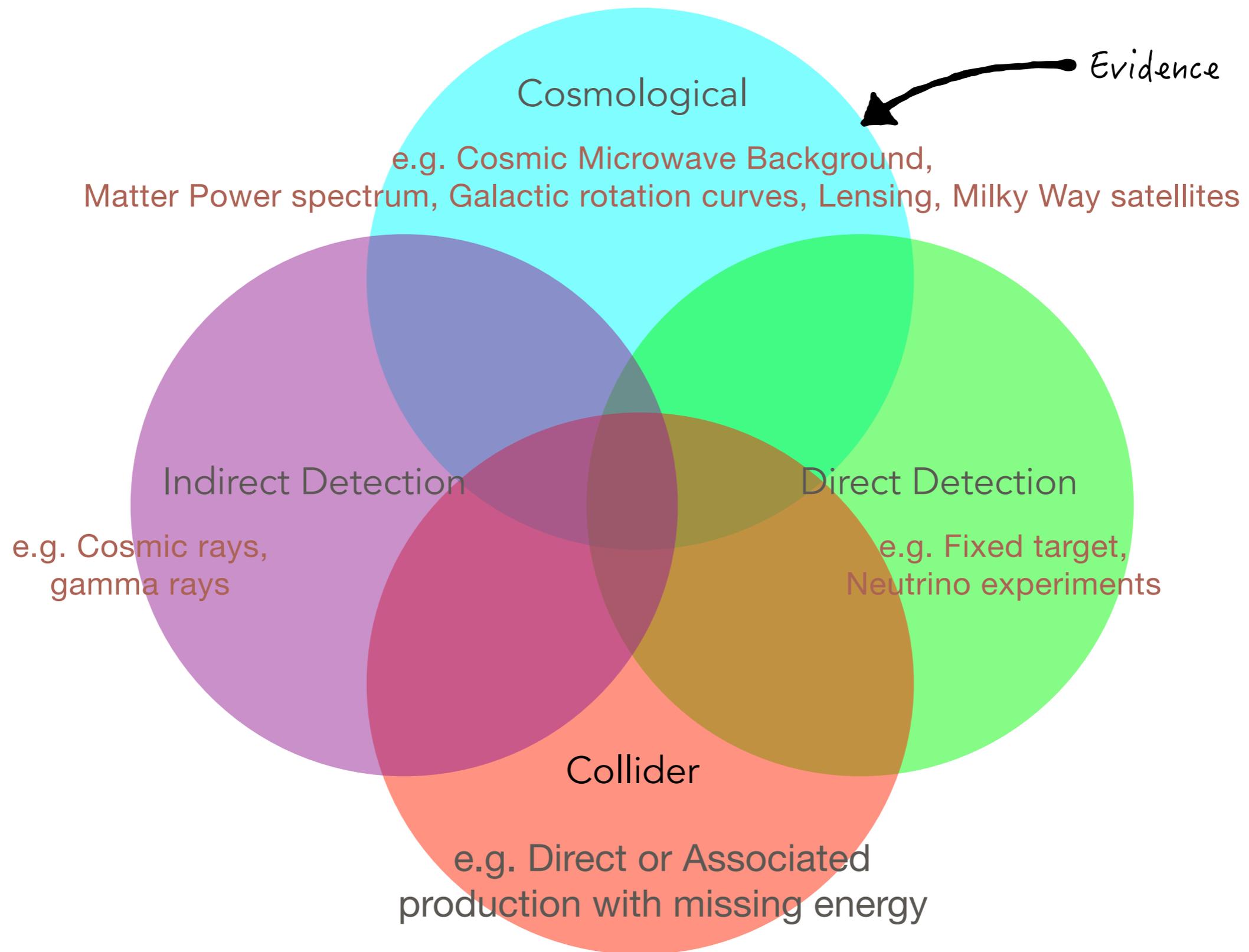


DM@Colliders

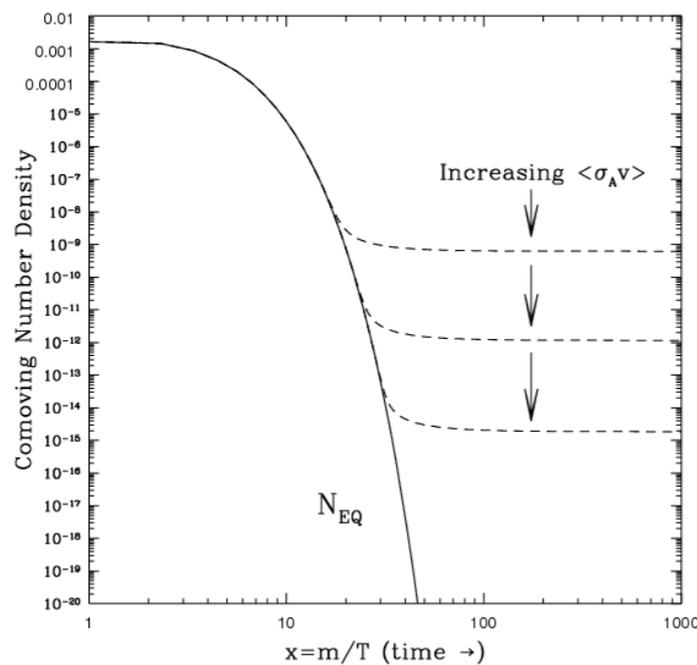
Nishita Desai & Suchita Kulkarni

Complementarity of DM searches



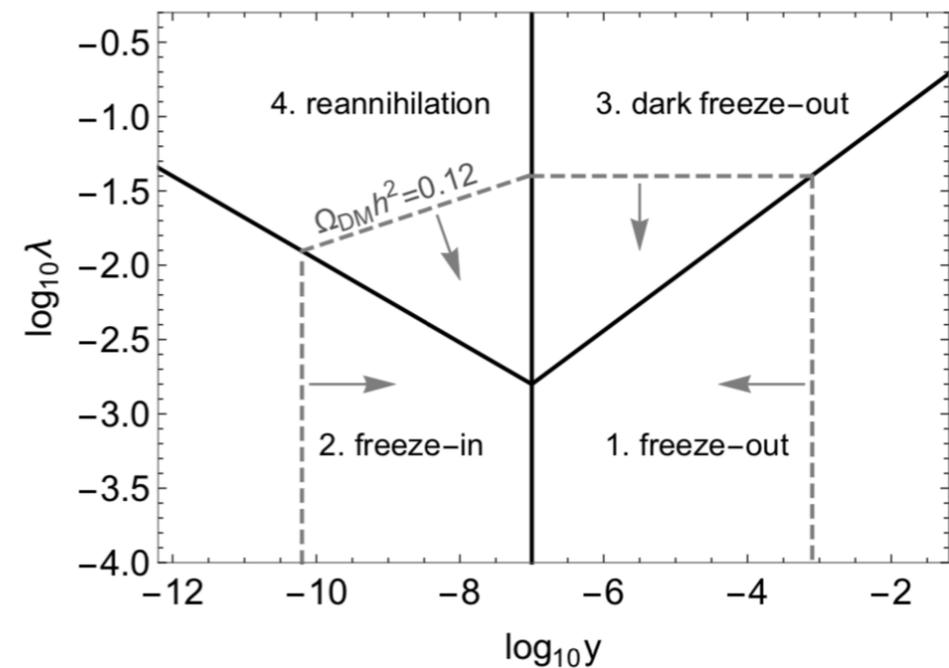
Changing the interesting mass/ coupling range

Older picture:



If coupling is too small, the leftover density is too high to explain DM. This gives a lower bound on couplings for any given model.

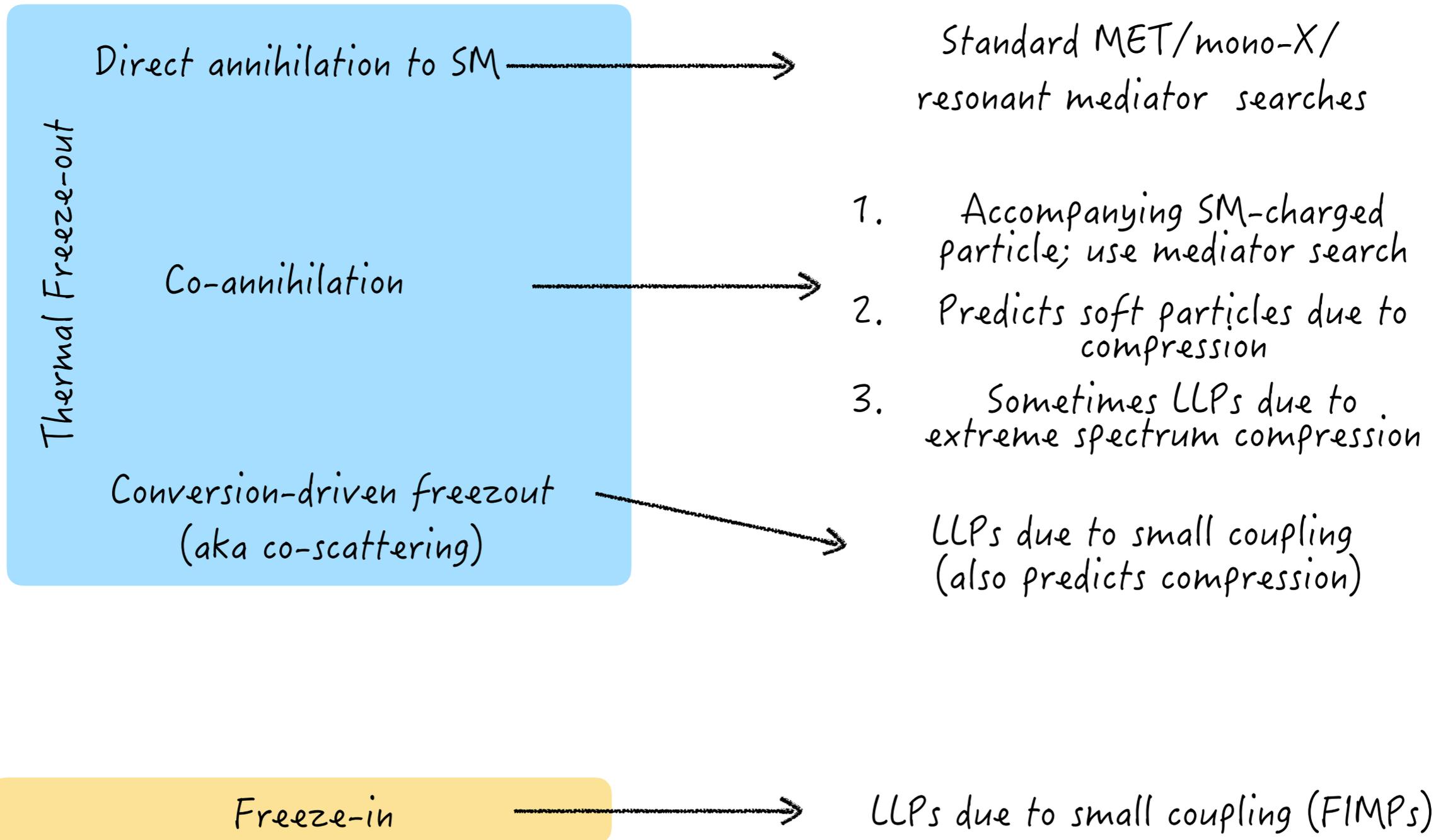
Modern picture:



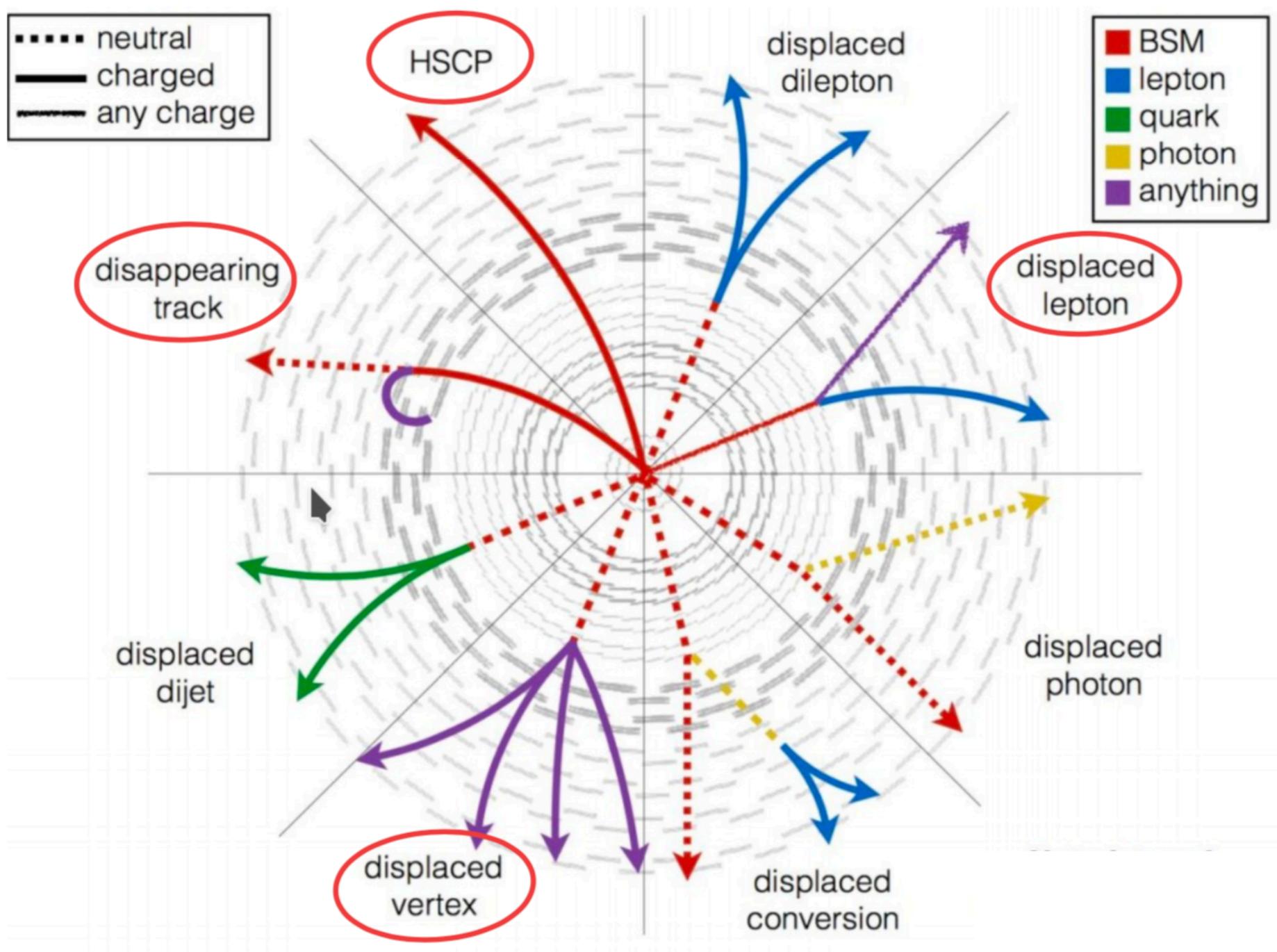
For the same model, a range of couplings is possible in different "regimes" that correspond to different mechanisms to get the right Ω

Make a (simplified) model, vary masses up to what is allowed by kinematics, and couplings over large range

Possible signatures



LLP searches

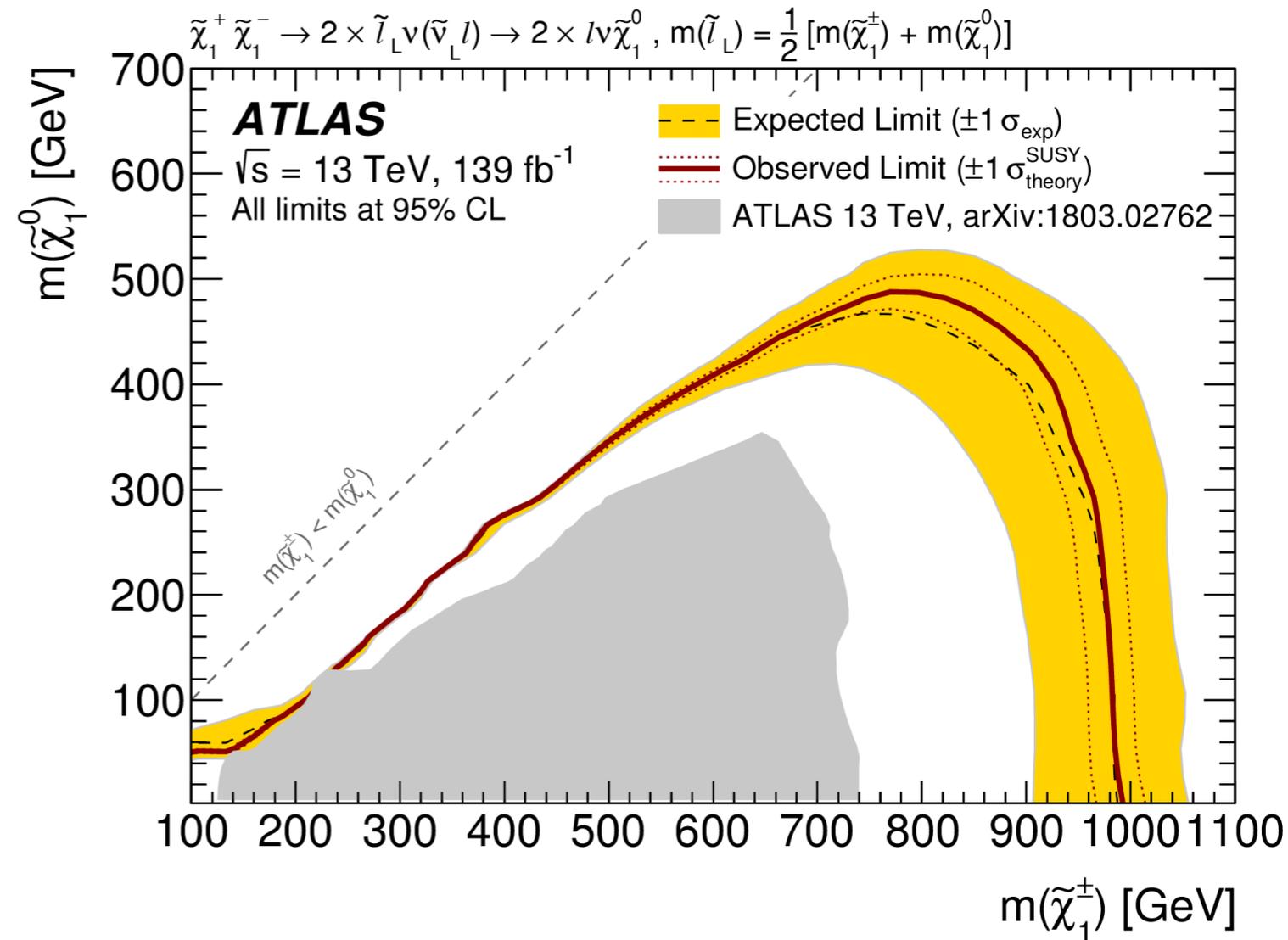
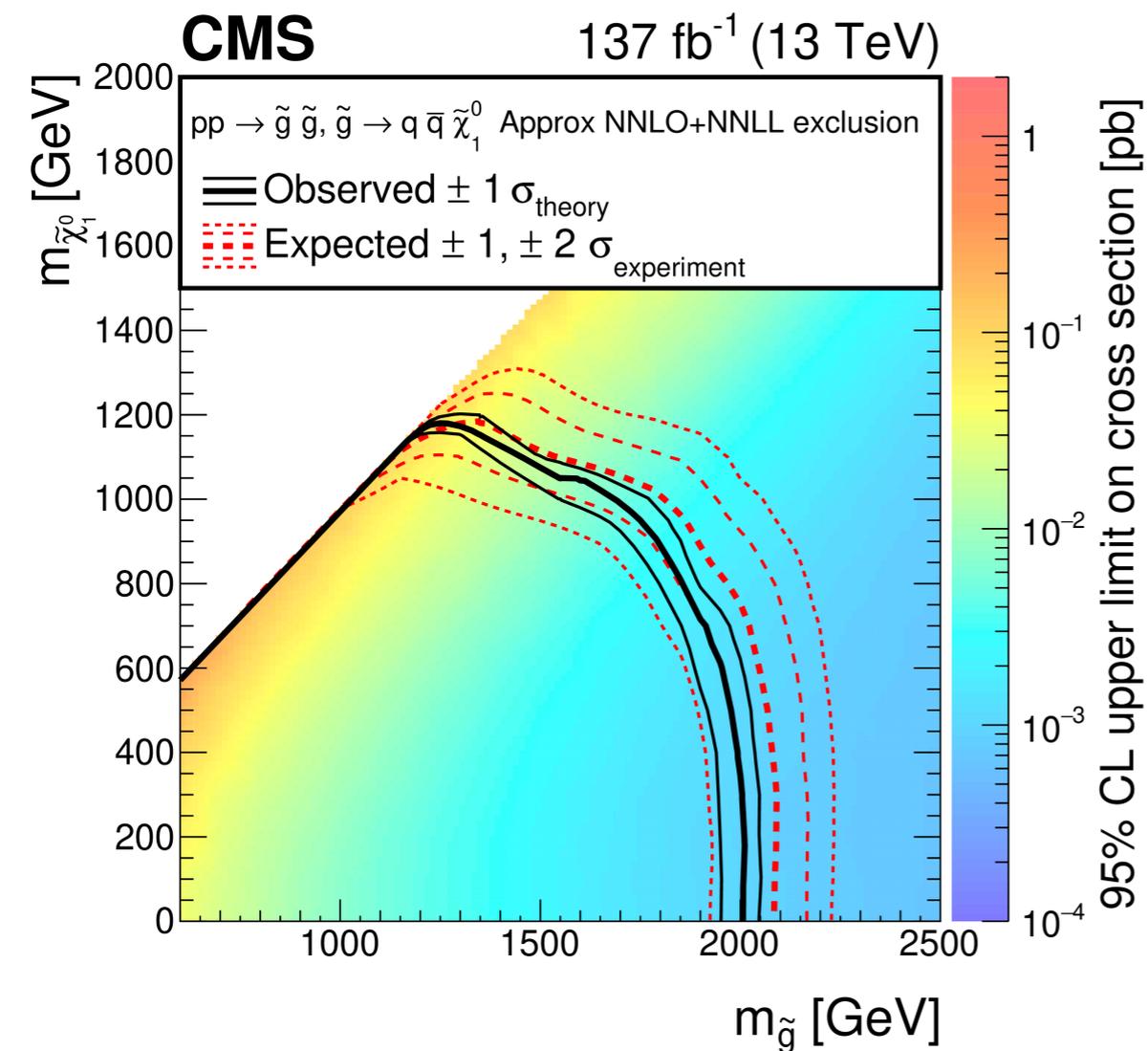


Before LHC turned on

(Already nearly 10 years ago now!)

- DM = SUSY neutralino \Rightarrow Jets + Missing transverse energy (MET)
- Otherwise use Effective Field Theoretical description (mostly look for jets + MET, in particular mono-jet)

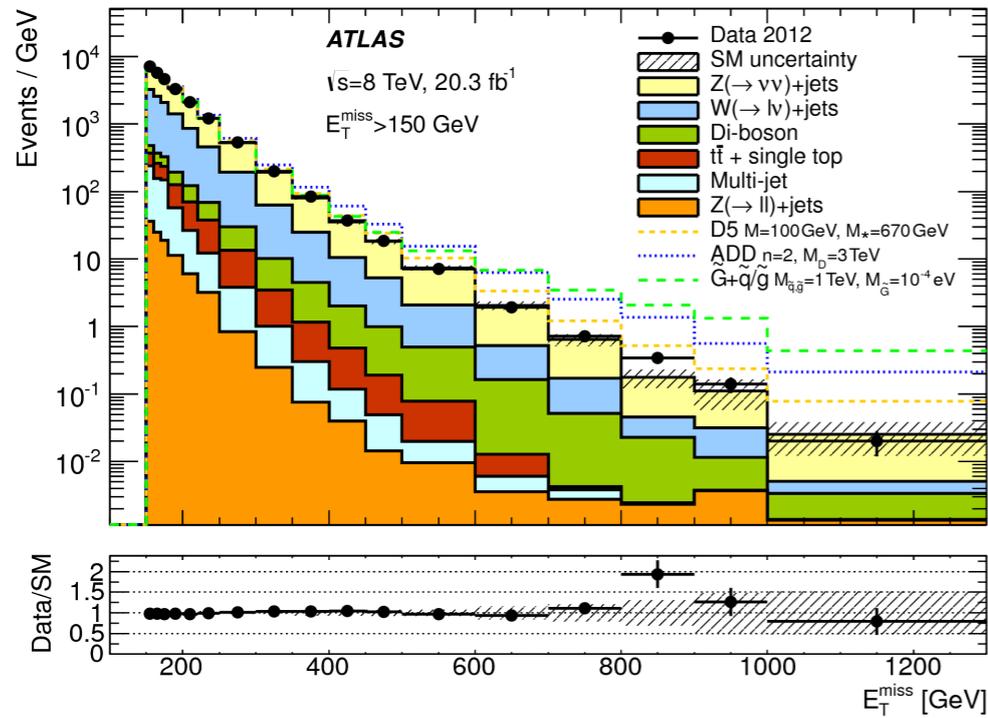
SUSY after LHC Run 2



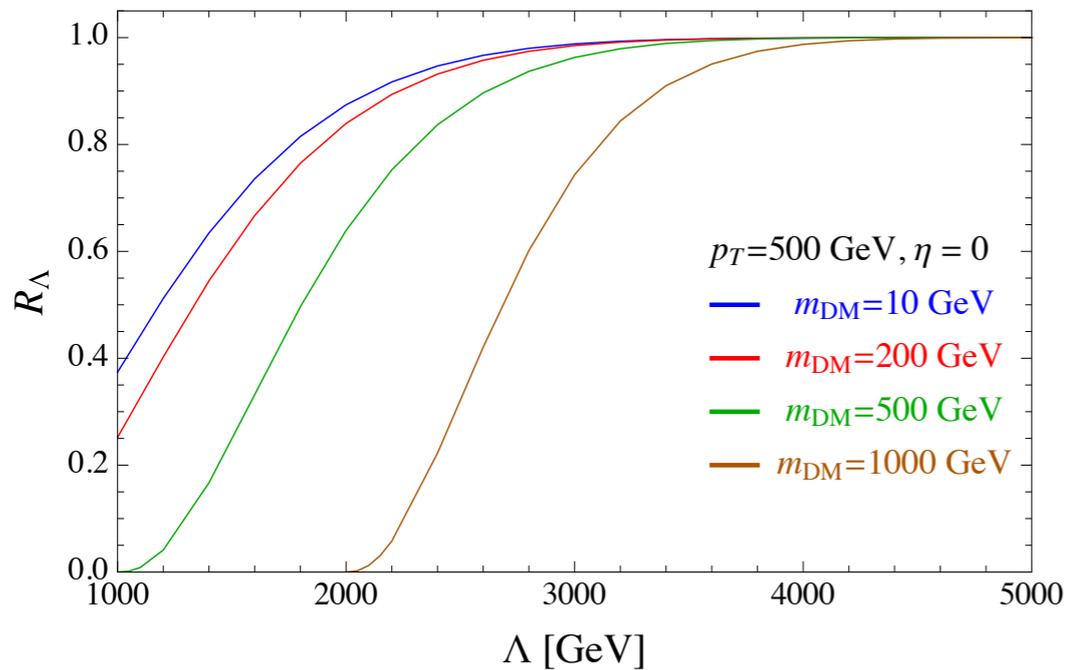
If we have a 2 sigma excess at $\sim 150/\text{fb}$, that can become 3-sigma by 300/fb.

To get a 5-sigma discovery, we need should have seen ~ 3.5 -sigma discrepancy already! => NOT GOING TO HAPPEN

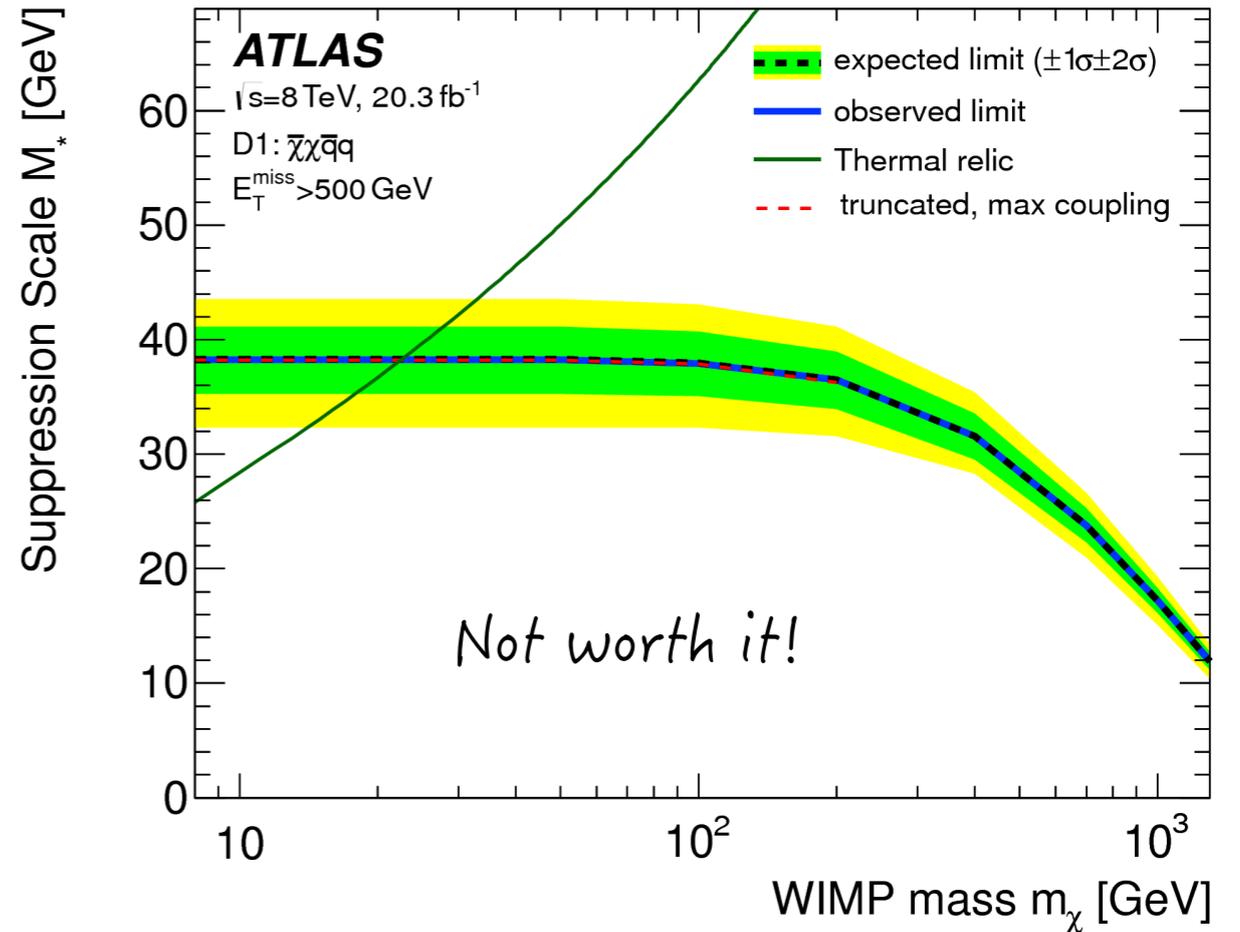
EFT after LHC Run 1



$$\bar{q}q \frac{g}{p^2 - M^2} \bar{\psi}\psi \xrightarrow{M \gg p} \frac{g}{M^2} \bar{q}q \bar{\psi}\psi$$

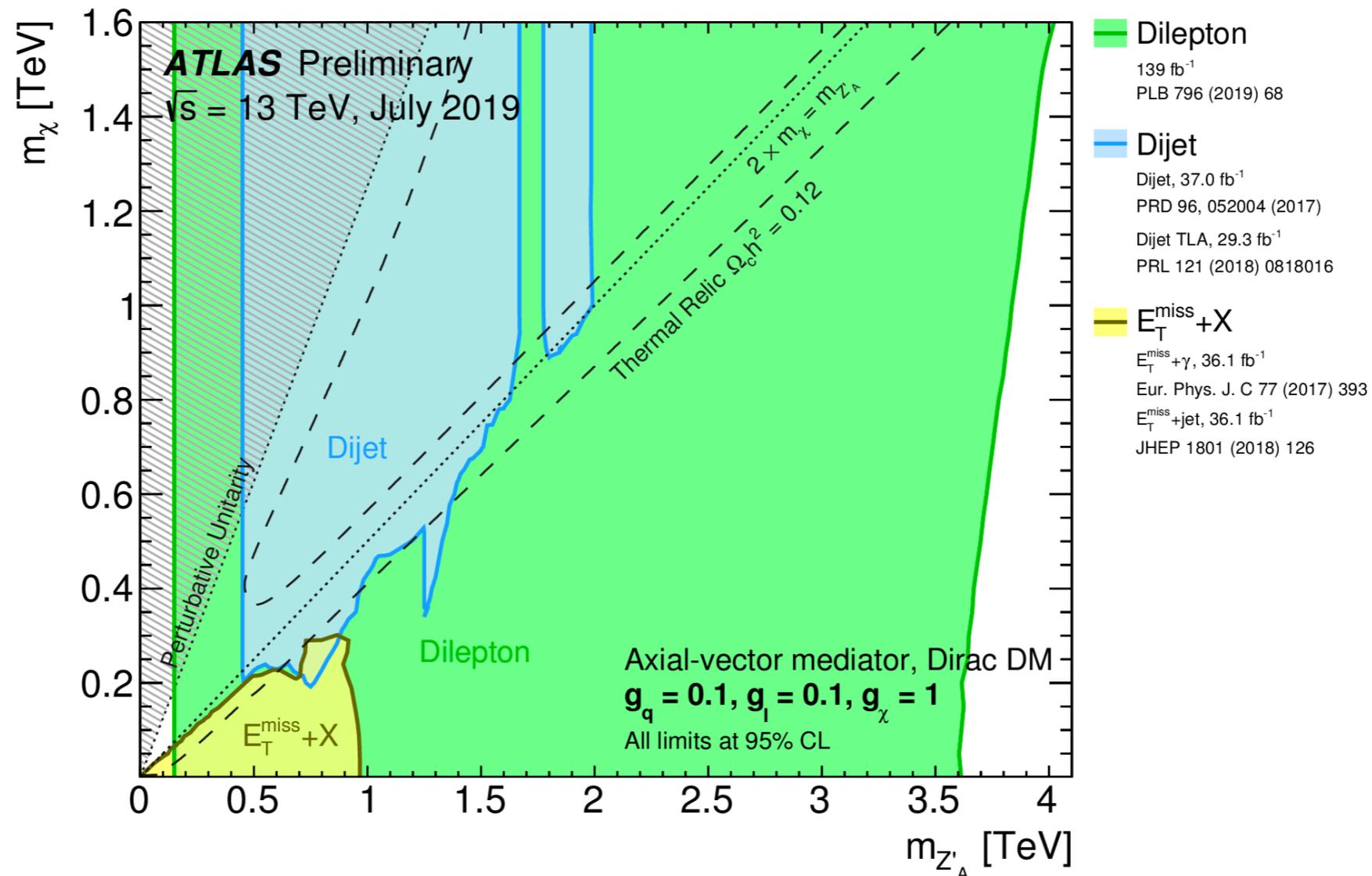


Busoni et al (2013)

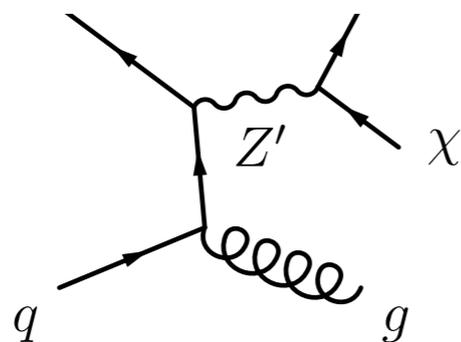


ATLAS Coll. EPJC (2015)

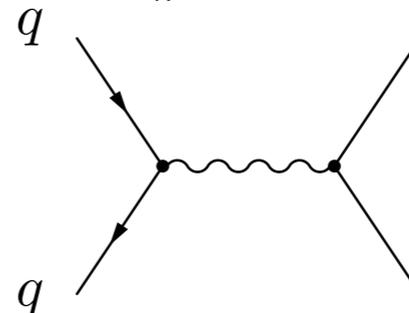
DM simplified models after LHC Run 2



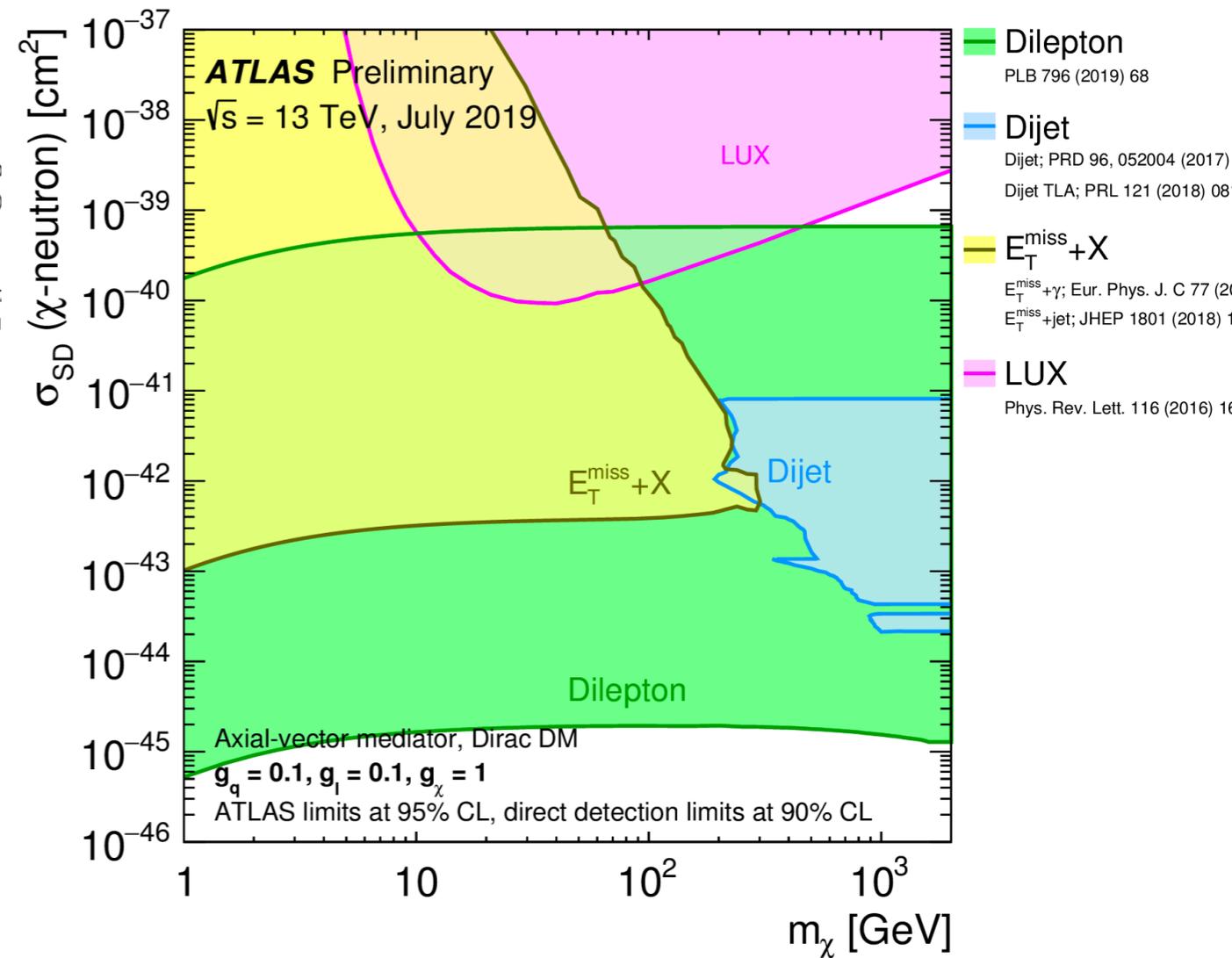
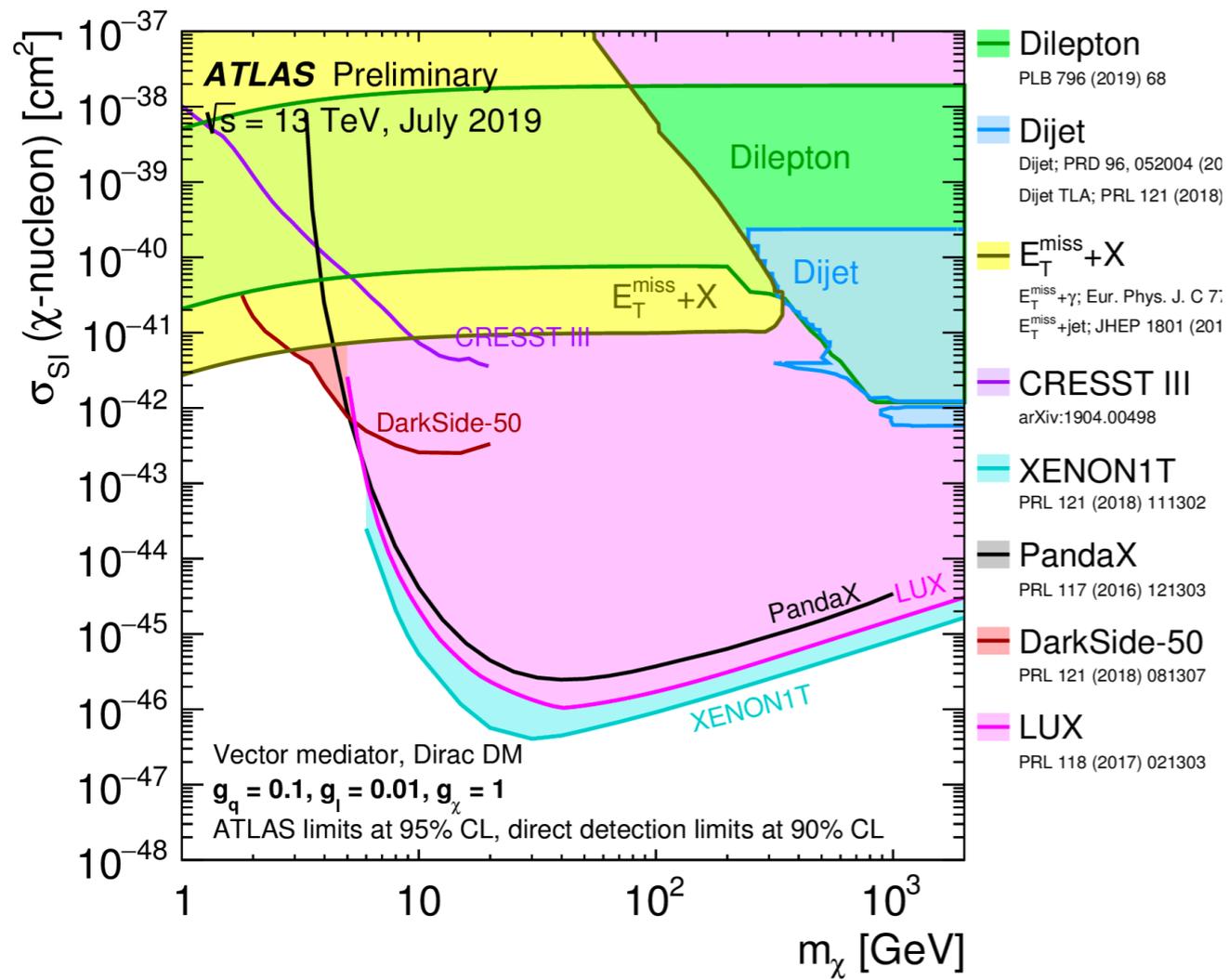
Monojet



Dijet/Di-lepton

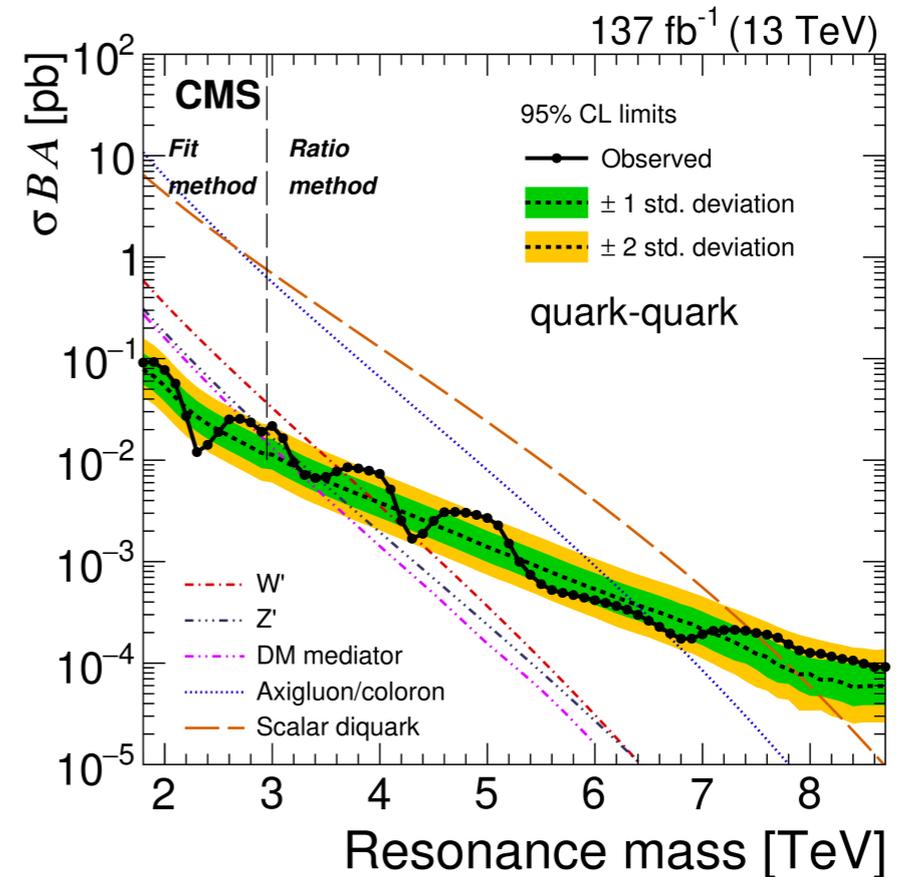
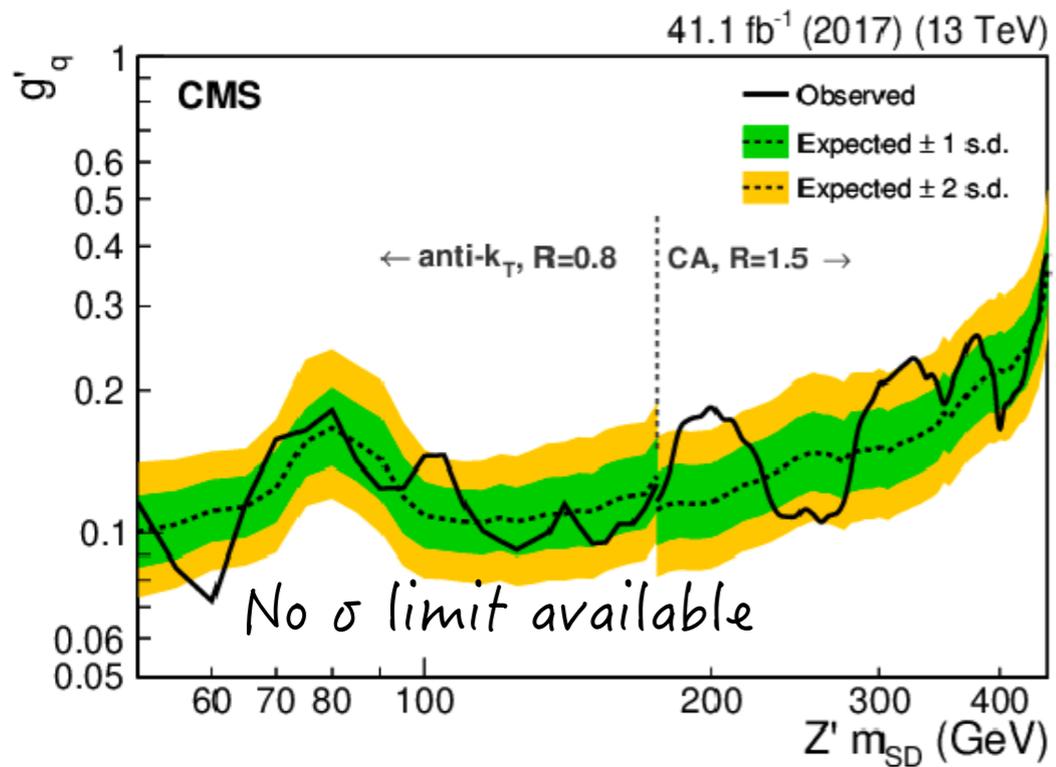
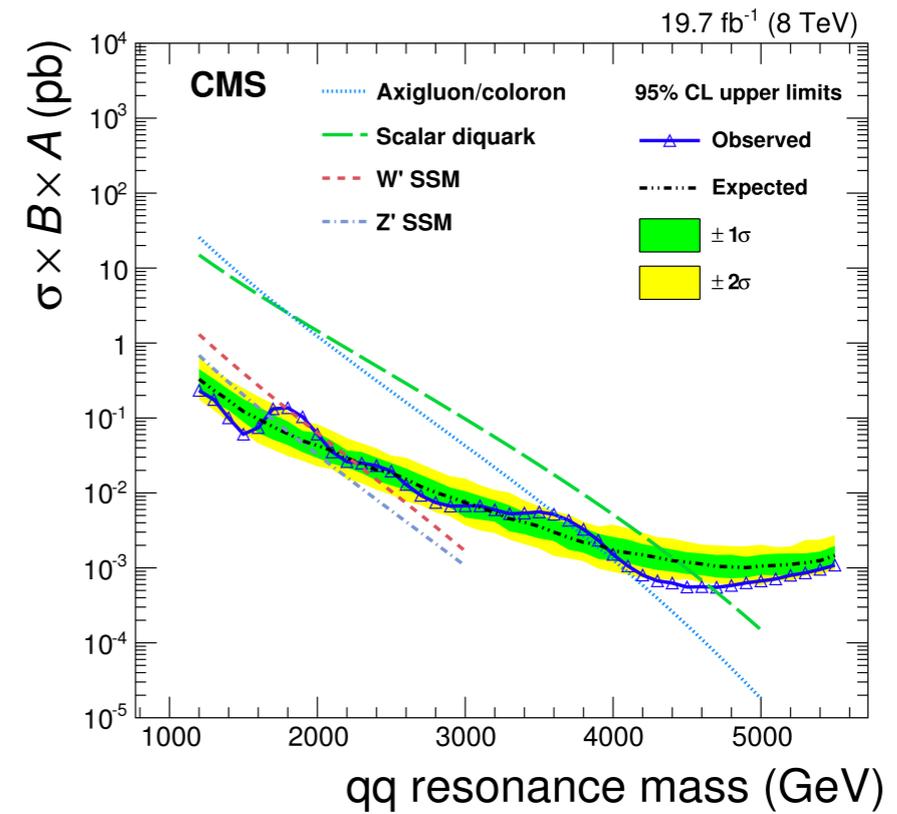
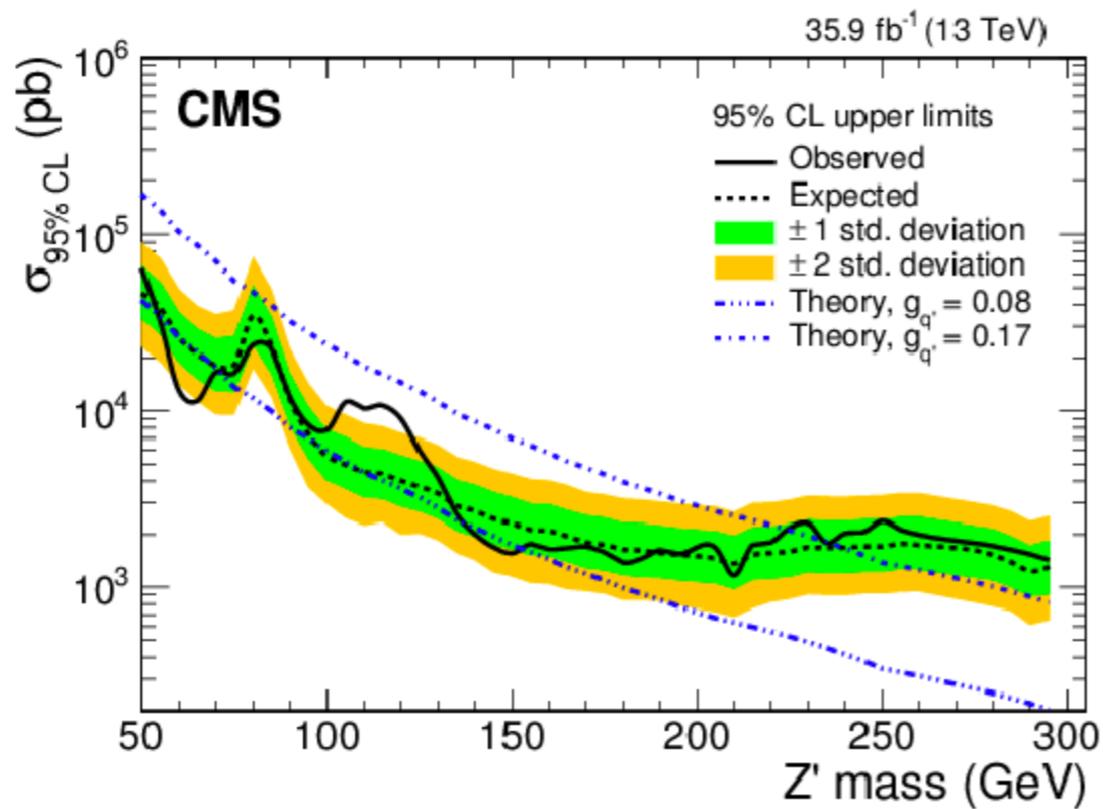


Comparison of DD and Collider



Remember these "DM" limits are limits on Z' from $SM \rightarrow Z' \rightarrow SM$ searches

Z' resonances



Possible Project idea

Global analysis of Z' mediated DM using
(g_{Vq} , g_{Aq} , $m_{Z'}$, g_{VD} , g_{AD} , m_X)

Alves et al arXiv:1501.03490, arXiv:1612.07282

Duerr et al arXiv:1606.07609

Fairbairn et al arXiv:1605.07940

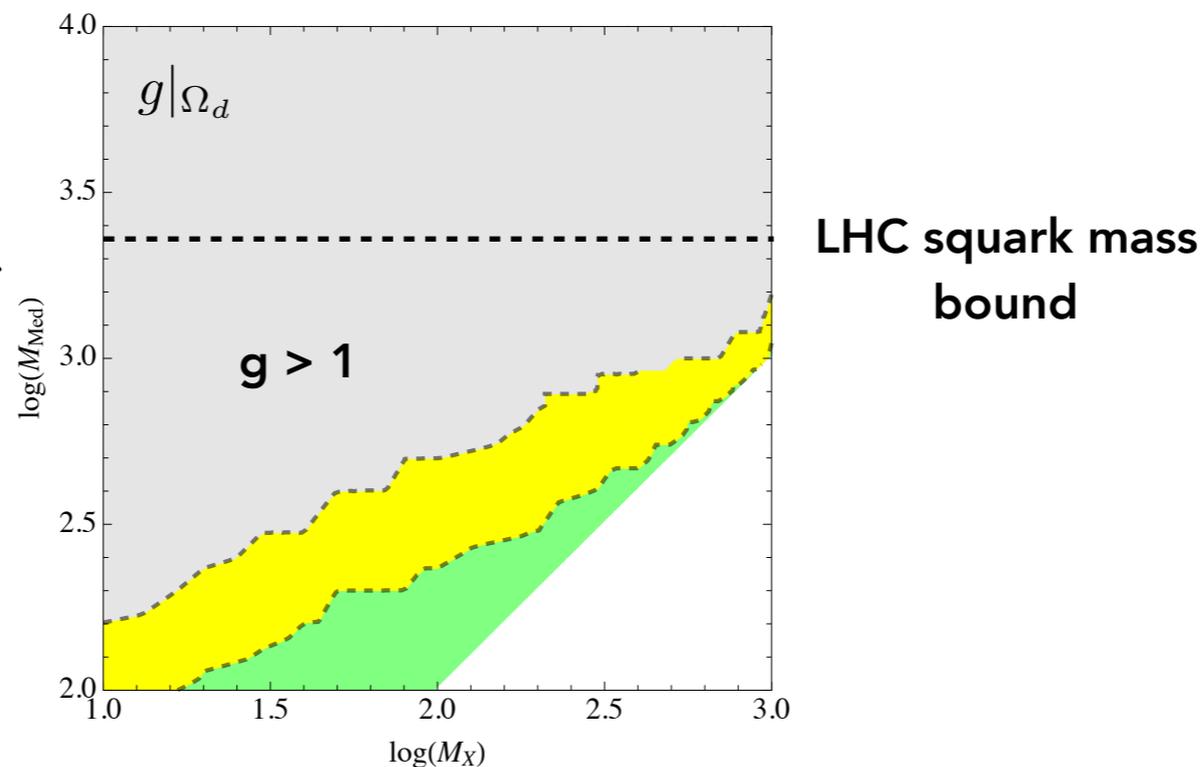
Other things: interference effects, width effects, precision measurement constraints

The trouble with easy simplified models for DM

They are too simple!

To produce mediators at LHC, you need to have large couplings to SM which means direct searches for the mediator are immediately very constraining!
(Driven by lamp-post thinking; not DM phenomenology)

Example: t-channel mediator



They are also hard to put into a self-consistent UV complete theory without having more particles that would affect other phenomenology significantly.

Possible Project idea

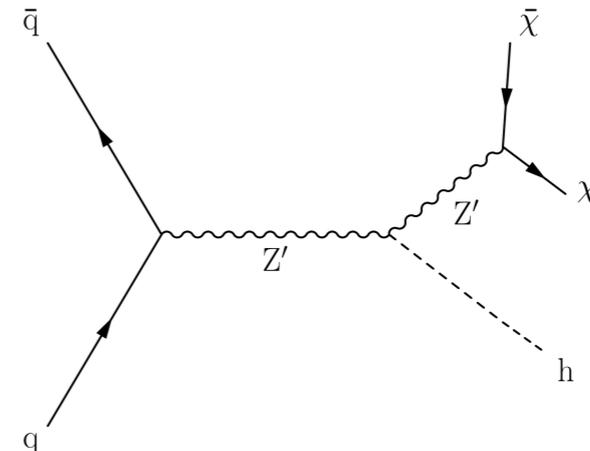
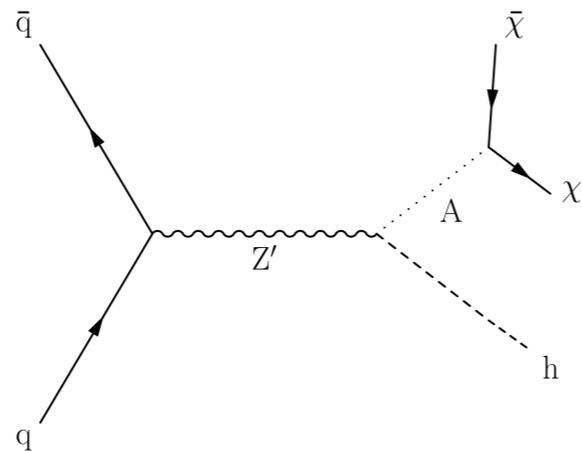
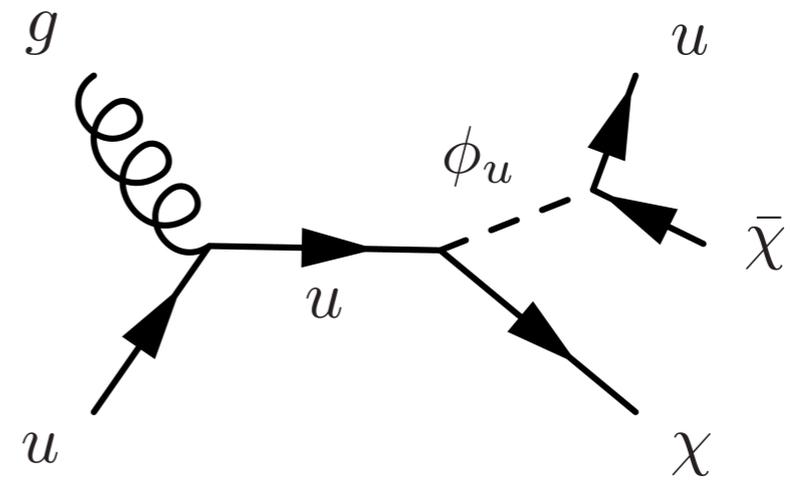
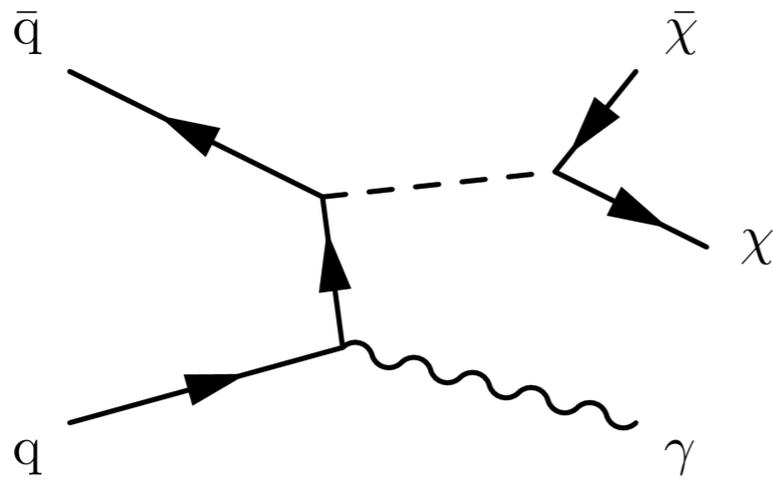
What is the parameter space that still allows t -channel mediators (that will give reasonable Ω)?

Co-annihilation* with completely free coupling

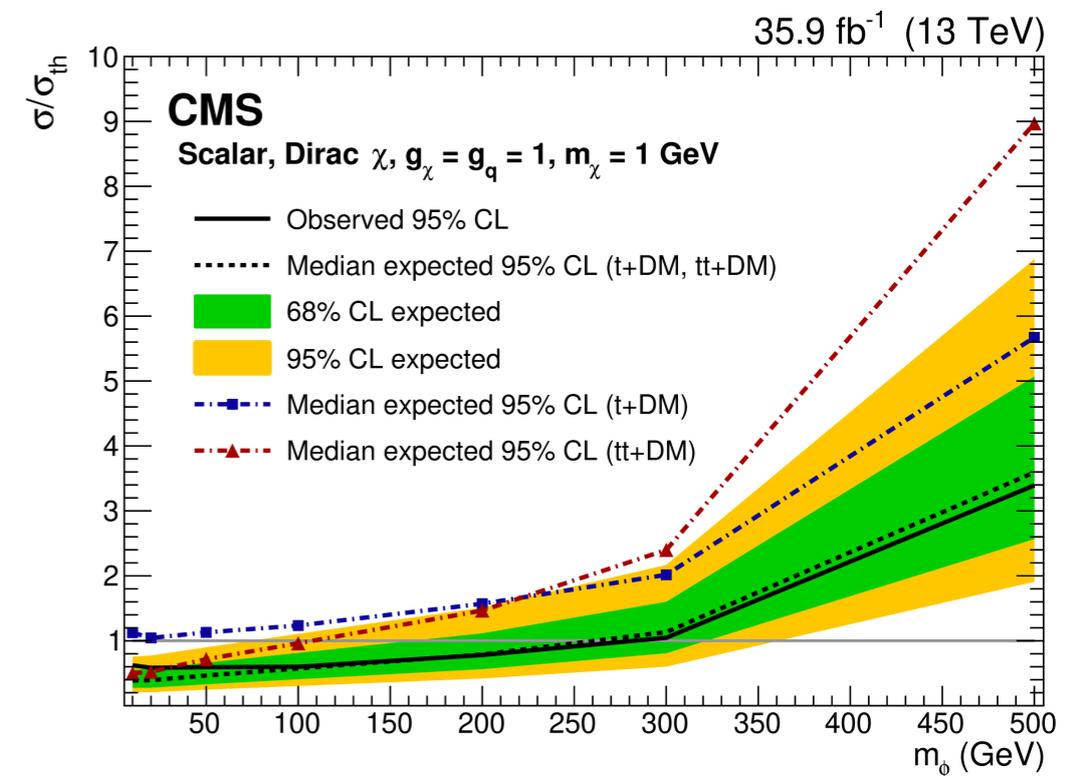
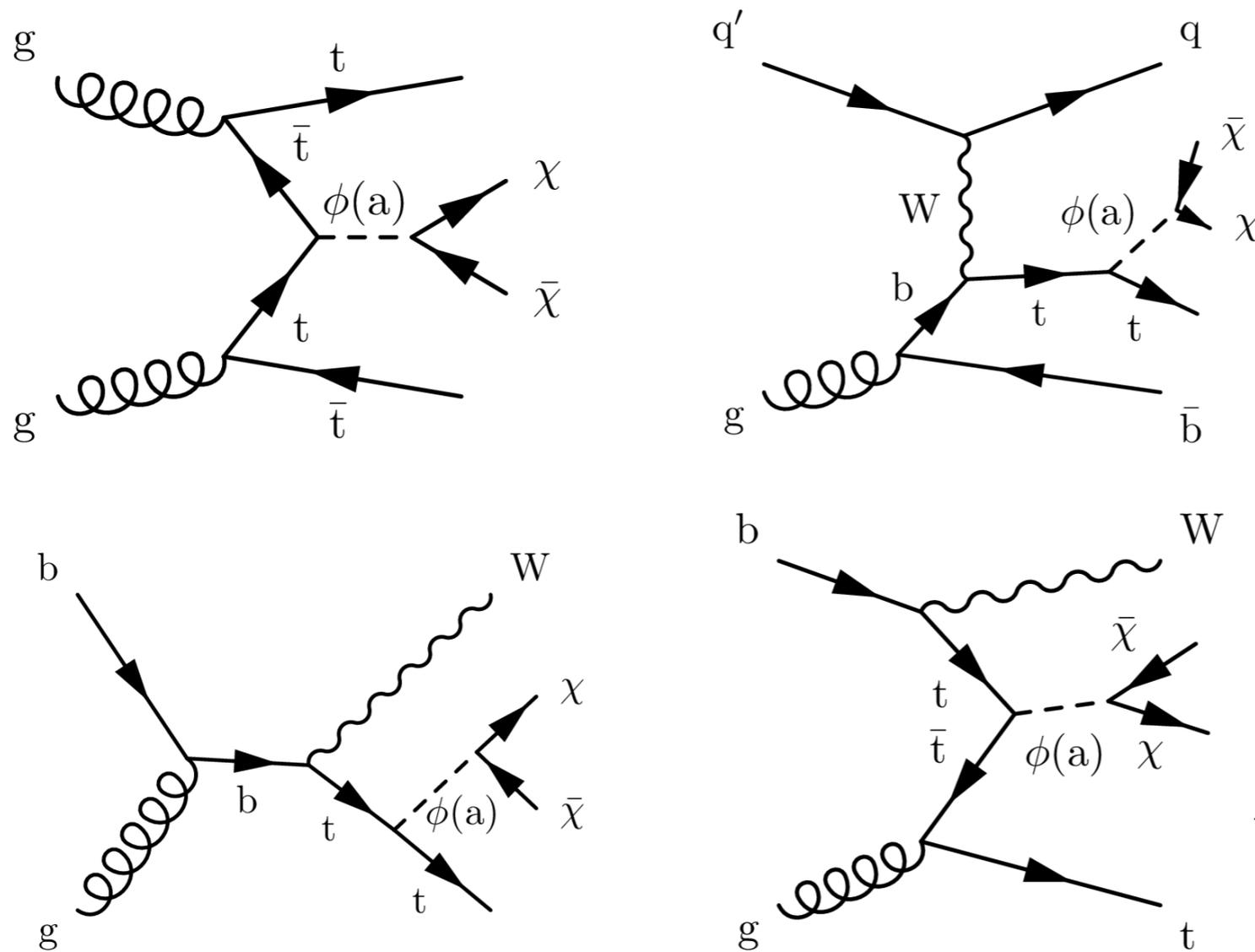
Go to 3rd gen?

Look at LLP signals?

Other simplified models (mono- X)



More associated final states



Other ideas

More complicated DM sectors

Singlet + N-plet / Multiparticle co-annihilation

(Subhadya Bhattacharya)

Neutrino mass-inspired models

(Tathagata Ghosh)

The story so far...

1. Start with EFT, not self-consistent, use “truncation” but this makes limits inconsequential.
2. Use simplified models, robust programme ongoing. Usually “too simple”. DM search is simply mediator search now. Good UV theories might predict better ways to constrain than simple searches.
3. Mono-X searches for “model independent” searches
4. Progress in cosmological understanding means more mass/coupling ranges: possible LLP signals
5. Growing community interest in ALP/dark photon models that may serve as a portal (need $\gamma\gamma$, ee , $\mu\mu$ spectrum beyond regions useful for higgses).

Future of DM searches at Colliders

- Obvious: Higher mass mediators
 - Need better collider ("Energy frontier")
 - Still well-motivated for pure Higgsino ~ 1.2 TeV
- Compressed spectra (also not new)
 - Use high luminosity for ISR jet tagging ("Intensity frontier")
- Long-lived mediators ("Lifetime frontier")
 - Many ongoing searches. Soft+LL is difficult because of triggering
 - MATHUSLA, SHiP, ...

Future of DM searches at Colliders

○ Low mass mediators

- Hard to do @ LHC due to *HUGE* QCD background, some progress based on “tricking” the triggers)
- Possibility to look at heavy meson decays for some mass ranges
- Possibility to look at associated production (with $W/b\text{-}b\bar{b}/t\bar{t}$?) where BG suppression using tagging — no “scouting” needed?

*Possible discussion/project: using exclusive single high- p_T electron/muon, what is the sensitivity that can be reached?
Can you use muons, or is it forbidden because of cosmic?*