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T.A.S.C. [Theoretical Astrophysics in Santa Cruz]

Fundamental Physics from the Sky

Latest News on Indirect Dark Matter Detection

"Shedding Light on the Nature of Dark Matter"

Keck Institute for Space Studies

Pasadena, July 13-24, 2009

WIMPs pair-annihilate to stable, SM particles

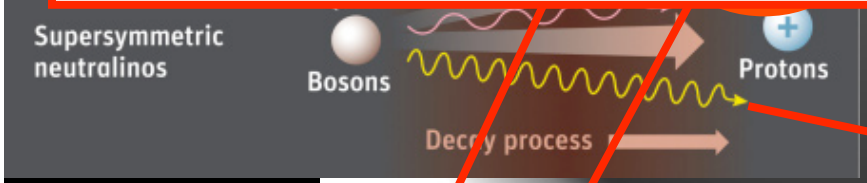
"Indirect" Dark Matter Detection

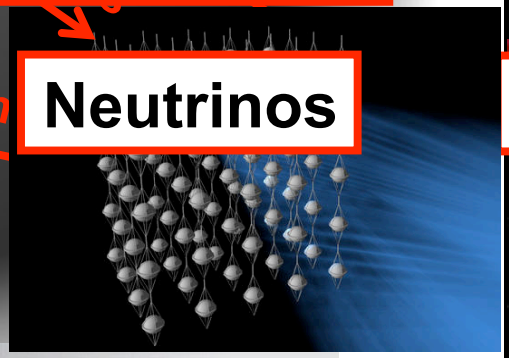
Can we do fundamental physics with indirect DM detection?

- ✓ **Multi-messenger endeavor**
- ✓ **Fight (understand) astro-physical backgrounds!**

Radio

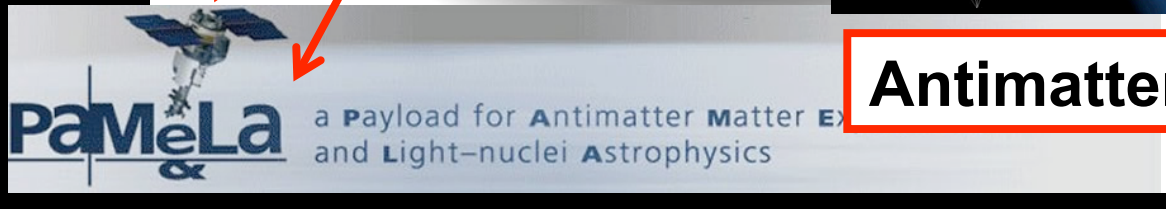
X-ray





Neutrinos

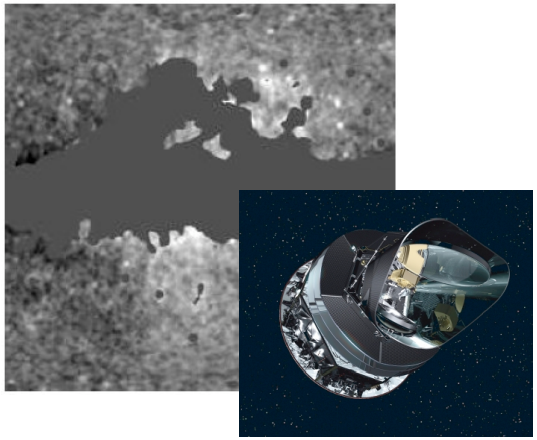
Gamma Ray



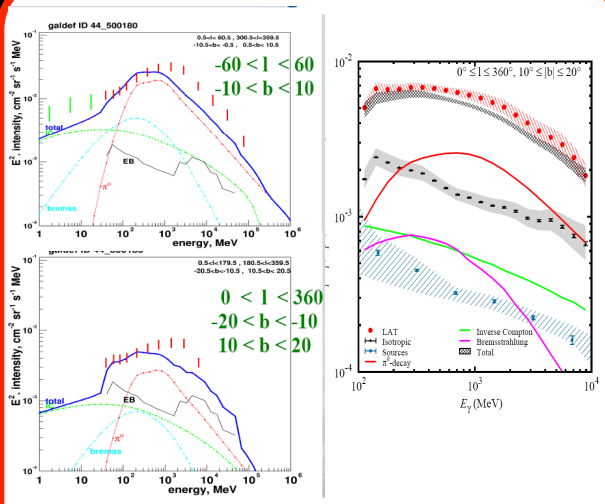
Antimatter

Indirect Detection: Latest News

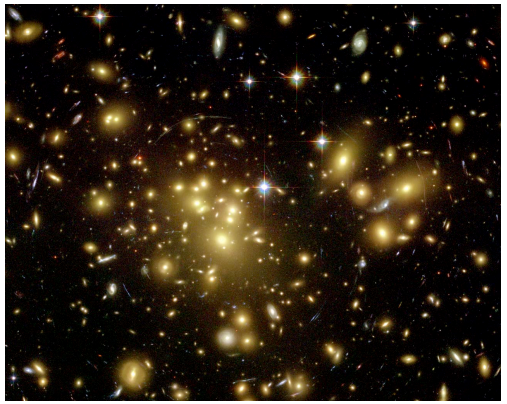
WMAP Haze – Planck in orbit!



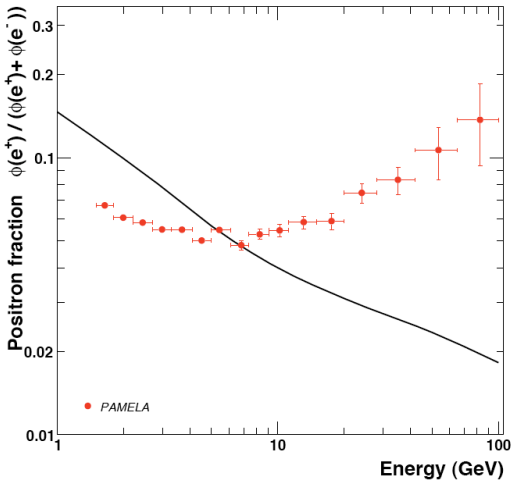
Fermi-LAT: GeV excess



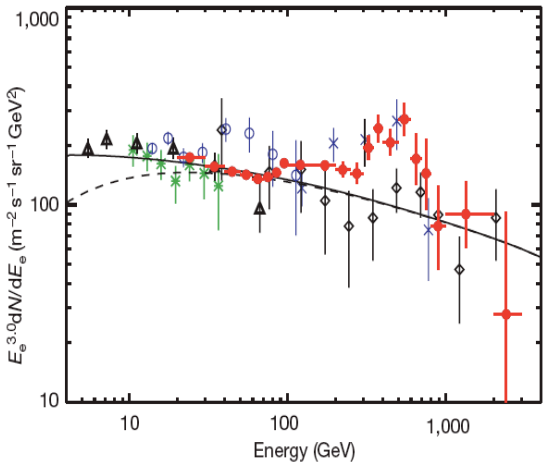
Fermi-LAT: γ-ray limits from local dwarfs and galaxy clusters



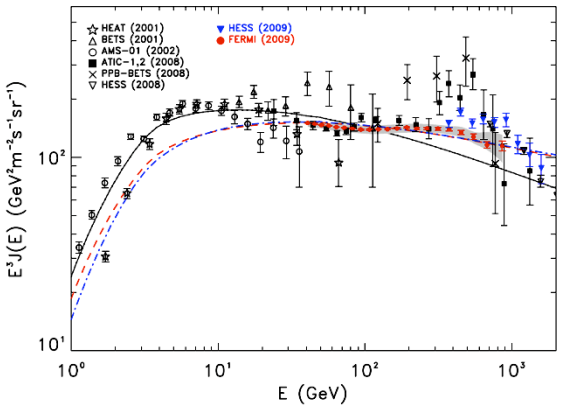
Pamela: positron fraction

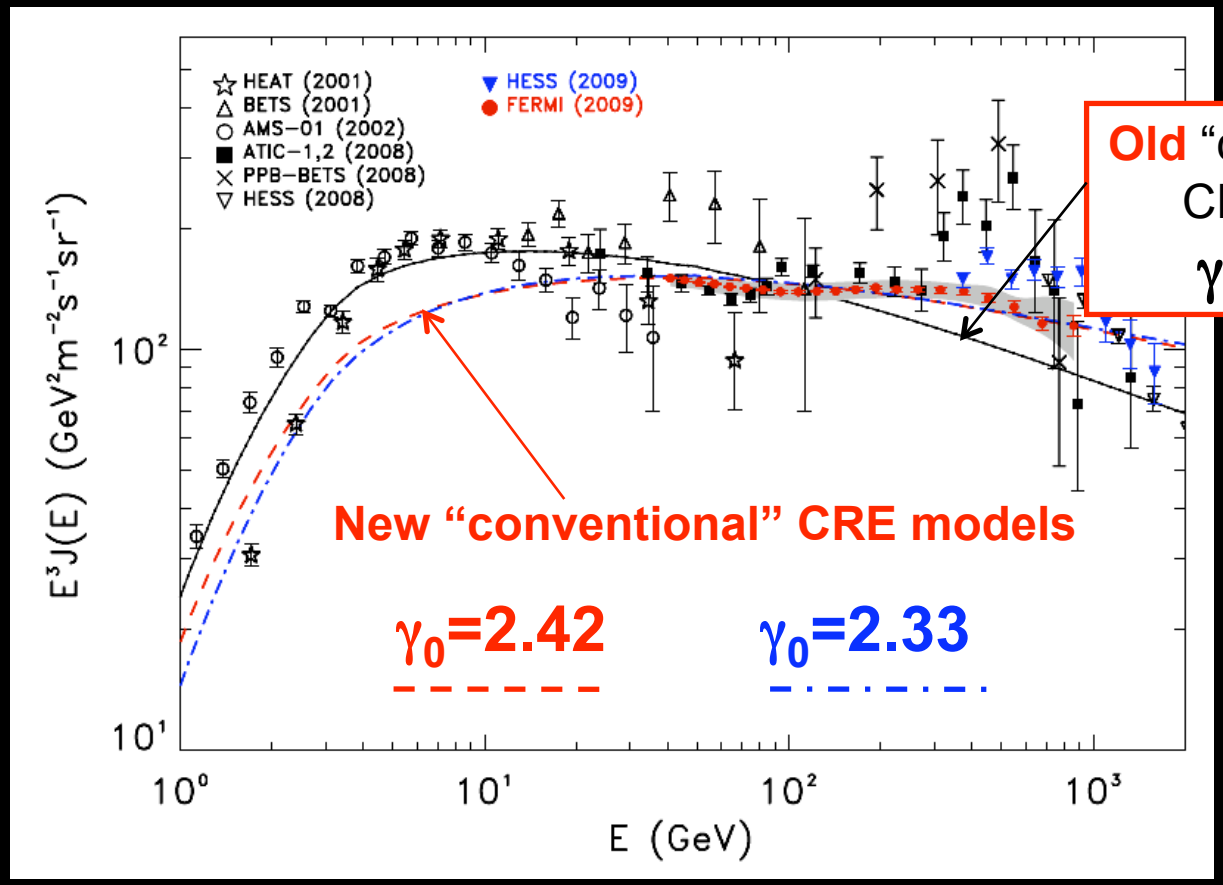


ATIC: e+e- anomaly



Fermi-LAT: e+e-





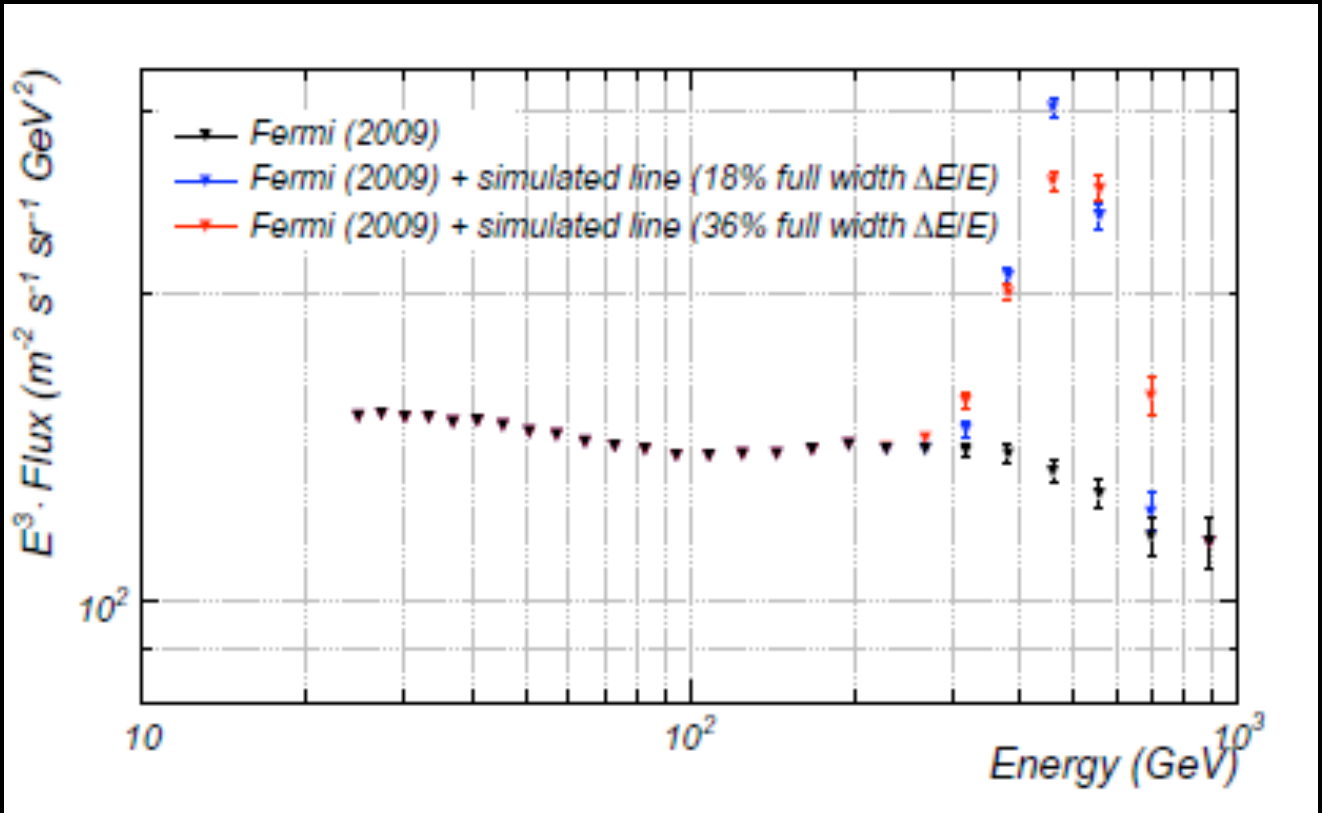
Spectrum well reproduced by **Diffuse Galactic Cosmic-Ray** Model,

with **harder** injection spectral index γ_0 than in previous CR models

[*electrons accelerated by continuously distributed astrophysical sources, e.g. Supernova Remnants*]

$$\gamma_{local} \sim \gamma_0 + \frac{\delta + 1}{2}$$

Simulations of what Fermi **would have seen** is the **ATIC** feature was there

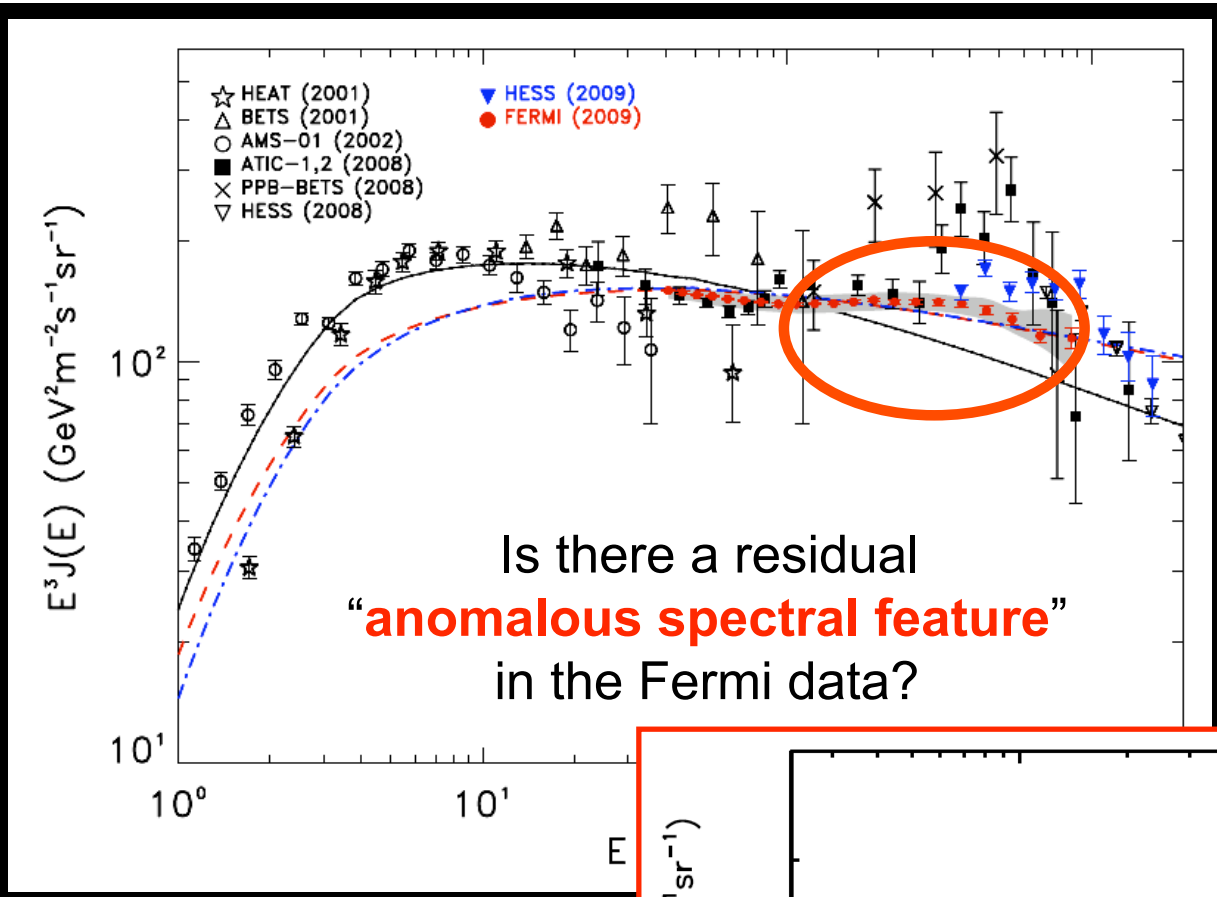


The **ATIC** anomalous bump is **not confirmed**!!

Tremendous jump in **statistics**

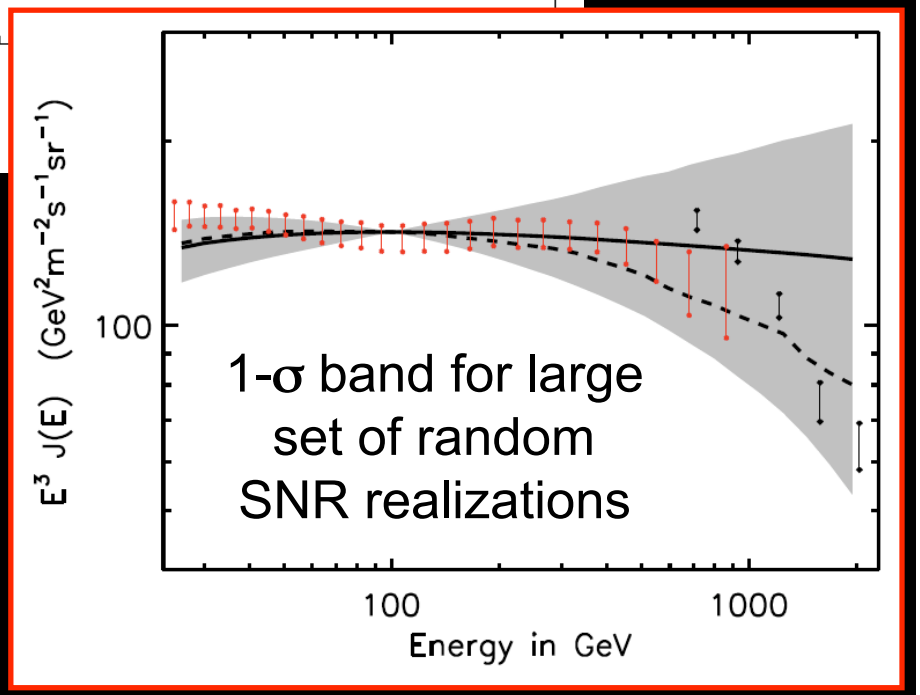
[ATIC counts above 100 GeV: **1,724**, PPB-BETS: **84**

Fermi-LAT: **233,409** (ATIC x 137)]



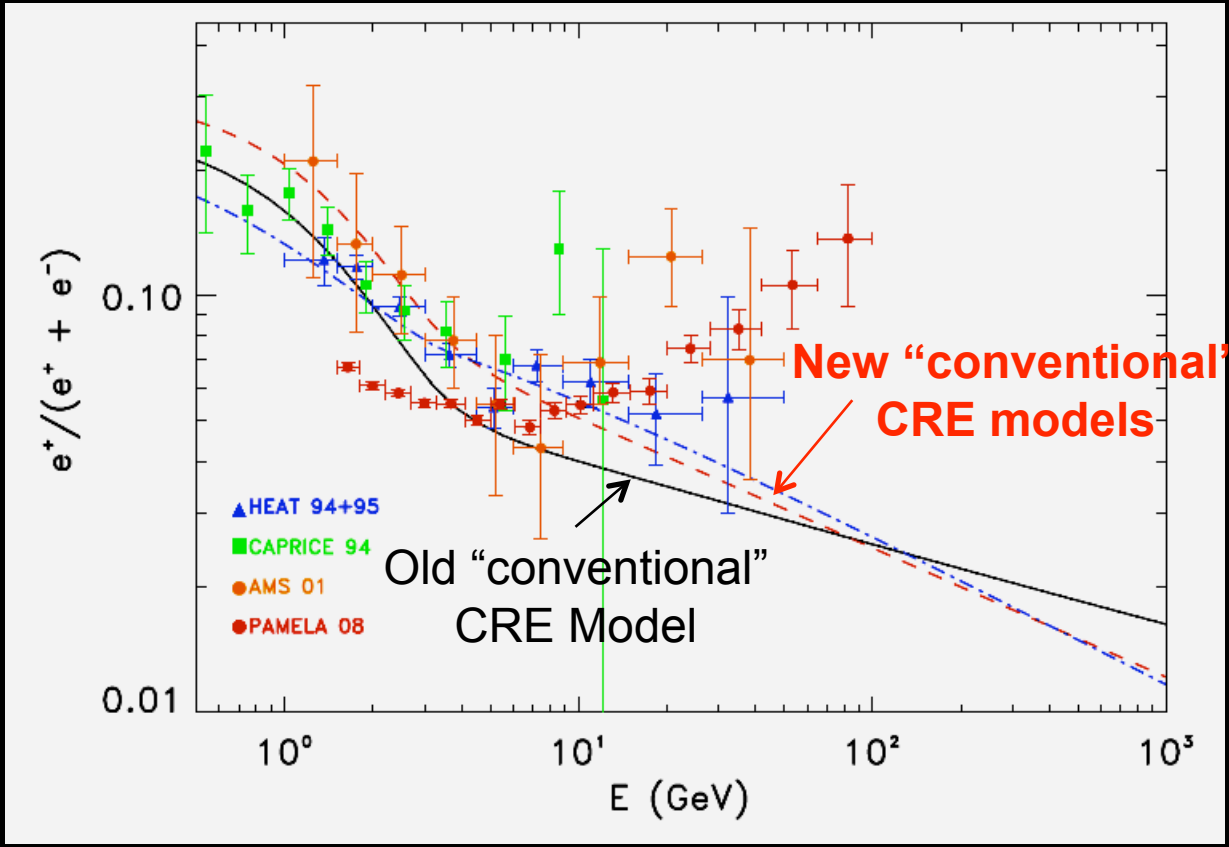
Most probably **NO**: in the ~ TeV range

- CR Source Spectrum **Cutoff**
- Diffusion **Radius** comparable to mean SNR **separation** → source **stochasticity** effects! [breakdown of spatial continuity and steady-state hypotheses]



Harder (larger flux at high energy) **e+ e-** spectrum

→ **steeper** secondary-to-primary positron fraction ratio



$$\frac{e^+}{e^+ + e^-} \propto E^{-\gamma_{protons} + \gamma_0 - \delta}$$

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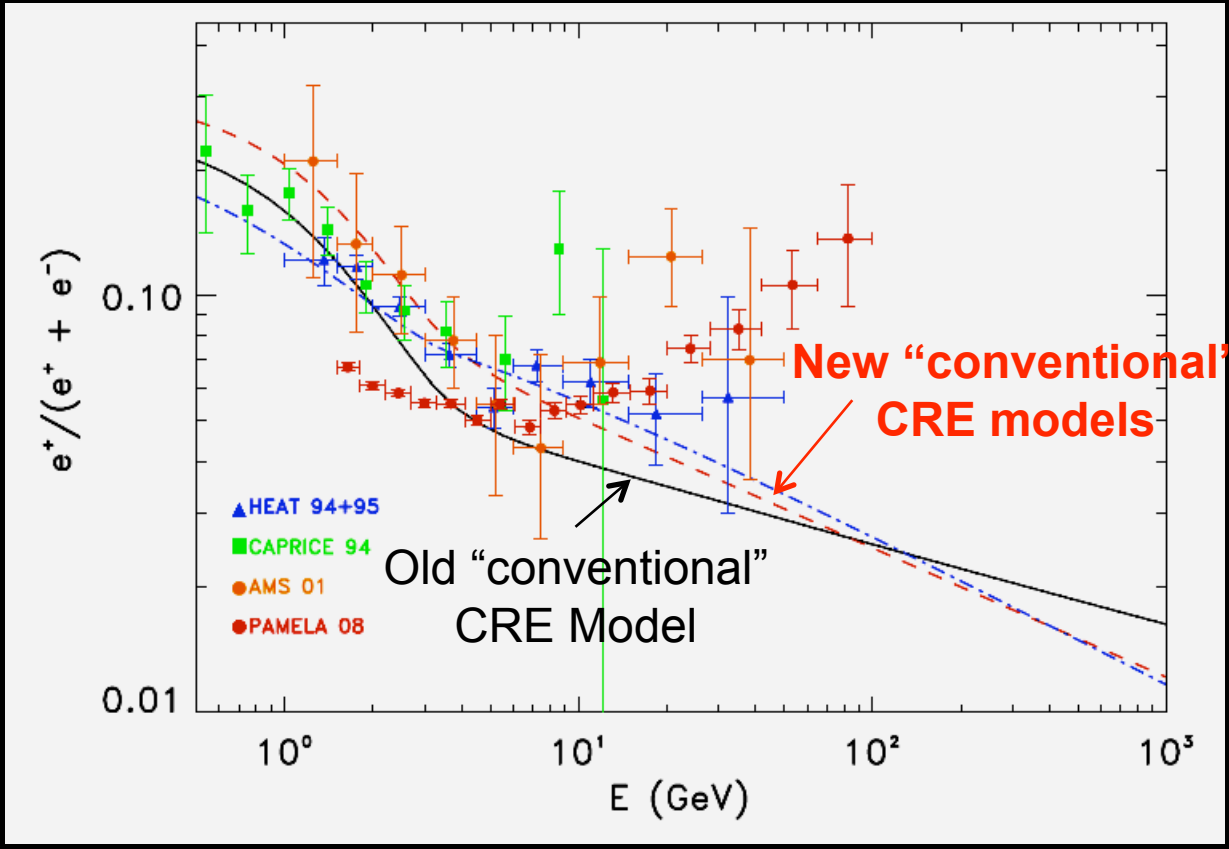
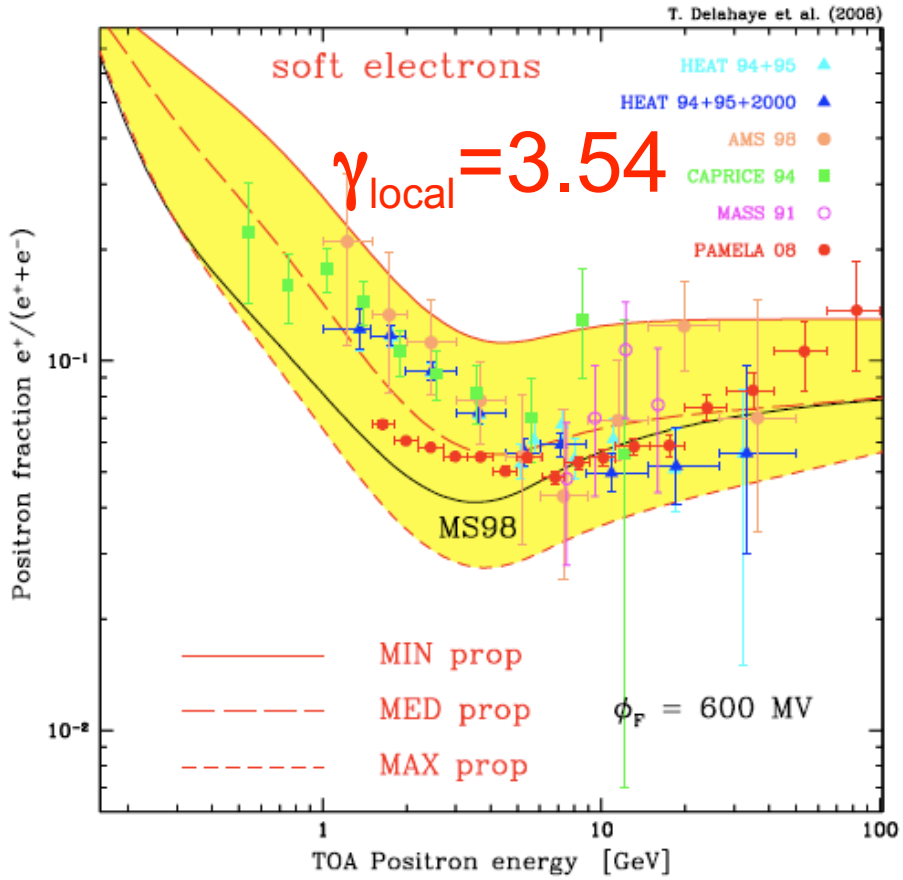
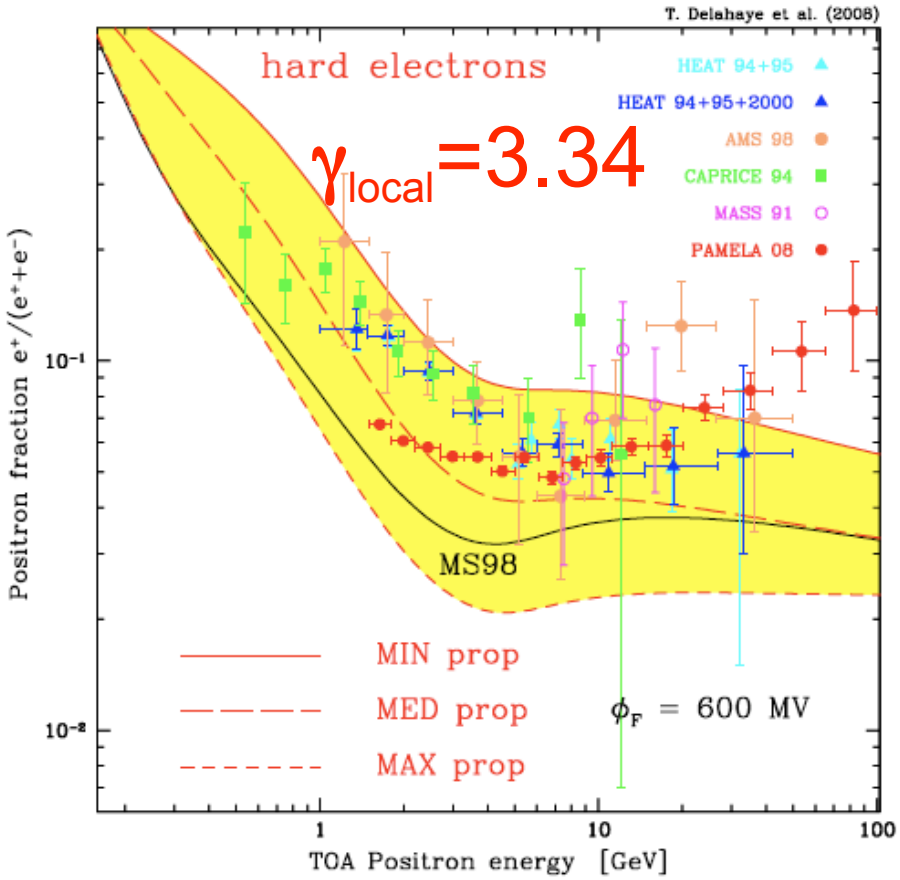


Fermi CRE data exacerbates the **discrepancy** between a purely secondary diffuse **cosmic-ray origin** for **positrons** and the positron fraction measured by **Pamela**

New Fermi-LAT Data: γ_{local}=3.045 +- 0.008





- No problem at **low energies** (both propagation and solar modulation)
- **Real troubles** at **high energies**: no way to fit with the hard e+e- Fermi data!!

Delahaye et al (2008) [0809.5268]

Fermi's precise measurement of a hard (~E^{-3}) CRE spectrum implies that one or more **additional positron sources** are **conclusively** needed to explain the **Pamela positron fraction** data

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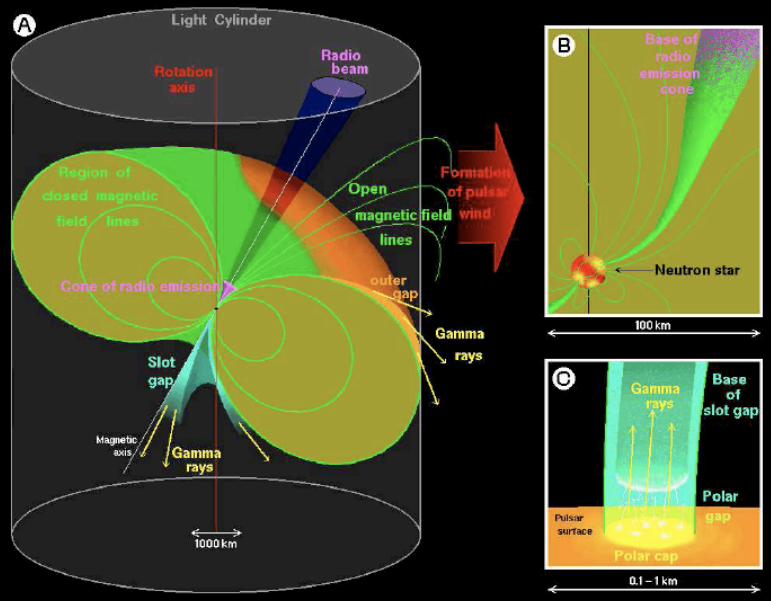

Pulsars

Image Credit: F. Paige

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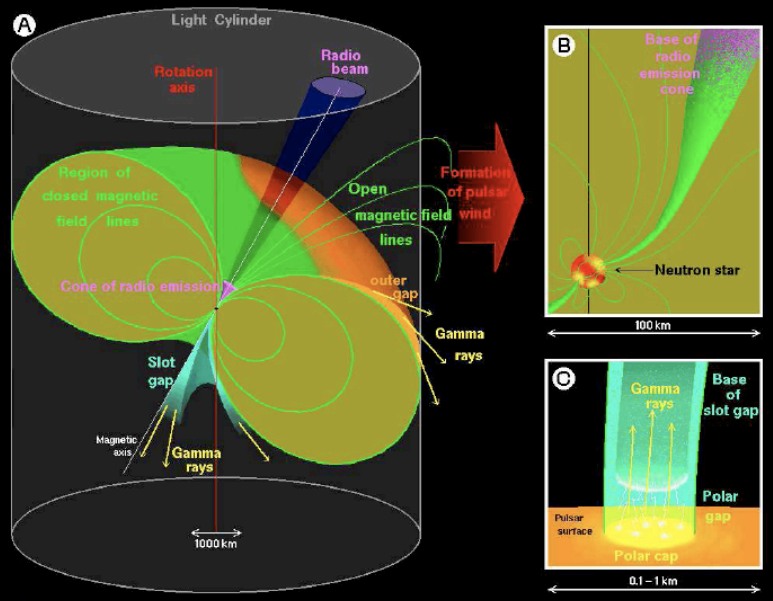
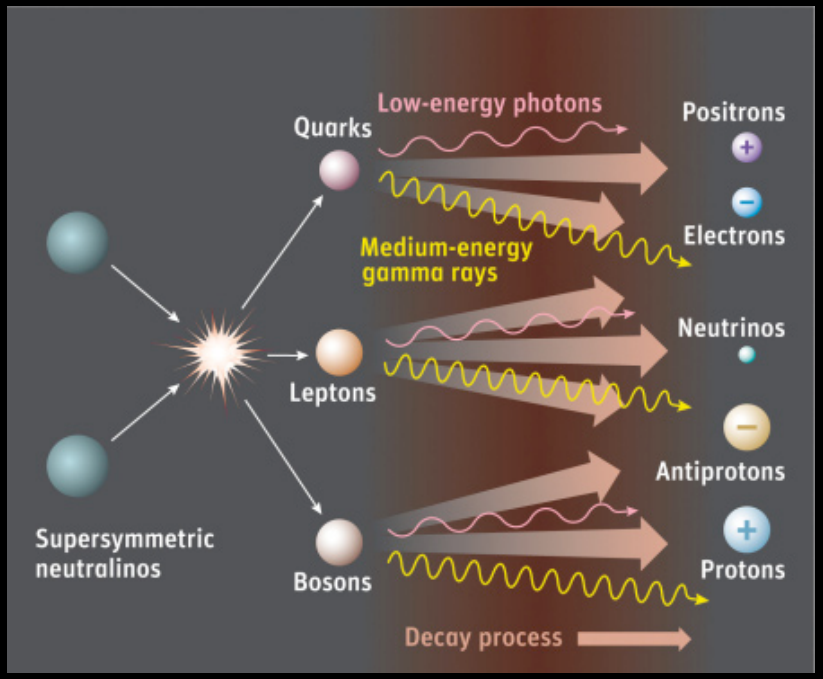


Pulsars



Dark Matter

Image Credit: F. Paige / Fermilab Webpage

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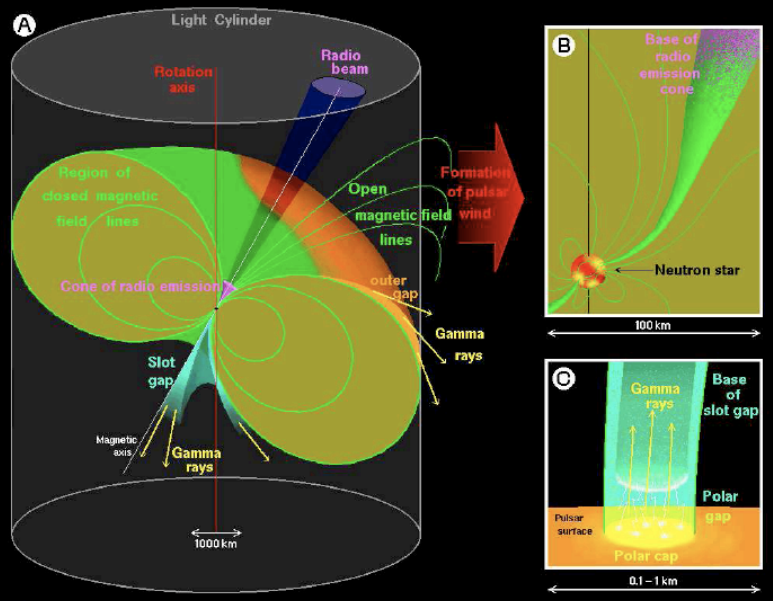

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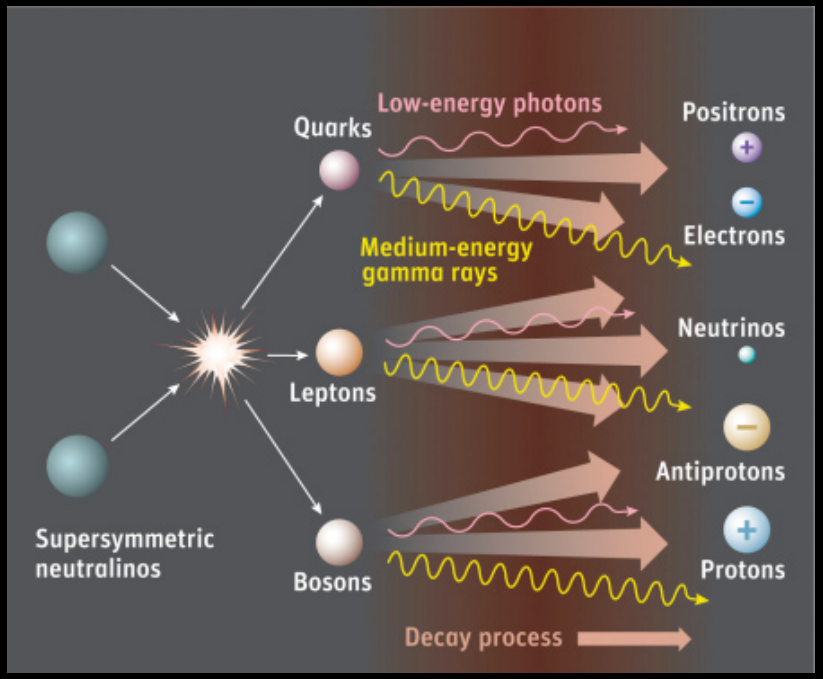
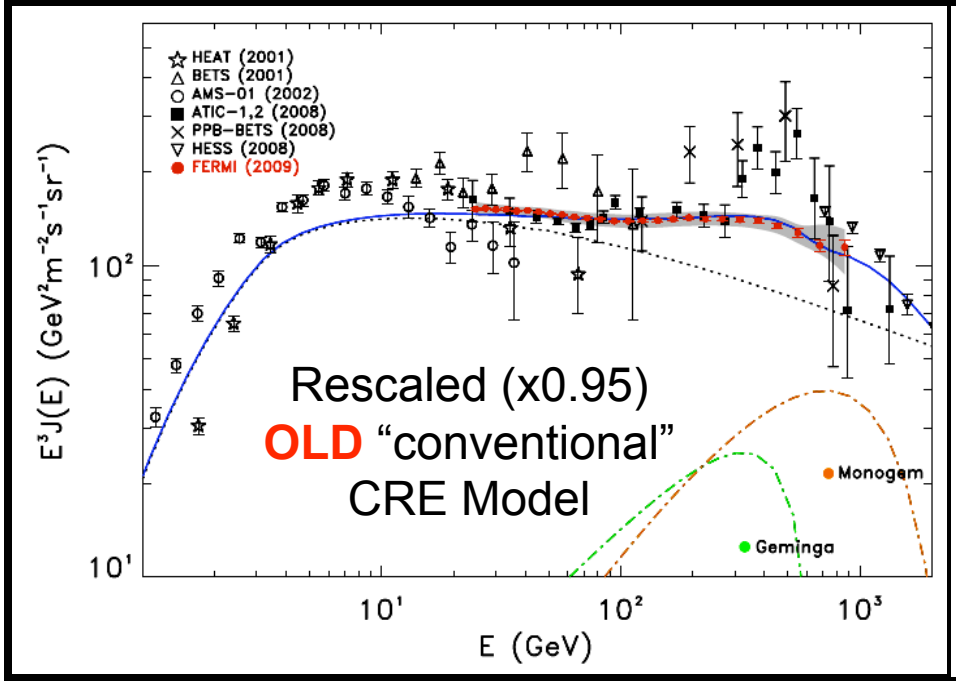
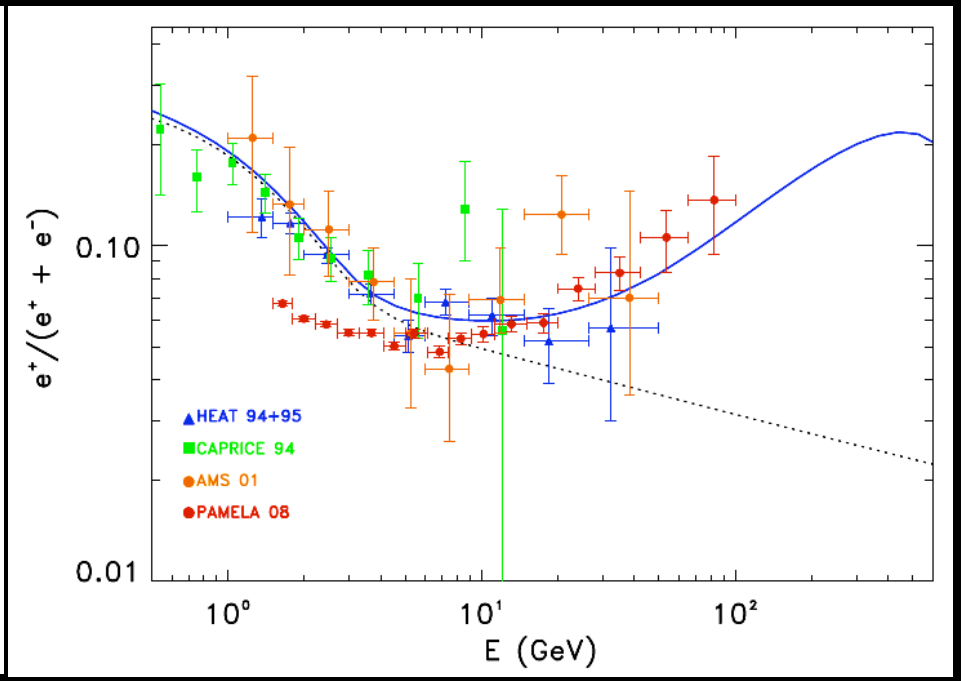


Dark Matter

What is the impact of the new Fermi CRE data?

Image Credit: F. Paige / Fermilab Webpage





Example of fit to both **Fermi** and **Pamela** data with known (**ATNF** catalogue) nearby, mature pulsars and with a single, nominal choice for the **e+/e- injection** parameters

$$\Gamma = 1.7 \qquad E_{\rm cut} = 1100\ {\rm GeV},$$
$$\eta_{e^\pm} = 40\% \qquad \Delta t = 6 \times 10^4\ {\rm yr}.$$

Grasso, Profumo, Strong et al., 0905.0636

What if we randomly vary the **pulsar parameters**

relevant for **e+e- production**?

[*injection spectrum, e+e- production efficiency, PWN "trapping" time*]

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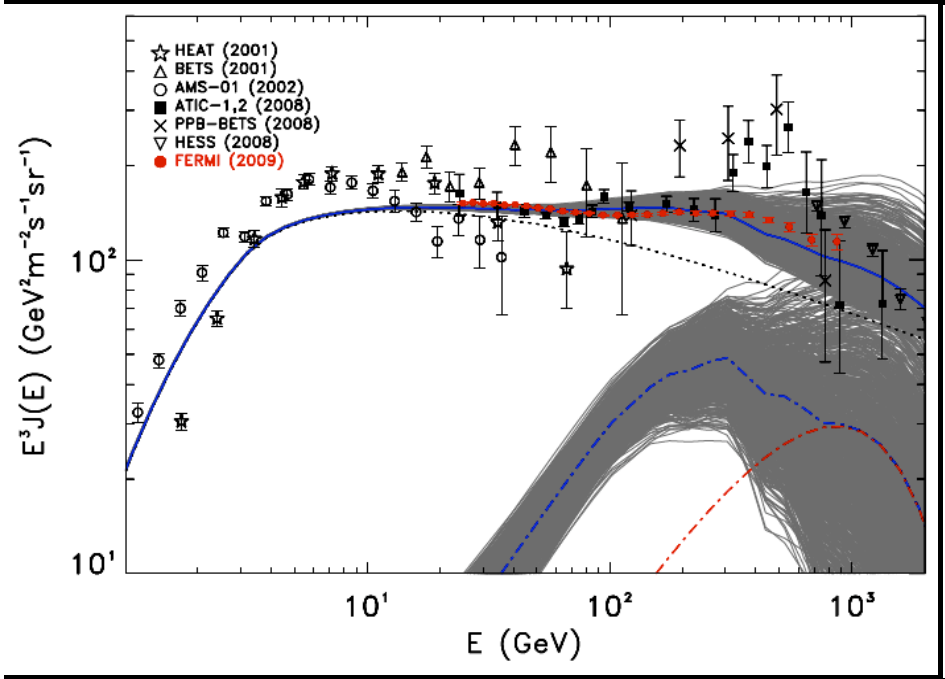

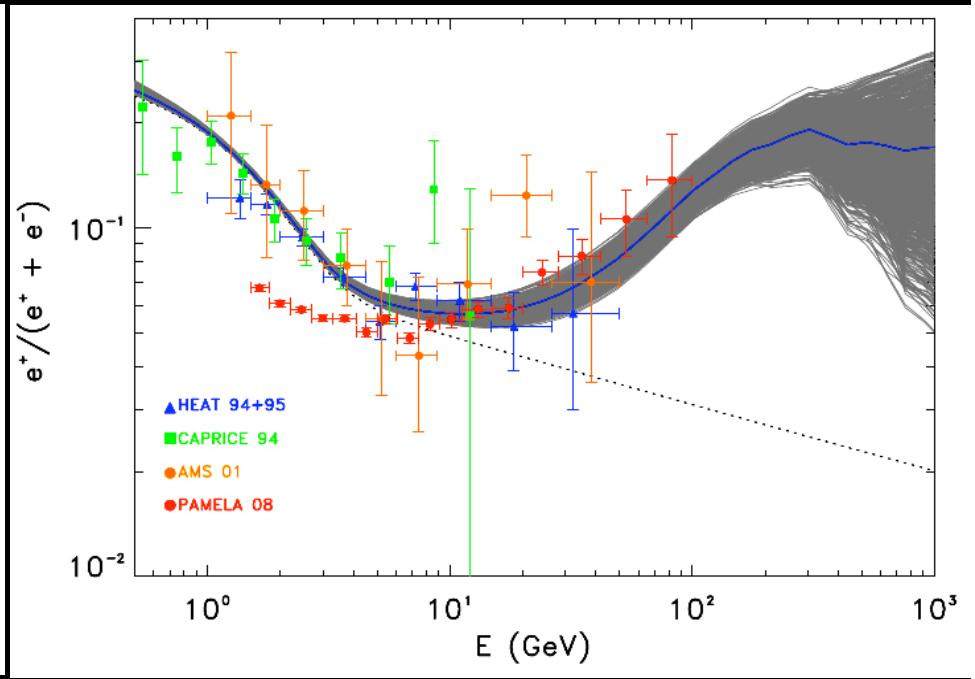

$$1.5 < \Gamma < 2.0. \qquad 800 < E_{\rm cut} < 1400 \ {\rm GeV},$$

$$10 < \eta_{e^\pm} < 30\ \% \qquad 5 < (\Delta t/10^4\ {\rm yr}) < 10\ ;$$

Grasso, Profumo, Strong et al., 0905.0636

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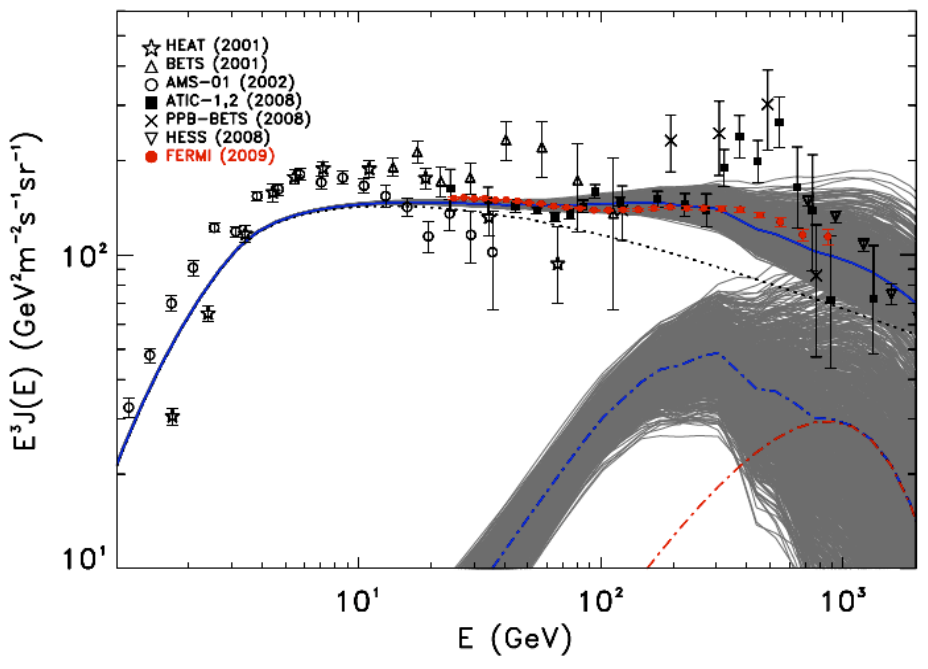
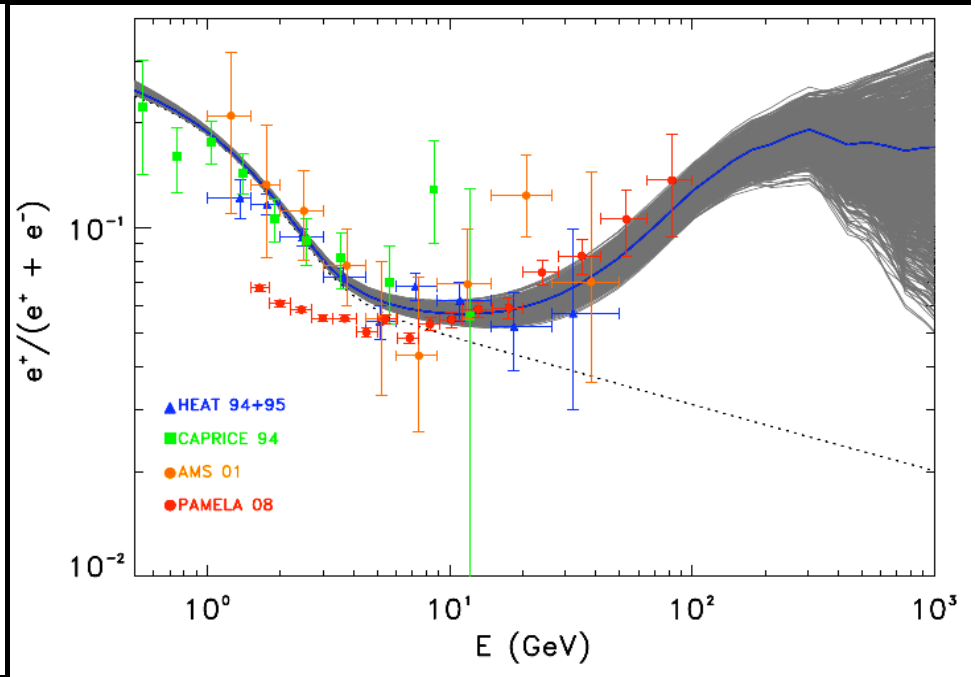
[*injection spectrum, e+e- production efficiency, PWN "trapping" time*]





Under reasonable assumptions, electron/positron **emission** from **pulsars** offers a **viable interpretation** of **Fermi** CRE data which is also **consistent** with the **HESS** and **Pamela** results

Grasso, Profumo, Strong et al., 0905.0636

Dark matter interpretation: quite a bit of interest

positrons and electrons originate from the annihilation or decay of particle dark matter (for a possibly incomplete list of related studies appeared before the first version of the present manuscript was released see Ref. [39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85]; further studies appeared between the first and the present version of this manuscript include [86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137]). As opposed to all of the other possibilities mentioned above, a dark matter interpretation invokes an entity whose fundamental particle physics nature has yet to be unveiled, and whose

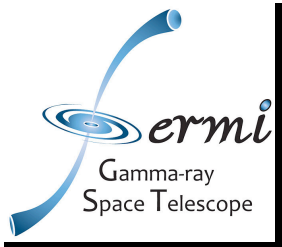
Profumo, “Dissecting Pamela (and ATIC) with Occam’s Razor…”, 0812.4457

An expected outcome of **Redman's Theorem**

"Any competent theoretician can fit any given theory to any given set of facts" (*)

(*) Quoted in M. Longair's "High Energy Astrophysics", sec 2.5.1 "The psychology of astronomers and astrophysicists"

Roderick O. Redman (b. 1905, d. 1975) Professor of Astronomy at Cambridge University



Dark matter: the impact of the new **Fermi** CRE data

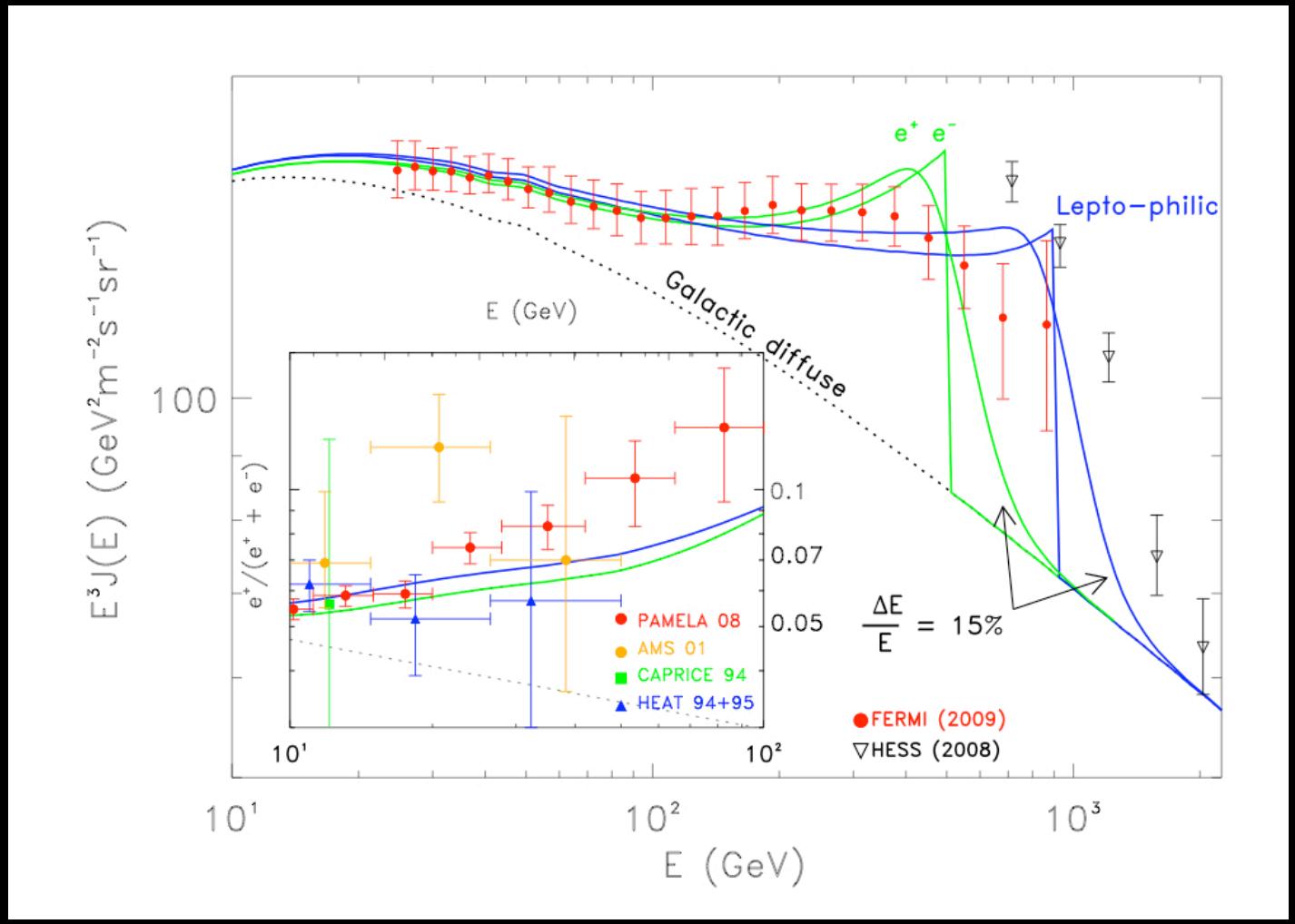
1. Much weaker rationale to postulate a **DM mass** in the 0.3-1 TeV range ("**ATIC bump**") motivated by the CR electron+positron spectrum

2. If the Pamela positron excess is from DM annihilation or decay, Fermi CRE data set **stringent constraints** on such interpretation

3. Even neglecting Pamela, Fermi CRE data are useful to put **limits** on rates for particle **DM annihilation** or **decay**

4. We find that a **DM interpretation** to the **Pamela** positron fraction data consistent with the new **Fermi-LAT** CRE is a **viable** possibility

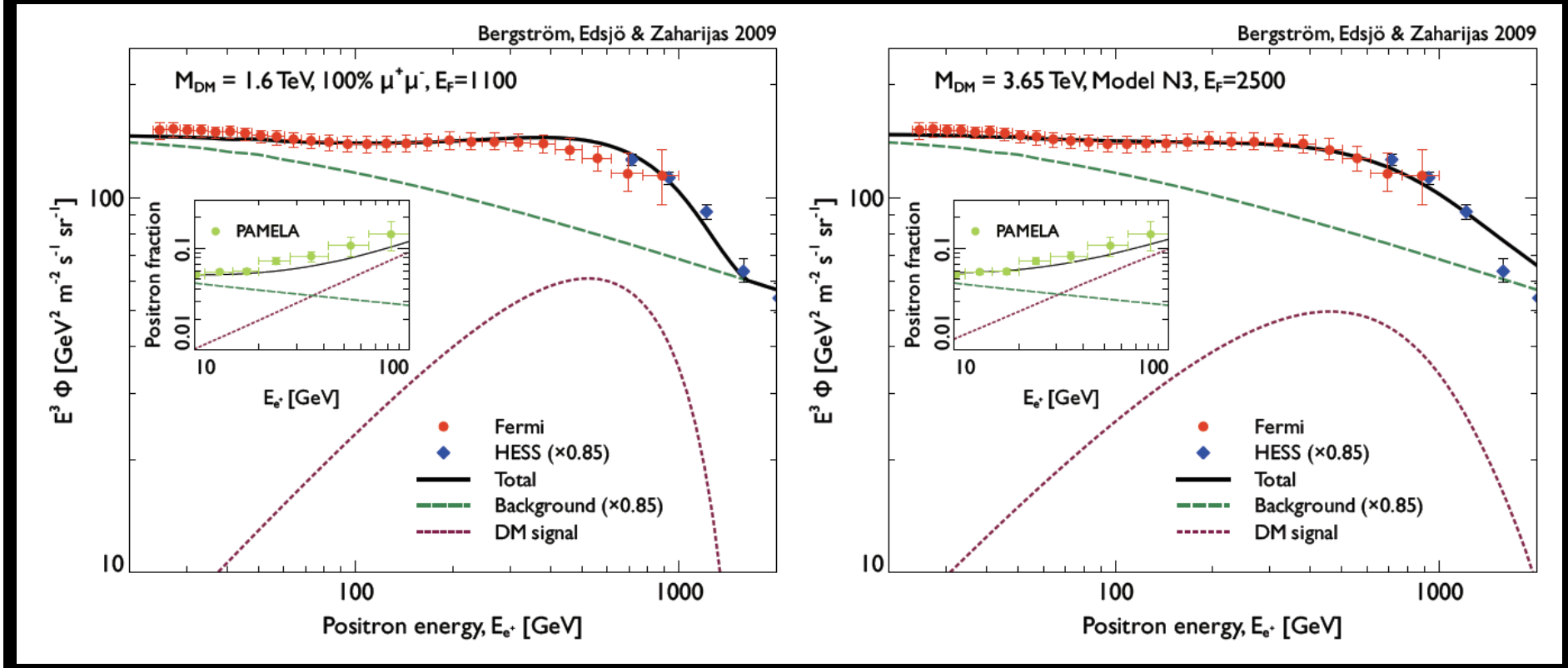
Examples of (poor man's) **Dark Matter** models that fit the Fermi data



Grasso, Profumo, Strong et al., 0905.0636

More examples of **Dark Matter** models that also fits the Fermi/Pamela data

(from Bergstrom et al, 2009)



Bergstrom, Edsjo and Zaharijas, 0905.0333

Role of **Fermi** to assess the **origin** of high-energy **CRE**:

1. Accurate CRE **Spectral Information** (probably not conclusive by itself)

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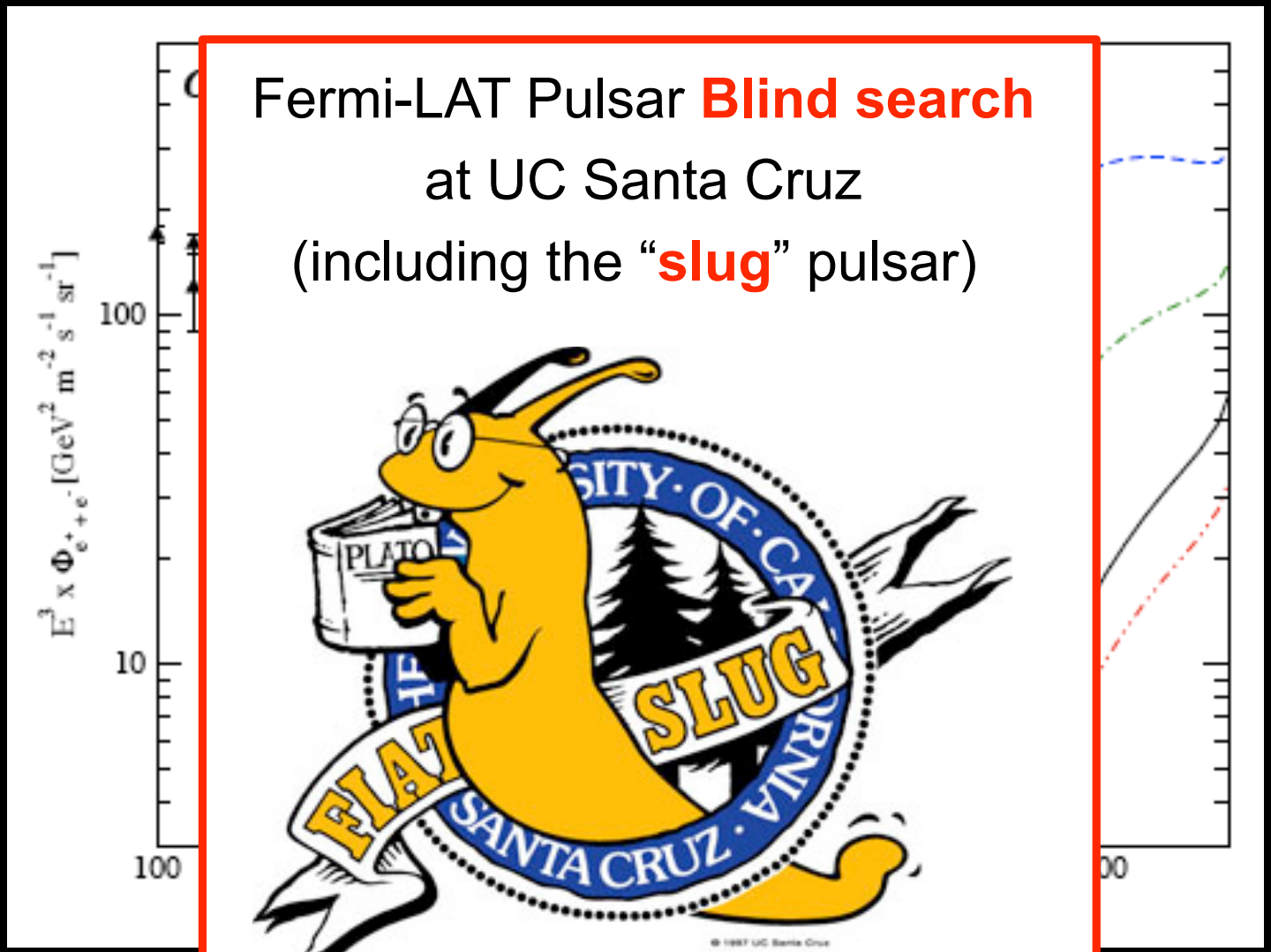
3. Discovery and improved understanding of **gamma-ray pulsars**

New radio-quiet **gamma-ray pulsars**

can play a decisive role!



Fermi-LAT Pulsar **Blind search**

at UC Santa Cruz

(including the "**slug**" pulsar)

Profumo, 0812.4457

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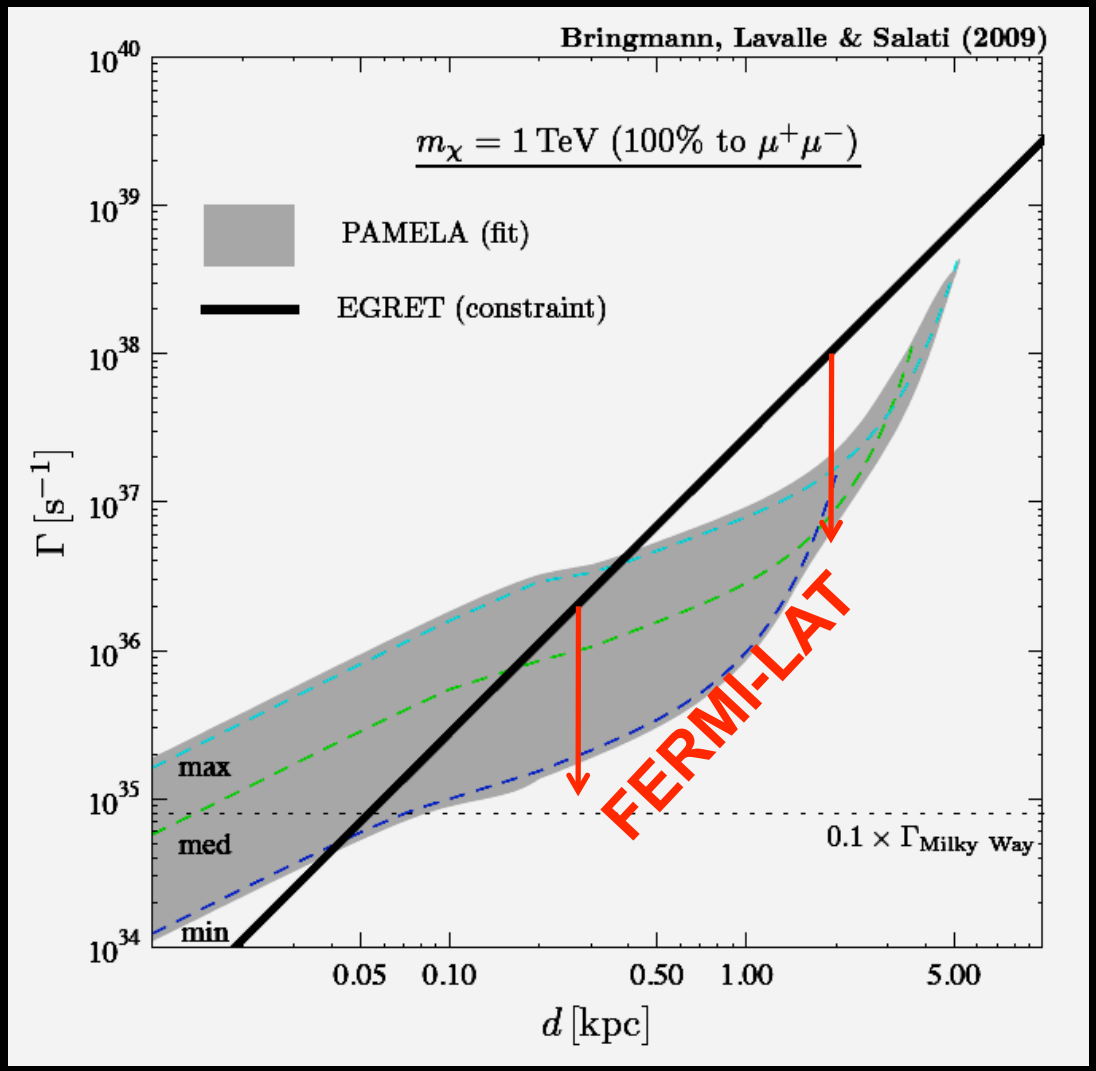
4. **Constraints** on **DM** interpretation with **gamma-ray** data (e.g. nearby clump)

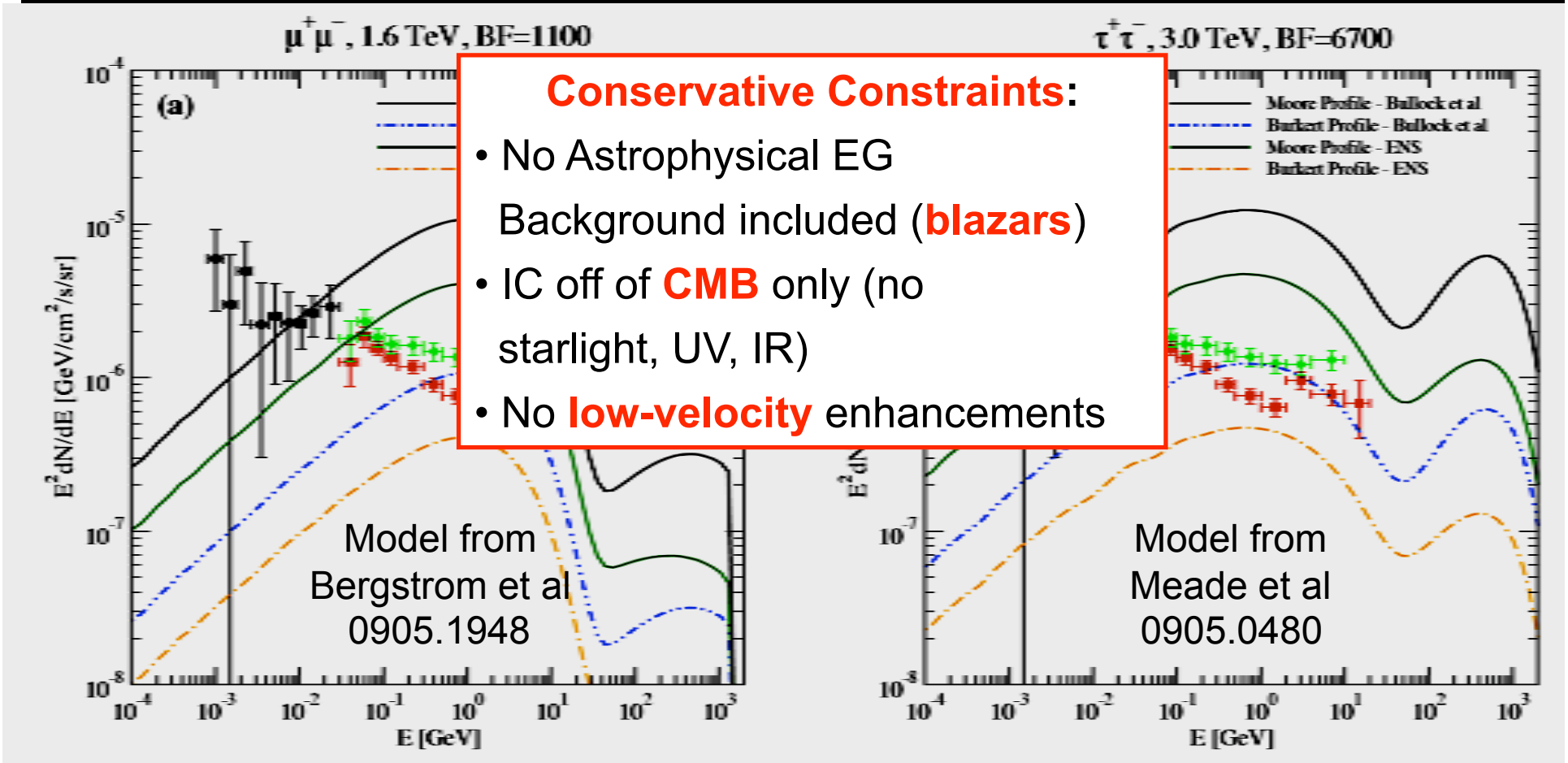
If a **nearby DM clump** is the source of the e+e- excess,

Fermi-LAT will detect a **gamma-ray** signal from it !!



Bringmann, Lavalle and Salati, 0902.3665

Best-case scenarios constrained via **multi-wavelength** observations



Conservative Constraints:

- No Astrophysical EG Background included (**blazars**)
- IC off of **CMB** only (no starlight, UV, IR)
- No **low-velocity** enhancements

Extra-galactic **all-redshift**, **all-halos** emission, including IC off CMB

Profumo and Jeltema, JCAP (2009), arXiv:0906.0001

Role of **Fermi** to assess the **origin** of high-energy **CRE**:

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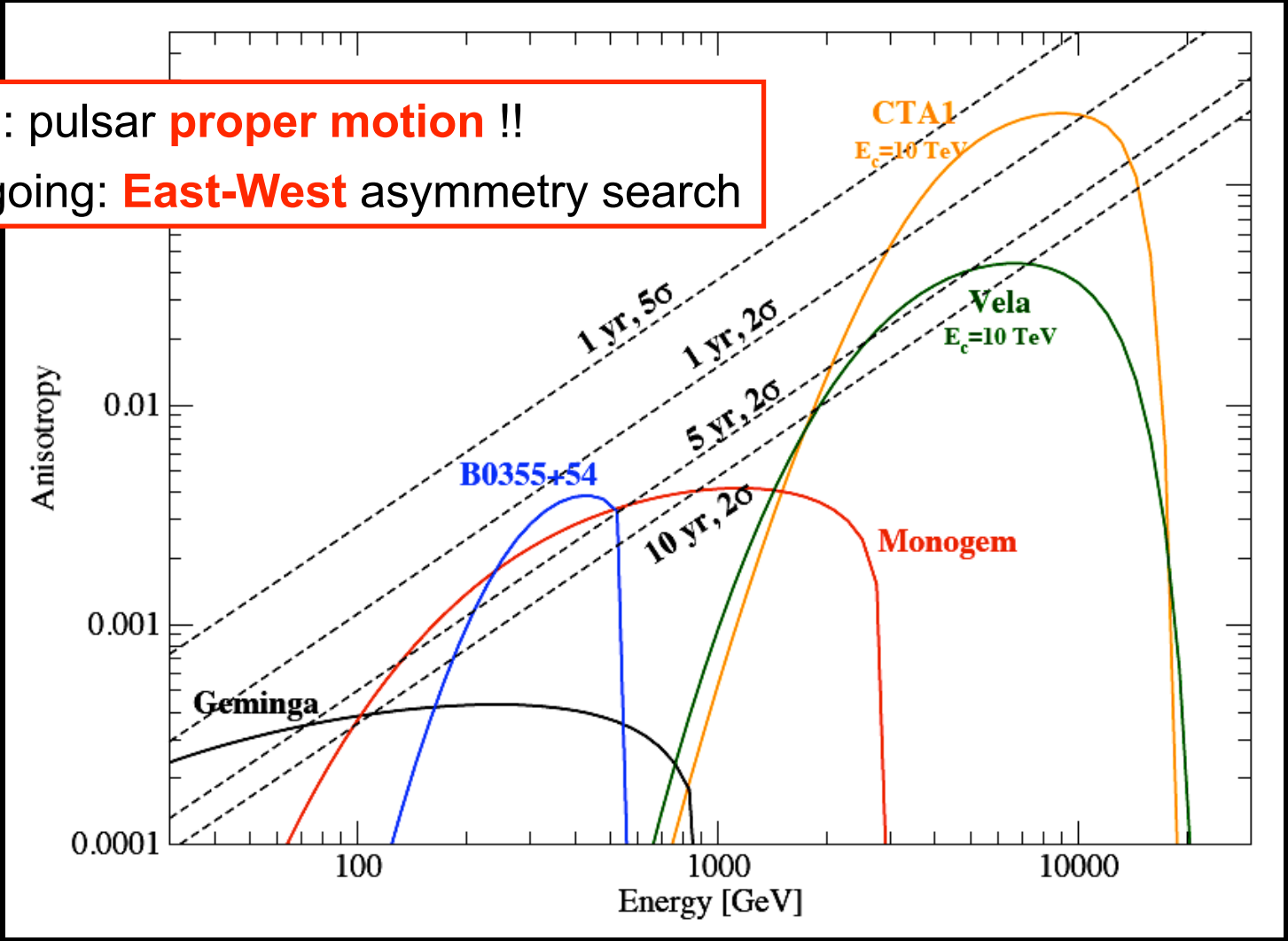
5. **Anisotropy**: search for excess CRE from bright nearby **pulsars**

Predicted **Anisotropy** for selected Pulsars

- Problem: pulsar **proper motion** !!
- Also ongoing: **East-West** asymmetry search



Profumo, 0812.4457

Latest News on Indirect Dark Matter Detection and the "**Lepton Anomalies**": Summary

- Fermi CRE data indicate a **hard** high-energy CRE **spectrum** (**$\Phi \sim E^{-3}$**)
- Data perfectly **compatible** with **Diffuse Galactic Cosmic Ray** origin, but, including Pamela data, a purely **secondary** diffuse CR origin for the **positron excess** is **extremely unlikely**
- **Pulsars** are strong **candidates** as primary electron/positron sources
- **Dark Matter** annihilation/decay is **constrained** but **not ruled out** by Fermi data as possible primary high-energy positron-electron source