Interpretation of the Cosmic Ray Positron and Antiproton Fluxes

10 years ago PAMELA presented evidence for the "Positron Anomaly"
what do we understand now ?

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Astrophysics + MAGIC

La Palma 27th june 2018

Measurements of
at the Earth:

Cosmic Rays

$$\phi_p(E,\Omega)\ ,\quad \phi_{\rm He}(E,\Omega)\ ,\quad \ldots\ ,\ \phi_{\{\rm A,Z\}}(E,\Omega)$$

protons+ nuclei

$$\phi_{e^-}(E,\Omega)$$

electrons

$$\phi_{e^+}(E,\Omega)$$

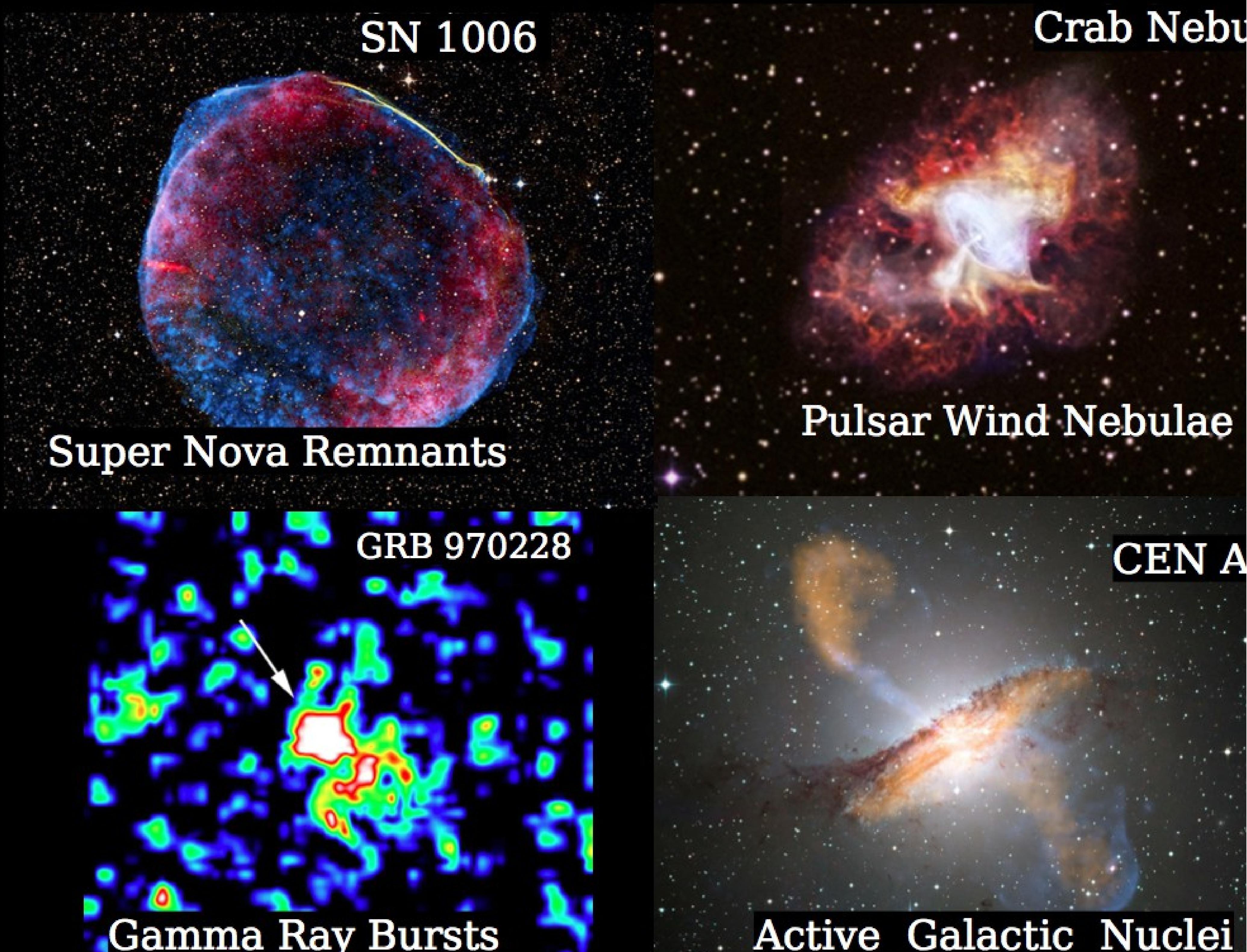
$$\phi_{\overline{p}}(E,\Omega)$$

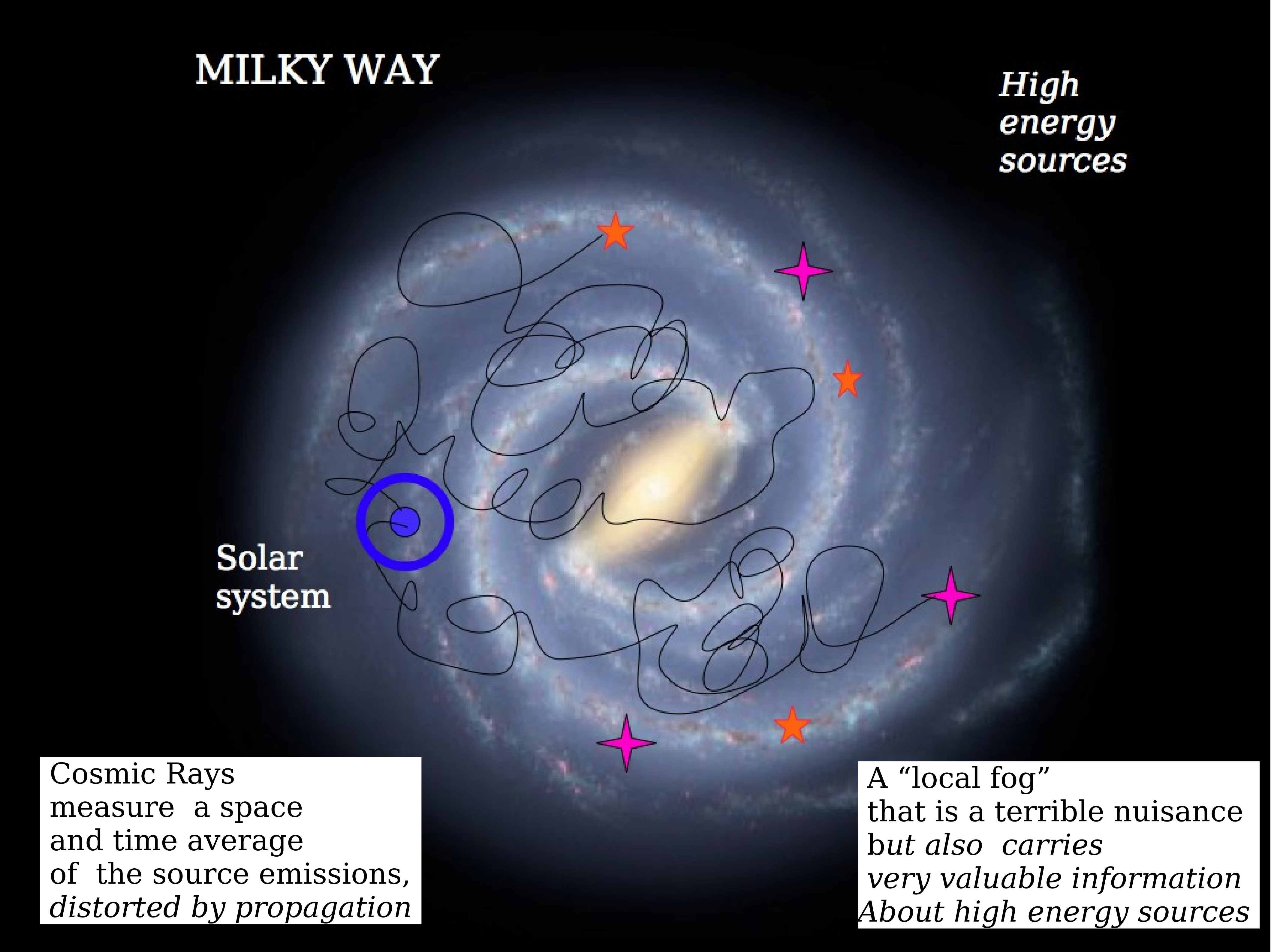
anti-particles

We are leaving a *“Golden Age”* for High Energy Astrophysics

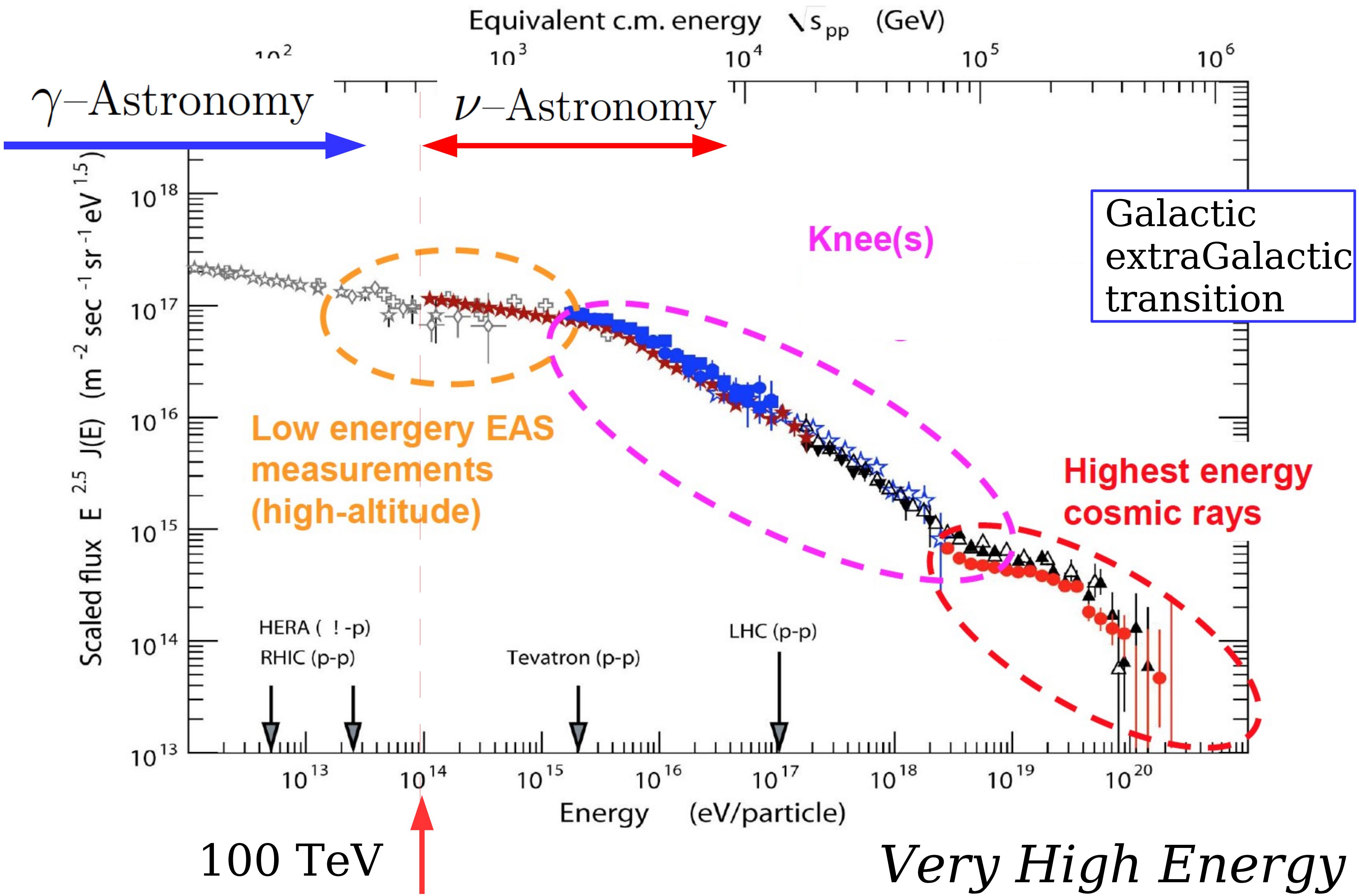
…. and I'm very glad to finally visit one the “fundamental sites” that generated this ongoing revolution

New extraordinary astrophysical “beasts” are discovered


SN 1006
Super Nova Remnants
Crab Nebu
Pulsar Wind Nebulae
GRB 970228
Gamma Ray Bursts
CEN A
Active Galactic Nuclei


MILKY WAY
High energy sources
Solar system
Cosmic Rays measure a space and time average of the source emissions, *distorted by propagation*
A “local fog” that is a terrible nuisance but *also carries very valuable information About high energy sources*

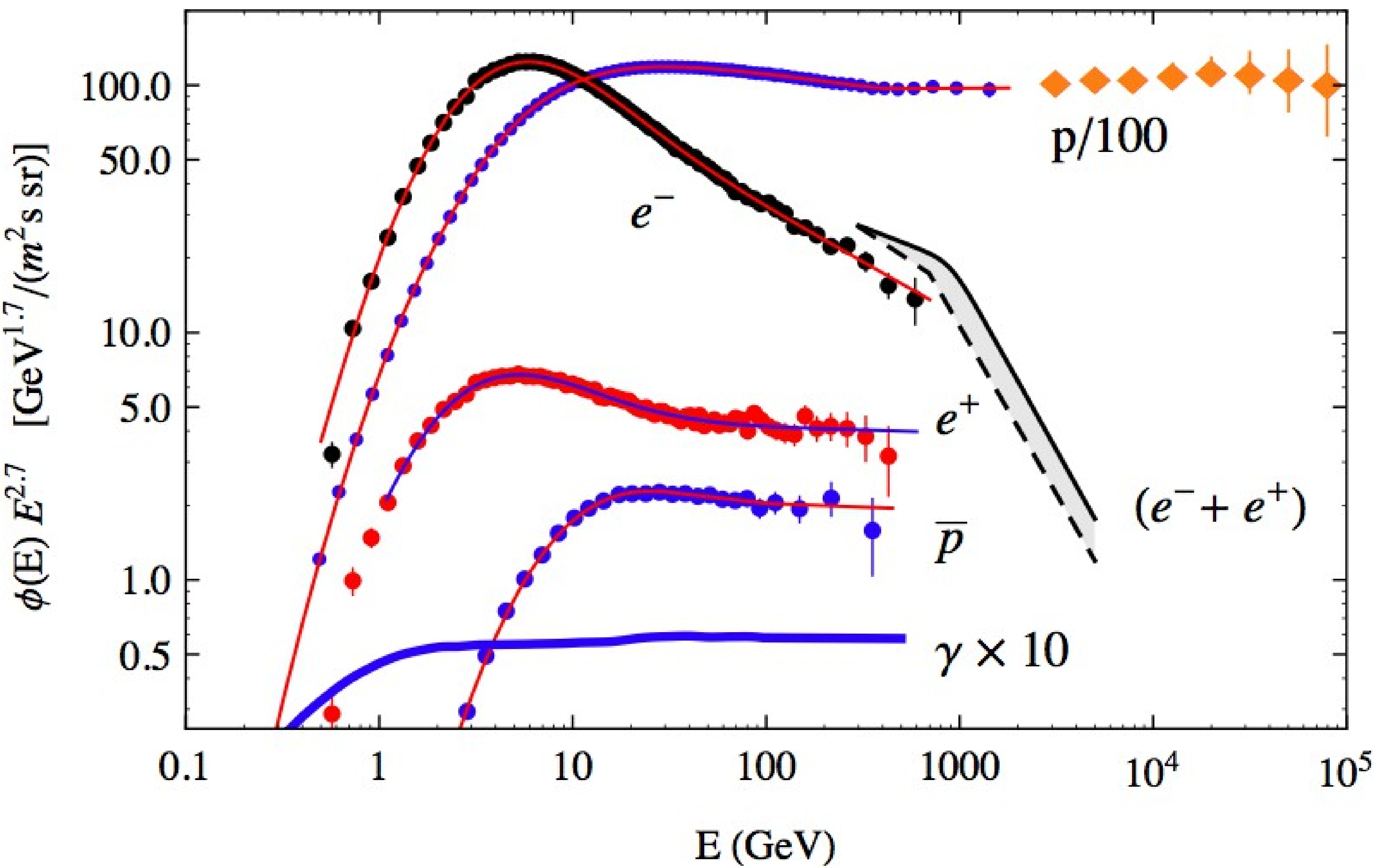
High Energy CR flux (Indirect Shower Observations)



Very High Energy

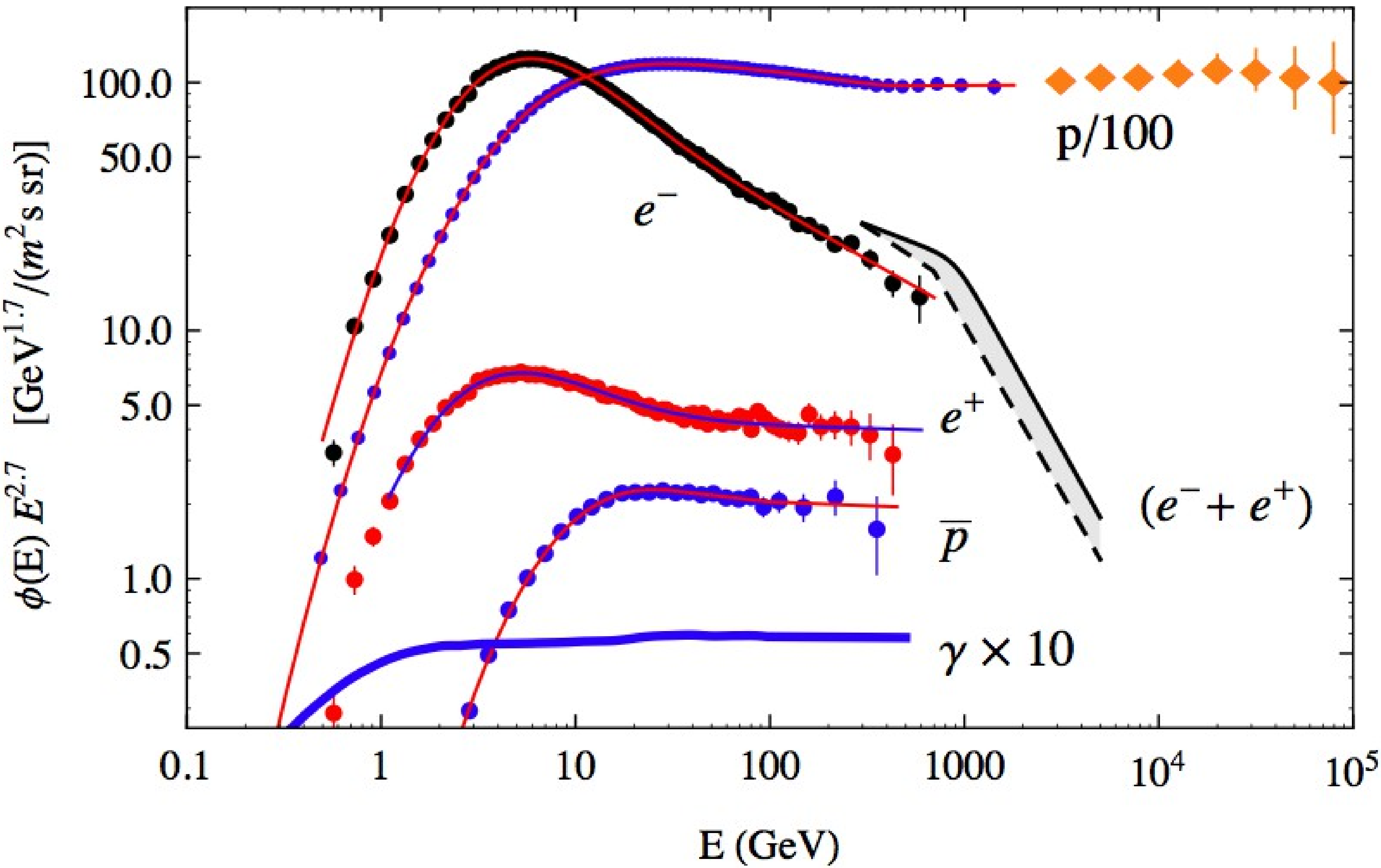
AMS02 p e^- e^+ $\overline{p}$

CREAM p data



angle averaged diffuse Galactic gamma ray flux (Fermi)

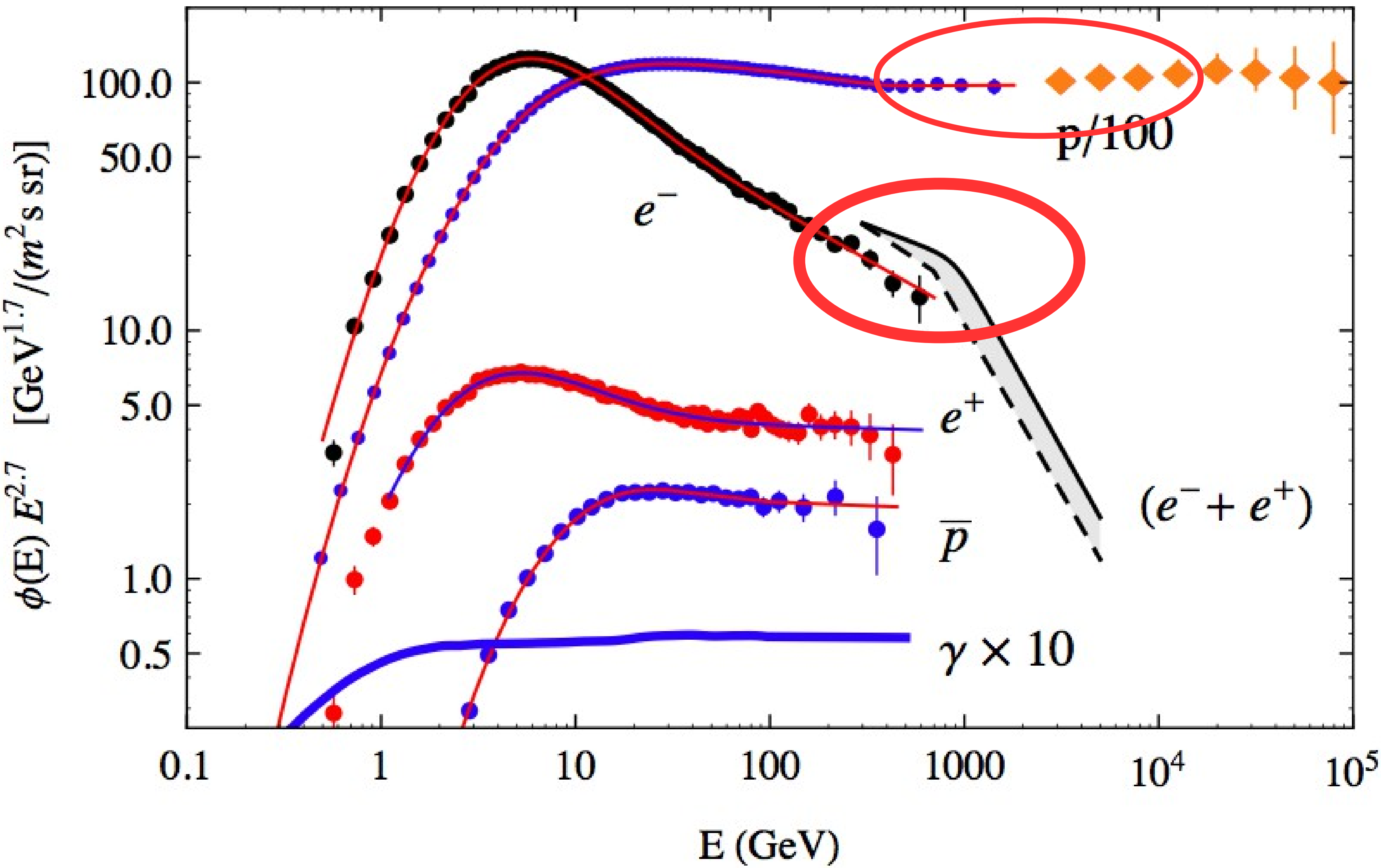
CREAM p data



striking results

Soft electron spectrum

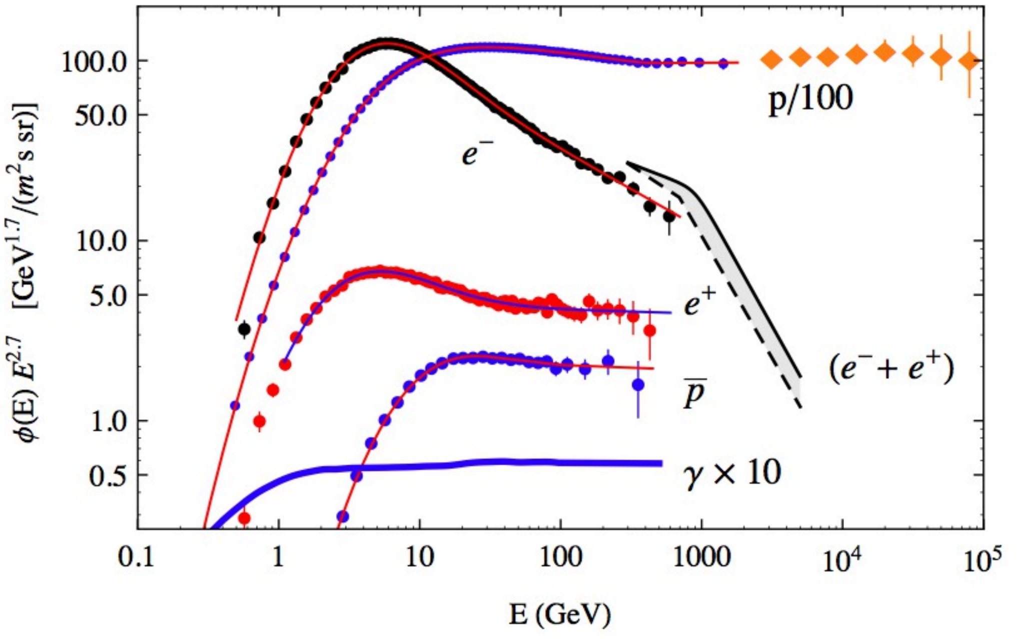
4 spectra
have approximately
the same slope



Spectral features

(need explanations)

4 spectra
have approximately
the same slope



"striking" qualitative features that "call out" for an explanation

4 spectra have approximately the same slope

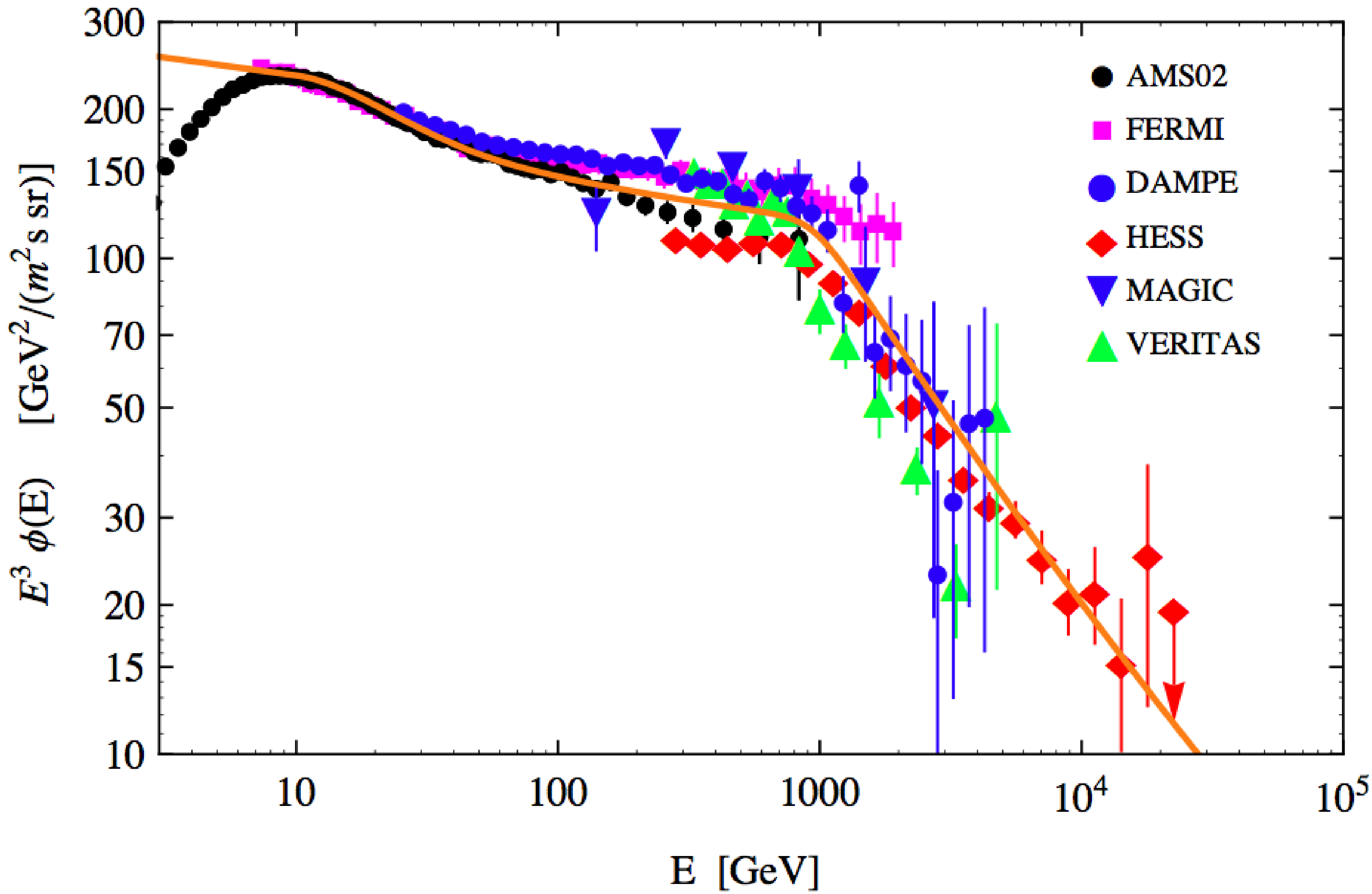
[A] *Proton* and *electron* spectra are very different.

- [a1] much smaller e- flux
- [a2] much *softer* electron flux
- [a3] evident "break"at 1 TeV in the $(e^+ + e^-)$ spectrum

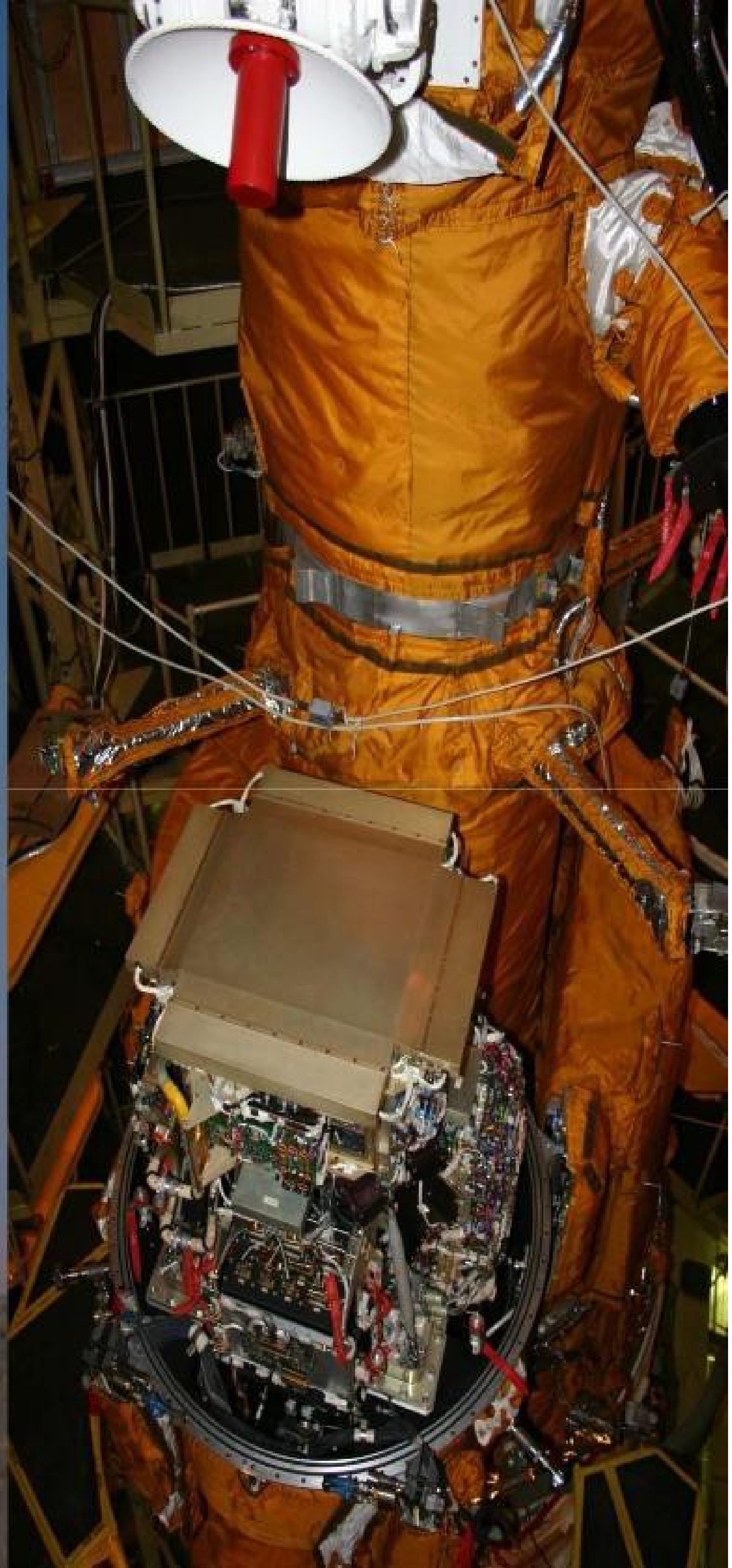
[B] *positron* and *antiproton* for (E> 30 GeV) have the same power law behavior and differ by a factor 2 (of order unity)

All electron spectrum $(e^- + e^+)$

Remarkable discovery of Cherenkov telescopes



Understanding this spectral structure is *crucial*



PAMELA
detector

Launch
15th june 2006

Summer 2008:
presentation of the
“positron anomaly”

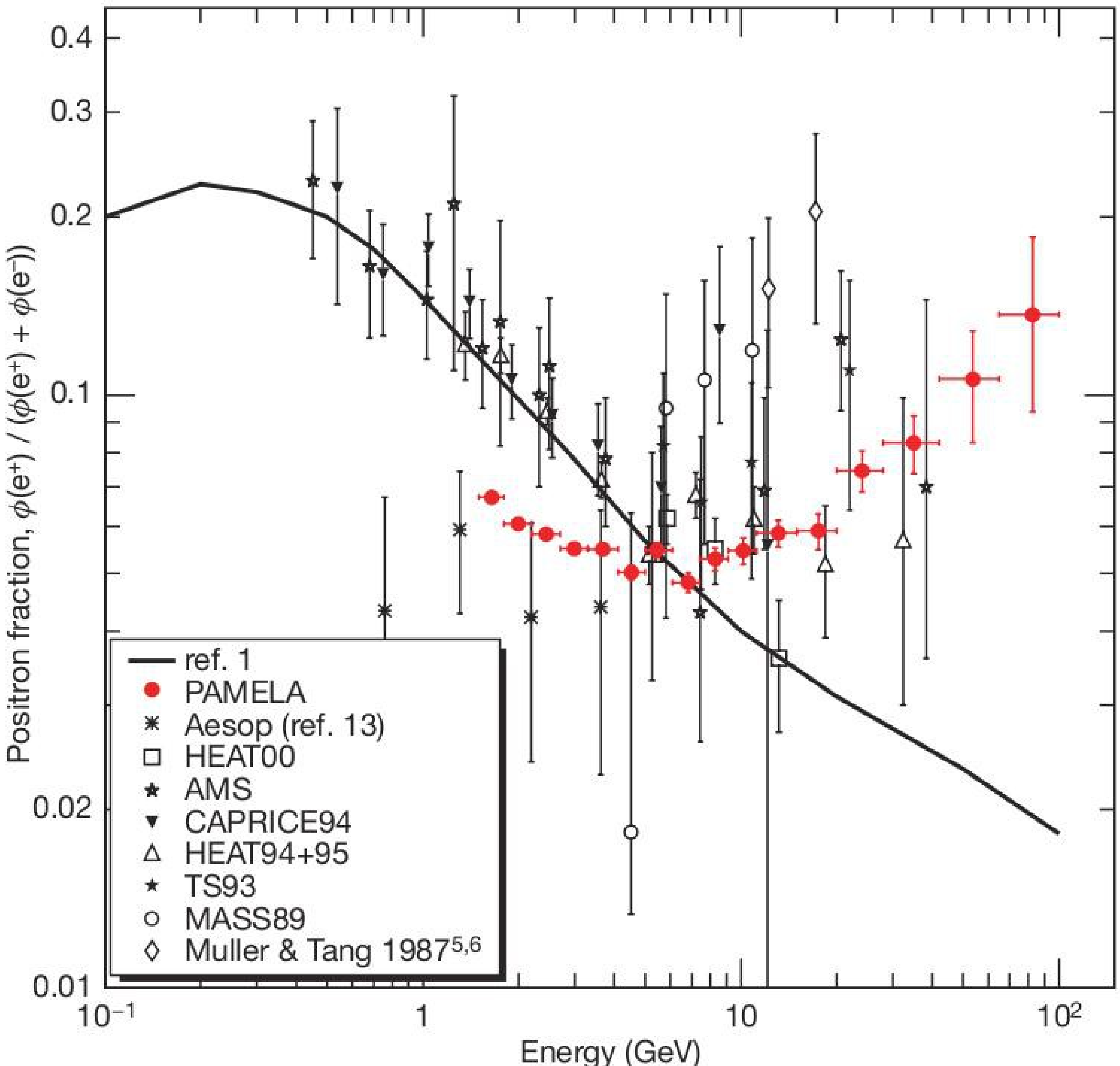
[Nature 2009]

Evidence for DM ?

Positron accelerators ?

An anomalous positron abundance in cosmic rays with energies 1.5–100 GeV

O. Adriani *et al.* [PAMELA Collaboration], Nature **458**, 607 (2009) [arXiv:0810.4995 [astro-ph]].



DATA

Prediction

10 years with the “positron anomaly"

Great excitement !

Published online 13 August 2008 | *Nature* **454**, 808-809 (2008) | doi:10.1038/454808b

News

Physicists await dark-matter confirmation

PAMELA mission offers tantalizing hint of success.

[.....]

For weeks, the physics community has been buzzing with the latest results on 'dark matter' from a European satellite mission known as PAMELA

“Paparazzi physicists” (is this ethical ?)

naturenews

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comments on this story

Published online 2 September 2008 | Nature | doi:10.1038/455007a

News

Physicists aflutter about data photographed at conference

Stories by subject

- Lab life
- Physics
- Space and astronomy

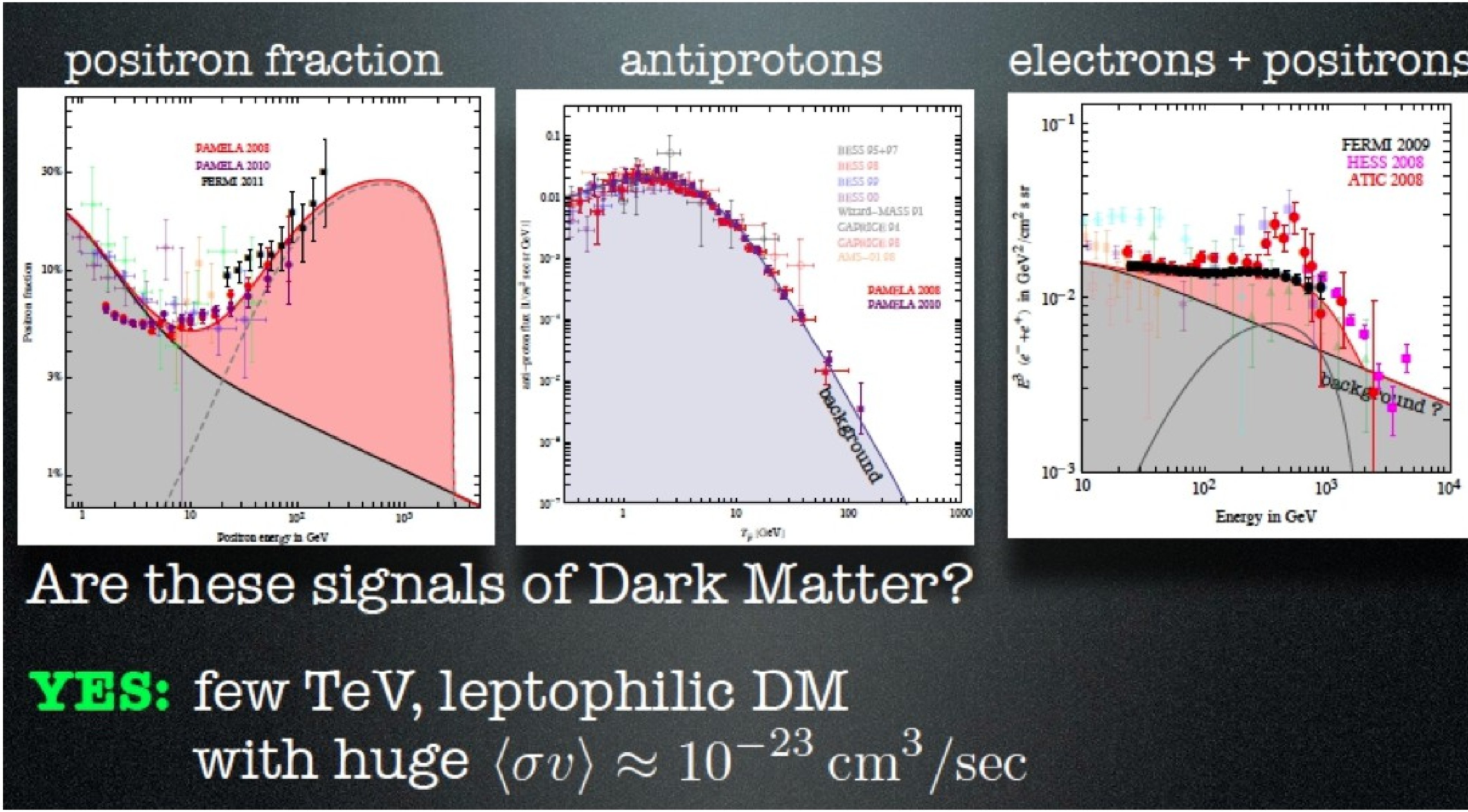
Digital cameras snap slides ahead of publication.

Is this the right place for digital cameras?

F. Chmura/Alamy

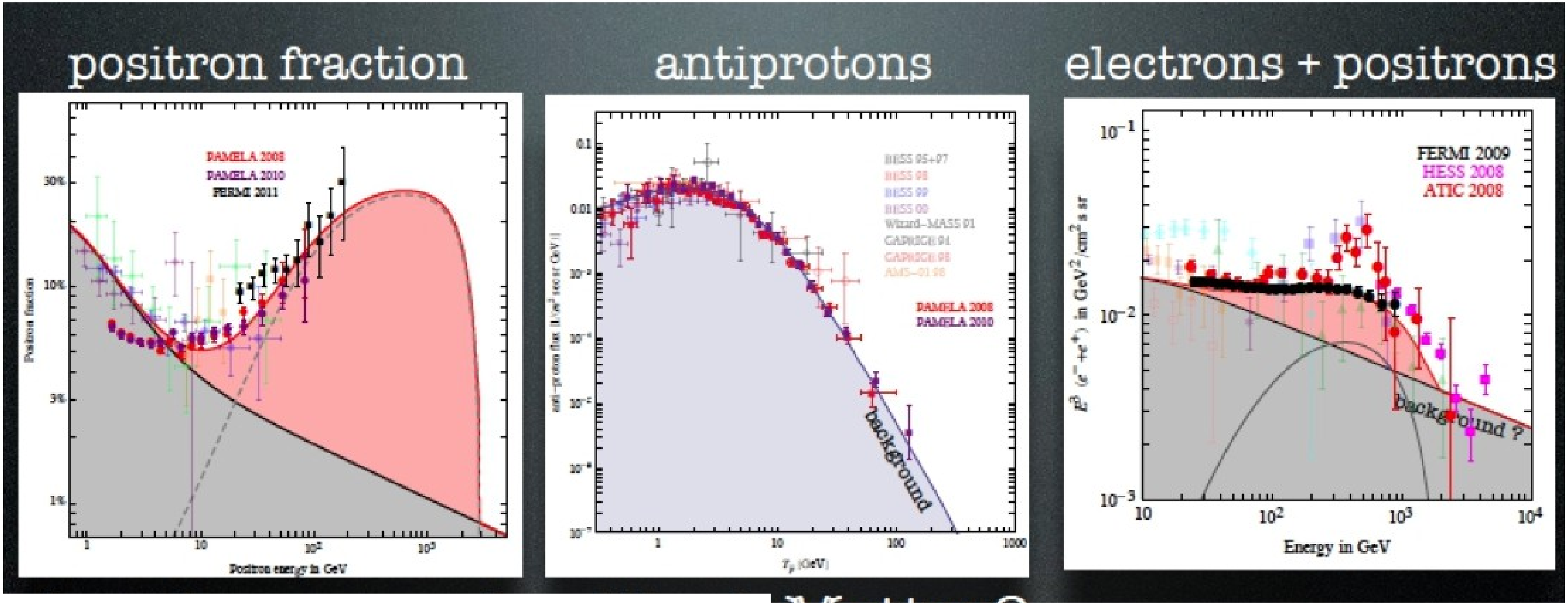
First (Dark Matter) interpretation
of the result published on “stolen data”

Now: approaching 2000 (1965 now) citations (SPIRES)
Problem still open (and of critical importance)



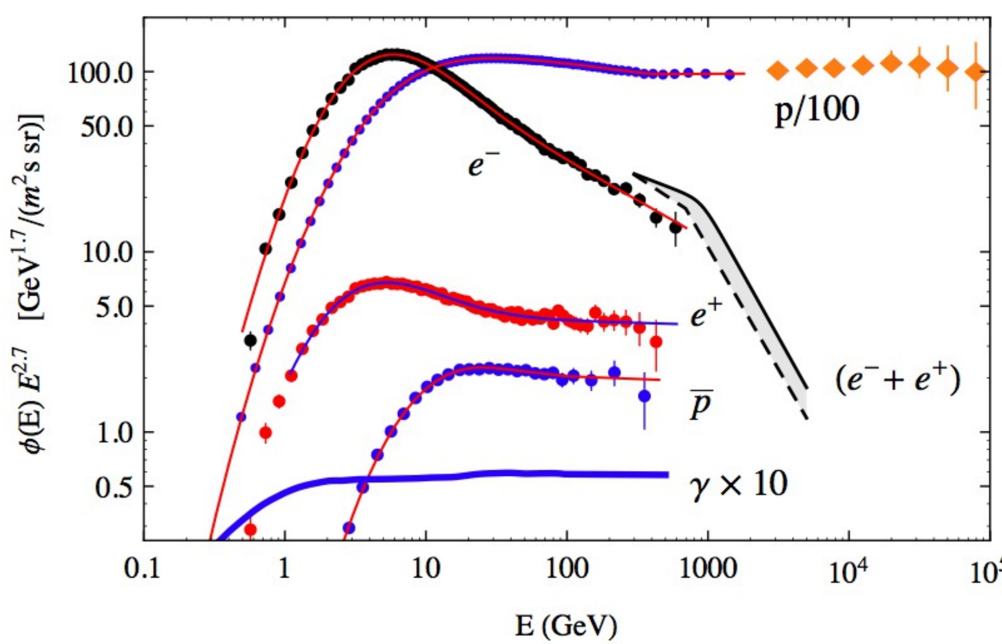
Example of (one of many)
Dark Matter interpretations
(Marco Cirelli Ricap-2014)

Note:
Crucial role of
“background calculation"



Note:
in these interpretations
at high energy
Positrons (that are generated by a "new source")
and Antiprotons have
completely different origin

Their similarity in spectrum is
only a coincidence.



"Conventional mechanism" for the production of positrons and antiprotons:

Creation of secondaries in the inelastic hadronic interactions of cosmic rays in the interstellar medium

$$pp \to \overline{p} + \ldots$$

$$pp \to \pi^+ + \ldots$$
$$\hookrightarrow \mu^+ + \nu_\mu$$
$$\hookrightarrow e^+ + \nu_e + \overline{\nu}_\mu$$

$$pp \to \pi^\circ + \ldots$$
$$\hookrightarrow \gamma + \gamma$$

"Standard mechanism" for the generation of positrons and anti-protons

Dominant mechanism for the generation of high energy gamma rays

intimately connected

Straightforward [hadronic physics] exercise:

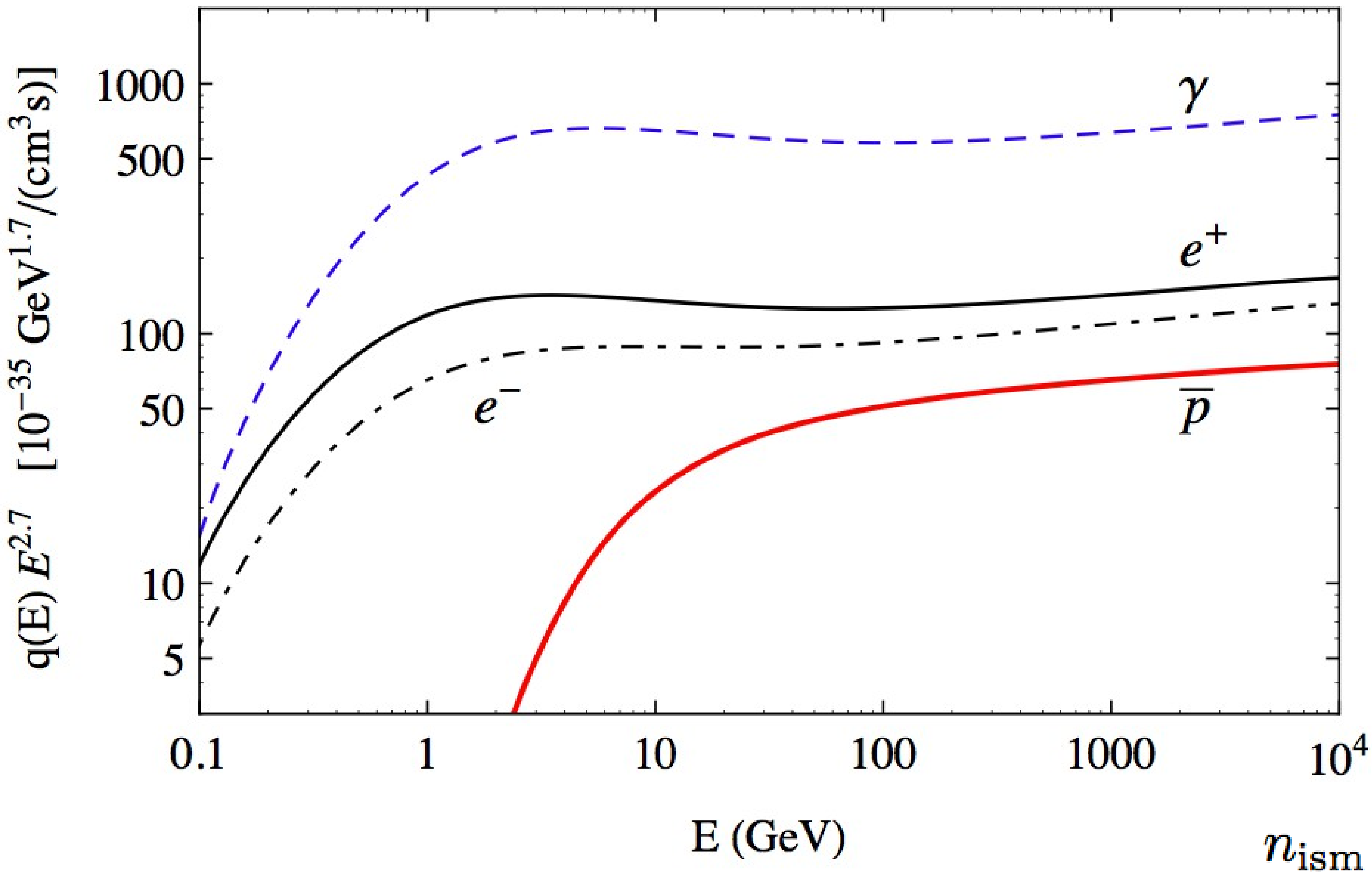
[1] Take spectra of cosmic rays (protons + nuclei) observed at the Earth

[2] Make them interact in the local interstellar medium (pp, p-He, He-p,...)

[3] Compute the rate of production of secondaries

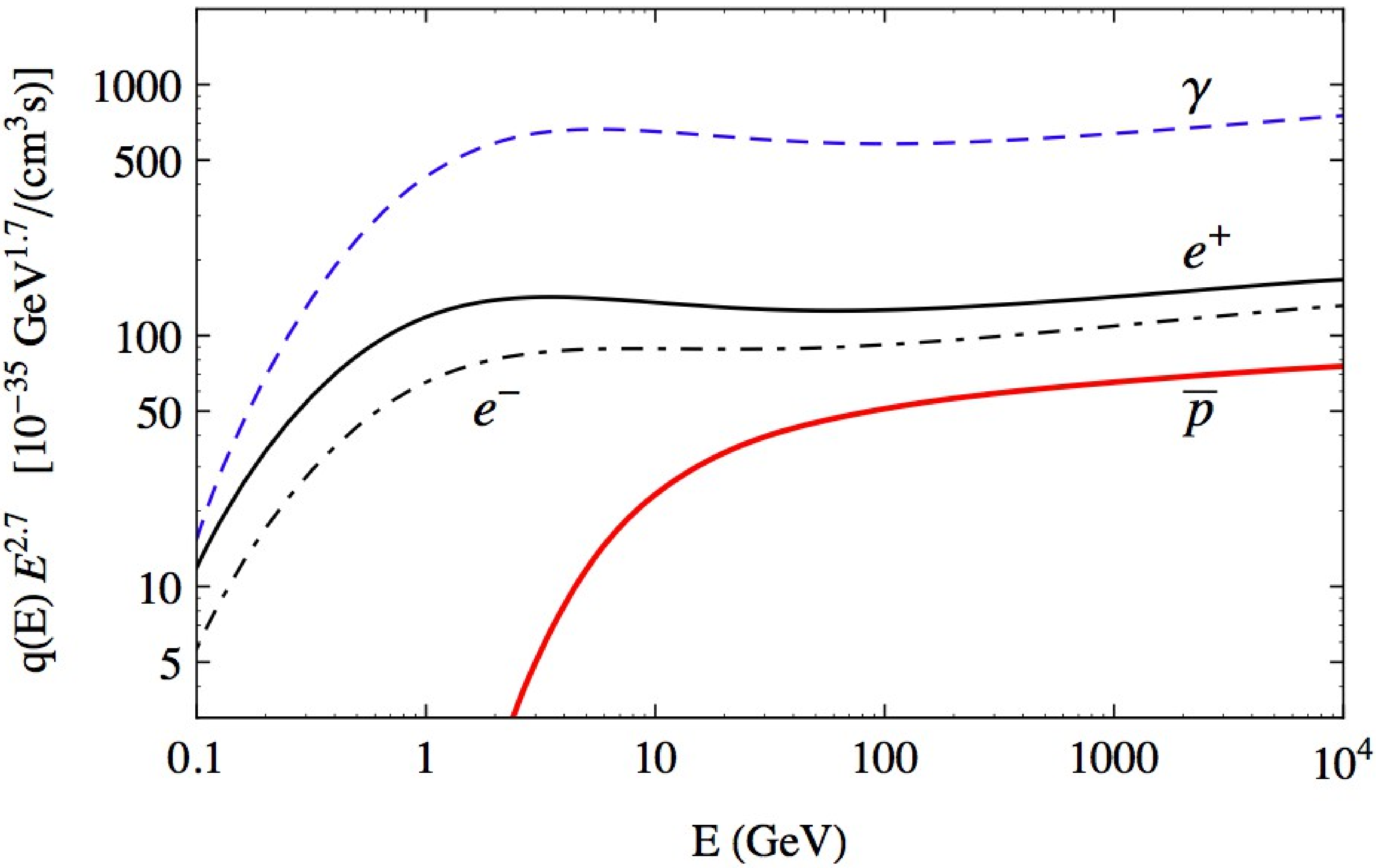
$$q_j(E, \vec{x}_\odot)$$

$$[\text{cm}^3 \text{ s GeV}]^{-1}$$



$$n_{\text{ism}}(\vec{x}_\odot) = 1 \text{ cm}^{-3}$$

"Local" Rate of production of secondaries



$$\frac{\gamma}{e^+} \approx 5.5$$

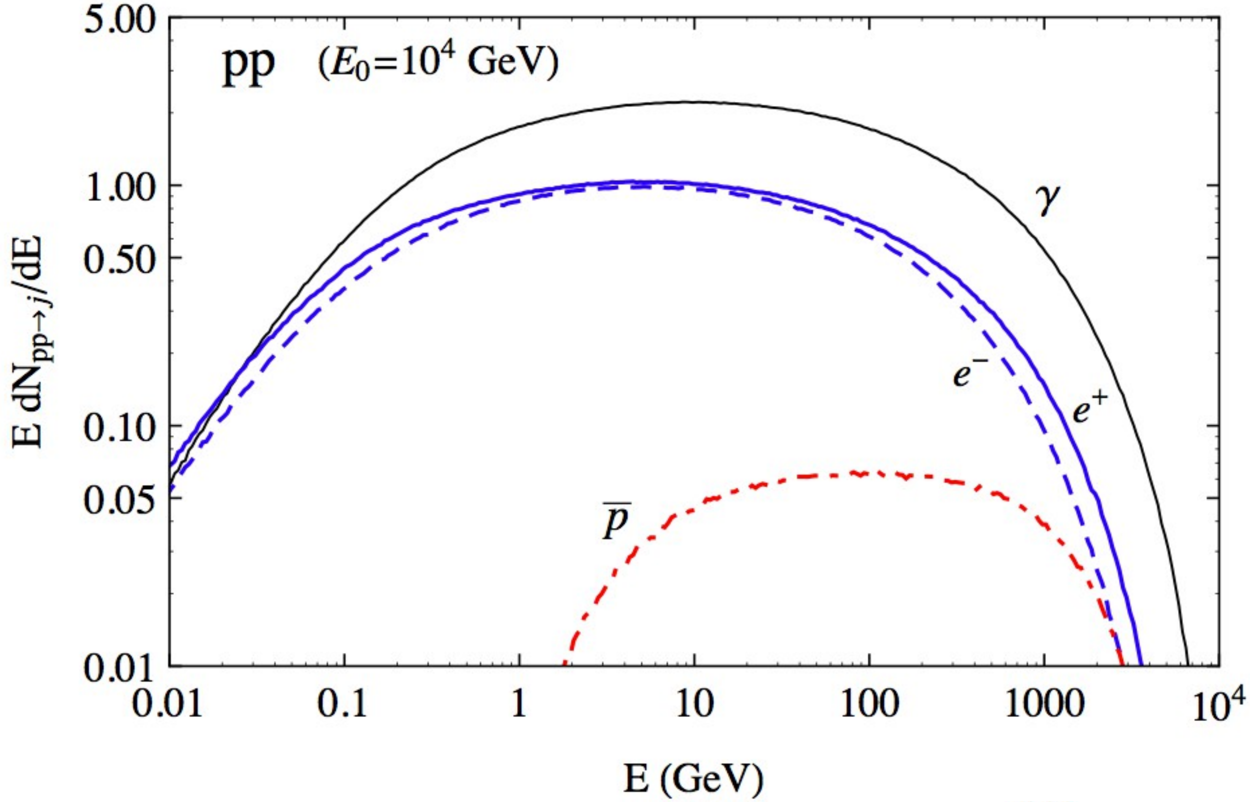
$$\frac{e^-}{e^+} \approx 0.8$$

$$\frac{e^+}{\overline{p}} \approx 2.0$$

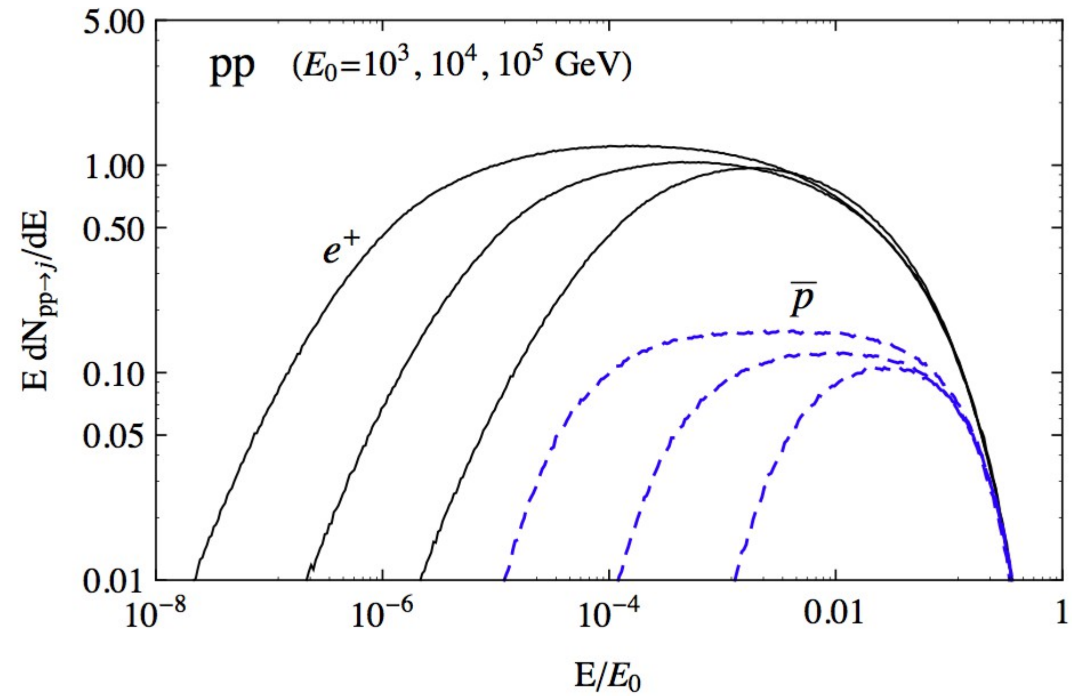
Different low energy behaviors
(low energy antiproton production suppressed)

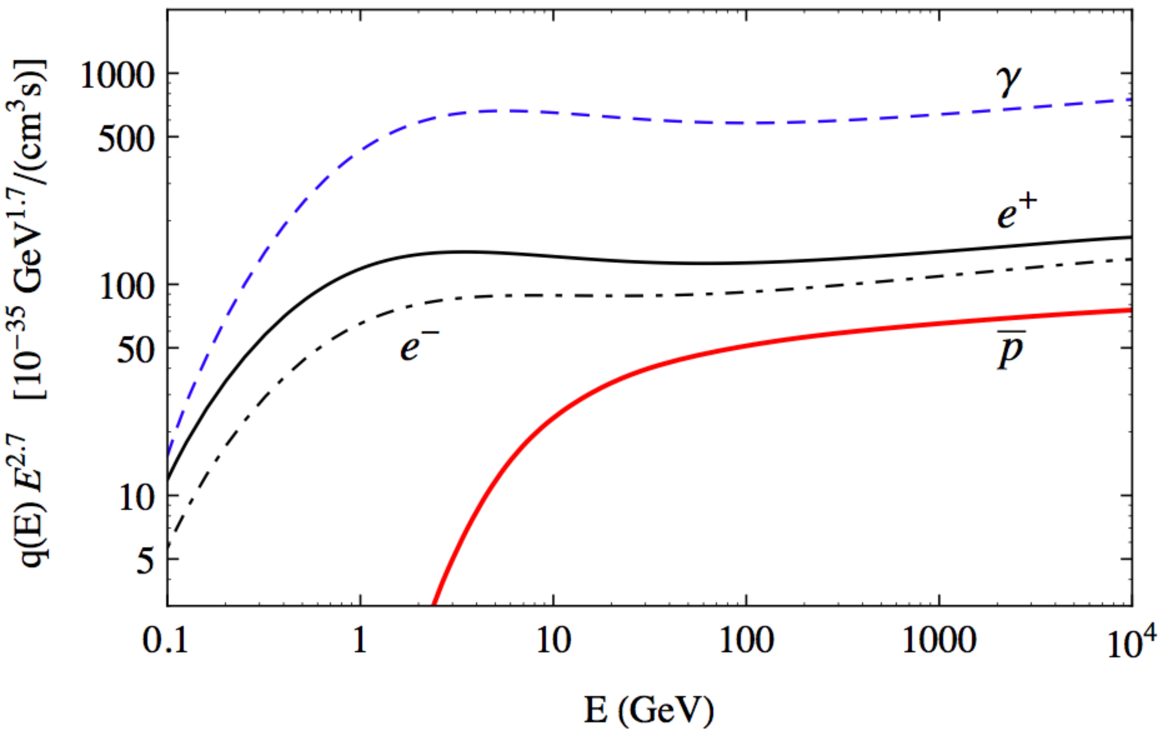
Power Law behavior at high energy

Secondary spectra



Scaling behavior

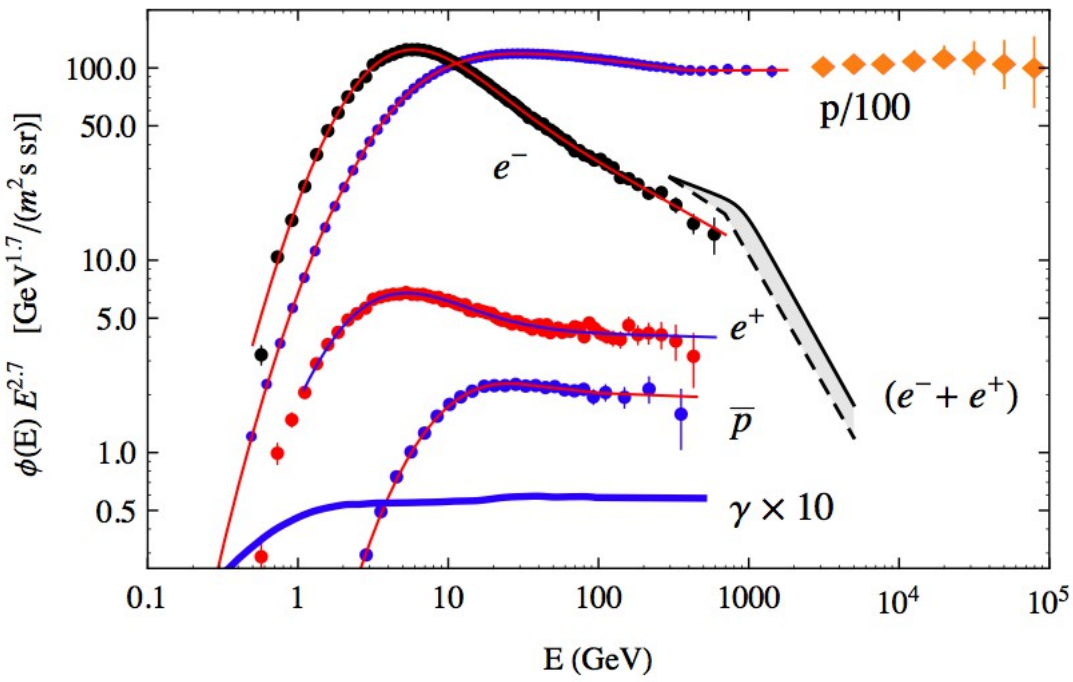




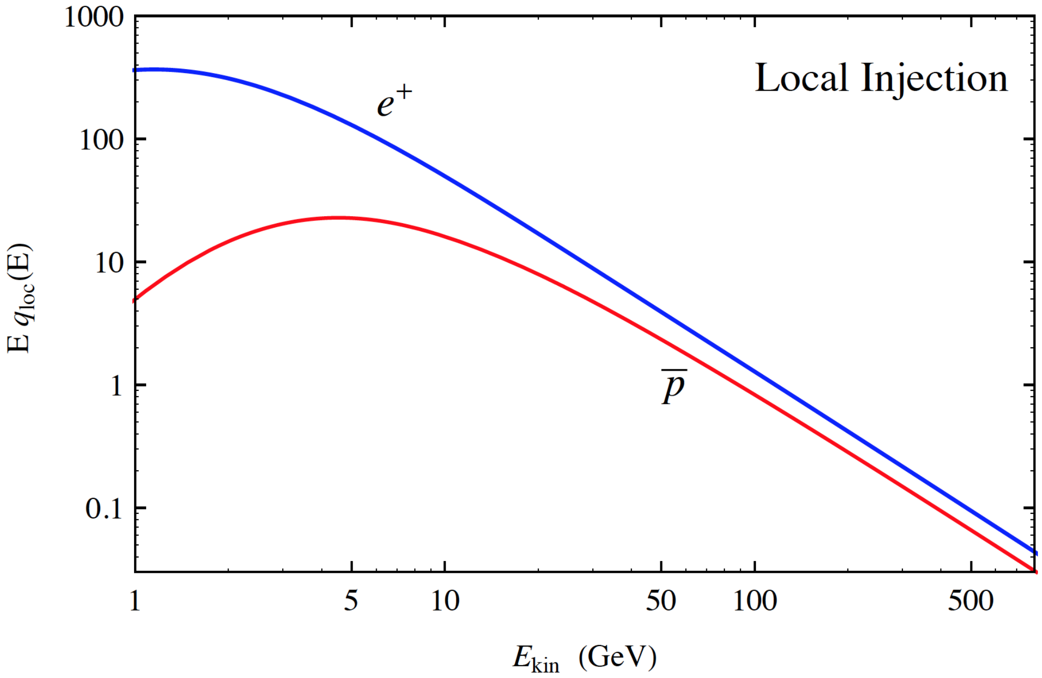
Local production rates of secondaries

e^+ $\overline{p}$

"striking" similarity

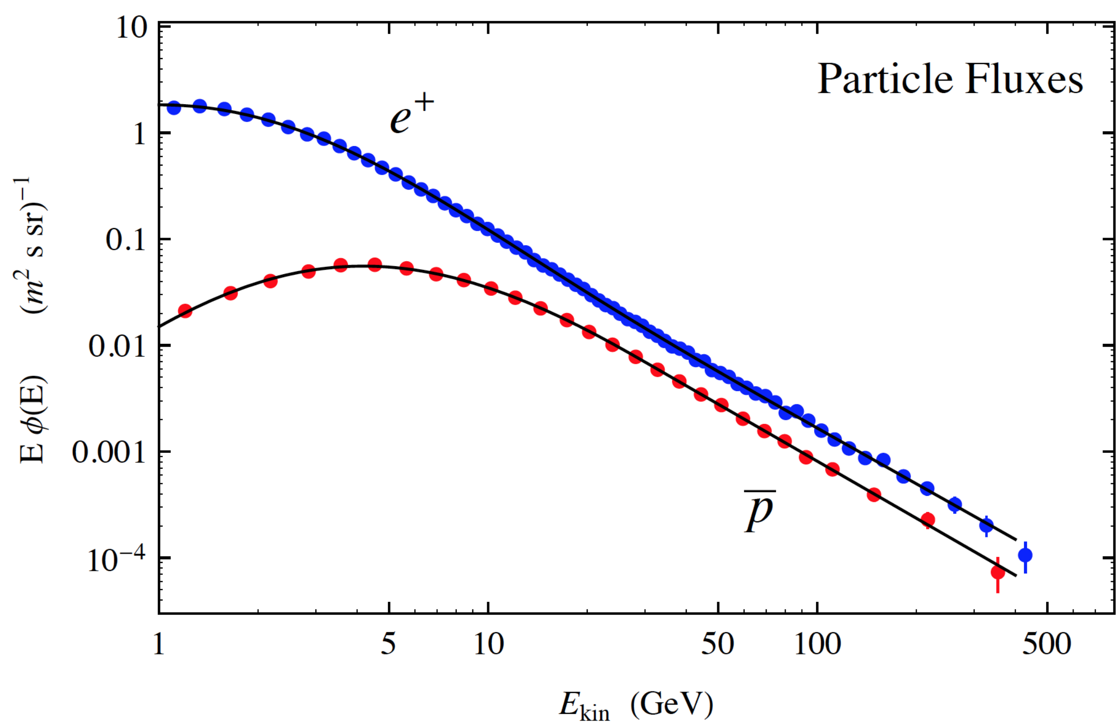


Observed fluxes



Local production rates of secondaries

“striking” similarity



Observed fluxes

$$\frac{\phi_{e^+}(E)}{\phi_{\overline{p}}(E)} \approx \frac{q^{\rm loc}_{e^+}(E)}{q^{\rm loc}_{\overline{p}}(E)}$$

The ratio positron/antiproton
Local source (secondary production)
(within systematic uncertainties)
is equal to the ratio of the observed fluxes

Does this result has a
"natural explanation" ?

There is a simple, natural interpretation that *“leaps out of the slide”* :

1. The “standard mechanism of secondary production is the main source of the antiparticles (and of the gamma rays)

2. Cosmic rays in the Galaxy (that generate the antiparticles and the photons) have spectra similar to what is observed at the Earth.

3. *The Galactic propagation effects for positrons and antiprotons are approximately equal*

4. The propagation effects have only a weak energy dependence.

The Logic of the discussion on the positron flux:

$$\phi_j(E) = q_j(E)\ \mathcal{P}_j(E)$$

Flux of particle type j is the source spectrum "distorted" by propagation effect.

Apply to positrons:

$$\phi_{e^+}(E) = [q_{e^+}^{\rm sec}(E) + q_{e^+}^{\rm new}(E)]\ \mathcal{P}_{e^+}(E)$$

DATA

model

model

New source of positrons (DM, pulsars,...)

Phenomenological observation

$$\frac{\phi_{e^+}(E)}{\phi_{\overline{p}}(E)} \approx \frac{q^{\rm sec}_{e^+}(E)}{q^{\rm sec}_{\overline{p}}(E)}$$

$$\phi_j(E) = q_j(E)\ \mathcal{P}_j(E)$$

Conventional scenario

Positrons have
an "energy loss sink"

$$\mathcal{P}_{e^+}(E) < \mathcal{P}_{\overline{p}}(E)$$

Meaningless (but strange)
numerical coincidence

$$[q^{\rm sec}_{e^+}(E) + q^{\rm new}_{e^+}(E)]\ \mathcal{P}_{e^+}(E) \approx$$

$$\approx q^{\rm sec}_{e^+}(E)\ \mathcal{P}_{\overline{p}}(E)$$

"Natural" explanation

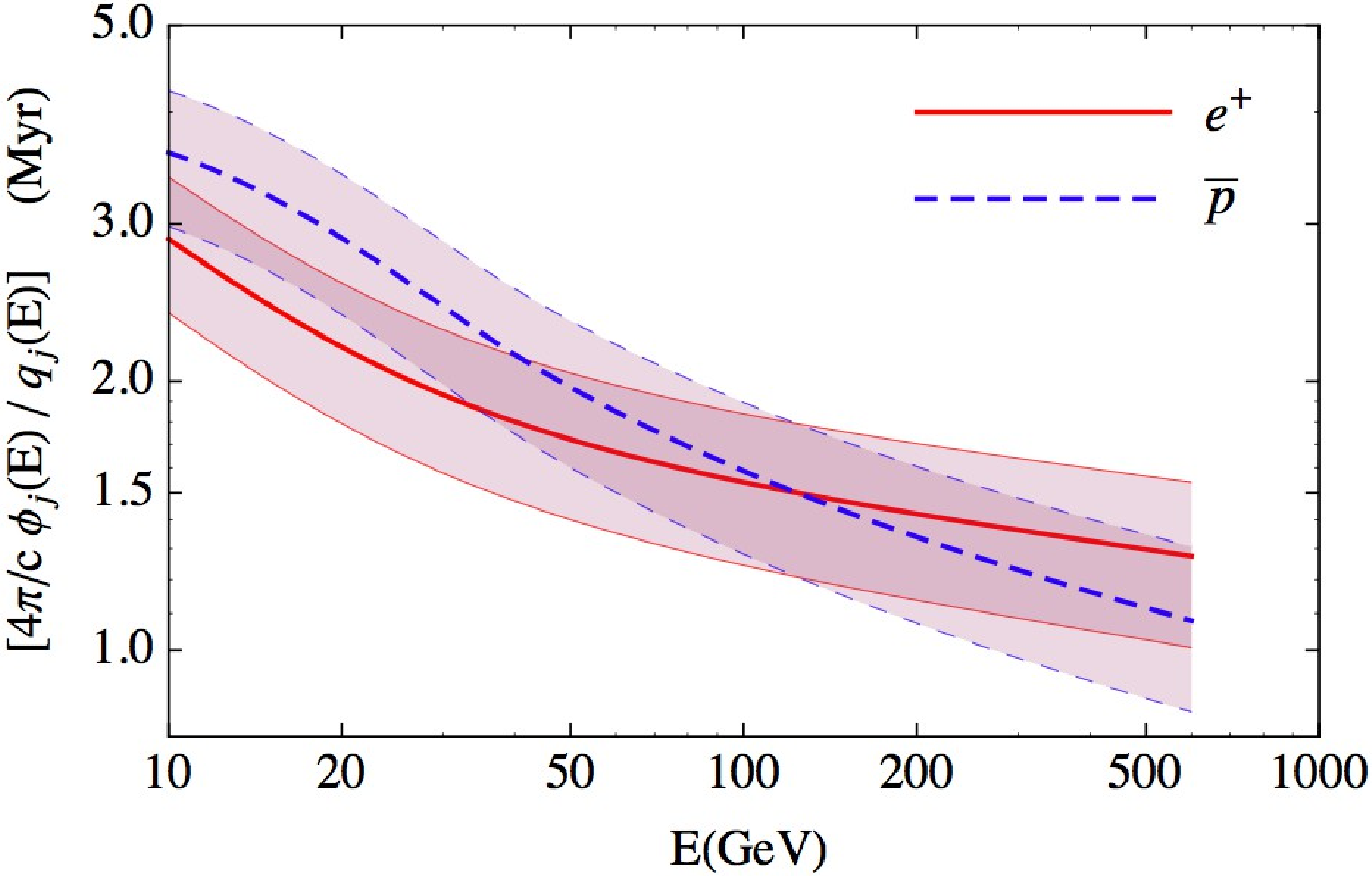
$$\mathcal{P}_{e^+}(E) \approx \mathcal{P}_{\overline{p}}(E)$$

$$q_{e^+}(E) \simeq q^{\rm sec}_{e^+}(E)$$

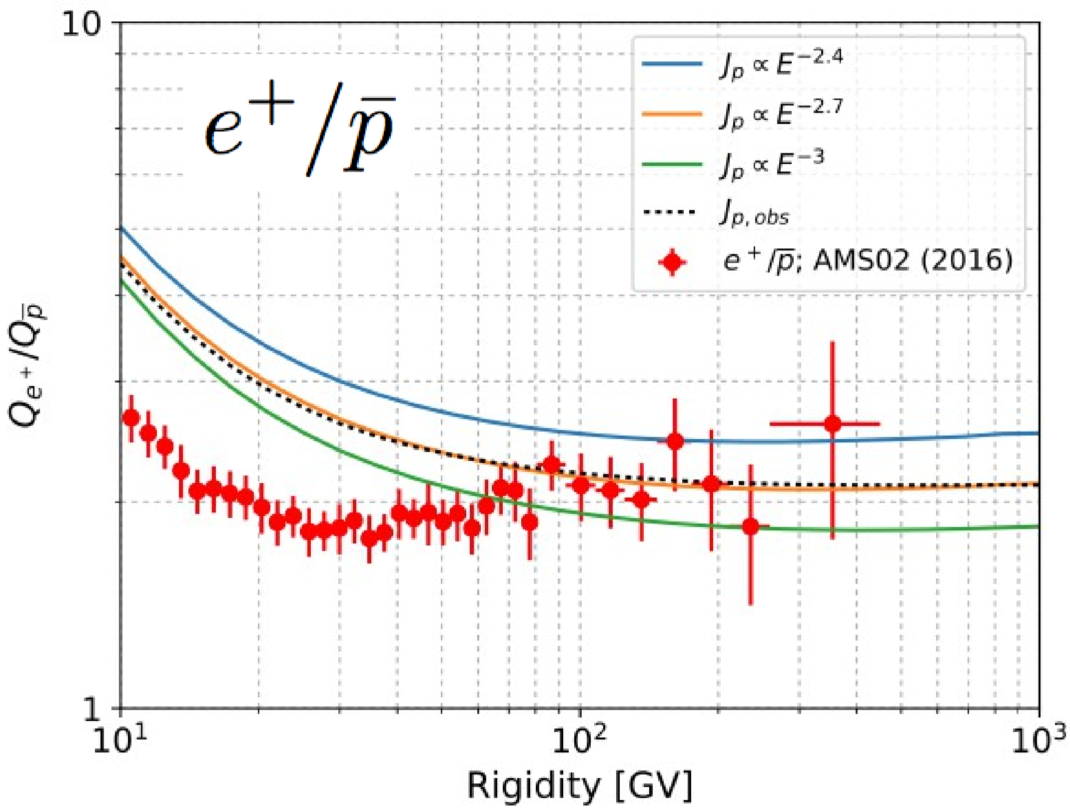
$$q_{\overline{p}}(E) \simeq q^{\rm sec}_{\overline{p}}(E)$$

$$\frac{\phi_{\overline{p}}(E)}{q_{\overline{p}}^{\rm loc}(E)} \approx \frac{\phi_{e^+}(E)}{q_{e^+}^{\rm loc}(E)}$$

Distortion of the source spectra created by propagation



Weak energy dependence of the propagation effects !



I'm asking for independent confirmations of the calculation of the positron/antiproton ratio at production

Hadronic Interactions modeling uncertainties

FIG. 4: The ratio of $Q_{e^+}/Q_{\bar{p}}$. The dashed line is calculated by using the observed proton flux. Blue, orange, and green solid lines are calculated by assuming $J_p \propto E^{-2.4}$, $E^{-2.7}$, E^{-3}, respectively. The observational data $e^+/\bar{p}$ is taken from Ref. [3].

For High Energy Astrophysics very desirable to improve our understanding of hadronic interactions

K. Blum, R. Sato and M. Takimoto,
"e^+ and $\bar{p}$ production in pp collisions and the cosmic-ray $e^+/\bar{p}$ flux ratio,"
arXiv:1709.04953 [astro-ph.HE].

Two crucial problems emerge :

[1.] The energy dependence of the propagation effects is significantly smaller than expectations
[based on the B/C ratio]
[theoretically motivated]

Problem
also for antiprotons !

[2.] The propagation effects for positrons and antiprotons are approximately equal.

Is this possible ?

$$-\frac{dE}{dt} \propto \frac{q^4}{m^4} \; E^2$$

Rates of energy losses for
positrons and antiprotons
differ by many orders of magnitude

Formation of the Galactic Cosmic Ray spectra
(for each particle type)
three elements are of fundamental importance:

1. Source spectrum

2. Magnetic confinement
   (CR residence time)

3. Energy losses
   (synchrotron + Compton scattering+ ....)

[4. hadronic + other interactions]

Brief historical note: References

P. Morrison, S. Olbert and B. Rossi,
"The Origin of Cosmic Rays"
Phys. Rev. **94**, 440 (1954)

Main "sink"
for Galactic cosmic rays
is escape from the Galaxy.

Model the magnetic effects
as diffusion
"in analogy with neutrons"

V. L. Ginzburg and S. I. Syrovatskii,
"The Origin of Cosmic Rays,"
Pergamon Press (1964).

"Classic reference"

Contemporary implementations:
[Galprop, Dragon, ...]

Energy Loss: main mechanisms

Synchrotron radiation
Compton scattering
strongly depend on the particle mass

quadratic in energy

$$-\frac{dE}{dt} \propto \frac{q^4}{m^4} E^2$$

$$T_{\rm loss}(E) = \frac{E}{|dE/dt|} \simeq \frac{1}{b\,E}$$

Characteristic time for energy loss

$$T_{\rm loss}(E) \approx \frac{620}{E_{\rm GeV}}\ {\rm Myr}$$

$$\approx \frac{0.62}{E_{\rm TeV}}\ {\rm Myr}$$

Energy losses can be the main *"sink"* for e+/e- CR

or be negligible

depending on the residence time of the particles in the Galaxy

Rate of Energy Loss depends on the energy density in magnetic field and radiation (and therefore *is a function of position*)

$$T_{\rm loss}(E) = \frac{E}{|dE/dt|} \simeq \frac{3\,m_e^2}{4\,c\,\sigma_{\rm Th}\,\langle \rho_B + \rho_\gamma^*(E)\rangle\; E}$$

$$\simeq 621.6 \left(\frac{\rm GeV}{E}\right) \left(\frac{0.5~{\rm eV/cm^3}}{\rho}\right)~{\rm Myr}$$

Average value for the particle confinement volume

$$\rho_b = \frac{B^2}{8\,\pi} \simeq 0.22 \left(\frac{B}{3~\mu{\rm G}}\right)^2 \frac{\rm eV}{\rm cm^3}$$

$$\rho_{\rm CMBR} \simeq 0.26~\frac{\rm eV}{\rm cm^3}$$

Simplest model to describe Cosmic Rays in the Galaxy: the "LEAKY BOX"

[No space variables. The Galaxy is considered as one single homogeneous volume (or point)]

Equation that describe the CR Galactic population

$$\frac{\partial n(E,t)}{\partial t} = q(E,t) - \frac{n(E,t)}{T_{\rm esc}(E)} + \frac{\partial}{\partial E}\left[\beta(E)\, n(E,t)\right]$$

Three functions of energy/rigidity define completely the model for one particle type

$q(E)$: Source spectrum (stationary)

$T_{\rm esc}(E)$ Escape time

$\beta(E) = -\frac{dE}{dt}$ Rate of energy loss $T_{\rm loss}(E) = E/\beta(E)$

Stationary solution for the Leaky Box model:

$$q(E) = q_0 \; E^{-\alpha}$$

$$T_{\rm esc}(E) = T_0 \; E^{-\delta}$$

$$\beta(E) = b \, E^2$$

Critical energy E^*

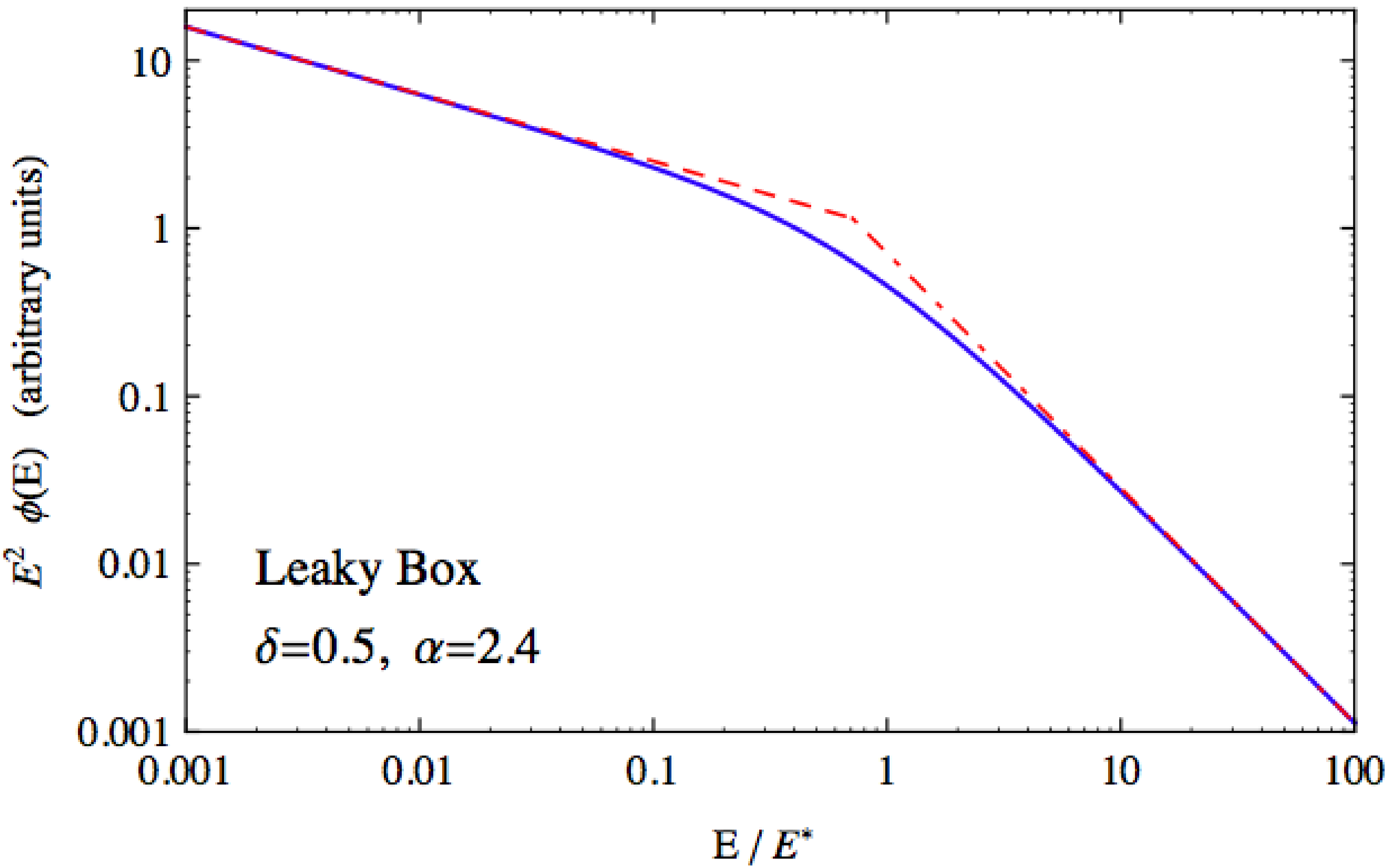
$$T_{\rm loss}(E^*) = T_{\rm esc}(E^*)$$

$$E^* = (T_0 \, b)^{1/(\delta - 1)}$$

Energy losses negligible

$$n(E) = \begin{cases} q(E) \; T_{\rm esc}(E) = q_0 \, T_0 \; E^{-(\alpha+\delta)} & \text{for } E \ll E^* \\ \dfrac{q(E) \; T_{\rm loss}(E)}{\alpha - 1} = \dfrac{q_0}{b \, (\alpha - 1)} \; E^{-(\alpha+1)} & \text{for } E \gg E^* \end{cases}$$

Energy losses dominant



Spectral feature:

$$E_b \approx E^*$$

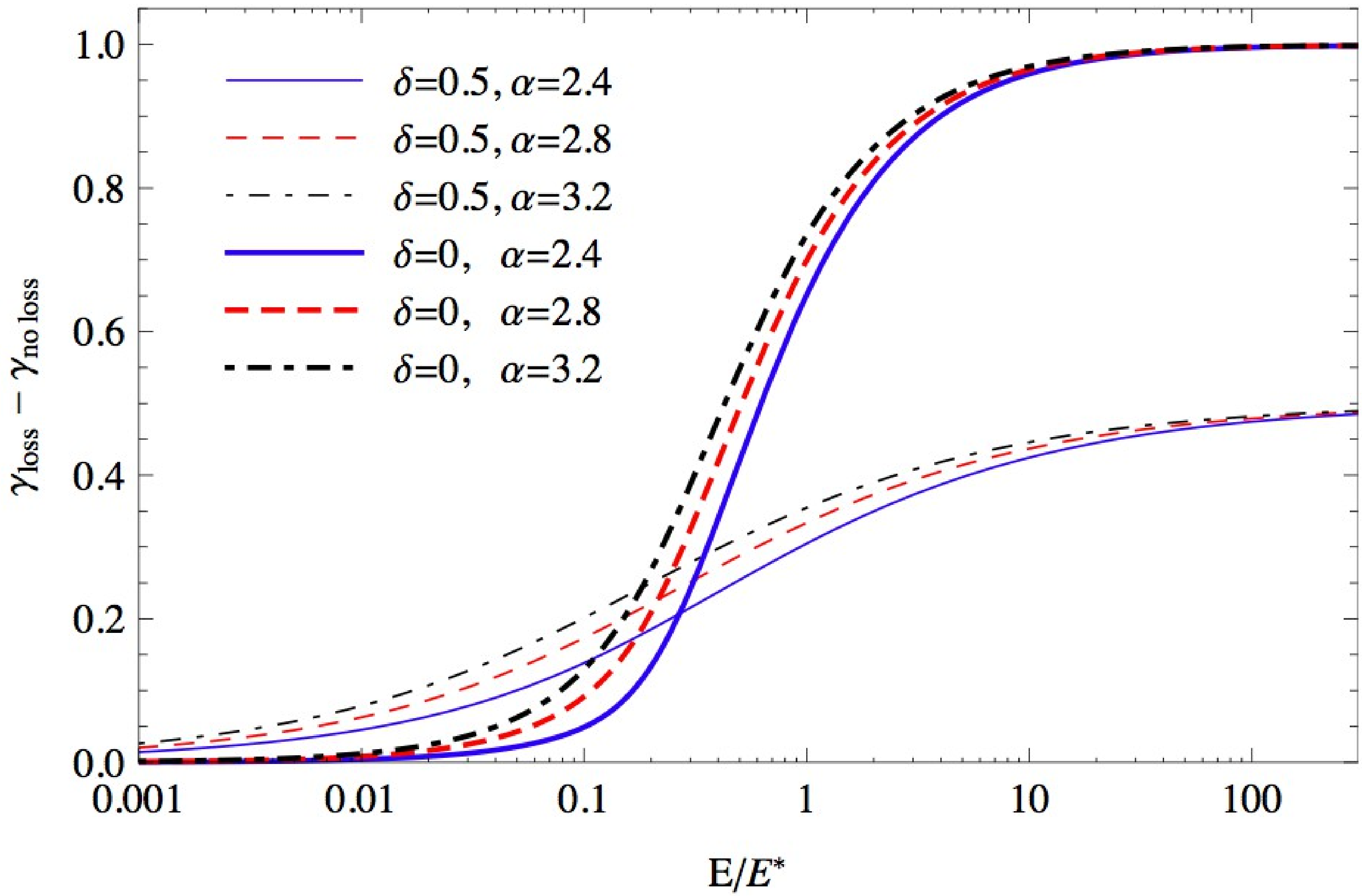
$$\Delta\gamma = 1 - \delta$$

$$E_b \approx E^* \, (\alpha - 1)^{1/(\delta - 1)}$$

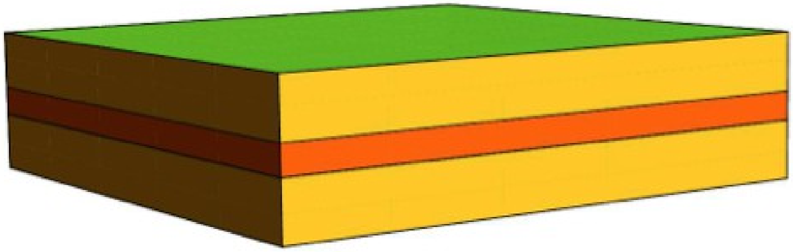
Exact solution:

$$n(E) = q(E)\, T_{\rm esc}(E) \times \int_0^{1/a} d\tau\, (1 - a\,\tau)^{\alpha-2}\, \exp\left[-\frac{1}{a\,(1-\delta)} \left[1 - (1 - a\,\tau)^{1-\delta}\right] \right]$$

$$a = \frac{T_{\rm esc}(E)}{T_{\rm loss}(E)} \simeq (T_0\, b)\, E^{1-\delta} = \left(\frac{E}{E^*}\right)^{1-\delta}$$

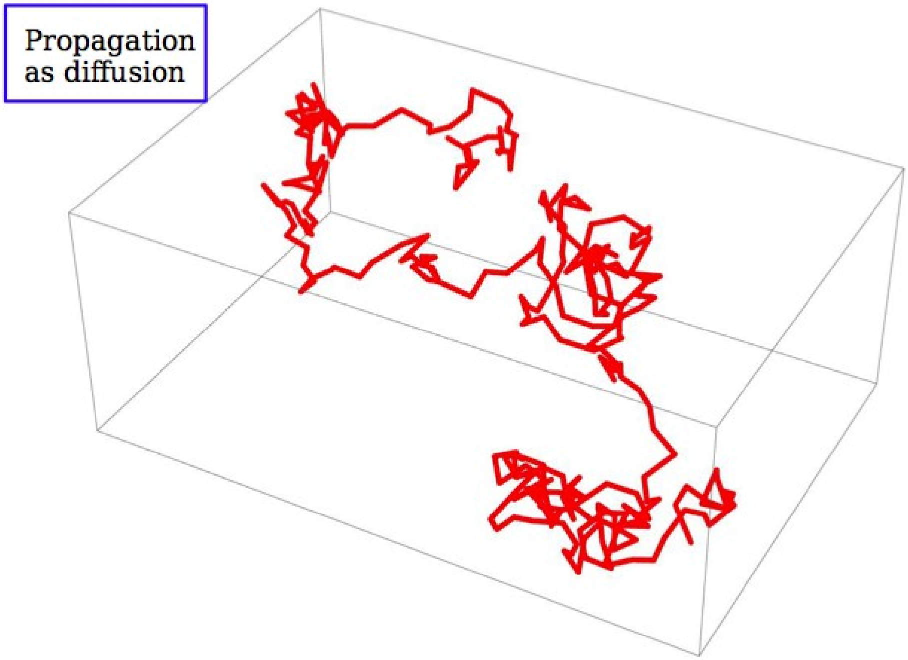


Diffusion Model ("minimal version")



Galaxy modeled as
a homogeneous slab
of a "diffusive medium"
with 2 absorption surfaces

$$z = \pm H$$



Model specified by H
+ 3 functions

$$D(E) = D_0 \; E^{\delta}$$

$$\beta(E) = b \, E^2$$

$$q(E, \vec{x}, t) \simeq q_0 \; E^{-\alpha} \; \delta[z]$$

[stationary, thin (plane) source]

Stationary solution for the model can be easily calculated

Energy losses negligible

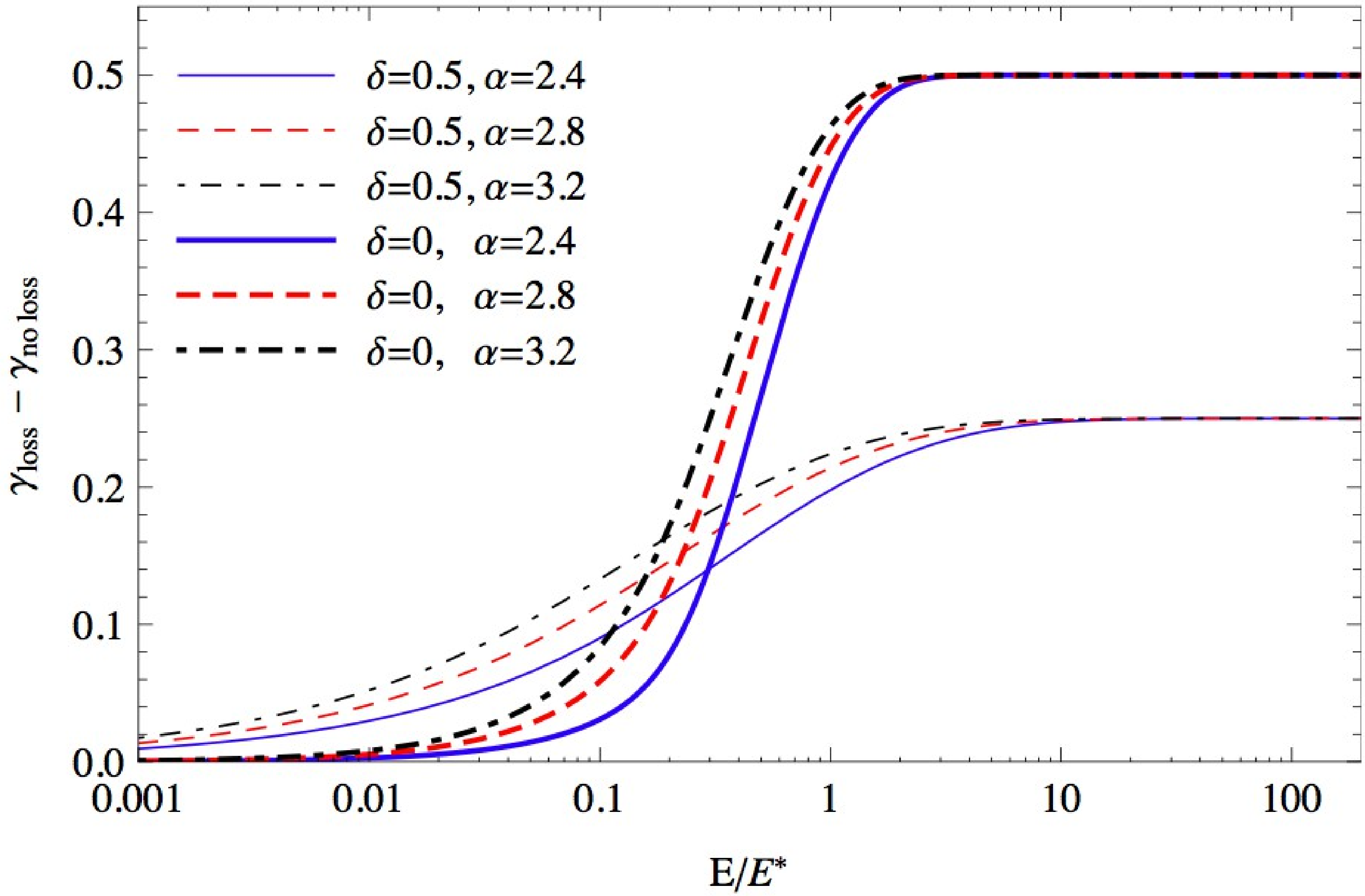
$$n(E) = \begin{cases} \dfrac{q_0\ H}{2\,D_0}\ E^{-(\alpha+\delta)} & \text{for } E \ll E^* \\[2ex] \dfrac{q_0}{\sqrt{2\,D_0\,b}}\ c(\alpha,\delta)\ E^{-[\alpha+(1+\delta)/2]} & \text{for } E \gg E^* \end{cases}$$

Energy losses dominant

$$c(\alpha,\delta) = \sqrt{\frac{1-\delta}{2\pi}} \int_0^1 d\tau\ \frac{(1-\tau)^{\alpha-2}}{\sqrt{1-(1-\tau)^{1-\delta}}}$$

$$\Delta\gamma = \frac{1-\delta}{2}$$

Imprint of the energy losses on the spectral index



$$\Delta\gamma = \frac{1-\delta}{2}$$

$$E_b \approx E^*$$

$$E_b \simeq c(\alpha,\delta)^{2/(\delta-1)}\ E^*$$

The point :
The effects of energy loss during the propagation of electrons and positrons should leave an "imprint" on the spectra: a softening feature.

The characteristic energy
of the softening has a simple physical meaning:
(in good approximation) it is the energy
where the Loss-Time is equal to the Escape Time
(or age) of the cosmic rays.

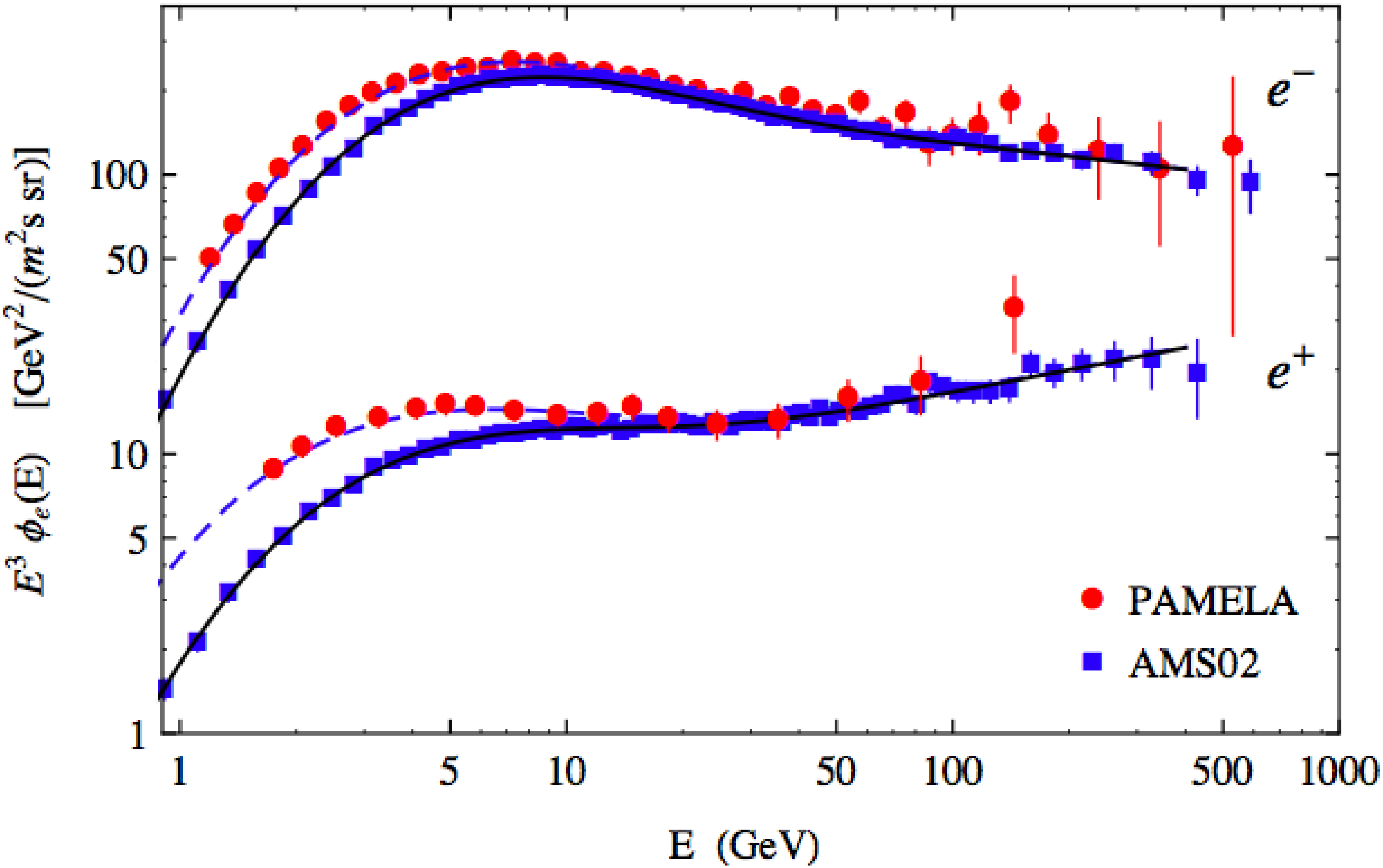
$$T_{\rm loss}(E^*) = T_{\rm esc}(E^*)$$

Identification of E^*
corresponds to a measurement of the CR residence time

Where is the energy loss softening feature ?

Electron and Positron spectra

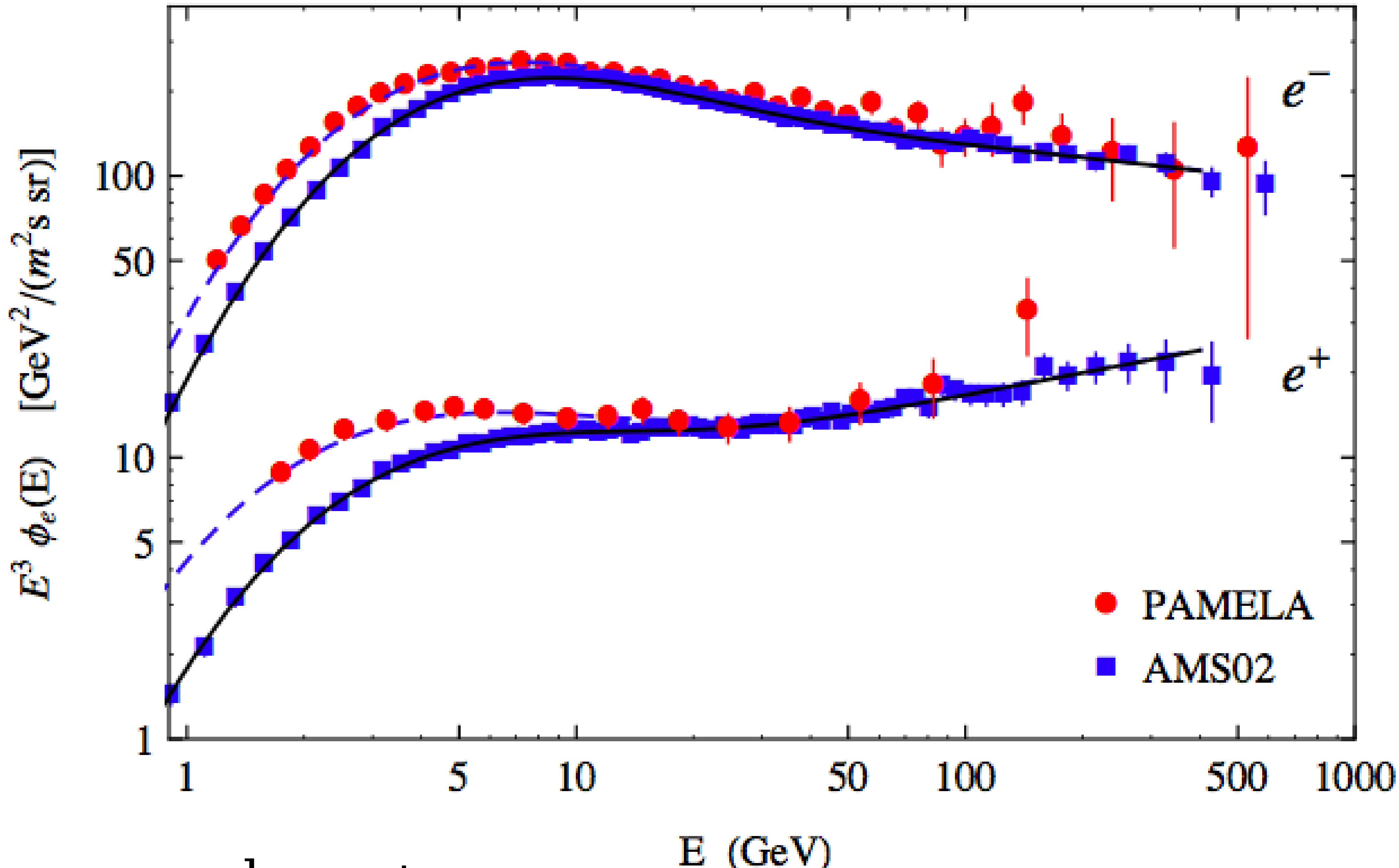
Use the lepton spectra as a *“cosmic ray clocks”*



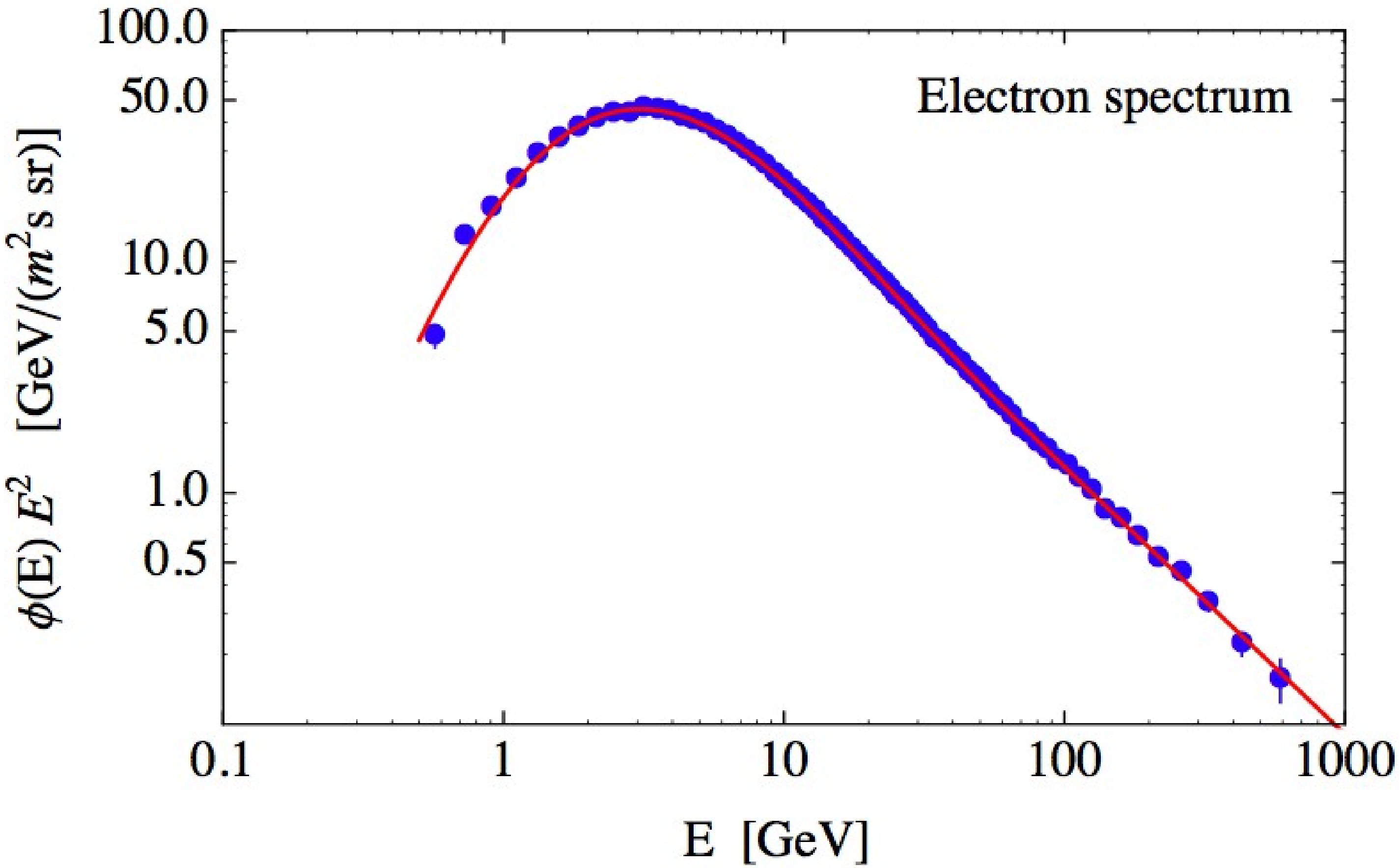
Where are the imprints of energy losses ?

Electron and Positron fluxes

very smooth spectra



Fits: power laws +
Solar modulations (FFA (Force Field) approximation)
+ hardening around 30 GeV



Fit =

$K\ E^{-3.17}$

$\otimes$

FFA Solar Modulations (1.44GeV)]

It is (in my view) difficult to accommodate a softening feature in the spectrum below 500 GeV

"hide the feature at low energy"

$E^* \lesssim 3$ GeV

$T_{\rm loss} \approx 100$ Myr

"push it to high energy"

$E^* \gtrsim 500$ GeV

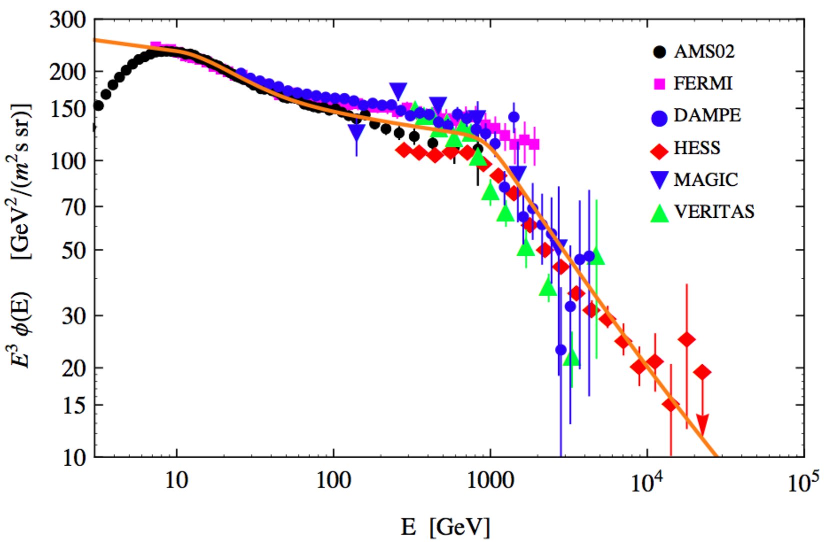
$T_{\rm loss} \approx 1$ Myr

Possible (and "natural") choice: identification of the sharp softening observed by the Cherenkov telescopes in the spectrum of $(e^+ + e^-)$ as the critical energy

$$E^* = E_{\rm HESS} \simeq 900 \text{ GeV}$$

$$T_{\rm confinement}[E \simeq 900 \text{ GeV}] \simeq 0.7 \div 1.3 \text{ Myr}$$

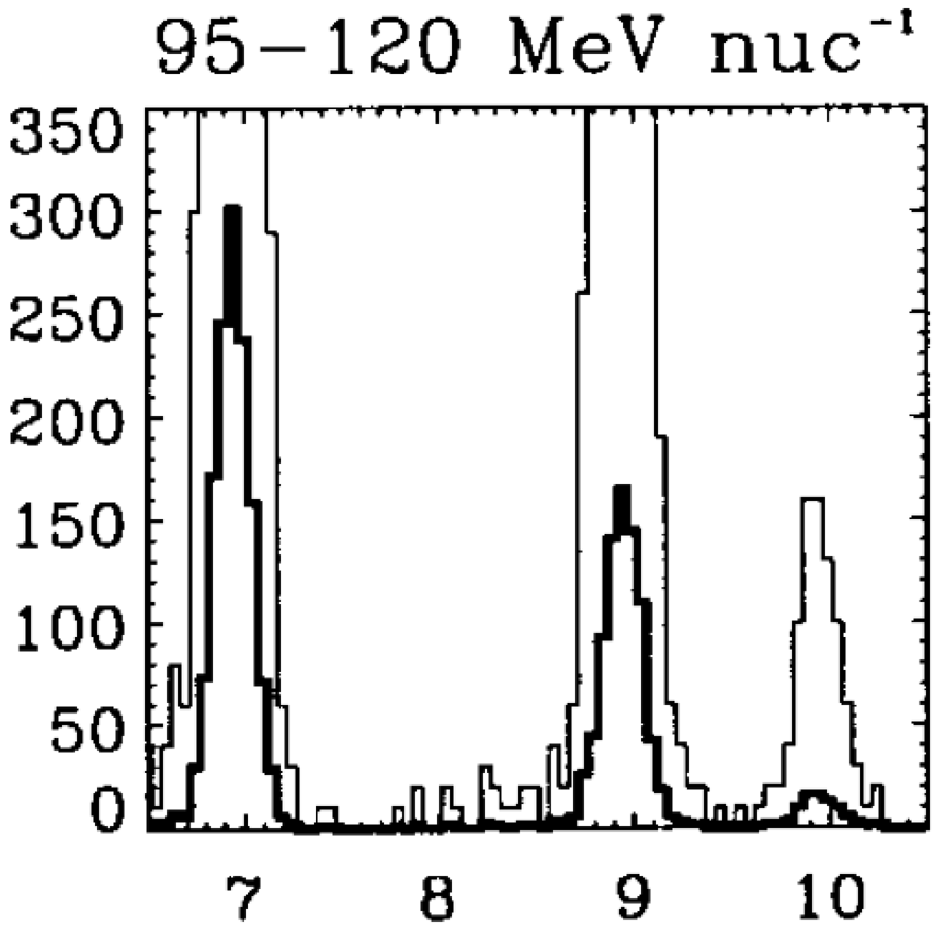
Range depends on volume of confinement



Propagation of positrons and antiprotons is approximately equal for

$$E \lesssim E^* \simeq 900 \text{ GeV}$$

Direct measurement of the cosmic ray "age"
unstable isotope Beryllium-10. $(T_{1/2} \simeq 1.51 \pm 0.04 \text{ Myr})$



N.E. Yanasak *et al.* Astrophys. J. **563**, 768 (2001).

Measurements
of Beryllium 10

Compare with
flux of stable isotopes

Decay suppression:
infer residence time

$$\langle P_{\rm surv} \rangle = 0.12 \pm 0.01$$

Estimate of suppression
in original paper

Extracting $\langle t_{\rm age} \rangle$ from $\langle P_{\rm surv} \rangle$

is in general *model dependent*
[depends on the distribution of the age]

Single age
for CR:

$$\langle P_{\rm surv} \rangle = e^{-t/\tau}$$

Distribution of ages

$$\langle P_{\rm surv} \rangle = \int_0^\infty dt \, \boxed{F(t, \langle t \rangle)} \, e^{-t/\tau}$$

Work of

N.E. Yanasak *et al.*

Astrophys. J. **563**, 768 (2001).

$E_0 = 70\text{–}145$ MeV/nucleon

$$\langle P_{\rm surv} \rangle = 0.12 \pm 0.01$$

$$\langle t_{\rm age} \rangle \simeq 15.0 \pm 1.6 \text{ Myr}$$

[Leaky Box framework]

Result reinterpreted with longer lifetimes in different frameworks

M. Kruskal, S. P. Ahlen and G. Tarlé,

Astrophys. J. **818**, no. 1, 70 (2016)

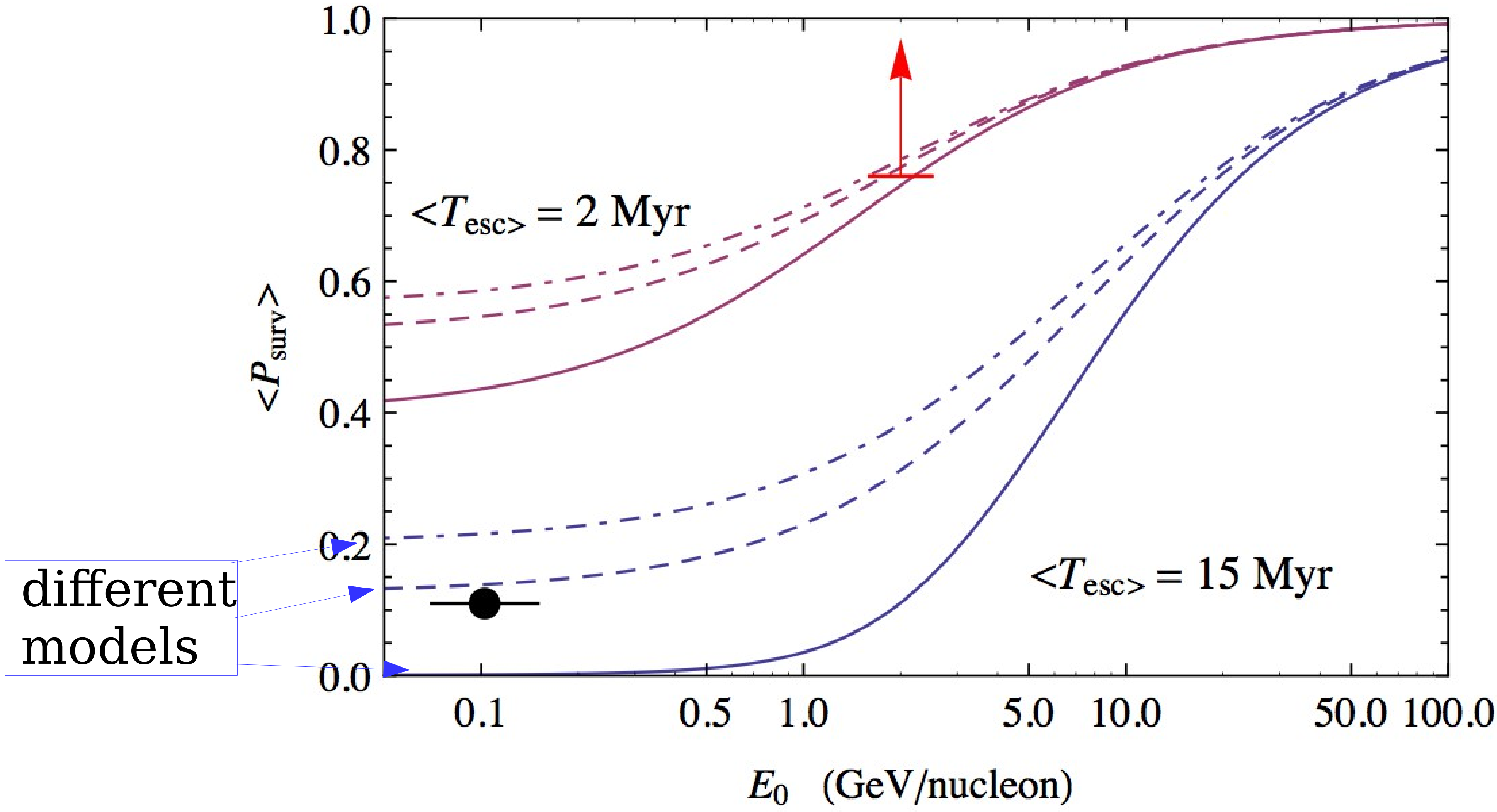
$E_0 = 2$ GeV/nucleon

very important to confirm !

$$\langle P_{\rm surv} \rangle \approx 1$$

$$\langle t_{\rm age} \rangle \leq 2.0 \text{ Myr}$$

Much smaller sensitivity to the modeling “theory”



N.E. Yanasak *et al.*

Astrophys. J. **563**, 768 (2001).

M. Kruskal, S. P. Ahlen and G. Tarlé,

Astrophys. J. **818**, no. 1, 70 (2016)

Proton versus electron

Acceleration in sources

Cosmic Ray generation

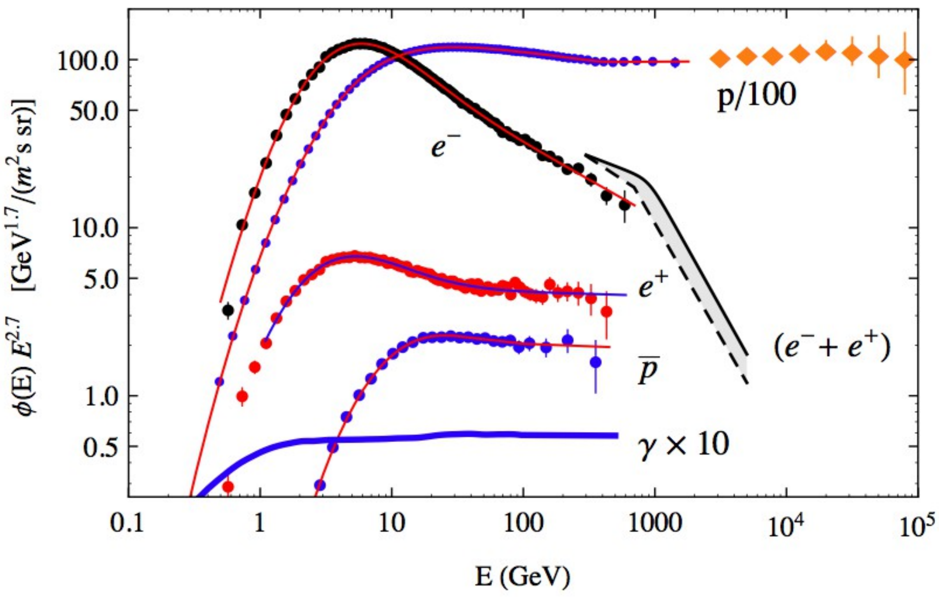
Problem of central importance in High Energy Astrophysics

If: positrons and antiprotons have equal propagation properties.

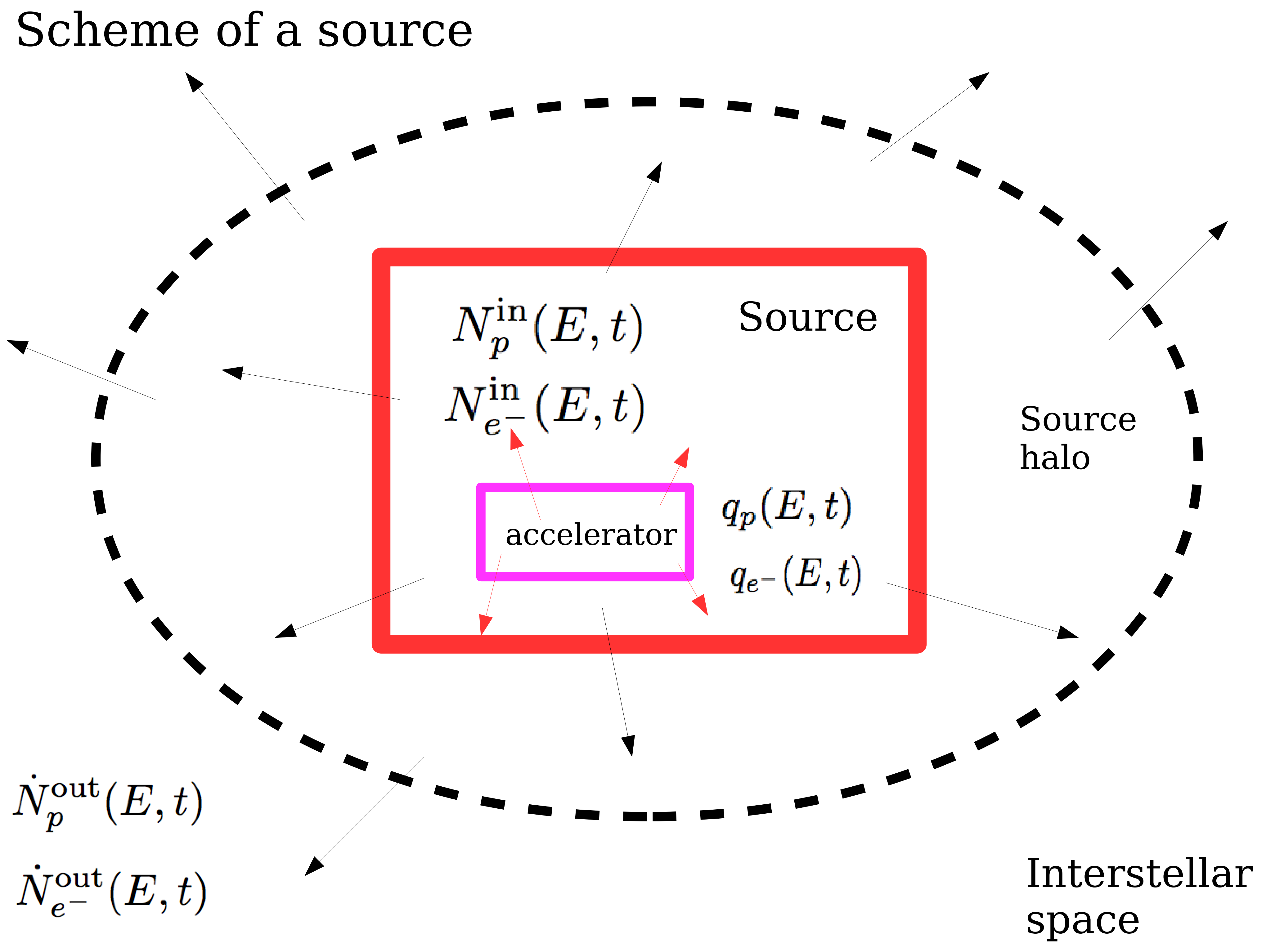
Then: also electron and protons have also the same propagation properties

But then:

why are the electron the proton spectra so different from each other ?!



The e/p difference must be generated by the sources


Scheme of a source
$N_p^{\rm in}(E,t)$
$N_{e^-}^{\rm in}(E,t)$
Source
accelerator
$q_p(E,t)$
$q_{e^-}(E,t)$
Source halo
$\dot{N}_p^{\rm out}(E,t)$
$\dot{N}_{e^-}^{\rm out}(E,t)$
Interstellar space

Primary Cosmic Rays:

understand the Accelerators

Nearly certainly the accelerators are *transients*

A single accelerator

t_i (Accelerator is born)

$t_i + T$ (Accelerator "disappears")

Integrating over its entire lifetime, the Accelerator "releases" in interstellar space populations of relativistic Particles.

$$N_p^{\rm out}(E) \quad , \quad N_{e^-}^{\rm out}(E) \quad , N_{\rm He}^{\rm out}(E) \quad , \ldots.$$

During its lifetime, $t_i < t < t_i + T$

the accelerator is a gamma ray and neutrino emitter

$$q_\gamma(E,t) \quad q_\nu(E,t)$$

Infer the populations of relativistic particles
inside (or near) the accelerators:

$$N_p^{\rm in}(E,t) \qquad N_{e^-}^{\rm in}(E,t)$$

Far from trivial to relate this information
to the CR spectra released in interstellar space

$$N_p^{\rm out}(E) \quad , \quad N_{e^-}^{\rm out}(E)$$

"Secondary Nuclei" Li, Be, B

Rare nuclei created in the fragmentation of primary (directly accelerated) more massive nuclei

Some examples:

$$^{12}\mathrm{C} + p \to {}^{10}\mathrm{B} + 2\,p + n$$

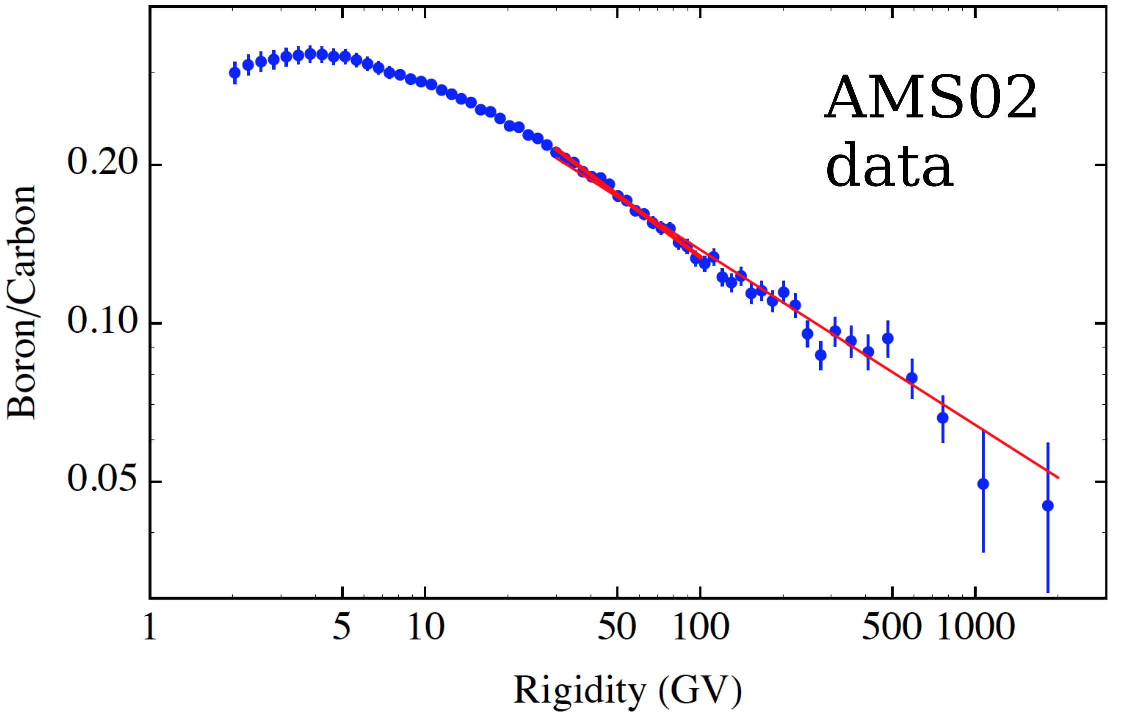
$$^{12}\mathrm{C} + p \to {}^{11}\mathrm{B} + 2\,p$$

$$^{16}\mathrm{O} + p \to {}^{11}\mathrm{B} + {}^{4}\mathrm{He} + 2\,p$$

....

$$\frac{\text{secondary nuclei}}{\text{primary nuclei}} \Longrightarrow$$

"grammage" traversed by the nuclei



$$\frac{\text{Boron}}{\text{Carbon}} \approx 0.21 \left(\frac{p/Z}{30 \text{ GV}}\right)^{-0.33}$$

$$\frac{\text{Boron}}{\text{Carbon}} \approx 0.21 \left(\frac{p/Z}{30 \text{ GV}} \right)^{-0.33}$$

Approximation of constant fragmentation cross sections

Interpretation in terms of Column density

$$\langle X \rangle \approx 4.7 \left(\frac{p/Z}{30 \text{ GV}} \right)^{-0.33} \frac{\text{g}}{\text{cm}^2}$$

[Assuming that the column density is accumulated during *propagation in interstellar space*]

$$\langle T_{\text{age}} \rangle \simeq 30 \text{ Myr} \left[\frac{0.1 \text{ g cm}^{-3}}{\langle n_{\text{ism}} \rangle} \right] \left(\frac{|p/Z|}{30 \text{ GV}} \right)^{-0.33}$$

Residence time inferred from B/C ratio
assuming that the column density crossed by the nuclei is accumulated in interstellar space

is *inconsistent* [as it is too long]
with the hypothesis that the energy losses of $e^{\pm}$
are negligibly small.

Possible solutions

1. [Energy dependence of fragmentation Cross sections]

2. Most of the column density inferred from the B/C ratio
   is integrated not in interstellar space
   but inside or in the envelope of the sources
   [Cowsik and collaborators]

The observations of the anti-particle fluxes

brings us to a *"Crossroad"*
in our studies of Cosmic Rays

electrons
positrons

protons
antiprotons

Propagation properties
in the Milky Way

[A] *"Conventional Scenario"*

Different propagation properties for $E \gtrsim 3 \text{ GeV}$

[B] *"Alternative Scenario"*

Equal propagation properties for $E \lesssim 900 \text{ GeV}$

Conventional propagation scenario:

A1. Very long lifetime for cosmic rays

A2. Difference between electron and proton spectra shaped by propagation effects

A3. New hard source of positrons is required

A4. Secondary nuclei generated in interstellar space

Alternative propagation scenario:

B1. Short lifetime for cosmic rays

B2. Difference between electron and proton spectra generated in the accelerators

B3. antiprotons and positrons of secondary origin

B4. Most secondary nuclei generated in/close to accelerators

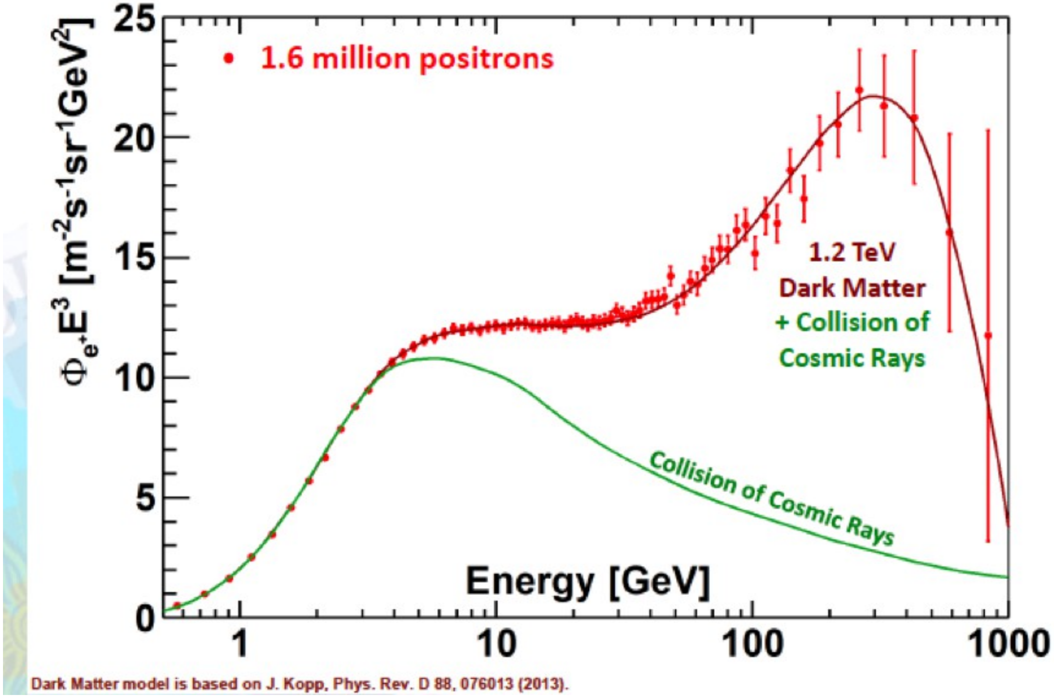
How can one discriminate between the two scenarios ?

1. Extend measurements of e+- spectra
   Different cutoffs can confirm the conventional picture

2. Extend measurements of secondary nuclei [B, Be, Li]. Look for signatures of nuclear fragmentation inside/near the accelerators.

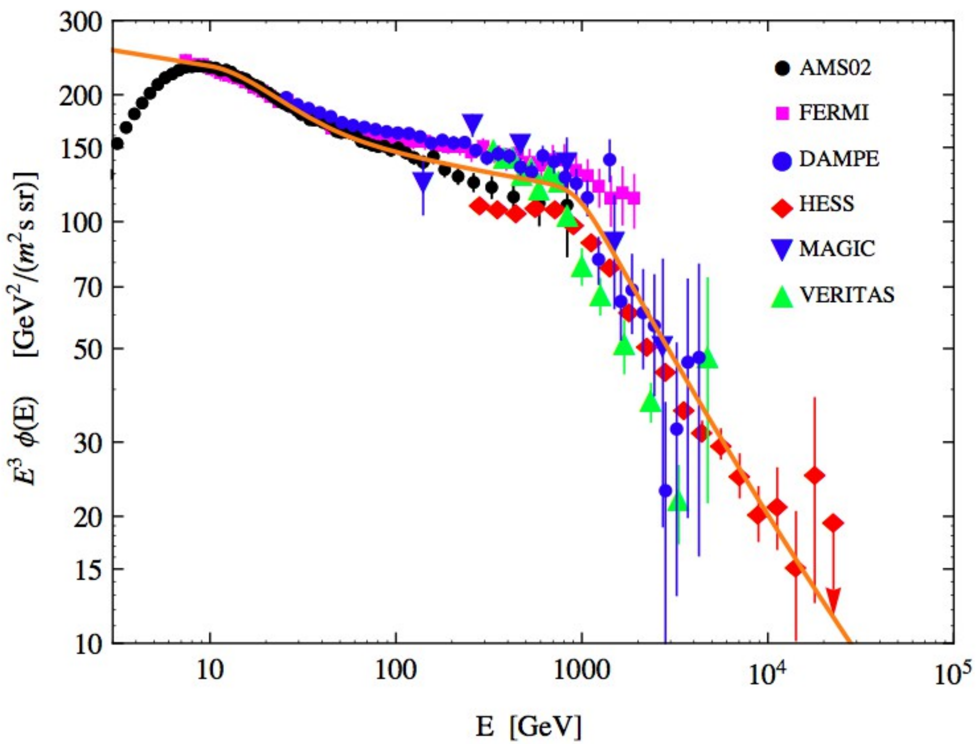
3. Study the space and energy distributions of the relativistic e+- in the Milky Way
   [from the analysis of diffuse Galactic gamma ray flux]

4. Develop an understanding of the CR sources
   Study the populations of e- and p in young SNR (assuming that they are the main sources of CR)



Electrons and
Positrons both have
a softening
at energy 500 – 1000 TeV.

Determining accurately
the shapes of
the two spectra is crucial



Conclusions:

An understanding of the origin of the
positron and antiproton fluxes
is of central importance for High Energy Astrophysics.

This problem touches the
"cornerstones" of the field
and it has profound and broad implications

Discovery of Dark Matter !!?
Possible antiparticle accelerators
Spectra (e and p) released by CR accelerators,
Fundamental properties of CR Galactic propagation

Crucial crossroad for the field.