Heavy wino Dark Matter model

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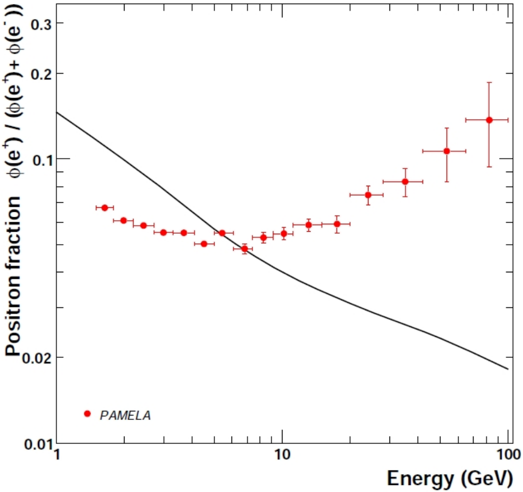
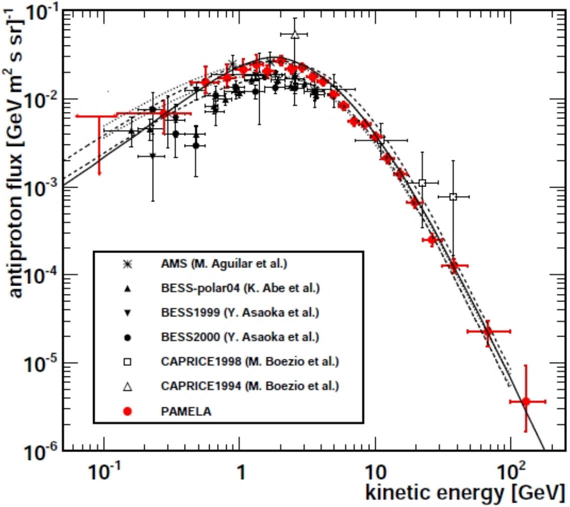
Introduction



Introduction



Introduction

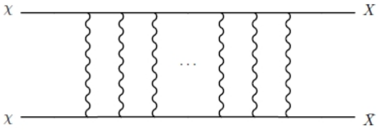
- DM annihilation rate(σv) required for producing the observed excess in PAMELA data $\sim 10^{-23}$ cm^{3}s^{-1}
- DM annihilation rate(σv) required for producing the cosmological relic DM density $\sim 3 \times 10^{-26}$cm^{3}s^{-1}

$$\Omega_{DM} \ \sim \ < \sigma v >^{-1}$$

- Boost factor of about 1000 required in DM annihilation rate
- Need to invoke Sommerfeld enhancement to explain the boost required to explain PAMELA data
- Large boost factor possible only near the Sommerfeld resonance region which corresponds to heavy mass leading to large relic density
- Feng et al.(2010) have shown that including Sommerfeld effect in relic density calculation also helps in achieving the correct relic density even though velocities are very large at freeze-out

Sommerfeld Enhancement

- Sommerfeld enhancement arises when there is an attractive force between the two annihilating particles which distorts their wavefunction.
- In field theory this corresponds to contribution of ladder diagram in which the force carrier is exchanged many times before annihilation.

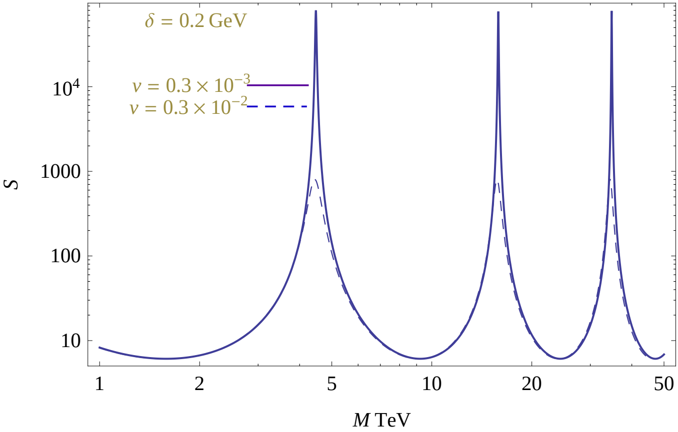


- "Sommerfeld enhanced" cross section :

$$\sigma v = S(\sigma v)_0$$

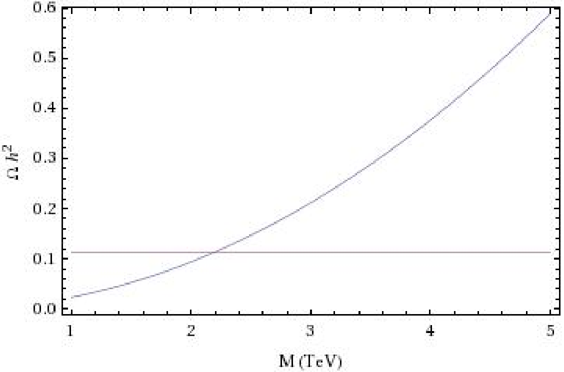
where $S = \dfrac{|\Psi(\infty)|^2}{|\Psi(0)|^2}$

Sommerfeld Enhancement



- DM mass of 4.55 TeV gives large sommerfeld enhancement for W exchange.

Sommerfeld Enhancement



- But Chattopadhyay et al.(2007) have shown that correct relic density is obtained for $M_\chi \sim 1.9 - 2.2$ TeV.
- At 4.55 TeV relic density too large and therefore need to incorporate Sommerfeld enhancement in relic density calculation as well

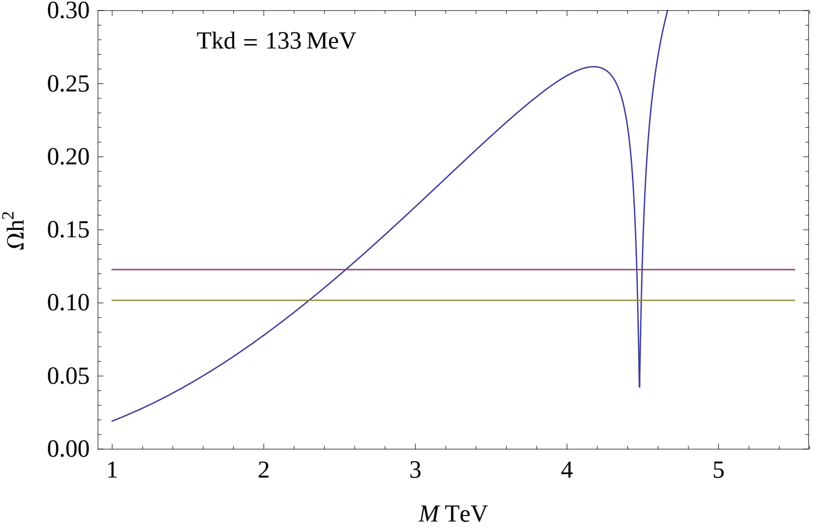
Kinetic Decoupling

- Momentum transferred to DM due to scattering

$$\Gamma_k = n_r \langle \sigma v \rangle \frac{T}{M}$$

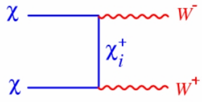
- DM temp. remains same as radiation bath as long as $\Gamma_k > H$
- Kinetic decoupling is the temperature at which $\Gamma_k = H$
- At $T > T_{kd}$, $T_\chi \propto \frac{1}{a}$ and at $T < T_{kd}$, $T_\chi \propto \frac{1}{a^2}$
- Process maintaining temp. equality between DM and radiation bath $\chi^0 f \leftrightarrow \chi^\pm f'$ which gives $T_{kd} = 133$ MeV

Relic Density with Sommerfeld effect



Wino LSP in AMSB Model

- The dominant contribution to positron, antiproton production comes from WW pair production by chargino exchange and subsequent decay of W's to fermion-antifermion pairs



- Thus wino LSP required which naturally occurs in the AMSB scenario

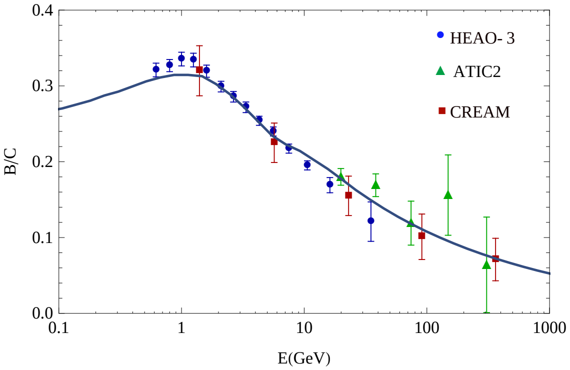
Obtaining Results

- In the AMSB scenario we consider a 4.55 TeV Wino DM and calculate positron and antiproton spectrum from wino annihilation to WW (using MicrOmegas)
- We then input the analytic fit functions for these spectra in Galprop and compute the positron and antiproton fluxes at earth
- The annihilation rate from MicrOmegas is boosted by the Sommerfeld enhancement factor which in this case is taken to be 8500

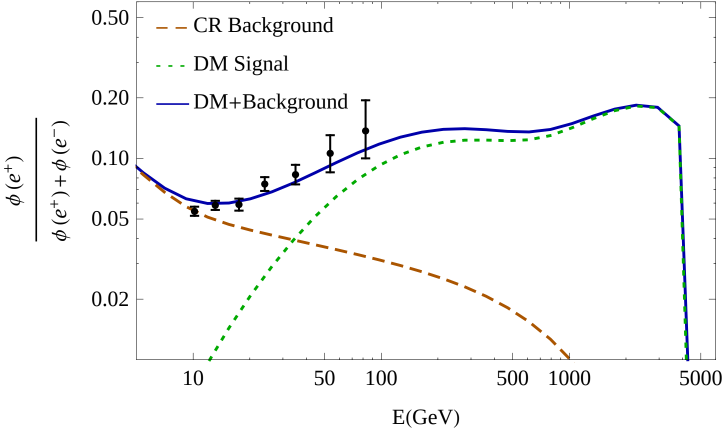
Galprop parameters

L (kpc)	D_{0xx} (10^{28} cm^2)	δ	V_a (km/s)	$\frac{\partial V_c}{\partial z}$ (km/s/kpc)	γ_n	γ_e	N_p at 100 GeV MeV^{-1}cm^{-2}s^{-1}sr^{-1}	N_e at 34.49 GeV MeV^{-1}cm^{-2}s^{-1}sr^{-1}
2.0	2.83	0.34	33.67	0.5	2.36	2.5	3.5×10^{-9}	0.4×10^{-9}

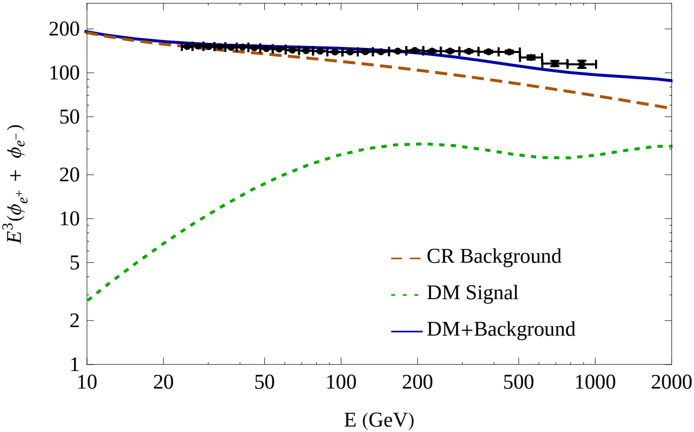
Table: Diffusion parameters and boost factor used as input in GALPROP.



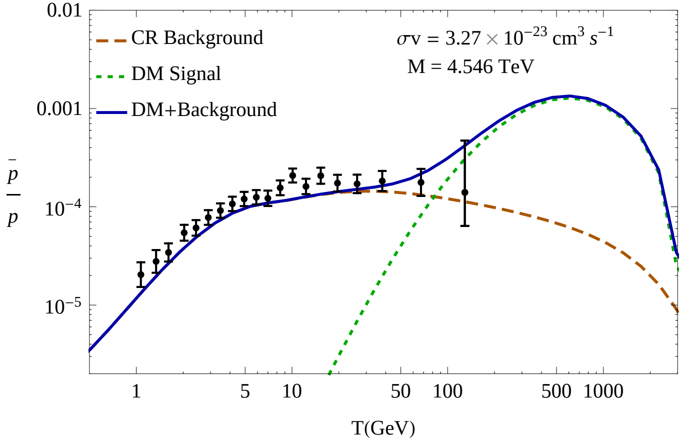
Results - PAMELA positron fraction



Results - FERMI $e^+ + e^-$ flux



Results - PAMELA $\bar{p}/p$



Summary

- To explain PAMELA positron excess need large annihilation cross section which is inconsistent with relic density that requires much smaller cross section
- To exlain the required boost in cross section Sommerfeld effect is invoked
- But Sommerfeld enhancement is large only at resonant mass of 4.5 TeV which is not consistent with relic density
- Incorporating Sommerfeld effect in relic density calculation leads to the right relic density even with a 4.5 TeV DM
- A wino LSP model in the AMSB scenario is chosen to give sufficiently large annihilation cross section
- A heavy wino DM with Sommerfeld effect is able to explain the PAMELA excess in positron fraction at the same time avoiding any excess in the antiproton flux and also being consistent with the relic density constraint