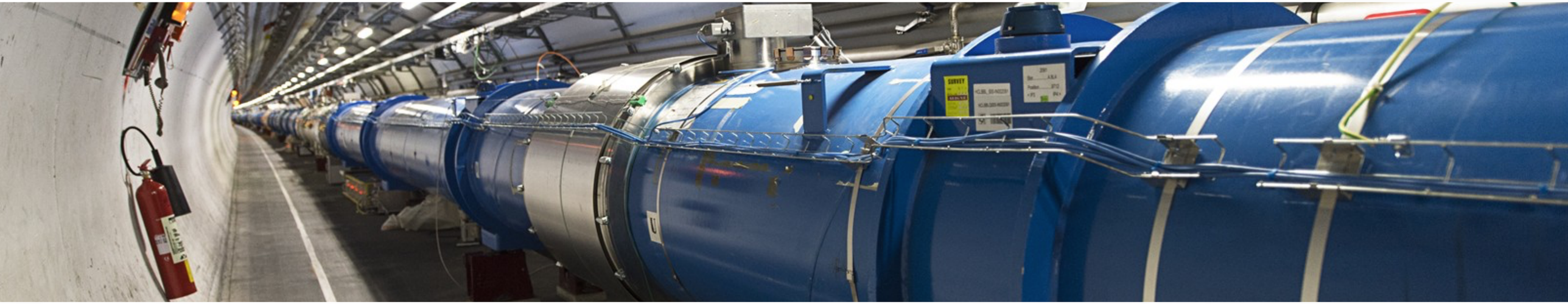


Generic Dark Matter Searches @ 13 TeV

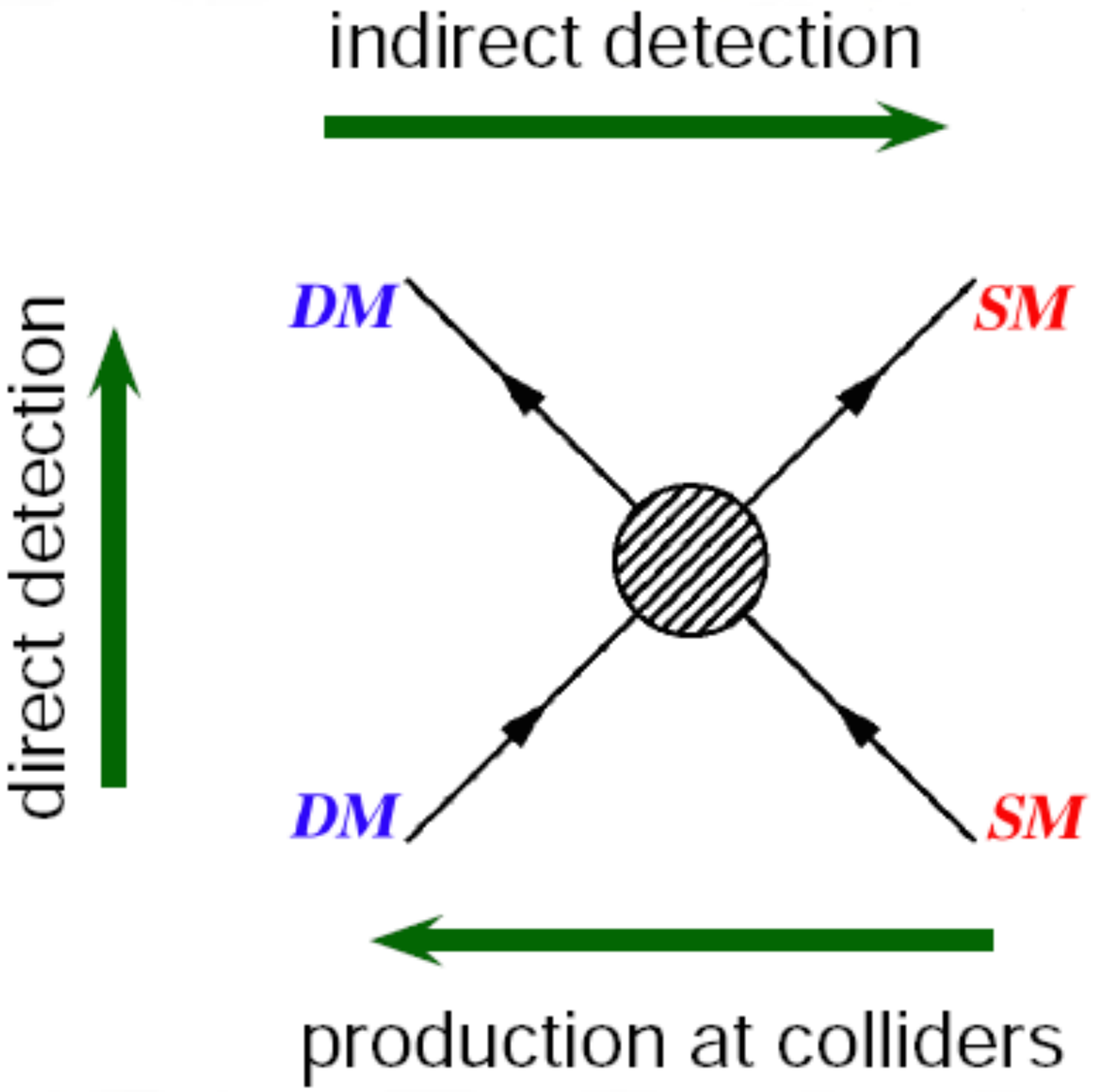
Matteo Cremonesi

FNAL

On behalf of the **ATLAS** and **CMS** Collaborations

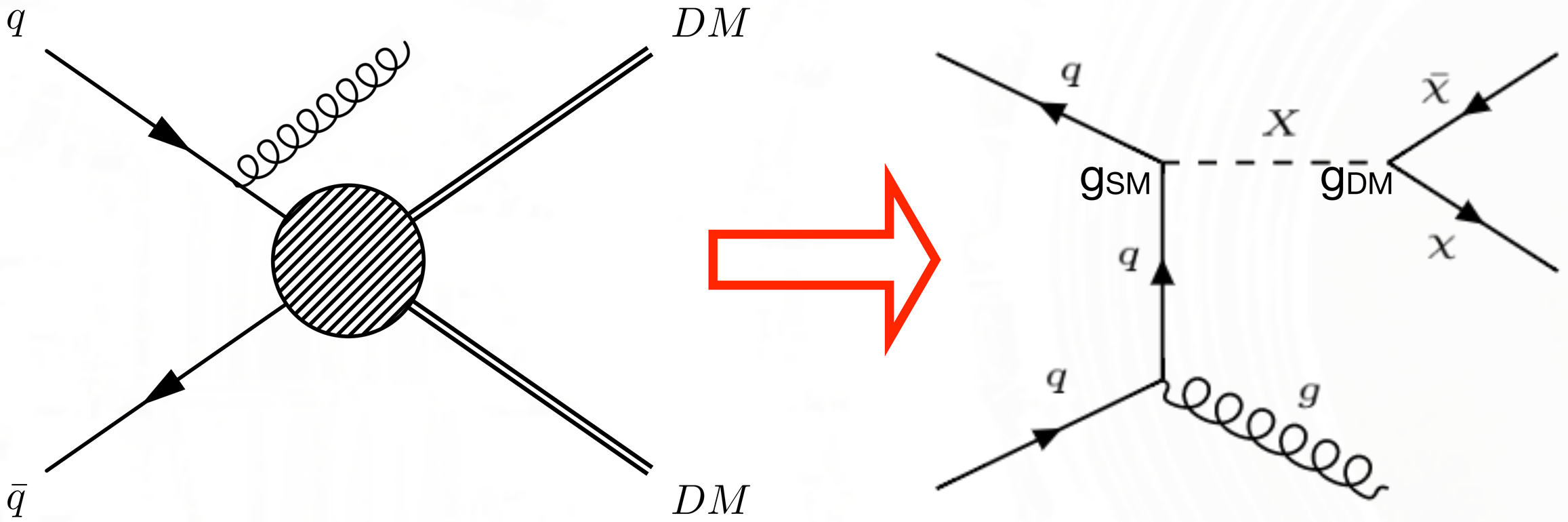
Moriond EWK - March 18, 2016

Introduction



- From **cosmological observations,** 85% of the matter comprised of dark matter (**DM**)
- Collider approach: DM production by colliding SM particles at high energies

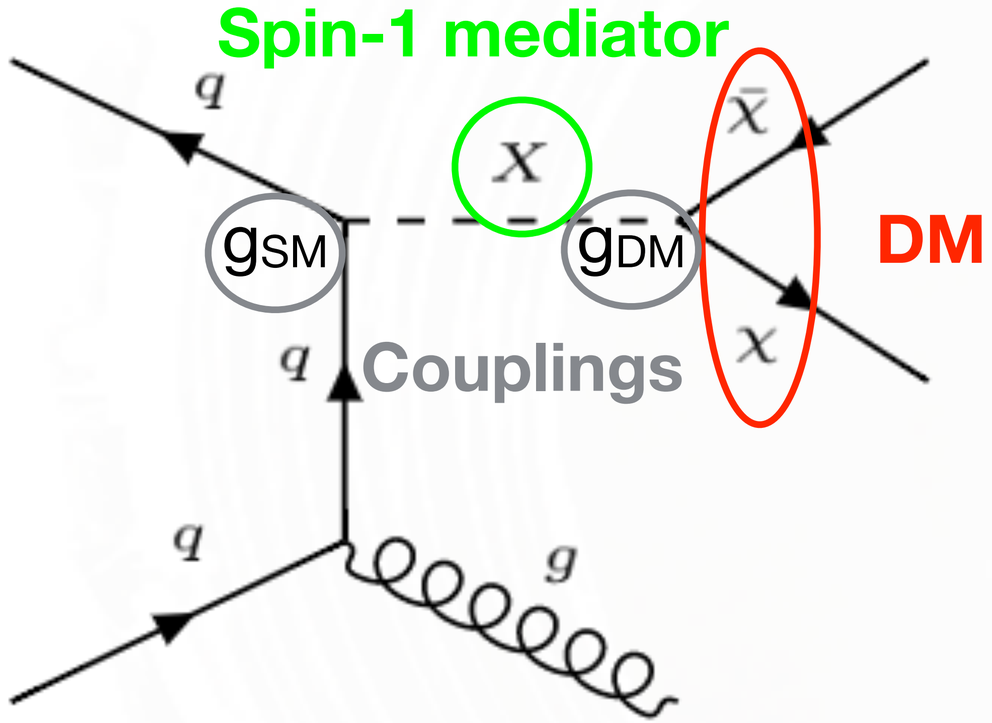
From EFT to Simplified Models



From EFT to Simplified Models

Described by a small number of **free parameters**:

- **M_{med}, M_{DM}, g_{SM}, g_{DM}**
- shapes of kinematic distributions not altered by coupling variations
  - **g_{SM}=0.25, g_{DM}=1(spin-1)**
  - **g_{SM}=1, g_{DM}=1(spin-0)**

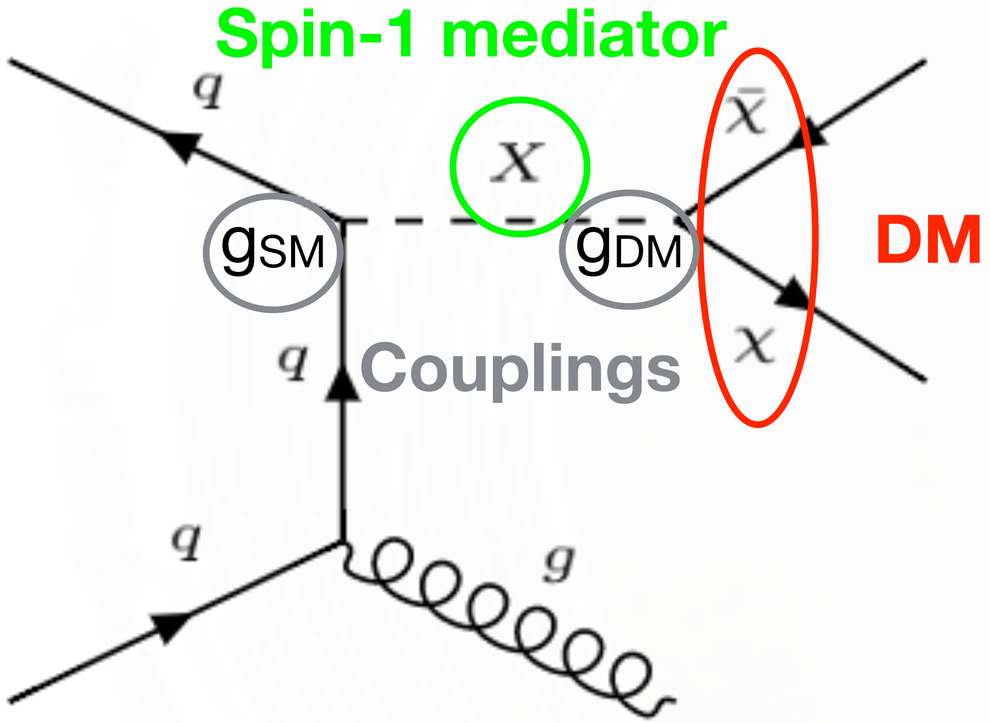


LHC DM Forum, arxiv:1507.00966v1

From EFT to Simplified Models

Assumptions:

- **DM:**
  - single particle, Dirac fermion
  - stable and non-interacting
- **Mediator**
  - Axial/Vector, Scalar/Pseudoscalar
  - minimal decay width
    (e.g. to DM and to quarks)



LHC DM Forum, arxiv:1507.00966v1

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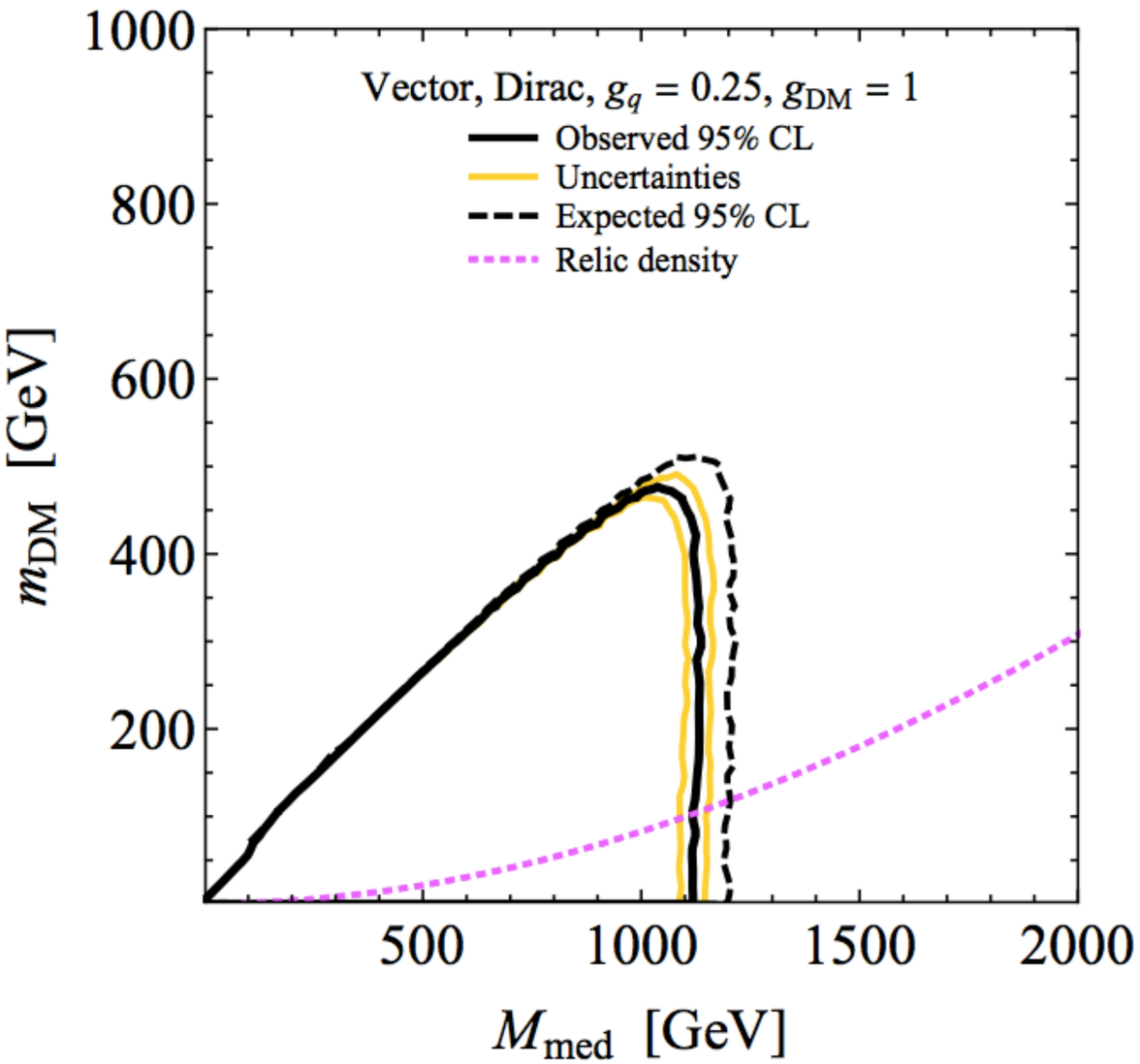
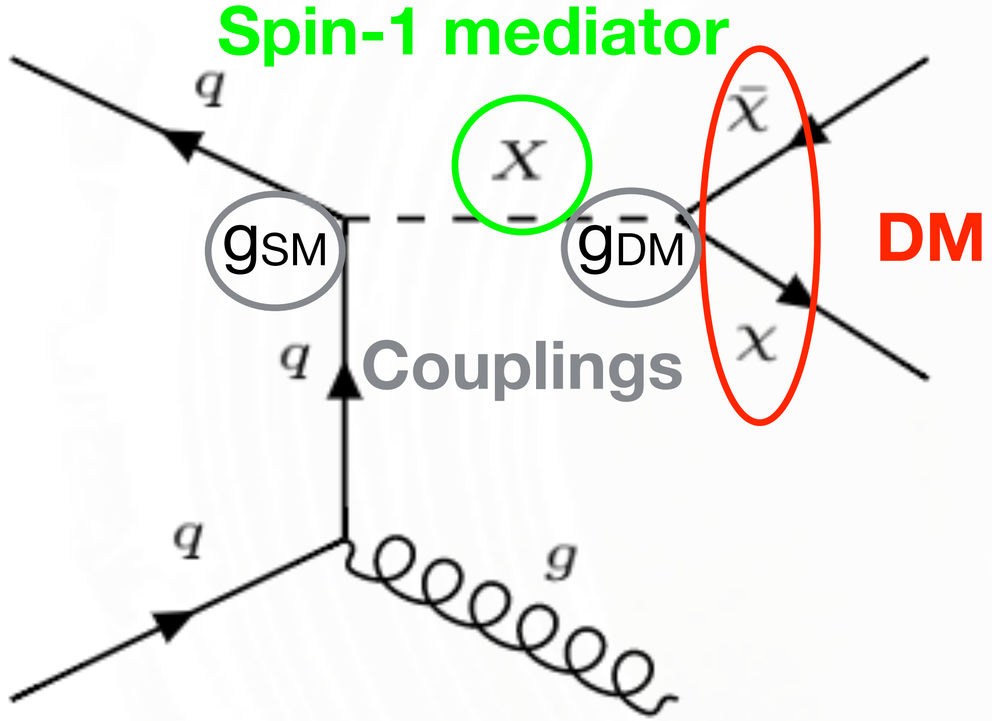
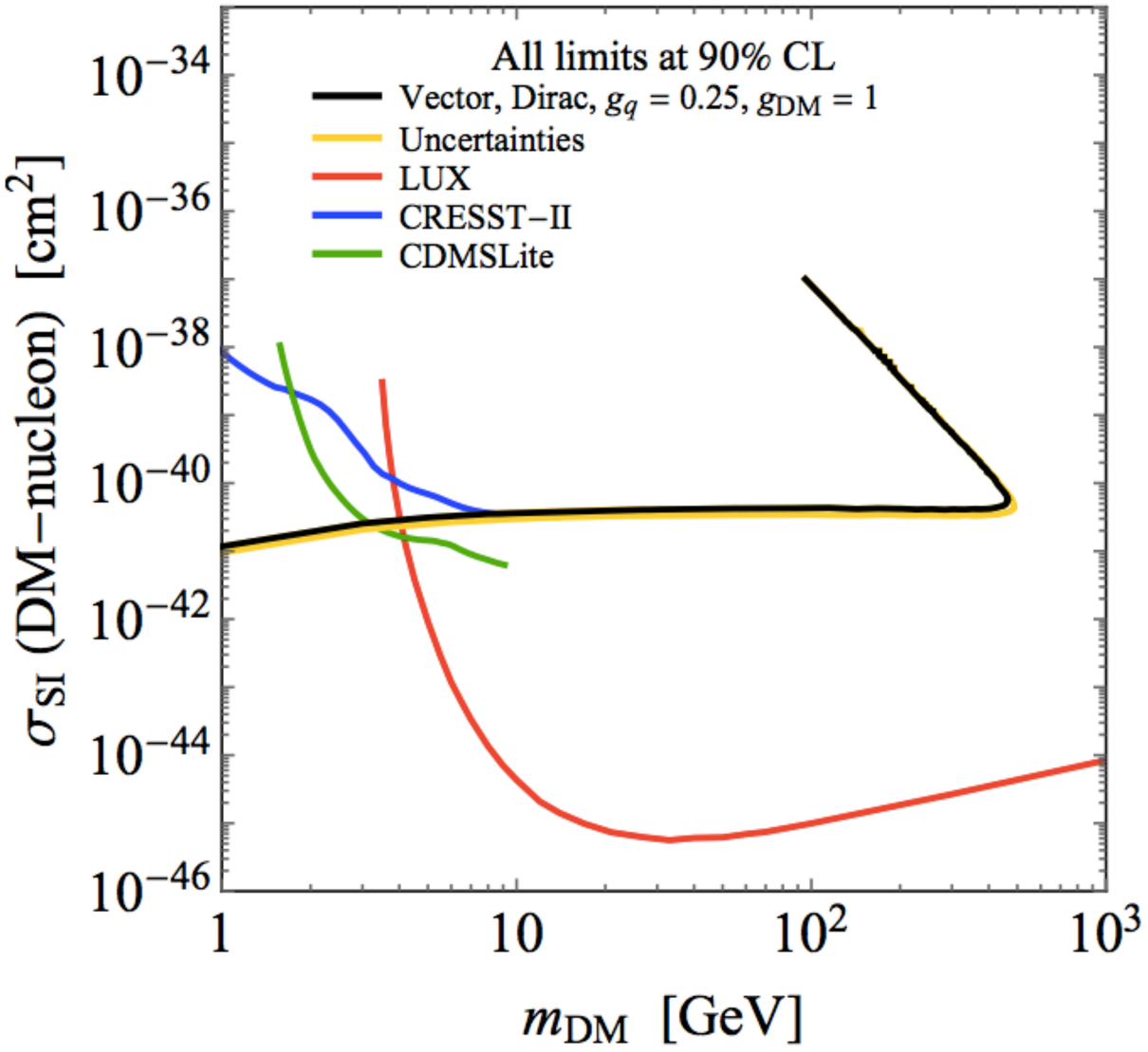
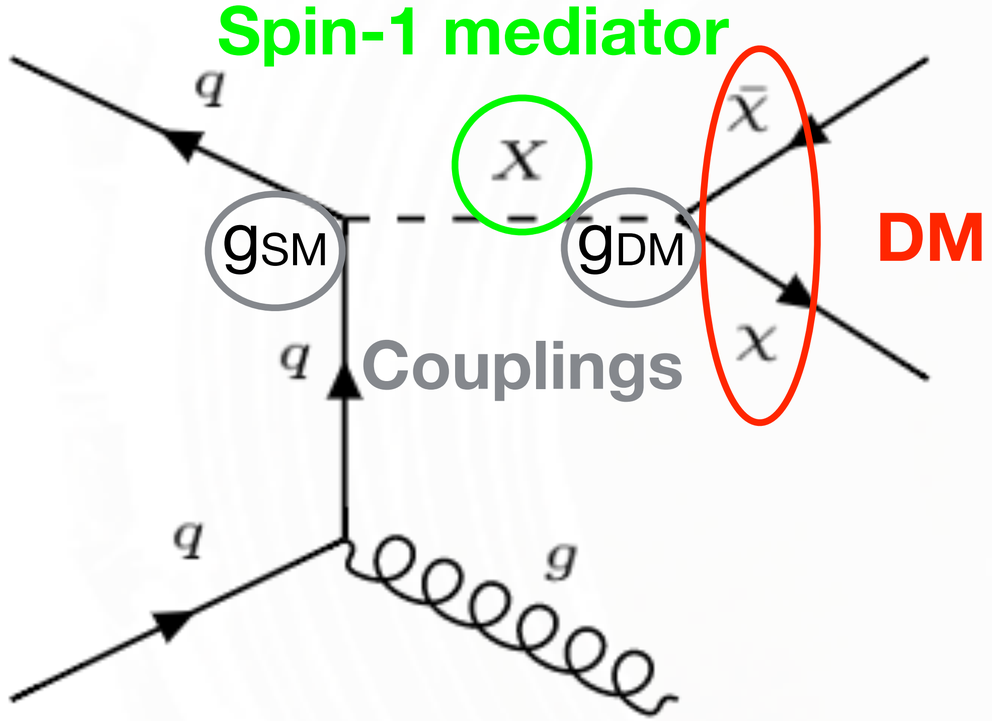




LHC DM WG, arxiv:1603.04156

From EFT to Simplified Models



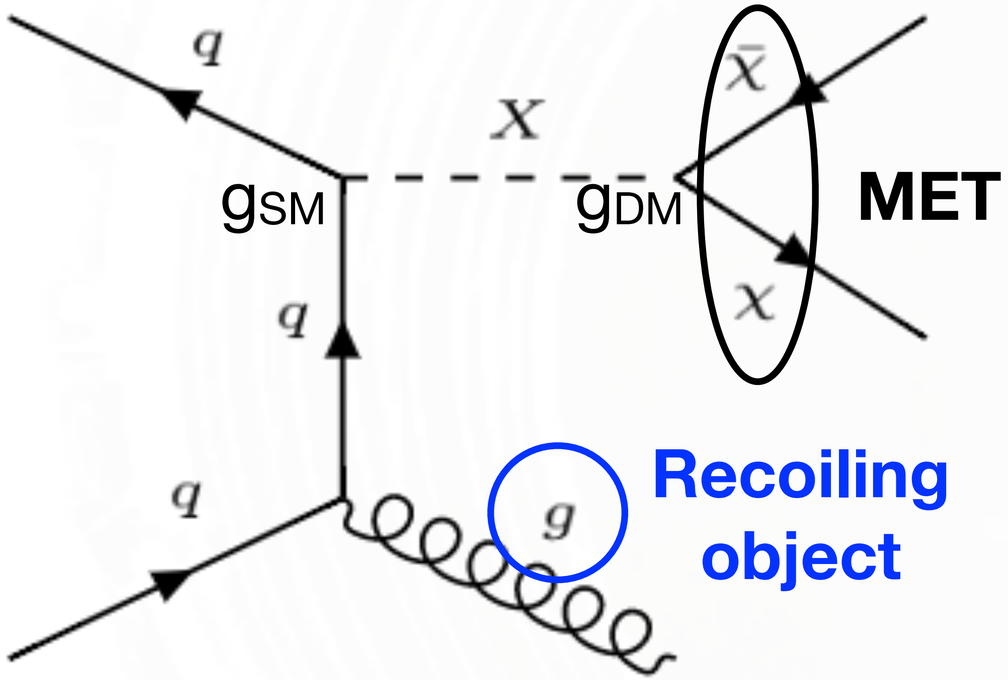


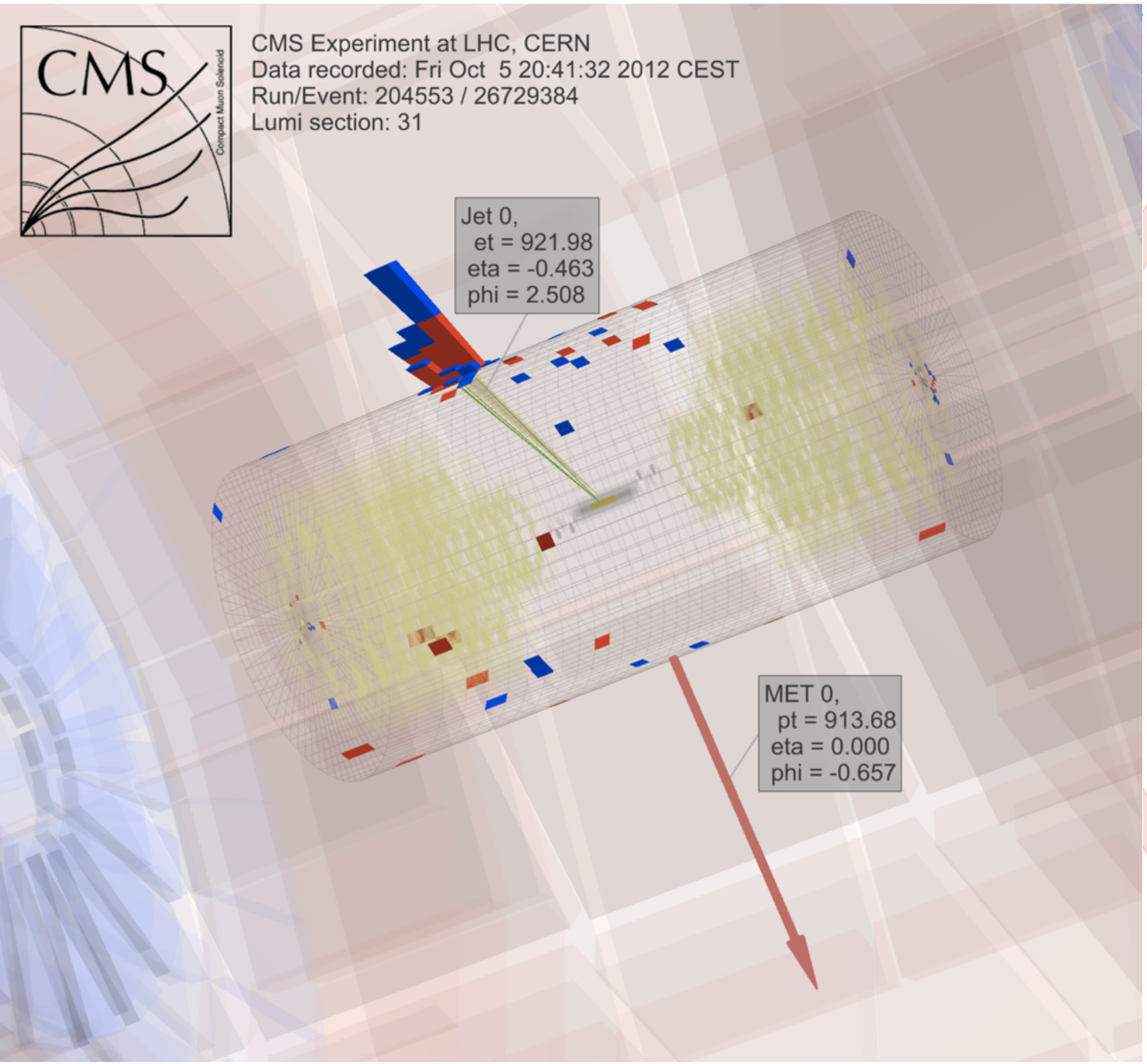
LHC DM WG, arxiv:1603.04156

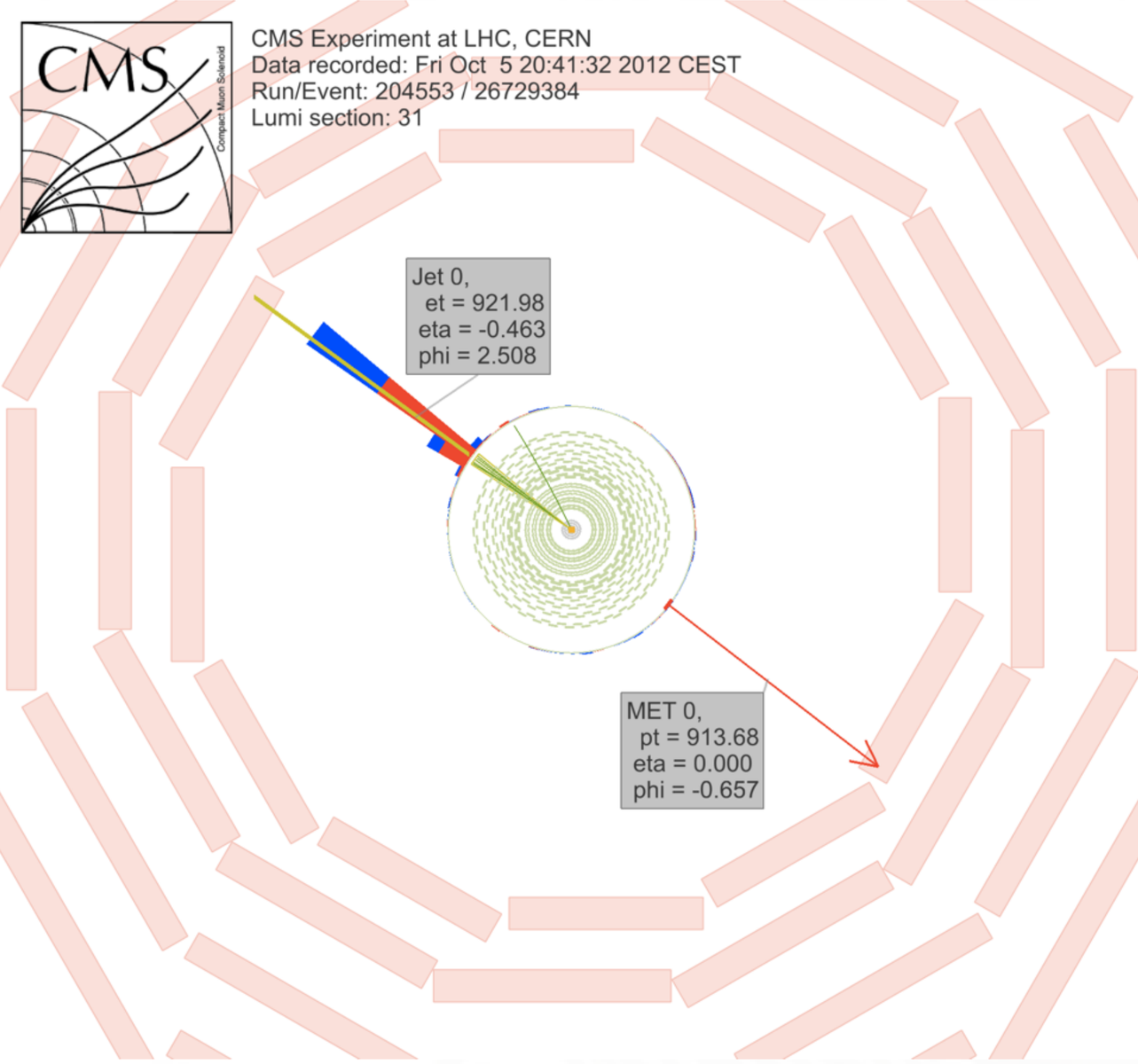
From EFT to Simplified Models

Experimental approach:

- tag events using **recoiling object(s)**
  - ISR: jet/gamma/W/Z
- measure missing transverse momentum (**MET**)




CMS Experiment at LHC, CERN
Data recorded: Fri Oct 5 20:41:32 2012 CEST
Run/Event: 204553 / 26729384
Lumi section: 31
Jet 0,
et = 921.98
eta = -0.463
phi = 2.508
MET 0,
pt = 913.68
eta = 0.000
phi = -0.657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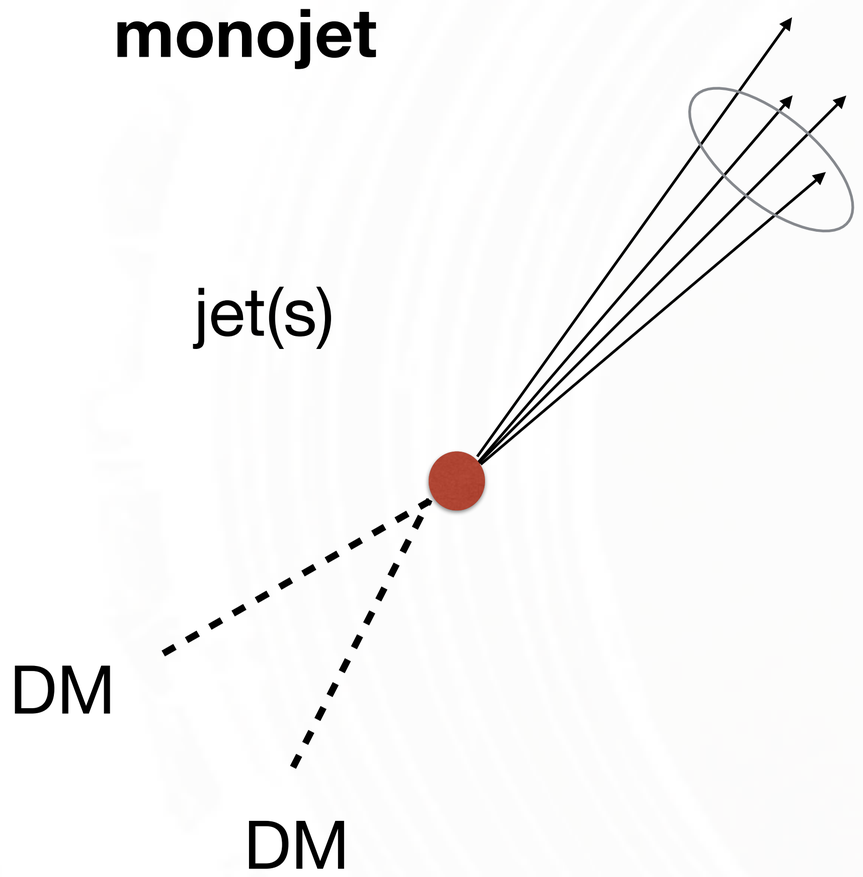
Monojet Signature

Looking for events with:

- Large MET
- At least one high Pt jet



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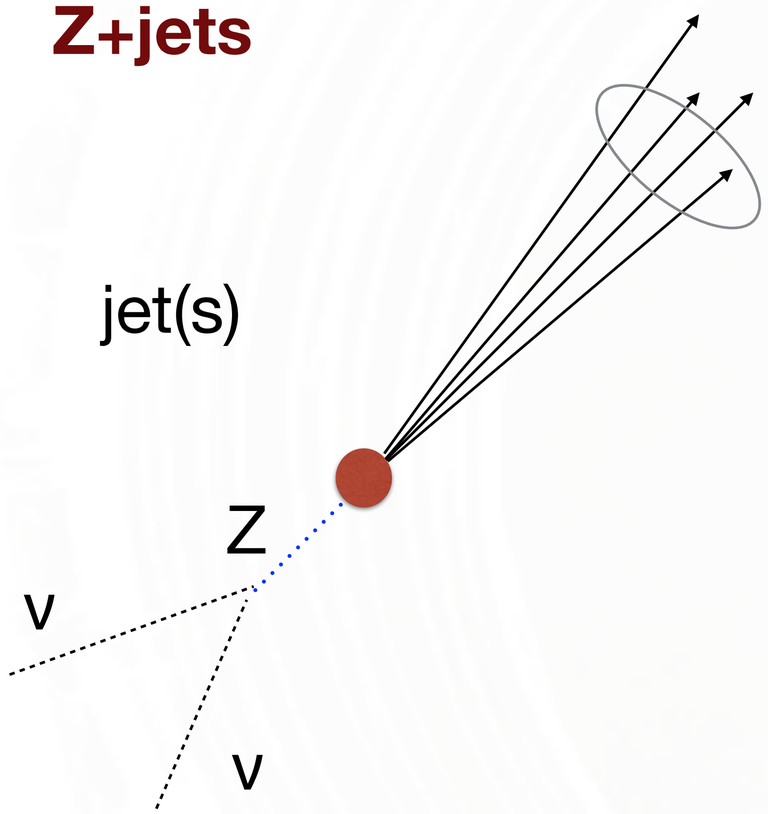

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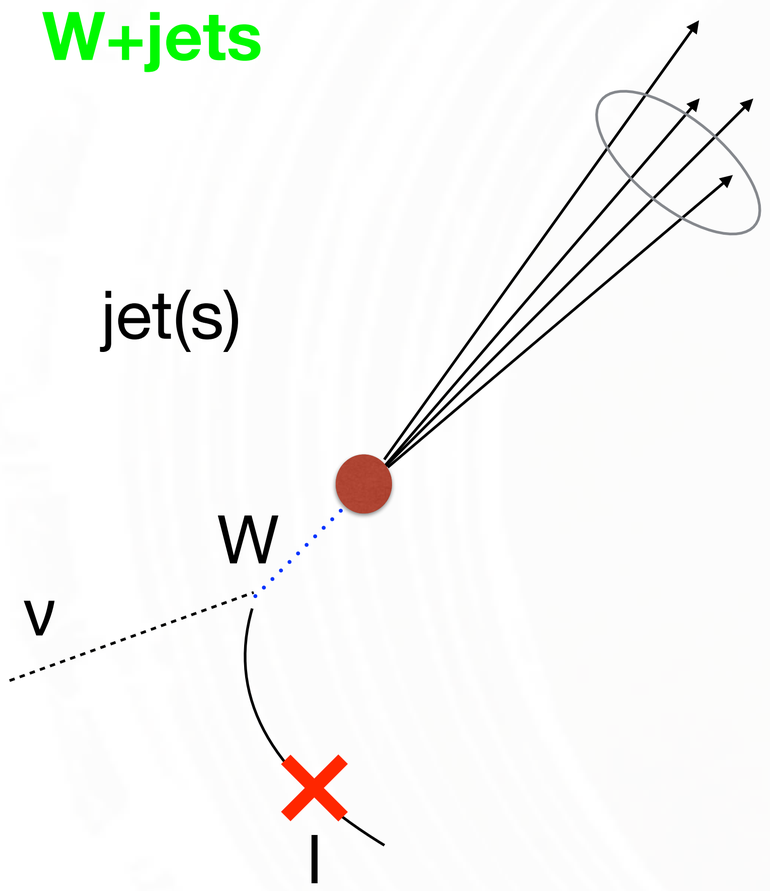
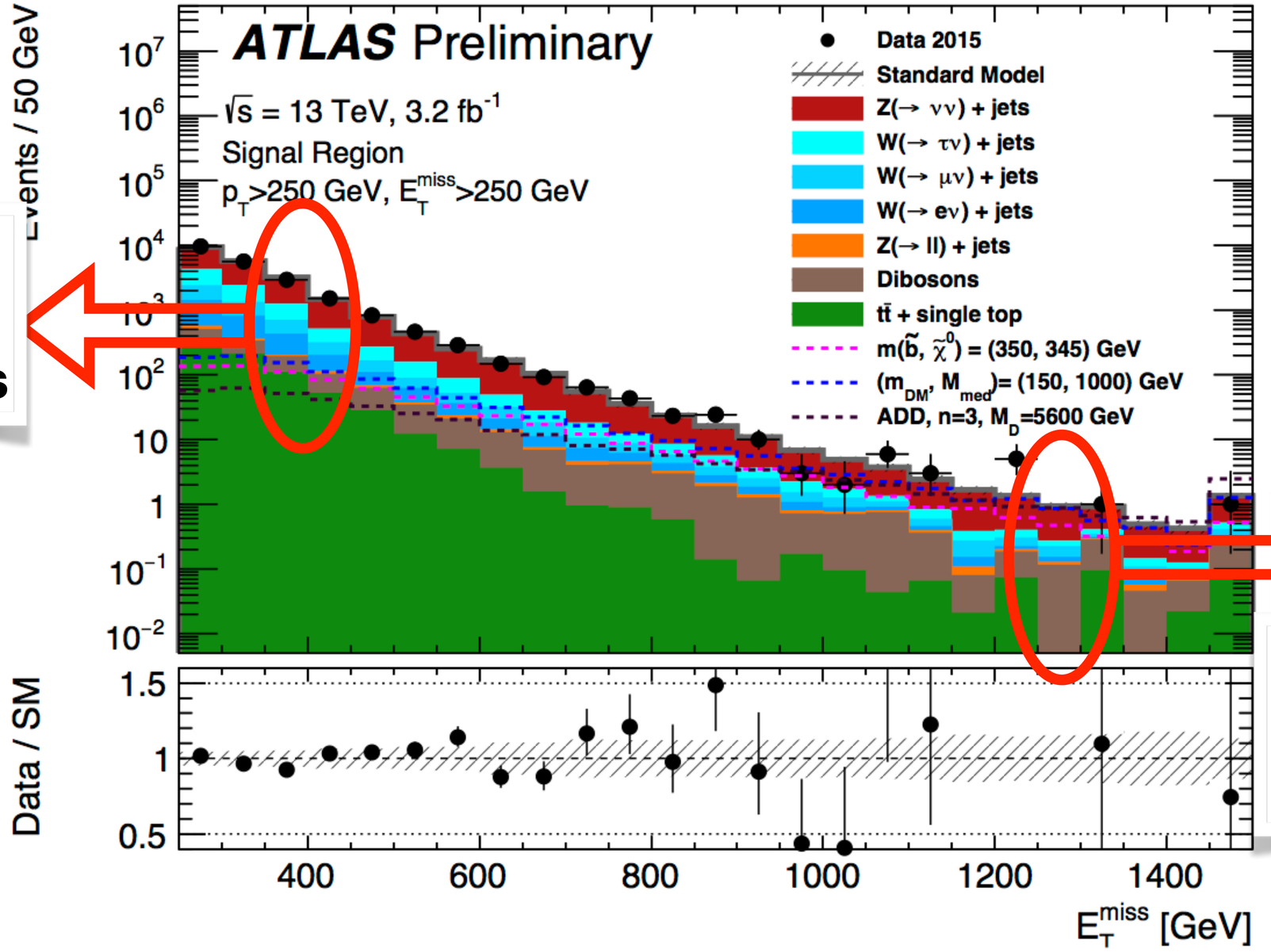
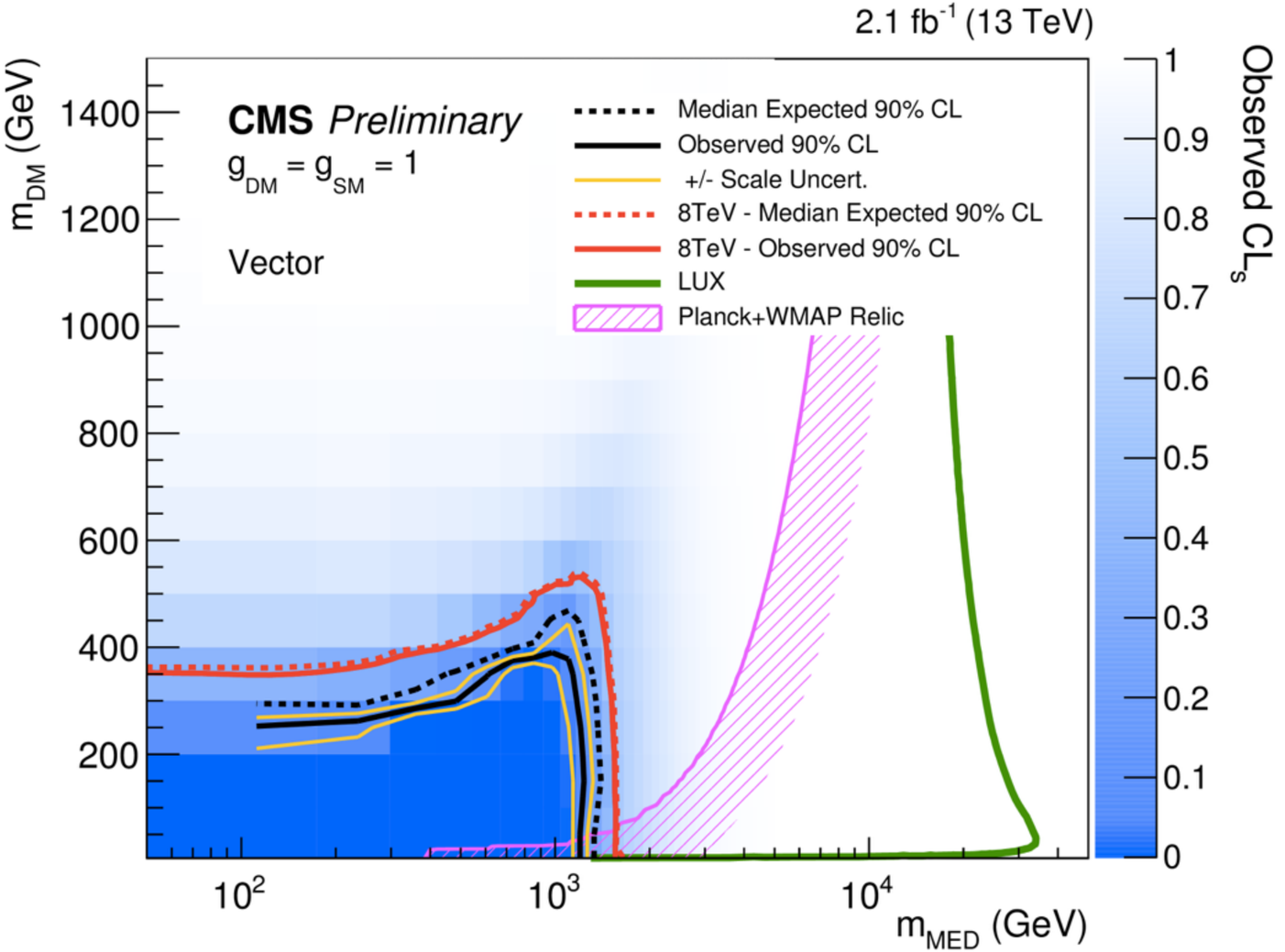


Largest backgrounds from **W/Z+jets**

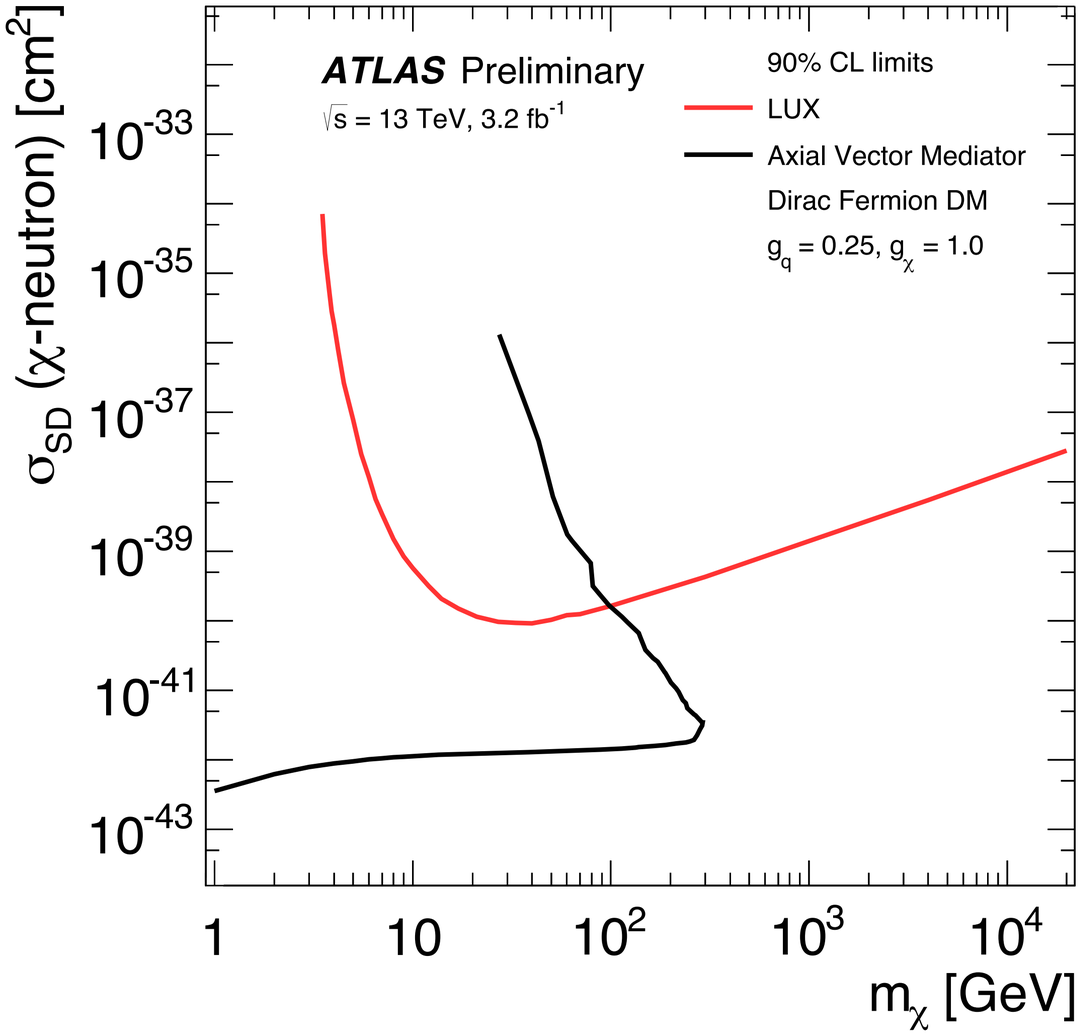


Signal populates **high MET**

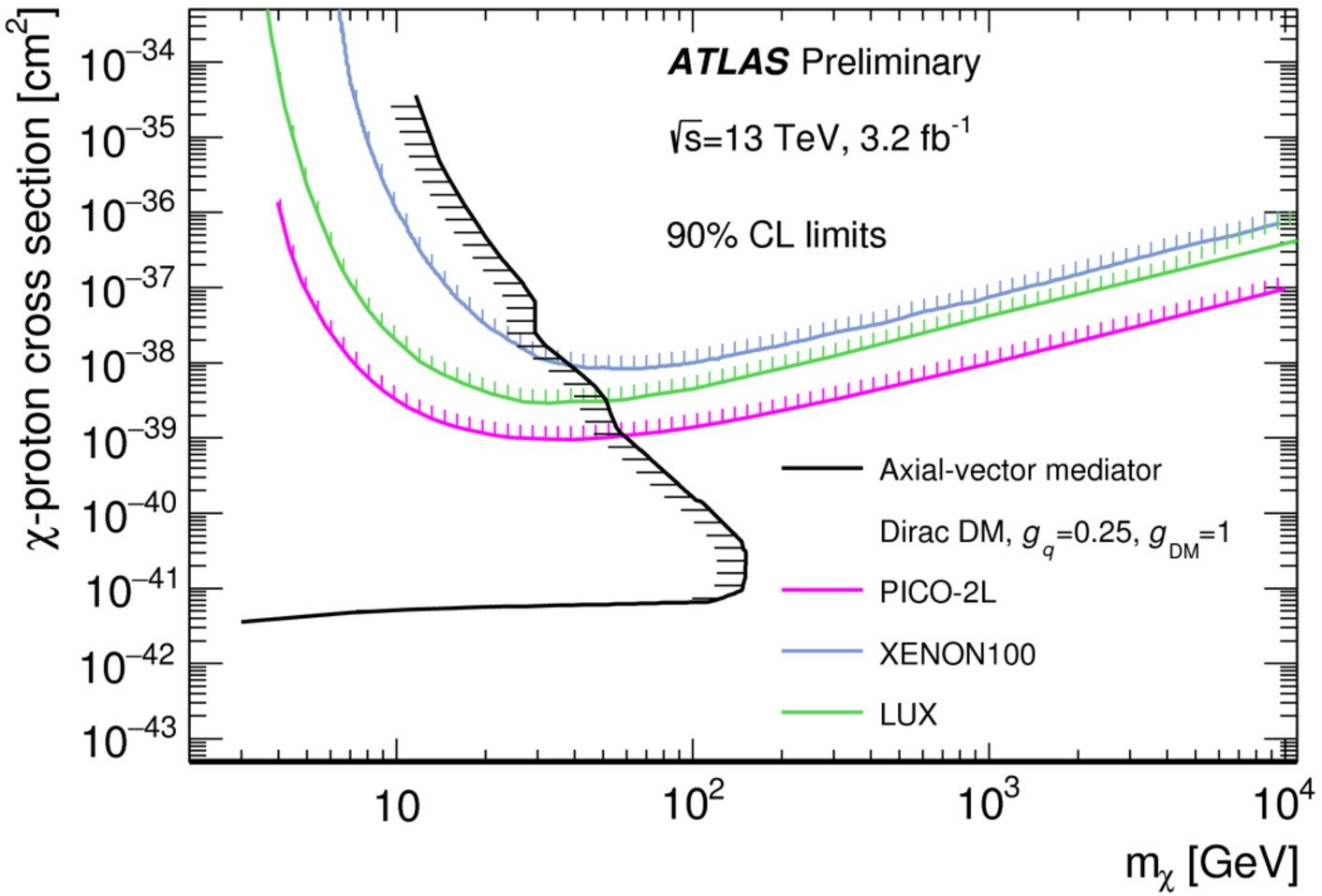
Monojet Results @ 13 TeV

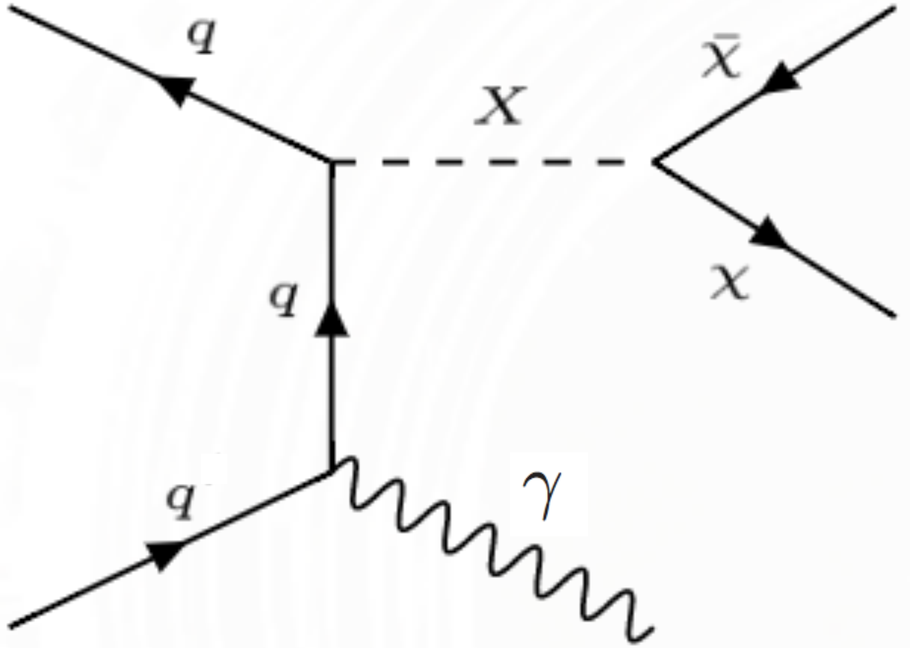


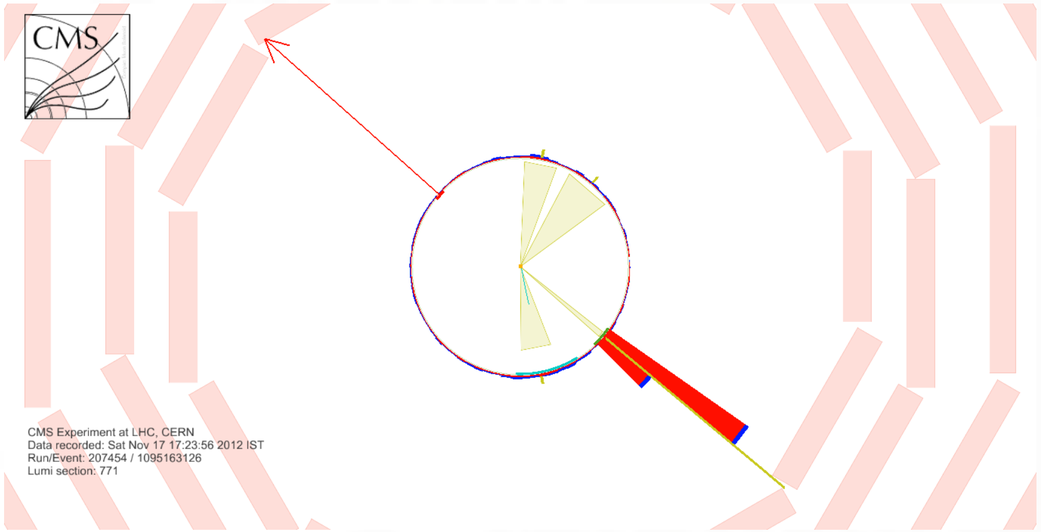
CMS PAS EXO-15-005



Monophoton @ 13 TeV

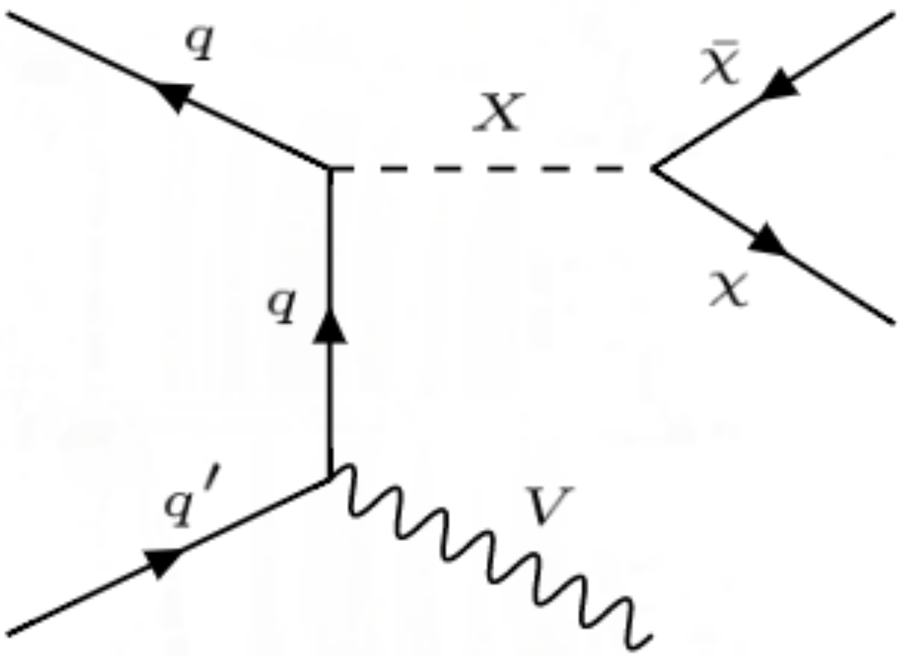


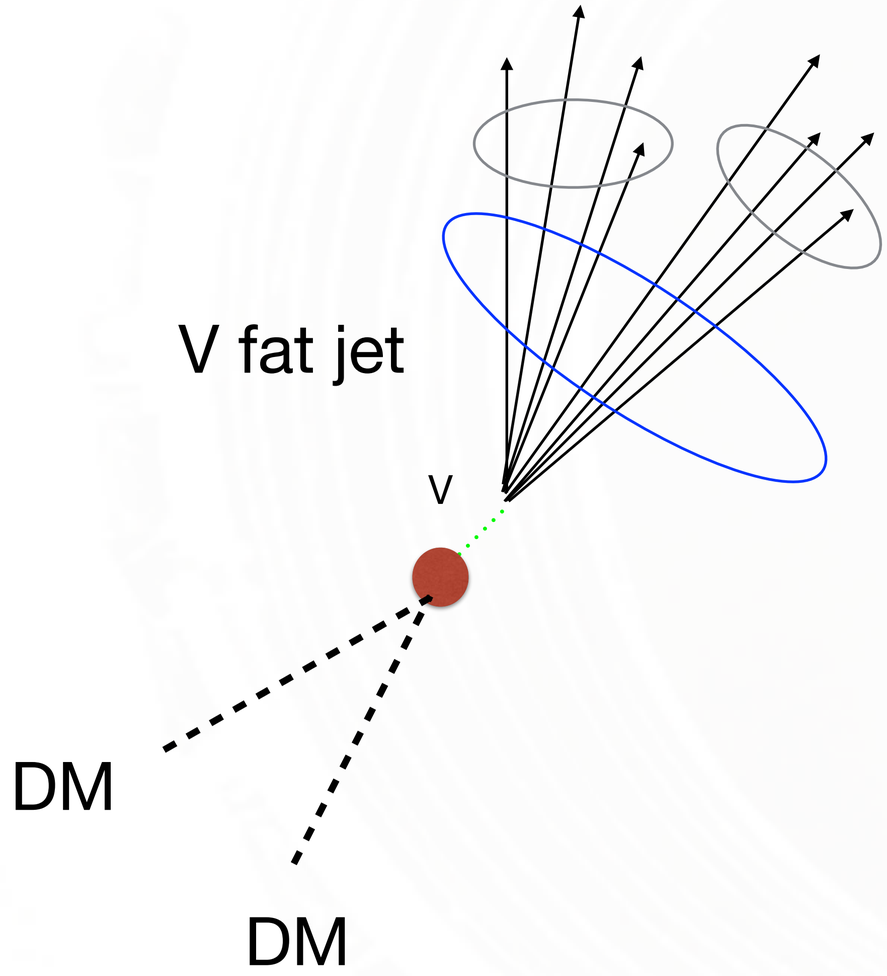




Hadronic Mono-V

Boosted boson decaying **hadronically** recoiling DM-pair
=> a **large-radius jet** and MET





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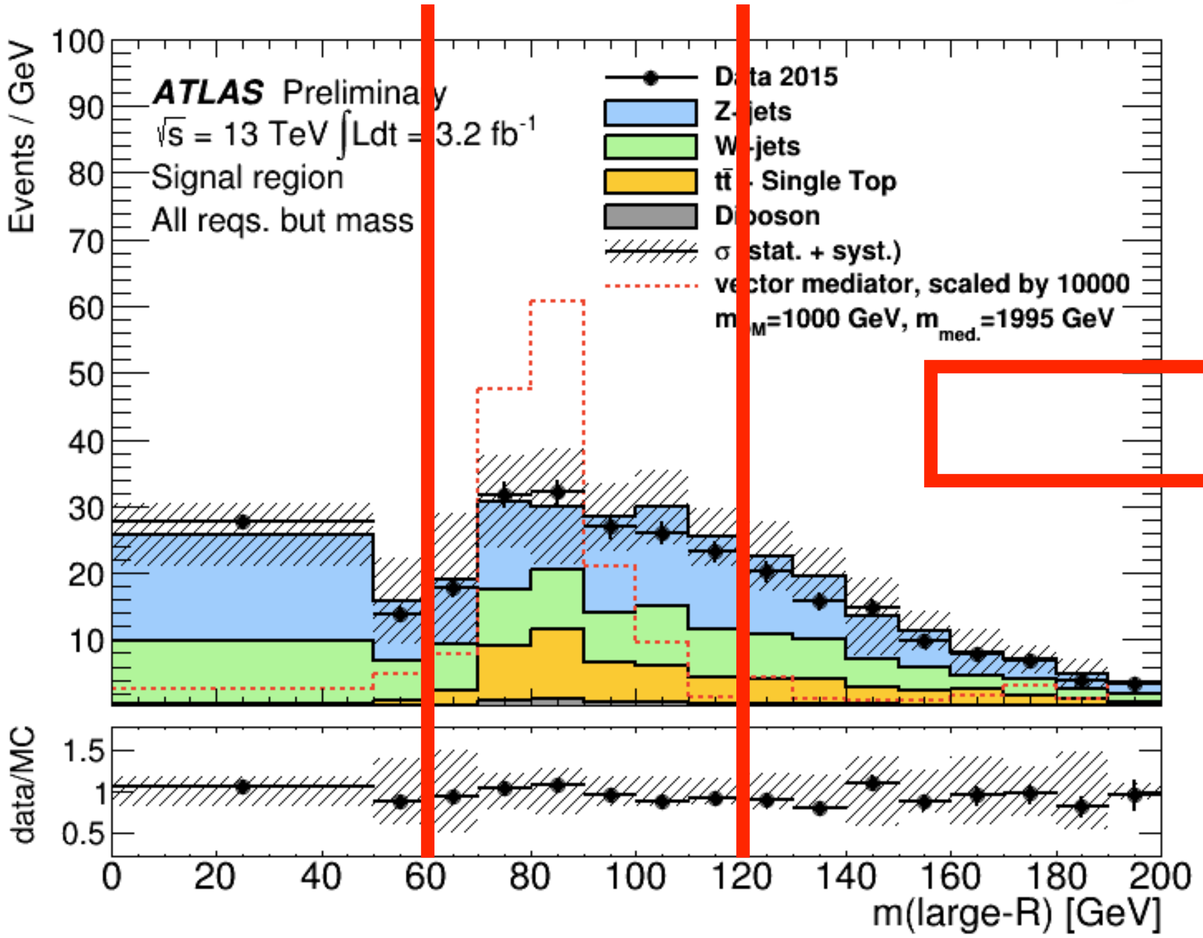
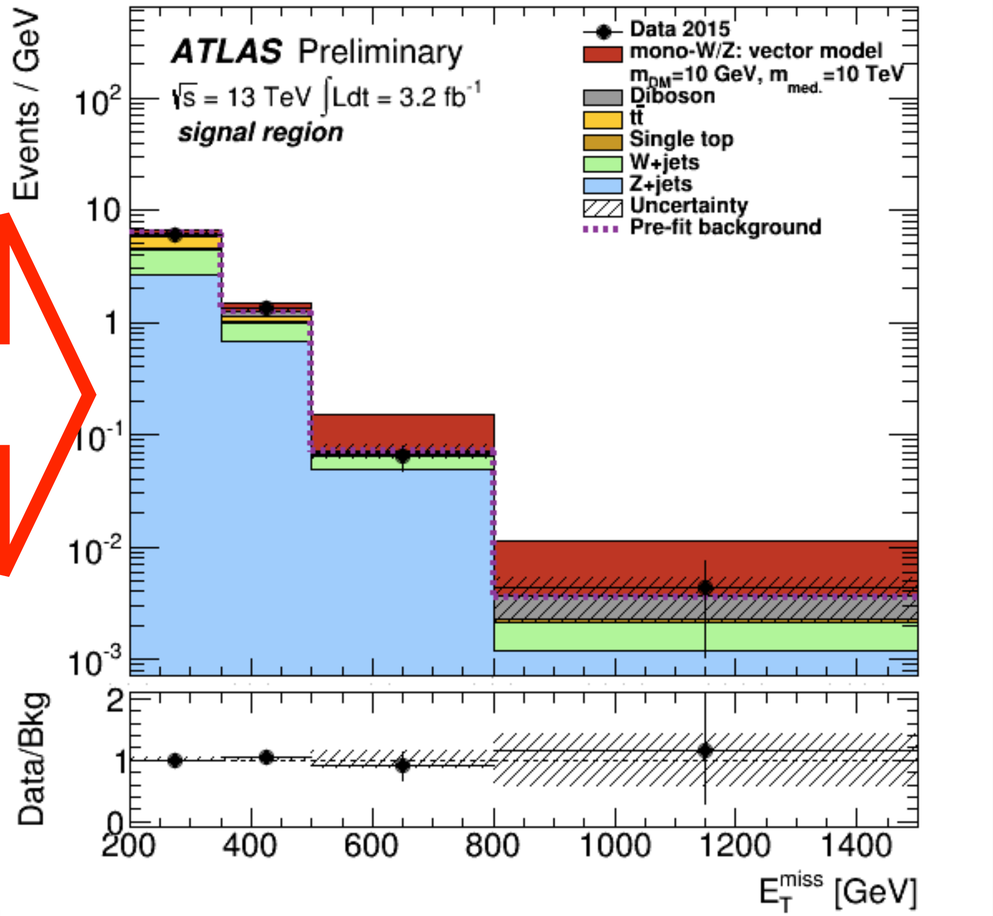
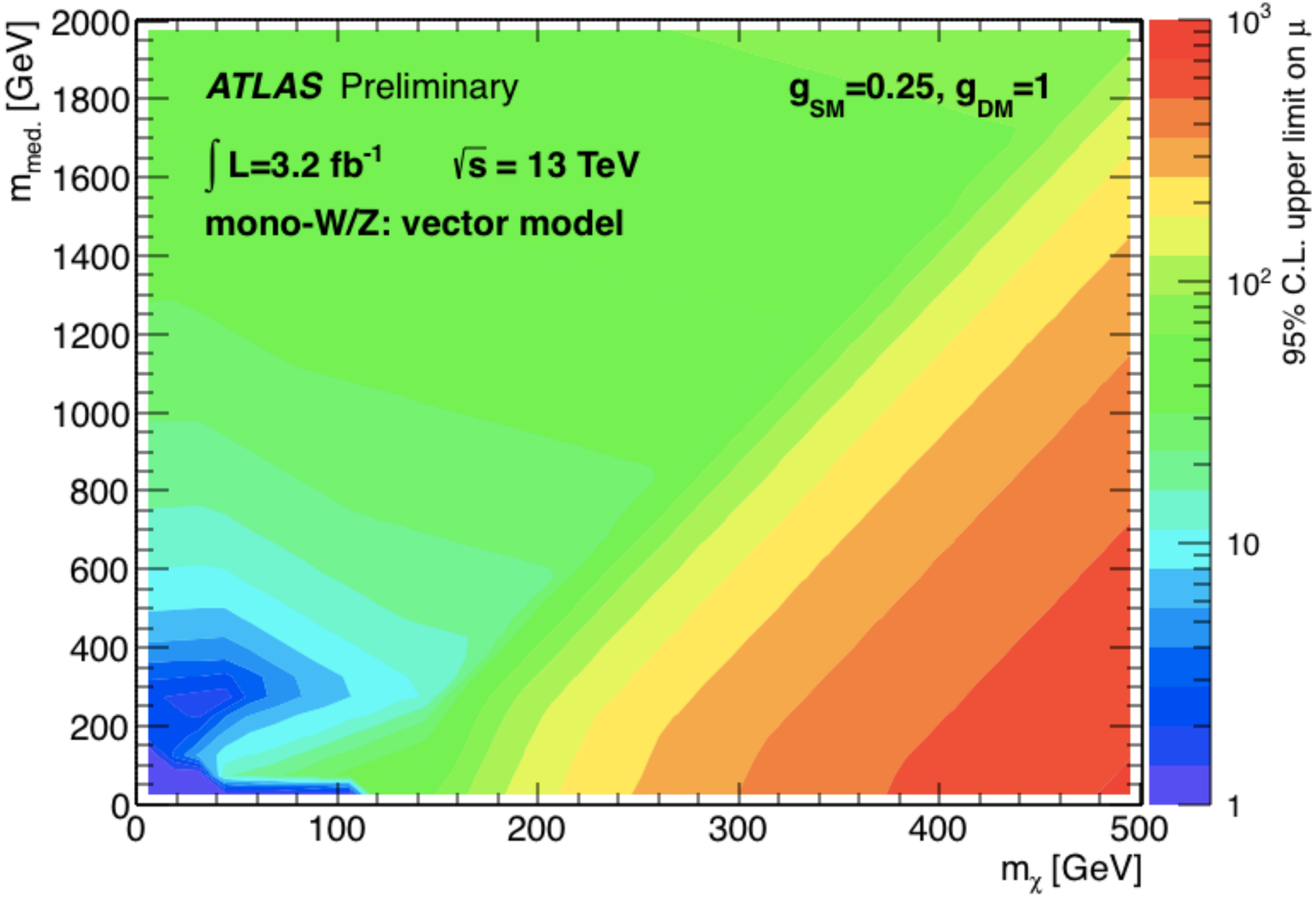




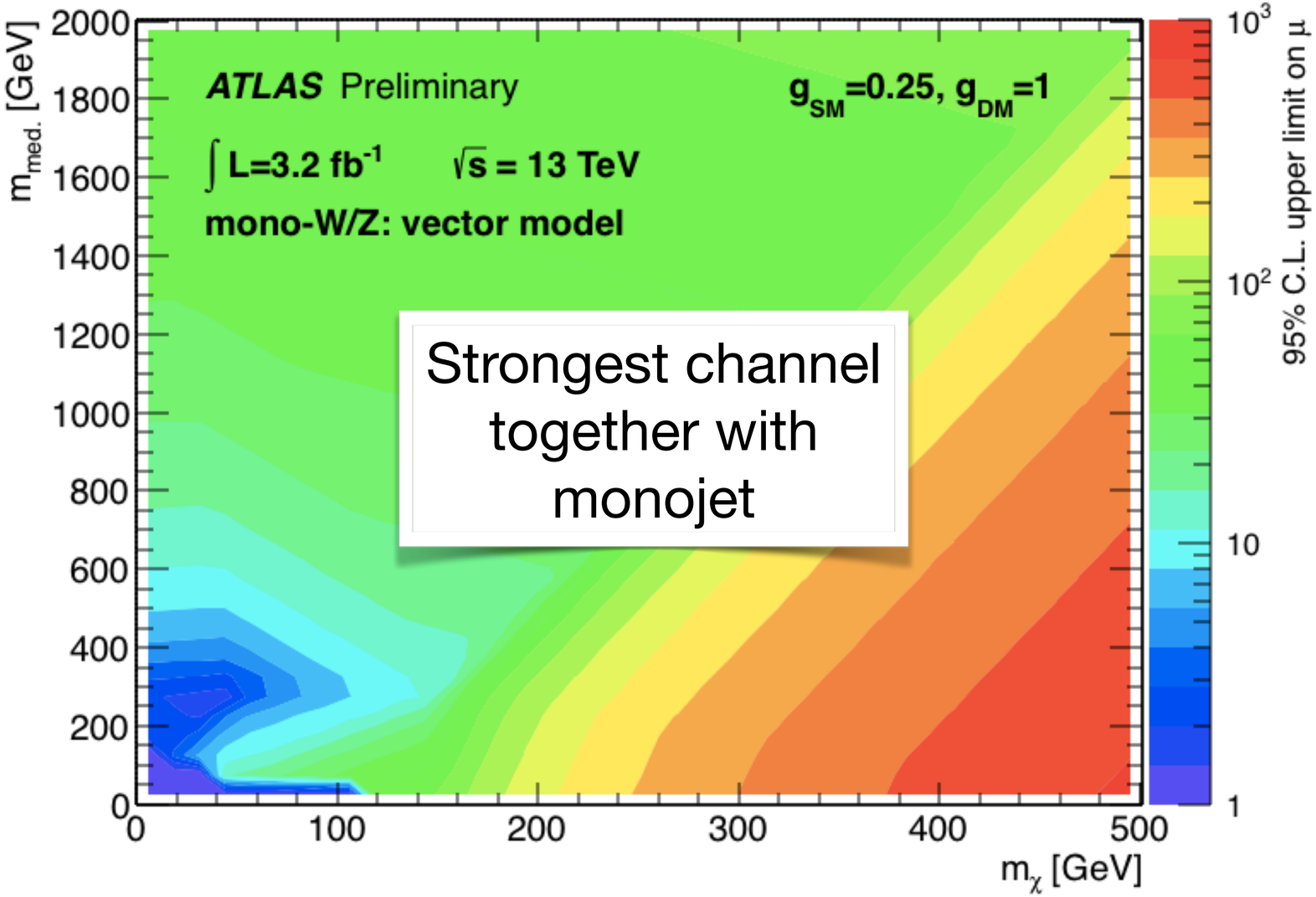
Hadronic Mono-V Results @ 13 TeV

ATLAS-CONF-2015-080

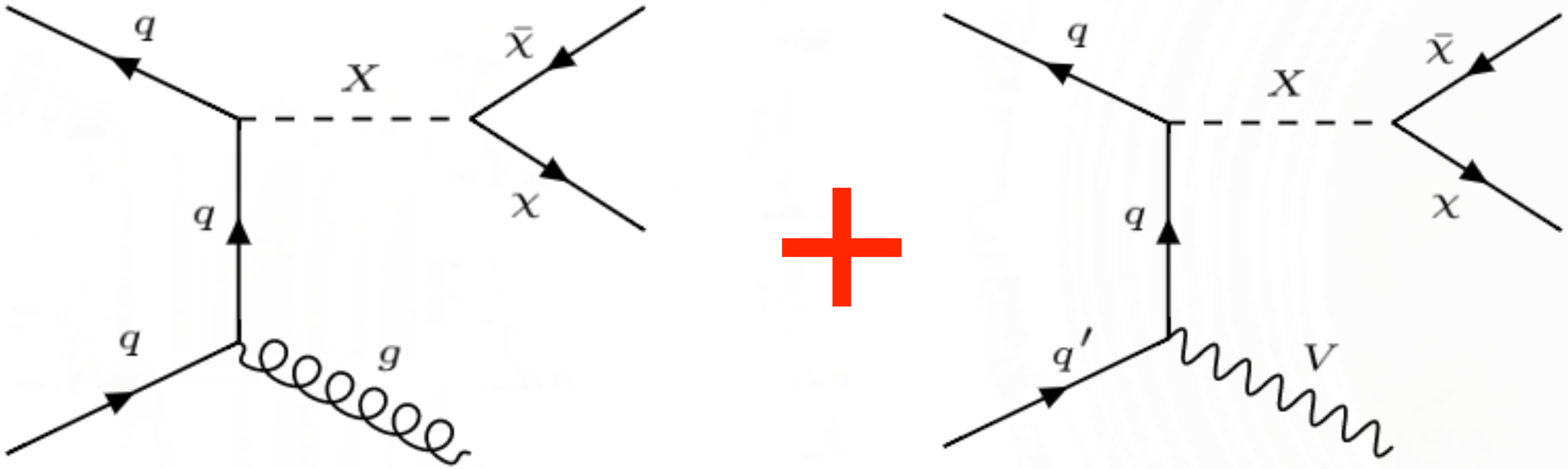


Hadronic Mono-V Results @ 13 TeV

ATLAS-CONF-2015-080



Monojet/Mono-V Combination



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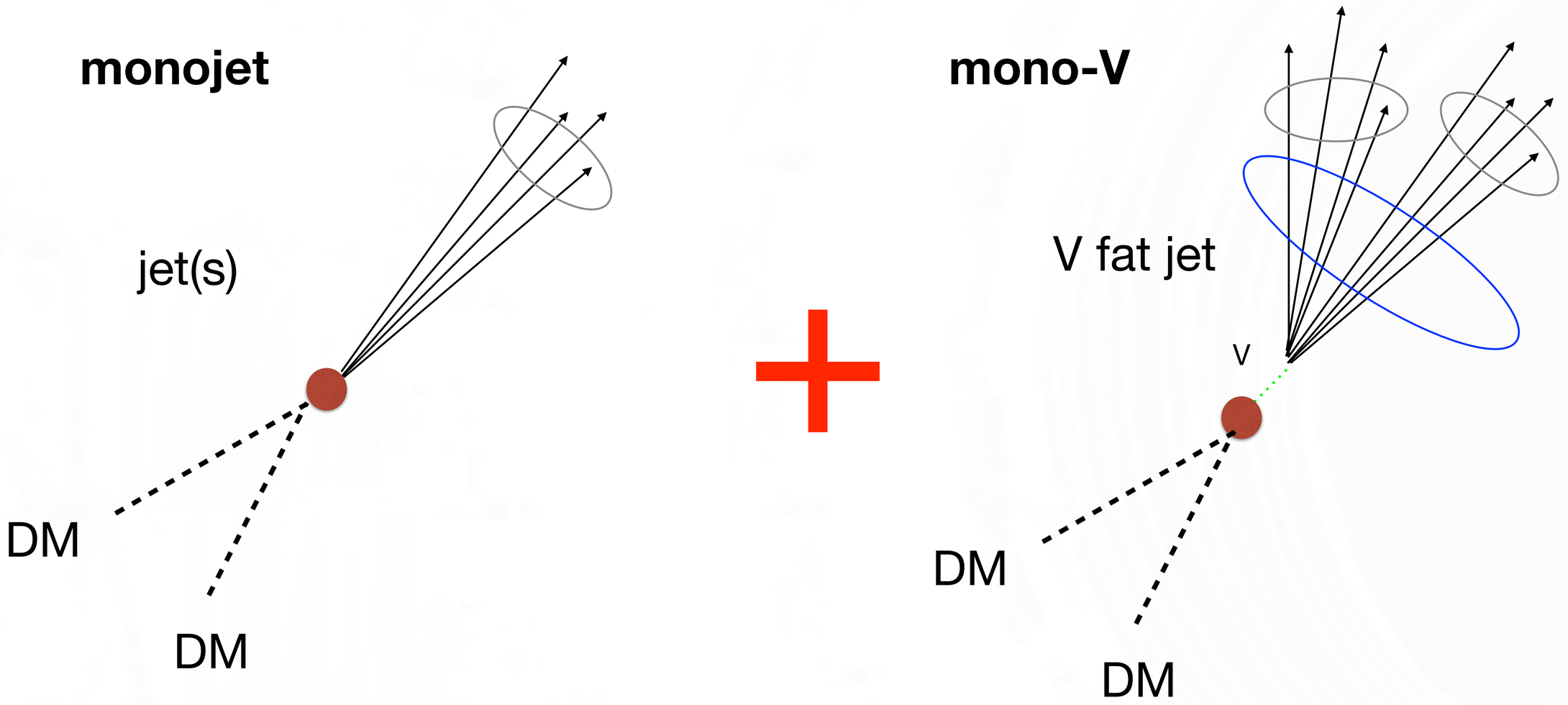
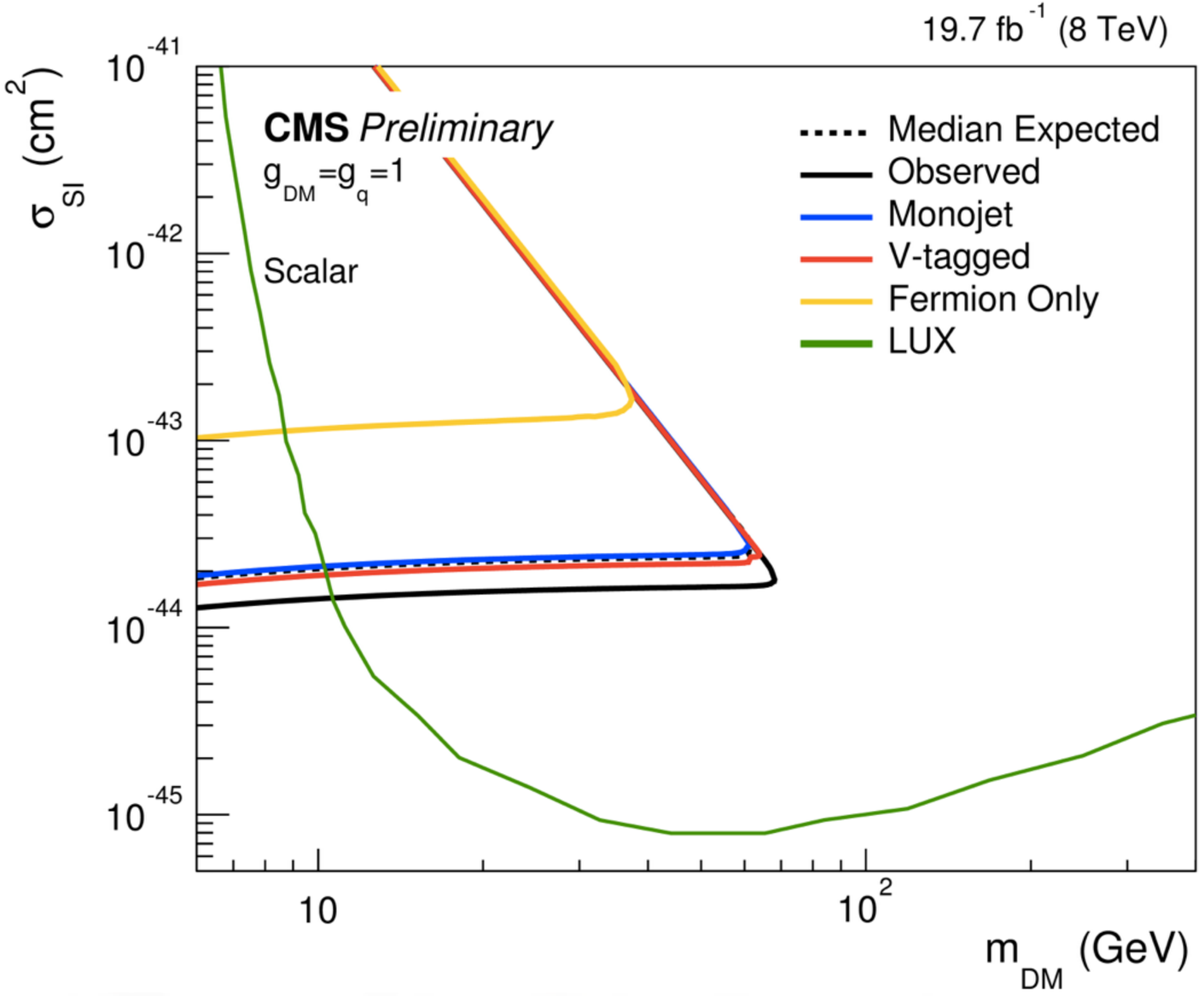


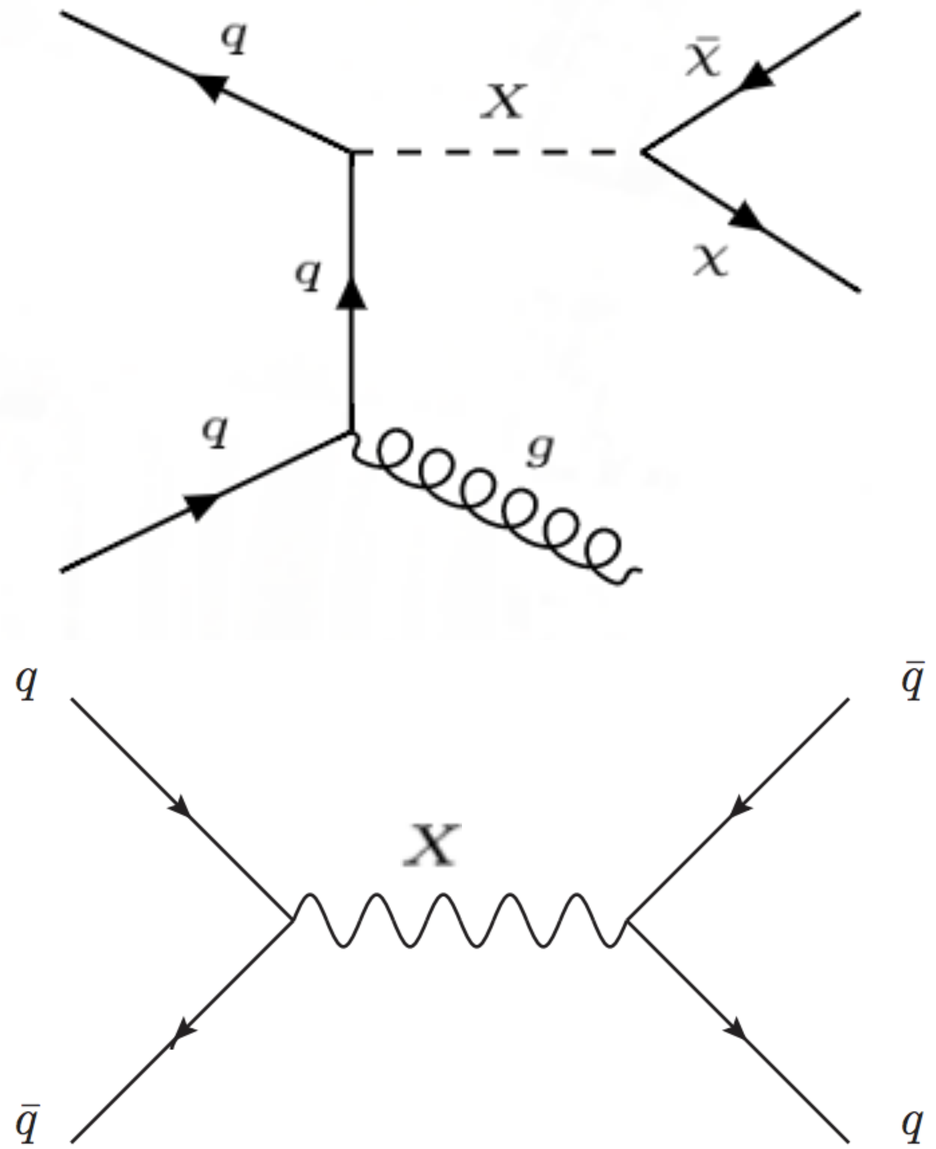
Monojet/Mono-V Combination Results @ 8 TeV



- Fitting simultaneously for both monojet and mono-V signals
- Considering all the analysis samples from both the searches

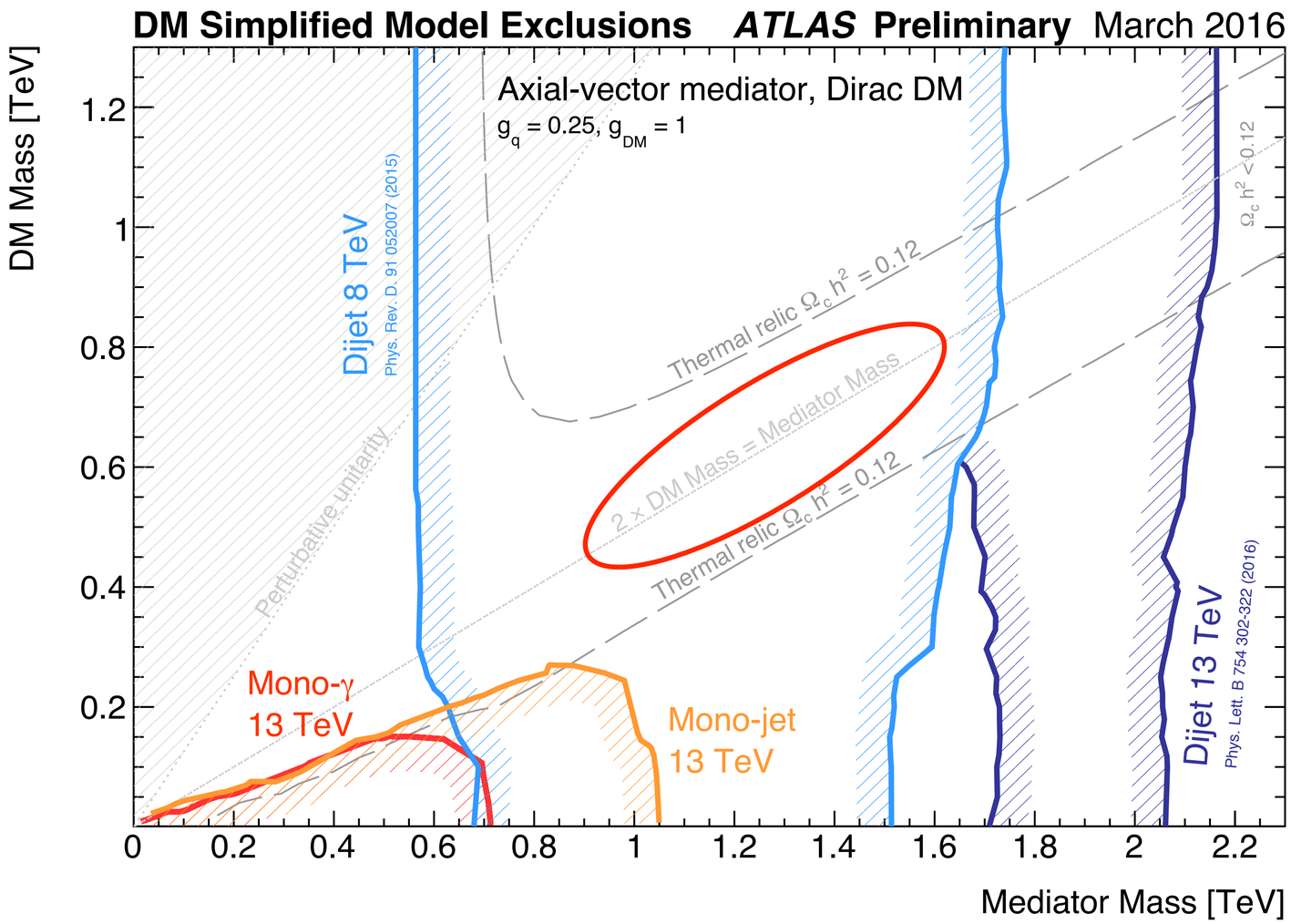
CMS PAS EXO-12-055

Dijet DM Interpretation



- BR of mediator to jets depends on m_{DM}:
  - for **large m_{DM}**, BR to jets is 100%
  - for **m_{DM} around 1 GeV**, BR to DM is about the same as BR to jets
    - dijet signal rate drops by a factor of ~2
  - above $m_{DM} = M_{Med}/2$ the limit is constant

Dijet DM Interpretation



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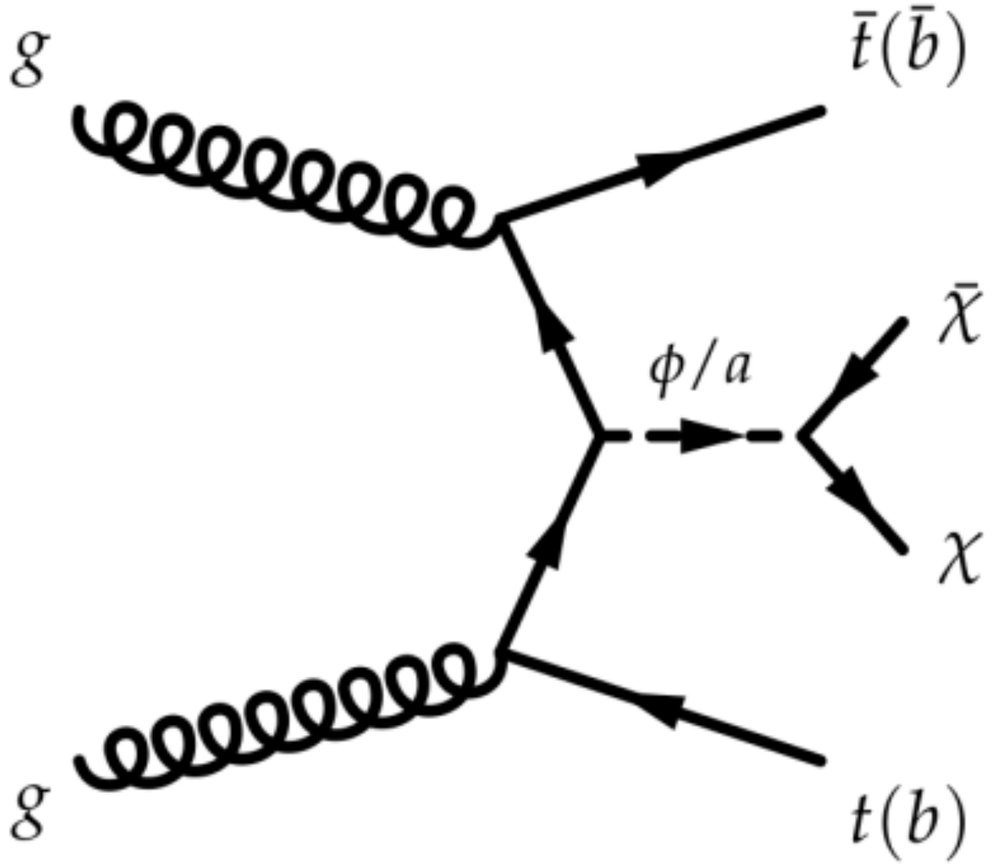
b(b)/tt+DM Models

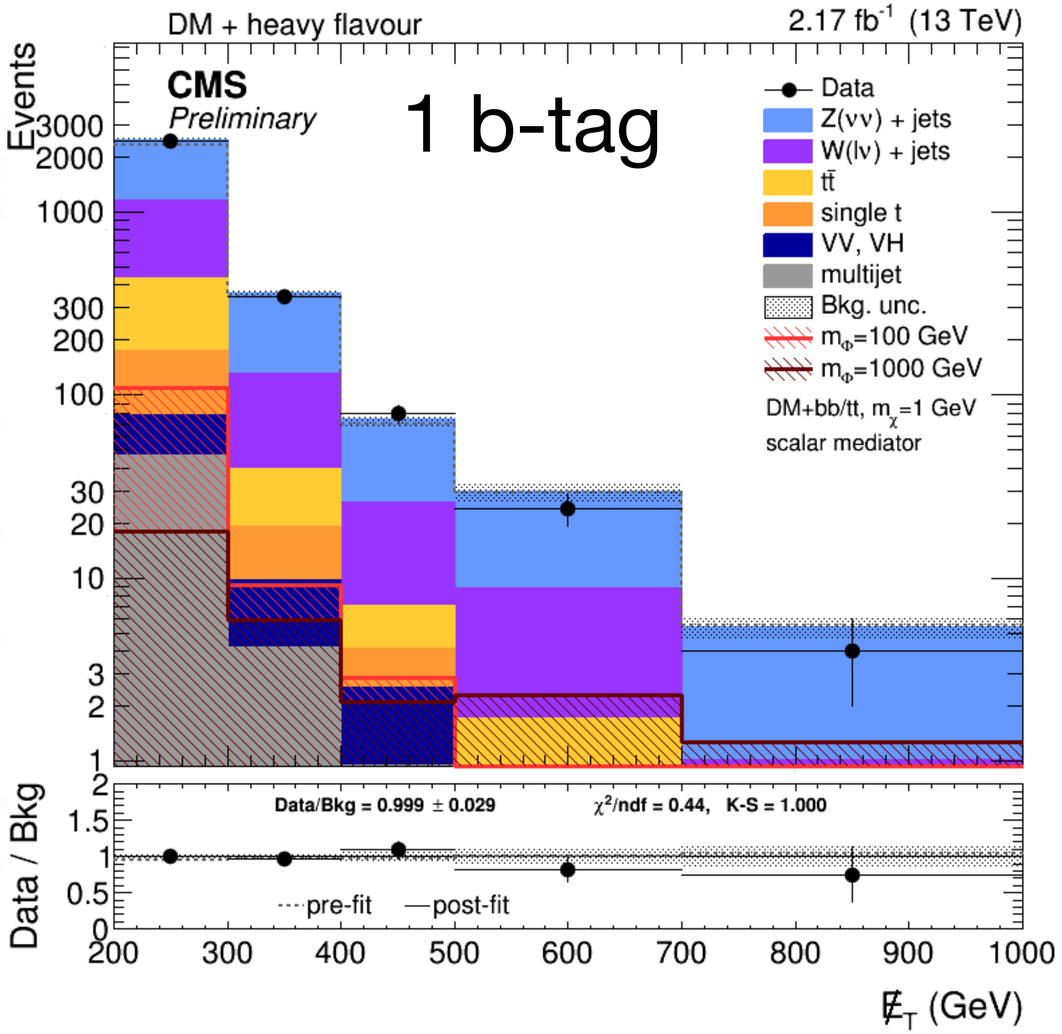
tt/bb+DM

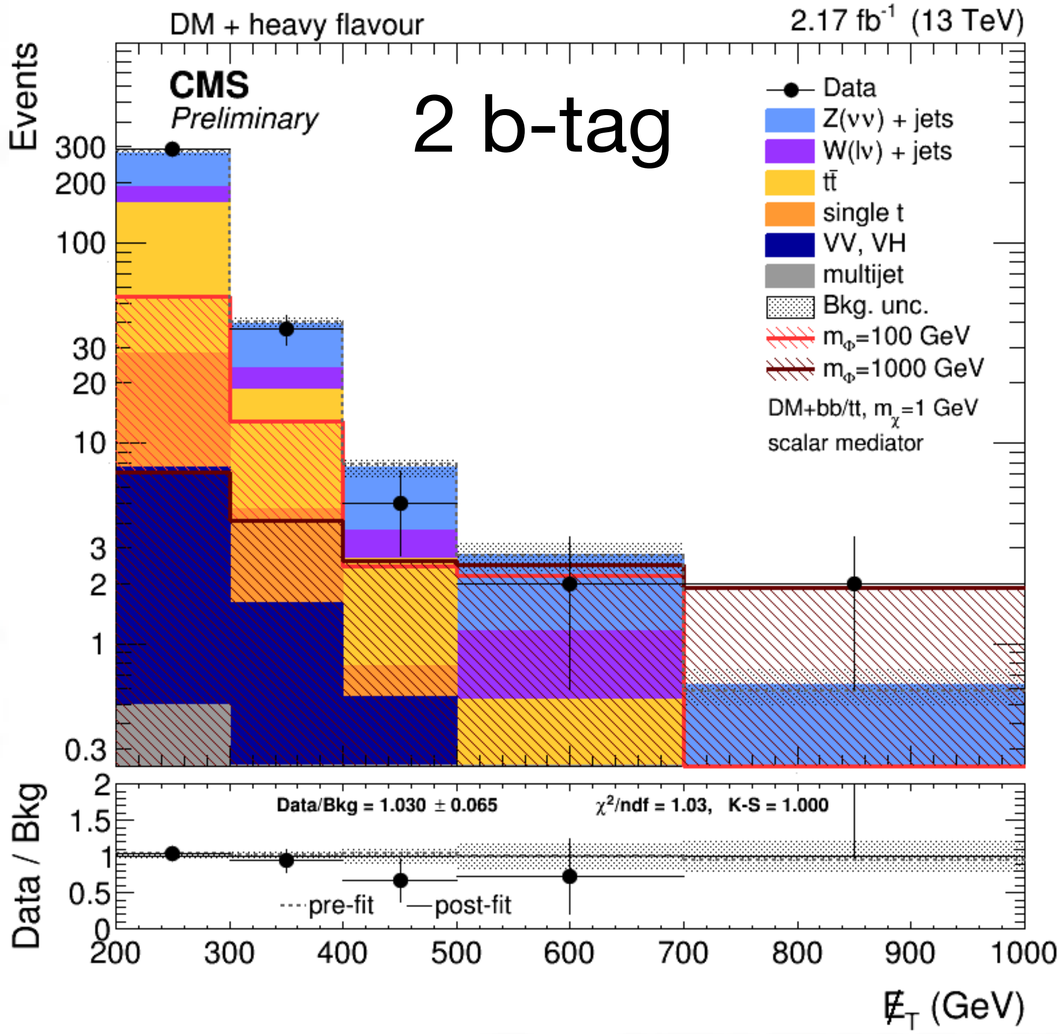


- More sensitive than other searches for the **scalar interactions** between DM and quarks
  - **Couplings** proportional to quark masses

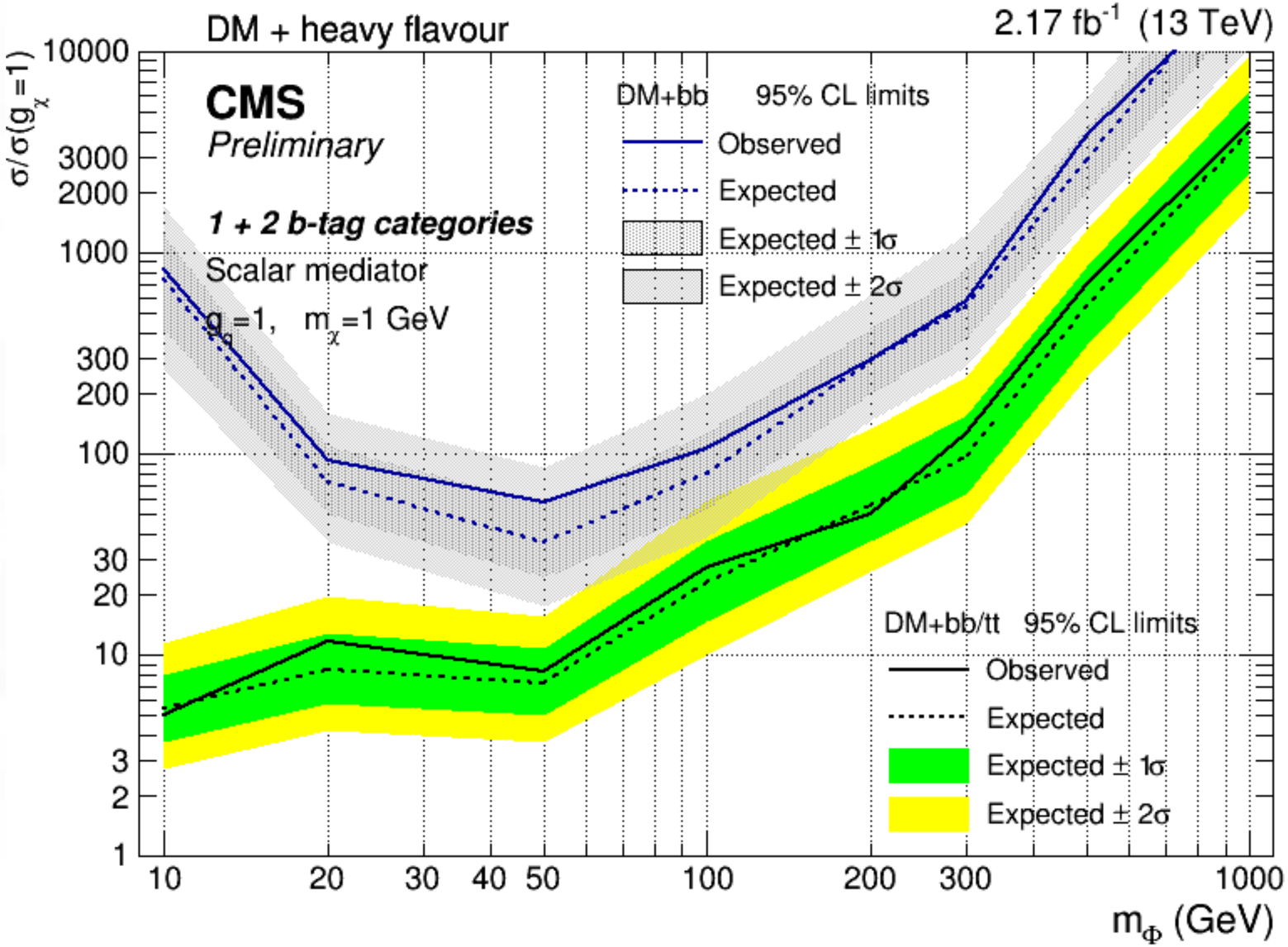
tt/bb+DM Analysis

Events with < 3 jets, different search regions based on b-jet multiplicity





tt/bb+DM Results



- Single and double b-tag categories combined
- Limits on **DM+bb only** and **DM+bb/tt combined**

CMS PAS B2G-12-007

Conclusion

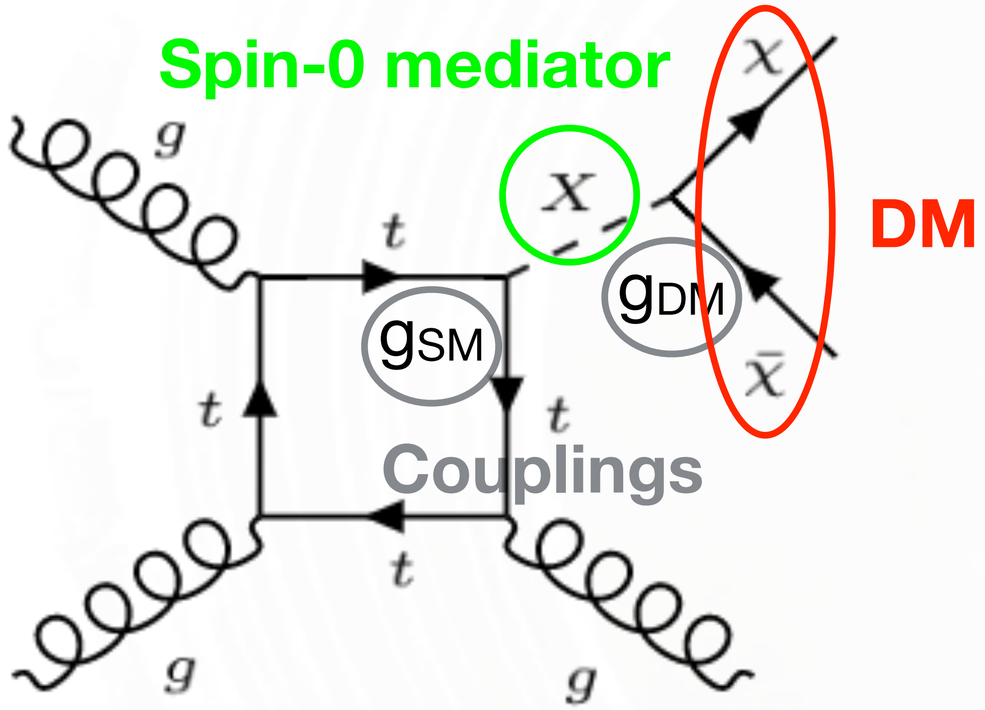
- Amazing work has been done in both experiments so far:
  - Unified interpretation and presentation of the results
  - Lots of channel already investigated: monojet/photon, mono-V, DM+bb/tt
- Results with first LHC Run II data have been presented, more to come in the next weeks
- No signs for DM so far, but new data will be recorded by the summer and new exciting results will be produced

Backup

From EFT to Simplified Models

Assumptions:

- **DM:**
  - single particle, Dirac fermion
  - stable and non-interacting
- **Mediator**
  - Axial/Vector, Scalar/Pseudoscalar
  - minimal decay width
    (e.g. to DM and to quarks)



LHC DM Forum, arxiv:1507.00966v1

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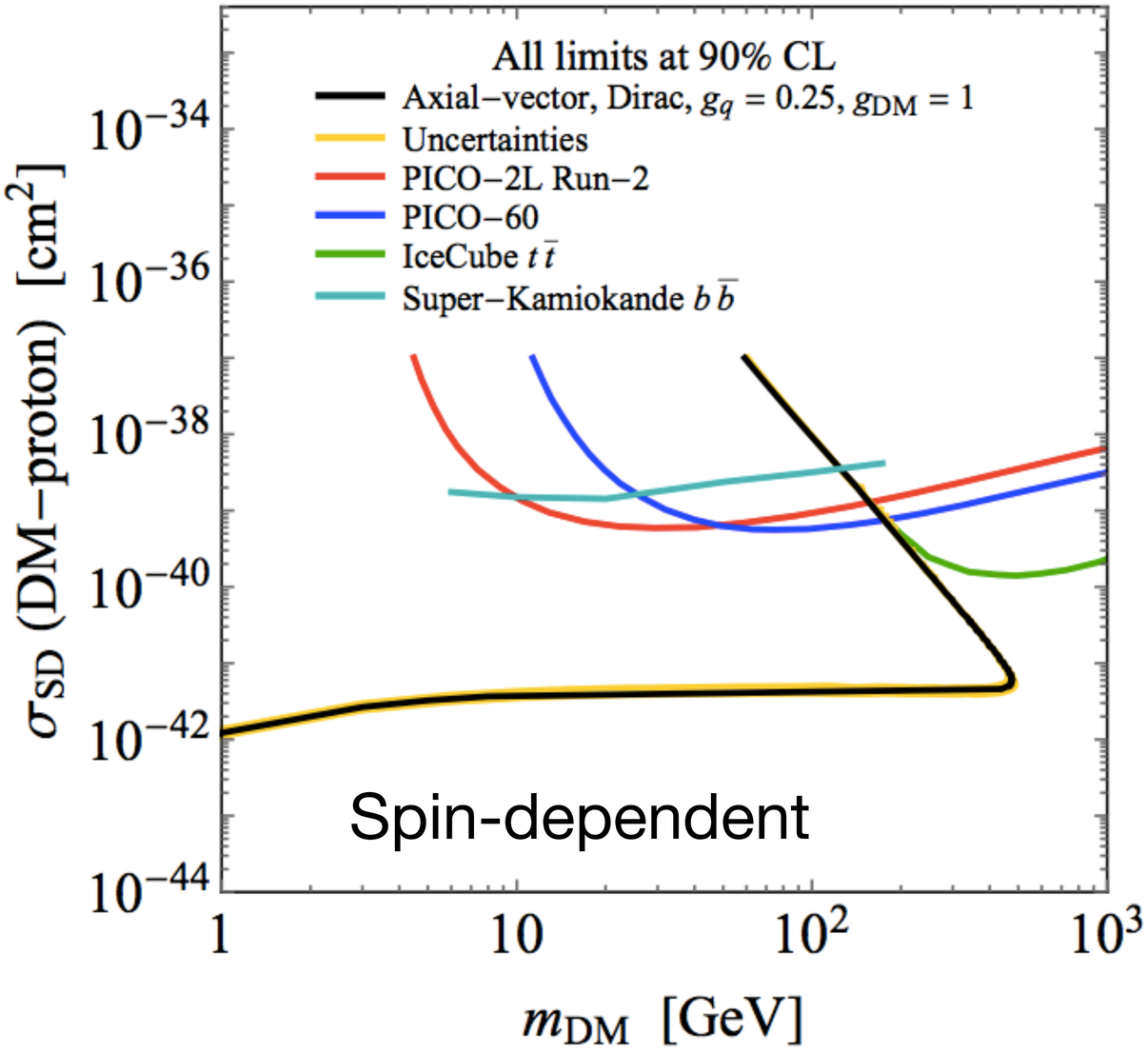
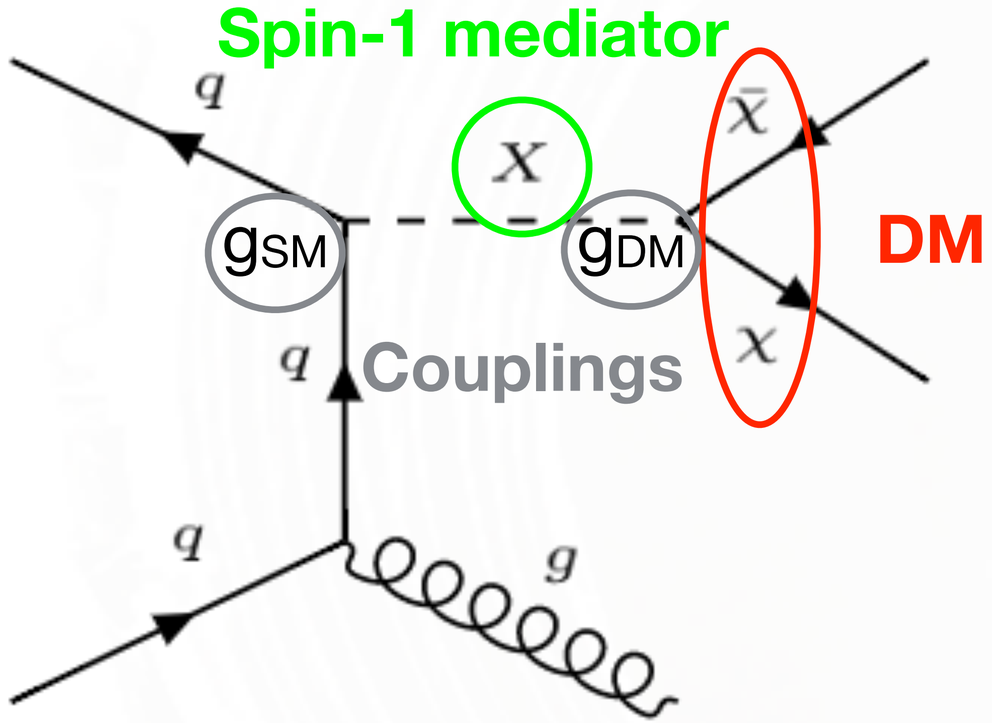




LHC DM WG, arxiv:1603.04156

Conversion into DM-Nucleon Scattering Cross Section

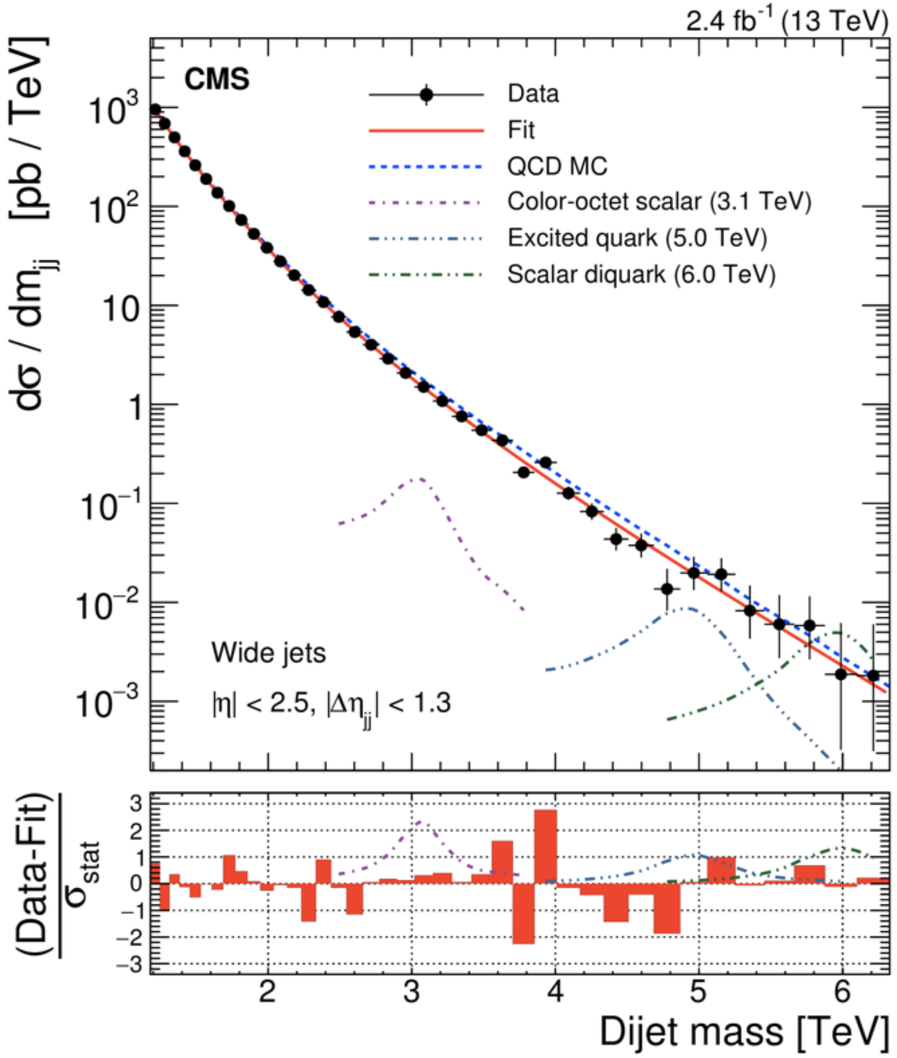
- SI-DM nucleon scattering cross section: $\sigma_{\rm SI} = \dfrac{f^2(g_q) g_{\rm DM}^2 \mu_{n\chi}^2}{\pi M_{\rm med}^4}$
  - DM-nucleon reduced mass: $\mu_{n\chi} = m_n m_{\rm DM}/(m_n + m_{\rm DM})$ $\qquad m_n \simeq 0.939\,{\rm GeV}$
  - Vector Mediator-nucleon coupling: $f(g_q) = 3 g_q$

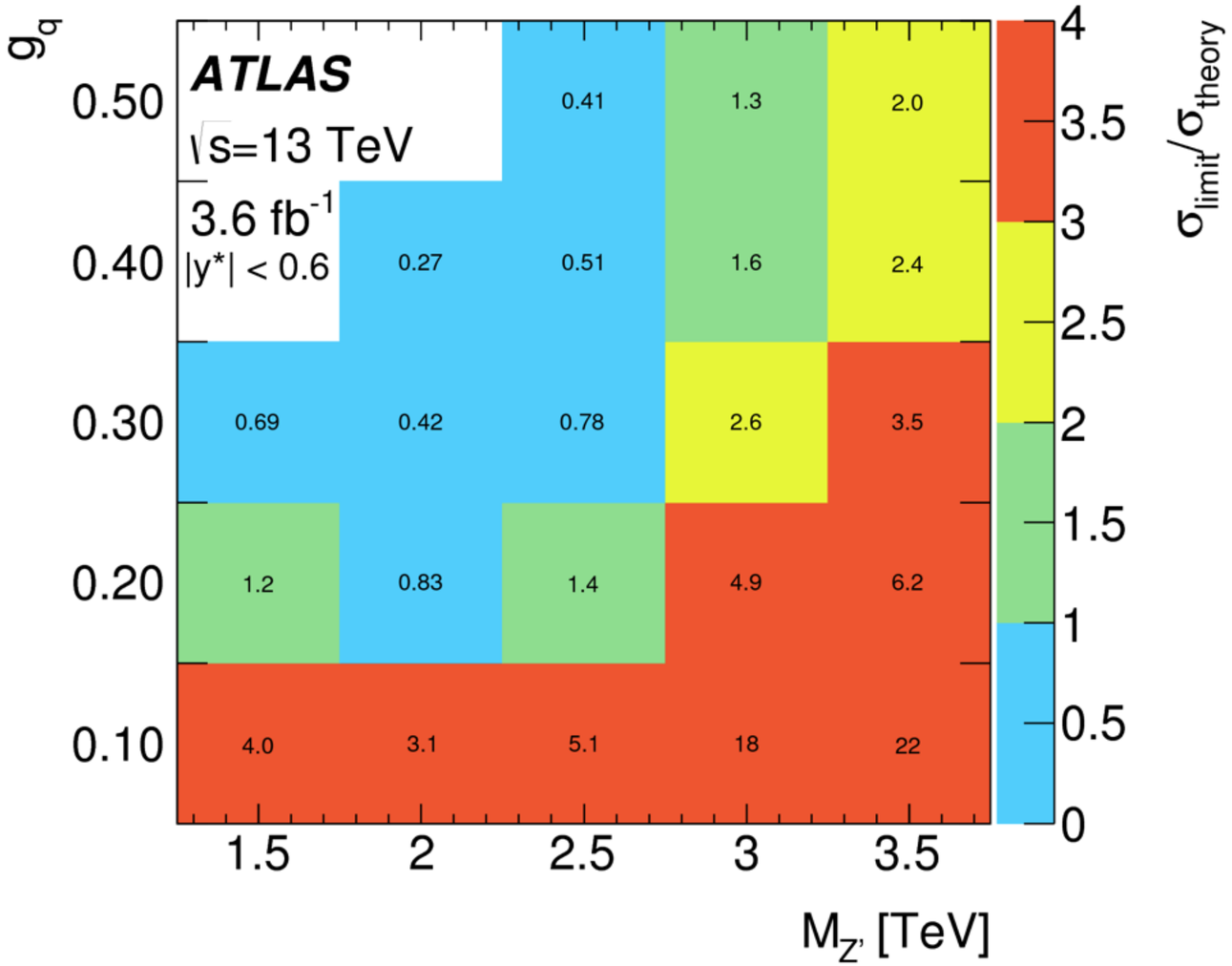
=> $$\sigma_{\rm SI} \simeq 6.9 \times 10^{-41}\ {\rm cm}^2 \cdot \left(\frac{g_q g_{\rm DM}}{0.25}\right)^2 \left(\frac{1\,{\rm TeV}}{M_{\rm med}}\right)^4 \left(\frac{\mu_{n\chi}}{1\,{\rm GeV}}\right)^2$$

Dijet Limit Conversion

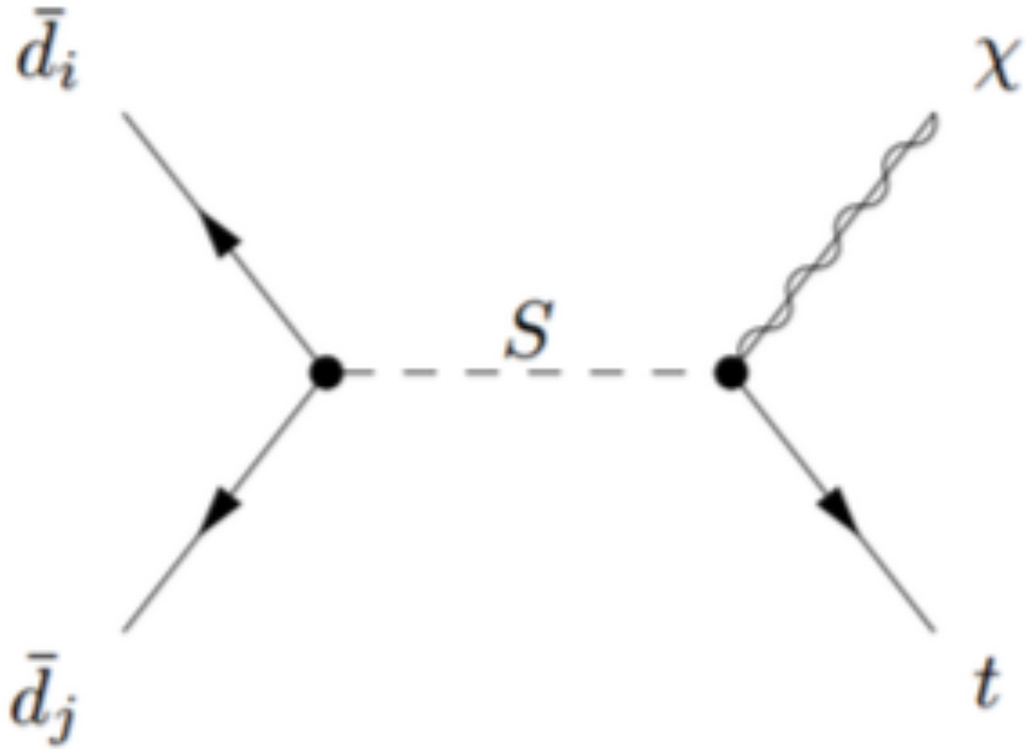
- Take the limits on gaussian-shaped resonances
- Compare these to MadGraph predictions for signal rates and shapes, after parton shower, detector smearing, and analysis cuts
- Not a full MC interpretation
  - from other studies we expect that it will match a full MC very well
  - Z' limits in the 13 TeV paper and it agrees with those in the large m_{DM} limit

Dijet Limits

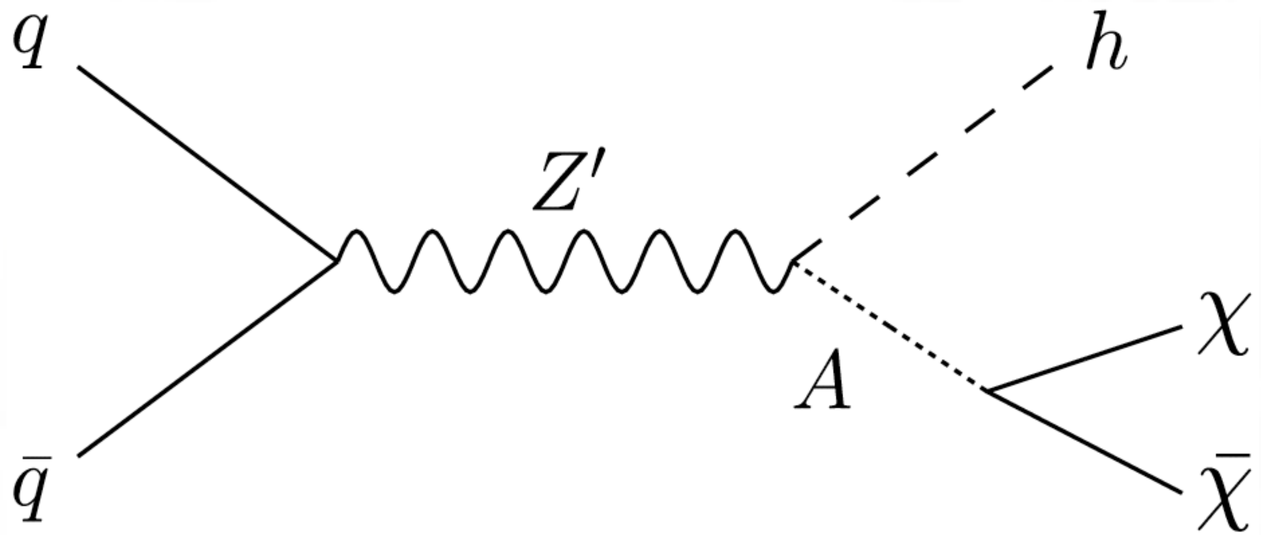




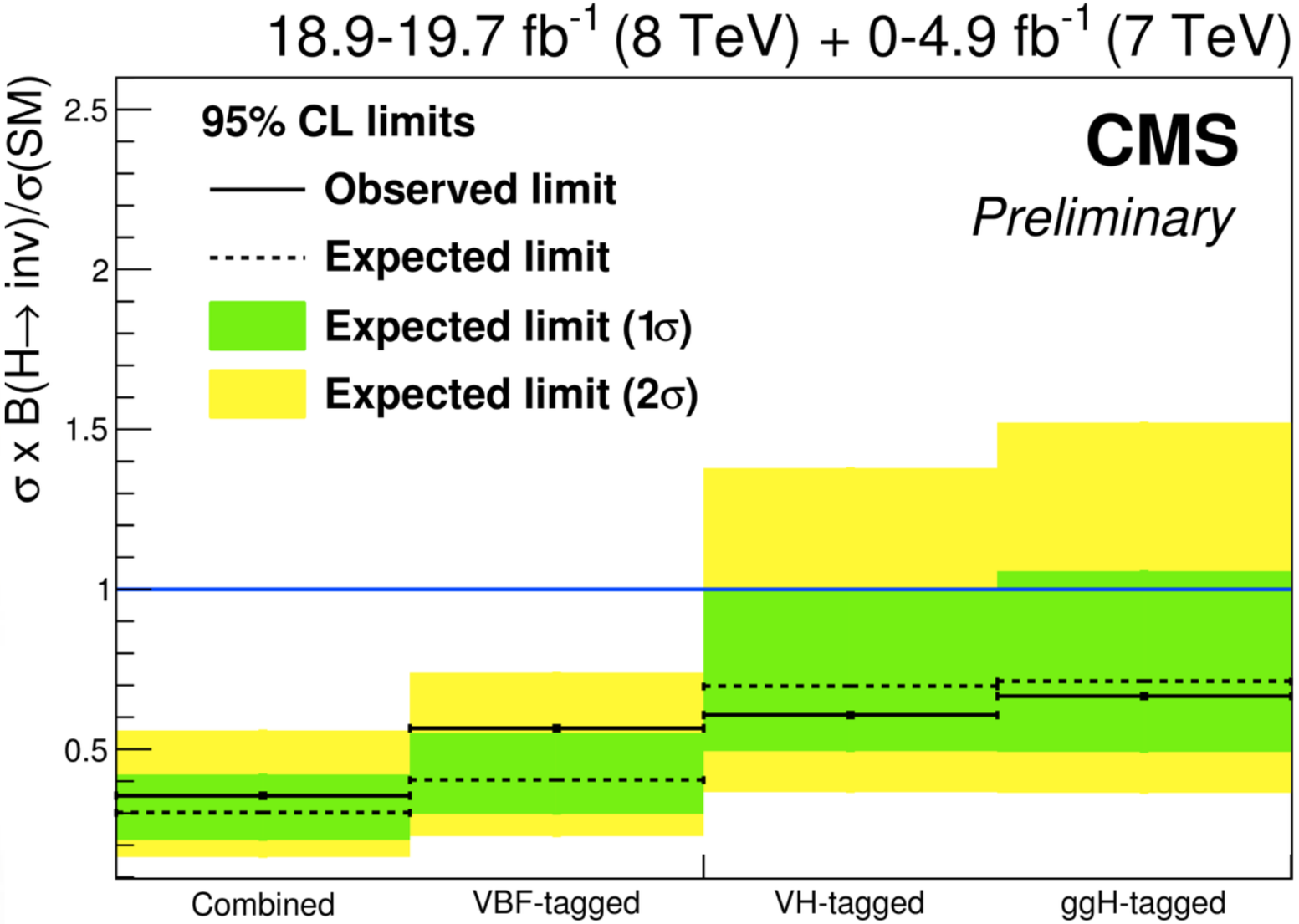
Monotop



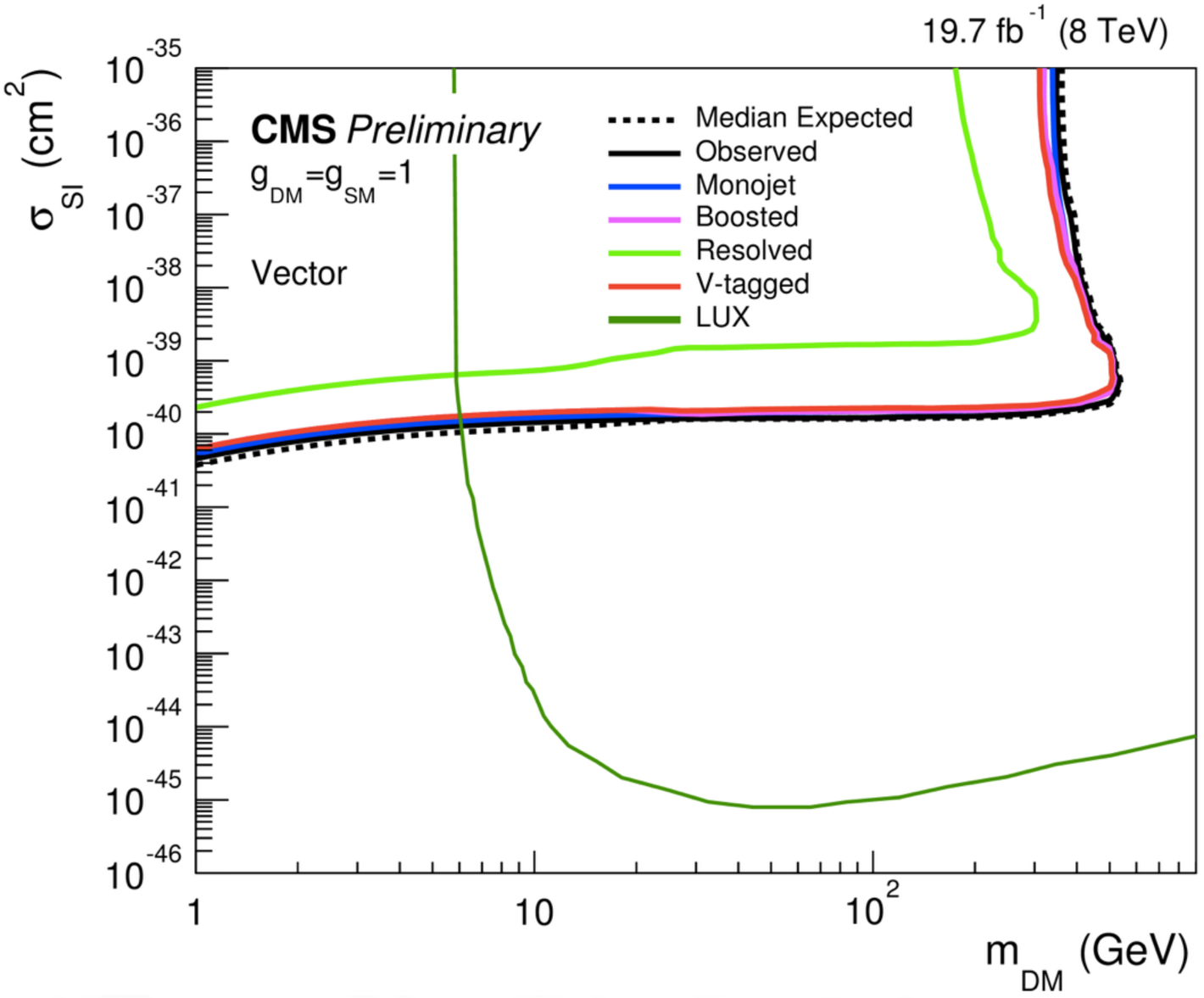
MonoHiggs



Invisible Higgs Limits



Monojet/Mono-V Combination @ 8 TeV

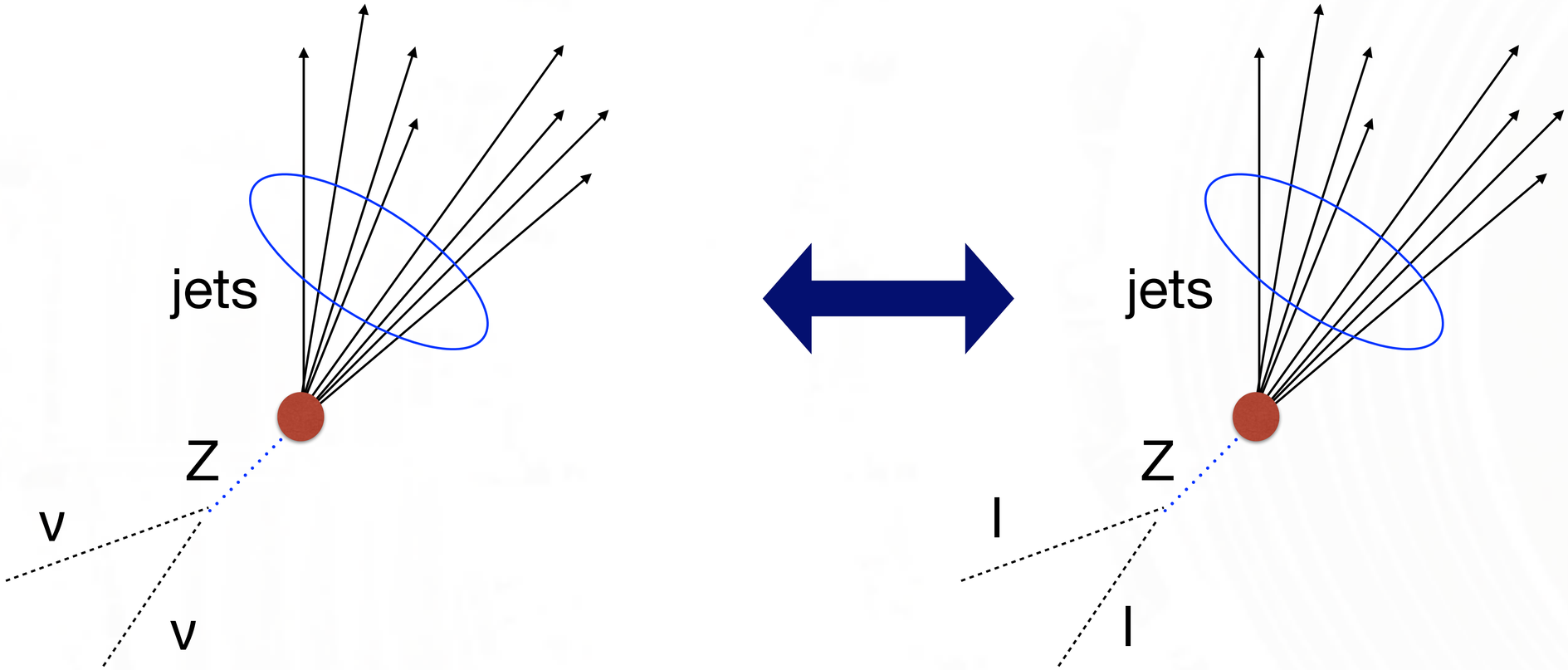


Fitting simultaneously for both monojet and mono-V signals

Considering all the analysis samples from both the searches

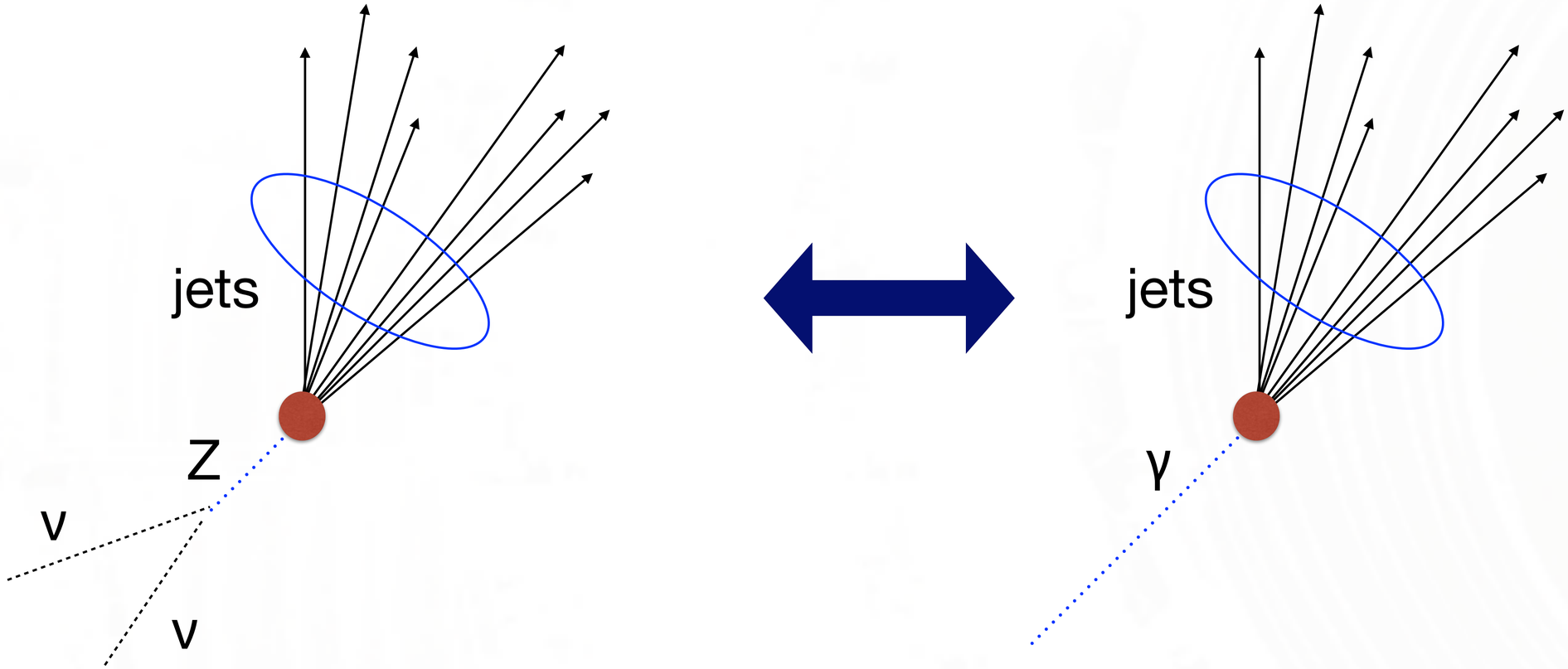
Z+jets Background Model

PROXY Di-mu/ele CR



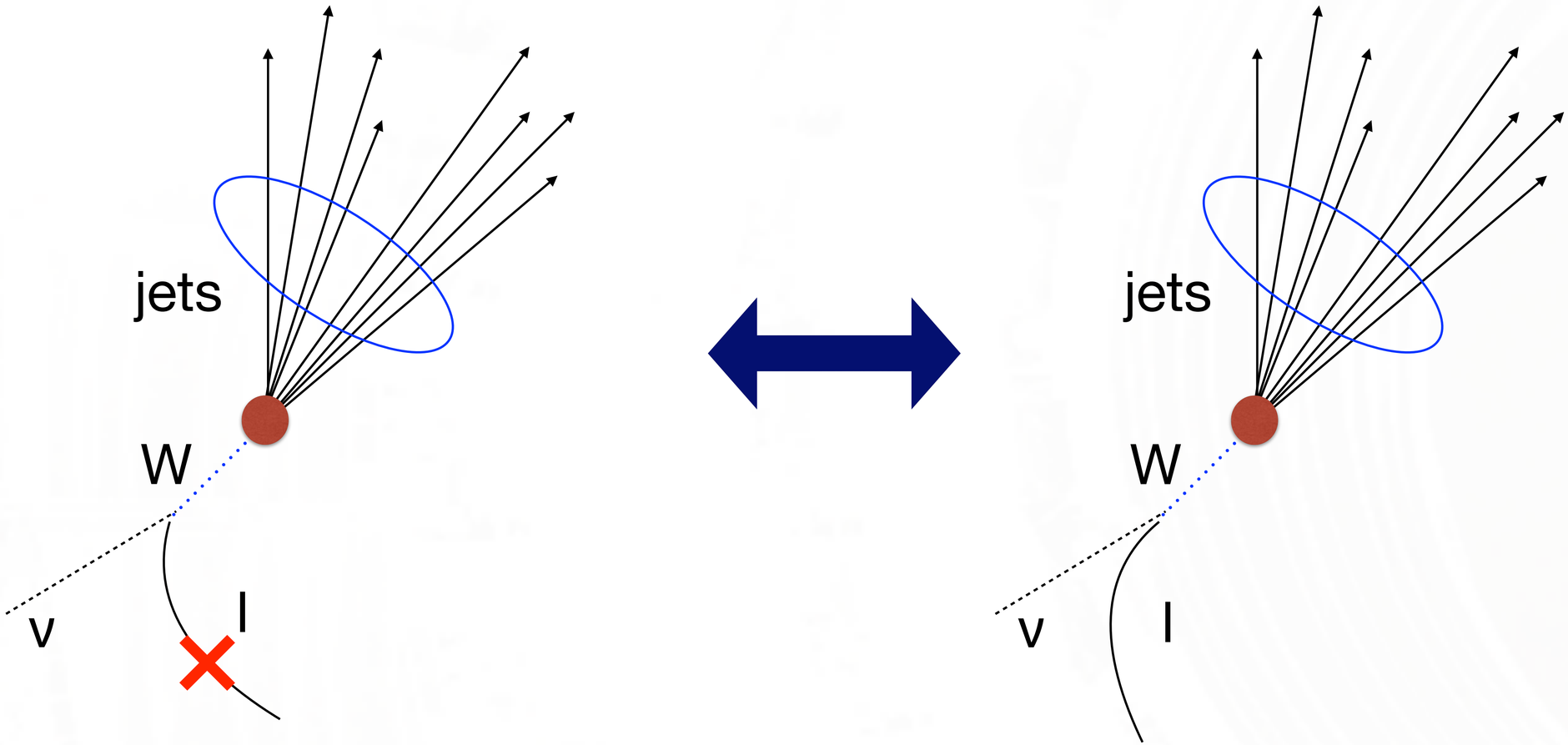
Z+jets Background Model

PROXY photon CR



W+jets Background Model

PROXY Single mu/ele CR



b(b)/tt+DM Signal

Looking for events with:

- Large MET
- At least one high Pt **b-tagged** jet