THE 14TH INTERNATIONAL WORKSHOP ON THE DARK SIDE OF THE UNIVERSE
DSU 2018
25 - 29 June 2018
LAPTh, Annecy, France
LAPTh

Astrophysical background and dark matter implication based on latest AMS-02 data

Hong-Bo Jin

Collaborators: Yu-Feng Zhou, Yue-Liang Wu

26 June 2018

ArXiv: 1701.02213, 1410.0171, 1504.04604

中国科学院大学
University of Chinese Academy of Sciences

NAOC
National Astronomical Observatories of China
Chinese Academy of Sciences

Institute of Theoretical Physics
Chinese Academy of Sciences

outline

- Motivation

Over-predicted background of cosmic ray positrons.

Under-predicted background of cosmic ray antiprotons.

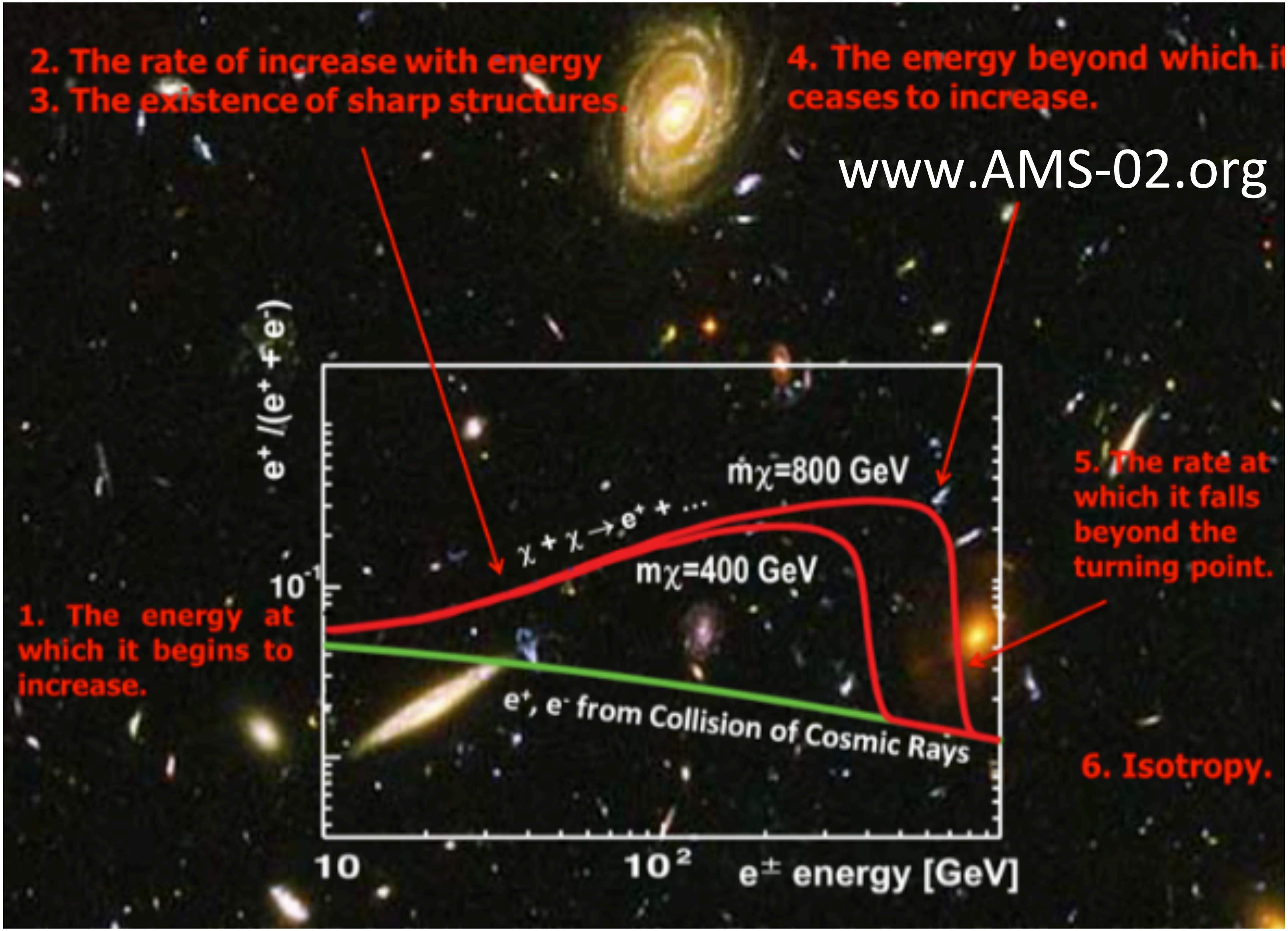
- Methods

Hadronic interaction model：choose QGSJET-II-4

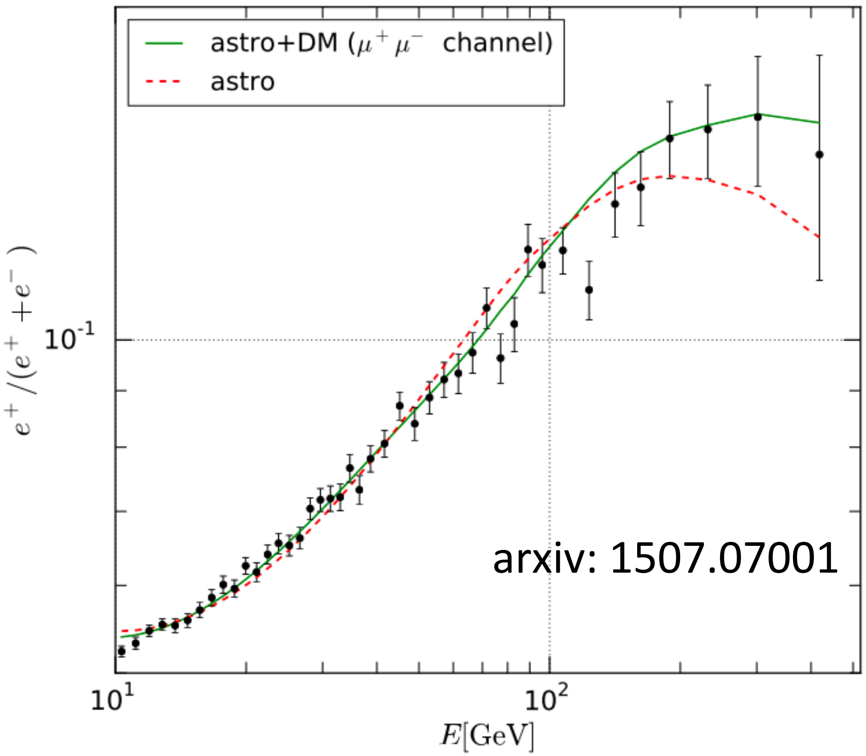
Propagation model: use convection and re-acceleration model(DCR) instead of the re-acceleration diffusion model(DR)

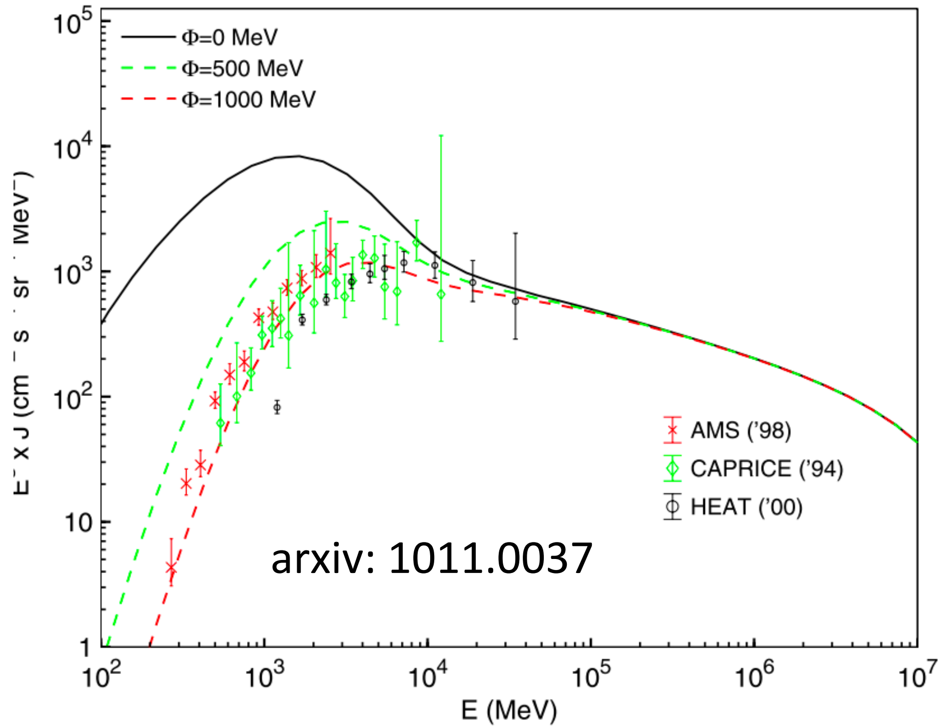
- conclusion

Positron excess: the flux of Cosmic ray positrons greater than the measured values from PAMELA, Fermi-LAT, AMS-02.



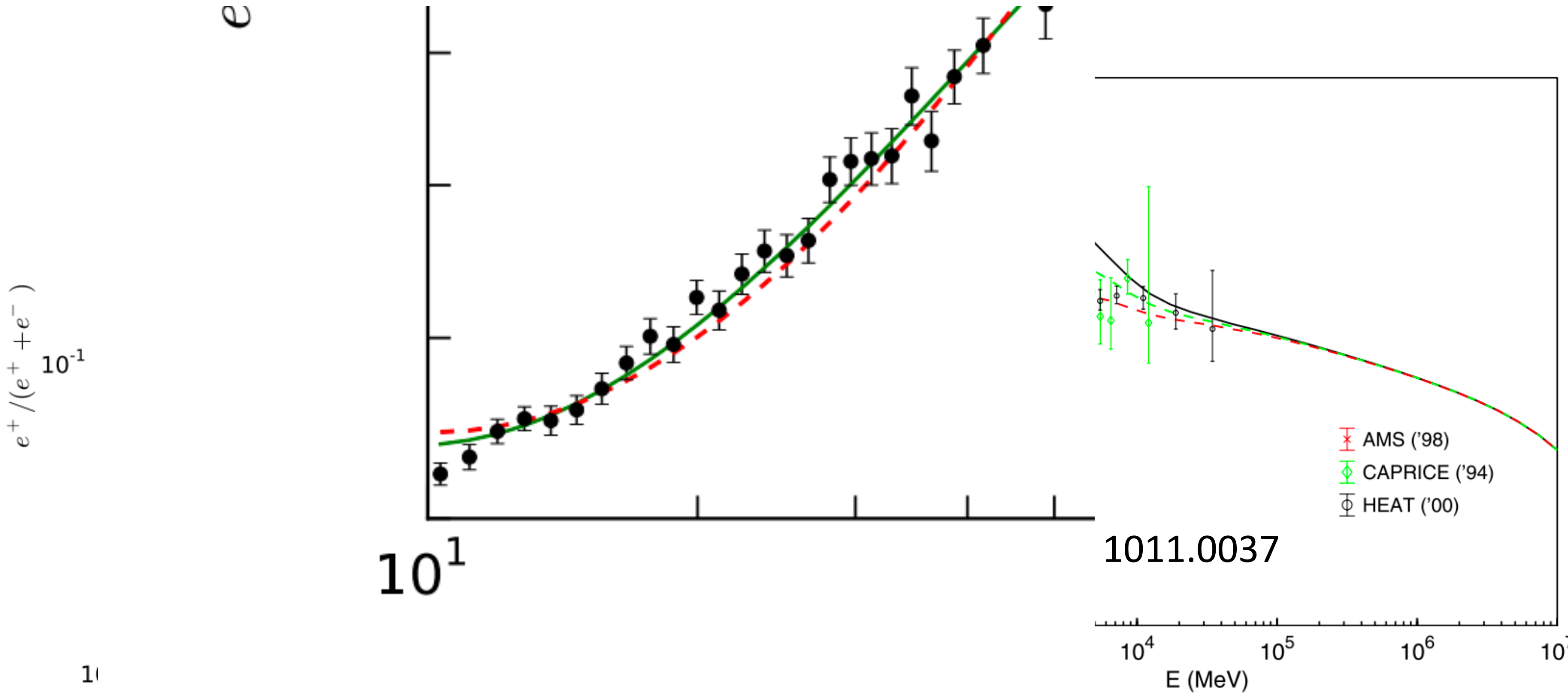
Cosmic ray Positrons: Over-predicted flux below 10GeV





CR Positrons is only from Collision product between the primary particles and interstellar medium, which is strongly constrained by the over-predicted flux of CR positron and exclude the primary positrons.

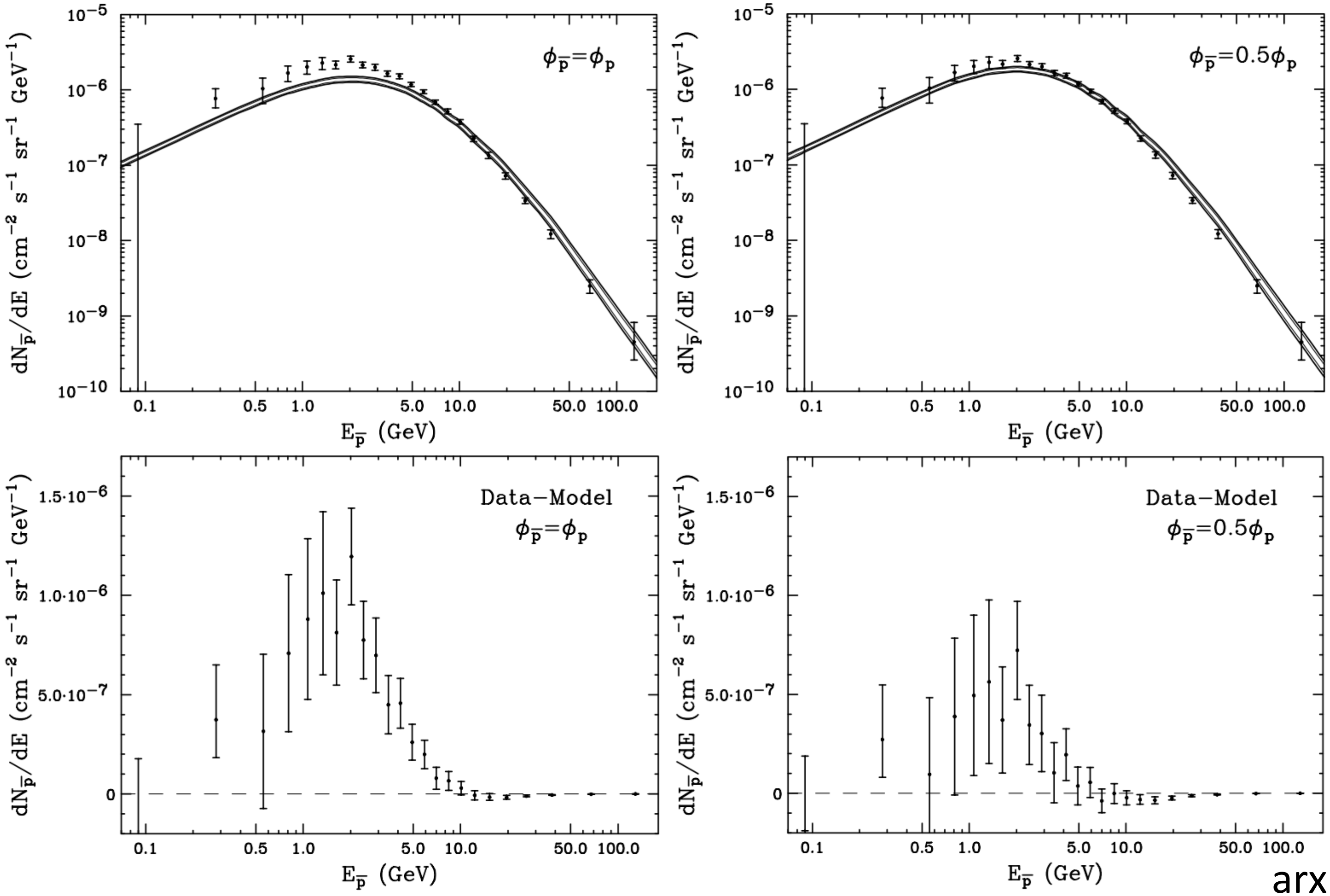
Cosmic ray Positrons: Over-predicted flux below 10GeV



CR Positrons is only from Collision product between the primary particles and interstellar medium, which is strongly constrained by the over-predicted flux of CR positron and exclude the primary positrons.

Antiproton excess below 10GeV:

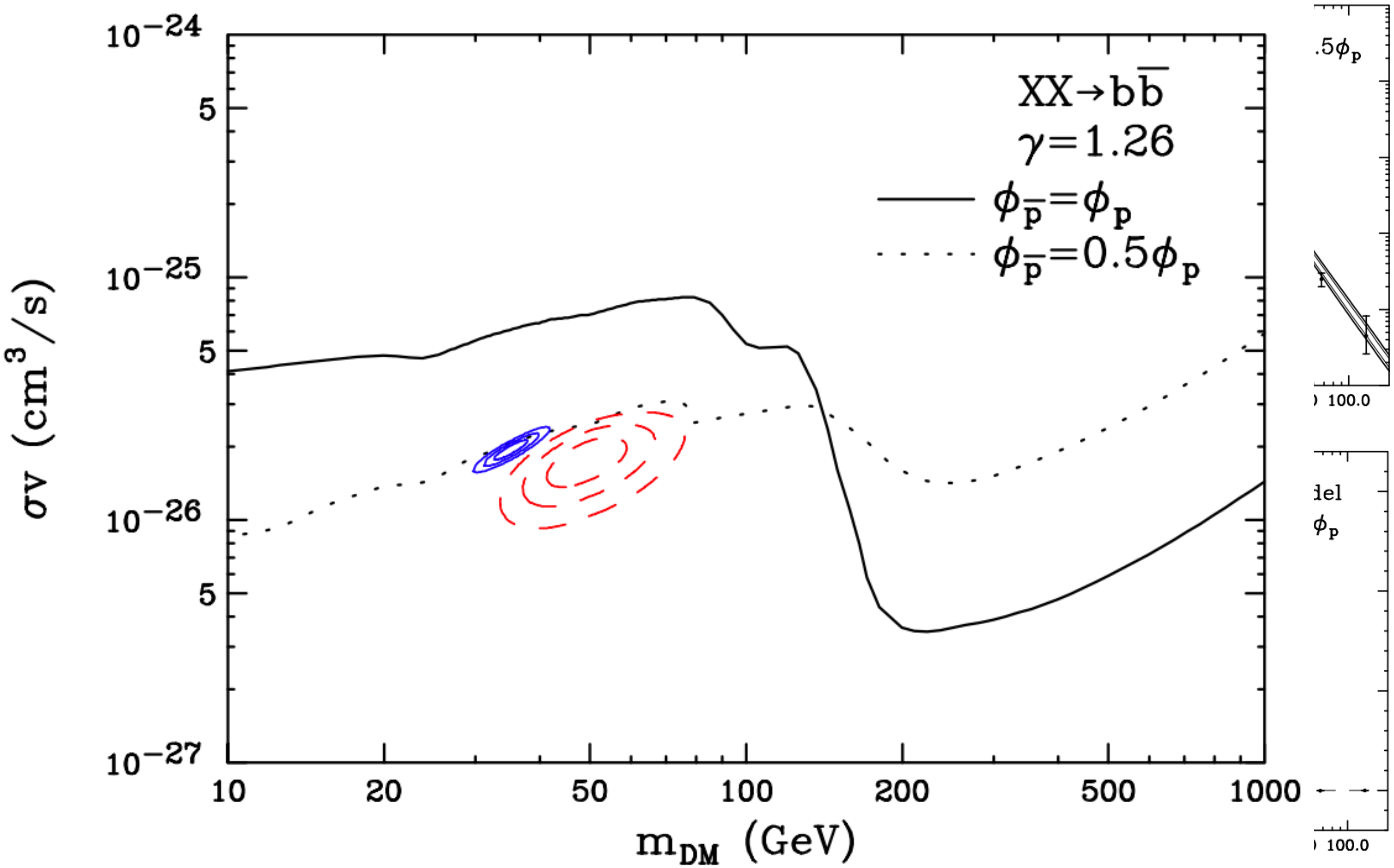
the difference between the measured data and model. If let the solar modulations of antiproton and proton are different, that difference is weaken but exist.
If dark matter contributes to it, the contour between the cross-section and mass of dark matter can be predicted in the confidence levels.



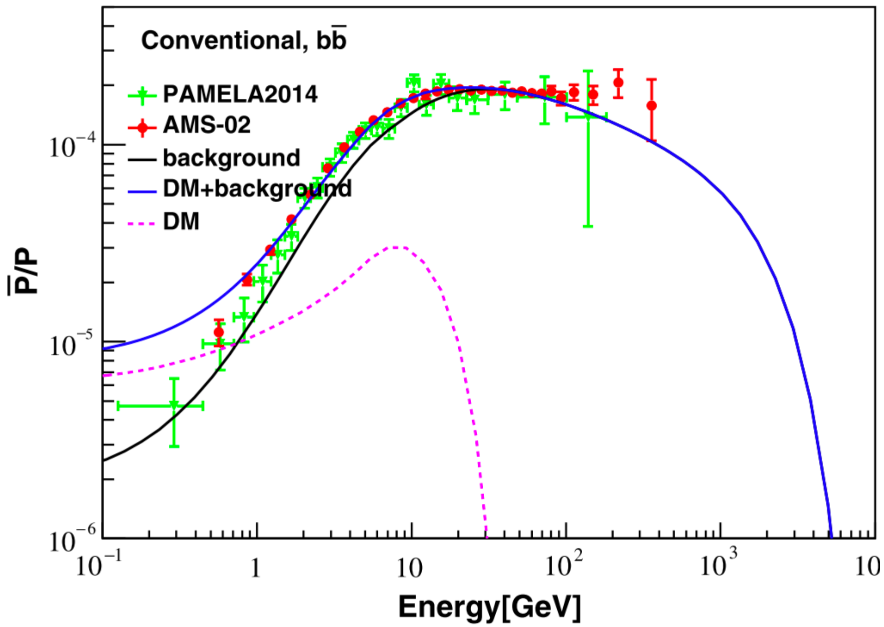
arxiv: 1410.1527

Antiproton excess below 10GeV:

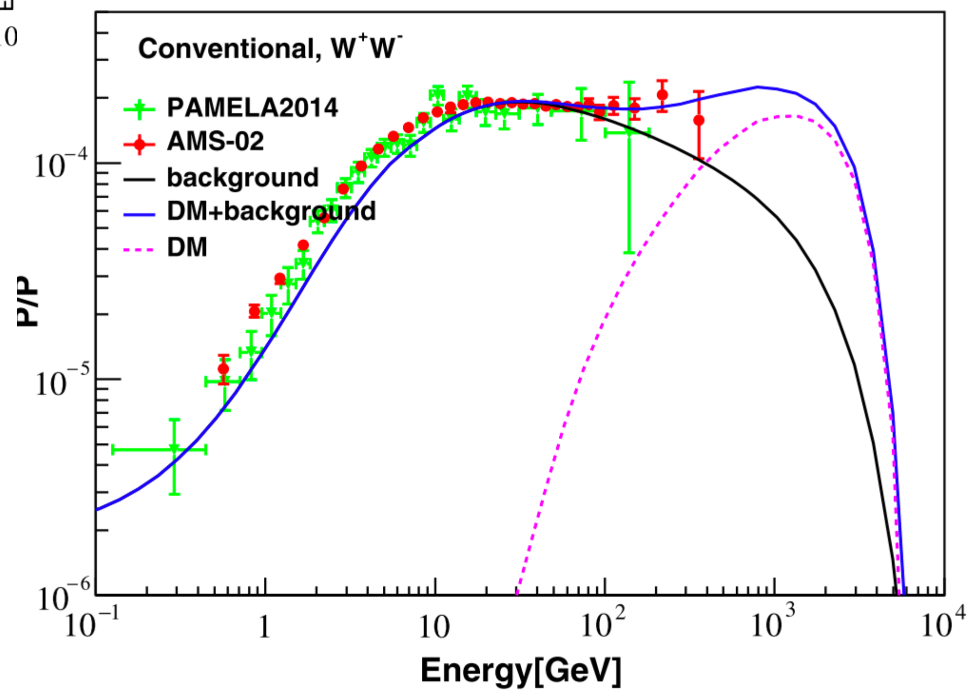
the difference between the measured data and model. If let the solar modulations of antiproton and proton are different, that difference is weaken but exist.
If dark matter contributes to it, the contour between the cross-section and mass of dark matter can be predicted in the confidence levels.



arxiv: 1410.1527



Antiproton excess above 100GeV:
same as the low energy excess, the background flux is greater than AMS-02 data. If dark matter contribute to it, the mass of dark matter up to TeV



Astrophysical background nee be re-predicted from the latest AMS-02 data

- Below 10 GeV, over-predicted flux of CR positrons are not natural.

  Some methods are used：

1, the difference solar modulation between the cosmic rays. But for force-field approximation model of the solar modulation does not favored

2, adding the normalization factor to CR positron flux works, but that is unreasonable.

- Below 10 GeV, under-predicted flux of CR antiprotons is not perhaps also natural.

Origin of the spectral structure alteration of the secondary particles

Since, CR positrons and antiprotons are only from collision product between the primary particles and interstellar medium, the origin of the alteration structure of their spectra should be considered to reduce the inconsistences.

The spectra of the primary particles → A simple power law with the breaks

Hadronic interaction model → Conventional model (parameterizations by Tan & Ng (1983))
QGSJET-II-4
EPOS-LHC
FLUKA

Propagation model

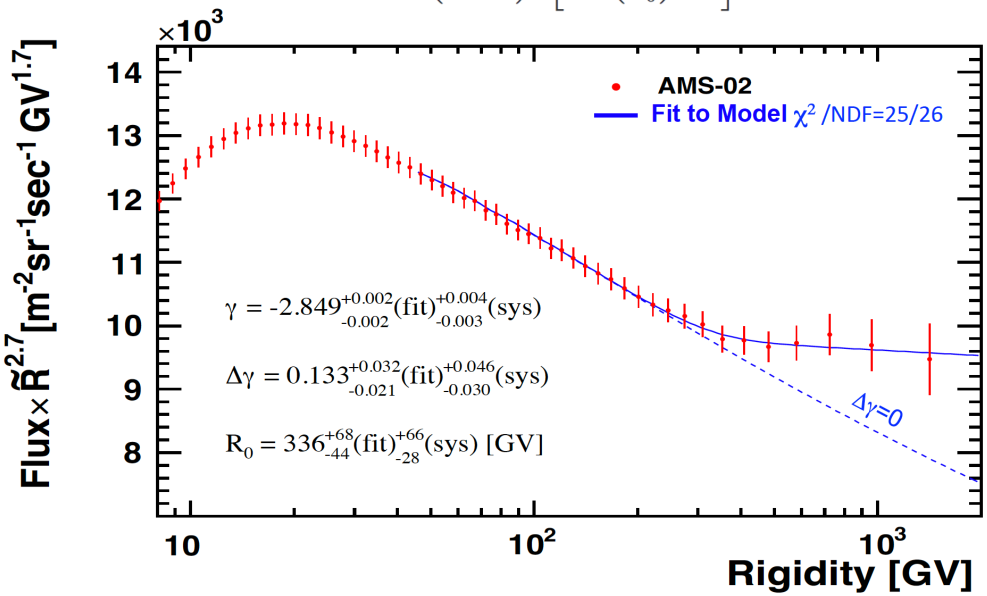
- Diffusion
- Energy loss(IC, synchrotron radiation etc.)
- Re-acceleration
- convection

Spectra of CR Protons

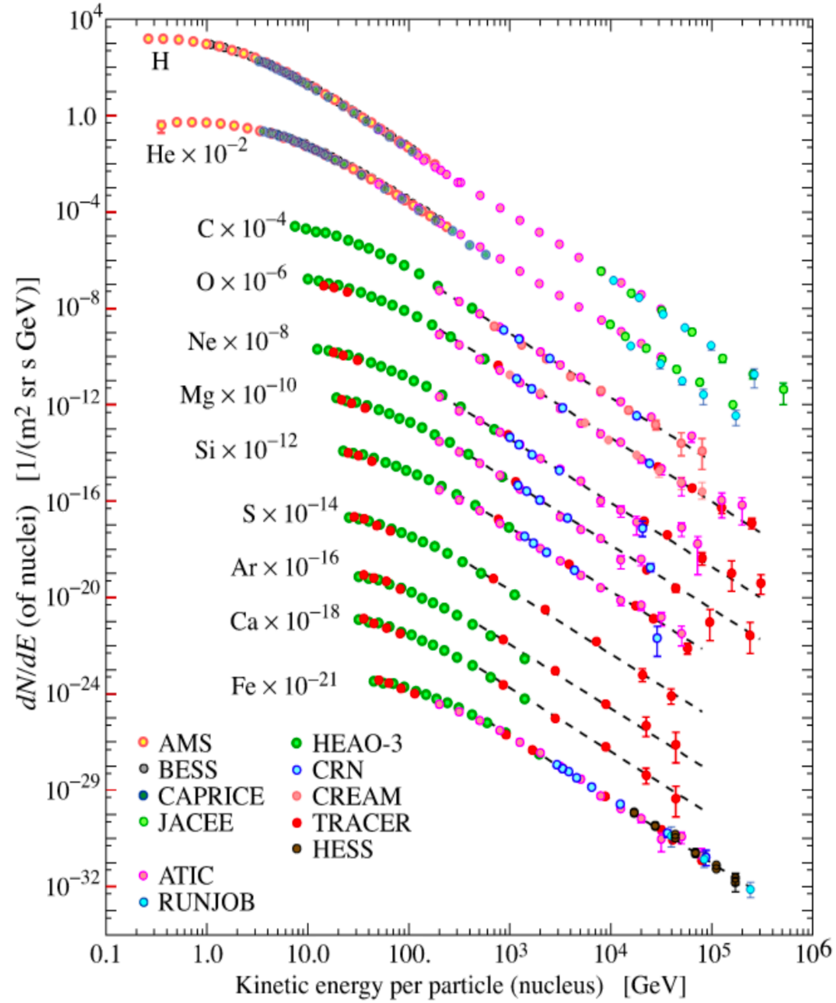
The secondary product is dominated by CR protons, but the two breaks are not sensitive to the feature of secondary antiprotons and positrons

Proton Flux Fit with the Model

$$\Phi = C\left(\frac{R}{45\,\mathrm{GV}}\right)^{\gamma}\left[1+\left(\frac{R}{R_0}\right)^{\Delta\gamma/s}\right]^{s}$$

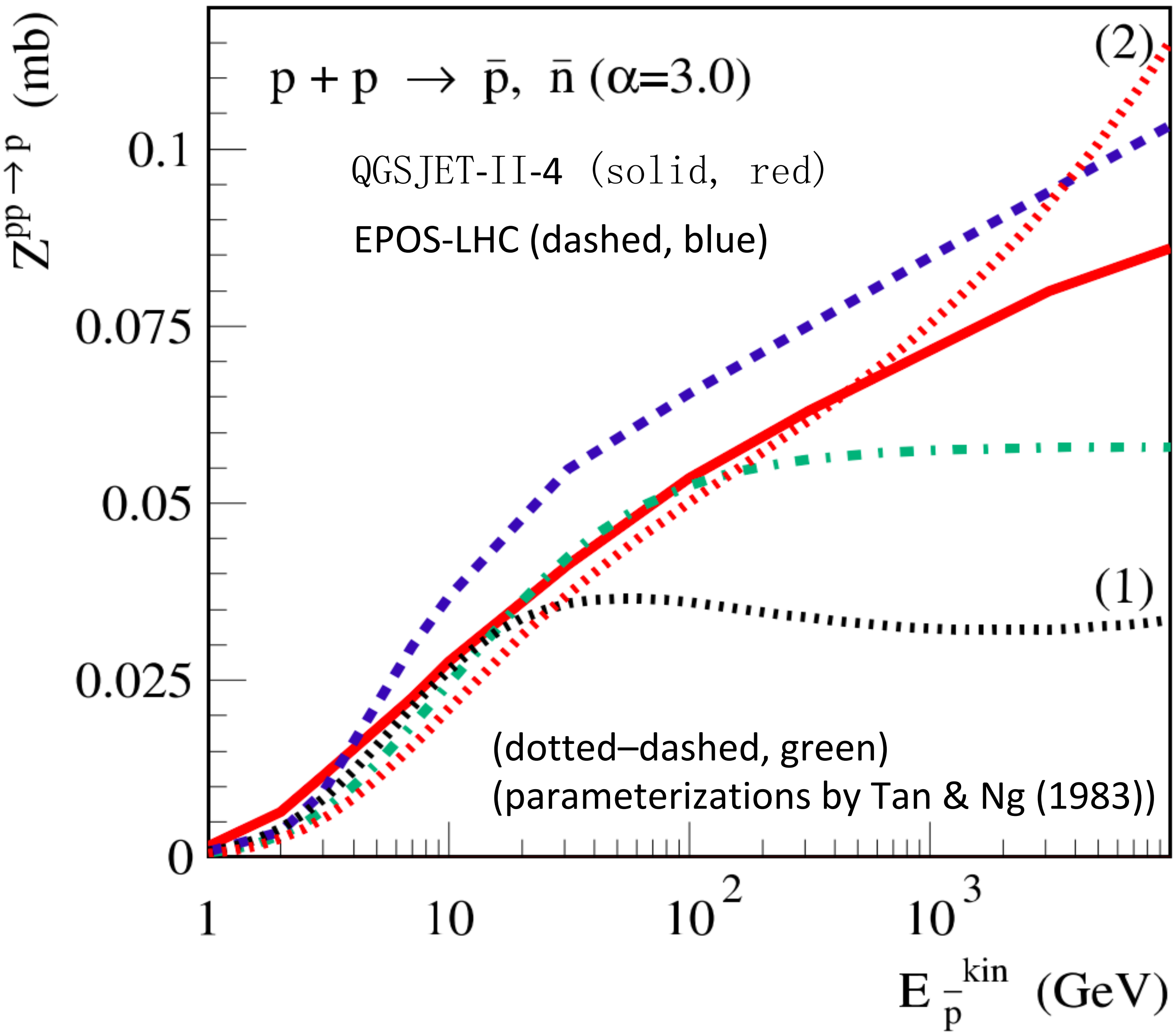


From V.Choutko AMS Days CERN



From Daniel Kerszberg

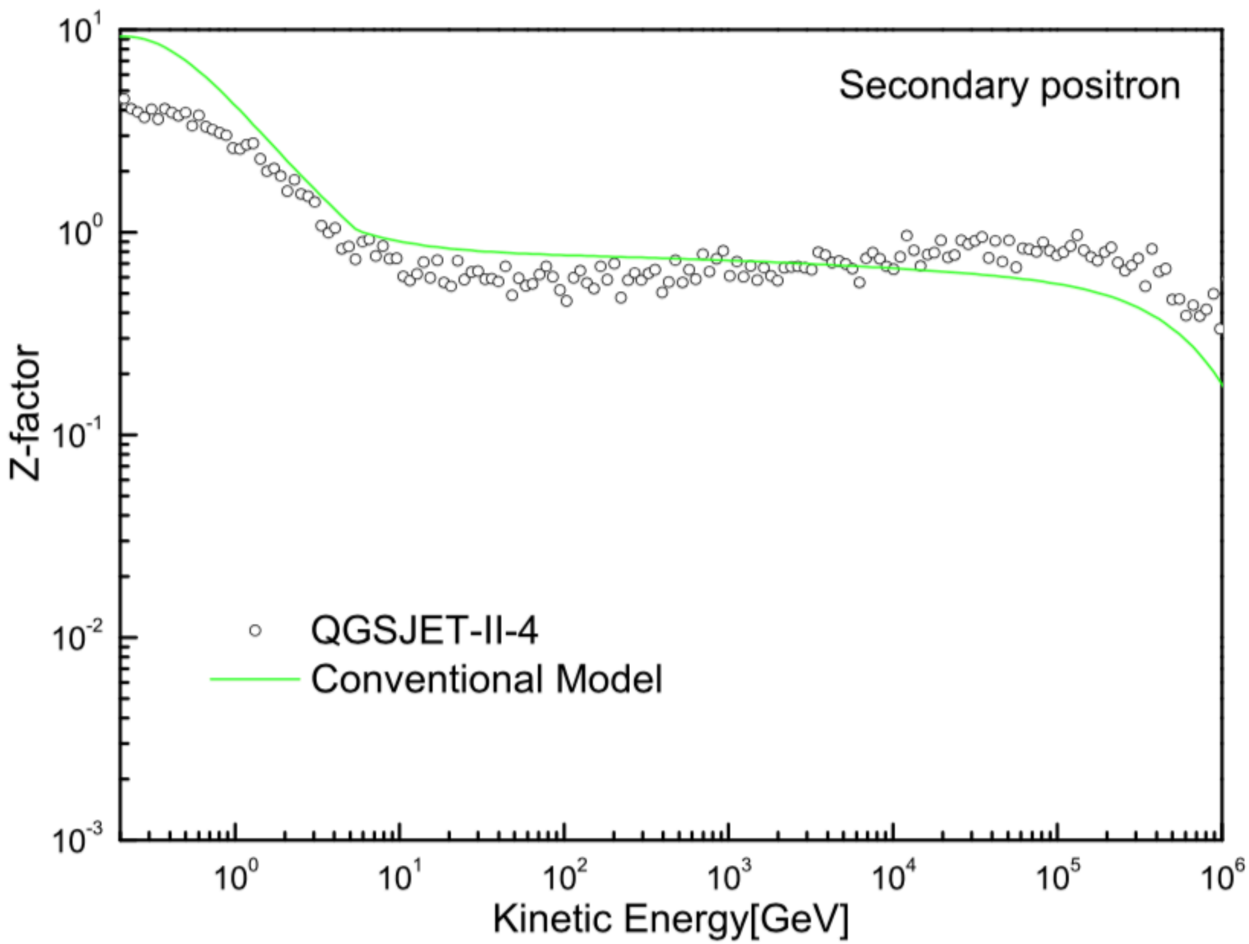
Hadronic interaction model



In the Conventional model, the antiproton yield is less than the others below 10 GeV. And in the ranges from 10 GeV to 100 GeV, EPOS-LHC model has more contribution to the antiproton yields than the Conventional and QGSJET-II-04 model. QGSJET-II-04 is moderate model to describe the hadronic interaction

arxiv: 1502.04158

Hadronic interaction model



As in the paper of arxiv:1502.04158, CR positron is not included to analyze the product of them.

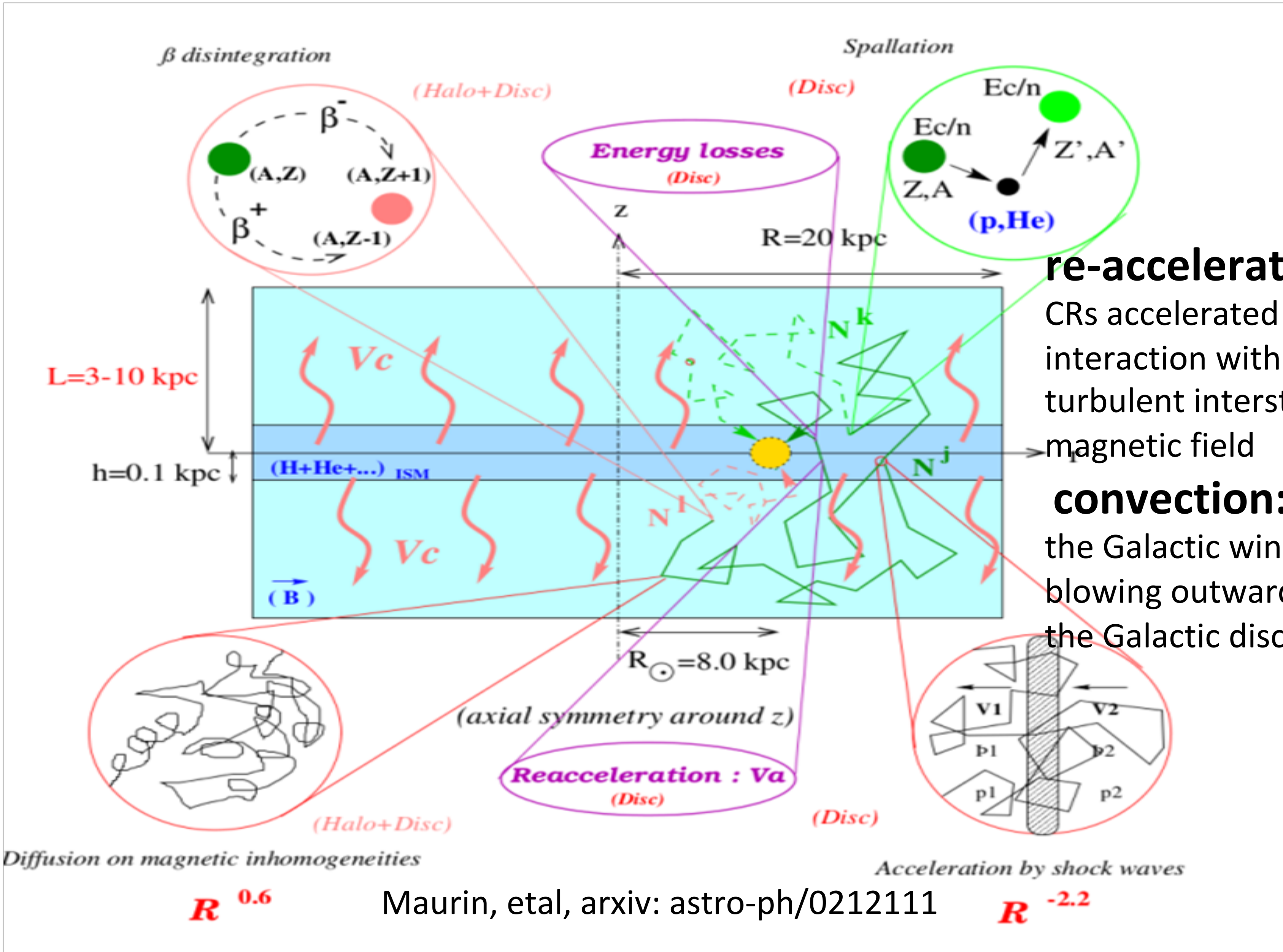
In our work, we re-calculate the cross-section relevant to CR positrons in QGSJET-II-04.

In the Conventional model, the positron yield is greater than the QGSJET-II-04 model.

QGSJET-II-04 is just used to decrease the product of CR positrons.

But the the positron yield is not enough in the QGSJET-II-04 model. Need the propagation model to depress it.

Propagation model: two-zone diffusion



re-acceleration: CRs accelerated via the interaction with the turbulent interstellar magnetic field

convection: the Galactic winds are blowing outwards from the Galactic disc.

Maurin, etal, arxiv: astro-ph/0212111

Propagation equation of CRs

the CR propagation equation is solved by GALPROP v54 package, which is based on a Crank-Nicholson implicit second-order scheme

$$\frac{\partial\psi}{\partial t} = \nabla\left(D_{xx}\nabla\psi - \mathbf{V}_c\psi\right) + \frac{\partial}{\partial p}p^2 D_{pp}\frac{\partial}{\partial p}\frac{1}{p^2}\psi - \frac{\partial}{\partial p}\left[\dot{p}\psi - \frac{p}{3}(\nabla\cdot\mathbf{V}_c)\psi\right] - \frac{1}{\tau_f}\psi - \frac{1}{\tau_r}\psi + q(\mathbf{r}, p),$$

Re-acceleration

$$D_{pp} = \frac{4V_a^2 p^2}{3D_{xx}\delta(4-\delta^2)(4-\delta)w},$$

Diffusion coefficient

$$D_{xx} = \beta D_0\left(\frac{\rho}{\rho_0}\right)^{\delta}$$

A.W. Strong et al, APJ 509:212

Primary source

$$q_A(\mathbf{r}, p) = c_A \frac{\rho}{\rho_{br}}^{-\gamma}\left(\frac{r}{8.5}\right)^{0.5}\exp\left(-1.0\frac{r-8.5}{8.5}\right)\exp\left(\frac{-|z|}{z_{scale}}\right)$$

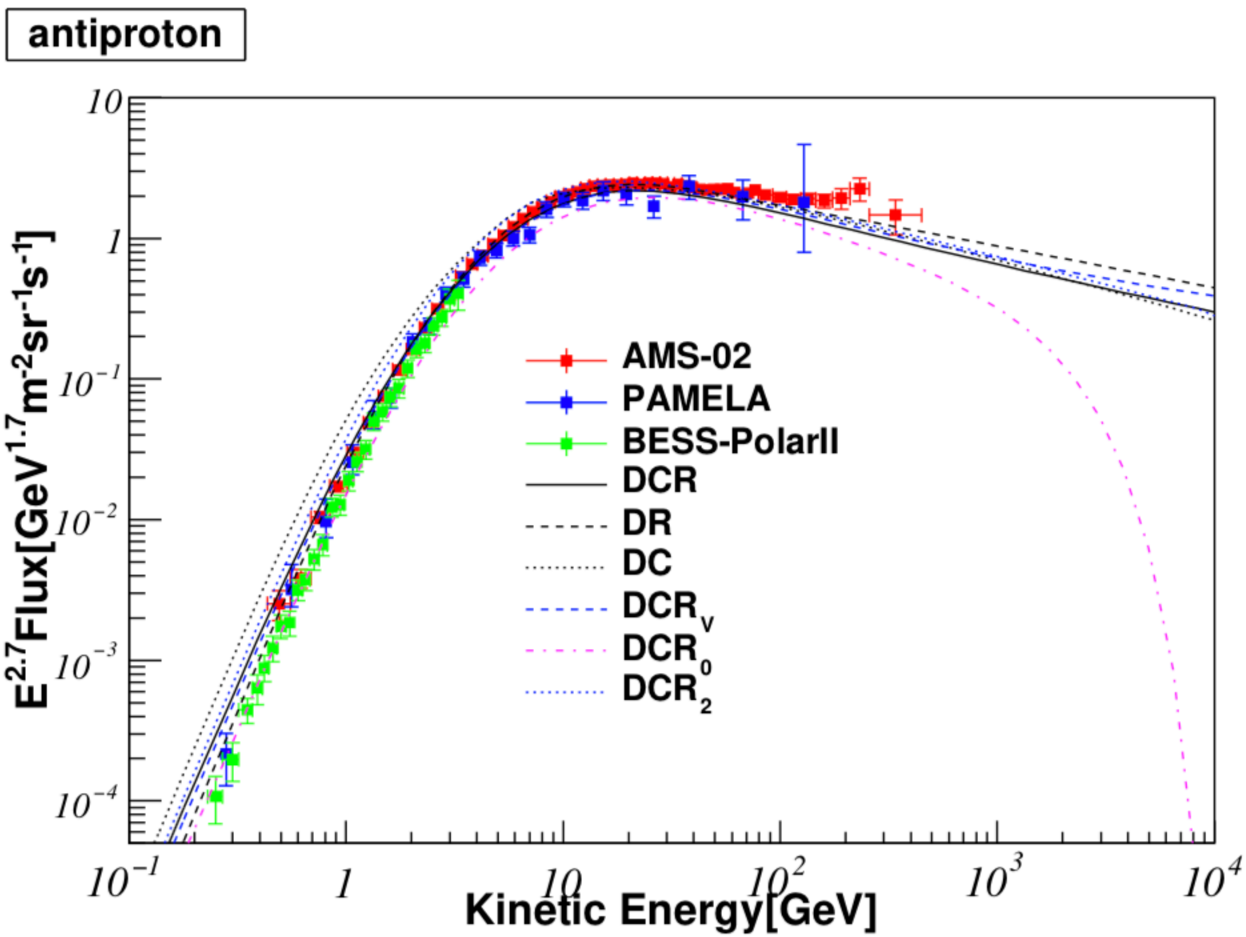
Secondary source

$$q_e(E_{tot}) = \frac{c}{4\pi}\frac{dn(p)}{dt} = \frac{c}{4\pi}\sum_{i=H,He} n_i \sum_j \int dp' \beta n_j(p')\frac{d\sigma_{ij}(E_{tot}, p')}{dE_{tot}}$$

In this work $\left(\frac{\rho}{\rho_{br}}\right)^{\gamma_s}$ is modified as $\left(\frac{\rho}{\rho_{br}}\right)^{-\gamma_1}\left(1+\left(\frac{\rho}{\rho_{br}}\right)^{\frac{-\gamma_1-(-\gamma_2)}{\alpha}}\right)^{-\alpha}$,

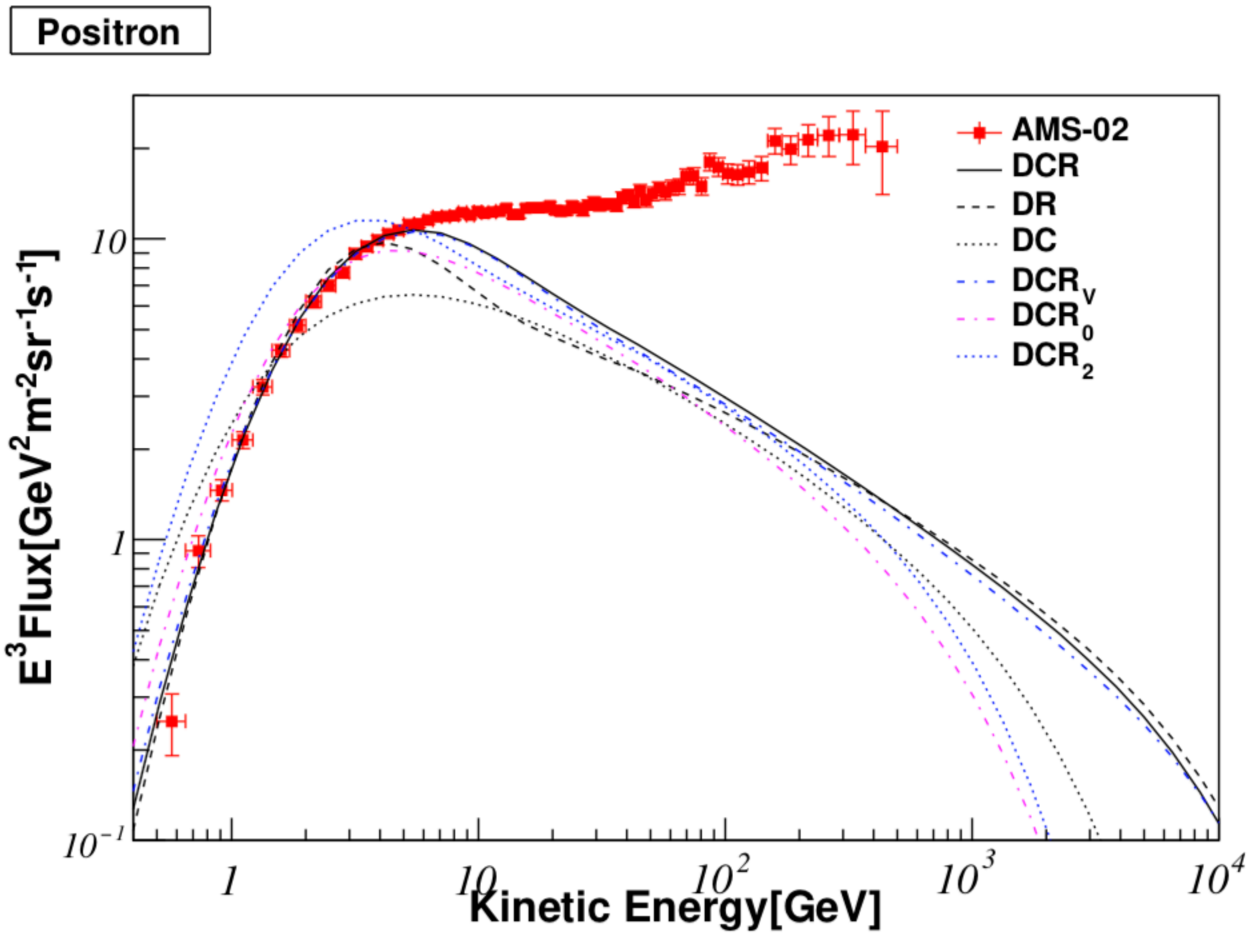
α determines the smoothness of the spectral change in the left and right sides of the referred rigidity, when α is 0, as a broken power law

The Consistence appears when QGSJET-II-4 and convection model are included



In the re-acceleration diffusion (DR) model the under-predicted flux of CR antiprotons has been intensified to be consistent with the AMS-02 data. The more product of antiprotons from QGSJET-II-04 model enhances the flux of CR antiprotons. Above 100 GeV, antiproton excess keeps.

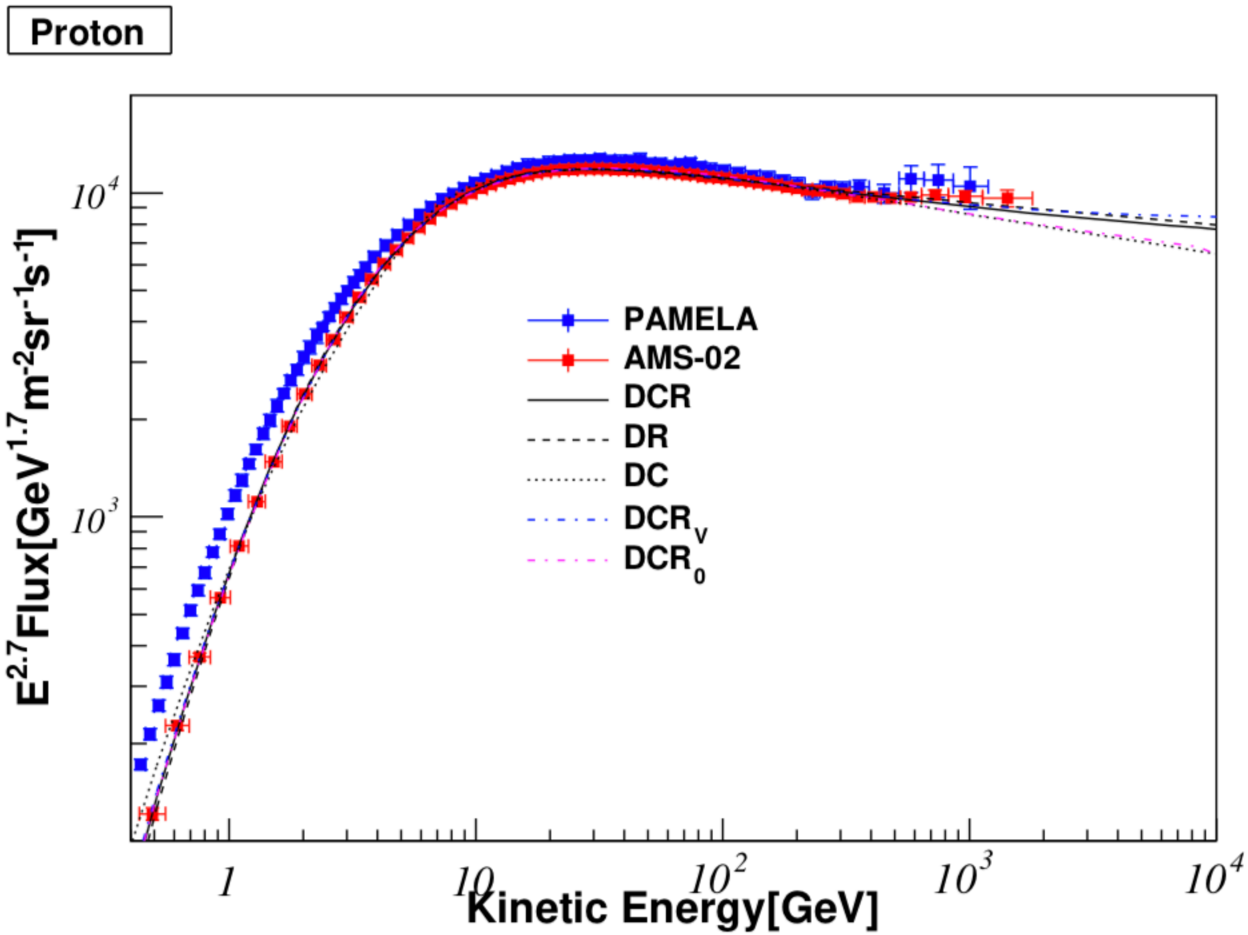
The Consistence appears when QGSJET-II-4 and convection model are included



While the predicted flux of CR positrons below 10 GeV keeps weak inconsistence with the AMS-02 data in DR model. When convection is included, the better consistence appears. That is called DCR model.

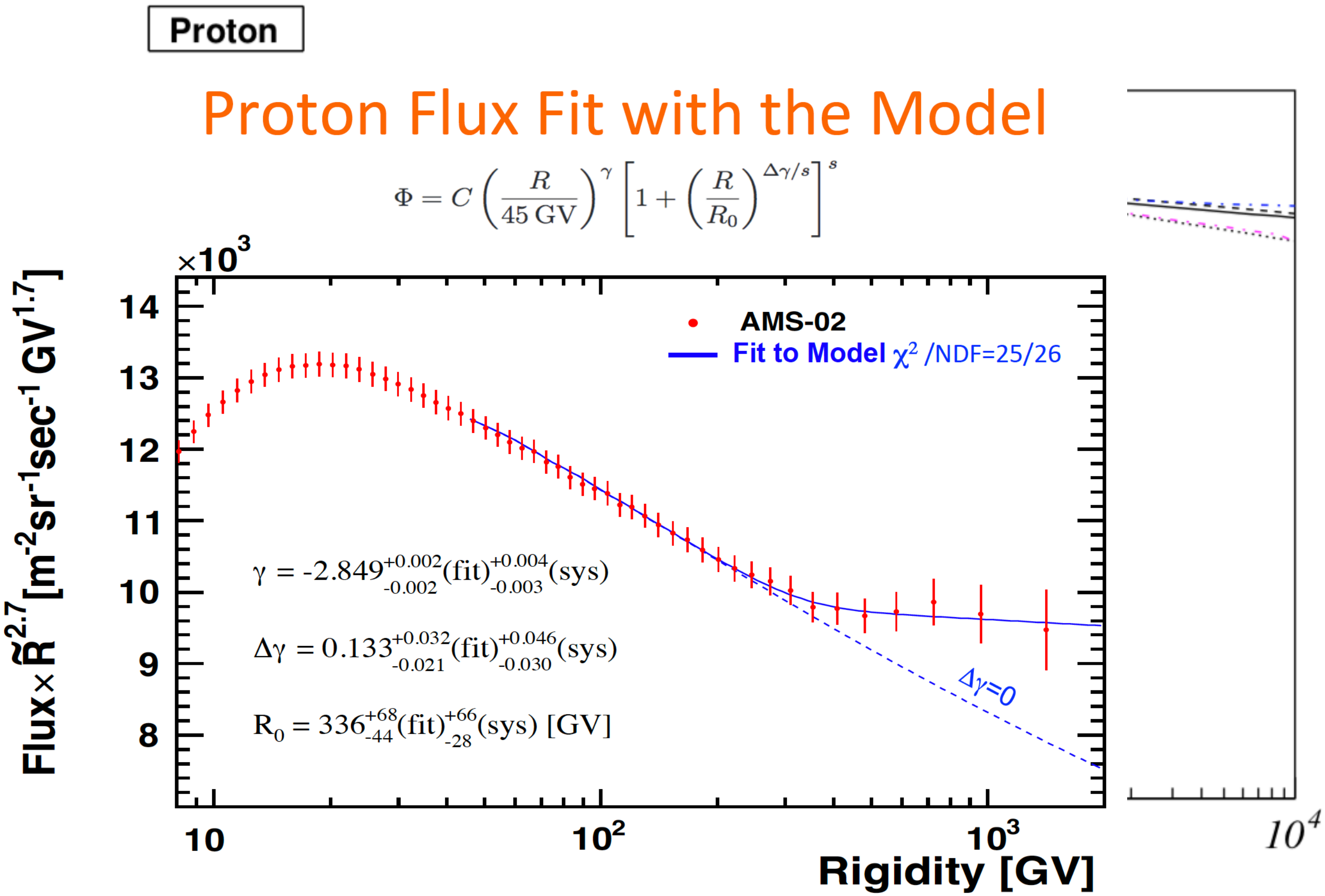
Above 10 GeV, the positron excess keeps apparently.

Un-expectable result for CR protons



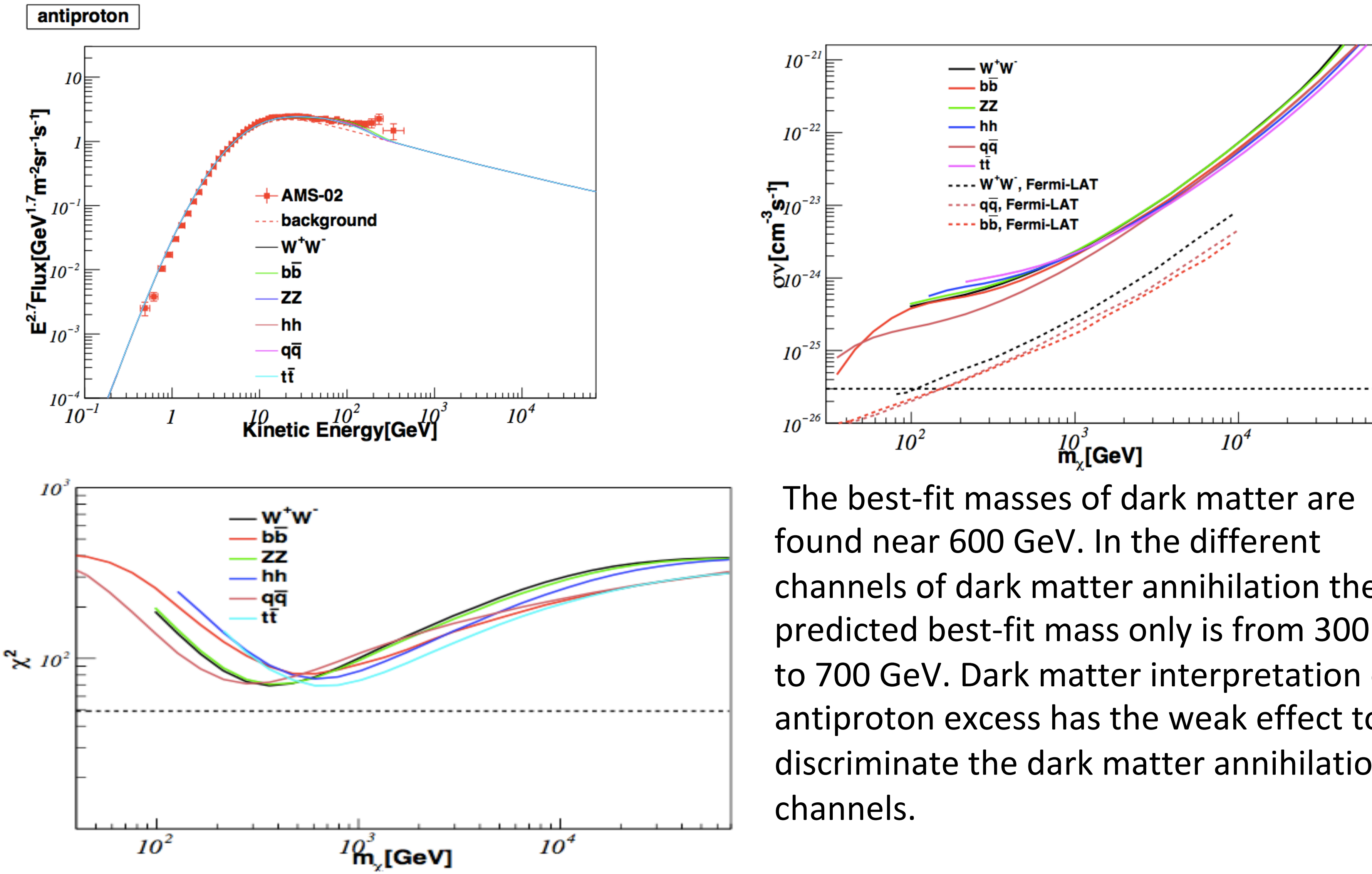
In DCR model, the predicted flux of CR protons is consistent with AMS-02 data whose hardening feature above 330 GeV is also matched. X^2/N is 22.2/72 and very small in DCR model. DR model is relevant to 47/72

Un-expectable result for CR protons



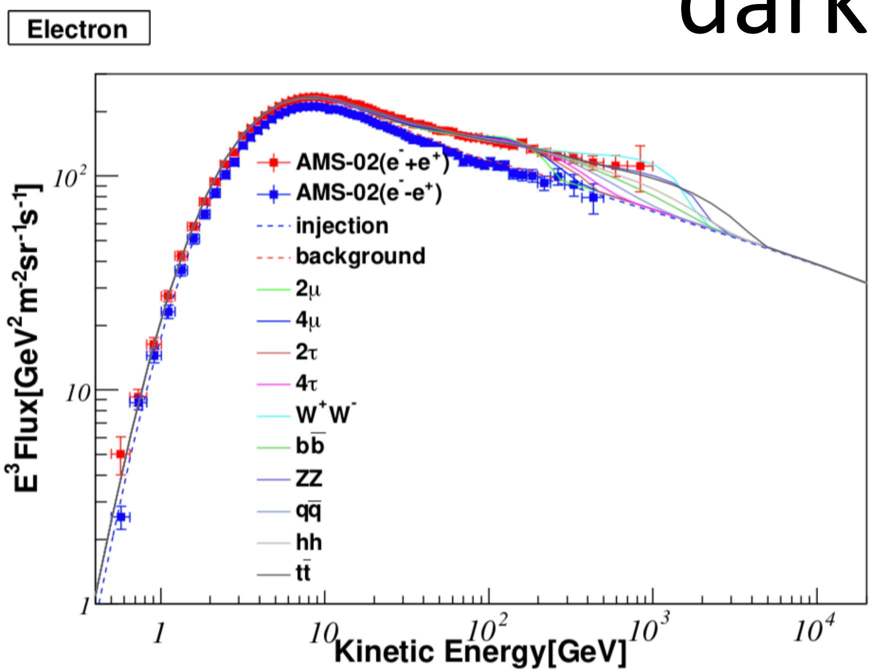
In DCR model, the predicted flux of CR protons is consistent with AMS-02 data whose hardening feature above 330 GeV is also matched. X^2/N is 22.2/72 and very small in DCR model. DR model is relevant to 47/72

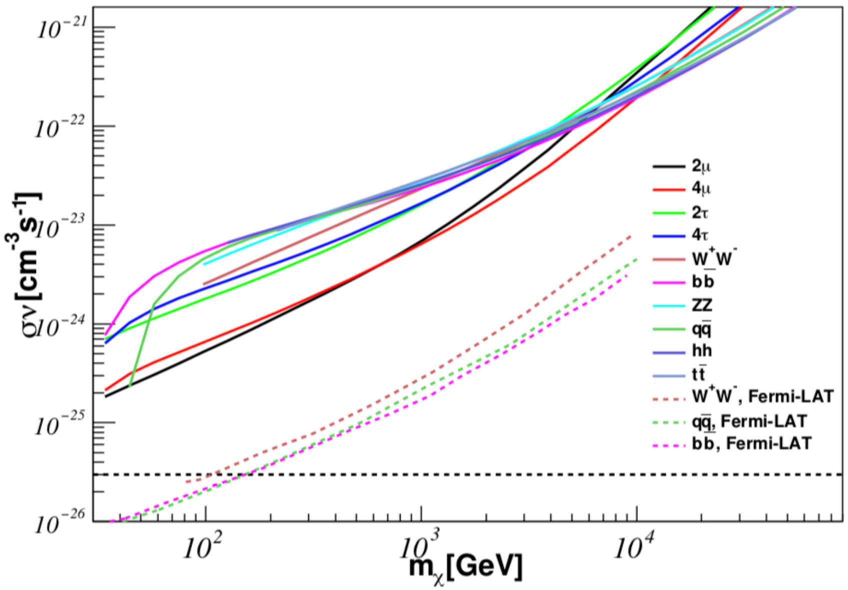
Interpretation of antiproton excess from dark matter

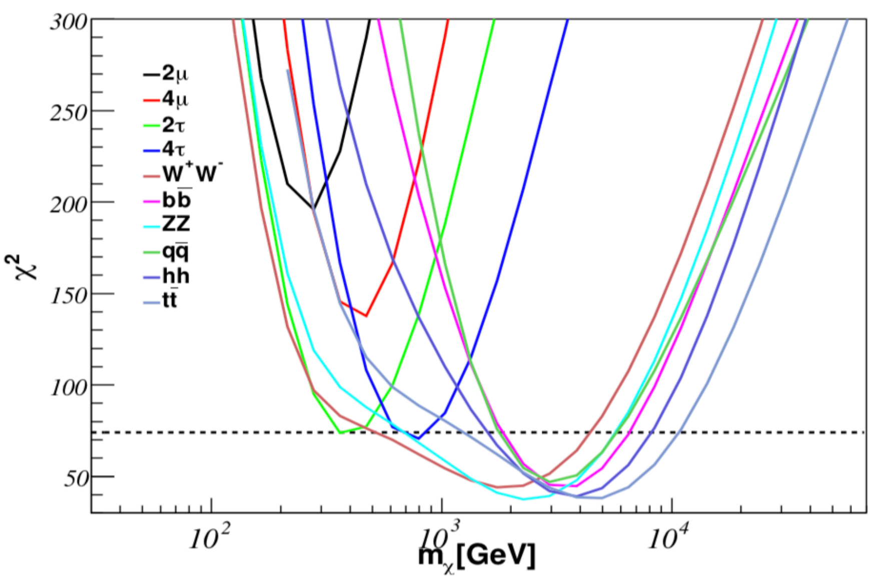


The best-fit masses of dark matter are found near 600 GeV. In the different channels of dark matter annihilation the predicted best-fit mass only is from 300 GeV to 700 GeV. Dark matter interpretation of CR antiproton excess has the weak effect to discriminate the dark matter annihilation channels.

Interpretation of positron excess from dark matter







The issues of the large annihilation cross-sections still exist.
Except for 2μ and 4μ final states, in the other channels, the best-fit masses of dark matter are from 400 GeV to 4 TeV.
The annihilation of heaviest dark matter is through the t\bar{t} final state and the lightest one is via the 2τ channel. The best flux fitting to AMS-02 data is relevant to the ZZ final state.

conclusion

- In low energies the predicted fluxes of CR antiprotons and positrons are consistent with AMS-02 data in the diffusion model combining the re-acceleration and convection terms.
- the excess of CR antiprotons in the low energy are not justified.
- The predicted flux of CR protons is consistent completely with AMS-02 data whose hardening feature above 330 GeV is also matched.
- The predicted best-fit masses of dark matter are from 400 GeV to 4 TeV. The DCR model does not give the unusual interpretation of the positron excess.

Axiv 1701.02213 will be updated on 2 July, 2018

Thank you!

谢谢!