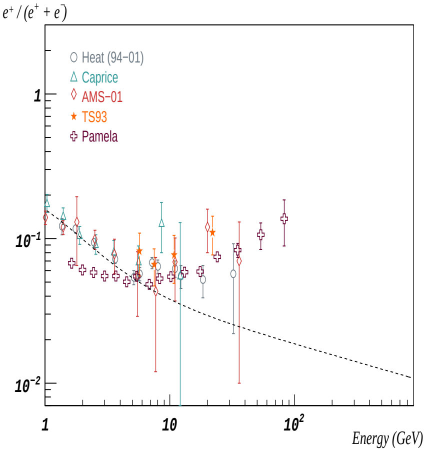
Positrons in AMS-02.
Positrons excess what can we say?

Jonathan Pochon

AMS-group from Instituto Astrofisica de Canarias (IAC)

AMS-02 workshop: march 9^{th} 2010

Positrons excess: why we started (again) with pulsars?



- From 70's, experiments show a possible excess on positron fraction above 10 GeV.
- At these energies, most of positrons are believed "secondaries", interactions between cosmic rays and gas: $pp, pHe, HeHe... \to e^+e^-$.
- We hoped that would be a sign from **Dark Matter**: SUSY, Kaluza-Klein,.....
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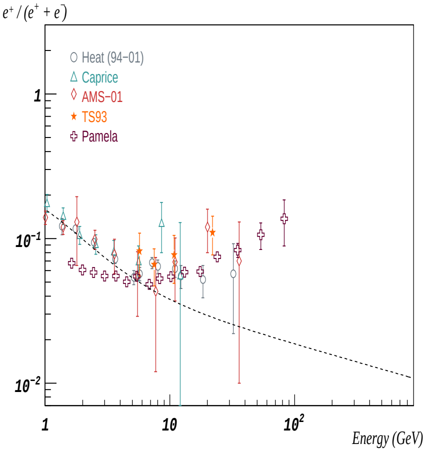

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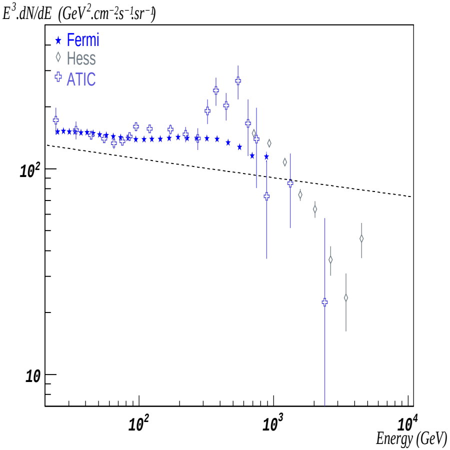

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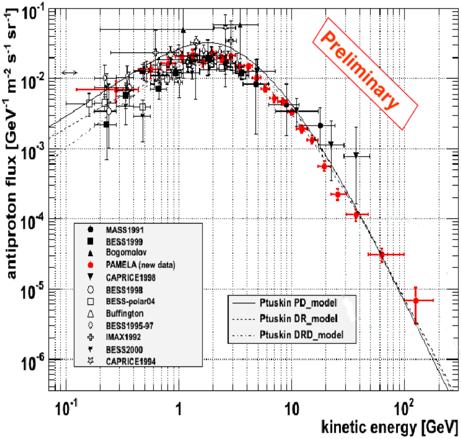

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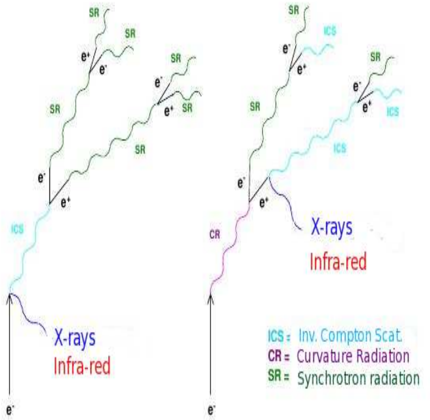
Pulsars: $e^\pm$ production



- Pulsar magnetic field takes away electrons from surface, and then interact with medium: magnetic field, thermal X-rays,....
- Almost **two locations** are possible acceleration zone: Polar Cap (PC) and Outer Gap (OG). Gamma-ray pulsar condition: "g<1".
- **Differences**: OG gives a harder $e^\pm$ flux, and PC has a higher contribution at low energy. But, more or less $e^\pm$ **output energy is the same.**

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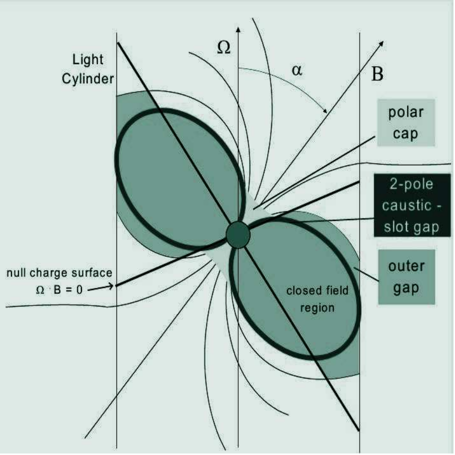

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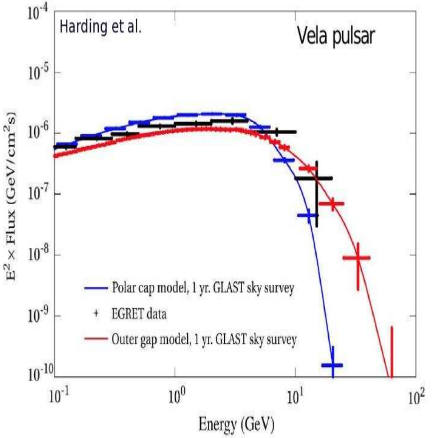

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Pulsars properties

$$E^{e^\pm}_{max} \propto 1/T$$

$$E^{e^\pm}_{max}(Vela) \sim 30 \text{ TeV},$$
$$E^{e^\pm}_{max}(Geminga) \sim 950 \text{ GeV}.$$

- Pulsars age T can be determined from pulsations, which gives maximum energy reached by $e^\pm$.......
- .....and a simple way to obtain $E^{e^\pm}_{out}$.
- The higher E_{max} we get, the lower $E^{e^\pm}_{out}$ we have.

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$$E_{out}^{e^\pm} \propto f_{e_\pm} \dot{E} T^2$$

$f_{e_\pm}$: pair prod. efficiency,
$\dot{E}$: spin-down luminosity $[erg.s^{-1}]$.

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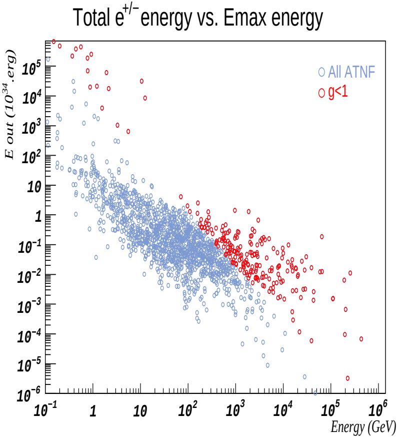

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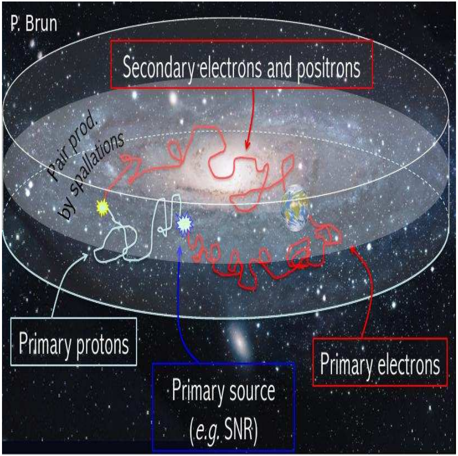
Electron propagation



- After $e^\pm$ production, $e^\pm$ loose energy by **synchrotron** and **inverse Compton** and diffuse in the galactic magnetic field.
- Transport equation in standard diffusion approximation (neglecting convection).
- Diffusion parameter $K(E) = K_0 E^{-\delta}$ $[cm^2.s^{-1}]$ manages electrons intensity and flux shape.
- Energy loss $b(E)$ determines energy maximum after a given time.

Electron propagation

$$\frac{\partial}{\partial t}\frac{dn_e}{dE_e} = \frac{K(E_e)}{r^2}\frac{\partial}{\partial r}\left[r^2\frac{\partial}{\partial r}\frac{dn_e}{dE_e}\right] + \frac{\partial}{\partial E_e}\left[b(E_e)\frac{dn_e}{dE_e}\right] + Q(E_e)$$

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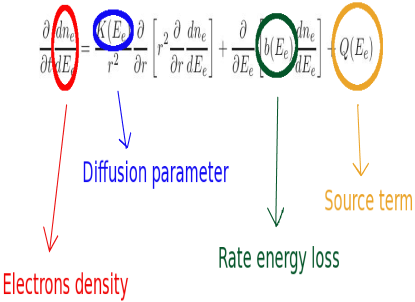

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Pulsars solution

- Pulsar injection flux $Q(E) \propto E^{-\alpha}$ ($1.5 < \alpha < 2.2$) gives a solution to propagation equation.
- *rdiff* is propagation length for a given energy which depending on pulsar age T.
- **Propagation effects**
  Intensity and shape depends on propagation parameters.
- **Age and distance conditions**
  In order to have some signal above 10 GeV, we need pulsars younger than 60.10^5 years. Below 1 kpc, pulsars could be considered individually.

Pulsars solution

$$\frac{dn_e}{dE_e} = \frac{Q(E_e)}{\pi^{3/2} r^3}(1 - E_e/E_{max})^{\alpha-2}\left(\frac{r}{r_{diff}}\right)^3 e^{(r/r_{diff})^2}$$

T: pulsar age, r: distance and $E_e < E_{max} \approx 1/(bT)$

$$r_{diff} \approx 2\sqrt{K(E_e)T\frac{1-(1-E_e/E_{max})^{1-\delta}}{(1-\delta)E_e/E_{max}}}$$

Propagation scenario Delahaye (2007)

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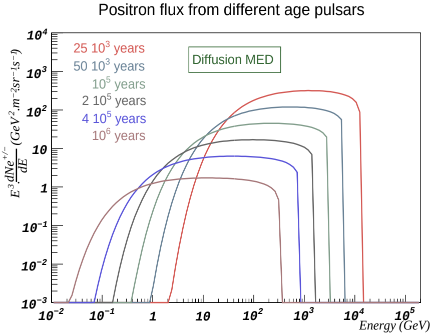

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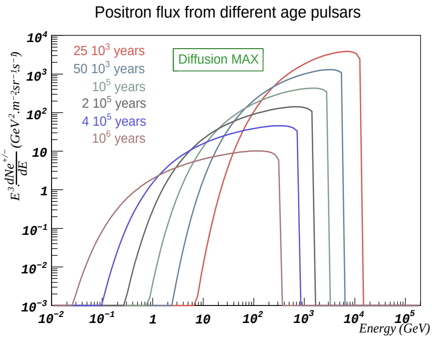

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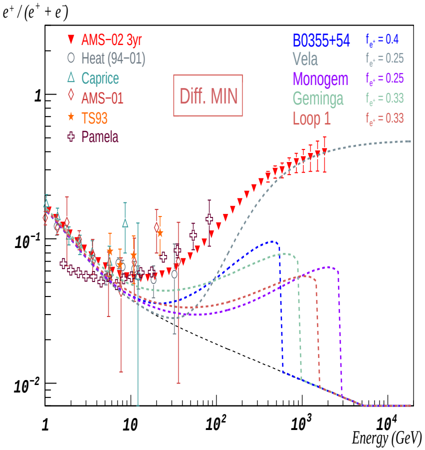

- Positron fraction in AMS-02 during 3 years with $Acc_{e^+} \sim 0.45 cm^2 \cdot sr$, and background from Edsjo (1997). Above 500 GeV is under studies.
- For both propagation scenario minimizing electrons flux (MIN) and median one (MED), pulsars contribution is rising above 10 GeV without cutoff.
- The one maximizing (MAX) lets open possibility to distinguish structure.
- From Fermi 1 year catalogue, a new pulsars set can be studied (*arXiv:1001.4540*).

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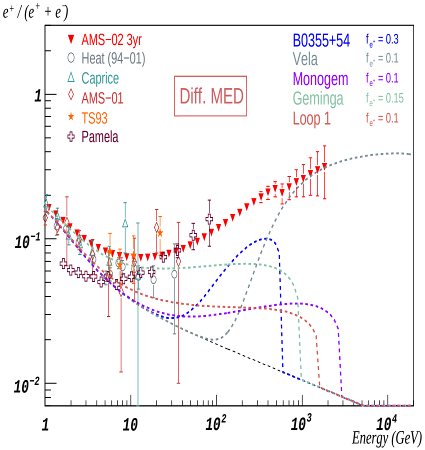

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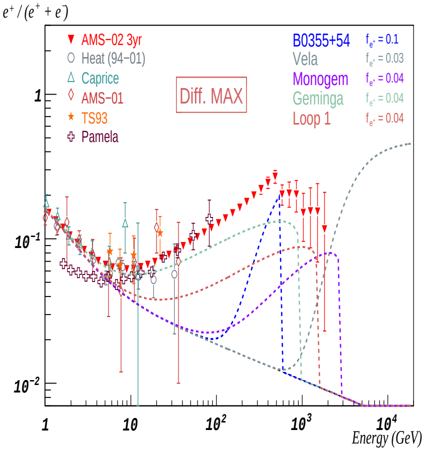

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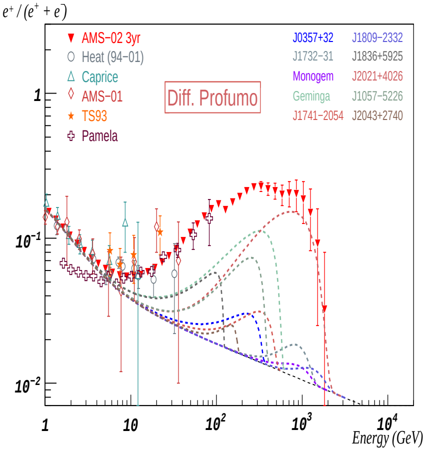

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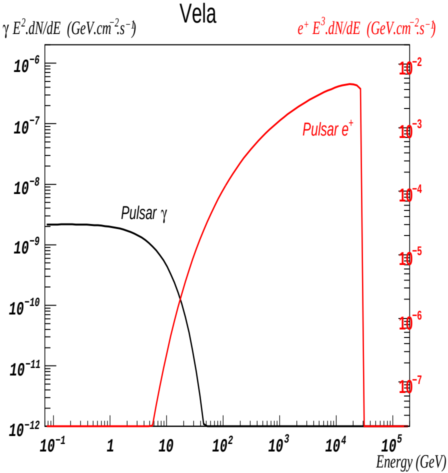
Can we constraint pulsars?



- Gammas are used to understand pulsars: Are they sufficient? What are uncertainties?
- Until now only pulsars was considered but most of the time, pulsars make part of objects complex: Supernova Remnant, Pulsar wind nebula,.... "Pulsars" spectra are more complicated.
- Can we use pulsars to probe local propagation?

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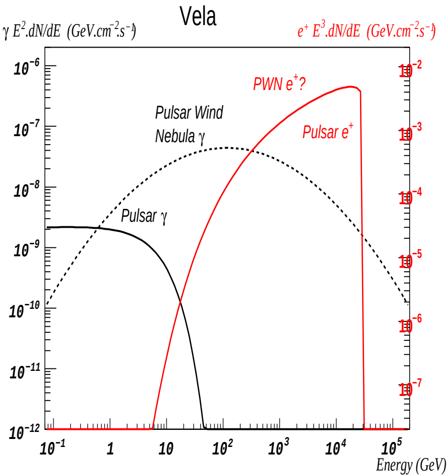

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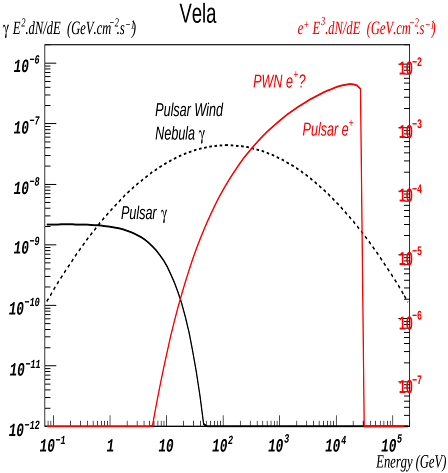

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Anisotropy: best way to distinguish pulsars?

$$Anis = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} = \frac{3K(E_e)|\nabla(dn_e/dE_e)|}{c(dn_e/dE_e)}$$

$$Anis^{max} = \frac{3}{2c}\frac{r}{T}$$

Name	Dist. (pc)	Age (years)	$Anis^{max}$ (%)
Geminga [J0633+1746]	160.	3.42 10^5	0.23
Monogem [B0656+14]	290.	1.11 10^5	1.28
Vela [B0833-45]	290.	1.13 10^4	12.5
B0355+54	1100.	5.64 10^5	0.95

- Anisotropy of the $e^{\pm}$ and e^+ flux with diffusive propagation where $\nabla(dn_e/dE_e)$ is the gradient of $e^{\pm}$ density
- Mao & Shen estimated maximum expected anisotropy $Anis^{max}$ (energy-independent diffusion) which gives indications near E_{max}
- For energy-dependent diffusion, propagation parameters
- Leptons background model modify anisotropy predictions.

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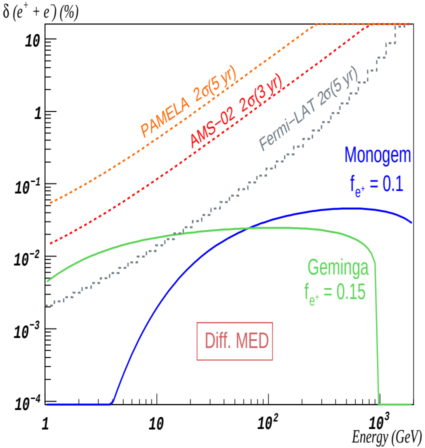
δ (e⁺ + e⁻) (%)
10
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
1
10
10²
10³
Energy (GeV)
PAMELA 2σ(5 yr)
AMS-02 2σ(3 yr)
Fermi-LAT 2σ(5 yr)
Monogem
f_e+ = 0.1
Geminga
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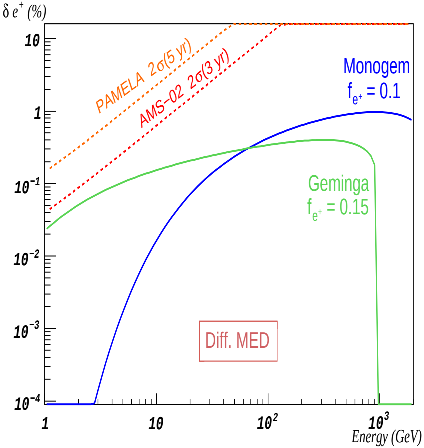
Diff. MED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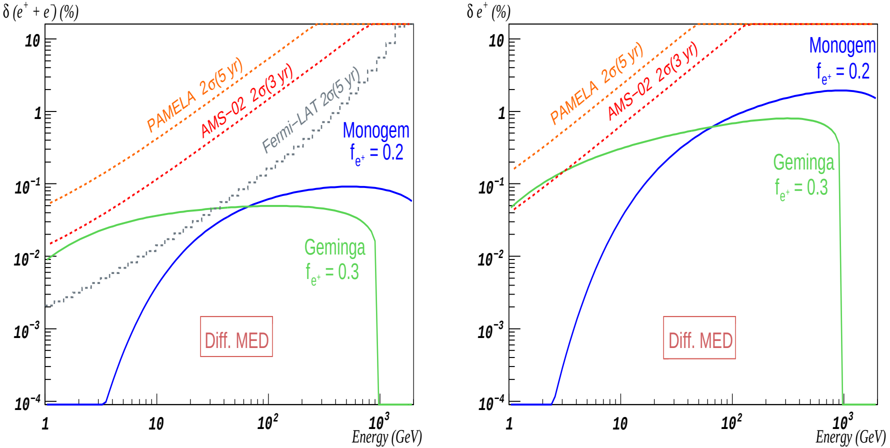

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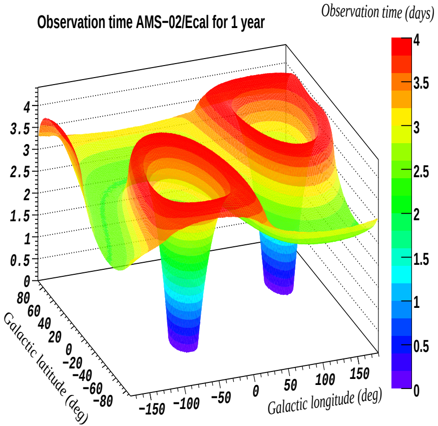

- Anisotropy from pulsars or local objects can be computed, but what is the background fluctuation or natural anisotropy?
- In AMS, discussions started to make electrons exposition map, including geomagnetic cutoff.
- What do we include? Sun position from source, to take in account heliomagnetic field?
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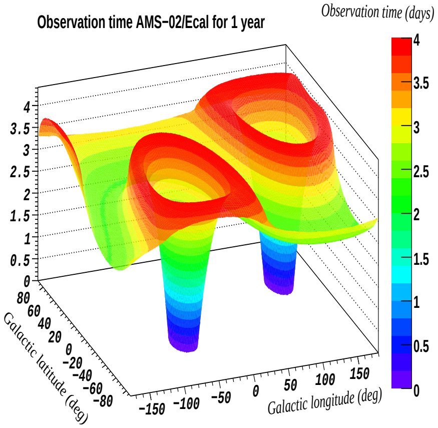

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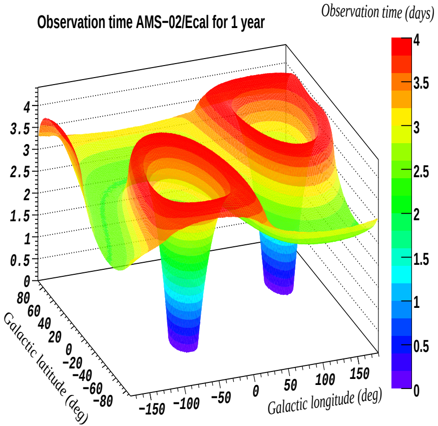

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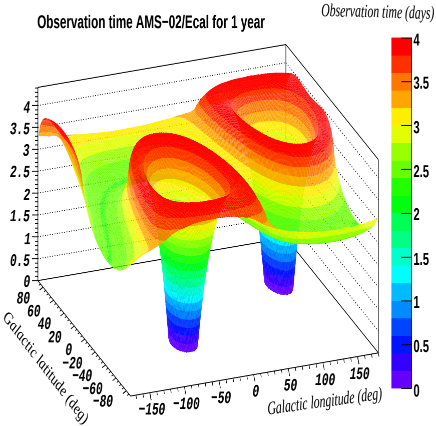

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Conclusions: a (new) long journey has started.......

- Uncertainties remain with pulsars: Local propagation and far away? Pair production efficiency? Which pulsars set?........
- With or without antiprotons rise-up, pulsars must be studied to understand background. What about pulsars at lower energy?
- Strategies for the analysis of the positron fraction and anisotropy must be discussed.
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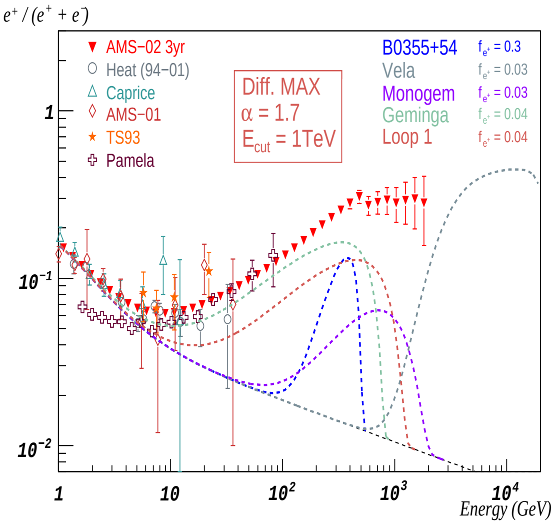
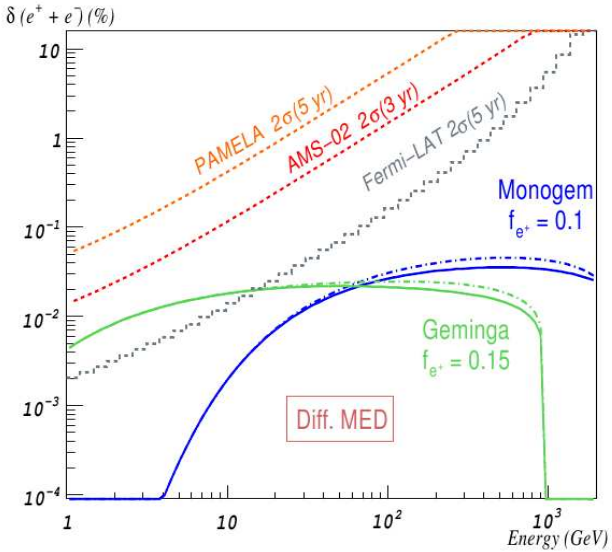
Bonus-track



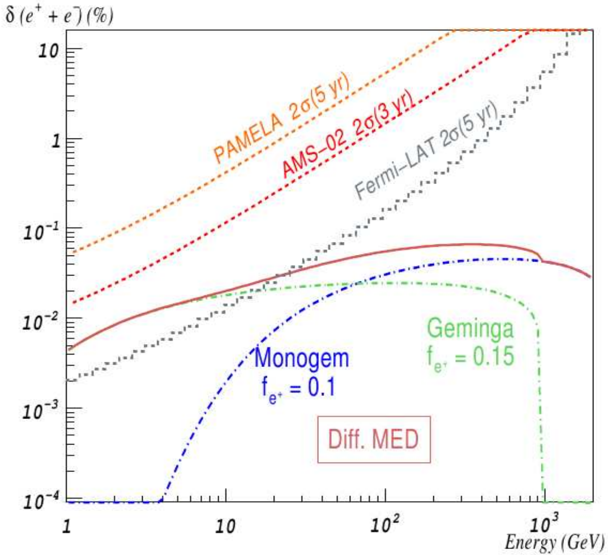
e+ / (e+ + e-)
AMS−02 3yr
Heat (94−01)
Caprice
AMS−01
TS93
Pamela
Diff. MAX
α = 1.7
E_cut = 1TeV
B0355+54 f_e+ = 0.3
Vela f_e+ = 0.03
Monogem f_e+ = 0.03
Geminga f_e+ = 0.04
Loop 1 f_e+ = 0.04
1
10^-1
10^-2
1
10
10^2
10^3
10^4
Energy (GeV)

Bonus-track

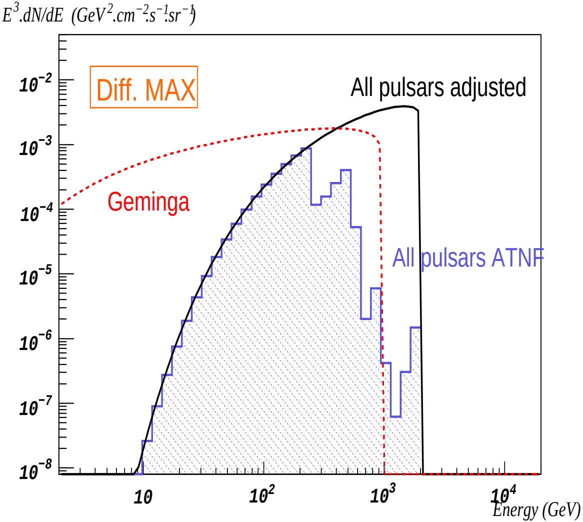


δ (e+ + e−) (%)
10
1
10−1
10−2
10−3
10−4
1
10
10²
10³
Energy (GeV)
PAMELA 2σ(5 yr)
AMS-02 2σ(3 yr)
Fermi-LAT 2σ(5 yr)
Monogem
fe+ = 0.1
Geminga
fe+ = 0.15
Diff. MED

Bonus-track

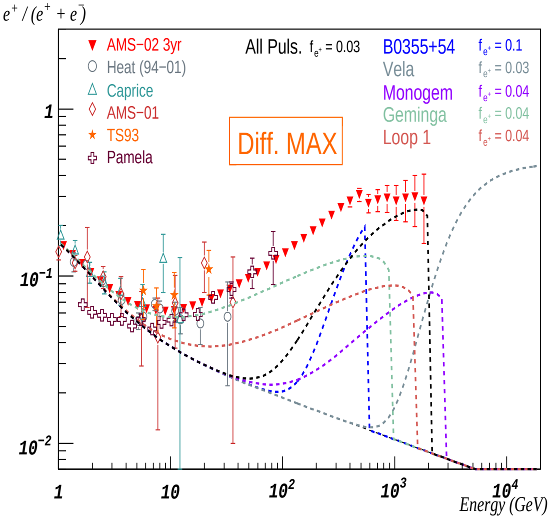

δ (e⁺ + e⁻) (%)
10
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
1
10
10²
10³
Energy (GeV)
PAMELA 2σ(5 yr)
AMS-02 2σ(3 yr)
Fermi-LAT 2σ(5 yr)
Geminga
f_{e+} = 0.15
Monogem
f_{e+} = 0.1
Diff. MED

Bonus-track

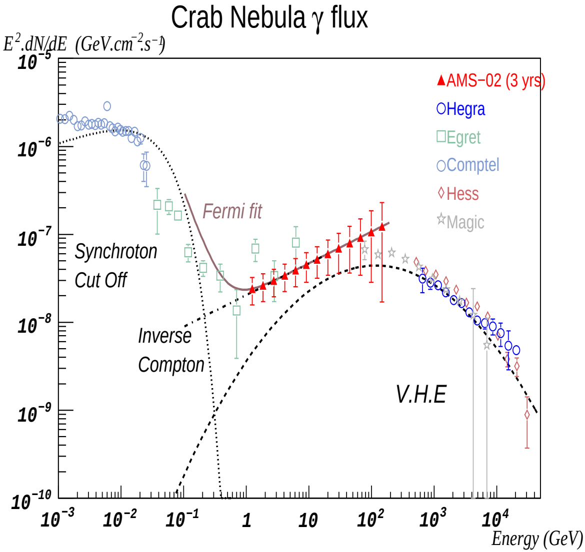


E^3.dN/dE (GeV^2.cm^-2.s^-1.sr^-1)
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
Diff. MAX
All pulsars adjusted
Geminga
All pulsars ATNF
10
10^2
10^3
10^4
Energy (GeV)

Bonus-track


$e^+/(e^+ + e^-)$
AMS−02 3yr
Heat (94−01)
Caprice
AMS−01
TS93
Pamela
All Puls. f_{e^+} = 0.03
B0355+54 f_{e^+} = 0.1
Vela f_{e^+} = 0.03
Monogem f_{e^+} = 0.04
Geminga f_{e^+} = 0.04
Loop 1 f_{e^+} = 0.04
Diff. MAX
1
10^{-1}
10^{-2}
1
10
10^2
10^3
10^4
Energy (GeV)

Bonus-track


Crab Nebula γ flux
E^2.dN/dE (GeV.cm^-2.s^-1)
▲AMS−02 (3 yrs)
○Hegra
□Egret
○Comptel
◊Hess
☆Magic
Fermi fit
Synchroton
Cut Off
Inverse
Compton
V.H.E
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
10^-3
10^-2
10^-1
1
10
10^2
10^3
10^4
Energy (GeV)