Dark photon interpretations in CMS

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Overview

Generally: What is a good benchmark?

- Easy to use by analysts, recasters
- Allows to compare all relevant searches
  - **Mass**:
    - $<< M_Z$
    - $M <\approx M_Z$
    - $M > M_Z$
  - **Production**:
    - DY,
    - Higgs,
    - radiation
  - **Lifetime**:
    - Prompt
    - displaced

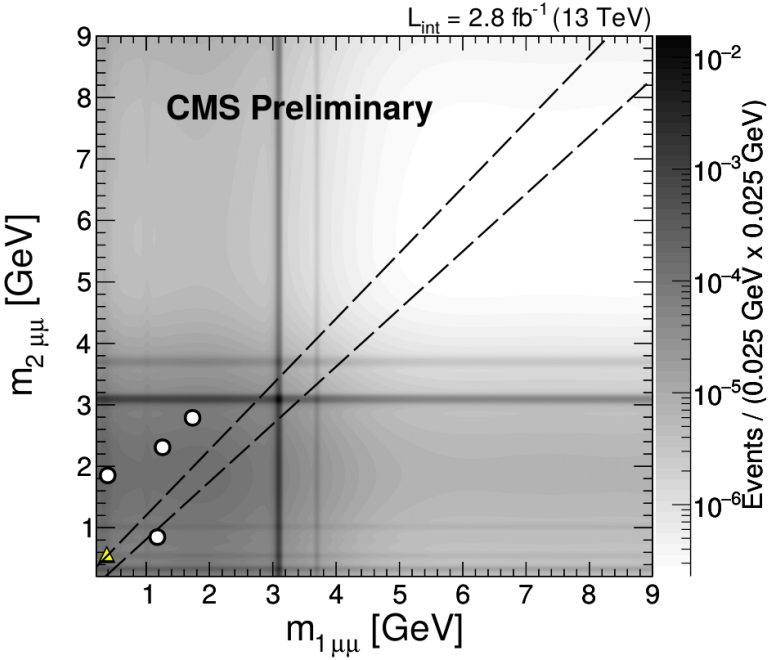
This talk: CMS-specific

- What interpretation material is provided?
- How useful is the provided information?
- Examples: Recasts of existing searches

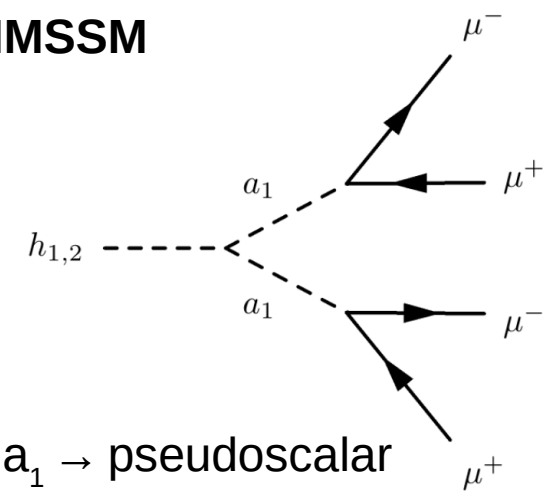
$h \rightarrow ZD\,ZD + X \rightarrow 4\mu + X$

CMS-PAS-HIG-16-035

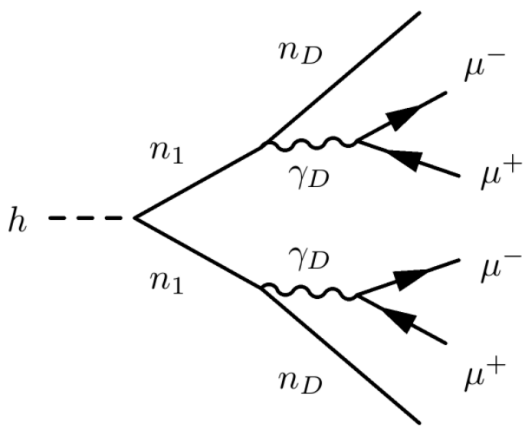
- Events with two muon pairs
- Signal has $m_{\mu\mu 1} = m_{\mu\mu 2}$
- Intepretation in SUSY scenarios
  → rather specific



NMSSM



a_1 → pseudoscalar

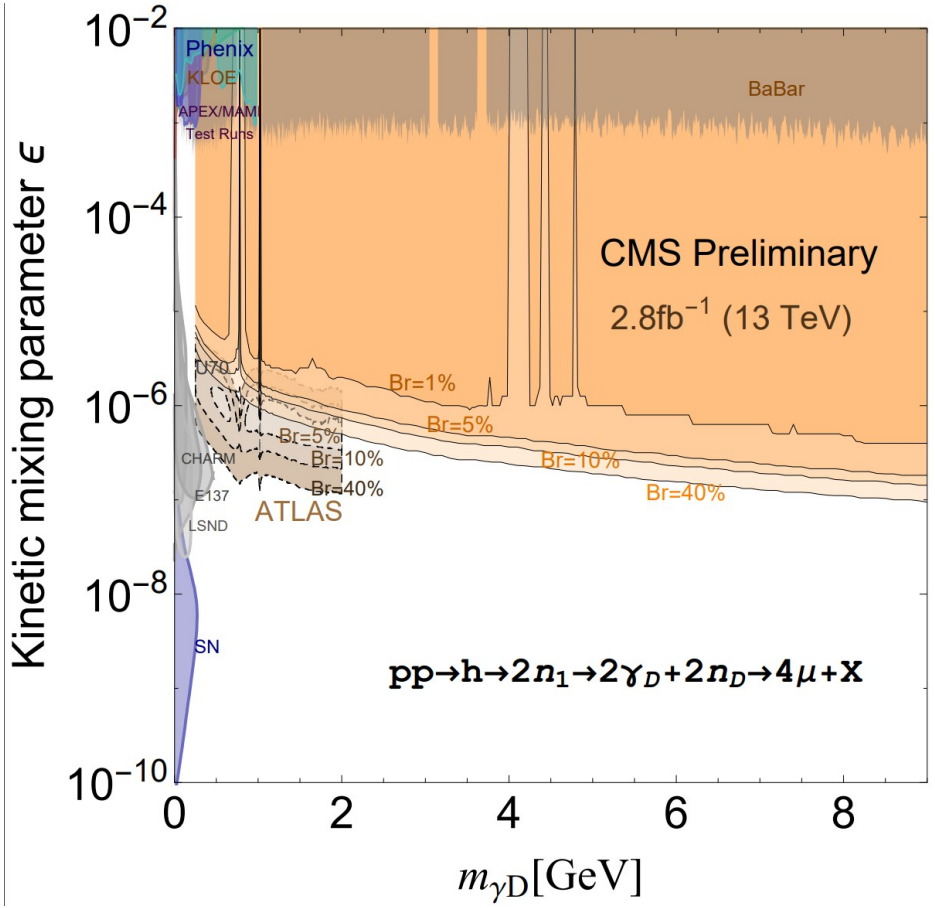


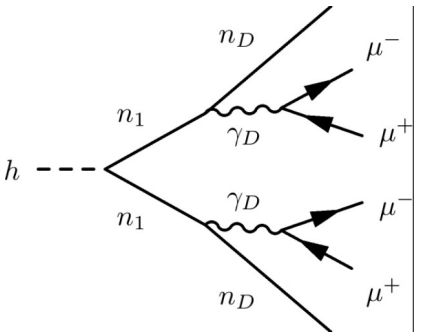
Dark SUSY

n_1 → Lightest visible neutralino
n_D → Lightest dark neutralino
γ_D → Dark photon

Model-specific limits

CMS-PAS-HIG-16-035





Topology dependence?
Not obvious for recasting

h → ZD ZD + X → 4μ + X

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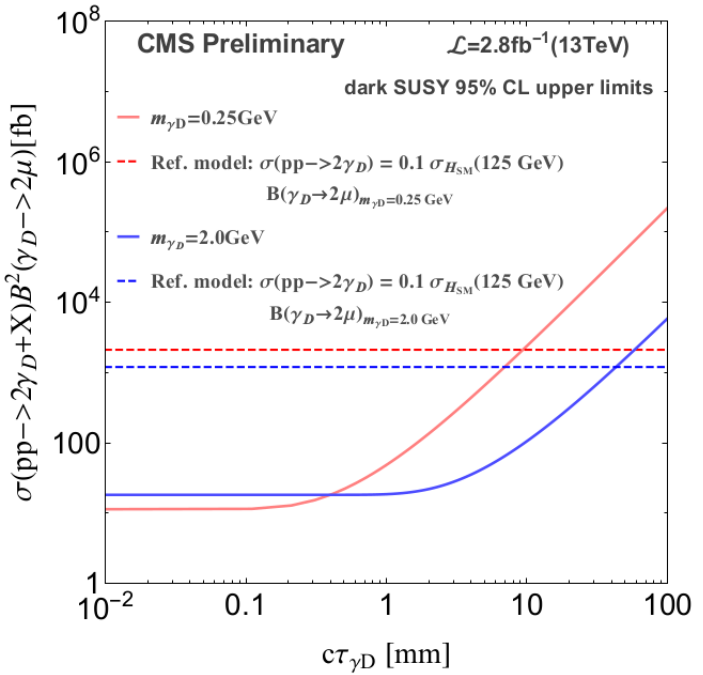
Also provide model independent limits

reported value for the ratio also includes its variation over all of the benchmark points. This model independent limit on $\sigma(\mathrm{pp} \to 2\mathrm{a} + \mathrm{X}) \times \mathcal{B}^2(\mathrm{a} \to 2\mu) \times \alpha_{\mathrm{gen}}$ is 1.7 fb and it is constant in the entire m_a range, as a consequence of having a constant $\epsilon_{\mathrm{full}}/\alpha_{\mathrm{gen}}$ for each signal mass.

Also as a function of life-time

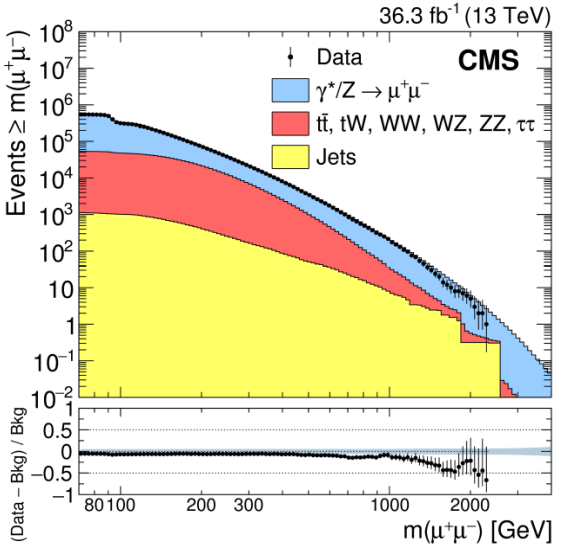
→ Should be recastable, but need to take into account acceptance effects

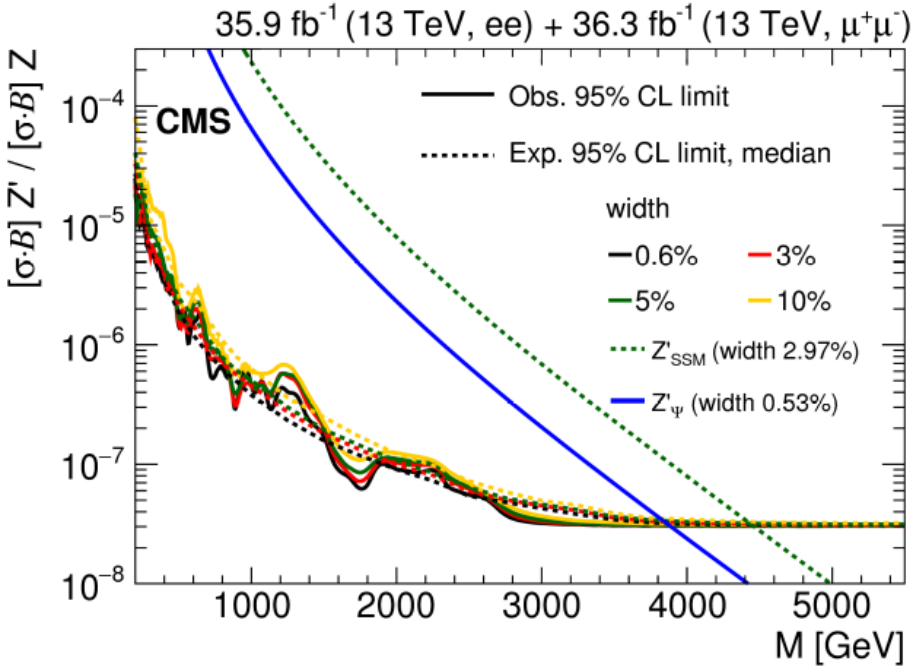


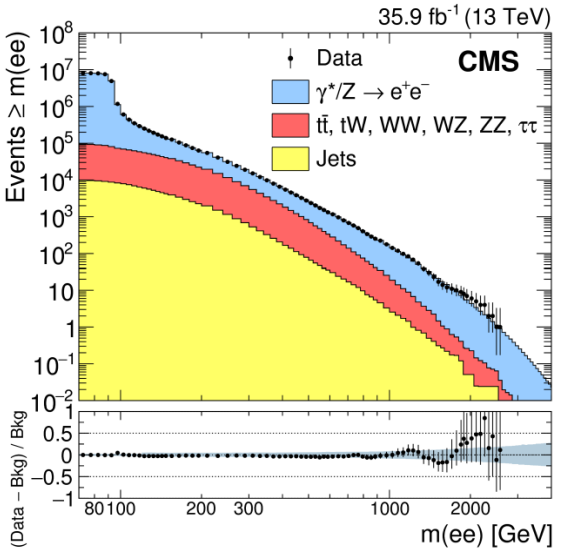
High-mass dilepton

Submitted to JHEP
arxiv:1803.06292

- Bump hunt in di-electron/muon mass spectrum
- XS*BR limits as a function of mediator mass for different widths
- Resonance mass range between 200 GeV to > 5 TeV





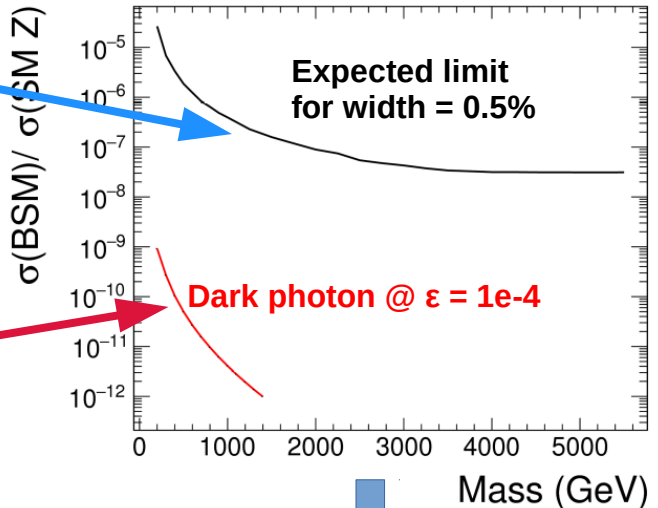


Recasting dilepton in minimal dark photon model

Easy!
Calculate signal XS and compare to XS limit

```
import HAHM_variableMW_v3_UFO

generate p p > zp > mu+ mu-
output output_darkphoton -nojpeg
launch
/path/to/run_card.dat
set epsilon 1e-4           # arbitrary
set kap 1e-20            # decouple scalar
set mhsinput 99999     # decouple scalar
set wzp auto
set mzdinput scan:range(200,1500,100)
```



UFO from arXiv:1412.0018

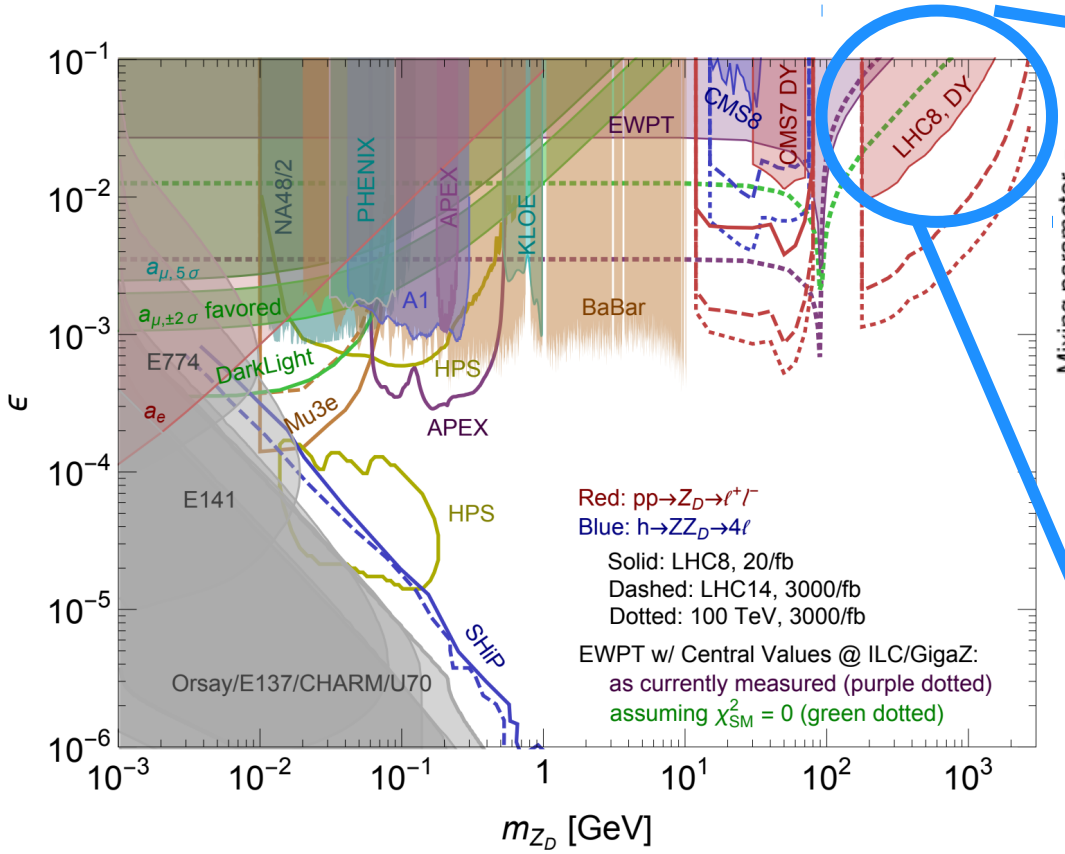
Illuminating Dark Photons with High-Energy Colliders

David Curtin,[a] Rouven Essig,[b] Stefania Gori,[c] and Jessie Shelton[d]

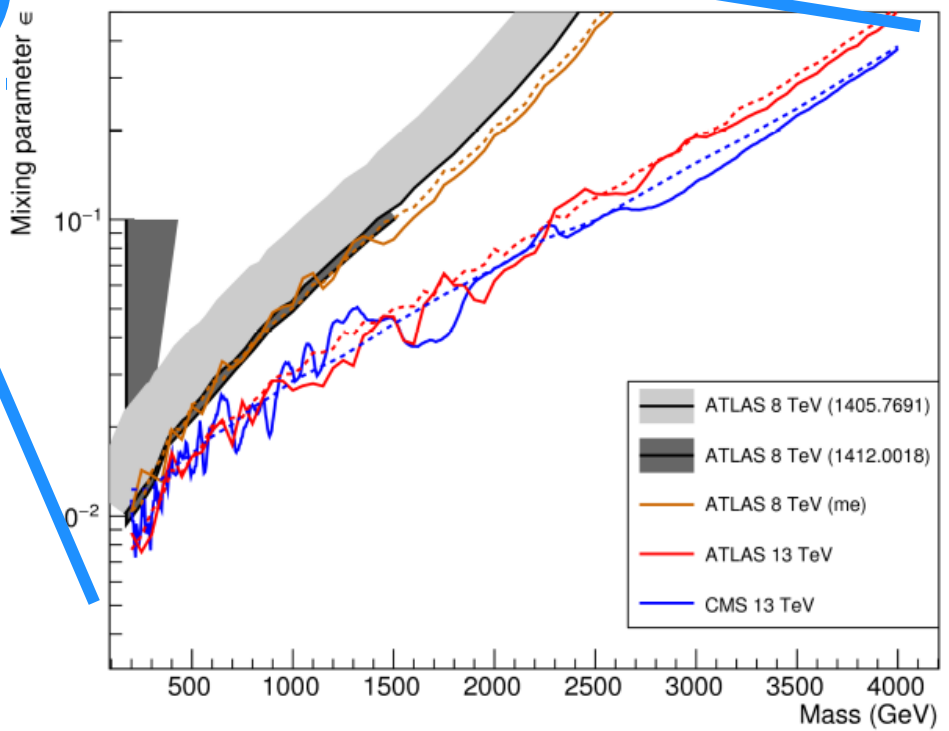
$$\mathcal{L} \subset -\frac{1}{4}\hat{B}_{\mu\nu}\hat{B}^{\mu\nu} - \frac{1}{4}\hat{Z}_{D\mu\nu}\hat{Z}_D^{\mu\nu} + \frac{1}{2}\frac{\epsilon}{\cos\theta}\hat{Z}_{D\mu\nu}\hat{B}^{\mu\nu} + \frac{1}{2}m_{D,0}^2\hat{Z}_D^{\mu}\hat{Z}_{D\mu}$$

$\varepsilon_{excluded} = 1e\text{-}4 * (\sigma_{excluded} / \sigma_{signal})^{0.5}$

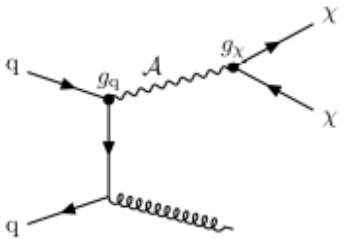
Recasting dilepton in minimal dark photon model



Result (assuming BR(inv) = 0)

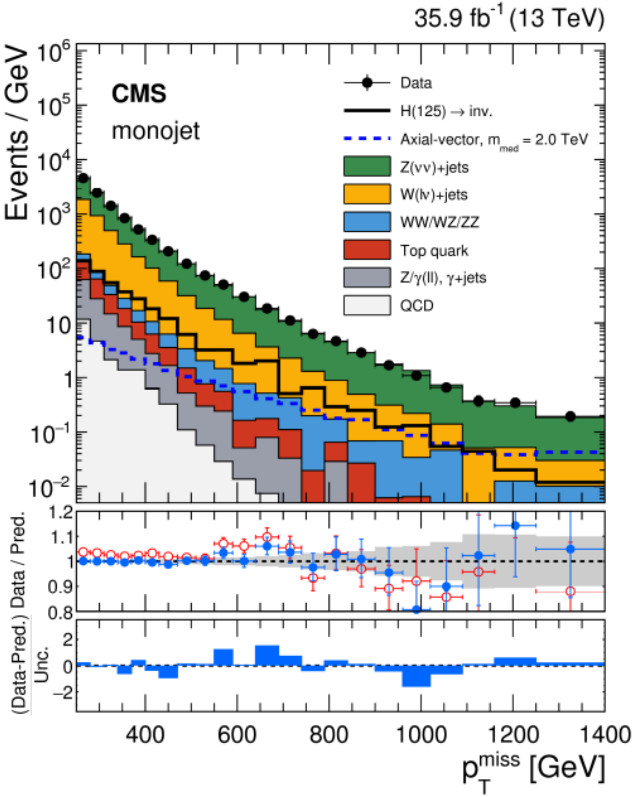


Monojet



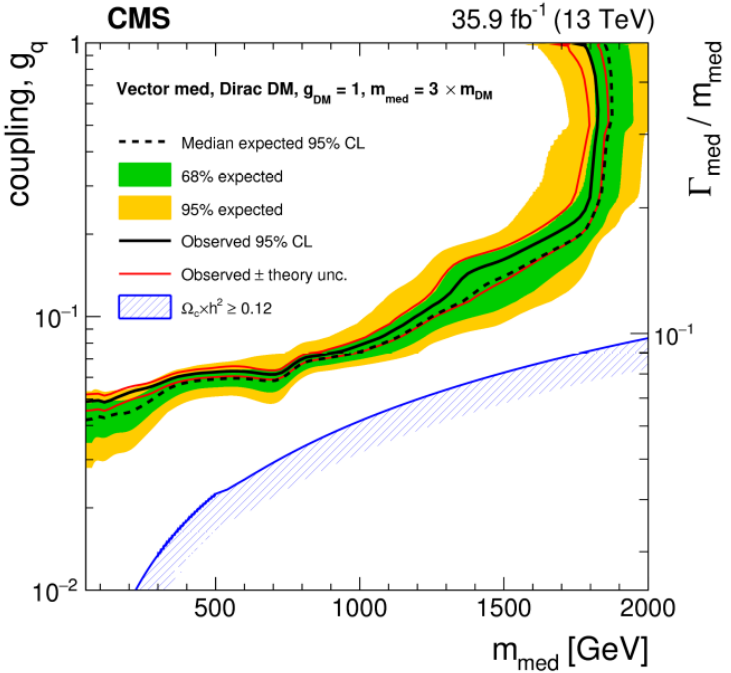
- Search for DM in jet+MET events
- Interpretation in DMWG simplified models
- **Good**:
  - DMWG vector mediator ≈ dark photon
- **Practical hurdles:**
  - Couplings non-uniformly different: g_q, g_l independent and not charge dependent

    → Different BR(Mediator → SM)
  - Large BR(Mediator → DM)



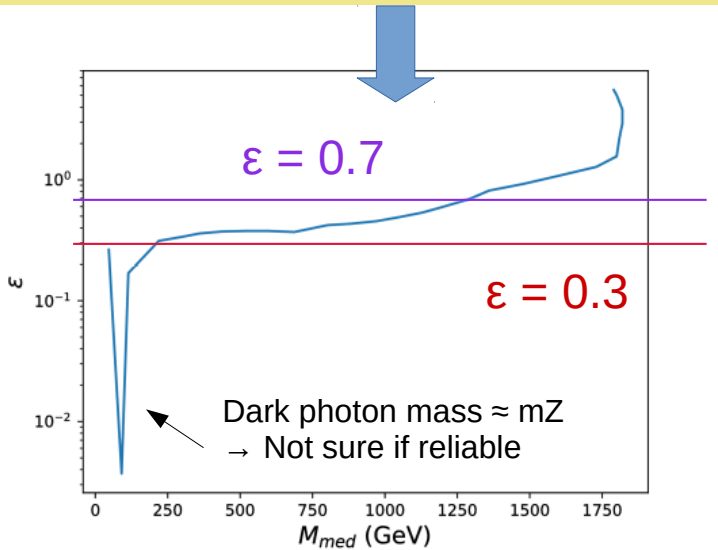
Recasting monojet

Way around: Use provided coupling limits



Method:

1) Calculate DMSimp XS for (Mmed, gq)
   generate p p > y1
2) Calculate Dark photon XS for Mmed
   generate p p > zd
3) Find ε for which dark photon XS = DMSimp XS



Assumes BR(inv) ≈ 1!

Summary

- Dark photon interpretations are case-by-case → no unified strategy
- Reinterpretation can work, but needs the right material
- **Examples:**
  - Higgs → dark photons
    - Signal model not very general → Direct recast hard
    - But: model independent limits
  - High mass dilepton, monojet:
    - Recast based on XS limits or DMSimp → relatively easy
    - Dependance on BR(inv)!
  - Agnostic as to what model should be used, but we love UFO's!

- More dedicated analysis in the pipeline → Let's be prepared!