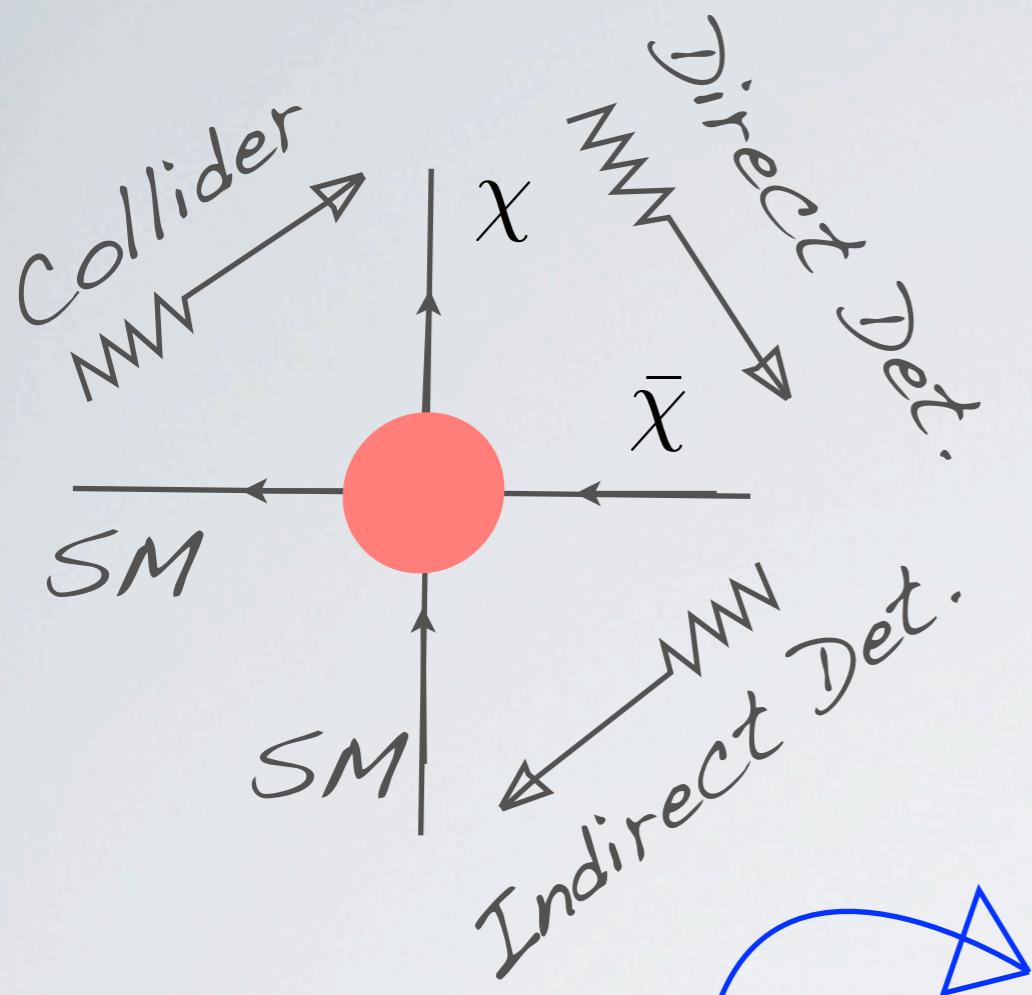


Collider searches for Dark Matter and their impact in Direct Detection

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ULB, Bruxelles
21/02/14

in collab. with
Giorgio Arcadi, Yann Mambrini, Michel Tytgat,
(mainly 1401.0221)



$$\mathcal{O} = \frac{(\bar{f}\Gamma_\mu f)(\bar{\chi}\Gamma^\mu\chi)}{\Lambda^2}$$

Indirect Det.

- positrons, anti-protons, anti-deut, gamma-rays, radio-synch, ...

- FERMI, AMS, PLANCK, WMAP, ...

Direct Det.

- DM-nucleon scatterings

- XENON, LUX, COUPP, CDMS, DAMA, ...

counts/
kg/day/keV

Direct Detection

$$\frac{dR}{dE_R} = \frac{\rho_0}{m_N m_\chi} \int_{v_0(E_R)}^{\infty} v f(v) \frac{d\sigma_{\chi N}}{dE_R}(v, E_R) dv$$

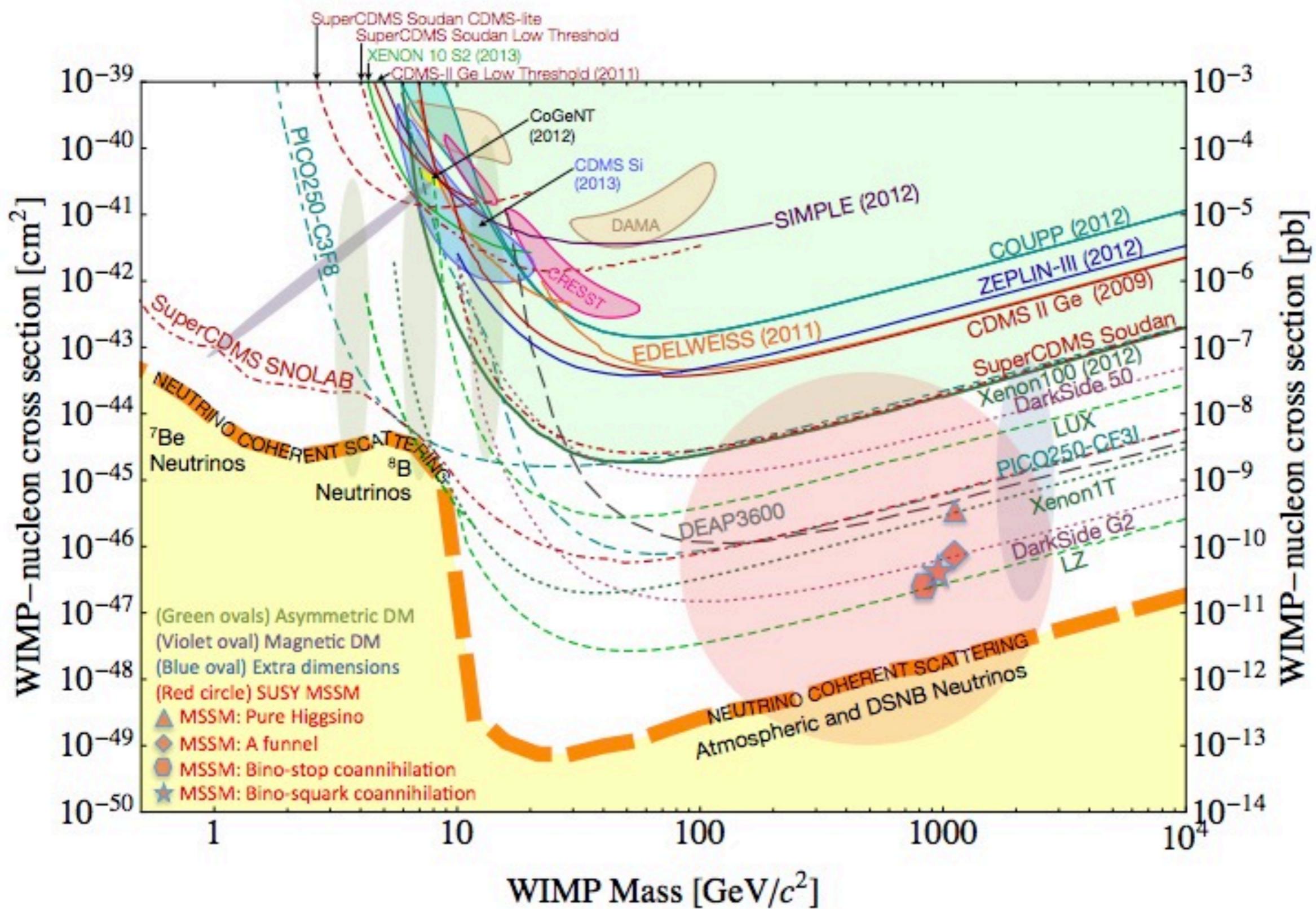
$$\frac{d\sigma_{\chi N}}{dE_R} = \frac{m_N}{2\mu_N^2 v^2} \left(\sigma_0^{\text{SI}} F_{\text{SI}}^2(E_R) + \sigma_0^{\text{SD}} F_{\text{SD}}^2(E_R) \right)$$

$$\mathcal{L} \supset \alpha_q^A (\bar{\chi} \gamma_\mu \gamma_5 \chi) (\bar{q} \gamma^\mu \gamma_5 q)$$
$$\mathcal{L} \supset \alpha_q^S (\bar{\chi} \chi) (\bar{q} q) + \alpha_q^V (\bar{\chi} \gamma_\mu \chi) (\bar{q} \gamma^\mu q)$$

Uncertainties:

- Form factors, $F_{\text{SI}}(E_R)$, s-quark content in nucleon
- Local DM density, $\sim 15\%$
- Speed distribution, $\sim 10\%$
- ...

Direct Detection



hep-ex/1310.8327

Colliders

$$\mathcal{N} = \sigma \cdot \epsilon \cdot L$$

$$\sigma = \int_0^1 dx_1 f_1(x_1, Q^2) \int_0^1 dx_2 f_2(x_2, Q^2) \sigma_{\text{hard}}(x_1, x_2, Q^2)$$

Tools

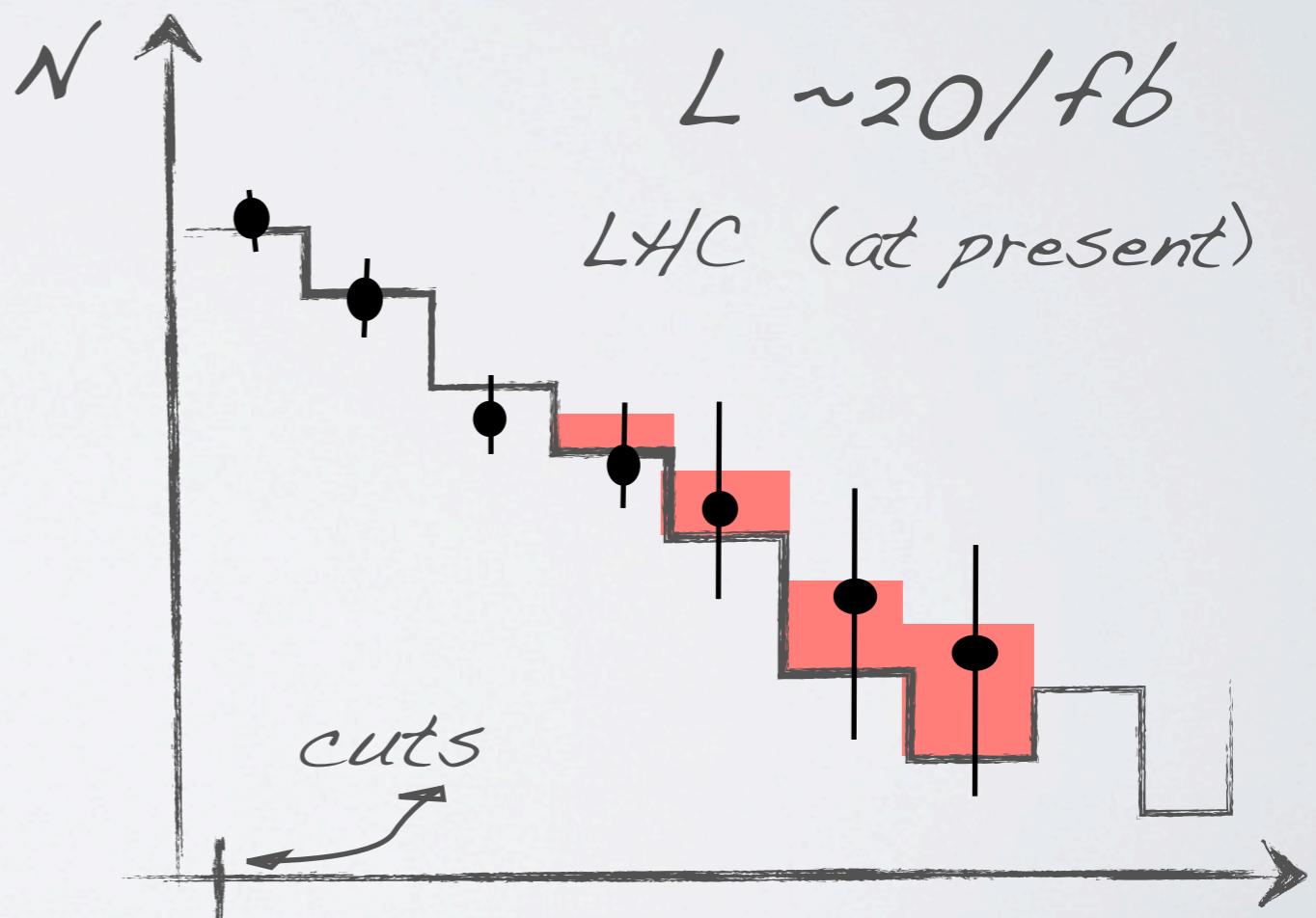
FeynRules,
MadGraph, CalcHep,
Pythia, POWHEG,
PGS, Delphes,...

Uncertainties:

- PDFs,
- event reconstruction,

Difficulties:

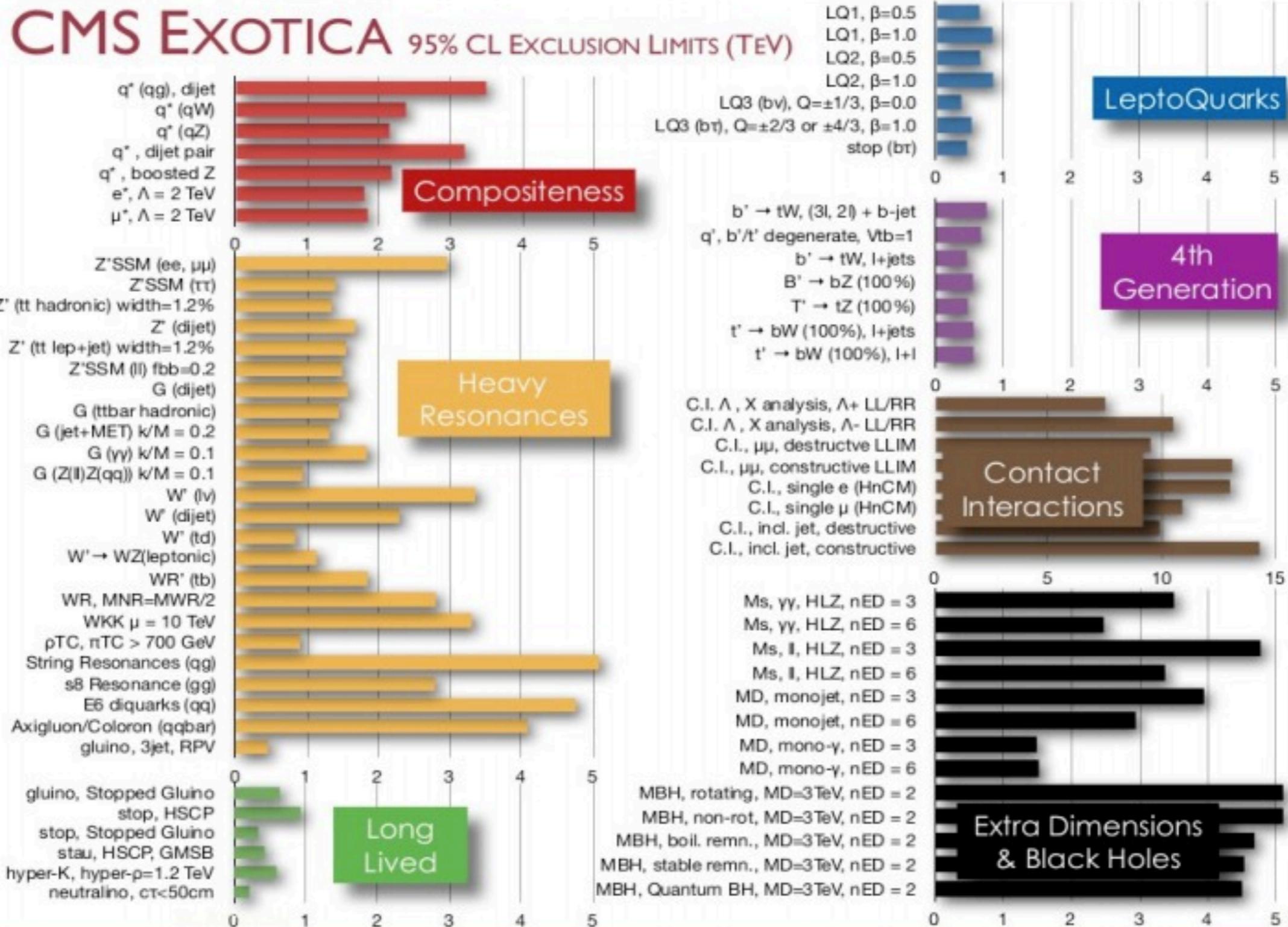
- low energy emission
- degenerate or heavy spectra



$\text{PT}, \text{ET}_{\text{miss}}, M_{jj}$

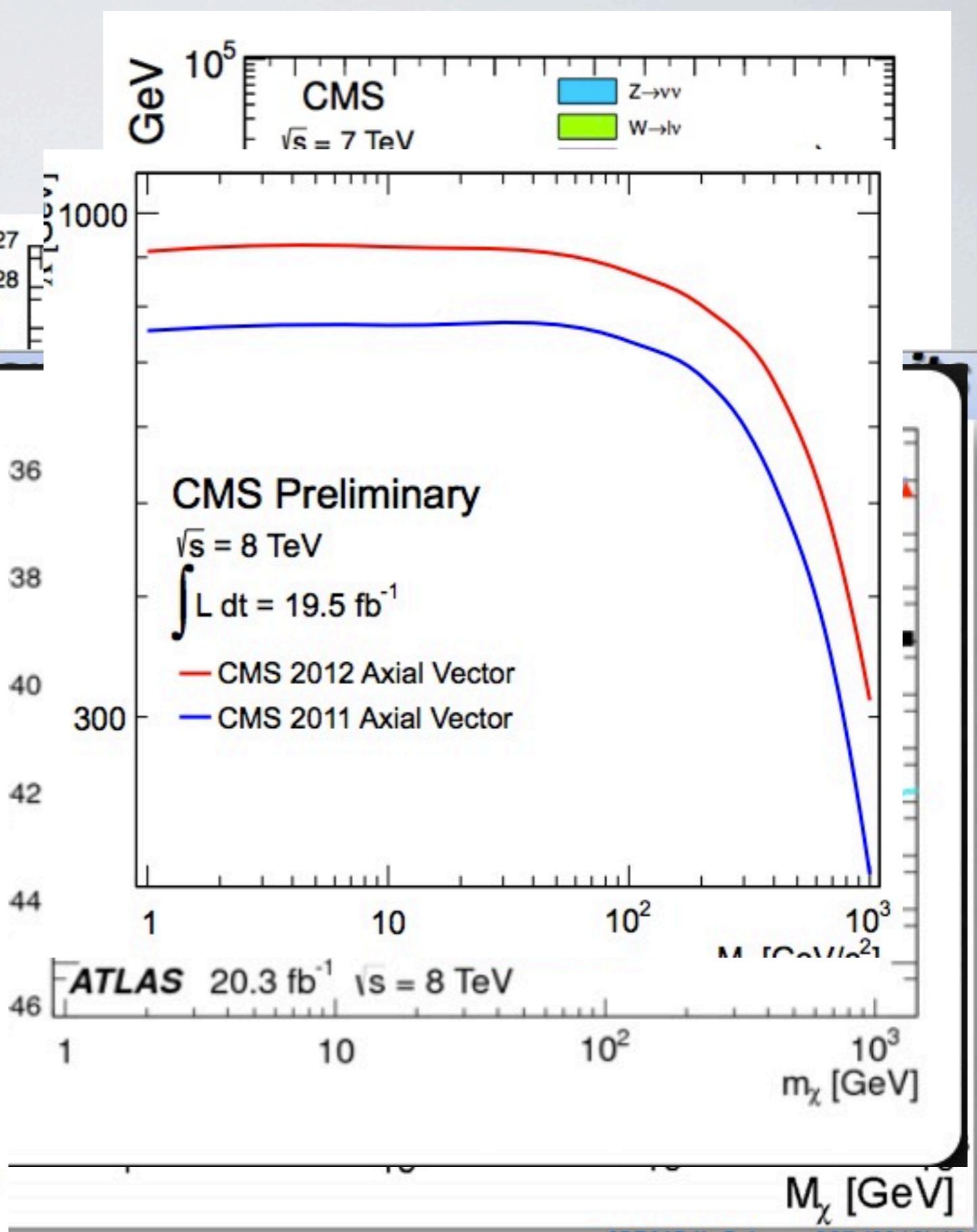
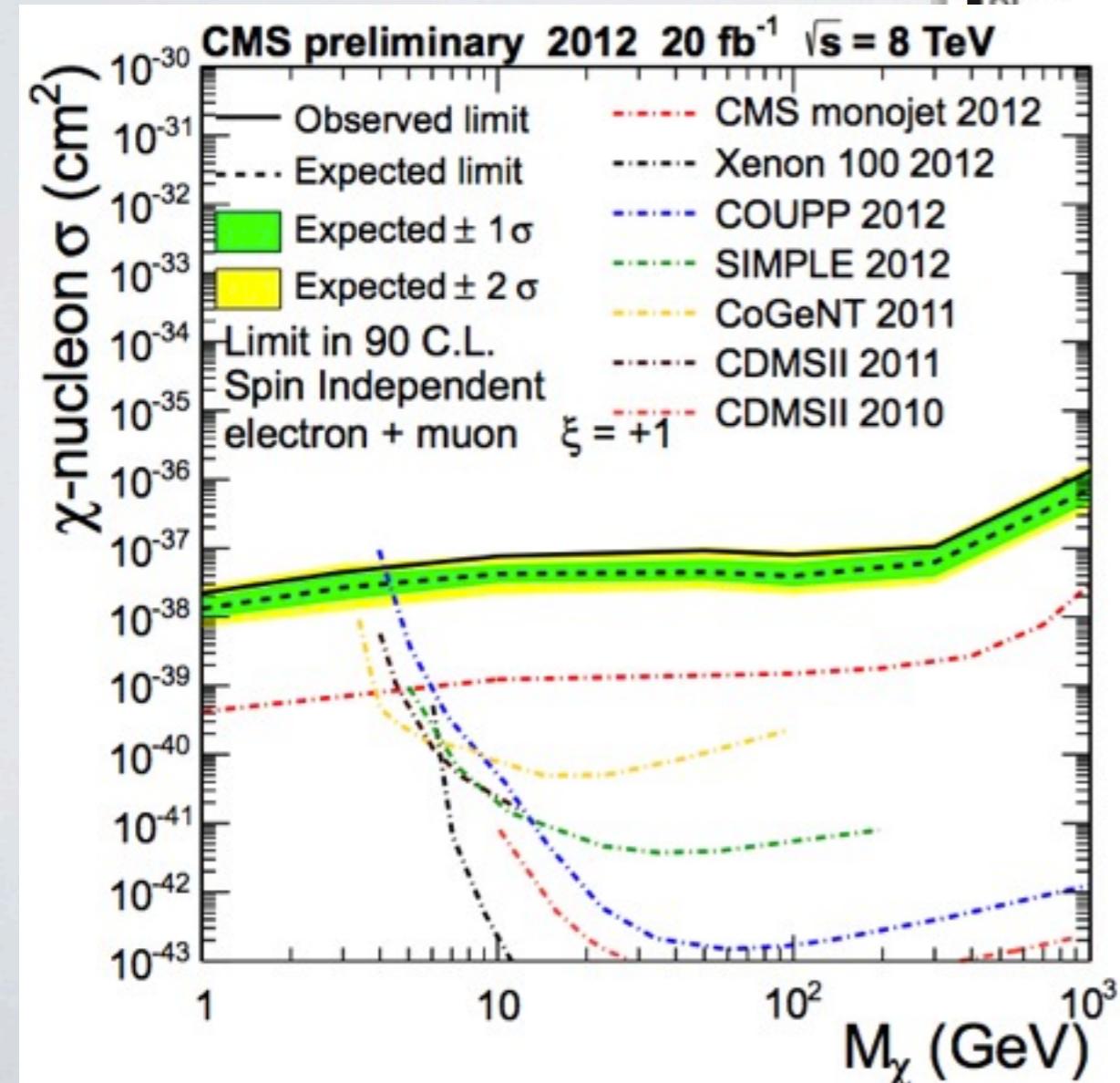
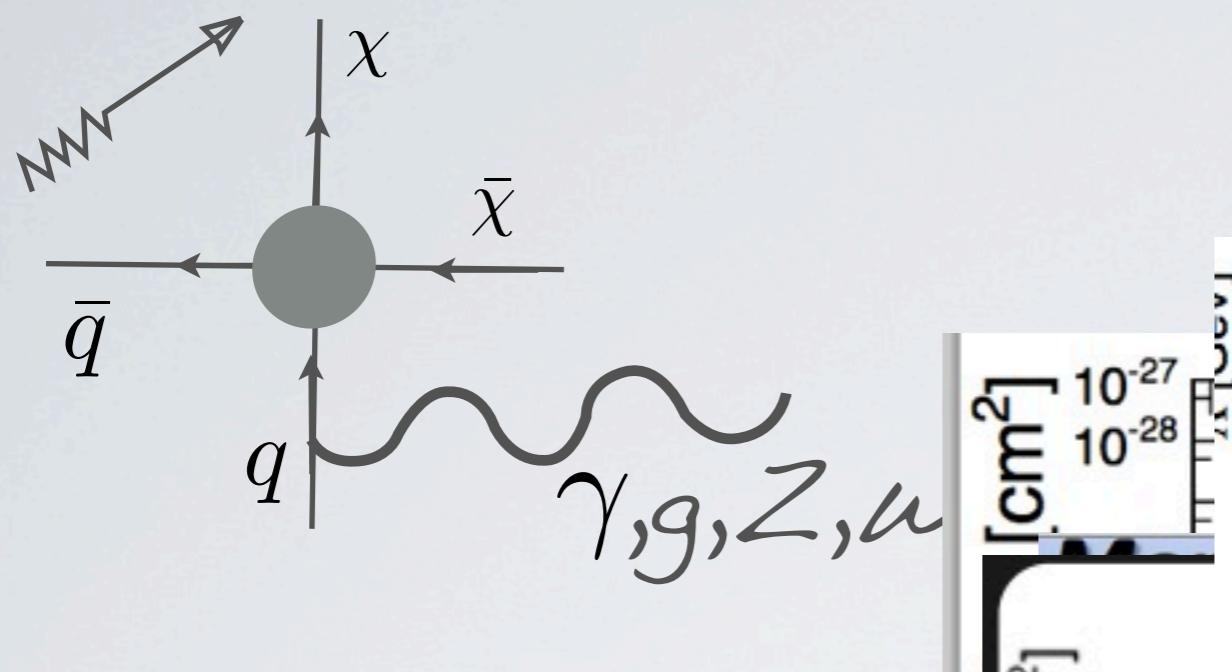
Colliders

Summary of exotic processes with mass scale probed



Mono-signals

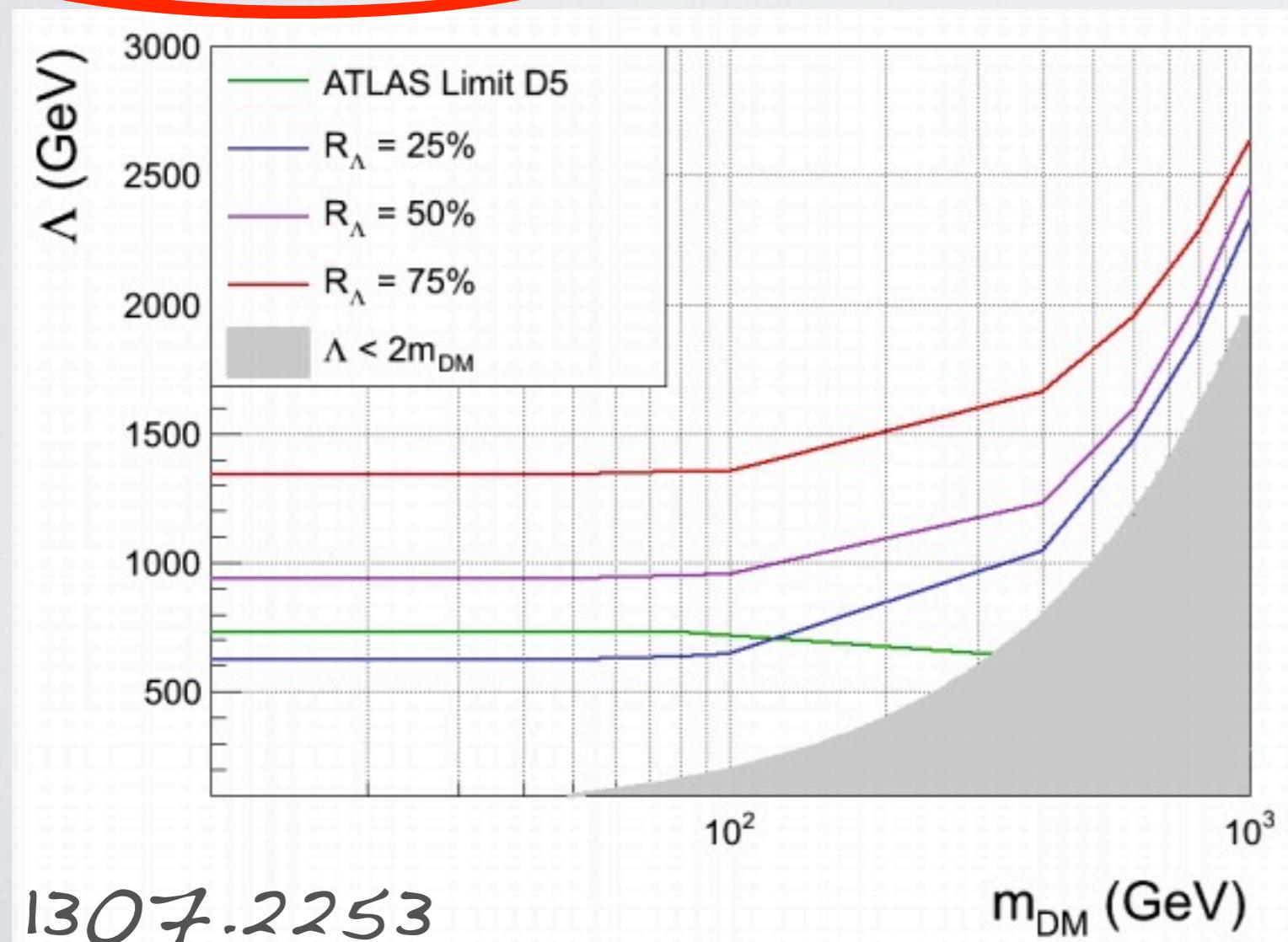
hep-ex/1206.5663



Validity of EFT

$$\left. \begin{aligned} \Lambda &\equiv M / \sqrt{g_v g_\chi} \\ g_v, g_\chi &< 2\sqrt{\pi} \\ 2m_\chi &< p_T < M \end{aligned} \right\}$$

$$R = \frac{\# \text{ valid events}}{\# \text{ total events}}$$



the natural step is
to look at simple
 \mathcal{UV} completions...

1308.2679

1308.6399

1308.6799

1308.0612

1402.2285

...do I continue?

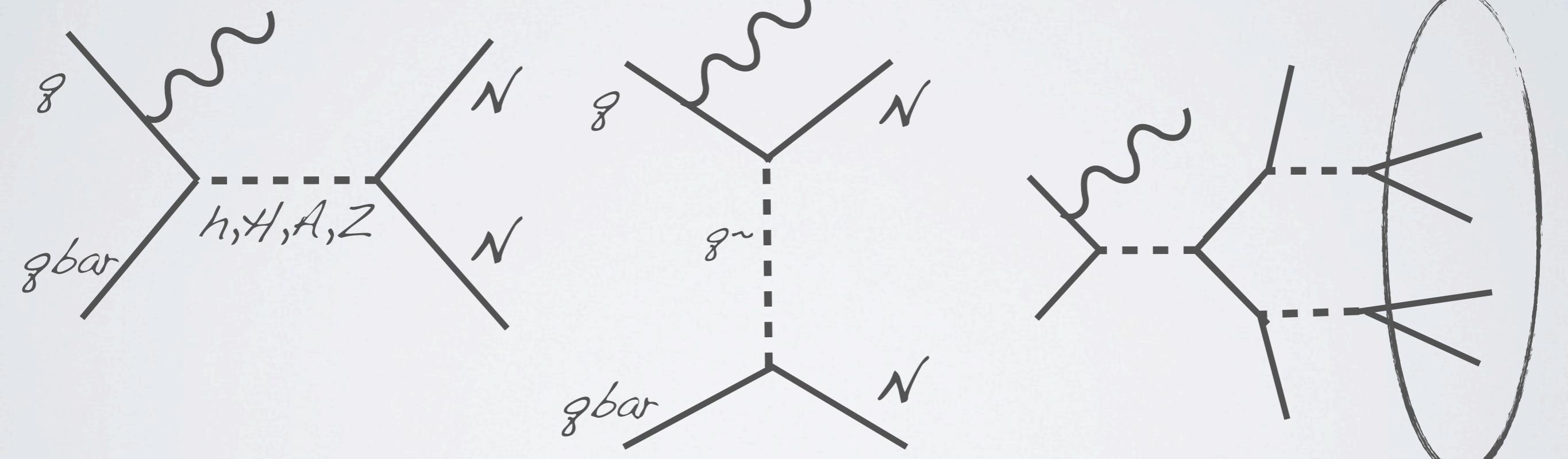
Why not just take ^{canonical}SUSY here?

- consistent UV model
- all the LHC phenomenology possible
- Quite "WIMPish" neutralino
- The susy is true, and it is out there



(even if untestable)

soft
radiation



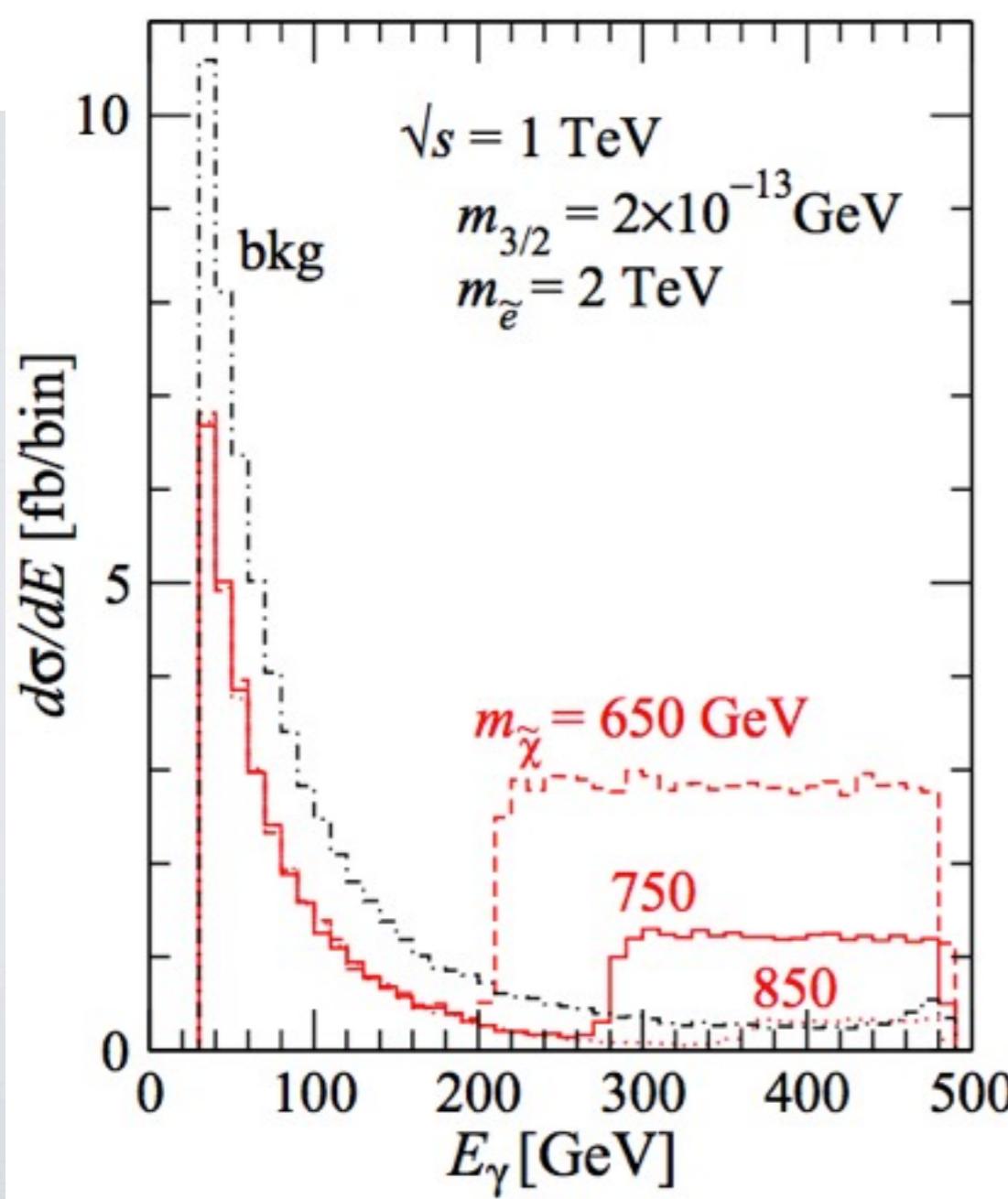
- $O(100)$ parameters (unless simplified)
- small couplings/heavy partners
(way out: compressed spectra)

BUT.....

There is a richer alternative...

Monophoton signals in light gravitino production at e^+e^- colliders

Kentarou Mawatari^a, Bettina Oexl



Universiteit Brussel,
Brussels, Belgium

hep-ph/1402.3223

$e^+e^- \rightarrow \gamma \tilde{G}\tilde{G}$
*4-point,
t-channel selectron*
 $e^+e^- \rightarrow \tilde{\chi}_1^0 \tilde{G} \rightarrow \gamma \tilde{G}\tilde{G}$
t-channel selectron
s-channel Z,A

similar analysis for LHC

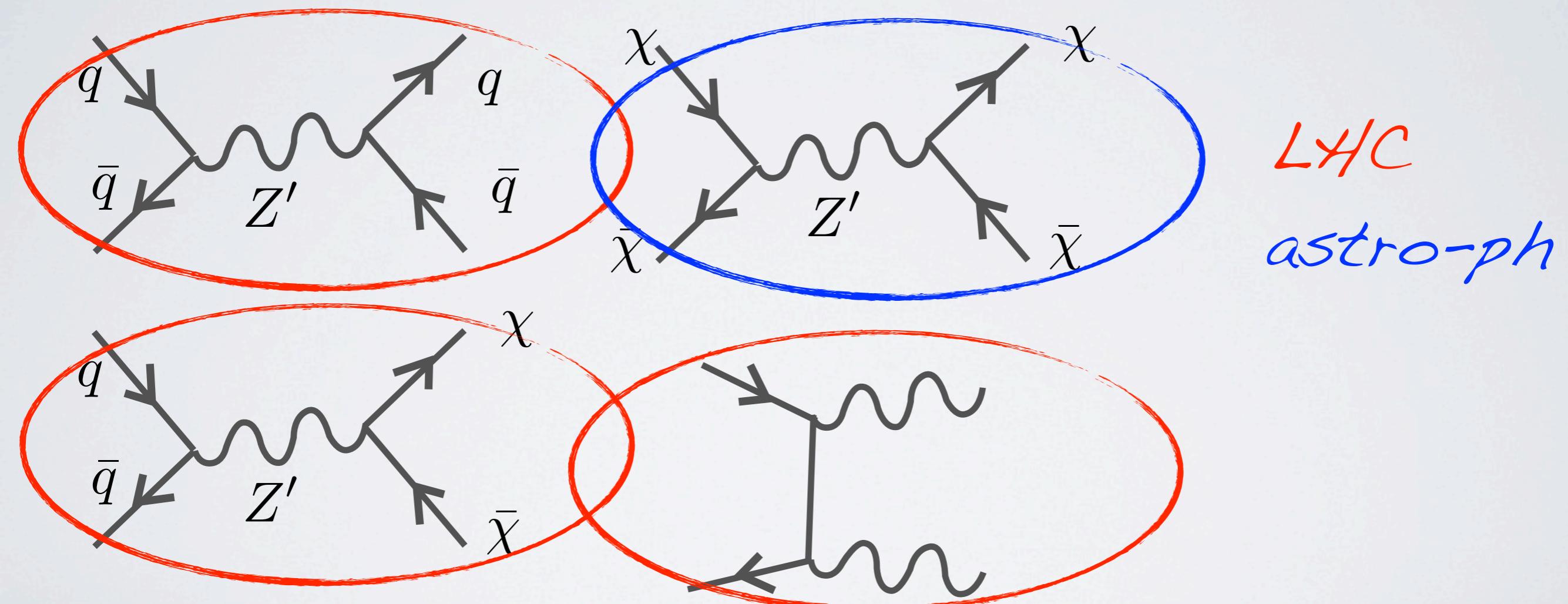
After SUSY parenthesis....
Toy Model



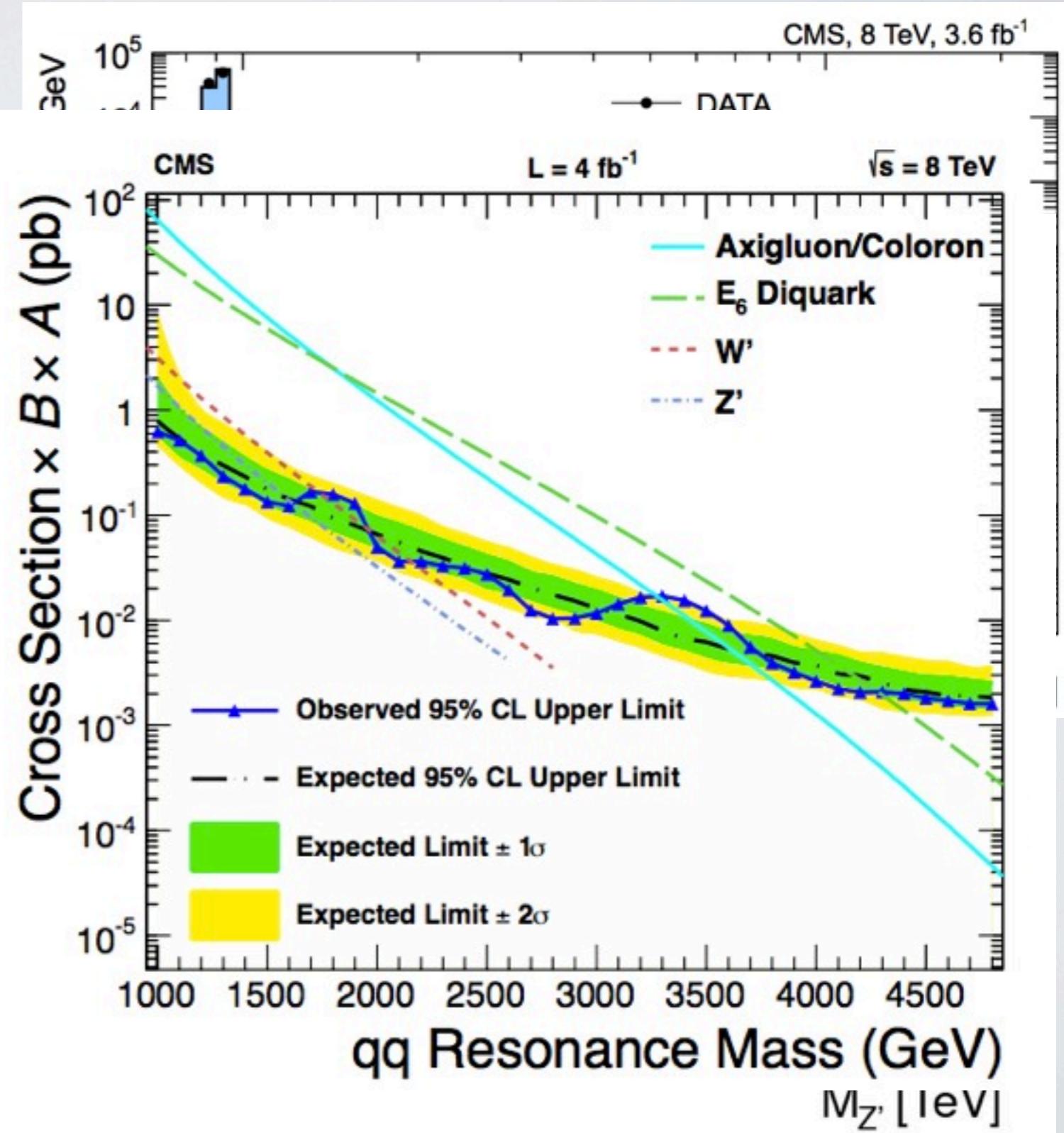
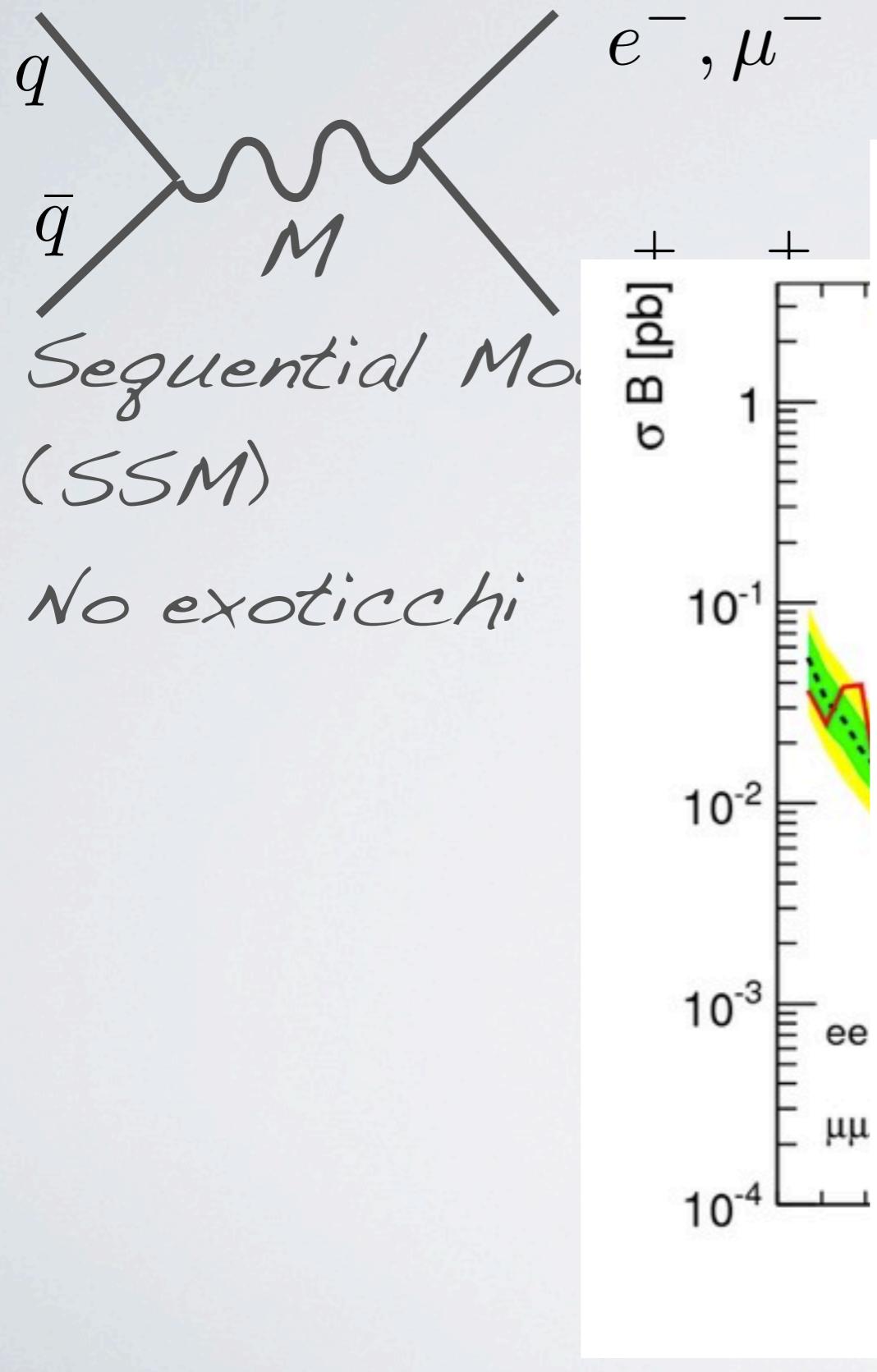
Simple Z' models

$$\Delta\mathcal{L} \supset g_D \bar{\chi} \gamma^\mu (V_D^\chi - A_D^\chi \gamma^5) \chi Z'_\mu + g_D \sum_f \bar{f} \gamma^\mu (V_D^f - A_D^f \gamma^5) f Z'_\mu$$

* $SM + Z' + DM$

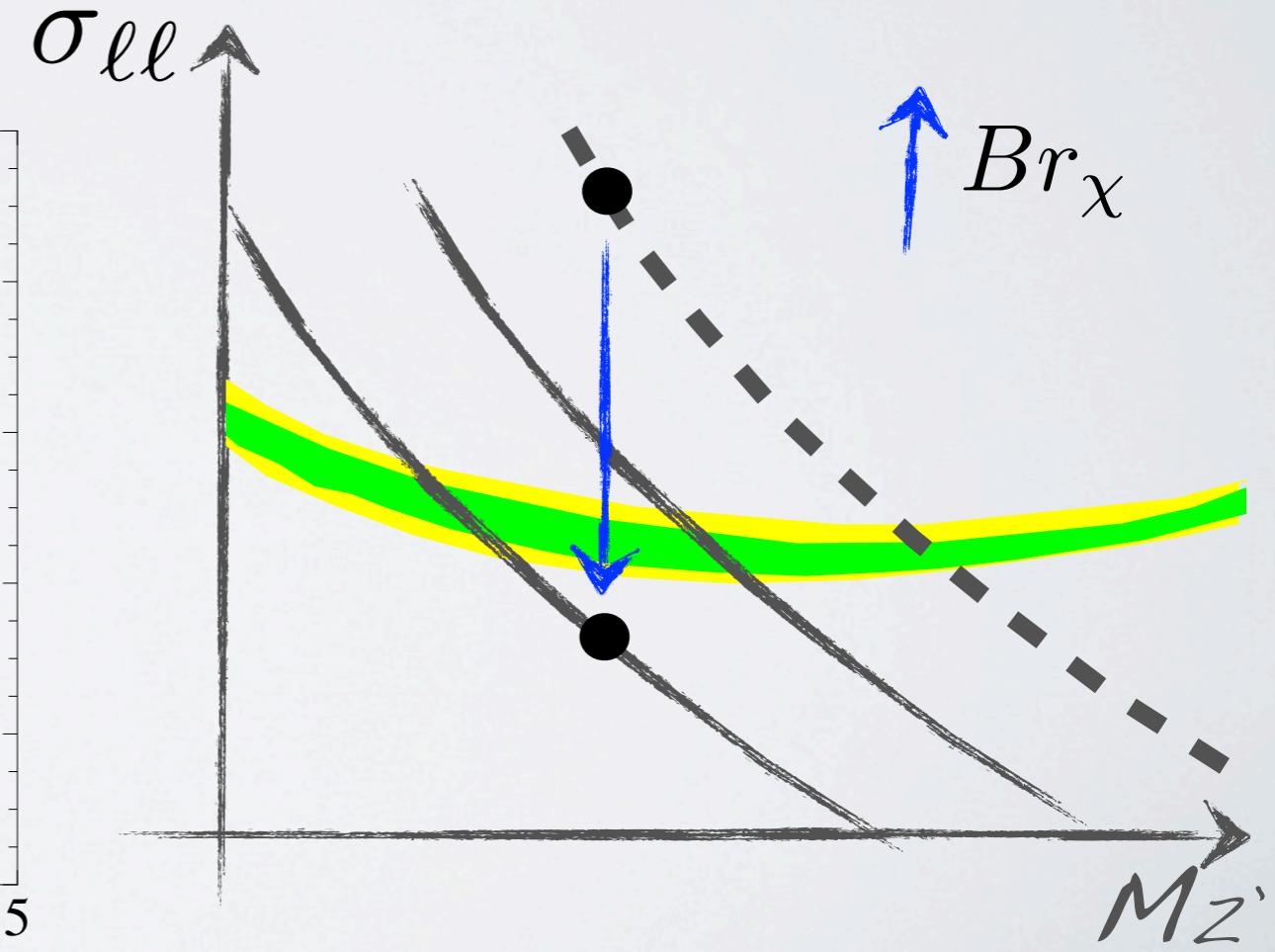
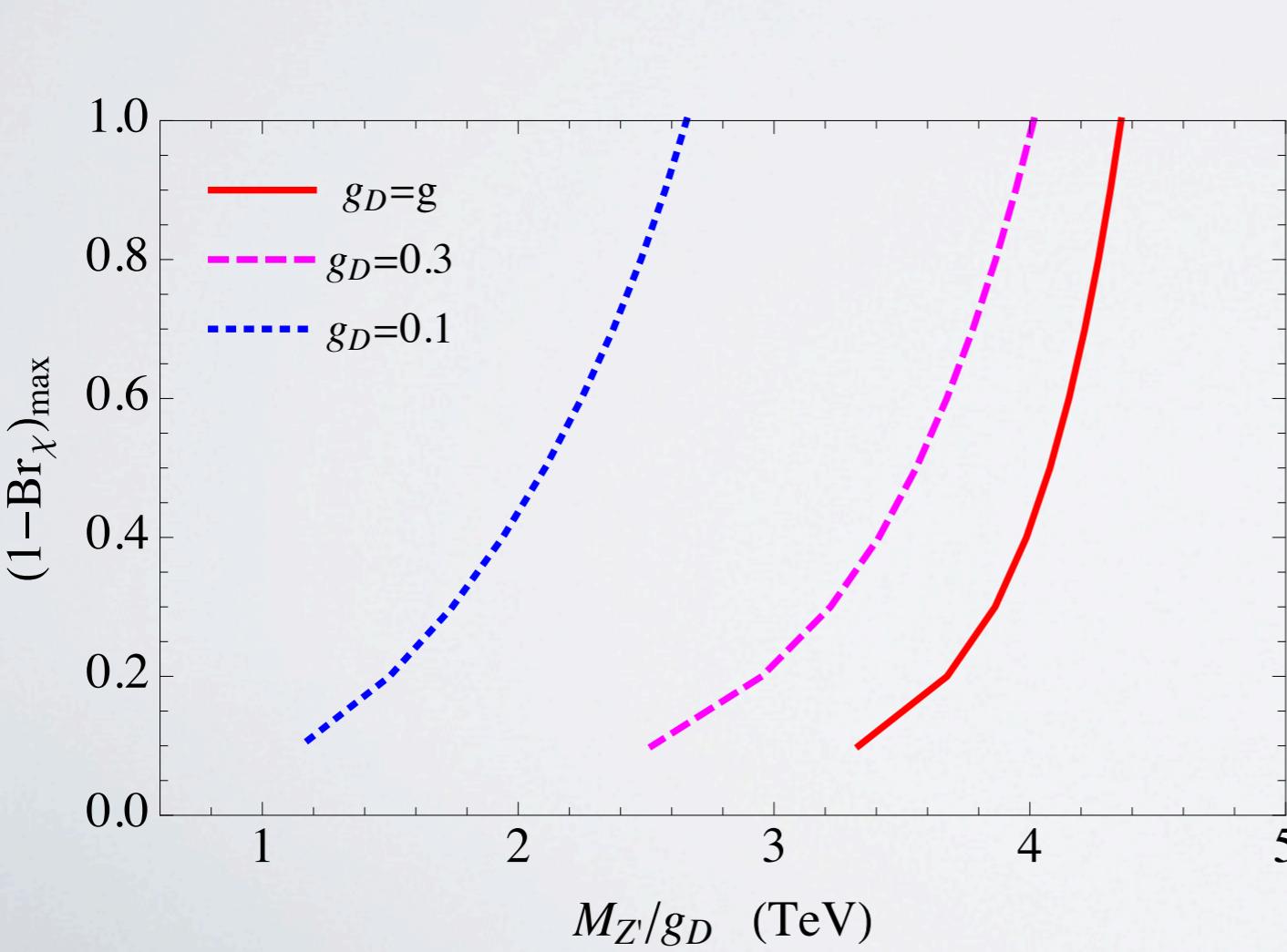
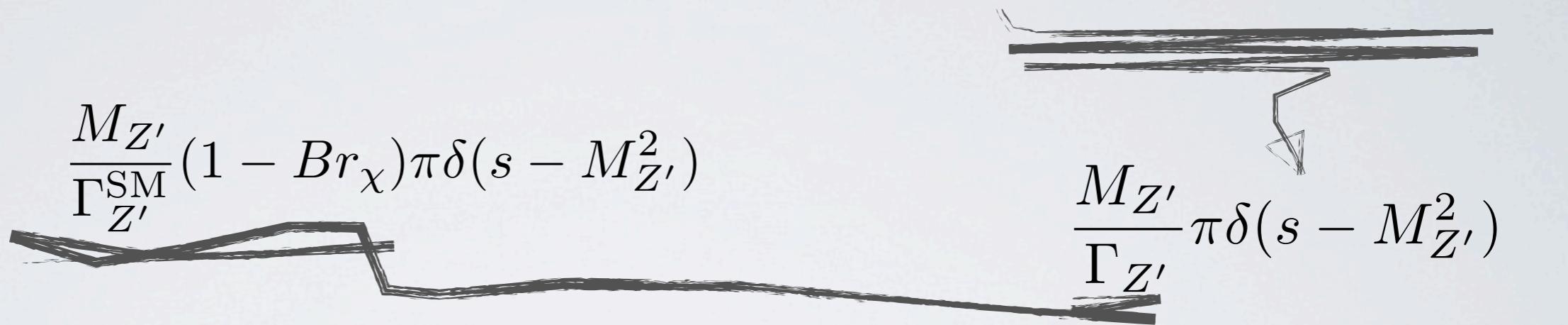


Resonance Searches (di-signals)



Arcadi, Mambrini, Tytgat, Cuba, 1401.0221

$$\sigma(q\bar{q} \rightarrow Z' \rightarrow \ell\ell) \approx \frac{g_D^4}{12\pi} (|V^q|^2 + |A^q|^2)(|V^\ell|^2 + |A^\ell|^2) \times \frac{s}{(s - M_{Z'}^2)^2 + \Gamma_{Z'}^2 M_{Z'}^2}$$



$$\sigma_{\text{DD}} \propto \frac{g_D^4 (V_D^\chi)^2}{M_{Z'}^4}$$

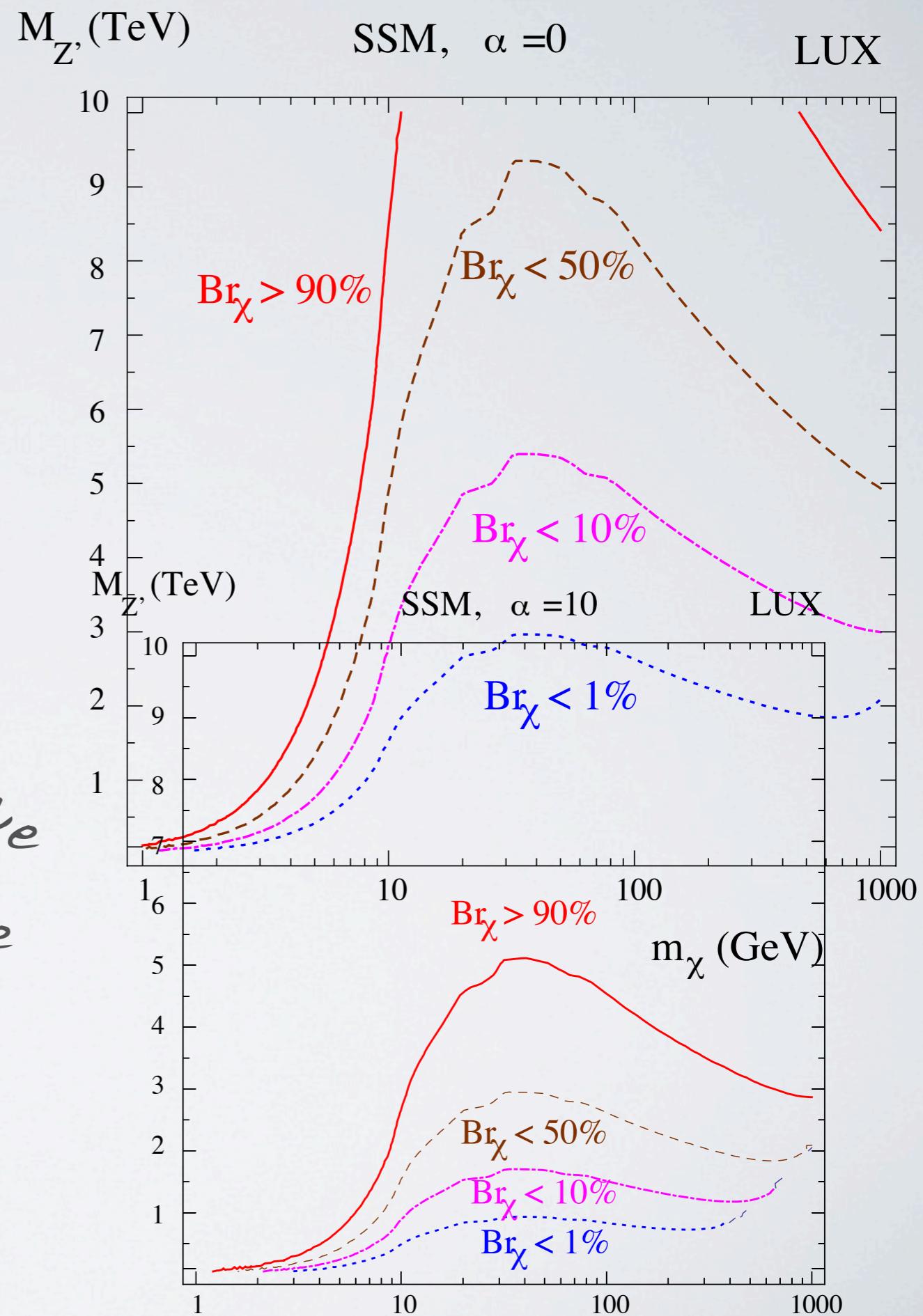
$$Br_\chi = \frac{\Gamma_{Z'}^\chi}{\Gamma_{Z'}^\chi + \sum_f \Gamma_{Z'}^f}$$

$$Br_\chi = \left[1 + \frac{g_D^4}{M_{Z'}^4} \frac{\#}{(1 + \alpha^2) \sigma_{\text{SI}}} \right]^{-1}$$

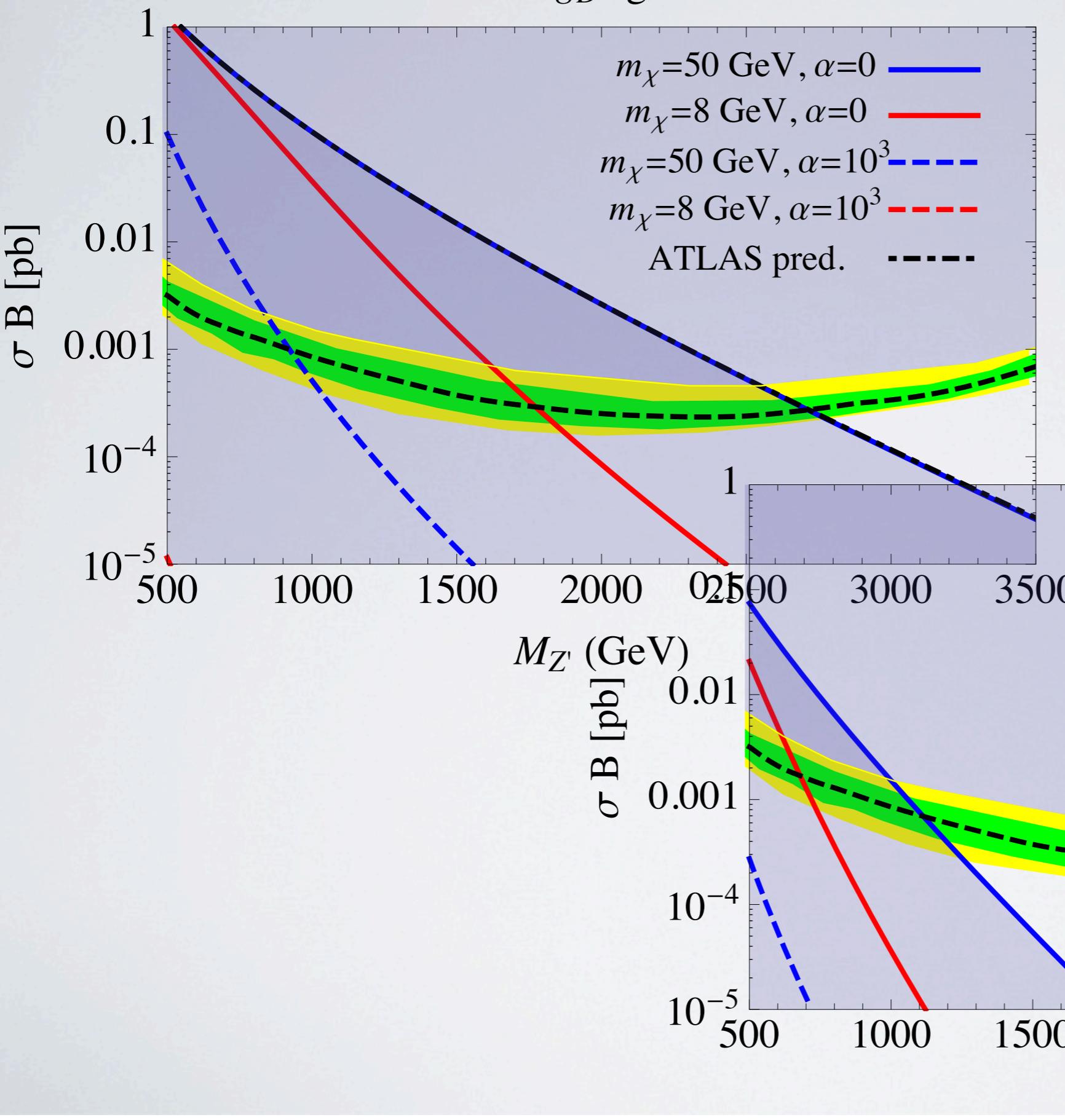
$\alpha \equiv A_D^\chi / V_D^\chi$

$\ll 1$, vector-like
 $\gg 1$, axial-like

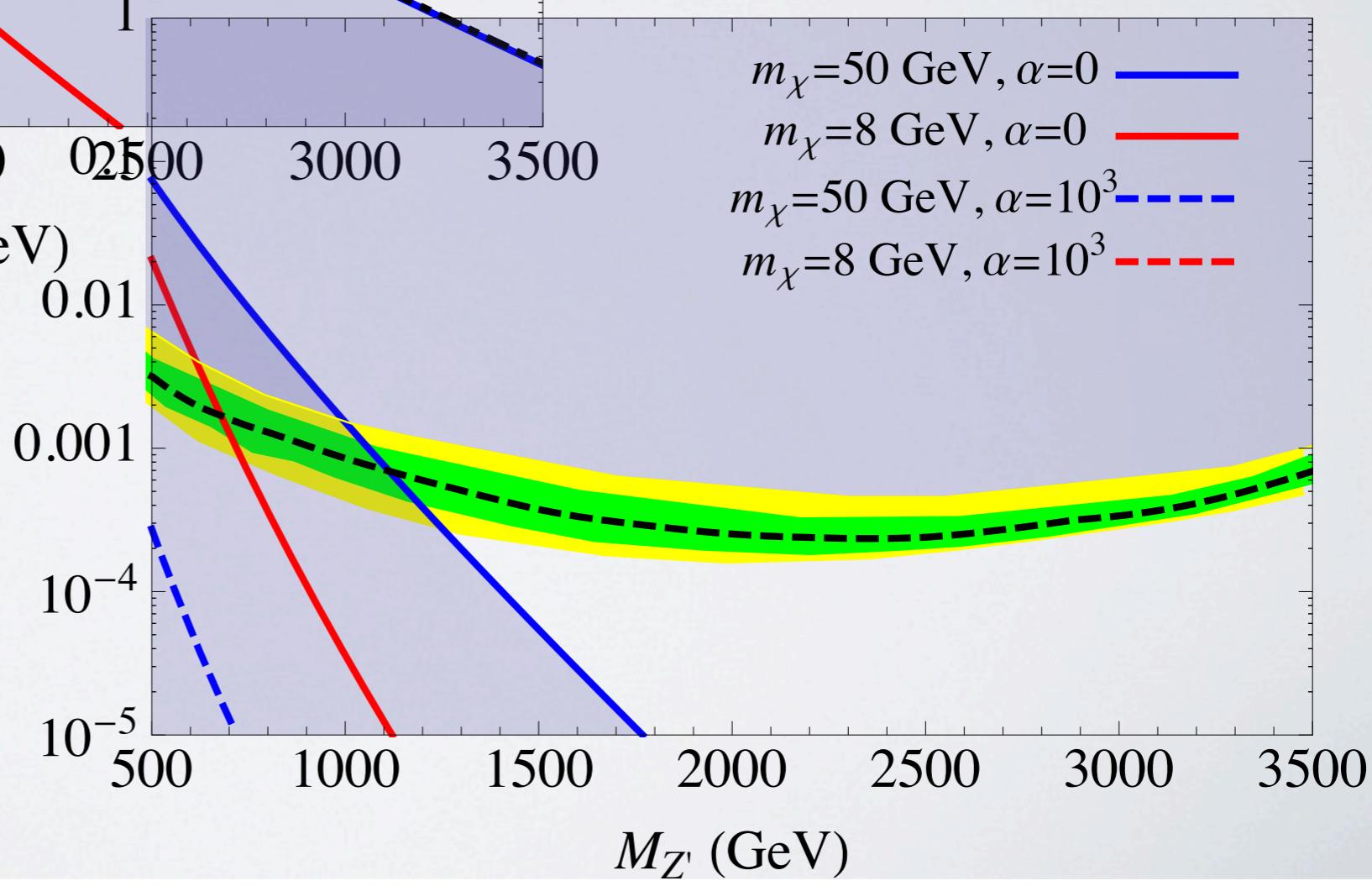
LUX
 upper bounds



$g_D=g$



$g_D=0.3$



what about mono jets here?

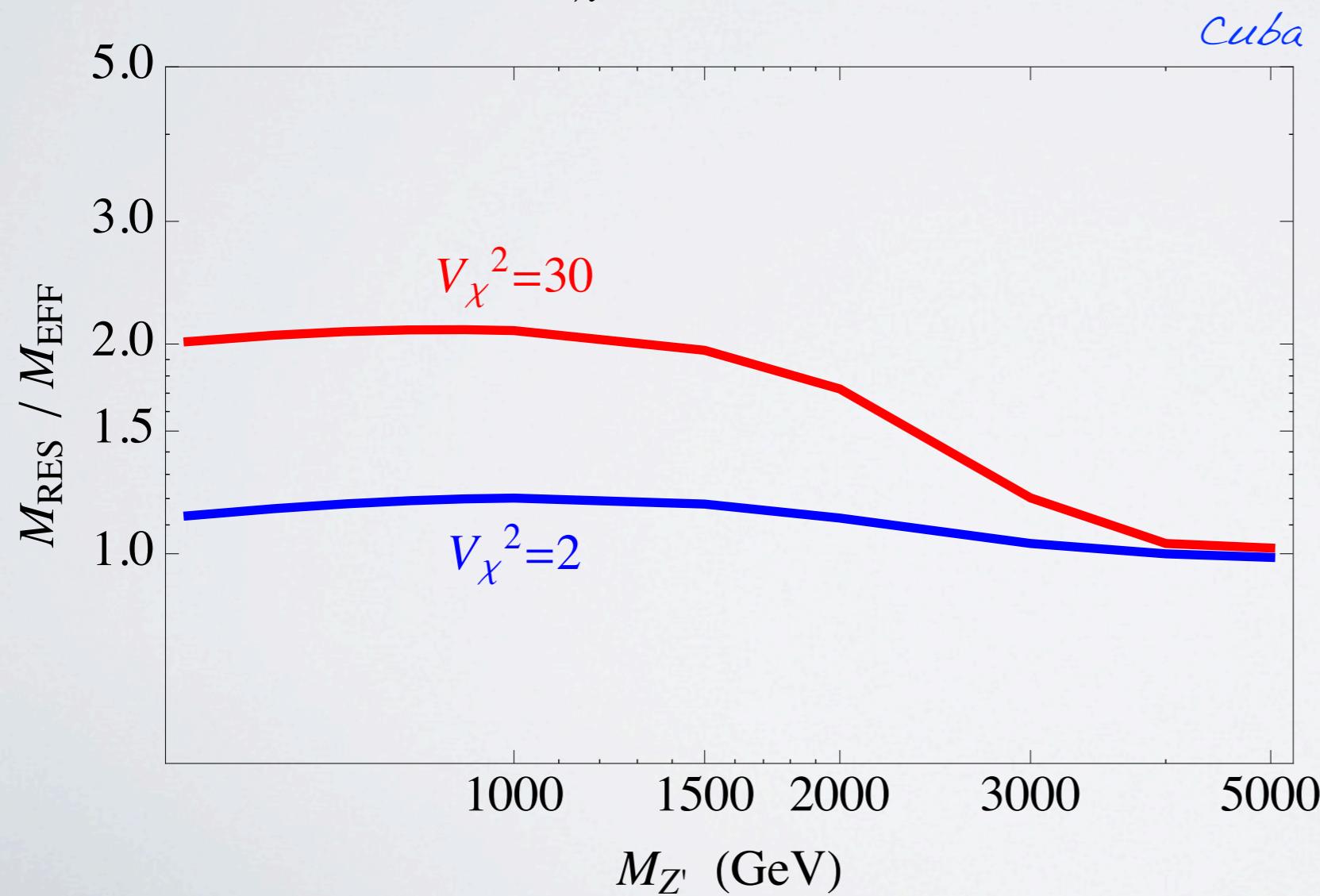
CMS PAS EXO-12-048

- Effective scale: $\sim 800 \text{ GeV}$ or larger

$$\Lambda = M / \sqrt{g_1 g_2}$$

$$\frac{M_{\text{res}}}{M_{\text{eff}}} = f(g_D, V_\chi, M, m_\chi, \sqrt{s})$$

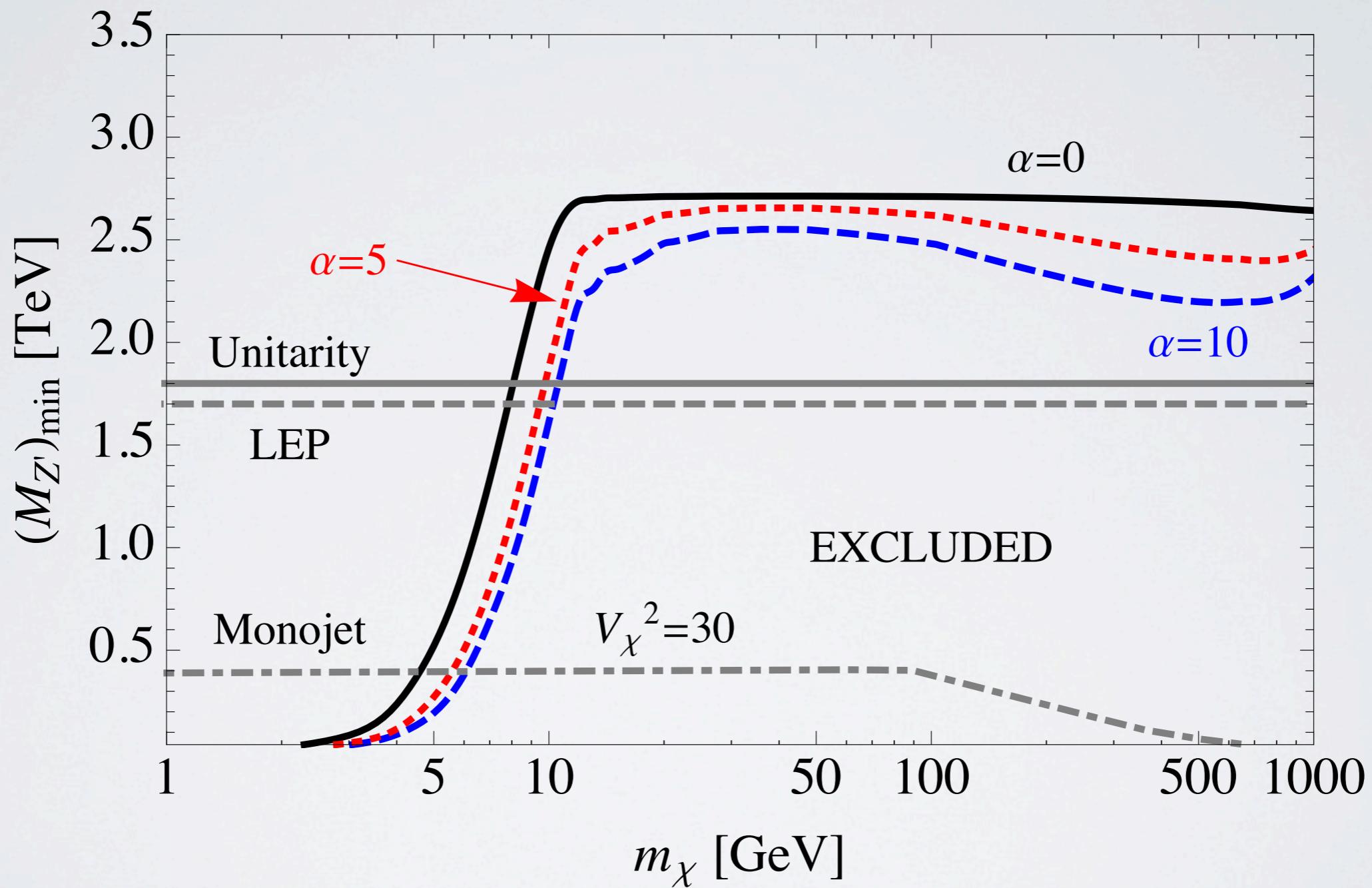
$$g_D = g, \quad m_\chi = 10 \text{ GeV}, \quad \sqrt{s} = 8 \text{ TeV}$$



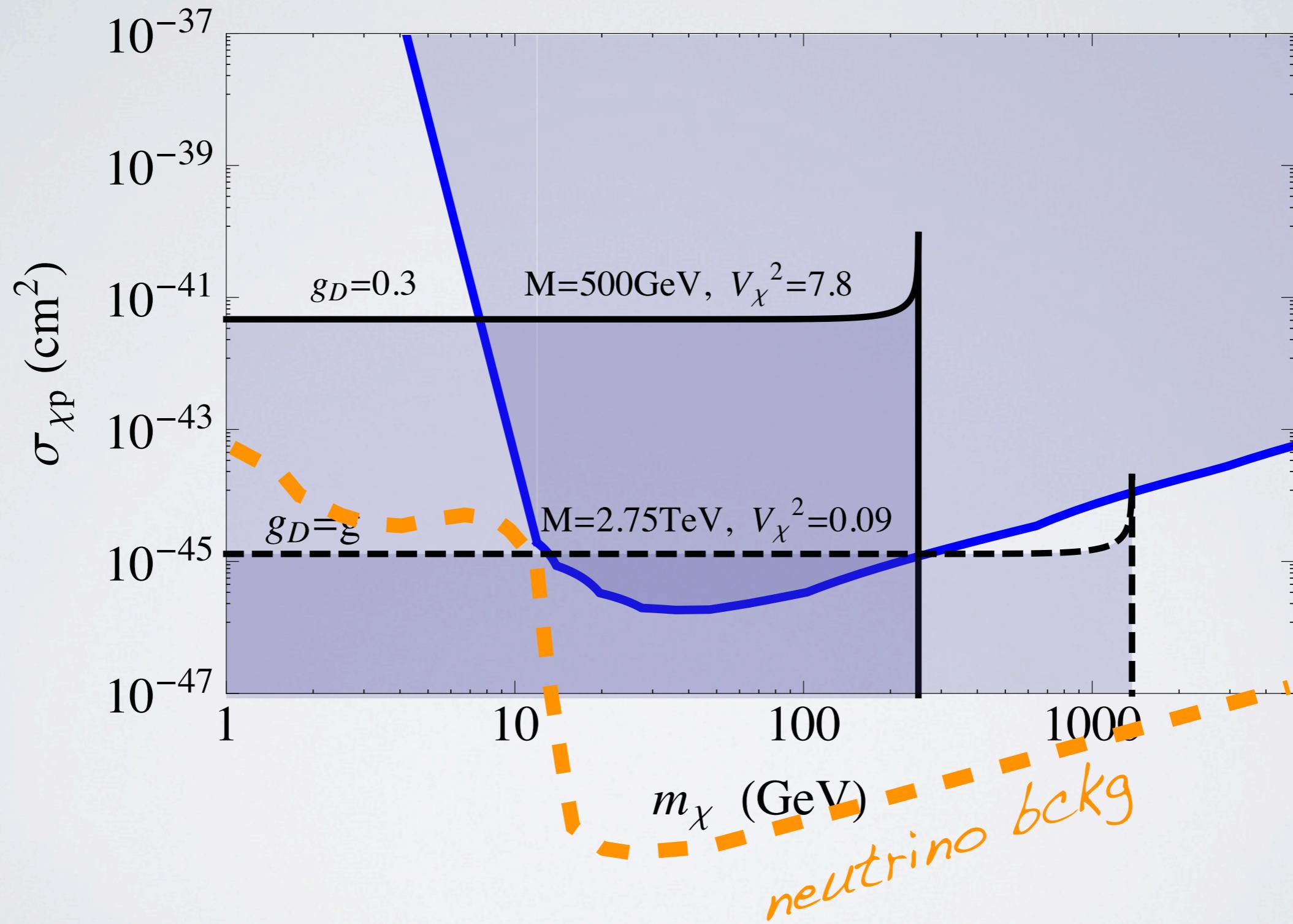
$M_{\text{res}} > 400 \text{ GeV}$
(SSM)

not too strong,
but
a priori relevant for
 $DM < 10 \text{ GeV}$
(LUX insensitive)

$g_D = g$

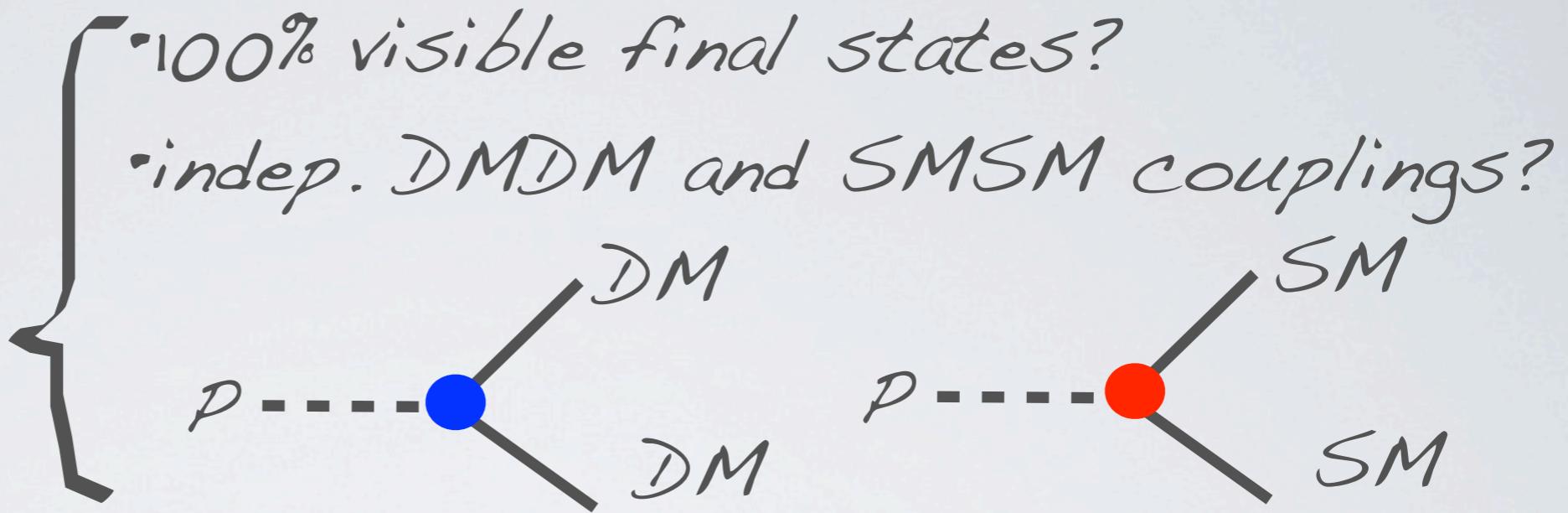


and for dessert...

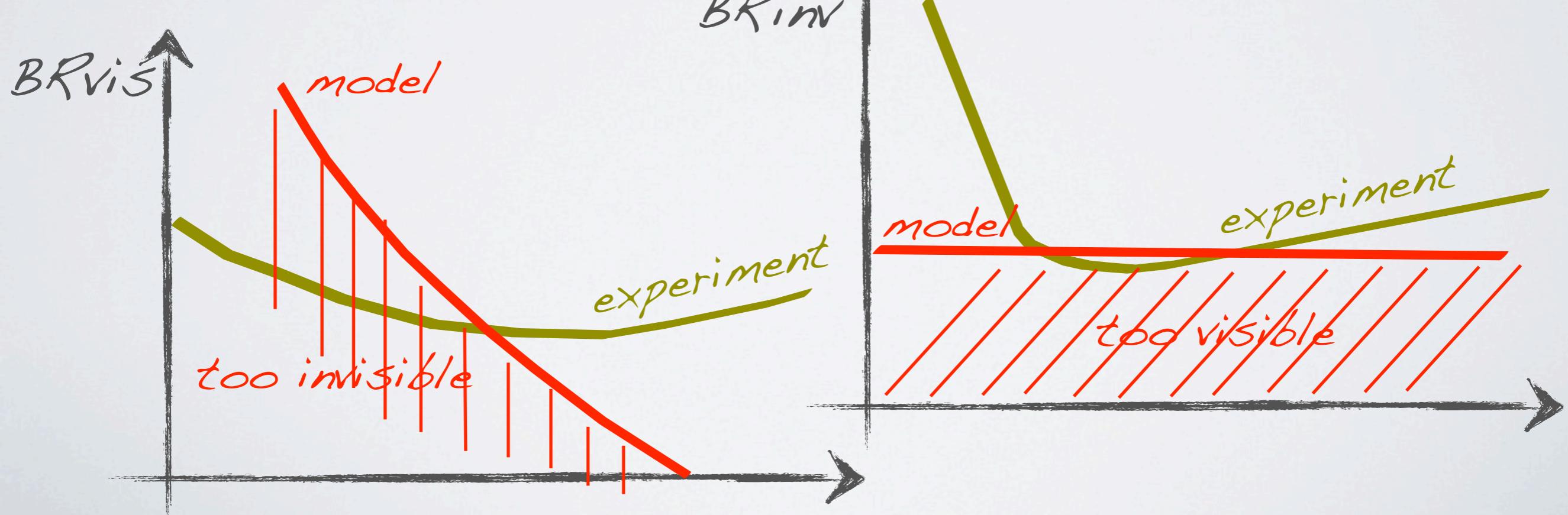


Summary

your favorite
DM model



$$BR_{\text{inv}} + BR_{\text{vis}} = 1$$



the "merci" slide