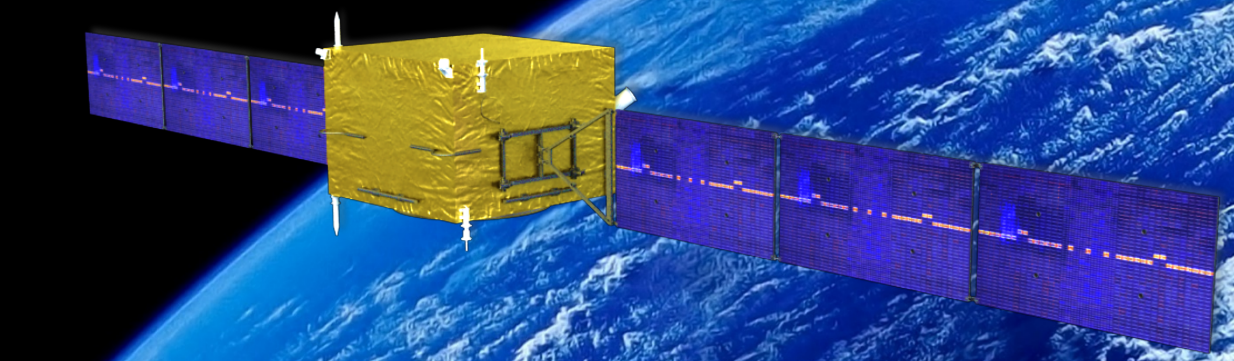
LP2019

DARK MATTER DAMPE PARTICLE EXPLORER

29° International Symposium on Lepton Photon interactions at High Energies

5-10 August 2019 Westin Harbour Castle, Toronto Canada



TeV Particle direct detection in space – Recent Results from the DAMPE mission

Giovanni Marsella

On behalf of the DAMPE Collaboration

giovanni.marsella@le.infn.it

UNIVERSITÀ DEL SALENTO

INFN Istituto Nazionale di Fisica Nucleare

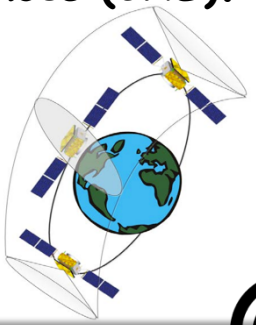
Outline

- Introduction
- DAMPE mission & detector
- On-orbit performance
- Physics Results
- Summary

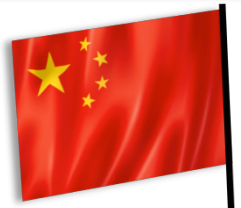
Dark Matter Particle Explorer

Satellite-borne particle detector, project of the *Strategic Pioneer Program on Space Science, promoted by the Chinese Academy of Sciences* (*CAS*).

ALTITUDE: 500 km
PERIOD: 95 minutes
ORBIT: Sun-synchronous



- Study of Cosmic Rays composition, origin and propagation
- Search for Dark Matter signatures in lepton and photon spectra
- High Energy Gamma-Ray Astronomy



- Purple Mountain Observatory
- University of Science and Technology
- Institute of High Energy Physics
- Institute of Modern Physics
- National Space Science Center

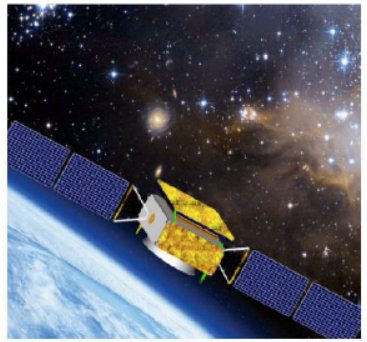
- INFN Lecce and University of Salento
- INFN Bari and University of Bari
- INFN Perugia and University of Perugia
- INFN LNGS and Gran Sasso Science Institute

- Geneva University

Cosmic Rays

3 Major Scientific goals

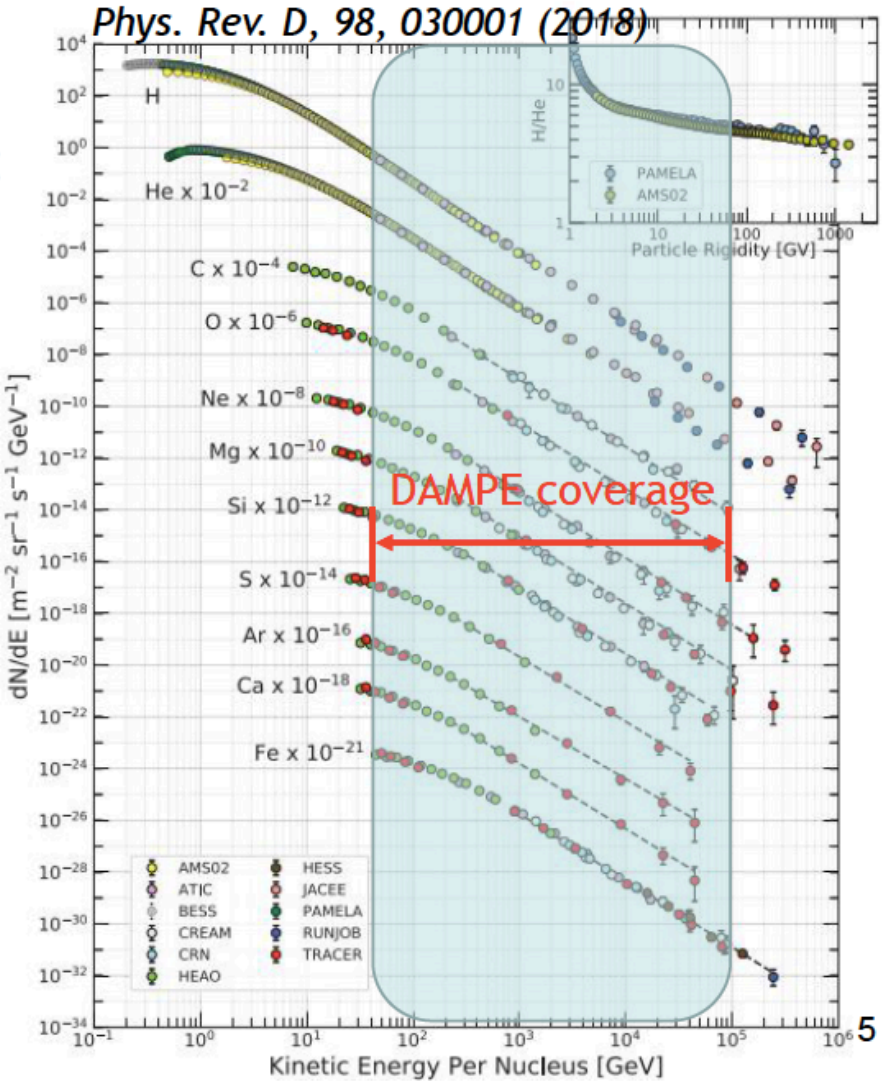
Cosmic ray physics



γ-ray astronomy

Dark matter indirect detection

- Precision measurements of cosmic ray spectra: cosmic ray origin, acceleration, and propagation
- The spectra above TeV are not well measured due to limited statistics of direct detection experiments



Detector Performance

Table 1: Summary of DAMPE instrument parameters and Expected performance

Parameter	Value
Energy range of γ−rays/electrons	5 GeV−10 TeV
Energy resolution of γ−rays/electrons	$\leq$ 1.5% at 800 GeV
Energy range of protons/heavy nuclei	50 GeV−100 TeV
Energy resolution of protons	$\leq$ 40% at 800 GeV
Effective area at normal incidence (γ−rays)	1100 cm^2 at 100 GeV
Geometric factor for electrons	0.3 m^2 sr above 30 GeV
Photon angular resolution[a]	$\leq 0.2^\circ$ at 100 GeV
Field of View (FoV)	$\sim$1.0 sr

Note: a. For the 68% containment radius.

DAMPE detector

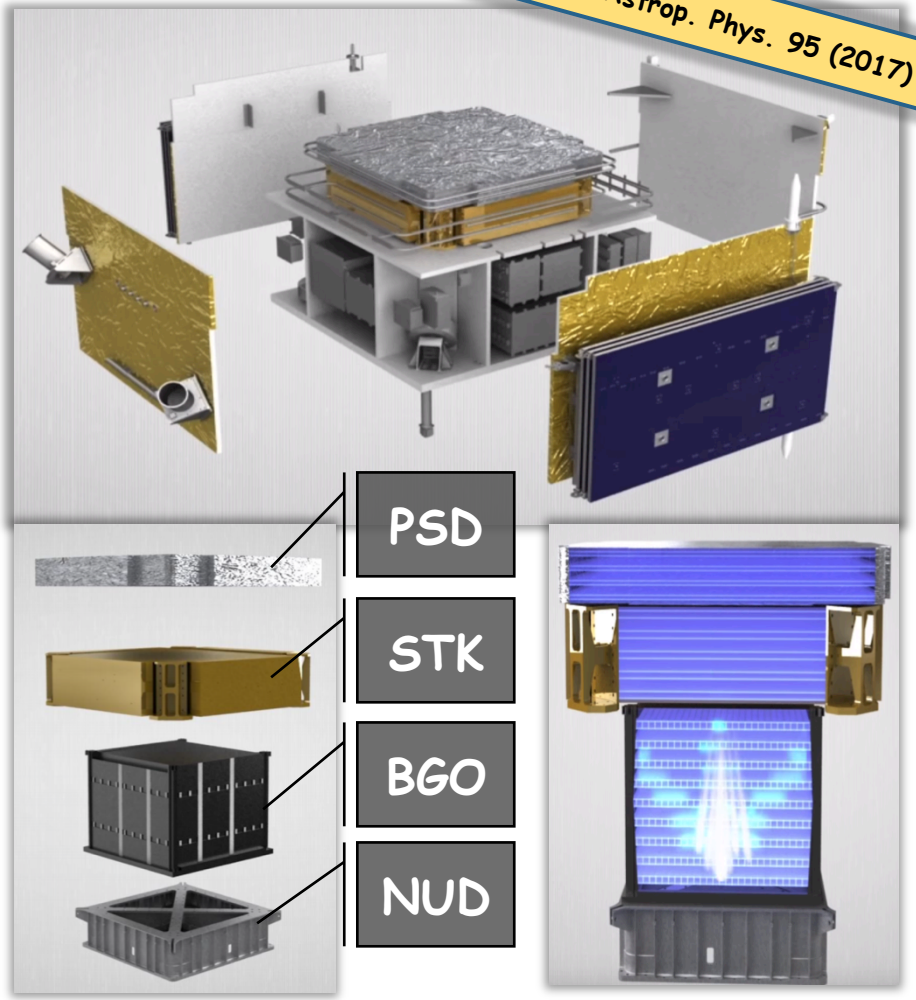
J. Chang et al., Astrop. Phys. 95 (2017) 6-24

PSD	• 2 planes with double layer configuration • 82 bars of plastic scintillator ❑ CHARGE MEASUREMENT ($Z<28$, $Z \propto \sqrt{E}$) ❑ γ-RAYS VETO

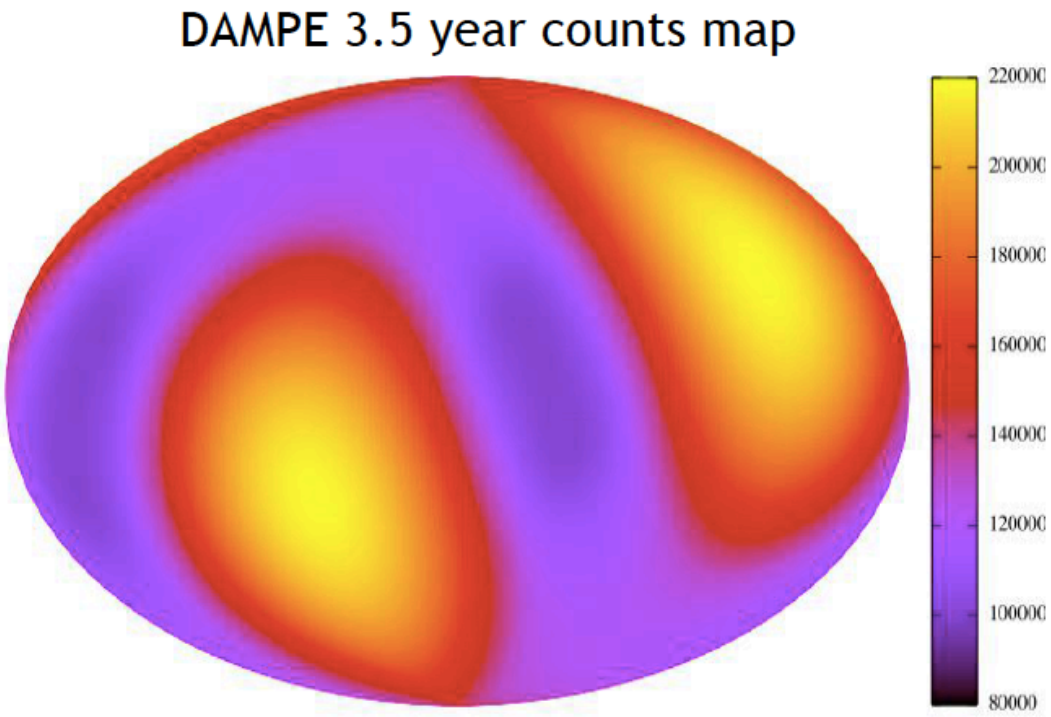
STK	• 6 planes with 2 single-sided silicon layers
	• 3 thin tungsten layers (for γ conversion in e^+/e^-)
	
	❑ TRACK RECONSTRUCTION
	  ❑ spatial resolution <70 μm for CR (θ_{inc}< 60°)
	  ❑ angular resolution ~0.2° for γ at 10 GeV
	❑ CHARGE MEASUREMENT ($Z \propto \sqrt{ADC}$)

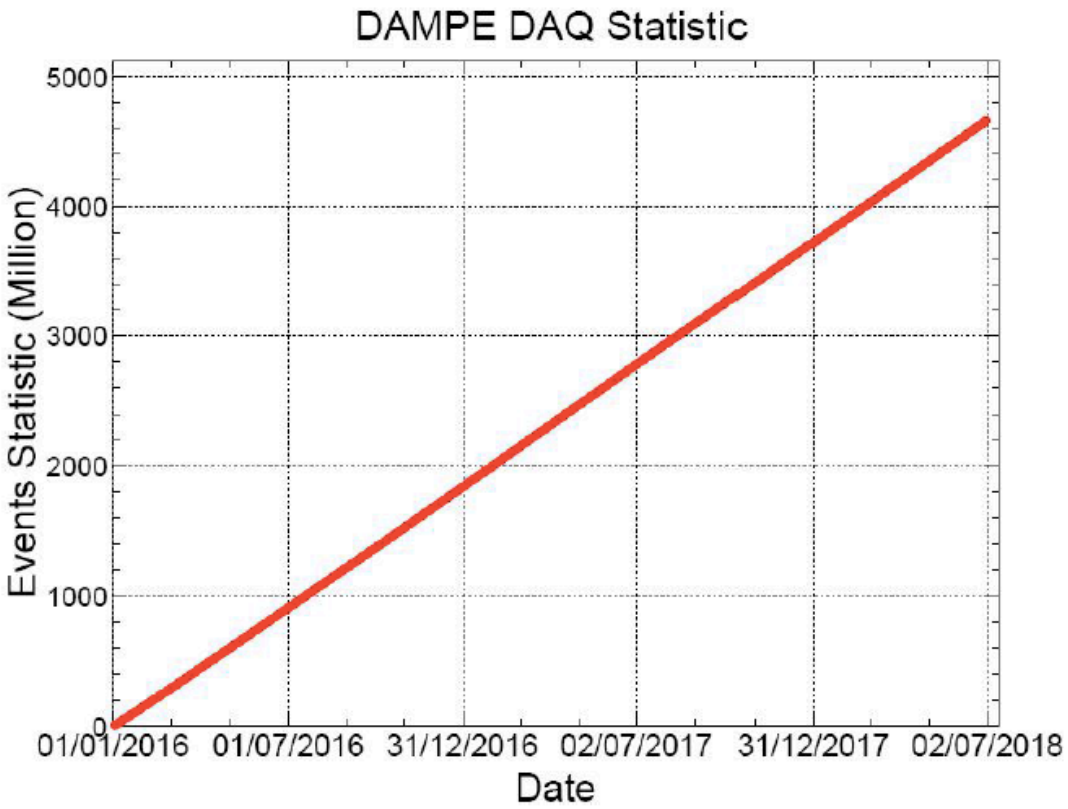
BGO	• 14 layers, each one with 22 bars of $Bi_3Ge_4O_{12}$,~32 X_0
	
	❑ ENERGY MEASUREMENT
	  ❑ 1 GeV - 10 TeV for electrons and γ
	  ❑ 50 GeV - 100 TeV for nuclei

NUD	• 1 layer, 4 boron-doped plastic scintillator ❑ detection of neutrons generated in the BGO for hadron/e.m. showers discrimination



Observation Overview

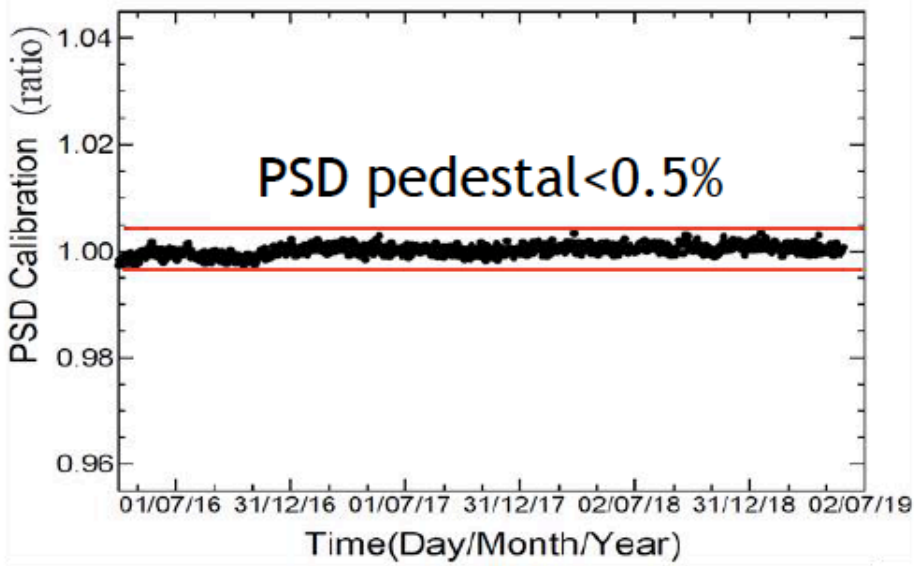


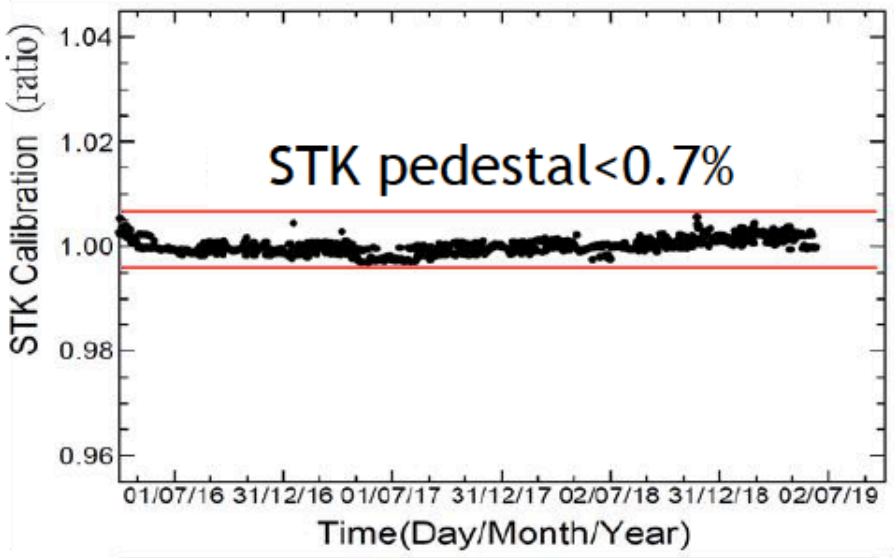


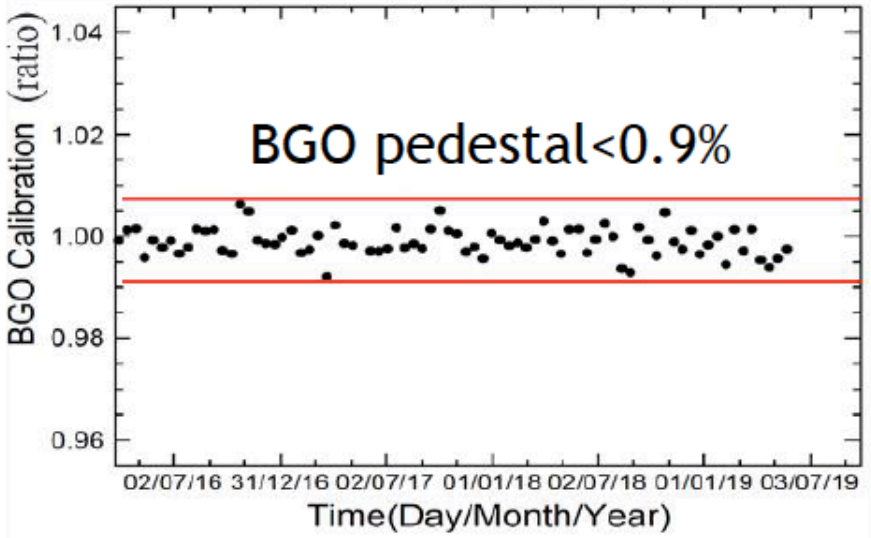
7 full scans of the sky

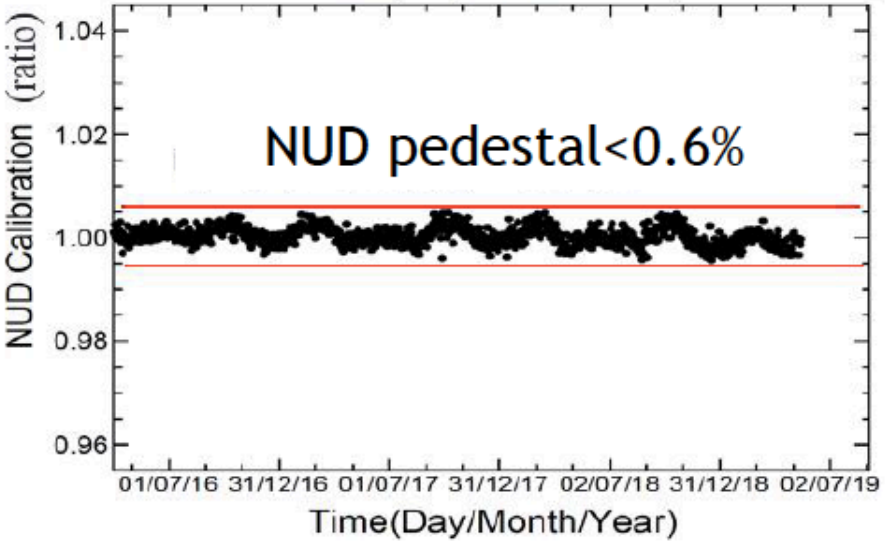
5M events/day
6.5 billion in total

Detector Stability









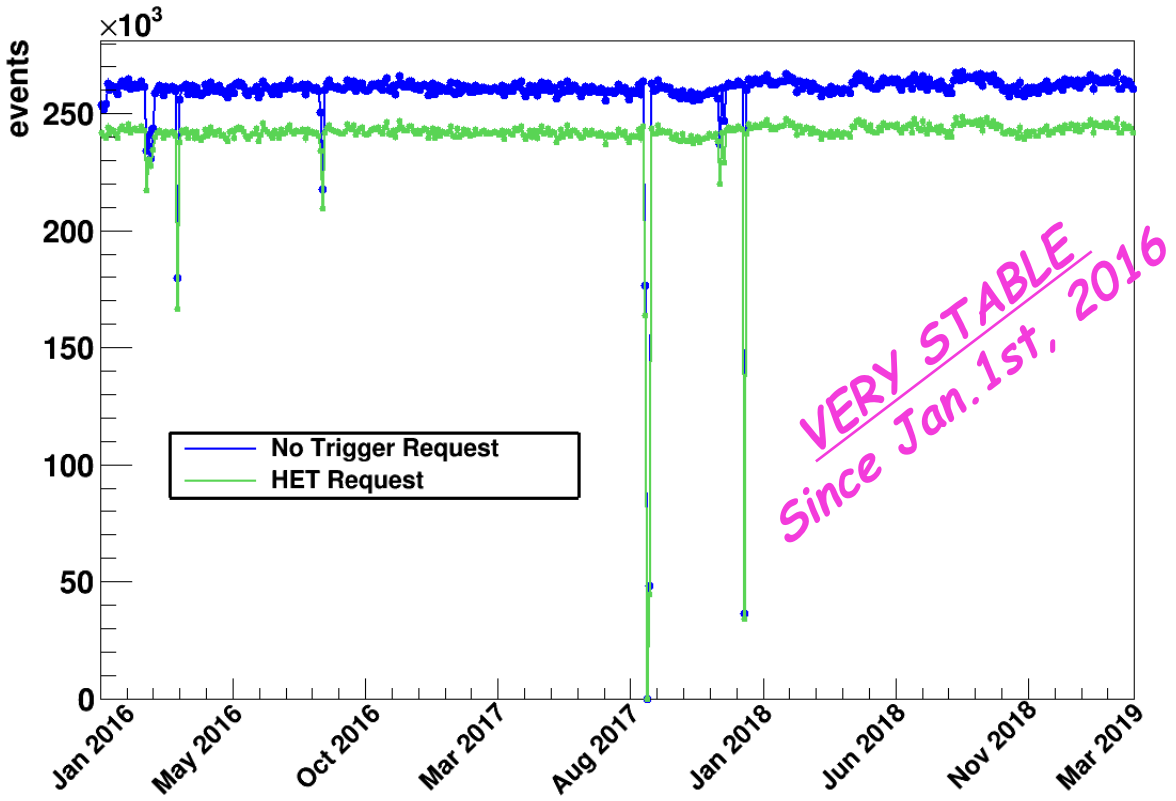
DATA-TAKING

DATA Taking: January 1st, 2016 to March 31th, 2019

EXPOSURE TIME: $7.86 \cdot 10^7$ s

Exposure time affected by:

- South Atlantic Anomaly (SAA) region
  (~ 4.5% of the operation time)
- on-orbit calibration data-taking
  (~ 1.5% of the operation time)
- instrumental dead time
  (~18.5% of the operation time)



High Energy Trigger (HET)
HET rate ~50 Hz
~4 M events recorded/day

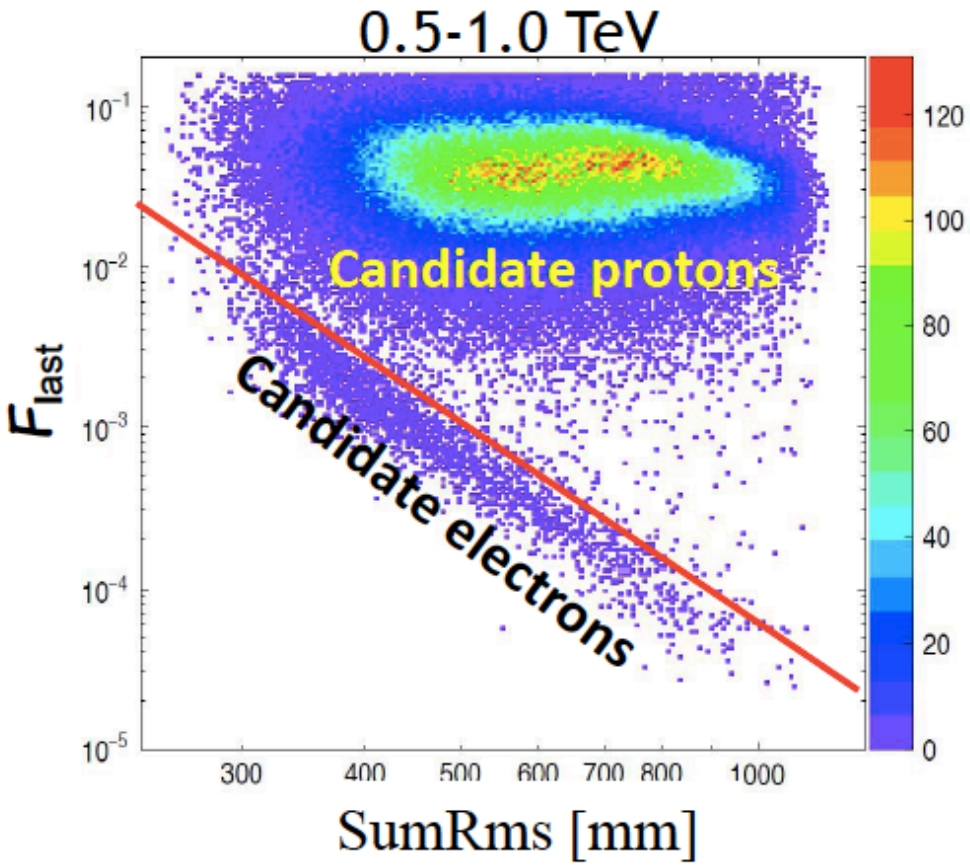
~12 GB/day transferred to ground

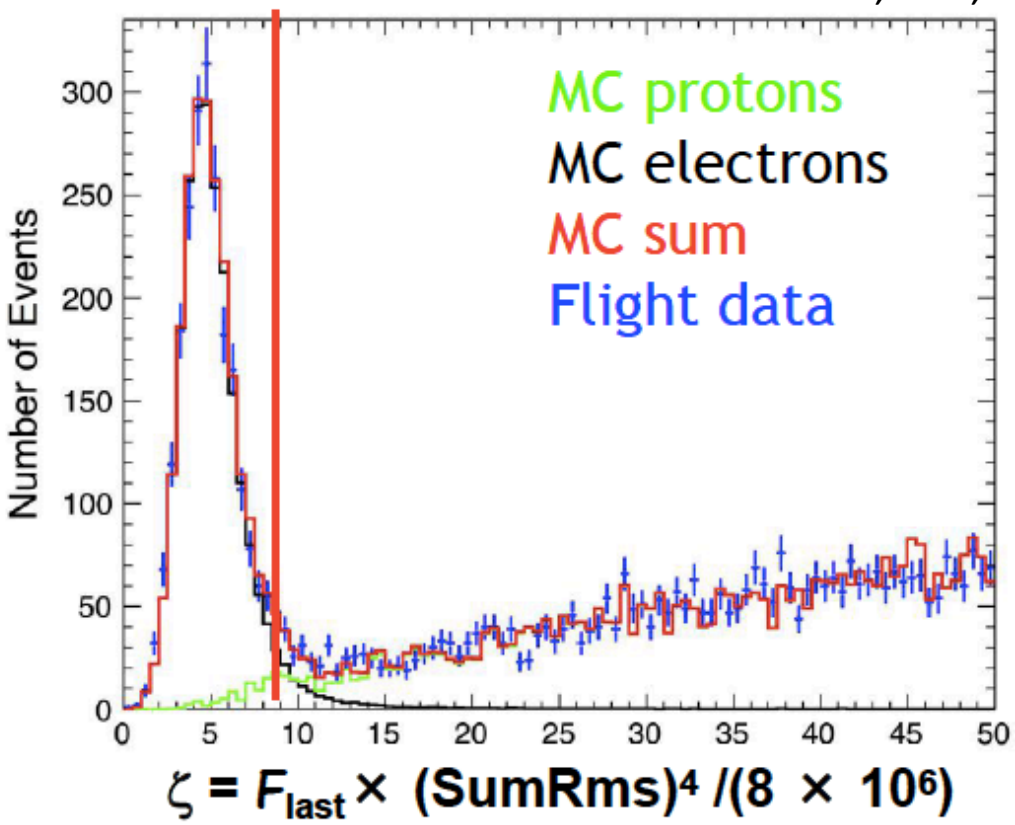
E_{dep} > 10 MIPs in first three BGO layers
E_{dep} > 2 MIPs in 4th BGO layer
(1 MIP_{BGO} = 23 MeV)

Lower rates:
- Events excluded due to Intense Solar flare
- Events excluded due to High Voltage reset
- Data acquisition suspended for calibrations, monitoring,…

e/p separation

Nature, 552, 63 (2017)

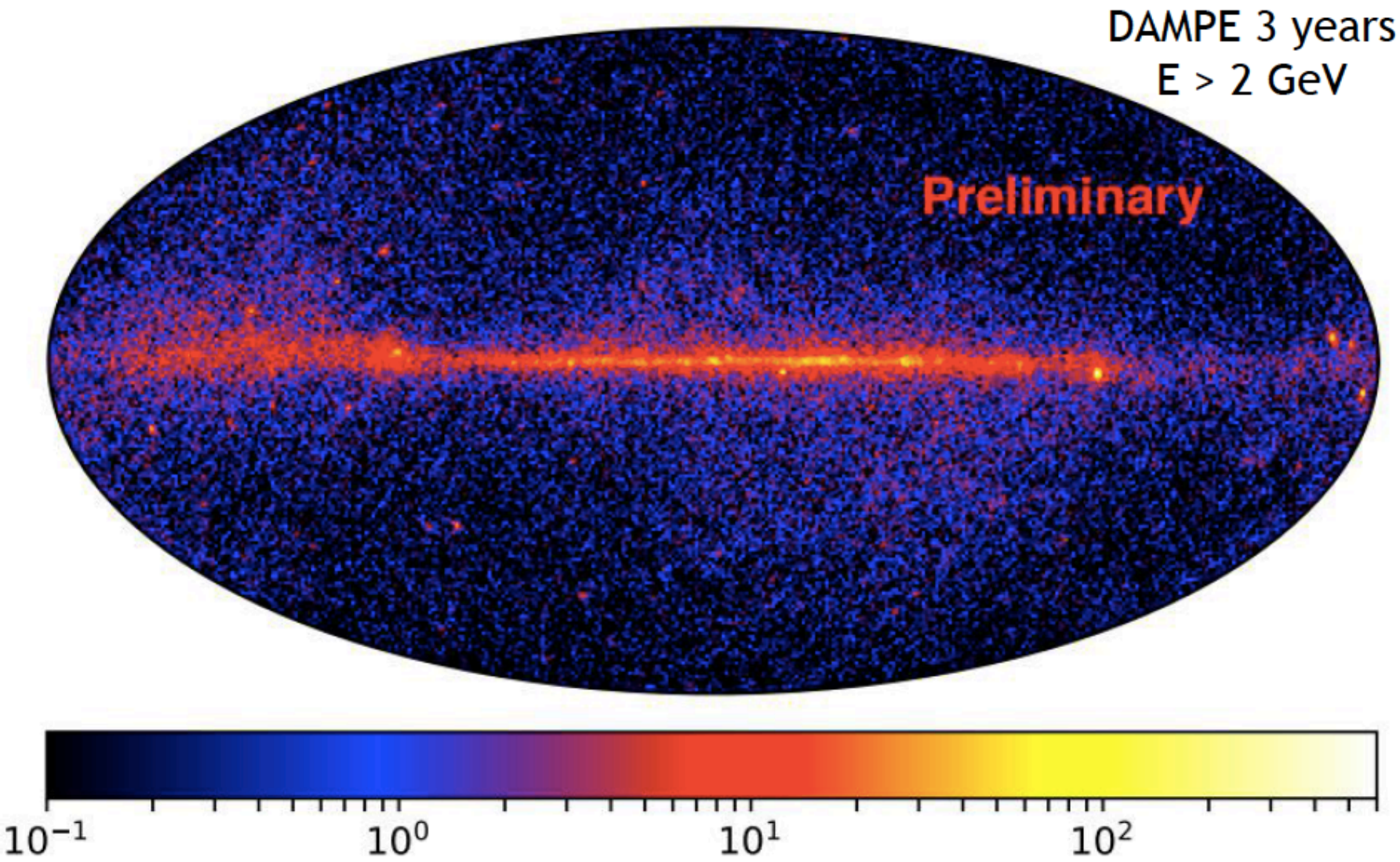




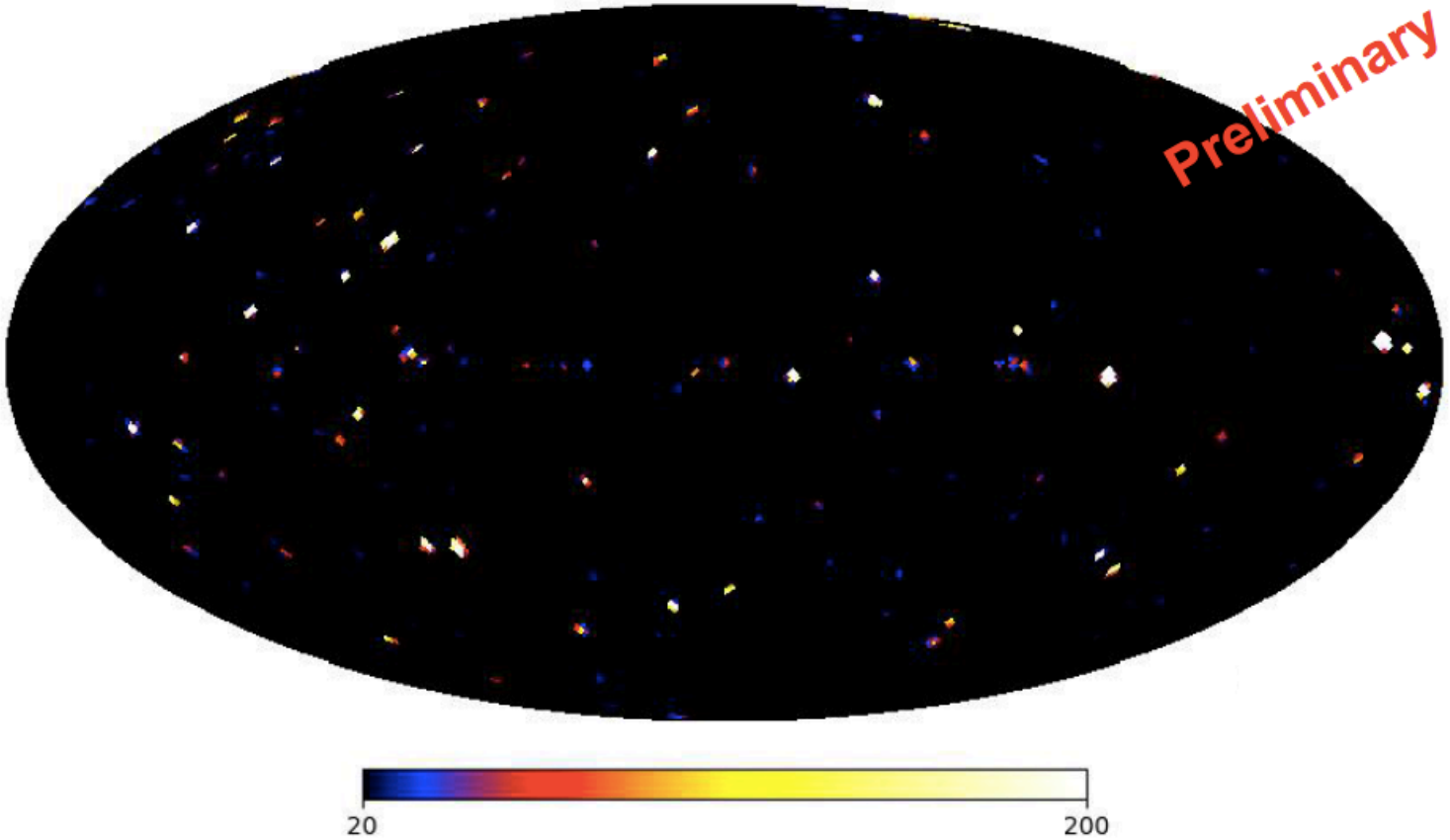
- We use the lateral (SumRMS) and longitudinal (energy ratio in last layer) developments of the showers to discriminate electrons from protons
- For 90% electron efficiency, proton background is ~2% @ TeV, ~5% @ 2 TeV, ~10% @ 5 TeV

- Physics Results

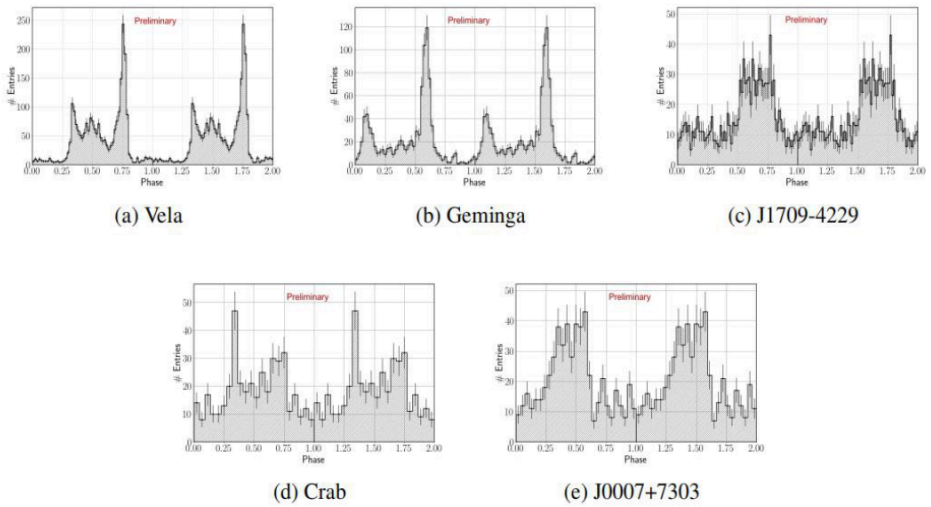
Gamma-Ray Sky Map



Gamma-Ray point sources

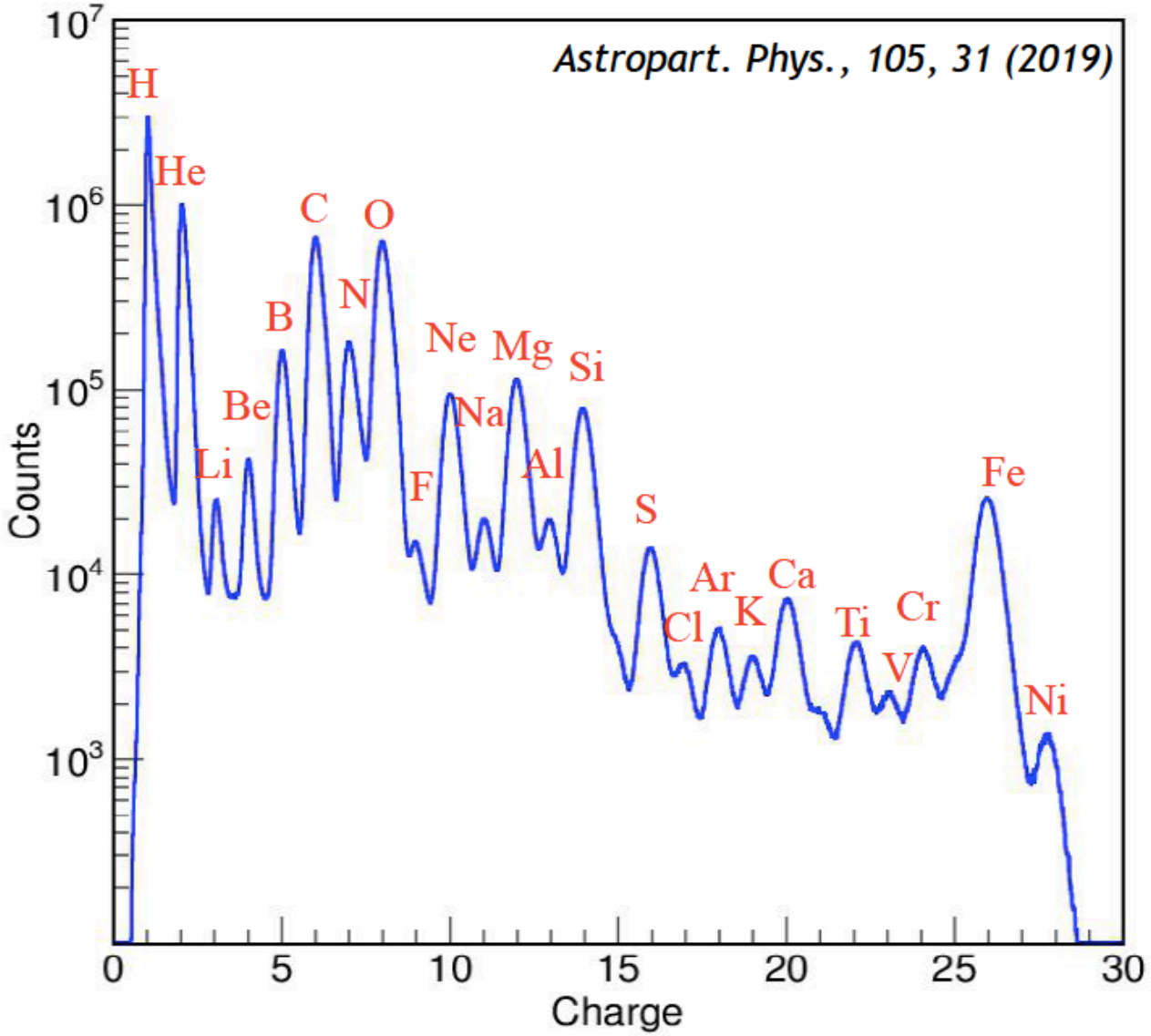


Gamma-Ray Pulsars



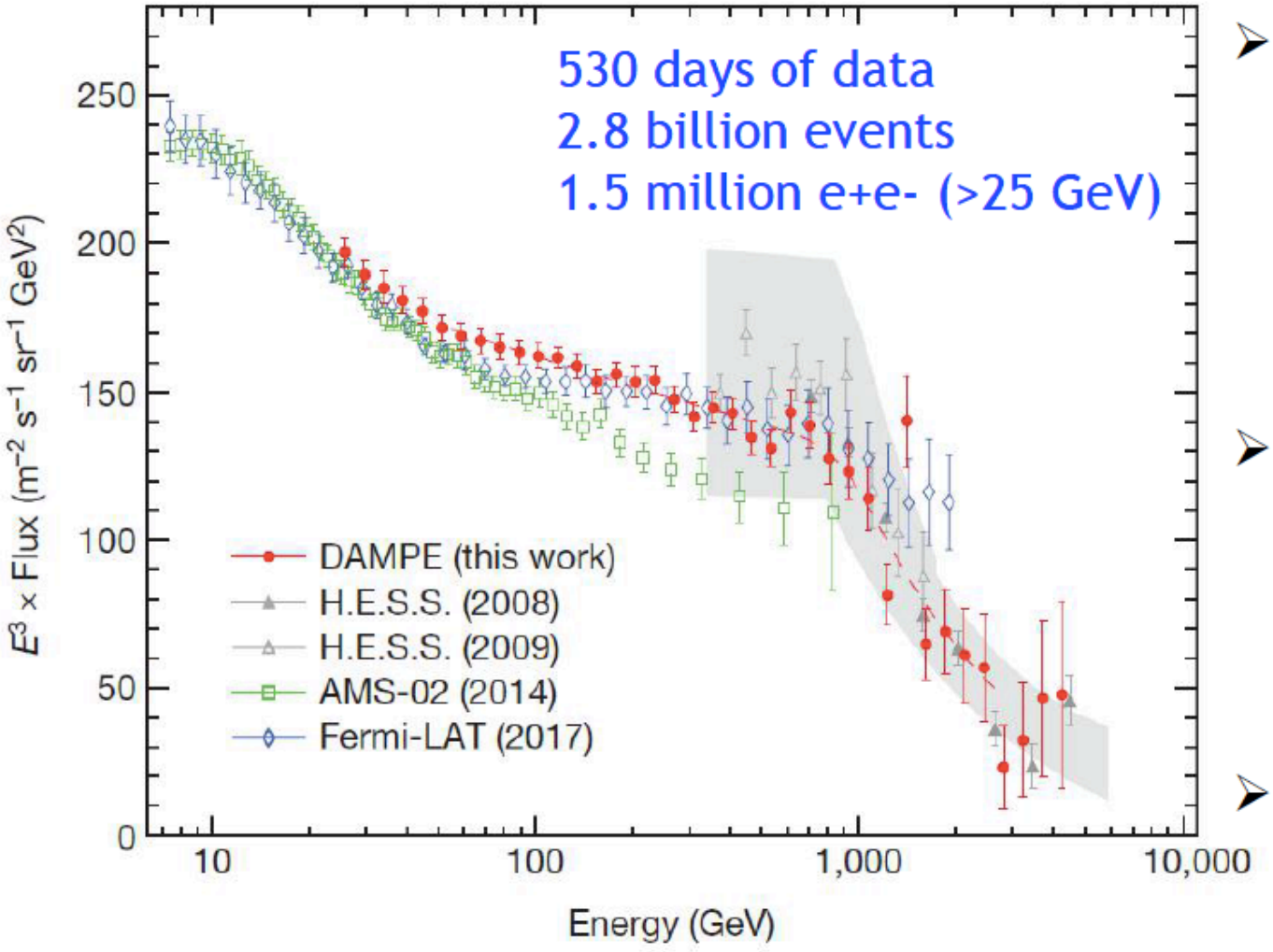
- 143 sources with TS > 20
- Most are pulsars and AGNs

PSD Charge Measurements



Species	Res.
P	0.07
He	0.12
Li	0.14
Be	0.21
B	0.17
C	0.18
N	0.21
O	0.21

$e^+ + e^-$ Spectrum

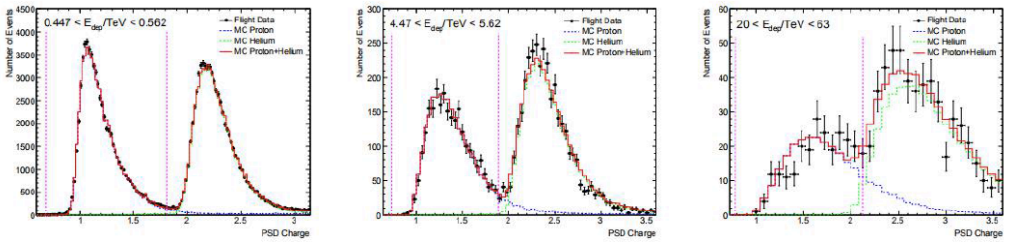


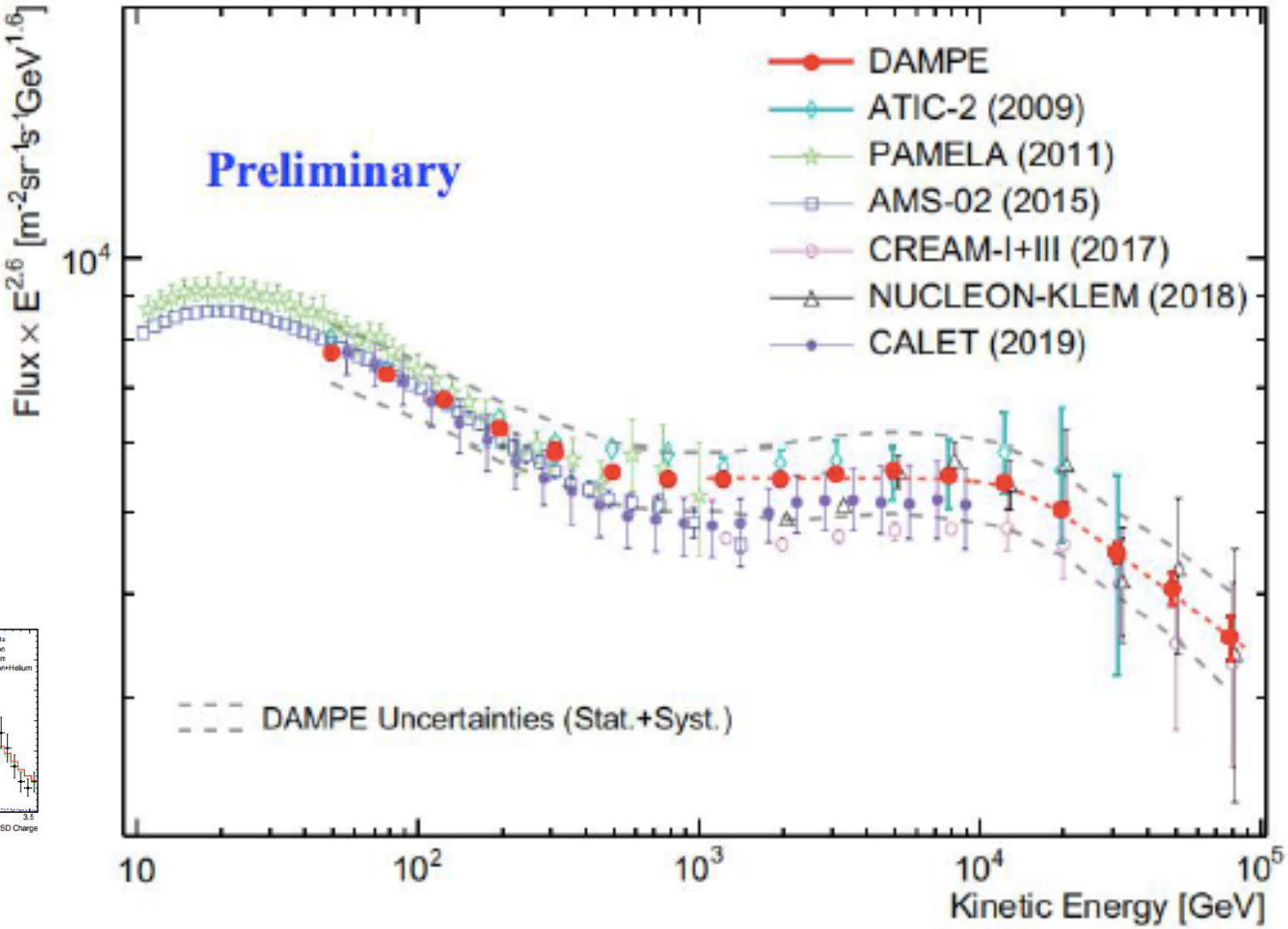
- Three different PID methods give very consistent results on event-by-event level
- Direct detection of a spectral break at ~1 TeV with 6.6σ confidence level
- Analysis with new data is on-going

Nature, 552, 63 (2017)

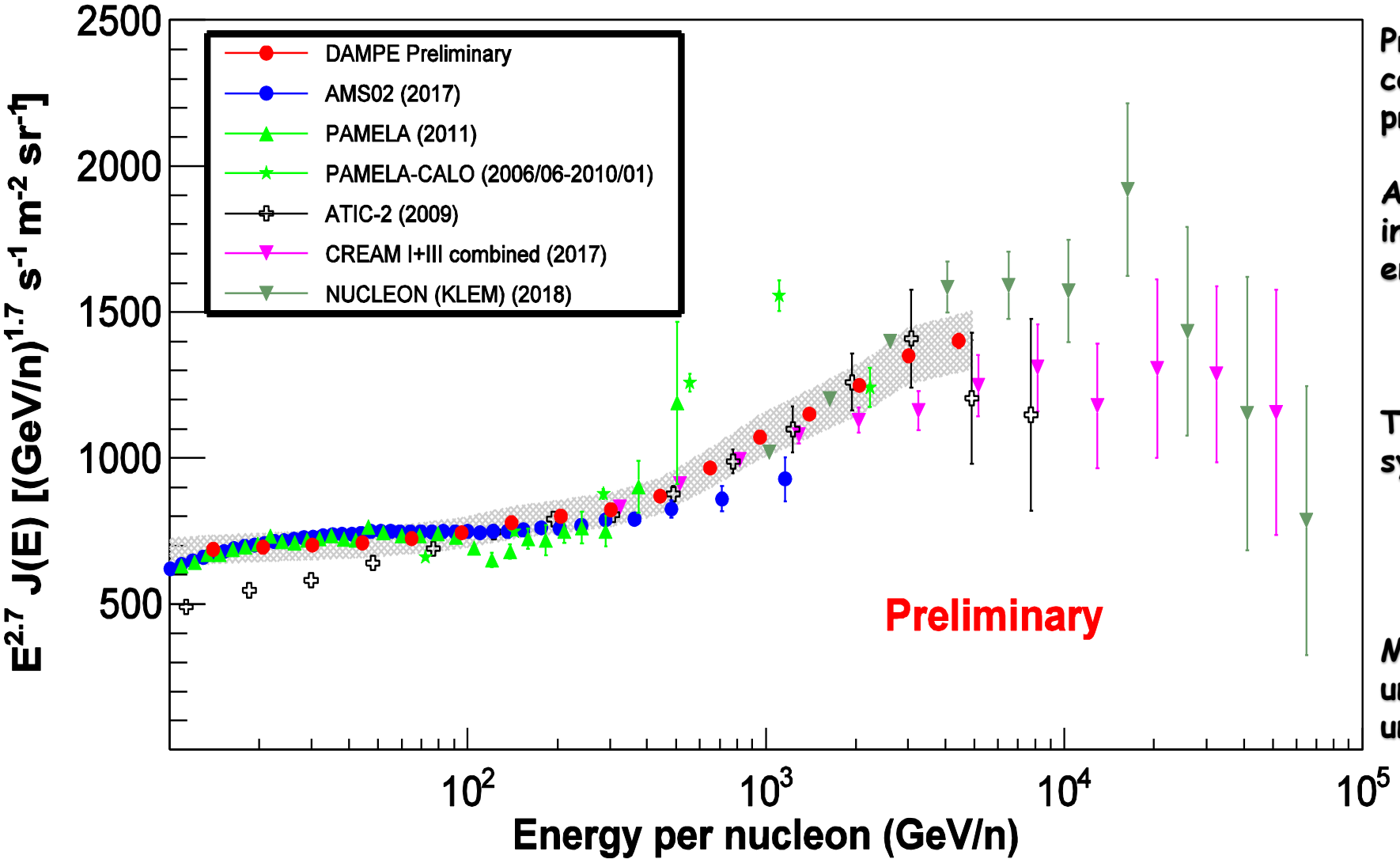
Preliminary Proton Flux

- Confirms the hundreds GeV hardening
- Detecting a softening at ~13 TeV with high significance





Preliminary Helium Flux



Preliminary Helium flux per nucleon compared with results obtained by previous experiments.

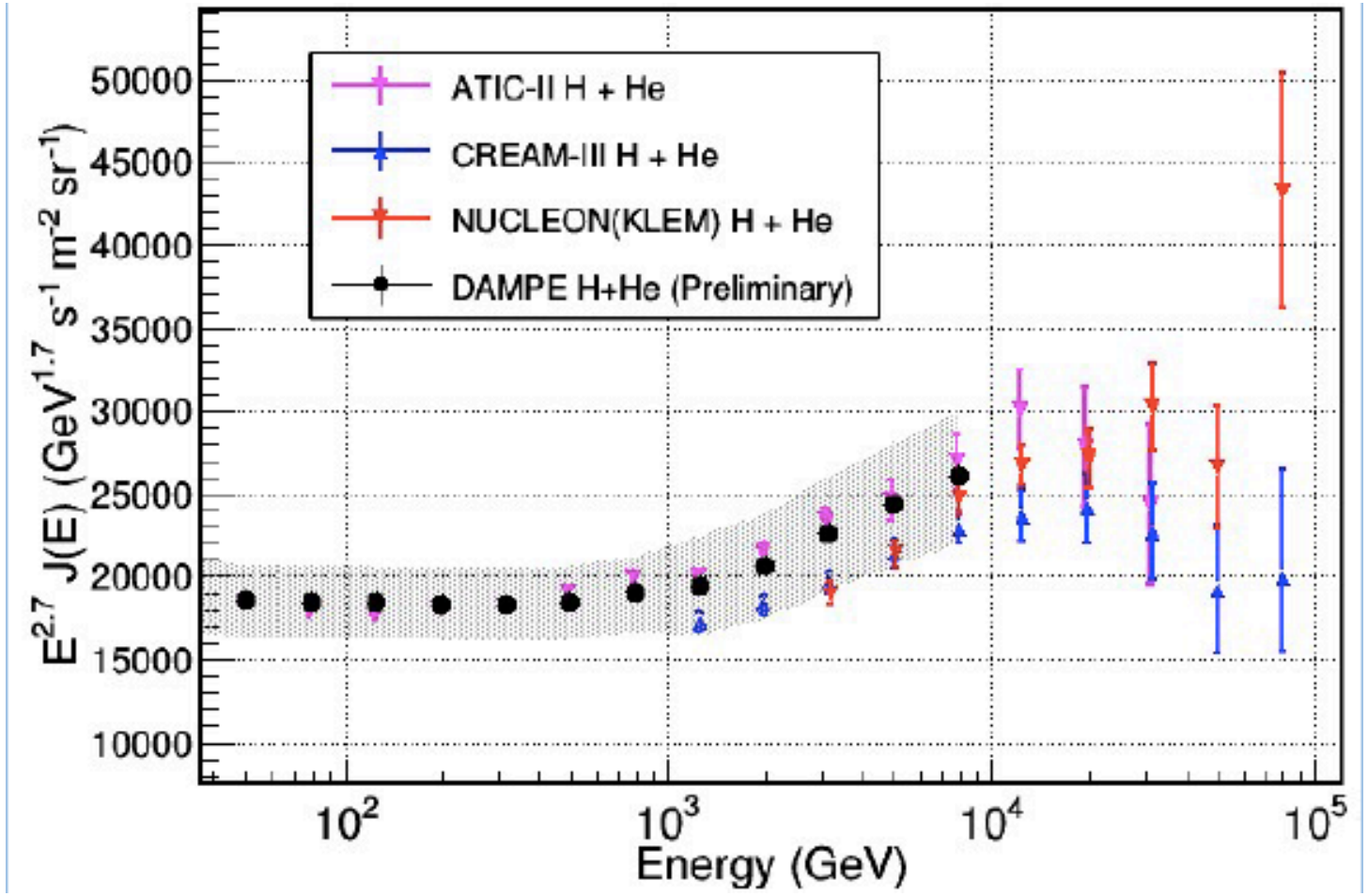
An unfolding method has been adopted in order to reconstruct the primary energy of Helium nuclei.

The grey band represents the total systematic uncertainty:

More studies on systematic uncertainties (hadronic model, unfolding, etc..) are in progress.

Preliminary Proton+Helium Flux

Ps1-36 PoS(ICRC2019)148



A spectral hardening can be observed Below 1 TeV (Energy/nucleus)

The full evaluation of systematic Uncertainties, for the extension of the Measurement up to about 100 TeV, is ongoing

Summary

- The DAMPE detector is in a stable data-taking at 500 km of altitude since Dec. 17, 2015
- Preliminary Photon Maps are available
- Very precise measurements of the e++e- spectrum from 25 GeV to 4.6 TeV have been obtained, showing a spectral break at ~TeV energies and possible new spectral features
- Proton and Helium preliminary results have been presented
- More results are coming…