Exotics searches in ATLAS

Michiru Kaneda (CERN)

On behalf of the ATLAS Collaboration

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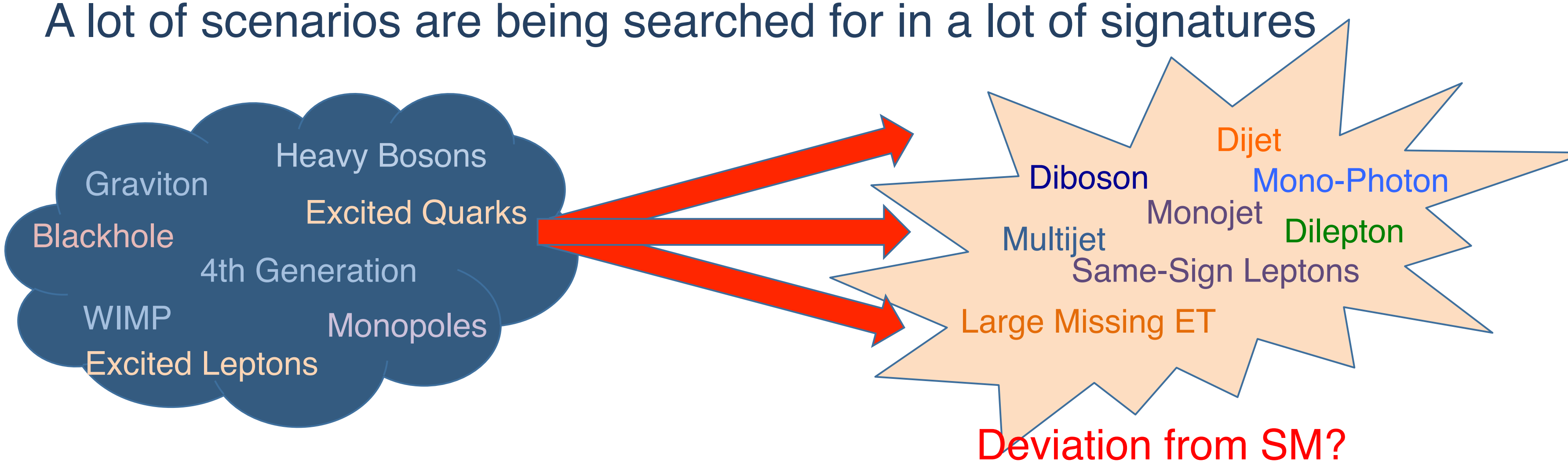
Exotics Searches at ATLAS

- After the discovery of Higgs-like particle, there are still some problems in the Standard Model

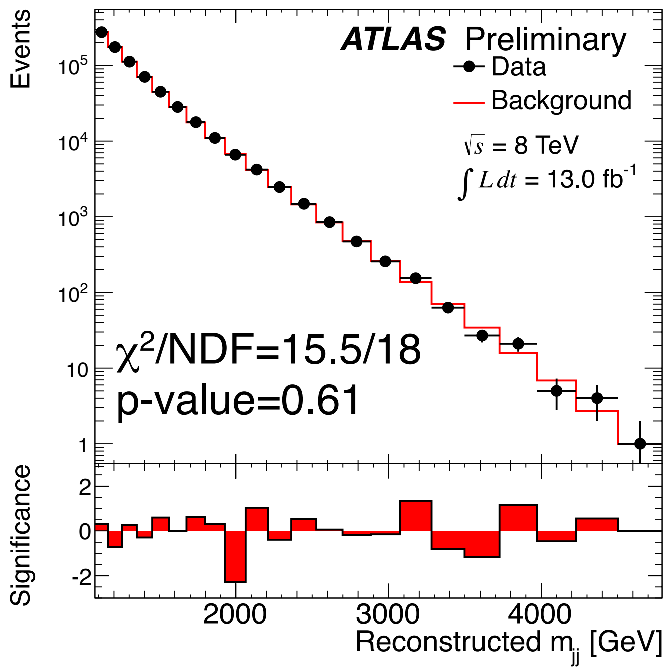
  →hierarchy problem, dark matter/energy, etc…
- There could be SUSY or other Exotics
- A lot of scenarios are being searched for in a lot of signatures



- More than 40 papers were published/submitted based on 7 TeV data of 2011
- 6 primary results are already available with 8 TeV data of 2012

New Phenomena in Dijet Mass

ATLAS-CONF-2012-148, 8TeV, 13fb^{-1}



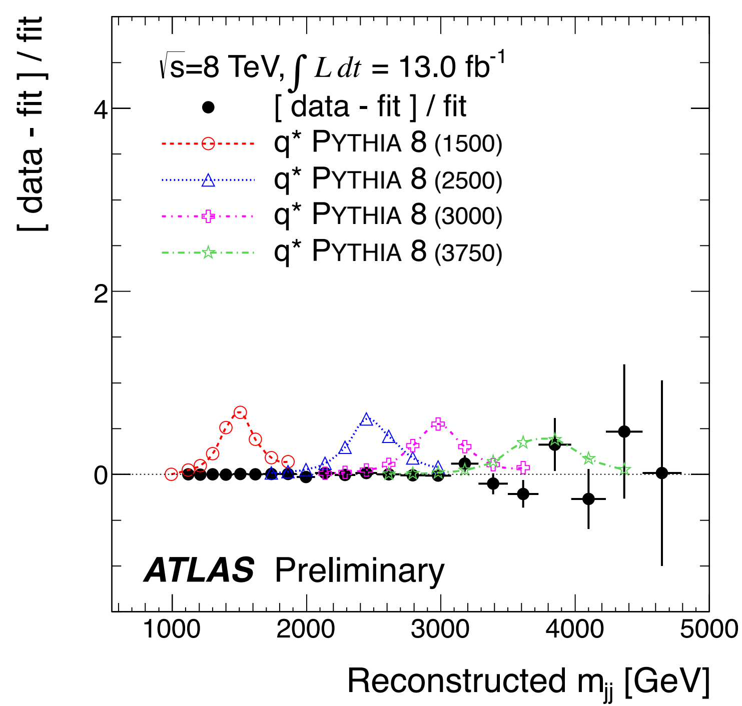
- Search for excess in m_{jj} distribution
- High p_T 2jets event
- Fit m_{jj} distribution with:

$$f(x) = p_1(1-x)^{p_2} x^{p_3 + p_4 \ln x}$$

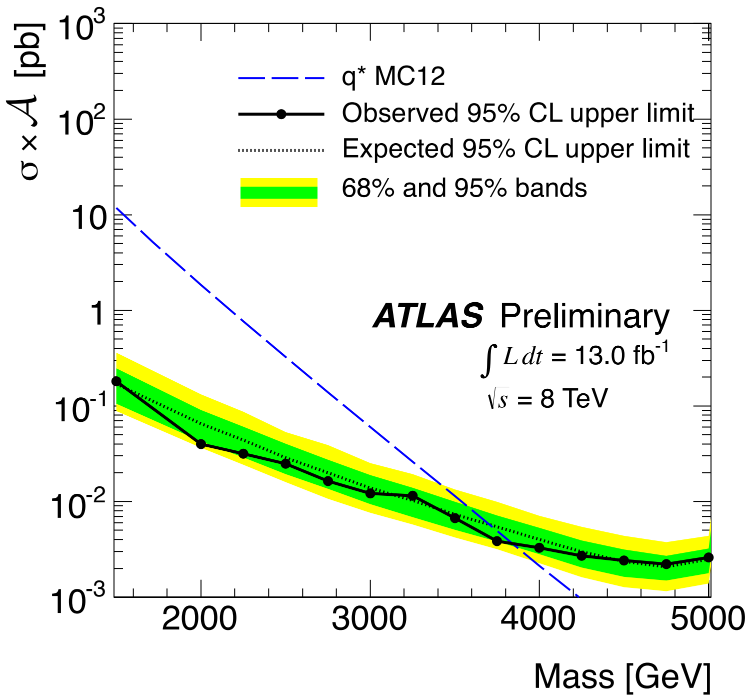
where $x = m_{jj}/\sqrt{s}$

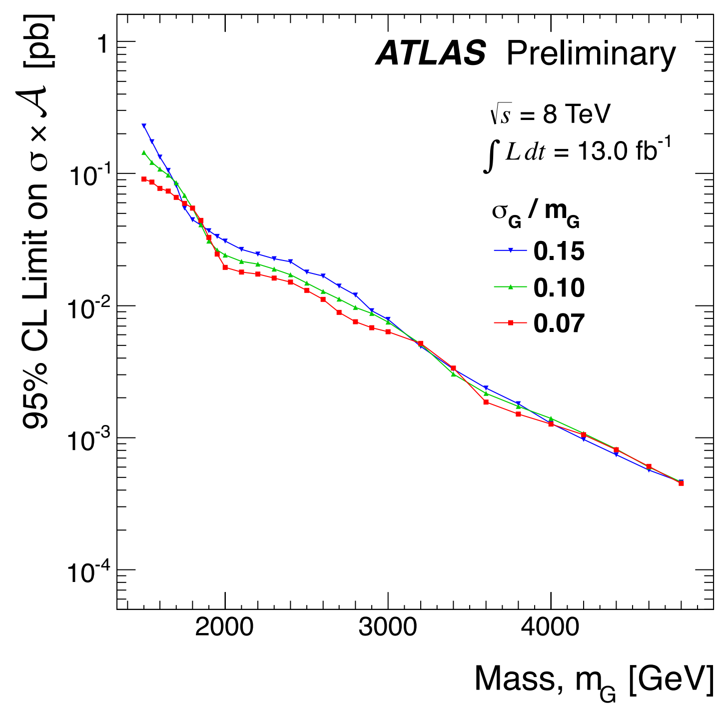
Highest jet p_T: 2.34TeV
Highest m_{jj}: 4.69TeV

m_{jj} resolution: ~5% at 3TeV
(<4% at 3TeV)



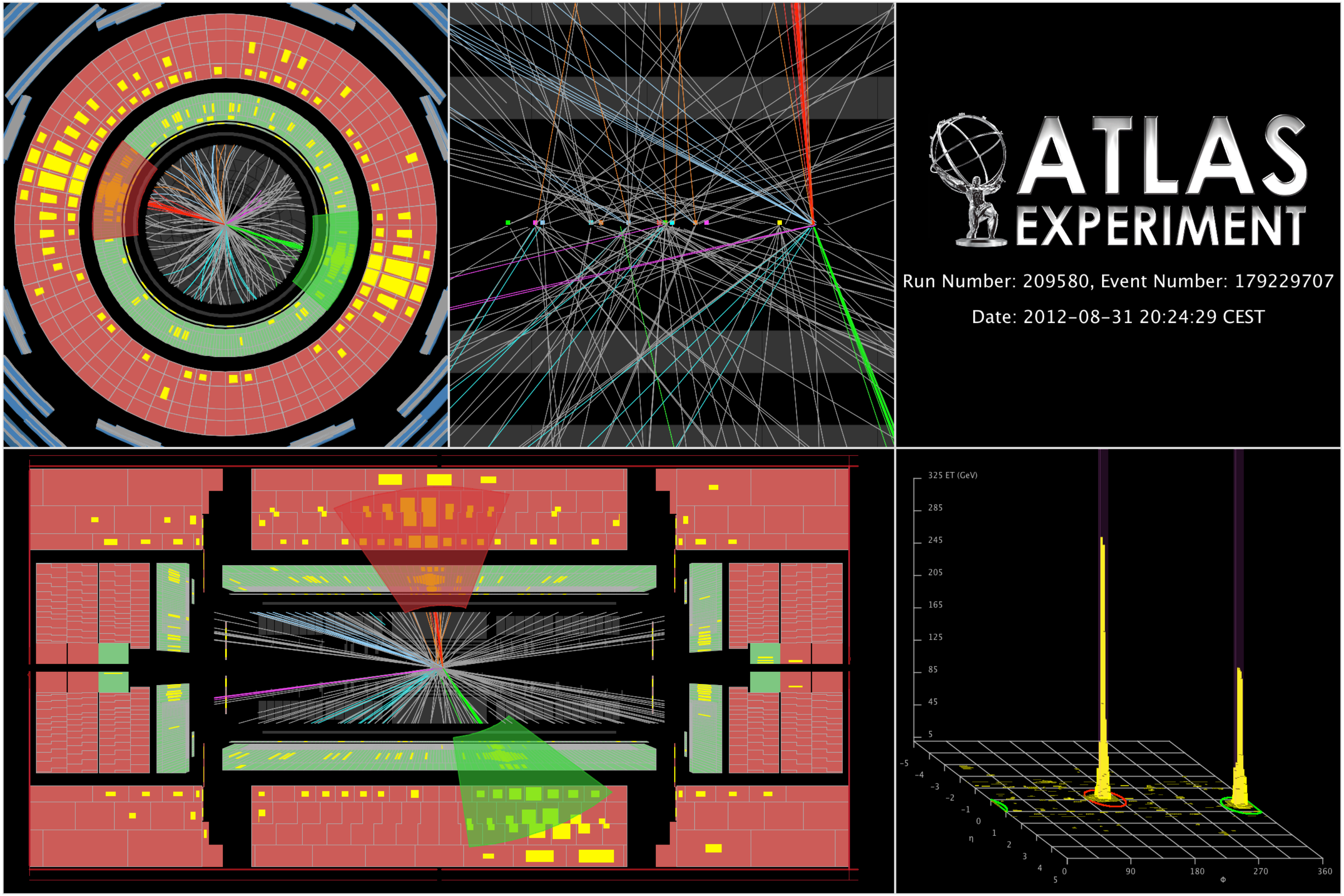
New Phenomena in Dijet Mass





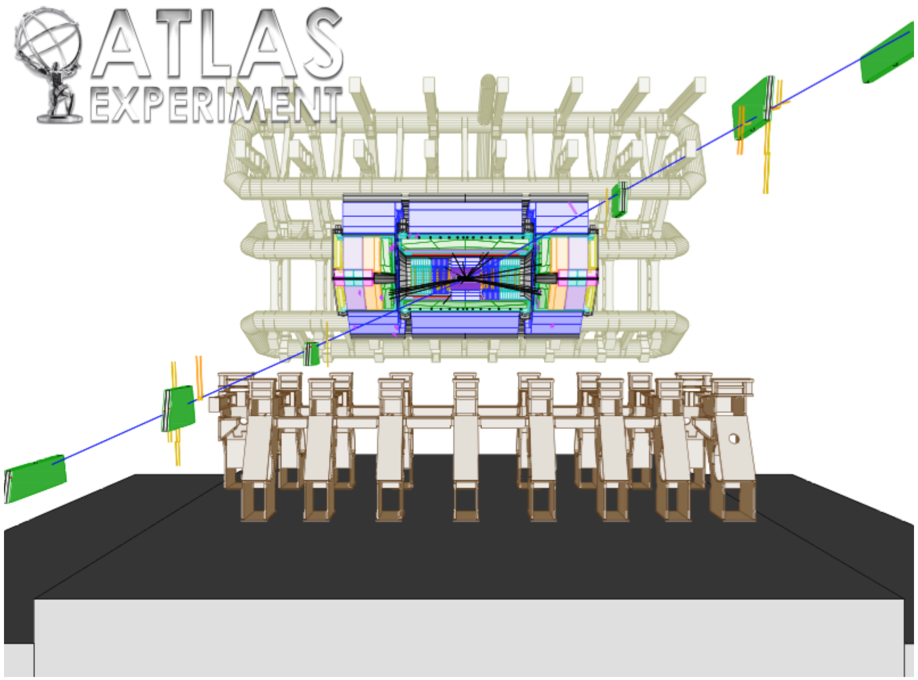
- Excited Quark Production:
  - → M_{q*} > 3.84 TeV
- Model Independent σxA limit
  - → Obtained by using simple Gaussian peaks with different width
- More models were searched for in 2011 study: arXiv:1210.1718
  - → Axigluon, Quantum Blackhole, RS Graviton
  - → Angular distribution of dijet was also studied in the same paper

New Phenomena in Dijet Mass



Highest m_{jj} event: m_{jj} = 4.69TeV, Jet p_T = 2.29TeV, 2.19TeV

New Phenomena in Dilepton Mass

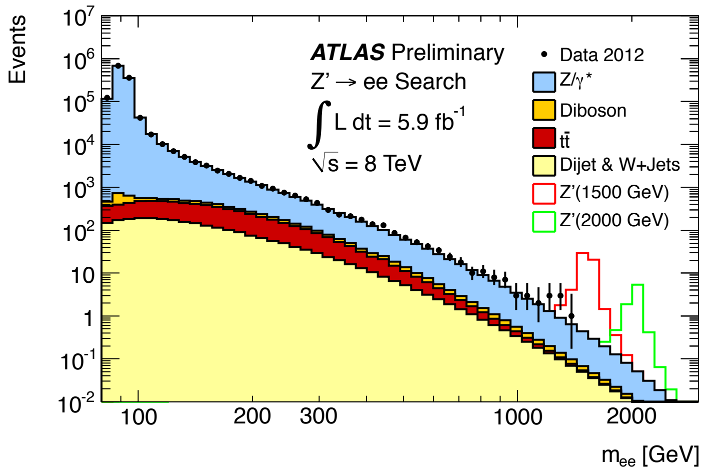


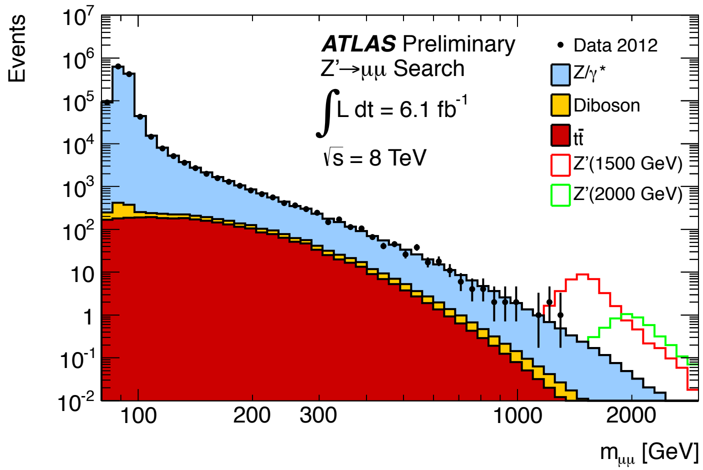
$m_{\mu\mu}$ = 1258GeV
p_{T_μ} = 289, 274 GeV

ATLAS-CONF-2012-129, 8TeV, 6.1fb^{-1}

- Search for high-mass dilepton resonances
- ee channel:
  - → E_T > 40, 30 GeV
  - → A × eff. (Z'(2TeV))=70%
- $\mu\mu$ channel
  - → p_T >25GeV, opposite sign
  - → A × eff. (Z'(2TeV))=39%
- Backgrounds
  - → Drell-Yan
  - → QCD multijet
  - → ttbar
  - → W+jets
  - → Diboson
- MC based except for QCD
  - → QCD distribution for m_{ee} was obtained in looser ID electron control region

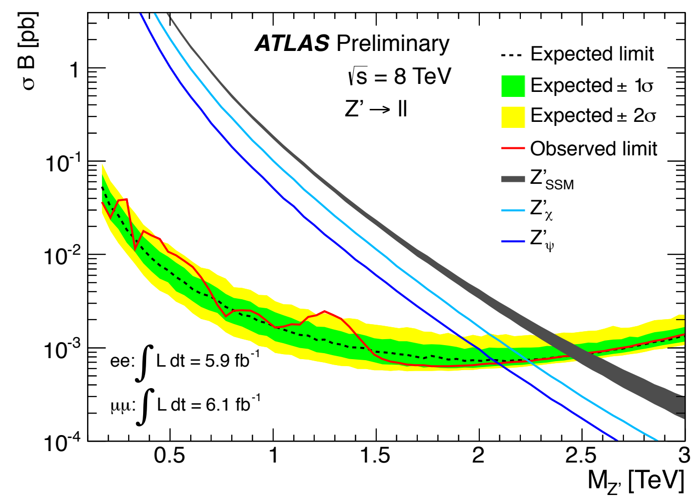
New Phenomena in Dilepton Mass





Uncertainties

Source	Dielectrons		Dimuons	
	Signal	Background	Signal	Background
Normalization	5%	NA	5%	NA
PDF / α_s / α_{em} / scale	NA	20%	NA	20%
Electroweak corrections	NA	4.5%	NA	4.5%
Efficiency	< 3%	< 3%	6%	6%
Dijet and W + jets background	NA	21%	NA	< 3%
Total	5%	30%	8%	21%



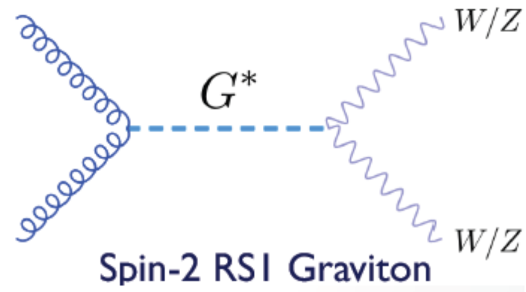
	$Z'_{SSM} \to e^+e^-$	$Z'_{SSM} \to \mu^+\mu^-$	$Z'_{SSM} \to \ell^+\ell^-$
Observed mass limit [TeV]	2.39	2.19	2.49
Expected mass limit [TeV]	2.39	2.17	2.49

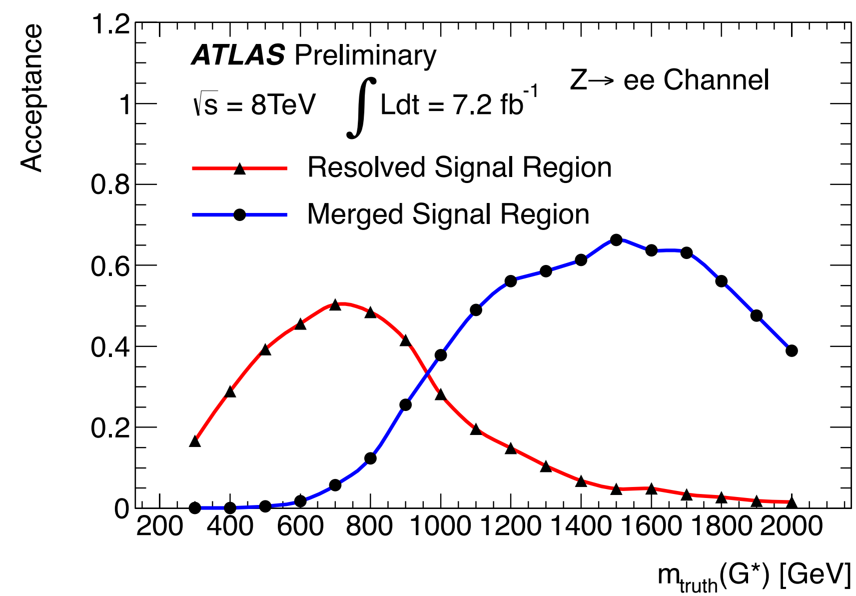
Model	Z'_ψ	Z'_N	Z'_η	Z'_I	Z'_S	Z'_χ
Observed mass limit [TeV]	2.09	2.10	2.15	2.14	2.18	2.24
Expected mass limit [TeV]	2.07	2.08	2.14	2.13	2.17	2.23

Resonant ZZ production Search

ATLAS-CONF-2012-150, 8TeV, 7.2fb^{-1}

- Search for a resonance in the di-boson mass spectrum (lljj final state)
- Z boson is highly boosted at high mass region
  - → Z boson hadronic decay products fall within the same jet
- Event selection
  - → ee or μμ event
  - → $66 < m_{ll} < 116$ GeV
  - → Resolved (Low mass) region (m_{lljj}<1TeV)
    - → $p_{T_ll} > 50$GeV, $\Delta\phi_{jj} < 1.6$, $65 < m_{jj} < 115$GeV
  - → Merged (High mass) region (m_{llj}>1TeV)
    - → $p_{T_ll} > 200$GeV, $p_{T_j1} > 200$GeV, $m_j > 40$GeV
  - → Regions were divided based on the sensitivity





Resonant ZZ production Search

Background estimation

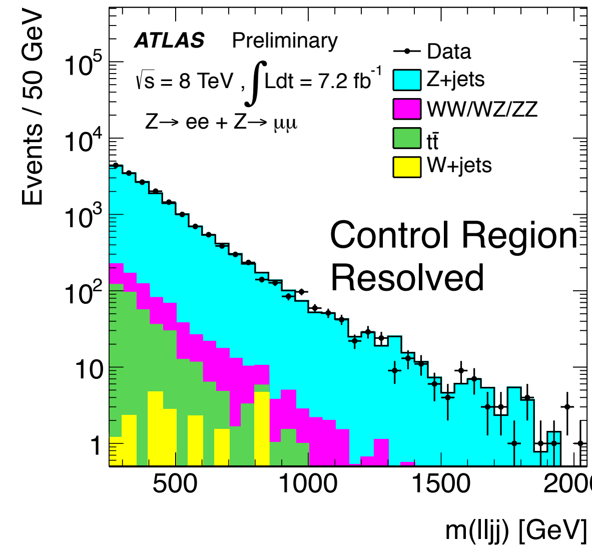
- Control region: inverted m_{jj} or m_j cut
- Fit m_{lljj} or m_{llj} with the function:

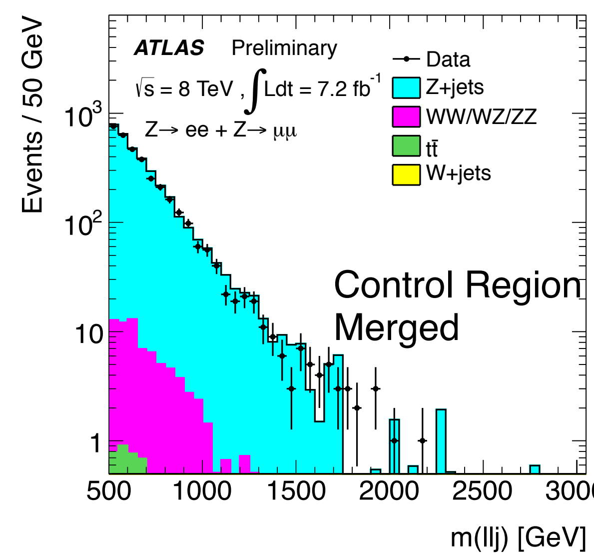
$$f(x) = p_1(1-x)^{p_2} x^{p_3 + p_4 \ln x}$$

where $x = m_{llj(j)}/\sqrt{s}$

Uncertainties:

- Fit uncertainties:
  - → <5% for m_{lljj} distribution
  - → 10-40% for m_{llj} distribution
- Signal acceptance (lepton efficiency, jet energy scale/resolution, PDF, ISR/FSR, luminosity)
  - → 11-15%





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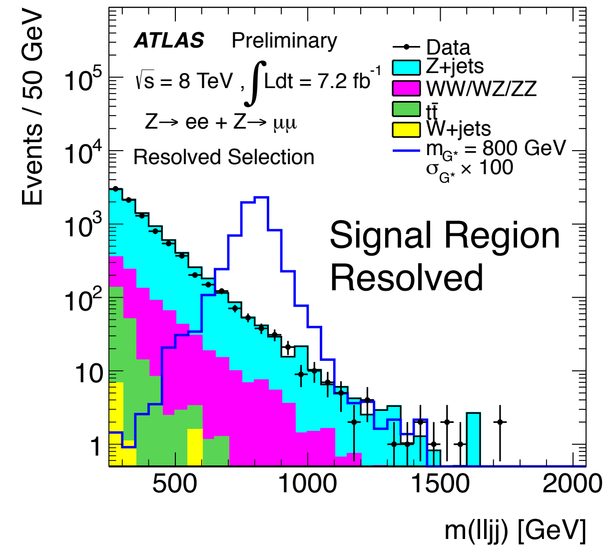
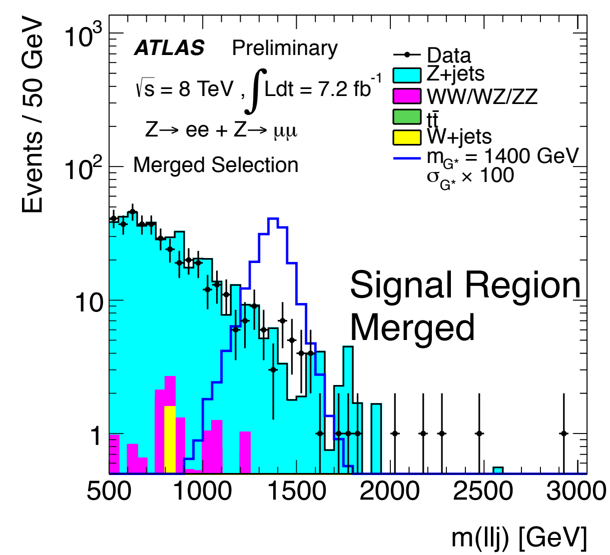
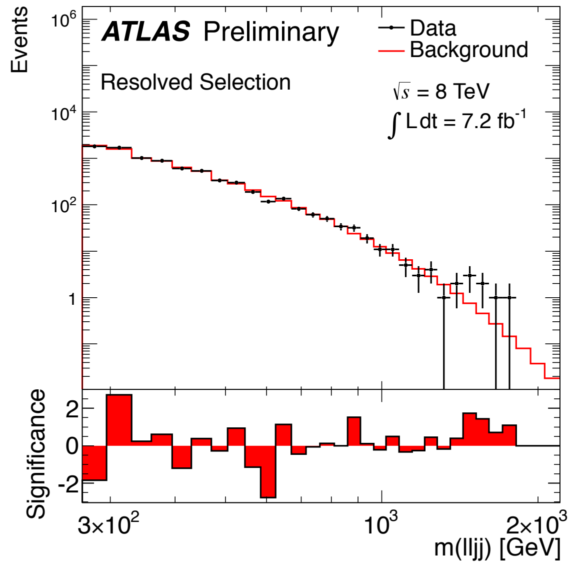
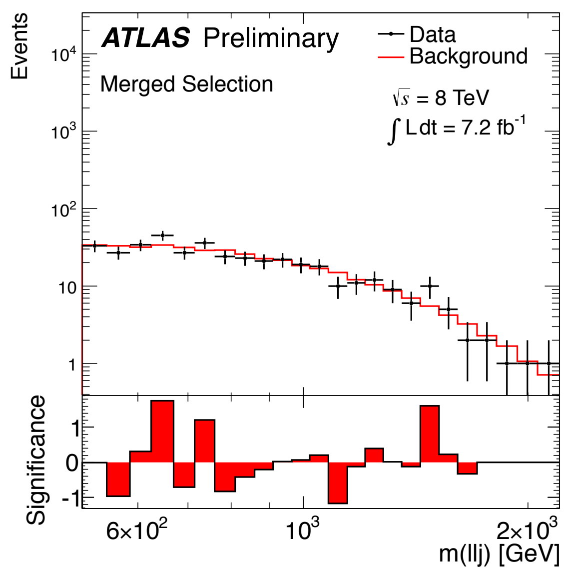
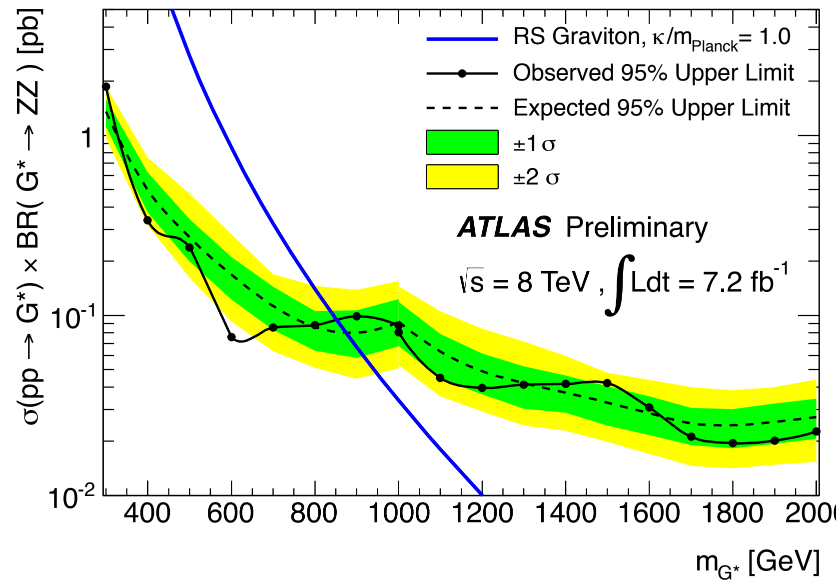




Resonant ZZ production Search







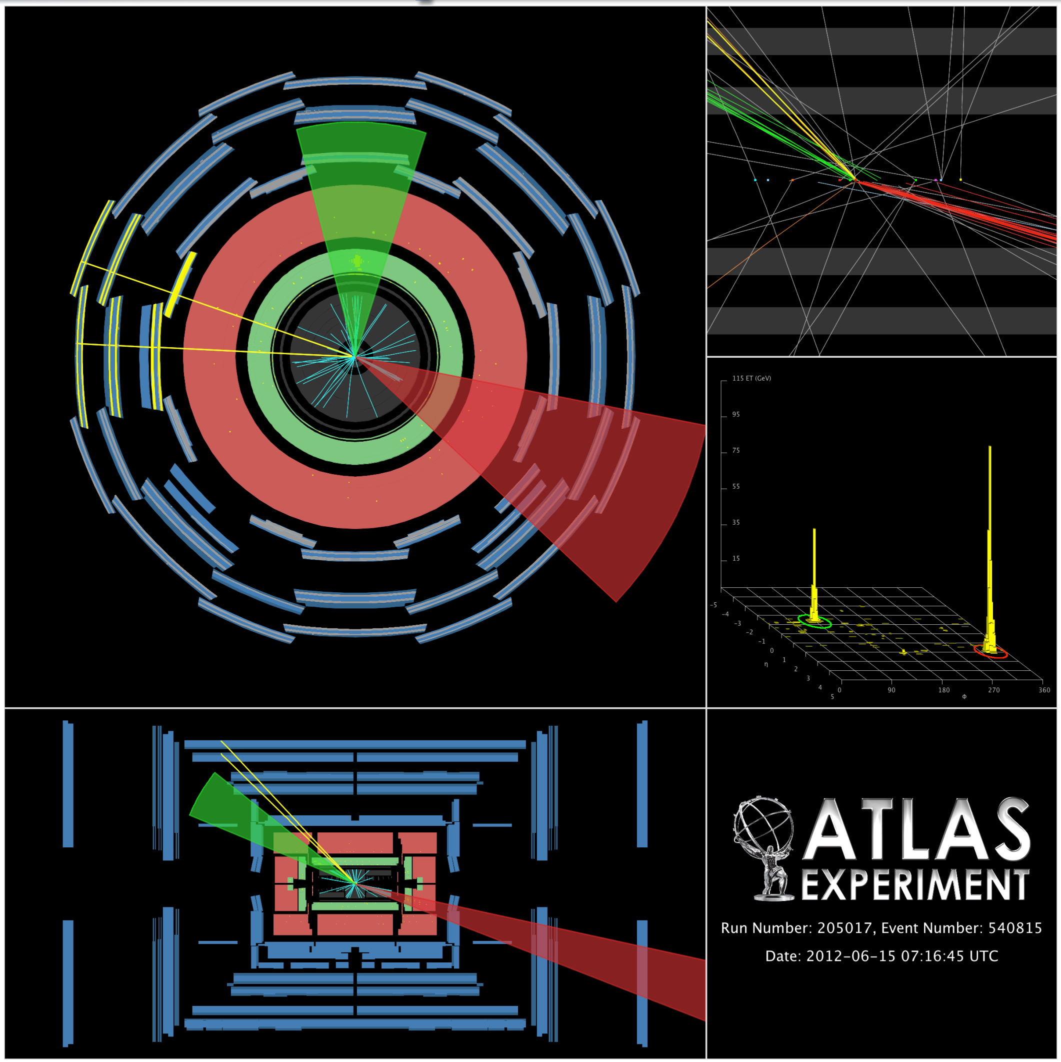
95% CL upper limits on $\sigma B(G^* \to ZZ)$

m_{lljj} (m_{llj}) was used for m_{G*} < (>) 1 TeV

Lower limit on the mass of the bulk RS Graviton

for $\kappa/\overline{M}_{pl}$ = 1.0: m_{G*} > 850 GeV

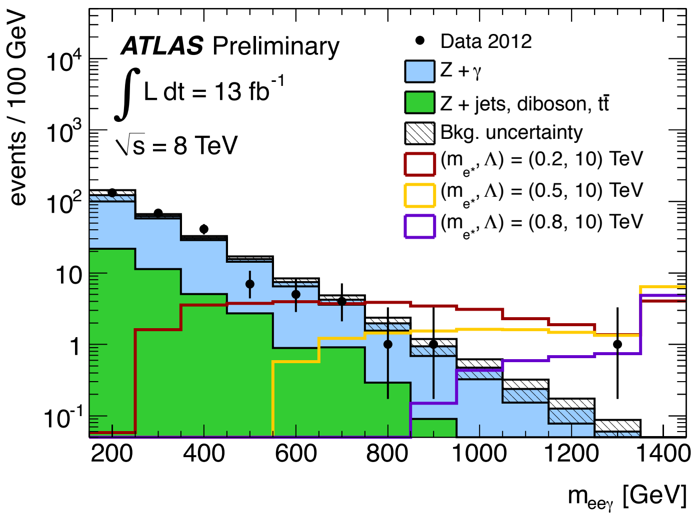
Resonant ZZ production Search

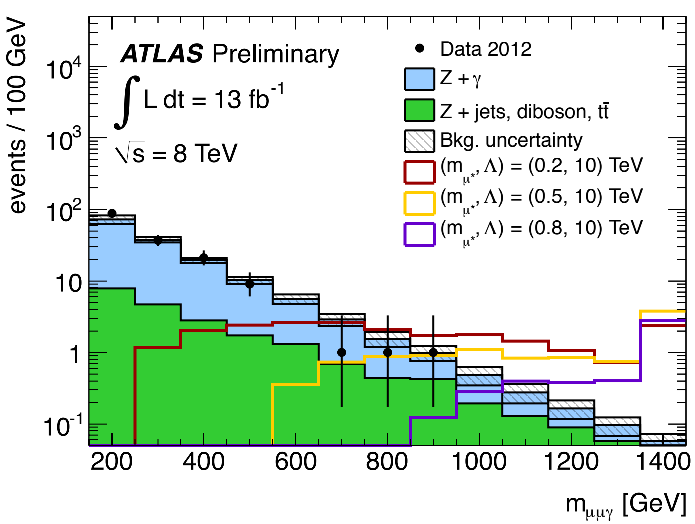


Muons: (p_T = 439.7 GeV, η= -0.833, ϕ = 2.81), (p_T = 207.5 GeV, η = -0.903, ϕ = 3.10)
Leading jet p_T = 718.9 GeV, η = 1.947, ϕ = -0.474, m = 46.0 GeV,
sub-leading jet p_T = 232.6 GeV, $p_{T\_\mu\mu}$= 641.3 GeV, $m_{\mu\mu}$ = 89.7GeV, $m_{\mu\mu j}$ = 2.93 TeV

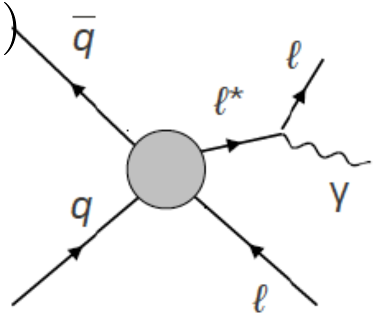
Excited Lepton Search

ATLAS-CONF-2012-146, 8TeV, $13 fb^{-1}$



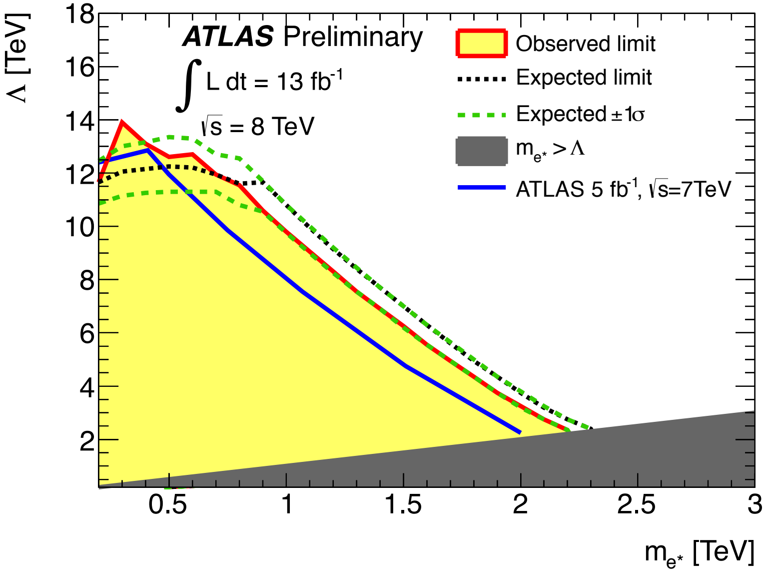


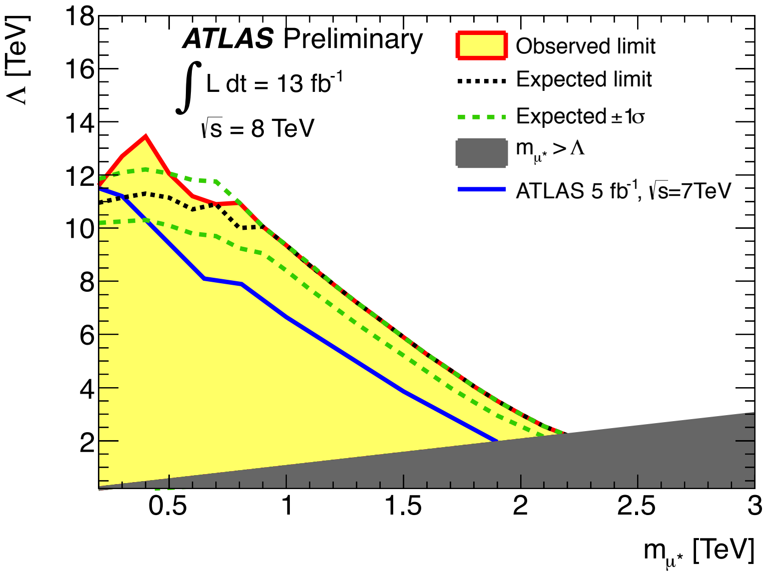
- Search for $q\bar{q} \rightarrow l^*\bar{l}(l^* \rightarrow l\gamma)$
- $e^+e^-\gamma$ and $\mu^+\mu^-\gamma$ final state
- Dominant background
  - → Drell-Yan:
  - Z+γ and Z+jets (fake photon)
  - Z+jets can be suppressed by tight photon requirement



- Selection:
  - → e channel:p_{T_e1}> 40GeV, p_{T_e2} > 35GeV
  - → μ channel:$p_{T\_\mu1,2}$> 25GeV
  - → p_{T_γ} > 30GeV, isolated from leptons
  - → m_{ll} > 100GeV
- Background estimation
  - → Based on Monte Carlo
  - → Z+jets scale factor was estimated from $70<m_{ll}<110$GeV (correct γ fake ratio)
  - → For m_{ll}>250GeV, Z+γ/jet distributions were extrapolated from low m_{ll} region using fitting

Excited Lepton Search





Uncertainties for m_{l^*}=200GeV

Source	e^*		μ^*	
	Signal	Background	Signal	Background
Extrapolation	NA	5%	NA	6%
Theory	NA	6%	NA	6%
Luminosity	4%	4%	4%	4%
Efficiency	4%	4%	4%	4%
Total	6%	10%	6%	10%

Uncertainties for m_{l^*}=2TeV

Source	e^*		μ^*	
	Signal	Background	Signal	Background
Extrapolation	NA	39%	NA	40%
Theory	NA	8%	NA	8%
Luminosity	4%	4%	4%	4%
Efficiency	6%	4%	6%	5%
Total	7%	40%	7%	41%

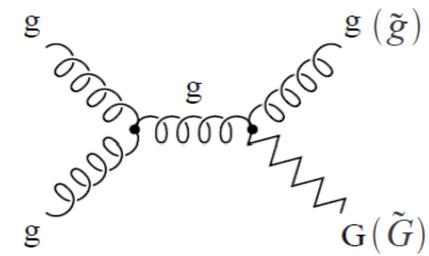
- Excited Electron
  - → $\sigma B < 0.6$ fb for m_{e^*}>0.8 TeV
  - → $m_{e^*} > 2.2$ TeV for $\Lambda = m_{e^*}$
- Excited Muon
  - → $\sigma B < 0.7$ fb for m_{e^*}>0.8 TeV
  - → $m_{\mu^*} > 2.2$ TeV for $\Lambda = m_{\mu^*}$

Mono-jet Search

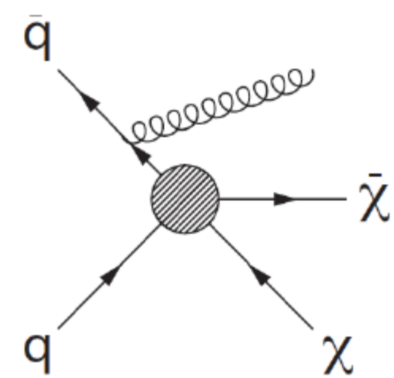
ATLAS-CONF-2012-147, 8TeV, $10fb^{-1}$

- Searched for new phenomena in mono-jet + missing E_T event
  - → ADD Graviton, squark/gluino+Gravitino
  - → Weakly Interacting Massive Particles (WIMP)
- Event selection
  - → missE_T>120GeV, Leading Jet p_T>120GeV
  - → $|\Delta\phi(\text{miss}E_T, \text{2nd Jet})|>0.5$
  - → 3rd Jet p_T < 30 GeV
  - → Lepton veto
  - → 4 Signal regions (SR1,2,3,4):

  missE_T, Leading Jet p_T > (120,220,350,500) GeV
- Backgrounds
  - → $Z(\nu\nu)$+jets (dominant): Data driven
  - → W/Z+jets: data driven
  - → QCD multijet: data driven
  - → Non-collision: data driven
  - → Top, Dibosons: MC based



ADD Graviton (LED)
squark/gluino+Gravitino



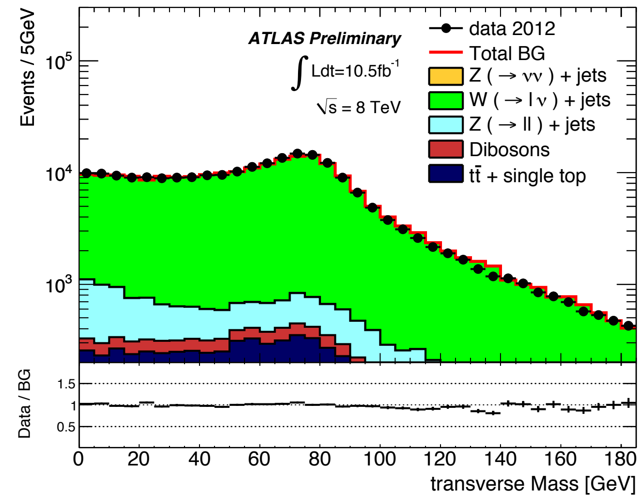
WIMP production

Mono-jet Search

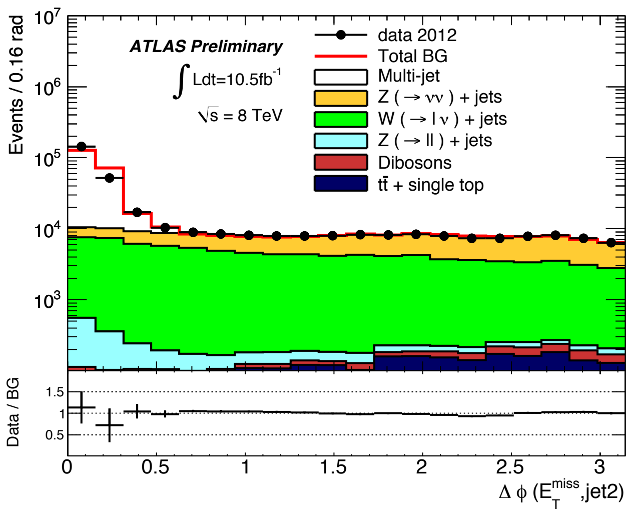
EW background estimation

- Control region: W(lν)+jets/Z(ll)+jets
  - → e.g.) W(μν)+jets: 1μ, 40<m_T<100 GeV
- Apply transfer factors (MC base)
  - → e.g.) Estimation Z(νν)+jets from W(μν)+jets

$$N(Z(\rightarrow \nu\bar{\nu}) + jets)_{SR} = (N^{data}_{W\rightarrow\mu\nu,CR} - N^{BG}_{W,CR}) \times \frac{N^{MC}(Z(\rightarrow\nu\bar{\nu}+jets)_{SR}}{N^{MC}_{W\rightarrow\mu\nu,CR}}$$



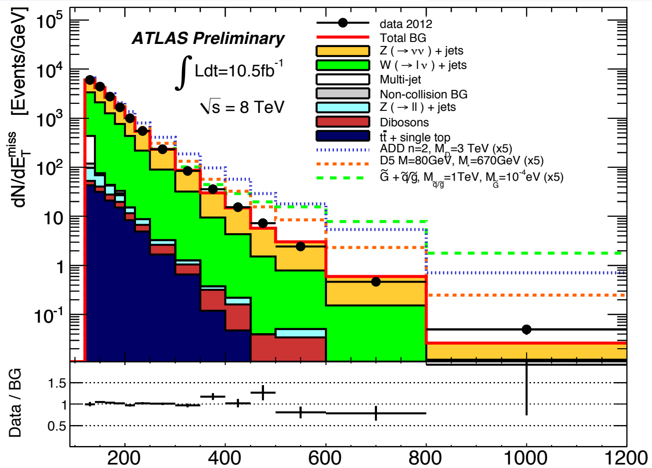
m_T distribution in SR1 but 1μ required instead of lepton veto



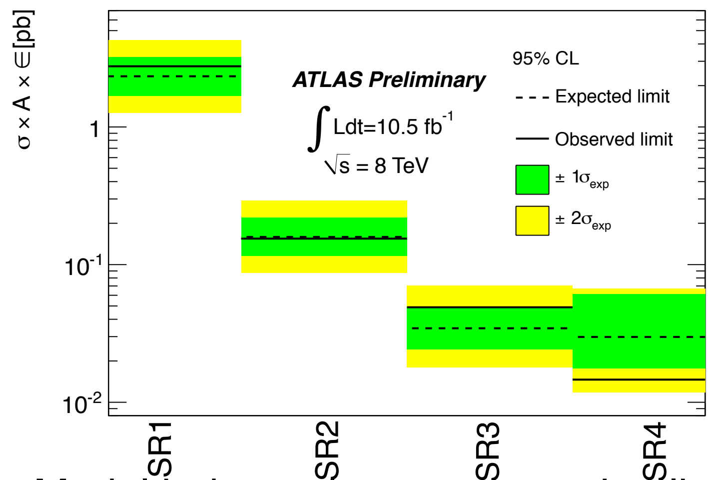
Multijet background estimation

- Main source is misreconstruction of the energy
- Control region
  - → Dijet (for single-jets data): |Δφ(missE_T,2nd Jet)| <0.5
  - → 3-jets (for two-jets data): require 3rd jet, |Δφ(missE_T,3rd Jet)|<0.5
- Extrapolate p_T distribution to below jet p_T threshold (30GeV)

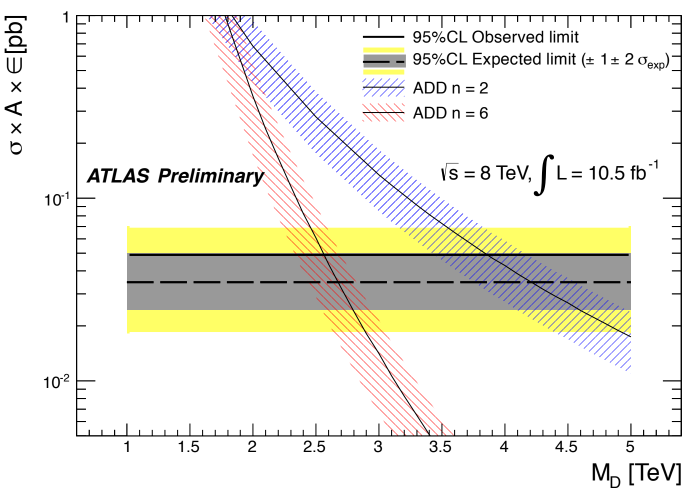
Mono-jet Search

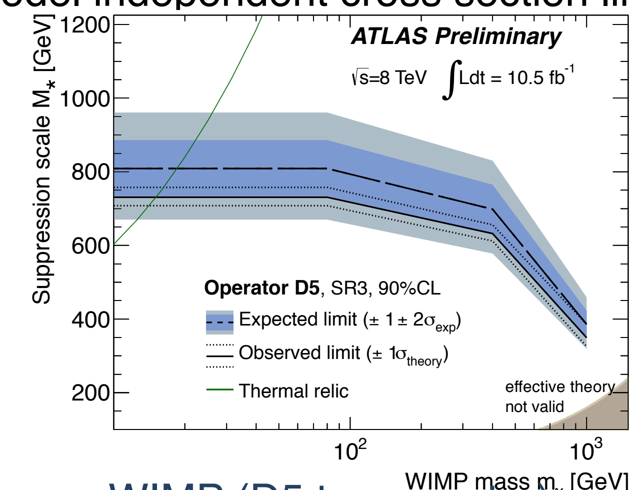


missE$_T$ in SR1



Model independent cross section limit





ADD Graviton:

$M_D >$ 3.88, 3.16, 2.84, 2.65, 2.58 TeV

for n=2,3,4,5,6

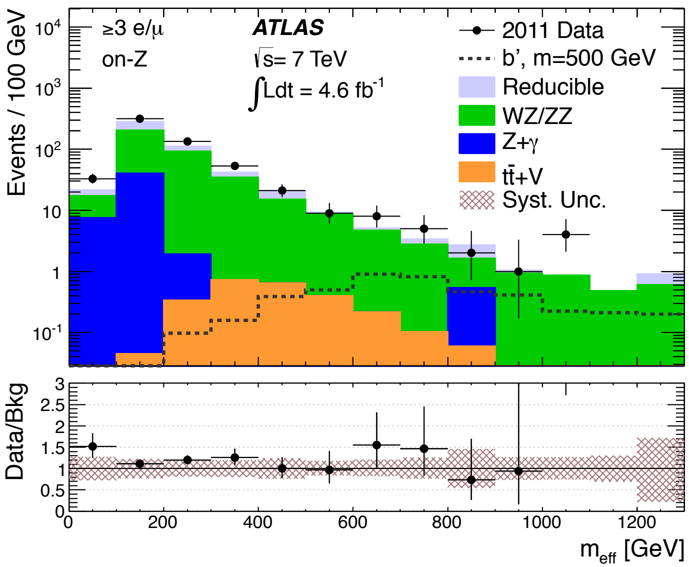
WIMP (D5 type, vector):

$M_* >$731, 632, 349 GeV

for $m_\chi \leq$ 80, =400, 1000GeV

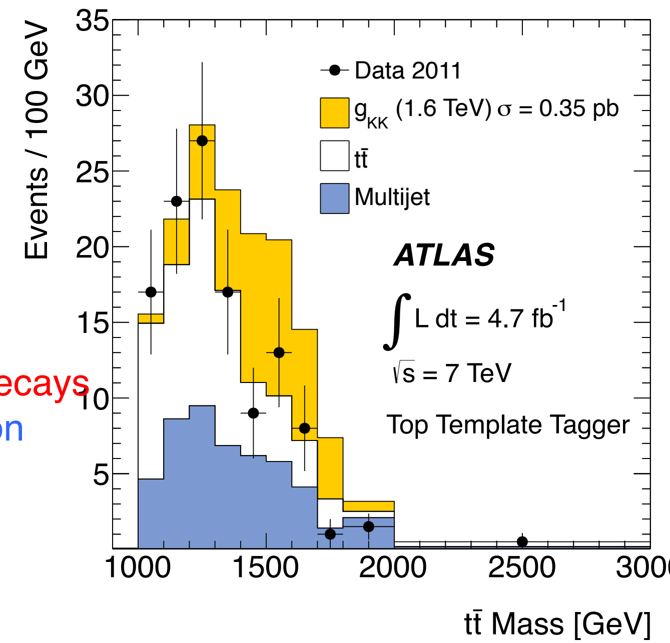
Similar search in mono-photon is available in arXiv:1209.4625 (7TeV)

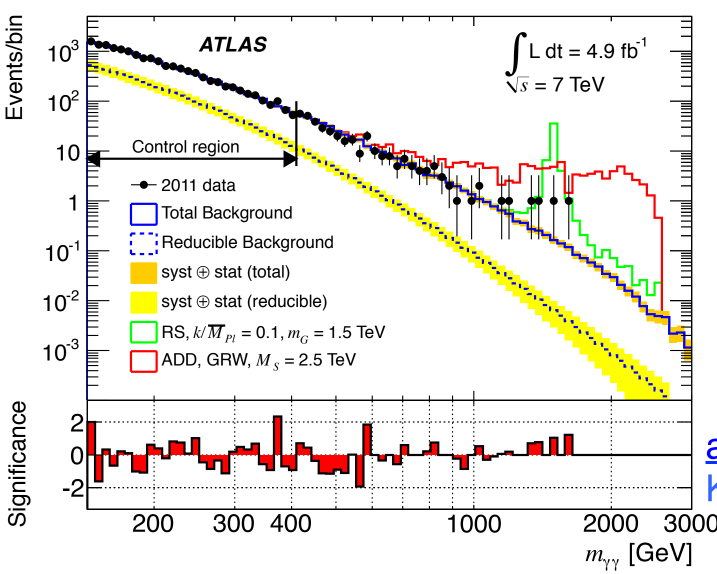
New Results with 7 TeV data



arXiv:1211.6312, 7TeV, 4.6fb^{-1} Three charged leptons final state
Doubly-charged Higgs Boson, Excited neutrino, 4th generation quarks, SUSY, etc…

arXiv:1211.2202, 7TeV, 4.7fb^{-1}
Resonant top-pair production,
in fully hadronic decays
KK Gluon, Z' boson





arXiv:1210.8389, 7TeV, 4.9fb^{-1}, Diphoton final state
KK Graviton

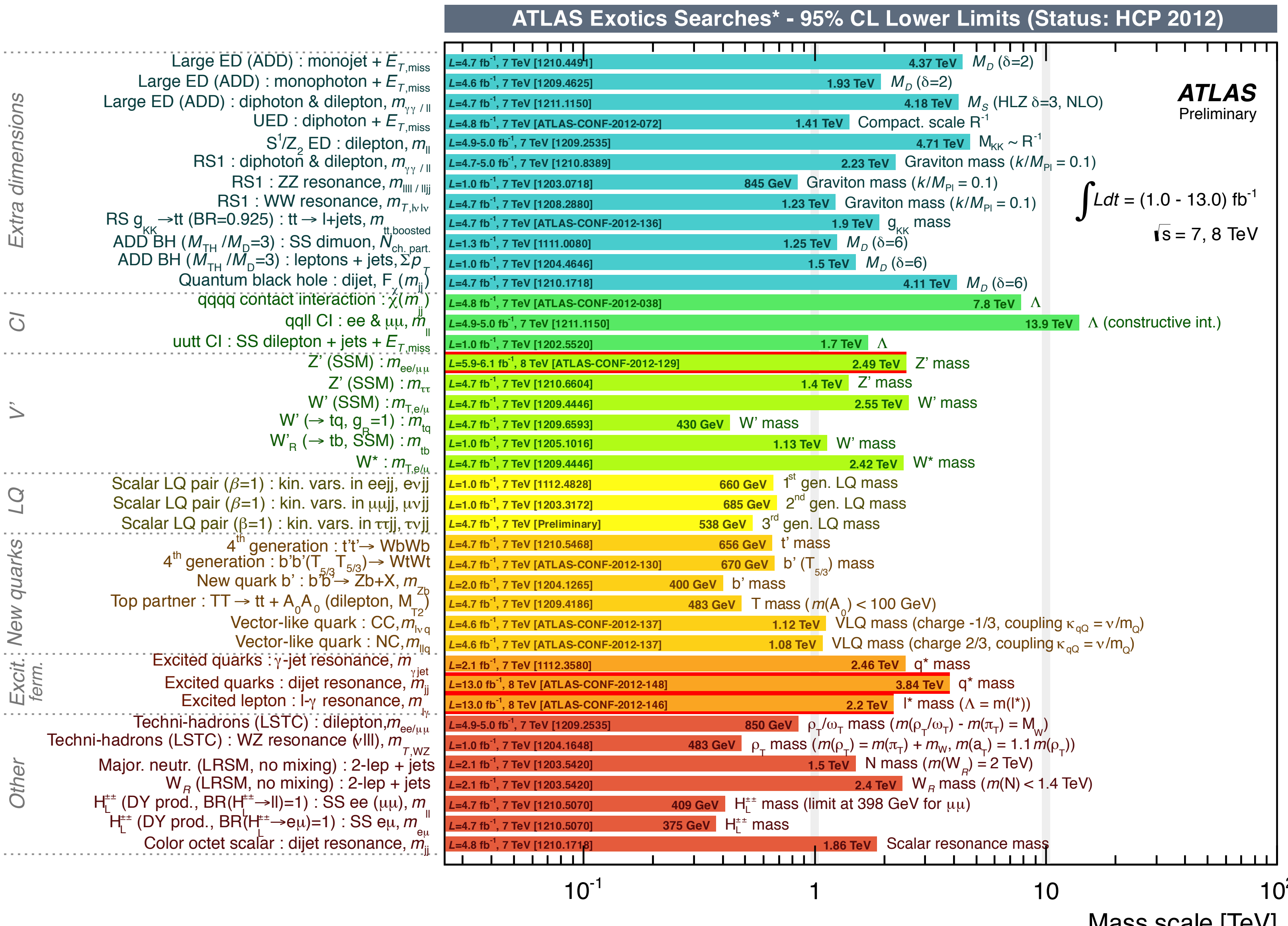
Summary

- A lot of signatures are being studied for the new physics search
  →No new physics indication has been found…
- More 8 TeV results will be coming soon!
- There will be more exciting challenges with 13-14 TeV run in 2015!

*Only a selection of the available mass limits on new states or phenomena shown

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

Summary



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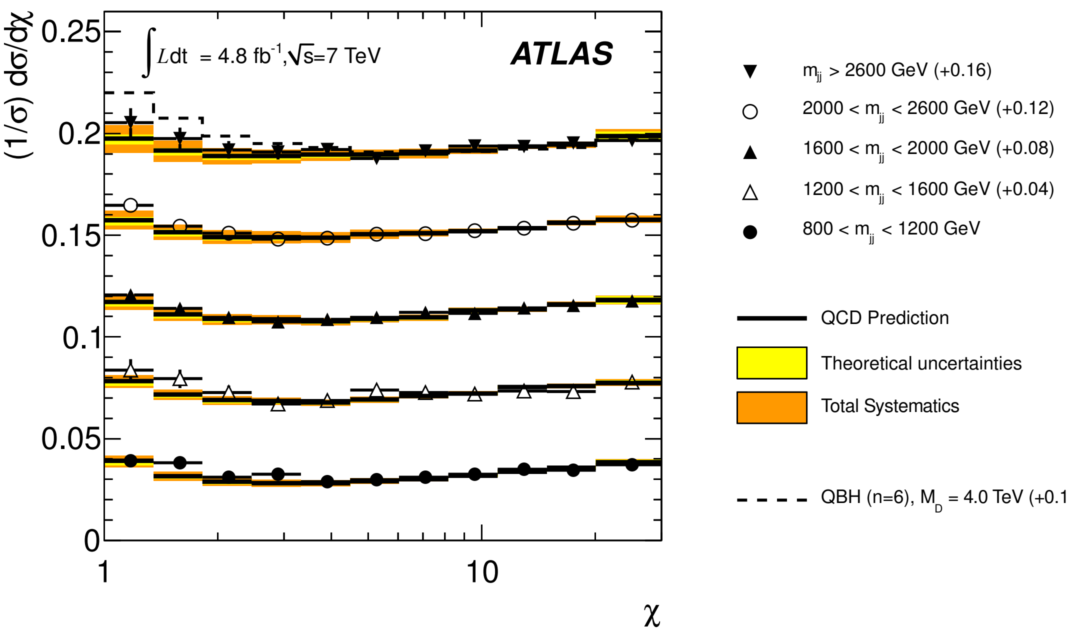
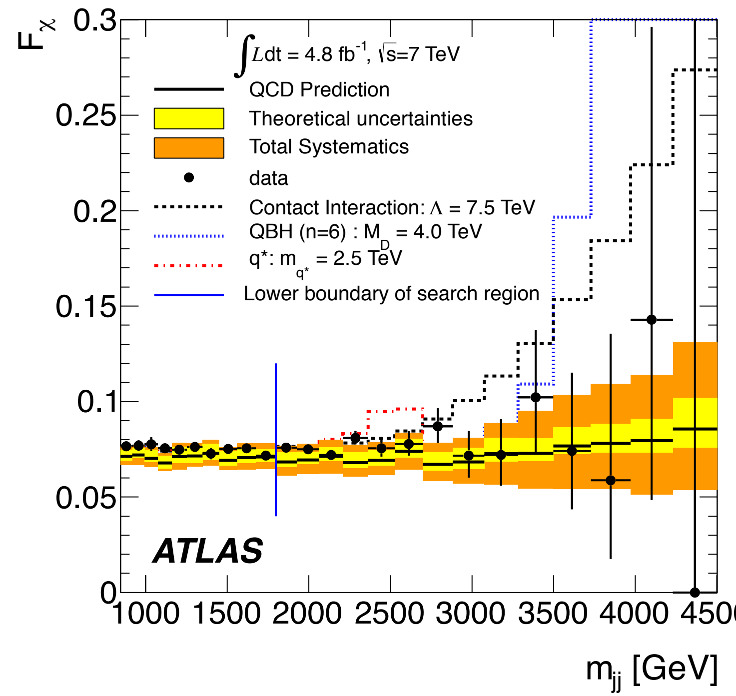
Backup

Dijet: Angular Distribution

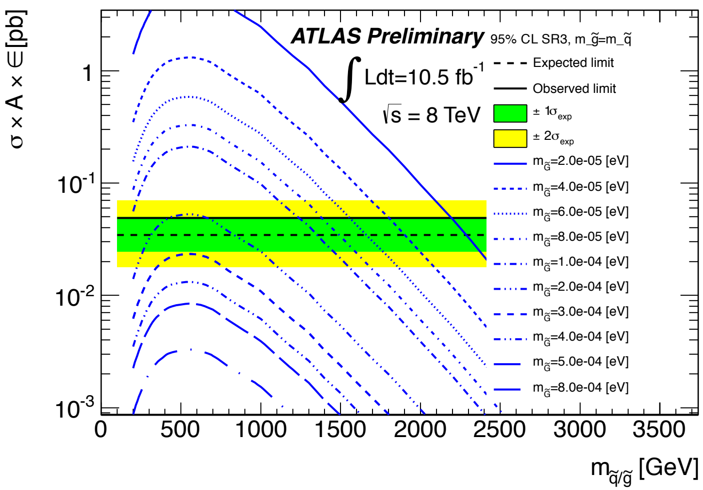
arXiv:1210.1718 , 7TeV, 4.8fb^{-1}

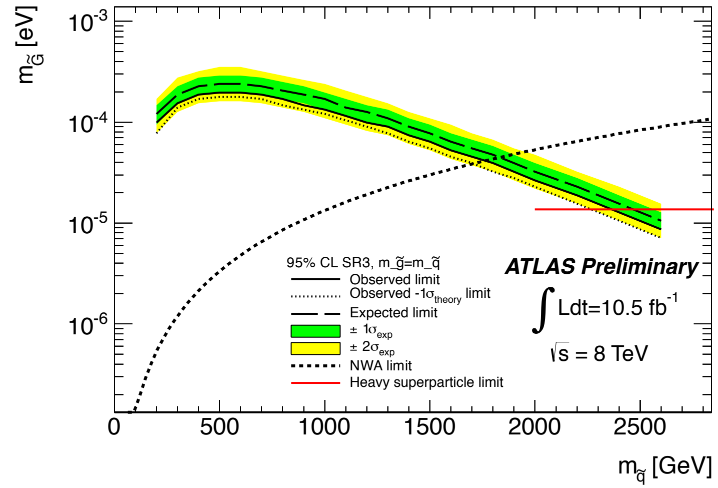




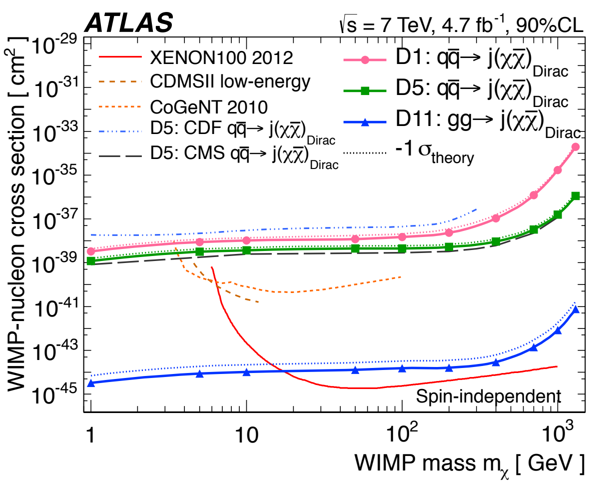
Mono-jet Search

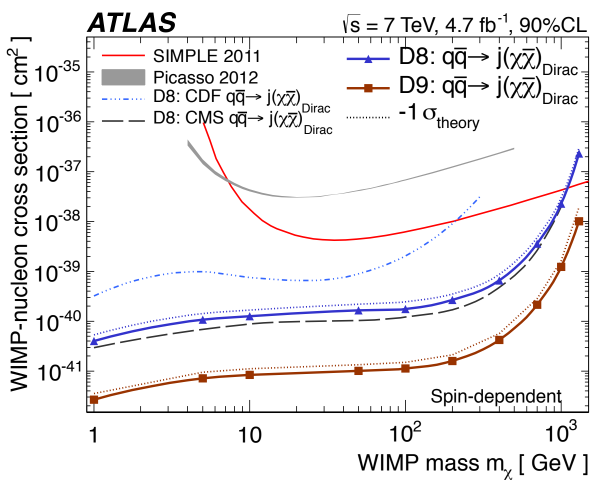
ATLAS-CONF-2012-147, 8TeV, $10fb^{-1}$

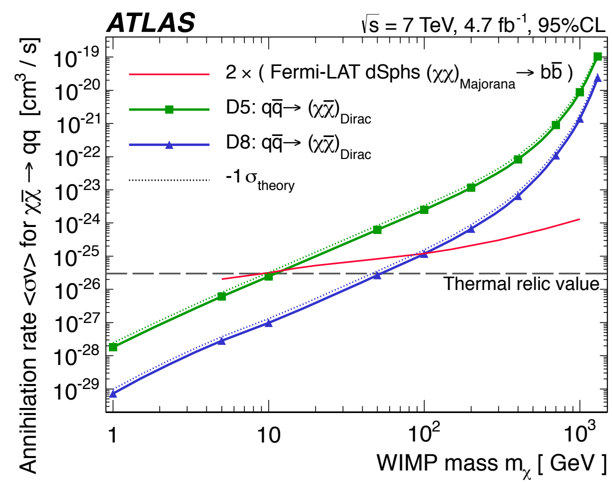




arXive:1210.4491, 7TeV, $4.7fb^{-1}$

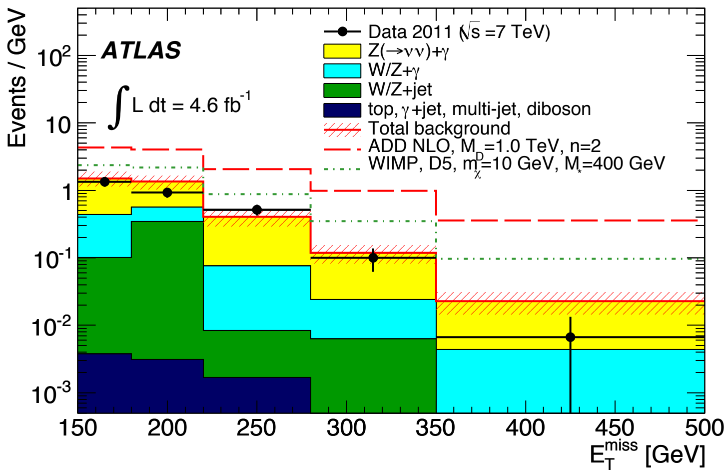


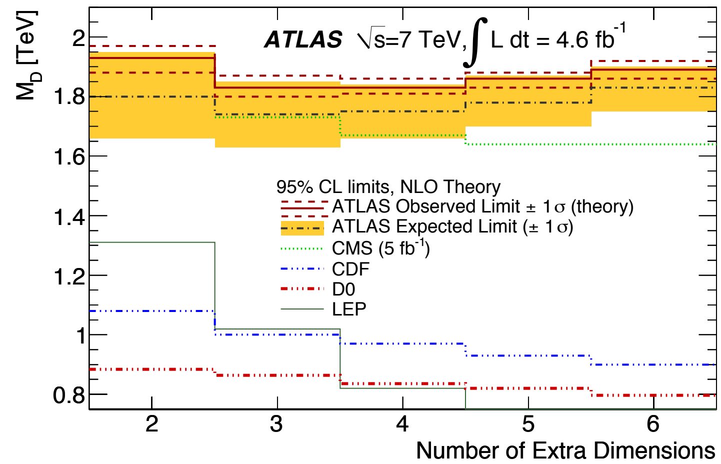


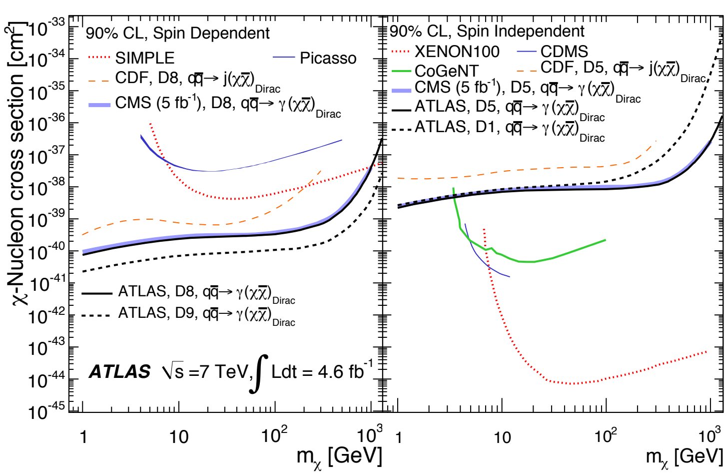


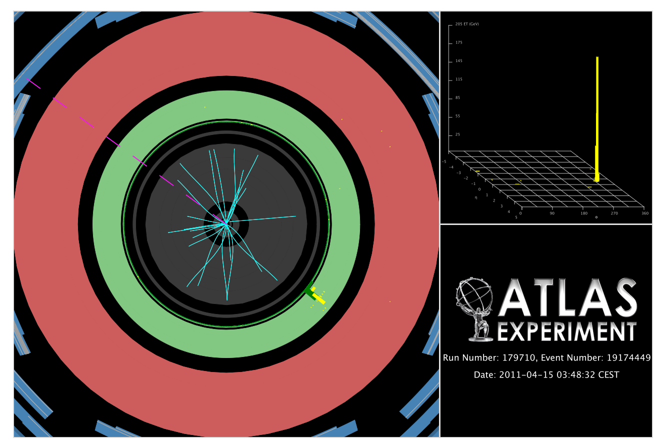
Mono-photon

arXiv:1209.4625, 7TeV, 4.6fb^{-1}



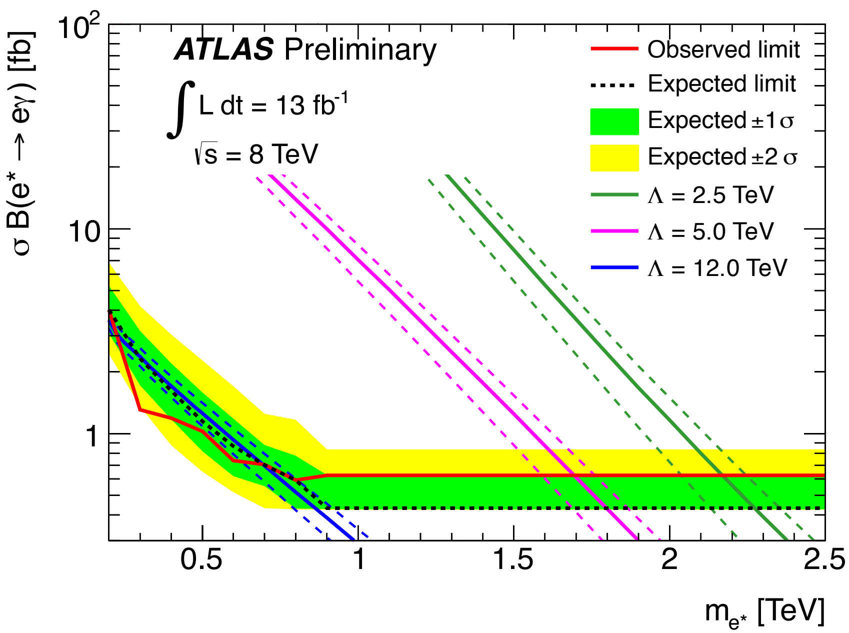


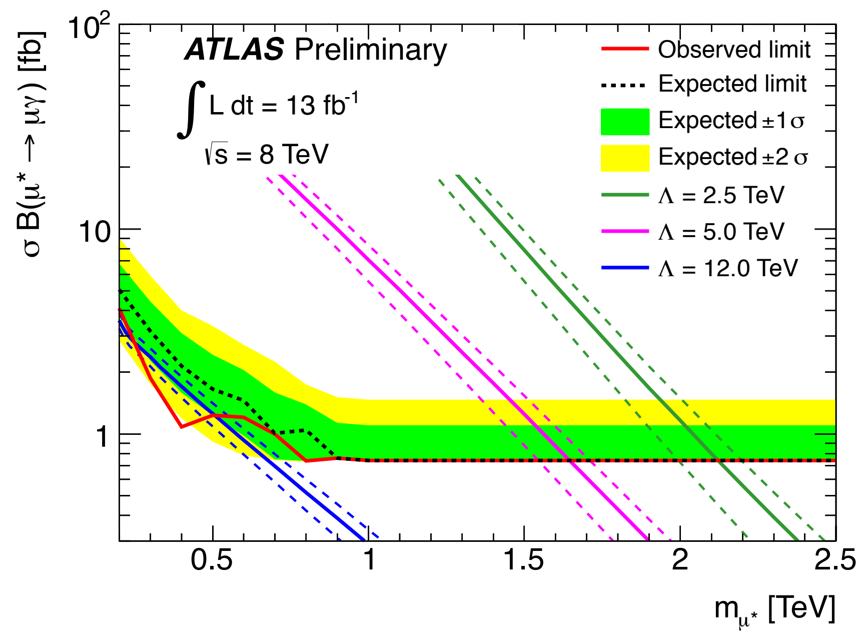




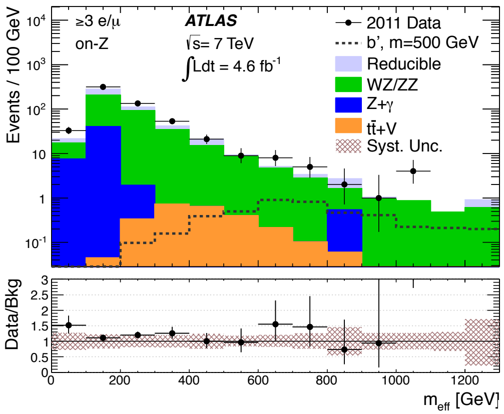
Photon p_T = 218GeV
MissintE_T = 218GeV

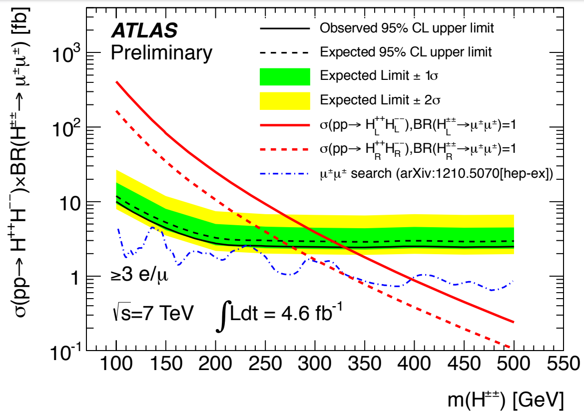
Excited Lepton Search





New Results with 7 TeV data





[arXiv:1211.6312](https://arxiv.org/abs/1211.6312), 7TeV, 4.6fb^{-1}

Three charged leptons final state

Doubly-charged Higgs Boson,

Excited neutrino,

4th generation qurarks

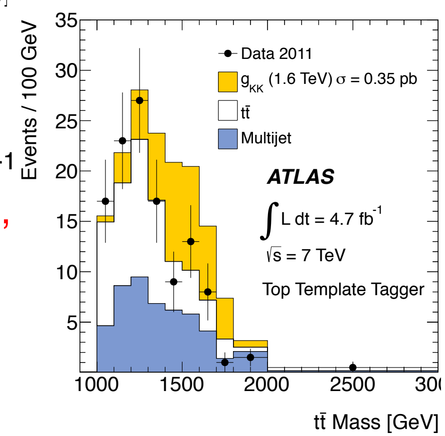
SUSY, etc…

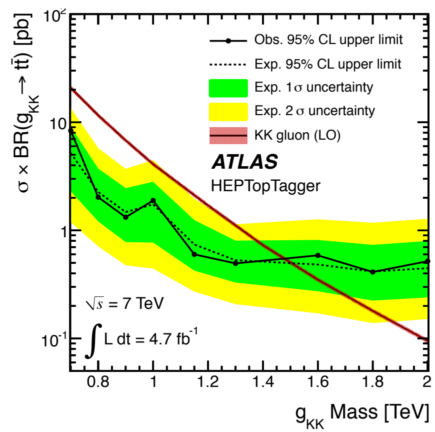
[arXiv:1211.2202](https://arxiv.org/abs/1211.2202), 7TeV, 4.7fb^{-1}

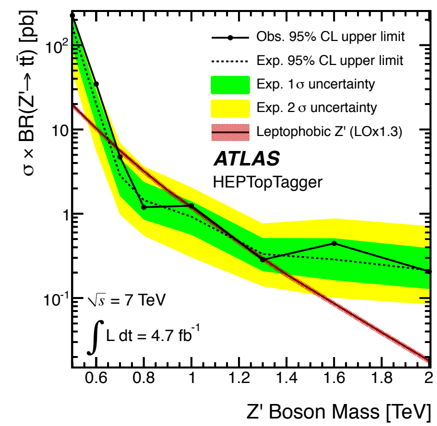
Resonant top-pair production,

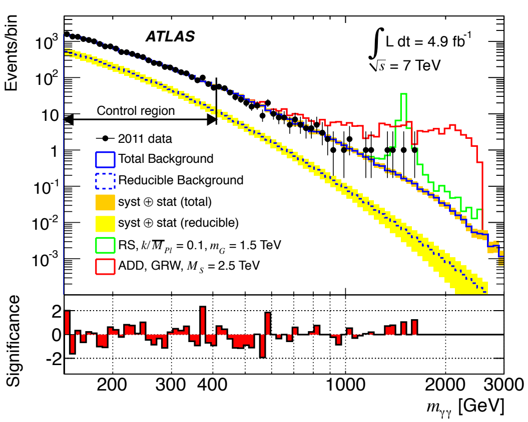
in fully hadronic decays

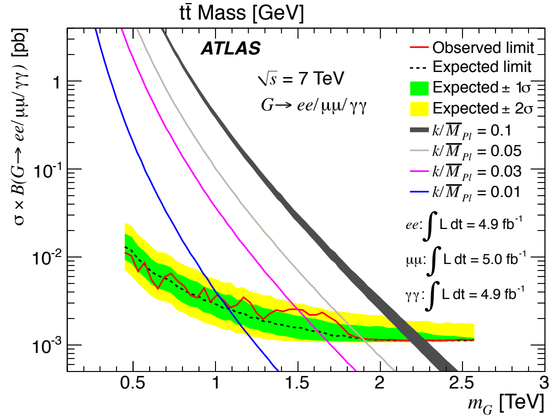
KK Gluon, Z' boson











[arXiv:1210.8389](https://arxiv.org/abs/1210.8389), 7TeV, 4.9fb^{-1}

Diphoton final state

KK Graviton