Secondaries from supernova remnants and new AMS-02 data

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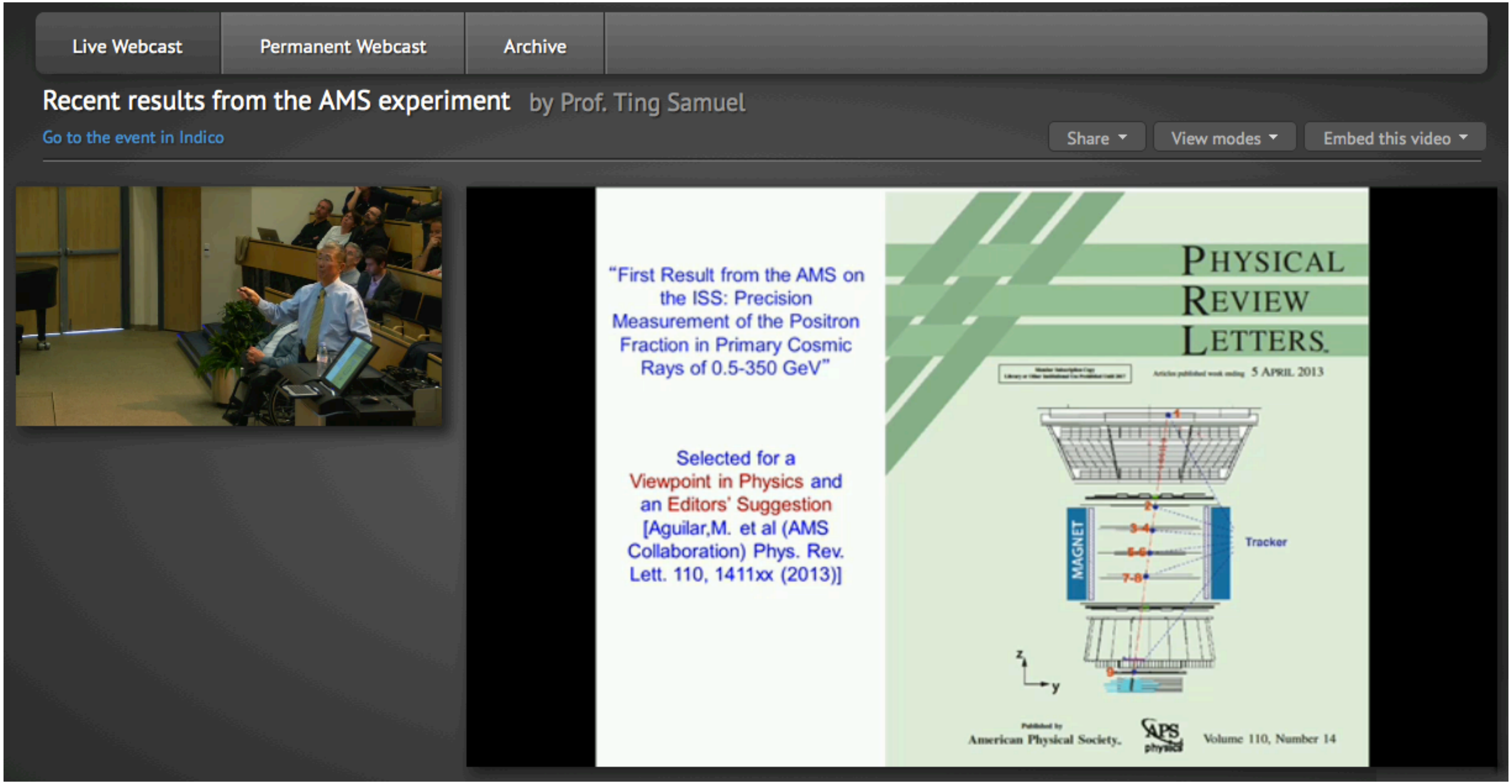
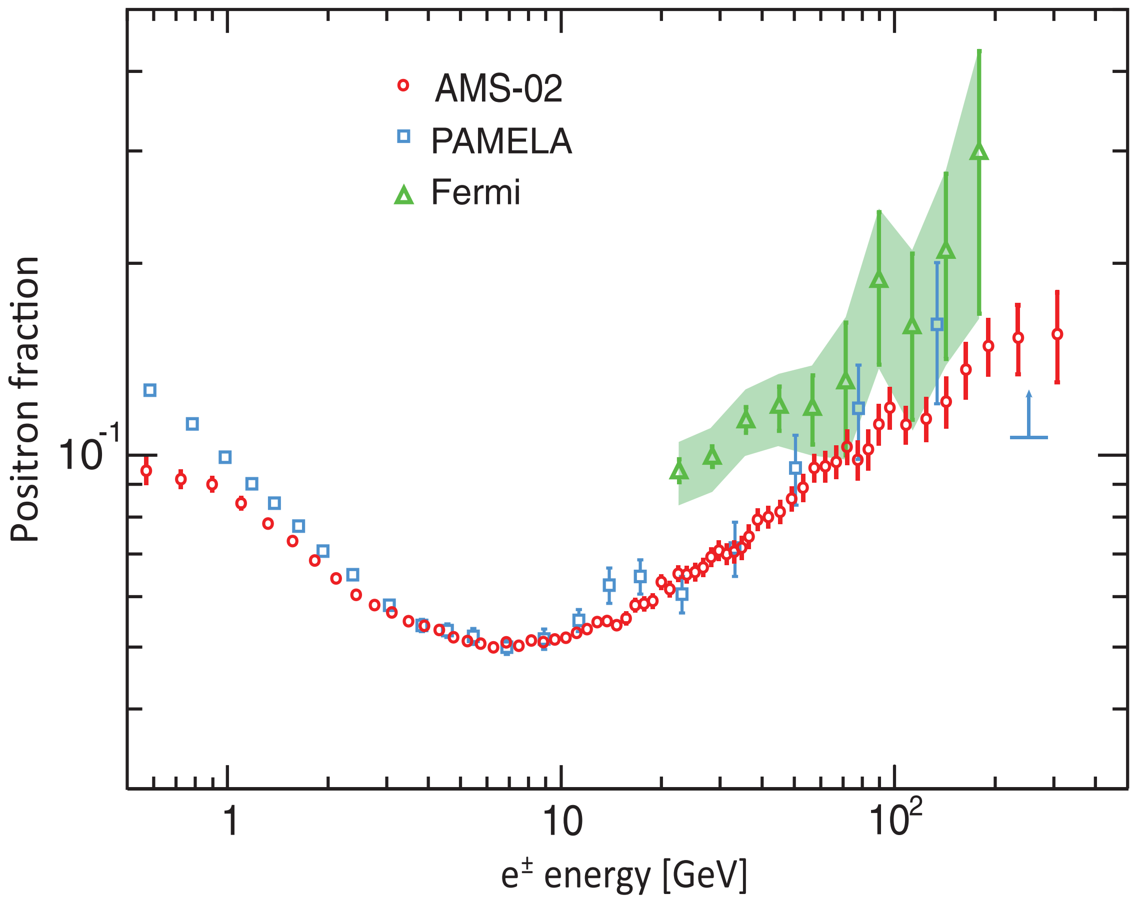
New AMS results



"There's no such thing as disappointing."

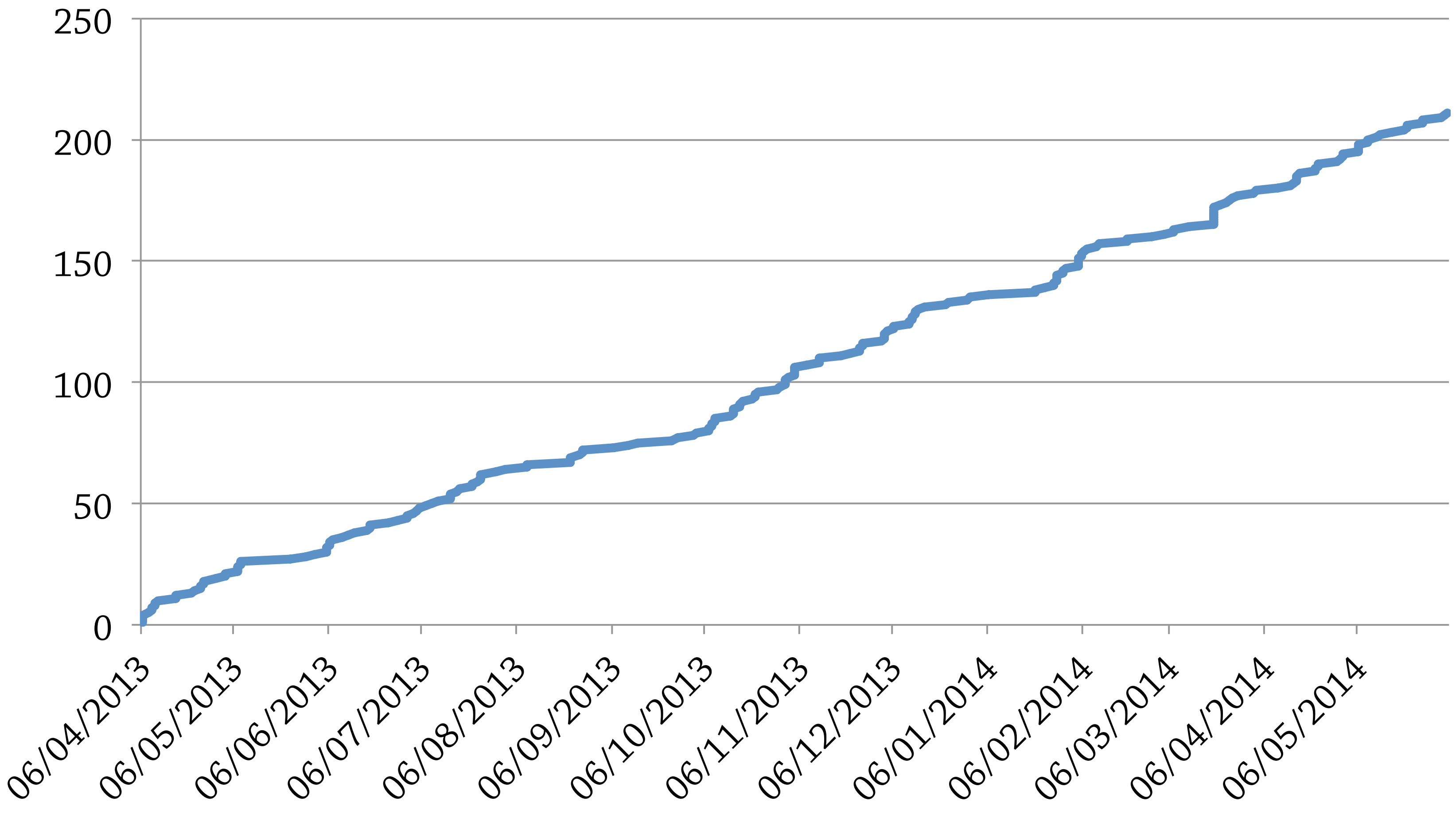
(Sam Ting)

New AMS results



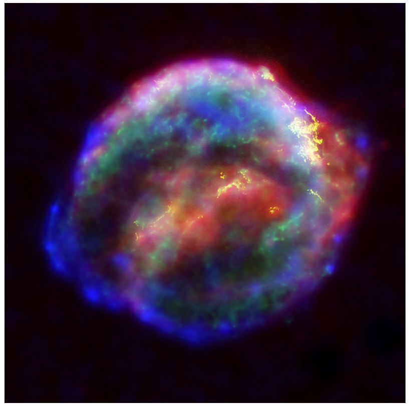
references to the paper

cumulative number of citations



Secondaries from the Source?

Common belief: secondaries from propagation dominate since the grammage in the ISM is larger than in the source



$$\langle \tau_{\mathrm{src}} \rangle \lesssim \tau_{\mathrm{SNR}} \approx 10^{4\ldots5}\,\mathrm{yr}$$

$$n_{\mathrm{src}} \lesssim 10\,\mathrm{cm}^{-3}$$

$$\Rightarrow \lambda_{\mathrm{src}} \approx 0.2\,\mathrm{g\,cm}^{-2}$$

$$\langle \tau_{\mathrm{ISM}} \rangle \sim \tau_{\mathrm{esc}} \approx 10^{7}\,\mathrm{yr}$$

$$n_{\mathrm{ISM}} \approx 0.1\,\mathrm{cm}^{-3}$$

$$\Rightarrow \lambda_{\mathrm{ISM}} \approx \mathrm{few}\,\mathrm{g\,cm}^{-2}$$

However, the secondaries from the source can have a much harder spectrum!

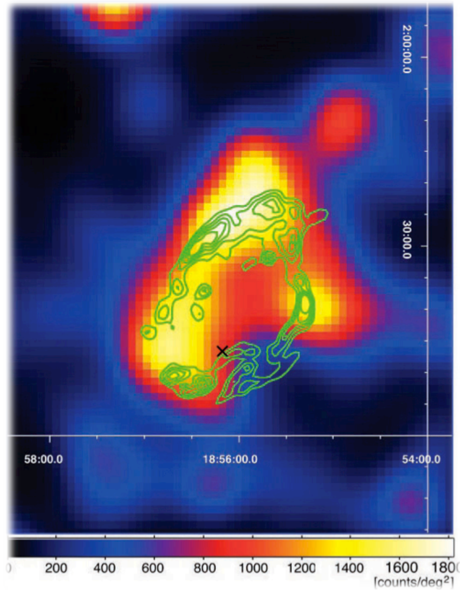
Secondary Origin of $e^{\pm}$

Rise in positron fraction could be due to secondary positrons produced during acceleration and accelerated along with primary electrons

Blasi, PRL **103** (2009) 051105

Assuming production of galactic CR in SNRs, positron fraction can be fitted

This effect is guaranteed, only its size depends on normalisation and one free parameter that needs to be fitted from observations

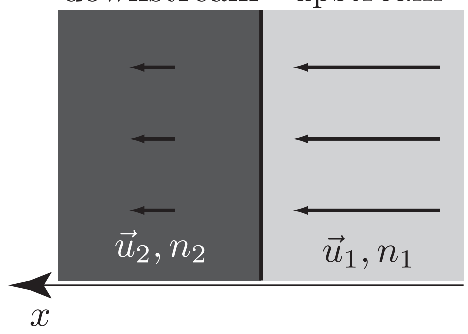


W44 in γ-rays from *Fermi*-LAT

DSA – Test Particle Approximation

Acceleration determined by compression ratio:

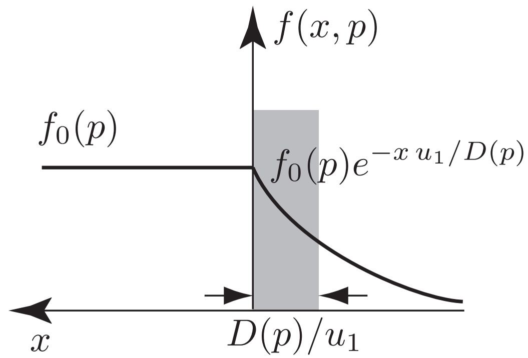
$$r = \frac{u_1}{u_2} = \frac{n_2}{n_1}, \qquad \gamma = \frac{3r}{r-1}$$



Solve transport equation,

$$u\frac{\partial f}{\partial x} = D\frac{\partial^2 f}{\partial x^2} + \frac{1}{3}\frac{\mathrm{d}u}{\mathrm{d}x}p\frac{\partial f}{\partial p}$$

$$f \xrightarrow{x\to-\infty} f_{\mathrm{inj}}(p), \qquad \left|\lim_{x\to\infty} f\right| \ll \infty$$



Solution for $x < 0:$

$$f = f_{\mathrm{inj}}(p) + (f^0(p) - f_{\mathrm{inj}}(p))e^{-x\,u_1/D(p)}$$

where

$$f^0(p) = \gamma\int_0^p \frac{\mathrm{d}p'}{p'}\left(\frac{p'}{p}\right)^{\gamma} f_{\mathrm{inj}}(p') + Cp^{-\gamma}$$

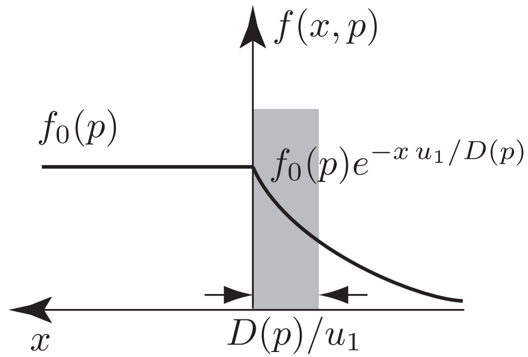
As long as $f_{\mathrm{inj}}(p)$ is softer than $p^{-\gamma}$, at high energies:

$$f(x,p) \sim p^{-\gamma}$$

DSA with Secondaries

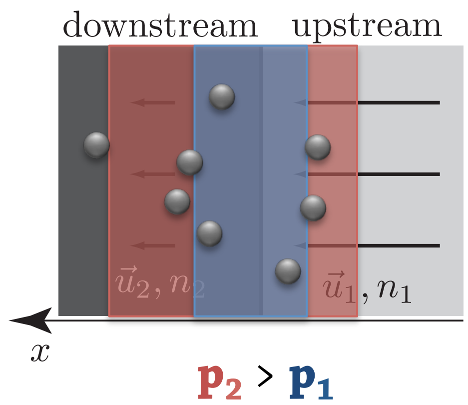
- Secondaries get produced with primary spectrum:

$$q_{e^\pm} \propto f_{\mathrm{CR}} \propto p^{-\gamma}$$



- Only particles with $|x| \lesssim D(p)/u$ can be accelerated

- Bohm diffusion: $D(p) \propto p$



- Fraction of secondaries that go into acceleration $\propto p$

- Equilibrium spectrum

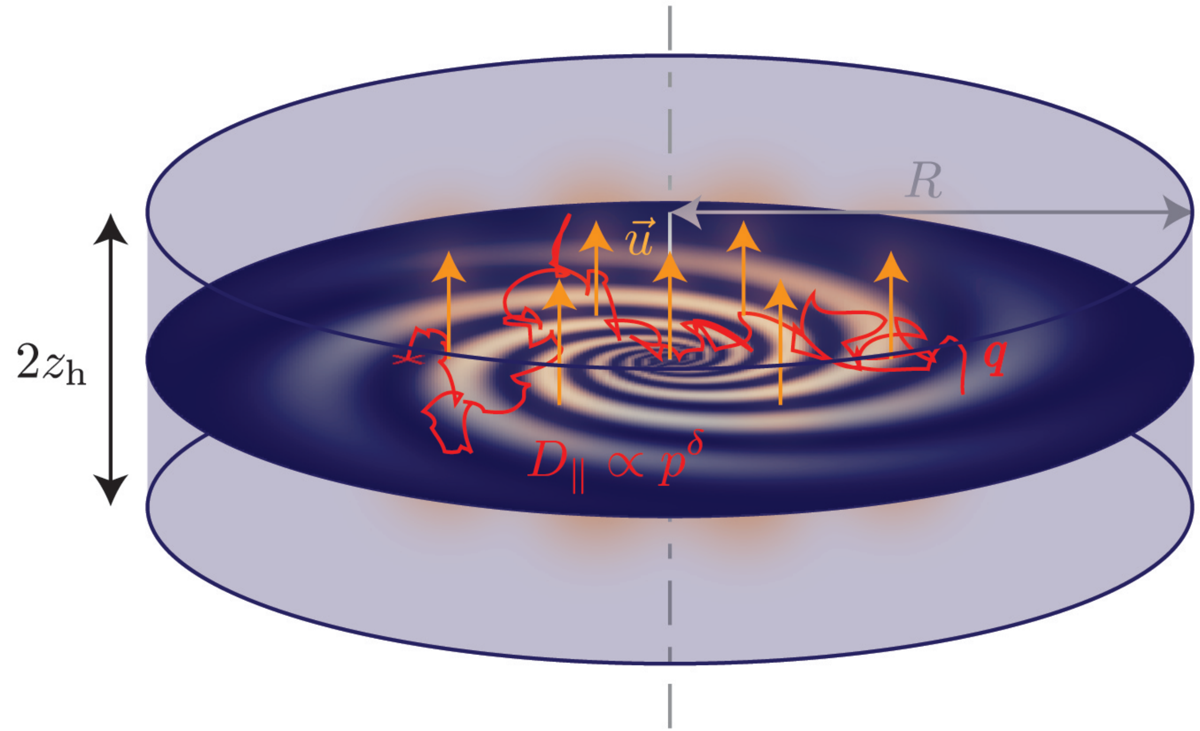
$$n_{e^\pm} \propto q_{e^\pm} \left(1 + \frac{p}{p_0}\right) \propto p^{-\gamma} + p^{-\gamma+1}$$

Rising positron fraction at source

Propagation Setup

$$\frac{\partial n_i}{\partial t} - \vec{\nabla} \cdot \left(D_{xx} \cdot \vec{\nabla} n_i - \vec{u}\, n_i \right) - \frac{\partial}{\partial p} p^2 D_{pp} \frac{\partial}{\partial p} \frac{1}{p^2} n_i - \frac{\partial}{\partial p} \left(\frac{\mathrm{d}p}{\mathrm{d}t} n_i - \frac{p}{3} \left(\vec{\nabla} \cdot \vec{u} \right) n_i \right)$$

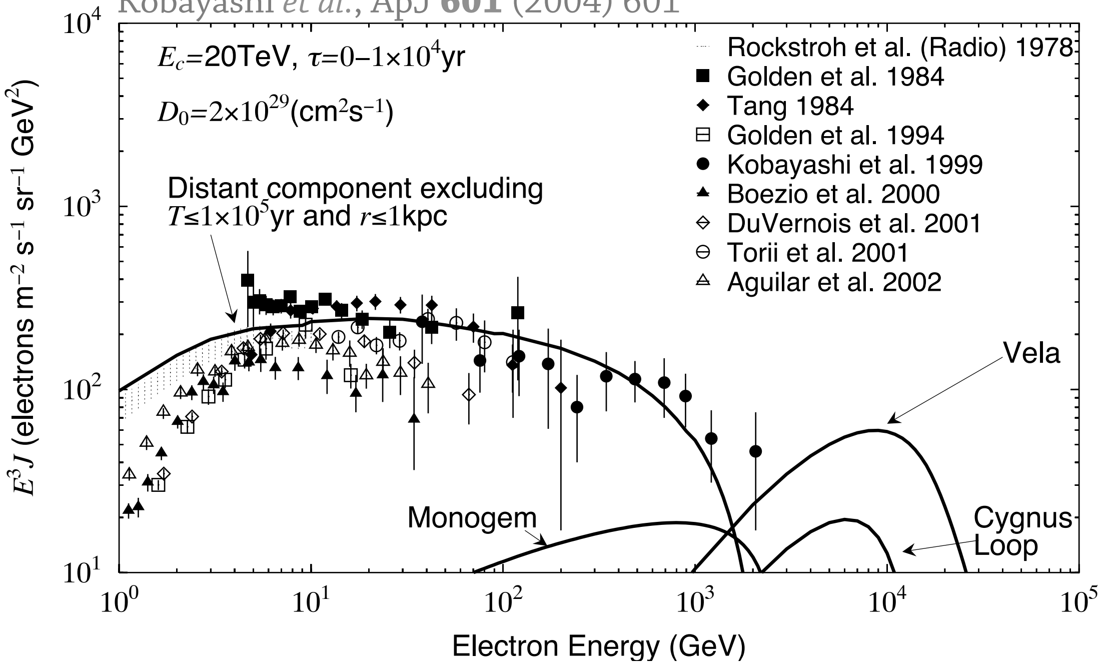
$$= q + \sum_{i<j} \left(c\, \beta\, n_{\mathrm{gas}}\, \sigma_{j \to i} + \gamma\, \tau_{j \to i}^{-1} \right) n_j - \left(c\, \beta\, n_{\mathrm{gas}}\, \sigma_i + \gamma\, \tau_i^{-1} \right) n_i \,,$$



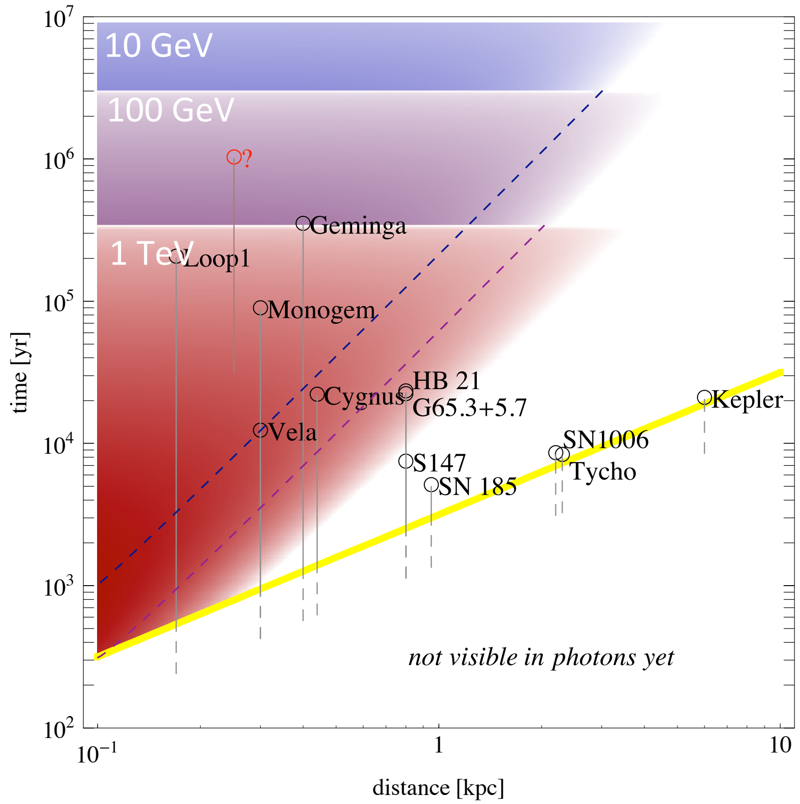
A Hybrid Model

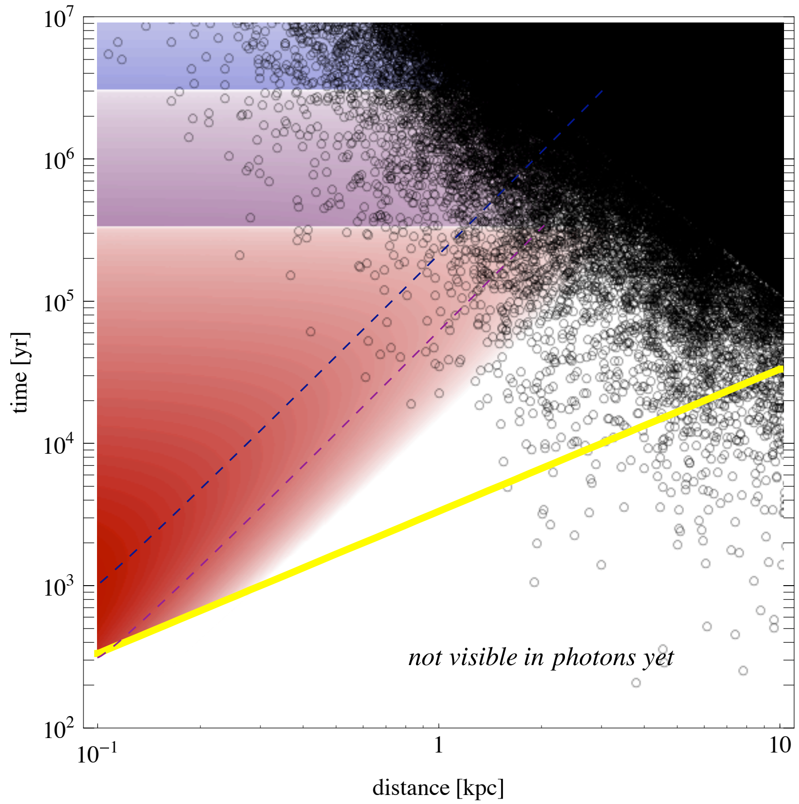
- homogeneous distribution for sources with distances $\gtrsim 1\,\mathrm{kpc}$ or ages $\gtrsim 10^5\,\mathrm{yr}$
- supplement with *known* young and nearby sources

Kobayashi *et al.*, ApJ **601** (2004) 601



A Caveat

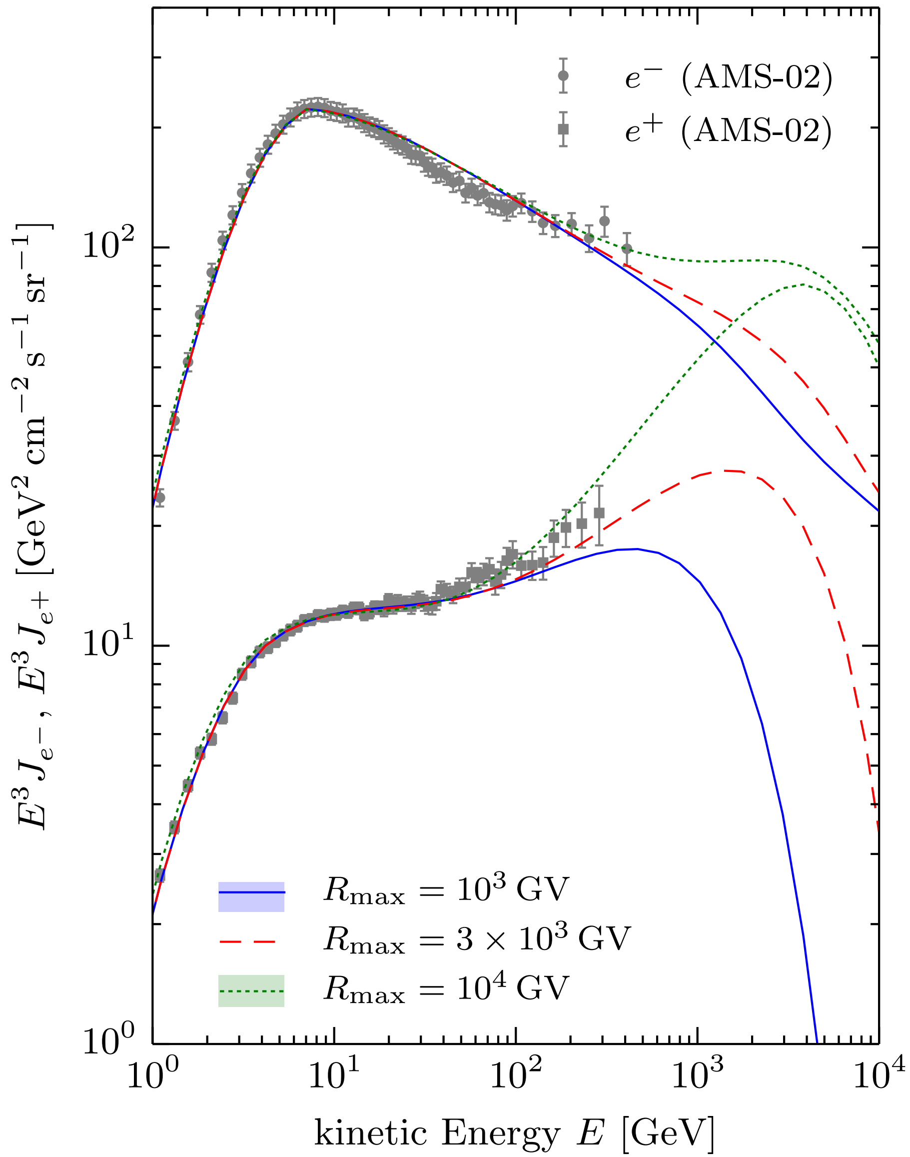




Not only observed sources contribute!

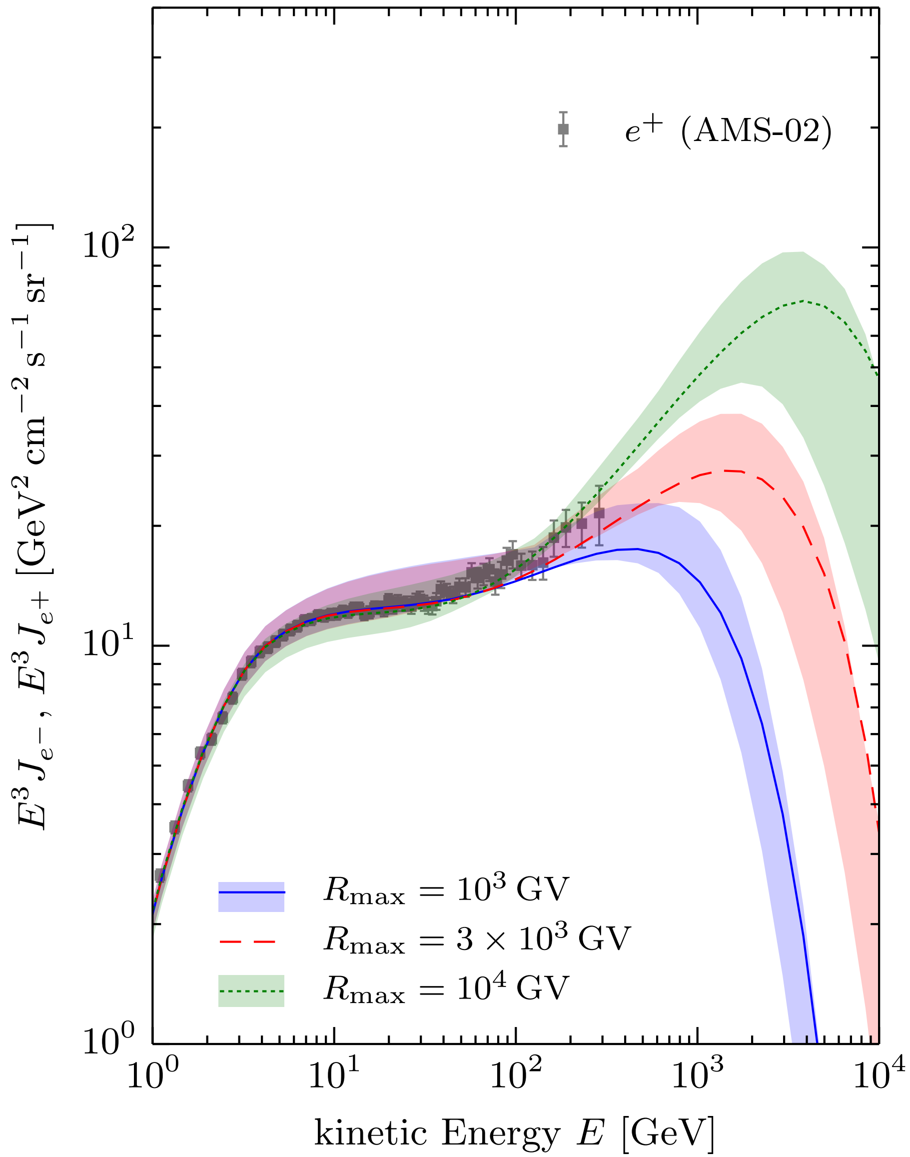
Ahlers, Mertsch, Sarkar, PRD **80** (2009) 123017

Electron and positron fluxes



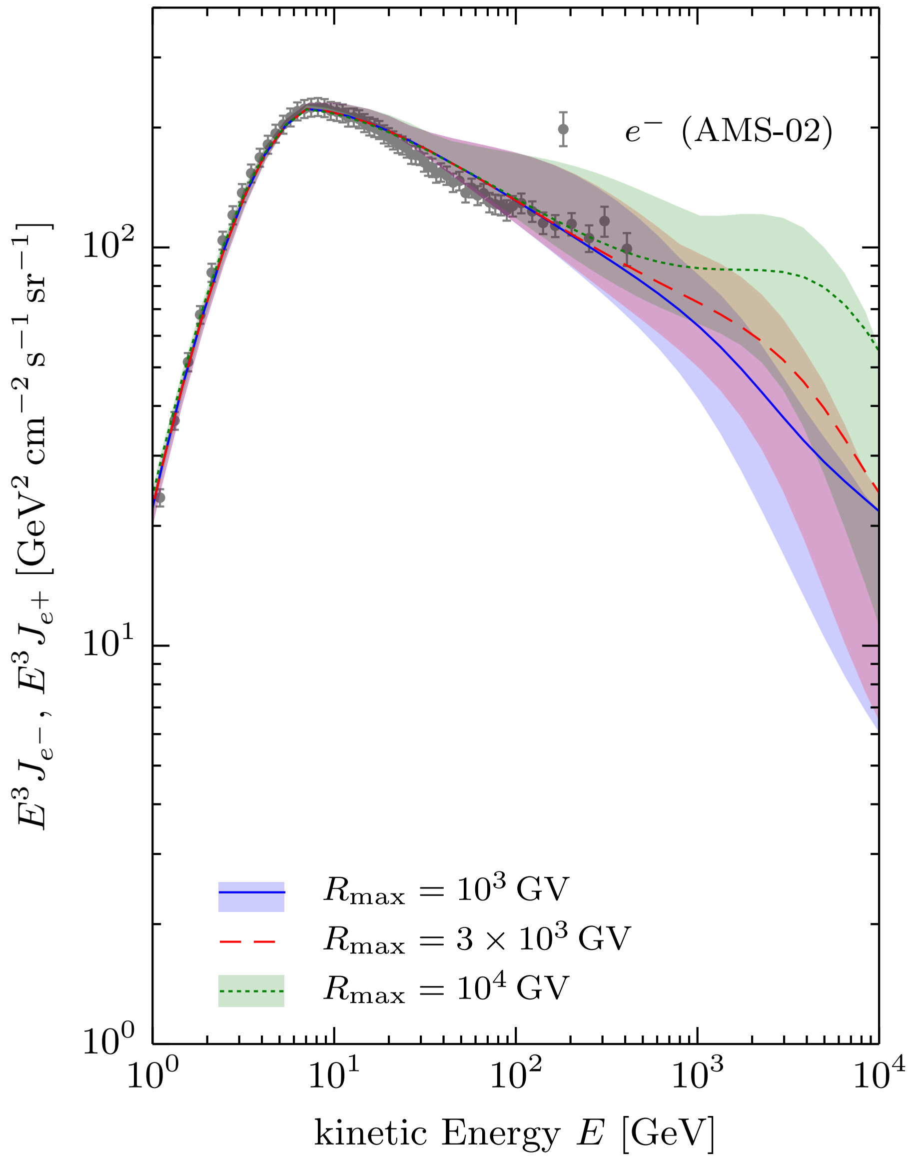
- smooth source distribution (lines)
- both, e^- and e^+ fluxes softer than reported by PAMELA and *Fermi*-LAT
- flattening or cut-off of positron flux depends on maximum energy -> old sources, so most likely TeV to tens of TeV

Electron and positron fluxes



- smooth source distribution (lines)
  point & burst-like sources (bands)
- both, e⁻ and e⁺ fluxes
  softer than reported by
  PAMELA and *Fermi*-LAT
- flattening or cut-off of positron
  flux depends on maximum energy
  -> old sources, so most likely TeV
  to tens of TeV

Electron and positron fluxes



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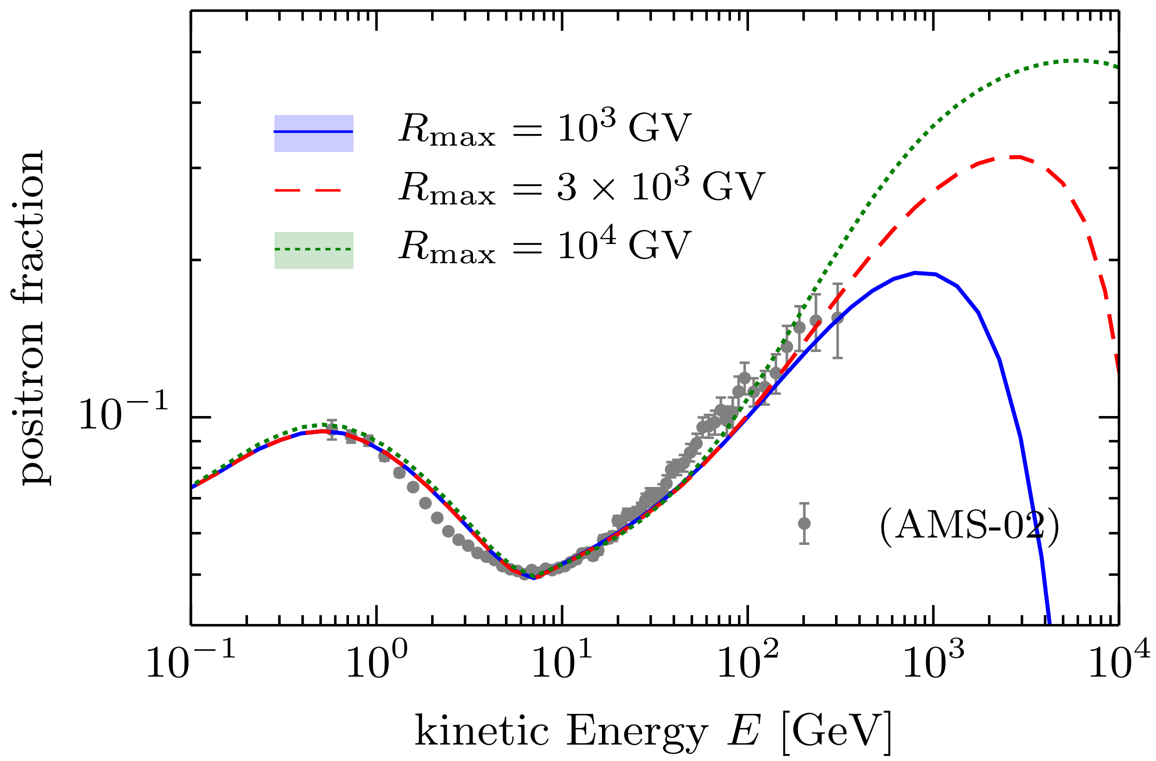
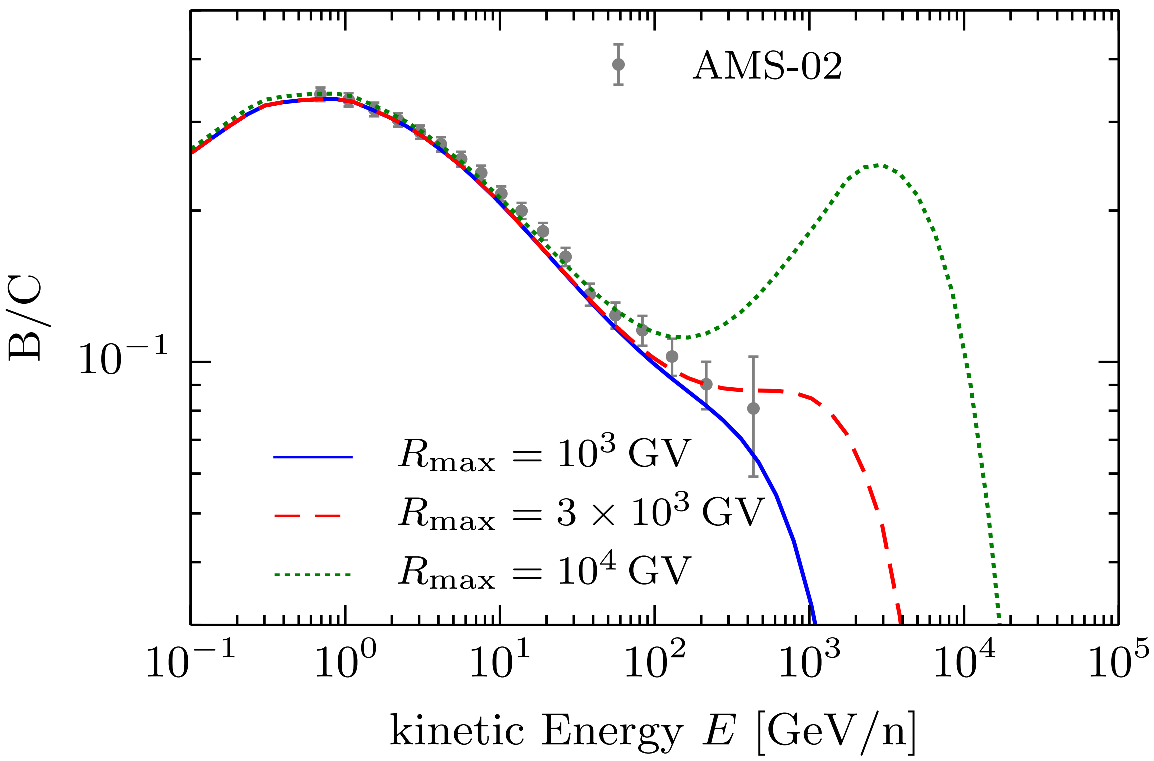
Positron fraction



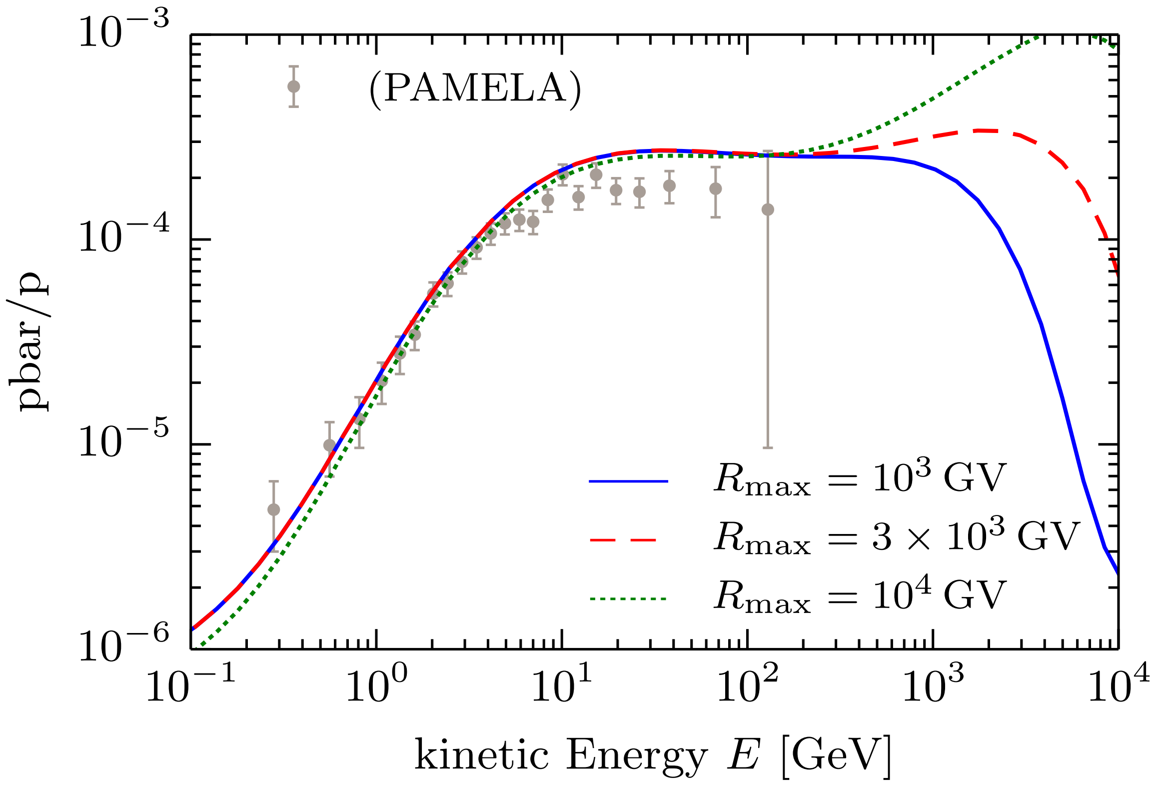
- stochastic fluctuations smaller in positron fraction
- spectral behaviour beyond last data point depends on max energy

Boron-to-Carbon ratio



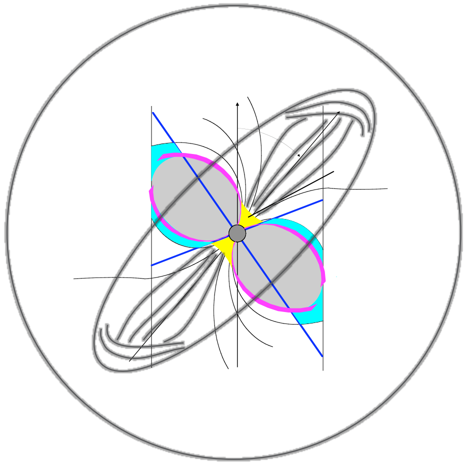
- spectral behaviour depends on maximum energy
- minimum at hundreds of GeV (cf. positron fraction)

Antiproton-to-proton ratio

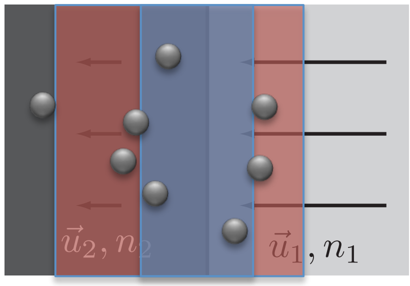


- spectral behaviour depends on maximum energy
- minimum at hundreds of GeV (cf. positron fraction)

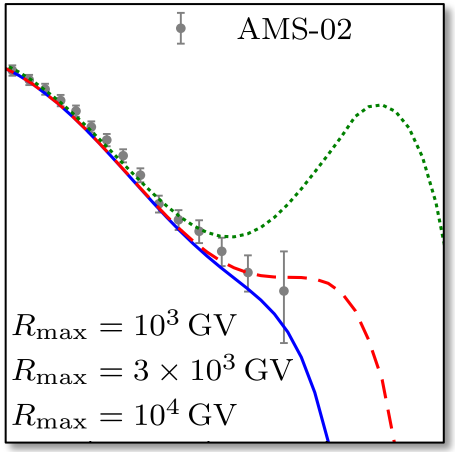
Conclusion



Astrophysical explantions of positron excess: pulsars?



Acceleration of secondary e⁺ in SNRs could explain positron excess



Very predictive model: nuclear secondary-to-primary ratios