Positrons as Dark Matter probes

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Workshop "Indirect Dark Matter Searches"

DESY, Hamburg 15.06.2011

Positrons as Dark Matter NON-probes??

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Topics:

- Propagation of astrophysical e^+, e^-
  → background **uncertainties**
- Propagation of positrons from DM sources
  → astrophysical **uncertainties**
- DM interpretation of e^+/e^++e^- data: is it a viable solution?
- Astrophysical sources & e^+/e^++e^- data: is it a viable solution?

POSITRONS & ELECTRONS in CRs

Secondary e^- & e^+: nuclear reactions on the ISM

Primary
- e^-: SNRs & pulsars
- e^+: pulsars
- e^- & e^+: DM annihilation/decay

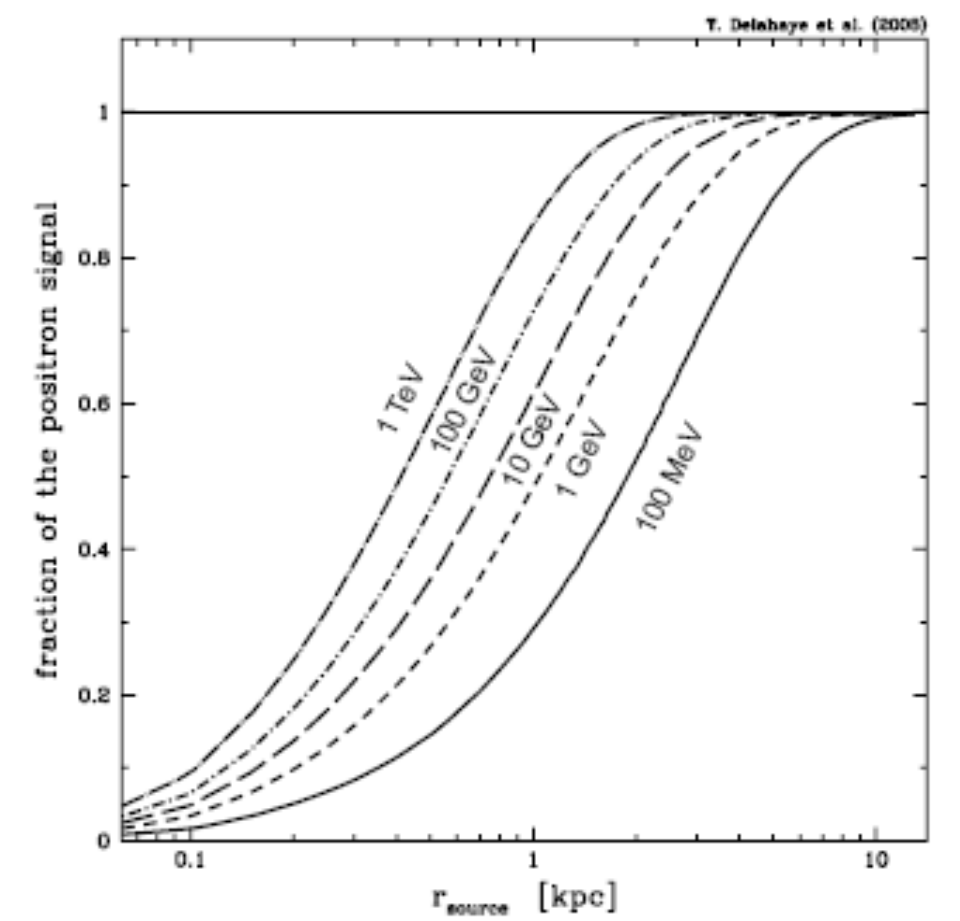
Propagation of e^+ & e^-

Delahaye, Lavalle, Lineros, FD, Fornengo, Salati, Taillet A&A 2009

Diffusive semi-analytical model:
Thin disk and confinement halo
Free parameters fixed by B/C

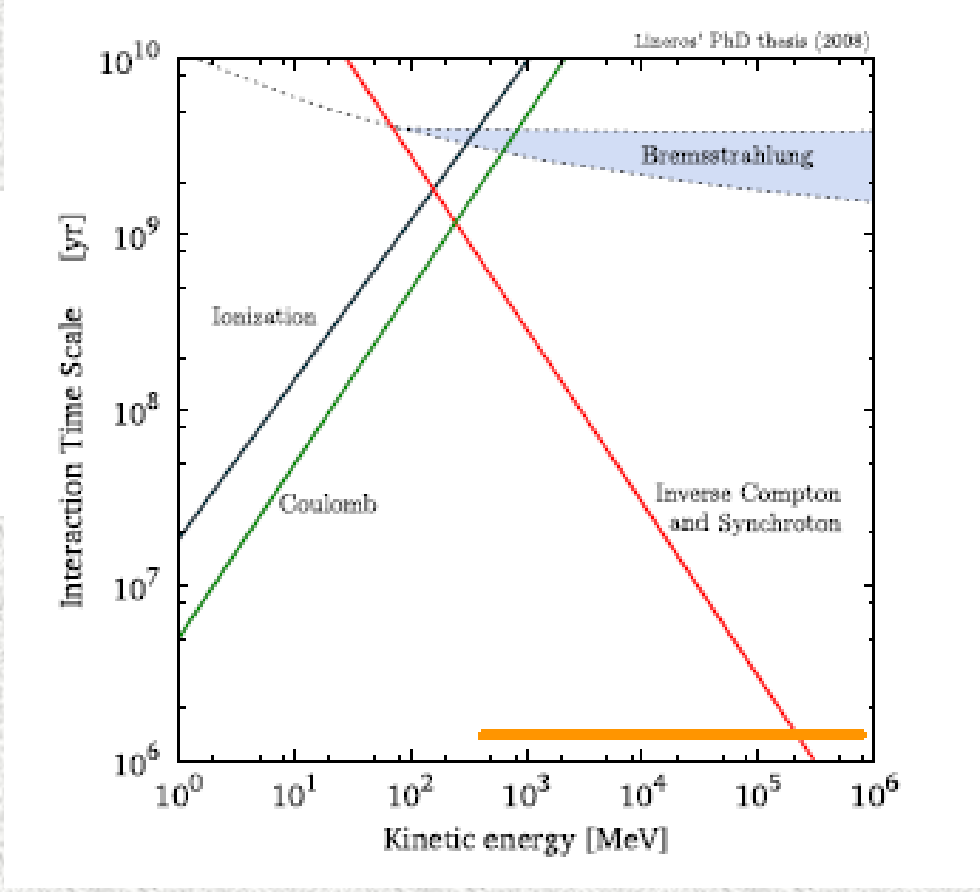
Above few GeV:
only spatial diffusion and
energy losses

Energetic positrons & electron are quite local



Energy losses for positrons/electrons

$$-b^{\rm loss}(\epsilon) = \begin{cases} \dfrac{\epsilon^2}{\tau_E} & \text{Inverse Compton and synchrotron} \\ +\nabla \cdot \mathbf{V}_C \, \dfrac{p^2}{6h\epsilon} & \text{Adiabatic losses} \\ +K_b \, n_H \, \epsilon & \text{Bremsstrahlung} \\ +K_i \, n_H \left\{ 3 \ln\left(\dfrac{E}{m_e}\right) + 19.8 \right\} & \text{Ionisation.} \end{cases}$$



Synchrotron and Inverse Compton* dominate

*IC=scattering of e- on photons (starlight, infrared, microwave)

2-zone Semi-analytic Diffusive Model

Maurin, FD, Taillet, Salati ApJ 2001; Maurin, Taillet, FD A&A 2002

& talks by D. Maurin, P. Salati, A. Putze

+All effects included ($V_A \neq 0$ & $V_C \neq 0$)

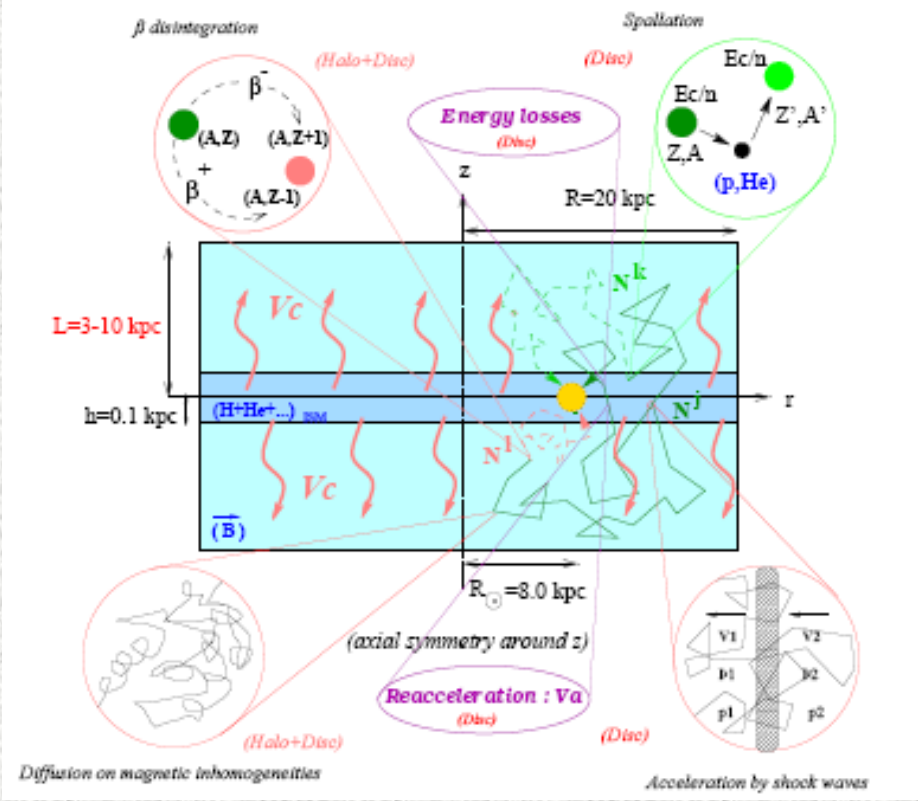
+2D semi-analytic

+ Local Bubble for radioactives

- ISM constant

-V_C constant throughout the halo

- V_A in the disk



- Diffusion coefficient $K(R)=K_0 \beta R^{\delta}$
- Convective velocity V_c
- Alfven velocity V_A
- Diffusive halo thickness L
- Acceleration spectrum $Q(E)=p^{\alpha}$

K_0, δ, V_c, V_A, L, (α)

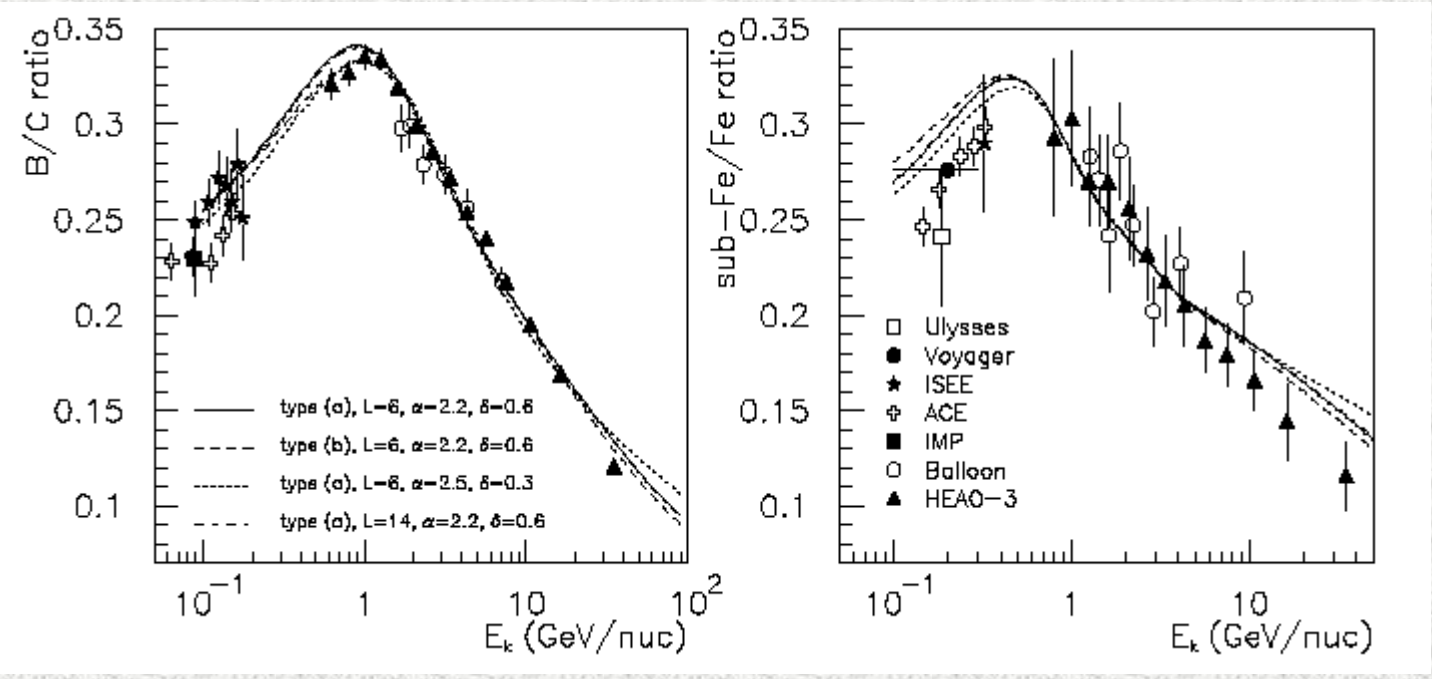
Systematic scan
of parameter space
Evaluation of uncertainties

Results on Observed Prim/Sec

Maurin, FD, Taillet, Salati, ApJ (2001) Maurin, Taillet, FD A&A (2002)

Systematic scan of the parameter space

6 free parameters: diffusion (K_0, δ), convection (V_C), acceleration(a), reacceleration (V_A), diffusive halo (L)



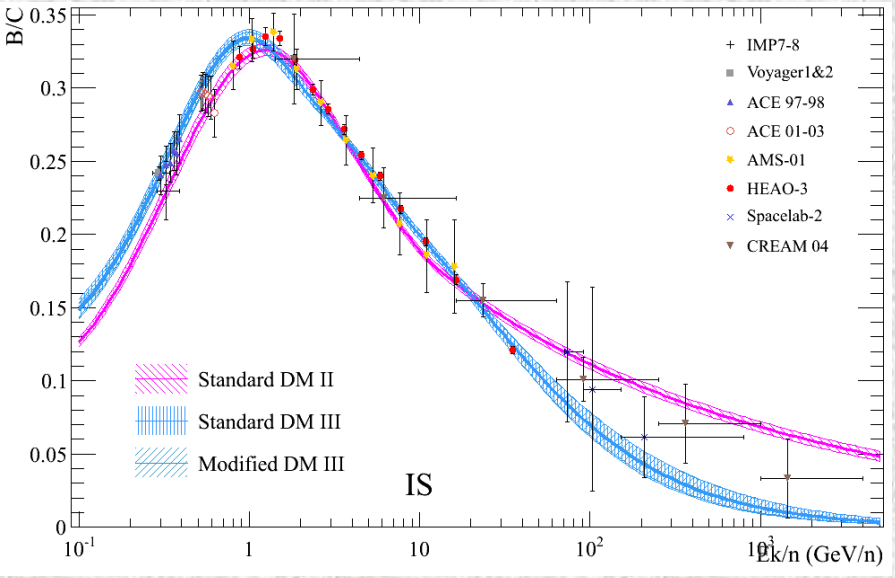
Only model WITH **convection** AND **reacceleration**

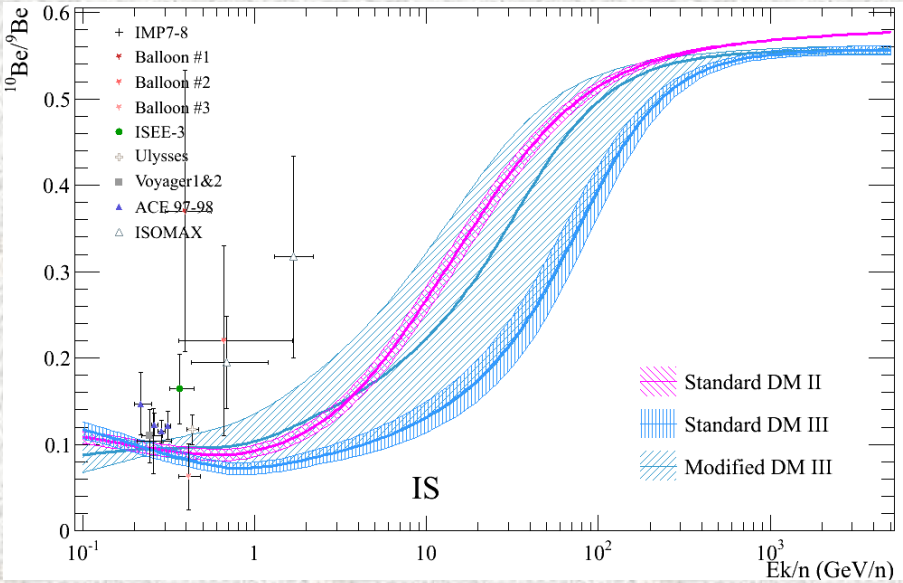
Kolmogorov (δ=0.3) spectrum disfavoured, δ ~ 0.6-0.7, K_0 ~ 0.003-0.1 kpc²/Myr

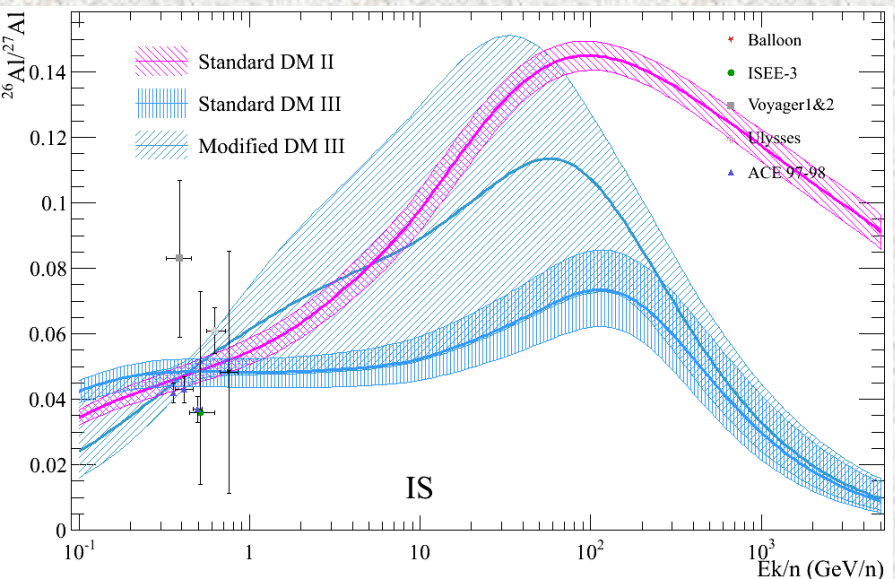
No need for **breaks** in K(E) or Q(E), also for p and He

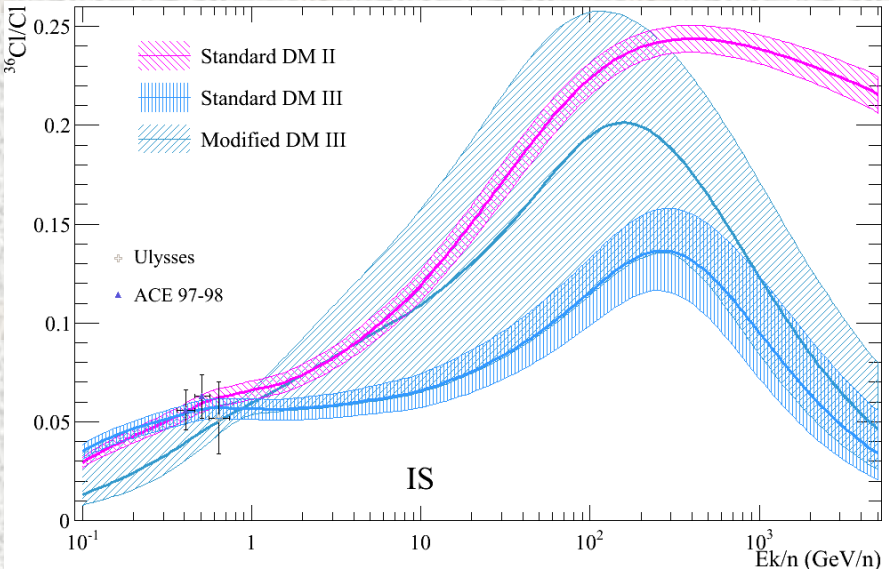
MCMC results on B/C AND radioactive isotopes

Putze, Derome, Maurin A&A 2010









Secondary positrons

(from CRs inelastic interactions on the interstellar medium)

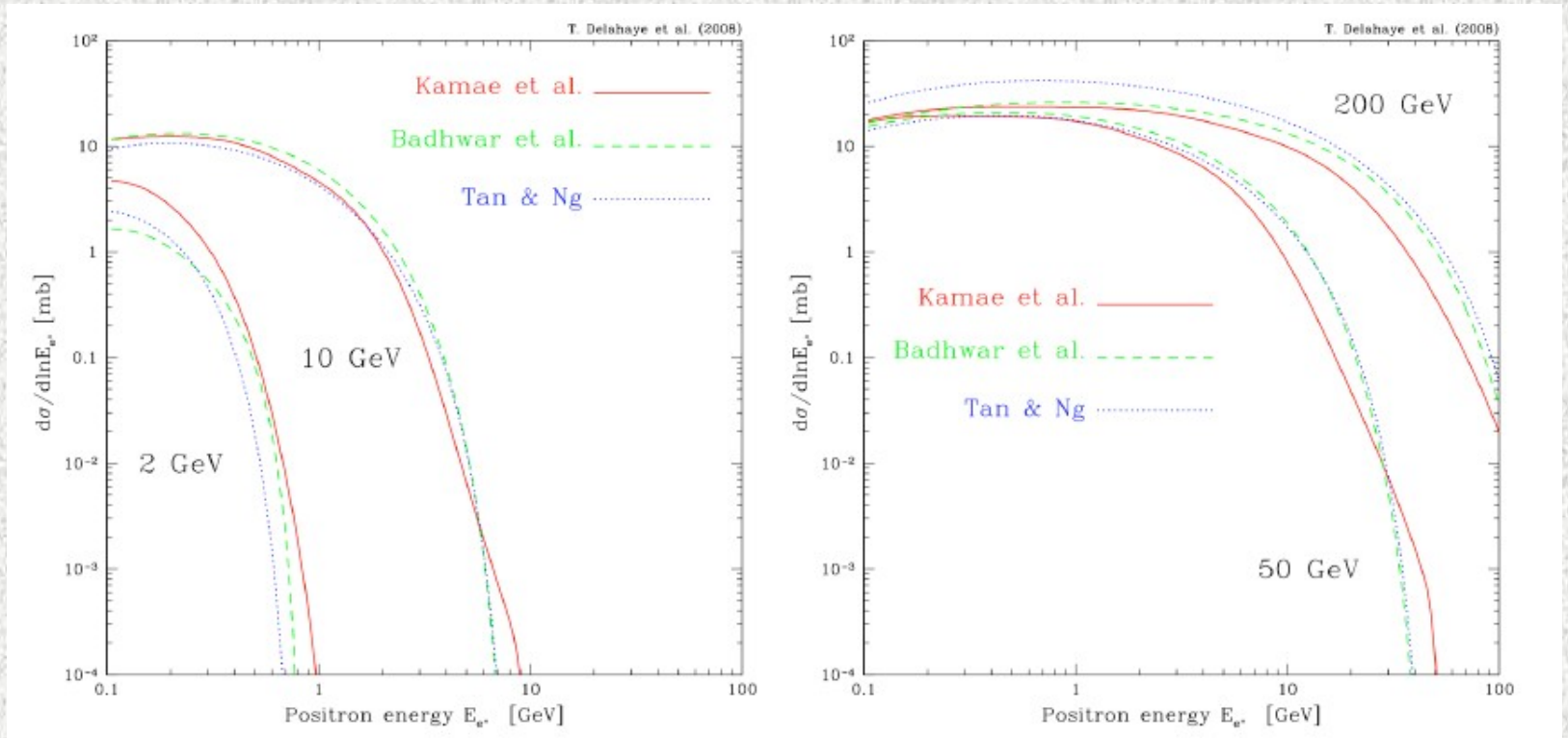
Secondary e^+ & e^- production

Spallation of proton and helium nuclei on the ISM (H, He)

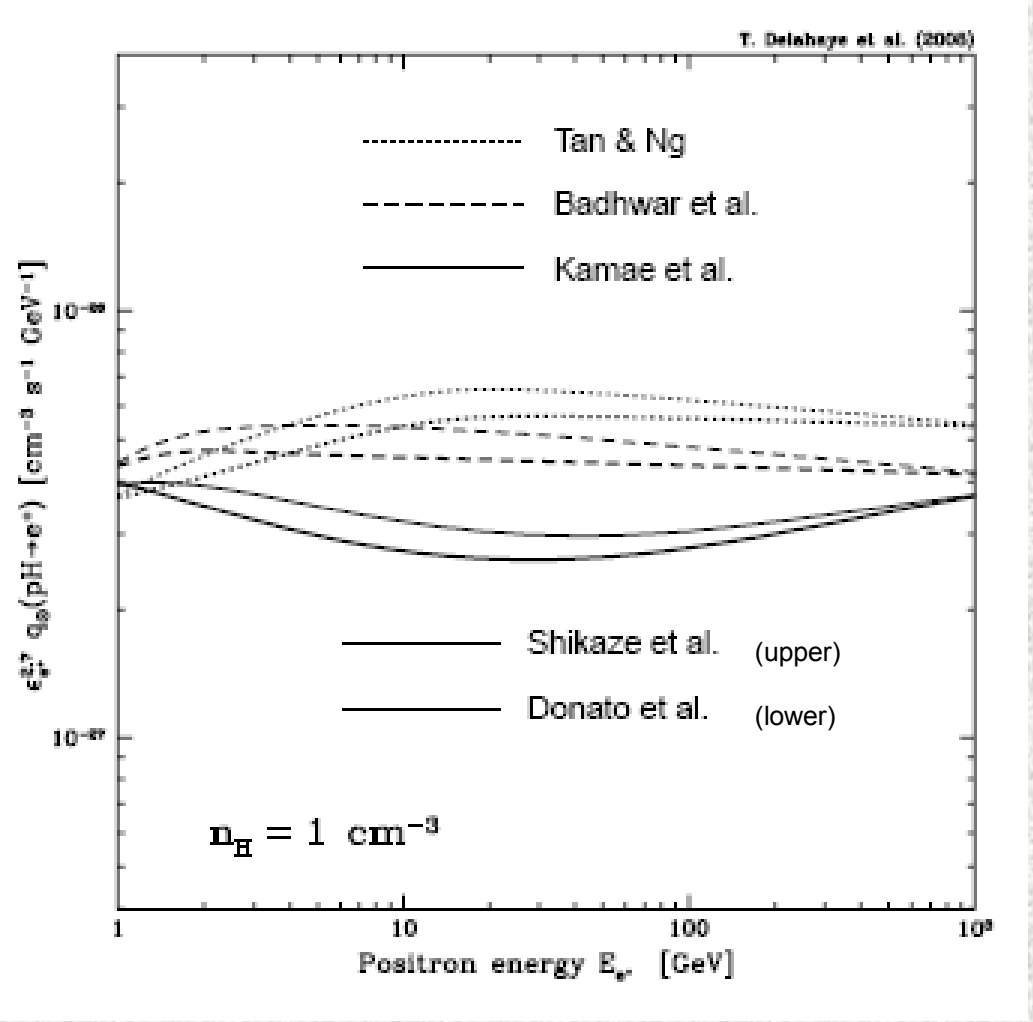
Delahaye et al. A&A 2009

- $p+H \rightarrow p+\Delta^+ \rightarrow p+\pi^0$ & $n+\pi^+$ (mainly below 3 GeV)
- $p+H \rightarrow p+n+\pi^+$
- $p+H \rightarrow X + K^{\pm}$

Different parameterizations of cross sections and incident p energy



Secondary e^+ & e^- source term



Effect of production cross sections is not negligible

Effect of proton flux determination - negligible

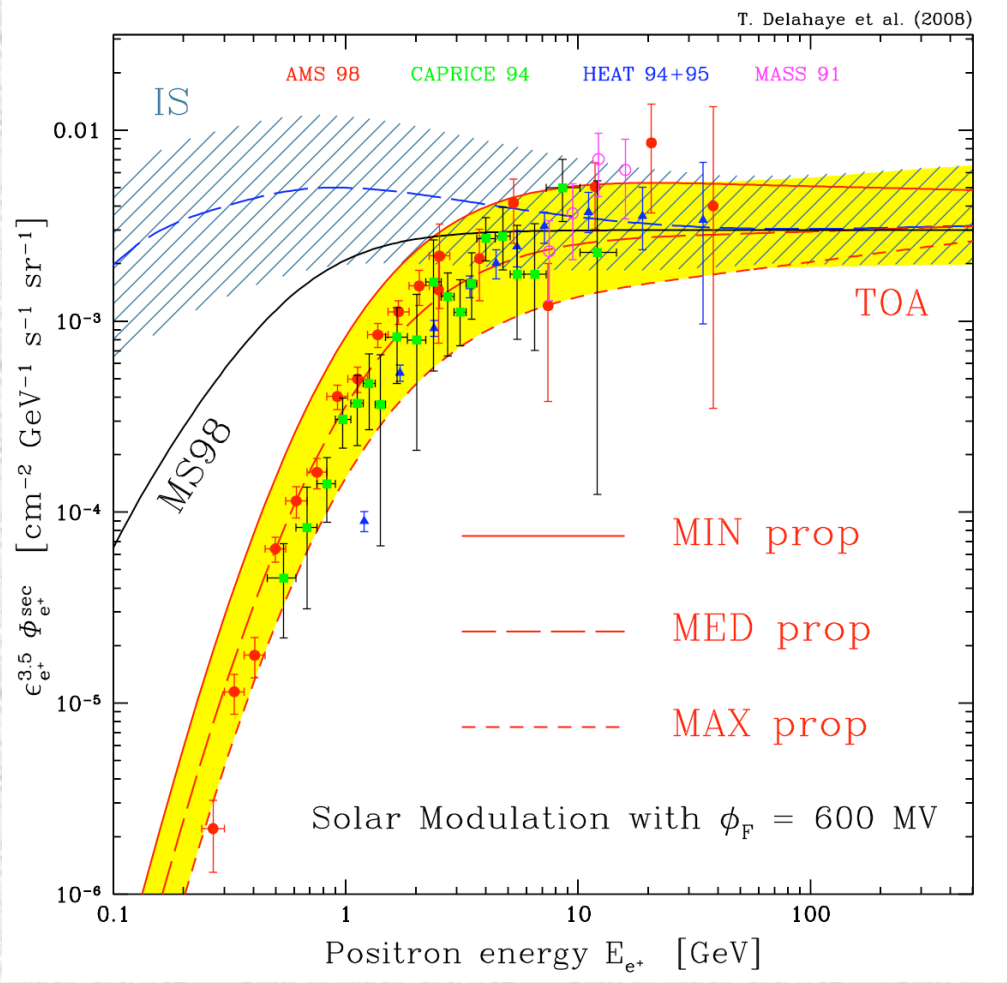
Positron flux: data and predictions

Delahaye et al. A&A 2009

<u>Same propagation models:</u>

Positrons as secondary CRs are well fit by predictions

Uncertainties due to propagation: 3-4



Secondary positrons +

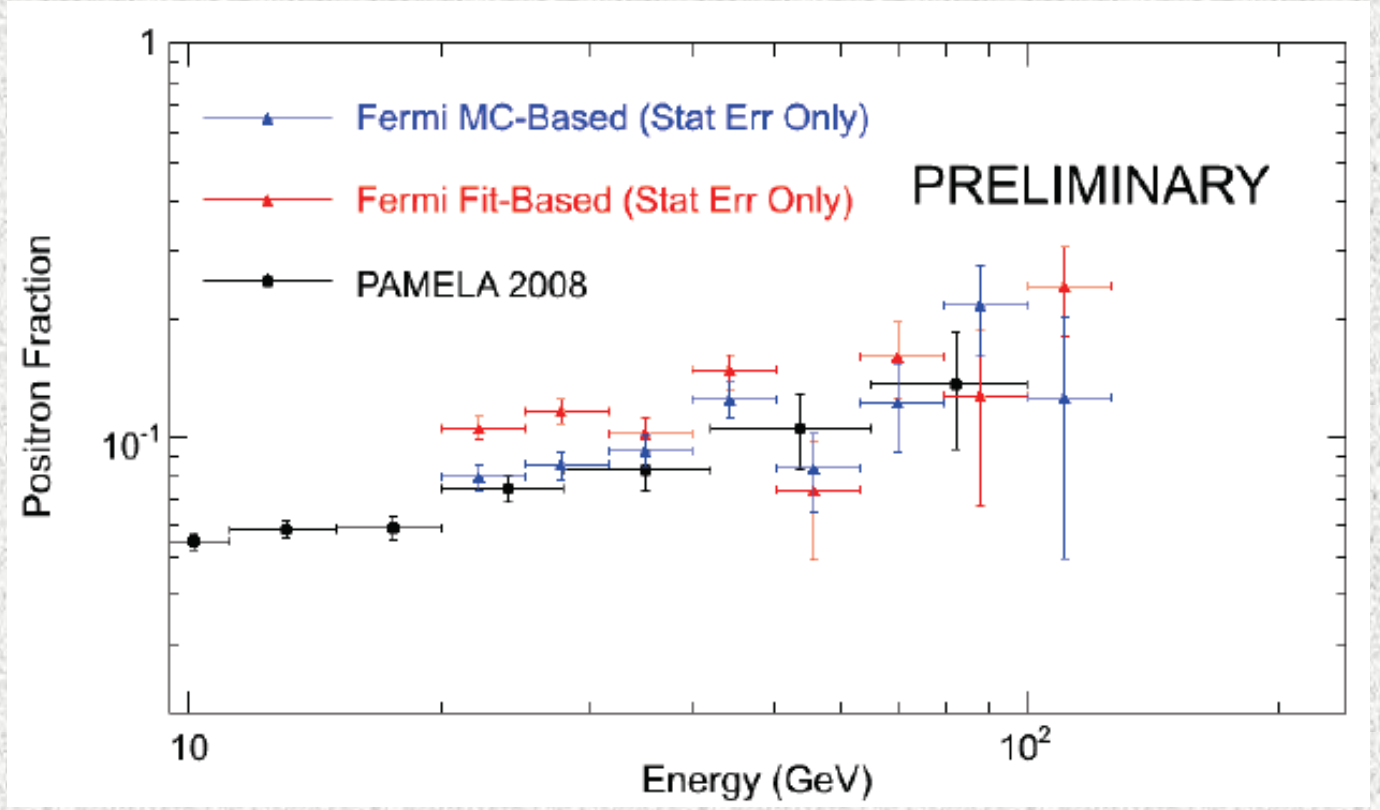
secondary electrons

+ primary electrons from SNR

Positron Fraction by Fermi-LAT

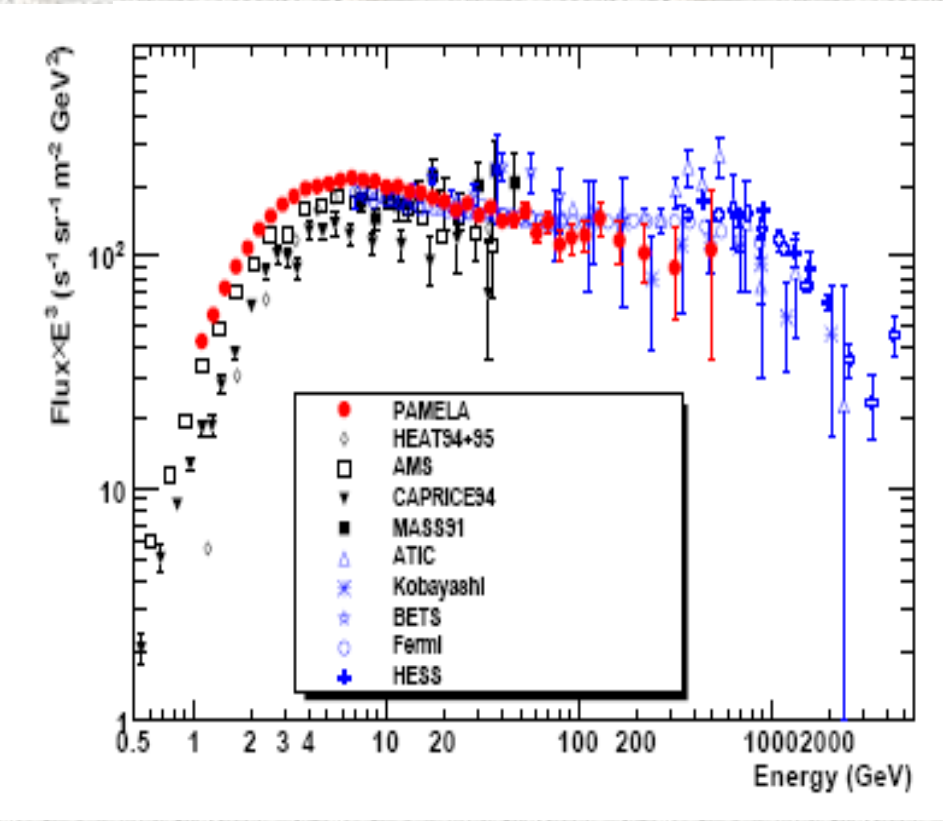
Mittshumsiri @ Fermi Symposium, Rome 2011

Charge discrimination using the Earth Magnetic Field

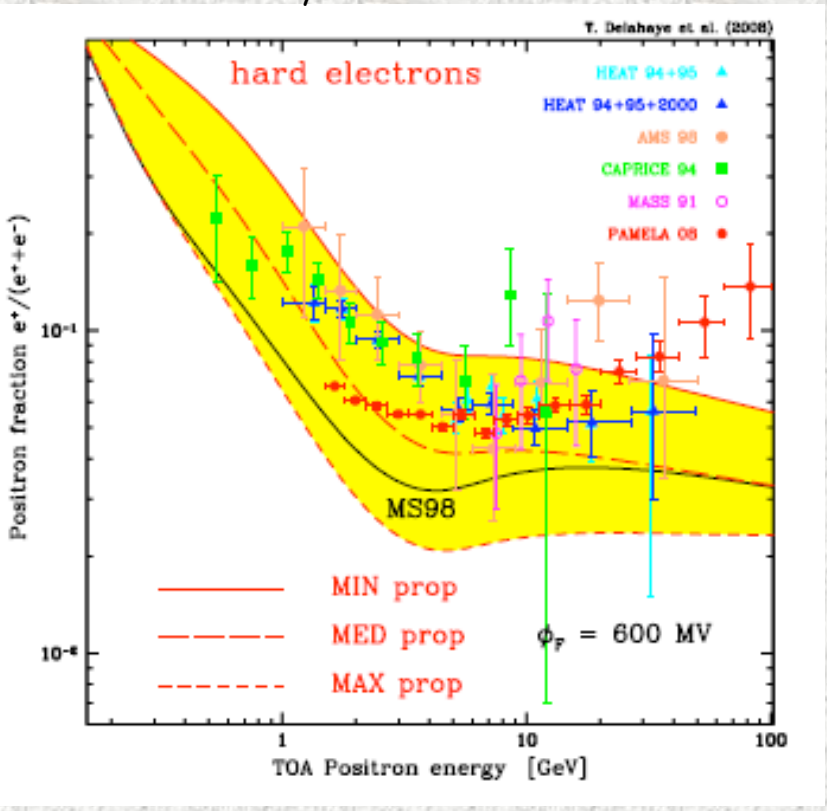


Positron/electron: data and predictions

Adriani et al. 2011



Delahaye et al. A&A 2009



Yellow band: secondary positrons & propagation uncertainties

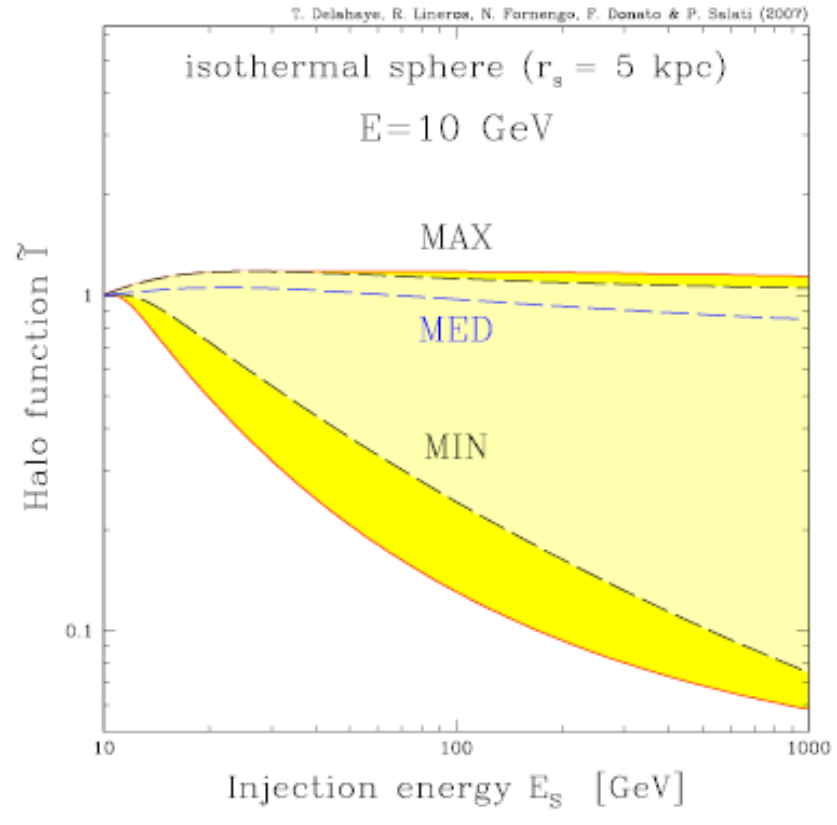
There is no "standard" predicted flux (dashed is B/C best fit)

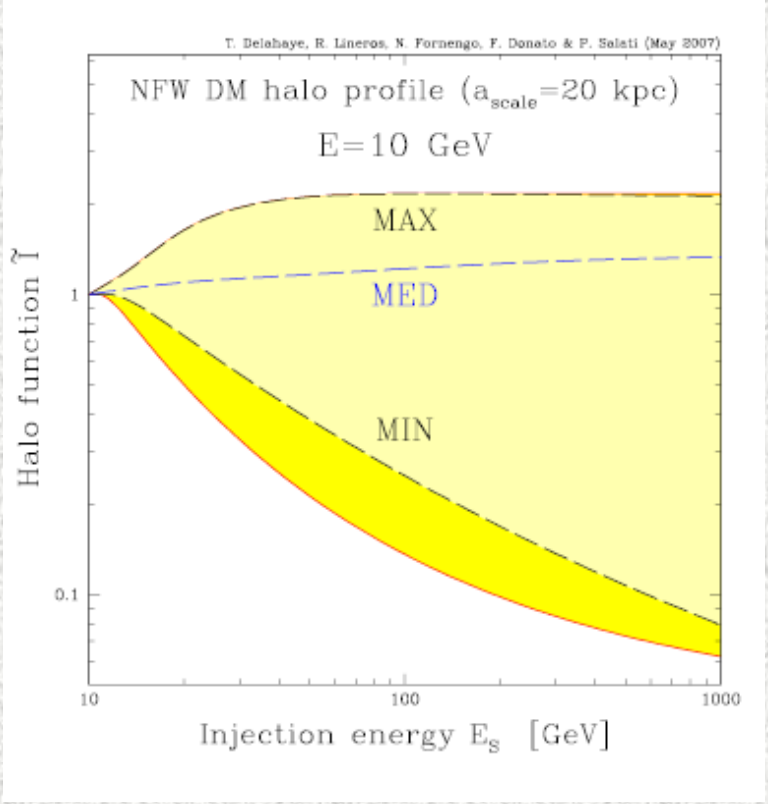
Dark Matter interpretation of the positron fraction

Propagation of positron from WIMP DM (neutralino) sources

$$\Phi(E) = k_{susy} \frac{\tau_E}{E_0 \varepsilon^2} \int_E^{\infty} dE_S f(E_S) \widetilde{I}(\lambda_D)$$

E_0=1 GeV
ε=E/ E_0
τ=10^{16} s



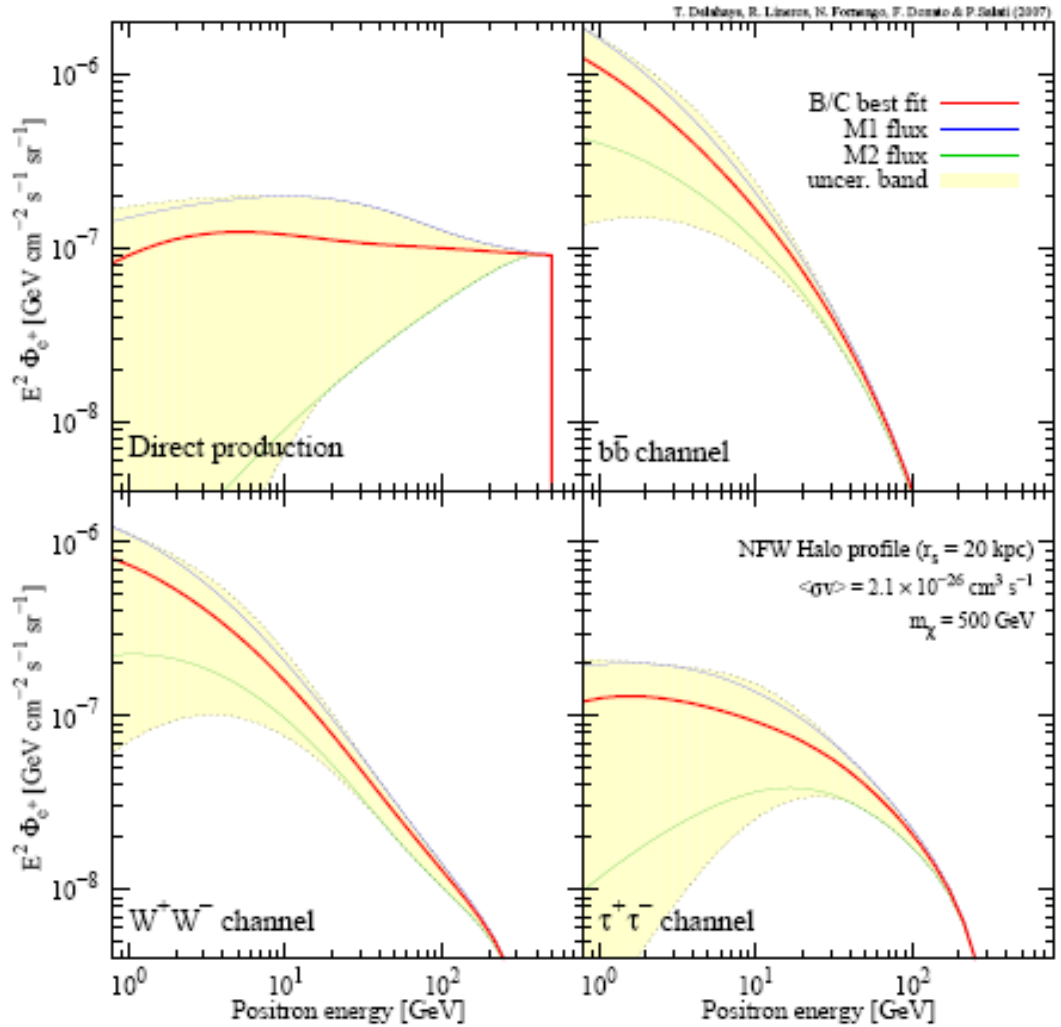


Propagation models allowed by B/C

Delahaye, Lineros, Fornengo, FD, Salati PRD 2008

Positron fluxes: effect of annihilation channels

Delahaye et al. PRD 2008



m=500 GeV

Direct annnihilation in e+, or in tau, are harder than bb or gauge boson

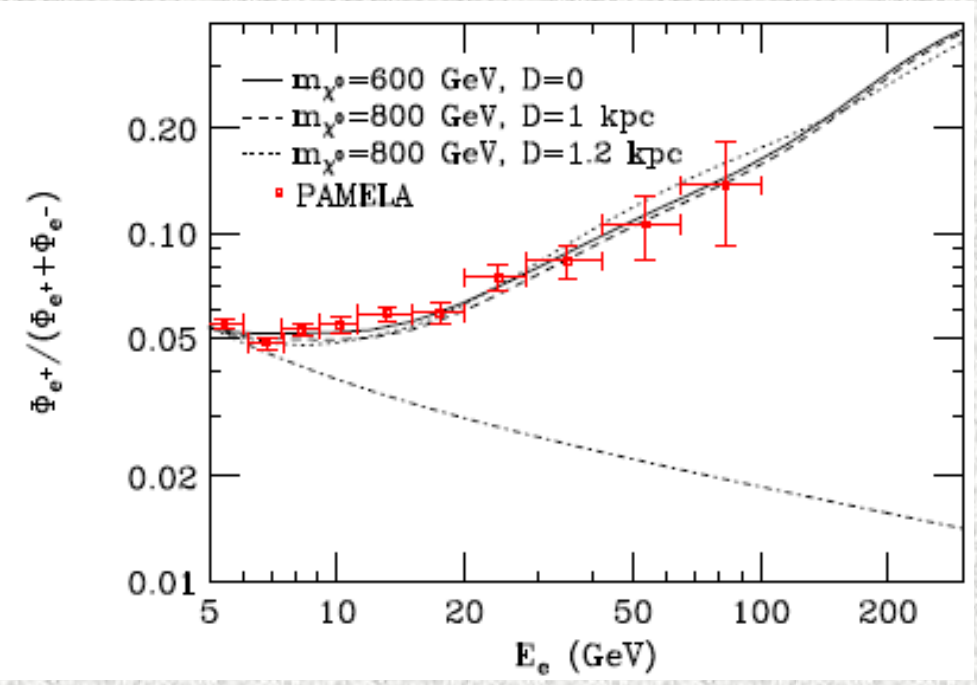
In typical SUSY models annihilation in leptons is suppressed wrt quark production

Uncertainties on primaries is 3-5, depending on:

- Energy
- Annihilation channel
- DM distribution

Supersymmetric DM interpretation of Pamela data

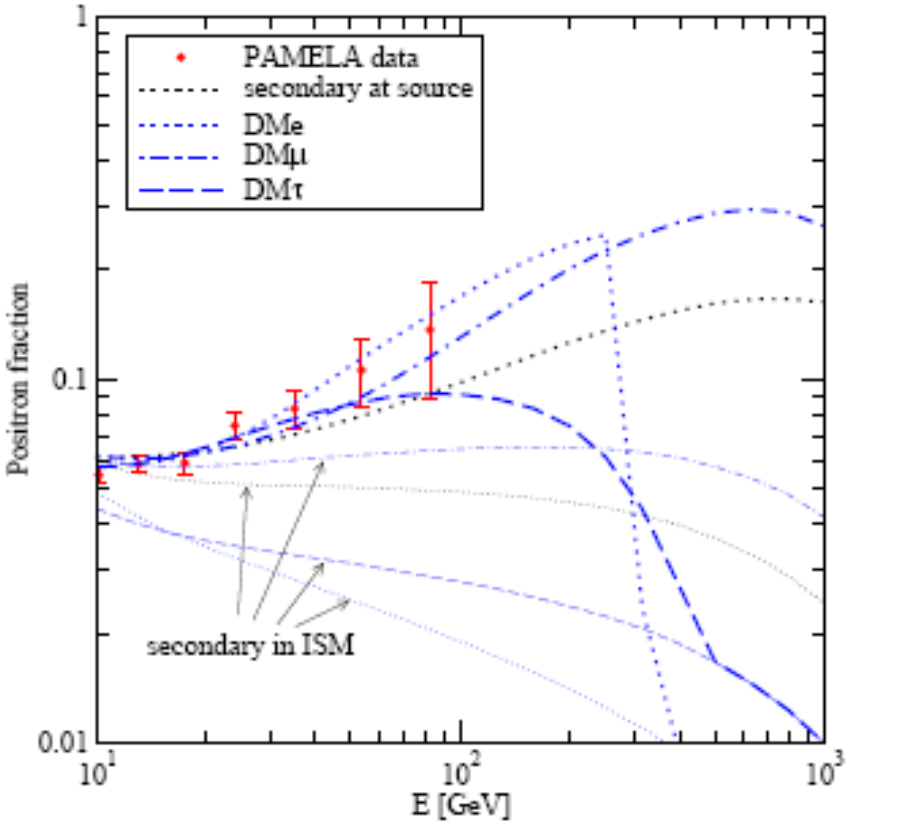
WW final state and very close clumps



Hooper, Stebbins, Zurek PRD 2009

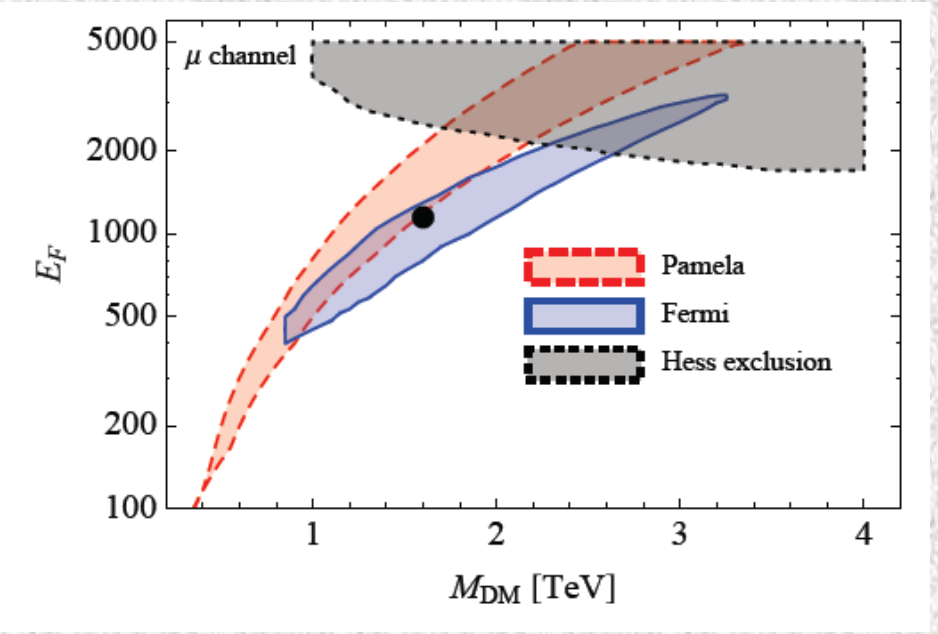
	M_χ [GeV]	$\sigma_a v$ [$cm^3 s^{-1}$]	annihilation modes	spatial profile	line coding
DMe	300	$2.5 \cdot 10^{-24}$	e^+e^-	Burkert	dotted
DMτ	400	$6.6 \cdot 10^{-24}$	$\tau^+\tau^-$	Burkert	dashed
DMμ	1500	$2.5 \cdot 10^{-23}$	$\mu^+\mu^-$	Burkert	dashed-dotted

Regis & Ullio PRD 2009

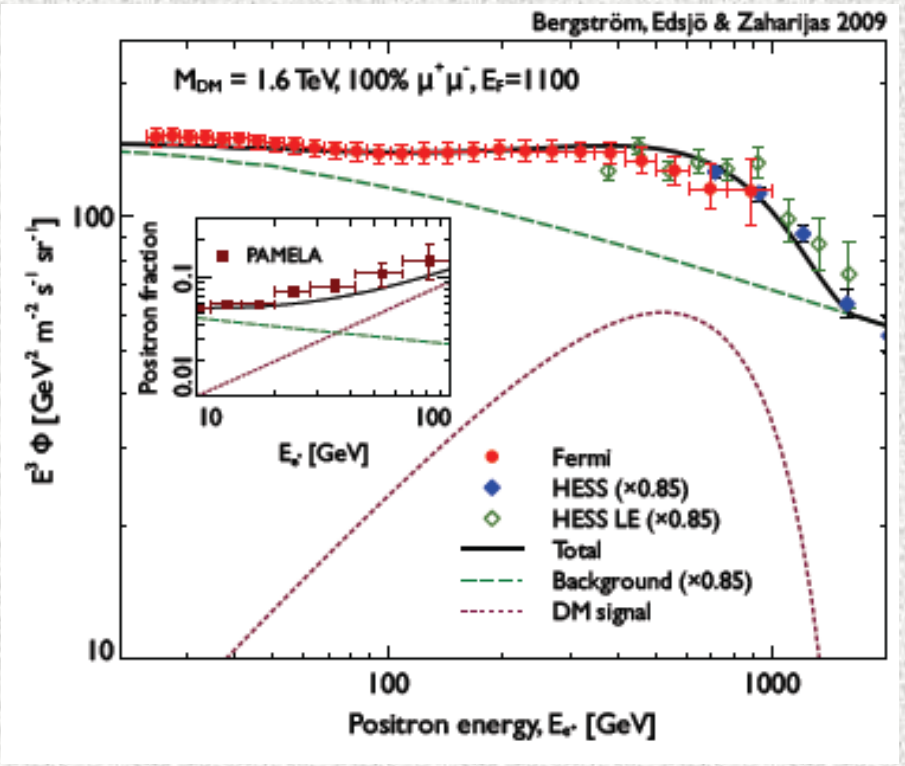


Boost factor from e^- and $e^+/e^+ + e^-$

Bergström, Edsjö, Zaharijas 2009



Ehancement factor

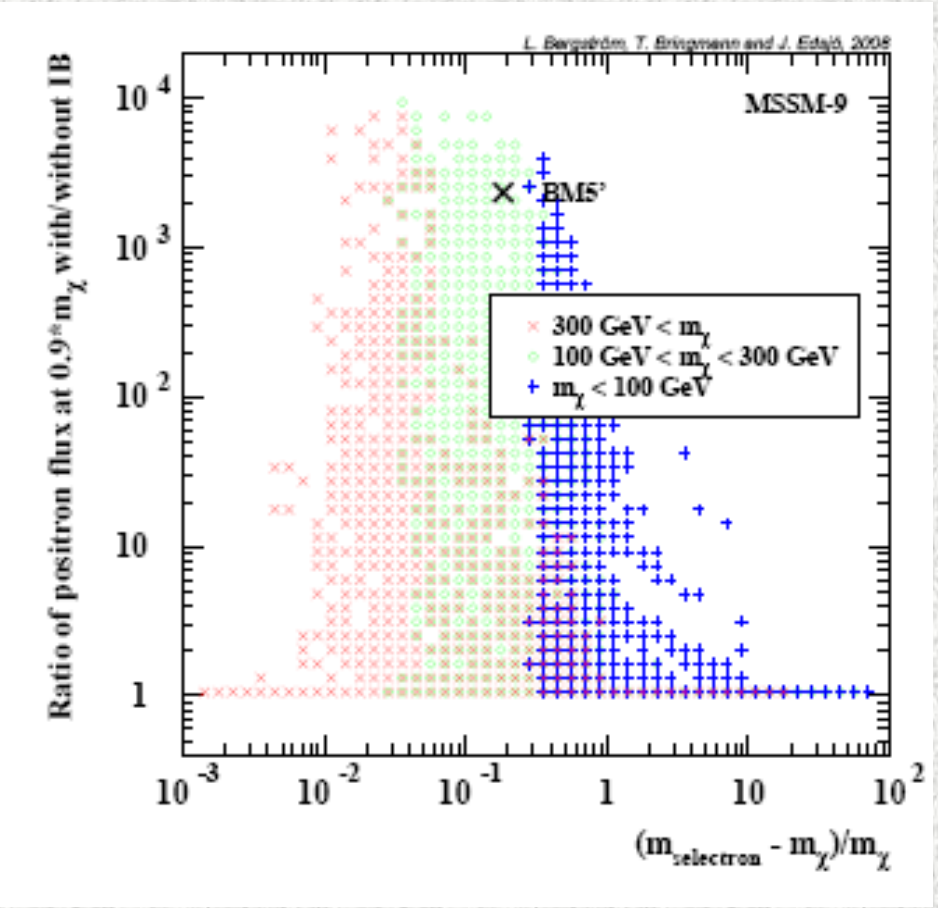


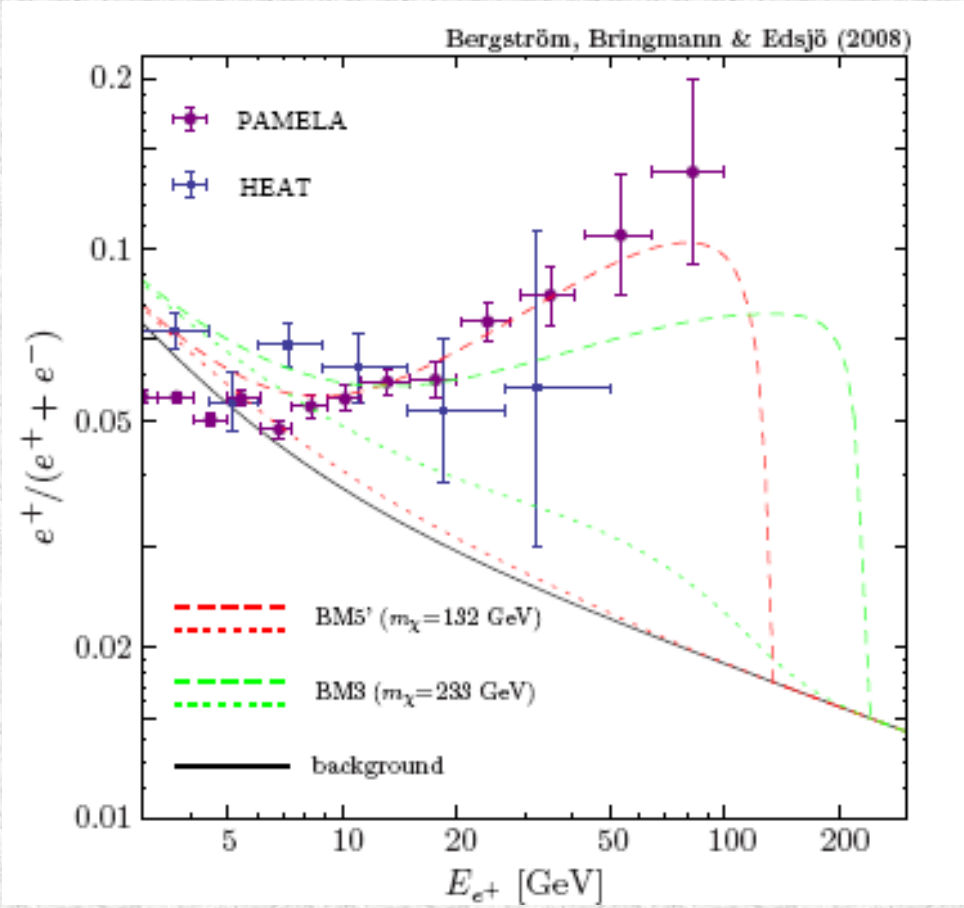
Fits to Pamela (ratio)
And Fermi (total e^+e^- flux)

Supersymmetric DM interpretation of Pamela data

Internal bremsstrahlung: $\chi\chi \rightarrow e^+e^-\gamma$

Bergstrom, Bringmann, Edsjo PRD2008





No elicity suppression for $\langle\sigma v\rangle$: α/π instead of $(m_e/m_\chi)^2$

Boundless literature….

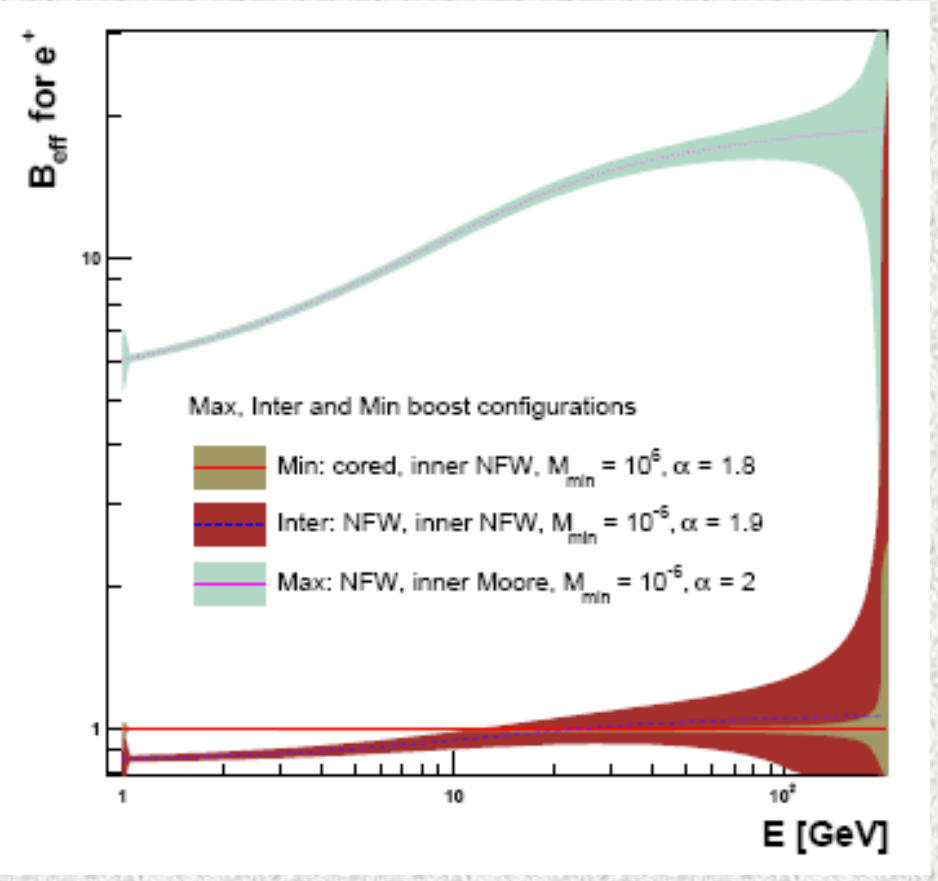
- SUSY interpretation (neutralino, gravitino, sneutrino): leptophilic DM
- Non-thermal DM production
- Dirac particles in NMSSM / KK / Minimal DM / Dark sectors
- New symmetries / New interactions / Nambu Goldston DM / Inert Doublet /…….

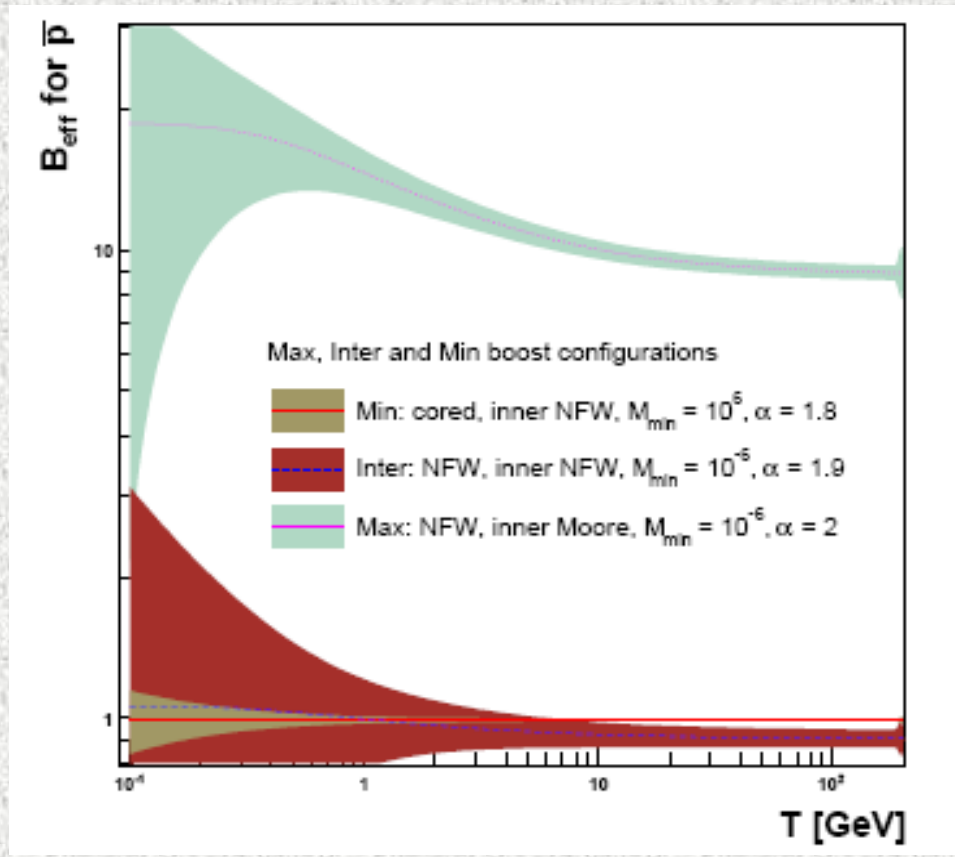
In order to reproduce data, a BOOST is needed and can be looked for in:

1. Astrophysics
1. Cosmology
1. Particle Physics

Astrophysical boosts: numerical simulations and propagation

Lavalle, Yuan, Maurin, Bi A&A 2008



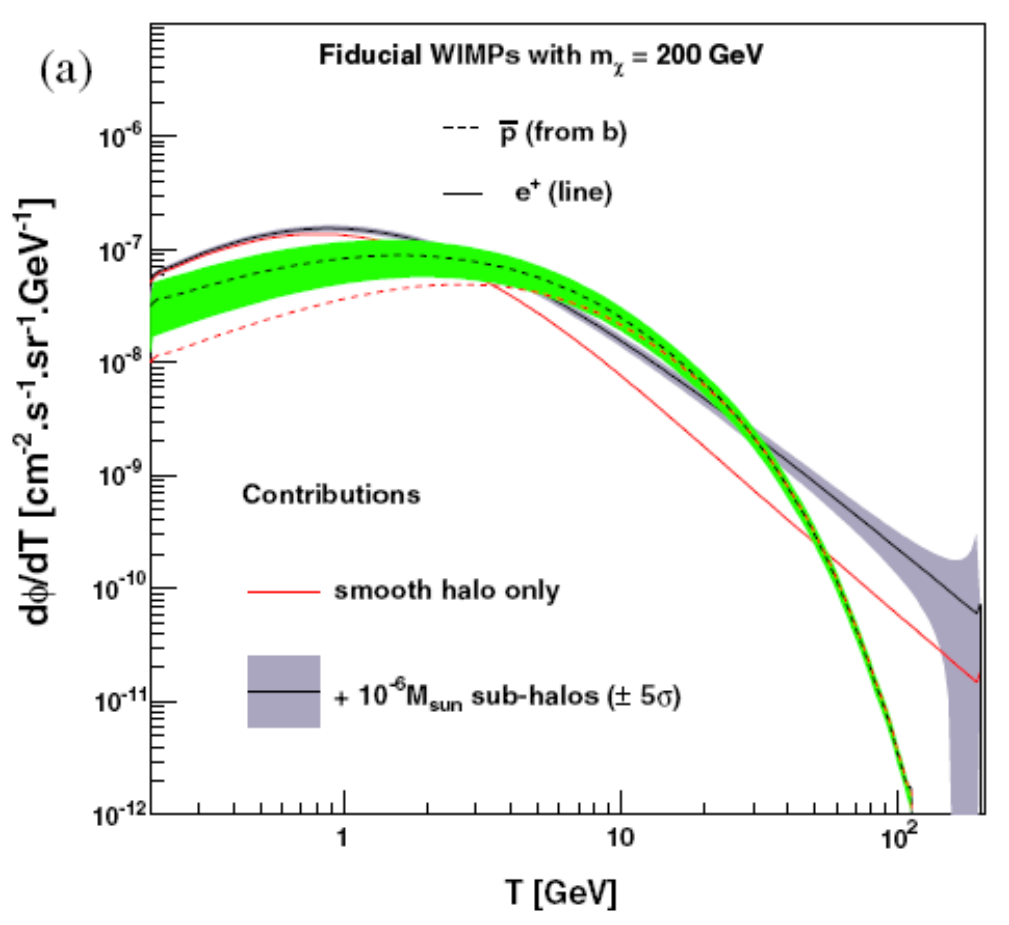


Energy dependent enhancements

Possible astrophysical boost factors

Lavalle, Nezri, Ling, Athanassoula, Theyssier PRD 2008

Horizon simulation (similar results For via lactea)

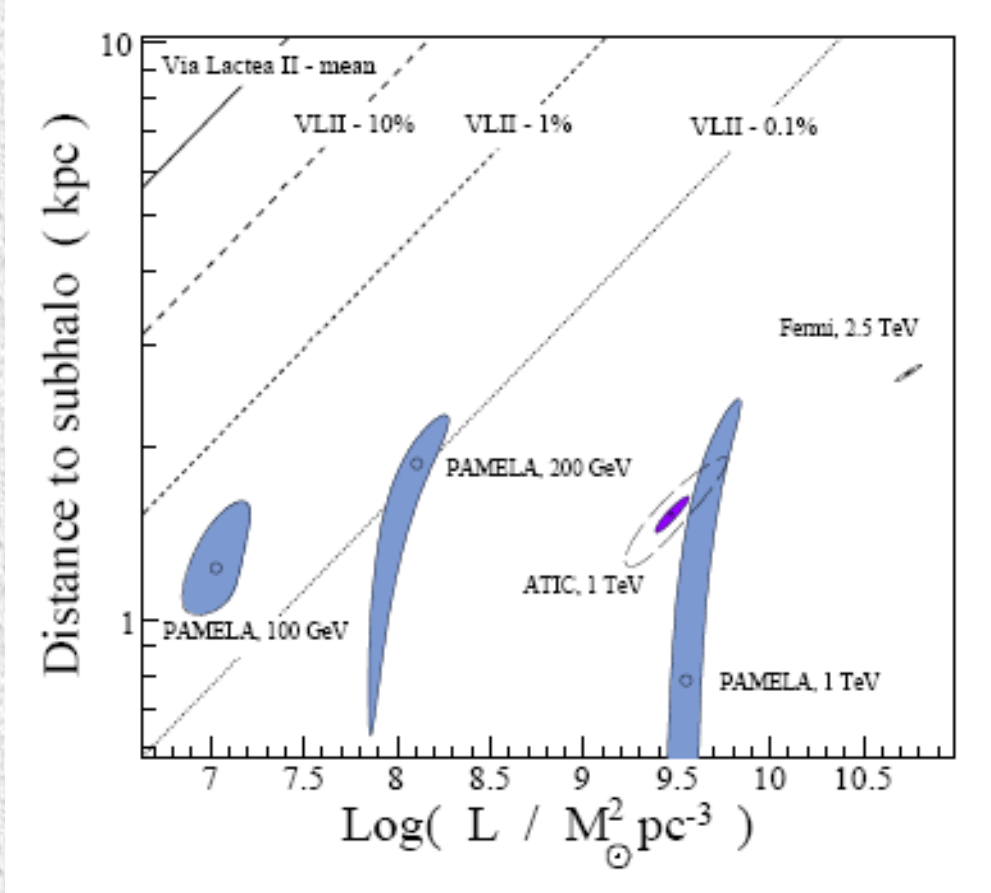


A big boost from DM substructure is not predicted

CR lepton puzzle & cosmological N-body simulations

Brun, Delahaye, Diemand, Profumo, Salati PRD2009

Luminosity vs distance: a statistical analysis



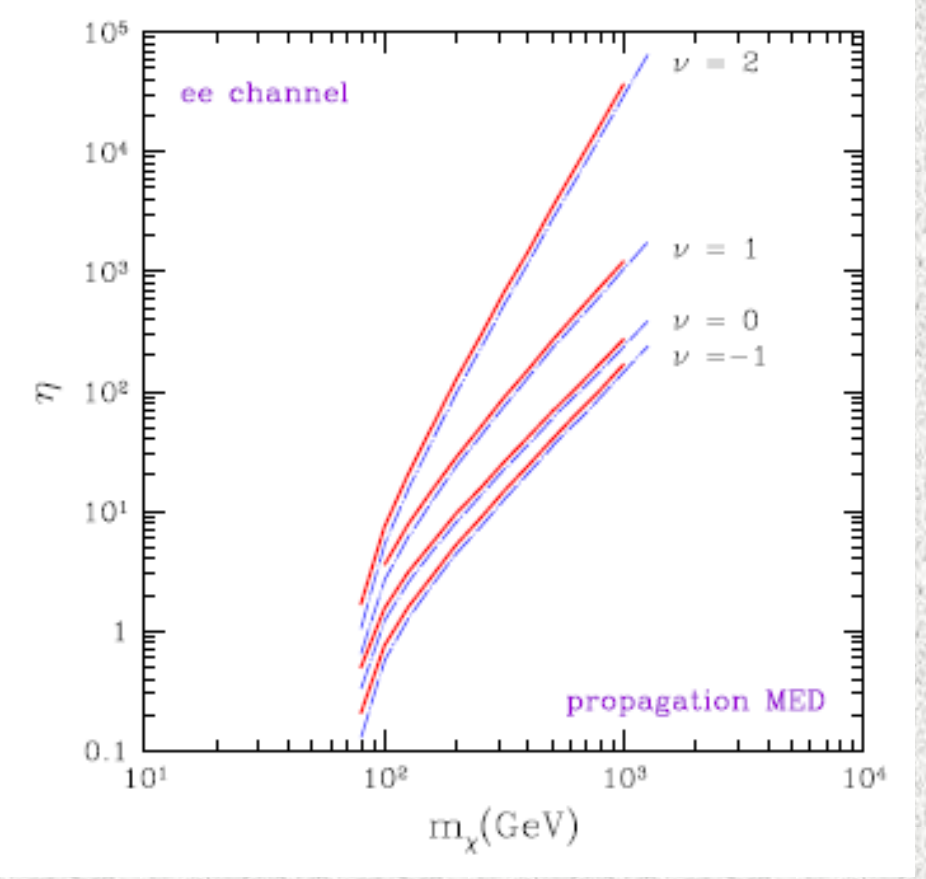
Unlikely scenarios

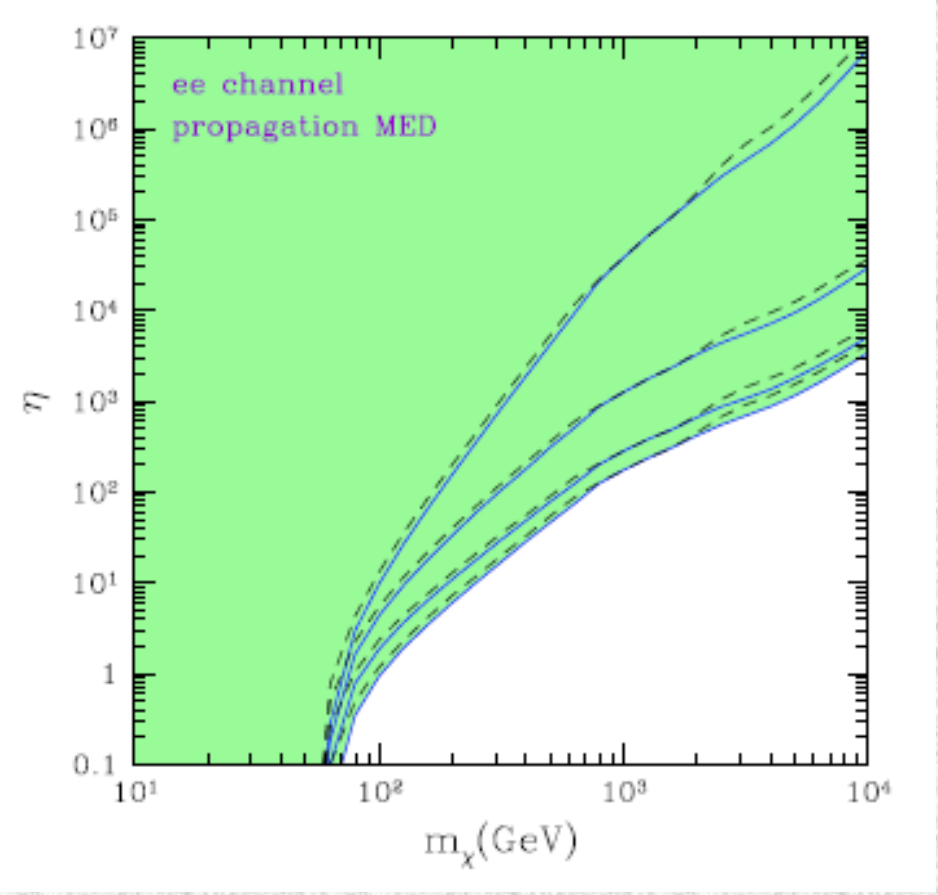
Cosmological Boosts

large $\langle\sigma v\rangle$ provided by modified cosmologies

Catena, Fornengo, Pato, Pieri, Masiero 2010

$H = H_{GR}[1 + \eta(T/T_F)^{\nu}$ (for $T >$ TBBM)





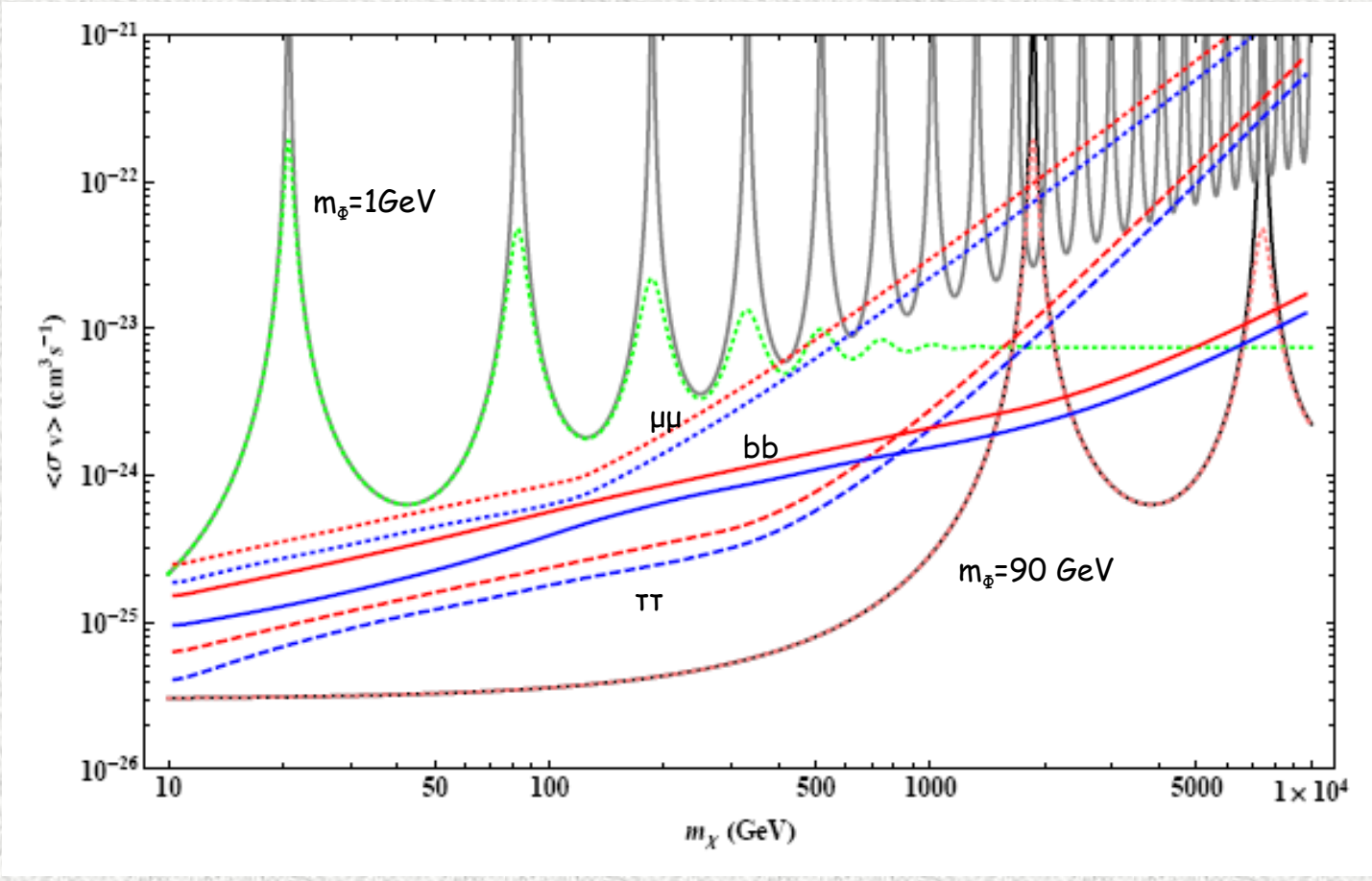
Boost required by Pamela

Astrophysical bounds

Boosts from Particle Physics: Sommerfeld effct

Calore, De Romeri, Donato 1105.4230

Upper limits from EGB γ-rays



2 Models for the EGB with unresolved sources subtraction

- **Analysis of e+e- data usually DO NOT consider astrophysical uncertainties on the signal AND on the background.**

Similarly, to constrain models by crossed analysis, uncertainties on the signals and all the backgrounds must be included

Otherwise, results have restricted validity

Constraints / Crossed checks in

- Antiprotons
- Multi-wavelength: Radio, IR,X-ray, Gamma rays (diffuse, IC, point sources,…)

Secondary e^+

+

secondary e^-

+

primary e^- from SNR

+

primary e^+ & e^- from pulsars

Primary e+ & e- from pulsars and SNR

e^+ and e^-: pair production in the strong PULSAR magnetoshpere
Polar cap (disfavoured by recent Fermi data) and outer gap models

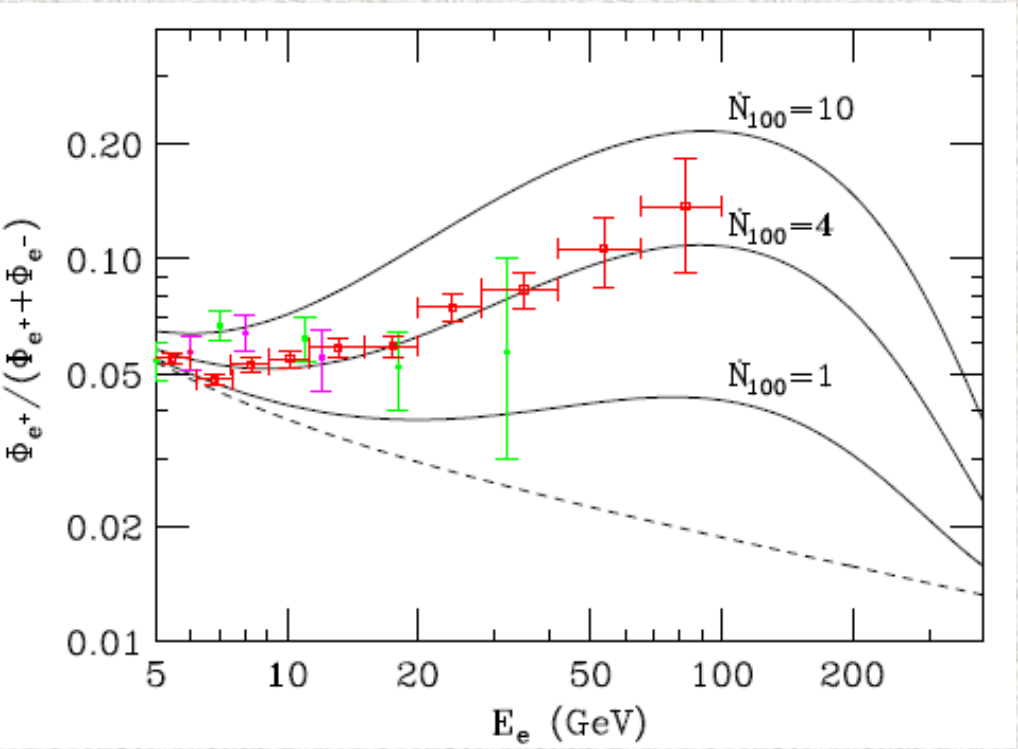
- High energy e- are accelerated by the strong pulsar electric field
- e- synchrotron radiate gamma rays
- e^+/e^- are produced by pair conversion in strong magnetic fields of the PSR or scattering off of thermal X-rays

SNR accelerate e- (in the ISM) by means of
1° order Fermi acceleration mechanism

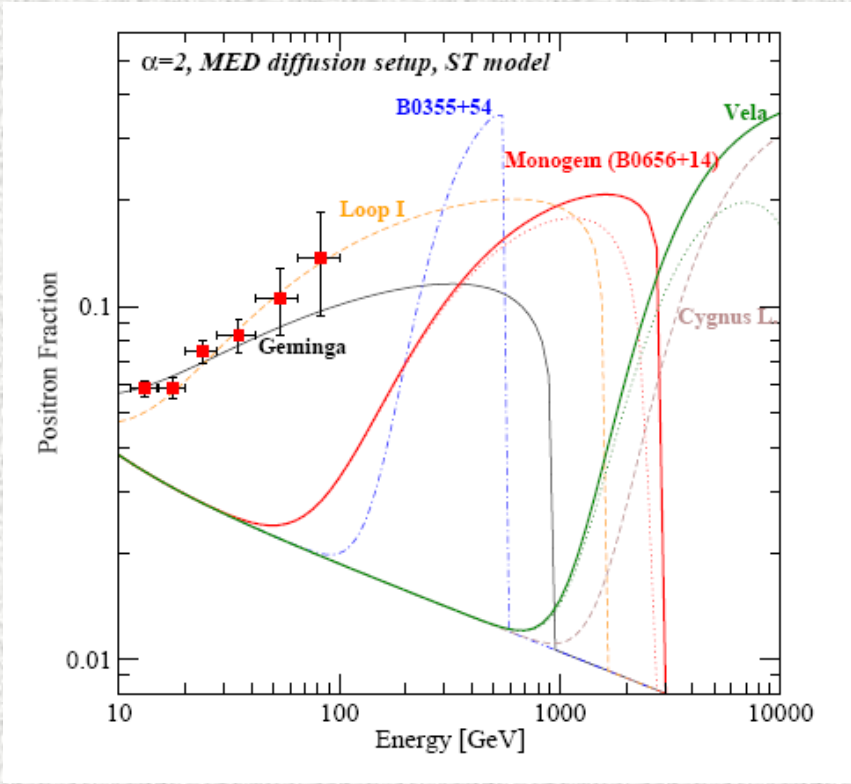
Primary positrons and electrons from pulsars

Pulsars can be the sources of energetic e^+ and e^-:
pair production in the strong pulsar magnetoshpere

Hooper, Blasi, Serpico, JCAP 2009

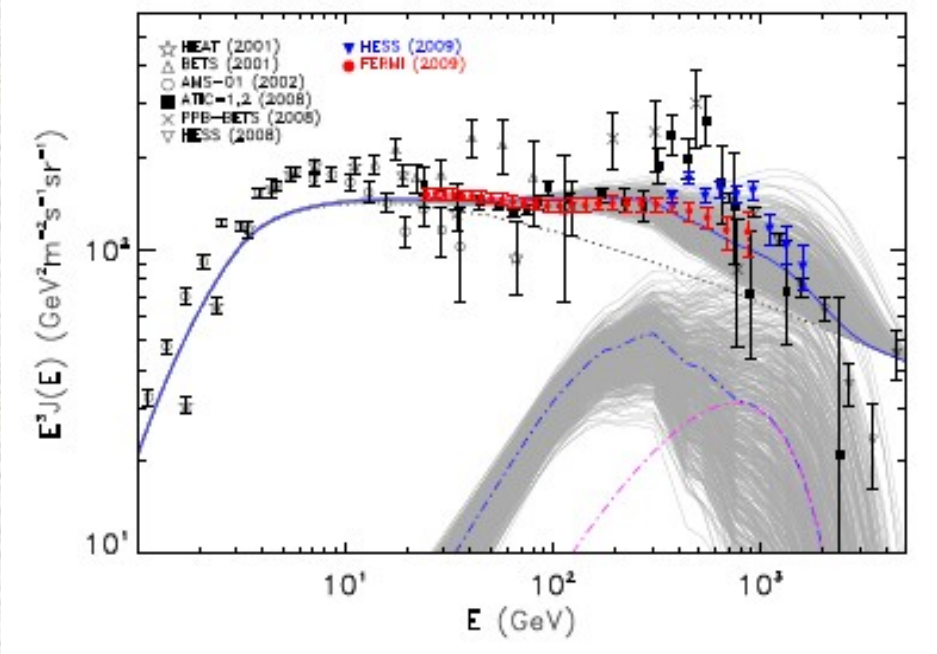


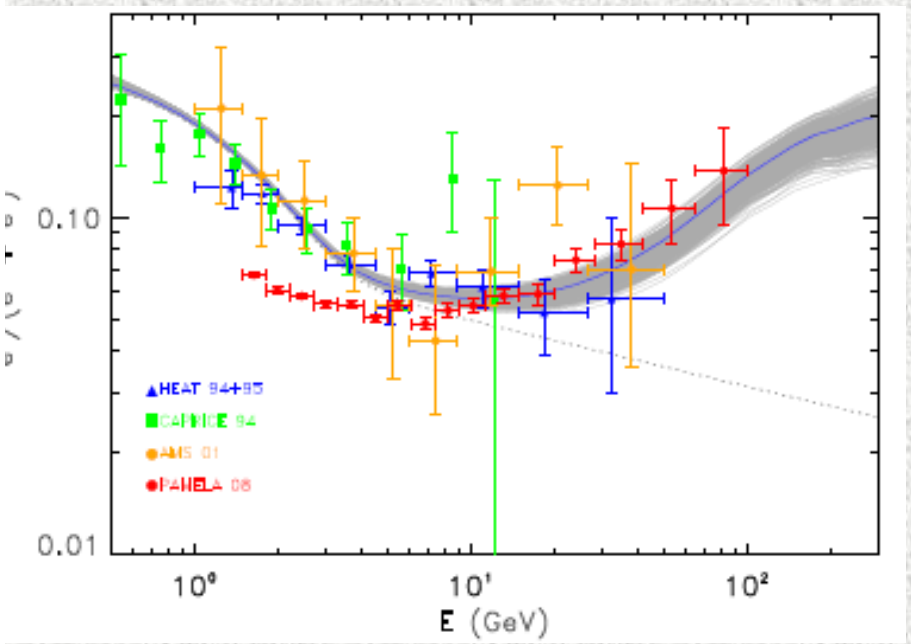
Profumo arxiv:0812.4457



FERMI electrons and PAMELA positron fraction: contribution from local pulsars (d<3 kpc)

(Grasso et. al 0905.0636)

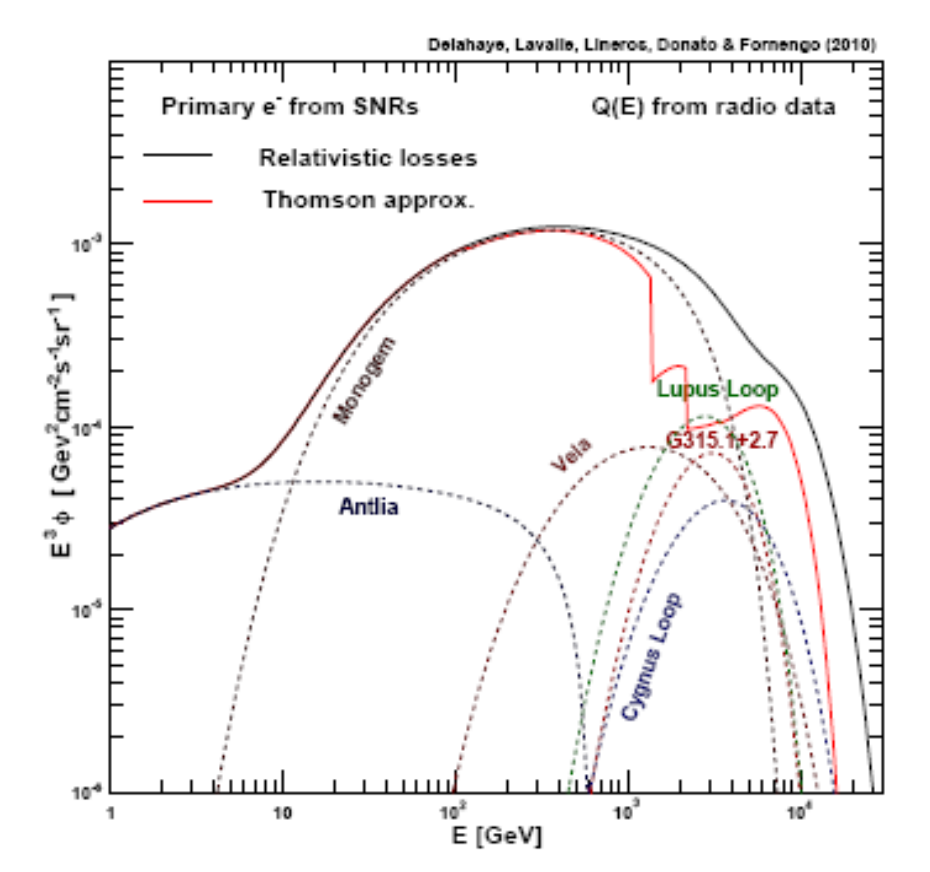




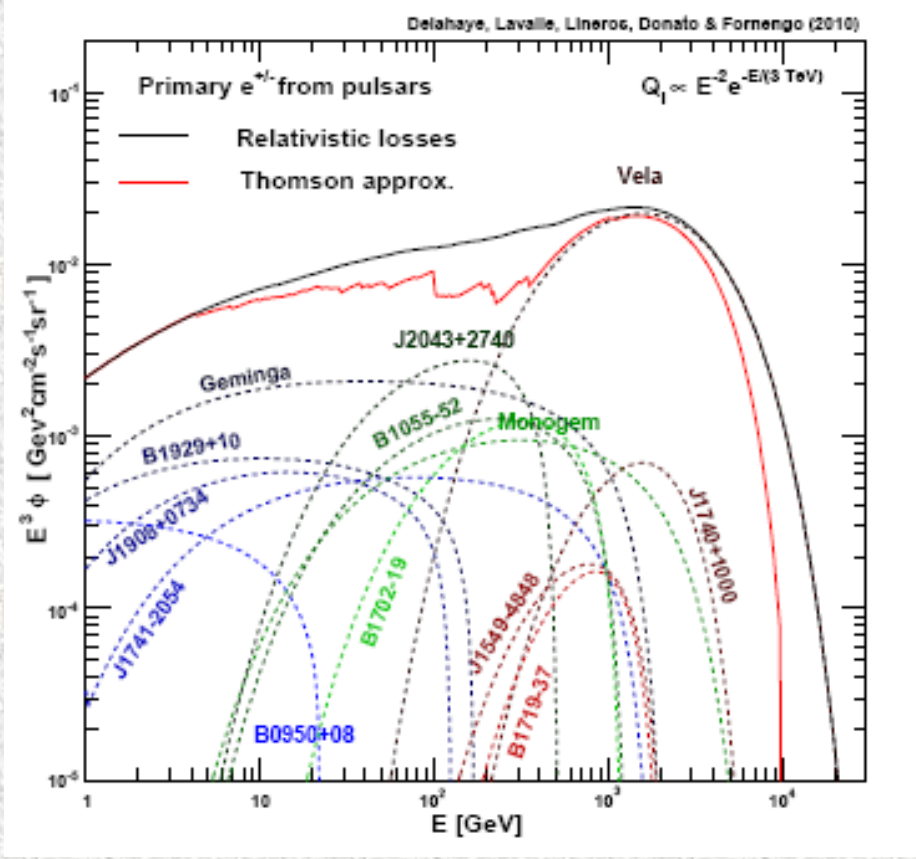
Good description of both e^- and $e^+/(e^+e^-)$

Primary e+ & e- from pulsars and SNR

Delahaye, Lavalle, Lineros, FD, Fornengo arxiv:1002.1910

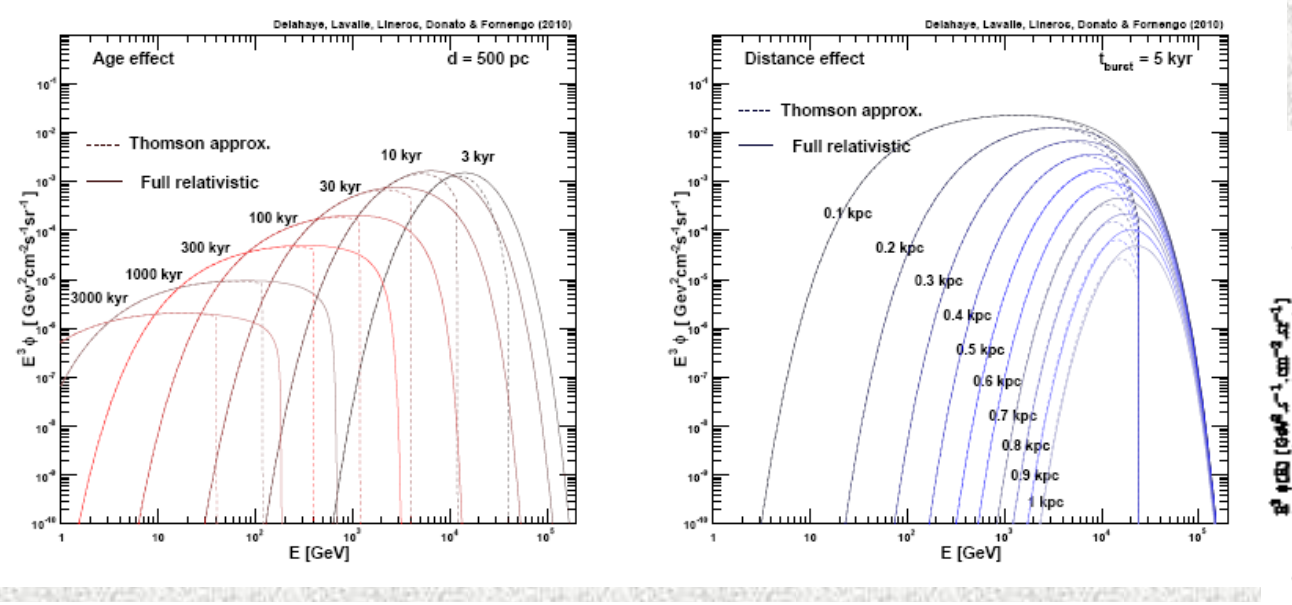


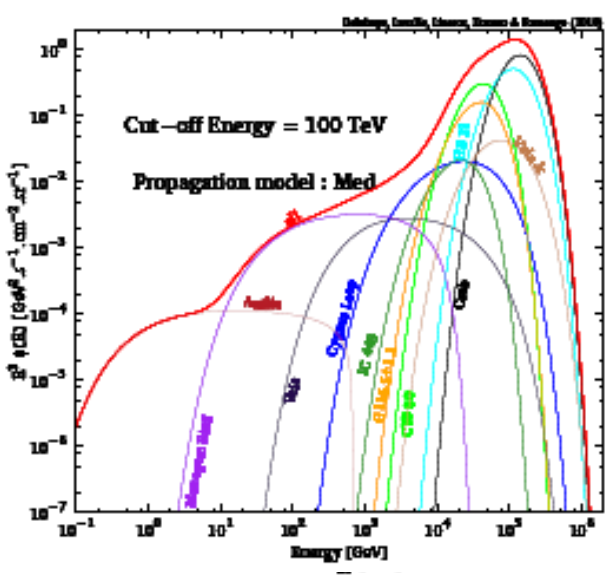
From SNR

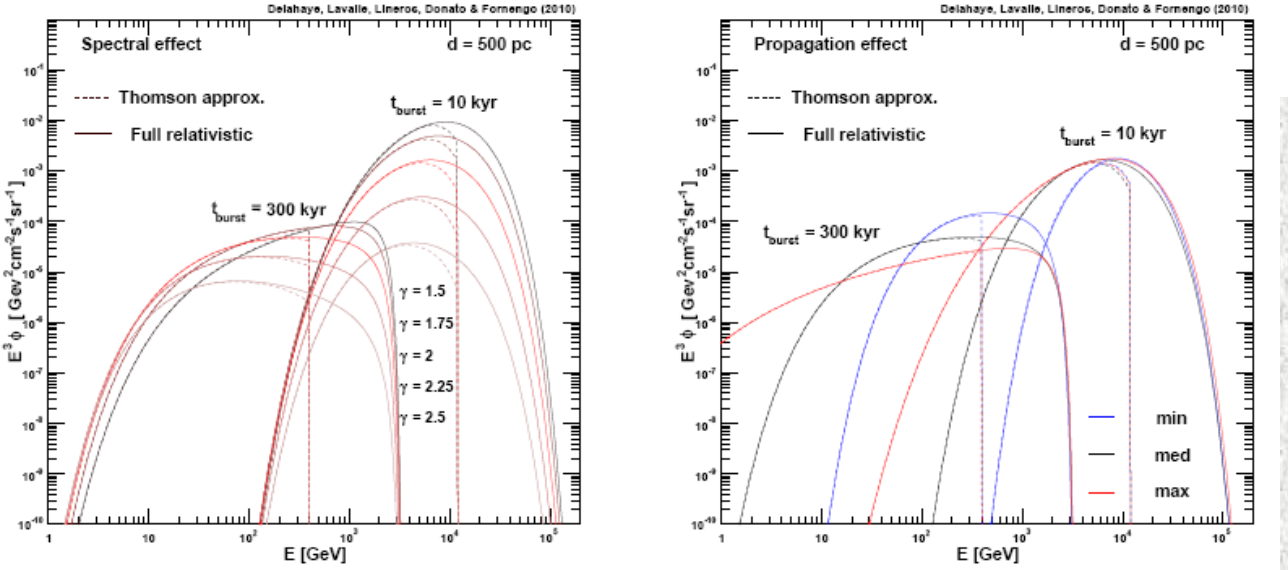


From pulsars

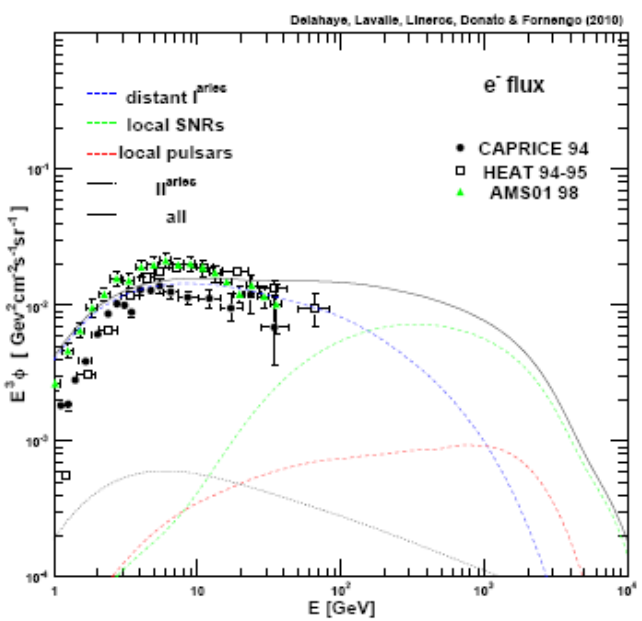
Astrophysical uncertainties in primary e-e+ Production from single source

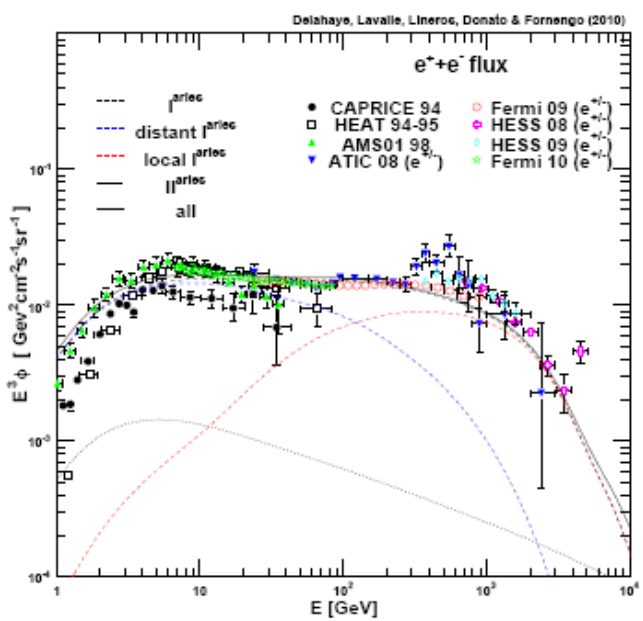


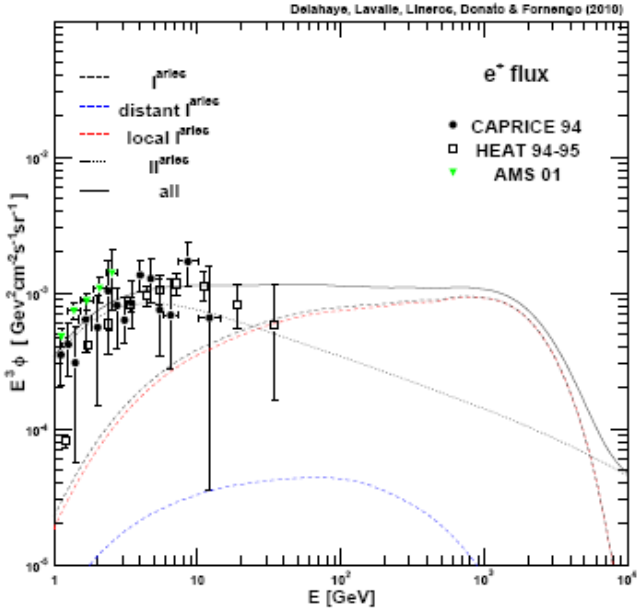


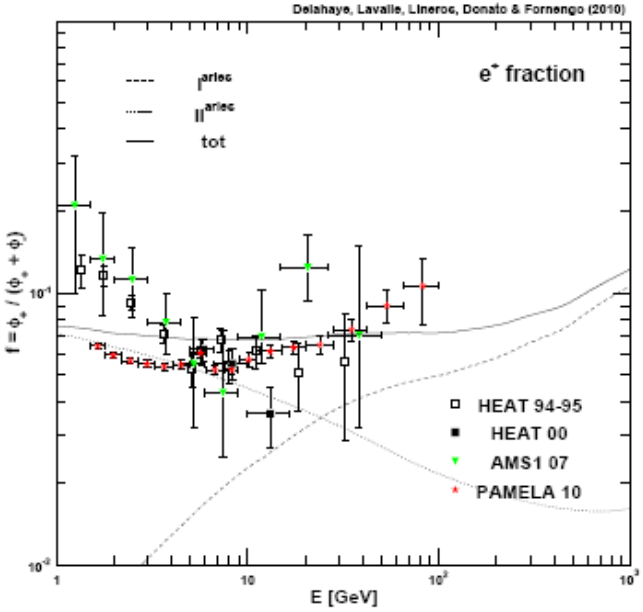


An example for all contributions





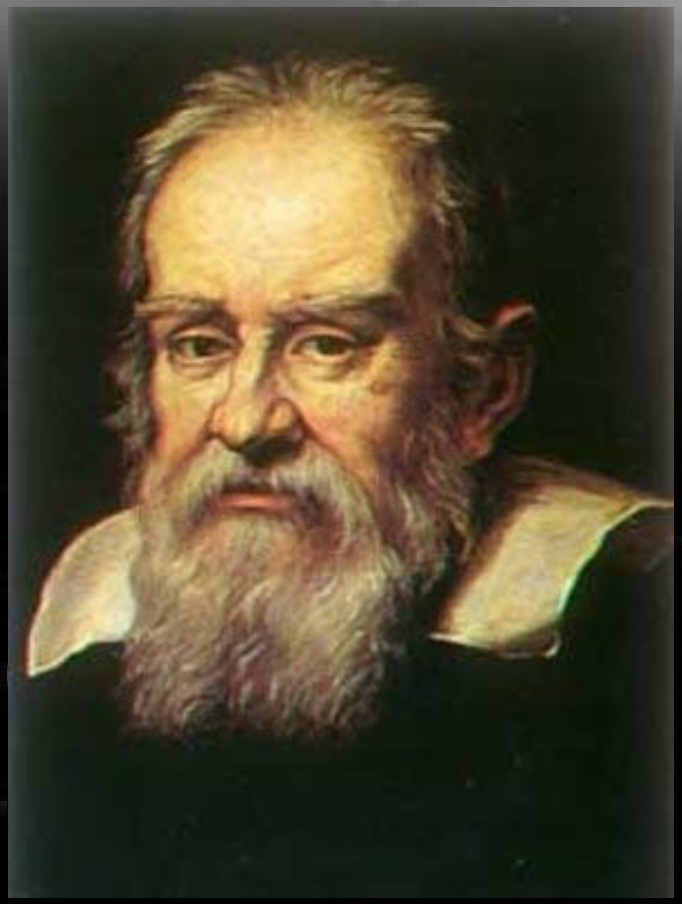




Conclusions

- Positron and electron data can be fitted by astrophyical sources
- DM interpretations are possible, but less natural
- Theoretical uncertainties affect predictions:
  - secondary e^+ : ~ 2-4
  - astro primary e^+ e^- : high
  - DM primary e^+ : ~ 5

Are positrons good DM probes??
Well, difficult probes…



"La filosofia è scritta in quel grandissimo libro che continuamente ci sta aperto innanzi agli occhi (io dico l'universo)" (Galileo)

"Philosophy is written in that immense book which continuously stands in front of our eyes (I call it the Universe)"