The 33rd General Assembly

of the International Union of Pure and Applied Physics

held jointly with

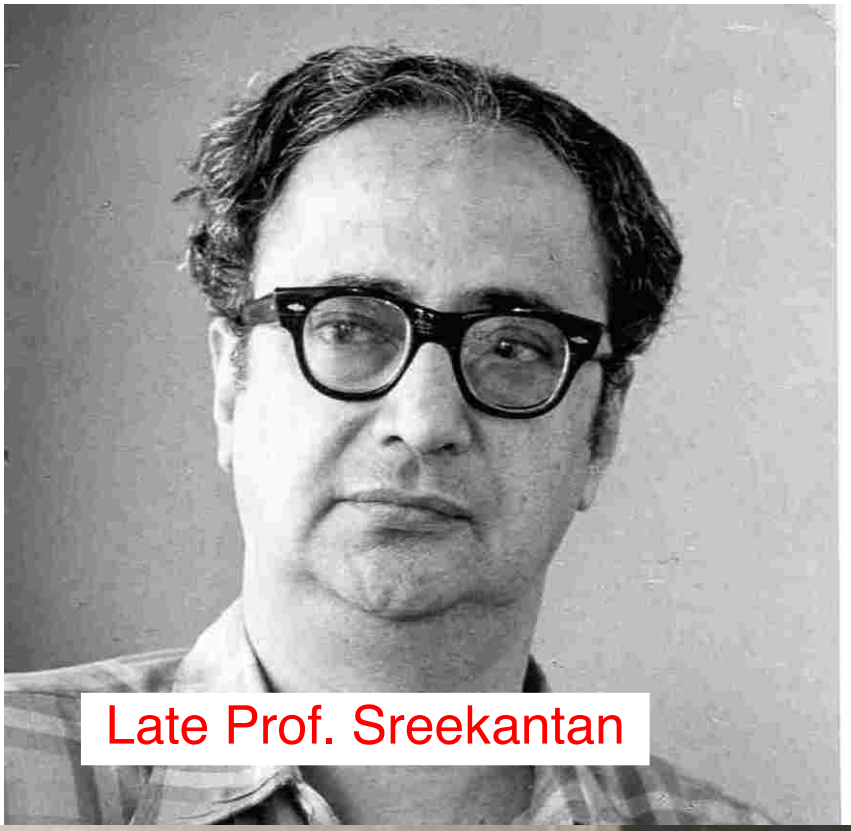
The IUPAP Executive Council & Commission Chairs Meeting

October 7-14, 2024 Haikou, China

My Journey

Sunil K. Gupta

Tata Institute of Fundamental Research, India



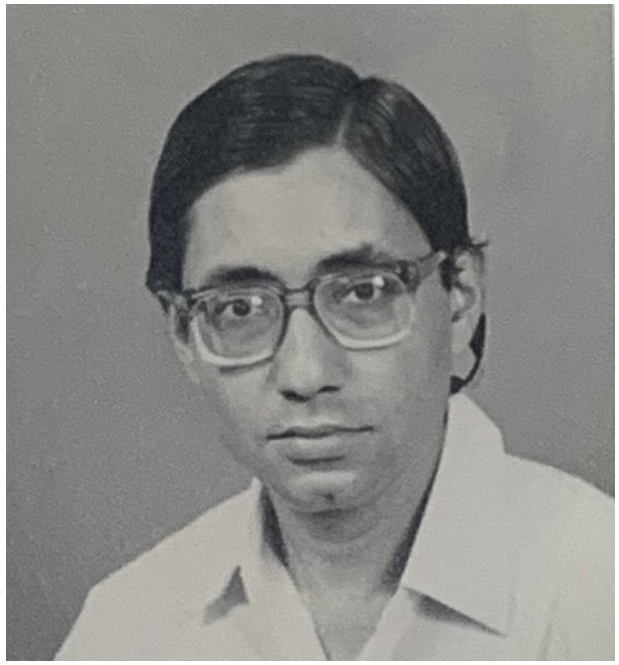
Late Prof. Sreekantan

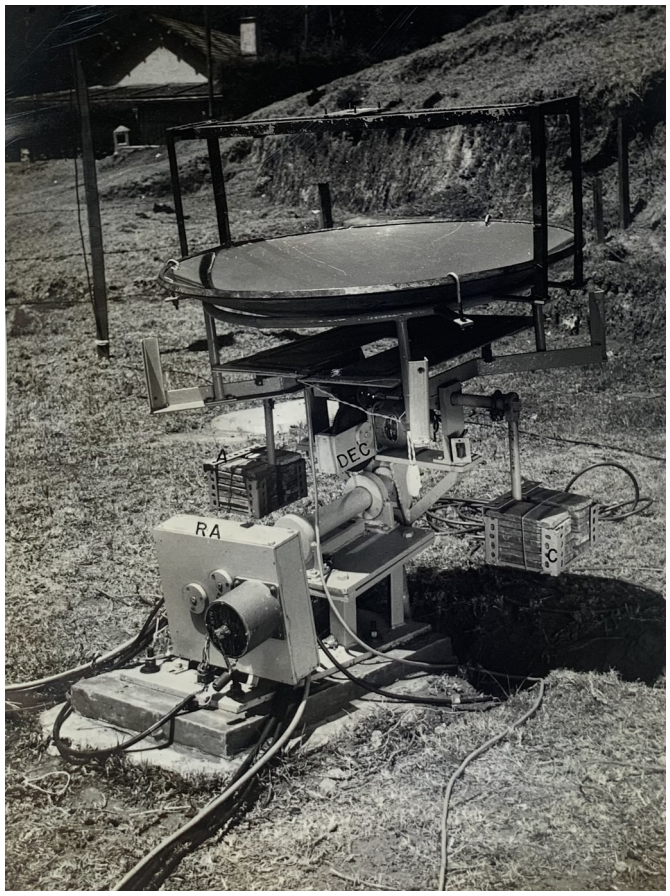
Late Prince Philip

Late Prof. Ramanamurthy

Begninning in 1976

Testing RA & Dec. Gearboxes





Atmospheric Cherenkov Array 1978

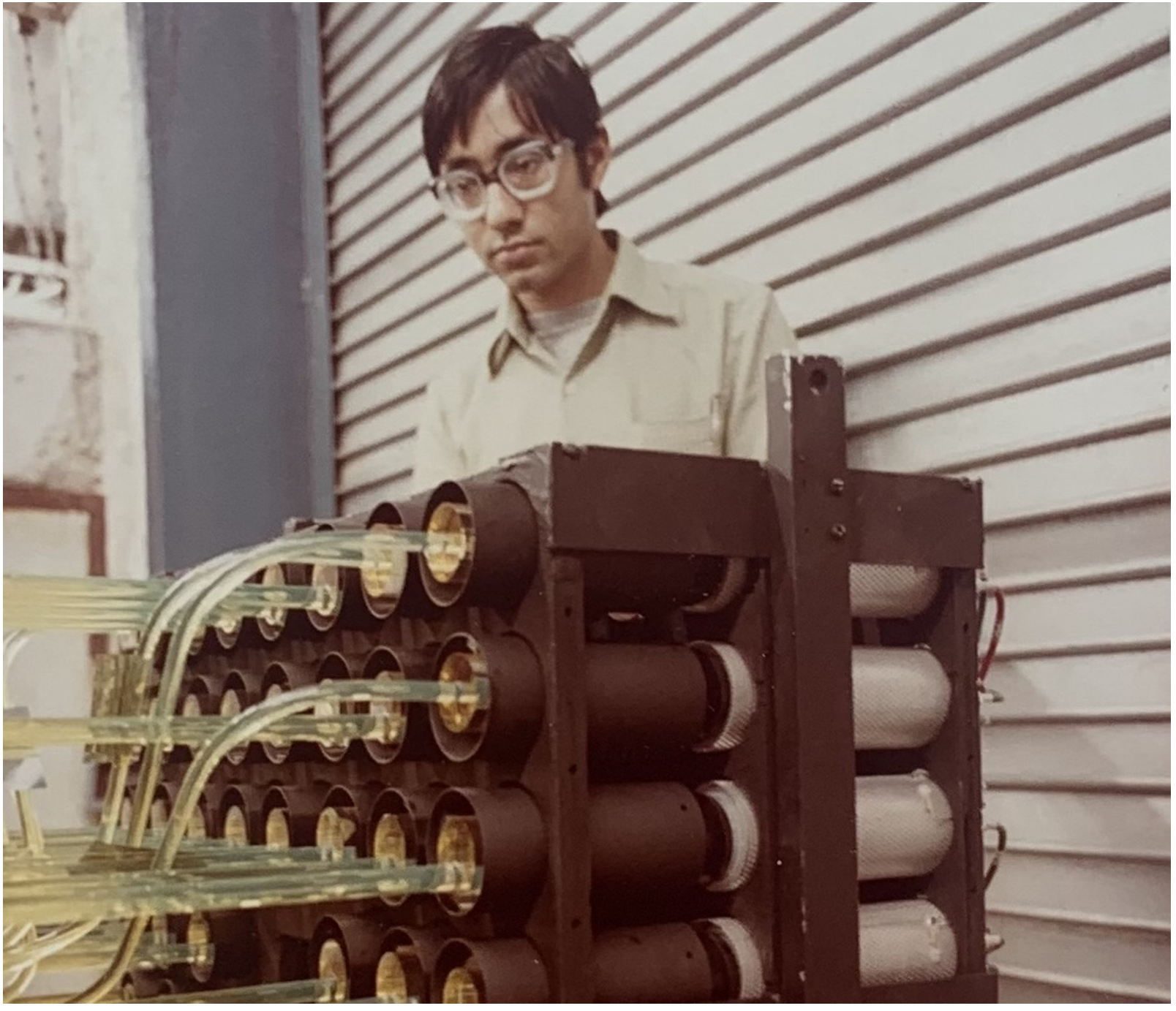
1980

SEARCH FOR VERY HIGH ENERGY
GAMMA RAYS FROM PULSARS

SUNIL K. GUPTA

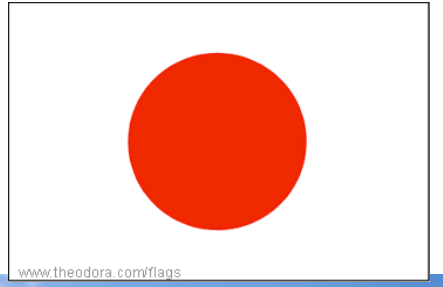
TATA INSTITUTE OF FUNDAMENTAL RESEARCH
BOMBAY, INDIA
1983

Forward Hadron Calorimeter E557/672 FermiLab 1983-1986
High P_t Jet production in p+nucleus collisions at 800 GeV



ISOMAX Magnetic Spectrometer NASA/GSFC 1996-1998
Measure the abundance of radioactive Be^{10} in cosmic rays

GRAPES-3 experiment
An India-Japan collaboration
Sunil K. Gupta



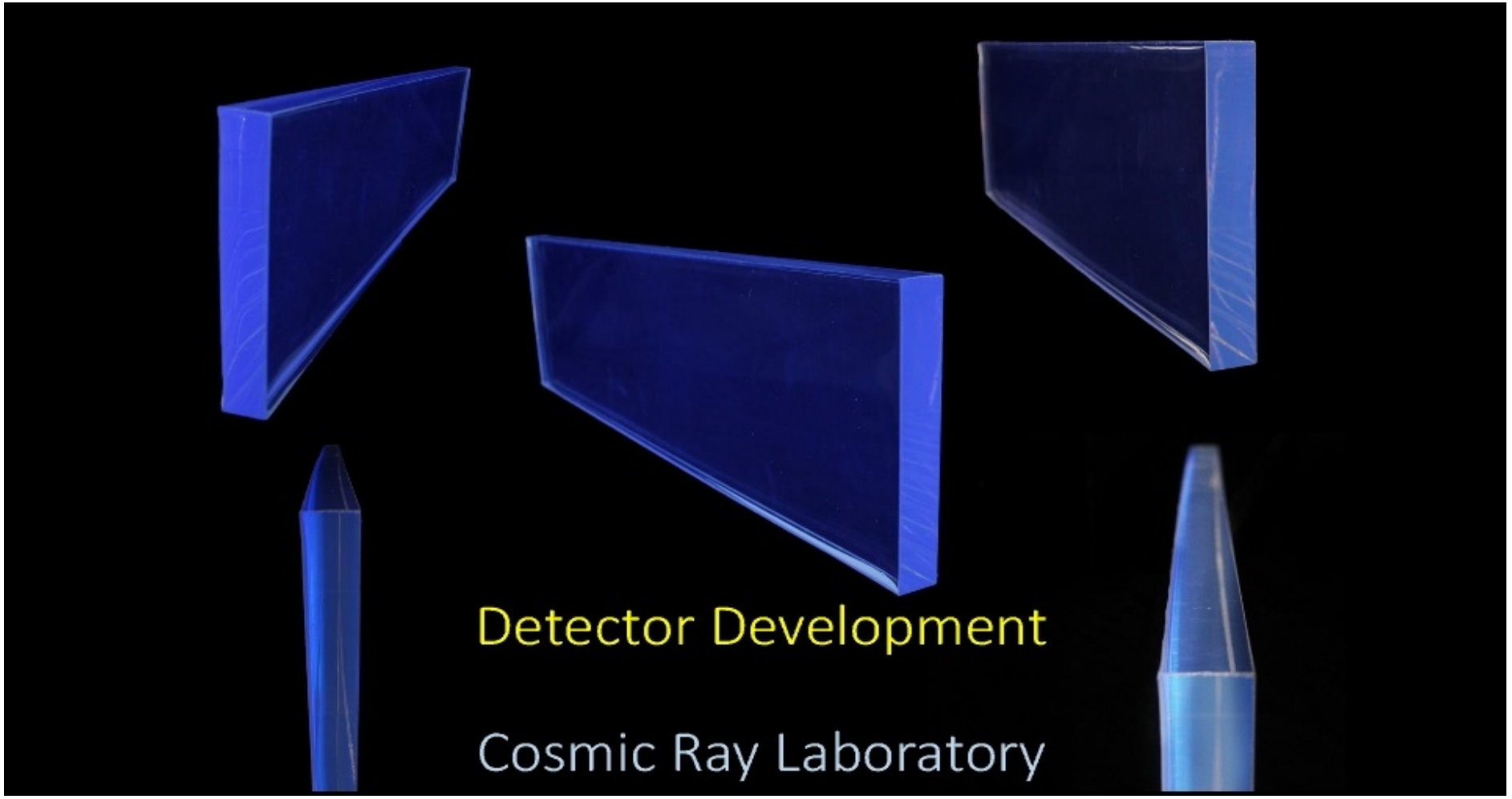
1993-Present

Plastic Scintillator (2000)
Proportional Counters (8000)
Signal processing (8000)
DAQ systems > 20
Computer Clusters (1500)

Top of GRAPES-3 Control Room constructed 1996

GRAPES-3 Experiment on Google Map

Fabrication of plastic scintillator detectors at Cosmic Ray Laboratory, Ooty



Plastic Scintillator development:

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

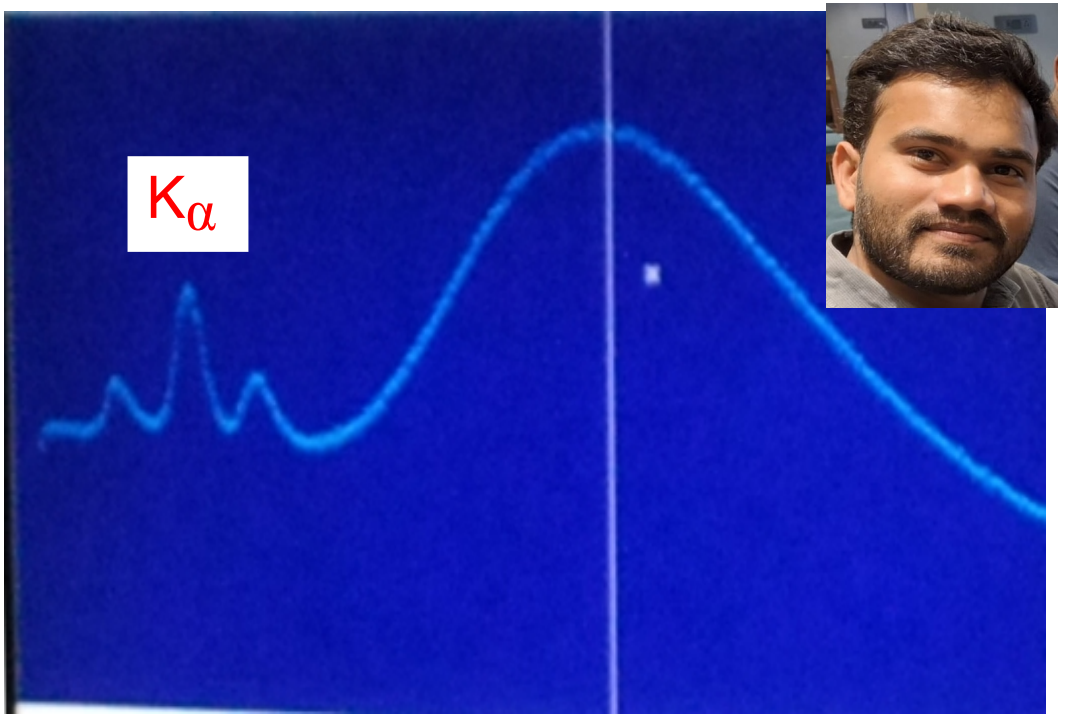
Timing 25% faster Atten. Length λ= 100cm Cost ~fraction of Bicron

Max Size 100cmX100cm Total > 2000

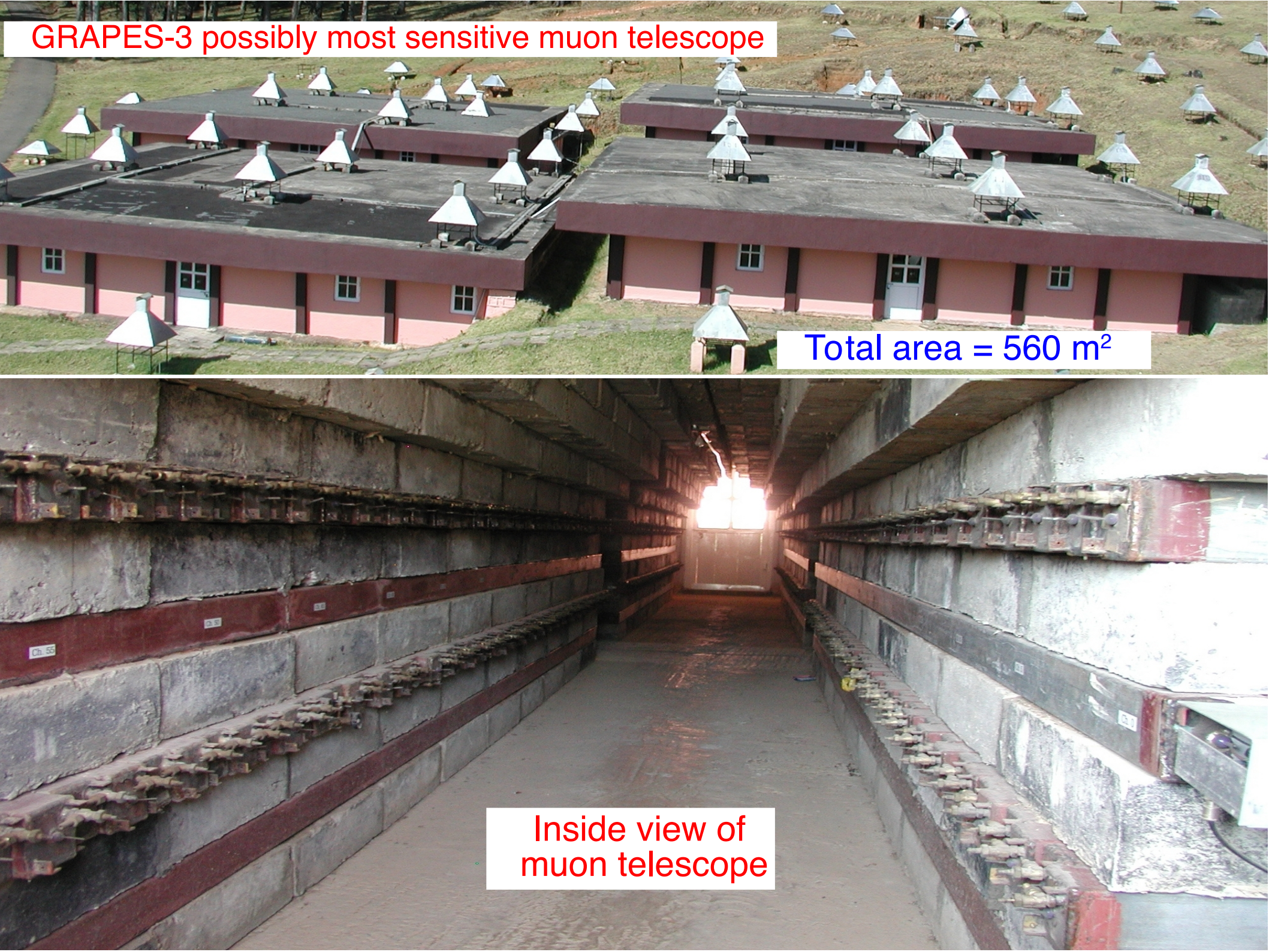
CERN, Osaka, IUAC Delhi, Bose, VECC, DEI Agra, BARC, ECIL, Utkal, BITS(H), IOP, ...

Proportional Counter (PRC) Fabrication

http://www.bbc.com/news/world-asia-india-39100109




2 May 2022


GRAPES-3 possibly most sensitive muon telescope
Total area = 560 m²
Inside view of
muon telescope

Physicists design experiments to study specific phenomenon. Sometimes unexpected surprises

1. Short-term (2 hour) weakening of Earth's magnetic field by a passing solar storm –> burst of cosmic rays. Potential to disrupt electric grids and communication satellites.

Physical Review Letter **117**, 171101 (2016)

2. 1.3 GV electric potential in a thunderstorm, energy stored >720 GJ → powered by > 2 GW thermal currents.

Physical Review Letter 122, 105101 (2019)

Physics ABOUT BROWSE PRESS COLLECTIONS Search articles

FOCUS

Muons Reveal Record-Breaking Thunderstorm Voltage

March 15, 2019 • *Physics* 12, 29

A thunderstorm probed with atmospheric muons had an electric potential exceeding one billion volts, much higher than values measured previously.

iStock.com/jerbarber

Quite a shock. Using a muon detector, researchers measured a record-breaking thunderstorm electric potential greater than 1 billion volts.

Researchers have documented a thunderstorm producing an electric potential of about 1.3 billion volts (GV), 10 times greater than the largest value ever reported. The team's new thunderstorm monitoring method makes use of the muons raining down on Earth, produced by cosmic rays hitting the atmosphere. A thundercloud's potential can reduce the energies of the charged particles and decrease the likelihood that they will be detected beneath the storm. The new measurement indicates that thunderstorms with several-billion-volt potentials are possible, voltages high enough to explain the mysterious flashes of high-energy gamma rays sometimes observed during thunderstorms.

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nature › research highlights › article

Lighting bolts sizzle over Johannesburg, South Africa. Credit: Mitchell Krog/Getty

PHYSICS · 22 MARCH 2019

Supercharged thunderstorm reaches a record 1.3 billion volts

Measurements also help to explain mysterious flashes of radiation i thunderclouds.

Thunderstorms can reach voltages recorded, a new measurement

Sunil Gupta at the and his colle storms , Mumbai, India, telescope to measure the top and bottom of a

NATIONAL GEOGRAPHIC

Lightning strikes in Casco Bay off the coast of Portland, Maine.
PHOTOGRAPH BY ROBBIE GEORGE

SCIENCE | NEWS

Most powerful electrical storm on record detected

The total charge in a single thundercloud could have powered New York City for half an hour.

BY ADAM MANN

NewScientist

Most powerful thunderstorm ever measured produced 1.3 billion volts

22

PHYSICS 20 March 2019

Thunderstorms can produce billions of volts
Enrique Diaz/7cero/Getty

By Chelsea Whyte

A thunderstorm in India produced an electric potential of 1.3 billion volts – 10 times the highest voltage previously recorded. The finding could help explain how high-energy gamma rays are produced during storms.

Science Contents News Careers Journals

Massive voltages in thunderclouds can slow down subatomic particles

By Sid Perkins | Mar. 14, 2019 , 11:50 AM

The electric potentials that build up in thunderclouds can exceed 1.3 billion volts, **about 10 times the voltages previously measured**, *Science News* reports. Besides being the driving forces for lightning, electric potentials in thunderclouds also tend to decelerate negatively charged subatomic particles known as muons, which rain down from the upper atmosphere where they are created when cosmic rays collide with gas molecules. The new finding, based on analyses of a severe thunderstorm that occurred in southern India in December 2014 and reported in a forthcoming issue of *Physical Review Letters*, **may help explain how strong storms can be a source of brief flashes of gamma rays**, researchers say.

S. Ramakrishnan

Srinivasan Ramakrishnan
Director
Tata Institute of Fundamental Research

Date March 31, 2022

T Kajita

Takaaki Kajita
Director
Institute for Cosmic Ray Research
The University of Tokyo

Date March 31, 2022

My 13-year IUPAP journey began as an Associate Member (2008-2011), Member (2011-2014), Vice-Chair (2014-2017), and Chair (2017-2021) of IUPAP Commission C4 on Astroparticle Physics.

As Chair, C4, in-person EC&CC meetings before the onset of Covid-19 pandemic. In Singapore, Vilnius and London were a great learning experience.

Interactactions with fellow 17 Commission Chairs from other disciplines (which I knew so little) was a priceless opportunity to learn & form strong bonds!

Claes Fahlander
Chair C12

(2017-2021)

Sekazi Mtingwa
Chair C13

Executive Council & Commission Chairs Meeting
Vilnius, Lithuania (30 October - 2 November 2018)

Executive Council & Commission Chairs Meeting
London, United Kingdom (1-3 October 2019)

The interactions with Executive Council during EC&CC meetings were a learning experience for me. Past President, Bruce McKellar and his encyclopedic knowledge of IUPAP rules, bye-laws & traditions made interactions memorable.

Late President, Kennedy Reed, with thoughtful, generous temperament was a great leader and role model that I could not but greatly admire. Renaming Kennedy Reed medal for enhancing physics in developing countries is a fitting tribute.

And then there is the infinitely resourceful and dynamic President-designate and then President, Michel Spiro who I came to know and learn so much from over the course of past seven years (IYBSSD, AC5, WG16...)

Silvina

Monica

Laura

Interaction with Silvina Ponce Dawson, Monica Pepe-Altatelli, Laura Greene, enlightened me to the systemic discrimination of female scientists, justified the need for rectification based on data gathered across continents.

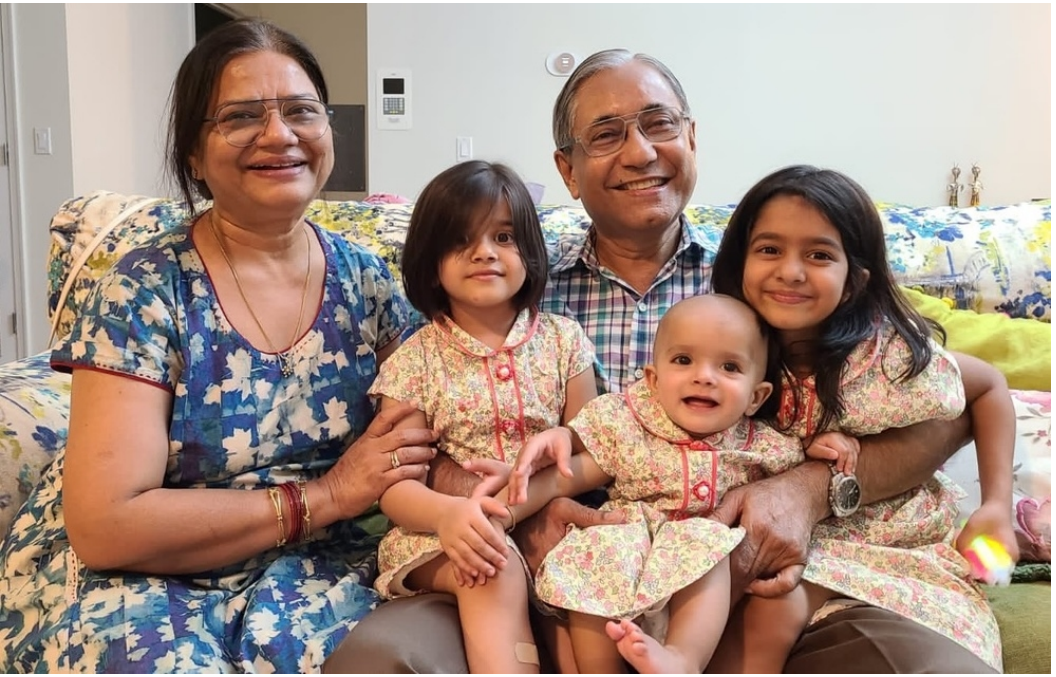
As Chair, C4 we proactively sought nominations of female scientists for the IUPAP Early Career (IEC) Prizes in 2019 and 2021, 3 out 4 IEC Prizes went to female colleagues!

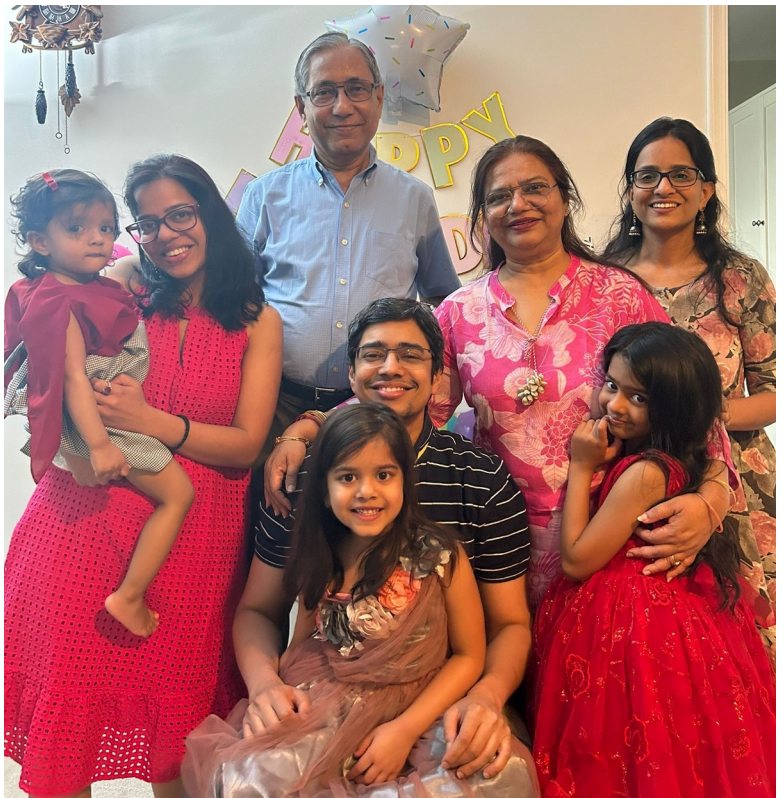
Working with the IUPAP Secretariat especially during the Centenary Celebrations of the founding of IUPAP in 2022 and representing Asia-Pacific region was a memborable experience. I would like to recall the role of Mihoko Nojiri, Kwek Leong Chuan, Kuijuan Jin, Jens Vigen, Stefano Fantoni, Sandro Scandolo, Rudzani Nemutudi, Gabriella, Cecilia, Anna Lisa.....



Nupur Gupta







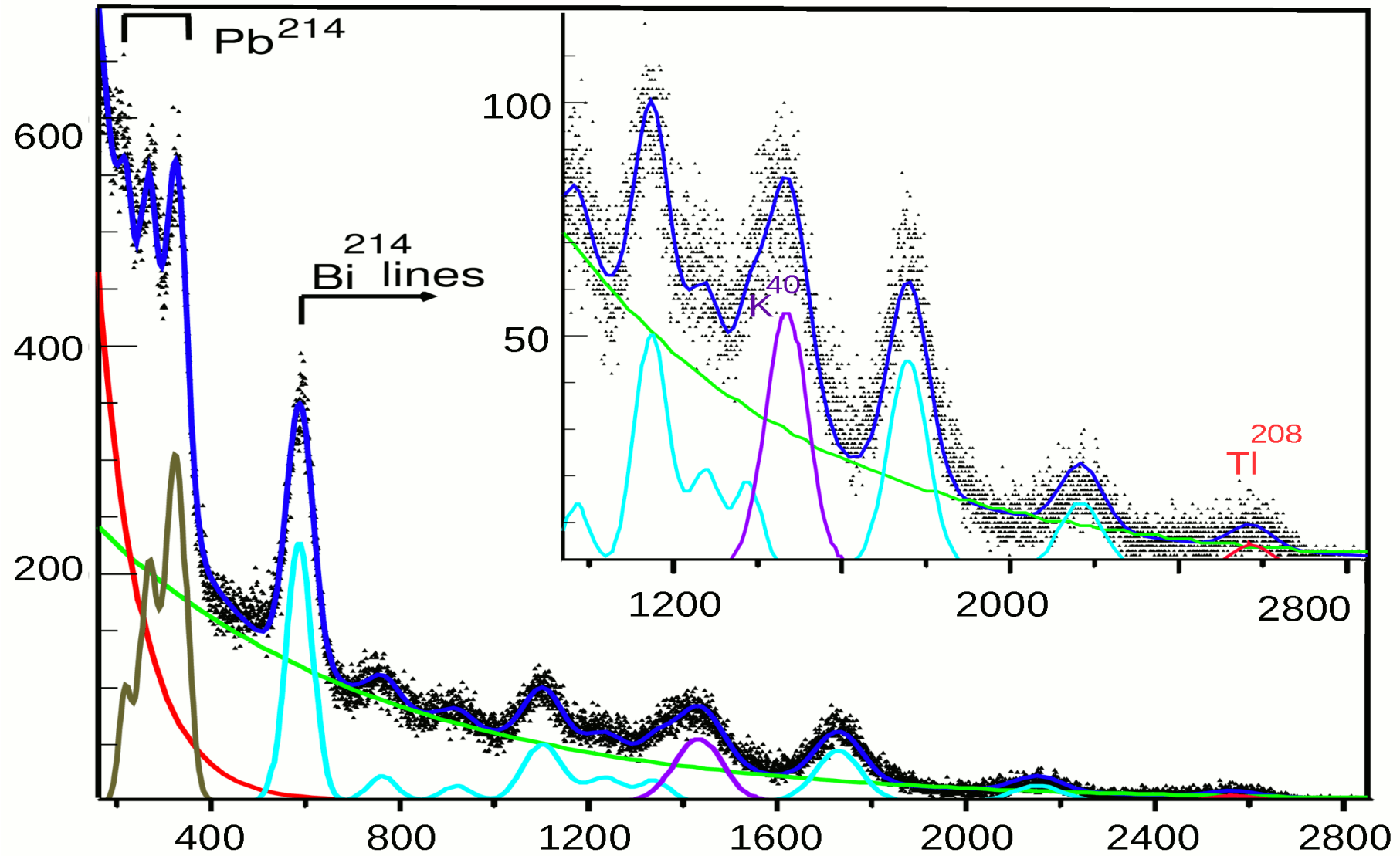
$_{92}U^{238}$ —α, 4.5x10⁹ Y→ $_{90}Th^{234}$ —β, 24.1 d→ $_{91}Pa^{234}$ —β, 70.2 s→ $_{92}U^{234}$ —α, 2.5x10⁵ Y→ $_{90}Th^{230}$ —α, 7.5x10⁴ Y→ $_{88}Ra^{226}$ —α, 1600 Y→ $_{86}Rn^{222}$

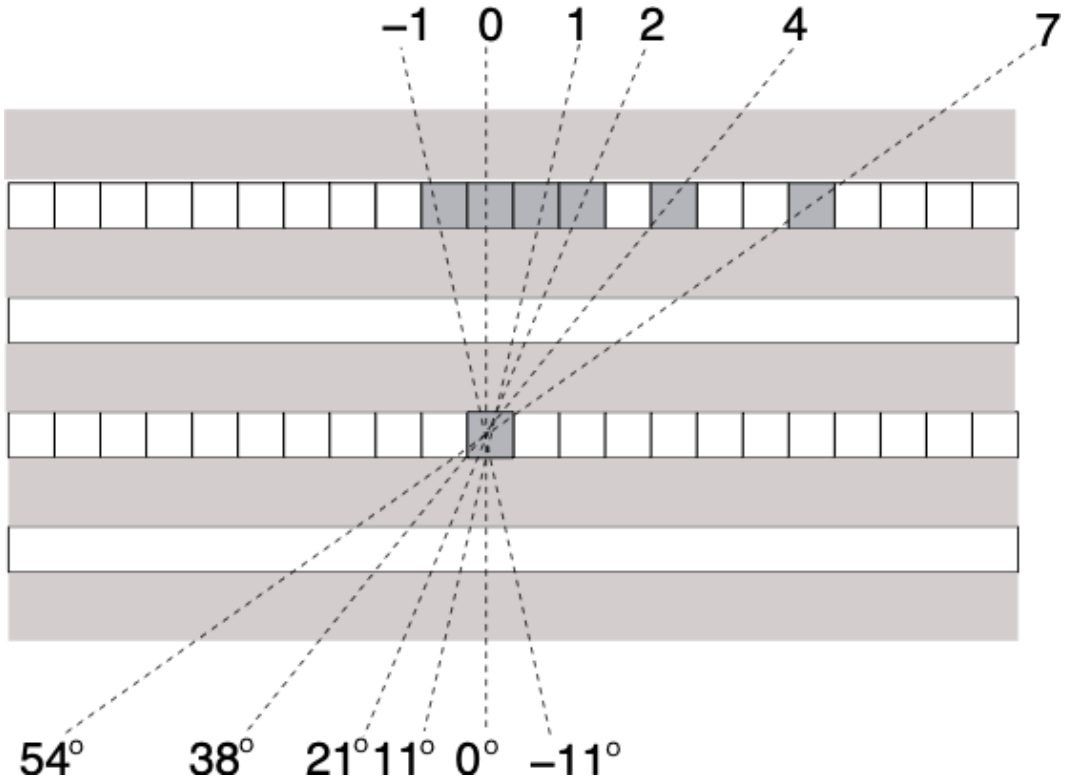
$T_{1/2}$

$_{86}Rn^{222}$ —α, 3.82 d→ $_{84}Po^{218}$ —α, 3.1 d→ $_{82}Pb^{214}$ —β,γ, 26.8 min→ $_{83}Bi^{214}$ —β,γ, 19.9 min→ $_{84}Po^{214}$

1 in 100,000,000,000,000,000,000

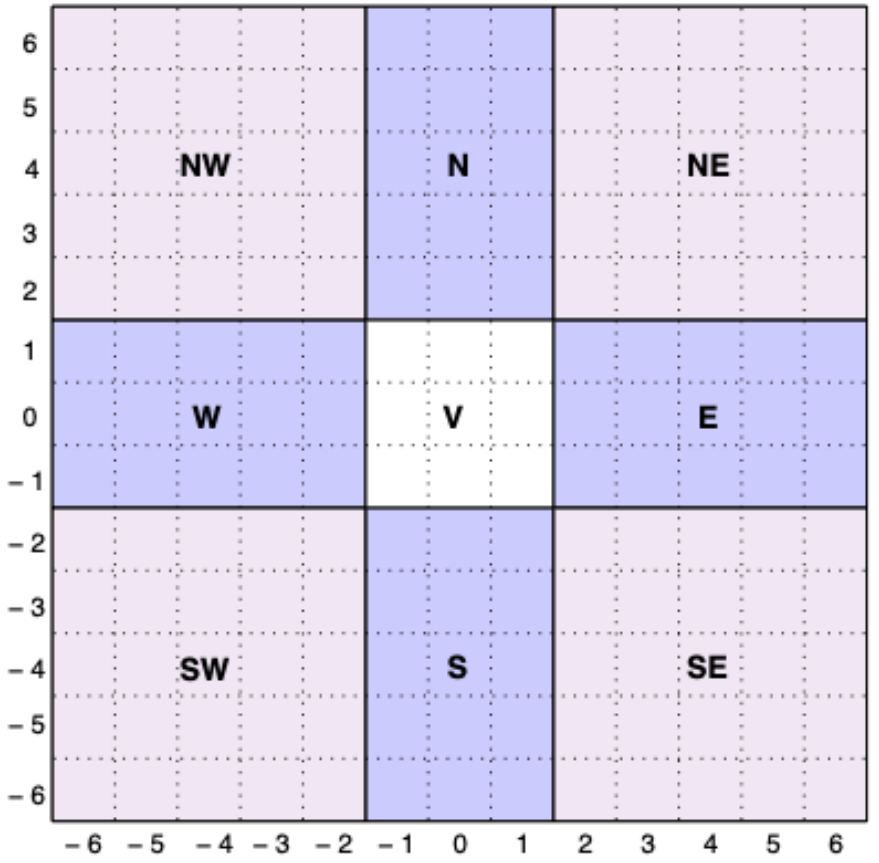
STORY OF THE EARTH

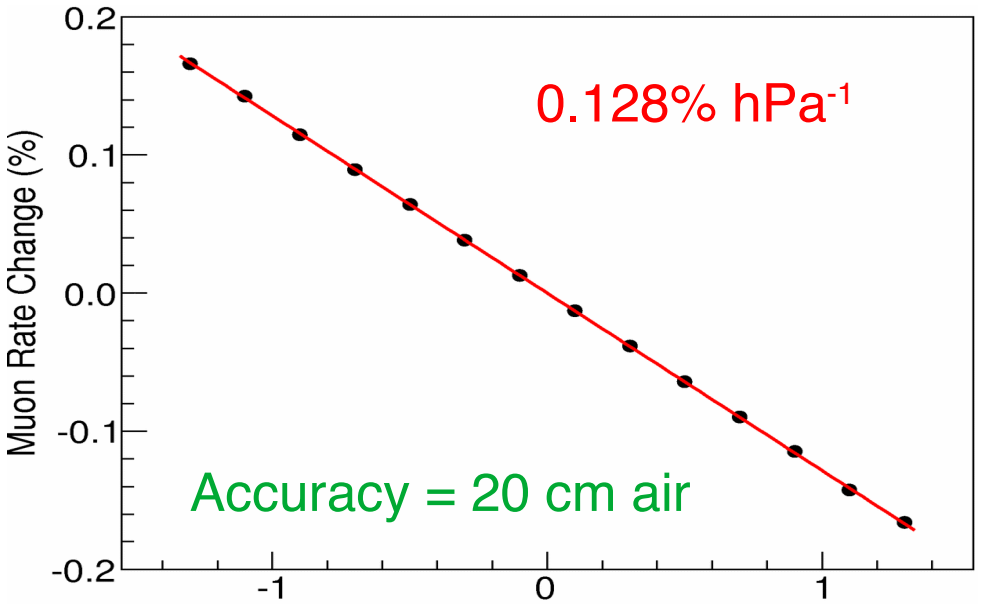


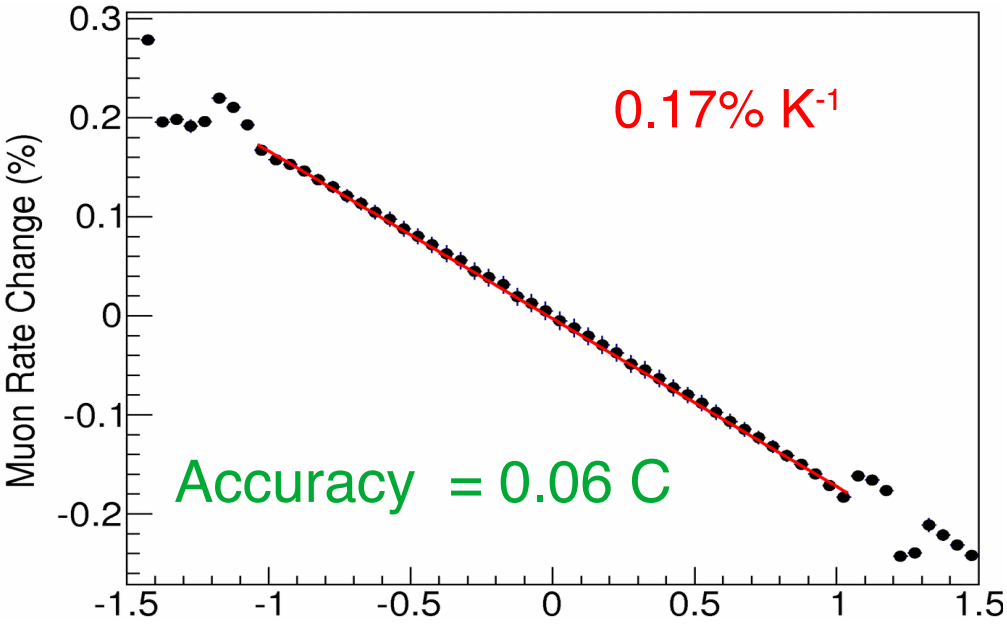


Muon Direction Reconstruction

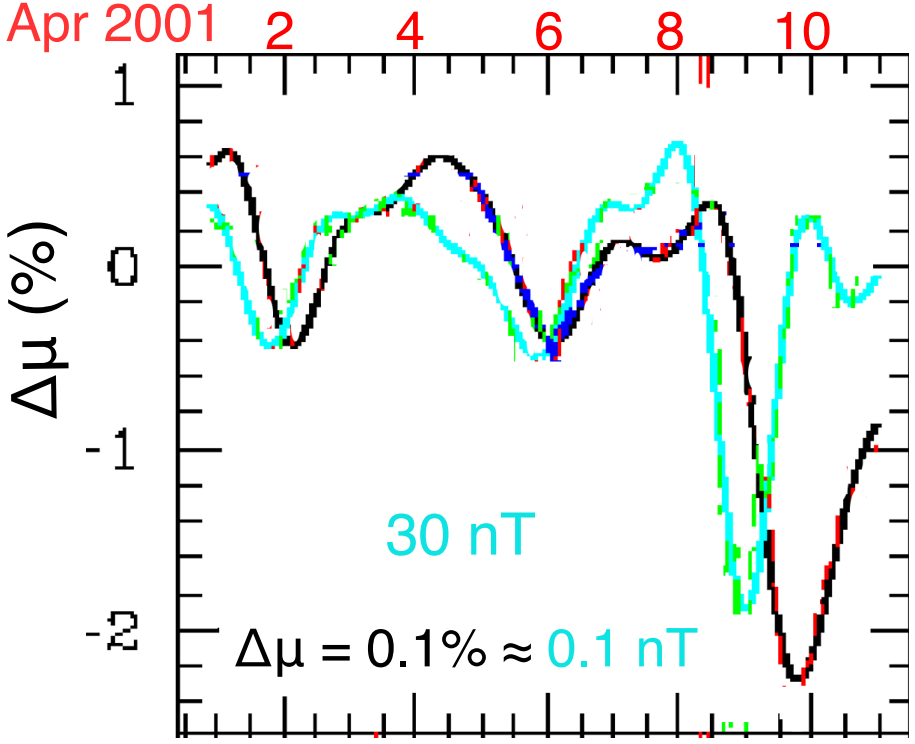
Field of View = 2.3 sr







Sensitivity of muons to IMF



GRAPES-3 is uniquely sensitive instrument;

1. Barometer (20 cm air column / 1/2000 BP)
2. Thermometer (0.06 K)
3. IMF magnetometer (0.1 nT = 10^{-6} GMF)
4. Atmospheric Voltmeter (GV electric potential)
5. Atmospheric ammeter (1 fA; ΔI=1 AA=10^{-18} A)

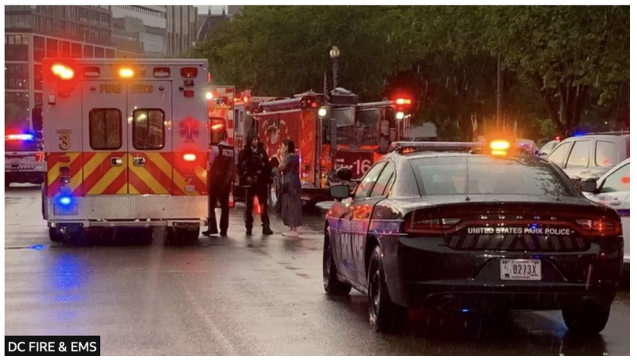
- There is good reason to study thunderstorms because they are the leading cause of death by a natural phenomenon across the globe;
- For example in India ~2000 people die every year due to lightning strikes and especially during thunderstorm season
- Worldwide several tens of thousands lives are lost due to thunderstorms

BBC

NEWS

Three dead after lightning strike near White House

6 August 2022



An elderly couple from Wisconsin are among three dead after they were struck by lightning near the White House in Washington DC, police say.

James Mueller, 76, and Donna Mueller, 75, were visiting the US capital to celebrate their 56th wedding anniversary, their niece said.

On Friday, an unnamed 29-year-old man injured in the strike also died. A fourth person was critically injured.

The victims were in Lafayette Park in a storm on Thursday when they were hit.

Bihar: Lightning strikes kill 20 in Indian state

27 July

Hundreds die in India every year in lightning incidents during monsoon rains

Lightning strikes have killed 20 people across eight districts of the eastern Indian state of Bihar in just 24 hours.

More thunderstorm with lightning has been forecast in northern parts of the state for Wednesday and Thursday.

EXPERIMENTS

AND

OBSERVATIONS

ON

ELECTRICITY,

MADE AT

Philadelphia in *America*,

BY

Mr. BENJAMIN FRANKLIN,

AND

Communicated in feveral Letters to Mr. P. COLLINSON, of *London*, F. R. S.

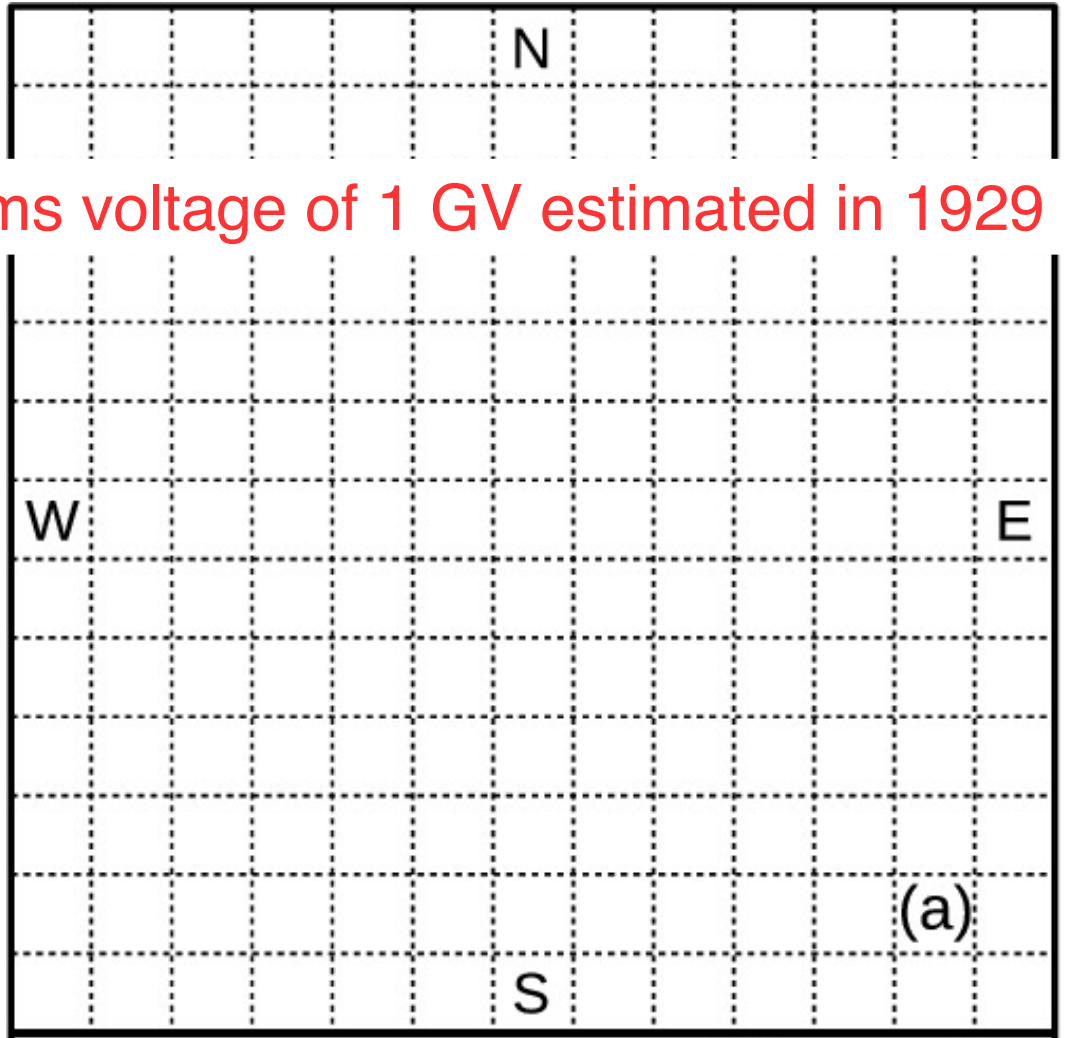
L O N D O N:

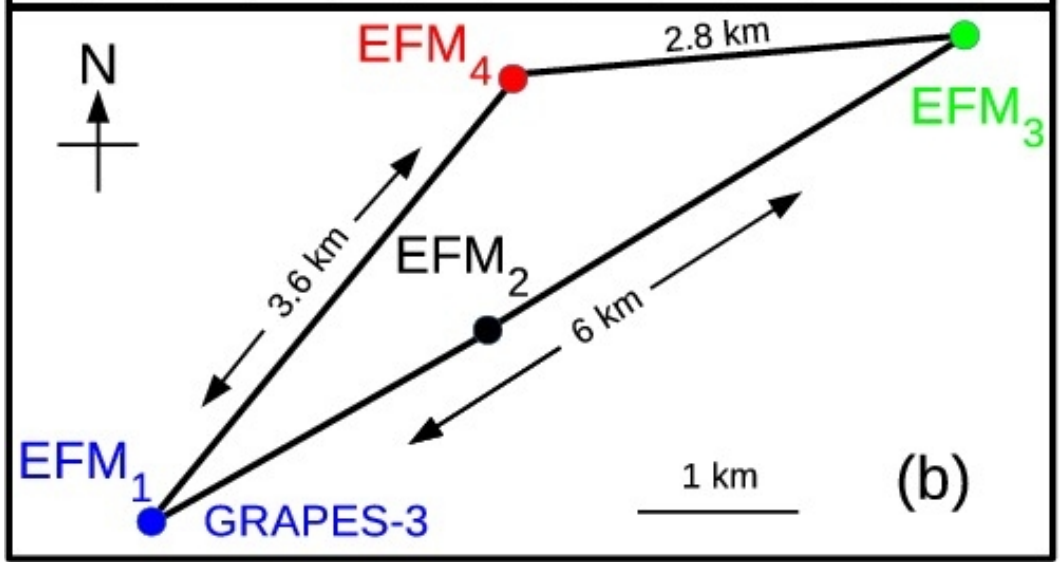
Printed and fold by E. CAVE, at *St. John's Gate.* 1751.

(Price 2s. 6d.)

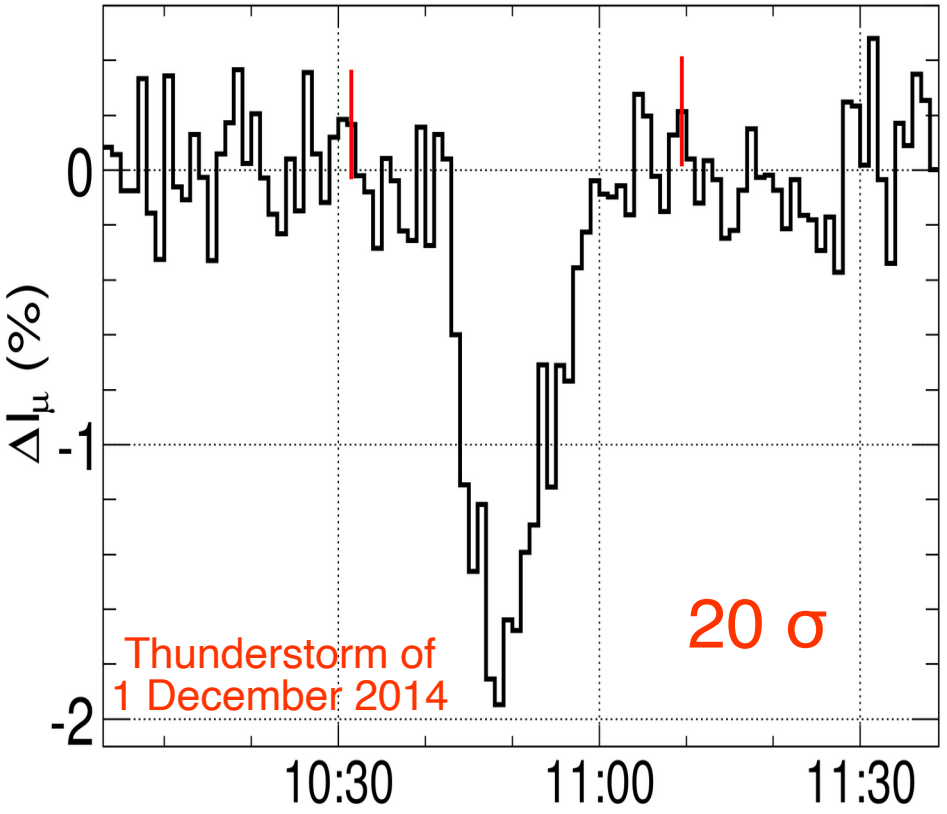
1740s: Benjamin Franklin
Electrical experiments

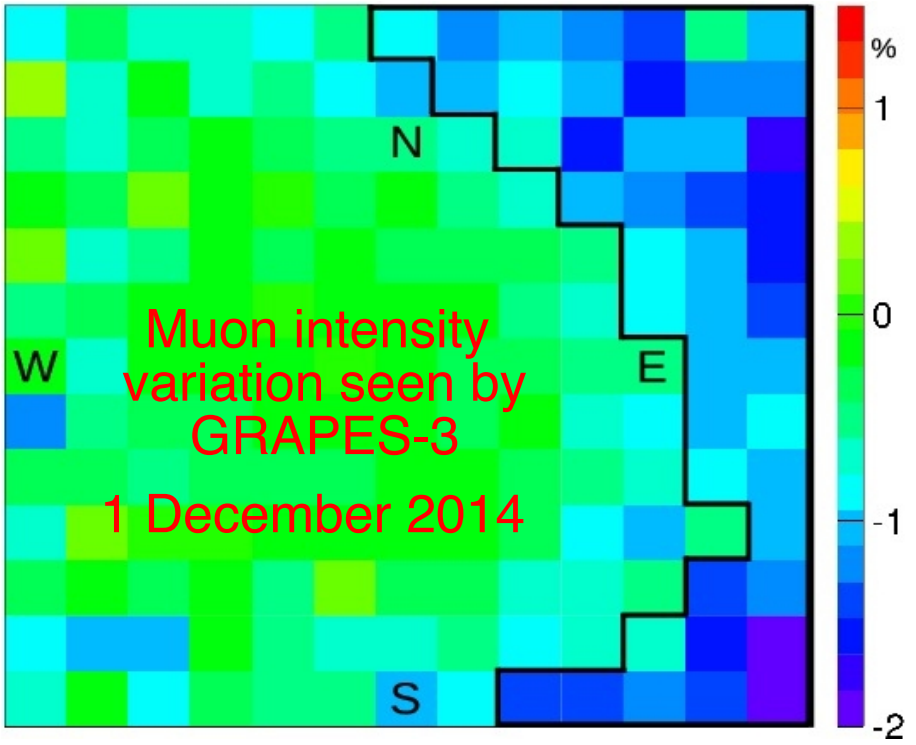
A thunderstorms voltage of 1 GV estimated in 1929 by C.T.R. Wilson

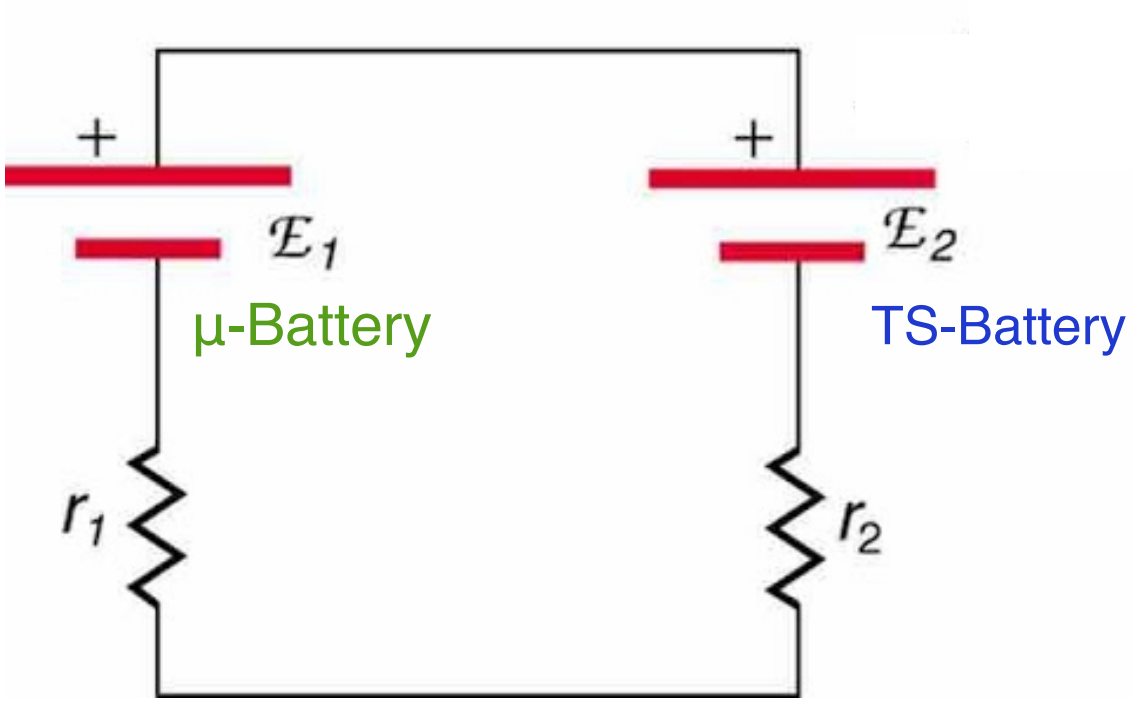




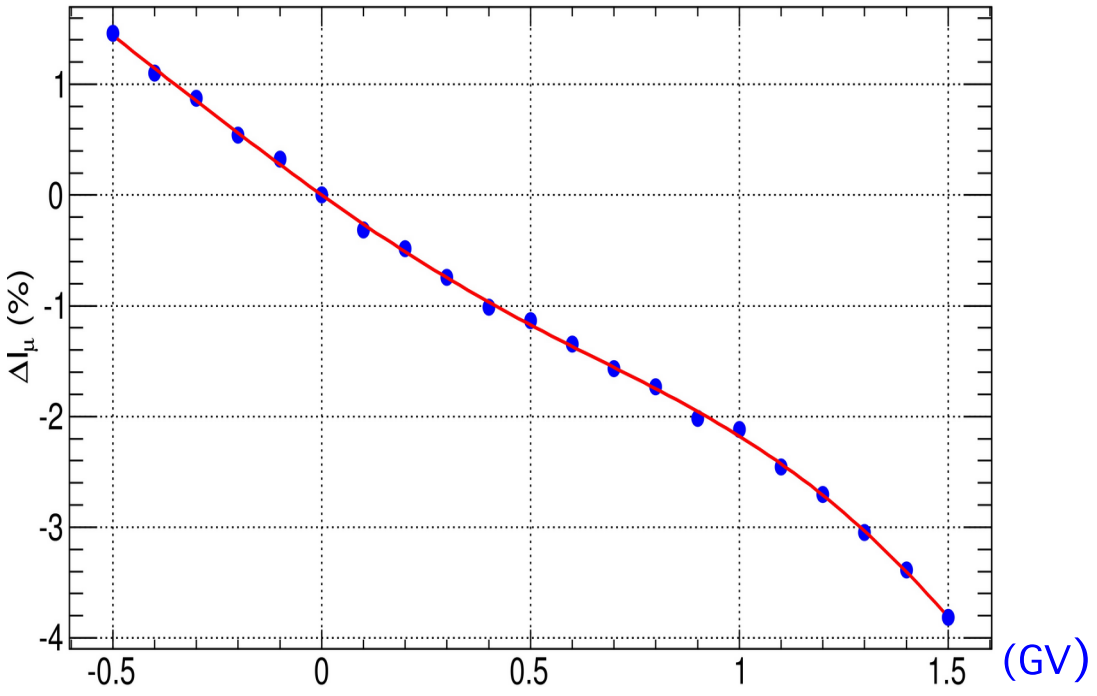
0.13 GV 2000





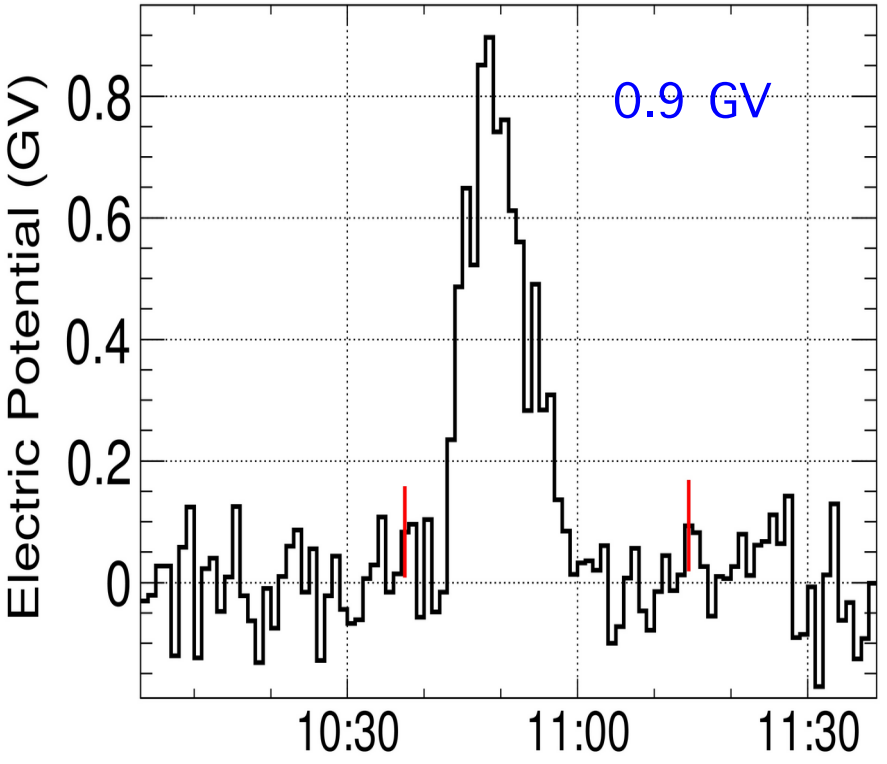


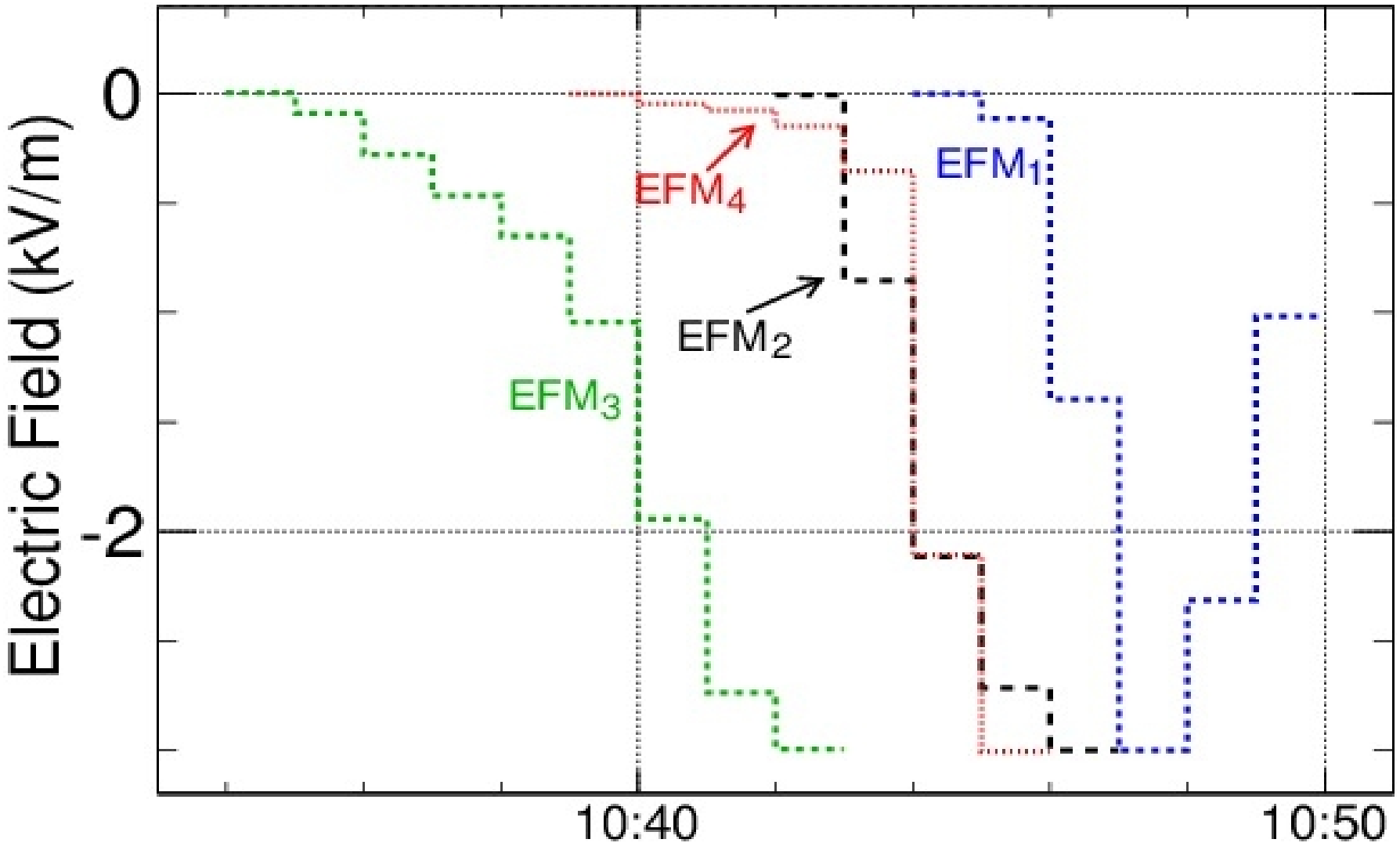
$I_1 = E_1/(r_1+r_2)$
$I_2 = (E_1-E_2)/(r_1+r_2)$
$\Delta I = E_2/(r_1+r_2)$
$E2 = \Delta I \times (r_1+r_2)$

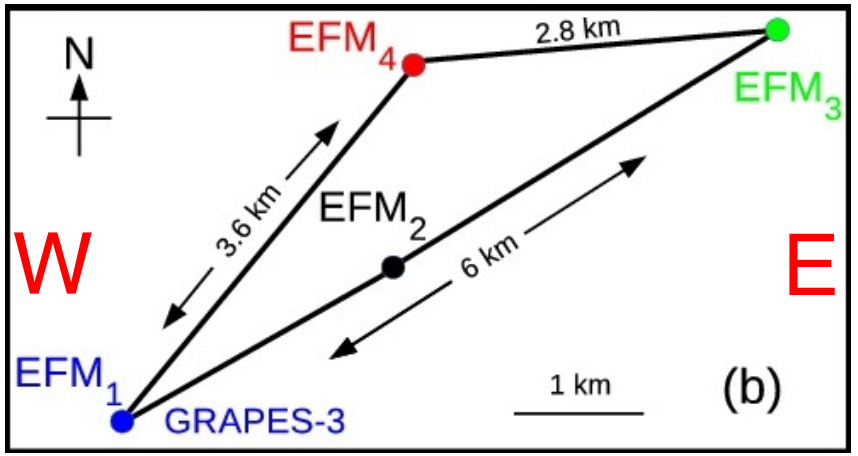


Equivalent Ohm's law

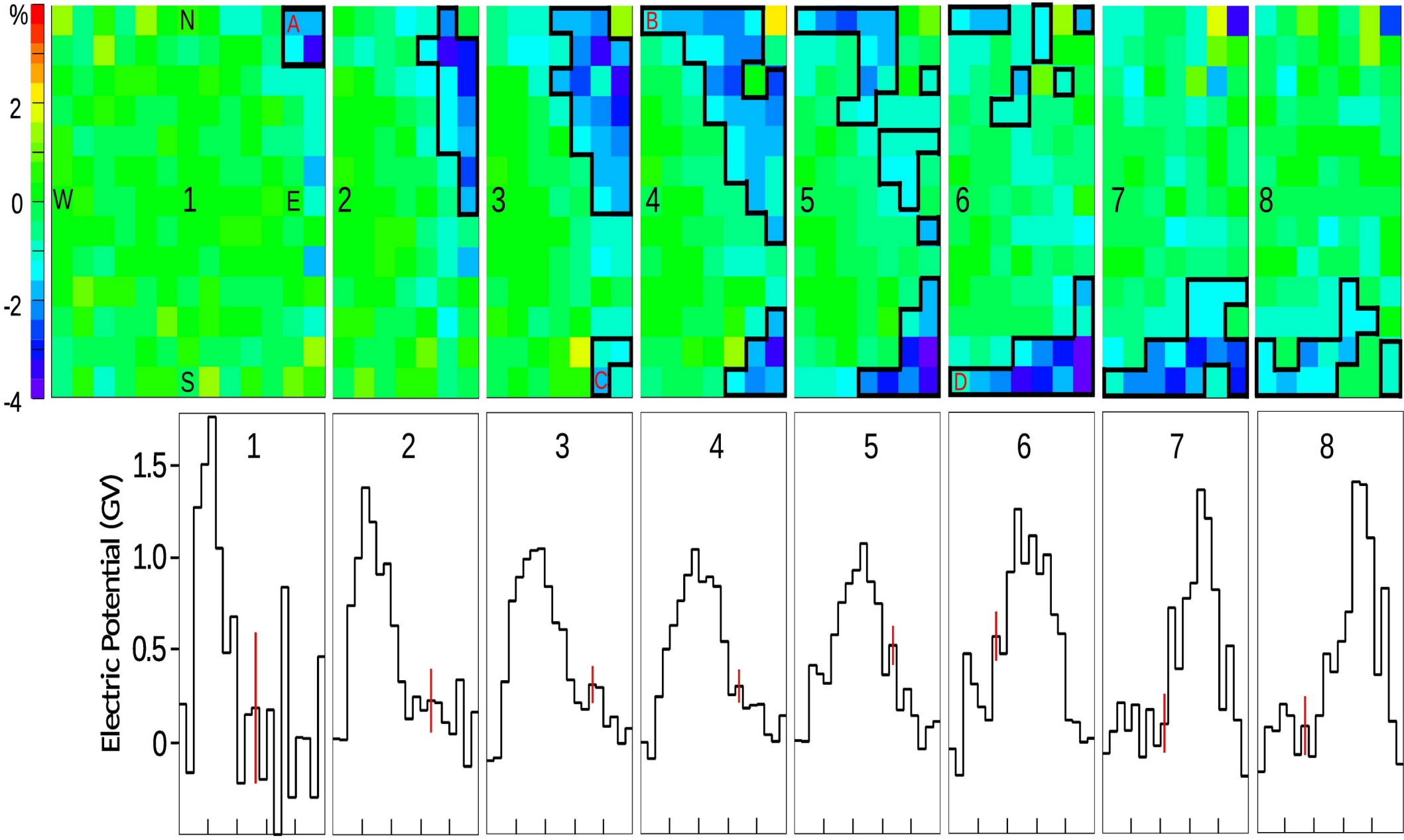
Phys. Rev. Lett. **122,** 105101 (2019)







6 km travel in 6 min
speed = 60 km h^{-1}



PRL, **122,** 105101(2019)

Mean = 1.3 GV

Charging Time = 6 min

Angular velocity = 6.2^{O} min^{-1}

Properties of 1 December 2014 Thunderstorm

(1) Electric potential of December 1, 2014 event = 1.3 GV
previously reported maximum = 0.13 GV.
Consistent with prediction of C.T.R. Wilson of 90 years ago.

(2) Gigavolt potentials can explain production of high-energy γ-rays in TGFs discovered by over 25 years back.

(3) Moving at a speed of 60 km h^{-1} near the top of the troposphere possibly carried by the westerly Jet stream.

(4) Area~400 $km^{2,}$ Charge stored ≥ 1100C Power ≥ 2 GW
Energy stored ~ 720 GJ → Mumbai or Nagoya for ~ 1h
Biggest nuclear reactor/ hydroelectric/ thermal generator

Editors' Suggestion | Featured in Physics

Measurement of the Electrical Properties of a Thundercloud Through Muon Imaging by the GRAPES-3 Experiment

B. Hariharan,[1,2] A. Chandra,[1,2] S. R. Dugad,[1,2] S. K. Gupta,[1,2,*] P. Jagadeesan,[1,2] A. Jain,[1,2] P. K. Mohanty,[1,2] S. D. Morris,[1,2] P. K. Nayak,[1,2] P. S. Rakshe,[1,2] K. Ramesh,[1,2] B. S. Rao,[1,2] L. V. Reddy,[1,2] M. Zuberi,[1,2] Y. Hayashi,[2,3] S. Kawakami,[2,3] S. Ahmad,[2,4] H. Kojima,[2,5] A. Oshima,[2,5] S. Shibata,[2,5] Y. Muraki,[2,6] and K. Tanaka[2,7]

(GRAPES-3 Collaboration)

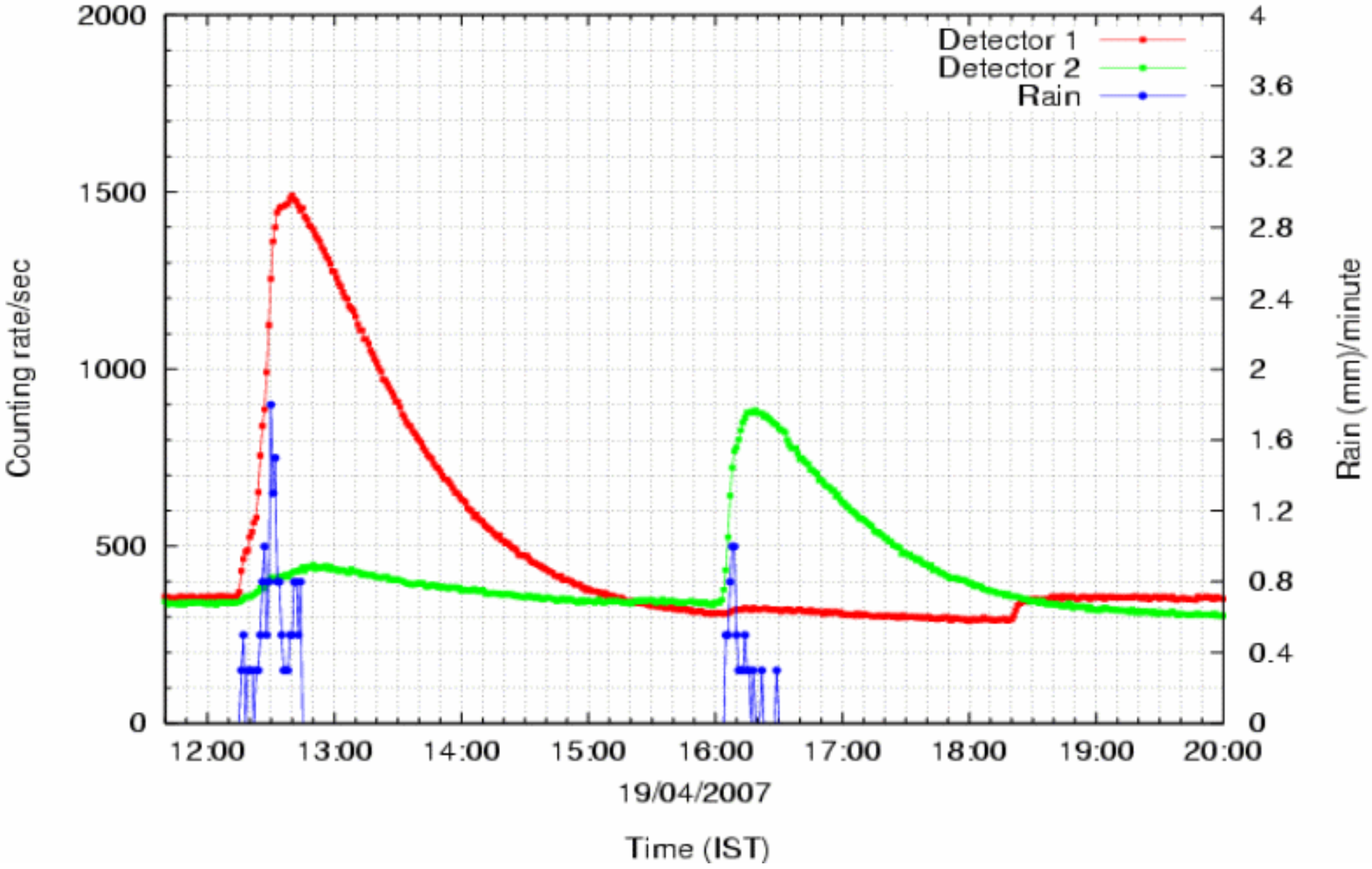
[1]*Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400005, India*
[2]*Cosmic Ray Laboratory, Raj Bhavan, Ooty 643001, India*
[3]*Graduate School of Science, Osaka City University, Osaka 558-8585, Japan*
[4]*Aligarh Muslim University, Aligarh 202002, India*
[5]*College of Engineering, Chubu University, Kasugai, Aichi 487-8501, Japan*
[6]*Institute for Space-Earth Environmental Research, Nagoya University, Nagoya, Aichi 446-8601, Japan*
[7]*Graduate School of Information Sciences, Hiroshima City University, Hiroshima 731-3194, Japan*

(Received 6 January 2019; revised manuscript received 21 January 2019; published 15 March 2019)

The GRAPES-3 muon telescope located in Ooty, India records rapid (~10 min) variations in the muon intensity during major thunderstorms. Out of a total of 184 thunderstorms recorded during the interval of April 2011–December 2014, the one on December 1, 2014 produced a massive potential of 1.3 GV. The electric field measured by four well-separated (up to 6 km) monitors on the ground was used to help estimate some of the properties of this thundercloud, including its altitude and area that were found to be 11.4 km above mean sea level and ≥ 380 km^2, respectively. A charging time of 6 min to reach 1.3 GV implied the delivery of a power of ≥ 2 GW by this thundercloud that was moving at a speed of ~60 km h^{-1}. This work possibly provides the first direct evidence for the generation of gigavolt potentials in thunderclouds that could also possibly explain the production of highest-energy (100 MeV) gamma rays in the terrestrial gamma-ray flashes.

DOI: 10.1103/PhysRevLett.122.105101

Radioactivity in rain water, using scintillators.



1. The Cosmic Ray Laboratory (CRL) at Ooty was set up by the Tata Institute of Fundamental Research (TIFR) as a field station nearly 69 years back. CRL is home to India's largest cosmic ray experiment GRAPES-3.

2. The research in CRL has become a multi-disciplinary, and multi-institutional activity in astroparticle physics, including atmospheric physics, solar physics, space weather, galactic and extragalactic cosmic ray physics, gamma-ray astronomy.

3. In recognition of these unique capabilities, the Council of Management of TIFR has approved the upgrade of CRL into National Cosmic Ray Centre (NCRC) to serve as a centre of excellence in astroparticle physics in India.

Summary

1. Ooty with its near equatorial location is a unique site
2. Development of new detector and analysis techniques bode well for a bright future
3. Based on successful past this India-Japan collaboration is poised for glorious scienctific discoveries