Alessandro Strumia, talk at Planck 2008

about the univocal **pre**dictions of Minimal Dark Matter: DM is an automatically stable weak 5plet with $M = 9.6$ TeV that gives a detectable cosmic ray positron excess thanks to Sommerfeld-enhanced annihilations into W^+W^-...:

page 35 of `http://www.ifae.es/planck2008/21-05_beta/Strumia.pdf`

Later seen by PAMELA, excluded by ATIC, which is now excluded by FERMI...

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 Planck 2009
From arXiv:0809.2409, 0811.3744, 0811.4153, 0905.0480 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

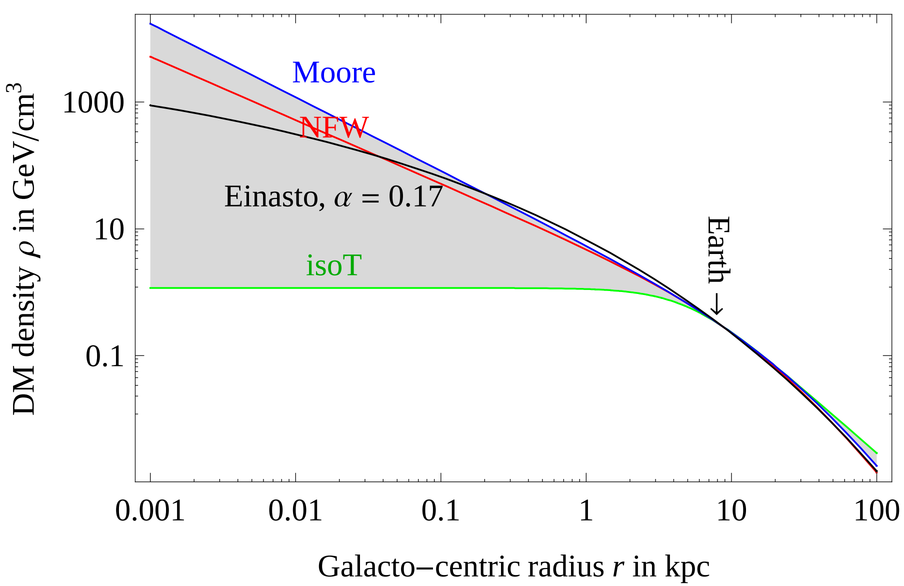
DM velocity: $\beta \approx 10^{-3}$. DM is spherically distributed with uncertain profile:

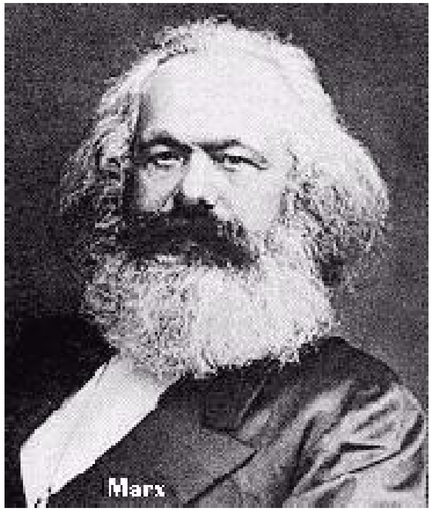
$$\rho(r) = \rho_\odot \left[\frac{r_\odot}{r}\right]^\gamma \left[\frac{1 + (r_\odot/r_s)^\alpha}{1 + (r/r_s)^\alpha}\right]^{(\beta-\gamma)/\alpha}$$

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

$\rho(r)$ 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 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

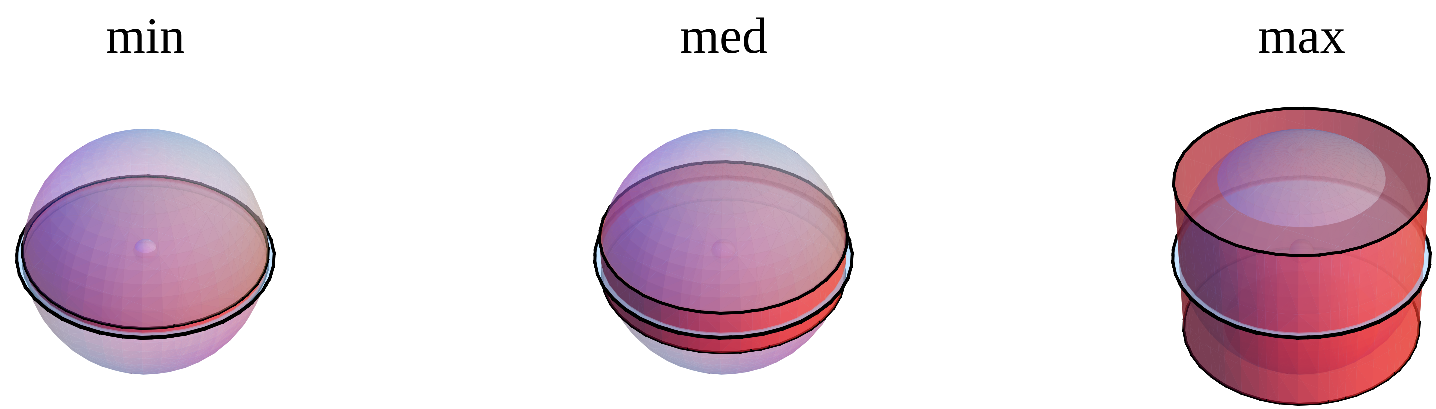
Simulations neglect normal matter, that locally is comparable to DM.

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: $K(E) = K_0(E/\,\mathrm{GeV})^{\delta} \sim R_{\rm Larmor} = E/eB$.
- **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	$V_{\rm conv}$ 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



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 $\bar{p}$.

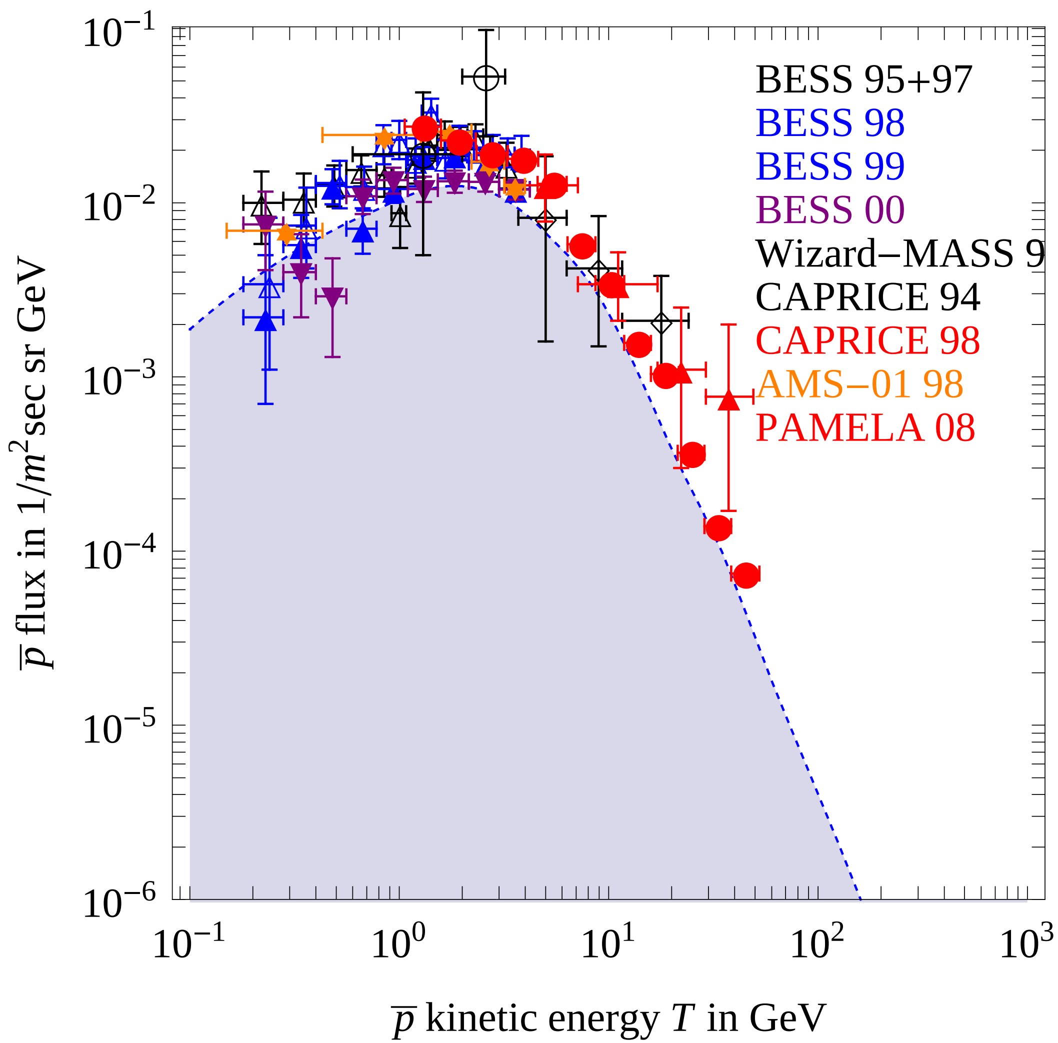
Experimentalists need to bring above the atmosphere (with balloons or satellites) a spectrometer and/or calorimeter, able of rejecting e^- and p.

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

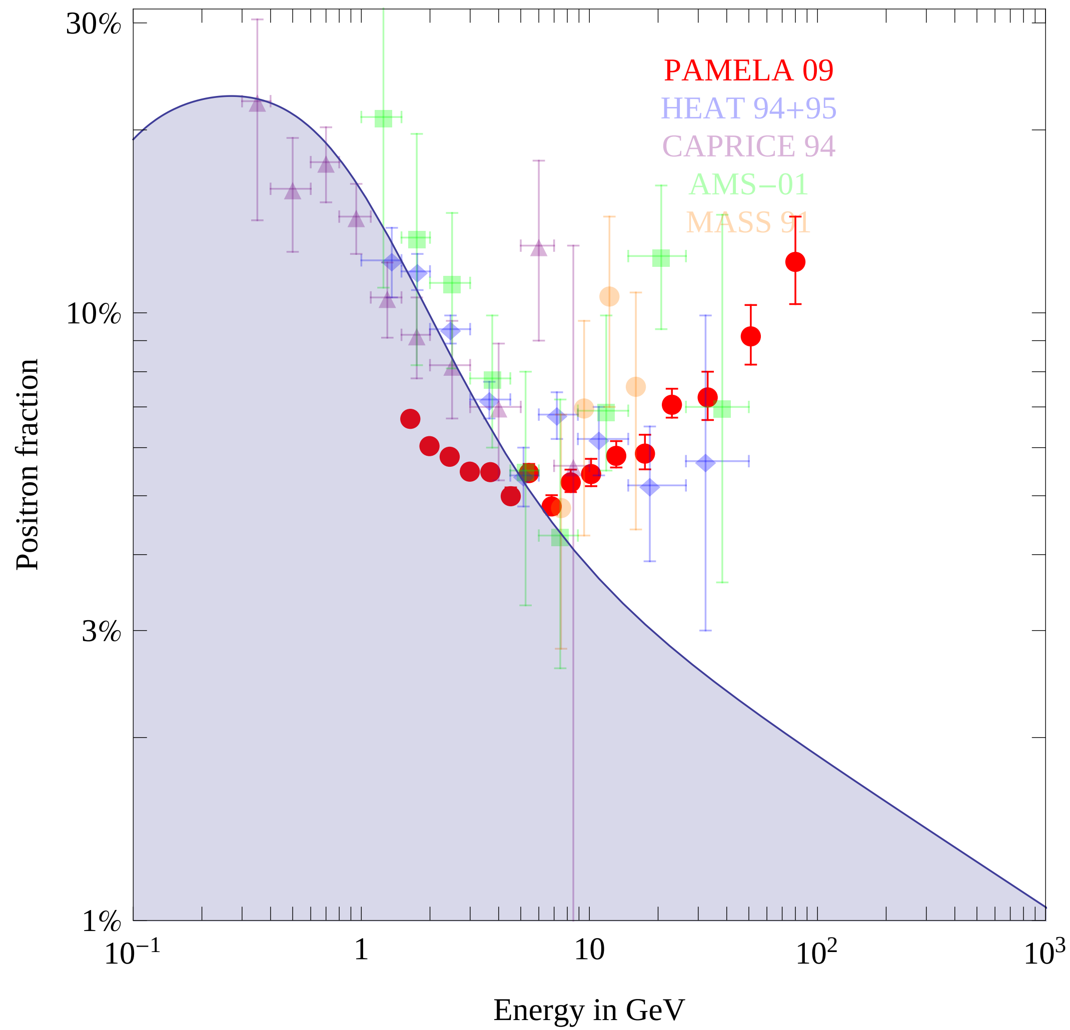


Future: PAMELA, AMS

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

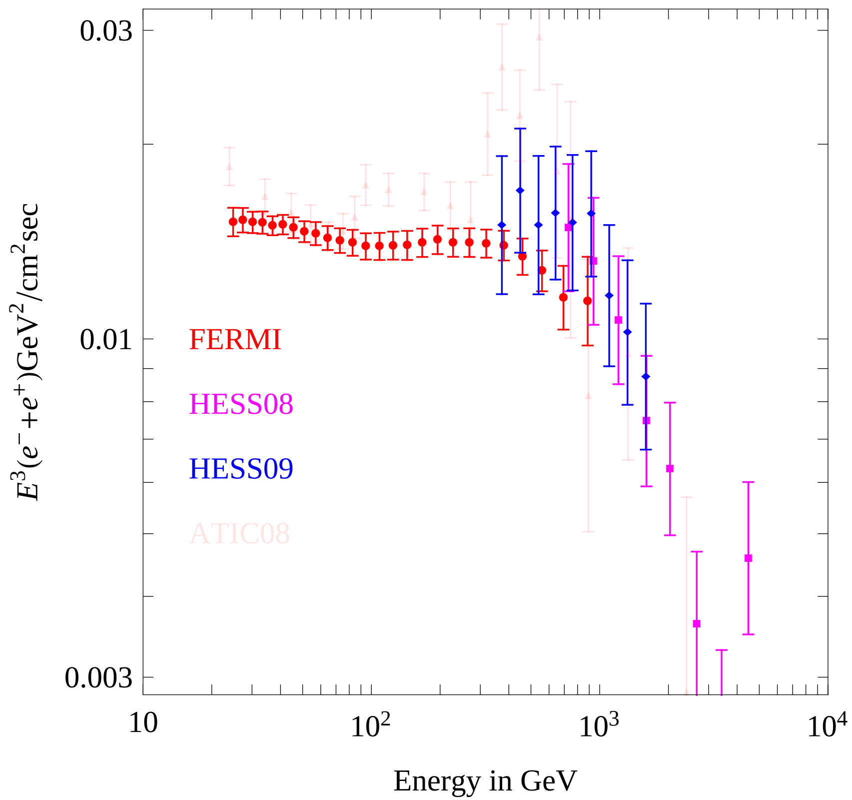
Growing excess above 10 GeV



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 and HESS

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



Hardening at 100 GeV + softening at 1 TeV

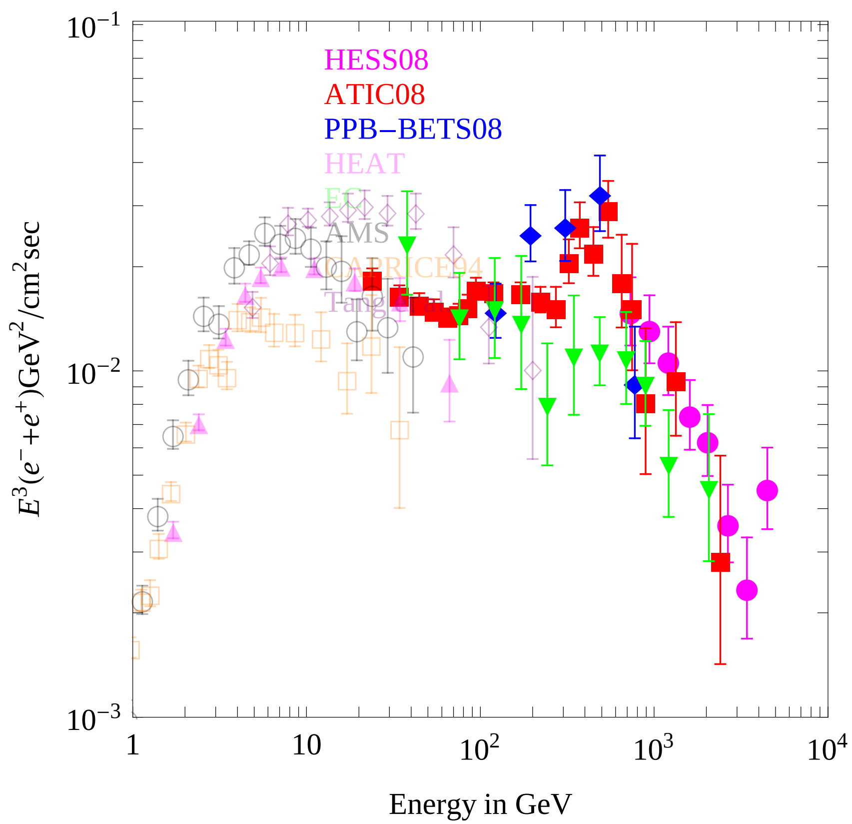
Are these real features? Likely yes.

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

(ATIC)

Peak at 800 GeV?

In arXiv:0809.2409 we proposed that the large e^+ excess could be seen also in $e^+ + e^-$ and found the ATIC anomaly on web sites of past minor conferences. ATIC was later published on Nature, and the topic attracted attention.
FERMI now finds that ATIC is wrong.
The FERMI paper was accepted in 3 days by PRL: a unpaid referee cannot validate an expensive experiment.
Why do pay (attention to) journals?



... 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 $e^\pm$: $\epsilon \sim 0.3$.

Tests: • γ (but beamed? still alive?); • angular anisotropies (but local B?);

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

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

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**. 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

- $\mathscr{D}$ 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

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

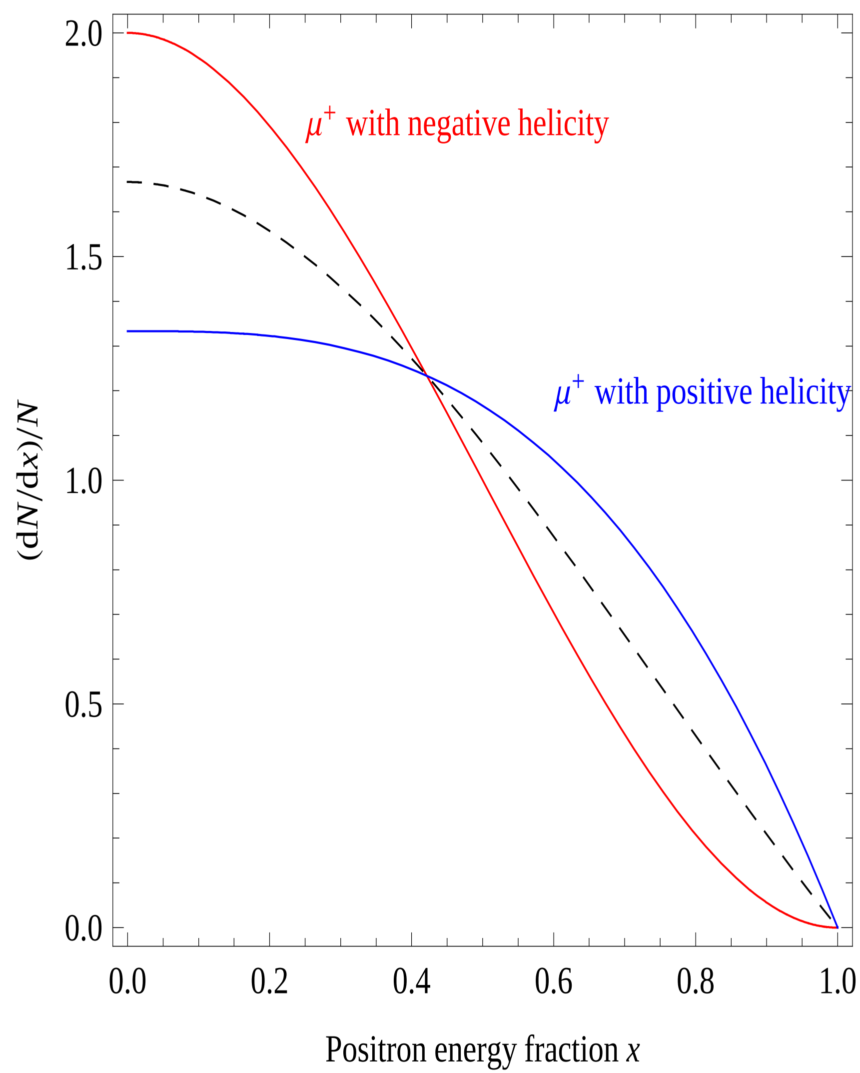
or

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

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

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

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



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

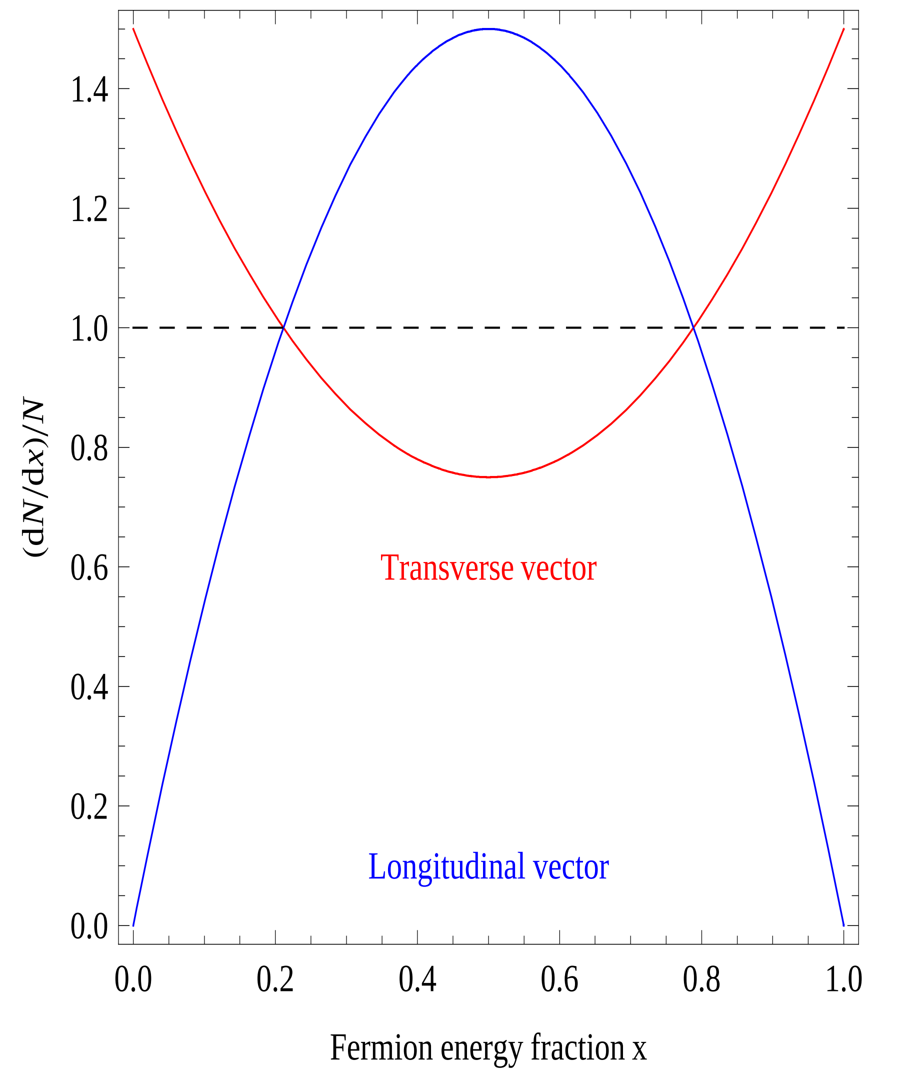
$$dN/d\cos\theta = 3(1+\cos^2\theta)/8$$

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

- $\mathscr{D} A_\mu^2$ 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 $m_h = 115\,\text{GeV}$, so h decays mostly into $b\bar{b}$.

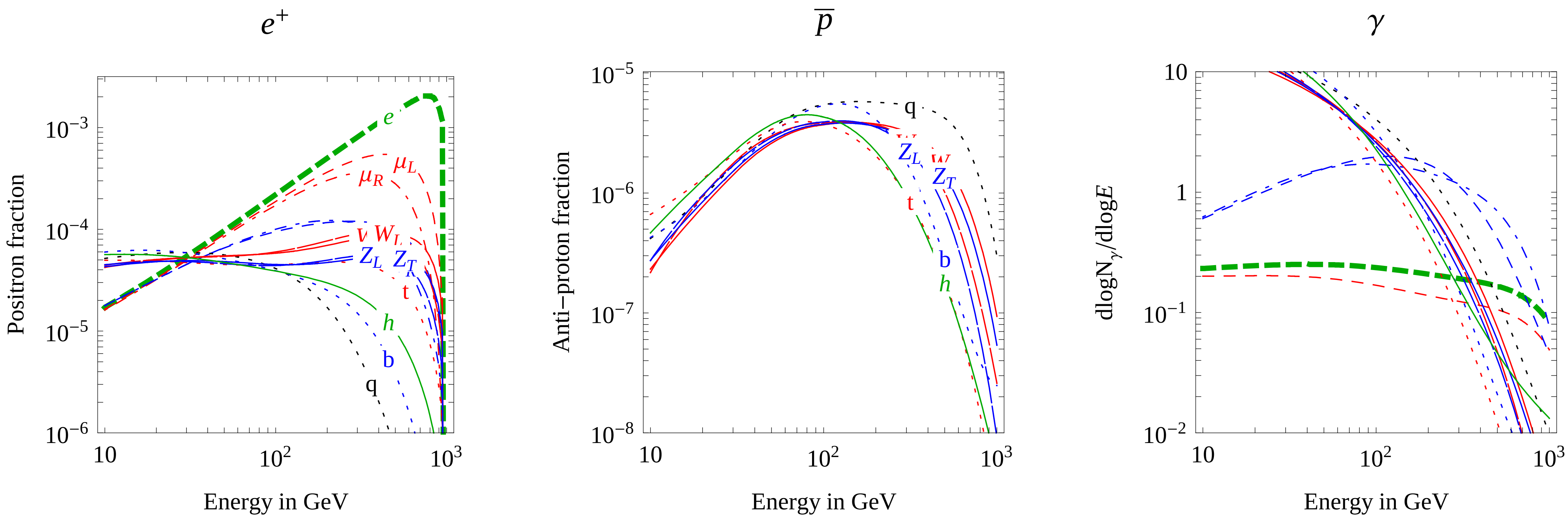
DM annihilations into Zh will not be considered, as they are are essentially given by the average of the $Z_L Z_L$ and hh channels.

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** 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.

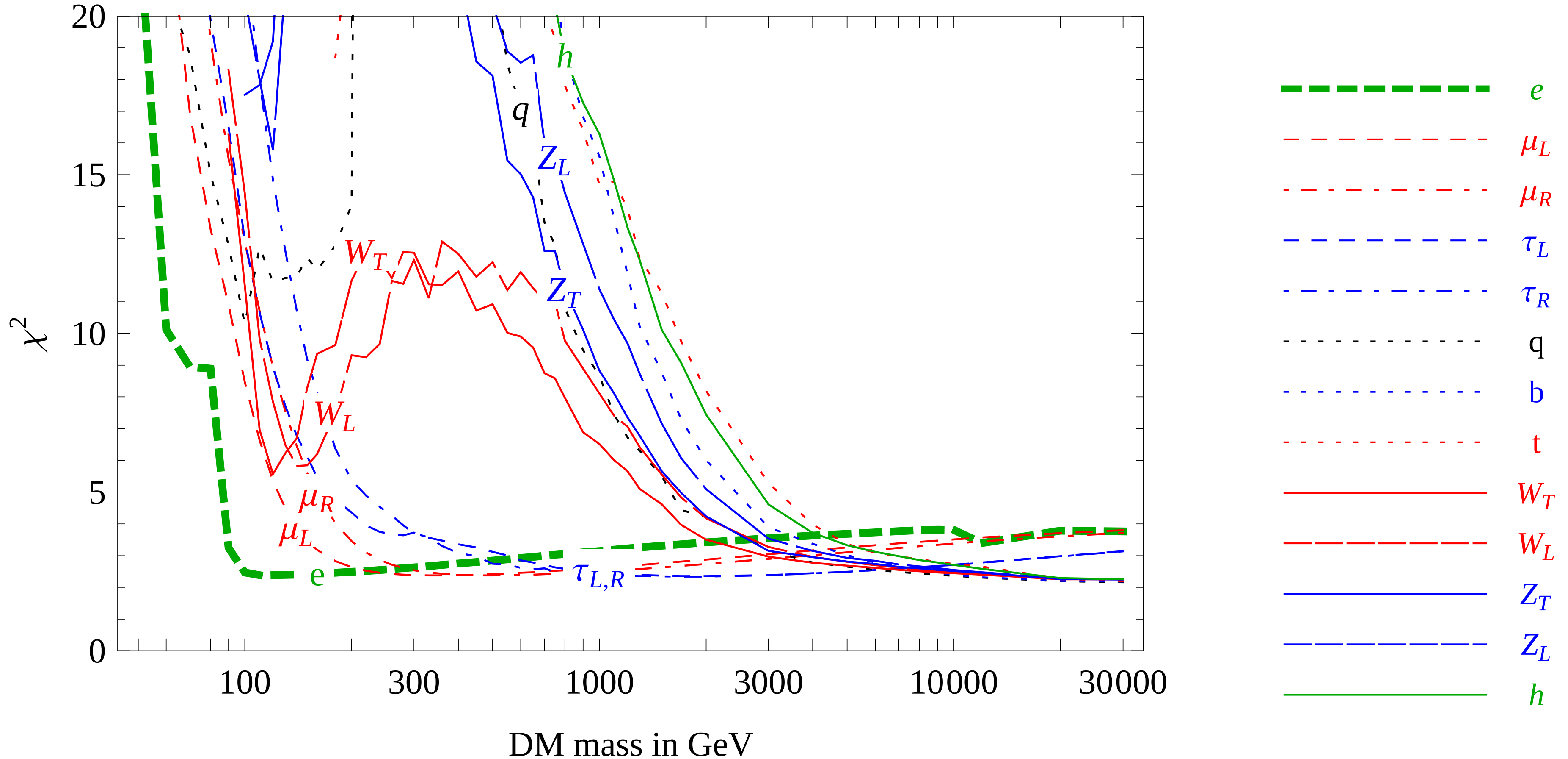
- **solar modulation** as uncorrelated uncertainty below 20 GeV: $\pm$6% at 10 GeV, $\pm$30% at 1 GeV.

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

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

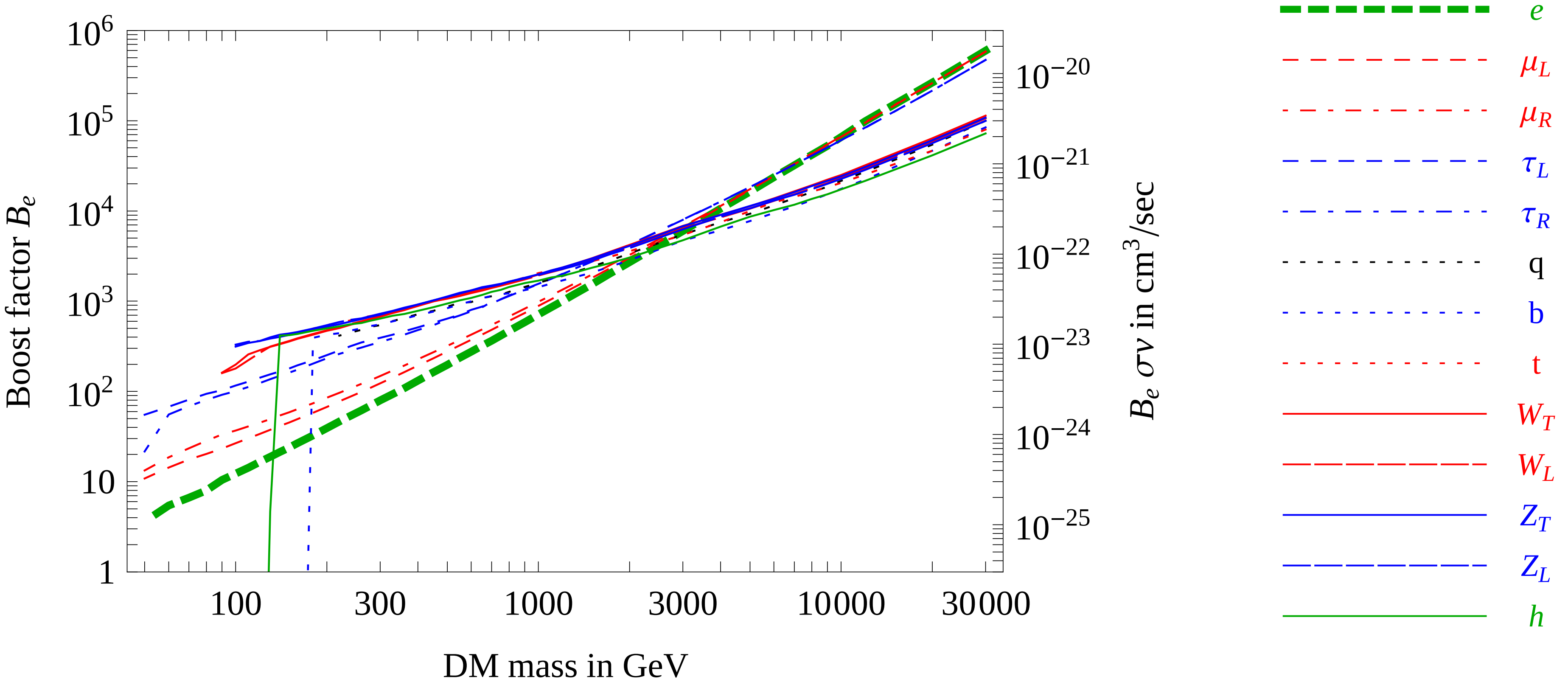
- Statistical techniques: as reviewed in appendix B of hep-ph/0606054.

Fitting PAMELA positron data



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

The σv needed for PAMELA



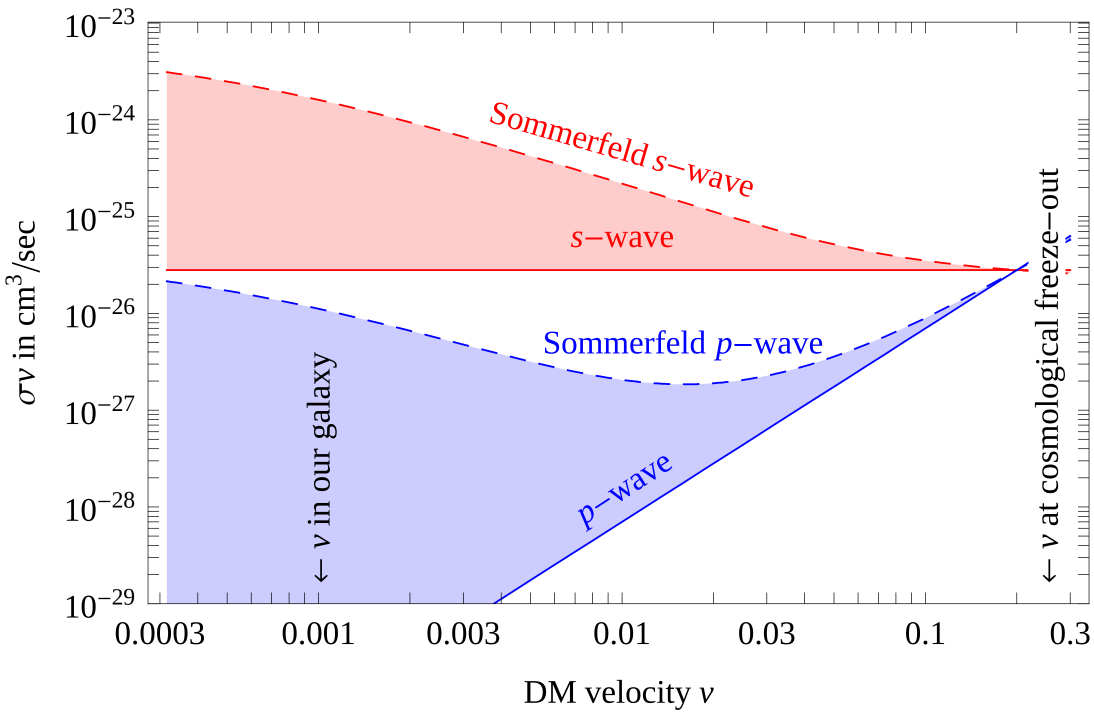
σv larger than what suggested by cosmology by a factor B_e

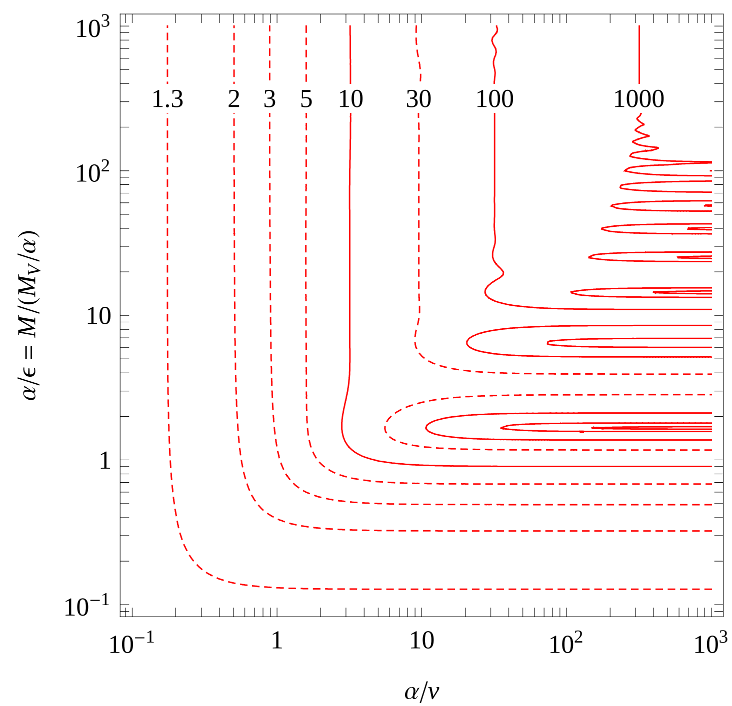
The cosmological σv

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

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

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)

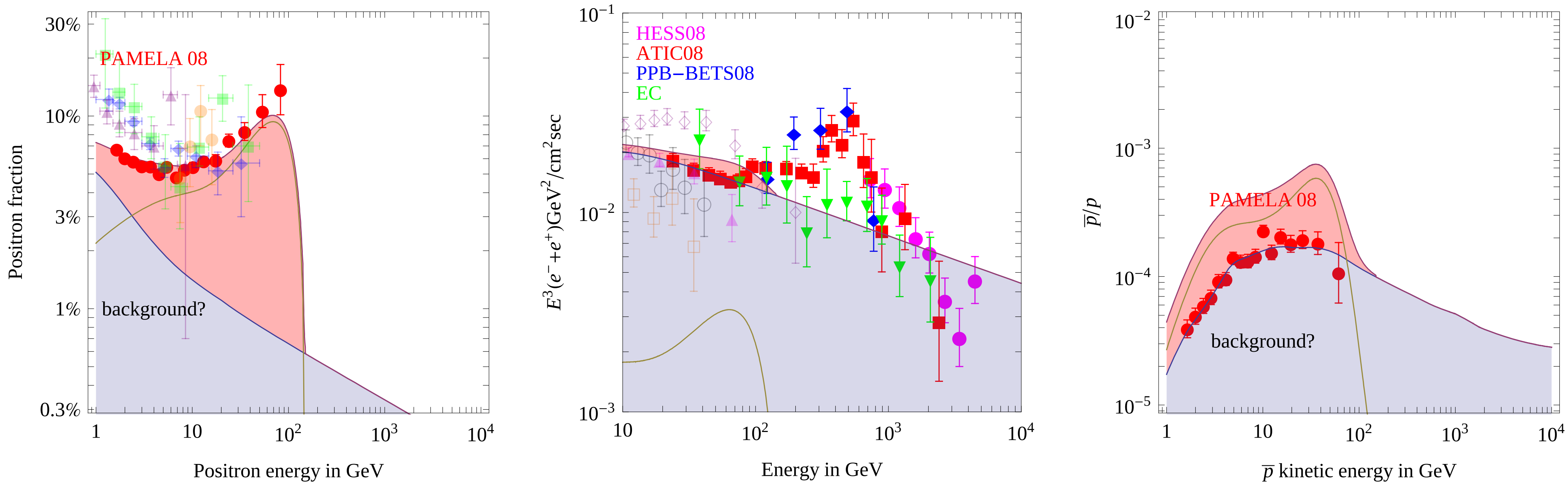
Non thermal DM

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

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

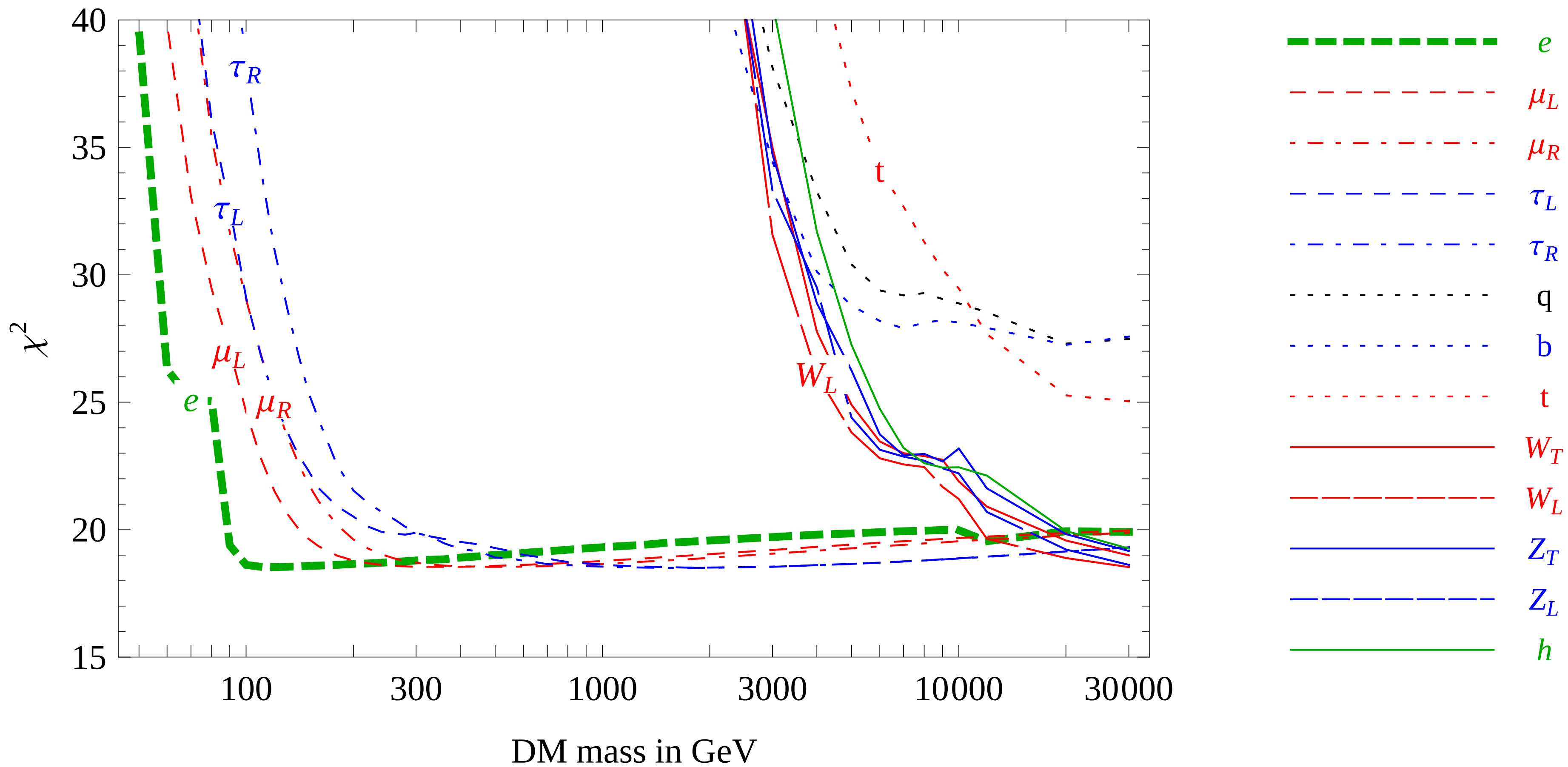
But it contradicts PAMELA $\bar{p}$ data (unless $B_p \ll B_e$ or low L or etc...):

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



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

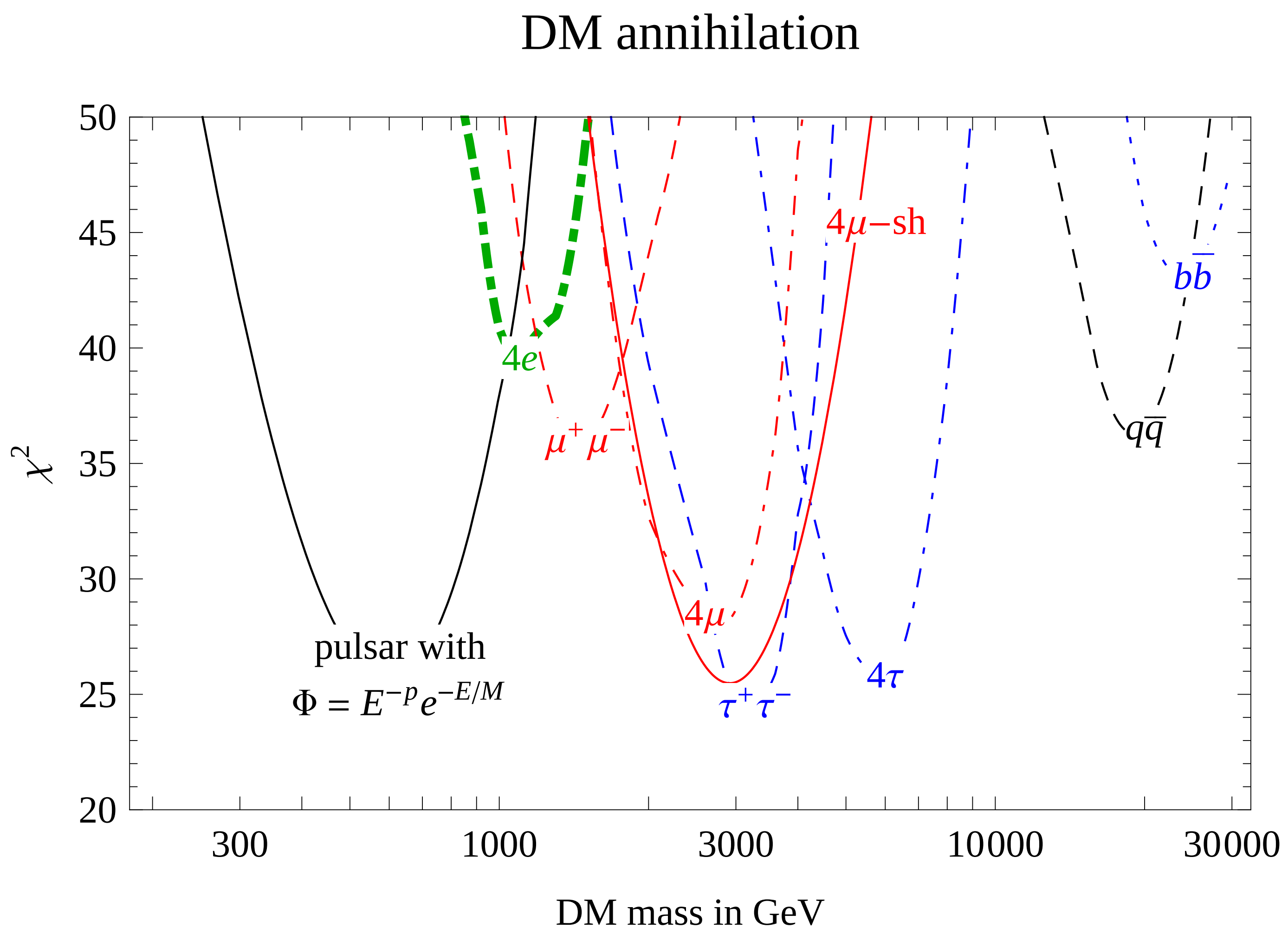
Assuming equal boost & propagation for e^+ and $\bar{p}$ (otherwise everything goes):



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 $M > 10\,\text{TeV}$.

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

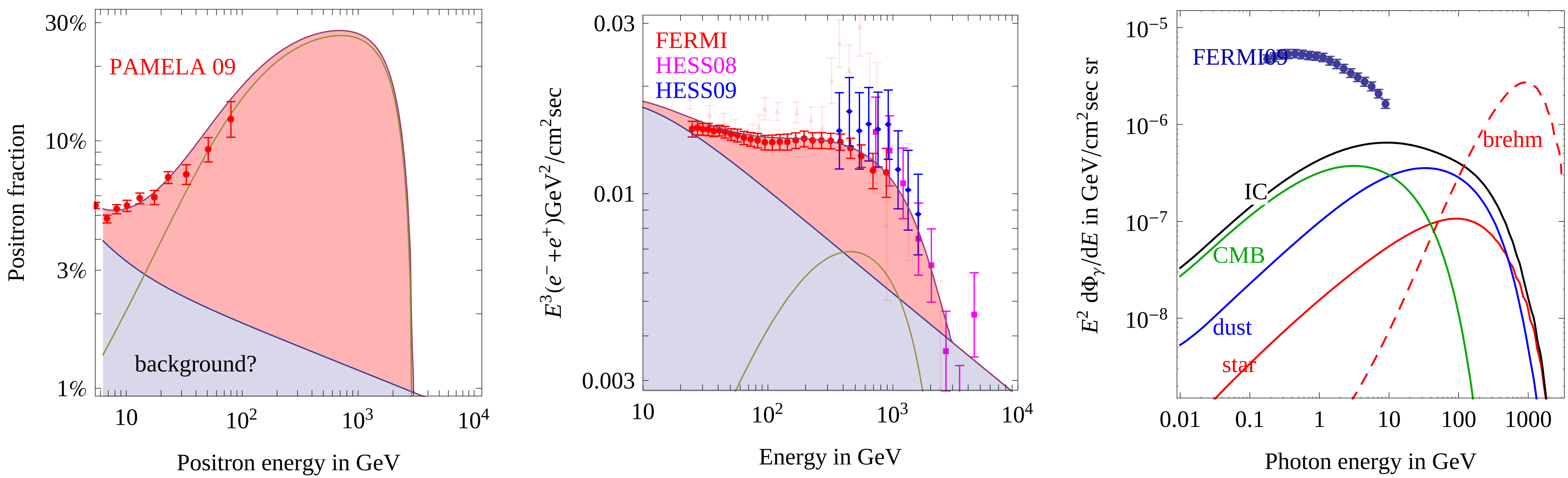


Compatible if DM has TeV mass and annihilates into some leptons.

FERMI excludes that PAMELA is due to a DM lighter than about 1 TeV.

Dark Matter identified?

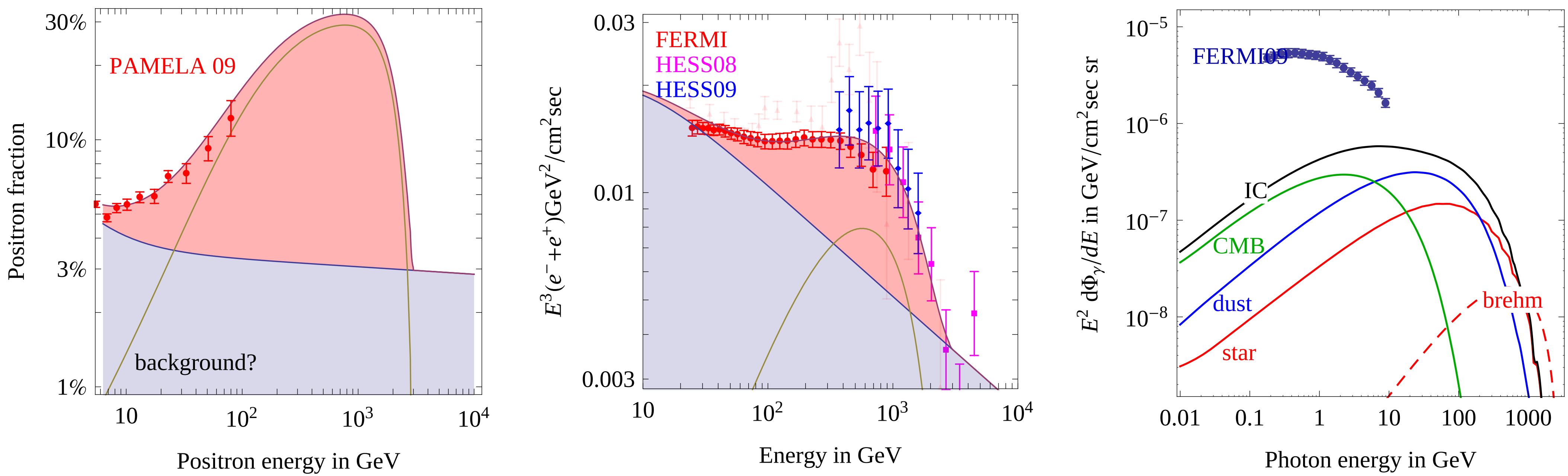
DM with $M = 3.$ TeV that annihilates into $\tau^+\tau^-$ with $\sigma v = 1.9 \times 10^{-22}$ cm^3/s



(The CDF μ anomaly motivates a hidden-sector that decays into $\tau^+\tau^-$)

New Dark Matter models

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



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 many TeV with σv enhanced by Sommerfeld;

- SUSY + ad hoc stable new particles. E.g. 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 FERMI

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

For PAMELA. [Cirelli, Kadastik, Raidal, Strumia] proposed that DM as a Dirac fermion with $M \approx 2\,\text{TeV}$ 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, ATIC (×), DAMA (?), INTEGRAL (×?) and EGRET (×?). [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 ($\overset{?}{\sim} \alpha_V M_V$) 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 γ, ν indirect detection

Photons from DM

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

- **Brehmstralung** from $\ell^\pm$ (if $\ell = \tau$ also $\tau \to \pi^0 \to \gamma\gamma$).
  Largest $E_\gamma \sim M_{\rm DM}$, probed by HESS.

- **Inverse Compton**: $e^\pm\gamma \to e^\pm\gamma'$ scatterings on CMB and star-light: $\dot{E} \propto u_\gamma$.
  Intermediate $E_{\gamma'} \sim E_\gamma (E_e/m_e)^2 \sim 10\,\text{GeV}$ probed by FERMI.

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

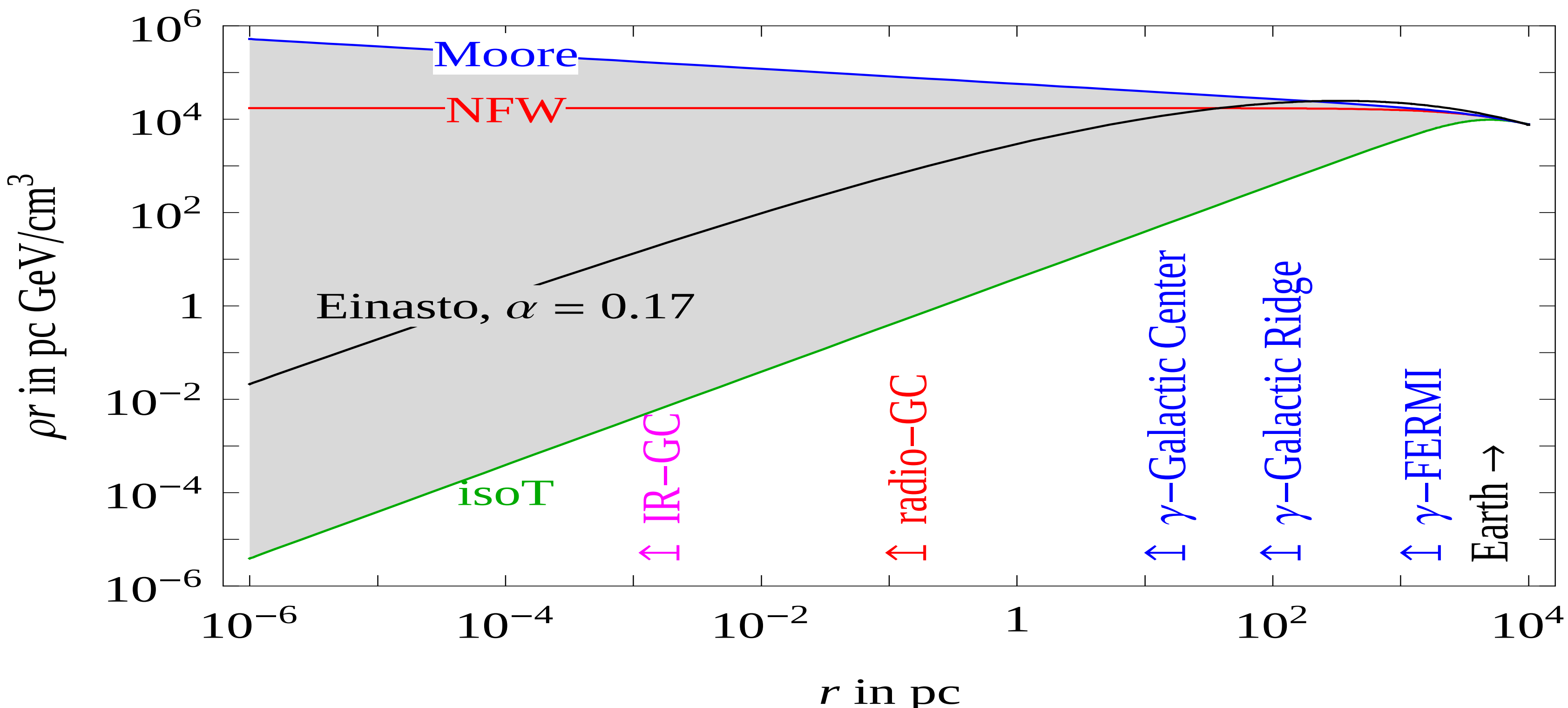
Problem: γ point to their source, and it is unclear which one is better for DM.
Solution: astrophysicists anyhow like to observe astrophysical backgrounds.

γ from brehmstralung

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

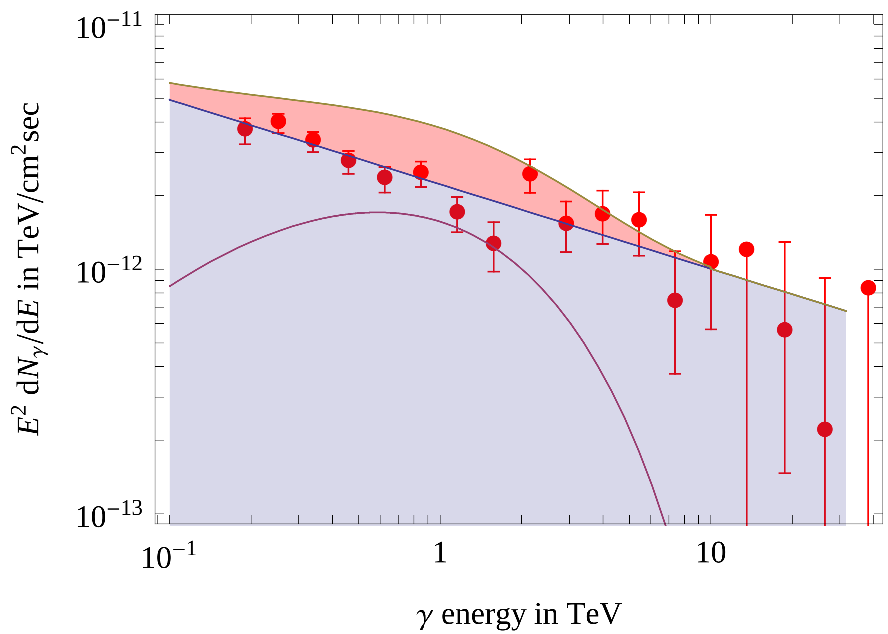
$\langle J \rangle_{\Delta\Omega} =$

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	$2 \cdot 10^{-5}$

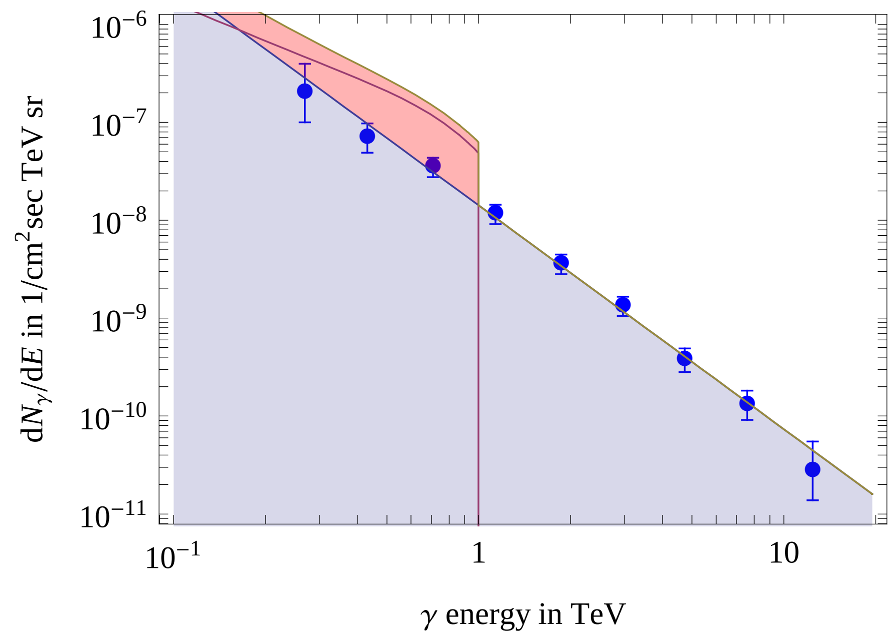


The HESS observations

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



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

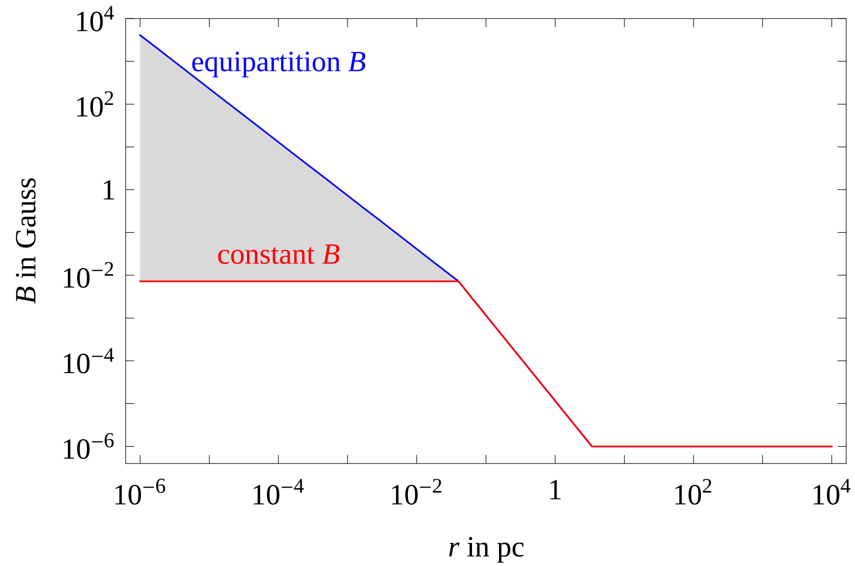


DM signals computed for NFW and $\sigma v = 10^{-23}\,\text{cm}^3/\text{sec}$. We **conservatively** impose that no point is exceeded at 3σ: so the 1st example above is allowed.

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 all the $e^{\pm}$ energy E goes into synchrotron radiation. The unknown B only determines the maximal ν_{syn}:



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

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:

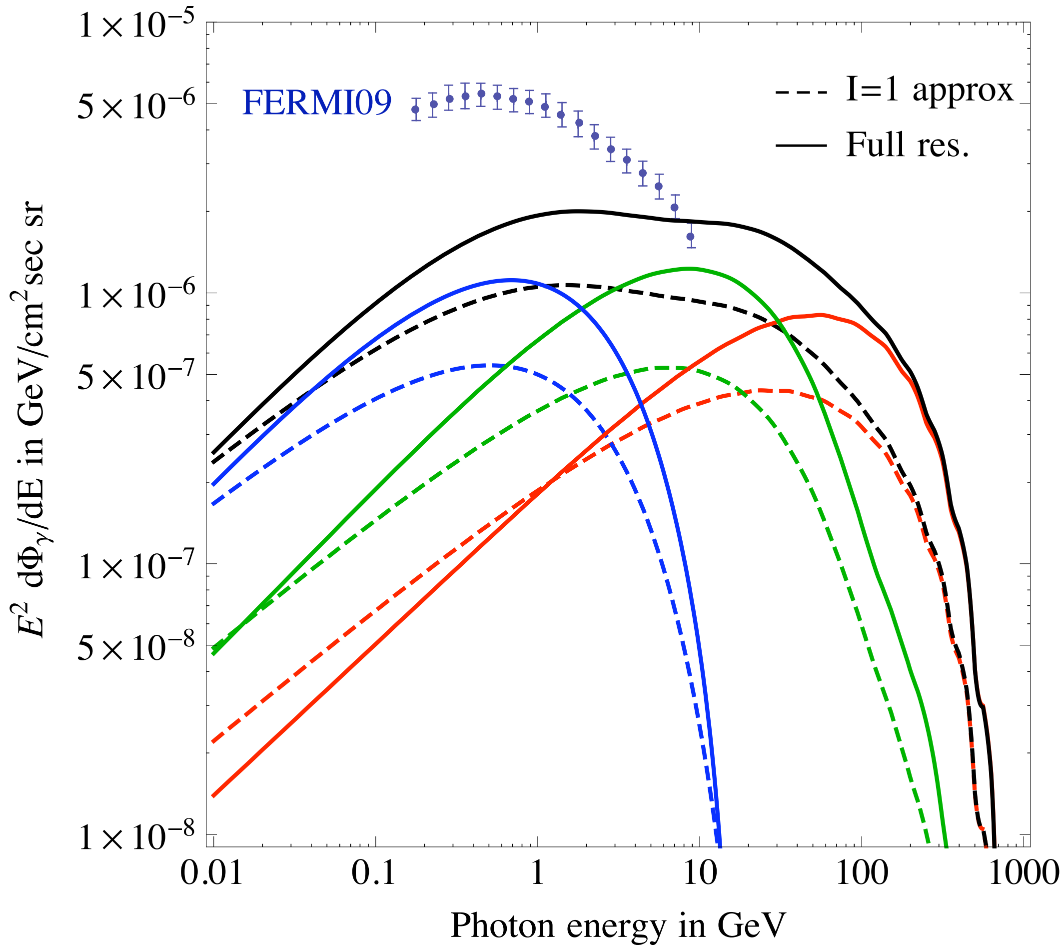
$$\nu\frac{dW_{\text{syn}}}{d\nu} = \frac{\sigma v}{2M^2}\int_{4'' \text{ cone}} dV\ \rho^2\ E(\nu)\ N_e(E(\nu)) < 4\pi r_\odot^2 \times 2\cdot 10^{-16}\,\frac{\text{erg}}{\text{cm}^2\,\text{s}}$$

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

Inverse Compton and FERMI

A fraction $u_\gamma/u_B \sim 1$ of the $e^\pm$ energy goes into $e\gamma \to e'\gamma'$.
Initial γ: $E_\gamma \sim$ eV from star-light and $E_\gamma \sim$ meV from CMB.
Final γ: $E_{\gamma'} \sim E_\gamma (E_e/m_e)^2 \sim 10\,\mathrm{GeV}$. IC dominates of brehms at lower E.

EGRET excess not confirmed by FERMI, that agrees with astro background.
FERMI data shown only below 10 GeV, away from GC ($10^\circ <$ latitude $< 20^\circ$).



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 $\alpha_\mu = 0.24\,\text{TeV/kmwe} = -dE/d\ell$ is the $\mu^\pm$ energy loss.

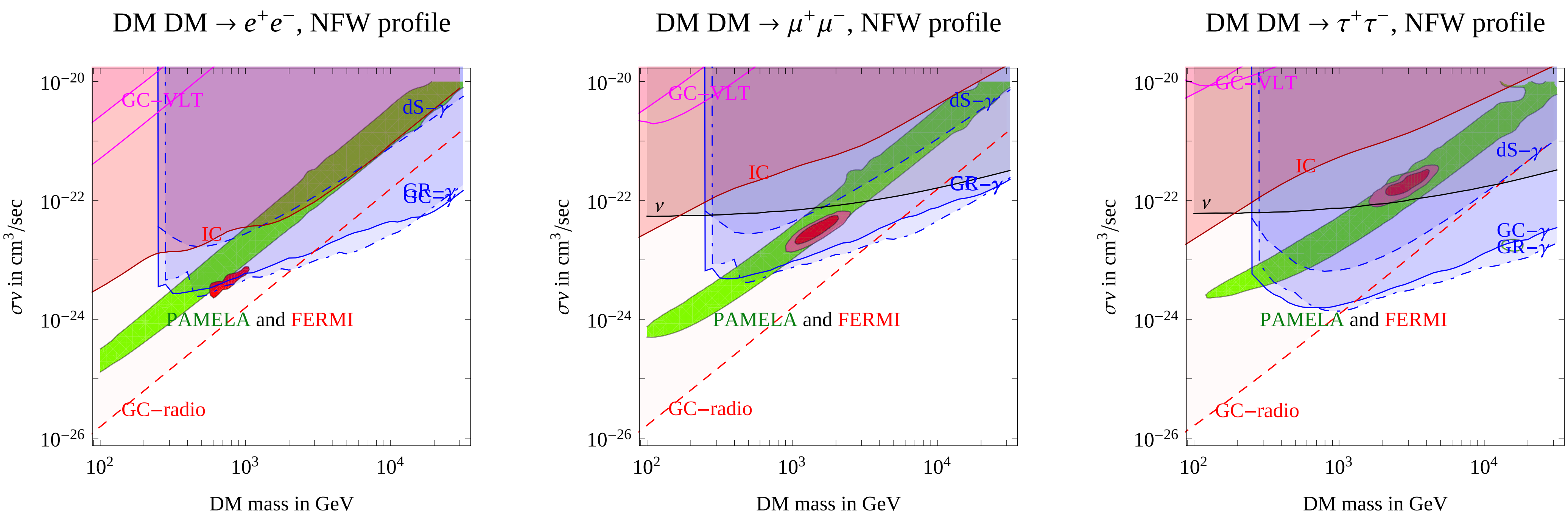
The total $\mu^\pm$ rate negligibly depends on the DM mass M.

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

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

The photon bounds

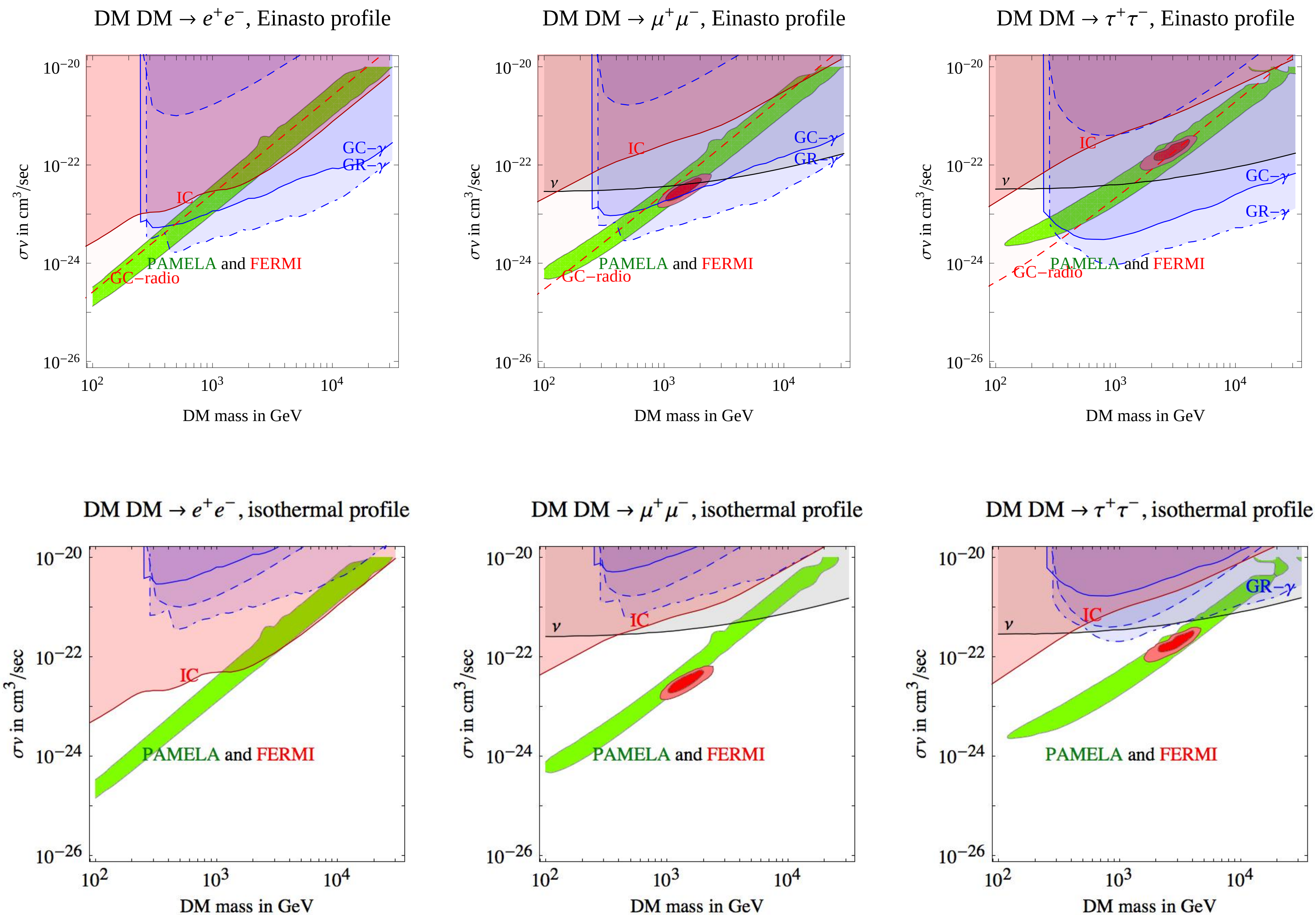
Assuming NFW, **conservative** bounds from HESS γ observations of the Galactic Center, Galactic Ridge, Sagittarius Dwarf and from and radio observations of the GC exclude the green (allowed by PAMELA) and red region (+FERMI):



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

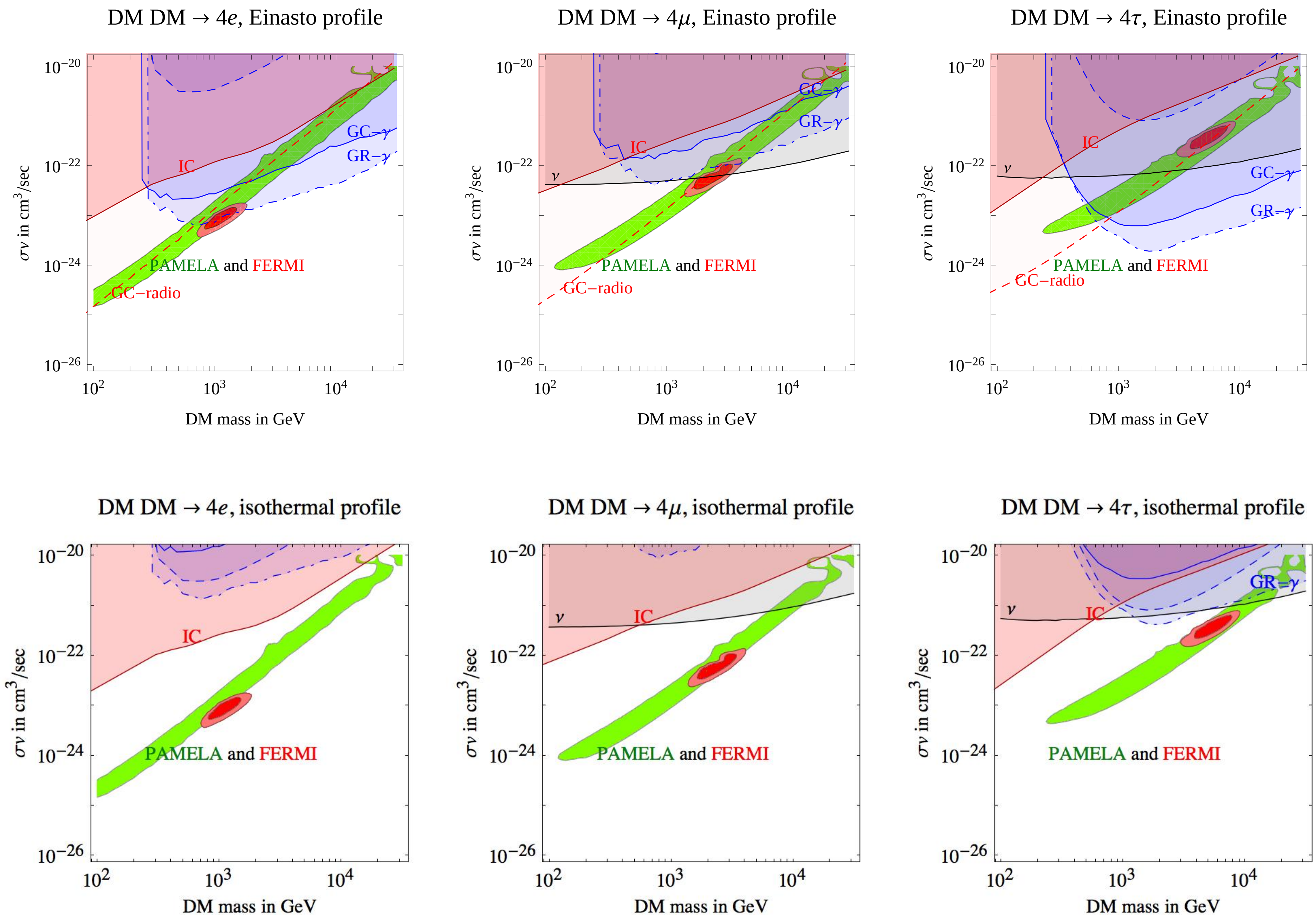
FERMI IC measurements can test if DM generates the $e^\pm$ excesses

An isotheramal profile is ok



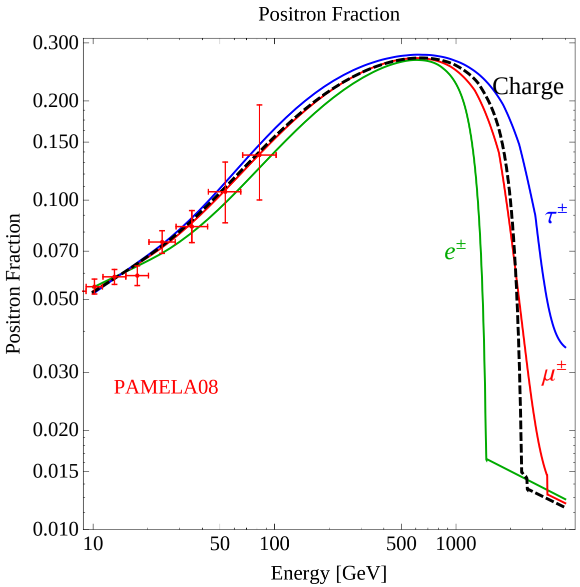
DM DM $\to VV \to \ell^+\ell^-\ell^+\ell^-$ is better

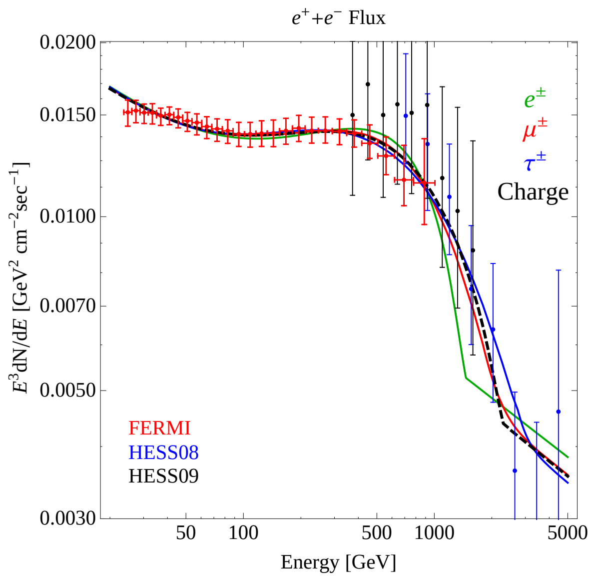
γ yield reduced from $\ln M/m_\ell$ to $\ln m_V/m_\ell$. And smoother $e^\pm$

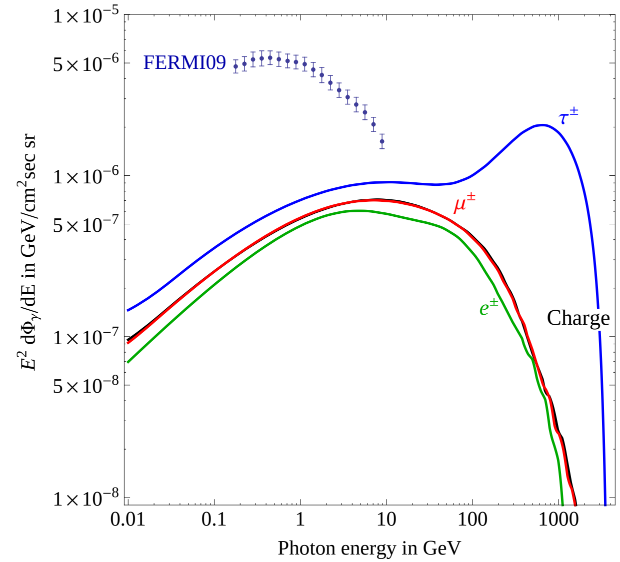


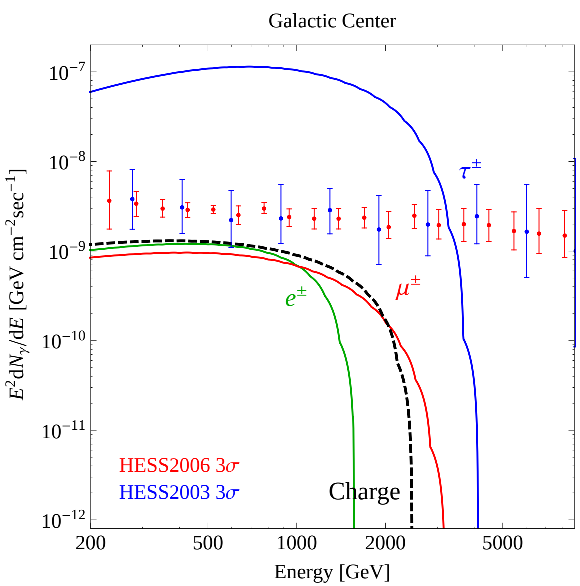
DM DM $\to 4e, 4\mu, 4\tau$

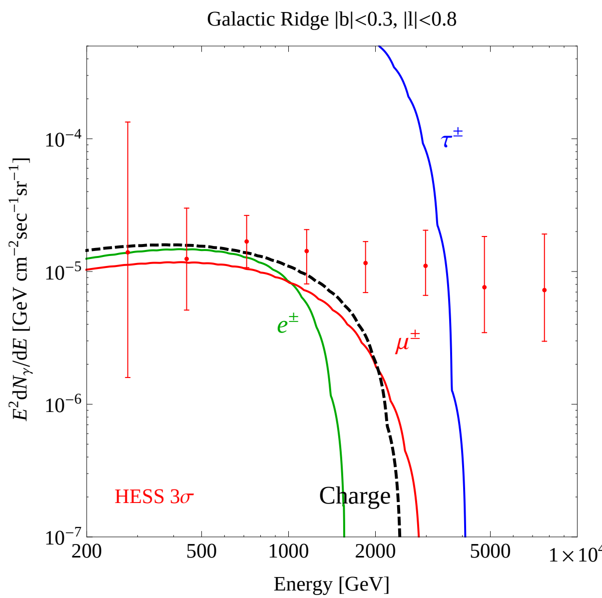
Best fits for Einasto MED. Charge is the coupling to electric charge:

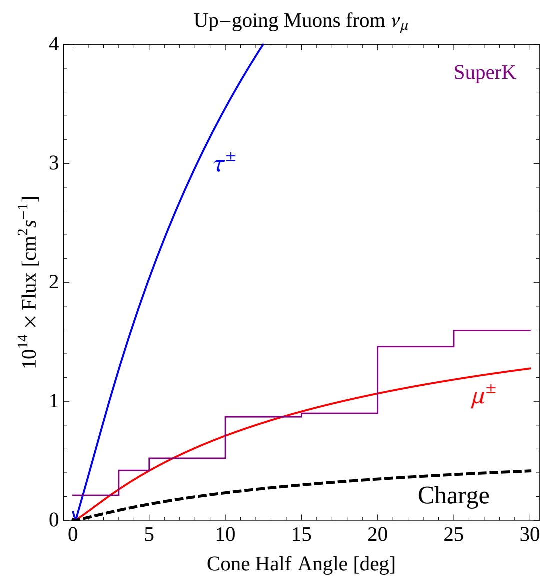












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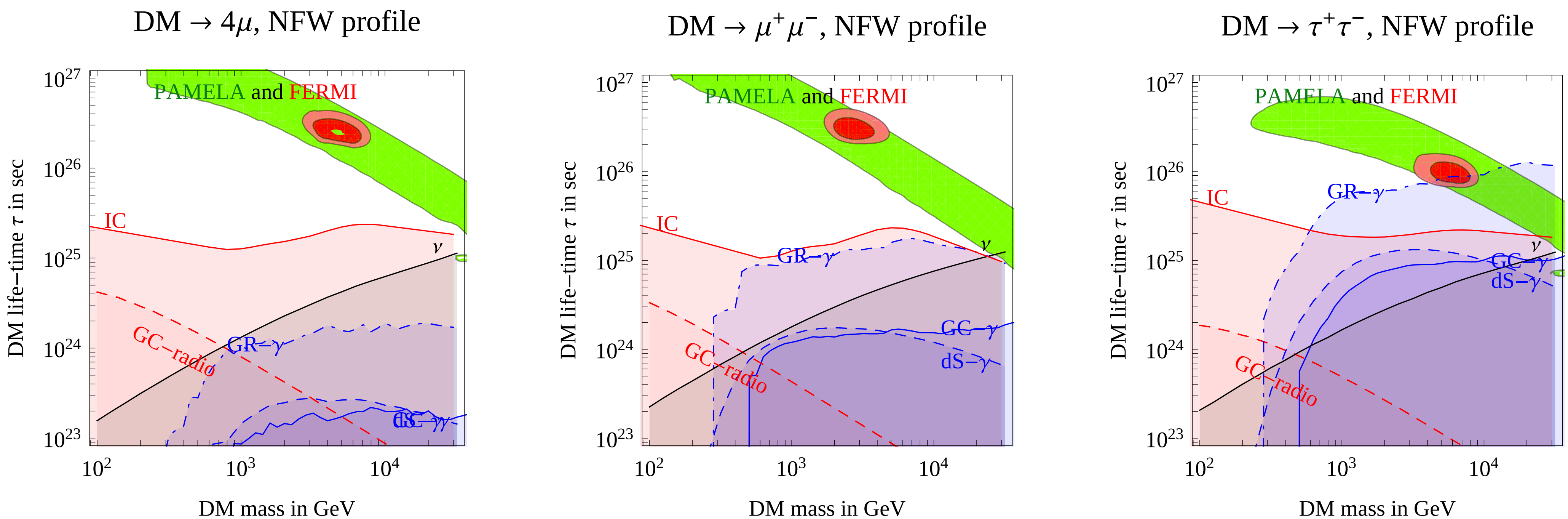
DM decays

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 decay not constrained by BBN, CMB

$e^{\pm}$ 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 $T_{\rm dec} \sim 200\,$GeV.

Possible if DM is a chiral fermion or is made of chiral fermions.
The DM mass is $M \sim \lambda v \sim 2\,$TeV for $\lambda \sim 4\pi$: strong dynamics a-la technicolor.
GUT-suppressed dimension 6 4-fermion operators give $\tau \sim M_{\rm GUT}^4/M^5 \sim 10^{26}\,$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/HESS excesses might be due to pulsars or to DM:

- 3 TeV DM that annihilates in $\tau^+\tau^-$ if the DM density $\rho(r)$ is quasi-constant.
- 3 TeV DM that annihilates in 4μ, better if $\rho_{\rm eff}$ is quasi-constant.
- DM that decays mostly into μ or τ, whatever $\rho(r)$ is.
- sub-TeV DM and a lot of the DM possibilities cannot fit the $e^\pm$ excesses.

This can soon be tested by new experimental results:

- **The e^+ fraction must continue to grow at higher energies?**
  PAMELA up to 270GeV, maybe on 15 May 09. Later AMS.
- **Is an excess present in $\bar{p}$ at higher energies?**
  One more data-point from PAMELA09? Later AMS up to 1 TeV?
- **IC (and maybe FSR) must give a γ excess**: FERMI on 12 August 09.