Searching for Dark Matter with the ATLAS Detector

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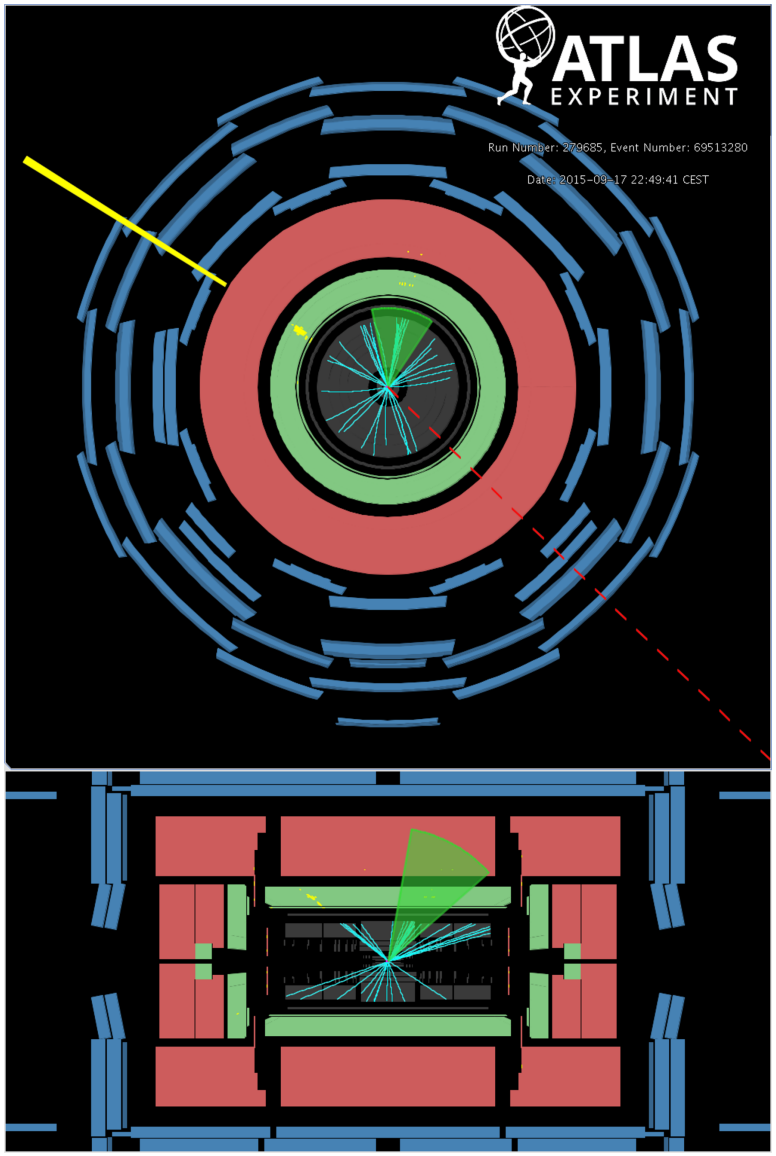
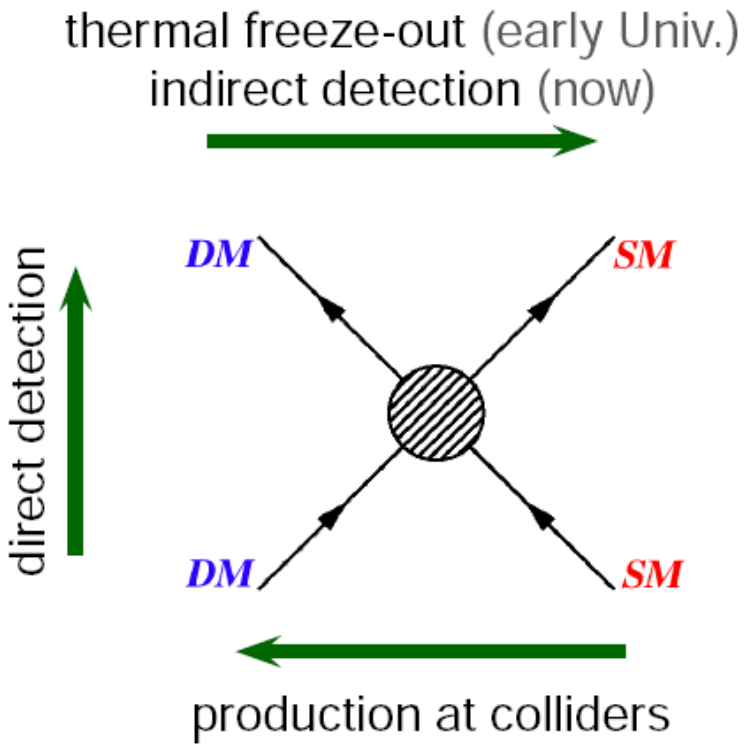
Introduction

- Signatures of dark matter at ATLAS
- The LHC Dark Matter Forum
- Mono-jet
- Mono-photon
- Di-jet
- Mono-V
- Mono-Higgs
- Conclusion



What Does Dark Matter Look Like at ATLAS?



- Dark matter physics at colliders looks at production of DM particles from interacting SM particles
- Models tested at ATLAS have DM as a weakly interacting massive particle (WIMP)
- Cannot directly detect DM particles, instead infer production through large amounts of missing transverse momentum

The detector signature for DM production is a well-defined SM particle strongly recoiling off a large amount of MET

The LHC Dark Matter Forum

- Summer 2015 saw a great collaboration between LHC physicists from both ATLAS and CMS as well as theorists to set a benchmark for dark matter models to be studied in Run-2

- Result of collaboration is the LHC Dark Matter Forum (DMF) report

- ATLAS has already released many public results on models proposed in this document with 2015 data, continuing with new 2016 data to include more models & phase space!

- The LHC Dark Matter Working Group is now active to continue defining benchmarks and help searches for Dark Matter at the LHC

Dark Matter Benchmark Models for Early LHC Run-2 Searches: Report of the ATLAS/CMS Dark Matter Forum

Daniel Abercrombie (MIT) , Nural Akchurin (Texas Tech.) , Ece Akilli (Geneva U.) , Juan Alcaraz Maestre (Madrid, CIEMAT) , Brandon Allen (MIT) , Barbara Alvarez Gonzalez (CERN) , Jeremy Andrea (Strasbourg, IPHC) , Alexandre Arbey (CERN) , Georges Azuelos (TRIUMF) , Patrizia Azzi (INFN, Padua) *et al.* Show all 139 authors

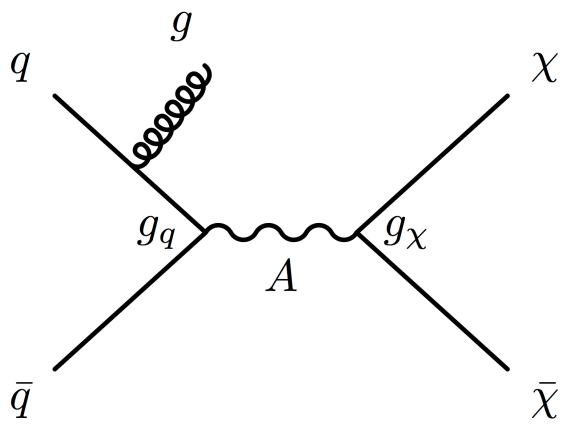
Jul 3, 2015 - 160 pages

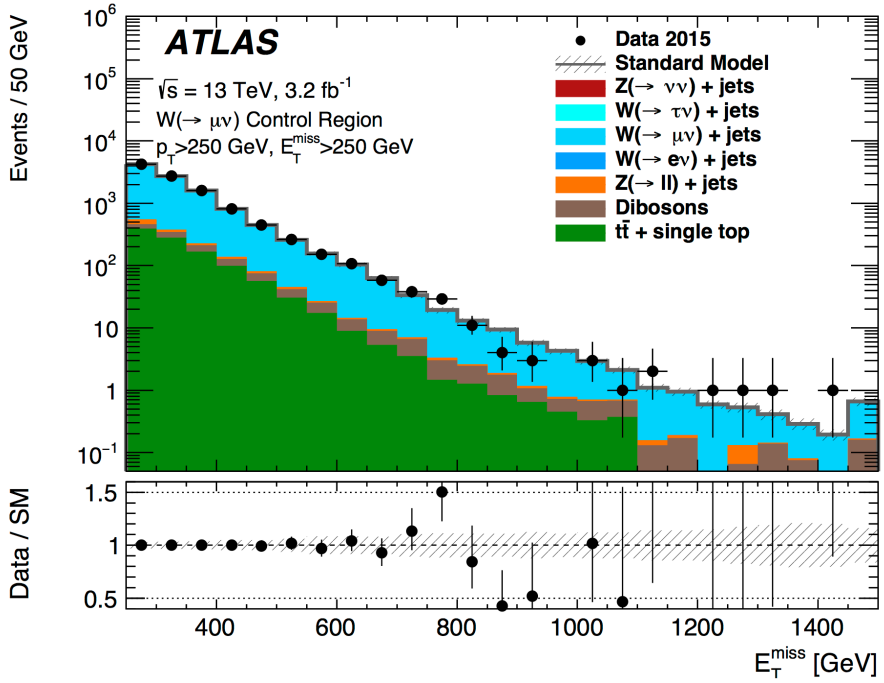
arXiv:1507.00966

arxiv:1604.07773

Mono-Jet

- Most powerful search channel at a hadron collider
- Signature is ISR gluon-jet recoiling off MET
- Production model assumes axial-vector mediator A which couples to quarks with strength g_q and to DM with strength g_χ

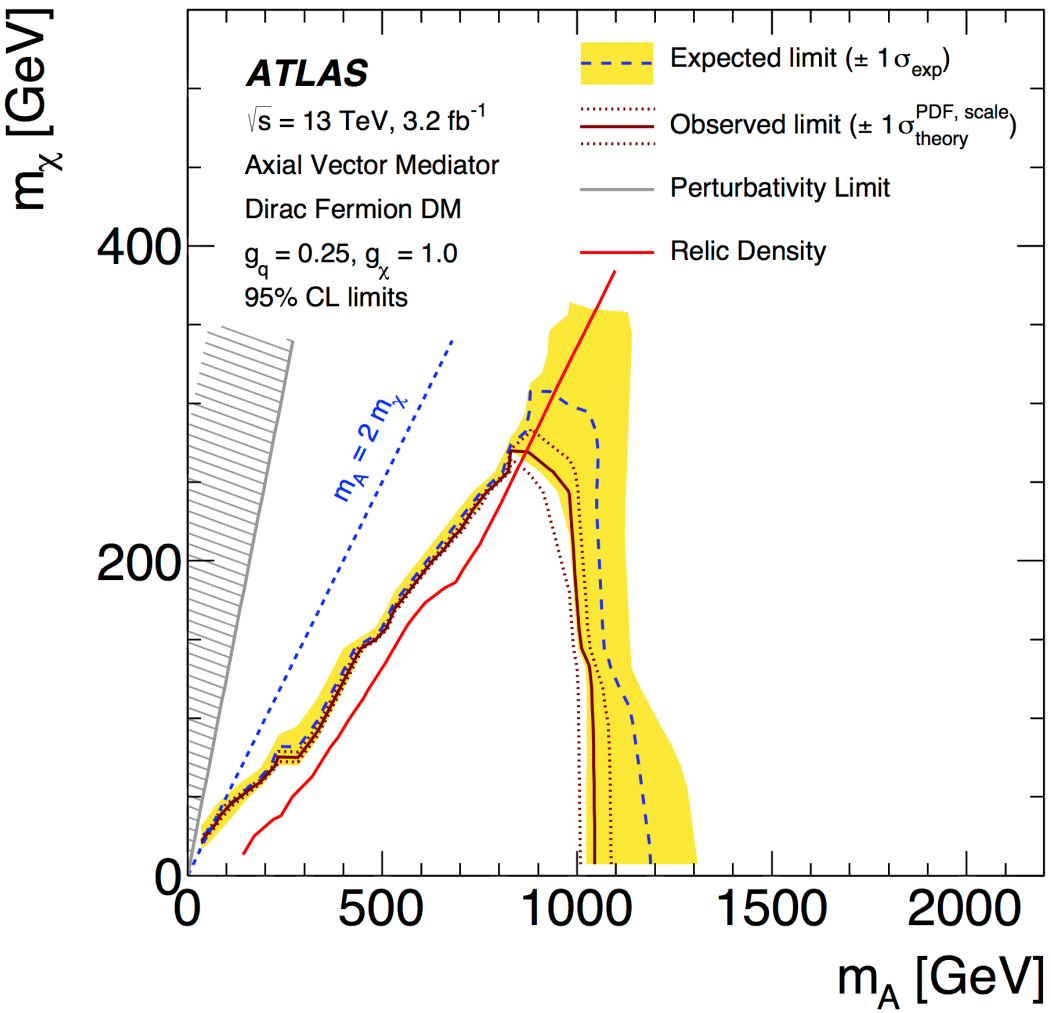




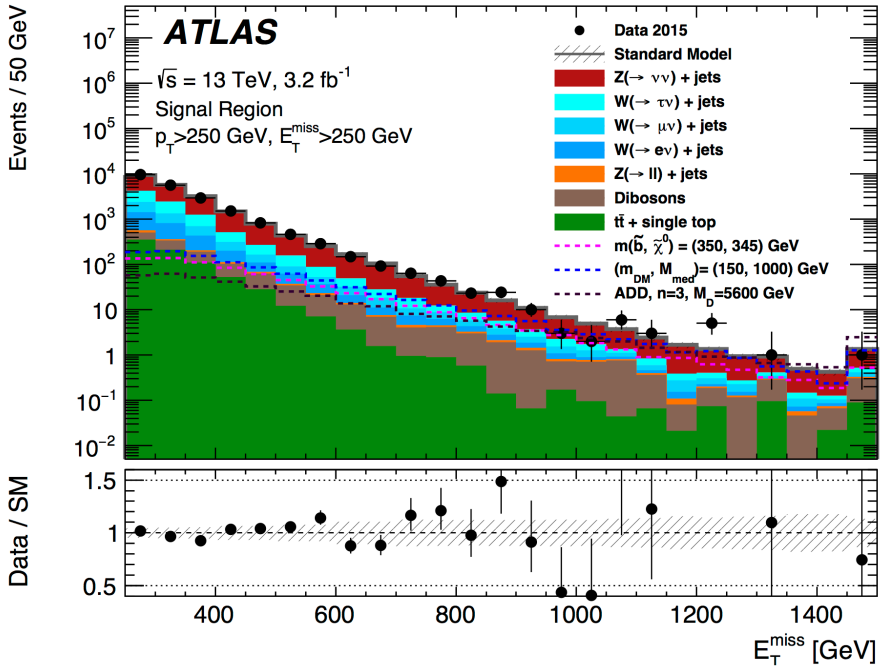
- Largest background from V+jets, in particular irreducible Z(→νν)+jets, estimated in dedicated control regions
- Other background sources from top, di-boson, and multi-jet
- Fit performed in multiple exclusive MET regions

arxiv:1604.07773

Mono-Jet



- No significance excess observed in MET spectrum with 2015 data
- Limits set in 2D DM mass and mediator mass plane



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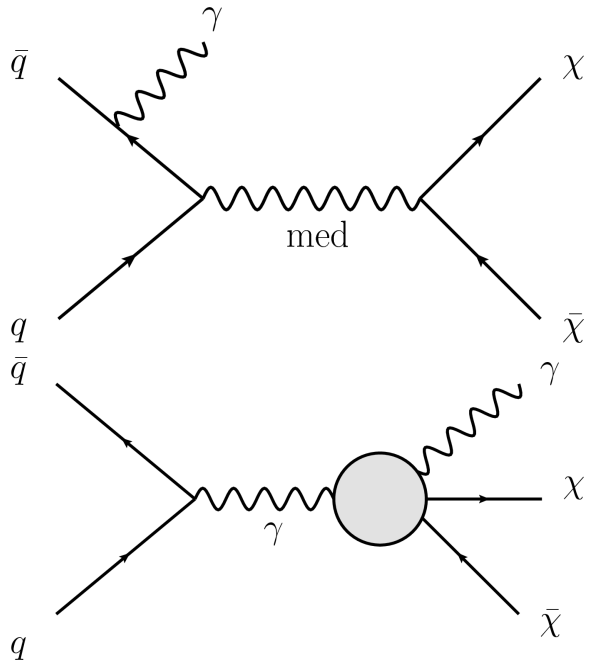
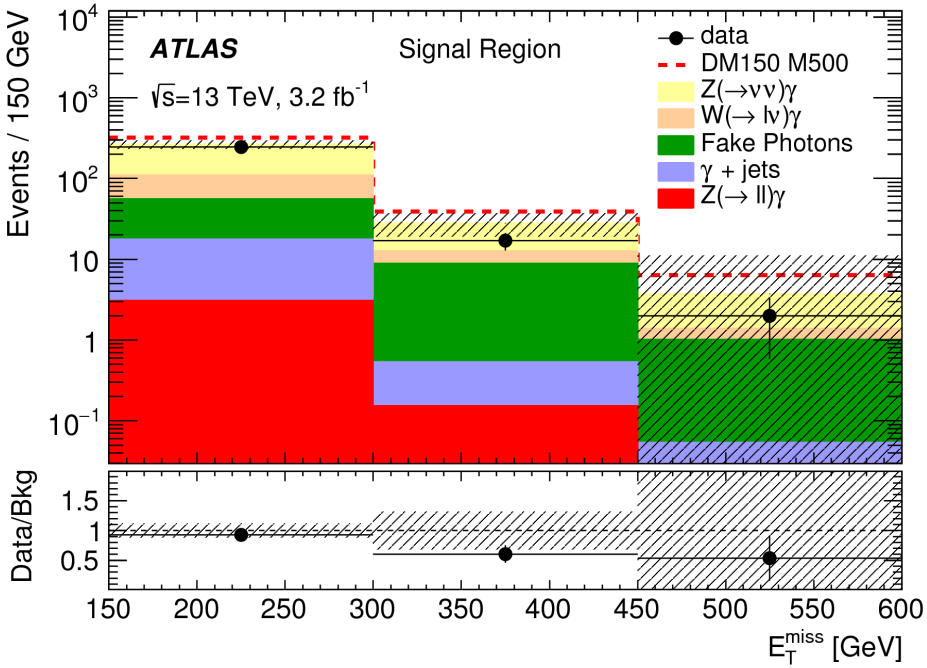
Mono-Photon



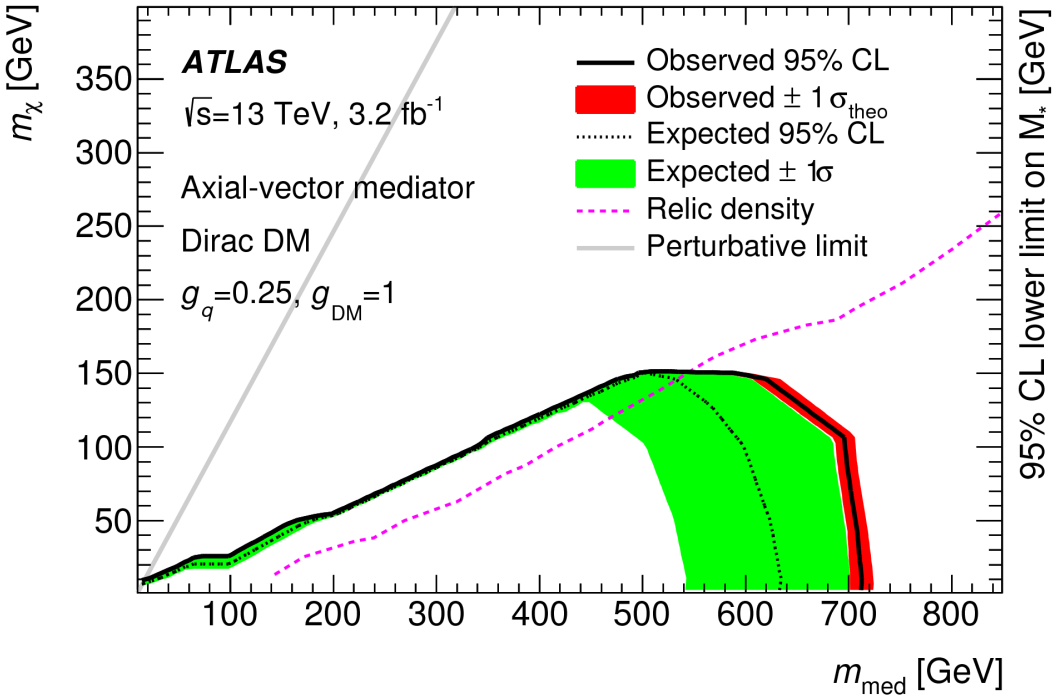


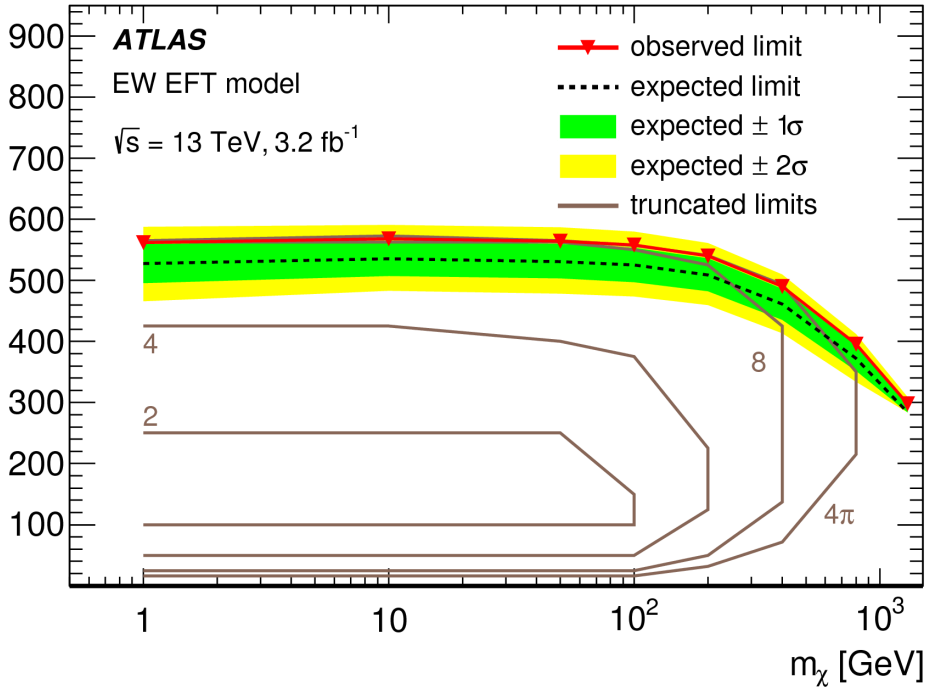
- Next most powerful final state is mono-photon, looking for either ISR photon from a simplified model or photon-DM EFT interaction
- Signal events have high-p_T, isolated photon with minimal extra jet activity and no charged leptons
- Dominant background from Z(→νν)γ and Wγ, estimated in various lepton control regions; additional backgrounds from misidentified (fake) photons and γ+jets

arxiv:1604.01306

Mono-Photon

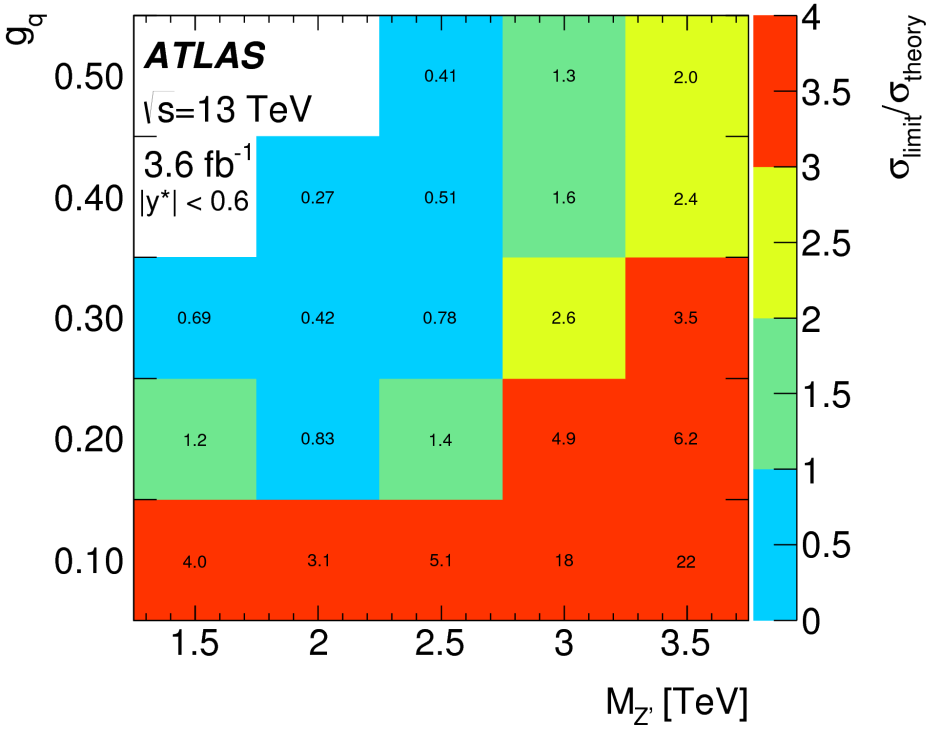
- No significant excess observed with 2015 data
- Limits set on simplified model mediator and DM mass, and EFT coupling scale
- Truncation is used to address EFT model validation





arxiv:1512.01530
ATLAS-CONF-2016-030

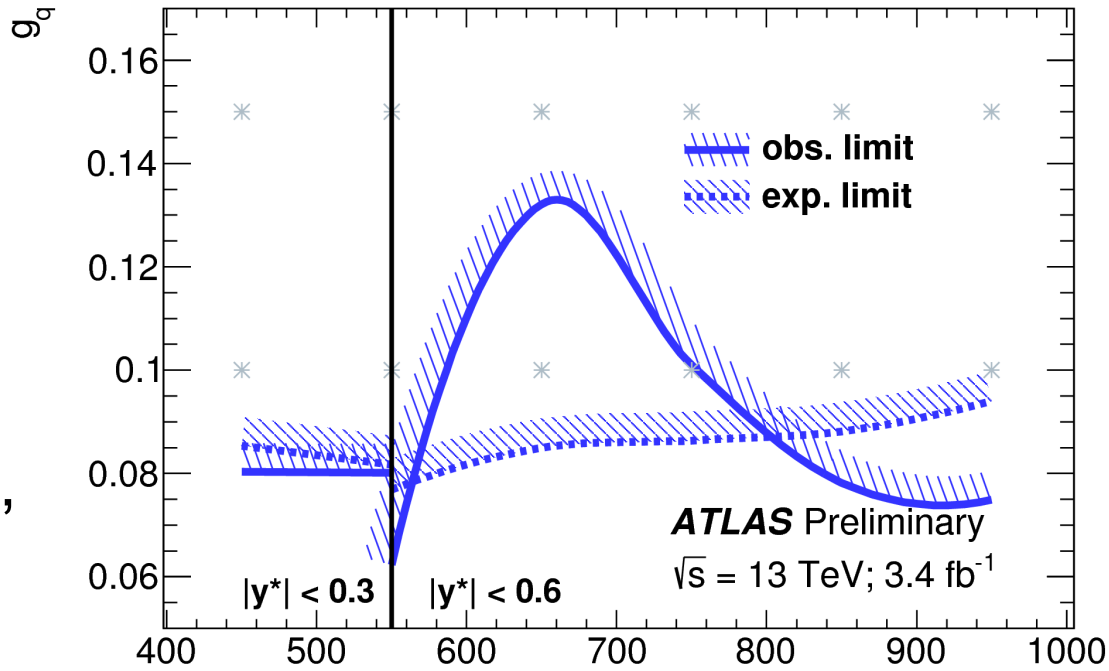
Di-Jet



Fully reconstructed analysis

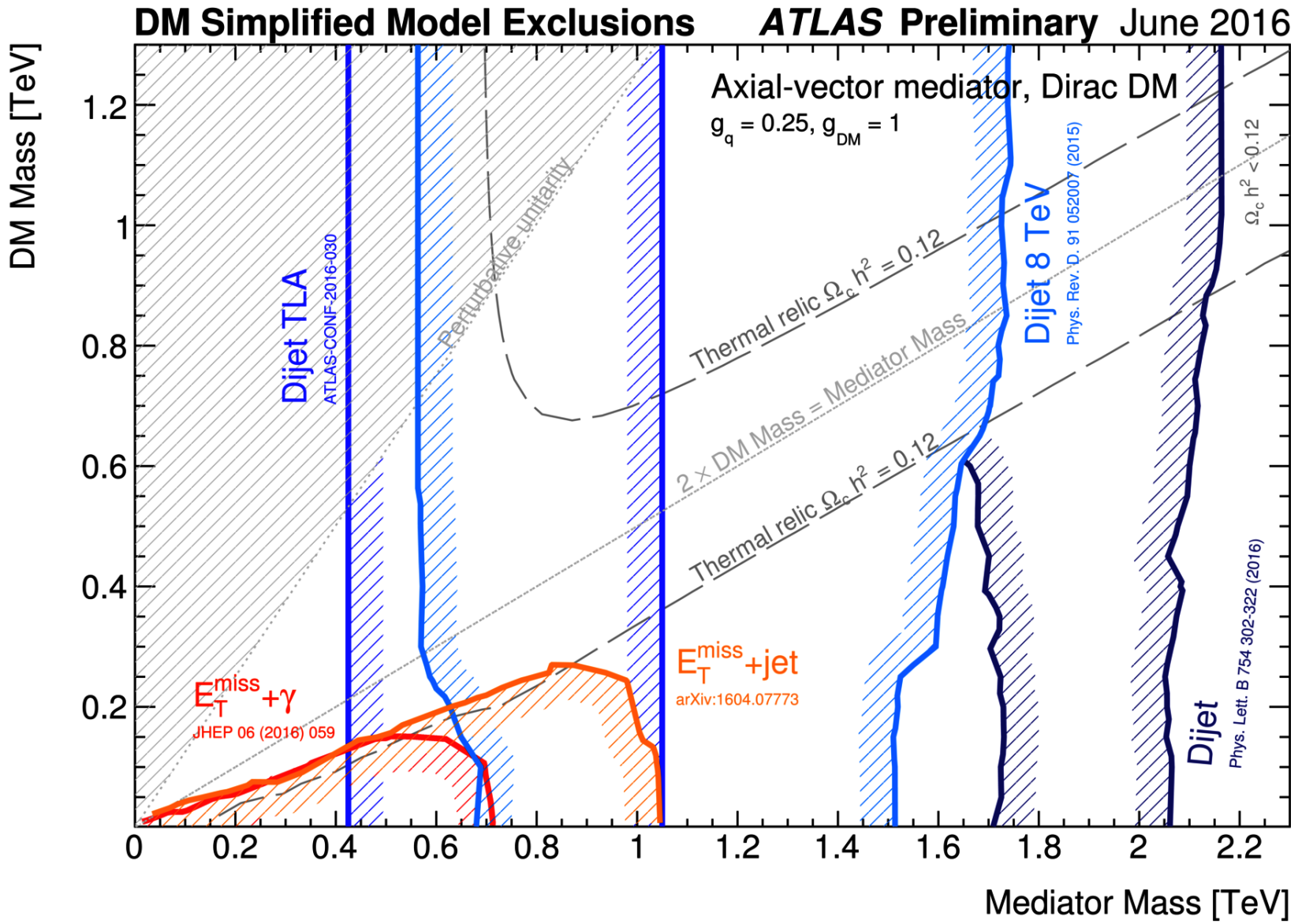
- Search for pair of close-by jets, bump hunt over falling QCD background

- Various di-jet analyses have also released results in the same simplified model interpretation as mono-jet and mono-photon



Trigger level analysis

Summary of Previous Results



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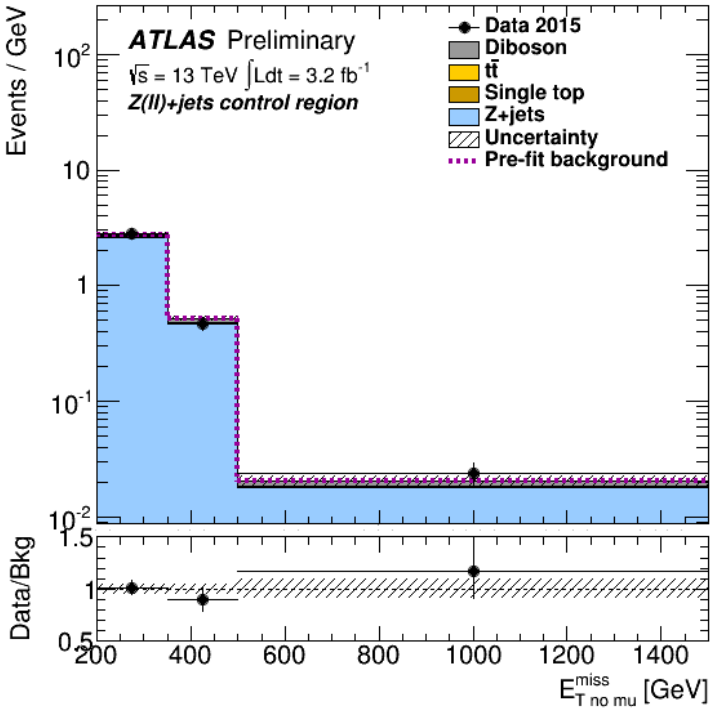
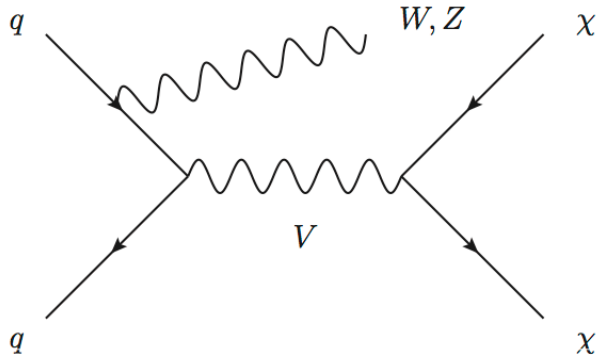
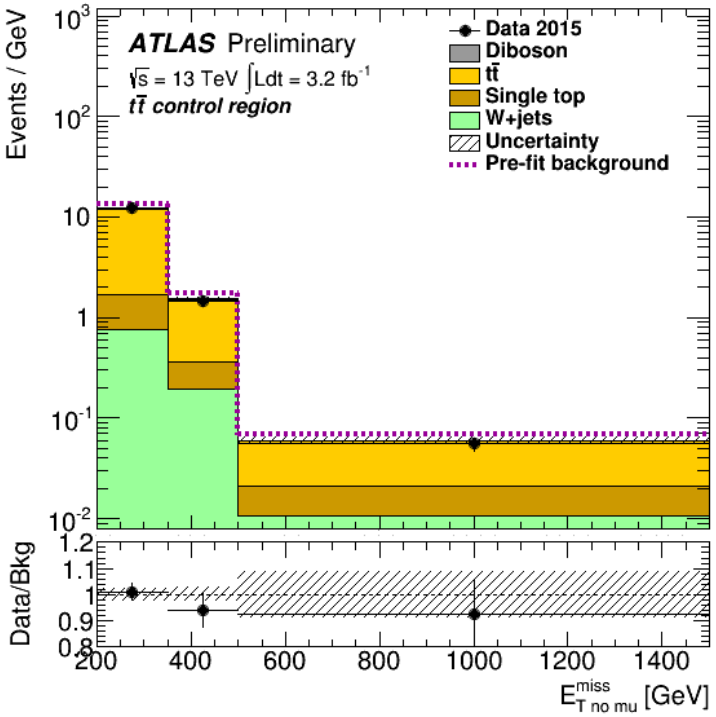
Mono-Vector Boson: Hadronic Mono-V





- While production cross section is much lower, mono-V (V=W/Z) much cleaner signal and benefits from extra information from hadronic V decay

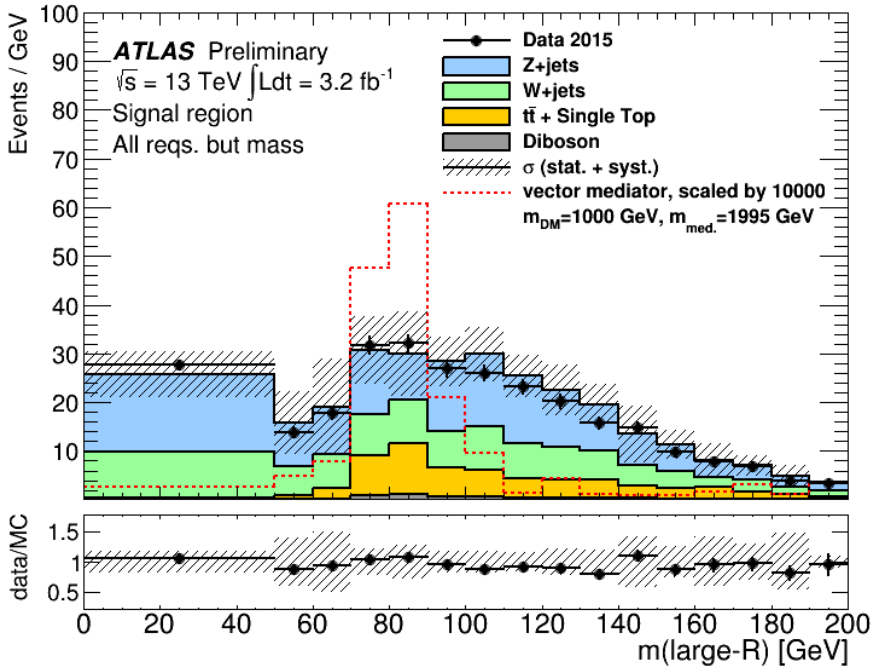


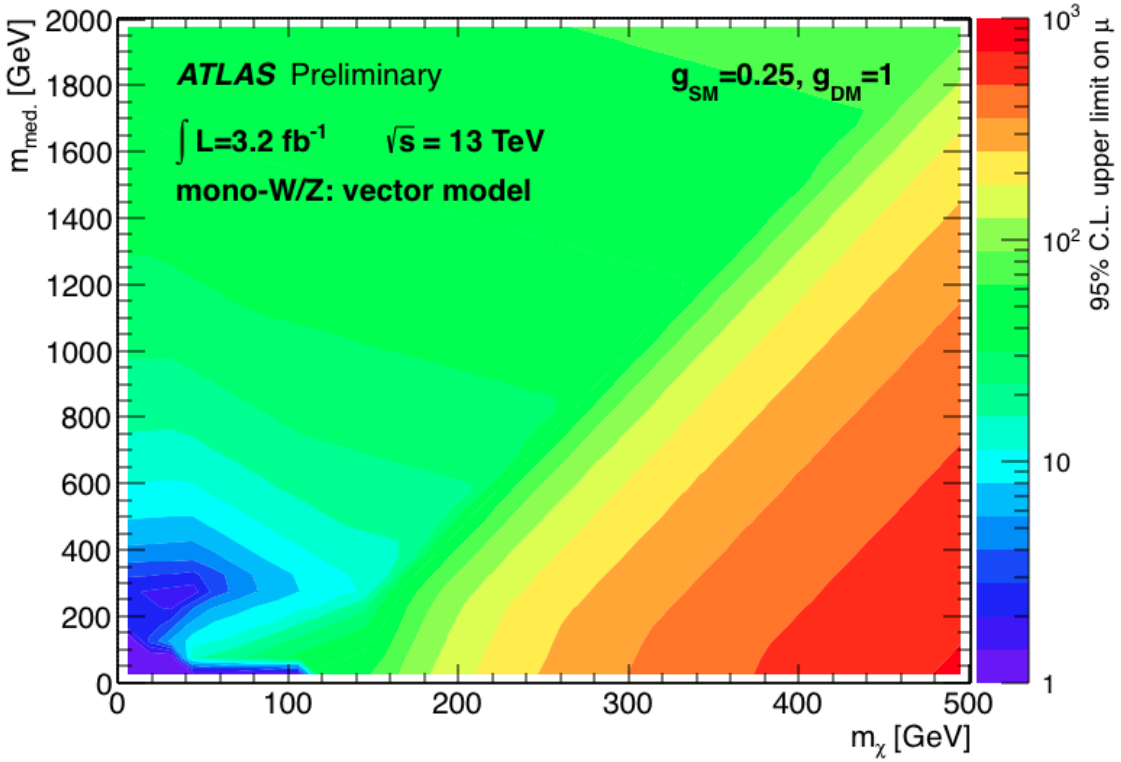
- Boosted boson tagging technology used to identify high-p_T large-R jets
- Major background from V+jets and top, measured in lepton control regions, estimated in shape fit

ATLAS-CONF-2015-080

Mono-Vector Boson: Hadronic Mono-V

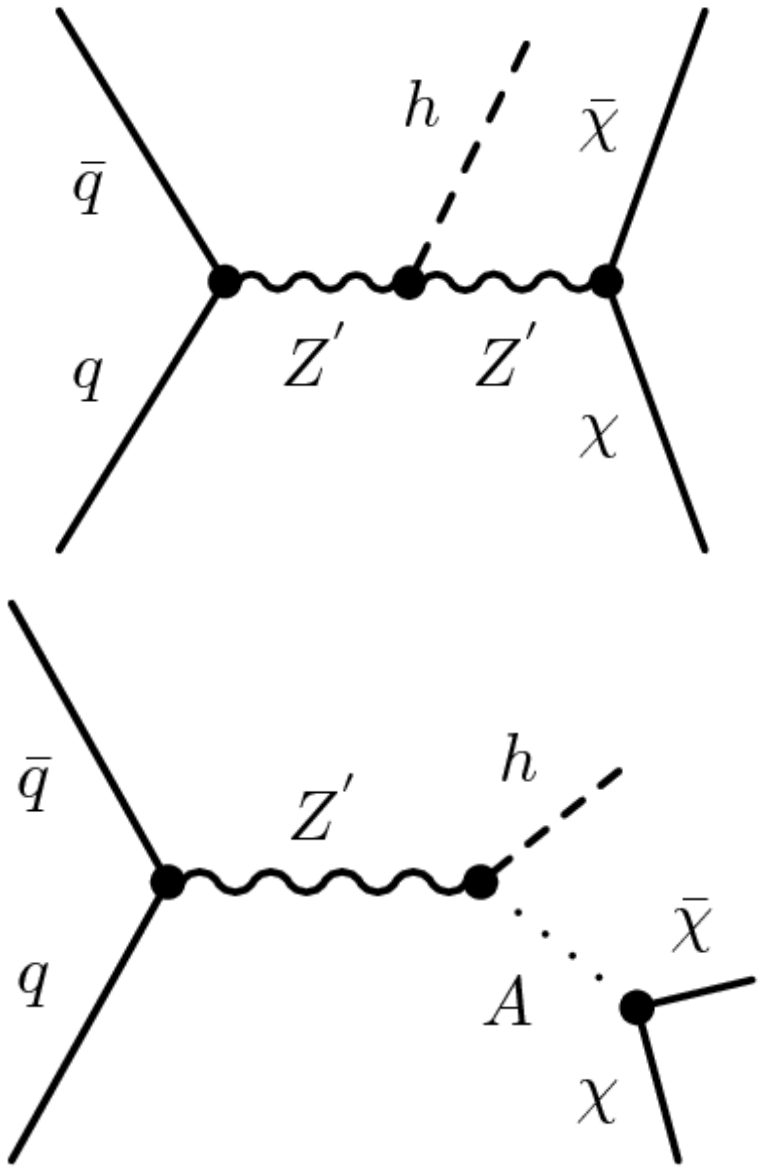
- No significant excess observed with 2015 data
- Limits set in 2D mediator and DM mass plane





Mono-Higgs

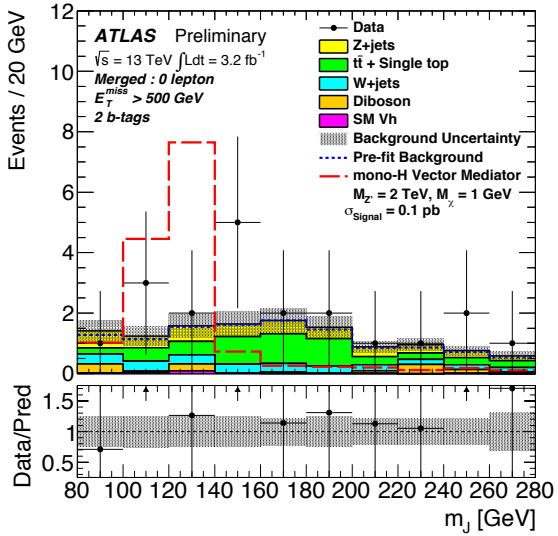
- Higgs boson discovery provides unique method for probing dark matter at LHC
- Due to very low ISR Higgs rates, mono-Higgs searches probe Higgs-DM coupling directly
- Higgs can also serve as mediator for DM particles to be generated

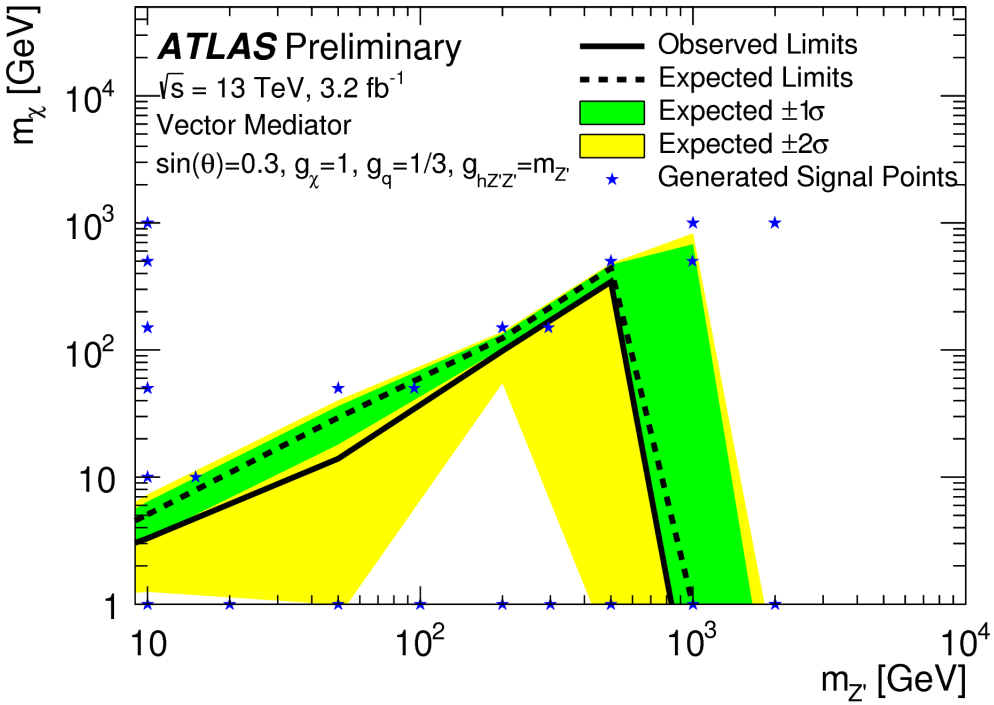


ATLAS-CONF-2016-019

Mono-Higgs: H→bb

- H(125)→bb branching ratio is ~60%
- Analysis combines resolved jet region and boosted Higgs-jet region for wide MET range search
- Resolved events characterized by two b-tagged jets with Higgs-like kinematics and minimal extra jet activity
- Boosted events characterized by one large-R jet with two b-tagged sub-jets made of matched tracks
- Dominant background comes from top
- Limits set for three simplified models

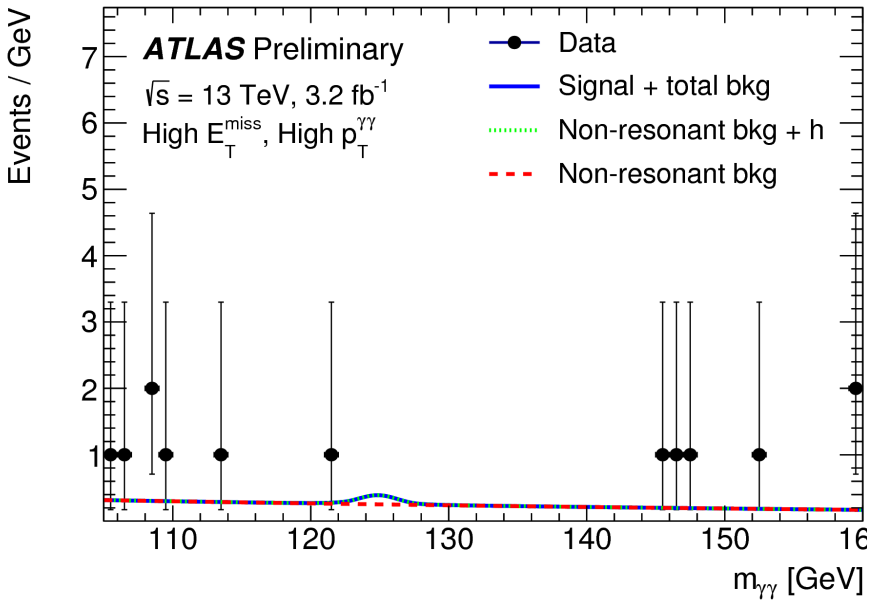


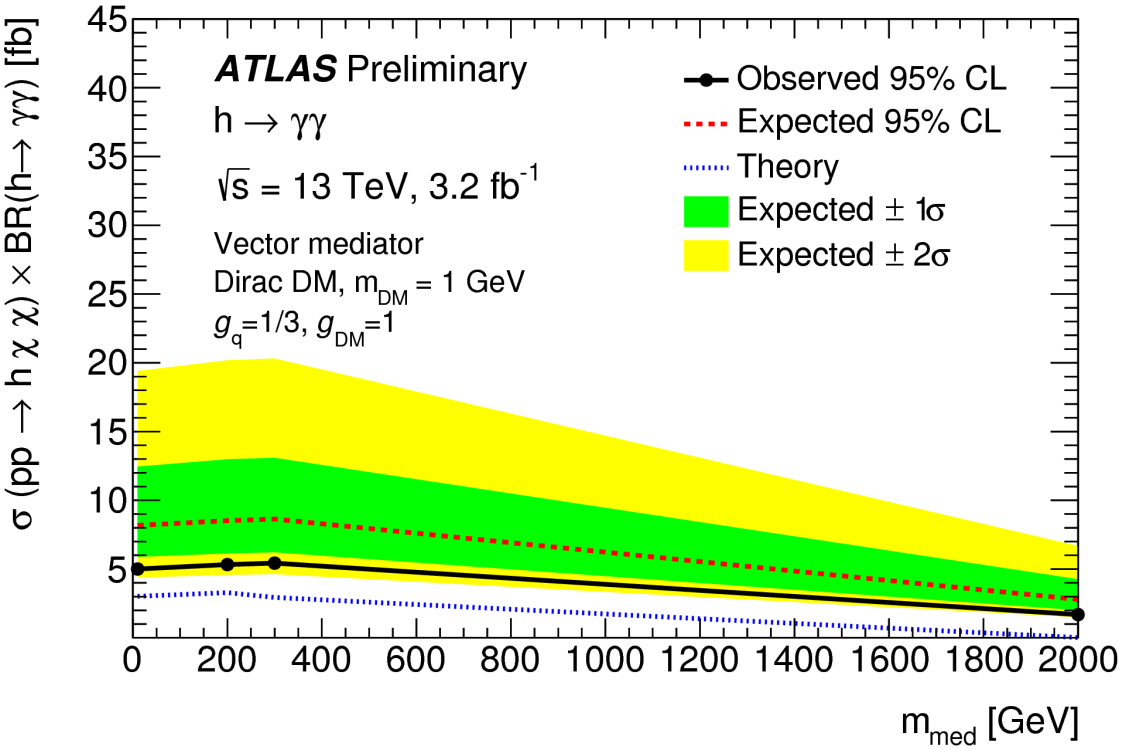


ATLAS-CONF-2016-011

Mono-Higgs: H→γγ

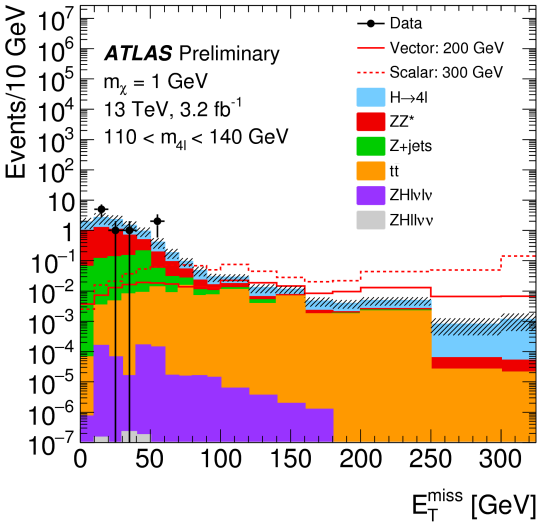
- Similar to SM H→γγ analysis, search for excess in falling di-photon mass spectrum in high MET category
- Largest backgrounds from non-resonant di-photon production and fake photons
- No significant excess seen with 2015 data

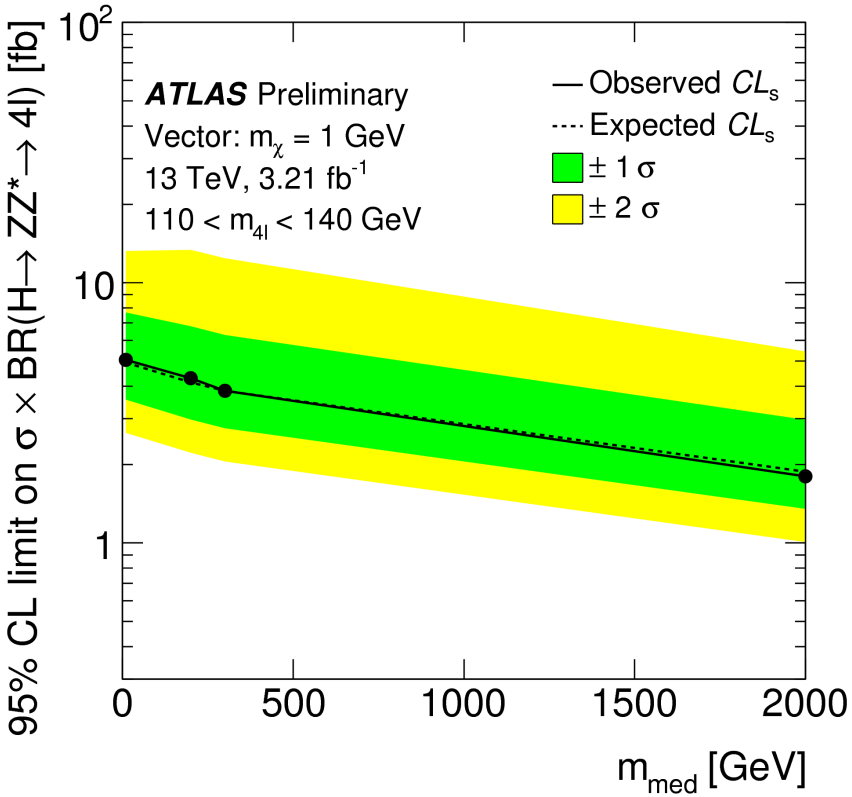




ATLAS-CONF-2015-059

Mono-Higgs: H→4l





- Extremely clean four lepton channel but very low branching ratio
- Very similar to SM Higgs analysis, use MET spectrum to search for excess
- Dominant background from di-boson ZZ in low MET region, top in high MET region
- Limits set on simplified models

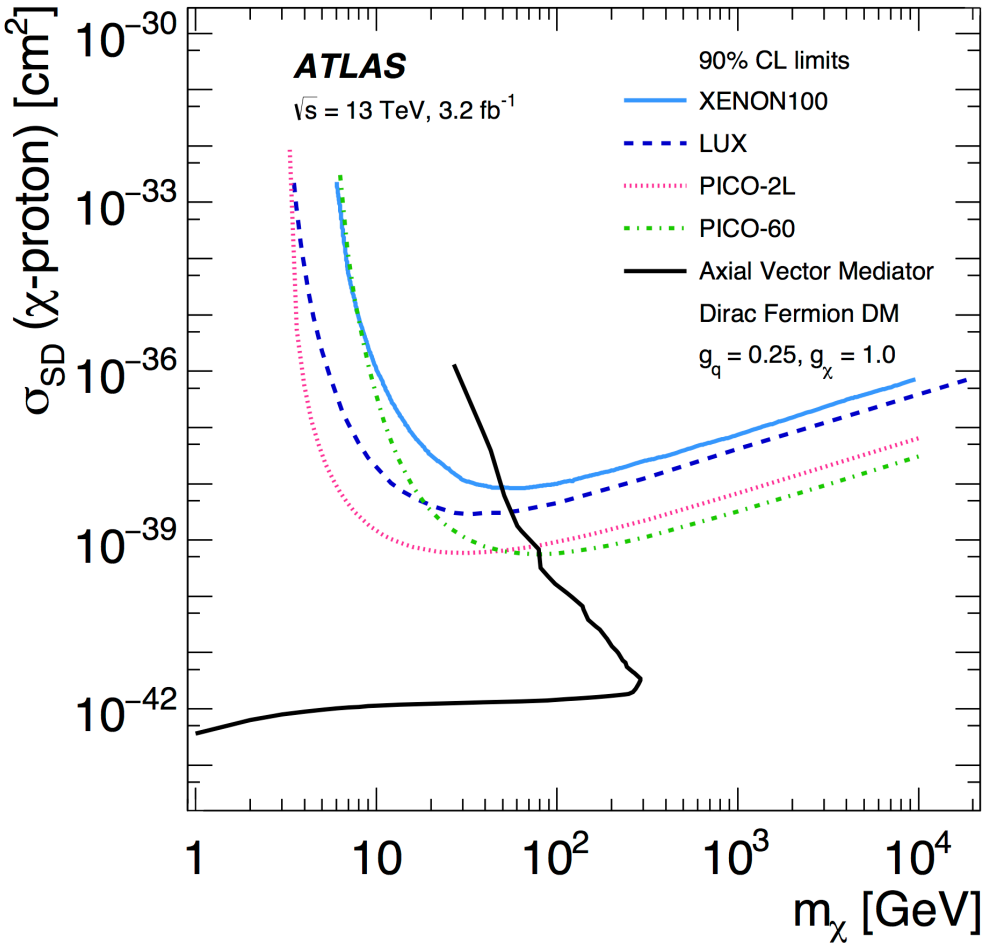
Conclusion

- Many new results from ATLAS in a variety of dark matter searches with 2015 data
- Mono-jet and mono-photon remain the most powerful channels, though other searches can look at interesting models and regions of phase space
- No significant excess observed in any analysis, limits placed and greatly improve upon direct detection searches for low DM masses
- Stay tuned for more updates with 2016 data and beyond

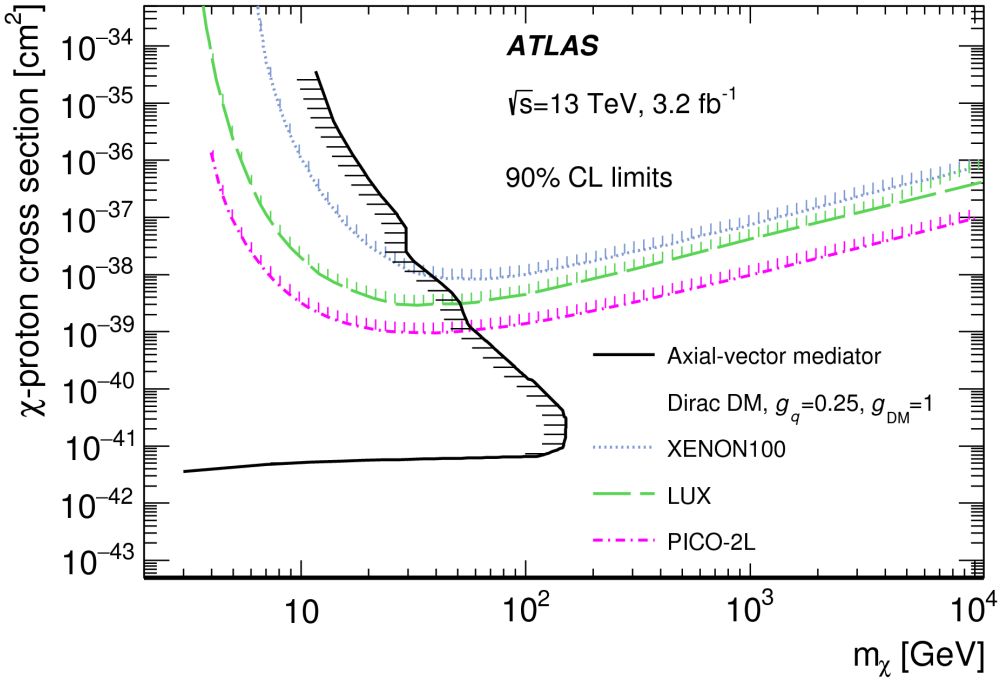
Thanks!

Back-up

ATLAS vs Direct Detection



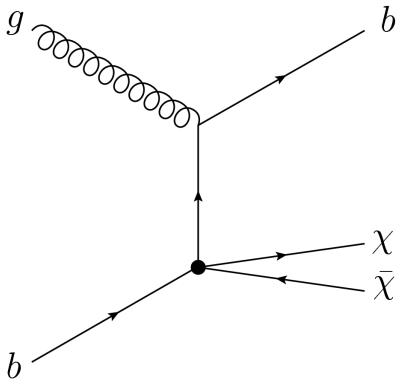
Mono-jet



Mono-photon

Mono-Heavy Flavor (Run-1)

arxiv:1410.4031



- Various EFT models with different final state b-jet multiplicities
- Limits also set on b-FDM model
- No Run-2 update yet