Search for heavy resonances with the ATLAS detector

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On behalf of the ATLAS Collaboration

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Motivation

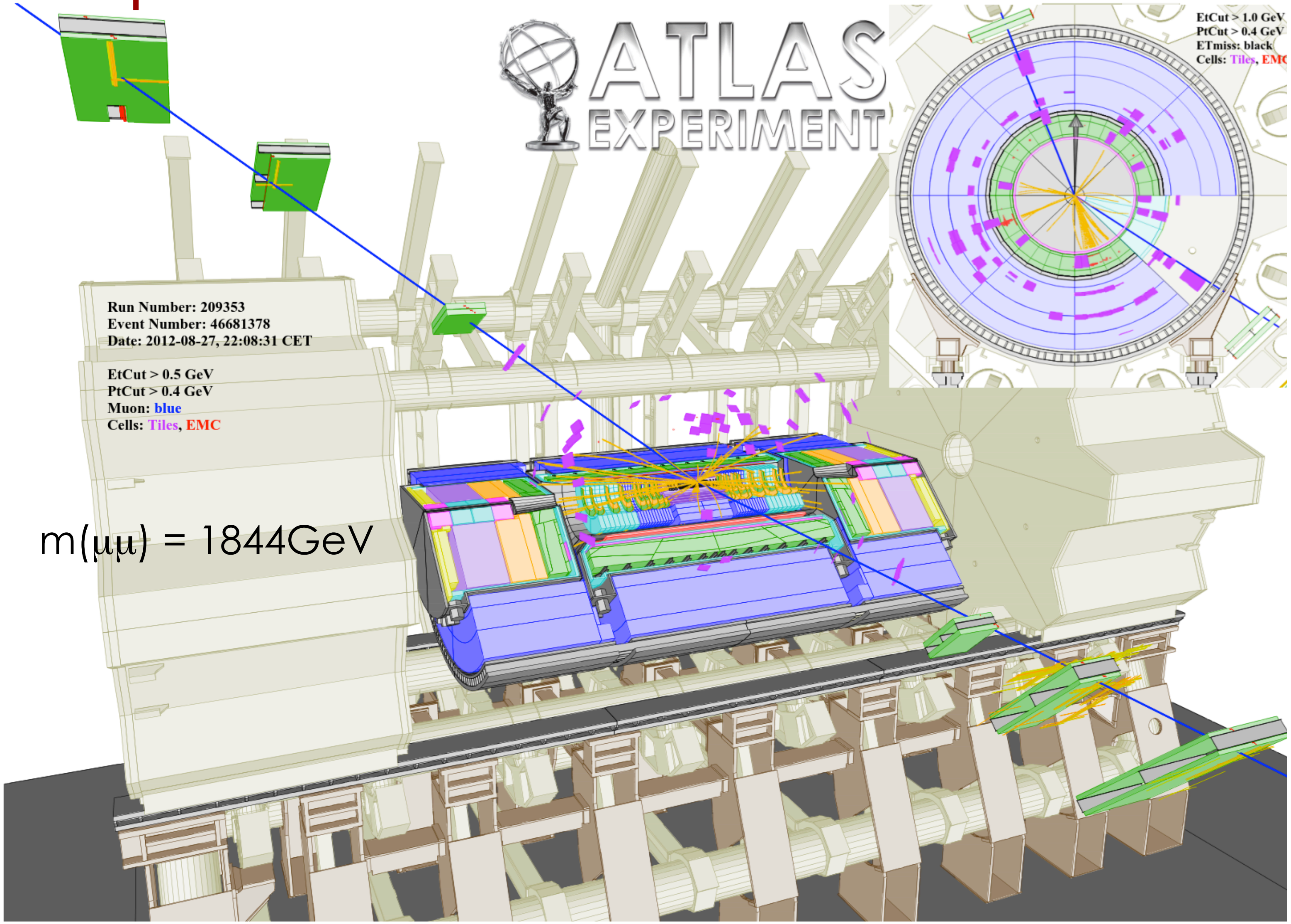
- The unification of fundamental interactions as well as some SM deficiencies have motivated the introduction of extended gauge symmetries, featured by several possible extensions of the SM
  - GUTs (E_6 model)
  - Extra-dimensions (Kaluza-Klein, Randall-Sundrum)
  - Technicolor (dynamic EWSB)
  - etc..

- Presenting in this talk the following signatures at 8TeV center-of-mass energy:

Signature	Model	$\mathcal{L}$ at 8TeV	References
$\ell^+\ell^-$	Z' G*	20fb^{-1}	ATLAS-CONF-2013-017 ATLAS-CONF-2013-083
jj	q*	13fb^{-1}	ATLAS-CONF-2012-148
$\ell\ell\gamma$	ℓ*	13fb^{-1}	ATLAS-CONF-2012-146
WZ(->$\ell\nu\ell\ell$)	W', ρ_T	13fb^{-1}	ATLAS-CONF-2013-015
ZZ(->$\ell\ell$ jj)	G*	7.2fb^{-1}	ATLAS-CONF-2012-150
γj	QBH, q*	20fb^{-1}	ATLAS-CONF-2013-059

- Other talks
  - **Searches for ttbar resonances with the ATLAS detector**: *Diedi Hu*
  - **Searches for resonant diboson production with the ATLAS detector**: *Viviana Cavaliere*

Dilepton

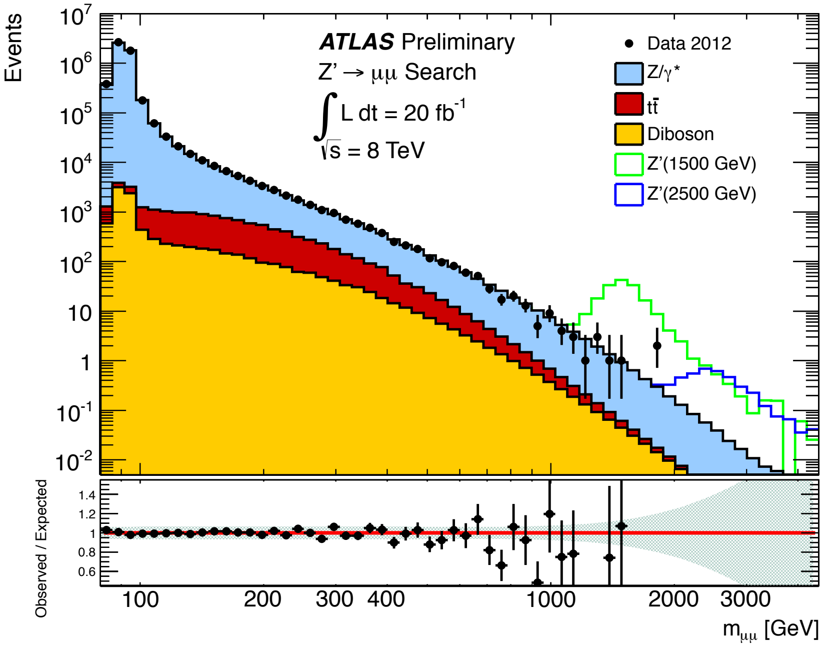


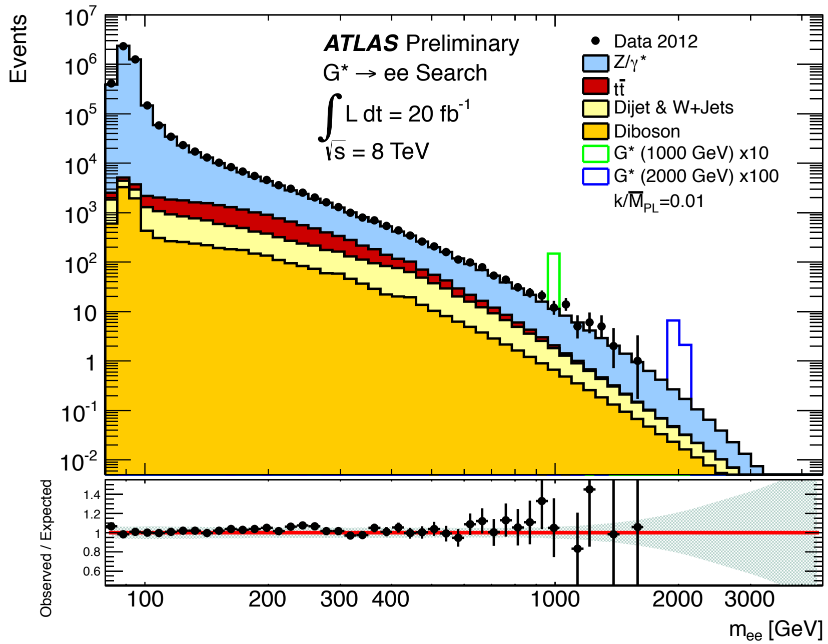
m(μμ) = 1844GeV

Dilepton ($\ell^+\ell^-$: ℓ=e, μ)

- Benchmark models: Z', G*
- Neutral gauge boson produced via Drell-Yan process: pp->Z'(G*)->$\ell^+\ell^-$ (ℓ=e, μ)
- Clean signature: ee or $\mu^+\mu^-$
- Drell-Yan is irreducible background

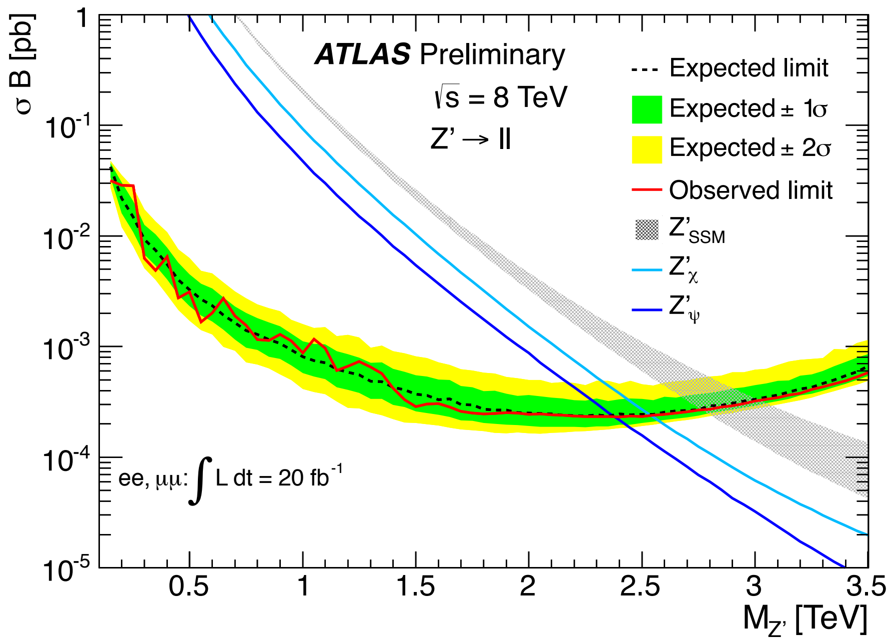
- Backgrounds
  - Data-driven method: multi-jets and W+jets
  - MC estimation: Drell-Yan, diboson and ttbar
- Normalizing with the Z peak (80GeV-110GeV)

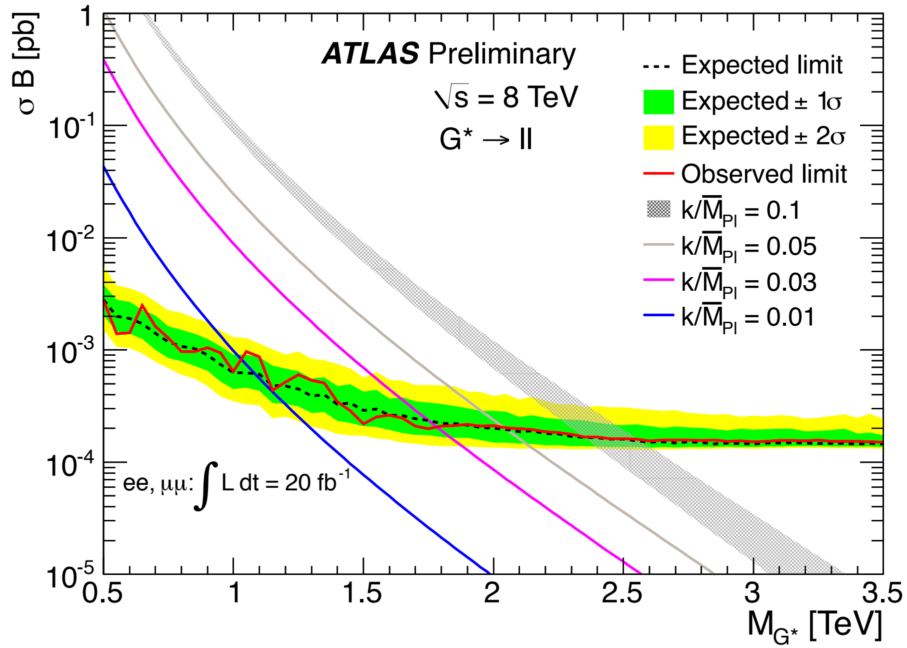




Dilepton ($\ell^+\ell^-$: ℓ=e, μ)

- 95% C.L. limits on $\sigma \times B(Z' \to \ell\ell)$ and on $\sigma \times B(G^* \to \ell\ell)$





- 95% C.L. limits on the Z'/G* mass

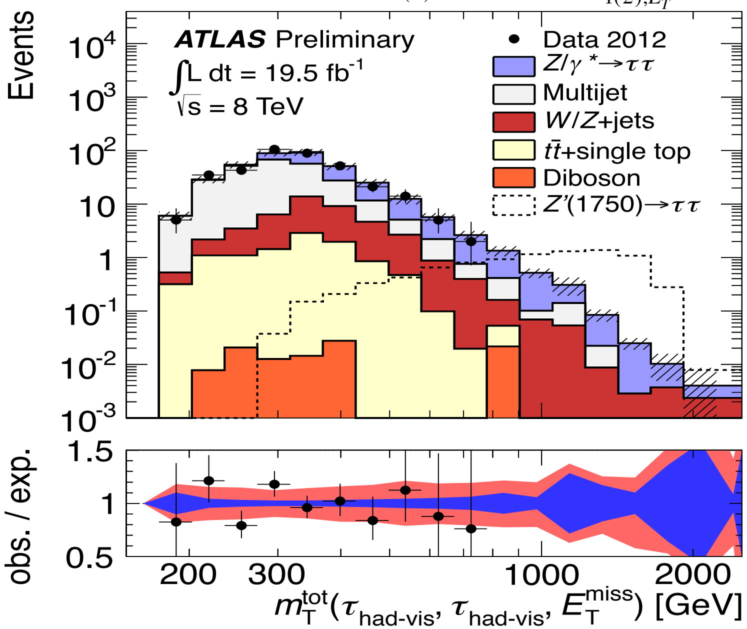
Model	Z'_{SSM}	Z'_{ψ}	Z'_{N}	Z'_{η}	Z'_{I}	Z'_{S}	Z'_{χ}	$G^* \to \ell^+\ell^-$
Observed mass limit [TeV]	2.86	2.38	2.39	2.44	2.42	2.47	2.54	2.47
Expected mass limit [TeV]	2.85	2.37	2.38	2.43	2.40	2.46	2.53	2.47

Dilepton ($\tau_{had}\tau_{had}$)

- Benchmark model: Z'
- τ_h defined as reconstructed jet with 1 or 3 associated tracks in the inner detector.
- At least 2 taus (no μ's and e's). The 2 highest-p_T taus must be opposite charged and back-to-back

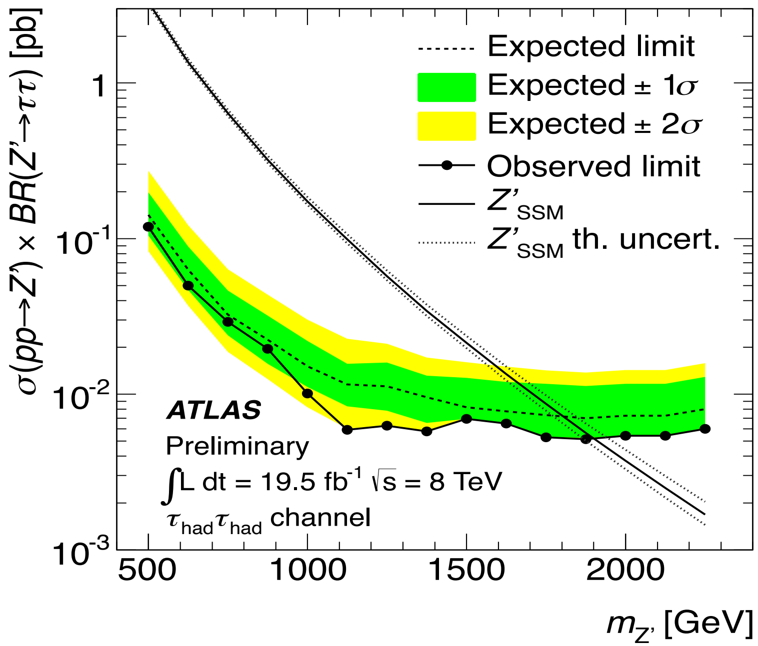
$$m_T^{tot} = \sqrt{2p_{T1}p_{T2}C + 2\left|E_T^{miss}\right|p_{T1}C_1 + 2\left|E_T^{miss}\right|p_{T2}C_2}$$

$$C = 1 - \cos\Delta\phi_{12}, \qquad C_{1(2)} = 1 - \cos\Delta\phi_{1(2),E_T^{miss}}$$

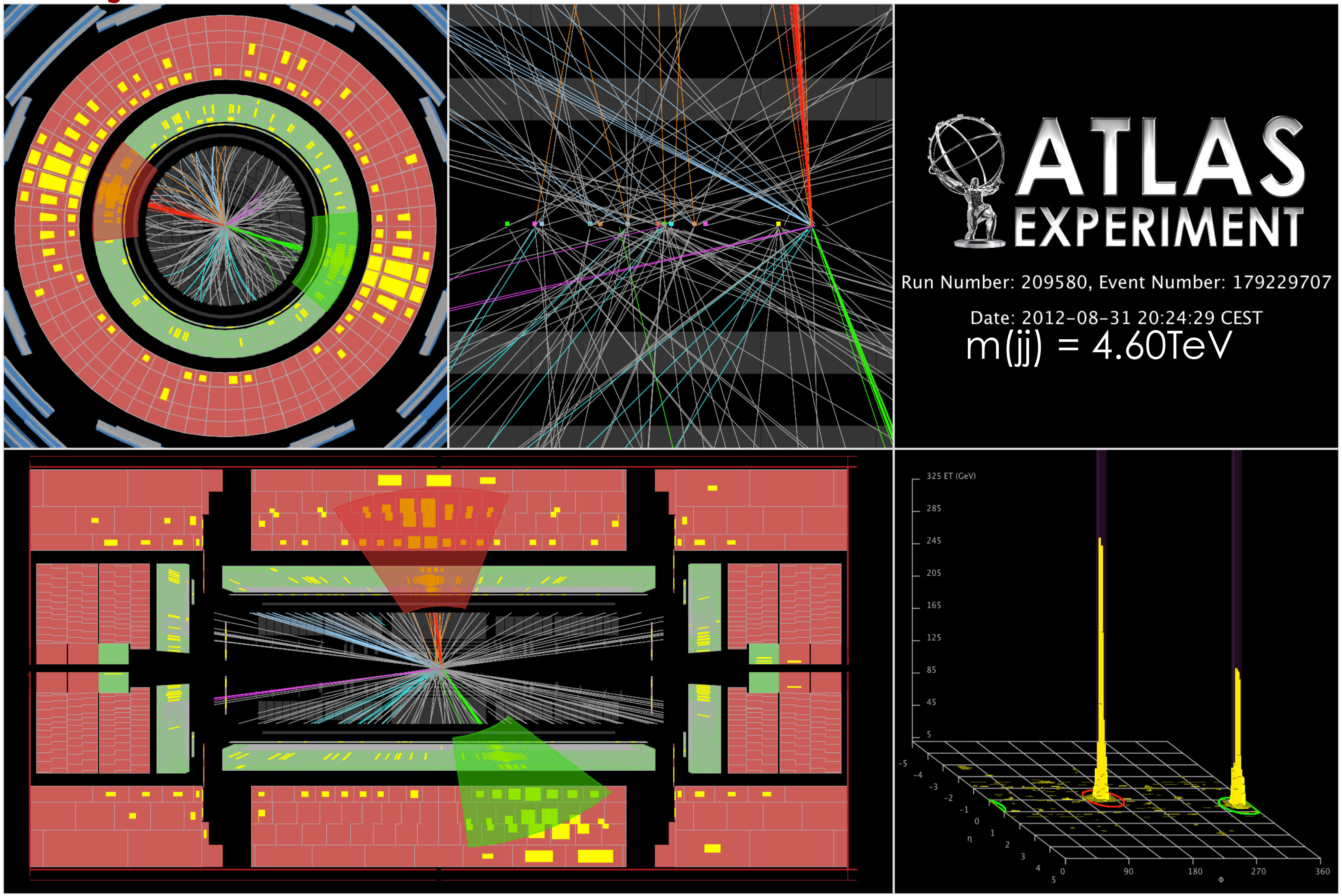


- Backgrounds
  - Data-driven method: multi-jets
  - MC estimation: Drell-Yan, diboson, ttbar and single top. The W/Z +jets are weighted with jet-to-tau fake rate

- 95%C.L. limits on $\sigma\times$B(Z'->ττ)

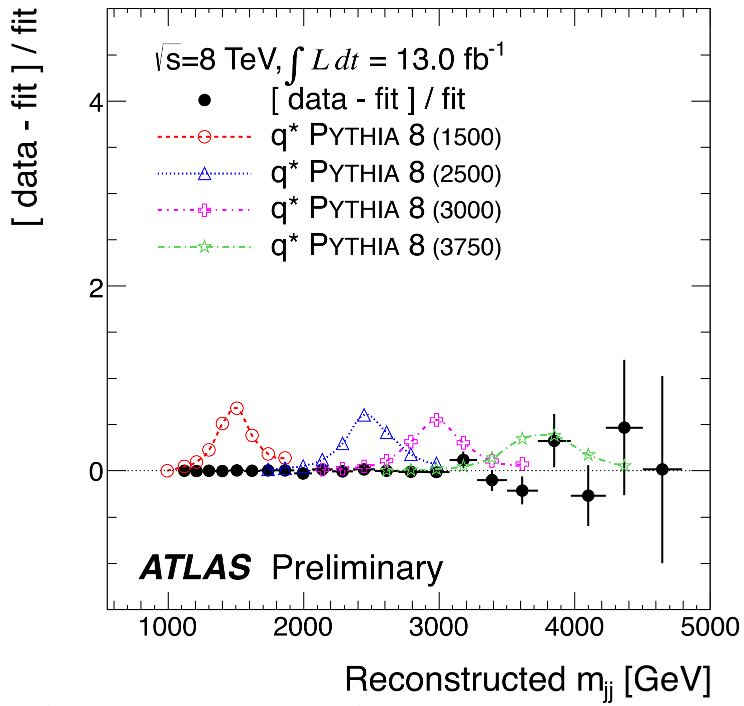


Dijet


ATLAS EXPERIMENT
Run Number: 209580, Event Number: 179229707
Date: 2012-08-31 20:24:29 CEST
m(jj) = 4.60TeV
325 ET (GeV)
η
φ

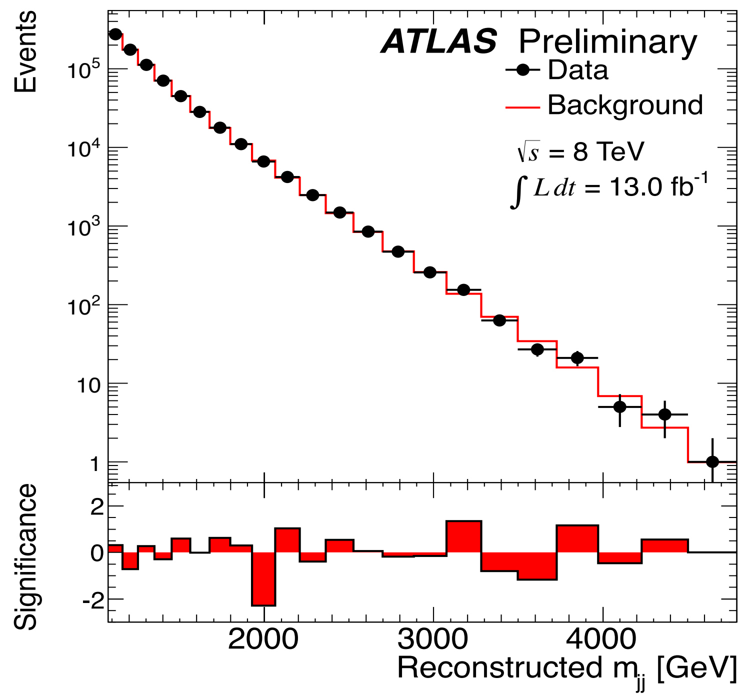
Dijet

- Benchmark model: q^*
- Events with at least 2 central jets
- The dijet invariant mass is computed with the highest p_T jets (leading) and the second-highest p_t (sub-leading).



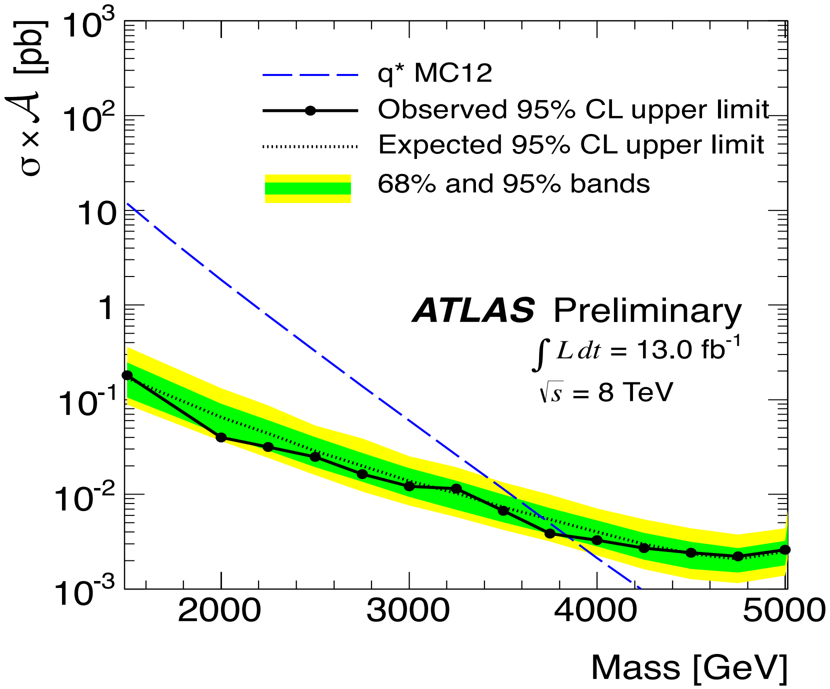
- Data-driven method used to estimate the dijet background.
- Using a functional form to fit the dijet background to avoid theoretical and systematic uncertainties using MC dijet background prediction.

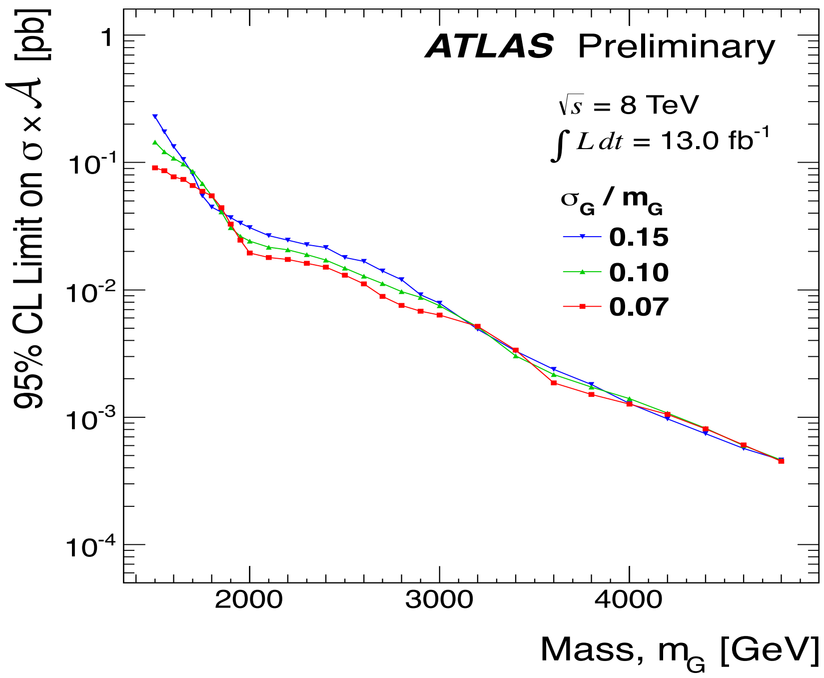
$$f(x \equiv m_{jj}/\sqrt{s}) = p_1 (1-x)^{p_2} x^{p_3 + p_4 \ln x}$$



Dijet

- 95% C.L. limits on $\sigma \times A$ for q^* and for a Gaussian resonance (Model independent)

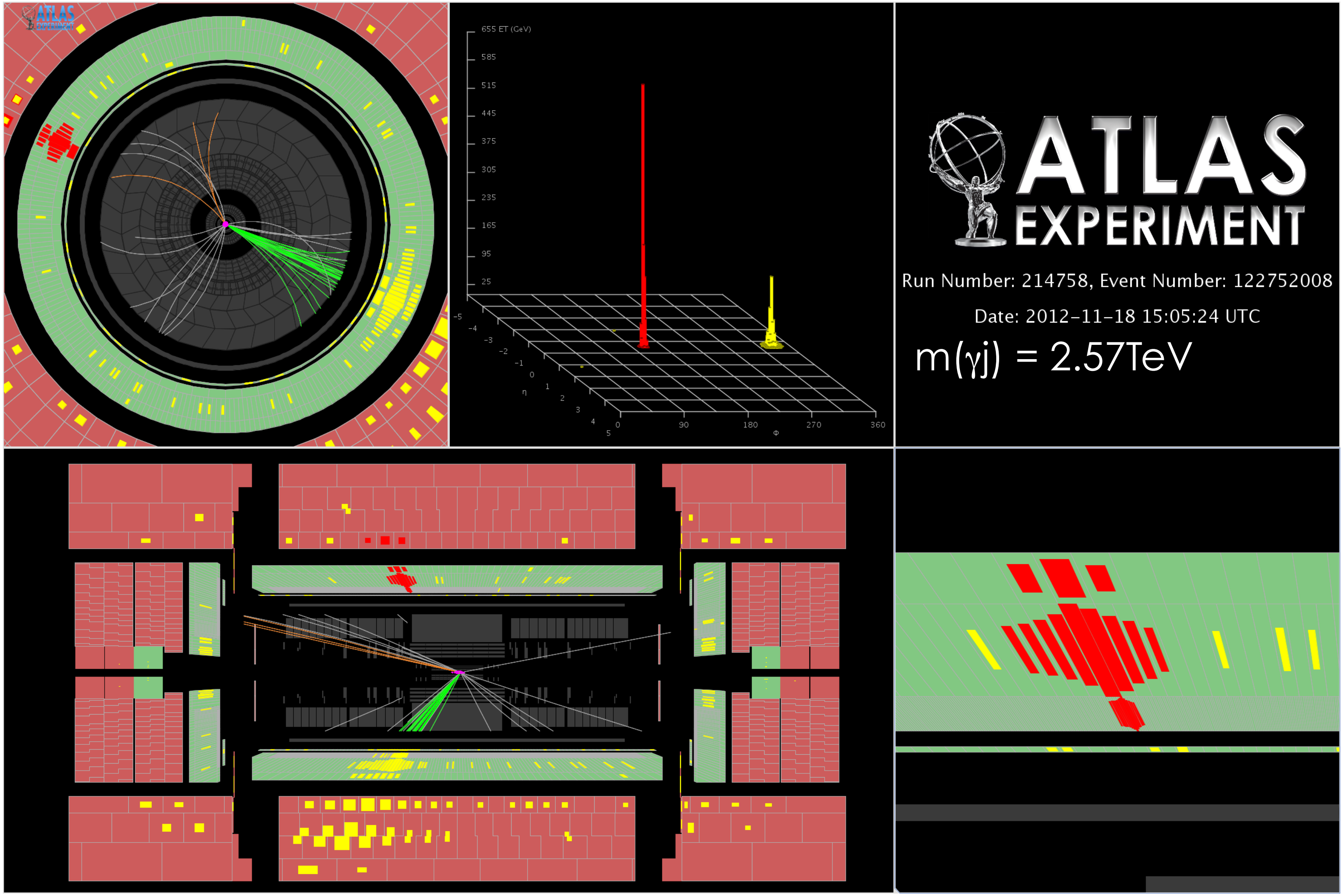




- 95% C.L. limits on q^* mass

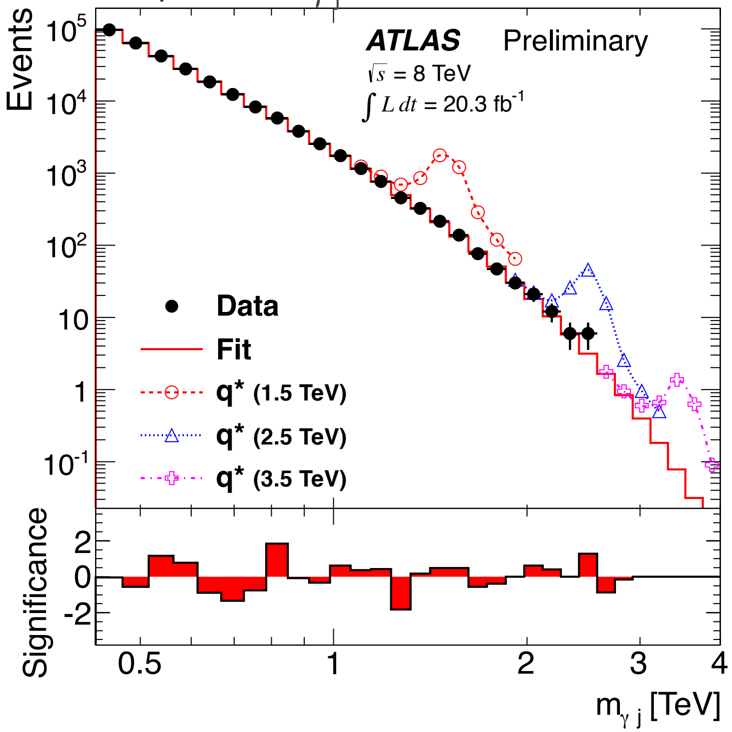
Model	q^*
Observed mass limit [TeV]	3.84
Expected mass limit [TeV]	3.70

Photon + jet


655 ET (GeV)
585
515
445
375
305
235
165
95
25
η
Φ
0
90
180
270
360
ATLAS
EXPERIMENT
Run Number: 214758, Event Number: 122752008
Date: 2012-11-18 15:05:24 UTC
m(γj) = 2.57TeV

Photon + jet

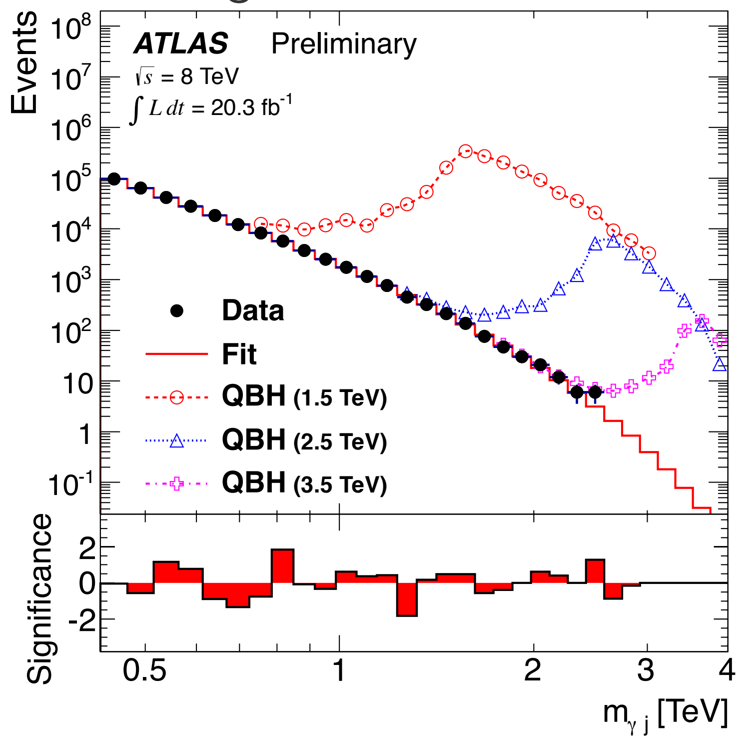
- Benchmark model: QBH, q^*
- Events with at least one γ and one jet. γ and jet are central.
- Events with more than one γ or jet, the highest p_T candidates are selected to compute $m_{\gamma j}$



- Data-driven method to estimate the background

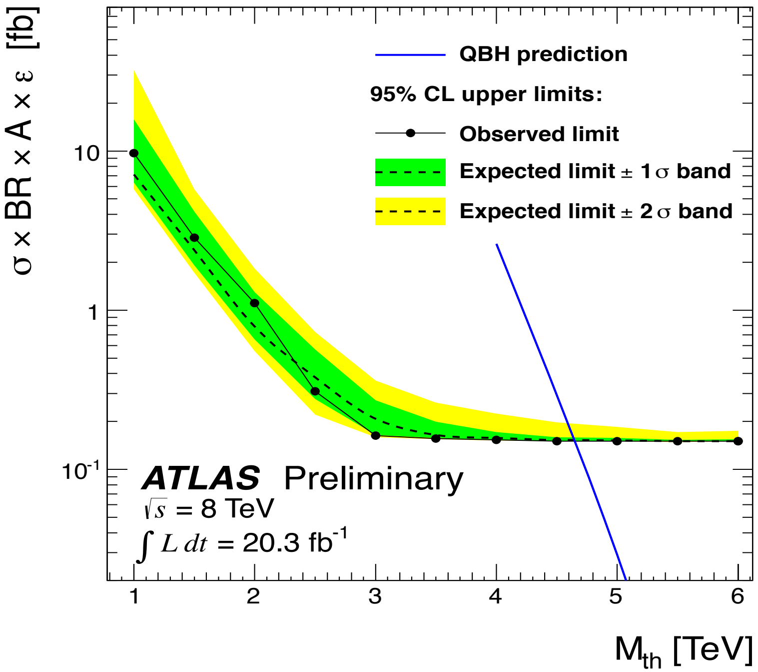
$$f(x \equiv m_{\gamma j}/\sqrt{s}) = p_1(1-x)^{p_2}\, x^{-(p_3+p_4 \ln x)}$$

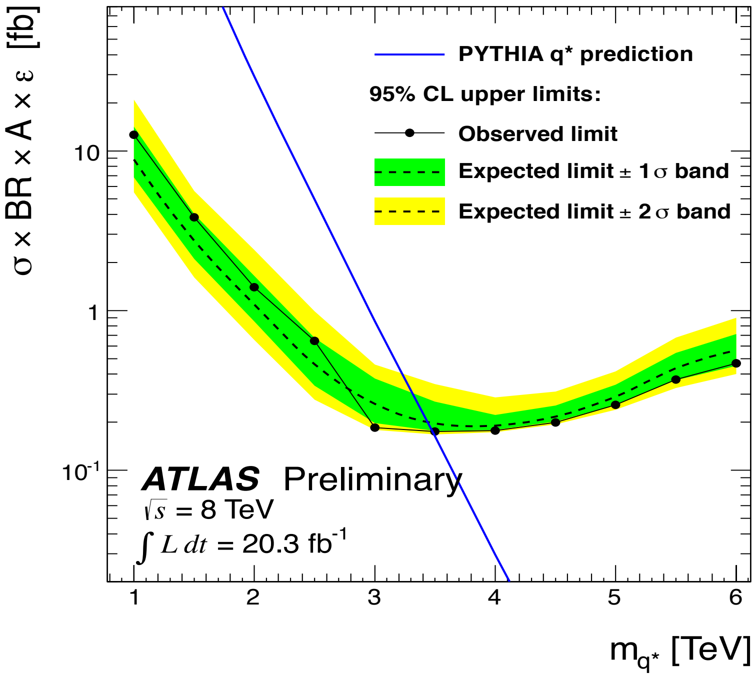
- Thorough checks of funtion behavior using the LO MC and NLO distributions of backgrounds



Photon + jet

- 95% C.L. limits on $\sigma \times B(QBH \to \gamma j, q^* \to \gamma j) \times A \times \varepsilon$



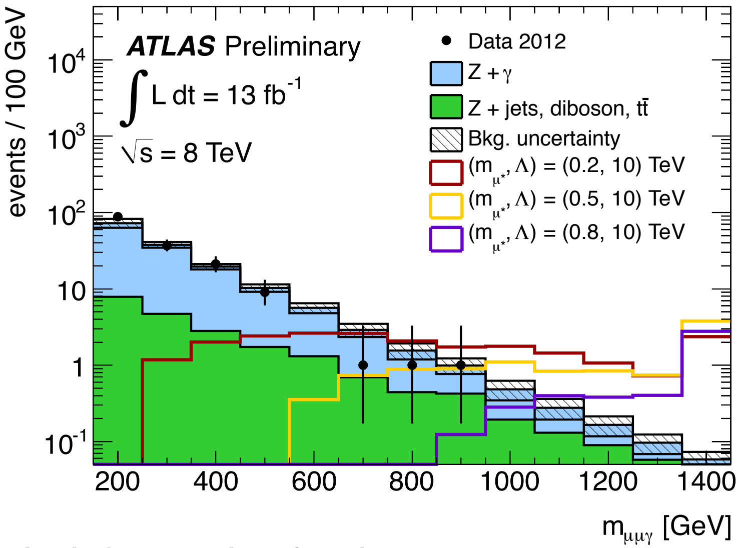


- 95% C.L. limits on *QBH*/q^* mass

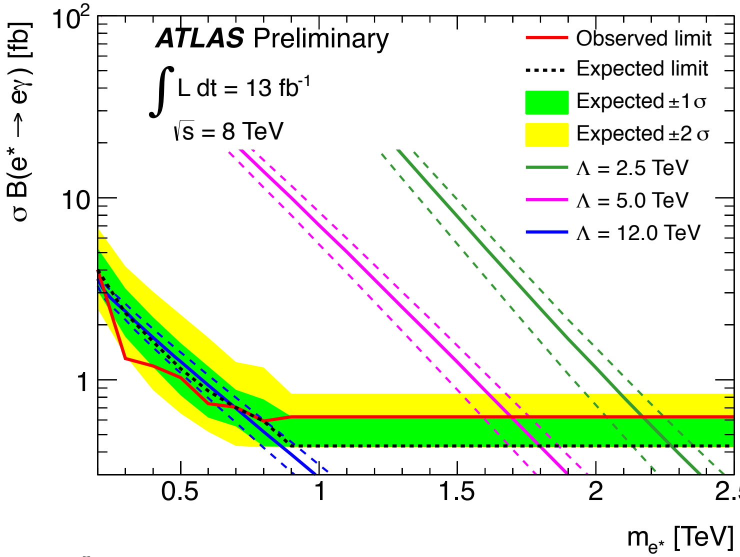
Model	*QBH*	q^*
Observed mass limit [TeV]	4.6	3.5
Expected mass limit [TeV]	4.6	3.4

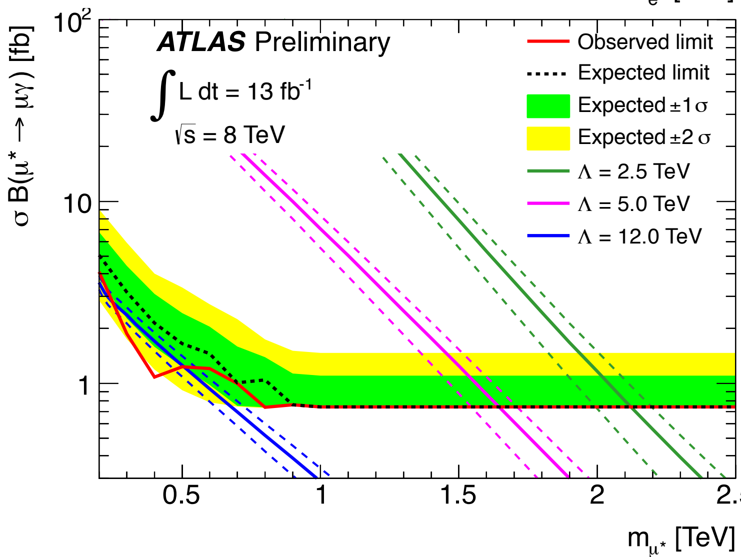
Excited leptons

- Benchmark model: ℓ^*
- Events with 2 same flavor leptons (e/μ) and a photon
- Backgrounds
  - MC estimation: Z+γ, Z+jets, ttbar and diboson
  - Scale factor applied to Z+jets in a region of (70GeV,110GeV)
- Fitted the Z+γ and Z+jets backgrounds to extrapolate in a region of 150GeV<$m_{ll\gamma}$<1050GeV



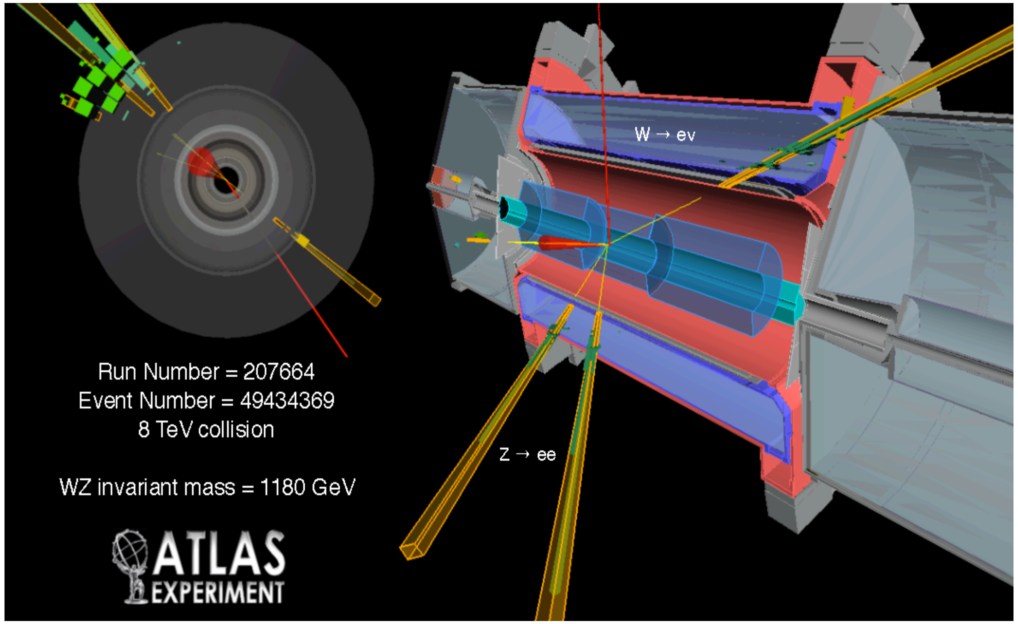
- 95% C.L. limits on $\sigma \times B(\ell^* \to \ell\gamma)$

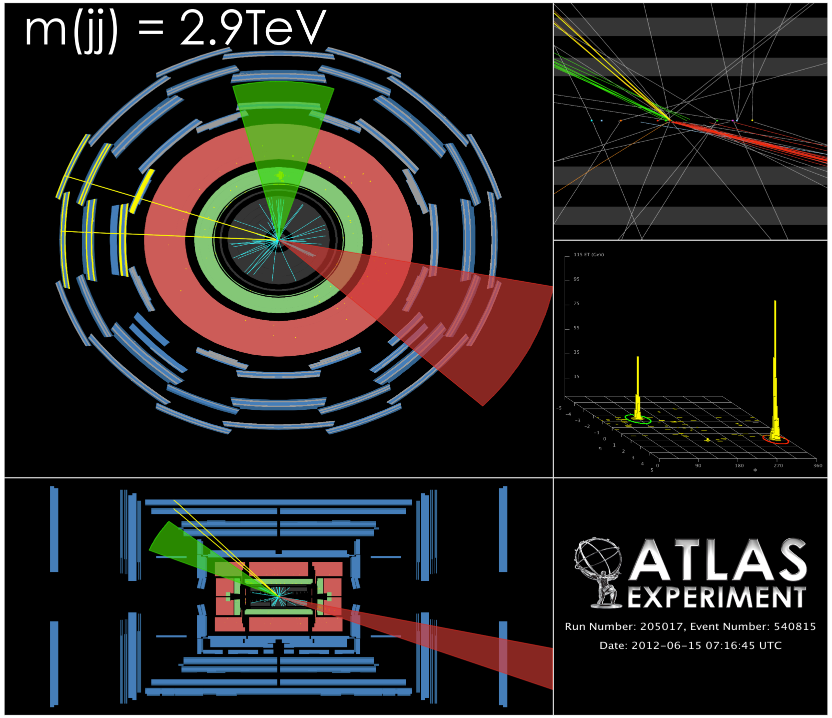




Diboson

WZ->$\ell\nu\ell\ell$





ZZ->$\ell\ell qq$

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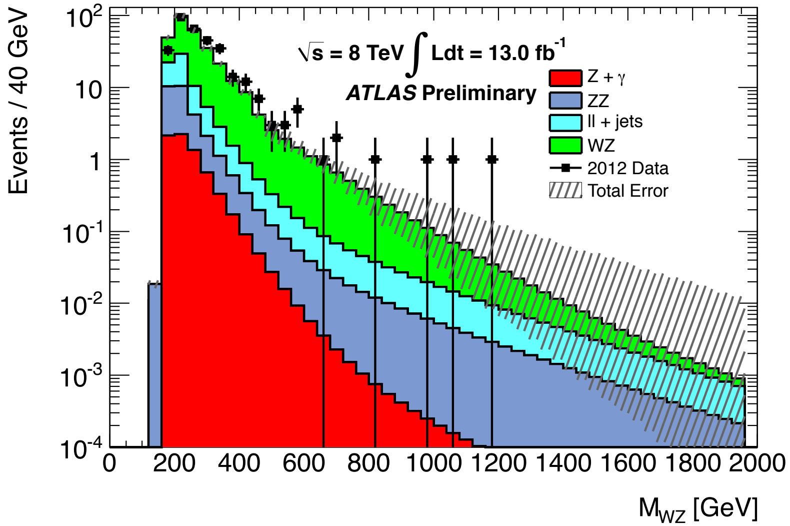
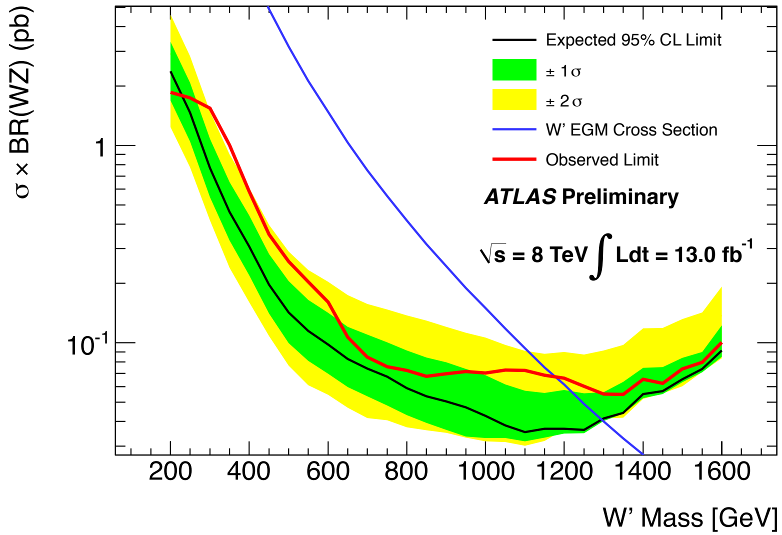
WZ->$\ell\nu\ell\ell$

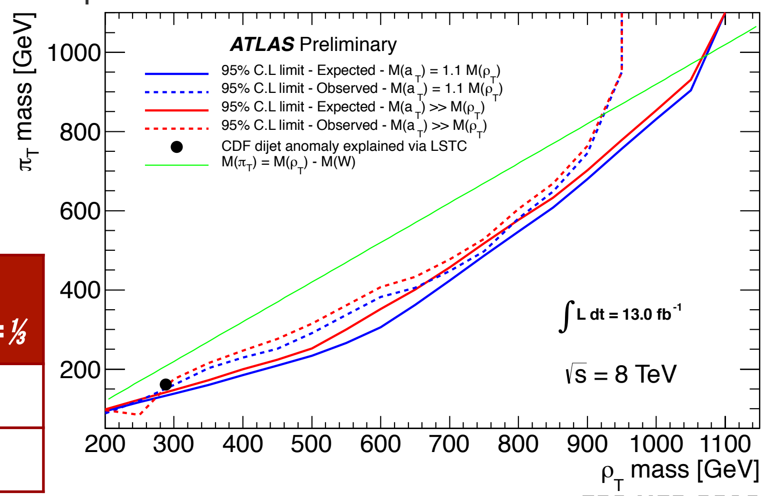
- Benchmark model: W', ρ_T
- Exactly 3 leptons with 2 opposite sign, same flavor leptons to reconstruct $W(\ell^{\pm}\nu)$ and $Z(\ell^{+}\ell^{-})$
- Backgrounds
  - Data-driven method: $\ell\ell$+jets (Z+jets, ttbar and Wt)
  - MC estimation: WZ/ZZ, Z+γ, W+γ



- 95% C.L. limits on $\sigma \times$B(W'->WZ)



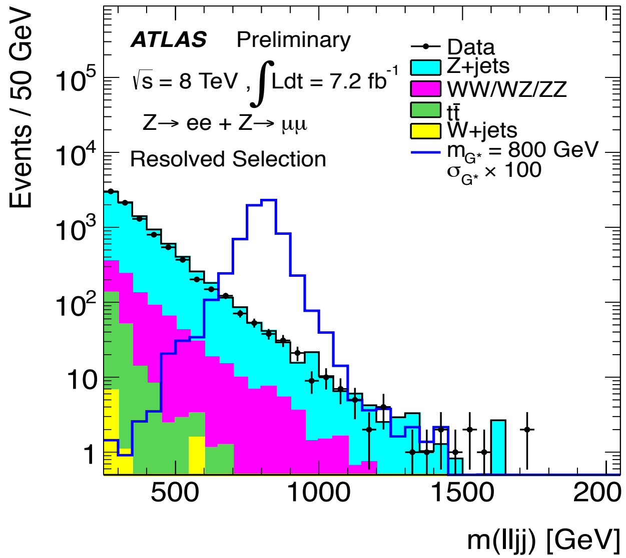
- Exclusion mass regions on (π_T, ρ_T) plane

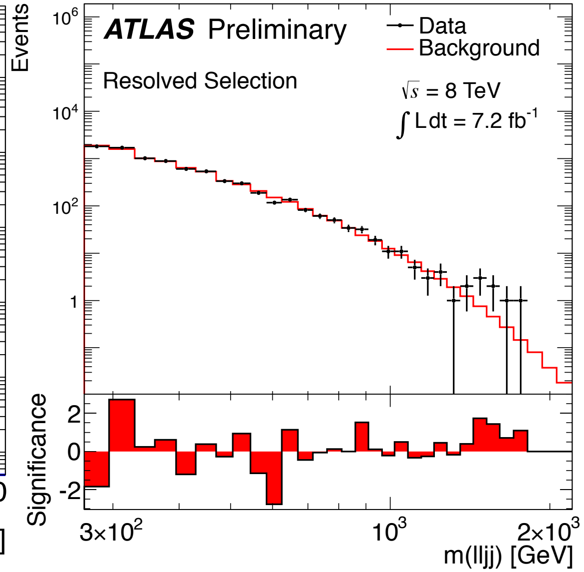


Model	W'	ρ_T : $m_{\rho T}=m_{\pi T}+m_W$, $m_{aT}=1.1m_{\rho T}$ (>>$m_{\rho T}$), sin χ=⅓
Obs. mass limit [TeV]	1.18	0.92
Exp. mass limit [TeV]	1.30	~1.07

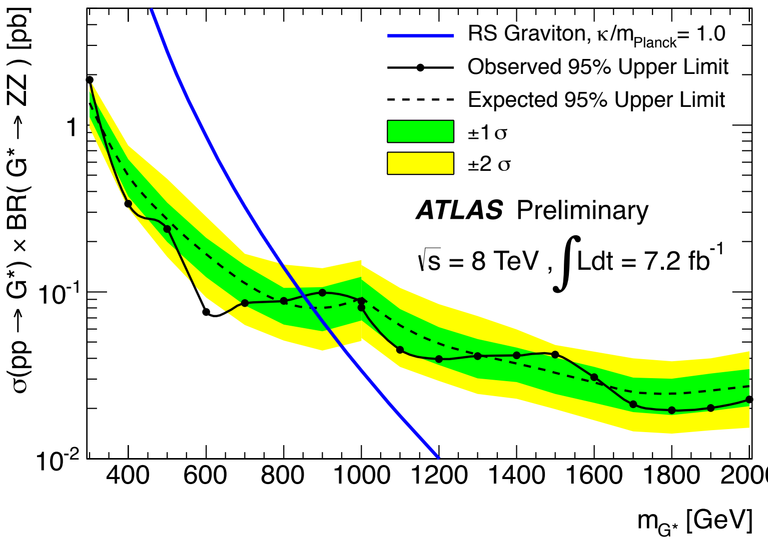
ZZ->ℓℓqq

- Benchmark model: bulk RS G*
- Exactly 2 leptons and $m_{\ell\ell}$ is between (66GeV,116GeV) (ℓℓ: ee or $\mu^+\mu^-$)
- 2 Signals regions for good acceptance over the wide mass range:
  - $m_{\ell\ell jj}$ for signal below 1TeV
  - $m_{\ell\ell j}$ for signal above 1TeV
- Data-driven method used to estimate the background
- Resonance signal is searched for by making a smooth function fit to the $m_{\ell\ell jj}$ and $m_{\ell\ell j}$ spectra in data





- 95% C.L. limits on $\sigma \times B(G^*\text{->}ZZ)$



Model	Bulk RS G* (κ/m_p=1.0l)
Obs. mass limit [TeV]	0.85
Exp. mass limit [TeV]	0.87

Summary

- The 8TeV running was successful, and the ATLAS Collaboration continues search for the physics beyond the Standard Model (BSM)
- In this talk we presented six different signatures at 8TeV center-of-mass energy constraining nine BSM models with the ATLAS detector
- Much improved reach with $\sqrt{s}$=14TeV
  - Expecting parton luminosities will increase

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Backup

Benchmark models

- Sequential Standard Model[1]: Z'_{SSM}
- E_6 model Grand Unification Theories (GUT's)[2] : $Z'_{(\psi, N, \eta, I, S, \chi)}$
- Randall-Sundrum Model[3]: (RS G^*)
- Excited quark and leptons[4,5,6]: (q^*, ℓ^*)
- New vector boson[7] : $g_{W'WZ}=g_{WWZ}\times(m_W m_Z/m_{W'}^2)$
- Low-scale Technicolor[8,9]
- Bulk Randall-Sundrum model[10]: (Bulk RS G^*)
- Low-scale quantum gravity[11,12]: (QBH)

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