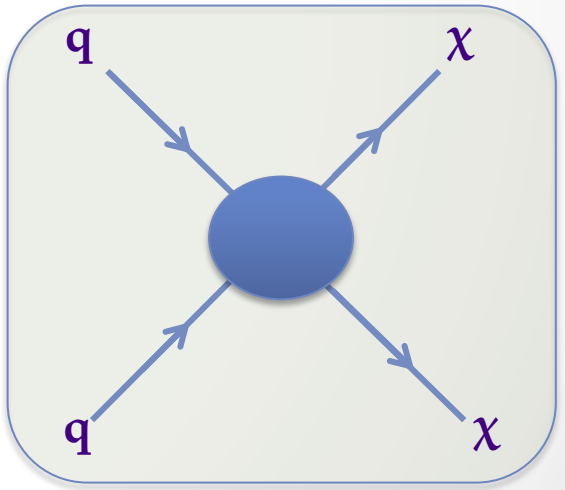
Search for Dark Matter in Jets plus MET final state of Non-thermal DM, Fermion Portal and ADD Models using Data from Proton Proton Collision at $\sqrt{s}$ = 13 TeV.

Sonaina Undleeb (Texas Tech University)
CMS Collaboration

Dark Matter Production at LHC

- Dark matter (DM) outweighs visible matter roughly six to one, making up about 27% of the universe.
- Several theories to predict its nature – i.e. DM could contain "supersymmetric particles"… etc
- Experiments at the **L**arge **H**adron **C**ollider may provide more direct clues.
  - DM would be light enough to be produced at the LHC.
  - Escape through the detector unnoticed.
  - Carries away energy and momentum so that its existence can be inferred through "missing" information.

$$q + q \rightarrow \chi + \chi$$



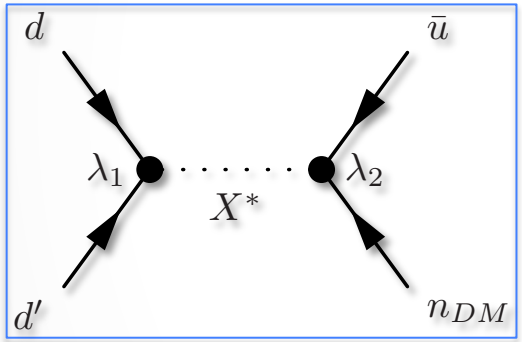
This talk includes monojet signal interpretation in terms of Non-thermal DM and Fermion Portal DM models.

Light Non-Thermal DM Model

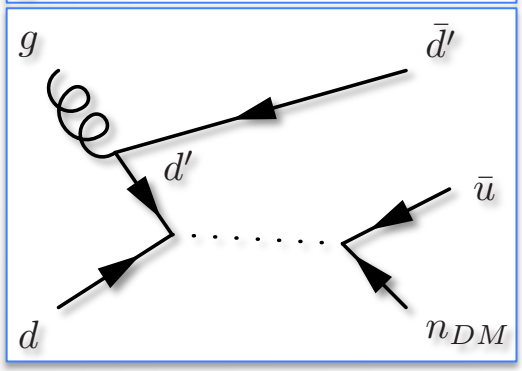
Simplified Model –

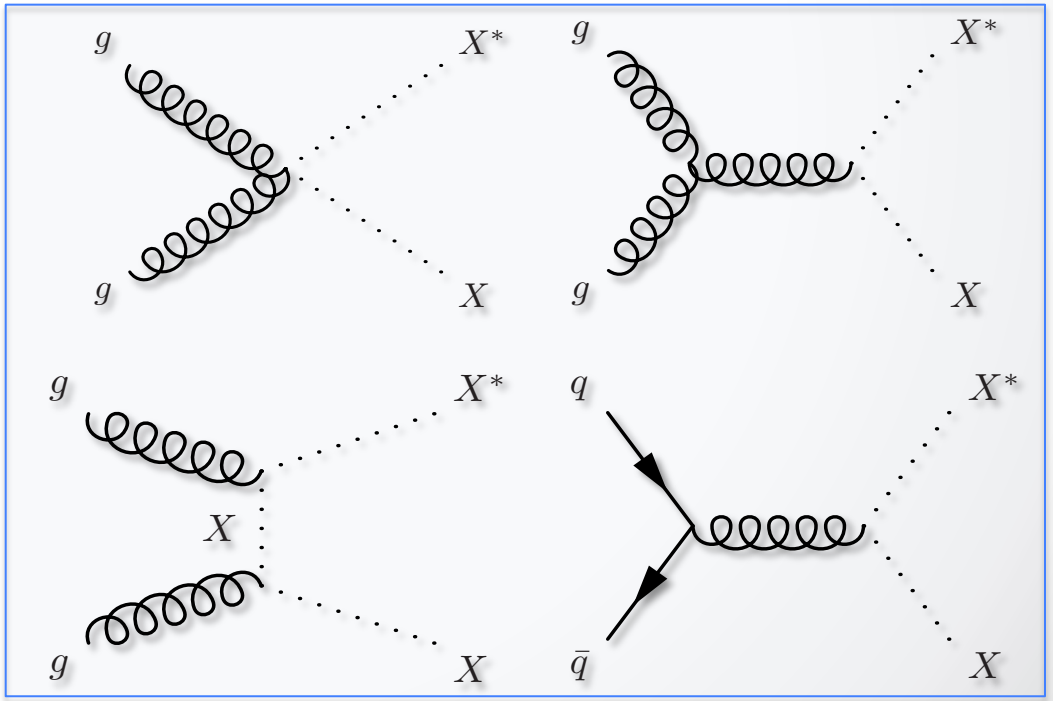
- predicts "light" dark matter ($\mathbf{M_{DM} \approx M_{Proton}}$).
- Mediator -- Heavy scalar color triplet(s) (~TeV)
- **Large missing energy** associated with an **energetic jet** – transverse momentum distribution shows jacobian-like shape.
- Parameters of the model are: $\boldsymbol{\lambda_1, \lambda_2}$ **(couplings)** , $\mathbf{M_X}$, $\mathbf{M_{DM}}$**(Masses)** and **Width** of mediator.

Monojet



ISGS

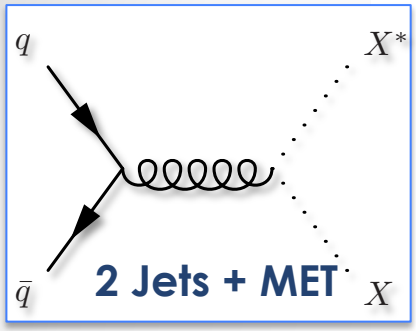


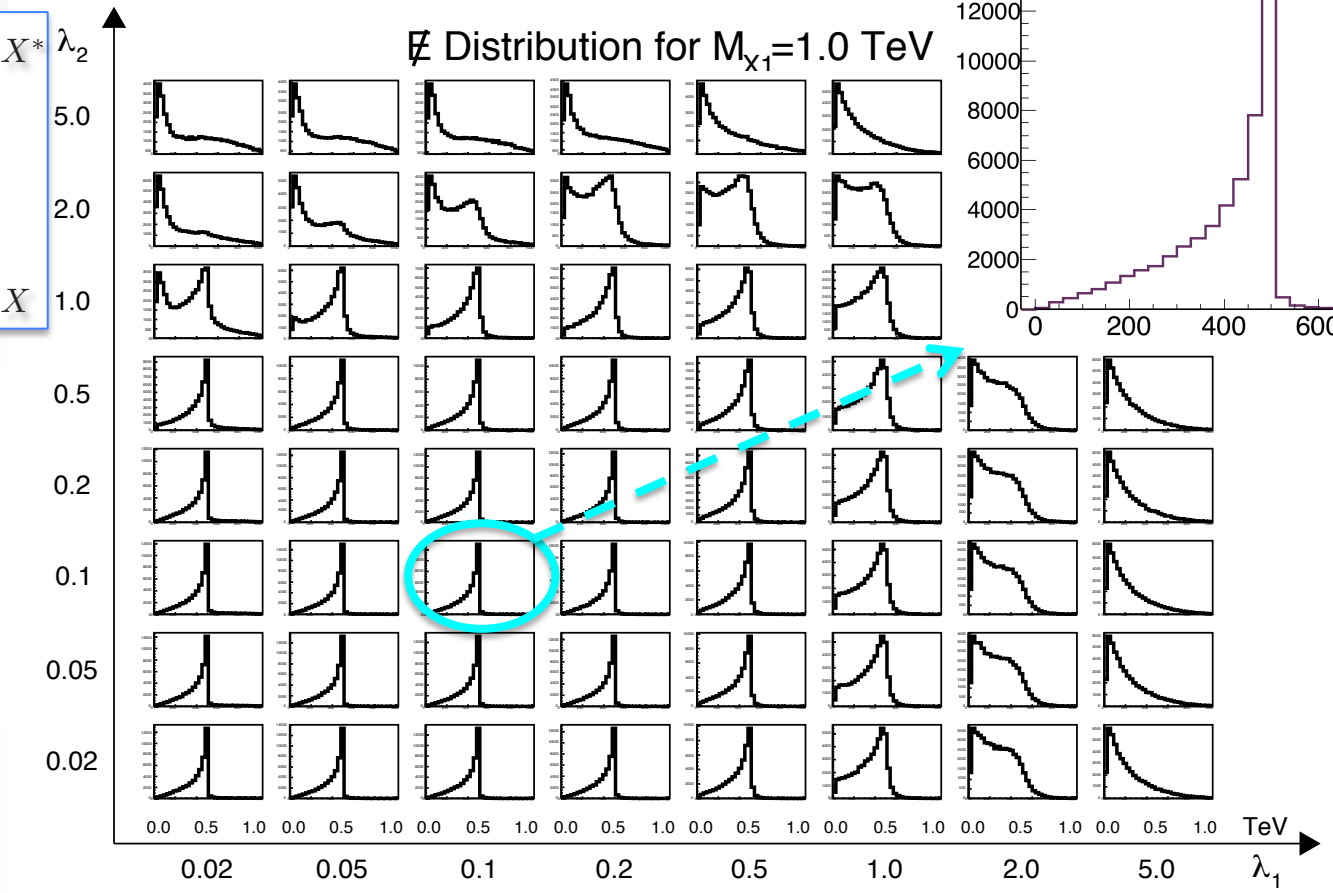


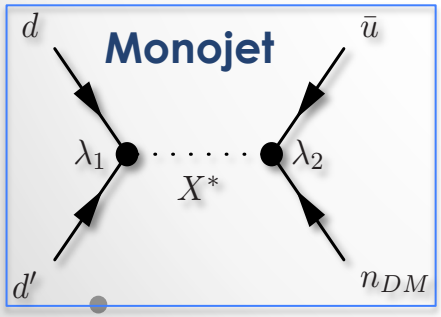
Pair Production of *X*

http://arxiv.org/abs/1401.1825 Bhaskar Dutta, Yu Gao and Teruki Kamon

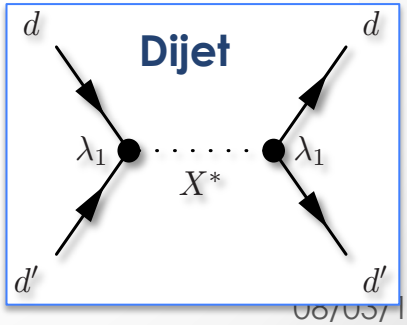
Light Non-Thermal DM Model -- MET







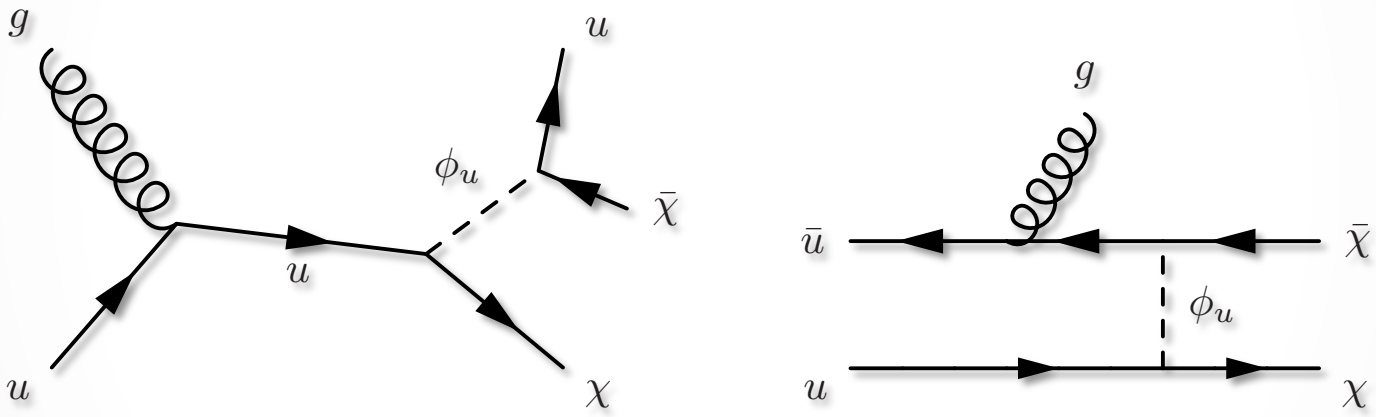
- Jacobian peak appears in most of coupling parameter space.
- Peaks at half of the mediator mass.



Fermion Portal DM Model

Simplified Model –

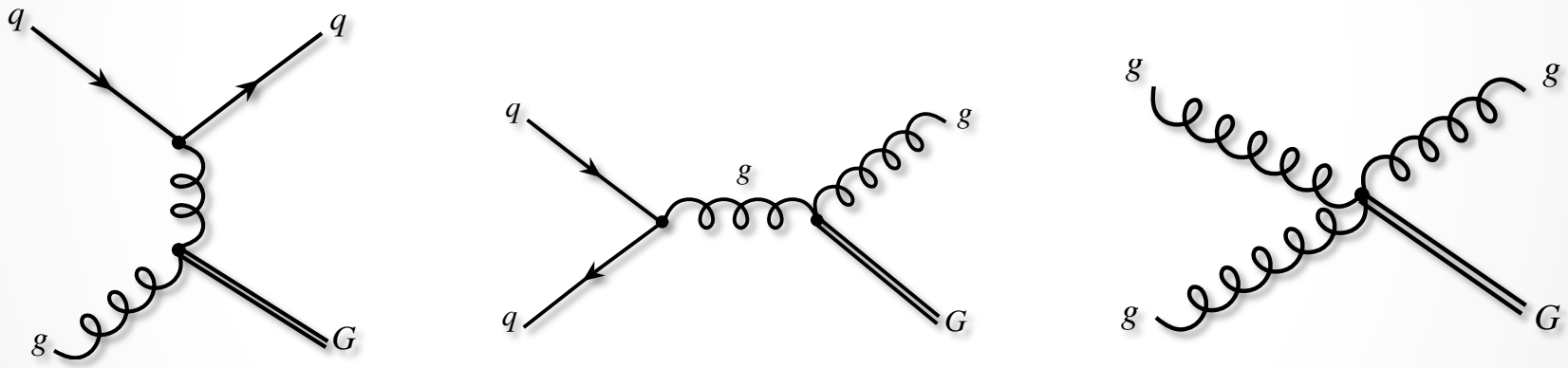
- DM particle couples with a scalar mediator (ϕ) and a SM fermion (up quark).
- Parameters **are mass of mediator (M_ϕ)** and **dark matter particle mass (M_χ)** .
- Coupling to up quark is set to 1.



- Production is similar to SUSY scenario of squark production in the limit of $\lambda_q << 1$.
- Monojet contribution is enhanced with $\boldsymbol{\lambda_q \rightarrow 1}$.
- The couplings are adjusted to be consistent with perturbation theory and to include all interesting production modes.

ADD Extra Dimension Model

- Attempts to solve the hierarchy problems by explaining the weakness of gravity relative to the other forces.
- Produces gravitons that interact weakly with the detector.
- Two free parameter: the **reduced plank scale (M_D)** and **number of extra dimensions (n_{ED}).**



- Graviton escapes detection and gives large missing transverse energy.
- Gluon balances momentum in transverse plane.

Backgrounds

Dominant Backgrounds:

- Z(νν)+Jets
- W(lν)+Jets

Together make up about 95% of total.

Subdominant Backgrounds:

- Z(ll)+Jets
- Top
- Diboson
- QCD

→ γ+ Jets (Serves as Control Region for background estimation)

Event Selection

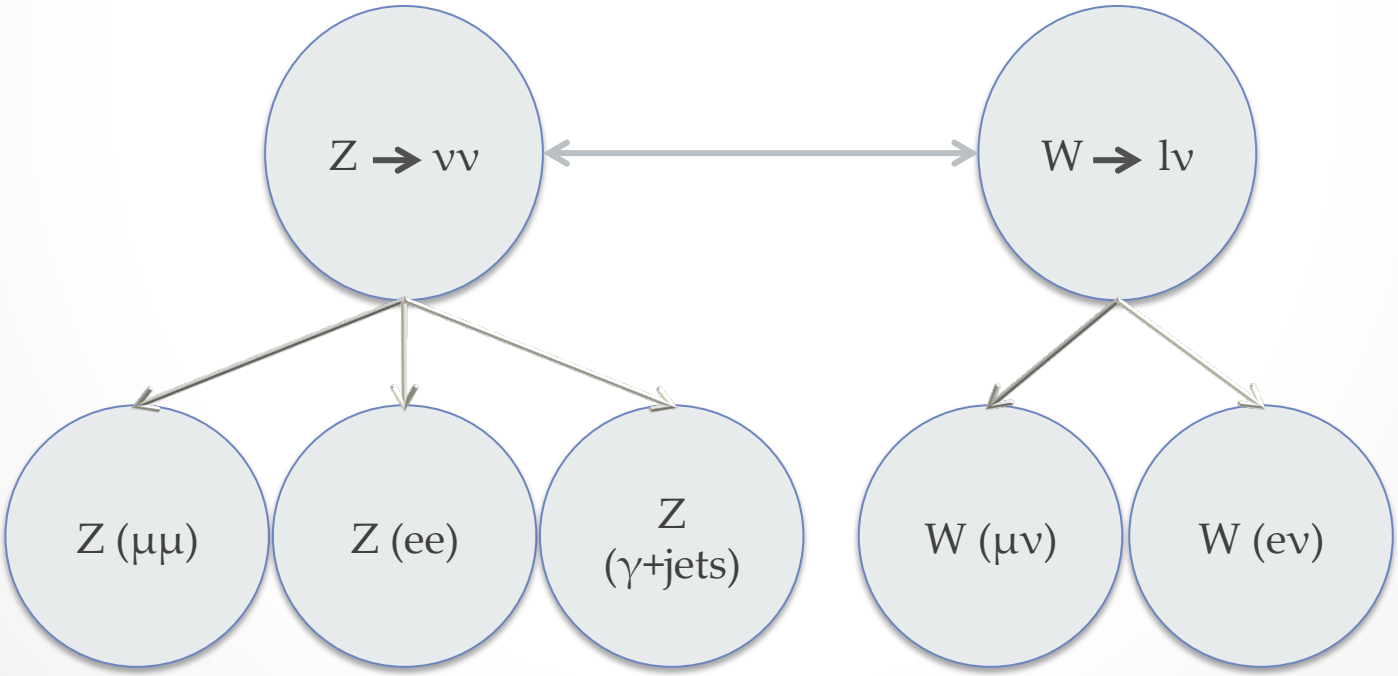
- The data is 35.9 fb^{-1} with $\sqrt{s}$=13 TeV

Baseline Selection:

- E_t^{miss} >250 GeV (consistent with trigger turn-on).
- Leading Jet (AK4) p_T > 100 GeV with $|\eta|$<2.5
- $\min\Delta\phi(E_t^{miss}, jets) > 0.5$
- $|E_t^{miss}{}_{calo} - E_t^{miss}{}_{PF}|/E_t^{miss}{}_{calo} < 0.5$

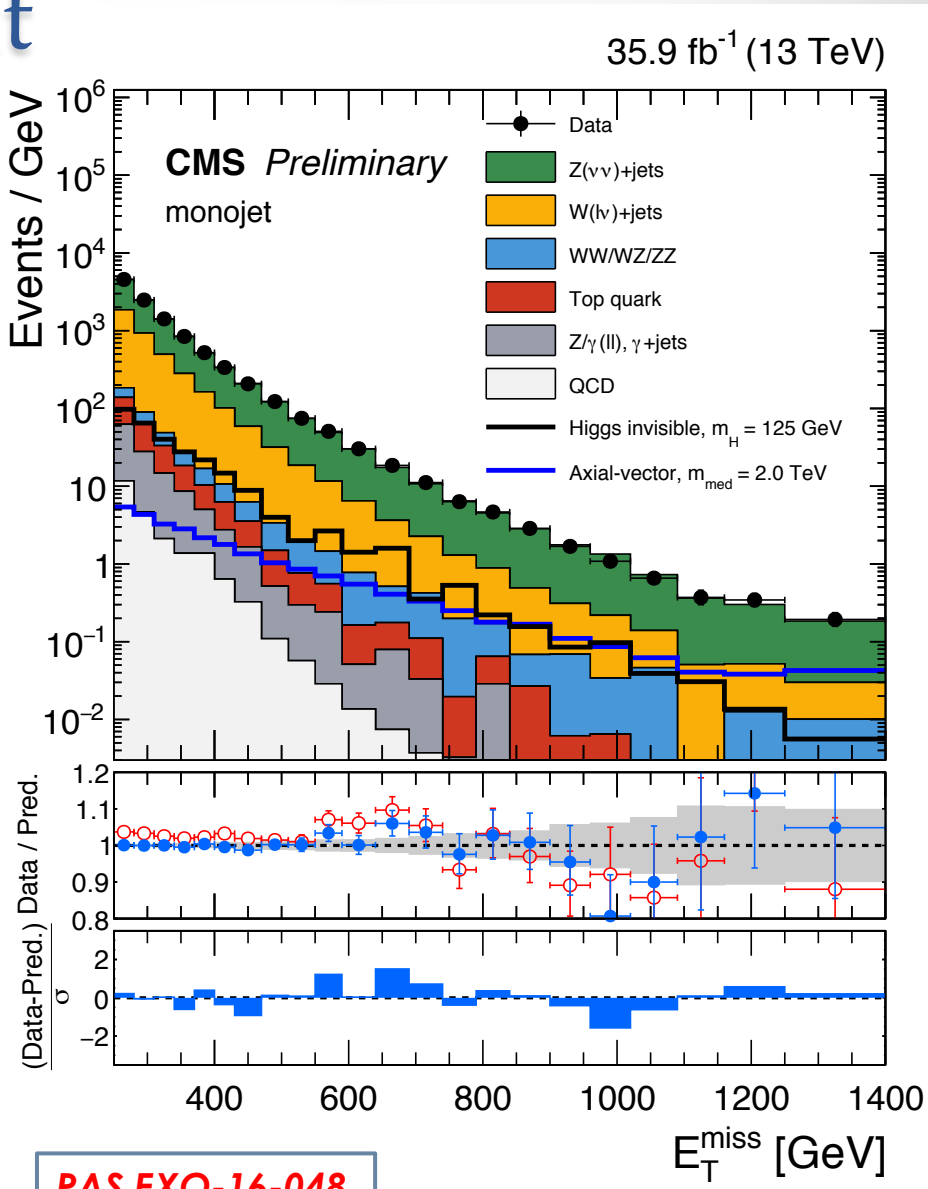
Background Estimation

- Leading Electroweak backgrounds are estimated using combined maximum likelihood fit of 5 Control Regions (CR).
- Transfer factors (TF) are used to translate yields from control regions to signal region.
- TF are derived through binned MC.



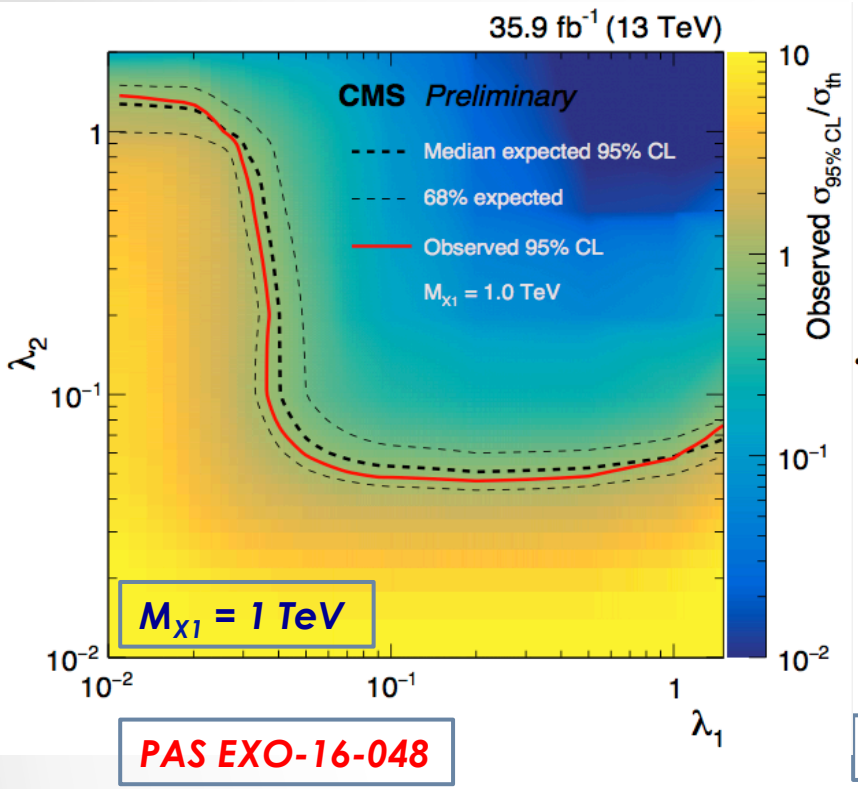
Signal Region Result

- Observed MET distribution in the signal regions compared with the post-fit background expectations for various SM processes.
- The last bin includes all events with MET > 1250 GeV



PAS EXO-16-048

Non-thermal DM Interpretation



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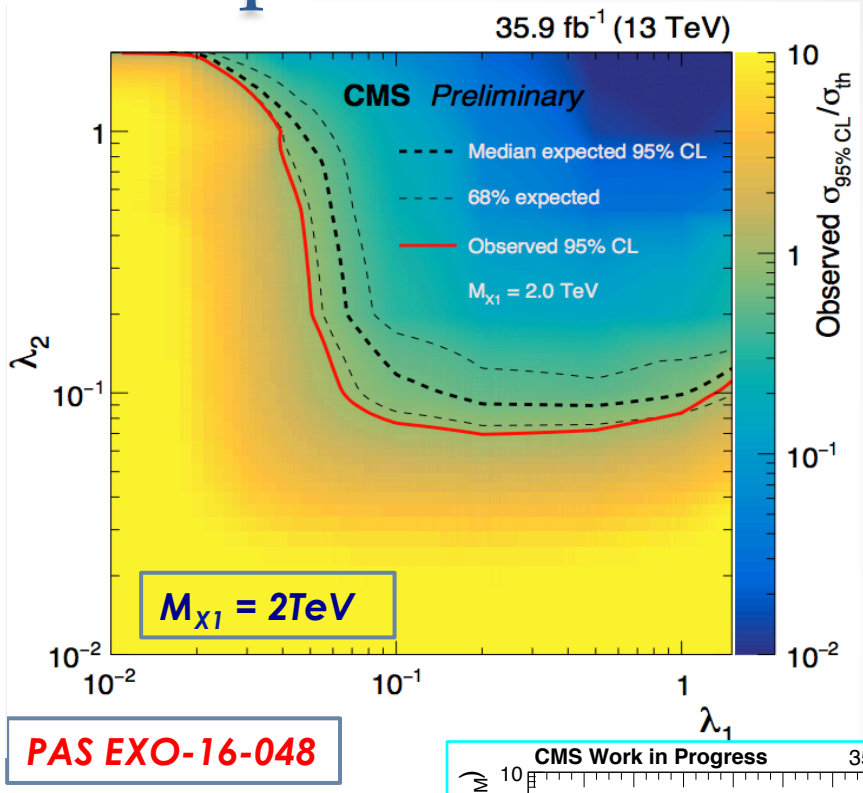
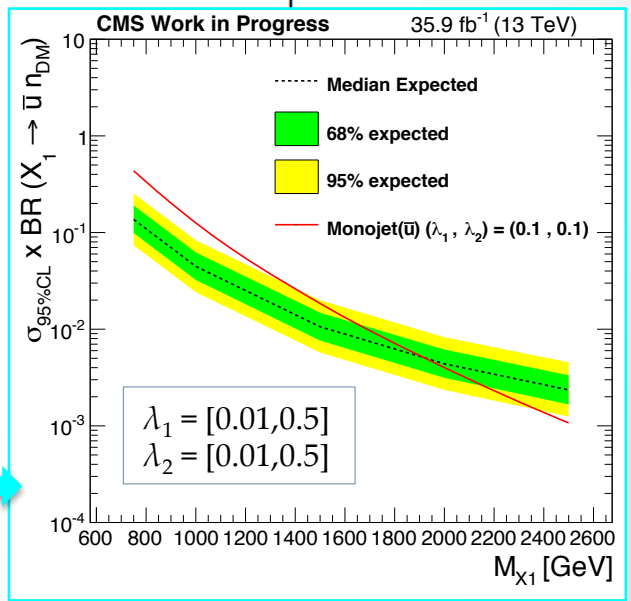


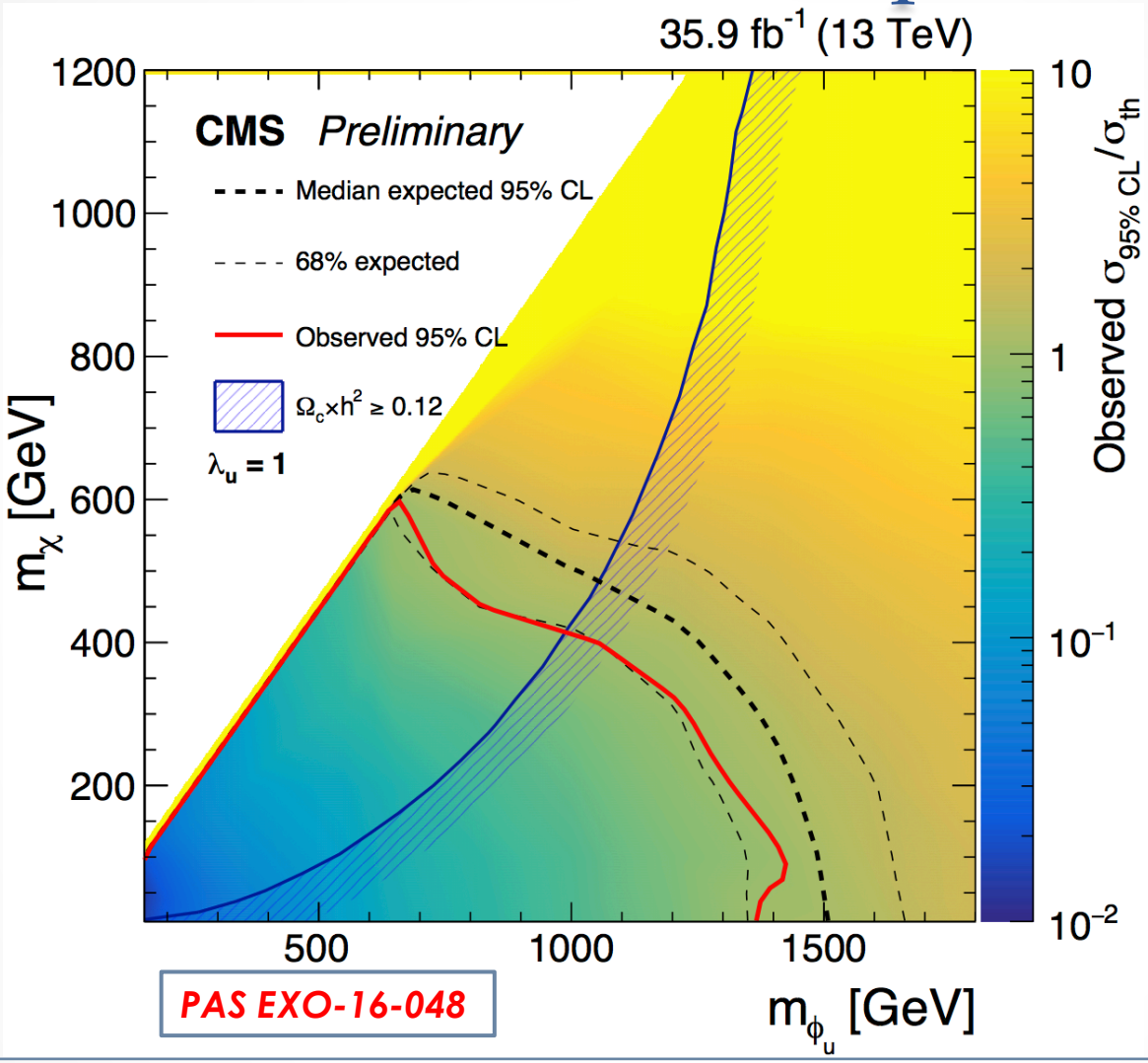
PAS EXO-16-048

95% CL expected (black dashed line) and observed (red solid line) upper limits on $\mu = \sigma/\sigma_{th}$ for a nonthermal DM particle for mediator masses M_{X1}= {1,2} TeV, in the $\lambda_1 - \lambda_2$ plane.

Expected upper limits on production cross-section for resonance process where the decay products are a light quark jet and light weakly interacting particle.

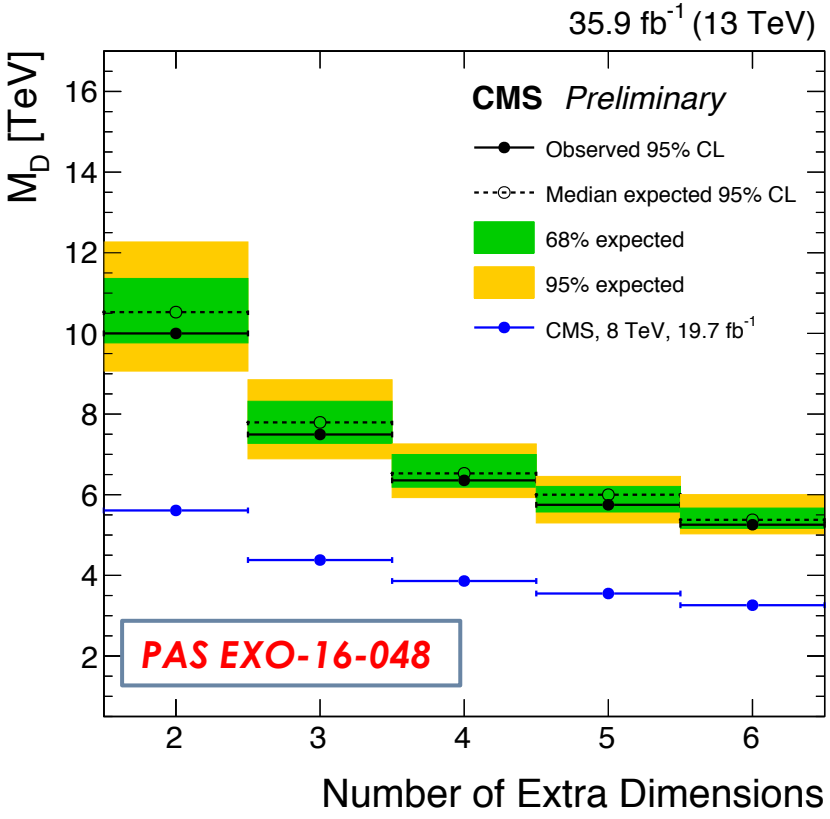


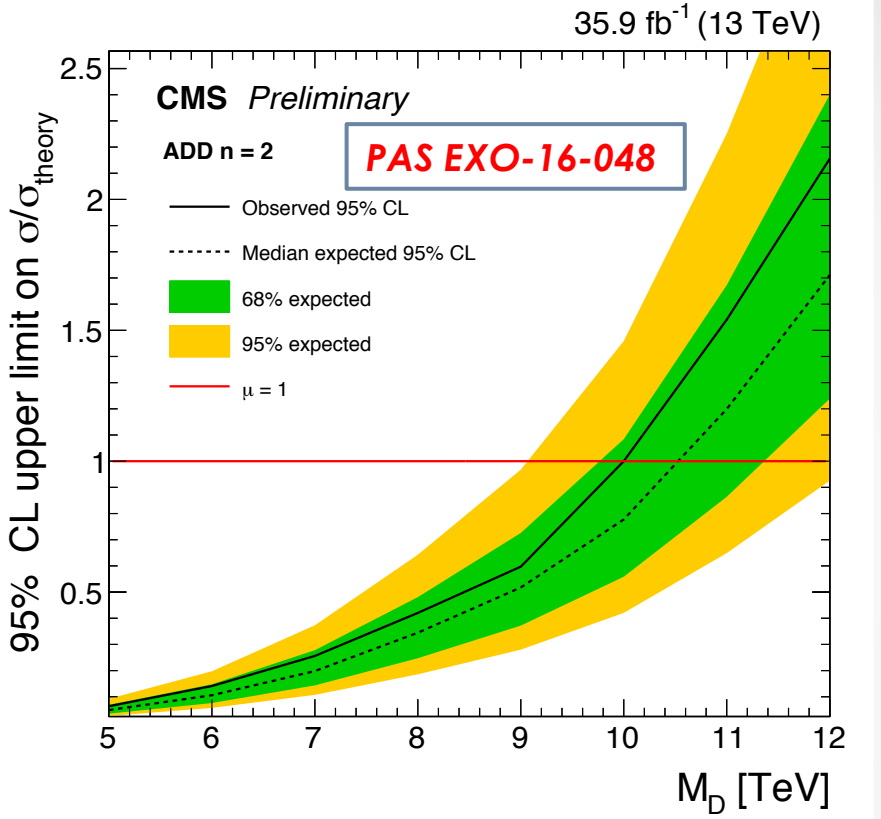
Fermion Portal DM Interpretation



95% CL expected (black dashed line) and observed (red solid line) upper limits on $\mu = \sigma/\sigma_{th}$ for Fermion Portal DM with the only coupling to the up quark with $\lambda_u = 1$ in the $M_\chi - M_\phi$ plane.

ADD ED Interpretation





95% CL lower limits on the M_D in the ADD model as a function of extra spatial dimensions 'n_{ED}' was obtained.

The exclusion is found to be varying between 10 TeV for n = 2 to 5 TeV for n = 6.

The observed and expected upper limit on the graviton production cross section. Shaded areas show the ±1σ (green) and ±2 σ (yellow) bands on the expected limits.

Summary

- We have presented the monojet analysis with Non-thermal DM, ADD and Fermion Portal DM interpretations, using full 2016 data.
- We do not see any significant deviation from the standard model expectation.
- We set upper limit for described models.
- We hope to see the signal with 2017 data.