PROCEEDINGS OF SCIENCE

Latest results from the DAMPE space mission

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The space-based DAMPE (DArk Matter Particle Explorer) detector has been taking data since its successful launch in December 2015. Its main scientific goals include the indirect search for dark matter signatures in the cosmic electron and gamma-ray spectra, the measurements of galactic cosmic ray fluxes from tens of GeV up to hundreds of TeV and high energy gamma ray astronomy above a few GeV.

Here we will focus on the measurements of galactic cosmic ray spectra. In particular, results on proton and helium, which revealed new spectral features, will be described. Ongoing analyses on light, medium, and heavy mass nuclei will be outlined, together with results on secondary-to-primary flux ratios.

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1. Introduction

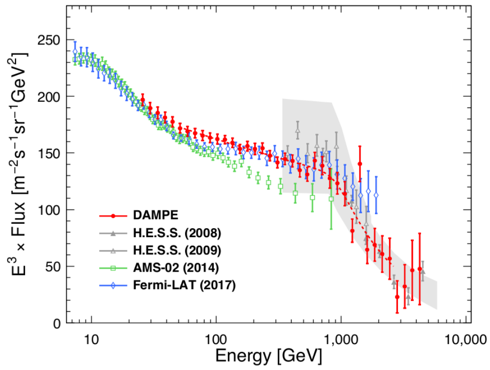

Figure 1: DAMPE all-electron spectrum (red markers) and smoothly broken power law fit (red dashed line). The error bars include both the systematic and the statistical uncertainties [5].

The DArk Matter Particle Explorer (DAMPE) is a space-borne particle detector that was launched in December 2015, at an altitude of ~500 km, in a sun-synchronous orbit. In these years of operation, DAMPE has been continuously collecting data with all its 4 subdetectors that operate to provide tracking, energy measurement and particle identification of CRs. On the top of the instrument there is a Plastic Scintillator Detector (PSD) [1] which provides the charge measurement of incident CRs and the rejection of charged-particle background for gamma-rays. Then, a Silicon-Tungsten tracker converter (STK) [2] operates for the particles trajectory reconstruction and an additional information on their charge. Next, a BGO calorimeter [3] measures the energy of incident particles and provides an efficient discrimination between electromagnetic and hadronic showers. Then, a NeUtron Detector (NUD) [4] provides a further improvement in the electron/hadron separation power. DAMPE, with high energy resolution and large acceptance, is able to detect cosmic electrons and photons in the energy range from ~10 GeV to ~10 TeV and measure the fluxes and the mass composition of galactic CR nuclei up to hundreds of TeV.

2. Measurements of galactic cosmic ray spectra

2.1 The all-electron (e^+ e^-) spectrum

The study of cosmic electrons and positrons is of great importance to probe local astrophysical sources and possible dark matter signatures. The all-electron spectrum, reported in figure 1, has been obtained in 2017 by DAMPE, in the energy range 25 GeV - 4.6 TeV, based on 1.5 years of data. DAMPE has been able to extend the measurement beyond the TeV, thanks to the higher energy resolution and higher acceptance, with respect to the previous experiments; leading to the first direct observation of a spectral break at an energy of ~0.9 TeV [5]. Currently, there are ongoing analyses updating the spectrum with larger statistics and implementing an even more powerful background rejection with the help of Machine Learning (ML) algorithms and Neural Networks [6, 7].

2.2 Proton and helium spectra

Protons and helium nuclei represents the two most abundant components of cosmic rays. DAMPE measured their individual spectra in 2019 (protons) and 2021 (helium), confirming the evidence of a spectral hardening and revealing the presence of a softening, in both fluxes. In particular, for the proton spectrum (left plot of figure 2) the hardening and the softening have been measured at ~500 GeV and ~14 TeV, respectively [8]. While, for helium (right plot of figure 2), these spectral features have been observed at ~1.4 TeV and ~34 TeV [9].

At the moment, the collaboration is working to update the proton and helium spectra including in the analysis the new collected flight data and employing ML techniques to improve tracking and identification of particles [11]. In figure 3 the two preliminary spectra are reported as function of kinetic energy per nucleon (left) and rigidity (right), with break positions marked with green vertical dashed lines. The alignment of the break positions in the rigidity plot suggests that these spectral features are better explained by charge-dependent processes rather than mass-dependent ones.

A further confirmation of the hardening and the softening features is given by the DAMPE p+He spectrum [10], shown in figure 4. This is not the sum of previously discussed p and He spectral measurements but it comes form an independent analysis that uses an event selection accepting both p and He candidate events. This allows using looser cuts (e.g. because of no problems of cross contamination) and then having very high statistics at high energies. Besides a cross check with independent p and He spectra, this allows extending the energy range up to unprecedented values for space-based measurements thus providing the possibility of a comparison with ground-based experiments results.

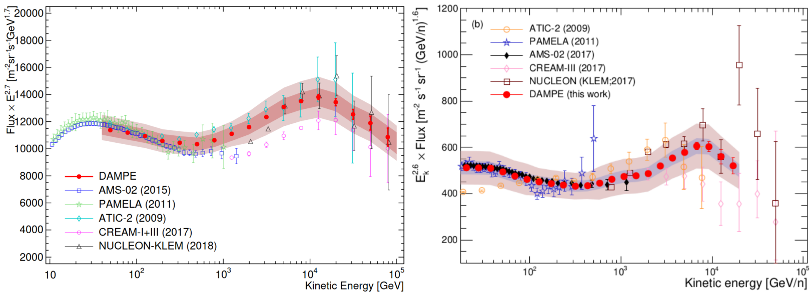

Figure 2: DAMPE proton (left) and He (right) individual spectra. The red error bars refer to the statistical uncertainties. The inner band shows the estimated systematic uncertainties, the outer band refers to the total systematic uncertainties including also those from the hadronic models [8, 9].

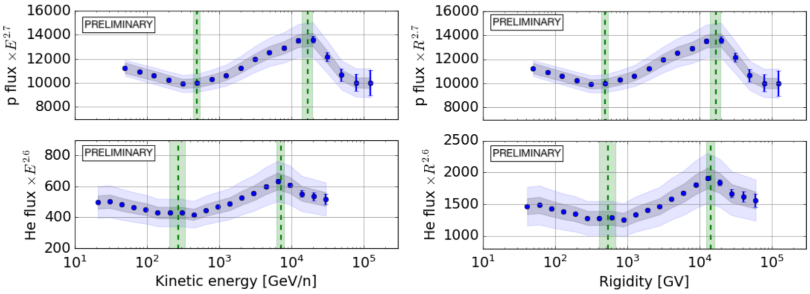

Figure 3: Preliminary updated DAMPE proton (top) and helium (bottom) fluxes as function of kinetic energy per nucleon (left) and rigidity (right). The most probable break positions are marked with vertical dashed lines [11].

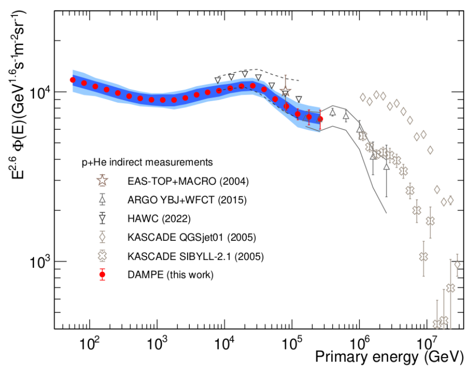

Figure 4: DAMPE p + He spectrum (red dots) [10].

2.3 Heavier nuclei spectra

There are different ongoing analyses that are studying the spectra of heavier nuclei. Recently, the fluxes of boron [14], carbon, oxygen and combined CNO group have been measured. They are shown in figure 5. Similarly to the analyses on proton and helium, the spectra are characterised by a hardening feature at a few hundred GeV per nucleon.

2.4 Flux ratios

In 2022 DAMPE measured the secondary-to-primary flux ratios B/C and B/O, fundamental to probe the CR diffusion mechanisms [13]. They are shown in figure 6, revealing a hardening at 100 GeV/n in both ratios with high significance. This supports the hypothesis of such feature being related to propagation effects.

Moreover, preliminary results on secondary - to - secondary flux ratios have been obtained. The analysis is still ongoing, focusing on the reduction of the background and a complete evaluation of the systematics [14].

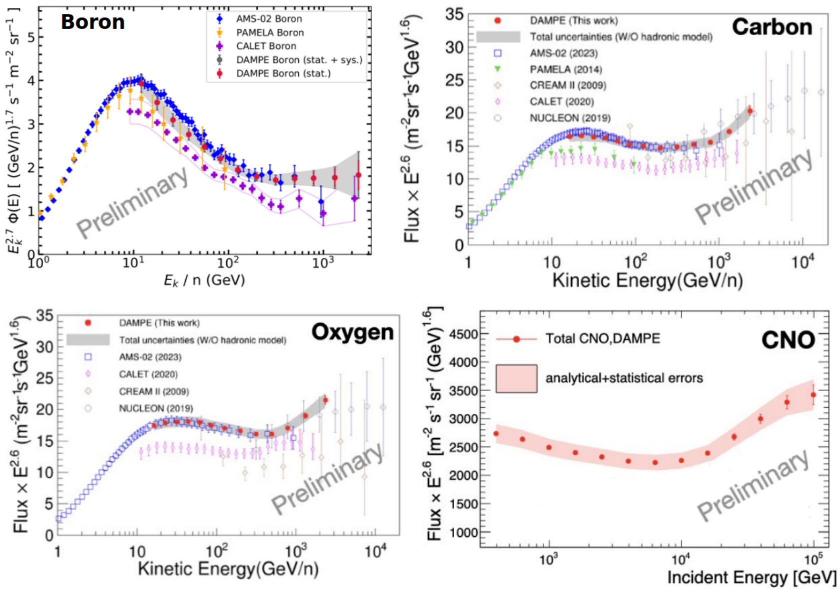

Figure 5: Preliminary DAMPE boron, carbon, oxygen and combined carbon-nitrogen-oxygen spectra [12].

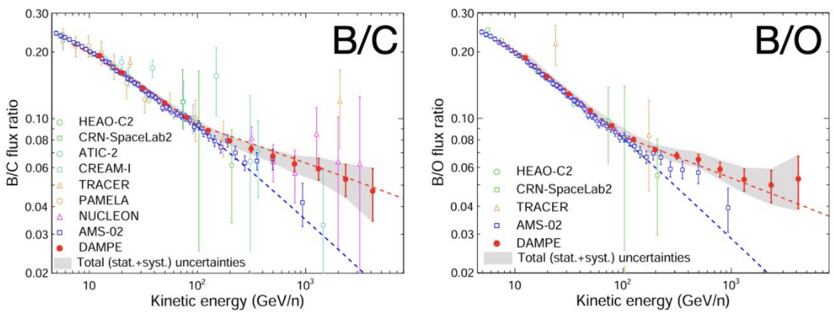

Figure 6: DAMPE secondary-to-primary flux ratios as function of kinetic energy per nucleon: boron-to-carbon (left) and boron-to-oxygen (right) [13].

3. Summary

DAMPE is a space-borne particle detector, that in these years of operation has continuously collected data with all its subdetectors, obtaining several results. Among them, the main ones achieved for CR nuclei include the measurement of the electron-positron spectrum, revealing the presence of a spectral break at ∼0.9 TeV, and the observation of proton and helium, which showed a softening feature at rigidities around 15 TV. DAMPE also measured the B/C and B/O ratios reporting a hardening at about 100 GeV/n. The new ongoing analyses are focused on reaching higher energies, studying heavier CR nuclei spectra and measuring the flux ratios with the aim to provide further insights on CR origin, acceleration and propagation in our Galaxy.

References

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