Decaying dark matter and the AMS-02 result

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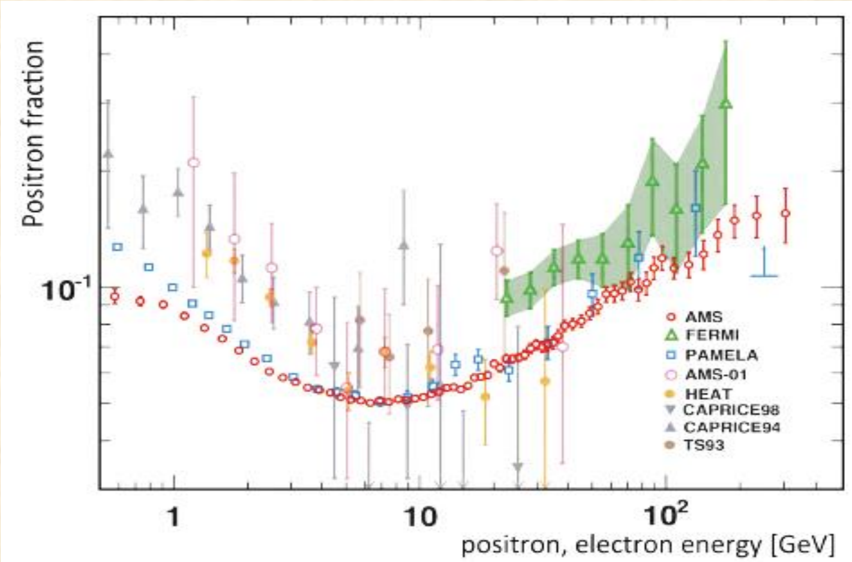
AMS-02 results & DM interpretation



AMS-02 confirmed the PAMELA result at the positron fraction measurements!

- The fraction observed at the AMS-02 is shallower than the PAMELA's one.
- $(e^+ + e^-)$ flux observed at the AMS-02 is softer than the Fermi-LAT's one.

Interpretation:

1. Astrophysical activities (Pulsar, etc.)
2. Annihilation products of dark matter
3. Decay products of dark matter

There are many past studies on this problem. Why should we rethink it?

1. A dark matter of O(1) TeV mass is well known to explain the PAMELA (AMS-02) anomaly when it decays.
2. In the framework of SUSY models, O(1) TeV dark matter seems to be favored because of LHC results.

Higgs mass of 126 GeV
No SUSY signals observed
↓
May be $M_{SUSY} \gg O(1)$ TeV
↓
$M_{LSP} \sim O(0.01-0.1)\, M_{SUSY}$

This is a good time to rethink the anomaly in term of a SUSY DM!

AMS-02 results & DM interpretation

The mass and lifetime required. [n_{DM} = O(0.1) GeV/cm³ assumed.]

The annihilation case:

1. The mass must be >> 350 GeV.
2. Rate producing e^+ and e^- must be
   $R = \langle\sigma v\rangle (n_{DM})^2 \sim 10^{-30}/\mathrm{cm}^3/\mathrm{sec}$
   $\rightarrow \langle\sigma v\rangle \sim 10^{-23}\ \mathrm{cm}^3/\mathrm{sec}$

The decay case:

1. The mass must be >> 700 GeV.
2. Rate producing e^+ and e^- must be
   $R = \Gamma_{DM}\, n_{DM} \sim 10^{-30}/\mathrm{cm}^3/\mathrm{sec}$
   $\rightarrow \Gamma_{DM} \sim 10^{-27}/\mathrm{sec}$

I focus on the DM interpretation of the AMS-02 result in terms of DM decays↓

For a SUSY DM, the R-parity must be (slightly) broken for the decay.

○ Which operator we should use?

Leading operators: LH_u, $U^cD^cE^c$, QLD^c, LLE^c

First three induces contributions to the anti-proton flux in the dark matter decay, which has already been severely constrained.

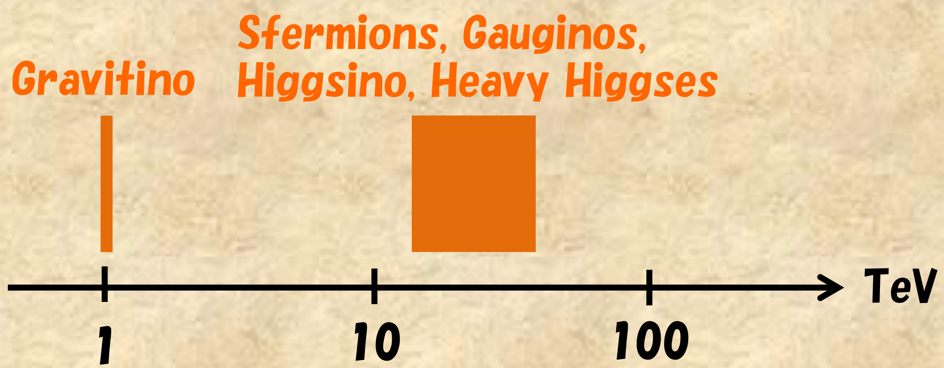
○ As a result, we consider the operator LLE^c assuming tiny coefficients. See →

$$W_{\not R} = \lambda_{ijk}\, L_i L_j E^c_k.$$

A case of the gravitino dark matter

~ Gauge Mediation Scenario ~

$$(m_0)^2 \sim (\alpha^2/8\pi^2)(F_{mess}/M_{mess})^2$$
$$m_{1/2} \sim (\alpha/4\pi)(F_{mess}/M_{mess})$$
$$m_{3/2} \sim F_{mess}/M_{pl}$$
$$\mu \sim m_0$$
$$B\mu \sim m_{3/2}\ [\tan\beta \sim 10]$$



$\rightarrow m_h \sim 125$ GeV when $M_{mess} \sim 10^{15}$ GeV & $F_{mess}/M_{mess} \sim 3000$ TeV

~ Attractive points ~

Consistent with 125 GeV Higgs
No SUSY signals at current LHC
No SUSY FCNC/CP problems.
[diagonal : off-diagonal = $1:10^{-2}$]
Coupling unification is kept.
Radiative breaking still happens.
Gravitino prob. solved because →

~ Gravitino dark matter ~

Gravitino is required to decay with the lifetime of $O(10^{27})$sec.

↓

NLSP decays before starting BBN through $\not{R}$-interactions.

Gravitino is produced by thermal scatterings just after inflation.

A case of the wino dark matter

~ Pure Gravity Mediation ~

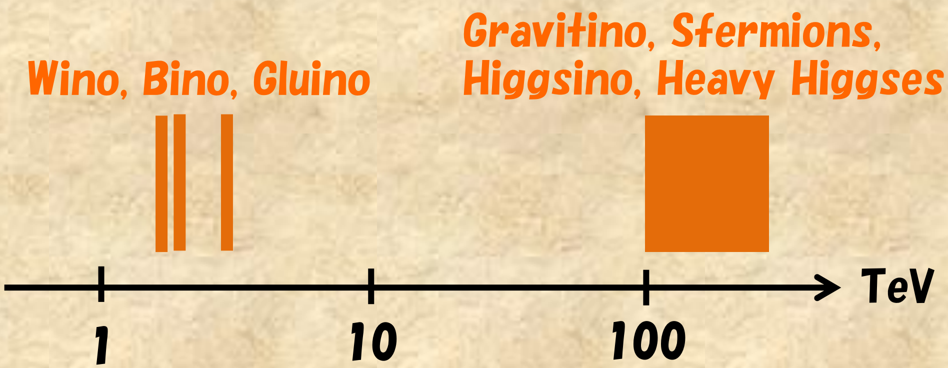
$(m_0)^2 \sim (m_{3/2})^2$

$m_{1/2} \sim (\alpha/4\pi)\, m_{3/2}$

[Anomaly mediated contribution]

$\mu \sim m_{3/2}$

$B\mu \sim m_{3/2}$ [$\tan\beta \sim O(1)$]



$\rightarrow m_h \sim 125$ GeV when $m_{3/2} \sim O(10^5\text{—}10^6)$ GeV [100—1000 TeV]

~ Attractive points ~

Consistent with 125 GeV Higgs
No SUSY signals at current LHC
SUSY FCNC/CP problems are mild.
Coupling unification is better.
Dim5 proton decays suppressed.
Radiative breaking still happens.
No Gravitino/Polonyi problems.

~ Wino dark matter ~

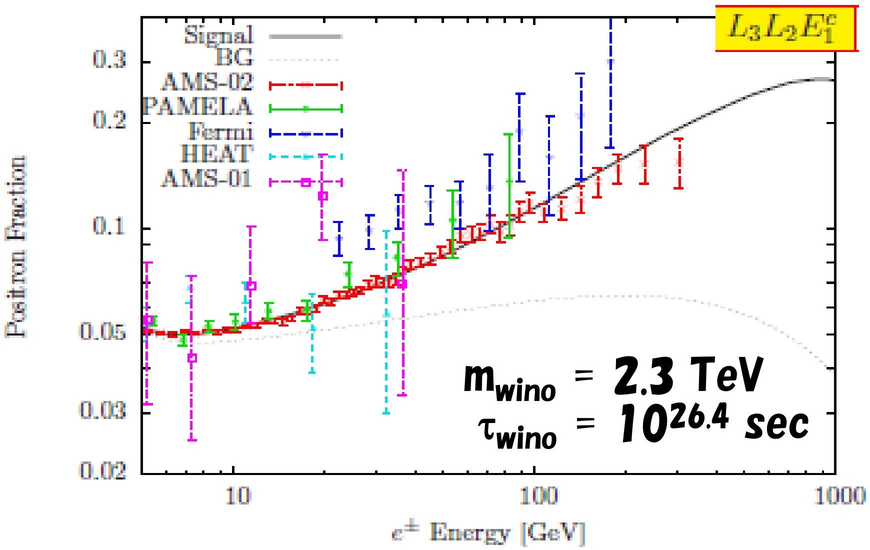
Wino is produced in a usual manner (say, WIMP miracle).

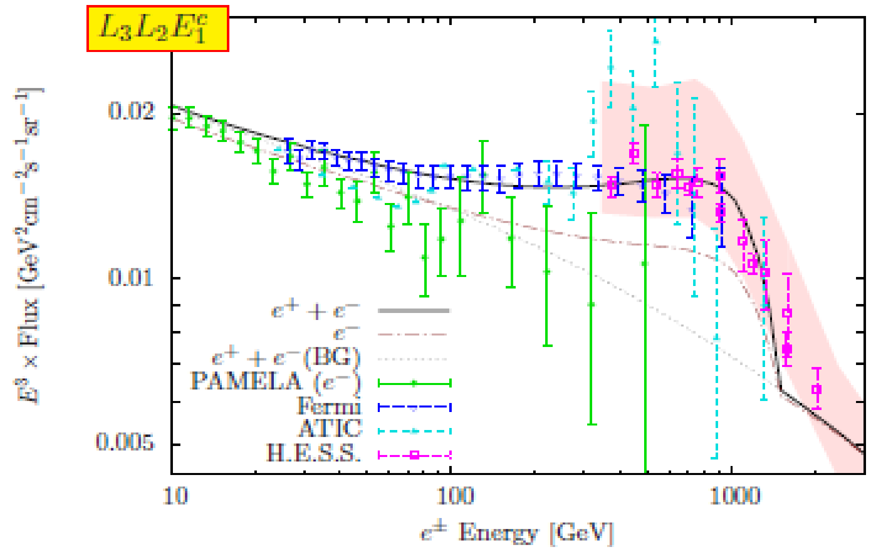
↓

Wino mass consistent with WMAP/PLANCK is ~ 3 TeV!

The wino dark matter is not necessarily to decay, though.

Positron fraction predicted





About diffusion equation:

NFW profile with r_c = 20 kpc, $\rho_\odot$ = 0.4 GeV/c.c., $r_\odot$ = 8.5 kpc used.
For parameters in the diffusion equation, the MED setup is used.

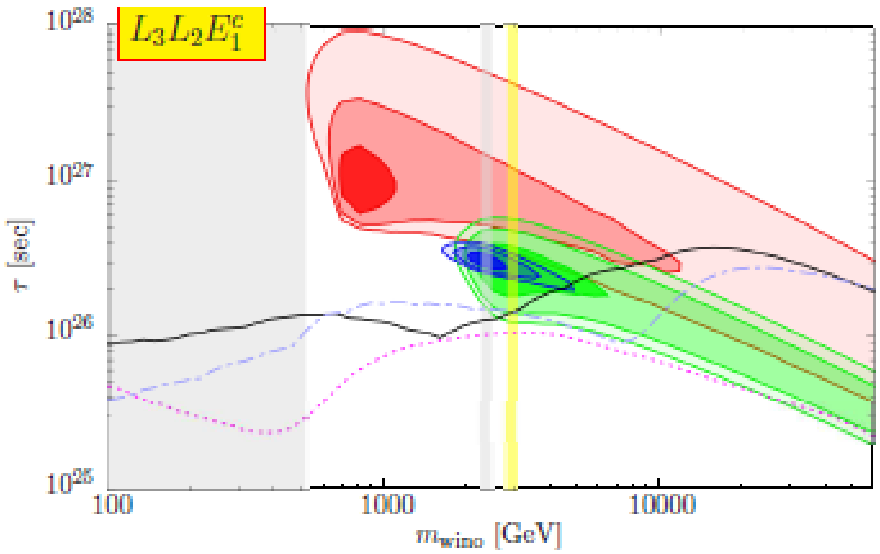
About CR backgrounds:

$\Phi_{BG}(E) = A\, E^{\gamma}\, \Phi_{ref}(E)$ for both electron & positron, where $\Phi_{ref}(E)$ is a reference BG flux from GALPROP. Parameters A & γ is fixed within appropriate ranges so that the flux fits the data well.

Annual modulation:

Force-field method is adopted (for low energy electrons & positrons).

Favored region & constraints



Data used:

PAMELA(e^-) + AMS-02 (fraction)

PAMELA(e^-) + Fermi-LAT (e^+ + e^-)

PAMELA(e^-) + AMS-02 (fraction)
+ Fermi-LAT (e^+ + e^-)

PAMELA(e^-) is important to fix the normalization of the electron flux.

Isotropic γ-ray (Black Solid line):

Prompt decay and Inverse Compton scattering (CMB) contributions are considered. Signal must be smaller than the Fermi-LAT data.

All sky γ-ray survey (blue dot-dashed line):

The same contributions as above are considered. The signal region includes the central galactic region except the one along the plane.

γ-ray from galactic cluster (pink dotted line):

Fornax cluster is considered as a target. NFW profile is adopted for the DM profile inside the cluster. Signal plus BG fit method is used.

Summary

- LHC results (Higgs and BSM searches) may indicate that SUSY scale M_{SUSY} is higher than expected. In such a case, the dark matter mass is likely to be O(1) TeV, which is quite compatible with that requited for explaining the AMS-02 result when the DM interpretation is adopted.

- We have shown two concrete examples, gravitino dark matter in GMSB and wino dark matter in pure gravity mediation SUSY breaking, and both predicts the dark matter mass of O(1) TeV with being m_h = 125 GeV.

- Model buildings of the R-parity violation is certainly needed to answer the questions whey the violation appears only in LLE^c type and why the corresponding coefficient is very suppressed. Product GUT + brane world setup may help it.