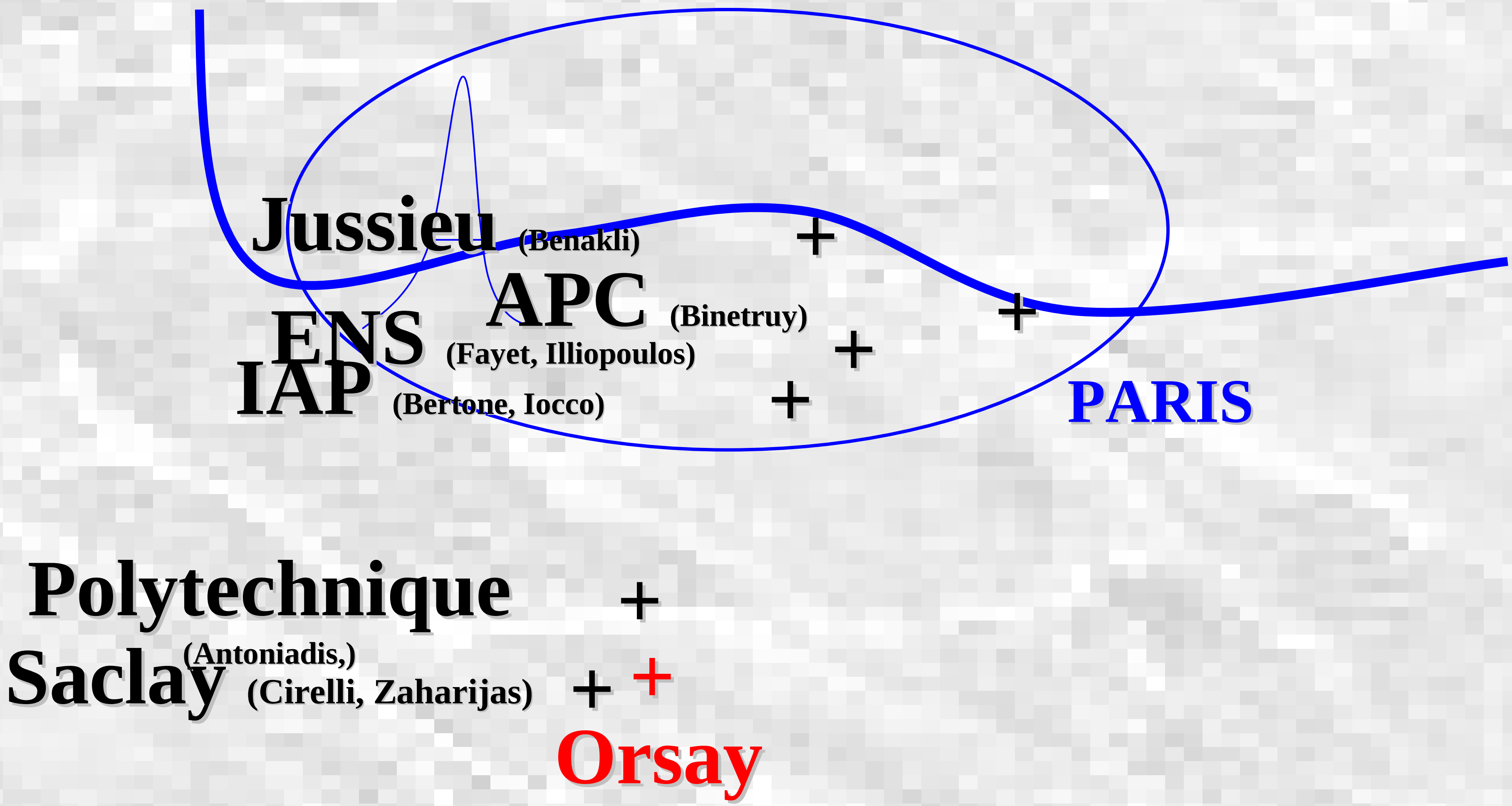
DM Signatures generated by anomalies in hidden sectors

Yann Mambrini **Laboratoire de Physique Théorique Orsay, Université Paris XI**

E. Dudas, S. Pokorski, A. Romagnoni

GGI, Florence,, May 20th 2010

Where is Orsay?



Overview

I) The DM puzzle

II) Gamma ray lines signals

III) Importance of Anomalies in Particle Physics

IV) Anomalies cancelation mechanisms

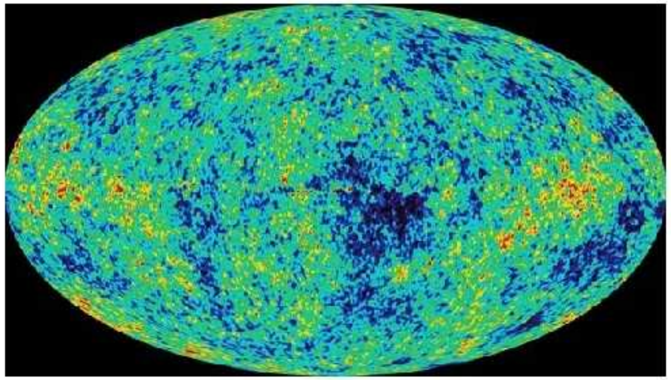
V) Gamma-ray lines generated by anomalies

VI) FERMI analysis

VII) Conclusions

Dark Matter Evidences

CMB (WMAP)



\+

Galactic Scale

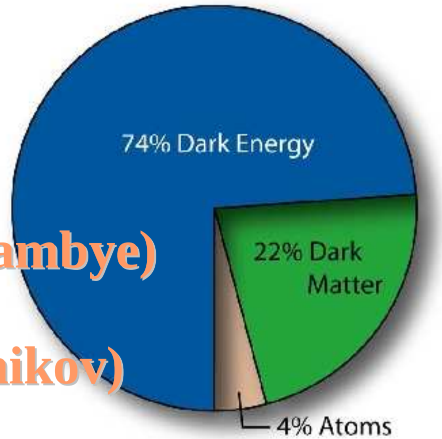
SUSY : neutralino, gravitino.. (N. Fornengo, P. Ullio, L. Covi)

KK modes (Extra Dim.) (Servant, Tait)

Extra U(1) boson (Arkani-Ahmed, T. Hambye)

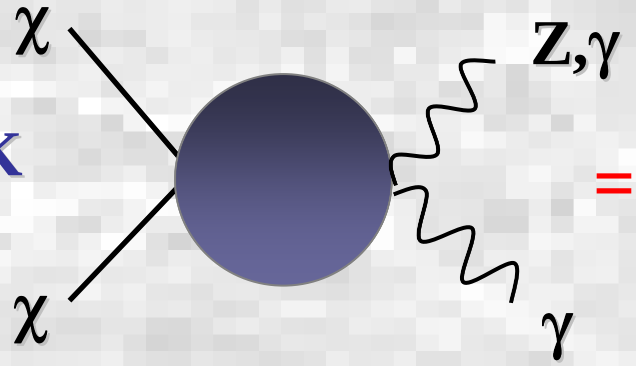
Sterile right handed neutrino (Shaposhnikov)

Weak scale scalar (Gustafsson, Tytgat)

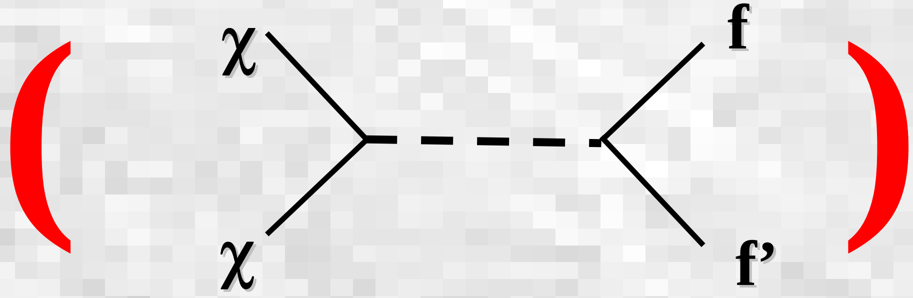


γ ray lines (annihilation)

SUSY/KK
[…]

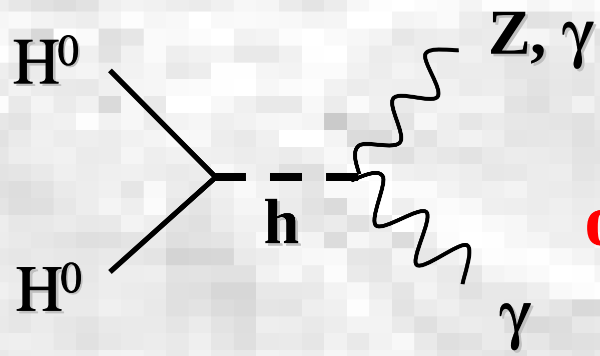


$= 10^{-2}$



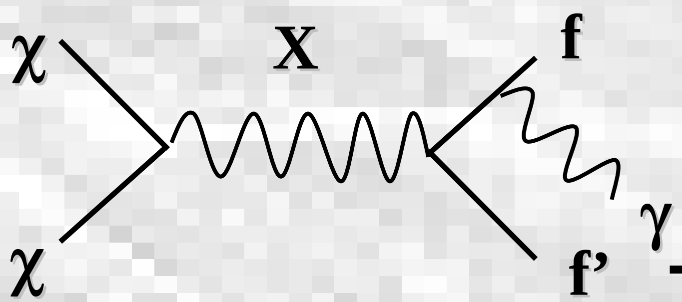
Inert Higgs Doublet
[Gustafsson, Lundstrom, Bergstrom, Edsjo 07]

If $m_{H0} < M_W$



2 lines
or $\gamma\gamma$ line

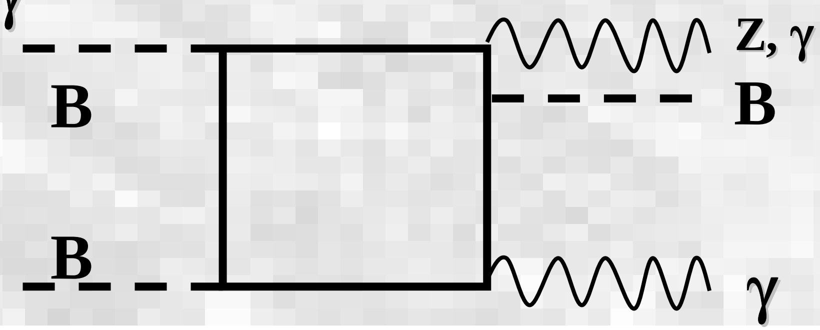
Visible X
[Baek & Ko, 08]
[Bergstrom, Bringmann, Edsjo 08]



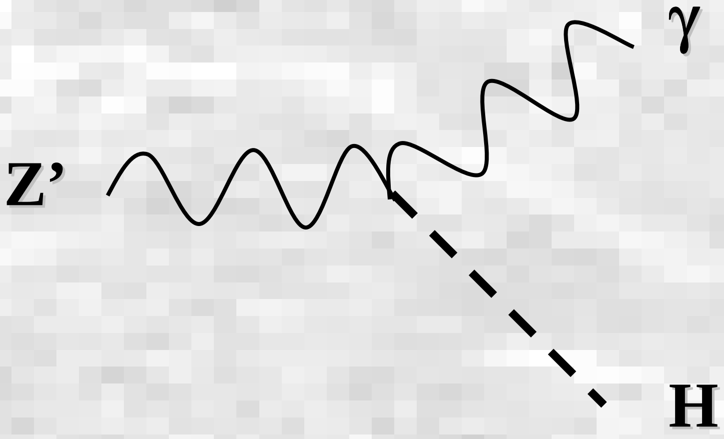
No visible line

3 visible lines

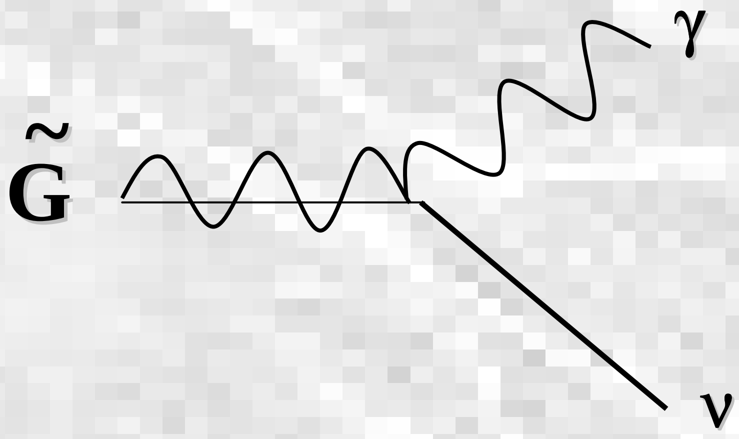
Chiral Square
[Bertone et al. 09]



γ ray lines (Decaying)



T. Hambye 09



K.Y. Choi, C. Munoz 08

G. Bertone, W. Buchmuller, L. Covi, A. Ibarra 07

Anomalies in particle physics

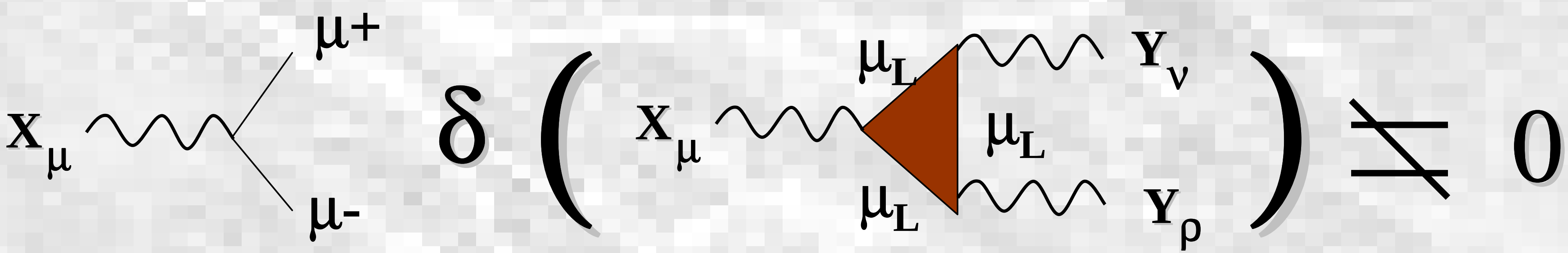
$$\cancel{\mathcal{L}_{Sym} + \delta\mathcal{L}_{quant}}$$

Anomalies : quantum corrections destroy the symmetries of the classical theory

If the symmetry is local, the gauge anomaly causes the loss of unitarity, which is to say the consistency of the theory

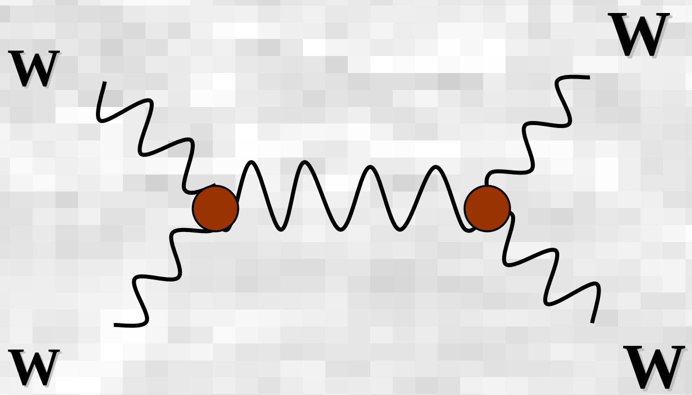
A mechanism of anomaly cancellation should be imposed to the model

Example : leptophylic DM

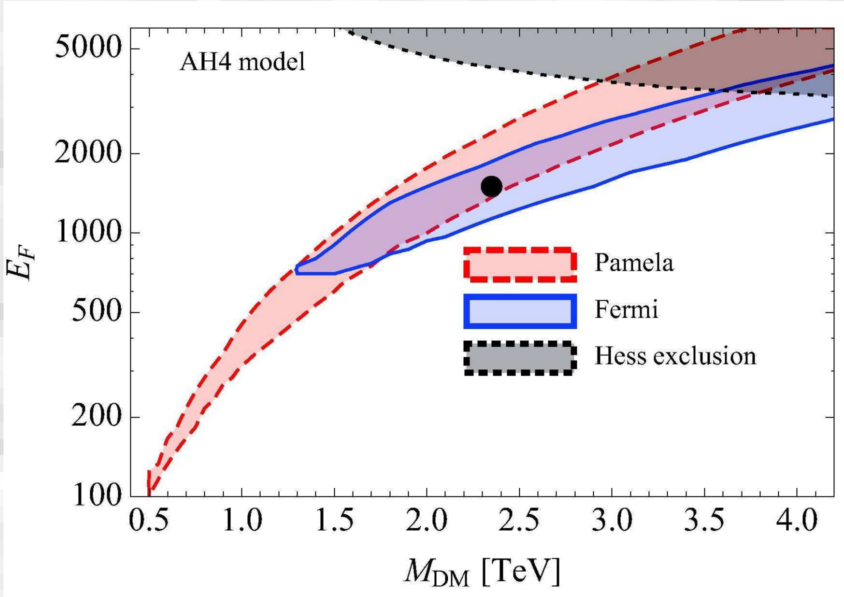


INDEPENDENT OF THE MASSES OF THE FERMIONS RUNNING IN THE LOOPS (decoupling theorem)

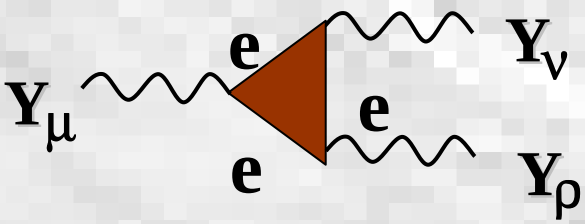
Solving the problem..



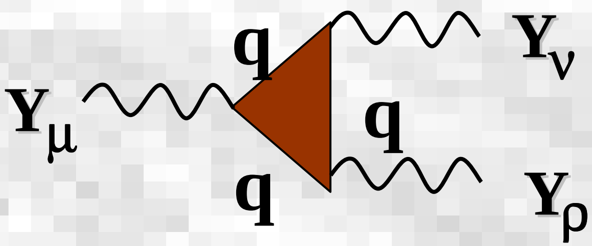
$\sim s \quad \sigma > 1$



Lost of unitarity



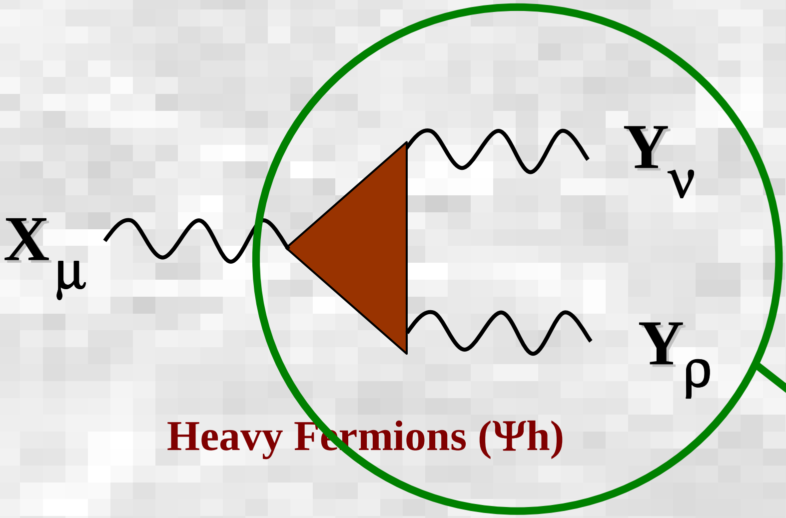
$+$

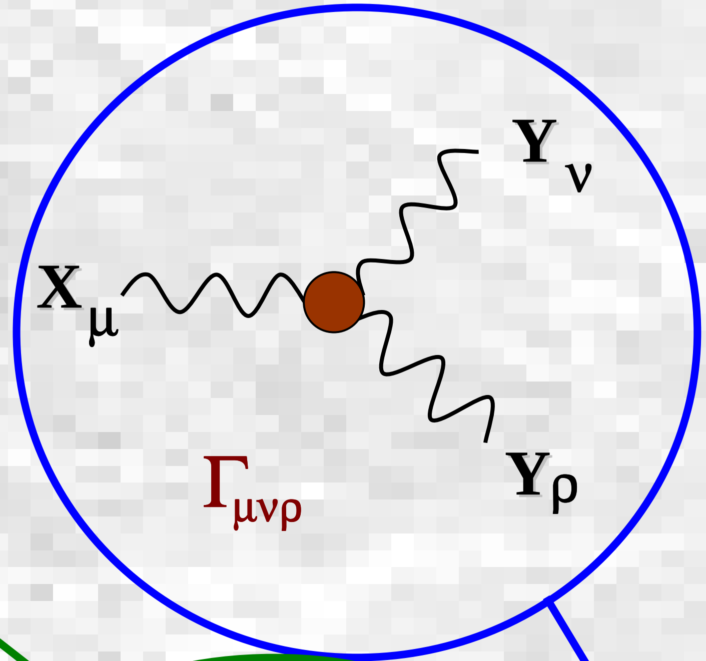


$\alpha(Q_e - 3\,Q_q)$

Miracle !!

Explicit construction





U'(1)

Ψ	U(1)	U'(1)
ΨSM	XSM	0
Ψi	Xi	X'i
Ψh	0	X'h

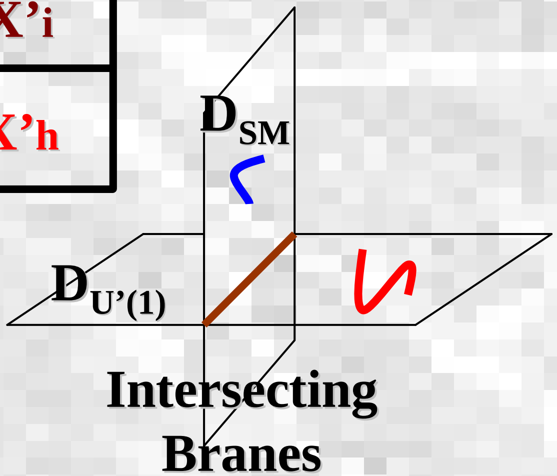
$$\mathcal{L} \xrightarrow{U'(1)} \mathcal{L} + \lambda\, \varepsilon^{\mu\nu\rho\sigma} F^{Y}_{\mu\nu} F^{Y}_{\rho\sigma} + \mathcal{L}_3$$

$$X_\mu \longrightarrow X_\mu + d_\mu \lambda$$

$$a \longrightarrow a - M_X \lambda$$

$$X_\mu + M_X d_\mu a \longrightarrow X_\mu + M_X d_\mu a$$

(Stuckelberg Langrangian)



Intersecting Branes

Anomalie cancellation : Green-Schwarz mechanism

Anastopoulos, Bianchi, Dudas, Kiritsis 06

Anastopoulos, Fucito, Lionetto, Pradisi, Racioppi, Stanev 08

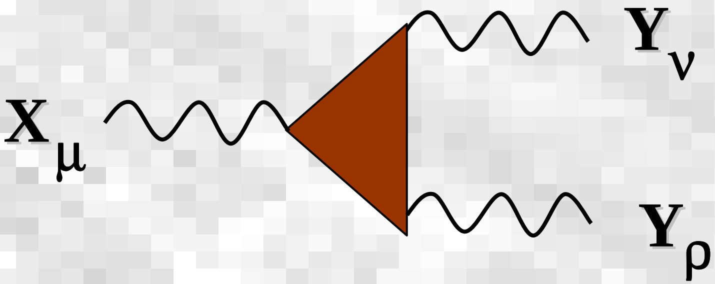
$$\mathcal{L}_{inv} = F^{Y\mu\nu} F^{Y}{}_{\mu\nu} - (d_\mu a - M_X X_\mu)^2 - i\, \overline{\Psi_h}\, \gamma^\mu D_\mu \Psi_h$$

$$\mathcal{L}_{var} = B\, a\, \varepsilon^{\mu\nu\rho\sigma} F^{Y}{}_{\mu\nu} F^{Y}{}_{\rho\sigma} + C\, \varepsilon^{\mu\nu\rho\sigma} X_\mu Y_\nu F^{Y}{}_{\rho\sigma}$$

Peccei-Quinn terms

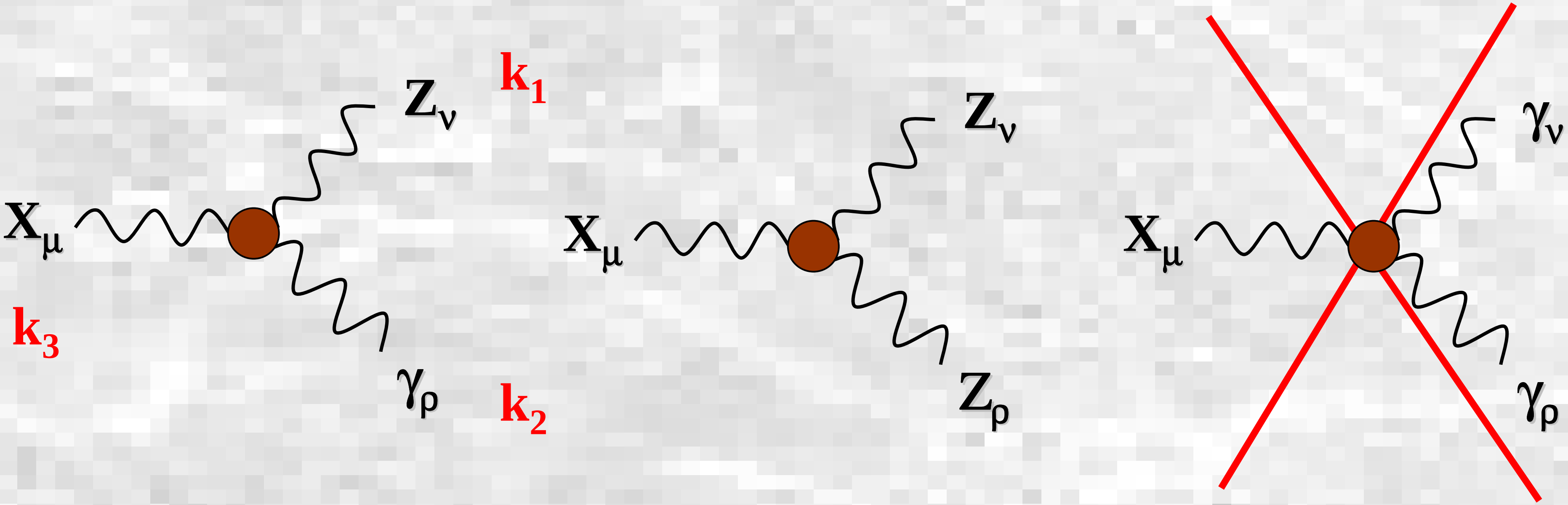
Chern-Simons terms

$$\delta \mathcal{L}_{var} = - \delta \Big(\quad \Big)$$



Heavy Fermions (Ψh)

Effective couplings : $\mathcal{L}_{eff} = \mathcal{L}_{loops} + \mathcal{L}_{var}$



$$\Gamma^{\alpha}_{\mu\nu\rho} = t^{\alpha} \{ A_1\, \varepsilon^{\mu\nu\rho\sigma} k_{2\sigma} - A_2\, \varepsilon^{\mu\nu\rho\sigma} k_{1\sigma}$$
$$+ B_1\, k_{2\nu}\, \varepsilon^{\mu\rho\sigma\tau} k_{2\sigma} k_{1\tau} + B_2\, k_{1\nu}\, \varepsilon^{\mu\rho\sigma\tau} k_{2\sigma} k_{1\tau} + B_3\, k_{2\rho}\, \varepsilon^{\mu\nu\sigma\tau} k_{2\sigma} k_{1\tau} + B_4\, \varepsilon^{\mu\nu\sigma\tau} k_{2\sigma} k_{1\tau}$$
$$+ C\, k_{3\mu}/k_3^{\,2}\, \varepsilon^{\nu\rho\sigma\tau} k_{2\sigma} k_{1\tau} \qquad + D\, \varepsilon^{\mu\nu\rho\sigma}(k_{2\sigma} - k_{1\sigma})\}$$

Peccei-Quinn

Chern-Simons

[Kumar, Rajaraman, Wells 08]
[YM 09]

$\delta\, \mathcal{L}_{eff} = 0$ 3 Ward identities + $(k_1;k_2)$ symmetries

-> the vertex can be express as function of $|B_2 - B_1| = 1/\Lambda^2_X$

With B_1, B_2 = <u>computable</u> loops integrals

Cc : only 3 parameters : Λ_X [<S>] ; M_X [g_X] ; $M\chi$ [Y_{heavy}]

Interpretation as higher dimensional operators

Antoniadis, Boyarski, Ruchavki, Wells 09
Dudas, YM, Pokorski, Romagnoni 09

$$\mathcal{L}_1 = 1/M^2 \;*\{b\ \mathrm{Tr}[F'\ F^Y\ F^Y] \;+ c\ \varepsilon^{\mu\nu\rho\sigma}(\mathcal{D}_\mu\ a)\ (D_\nu\ H)^+\ F^Y{}_{\rho\sigma}\ H\},$$

with

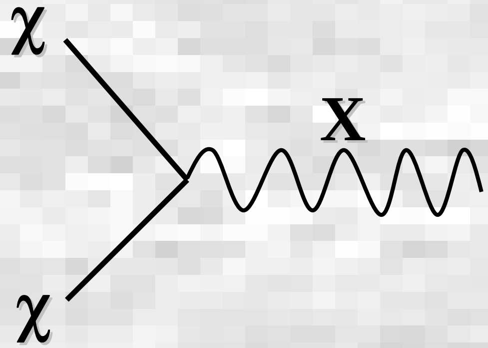
$$\mathcal{D}_\mu a = d_\mu\ a - g' A'_\mu \;;\quad D_\nu = d_\nu - ig\ Y_\nu - i\ g'\ A'_\nu$$

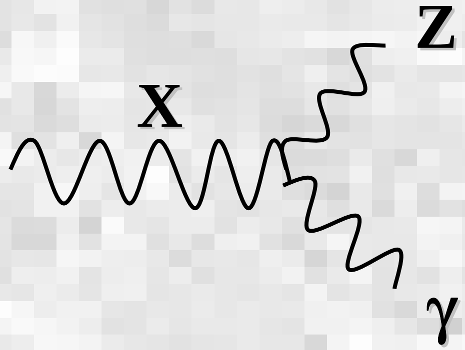
Masses suppression coming from the fermions
which decouple after U'(1) breaking

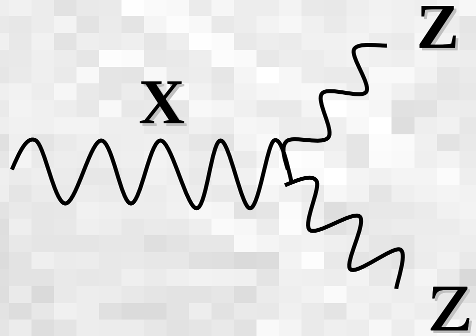
Equivalent to the D'Hoker-Farhi term
$\{1/(H^+H)\ \varepsilon^{\mu\nu\rho\sigma}\ (\mathcal{D}_\mu\ a)\ (D_\nu\ H)^+\ F^Y{}_{\rho\sigma}\ H\}$ for SM

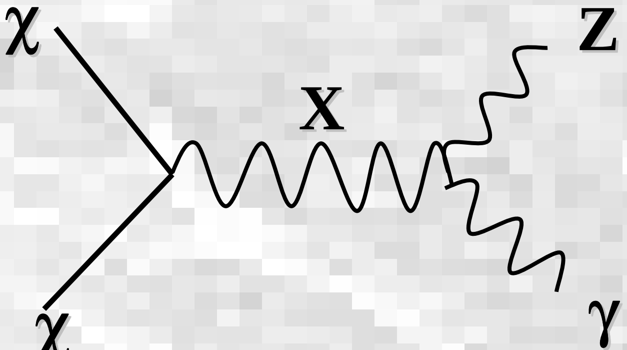
Remark :if two Z' are present, we can build an unsupressed operator,
$\varepsilon^{\mu\nu\rho\sigma}\ (\mathcal{D}_\mu a_1)\ (\mathcal{D}_\nu a_2)\ F^Y{}_{\rho\sigma}$

Dark matter: Annihilation channels

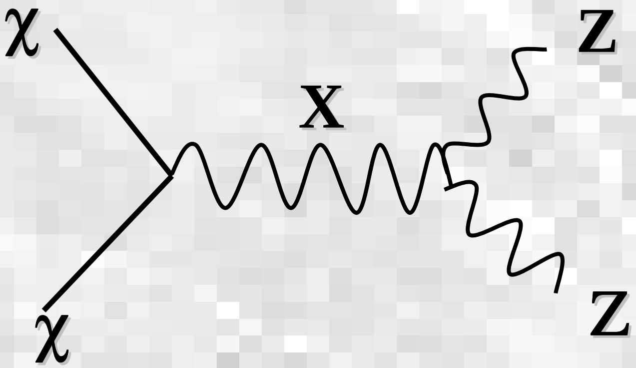


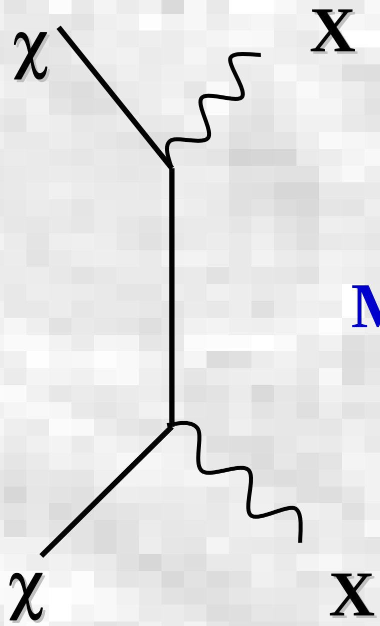






$M_X > M\chi$ (natural)

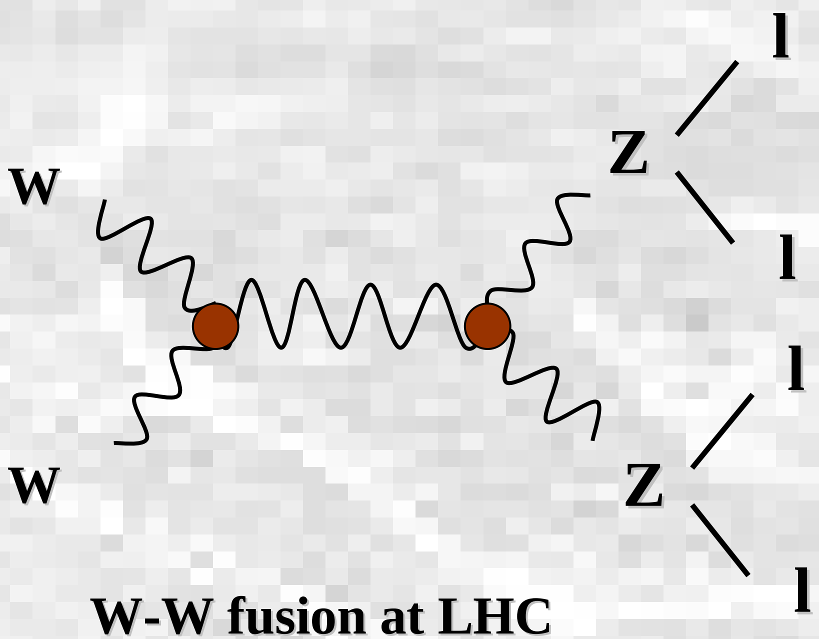




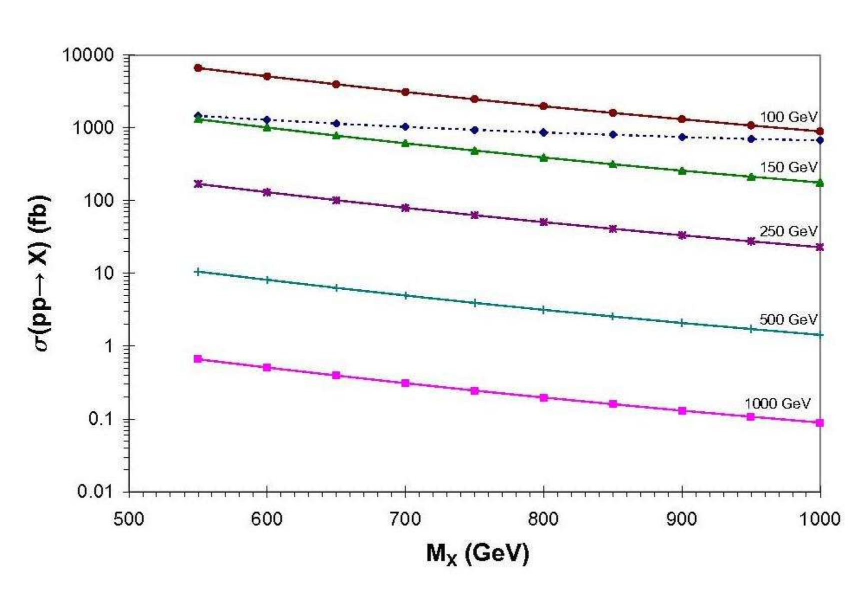
$M_X < M\chi$ (unatural)

LHC production

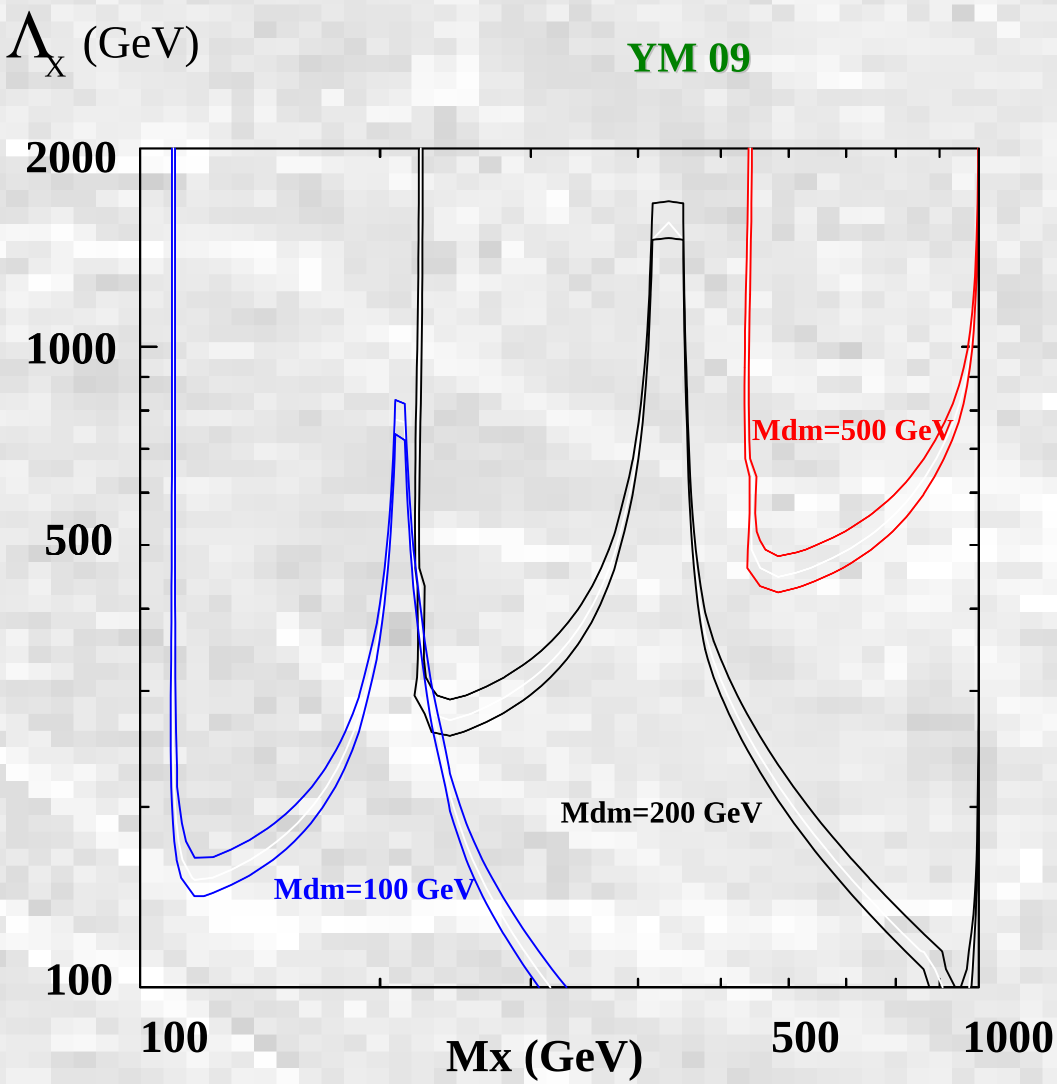
Kumar,Wells 08
Antoniadis Boyarski Ruchavski, Wells 09



W-W fusion at LHC

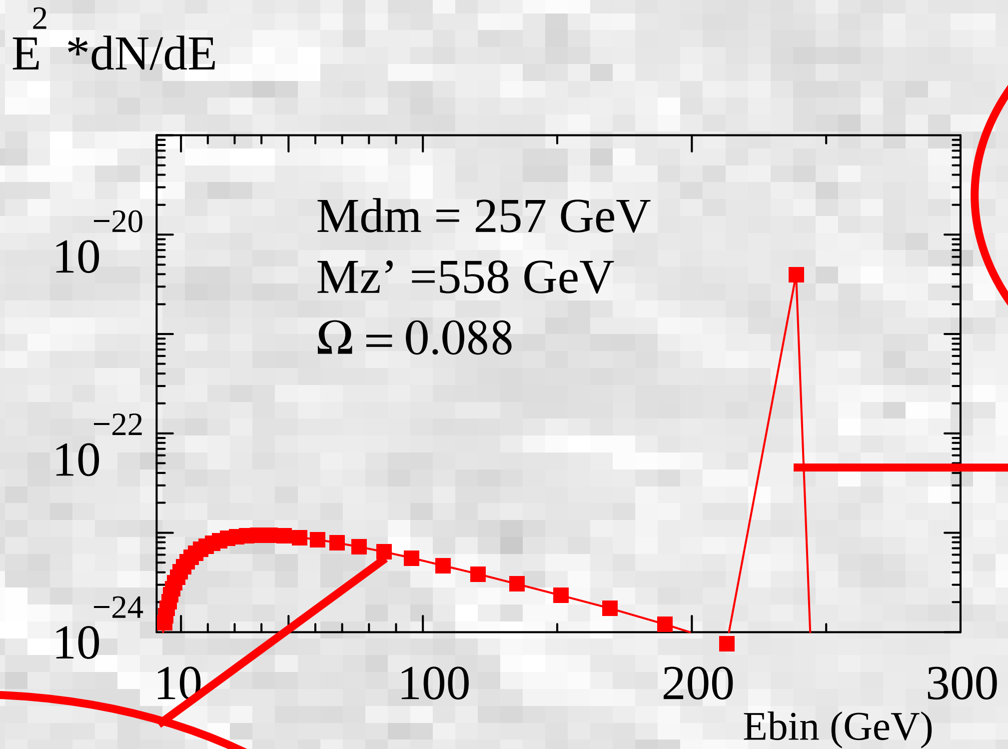


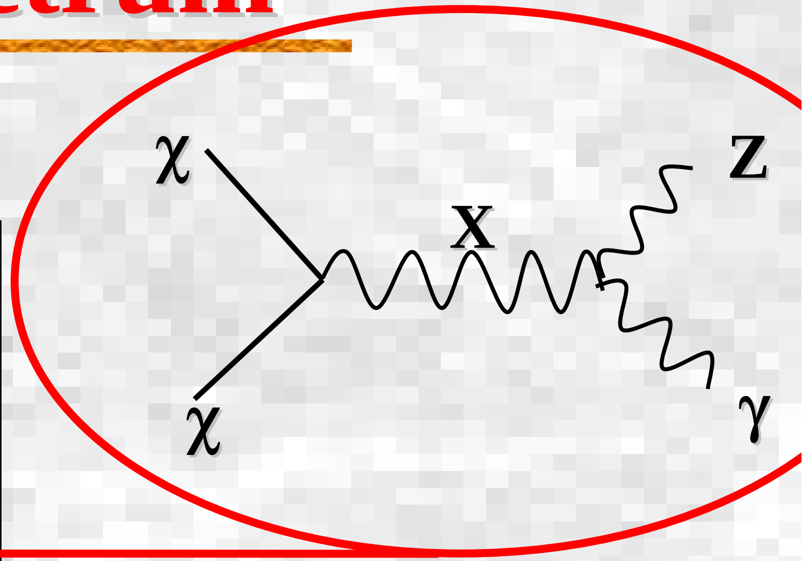
The relic density

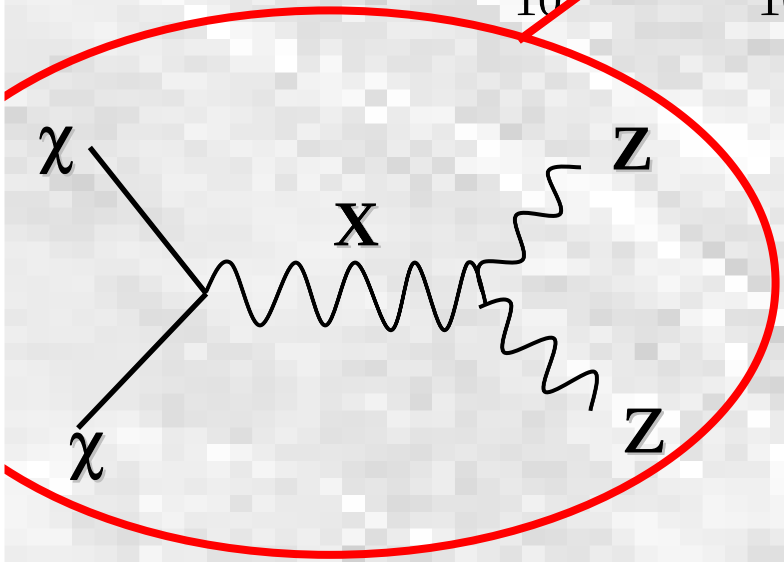


$$1/\Lambda^2_X = |B_2 - B_1| = g_h * g^2/(8\pi^2) * \mathrm{Tr}[X' X^2/M^2_{heavy}] * \mathrm{Integral}$$

Indirect detection: examples of spectrum

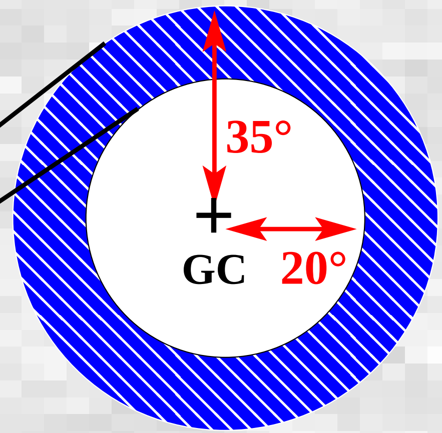




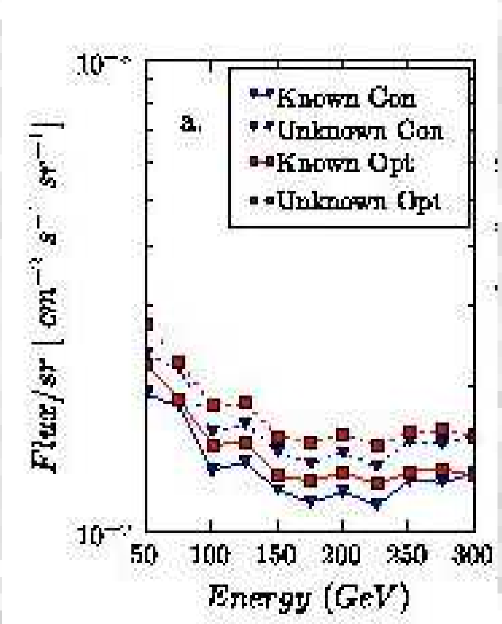


$$E_\gamma = M_\chi \,[1 - (M_Z/2M_\chi)^2]$$

Indirect detection astro-parameters



Galactic Centered Annulus
(Stoehr et al 2003, GLAST col. 2008)



Signal to noise ratio 12 time greater than GC

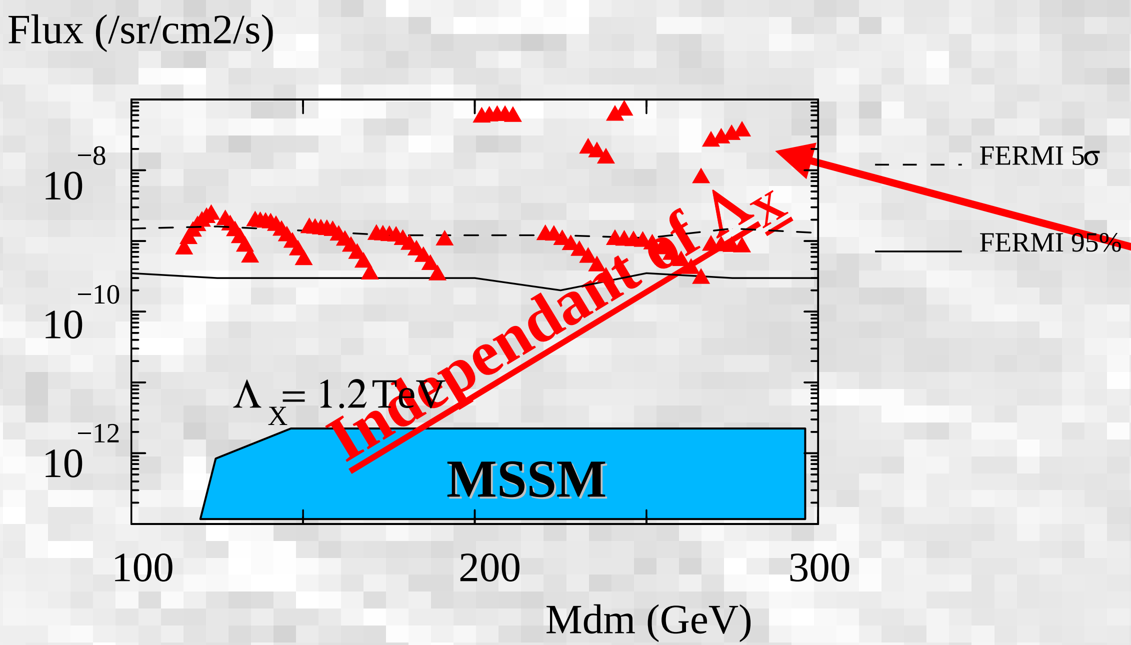
Independant of the Galactic profile

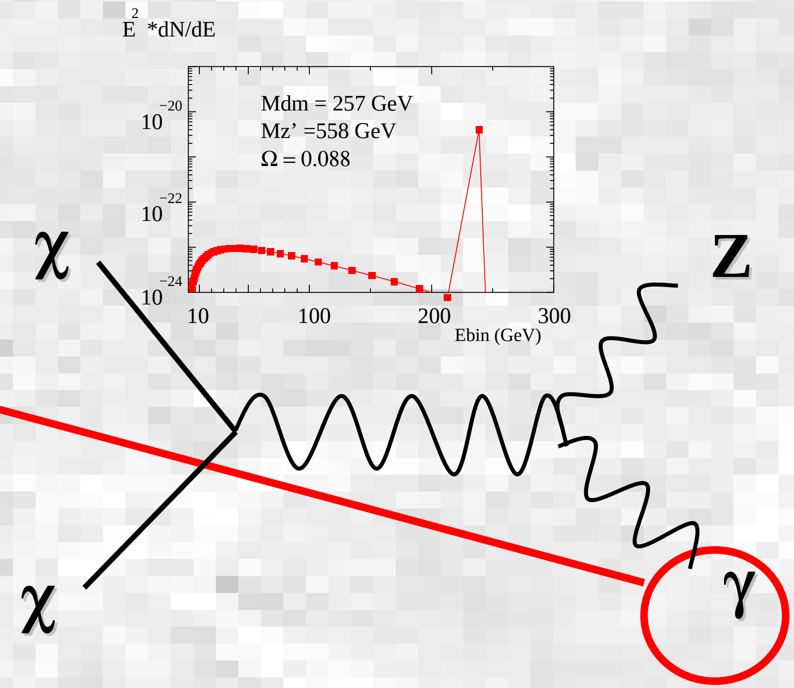
$J\ \Delta\Omega \sim 10$

Galprop conventional model for the background

5 years of data, signals at 5σ and 95% CL
[FERMI estimates, Morselli et al. 08]

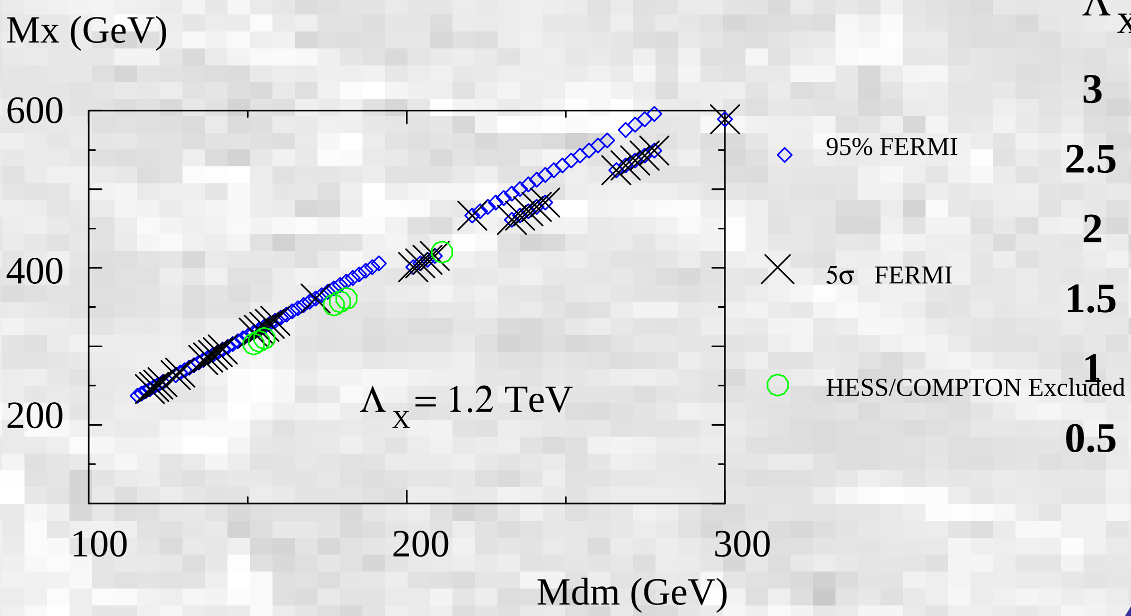
Observability

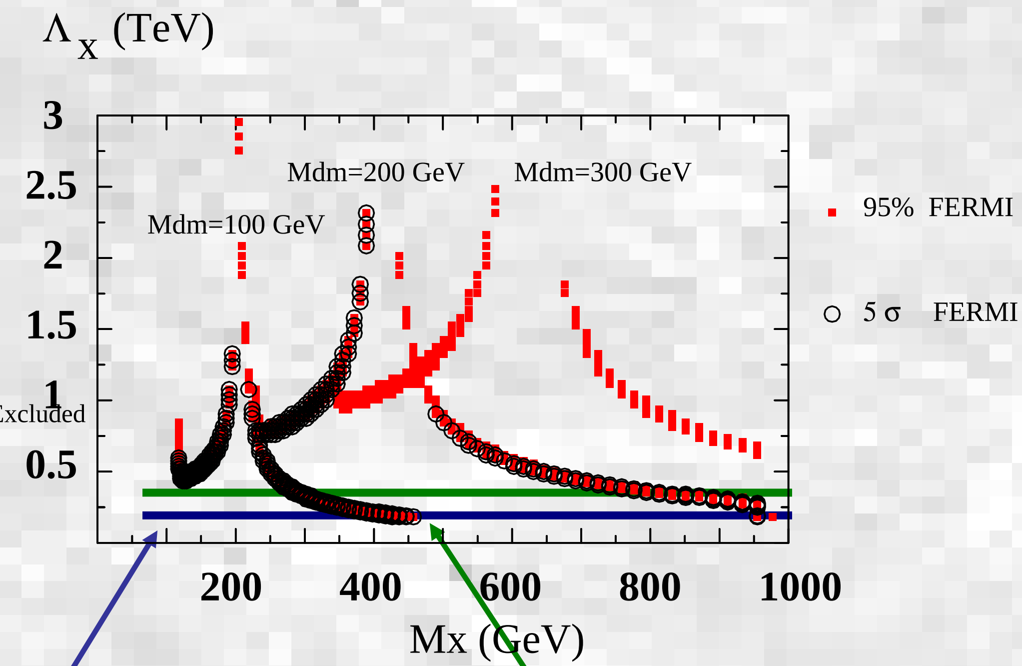




No excess with courent constraints (EGRET, HESS.. [Jacques, Bell 08])

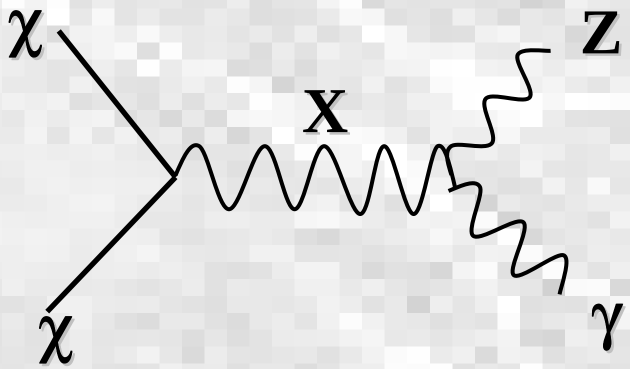
Consequences on Mx and Mchi





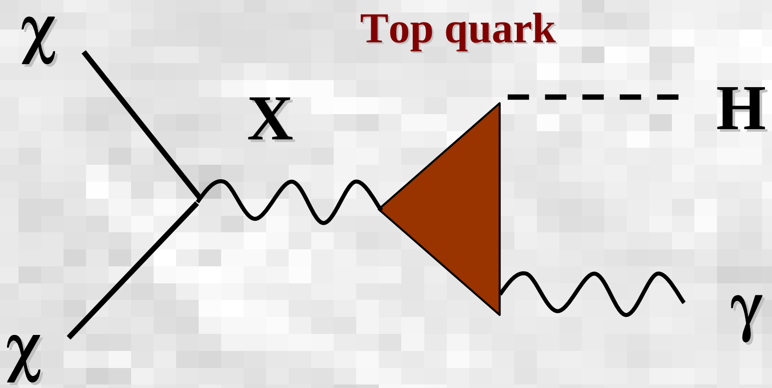
LHC (Wells 08, Antoniadis 09)

FERMI 10

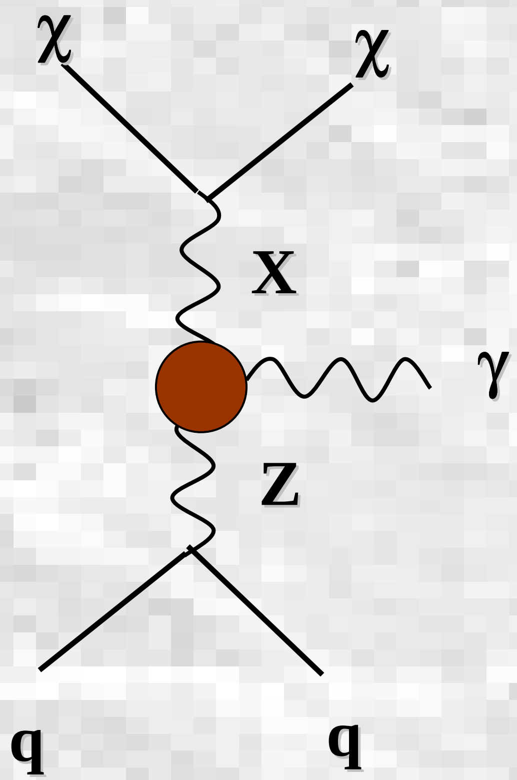


An extension : Higgs in Space

Jackson, Servant, Shaughnessz, Tait, Taoso 09



Direct detection



Mini-conclusions

An (In)visible Z’ can be quite visible

Indirect detection could be THE ONLY WAY to observe it

1 γ ray line is a smoking gun signal distinguishing it clearly from other constructions

Possibility to test up to 5TeV BSM scale at FERMI telescope