Large-scale cosmic ray anisotropy measured by the GRAPES-3 experiment

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on behalf of GRAPES-3 collaboration
PoS(ICRC2021)393

Outline

- Motivation
- GRAPES-3
- Analysis
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- Summary and future work

Motivation

- Provides insight about acceleration and propagation of CRs
- Diffusion under random magnetic fields, inhomogeneous distribution of sources
- Several experiments have observed cosmic ray anisotropy in the Northern and Southern skies for different energy ranges.
- The near equatorial location of GRAPES-3 gives it the advantage to study the overlapping region in between both hemispheres
- Good overlapping results in energy in the TeV-PeV scale.

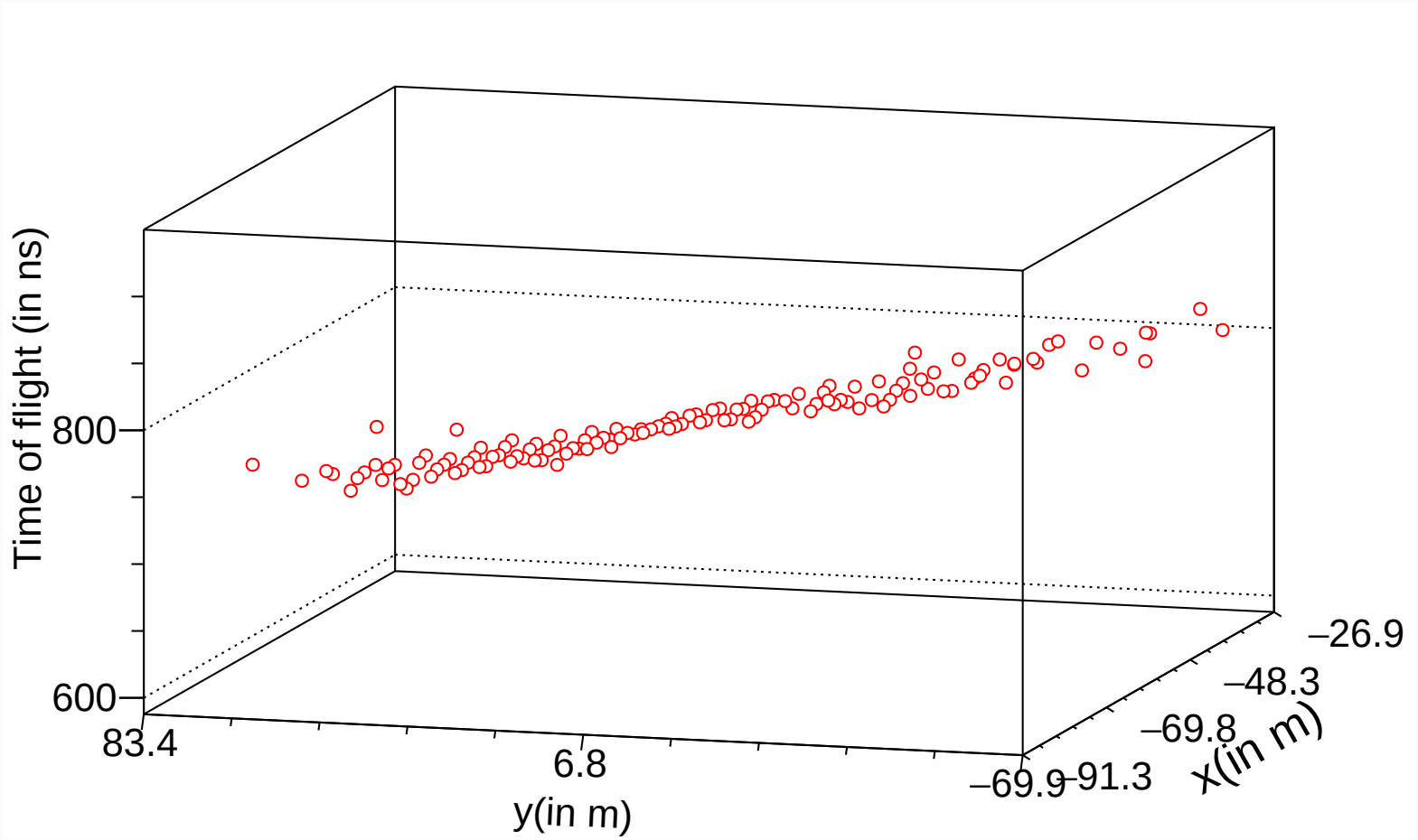
GRAPES-3 air shower array

- $11.4^{\circ}N, 76.7^{\circ}E$
- Area $25000 m^2$
- 400 plastic scintillators
- Detector separation 8 m
- 560 m^2 muon detector with 3712 proportional counters

- Energy : 10 TeV – 10 PeV
- Particle densities and relative arrival times recorded
- $\sim$3 million showers recorded per day

Direction reconstruction

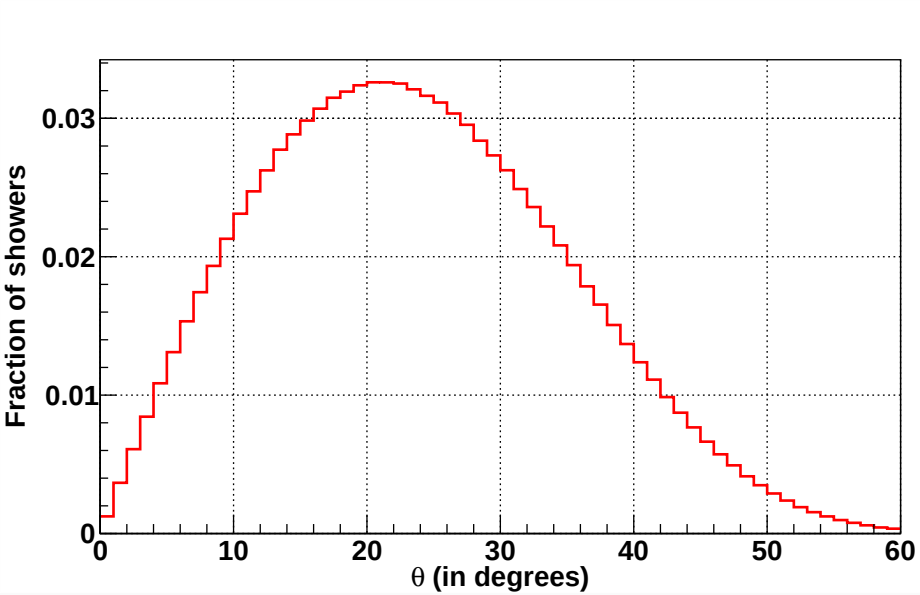
A planar fit is performed on the arrival times of the showers to obtain the direction.

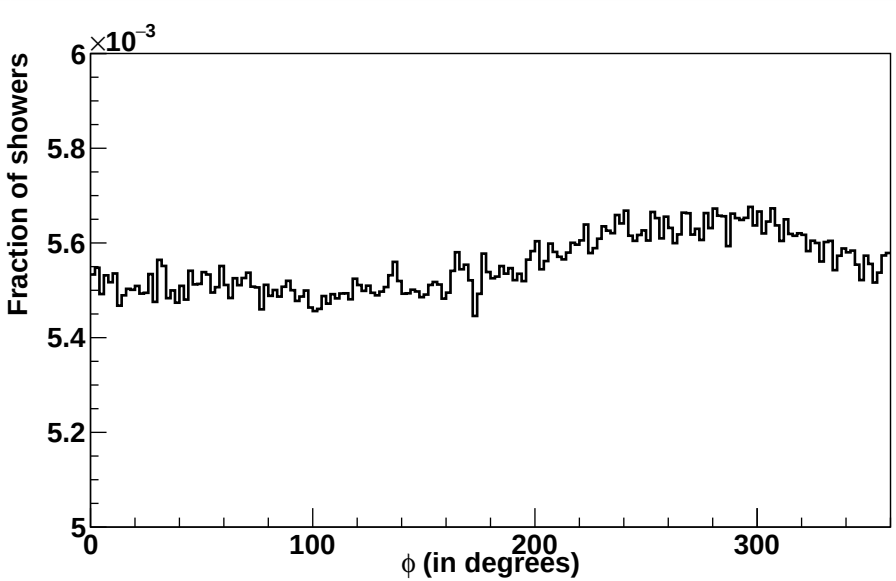


Later, curvature correction is done to get a better estimate of direction.

V.B. Jhansi et al JCAP07(2020)024

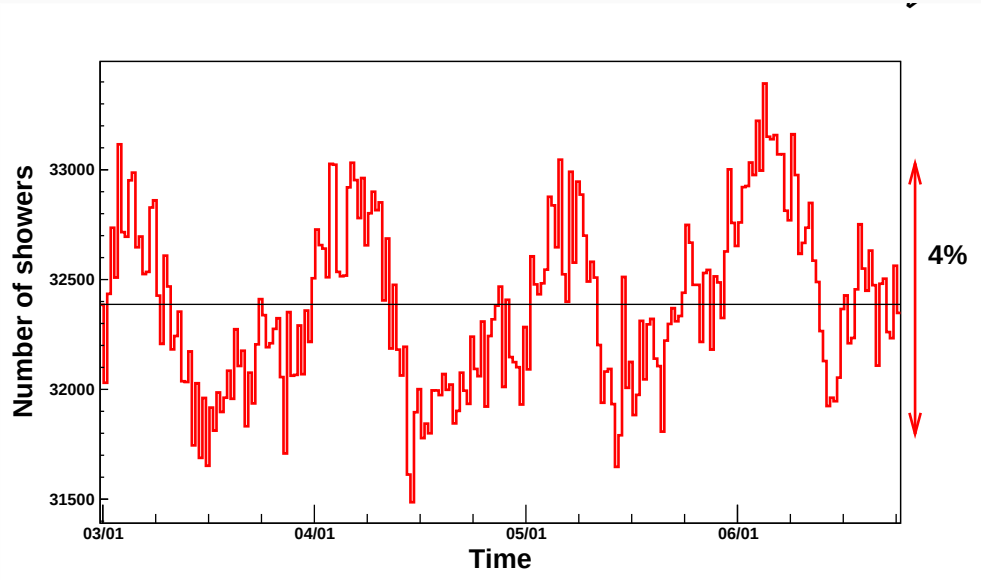
Zenith and azimuth distributions

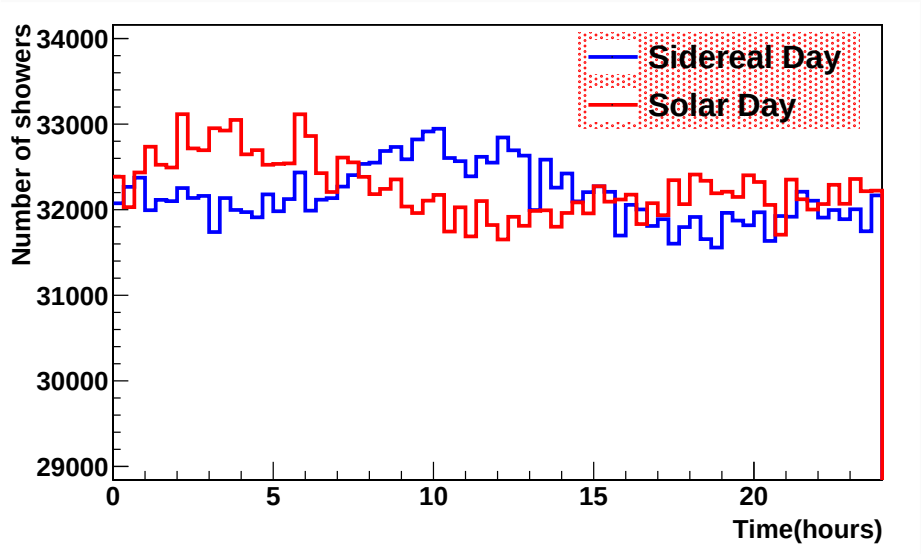




Systematics

- Atmospheric effects induce about 4% change peak to peak and about 2% from mean. Bin width : 20 mins, Year: 2015.





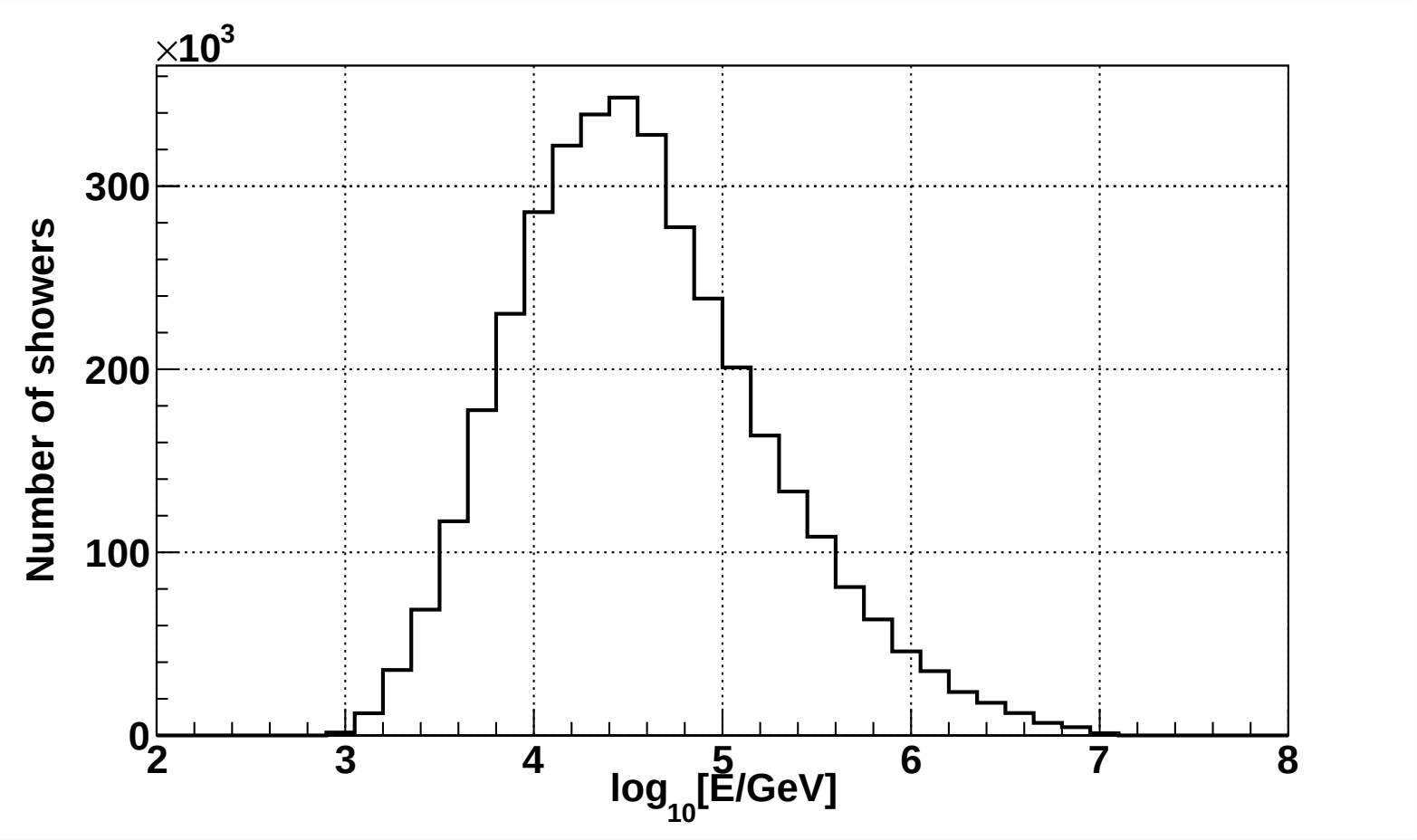
- Breaks in DAQ, fake triggers.

Selection criteria

- Year: 2014-2016
- No of showers : $\sim$ 2.5 billion
- $0^\circ \leq \theta \leq 60^\circ$
- $0^\circ \leq \phi \leq 360^\circ$
- $0 < \mathit{ChiSq} < 10000$, ChiSq of planar fit used to obtain zenith and azimuth. This ensured better angular accuracy.
- No of detectors hit > 12, removes fake trigger events.

Median energy

The median energy is estimated from Monte-Carlo simulations



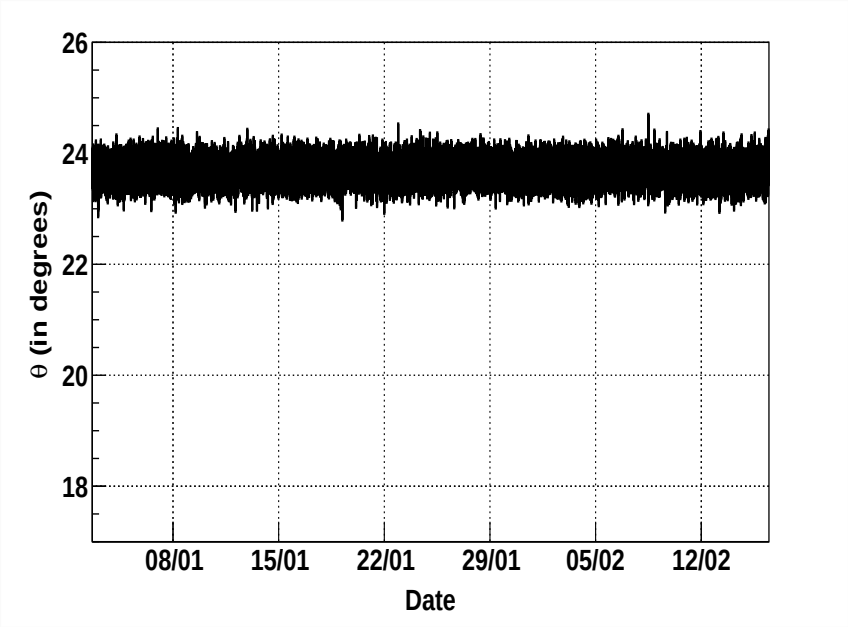
Median energy = 28.1 TeV

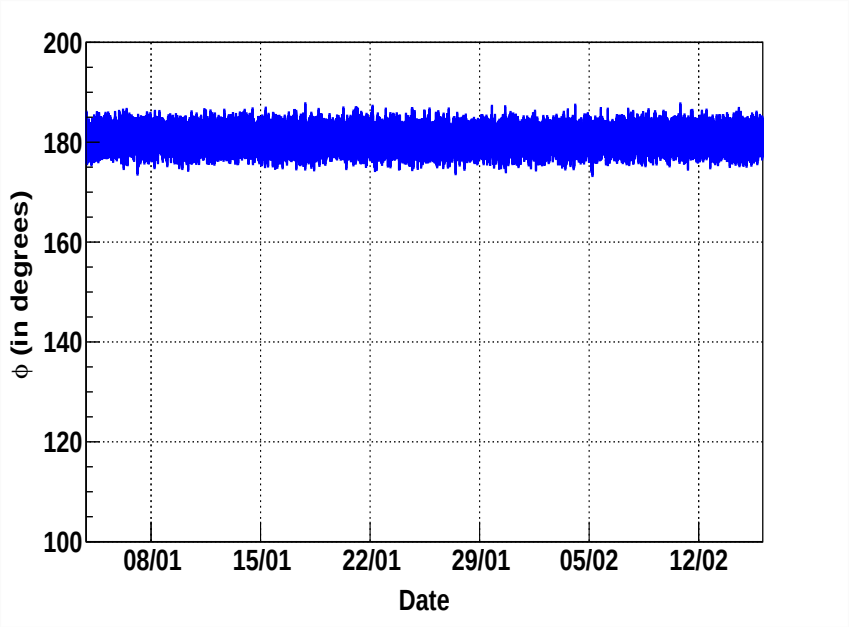
Analysis

- $(t, \theta, \phi) \rightarrow (\alpha, \delta)$
  t: event time, α : RA , δ : Declination
- Data map: Zenith and azimuth are converted to equatorial coordinates
- Reference map: Events are assigned a random time $(t', \theta, \phi) \rightarrow (\alpha', \delta)$
  t' is chosen from the event time sample of data. So this this takes care of breaks in DAQ. For each event 20 fake events are generated.
- Relative intensity map :
$$\frac{N_i - N_{ri}}{N_{ri}}$$
  N_i : Number of events in i-th pixel of data map, N_{ri} : Number of events in i-th pixel of reference map properly weighted.
- Significance using LiMa formula

Scrambling period

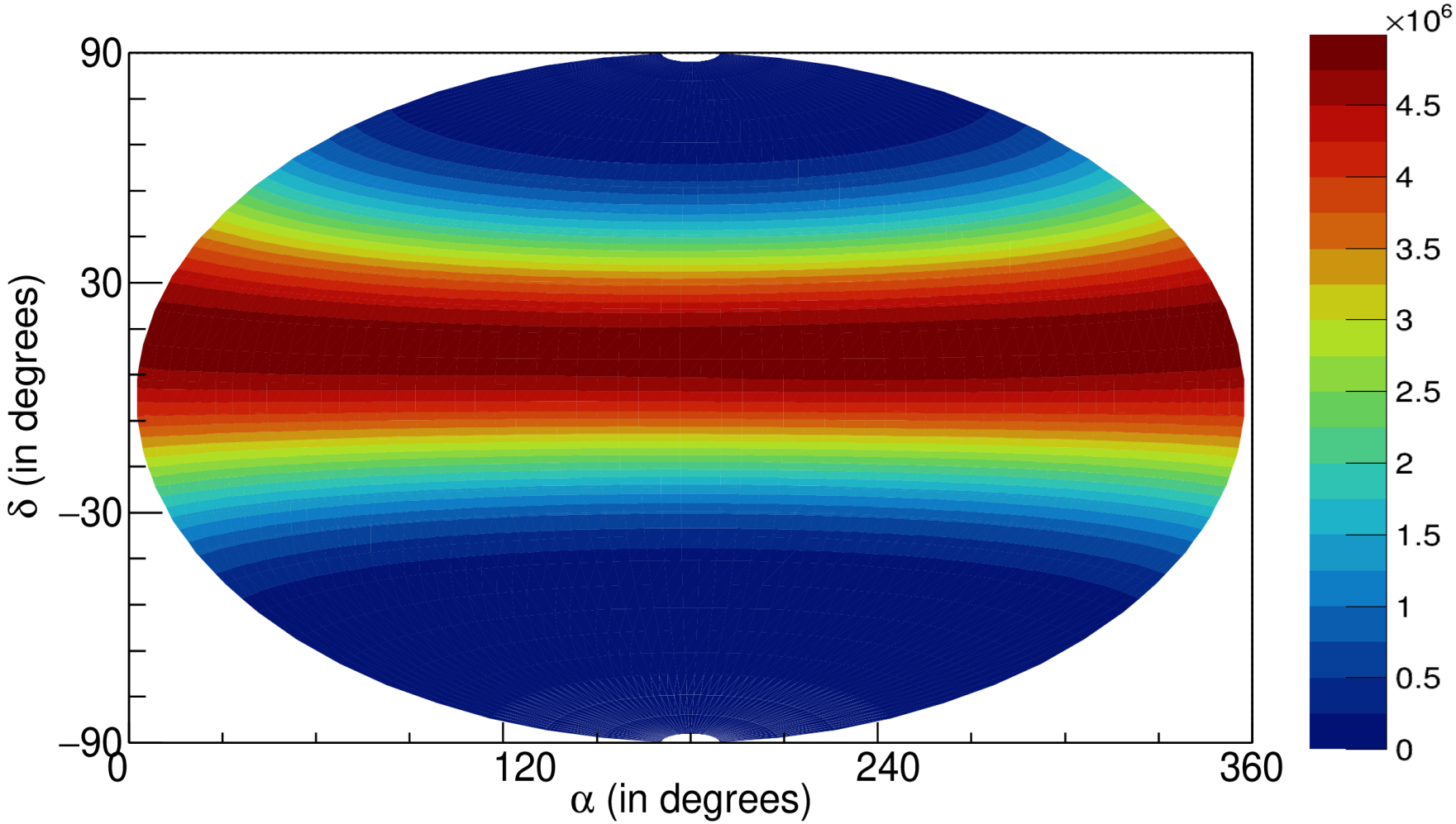
The zenith and azimuth distributions are stable over time. Any period with fluctuations in the horizontal coordinates were removed. Bin width: 2 mins.



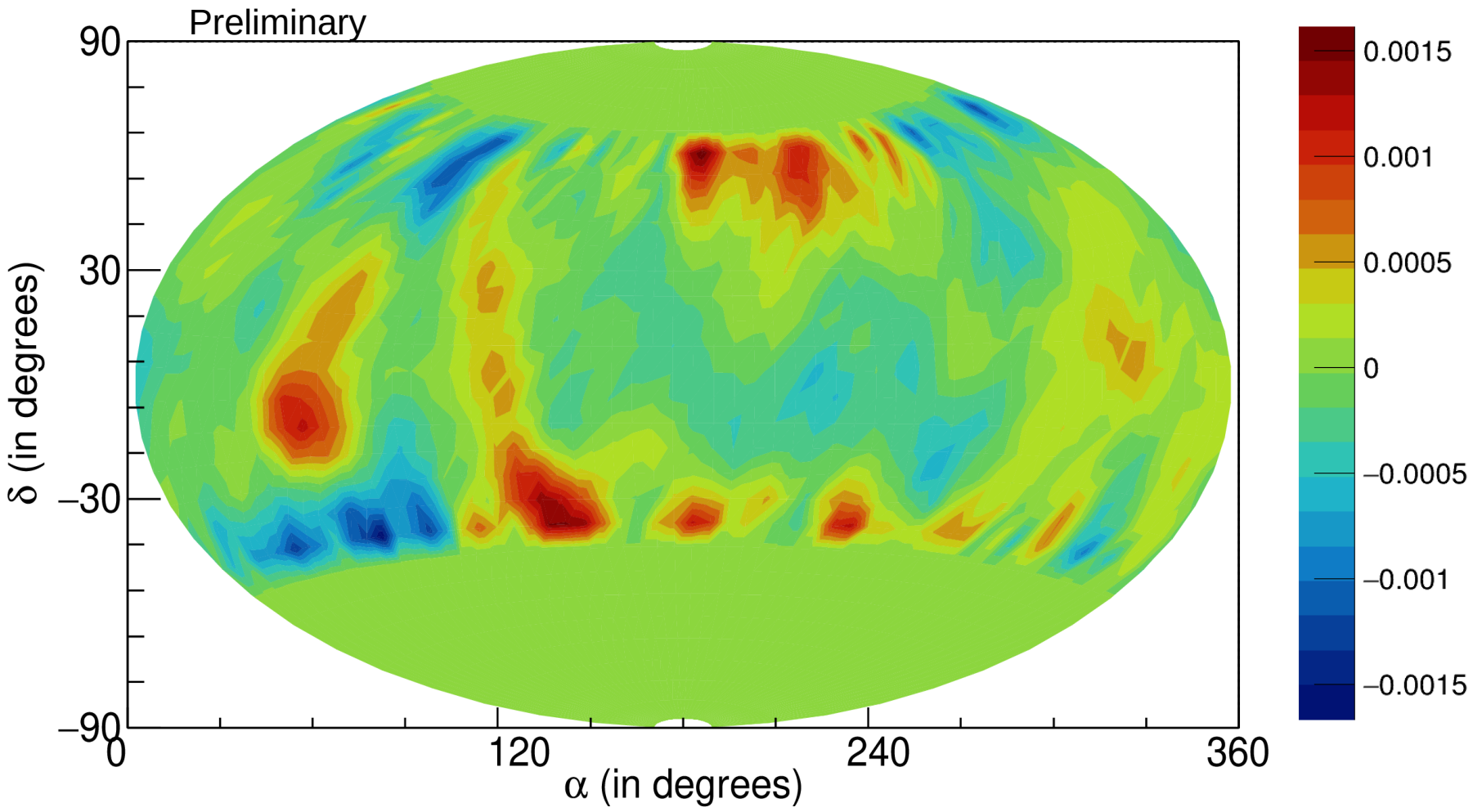


Scrambling period was taken as 24 hrs.

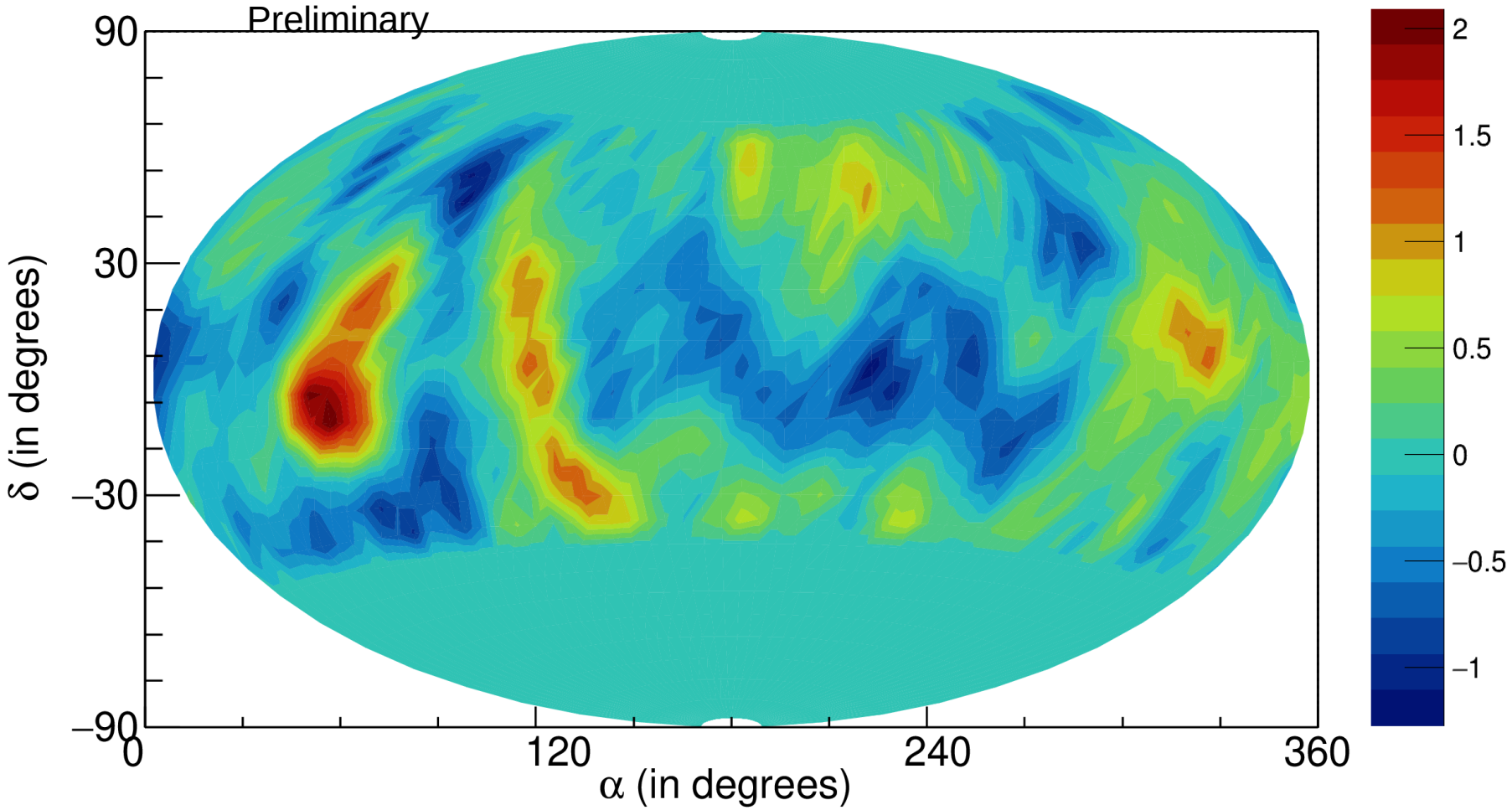
Data map


90
30
−30
−90
δ (in degrees)
0
120
240
360
α (in degrees)
×10^6
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

Anisotropy observation



Significance



Summary and future work

- The time-scrambling method has been implemented.
- We observe some excess structure within $\sim 45^\circ - 80^\circ$ with a significance of 2.1, of a strength around 1.2×10^{-3}
- Methods to remove remaining systematic effects will be implemented so that large-scale structures are prominent.
- More years of data will be added.


Thank You
Images:Google