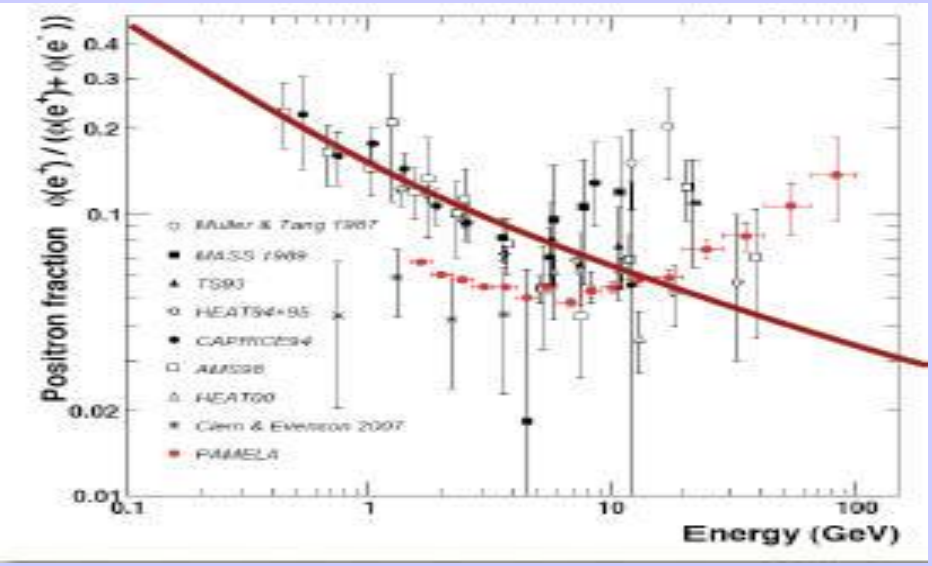
Cosmic Ray Anomalies from the MSSM?

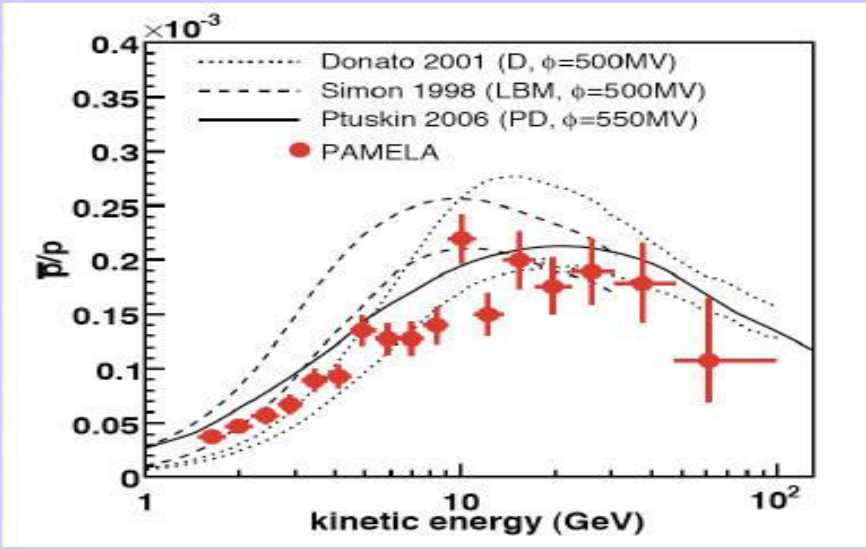
Cotta, Conley, Gainer, Hewett, Rizzo
1007.5520

"Anomalies" in the Data

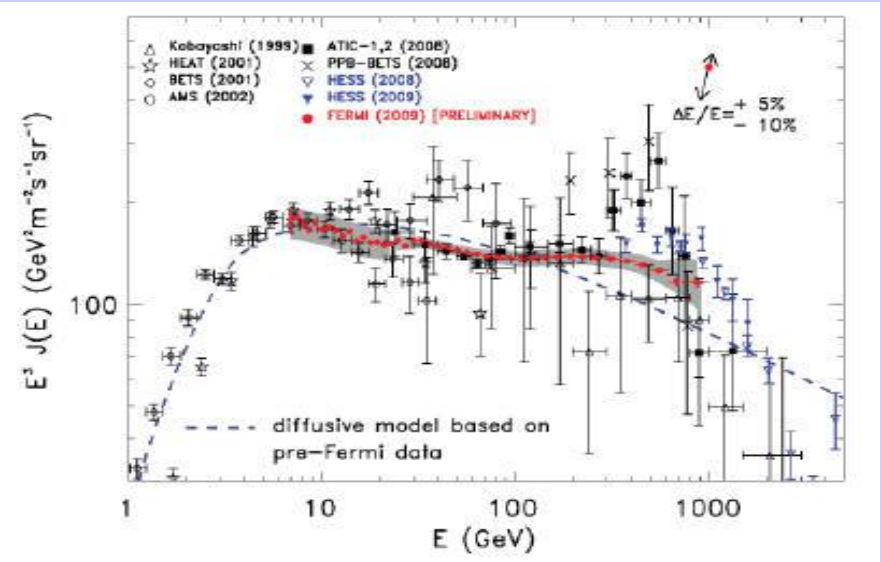
Pamela e^+ Fraction



Pamela anti-p Fraction



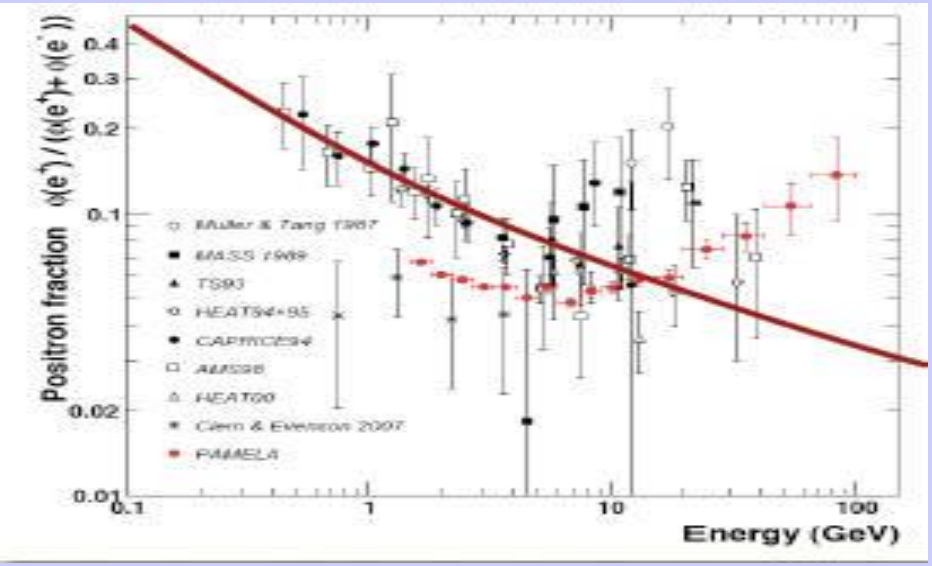
Fermi $e^- + e^+$



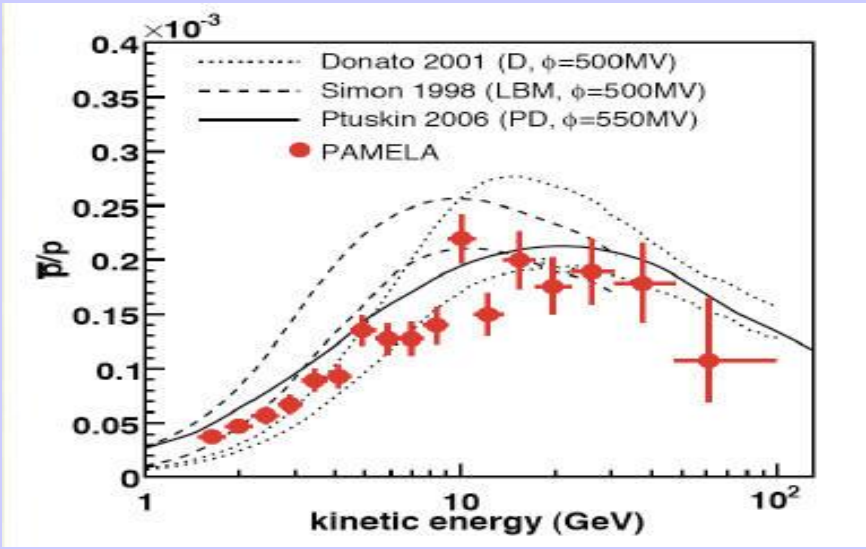
- Could be due to astrophysical objects, such as pulsars…
- Could be detector effects

"Anomalies" in the Data: Could be Dark Matter!

Pamela e^+ Fraction



Pamela anti-p Fraction



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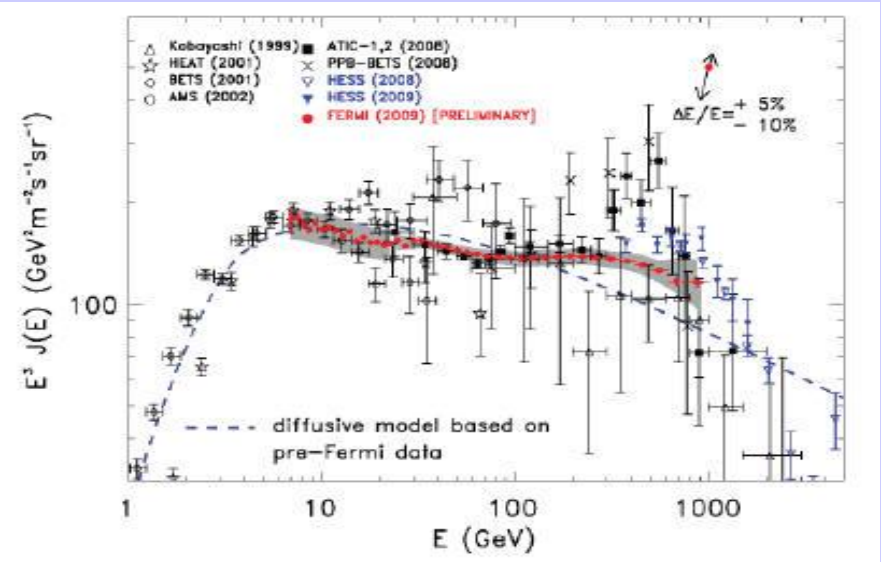


$$\Phi(\epsilon) = \int_{Halo} d^3x \cdot \rho^2(x) \cdot \int_{\epsilon}^{\infty} d\epsilon' \langle \sigma v \rangle_{tot} \frac{d\phi}{d\epsilon'} \cdot G(\epsilon, \epsilon')$$

Particle Physics

Halo

Astrophysics

??????????????????????????????

Could it be MSSM?

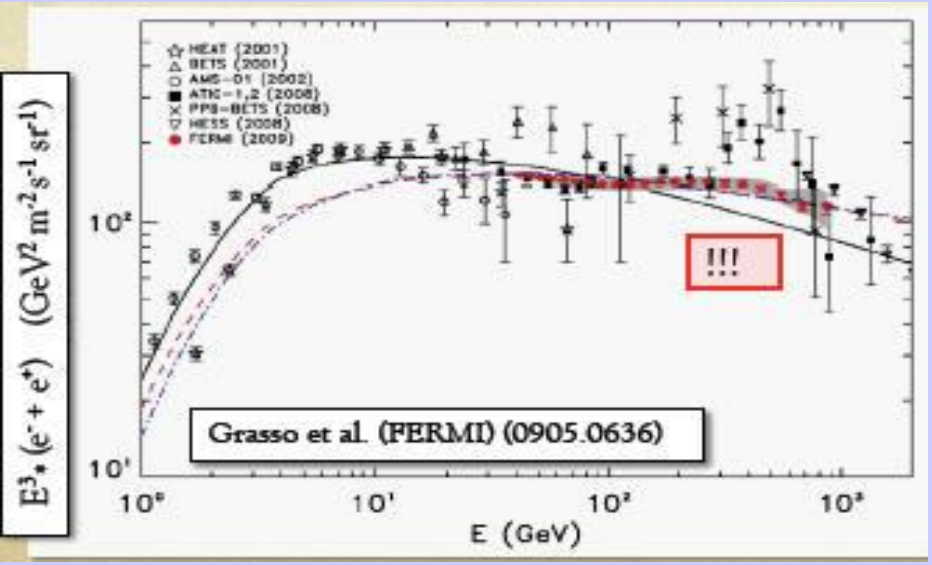
- Thermal Cosmology: $\langle\sigma v\rangle \sim 10^{-26}\ cm^3\ s^{-1}$

  This is too small!!!

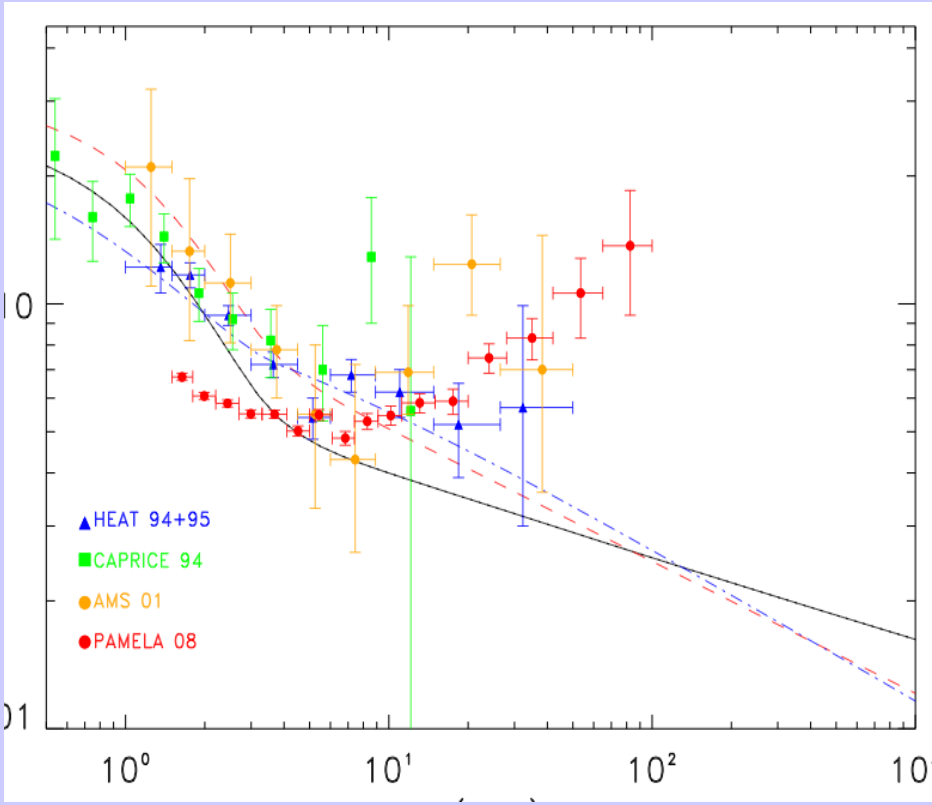
- Requires a ~~Fudge~~ Boost Factor ~ 10^4 (Halo uncertainties not that large…)
- Other possibilities (within SUSY)
  - Resonances, Sommerfeld enhancement
  - Non-thermal Cosmology
  - NMSSM
- The Goal for Today:
  - Explore uncertainties in CR propagation
  - Explore broader MSSM parameter space

Electron CR Spectra

Fermi $e^- + e^+$



Pamela e^+ Fraction



$$(e^- + e^+) \sim E^{\gamma_{obs}}$$

~~$\gamma_{obs} \sim \{3.34 - 3.54\}$~~

$$\gamma_{obs} = 3.045 \pm 0.008$$

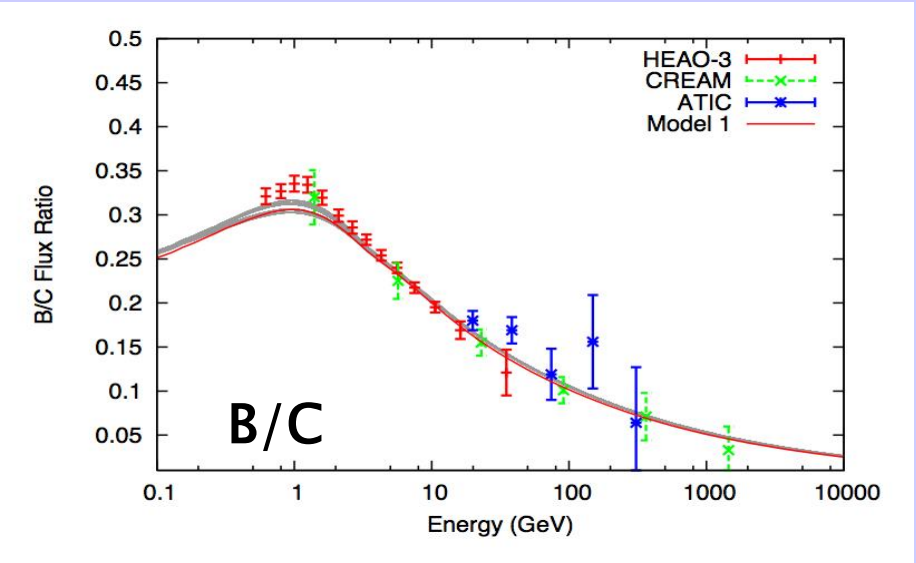
Parameterizing CR Propagation

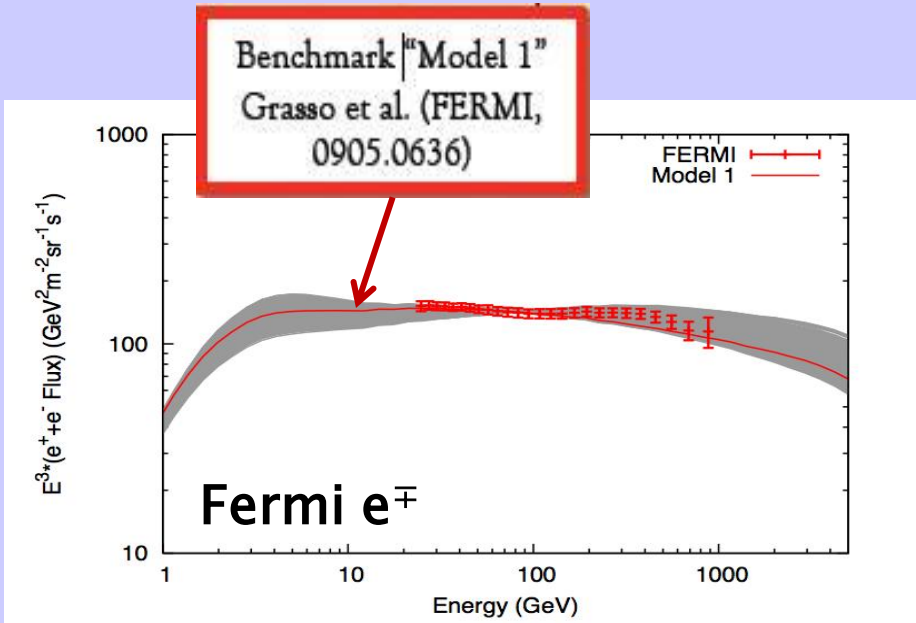
We scan over these parameters

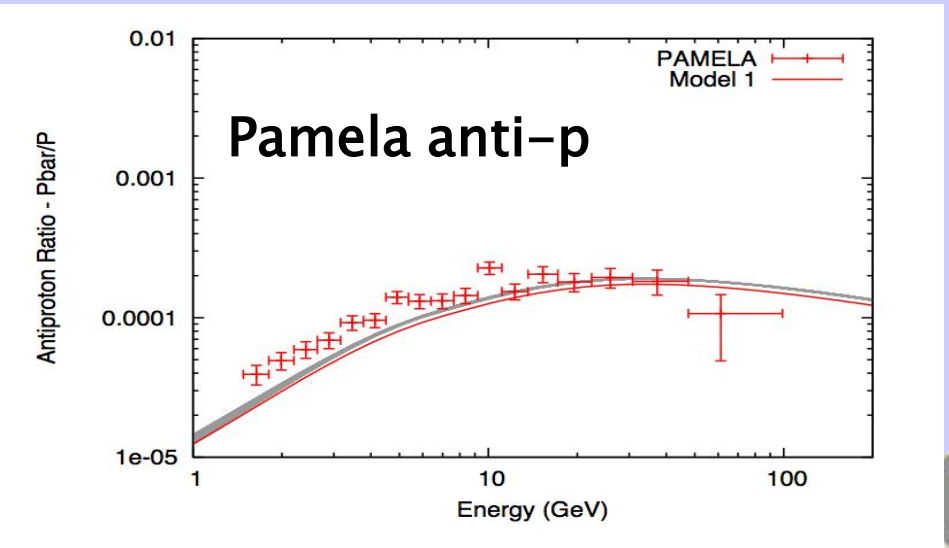
Par. Type	Par. Names	Constrained By	Also Note…
Proton Source	N_n, γ_n	Proton Abs. Flux (AMS01,ATIC,BESS, CAPRICE)	These are fixed at the beginning and never floated thereafter
Diffusion	z_h, D_{0xx}, δ, V_A, V_c	B/C (HEAO-3, ATIC, CREAM)	z_h and D_{0xx} are "degenerate," we scan z_h. Radio clocks: z_h>~2Kpc. δ expected in ~ 0.3-0.8. Here δ=0.33
Electron Source	N_e, γ_e	$e^+/(e^++e^-)$, (e^++e^-)	
B-Field	N_B	$e^+/(e^++e^-)$, (e^++e^-) Diffuse γ's	N_B~ few μG
ISRF	$(u_{FIR}+u_{optical})$, $u_{optical}/u_{FIR}$	$e^+/(e^++e^-)$, (e^++e^-) Diffuse γ's	$(u_{FIR}, u_{optical})$ ~ default, Scan similar to Blandford etal. (0908.1094)

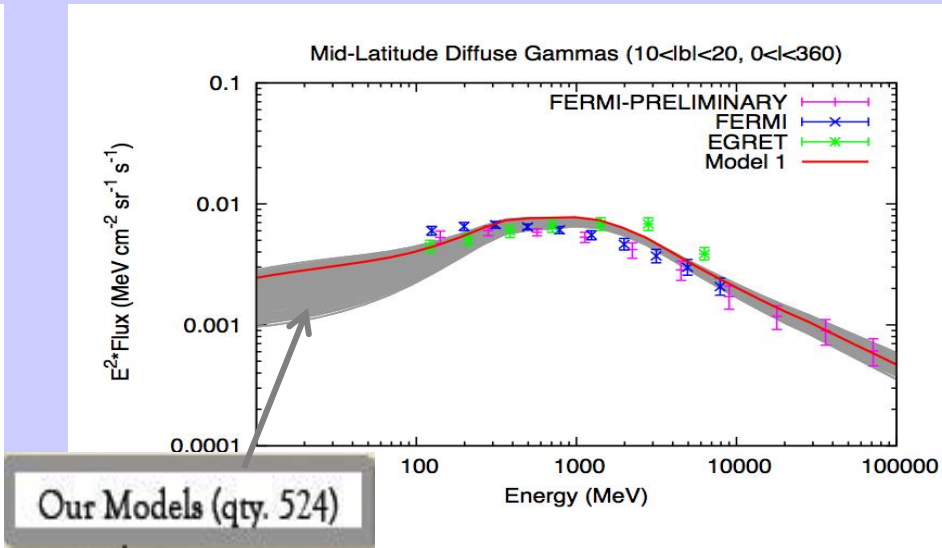
$e^+/(e^++e^-)$, (e^++e^-), pbar/p, fit above 10GeV

Consistency with Data: Best-fit 524 CR Models









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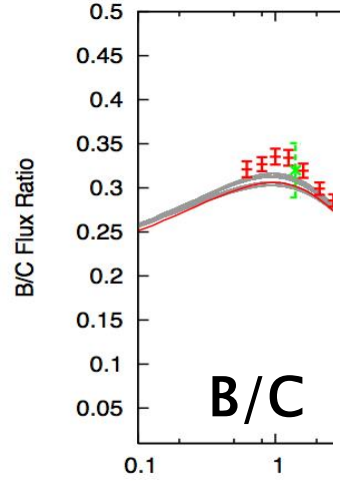
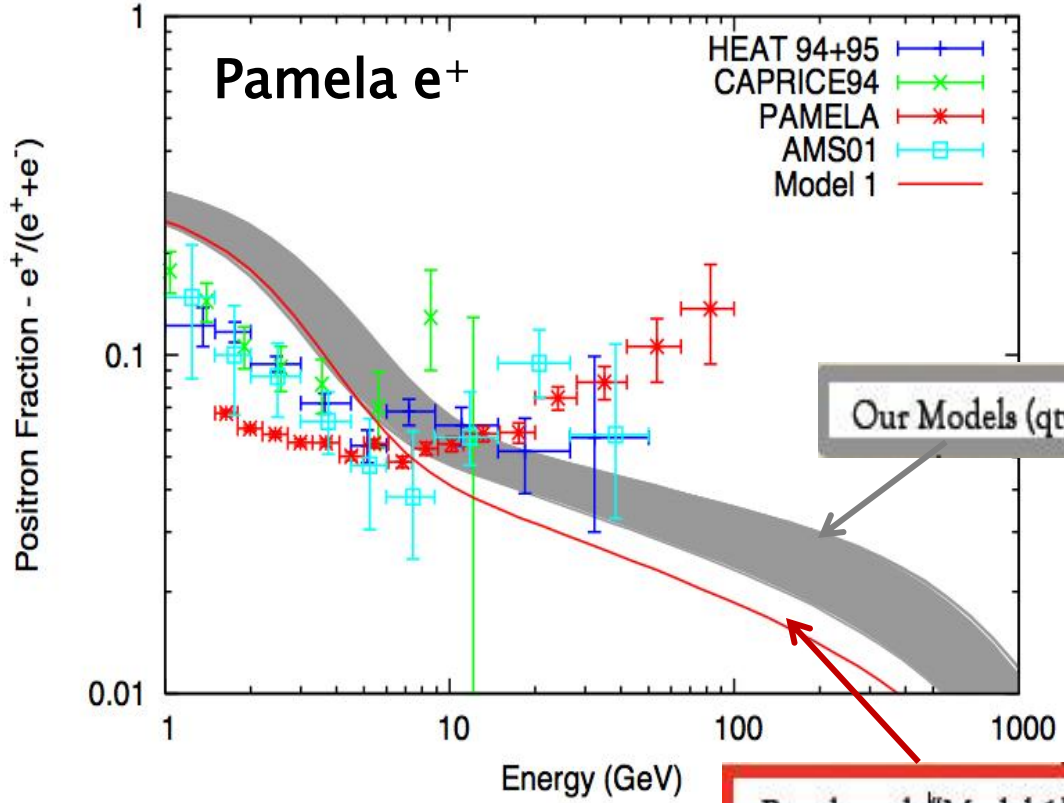
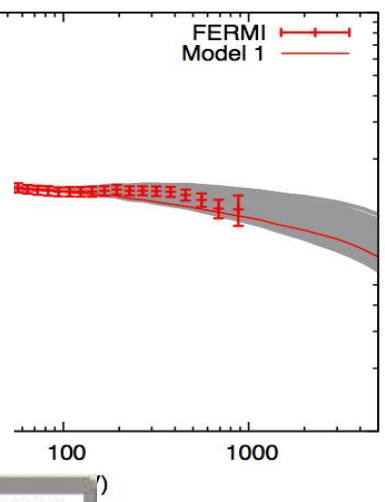
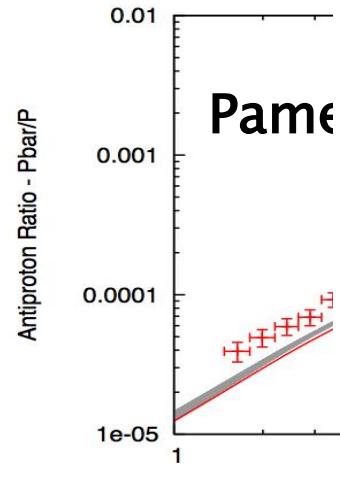
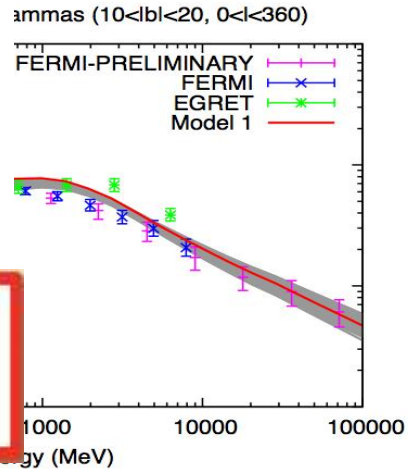






Our Models (qty. 524)





Benchmark "Model 1" Grasso et al. (FERMI, 0905.0636)

Supersymmetry Without Prejudice

Berger, Gainer, JLH, Rizzo, arXiv:0812.0980

- Study Most general CP-conserving MSSM
  - Minimal Flavor Violation
  - Lightest neutralino is the LSP – thermal cosmology
  - First 2 sfermion generations are degenerate w/ negligible Yukawas
  - No GUT, SUSY-breaking assumptions

- ⇒ pMSSM: 19 real, weak-scale parameters

  scalars:

  m_{Q_1}, m_{Q_3}, m_{u_1}, m_{d_1}, m_{u_3}, m_{d_3}, m_{L_1}, m_{L_3}, m_{e_1}, m_{e_3}

  gauginos: M_1, M_2, M_3

  tri-linear couplings: A_b, A_t, A_τ

  Higgs/Higgsino: μ, M_A, $\tan\beta$

Perform Random Scan in pMSSM

Linear Priors

10^7 points – emphasize moderate masses

$100\ \text{GeV} \leq m_{\text{sfermions}} \leq 1\ \text{TeV}$

$50\ \text{GeV} \leq |M_1, M_2, \mu| \leq 1\ \text{TeV}$

$100\ \text{GeV} \leq M_3 \leq 1\ \text{TeV}$

$\sim 0.5\ M_Z \leq M_A \leq 1\ \text{TeV}$

$1 \leq \tan\beta \leq 50$

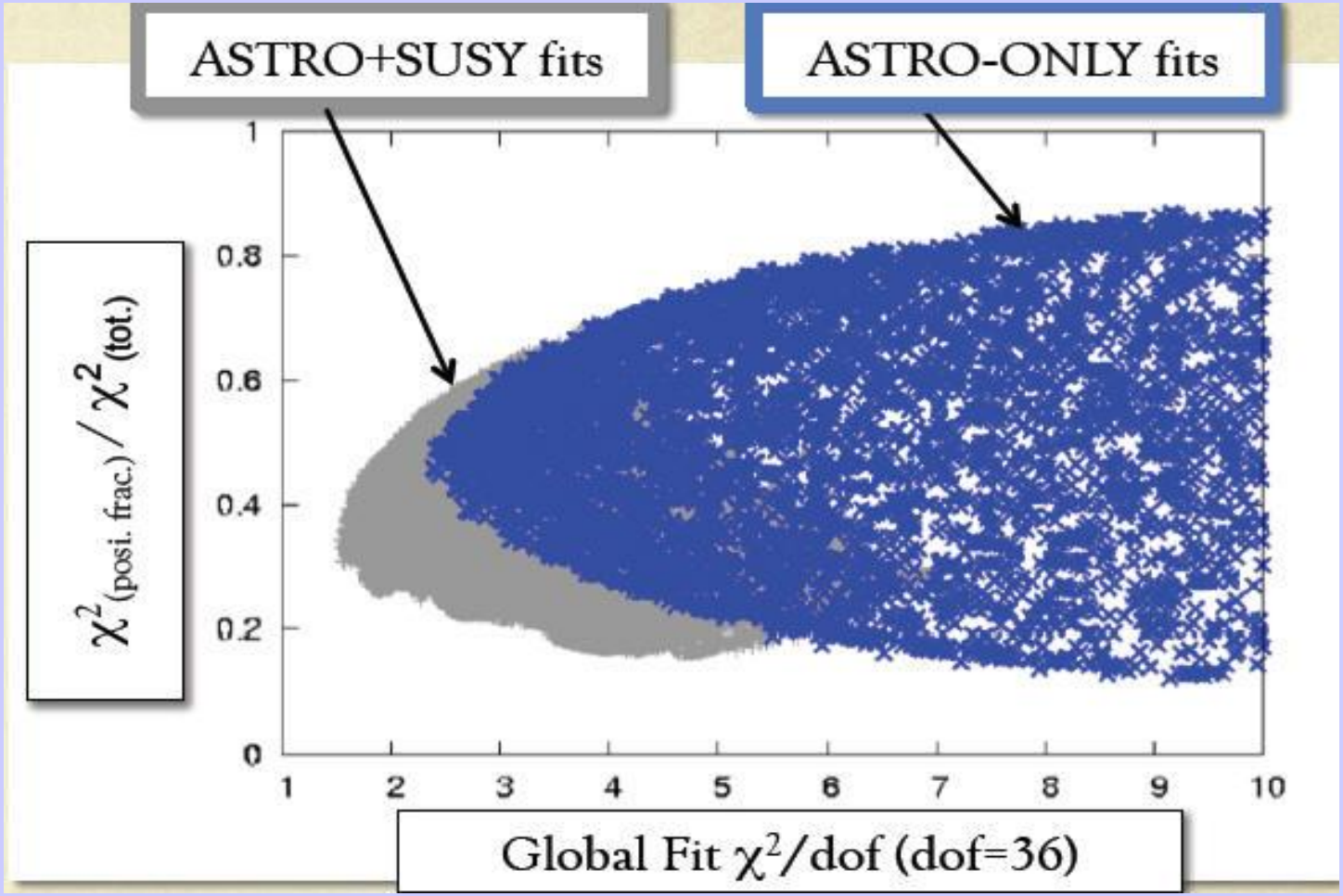
$|A_{t,b,\tau}| \leq 1\ \text{TeV}$

Theory + Exp't Constraints

- Theoretical requirements on spectra
- EW Precision observables
- B–Physics
- Collider searches
- Astrophysical measurements

68.5k models survive these constraints!

X^2 Fit to CR Data

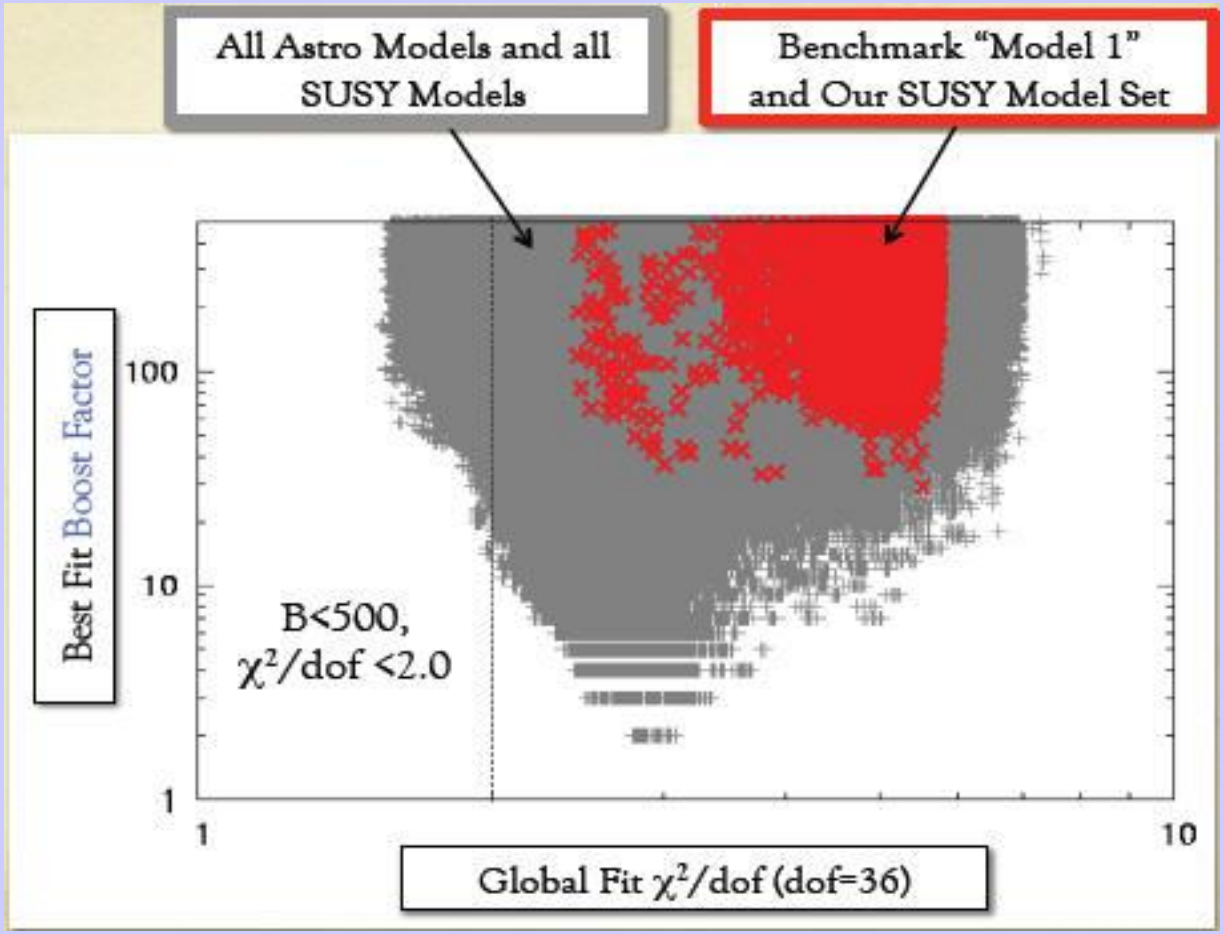


SUSY improves the quality of the fit!

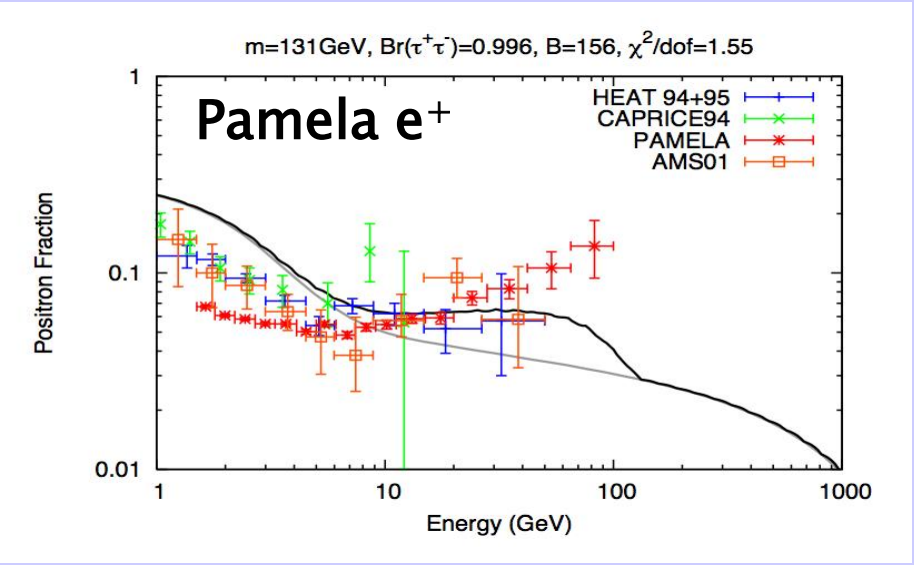
Minimum Boost for Best-Fit

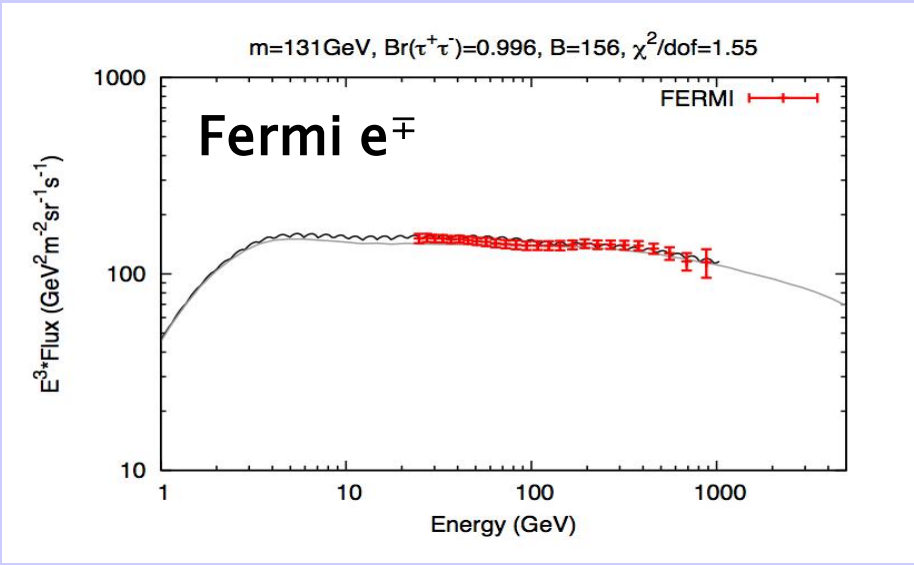
Best Fits:

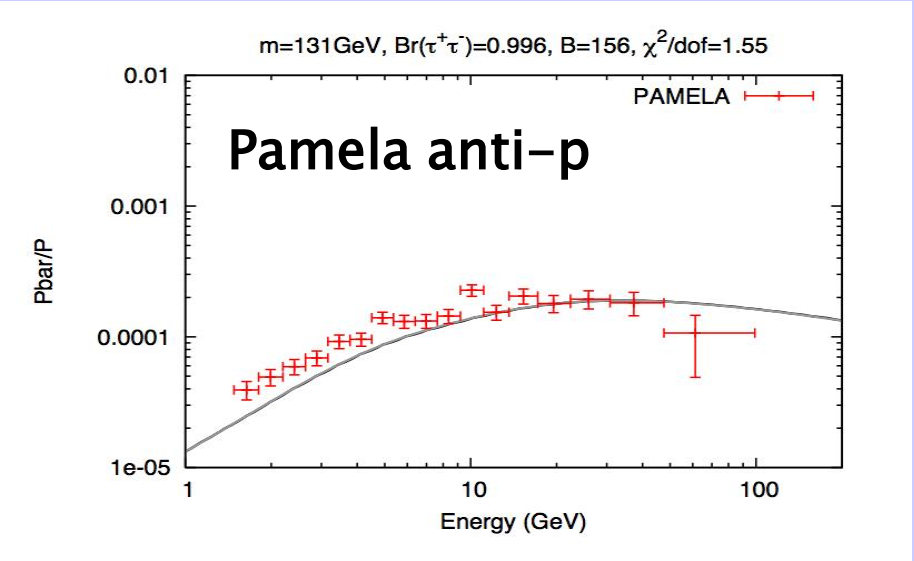
X^2 /dof = 1.54
With boosts of
~ 70-150

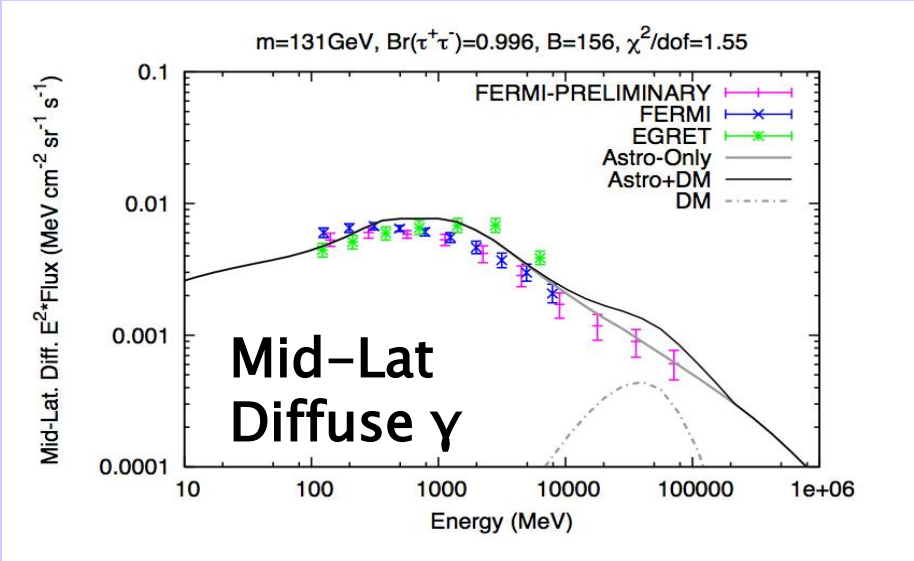


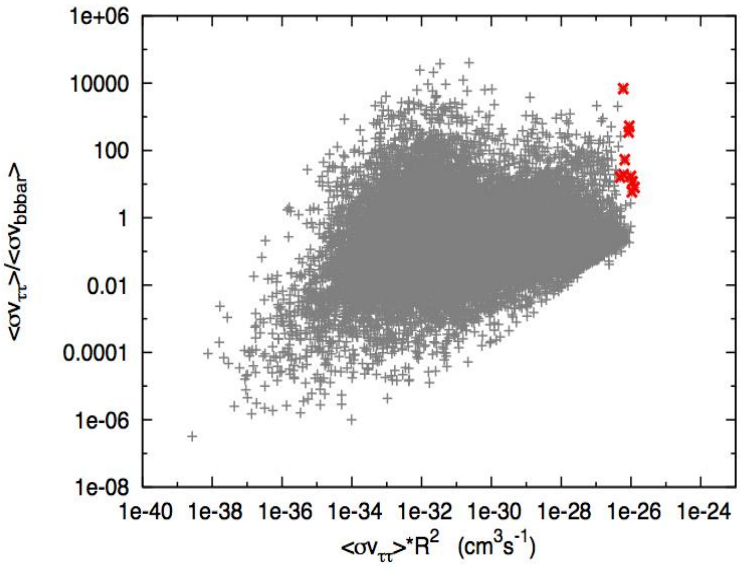
CR Data with Best-Fit pMSSM/CR Model









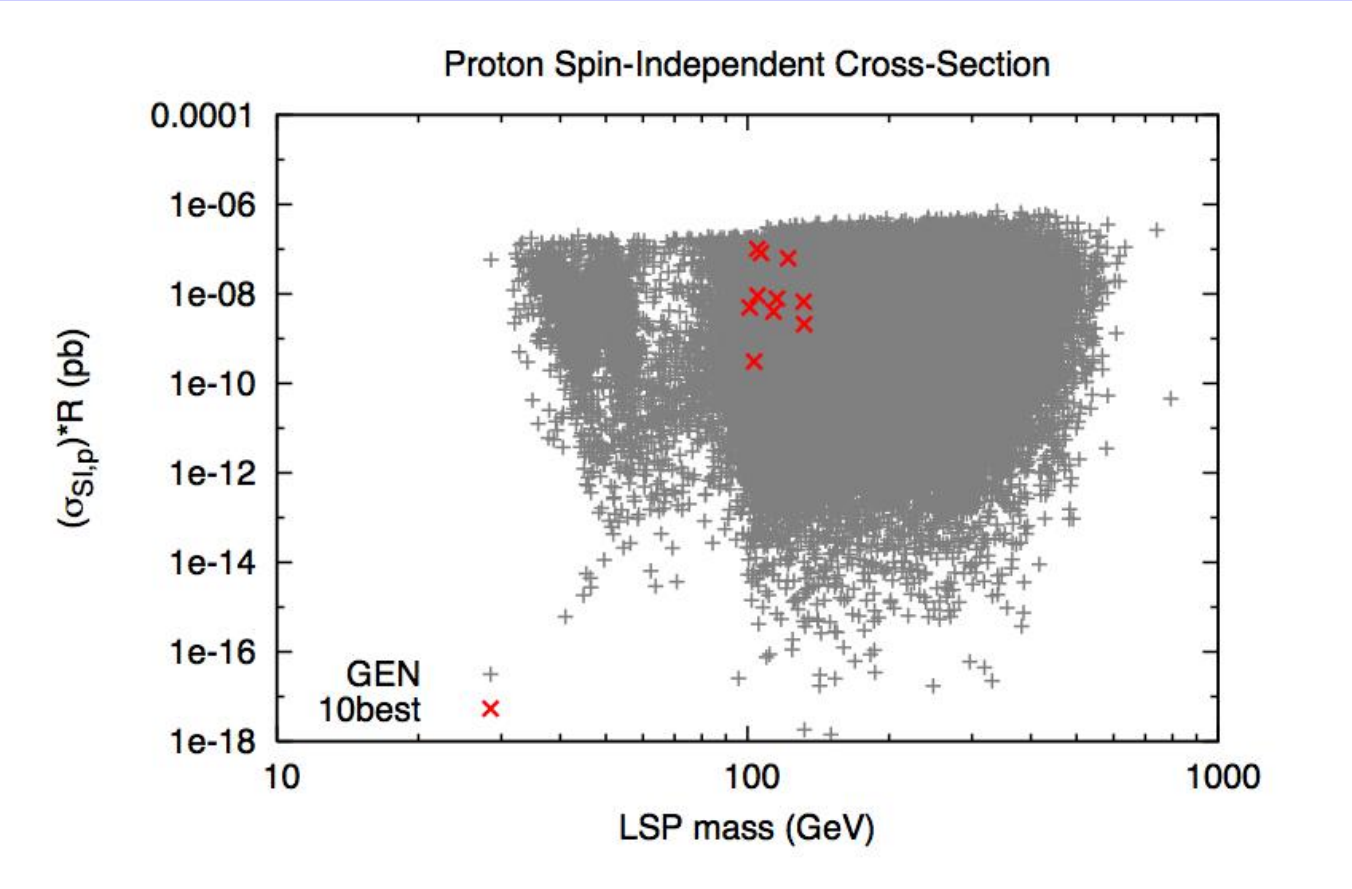


DM Annihilation properties of top ten pMSSM models

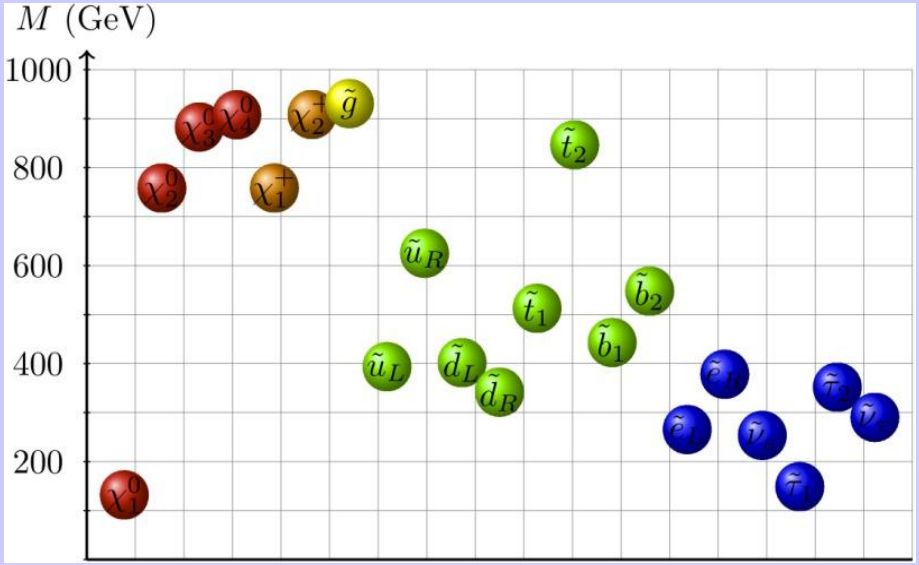
Leptophillic!

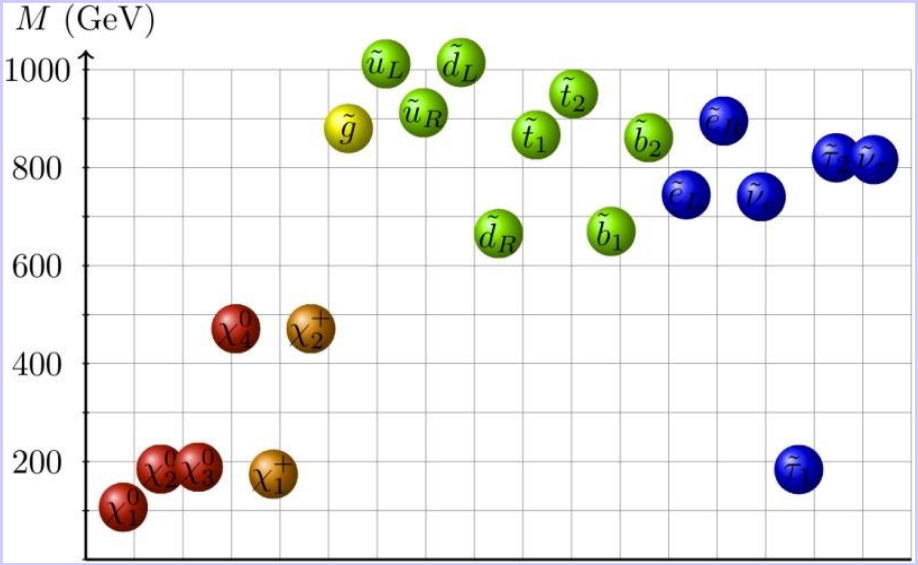
Mod	$m_{\tilde{\chi}_1^0}$ (GeV)	R	B	$B\langle\sigma v\rangle R^2$	$\langle\sigma v\rangle_\tau/\langle\sigma v\rangle$	$\langle\sigma v\rangle_b/\langle\sigma v\rangle$	$\langle\sigma v\rangle_Z/\langle\sigma v\rangle$	$\langle\sigma v\rangle_W/\langle\sigma v\rangle$
1	101	0.64	115	1.23	0.46	0.03	0.13	0.37
2	107	0.99	72	1.27	0.71	0.09	0.05	0.14
3	132	0.91	99	1.55	0.68	0.11	0.08	0.11
4	122	0.73	102	1.39	0.81	0.07	0.05	0.07
5	116	0.64	163	1.27	0.85	0.02	0.05	0.08
6	105	0.67	104	1.15	0.90	0.05	0.01	0.02
7	114	0.74	187	1.21	0.95	0.05	<0.01	<0.01
8	103	0.80	119	1.07	0.997	<0.01	<0.01	<0.01
9	105	0.68	179	1.08	0.999	<0.01	<0.01	<0.01
10	132	1.03	156	1.34	0.996	<0.01	<0.01	<0.01

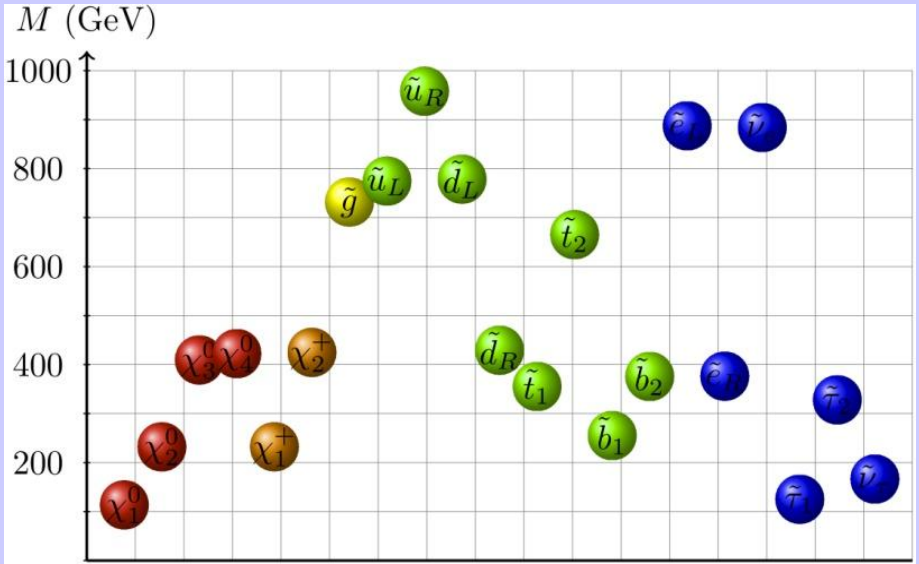
Spin-Independent Direct Detection Predictions

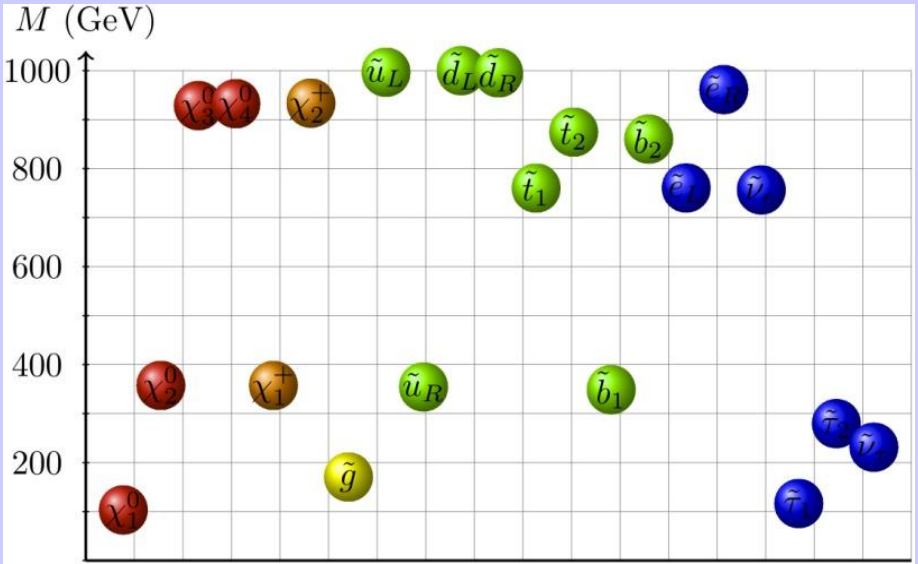


Sample Best-Fit pMSSM Spectra









Conclusions

- We have performed a scan over the variables parametrizing the uncertainties inherent in CR propagation
- We coupled this scan with a broad scan over the 19-dimensional pMSSM parameter space
- We found that the addition of the pMSSM improved the fit to the CR data
- The requisite thermal Boost factors are lowered to ~100
- Best fit models are leptophillic with large annihilation rates to tau pairs