

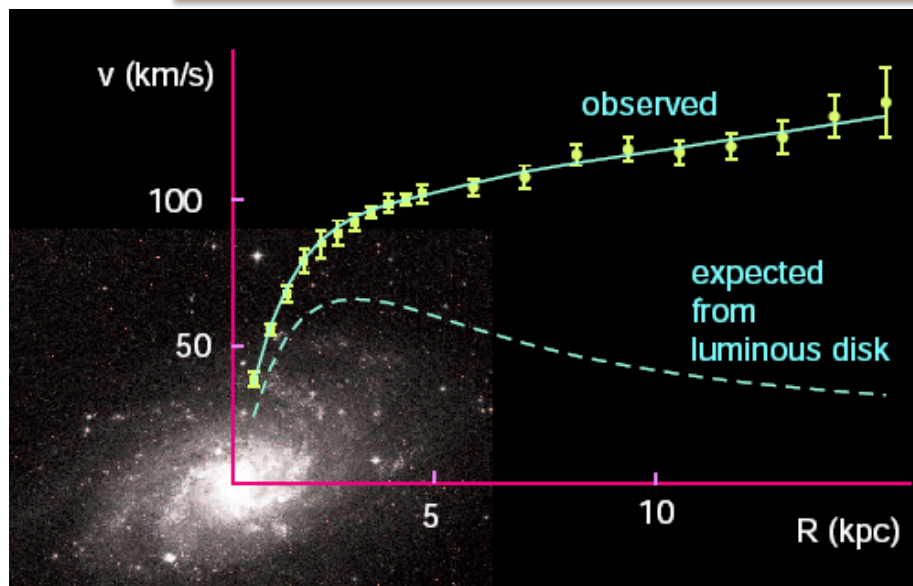
# Searches for Dark Matter at ATLAS and CMS

Zhenbin Wu

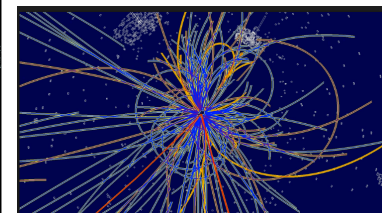
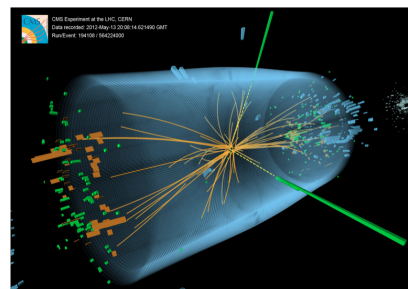
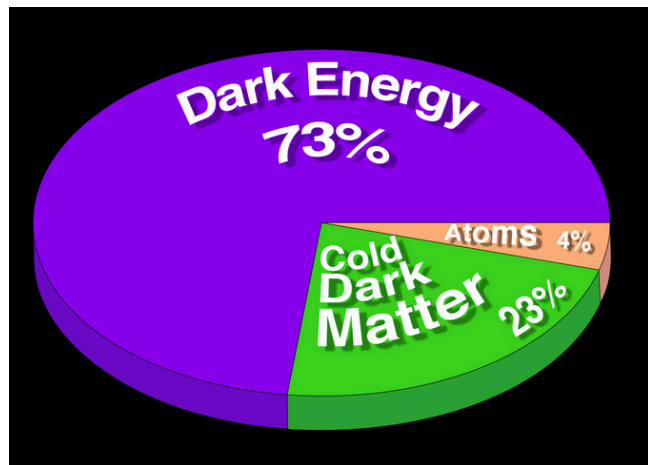
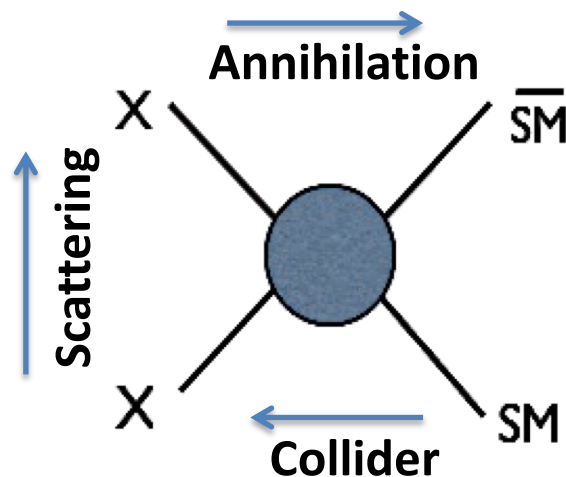
*(University of Illinois at Chicago)*

*-- On behalf of the ATLAS and CMS Collaboration*

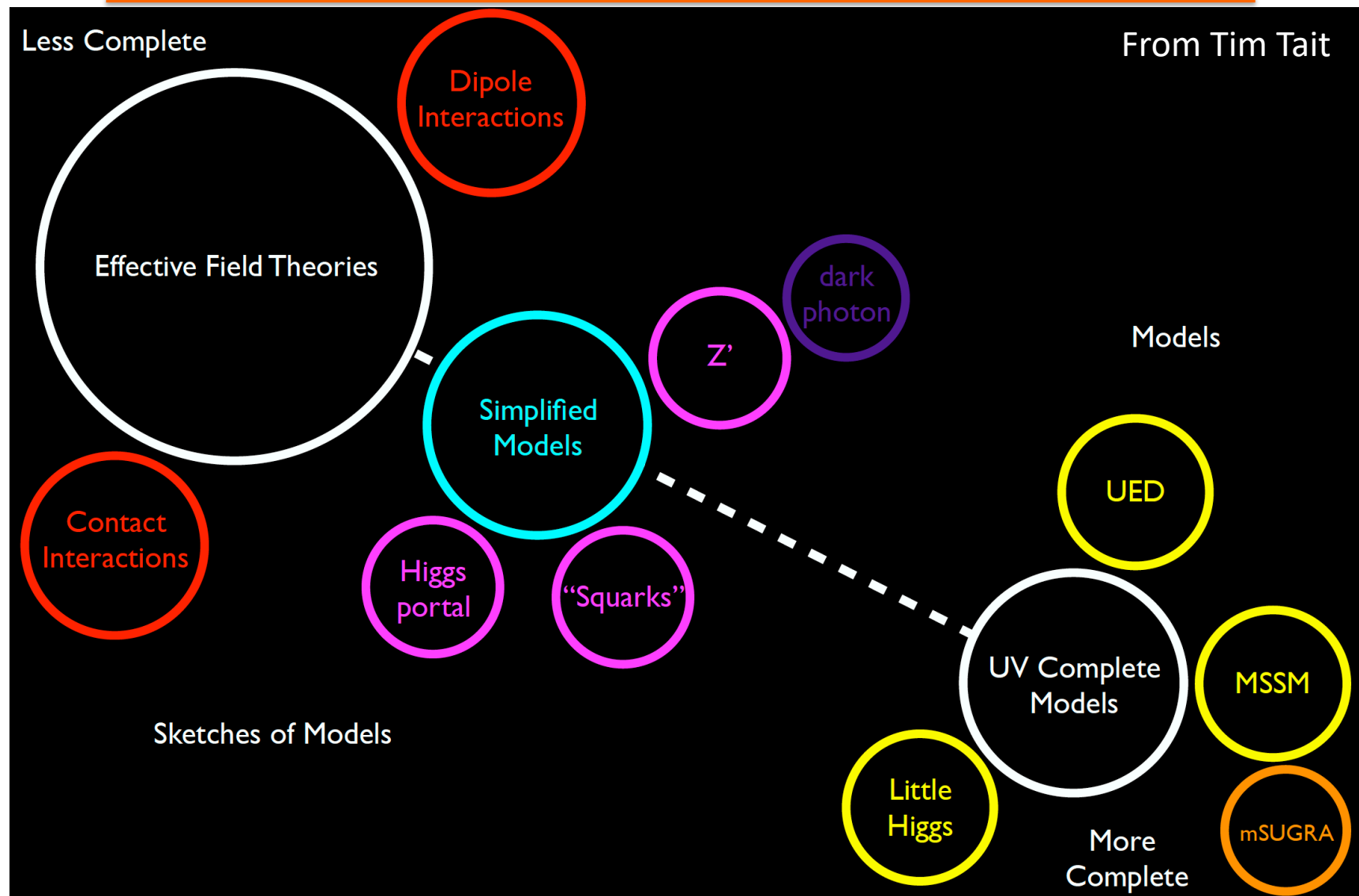
# Dark Matter



- We know both A LOT and VERY LITTLE about Dark Matter



# Abundant Theory Space



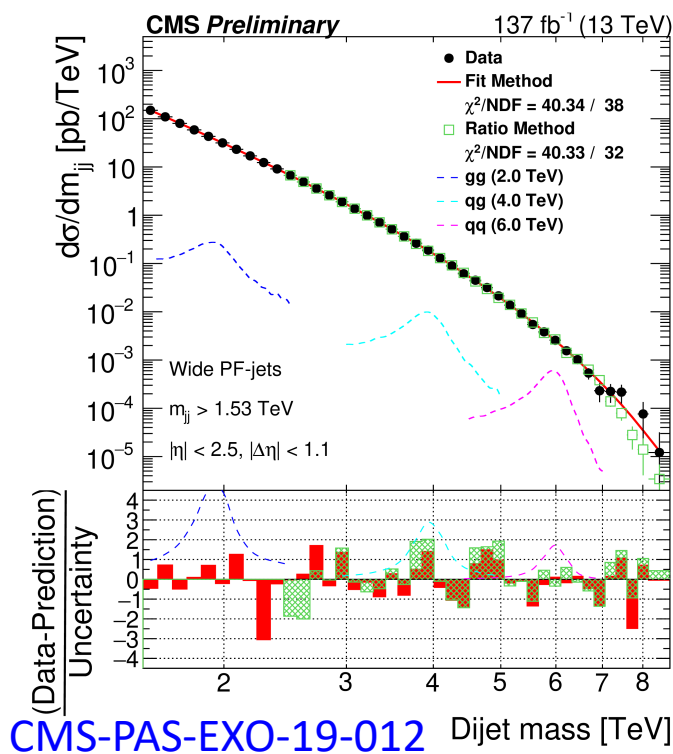
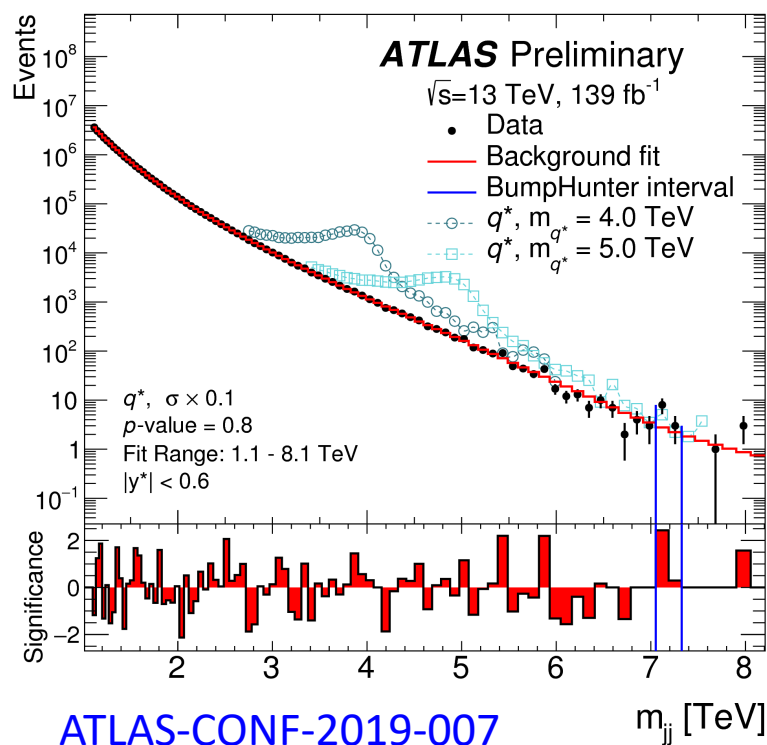
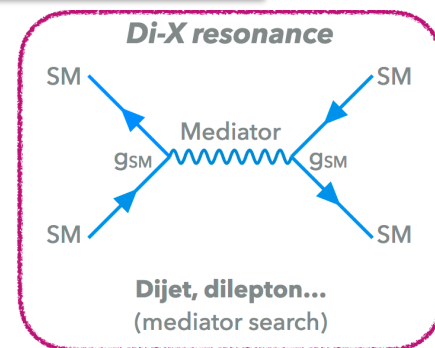
# DM Searches in Hadron Colliders

- DM particles not expected to interact with the detector material
  - Inferred from the imbalance in the visible momentum
- Simplified models: mediator particle which couples DM to SM
  - **Resonances**: search for a resonance at mediator mass when it decays to SM particles
  - **Mono-X**: search for DM recoiling against visible particles (ISR or associated production) leading to a momentum imbalance
- **Dark sector**: DM may sit in a larger hidden or dark sector with additional new states and new interactions
- Most of the **SUSY** searches have a DM interpretation
  - With R-parity conservation, the lightest supersymmetric particle (LSP) is a dark matter candidate
- Won't be able to cover all in 15 min, only selected (biased) topics



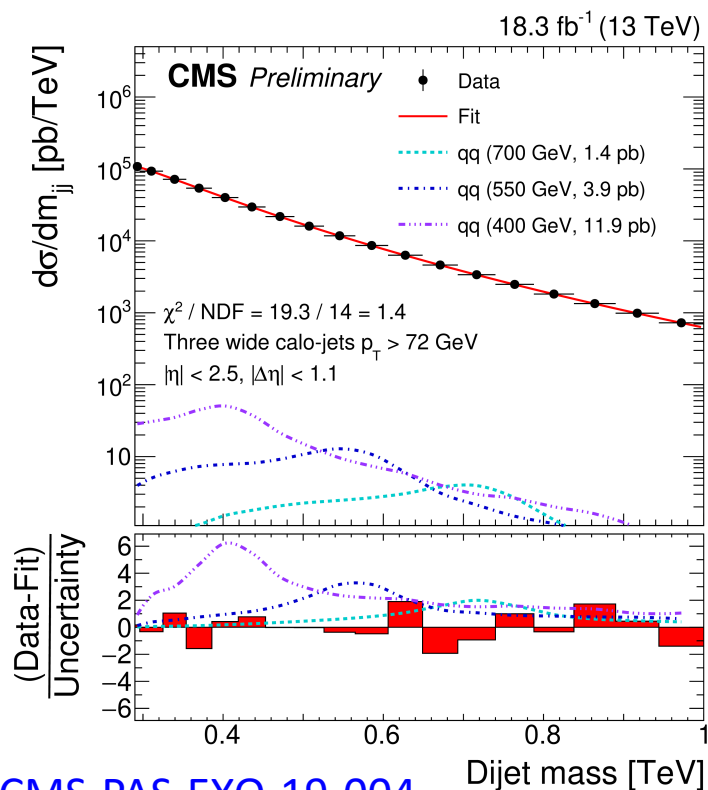
# Dijet Resonance Searches

- Many simplified DM models include a mediator, which can decay to dark matter
  - If a mediator is produced from SM particles, it should decay to them
- “Classic” high-mass dijet resonance channel (bump hunt) for NP

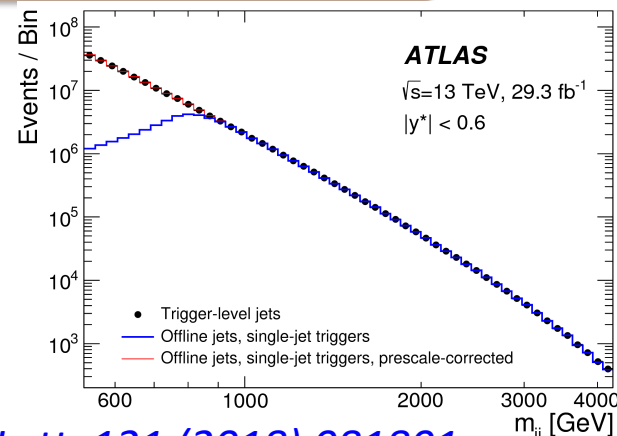


# Trigger-Level Dijet Searches

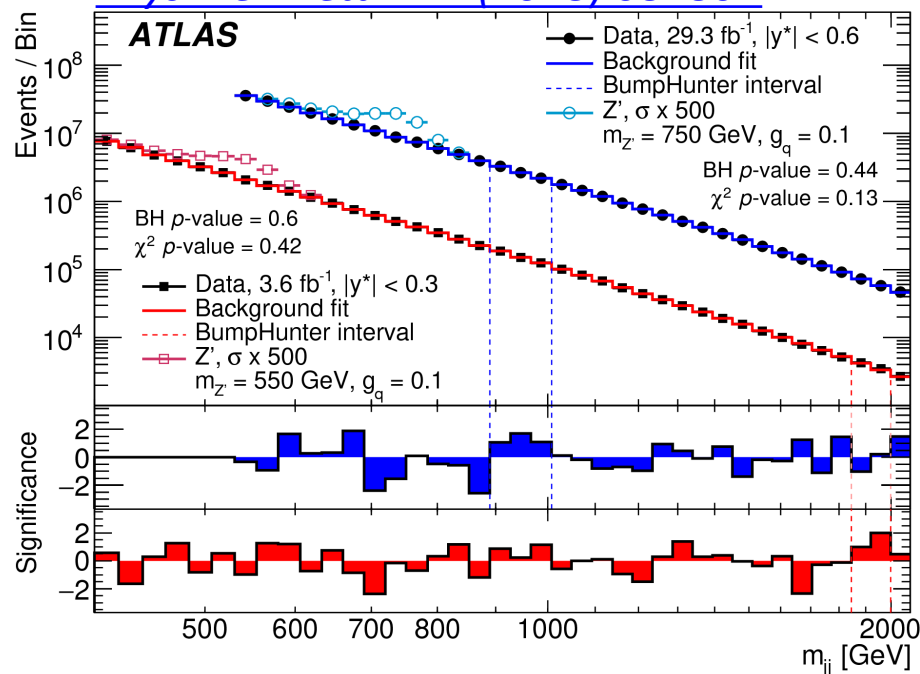
- Trigger-level analysis (scouting) by recording trigger-level objects, containing limited information
- Recover the low dijet mass phase space



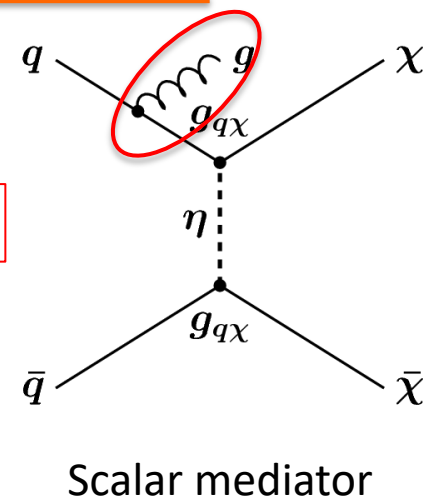
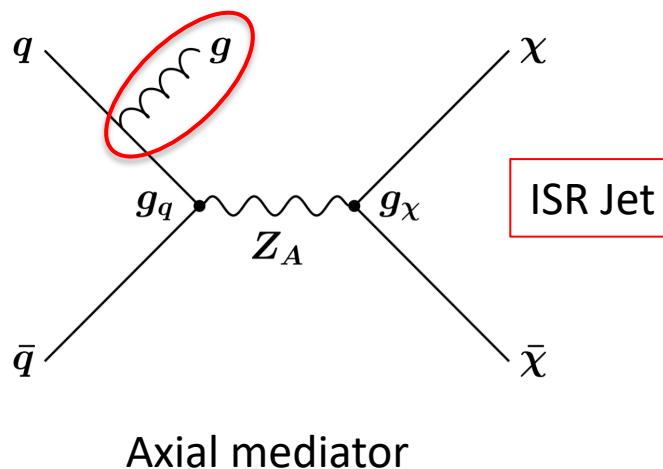
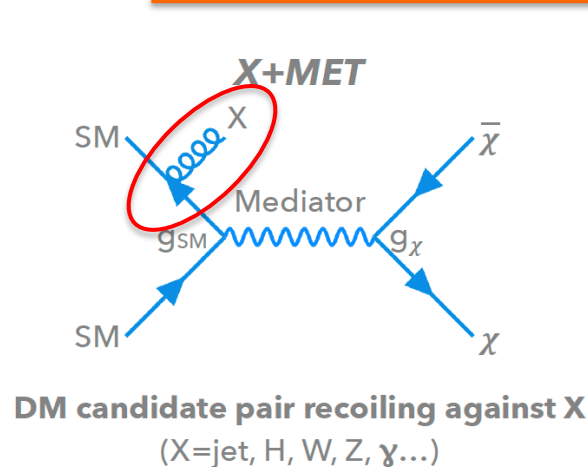
[CMS-PAS-EXO-19-004](#)



[Phys. Rev. Lett. 121 \(2018\) 081801](#)



# Mono-X Search

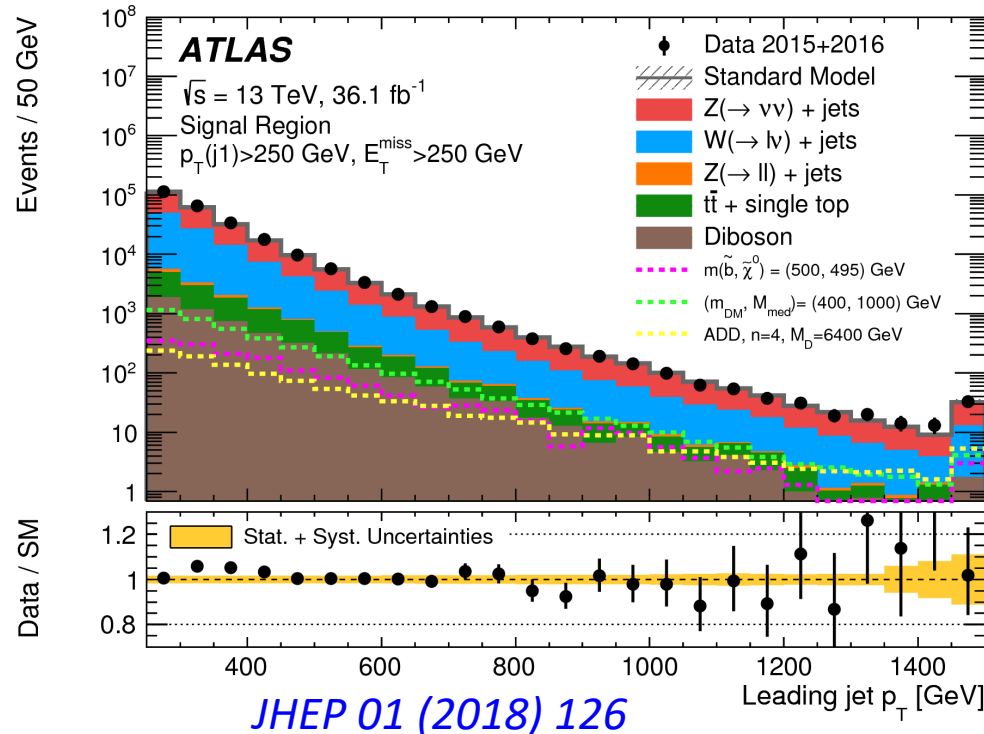
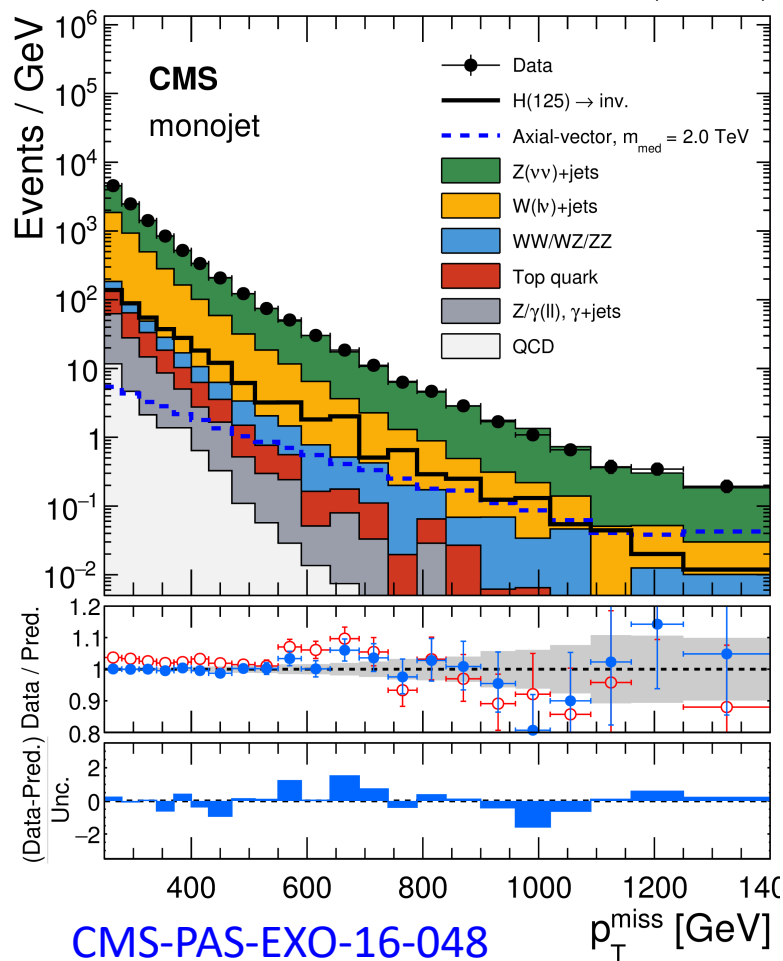


- DMs escape the detector without interactions
- Need additional visible particle for triggering event readout and boost WIMP system
- Models with vector-like mediator, color-charged mediator or even full SUSY models can result in final states with one high-energetic jet and  $E_T^{\text{miss}}$

# Mono-Jets

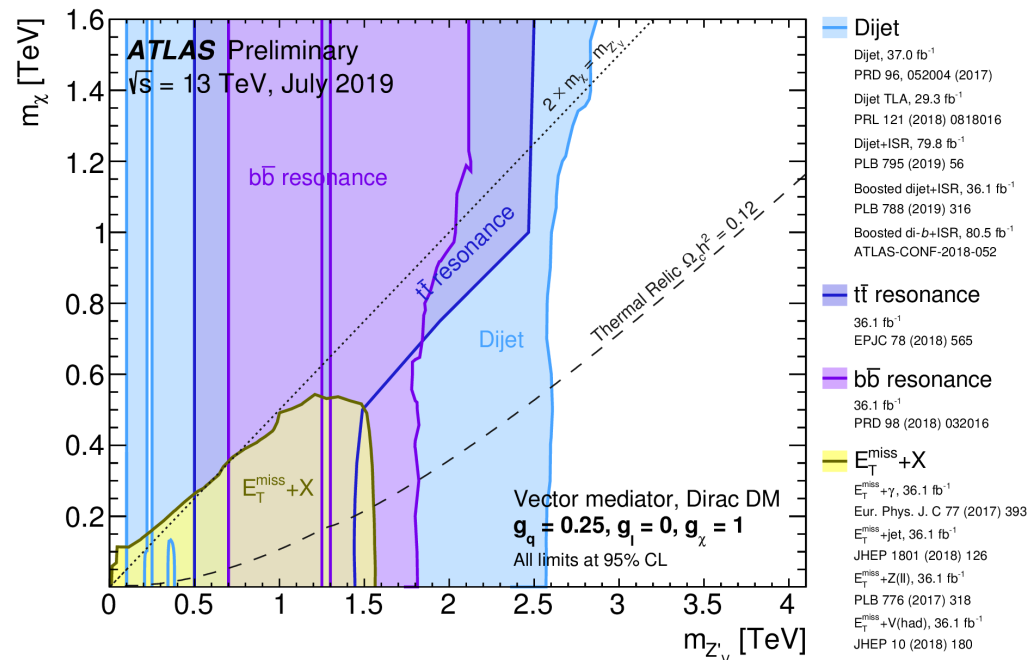
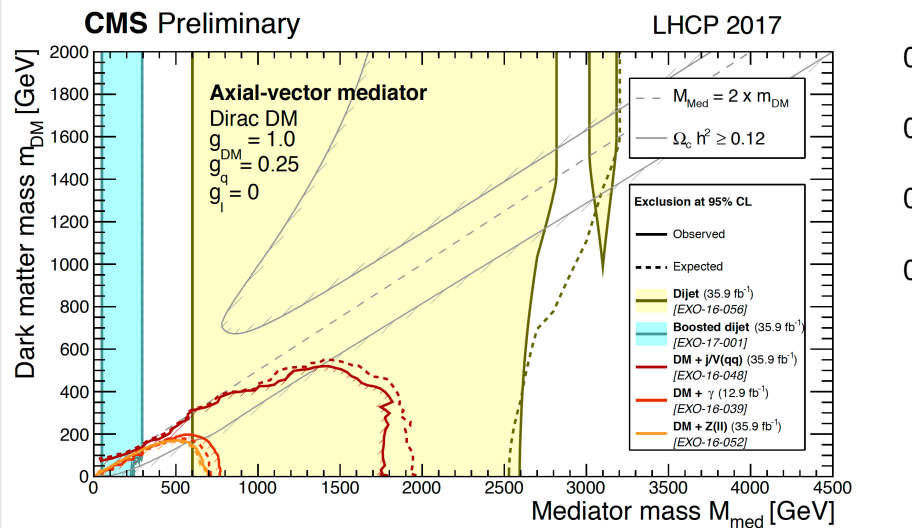
- Data driven method for background
- ATLAS vetoes events containing more than four jets
- CMS vetoes events with b-jets to suppress top backgrounds

35.9 fb<sup>-1</sup> (13 TeV)



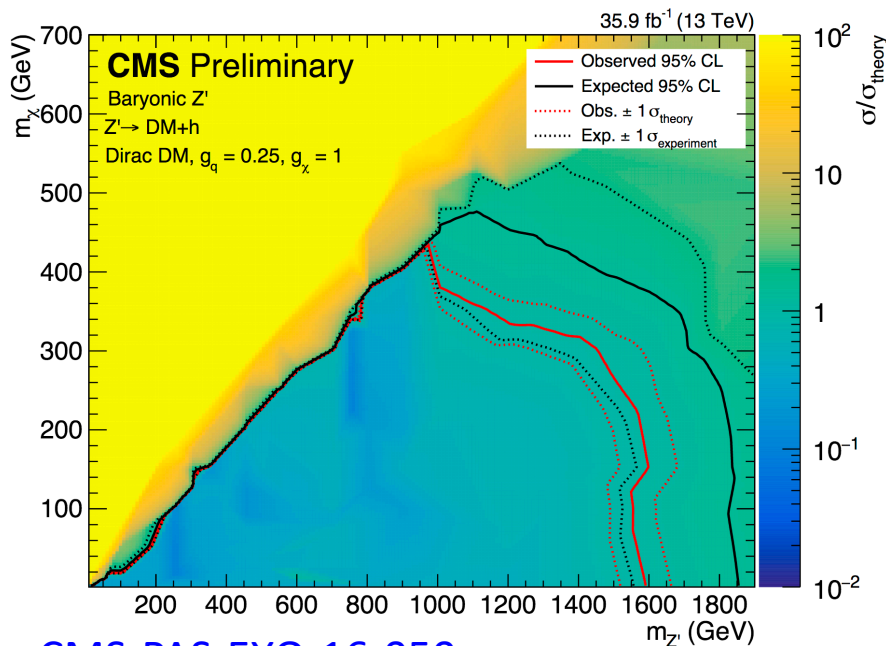
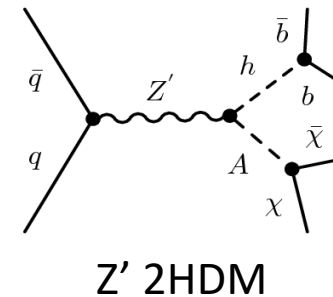
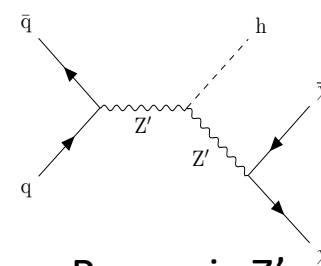
# Simplified Model Exclusion

- Mono-X searches with  $\gamma$ , boson, top
- For baseline parameters, mediator searches are generally more powerful than mono-X

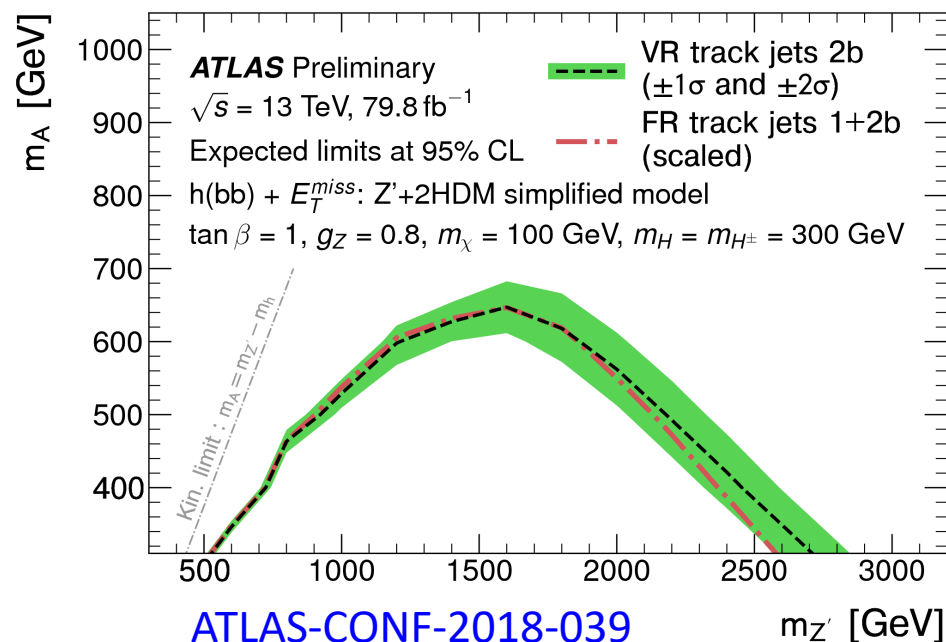


# Mono-Higgs

- Production in association with Higgs boson realized in extended 2HDM or baryonic  $Z'$  models
- Dominating Higgs decay to  $b\bar{b}$
- CMS: large R jet for boosted Higgs
- ATLAS: variable-R jet for resolved/boosted

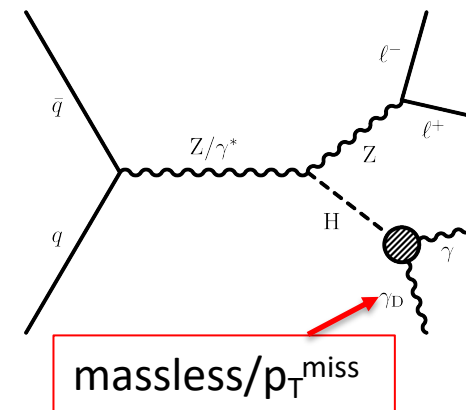
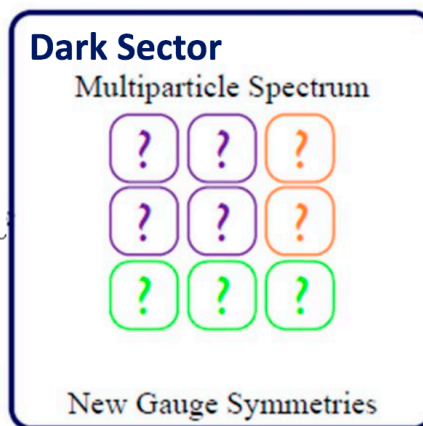
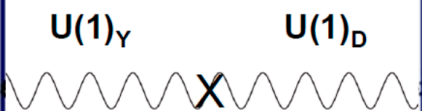
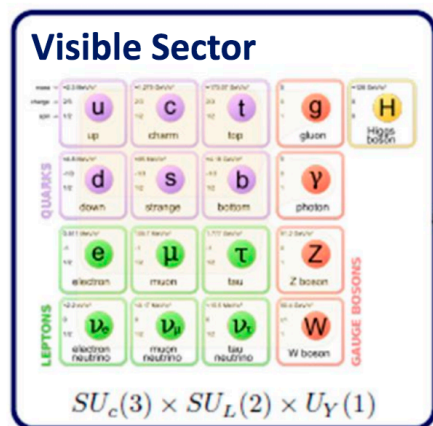


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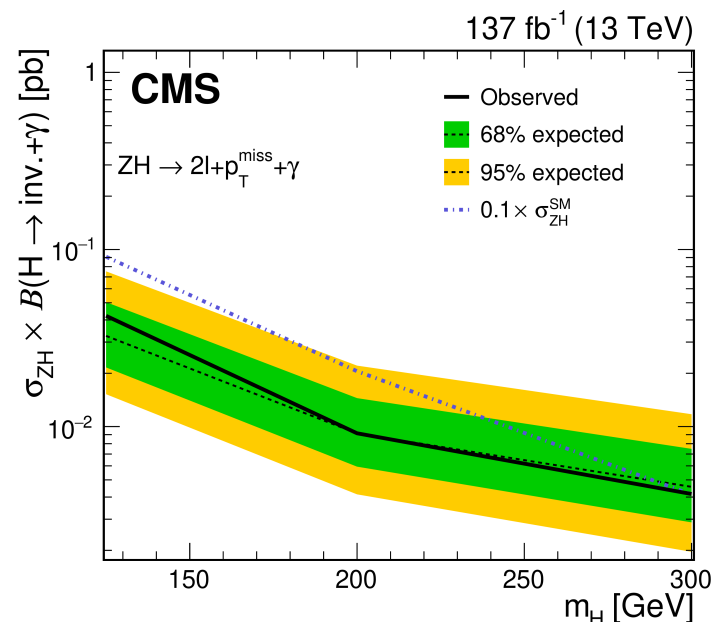


[ATLAS-CONF-2018-039](#)

# Dark Photon



- Extend SM symmetries to new  $U(1)$  hidden symmetry
- Dark photon-photon mixing mediates SM & hidden sector
- SFOS high- $p_T$  isolated leptons; one high  $p_T$  photon + large  $p_T^{\text{miss}}$
- Signal extraction from transverse mass of photon+ $p_T^{\text{miss}}$



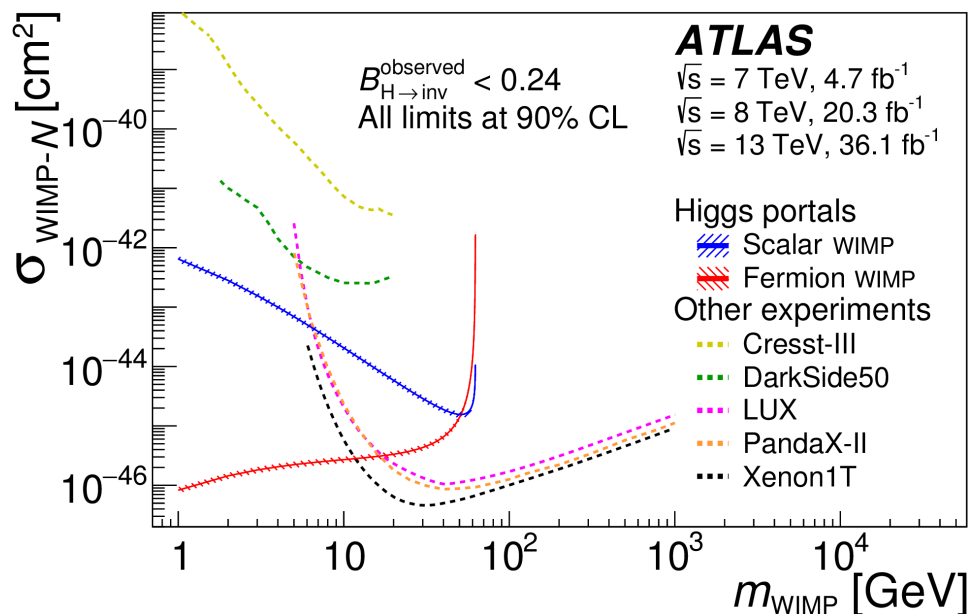
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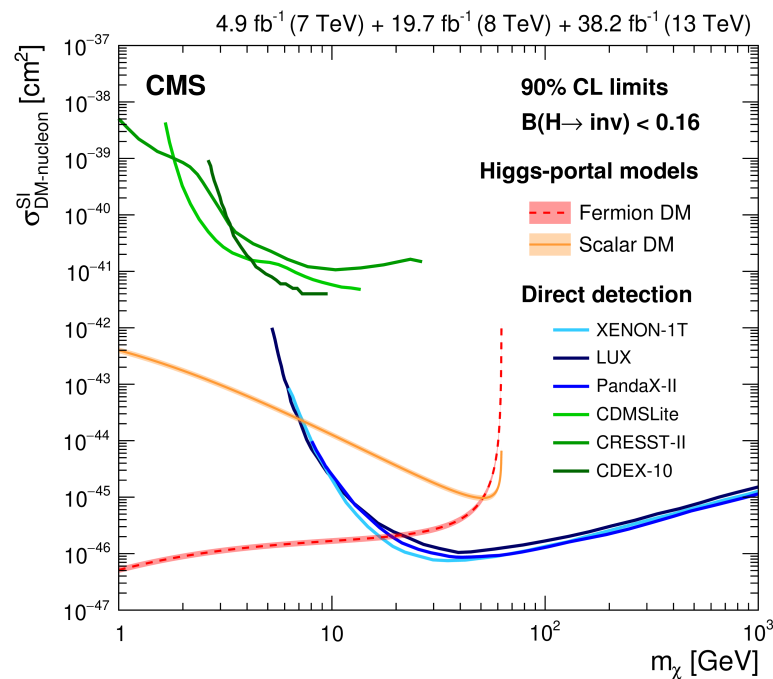
# Invisible Higgs

- The Higgs boson may act as a mediator between the Standard Model and the Dark Sector
- Higgs portal to dark matter probes for masses less than half the mass of the Higgs

[\*Phys. Rev. Lett.\* 122 \(2019\) 231801](#)



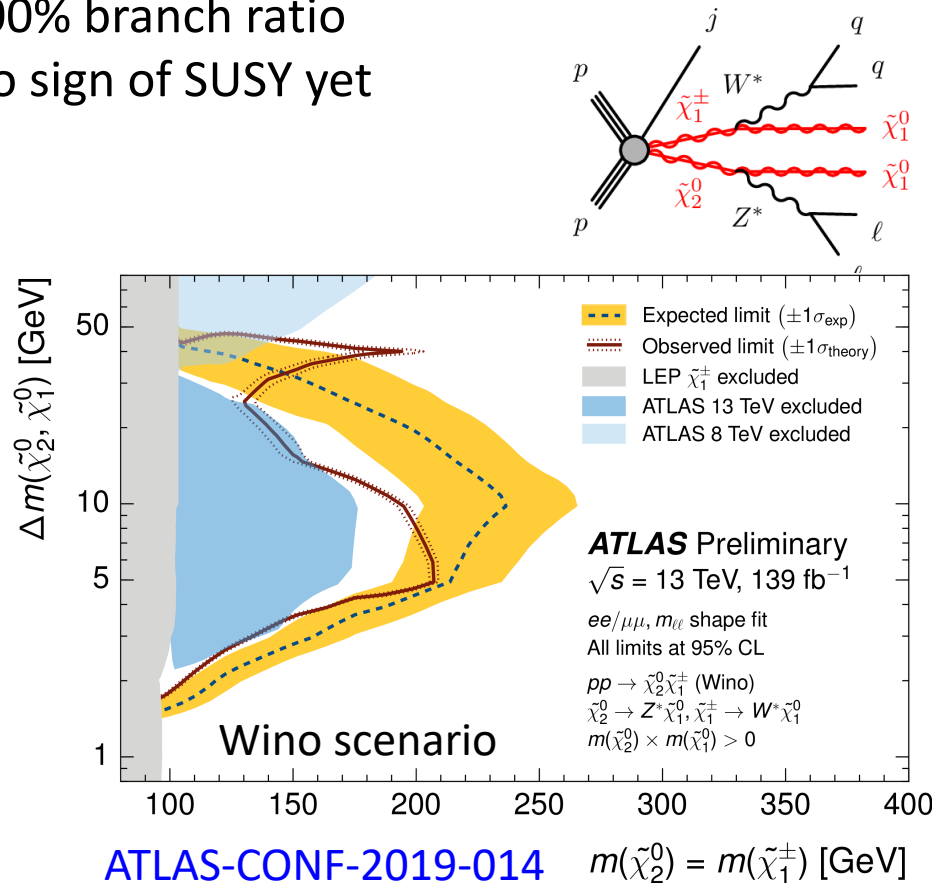
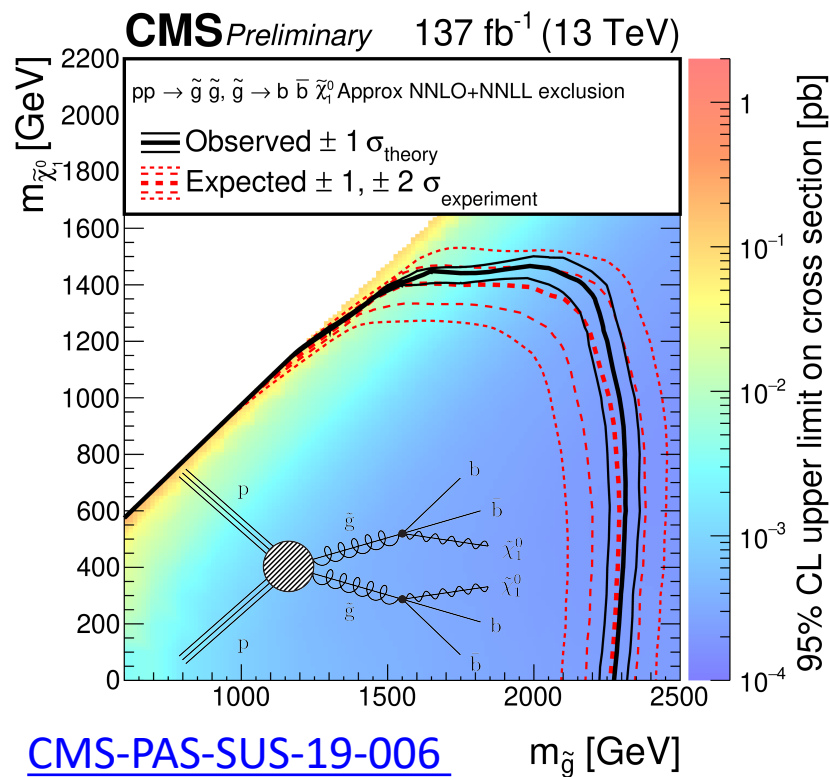
[\*Phys. Lett. B\* 793 \(2019\) 520](#)





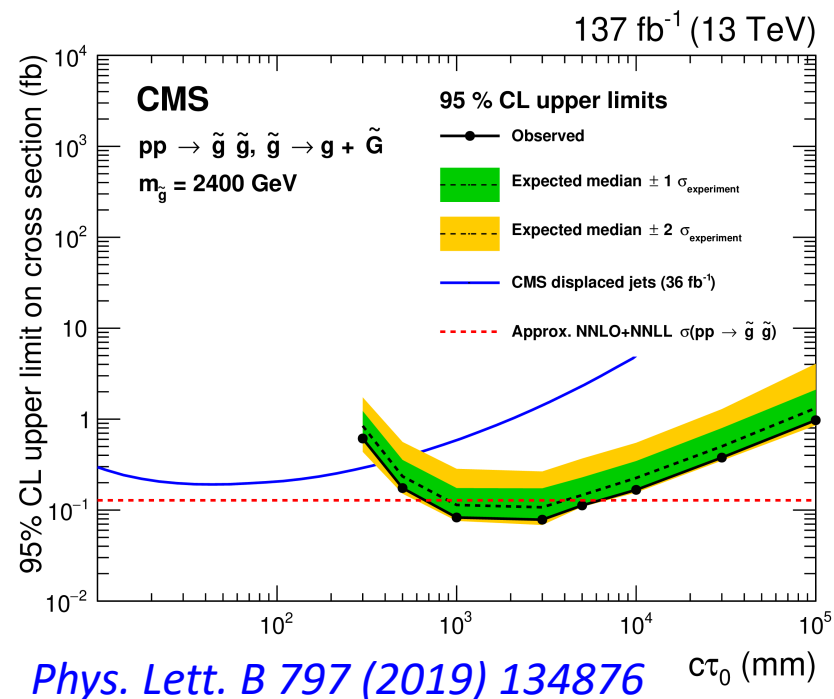
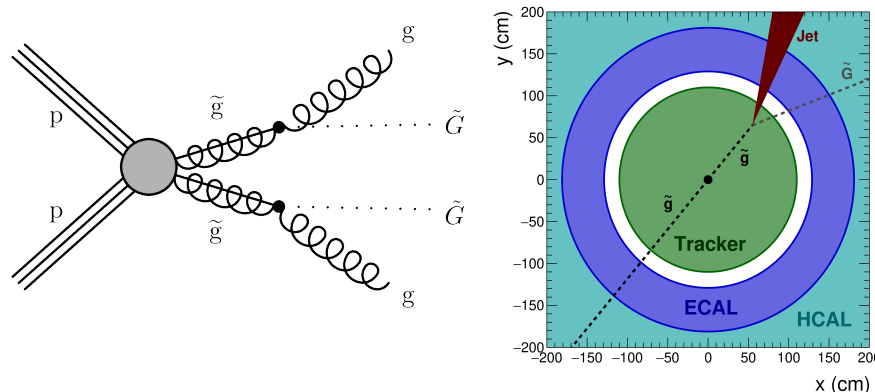
# Supersymmetry

- With R-parity conservation, the lightest supersymmetric particle (LSP) is a dark matter candidate
- Use **Simplified Model Spectra** as guideline, consider  $\tilde{\chi}_1^0$  as LSP
  - Simple decay chain, assuming 100% branch ratio
- Vast phase space/channel in SUSY. No sign of SUSY yet



# Long-live Particle Searches

- In SUSY with gauge-mediated SUSY breaking (GMSB) model, paired long-live gluinos
- Search for long-lived particles leading to missing transverse momentum and displaced, non-prompt jets
  - identified using the timing capabilities of the CMS electromagnetic calorimeter.
  - Shower would arrive late at the ECAL  $\rightarrow$  use ECAL timing ( $\sigma \sim 100\text{ps}$ )
  - Targeting decays beyond the acceptance of the tracker  $\rightarrow$  (0.5-1.5 m)



# Summary and Outlook

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- Dark matter searches at LHC have evolved a lot during Run-2
- Simplified DM models are powerful tools to span signature space for typical signatures
  - New method like Trigger-level analysis to complete the phase space
- Dark Sector program is also evolving in scope
  - New models and signatures being explored
- Searches for SUSY is still continuing at LHC
- Growing interest for long-live particles in both theory and experimental community
  - Many mechanisms that give models good DM properties also give LLPs
- The enormous experience from Run-2 will certainly be useful to push the dark matter searches further in Run-3/HL-LHC
- More results with full Run-2 dataset coming out. Stay tune!



# BACKUP

# CMS and ATLAS

