Anisotropy Studies with DAMPE

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On behalf of the DAMPE Collaboration
July 26th, 2019
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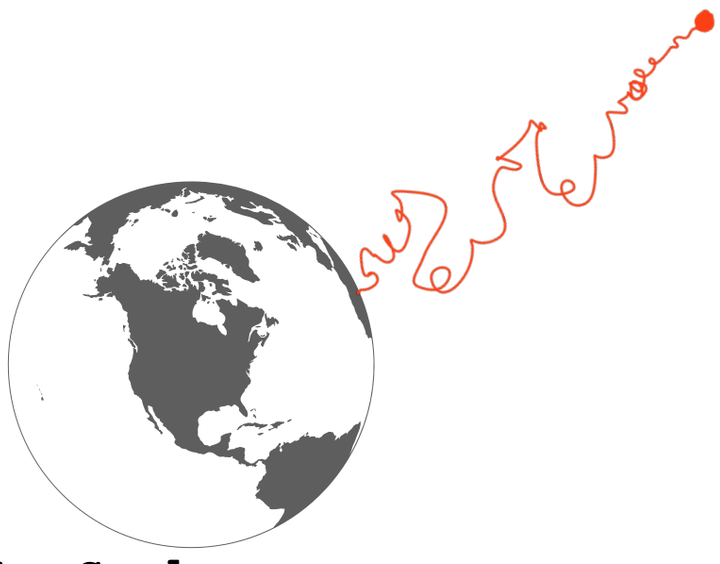
Outline

- Introduction
- DAMPE
- Data Selection
- Anisotropy studies
- Preliminary results
- Conclusions & Outlook

Introduction

The origin propagation and acceleration of cosmic rays from galactic and extra-galactic origin.



Not to Scale

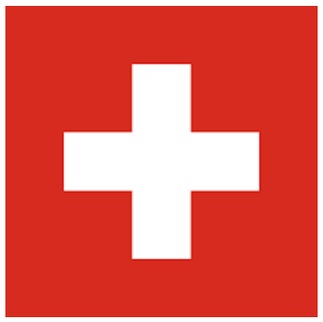
The interstellar medium is filled with turbulent magnetic fields which make the arrival direction of the cosmic rays highly uniform.

Predictions suggest the strongest anisotropy would be the dipole one and that it might have the amplitude around ~ 3–5 × 10^{-4} at the energies of order a hundred GeV.

The Collaboration

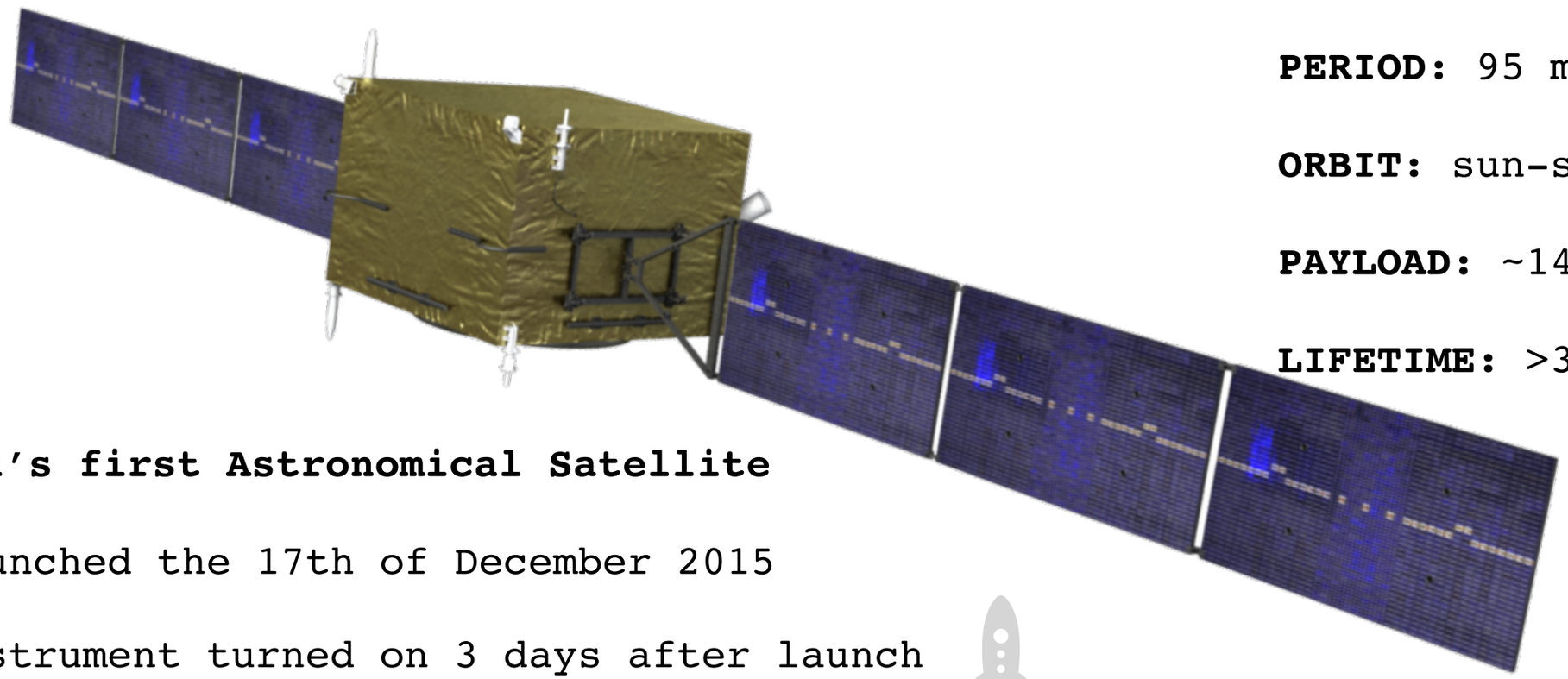
- China:
  - Purple Mountain Observatory, CAS, Nanjing.
  - University of Science and Technology of China, Hefei
  - Institute of High Energy Physics,CAS,Beijing
  - Institute of Modern Physics,CAS,Lanzhou
  - National Space Science Centre, CAS, Beijing

- Switzerland
  - University of Geneva, Switzerland



- Italy:
  - INFN Perugia and University of Perugia
  - INFN Bari and University of Bari
  - INFN Lecce and University of Salento

DArk Matter Particle Explorer | DAMPE| WUKONG



ALTITUDE: 500 km

INCLINATION: 97.4065°

PERIOD: 95 minutes

ORBIT: sun-synchronous

PAYLOAD: ~1400 Kg, 400 KW

LIFETIME: >3 years

China's first Astronomical Satellite

- Launched the 17th of December 2015
- Instrument turned on 3 days after launch

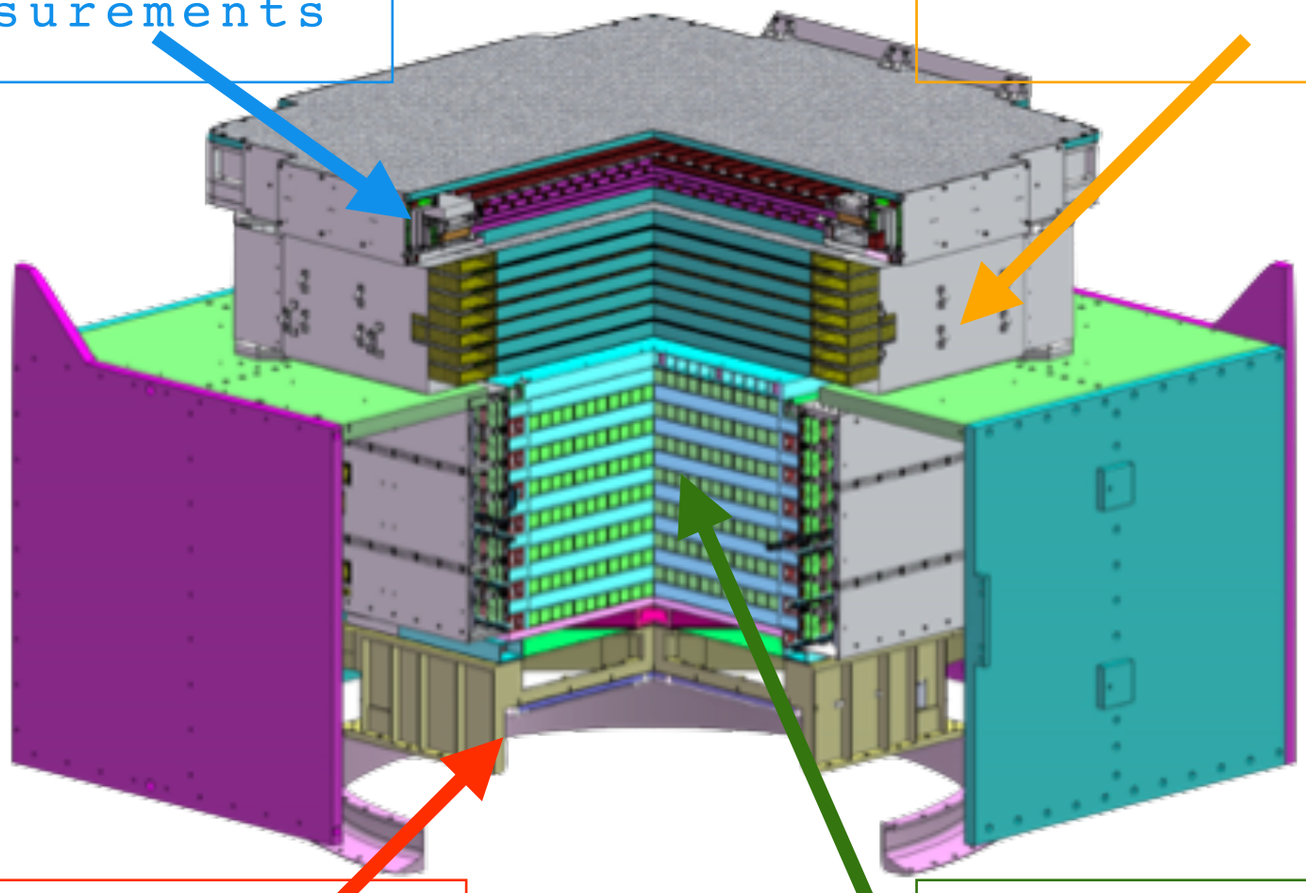
DAMPE taking good data since 10 days after the launch

- **Study of Cosmic Rays composition, origin and propagation**
- **Search of Dark Matter signatures**
- **High Energy Gamma-ray Astronomy**

Instrument Design

Plastic Scintillator Detector (PSD):which is used both as an anti-coincidence detector and for charge measurements

Silicon TracKer(STK): six double layers, the first layers are interspaced with tungsten for pair conversion of Gamma-Rays.



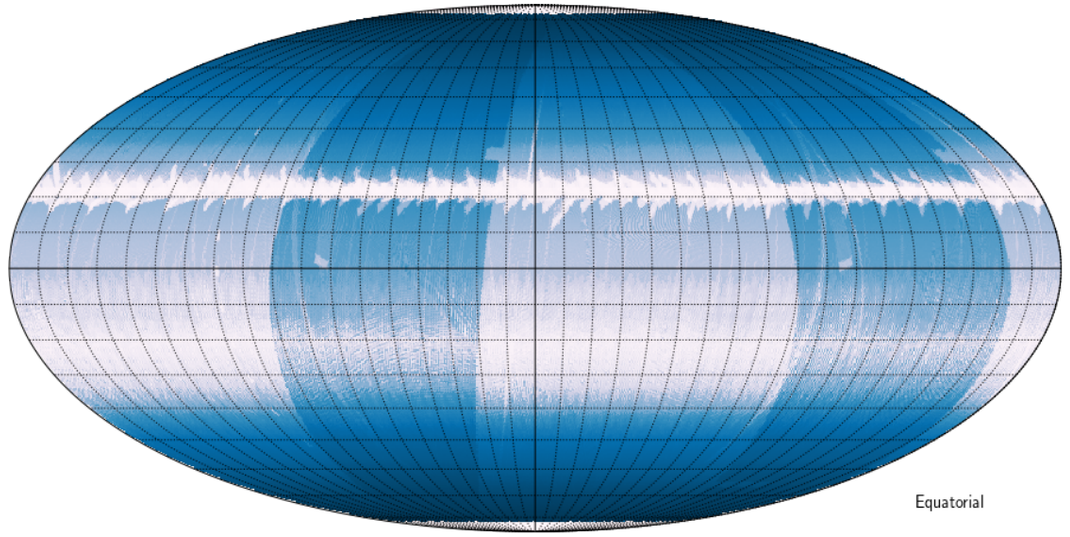
NeUtron Detector(NUD): 4 blocks of boron-loaded plastics scintillators, for hadrons identification for energies above 150 GeV.

BGO Electromagnetic Calorimeter for electron/ proton separation, and energy measurements.

Importance of DAMPE?

- Earth-based instrument:
  - might have a large bias when measuring anisotropy due to: Partial sky coverage
  - New results in the last years at very high energies.
- Spaced-based instrument capable of reducing bias, with a full sky coverage.

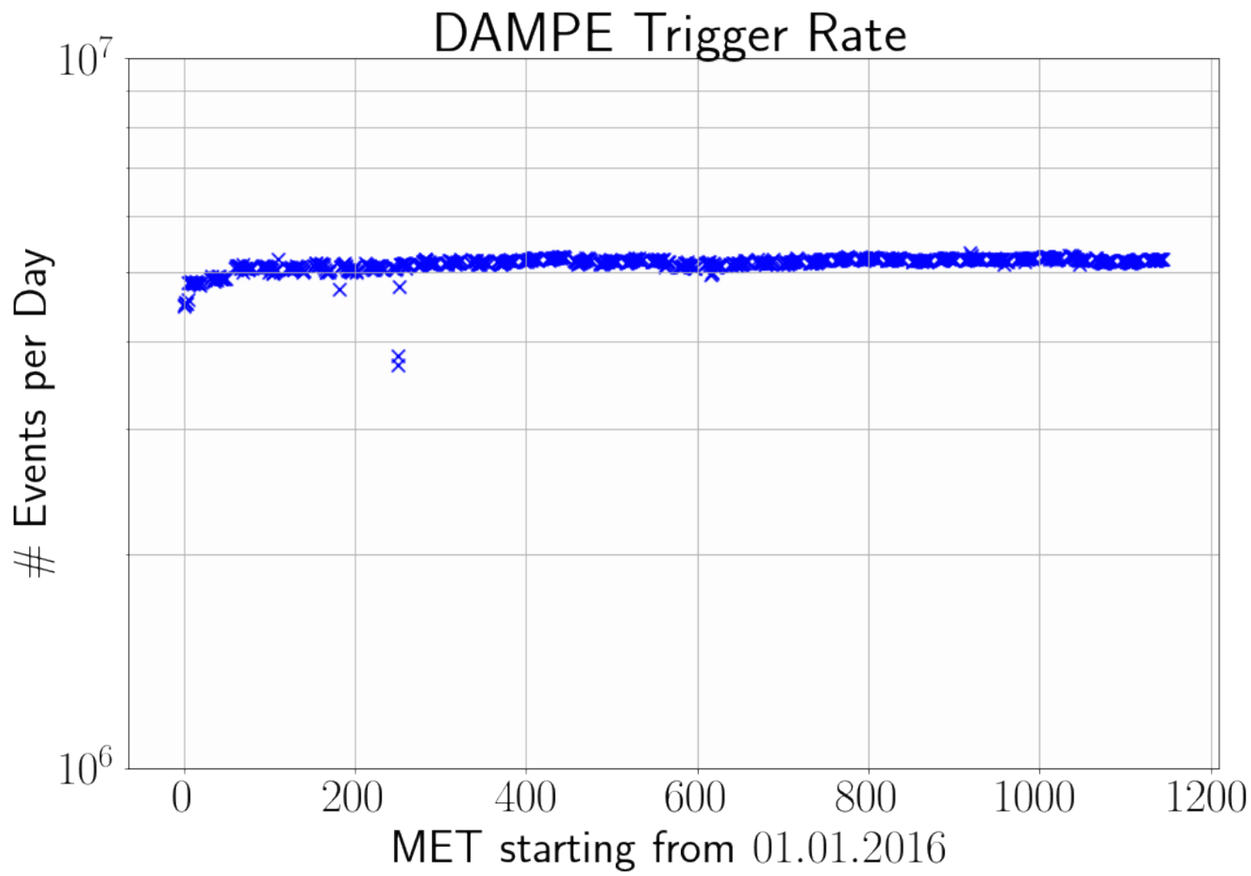
Field of View ~1.0sr
DAMPE observes the full sky twice in a year.



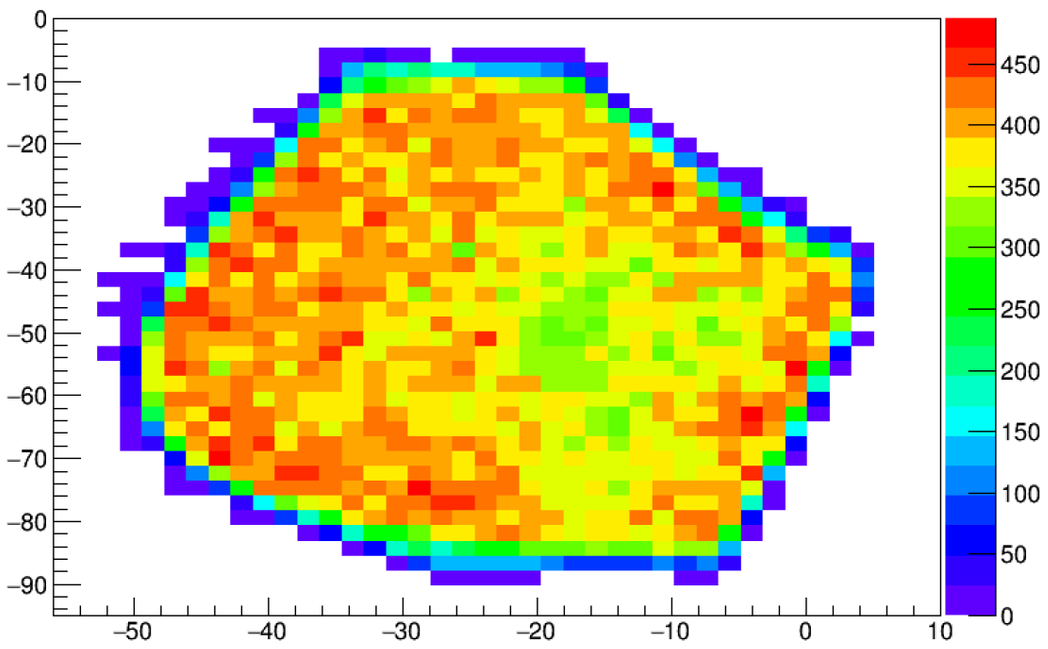
DAMPE Data Set

>6Billion events collected in over 3 years of observation.

Stable event rate



Quality cuts

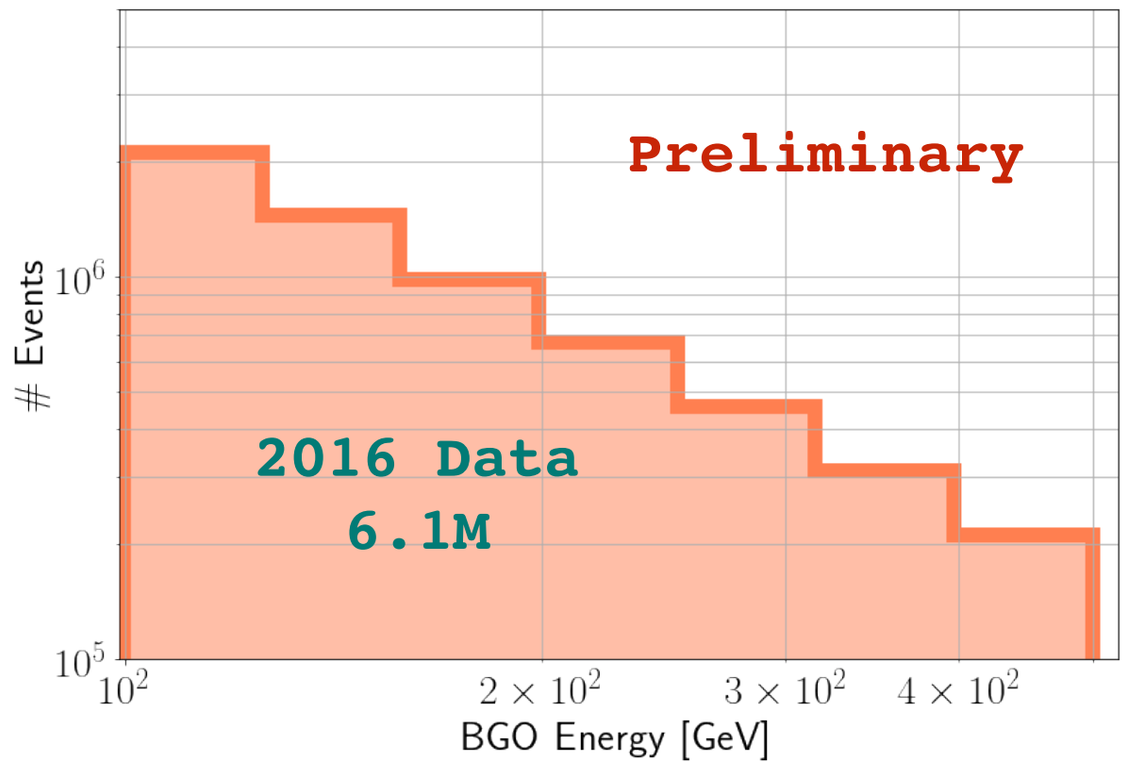


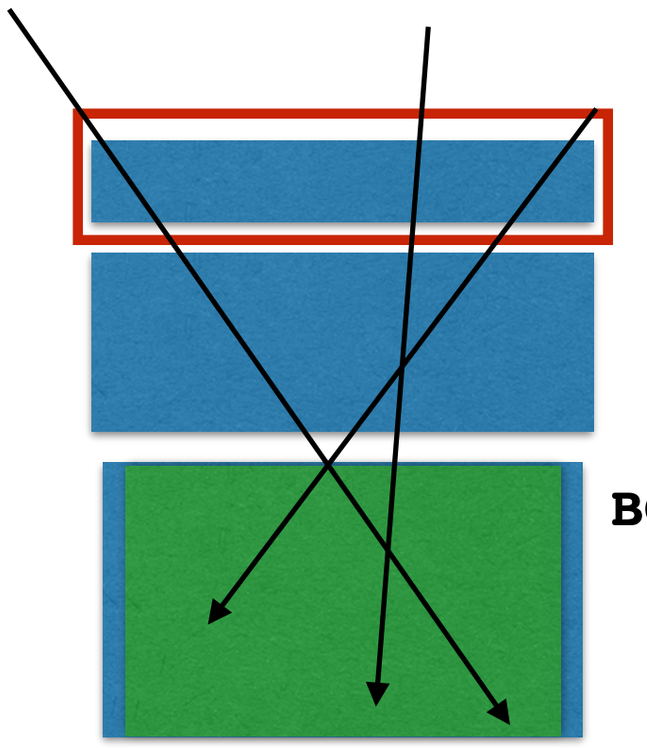
Remove South Atlantic Anomaly (SAA)

~ 5% of the operation time

DATA Selection

- **BGO energy deposited 100 GeV to 500 GeV**
- **Max Energy deposited in BGO fiducial volume**
- **Track crosses BGO, STK and PSD**
- **Maximum incoming angles (\theta) 60 deg**





All-Particle Selection
Why all particles? Clean proton/ electron sample is too small for the anisotropy search.
~98% Hadrons->~90% Protons

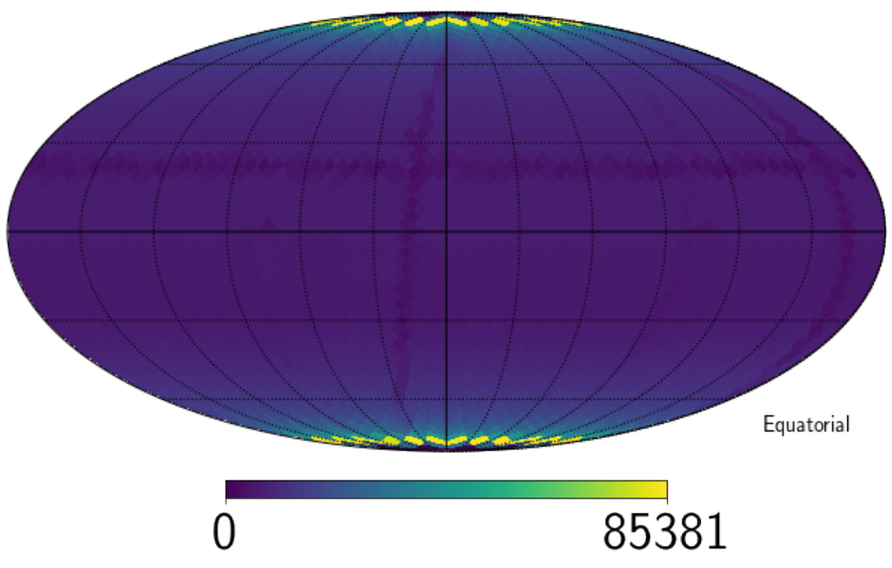
BGO energy->Energy deposited in the BGO
800 GeV proton has a 40% energy resolution.

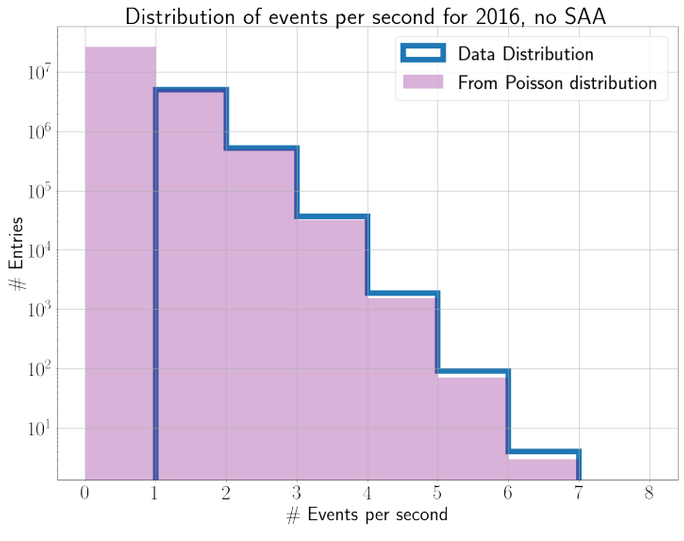
Method

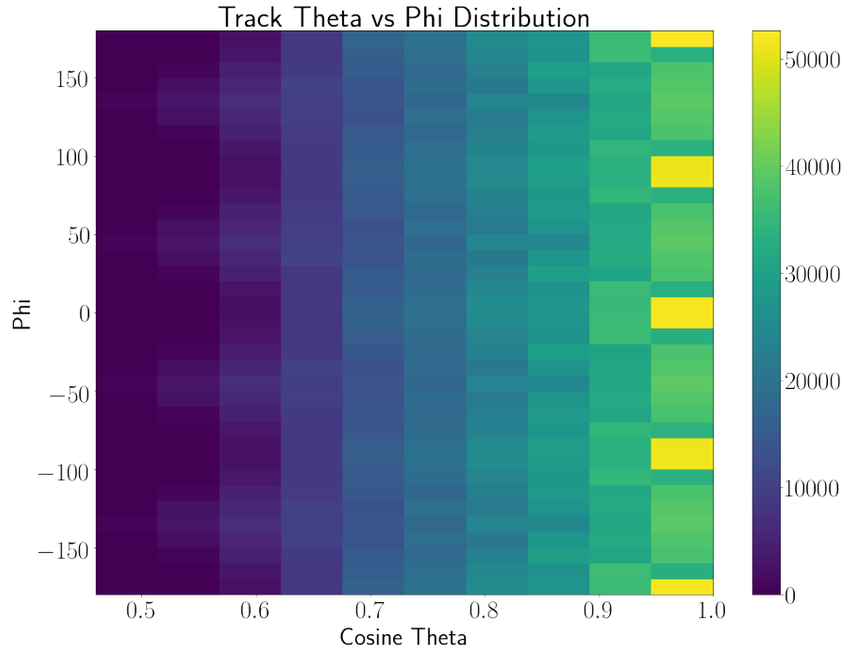
Application of the Rate-based Method presented in

A Search for Cosmic-ray Proton Anisotropy with the Fermi Large Area Telescope [arXiv:1903.02905]

- Collect the position of DAMPE (RA, dec)
- Rate of detected events/per second and per year of data
- Direction the detected CR in detector coordinates(\theta, \phi)



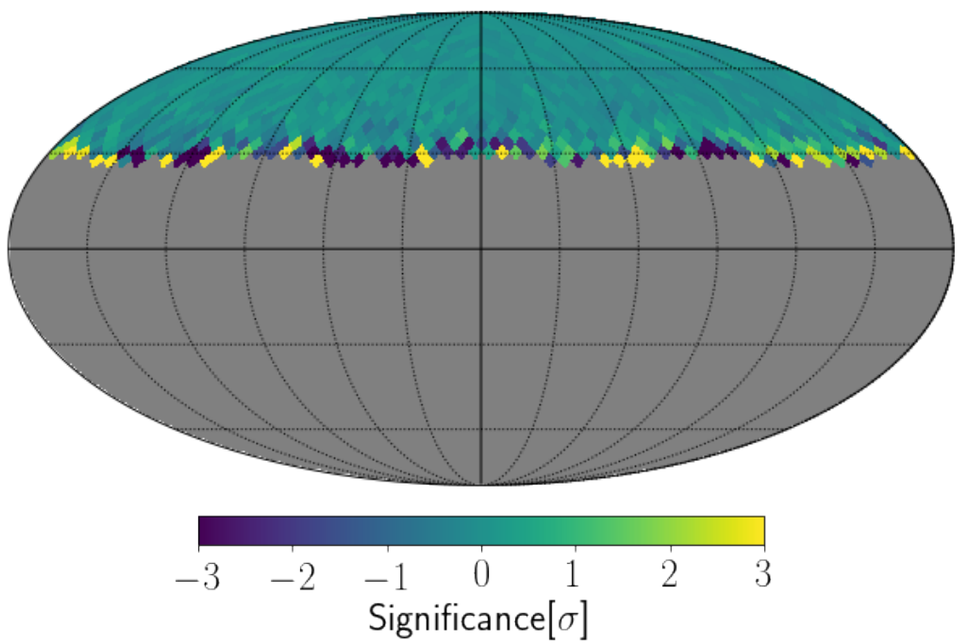




East-West Effect

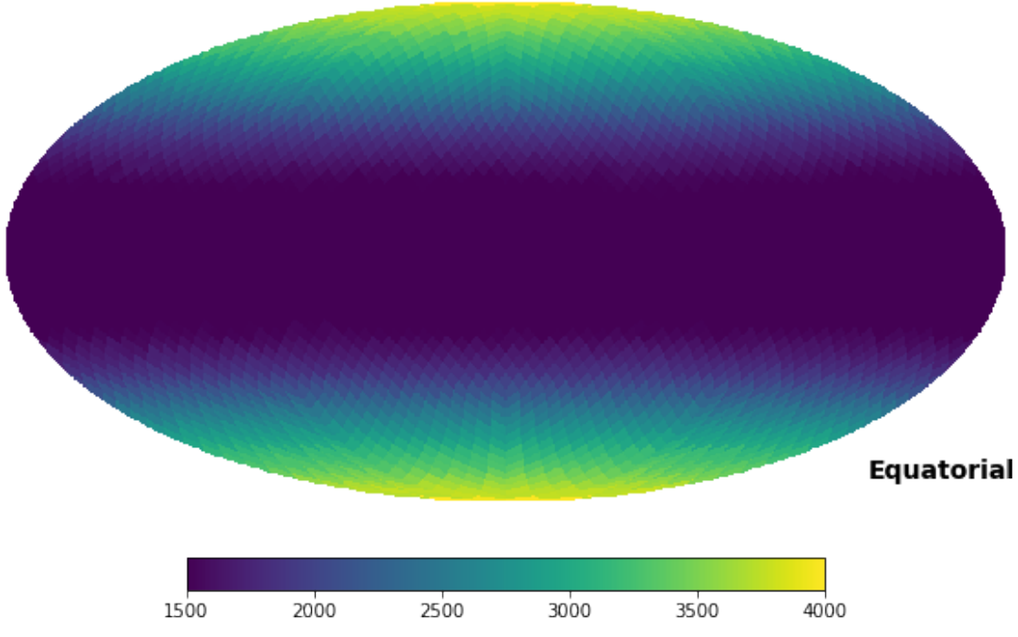
- Sky map in altitude-azimuth coordinates.
- The East-west effect is not visible on our data set thanks to the 60 degree imposed cut on the data.

Larger flux of particles traveling from west-east.
This is the result of the Earth's magnetic field.

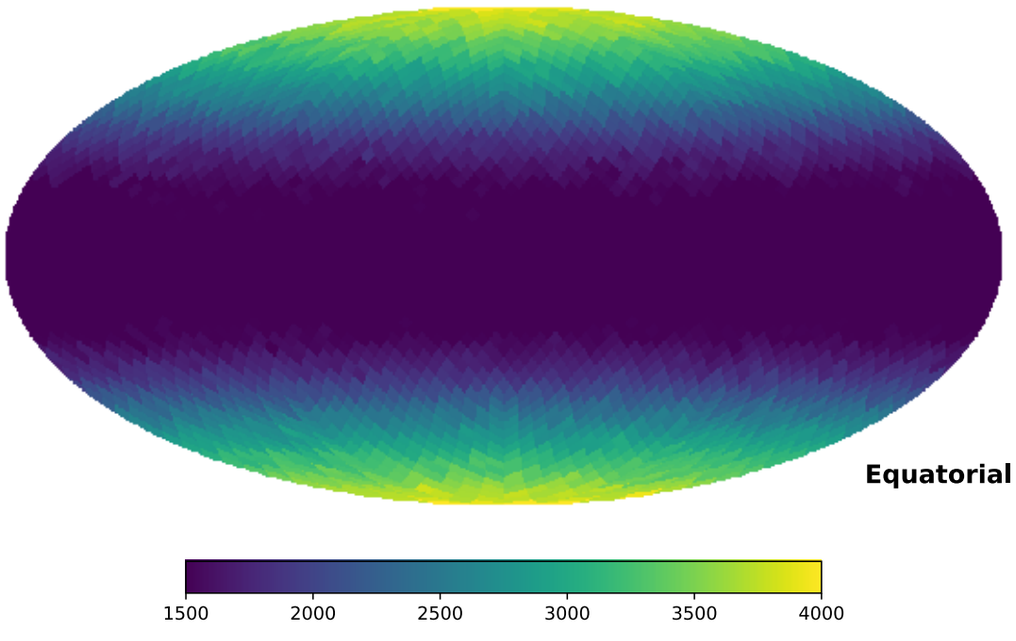


Reference Map

- 100 Maps created
- Reference map is the average.
- Represents the same as data and features from DAMPE's orbit and satellite exposure
- HEALPix binning
- Maps presented NSIDE=16
- Equatorial Coordinates
- 6.1×10^6 Events

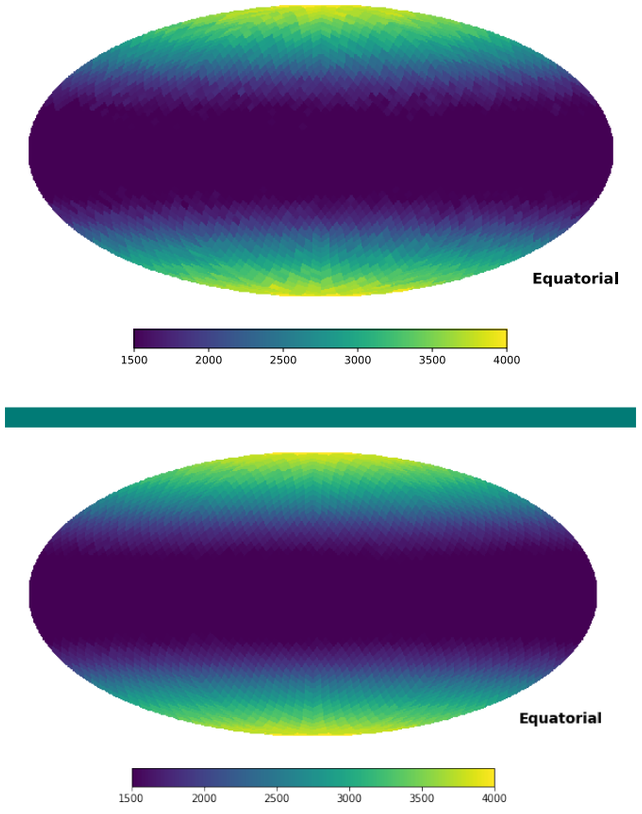


Reference Map

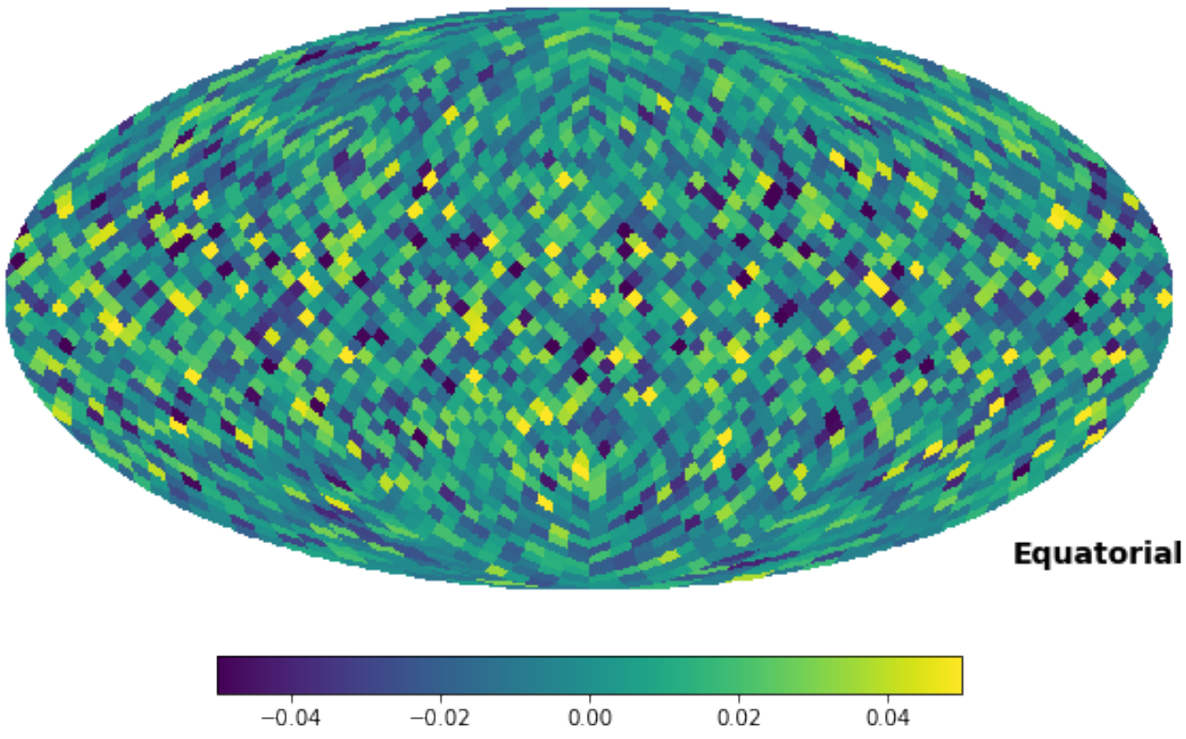


Observation Map

Anisotropy



Preliminary

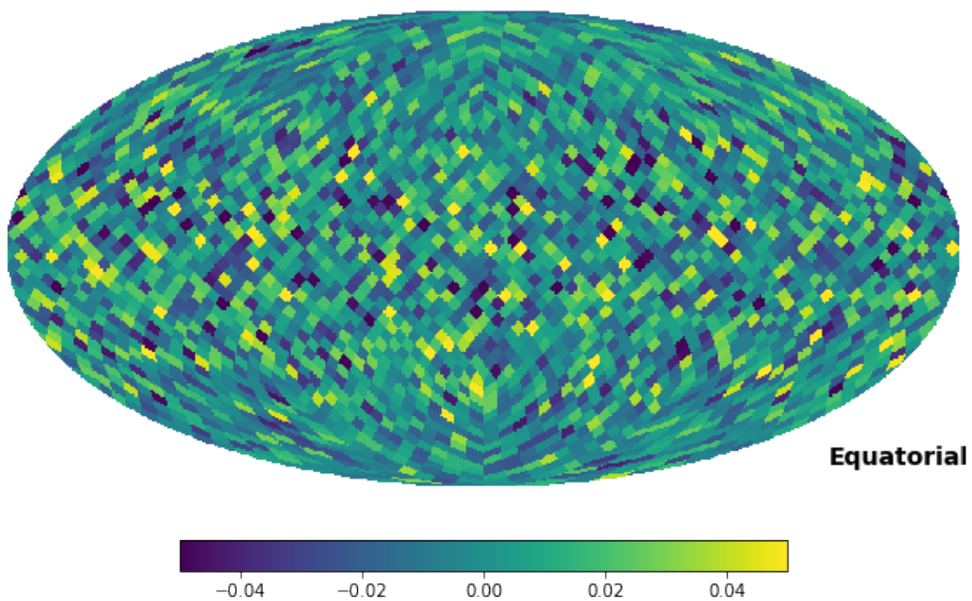


Anisotropy Map

$$\delta I = \frac{D}{R} - 1$$

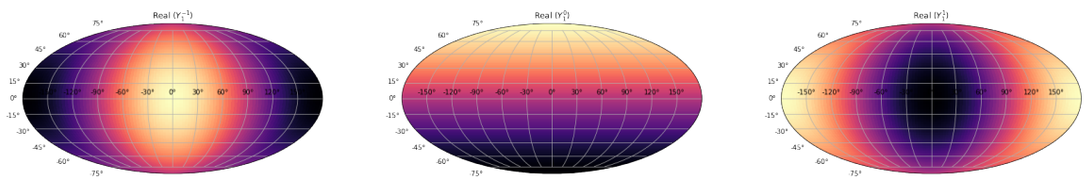
Dipole

Preliminary



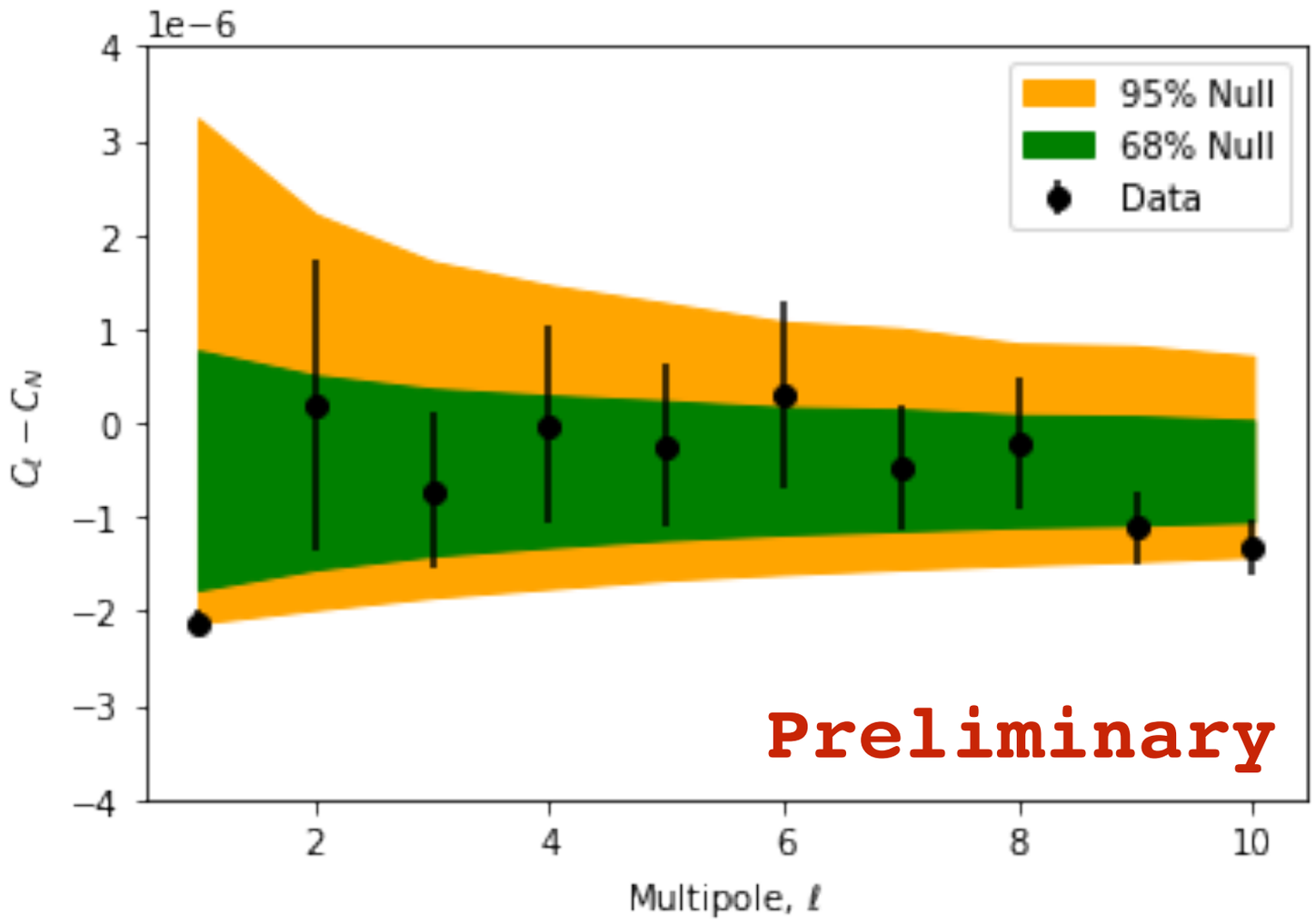
To analyse the relative intensity map we use the spherical harmonic analysis and estimate the angular power spectrum of the observed anisotropies:

$$\delta = 3\sqrt{\frac{C_1}{4\pi}}$$



The total number of events is 6.1×10^6 and the 95% C. L. upper limit on the dipole amplitude is $4.0 \times 10-3$.

Anisotropy Angular Spectrum



The green and orange bands show correspondingly the 68% and 95% limits calculated with the null hypothesis (i. e. perfect isotropy).

Conclusions

- In this work we report on the analysis of one year data set of DAMPE for the search of the arrival direction anisotropies of the cosmic rays for an all-particle sample.

- The total number of events is 6.1Million events and the 95%C. L. upper limit on the dipole amplitude is 4.0×10^{-3}.

- On-going work to increase the data sample both by loosening the selection cuts and accepting events outside the BGO fiducial volume but still with a good angular resolution, with the goal to increase the total number of events by a factor up to 3.

- Future analysis for particle dependent analysis and for longer period of time.

Significance (Li & Ma)

$$S = \sqrt{2}\left\{ N_D ln[\frac{1+\alpha}{\alpha}(\frac{N_D}{N_D+N_R})] + N_R ln[(1+\alpha)(\frac{N_R}{N_D+N_R})] \right\}^{1/2}$$

Future Scope

Sensitivity for the anisotropies improves as a square root of the available number of events we can expect to reach the level of 2.1×10^{-3} analysing the full DAMPE data set.

Performance

Parameter	Value
Energy range of gamma-rays/electrons	5 GeV to 10 TeV
Energy resolution (electron and gamma)	<1.5% at 800 GeV
Energy range of protons/heavy nuclei	50 GeV to 100 TeV
Energy resolution of protons	<40% at 800 GeV
Eff. area at normal incidence (gamma)	1100 cm^2 at 100 GeV
Geometric factor for electrons	0.3 m^2 sr above 30 GeV
Photon angular resolution	<0.2 degree at 100 GeV
Field of View	1.0 sr

DAMPE Coll. [arXiv:1706.08453]

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