Galactic sources of high-energy positrons

Martin Pohl

Cosmic-ray electrons

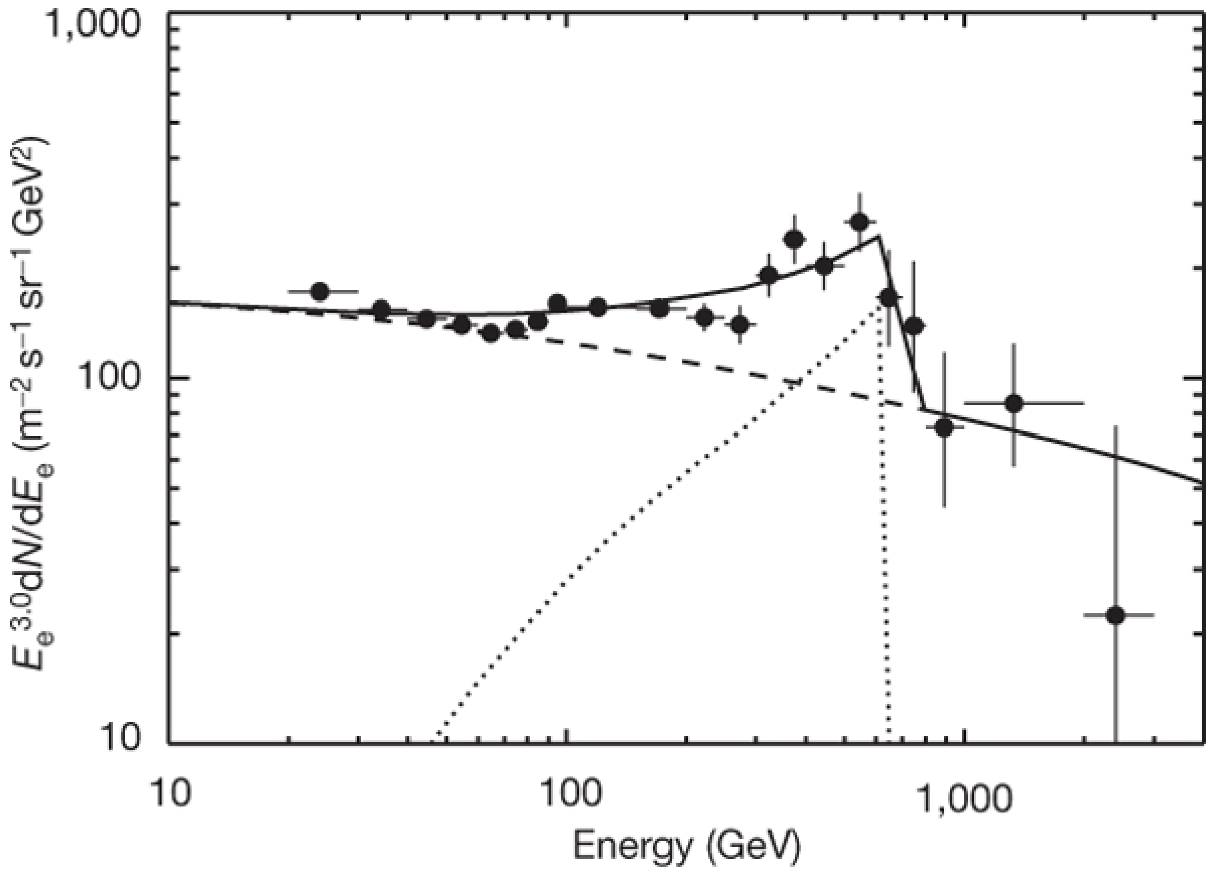
ATIC: cosmic-ray electrons

Excess at 500 GeV

Dashed line:
Normal CR electrons

Dotted line:
Kaluza-Klein DM

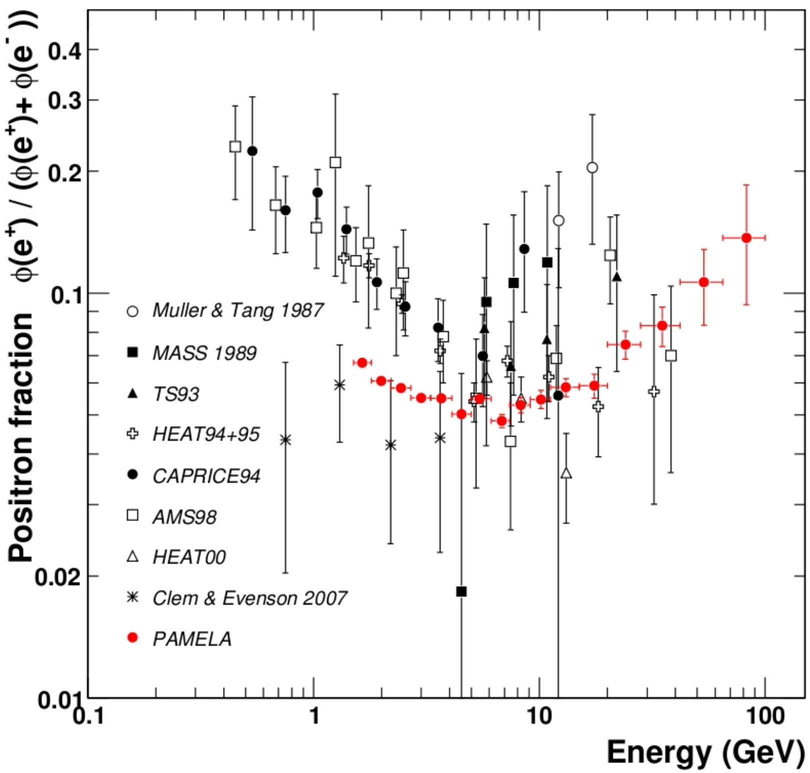
Needs boost by ~200

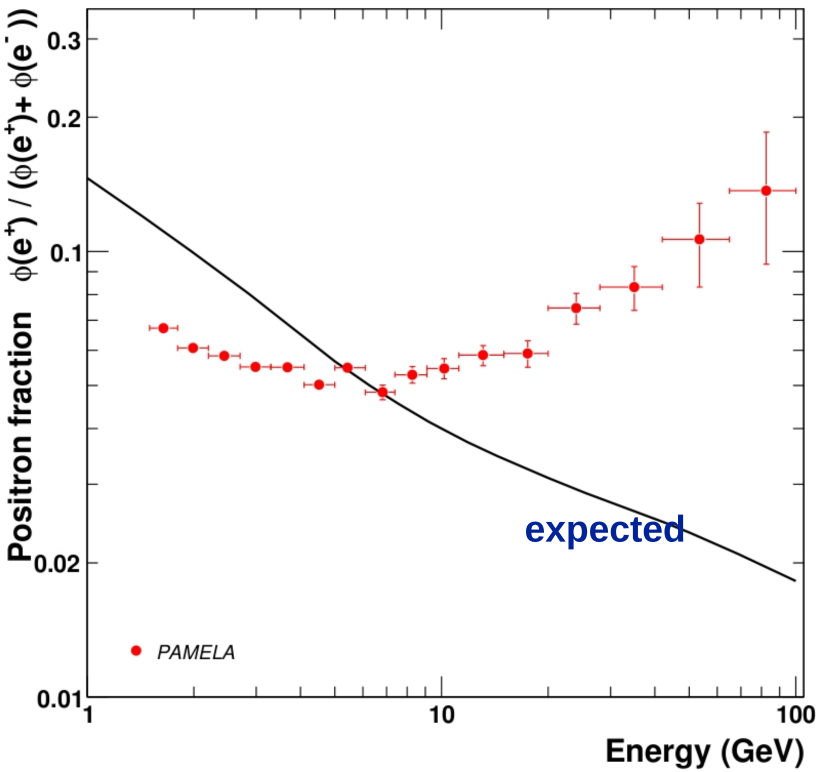


Positrons with Pamela

May be a new source of electron-positron pairs

but no excess in antiproton spectra





Kaluza-Klein dark matter

- Interest: Could be dark matter!
  - Needs boost factor of ~200
  - Needs e+/e- pairs as main decay channel
- Kaluza-Klein dark-matter
  - Produces monoenergetic pairs
  - Supports theories with extra dimensions
- Electron spectrum modified by propagation

The transport equation

Consider main issues:

Energy loss **diffusion** **injection**

$D = D_0 E^a$

Two classes of models:

pure diffusion	$a=0.6$
reacceleration	$a=0.33$

Dark matter: depends on clump density

Boosting required ➔ clumps

Realistic case: mass spectrum $$\frac{dn}{dM} = n_0 M^{-b}$$

But electron source rate: $$Q \propto \rho_0^2 r_0^3 \propto M^d \,, \quad d \approx 1$$

$$\frac{dQ}{d\log M} \propto M^{1+d-b}$$

d+1-b > 0 ➔ Annihilation dominated by a few massive clumps

Dark matter: depends on clump density

Pure diffusion model

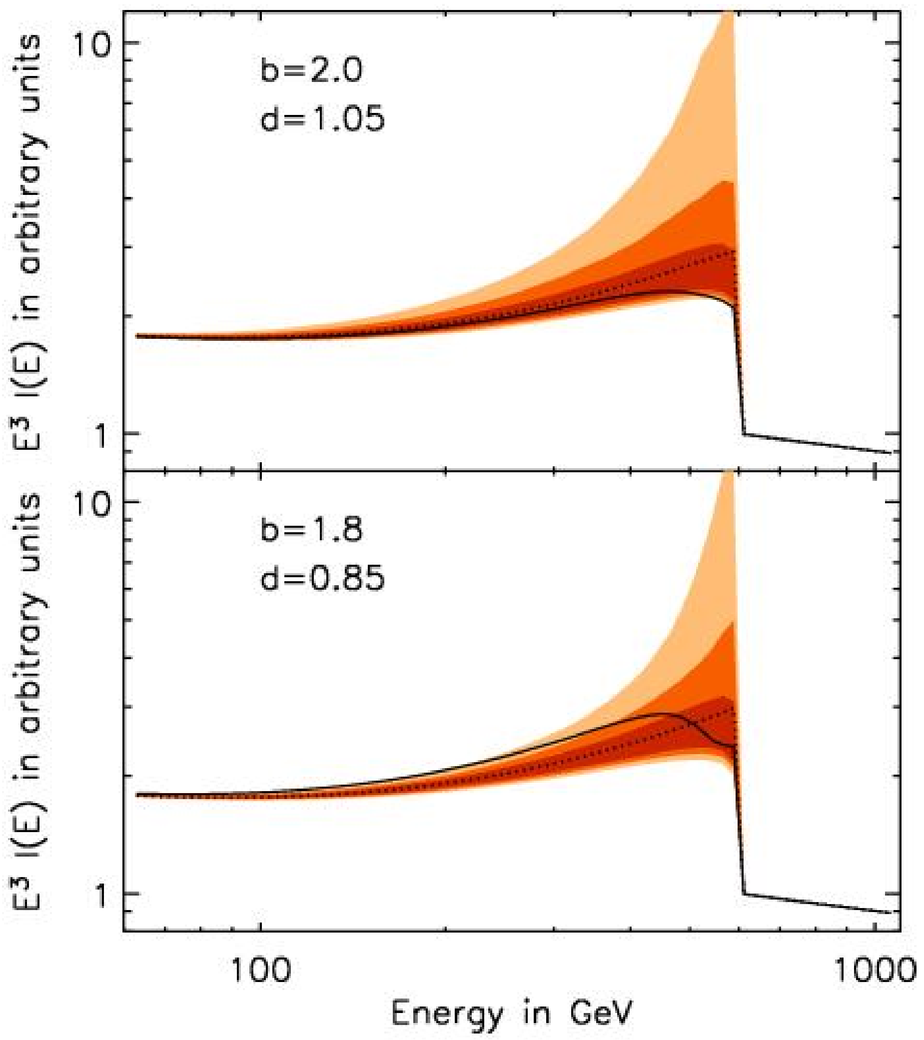
added to normal electron flux

Dotted line:
average spectrum

Dashed line:
randomly selected spectrum

Color shades:

- **Light: 68%**
- **Medium: 90%**
- **Dark: 99%**



Pulsars may also leak pairs …

Source spectrum (dotted)

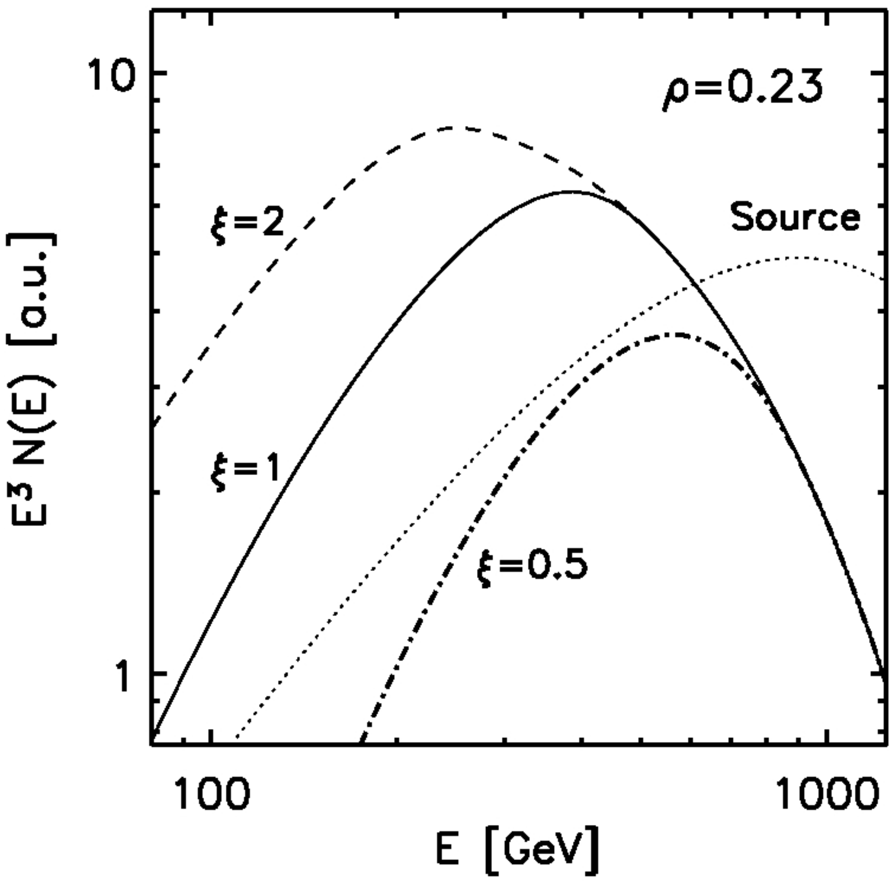
$$Q(E) \propto E^{-1.5} \exp\left(-\frac{E}{E_0}\right)$$

Age in units of energy-loss time at 600 GeV:

$$\xi = 1 \quad \leftrightarrow \quad t = 140{,}000 \text{ yrs}$$

Distance in units of diffusion distance at 600 GeV

$$\left(\frac{\rho}{0.23}\right) = \left(\frac{r}{700\text{ pc}}\right)^2$$



The riddle: which is which?

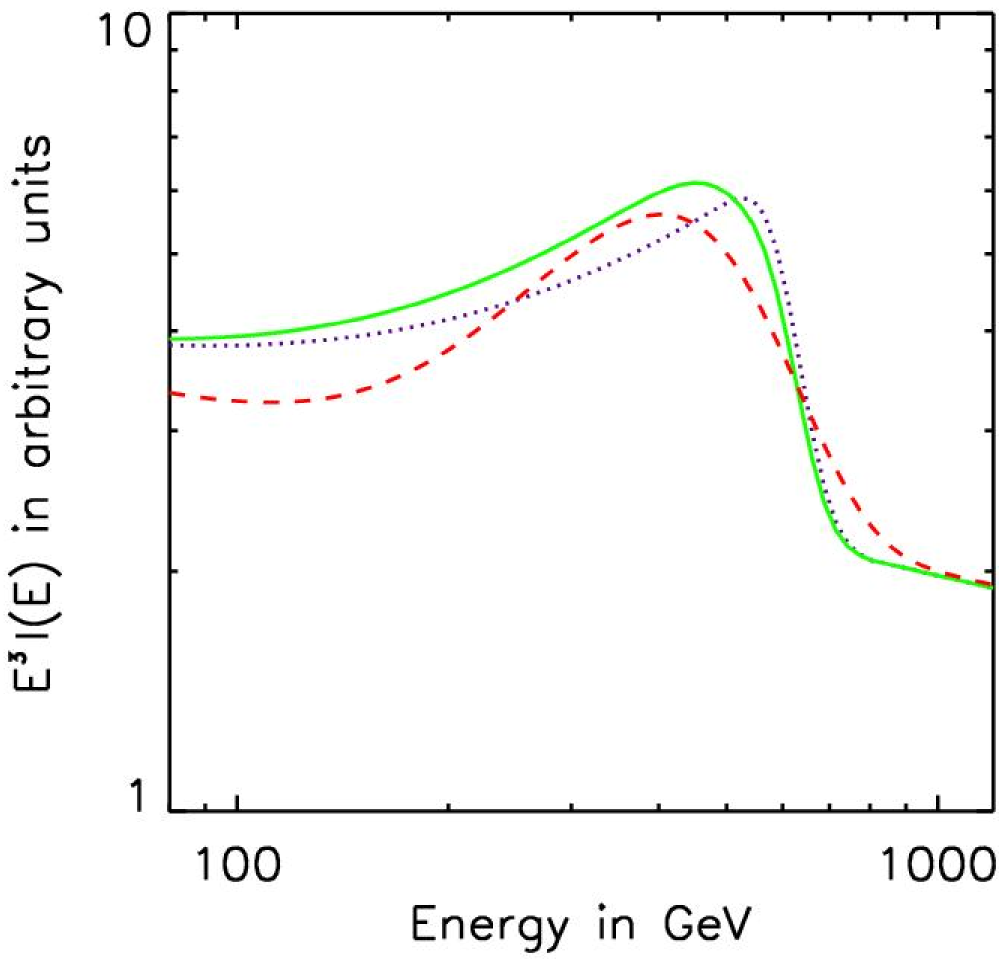
All 8% energy resolution

A)Homogeneous dark matter

B)Clumpy dark matter

C)Pulsar

> **Distance 1.1 kpc**
> **Start time 70 kyr**
> **End time 14 kyr**



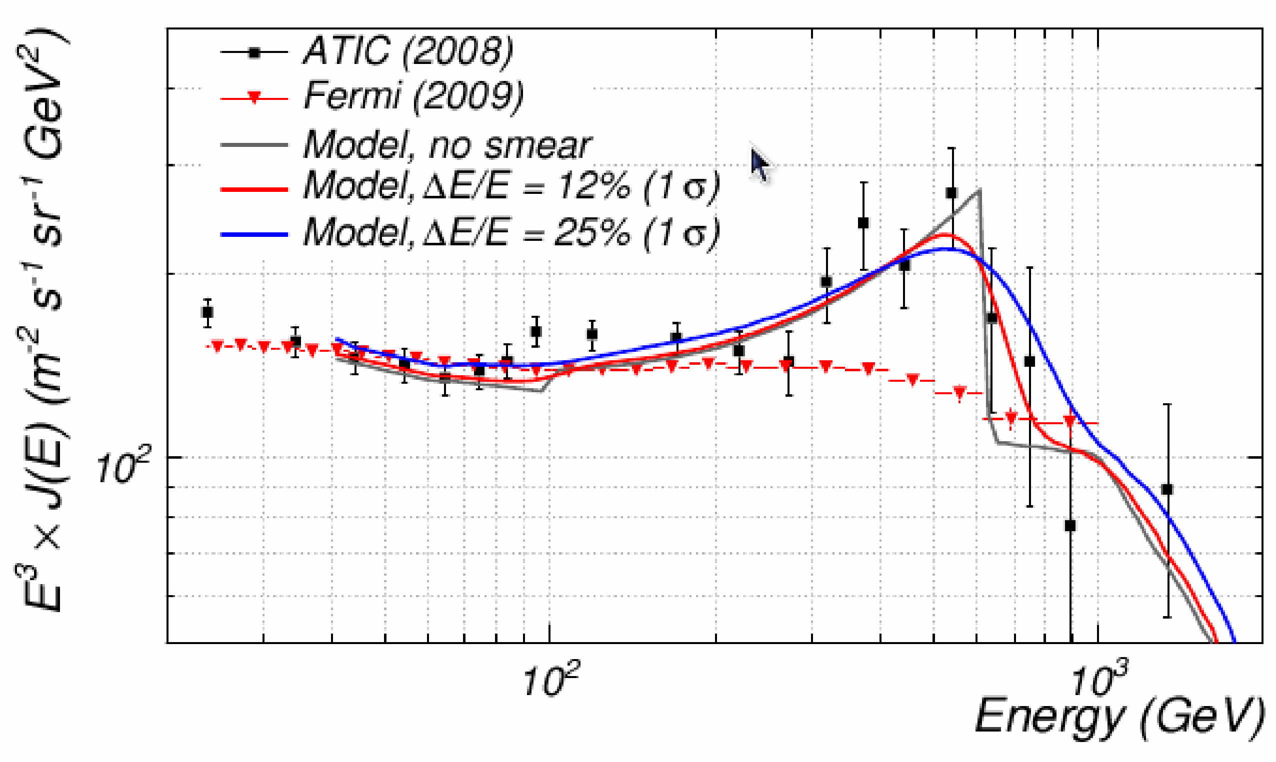
MP, PRD 79, 041301 (2009)

Fermi-LAT data and other sources

LAT data: much weaker excess (Abdo et al. 2009)

Narrow peak would have been seen!

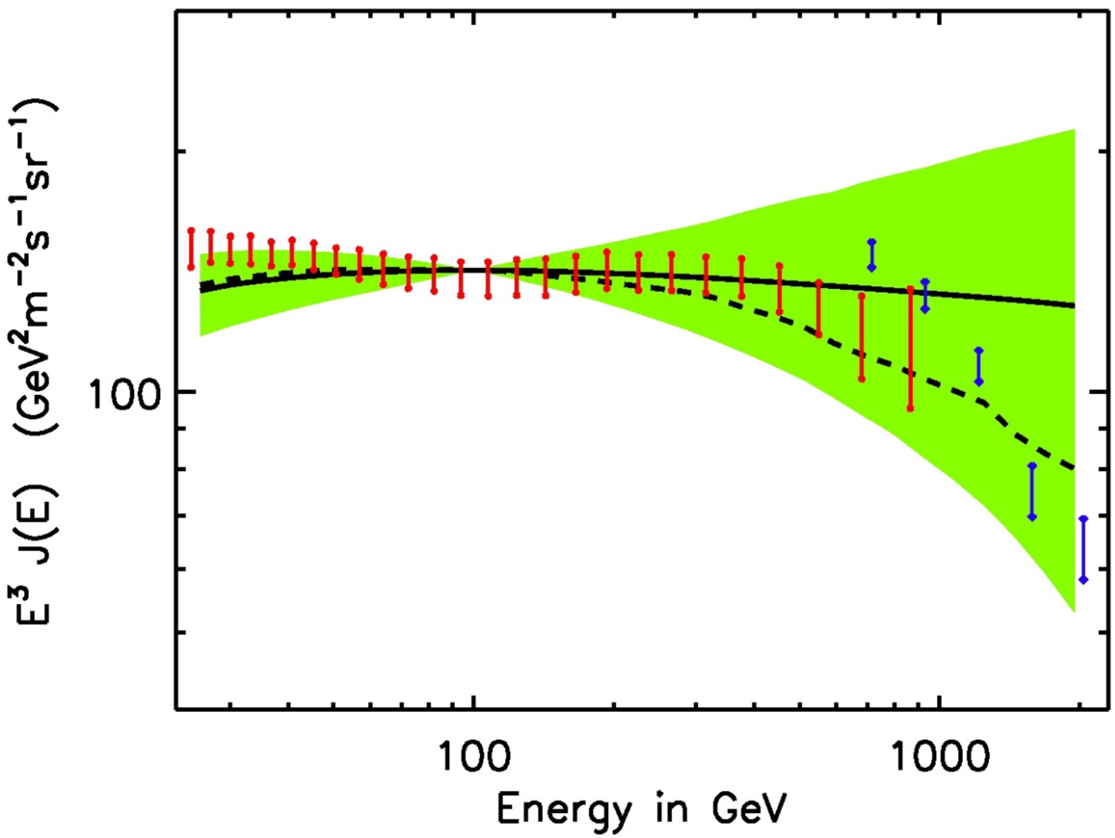
Positron excess must roll off at ~ 200 GeV



LAT data and other sources

Uncertainty in power-law index much smaller

than local fluctuations (Grasso et al. 2009)



Assume SNR as

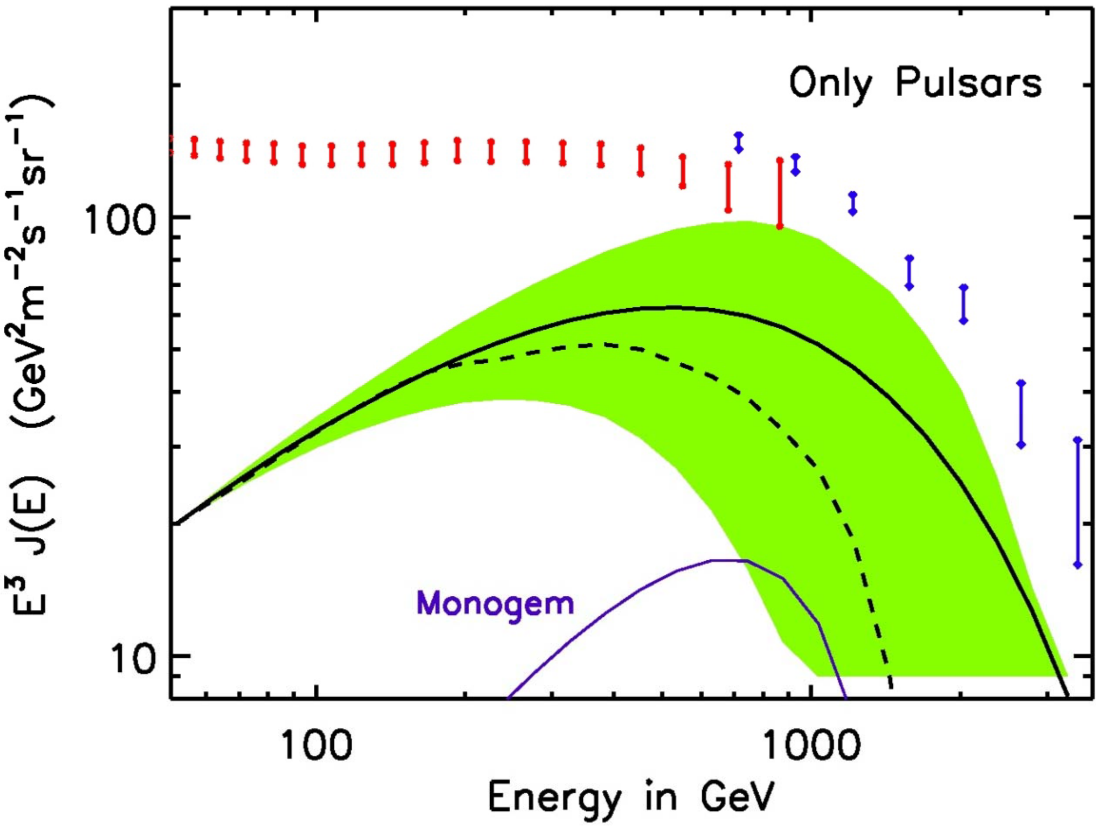
electron sources

(following
MP+ Esposito 98;
MP et al. 03)

LAT data plus pulsars

Assume pulsars provide extra positrons to fit PAMELA @ 50 GeV

Injection spectrum $Q \propto E^{-1.5} \exp[-\mathrm{E}/(600\,\mathrm{GeV})]$



Other pulsars are important!

→ Broad bump

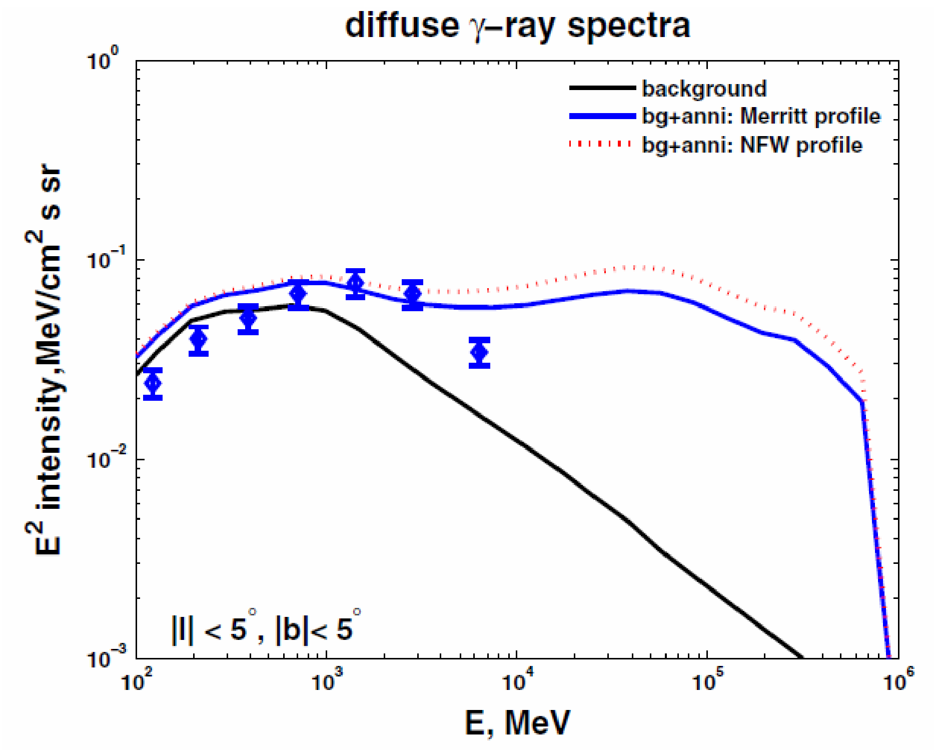
Careful: Here D ~ $E^{0.33}$

Limits on dark-matter annihilation

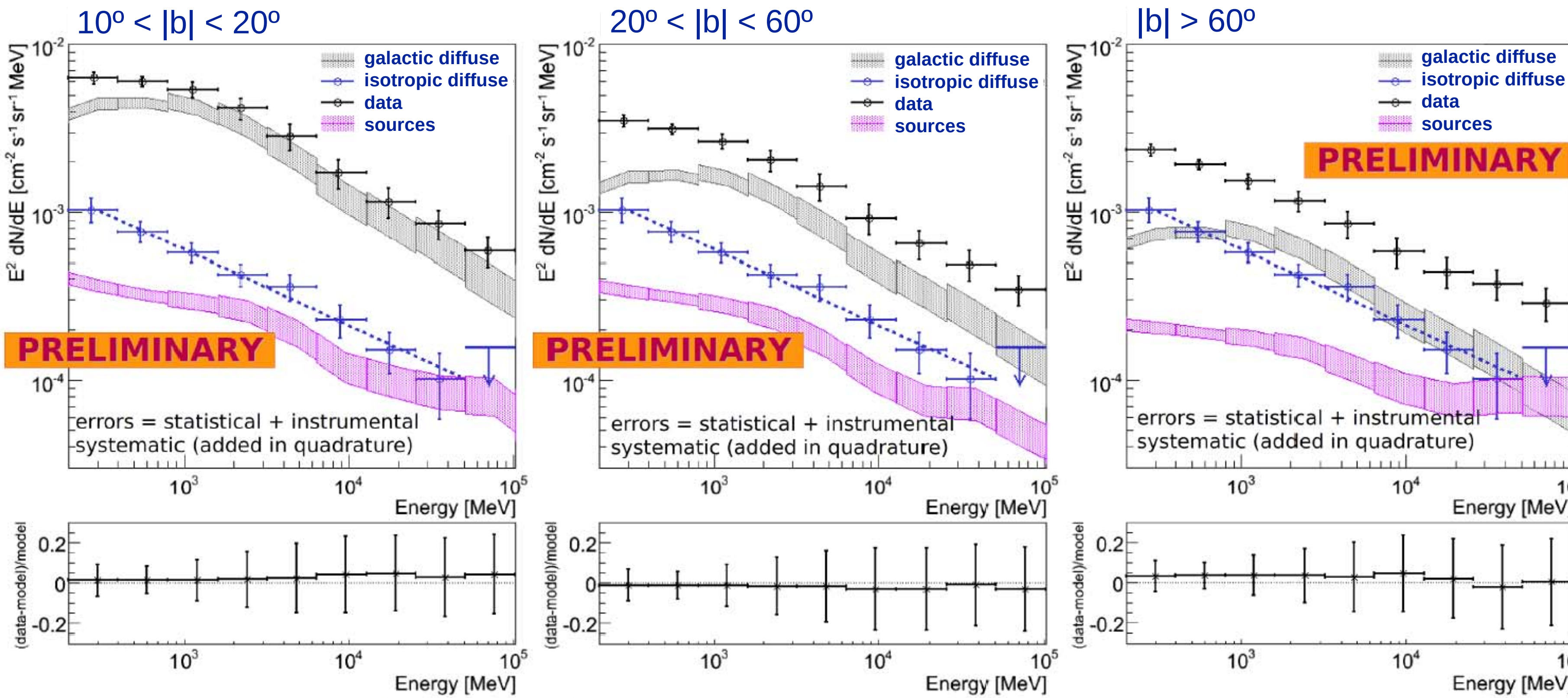
Too high extragalactic background **(e.g. Profumo & Jeltema)**

Too high gamma-ray intensity from GC region

(e.g. Zhang et al., Boriello et al., Maeda et al., Ullio et al.)



The LAT isotropic diffuse flux (200 MeV – 100 GeV)



Low galactic latitudes | High galactic latitudes | Galactic poles

Galactic diffuse flux (from fit)

Total point source contribution (from fit)

Isotropic diffuse emission (isotropic component from fit, residual CR background subtracted)

Power law fit to isotropic diffuse emission with index γ = 2.45

LAT data

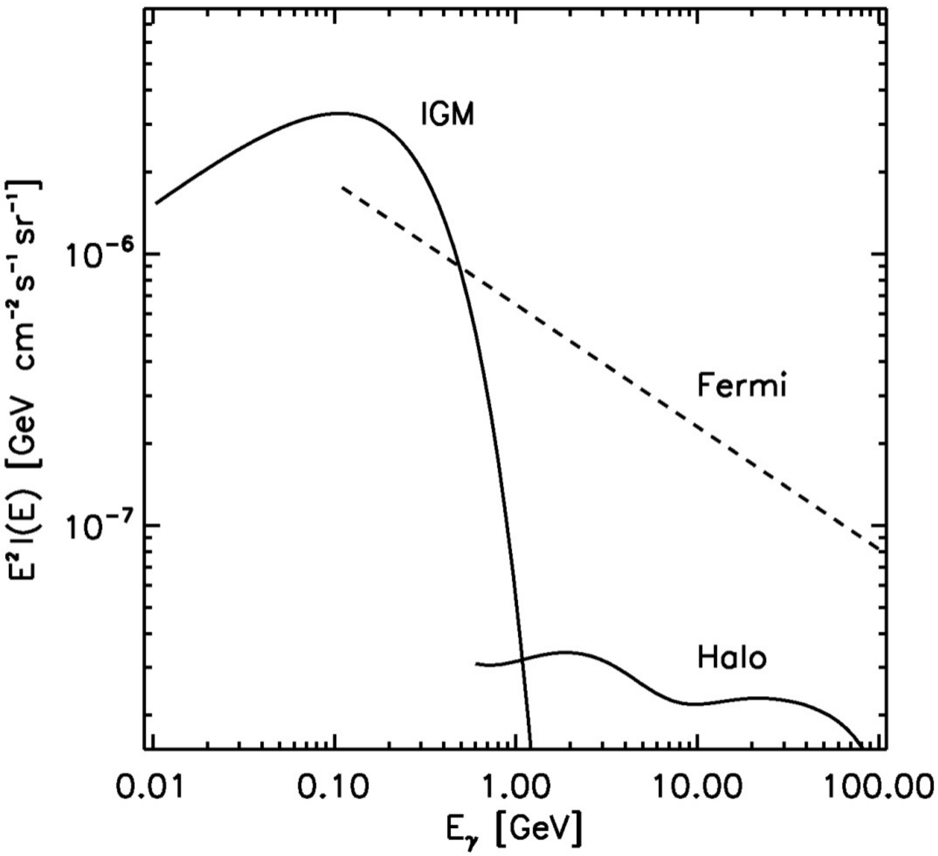
error bars / bands:
statistical error + LAT effective area uncertainty + residual background contamination uncertainty

Limits on dark matter decay

Inverse-Compton emission from electrons/positrons

Exceeds preliminary EDGB spectrum from Fermi

(Pohl & Eichler in prep.)



Conclusions

- **Positron excess seen with PAMELA**
  - **No excess in antiproton data**
  - **Can't extend much beyond ~ 200 GeV**
- **Investigate pulsars, DM annihilation and decay**
  - **Annihilation implies strong γ-ray signal from GC**
  - **Decay implies strong γ-ray signal from Galactic poles**
  - **Positron production near SNR shocks → B/C ratio?**
  - **Pulsar scenario is least uncomfortable**
  - **Pulsars also explain WMAP haze**

Postdoc positions available

Potsdam University/DESY Zeuthen

pohlmadq@gmail.com

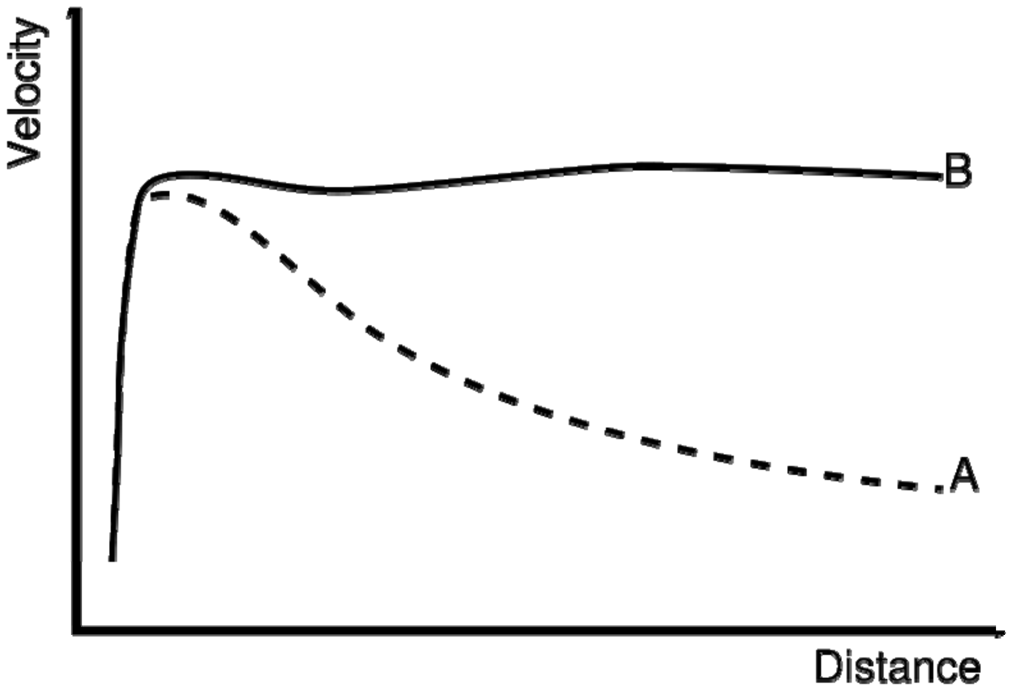
Backup slides

Dark matter

Known for 40 years:

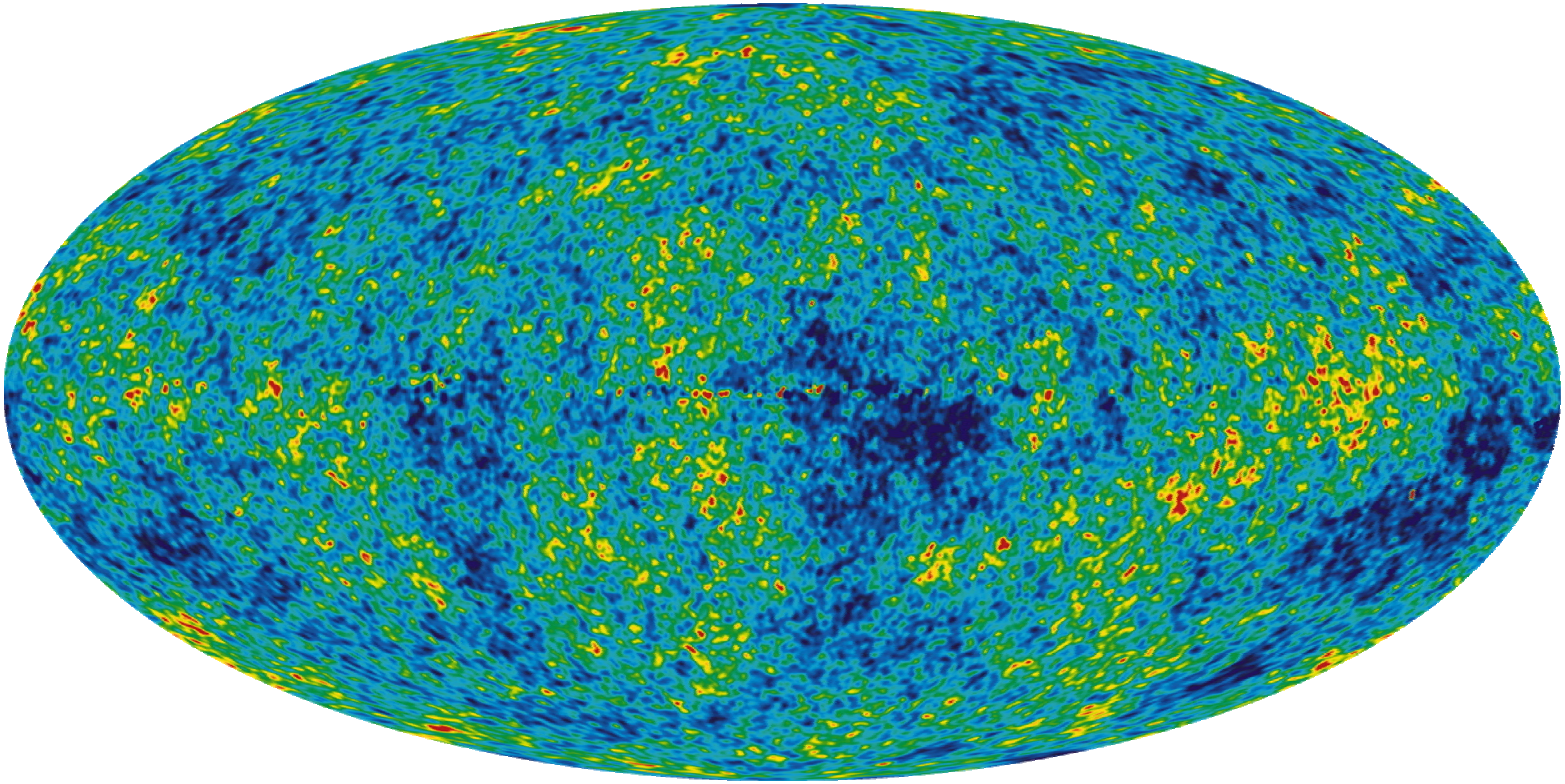
Rotation curves are flatter (B) than expected for observed matter (A)

➔ Dark matter

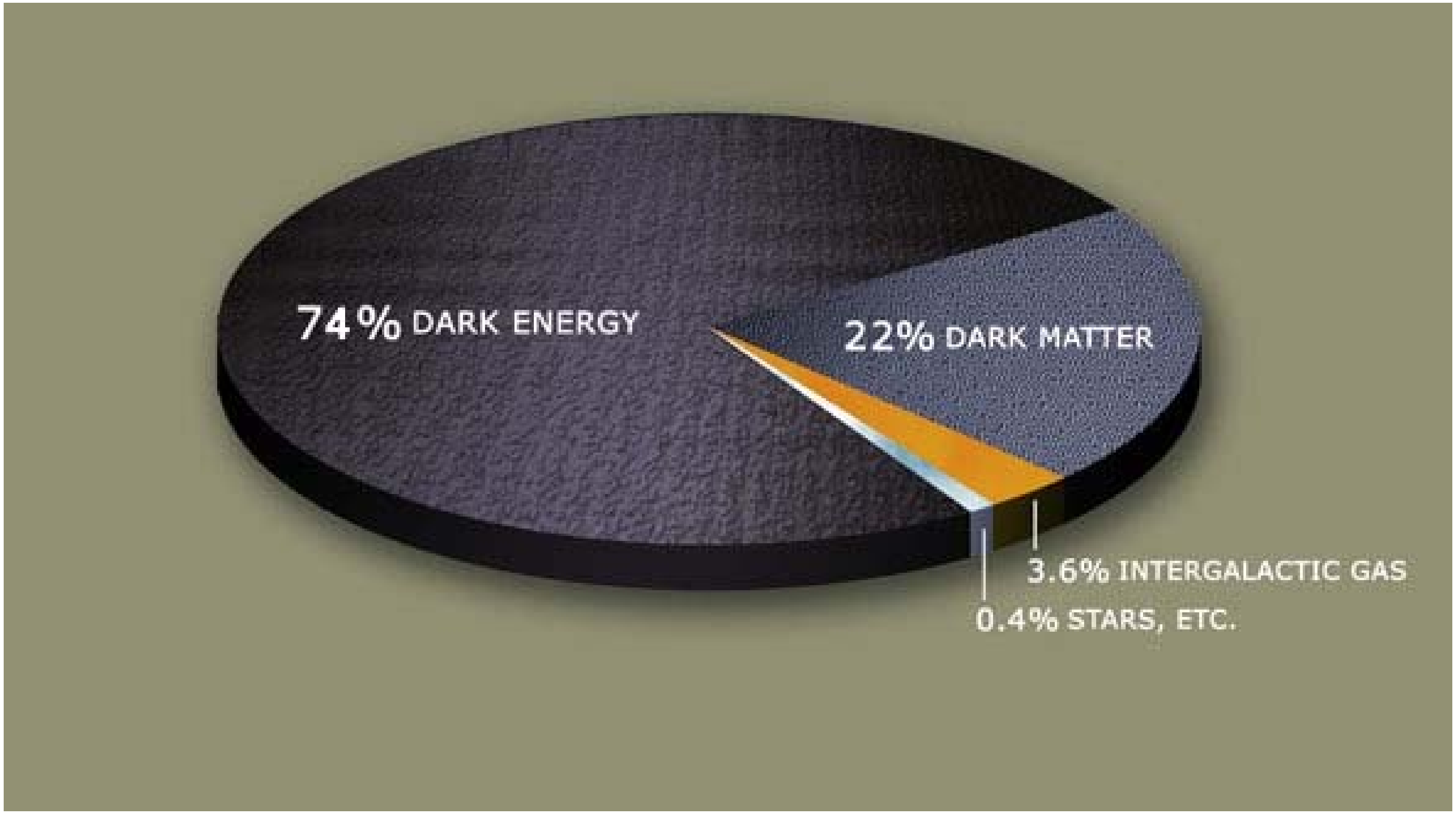


Dark matter

Structure formation ➔ Dark matter must be cold!



Dark matter


74% DARK ENERGY
22% DARK MATTER
3.6% INTERGALACTIC GAS
0.4% STARS, ETC.

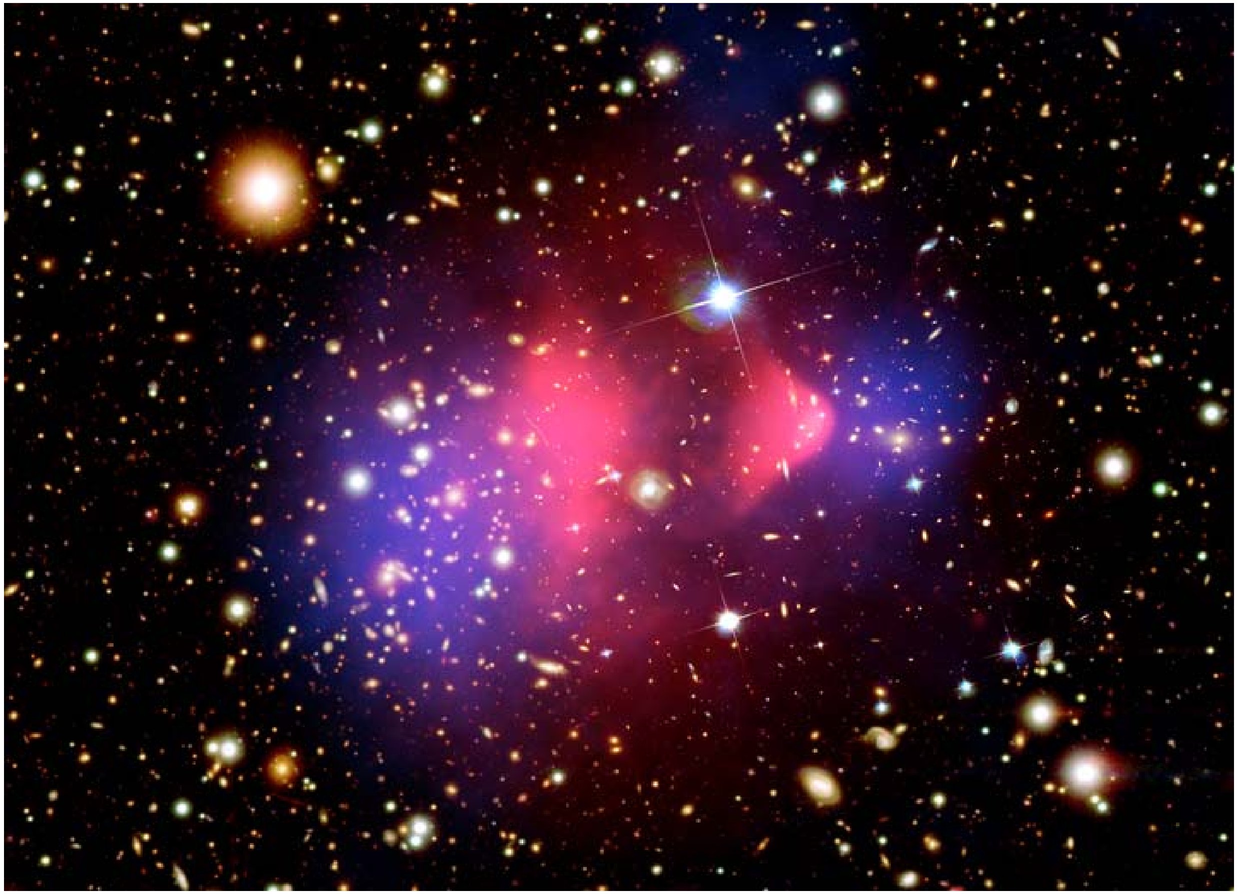
Dark matter

Can't be gas!

Colliding clusters:

Blue: (dark) matter

Red: (hot) gas



Indirect detection: cosmic rays

Galactic cosmic rays

Relativistic charged particles

88% p, 10% α, 1% e^-

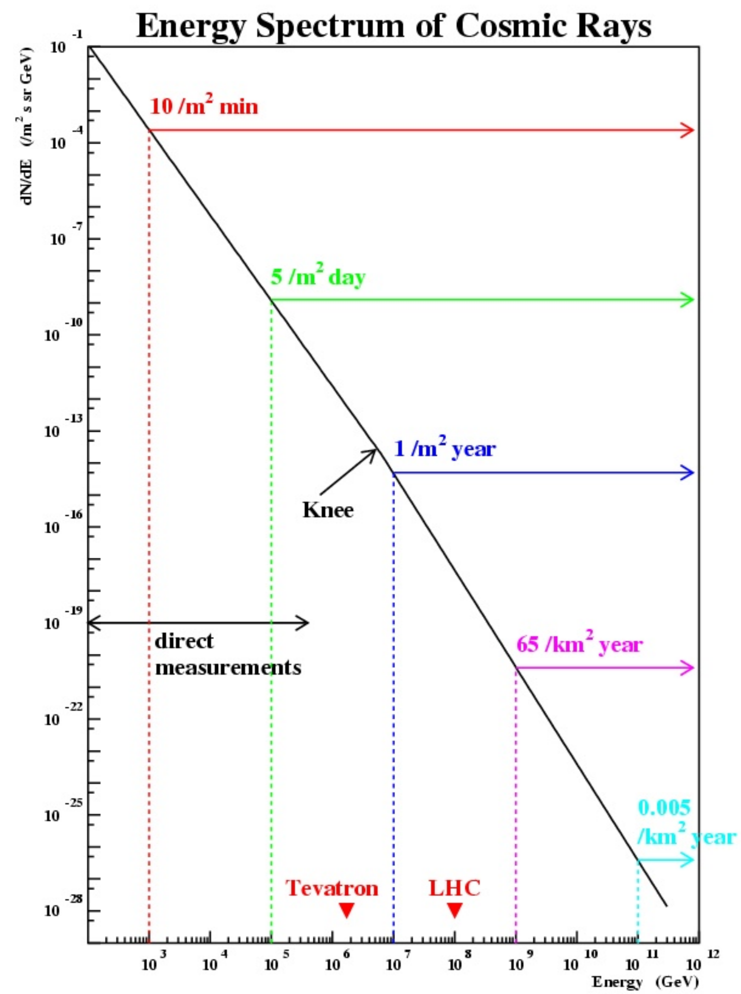
Gamma rays from

$p + p \rightarrow \pi^0 \rightarrow \gamma$

Antiparticles from, e.g.,

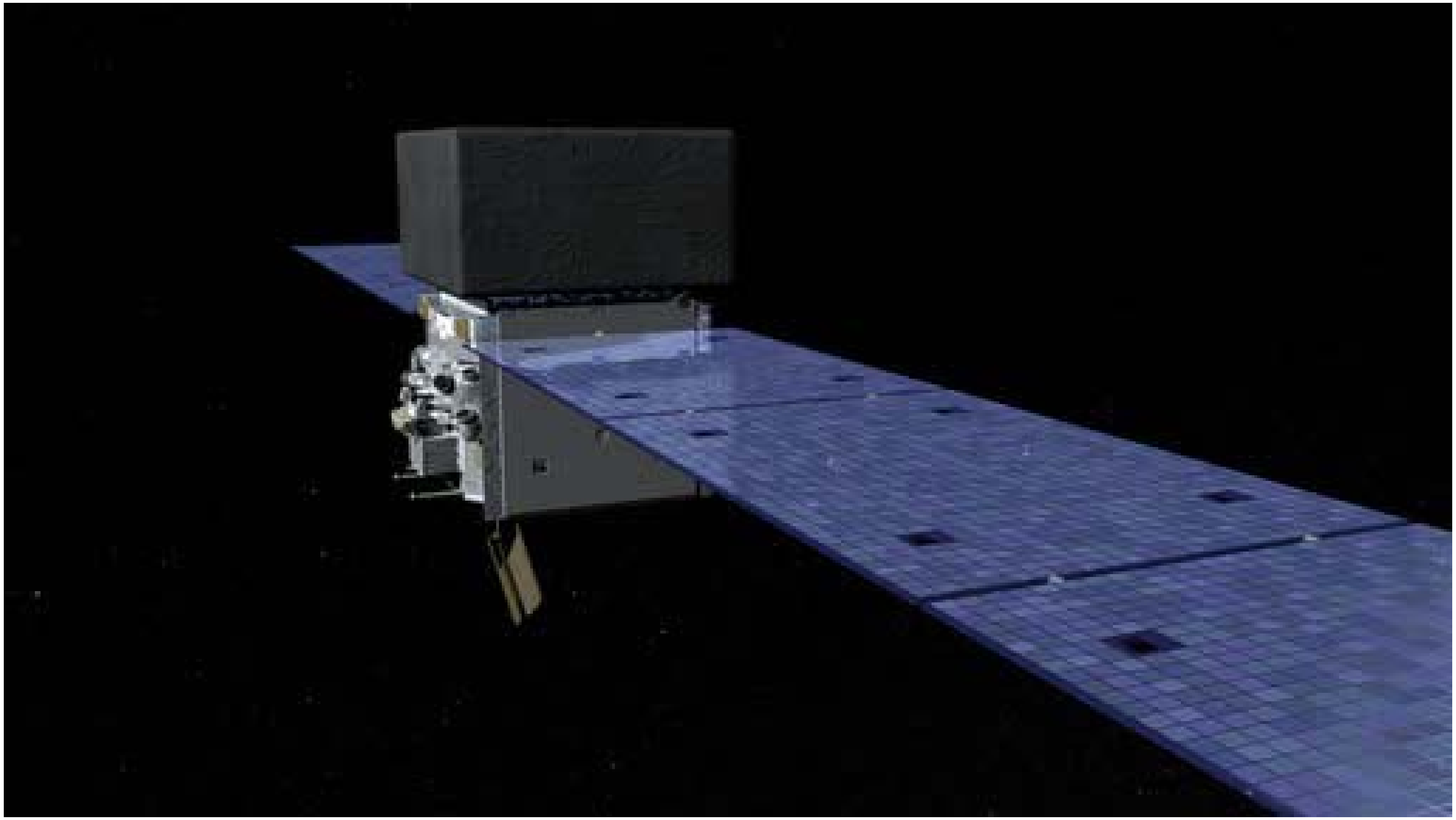
$p + p \rightarrow \pi^+ \rightarrow e^+ + \nu$

} Also from dark matter



What will GLAST/Fermi add?

Designed to measure gamma rays, but can also measure electrons

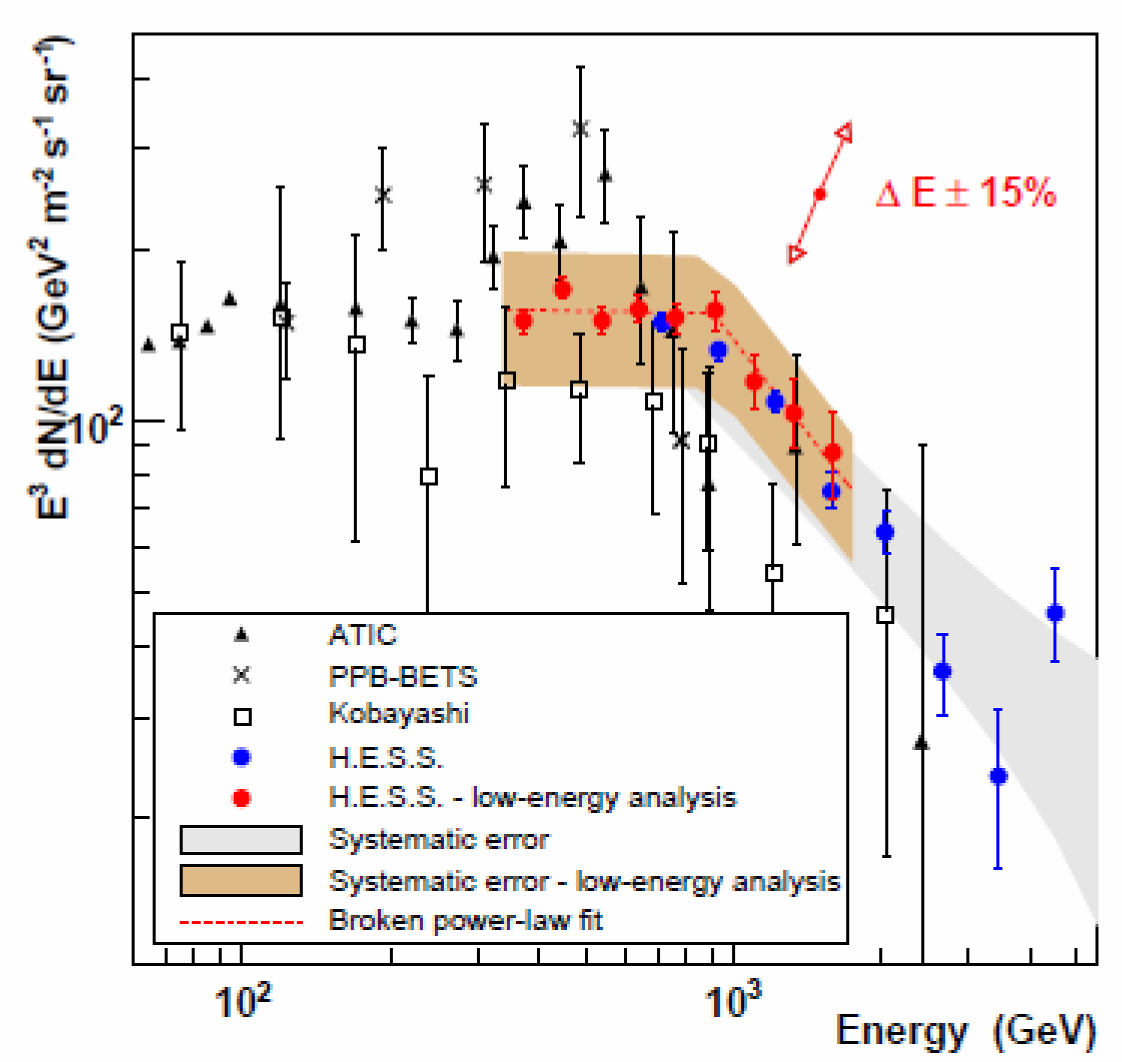


No bump?

Low-energy analysis

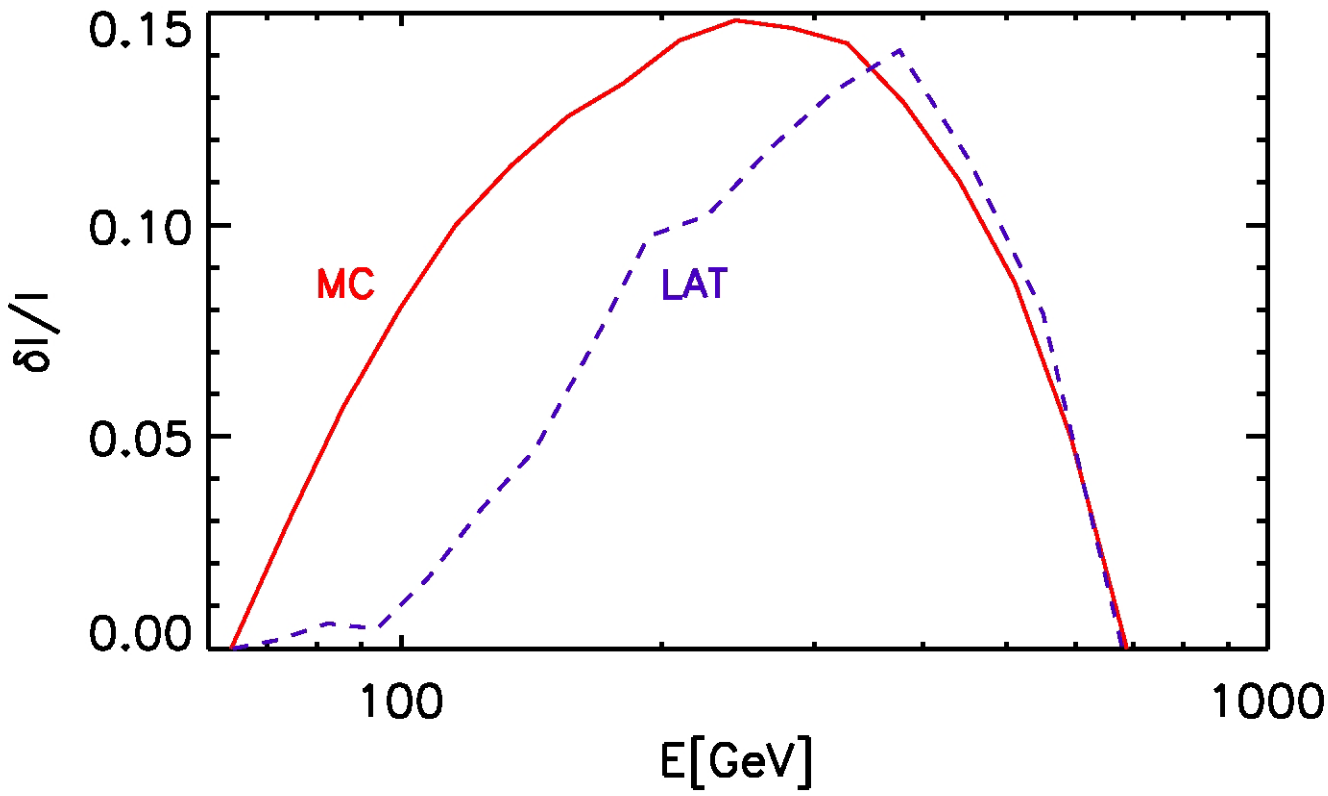
of HESS data

→ **No bump!**



Bumpyness for SNR origin

Compare with power law between 65 GeV and 680GeV



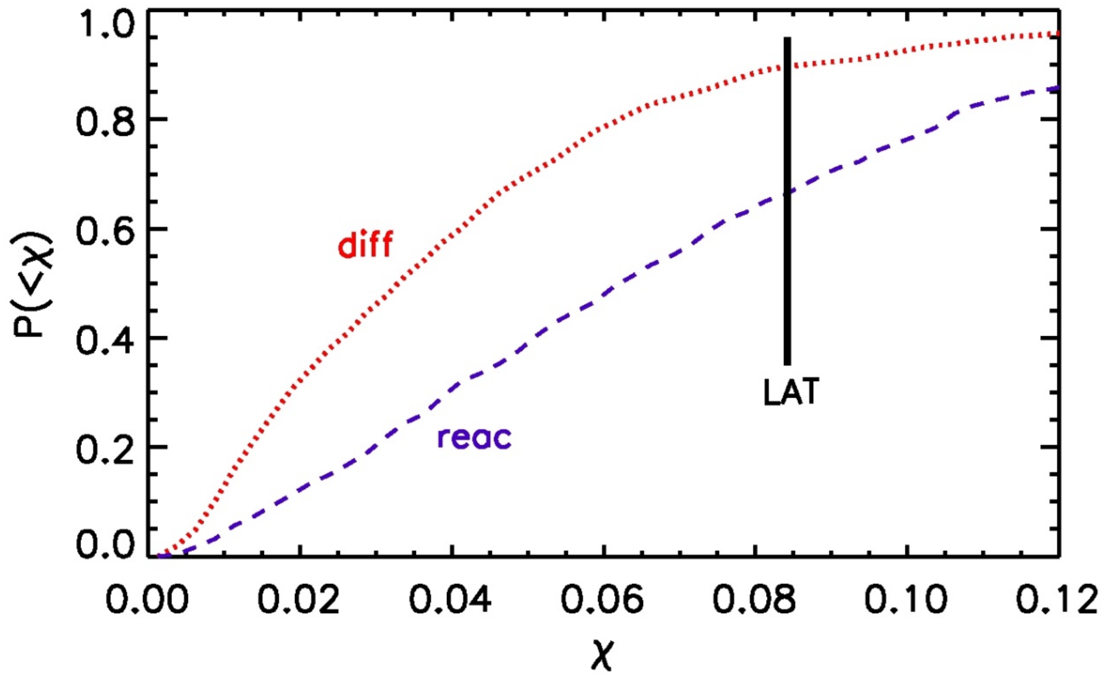
Bumpyness for SNR origin

Average fluctuation level

I data

J power-law

$$\chi = \sqrt{\frac{1}{N}\sum^{N}\frac{\left(I - J_{PL}\right)^2}{J_{PL}^{\;2}}}$$



Fluctuations in LAT data enhanced by errors

→ no evidence for additional sources