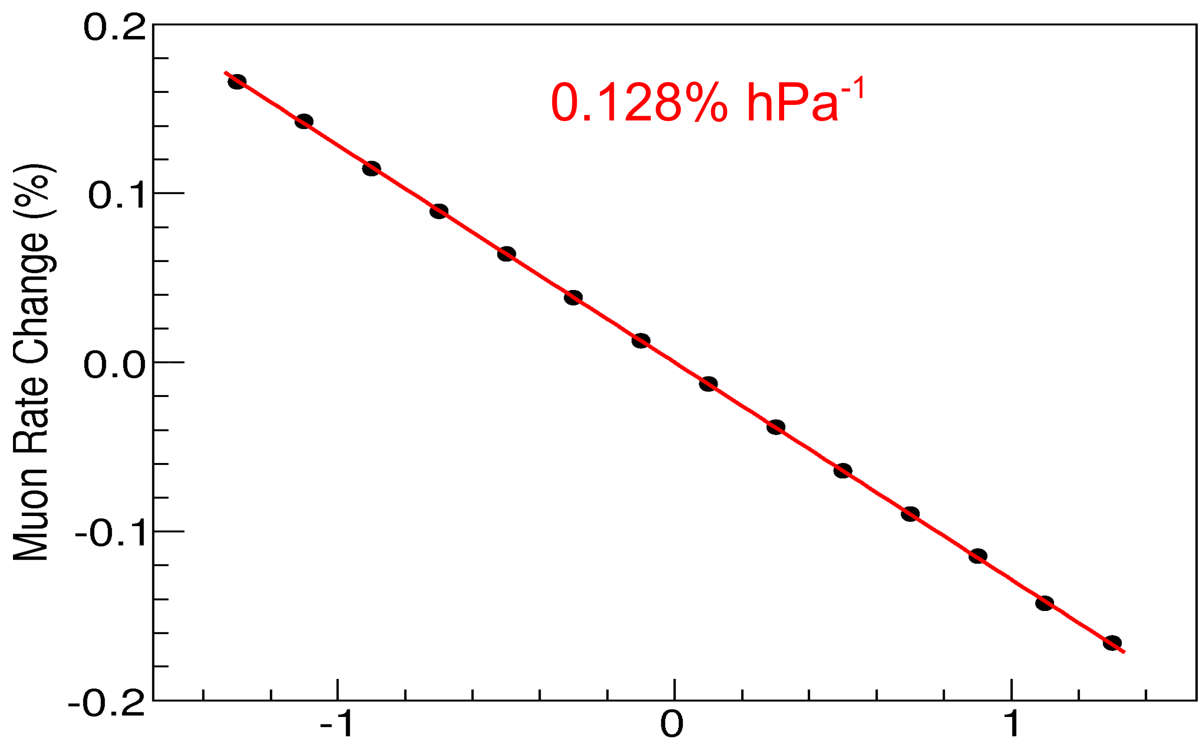
4. Diffuse multi-TeV **γ**-rays
   Energy ~100 EeV Scale ~10^{24}-10^{26} cm



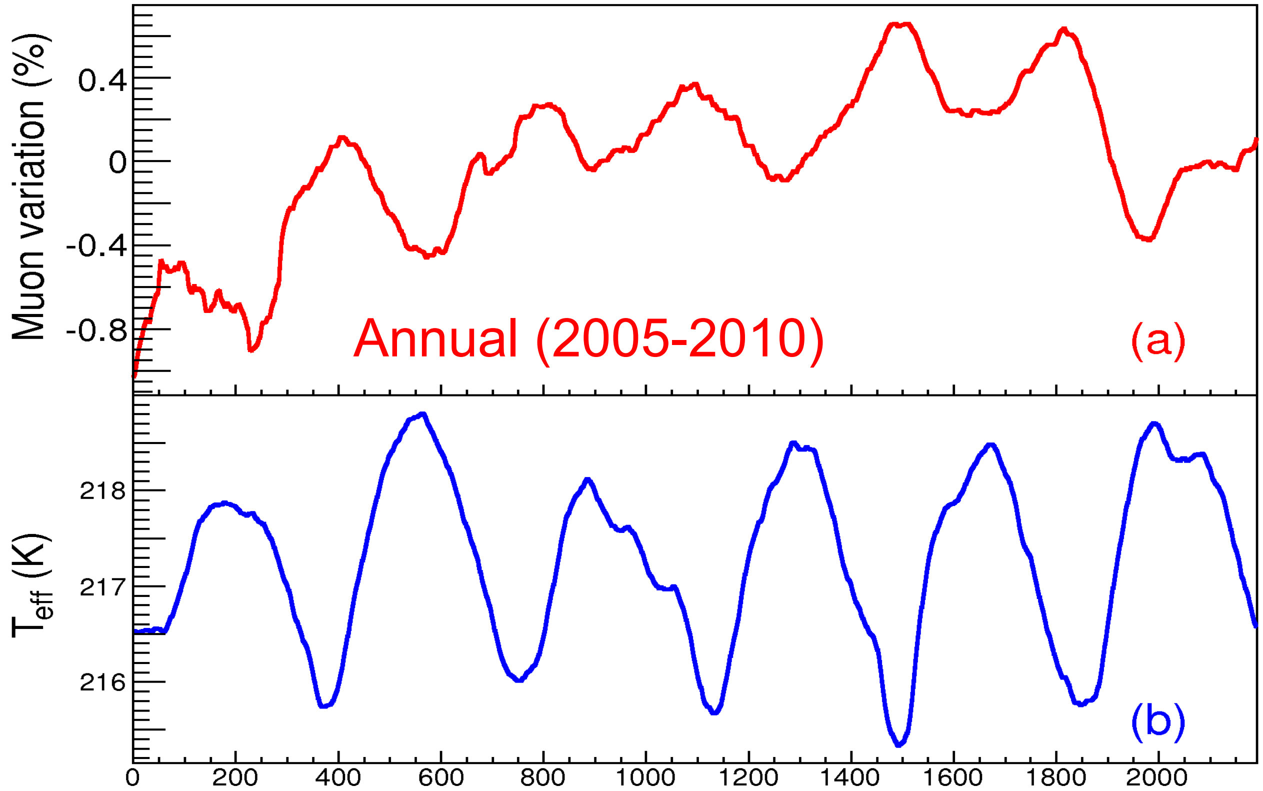

World's most sensitive muon telescope
Total area = 560 m²


Inside view of
muon telescope



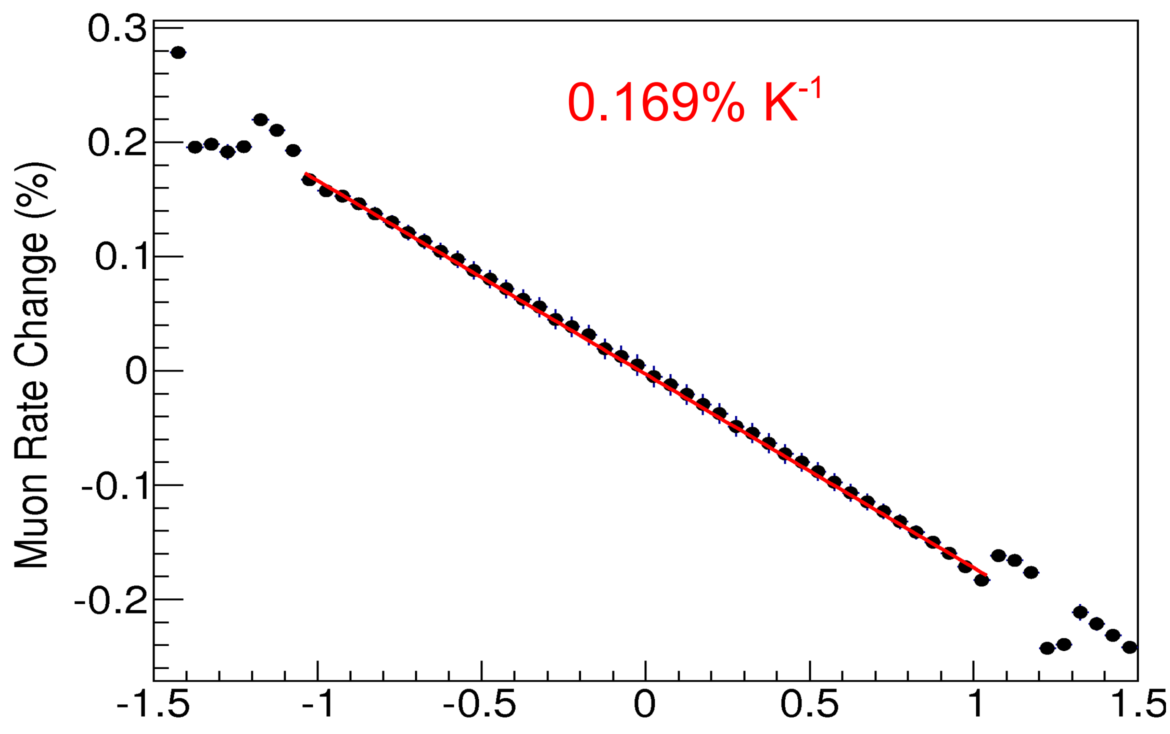


1 m air column = 5σ

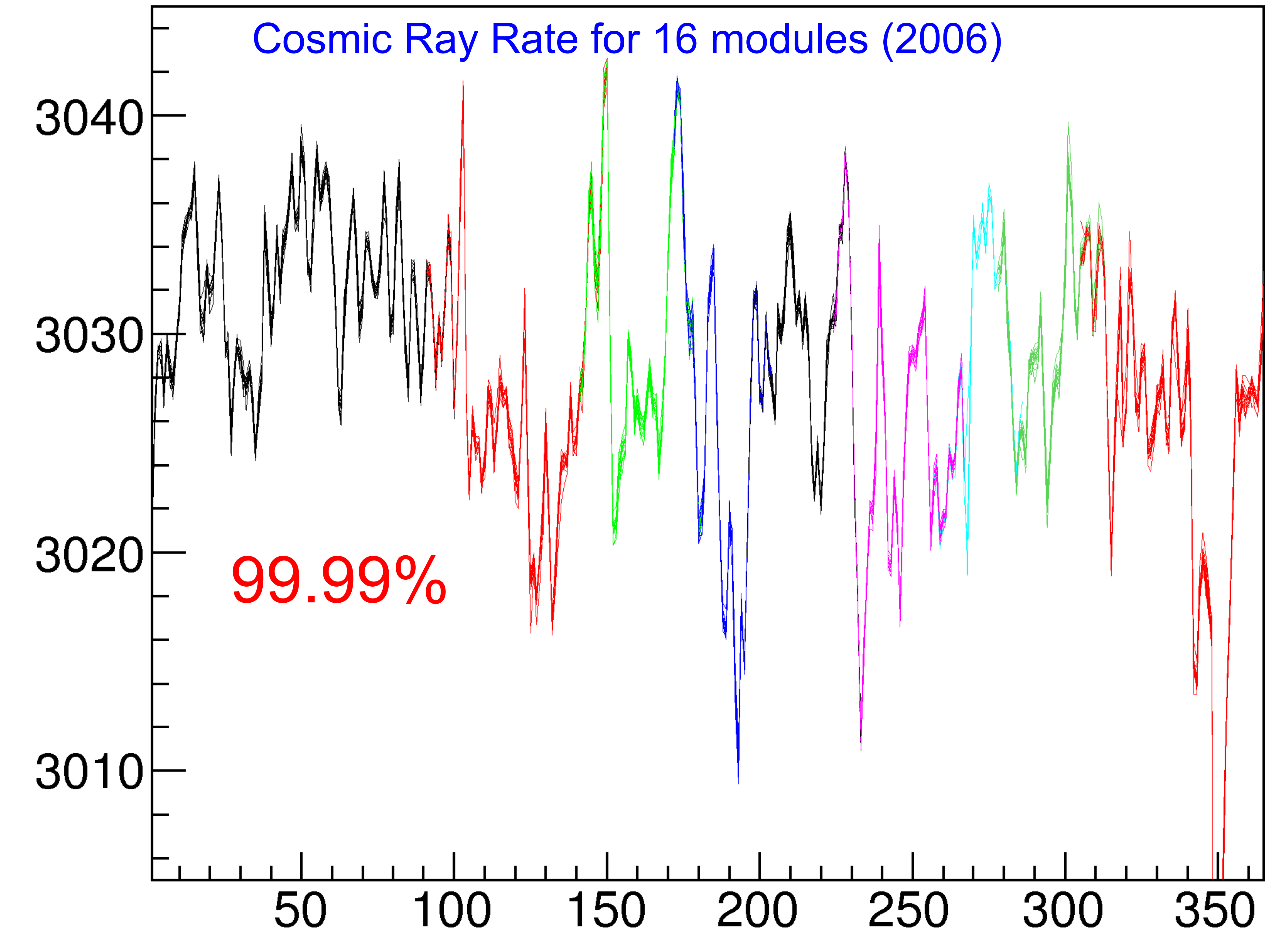


Muon variation (%)
0.4
0
-0.4
-0.8
Annual (2005-2010)
(a)
T_{eff} (K)
218
217
216
(b)
0
200
400
600
800
1000
1200
1400
1600
1800
2000

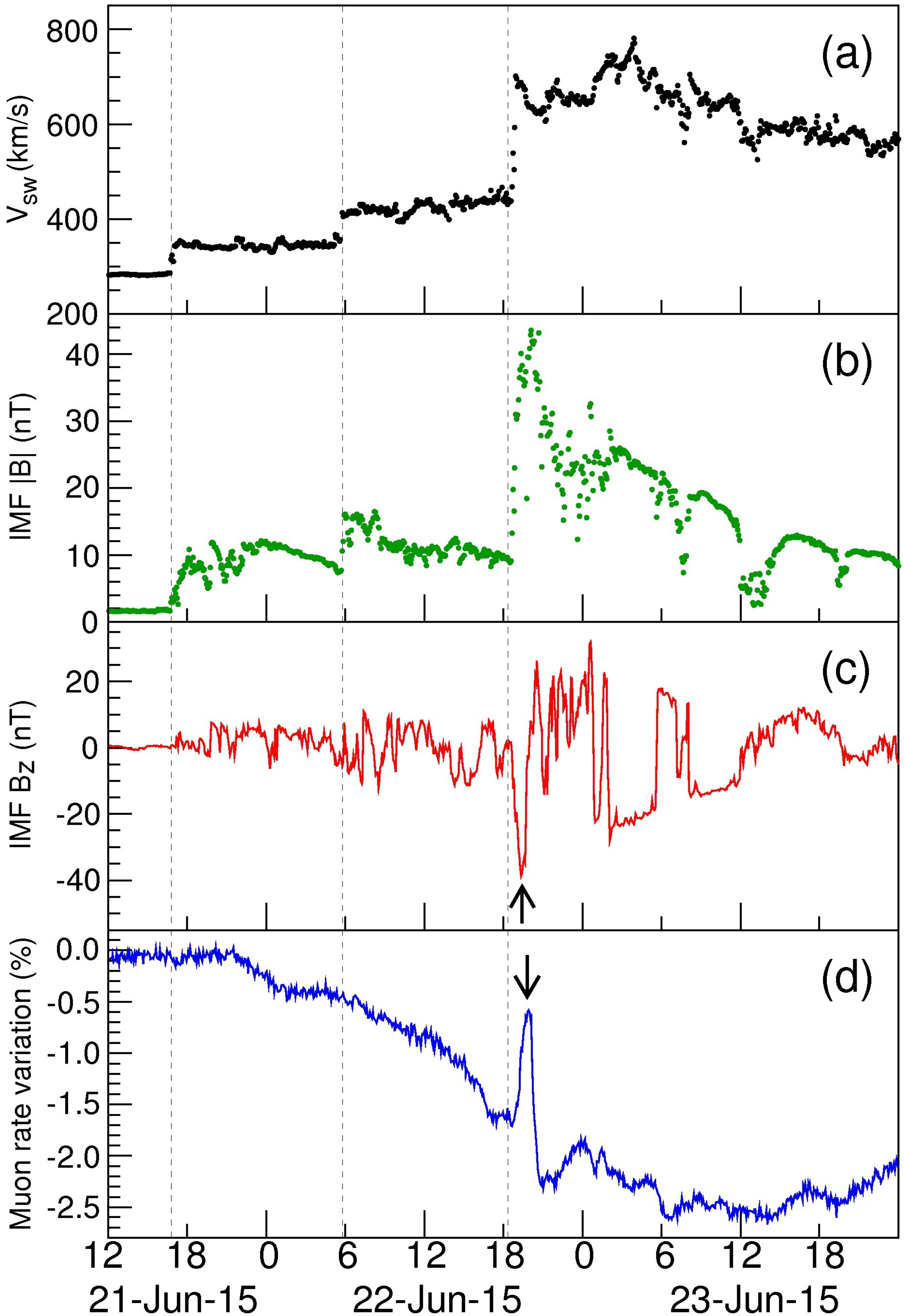
0.3 ℃ = 5σ



0.169% K-1
Muon Rate Change (%)
0.3
0.2
0.1
0
-0.1
-0.2
-1.5
-1
-0.5
0
0.5
1
1.5



Cosmic Ray Rate for 16 modules (2006)
3040
3030
3020
3010
99.99%
50
100
150
200
250
300
350

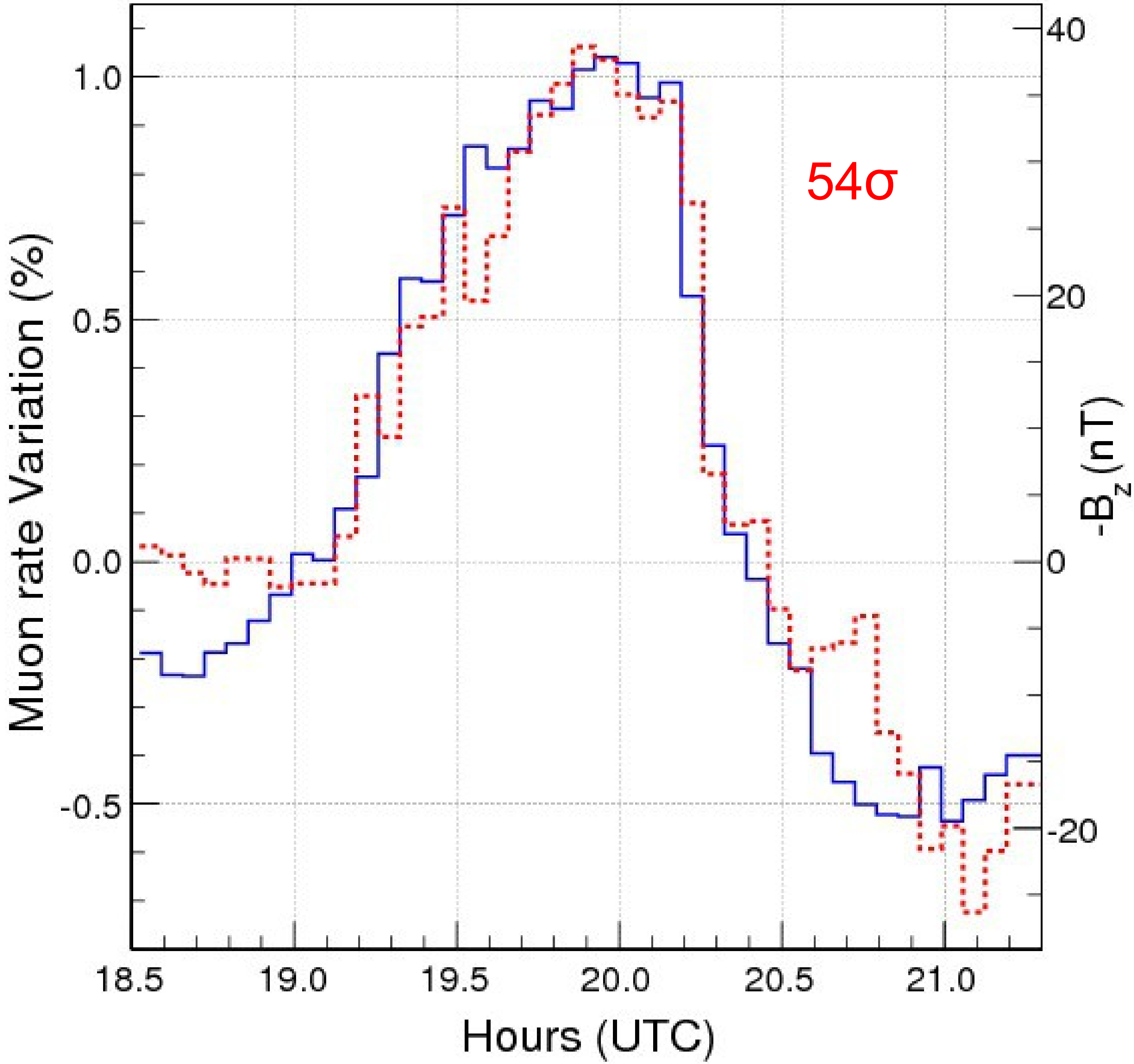


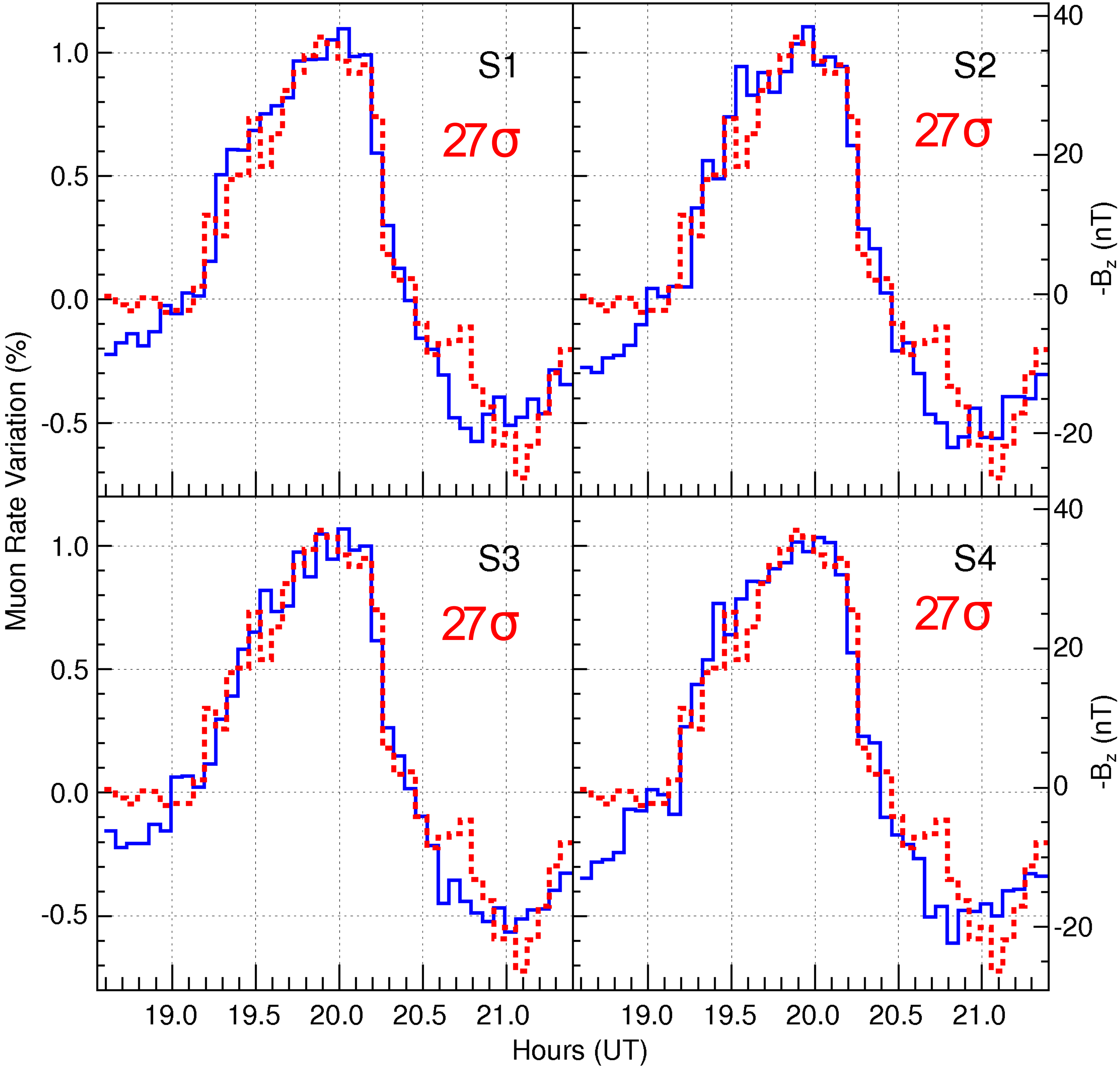
CME characteristics
for 22 June 2015 event

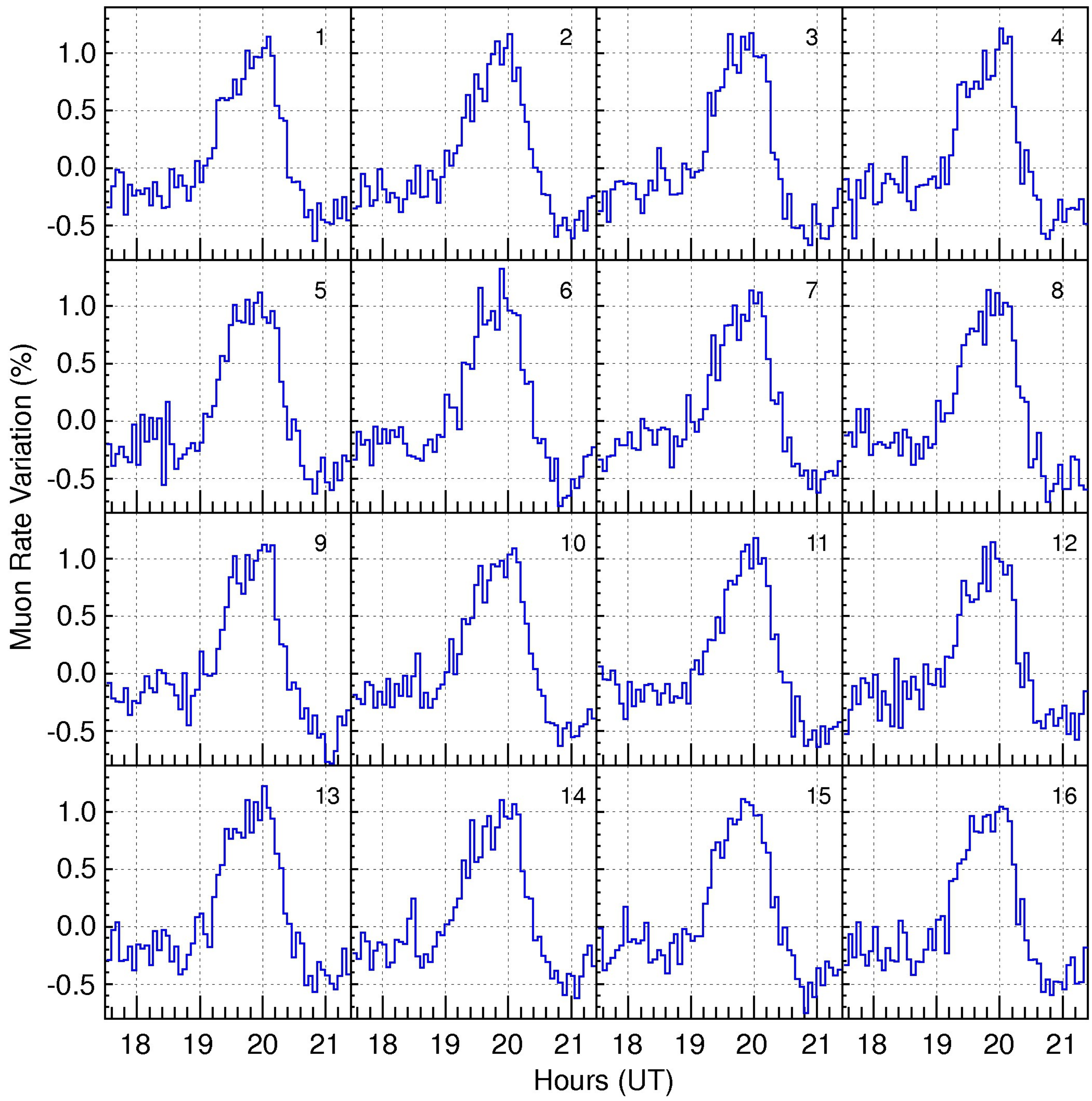
Mass=10^{10} tonne
Energy=10^{33} erg
Solar power= 4×10^{33} erg/s

Initial Speed= 1400 km/s
Speed at L1=700 km/s

22 June 2015 Ooty, midnight

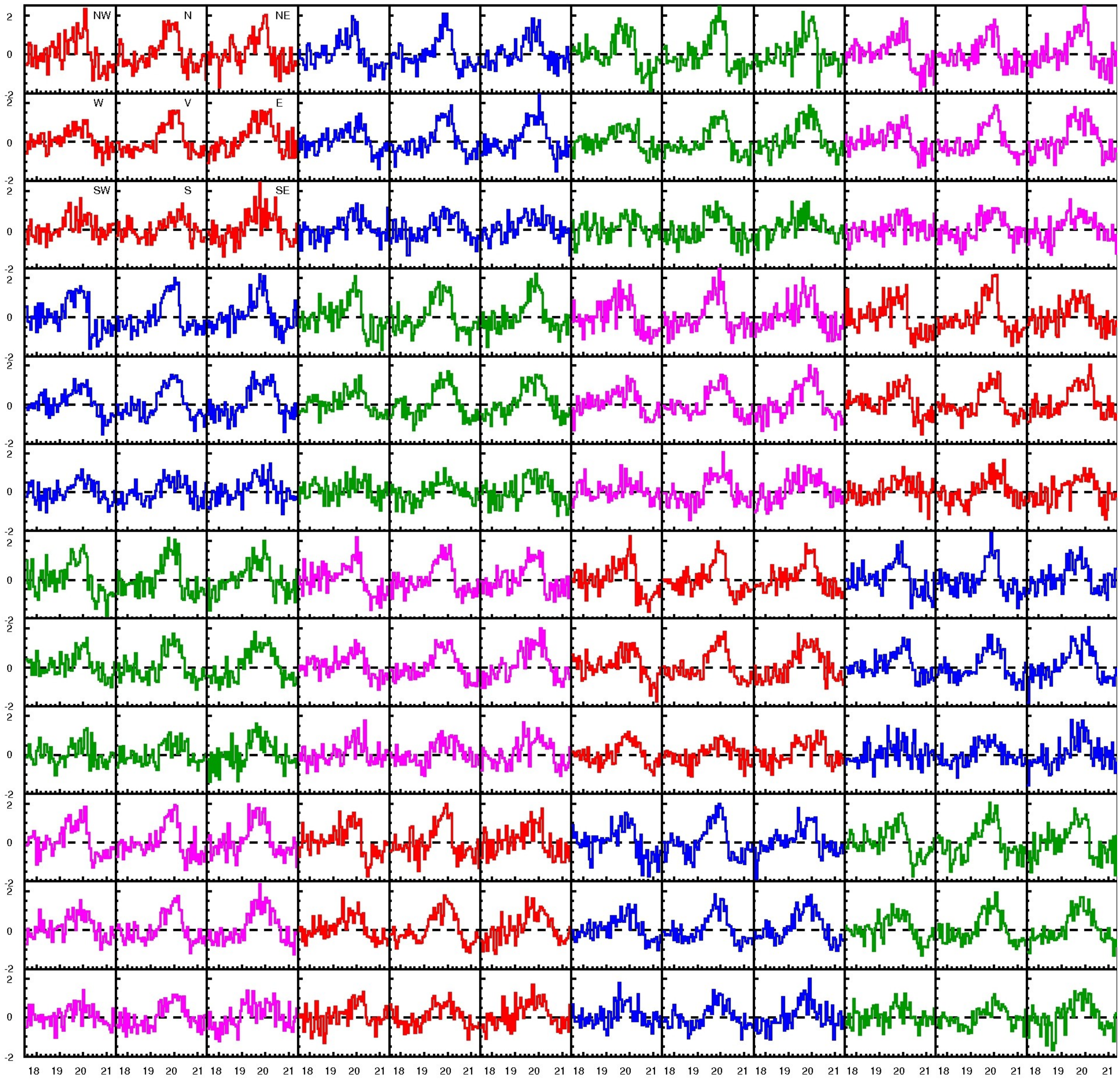



S1
27σ
S2
27σ
S3
27σ
S4
27σ
Muon Rate Variation (%)
1.0
0.5
0.0
-0.5
$-B_z$ (nT)
40
20
0
-20
19.0
19.5
20.0
20.5
21.0
Hours (UT)



Muon Rate Variation (%)
Hours (UT)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
1.0
0.5
0.0
-0.5
18
19
20
21

13σ



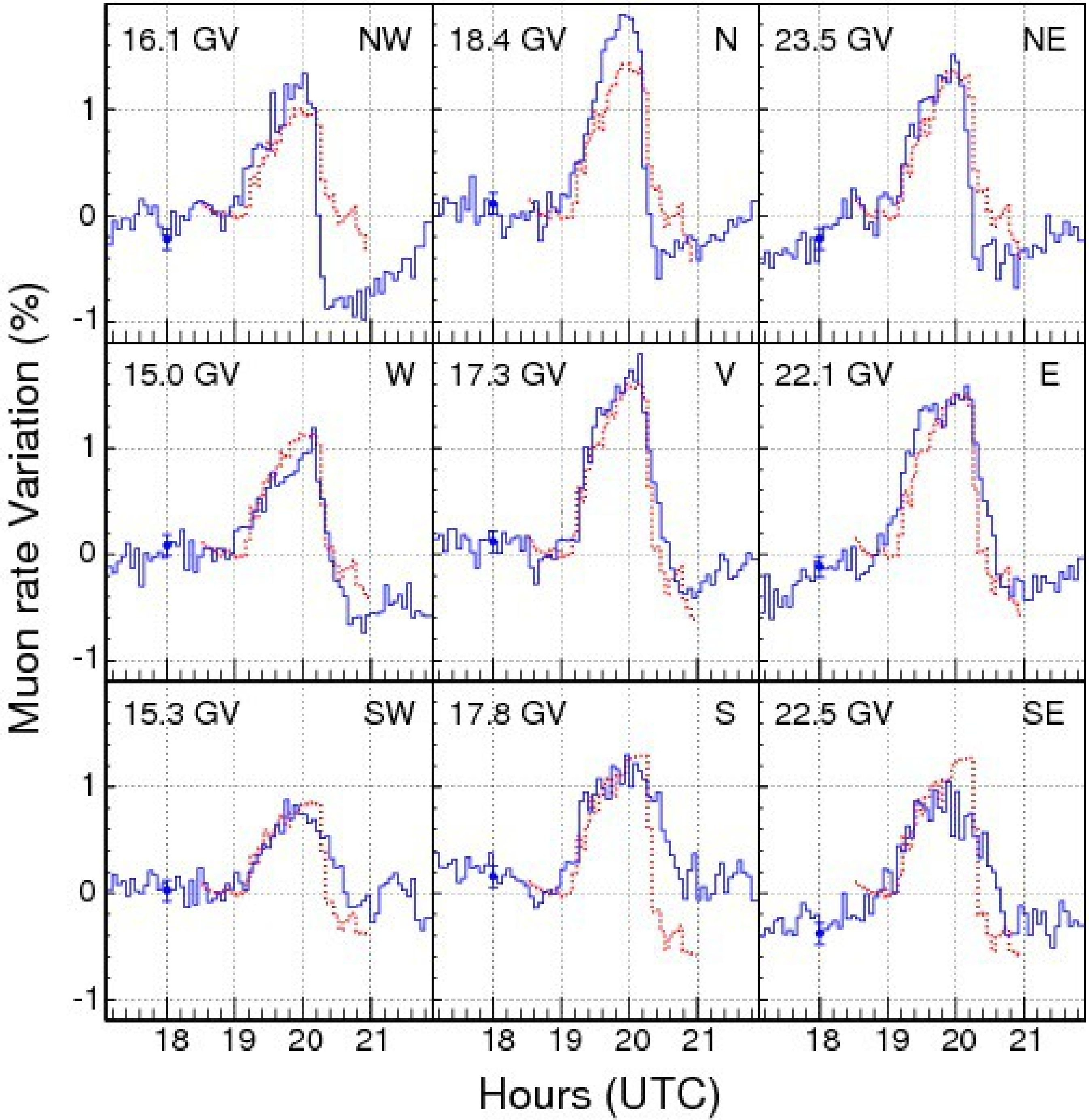
>5σ 42

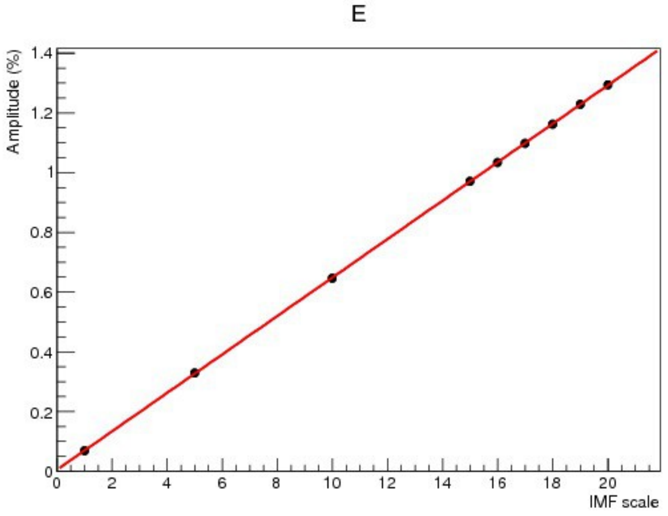
4-5σ 37

3-4σ 40

<3σ 25

-Bz=680 nT



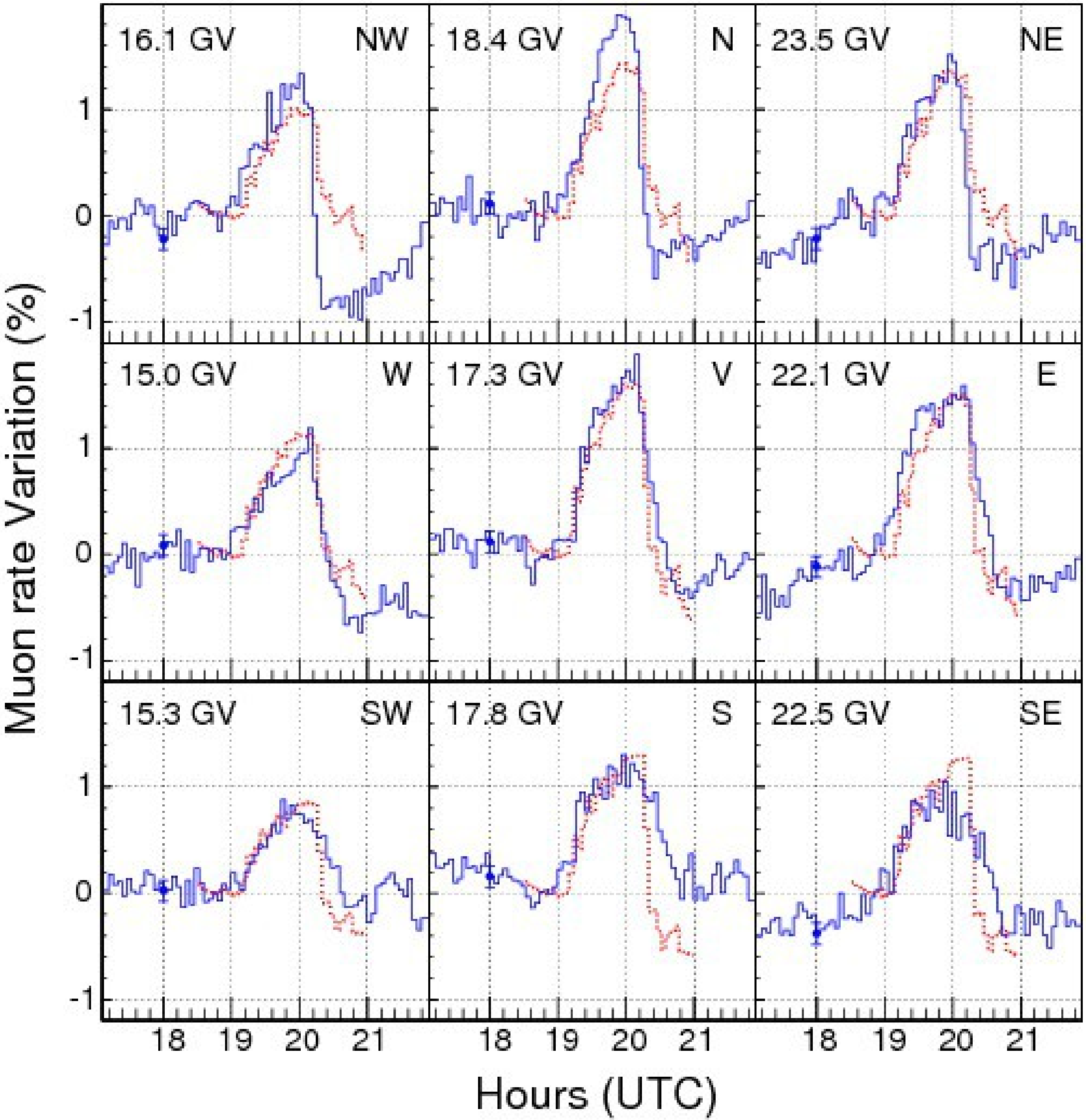


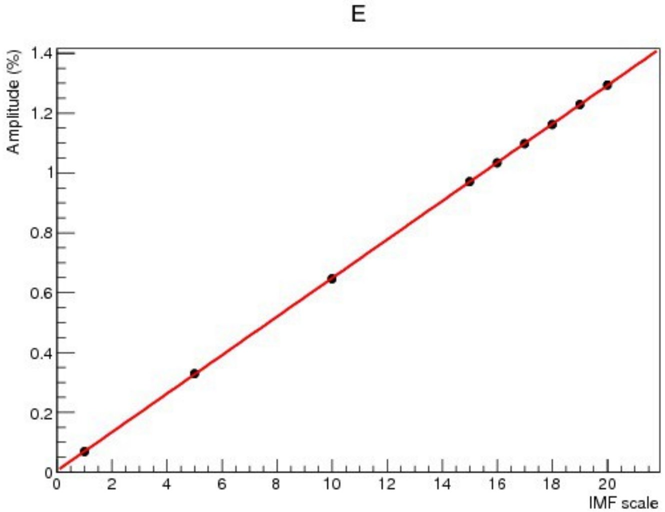
0.7 GeV

0.6 GeV

0.5 GeV

-Bz=680 nT

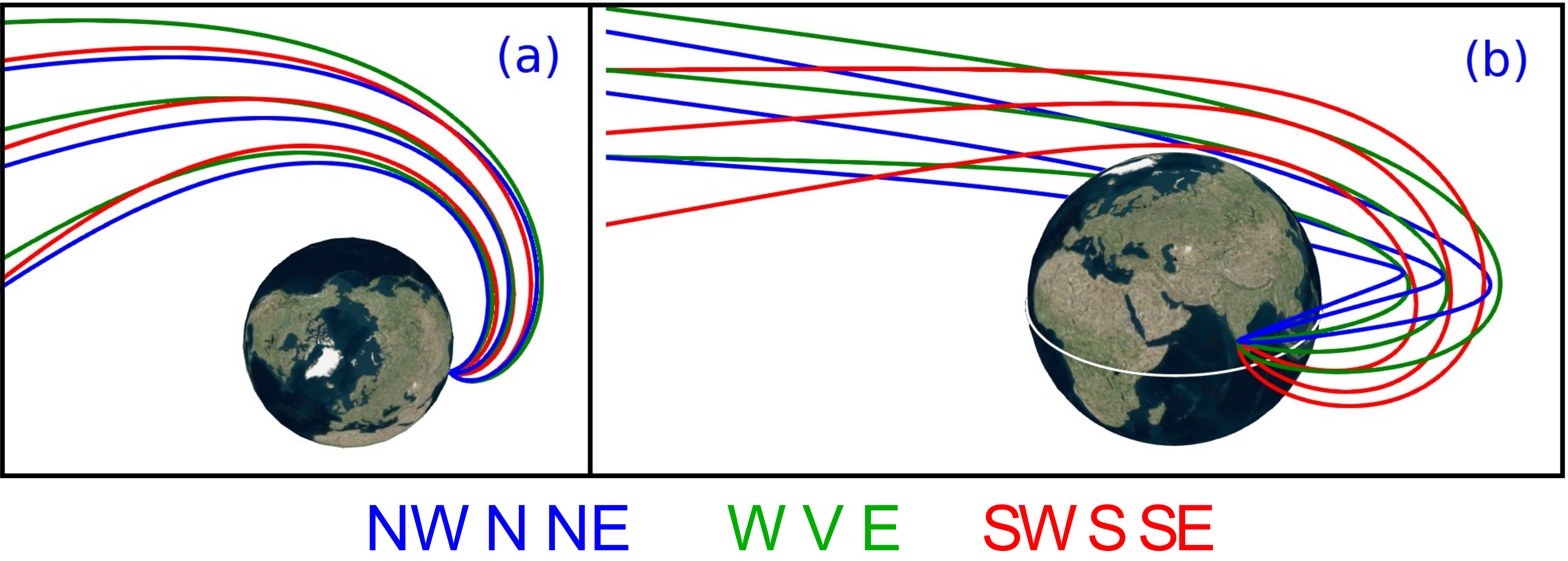




0.7 GeV

0.6 GeV

0.5 GeV


(a)
(b)
NW N NE
W V E
SW S SE

http://www.sciencemag.org/news/2016/07/here-s-how-world-could-end-and-what-we-can-do-about-it

Here's how the world could end—and what we can do about it

sciencemag.org/news/2016/07/here-s-how-world-could-end-and-what-we-can-do-about-it

By Julia Rosen Jul. 14, 2016 , 2:00 PM

08/07/2016

Threat one: Solar storms

CMEs don't harm human beings directly, and their effects can be spectacular. By funneling charged particles into Earth's magnetic field, they can trigger geomagnetic storms that ignite dazzling auroral displays. But those storms can also induce dangerous electrical currents in long-distance power lines. The currents last only a few minutes, but they can take out electrical grids by destroying high-voltage transformers—particularly at high latitudes, where Earth's magnetic field lines converge as they arc toward the surface.

Threat two: Cosmic collisions

For another menace from the sky—an impact by a large asteroid or comet—there is no way to limit the damage. The only way for humanity to protect itself, researchers say, is to prevent the collision altogether.

Threat three: Supervolcanoes

The most inexorable threat to our modern civilization, however, is homegrown—and it strikes much more often than big cosmic impacts do. Every 100,000 years or so, somewhere on Earth, a caldera up to 50 kilometers in diameter collapses and violently expels heaps of accumulated magma. The resulting supervolcano is both unstoppable and ferociously destructive. One such monster, the massive eruption of Mount Toba in Indonesia 74,000 years ago, may have wiped out most humans on Earth, causing a genetic bottleneck still apparent in our DNA—although the idea is controversial.

whitehouse.gov/the-press-office/2016/10/13/executive-order-coordinating-efforts-prepare-nation-space-weather-events

EXECUTIVE ORDER

COORDINATING EFFORTS TO PREPARE THE NATION FOR SPACE WEATHER EVENTS

By the authority vested in me as President by the Constitution and the laws of the United States of America, and to prepare the Nation for space weather events, it is hereby ordered as follows:

Section 1. Policy. Space weather events, in the form of solar flares, solar energetic particles, and geomagnetic disturbances, occur regularly, some with measurable effects on critical infrastructure systems and technologies, such as the Global Positioning System (GPS), satellite operations and communication, aviation, and the electrical power grid. Extreme space weather events -- those that could significantly degrade critical infrastructure -- could disable large portions of the electrical power grid, resulting in cascading failures that would affect key services such as water supply, healthcare, and transportation. Space weather has the potential to simultaneously affect and disrupt health and safety across entire continents. Successfully preparing for space weather events is an all-of-nation endeavor that requires partnerships across governments, emergency managers, academia, the media, the insurance industry, non-profits, and the private sector.

Transient Weakening of Earth's Magnetic Shield Probed by a Cosmic Ray Burst

P. K. Mohanty, K. P. Arunbabu, T. Aziz, S. R. Dugad, S. K. Gupta,*
B. Hariharan, P. Jagadeesan, A. Jain, S. D. Morris, and B. S. Rao
Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400005, India†

Y. Hayashi and S. Kawakami
Graduate School of Science, Osaka City University, 558-8585 Osaka, Japan†

A. Oshima and S. Shibata
College of Engineering, Chubu University, Kasugai, Aichi 487-8501, Japan†

S. Raha
Bose Institute, 93/1, A.P.C. Road, Kolkata 700009, India†

P. Subramanian
Indian Institute of Science Education and Research, Pune 411021, India†

H. Kojima
Faculty of Engineering, Aichi Institute of Technology, Toyota City, Aichi 470-0392, Japan†
(Received 16 June 2016; published 20 October 2016)

The GRAPES-3 tracking muon telescope in Ooty, India measures muon intensity at high cutoff rigidities (15–24 GV) along nine independent directions covering 2.3 sr. The arrival of a coronal mass ejection on 22 June 2015 18:40 UT had triggered a severe G4-class geomagnetic storm (storm). Starting 19:00 UT, the GRAPES-3 muon telescope recorded a 2 h high-energy (~20 GeV) burst of galactic cosmic rays (GCRs) that was strongly correlated with a 40 nT surge in the interplanetary magnetic field (IMF). Simulations have shown that a large (17×) compression of the IMF to 680 nT, followed by reconnection with the geomagnetic field (GMF) leading to lower cutoff rigidities could generate this burst. Here, 680 nT represents a short-term change in GMF around Earth, averaged over 7 times its volume. The GCRs, due to lowering of cutoff rigidities, were deflected from Earth's day side by ~210° in longitude, offering a natural explanation of its night-time detection by the GRAPES-3. The simultaneous occurrence of the burst in all nine directions suggests its origin close to Earth. It also indicates a transient weakening of Earth's magnetic shield, and may hold clues for a better understanding of future superstorms that could cripple modern technological infrastructure on Earth, and endanger the lives of the astronauts in space.

DOI: 10.1103/PhysRevLett.117.171101

Science

http://www.sciencemag.org/news/2016/10/solar-storms-can-weaken-earth-s-magnetic-field

American Physical Society

http://physics.aps.org/synopsis-for/10.1103/PhysRevLett.117.171101

Physical World

http://physicsworld.com/cws/article/news/2016/oct/21/flash-physics-physicists-call-for-food-strategy-lhc-trio-bag-prize-cosmic-rays-elude-geomagnetic-field

Nature

http://www.natureasia.com/en/nindia/article/10.1038/nindia.2016.141

BBC

http://www.bbc.co.uk/news/science-environment-38849147

Weather.com

https://weather.com/science/space/news/earth-magnetic-field-crack-solar-flare-radiation

The Hindu

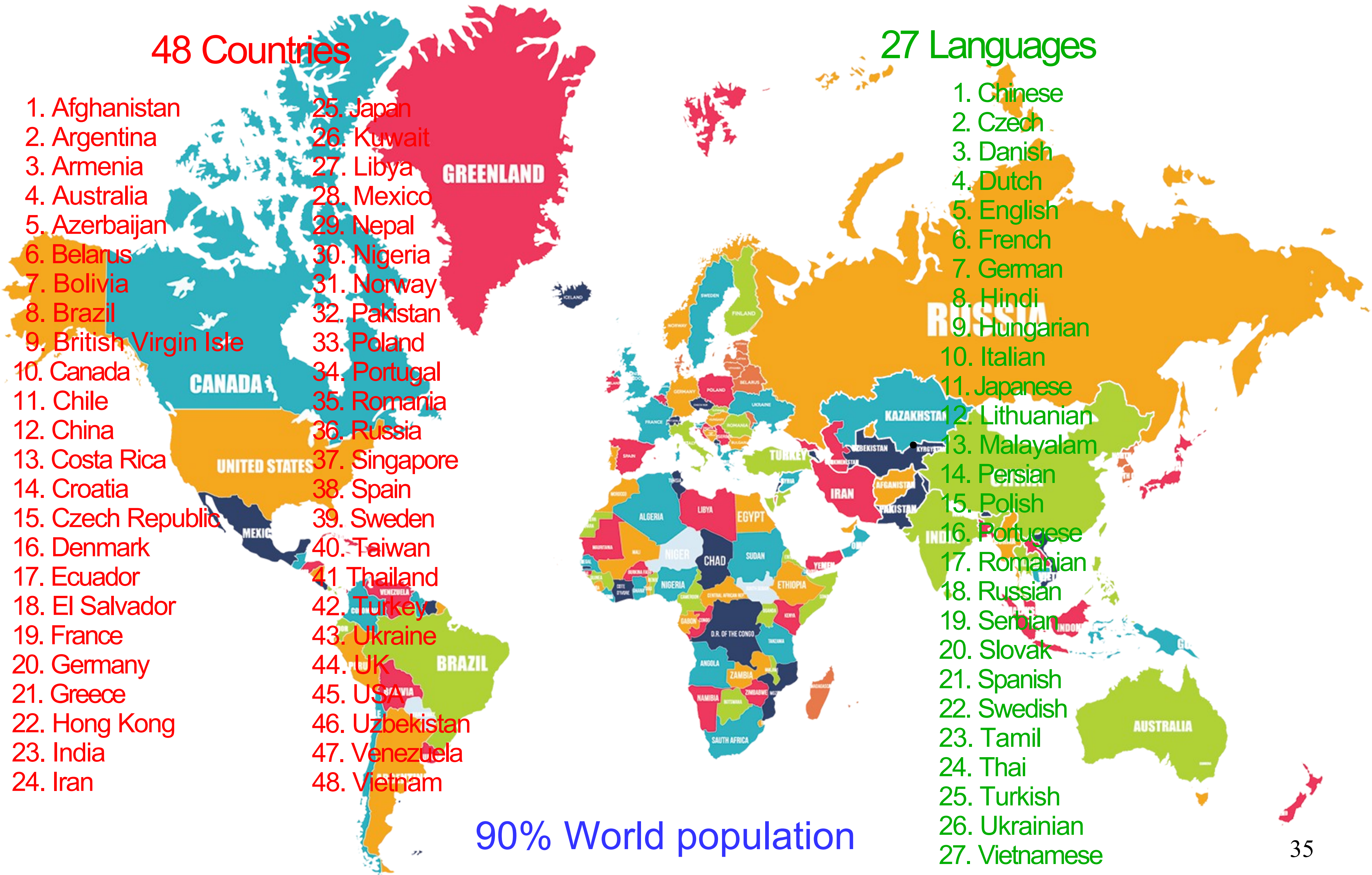
http://www.thehindu.com/sci-tech/science/Indian-muon-trackers-get-a-handle-on-solar-storms/article16085296.ece

Silicon Valley Tech Times

http://www.techtimes.com/articles/185158/20161108/grapes-3-telescope-records-cosmic-ray-burst-highlights-crack-in-earth-s-magnetic-field.htm


1. English : 174
2. Asian : 103
3. East Euro : 131
4. West Euro : 79
Total= 484 News Reports Worldwide

Captures worldwide scientific and public imagination
500 websites reported GRAPES-3 result



48 Countries

1. Afghanistan
2. Argentina
3. Armenia
4. Australia
5. Azerbaijan
6. Belarus
7. Bolivia
8. Brazil
9. British Virgin Isle
10. Canada
11. Chile
12. China
13. Costa Rica
14. Croatia
15. Czech Republic
16. Denmark
17. Ecuador
18. El Salvador
19. France
20. Germany
21. Greece
22. Hong Kong
23. India
24. Iran
25. Japan
26. Kuwait
27. Libya
28. Mexico
29. Nepal
30. Nigeria
31. Norway
32. Pakistan
33. Poland
34. Portugal
35. Romania
36. Russia
37. Singapore
38. Spain
39. Sweden
40. Taiwan
41 Thailand
42. Turkey
43. Ukraine
44. UK
45. USA
46. Uzbekistan
47. Venezuela
48. Vietnam

27 Languages

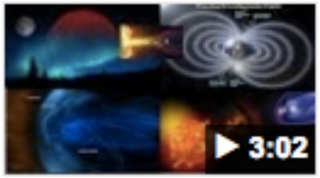
1. Chinese
2. Czech
3. Danish
4. Dutch
5. English
6. French
7. German
8. Hindi
9. Hungarian
10. Italian
11. Japanese
12. Lithuanian
13. Malayalam
14. Persian
15. Polish
16. Portugese
17. Romanian
18. Russian
19. Serbian
20. Slovak
21. Spanish
22. Swedish
23. Tamil
24. Thai
25. Turkish
26. Ukrainian
27. Vietnamese

90% World population

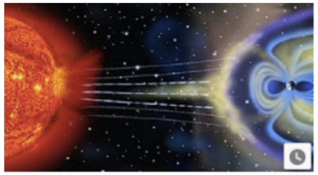
18 YouTube Videos

1. The Earth's Magnetic Shield Cracked, Are We Doomed?
https://www.youtube.com/watch?v=IYFt40J12go
390K

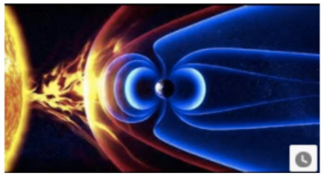
2. ALERT: Crack in Earth's Magnetic Shield Just Detected, 'A Flip is Overdue' Experts say
https://www.youtube.com/watch?v=kFdxA8MRNmo
8K



3. Powerful geomagnetic storm cracks Earth's magnetosphere
https://www.youtube.com/watch?v=82X0V7yQmoE
7K

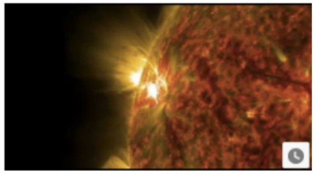


4. TERRIFYING! Earth's Magnetic Shield Has CRACKED And We Could FRY At Any Moment!
https://www.youtube.com/watch?v=hVERCMe9k0o
5K



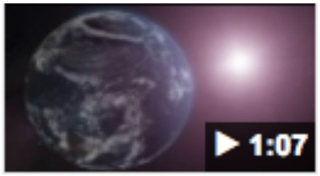
5. Earth's Magnetosphere Has Cracked ★★★
https://www.youtube.com/watch?v=WWQnyQhQ7Xc
5K

6. Solar flare radiation burst cracked Earth's magnetic field caused radio blackouts
https://www.youtube.com/watch?v=2F8Ud-gDDnU
1.5K



7. The crack indicates that Earth's magnetic shield is weakening
https://www.youtube.com/watch?v=XAjk_pI88yY
1K

8. Study: Solar Flare Caused A 'Crack' In Protective Field Around Earth
https://www.youtube.com/watch?v=SDoi5HTyv8I
1K



Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC

Overview of attention for article published in Physics Letters B, January 2012

SUMMARY | News | Blogs | Twitter | Weibo | Facebook | Wikipedia | Google+ | Reddit | Q&A | Video

You are seeing a free-to-access but limited selection of the activity Altmetric has collected about this research output. **Click here to find out more**.

Title	Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC
Published in	Physics Letters B, January 2012
DOI	10.1016/j.physletb.2012.08.021
Authors	S. Chatrchyan, V. Khachatryan, A.M. Sirunyan, A. Tumasyan, W. Adam, E. Aguilo, T. Bergauer, M... [show]

View on publisher site

Alert me about new mentions

About this Attention Score

In the top 5% of all research outputs scored by Altmetric

MORE...

Mentioned by

- **7** news outlets
- **23** blogs
- **267** tweeters
- **1** weibo user
- **18** Facebook pages
- **5** Wikipedia pages
- **22** Google+ users
- **2** Redditors
- **1** Q&A thread
- **1** video uploader

Readers on

TWITTER DEMOGRAPHICS | MENDELEY READERS | **ATTENTION SCORE IN CONTEXT**

This research output has an **Altmetric Attention Score** of **456**. This is our high-level measure of the quality and quantity of online attention that it has received. This Attention Score, as well as the ranking and number of research outputs shown below, was calculated when the research output was last mentioned on **23 January 2017**.

ALL RESEARCH OUTPUTS	OUTPUTS FROM PHYSICS LETTERS B	OUTPUTS OF SIMILAR AGE	OUTPUTS OF SIMILAR AGE FROM PHYSICS LETTERS B
#6,941	#4	#177	#1
of 6,988,497 outputs	of 1,801 outputs	of 285,416 outputs	of 117 outputs

Altmetric has tracked 6,988,497 research outputs across all sources so far. Compared to these this one has done particularly well and is in the 99th percentile: it's **in the top 5% of all research outputs ever tracked** by Altmetric.

Altmetric

? What is this page? | Embed badge | Share

Transient Weakening of Earth's Magnetic Shield Probed by a Cosmic Ray Burst

Overview of attention for article published in Physical Review Letters, October 2016

SUMMARY | News | Blogs | Twitter | Facebook | Wikipedia | Google+ | Reddit | Misc.

Title	Transient Weakening of Earth's Magnetic Shield Probed by a Cosmic Ray Burst
Published in	Physical Review Letters, October 2016
DOI	10.1103/physrevlett.117.171101
Pubmed ID	27824449
Authors	P. K. Mohanty, K. P. Arunbabu, T. Aziz, S. R. Dugad, S. K. Gupta, B. Hariharan, P. Jagadeesan, A... [show]
Abstract	The GRAPES-3 tracking muon telescope in Ooty, India measures muon intensity at high cutoff... [show]

View on publisher site

Alert me about new mentions

About this Attention Score

In the top 5% of all research outputs scored by Altmetric

MORE...

Mentioned by

- **54** news outlets
- **8** blogs
- **61** tweeters
- **7** Facebook pages
- **1** Wikipedia page
- **12** Google+ users
- **1** Redditor

Readers on

TWITTER DEMOGRAPHICS | MENDELEY READERS | ATTENTION SCORE IN CONTEXT

This research output has an **Altmetric Attention Score** of **535**. This is our high-level measure of the quality and quantity of online attention that it has received. This Attention Score, as well as the ranking and number of research outputs shown below, was calculated when the research output was last mentioned on **04 February 2017**.

ALL RESEARCH OUTPUTS	OUTPUTS FROM PHYSICAL REVIEW LETTERS	OUTPUTS OF SIMILAR AGE	OUTPUTS OF SIMILAR AGE FROM PHYSICAL REVIEW LETTERS
#4,996	#12	#604	#1
of 7,103,764 outputs	of 15,124 outputs	of 227,964 outputs	of 430 outputs

Altmetric has tracked 7,103,764 research outputs across all sources so far. Compared to these this one has done particularly well and is in the 99th percentile: it's **in the top 5% of all research outputs ever tracked** by Altmetric.

Post PRL grapes-3.tifr.res.in 20K hits, TIFR GRAPES-3 5K hits

Some facts:

(1) GRAPES-3 detected burst of cosmic rays due to weakening of geomagnetic field for 2 hours.
Amplitude = 0.5% Sensitivity = 0.01% 54σ

(2) Led to entry of solar plasma into atmosphere, caused radio blackouts, tripping of electric grids.

(3) Four spacecrafts at L1 give advance warning of solar storms (30 min). ISRO to launch Aditya for such studies.

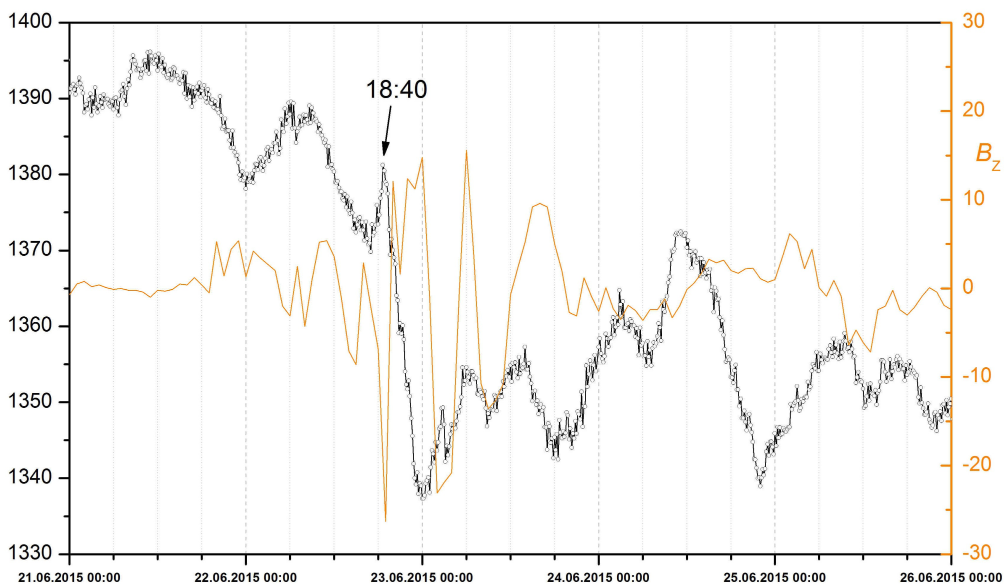
(4) Spacecrafts fail for short periods, may be due to cosmic rays.

Unique Features of GRAPES-3 :

(1) Combination of (i) Large area 560 m^2, (ii) Nine independent telescopes make GRAPES-3 the most sensitive instrument.

(2) In-house technology development, including muon telescope and plastic scintillators, allowed 100% observation during last 17 years (2000-2016). Important for rare event studies. e.g. Benefits accruing to DAE through scintillator based radiation monitor for RPG, and portal monitors for the nation.

(3) Major facilities worldwide, (i) ICECUBE (2000 m^2) in Antacrtica, (ii) TA (2000 m^2) in USA, (iii) Auger (15000 m^2) in Argentina, (iv) HAWC (12000 m^2) in Mexico, (v) AMS on Int. Space Stn. (vi) URAGAN in Russia 4-5σ (limited success, lack of sensitivity)



Perspective :

(1) According to a report published in August 2016 in "Science" number one threat to humans is from solar super storms. On 13 October 2016, USA President Obama signed an Executive Order to prepare them for such events. Our result in "Physical Review Letters" on 20 October 2016. " APS" highlighted it, followed by an article in "Science".

(2) NAS, USA reports that a super storm (July 2012 missed Earth) can disrupt satellites in space, communication systems and electronic devices on ground, short-circuit transformers, may cause losses of trillions of dollars.

(3) Early warning spacecrafts may get disabled. However, GRAPES-3 due to equatorial location on Earth is well-shielded, will continu to operate providing valuable data.

(4) "Science" article explains that a cosmic ray instrument may provide less but more accurate warning than satellites.

Future:

GRAPES-3 is capable of studying solar storms with highest sensitivity at present. Being a research instrument data is analyzed after the event. If it is be converted into an advance warning instrument, following objectives have to be met.

(1) Large analysis effort to better understand existing 17 years of data for signs of storm-like events. Algorithms to predict storms using known events.

(2) Develop suitable hardware trigger to provide advance warning in real time, and improve precision by cross checking with known events.

(3) Accelerate the ongoing expansion of muon telescope, including upgrade of electronics.


Videos

Summary

1. High precision measurements vital for progress

2. Research where natural advantage exists

3. Universe is the best laboratory

4. High energy particles are best messengers

Workshop & Winter School on Astroparticle Physics
GRAPES-3, Ooty 17-29 December 2016

http://grapes-3.tifr.res.in

Education: ~400 attended 11 winter schools
~300 B.E./M.Sc students ~80 projects 2010-16
Visitors: ~2500 in 2016 Thanks