

Dark Matter Indirect Searches, multi-wavelength and multi-messenger data

Cosmic rays

Fiorenza Donato
Torino University and INFN

Fermi Open Day
Torino, 04.09.2015

Cosmic rays at galactic energies:

a breakthrough in observations,

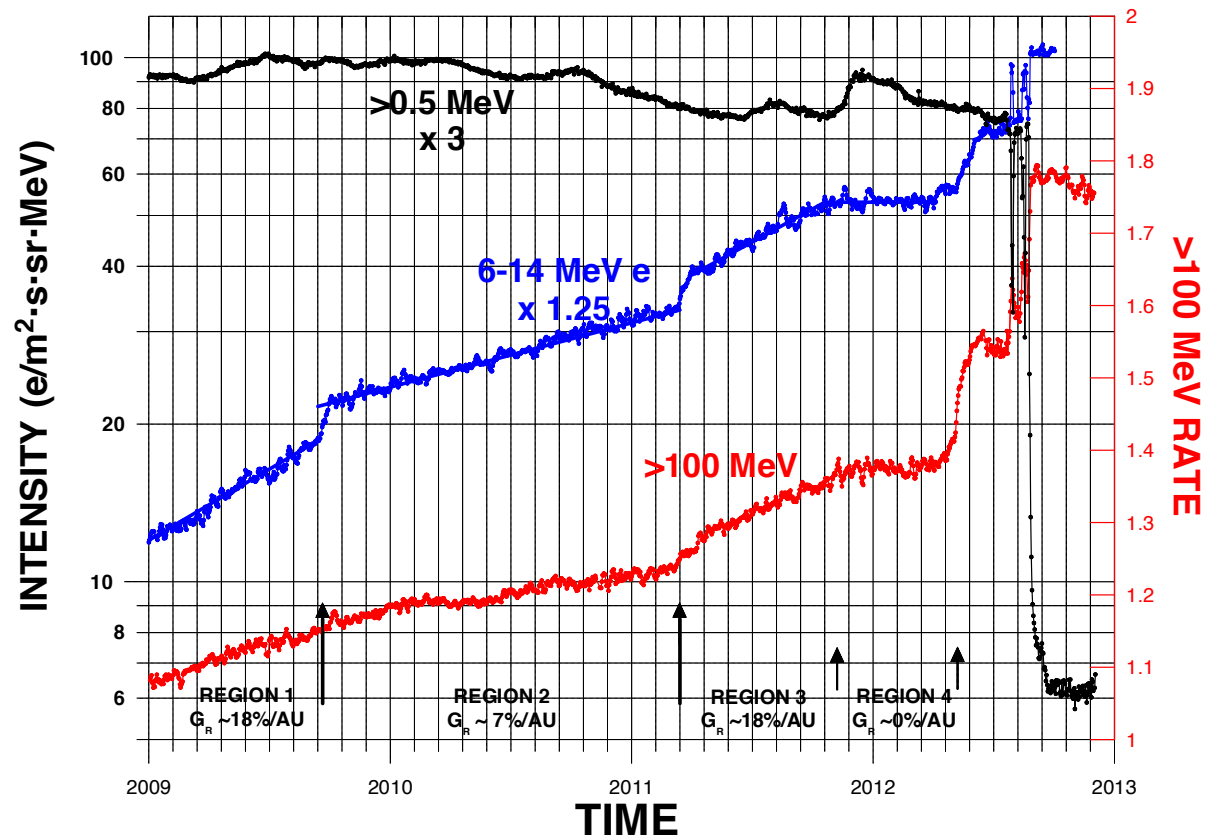
a demanding effort for phenomenology

Here, very few remarks out of many open problems, ideas, strategies ...

AT VOYAGER 1 STARTING ON ABOUT AUGUST 25, 2012 AT A DISTANCE OF 121.7 AU FROM THE SUN, A SUDDEN SUSTAINED DISAPPEARANCE OF ANOMALOUS COSMIC RAYS AND AN UNUSUALLY LARGE SUDDEN SUSTAINED INCREASE OF GALACTIC COSMIC RAY H AND HE NUCLEI AND ELECTRONS OCCURRED

arxiv:1212.0883

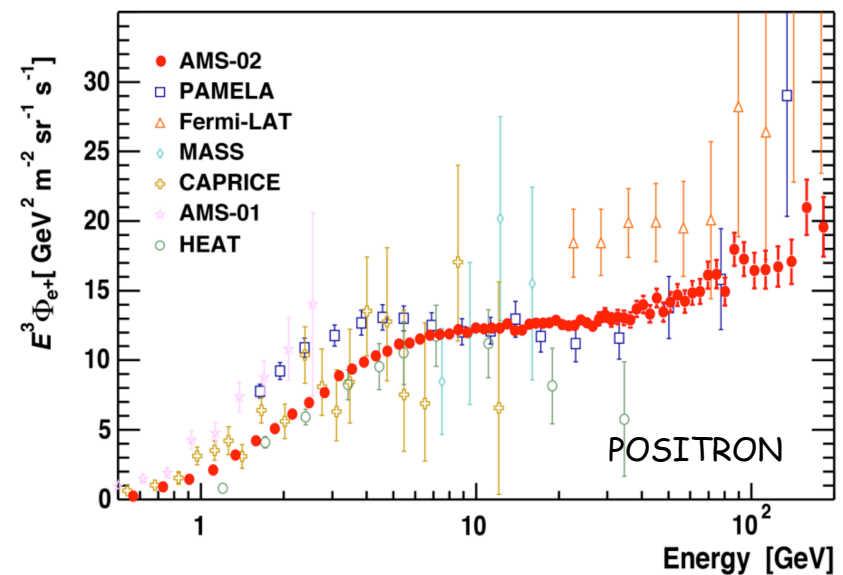
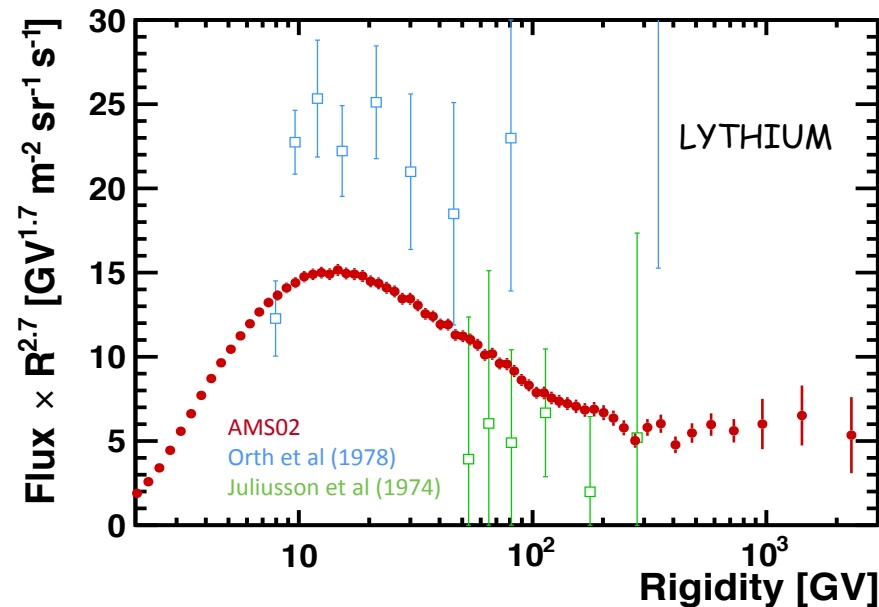
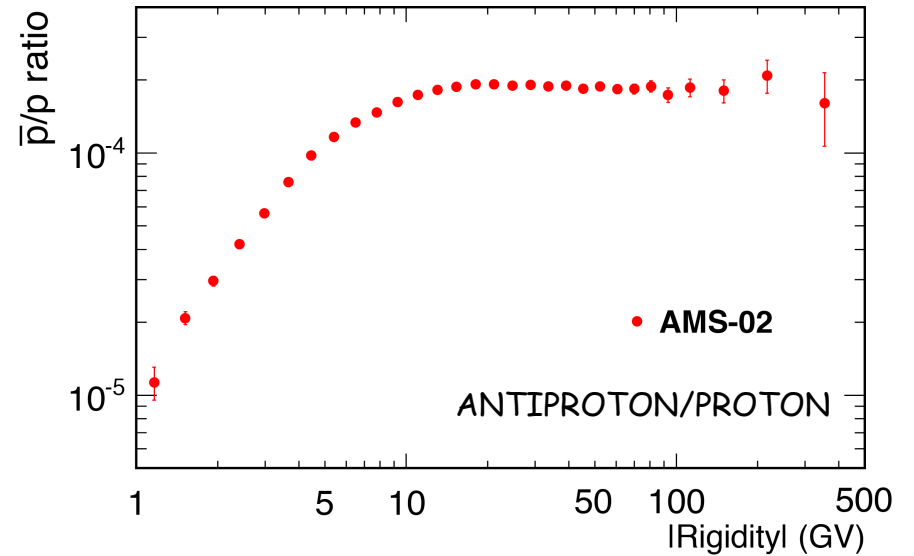
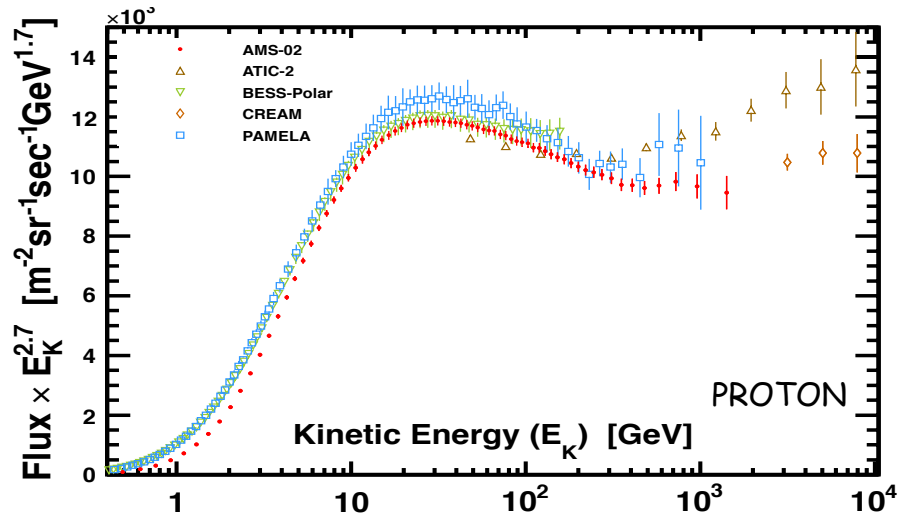
W.R. Webber¹, F.B. McDonald²⁺, A.C. Cummings³, E.C. Stone³,
B. Heikkila⁵ and N. Lal⁵



The Voyager probe is sending data from the true INTERSTELLAR SPACE!!
Now many decades in energy are covered by data

AMS-02 Data (some are preliminary)

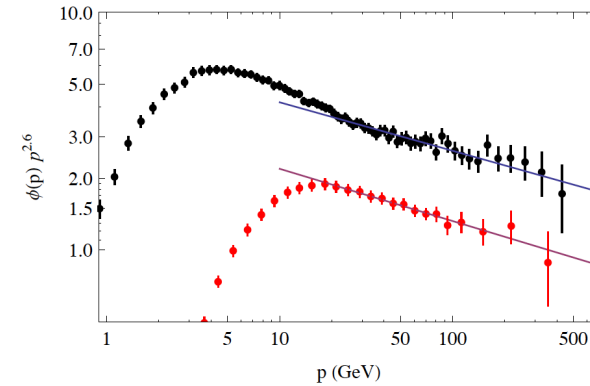
AMS \bar{p}/p results



From P. LIPARI, pHe workshop, 07/2015

$$\phi_j(E) = K_j E^{-\alpha}$$

$$E > 20 \text{ GeV}$$



$$\chi_{\min}^2 = 1.70 \quad (15\text{d.o.f.})$$

$$\alpha \simeq 2.82 \pm 0.02$$

\bar{p}

$$\chi_{\min}^2 = 18.21 \quad (37\text{d.o.f.})$$

$$\alpha \simeq 2.80 \pm 0.01$$

e^+

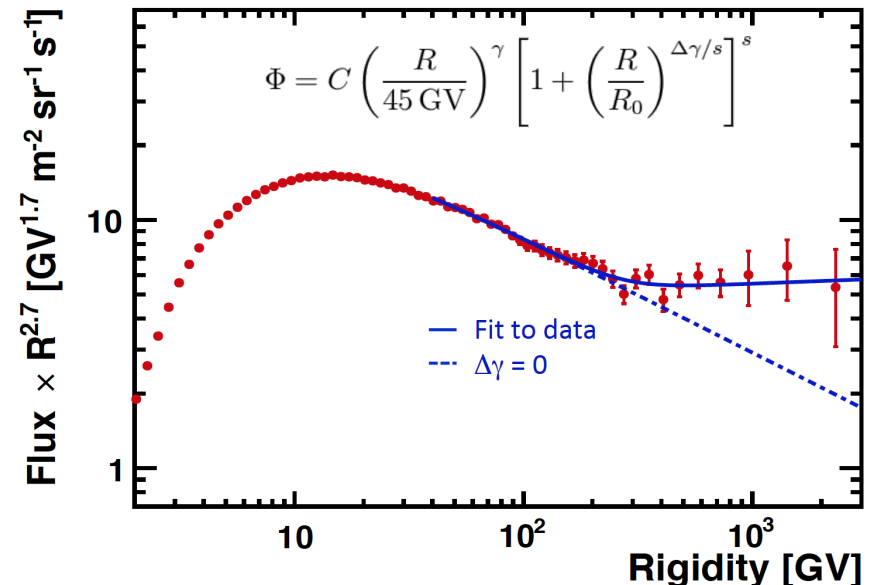
In the “Conventional Model”
the similarity of the positron and anti-proton fluxes
is simply a *coincidence*.

From P. LIPARI, pHe workshop, 07/2015

The propagation of electrons/positrons
and protons/anti-protons/nuclei
is considered as very different

Fit of Lithium flux

Same model as the one used for proton and helium (double power law
with smooth transition) between 45 GV and 3 TV:

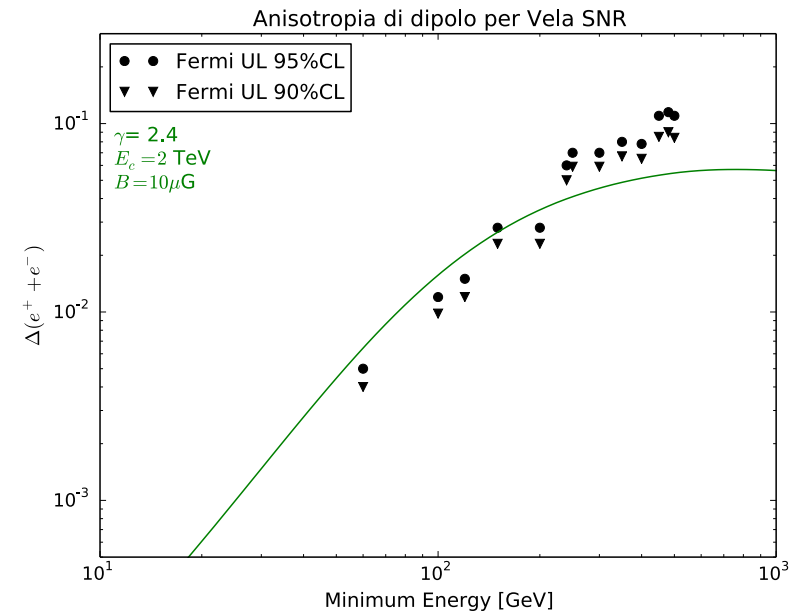
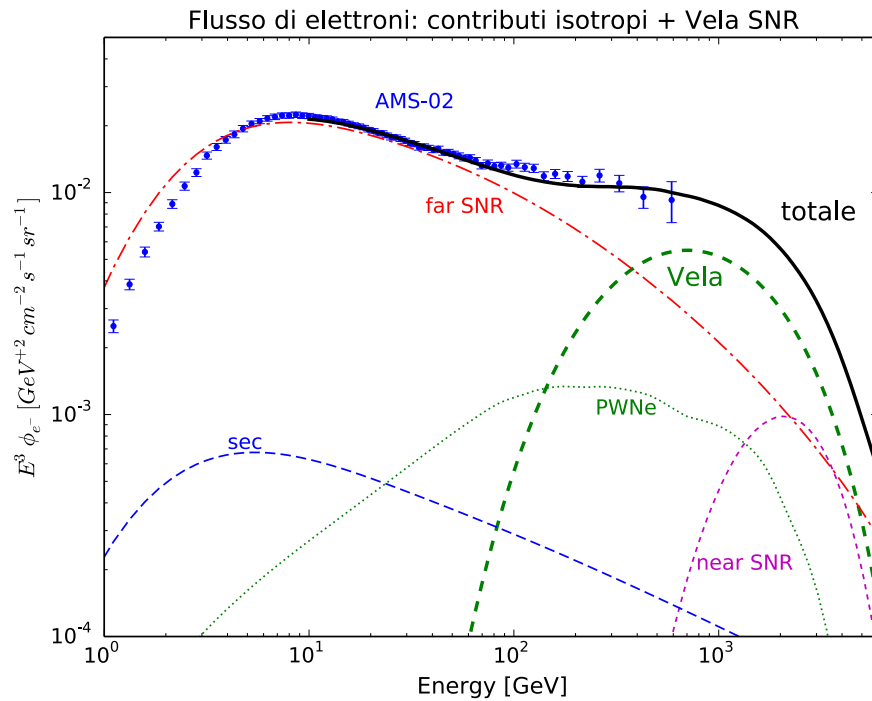


→ Change of slope at the same range than for the one found for
Proton and Helium.

Is this all a coincidence?
Probably yes, but then
The physics is in the details

About sources - electrons

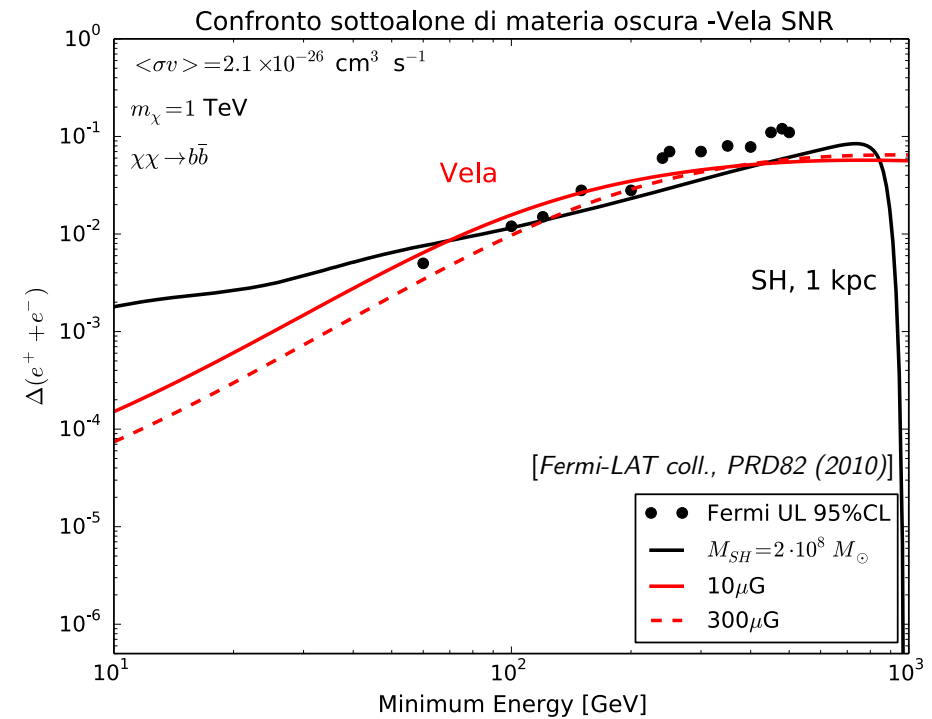
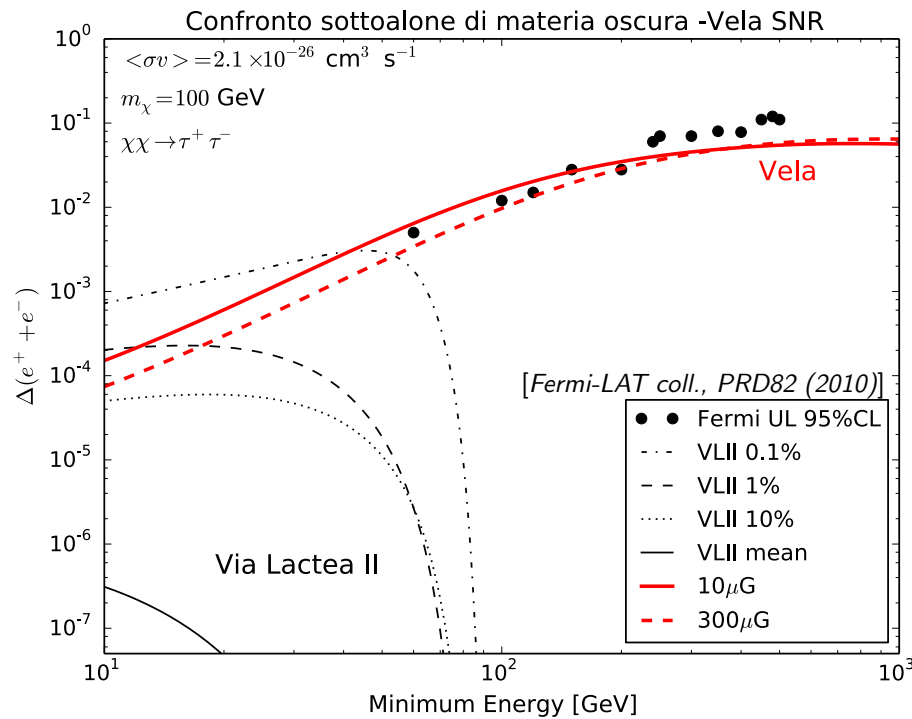
Silvia Manconi, master thesis, 2015



Vela SNR can explain electron high energy data (Di Mauro+2014)
The source gives a sizeable anisotropy in e^+e^-

About sources: adding Dark Matter annihilation Anisotropies in the electrons

Silvia Manconi, master thesis, 2015



Vela SNR and 1 Dark Matter sub-halo

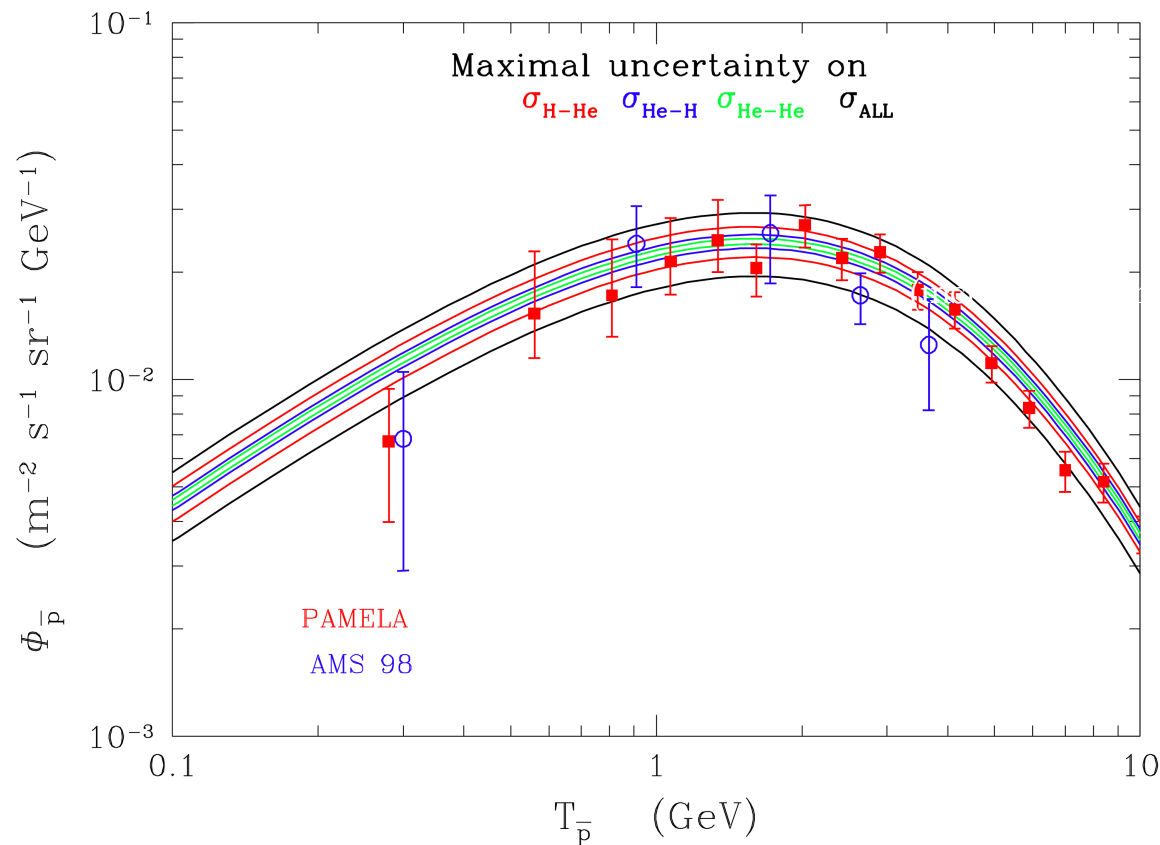
For positrons: we do not have data for e^+ anisotropy

About sources - secondary antiprotons

A case for cross sections

Uncertainties on the antiproton flux from nuclear cross sections

(Donato+ ApJ 2001, PRL 2009)

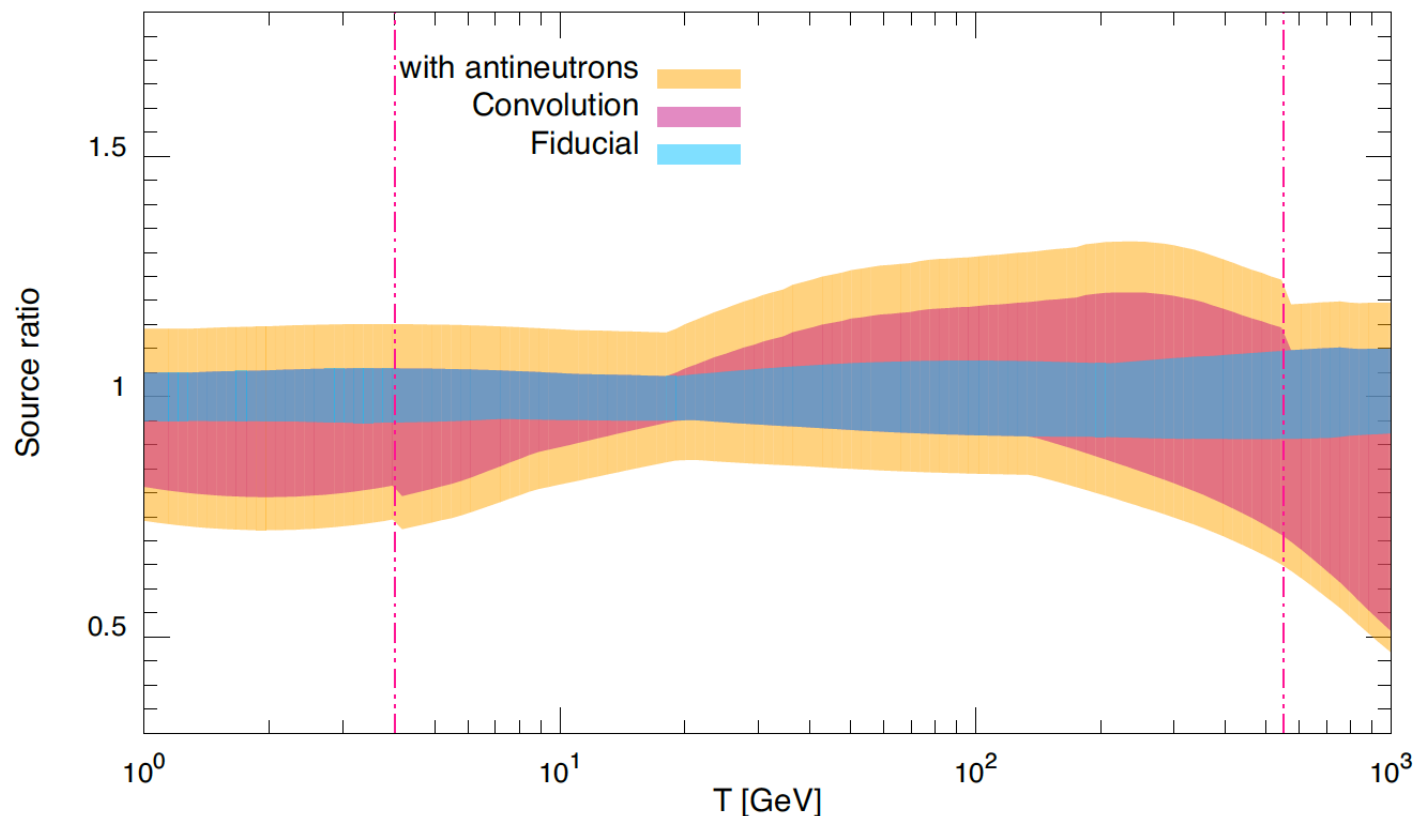


- pp: Tan& Ng
- H-He, He-H, He-He: DTUNUC MC
- Functional form for the cross section derived from other reactions, given **NO DATA!!**

Maximal uncertainty from p-He cross sections: 20-25%!

Data from AMS-02 on cosmic antiprotons are at ~ 10% accuracy

Uncertainties due p-p scattering



Uncertainties in the $p\bar{p}$ production spectrum from p-p scattering are at least 10%.

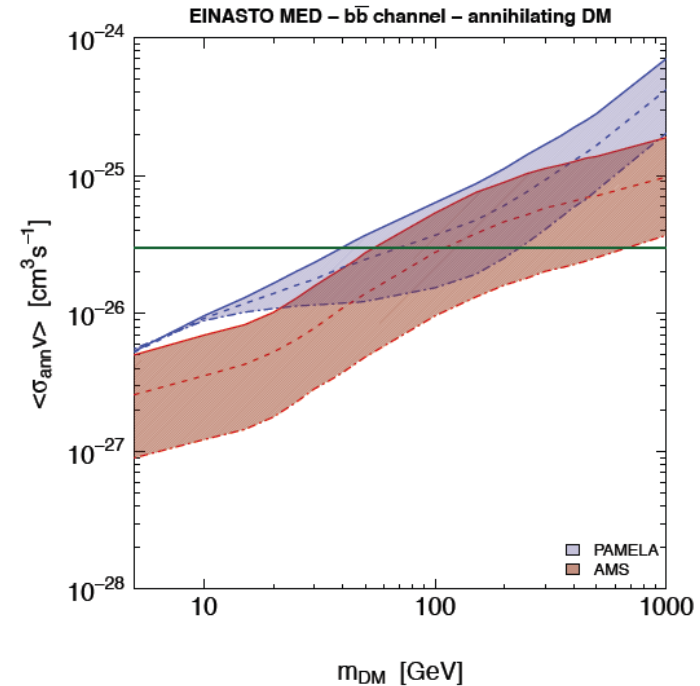
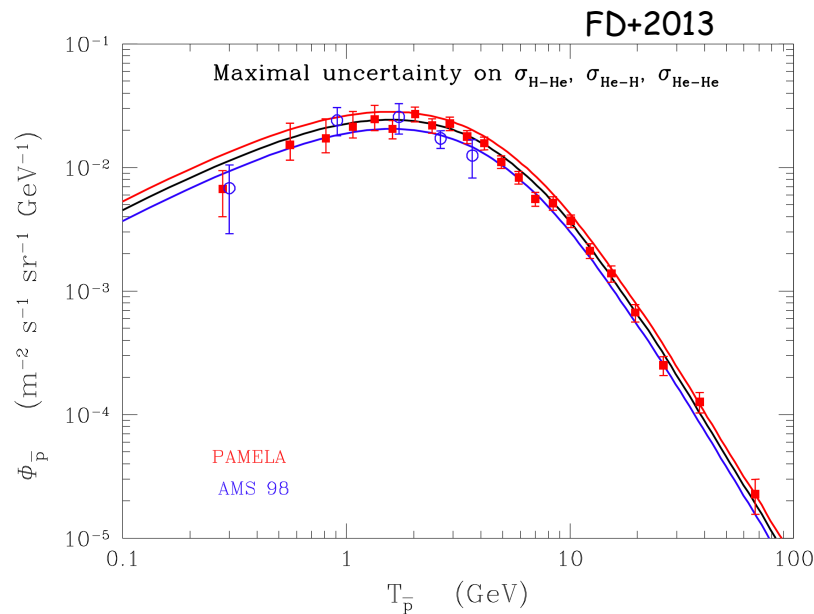
Conservative: 20% at low energies (GeV) up to 50% (TeV)
(data expected at least up to ~ 500 GeV)

Reactions involving helium & higher energies

Uncertainties due to helium reactions range 40-50% on Secondary CR flux

Effect of cross section uncertainty on DARK MATTER interpretation

Fornengo, Maccione, Vittino JCAP2014



AMS-02 is providing data with much higher precision up to hundreds of GeV!!!
Their interpretation risks to be seriously limited by nuclear physics

Final (or starting!) observations - I

- **Voyager** is taking data in the interstellar space!! Now, models should include them and work out effects down to **$O(10)\text{MeV}$**
- **AMS** is providing high precision data, not easy to arrange them in one simple model
- High precision CR data imply **refined models** for: the sources, the propagation, the evolution of the Galaxy with time
- Physics and astrophysics of the **sources** will take a prominent role in the models: astrophysical sources (primary & secondary CRs); production through particle scatterings (secondaries in the sources, in the ISM)
→ **astronomy** with charged CRs?1

Final (or starting!) observations - II

- The data are such that **charged CRs and photons** can be studied in the same physics context.
Multi-species and multi-wavelength approach
- Does it still make to speak of *standard CR models* and *standard codes*?
- The nuclear processes from the highest nuclei to light antimatter (total inelastic, production, branching ratios, inelastic non-annihilating, nuclear fusion, ...) are modeled according to LAB experiments and many cross sections are NOT measured at all, or data are largely insufficient
- The lack of data on several lab **cross sections** puts serious limits in the interpretation of forthcoming cosmic ray data:
i.e.: Cosmic antiproton data are expected with few% errors, while nuclear physics may bring uncertainties ~ 50%

→ A HUGE LAB EXPERIMENTAL PROGRAM IS NEEDED