Exotic Searches at ATLAS

Doug Gingrich
(University of Alberta/TRIUMF)
on behalf of the ATLAS Collaboration

Searches

Concentrate on five searches (last three analyses based on full 2010 data set):

- Highly ionising particles.
- Diphoton events with large missing transverse energy (universal extra dimensions).
- Searches for new physics in dijets (update of Phys. Rev. Lett. 105 (2010) 161801 and Phys. Lett. B694 (2011) 327).
- High-mass states with lepton plus missing transverse energy (W'/W*).
- High-mass dilepton resonances (Z').

Long-Lived Highly Ionising Particles

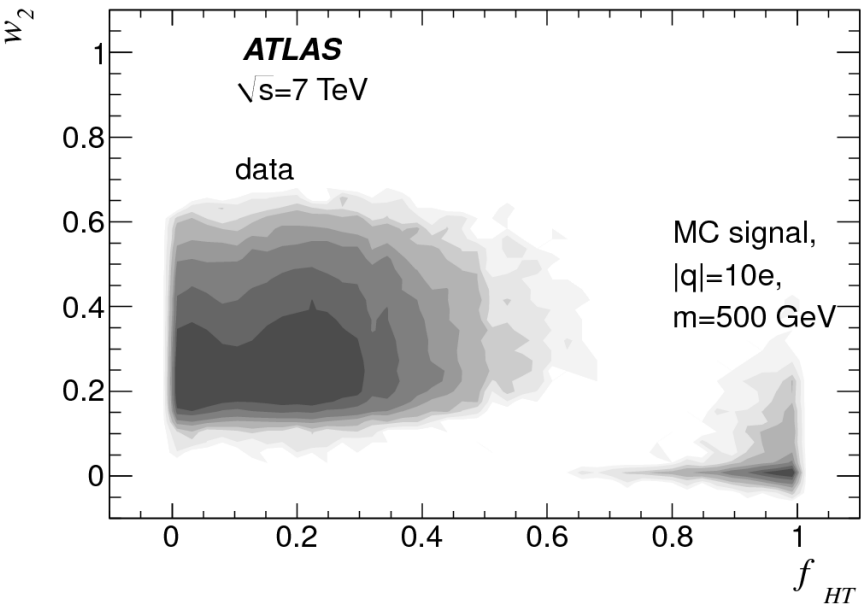
- Search for massive long-lived highly ionising particles (HIP).
  - http://arxiv.org/abs/1102.0459 (submitted to Phys. Lett. B)
- Examples that give rise to highly ionizing particle signatures are Q-balls, black hole remnants, magnetic monopoles, and dyons.
- We present a model independent search.
- Due to large mass, HIPs also characterised by their non-relativistic speeds, as well as, high electric charge.
- Expect large amounts of energy loss through ionisation.
- In ATLAS:
  - leave tracks in inner tracking detector, matched to
  - narrow energy loss in electromagnetic calorimeter.

Long-Lived Highly Ionising Particles (2)

- Accessible parameter space:
  - $|q| \geq 6e$ bound determined by $E_T > 10$ GeV trigger threshold.
  - $|q| \leq 17e$ bound determined by delta electrons and electron recombination.
  - mass $\leq$ 1000 GeV bound determined by trigger timing constraints.
  - Lifetimes > 100 ns to maintain narrow energy deposit.
- Data luminosity 3.1 pb^{-1}.

Long-Lived Highly Ionising Particles (3)

- Discriminate by proportion of high-ionisation hits and lateral extent of energy deposition.
  - Fraction of TRT hits on the track which pass a high threshold: f_{HT}.
  - Fraction of energy outside the three most energetic cells associated to a selected EM cluster, in the second EM calorimeter layer: w_2.
- Data matches Standard Model Monte Carlo.
- No such particles are found.
- Estimated background 0.019 ± 0.005 events.
- Limits for particles produced in the acceptance kinematic region
- HIP masses above 800 GeV probed for the first time at particle colliders (Europhys. Lett. 12 (1990) 613).



Inclusive HIP cross section upper limits (95% CL)

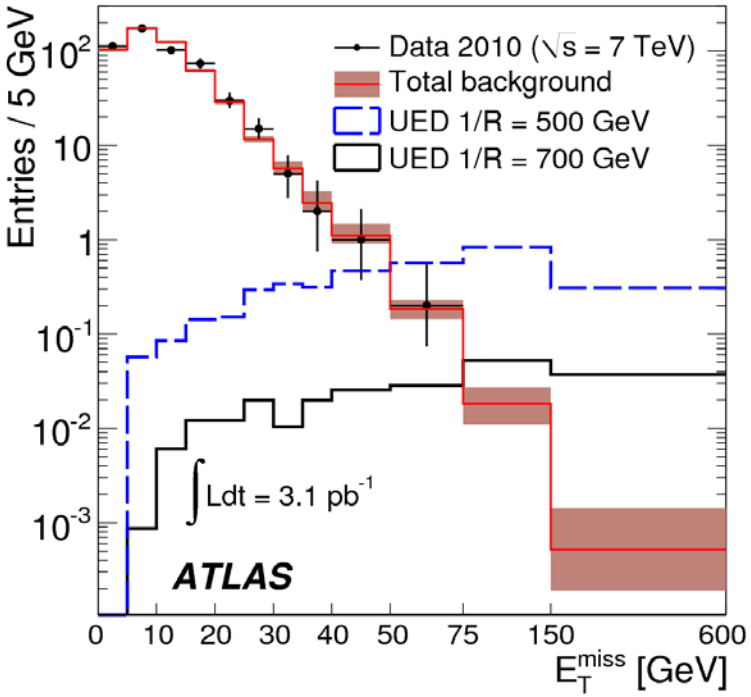
m (GeV)	|q| = 6e	|q| = 10e	|q| = 17e
200	1.4 pb	1.2 pb	2.1 pb
500	1.2 pb	1.2 pb	1.6 pb
1000	2.2 pb	1.2 pb	1.5 pb

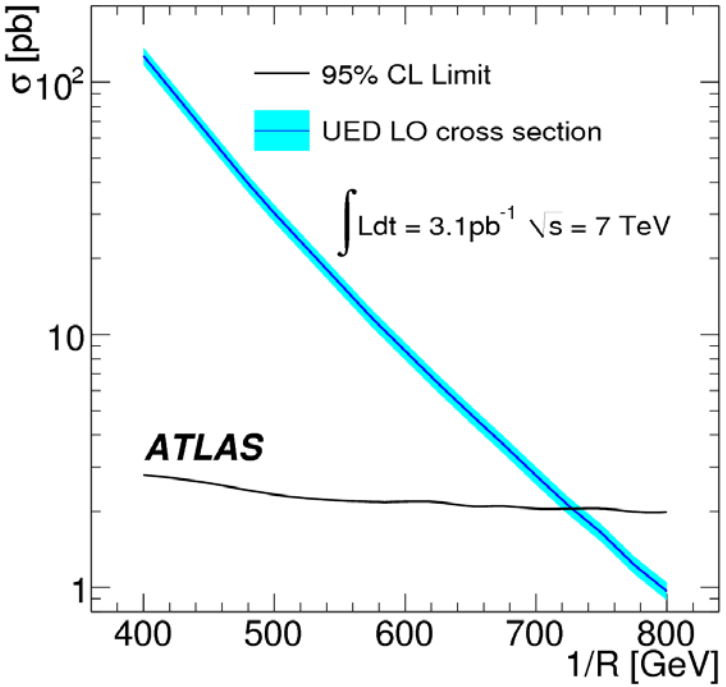
Diphoton with Large Missing Energy

- Diphoton ($\gamma\gamma$) events with large missing energy (E_T^{miss}).
  - http://arxiv.org/abs/1012.4272 (accepted by Phys. Rev. Lett.)
- Interpret in context of Universal Extra Dimension (UED) model.
- Consider single TeV^{-1} sized UED, with compactification radius R.
- Lightest Kaluza-Klein (KK) particle (LKP) is KK photon γ^*.
- Strong pair production of KK quarks and/or gluons.
- Decay down via KK states to LKP.
- LKP decays by $\gamma^* \rightarrow \gamma + G$.
- Use model in which $\Lambda R = 20$, Λ is UV cutoff and R free parameter.

Diphoton with Large Missing Energy (2)

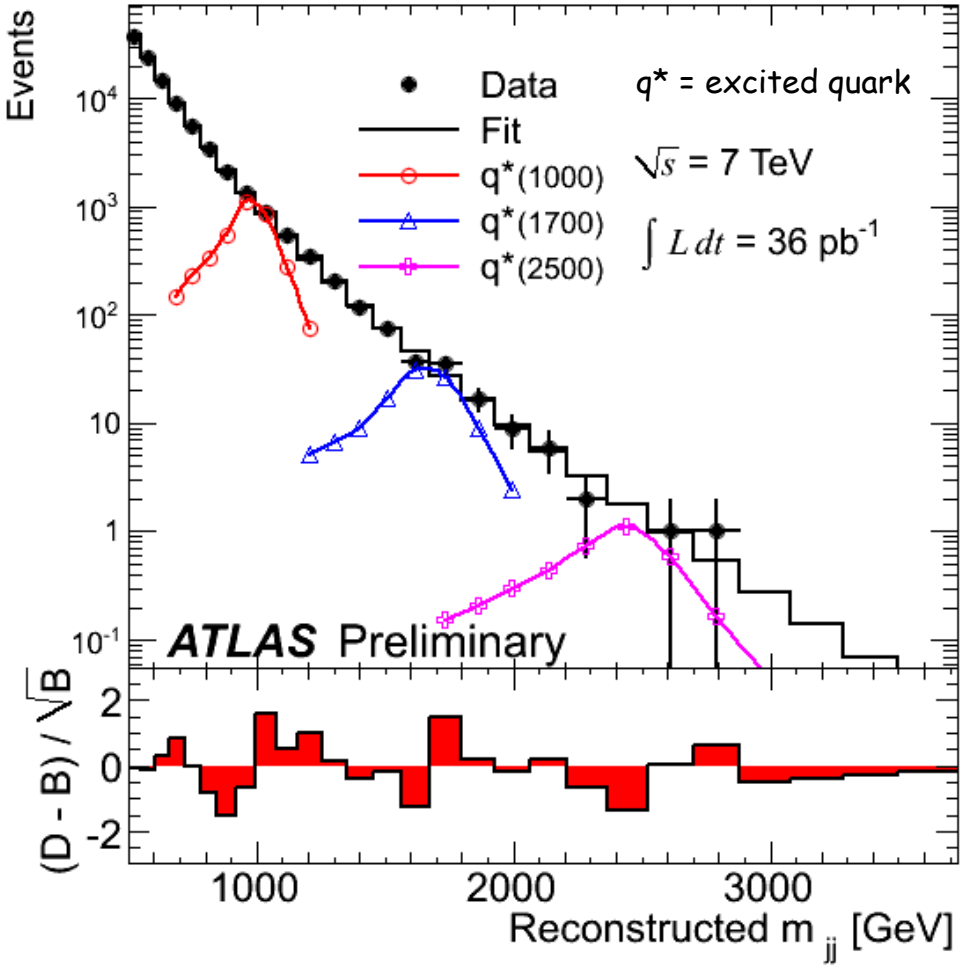
- Two photons with E_T > 25 GeV and event E_T^{miss} > 75 GeV.
- Zero observed events, estimated background 0.32 ± 0.16 + 0.37 - 0.10 events.
- In context of previous specified model, values of 1/R < 728 GeV are excluded.
- Most sensitive limit on this model to date
  - 1/R < 477 GeV, DØ experiment, Phys. Rev. Lett. 105 (2010) 221802.





New Physics in Dijets

- Study both dijet invariant mass of final state and angular distributions of energetic jets up to 3.5 TeV.
- $p_T^{J1} > 150$ GeV, $p_T^{J2} > 30$ GeV.
- $|\Delta\eta_{jj}| < 1.3$ (mass spectrum only).
- Invariant mass distribution found to be smooth, in agreement with SM.



Angular Distributions

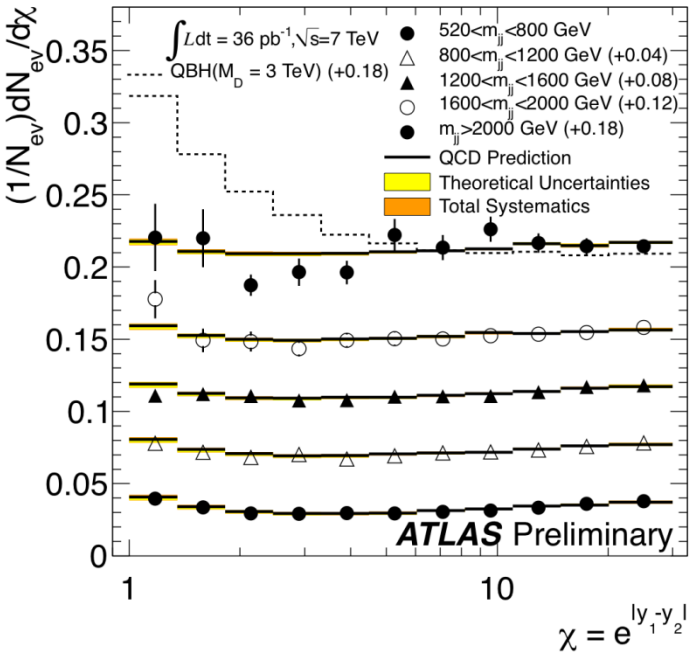
- $p_T^{J1} > 60$ GeV, $p_T^{J2} > 30$ GeV.
- $y_B = 0.5\,(y_1 + y_2) < 1.10$
- $y^* = 0.5\,(y_1 - y_2) < 1.70$
- Data consistent with QCD.

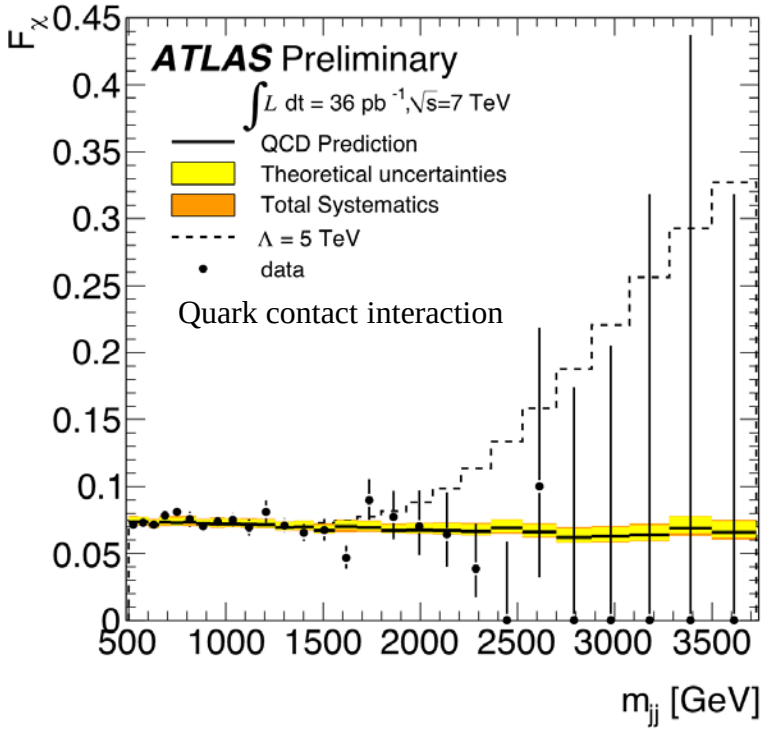
$$\chi = \exp(|y_1 - y_2|) = \exp(2|y^*|)$$

Dijet centrality

$$F_\chi(m_{jj}) = \frac{N_{events}(|y^*| < 0.6)}{N_{events}(|y^*| < 1.7)}$$

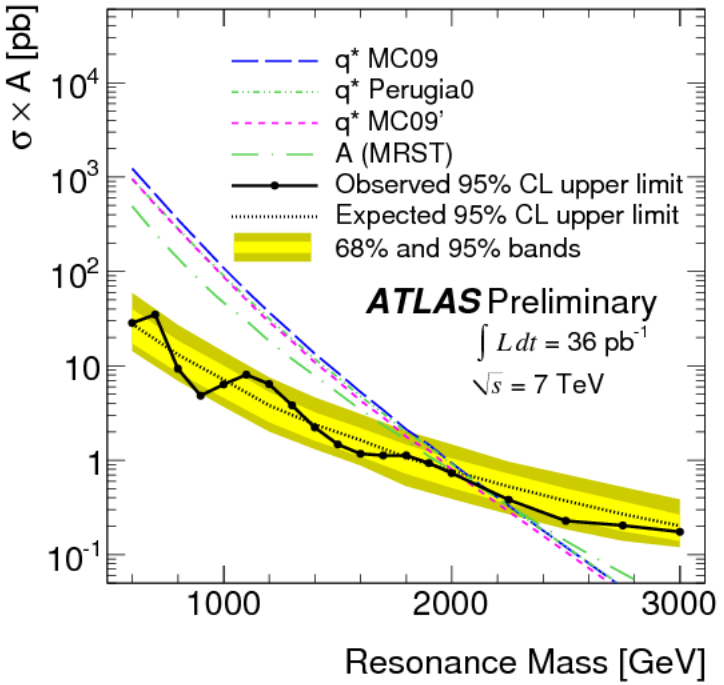
QBH = quantum black hole





Excited Quarks and Axigluon

- Excited quarks production: q g → q*.
- Excited quark decay: q* → qg, qW/Z/γ.

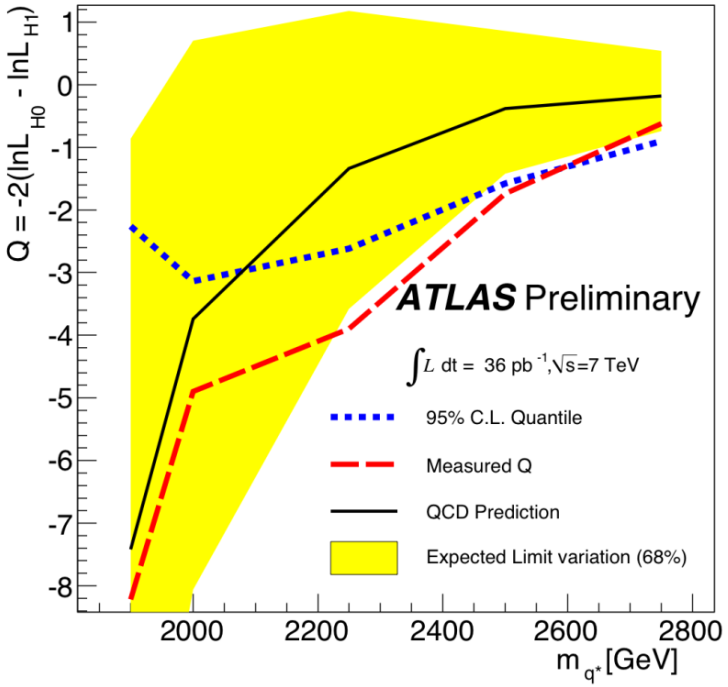


Resonance search

- Excited quark: 0.60 < m < 2.15 TeV.
- Axigluon: 0.60 < m < 2.10 TeV.

$$Q = -2[\ln L(F_\chi(m_{jj}) \mid H0) - \ln L(F_\chi(m_{jj}) \mid H1)]$$

H0 null hypothesis (QCD only),
H1 hypothesis for new physics.

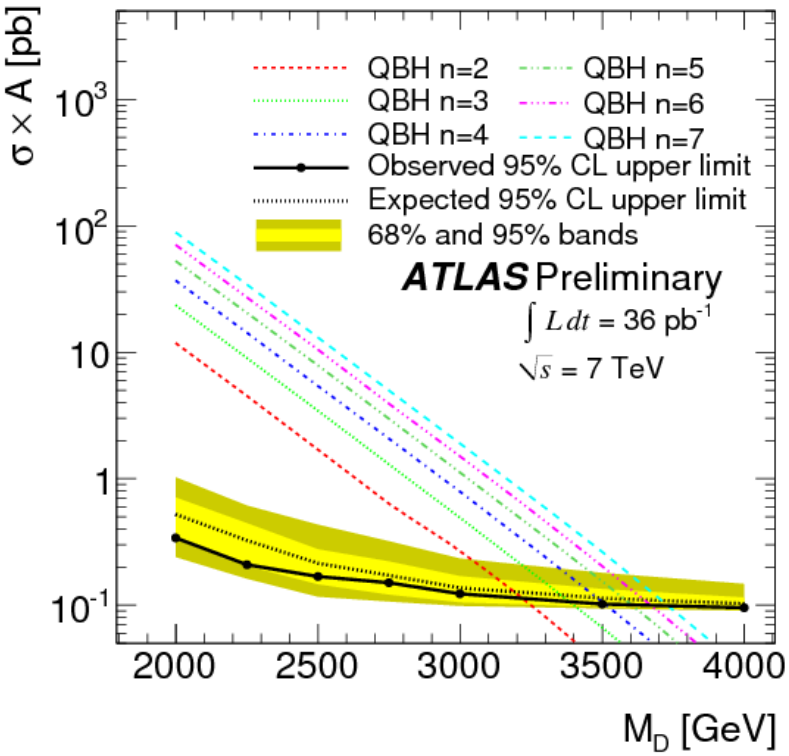


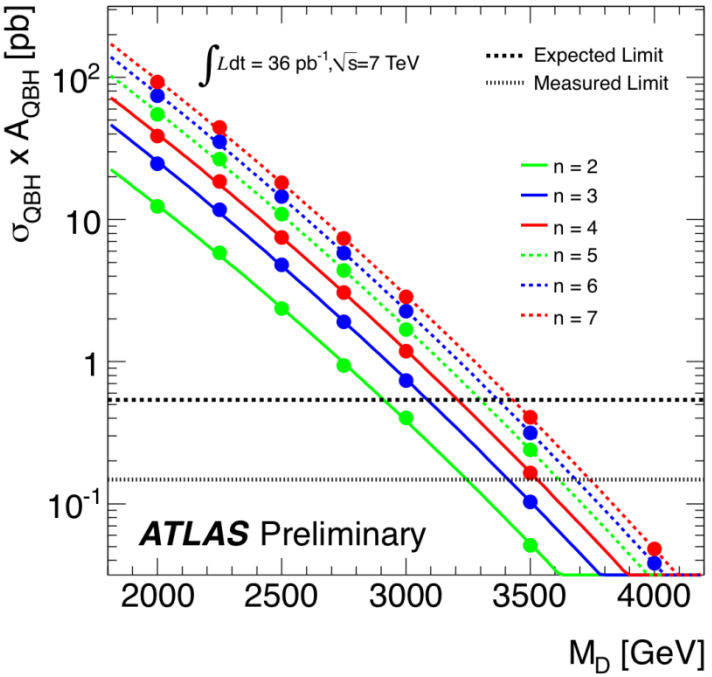
Angular distribution analysis

- Excited quark: 0.60 < m < 2.64 TeV.

Quantum Black Holes (QBH)

- Dijet decays of black holes:
  - M_D = higher dimensional Planck scale, n = number of extra dimension.
- Large threshold effect with long tails to higher masses.





Resonance search

- Exclude 0.75 < M_D < 3.67 TeV.

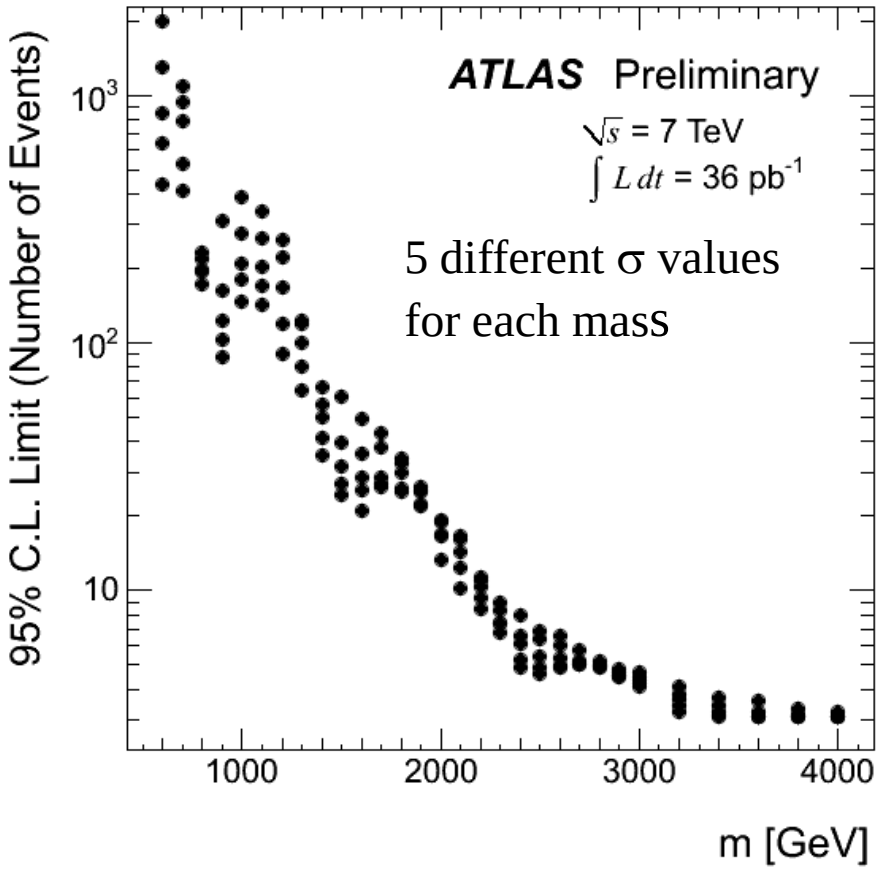
Angular distribution analysis

- dN/dχ distribution: Exclude M_D < 3.69 TeV.
- $F_\chi(m_{jj})$ distribution: Exclude M_D < 3.78 TeV.

Gaussian Limits

- Gaussian profile as signal template: 0.6 < m < 4.0, 3% < σ < 15% (5 different σ values).
- Can be used for different models:
  - Check validity of gaussian signal approximation and determine peak and width.
  - Determine model acceptance.
  - Calculate event yield for model cross section and 36 pb^{-1}.
  - Compare this event yield with limits.

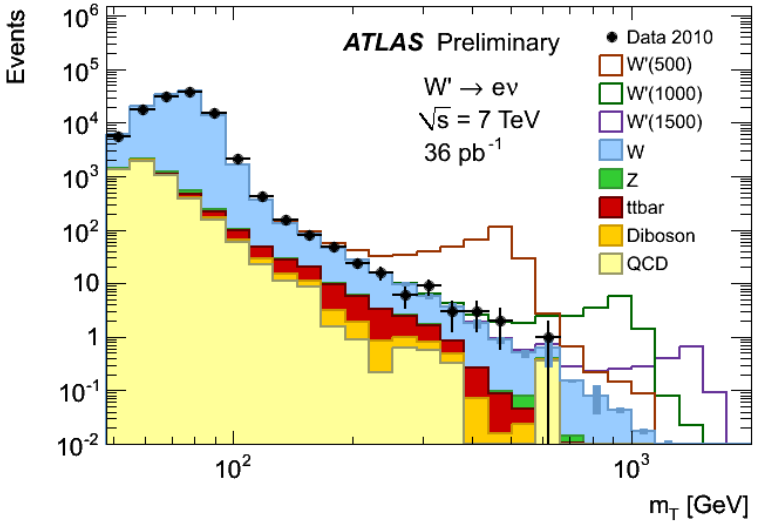
Exclusion limit on number of events



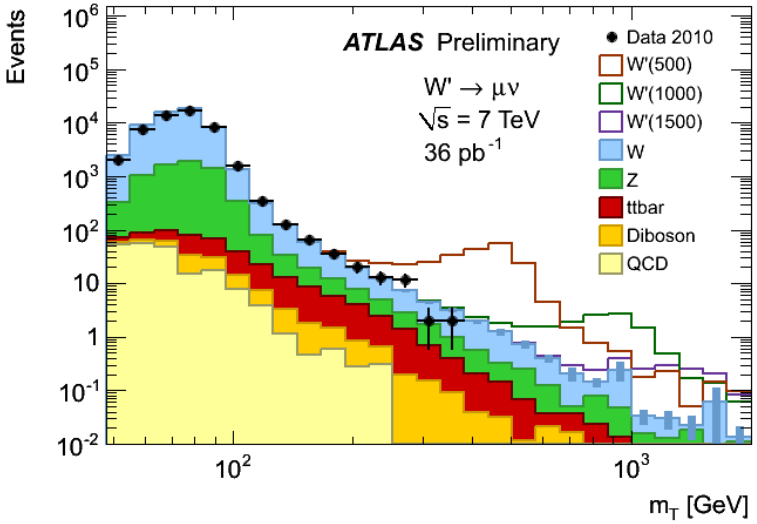
Lepton plus Missing Transverse Energy

- $W'/W^* \rightarrow (e/\mu)\,\nu$.
- W': same SM couplings as W.
- W*: anomalous magnetic moment type couplings.

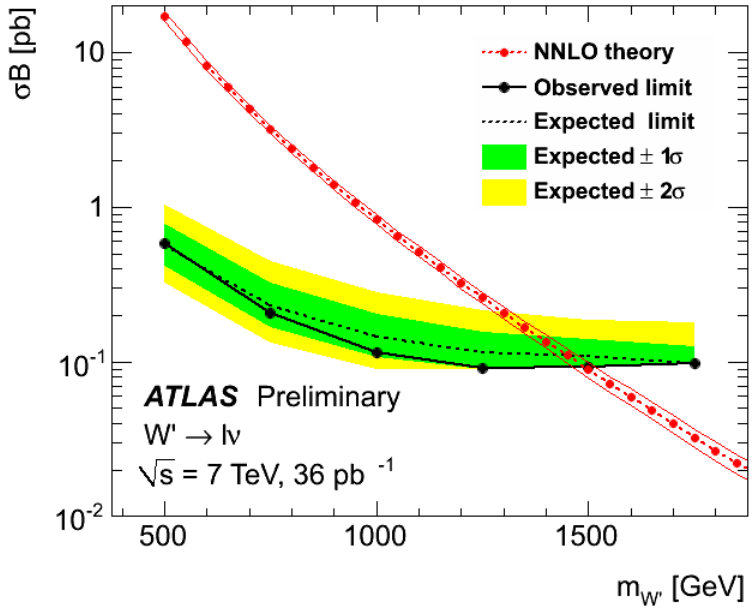
$$m_T = \sqrt{2 p_T E_T^{miss} (1 - \cos\phi_{l\nu})}$$

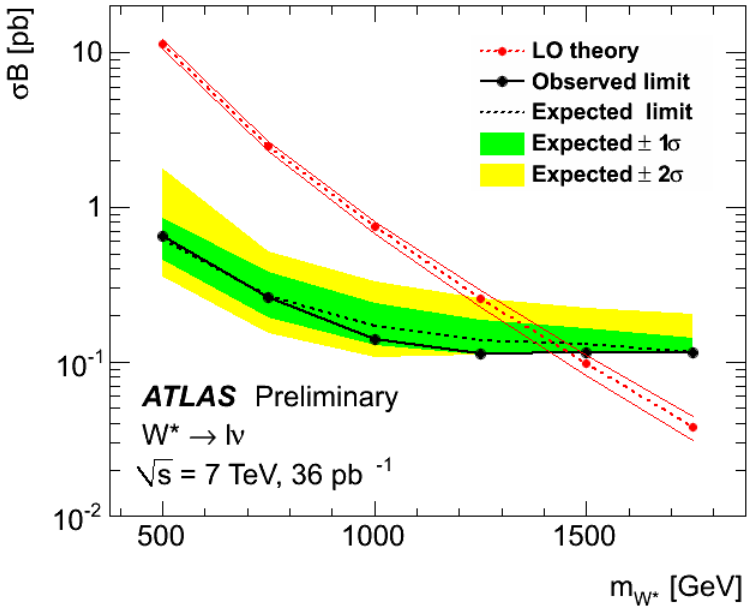


- Electron: $E_T > 25$ GeV, $E_T^{miss} > 25$ GeV, $E_T^{miss}/E_T > 0.6$.
- Muon (barrel only): $p_T > 25$ GeV , $E_T^{miss} > 25$ GeV.



Lepton plus Missing Transverse Energy (2)

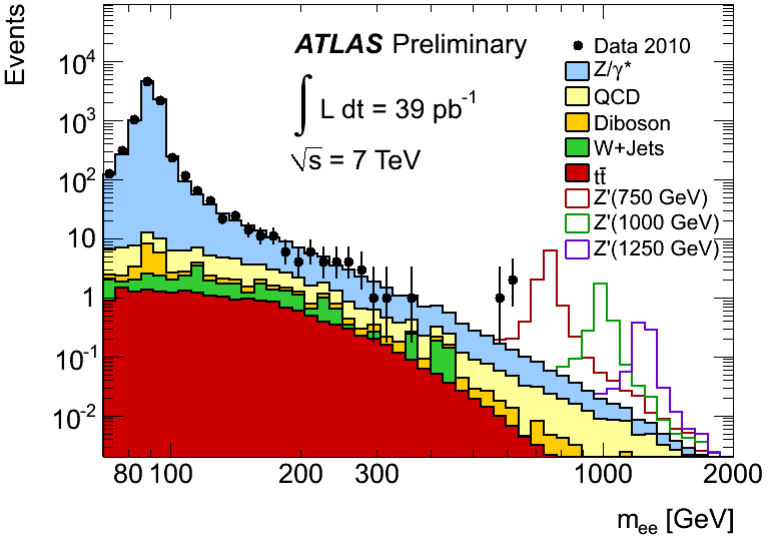


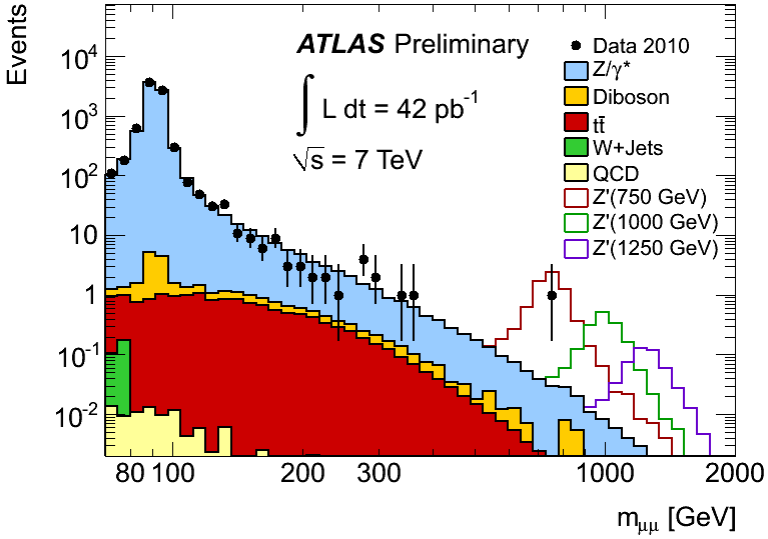


- Agreement between data and expected backgrounds good.
- Count events with $m_T > 0.5\ m_{W'/W^*}$.
- W′ mass > 1.49 TeV.
- W* mass > 1.47 TeV.

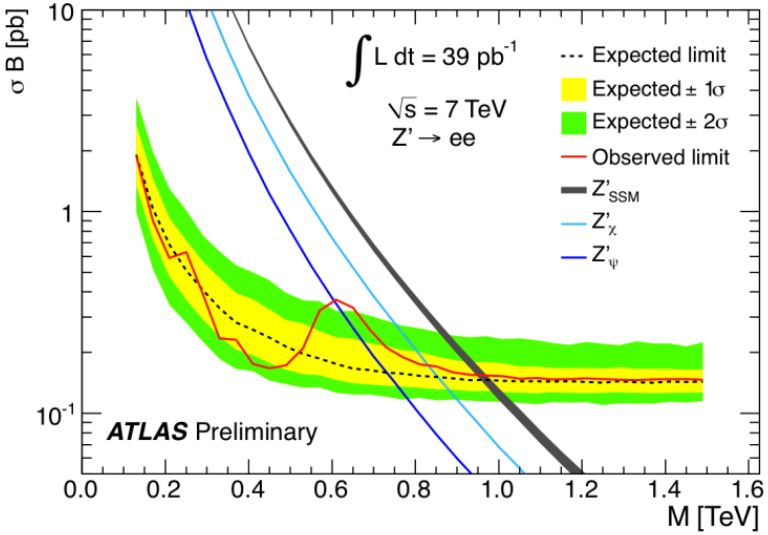
High Mass Dilepton Resonances

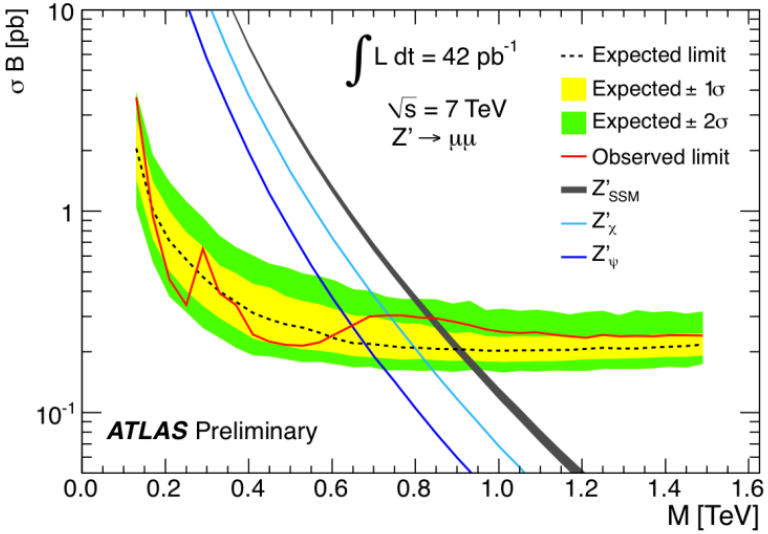
- Examples of high-mass resonances:
  - New heavy neutral gauge boson (Z′, Z*)
  - Randall-Sundrum spin-2 graviton
  - Spin-1 techni-meson
- In this search Z′ → ee or μμ.
- Z′: sequential SM with SM couplings.
- Z′: E_6 motivated, 6 models with different mixing angles between two U(1) states.
- Assume resonance has narrow intrinsic width compared to detector mass resolution.
- E_T > 25 GeV (electrons).
- p_T > 25 GeV (muons).

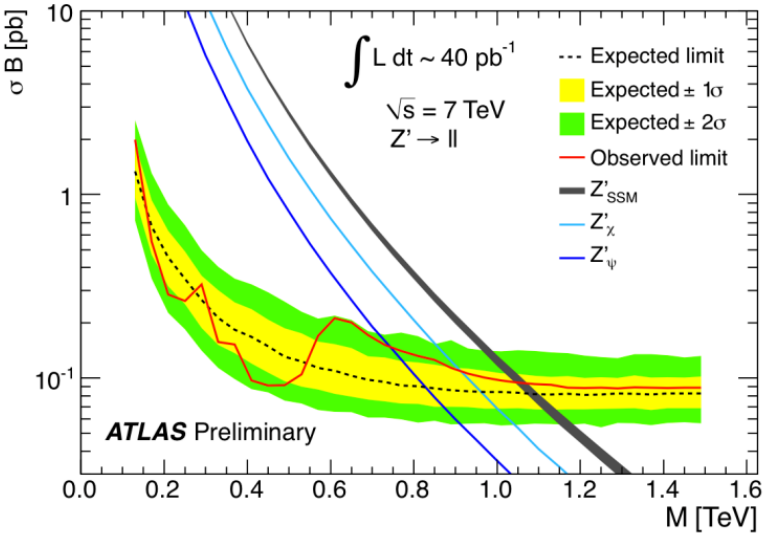




High Mass Dilepton Resonances (2)







Measured (expected) limits:

Z′ (ee) mass > 0.957 (0.964) TeV.

Z′ (μμ) mass > 0.834 (0.895) TeV.

Z′ (ll) mass > 1.048 (1.084) TeV.

Z′ (E_6) mass > 0.738-0.900 TeV.

Conclusions

- Presented first results of searches for new physics with ATLAS detector using the 2010 LHC pp-collision data at $s^{1/2}$ = 7 TeV.
- After a few months of operations, these searches already go beyond the reach of previous experiments, and start to explore new territories.

Backup Slides

Long-Lived Highly Ionising Particles

- Different hypothesis on the production mechanism.
  - Inclusive HIP cross section produced in regions of pseudorapidity and kinetic energy acceptance.
  - Pair production cross section upper limits assuming a Drell-Yan production mechanism.

Inclusive HIP cross section upper limits

m (GeV)	|q| = 6e	|q| = 10e	|q| = 17e
200	1.4 pb	1.2 pb	2.1 pb
500	1.2 pb	1.2 pb	1.6 pb
1000	2.2 pb	1.2 pb	1.5 pb

Pair production cross section upper limits

m (GeV)	|q| = 6e	|q| = 10e	|q| = 17e
200	11.5 pb	5.9 pb	9.1 pb
500	7.2 pb	4.3 pb	5.3 pb
1000	9.3 pb	3.4 pb	4.3 pb

Diphoton with Large Missing Energy

- Relative systematic uncertainties on the expected UED signal cross section.

Source of uncertaintiy	Uncertaintiy
Integrated luminosity	11%
Photon reconstruction and identification	4%
Effect of pileup	2%
MET reconstruction and scale	1%
Signal MC statistics	1%
Total	12%

High Mass Dilepton Resonances

- Summary of systematic uncertainties on the expect number of events at M_{ll} = 1 TeV.

Source	dielectrons		dimuons	
	Z' signal	background	Z' signal	background
Normalization	5%	5%	5%	5%
PDFs	6%	6%	6%	6%
QCD K-factor	3%	3%	3%	3%
Weak K-gactor	NA	4.5%	NA	4.50%
Efficiency	-	-	3%	3%
Resolution	-	-	3%	3%
Total	9.4%	9.5%	9.4%	10.4%