Review of LHC Dark Matter Searches

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Content

- Introduction
- DM Searches at ATLAS
- Searching Heavy Neutral Leptons
- Summary

Introduction

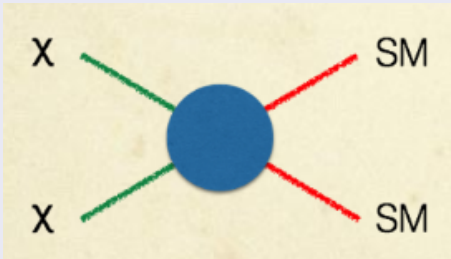
Dark Matter

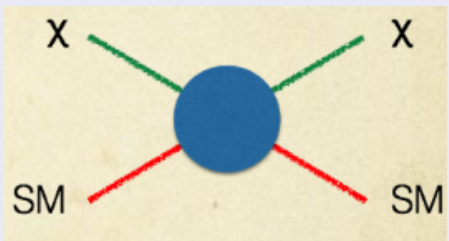
1. Unsolved problem
2. No SM particle can explain it
3. DM evidence coming from diverse sources

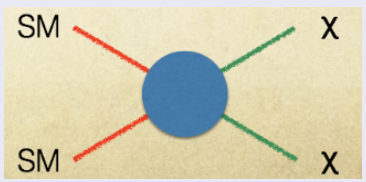
How to detect it?

Assuming weakly interaction with SM

1. Indirect detection
2. Direct Detection
3. Colliders production

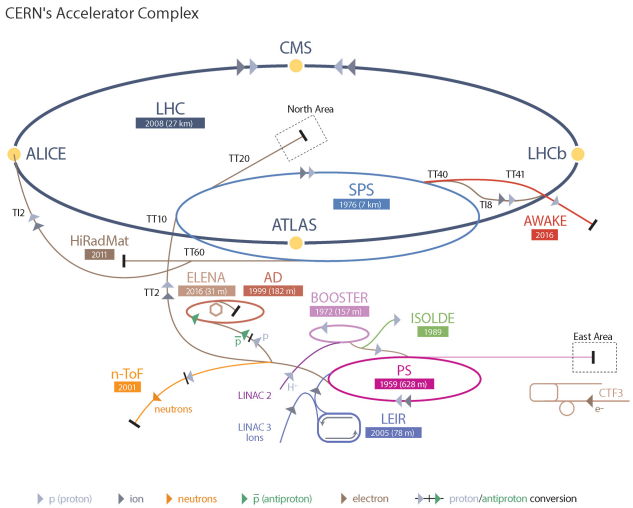


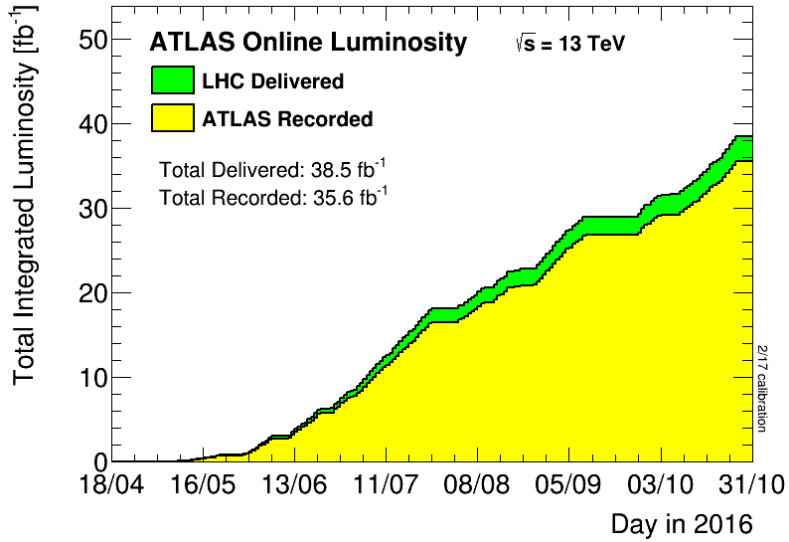


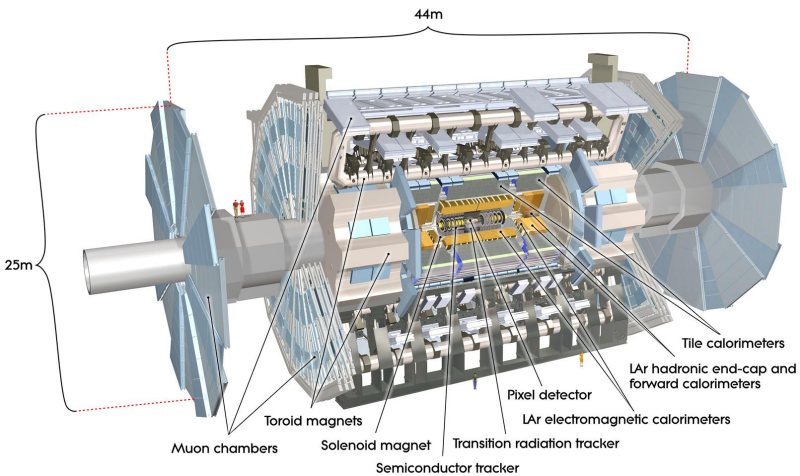


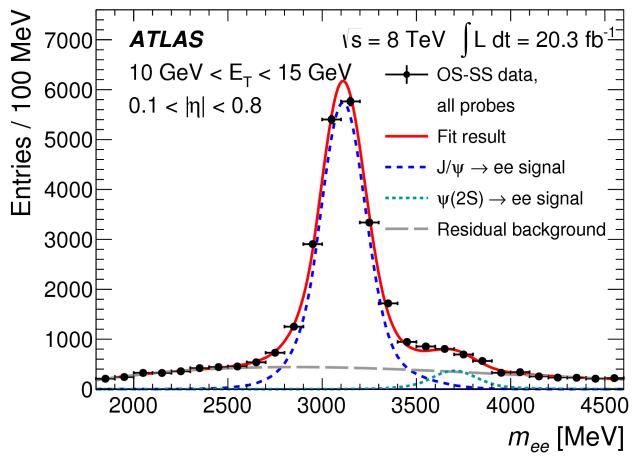
https://cds.cern.ch/record/2262480/files/ATL-COM-PHYS-2017-546.pdf

The LHC







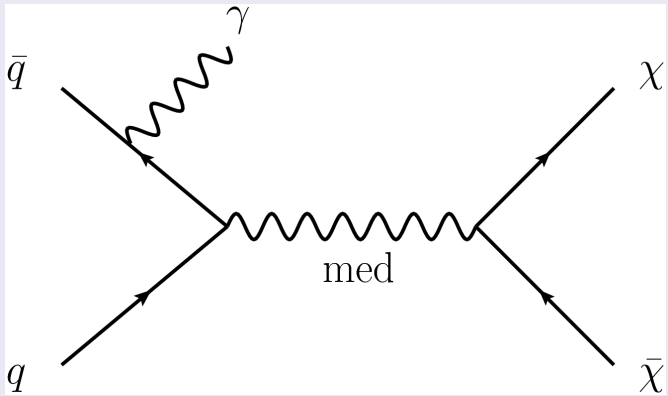


http://arxiv.org/pdf/1502.06541v3.pdf

General Searches

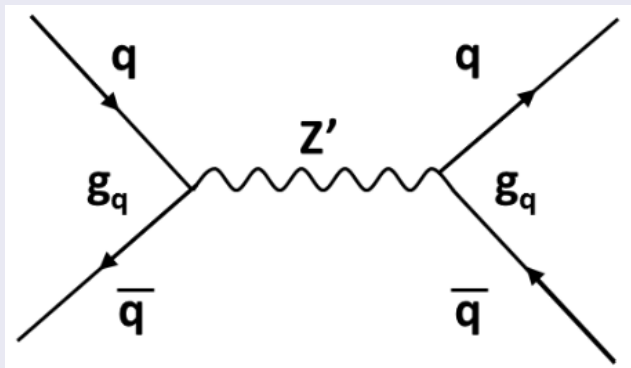
Mono-X Searches

1. Produced invisible DM escape from detector
2. Measurement of the momentum imbalance from DM and SM being produced simultaneously
3. E_t^{miss} variable of interest



Mediator Searches

1. If DM mediator produced at LHC, the mediator should decay back to SM
2. This will produce a resonance, in the invariant mass of decays
3. Invariant mass is the variable of interest



http://arxiv.org/pdf/1502.06541v3.pdf

Content

Mono-Photon

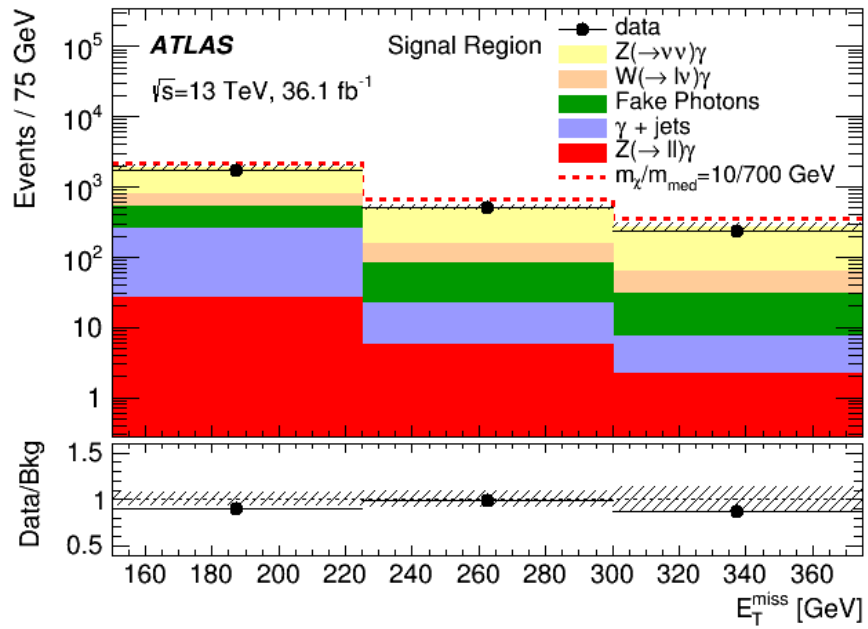
Event Selection

1. Dataset: 2015+2016 (36.1 fb^{-1})
2. Photon $pT > 150\,\mathrm{GeV}$,
3. $E_T^{miss} > 150\,\mathrm{GeV}$
4. 0 or 1 jets

Background

1. $Z(\to \nu\nu) + \gamma$ estimated from CR
2. $W(\to \ell\nu) + \gamma$ estimated from CR
3. Fake photons
4. γ+Jets

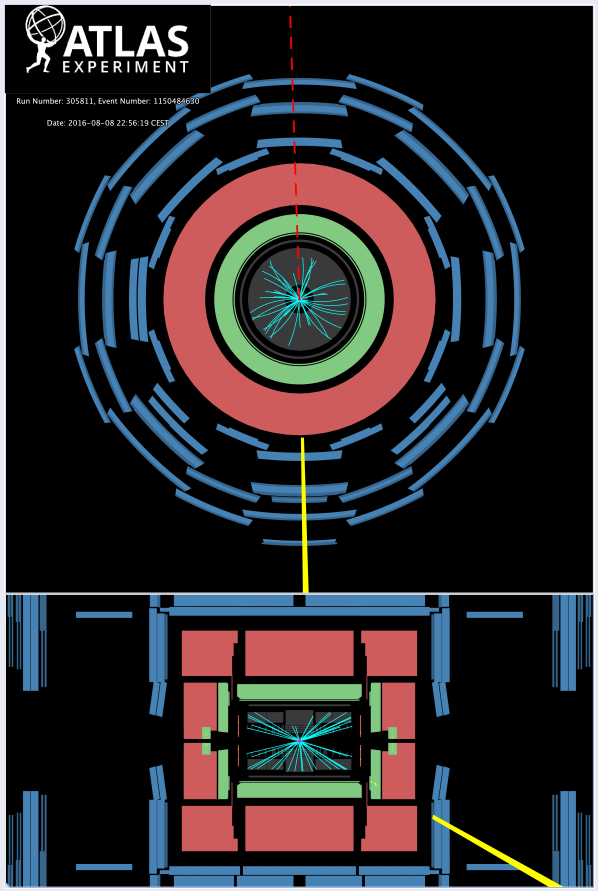
Eur. Phys. J. C 77 (2017) 393

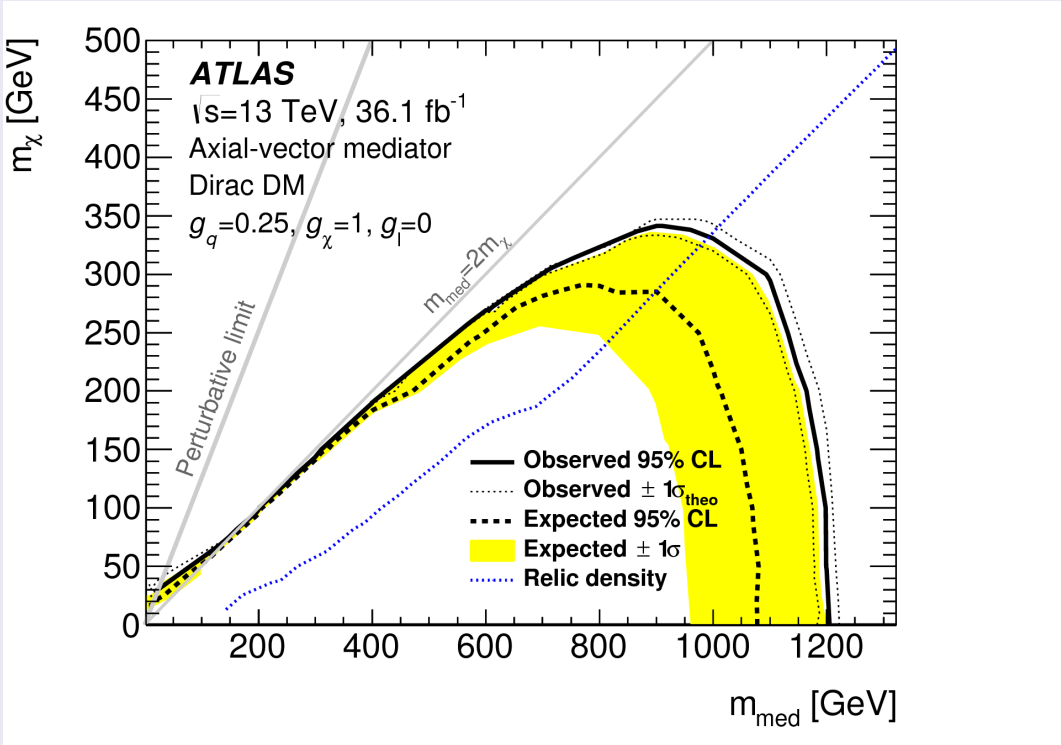


Signal regions:
Inclusive and exclusive signal regions defined by E_t^{miss} cuts and range

Mono-Photon

Eur. Phys. J. C 77 (2017) 393





Observed limits are set on a vector mediated model with axial-vector couplings for mediator masses up to 1.2 TeV and DM masses up to 350 GeV

MET+$b\bar{b}$

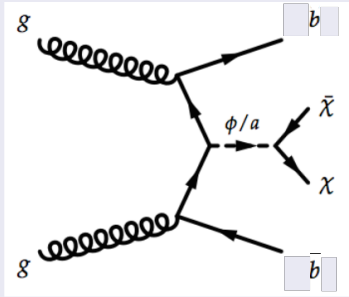
Event Selection

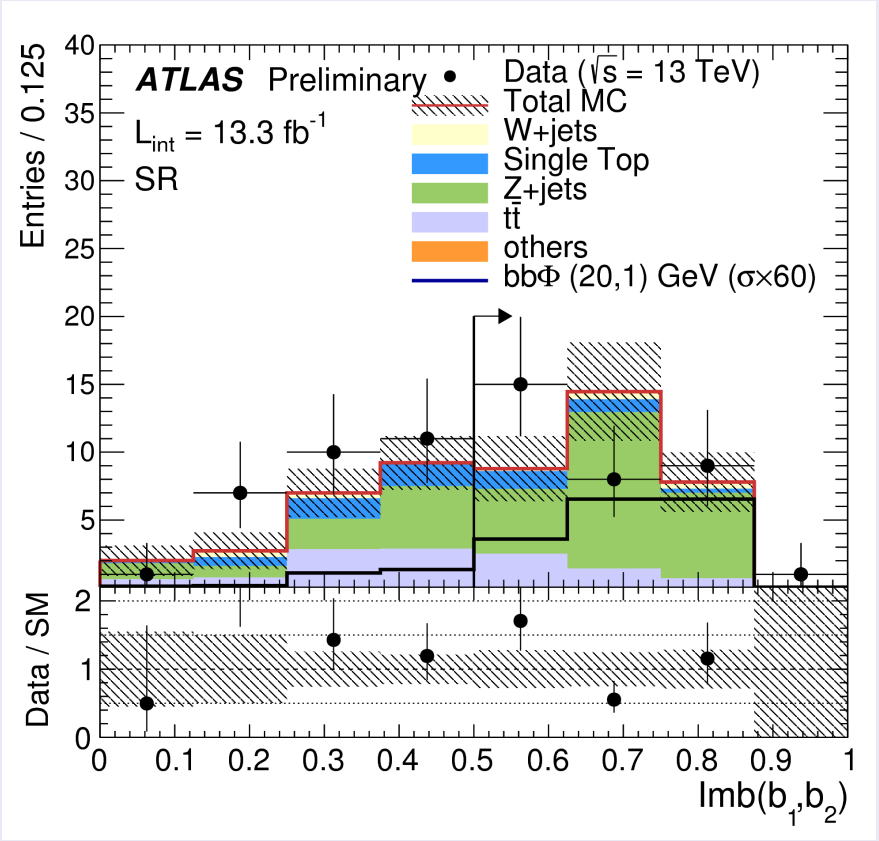
1. Dataset: 2015 (13.3 fb^{-1})
2. Two b-tagged jets
3. $E_T^{miss} > 150\,\mathrm{GeV}$
4. Lepton and third jet veto

Background

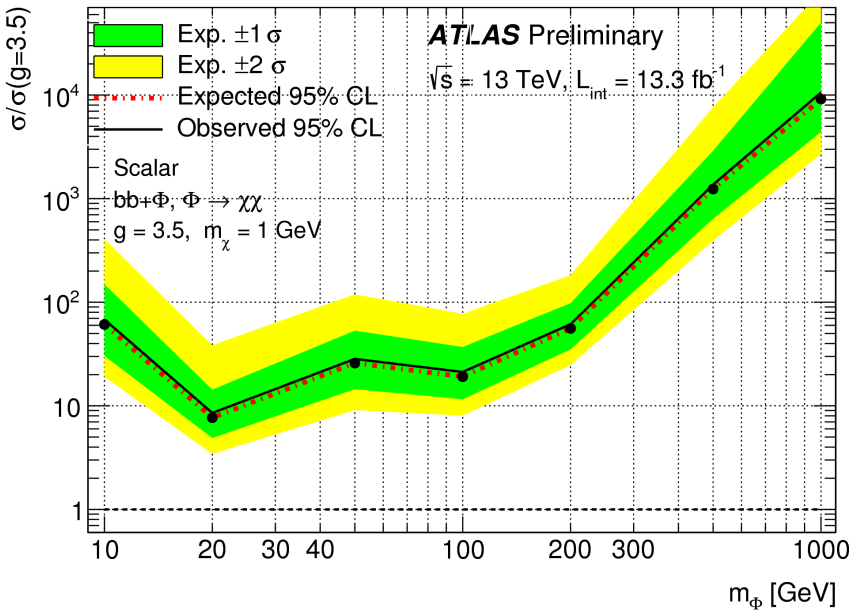
1. $Z(\to \nu\nu) + \gamma$ estimated from CR
2. Top-estimated with 1 lepton CR in data
3. $W(\to \ell\nu) + \gamma$ estimated from 1 lepton +1 b-jet CR in data

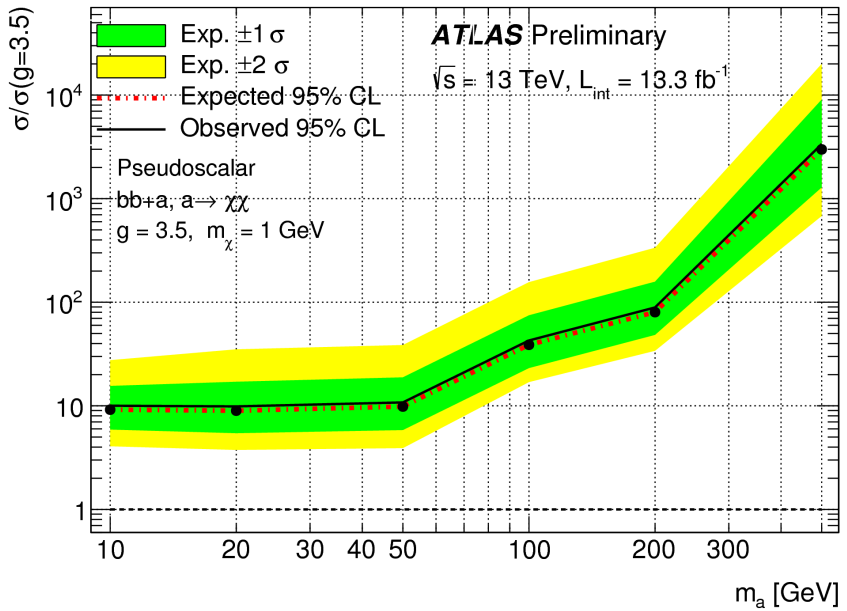
ATLAS-CONF-2016-086





MET+$b\bar{b}$





Limits on DM+$b\bar{b}$ with scalar and Pseudoscalar mediator for DM mass of 1 GeV

Dijet

Event Selection

1. Dataset: 2015+2016 (37 fb^{-1})
2. At least two jets $pT > 440\,\mathrm{GeV}$

Background

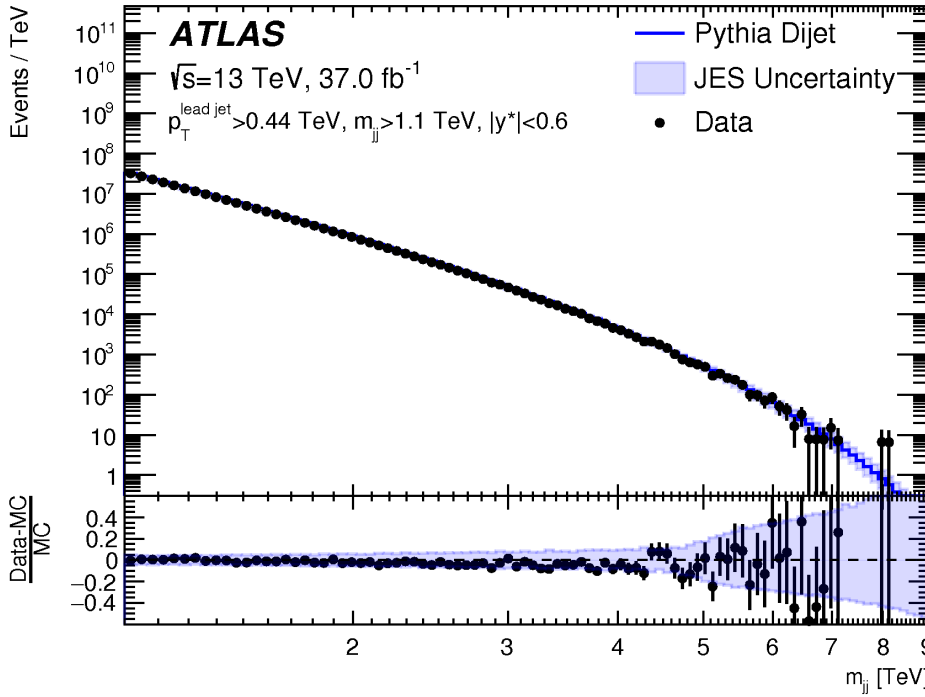
1. Modeled using a fit function

Analysis complemented by:

1. Trigger Level Analysis :

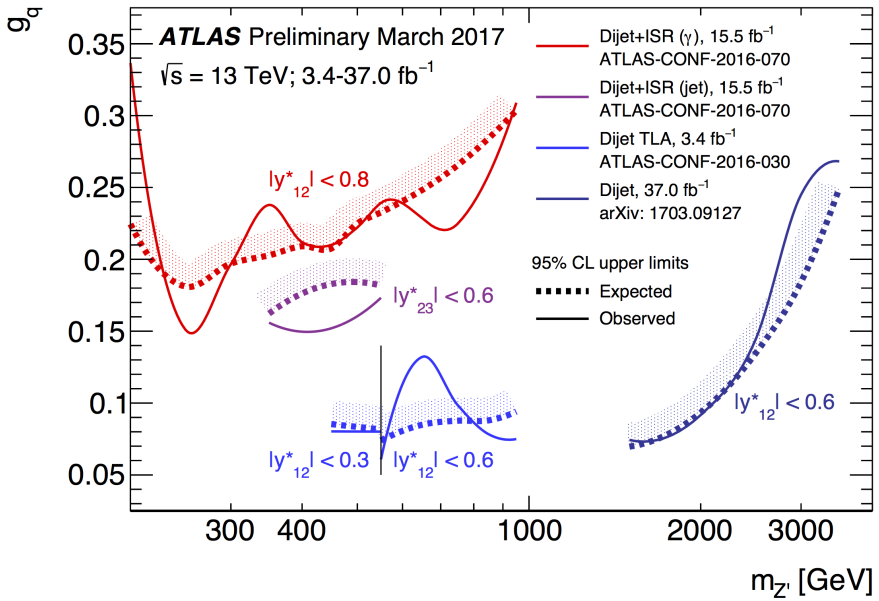
   ATLAS-CONF-2016-030
2. Dijets + ISR: ATLAS-CONF-2016-070

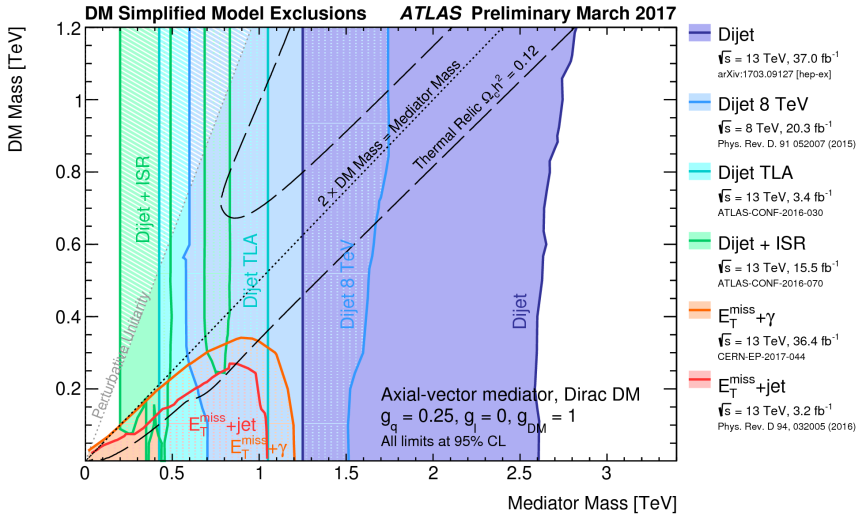
arXiv:1703.09127



Looking for bumps on the m_{jj} spectrum

Dijet


ATLAS Preliminary March 2017
√s = 13 TeV; 3.4-37.0 fb⁻¹
Dijet+ISR (γ), 15.5 fb⁻¹
ATLAS-CONF-2016-070
Dijet+ISR (jet), 15.5 fb⁻¹
ATLAS-CONF-2016-070
Dijet TLA, 3.4 fb⁻¹
ATLAS-CONF-2016-030
Dijet, 37.0 fb⁻¹
arXiv: 1703.09127
95% CL upper limits
Expected
Observed
|y*12| < 0.8
|y*23| < 0.6
|y*12| < 0.3
|y*12| < 0.6
|y*12| < 0.6
gq
mZ' [GeV]


DM Simplified Model Exclusions
ATLAS Preliminary March 2017
DM Mass [TeV]
Mediator Mass [TeV]
Perturbative Unitarity
Dijet + ISR
Dijet TLA
Dijet 8 TeV
Dijet
2 × DM Mass = Mediator Mass
Thermal Relic Ω_χh² = 0.12
Axial-vector mediator, Dirac DM
g_q = 0.25, g_l = 0, g_DM = 1
All limits at 95% CL
Dijet
√s = 13 TeV, 37.0 fb⁻¹
arXiv:1703.09127 [hep-ex]
Dijet 8 TeV
√s = 8 TeV, 20.3 fb⁻¹
Phys. Rev. D. 91 052007 (2015)
Dijet TLA
√s = 13 TeV, 3.4 fb⁻¹
ATLAS-CONF-2016-030
Dijet + ISR
√s = 13 TeV, 15.5 fb⁻¹
ATLAS-CONF-2016-070
E_T^miss +γ
√s = 13 TeV, 36.4 fb⁻¹
CERN-EP-2017-044
E_T^miss +jet
√s = 13 TeV, 3.2 fb⁻¹
Phys. Rev. D 94, 032005 (2016)

Other DM searches

1. Search for dark matter produced in association with a hadronically decaying vector boson in pp collisions at $\sqrt{s} = 13\,\mathrm{TeV}$ with the ATLAS detector Phys. Lett. B 763 (2016) 251
2. Mono-Z ATLAS-CONF-2016-056
3. Mono-Higgs ATLAS-CONF-2017-028
4. DM + $t\bar{t}$ ATLAS-CONF-2016-077
5. And many others

Content

Motivation

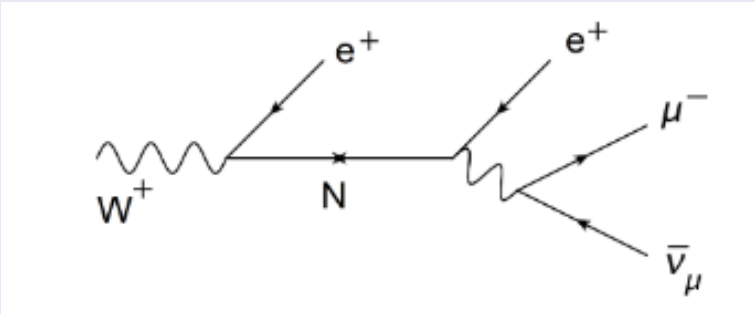
νMinimal SM

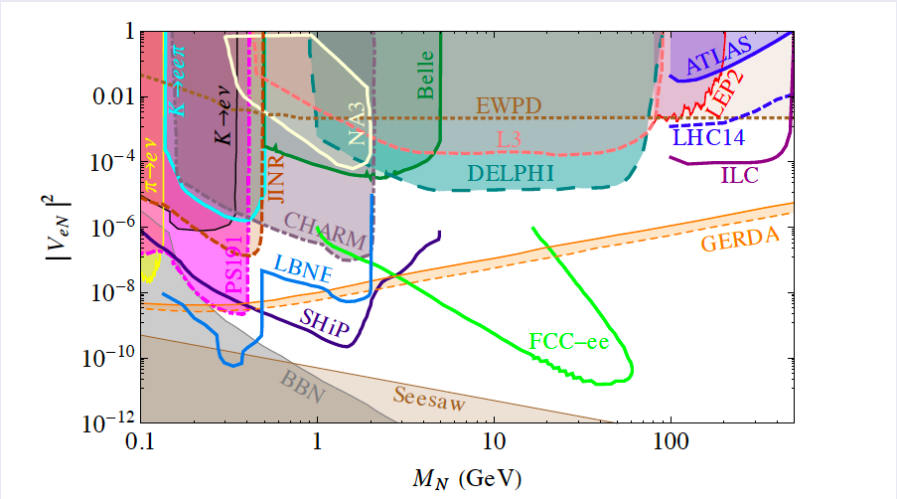
1. DM candidate
2. Three RH sterile neutrinos with $M_{HNL} << M_W$
3. The HNL mixes with SM neutrinos.

Proposal

1. Production of HNL via $W^{\pm}$
2. Displaced vertices

Experimental limits on HNL mixing.



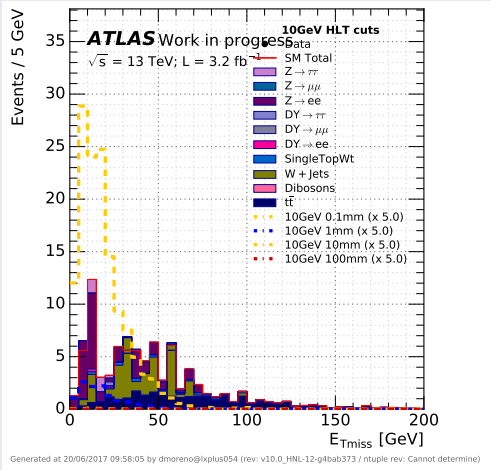


http://arxiv.org/pdf/1502.06541v3.pdf

MC Simulation

Cuts Optimization

1. Number of leptons
2. No-OSSF leptons
3. HLT
4. $|\eta| < 2.47$ for all electrons
   $|\eta| < 2.6$ for muons
5. $pT(Lead) > 15.0 GeV$
   $pT(subLead) > 6.0\,\mathrm{GeV}$
   $pT(\mu) > 5.0\,\mathrm{GeV}$
6. Work in Progress



MC parameters

1. Pythia 8
2. NN PDF2.3LO
3. HNL Mass:
   $5, 10, 20, 30, 50\,\mathrm{GeV}$
4. Decay lenghts:
   $0.1, 1.0, 10.0, 100\,\mathrm{mm}$

Summary

1. Searches for DM at the LHC are complementary to other DM searches
2. ATLAS is doing well looking for DM
3. No evident excess until now
4. Plenty of room to improvement