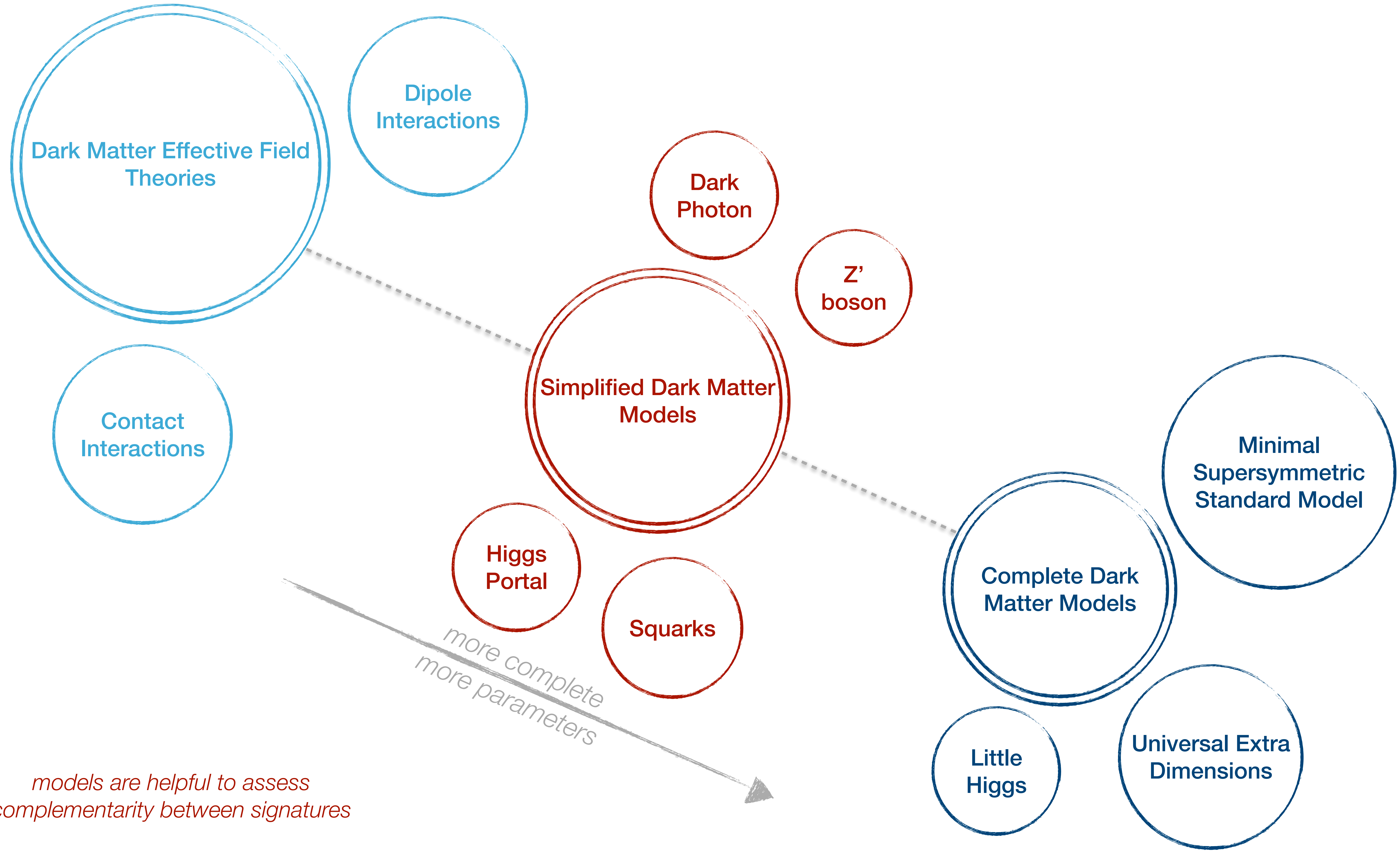
Istituto Nazionale di Fisica Nucleare
Sezione di Roma

ATLAS & CMS LEGACY S-CHANNEL RESULTS

M. Bauce

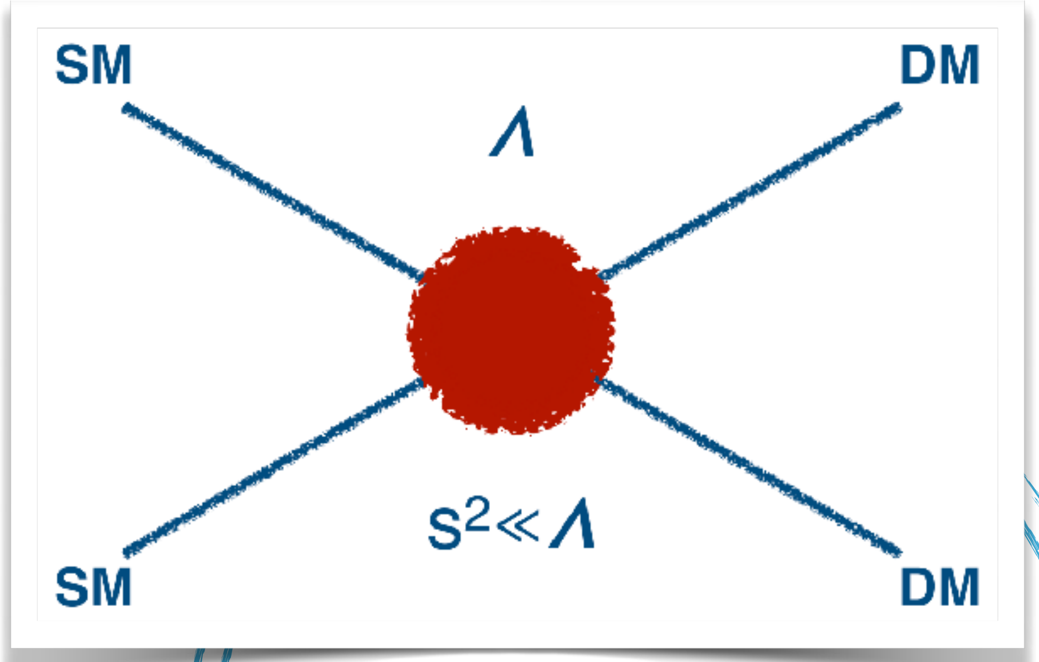
Roadmap to DM Models for Run 3, May 13-17 2024

DARK MATTER BENCHMARK MODELS

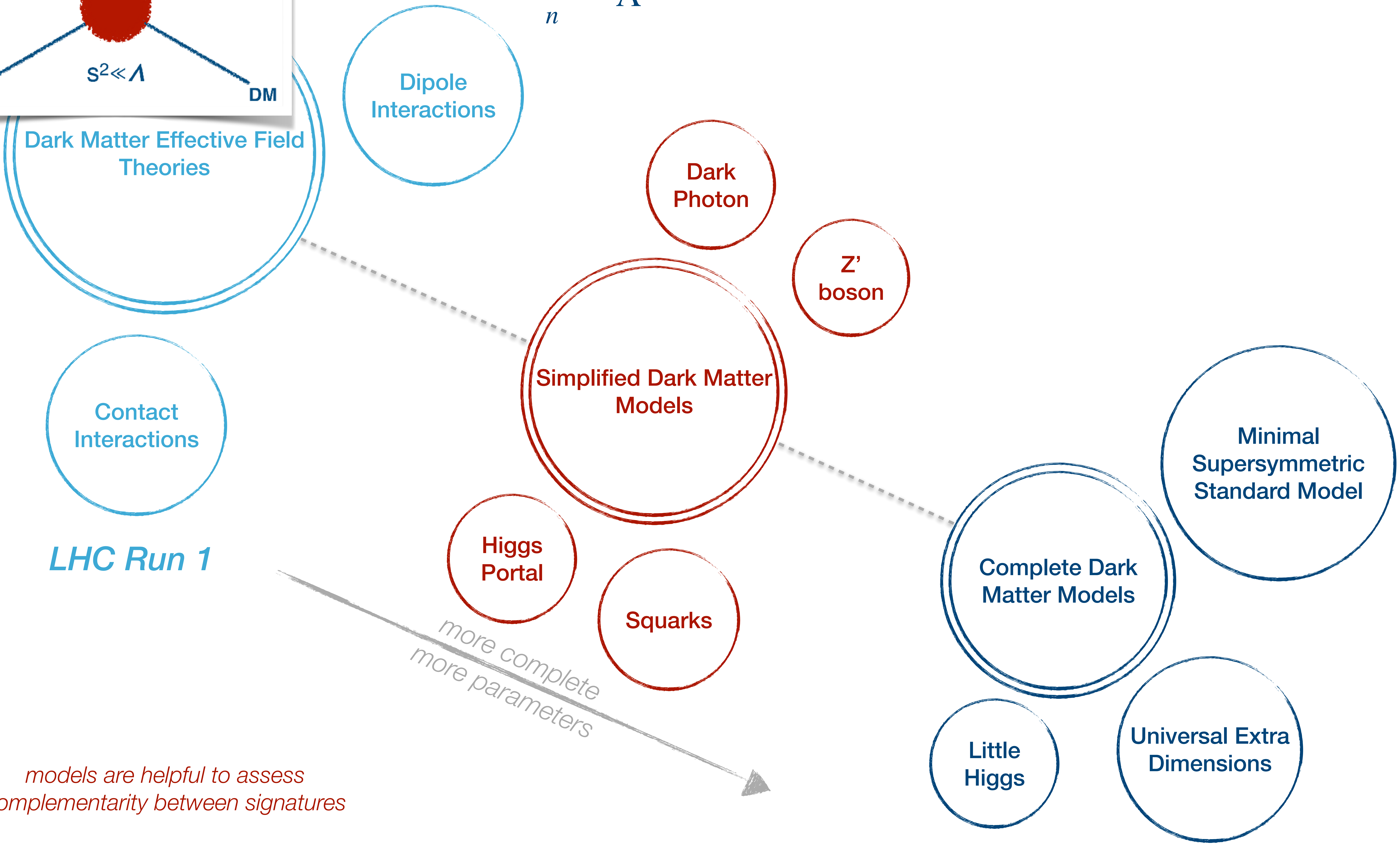


models are helpful to assess complementarity between signatures

DARK MATTER BENCHMARK MODELS

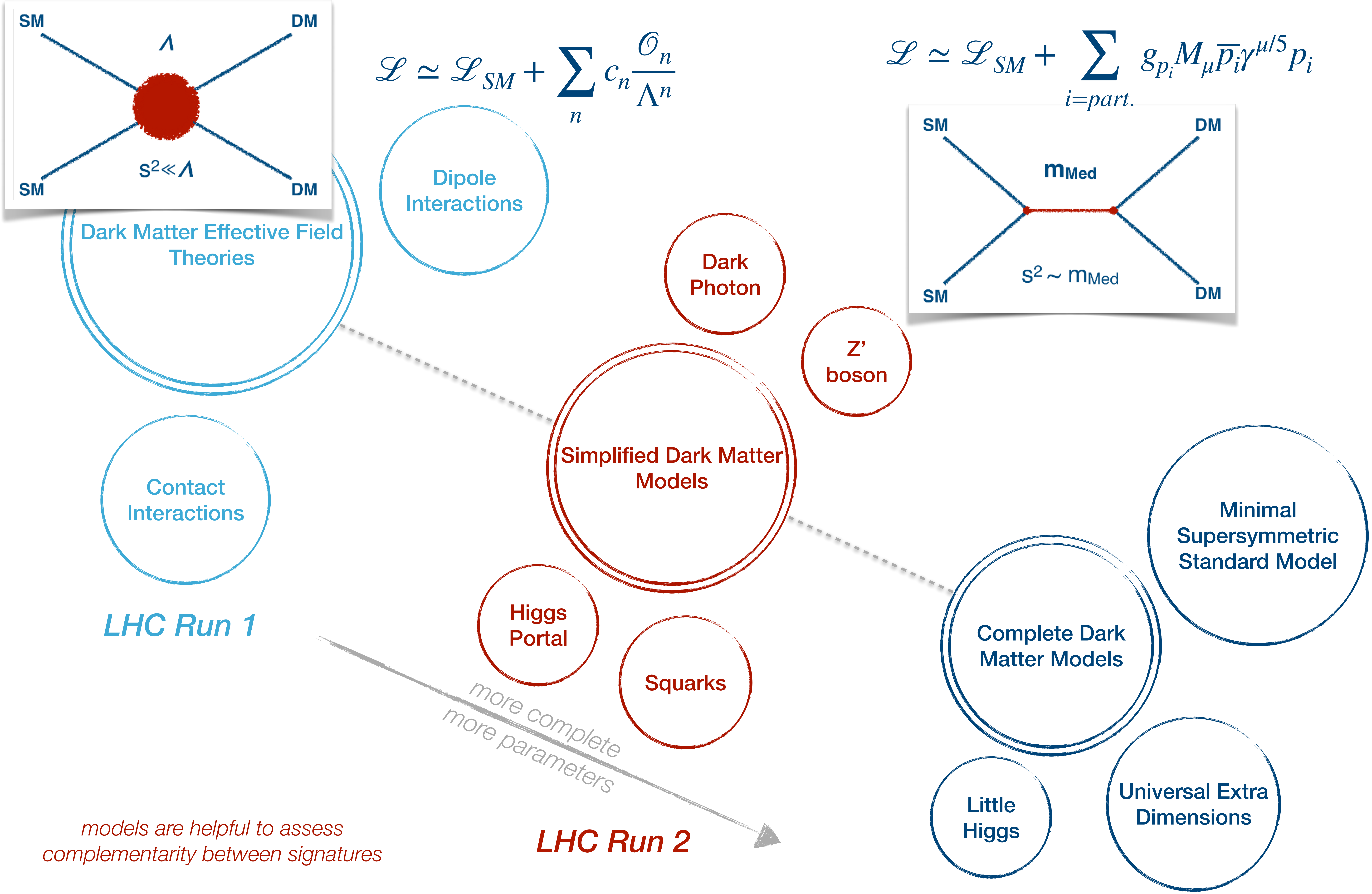


$$\mathscr{L} \simeq \mathscr{L}_{SM} + \sum_n c_n \frac{\mathcal{O}_n}{\Lambda^n}$$



models are helpful to assess complementarity between signatures

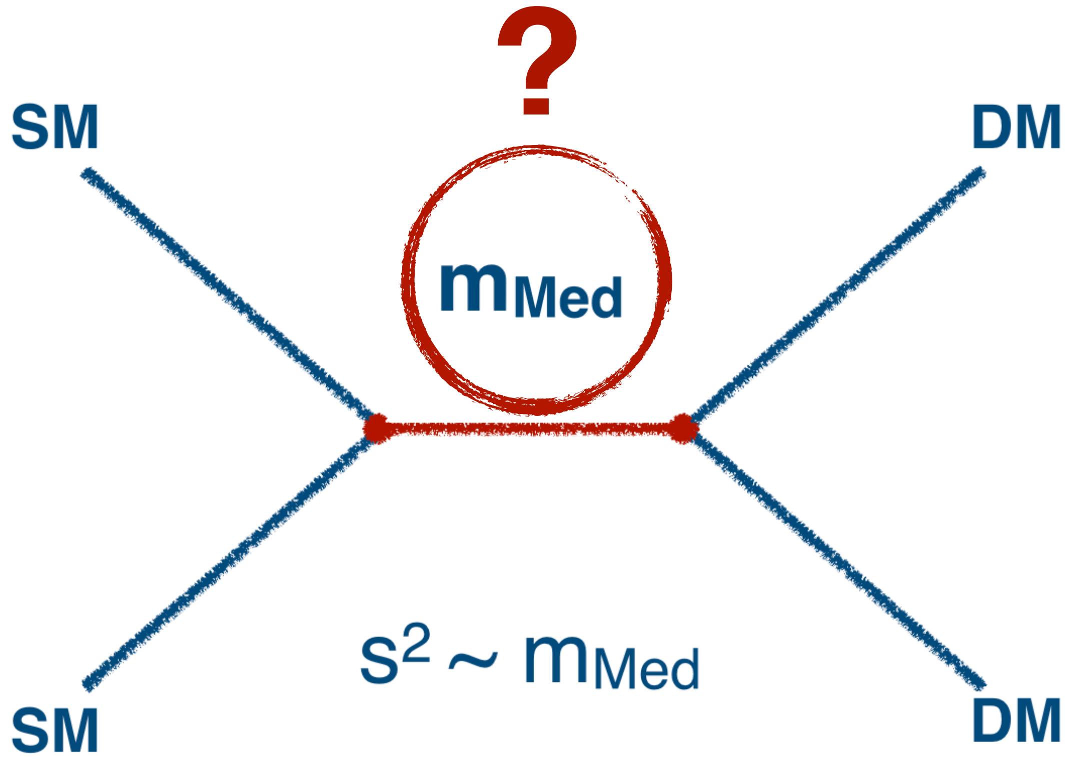
DARK MATTER BENCHMARK MODELS



models are helpful to assess complementarity between signatures

DARK MATTER SIMPLIFIED MODELS

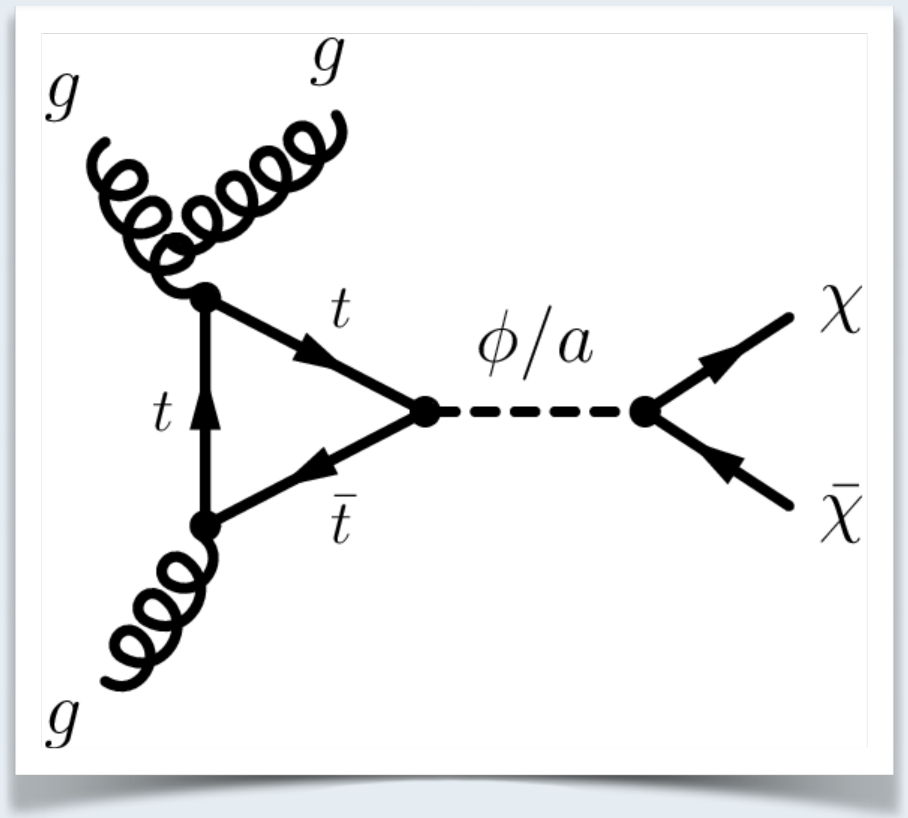
- Among DM-related models, these are the simplest SM extension
- Foreseen the existence of a single mediator and a DM particle χ
- The mediator connects SM and DM particles - different decays allowed, different signatures
- *'s-channel'* refers to a specific mediator decay to DM candidate
- These models are non-renormalizable, though useful for the limited number of parameters
- More complex models can produce similar signatures to the simplified ones for specific parameter choices

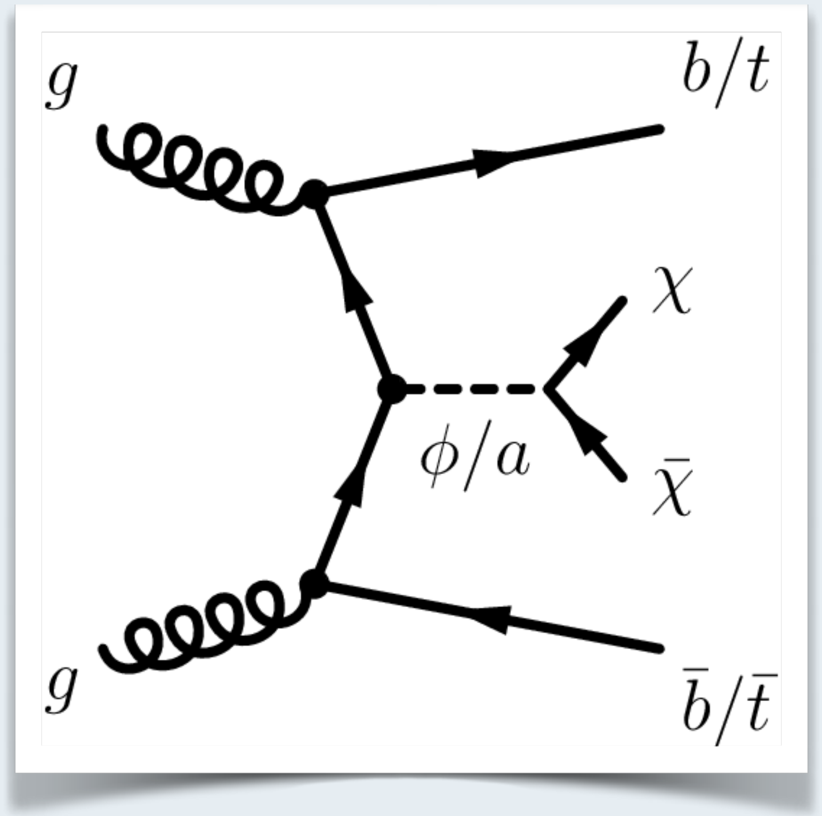


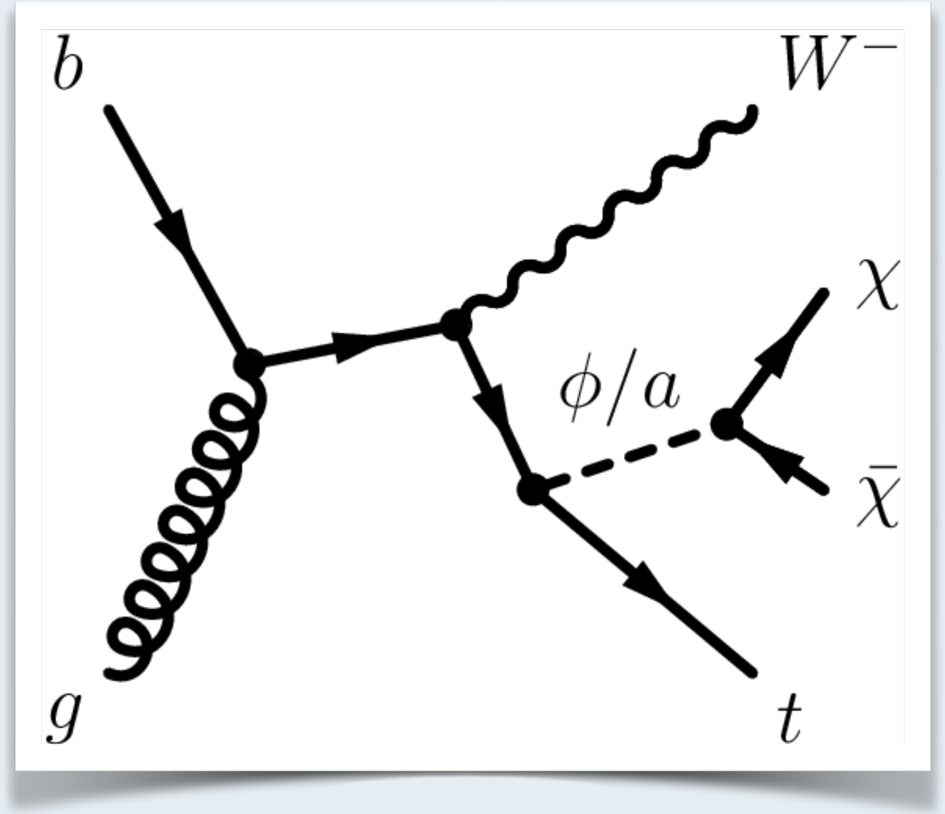
WHICH KIND OF MEDIATOR?

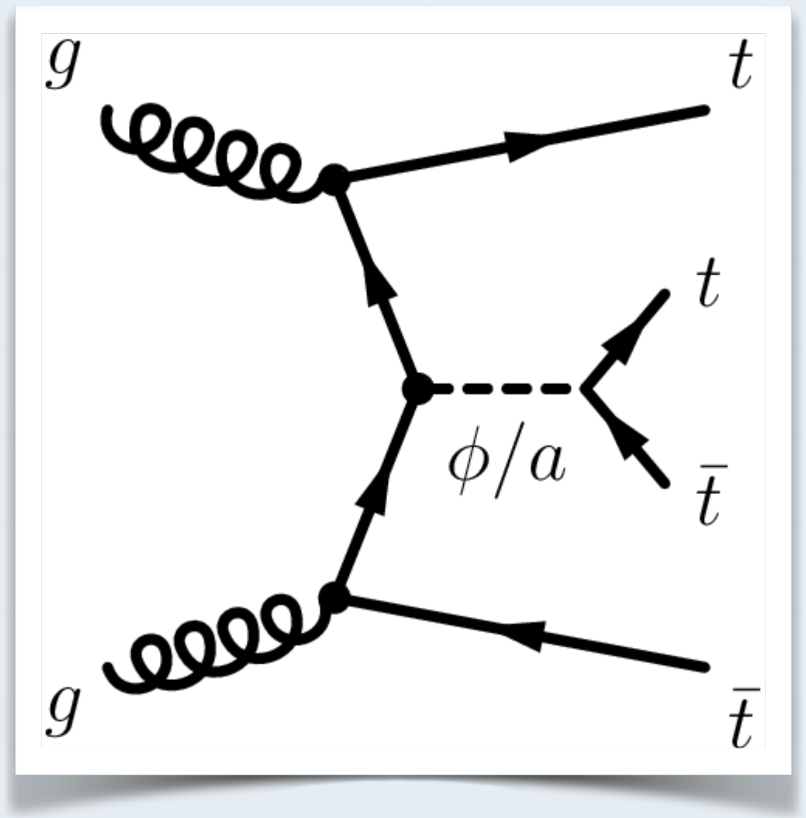
Option 1: Spin-0 mediator
Scalar/Pseudoscalar

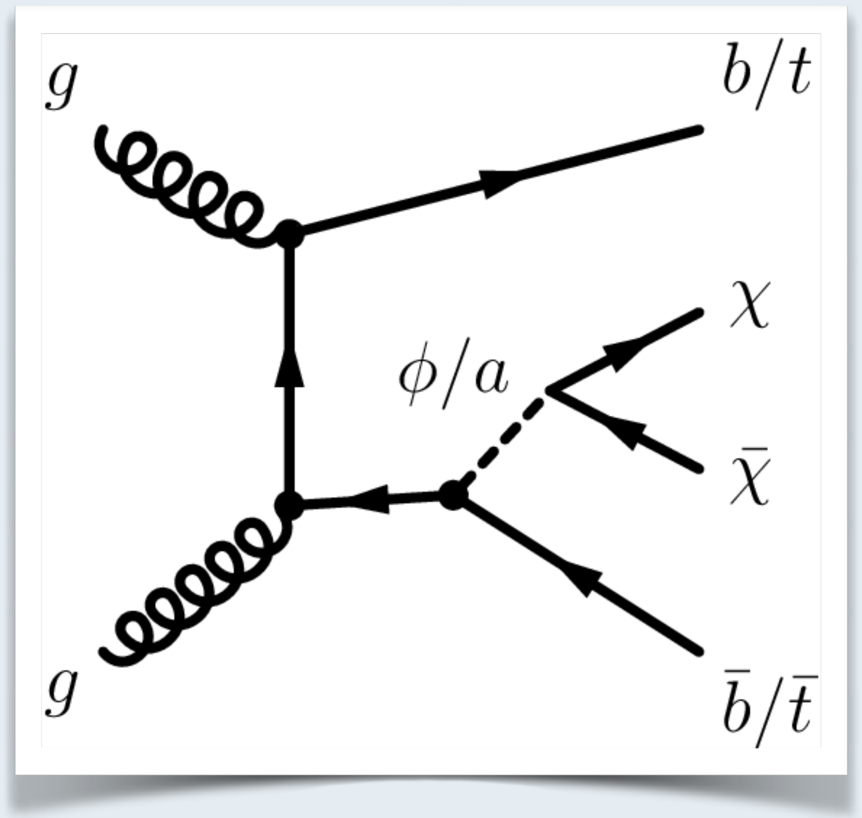
Yukawa-like couplings







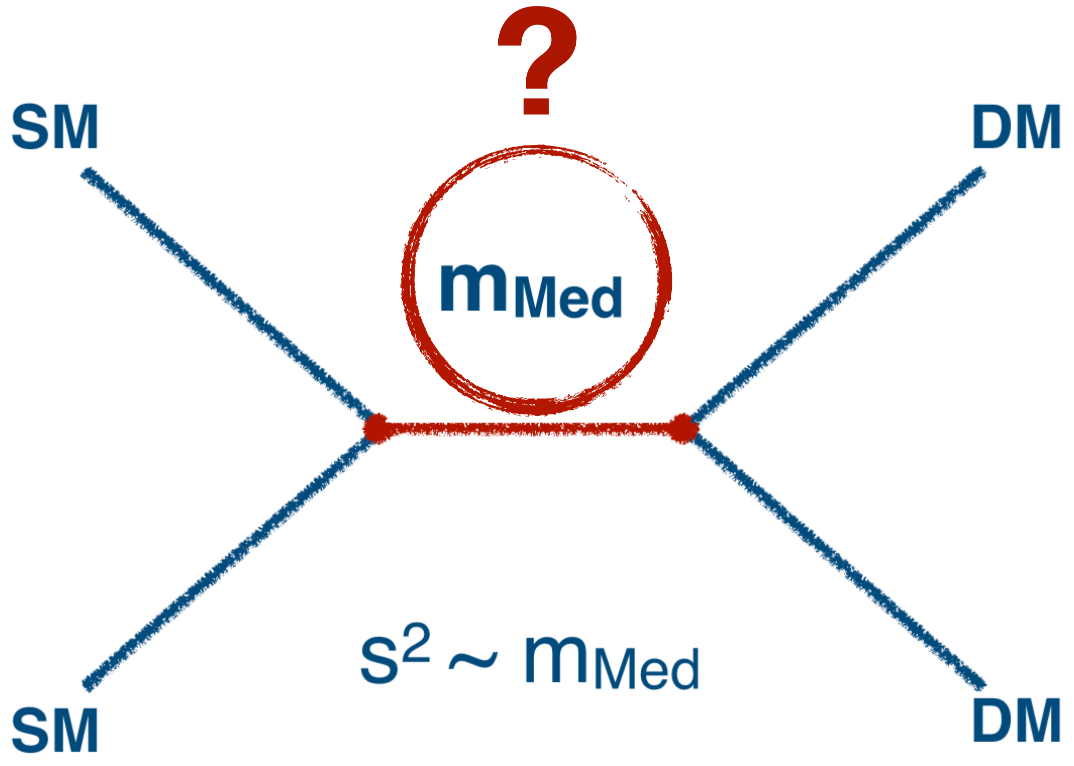




Free parameters: $g=g_u=g_d=g_l$, g_{DM}, m_{Med}, m_{DM}

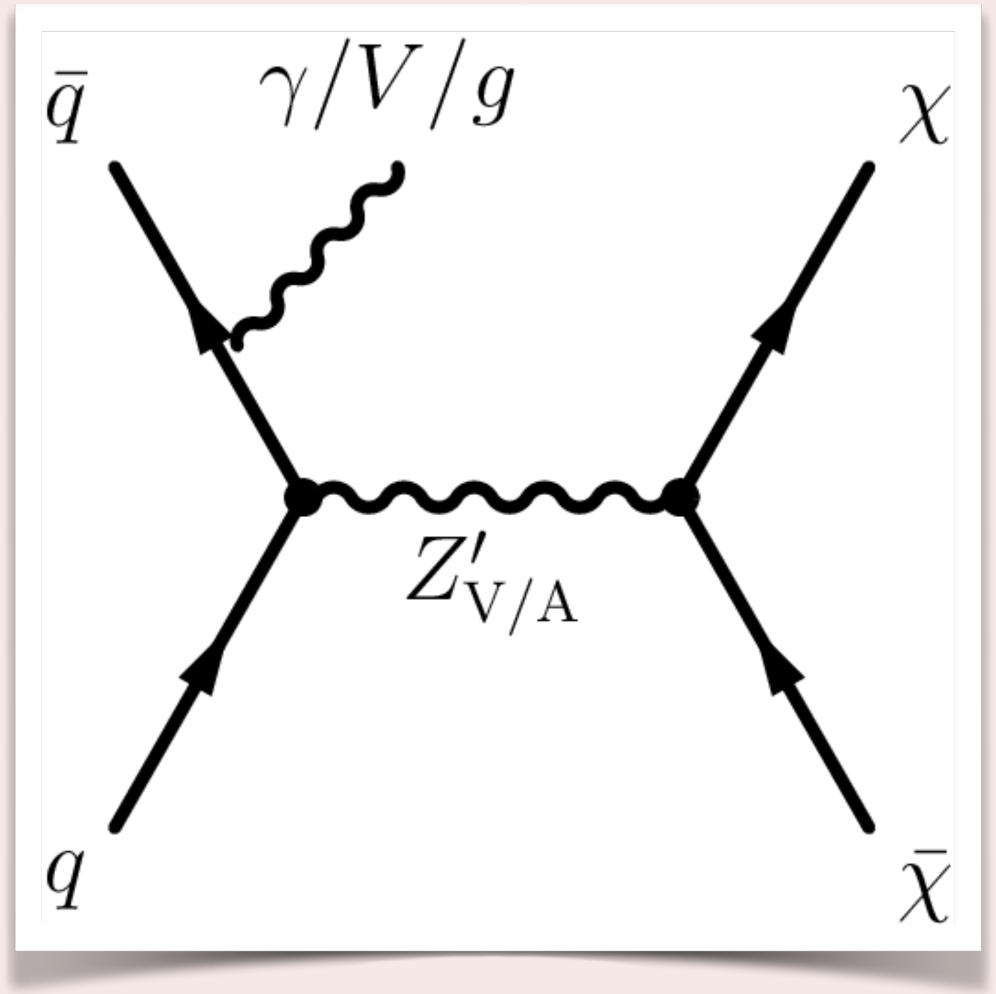
g is combined with corresponding Yukawa factor to determine mediator's coupling to each particle

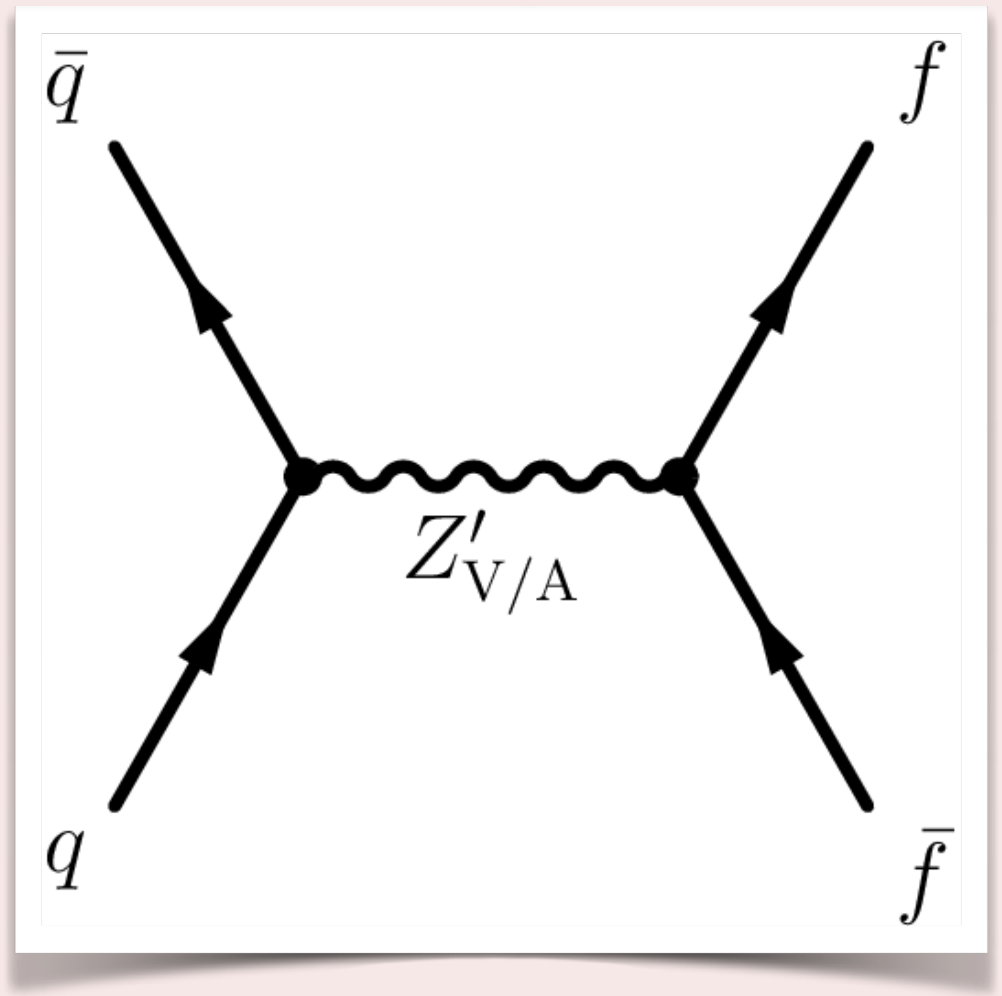
WHICH KIND OF MEDIATOR?



Option 2: Spin-1 mediator
Vector/Axial-Vector

γ^μ / γ^5 couplings





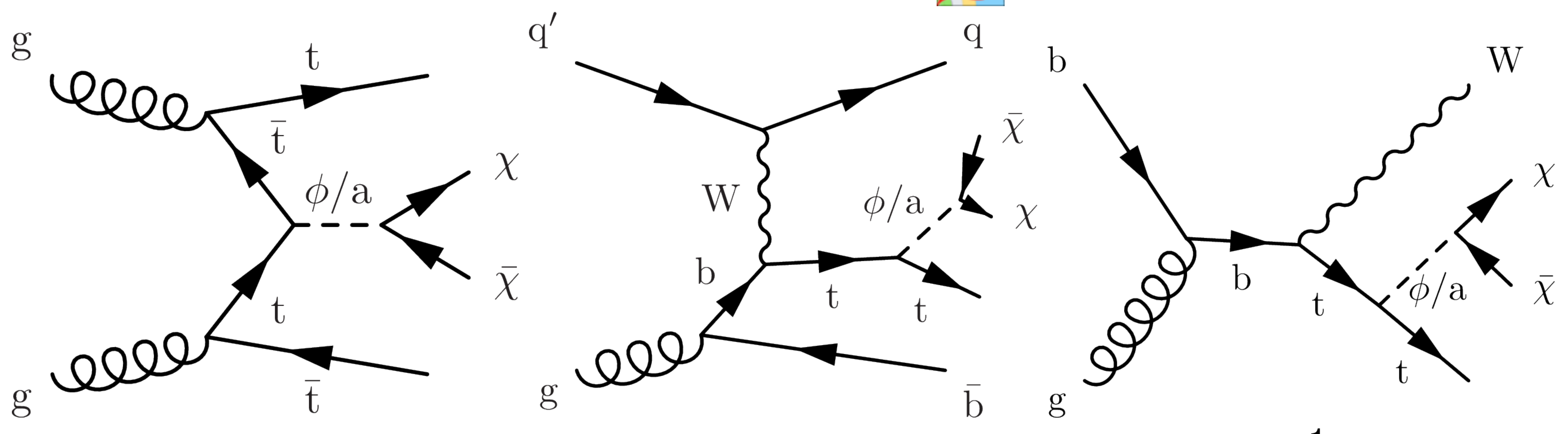
$$\mathscr{L} \simeq \mathscr{L}_{SM} + \sum_{i=part.} g_{p_i} M_\mu \overline{p}_i \gamma^{\mu/5} p_i$$

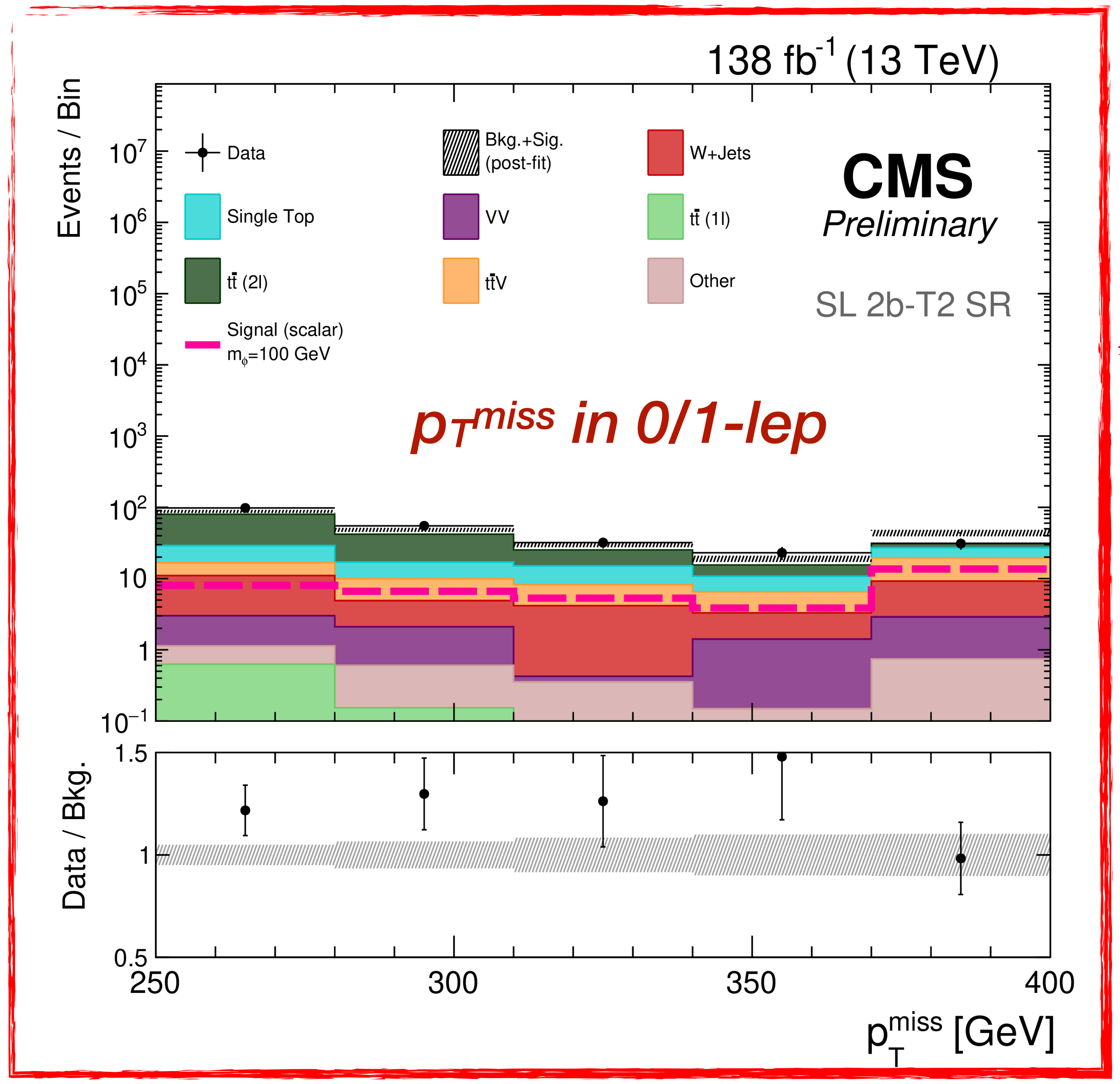
Free parameters: g_q, g_l, g_{DM}, m_{Med}, m_{DM}

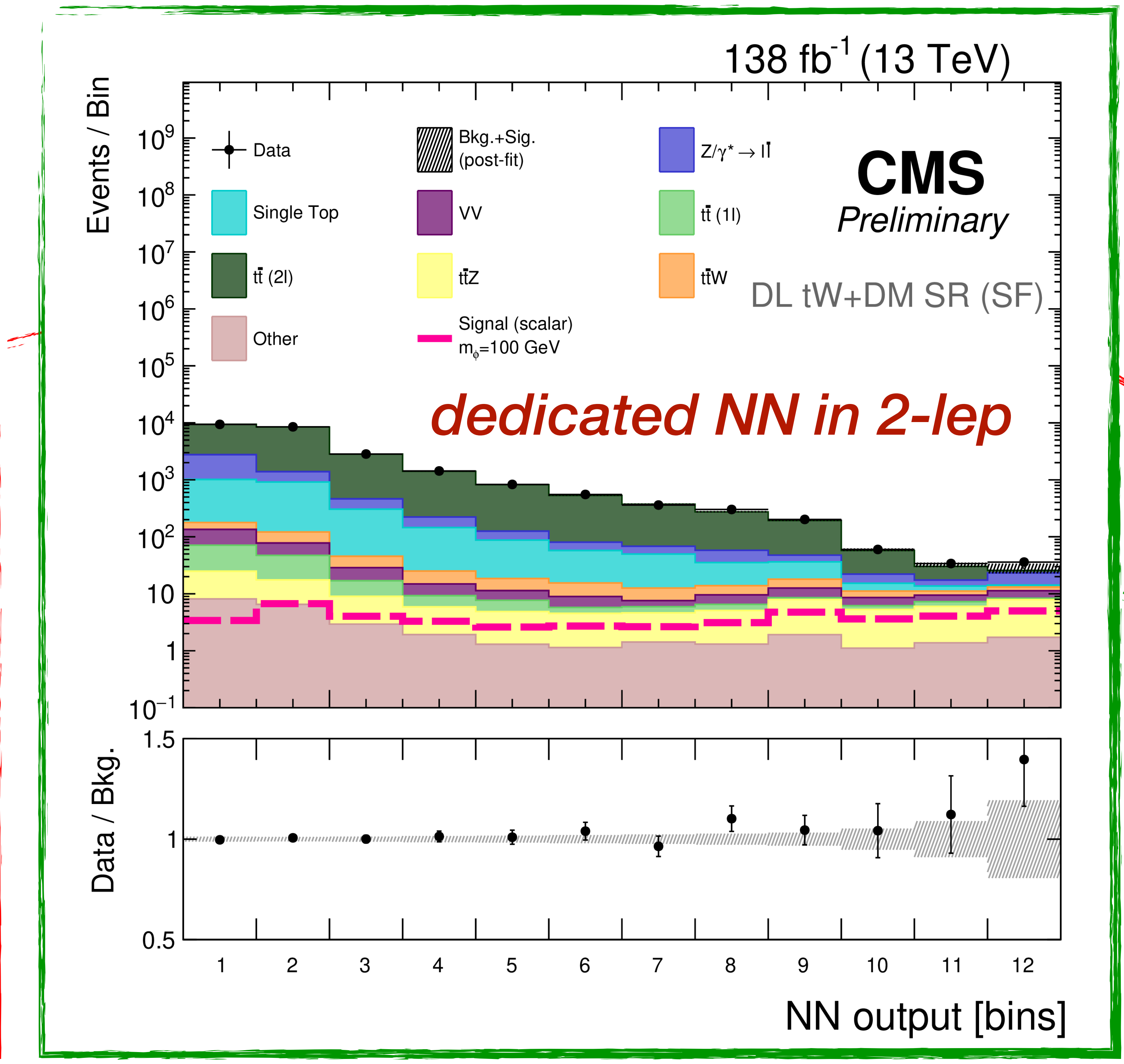
[CMS-PAS-EXO-22-014]

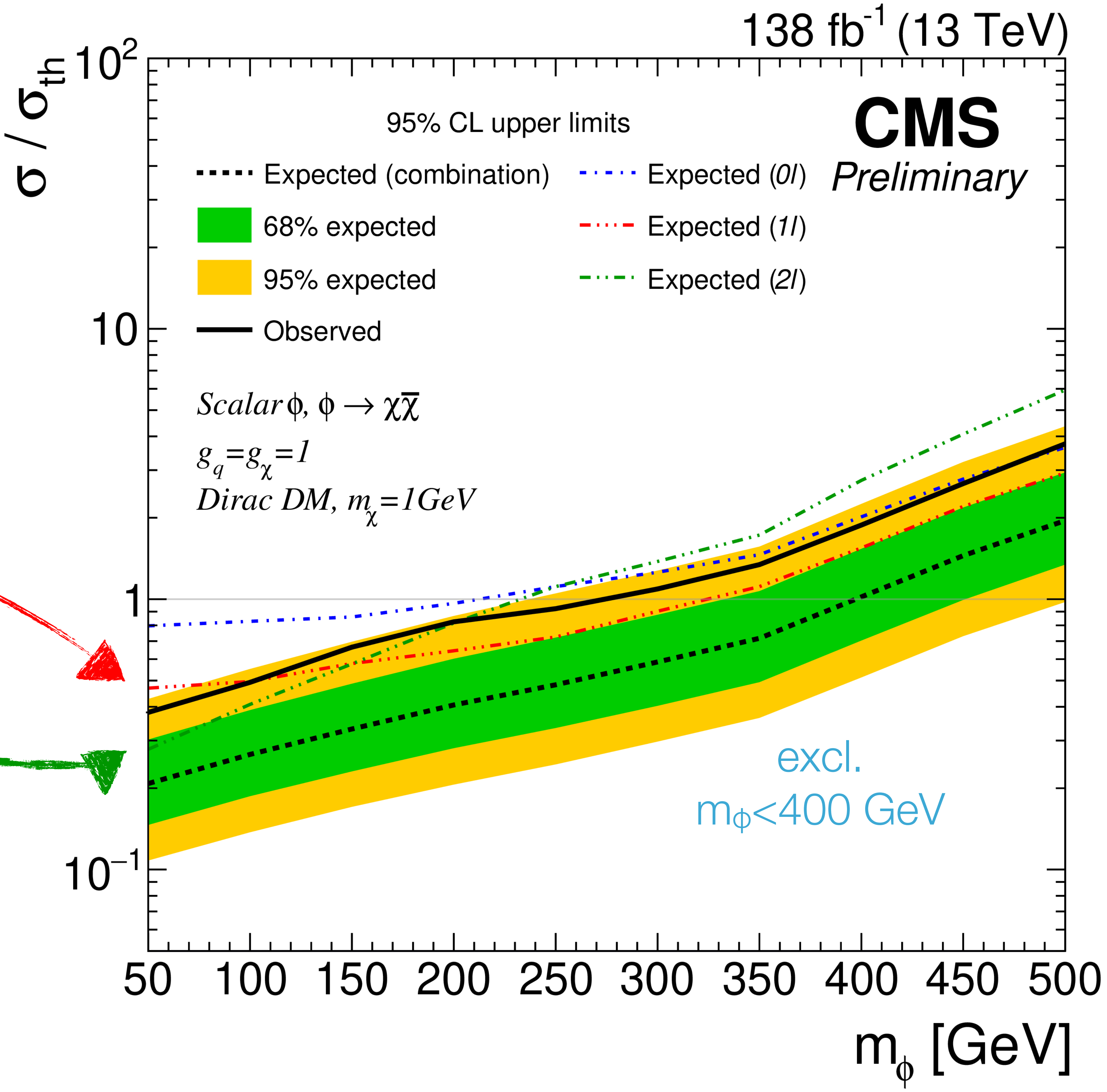
T+DM AND TT+DM SEARCH

- Categorise events based on final state signature:
  - top decays (0lep,1lep,2lep)
  - b-tagged jets (1,2)
  - forward jets (0,1)









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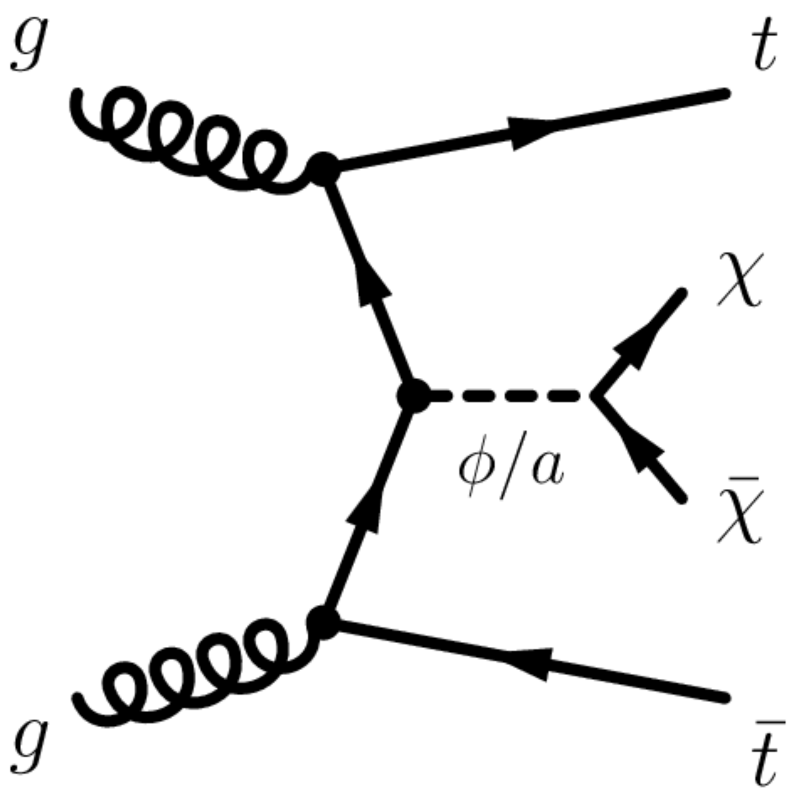
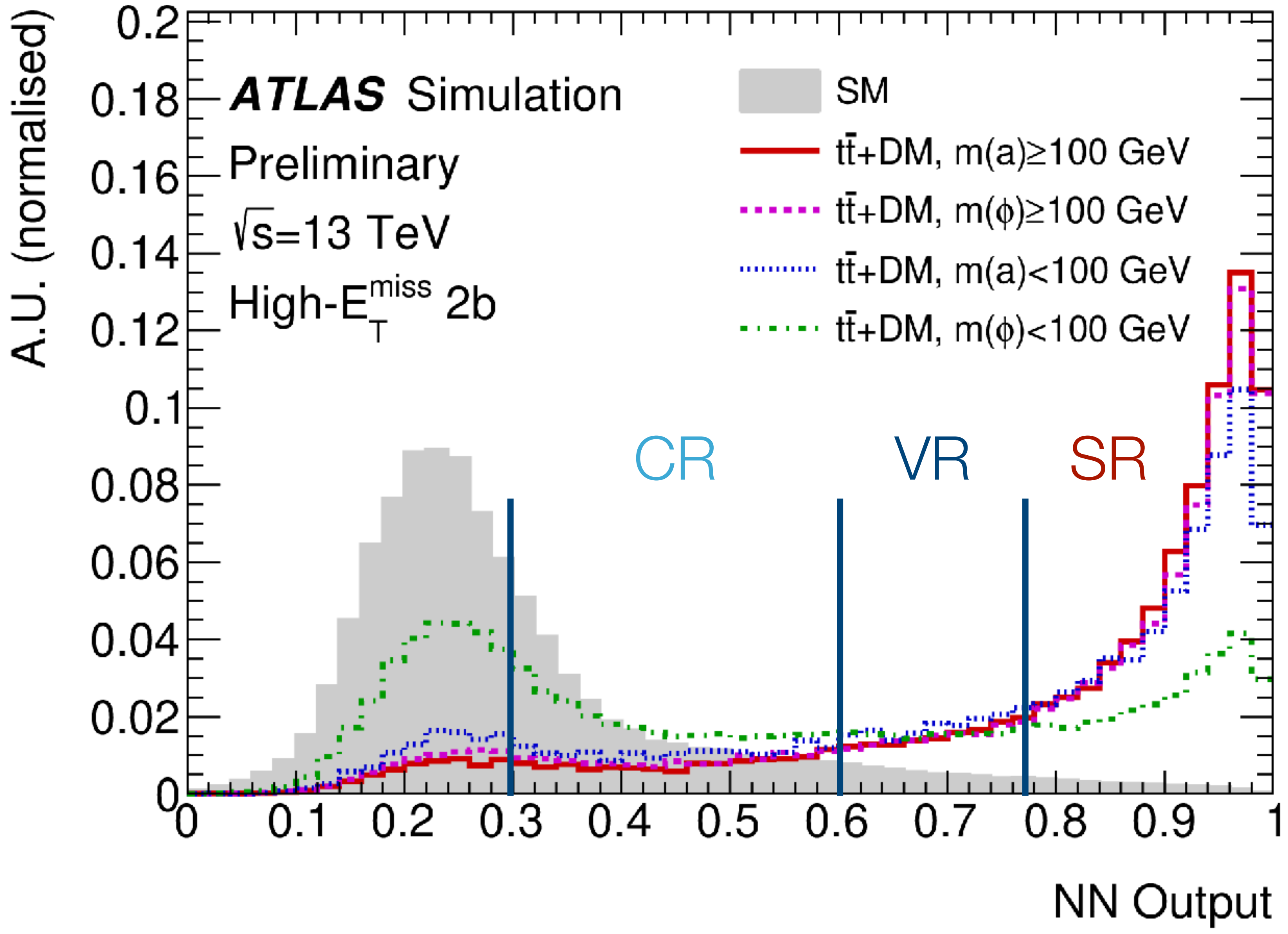
TT+ DARK MATTER SEARCH

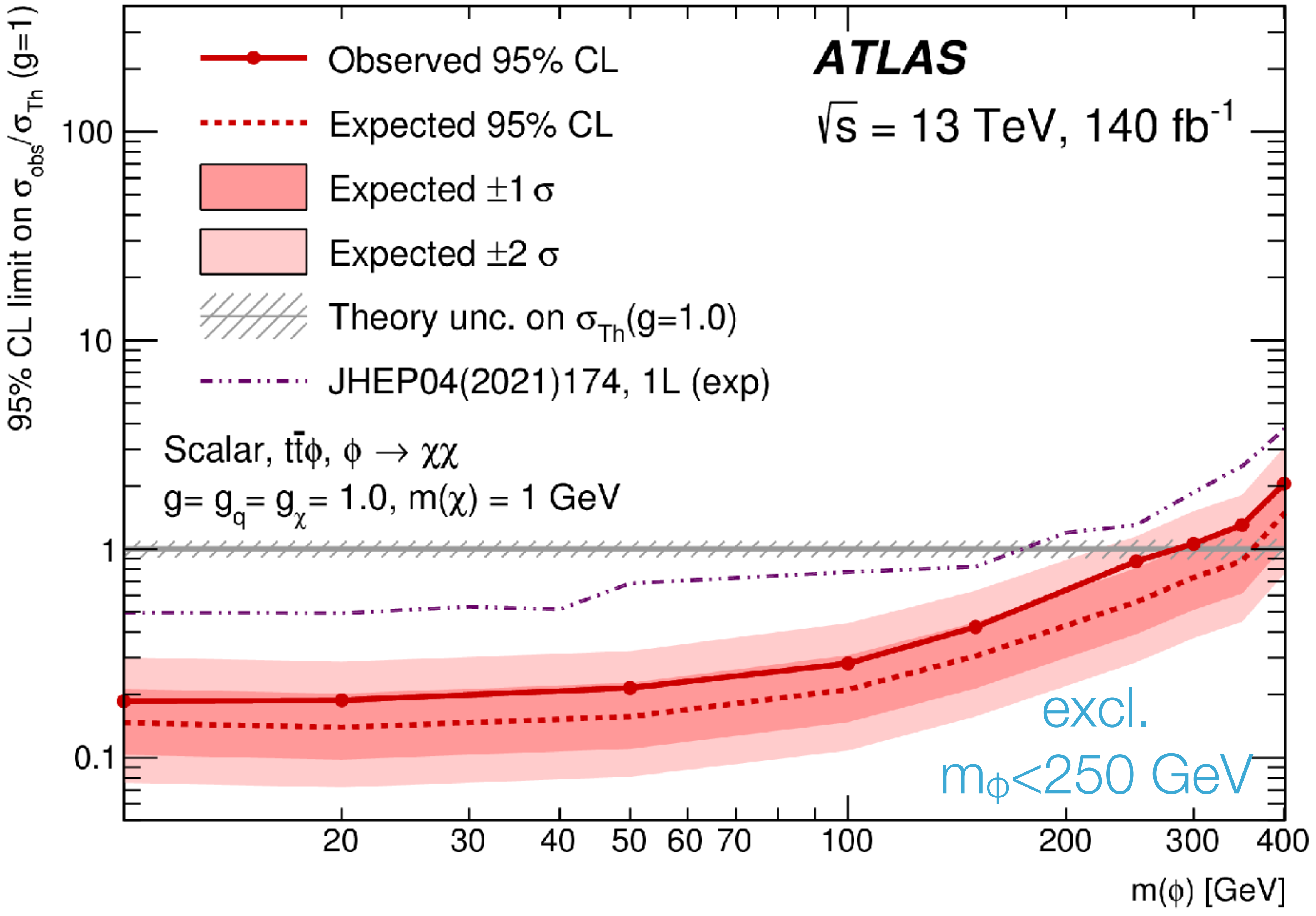


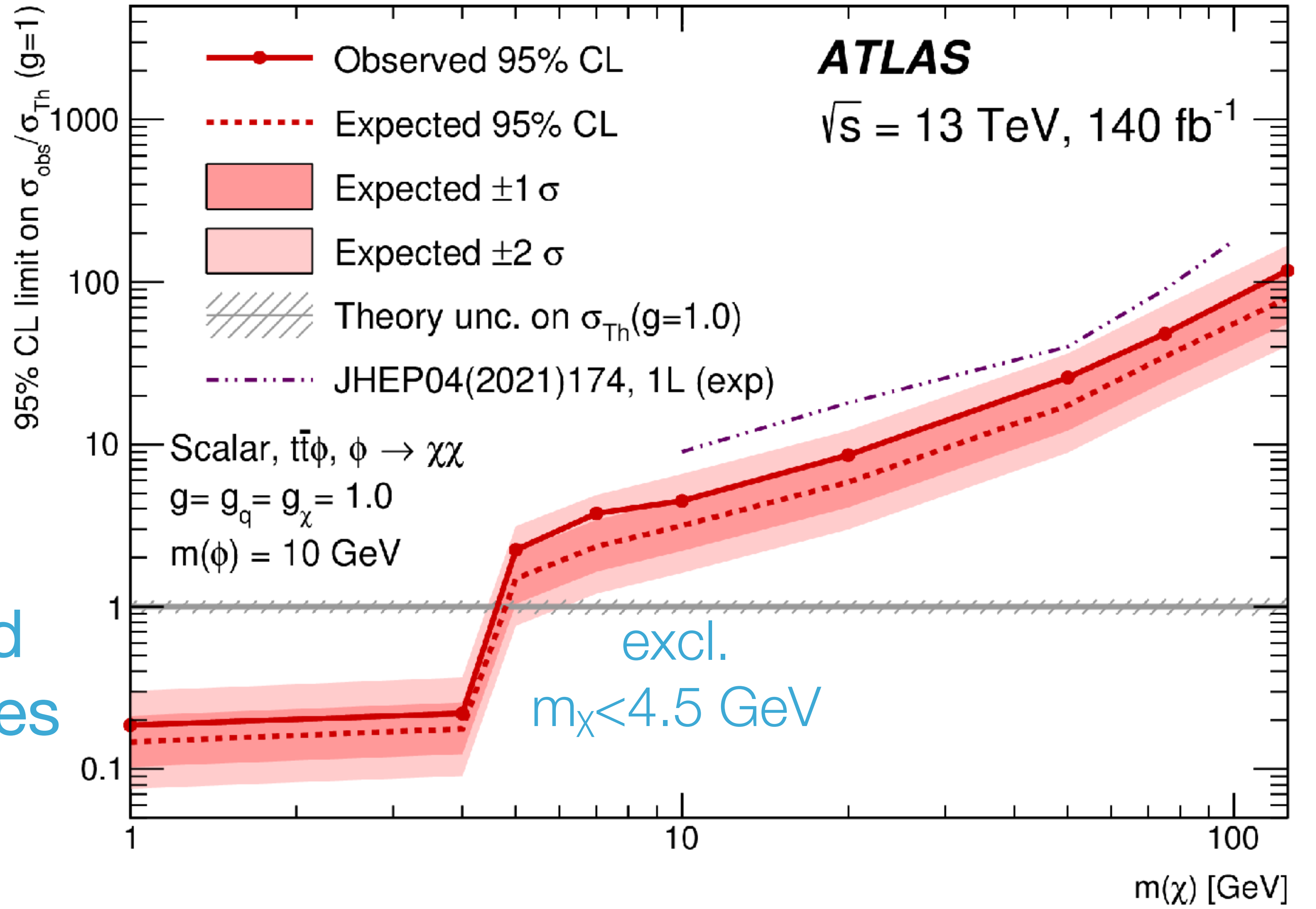
$E_T^{miss} > 230\ GeV$
1 lepton
1, ≥2 b-jets
≥2, ≥1 jets
top-tagged jet multiplet

NN exploited for signal events separation



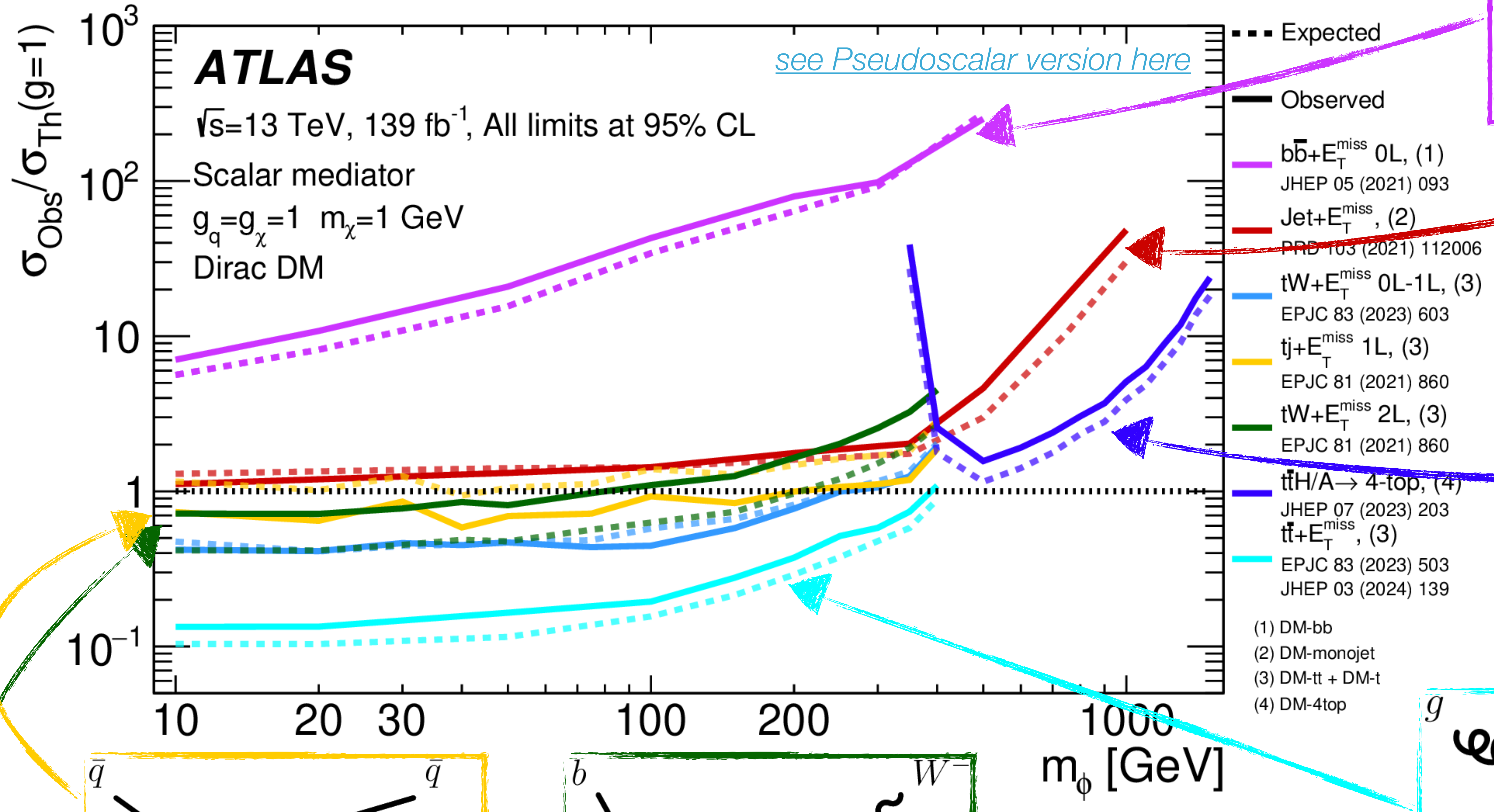
1-lep channel combined with other ttbar final states

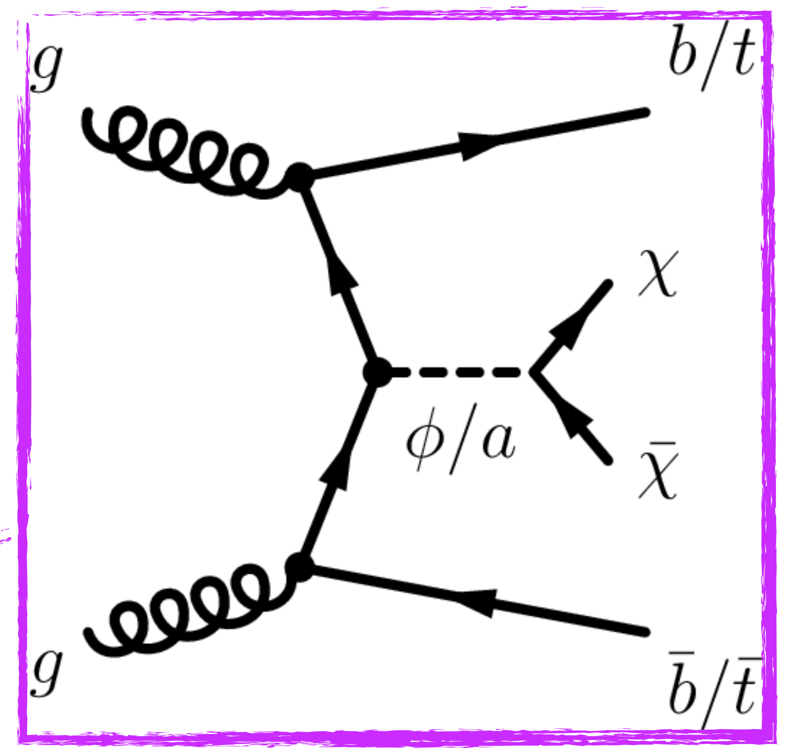


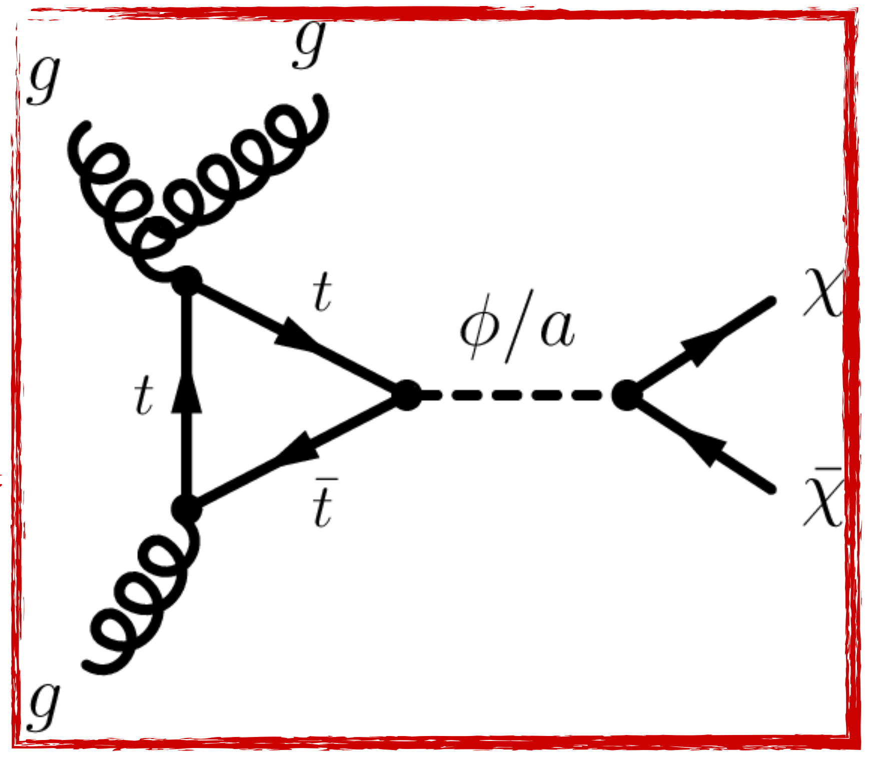


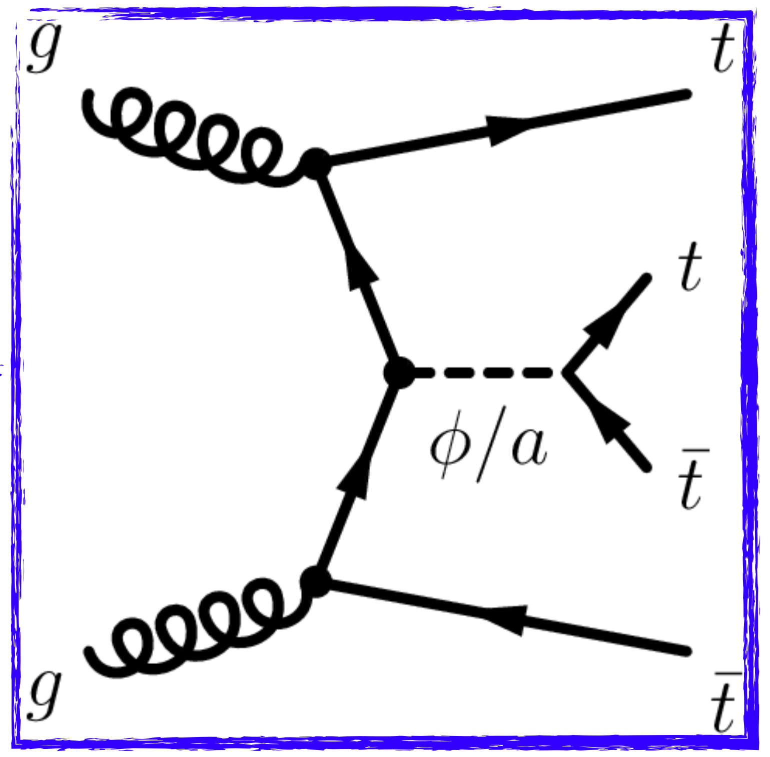
EXOT-2018-62

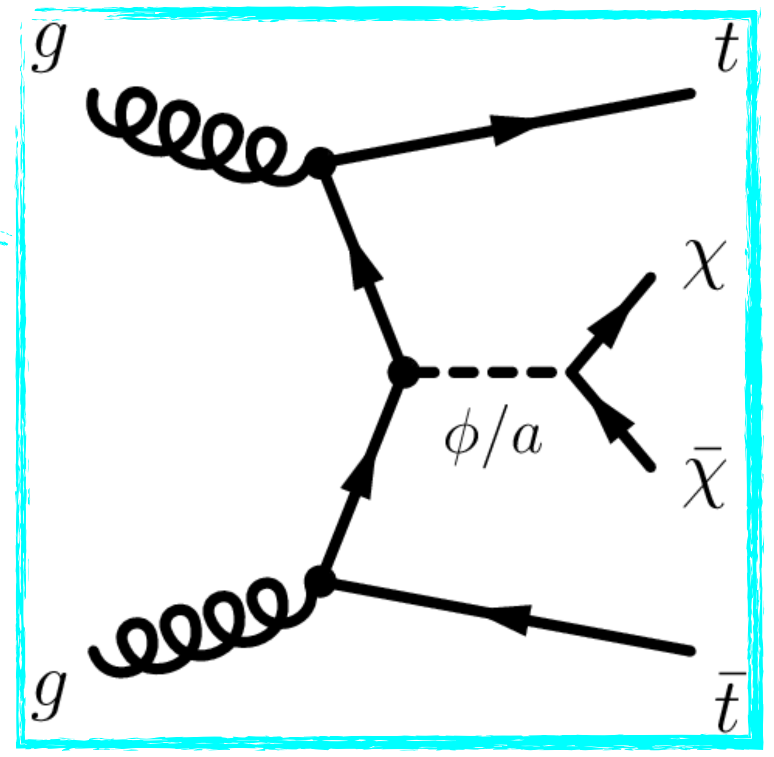
CONSTRAINTS ON SCALAR MEDIATOR

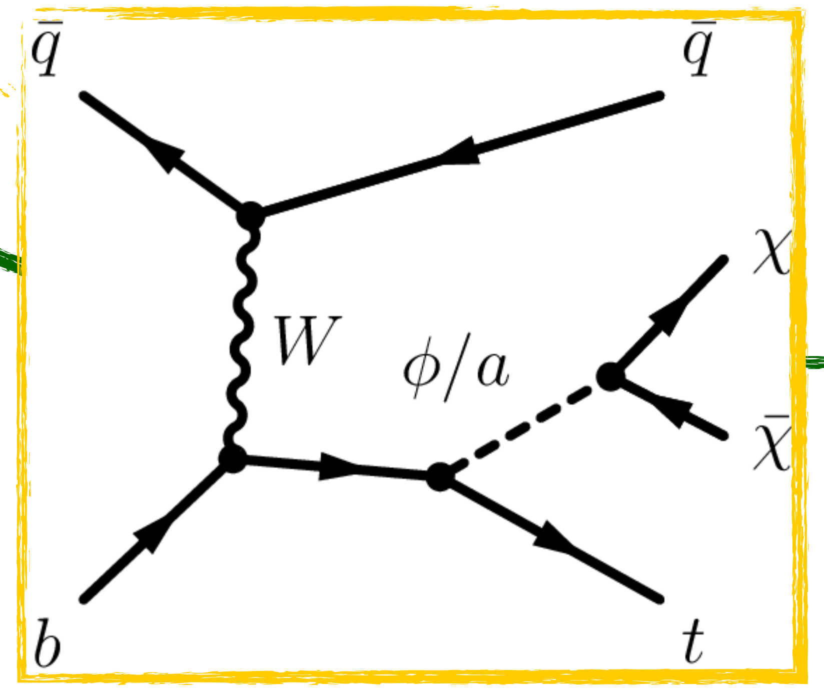


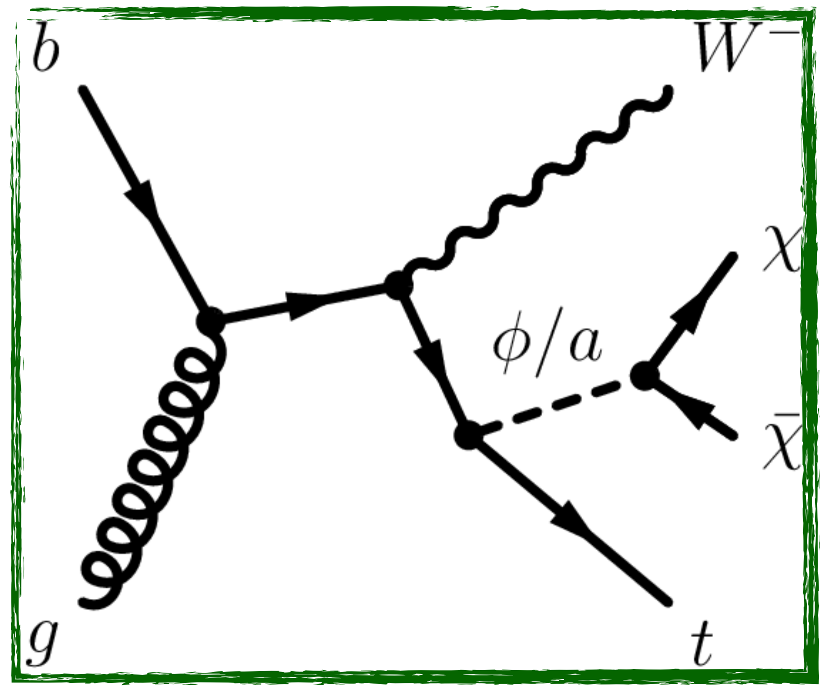






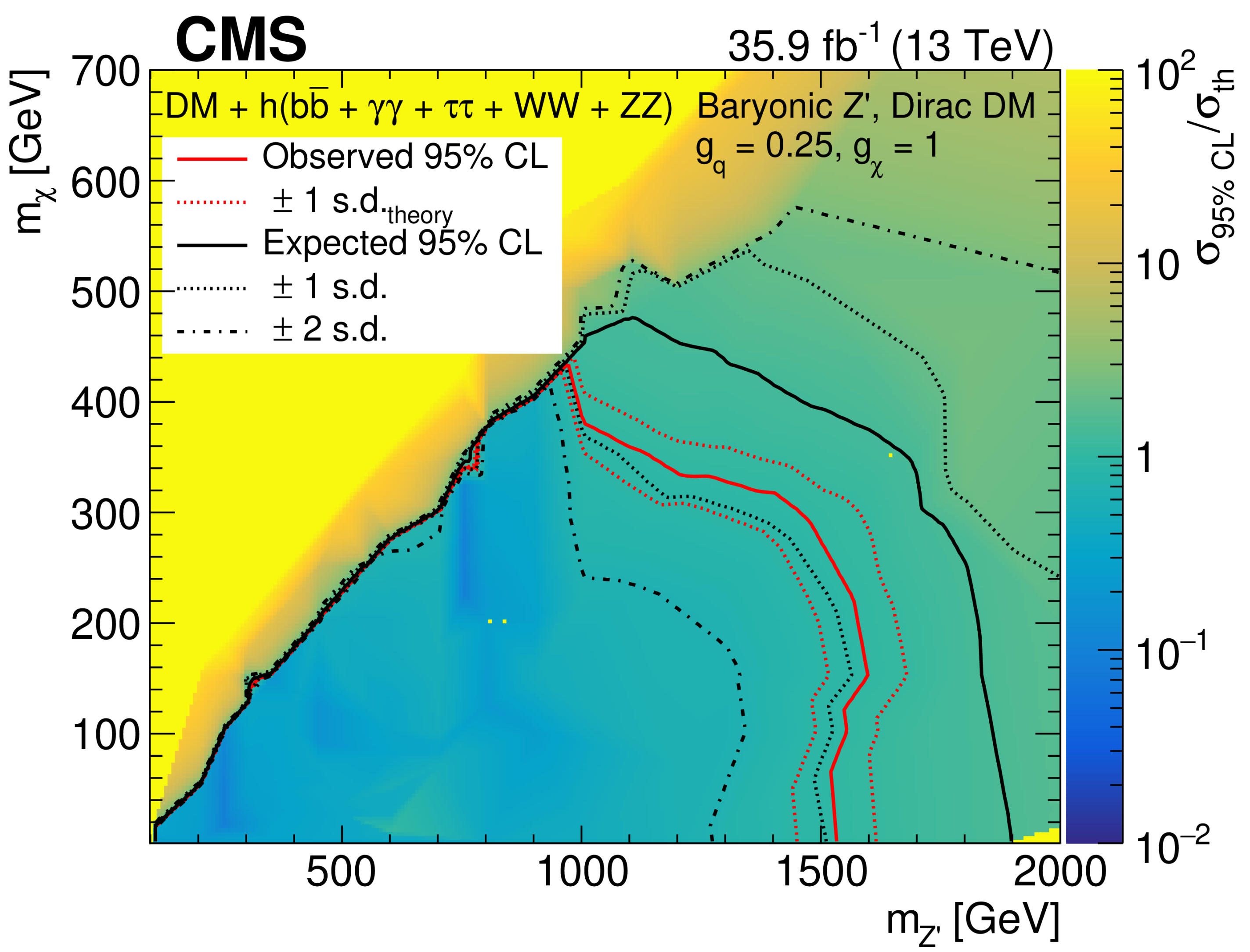




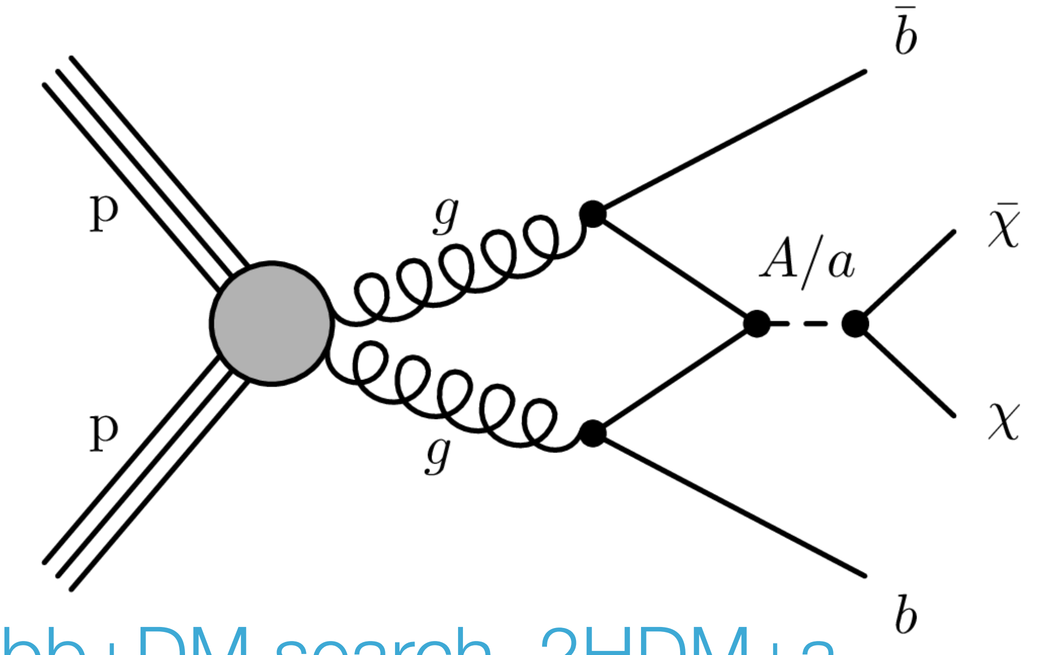


CONSTRAINTS ON PSEUDOSCALAR MEDIATOR

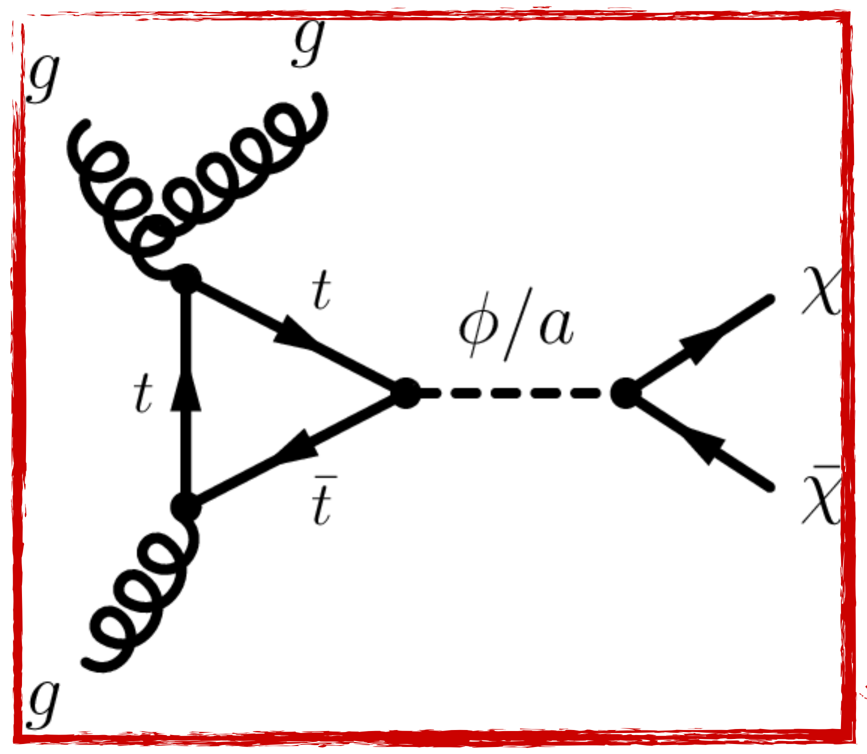
also JHEP 03 (2020) 025

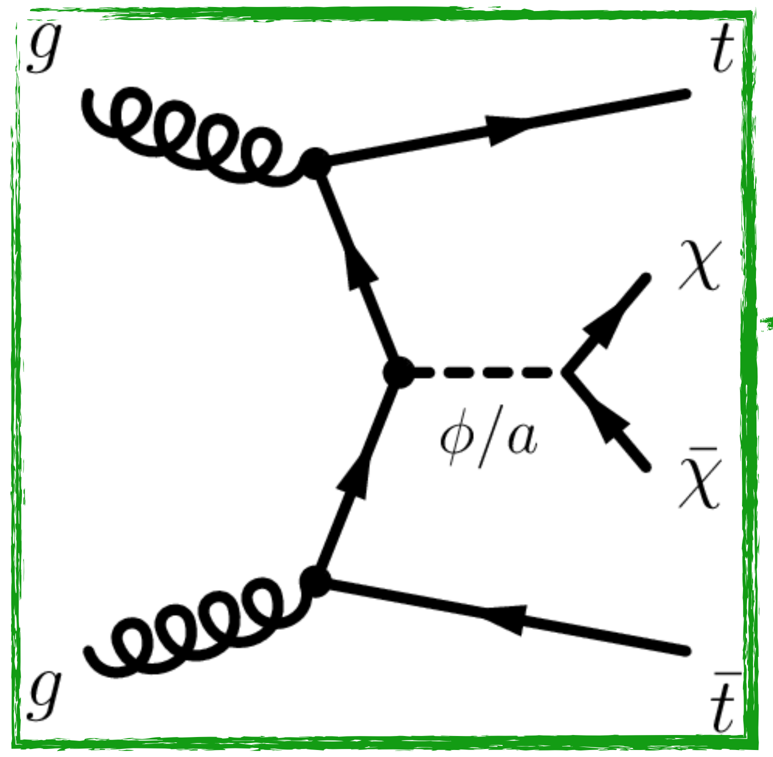


also CMS-PAS-SUS-23-008

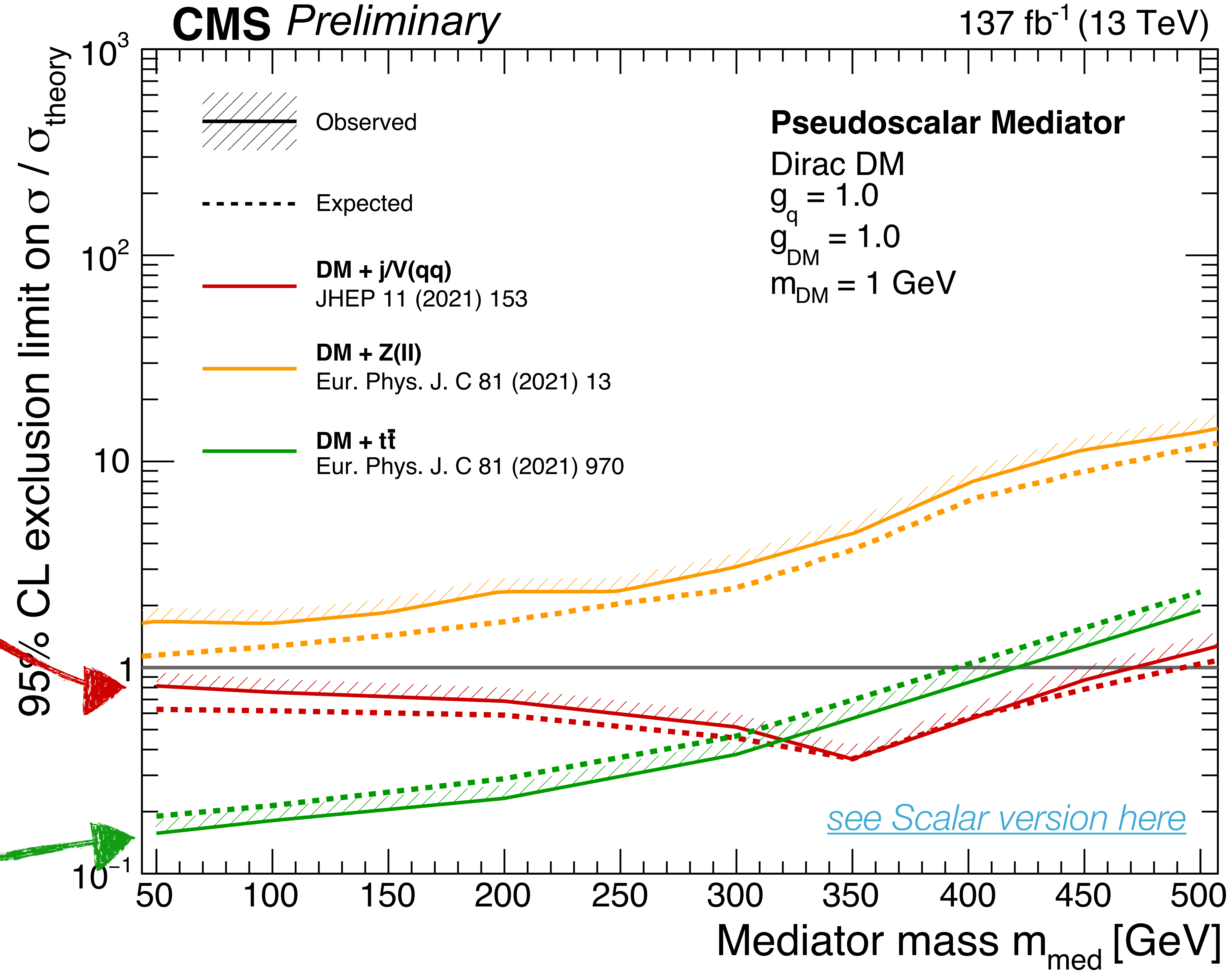


bb+DM search, 2HDM+a only interpretation

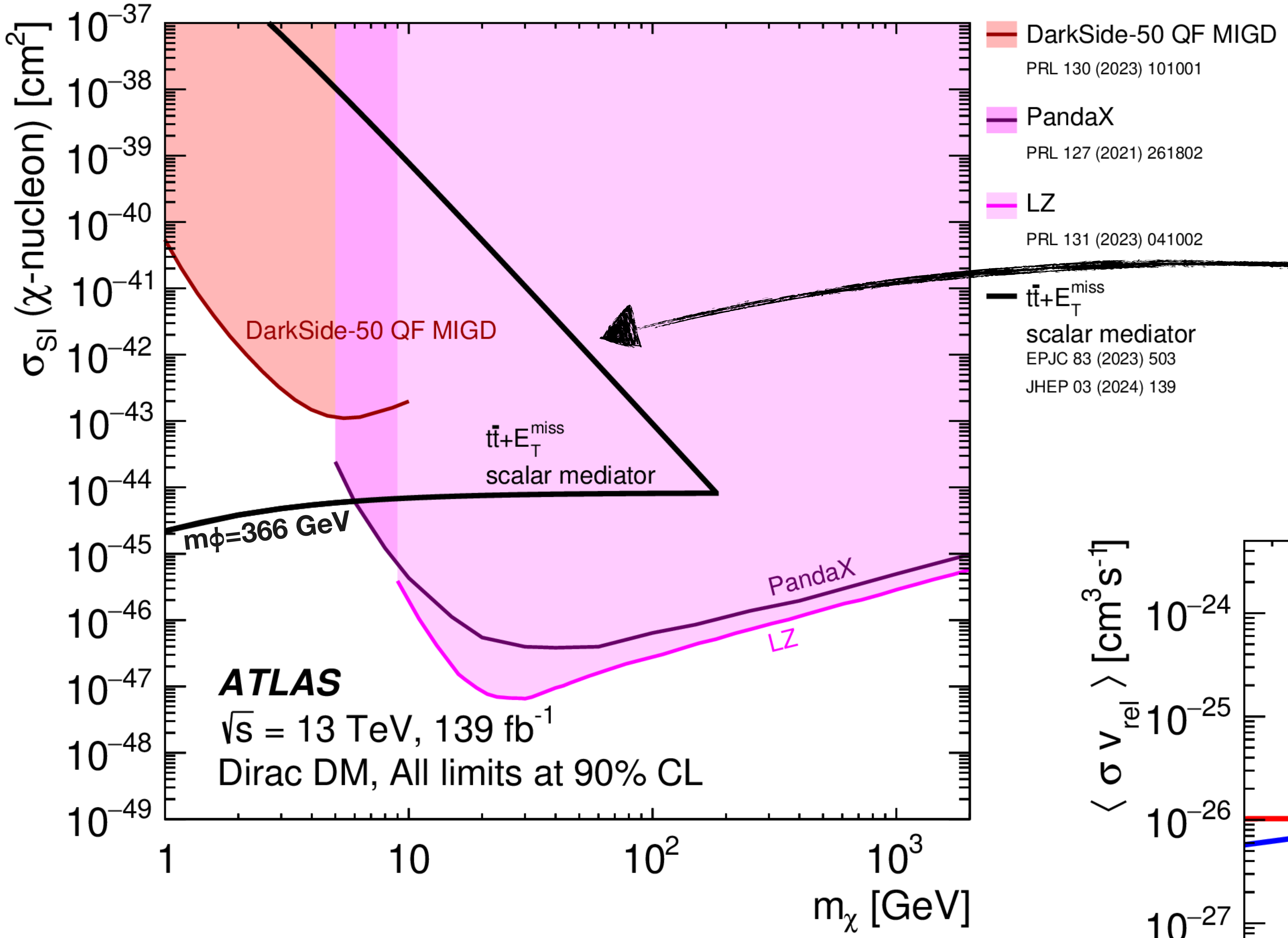


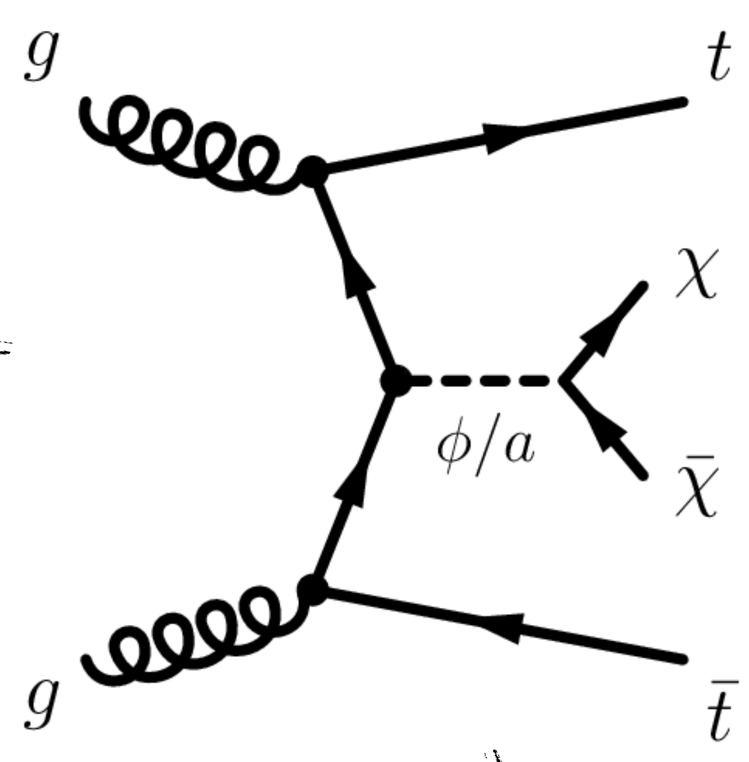


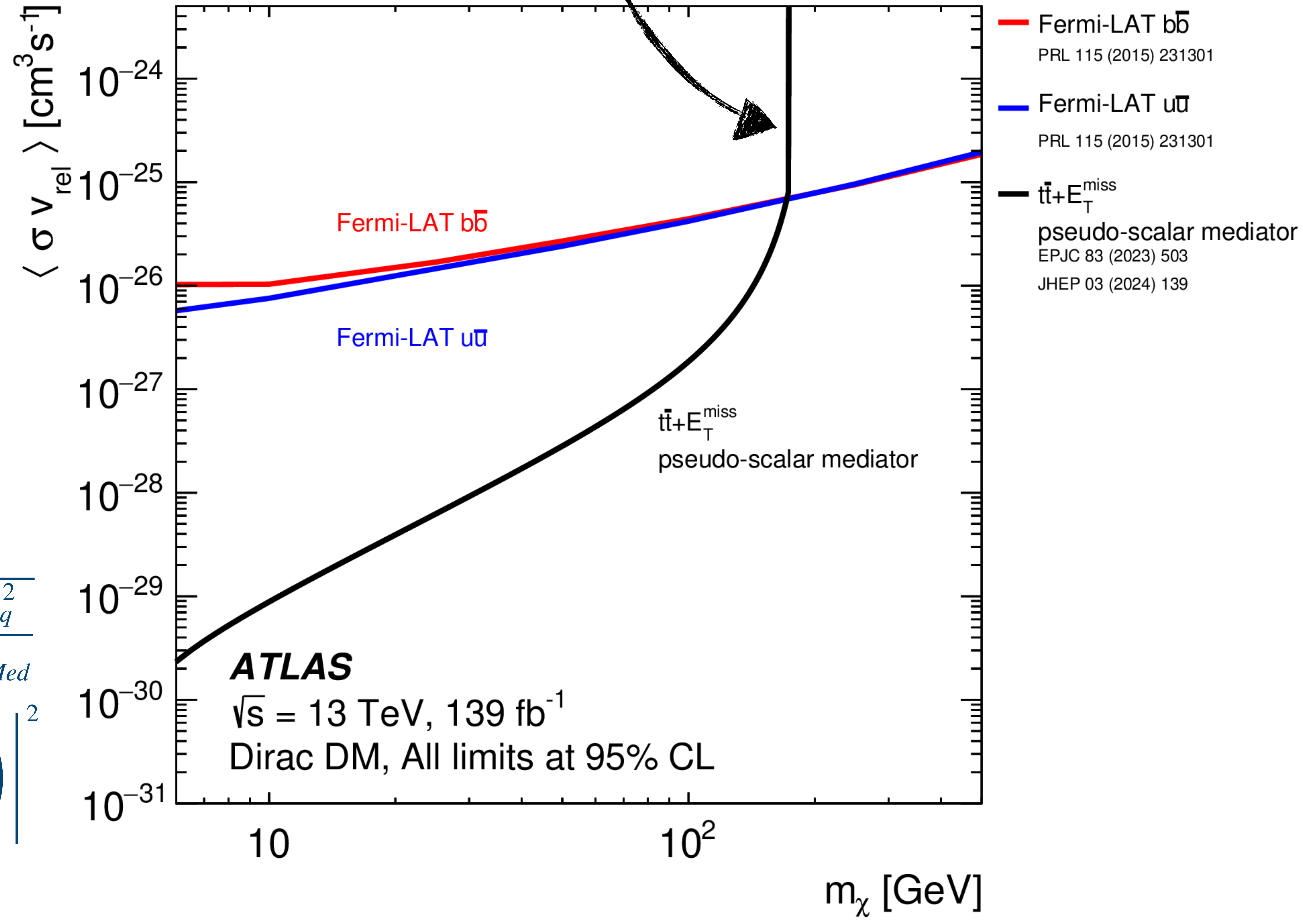
CMS DM Summary



DIRECT DETECTION COMPARISON



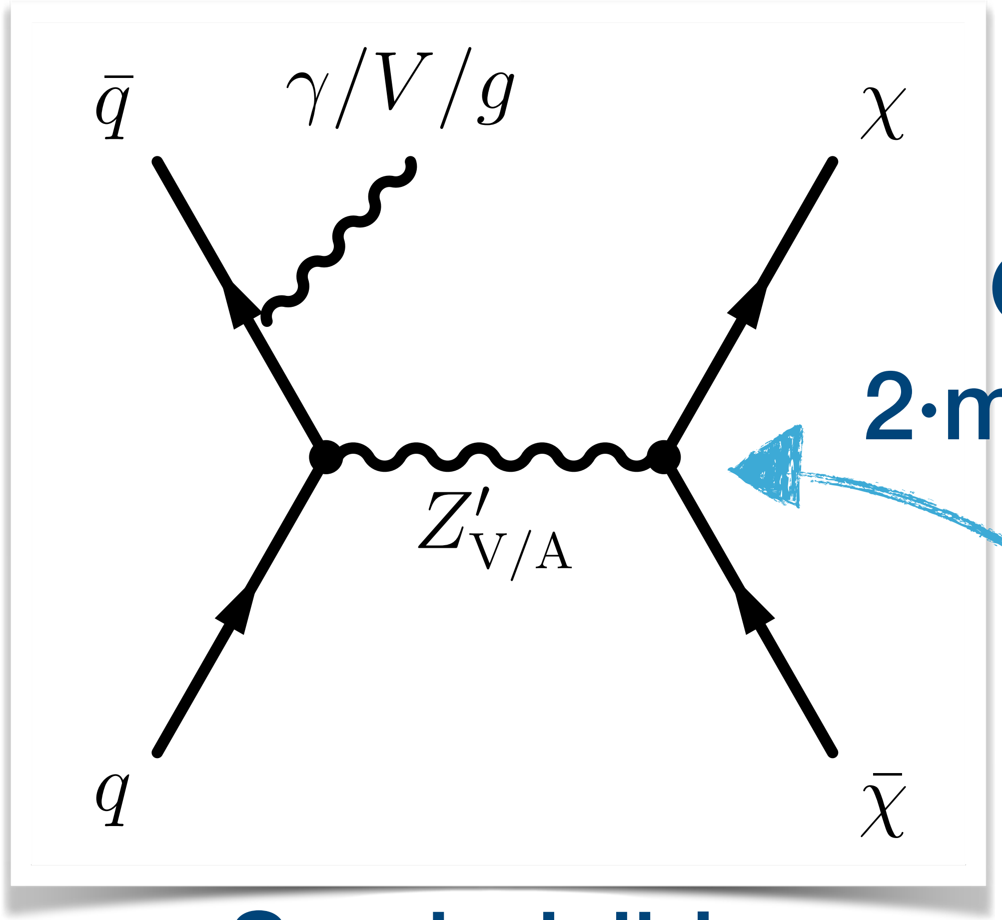




$$\langle\sigma v_{rel}\rangle_q = \frac{3m_q^2}{2\pi v^2}\frac{g_q^2 g_\chi^2 m_\chi^2}{(m_{Med}^2-4m_\chi^2)^2+m_{Med}^2\Gamma_{Med}^2}\sqrt{1-\frac{m_q^2}{m_{Med}^2}}$$

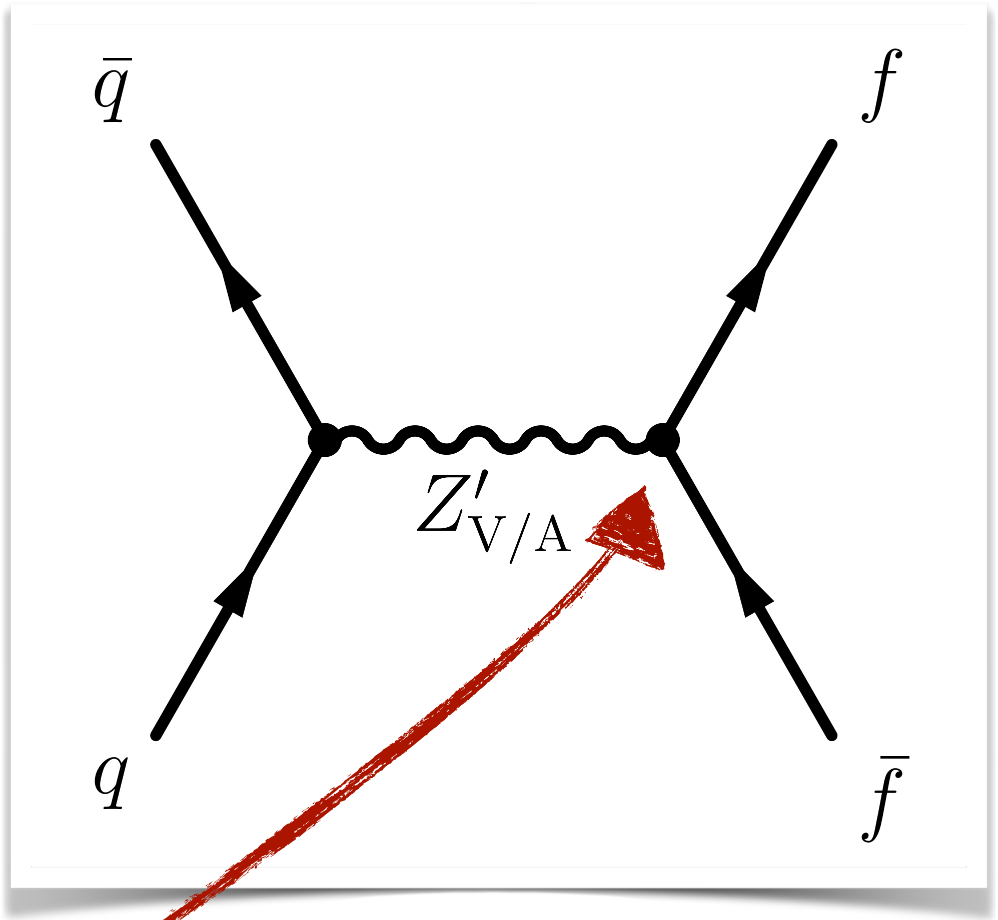
$$\langle\sigma v_{rel}\rangle_g = \frac{\alpha_s^2}{2\pi^3 v^2}\frac{g_q^2 g_\chi^2}{(m_{Med}^2-4m_\chi^2)^2+m_{Med}^2\Gamma_{Med}^2}\cdot\left|\sum_q m_q^2 f_{PS}\left(\frac{m_q^2}{m_\chi^2}\right)\right|^2$$

(Axial-)Vector – Signature Complementarity



Semi-visible

Only if
$2 \cdot m_{DM} \lesssim m_{Med}$



Visible

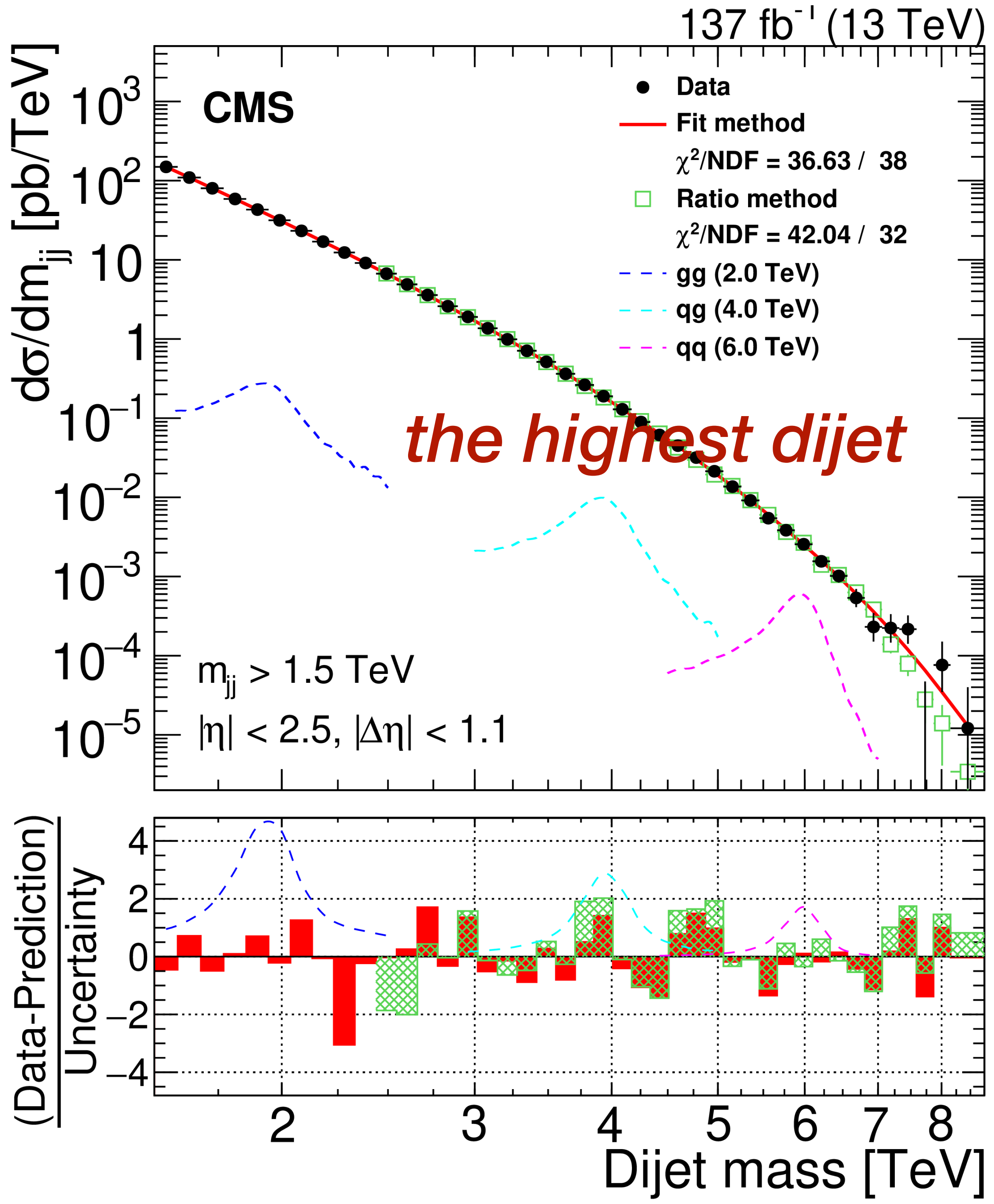
$$\mathscr{L} \simeq \mathscr{L}_{SM} + g_\chi Z'_\mu \bar{\chi}\gamma^\mu\gamma^5\chi + g_f Z'_\mu \bar{f}\gamma^\mu\gamma^5 f$$

$$\Gamma^{\chi\bar{\chi}}_{AV} = \frac{g_\chi M_{med}}{12\pi}\left(1 - 4\frac{m_\chi^2}{M_{med}^2}\right)^{3/2}$$

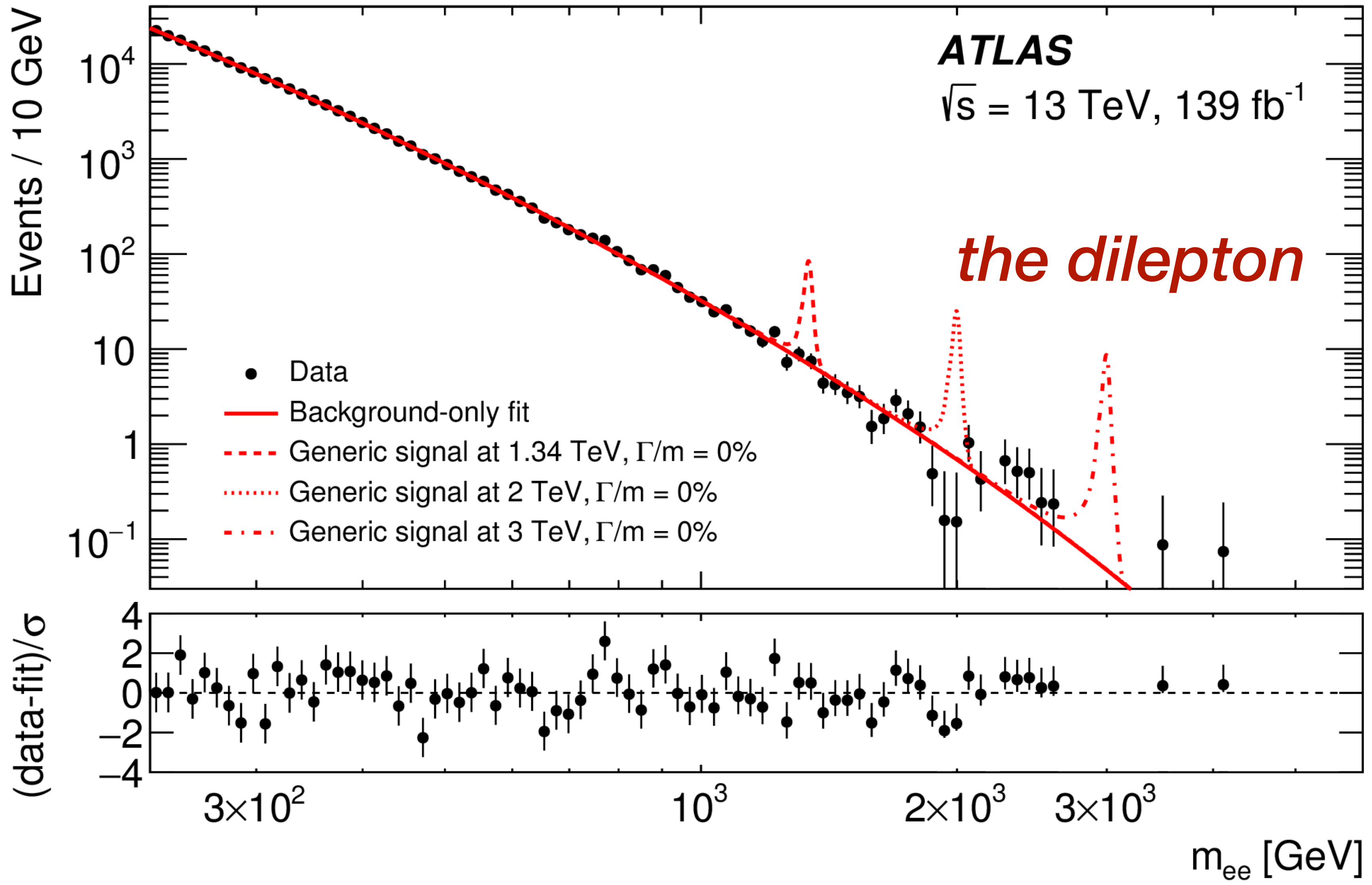
$$\Gamma^{f\bar{f}}_{AV} = \frac{g_f M_{med}\, c_f}{12\pi}\left(1 - 4\frac{m_f^2}{M_{med}^2}\right)^{3/2}$$

(AXIAL-)VECTOR MEDIATOR SEARCHES

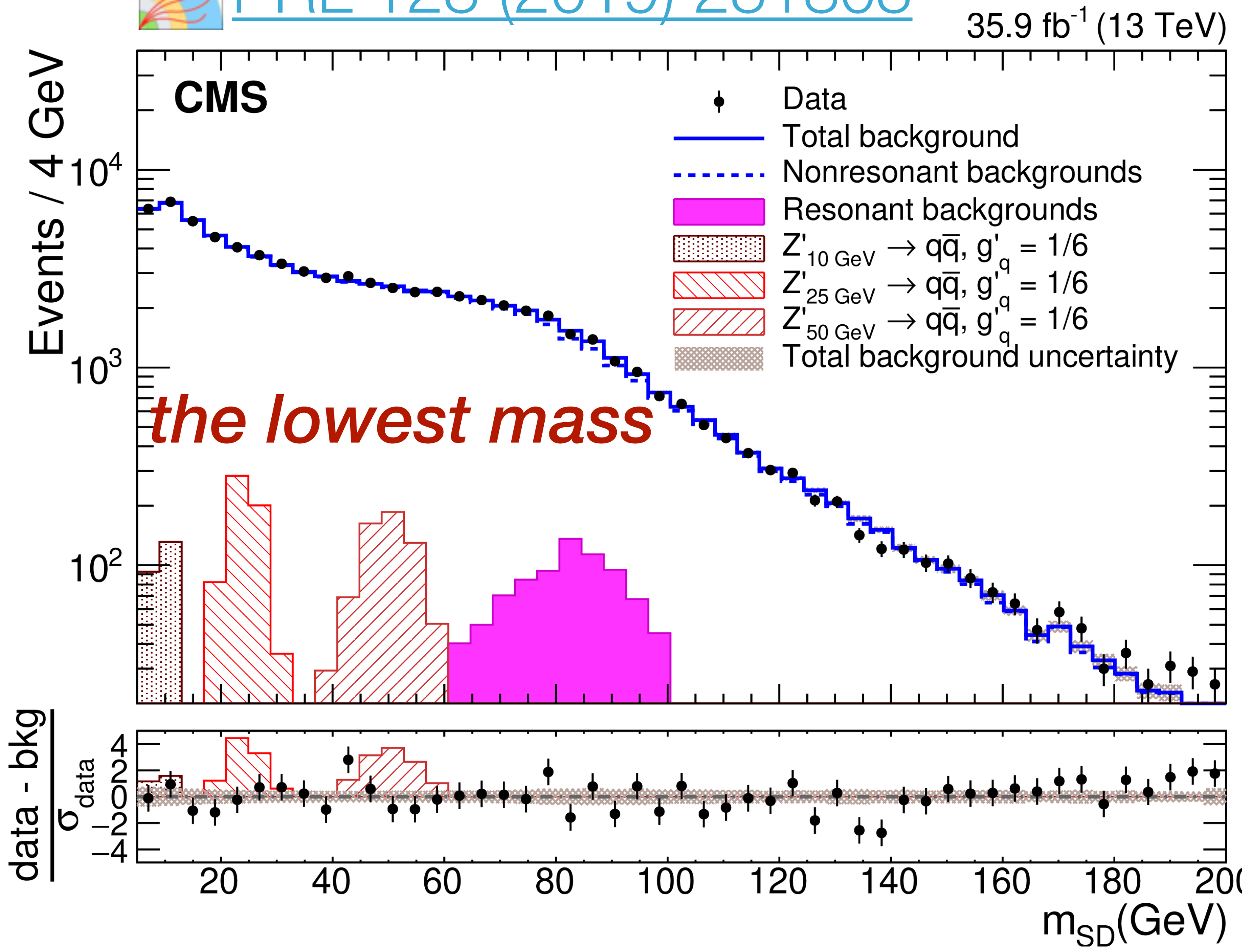
JHEP 05 (2020) 033



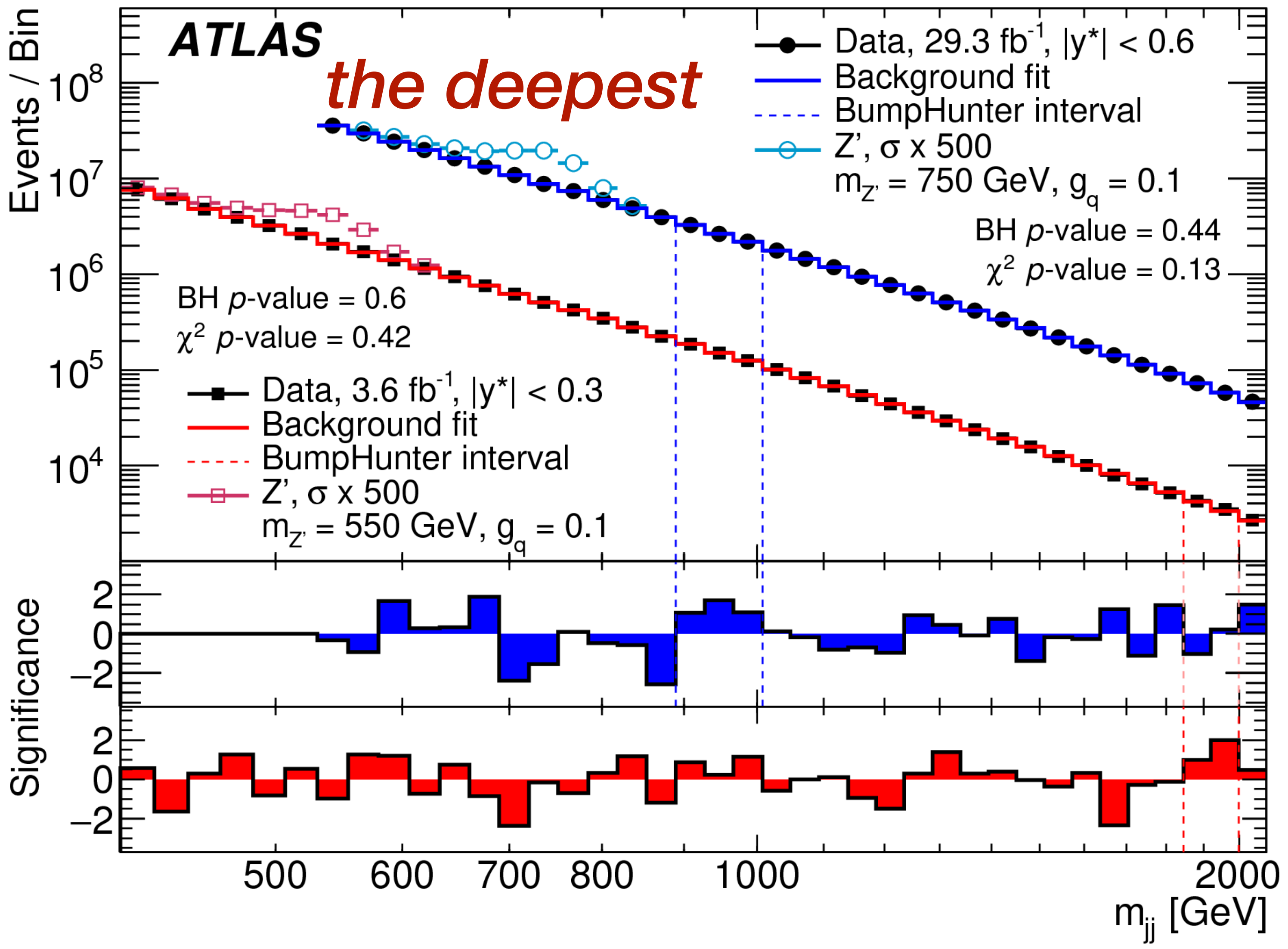
PLB 796 (2019) 68



PRL 123 (2019) 231803

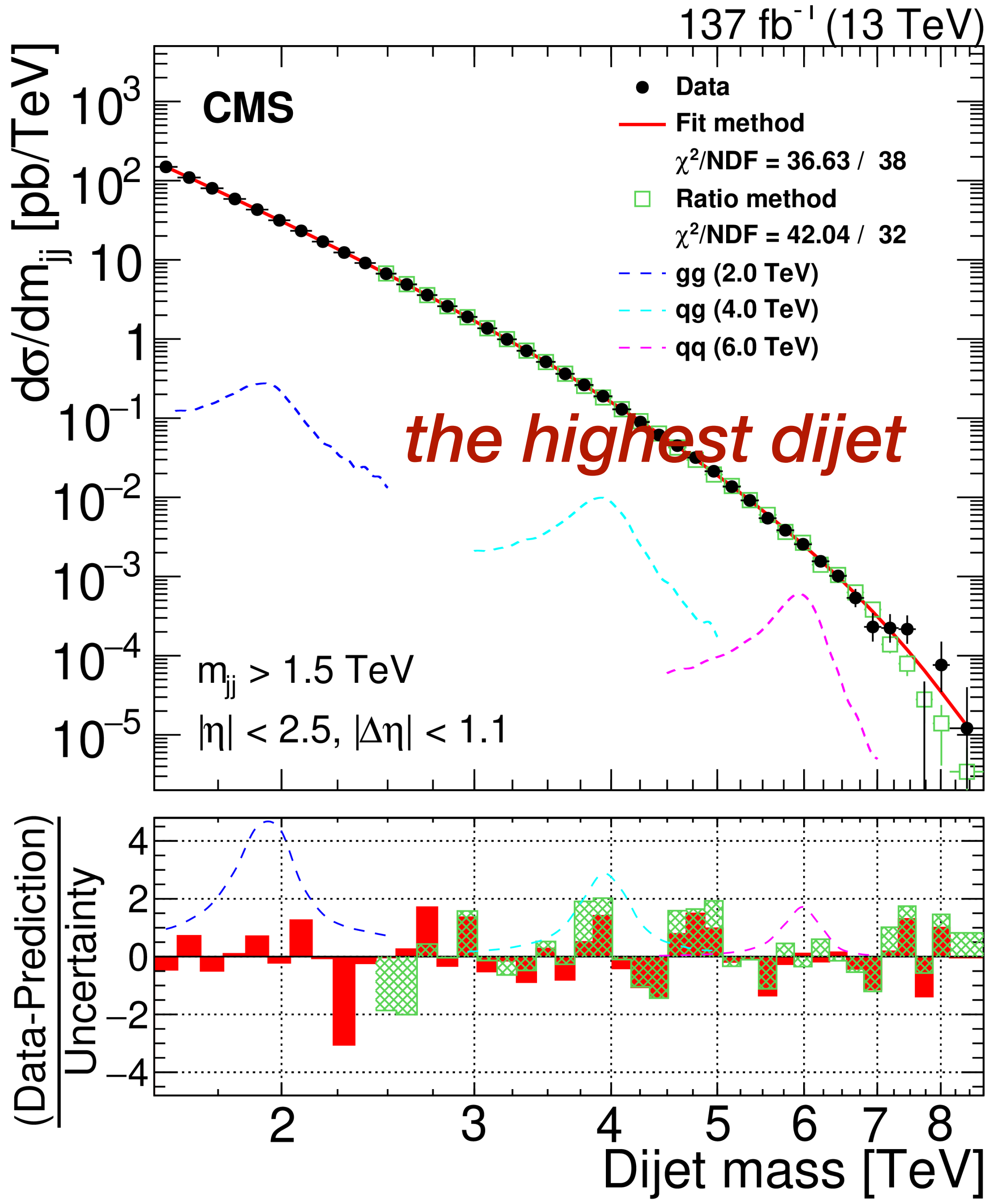


PRL 121 (2018) 081801



(AXIAL-)VECTOR MEDIATOR SEARCHES

JHEP 05 (2020) 033



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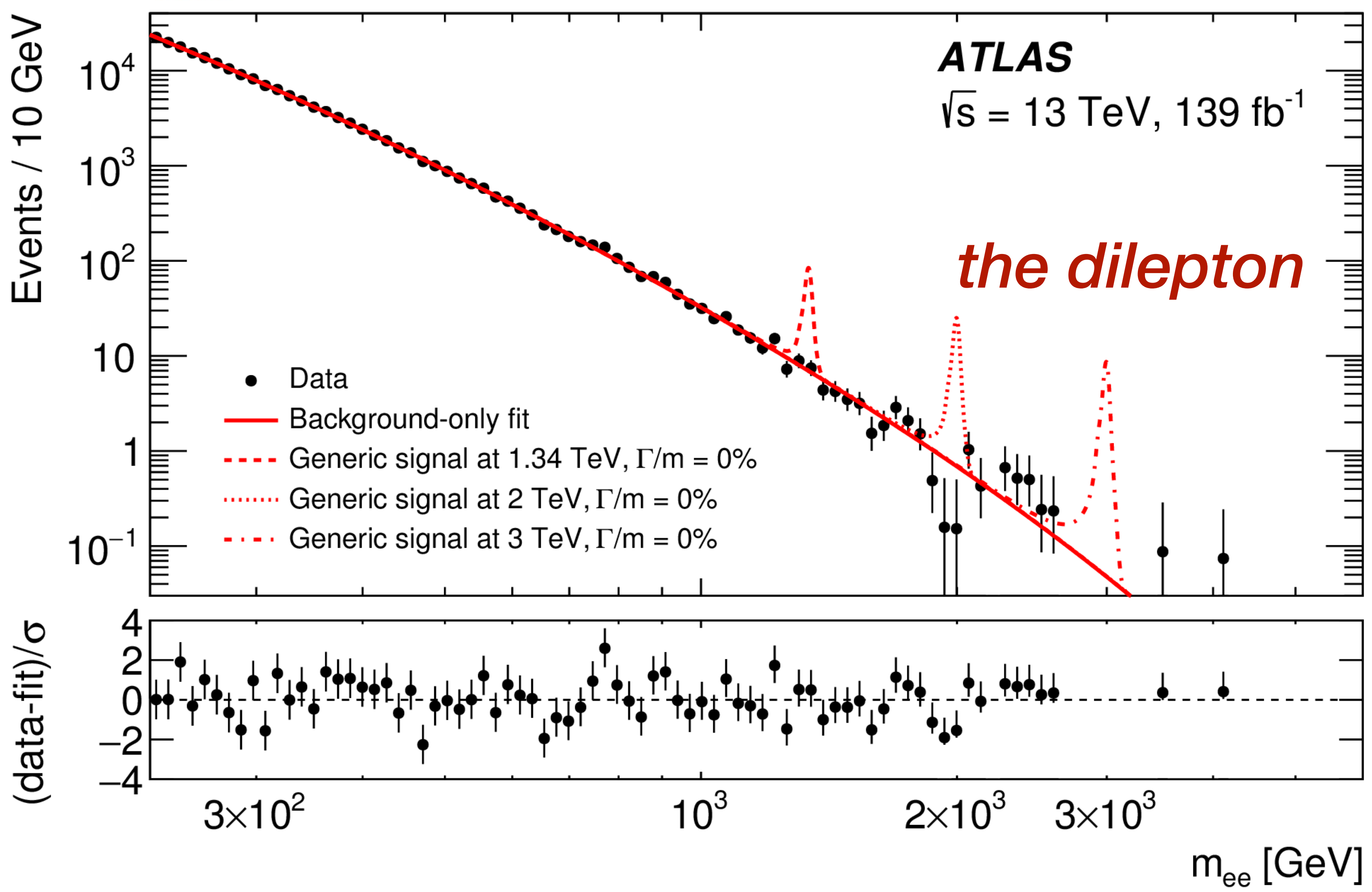
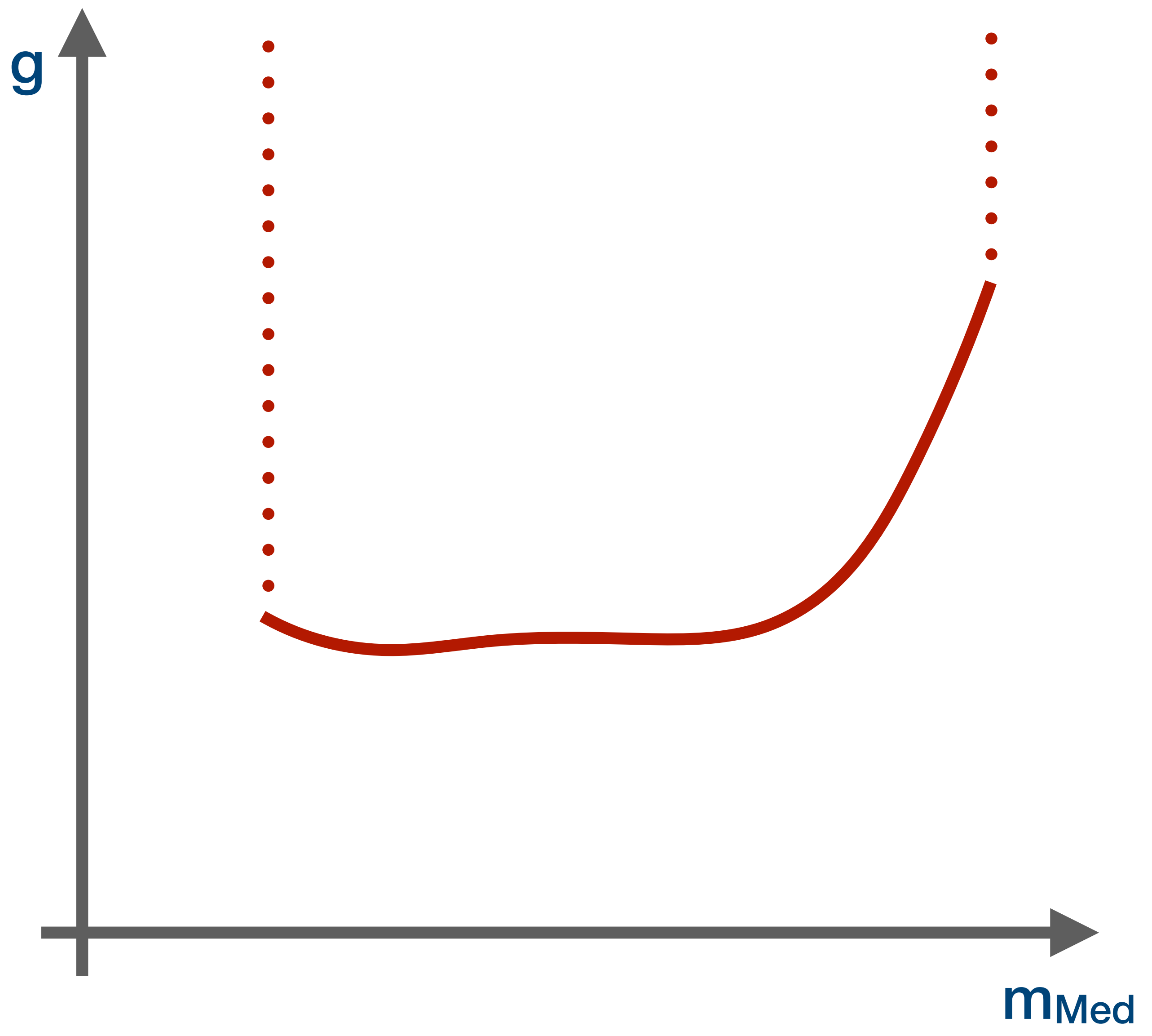


95% CL upper limit



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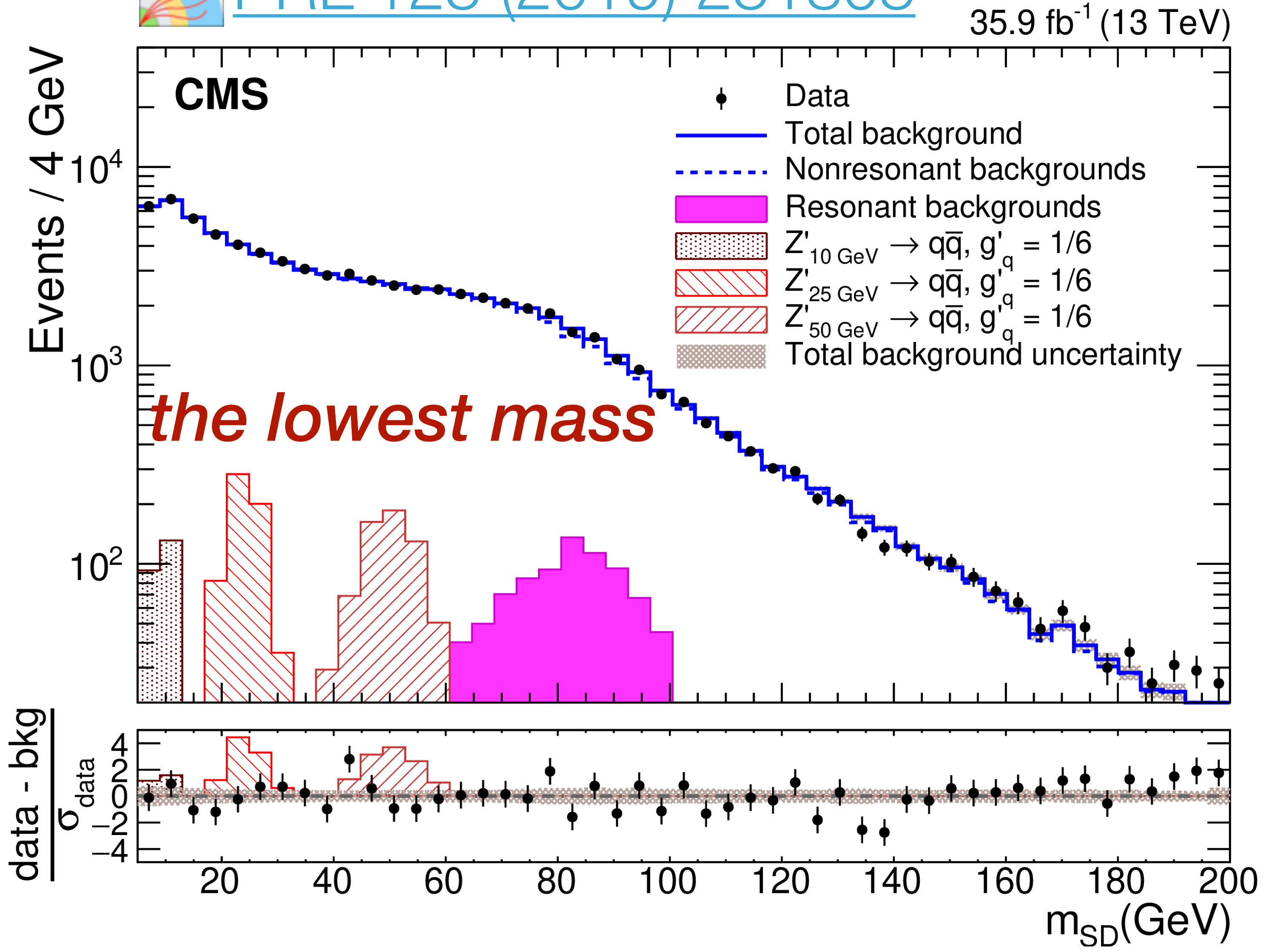
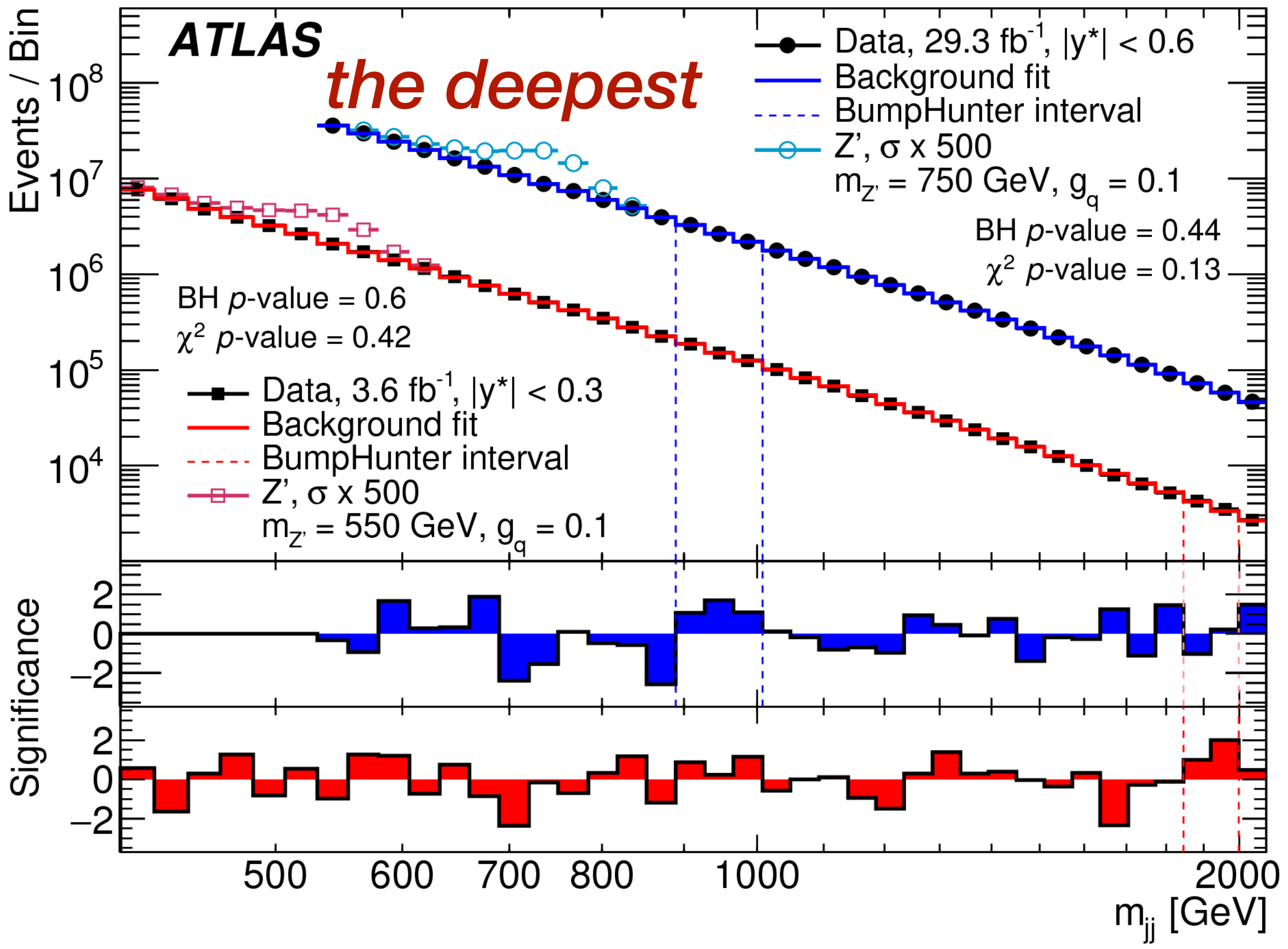
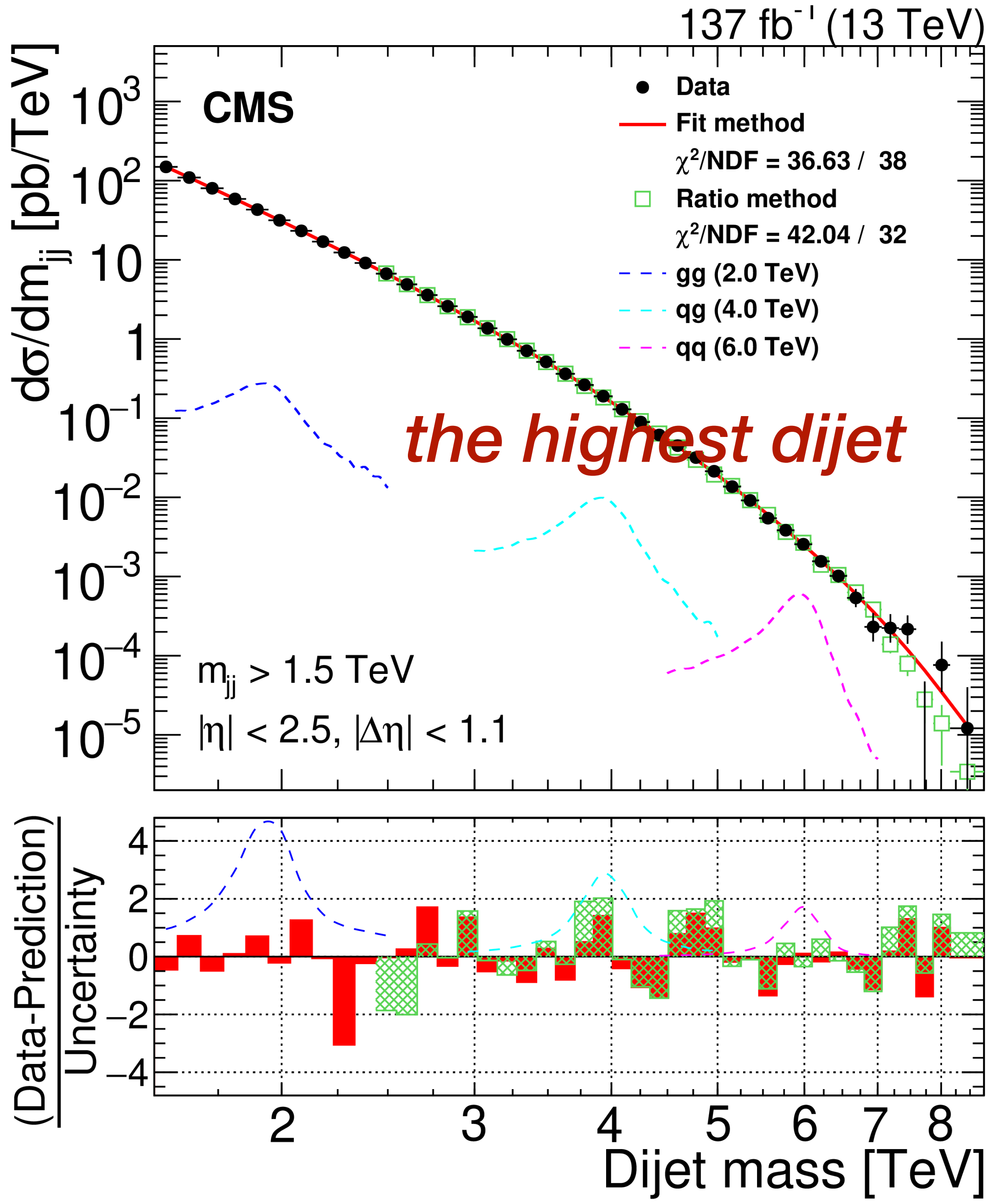


PRL 121 (2018) 081801



(AXIAL-)VECTOR MEDIATOR SEARCHES

JHEP 05 (2020) 033



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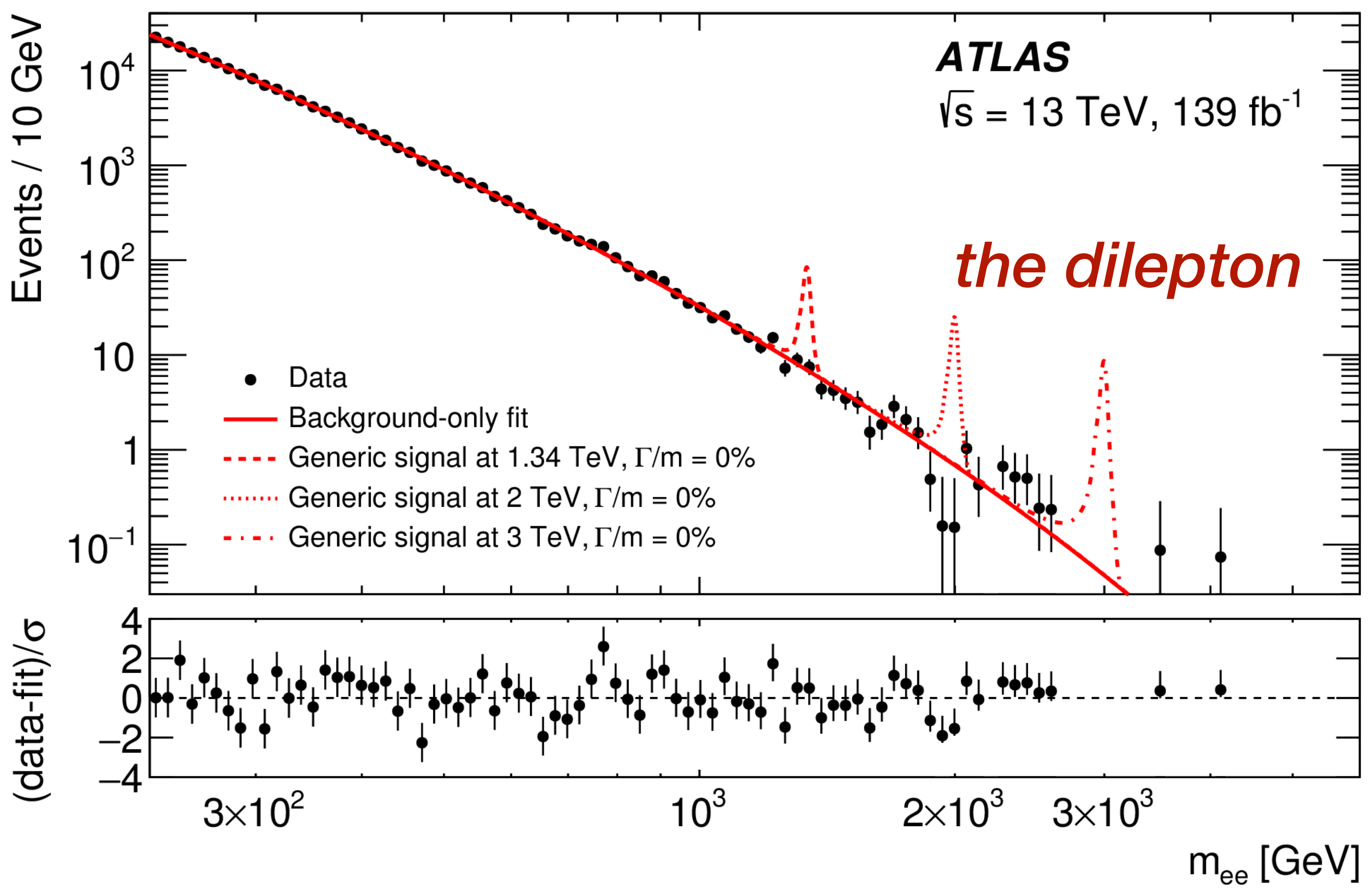

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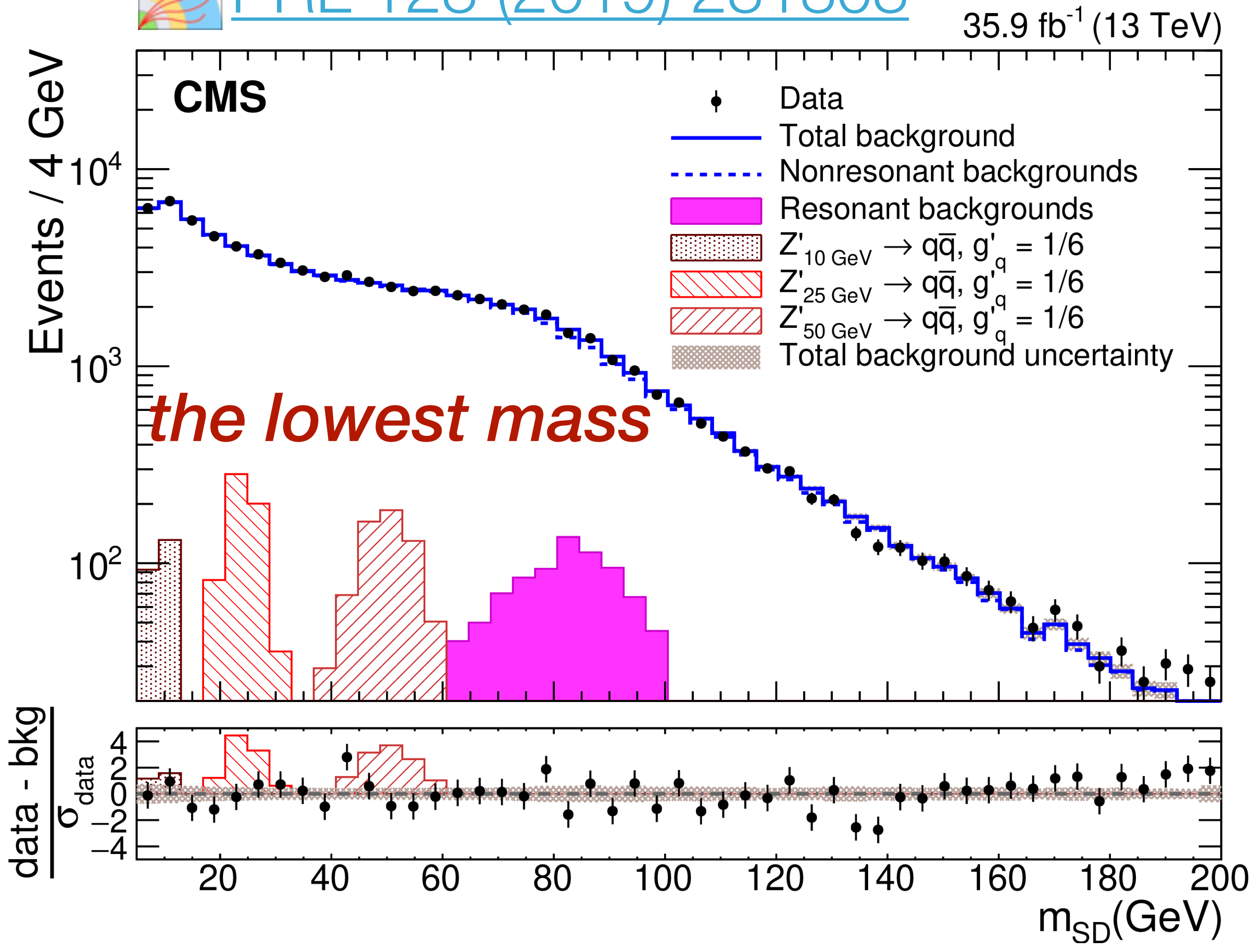

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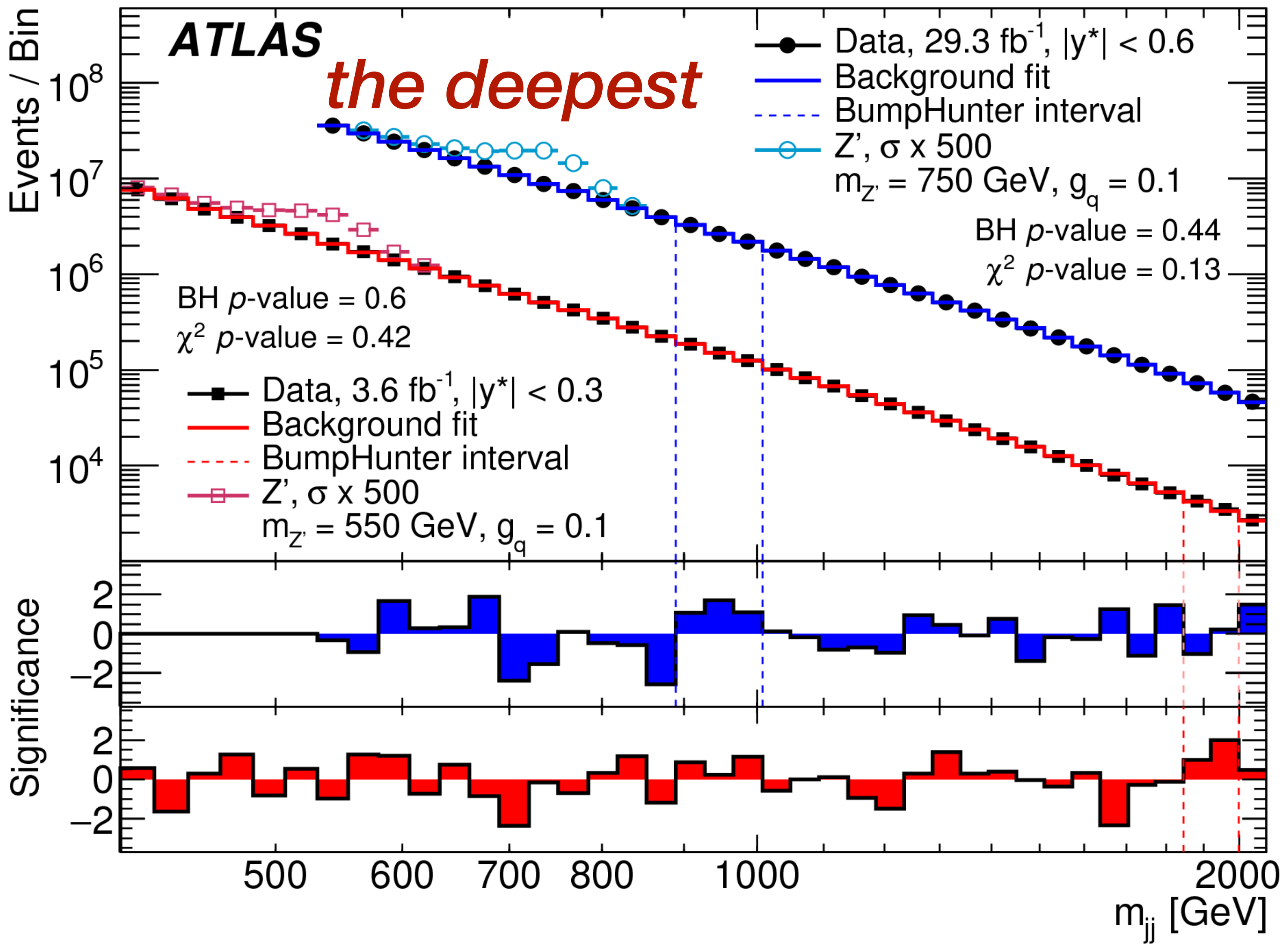

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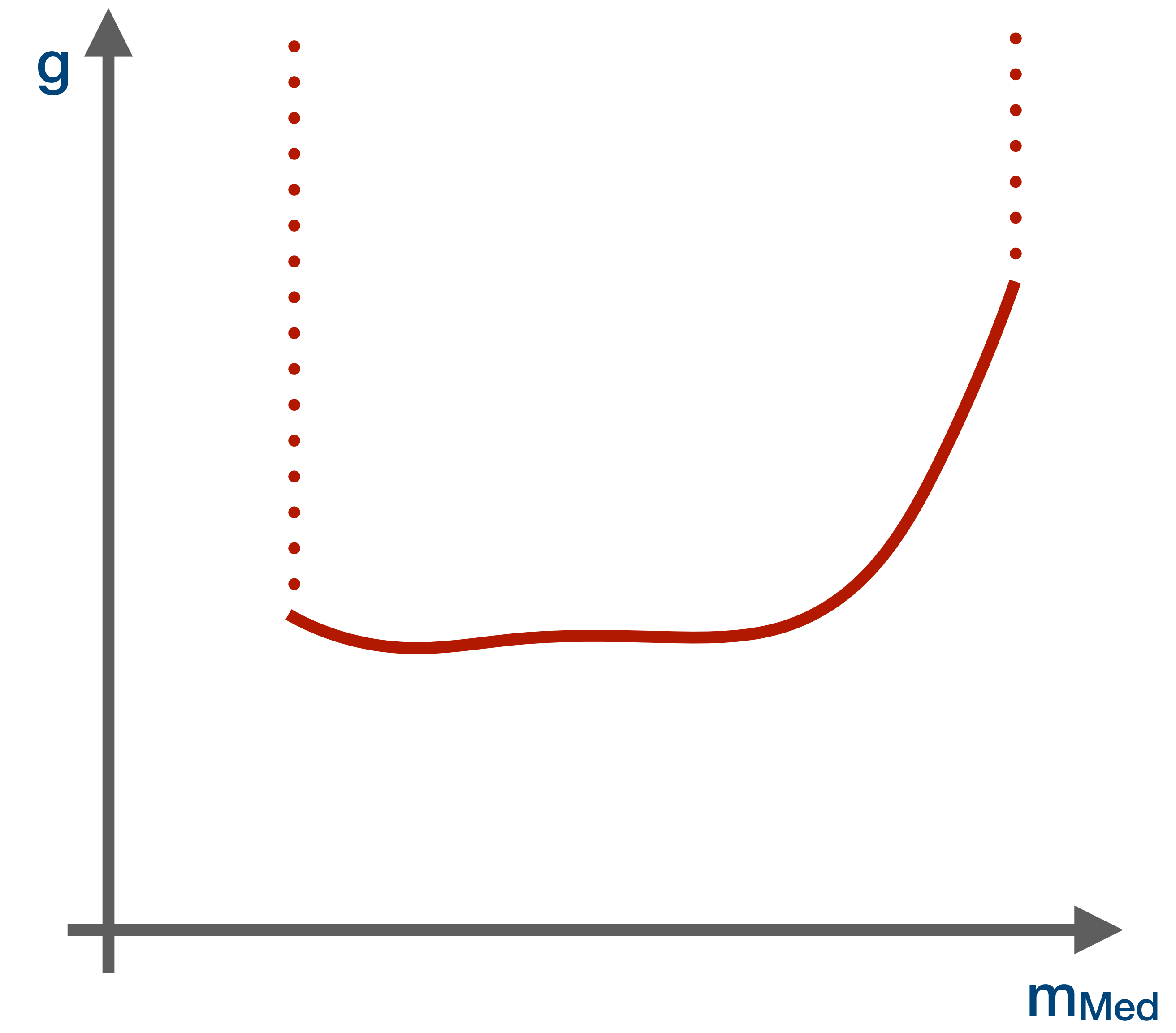
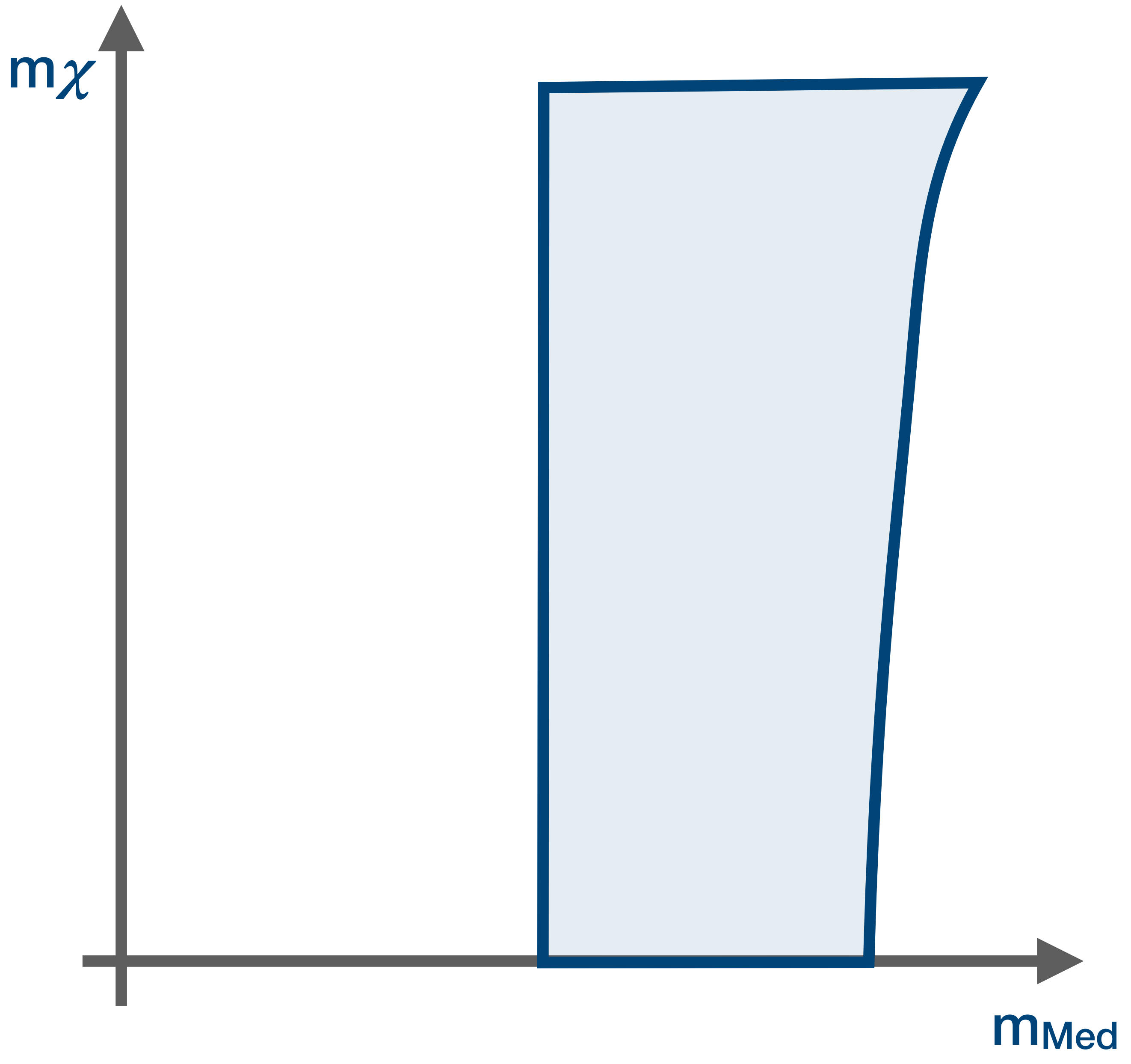
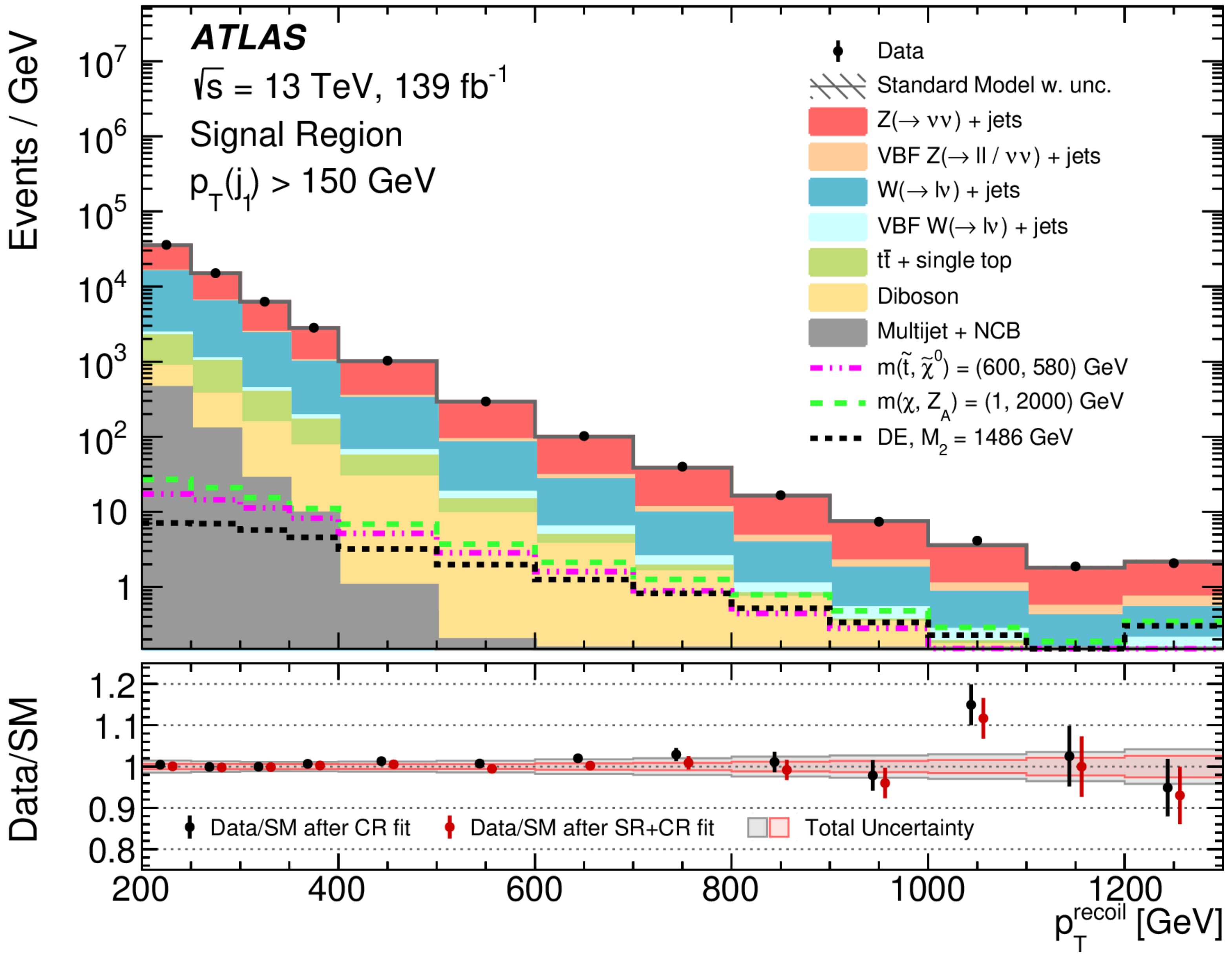


95% CL exclusion contours



INVISIBLE MEDIATOR DECAYS

PRD 103 (2021) 112006



the monojets

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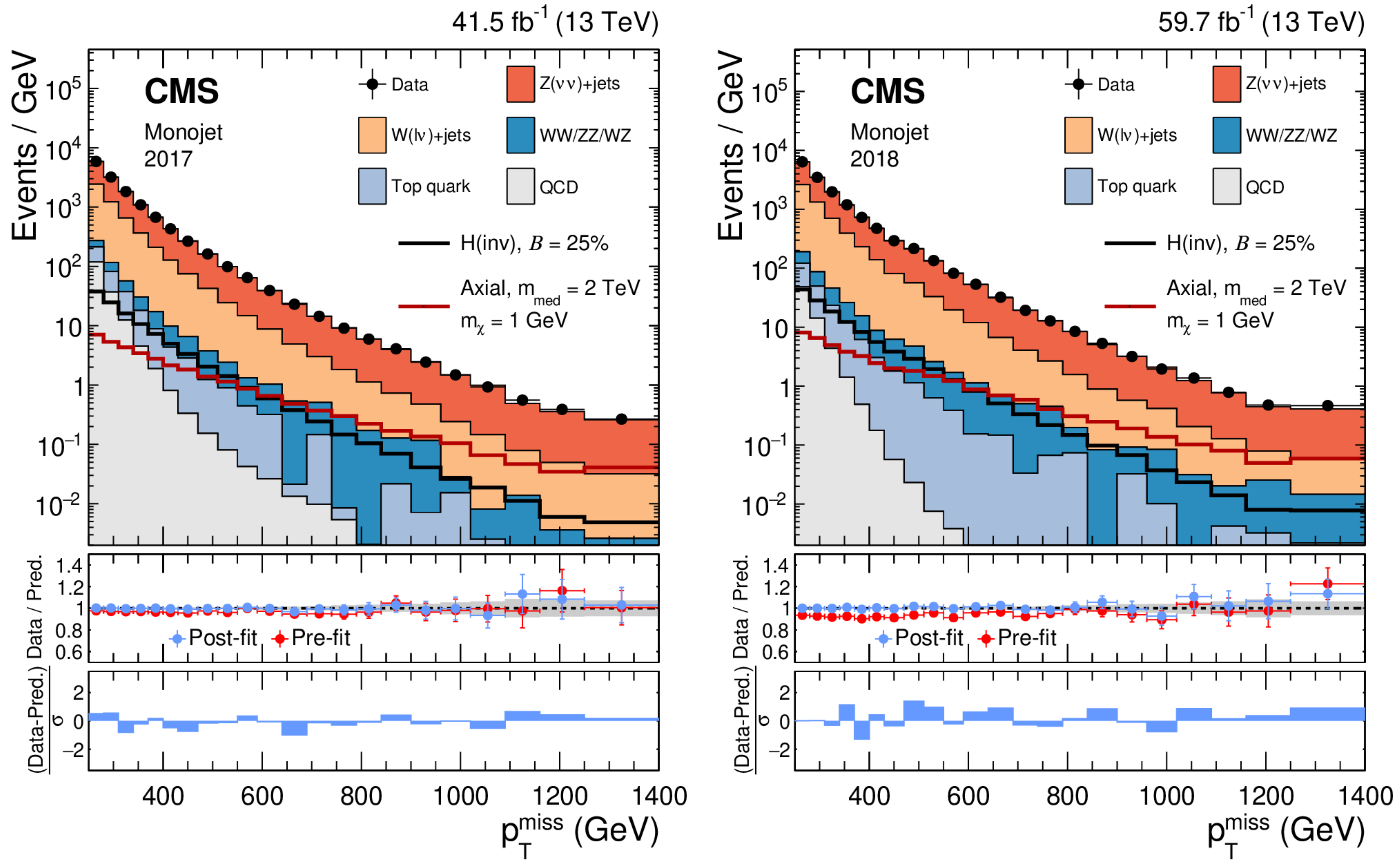
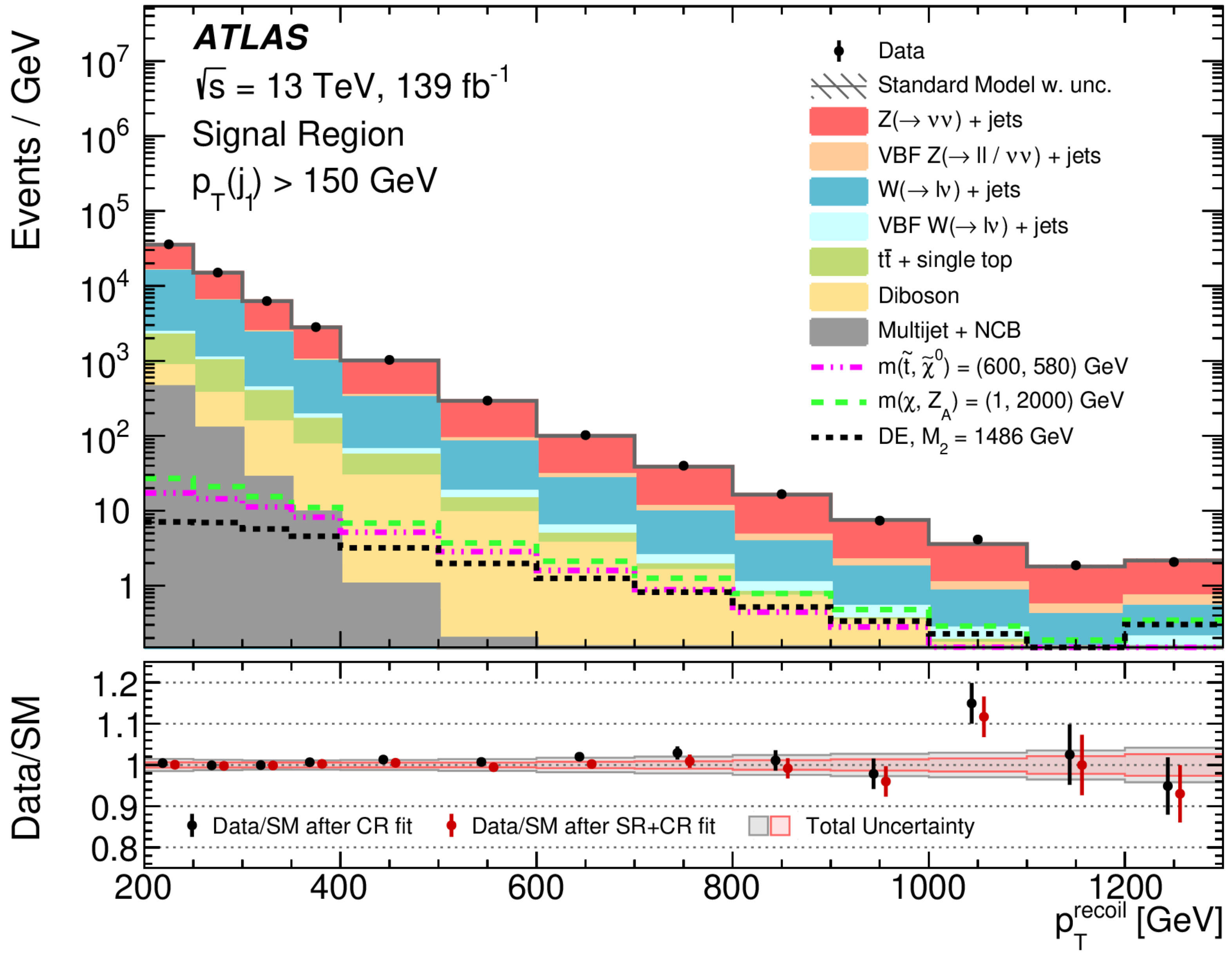


INVISIBLE MEDIATOR DECAYS

the monojets

PRD 103 (2021) 112006



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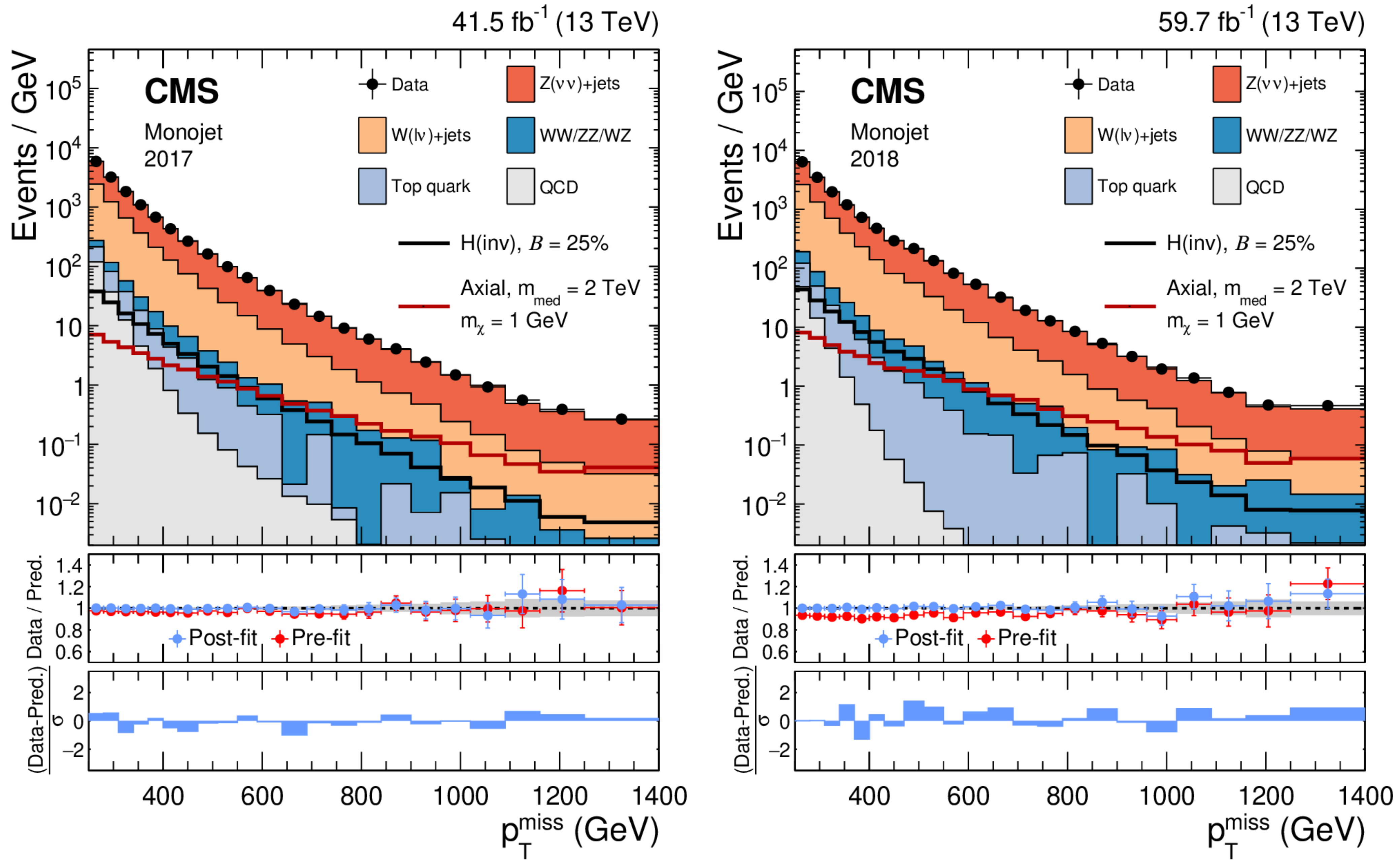

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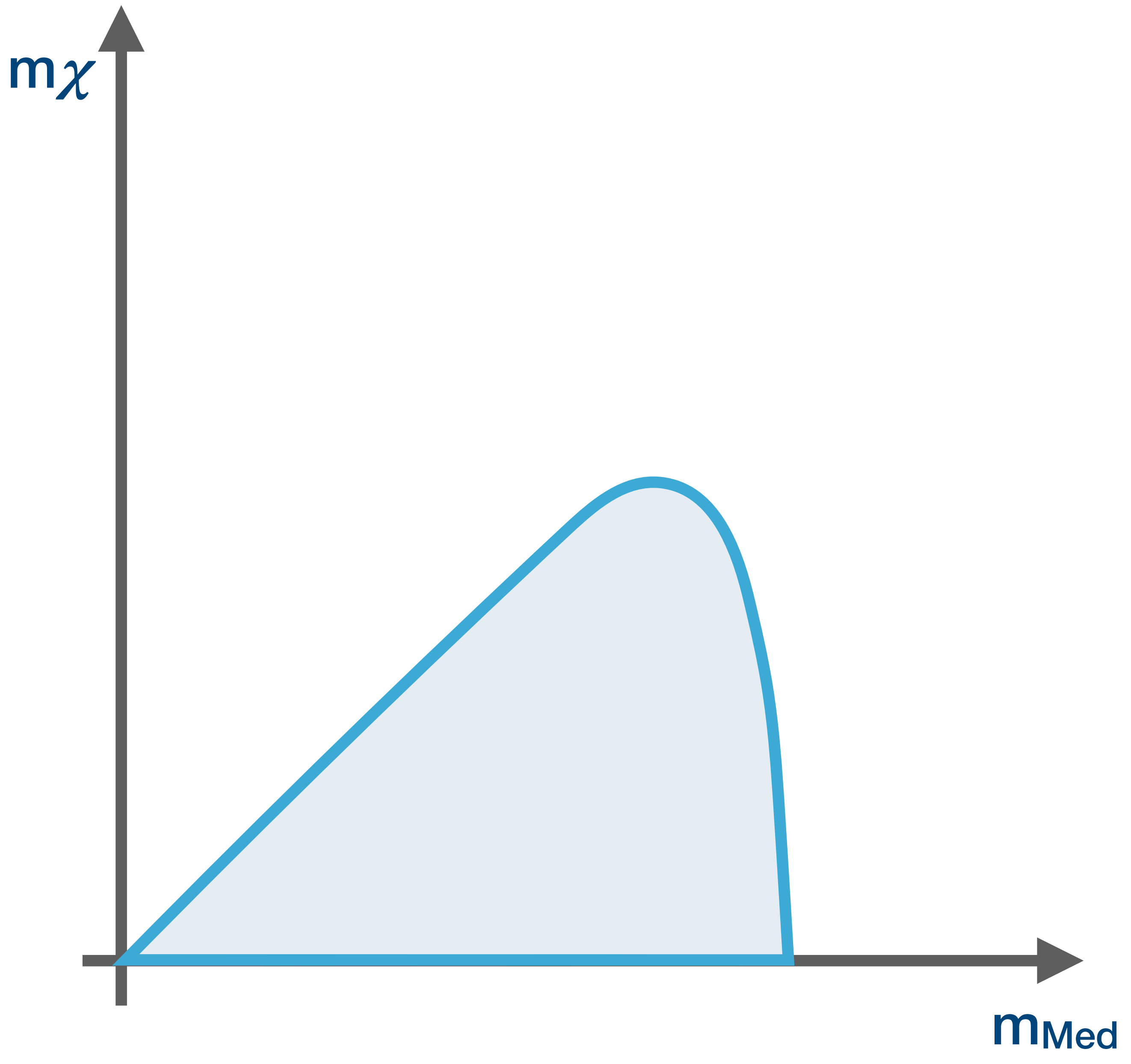
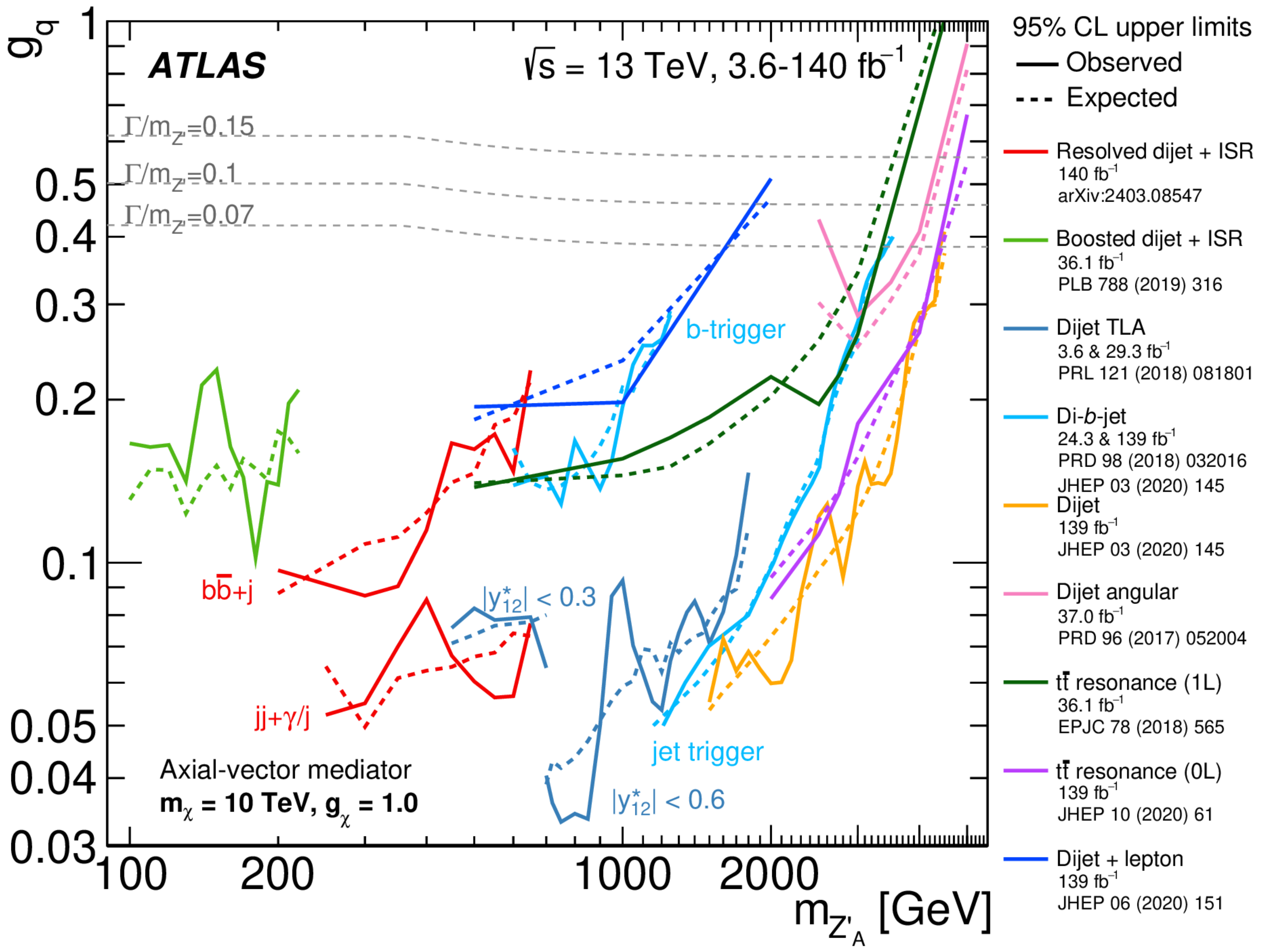
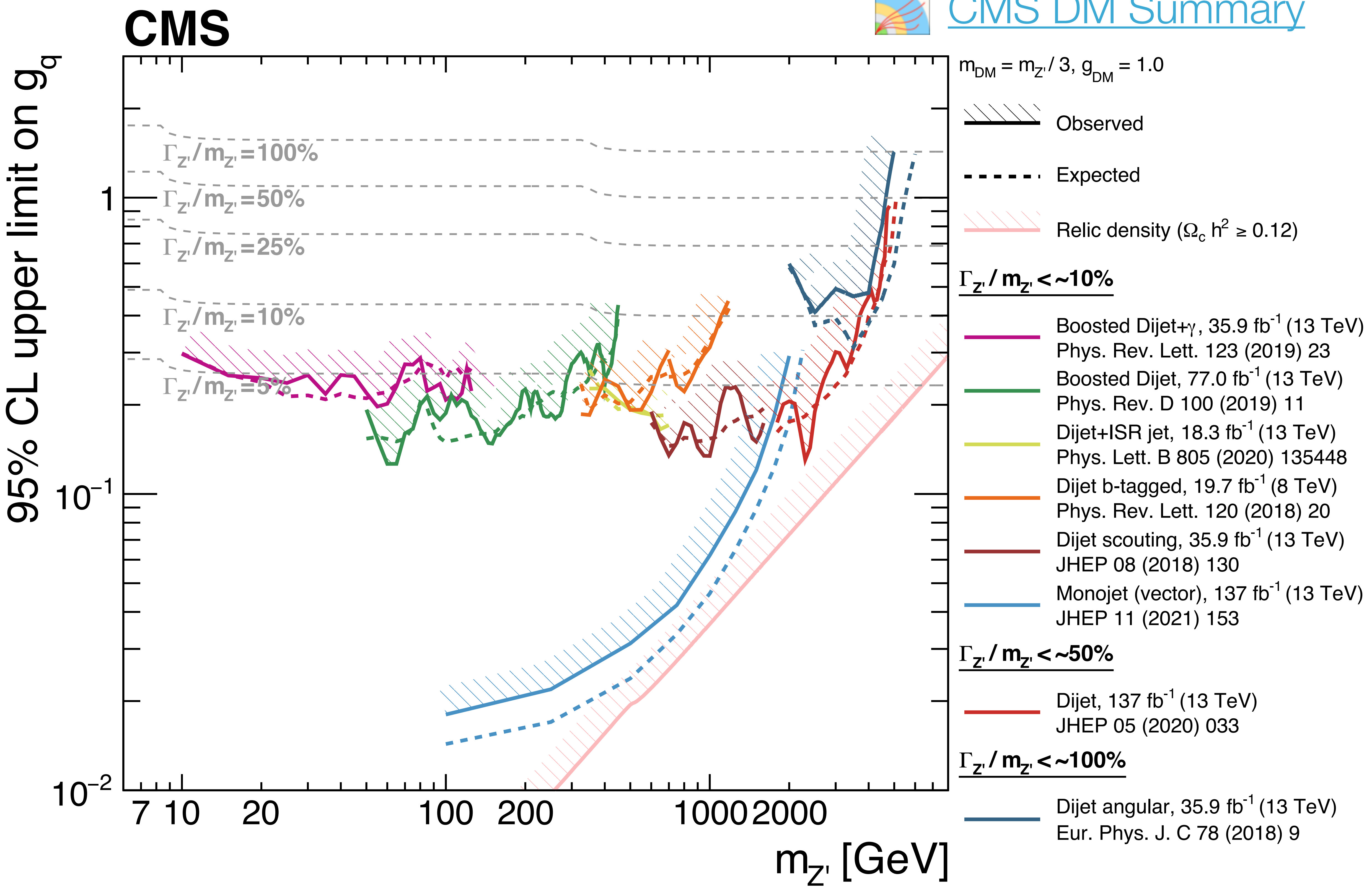


CONSTRAINTS ON MEDIATOR COUPLINGS

EXOT-2018-62



CMS DM Summary



CONSTRAINTS ON MEDIATOR COUPLINGS

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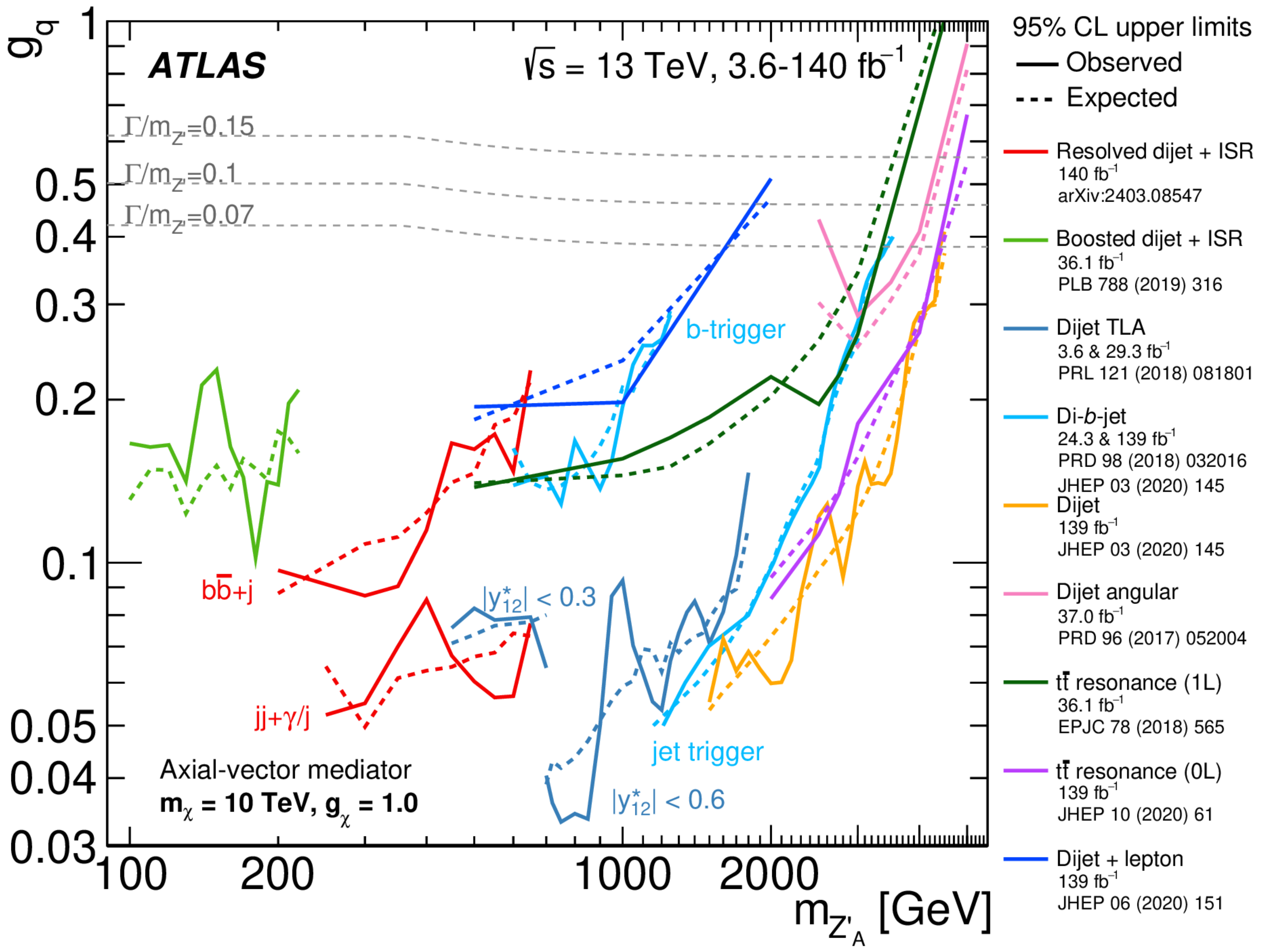

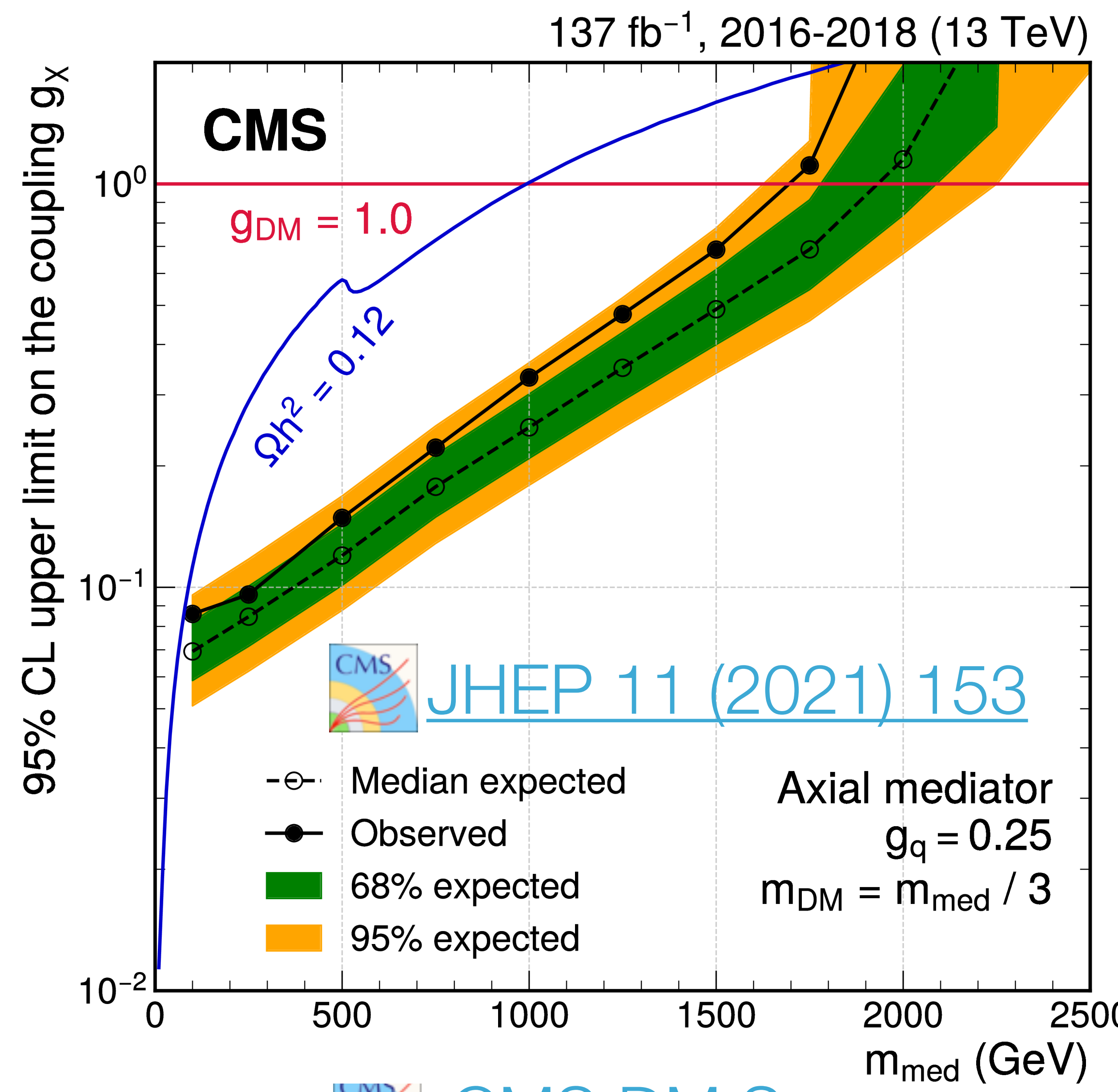

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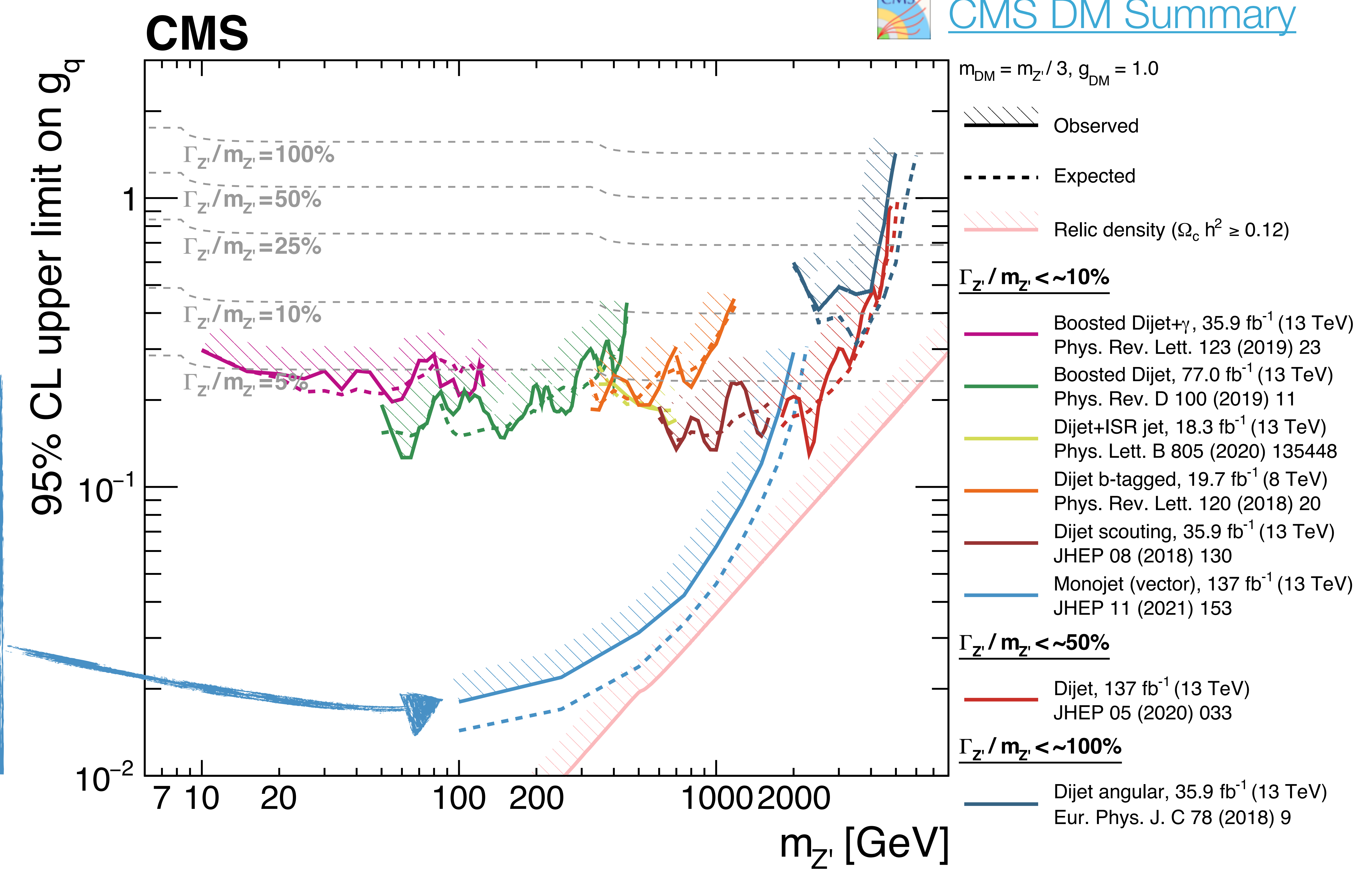
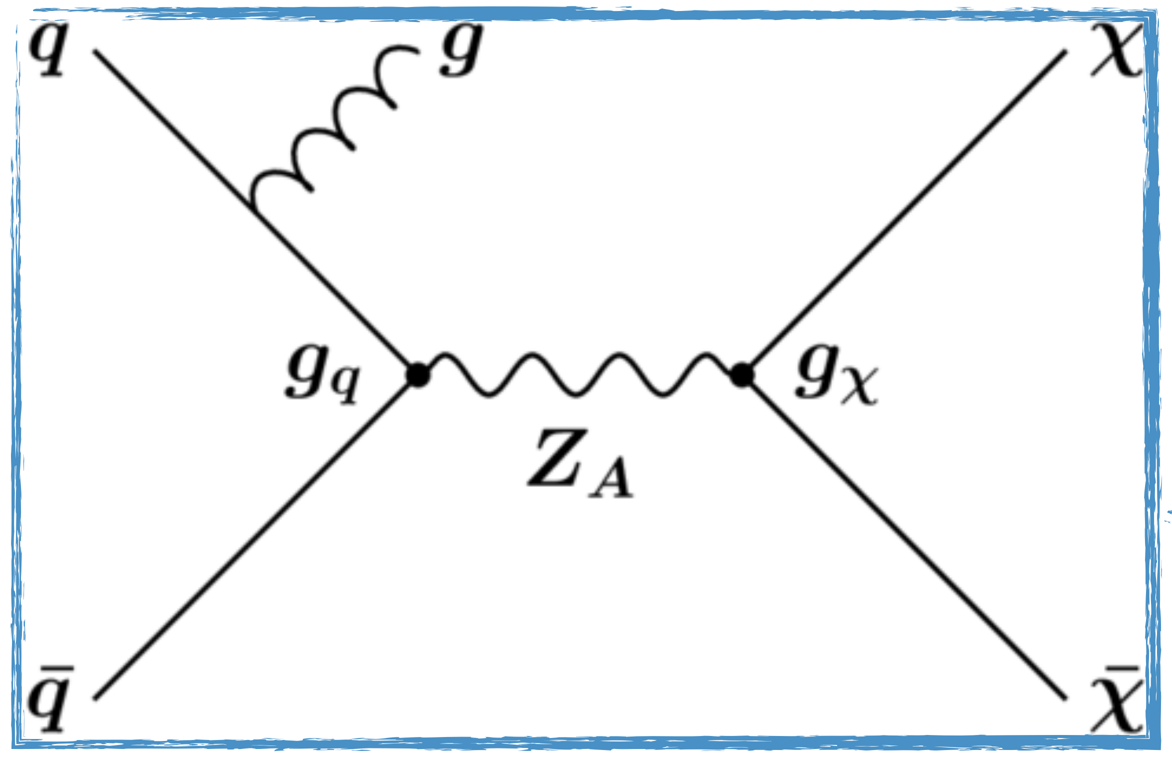
CMS DM Summary

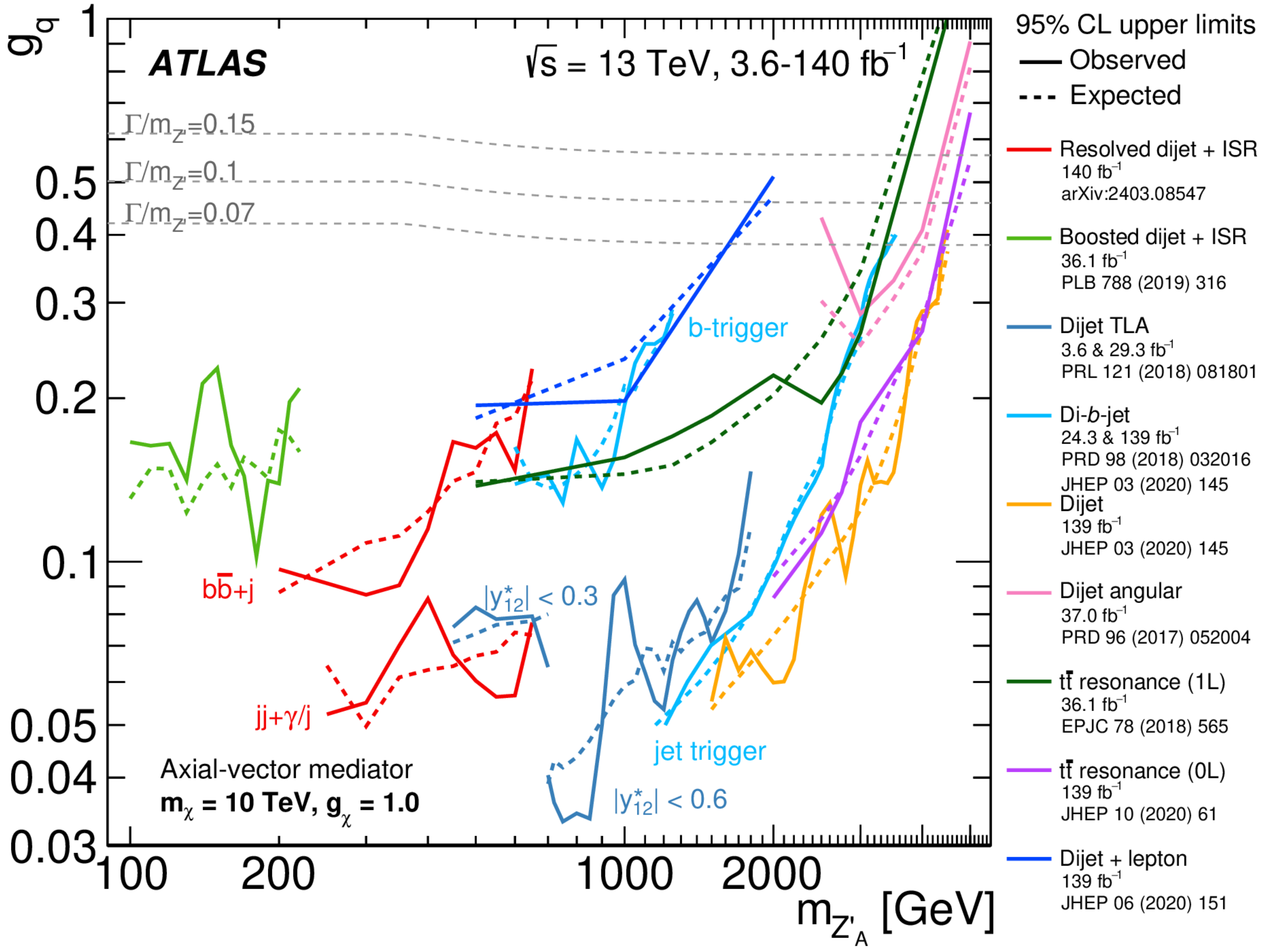


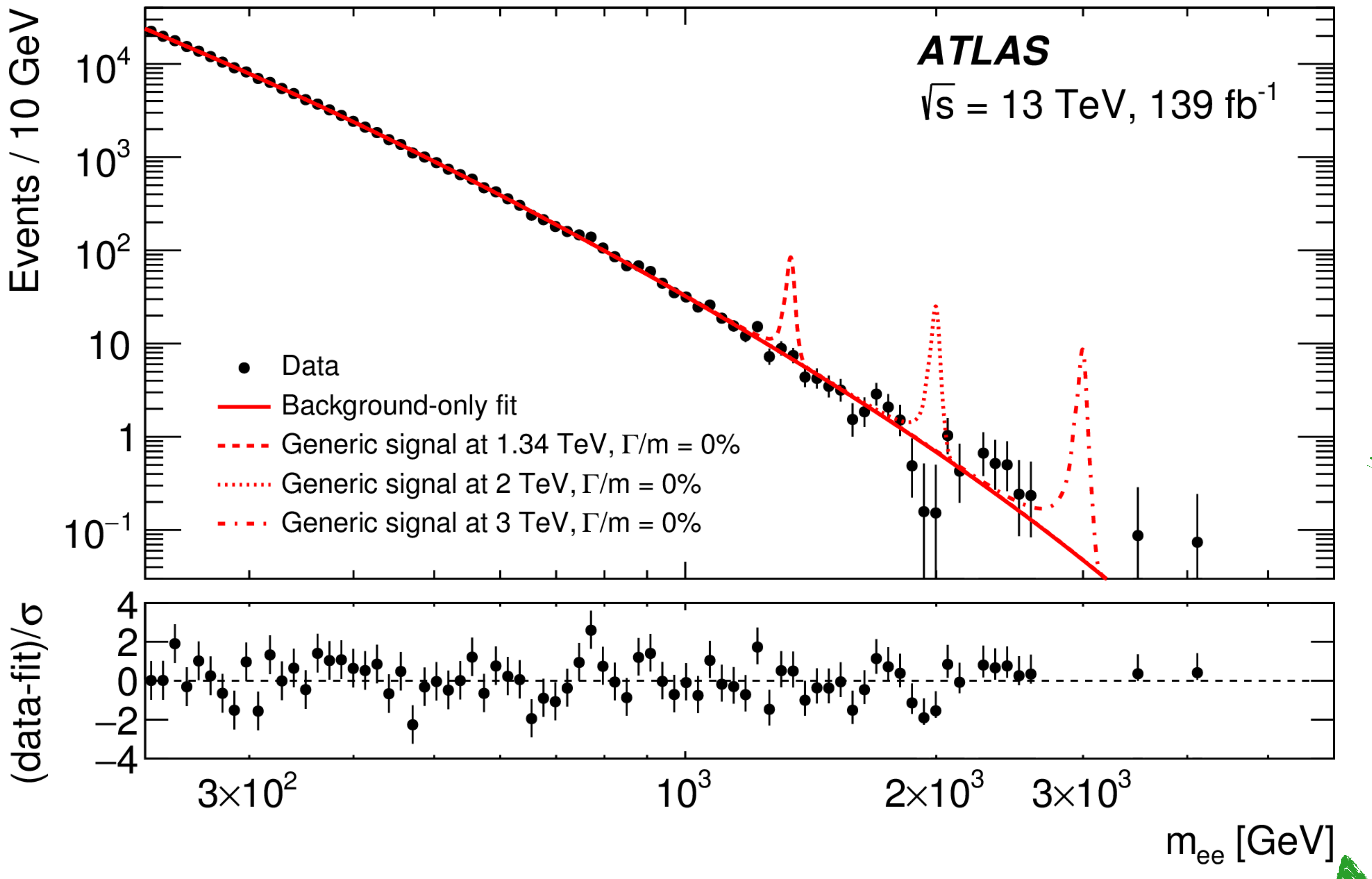


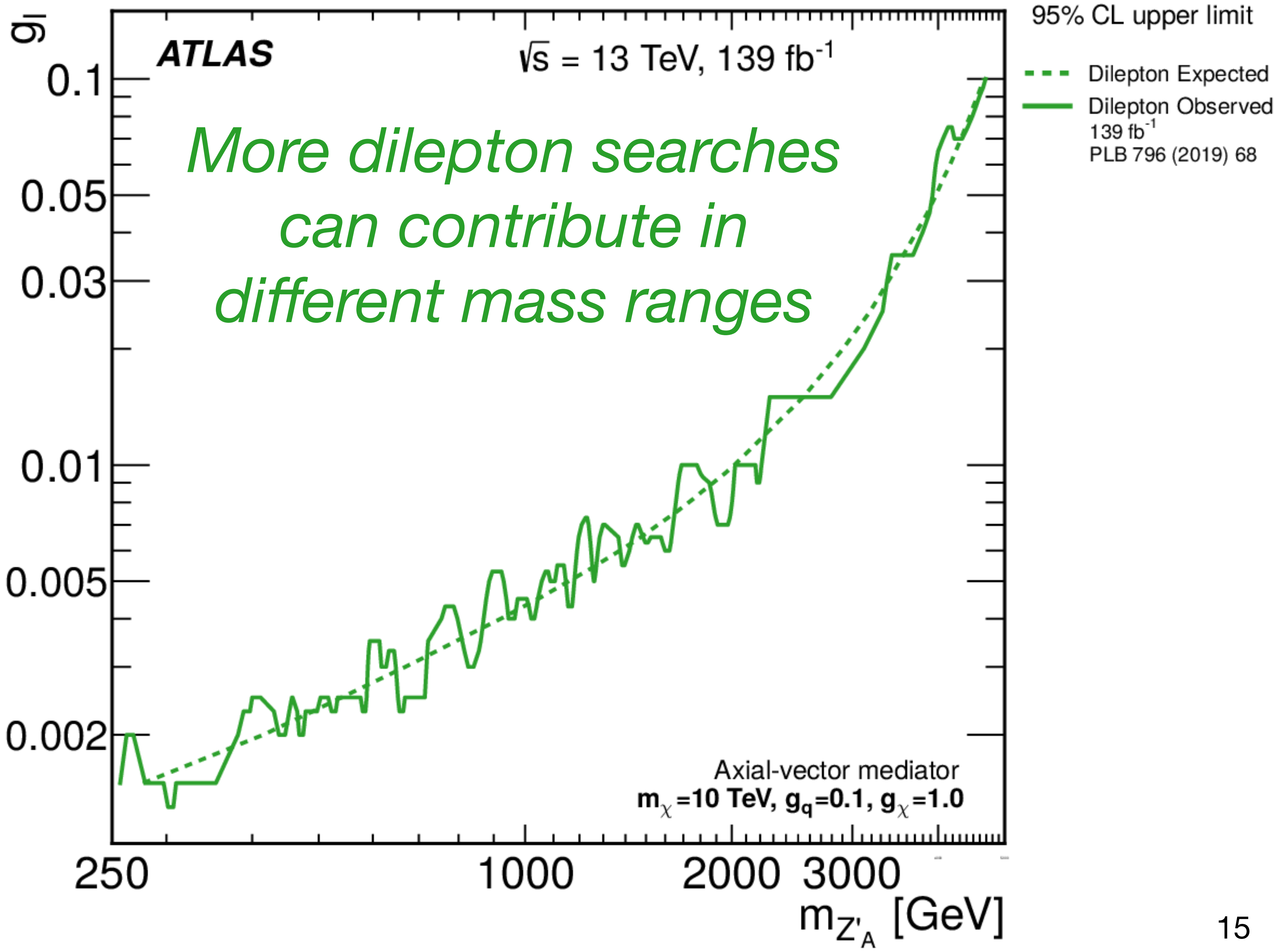
constraint also from monojet analysis

CONSTRAINTS ON MEDIATOR COUPLINGS

EXOT-2018-62

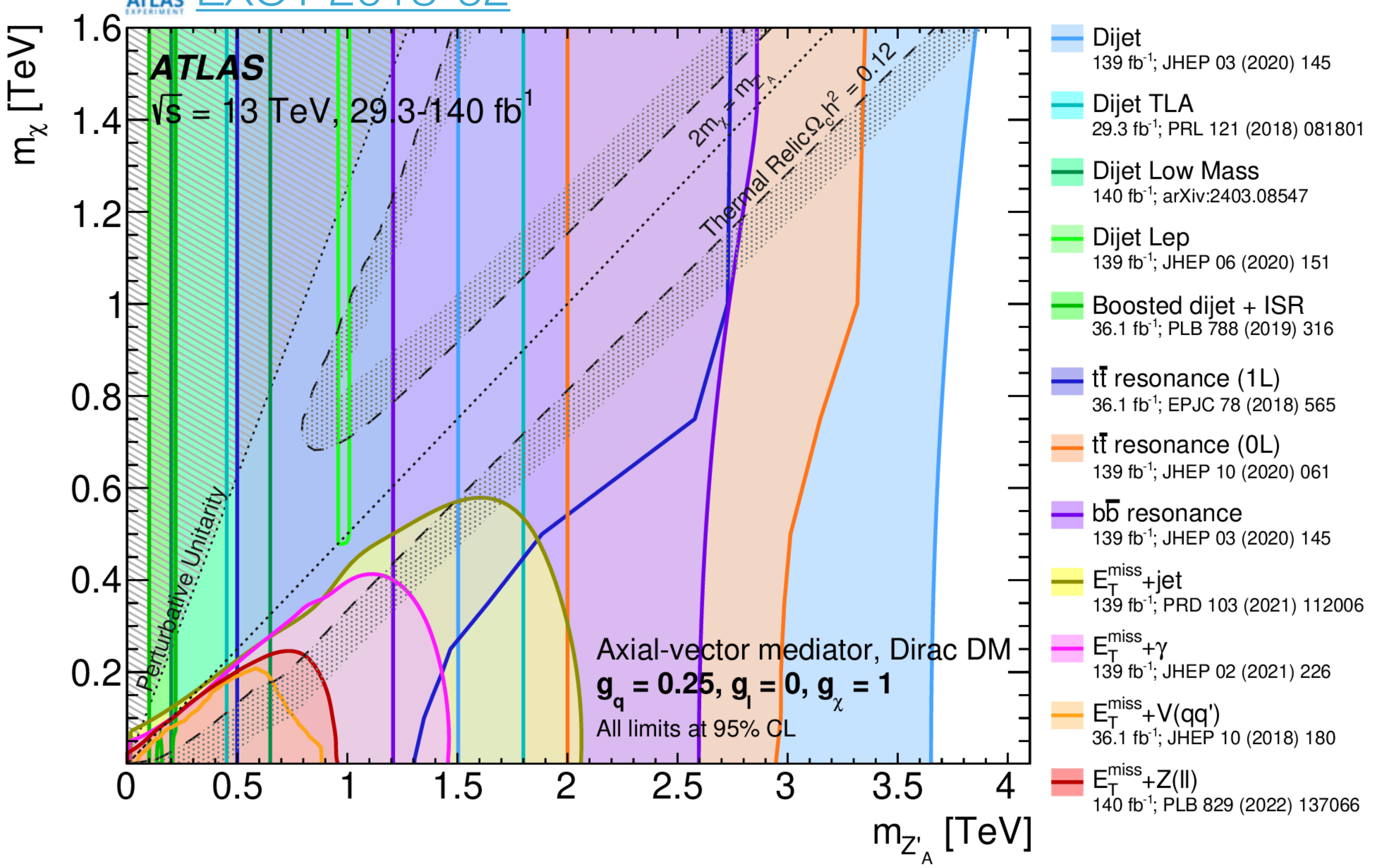






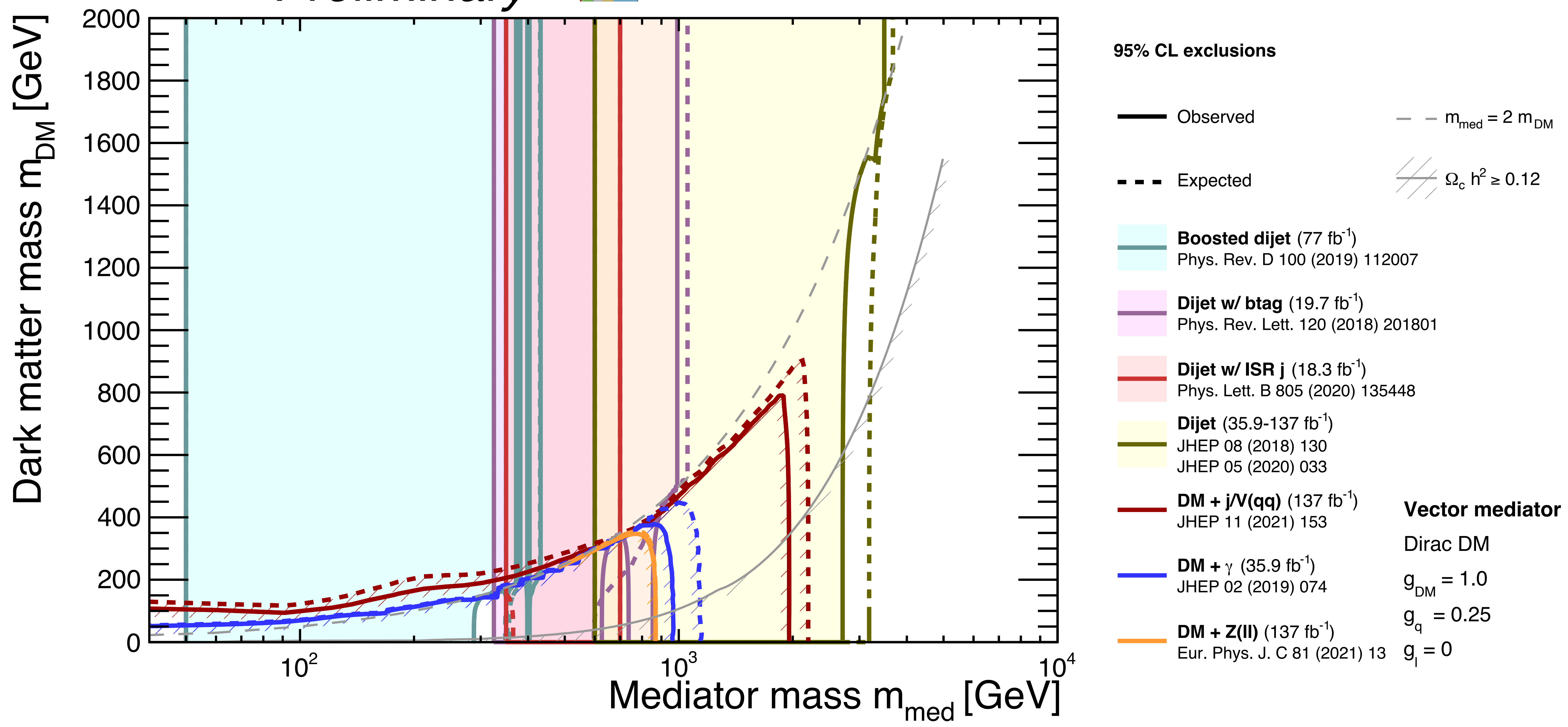
MASS-MASS PLANE EXPLORATION

EXOT-2018-62



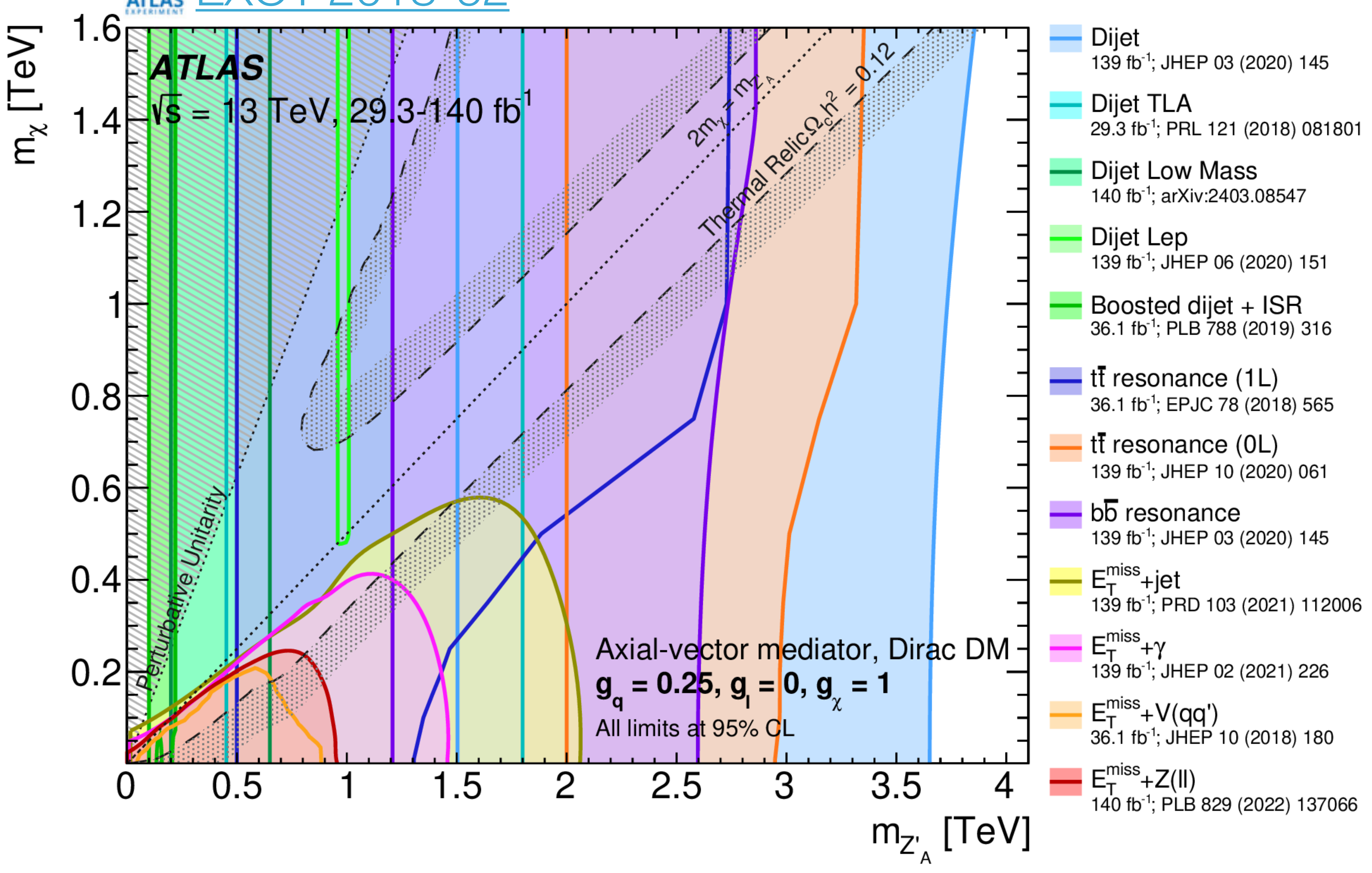
during the LHC Run 2 a large range of the m_χ-m_{Med} plane has been explored

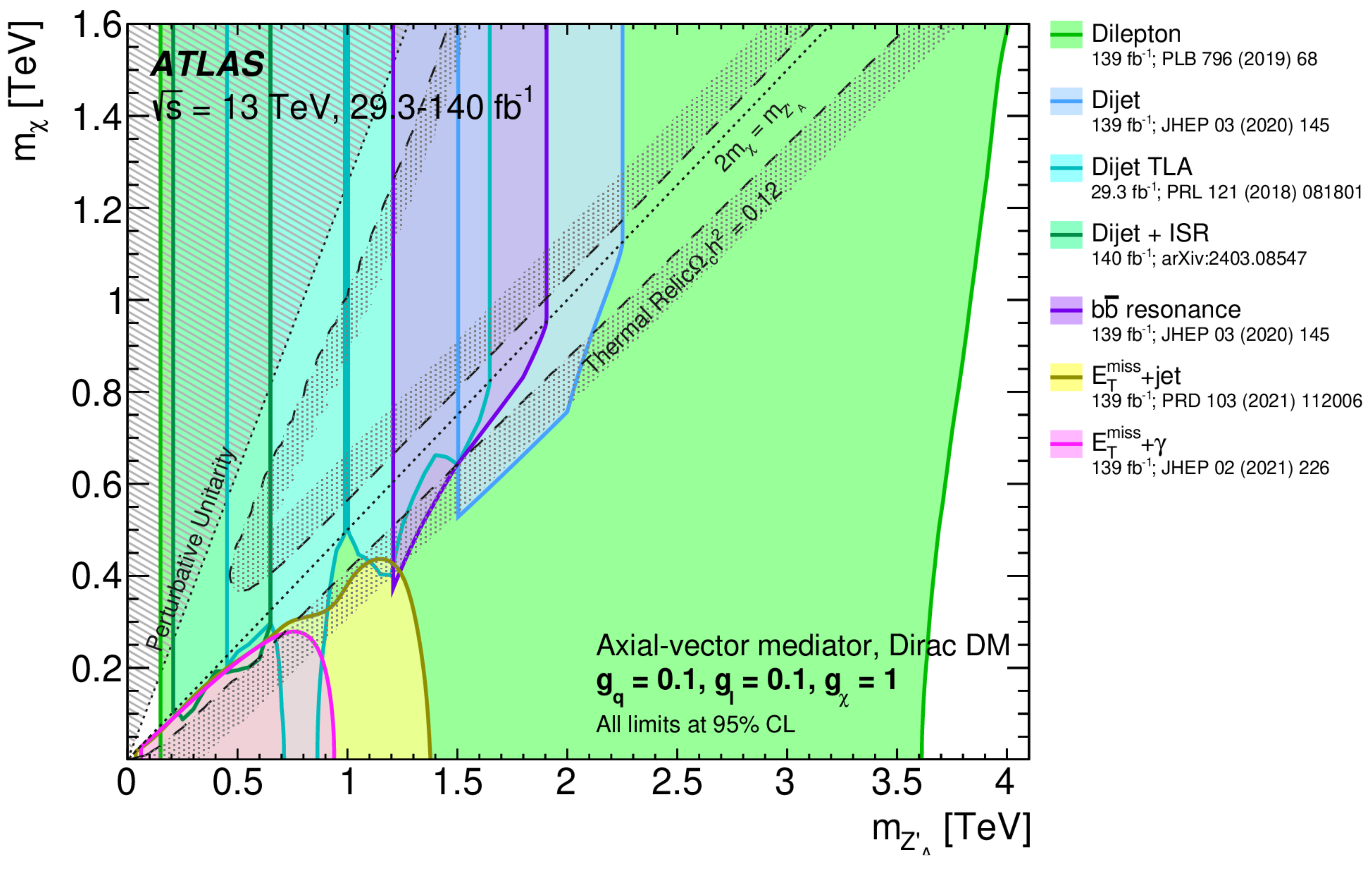
CMS DM Summary



MASS-MASS PLANE EXPLORATION

[EXOT-2018-62]

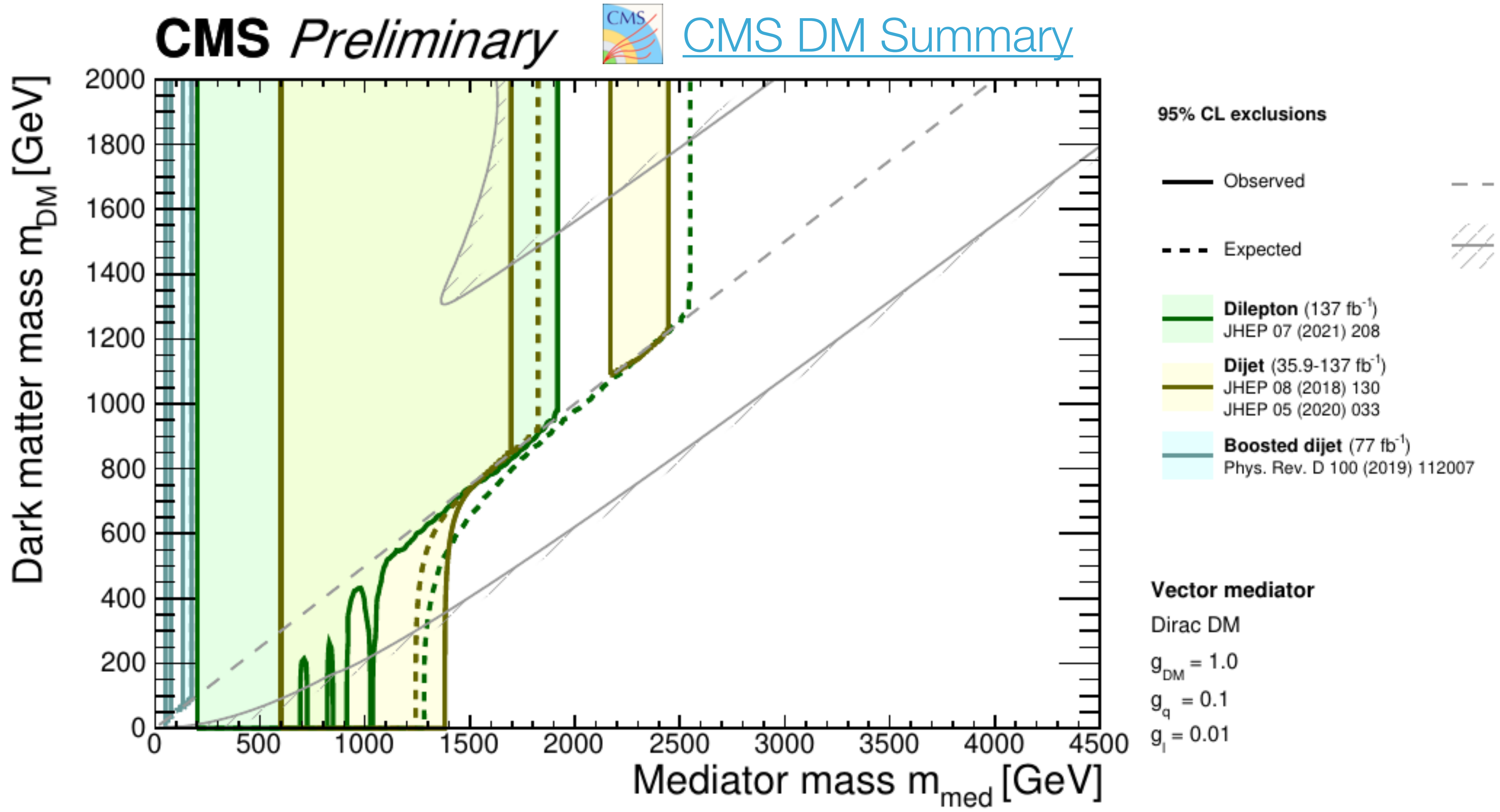




during the LHC Run 2 a large range of the m_χ-m_{Med} plane has been explored

things are changing, as soon as you change the coupling parameters

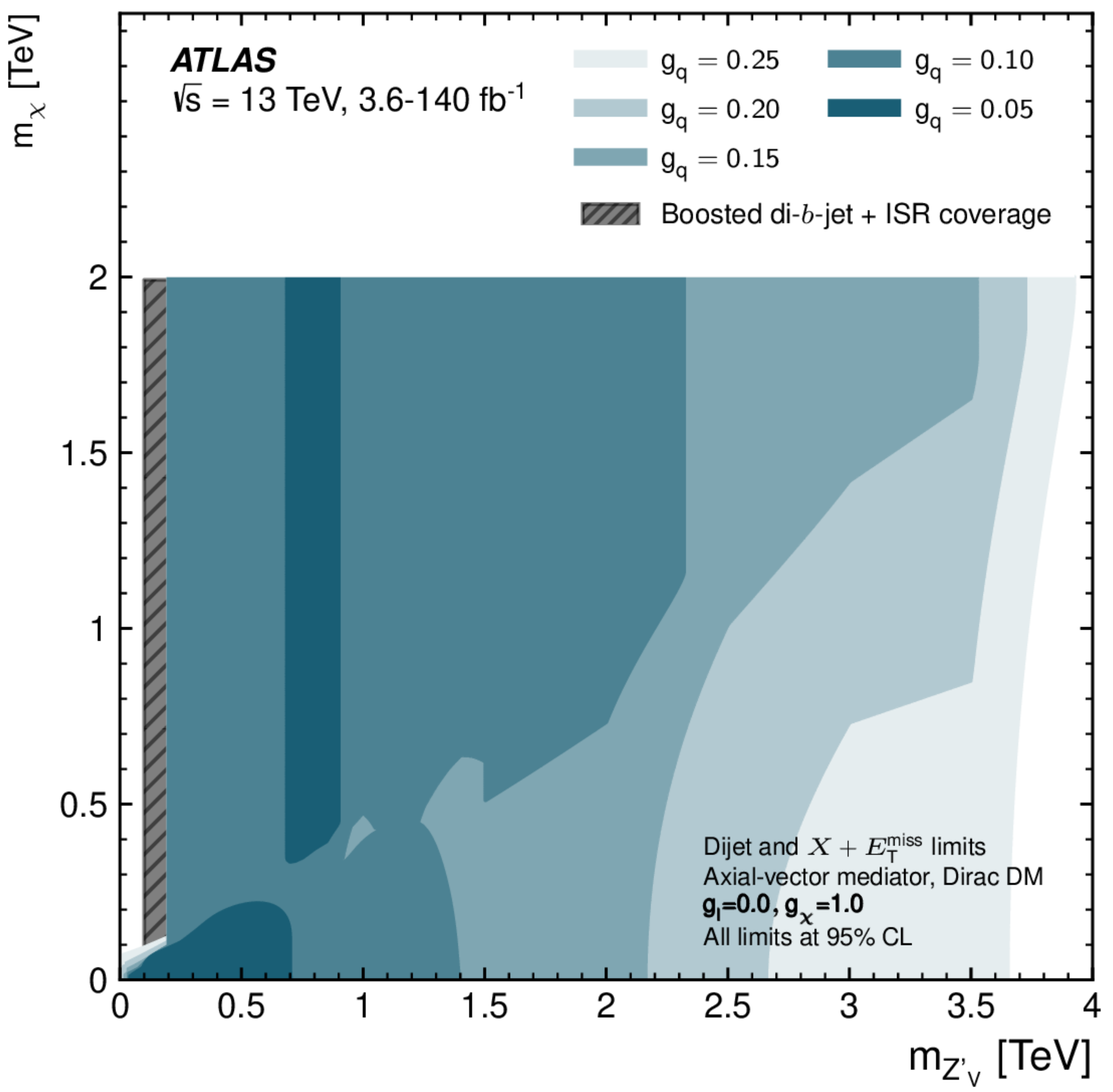
[CMS DM Summary]



MASS-MASS: HOW ARE THING EVOLVING?

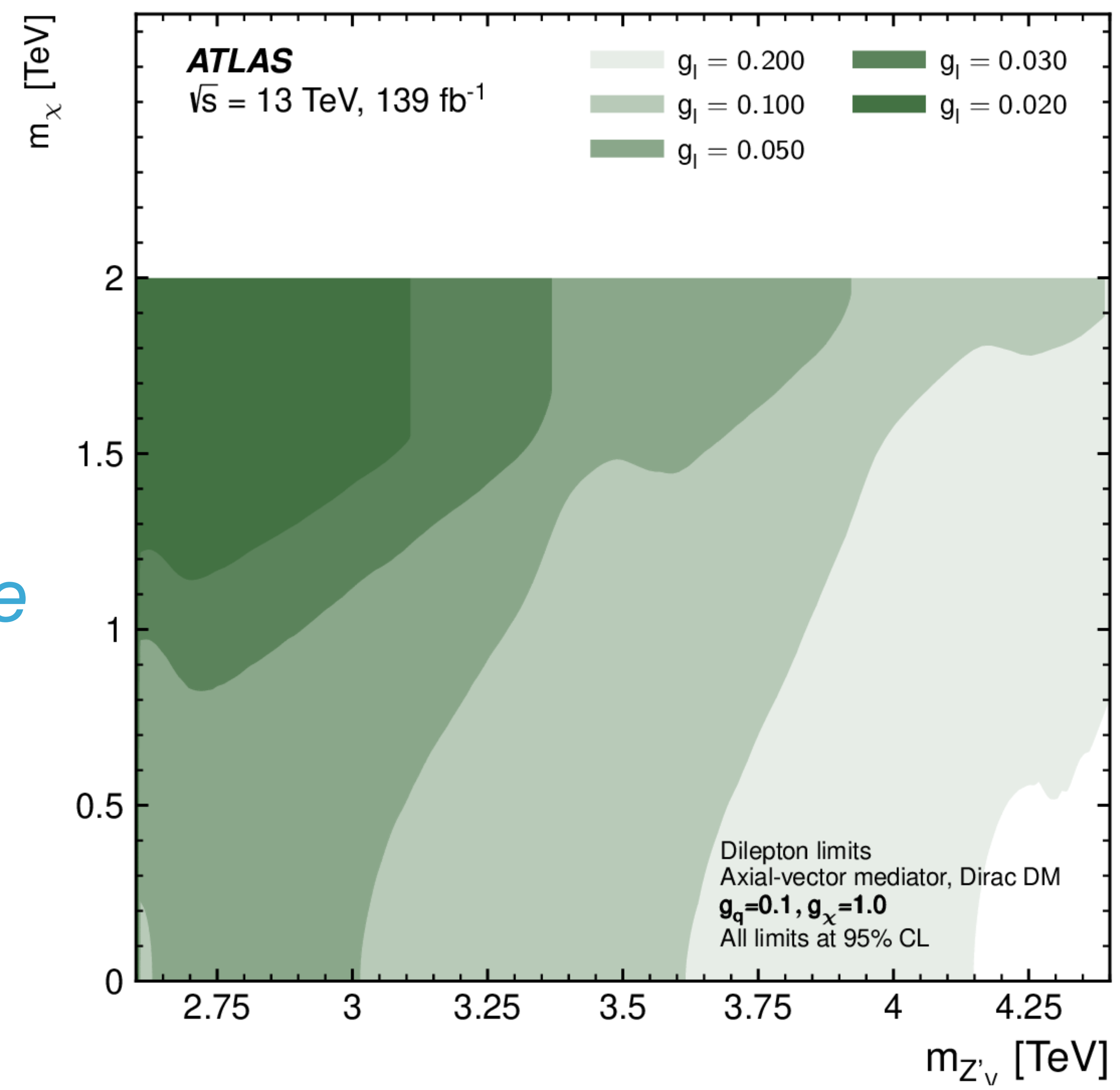
EXOT-2018-62

thanks to arXiv:2203.12035

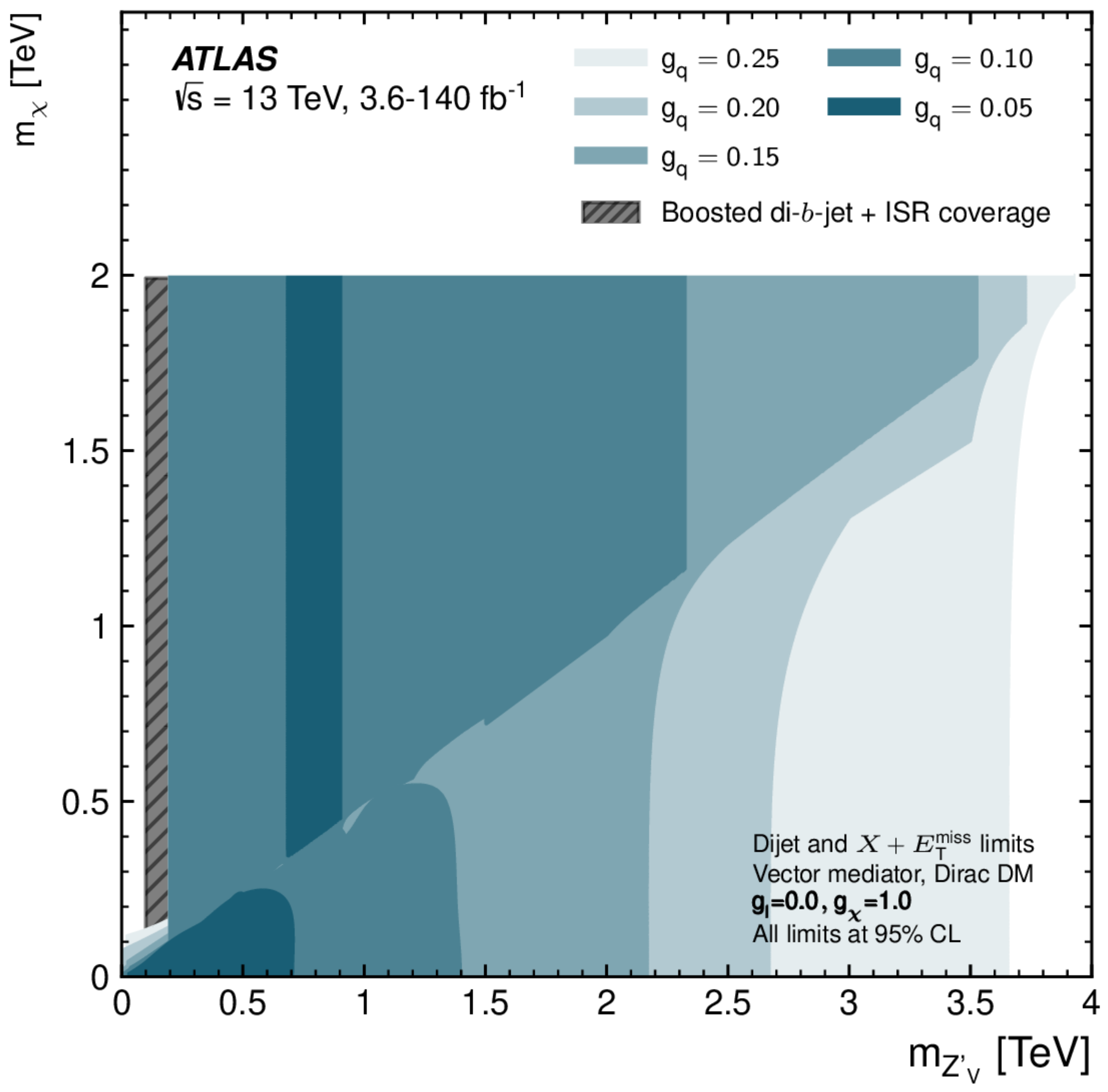


m_χ-m_{Med} plane coverage for variable couplings

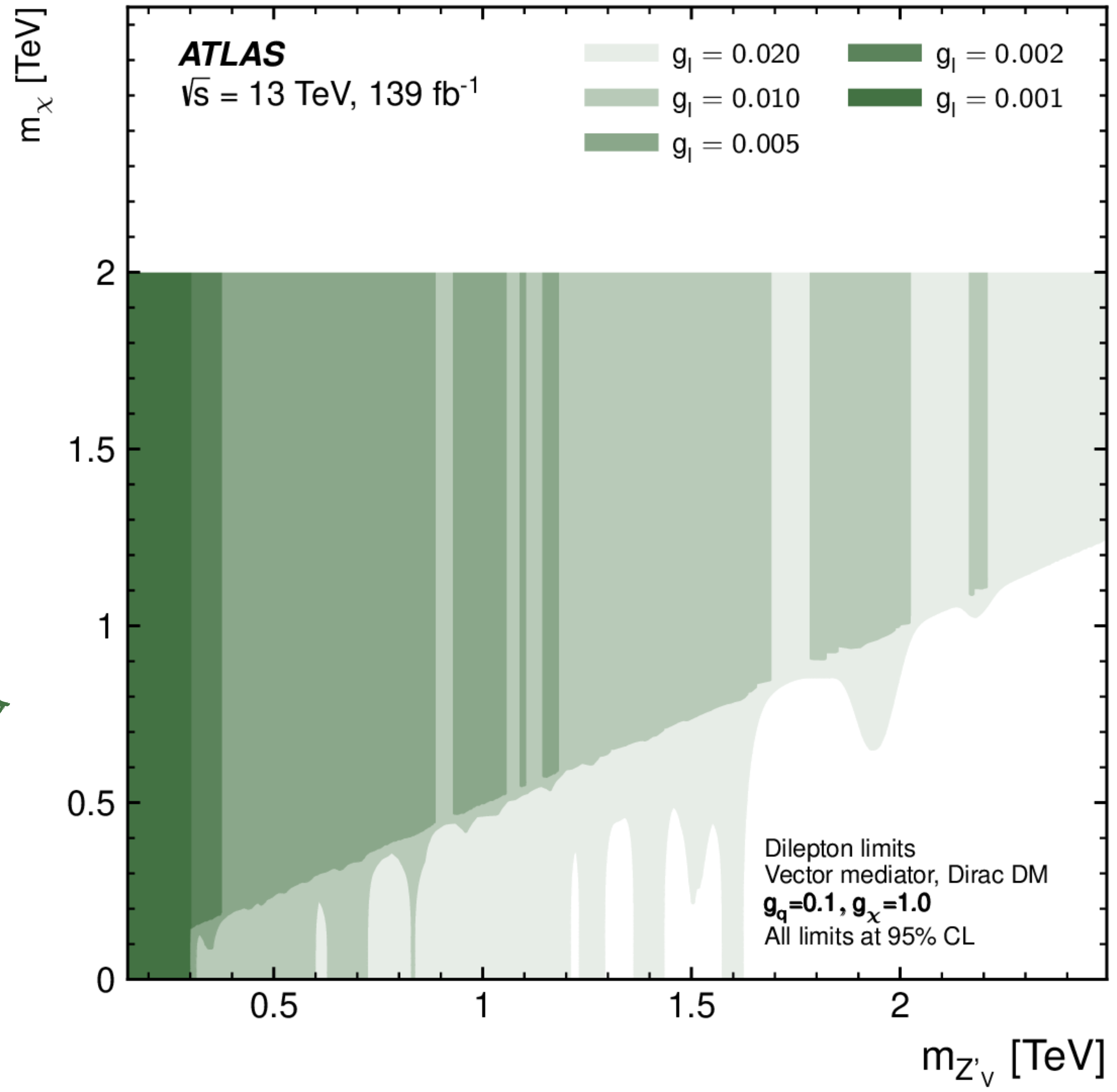
possible to appreciate sensitivity trends



hadronic dijets and X+MET



dilepton

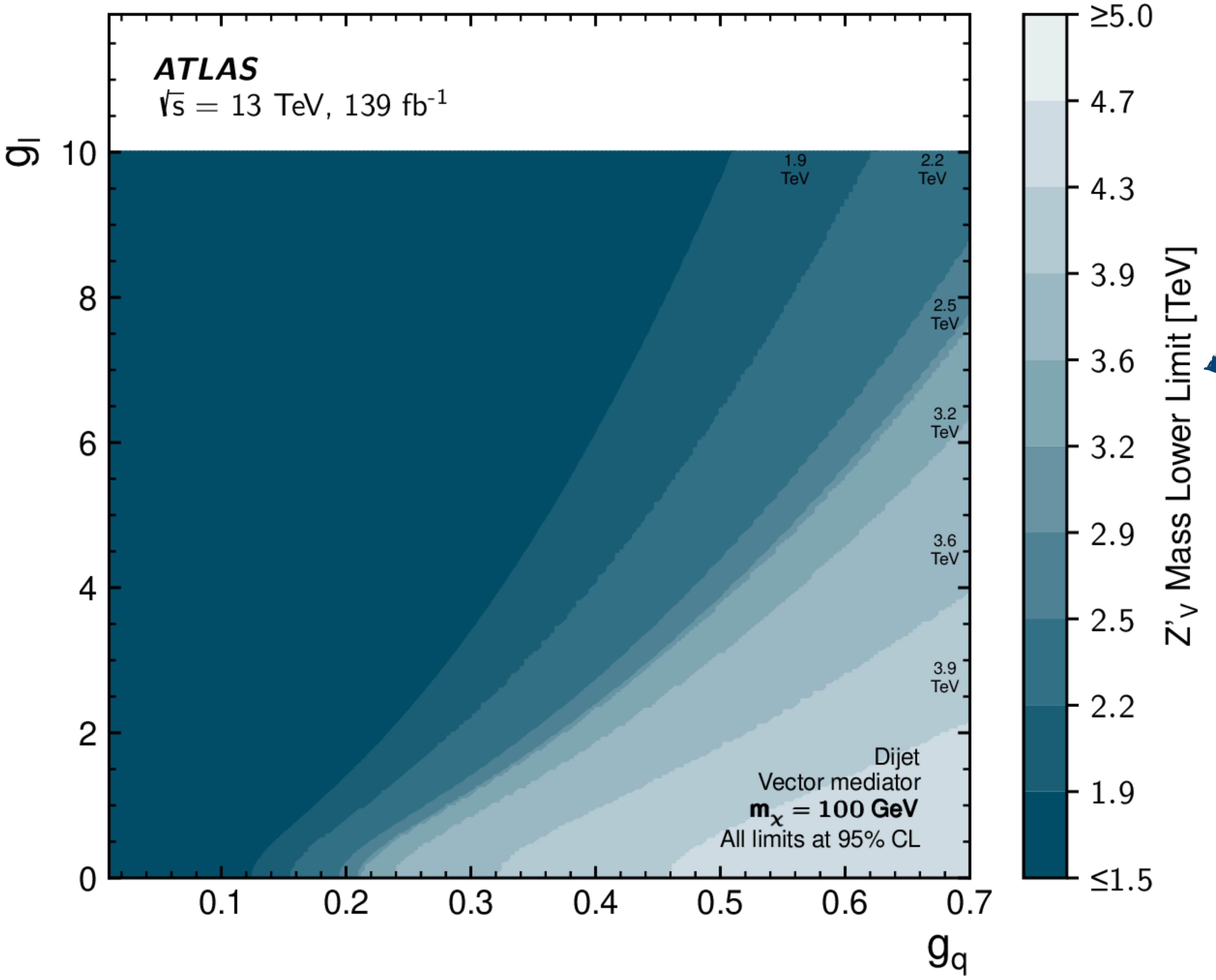


MEDIATOR MASS REACH

EXOT-2018-62

thanks to arXiv:2203.12035

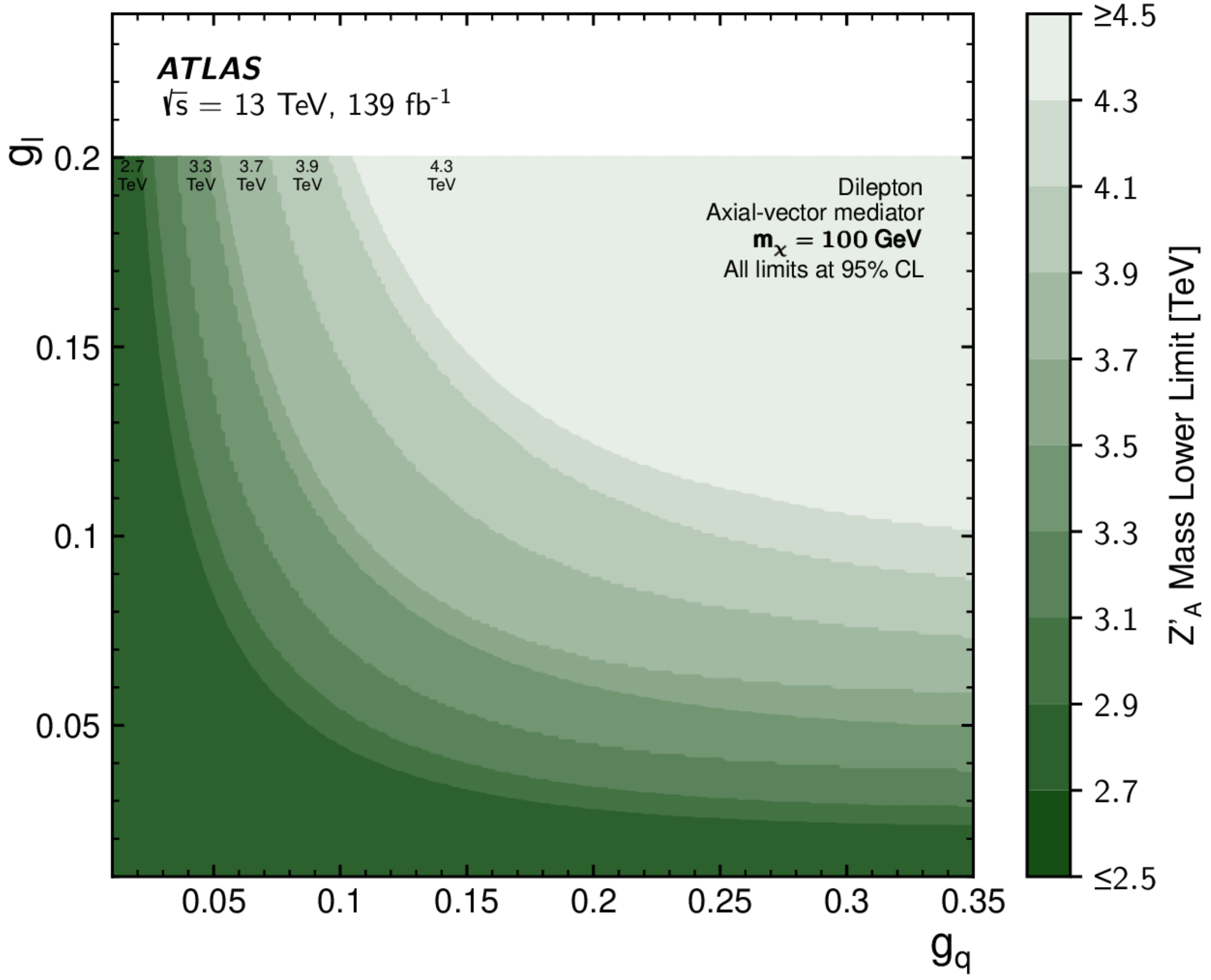
dijet searches



if g_q and g_l are varying together?

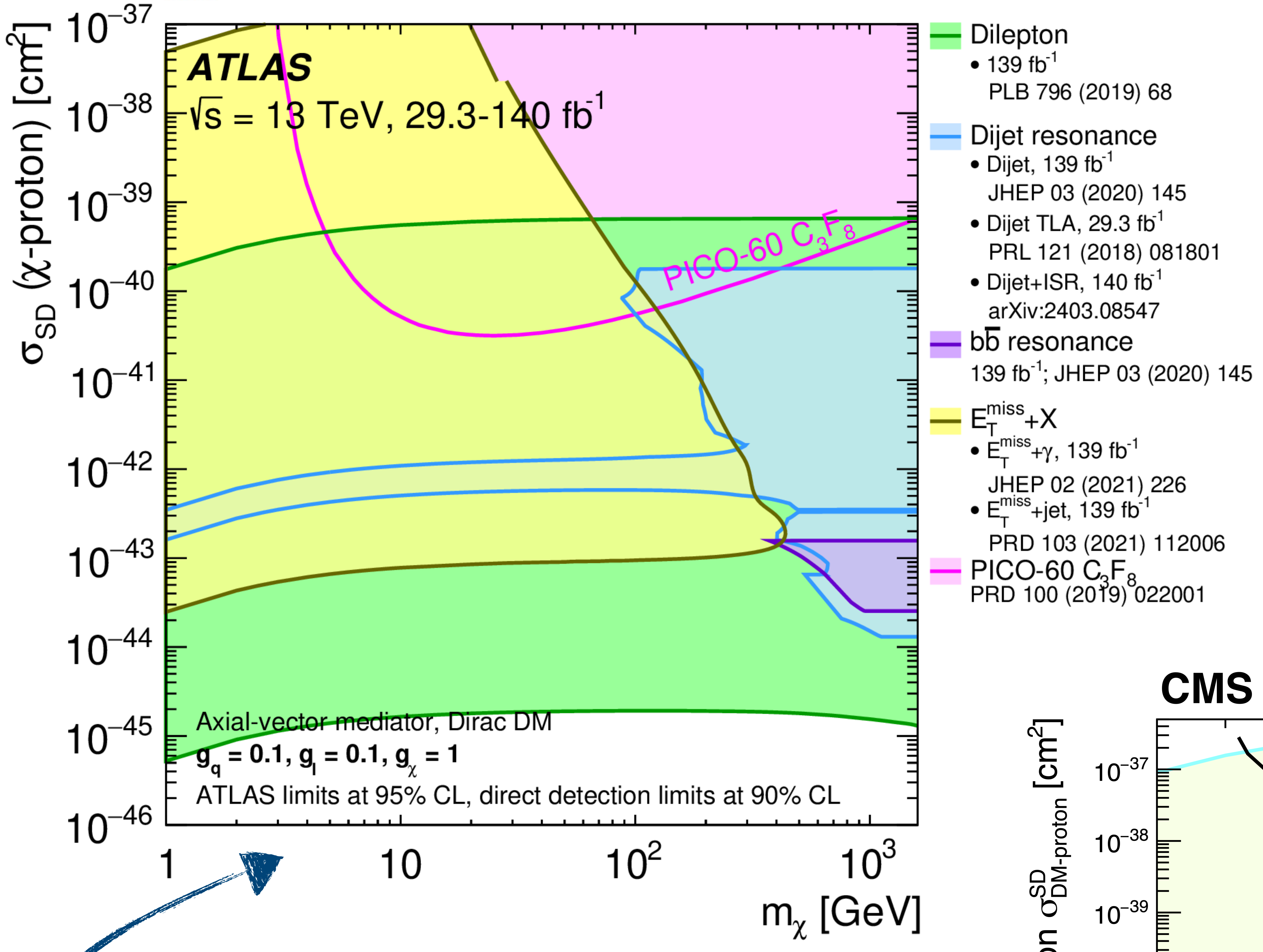
shows the lowest m_{Med} unexcluded

dilepton



DIRECT DETECTION COMPARISON

[EXOT-2018-62]



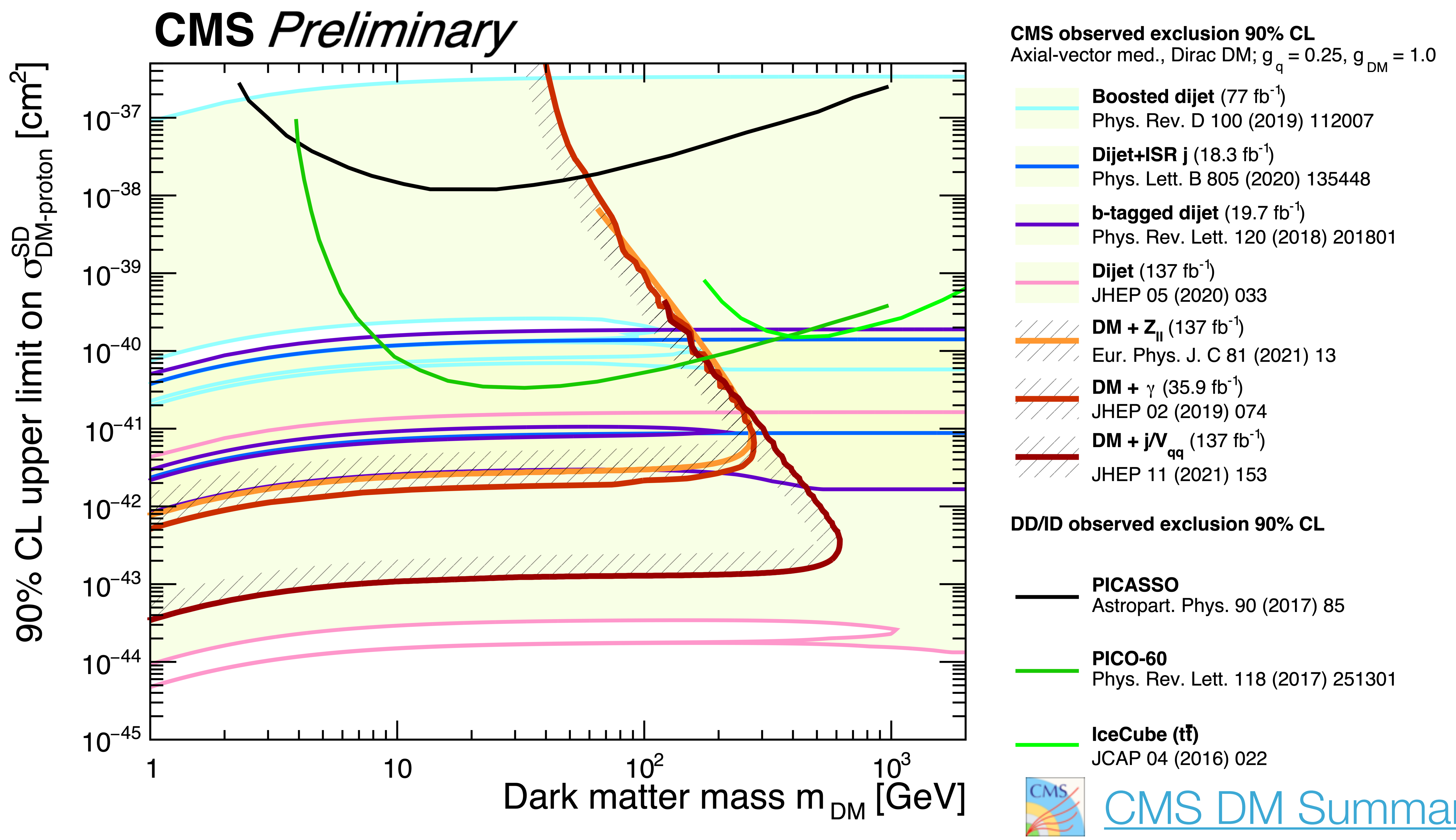
Limits on cross sections given by:

$$\sigma_{SD} = \frac{3f^2(g_q)g_\chi^2\mu_{n\chi}^2}{\pi m_{Med}^4} \qquad \sigma_{SI} = \frac{f^2(g_q)g_\chi^2\mu_{n\chi}^2}{\pi m_{Med}^4}$$

LHC searches largely exceeded Direct Detection constraints according to this models' reinterpretation

equally coupled to leptons and hadrons

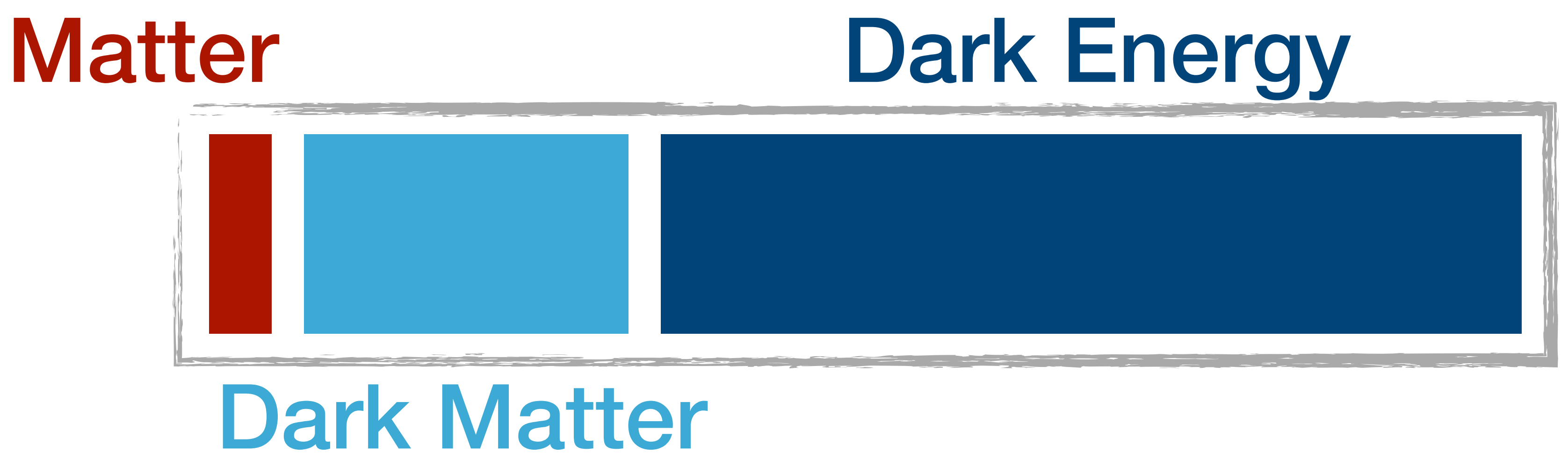
leptophobic scenario



CMS DM Summary

CONCLUSIONS

- Still a lot of things to understand about Dark Matter, unfortunately still unobserved at colliders
- Simplified models have been *guiding us* during the LHC Run 2
- Difficult to span the entire range of parameters, but we did out best
- Effort in place to make ATLAS and CMS constraints easy to reinterpret
- Maybe the LHC Run 3 can bring some good news on this topic



BACKUP

You never know what you might need