The electron plus positron spectrum from annihilation of Kaluza-Klein dark matter and comparison with recent measurements

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- Kaluza-Klein Dark Matter
- LKP annihilation modes
- The effects of propagation
- Total positron fraction
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Kaluza-Klein Dark Matter

- UED (Universal Extra Dimensions)

  ➡ Only 1 extra dimension

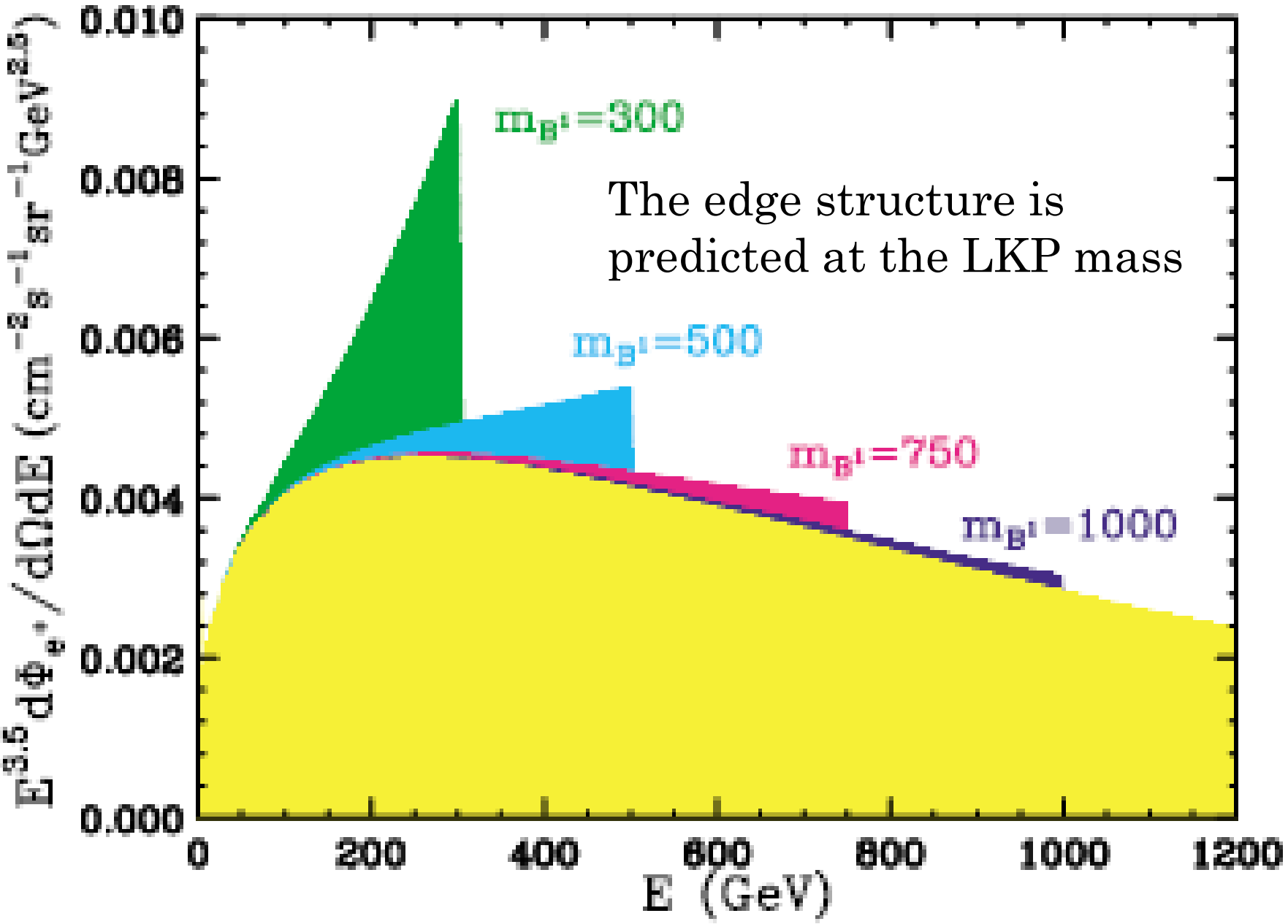
- Kaluza-Klein dark matter mass

$$m^{(n)} = \sqrt{\left(\frac{n}{R}\right)^2 + m_{\mathrm{EW}}^2}$$

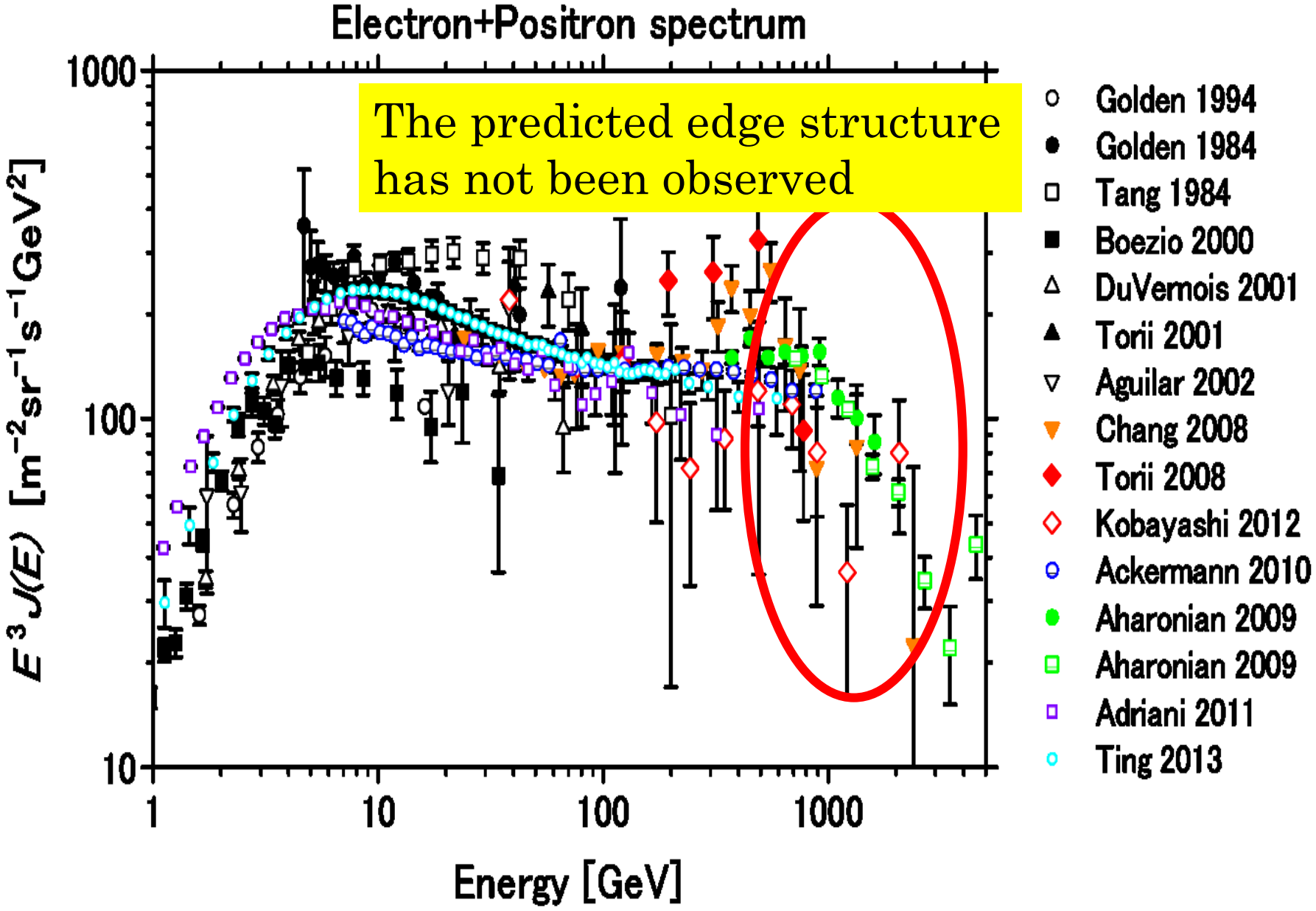
We assume the first excited state (LKP) : $n = 1$

➡ Mass range m_B = 300GeV - 1000GeV

L. Bergstrom et al, Phys. Rev. Lett 94(2005) 131301



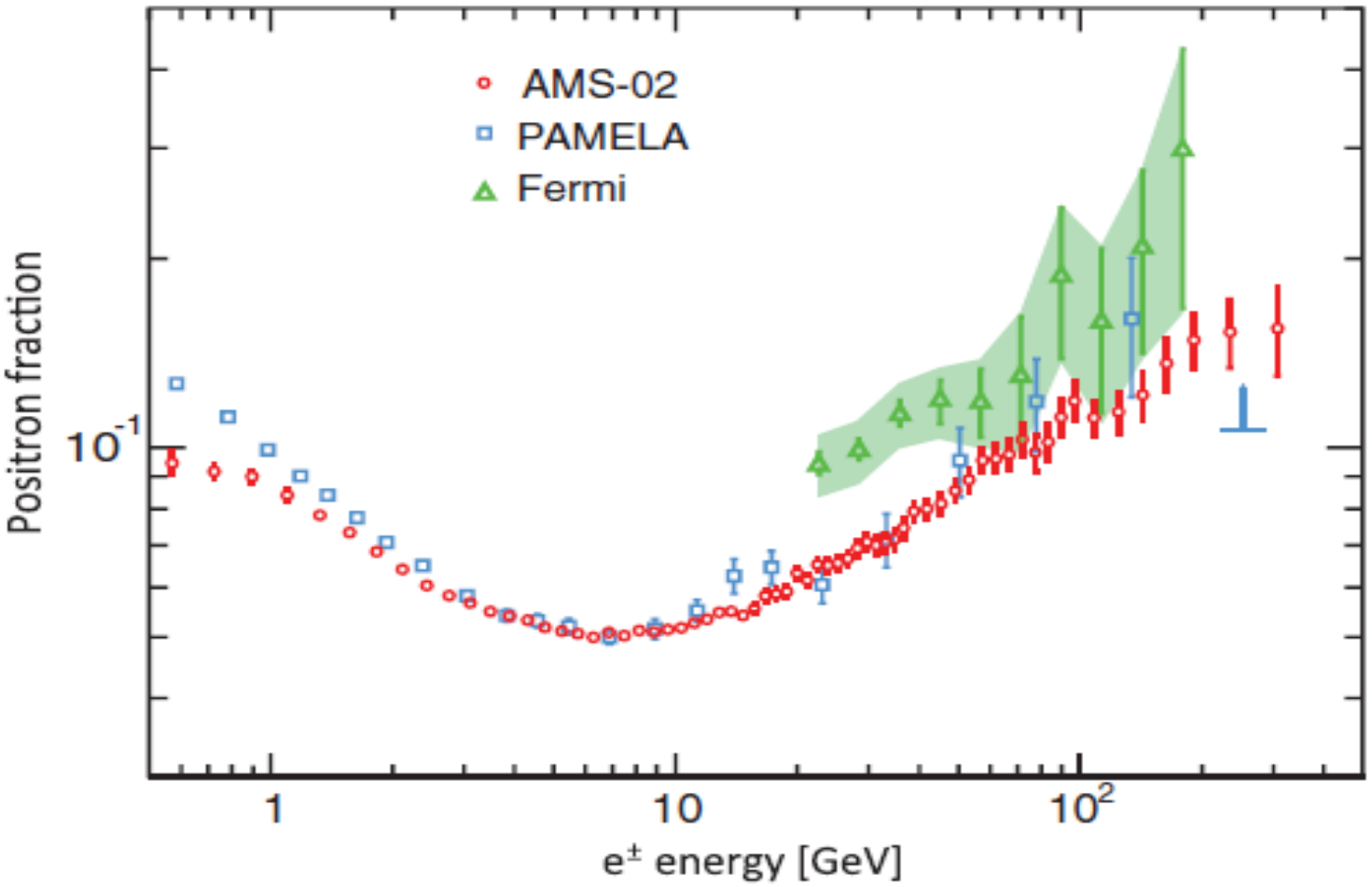
Cheng et al., Phys. Rev. Lett. 89 (2002) 211301


Electron+Positron spectrum
The predicted edge structure has not been observed
$E^3 J(E)$ [$m^{-2} sr^{-1} s^{-1} GeV^2$]
Energy [GeV]
1000
100
10
1
10
100
1000
Golden 1994
Golden 1984
Tang 1984
Boezio 2000
DuVernois 2001
Torii 2001
Aguilar 2002
Chang 2008
Torii 2008
Kobayashi 2012
Ackermann 2010
Aharonian 2009
Aharonian 2009
Adriani 2011
Ting 2013

Positron fraction

By AMS-02 observation…

The positron excess above 10 GeV is reported



M. Aguilar et al., PRL 110. 141102 (2013)

Annihilation modes

- Kaluza-Klein dark matter

There are many modes containing the electron as the final products

Line

Electron – Positron Pair (e^+e^-)

Continuum

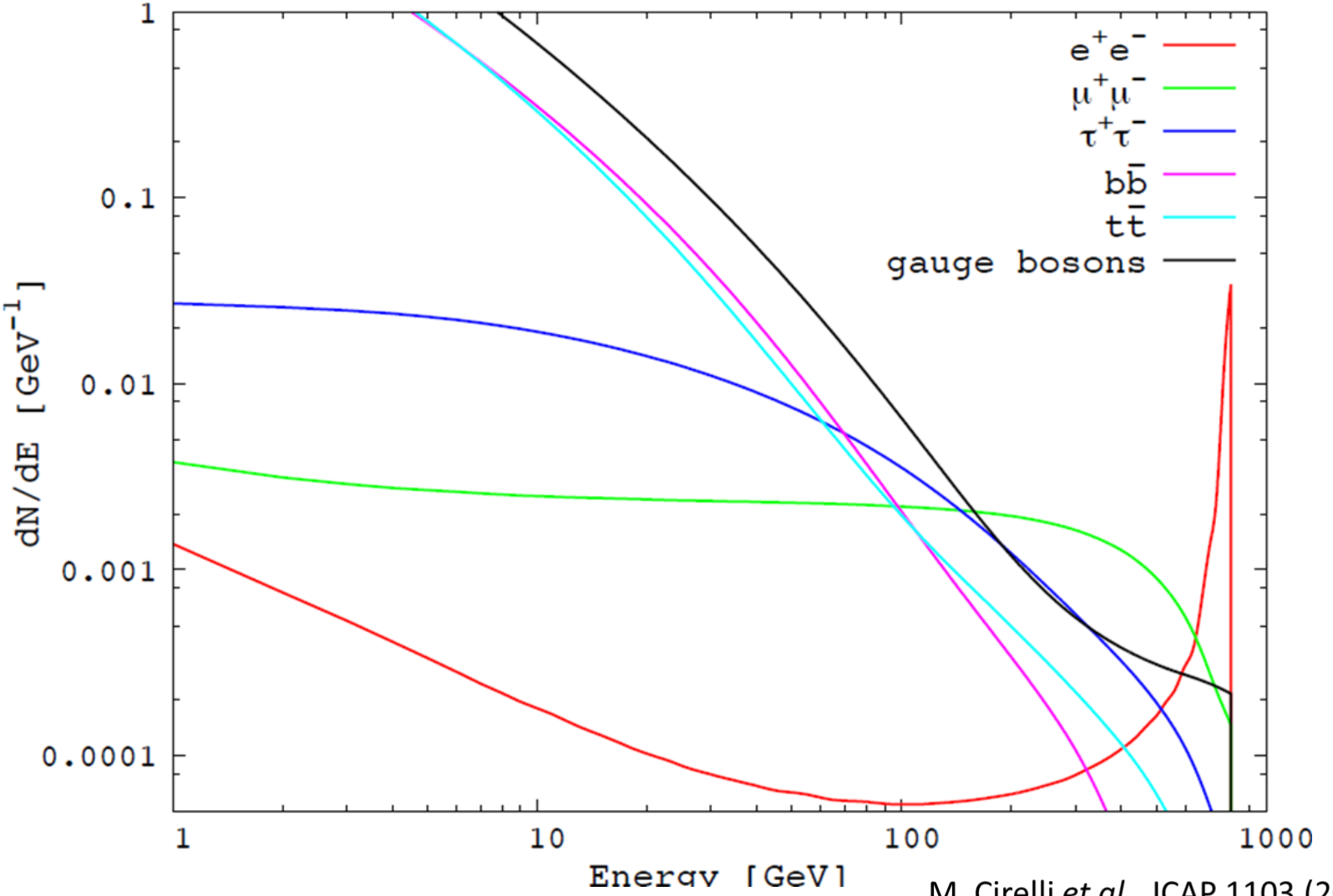
Components	Branching Ratio
Muon Pair ($\mu^+\mu^-$)	20 %
Tauon Pair ($\tau^+\tau^-$)	20 %
Quark Pairs	12 %
Gauge Bosons	1.5 %

Total

L. Bergstrom, Phys. Rev. Lett. 131301 (2005)

Creation

The energy distribution for Line and Continuum components when LKP annihilates in the Galactic halo



M. Cirelli *et al.*, JCAP 1103 (2011) 051

Flux

- The Electron-Positron Flux

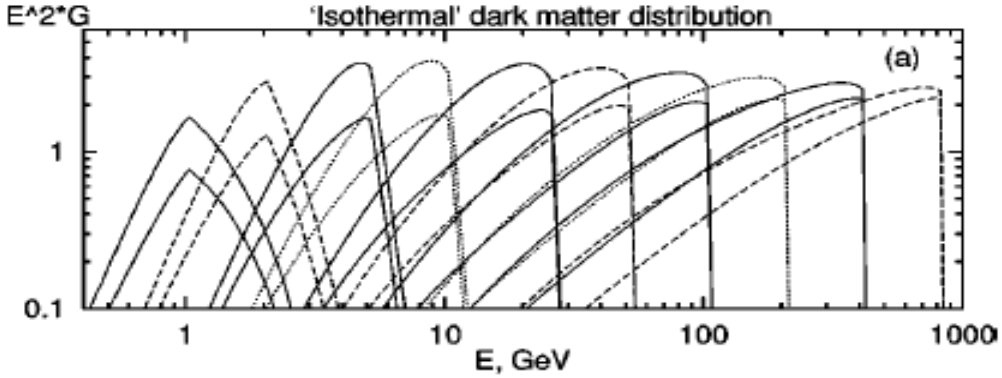
$$\frac{d\Phi_{e+}}{d\Omega dE} = 2.7 \times 10^{-4} B_f \times B \frac{\langle \sigma v \rangle_{\mathrm{LKP}}}{\mathrm{pb}} \left(\frac{\rho_0}{0.3\ \mathrm{GeV/cm^3}} \right)^2 \times \left(\frac{1000\ \mathrm{GeV}}{m_{B^{(1)}}} \right)^2 g\left(1, \frac{E}{m_{B^{(1)}}}\right)\ \mathrm{cm^{-2} s^{-1} sr^{-1} GeV^{-1}}$$

- The Green function for Propagation

$$g\left(1, \frac{E}{m_{B^{(1)}}}\right) \propto \frac{10^{a(\log_{10} E)^2 + b(\log_{10} E) + c}}{E^2} \theta(m_{B^{(1)}} - E)$$

→ By determining the parameters a, b, and c, the form of propagation is determined

I. V. Moskalenko & A. W. Strong, PRD 60 (1999) 063003

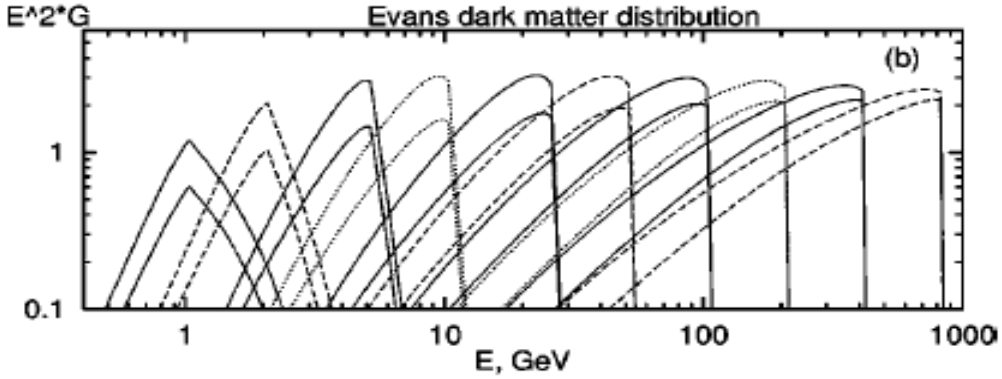


Isothermal model

$\rho = 0.43$ GeV/cm^3 :

Local DM density

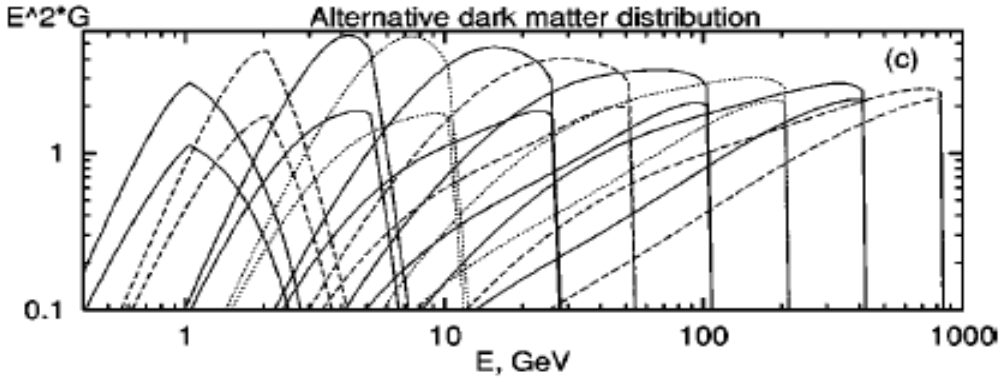
$r_c = 2.8$ kpc : Core radius



Evans model

$\rho = 0.51$ GeV/cm^3

$r_c = 7.0$ kpc



Alternative model

$\rho = 0.38$ GeV/cm^3

$r_c = 0.9$ kpc

$$B = 6 \exp\left[-\frac{|z|}{5\text{kpc}} - \frac{R}{20\text{kpc}}\right] \ \mu\text{G}$$

Upper case 10 kpc

Lower case 4 kpc

Our case 8.5 kpc

I. V. Moskalenko & A. W. Strong, PRD 60 (1999) 063003

I. V. Moskalenko & A. W. Strong, ApJ 493 (1998) 694

Boost factor

- Boost factor

  The factor which may enhance the signal from LKP annihilation in the Galactic halo

$$B_f = B_\rho \times B_{\sigma v}$$

$$= \left(\frac{\langle \rho^2(l) \rangle_{\Delta V}}{\langle \rho_0^2(l) \rangle_{\Delta V}} \right) \left(\frac{\langle \sigma v \rangle}{3 \times 10^{-26}\ \mathrm{cm^3 s^{-1}}} \right)_{\Delta V}$$

- Cross Section

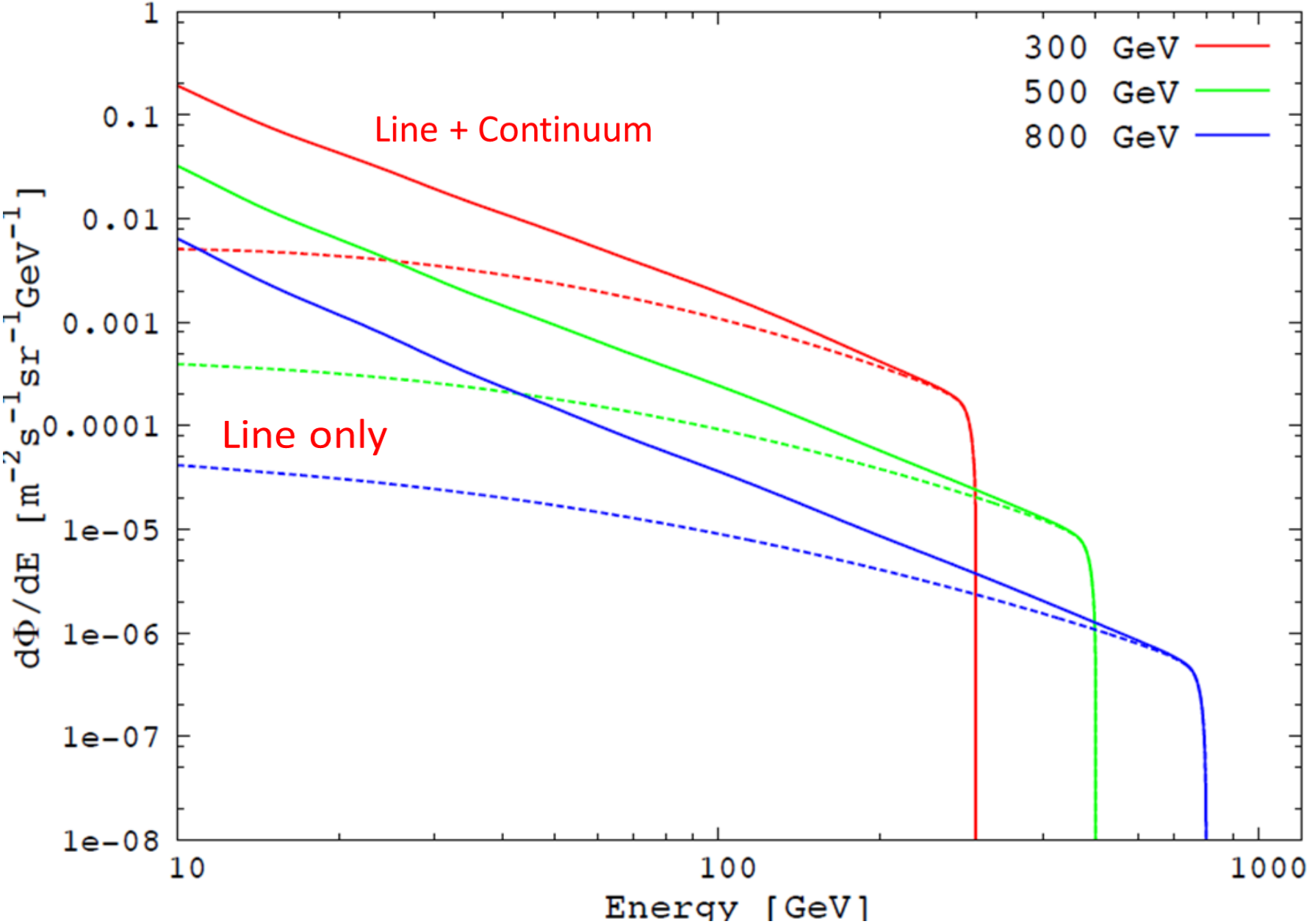
$$\langle \sigma v \rangle_{\mathrm{LKP}} = \frac{e^4}{9\pi \cos^4 \theta_w} \left[\frac{Y^4_{e_L^{(1)}}}{m^2_{B^{(!)}} + m^2_{e_L^{(1)}}} + (L \to R) \right]$$

$$\simeq 6 \times 10^{-22} (1\ \mathrm{GeV}/m_{B^{(1)}})^2\ \mathrm{cm^3 s^{-1}}$$

Cheng et al., Phys. Rev. Lett. 89 (2002) 211301

The value of boost factor is determined based on this cross section

Line and Continuum Flux



Positron Fraction

Total positron fraction

$$\frac{F_{\mathrm{LKP}} \times B_f \times f_{\mathrm{LKP}} + F_{\mathrm{Conv}} \times f_{\mathrm{Conv}}}{F_{\mathrm{LKP}} \times B_f + F_{\mathrm{Conv}}}$$

F_{LKP} : Flux from LKP annihilation

F_{Conv} : The "Conventional" Flux

f_{LKP} : Positron fraction for the LKP (=0.5)

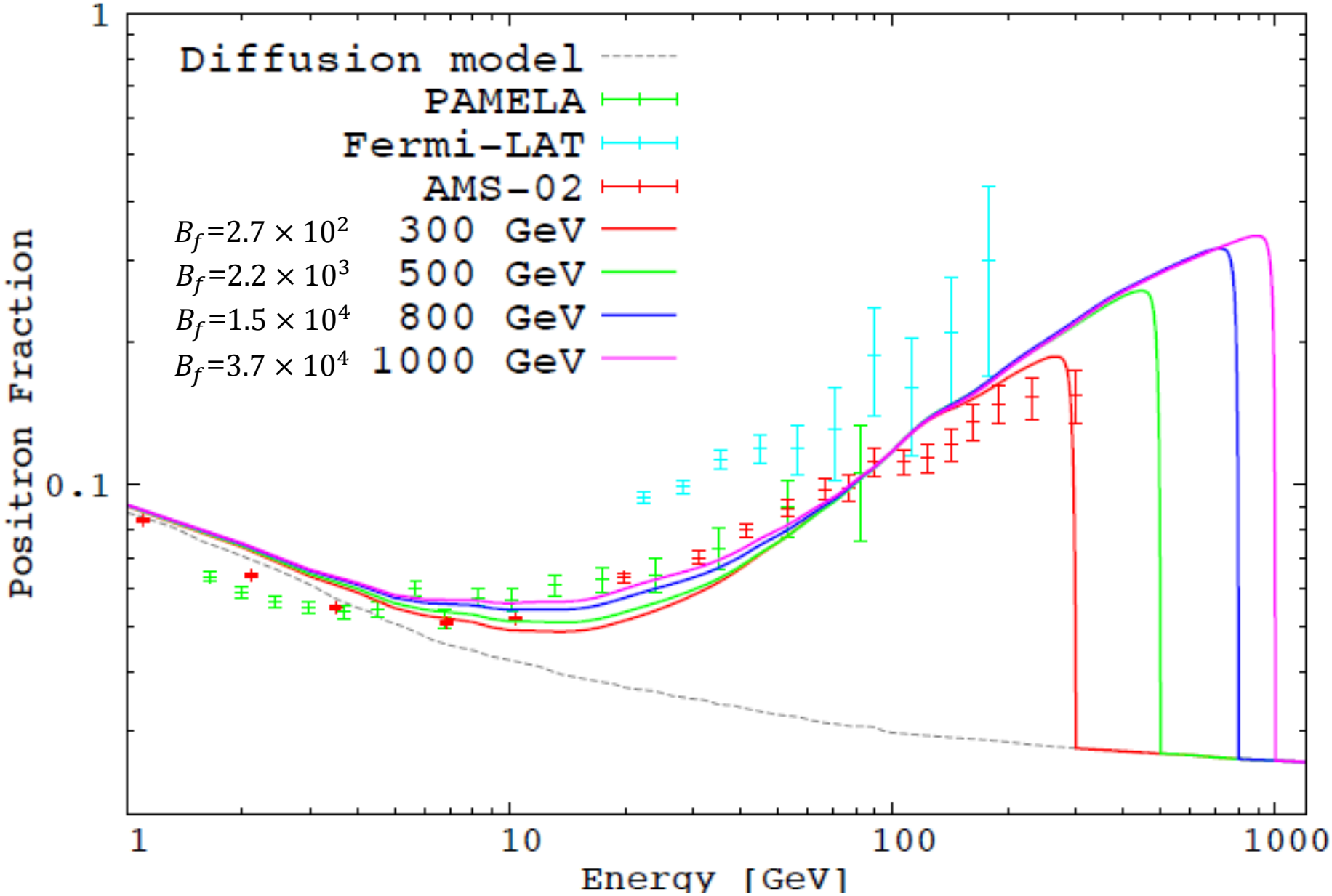
f_{Conv} : Positron fraction for F_{conv}

B_f : The Boost Factor

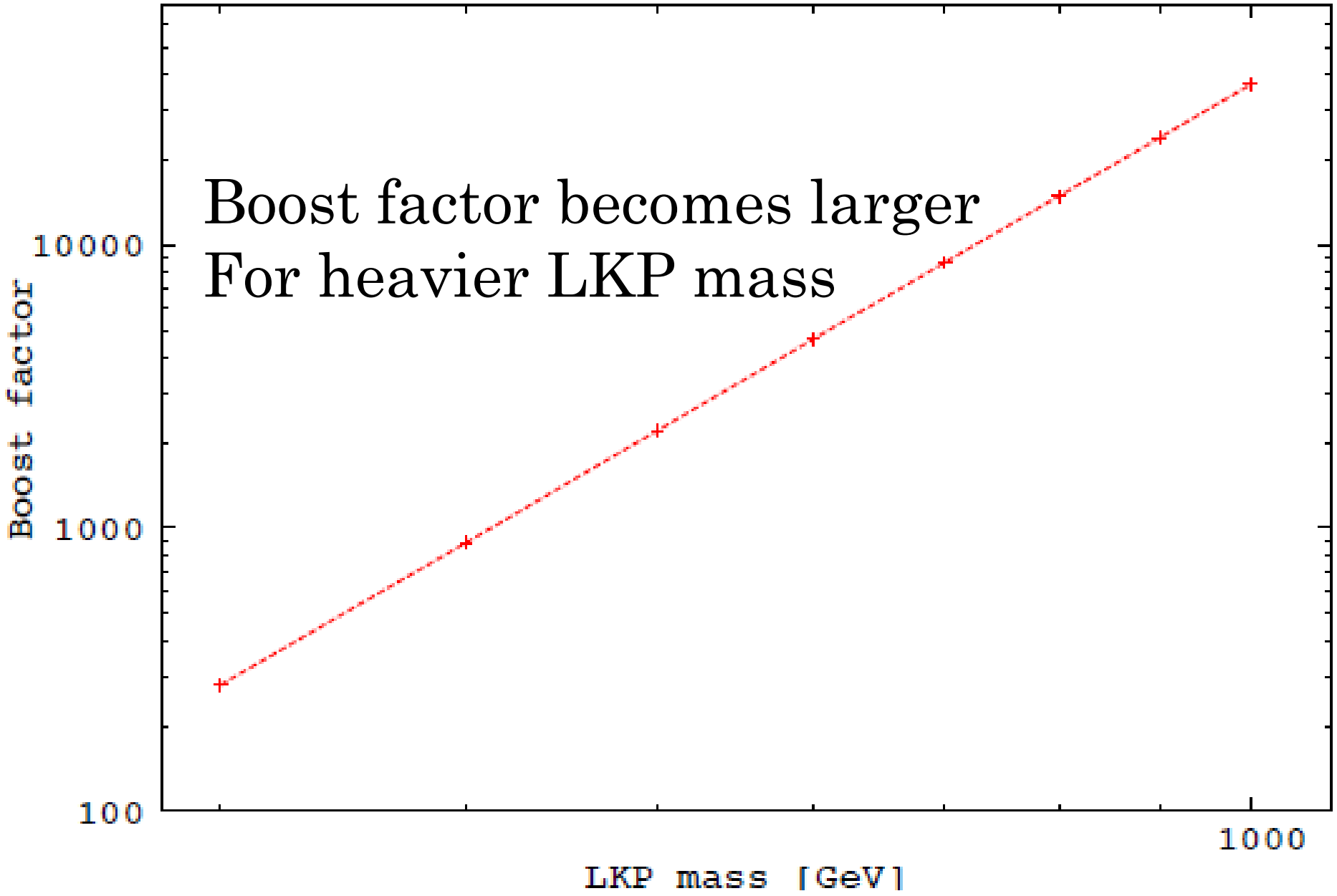
Q. Yuan and X. J. Bi, Phys. Lett. B727, 1 (2013)

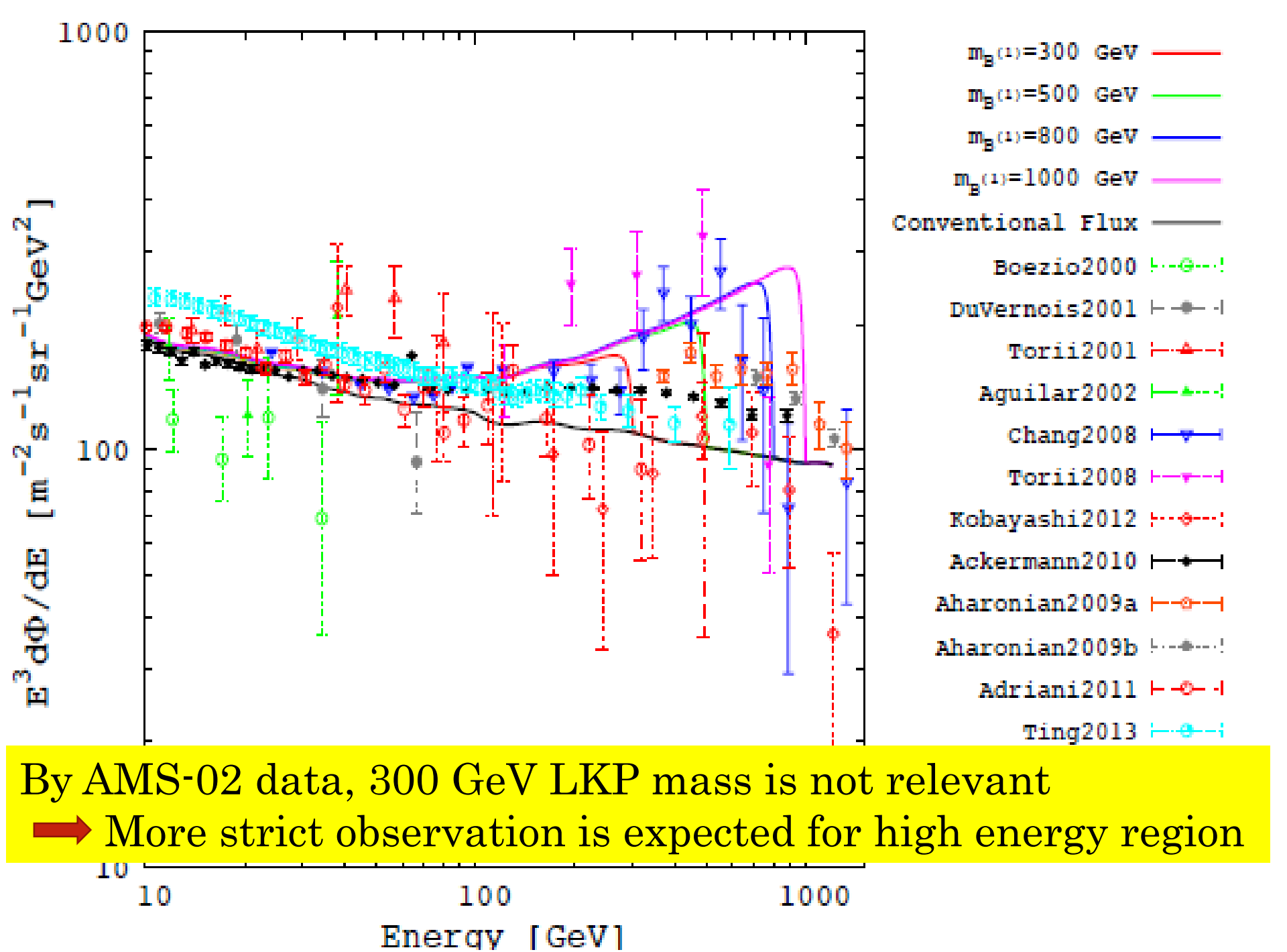
I. V. Moskalenko and A. W. Strong, Astrophys. J 493, 694 (1998).

Comparison with recent measurements



Boost factor





By AMS-02 data, 300 GeV LKP mass is not relevant

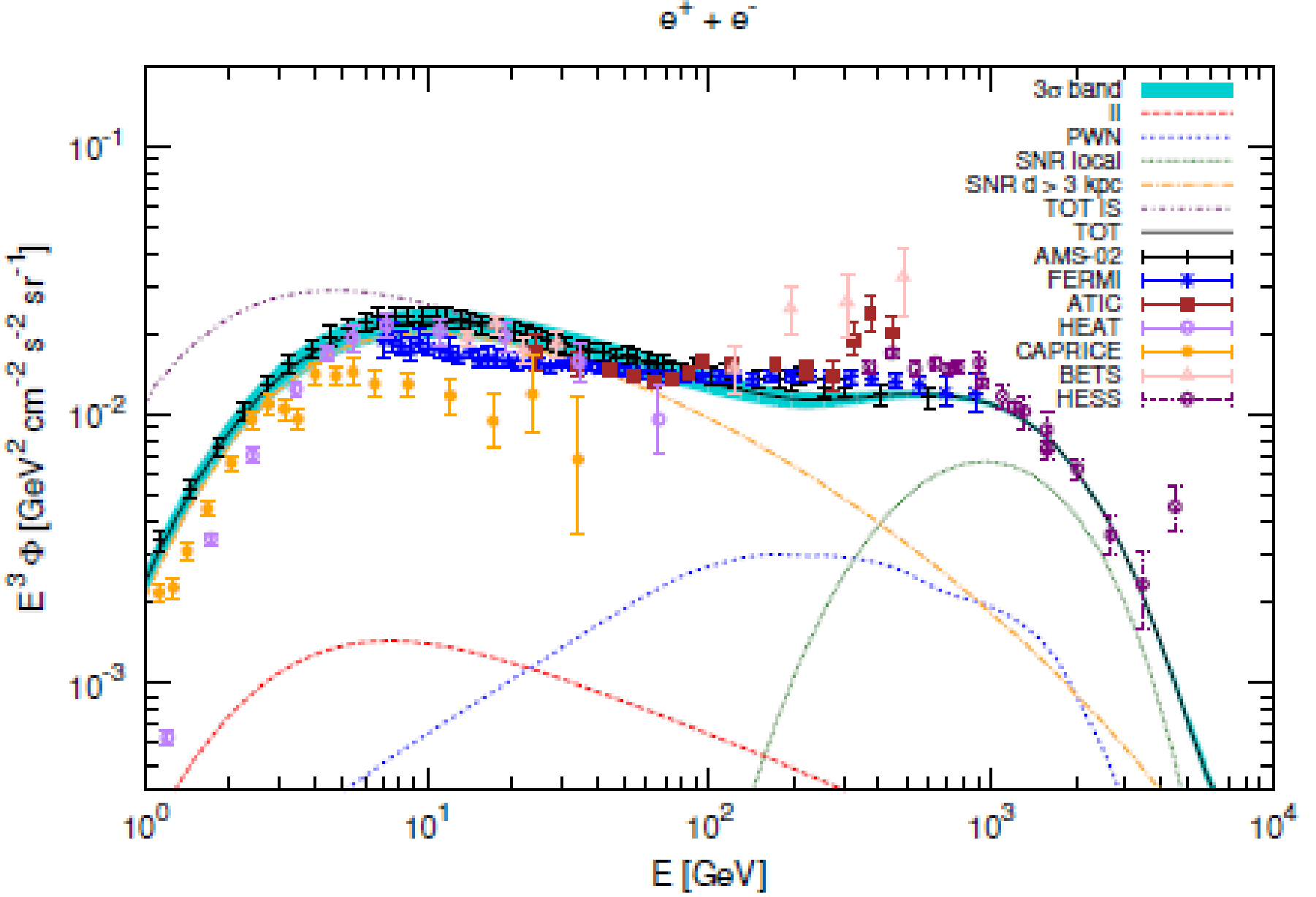
➡ More strict observation is expected for high energy region

Summary

- The flux from LKP can fit to AMS-02 data for positron excess
- The value of boost factor depends on LKP mass, and it is larger for heavier LKP mass than for lighter
- Light LKP mass, such as 300 GeV, may be excluded, because the edge structure has not been observed by some experimental data

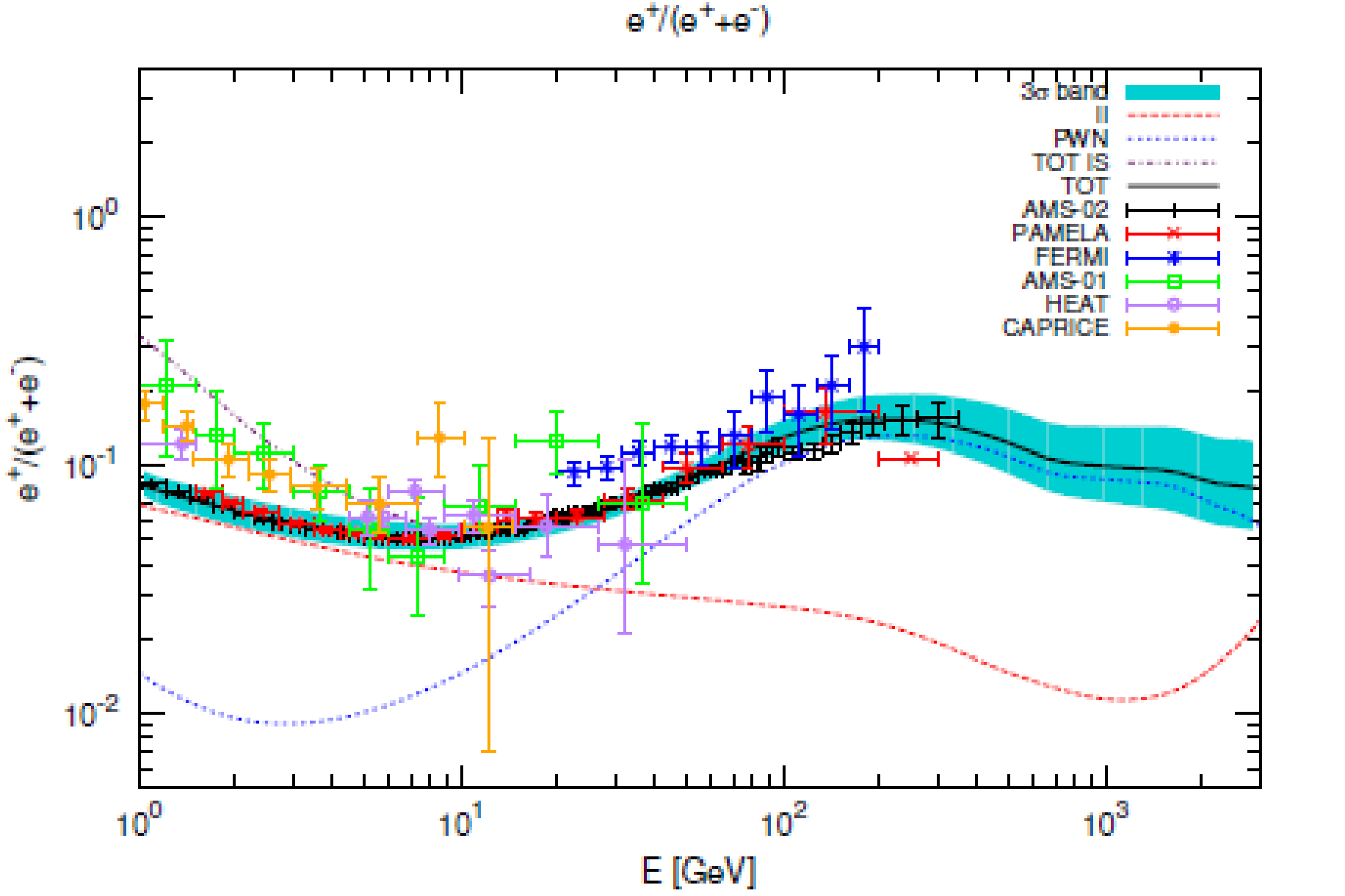
Thank you for listening

Electron plus positron spectrum



M. Di Mauro et al., JCAP 04 (2014) 006

Positron Fraction



M. Di Mauro et al., JCAP 04 (2014) 006