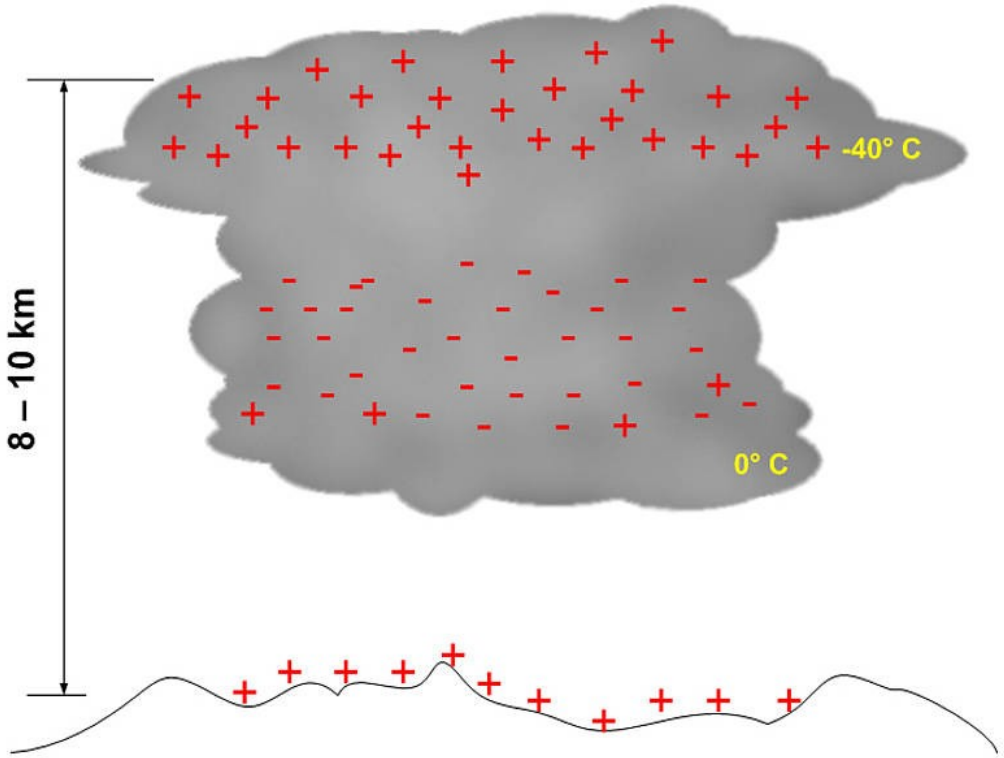
The azimuthal distribution of thunderstorm events recorded by the GRAPES-3 experiment

B. Hariharan, GRAPES-3, TIFR

PoS(ICRC2021)378

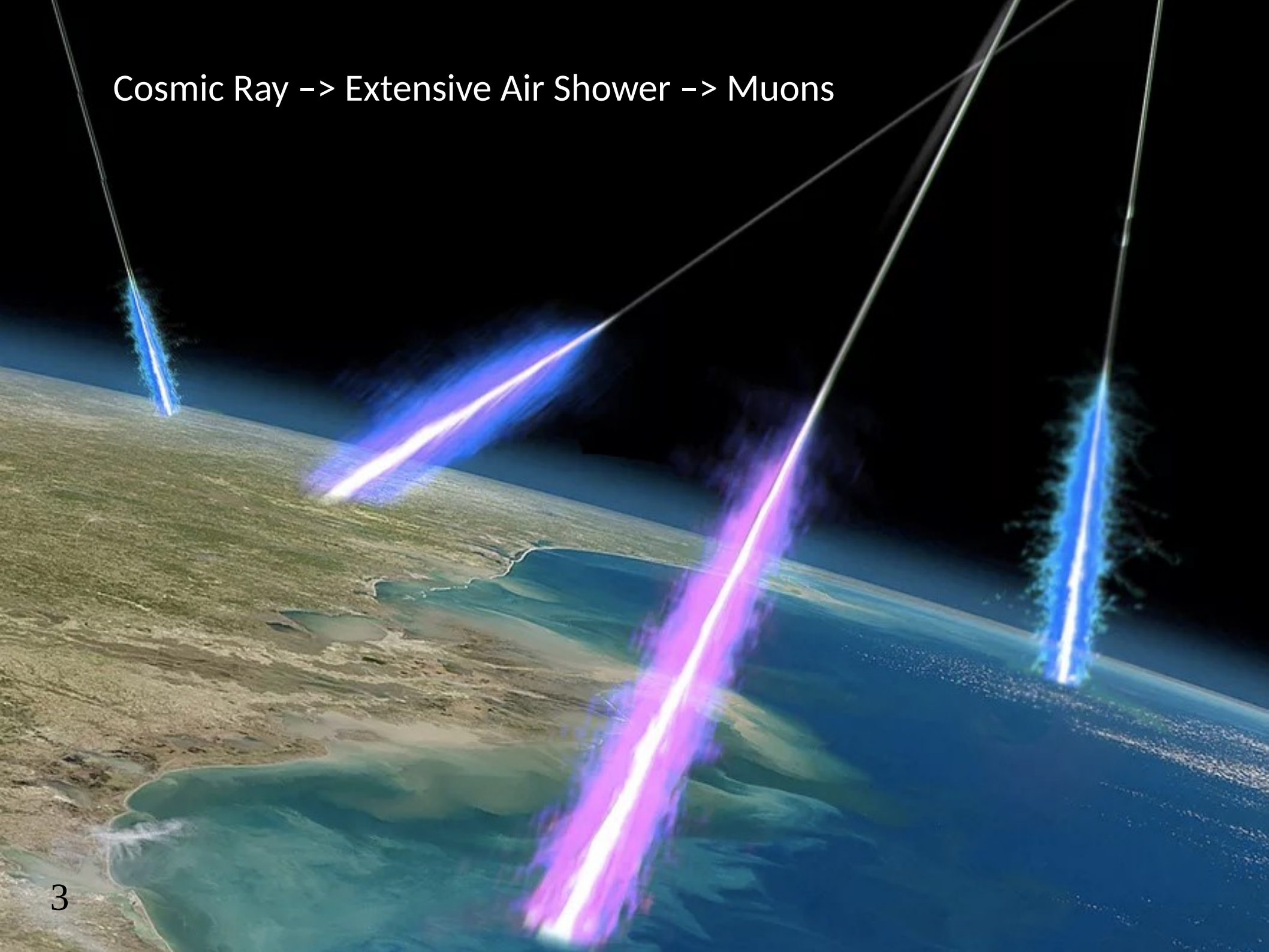
Thunderstorm



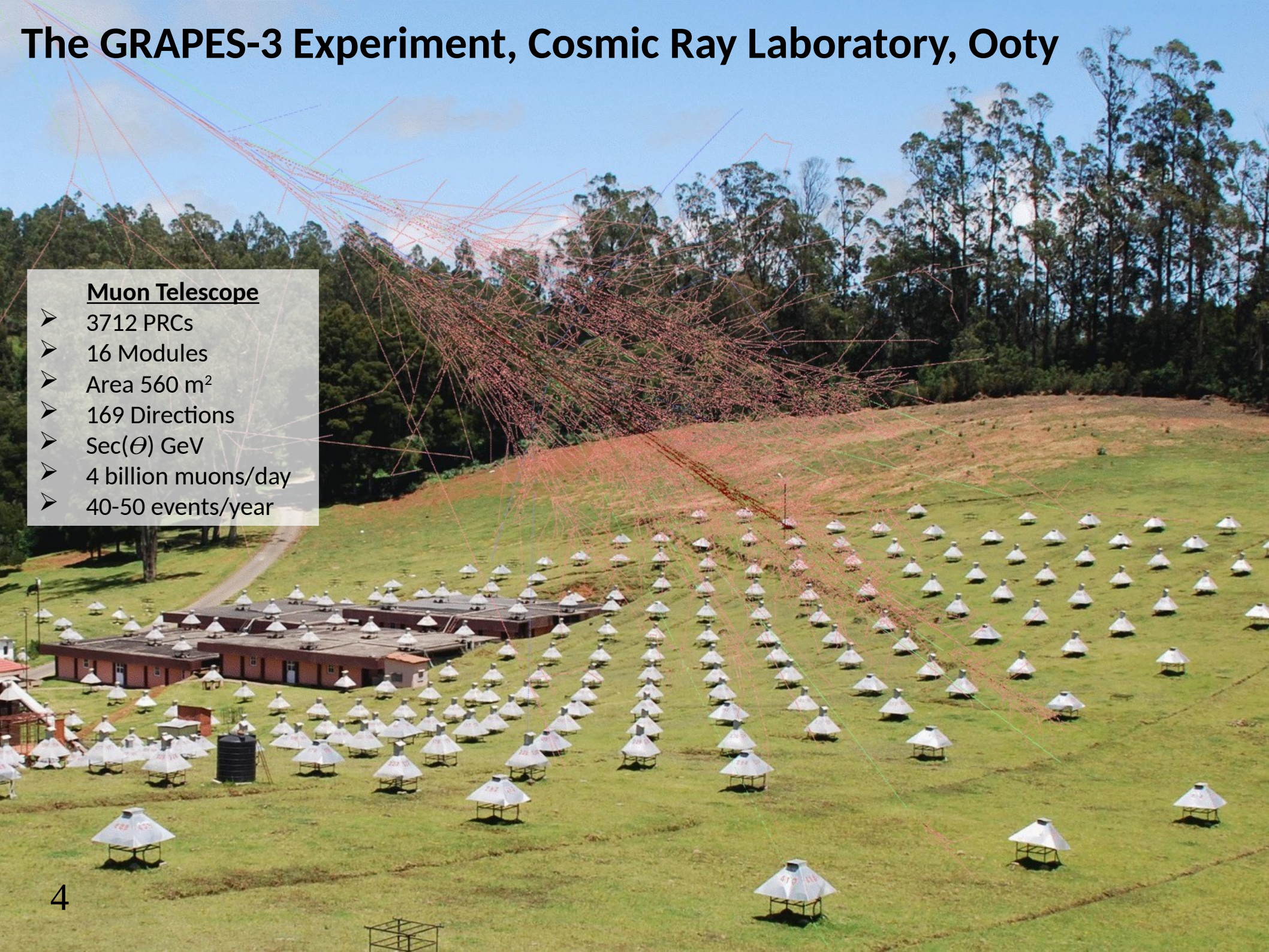
Dipolar structure (actual structure is complex)

V >1 billion volts (predicted by C.T.R. Wilson 90 years ago)

Measurements?


Cosmic Ray –> Extensive Air Shower –> Muons

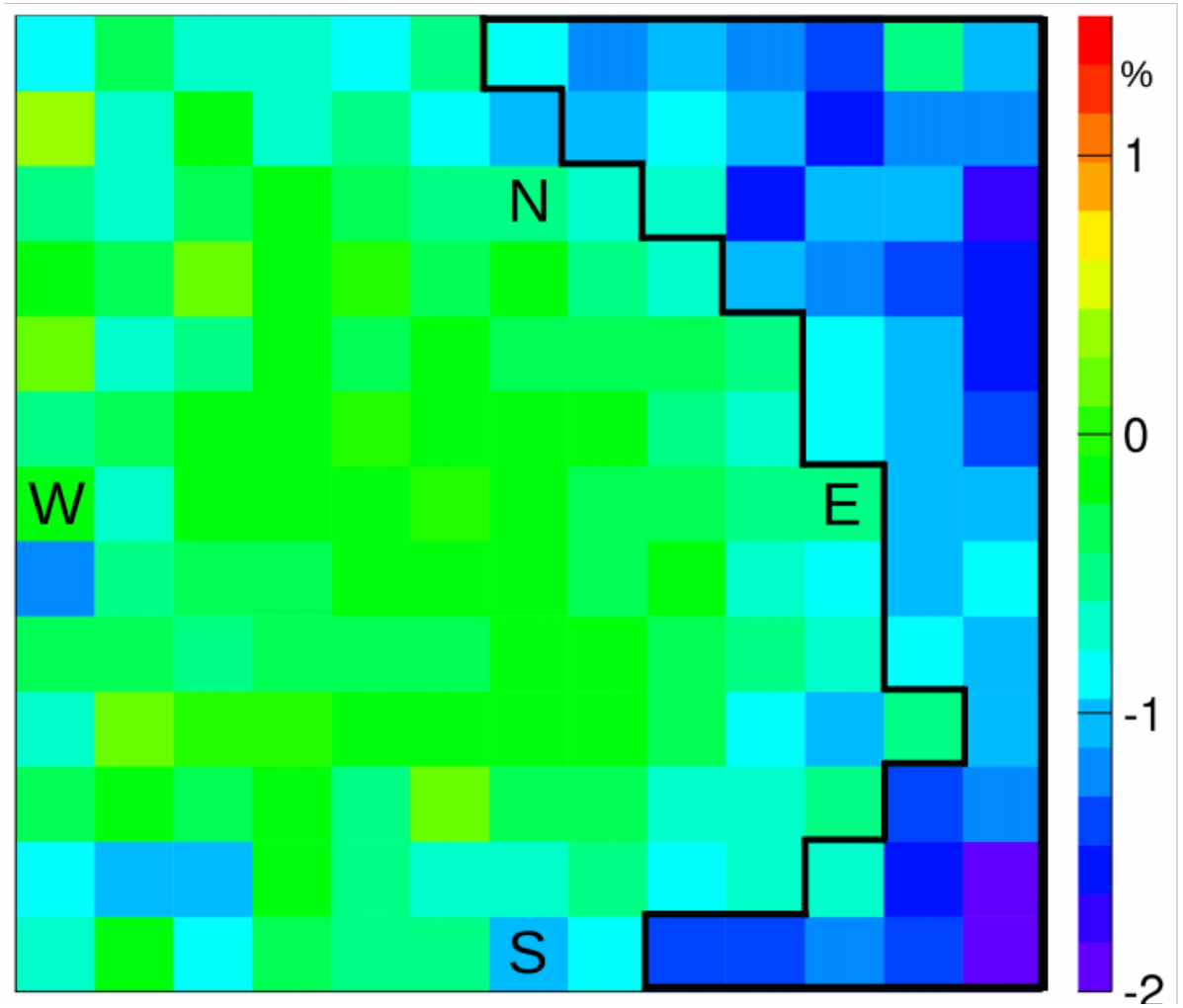
The GRAPES-3 Experiment, Cosmic Ray Laboratory, Ooty



Muon Telescope

- 3712 PRCs
- 16 Modules
- Area 560 m^2
- 169 Directions
- Sec(θ) GeV
- 4 billion muons/day
- 40-50 events/year

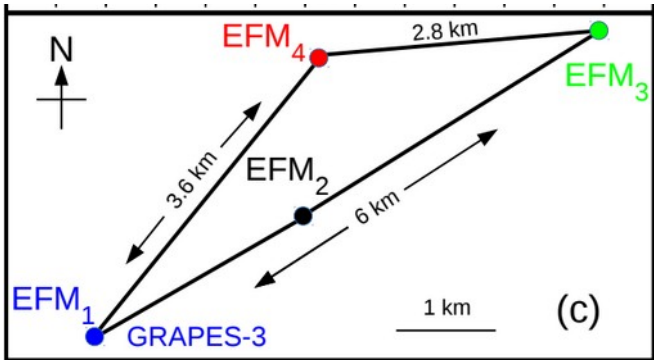
Muon image of event 1st Dec 2014

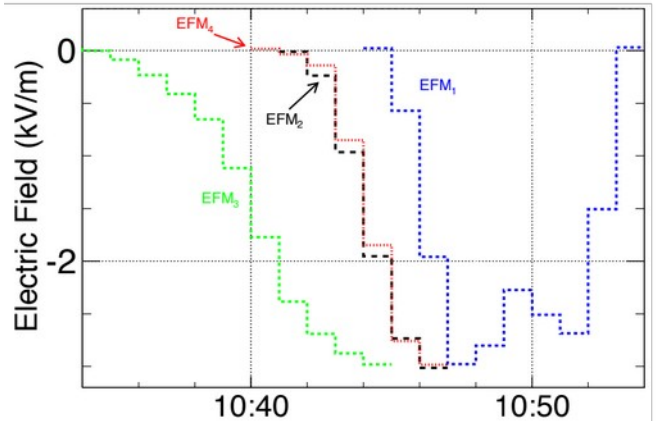


18 minutes

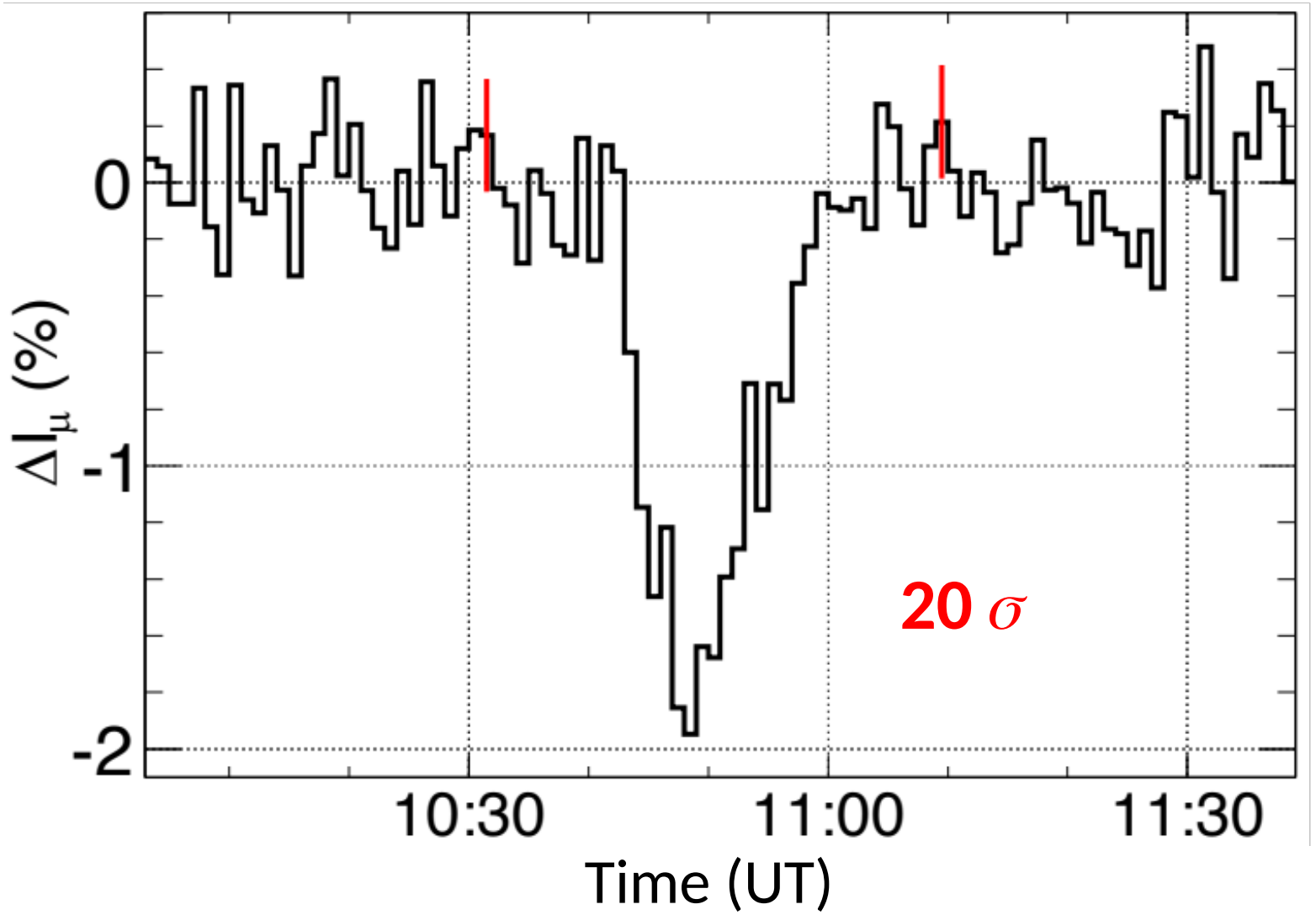
45 directions

EFM – Electric Field Mill



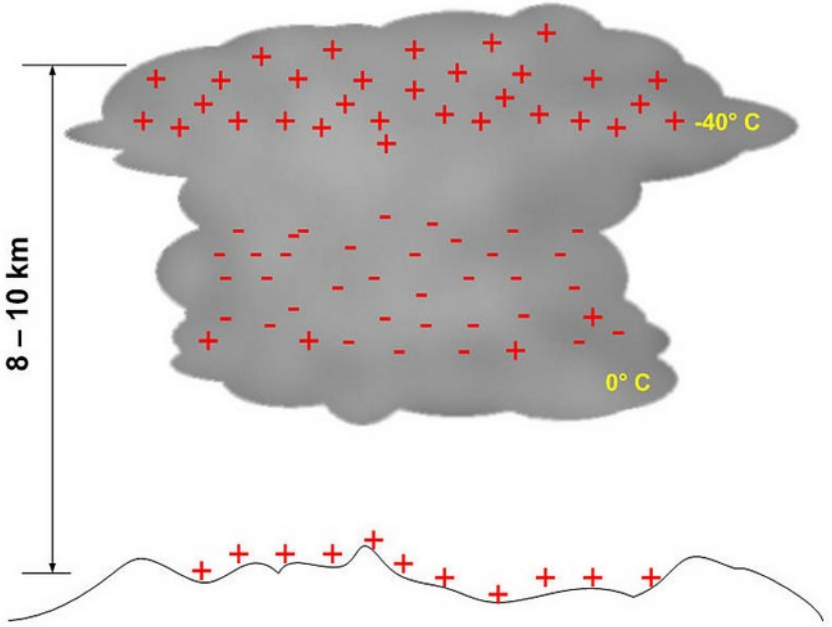


Muon intensity variation on 1st Dec 2014



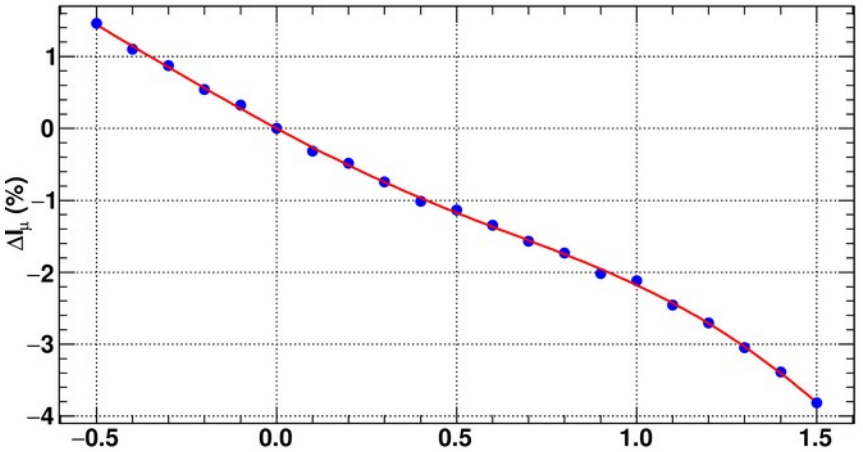
Monte Carlo simulation

- CORSIKA and in-house
- 169 direction simulation (accuracy of ~0.1%)
- Cloud model inside CORSIKA

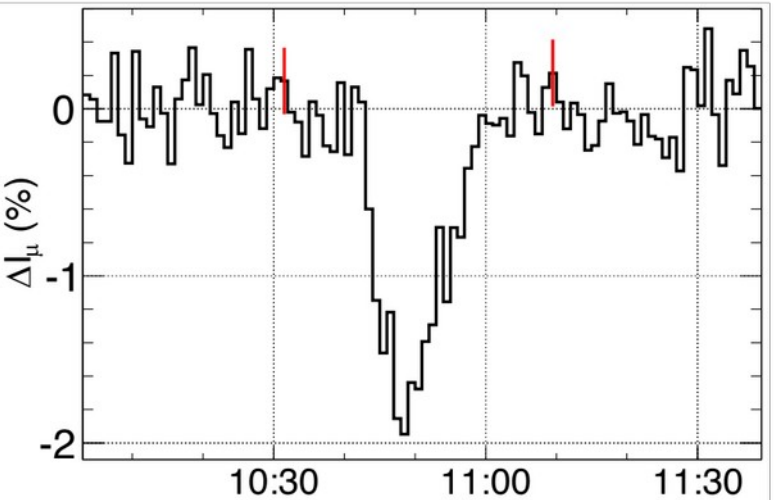


Monte Carlo simulation

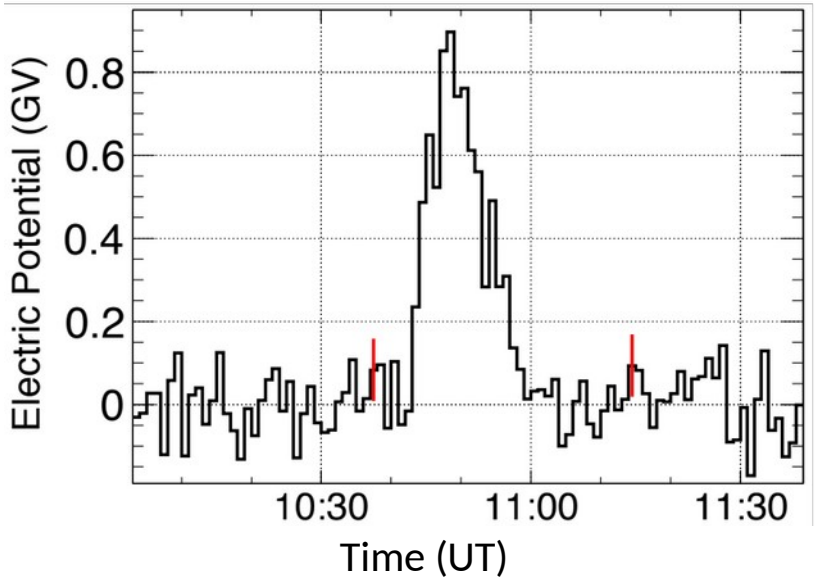
MC



Data



Derived



- $\Delta I_{\mu(Peak)}$ = (-2 ± 0.2) %
- V_{Peak} = (0.90 ± 0.08) GV

Cloud movement

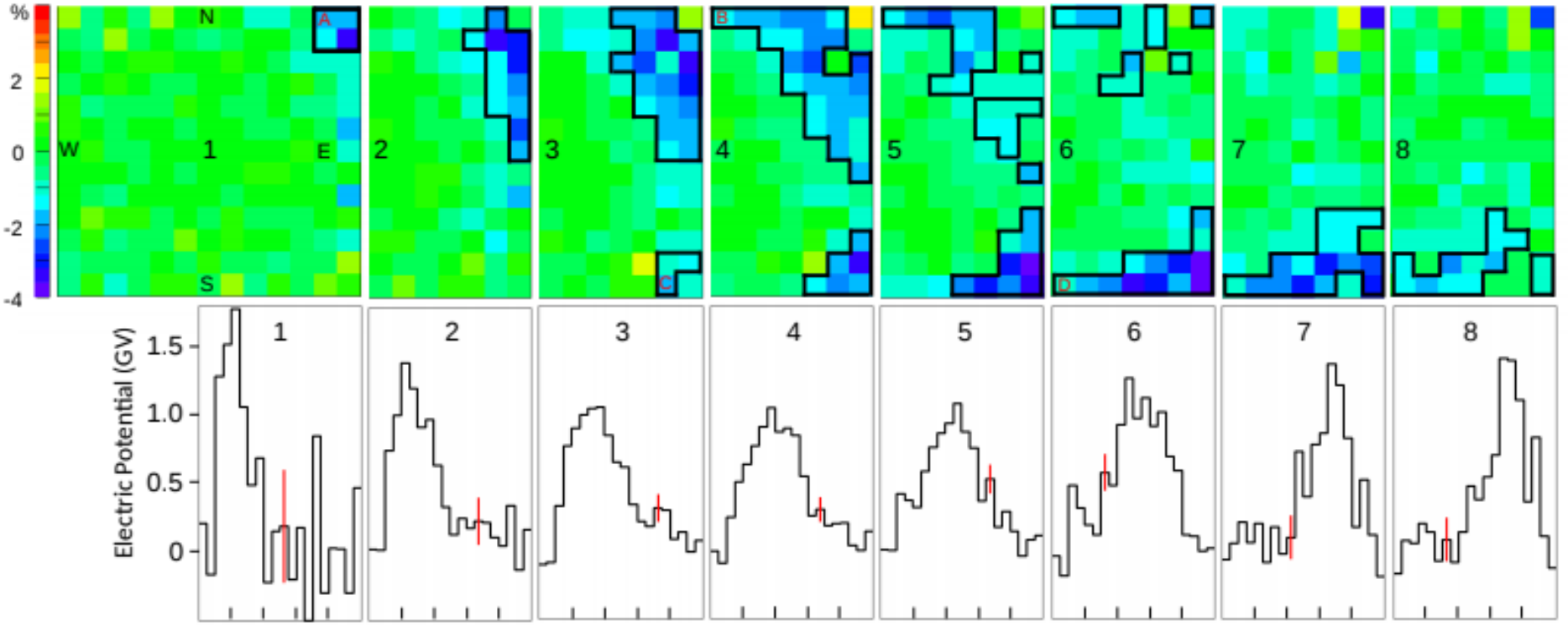


Image	Dir	V (GV)
1	4	1.8
2	12	1.4
3	23	1.0
4	32	1.0

Image	Dir	V (GV)
5	28	1.1
6	23	1.2
7	16	1.3
8	13	1.4

- Mean V = 1.3 GV
- Angular Velocity = 6.2° min^{-1}

Electrical properties of the cloud

- Mean V = 1.3 GV
- Lin. Vel. = 60 km hr^{-1}
- Ang. Vel. = 6.2° min^{-1}
- Height = 11.4 km amsl
- Radius ≥ 11 km
- Area ≥ 380 km^2
- C ≥ 0.85 µF
- Q ≥ 1100 C
- E ≥ 720 GJ
- P ≥ 2 GW

- Comparable to biggest nuclear reactor / hydroelectric / thermal power plants
- Enough to power a big town

B. Hariharan et al.,
Physical Review Letters 122, 105101 (2019)
(Focus article & Editors‘ suggestion)

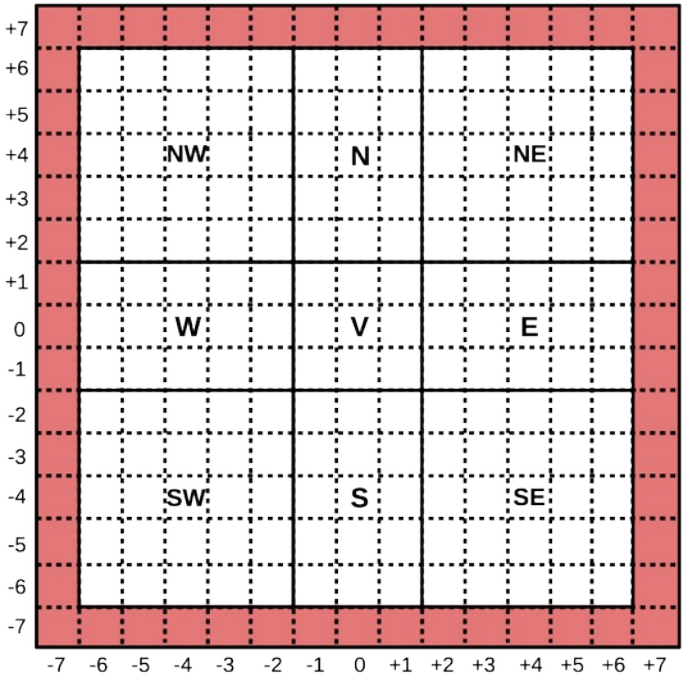
Giga-Volt natural particle accelerator above our head !!!

Event statistics

Year	# of events
2011	49
2012	43
2013	40
2014	52
2015	46

Year	# of events
2016	18
2017	49
2018	48
2019	88
2020	54
Total	**487**

Distribution of events

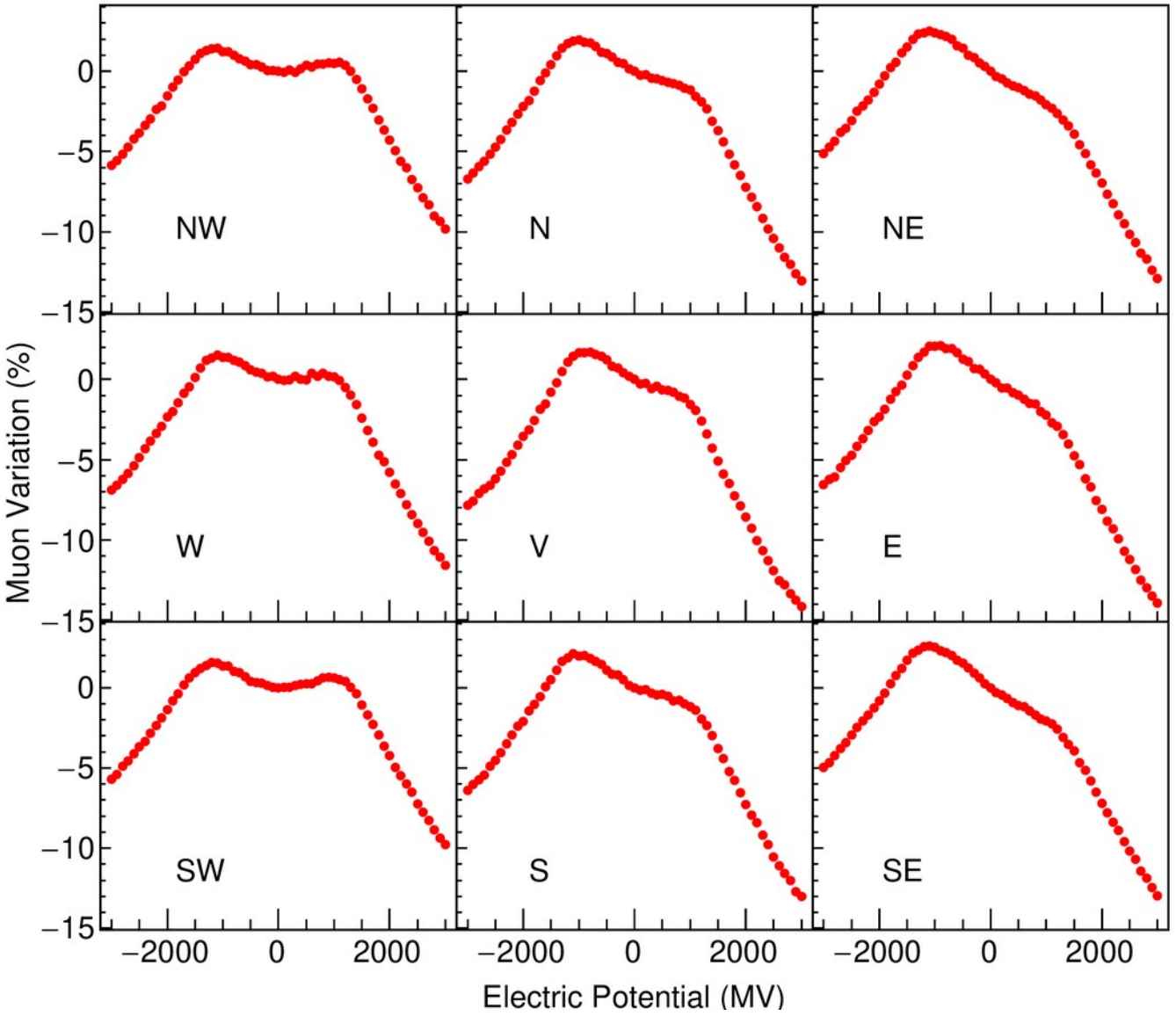


Muon directions in GRAPES-3 FOV

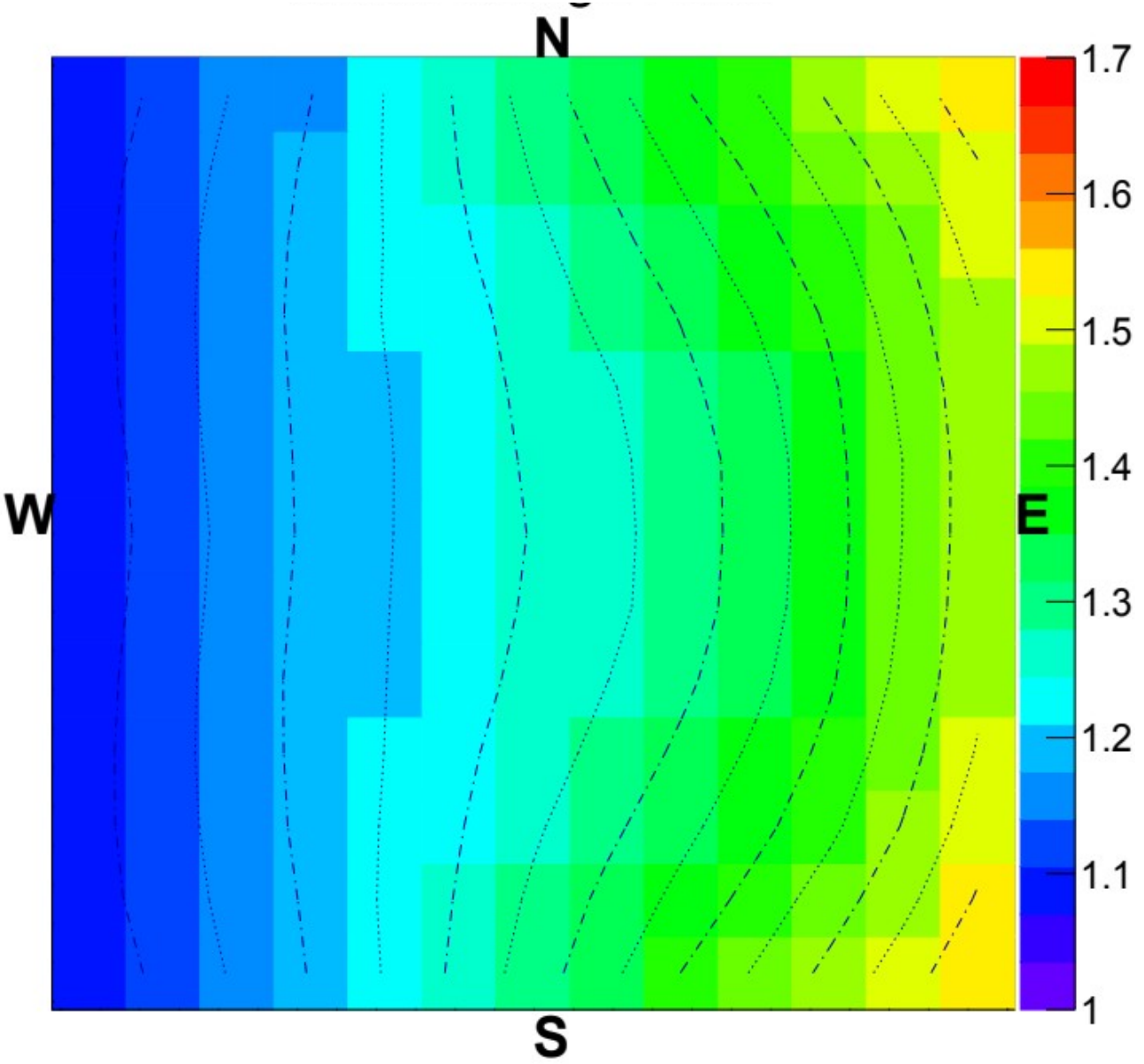
6.2	1.8	30.1
0.6	0.2	2.8
7.0	2.8	48.6

(% of events)

Simulation of 9-direction



Muon charge ratio



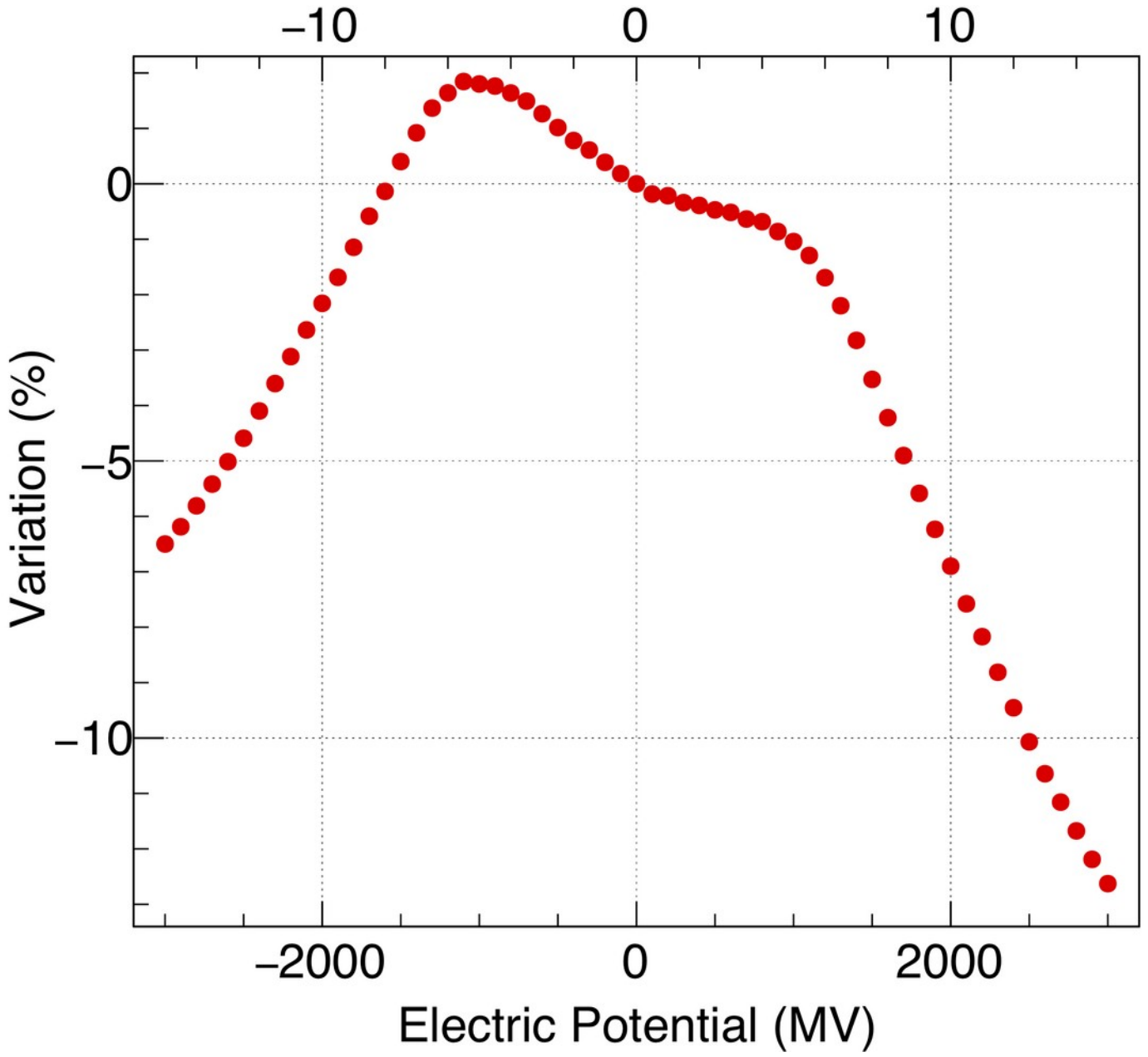
Conclusions

- 487 significant thunderstorm events during (Apr 2011 – Dec 2020)
- Azimuthal asymmetry in the event distribution
- Explained with aid of Monte Carlo
- Caused by the muon charge ratio

Thank You

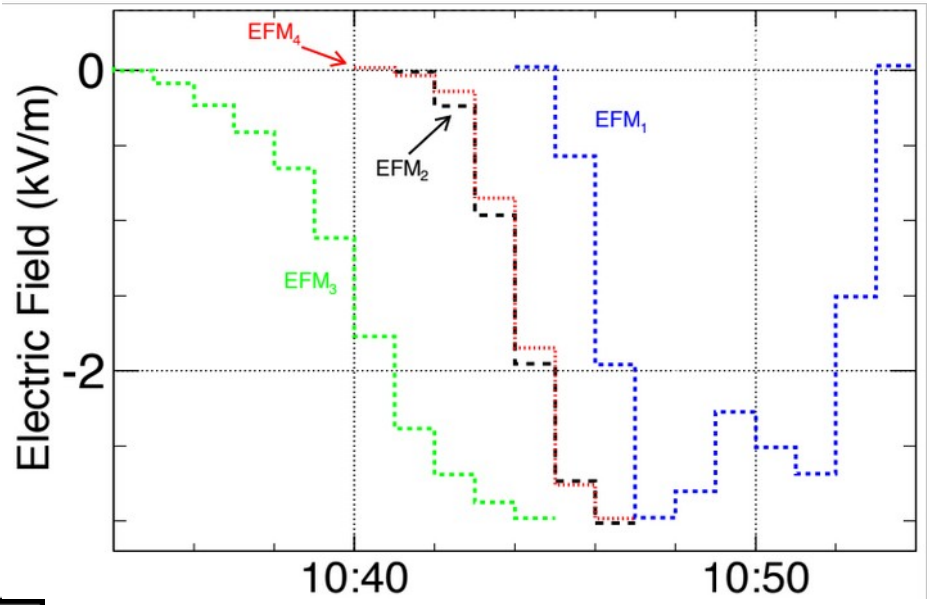
Backup Slides

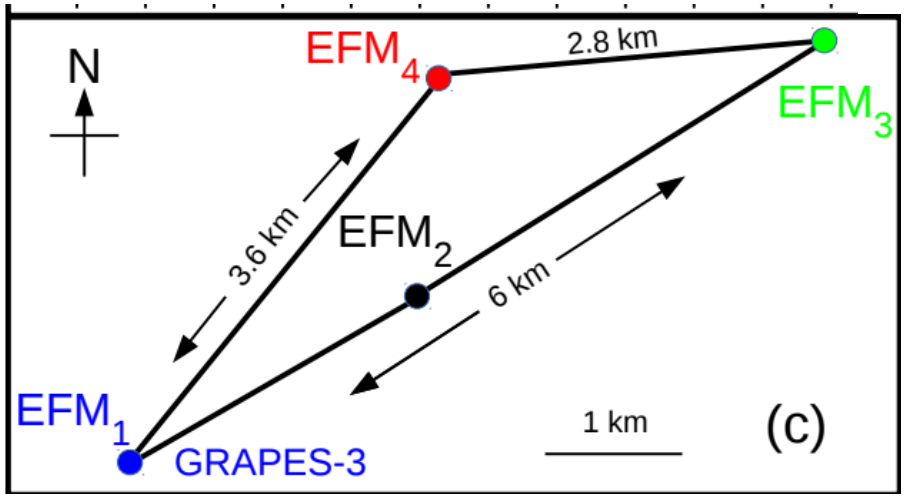
Monte Carlo simulation



Electric Field Mills

- 4 Monitors
- Maximum distance of 6 km





- Velocity = 60 km hr^{-1}