

Measurement of proton and helium energy spectra with the DAMPE space mission

Francesca Alemanno*

on behalf of the DAMPE collaboration

Gran Sasso Science Institute (GSSI) & INFN-LNGS

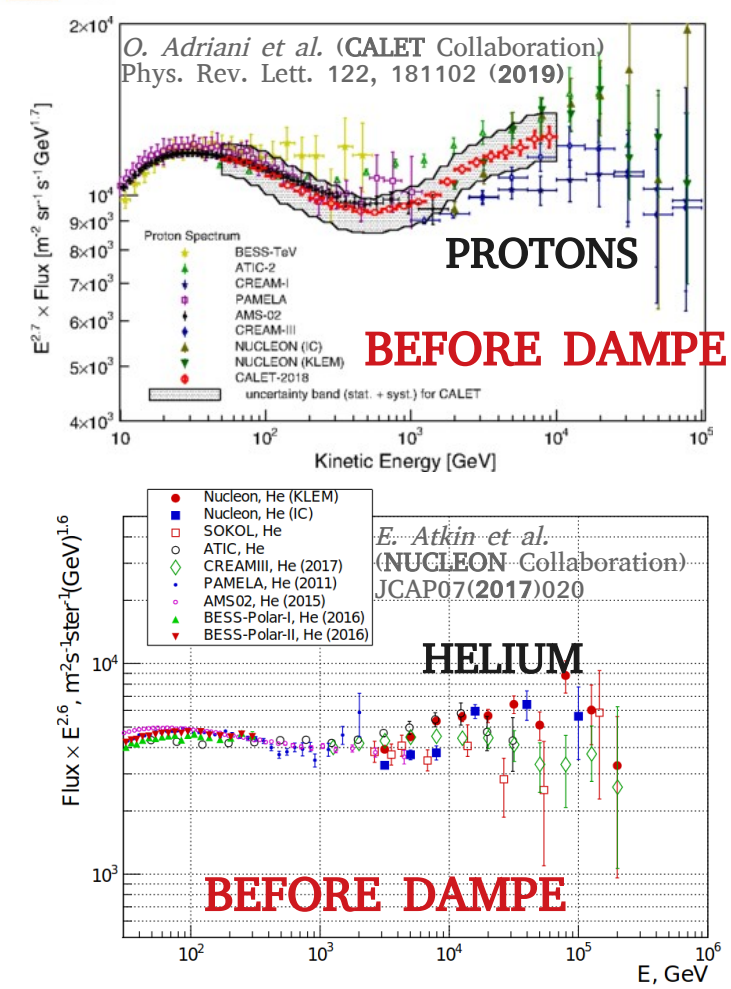
*email: francesca.alemanno@gssi.it



COSPAR 2022
44th SCIENTIFIC ASSEMBLY

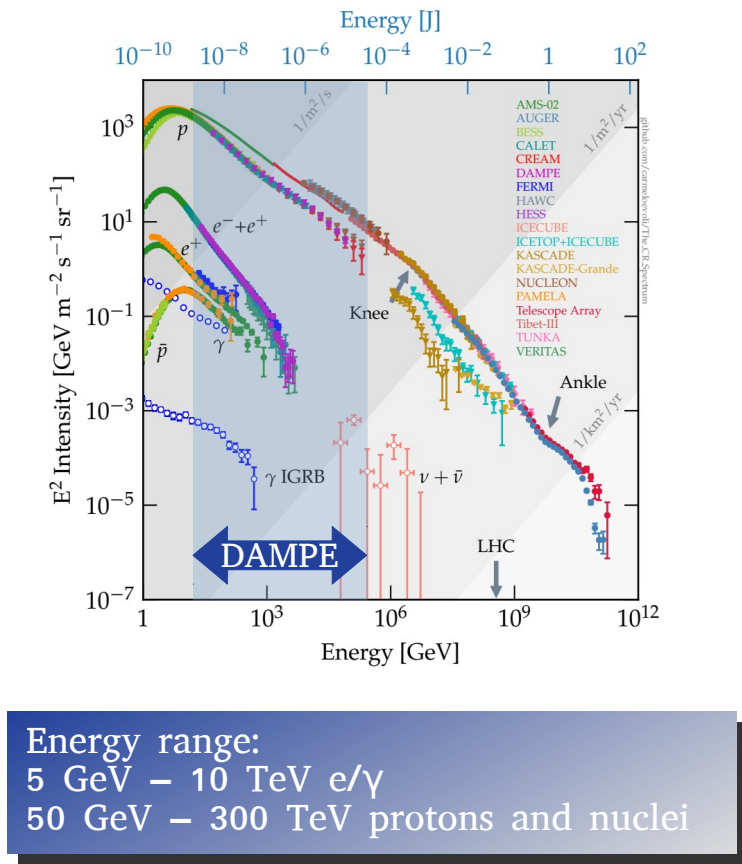
16-24 July 2022, Athens, Greece

aMUSED by the Athenian **URANIA**

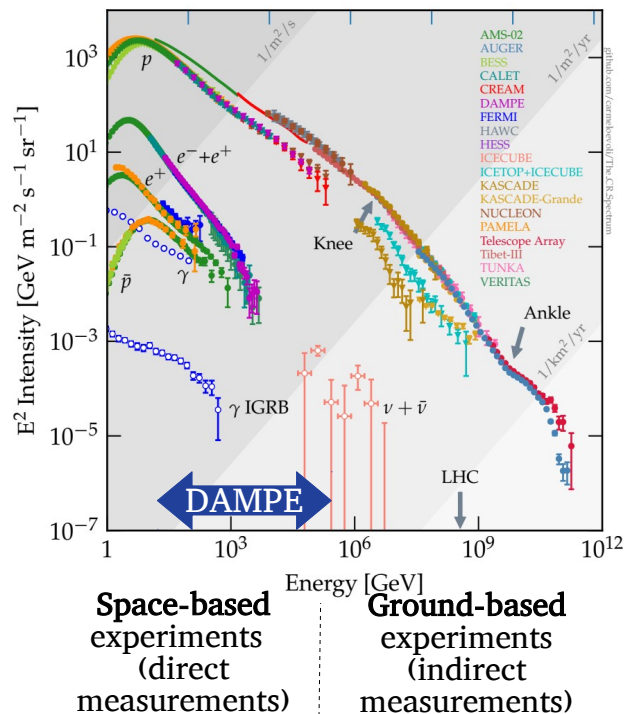


Several measurements:

- spectral **hardening** at few hundreds GeV
- hints of a **softening** above ~ 10 TeV
- Nearby **sources**?
- **Acceleration** mechanisms?
- **Propagation** effects?



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

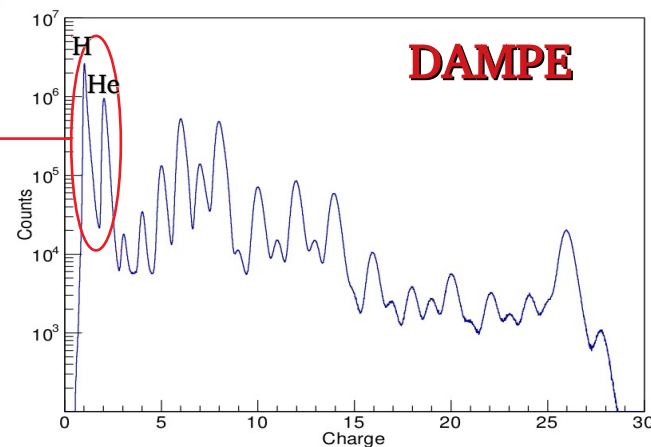
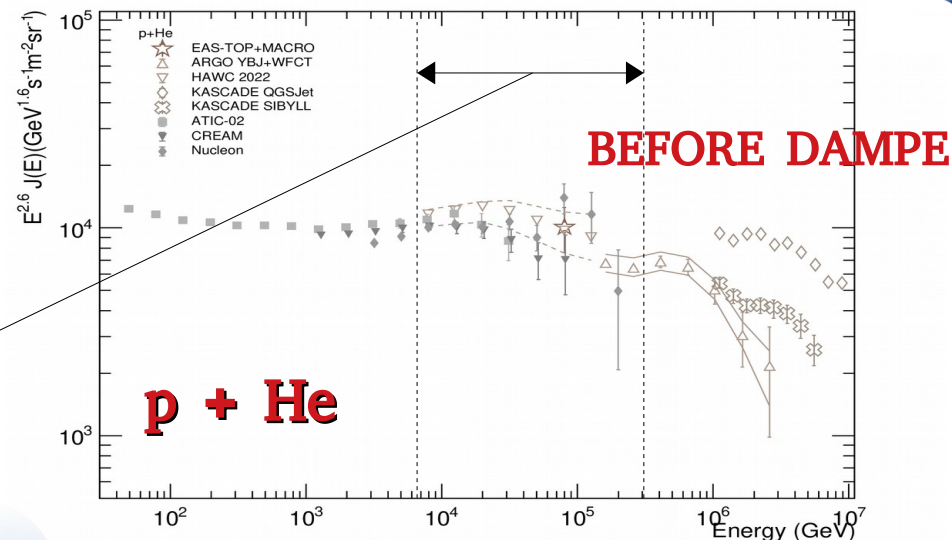


In this energy region
direct and indirect
spectra can be compared

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 **D**ARk **M**ATTER **P**ARTICLE **E**XPLORER (DAMPE) is a satellite-based experiment

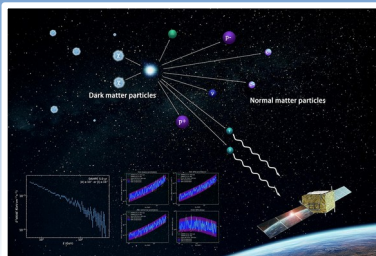
DAMPE was successfully launched
on **December 17th 2015** from
the Jiuquan Satellite Launch Center



- ORBIT: Sun-synchronous
- ALTITUDE: 500 km
- INCLINATION: 97°
- PERIOD: 95 minutes

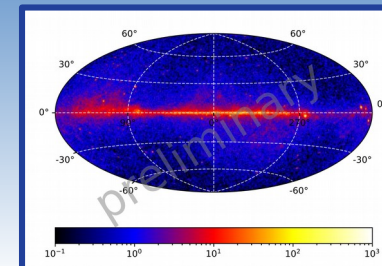
军报记者总装
HTTP://ZZ.81.CN

The DAMPE collaboration involves several institutes in China and Europe



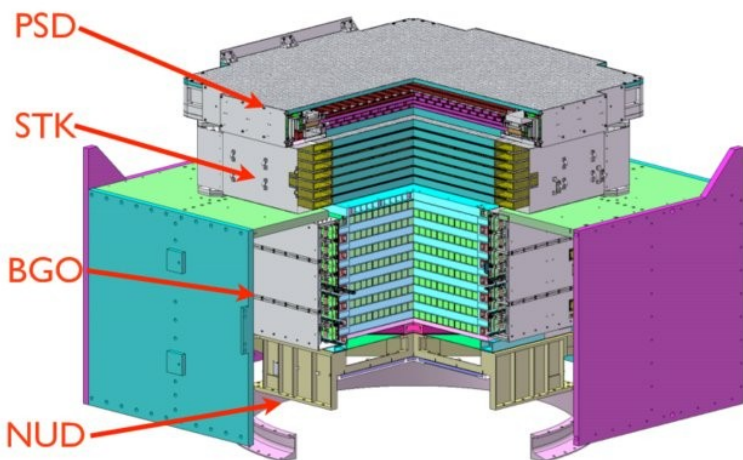
The main objectives
of the DAMPE mission are:

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

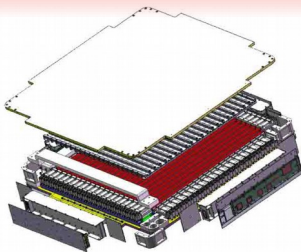


Detector structure

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

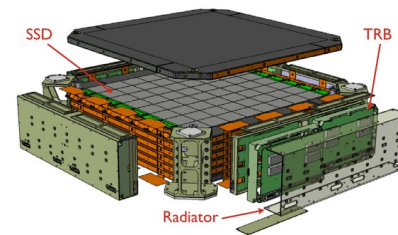


Plastic Scintillator Detector (PSD)



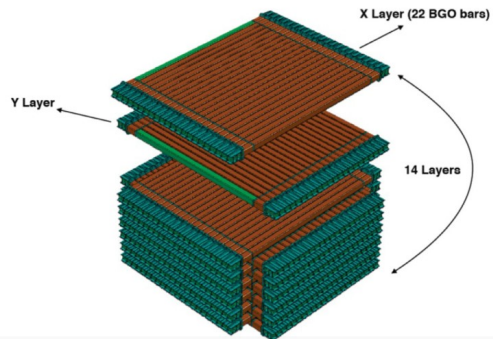
Charge measurement +
identification of electrons and
gamma-rays

Silicon-Tungsten tracker (STK)



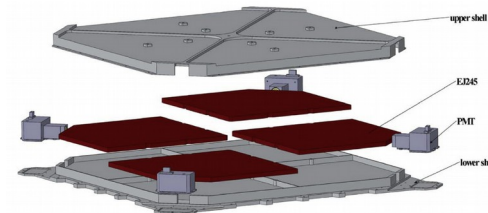
Silicon strips (precise tracking) +
tungsten converter (pair production)

BGO Calorimeter (BGO)



Energy measurement + e/p
separation

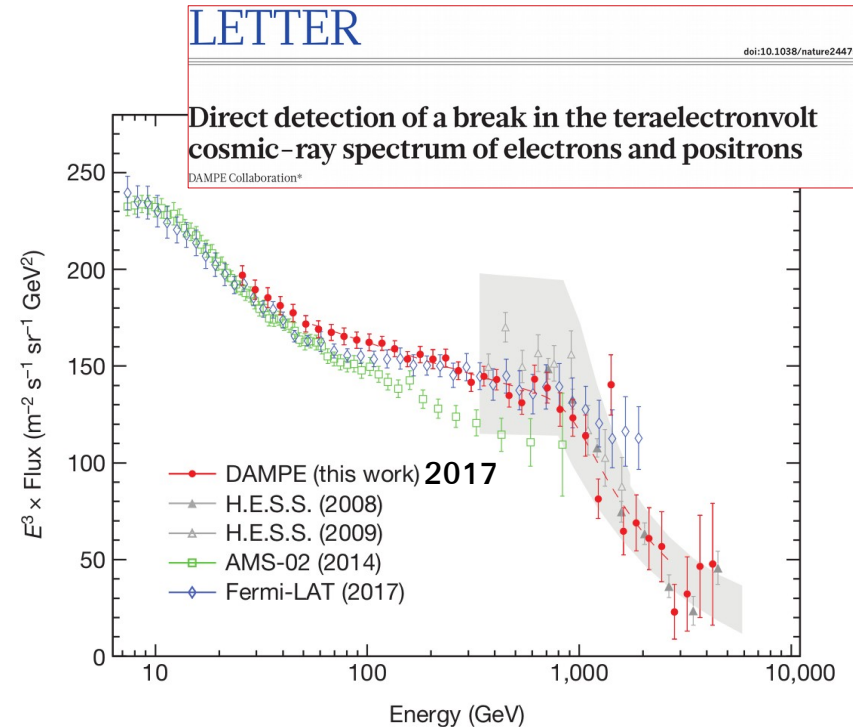
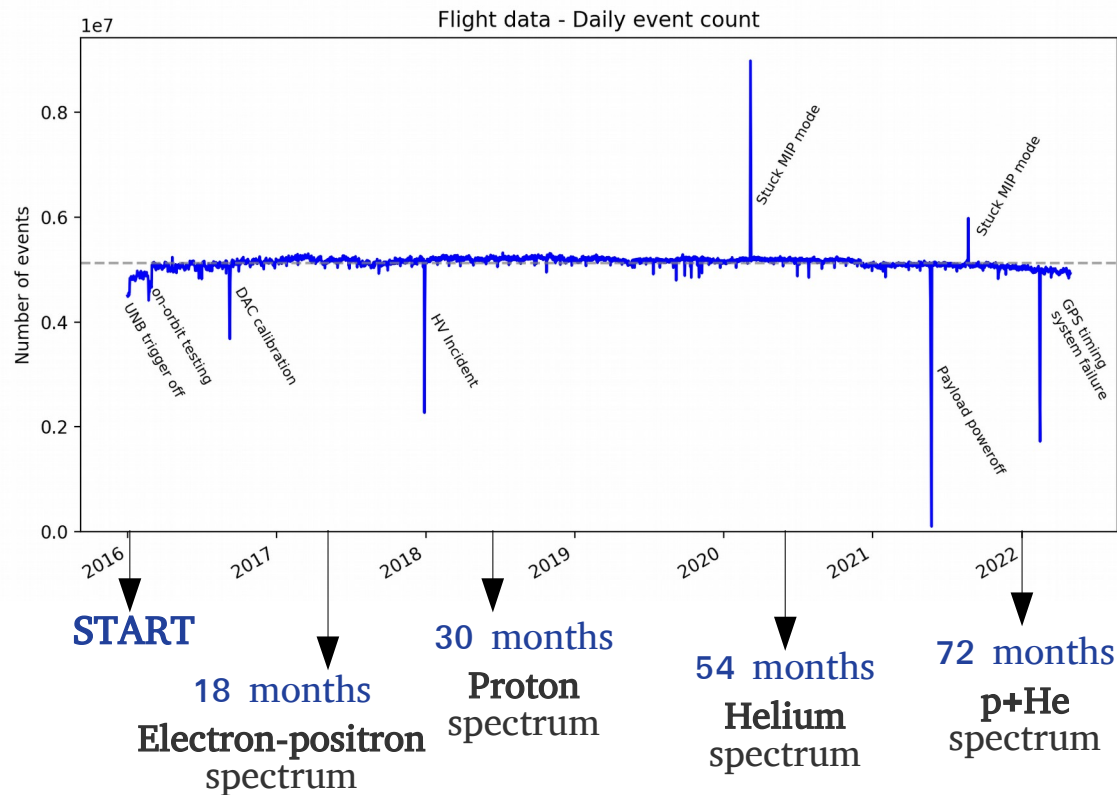
Neutron Detector (NUD)



Additional hadrons rejection

CR data collected

DAMPE collects ~5 million CR events per day



**EVIDENCE OF
A BREAK AT ~ 0.9 TeV
with 6.6 σ significance**

Selection cuts

Preselection
of good quality events

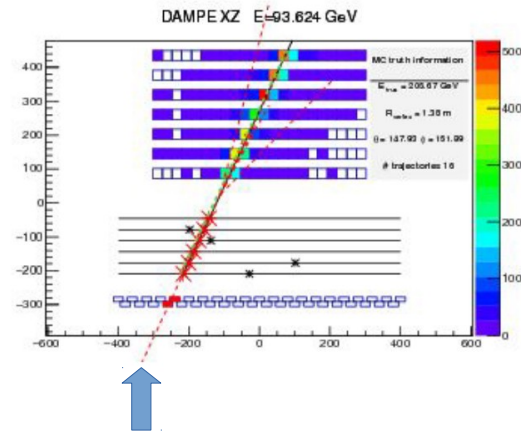
- Energy deposited in the BGO calorimeter > 20 GeV to avoid the effect of the geomagnetic rigidity cutoff
- Rejection of events entering the detector from the side and events with maximum energy deposition at the edge of the BGO
- The track has to be fully contained in the PSD

Track selection

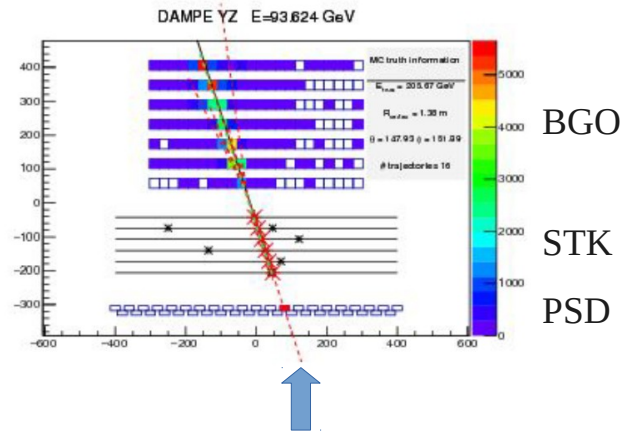
- Match of the track reconstructed in BGO & STK and PSD & STK

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)

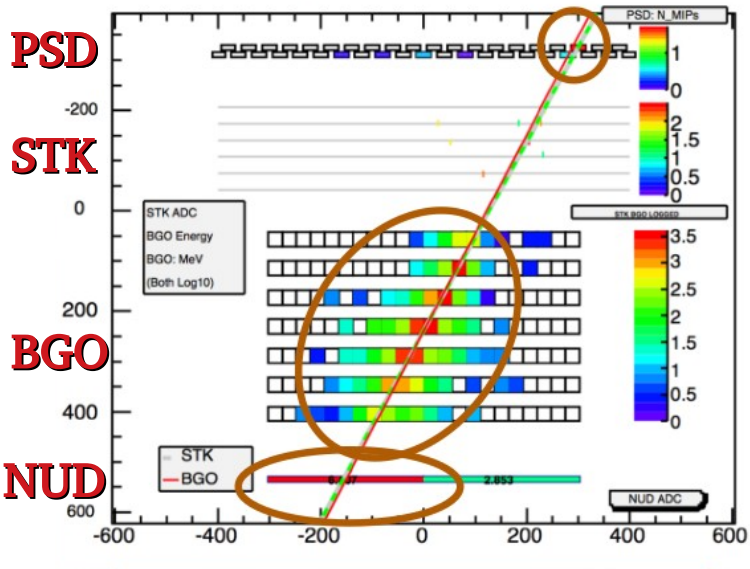


Incoming particle

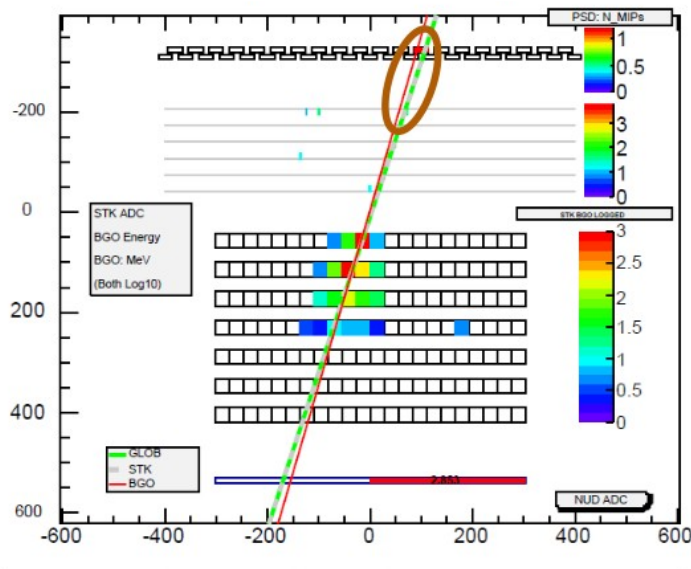


Incoming particle

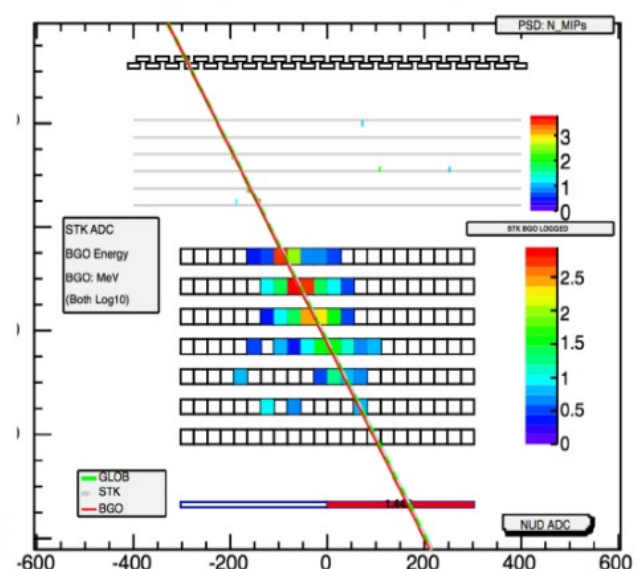
Proton



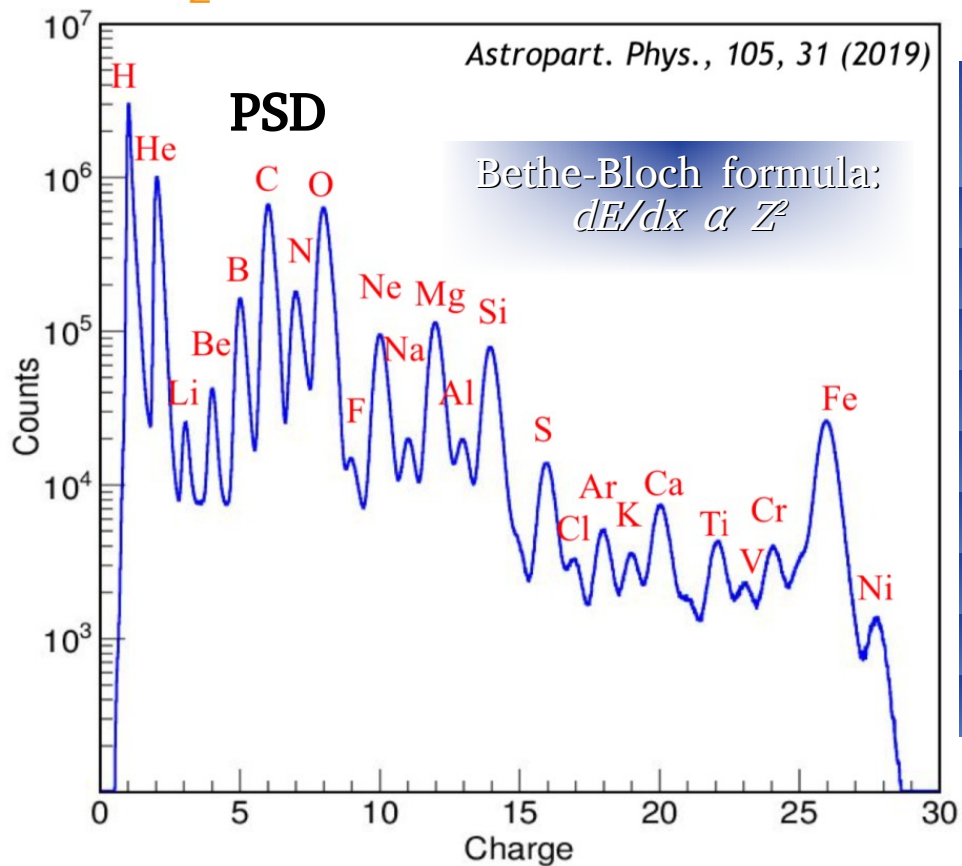
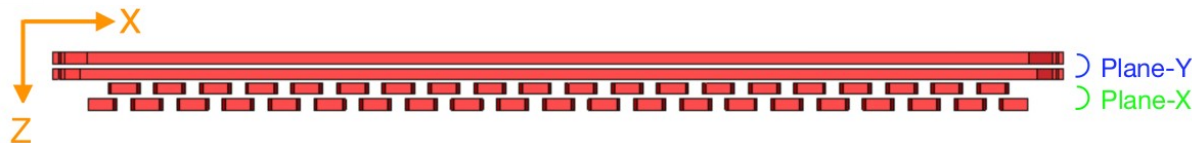
Electron



Gamma

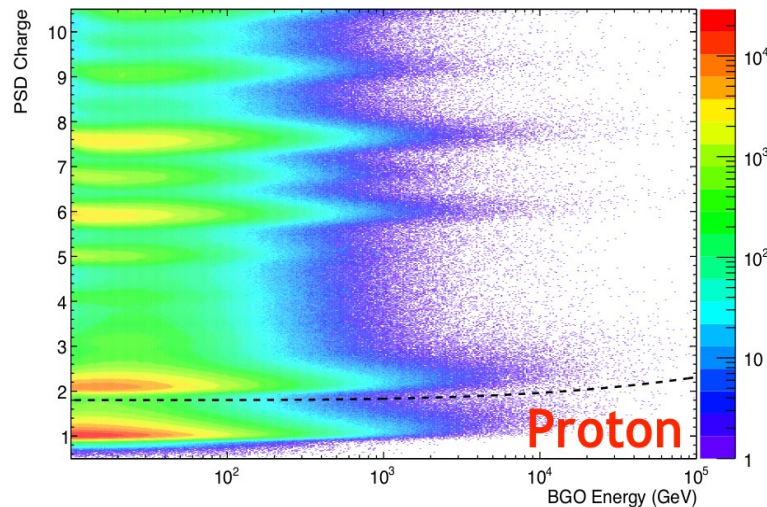


Plots from F. Gargano @MG15 ROME 2018



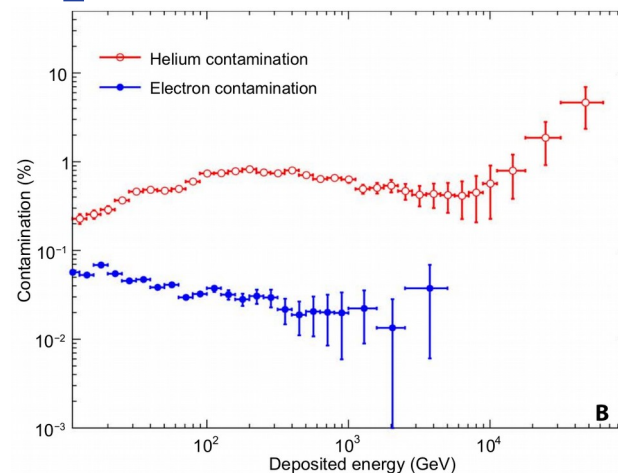
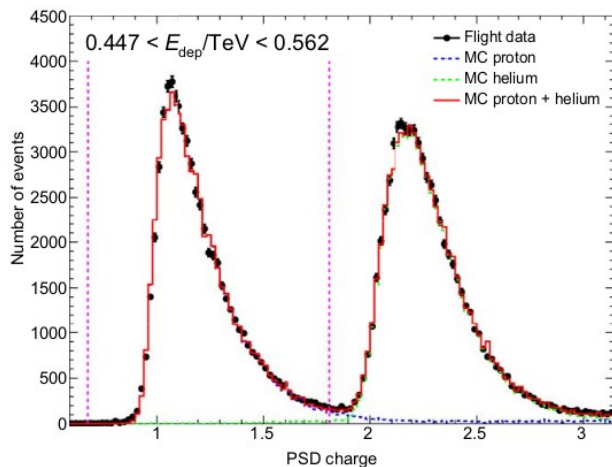
Nuclei	Charge Resolution
p	0.13
He	0.12
Li	0.14
Be	0.21
B	0.17
C	0.18
N	0.21
O	0.21
Fe	0.32

Charge measurement also performed by **STK** and (with lower precision) by **BGO** bars



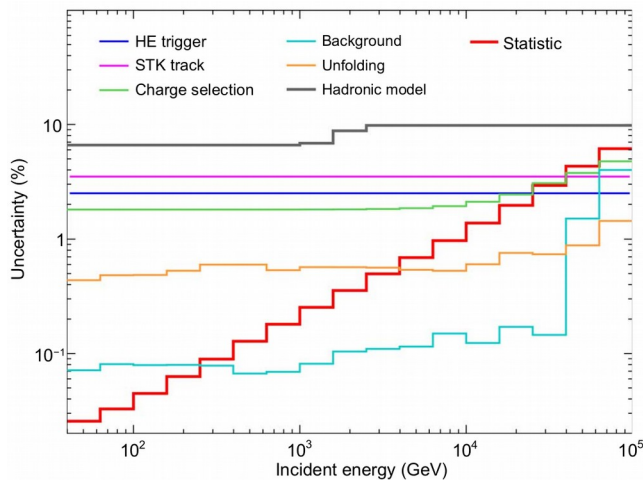
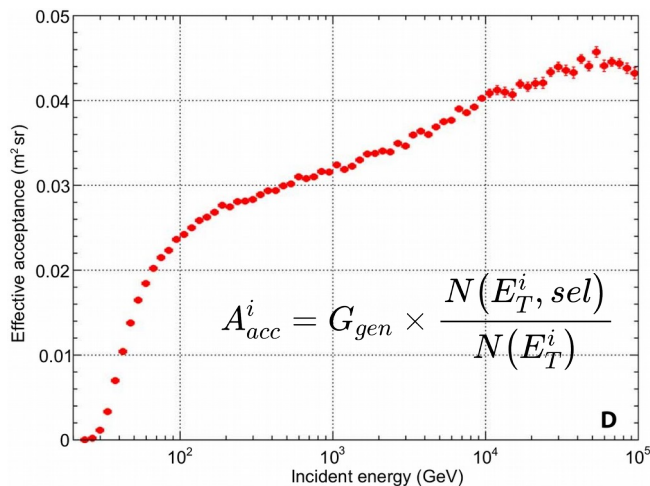
Proton spectrum

Charge
selection



Contamination

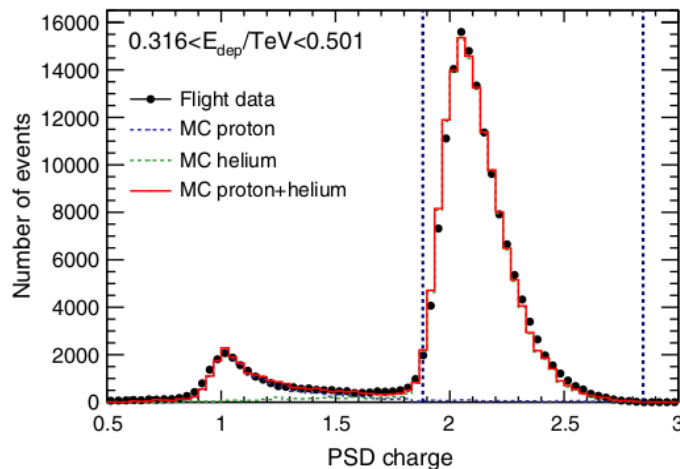
Acceptance



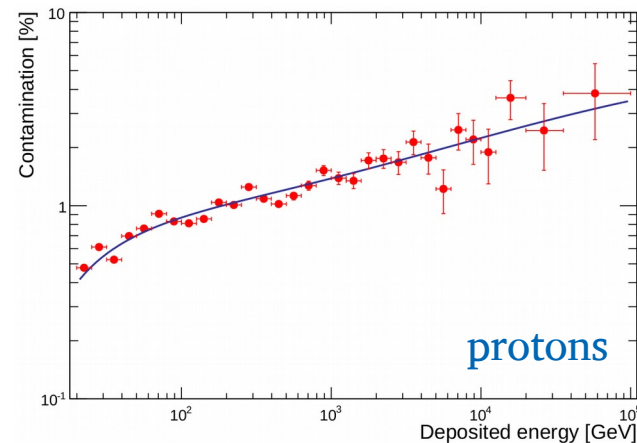
Uncertainty

Helium spectrum

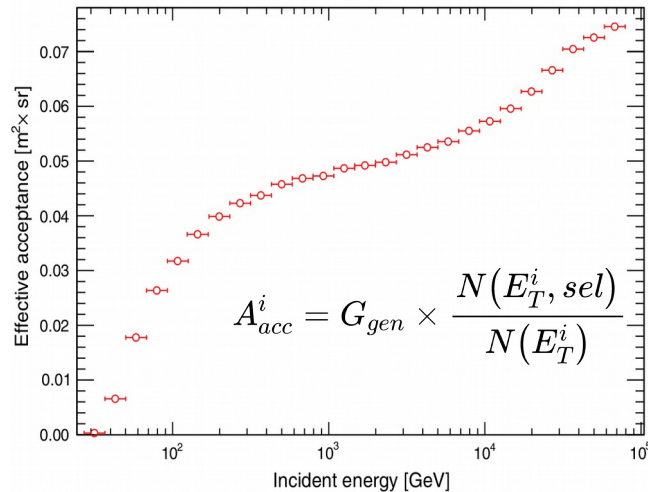
Charge
selection



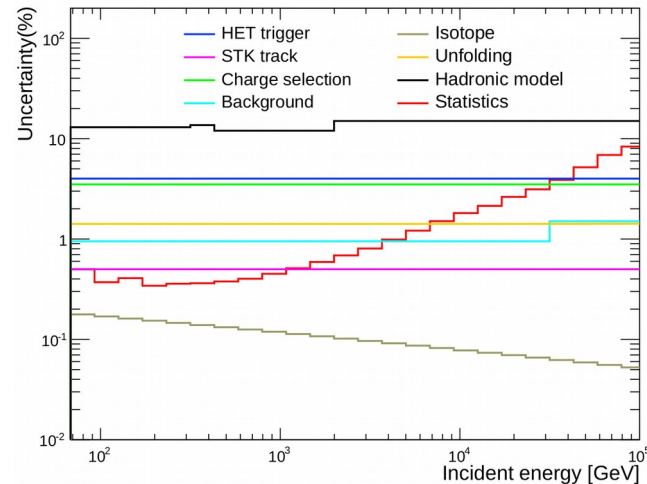
Contamination



Acceptance

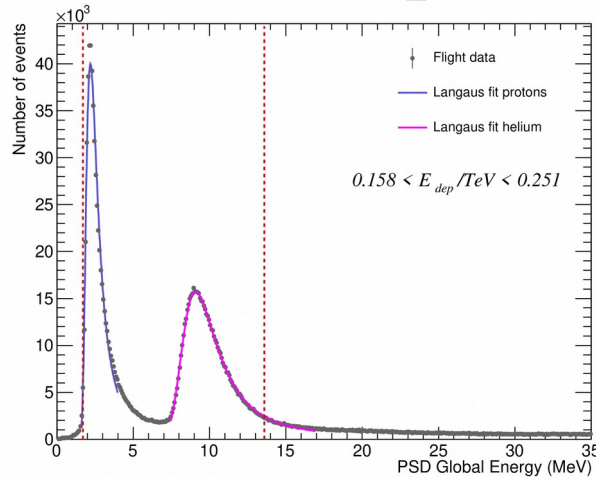


Uncertainty

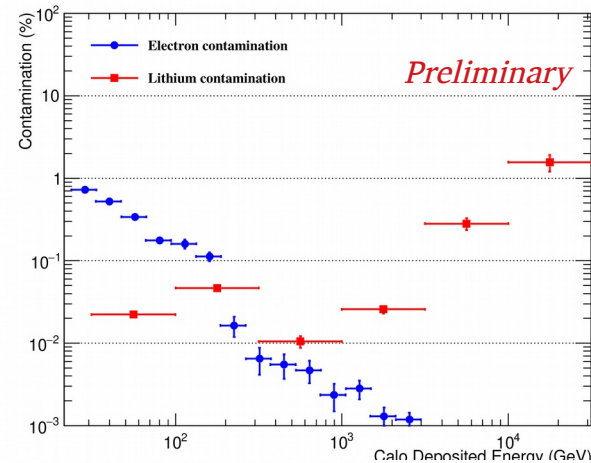


p+He spectrum

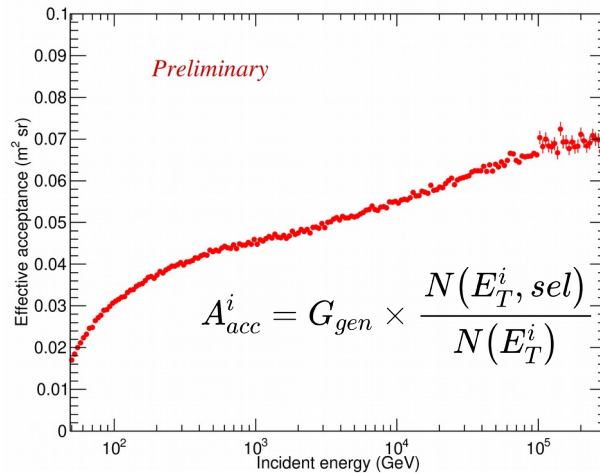
Charge
selection



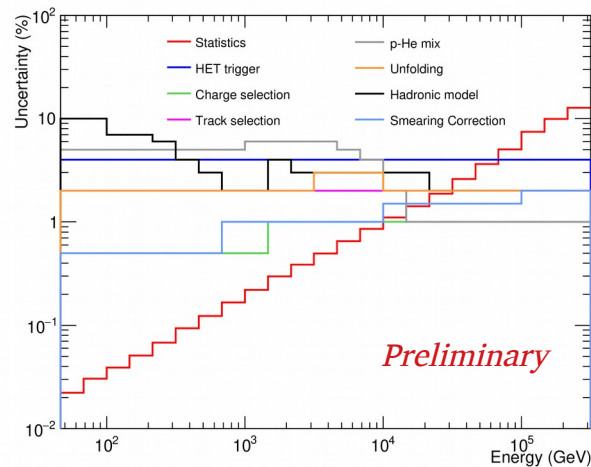
Contamination



Acceptance



Uncertainty



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

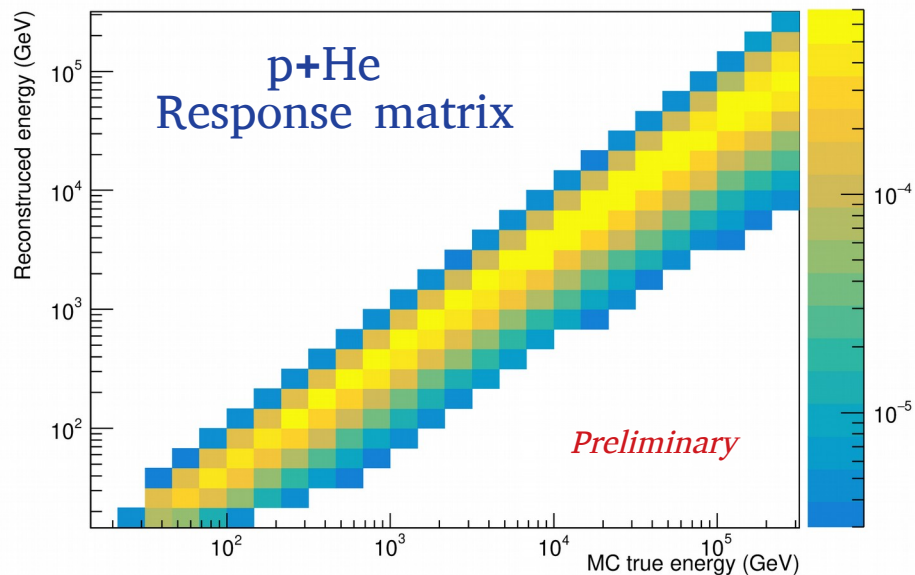
$$N(E_T^i) = \frac{1}{\varepsilon_i} \sum_{j=1}^n P(E_T^i | E_O^j) N(E_O^j)$$

$N(E_T^i)$ Primary spectrum

$N(E_O^j)$ Observed spectrum

$P(E_T^i | E_O^j)$ Response matrix derived from MC using the Bayes theorem

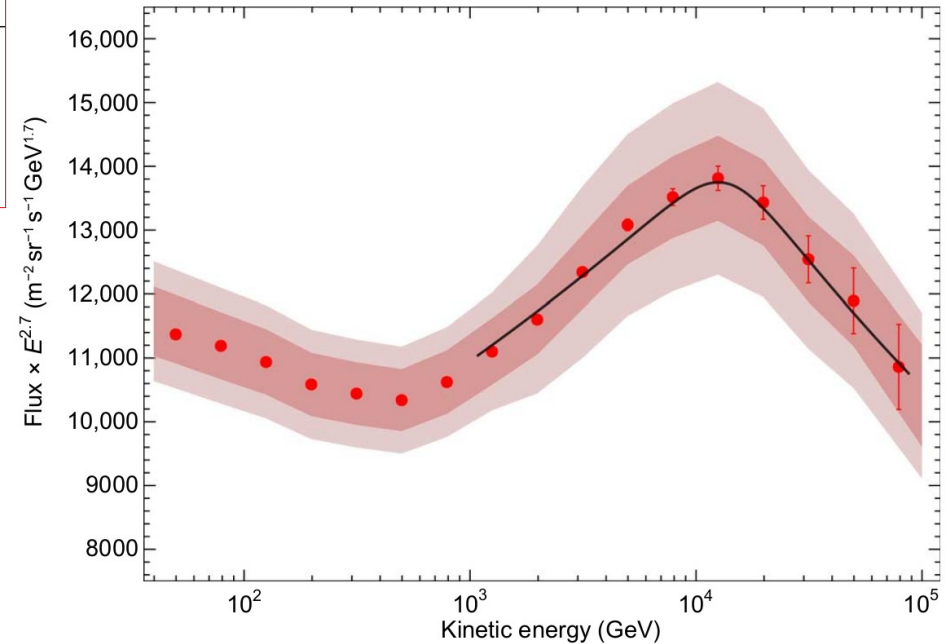
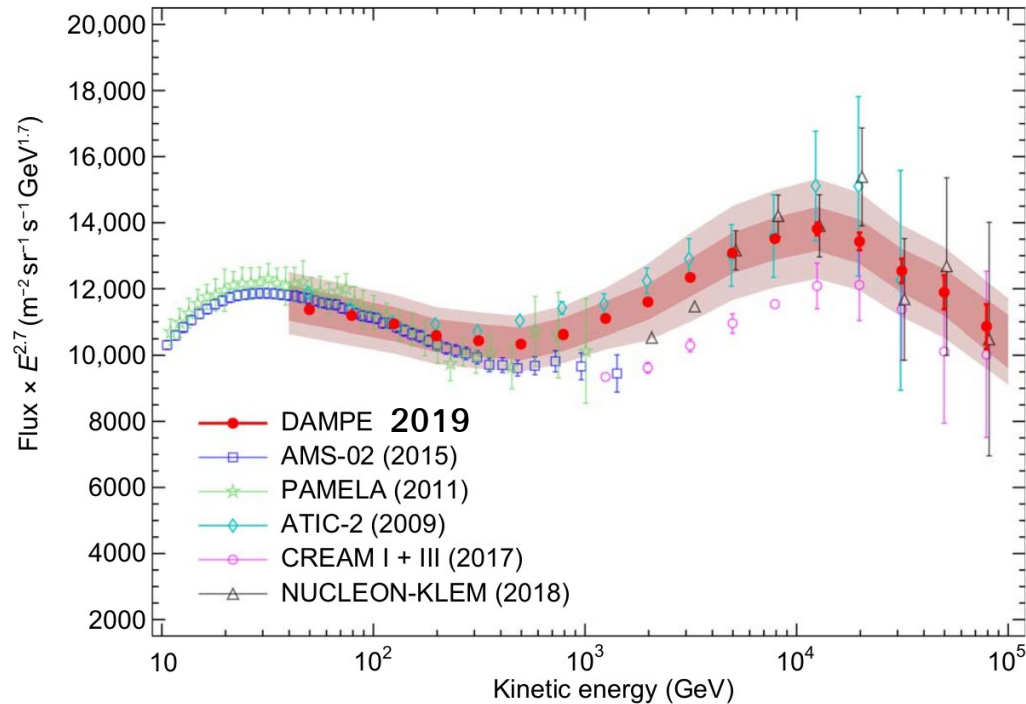
ε_i Detection efficiency



SCIENCE ADVANCES | RESEARCH ARTICLE

PHYSICS

Measurement of the cosmic ray proton spectrum from 40 GeV to 100 TeV with the DAMPE satellite



- Confirmation of a **hardening** structure at 480 ± 10 GeV
- Detection of a **softening** at $13.6^{+4.1}_{-4.8}$ TeV with significance of $\sim 4.7\sigma$

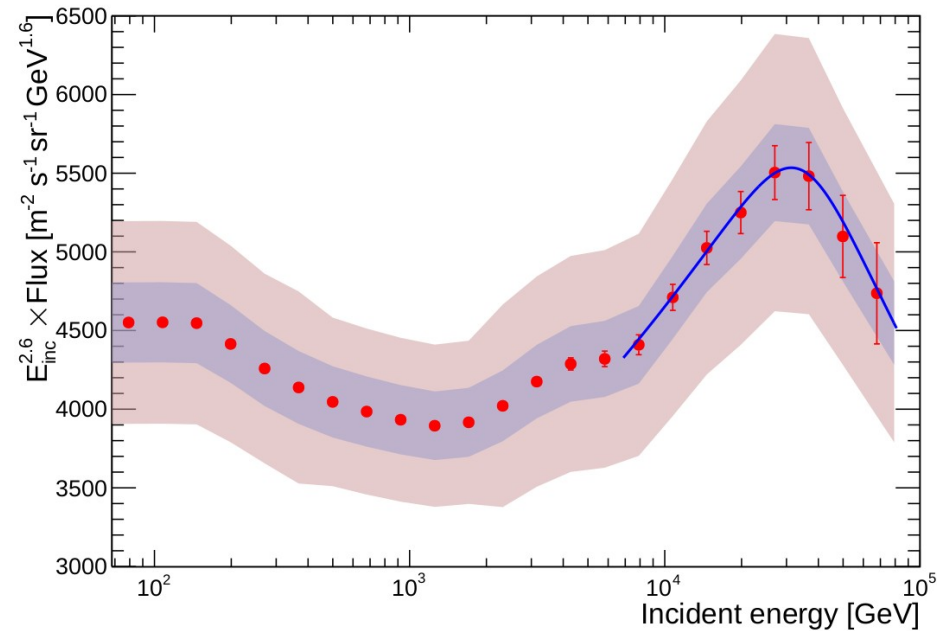
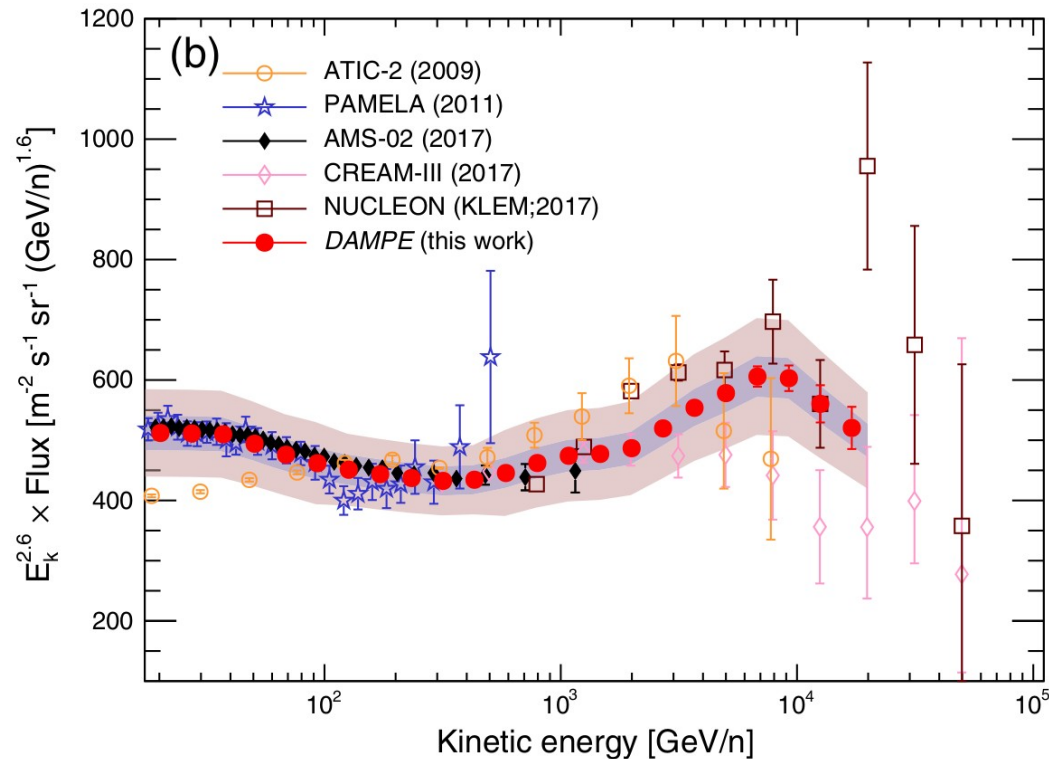
Helium spectrum

PHYSICAL REVIEW LETTERS **126**, 201102 (2021)

Editors' Suggestion

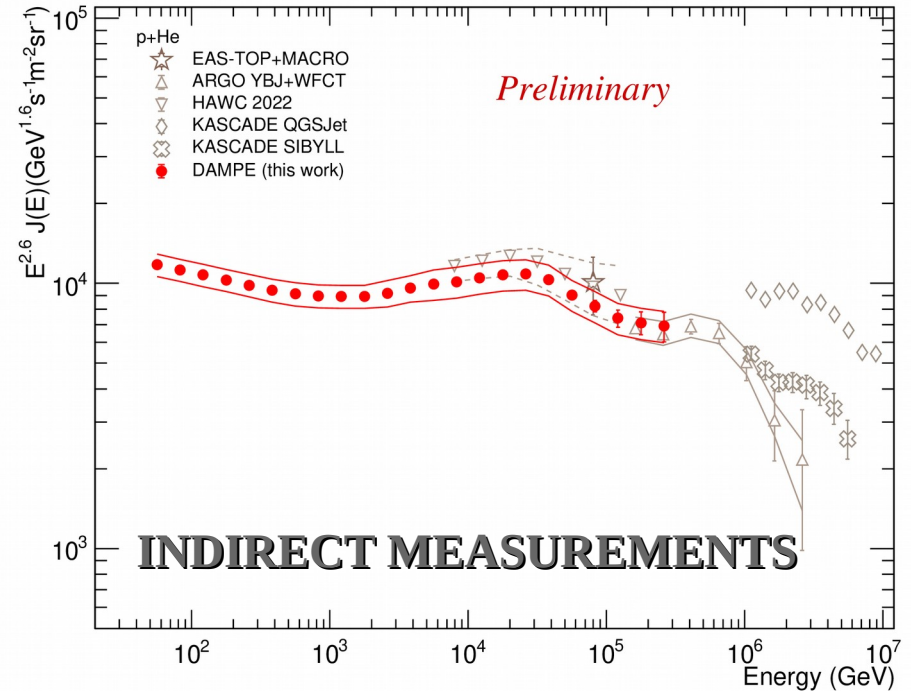
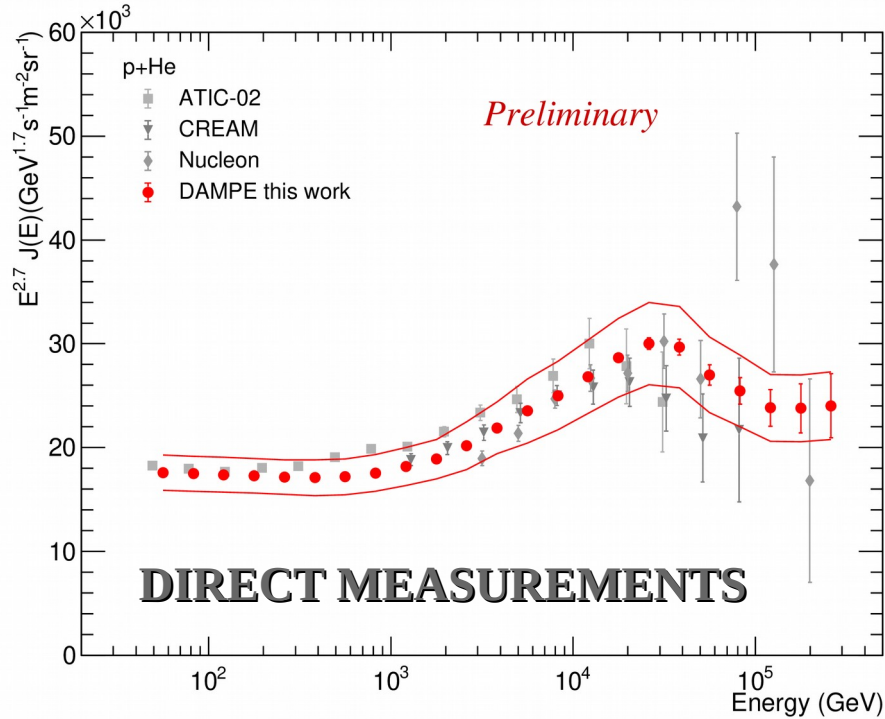
Featured in Physics

Measurement of the Cosmic Ray Helium Energy Spectrum from 70 GeV to 80 TeV with the DAMPE Space Mission



- First detection of a **softening** at $34.4^{+6.7}_{-9.8}$ TeV with significance of $\sim 4.3\sigma$
- Suggesting a **charge dependent** feature

p+He spectrum



- General agreement with DAMPE proton and helium independent analyses
 - Evidence of the combined proton and helium softening at ~ 25 TeV
- Extension to higher energy (300 TeV) and comparison with ground-based experiments

- The DArk Matter Particle Explorer, was launched in December 2015 and it is smoothly taking data since then
 - Direct detection of a **break** at ~ 1 TeV in the **electrons and positrons** spectrum
 - Detection of a **softening** at ~ 14 TeV in the **proton** spectrum
 - First detection of a **softening** in the **helium** spectrum at ~ 34 TeV, suggesting a Z dependence
- Evidence of a combined proton and helium softening in the **p+He** spectrum at ~ 25 TeV
 - Comparison between **space-based** and **ground-based** experiments

Thank you for the attention!