Implications of the positron/electron excesses on Dark Matter properties

1) The data
2) DM annihilations?
3) γ and ν constraints
4) DM decays?

Alessandro Strumia, talk at IPMU, kaizen-ed to December 10, 2009
From arXiv:0809.2409, 0811.3744, 0811.4153, 0905.0480, 0908.1578, 0912.0742
with M. Cirelli, G. Bertone, M. Kadastik, P. Meade, M. Papucci, M. Raidal
M. Taoso, E. Nardi, F. Sannino, T. Volansky, www.cern.ch/astrumia/PAMELA.pdf

Indirect signals of Dark Matter

DM DM annihilations in our galaxy might give detectable γ, e^+, $\bar{p}$, $\bar{\mathrm{d}}$.

The galactic DM density profile

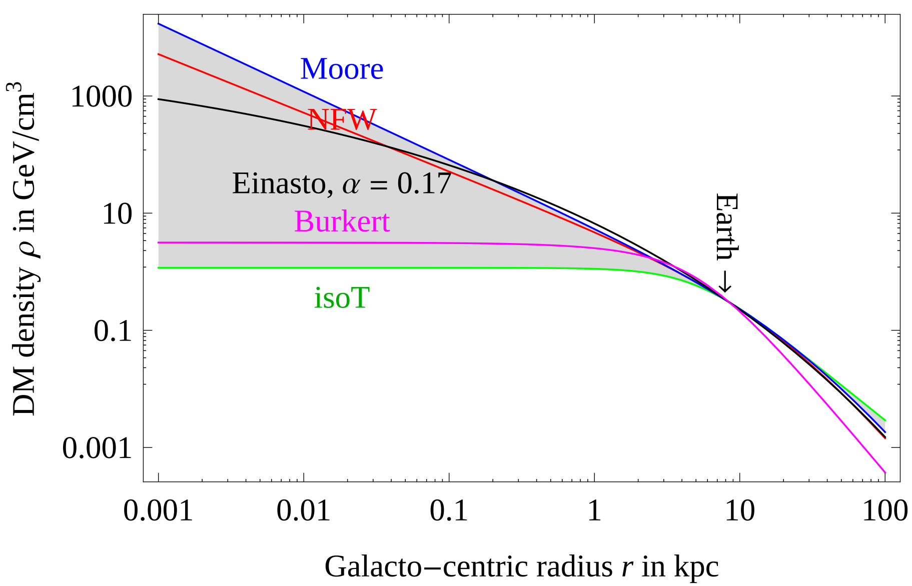
DM velocity: $\beta \approx 10^{-3}$. DM is spherically distributed with uncertain profile:

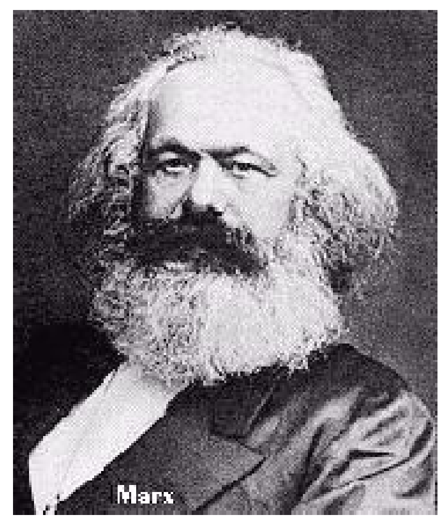
$$\rho(r) = \rho_\odot \left[\frac{r_\odot}{r}\right]^\gamma \left[\frac{1 + (r_\odot/r_s)^\alpha}{1 + (r/r_s)^\alpha}\right]^{(\beta-\gamma)/\alpha}$$

$r_\odot = 8.5\,\mathrm{kpc}$ is our distance from the Galactic Center, $\rho_\odot \equiv \rho(r_\odot) \approx 0.38\,\mathrm{GeV/cm^3}$,

DM halo model		α	β	γ	r_s in kpc
Isothermal	'isoT'	2	2	0	5
Navarro, Frenk, White	'NFW'	1	3	1	20

$\rho(r)$ is uncertain because DM is like capitalism according to Marx:
a gravitational system (slowly) collapses to the ground state $\rho(r) = \delta(r)$.
Maybe our galaxy, or spirals, is communist: $\rho(r) \approx$ low constant, as in isoT.





DM DM signal boosted by sub-halos?

N-body simulations suggest that DM might clump in subhalos:

Annihilation rate $\propto \int dV\ \rho^2$ increased by a boost factor $B = 1 \leftrightarrow 100 \sim$ a few

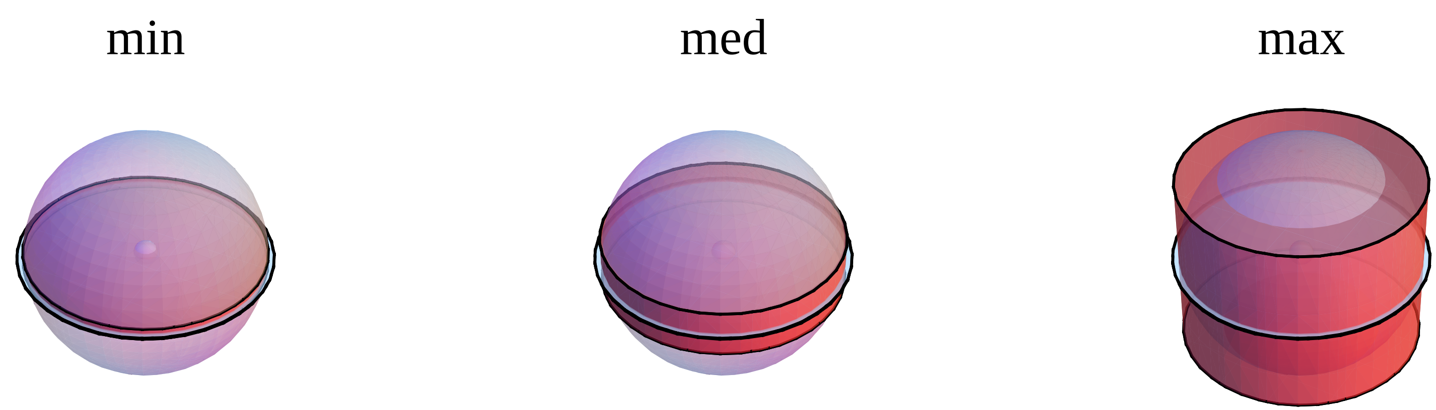
Simulations neglect normal matter, that locally is comparable to DM.

Propagation of $e^{\pm}$ in the galaxy

$\Phi_{e^+} = v_{e^+} f/4\pi$ where $f = dN/dV\,dE$ obeys: $-K(E)\cdot\nabla^2 f - \frac{\partial}{\partial E}(\dot{E} f) = Q$.

- **Injection**: $Q = \frac{1}{2}\left(\frac{\rho}{M}\right)^2 \langle\sigma v\rangle \frac{dN_{e^+}}{dE}$ from DM annihilations.
- **Diffusion** coefficient: $K(E) = K_0(E/\,\text{GeV})^\delta \sim R_{\text{Larmor}} = E/eB$.
- **Energy loss** from IC + syn: $\dot{E} = E^2\cdot(4\sigma_T/3m_e^2)(u_\gamma + u_B)$.
- **Boundary**: f vanishes on a cylinder with radius $R = 20\,\text{kpc}$ and height $2L$.

Propagation model	δ	K_0 in kpc^2/Myr	L in kpc	V_{conv} in km/s
min	0.85	0.0016	1	13.5
med	0.70	0.0112	4	12
max	0.46	0.0765	15	5



Small diffusion in a small volume, or large diffusion in a large volume?
Main result: $e^{\pm}$ reach us from the Galactic Center only in the max case

1

The data

ABC of charged cosmic rays

$e^\pm$, $p^\pm$, He, B, C... Their directions are randomized by galactic magnetic fields $B \sim \mu$G. The info is in their energy spectra.

We hope to see DM annihilation products as excesses in the rarer e^+ and $\bar{p}$.

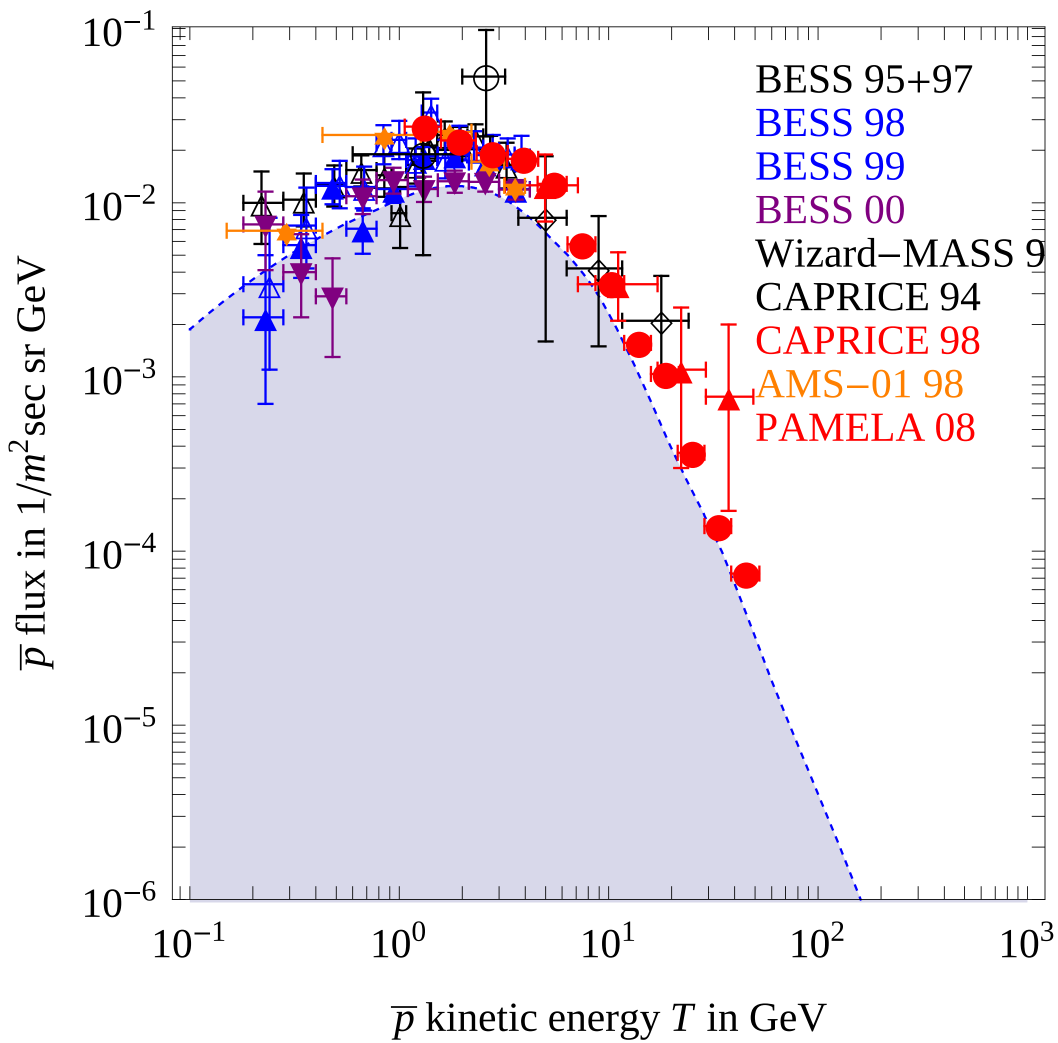
Experimentalists need to bring above the atmosphere (with balloons or satellites) a spectrometer and/or calorimeter, able of rejecting e^- and p.

This is difficult above 100 GeV, also because CR fluxes decrease as $\sim E^{-3}$.

Energy spectra below a few GeV are $\sim$useless, because affected by solar activity.

$\bar{p}/p$: PAMELA

Consistent with background

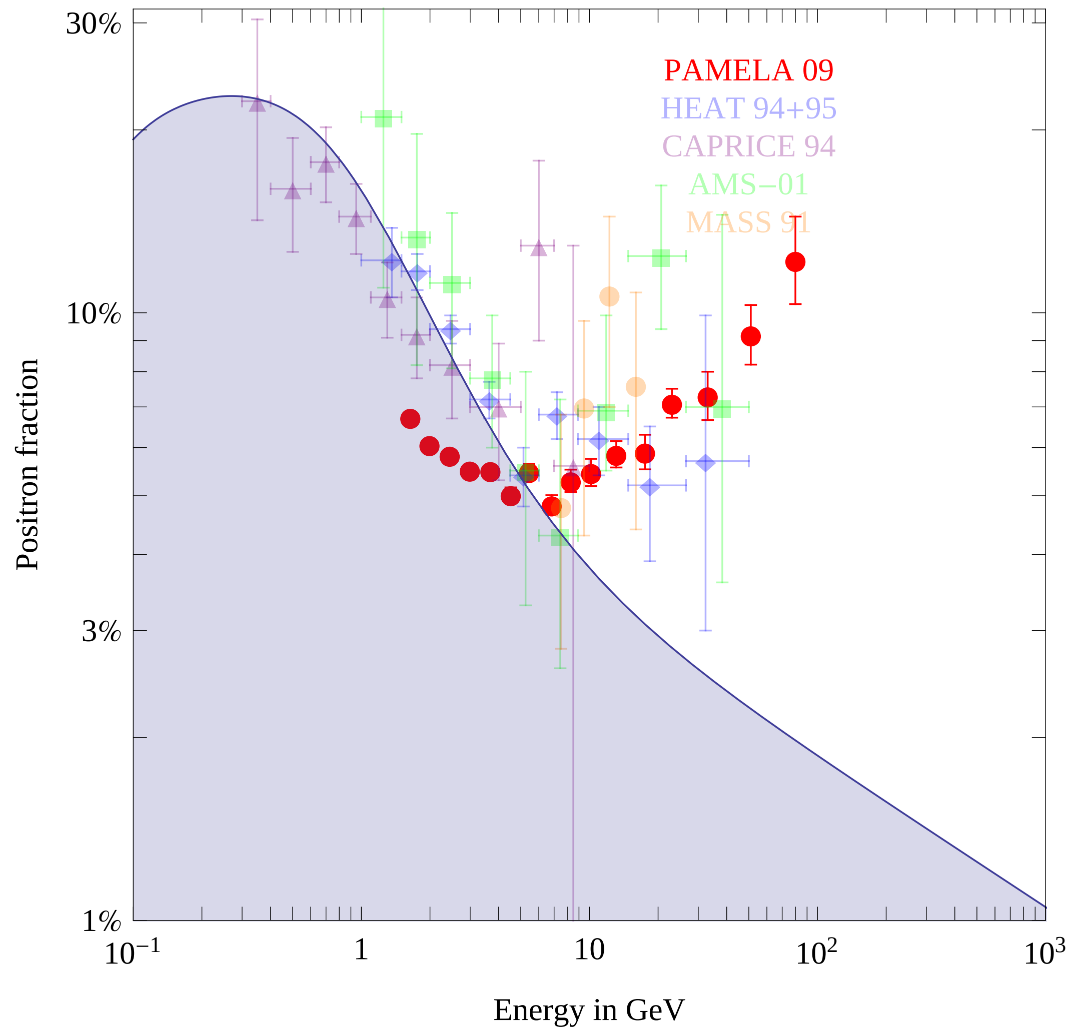


Future: PAMELA, AMS

$e^+/(e^+ + e^-)$: PAMELA

PAMELA is a spectrometer + calorimeter sent to space. It can discriminate $e^+, e^-, p, \bar{p}, \ldots$ and measure their energies up to (now) 100 GeV. Astrophysical backgrounds should give a positron fraction that decreases with energy. This happens below 10 GeV, where the flux is reduced by the present solar polarity.

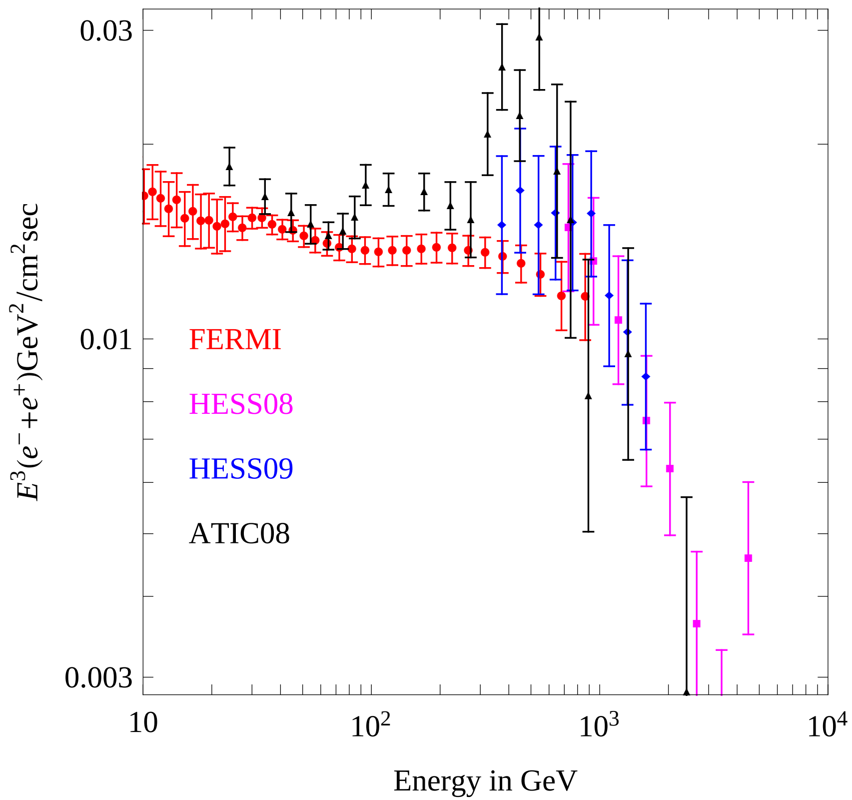
Growing excess above 10 GeV



The PAMELA excess suggest that it might manifest in other experiments: if e^+/e^- continues to grow, it reaches $e^+ \sim e^-$ around 1 TeV...

$e^+ + e^-$: FERMI, ATICs, HESS, BETS

These experiments cannot discriminate e^+/e^-, but probe higher energy.



Hardening at 100 GeV + softening at 1 TeV

Are these real features? Likely yes. Hardening also in ATICs.

Systematic errors, not yet defined, are here incoherently added bin-to-bin to the smaller statistical error, allowing for a power-law fit.

... Just a pulsar?

A pulsar is a neutron star with a rotating intense magnetic field. The resulting electric field ionizes and accelerates e^- (and maybe iron) $\to \gamma \to e^+e^-$, that are presumably further accelerated by the pulsar wind nebula (Fermi mechanism).

- $E_{\text{pulsar}} = I\omega^2/2$, $\dot{E}_{\text{pulsar}} = -B^2_{\text{surface}}R^2\omega^4/6c^3 =$ magnetic dipole radiation.

- The guess is $\Phi_{e^-} \approx \Phi_{e^+} \propto \epsilon \cdot e^{-E/M}/E^p$ where $p \approx 2$ and M are constants.

Known nearby pulsars (B0656+14, Geminga, ?) would need an unplausibly (?) large fraction ϵ of energy that goes into $e^\pm$: $\epsilon \sim 0.3$.

Test: angular anisotropies (but can be faked by local $B(\vec{x})$, pulsar motion).

2

Model-independent theory of DM indirect detection

Model-independent DM annihilations

Indirect signals depend on the DM mass M, non-relativistic σv, primary BR:

$$\text{DM DM} \to \begin{cases} W^+W^-, \quad ZZ, \quad Zh, \quad hh & \text{Gauge/higgs sector} \\ e^+e^-, \quad \mu^+\mu^-, \quad \tau^+\tau^- & \text{Leptons} \\ b\bar{b}, \quad t\bar{t}, \quad q\bar{q} & \text{quarks, } q = \{u, d, s, c\} \end{cases}$$

No γ because DM is neutral. Direct detection bounds suggest no Z.

The energy spectra of the stable final-state particles

$$e^{\pm}, \qquad p^{\mp}, \qquad \overset{(-)}{\nu}_{e,\mu,\tau}, \qquad \bar{d}, \qquad \gamma$$

depend on the polarization of primaries: $W_{L \text{ or } T}$ and $\mu_{L \text{ or } R}$.

The γ spectrum is generated by various higher-order effects:

$$\gamma = (\text{Final State Radiation}) + (\text{one-loop}) + (\text{3-body})$$

We include FSR and ignore the other comparable but model dependent effects

The DM spin

Non-relativistic s-wave DM annihilations can be computed in a model-independent way because they are like decays of the two-body $\mathscr{D} = (\text{DM DM})_{L=0}$ state.

If DM is a fundamental weakly-interacting particle, its spin J can be 0, 1/2 or 1, so the spin of $\mathscr{D}$ can only be 0, 1 or 2:

$$1 \otimes 1 = 1, \qquad 2 \otimes 2 = 1_{\text{asymm}} \oplus 3_{\text{symm}}, \qquad 3 \otimes 3 = 1_{\text{symm}} \oplus 3_{\text{asymm}} \oplus 5_{\text{symm}}$$

So:

- **$\mathscr{D}$ can have spin 0 for any DM spin**. It couples to vectors $\mathscr{D}F^2_{\mu\nu}$ and to higgs $\mathscr{D}h^2$, not to light fermions: $\mathscr{D}\ell_L\ell_R$ is m_ℓ/M suppressed.

- **$\mathscr{D}$ can have spin 1 only if DM is a Dirac fermion or a vector**. PAMELA motivates a large $\sigma(\text{DM DM} \to \ell^+\ell^-)$: only possible for $\mathscr{D}_\mu[\bar{\ell}\gamma_\mu\ell]$.

DM annihilations into fermions f

- Scalar $\mathscr{D}$ can only couple as

$$\mathscr{D} f_L f_R + \text{h.c.} = \mathscr{D} \bar{\Psi}_f \Psi_f$$

with $\Psi_f = (f_L, \bar{f}_R)$ in Dirac notation. It means zero helicity on average, and is typically **suppressed by** m_f/M. *Huge* weak corrections if $M \gg M_W$.

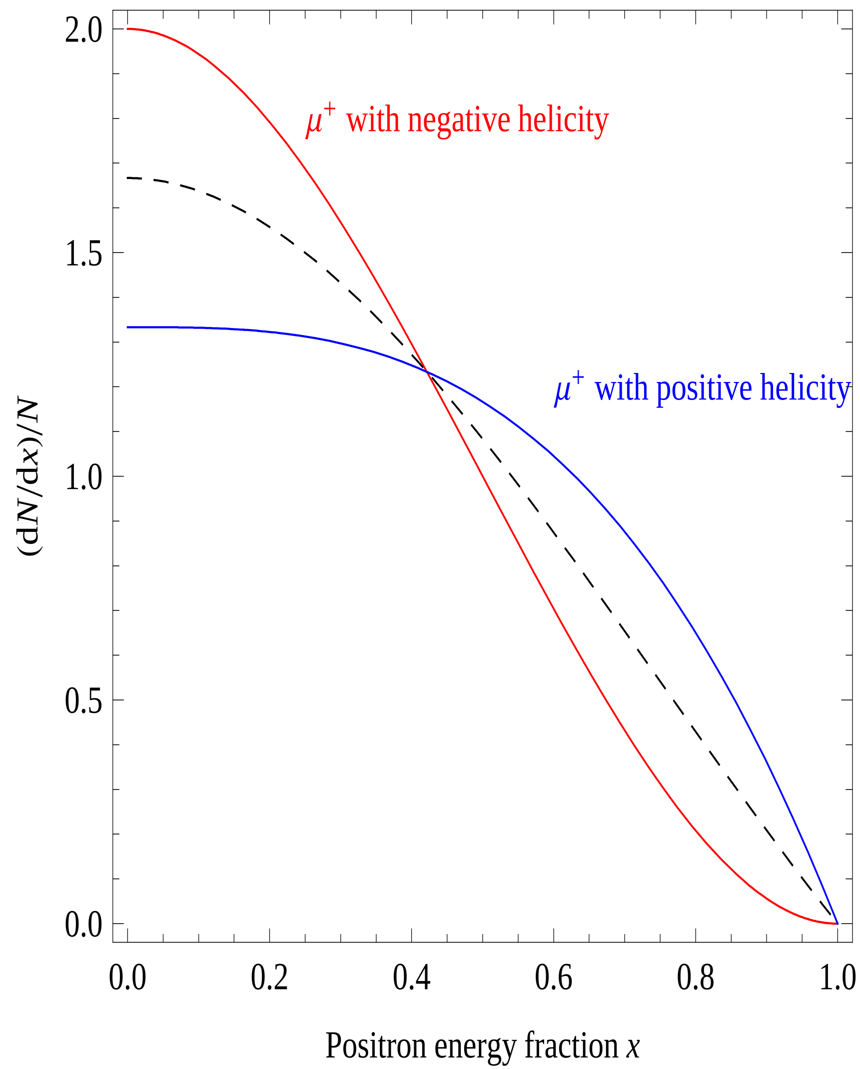
- Vector $\mathscr{D}_\mu$ can couple as

$$\mathscr{D}_\mu[\bar{f}_L \gamma_\mu f_L] \qquad \text{or} \qquad \mathscr{D}_\mu[\bar{f}_R \gamma_\mu f_R]$$

i.e. fermions with *Left* or *Right* helicity. Decays like $\mu^+ \to \bar{\nu}_\mu e^+ \nu_e$ give e^+ with

$$dN/dx|_L = 2(1-x)^2(1+2x)$$

$$dN/dx|_R = 4(1-x^3)/3$$



DM annihilations into W, Z

- The effective interactions

$$\mathscr{D} F_{\mu\nu}\epsilon_{\mu\nu\rho\sigma}F_{\rho\sigma} \qquad \text{and} \qquad \mathscr{D} F^2_{\mu\nu}$$

give vectors with *T*ranverse polarization (with different unobservable helicity correlations), that decay in $f\bar{f}$ with $E = x\,M$ as:

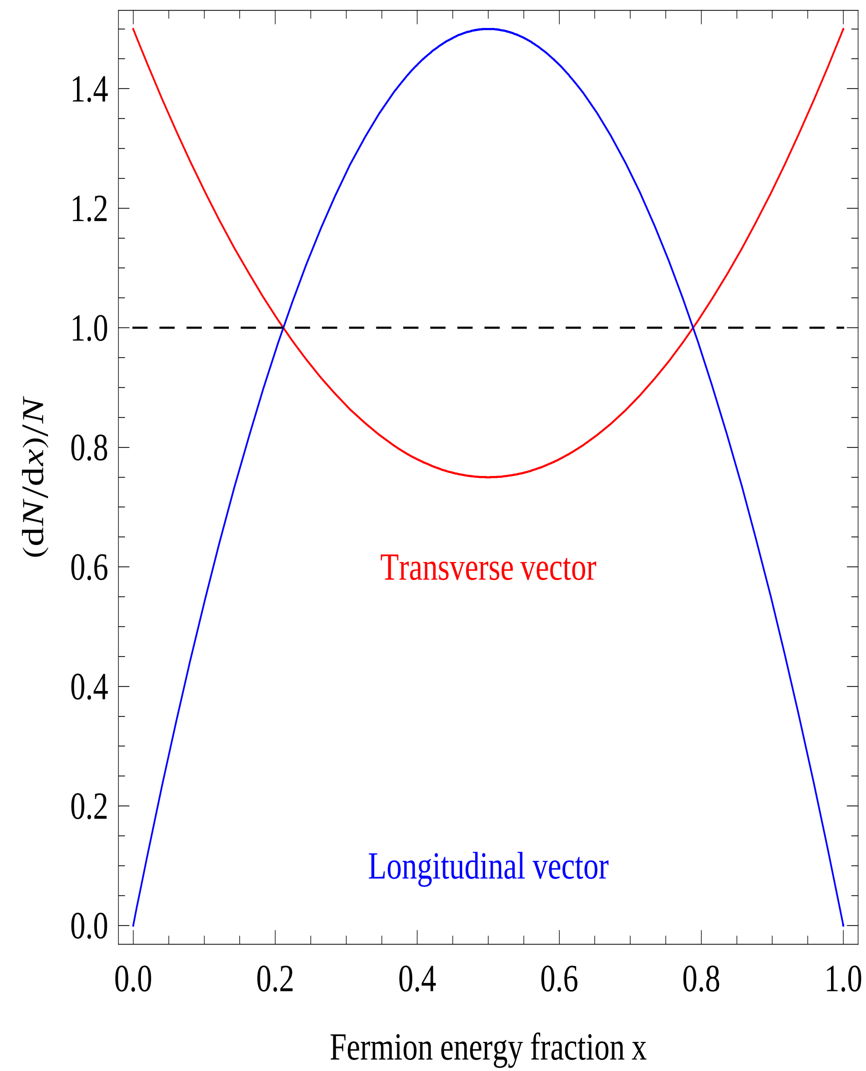
$$dN/d\cos\theta = 3(1+\cos^2\theta)/8$$

$$dN/dx = 3(1-2x+3x^2)/2,$$

- $\mathscr{D} A^2_\mu$ gives *L*ongitudinal vectors (acconting for DM annihilations into Higgs Goldstones), that decay as

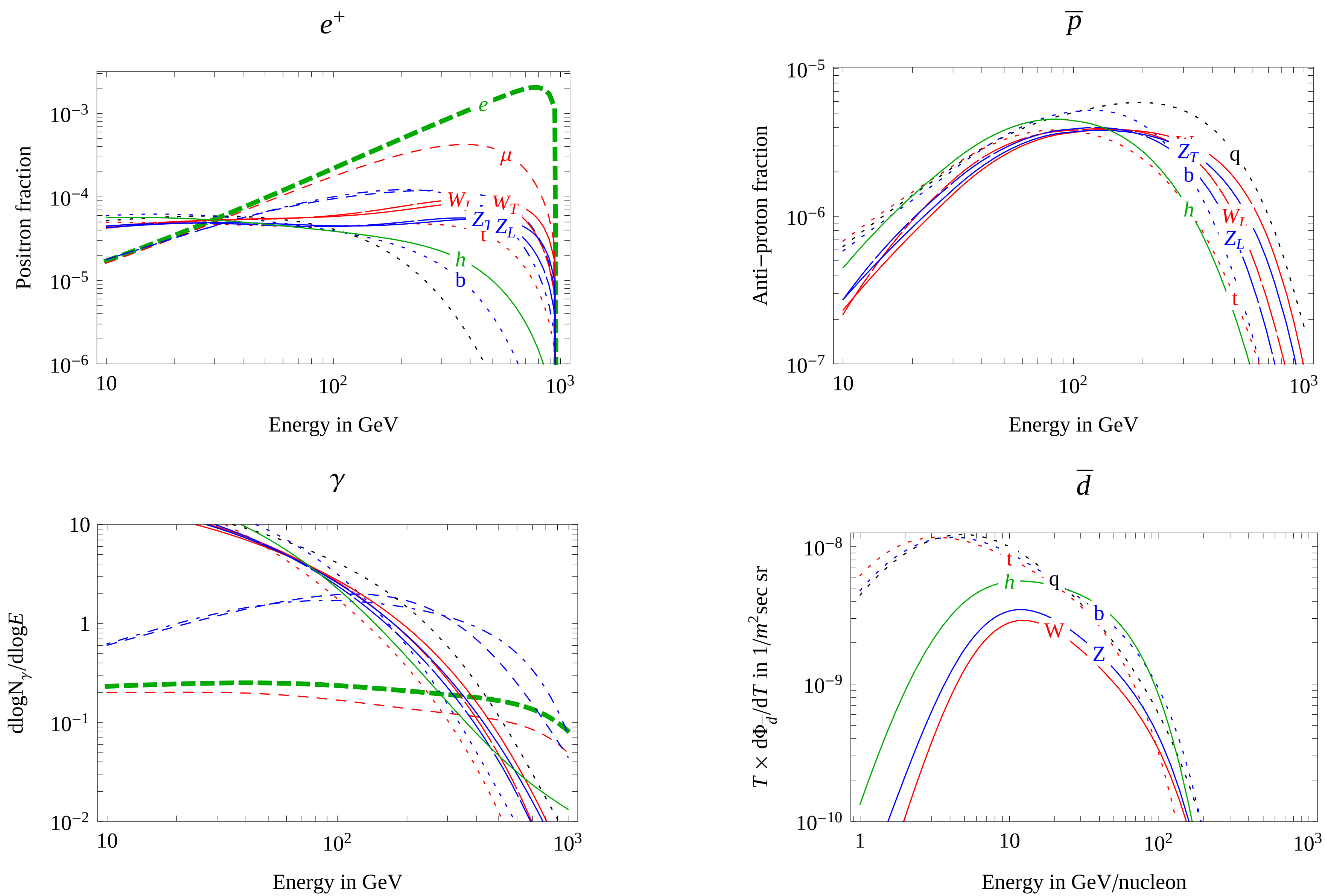
$$dN/d\cos\theta = 3(1-\cos^2\theta)/4$$

$$dN/dx = 6x(1-x).$$



Final state spectra for $M = 1$ TeV

Two-body primary channels: $e, \mu_L, \mu_R, \tau_L, \tau_R,\ W_L, W_T, Z_L, Z_T, h,\ q, b, t.$



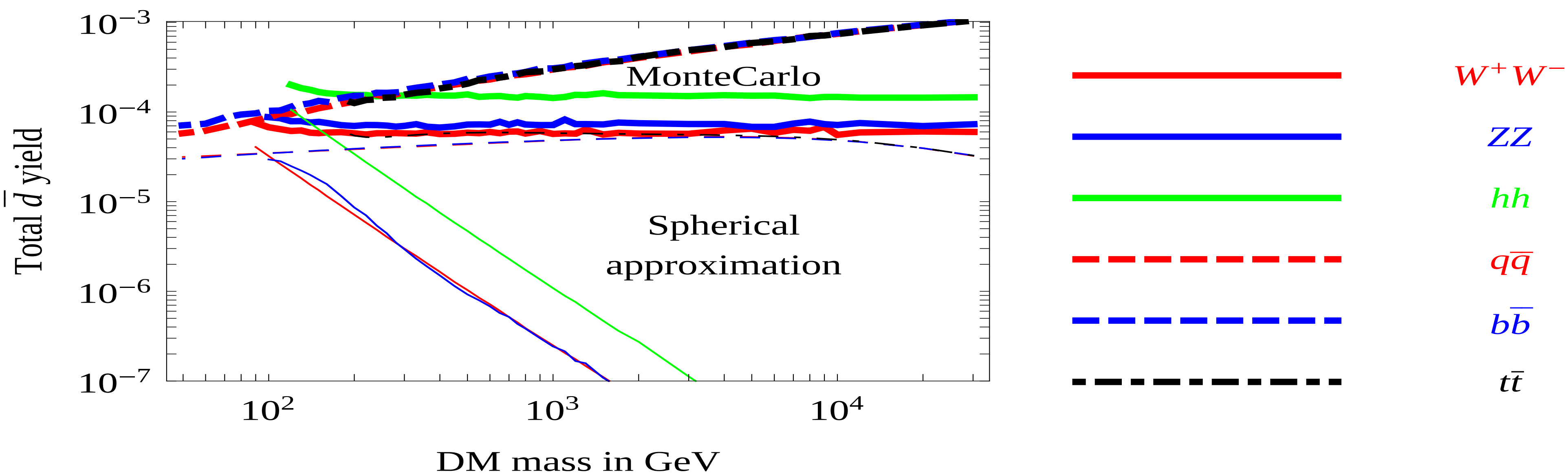
Annihilations into leptons give qualitatively different energy spectra.

Anti-deuterium

$\bar{d}$ forms when DM produces a $\bar{p}$ and a $\bar{n}$ with momentum difference below $p_0 \approx 160\,\text{MeV}$. The analytical appoximation assuming spherical-cow events

$$\frac{dN_{\bar{d}}}{dT_{\bar{d}}} = \frac{p_0^3}{3k_{\bar{d}} m_p} \left(\frac{dN_{\bar{n},\bar{p}}}{dT}\right)^2_{T=T_{\bar{d}}/2}$$

misses the jet structure of events, such that $N_{\bar{d}} \propto 1/M^2$ is very wrong. Relativity demands that higher M boosts $\bar{p}, \bar{n}, \bar{d}$, leaving $N_{\bar{d}} \sim$ constant. Running PYTHIA on GRID we find orders of magnitude enhancement:



3

Implications of the data

Fitting procedure

- **PAMELA** and **FERMI systematic uncertainties?**

- multiply each expected e^+, e^-, p^+/p^- **backgrounds** times $A_i E^{p_i}$ with free A_i and $p_i = 0 \pm 0.05$, and marginalize over A_i, p_i.

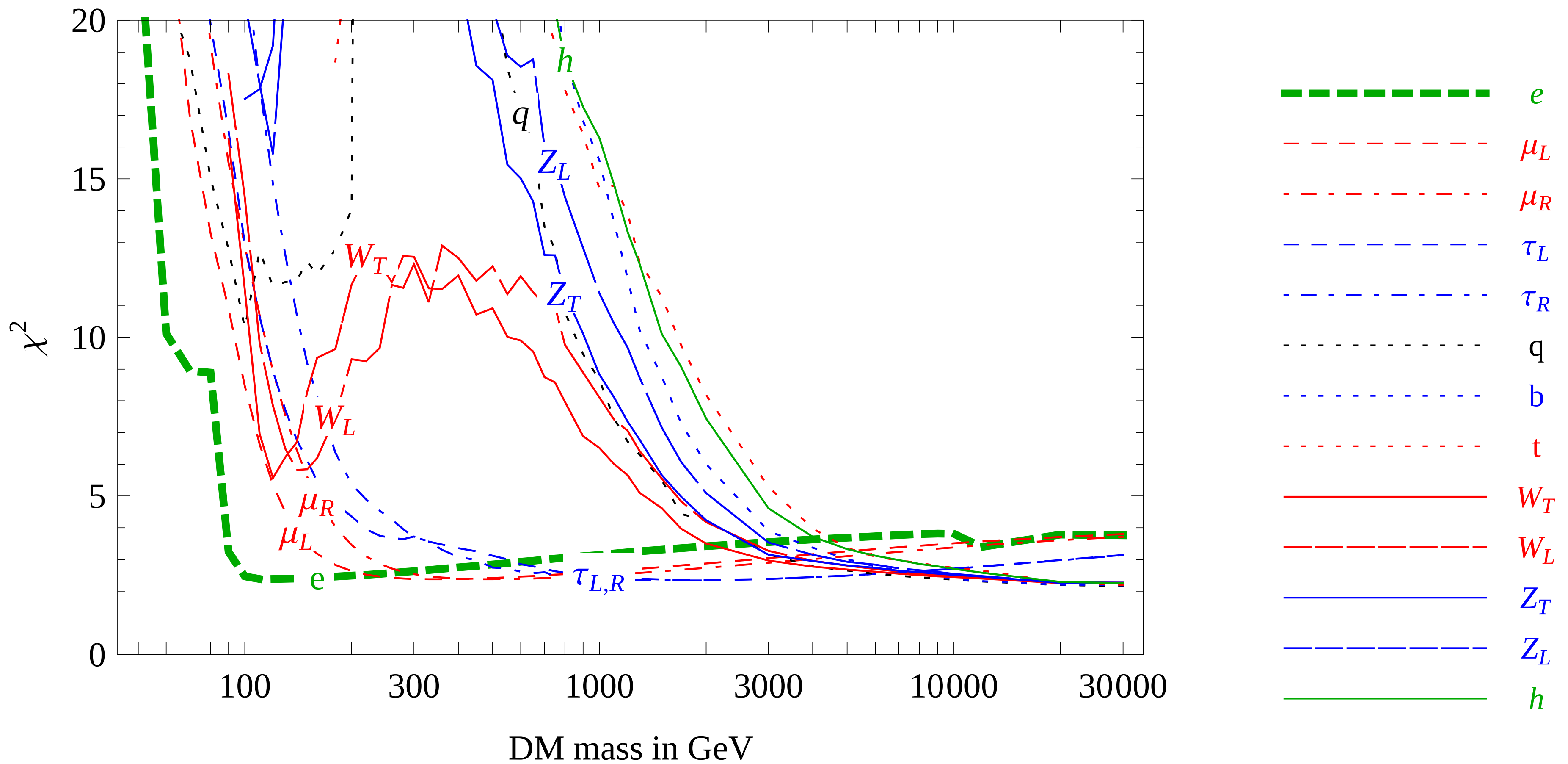
- **solar modulation** as uncorrelated uncertainty below 20 GeV:
  $\pm$6% at 10 GeV, $\pm$30% at 1 GeV.

- **DM halo**: marginalize over isoT/NFW/Moore with flat prior.

- **Propagation**: marginalize over MIN/MED/MAX with flat prior.
  (MED is favored?).

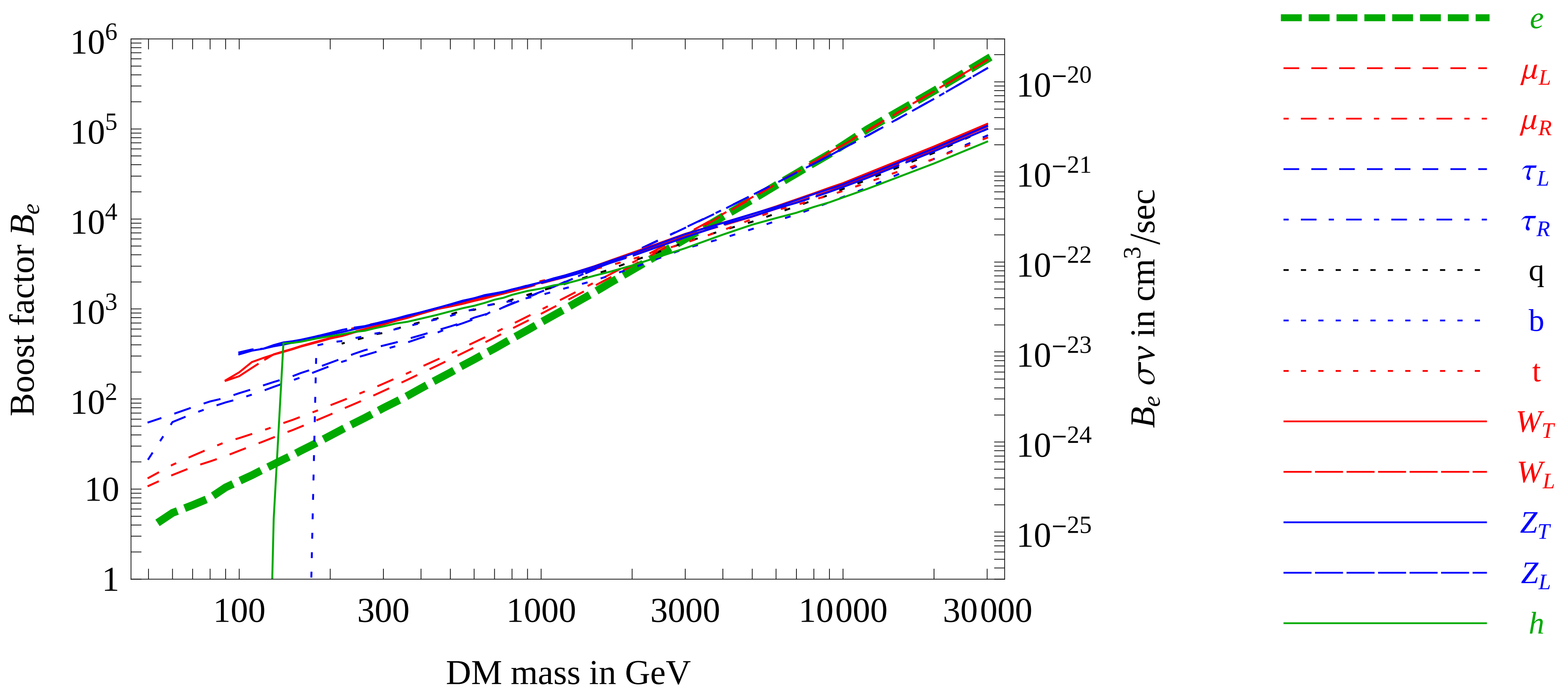
- Statistical techniques: as reviewed in appendix B of hep-ph/0606054.

Fitting PAMELA positron data



If $M >$ TeV everything fits. At smaller M only annihilations into leptons or W.

The σv needed for PAMELA



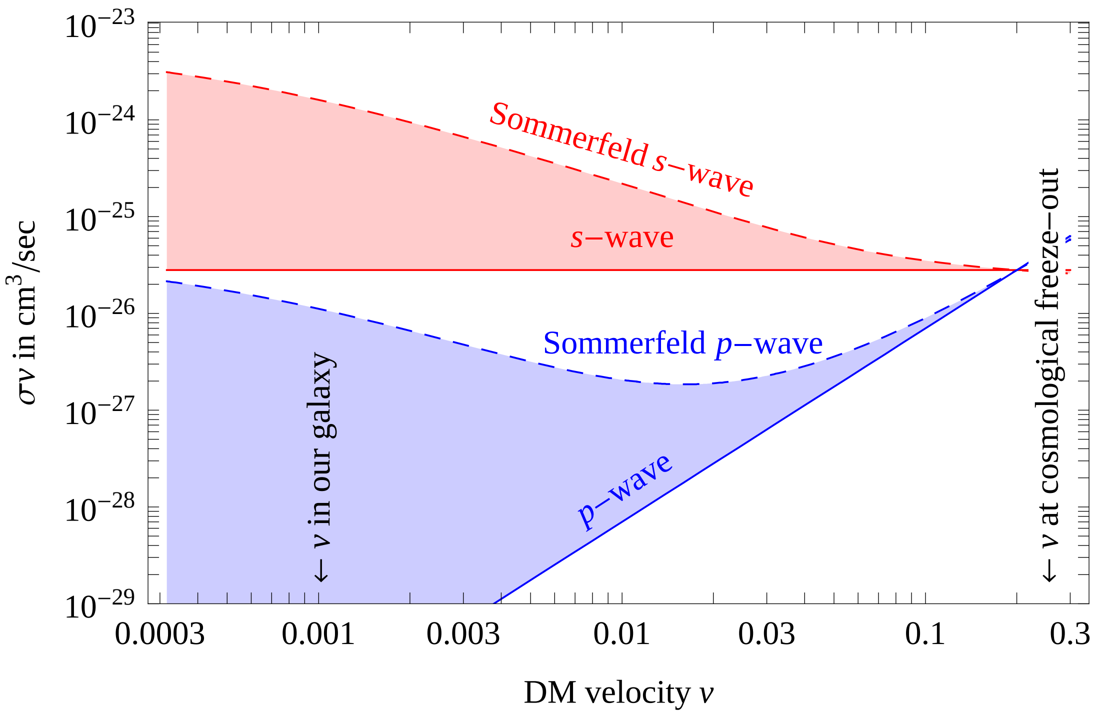
σv larger than what suggested by cosmology by a factor B_e

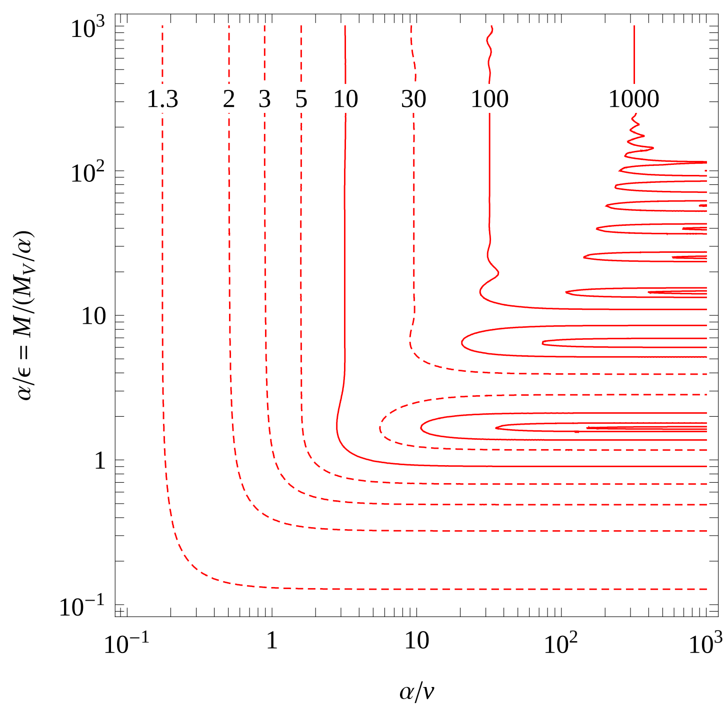
The cosmological σv

Thermal DM reproduces the cosmological DM abundance $\Omega_{\rm DM} h^2 \approx 0.11$ for

$$\sigma v \approx 3 \times 10^{-26}\,\text{cm}^3/\text{sec} \qquad \text{around freeze-out, i.e. } v \sim 0.2.$$

up to co-annihilations and resonances. Possible extrapolations to $v \sim 10^{-3}$:





The Sommerfeld effect is the quantum analogous of this classical effect: the sun attracts slower bodies, enhancing its cross section: $\sigma = \pi R_\odot^2 (1 + v_{\rm escape}^2/v^2)$

If DM is thermal PAMELA needs s-wave + Sommerfeld and/or a boost factor (DM in sub-halos has small velocity dispersion: Sommerfeld boosts the boost)

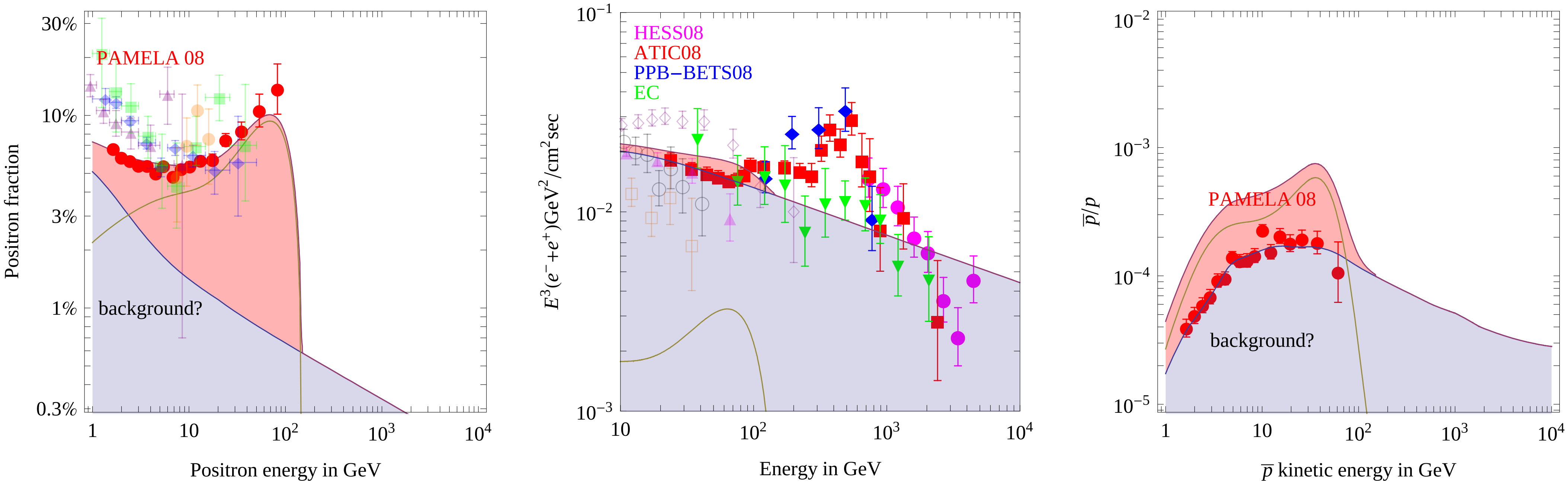
Non thermal DM

E.g. a wino that with $M \approx 100\,\text{GeV}$ annihilates into $W_T^+ W_T^-$ with the correct

$$\sigma v = \frac{g_2^4 (1 - M_W^2/M^2)^{3/2}}{2\pi M^2 (2 - M_W^2/M^2)^2}$$

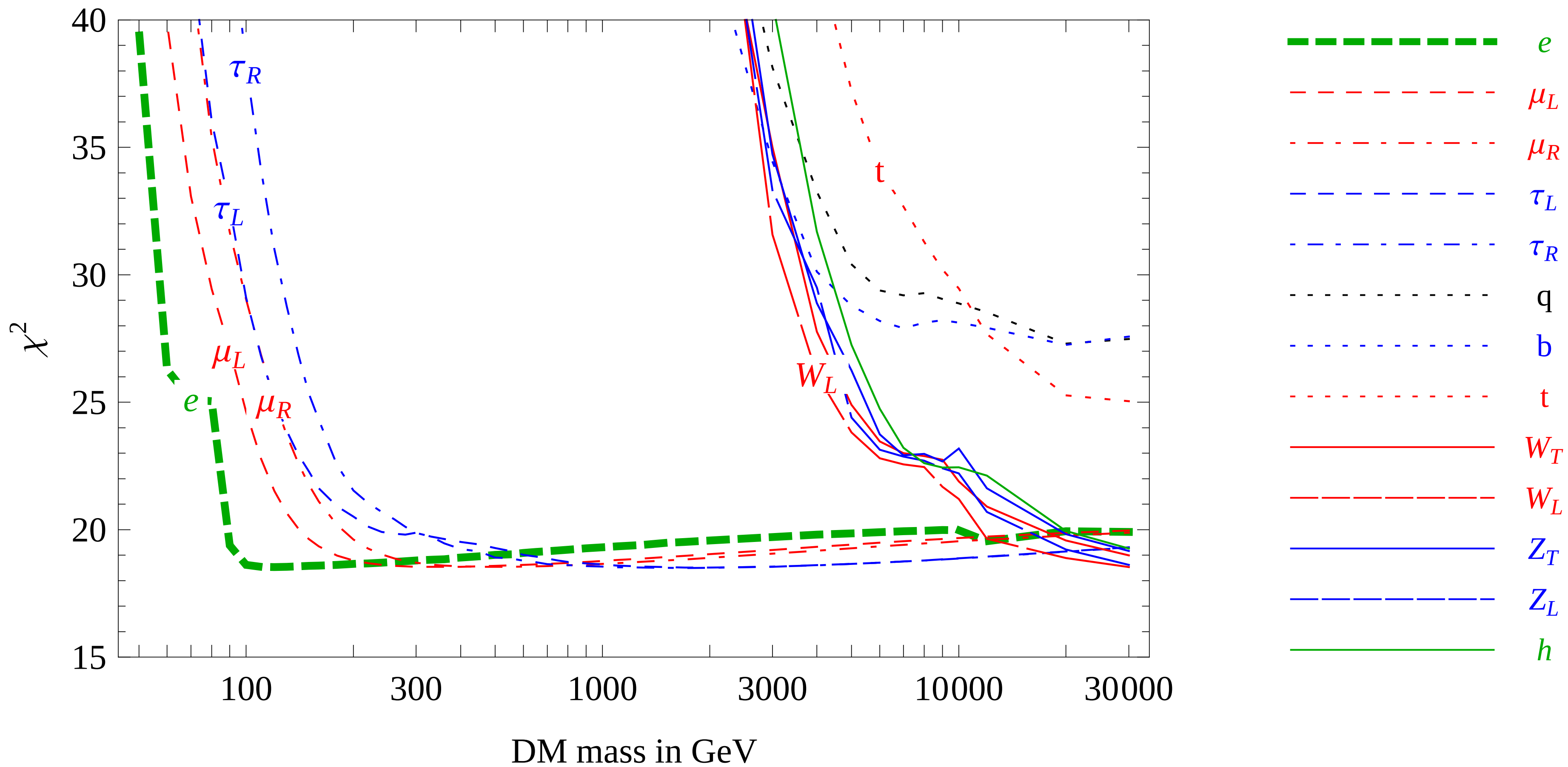
Problematic with PAMELA $\bar{p}$, reconsidered by Kane et al., excluded by FERMI.

DM with M = 150 GeV that annihilates into W^+W^-



Fitting PAMELA e^+ anti $\bar{p}$ data

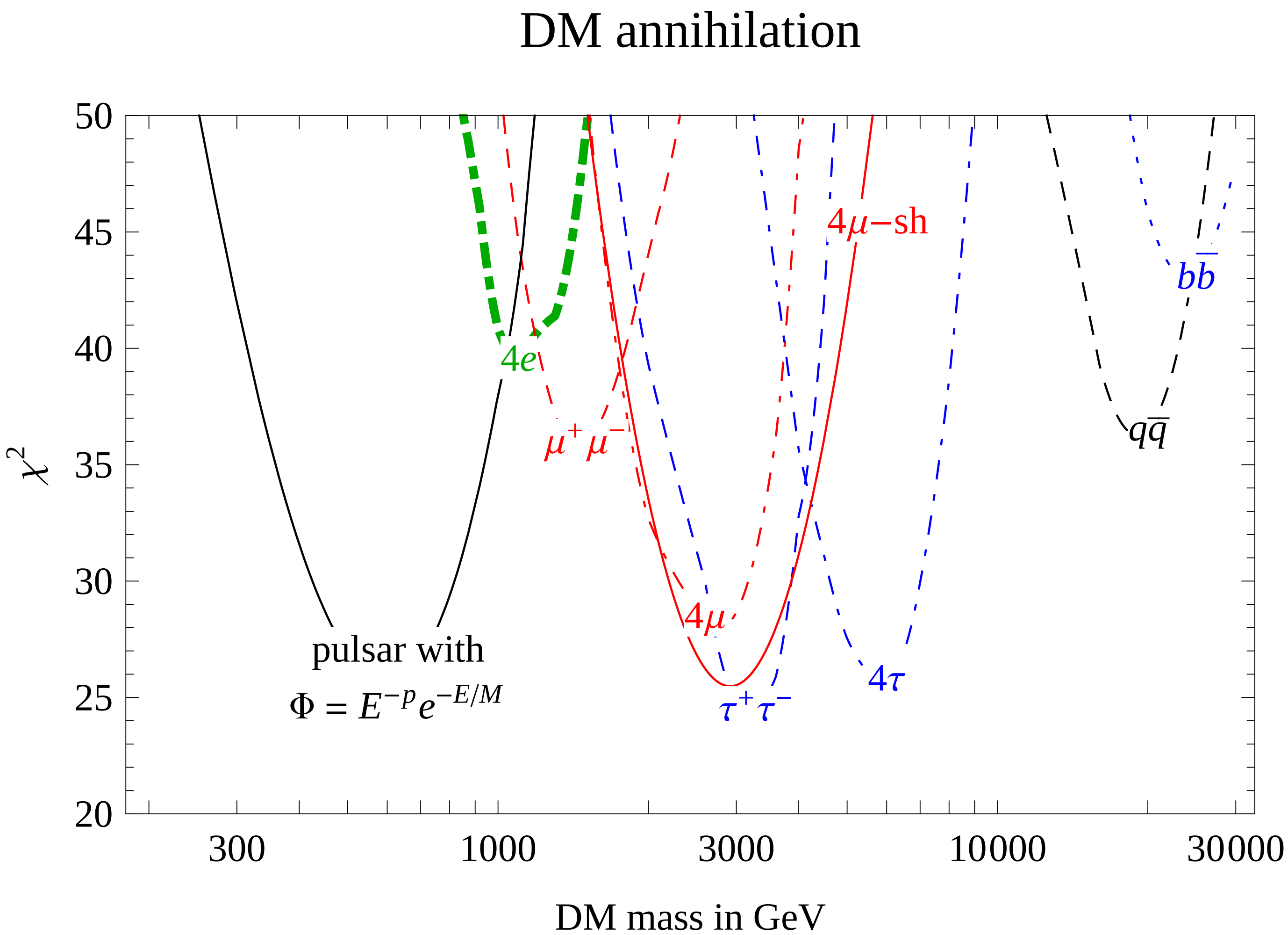
Assuming equal boost & propagation for e^+ and $\bar{p}$ (otherwise everything goes):



DM must annihilate into leptons or into W, Z with $M \gtrsim$ 10 TeV

Indeed a W at rest gives $\bar{p}$ with $E_p > m_p$. So a W with energy $E = M$ gives $E_p > M m_p / M_W$, above the PAMELA threshold for $M > 10\,\text{TeV}$.

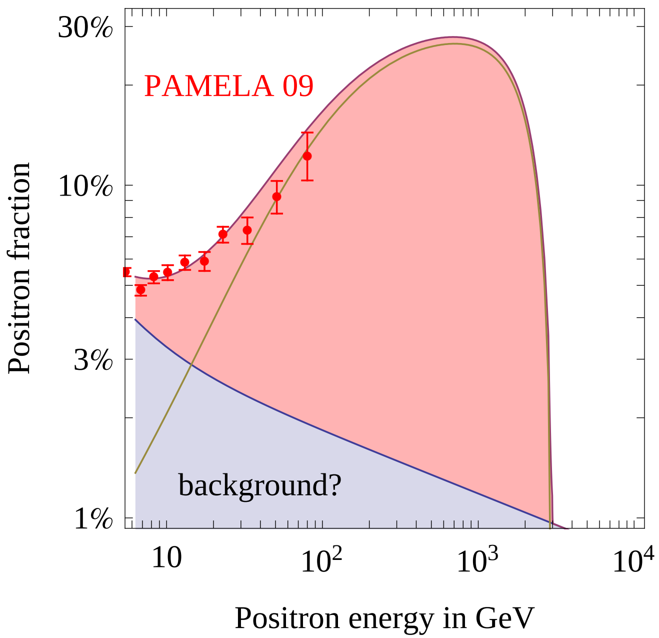
Fitting PAMELA e^+ and FERMI $e^+ + e^-$

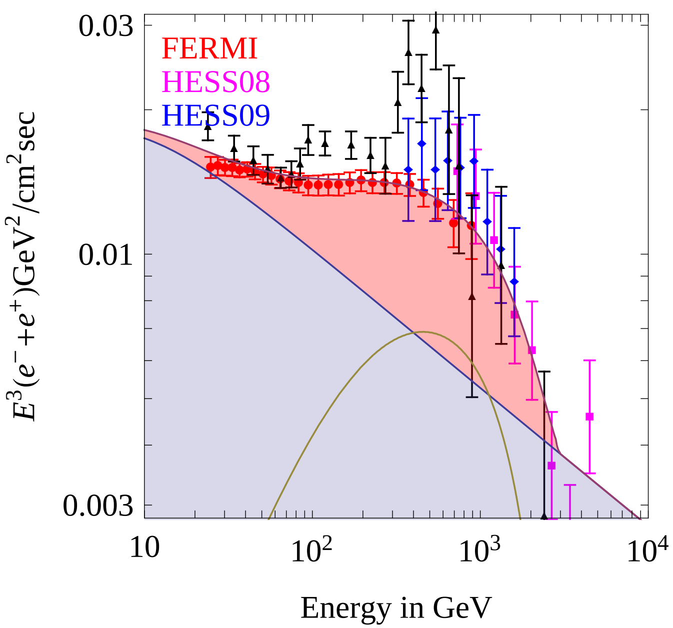


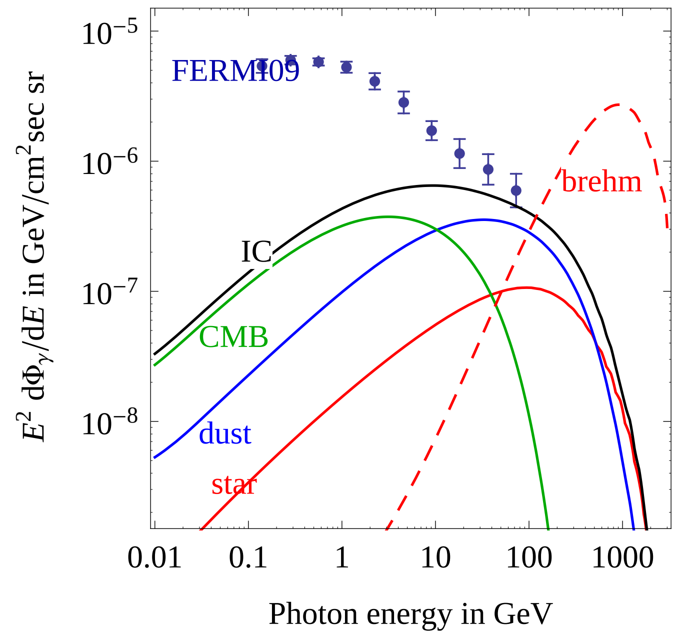
Compatible if DM has few TeV mass and annihilates into some leptons

Dark Matter best fit

DM with $M = 3.$ TeV that annihilates into $\tau^+\tau^-$ with $\sigma v = 1.9 \times 10^{-22}$ cm^3/s



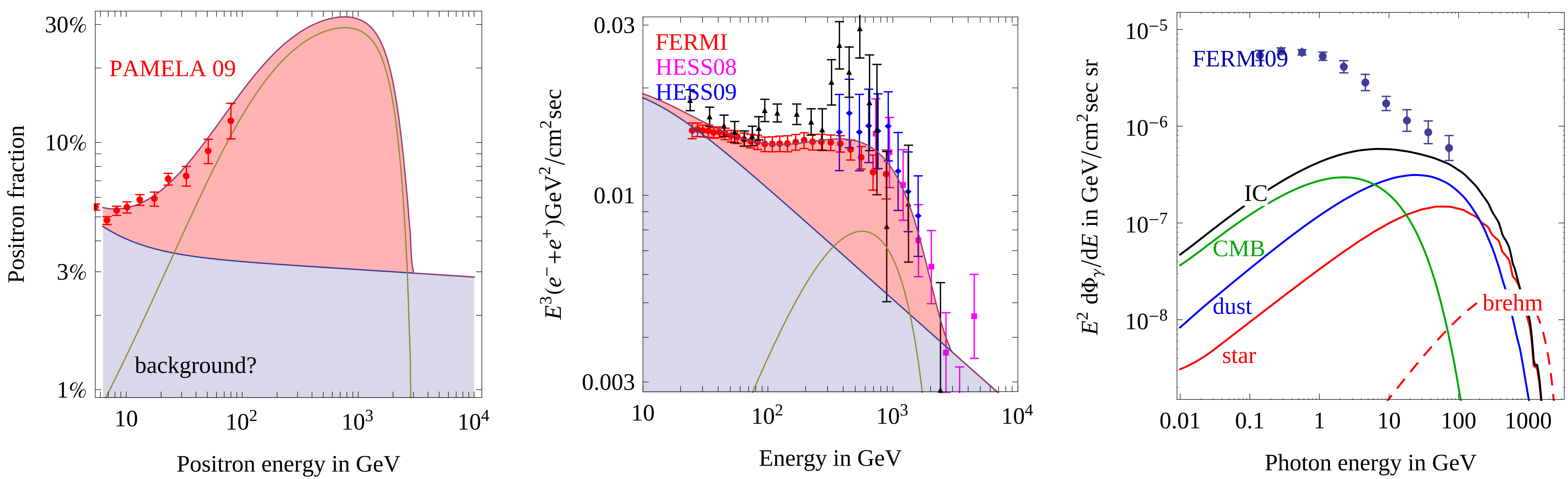




New DM theories

(Neutralinos and standard DM models can hardly fit the $e^\pm$ excesses).
DM is charged under a dark gauge group, to get the Sommerfeld enhancement.
DM annihilates into the new vector. If light, $m \lesssim$ GeV, it can only decay into the lighter leptons. Large $\sigma(\text{DM DM} \to \ell^+\ell^+\ell^-\ell^-)$ obtained.

DM with $M = 3.$ TeV that annihilates into 4μ with $\sigma v = 8.4 \times 10^{-23}$ cm^3/s



Smoother $e^\pm$ spectrum good for FERMI

γ brehmstralung reduced from $\ln M/m_\ell$ to $\ln m/m_\ell$

γ has a mixing θ with the new light vector, giving a σ(DM N) which is too large if elastic or invisible or consistent with DAMA if inelastic thanks to a $\Delta M \gtrsim 100$ keV splitting among Re DM and Im DM induced by the dark higgs.

Sensitivity to θ, m can be best improved by e beam-dump experiments.

3

Bounds from γ, ν indirect detection

Bounds on DM from γ and ν

DM DM $\to \ell^+\ell^-$ is unavoidably accompanied by photons:

- **Bremstrahlung** from $\ell^\pm$ (if $\ell = \tau$ also $\tau \to \pi^0 \to \gamma\gamma$).
  Largest $E_\gamma \sim M$, probed by HESS.

- **Inverse Compton**: $e^\pm\gamma \to e^\pm\gamma'$ scatterings on CMB and star-light: $\dot{E} \propto u_\gamma$.
  Intermediate $E_{\gamma'} \sim E_\gamma(E_e/m_e)^2 \sim 50\,\mathrm{GeV}$ being probed by FERMI.

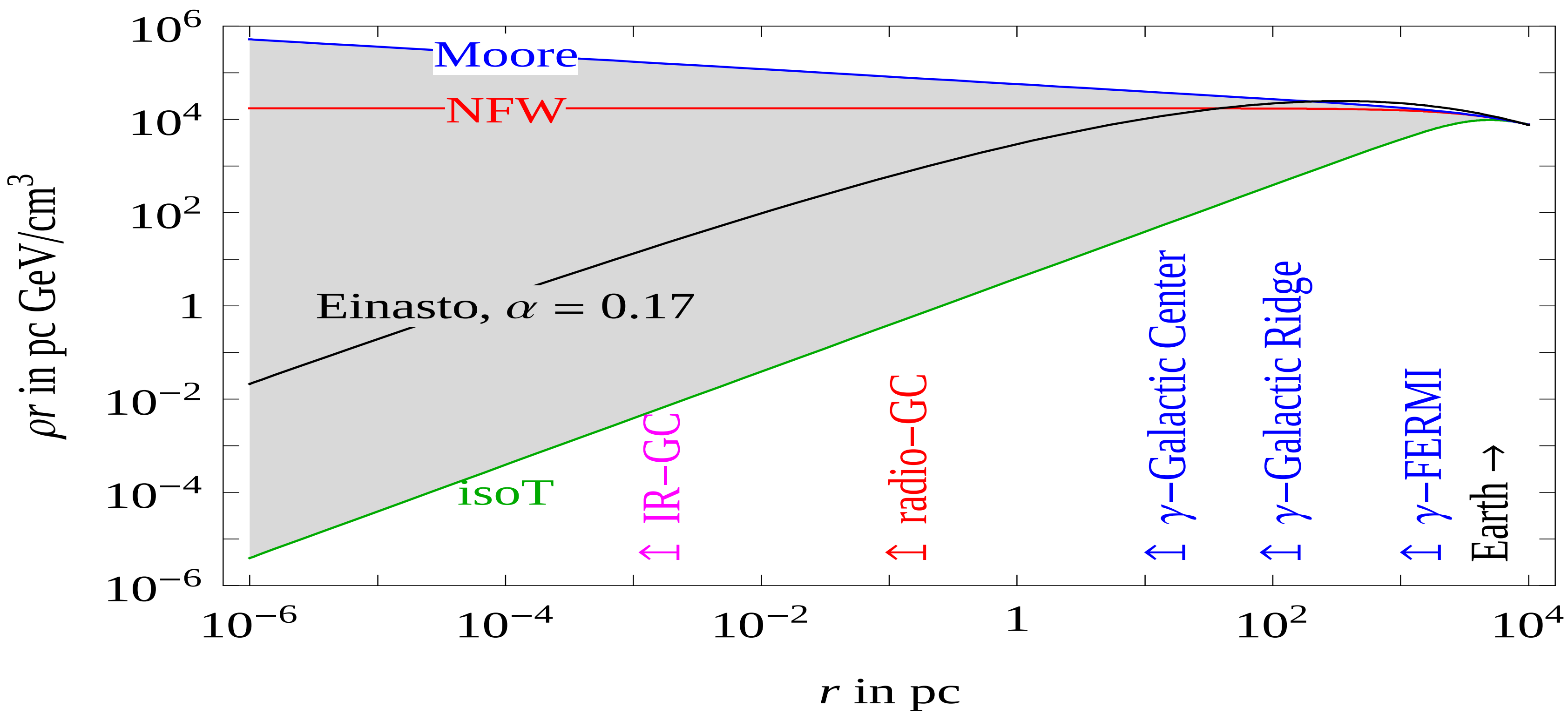
- **Synchrotron**: $e^\pm$ in the galactic magnetic fit: $\dot{E} \propto u_B = B^2/2$.
  Small $E_\gamma \sim 10^{-6}\,\mathrm{eV}$, probed by radio-observations: Davies, VLT, WMAP.

γ from bremstrahlung

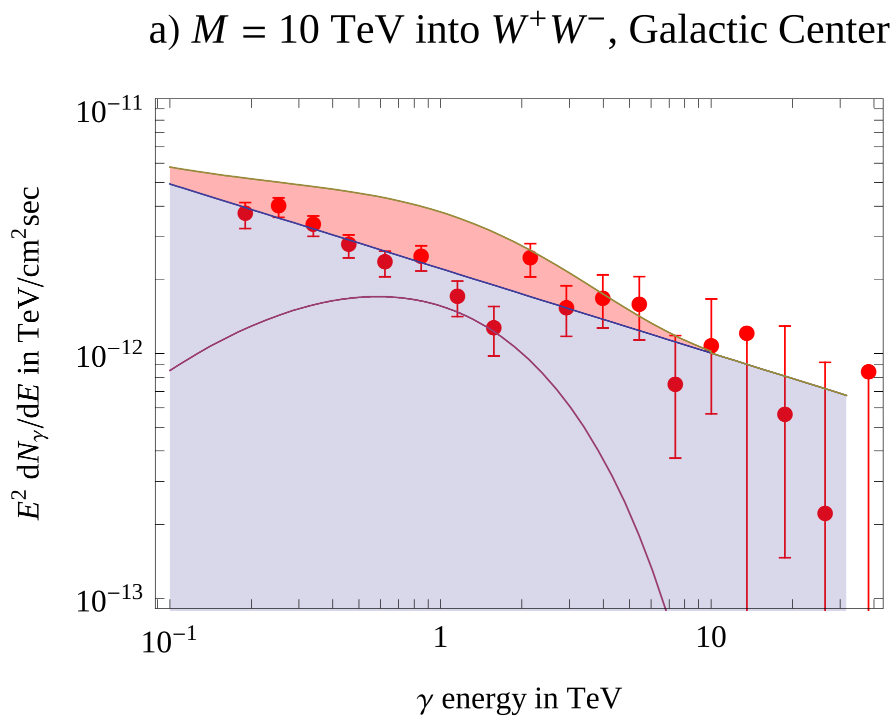
$$\frac{d\Phi_\gamma}{d\Omega\, dE} = \frac{1}{2}\frac{r_\odot}{4\pi}\frac{\rho_\odot^2}{M_{\rm DM}^2} J \langle\sigma v\rangle \frac{dN_\gamma}{dE}, \qquad J = \int_{\rm line-of-sight} \frac{ds}{r_\odot}\left(\frac{\rho(r)}{\rho_\odot}\right)^2$$

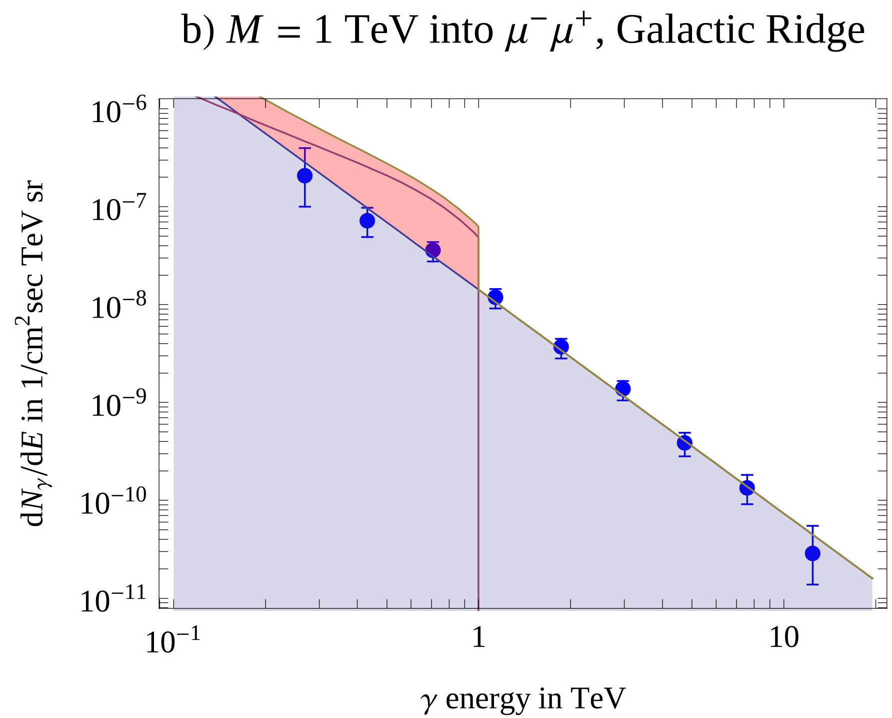
$\langle J\rangle_{\Delta\Omega} =$

NFW	Einasto	isoT	region	$\Delta\Omega$
14700	7600	14	Galactic Center	$1\cdot 10^{-5}$
2400	3000	14	Galactic Ridge	$3\cdot 10^{-4}$



HESS observations





DM signals computed for NFW and $\sigma v = 10^{-23}\,\mathrm{cm}^3/\mathrm{sec}$. We **conservatively** impose that no point is exceeded at 3σ: so the 1st example above is allowed.

Other bounds from DM-dominated dwarf spheroidals around the Milky Way.

Inverse Compton

Galactic $e^{\pm}$ diffuse ($I \neq 1$) while loosing most of their energy as

$$e\gamma \to e'\gamma' \qquad E_{\gamma'} \sim E_\gamma \frac{E_e^2}{m_e^2} \sim 30\,\text{GeV}$$

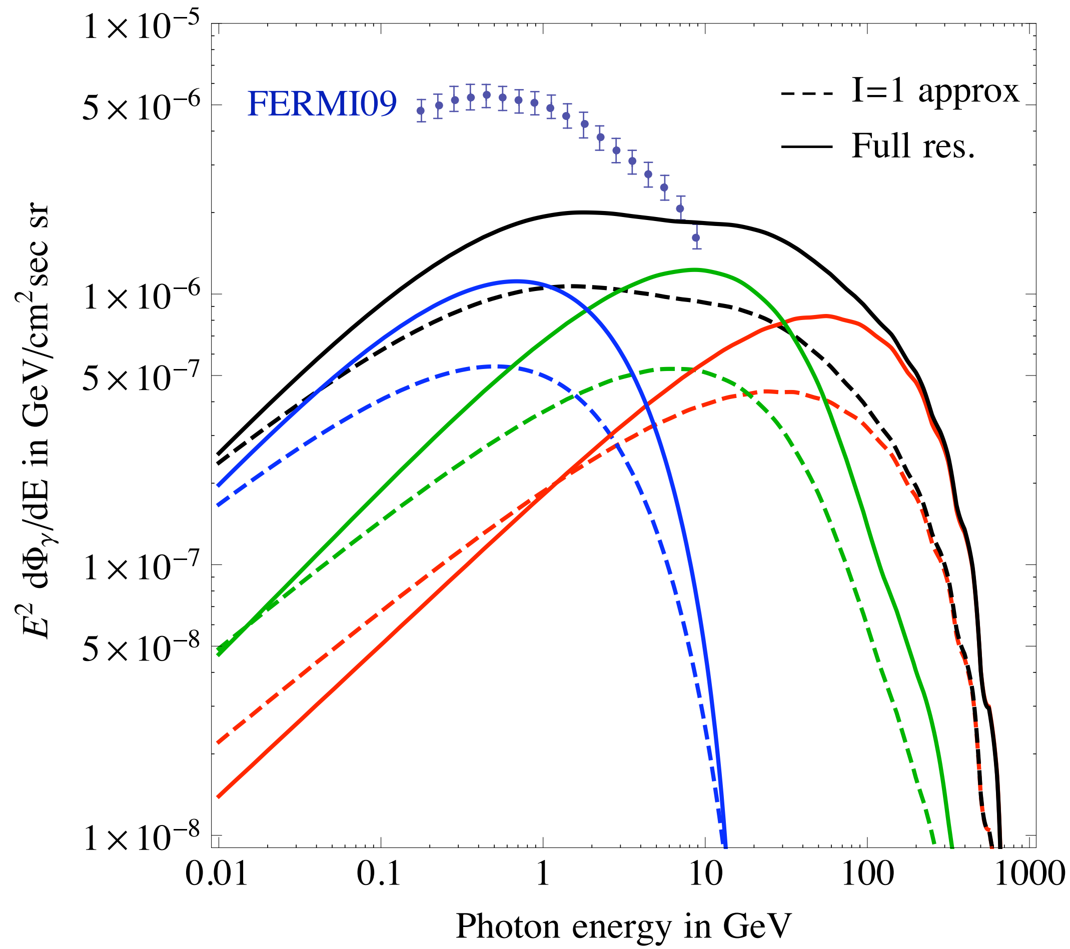
Initial γ:

i) $E_\gamma \sim$ eV from star-light;

ii) $E_\gamma \sim 0.1\,$eV from dust rescattering;

iii) $E_\gamma \sim$ meV from CMB.

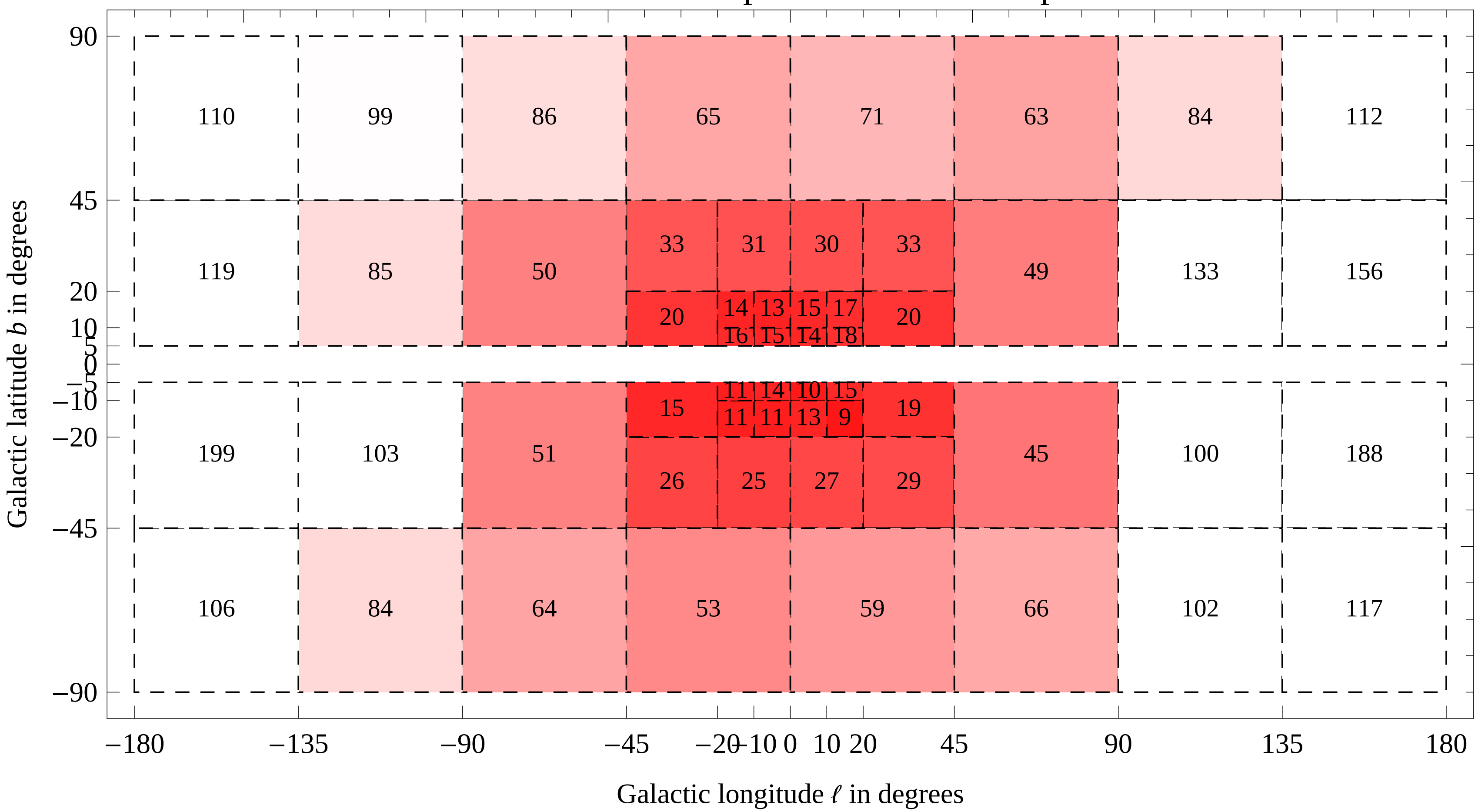
ICγ dominate over FSRγ at FERMI E



FERMI full-sky observations

Point sources and hadron contamination (around 100 GeV) still present. **No clear excess**. Robust bounds imposing DM $<$ exp in all sky and energy regions:

IC bound on $\sigma v(\mathrm{DM\,DM} \to \mu^+\mu^-)$ in $10^{-23}\mathrm{cm}^3/\mathrm{sec}$ for $M = 1.3$ TeV
isothermal DM profile with $L = 4$ kpc



$$\text{global fit: } \chi^2 = \sum_i^{\text{all bins}} \frac{(\Phi_i^{\rm DM} - \Phi_i^{\rm exp})^2}{\delta\Phi^2}\Theta(\Phi_i^{\rm DM} - \Phi_i^{\rm exp}) < 9$$

ν observations

$\overset{(-)}{\nu}_\mu$ scattering in the rock below the detector produce trough-going $\mu^\pm$

$$\Phi_\mu \approx \frac{r_\odot \langle \sigma v\rangle}{8\pi}\frac{\rho_\odot^2}{M^2}\frac{3G_F^2 M^2 p}{\pi\alpha_\mu}\cdot J\cdot\Delta\Omega\cdot\int_0^1 dx\ x^2\frac{dN_\nu}{dx}$$

where $p \sim 0.125$ is the momentum fraction carried by each quark in the nucleon and $\alpha_\mu = 0.24\,\mathrm{TeV/kmwe} = -dE/d\ell$ is the $\mu^\pm$ energy loss.

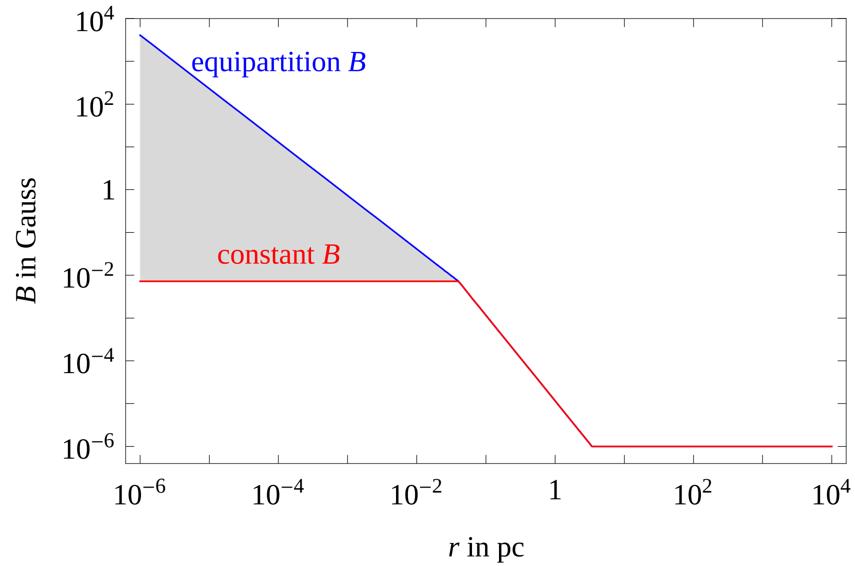
The total $\mu^\pm$ rate negligibly depends on the DM mass M.

SuperKamiokande got the dominant bounds in cones up to 30° around the GC

$$\Phi_\mu < 0.02/\mathrm{cm}^2\mathrm{s}$$

Radio observations

Around the GC magnetic fields B contain more energy than light, diffusion and advection seem negligible, so all the $e^{\pm}$ energy E goes into synchrotron radiation. The unknown B only determines the maximal $\nu_{\rm syn}$:



$$\frac{dW_{\rm syn}}{d\nu} \approx \frac{2e^3 B}{3m_e}\delta(\frac{\nu}{\nu_{\rm syn}} - 1) \qquad \text{where} \qquad \nu_{\rm syn} = \frac{eBE^2}{4\pi m_e^3} = 1.4\,\text{MHz}\frac{B}{\text{G}}\left(\frac{p}{m_e}\right)^2.$$

Davies 1976 oservations at the lower $\nu = 0.408\,\text{GHz}$ give the robust and dominant bound as the observed GC radio-spectrum is harder than synchrotron:

$$\nu\frac{dW_{\rm syn}}{d\nu} = \frac{\sigma v}{2M^2}\int_{4'' \text{ cone}} dV\ \rho^2\ E(\nu)\ N_e(E(\nu)) < 4\pi r_\odot^2 \times 2\cdot 10^{-16}\,\frac{\text{erg}}{\text{cm}^2\,\text{s}}$$

BIG uncertainty in the DM density ρ at 1pc from the GC: NFW or ...?

Bounds from cosmology

DM annihilation rate $\propto \rho^2$ is enhanced in the early universe: its products can

1. affect BBN at $T \sim$ MeV fragmenting ^{4}He, D, ^{3}He...
   Primordial abundances are not safely known.

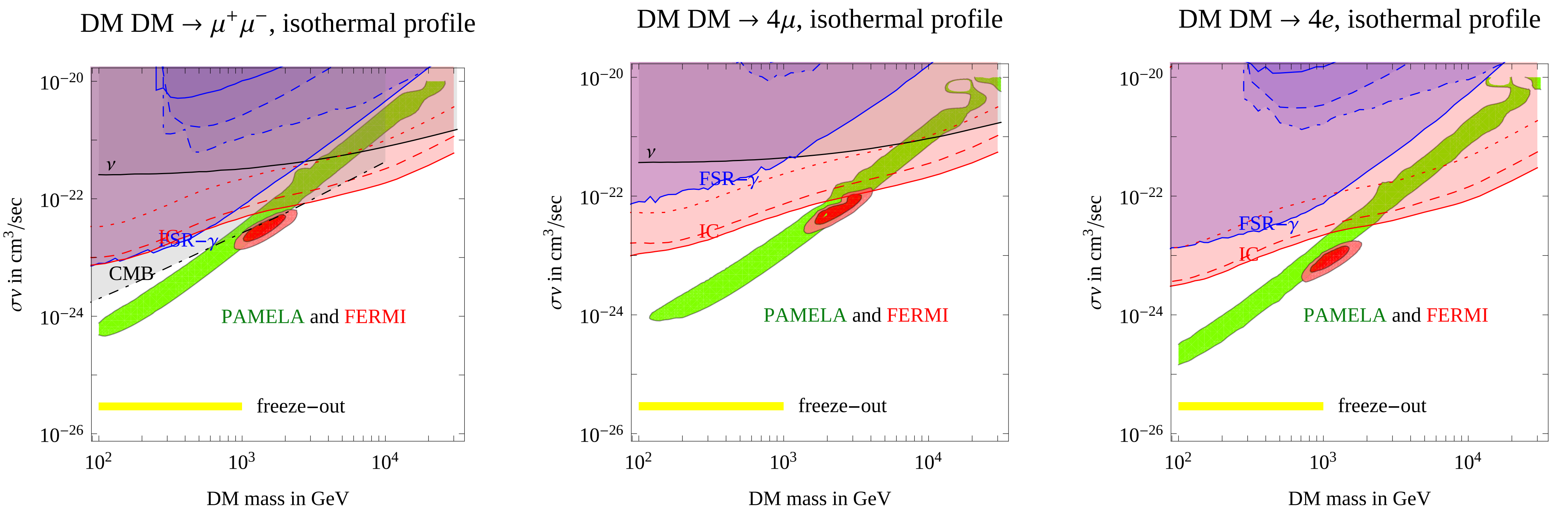
2. affect CMB reionizing H after matter/radiation decoupling, $z \lesssim 1000$.
   $13.6\,\mathrm{eV} \times n_e \ll u_\gamma$ ionizes all H changing CMB anisotropies

3. heat gas after structure formation $z \sim 10$.
   Depends on unknown non-linear small-scale DM clustering.

1, 2 and 3 give comparable constraints at the PAMELA-level, $\sigma v \sim 10^{-23}\,\mathrm{cm}^3/\mathrm{sec}$.
2 is stronger and robust and can be improved by PLANCK.

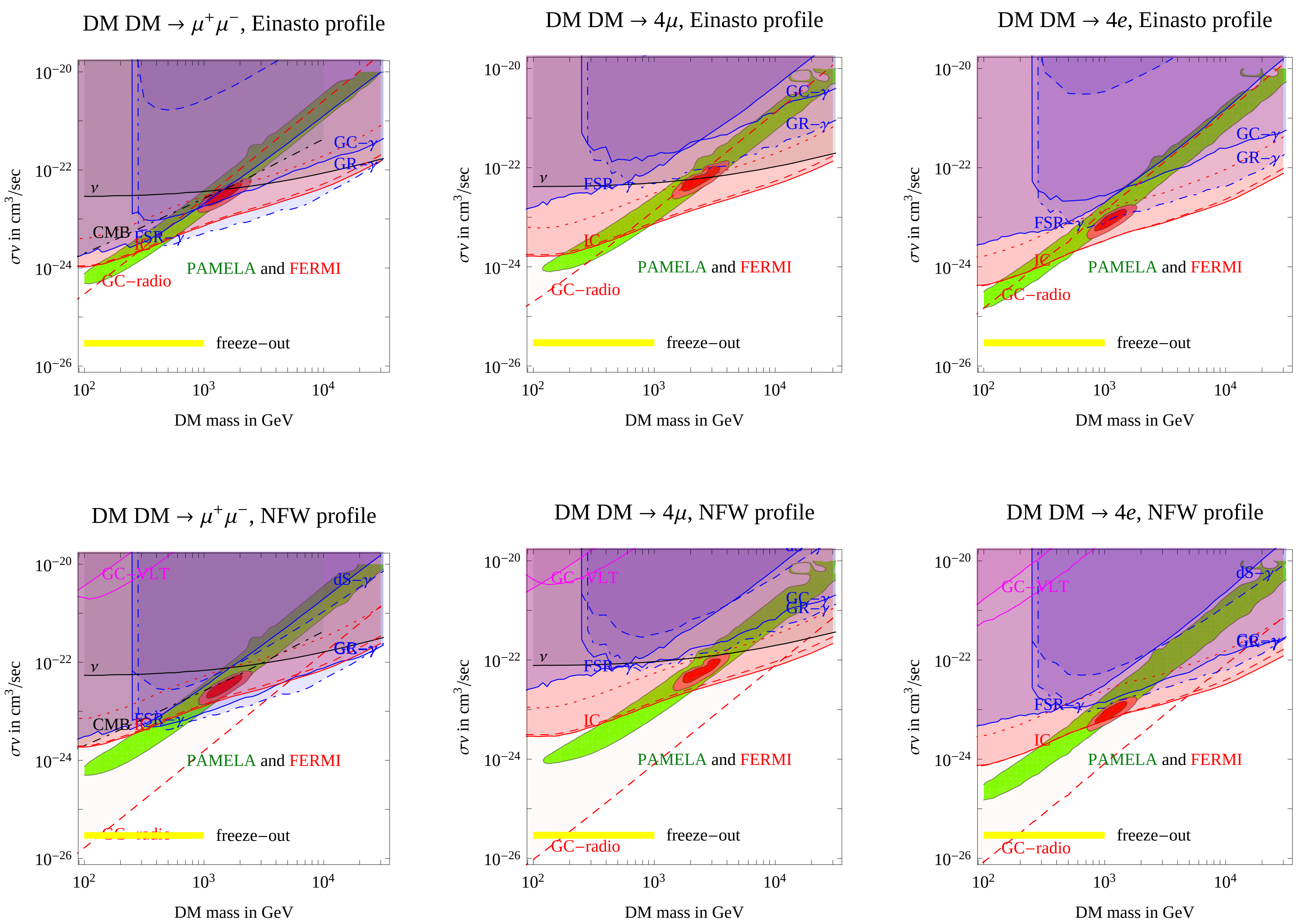
$e^{\pm}$ signals vs bounds

All at 3σ: region allowed by PAMELA e^+ and FERMI $e^+ + e^-$ vs bounds on: • FSR-γ from FERMI full sky, HESS Galactic Center, Ridge, Dwarf Spheroidals; • IC$-\gamma$ for $L = 4, 2, 1$ kpc; • CMB; • ν; • radio observations of the GC



$e^{\pm}$ excesses can be DM DM $\to 2\mu, 4\mu, 4e$ if ρ is isothermal

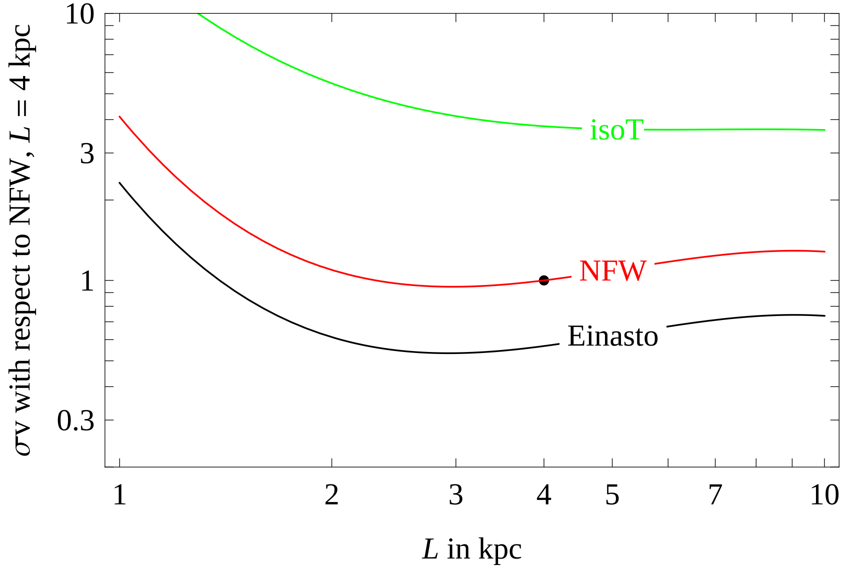
not if Einasto or NFW



The problem is no longer only at small scales not tested by N-body simulations

Caveats

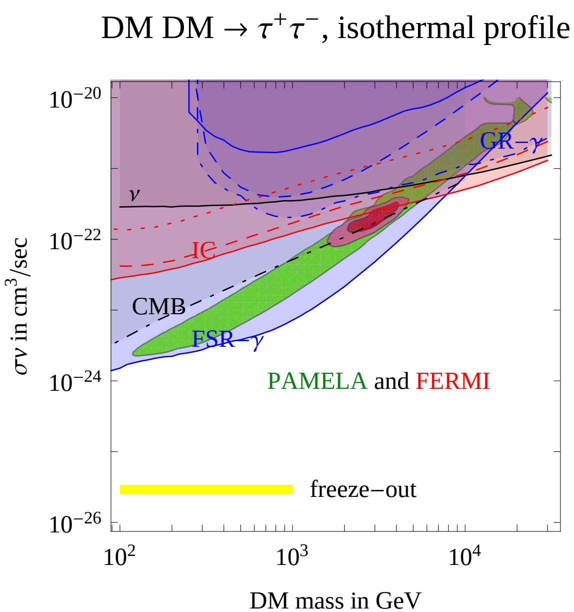
$L = 1$ kpc at the GC (ok?) would relax NFW or Einasto down to isoT: DM annihilations outside the diffusion volume contribute to FSR, but not to IC:

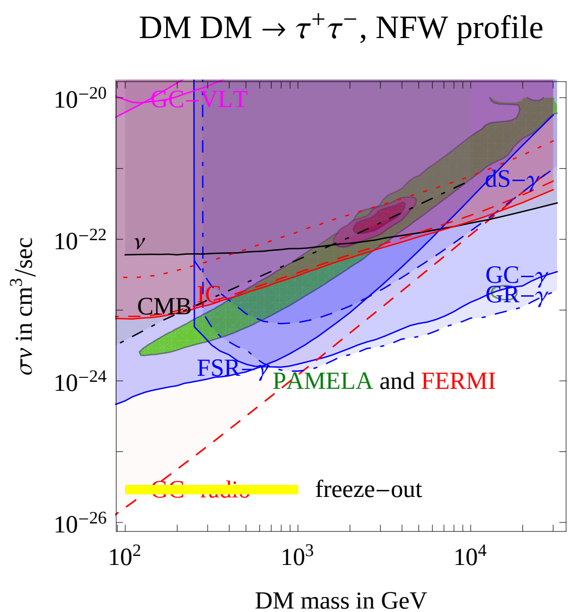


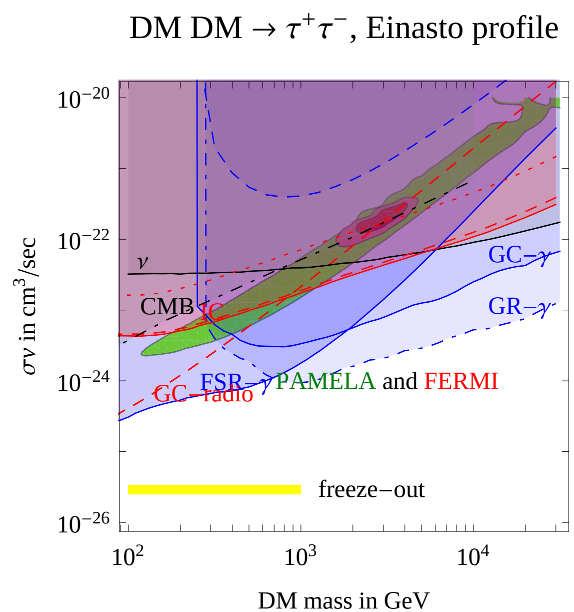
Disavored by a) global fits of charged CR; b) abundances of CR with $\tau \sim \tau_{\text{diff}}$; c) FERMI sees γ away from the GC. d) realistic smooth growth of $K(z)$.

Can synchrotron dominate over IC? Only around the GC.

not if τ channels



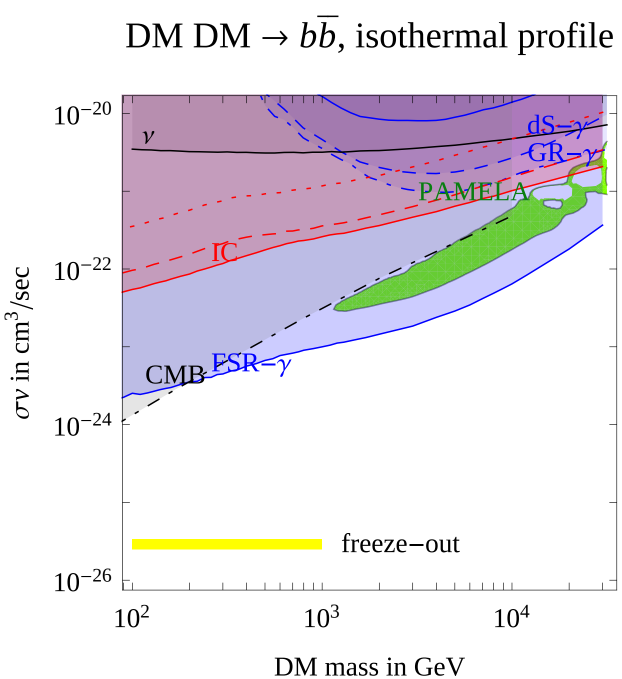


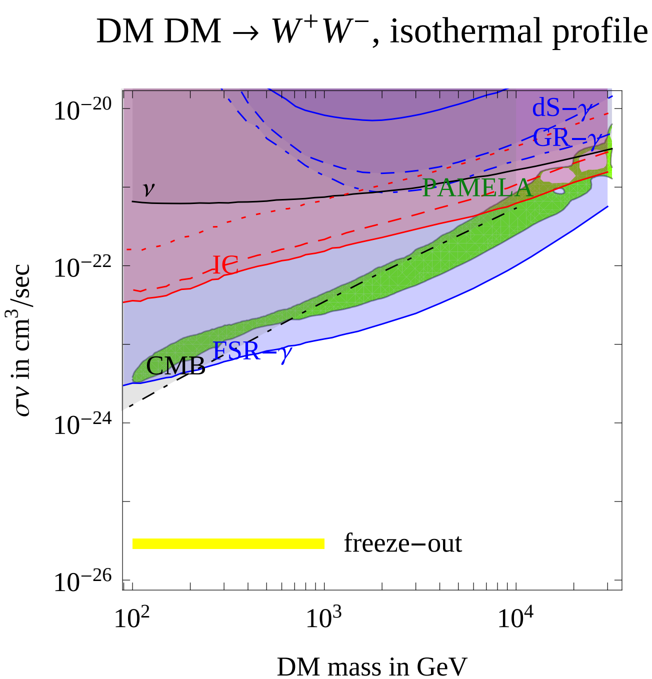


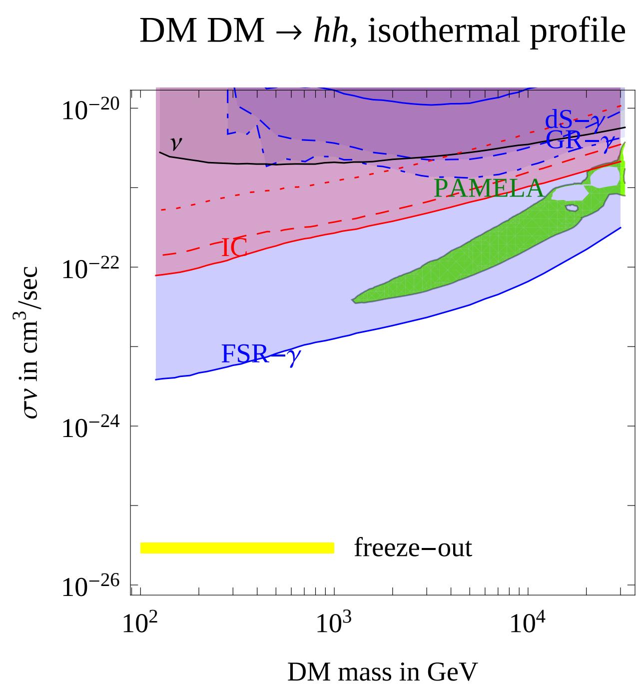
Too many $\tau \to \pi^0 \to \gamma$: FSR direct exclusion for any reasonable profile.

not if non-leptonic channels

Non-leptonic channels give many FSR$-\gamma$ and can at most be subdominant:







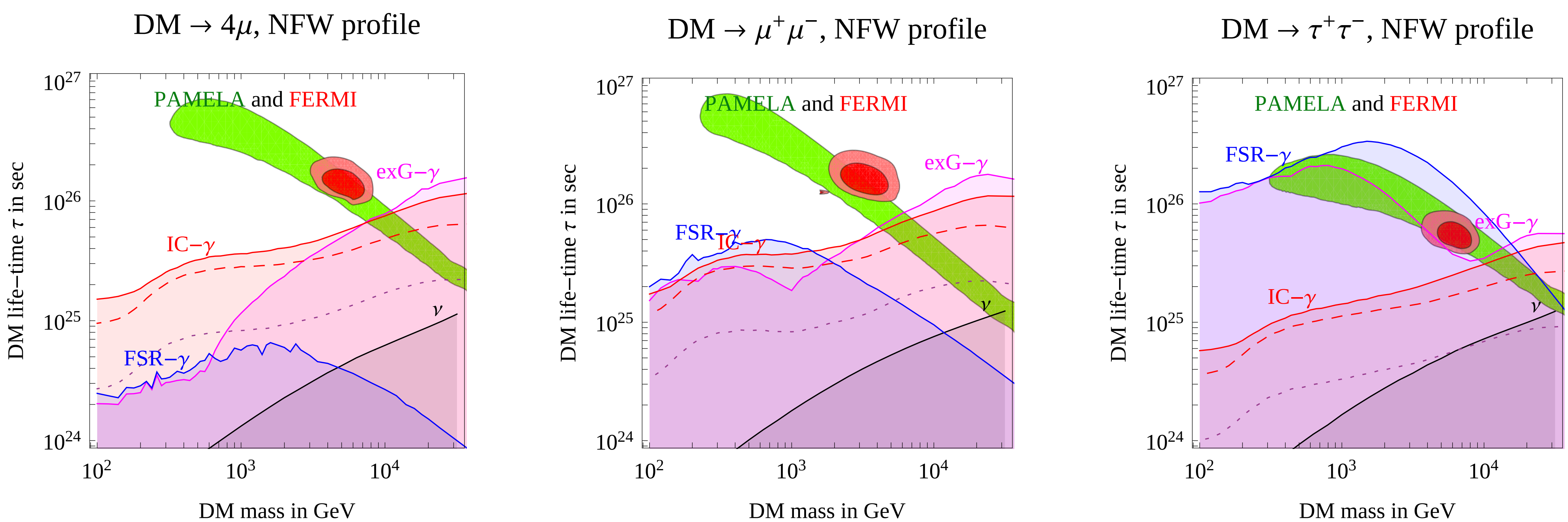
The SUSY wino or Minimal Dark Matter no longer can fit PAMELA .

4

DM decays

DM decays are compatible with NFW

If instead DM **decays** with life-time τ, replace $\rho^2 \sigma v / 2M^2 \to \rho^1 / M\tau$:



With DM decay PAMELA/FERMI are allowed for all DM density profiles

DM decays are compatible with cosmology

Weak bounds from BBN and CMB, again due to $\rho^{2}(t) \to \rho^{1}(t)$.

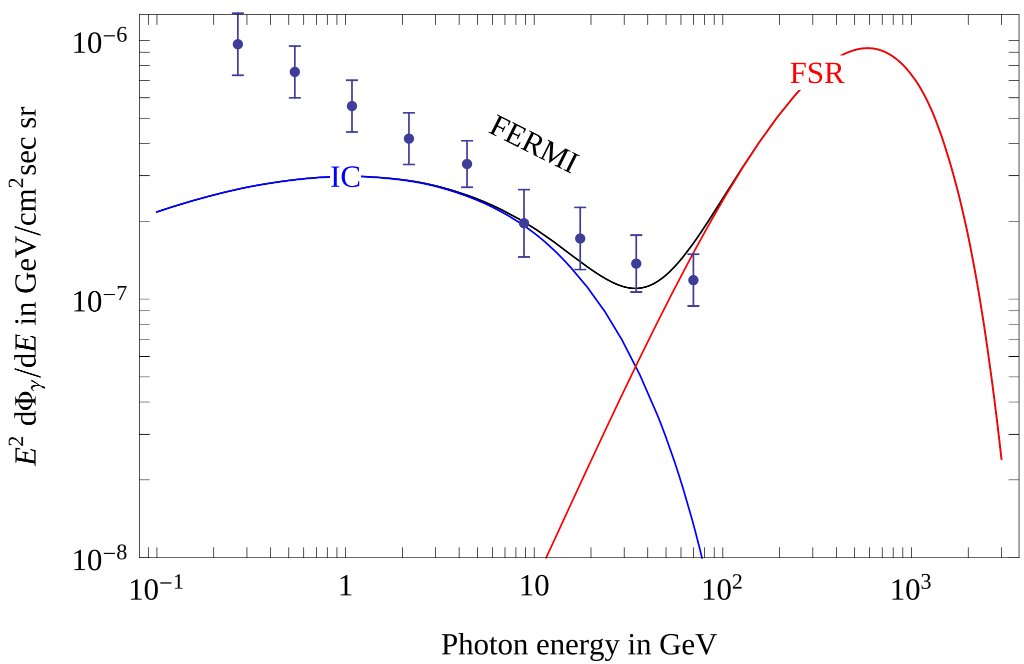
The extra-galactic γ flux is significant:

$$\frac{\Phi_{\rm cosmo}}{\Phi_{\rm galactic}} \sim \frac{\rho_{\rm cosmo} R_{\rm cosmo}}{\rho_\odot R_\odot} \sim 1$$

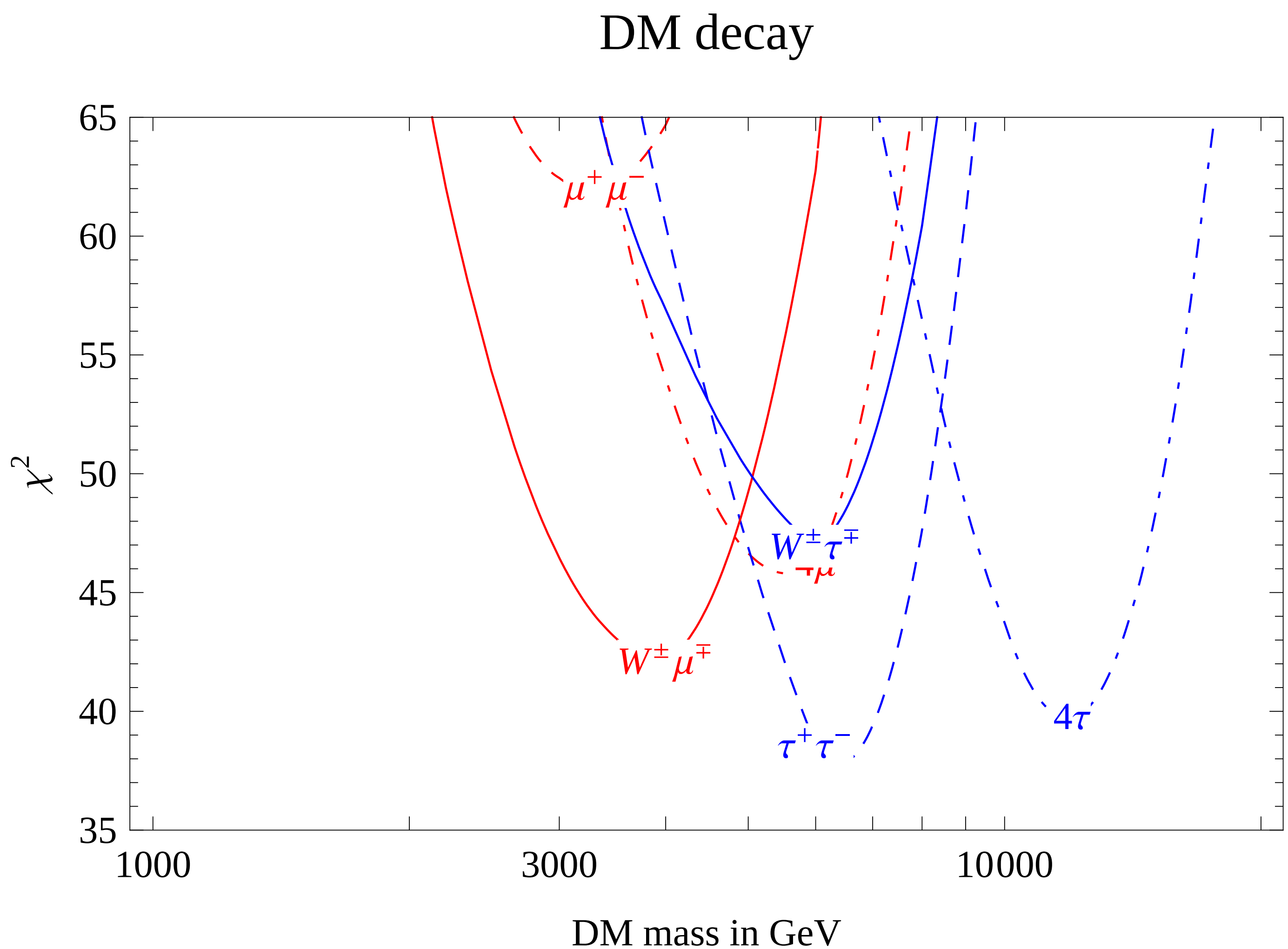
and can be computed reliably: no dependence on small-scale DM clustering.

The 'exG-γ' bound on FSR+IC is competitive, helped by FERMI who already extracted (?) the diffuse γ flux, a few times below the less bright sky.

DM $\to \tau^+\tau^-$ with M = 6. TeV and $\tau = 5.4 \times 10^{25}$ sec



PAMELA and FERMI as DM decay



$e^{\pm}$ excesses suggest SU(2) technicolor!?

DM decays suggests $M \sim$ few TeV, which naturally implies the observed

$$5 \sim \frac{\rho_{\rm DM}}{\rho_b} \sim \frac{M}{m_p}\left(\frac{M}{T_{\rm dec}}\right)^{3/2} e^{-M/T_{\rm dec}}$$

if the DM density is due to a baryon-like asymmetry kept in thermal equilibrium by weak sphalerons down to $T_{\rm dec} \sim 200\,\rm GeV$.

Possible if DM is a chiral fermion or is made of chiral fermions.
The DM mass is $M \sim \lambda v \sim 2\,\rm TeV$ for $\lambda \sim 4\pi$: strong dynamics a-la technicolor.
GUT-suppressed dimension 6 4-fermion operators give $\tau \sim M_{\rm GUT}^4/M^5 \sim 10^{26}\,\rm s$.
If the technicolor group is SU(2) with techni-q $\mathcal{Q} = (2,0)$ under $\mathrm{SU}(2)_L \otimes \mathrm{U}(1)_Y$

- DM is a $\mathcal{Q}\mathcal{Q}$ bound state, scalar and SU(2)-singlet as suggested by data.

- A 4-fermion $\mathcal{Q}\mathcal{Q}\bar{L}L$ operator allows a slow DM $\to \ell^+\ell^-$: no $\Pi \simeq W_L$ involved.

- Usual problems of technicolor: minimal correction to the S parameter...

Conclusions

The PAMELA, FERMI-ATIC, HESS $e^{\pm}$ excesses attracted most attention. They could be due to astrophysics or to unexpected DM as follows:

× $2e$ channel gave the ATIC peak, not the FERMI $e^+ + e^-$ excess.

× τ channels give too much γ.

× W, Z, q, b, h, t channels can only fit PAMELA e^+ and give too much γ.

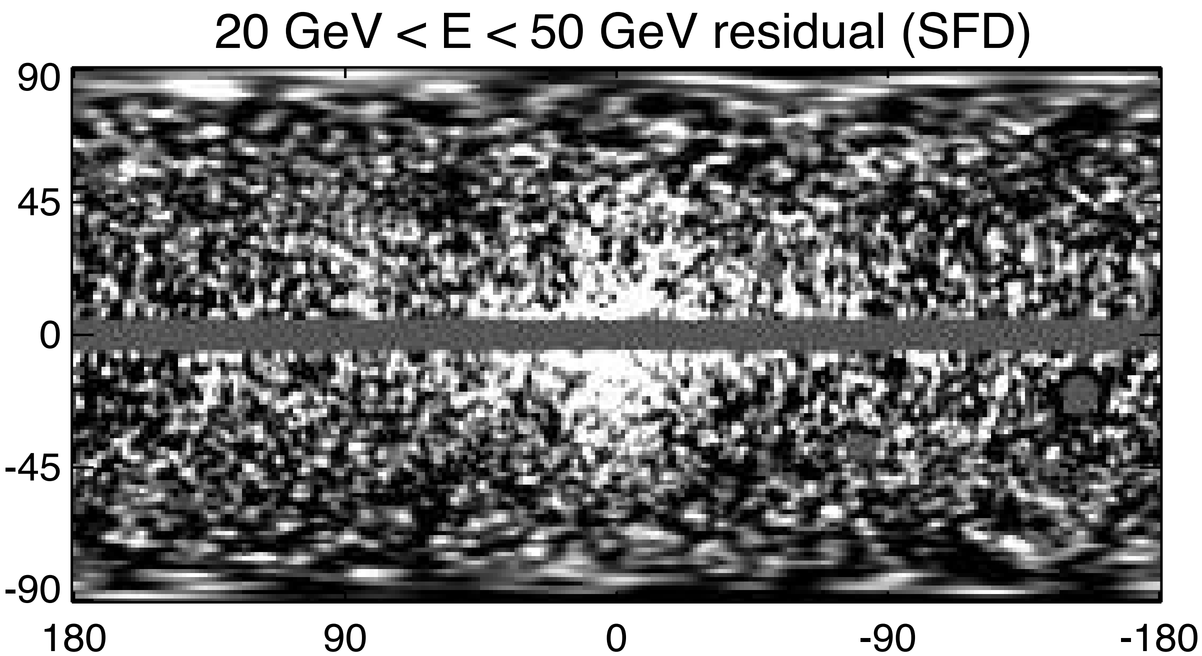
- 3 TeV DM that annihilates in $2\mu, 4\mu, 4e$. But only if the injection term is quasi constant: i) Isothermal profile; ii) DM decays.

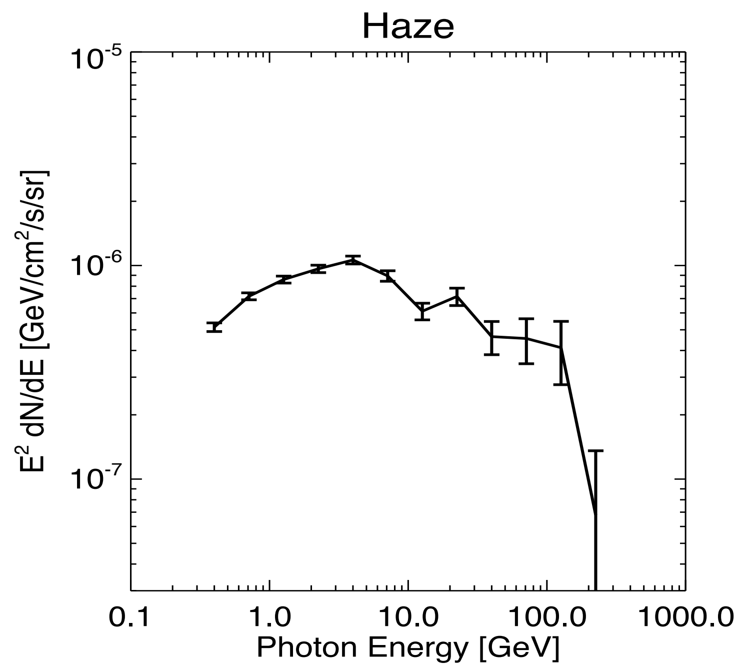
DM predicts that the e^+ fraction must grow. DM IC-γ must be in FERMI sky.

Next: FERMI, PAMELA, AMS, PLANCK

The FERMI haze?

Some theorists claim they see a quasi-spherical 'FERMI haze' excess:





FERMIons suggest the haze is due to Loop I (a SN remnant close to us)