Search for Dark Matter with CMS

Sudha Ahuja

On behalf of the CMS collaboration

SPRACE-UNESP, São Paulo, Brazil

LHCP, Bologna, Italy, June 4-9 2018

Outline

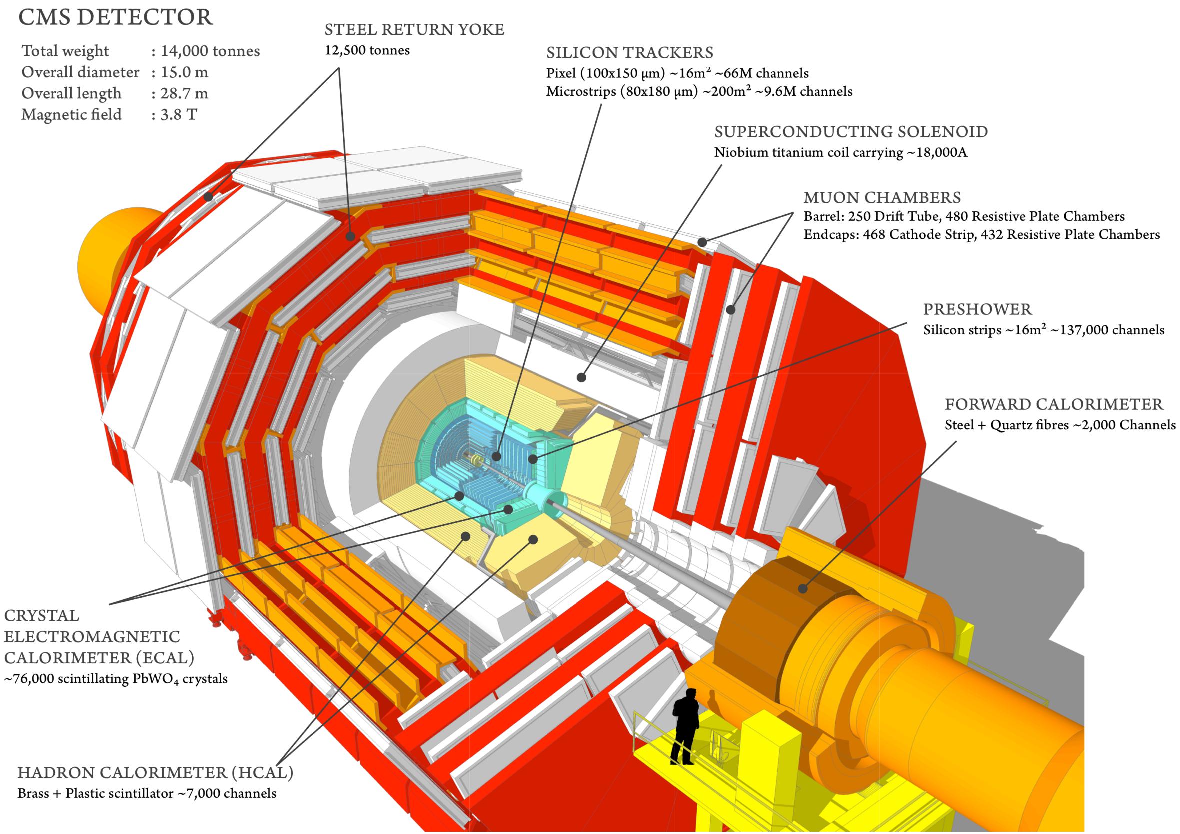
Introduction

- ❑ Dark Matter
- ❑ Collider Searches

CMS results

- ❑ Mono-X searches
- ❑ Mediator searches

Summary



http://cms-results.web.cern.ch/cms-results/public-results/publications/EXO/index.html
http://cms-results.web.cern.ch/cms-results/public-results/preliminary-results/EXO/index.html

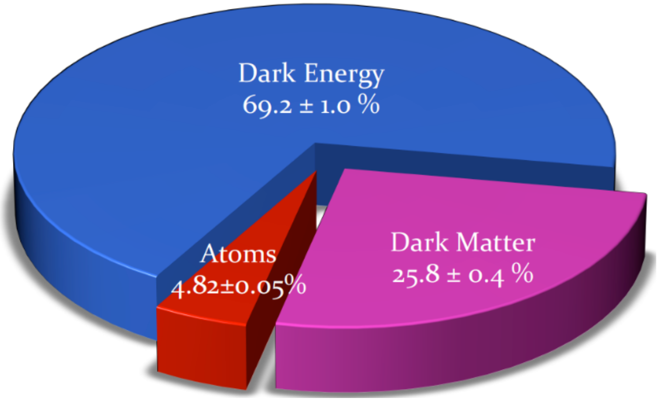
Dark Matter

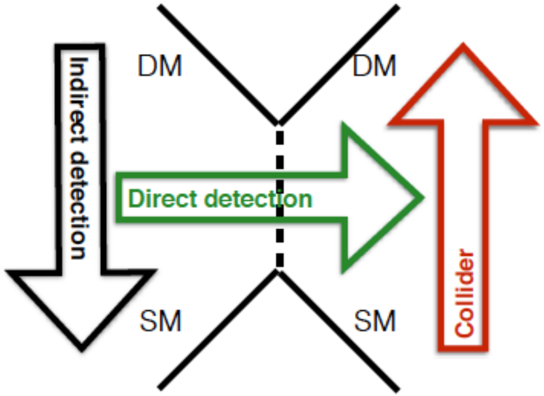
Well established evidence

- ❑ Underlying nature still unknown

Hunt for DM

- ❑ Direct detection
  - LUX, XENON, SuperCDMS, CRESST
- ❑ Indirect detection
  - Pamela, Fermi, AMS, IceCube
- ❑ *Production at Colliders*
  - Rich playground for DM production & detection
  - Sensitive to wide-mass range

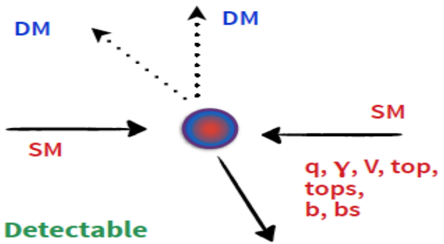




Collider Searches

DM signal at colliders

- Trigger events using recoiling SM objects
- Initial-state radiation to rescue (X)
  - X = jet/photon/W/Z
- Infer presence by large amount of missing transverse energy (MET)

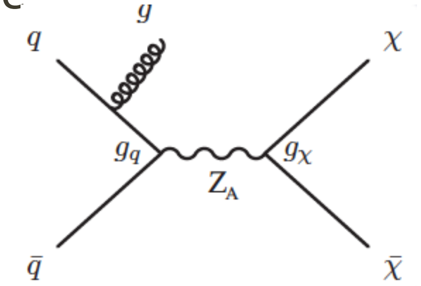


Search for DM in tails of MET spectrum

arXiv:1002.4137

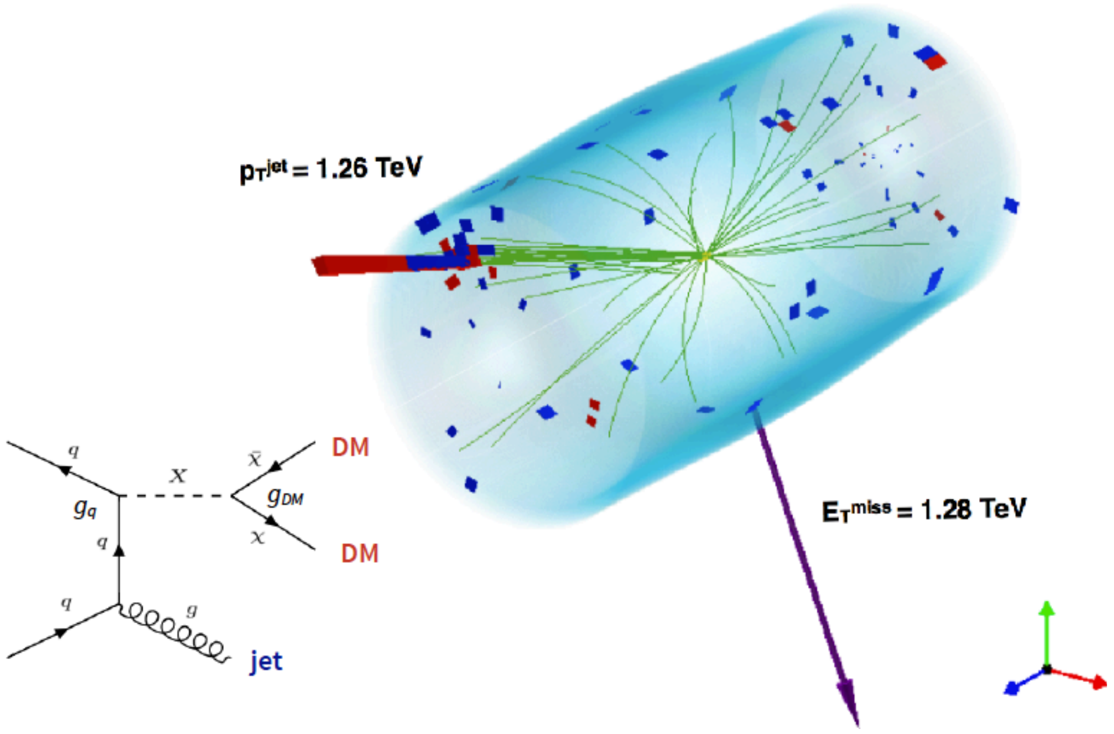
Run2: Simplified Models

- DM interaction through mediator
  - Explicit definition of mediator
  - Multiple parameters
    - M_{med}, M_{DM}, g_{SM}, g_{DM}
  - High momentum transfer possible



LHC DM Forum, arxiv:1507.00966v1

Mono-X Searches



The Classic: Mono-J/V Searches

Most sensitive final state

Large MET signals

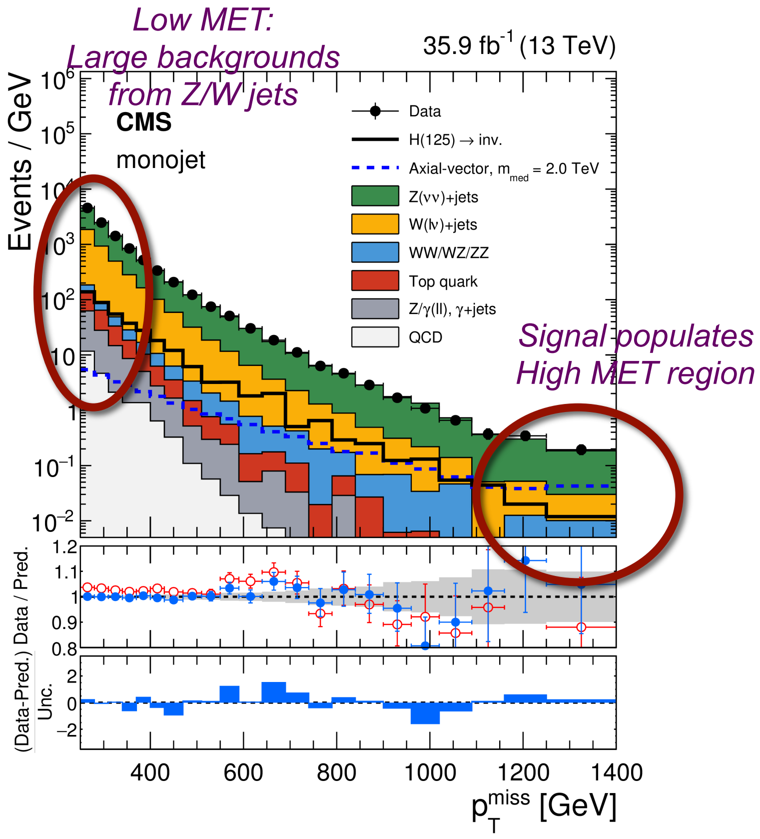
Signal extraction based on MET distribution

Main backgrounds: Z(νν)+jets & W(lν)+jets

- Well modeled from control regions in data
  - Z(μμ)+jets, Z(ee)+jets, γ+jets, W(μν)+jets, W(eν)+jets
  - Simultaneous fit to signal and control regions
- No deviation observed w.r.t. SM expectation

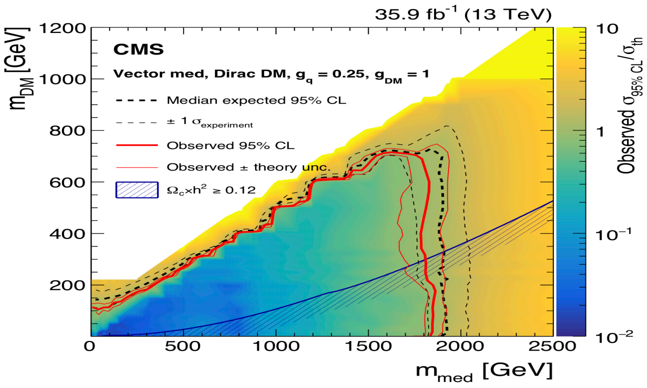
Signature similar to hadronically decaying boosted mono-V

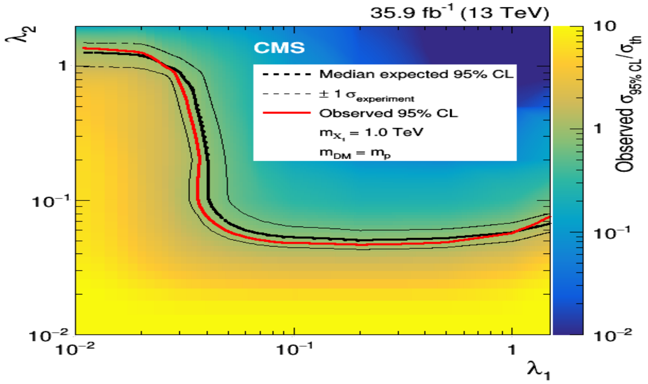
- Use jet substructure for identification

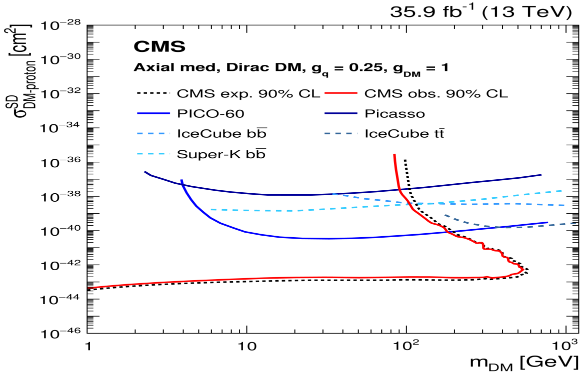


PRD 97 (2018) 092005

DM Interpretations







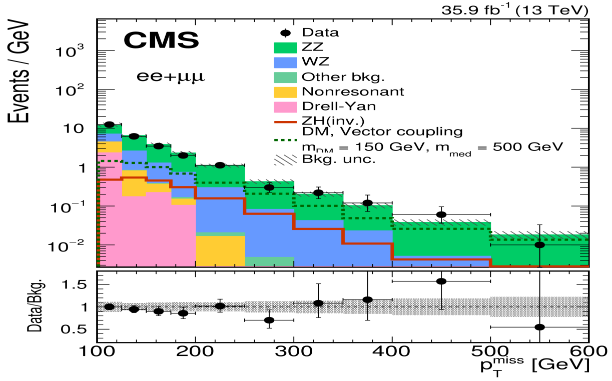
95% C.L. upper limits obtained in the M_{DM}-M_{med} plane

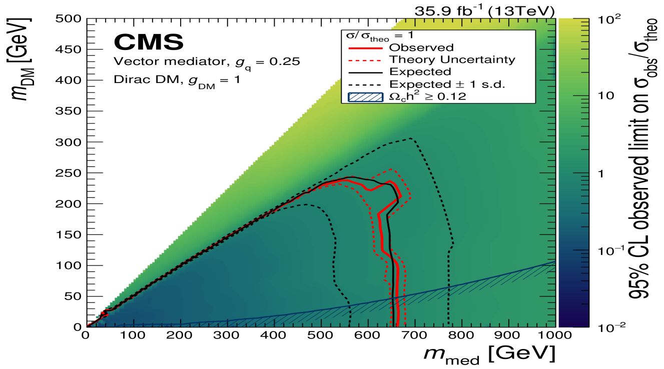
Results translated to 90% C.L upper limits in comparison to DD experiments

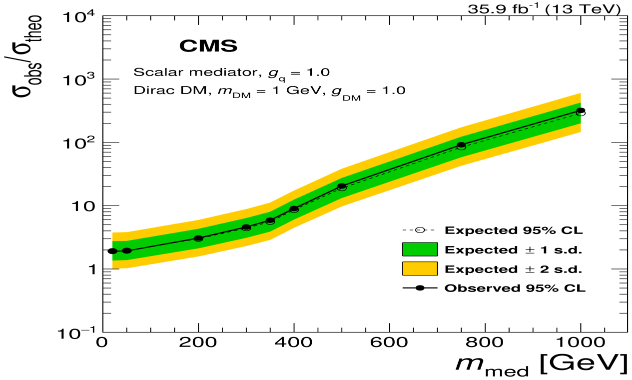
Various other interpretations such as fermion portal DM, non thermal DM results etc. also presented

PRD 97 (2018) 092005

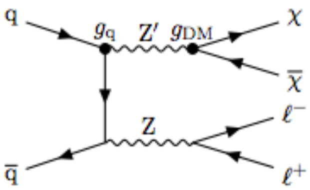
Mono-Z (leptonic) Searches







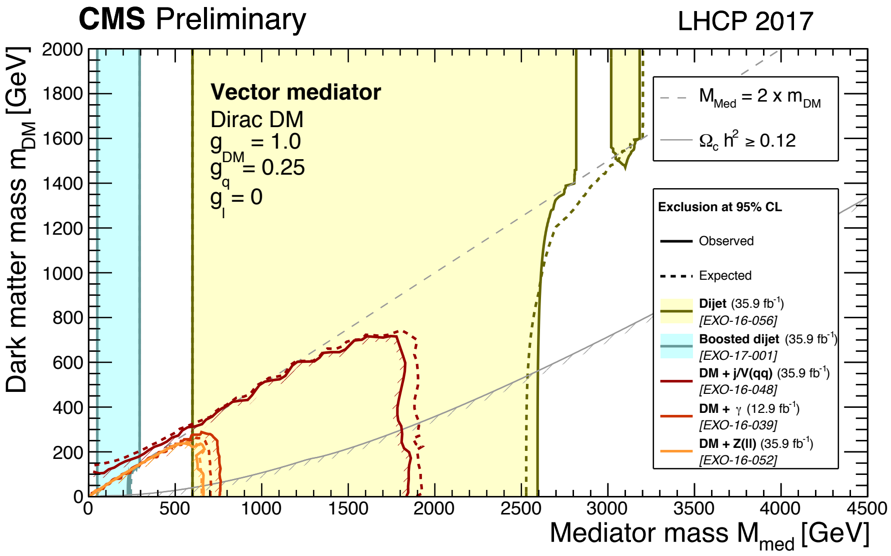
- Complements the monojet searches in exploring the mono-V aspects of DM models
  - Main backgrounds: ZZ, WZ
- Lacks sensitivity to scalar mediators



EPJC 78 (2018) 291

Mono-X summary 2017

Not sensitive to region $M_{med} < 2M_{DM}$



Hadronic Mono-Top

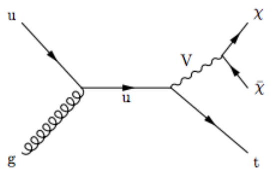
Hadronically decaying boosted Top Quark (67% BR)

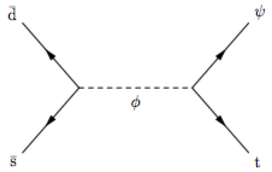
- ❑ Substructure techniques for Top tagging
  - ▪ Energy correlation function, N-subjettiness & top-tagger
  - ▪ Inputs used in BDT to discriminate backgrounds
- ❑ Z(νν)+jets, W(lν)+jets & ttbar

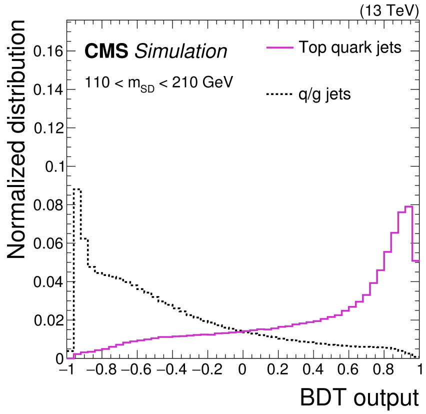
DM Models

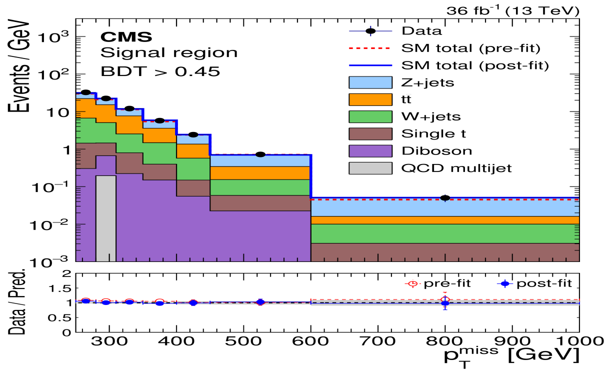
- ❑ FCNC mediator (V): decays to DM pair
- ❑ Colored charged scalar: decays to DM+top

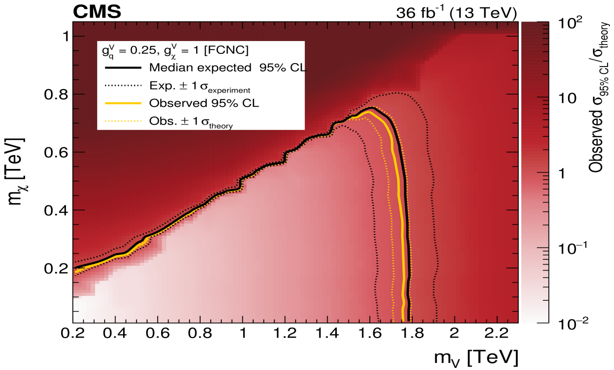
Simultaneous fit 2 SR and CRs







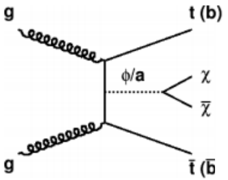




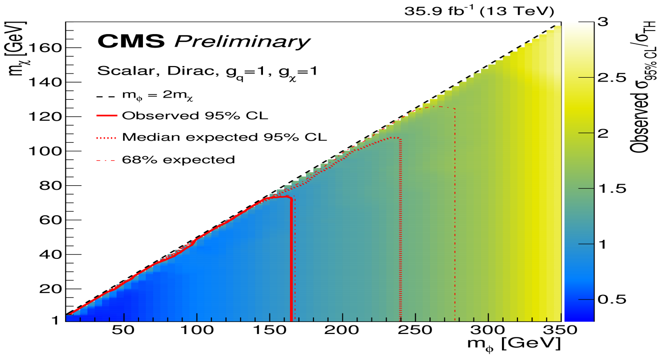
CMS-PAS-EXO-16-051; arXiv 1801.08427

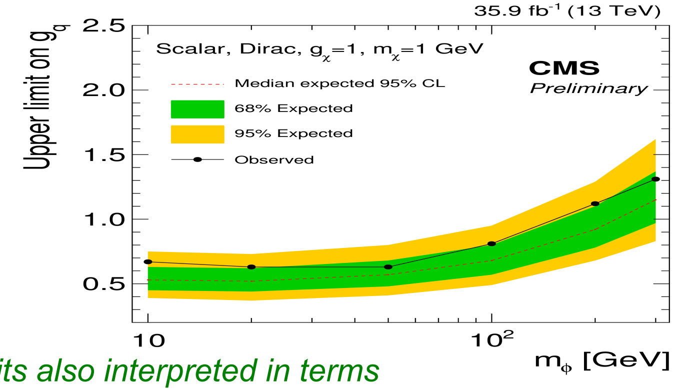
DM With Top Quark Pair

- DM couples preferentially to top quarks via spin-0 mediators
  - Results interpreted in terms of Spin-0 mediators
- Combination of hadronic, semi-leptonic, di-leptonic channels
  - Final states with 0,1, or 2 leptons presented
- Obtained exclusion upto 100 GeV mediator mass even with dileptonic channel alone
- 2D exclusion limits on coupling strength as a function of mediator & DM mass

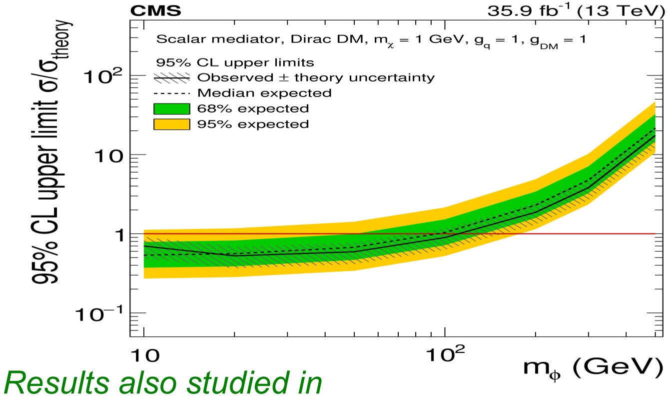


CMS-PAS-EXO-16-049





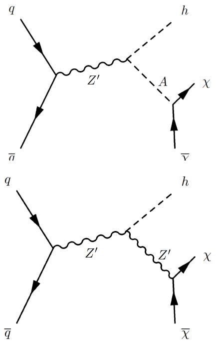
Limits also interpreted in terms of mediator couplings to quarks **CMS-PAS-EXO-16-049**

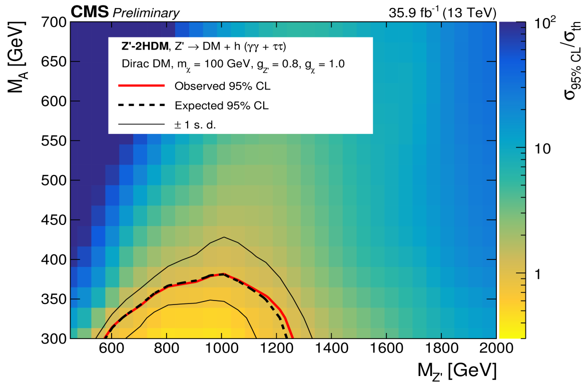


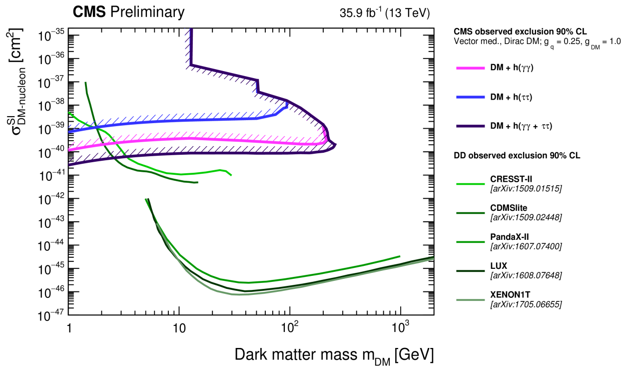
Results also studied in context of SUSY searches **PRD 97 (2018) 032009**

Mono-Higgs Analysis (1)

- WIMP may interact with SM through the Higgs sector
- Two benchmark models: Z'-2HDM (resonant) & baryonic Z'
- Combination of γγ (experimentally simple) & ττ (lower background) modes
  - ❑ More discrimination power
  - ❑ Can probe lower MET states
  - ❑ ττ channel
    - $e\tau_h$, $\mu\tau_h$, $\tau_h\tau_h$ final states
    - W+jets & QCD major backgrounds
- Signal extraction: Simultaneous fits to transverse mass in SR and CR



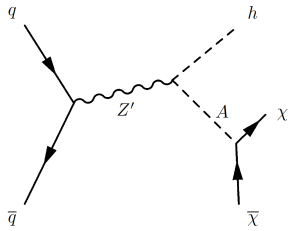


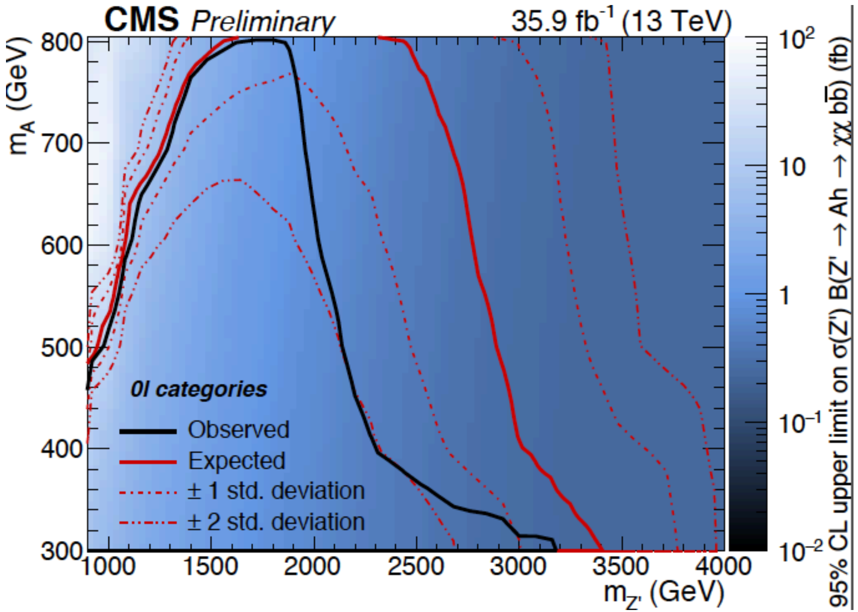


CMS-PAS-EXO-16-055

Mono-Higgs Analysis (2)

- Mono-Higgs (bb) is the most sensitive channel
- Single Fat-jet with mass consistent with the SM Higgs
  - B-tagged & 2 prong structure
- Sets most stringent constrain to date on Z'-2HDM model





CMS-PAS-B2G-17-004

Mediator Searches: Dijet Analysis

Mediators couple to SM particles

DM particles couple to quarks via spin-1 DM mediator

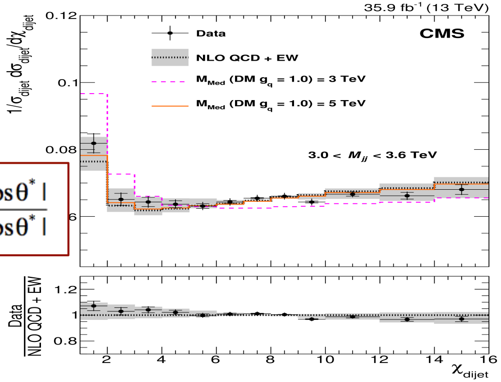
Dijet angular analysis: angular distributions fit for different di-jet mass bins

- New physics identified by excess at low values

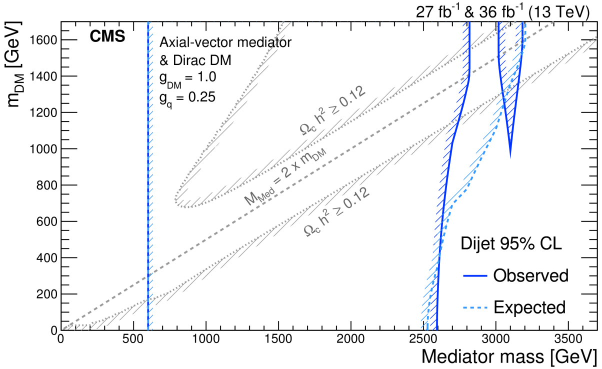
Resonance searches:

- Mediator decays to pair of DM particles or jets
- Narrow or broad resonance (explore various quark coupling strength)
- Limits on mediator in the plane of m_{DM} vs the M_{med}
  - Excluded value of M_{med} increases with m_{DM}

$$\chi_{dijet} = e^{|y_1 - y_2|} \sim \frac{1+|\cos\theta^*|}{1-|\cos\theta^*|}$$



CMS-PAS-EXO-16-046



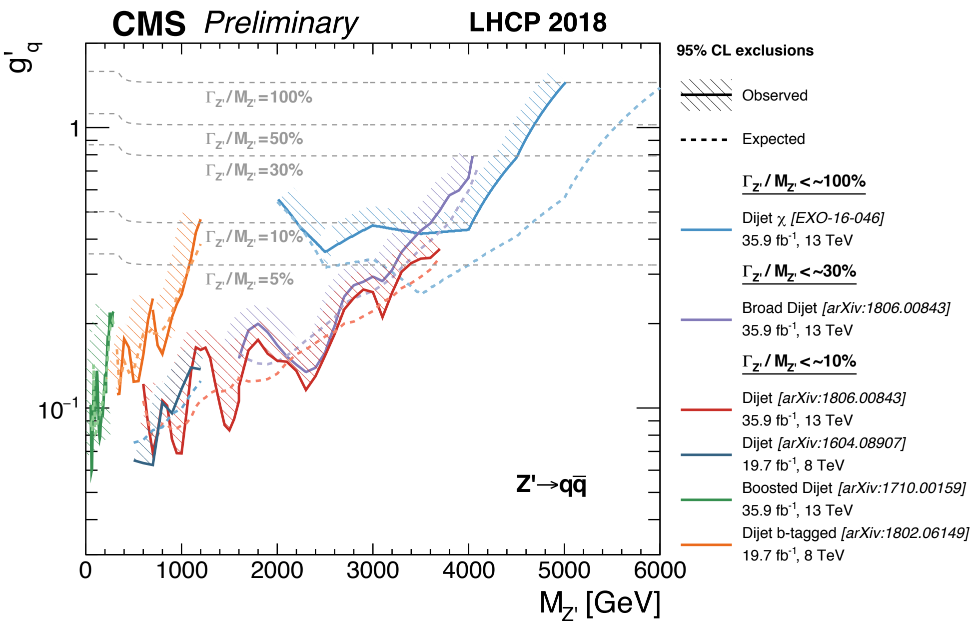
CMS-PAS-EXO-16-056; arXiv 1806.00843

Dijet Summary

Limits on universal coupling (between leptophobic Z' and quarks) from various di-jet analyses

For $M_{DM} > M_{med}/2$:

Dijet cross-section from mediator models identical to leptophobic Z' models



Summary

Wide range of rich CMS program for DM searches

- ❑ Mono-X searches
- ❑ Mediator parameters constrained by di-jet or di-lepton searches

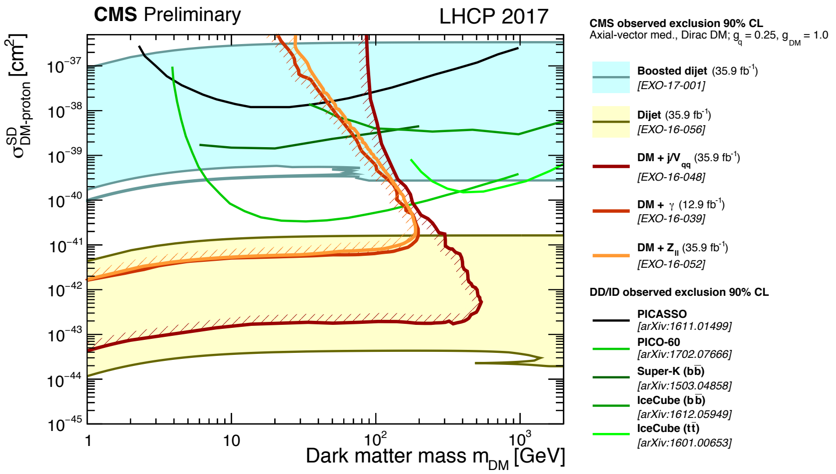
Results interpreted in terms of simplified models

Substructure techniques used for boosted objects

Lot more data to analyze from 2017

- ❑ Gain sensitivity to various searches

Stay Tuned!!



Comparison with Direct Detection experiments