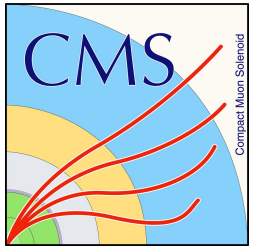


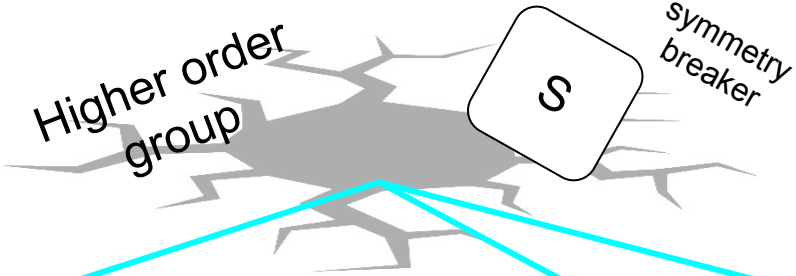
Fermilab

Resonant searches for Dark Matter mediators @ CMS

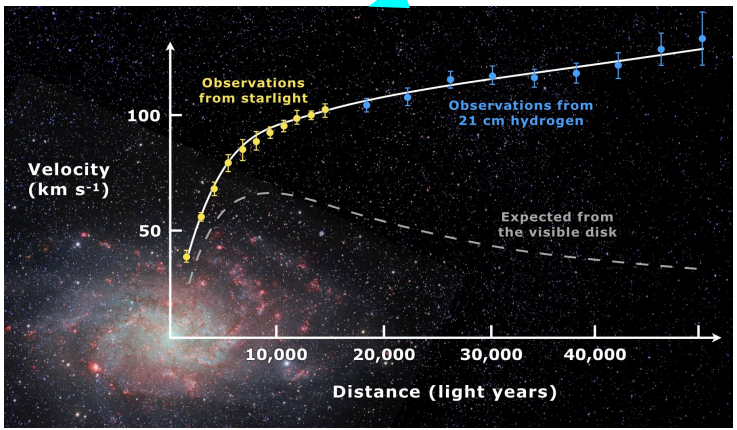
Grace Cummings, on behalf of the CMS Collaboration

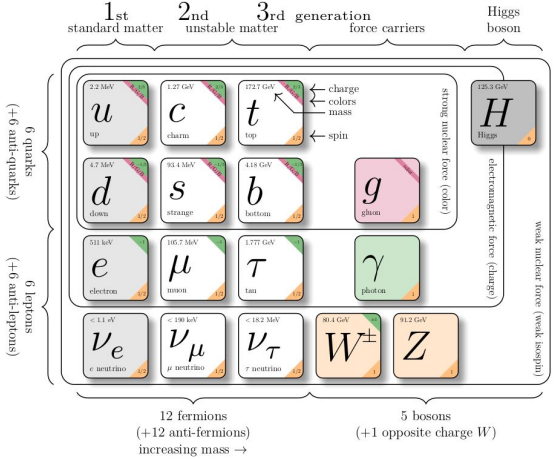
LHCP Boston, 03 June - 07 June 2024

Generically… Dark Matter (DM) mediators



Z’

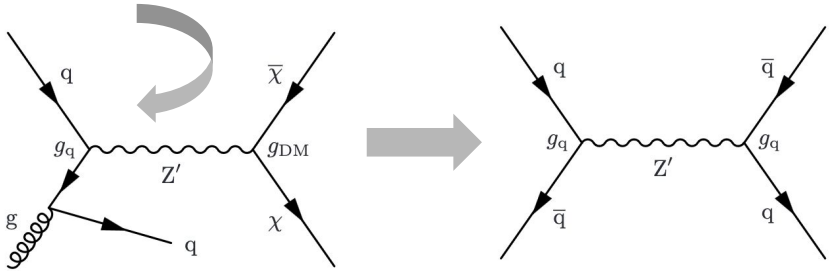




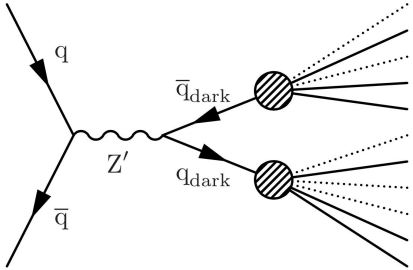
$\times$ U(1)

Analysis Methods - Bumps and Backgrounds

Look for the **mediator(s)** going to SM particles



Dijet!
(spin 1 portal)



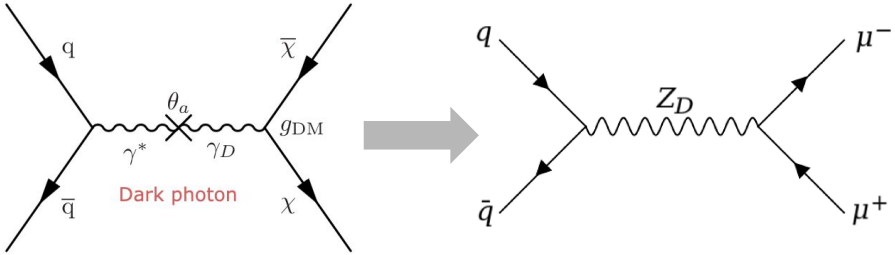
Semivisible jets
(hidden valley)

- Bumps on mass or mass estimator spectra
- Large backgrounds
  - Data-driven approaches
  - QCD multijet dominant

diagrams: 2405.13778

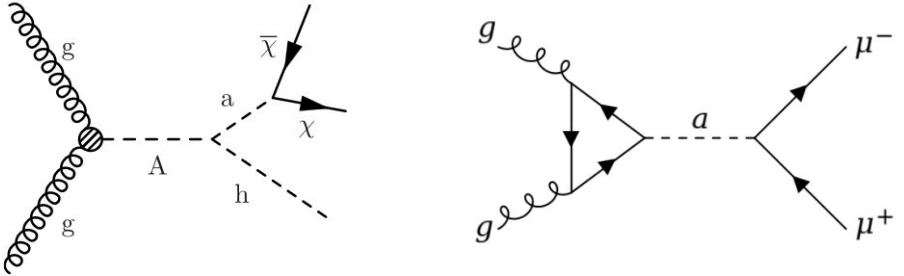
Analysis Methods - Bumps and Backgrounds

Look for the **mediator(s)** going to SM particles



(Spin 1 portal)

Dimuon Resonances



(2HDM+a)

- High-rate data stream allows for access to low mass mediators
  - trigger level objects
- Bumps on mass spectra
- Low-mass resonances as backgrounds
  - Data-driven approaches
  - J/Ψ resonance
  - Y(1S) resonance

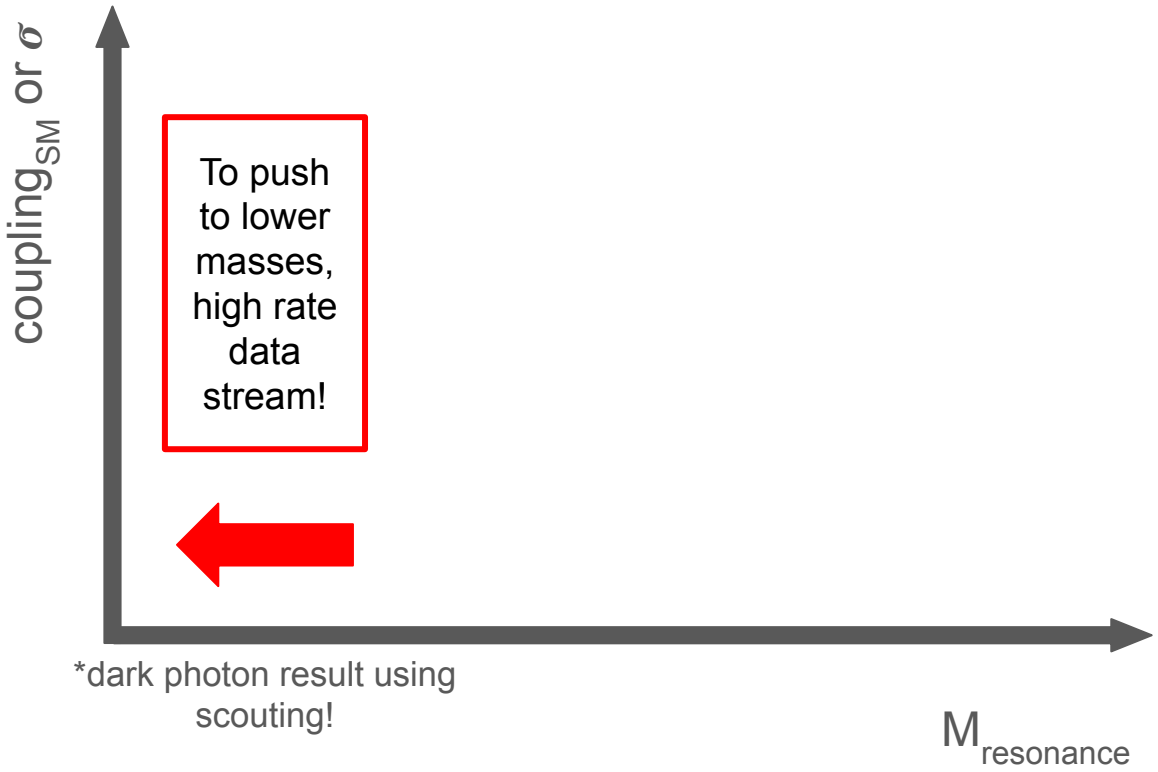
diagrams: 2405.13778, JHEP12(2023)070

Resonance landscape

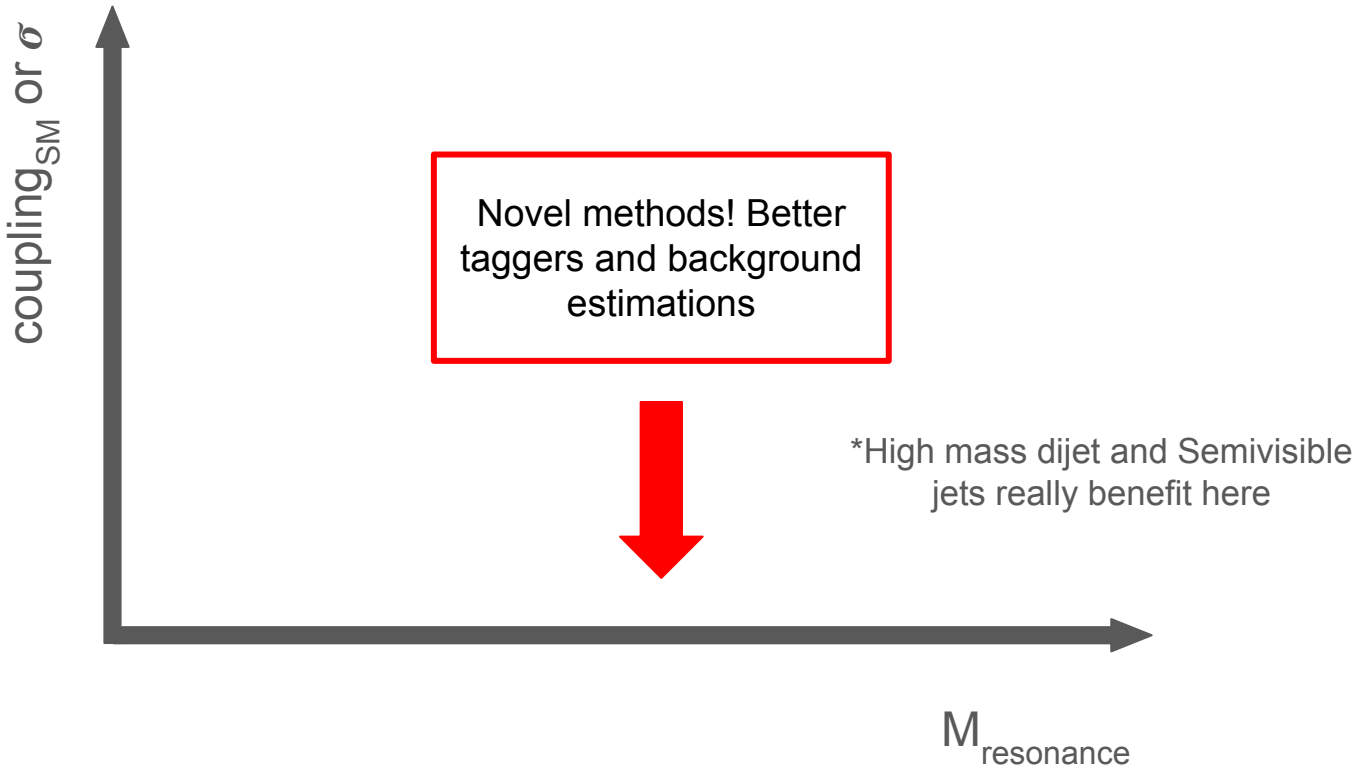
To push to higher masses

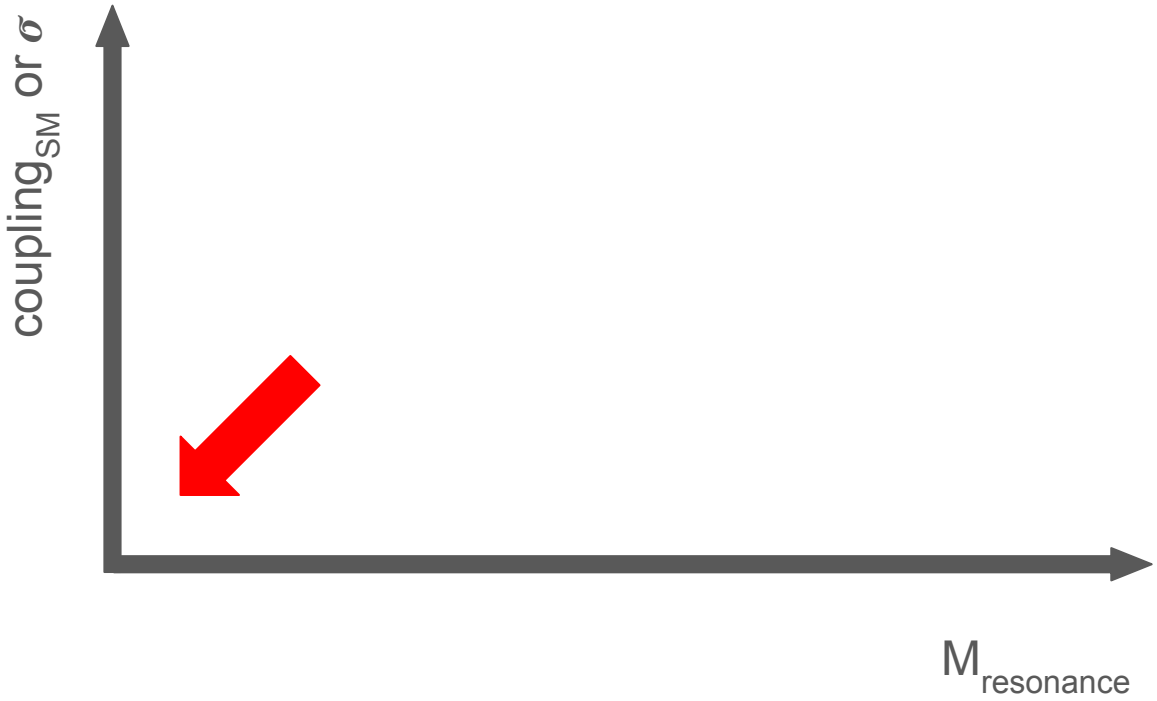
need sqrt(s)

Resonance landscape



Resonance landscape



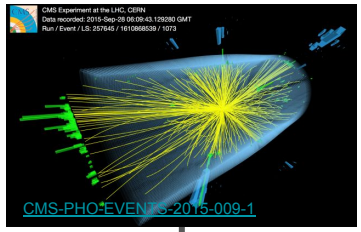


GeV-scale dimuon resonances

Data Scouting

arXiv:2403.16134

- High rate scouting with **lower thresholds**



40 MHz

Trigger Primitives

L1

~100 KHz
4-8 kB / event

Online Reconstruction

Scouting

~100 KHz
4-8 kB / event

HLT

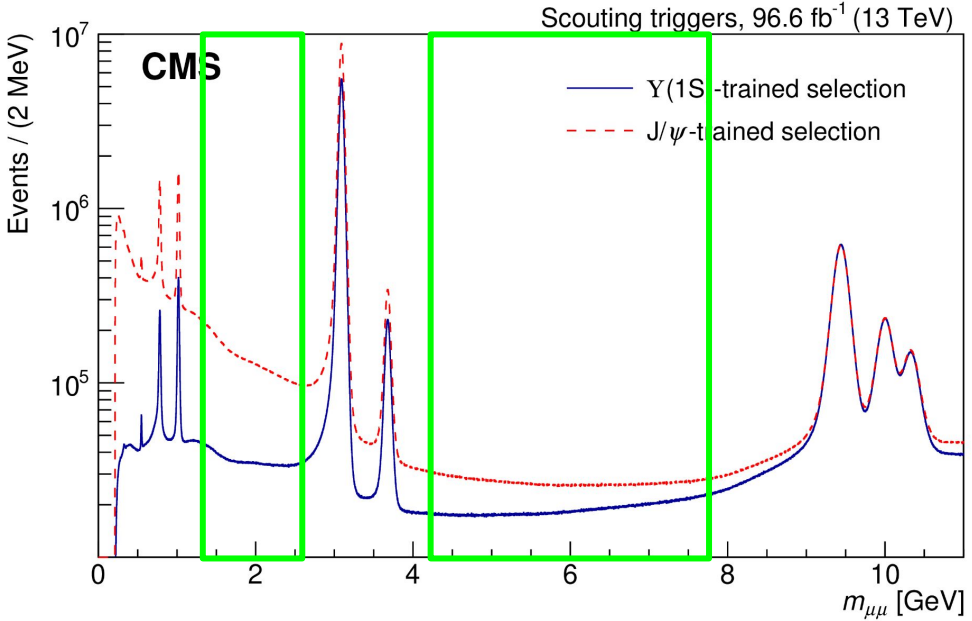
Offline

Less information allows for high rate

GeV-scale dimuon resonances

JHEP12(2023)070

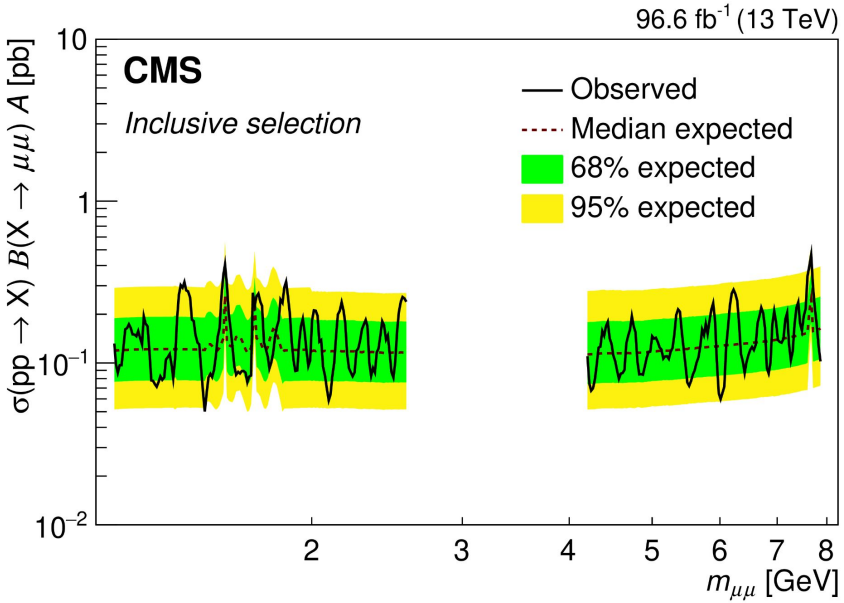
- Dimuon scouting dataset for low mass sensitivity
- Dark photon and 2HDM+S interpretations
- 2 MVA based muon IDs
  - J/Ψ trained set for
    - low mass
    - high p_T
  - Υ(1S) trained set for high mass
  - Same-sign pairs used as background
- Data-driven estimation for background processes

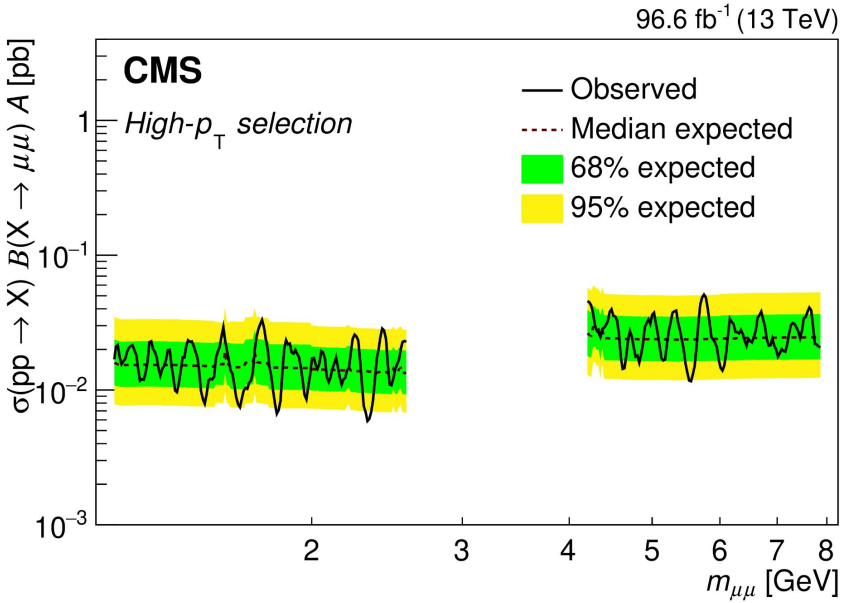


GeV-scale dimuon resonances

JHEP12(2023)070

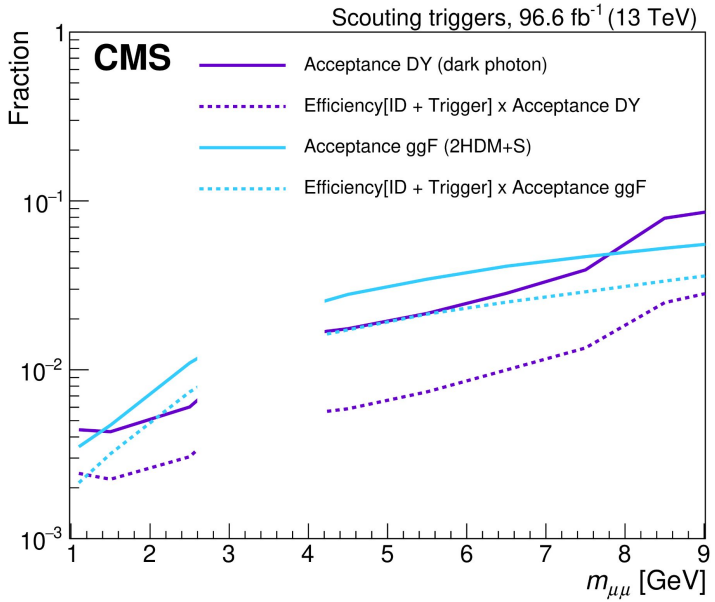
- Model independent limits
- J/Ψ region blinded due to resonances

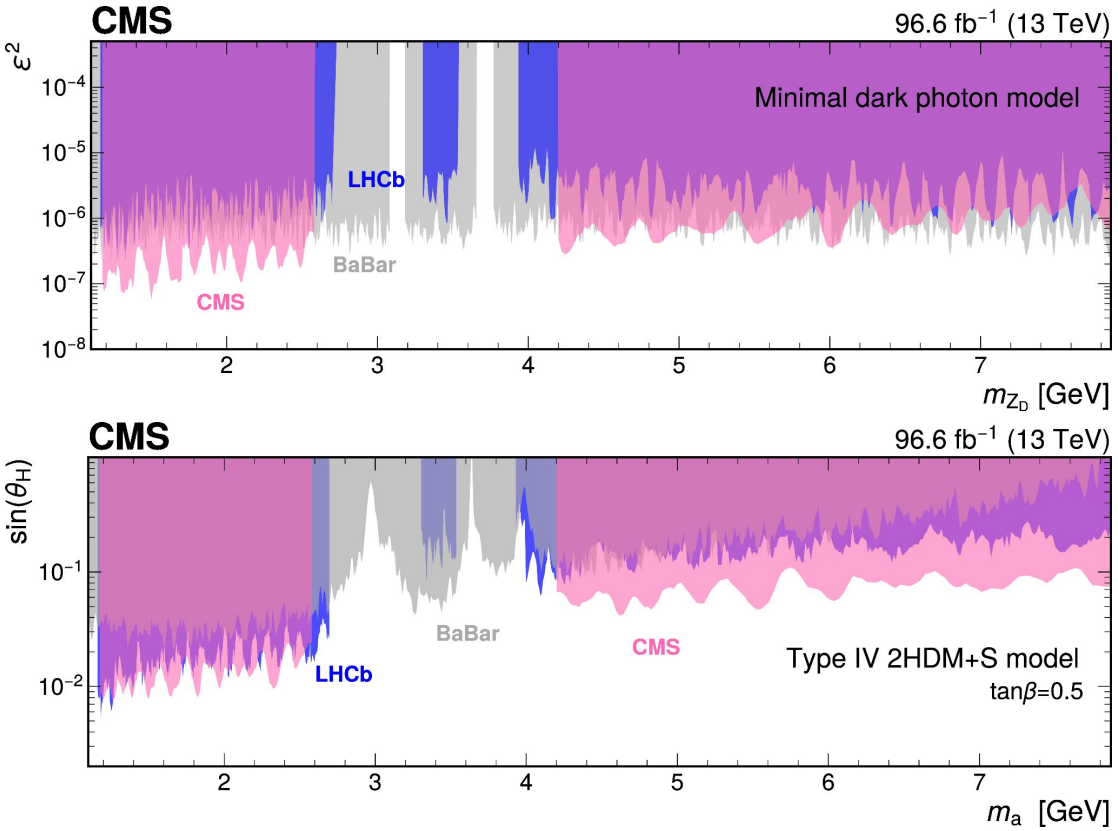


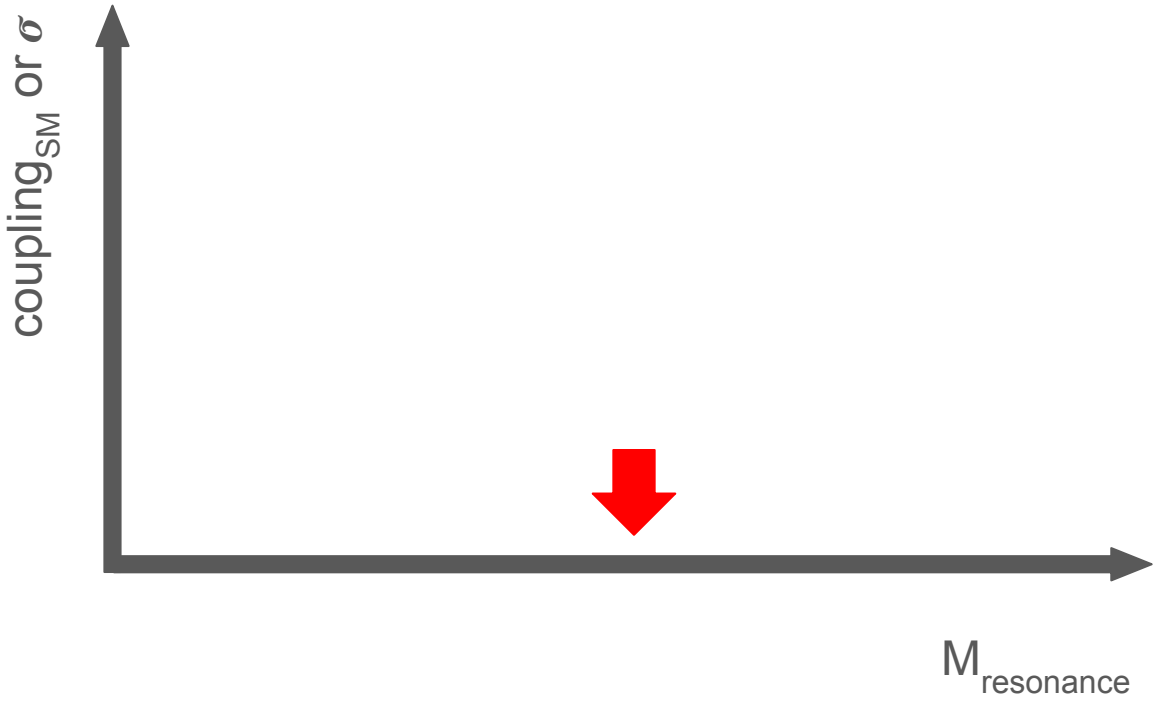


GeV-scale dimuon resonances

JHEP12(2023)070





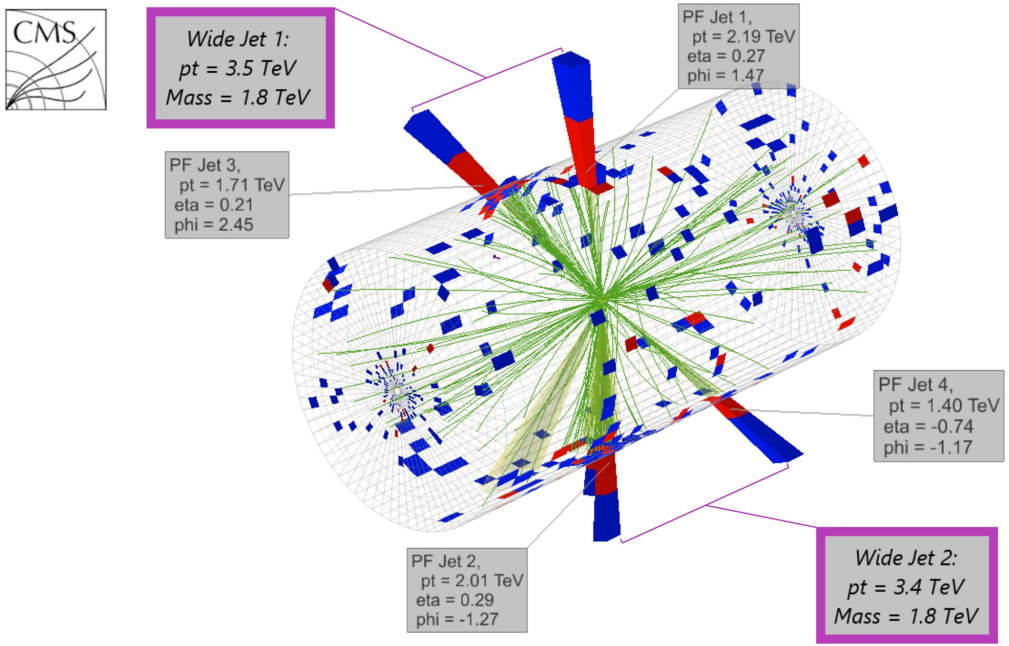


High Mass Dijet Resonances

High Mass Dijet Resonances

JHEP05(2020)033

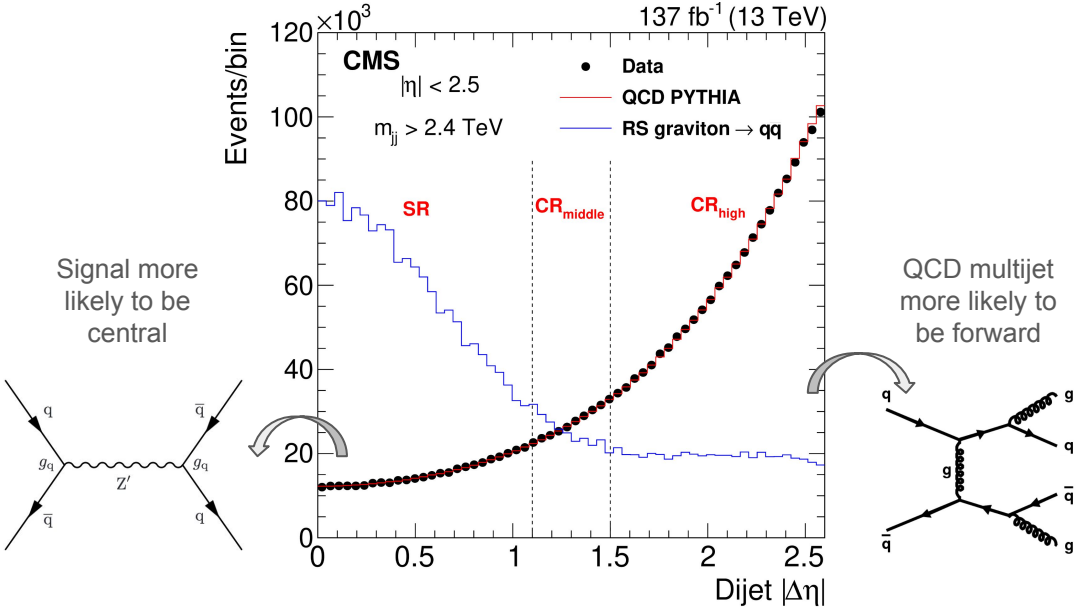
- Narrow and broad resonances
  - “broad” → width up to 55% of res mass
  - > 1.8 TeV
- Use R = 0.4 jets
  - combine with nearby jets (ΔR < 1.1) to recover FSR
  - $|\Delta\eta|$ < 1.1 signal region
- Two background estimation methods
  - 4 parameter fit (traditional)
  - “Ratio” method



High Mass Dijet Resonances

JHEP05(2020)033
QCD Diagram:
FERMILAB-THESIS-2011-38

- Ratio method → new background method
  - transfer factor from CR_{high} → SR
  - factor gets correction from CR_{middle}



High Mass Dijet Resonances

JHEP05(2020)033

QCD Diagram: FERMILAB-THESIS-2011-38

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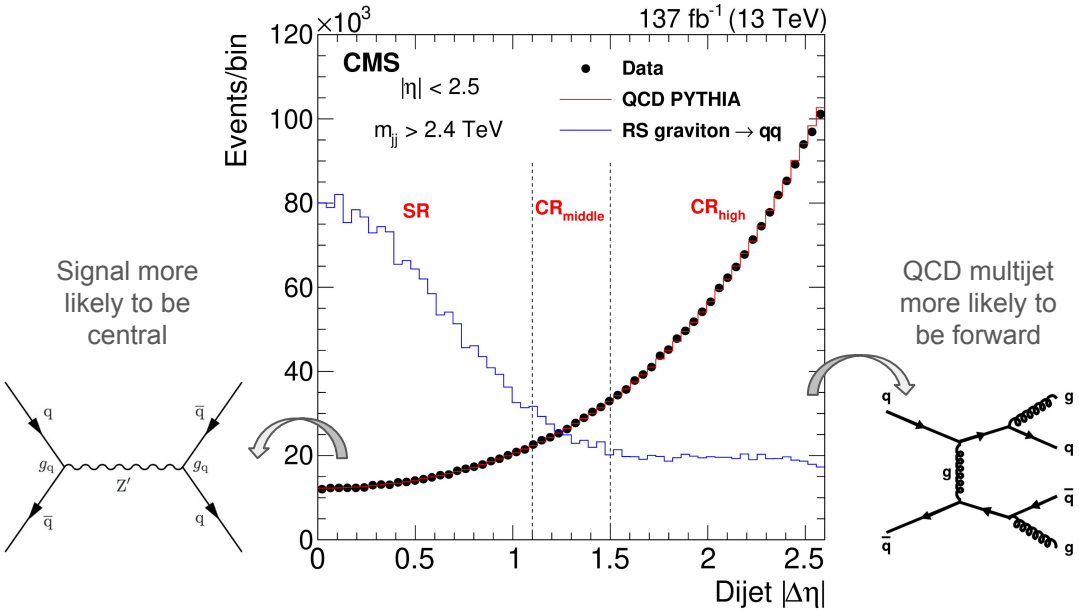

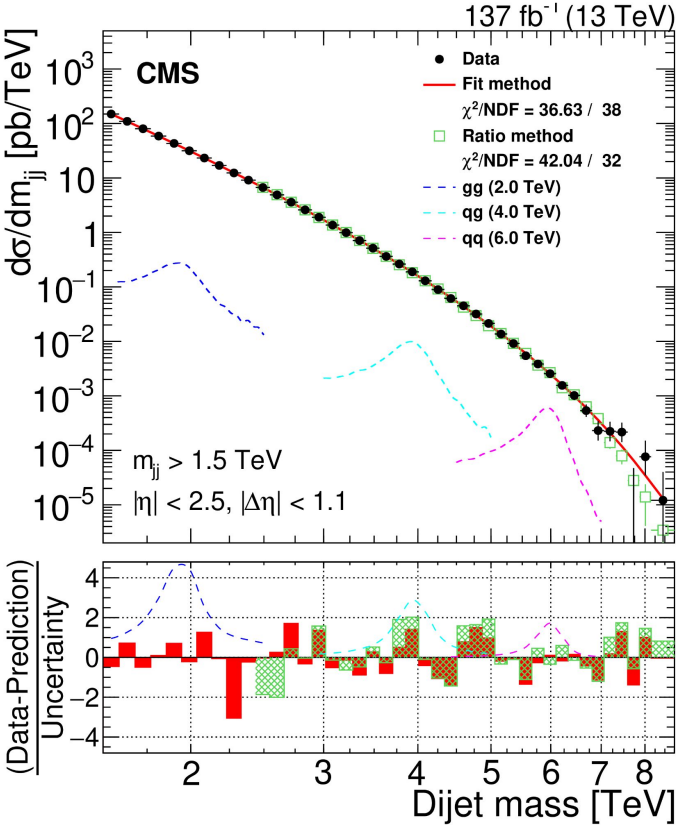

High Mass Dijet Resonances

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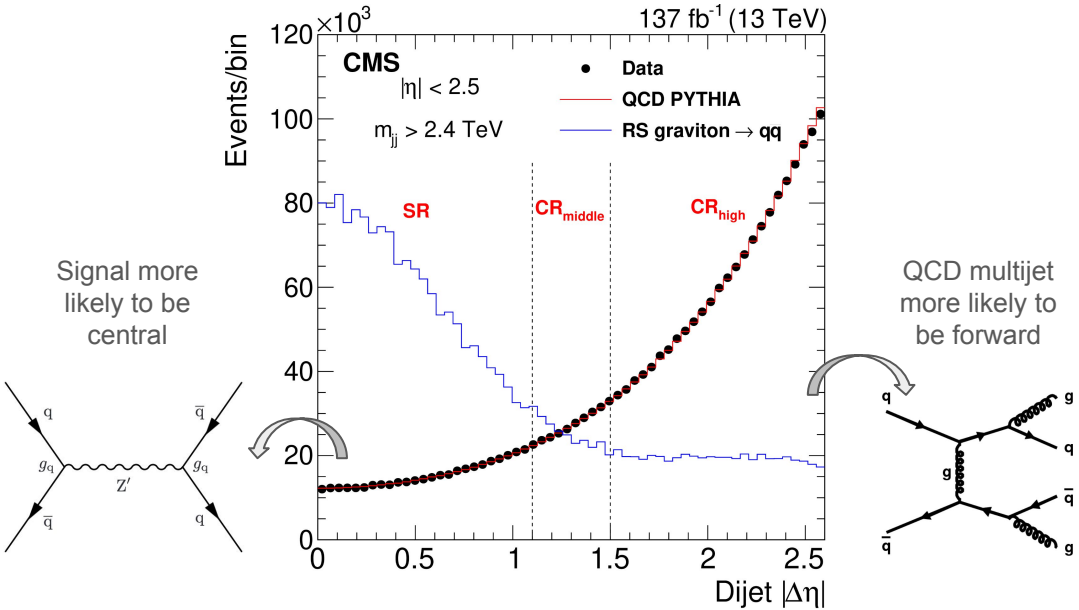
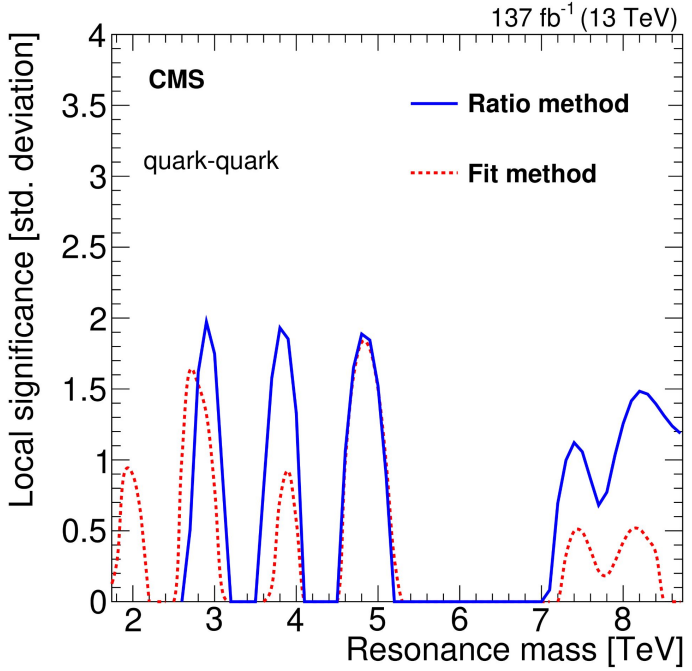
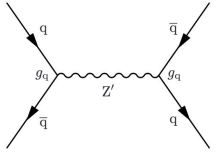
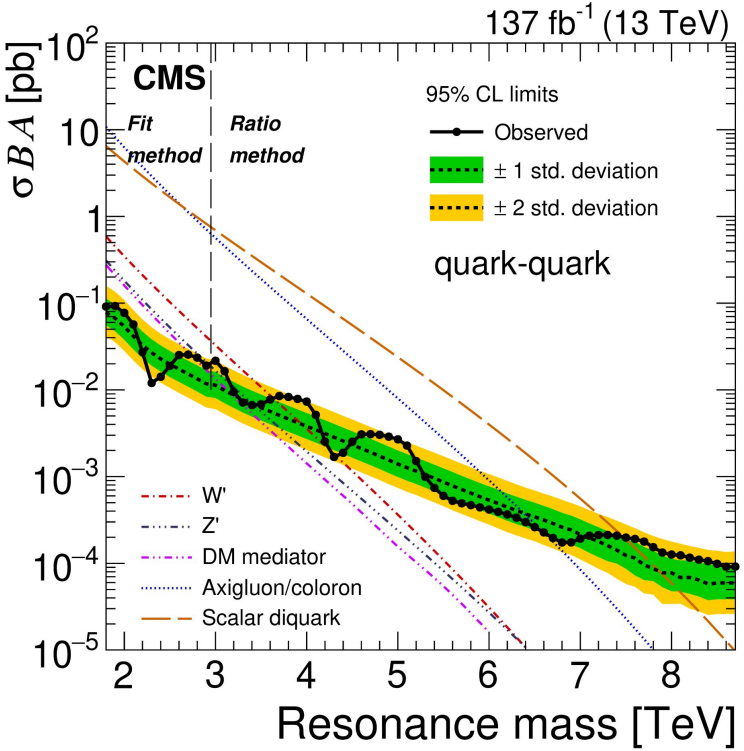


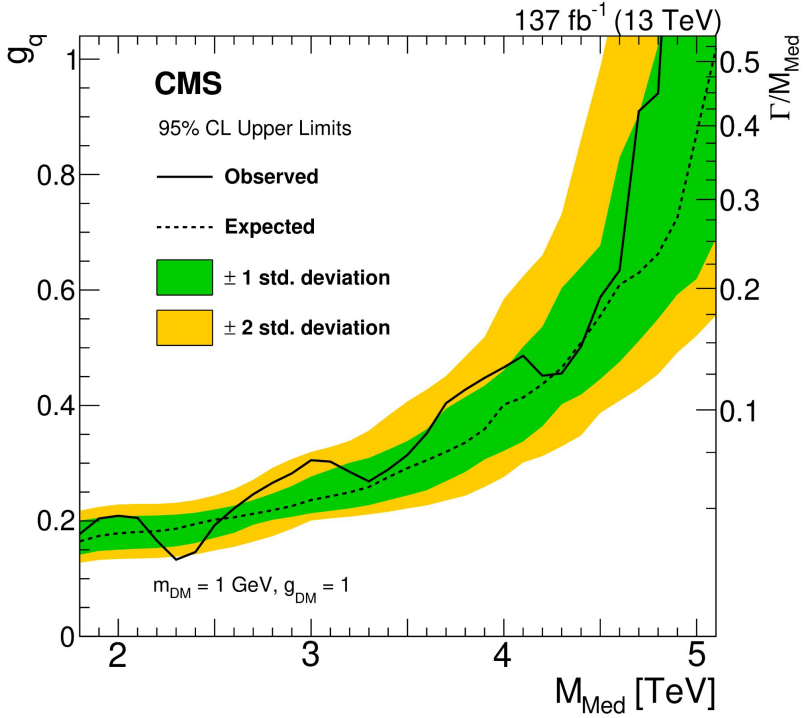


High Mass Dijet Resonances

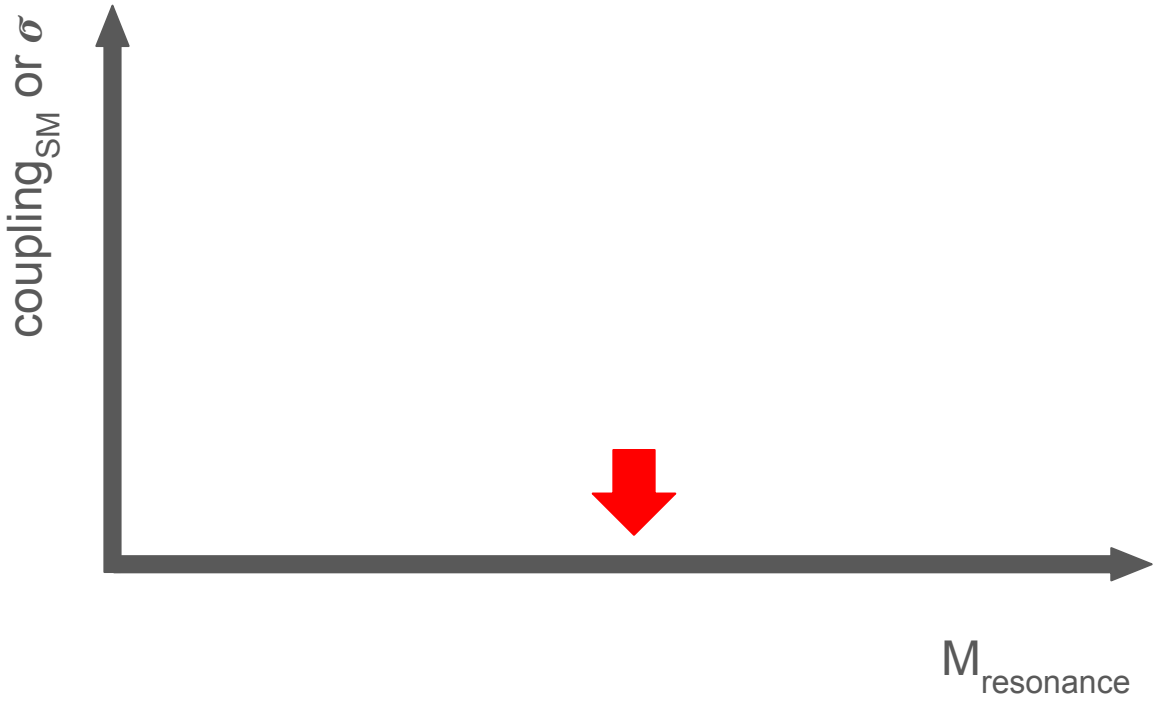


JHEP05(2020)033



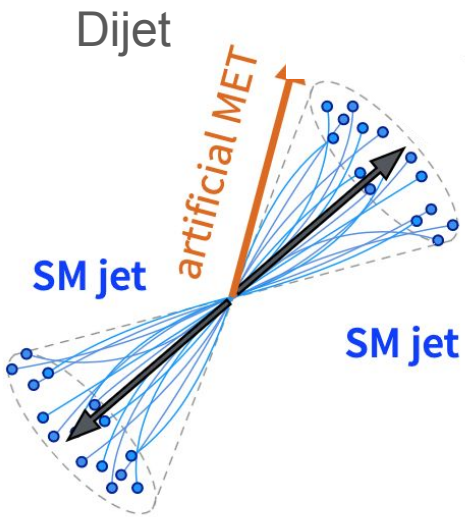


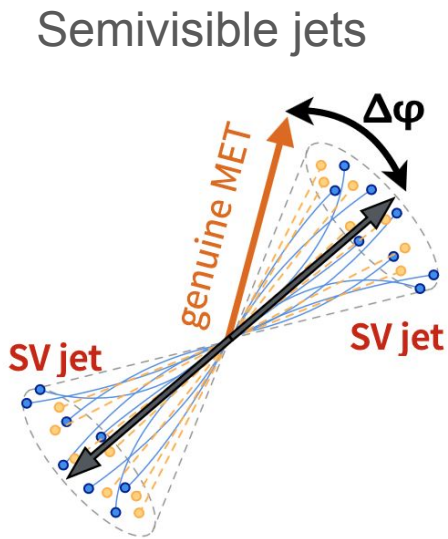
Exclude DM mediator between 1.8 TeV and 2.8 TeV



Semivisible Jets

Semivisible Jets





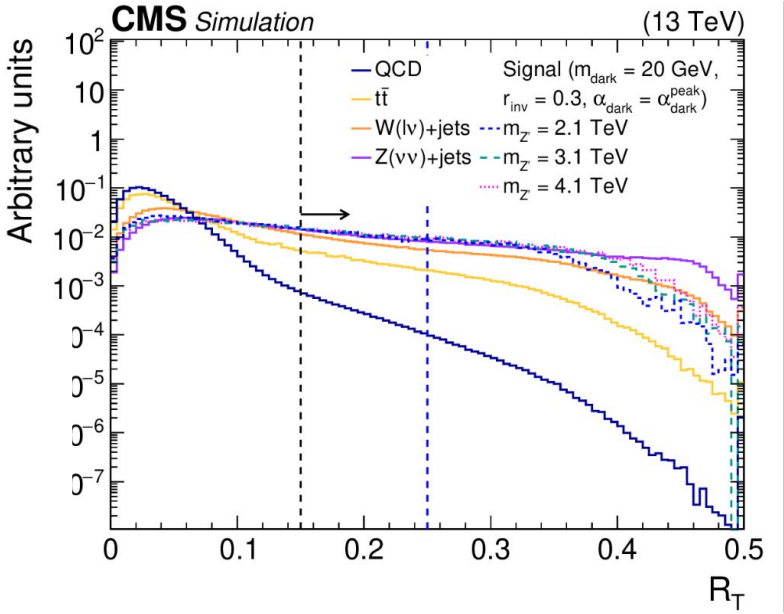
- R = 0.8 jets
- Can use jet substructure

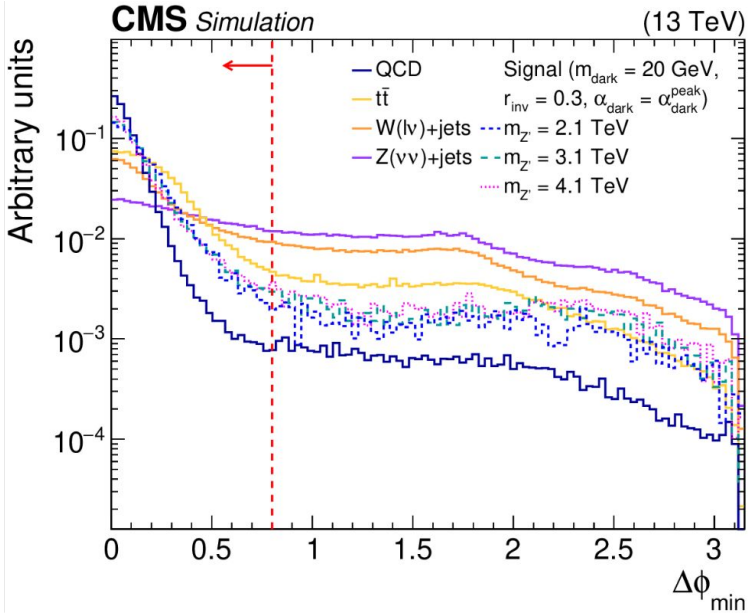
r_{inv} = invisible particles/visible particles (can be varied)

Semivisible Jets (SVJ) Strategy

JHEP06(2022)156

- Model independent and model dependent interpretations
  - BDT-based SVJ tagger using jet substructure
- R_T and $\Delta\phi(p_T^{miss}, jet)$ define the control and signal regions





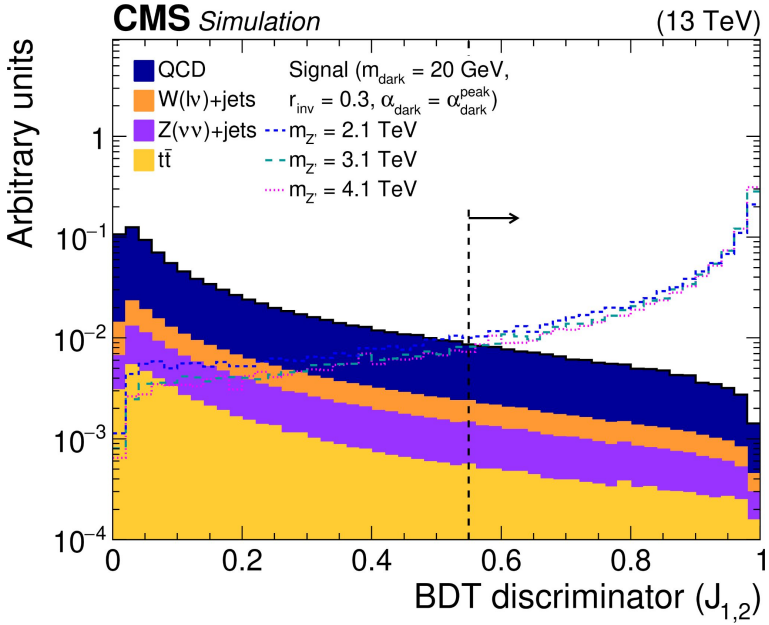
$R_T = p_T^{miss}/m_T$

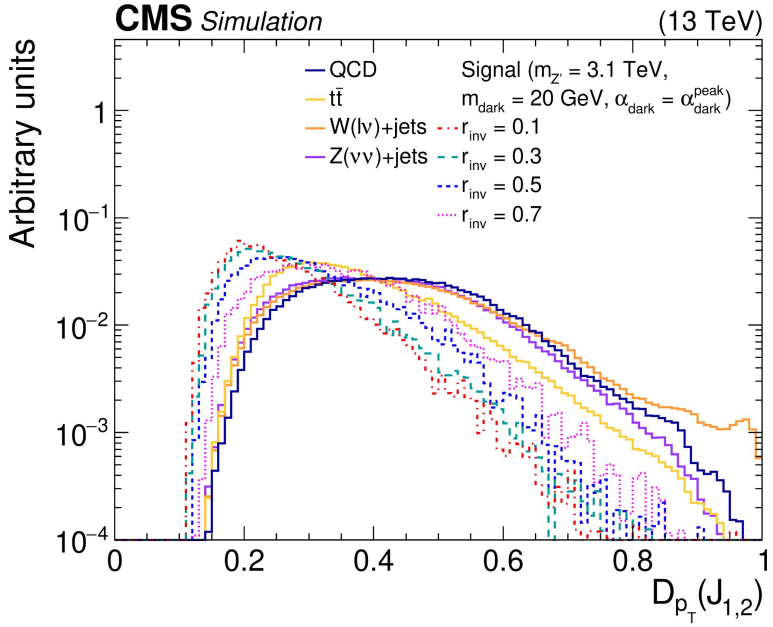
Proxy for p_T^{miss}: most high values in background removed by dedicated filters (instrumental effects)

Semivisible Jets - Model Dependent Strategy

JHEP06(2022)156

- Added selection on top of model independent search
- SVJ Tagger
  - BDT based on substructure variables



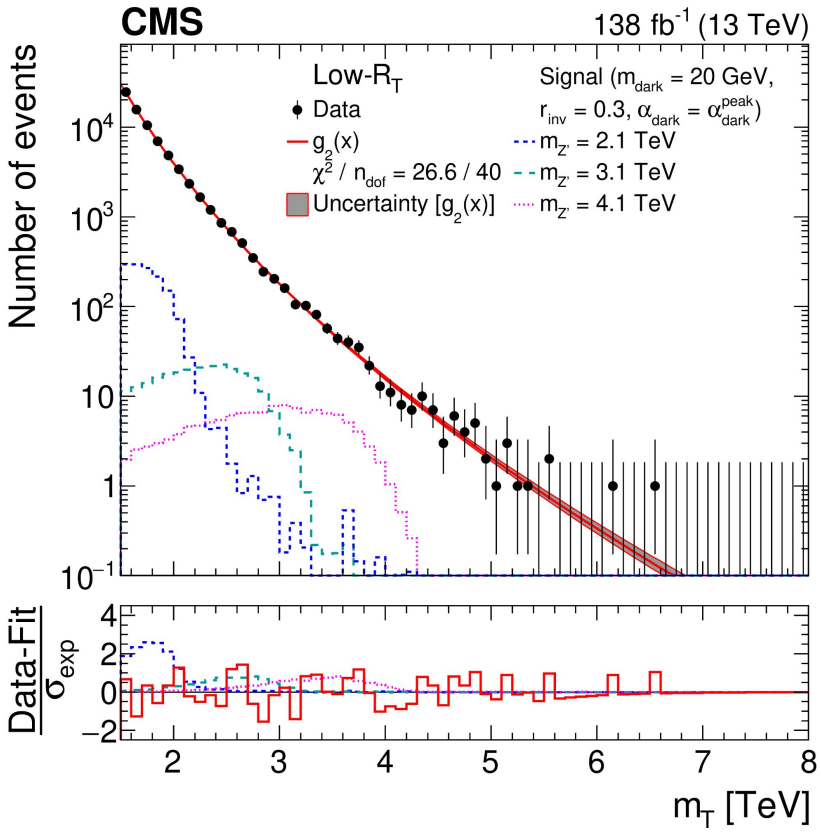


Semivisible Jets Strategy

JHEP06(2022)156

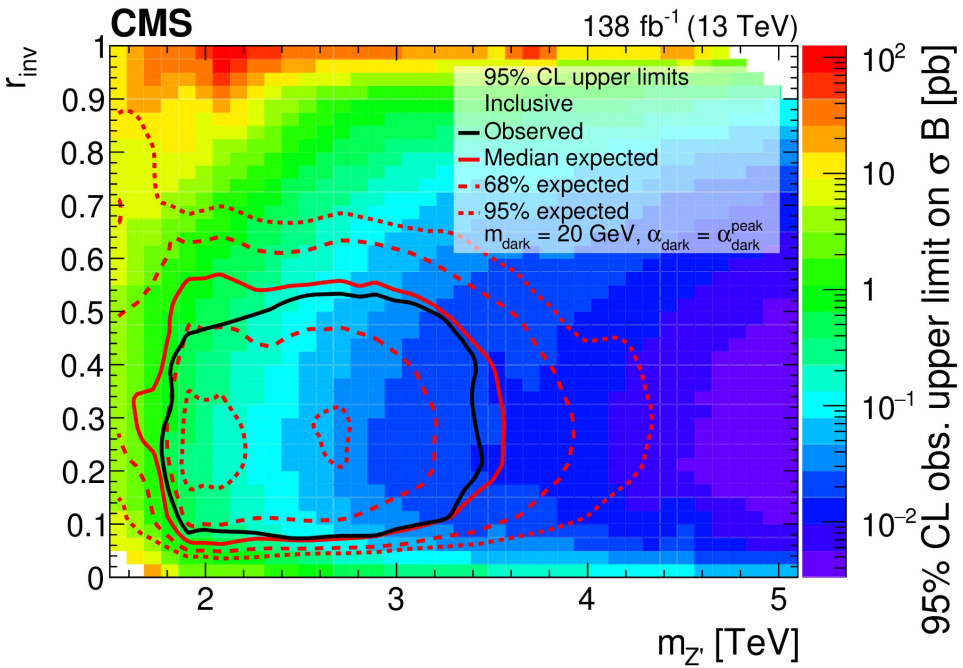
- Transverse mass (m_T) spectrum as the final observable
  - m_T of dijet system and p_T^{miss}
  - assume only “one” invisible particle in final state

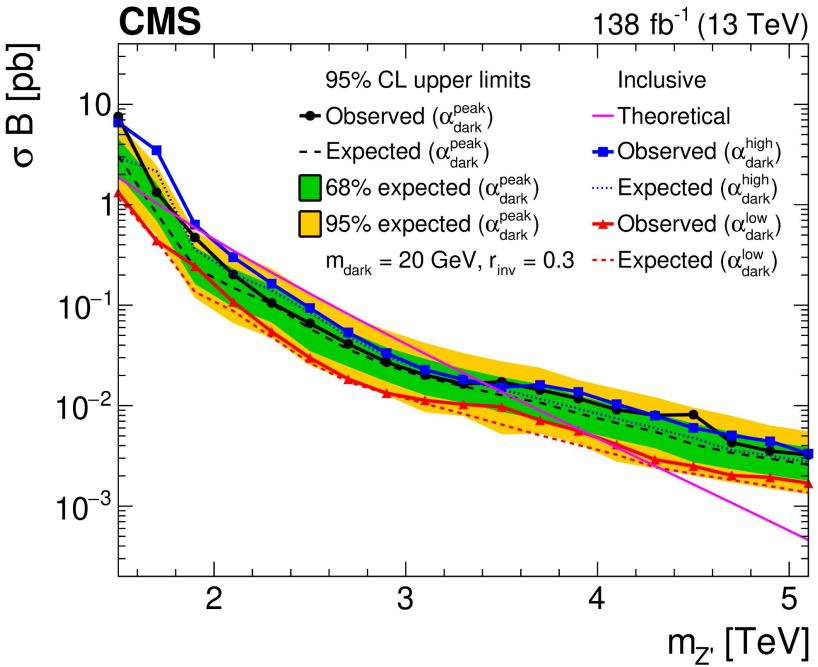
$$m_T^2 = \left[E_{T,JJ} + E_T^{miss}\right]^2 - \left[\vec{p}_{T,JJ} + \vec{p}_T^{miss}\right]^2$$
$$= m_{JJ}^2 + 2p_T^{miss}\left[\sqrt{m_{JJ}^2 + p_{T,JJ}^2} - p_{T,JJ}\cos(\phi_{JJ,miss})\right]$$



Semivisible Jets Results - Model Independent

JHEP06(2022)156

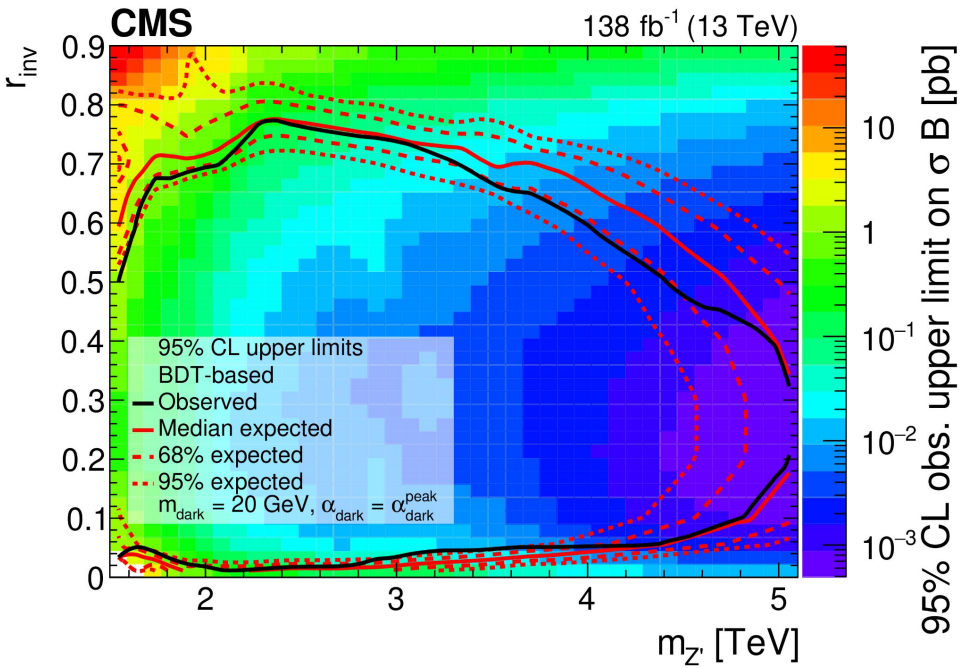


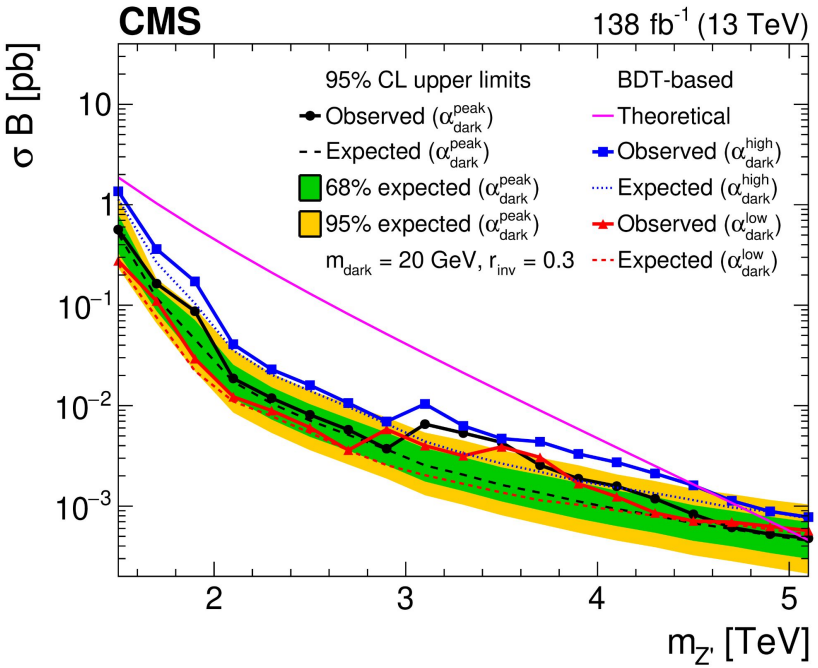


Exclude Z' between 1.5 and 4.0 GeV

Semivisible Jets Results - Model Dependent

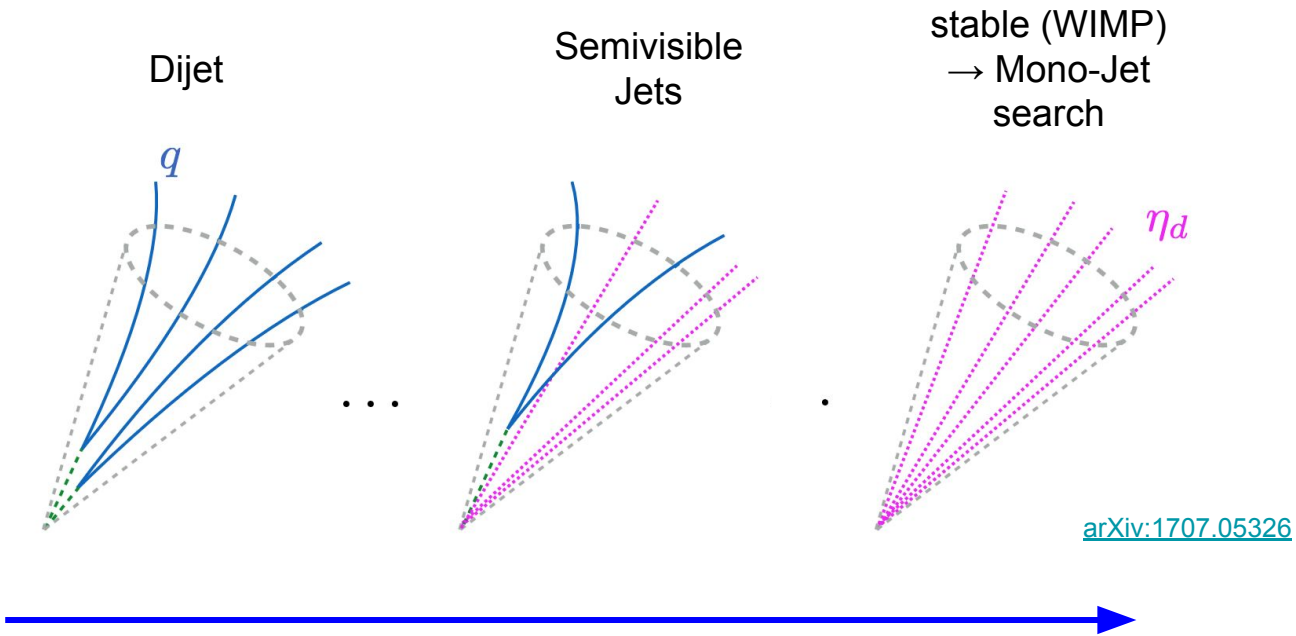
JHEP06(2022)156





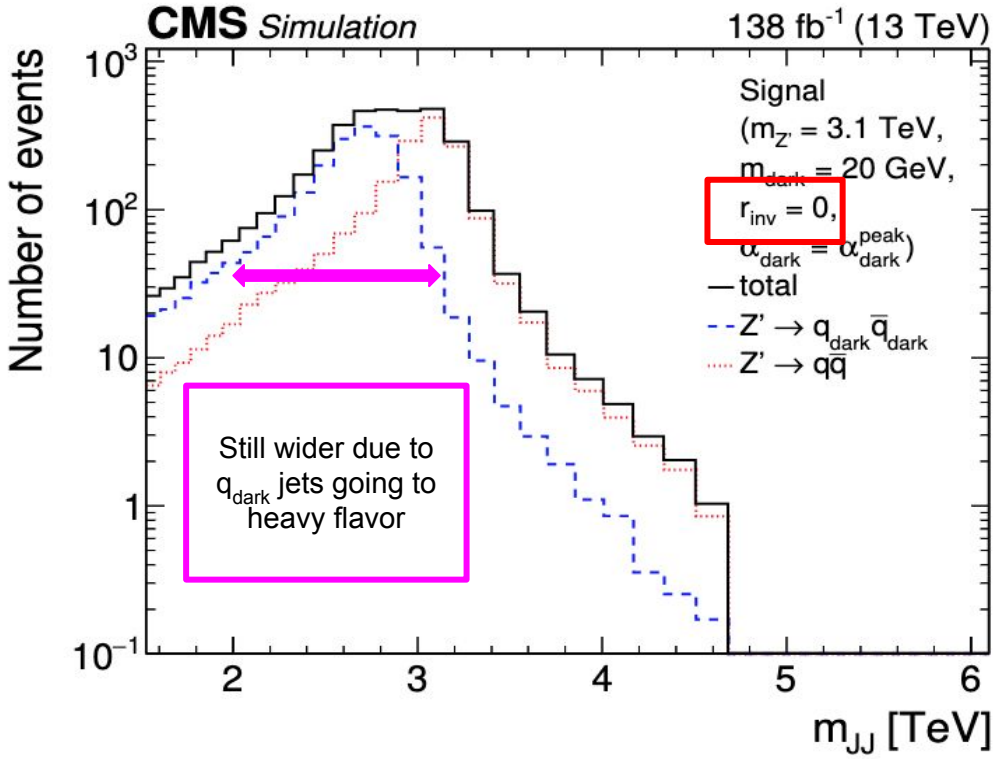
Exclude Z' between 1.5 and 5.1 GeV

The invisible continuum



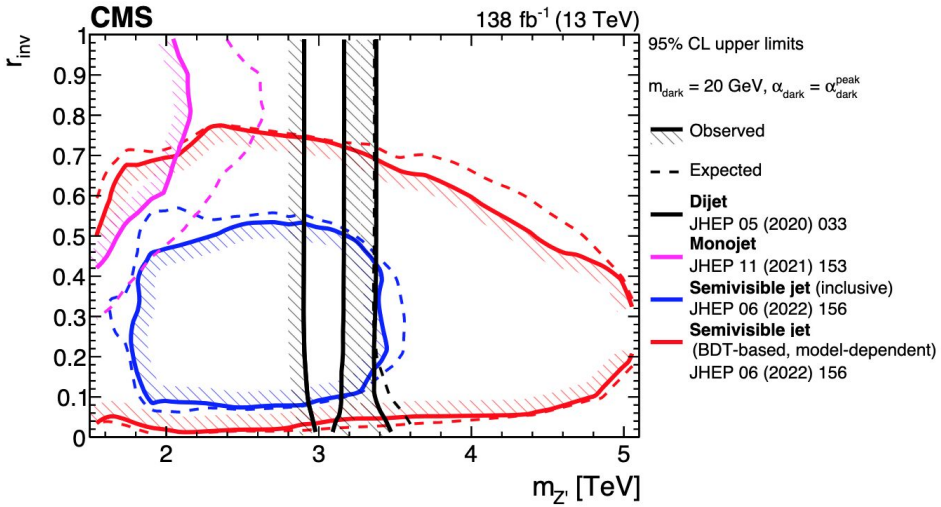
Building the dijet reinterpretation with r_{inv}

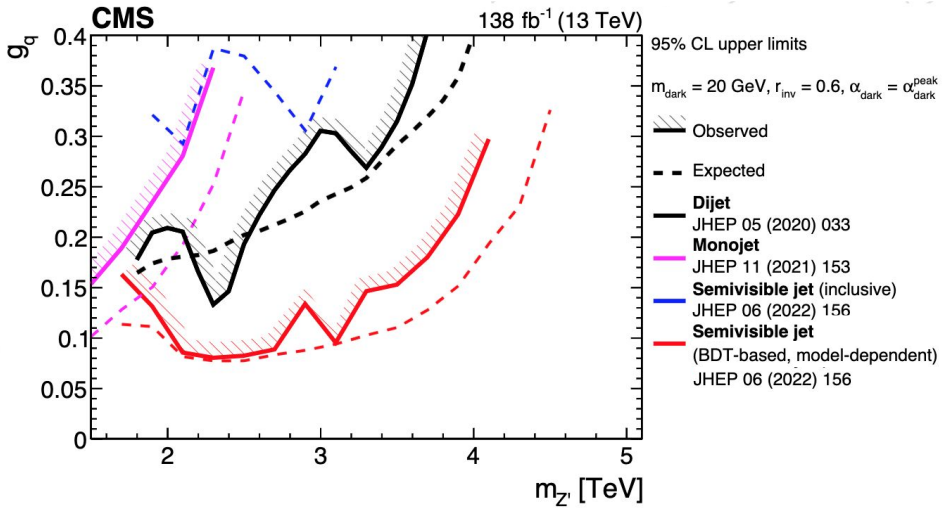
2405.13778



Dijet + Monojet reinterpretation for SVJ

2405.13778





Reinterprets using the signatures with “everything visible” (dijet) and “everything invisible” (mono-jet) → Excludes new phase space!

Summary

- Cohesive and complementary DM mediator search program in CMS
  - Resonant search program strong!
- Extend phase space coverage with new triggers and new methods
  - Use dimuon scouting to probe GeV level DM mediator mass
  - New approaches in dijet searches to increase discovery power
  - Signatures like SVJ give sensitivity to extended sectors
- Reinterpret existing analyses to fully exploit power of all searches
  - Review paper gave the space to combine efforts
  - Cover completely visible to completely invisible ranges in r_{inv}
    - SVJ reinterpretation of high mass dijet and mono-jet searches
- Looking forward to more exotic CMS 13.6 TeV (Run 3) results!
  - See some at this conference! Some examples:
    - Raphael Haberle's LLP → Hadronic talk
    - Anna Mascellani's LLP→ (Semi)leptonic talk