BCAS Vol.34 No.4 2020

Tens GeV Dark Matter Interpreted by Antiproton Excess Is Constrained

In recent years, the cosmic-ray positron excess above tens GeV beyond the astrophysical background has been considered as possible evidence of dark matter particles. Since the release of the data of cosmic-ray antiprotons from the AMS-02 experiment, many papers have proposed that there is also excess of cosmic ray antiprotons below 10 GeV, possibly resulting from the annihilation or decay of dark matter particles. However, the paper, published in *The Astrophysical Journal* with Dr. JIN Hongbo from the National Astronomical Observatories of CAS (NAOC) as the first author, shows that the excess of antiprotons in the GeV energy range is not reasonable. The latest AMS-02 data and QGSJET-II-04 model both prevent that excess.

AMS-02 experiment is a search for antimatter in the universe led by Samuel C. C. Ting, a Nobel laureate in physics. The experiment measures the positrons and antiprotons in cosmic rays, as well as a large number of cosmic-ray nuclei with high precision, bringing cosmic-ray detection experiments into the era of precise measurement.

QGSJET-II-04 model is the strong interaction model of elementary particles used to calculate the background of cosmic-ray positrons and antiprotons. In previous studies, dark matter interpretation of the anti-proton excesses in low-energy region were derived from the conventional model, which had not been updated in light with the latest experimental data, such as that from LHC experiment, *etc*.

As shown in Figure 1, the QGSJET-II-04 model, which was adopted in the current study, gives results in a high degree of consistency with the experiment. The calculated numbers of positrons are consistent in most energy regions with the traditional model, while the numbers of produced antiprotons, however, are inconsistent with the conventional model, indicating that the antiprotons excess as mentioned before in the low energy region might be problematic. The blue curve on the left is the best model selected to produce antiprotons, and the number of antiprotons in the low energy region is significantly higher than the value given by the traditional model.

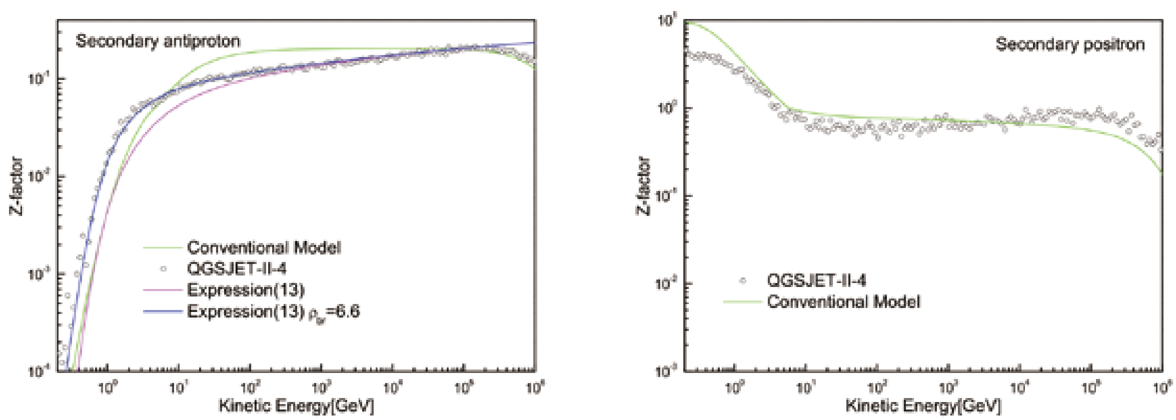

Figure 1: Z factors of antiproton and positron products in the QGSJET-II-04 model compared with the Conventional model. (Credit: JIN Hongbo)

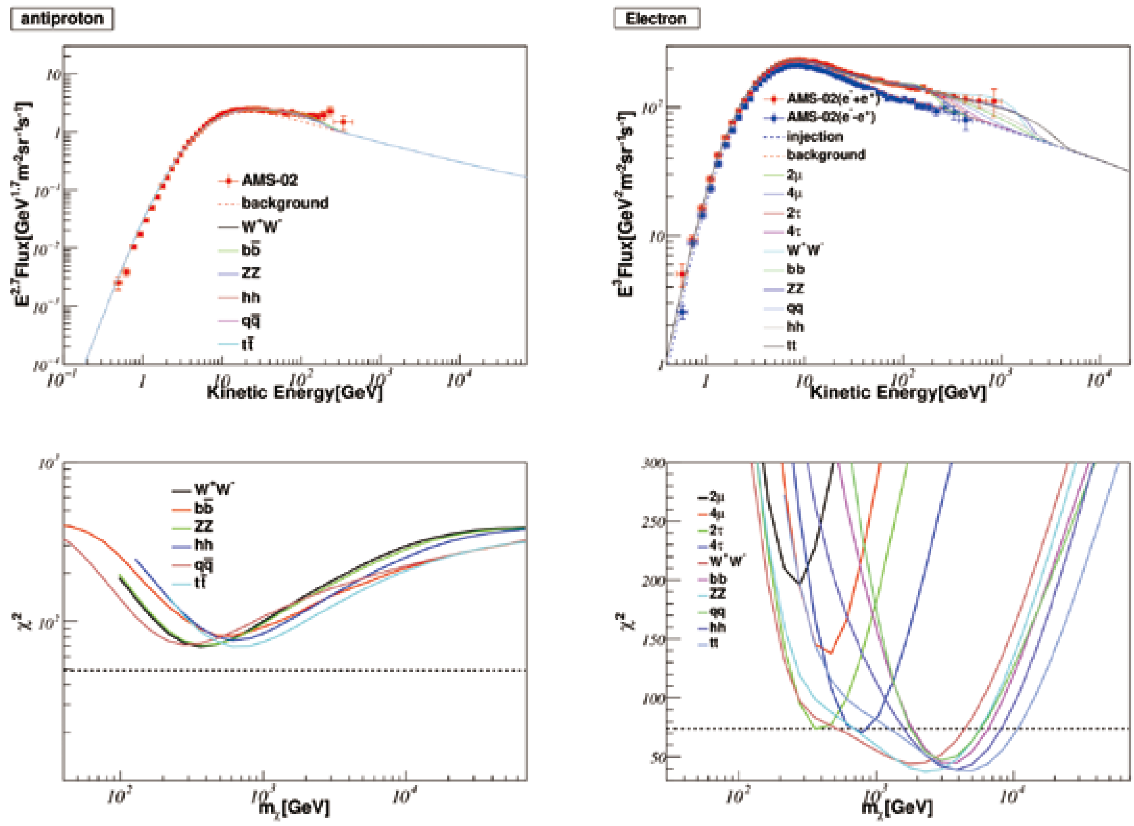

Figure 2: The X^2 distribution of antiprotons and positrons produced by the annihilation of dark matter particles with different masses to multiple final states (last row) and the associated cosmic ray energy spectrum (first row). (Credit: JIN Hongbo)

The positron excess predicts that the masses of dark matter particles should range from a few hundred GeV to more than TeV. If the above-mentioned antiproton excess was reasonable, however, the predicted dark matter mass would fall in the tens-GeV range. This discrepancy in energy region implies the predicted positron and antiproton excesses are not consistent with each other; wither is the prediction convinced in the experiment to detect dark matter particles from cosmic rays.

Based on QGSJET-II-04 model etc., the current study gives possible mass distribution of dark matter particles through analysis of the energy spectrum from the AMS-02 experiment in relation to antiprotons and so on. As seen in Figure 2, the mass distribution of dark matter particles goes beyond the exclusion line and hence is not acceptable, although various channels of dark matter annihilation have been taken into account to produce antiprotons. From the corresponding antiproton energy spectrum, it can also be seen that the energy in the low energy region fails to go beyond the background. On the contrary, according to the energy spectrum analysis of total electrons in cosmic rays, due to the positron excess, it is obvious that in the energy spectrum of total electron flux of cosmic rays, there is an obvious background excess near TeV. Obviously, there are several annihilation channels below the exclusion line corresponding to the mass distribution of dark matter. It is accepted that the mass range of the predicted dark matter is distributed in the range from several hundred GeV to above TeV. Therefore, such analysis results also confirm the feasibility of relevant experiments to search for dark matter by detecting cosmic rays above TeV.

The paper can be accessed at https://iopscience.iop.org/article/10.3847/1538-4357/abb01a

(NAOC)