Implications of the PAMELA & ATIC? excesses on Dark Matter properties

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

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M. Cirelli, M. Kadastik, M. Raidal, M. Taoso, G. Bertone, E. Nardi, F. Sannino
GGI, 2009/2/9, 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

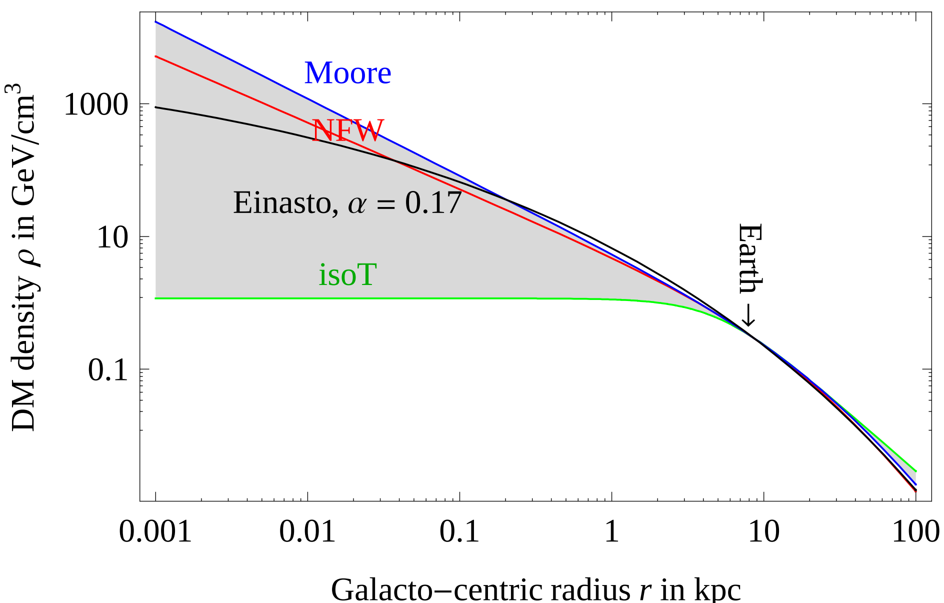
DM velocity: $\beta \approx 10^{-3}$. DM is spherically distributed with uncertain profile:

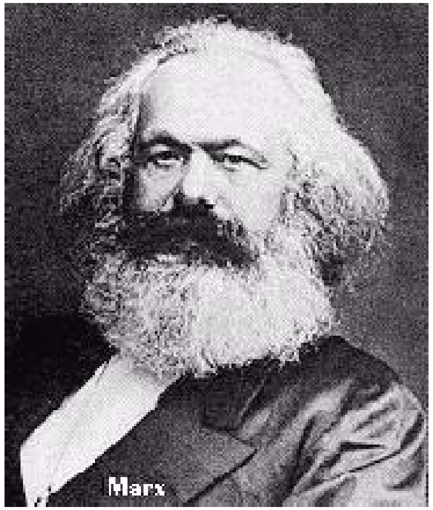
$$\rho(r) = \rho_\odot \left[\frac{r_\odot}{r}\right]^\gamma \left[\frac{1 + (r_\odot/r_s)^\alpha}{1 + (r/r_s)^\alpha}\right]^{(\beta-\gamma)/\alpha}$$

$r_\odot = 8.5\,\text{kpc}$ is our distance from the Galactic Center, $\rho_\odot \equiv \rho(r_\odot) \approx 0.3\,\text{GeV/cm}^3$,

DM halo model		α	β	γ	r_s in kpc
Isothermal	'isoT'	2	2	0	5
Navarro, Frenk, White	'NFW'	1	3	1	20
Moore	'Moore'	1	3	1.16	30

DM is like capitalism according to Marx: a gravitational system has no ground state so everything is (slowly) collapsing to a point and maybe $\rho(r \to 0) = \infty$.





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

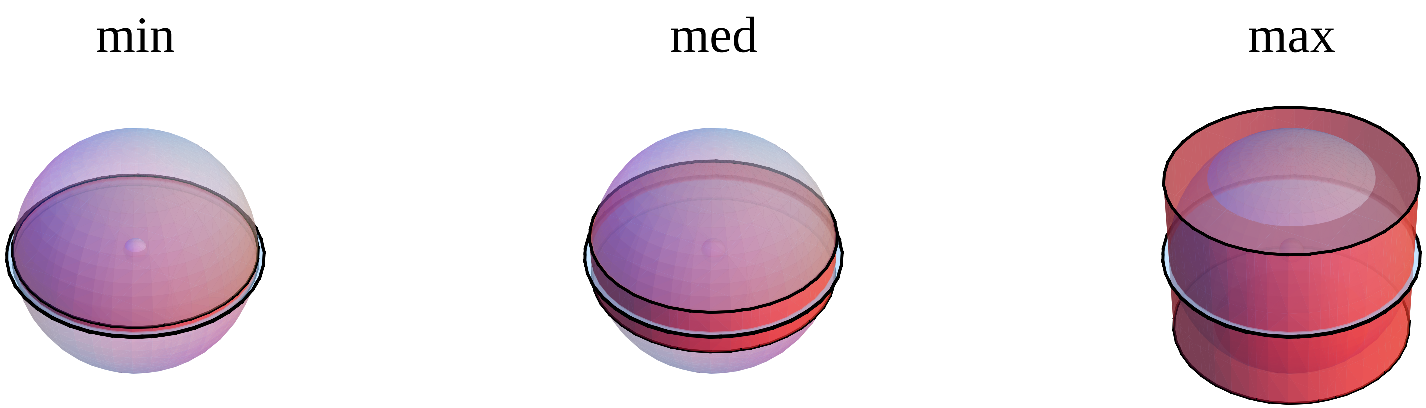
Simulations neglect normal matter, that locally is comparable to DM.

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

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

- DM DM injection term: $Q = \frac{1}{2}\left(\frac{\rho}{M}\right)^2 \langle\sigma v\rangle \frac{dN_{e+}}{dE}$.
- Diffusion coefficient: $K(E) = K_0 (E/\,\text{GeV})^{\delta}$. ($K \sim R_{\text{Larmor}} = E/eB$).
- Energy loss: $b(E) = E^2/\,\text{GeV}/\tau_E$ with $\tau_E = 10^{16}\,$s.
- Boundary: f vanishes on a cylinder with radius $R = 20\,$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

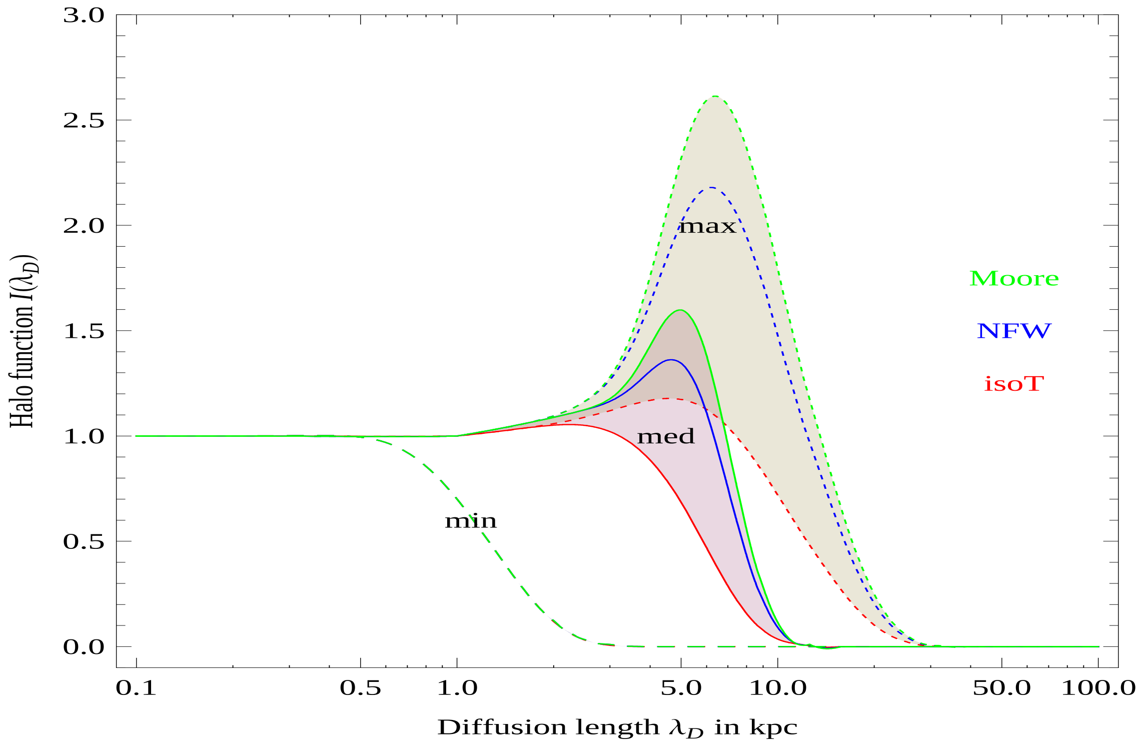


Do $e^{\pm}$ reach us from the Galactic Center?

Maybe, if $r_\odot \lesssim L, \lambda_D$ where λ_D is the diffusion length from energy E' to E:

$$\lambda_D(E', E) = \sqrt{4K_0\tau_E \left[\frac{(E/\,\text{GeV})^{\delta-1} - (E'/\,\text{GeV})^{\delta-1}}{\delta - 1}\right]}$$

Semi-analytic solution: $\Phi_{e^+}(E) = B\frac{v_{e^+}}{4\pi}\frac{\tau_E}{E^2}\int_E^{M_{\text{DM}}} dE'\; Q(E') \cdot I(\lambda_D(E', E))$ with



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 $\bar{p}$.

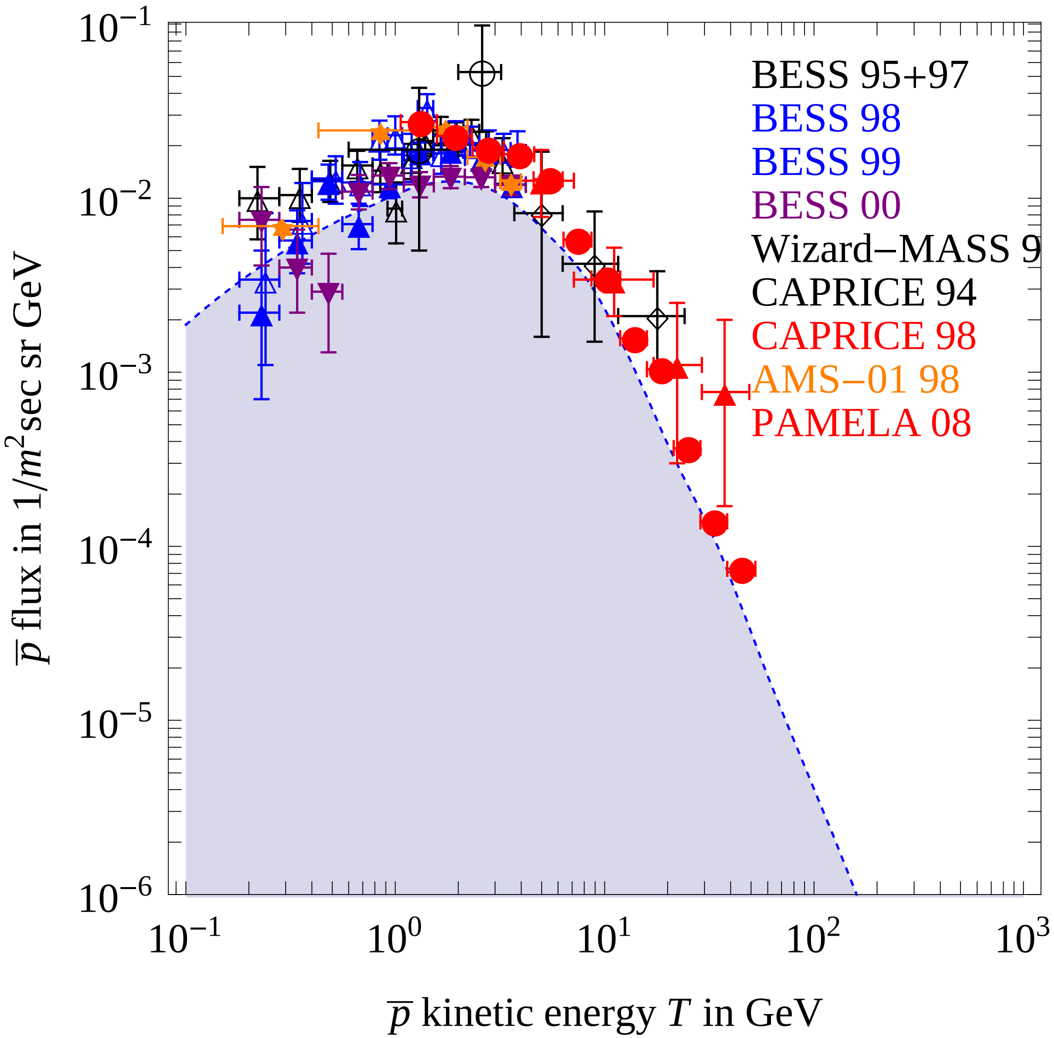
Experimentalists need to bring above the atmosphere (with balloons or satellites) a spectrometer and/or calorimeter, able of rejecting e^{-} and p.

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

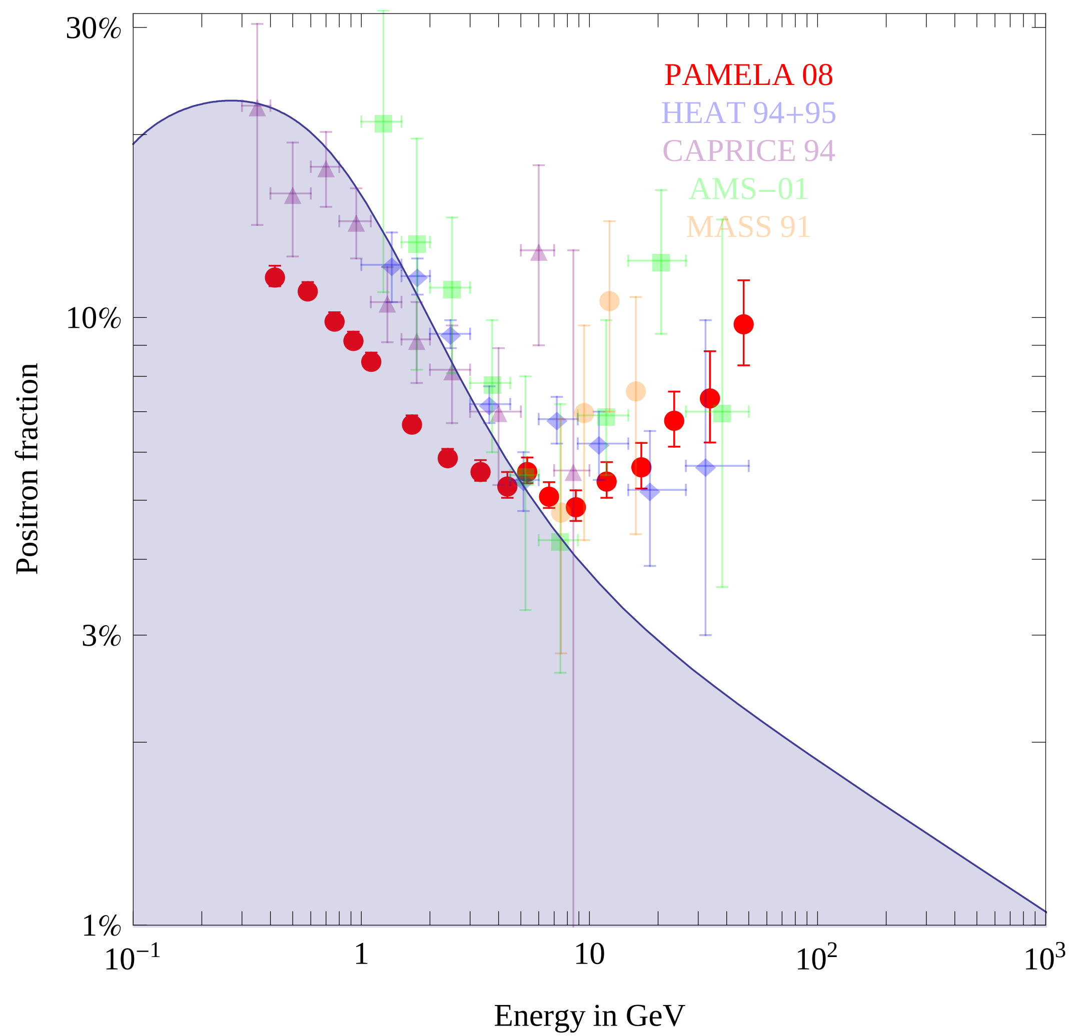


Future: PAMELA, AMS

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

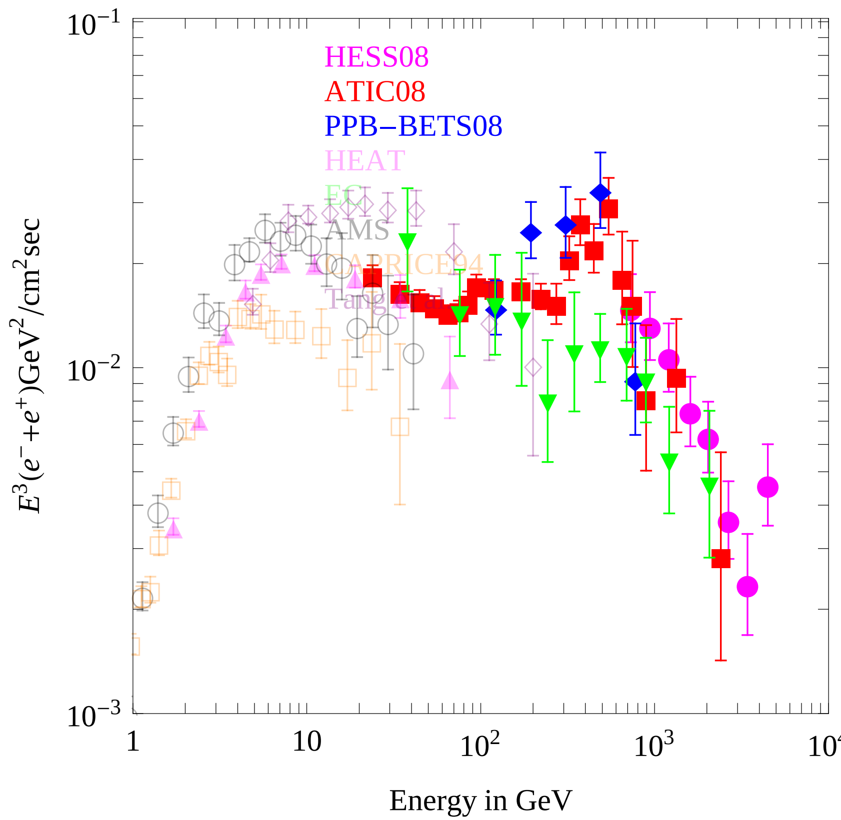


The PAMELA excess suggest that it might manifest in other experiments: if e^+/e^- continues to grow, it reaches $e^+ \sim e^-$ around 1 TeV...

$e^+ + e^-$: ATIC, PPB/BETS, HESS

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

Peak at 800 GeV?



Near future: ATIC-4, GLAST/Fermi, PAMELA

ATIC-4 preliminary results: [redacted]

FERMI preliminary results: [redacted]

PAMELA: $\Phi_{e^-} \propto E^{-3.3}$ today. Precise points of ATIC tell $\Phi_{e^+ + e^-} \propto E^{-3}$

Systematics? Dark Matter? ...

Could the excesses be due to systematics?

- ATIC. The problem could be **discriminating** 1 $e^{\pm}$ from 1000 $p \to \pi^0$: MC tested below 200 GeV. The peak is a few points. ATIC-4 enlarged the calorimeter, so that a elecromagnetic shower is contained.
- PPB-BETS. Very small. **Not cleanly compatible** with ATIC-2 and EC.
- PAMELA. Needs to find $1e^{+}$ among 5000 p. Calibrated below 200 GeV. Due to small size, $\sim 50\%$ of the shower is lost laterally.

If the excess is due to DM:

- DM is a WIMP. (A gravitino-like particle is allowed if unstable).
- DM annihilates, so it is not there due to an asymmetry like protons
- DM is a strange WIMP...

... 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.

Far galactic pulsars can fit PAMELA, but M is (?) too low M for ATIC?

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

Tests: • γ (but beamed? pulsar still alive?); • angular anisotropies (but local B?); • is the ATIC peak smooth? (but a $\delta(t)$ pulsar can be sharper than DM)

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

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

depend on the **polarization of primaries**.

The higher-order γ spectrum is model-dependent:

$$\gamma = (\text{Brehmstalung/fragmentation}) + (\text{one-loop}) + (\text{3-body})$$

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 $\mathscr{D} =$ DM DM state.

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

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

So:

- $\mathscr{D}$ can have spin 0 for any DM spin;
- $\mathscr{D}$ **can have spin 1 only if DM is a Dirac fermion or a vector**.
  We will see that this is needed for having large DM DM $\to f\bar{f}$

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

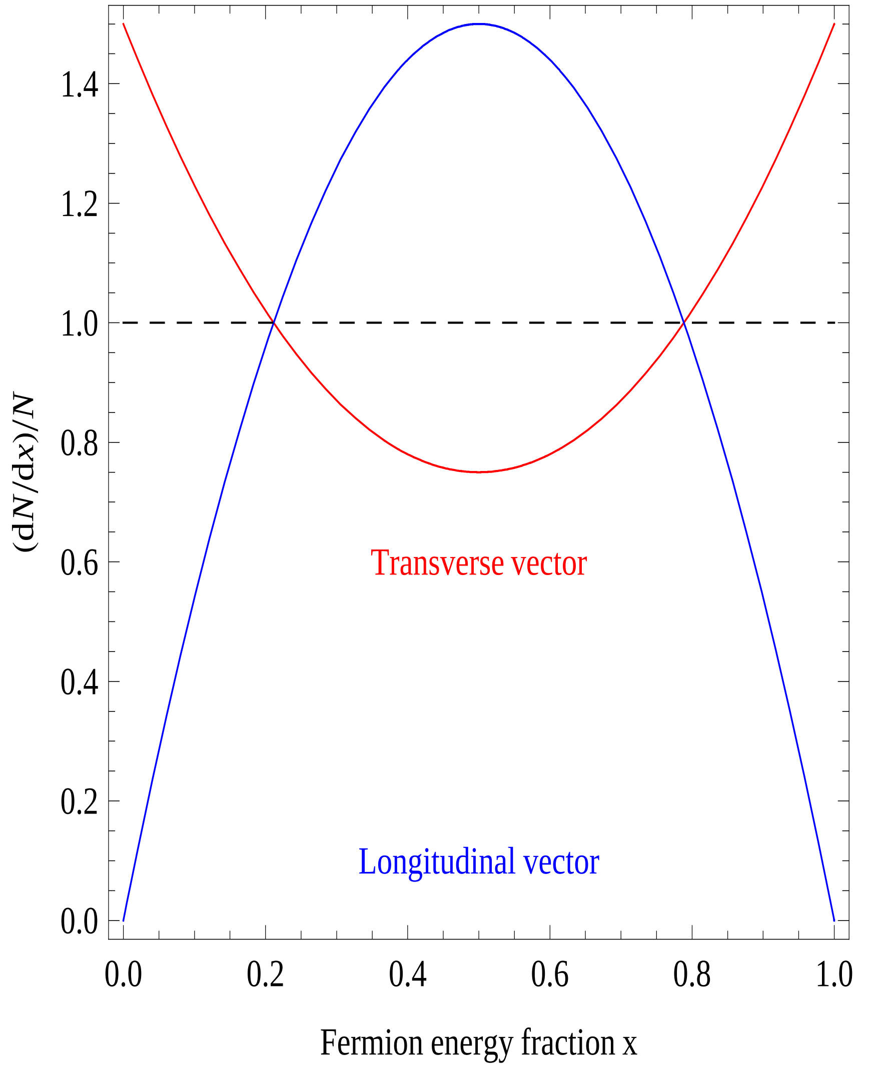
$$dN/d\cos\theta = 3(1+\cos^2\theta)/8$$

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

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

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

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



DM annihilations into the higgs h

We can again focus on $\mathscr{D}$, so that the effective interaction $\mathscr{D}h^2$ gives DM annihilations into hH Since they have no spin, there are no polarization issues.

We assume $m_h = 115\,\mathrm{GeV}$, so h decays mostly into $b\bar{b}$.

DM annihilations into Zh will not be considered, as they are are essentially given by the average of the $Z_L Z_L$ and hh channels.

DM annihilations into fermions f

- $\mathscr{D}$ 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.

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

$$\mathscr{D}_\mu[\bar{f}_L \gamma_\mu f_L] = \mathscr{D}_\mu[\bar{\Psi}_f \gamma_\mu P_L \Psi]$$

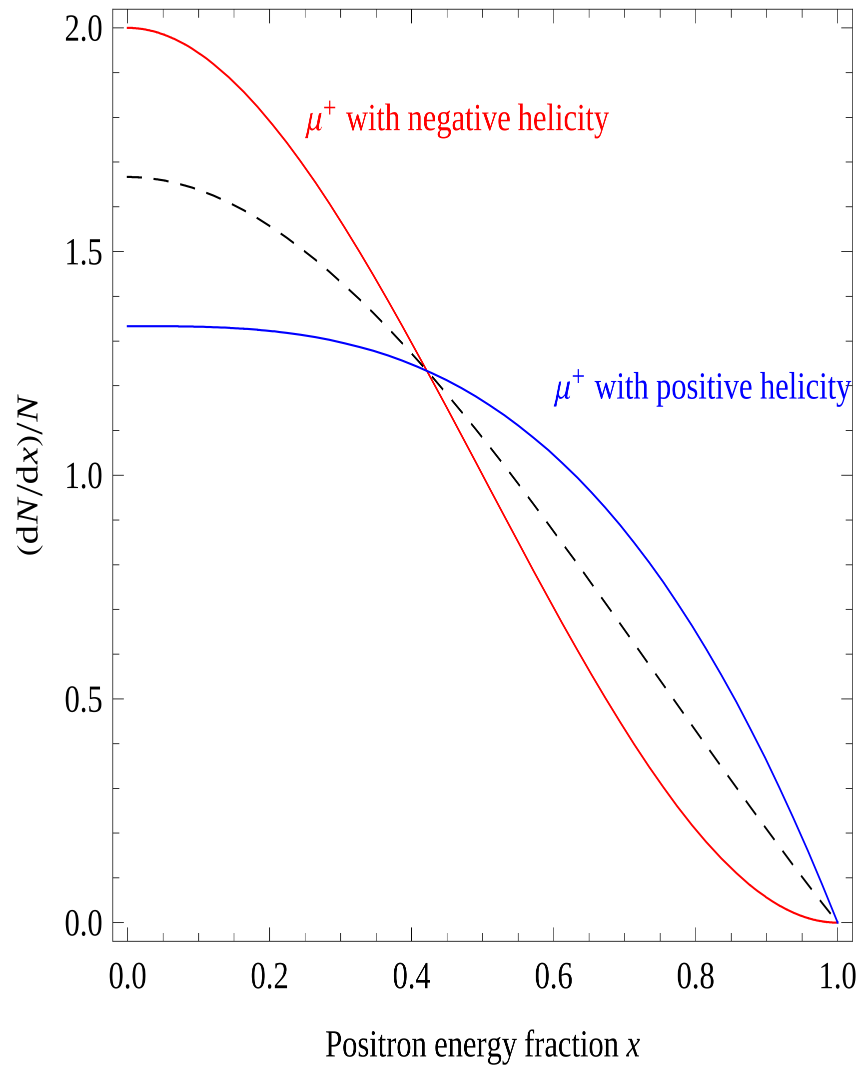
or

$$\mathscr{D}_\mu[\bar{f}_R \gamma_\mu f_R] = \mathscr{D}_\mu[\bar{\Psi}_f \gamma_\mu P_R \Psi]$$

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

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

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

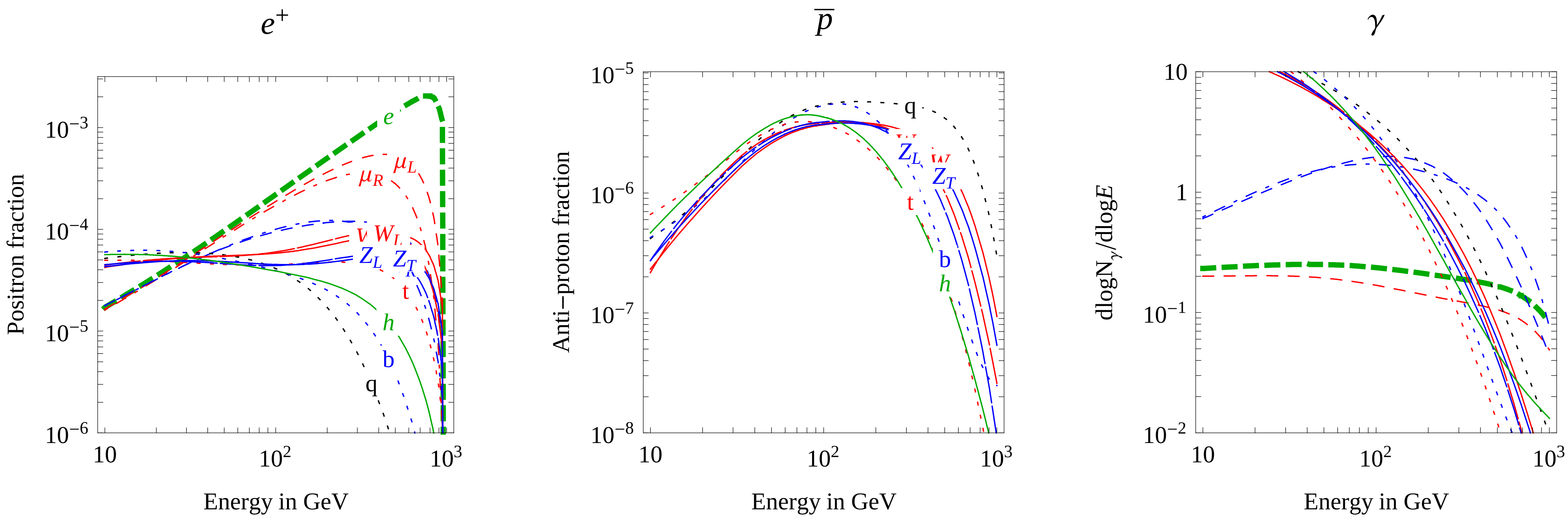


Final state spectra for $M = 1$ TeV

We consider the allowed s-wave primary annihilation channels:

$$\{e, \mu_L, \mu_R, \tau_L, \tau_R,\ W_L, W_T, Z_L, Z_T, h,\ q, b, t\},$$

computed with our Mathematica MonteCarlo + Phytia8 + (Tauola+Phytia6)



Annihilations into leptons give qualitatively different energy spectra.

3

Implications of the data

Fitting procedure

- **PAMELA 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.

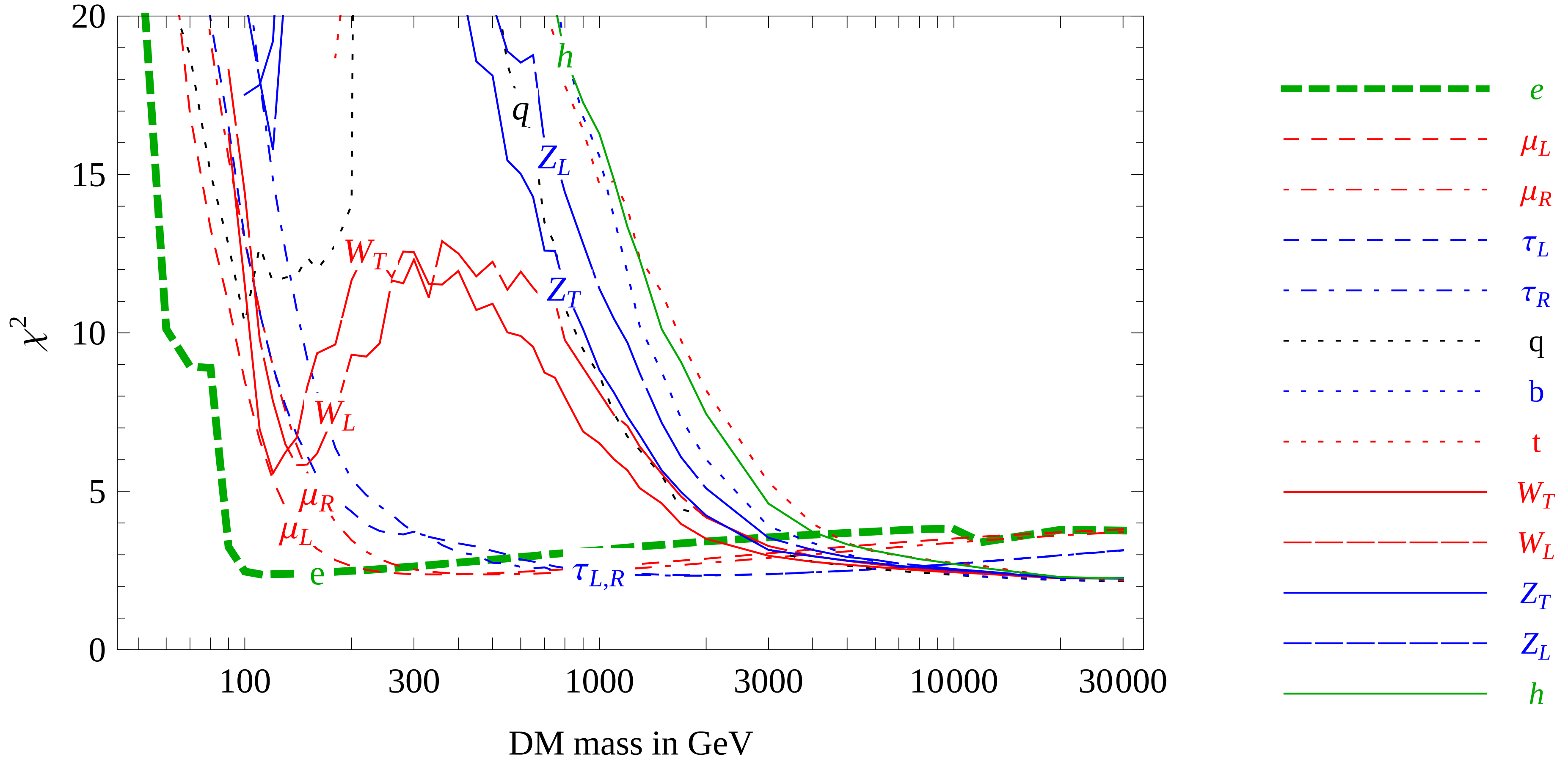
- **solar modulation** as uncorrelated uncertainty below 20 GeV: $\pm$6% at 10 GeV, $\pm$30% at 1 GeV.

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

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

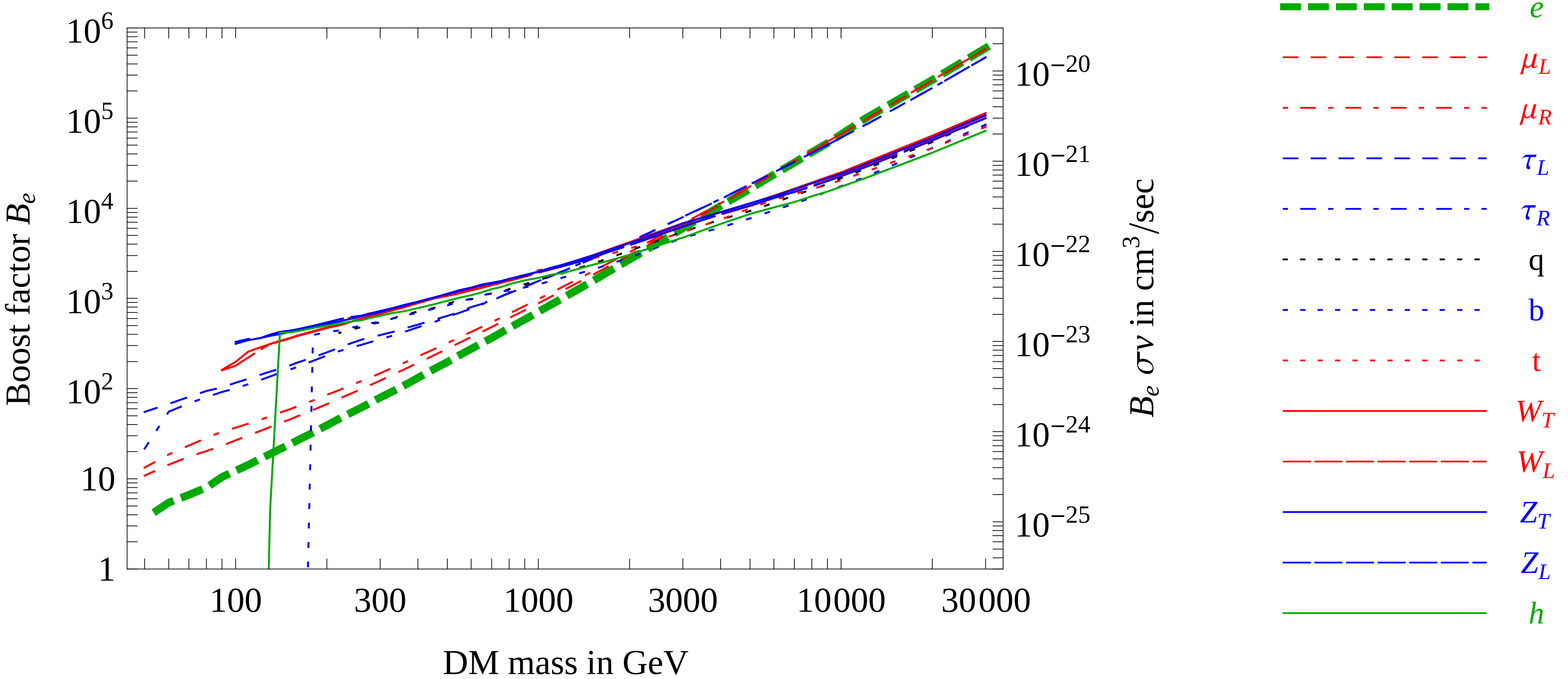
- Statistical techniques: as reviewed in appendix B of hep-ph/0606054.

Fitting PAMELA positron data



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

The σv needed for PAMELA



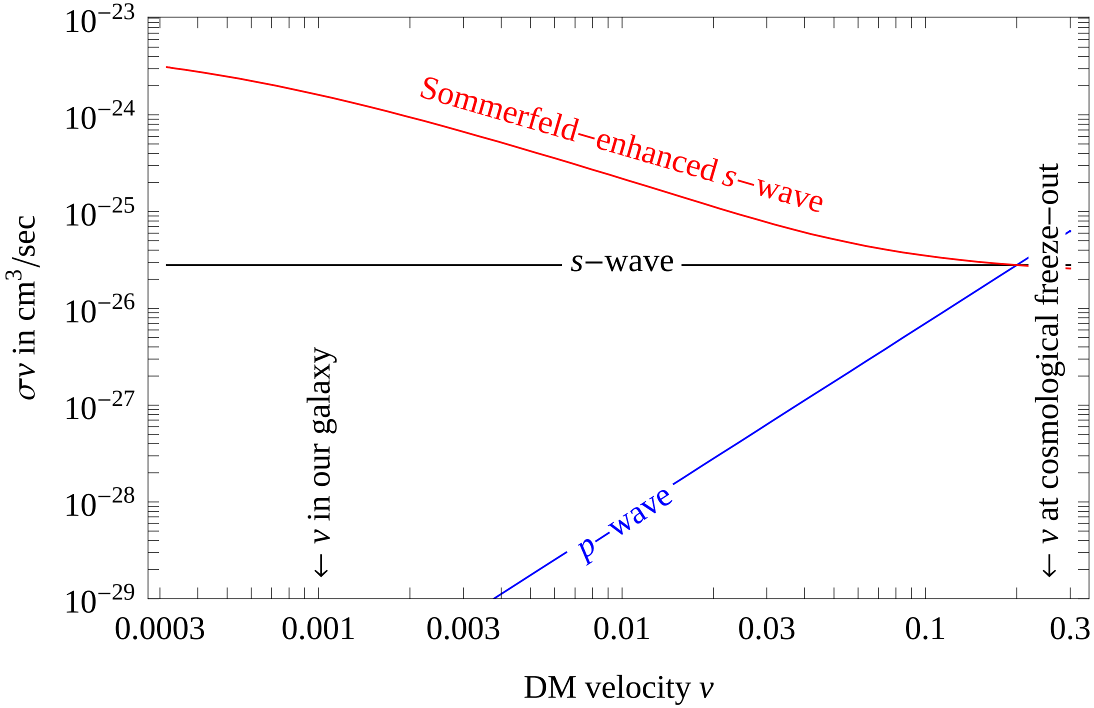
σv larger than what suggested by cosmology by a factor B_e

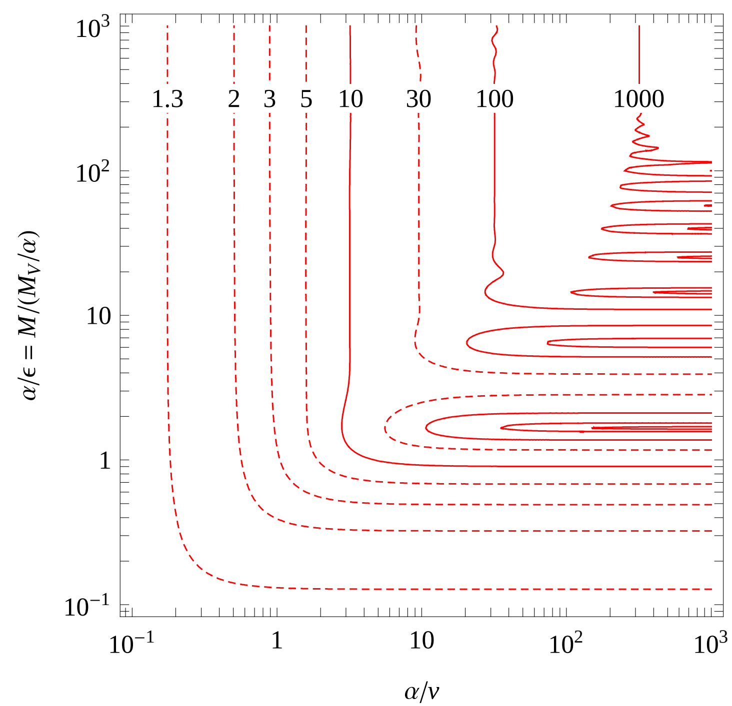
The cosmological σv

Thermal DM reproduces the cosmological DM abundance $\Omega_{DM}h^2 \approx 0.11$ 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: $\sigma = \pi R_\odot^2(1+v_{\text{escape}}^2/v^2)$

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)

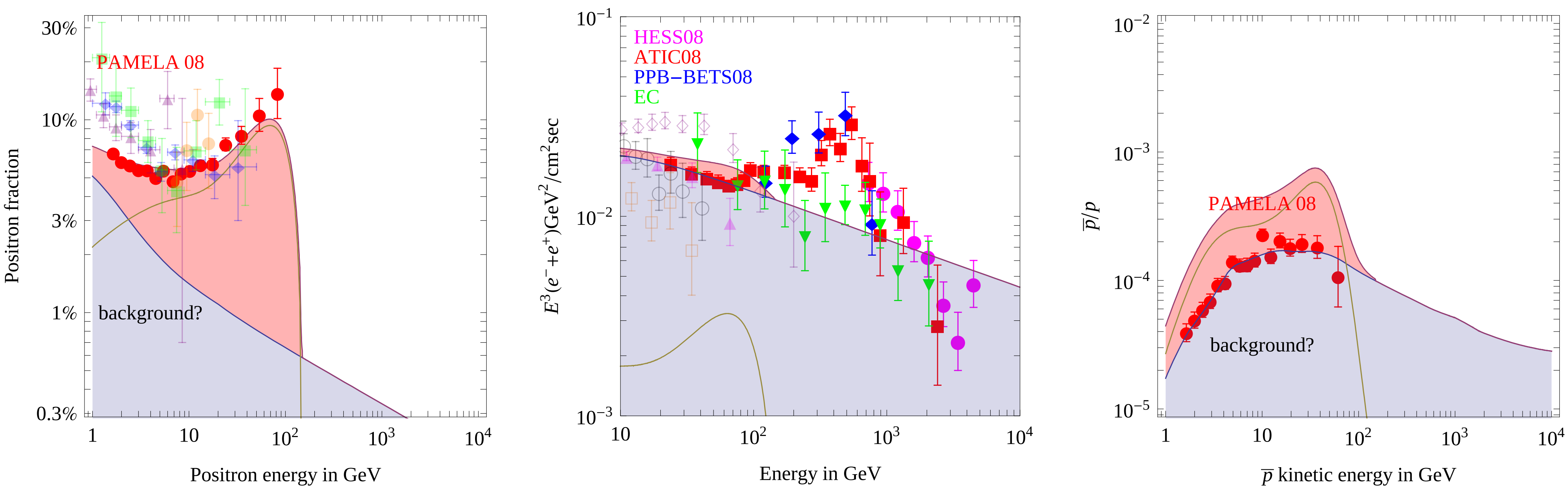
Non thermal DM

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

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

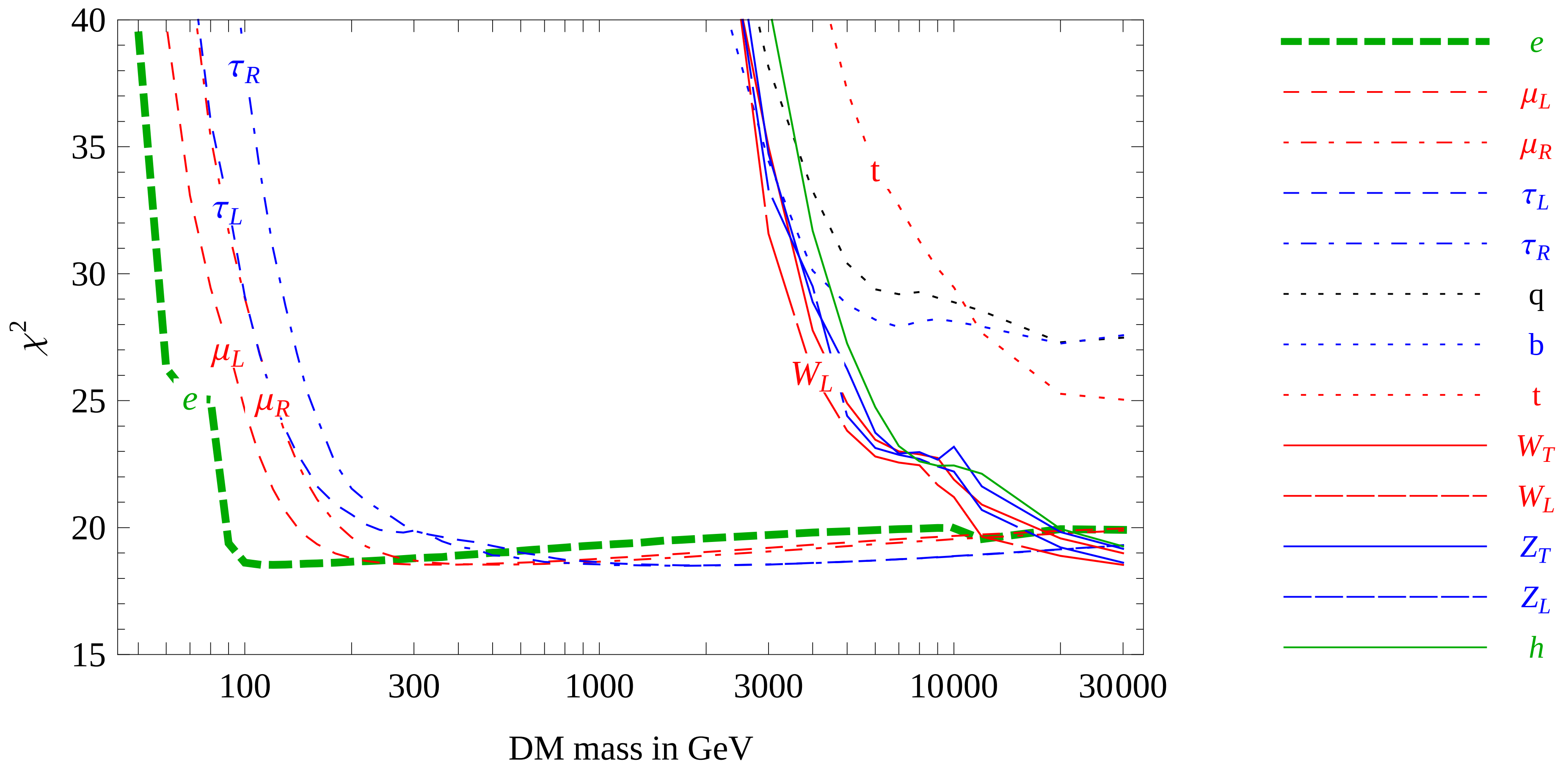
But it contradicts PAMELA $\bar{p}$ data (unless $B_p \ll B_e$ or low L or etc...):

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):



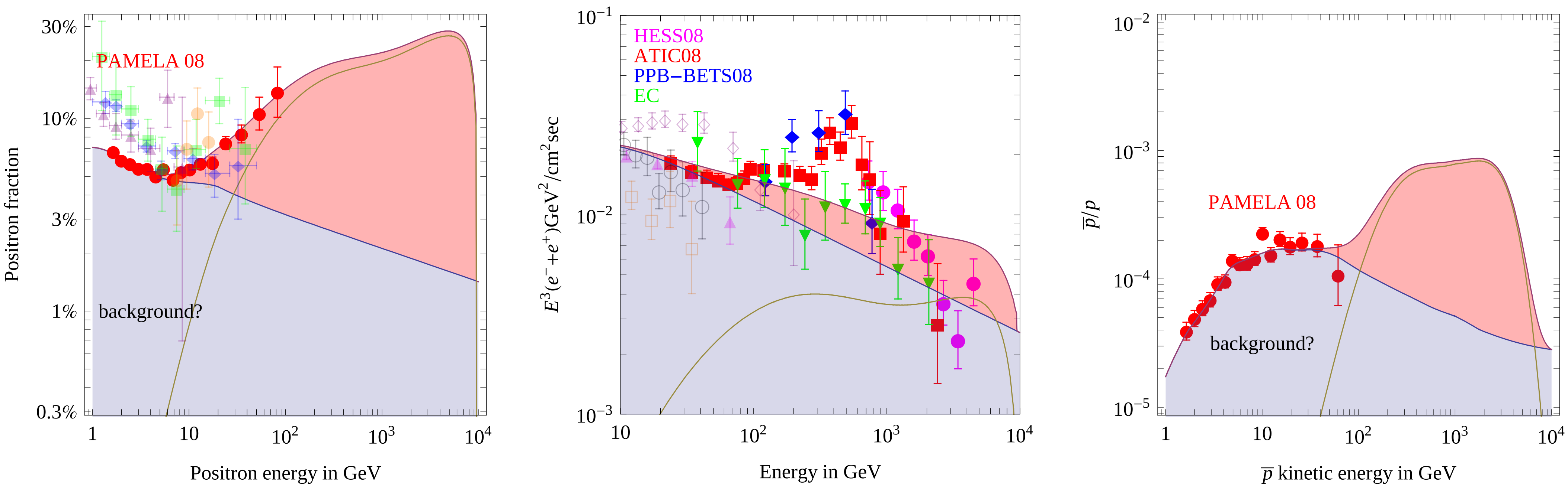
DM must annihilate into leptons or into W, Z with $M \gtrsim$ 10 TeV

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.

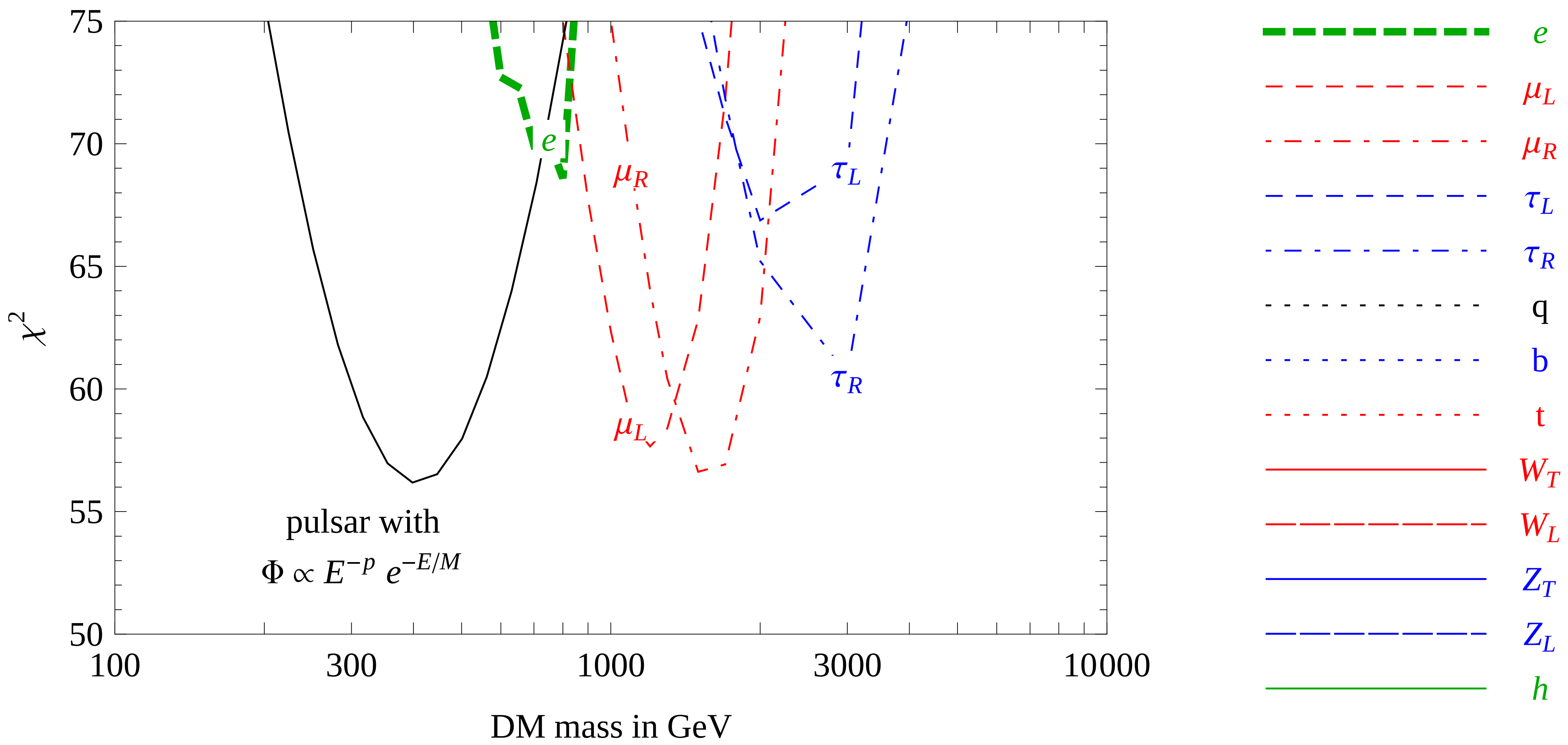
The Minimal Dark Matter 5-plet

MDM predicted: • annihilations into $W_T^+ W_T^-$; • $M = 9.6 \pm 0.2$ TeV, imposing $\Omega_{\rm DM} h^2 \approx 0.11$; • a 10^3 Sommerfeld enhancement; • no ATIC peak.

DM with $M = 10$ TeV that annihilates into W^+W^-



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

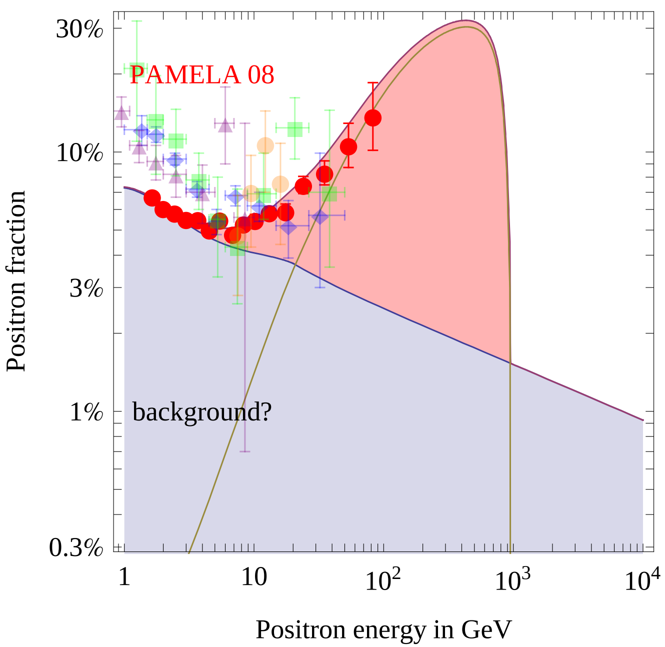


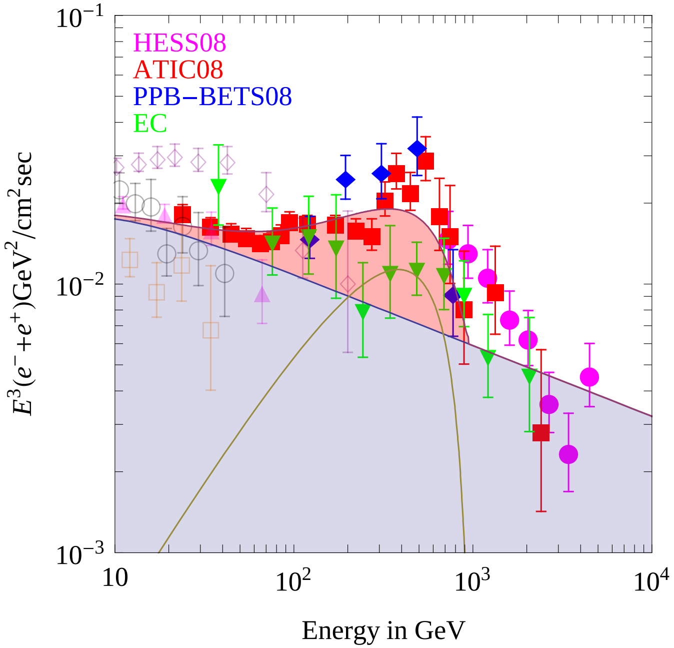
The possible excess in $e^+ + e^-$ around 700 GeV is compatible with the PAMELA excess in e^+ above 10 GeV, if DM annihilates into leptons with TeV mass.

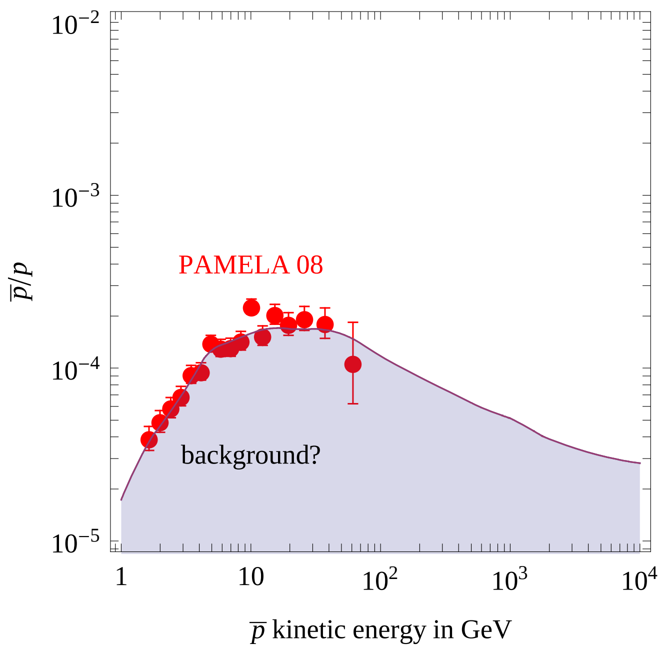
In any case, balloons disfavor/exclude the following PAMELA interpretations:
• DM with mass $M \lesssim$ TeV • DM that annihilates in leptons with $M \gtrsim$ TeV.

Dark Matter identified?

DM with $M = 1$ TeV that annihilates into $\mu^+\mu^-$

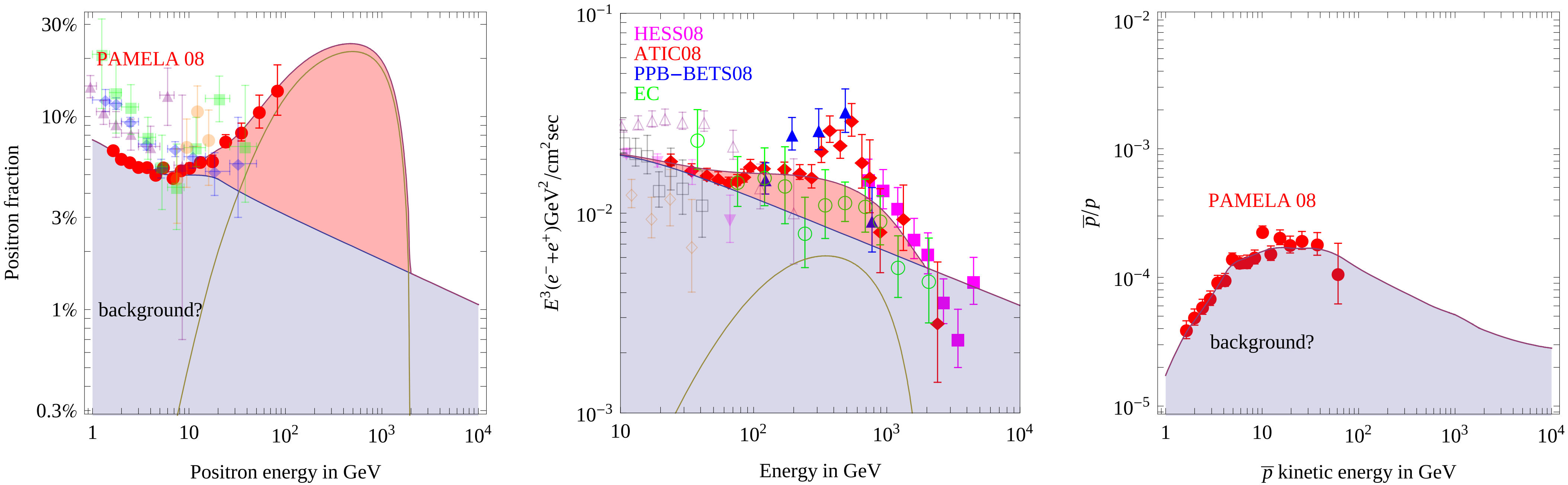






Dark Matter mis-identified?

DM with $M = 2$ TeV that annihilates into $\tau^+\tau^-$



Connection with direct detection

Qualitative connection between $\sigma_{\rm ann} v \sim 3\cdot 10^{-23}\,{\rm cm}^3/{\rm sec}\cdot(M/\,{\rm TeV})^2$ and $\sigma_{\rm dir}$:

i) if DM annihilates into quarks:

$$\sigma_{\rm dir} \sim \frac{m_N^2}{M^2}\frac{\sigma_{\rm ann} v}{B_e S} \sim \frac{10^{-39}\,{\rm cm}^2}{B_e S}$$

(possibly times m_N^2/M^2). The experimental bound is $\sigma_{\rm dir} \gtrsim 10^{-41}\,{\rm cm}^2$.

ii) if DM annihilates into W, Z, h, μ, τ, the connection is model-dependent: as in i) times one or two loop factors $\sim (4\pi)^{-2}$, possibly times M^2/M_W^2. The MDM 5plet predicts $\sigma_{\rm dir} \sim 10^{-44}\,{\rm cm}^2$.

iii) if DM annihilates into and interacts with e (that in atoms reach $p \sim m_e$), the recoil energy is $\Delta E \sim vp$, above threshold in DAMA, but

$$\sigma_{\rm dir} \sim \frac{m_e^2}{M^2}\frac{\sigma_{\rm ann} v}{B_e S} \sim \frac{10^{-45}\,{\rm cm}^2}{B_e S}.$$

is negligibly small.

PAMELA vs SUSY & co

- Fit PAMELA with a neutralino at $M \sim 100\,\text{GeV}$ that annihilates into $e^+e^-\gamma$ thanks to a fine-tuned slepton mass, invoking a huuge boost $B_e \sim 10^6$;

- Unnatural SUSY at 10 TeV with σv enhanced by Sommerfeld;

- Unnatural SUSY at 1 TeV and we are inside/close to a DM clump. (γ?)

- SUSY + ad hoc stable new particles. 2-component DM: one more abundant (small σv) that decays in the other (bigger σv for PAMELA).

- a $\tilde{\nu}_R$ lighter than M_W and with a large Yukawa $\nu_R L H$ annihilates into L;

- DM vectors or fermions suggested by wUED (would be Universal Extra Dimensions) or by LHT (Little Higgs with non-anomalous T-parity) annihilate $\sim 30\%$ into leptons, but $\sim 70\%$ into q, W.

DM models for PAMELA and ATIC

DM is charged under a dark gauge group, to get the Sommerfeld enhancement.

For PAMELA and ATIC. [Cirelli, Kadastik, Raidal, Strumia] proposed that DM as a Dirac fermion with $M \approx 1.5\,\text{TeV}$ and charge $q \approx 2$ under $L_\mu - L_\tau$ (suggested by $\theta_{23} \approx \pi/4$), gauged with $\alpha_V \approx 1/50$ (giving the correct thermal abundance) and mass $M_V \approx M_Z$, giving the $g_\mu - 2$ anomaly + Sommerfeld.

At 1 loop $L_\mu - L_\tau$ mixes with the photon: $\theta \sim e g_V \ln(m_\tau/m_\mu)/6\pi^2 \sim 0.005$. Direct cross section: $\sigma_{\rm SI} = 4\pi q^2 \alpha_V \alpha m_N^2 \theta^2 / M_V^4 \approx 10^{-42}\,\text{cm}^2$

For PAMELA and ATIC and DAMA (?) and INTEGRAL (?). [Arkani-Hamed, Weiner et al.] proposed that **the new vector is light** $M_V \lesssim m_N$ and couples to SM particles only via a mixing with the photon,

$$\theta \sim e g_V \ln(M_{\rm Pl}/M_?)/6\pi^2 \sim 10^{-2\div 3}$$

so that: • V automatically decays into light leptons $e, \mu, \pi^\pm$; • V gives a small $\delta a_\mu \sim \alpha\theta^2 (m_\mu/M_V)^2/\pi \sim 10^{-9}$; V gives a $10^{\sim 6}$ too large elastic $\sigma_{\rm SI}$. **If the DM gauge group is non abelian**, DM has multiple components with 100 keV ($\stackrel{?}{\sim} \alpha_V M_V$) mass splittings, one can instead get an **inelastic** $\sigma_{\rm dir}$ that can explain DAMA (but $M = 1\,\text{TeV}$ is too heavy?)

3

Bounds from photon indirect detection

Photons from DM

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

- γ from brehmstralung.

- $e^\pm$ synchrotron in the galactic magnetic fit.

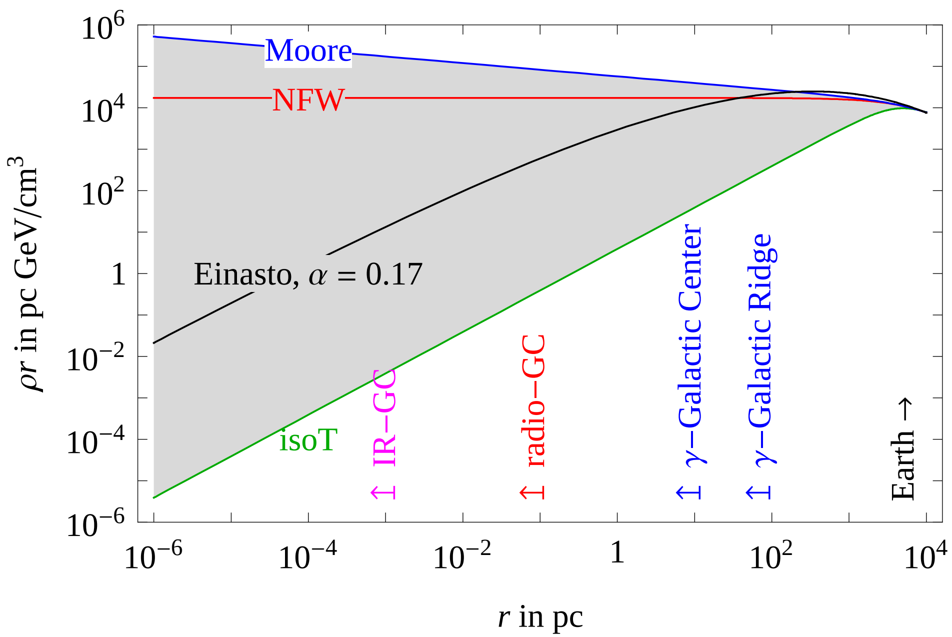
- γ from $e^\pm$ scatterings on star-light

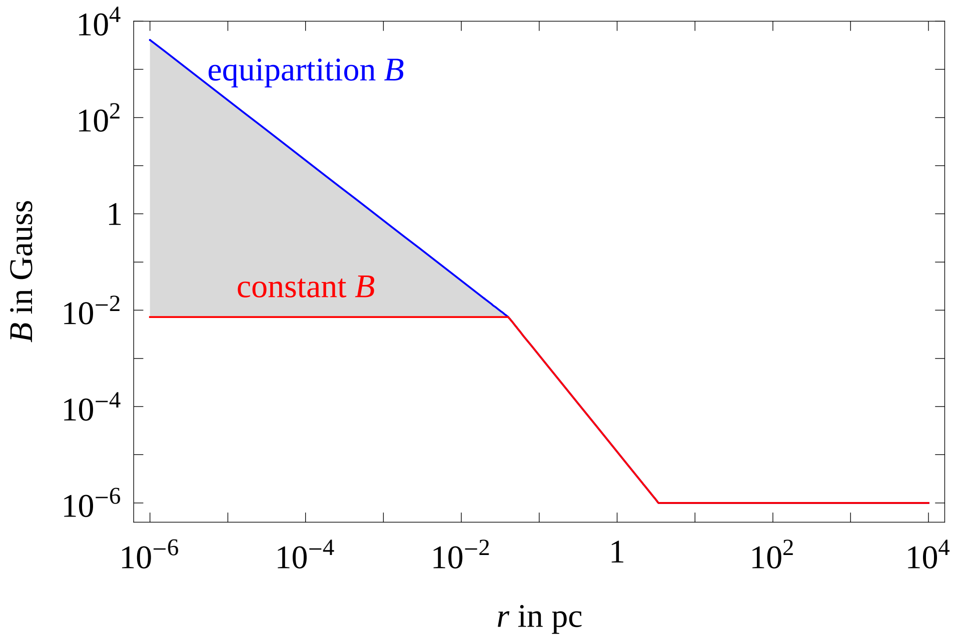
γ from brehmstralung in DM annihilations

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

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

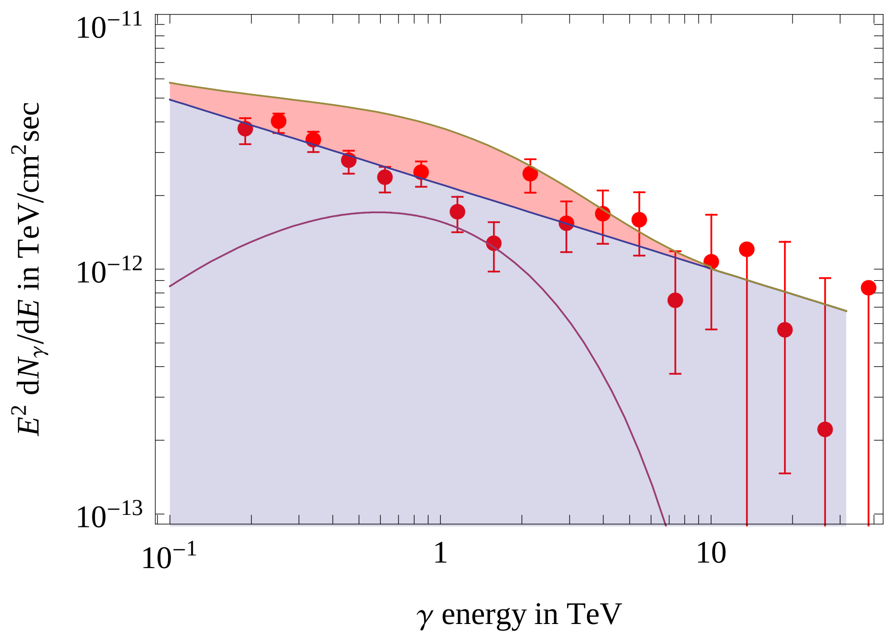
NFW	Einasto	isoT/cored	region	$\Delta\Omega$
14700	7600	14	Galactic Center	$1\cdot 10^{-5}$
2400	3000	14	Galactic Ridge	$3\cdot 10^{-4}$
1000	–	140	Sagittarius dSph	$2\cdot 10^{-5}$



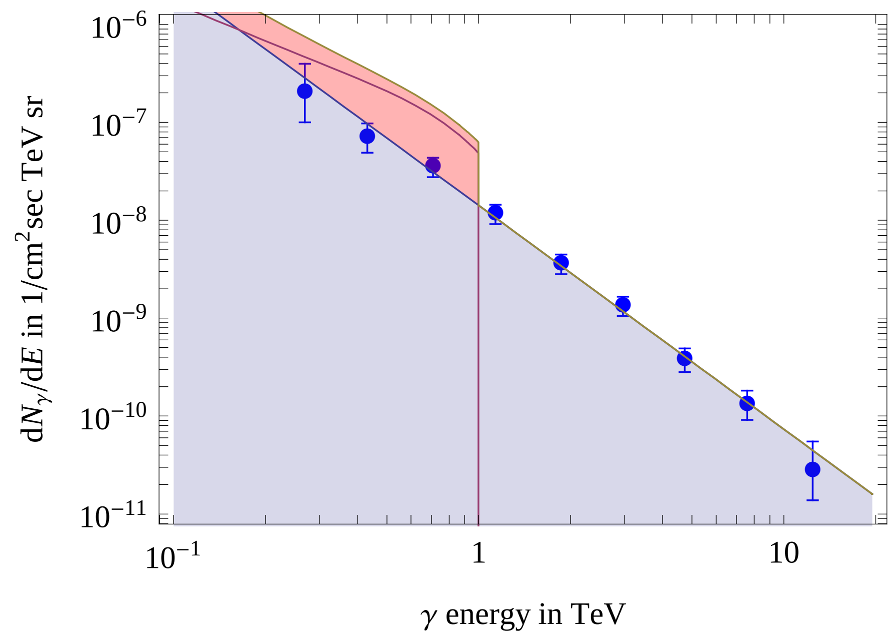


The HESS observations

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



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



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

Another bound from the DM-dominated Sagittarius dwarf spheroidal galaxy at 24 kpc from us, that was observed by HESS for 11h finding no γ excess.

Radio observations

Around the GC magnetic fields B contain more energy than light, diffusion and advection seem negligible, so 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:

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

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

ν observations

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

$$\Phi_\mu \overset{?}{=} \frac{r_\odot}{8\pi}\frac{\rho_\odot^2}{M^2}\frac{3G_\mathsf{F}^2 M^2 p}{2\pi\alpha_\mu} \times J \cdot \Delta\Omega \cdot \int_0^1 dx \; x^2 \frac{dN_\nu}{dx}$$

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

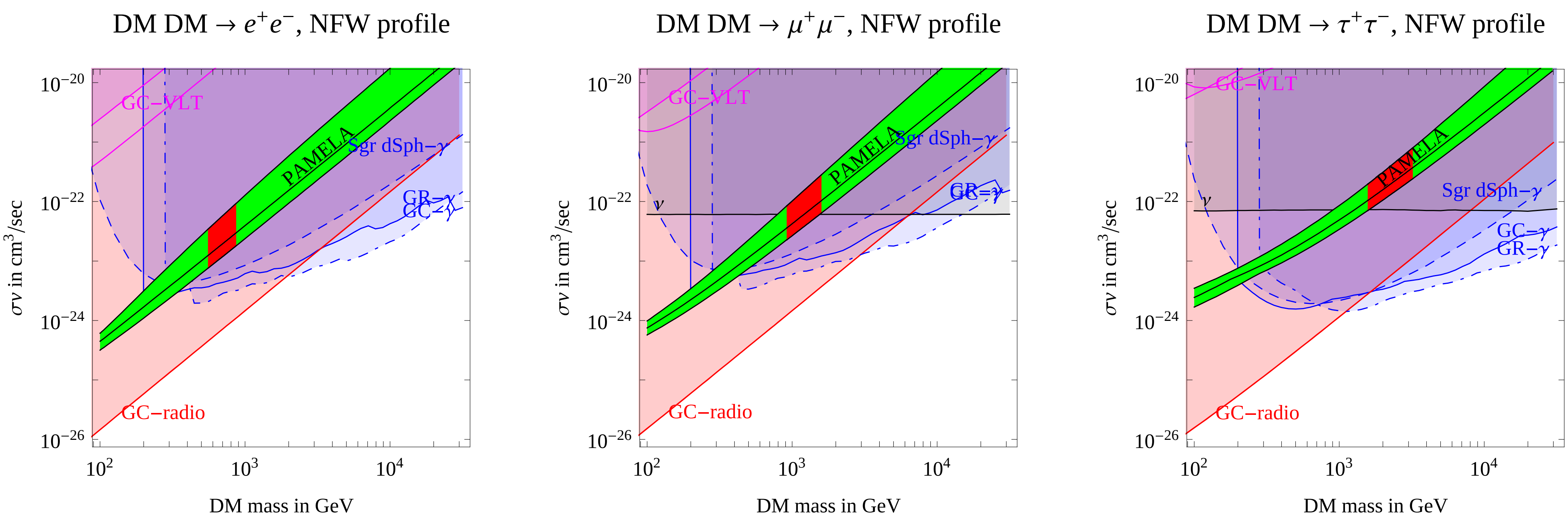
The total $\mu^\pm$ rate negligibly depends on the DM mass M.

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

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

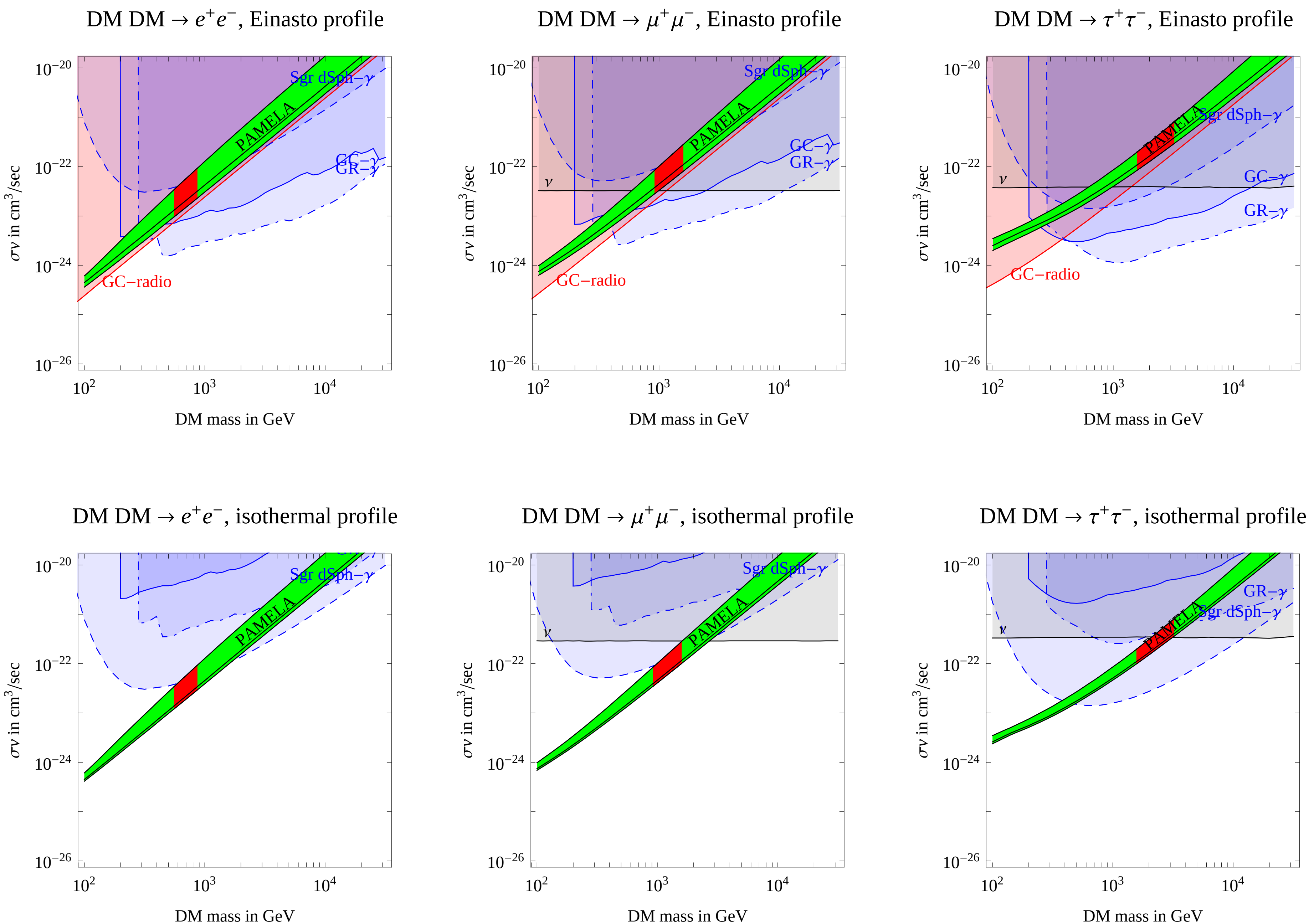
The photon bounds

Assuming NFW, **conservative** bounds from HESS γ observations of the Galactic Center, Galactic Ridge, Sagittarius Dwarf and from radio observations of the GC exclude the green (region allowed by PAMELA) and red bands (ATIC):



Way out: Sommerfeld $\times$ boosts can enhance GC γ less than $e^{\pm}$?

An isotheramal profile is ok

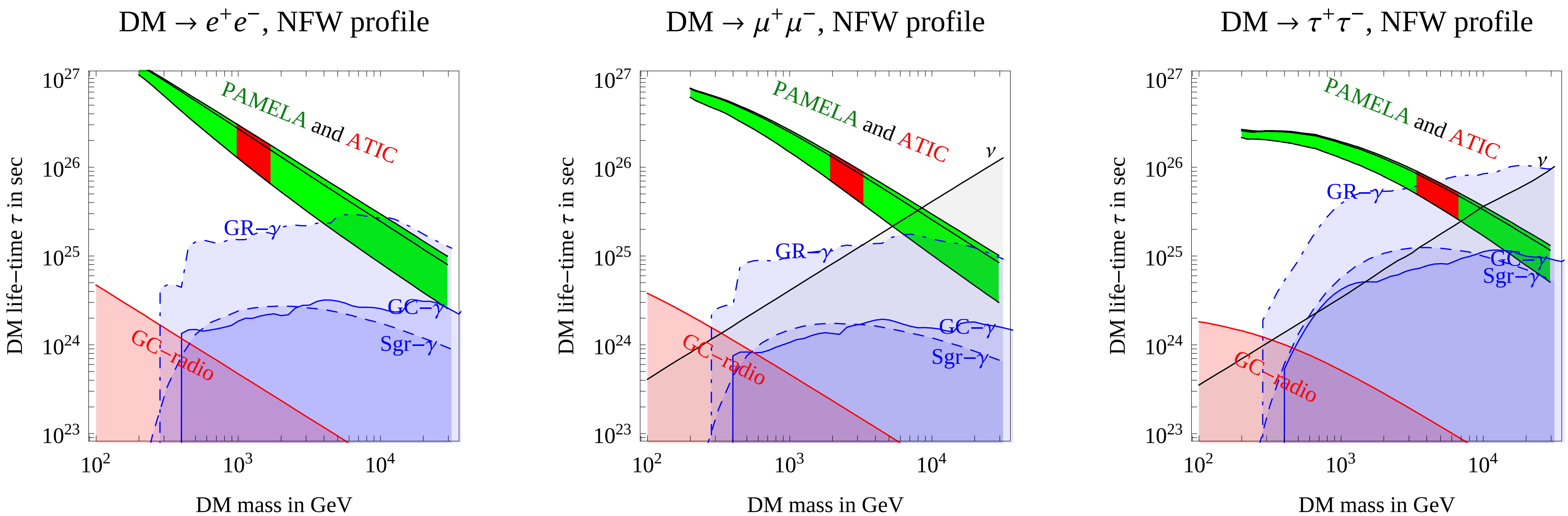


4

DM decays

DM decays are compatible with NFW

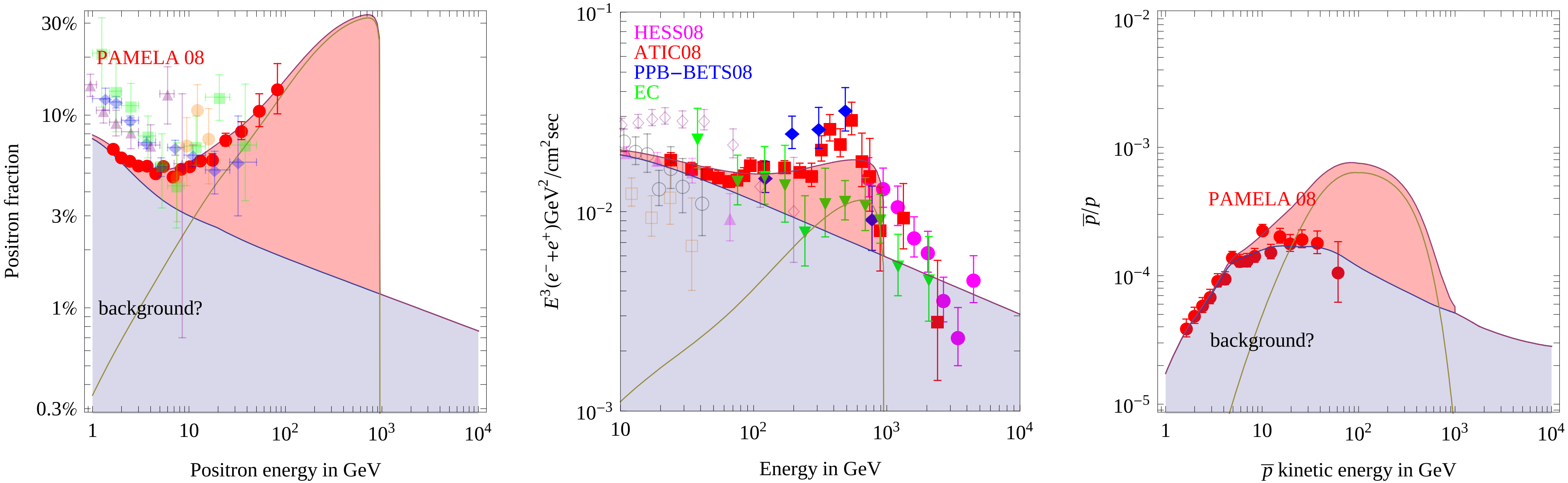
If instead DM **decays** with life-time τ, replace $\rho^2\sigma v/2M^2 \to \rho^1/M\tau$:



PAMELA/ATIC are allowed with all profiles and testable by GR observations

Fermion DM $\to W^{\pm}\ell^{\mp}$

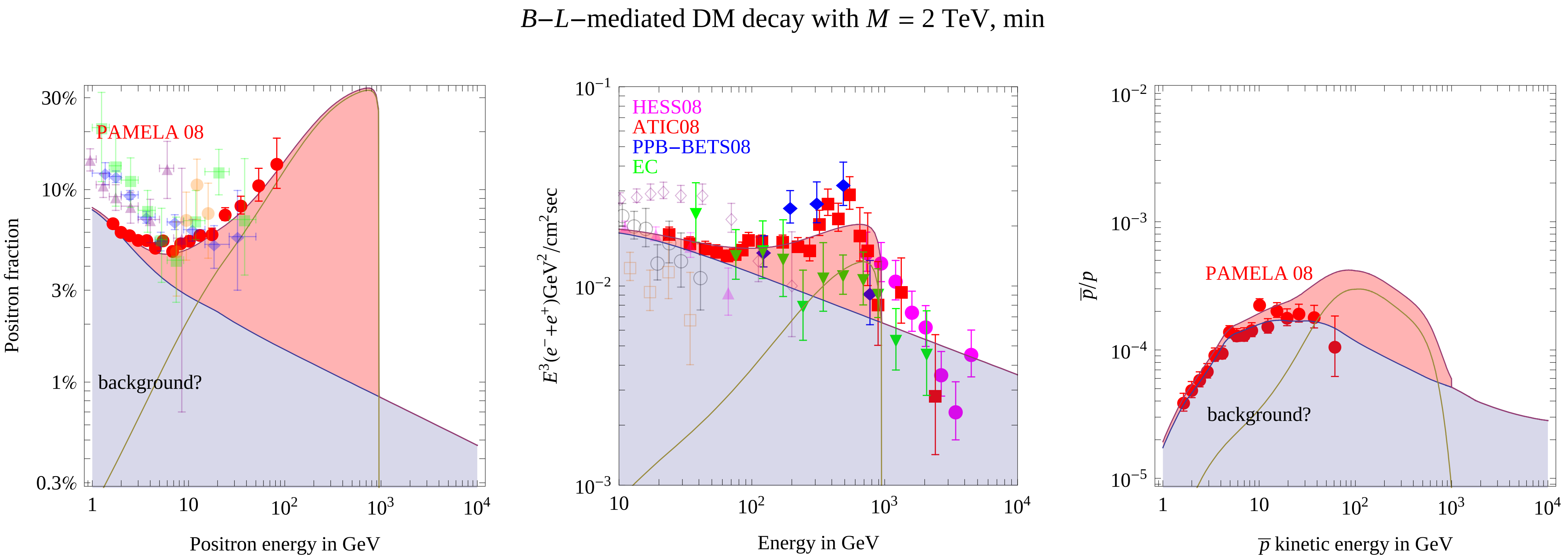
DM with $M = 2$ TeV that decays into $W^{\pm}\ell^{\mp}$



Too much $\bar{p}$

$B-L$-mediated DM $\to f\bar{f}$

BR in $\ell^+\ell^-$ 3 times higher than BR into $q\bar{q}$:



Too much $\bar{p}$ even for min?

ATIC suggests SU(2) technicolor!?

ATIC as DM decays needs $M \sim 2\,\text{TeV}$, which naturally implies the observed

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

if the DM density is due to a baryon-like asymmetry kept in thermal equilibrium by weak sphalerons down to $T_{\rm dec} \sim 200\,\text{GeV}$: $\rho_{\rm DM}/\rho_b \sim 5$ if $M \approx 9T_{\rm dec} \sim 2\,\text{TeV}$

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

- 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/ATIC excesses might be due to pulsars or to DM:

- if the ATIC peak is true: DM as 1 TeV WIMP that annihilates into e, μ, τ;
- if not: a 10 TeV WIMP that annihilates into W, Z, h as predicted by MDM;
- $M \sim 100$ GeV seems disfavored/excluded by $\bar{p}$ and/or $e^+ + e^-$ data.
- Photon bounds might disfavor DM annihilations and hint to DM decays.

This can soon be tested by new experimental results:

- **The e^+ fraction at higher energies continues to grow?**
  PAMELA09 up to 270GeV? Later AMS.

- **Is an excess present in $\bar{p}$ at higher energies?**
  One more data-point from PAMELA09? Later AMS up to 1 TeV?

- **Is the $e^+ + e^-$ ATIC peak really there?**
  ATIC-4 and Fermi with its LAT calorimeter in space already have data.