ATLAS results on Beyond the Standard Model

Iain Bertram for the ATLAS Collaboration

Lancaster University, 18 May 2017

13TH PATRAS WORKSHOP ON AXIONS, WIMPS AND WISPS

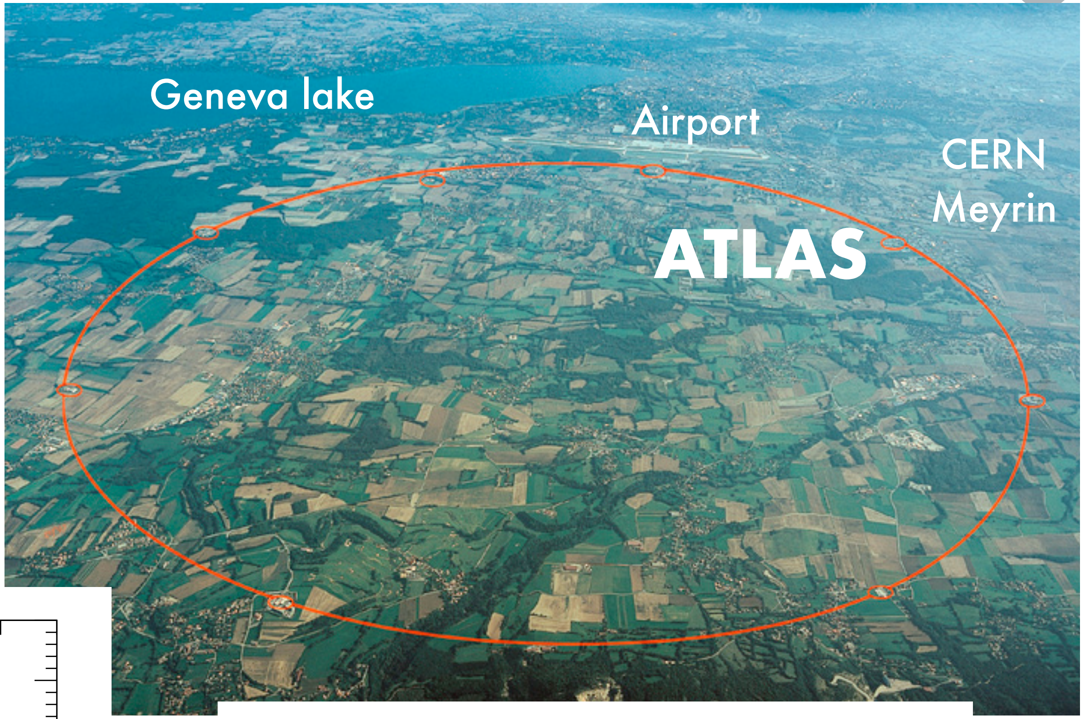
There are more things in heaven and earth, Horatio,
Than are dreamt of in your philosophy.

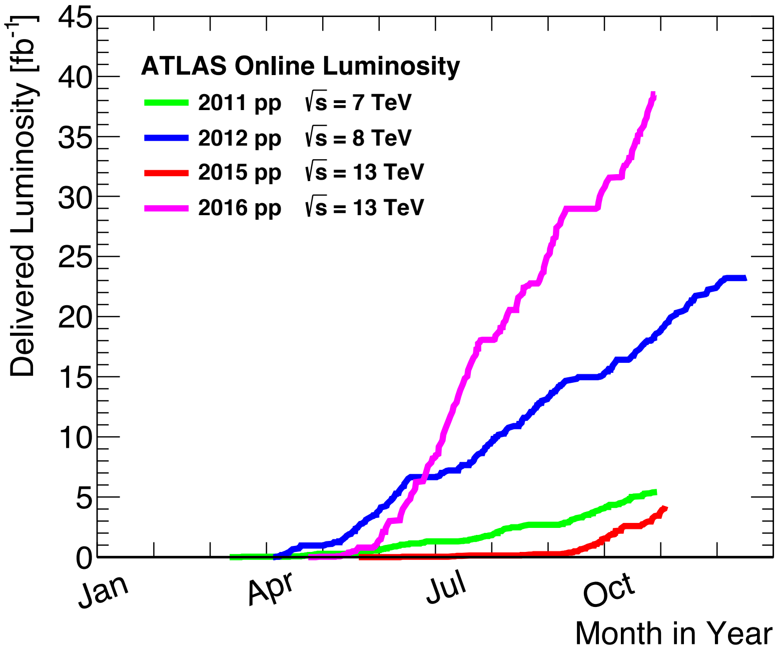
Overview

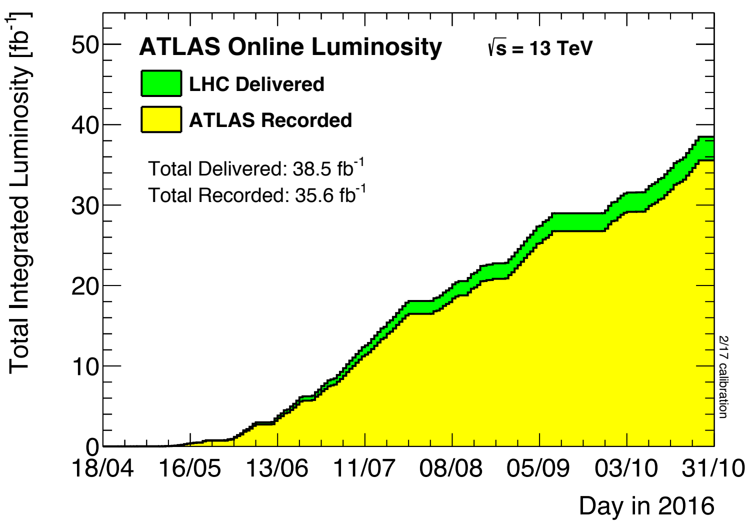
- I will present details on three recent analyses (all released since March).
  - Search for dark matter in final states containing an energetic photon and large missing transverse momentum.
  - Search for new phenomena in dijet events.
  - Search for long-lived charginos based on a disappearing-track signature
- The first two analyses illustrate searches for Dark Matter at hadron colliders
- The third is a non-standard technique for searching for Supersymmetry.

LHC

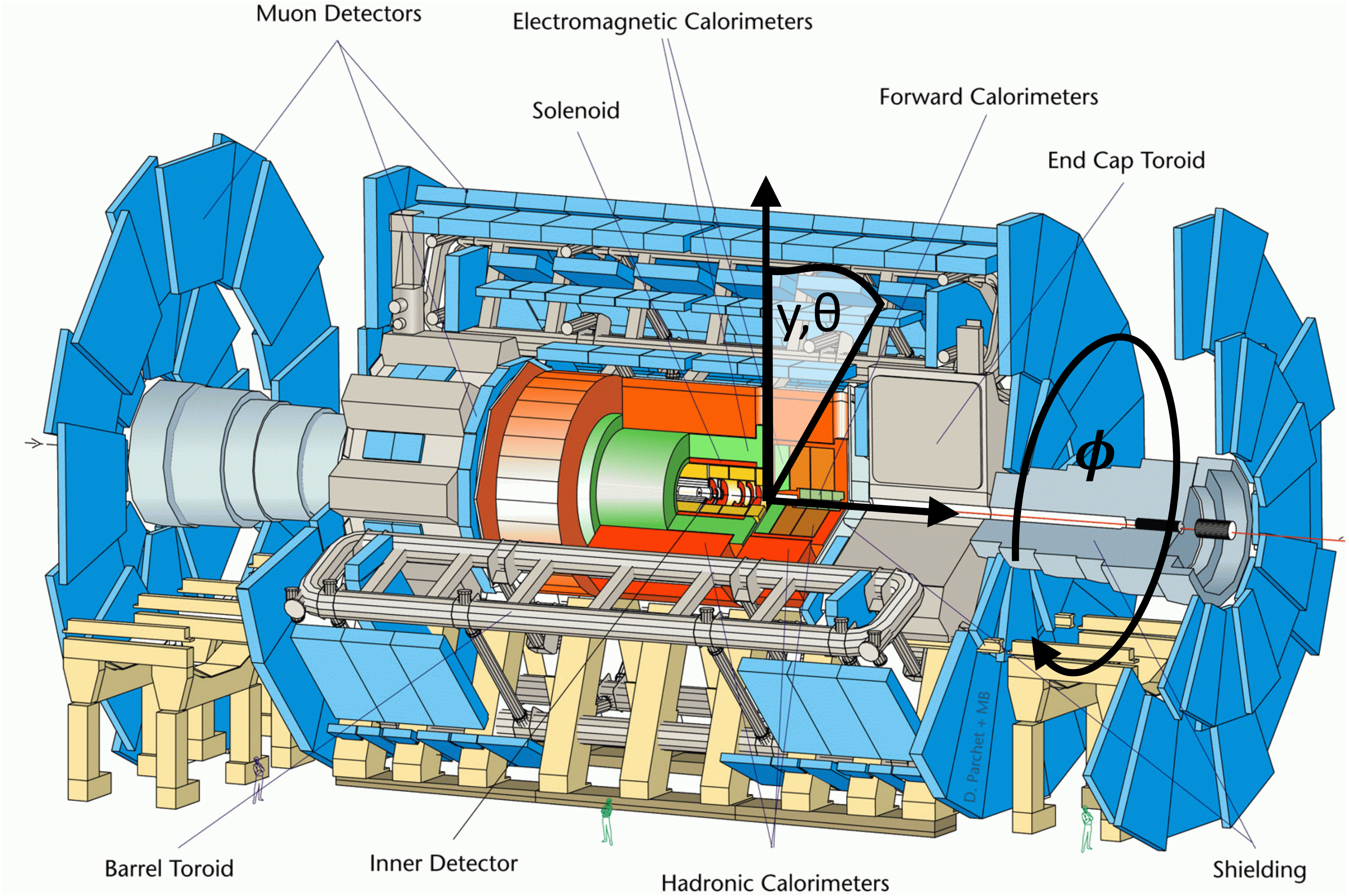
- Proton-proton collisions at a centre-of-mass of 13 TeV.
- Presenting results from 2015/16 data taking with a data sample of approximately 37 fb^{-1} collected by the ATLAS experiment.







The ATLAS Experiment

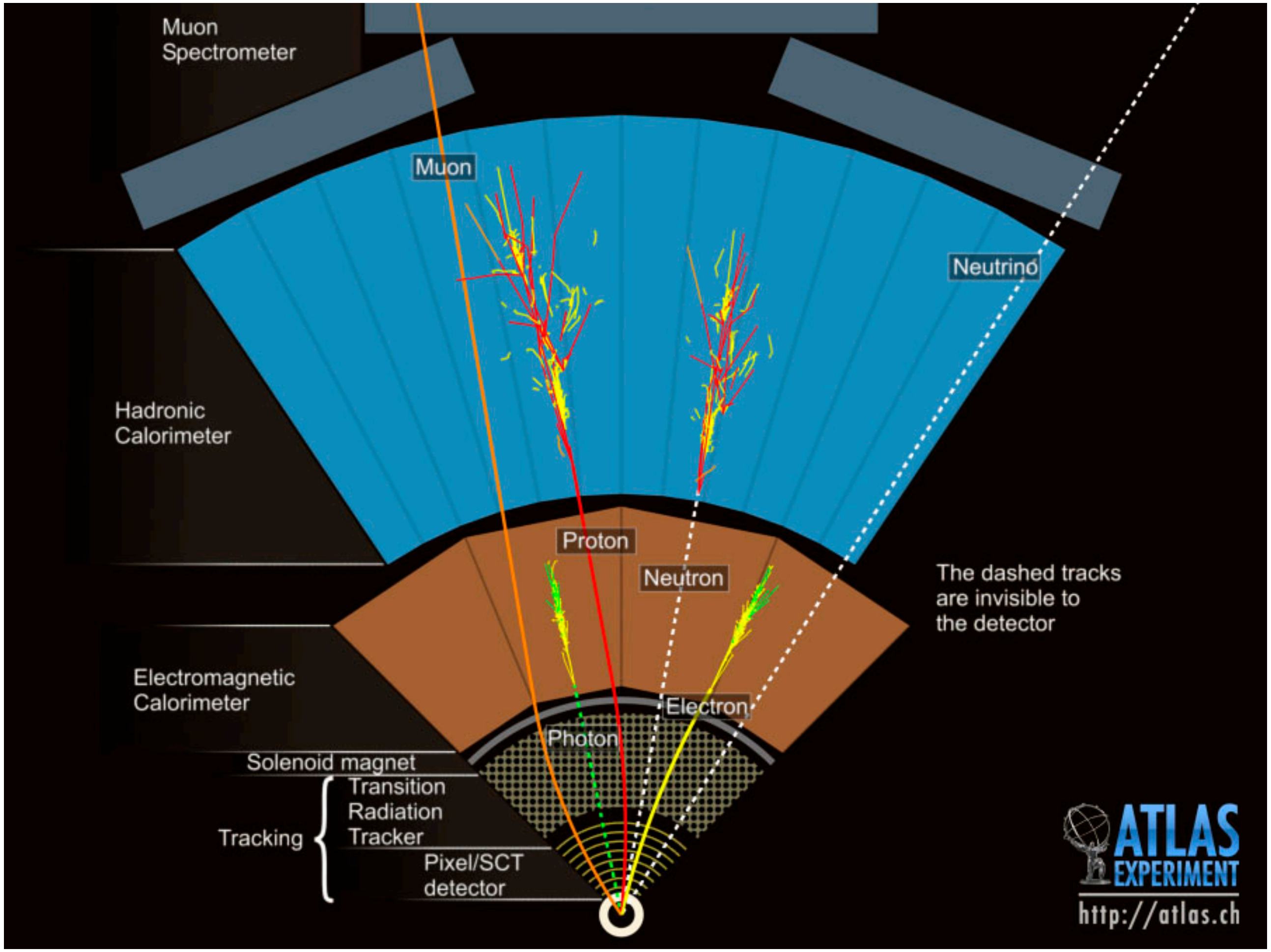


$$y = \frac{1}{2} \ln \left(\frac{E + p_z}{E - p_z} \right)$$

$$\eta = \ln \left[\tan(\theta/2) \right]$$

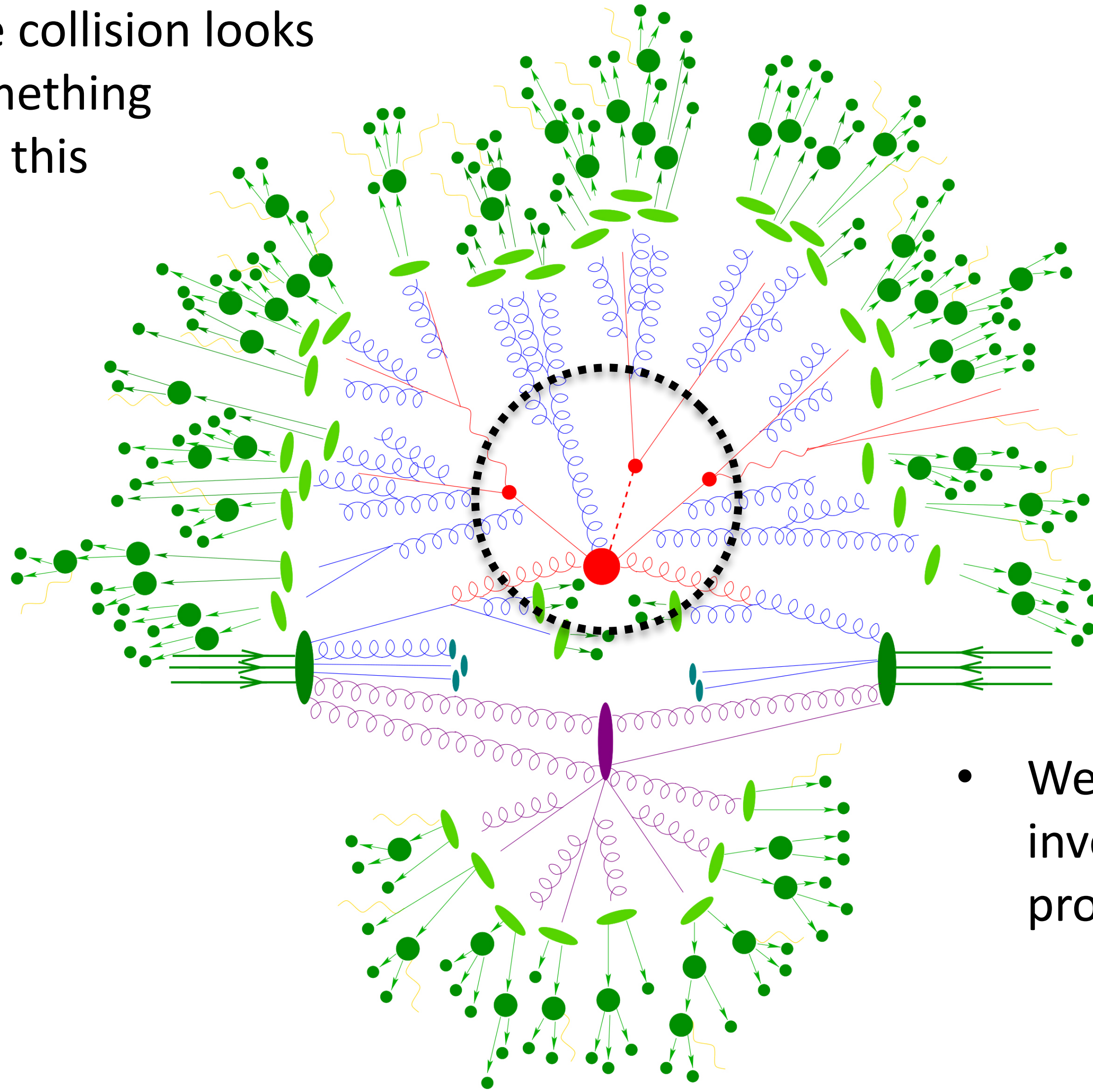
Particle Identification

- Measure change and momentum of particles in the tracking detectors.
- Use energy deposition and range of particles to separate electrons, photons, hadrons and muons.



Proton - Proton Collision

- The collision looks something like this



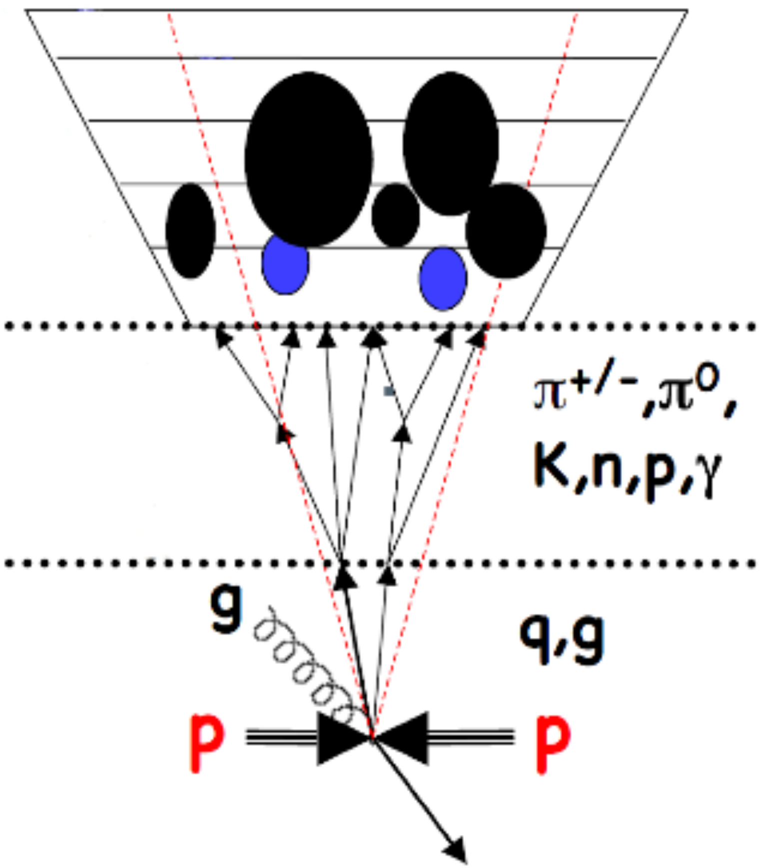
- We usually want to investigate the "hard" process…

Jet Reconstruction

- Quarks and gluons produced in the hard interaction undergo fragmentation and hadronisation before entering the ATLAS detector
- Reconstructed as "Jets" via a clustering algorithm (anti-k_t) using calorimeter clusters as input.
- Combines pairs of objects recursively based on their separation:

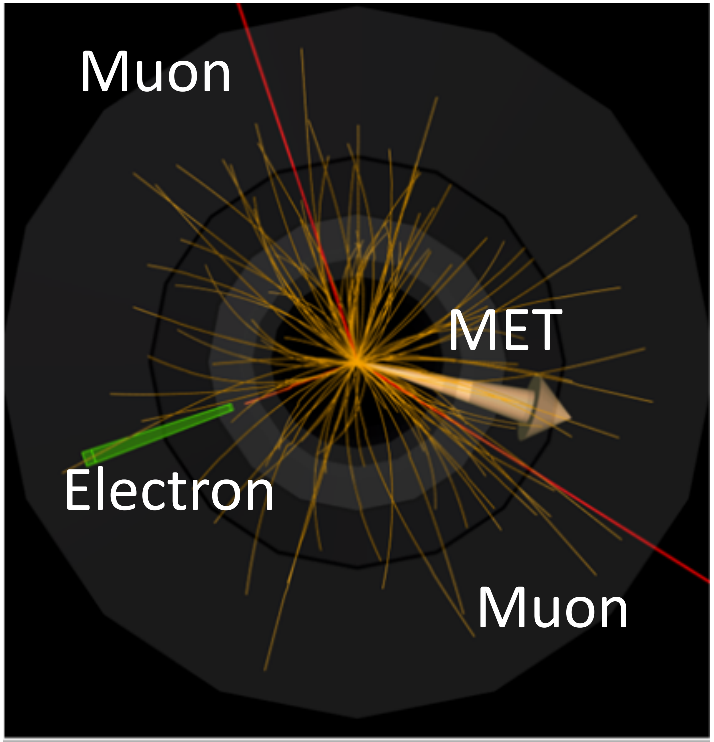
$$\Delta R_{ij} = \sqrt{\Delta y_{ij}^2 + \Delta \phi_{ij}^2}$$

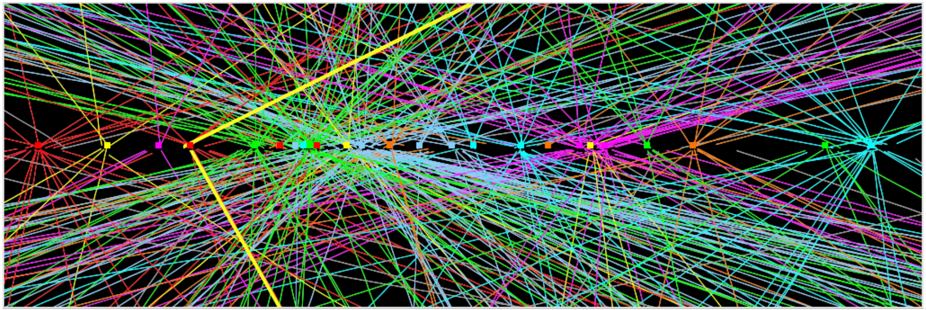
- A radius parameter defines the size of the size of the jet (standard size is 0.4).



Missing Transverse Energy

- Reconstruction of particles that do not interact with the detector is crucial for searches for new phenomena.
  - Neutrinos are main cause.
- Infer from the imbalance of the total transverse momentum of all reconstructed objects
  → Missing transverse Energy (MET)
  - transverse momentum is given by $$p_T = \sqrt{p_x^2 + p_y^2}$$
- Effects due to additional collisions can be mitigated using information from the tracking detector.

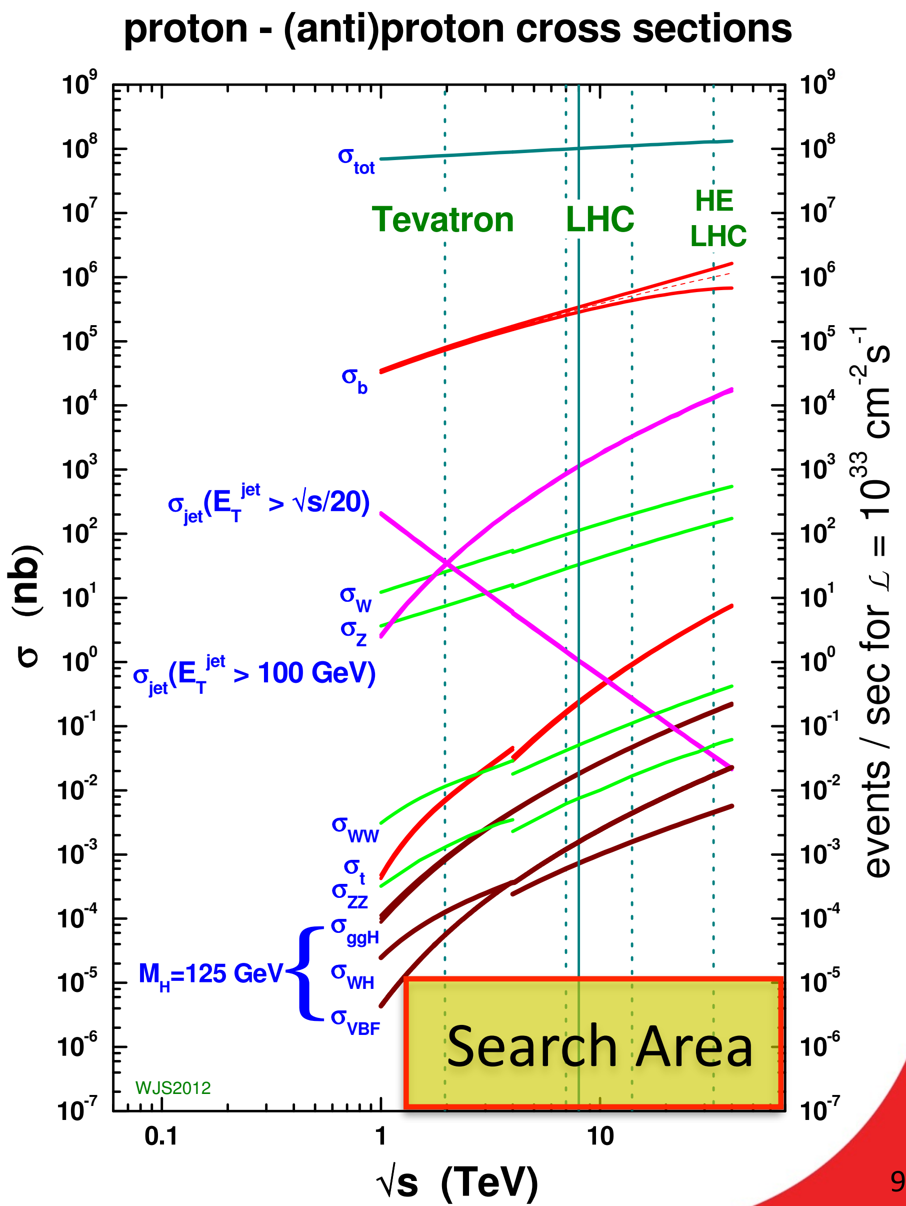




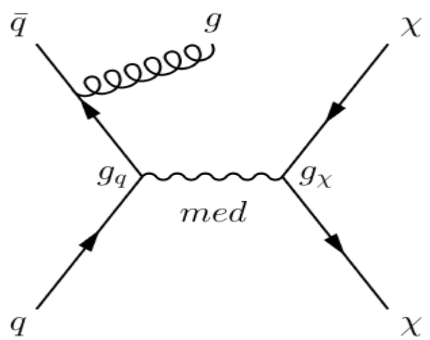
Z → μμ with 20 “pile up” events.

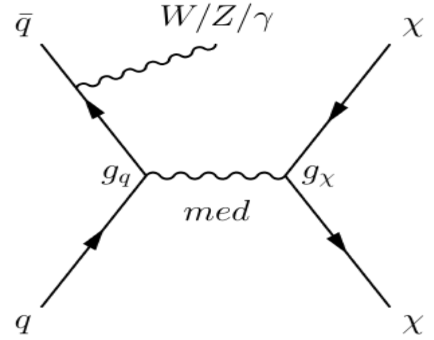
Triggering

- Peak luminosity achieved:
  L= 1.4x10^{34} cm^{-2}s^{-1} (design: 1.0x10^{34} cm^{-2}s^{-1})
- Approximately 10^9 interactions per second. We need to filter out the events of interest.
  - Side Note: Many interactions per proton bunch crossing:
    On average 24 interactions.
- Technical Details
  - LHC generates 30 MHz bunch crossings
  - Hardware Trigger in detectors reduces rate to 100 kHz
  - Software Trigger (partial reconstruction) writes out 1 kHz events.

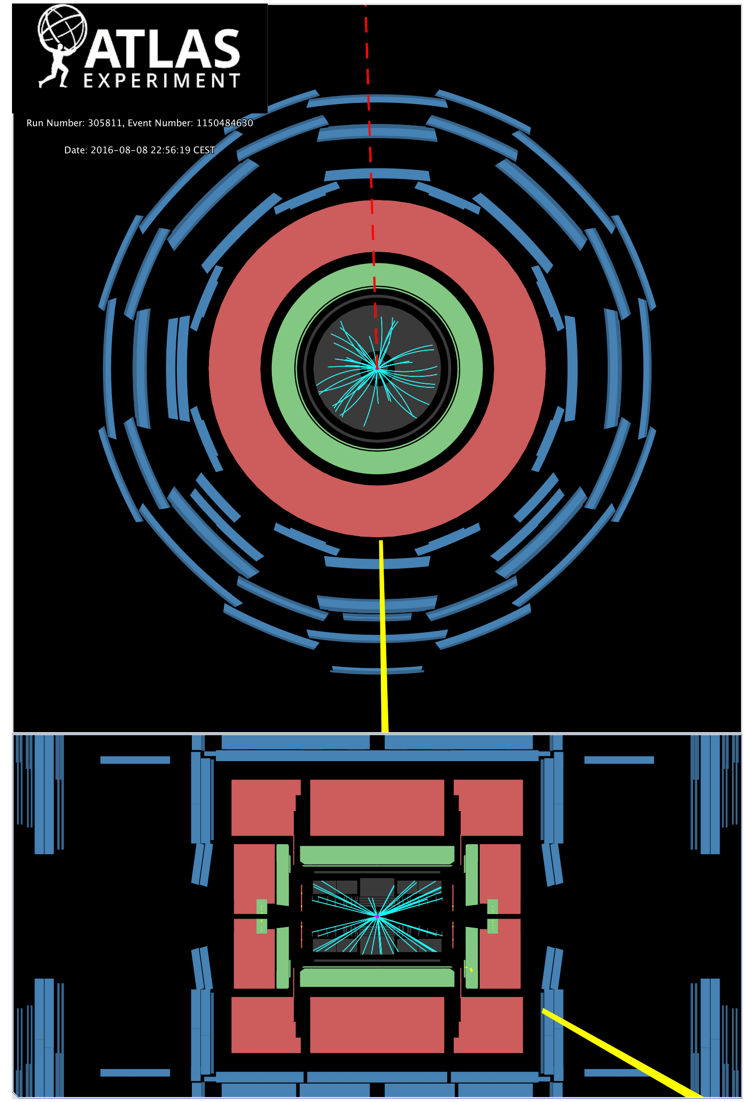


Something plus MET





- WIMPs can be recognised as a large amount of MET in the ATLAS detector.
- Need an associated recoil object in the interaction to trigger on the event.
  - jets, W/Z, γ, Higgs are possibilities.
- Event Signatures are denoted as Mono-X
  - Look for single high-p_T object and nothing else in the event.
  - W/Z, γ are nice clean signatures with "small" backgrounds.

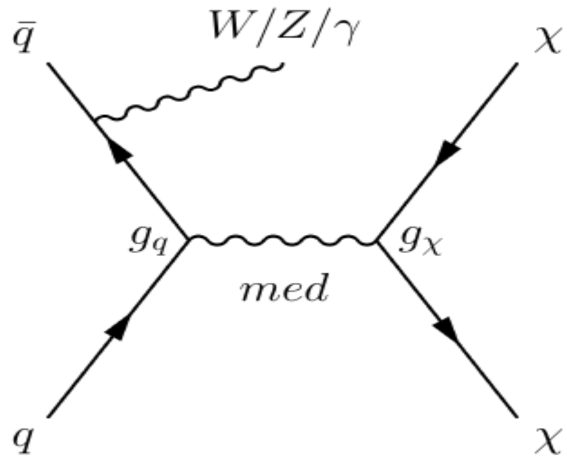


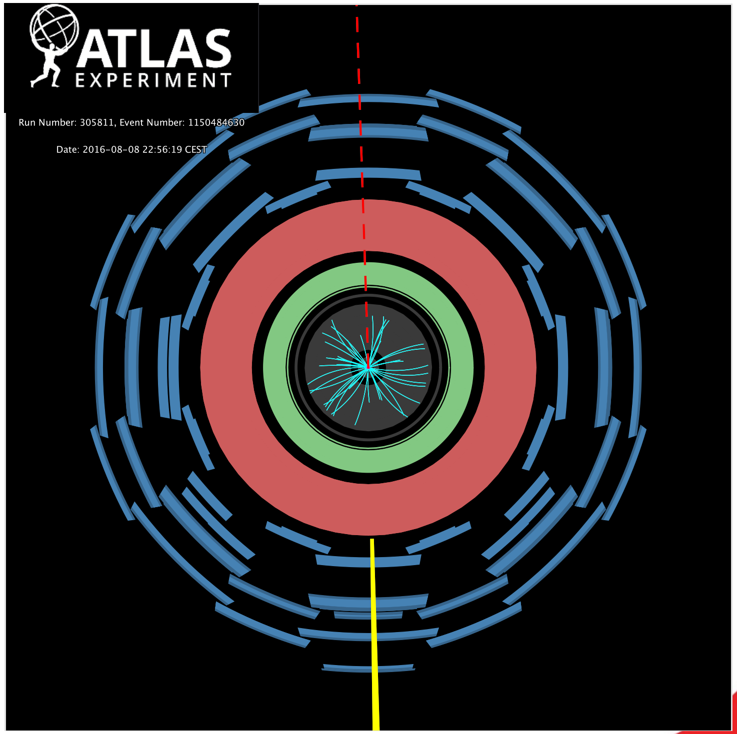
γ + MET event

Photon plus MET

arXiv:1704.03848 submitted to EPJC

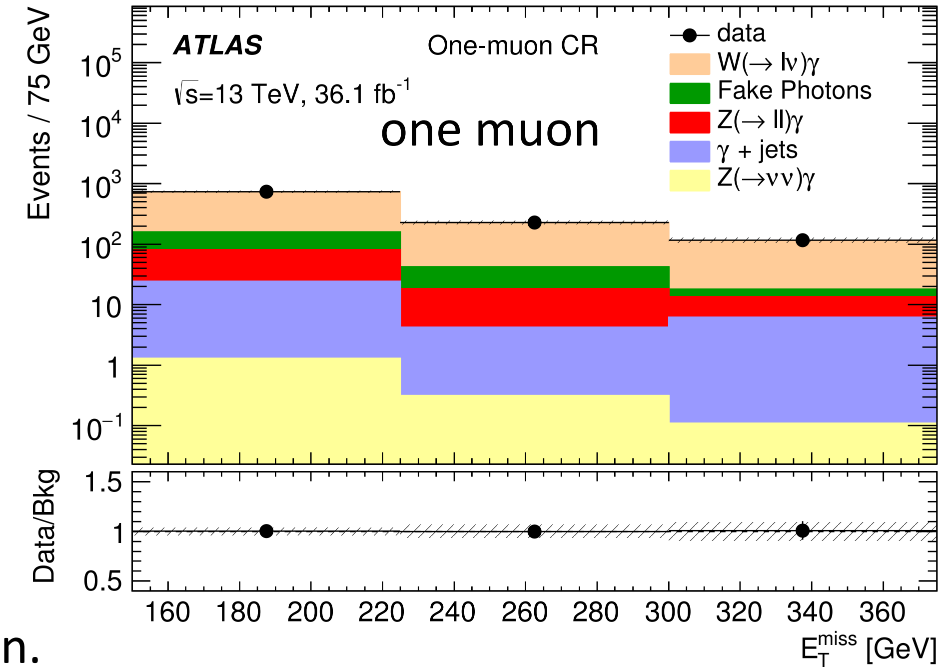
- Select events with one high p_T photon $p_T > 150$ GeV.
  - Veto on reconstructed electrons and muons in the event.
- MET > 150 GeV
  - at most one jet with $p_T > 30$ GeV.
- Photon and MET must not collinear
  - also jet and MET must not be aligned
  - remove backgrounds due to miss-measurement.
- Main Backgrounds
  - SM $Z \rightarrow (\nu\nu)\gamma$
  - Irreducible and identical kinematics to the signal.

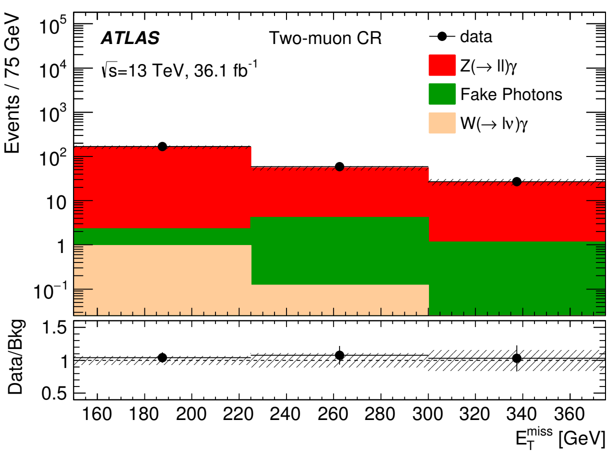




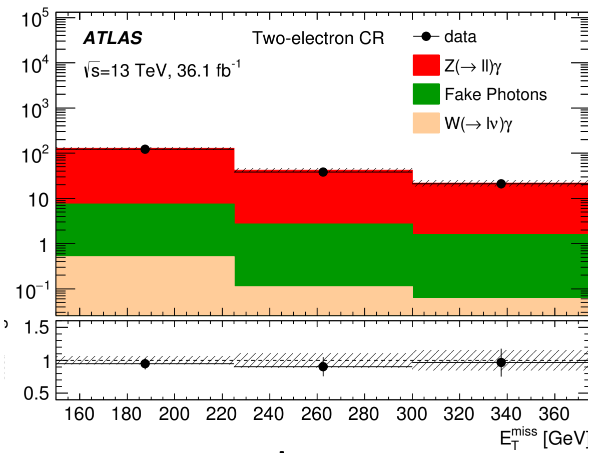
Photon plus MET

- Strategy:
  - Use data to confirm simulation (MC) of backgrounds.
  - Dominant background Z → (νν)γ is scaled by Z → (ll)γ rates.
  - Extract signal by fitting to MET distributions.
- Use events with one muon, two muons, two electrons and a photon plus jet to check/correct the simulation.

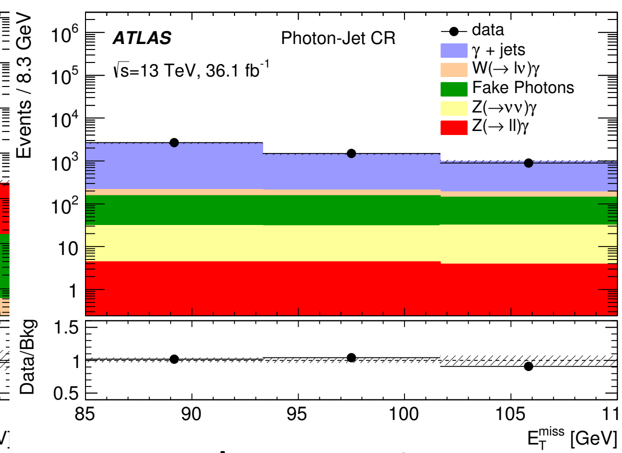




two muons



two electrons

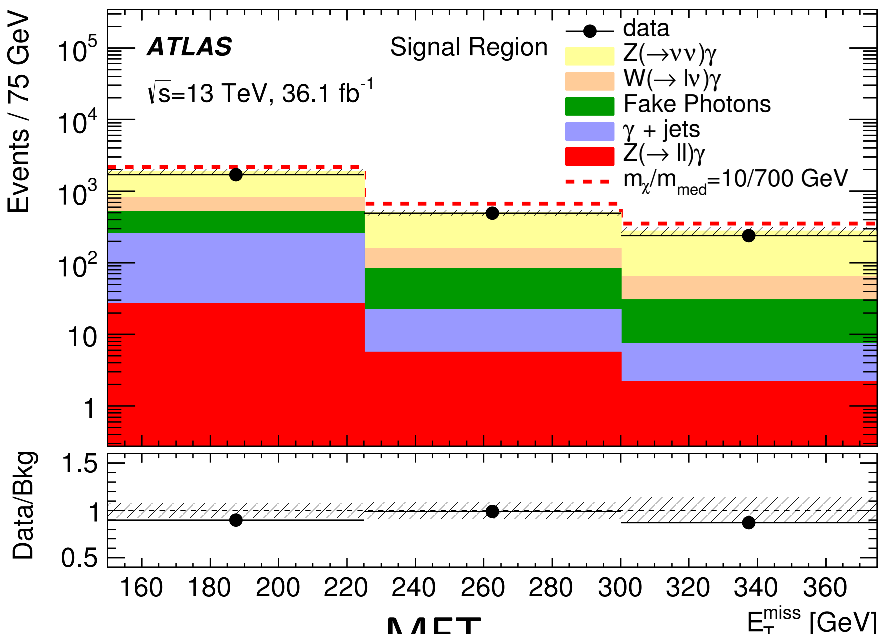


photon + jet

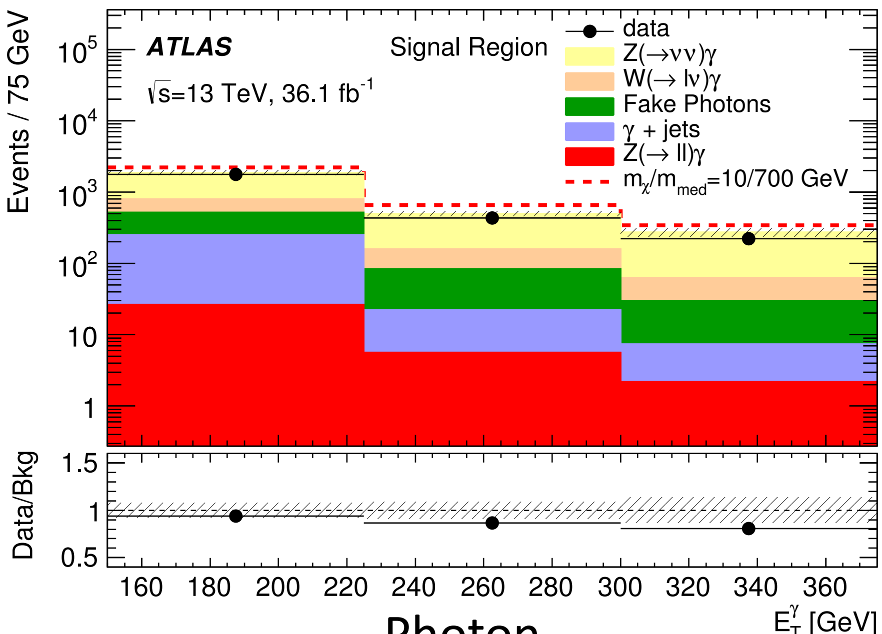
Photon plus MET

- Event yield consistent with background.
- Calculate upper limits on the visible cross section.
  - sensitivity limited by statistical uncertainty in the control regions.

	$\sigma \times A$ limit [fb]		
Region	SRI1	SRI2	SRI3
95% CL observed	7.0	3.7	2.3
95% CL expected	10.6	4.5	3.0
95% CL expected ($\pm 1\sigma$)	14.5, 7.7	6.2, 3.3	4.2, 2.2
A [%]	14–48	5–31	2–19
ϵ [%]	84–95	73–86	64–85



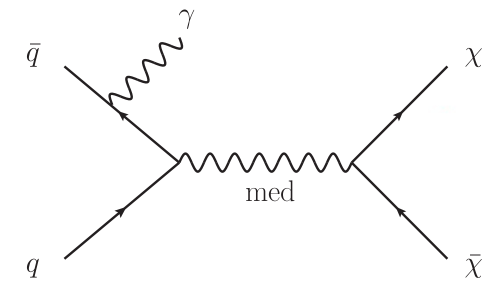
MET



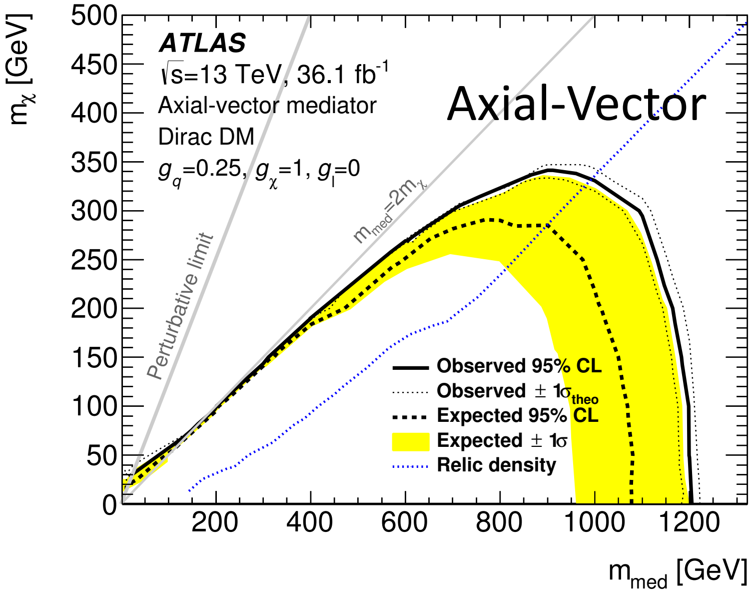
Photon

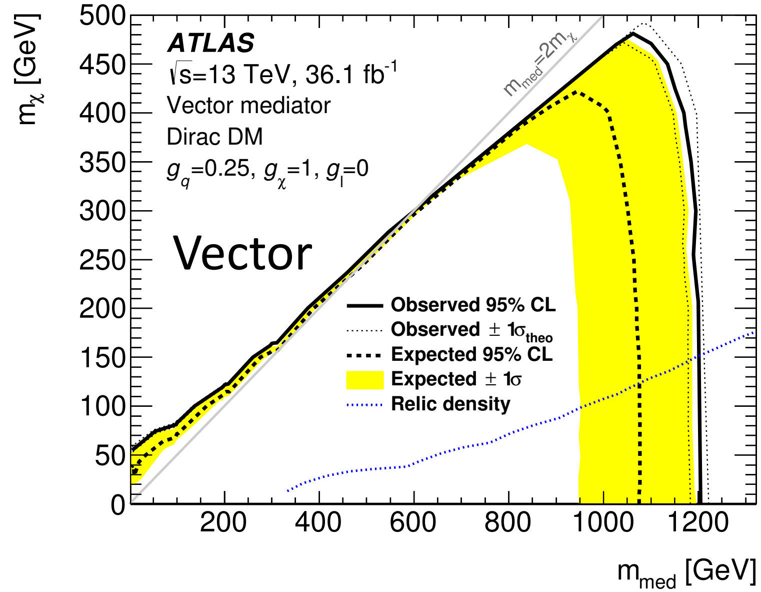
Photon plus MET: Limits

- Use binned fit to MET -distribution to interpret results in terms of DM models
- Limits given in plane of DM and mediator mass (CL=95%)
- Model dependent (Axial Vector or Axial mediator, g_q=0.25, g_χ=1.0, g_l=0, or g_q=0.1, g_χ=1.0, g_l=0.01)



Model	Mediator	g_q	g_χ	g_ℓ	Limit on m_{med} [GeV] for low m_χ	Limit on m_χ [GeV] reaching as high as
A1	axial-vector	0.25	1	0	1200	340
A2	axial-vector	0.1	1	0.1	750	230
V1	vector	0.25	1	0	1200	480
V2	vector	0.1	1	0.01	750	320





Photon plus MET: Limits

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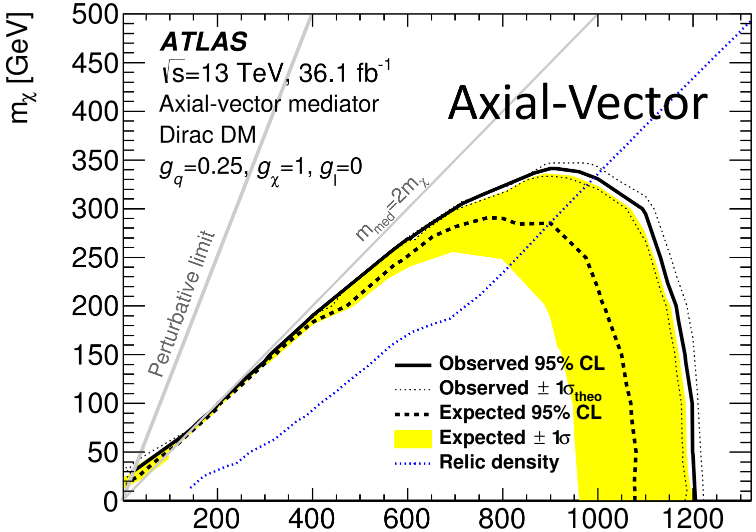
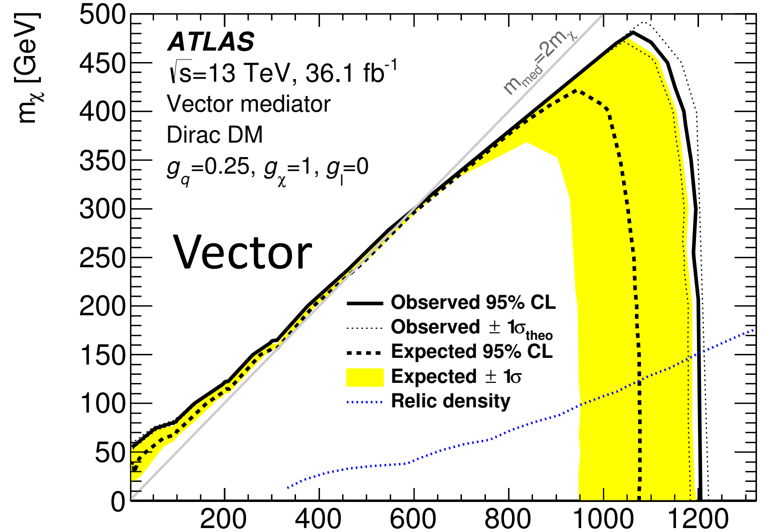
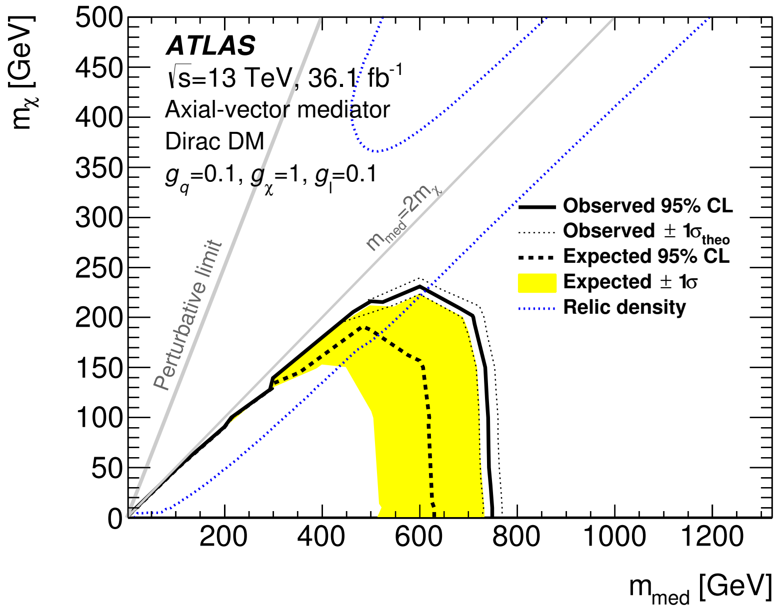
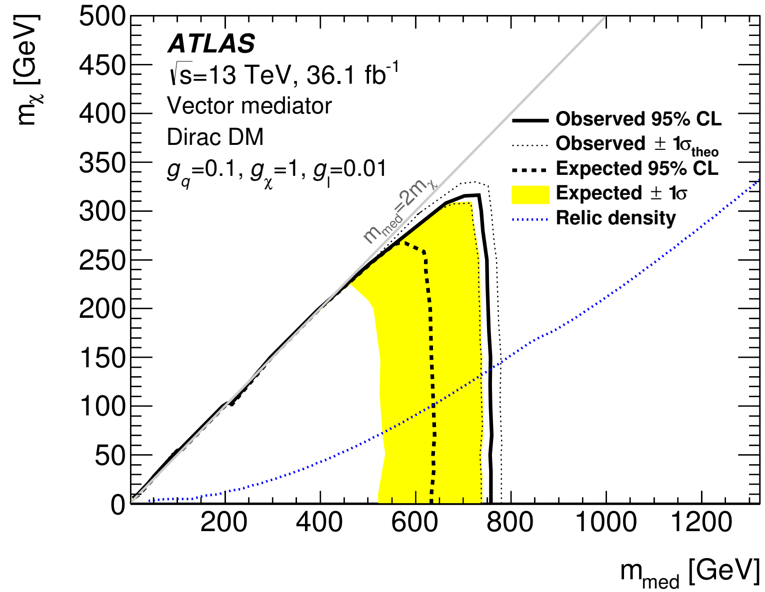


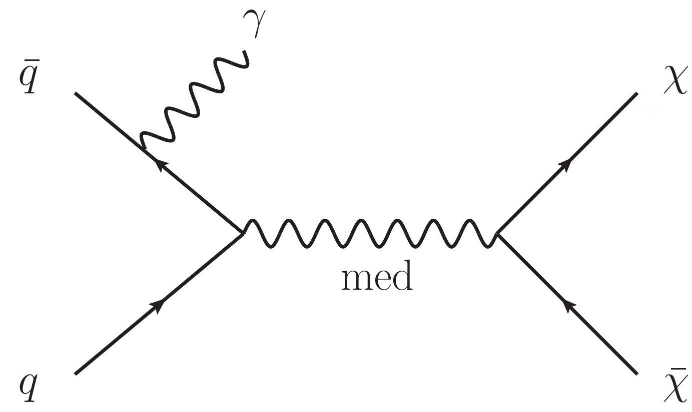


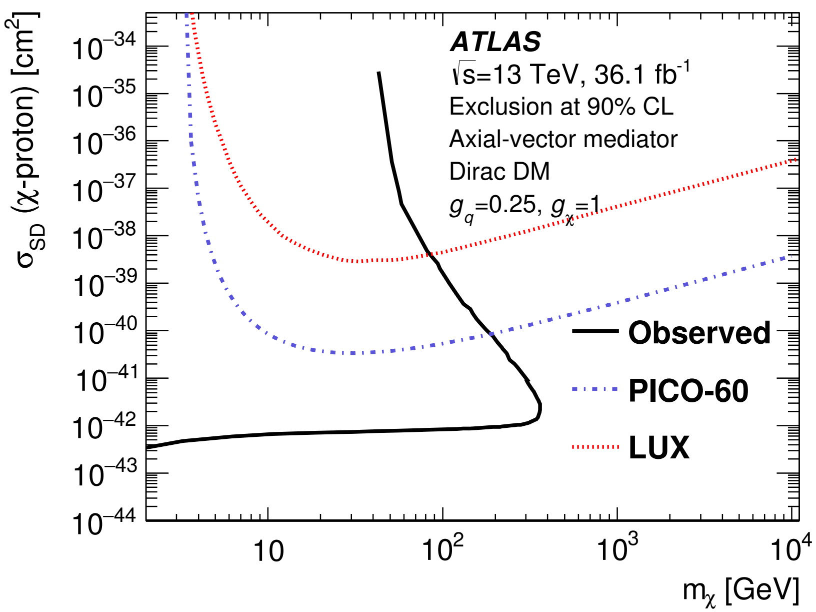




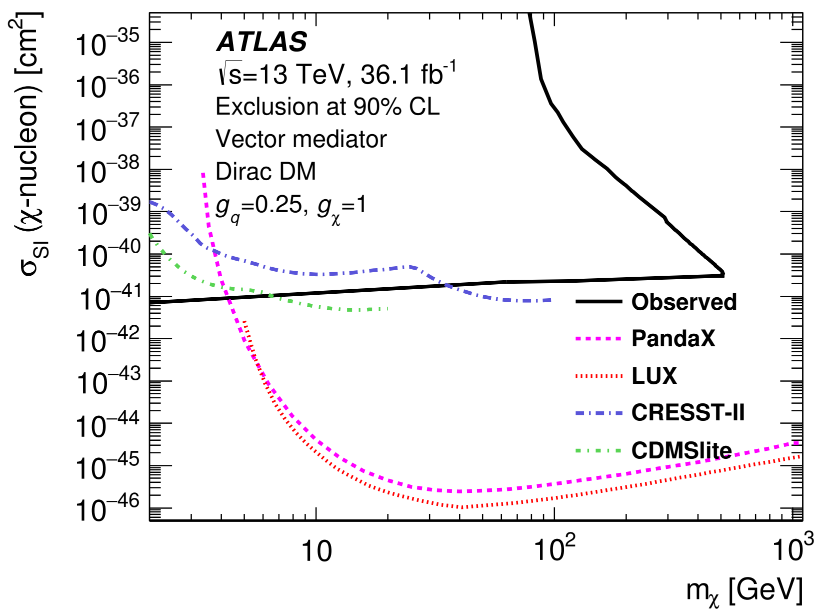
Photon plus MET: Limits

- Comparisons with Direct Searches Limits given in plane of χ-nucleon scattering cross section and DM mass (CL=90%)
- Model dependent
  Axial Vector or Axial mediator,
  g_q=0.25, g_χ=1.0, g_l=0.



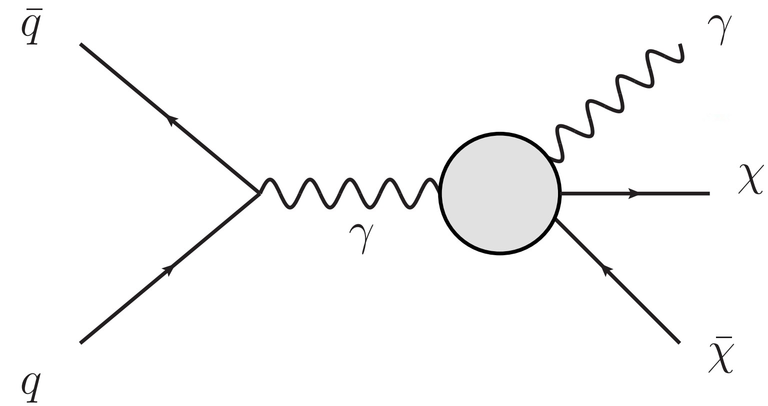


Axial-Vector



Vector

Photon plus MET: Limits



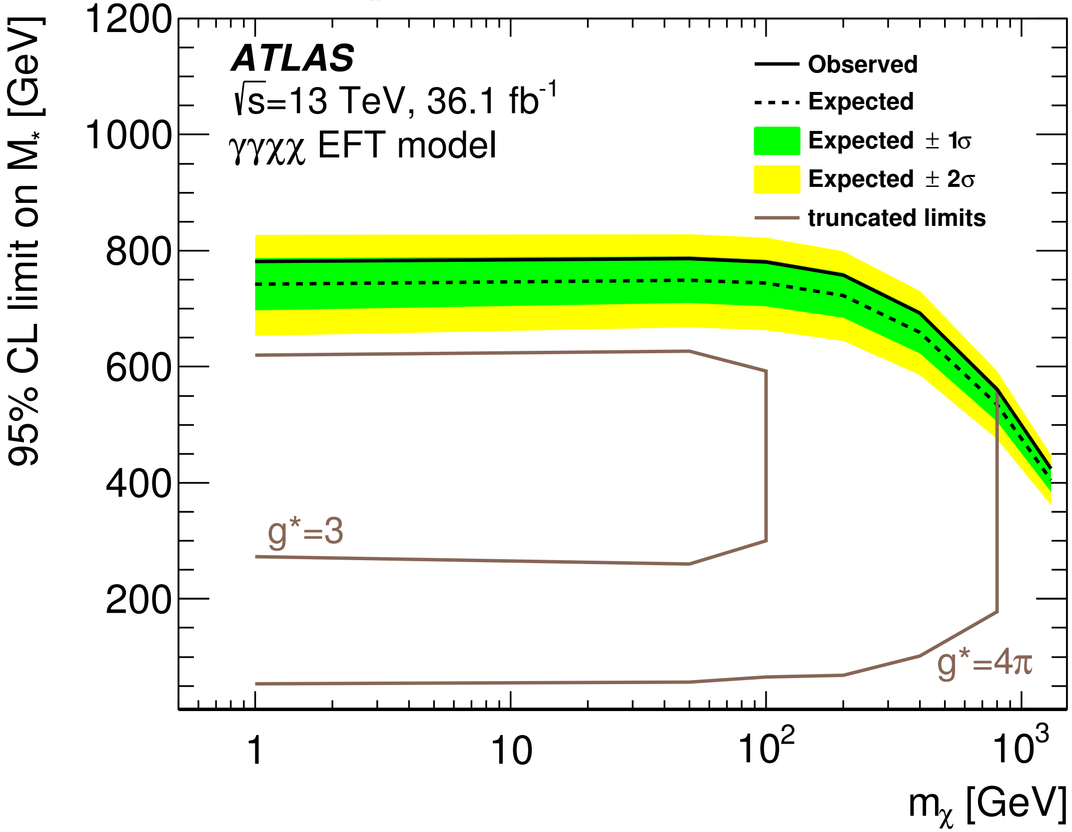
- Observed and expected 95% CL limits on M* for a dimension-7 operator EFT model with a contact interaction of type γγχχ as a function of dark-matter mass mχ.
- These limits depend on number of events where MET > 300 GeV.

$$M_* = \frac{m_{\text{med}}}{\sqrt{g_q g_\chi}}$$

The EFT model becomes invalid when $M_{cut} = g^* M_*$.

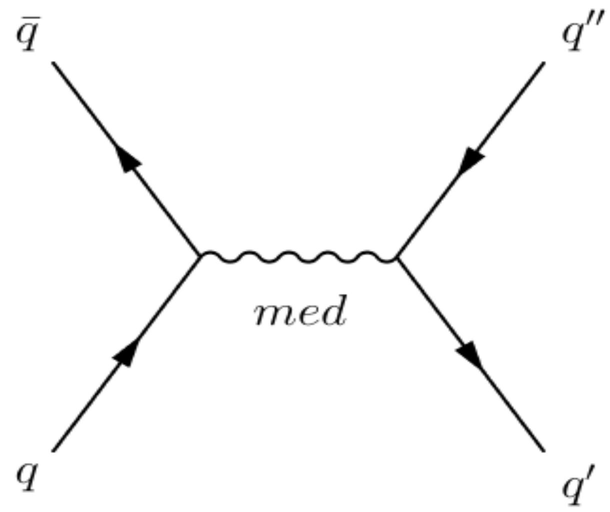
M_* is the effective mass scale.

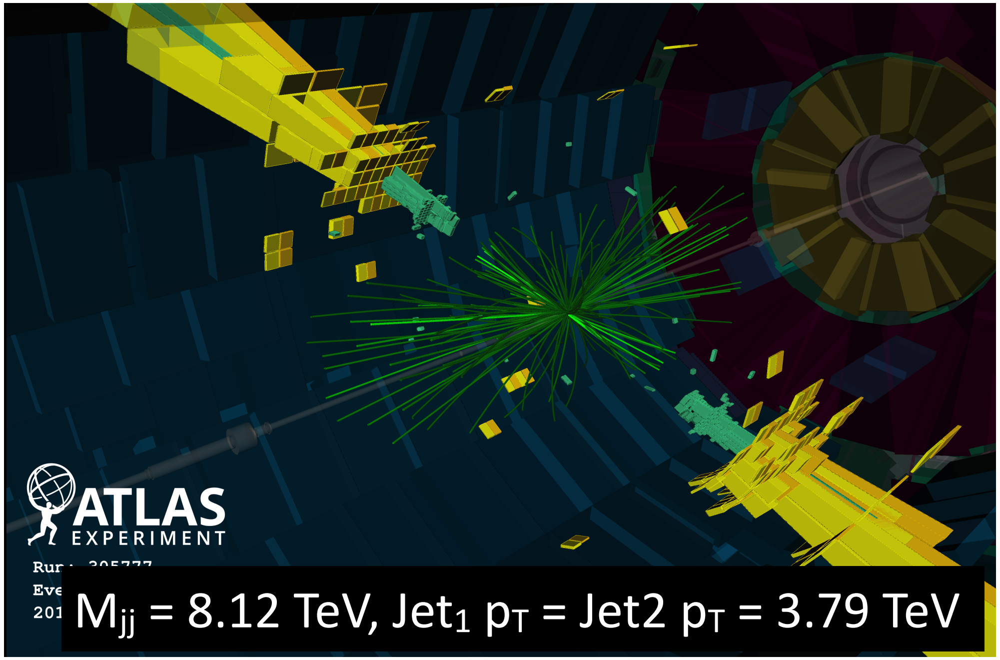
The truncated limits show where this occurs for different values of M_*.

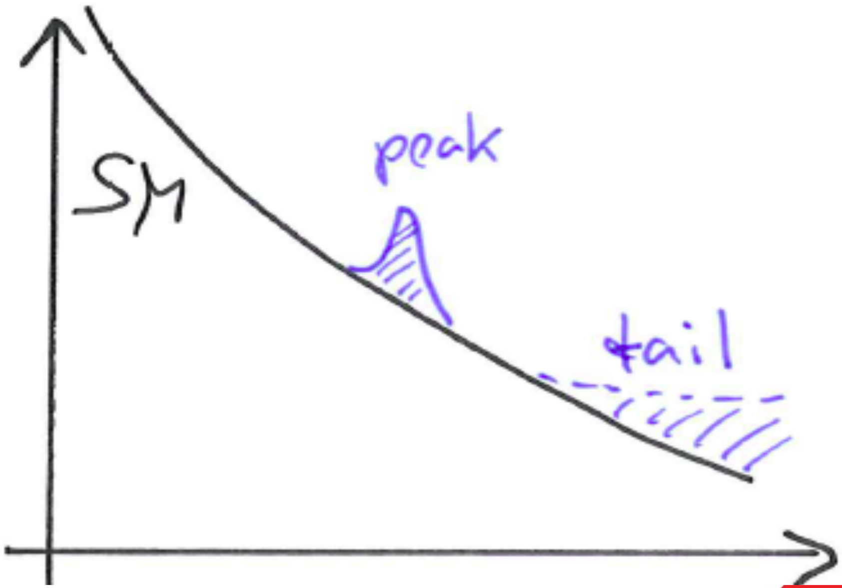


High Mass Resonances

- On-shell production of new particles leads to resonance in the mass spectrum.
- Off-shell: Modifies shape of SM distributions (think Rutherford Scattering), e.g. 4-point contact interaction model of compositeness.



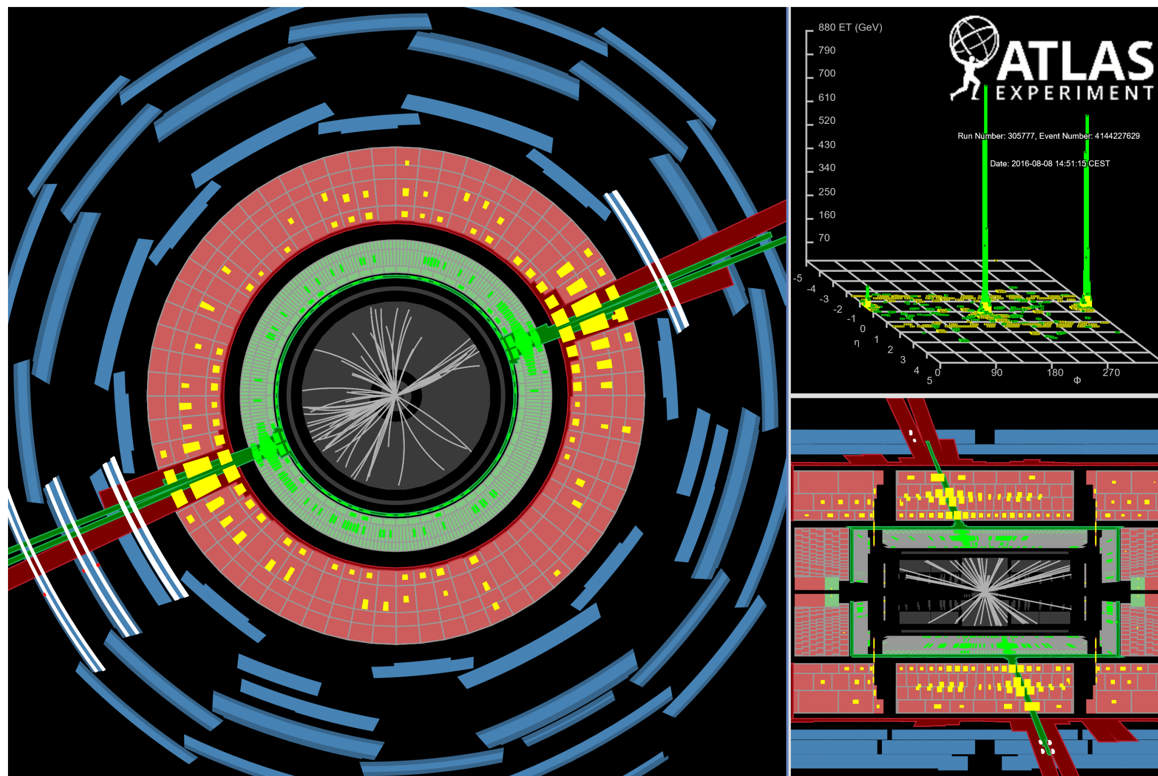




Dijet Bump Hunt

- Quarks and gluons lead to jets of particles in the detector.

- reconstruct energy deposition in calorimeter within a cone ("anti-k_t" clustering algorithm with R=0.4).
- we select events where at least on jet has transverse momentum > 380 GeV.
- offline we apply quality cuts to remove "detector noise"
- apply kinematic cuts to ensure that trigger is 100% efficient and to optimise signal to background.
  - p_T(jet 1) > 440 GeV
  - p_T(jet 2) > 60 GeV
  - m_{jj} > 1.1 TeV
  - $|y^*|$ < 0.6 or 1.2



arXiv:1703.09127 submitted to PRD

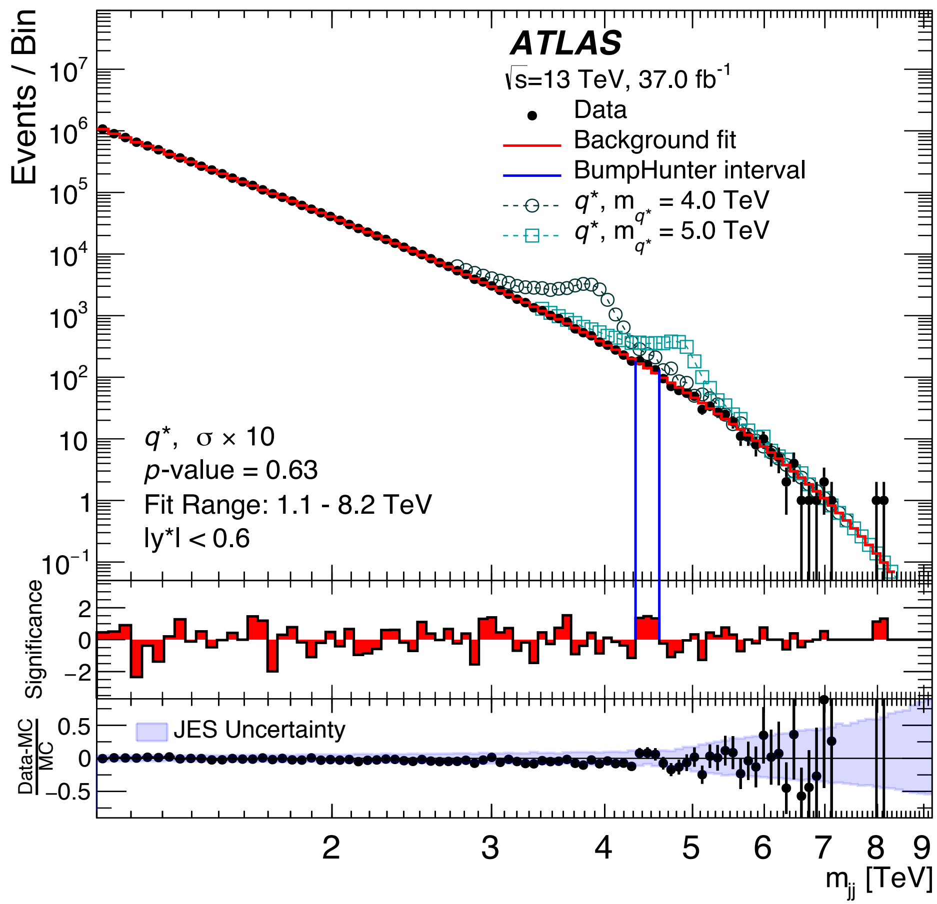
Dijet Bump Hunt

- Calculate the invariant mass for each event
- Fit the data to

$$f(z) = p_1(1-z)^{p_2} z^{p_3} z^{p_4 \log z}$$

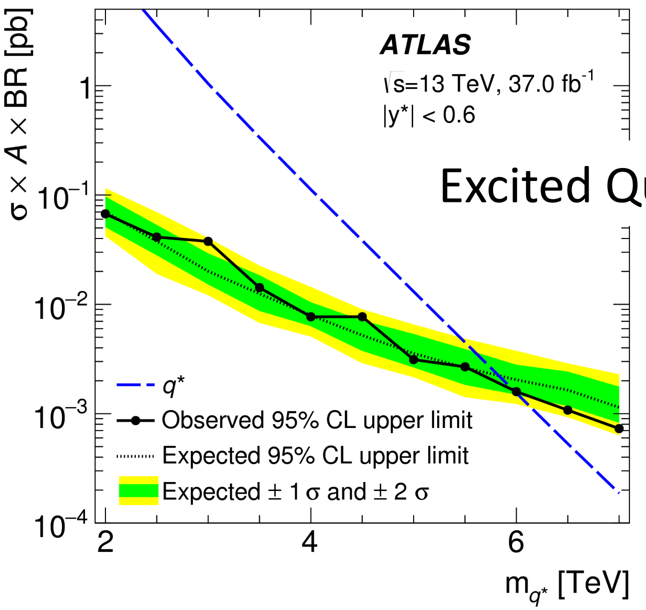
$$z = m_{jj}/\sqrt{s}$$

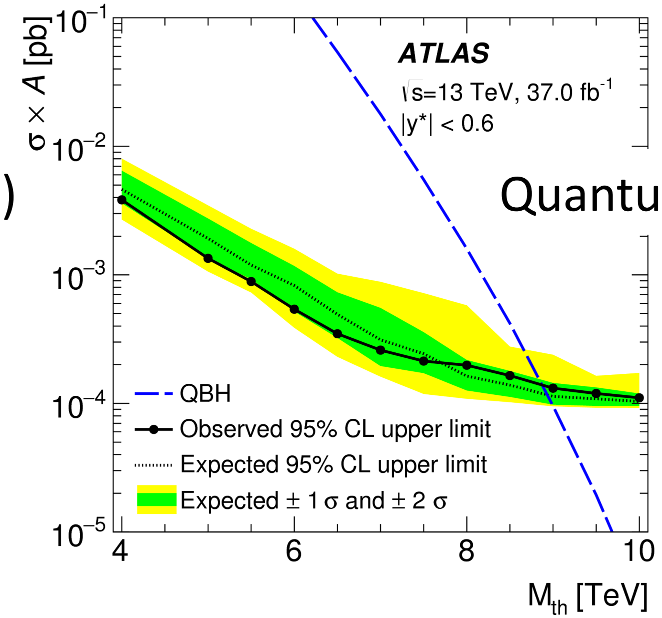
- Exclude a window from the fit
  - find the window with the largest excess.
  - method does not depend on a signal model.
  - the probability that fluctuations of the background model would produce an excess at least as significant as the one observed in data anywhere in the distribution is 0.63 including the look elsewhere effect.
  - Place Limits on different models

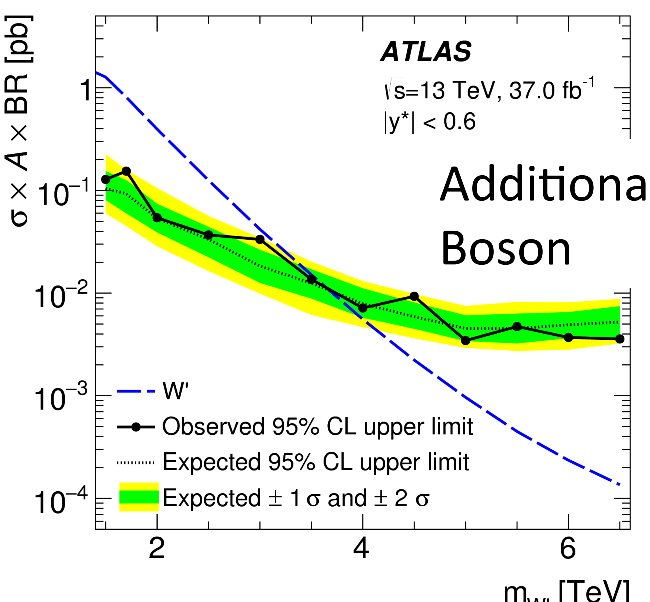


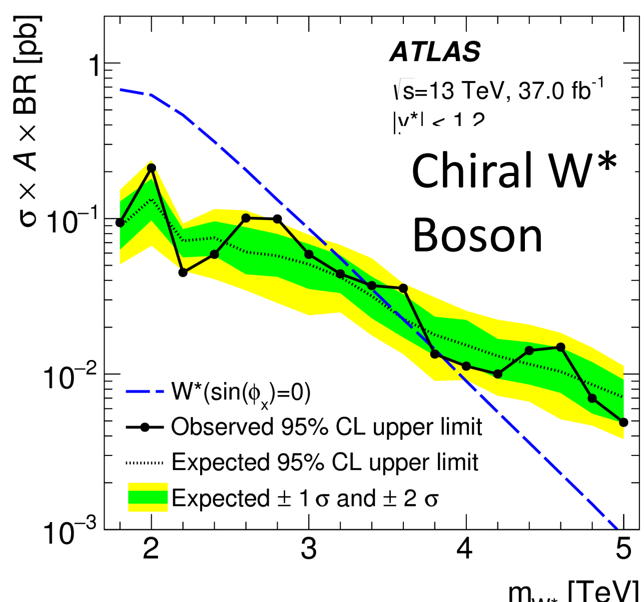
- Signal shapes depend on the decay products (quark or gluon)

Dijet Bump Hunt



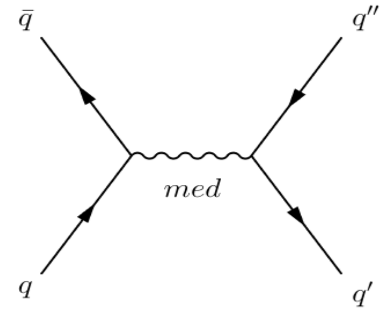






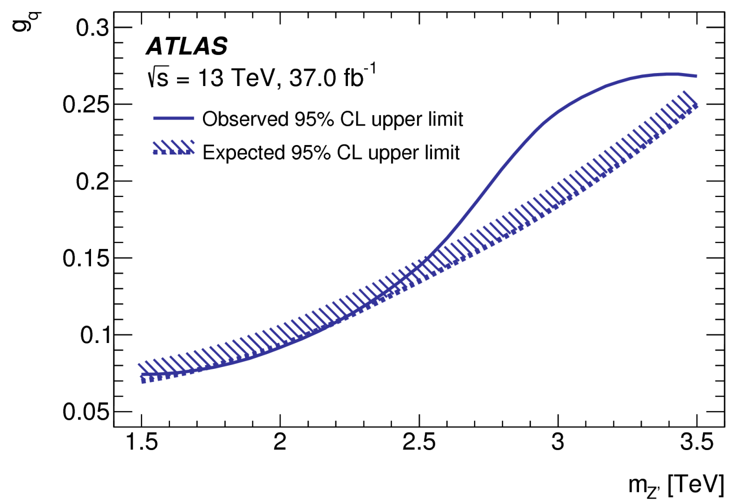
Dijet Bump Hunt

Can interpret a Z’ as a DM mediator with a coupling to quarks of g_q and a coupling to DM of $g_\chi = 1$.

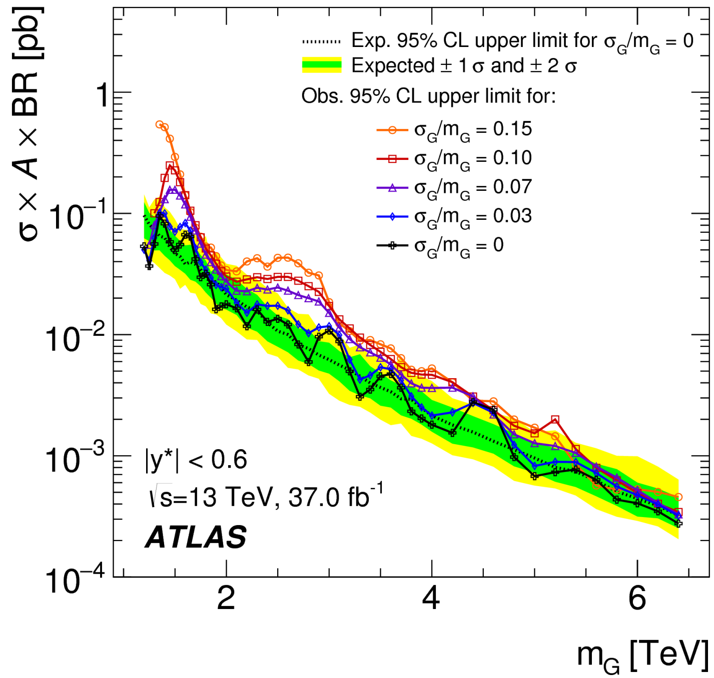


Folded Gaussians signal shapes

Leptophobic Z’:
Dark Matter Candidate



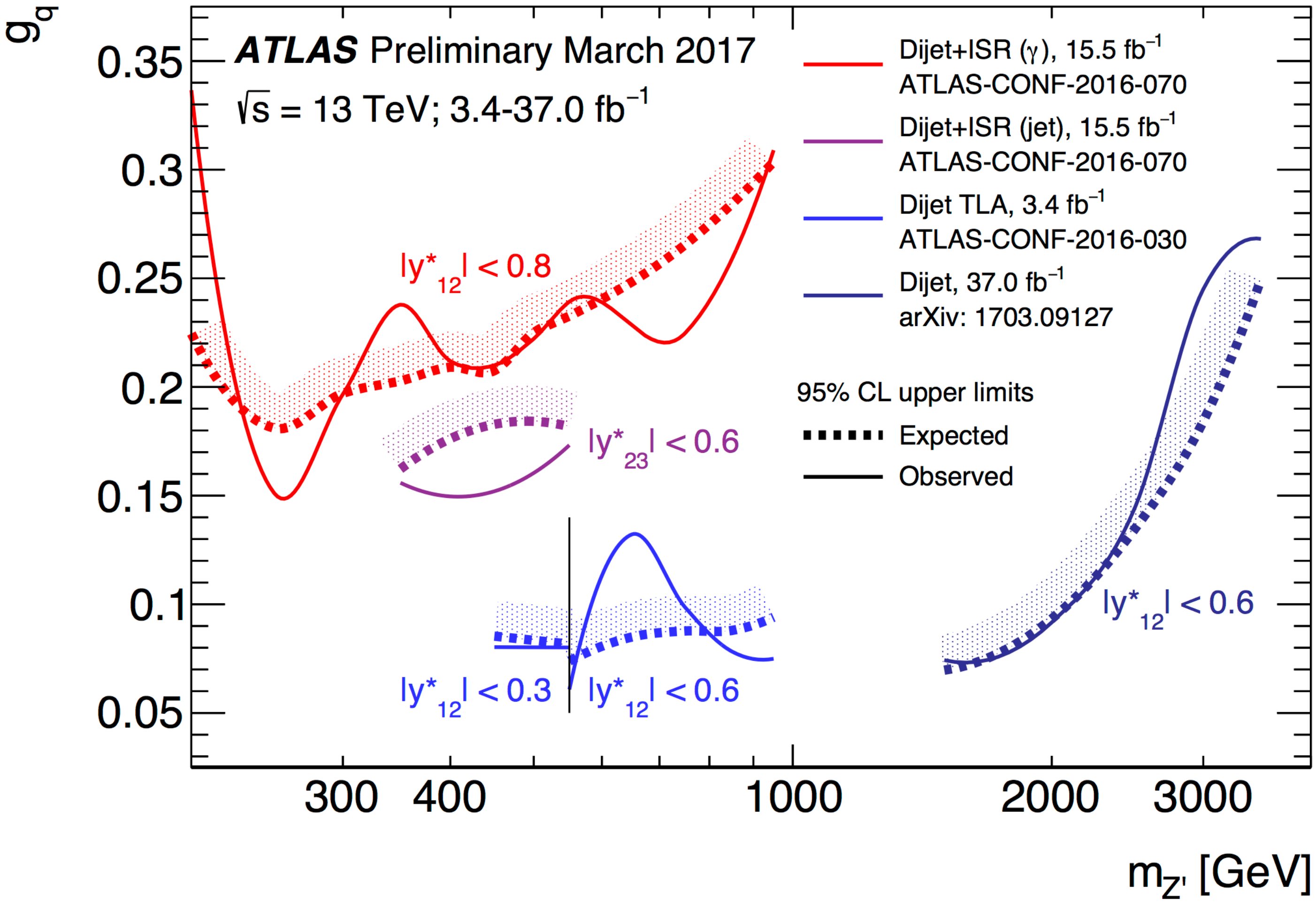
2D limits: coupling to quark (g_q) vs Z’ mass



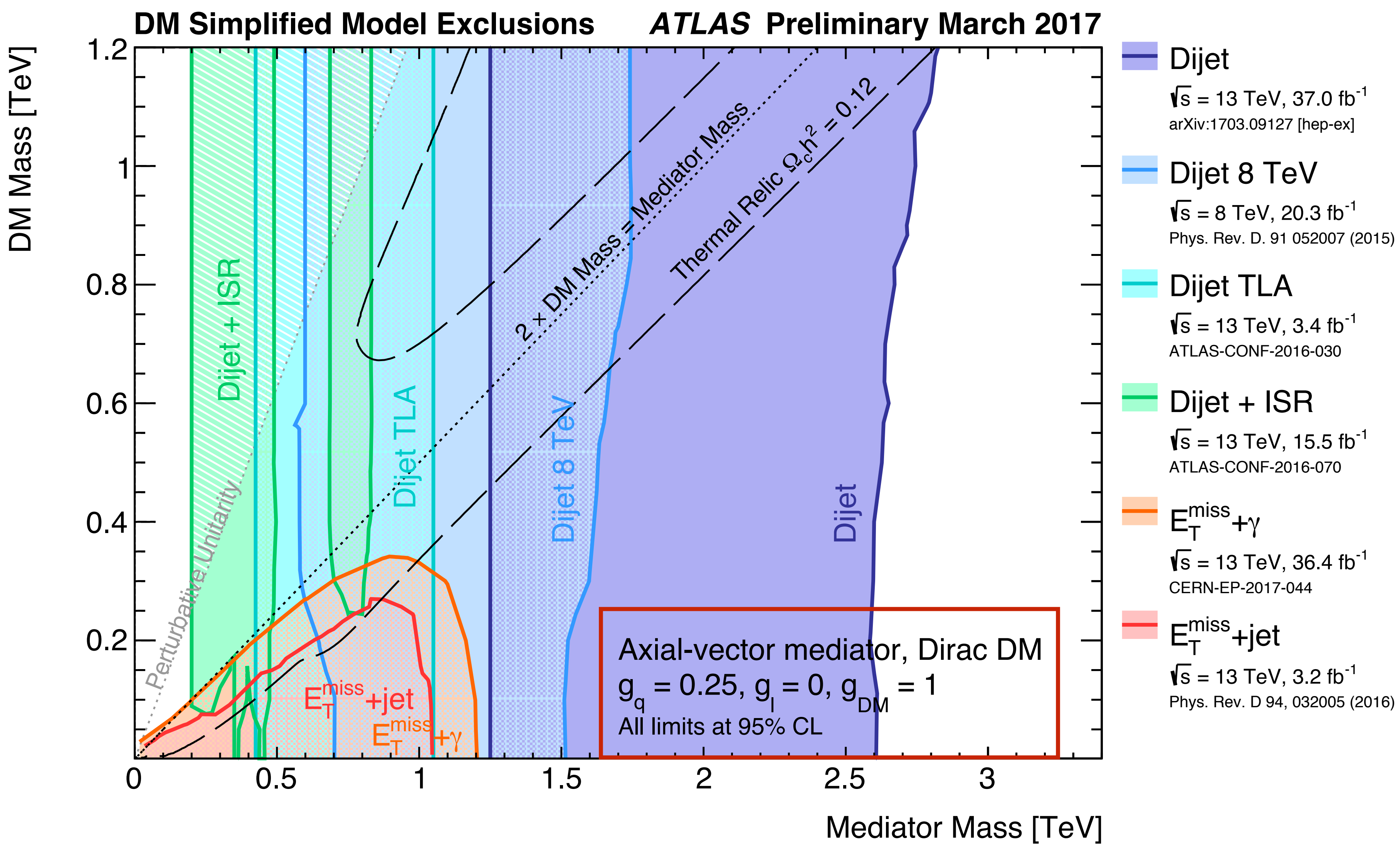
Apply jet energy folding to separate detector effects from intrinsic width

Dijet Bump Hunt: Z'

- Combine results with analysis carried out using information collected by the trigger and an analysis using events tagged by initial state radiation for more extensive limits (ATLAS Summary Plots).

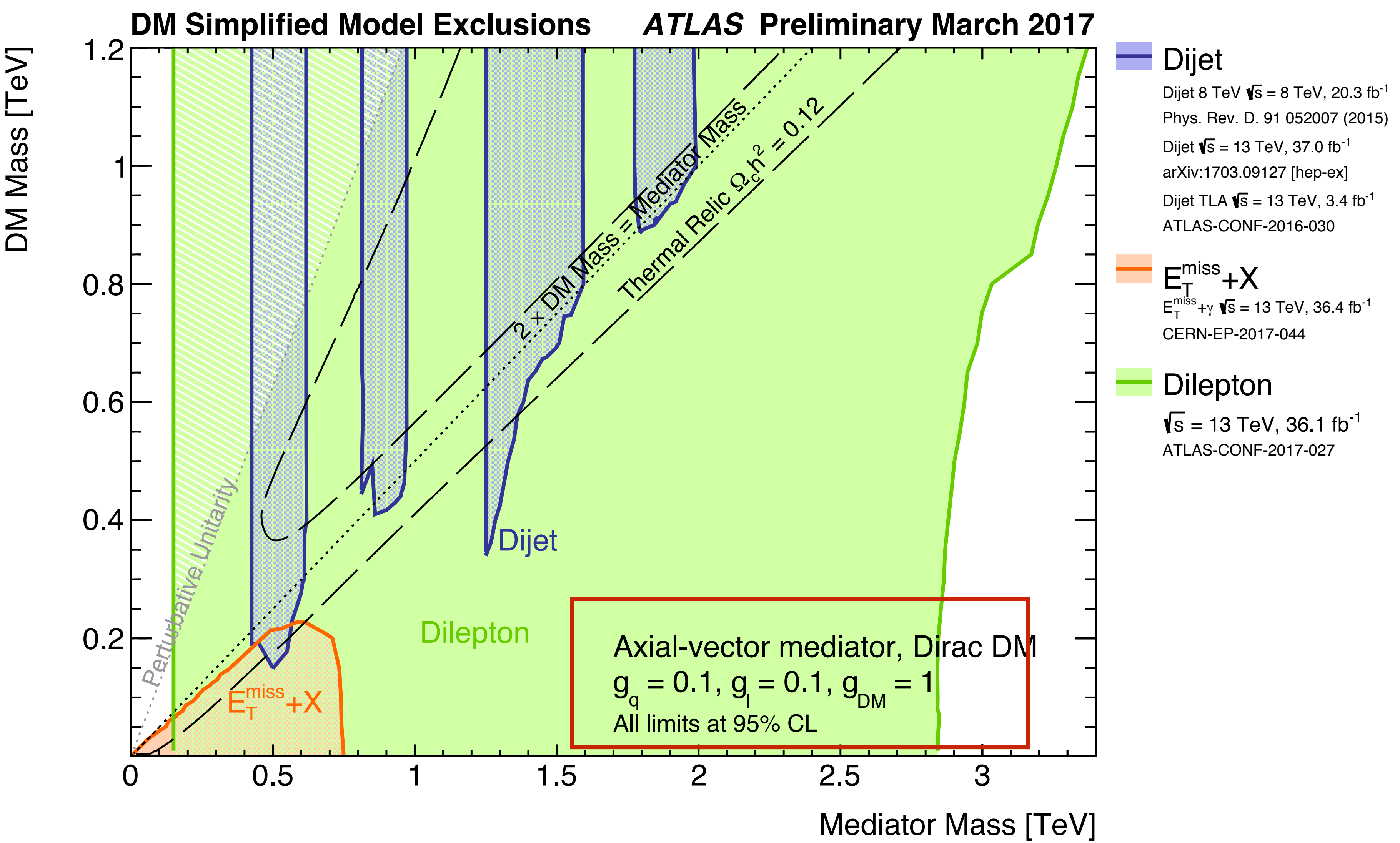


Combined DM Limits

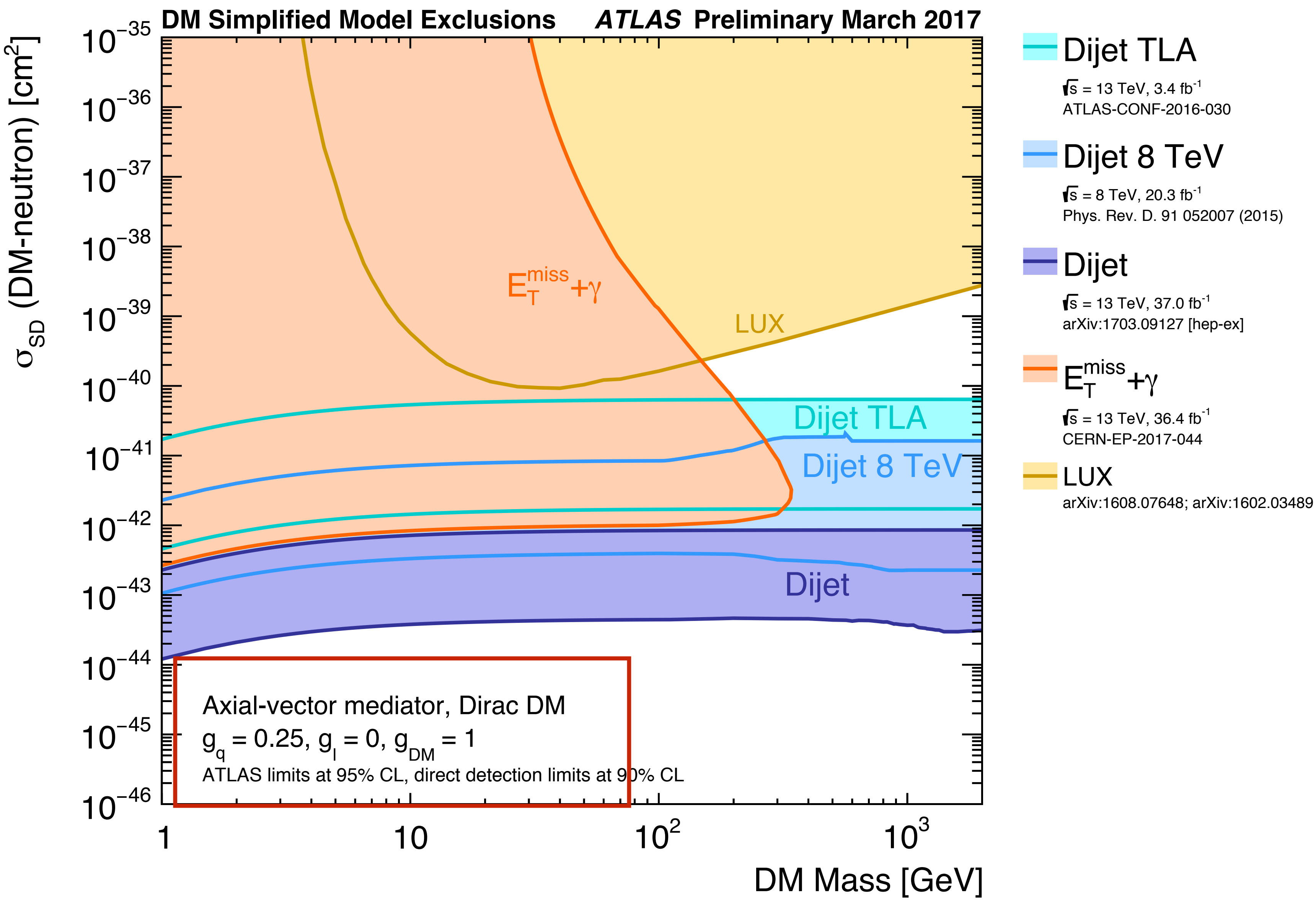


Combined DM Limits

Effect of changing couplings



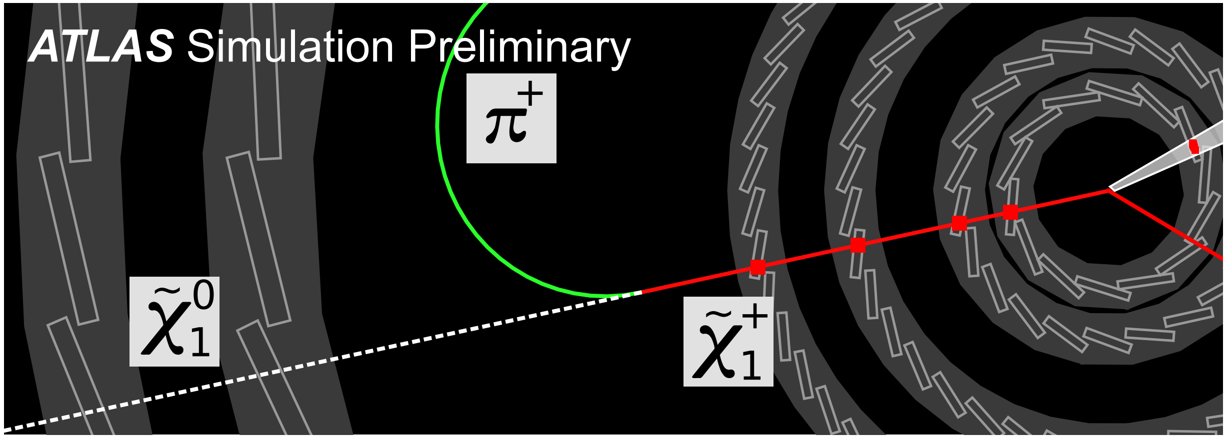
Combined DM Limits



Disappearing Tracks

ATLAS-CONF-2017-017

- In many supersymmetric models, the supersymmetric partners of the SM boson W fields, the wino fermions, are the lightest gaugino states.
- This implies that the lightest chargino is nearly mass-degenerate with the LSP, and its lifetime can be long enough to have measurable effects

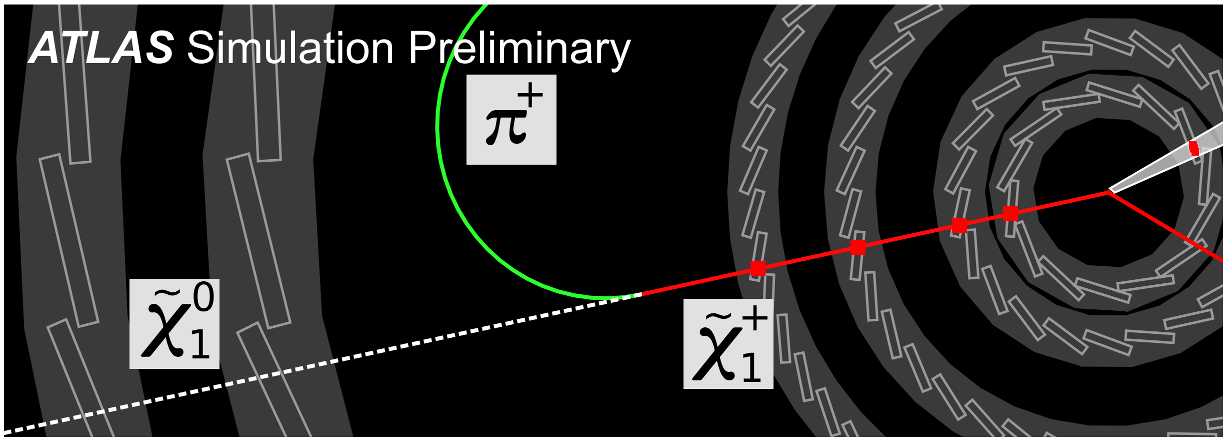


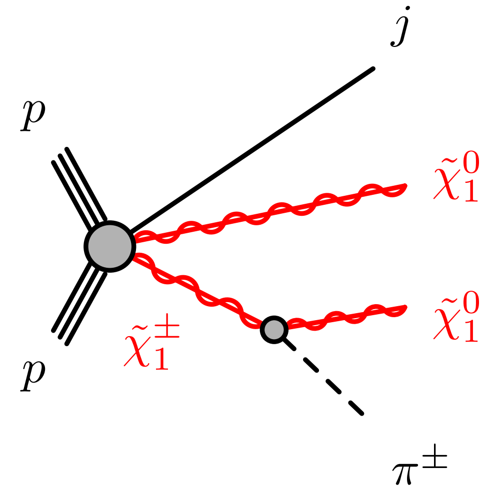
- For Wino LSP generic prediction of ~160 MeV splittings, or lifetimes of ~0.2ns -> 6cm distance travelled in the detector.
  - Chargino leaves a short track!

Disappearing Tracks

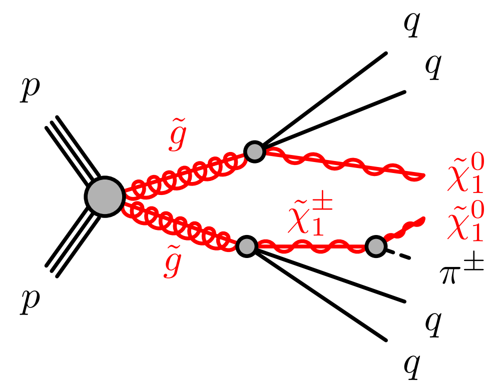
ATLAS-CONF-2017-017

- Search for long-lived charginos based on a disappearing-track signature.





- Chargino and neutralino are nearly mass degenerate.
  - The soft pions in the decays are not reconstructed.
  - Chargino leaves a short track!

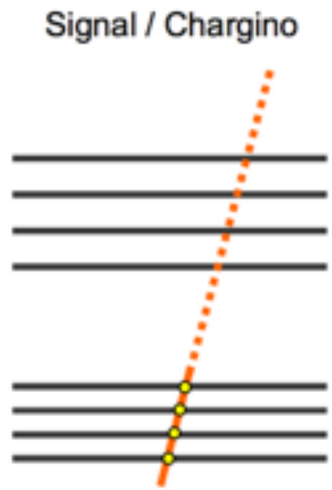


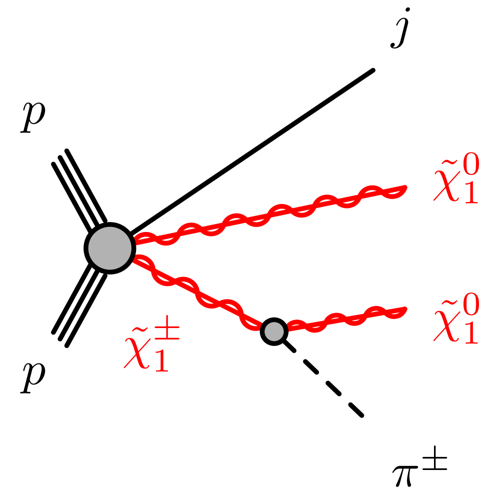
Disappearing Tracks

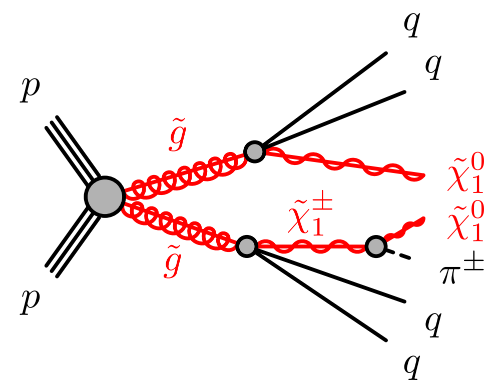
ATLAS-CONF-2017-017

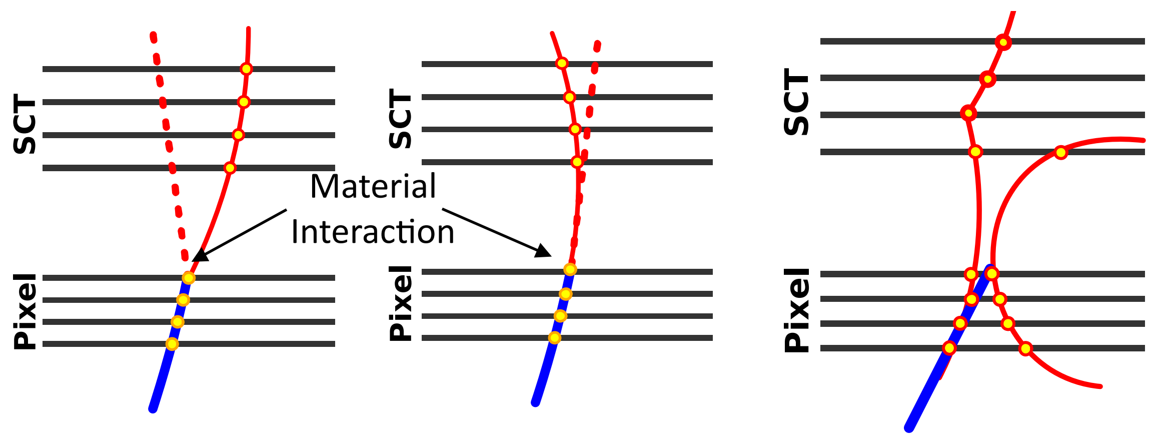
- Search for long-lived charginos based on a disappearing-track signature.

- Background to the signal are caused by
  - hard scatters of hadrons and leptons.
  - fake trackless from noise or combinatorics from multiple tracks.









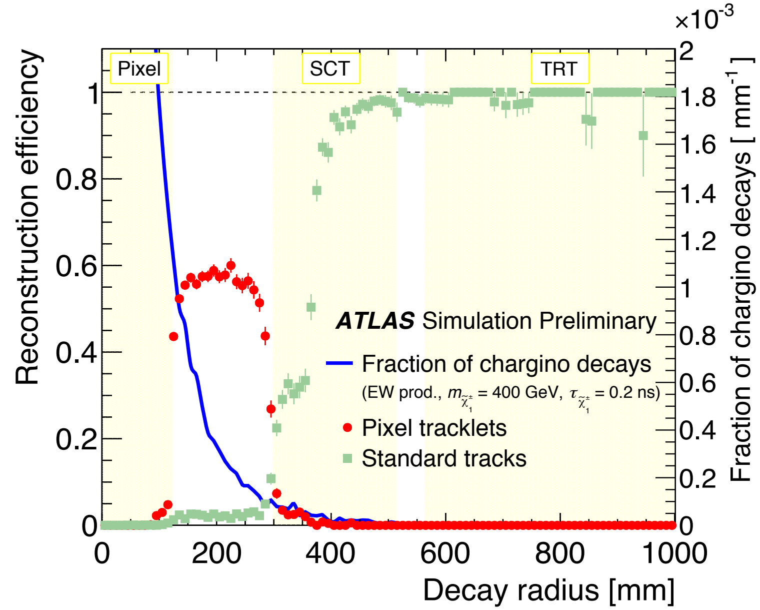
hadron background

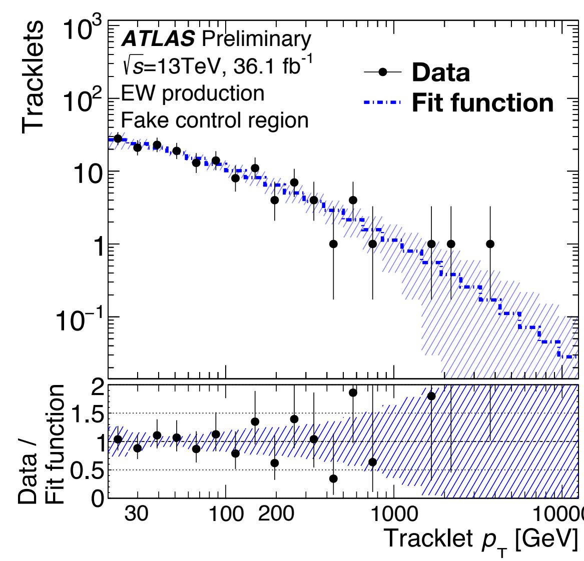
lepton background

fake background

Disappearing Tracks

- Using tracks that are only visible in the pixel detector to increase acceptance for small lifetimes by a factor of 10.
- Data Selection
  - **Tracklets (signal)**
    p_T > 20 GeV and highest in event, are isolated ($p_T^{cone(0.4)}/p_T < 0.04$), $0.1 < |\eta| < 1.9$, all pixel layers and no additional hits
  - **Electroweak chargino production**:
    MET > 140 GeV, at least one jet p_T > 140 GeV, jet and MET are not collinear ($\Delta\phi > 1.0$)
  - **Strong production**:
    MET > 150 GeV, one jet p_T > 100 GeV, and at least two additional jets with p_T > 50 GeV and the jets & MET are not collinear ($\Delta\phi > 0.4$)

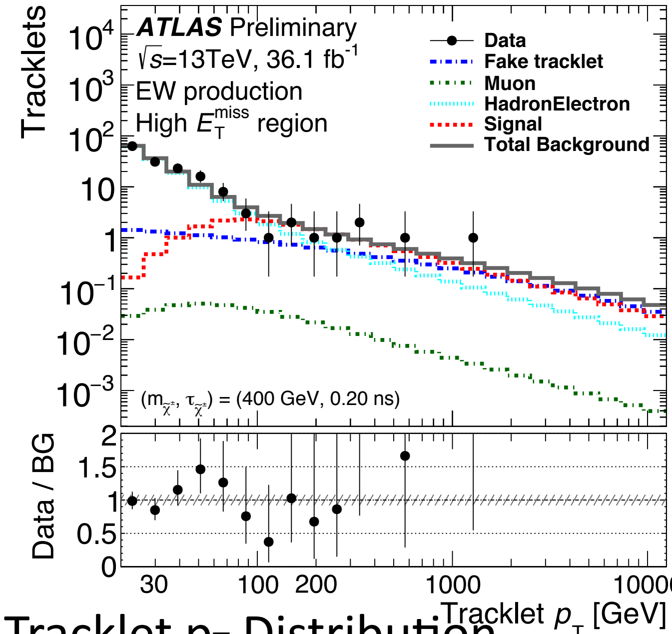




Background Estimation

Disappearing Tracks

- Backgrounds estimated by a simultaneous fit to the tracklet p_T distribution
  - p_T templates are built for each background category
  - No significant excess is observed



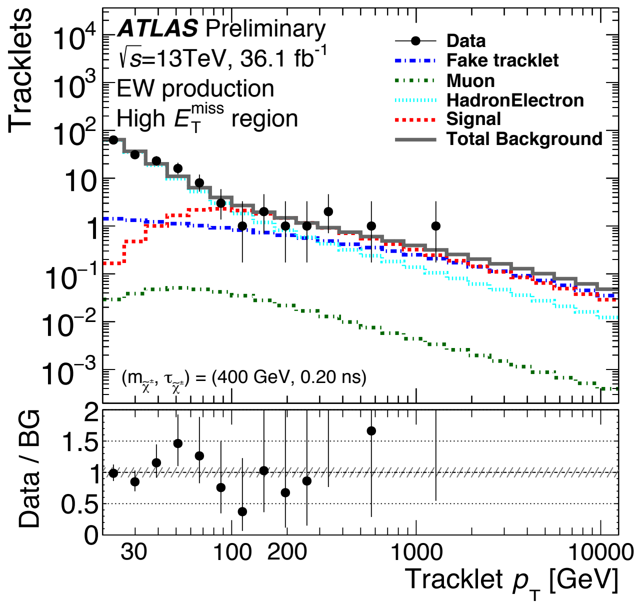
Tracklet p_T Distribution

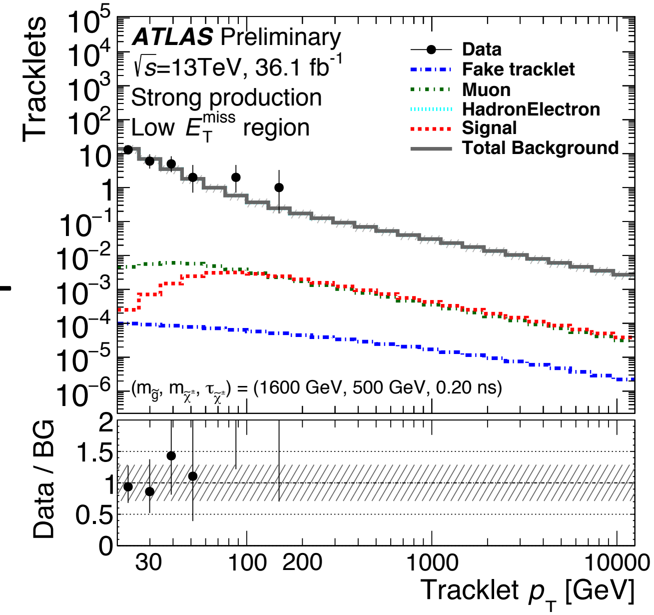
High E_T^{miss} region	Electroweak channel $(m_{\tilde{\chi}_1^\pm}, \tau_{\tilde{\chi}_1^\pm})$ =(400 GeV, 0.2 ns)	Strong channel $(m_{\tilde{g}}, m_{\tilde{\chi}_1^\pm}, \tau_{\tilde{\chi}_1^\pm})$ =(1600 GeV, 500 GeV, 0.2 ns)
Number of observed events with $p_T > 100$ GeV		
Observed	9	2
Number of expected events with $p_T > 100$ GeV		
Hadron+electron background	6.1 ± 0.6	2.08 ± 0.35
Muon background	0.1549 ± 0.0022	0.0385 ± 0.0005
Fake background	5.5 ± 3.3	0.0 ± 0.8
Total background	11.8 ± 3.1	2.1 ± 0.9
Expected signal	10.4 ± 1.7	4.1 ± 0.5
CL_b	0.39	0.702
Observed $\sigma_{vis}^{95\%}$ [fb]	0.22	0.14
Expected $\sigma_{vis}^{95\%}$ [fb]	$0.24^{+0.10}_{-0.07}$	$0.11^{+0.06}_{-0.04}$

Disappearing Tracks

EW Production

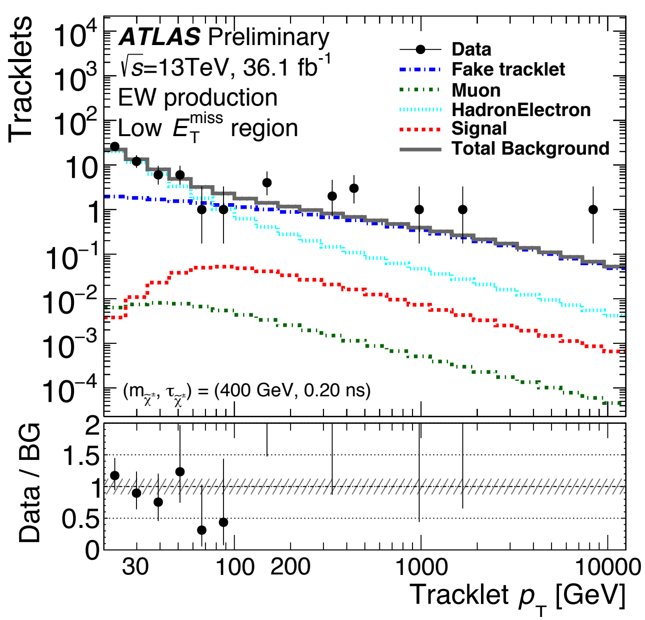
Low MET

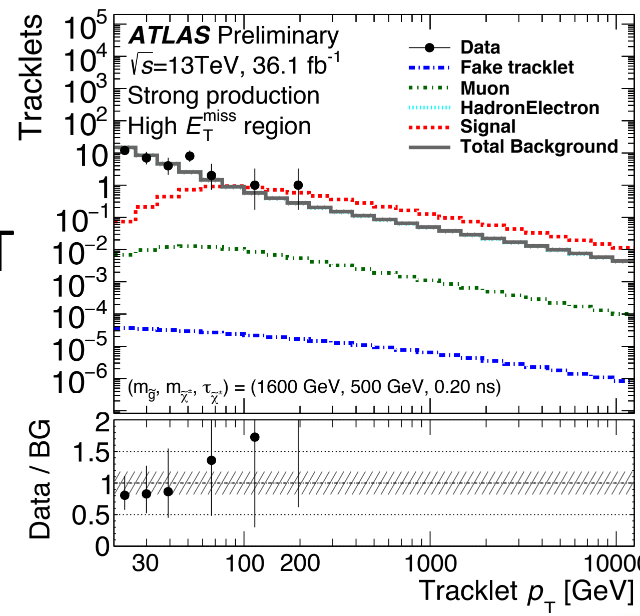




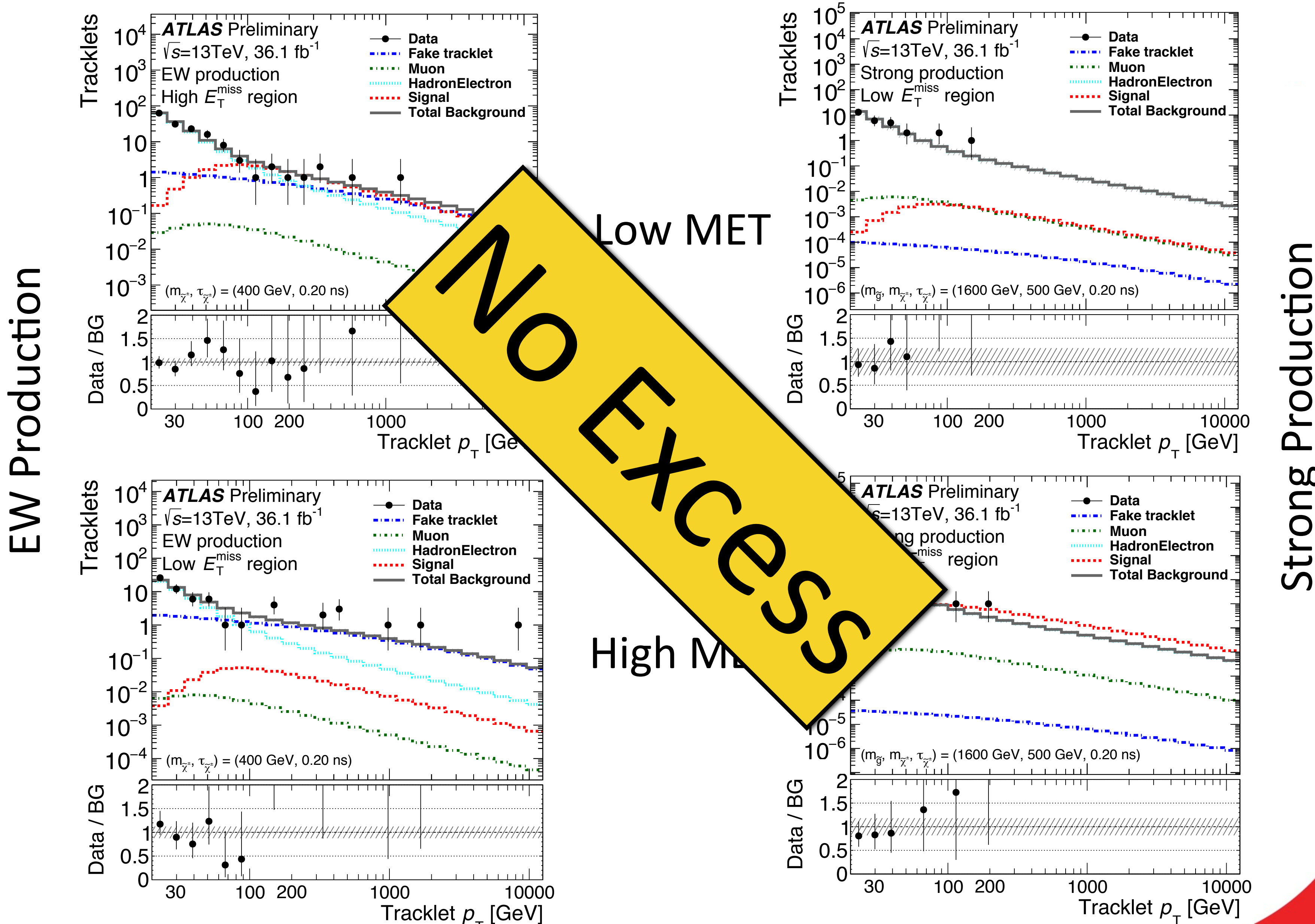
Strong Production

High MET





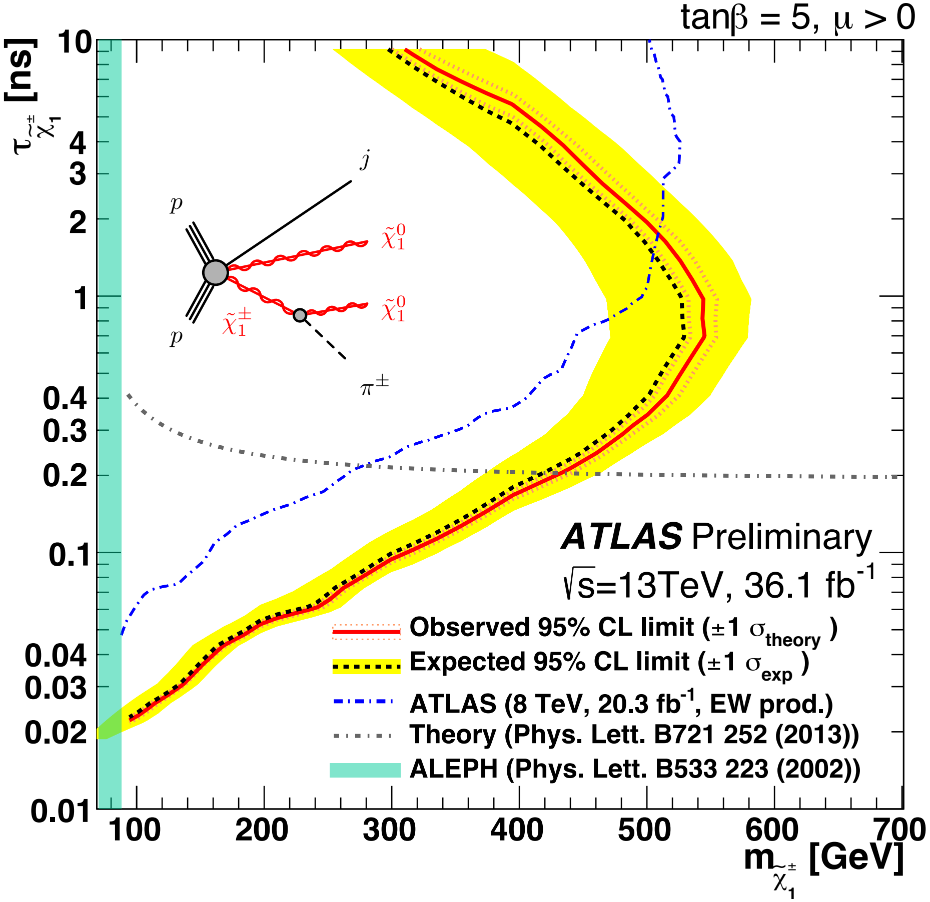
Disappearing Tracks



Disappearing Tracks

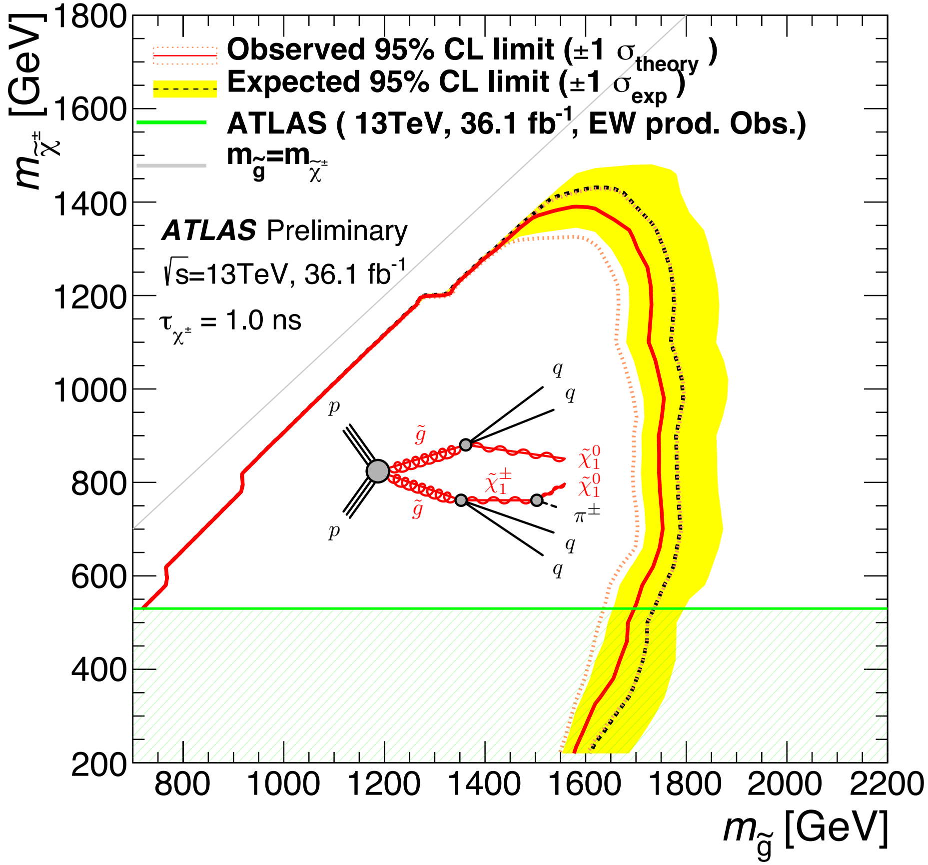
- Extract Limits based on cross section

Electroweak Limits



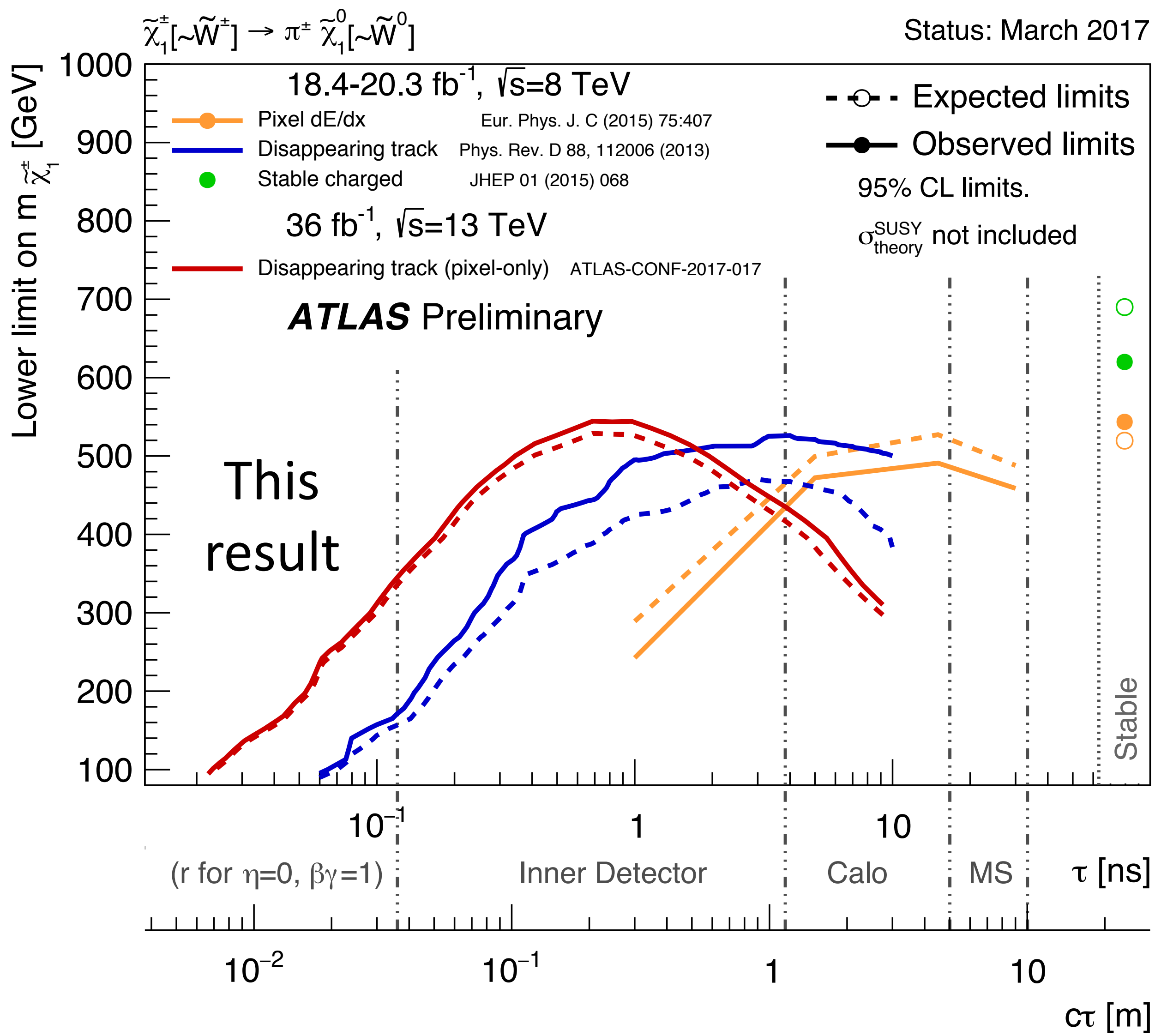
Strong Limits

Lifetime = 1.0 ns



Disappearing Tracks

- Combined with other ATLAS analyses



ATLAS EXPERIMENT

SUSY Summary

Lancaster University

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: March 2017

ATLAS Preliminary

$\sqrt{s}$ = 7, 8, 13 TeV

$\sqrt{s}$ = 7, 8 TeV | $\sqrt{s}$ = 13 TeV

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt[\mathrm{fb}^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0-3 e,μ/1-2 τ	2-10 jets/3 b	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.85 TeV	$m(\tilde{q})=m(\tilde{g})$	1507.05525
	$\tilde{q}\tilde{q}, \tilde{q}\rightarrow q\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	$\tilde{q}$ 1.57 TeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(1^{st}$ gen. $\tilde{q})=m(2^{nd}$ gen. $\tilde{q})$	ATLAS-CONF-2017-022
	$\tilde{q}\tilde{q}, \tilde{q}\rightarrow q\tilde{\chi}_1^0$ (compressed)	mono-jet	1-3 jets	Yes	3.2	$\tilde{q}$ 608 GeV	$m(\tilde{q})-m(\tilde{\chi}_1^0)$<5 GeV	1604.07773
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	$\tilde{g}$ 2.02 TeV	$m(\tilde{\chi}_1^0)$<200 GeV	ATLAS-CONF-2017-022
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow qq\tilde{\chi}_1^{\pm}\rightarrow qqW^{\pm}\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	$\tilde{g}$ 2.01 TeV	$m(\tilde{\chi}_1^0)$<200 GeV, $m(\tilde{\chi}^{\pm})=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	ATLAS-CONF-2017-022
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow qq(\ell\ell/\nu\nu)\tilde{\chi}_1^0$	3 e,μ	4 jets	-	13.2	$\tilde{g}$ 1.7 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	ATLAS-CONF-2016-037
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow qqWZ\tilde{\chi}_1^0$	2 e,μ (SS)	0-3 jets	Yes	13.2	$\tilde{g}$ 1.6 TeV	$m(\tilde{\chi}_1^0)$ <500 GeV	ATLAS-CONF-2016-037
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	3.2	$\tilde{g}$ 2.0 TeV		1607.05979
	GGM (bino NLSP)	2 γ	-	Yes	3.2	$\tilde{g}$ 1.65 TeV	$c\tau$(NLSP)<0.1 mm	1606.09150
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	20.3	$\tilde{g}$ 1.37 TeV	$m(\tilde{\chi}_1^0)$<950 GeV, $c\tau$(NLSP)<0.1 mm, μ<0	1507.05493
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	13.3	$\tilde{g}$ 1.8 TeV	$m(\tilde{\chi}_1^0)$>680 GeV, $c\tau$(NLSP)<0.1 mm, μ>0	ATLAS-CONF-2016-066
	GGM (higgsino NLSP)	2 e,μ (Z)	2 jets	Yes	20.3	$\tilde{g}$ 900 GeV	m(NLSP)>430 GeV	1503.03290
	Gravitino LSP	0	mono-jet	Yes	20.3	$F^{1/2}$ scale 865 GeV	$m(\tilde{G})>1.8\times10^{-4}$ eV, $m(\tilde{g})=m(\tilde{q})$=1.5 TeV	1502.01518
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	36.1	$\tilde{g}$ 1.92 TeV	$m(\tilde{\chi}_1^0)$<600 GeV	ATLAS-CONF-2017-021
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	36.1	$\tilde{g}$ 1.97 TeV	$m(\tilde{\chi}_1^0)$<200 GeV	ATLAS-CONF-2017-021
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.37 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	1407.0600
3^{rd} gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\rightarrow b\tilde{\chi}_1^0$	0	2 b	Yes	3.2	$\tilde{b}_1$ 840 GeV	$m(\tilde{\chi}_1^0)$<100 GeV	1606.08772
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\rightarrow t\tilde{\chi}_1^{\pm}$	2 e,μ (SS)	1 b	Yes	13.2	$\tilde{b}_1$ 325-685 GeV	$m(\tilde{\chi}_1^0)$<150 GeV, $m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_1^0)$+100 GeV	ATLAS-CONF-2016-037
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow b\tilde{\chi}_1^{\pm}$	0-2 e,μ	1-2 b	Yes	4.7/13.3	$\tilde{t}_1$ 117-170 GeV; 200-720 GeV	$m(\tilde{\chi}_1^{\pm}) = 2m(\tilde{\chi}_1^0)$, $m(\tilde{\chi}_1^0)$=55 GeV	1209.2102, ATLAS-CONF-2016-077
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow Wb\tilde{\chi}_1^0$ or $t\tilde{\chi}_1^0$	0-2 e,μ	0-2 jets/1-2 b	Yes	20.3	$\tilde{t}_1$ 90-198 GeV; 205-950 GeV	$m(\tilde{\chi}_1^0)$=1 GeV	1506.08616, ATLAS-CONF-2017-020
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow c\tilde{\chi}_1^0$	0	mono-jet	Yes	3.2	$\tilde{t}_1$ 90-323 GeV	$m(\tilde{t}_1)-m(\tilde{\chi}_1^0)$=5 GeV	1604.07773
	$\tilde{t}_1\tilde{t}_1$ (natural GMSB)	2 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$ 150-600 GeV	$m(\tilde{\chi}_1^0)$>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\rightarrow\tilde{t}_1 + Z$	3 e,μ (Z)	1 b	Yes	36.1	$\tilde{t}_2$ 290-790 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2017-019
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\rightarrow\tilde{t}_1 + h$	1-2 e,μ	4 b	Yes	36.1	$\tilde{t}_2$ 320-880 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2017-019
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\rightarrow\ell\tilde{\chi}_1^0$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$ 90-335 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\rightarrow\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	13.3	$\tilde{\chi}_1^{\pm}$ 640 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2016-096
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\rightarrow\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	14.8	$\tilde{\chi}_1^{\pm}$ 580 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2016-093
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\rightarrow\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	13.3	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 1.0 TeV	$m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2016-096
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\rightarrow W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	2-3 e,μ	0-2 jets	Yes	20.3	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 425 GeV	$m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $\tilde{\ell}$ decoupled	1403.5294, 1402.7029
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\rightarrow W\tilde{\chi}_1^0 h\tilde{\chi}_1^0, h\rightarrow b\bar{b}/WW/\tau\tau/\gamma\gamma$	e,μ,γ	0-2 b	Yes	20.3	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 270 GeV	$m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $\tilde{\ell}$ decoupled	1501.07110
	$\tilde{\chi}_2^0\tilde{\chi}_3^0, \tilde{\chi}_{2,3}^0\rightarrow\tilde{\ell}_R\ell$	4 e,μ	0	Yes	20.3	$\tilde{\chi}_{2,3}^0$ 635 GeV	$m(\tilde{\chi}_2^0)=m(\tilde{\chi}_3^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_2^0)+m(\tilde{\chi}_1^0))$	1405.5086
	GGM (wino NLSP) weak prod.	1 e,μ + γ	-	Yes	20.3	$\tilde{W}$ 115-370 GeV	$c\tau$<1 mm	1507.05493
	GGM (bino NLSP) weak prod.	2 γ	-	Yes	20.3	$\tilde{W}$ 590 GeV	$c\tau$<1 mm	1507.05493
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	Disapp. trk	1 jet	Yes	36.1	$\tilde{\chi}_1^{\pm}$ 430 GeV	$m(\tilde{\chi}_1^{\pm})-m(\tilde{\chi}_1^0)$~160 MeV, $\tau(\tilde{\chi}_1^{\pm})$=0.2 ns	ATLAS-CONF-2017-017
	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	dE/dx trk	-	Yes	18.4	$\tilde{\chi}_1^{\pm}$ 495 GeV	$m(\tilde{\chi}_1^{\pm})-m(\tilde{\chi}_1^0)$~160 MeV, $\tau(\tilde{\chi}_1^{\pm})$<15 ns	1506.05332
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$ 850 GeV	$m(\tilde{\chi}_1^0)$=100 GeV, 10 $\mu s<\tau(\tilde{g})$<1000 s	1310.6584
	Stable $\tilde{g}$ R-hadron	trk	-	-	3.2	$\tilde{g}$ 1.58 TeV		1606.05129
	Metastable $\tilde{g}$ R-hadron	dE/dx trk	-	-	3.2	$\tilde{g}$ 1.57 TeV	$m(\tilde{\chi}_1^0)$=100 GeV, τ>10 ns	1604.04520
	GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0\rightarrow\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	19.1	$\tilde{\chi}_1^0$ 537 GeV	10<tanβ<50	1411.6795
	GMSB, $\tilde{\chi}_1^0\rightarrow\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	20.3	$\tilde{\chi}_1^0$ 440 GeV	$1<\tau(\tilde{\chi}_1^0)$<3 ns, SPS8 model	1409.5542
	$\tilde{g}\tilde{g}, \tilde{\chi}_1^0\rightarrow ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	$\tilde{\chi}_1^0$ 1.0 TeV	7 $<c\tau(\tilde{\chi}_1^0)<$ 740 mm, $m(\tilde{g})$=1.3 TeV	1504.05162
	GGM $\tilde{g}\tilde{g}, \tilde{\chi}_1^0\rightarrow Z\tilde{G}$	displ. vtx + jets	-	-	20.3	$\tilde{\chi}_1^0$ 1.0 TeV	6 $<c\tau(\tilde{\chi}_1^0)<$ 480 mm, $m(\tilde{g})$=1.1 TeV	1504.05162
RPV	LFV $pp\rightarrow\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\rightarrow e\mu/e\tau/\mu\tau$	$e\mu,e\tau,\mu\tau$	-	-	3.2	$\tilde{\nu}_\tau$ 1.9 TeV	λ'_{311}=0.11, $\lambda_{132/133/233}$=0.07	1607.08079
	Bilinear RPV CMSSM	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.45 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^0\rightarrow ee\nu, e\mu\nu, \mu\mu\nu$	4 e,μ	-	Yes	13.3	$\tilde{\chi}_1^{\pm}$ 1.14 TeV	$m(\tilde{\chi}_1^0)$>400GeV, $\lambda_{12k}\neq0$ $(k = 1, 2)$	ATLAS-CONF-2016-075
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^0\rightarrow\tau\tau\nu_e, e\tau\nu_\tau$	3 e,μ + τ	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 450 GeV	$m(\tilde{\chi}_1^0)>0.2\times m(\tilde{\chi}_1^{\pm})$, $\lambda_{133}\neq0$	1405.5086
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow qqq$	0	4-5 large-R jets	-	14.8	$\tilde{g}$ 1.08 TeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2016-057
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow qq\tilde{\chi}_1^0, \tilde{\chi}_1^0\rightarrow qqq$	0	4-5 large-R jets	-	14.8	$\tilde{g}$ 1.55 TeV	$m(\tilde{\chi}_1^0)$=800 GeV	ATLAS-CONF-2016-057
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow t\bar{t}\tilde{\chi}_1^0, \tilde{\chi}_1^0\rightarrow qqq$	1 e,μ	8-10 jets/0-4 b	-	36.1	$\tilde{g}$ 2.1 TeV	$m(\tilde{\chi}_1^0)$= 1 TeV, $\lambda_{112}\neq0$	ATLAS-CONF-2017-013
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{t}_1 t, \tilde{t}_1\rightarrow bs$	1 e,μ	8-10 jets/0-4 b	-	36.1	$\tilde{g}$ 1.65 TeV	$m(\tilde{t}_1)$= 1 TeV, $\lambda_{323}\neq0$	ATLAS-CONF-2017-013
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow bs$	0	2 jets + 2 b	-	15.4	$\tilde{t}_1$ 410 GeV; 450-510 GeV		ATLAS-CONF-2016-022, ATLAS-CONF-2016-084
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow b\ell$	2 e,μ	2 b	-	20.3	$\tilde{t}_1$ 0.4-1.0 TeV	BR($\tilde{t}_1\rightarrow be/\mu$)>20%	ATLAS-CONF-2015-015
Other	Scalar charm, $\tilde{c}\rightarrow c\tilde{\chi}_1^0$	0	2 c	Yes	20.3	$\tilde{c}$ 510 GeV	$m(\tilde{\chi}_1^0)$<200 GeV	1501.01325

Mass scale [TeV] (axis: 10^{-1} – 1)

*Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

Inclusive | 3rd gen | EW direct | long life | RPV

March 2017

ATLAS EXPERIMENT

Many Searches: Exotics

Lancaster University

ATLAS Exotics Searches* - 95% CL Exclusion

Status: August 2016

ATLAS Preliminary

$\int \mathcal{L}\, dt = (3.2 - 20.3)\ \text{fb}^{-1}$ $\quad \sqrt{s} = 8, 13$ TeV

	Model	ℓ, γ	Jets†	E_T^{miss}	$\int \mathcal{L}\, dt [\text{fb}^{-1}]$	Limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	–	≥ 1 j	Yes	3.2	M_D 6.58 TeV	$n = 2$	1604.07773
	ADD non-resonant $\ell\ell$	2 e, μ	–	–	20.3	M_S 4.7 TeV	$n = 3$ HLZ	1407.2410
	ADD QBH $\to \ell q$	1 e, μ	1 j	–	20.3	M_{th} 5.2 TeV	$n = 6$	1311.2006
	ADD QBH	–	2 j	–	15.7	M_{th} 8.7 TeV	$n = 6$	ATLAS-CONF-2016-069
	ADD BH high $\sum p_T$	≥ 1 e, μ	≥ 2 j	–	3.2	M_{th} 8.2 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1606.02265
	ADD BH multijet	–	≥ 3 j	–	3.6	M_{th} 9.55 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1512.02586
	RS1 $G_{KK} \to \ell\ell$	2 e, μ	–	–	20.3	G_{KK} mass 2.68 TeV	$k/\overline{M}_{Pl} = 0.1$	1405.4123
	RS1 $G_{KK} \to \gamma\gamma$	2 γ	–	–	3.2	G_{KK} mass 3.2 TeV	$k/\overline{M}_{Pl} = 0.1$	1606.03833
	Bulk RS $G_{KK} \to WW \to qq\ell\nu$	1 e, μ	1 J	Yes	13.2	G_{KK} mass 1.24 TeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2016-062
	Bulk RS $G_{KK} \to HH \to bbbb$	–	4 b	–	13.3	G_{KK} mass 360-860 GeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2016-049
	Bulk RS $g_{KK} \to tt$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	20.3	g_{KK} mass 2.2 TeV	BR = 0.925	1505.07018
	2UED / RPP	1 e, μ	≥ 2 b, ≥ 4 j	Yes	3.2	KK mass 1.46 TeV	Tier (1,1), BR($A^{(1,1)} \to tt$) = 1	ATLAS-CONF-2016-013
Gauge bosons	SSM $Z' \to \ell\ell$	2 e, μ	–	–	13.3	Z' mass 4.05 TeV		ATLAS-CONF-2016-045
	SSM $Z' \to \tau\tau$	2 τ	–	–	19.5	Z' mass 2.02 TeV		1502.07177
	Leptophobic $Z' \to bb$	–	2 b	–	3.2	Z' mass 1.5 TeV		1603.08791
	SSM $W' \to \ell\nu$	1 e, μ	–	Yes	13.3	W' mass 4.74 TeV		ATLAS-CONF-2016-061
	HVT $W' \to WZ \to qq\nu\nu$ model A	0 e, μ	1 J	Yes	13.2	W' mass 2.4 TeV	$g_V = 1$	ATLAS-CONF-2016-082
	HVT $W' \to WZ \to qqqq$ model B	–	2 J	–	15.5	W' mass 3.0 TeV	$g_V = 3$	ATLAS-CONF-2016-055
	HVT $V' \to WH/ZH$ model B	multi-channel			3.2	V' mass 2.31 TeV	$g_V = 3$	1607.05621
	LRSM $W'_R \to tb$	1 e, μ	2 b, 0-1 j	Yes	20.3	W' mass 1.92 TeV		1410.4103
	LRSM $W'_R \to tb$	0 e, μ	≥ 1 b, 1 J	–	20.3	W' mass 1.76 TeV		1408.0886
CI	CI $qqqq$	–	2 j	–	15.7	Λ 19.9 TeV	$\eta_{LL} = -1$	ATLAS-CONF-2016-069
	CI $\ell\ell qq$	2 e, μ	–	–	3.2	Λ 25.2 TeV	$\eta_{LL} = -1$	1607.03669
	CI $uutt$	2(SS)/≥3 e, μ	≥1 b, ≥1 j	Yes	20.3	Λ 4.9 TeV	$\lvert C_{RR} \rvert = 1$	1504.04605
DM	Axial-vector mediator (Dirac DM)	0 e, μ	≥ 1 j	Yes	3.2	m_A 1.0 TeV	g_q=0.25, g_χ=1.0, $m(\chi) < 250$ GeV	1604.07773
	Axial-vector mediator (Dirac DM)	0 e, μ, 1 γ	1 j	Yes	3.2	m_A 710 GeV	g_q=0.25, g_χ=1.0, $m(\chi) < 150$ GeV	1604.01306
	$ZZ\chi\chi$ EFT (Dirac DM)	0 e, μ	1 J, ≤ 1 j	Yes	3.2	M_* 550 GeV	$m(\chi) < 150$ GeV	ATLAS-CONF-2015-080
LQ	Scalar LQ 1st gen	2 e	≥ 2 j	–	3.2	LQ mass 1.1 TeV	$\beta = 1$	1605.06035
	Scalar LQ 2nd gen	2 μ	≥ 2 j	–	3.2	LQ mass 1.05 TeV	$\beta = 1$	1605.06035
	Scalar LQ 3rd gen	1 e, μ	≥1 b, ≥3 j	Yes	20.3	LQ mass 640 GeV	$\beta = 0$	1508.04735
Heavy quarks	VLQ $TT \to Ht + X$	1 e, μ	≥ 2 b, ≥ 3 j	Yes	20.3	T mass 855 GeV	T in (T,B) doublet	1505.04306
	VLQ $YY \to Wb + X$	1 e, μ	≥ 1 b, ≥ 3 j	Yes	20.3	Y mass 770 GeV	Y in (B,Y) doublet	1505.04306
	VLQ $BB \to Hb + X$	1 e, μ	≥ 2 b, ≥ 3 j	Yes	20.3	B mass 735 GeV	isospin singlet	1505.04306
	VLQ $BB \to Zb + X$	2/≥3 e, μ	≥2/≥1 b	–	20.3	B mass 755 GeV	B in (B,Y) doublet	1409.5500
	VLQ $QQ \to WqWq$	1 e, μ	≥ 4 j	Yes	20.3	Q mass 690 GeV		1509.04261
	VLQ $T_{5/3} T_{5/3} \to WtWt$	2(SS)/≥3 e, μ	≥1 b, ≥1 j	Yes	3.2	$T_{5/3}$ mass 990 GeV		ATLAS-CONF-2016-032
Excited fermions	Excited quark $q^* \to q\gamma$	1 γ	1 j	–	3.2	q^* mass 4.4 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1512.05910
	Excited quark $q^* \to qg$	–	2 j	–	15.7	q^* mass 5.6 TeV	only u^* and d^*, $\Lambda = m(q^*)$	ATLAS-CONF-2016-069
	Excited quark $b^* \to bg$	–	1 b, 1 j	–	8.8	b^* mass 2.3 TeV		ATLAS-CONF-2016-060
	Excited quark $b^* \to Wt$	1 or 2 e, μ	1 b, 2-0 j	Yes	20.3	b^* mass 1.5 TeV	$f_g = f_L = f_R = 1$	1510.02664
	Excited lepton ℓ^*	3 e, μ	–	–	20.3	ℓ^* mass 3.0 TeV	$\Lambda = 3.0$ TeV	1411.2921
	Excited lepton ν^*	3 e, μ, τ	–	–	20.3	ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	LSTC $a_T \to W\gamma$	1 e, μ, 1 γ	–	Yes	20.3	a_T mass 960 GeV		1407.8150
	LRSM Majorana ν	2 e, μ	2 j	–	20.3	N^0 mass 2.0 TeV	$m(W_R) = 2.4$ TeV, no mixing	1506.06020
	Higgs triplet $H^{\pm\pm} \to ee$	2 e (SS)	–	–	13.9	$H^{\pm\pm}$ mass 570 GeV	DY production, BR($H_L^{\pm\pm} \to ee$)=1	ATLAS-CONF-2016-051
	Higgs triplet $H^{\pm\pm} \to \ell\tau$	3 e, μ, τ	–	–	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, BR($H_L^{\pm\pm} \to \ell\tau$)=1	1411.2921
	Monotop (non-res prod)	1 e, μ	1 b	Yes	20.3	spin-1 invisible particle mass 657 GeV	$a_{\text{non-res}} = 0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	multi-charged particle mass 785 GeV	DY production, $\lvert q \rvert = 5e$	1504.04188
	Magnetic monopoles	–	–	–	7.0	monopole mass 1.34 TeV	DY production, $\lvert g \rvert = 1 g_D$, spin 1/2	1509.08059

$\sqrt{s} = 8$ TeV $\quad \sqrt{s} = 13$ TeV

Mass scale [TeV] (10^{-1}, 1, 10)

*Only a selection of the available mass limits on new states or phenomena is shown. Lower bounds are specified only when explicitly not excluded.

†Small-radius (large-radius) jets are denoted by the letter j (J).

August 2016

Summary

- ATLAS has searched for Beyond the Standard Model Phenomena using many different signatures
  - No sign of new physics.
- The LHC goals for 2017 is to reach an integrated luminosity of 45 fb^{-1} [reached 40 fb^{-1} last year] and preferably go beyond.
  - based on past performance could go as high as 60 fb^{-1} with luck.
- Stay Tuned for new and interesting results over the coming year.

ATLAS Physics Results

https://twiki.cern.ch/twiki/bin/view/AtlasPublic

Full Title	Journal	Links	Status	Groups
Search for new phenomena in a lepton plus high jet multiplicity final state with the ATLAS experiment using $\sqrt{s}$ = 13 TeV proton-proton collision data	JHEP	Inspire, arXiv, Figures	Submitted: 2017/04/27	SUSY
Performance of the ATLAS Track Reconstruction Algorithms in Dense Environments in LHC run 2	EPJC	Inspire, arXiv, Figures	Submitted: 2017/04/26	IDTR
Measurements of integrated and differential cross sections for isolated photon pair production in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector	PRD	Inspire, arXiv, Figures	Submitted: 2017/04/12	STDM
Search for dark matter at $\sqrt{s} = 13$ TeV in final states containing an energetic photon and large missing transverse momentum with the ATLAS detector	EPJC	Inspire, arXiv, Figures	Submitted: 2017/04/12	EXOT
Measurement of the k_t splitting scales in $Z \to \ell\ell$ events in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector	JHEP	Inspire, arXiv, Figures	Submitted: 2017/04/05	STDM