GRAN SASSO SCIENCE INSTITUTE
SCHOOL OF ADVANCED STUDIES
Scuola Universitaria Superiore

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

DARK MATTER PARTICLE EXPLORER

Measuring light elements in space with the DAMPE mission

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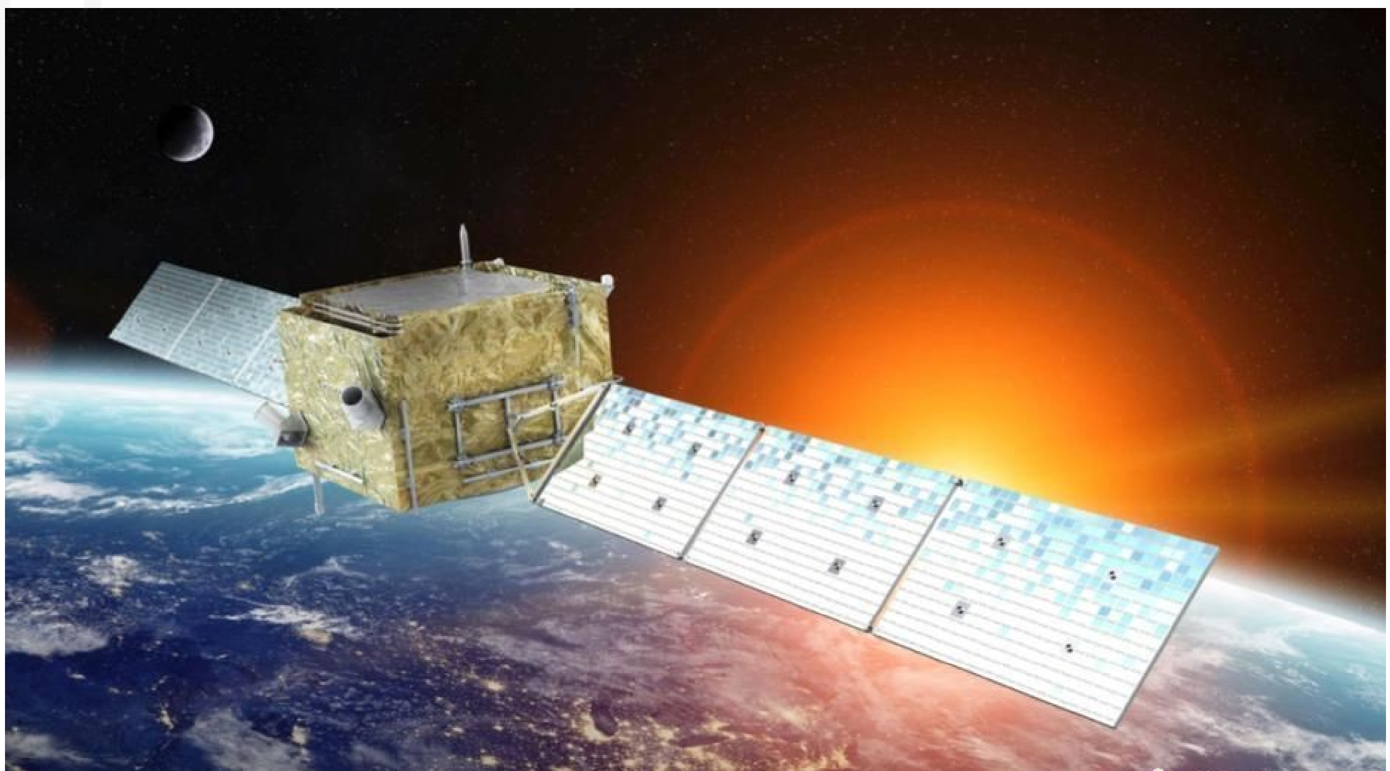
Gran Sasso Science Institute (GSSI) &
INFN - Laboratori Nazionali del Gran Sasso (LNGS)



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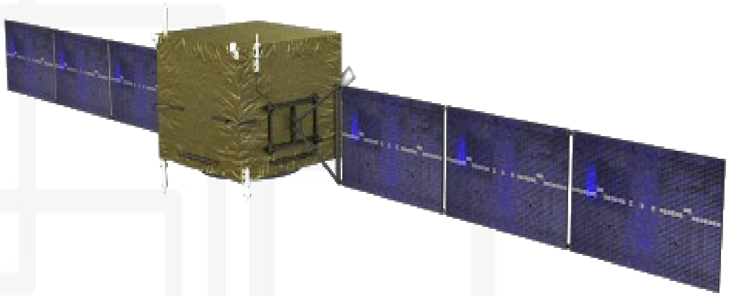
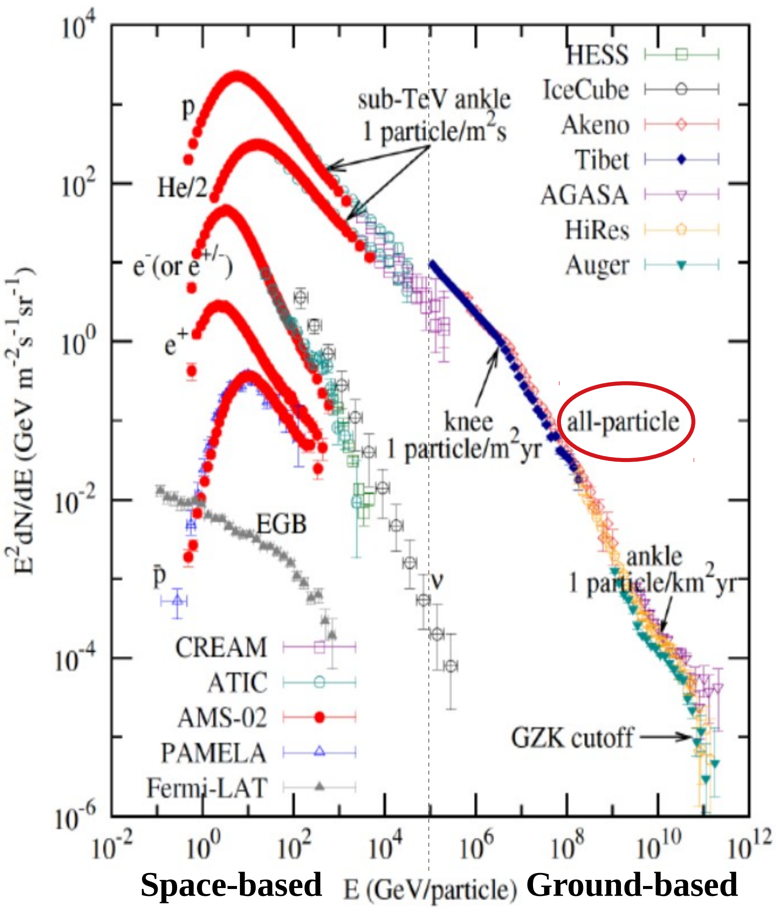


Overview

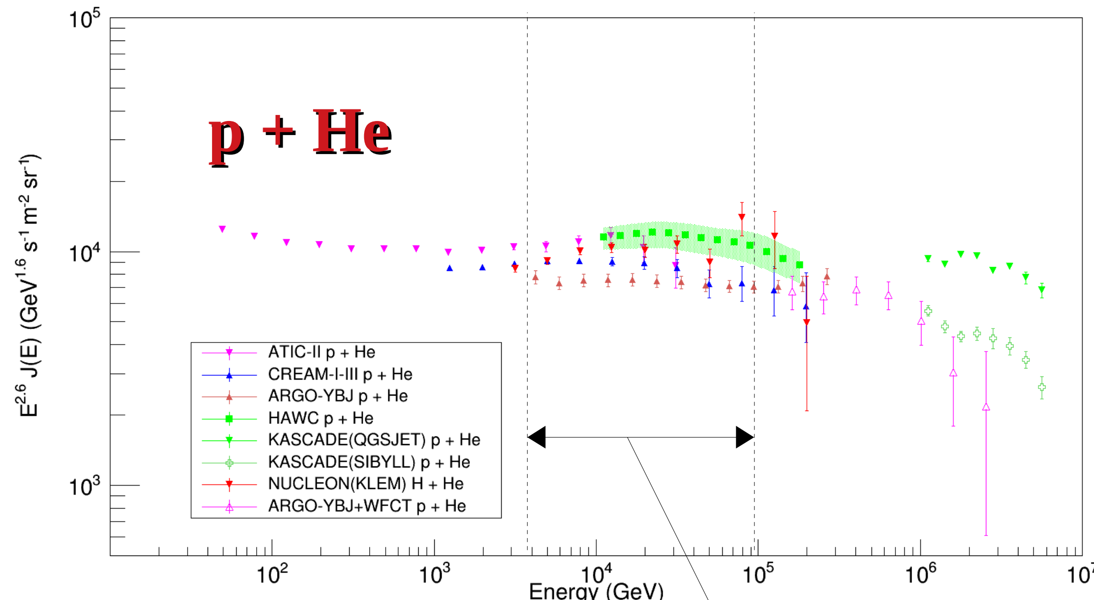
Motivation

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)

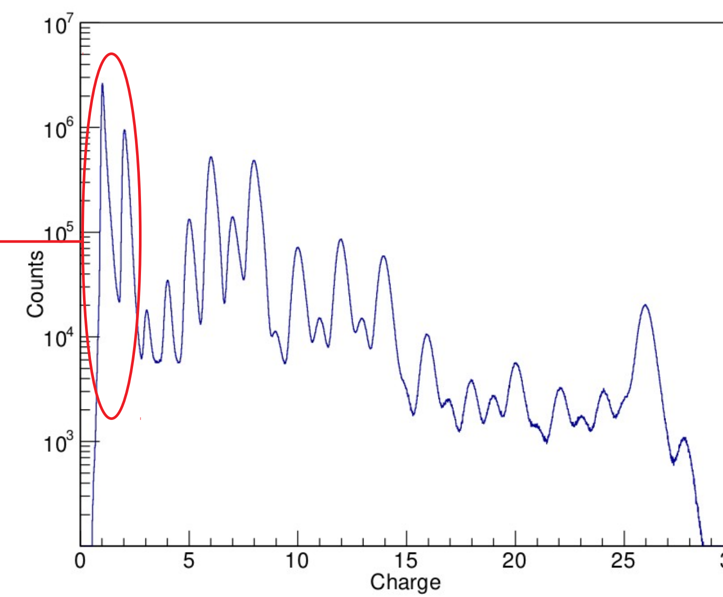
Ground-based experiments (indirect measurements)



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 %)



The DAMPE space mission

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

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*
- *National Space Science Center, CAS, Beijing*
- *Institute of Modern Physics, CAS, Lanzhou*

ITALY

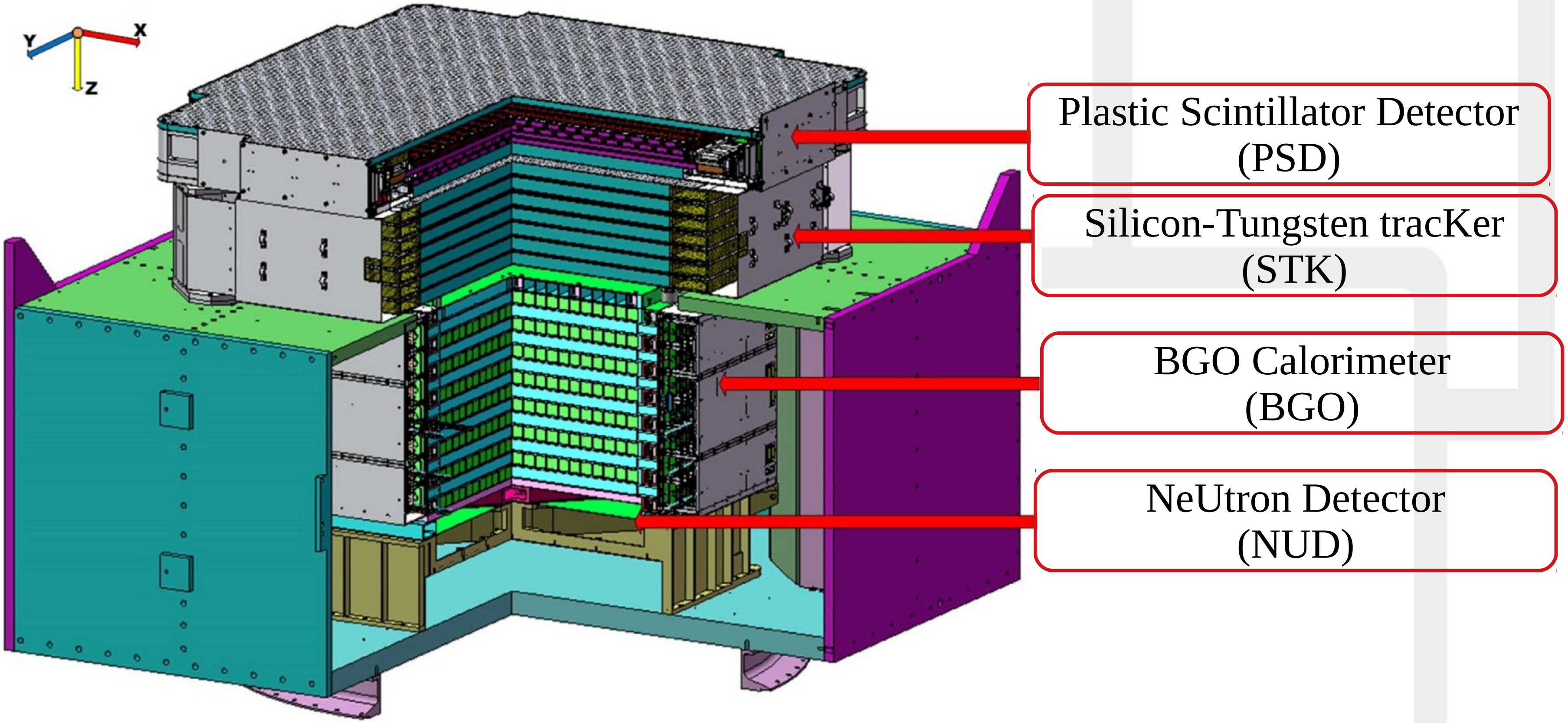
- *INFN Perugia and University of Perugia*
- *INFN Bari and University of Bari*
- *INFN Lecce and University of Salento*
- *INFN LNGS and Gran Sasso Science Insitute*

SWITZERLAND

- *University of Geneva*

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

Detector structure



PSD → *Charge measurement + identification of electrons and gamma-rays*
STK → *Silicon strips (precise tracking) + tungsten converter (pair production)*
BGO → *Energy measurement + e/p separation*
NUD → *Hadrons rejection*

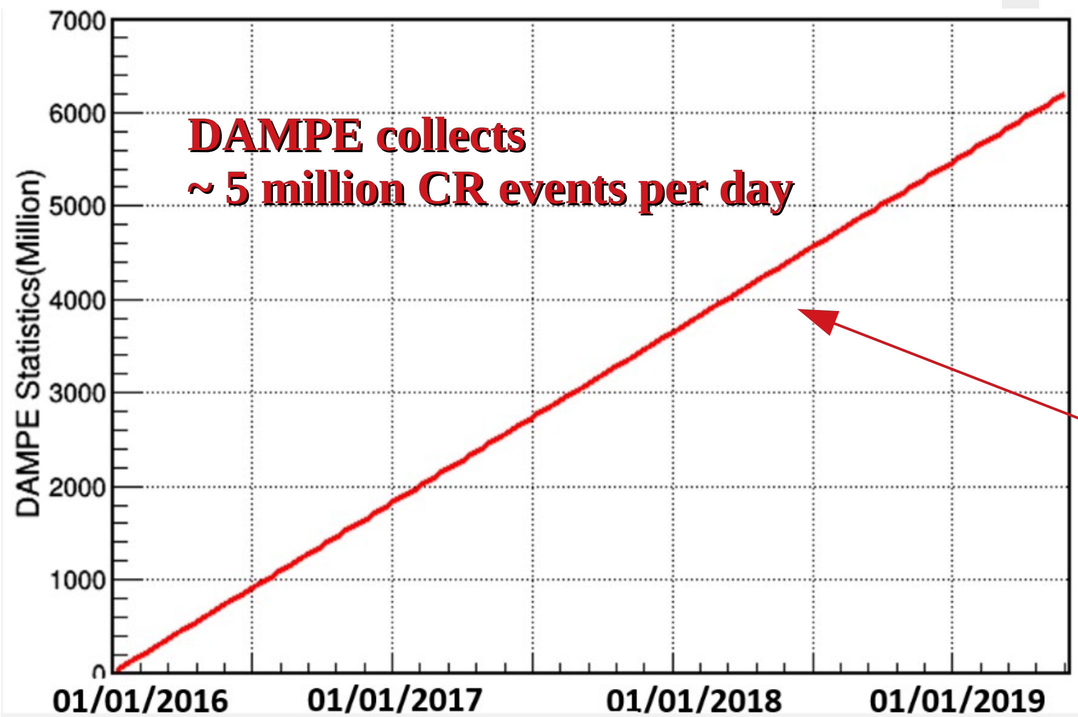
Utilized data

MONTE CARLO DATA (simulated):
- Proton [1 GeV – 1 PeV]
- Helium [10 GeV – 200 TeV]

ORBITAL DATA (from the satellite):
44 months → January 2016 – August 2019

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 ~ 1014 days



The cumulative counts of DAMPE

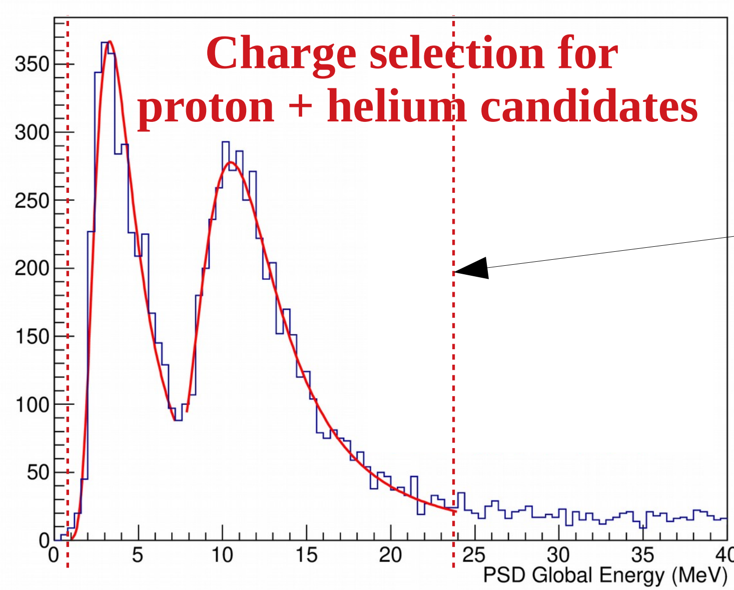
Selection criteria

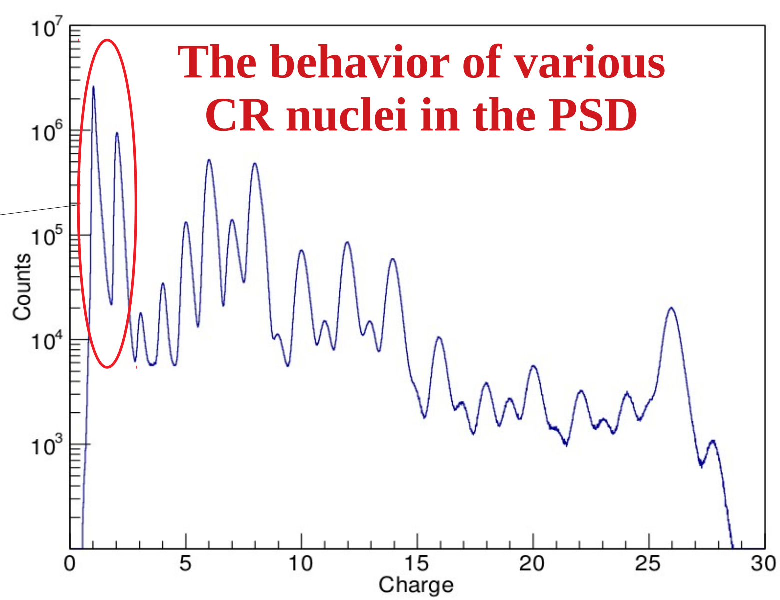
Pre-selection:
Performed to eliminate events entering the detector from the side and to avoid the effect of geomagnetic rigidity cutoff

Trigger selection:
Events must activate the high energy trigger of DAMPE i.e. energy deposition in the top 4 BGO layers exceeding the threshold of ~ 10 MIPs in each hit BGO bar

Track selection:
To ensure that events have good quality of the reconstructed trajectories

Charge selection for p+He:
To reject CR nuclei with charge larger than 2 (Li, Be, B …)





Energy reconstruction

The nuclear interaction length of DAMPE is ~ 1.6
Therefore, for protons and helium nuclei, a certain fraction of the 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

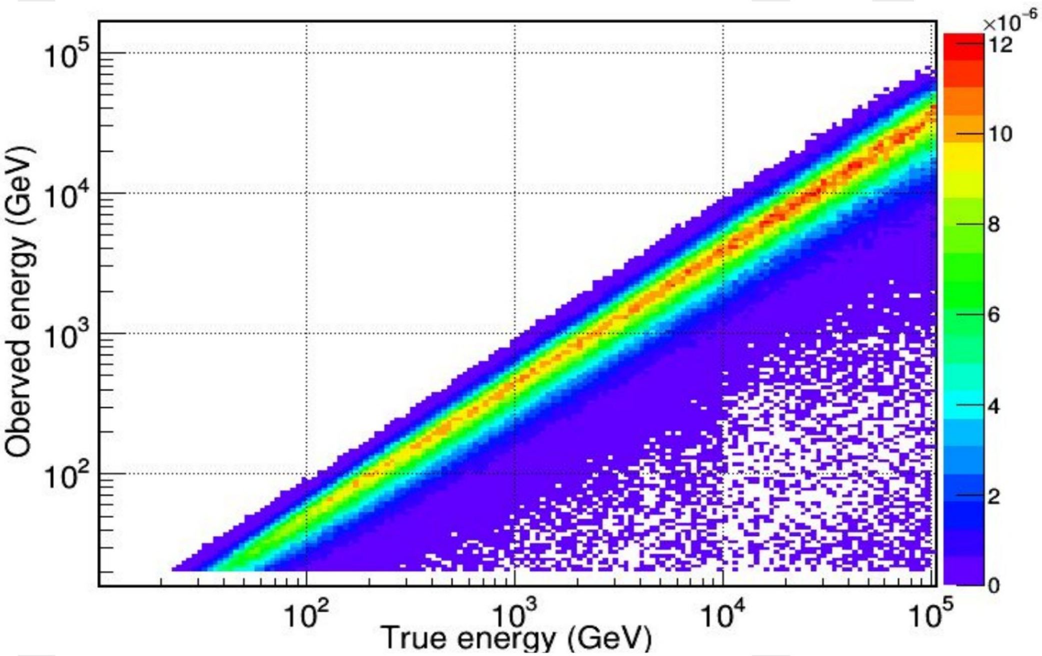
$$N\left(E_T^i\right) = \frac{1}{\varepsilon_i} \sum_{j=1}^{n} P\left(E_T^i \mid E_O^j\right) N\left(E_O^j\right)$$

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

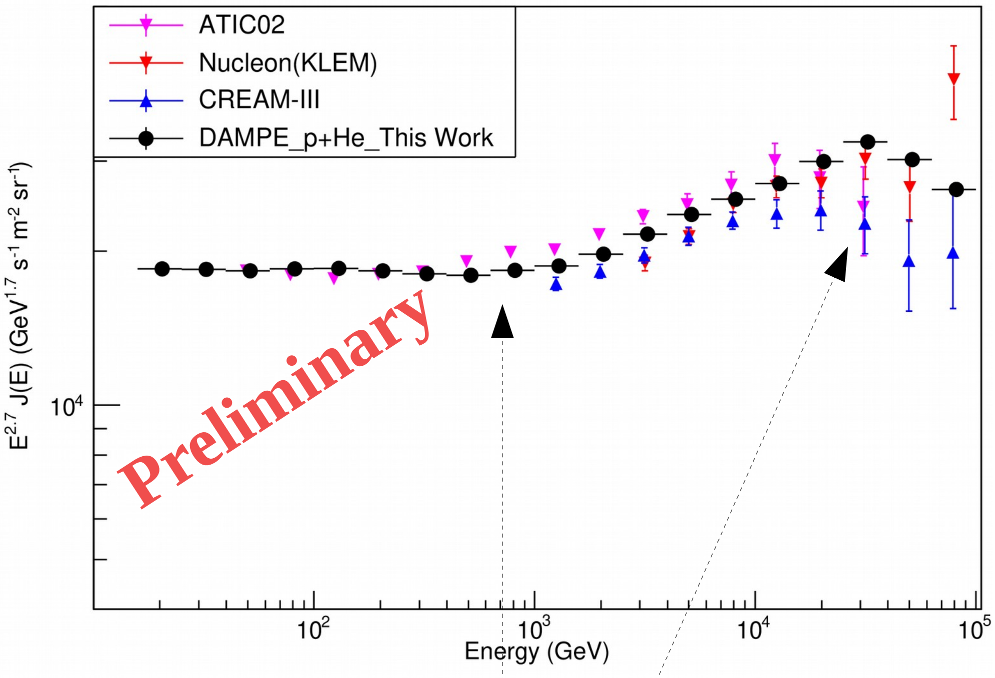
ε_i Detection efficiency



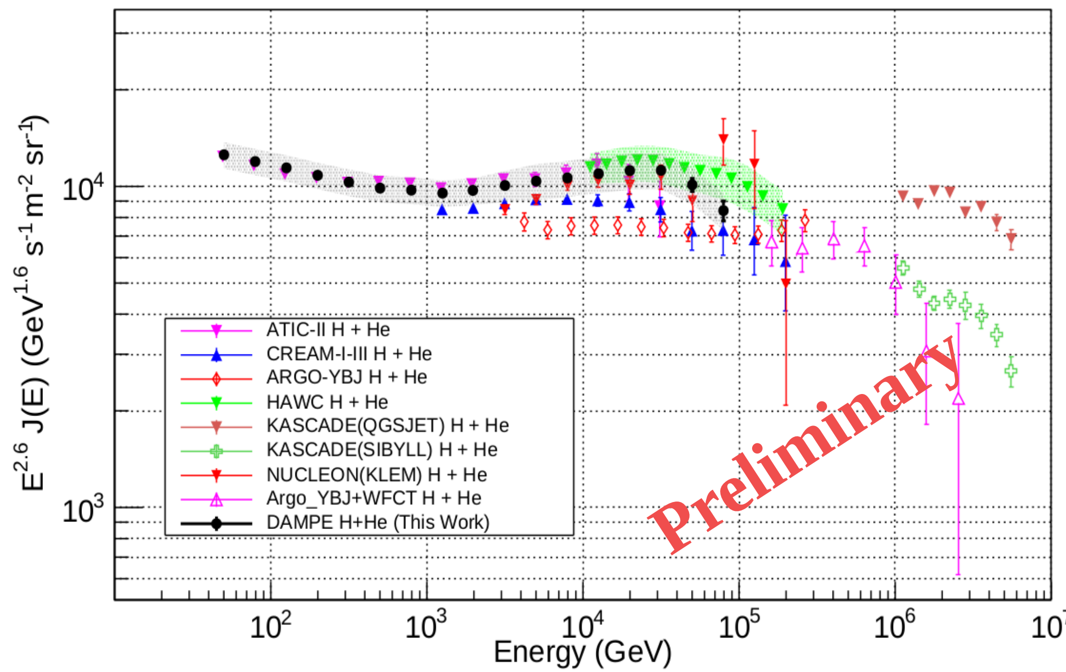
Using this fromula, the primary spectrum can be obtained from the observed spectrum in the BGO calorimeter

p + He spectrum

Comparison with **direct** detection experiments



Comparison with **indirect** detection experiments



A spectral hardening can be observed for energy lower than 1 TeV, followed by a softening at energy larger than 10 TeV

The total systematic uncertainty is
~ 12 % for energy lower than 1 TeV
~ 16 % for energy larger than 1 TeV

Systematic uncertainties come from:
selection efficiency and
hadronic reaction models in the MC simulation

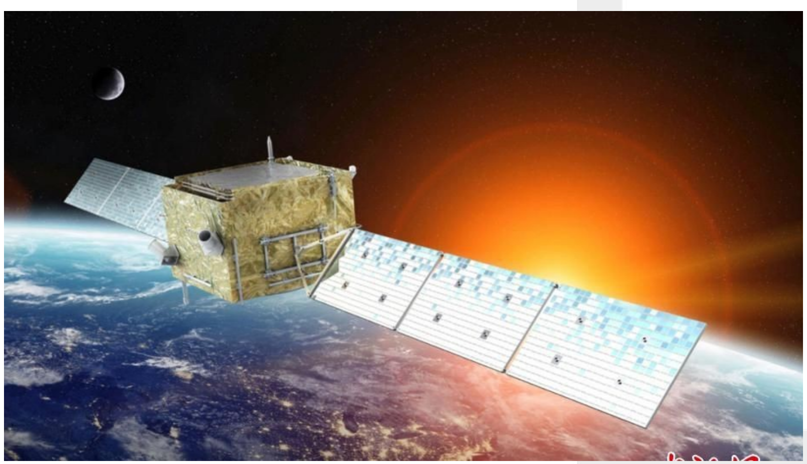
Summary and conclusion

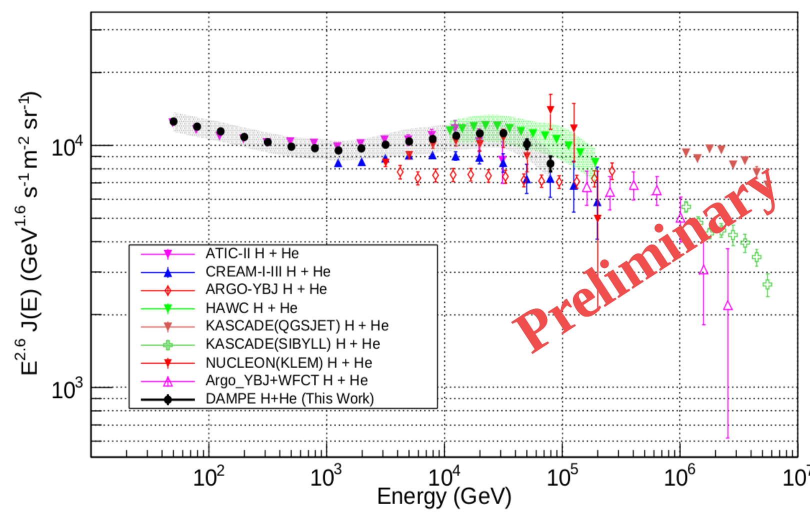
- DAMPE is an international high-energy cosmic-ray experiment
  It has been working extremely well for more than 4 years

- The data analysis procedure has been introduced
  (including data selection and primary energy reconstruction)

- The preliminary proton + helium spectrum from 50 GeV to 100 TeV has been shown and compared with both direct and indirect CR measurements

Final cross-checks on the spectrum measurement and its extension to the highest energies are currently ongoing





Thank you for your attention!