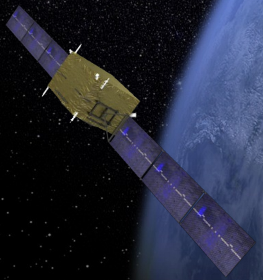
Measurement of the light component (p+He) energy spectrum with the DAMPE space mission

Francesca Alemanno*

(on behalf of the DAMPE collaboration)

*email: francesca.alemanno@gssi.it



DARK MATTER PARTICLE EXPLORER DAMPE

GRAN SASSO SCIENCE INSTITUTE
SCHOOL OF ADVANCED STUDIES
Scuola Universitaria Superiore

INFN LNGS
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Gran Sasso

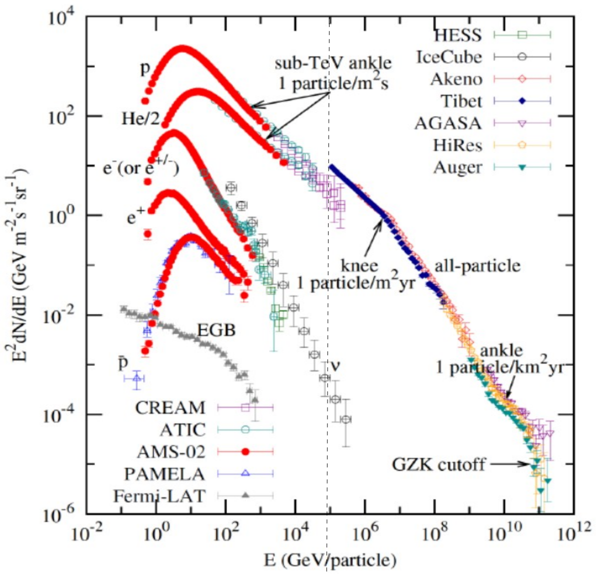
ICRC 2021
THE ASTROPARTICLE PHYSICS CONFERENCE
Berlin | Germany
37th International Cosmic Ray Conference
12–23 July 2021

OVERVIEW

1. Motivation
2. The DAMPE space mission: collaboration and detector structure
3. Data sample
4. Selection criteria
5. Acceptance
6. Energy reconstruction
7. Result: p + He spectrum

Study of light CR component: motivations

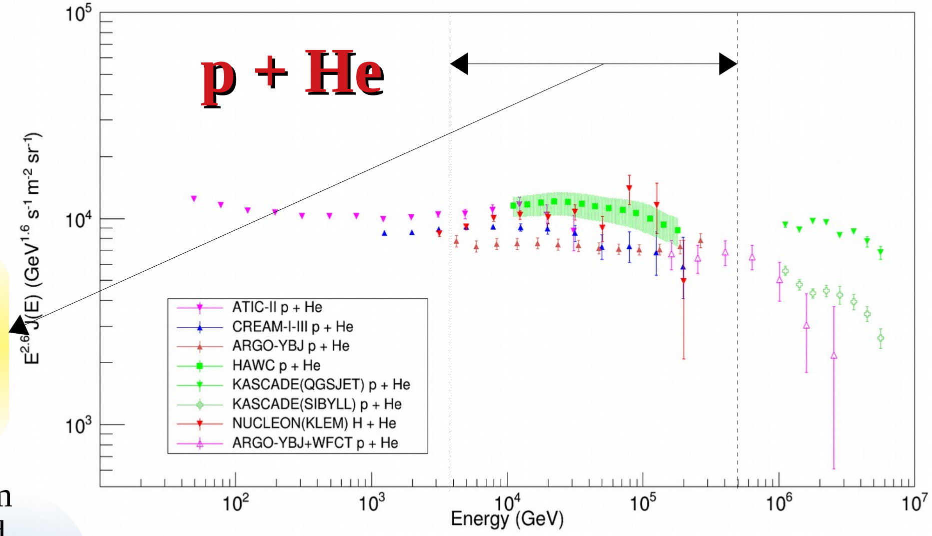
Measuring light elements in space (i.e. proton + helium spectrum) gives the **possibility to compare results between direct and indirect experiments**



Space-based experiments (direct measurements)

Ground-based experiments (indirect measurements)

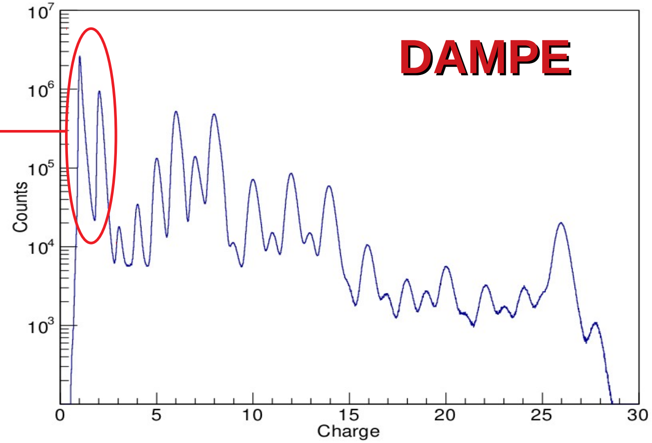
In this energy region direct and indirect spectra can be compared



Proton and Helium are well separated from other peaks

VERY LOW CONTAMINATION
(less than 0.1 %)

Looser cuts
Possibility to go to higher energy



The DAMPE space mission

The DArk Matter Particle Explorer (DAMPE) is a high-energy particle detector

DAMPE was successfully launched in a Sun-synchronous orbit on December 17th 2015 from the Jiuquan Satellite Launch Center

The main objectives of the DAMPE mission are:

- Study of galactic cosmic-ray physics
- Dark matter searches
- High-energy gamma-ray astronomy

The DAMPE collaboration involves several institues in China and Europe

CHINA

- *Purple Mountain Observatory, CAS, Nanjing*
- *University of Science and Technology of China, Hefei*
- *Institute of High Energy Physics, CAS, Beijing*
- *University of Chinese Academy of Sciences, Beijing*
- *National Space Science Center, CAS, Beijing*
- *Institute of Modern Physics, CAS, Lanzhou*
- *University of Hong Kong, Hong Kong*

ITALY

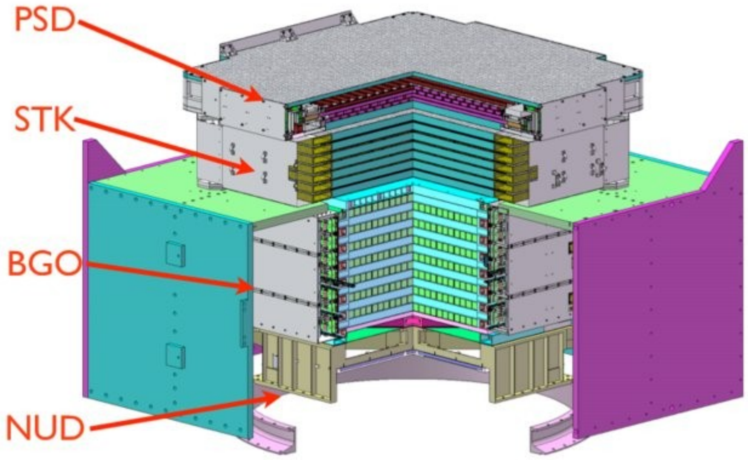
- *INFN Perugia and University of Perugia*
- *INFN LNGS and Gran Sasso Science Institute*
- *INFN Bari and University of Bari*
- *INFN Lecce and University of Salento*

SWITZERLAND

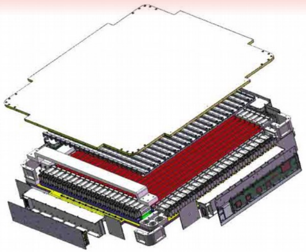
- *University of Geneva*

Detector structure

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

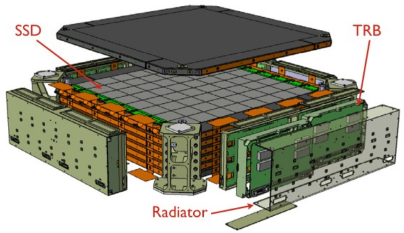


Plastic Scintillator Detector (PSD)



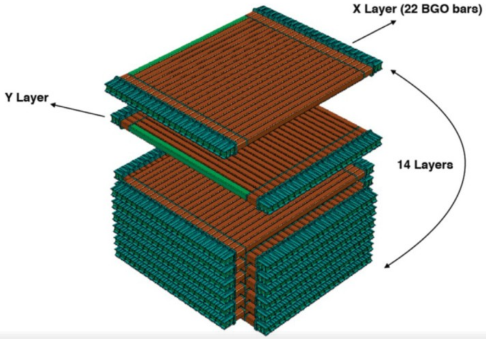
Charge measurement + identification of electrons and gamma-rays

Silicon-Tungsten tracKer (STK)



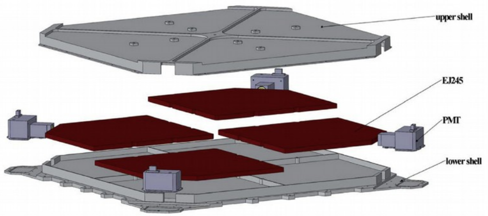
Silicon strips (precise tracking) + tungsten converter (pair production)

BGO Calorimeter (BGO)



Energy measurement + e/p separation

NeUtron Detector (NUD)



Additional hadrons rejection

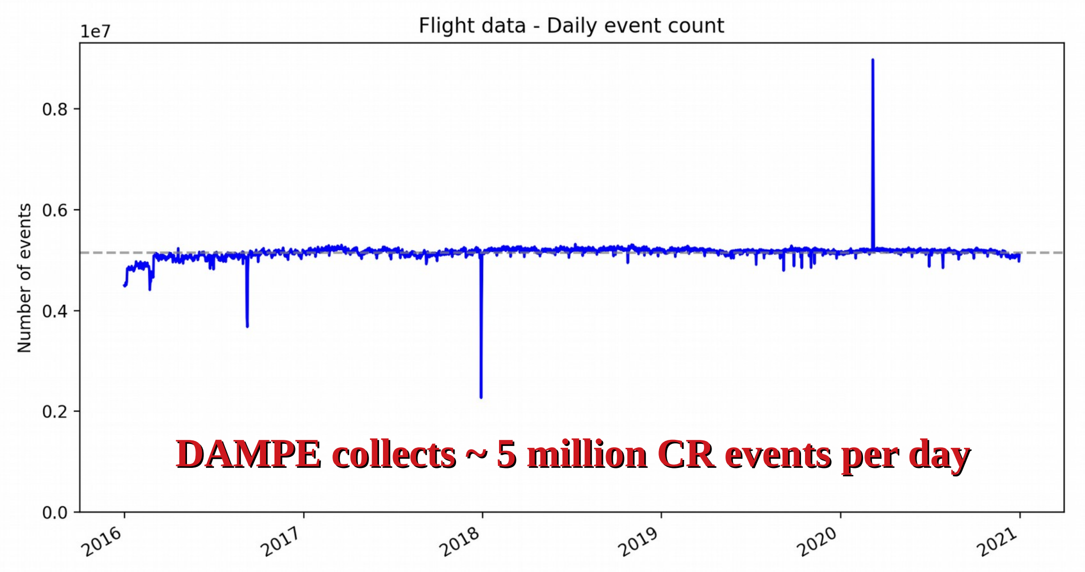
Data sample

<u>MONTE CARLO DATA</u> (simulated):

- Proton [1 GeV – 1 PeV]
- Helium [10 GeV – 500 TeV]

<u>ORBITAL DATA</u> (from the satellite):

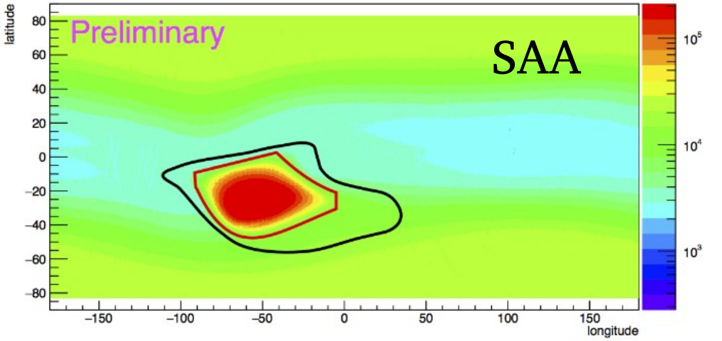
60 months → January 2016 – December 2020



Data taken during the *dead time* are removed:

1) DAMPE passes through the SAA region 6-7 times per day (~ 4.5 % of total flying time)
2) The responding time of the electronics is ~ 3 ms for each triggered event (~ 18 % of total flying time)
3) The daily on-orbit calibration + the monthly electronics-linearity calibration (~ 1.8 % of total flying time)

Total time ~ 12x10^7 s



Selection cuts

Preselection of good quality events →

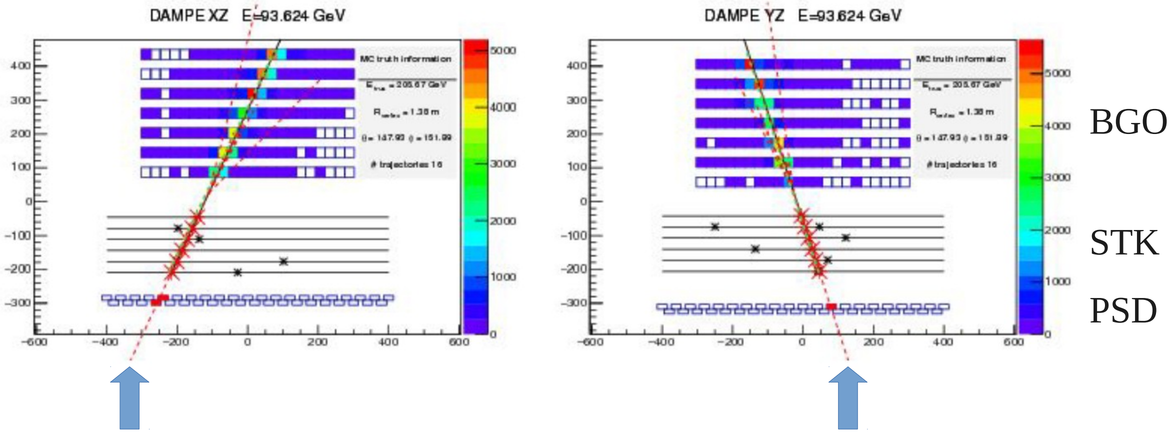
- **Energy deposited in the BGO calorimeter > 20 GeV to avoid the effect of the geomagnetic rigidity cutoff**
- **Rejection of events entering the detector from the side and events with maximum energy deposition at the edge of the BGO**
- **The track has to be fully contained in the PSD**

Track selection →

- **Match of the track reconstructed in BGO & STK and PSD & STK**

Trigger selection

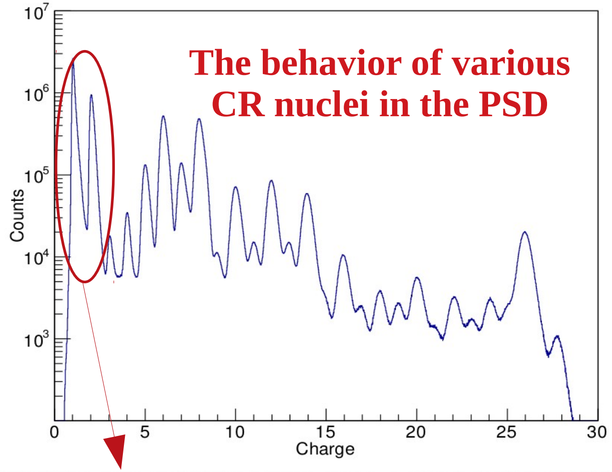
- **Events must activate the High Energy Trigger of DAMPE** (energy deposition in the top 4 BGO layers exceeding the threshold of ~10 MIPs in each hit BGO bar)

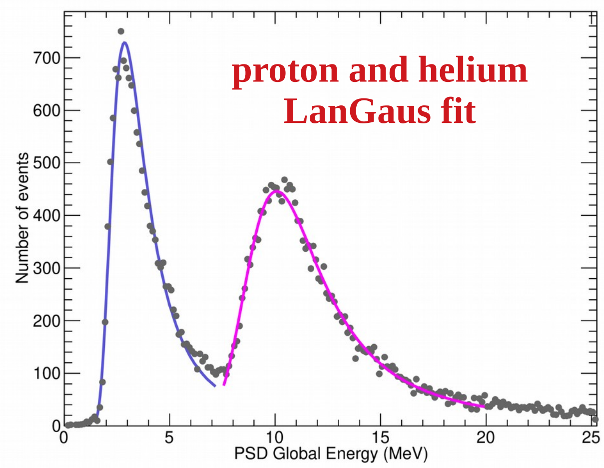


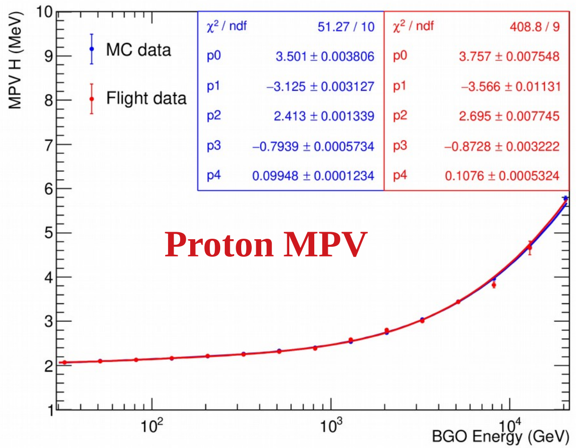
Incoming particle

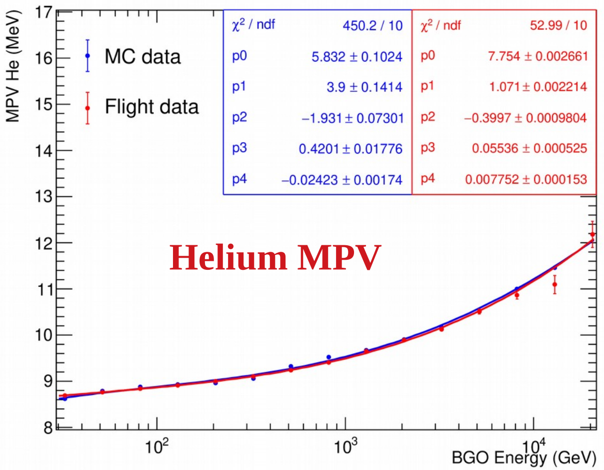
Incoming particle

p + He charge selection

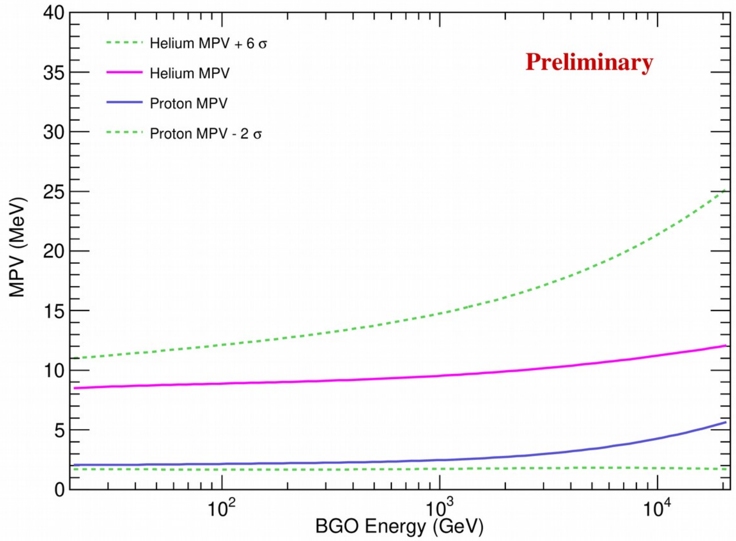








Charge selection range for proton + helium



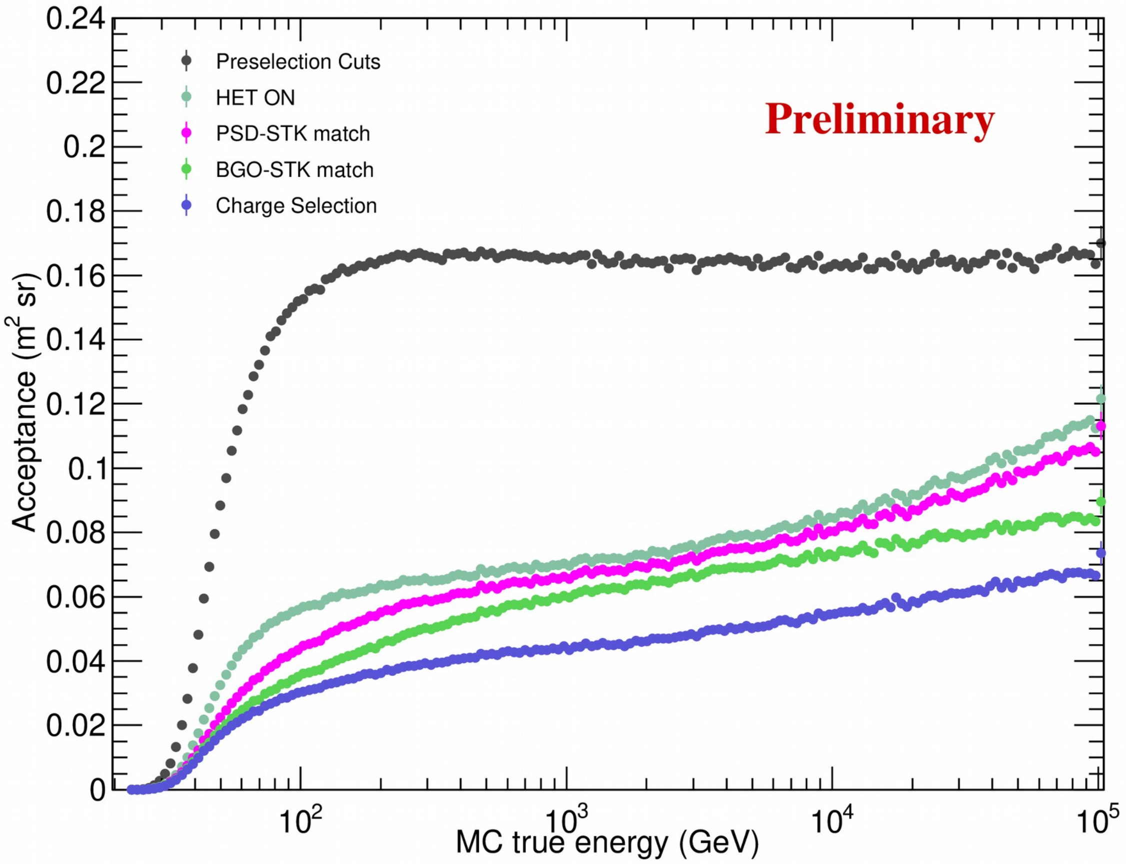
Effective acceptance

$$A^i_{acc} = G_{gen} \times \frac{N(E^i_T, sel)}{N(E^i_T)}$$

G_{gen} = geometrical acceptance used for generating MC data

$N(E^i_T)$ = number of MC generated events in the i-th bin of primary energy

$N(E^i_T, sel)$ = number of MC events surviving all the selection cuts



Energy reconstruction

The nuclear interaction length of DAMPE is ~ 1.6. Therefore, for protons and helium nuclei, a certain fraction of primary energy is undetectable. The energy deposition for protons and helium nuclei in the BGO is only 35% - 40%

In order to obtain the primary energy of an entering event, a method based on the Bayes theorem is used.

Using this formula, the primary spectrum can be obtained from the observed spectrum in the BGO calorimeter

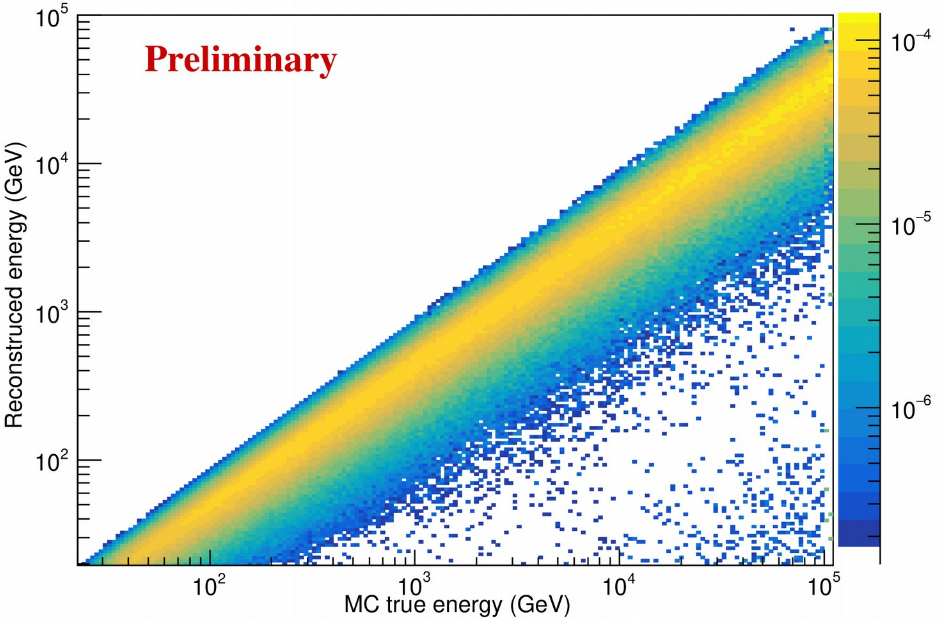
$$N\left(E_T^i\right) = \frac{1}{\varepsilon_i} \sum_{j=1}^{n} P\left(E_T^i \mid E_O^j\right) N\left(E_O^j\right)$$

$N\left(E_T^i\right)$ Primary spectrum

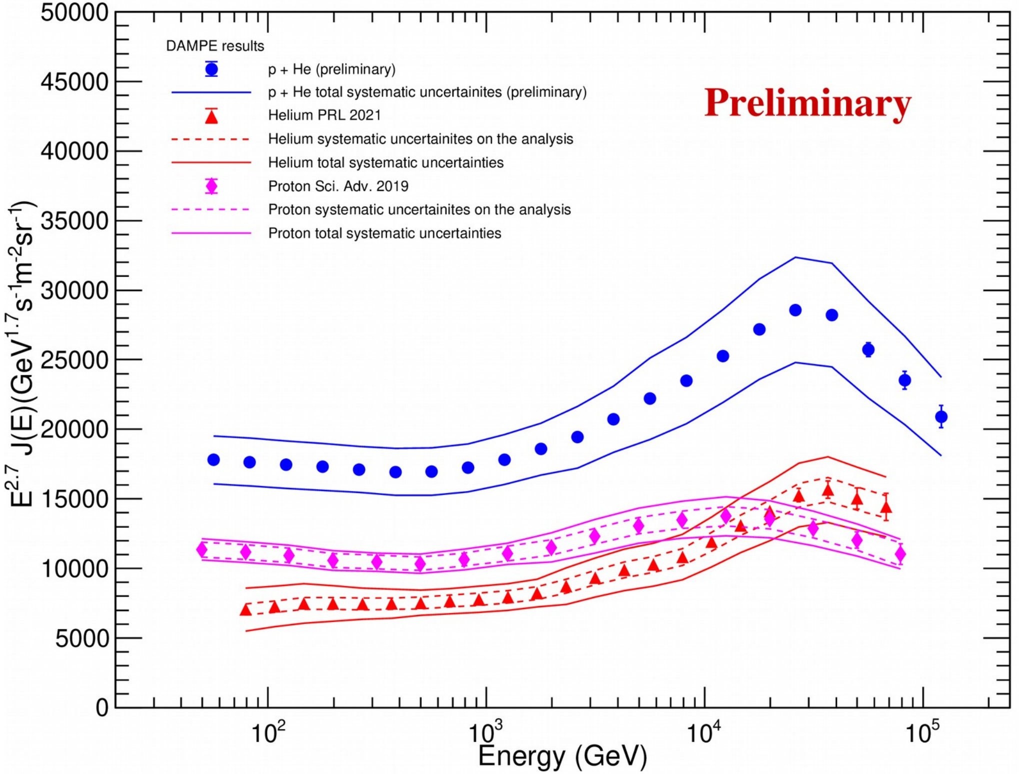
$N\left(E_O^j\right)$ Observed spectrum

$P\left(E_T^i \mid E_O^j\right)$ Response matrix derived from MC using the Bayes theorem

ε_i Detection efficiency

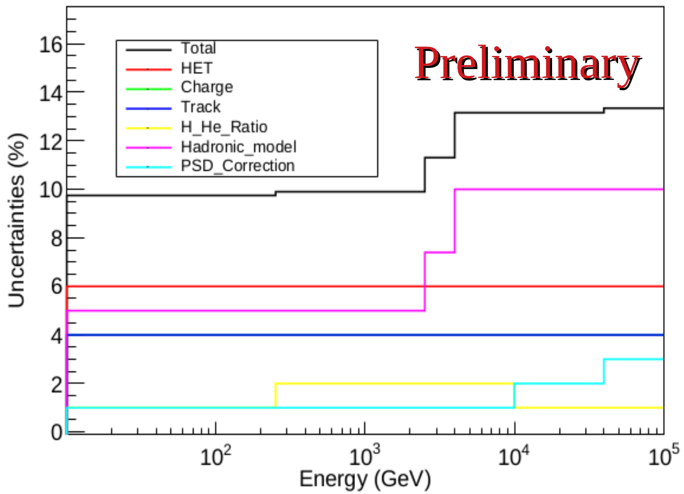


p+He spectrum



Good agreement with the sum of the two proton and helium independent analysis!

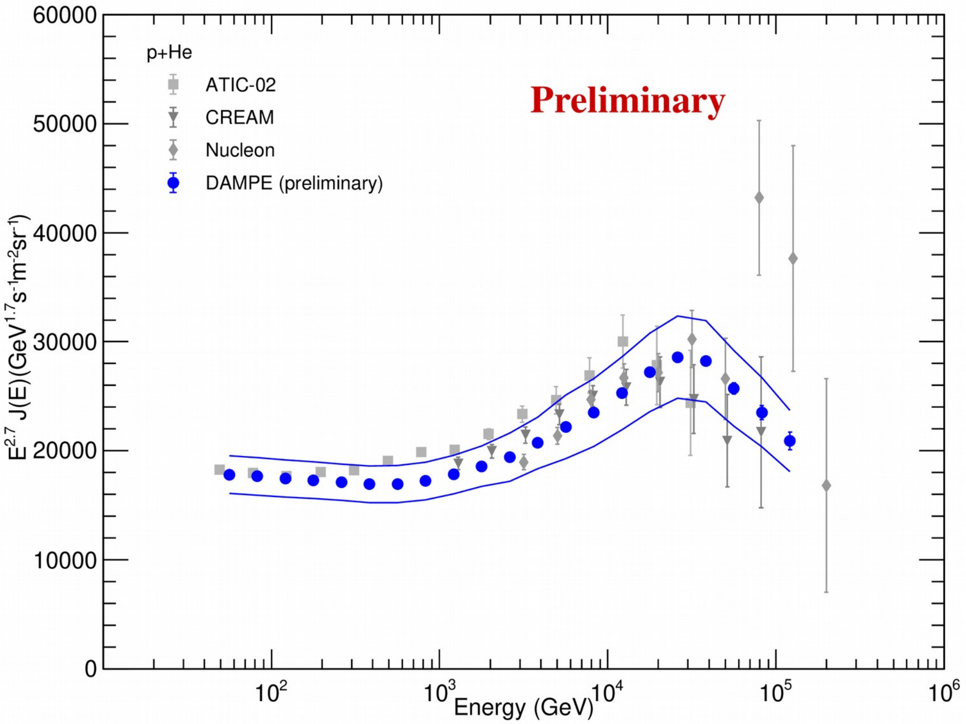
p+He systematic uncertainties



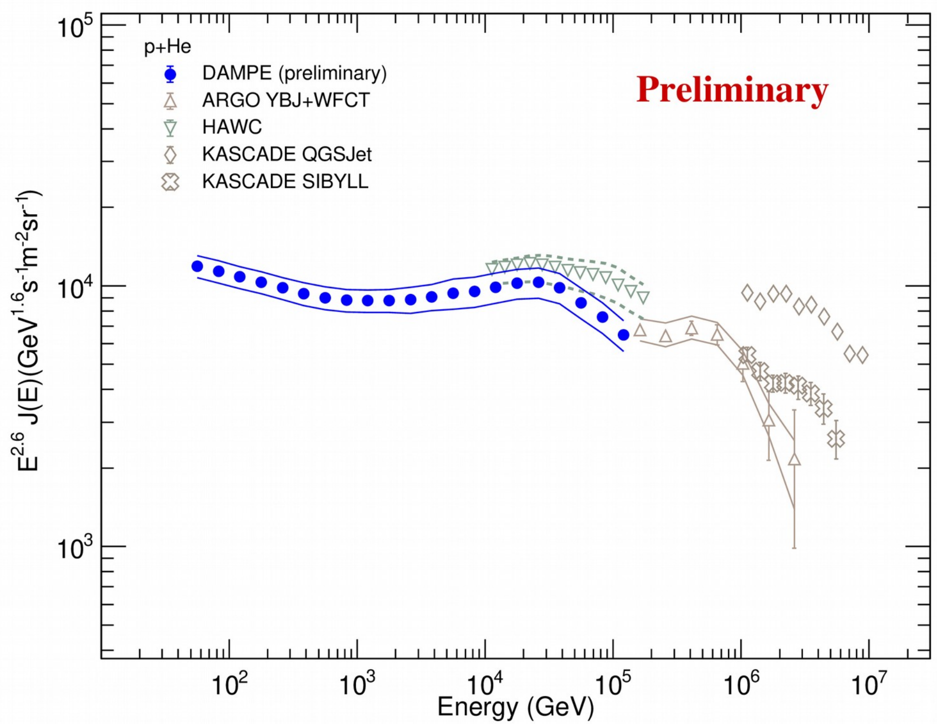
The p+He spectrum shows a spectral **hardening at ~ 600 GeV** and a **softening at ~ 25 TeV**

Comparison with other experimental results

DIRECT MEASUREMENTS



INDIRECT MEASUREMENTS



The extension of the p+He spectrum to higher energy is ongoing

Conclusions

- **p+He spectrum computed with <u>60 months of data</u> collected by the DAMPE satellite**
- **Good agreement between the <u>p+He</u> analysis and the 2 independent <u>p and He</u> analyses**
- **Good agreement with <u>other experiments</u> within the uncertainties**
- **<u>Hardening</u> and <u>softening</u> features observed, confirming the results obtained by DAMPE and by other experiments**
- **Final evaluation of systematic uncertainties in progress**
- **Extension of the spectrum to <u>higher energy</u> (~ 500 TeV) ongoing**

Thank you for the attention!