Flavor Symmetries and Dark Matter

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Hiroshi Okada (KIAS)

Outline

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- Indirect and direct dection of dark matter
  - $e^{\pm}$ excess in cosmic ray
  - Flavor dependence of $e^{\pm}$ flux
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  - Direct detection of dark matter
- Flavor Models
  - D_6 model
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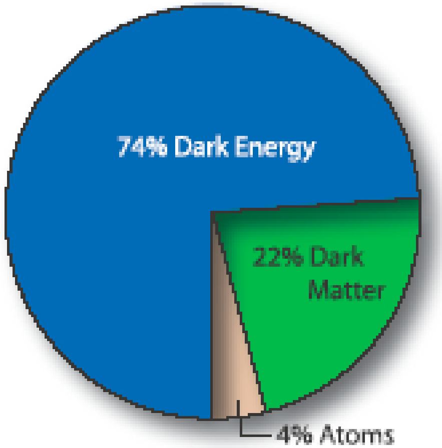
• Introduction

Many experimental evidences are found for dark matter (DM).

- rotation curves of spiral galaxy
- CMB observation by WMAP
- gravitational lensing
- large scale structure of the universe

etc...

DM exists !



The Nature of DM

- Zero electric charge
- Non-relativistic particle
- Stable or extremely long lifetime

$$\chi\chi \to \text{SM particles}$$

$$\Omega h^2 \simeq 0.11 \times \left(\frac{3.0 \times 10^{-26}}{\langle \sigma v \rangle \, [\mathrm{cm}^3/\mathrm{s}]} \right)$$

$$\downarrow$$

WMAP requires the annihilation cross section:

$$\begin{aligned} \langle \sigma v \rangle &\sim 3 \times 10^{-26} [\mathrm{cm}^3/\mathrm{s}] \\ &\sim 10^{-9} [\mathrm{GeV}^{-2}] \end{aligned}$$

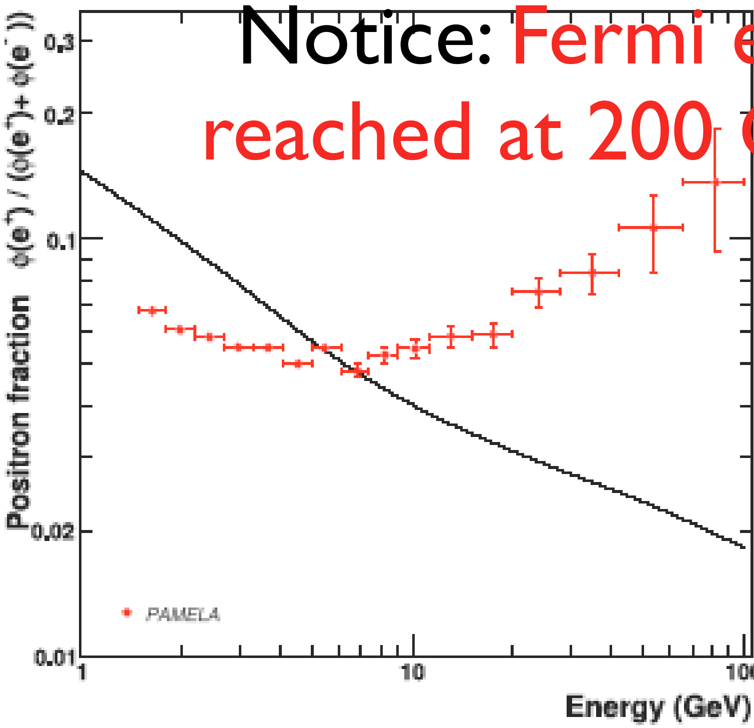
Indirect detection

The produced particles are observed as the cosmic ray ($e^{\pm}, \gamma, p, \nu$ etc).

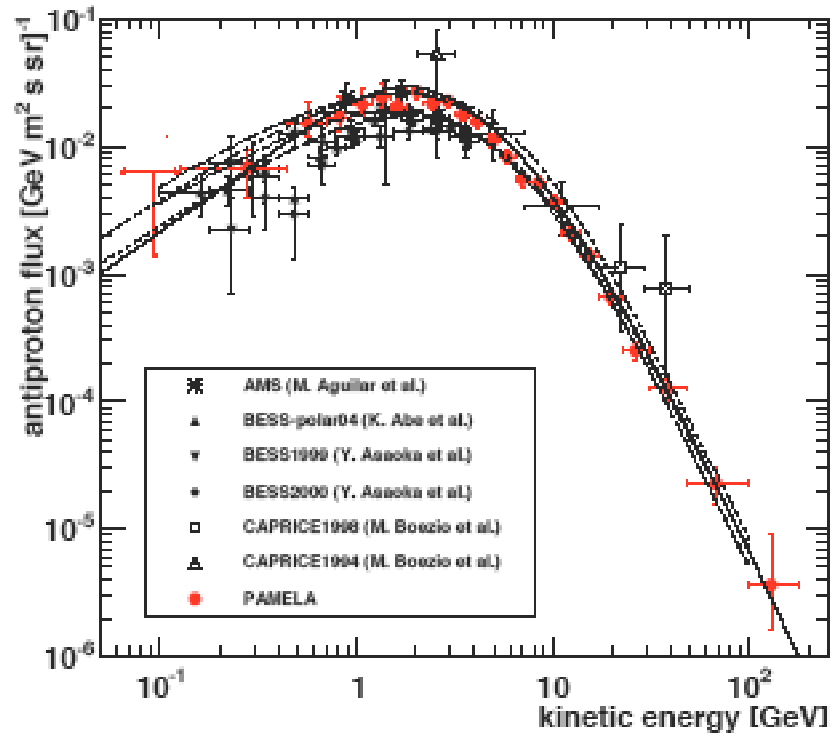
PAMELA O. Adriani et al. arXiv:0810.4995, arXiv:1007.0821

$e^{\pm}$ observation

Notice: Fermi exp. reached at 200 GeV.



anti-proton observation



Leptophilic DM is in favor of explaining the observation of the positron excess and no excess of anti-proton.

Annihilation DM

$\langle \sigma v \rangle \sim 10^{-7} [\mathrm{GeV}^{-2}]$ for $e^{\pm}$ excess of PAMELA

$\langle \sigma v \rangle \sim 10^{-9} [\mathrm{GeV}^{-2}]$ for correct relic abundance

$\mathcal{O}(100)$ difference

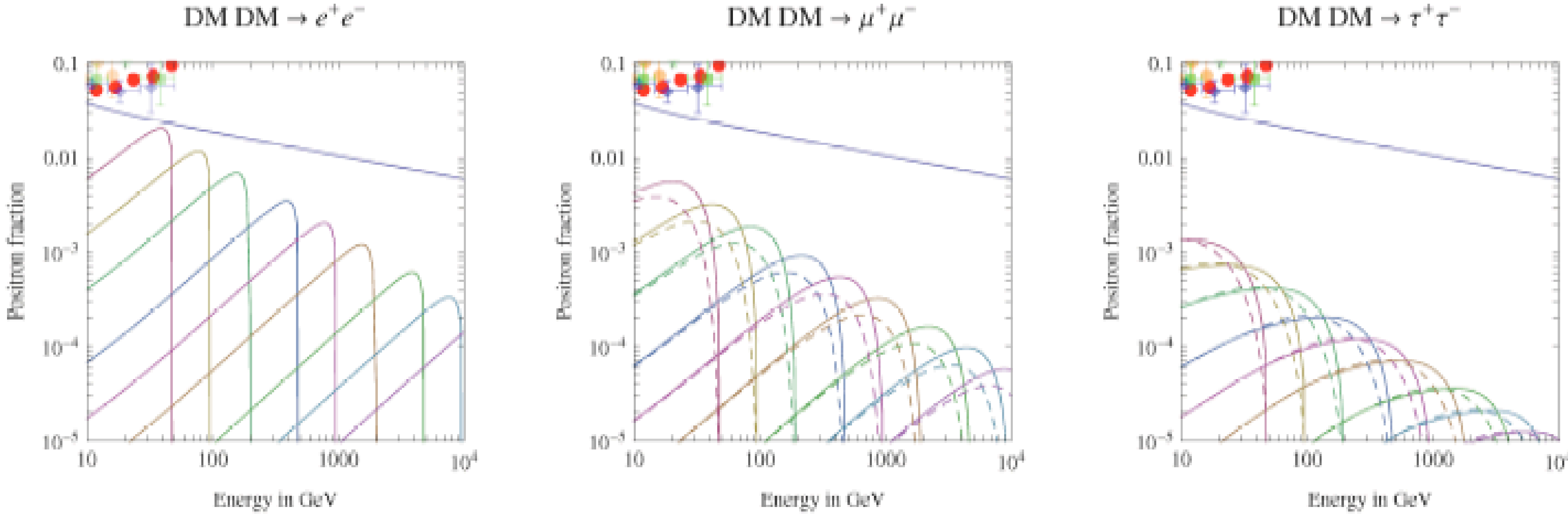
Techniques:

- Breit-Wigner enhancement
- Sommerfeld enhancement
- Non-thermal production of DM

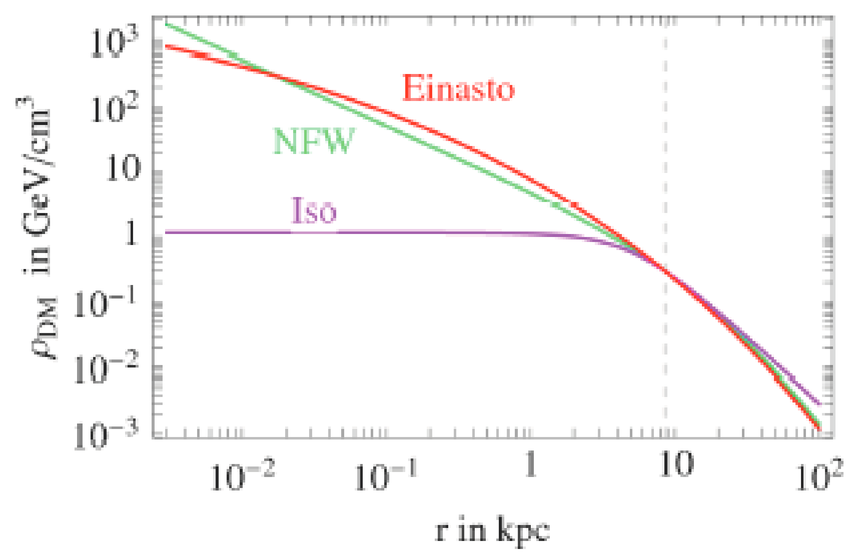
Decaying DM

$\Gamma \sim (\mathrm{TeV})^5/\Lambda^4 \sim 10^{-26}/\mathrm{sec}.$

Flavor dependence on $e^{\pm}$ flux M. Cirelli et al., arXiv:0809.2409



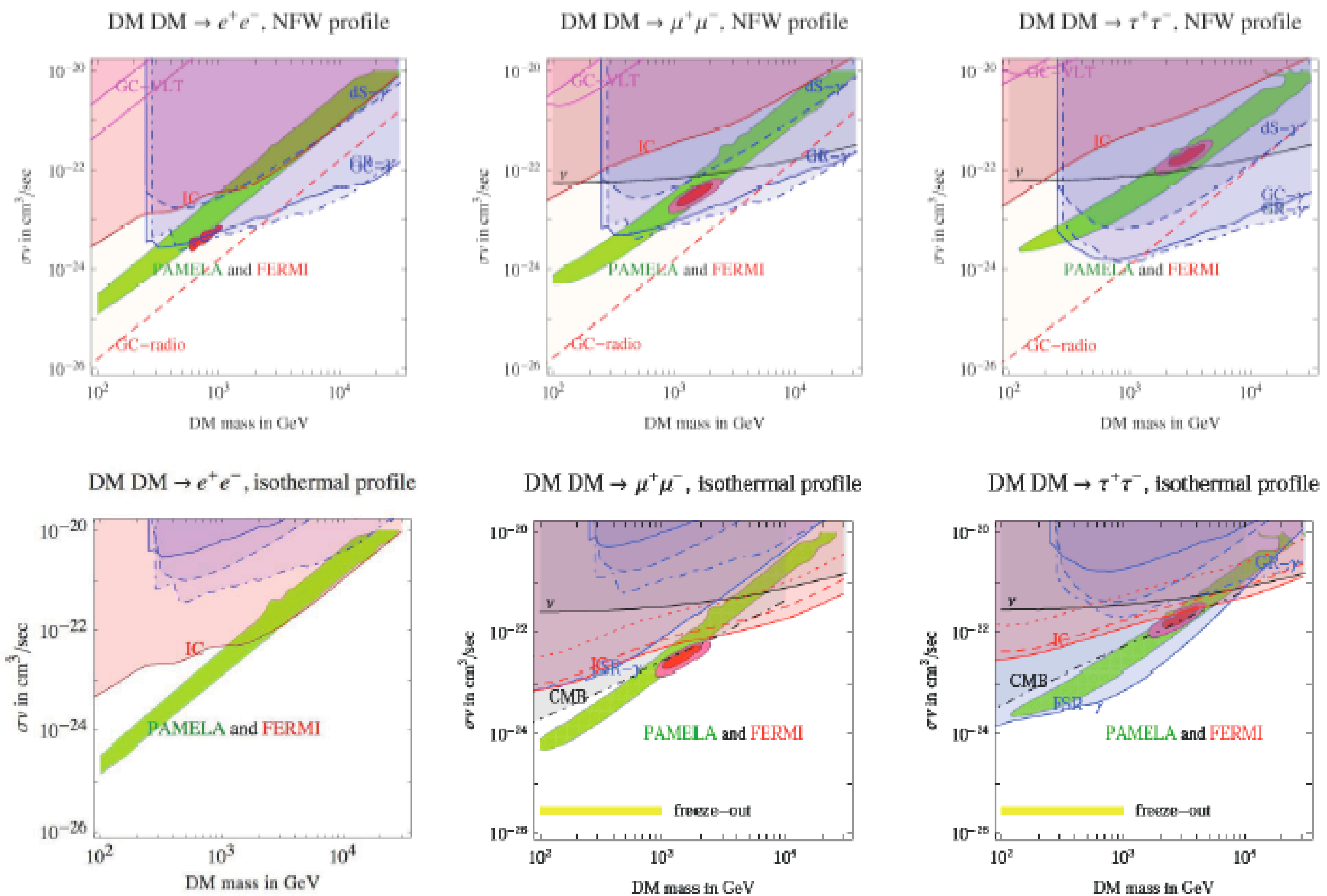
Notice: Profile dependence exists for gamma ray flux.



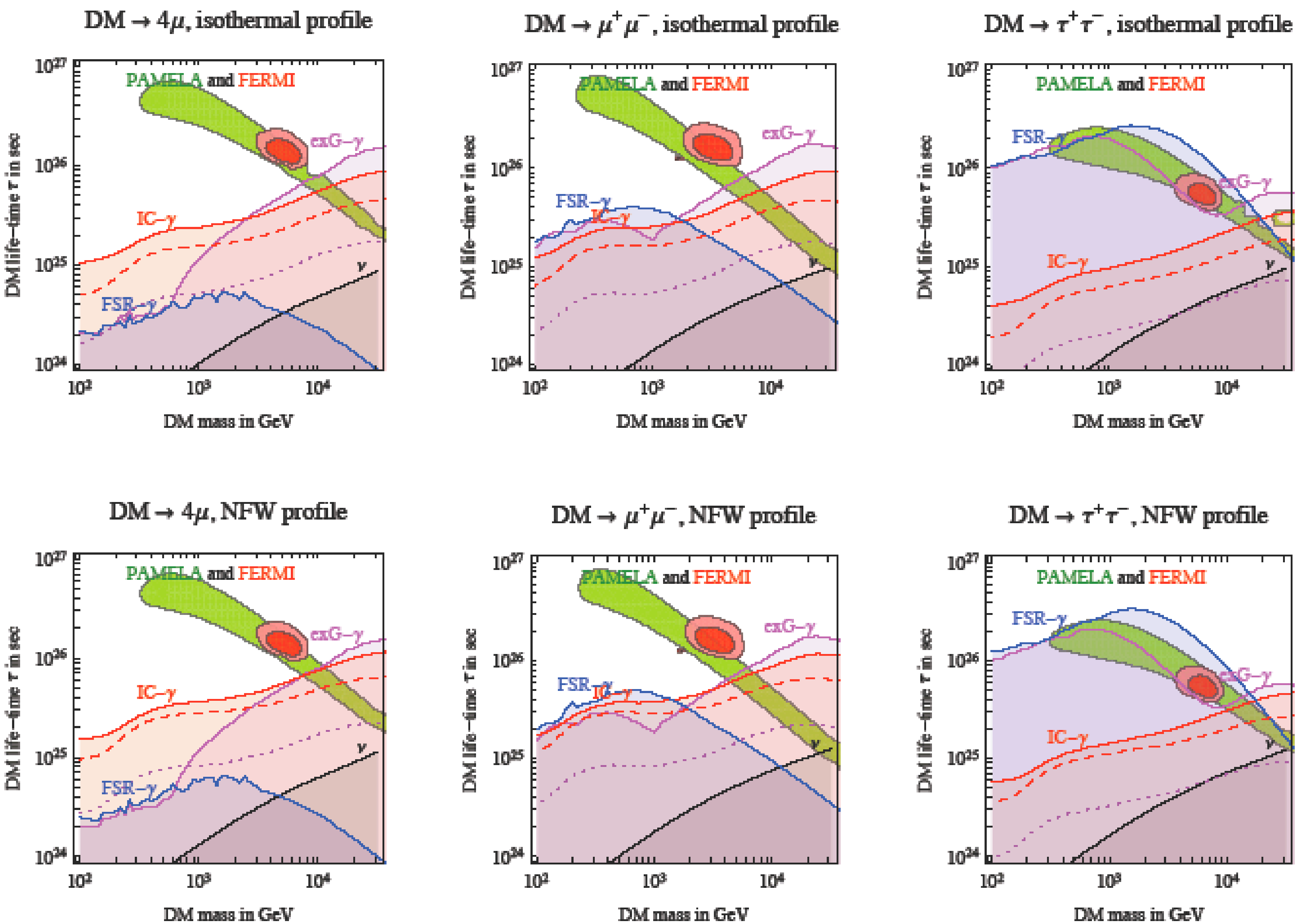
M. Cirelli and P. Panci, arXiv:0904.3830

Constraint from gamma ray P. Meade et al., arXiv:0905.0480; M. Papucci et al., 0912.0742

Annihilation



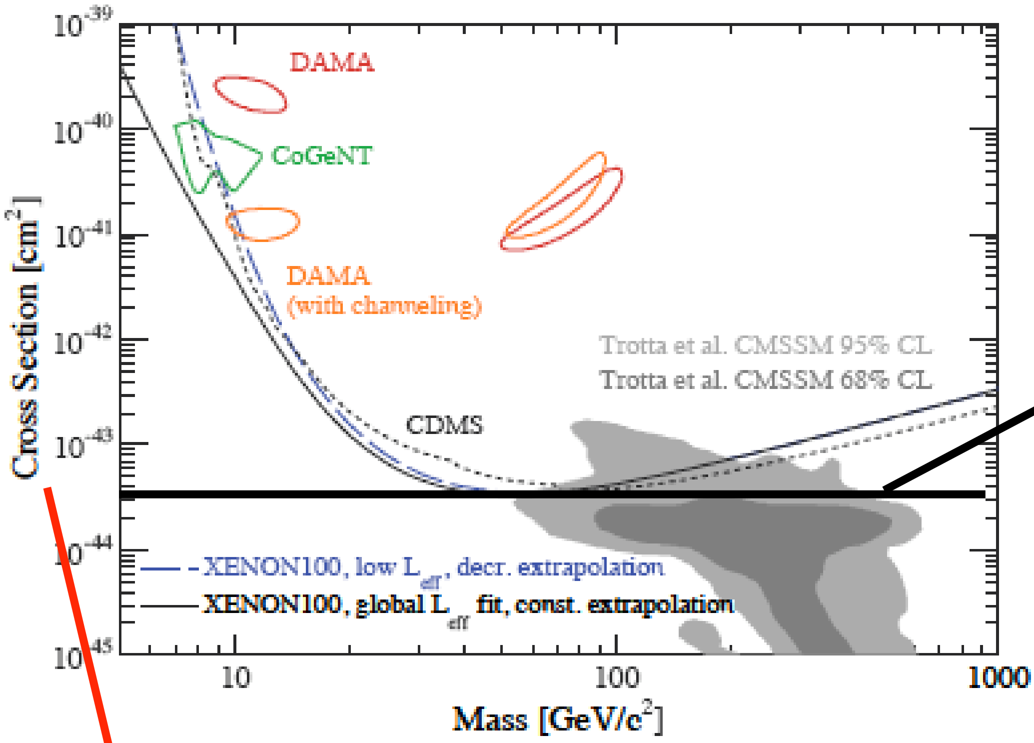
Decaying



DM → 4μ, isothermal profile
DM → μ⁺μ⁻, isothermal profile
DM → τ⁺τ⁻, isothermal profile
DM → 4μ, NFW profile
DM → μ⁺μ⁻, NFW profile
DM → τ⁺τ⁻, NFW profile
PAMELA and FERMI
exG−γ
IC−γ
FSR−γ
ν
DM life−time τ in sec
DM mass in GeV
10^24
10^25
10^26
10^27
10^2
10^3
10^4

Direct detection

Important to search the DM!



Upper bound of elastic cross section
$\sigma_0^{\rm SI} \lesssim 3.4 \times 10^{-44} [\mathrm{cm}^2]$

XENON100 Collaboration arXiv:1005.0380

Elastic scattering between DM and nucleus $\chi N \to \chi N$

D_6 Model

D_6 Group

- Dihedral groups N(N=3,4,5,...) are the non-abelian finite subgroups of SO(3).

The element

$$R_N = \begin{pmatrix} \cos\theta_N & \sin\theta_N \\ -\sin\theta_N & \cos\theta_N \end{pmatrix}, \theta_N = \frac{2\pi}{N}$$

$$P = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}, P' = \begin{pmatrix} i & 0 \\ 0 & -i \end{pmatrix}$$

12 elements, four singlets and two doubles.

D_6 Flavor Symmetric Model **Eur.Phys.J.C71:1688,2011**. (Y. kajiyama, H.O., T. Toma)

- Field contents

  SM + n_i, η and φ

$D_6 \times \hat{Z}_2 \times Z_2$ symmetry is imposed.

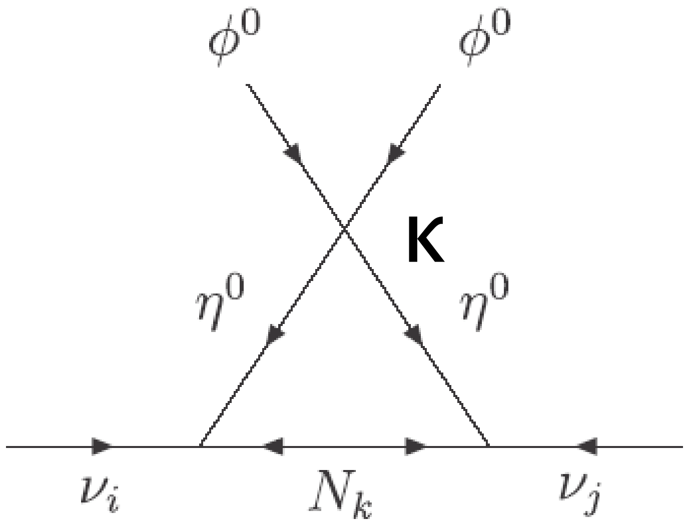
	L_S	n_S	e^c_S	L_I	n_I	e^c_I
$SU(2)_L \times U(1)_Y$	$(\mathbf{2}, -1/2)$	$(\mathbf{1}, 0)$	$(\mathbf{1}, 1)$	$(\mathbf{2}, -1/2)$	$(\mathbf{1}, 0)$	$(\mathbf{1}, 1)$
D_6	$\mathbf{1}$	$\mathbf{1}'''$	$\mathbf{1}$	$\mathbf{2}'$	$\mathbf{2}'$	$\mathbf{2}'$
$\hat{Z}_2$	$+$	$+$	$-$	$+$	$+$	$-$
Z_2	$+$	$-$	$+$	$+$	$-$	$+$

	ϕ_S	ϕ_I	η_S	η_I	φ
$SU(2)_L \times U(1)_Y$	$(\mathbf{2}, -1/2)$	$(\mathbf{2}, -1/2)$	$(\mathbf{2}, -1/2)$	$(\mathbf{2}, -1/2)$	$(\mathbf{1}, 0)$
D_6	$\mathbf{1}$	$\mathbf{2}'$	$\mathbf{1}'''$	$\mathbf{2}'$	$\mathbf{1}$
$\hat{Z}_2$	$+$	$-$	$+$	$+$	$+$
Z_2	$+$	$+$	$-$	$-$	$+$

- $D_6 \rightarrow$ predict the lepton mixing, **restrict annihilation channels of DM**
- $\hat{Z}_2 \rightarrow$ suppress FCNC of the quark sector
- $Z_2 \rightarrow$ forbid Dirac neutrino masses and stabilize DM candidate

$$
\begin{aligned}
\mathcal{L}_{\text{lepton}} &= \sum_{a,b,d=1,2,S} \left[Y^{ed}_{ab}(L_a i\sigma_2 \phi_d) e^c_b + Y^{\nu d}_{ab}(\eta^\dagger_d L_a) n_b \right] \\
&\quad - \sum_{I=1,2} \frac{M_1}{2} n_I n_I - \frac{M_S}{2} n_S n_S \\
&\quad - \sum_{I=1,2} \frac{\mathfrak{S}_1}{2} \varphi n_I n_I - \frac{\mathfrak{S}_S}{2} \varphi n_S n_S + \text{h.c.}
\end{aligned}
$$

After the EW breaking, the neutrino masses are radiatively generaed.



E. Ma(Phys.Rev.D73:077301,2006)

$$m_\nu \sim \frac{Y^\nu Y^\nu \kappa}{(4\pi)^2} \frac{v^2}{M_S} I_1\left(\frac{M_S^2}{M_\eta^2}\right)$$

$$\kappa \ll 1, \quad Y^\nu \sim 1, \quad M_S, M_\eta \sim 1 \text{ [TeV]}.$$

Predictions:

- The maximal mixing of atmospheric neutrino is derived.
- Inverted hierachy is only allowed. ($|\Delta m^2_{21}| < |\Delta m^2_{23}|$)

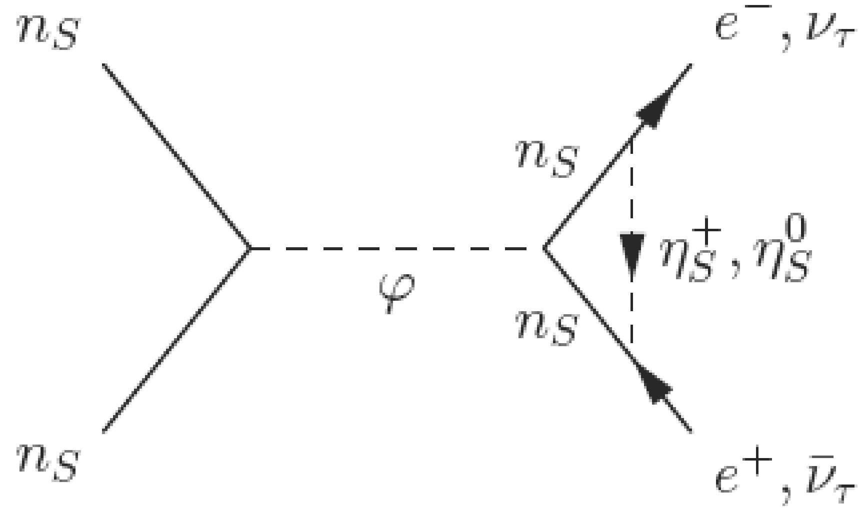
DM candidates :Z_2 odd particles
$\rightarrow \eta_I^0,\ \eta_S^0,\ n_I,\ n_S$
We assume n_S to be DM. It is interesting because there are only a few parameters due to D_6 flavor symmetry.

We have to study whether n_S can satisfy the correct relic abundance.

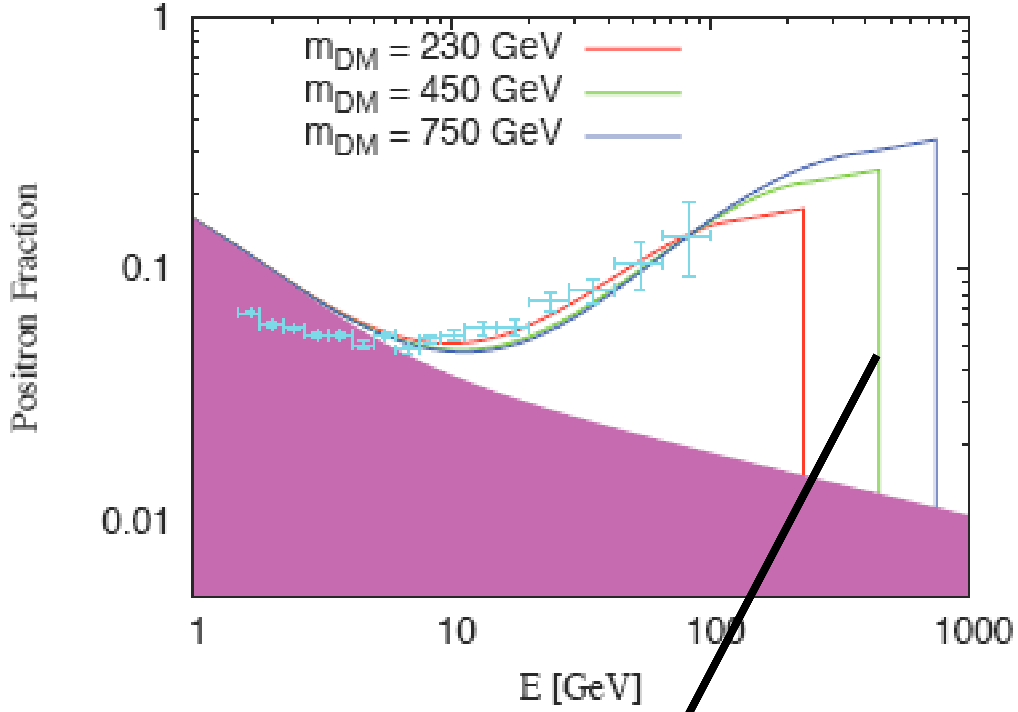
$$\mathcal{L} \supset \eta_S^+ \overline{\ell_i} Y_{ij} n_j, \quad Y \simeq \begin{array}{cc} \begin{array}{ccc} n_1, & n_2, & n_S \end{array} & \\ \begin{pmatrix} 0 & 0 & h \\ 0 & 0 & \frac{m_e}{m_\mu} h \\ 0 & 0 & 0 \end{pmatrix} & \begin{array}{c} e \\ \mu \\ \tau \end{array} \end{array} \quad \text{for charged leptons}$$

$$\mathcal{L} \supset \eta_S^0 \overline{\ell_i} Y_{ij} n_j, \quad Y = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & h \end{pmatrix} \begin{array}{c} \nu_e \\ \nu_\mu \\ \nu_\tau \end{array} \quad \text{for neutrinos}$$

Indirect Detection ($e^{\pm}$ excess)



This process is enhanced by the Breit-Wigner enhancement, and effective at only the present universe, and neglected at the early universe.



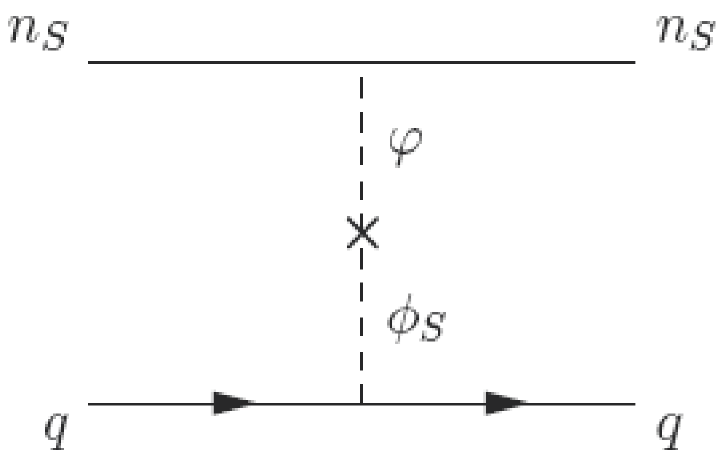
Note:

$$230\text{GeV} < M_S < 750\text{GeV}$$

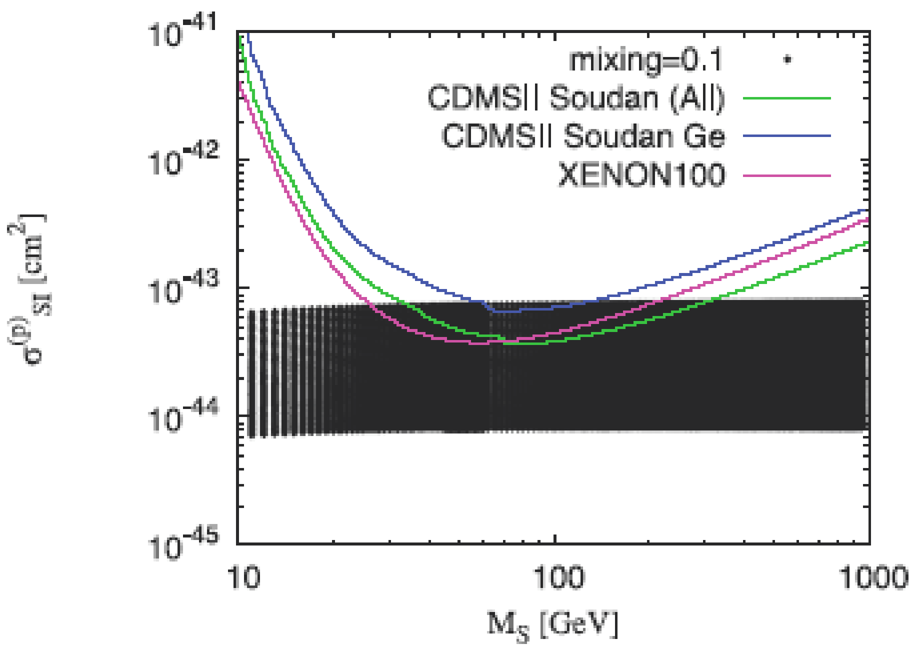
comes from the WMAP and LFV experiments.

Remarks: These shapes of the line are only determined by the final particles.

Direct Detection



This process ocuurs through the Higgs mixing.



$m_{SM-Higgs} = 115$ GeV

$\Updownarrow$

$m_{SM-Higgs} = 200$ GeV

	ϕ_S	ϕ_I	η_S	η_I	φ
$SU(2)_L \times U(1)_Y$	$(2,-1/2)$	$(2,-1/2)$	$(2,-1/2)$	$(2,-1/2)$	$(1,0)$
D_6	1	$2'$	$1'''$	$2'$	1
$\hat{Z}_2$	$+$	$-$	$+$	$+$	$+$
Z_2	$+$	$+$	$-$	$-$	$+$

NOTE:
If the sign is changed to minus, then a light dark matter can be considered to explain CoGent.
(1109.2722; Y. Kajiyama, H.O., T. Toma)

Decaying DM Model (A_4,T_13)

Decaying Dark Matters

To minimaly well-explain Indirect detection like PAMELA/Fermi-Lat

L= $LELX/\Lambda^2$ +MXX

Λ~GUT scale(10^16 GeV) ⟶ $\Gamma \sim (\mathrm{TeV})^5/\Lambda^4 \sim 10^{-26}/\mathrm{sec}$

However one simultaneously has to forbid many terms in the SM model without any symmetries except the baryon number !

Dimensions	DM decay operators
4	LH^cX
5	–
6	$LELX$, $H^\dagger HLH^cX$, $(H^c)^\dagger D_\mu H^c E\gamma^\mu X$, $QDLX$, $UQLX$, $LDQX$, $U\gamma_\mu DE\gamma^\mu X$, $D^\mu H^c D_\mu LX$, $D^\mu D_\mu H^c LX$, $B_{\mu\nu}L\sigma^{\mu\nu}H^cX$, $W^a_{\mu\nu}L\sigma^{\mu\nu}\tau^a H^cX$

(Baryon number is conserved)

Table 3: The decay operators of the gauge-singlet fermionic dark matter X up to dimension six. $B_{\mu\nu}$, $W^a_{\mu\nu}$, and D_μ are the field strength tensor of hypercharge gauge boson, weak gauge boson, and the electroweak covariant derivative.

NOTE I...How to realize such a situation?

NOTE II...How to control the final state enough?

(No pure tauon by gamma ray Fermi-Lat exp.)

arXiv:0912.0742

Non-Abelian discrete symmetries might give us an answer!!

○ A_4 Model **Matsumoto, H.O., Yoshioka, etc, (Phys.Lett.B695:476-481,2011.)**

Complete universal decay mode is achieved.

○ T_13 Model **Yajiyama, H.O., (Nucl.Phys.B848:303-313,2011.)**

Two family universal decay mode is achieved.

(If you assgin appropriately.)

A_4 Model

Even permutation of N objects. It has N!/2 elements.

A_4...It is known as a minimal group with triplet (three singlets and one triplets).

	Q	U	D	L	E	H	X
$\mathrm{SU}(2)\times\mathrm{U}(1)$	$\mathbf{2}_{1/6}$	$\mathbf{1}_{2/3}$	$\mathbf{1}_{-1/3}$	$\mathbf{2}_{-1/2}$	$\mathbf{1}_{-1}$	$\mathbf{2}_{1/2}$	$\mathbf{1}_0$
A_4	singlets	singlets	singlets	$\mathbf{3}$	$\mathbf{3}$	$(\mathbf{1},\mathbf{1}',\mathbf{1}'')$	$\mathbf{1}$

Table 2: The A_4 charge assignment of the SM fields and the dark matter X.

This assignmnets derive the universal decay mode.

※A_5 (A'_5) can derive the decay mode.
(1110.3640 with K. Hashimoto and H.O.)

The symemtries determind the final states!!!

$$\mathrm{Br}(X \to e^{\pm}\mu^{\mp}\nu_{\tau}) = \mathrm{Br}(X \to \tau^{\pm}e^{\mp}\nu_{\mu}) = \mathrm{Br}(X \to \mu^{\pm}\tau^{\mp}\nu_{e}) = \frac{1}{6}.$$

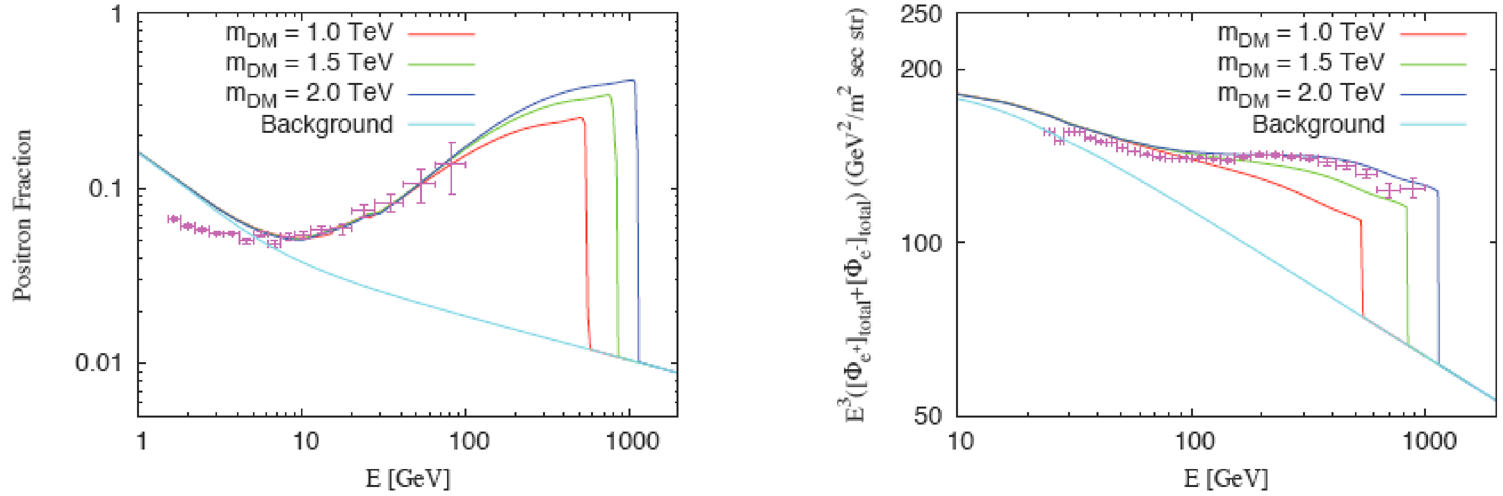


Figure 1: The positron fraction and the total $e^+ + e^-$ flux predicted in the leptonically-decaying DM scenario with A_4 symmetry. The DM mass is fixed to 1, 1.5, and 2 TeV. As for the DM decay width used in the fit, see the text.

The universal decay mode is fitting well !

T_13 Model

It consists of 4 triplets and 3 singlets.

The generators, a and b, are represented e.g. as

$$b = \begin{pmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{pmatrix}, \quad a = \begin{pmatrix} \rho & 0 & 0 \\ 0 & \rho^3 & 0 \\ 0 & 0 & \rho^9 \end{pmatrix}, \tag{2.3}$$

where $\rho = e^{2i\pi/13}$. These elements are classified into seven conjugacy classes,

$$\begin{array}{lcl}
C_1: & \{e\}, & h=1, \\
C_{13}^{(1)}: & \{b\ ,\ ba\ ,\ ba^2\ ,\ \ \dots\ \ ,\ ba^{10}\ ,\ ba^{11}\ ,\ ba^{12}\}, & h=3, \\
C_{13}^{(2)}: & \{b^2\ ,\ b^2a\ ,\ b^2a^2\ ,\ \ \dots\ \ ,\ b^2a^{10}\ ,\ b^2a^{11}\ ,\ b^2a^{12}\}, & h=3, \\
C_{3_1}: & \{a\ ,\ a^3\ ,\ a^9\}, & h=13, \\
C_{\bar{3}_1}: & \{a^4\ ,\ a^{10}\ ,\ a^{12}\}, & h=13, \\
C_{3_2}: & \{a^2\ ,\ a^5\ ,\ a^6\}, & h=13, \\
C_{\bar{3}_2}: & \{a^7\ ,\ a^8\ ,\ a^{11}\}, & h=13.
\end{array} \tag{2.4}$$

The T_{13} group has three singlets $\mathbf{1}_k$ with $k = 0,\ 1,\ 2$ and two complex triplets $\mathbf{3}_1$ and $\mathbf{3}_2$ as irreducible representations. The characters are shown in Table 1, where $\xi_1 \equiv \rho + \rho^3 + \rho^9$, $\xi_2 \equiv \rho^2 + \rho^5 + \rho^6$, and $\omega \equiv e^{2i\pi/3}$.

Next we show the multiplication rules of the T_{13} group. We define the triplets as

$$\mathbf{3}_1 \equiv \begin{pmatrix} x_1 \\ x_3 \\ x_9 \end{pmatrix}, \quad \bar{\mathbf{3}}_1 \equiv \begin{pmatrix} x_{12} \\ x_{10} \\ x_4 \end{pmatrix}, \quad \mathbf{3}_2 = \begin{pmatrix} y_2 \\ y_6 \\ y_5 \end{pmatrix}, \quad \bar{\mathbf{3}}_2 \equiv \begin{pmatrix} y_{11} \\ y_7 \\ y_8 \end{pmatrix}, \tag{2.5}$$

where the subscripts denote Z_{13} charge of each element.

The tensor products between triplets are obtained as

$$\begin{pmatrix} x_1 \\ x_3 \\ x_9 \end{pmatrix}_{\mathbf{3}_1} \otimes \begin{pmatrix} y_1 \\ y_3 \\ y_9 \end{pmatrix}_{\mathbf{3}_1} = \begin{pmatrix} x_3 y_9 \\ x_9 y_1 \\ x_1 y_3 \end{pmatrix}_{\mathbf{3}_1} \oplus \begin{pmatrix} x_9 y_3 \\ x_1 y_9 \\ x_3 y_1 \end{pmatrix}_{\mathbf{3}_1} \oplus \begin{pmatrix} x_1 y_1 \\ x_3 y_3 \\ x_9 y_9 \end{pmatrix}_{\mathbf{3}_2}, \tag{2.6}$$

$$\begin{pmatrix} x_{12} \\ x_{10} \\ x_4 \end{pmatrix}_{\mathbf{3}_1} \otimes \begin{pmatrix} y_{12} \\ y_{10} \\ y_4 \end{pmatrix}_{\mathbf{3}_1} = \begin{pmatrix} x_{10} y_4 \\ x_4 y_{12} \\ x_{12} y_{10} \end{pmatrix}_{\mathbf{3}_1} \oplus \begin{pmatrix} x_4 y_{10} \\ x_{12} y_4 \\ x_{10} y_{12} \end{pmatrix}_{\mathbf{3}_1} \oplus \begin{pmatrix} x_{12} y_{12} \\ x_{10} y_{10} \\ x_4 y_4 \end{pmatrix}_{\mathbf{3}_2}, \tag{2.7}$$

$$\begin{pmatrix} x_1 \\ x_3 \\ x_9 \end{pmatrix}_{\mathbf{3}_1} \otimes \begin{pmatrix} y_{12} \\ y_{10} \\ y_4 \end{pmatrix}_{\mathbf{3}_1} = \sum_{k=0,1,2} (x_1 y_{12} + \omega^k x_3 y_{10} + \omega^{2k} x_9 y_4)_{\mathbf{1}_k} \oplus \begin{pmatrix} x_3 y_{12} \\ x_9 y_{10} \\ x_1 y_4 \end{pmatrix}_{\mathbf{3}_2} \oplus \begin{pmatrix} x_1 y_{10} \\ x_3 y_4 \\ x_9 y_{12} \end{pmatrix}_{\mathbf{3}_2}, \tag{2.8}$$

$$\begin{pmatrix} x_2 \\ x_6 \\ x_5 \end{pmatrix}_{\mathbf{3}_2} \otimes \begin{pmatrix} y_2 \\ y_6 \\ y_5 \end{pmatrix}_{\mathbf{3}_2} = \begin{pmatrix} x_5 y_6 \\ x_2 y_5 \\ x_6 y_2 \end{pmatrix}_{\mathbf{3}_2} \oplus \begin{pmatrix} x_6 y_5 \\ x_5 y_2 \\ x_2 y_6 \end{pmatrix}_{\mathbf{3}_2} \oplus \begin{pmatrix} x_6 y_6 \\ x_5 y_5 \\ x_2 y_2 \end{pmatrix}_{\mathbf{3}_1}, \tag{2.9}$$

$$\begin{pmatrix} x_{11} \\ x_7 \\ x_8 \end{pmatrix}_{\mathbf{3}_2} \otimes \begin{pmatrix} y_{11} \\ y_7 \\ y_8 \end{pmatrix}_{\mathbf{3}_2} = \begin{pmatrix} x_8 y_7 \\ x_{11} y_8 \\ x_7 y_{11} \end{pmatrix}_{\mathbf{3}_2} \oplus \begin{pmatrix} x_7 y_8 \\ x_8 y_{11} \\ x_{11} y_7 \end{pmatrix}_{\mathbf{3}_2} \oplus \begin{pmatrix} x_7 y_7 \\ x_8 y_8 \\ x_{11} y_{11} \end{pmatrix}_{\mathbf{3}_1}, \tag{2.10}$$

ex.

$$\begin{pmatrix} x_2 \\ x_6 \\ x_5 \end{pmatrix}_{\mathbf{3}_2} \otimes \begin{pmatrix} y_{11} \\ y_7 \\ y_8 \end{pmatrix}_{\mathbf{3}_2} = \sum_{k=0,1,2} (x_2 y_{11} + \omega^k x_6 y_7 + \omega^{2k} x_5 y_8)_{\mathbf{1}_k} \oplus \begin{pmatrix} x_6 y_8 \\ x_5 y_{11} \\ x_2 y_7 \end{pmatrix}_{\mathbf{3}_1} \oplus \begin{pmatrix} x_5 y_7 \\ x_2 y_8 \\ x_6 y_{11} \end{pmatrix}_{\mathbf{3}_1}, \tag{2.11}$$

Two triplet multiplication rules give different type of triplets that is different from A4 and Δ(27).

$$\begin{pmatrix} x_1 \\ x_3 \\ x_9 \end{pmatrix}_{\mathbf{3}_1} \otimes \begin{pmatrix} y_2 \\ y_6 \\ y_5 \end{pmatrix}_{\mathbf{3}_2} = \begin{pmatrix} x_9 y_6 \\ x_1 y_5 \\ x_3 y_2 \end{pmatrix}_{\mathbf{3}_2} \oplus \begin{pmatrix} x_9 y_2 \\ x_1 y_6 \\ x_3 y_5 \end{pmatrix}_{\bar{\mathbf{3}}_2} \oplus \begin{pmatrix} x_9 y_5 \\ x_1 y_2 \\ x_3 y_6 \end{pmatrix}_{\mathbf{3}_1}, \tag{2.12}$$

$$\begin{pmatrix} x_1 \\ x_3 \\ x_9 \end{pmatrix}_{\mathbf{3}_1} \otimes \begin{pmatrix} \bar{y}_{11} \\ \bar{y}_7 \\ \bar{y}_8 \end{pmatrix}_{\bar{\mathbf{3}}_2} = \begin{pmatrix} x_1 \bar{y}_{11} \\ x_3 \bar{y}_7 \\ x_9 \bar{y}_8 \end{pmatrix}_{\bar{\mathbf{3}}_1} \oplus \begin{pmatrix} x_3 \bar{y}_8 \\ x_9 \bar{y}_{11} \\ x_1 \bar{y}_7 \end{pmatrix}_{\bar{\mathbf{3}}_2} \oplus \begin{pmatrix} x_3 \bar{y}_{11} \\ x_9 \bar{y}_7 \\ x_1 \bar{y}_8 \end{pmatrix}_{\mathbf{3}_1}, \tag{2.13}$$

$$\begin{pmatrix} x_2 \\ x_6 \\ x_5 \end{pmatrix}_{\mathbf{3}_2} \otimes \begin{pmatrix} \bar{y}_{12} \\ \bar{y}_{10} \\ \bar{y}_4 \end{pmatrix}_{\bar{\mathbf{3}}_1} = \begin{pmatrix} x_2 \bar{y}_{12} \\ x_6 \bar{y}_{10} \\ x_5 \bar{y}_4 \end{pmatrix}_{\bar{\mathbf{3}}_1} \oplus \begin{pmatrix} x_2 \bar{y}_{10} \\ x_6 \bar{y}_4 \\ x_5 \bar{y}_{12} \end{pmatrix}_{\bar{\mathbf{3}}_1} \oplus \begin{pmatrix} x_5 \bar{y}_{10} \\ x_2 \bar{y}_4 \\ x_6 \bar{y}_{12} \end{pmatrix}_{\mathbf{3}_2}, \tag{2.14}$$

$$\begin{pmatrix} \bar{x}_{12} \\ \bar{x}_{10} \\ \bar{x}_4 \end{pmatrix}_{\bar{\mathbf{3}}_1} \otimes \begin{pmatrix} \bar{y}_{11} \\ \bar{y}_7 \\ \bar{y}_8 \end{pmatrix}_{\bar{\mathbf{3}}_2} = \begin{pmatrix} \bar{x}_4 \bar{y}_8 \\ \bar{x}_{12} \bar{y}_{11} \\ \bar{x}_{10} \bar{y}_7 \end{pmatrix}_{\bar{\mathbf{3}}_1} \oplus \begin{pmatrix} \bar{x}_4 \bar{y}_7 \\ \bar{x}_{12} \bar{y}_8 \\ \bar{x}_{10} \bar{y}_{11} \end{pmatrix}_{\bar{\mathbf{3}}_2} \oplus \begin{pmatrix} \bar{x}_4 \bar{y}_{11} \\ \bar{x}_{12} \bar{y}_7 \\ \bar{x}_{10} \bar{y}_8 \end{pmatrix}_{\mathbf{3}_2}. \tag{2.15}$$

The tensor products between singlets are obtained as

$$\begin{aligned} &(x)_{\mathbf{1}_0}(y)_{\mathbf{1}_0} = (x)_{\mathbf{1}_1}(y)_{\mathbf{1}_2} = (x)_{\mathbf{1}_2}(y)_{\mathbf{1}_1} = (xy)_{\mathbf{1}_0}, \\ &(x)_{\mathbf{1}_1}(y)_{\mathbf{1}_1} = (xy)_{\mathbf{1}_2}, \ (x)_{\mathbf{1}_2}(y)_{\mathbf{1}_2} = (xy)_{\mathbf{1}_1}. \end{aligned} \tag{2.16}$$

The tensor products between triplets and singlets are obtained as

$$(y)_{\mathbf{1}_k} \otimes \begin{pmatrix} x(\bar{x})_1 \\ x(\bar{x})_2 \\ x(\bar{x})_3 \end{pmatrix}_{\mathbf{3}(\bar{\mathbf{3}})} = \begin{pmatrix} yx(\bar{x})_1 \\ yx(\bar{x})_2 \\ yx(\bar{x})_3 \end{pmatrix}_{\mathbf{3}(\bar{\mathbf{3}})}. \tag{2.17}$$

In the following section, we discuss mass matrices of the lepton sector determined by the T_{13} flavor symmetry.

T(13) assignments

	Q	U	D	L	E	H	H'	X
$SU(2)_L \times U(1)_Y$	$2_{1/6}$	$1_{2/3}$	$1_{-1/3}$	$2_{-1/2}$	1_{-1}	$2_{1/2}$	$2_{1/2}$	1_0
T_{13}	$1_{0,1,2}$	$1_{0,1,2}$	$1_{0,1,2}$	3_1	3_2	$3_1, \bar{3}_2$	$1_{0,1,2}$	1_0
Z_3	1	ω	ω^2	1	1	1	ω	1

Table 2: The T_{13} and Z_3 charge assignment of the SM fields and the dark matter X, where $\omega = e^{2i\pi/3}$.

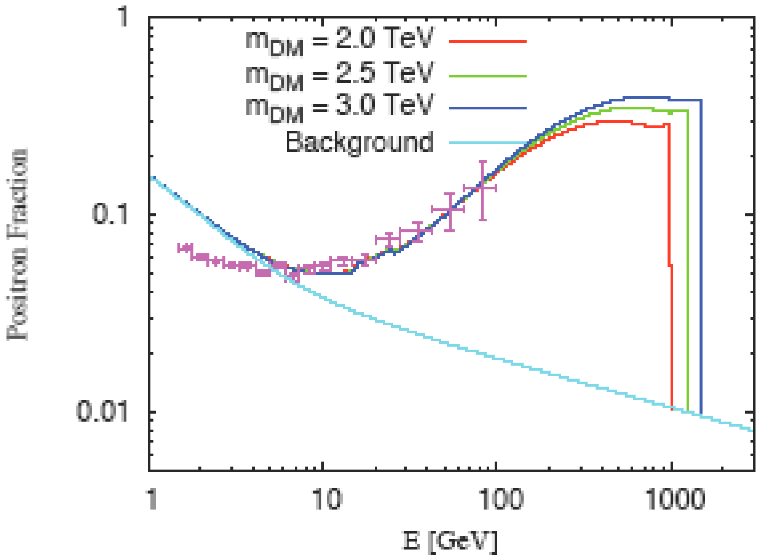
This assignmnets derive the two family universal decay mode.

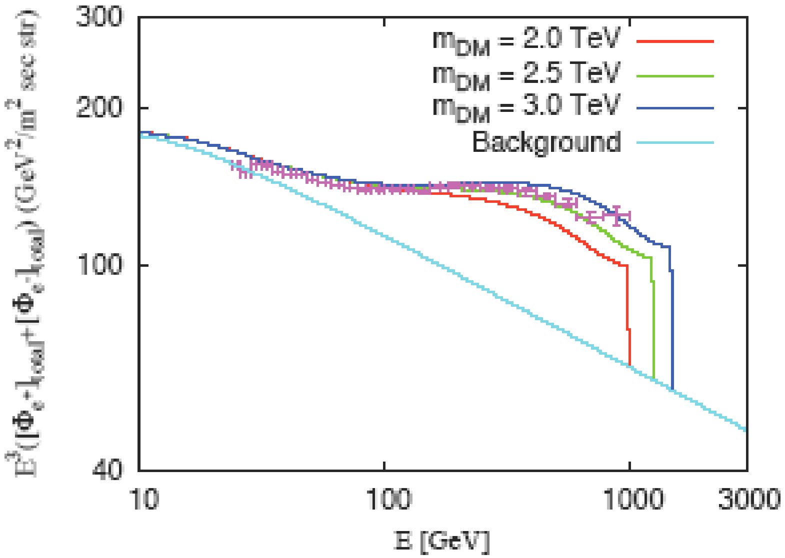
The symemtries determind the final states!!!

$$BR(X \to \nu_\alpha \ell^+_\beta \ell^-_\gamma)$$

(α,β,γ)=[(eτe), (μeμ),(τμτ), (eeτ), (μμe),(ττμ),]/6

...three families are mixed





The two family universal decay mode is also fitting well !

○ Summary

Some Non-Abelian discrete symmeties could have a possibilities to well-explain direct and indirect detection without spoiling lepton/quark sectors.

(D_6, A_4, T(13),...)

In decaying DM scenario, if one wants to predict lepton/quark sector maintaining the explanation of PAMELA/Fermi-lat,

some more complicated groups might be promising

(S_4, A_5,...)

NOTE;

Higgs sector is discussed more seriouly.

Thanks !