

" LHC Dark Matter Working Group  
1<sup>st</sup> meeting "

" DILEPTON CONSTRAINTS ON  
DARK MATTER SIMPLIFIED MODELS "

Bryan Zaldivar  
@LAPTh, Annecy, France

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# SIMPLIFIED MODELS FOR S-CHANNEL [1]

- Scalar Mediator,  $\phi$ :

$$\mathcal{L} \supset -g_\chi \phi \bar{\chi} \chi - g_f \frac{\phi}{\Lambda} \bar{f} f$$

- Pseudoscalar,  $a$ :

$$\mathcal{L} \supset -ig_\chi a \bar{\chi} \gamma_5 \chi - ig_f \frac{a}{\Lambda} \bar{f} f$$

- Vector,  $V_\mu$ :

$$\mathcal{L} \supset v_\mu \bar{\chi} \gamma^\mu \chi (g_\chi^V - g_\chi^A) + \chi (g_\chi^V \gamma^\mu - g_\chi^A \gamma^\mu \gamma_5) \chi + \chi (g_f^V \gamma^\mu - g_f^A \gamma^\mu \gamma_5) \chi$$

MFV  
prescription  
otherwise  
Mediator  $\gg$  LHC  
scale

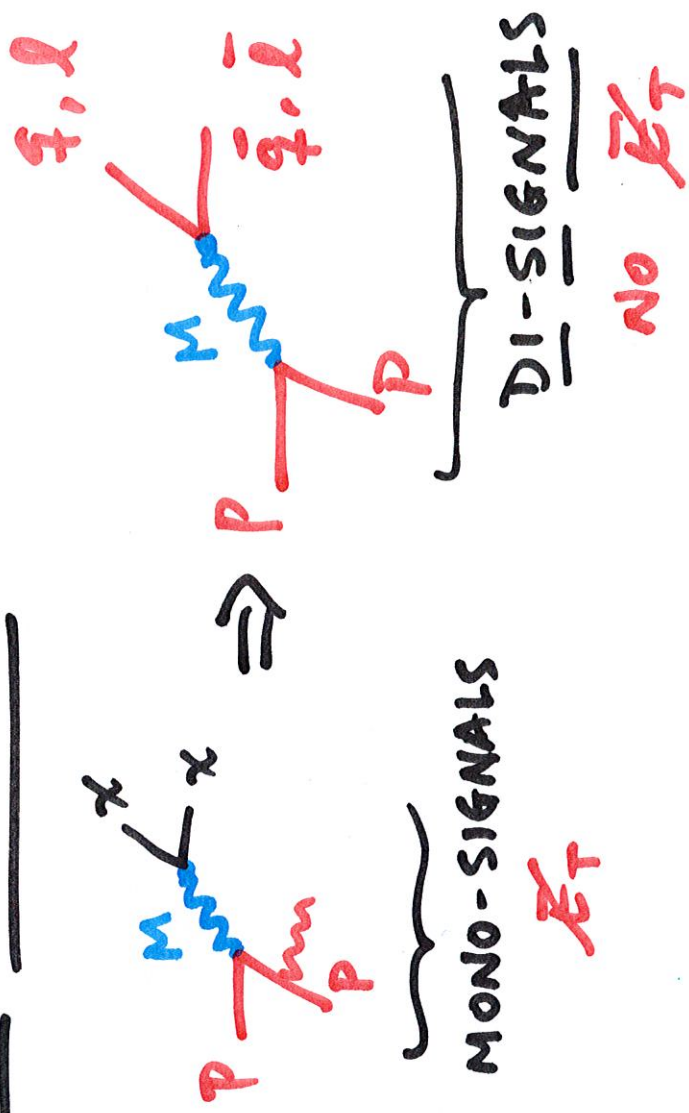
## 2] DIRECT PROBES OF THE MEDIATOR

- Scalar mediators

less appealing:

MFV  $\rightarrow$  top coupling  $\downarrow$

Loop diagrams



- Vector mediators

- Searches for dilepton narrow resonances

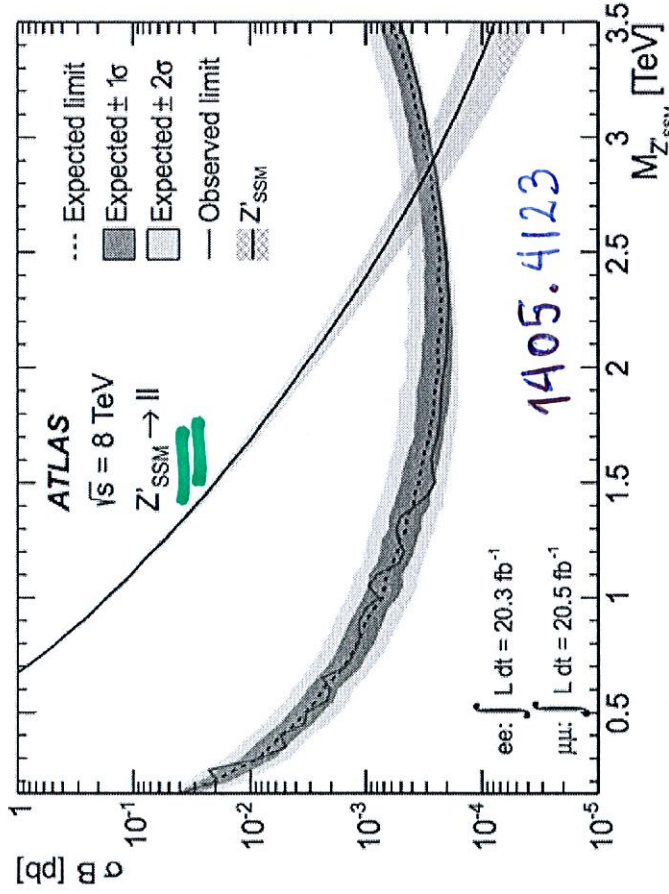
\* Upper limit to the couplings to fermions (applicability)

Dileptons  $\left\{ \begin{array}{l} \text{Gaussian} \rightarrow g_f \lesssim 1.4/\sqrt{N_f} \\ \text{Breit-Wigner} \rightarrow g_f \lesssim 0.8/\sqrt{N_f} \end{array} \right.$

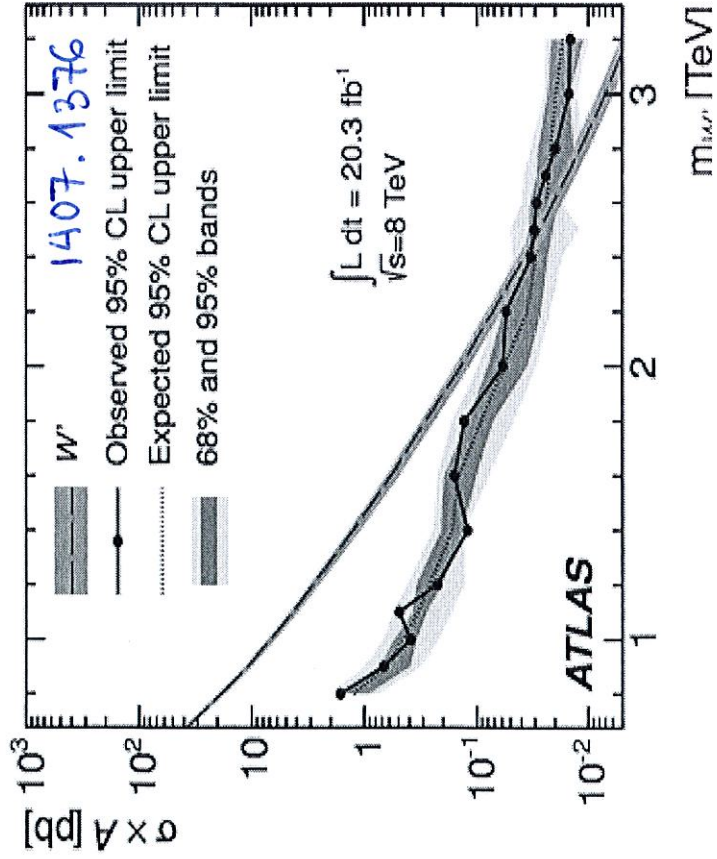
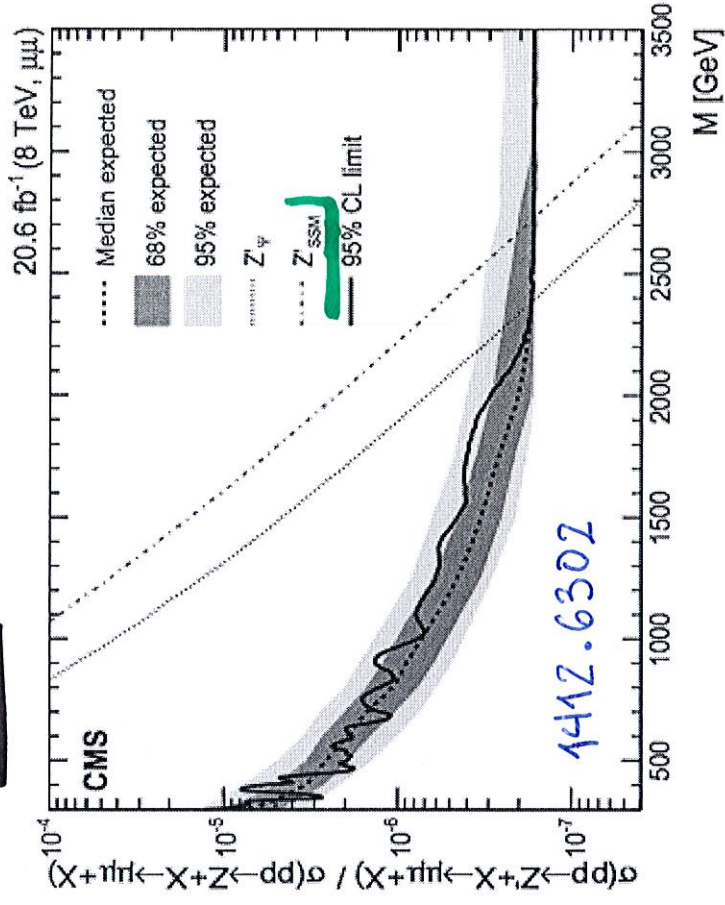
# DILEPTONS & DIJETTS

@ LHC

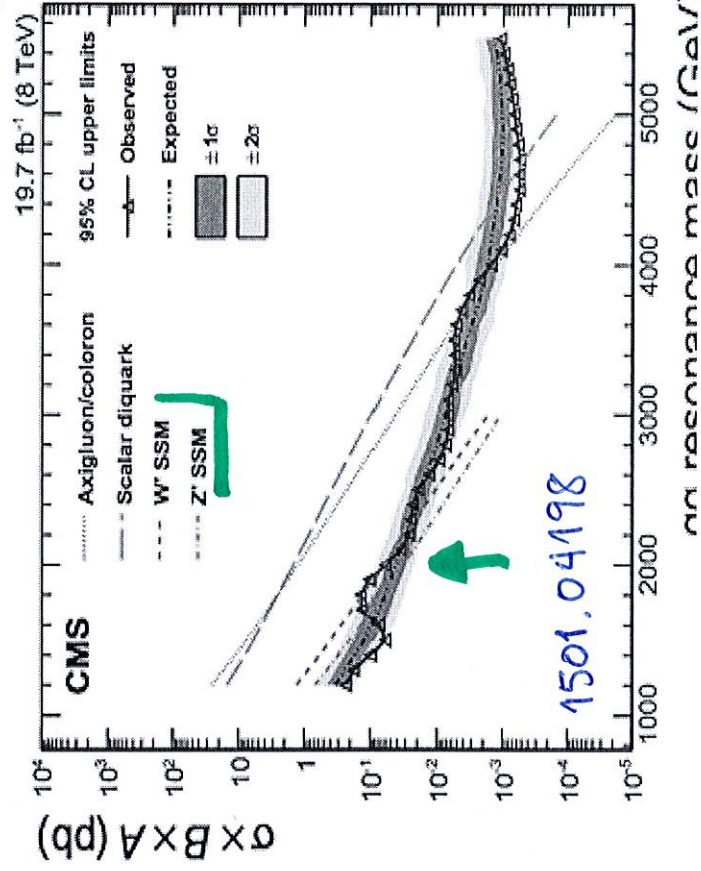
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dILEPTONS



dIJETS



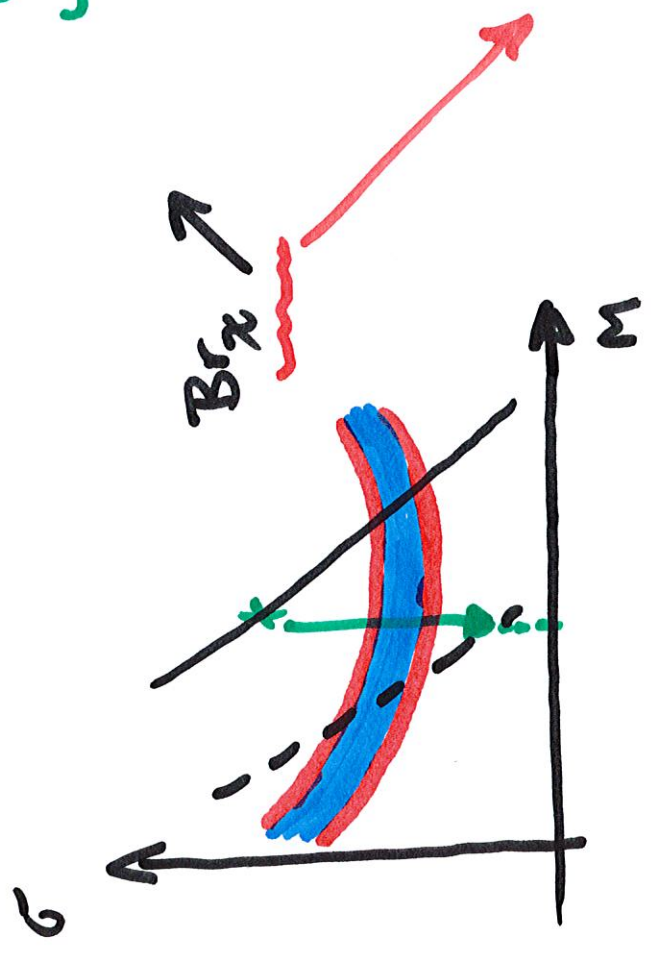
# SIGNALS + INVISIBLE BRANCHING

$$\sigma(\bar{s}s \rightarrow \bar{t}t) \approx \frac{1}{s} (|f_{\bar{t}}|^2 + |f_t|^2) (|g_{\bar{t}}|^2 + |g_t|^2)$$

$$\times \frac{s}{(s-M^2)^2 + \Gamma^2 M^2}$$

$$\sim \frac{M}{\Gamma} \pi \delta(s-M^2) = \frac{M}{\Gamma_{SM}} (1 - Br_{\chi}) \pi \delta(s-M^2)$$

$$\Gamma = \Gamma_{SM} + \Gamma_{\chi}$$

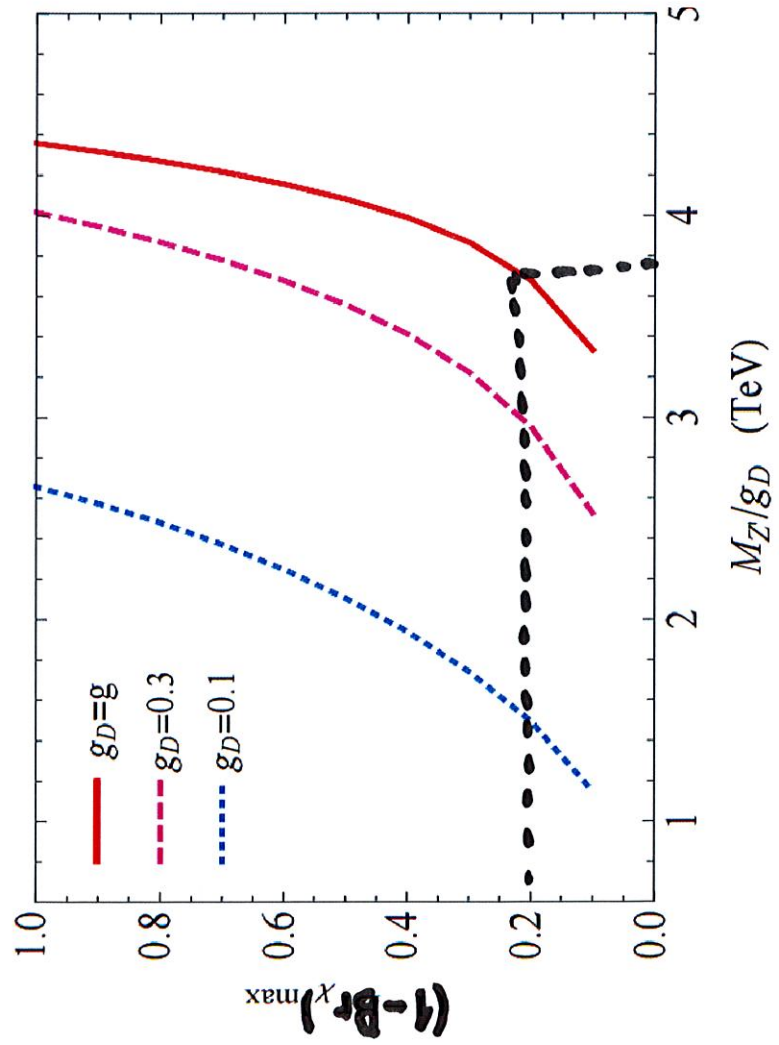


CANNOT INCREASE ARBITRARILY:

- ~~FT~~ SEARCHES
- DIRECT DETECTION

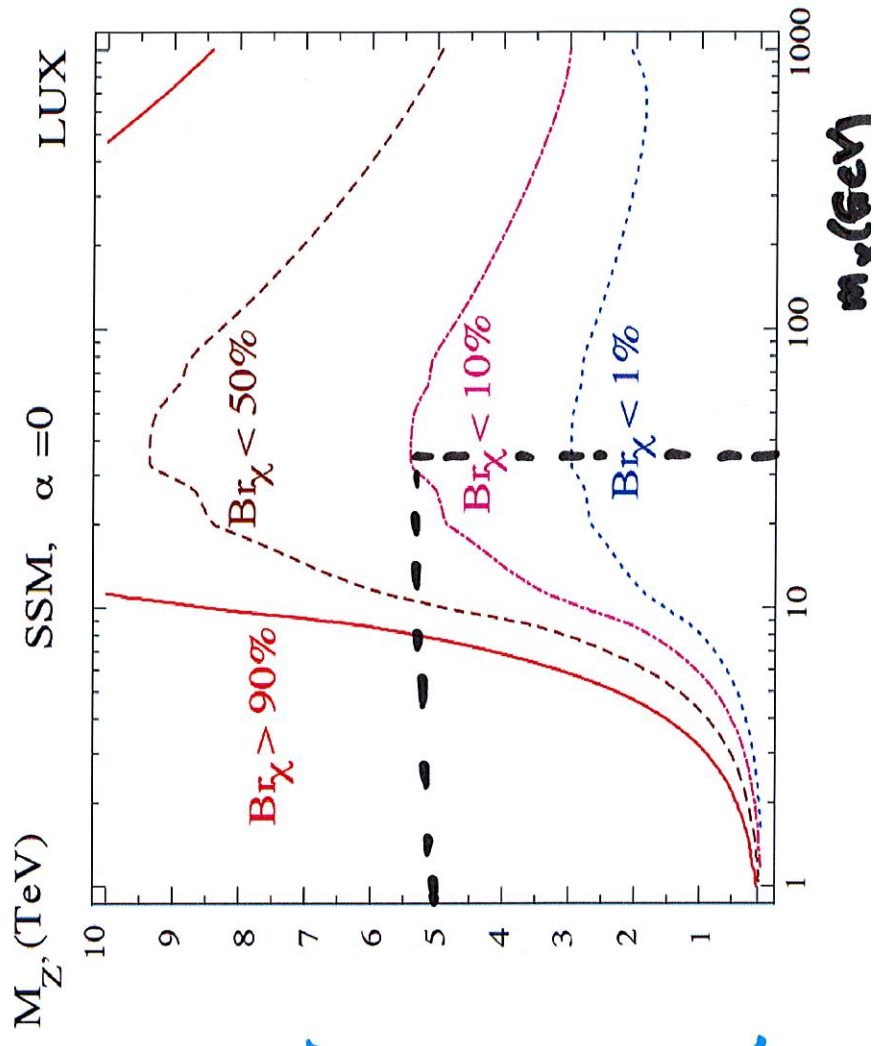
# ABOUT BRANCHING RATIOS

1401.0221



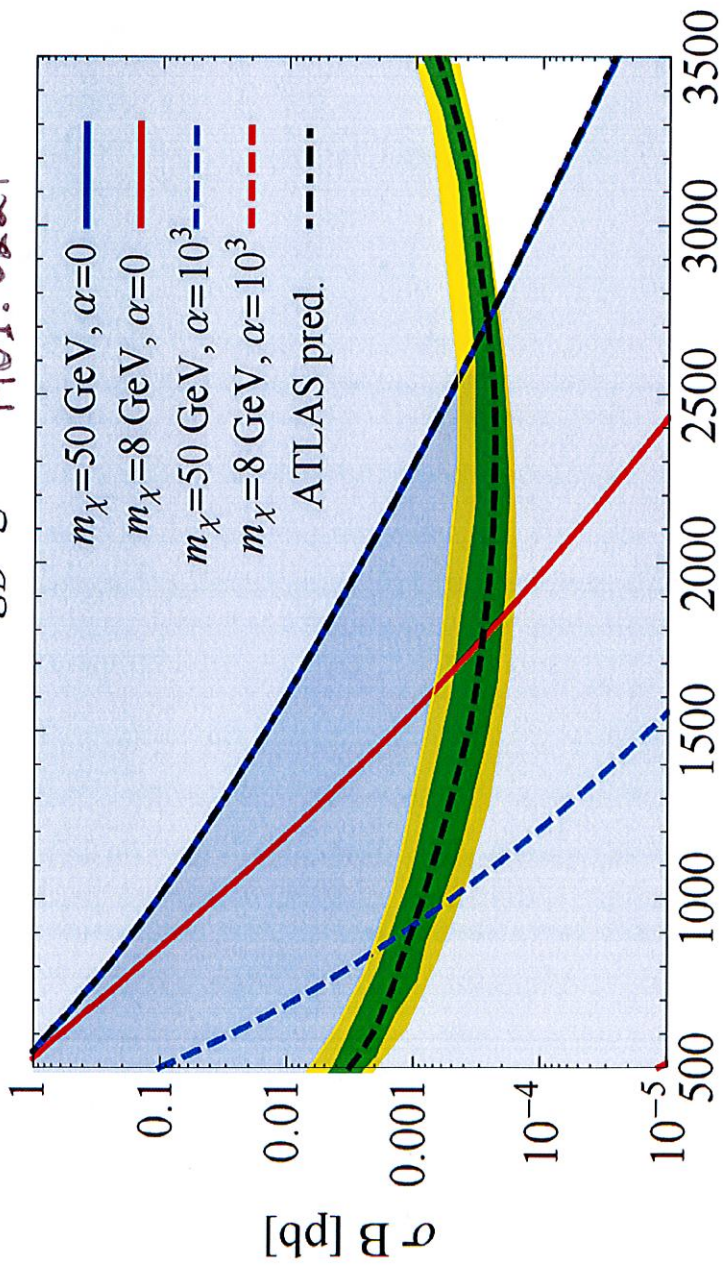
maximum visible Br (or  $1 - Br_\chi$ )  
 allowed by dilepton searches

Minimum  $M_Z$  allowed  
 by LUX, for given  $Br_\chi$

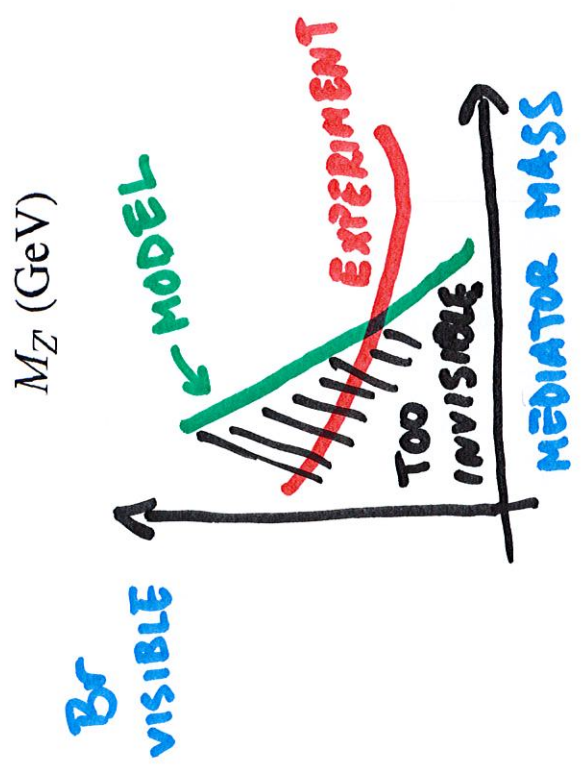
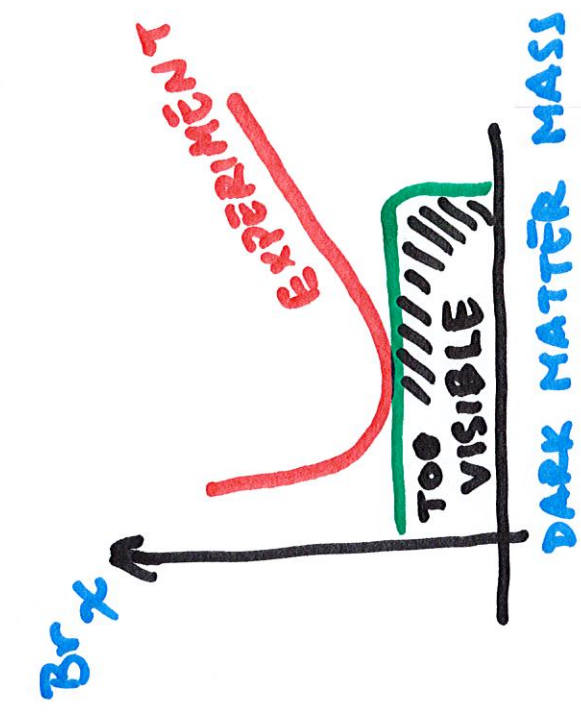


# DILEPTONS VS. DIRECT DETECTION [6]

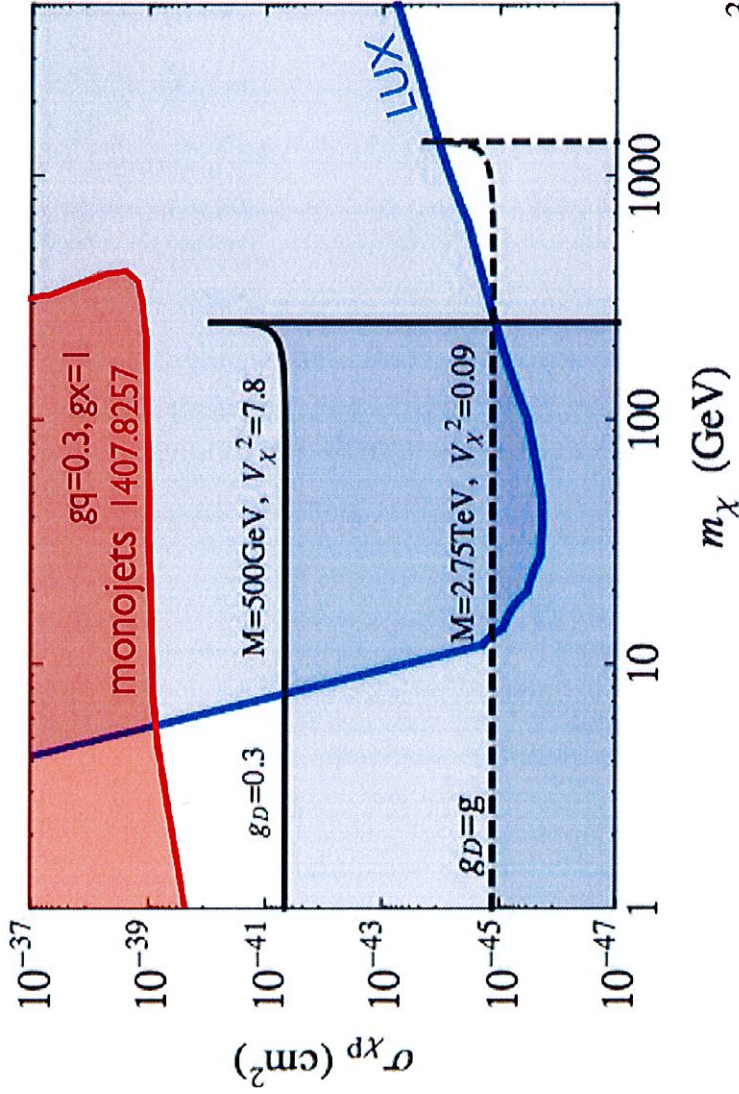
$g_D = g$  1401.0221



- Relax dilepton bound by increasing  $Br_\chi$
- $Br_\chi$  bounded by DD
- DD bound depends on DM mass



# DILEPTONS VS. DD VS. MONOSIGNALS [7]



- DIRECT DETECTION BOUNDED FROM BELOW

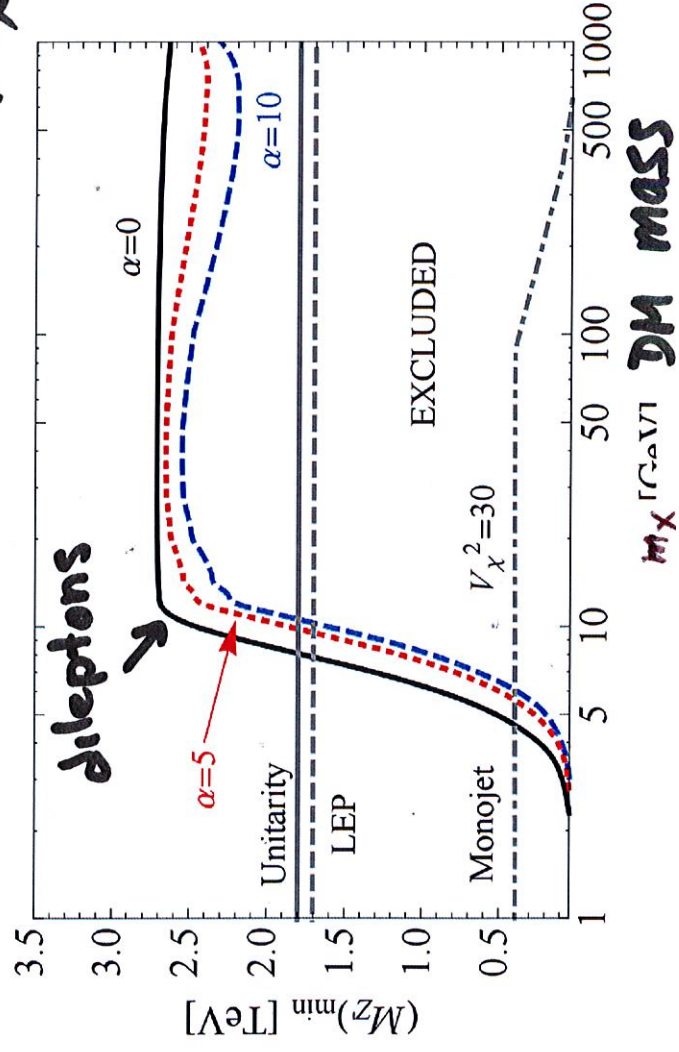
1401.0221

- LEP limits from non-resonant dilepton production

- Unitarity: dark coupling  $\leq \sqrt{4\pi}$   
 & lower bound on  $M_Z$

- Monojets subdominant

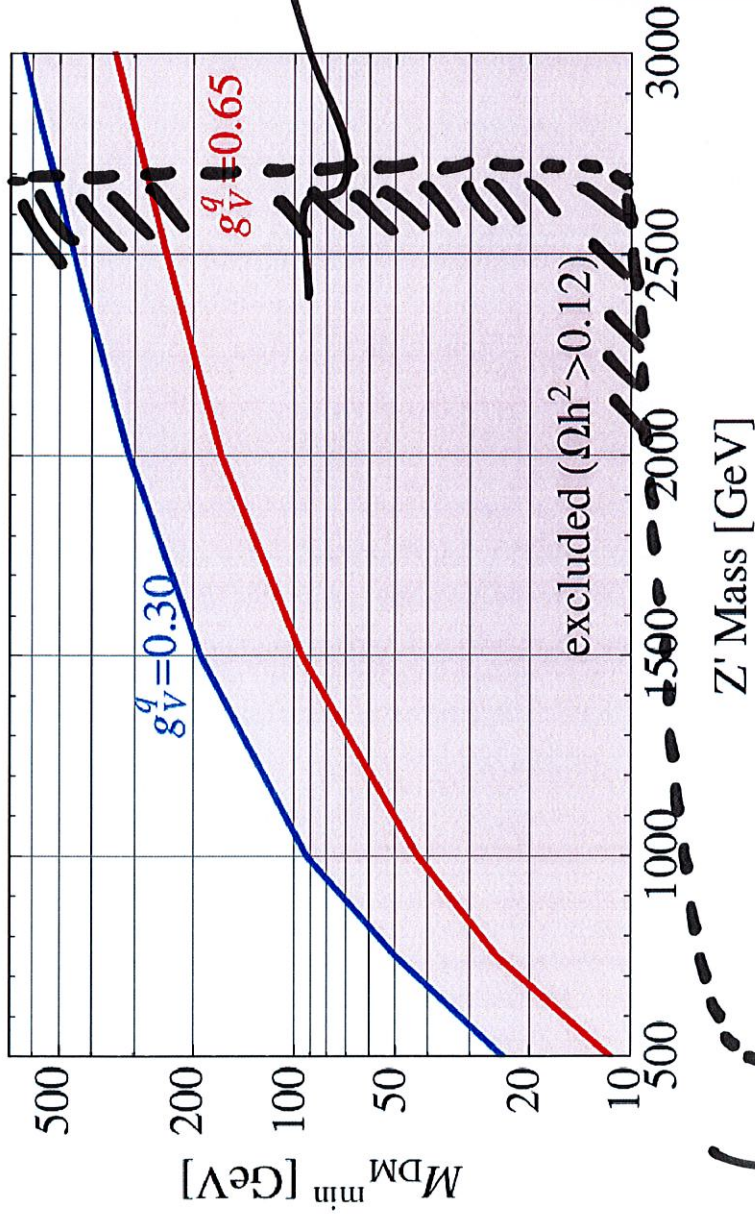
$$g_D = g \quad \alpha \equiv A_\chi / V_\chi$$





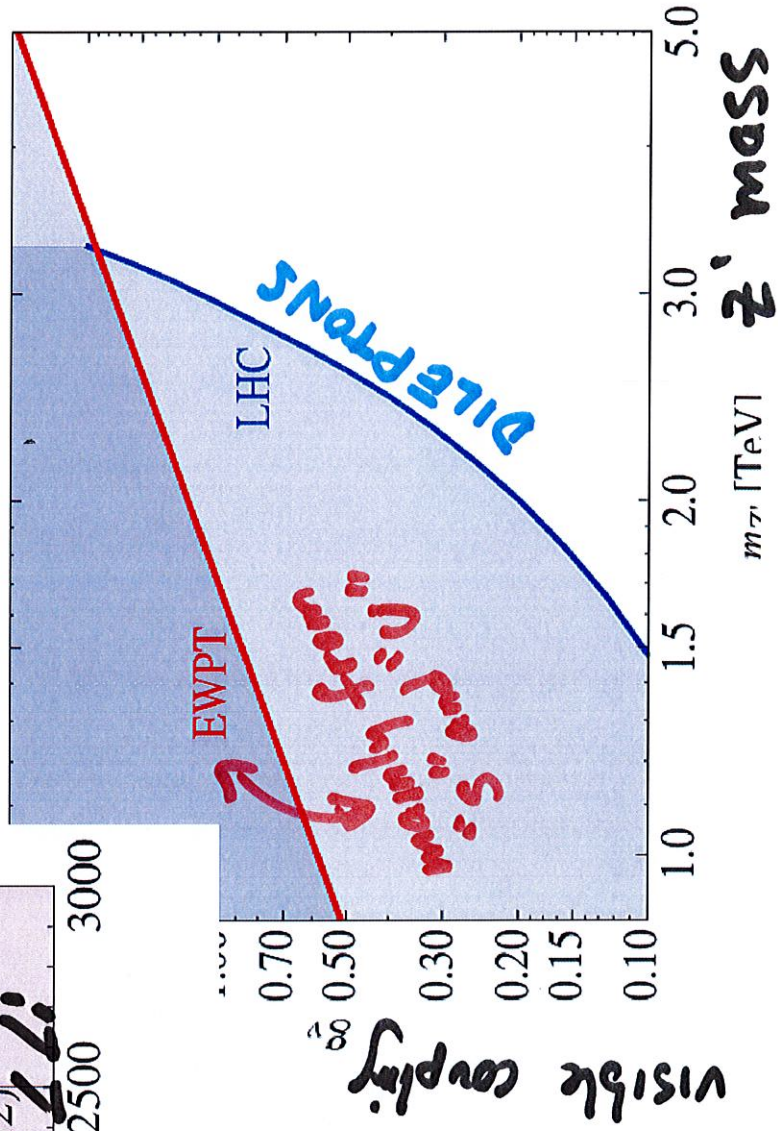
# DILEPTONS VS. RELIC DENSITY

$g_V^X=1, g_A^X=0, \Omega h^2 \sim 0.12$



EXCLUDED BY  
DILEPTON SEARCHES

(plots prepared for this talk)



- assumes  $M_{Z'} > m_\chi$

- assumes thermal history



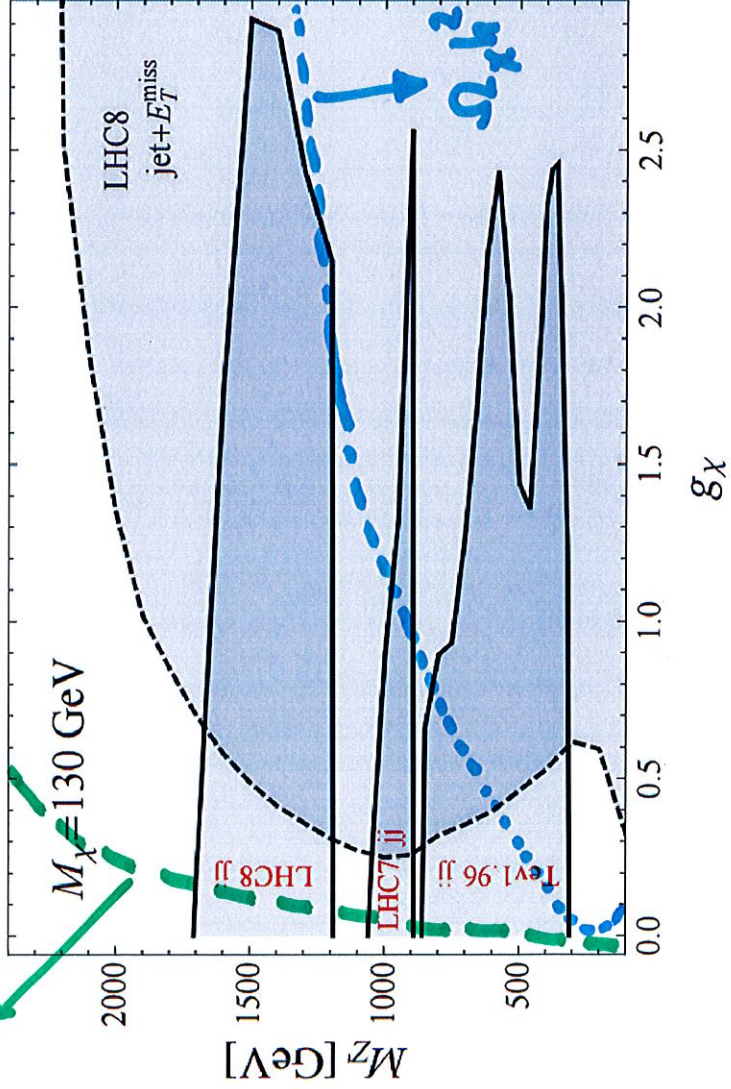
# DIJETS

# BRIEFLY

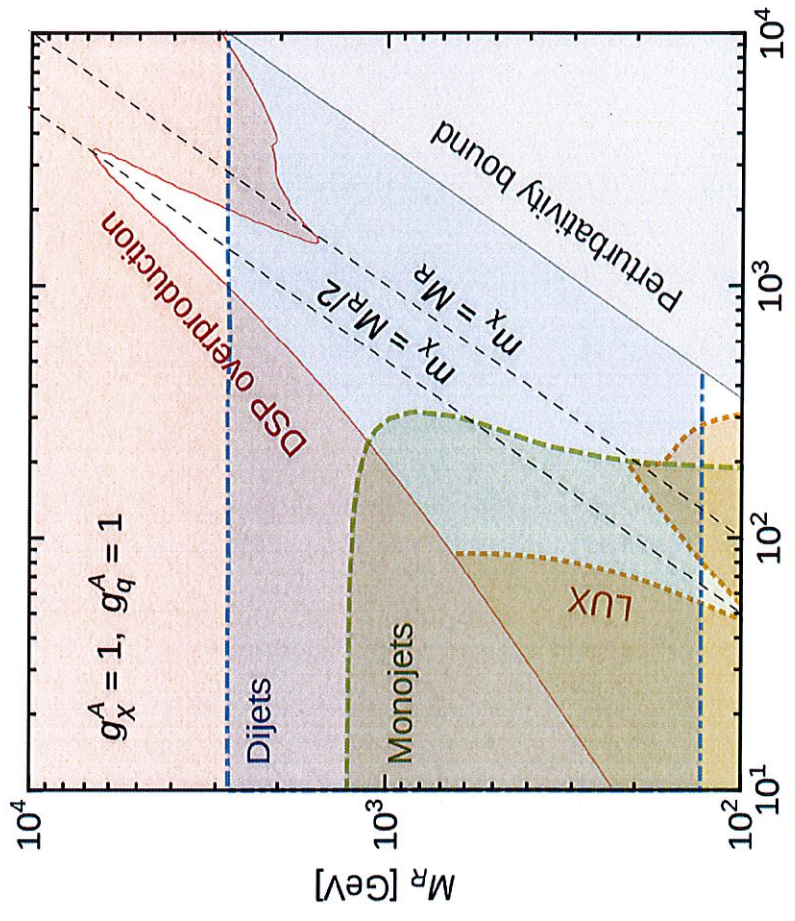
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ARCS  
→

1312.5281



- pure axial model
- axial coupling = SSM
- DD rescaled by  $\Omega_\chi h^2$
- Perturbativity becomes relevant!



- SSM couplings to quarks
- DD assumes  $\Omega_\chi h^2 = 0.12$
- LOWER DM masses give less exclusion.

# CONCLUSIONS

- A priori models with scalar mediators seem less interesting for direct mediator searches

- In general models with extra gauge bosons have couplings to leptons and quarks  $\Downarrow$

dilepton searches apply  
and are the most relevant

- Complementarity between

Disignals  $\rho$  • Mono-signals

- Direct Detection
- Relic Abundance

Exclusion from  
above and from below

- Minimal Realisations of Thermal Relic in tension with  
Direct Mediator searches

Thank you!