PROCEEDINGS OF SCIENCE

Galactic cosmic ray studies with DAMPE

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The DArk Matter Particle Explorer (DAMPE), operative since its launch in December 2015, is a space-based experiment with primary objectives including the indirect detection of dark matter signatures, the measurement of galactic cosmic ray fluxes spanning tens of GeV to hundreds of TeV, and high-energy gamma-ray astronomy.

An overview of the DAMPE results on galactic cosmic rays will be provided, focusing on precision measurements that revealed distinctive spectral features in proton and helium fluxes. The discussion will also outline the measured secondary-to-primary flux ratios, such as boron-to-carbon (B/C), as well as ongoing studies of light, medium, and heavy nuclei spectra.

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1. Introduction

The DArk Matter Particle Explorer (DAMPE) is a space-based satellite launched in December 2015. It was designed to achieve several objectives, including indirect dark matter searches, monitoring the gamma-ray sky and transient events, and conducting cosmic ray (CR) studies over a broad energy range (from tens of GeV to hundreds of TeV). DAMPE consists of four sub-detectors: the Plastic Scintillator Detector (PSD), the Silicon-Tungsten Tracker (STK), a Bismuth Germanium Oxide (BGO) calorimeter and a NeUtron Detector (NUD) [1].

2. Measurements of galactic CR

2.1 CR spectra

Using 530 days of data, DAMPE measured the all-electron spectrum ($e^+ + e^-$) between 25 GeV and 4.6 TeV, identifying a spectral break near 0.9 TeV [2]. The analysis achieved a high-purity selection of electrons through efficient background rejection with a BGO calorimeter, reaching a proton rejection factor of 10^5–10^6 and an electron selection efficiency of 90%. Current analyses are in progress aiming to extend this measurement beyond 10 TeV using advanced background rejection methods [3].

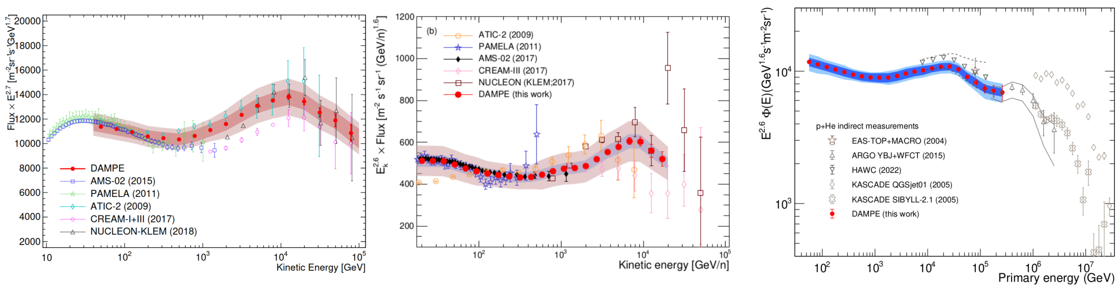

Figure 1: DAMPE proton (left) and He (central) individual spectra, together with p+He combined spectrum (right) compared with measurements from other experiments.

DAMPE's measurements of proton (40 GeV–100 TeV) and helium (70 GeV–80 TeV) spectra (see fig.1) revealed spectral hardening and softening features [4, 5]. The proton spectrum confirmed a hardening at ~500 GeV and showed a softening at ~14 TeV, while helium exhibited these features at ~1.3 TeV and ~34 TeV, respectively. These findings suggest to be related to rigidity-dependent CR processes.

An independent analysis obtained the p+He combined flux (see right plot in fig.1), based on an event selection accepting both p and He candidate events, allowing to use looser cuts. This approach enabled to have large statistics and extend the measured energy range up to ~464 TeV, confirming spectral features and hinting at a new hardening at ~150 TeV [6].

Moreover, DAMPE has measured secondary-to-primary flux ratios, such as B/C and B/O, shown in fig.2, revealing the hardening at ~100 GeV/n with high significance [8]. This supports the interpretation that the observed feature is associated with propagation processes.

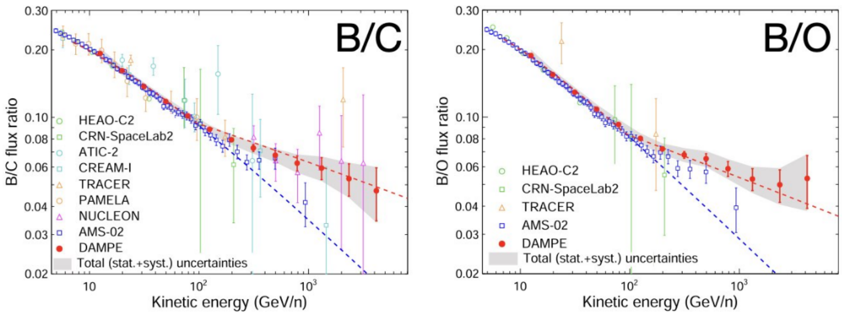

Figure 2: DAMPE secondary-to-primary flux ratios as function of kinetic energy per nucleon: boron-to-carbon (left) and boron-to-oxygen (right)

Ongoing CR analyses focus on spectral measurements of secondary CRs, such as Li, Be, B, as well as medium-to-heavy nuclei, such as C, O, Ne, Mg, Si and Fe. A hardening feature is observed in these individual CR nuclei spectra at hundreds GeV/n [7].

DAMPE's contribution to CR research extends beyond precise spectral measurements of galactic CRs to include the investigation of hadronic cross-sections. It measured inelastic cross-sections for protons (19 GeV–9 TeV) and helium-4 (5 GeV/n–3 TeV/n) using the BGO calorimeter [9]. These measurements improve CR flux corrections, reducing normalization discrepancies in proton and helium fluxes.

3. Conclusion

DAMPE has demonstrated stable and smooth performance since its launch in 2015, contributing significantly in advancing the understanding of CR physics, with precise measurements of nuclei spectra and flux ratios. Future work will extend the CR measurements to higher energies and refine analysis techniques, in order to provide valuable insights and clarify the CR acceleration and propagation mechanisms in our galaxy.

References

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