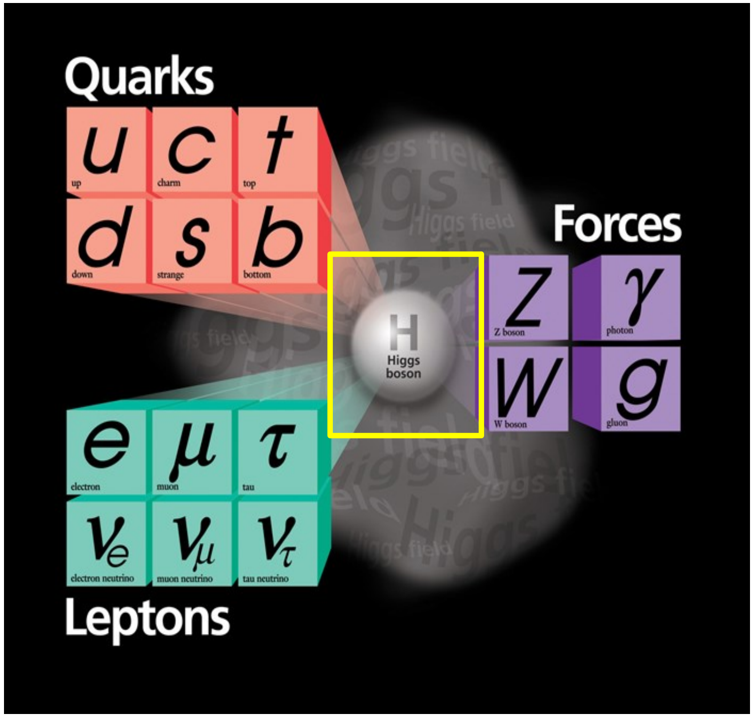
The 4th China LHC Physics Workshop
CLHCP 2018

Search for Exotics Physics at ATLAS and CMS

Liang Li
Shanghai Jiao Tong University
On Behalf of ATLAS and CMS Collaborations

Outline

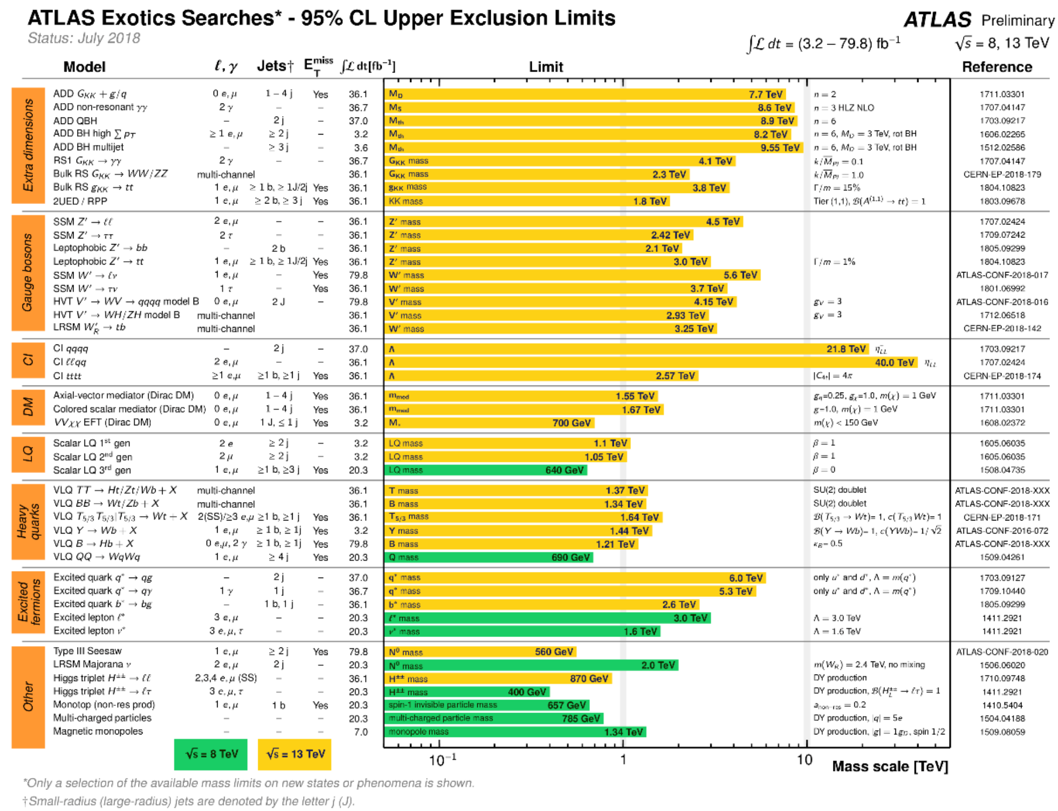
- Motivation
- Resonances Search
- Dark Matter Search
- Long-lived Particles Search
- Summary



Why Exotics?

Finding new physics

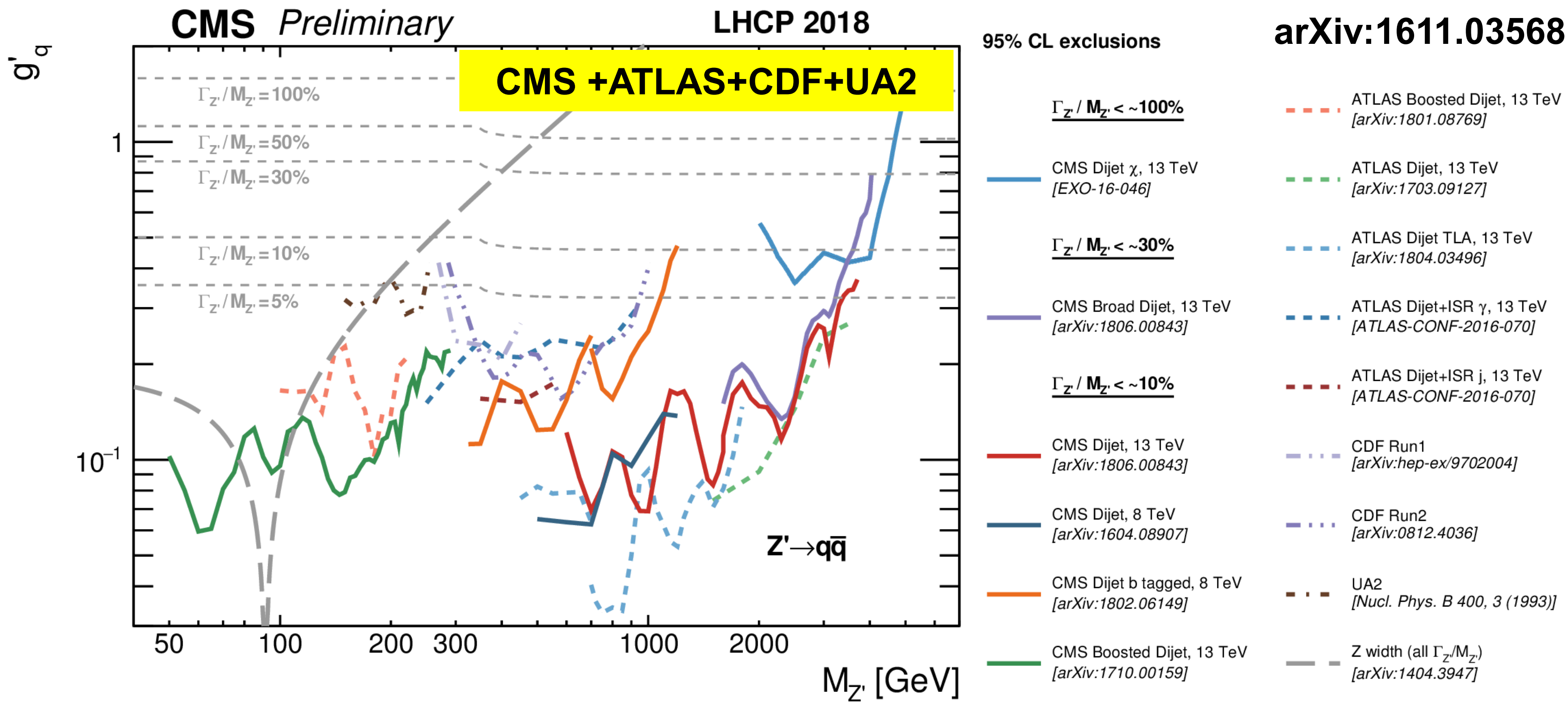
- No one knows for sure where is the new physics
  - Leave nothing untouched
  - Go “exotic”!
- How “exotic” can one go?
  - New interactions and products: resonances
  - Broad kinematic reach
    - Low to high masses
    - 28 GeV resonances not covered here, sorry!
  - New signatures: long-lived particles, emerging jet
  - Dark matter
- Model independent if possible



Not possible to cover all searches

- Only focus on recent results
- Personal taste

Resonances: Dijet Scan

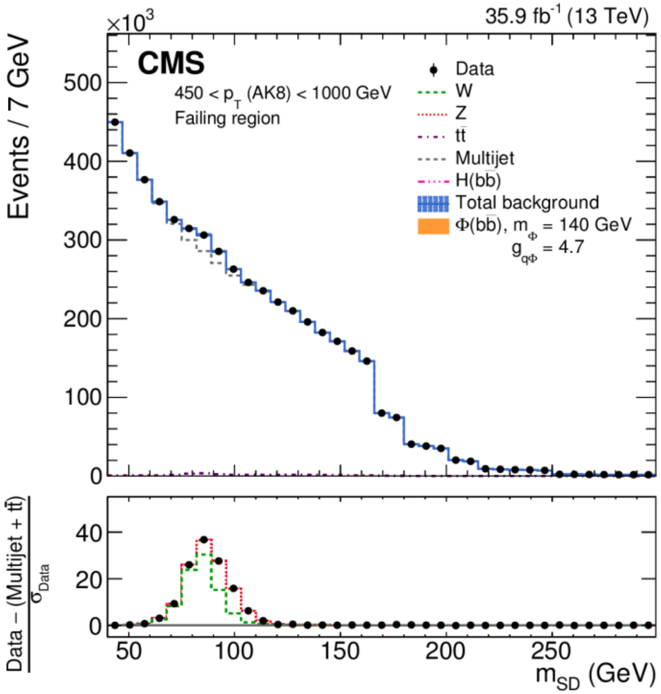


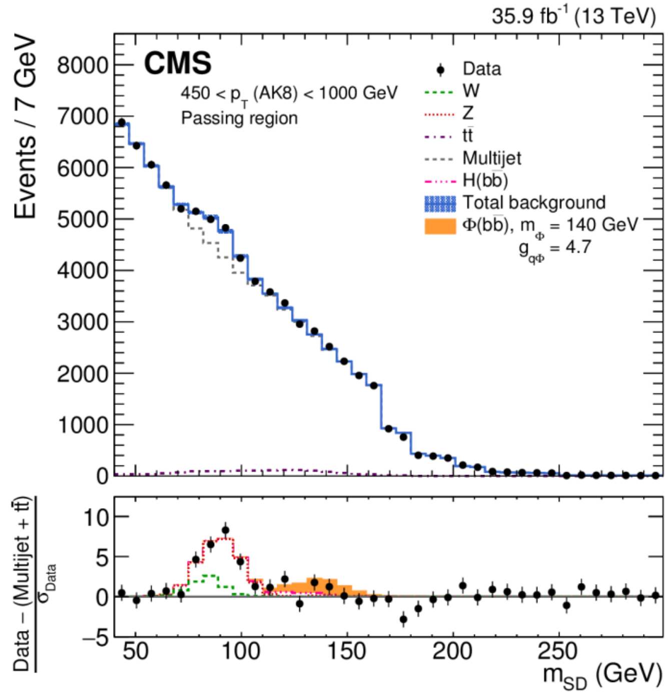
Large kinematic range scan

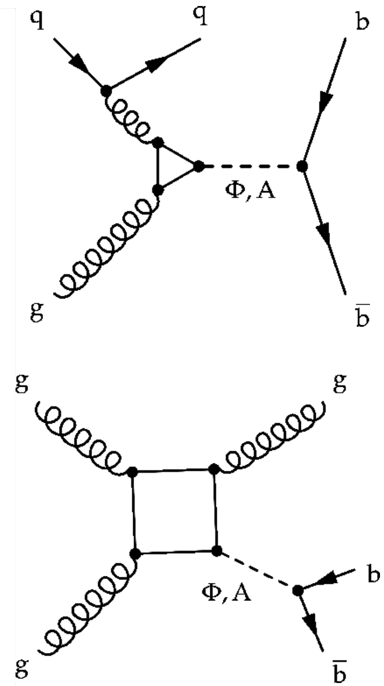
- **Limits on the universal coupling g'_q between a leptophobic Z' boson and quarks for various assumed Z' width**
- **More beyond simple dijets: b-jets, top quark jets…**

Resonances: Double b-jets

CMS-EXO-17-024



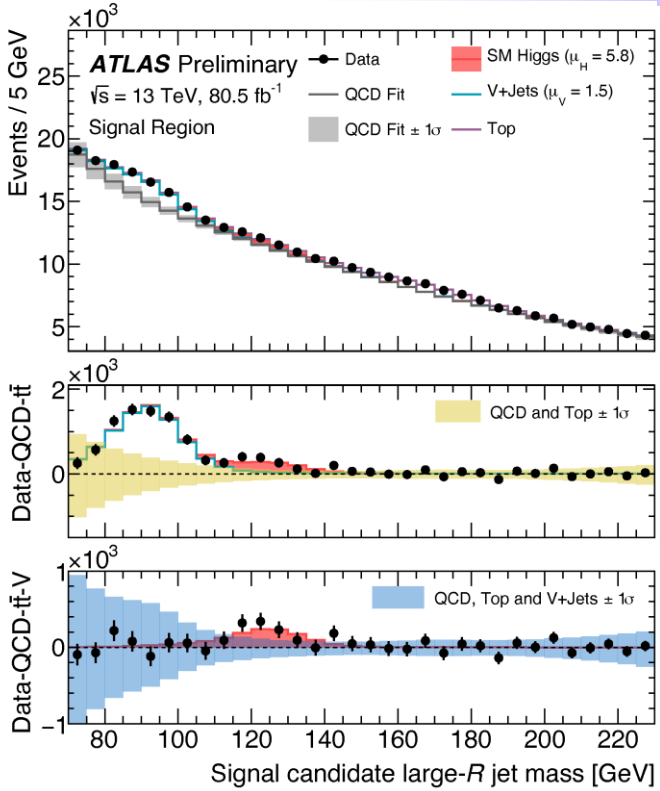


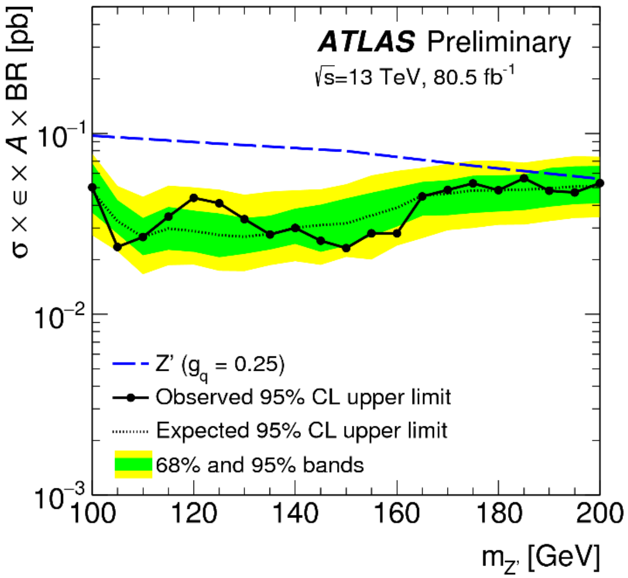


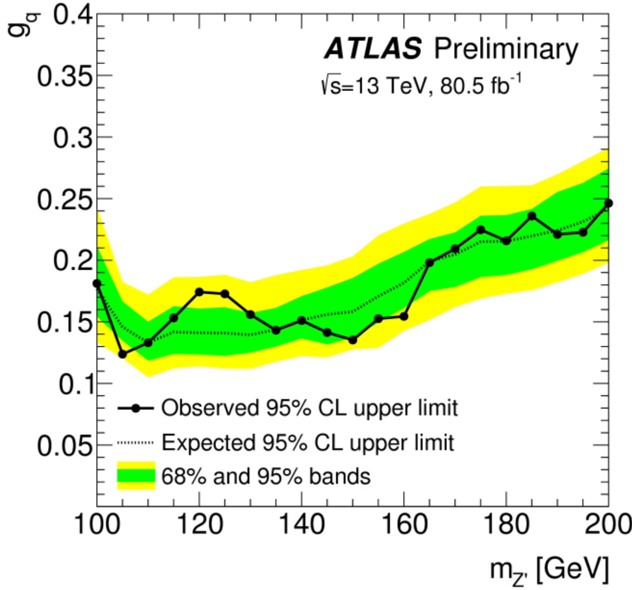
Select events with dedicated double-b tagger and constrain main QCD backgrounds with control region using "pass-fail ratio"

- **Soft-drop jet mass M_{SD} peaks at ϕ(bb)/A(bb) for signals (AK8/CK15)**
- **Background only fits show good agreement with data, with clear W and Z contributions**
- **No significant excess for signal masses between 50-350 GeV**
- **Exclusion limits: $\sigma X \phi$(bb)/A(bb) ~ 79(86)pb, coupling $g_{q\phi}/g_{qA}$ ~ 3.9 (2.5)**

Resonances: Double b-jets (Boosted)







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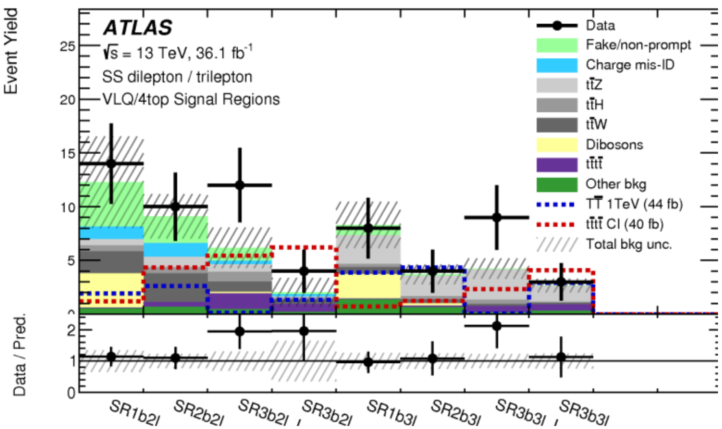
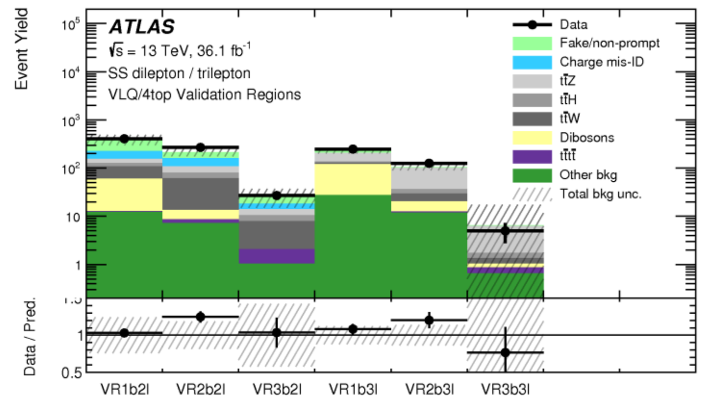
Select large-R jet for hadronically decaying resonance

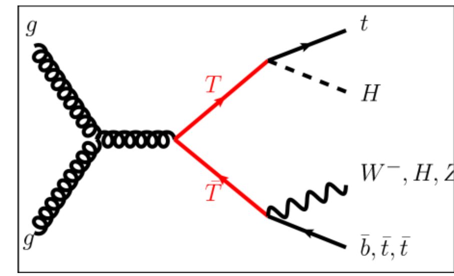
- **Data-driven estimation via fitting large-R jet mass distribution m_J in SR, validated by data in CR_{QCD}**
- **Boosted tt events constrained by MC template fitted to CR_{tt} data**
- **Combined SM fit of V + jets, H + jets process and search for extra exotic signals in m_J distribution with the range of 70 and 230 GeV**

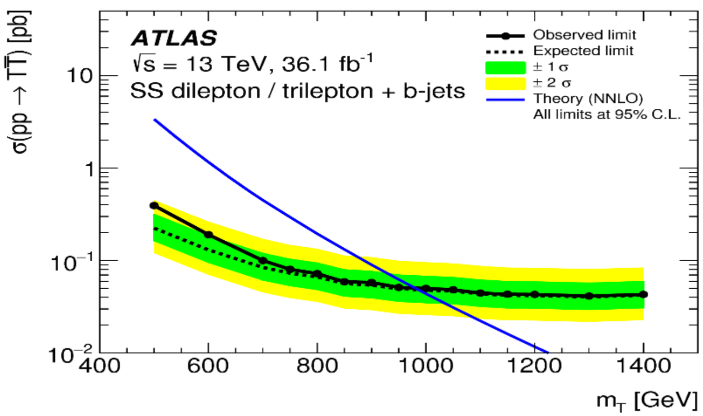
Resonances: Top Quark Jets

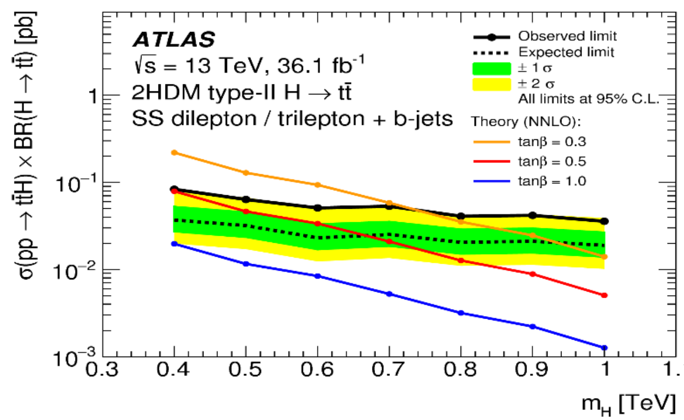
arXiv:1807.11883

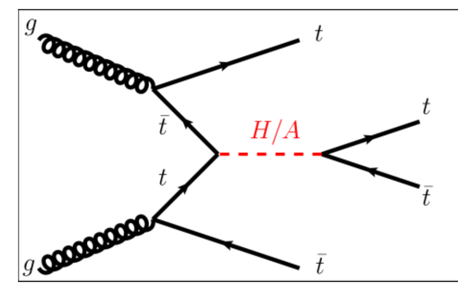








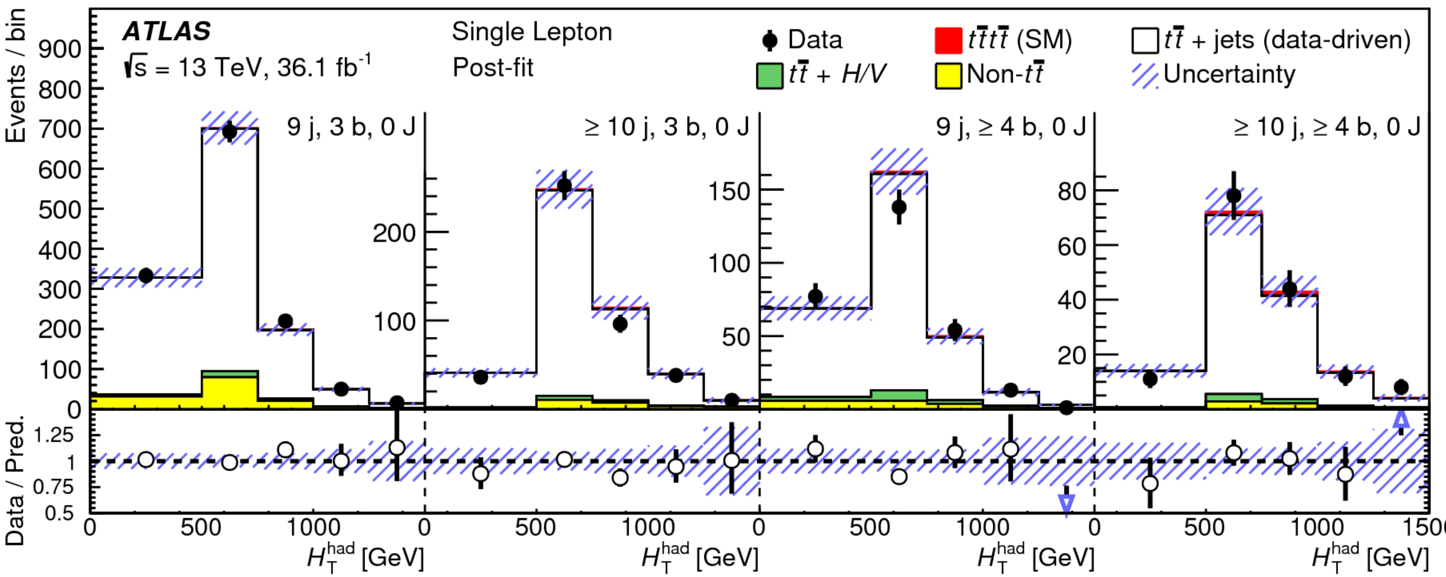




Select same-sign leptons with b-jet to look for vector-like quark, four-top-quark, and same-sign top-quark pair production

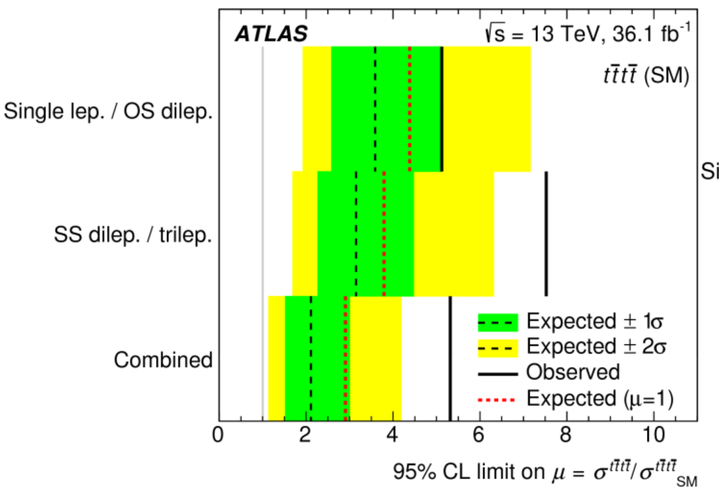
- **Fake lepton background estimated by matrix method, mis-charge ID estimated by Z->ee enriched data sample**
- **Use validation region (VR) to verify background modelling in SR**

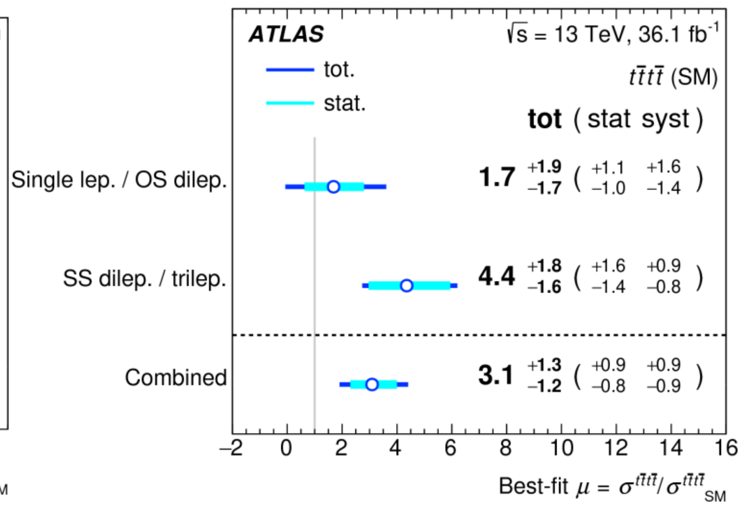
Resonances: Top Quark Jets



arXiv:1811.02305

- **Select single or opposite-sign di-leptons with jets**
- **Major tt+jets backgrounds modelled by TRF method**
- **VR and SR divided by #jets, #b-jets, #large-R jets**
- **Signal + background fit H_T^{had} distribution shows good agreement**





Combined upper observed(expected) limit on μ(tttt): 5.3 (2.1)

Observed(expected) limit on BSM EFT (tttt) cross section: 21fb (15fb)

New Signatures: Long-lived Particles

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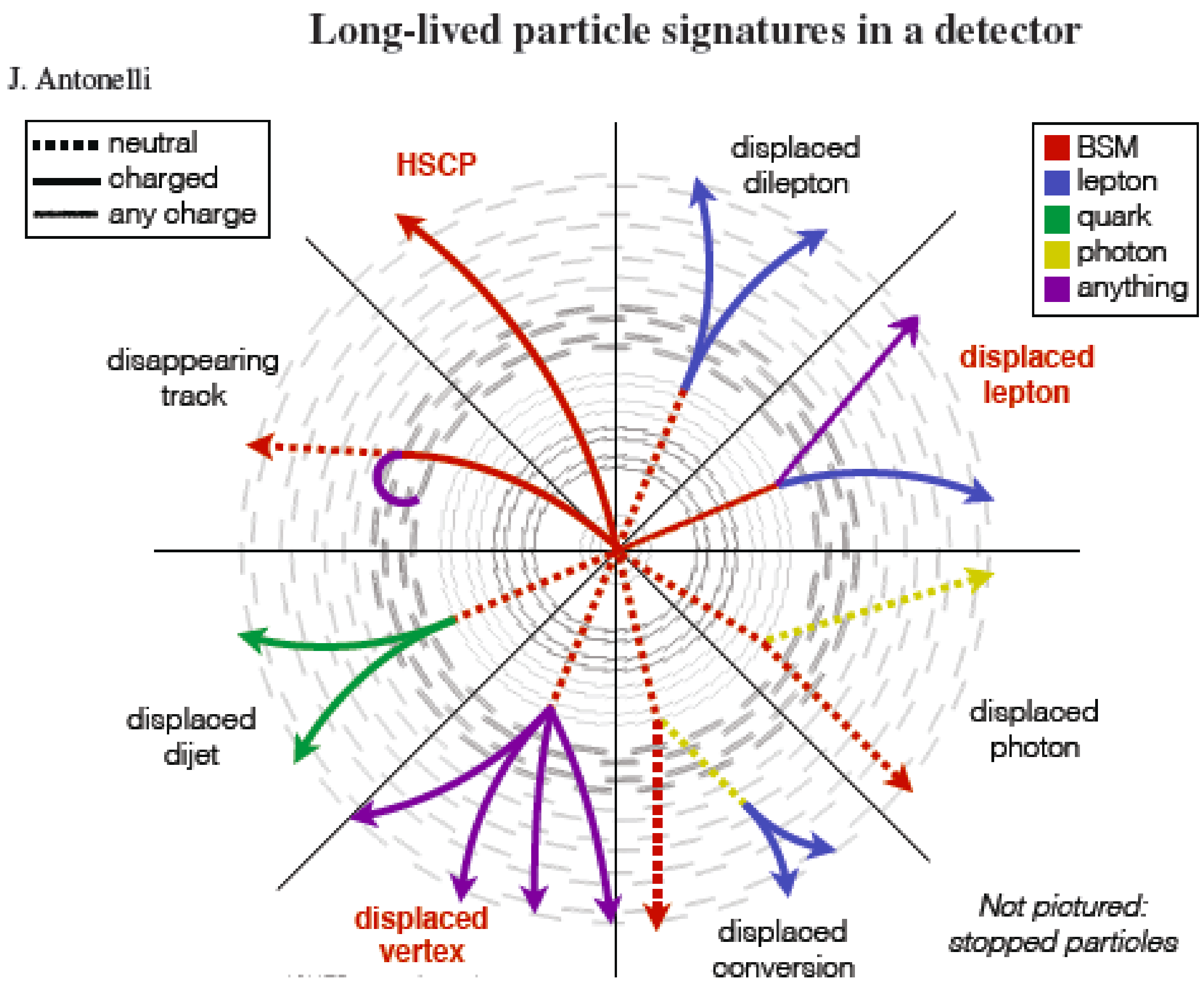

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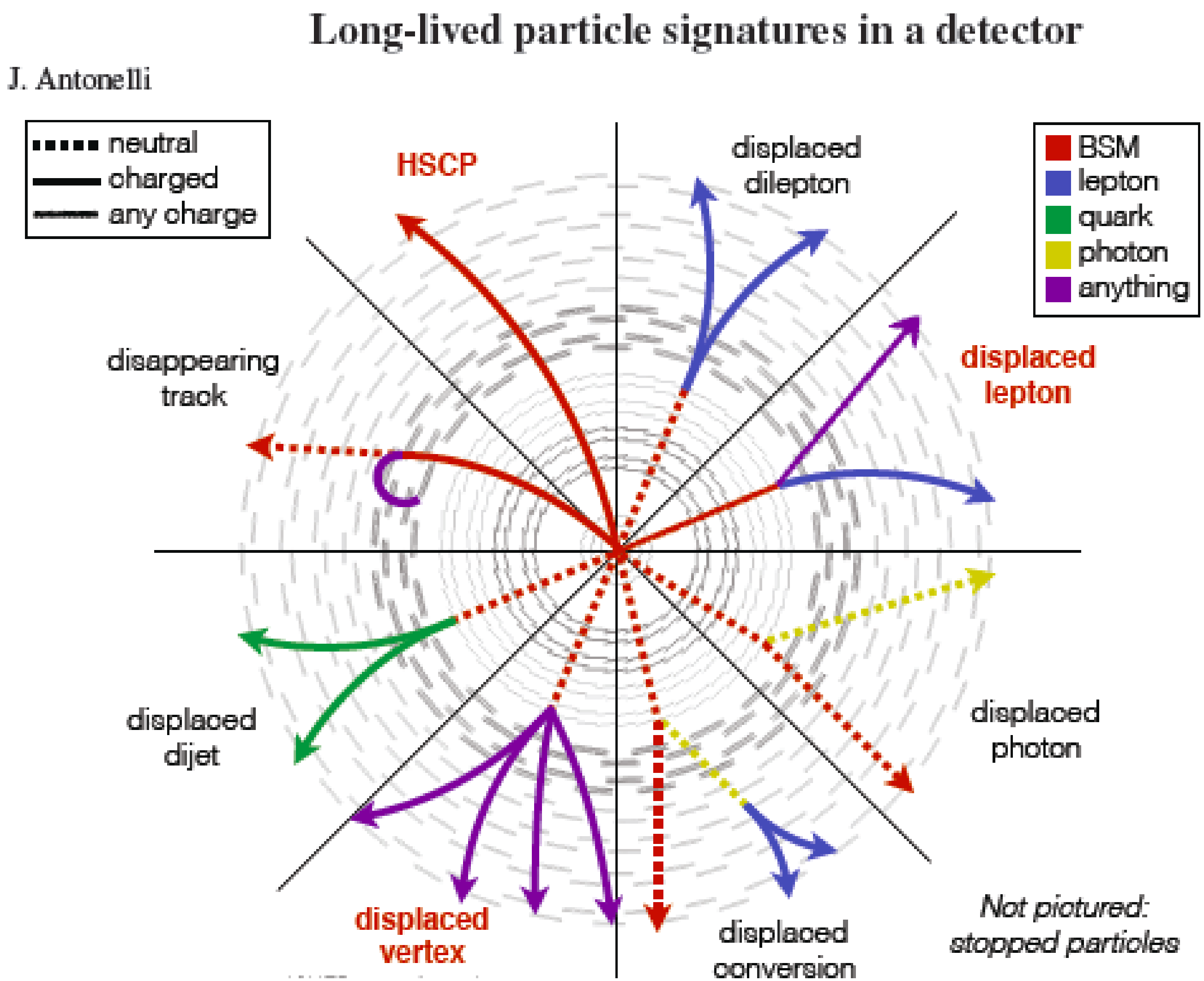

- ✓ Displaced objects: vertices, leptons, jets…
- ✓ Disappearing tracks, (Heavy/Multi-) Charged Particles…

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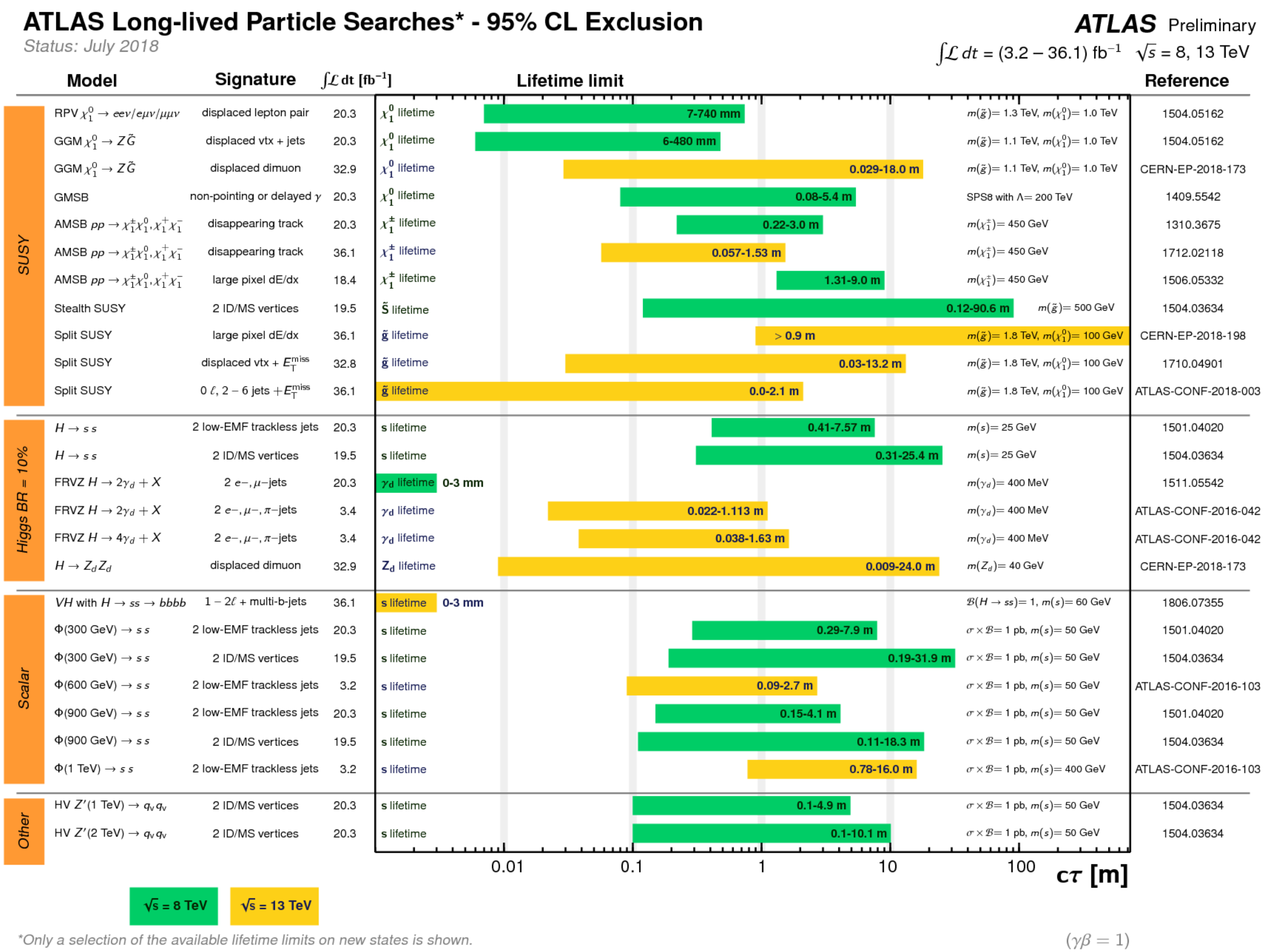
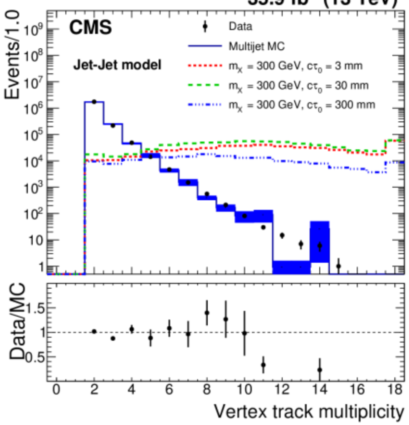


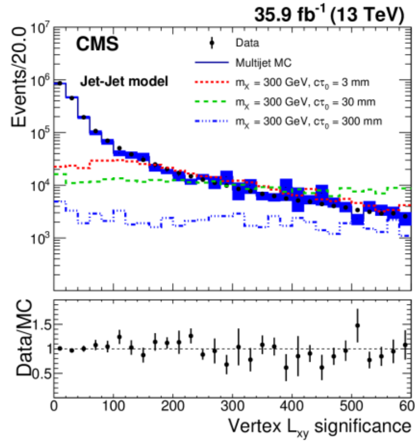
✓ **Displaced objects: vertices, leptons, jets…**

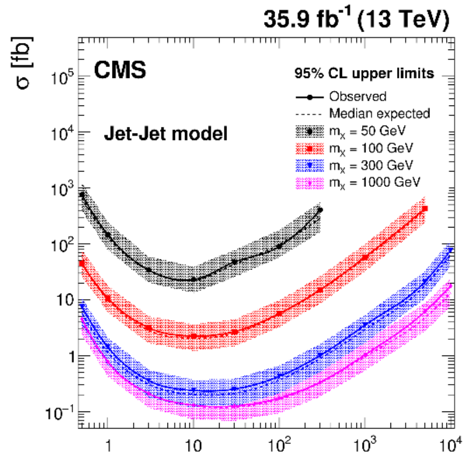
✓ **Disappearing tracks, (Heavy/Multi-) Charged Particles…**

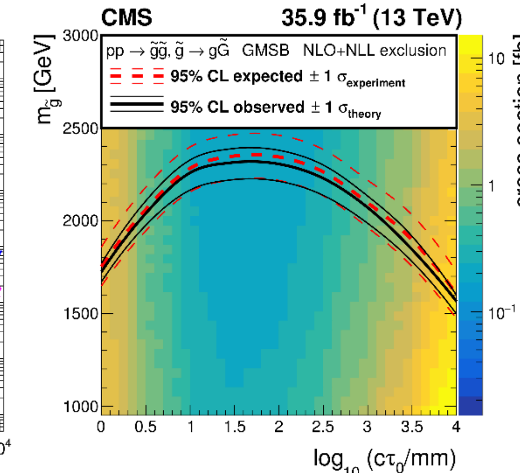
Long-lived Particles: Displaced Jets

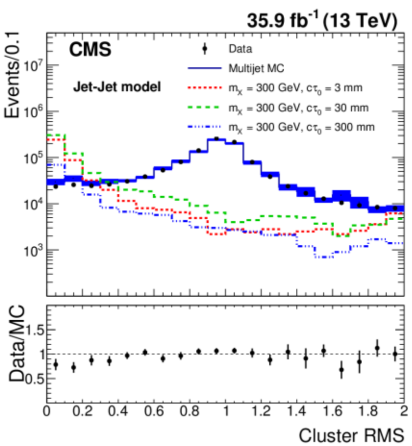
CMS-EXO-18-007

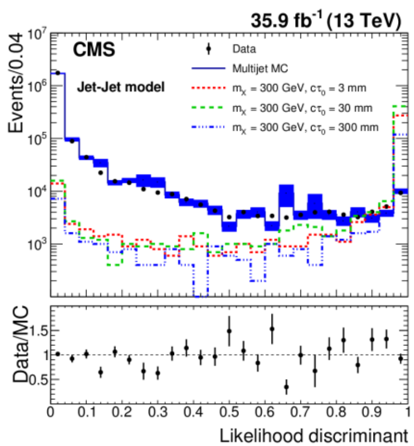


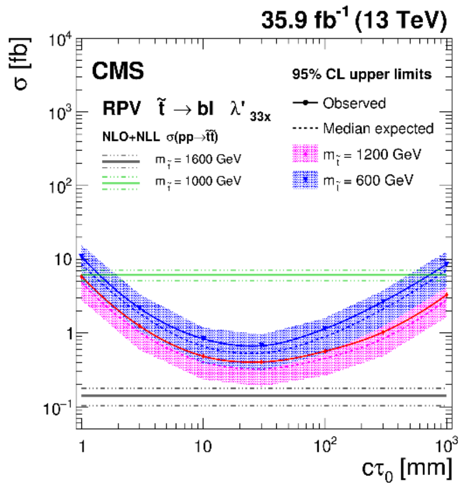


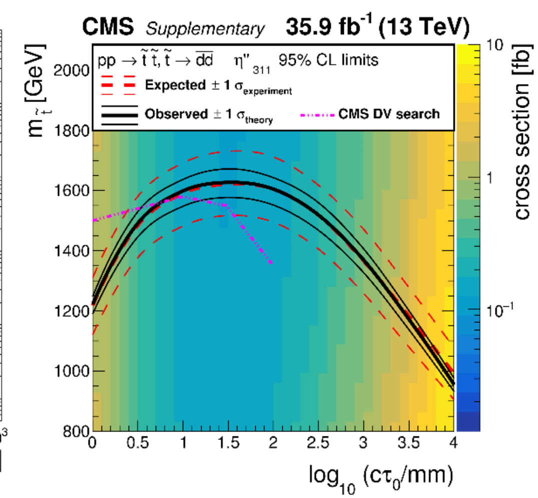








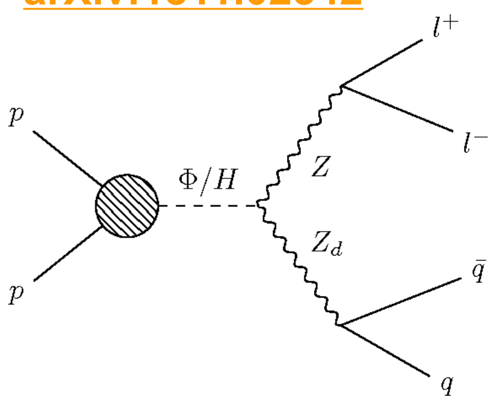


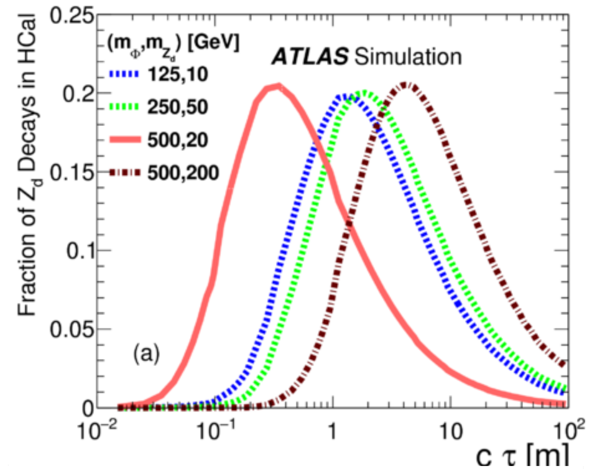


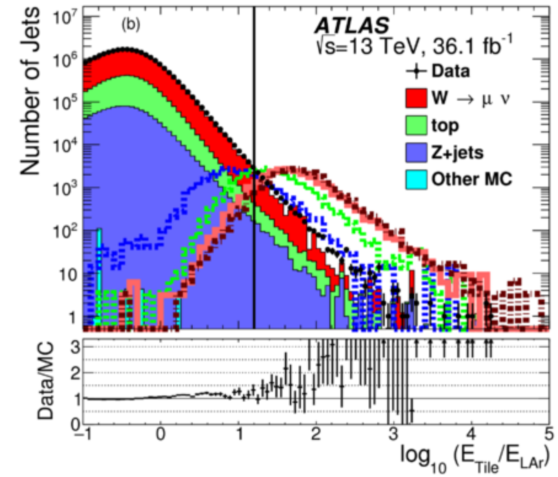
- **Displaced vertex associated with dijet, build discriminant from vertex track multiplicity, vertex L_{xy} significance and Cluster RMS**
- **Limits obtained for pair-produced LLPs, gluino and squark masses**

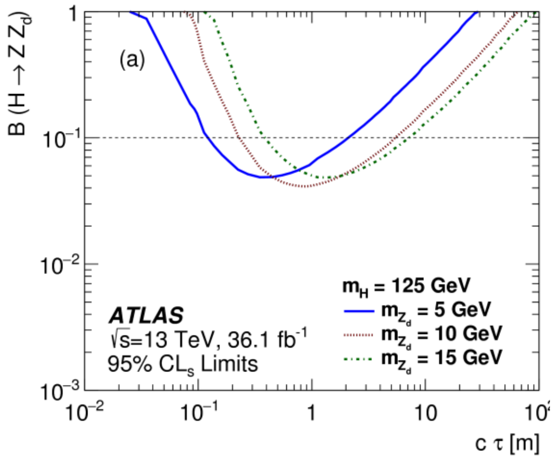
Long-lived Particles: Displaced Jets

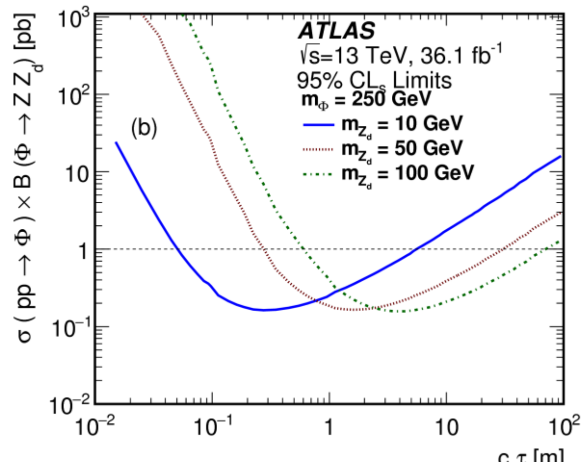
arXiv:1811.02542

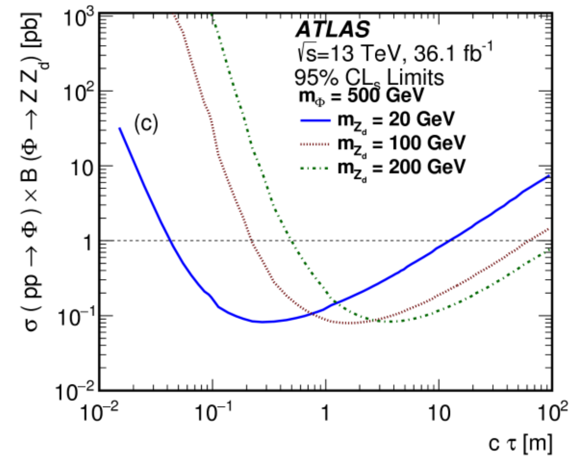








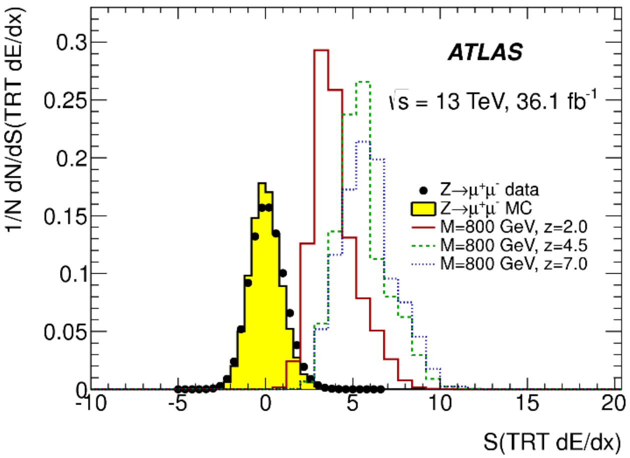


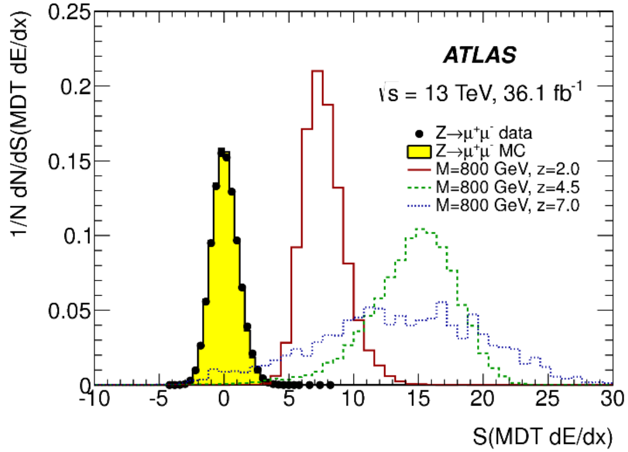


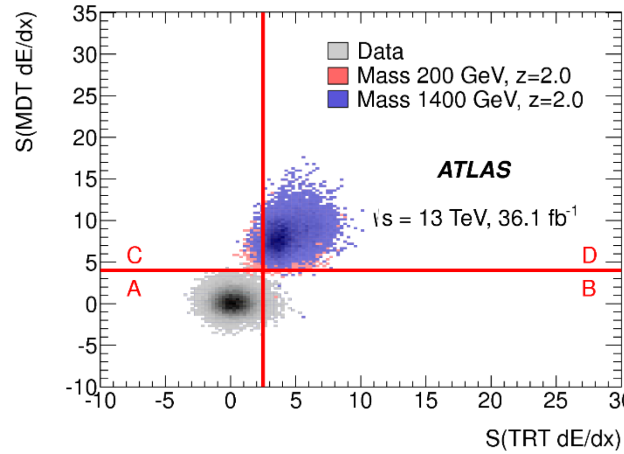
Event signature: Z_d decaying within the TileCal and no charged tracks point to the primary vertex

- **Define calorimeter-ratio jet (CRjet) with $\log_{10}(E_{Tile}/E_{LAr})>1.2$**
- **Data-driven method to estimate background using W+jets sample**

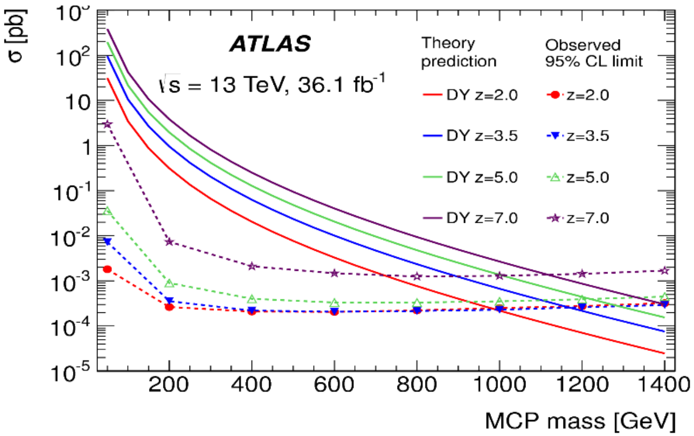
Long-lived Particles: Multi-charged Particles

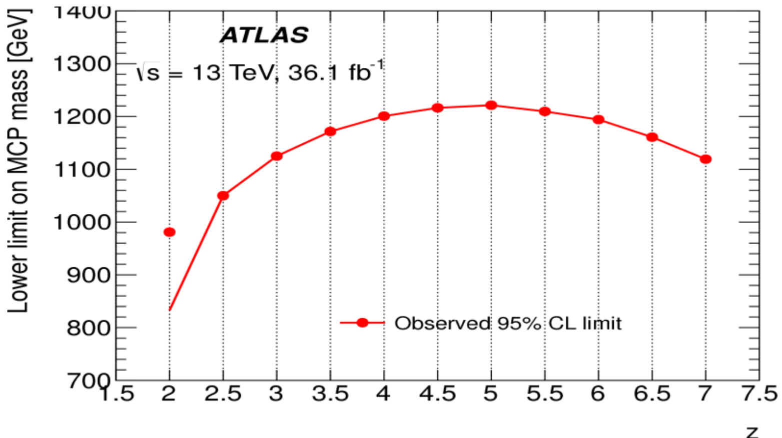






arXiv:1812.03673

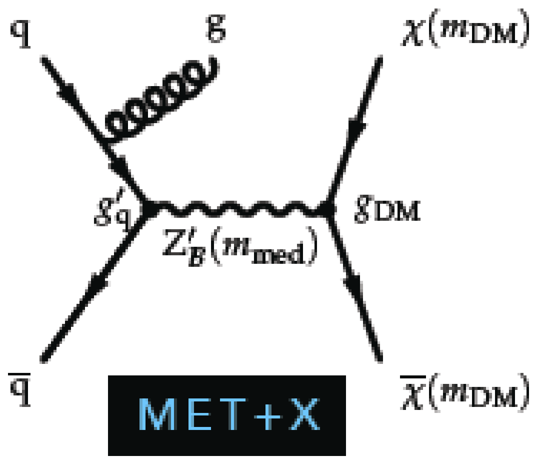


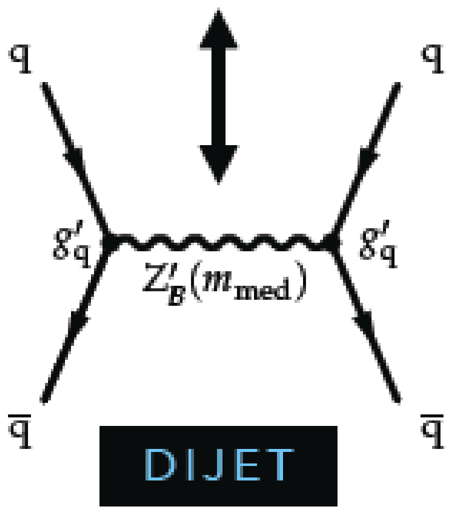


The significance variable of S(dE/dx) is a powerful discriminator

- **Use 2D S(TRT dE/dx) S(MDT dE/dx) to define signal and control region, background estimation using ABCD method and sideband**
- **No observed events (<1 background expected)**
- **Multi-charged particles mass lower limit: 980–1220 GeV**

Dark Matter Searches





✓ **(Mono-)X + MET**

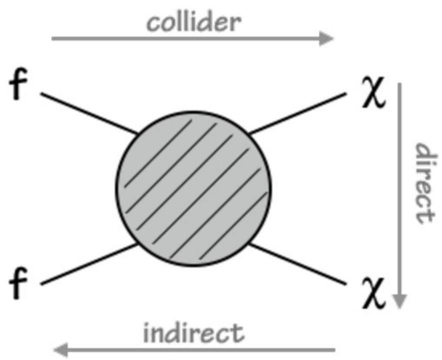
- X=jet, photon, W, Z, H, t…
- jet: most general and powerful
- photon: less powerful
- W/Z hadronic: large background
- W/Z leptonic: clean signature, small signal
- Higgs: Higgs portal
- Top: Yukawa-like coupling, more complex signature

✓ **Di-X Resonance**

- X=jet, photon, W, Z, H, t…
- Resonance scan

✓ **Searches comparison**

- Collider vs. direct/indirect searches



Dark Matter Searches

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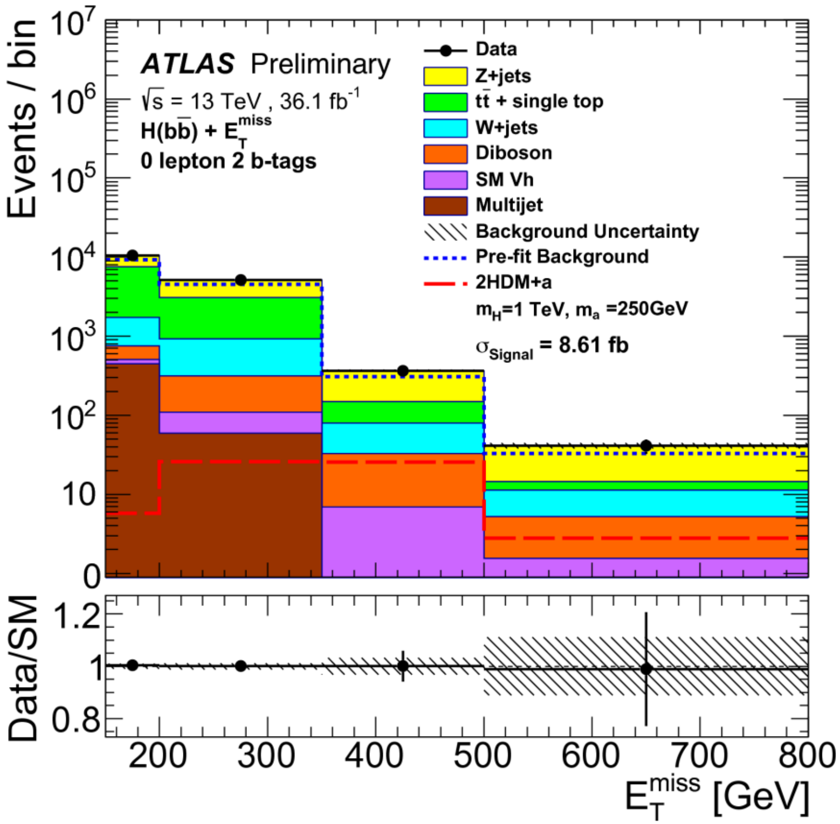
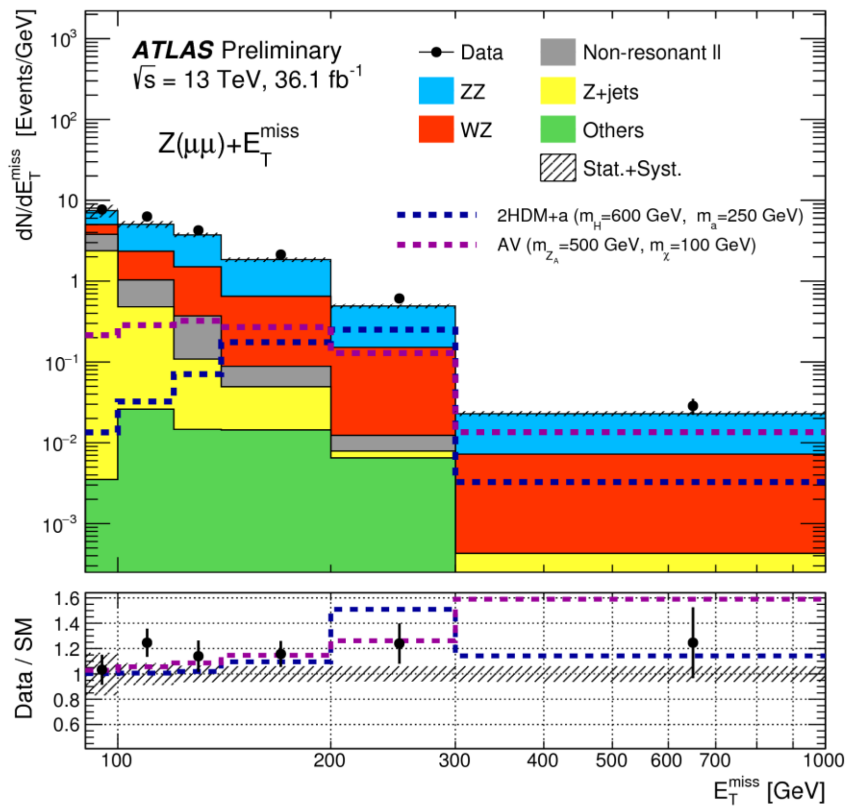
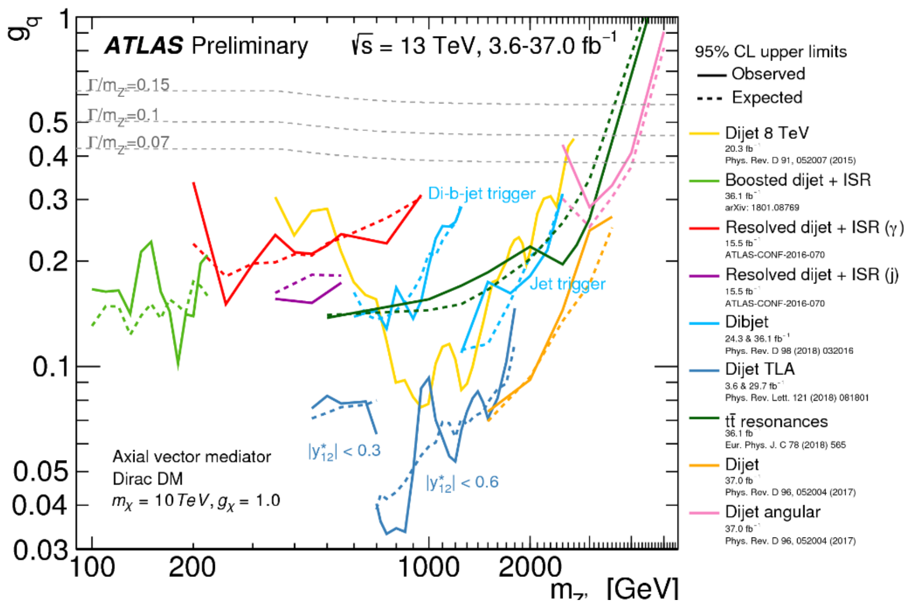


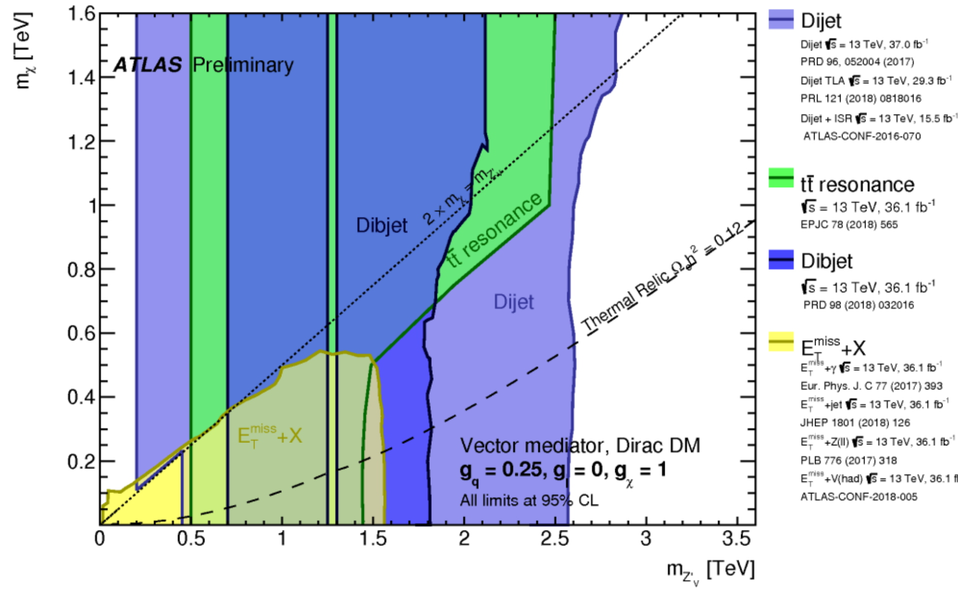


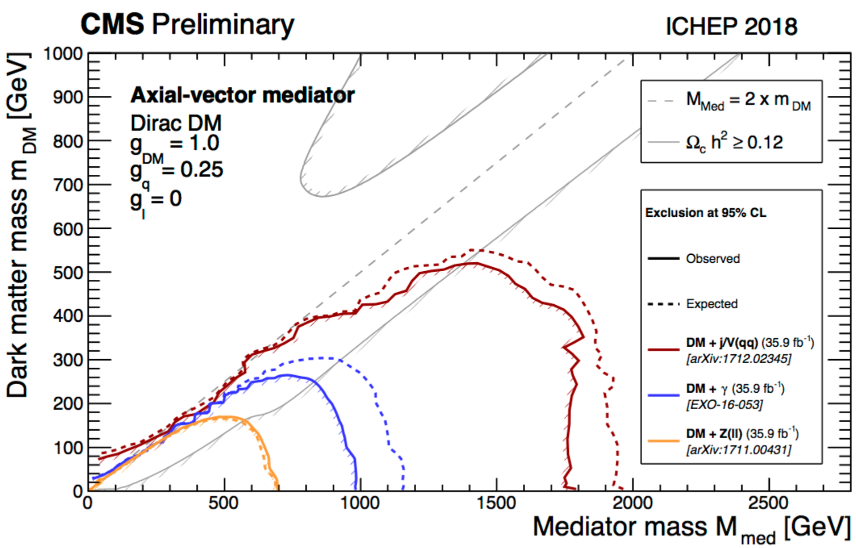
✓ **Use MET distribution to extract signal**
   ✓ **Different shape, although overwhelming background**
✓ **Background modelling important**

Dark Matter Searches: Vector or Axial Vector Mediator

ATLAS-CONF-2018-051







g_q = coupling to SM

g_{DM} = coupling to DM

M = mediator mass

Γ_{med} = mediator width

Dark Matter Searches: Scalar or Pseudo-Scalar

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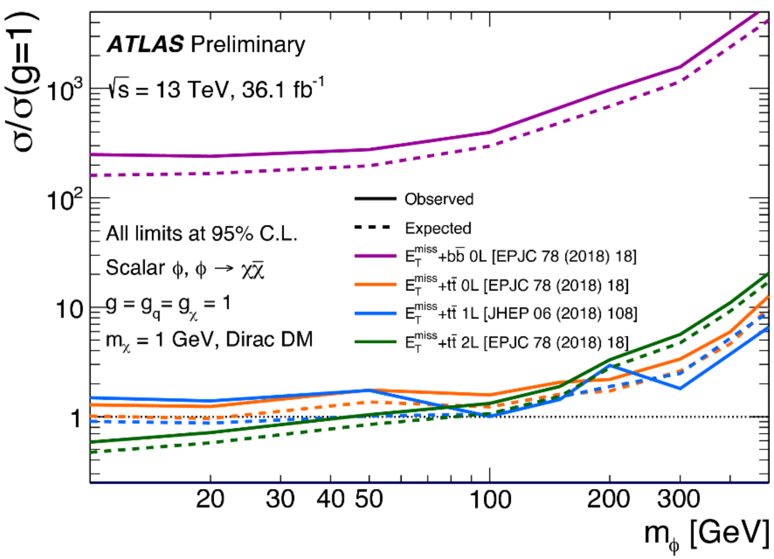

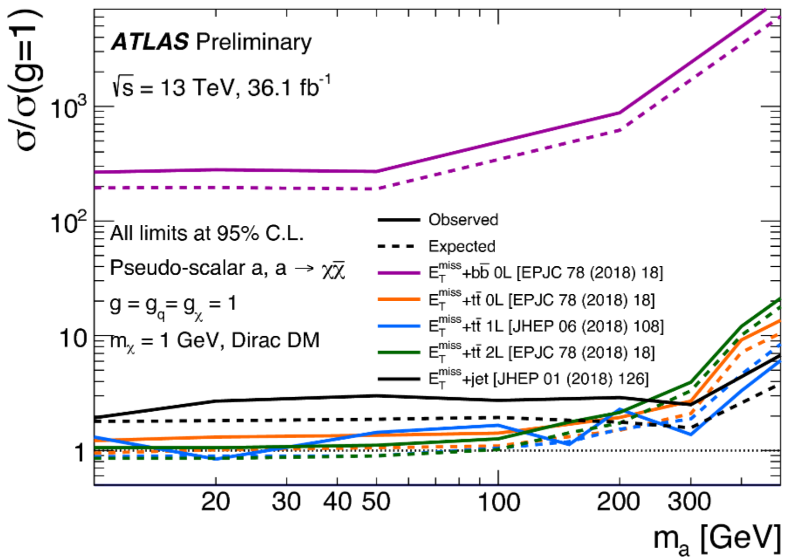

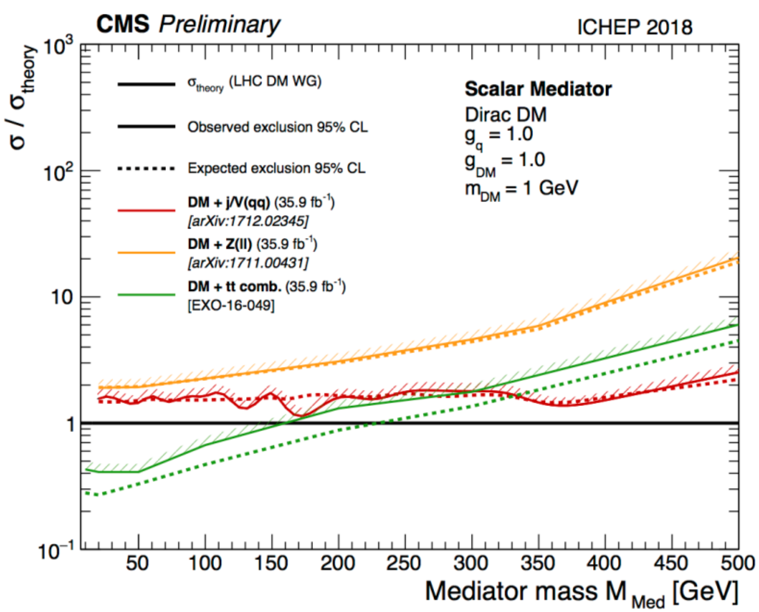

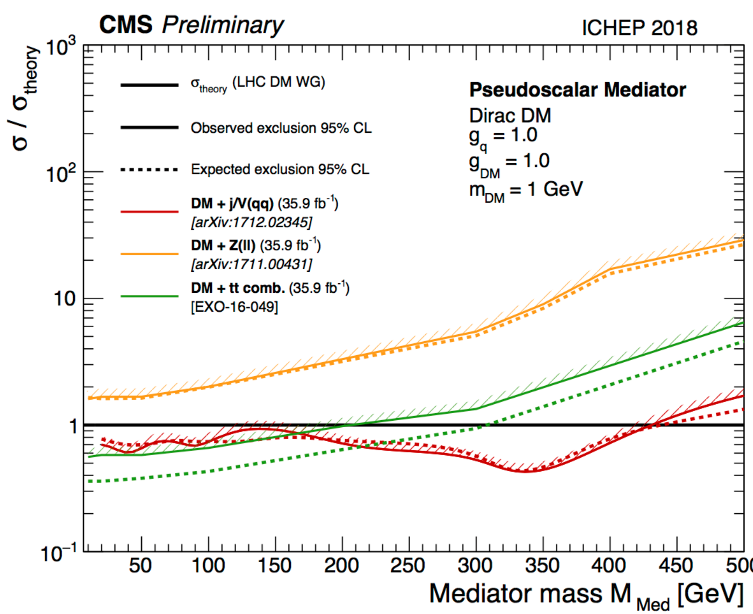

Dark Matter Searches Comparison: Spin Dependent

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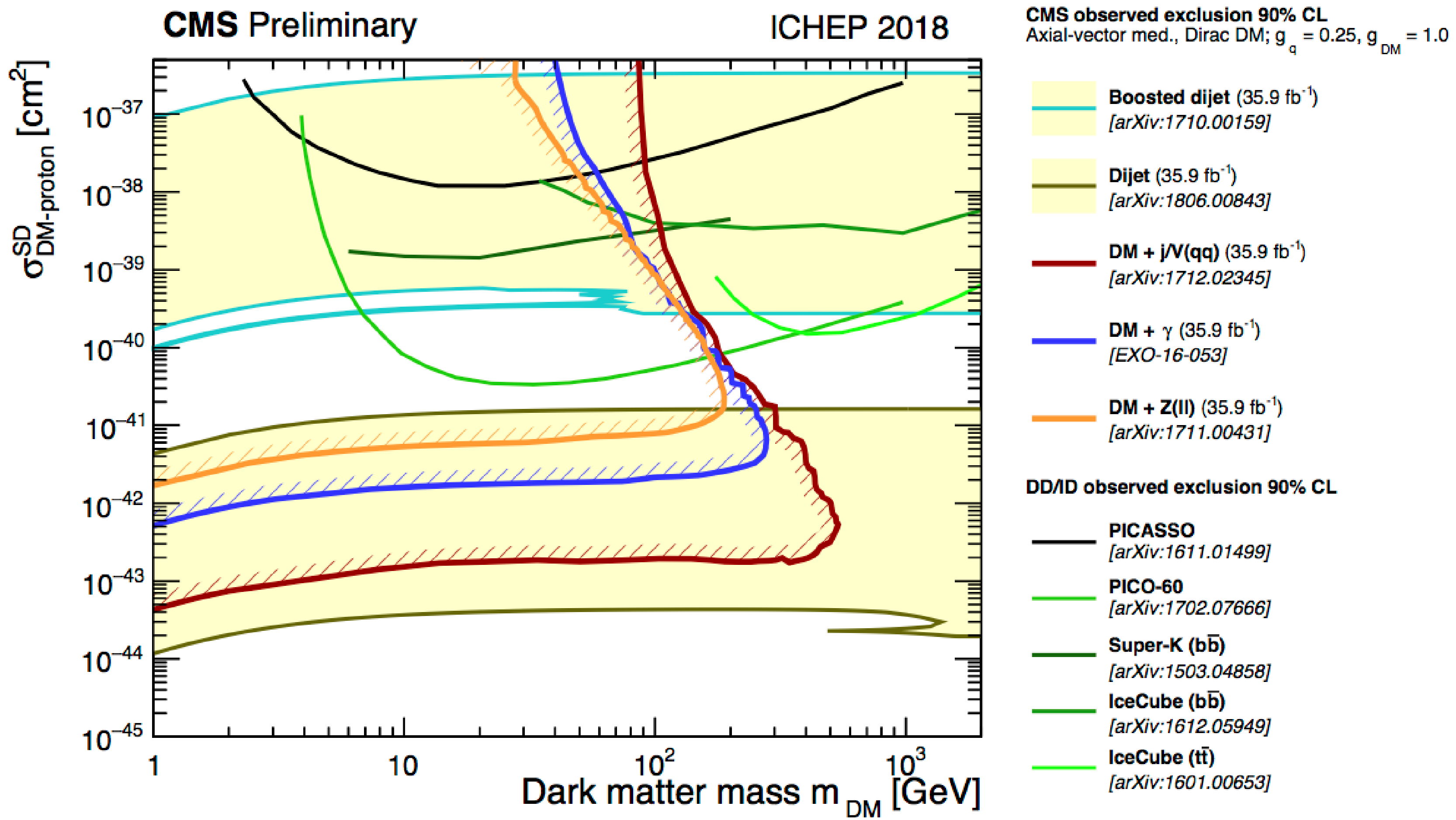
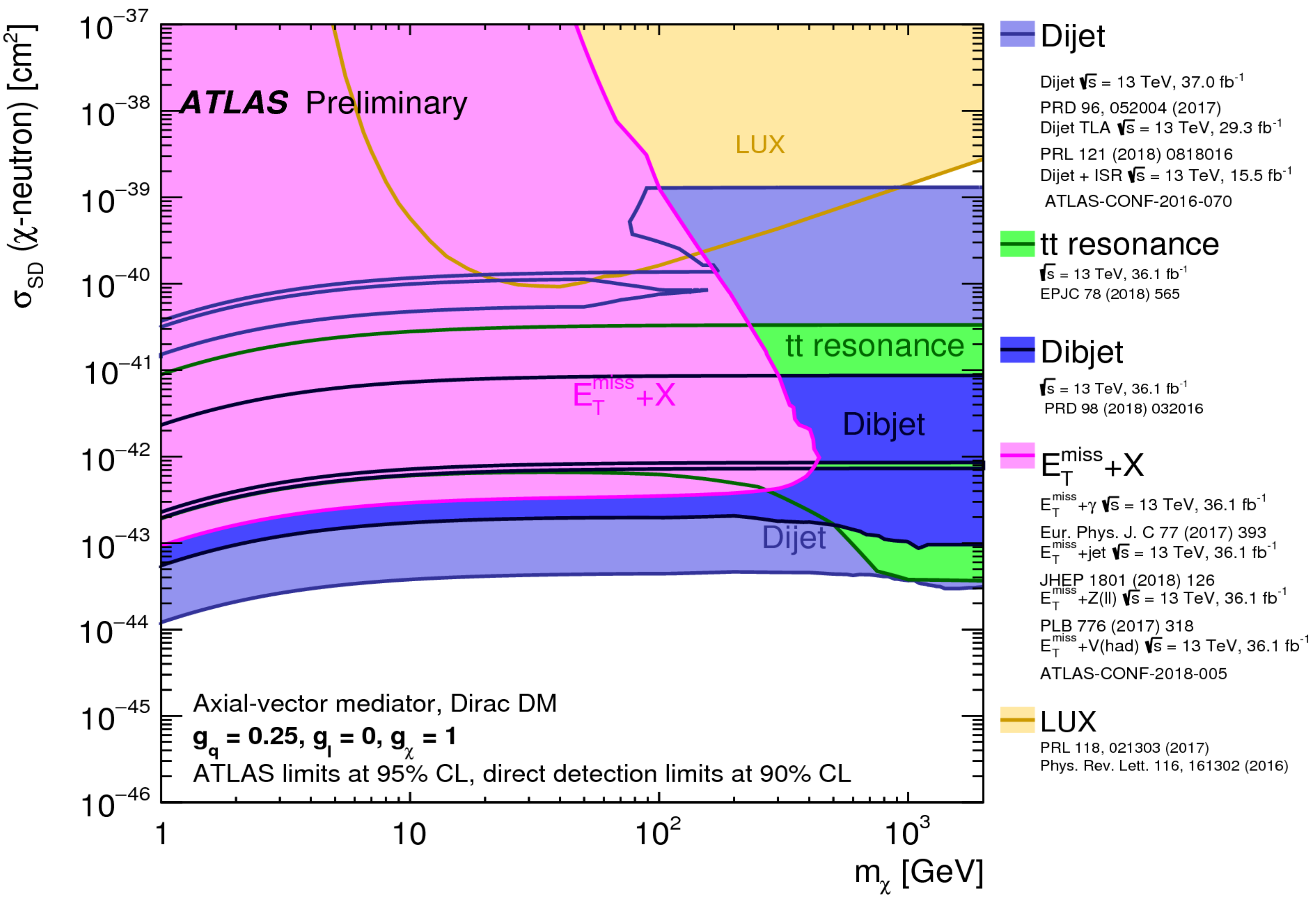


Dark Matter Searches Comparison: Spin Dependent



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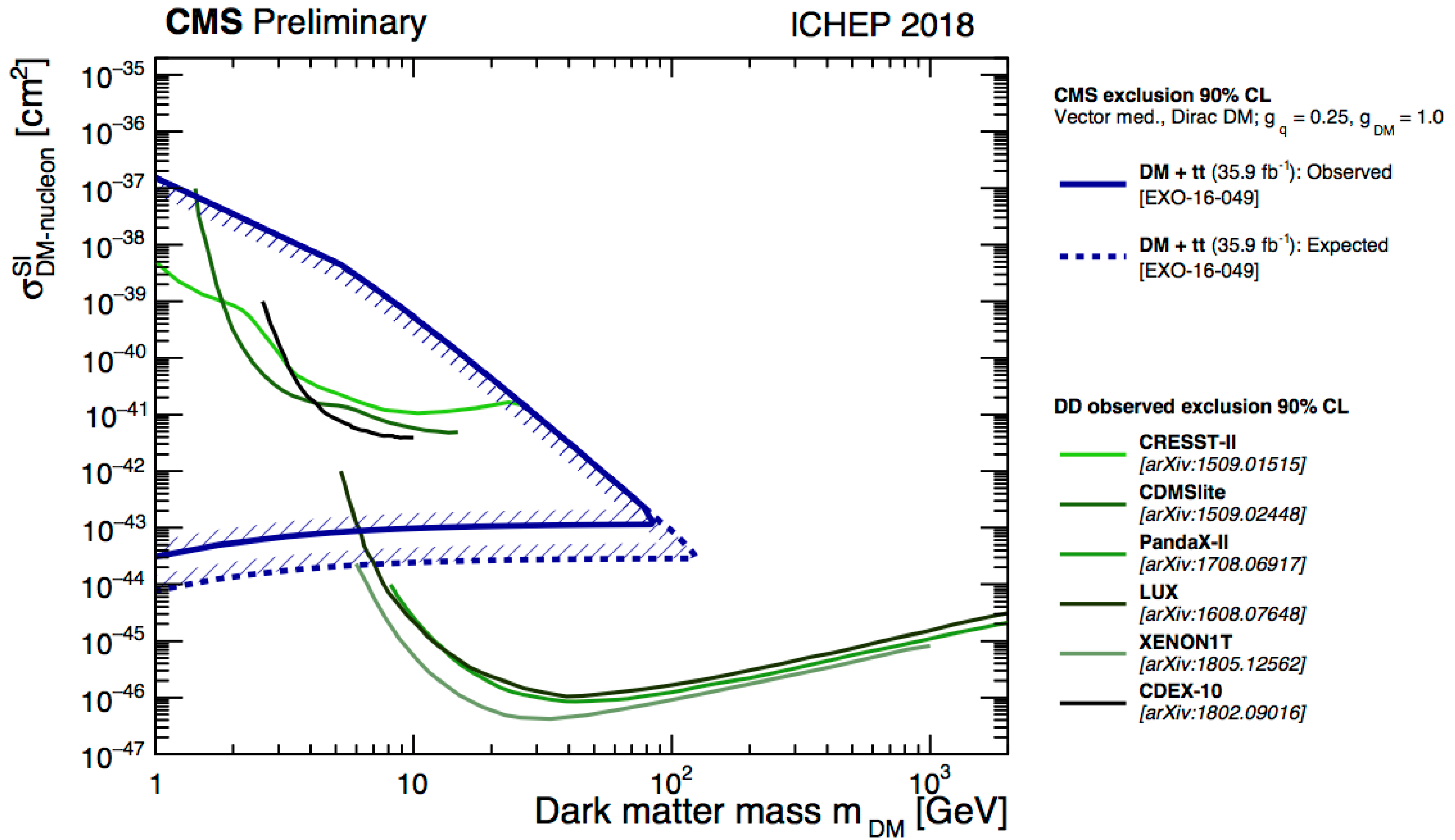

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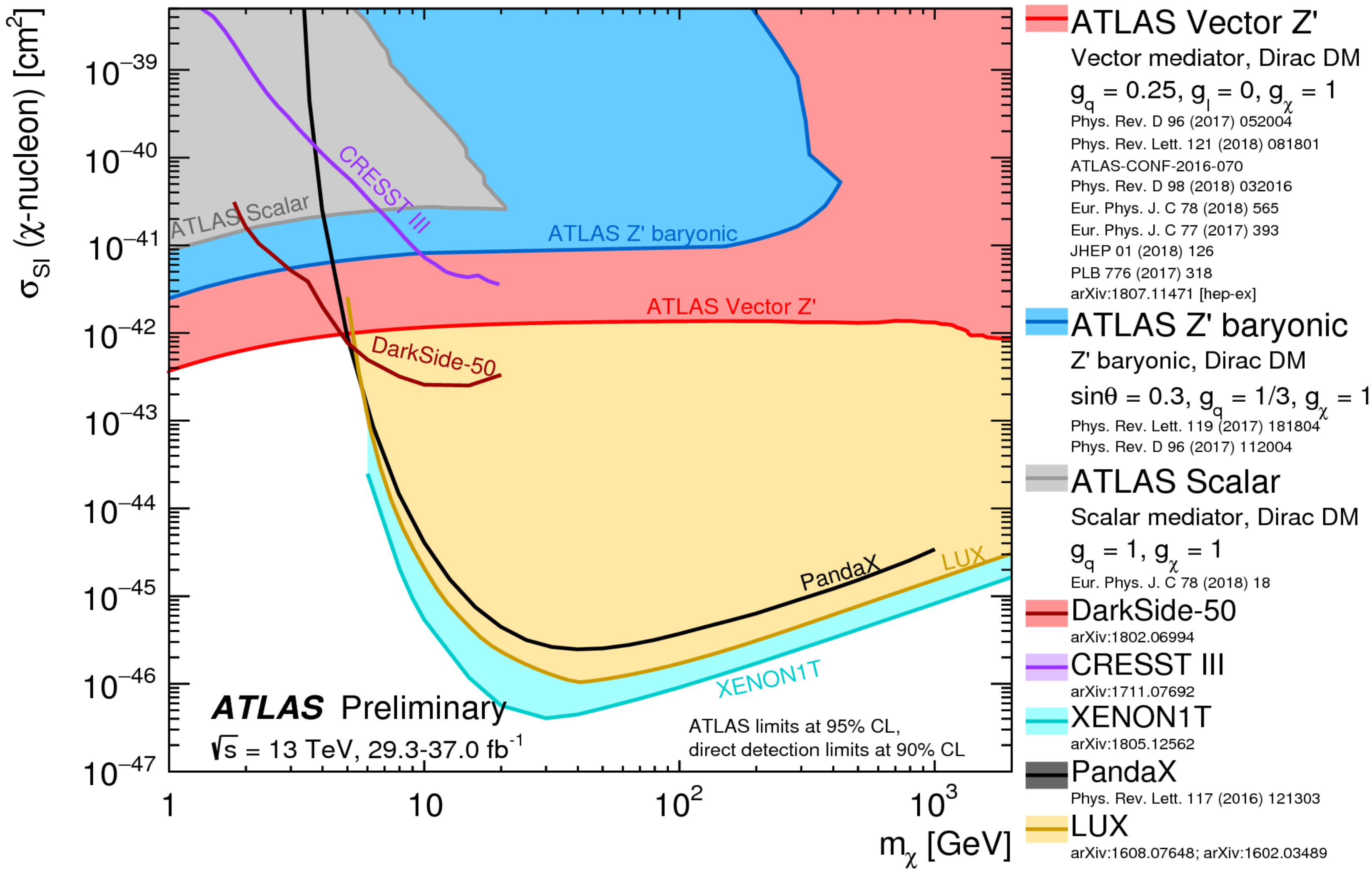

1.0

Summary

Extensive exotics searches done at LHC

- Most searches analyzed 36fb^{-1} data
  - Resonances scan
  - New signatures
  - Long-lived particles
  - Dark matter
- 150fb^{-1} already collected
- No new (exotic) physics found so far
- Continue the effort to search for all possible final states and signatures
  - Many more interesting ideas to test and search
  - No one knows when or where the new physics will appear