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, GGI, March 23, 2010

Indirect signals of Dark Matter

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

The galactic DM density profile

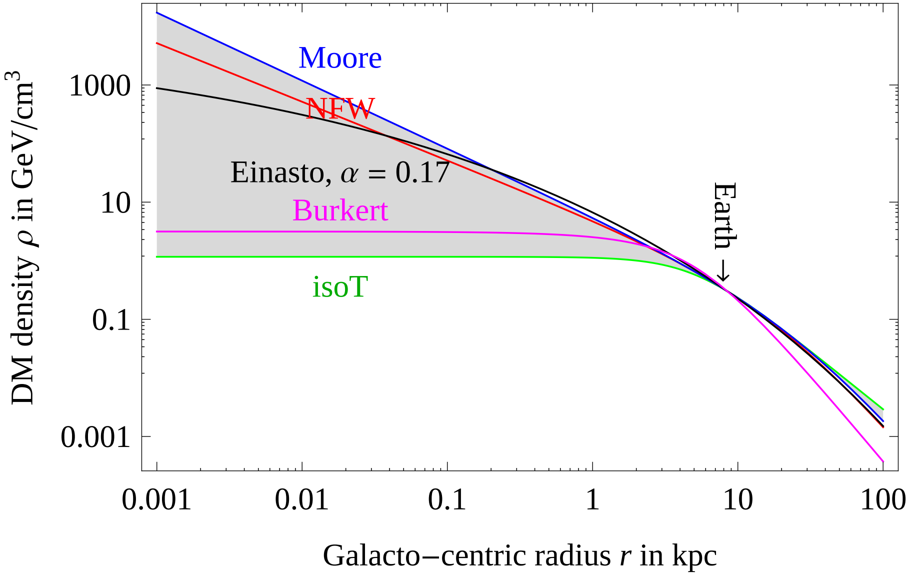
DM velocity: $\beta \approx 10^{-3}$. DM is spherically distributed with uncertain profile:

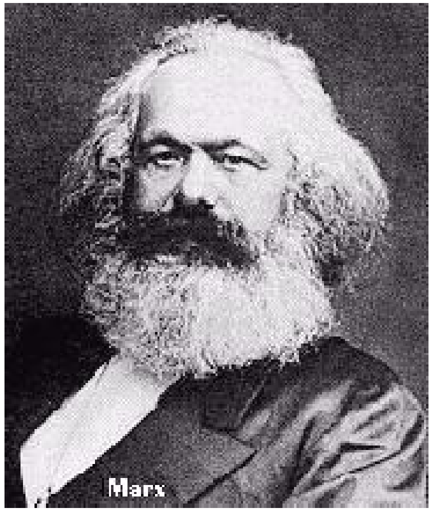
$$\rho(r) = \rho_\odot \left[\frac{r_\odot}{r}\right]^\gamma \left[\frac{1 + (r_\odot/r_s)^\alpha}{1 + (r/r_s)^\alpha}\right]^{(\beta-\gamma)/\alpha}$$

$r_\odot = 8.5\,\mathrm{kpc}$ 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

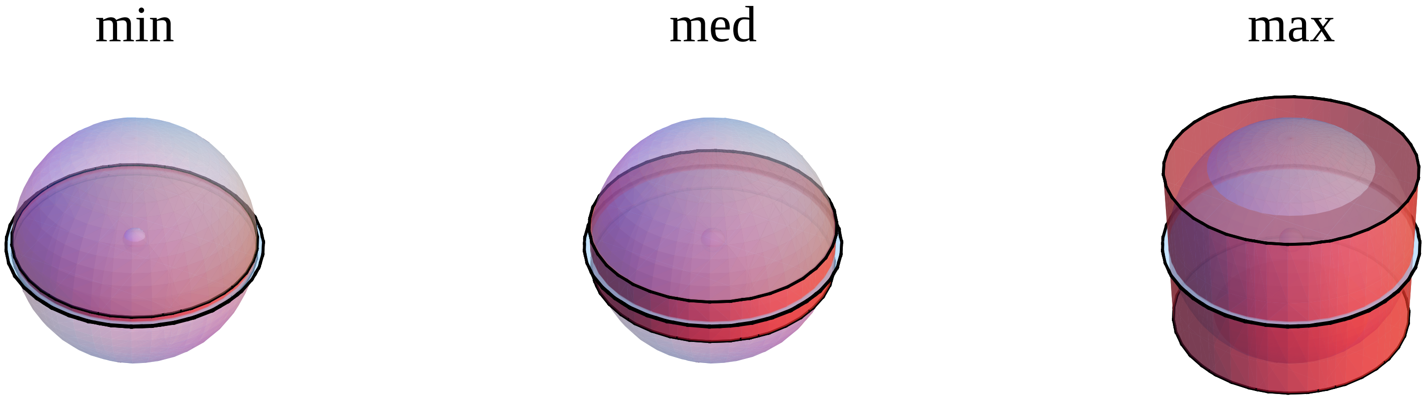
Simulations neglect normal matter, that locally is comparable to DM.

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: $K(E) = K_0(E/\,\mathrm{GeV})^{\delta} \sim R_{\mathrm{Larmor}} = E/eB$.
- **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 $R = 20\,\mathrm{kpc}$ 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 $\bar{p}$.

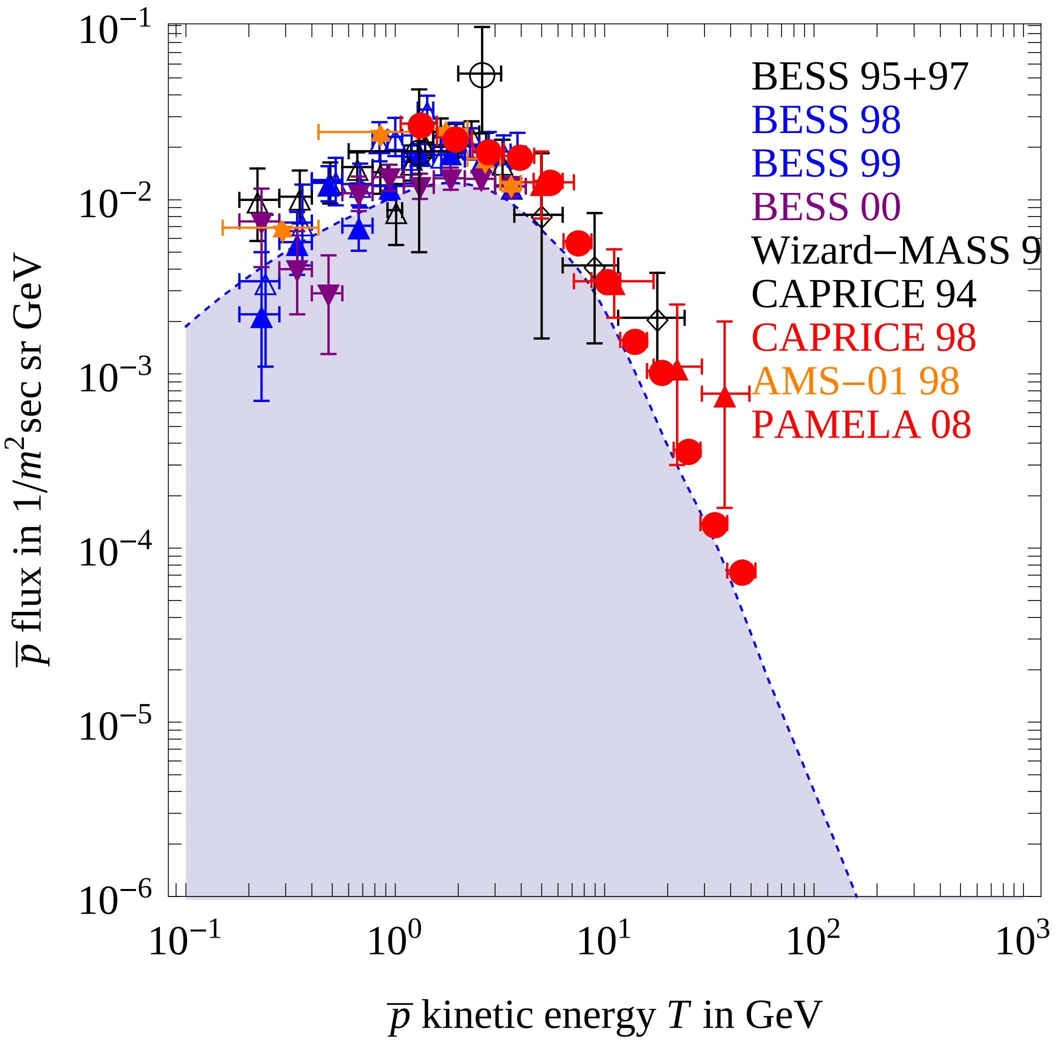
Experimentalists need to bring above the atmosphere (with balloons or satellites) a spectrometer and/or calorimeter, able of rejecting e^- and p.

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

Energy spectra below a few GeV are ∼useless, because affected by solar activity.

$\bar{p}/p$: PAMELA

Consistent with background



Future: PAMELA, AMS

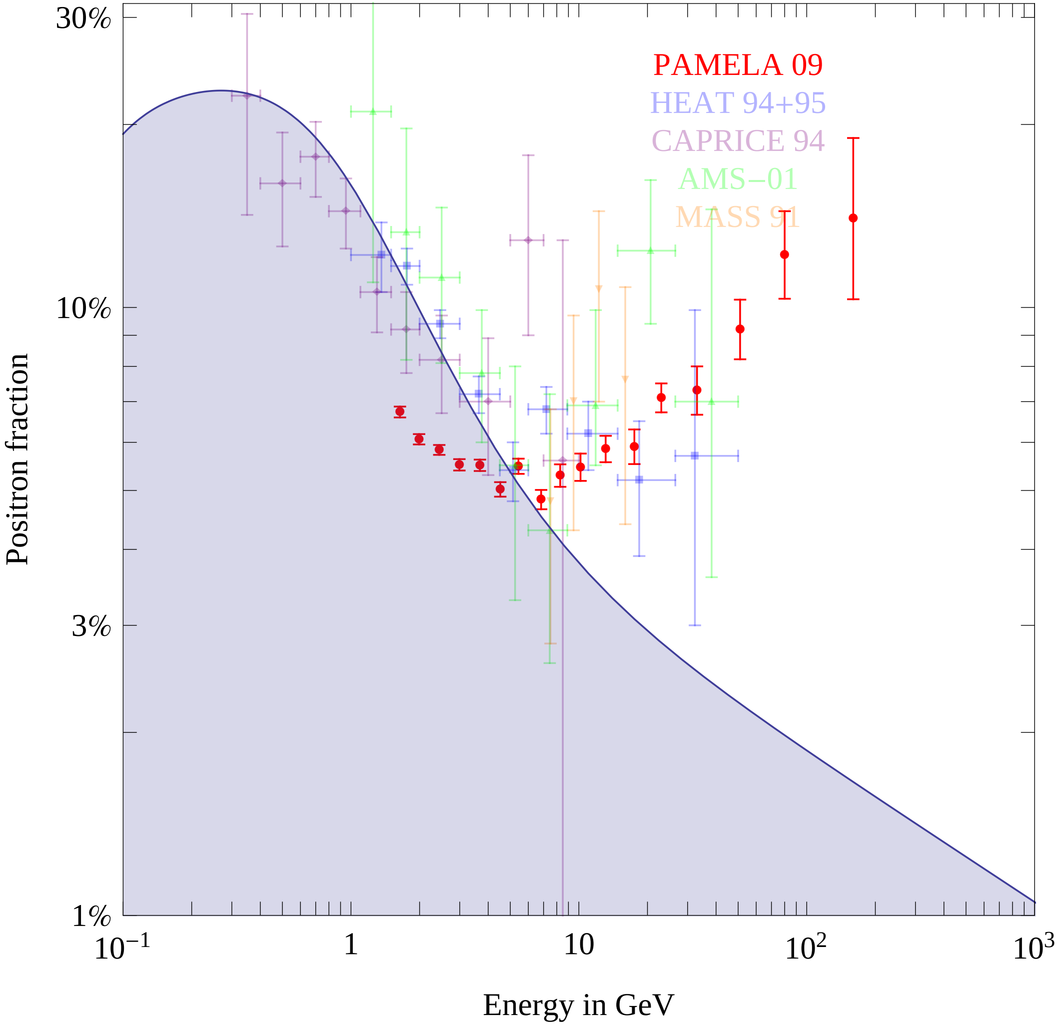
$e^+/(e^+ + e^-)$: PAMELA

PAMELA is a spectrometer + calorimeter sent to space. It can discriminate $e^+, e^-, p, \bar{p}, \ldots$ and measure E up to ∼200 GeV.

e^- are primaries and e^+ secondaries, so e^+/e^- decreases as the containment time $\tau \sim E^{-\delta}$.

Spectra below 10 GeV distorted by the present solar polarity.

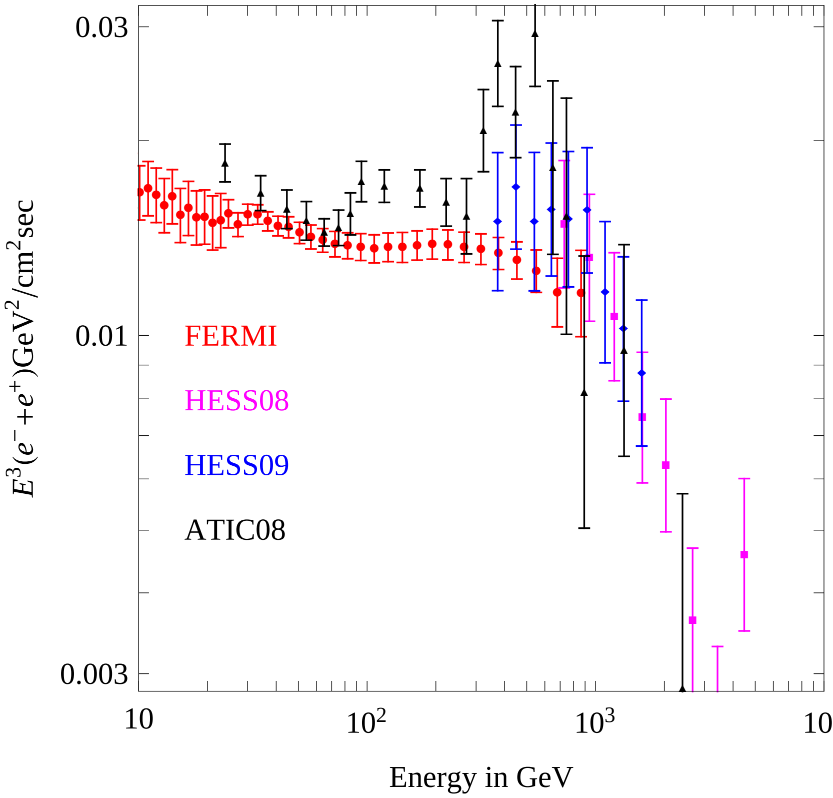
Growing excess above 10 GeV



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 astrophysics?

1) Maybe secondaries are produced in the acceleration region: then e^+/e^- can grow with E, but also $\bar{p}/p$, B/C, Ti/Fe...

2) A pulsar is a neutron star with a rotating intense magnetic field. The resulting electric field ionizes and accelerates $e^- \to \gamma \to e^+e^-$, 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 $\mathscr{D} F_{\mu\nu}^2$ 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 $M \gg M_W$.

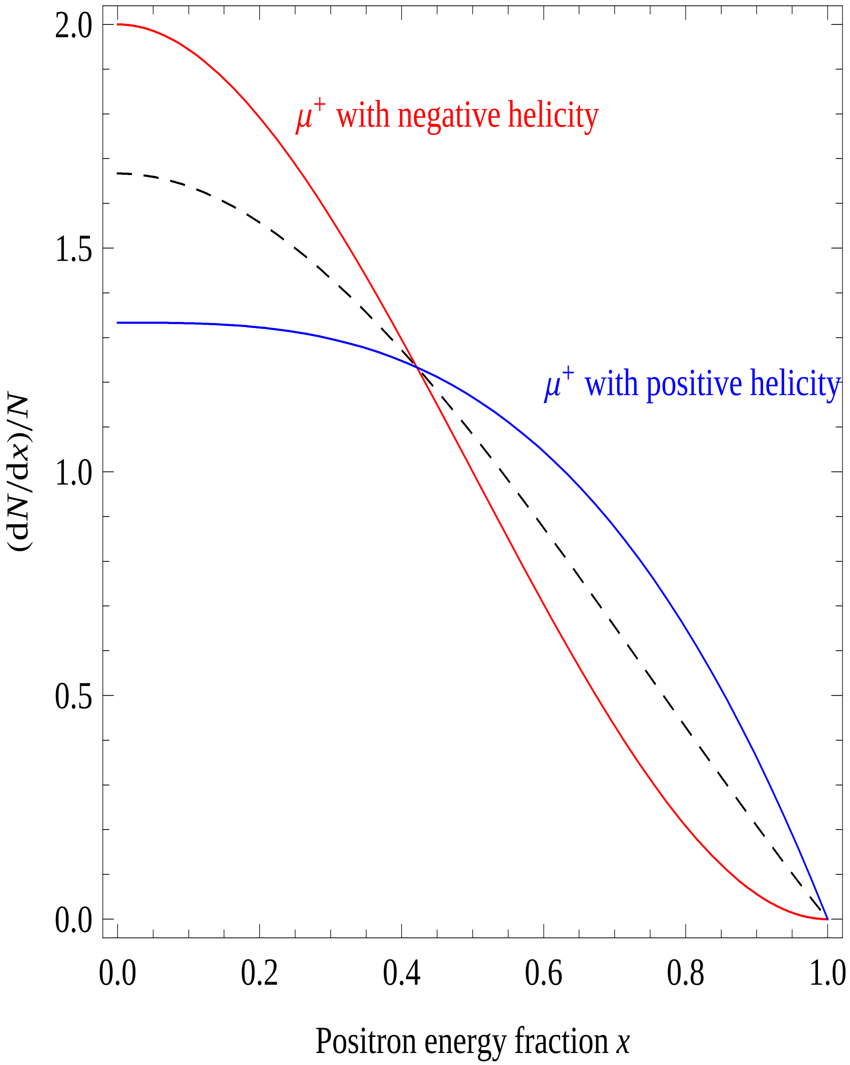
- Vector $\mathscr{D}_\mu$ can couple as

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

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

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

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

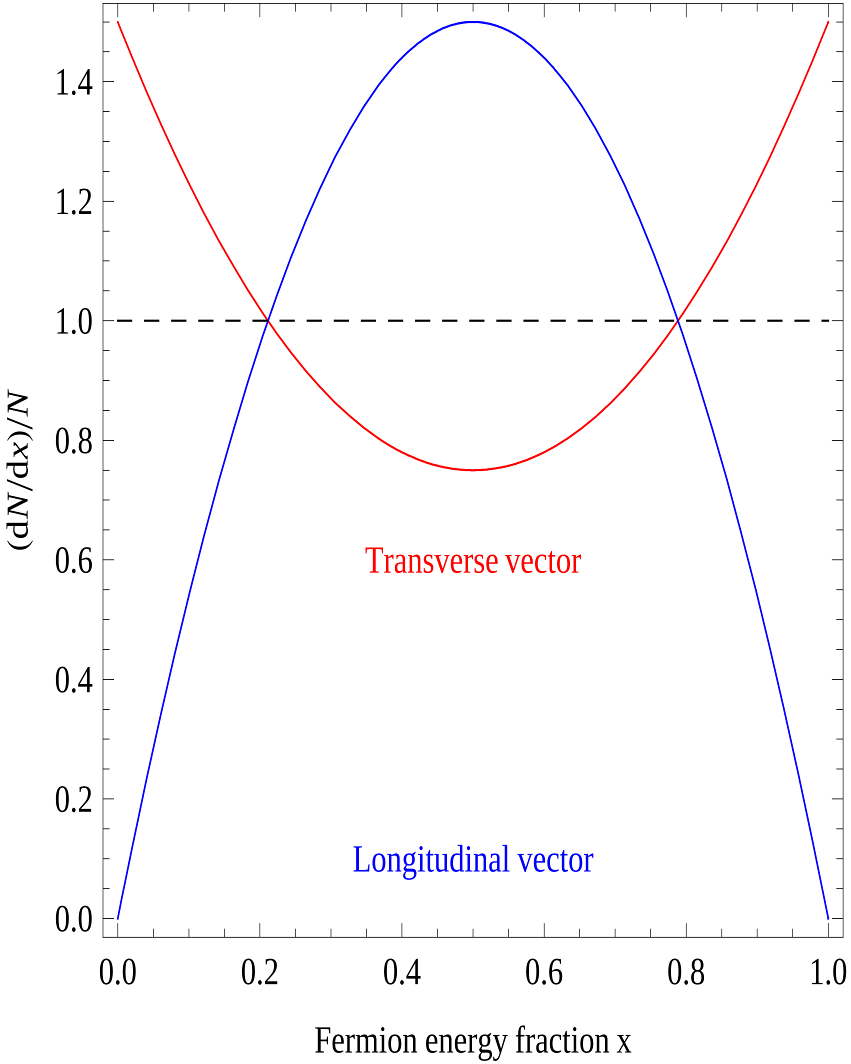
$$dN/d\cos\theta = 3(1+\cos^2\theta)/8$$

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

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

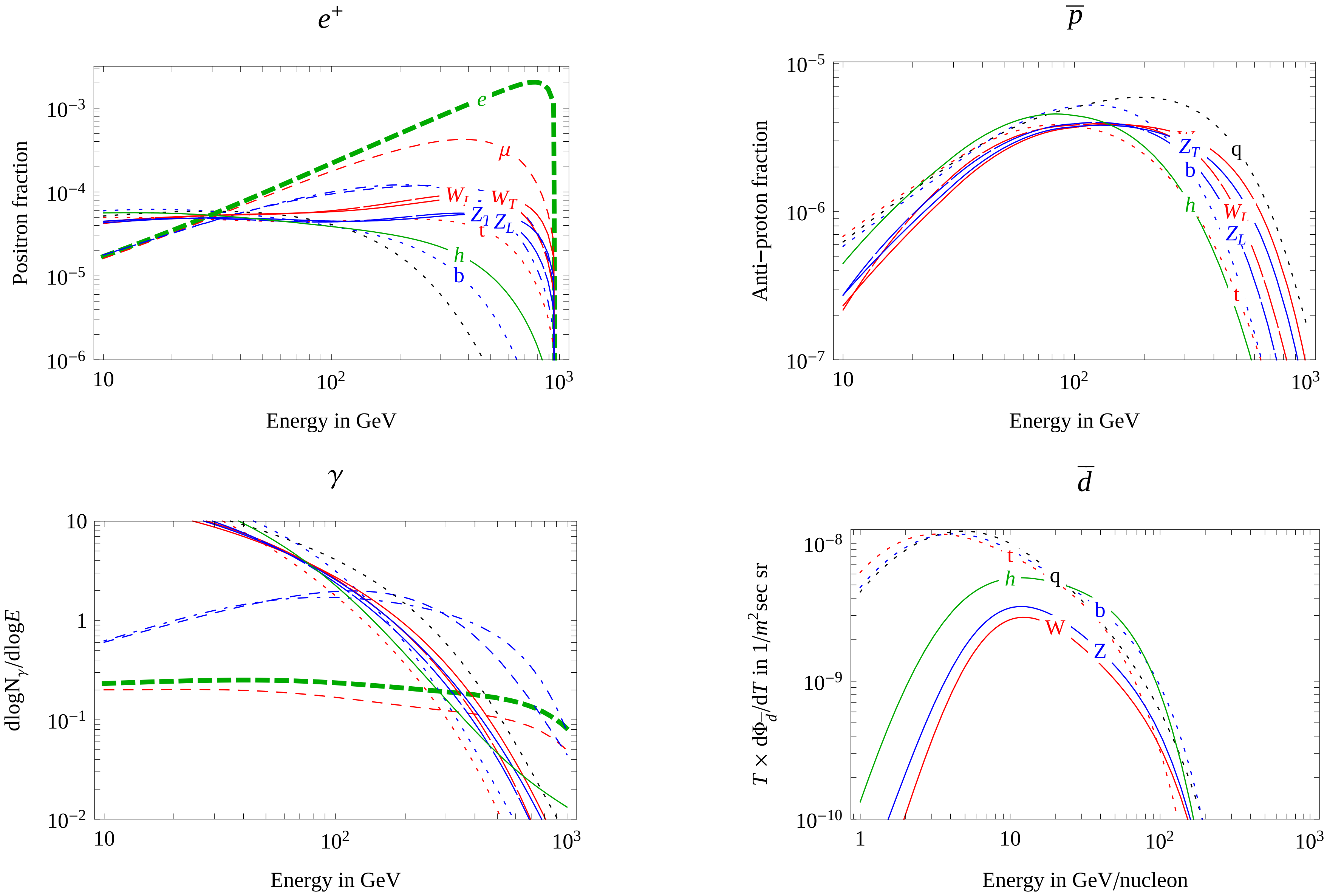
$$dN/d\cos\theta = 3(1-\cos^2\theta)/4$$

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



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.



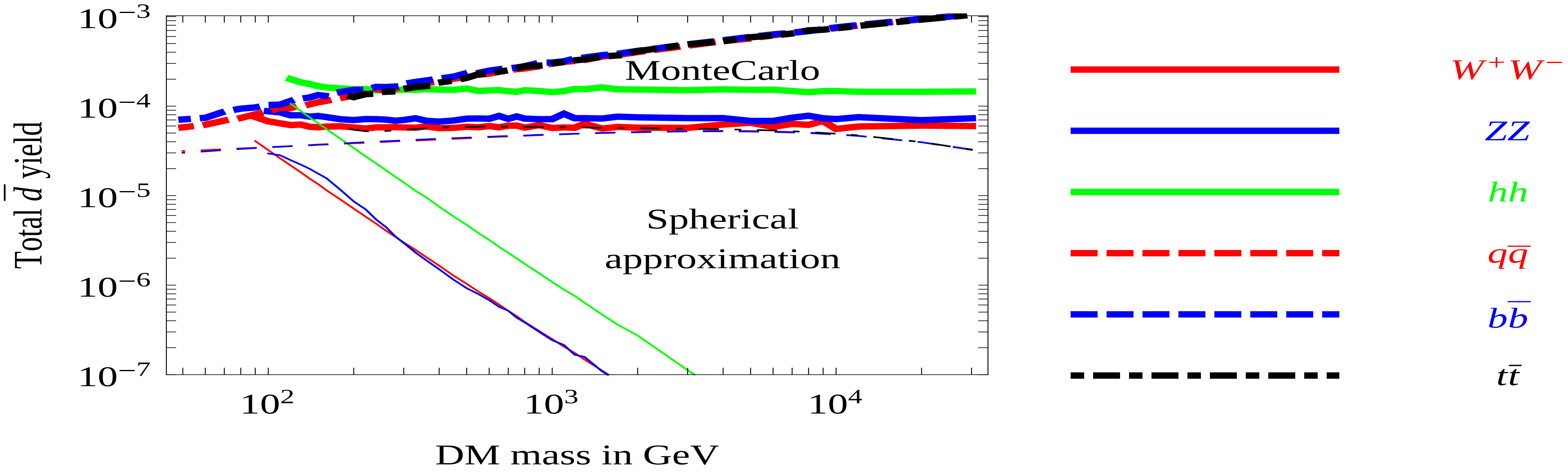
Annihilations into leptons give qualitatively different energy spectra.

Anti-deuterium

$\bar{d}$ forms when DM produces a $\bar{p}$ and a $\bar{n}$ with momentum difference below $p_0 \approx 160\,$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:



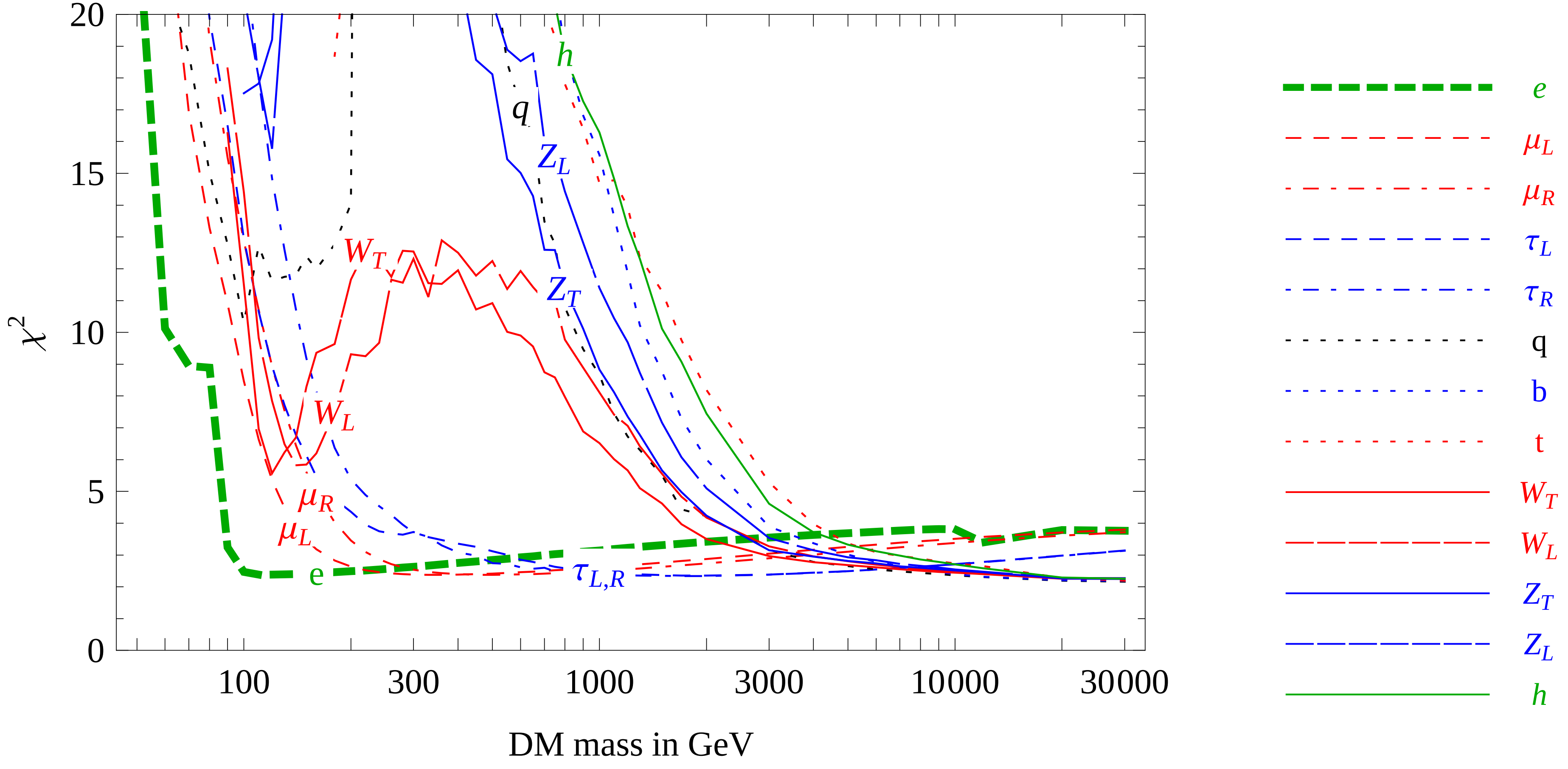
3

Implications of the data

Fitting procedure

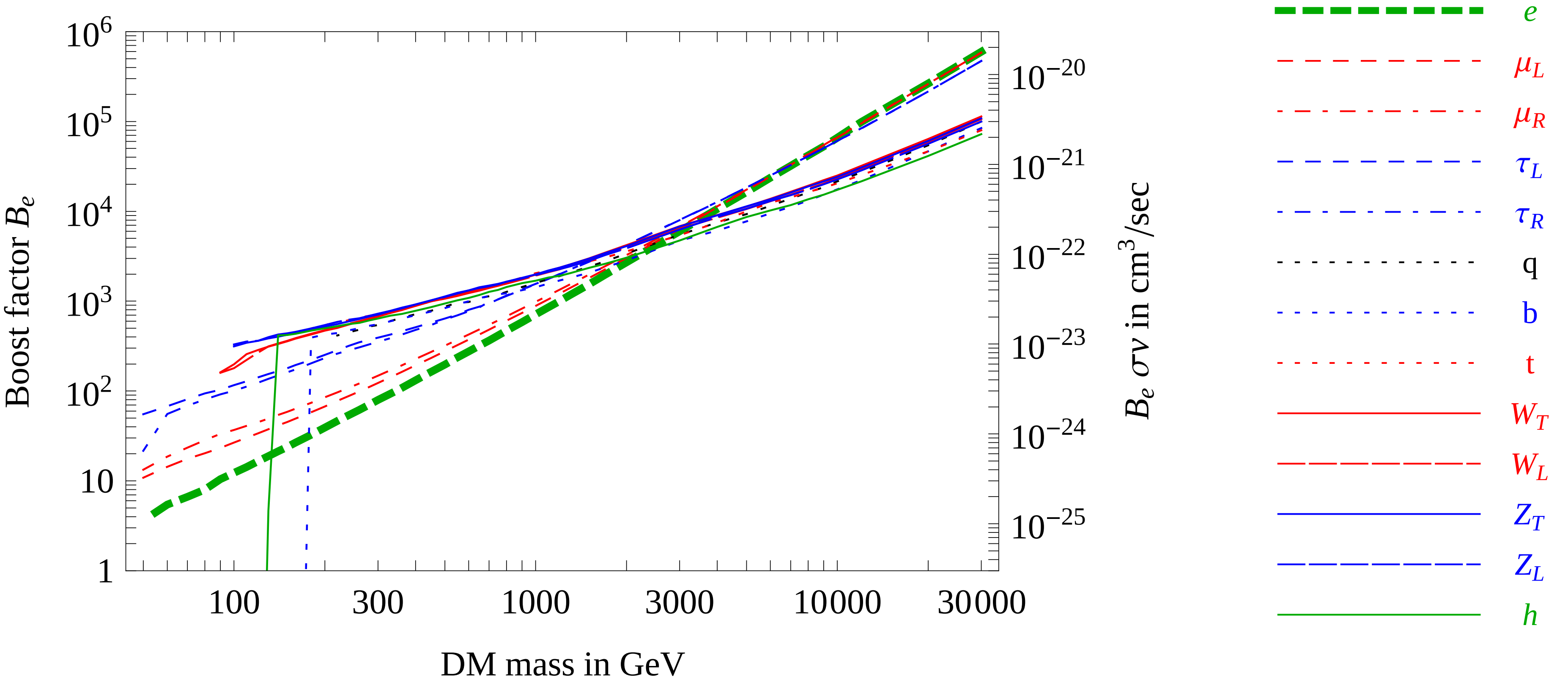
- **PAMELA** and **FERMI systematic uncertainties?**
- multiply each expected e^+, e^-, p^+/p^- **backgrounds** times $A_i E^{p_i}$ with free A_i and $p_i = 0 \pm 0.05$, and marginalize over A_i, p_i.
- **solar modulation** as uncorrelated uncertainty below 20 GeV: ±6% at 10 GeV, ±30% at 1 GeV.
- **DM 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



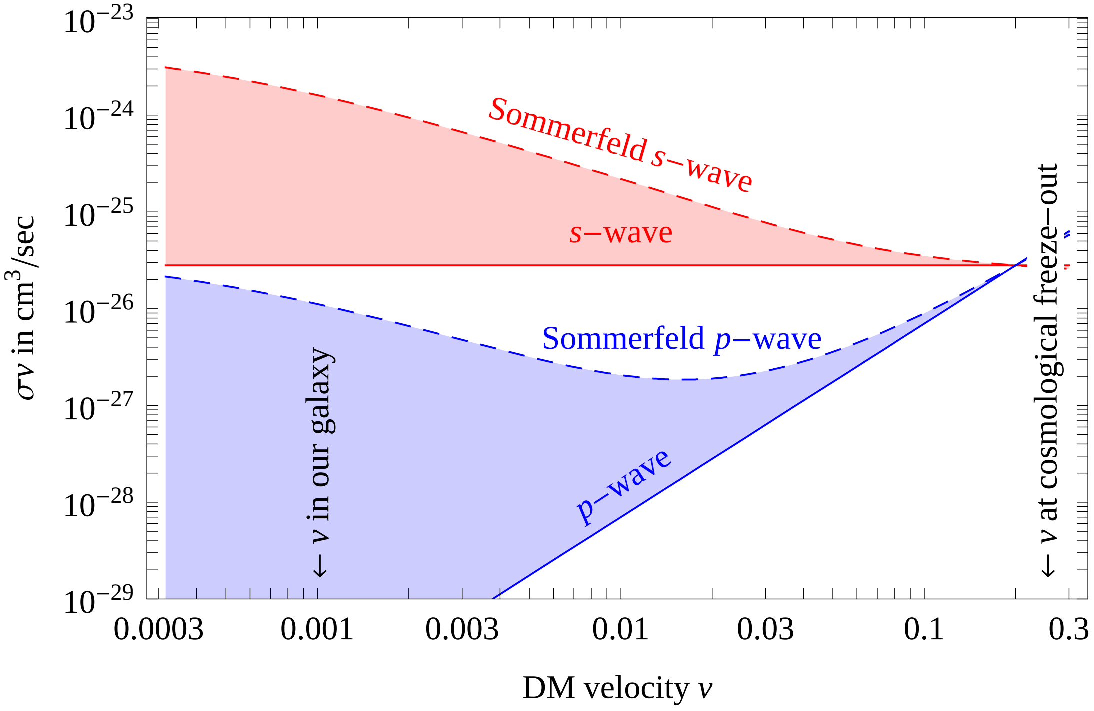
σv larger than what suggested by cosmology by a factor B_e

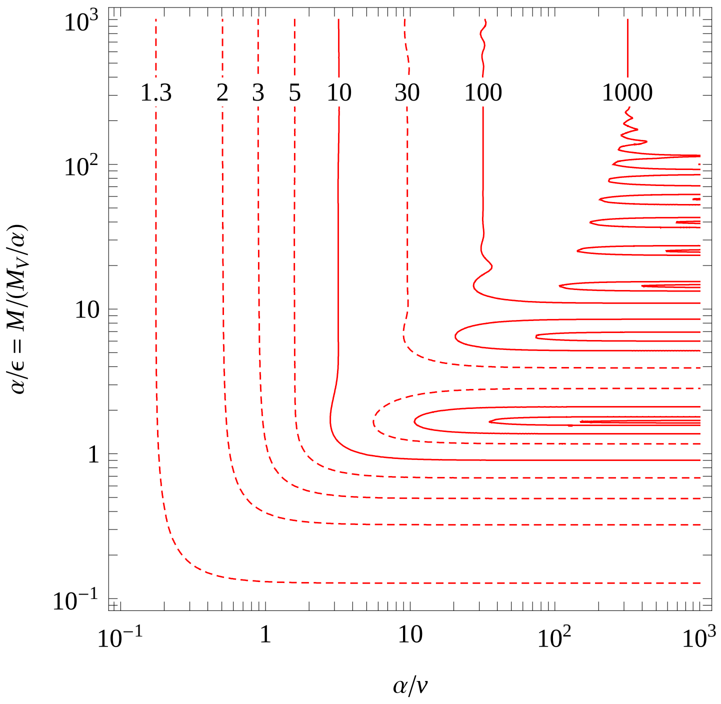
The cosmological σv

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)

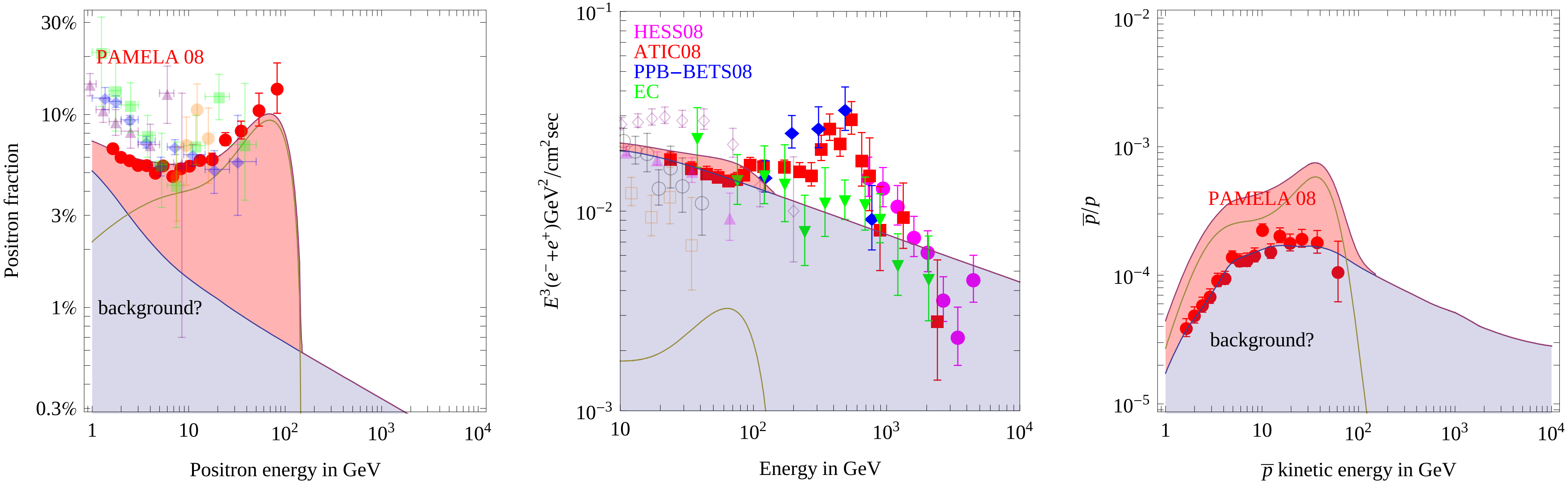
Non thermal DM

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

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

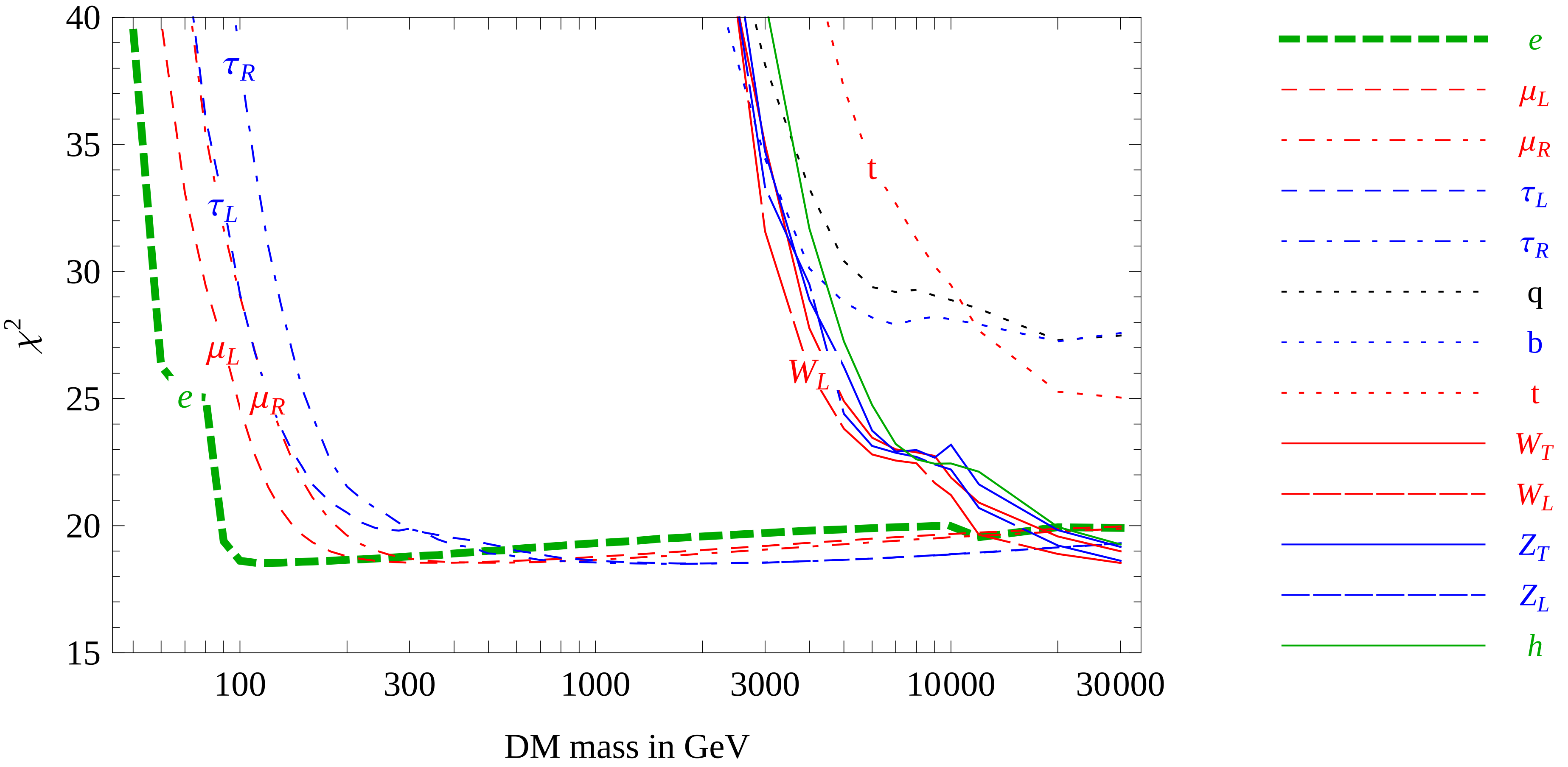
Problematic with PAMELA $\bar{p}$, reconsidered by Kane et al., excluded by FERMI.

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



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

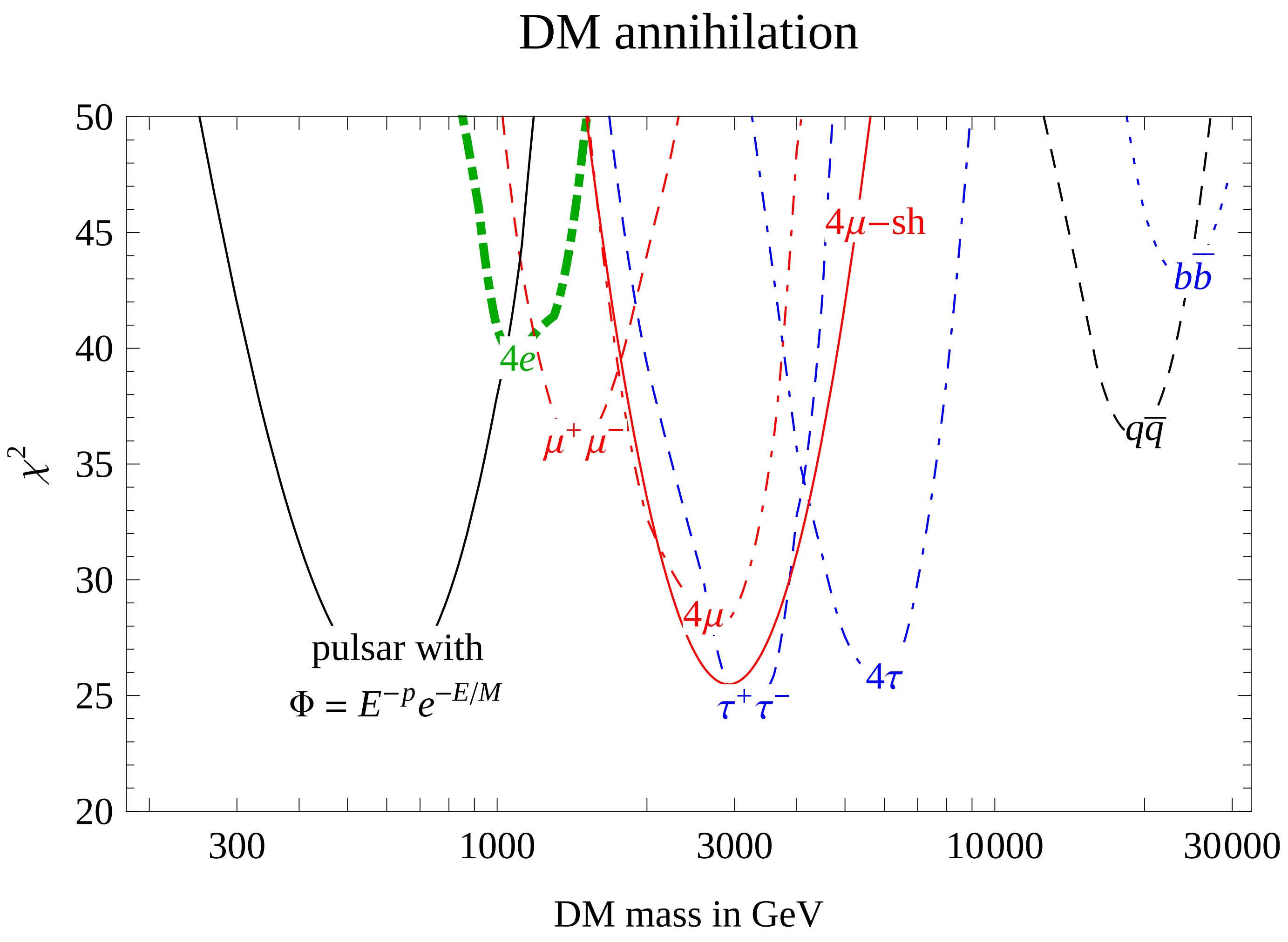
Assuming equal boost & propagation for e^+ and $\bar{p}$ (otherwise everything goes):



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 $M > 10$ TeV.

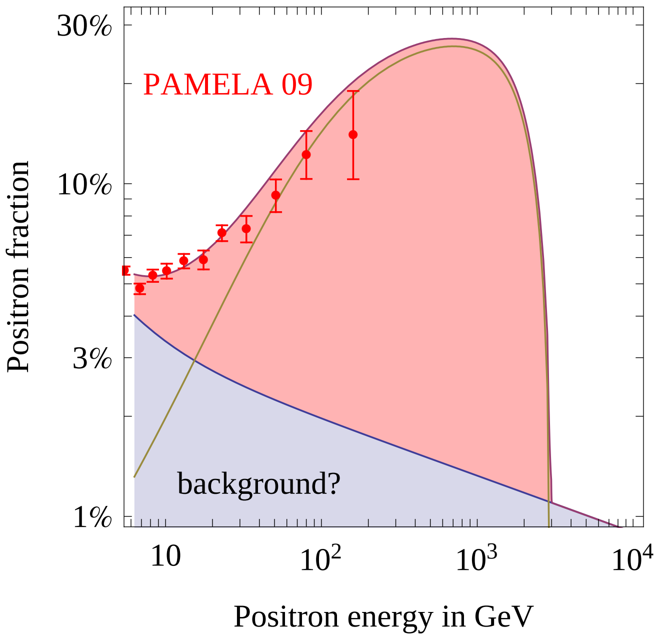
Fitting PAMELA e^+ and FERMI $e^+ + e^-$

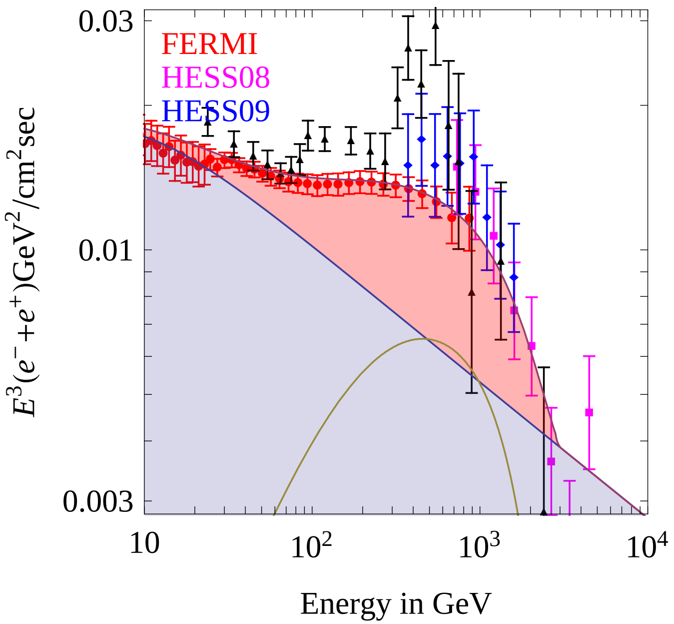


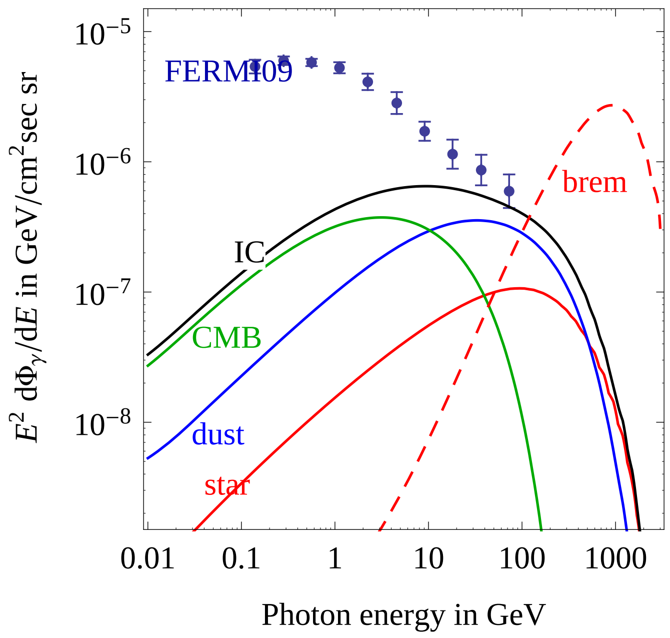
Compatible if DM has few TeV mass and annihilates into some leptons

Dark Matter best fit

DM with $M = 3.$ TeV that annihilates into $\tau^+\tau^-$ with $\sigma v = 1.8 \times 10^{-22}$ cm^3/s



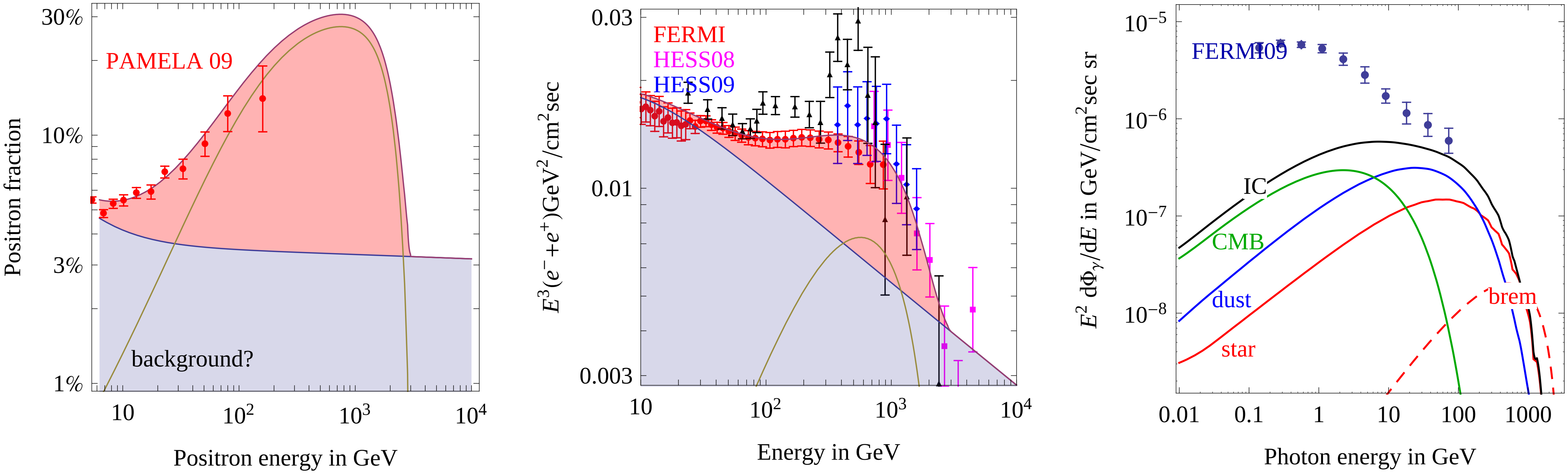




New DM theories

(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 $\sigma v = 7.7 \times 10^{-23}$ 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.

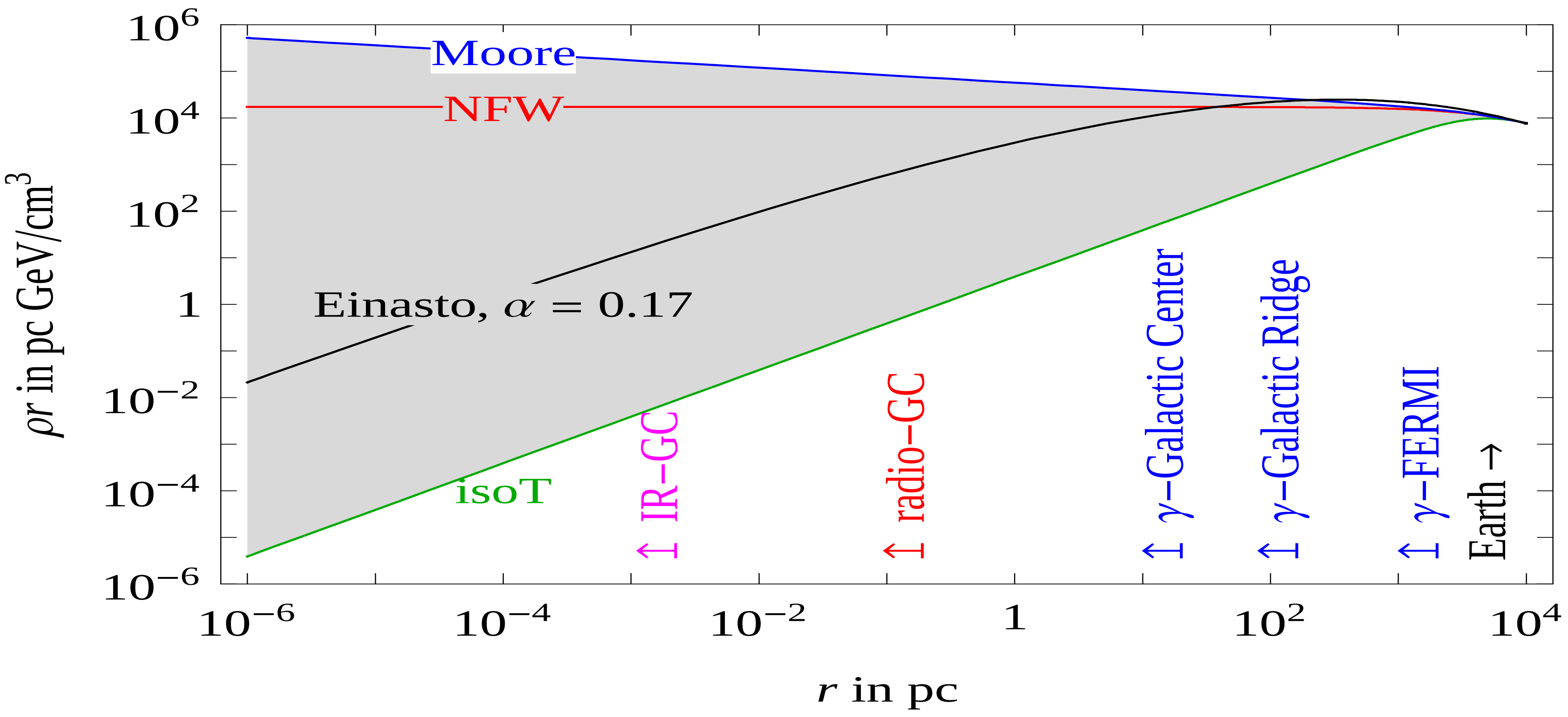
- **Synchrotron**: $e^\pm$ in the galactic magnetic fit: $\dot{E} \propto u_B = B^2/2$.
  Small $E_\gamma \sim 10^{-6}\,\mathrm{eV}$, probed by radio-observations: Davies, VLT, WMAP.

γ from bremstrahlung

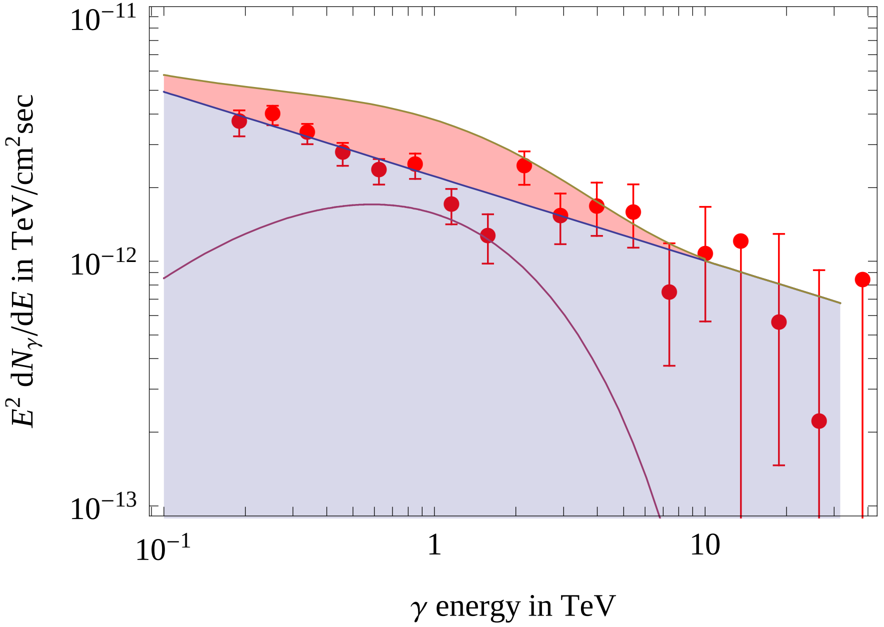
$$\frac{d\Phi_\gamma}{d\Omega\, dE} = \frac{1}{2}\frac{r_\odot}{4\pi}\frac{\rho_\odot^2}{M_{\rm DM}^2} {\color{red}J} \langle\sigma v\rangle \frac{dN_\gamma}{dE}, \qquad {\color{red}J} = \int_{\rm line-of-sight} \frac{ds}{r_\odot}\left(\frac{\rho(r)}{\rho_\odot}\right)^2$$

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

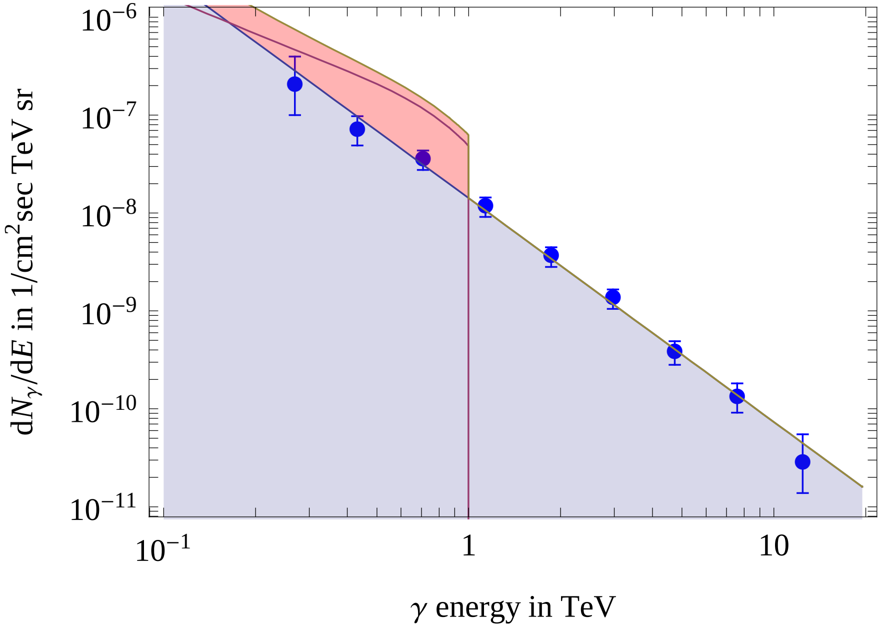
NFW	Einasto	isoT	region	$\Delta\Omega$
14700	7600	14	Galactic Center	$1 \cdot 10^{-5}$
2400	3000	14	Galactic Ridge	$3 \cdot 10^{-4}$



HESS observations



a) M = 10 TeV into W^+W^-, Galactic Center



b) M = 1 TeV into $\mu^-\mu^+$, Galactic Ridge

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

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

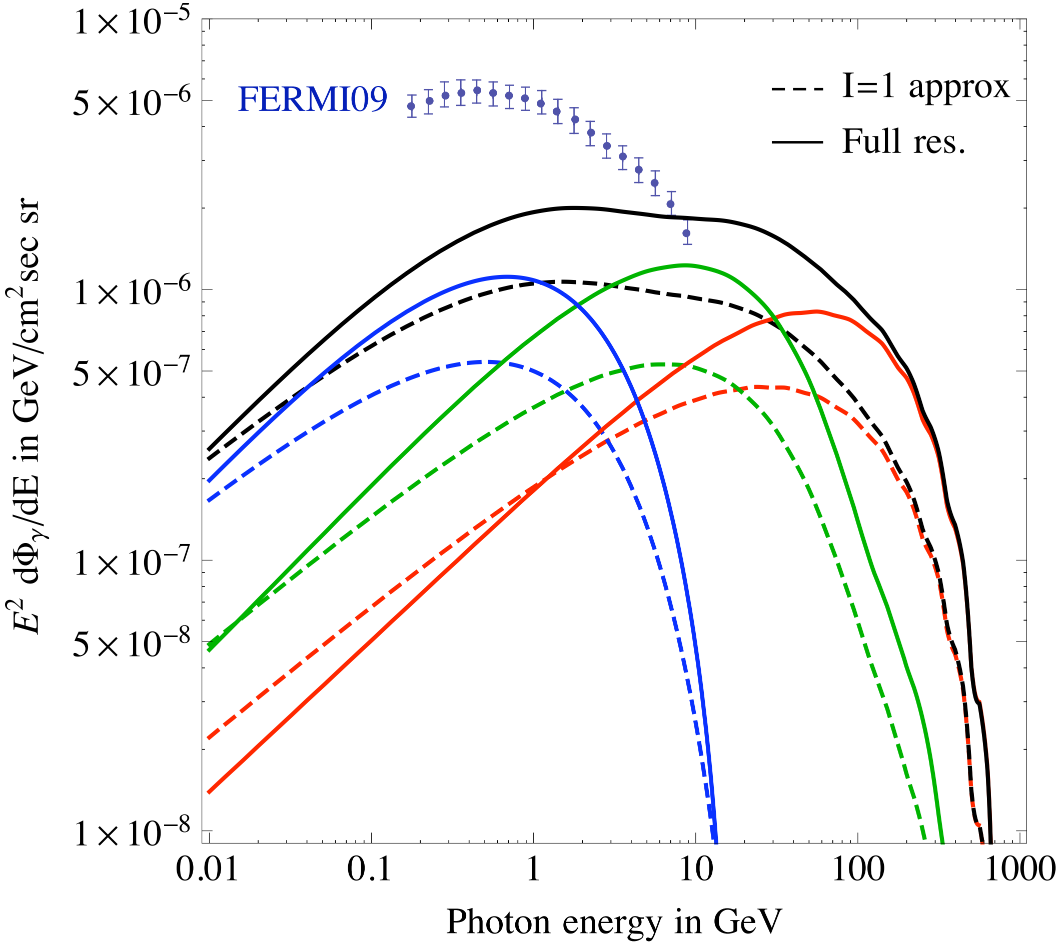
Initial γ:

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

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

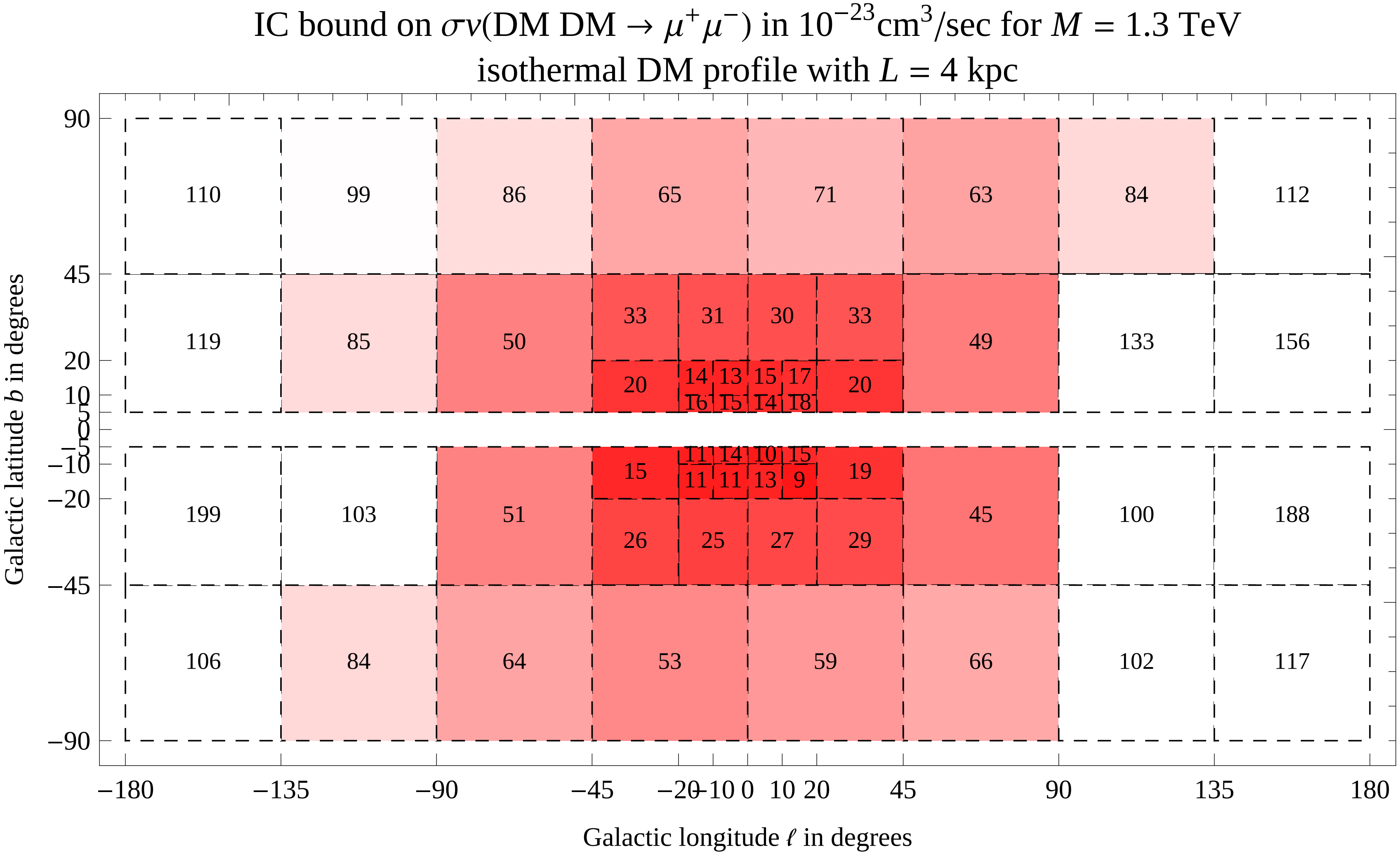
iii) $E_\gamma \sim$ meV from CMB.

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 $\sigma v(\text{DM DM} \to \mu^+\mu^-)$ in $10^{-23}\text{cm}^3/\text{sec}$ for $M = 1.3$ TeV

isothermal DM profile with $L = 4$ kpc

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

ν observations

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

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

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

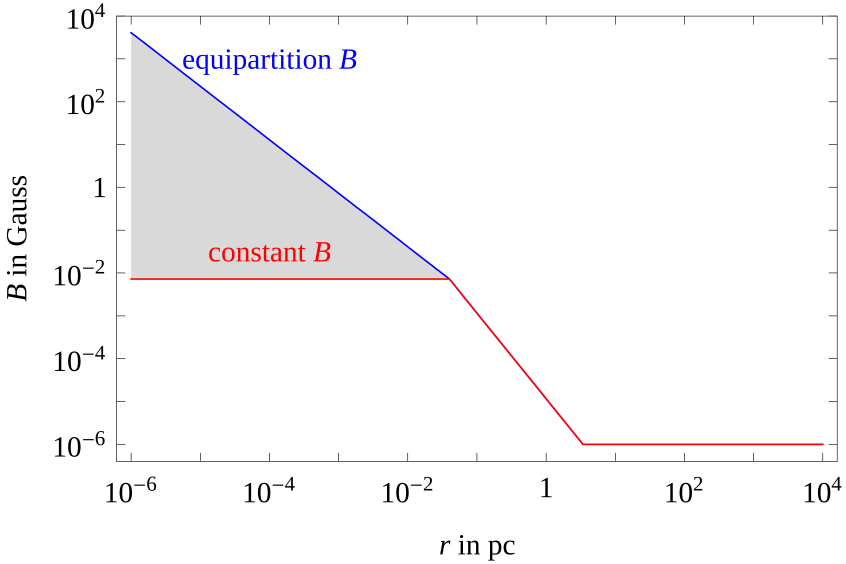
The total $\mu^\pm$ rate negligibly depends on the DM mass M.

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

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

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 $\nu_{\rm syn}$:



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

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

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

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 eV $\times\, n_e \ll u_\gamma$ ionizes all H changing CMB anisotropies

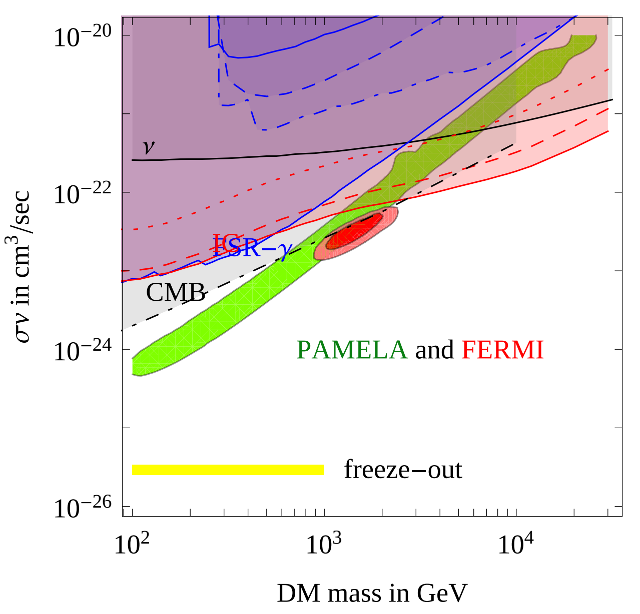
3. heat gas after structure formation $z \sim 10$.
   Depends on unknown non-linear small-scale DM clustering.

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.

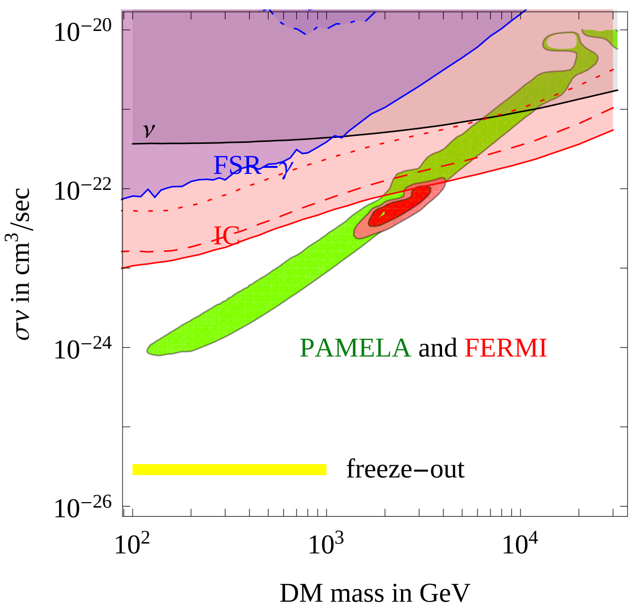
$e^{\pm}$ signals vs bounds

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

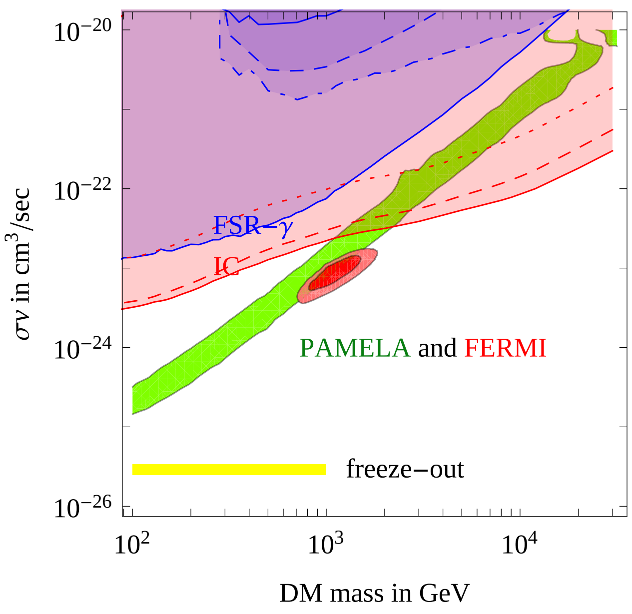
DM DM → $\mu^+\mu^-$, isothermal profile



DM DM → 4μ, isothermal profile

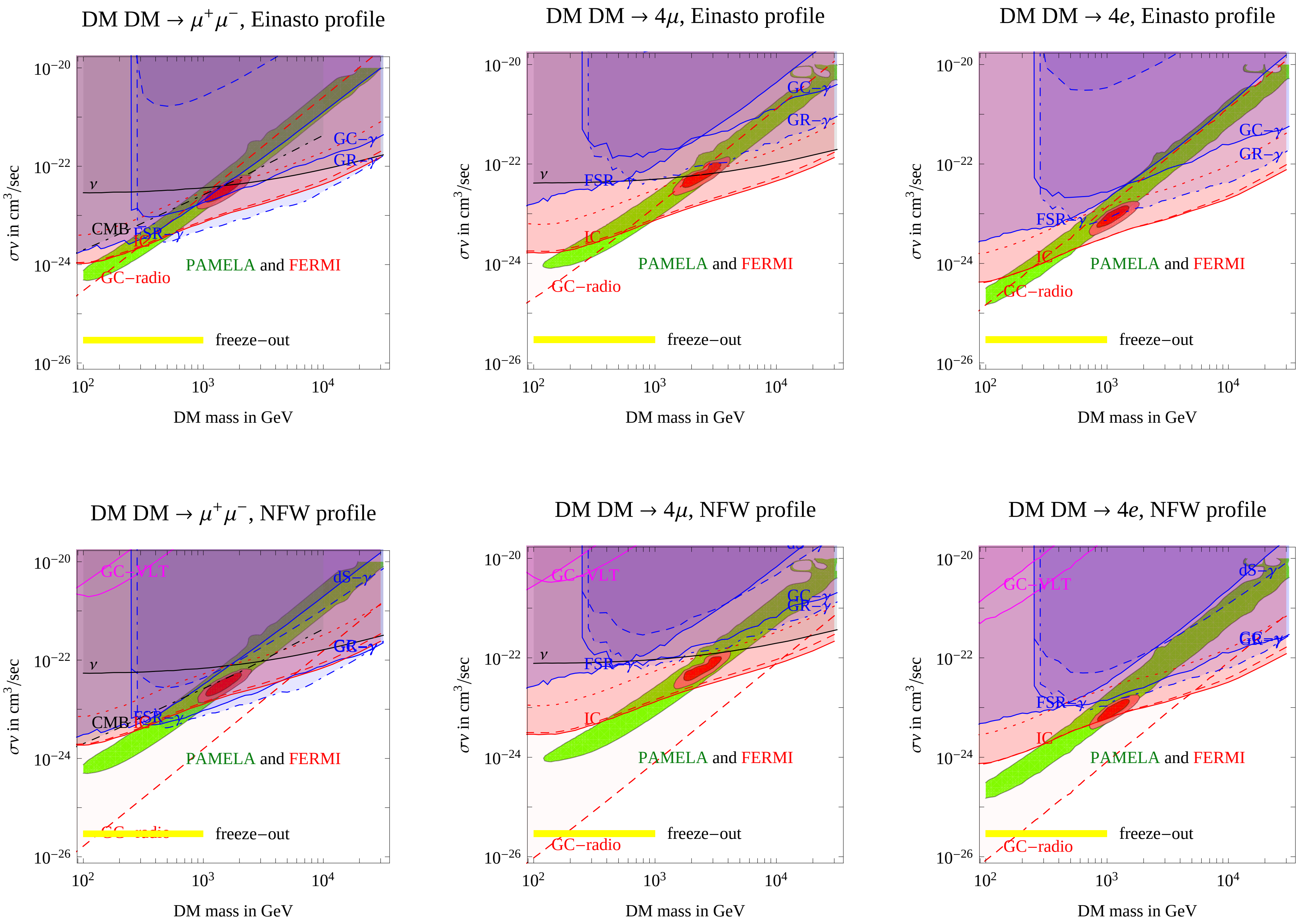


DM DM → $4e$, isothermal profile



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

not if Einasto or NFW



DM DM → $\mu^+\mu^-$, Einasto profile

DM DM → 4μ, Einasto profile

DM DM → $4e$, Einasto profile

DM DM → $\mu^+\mu^-$, NFW profile

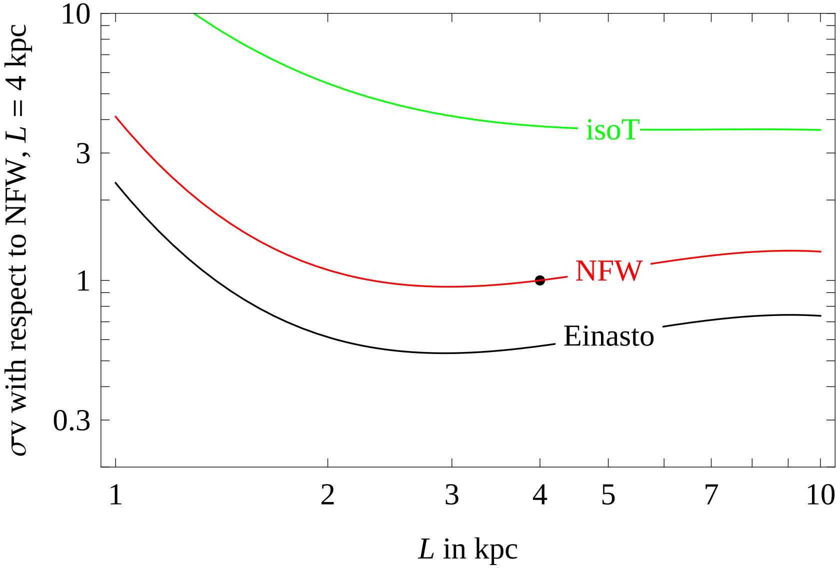
DM DM → 4μ, NFW profile

DM DM → $4e$, NFW profile

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

Caveats

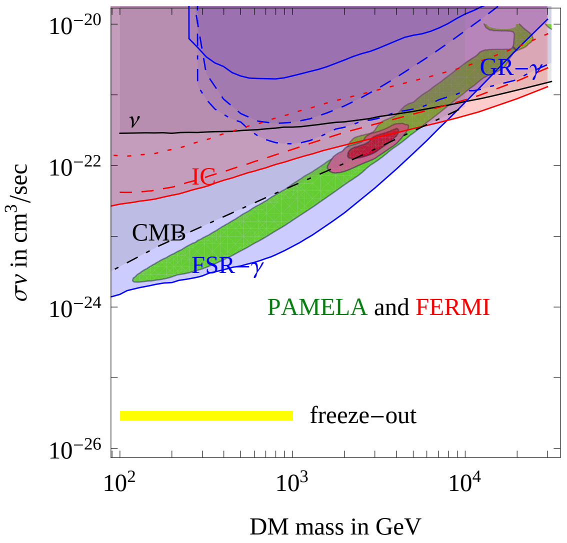
$L = 1$ kpc at the GC (ok?) would relax NFW or Einasto down to isoT: DM annihilations outside the diffusion volume contribute to FSR, but not to IC:



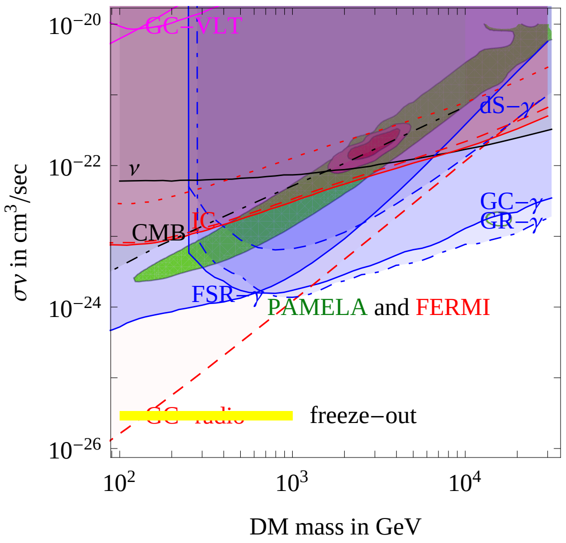
Disavored by a) global fits of charged CR; b) abundances of CR with $\tau \sim \tau_{\rm diff}$; c) FERMI sees γ away from the GC. d) realistic smooth growth of $K(z)$.

Can synchrotron dominate over IC? Only around the GC.

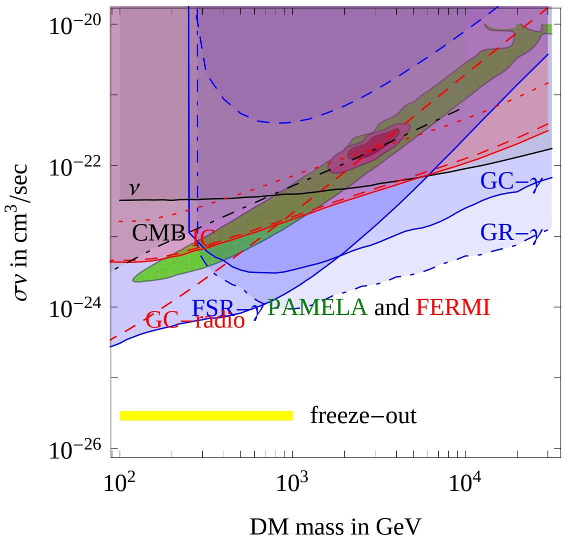
not if τ channels



DM DM → $\tau^+\tau^-$, isothermal profile



DM DM → $\tau^+\tau^-$, NFW profile

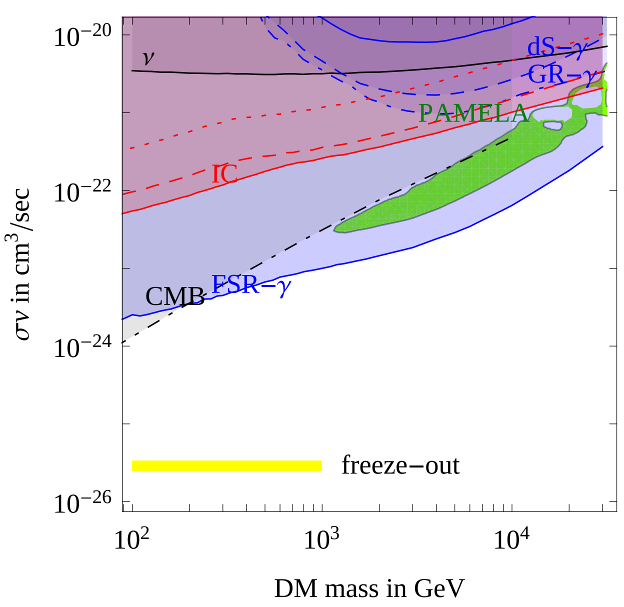


DM DM → $\tau^+\tau^-$, Einasto profile

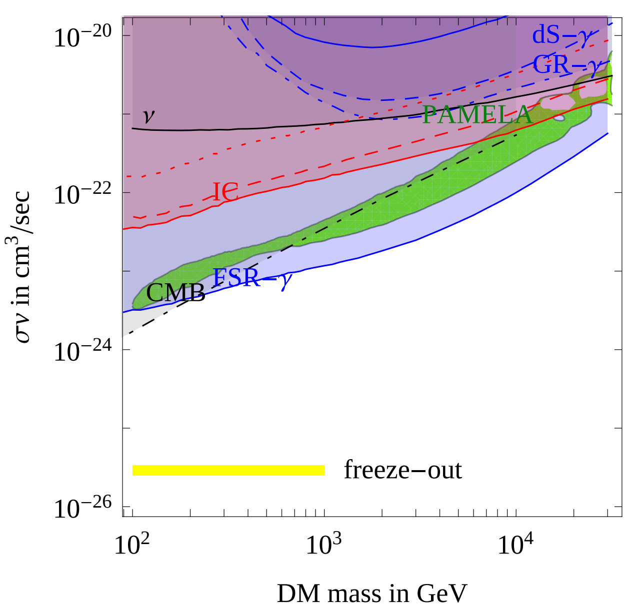
Too many $\tau \to \pi^0 \to \gamma$: FSR direct exclusion for any reasonable profile.

not if non-leptonic channels

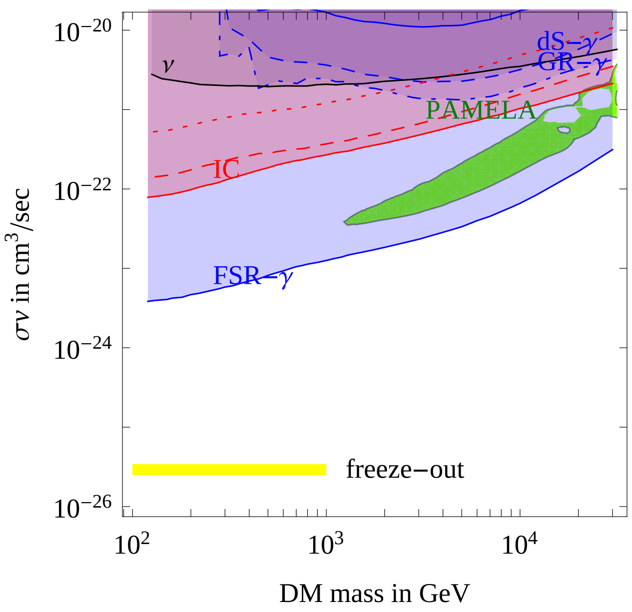
Non-leptonic channels give many FSR$-\gamma$ and can at most be subdominant:



DM DM $\to b\bar{b}$, isothermal profile



DM DM $\to W^+W^-$, isothermal profile



DM DM $\to hh$, isothermal profile

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

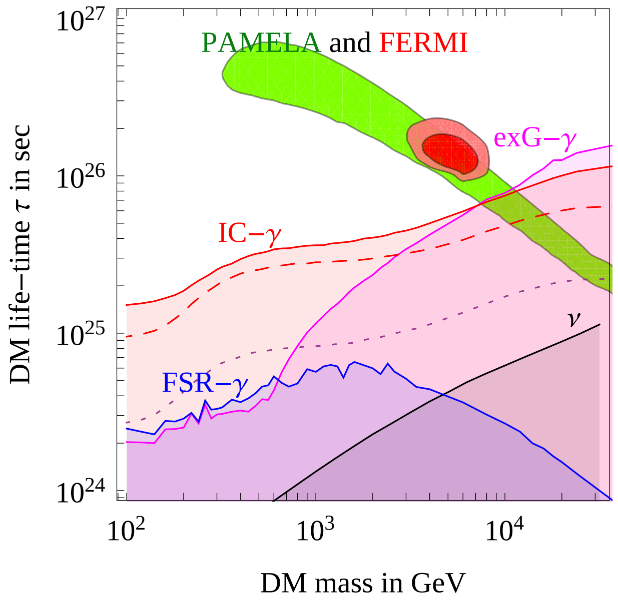
4

DM decays

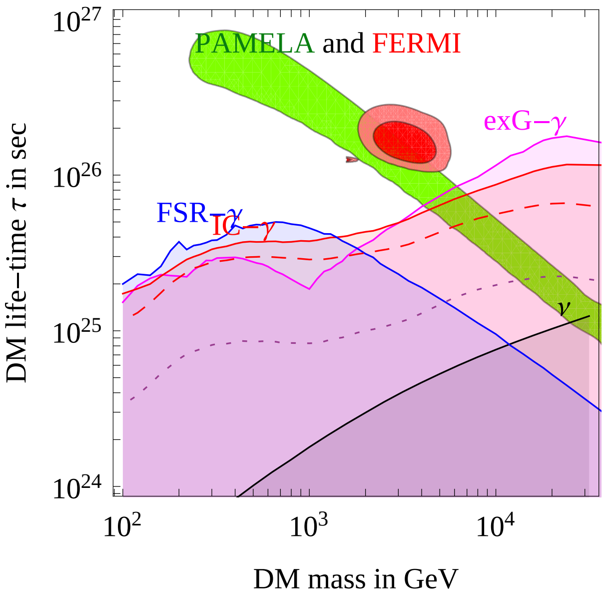
DM decays are compatible with NFW

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

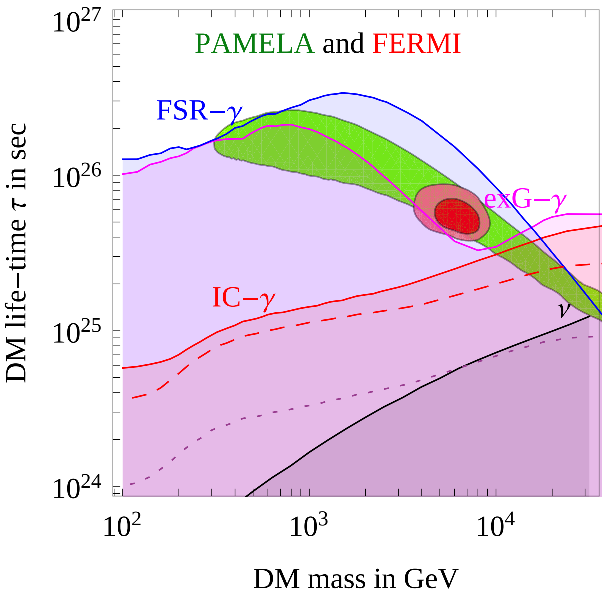
DM $\to 4\mu$, NFW profile



DM $\to \mu^+\mu^-$, NFW profile



DM $\to \tau^+\tau^-$, NFW profile



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 $\rho^2(t) \to \rho^1(t)$.

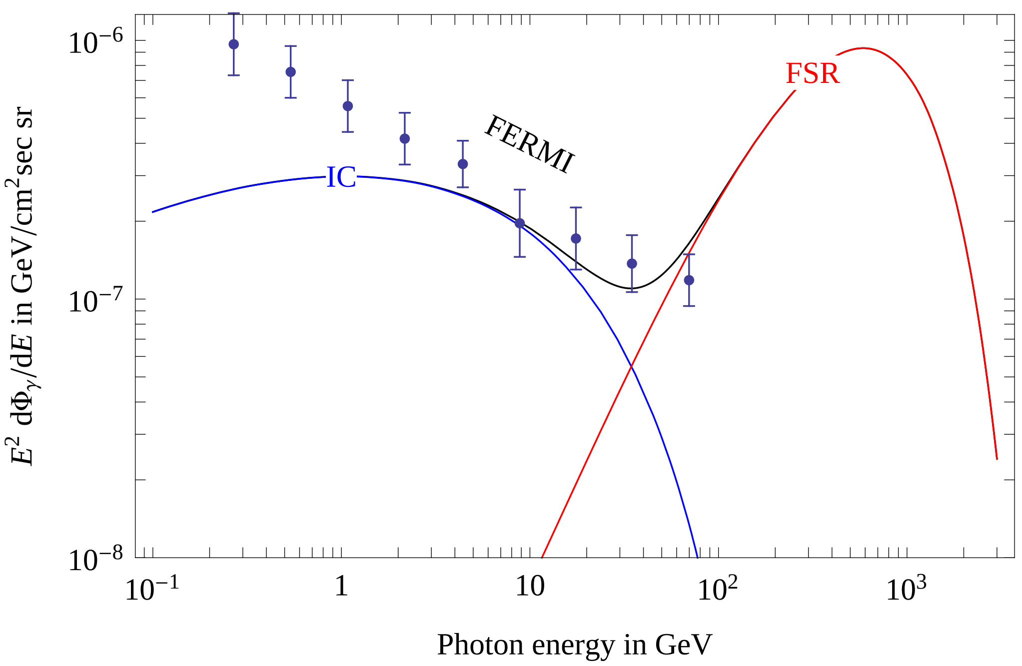
The extra-galactic γ flux is significant:

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

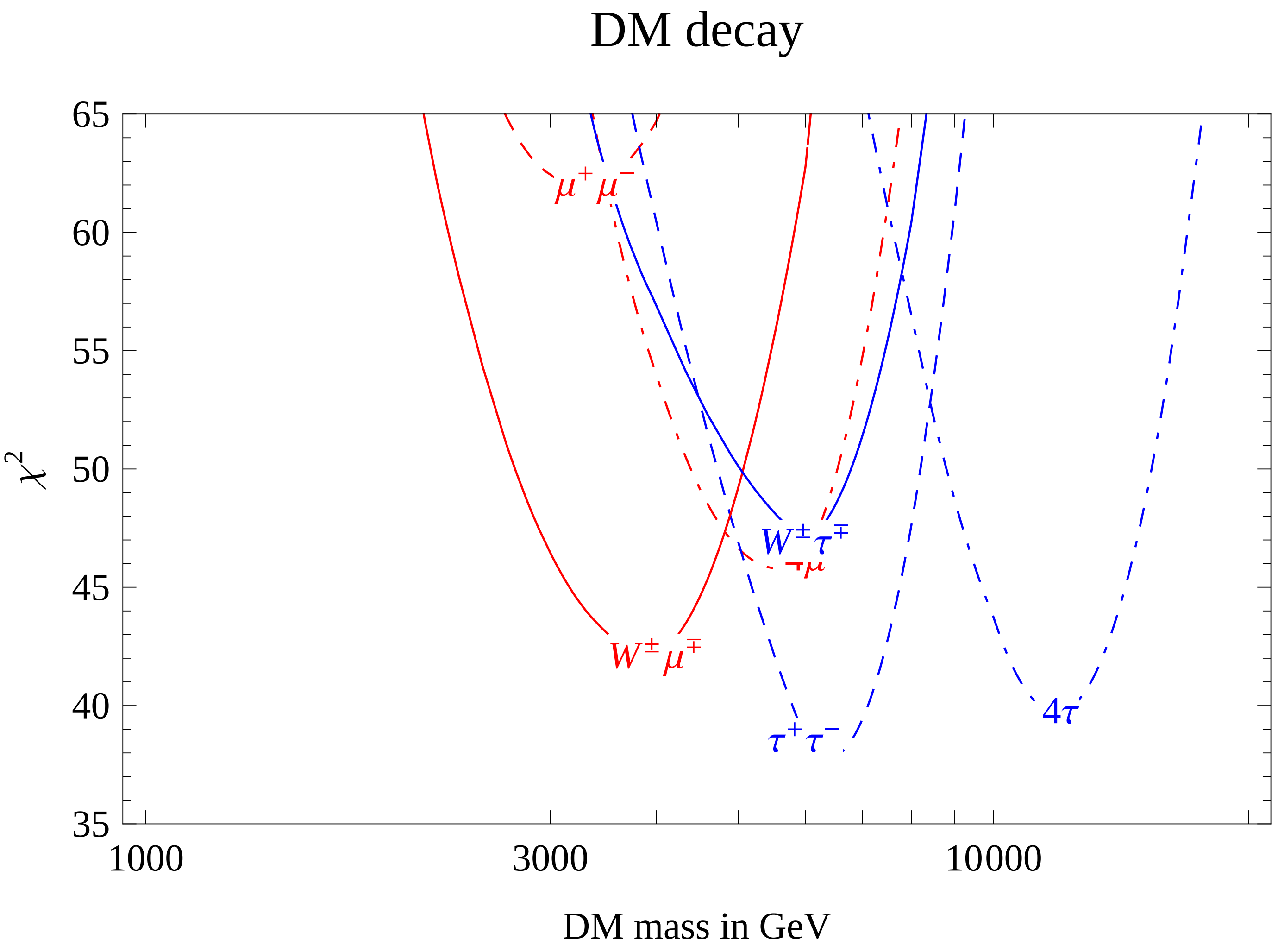
and can be computed reliably: no dependence on small-scale DM clustering.

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 → $\tau^+\tau^-$ 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:

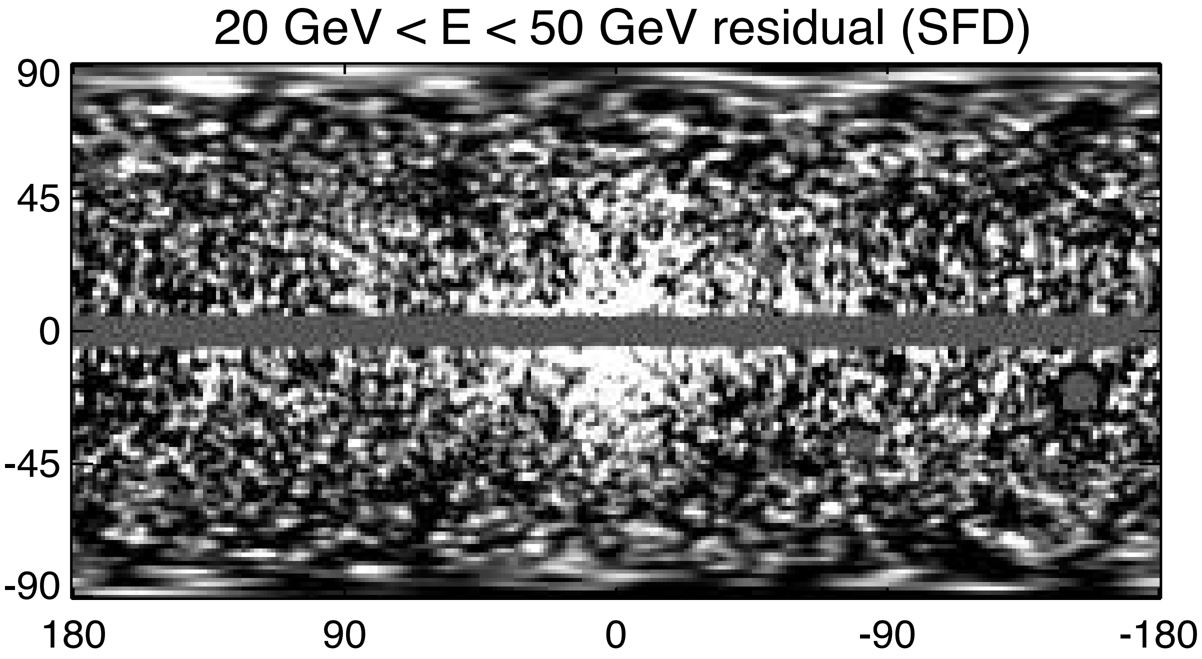
- × $2e$ channel gave the ATIC peak, not the FERMI $e^{+}+e^{-}$ excess.
- × τ channels give too much γ.
- × W, Z, q, b, h, t channels can only fit PAMELA e^{+} and give too much γ.
- • 3 TeV DM that annihilates in $2\mu, 4\mu, 4e$. But only if the injection term is quasi constant: i) Isothermal profile; ii) DM decays.

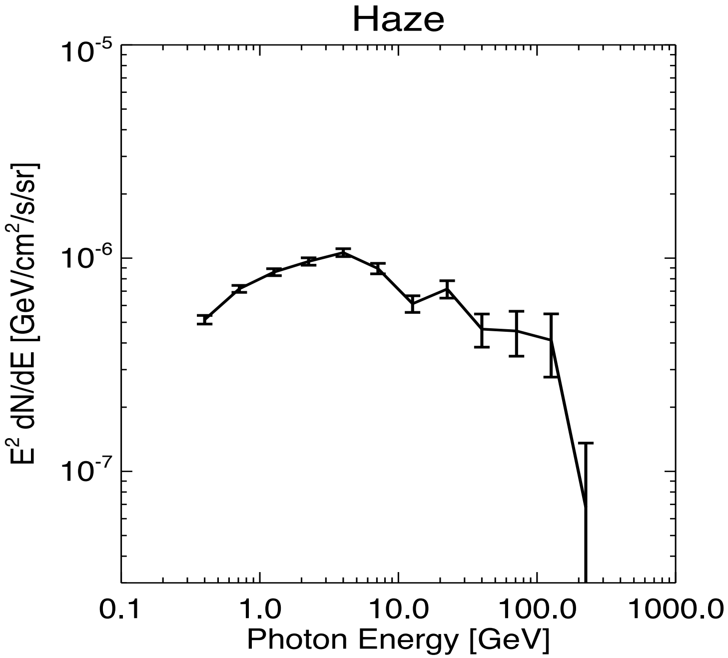
DM predicts that the e^{+} fraction must grow. DM IC-γ must be in FERMI sky.

Next: FERMI, PAMELA, AMS, PLANCK

The FERMI haze?

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





FERMIons disagree [arXiv:1003.0002]