Possible origins of electron/positron excesses of PAMELA/ATIC

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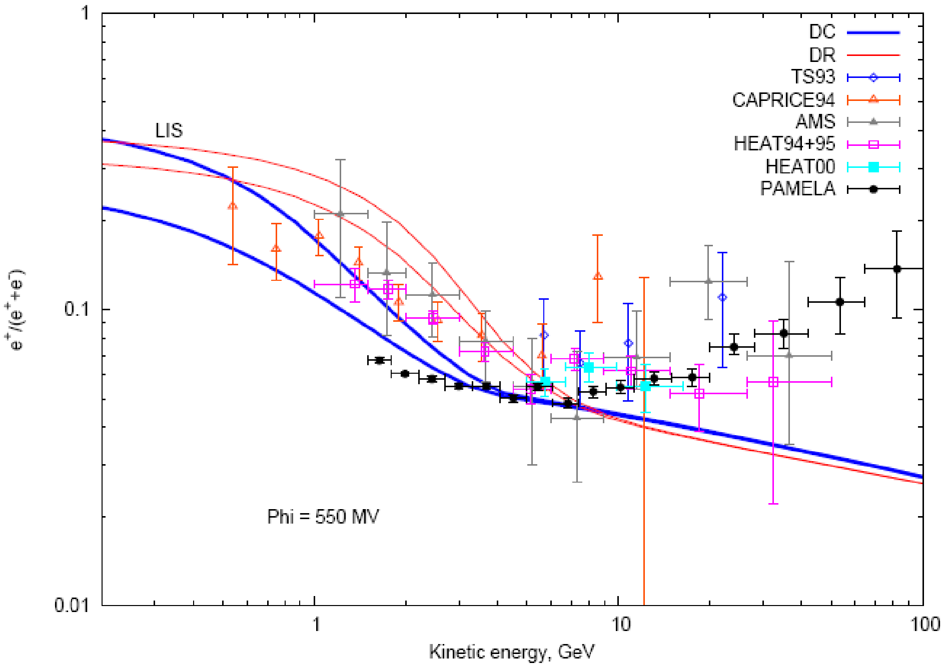
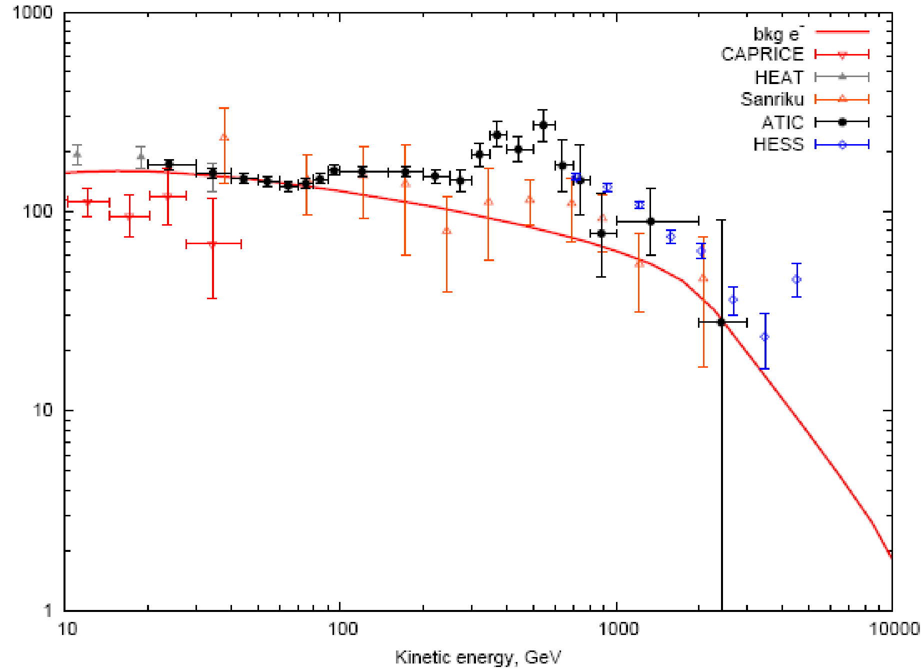
Outline

- Introduction to observational results
- Proposed explanations
- Observational signals to discriminate different models
- A cosmic ray scenario with pair production
- Summary

Observational results





PAMELA, arXiv:0801.4995

ATIC, 2008, Nature, 456, 362
HESS, 2008, PRL, 101, 261104

The excesses of both positrons and electrons imply the sources of e^+e^- pairs. And the non-excess of antiprotons needs no hadronic origin!

Possible origins of e^+e^- pairs in the universe

I. $\gamma+\gamma \to e^+ + e^-$ (pulsar, GRB…)

II. $$p+p \to \begin{cases} \pi^+ + \cdots \to e^+ + \cdots \\ \pi^- + \cdots \to e^- + \cdots \end{cases}$$

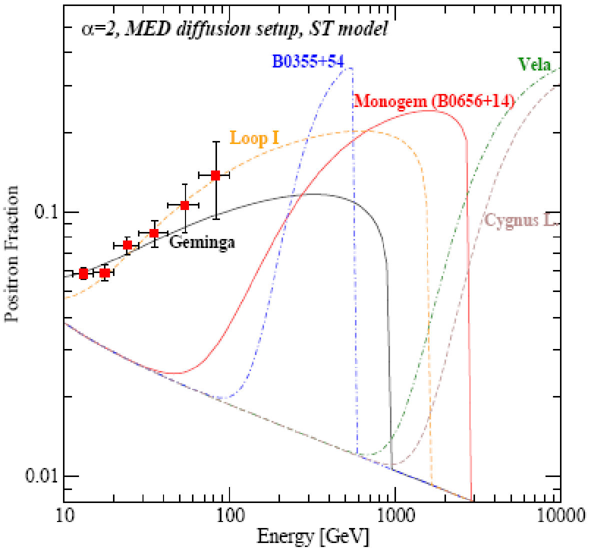
The problem is the accompanied antiproton production

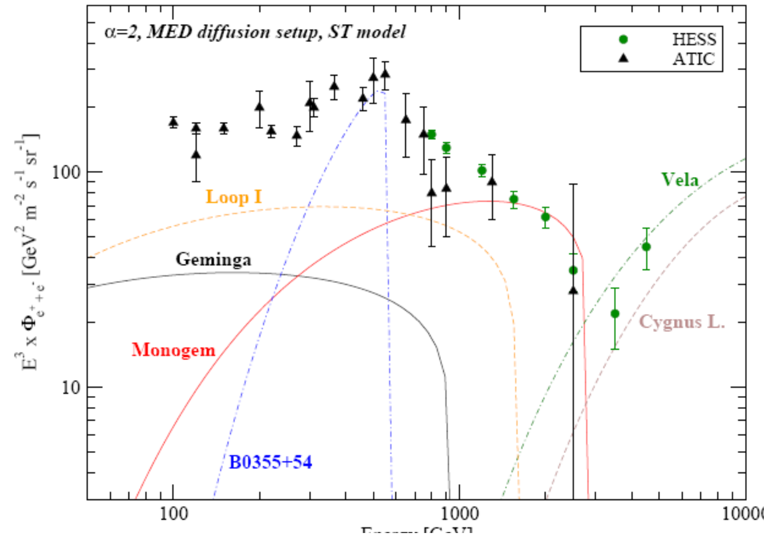
III. dark matter annihilation or decay
The final states should be leptons dominated

IV. $p+\gamma \to p+e^+ + e^-$(occur near cosmic ray sources)

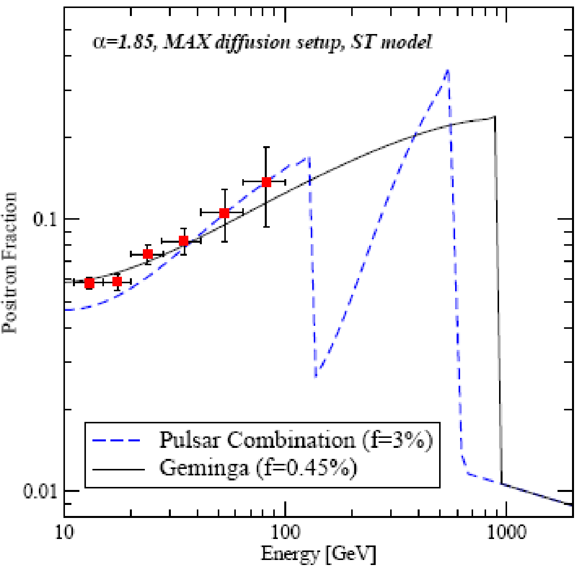
V. …

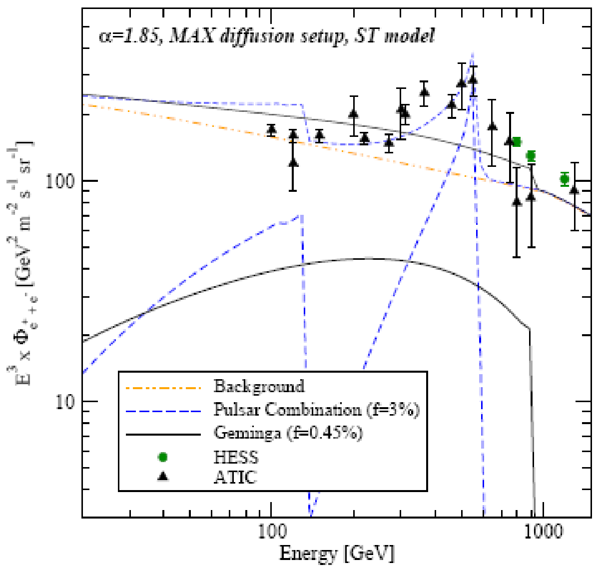
Possible origins of e^+e^- I: pulsar (Profumo, 0812.4457)





For some nearby pulsars

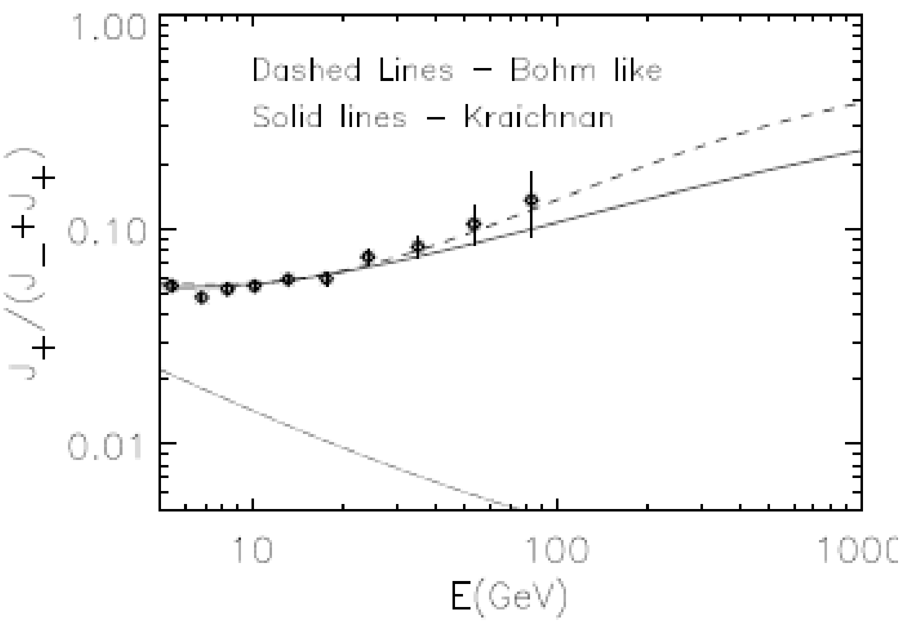


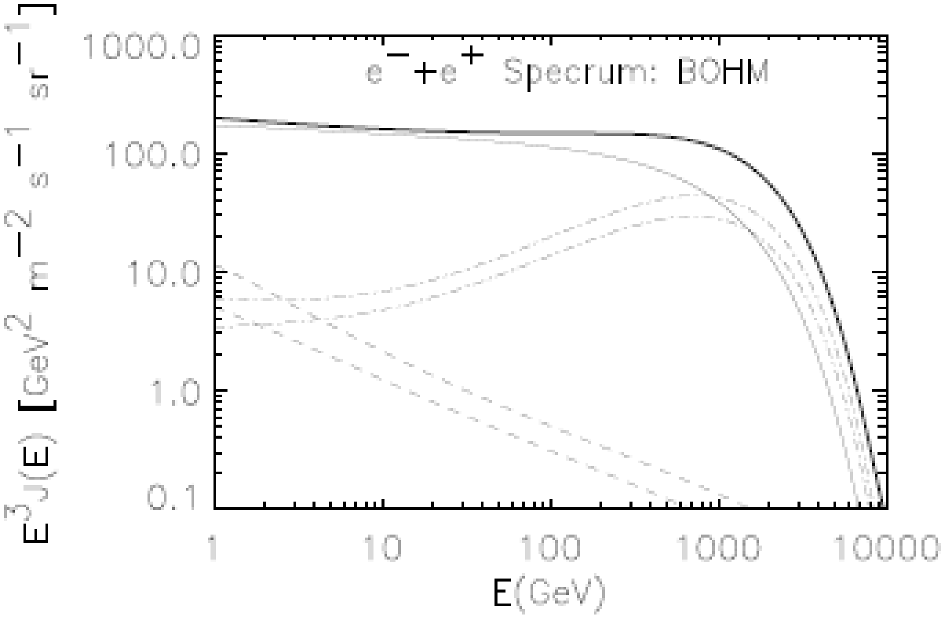


Fit with some other known pulsars with larger distance >0.7 kpc

Possible origins of e^+e^- II: pp interaction (Blasi, 0903.2794)

Occur at the cosmic ray acceleration source: hard spectrum

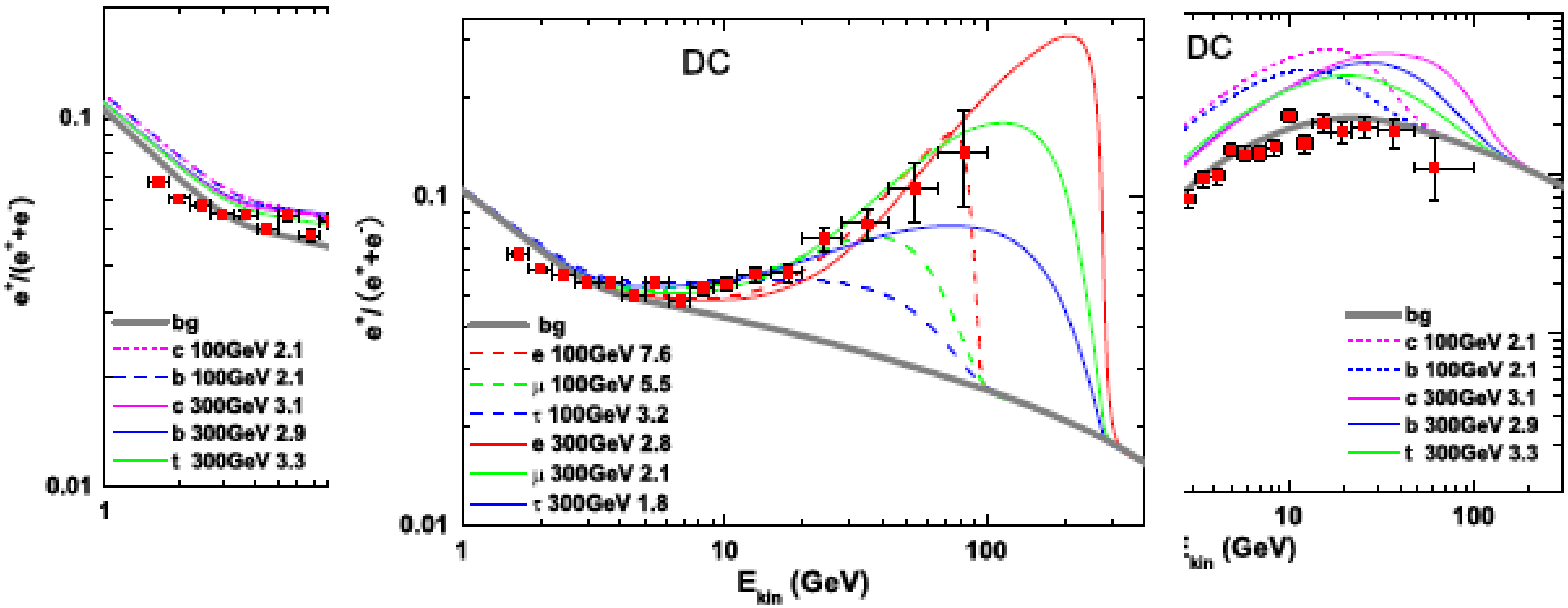




Comment: antiprotons may set constraints on this picture

Possible origins of e^+e^- III: dark matter (a series of papers)

Why to leptons?

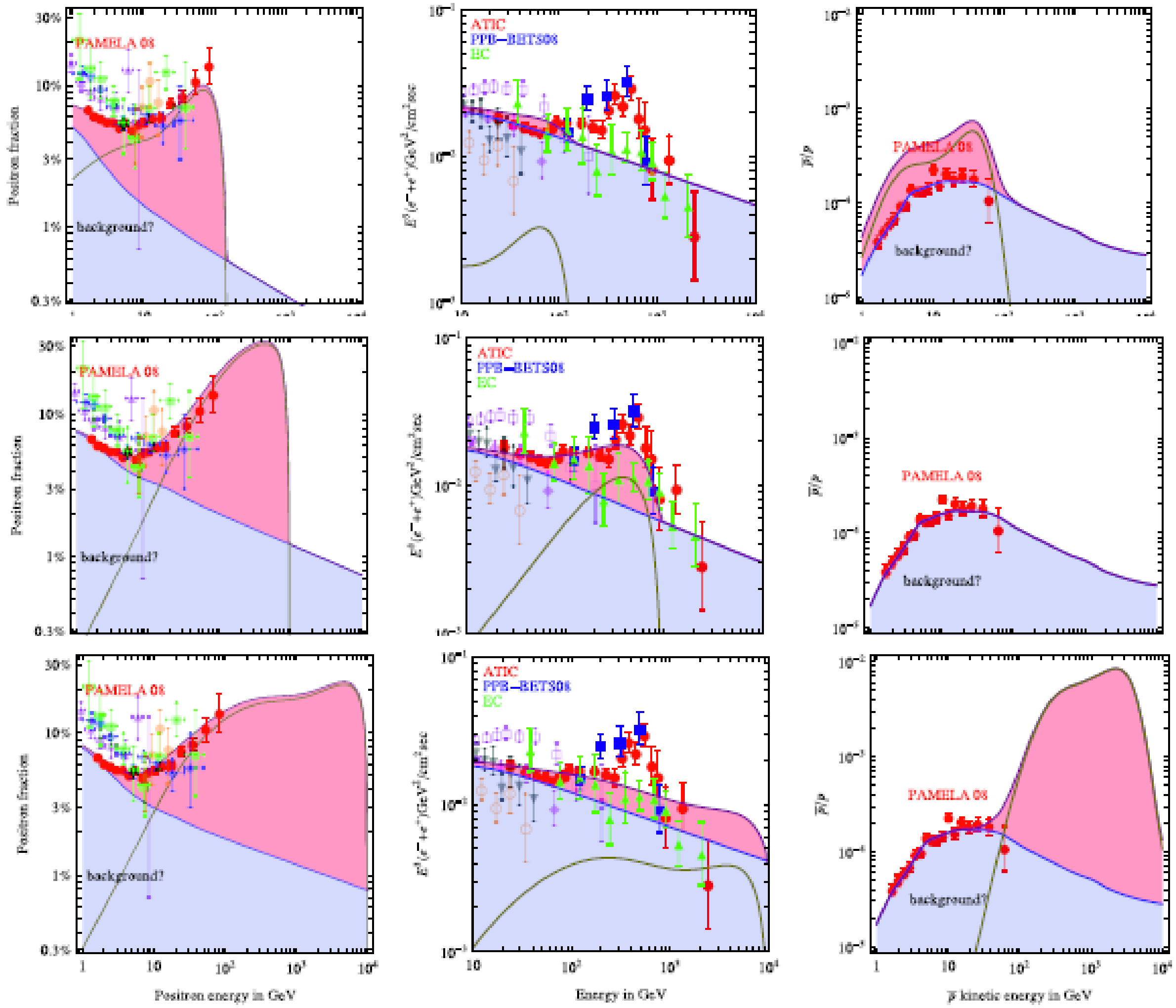


Yin et al., 2009, PRD, 79, 023512

Possible origins of e^+e^- III: dark matter (continued)

Heavy dark matter particle can survive the antiproton constraint, however, is not consistent with ATIC.

Cirelli et al., 2009, NPB, 813, 1

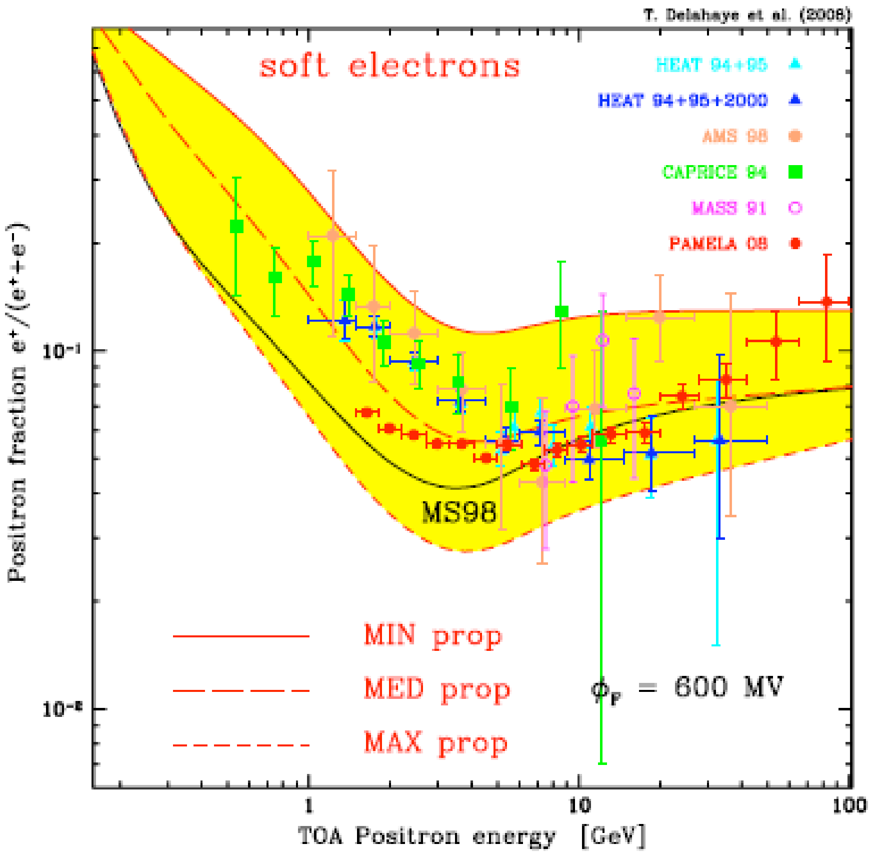


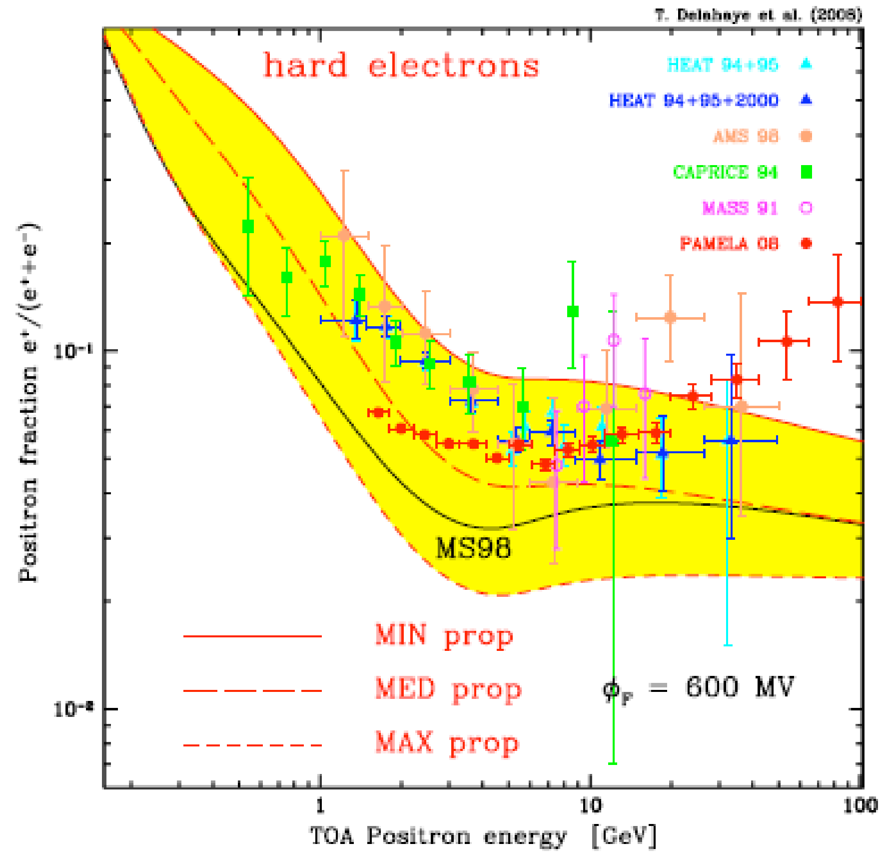
M=150 GeV, W^+W^-

M=1 TeV, $\mu^+\mu^-$

M=10 TeV, W^+W^-

Another idea: PAMELA result might not be really an excess but due to the uncertainty of background estimate



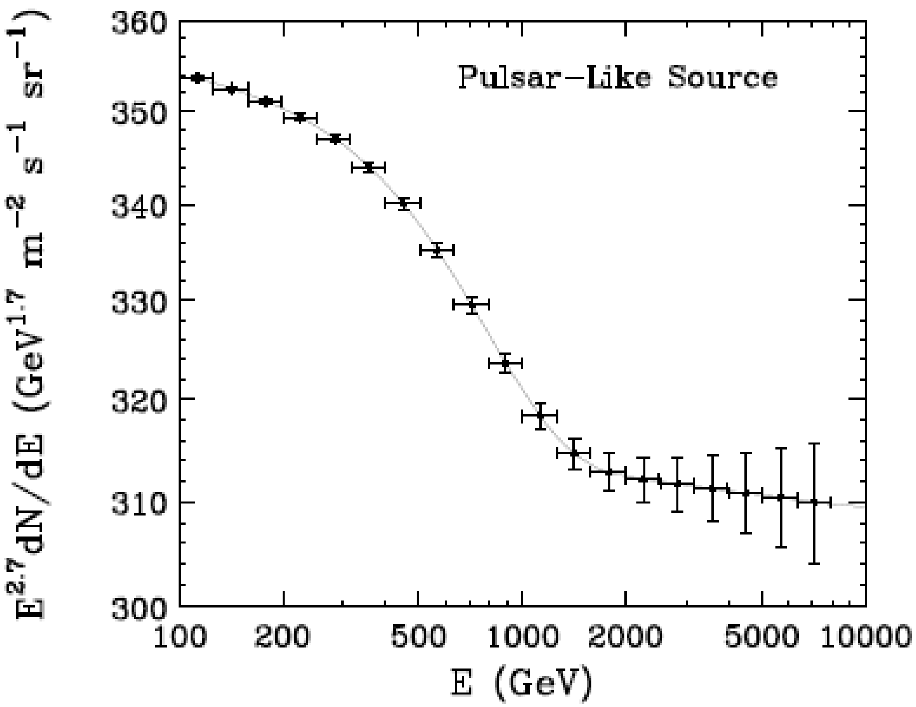


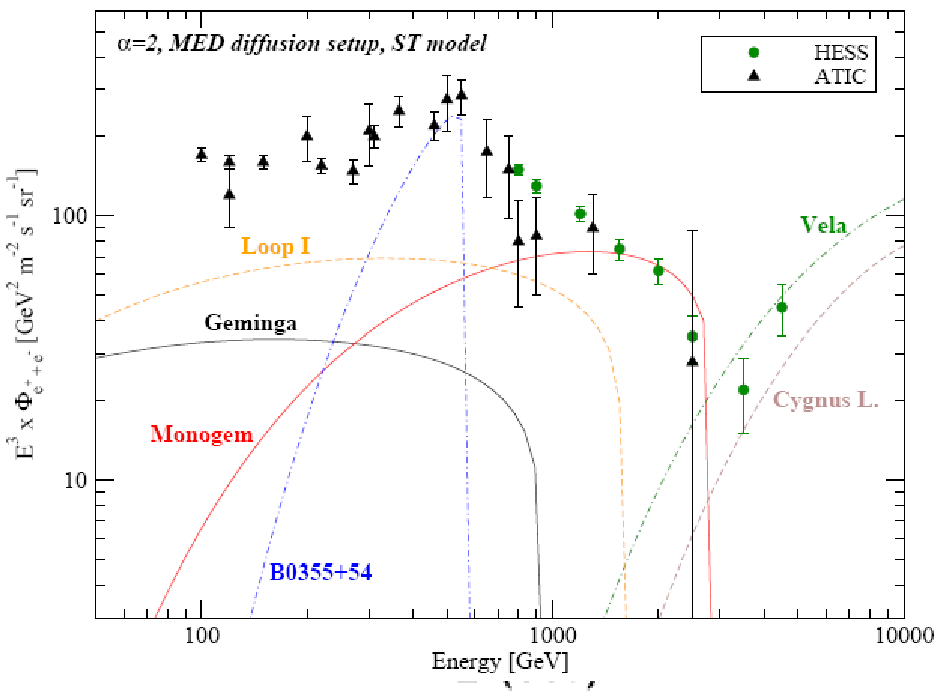
But cannot explain ATIC result

Delahaye et al., 0809.5268

Discrimination I. precise spectrum measurement of e^+e^-

Dark matter vs. pulsar: sharp drop or not? (Hall & Hooper, 0811.3362)

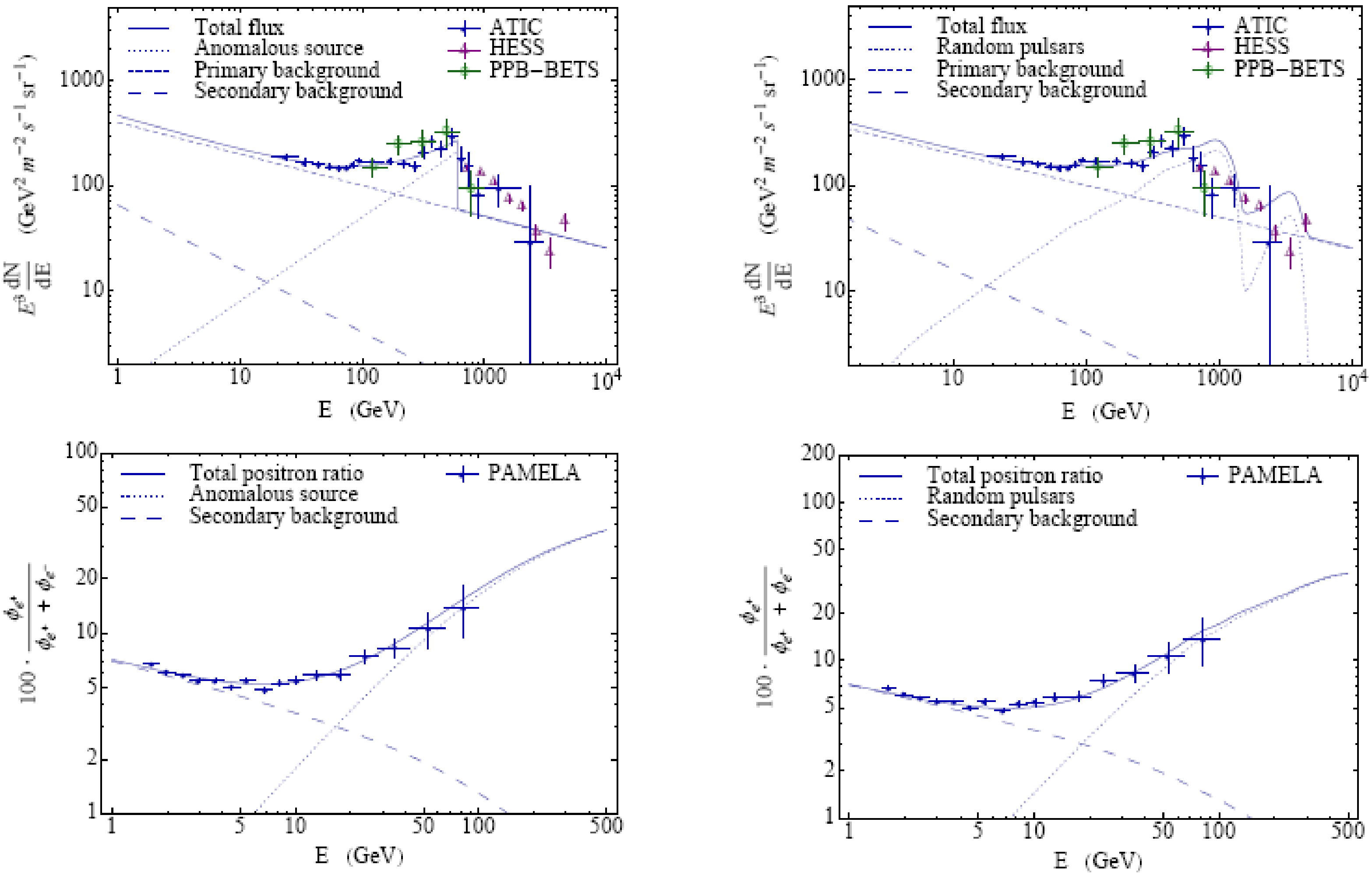




However, pulsars can also result in sharp cut in some cases (Profumo, 0812.4457)

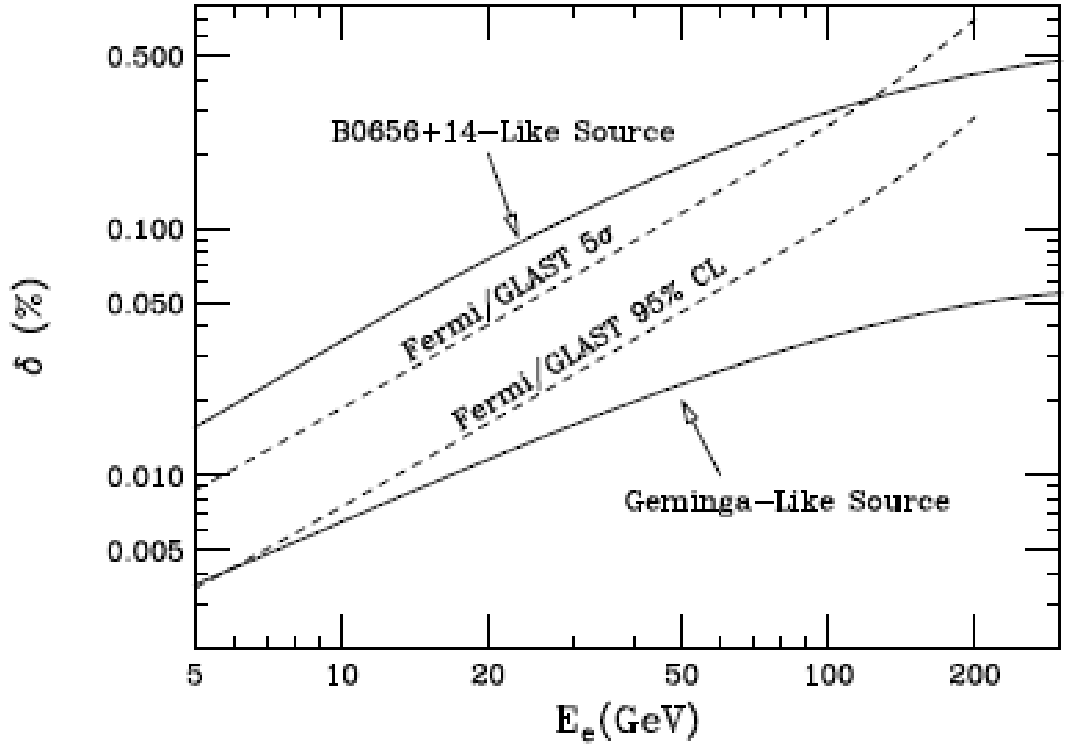
Discrimination I. precise electron spectrum (continued)

Dark matter vs. pulsar: fluctuations on the spectrum? (Malyshev et al., 0903.1310)



Discrimination II. anisotropy of electron flux

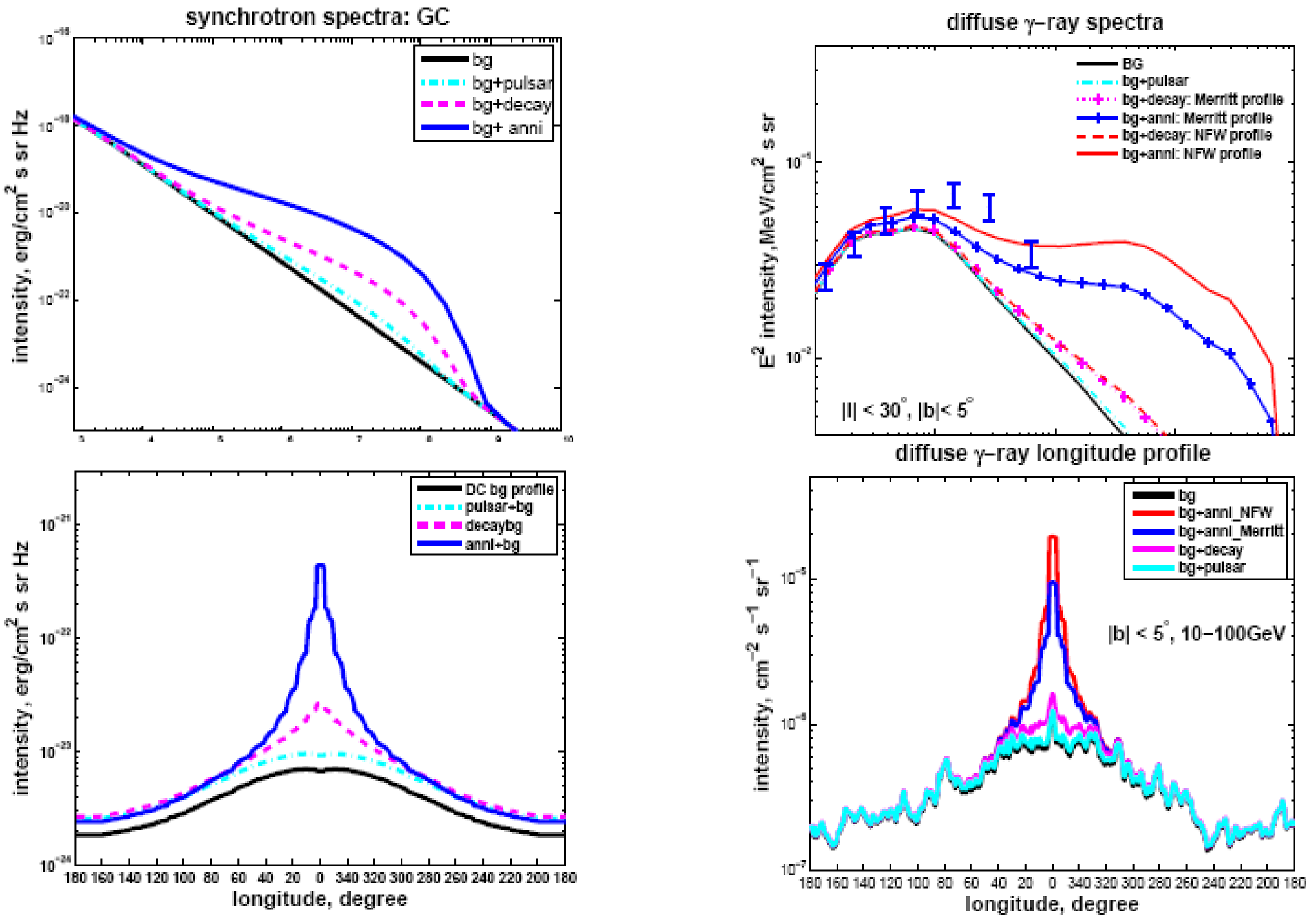
Diffuse vs. point (Hooper et al., 2009, JCAP, 01, 025)



A local dark matter clump may also behave like this.

Discrimination III. associated photon emission

Dark matter vs. pulsars: synchrotron and IC from e^+e^- (Zhang et al., 0812.0522)



Depend on extrapolation of source distributions and suffer astrophysical uncertainties

Our proposal: pair production of photon-nuclei interaction

- There might be strong background radiation field around the acceleration source of cosmic rays, e.g. soon after the explosion of supernova, and the interaction between nuclei is inevitable.

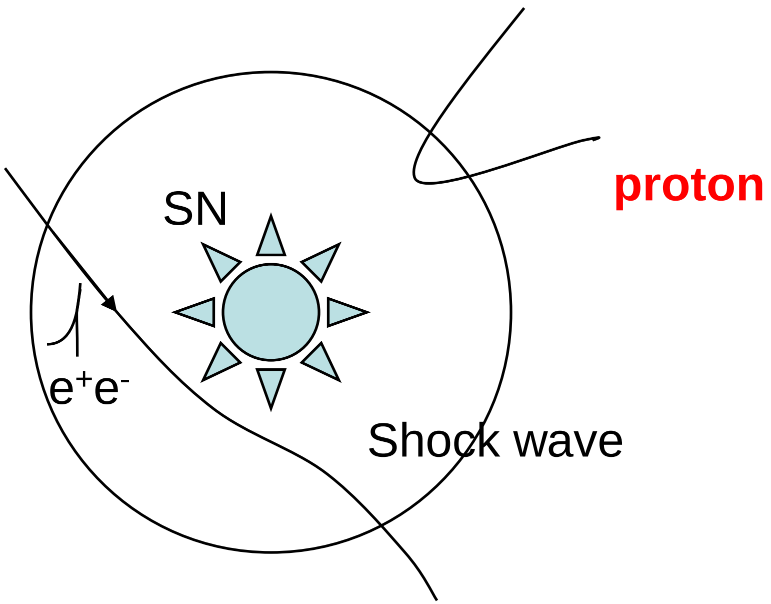
- The threshold of pair production is $(\text{MeV})^2$, for optical background photon(1eV), the energy of responsible cosmic ray is ~1PeV, just around the "knee" region, and the energy of produced e^+e^- is about TeV !

- The energy density of ATIC excess electrons is 3e-5 eV cm^{-3}, just of the same order of cosmic ray loss energy assuming spectrum changes from -2.7 to -3.1 at ~1PeV.

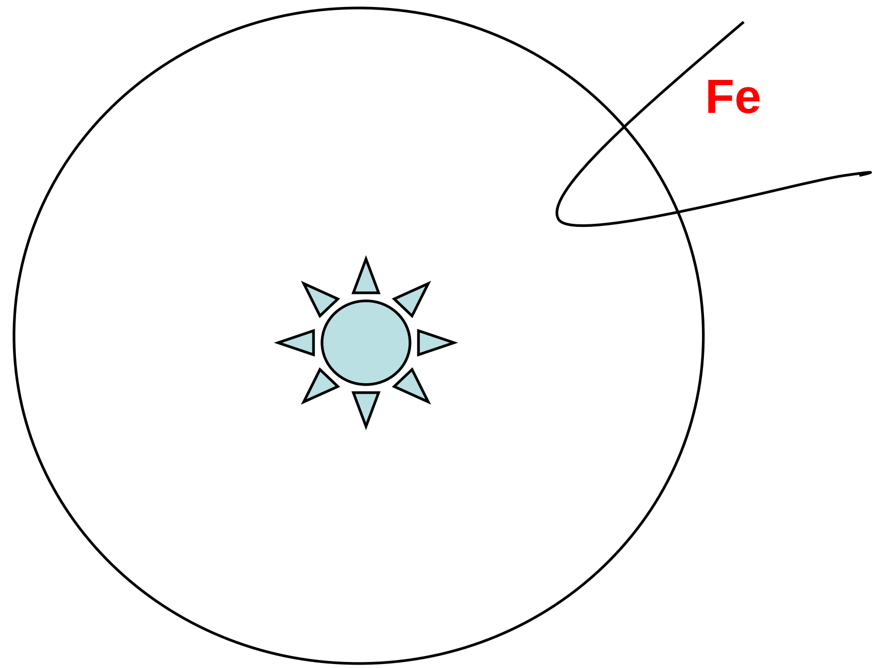
Thus we bridge the knee of cosmic rays and excesses of e^+e^-.

Accelerating and interaction scheme

1) At early time when CR's energy is low, the number density of background light is high, also the photon temperature might be high.



2) At later time, when CR energy is higher, the photon density and temperature maybe low.

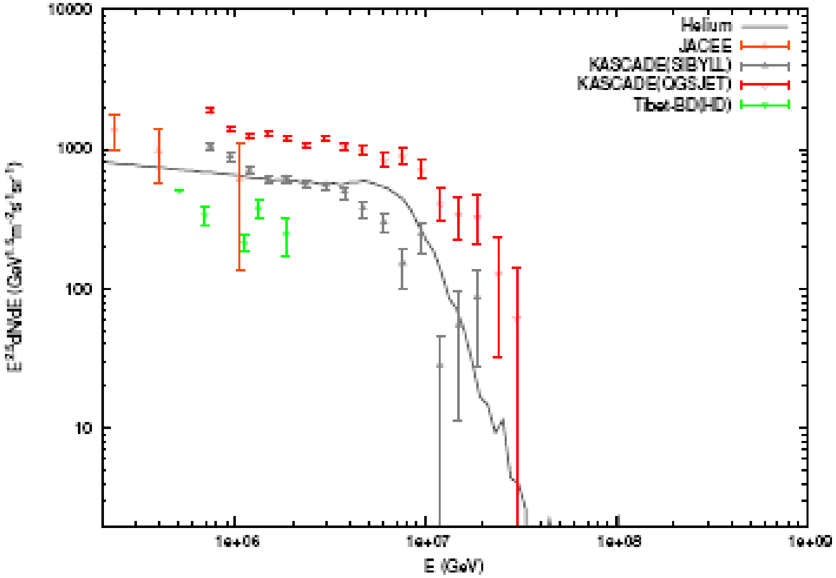


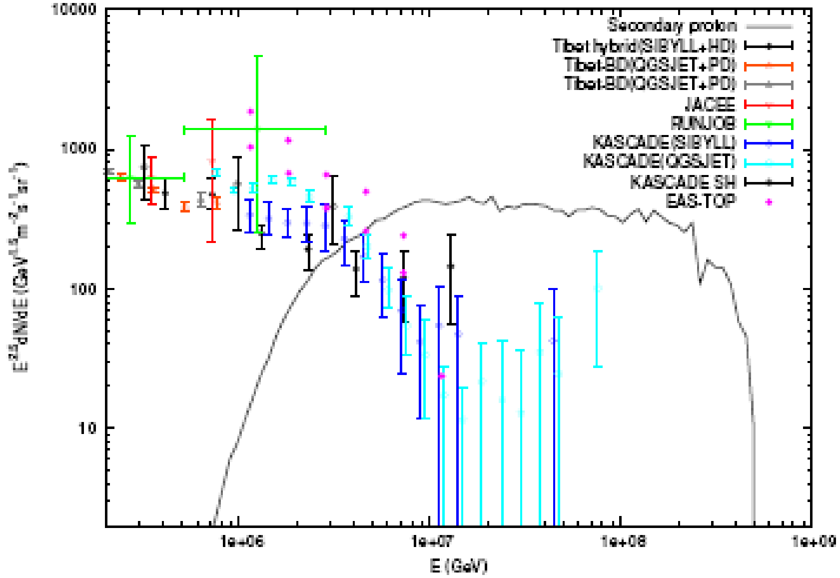
3) Background light maybe fill the SNR or mainly a point like source. When filled, electron interact with it as well. Only when it is not so much filled, the e^+e^- pair are observable.

There should be three types of photon-nuclei interactions:

pair production, photodisintegration and pion production

If photodisintegration is included, protons will be over produced

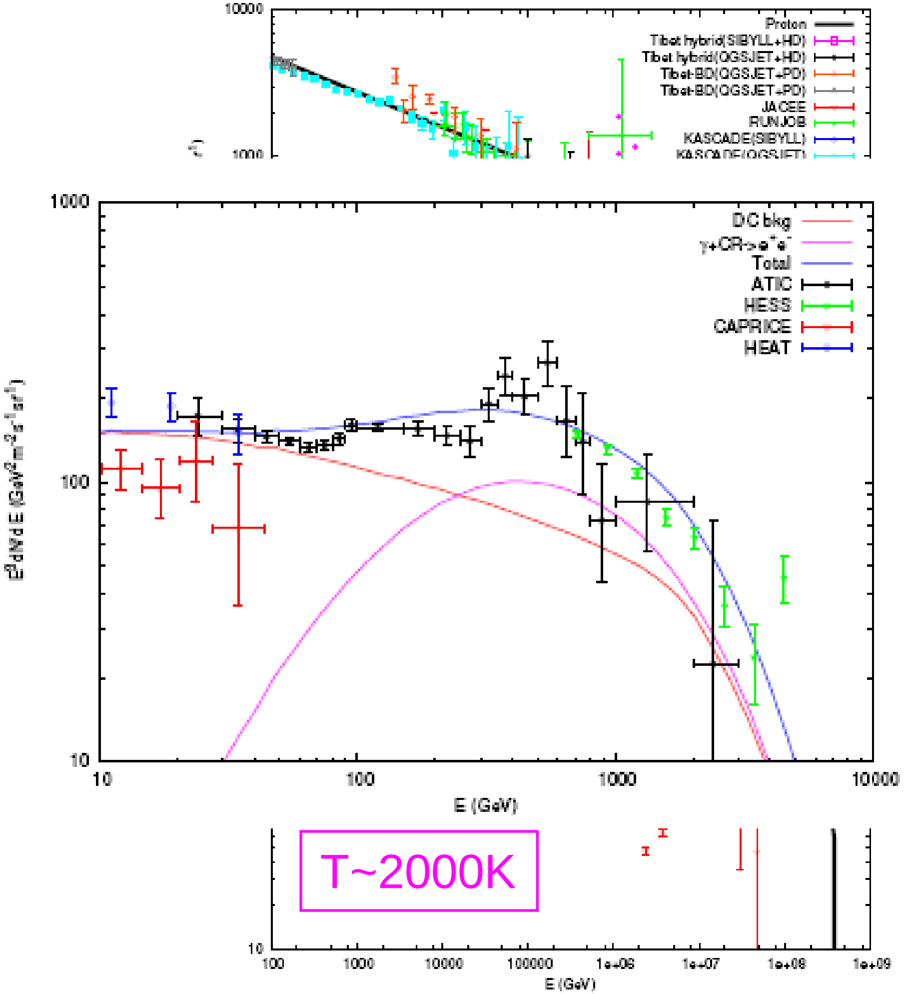


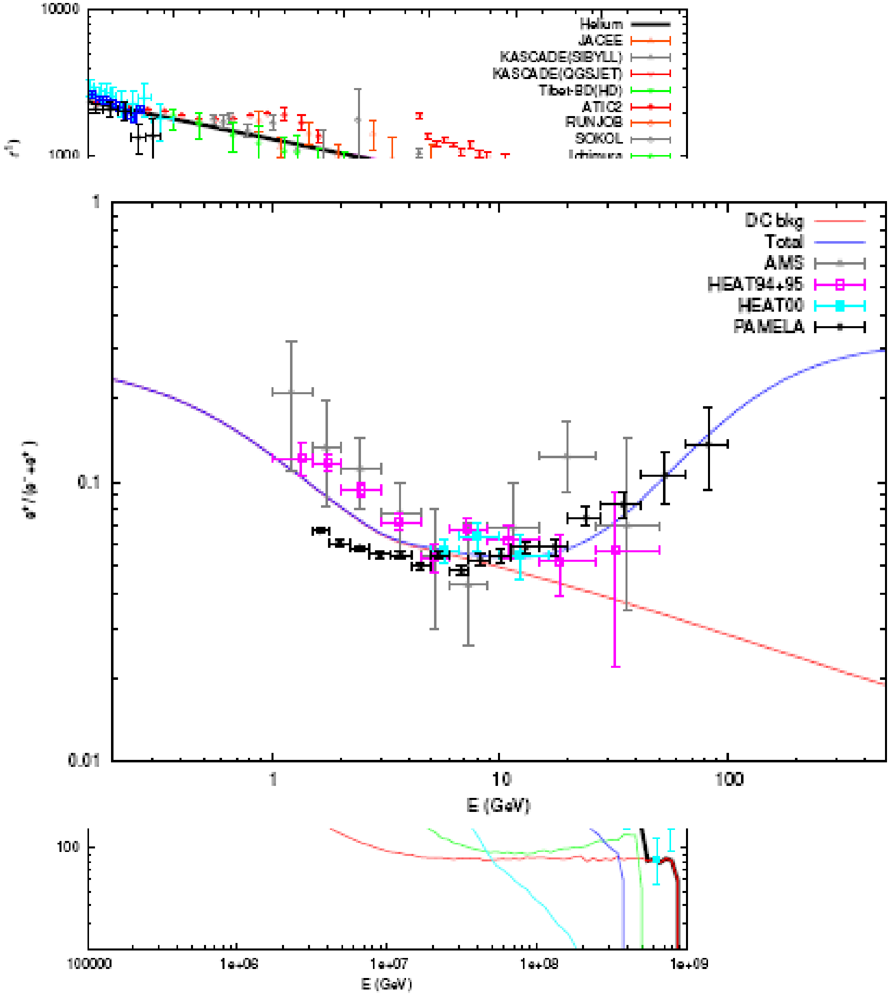


Some mechanism is needed to avoid the photodisintegration and pion production. For a time-evolution picture, it can be realized because the thresholds for the two interactions are higher while photon intensity becomes lower as time evolution.

Only the pair production is adopted

Hu et al., 0901.1520





Summary

- Recent measurements of anomaly signals in cosmic ray e+e- are big challenges on the understanding of cosmic ray physics.

- Many models are proposed to explain the observations, including the well known astrophysical sources like pulsars, the interactions between cosmic rays and photons, and new exotic sources like dark matter.

- Each of the present models seems to be able to give fairly good fit to the current data. However, useful implications on model parameters can be derived.

- New experimental results are extremely important in understanding the fundamental underlying problems.

The End

Thank You