Searches for exotic particles in the dilepton and lepton plus missing transverse energy final states with ATLAS

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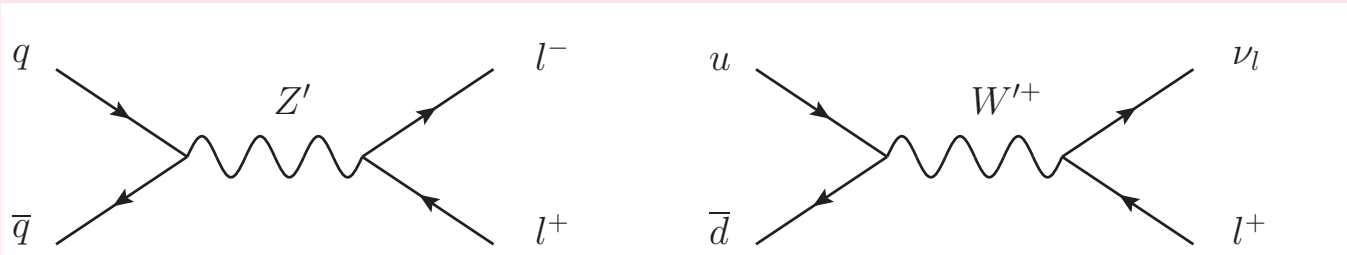
Motivation

- In spite of the enormous success of the Standard Model, there are reasons to look for physics beyond it
  - unification of the forces - extended gauge symmetries?
  - gravity - the graviton?
  - ...
- For these reasons, many models going beyond the Standard Model have been proposed
- One way to look for physics beyond the Standard Model, is to search for new particles
- In this talk the ATLAS searches in the dilepton and lepton-neutrino mass spectra are presented, where the leptons are electrons or muons, with proton-proton data corresponding to about $1\,\mathrm{fb}^{-1}$ of integrated luminosity at $\sqrt{s} = 7\,\mathrm{TeV}$

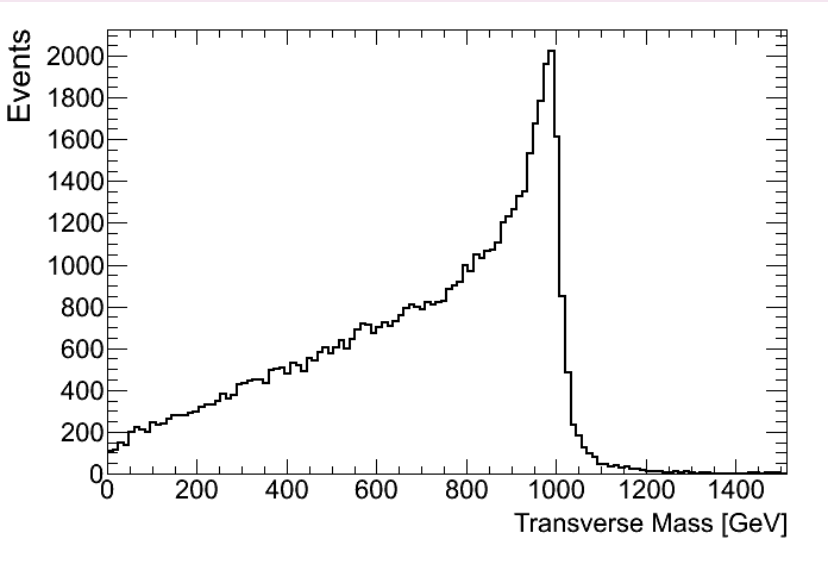
Candidates for new physics

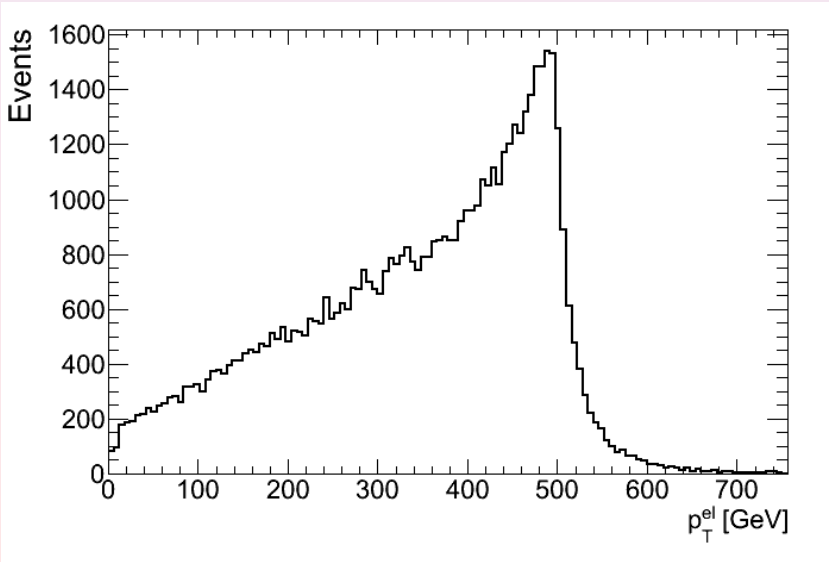
- New, massive gauge bosons may arise from broken symmetries arising in grand unified theories or other extended gauge models
  - Charged bosons, W', could be observed through the decay $W' \rightarrow l\,\nu_l$
  - Neutral bosons, Z', could be observed through the decay $Z' \rightarrow l^+\,l^-$
- In addition, excited Kaluza-Klein modes of the graviton may appear as spin-2 resonances in the $l^+\,l^-$ mass spectrum in models with extra dimensions
- In the common reference model called the Sequential Standard Model, a W' or Z' boson is added which has the same couplings to fermions as the corresponding Standard Model boson



Discriminating variables

- In the dilepton search, the invariant mass of the lepton pair is used to search for new resonances
- In the lepton-neutrino search the invariant mass can not be reconstructed due to the missing longitudinal component of the neutrino momentum
- Here, the transverse mass is used instead, which is nothing but the invariant mass calculated from only the transverse components of the lepton and neutrino momenta





Electron selection

- $E_{\mathrm{T}} > 25\,\mathrm{GeV}$
- $|\eta| < 2.47$ and $|\eta| \notin [1.37, 1.52]$
- cuts on the shower shapes, leakage into the hadronic calorimeter, and the inner detector track associated to the electron (ATLAS “medium” electron)
- a hit in the first pixel layer (B-layer) if such a hit is expected
- isolation: $\sum_{\Delta R<0.2} E_{\mathrm{T}} < 7\,\mathrm{GeV}$ for the Z' search and $\sum_{\Delta R<0.4} E_{\mathrm{T}} < 9\,\mathrm{GeV}$ for the W' search
- impact parameters $|d_0| < 0.2\,\mathrm{mm}$ and $|z_0| < 1.0\,\mathrm{mm}$ for the Z' search $|d_0| < 1.0\,\mathrm{mm}$ and $|z_0| < 5.0\,\mathrm{mm}$ for the W' search, where d_0 (z_0) is the transverse (longitudinal) impact parameter wrt. the reconstructed primary vertex

Muon selection

- $p_{\mathrm{T}} > 25\,\mathrm{GeV}$
- cuts on the quality of the inner detector track (hits, holes, and outliers in the various sub-detectors)
- cuts on the quality of the muon spectrometer track, in particular:
  - hits in all three layers of the muon spectrometer
  - acceptance limited to the regions where the alignment is best understood
- $\sum_{\Delta R<0.3} p_{\mathrm{T}}/p_{\mathrm{T}}^{\mu} < 0.05$
- impact parameters $|d_0| < 0.2\,\mathrm{mm}$ and $|z_0| < 1.0\,\mathrm{mm}$ for the Z' search $|d_0| < 1.0\,\mathrm{mm}$ and $|z_0| < 5.0\,\mathrm{mm}$ for the W' search, where d_0 (z_0) is the transverse (longitudinal) impact parameter wrt. the reconstructed primary vertex

Event selection

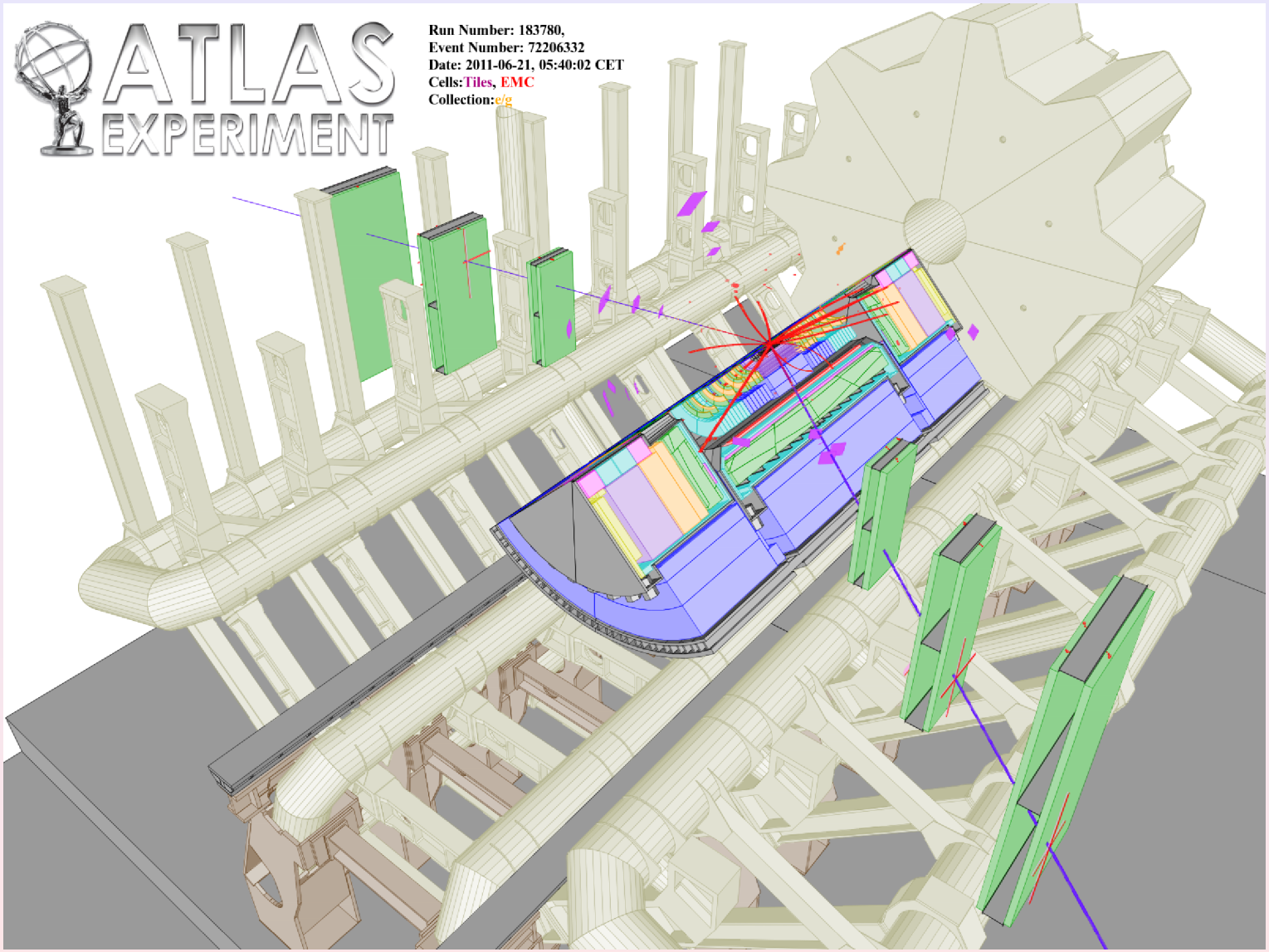
For the W' search:

- Exactly one electron or muon passing the above selection
- Missing transverse energy $\not{E}_{\mathrm{T}} > 25\,\mathrm{GeV}$
- $\not{E}_{\mathrm{T}}/E_{\mathrm{T}}^{e} > 0.6$ in the electron channel
  - Suppresses QCD events, where the $\not{E}_{\mathrm{T}}$ is typically small compared to E_{T}^{e}

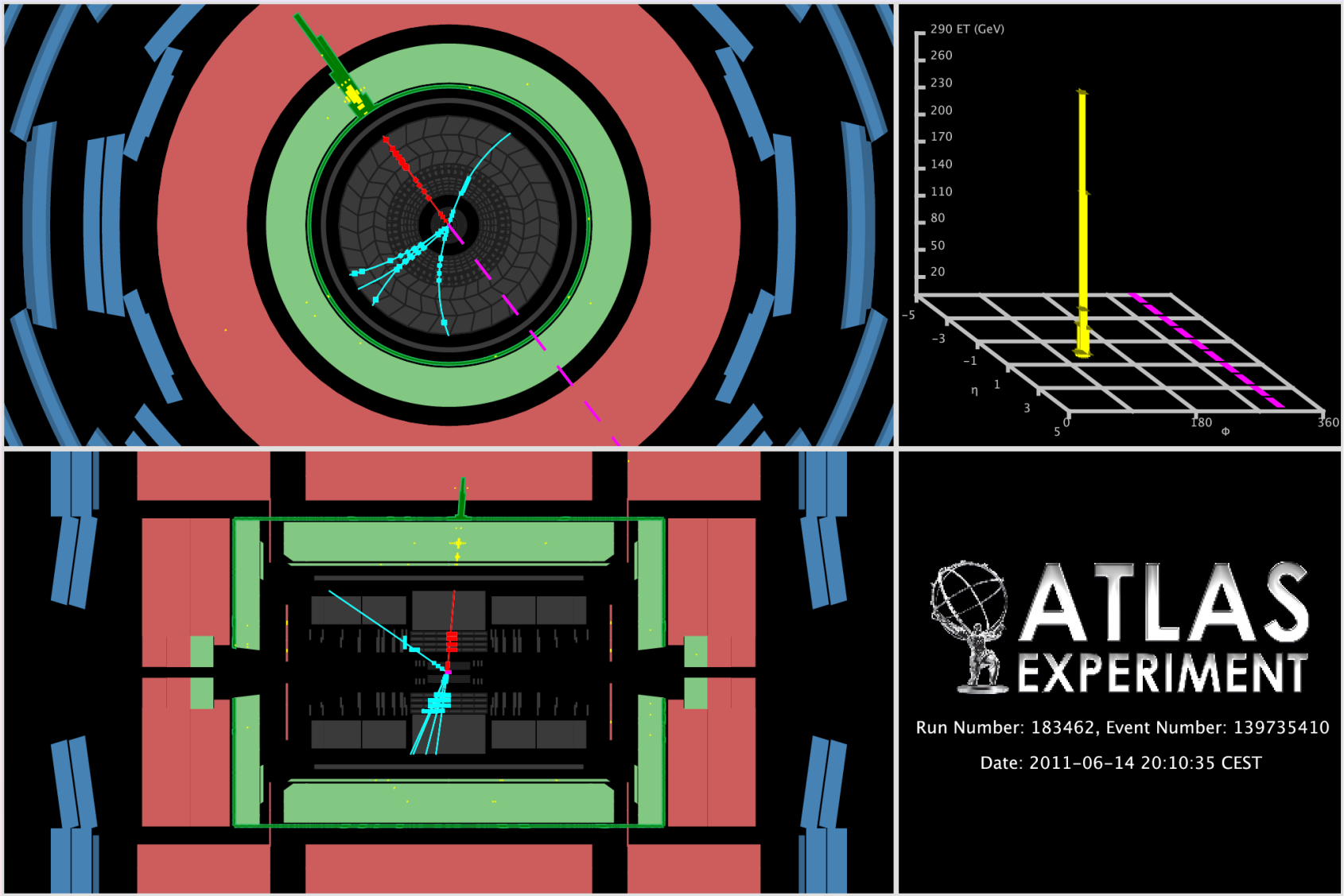
For the Z' search:

- Two electrons or muons passing the above selection
- The muons are required to have opposite charge

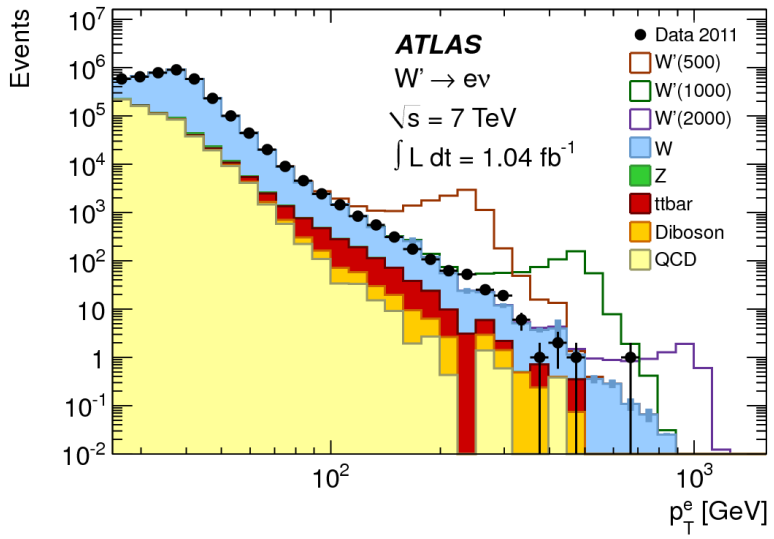
High mass dimuon event display

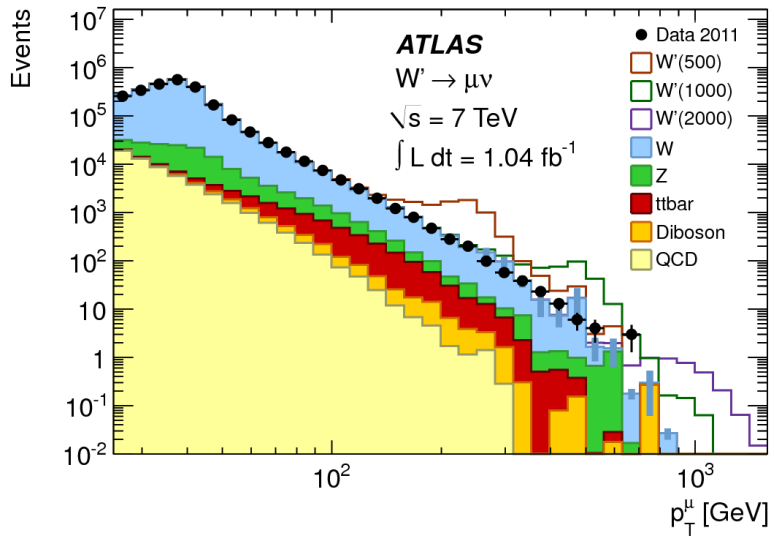


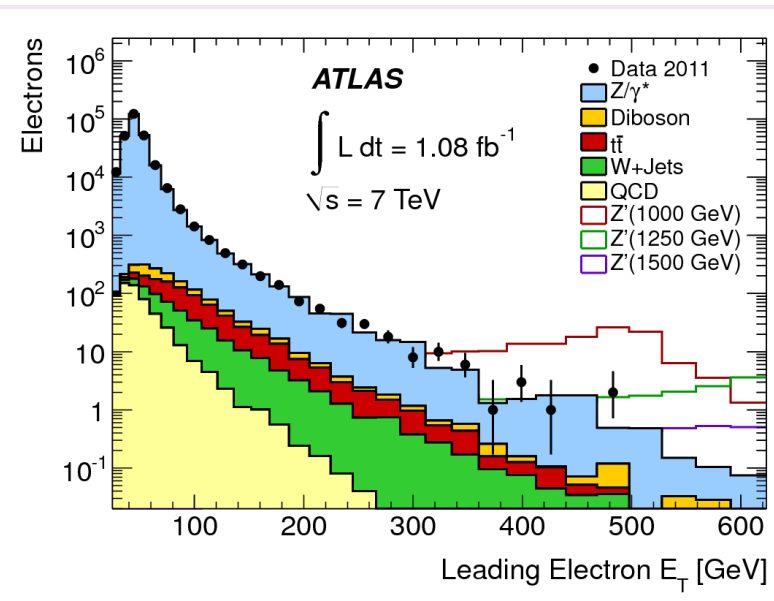
High mass electron+$\not{E}_T$ event display

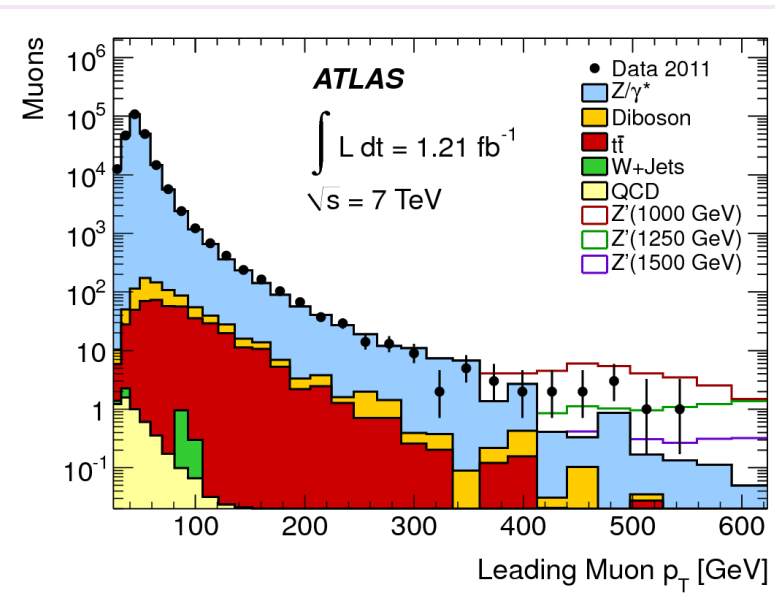


p_T distributions

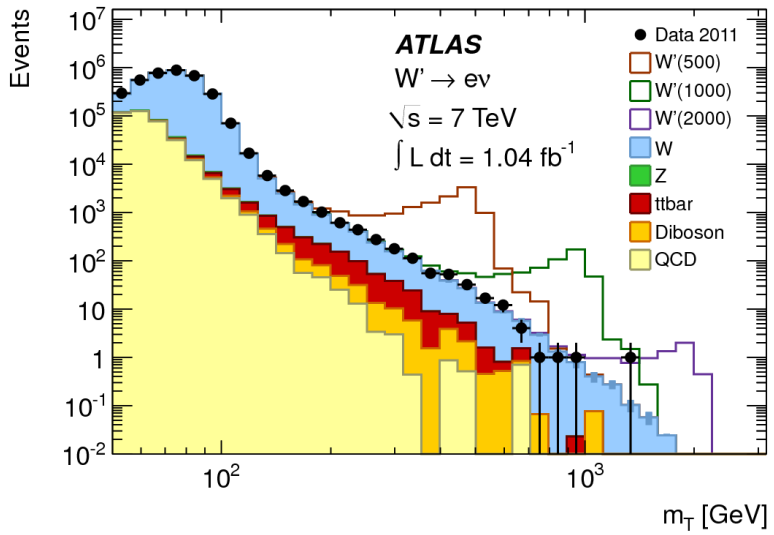


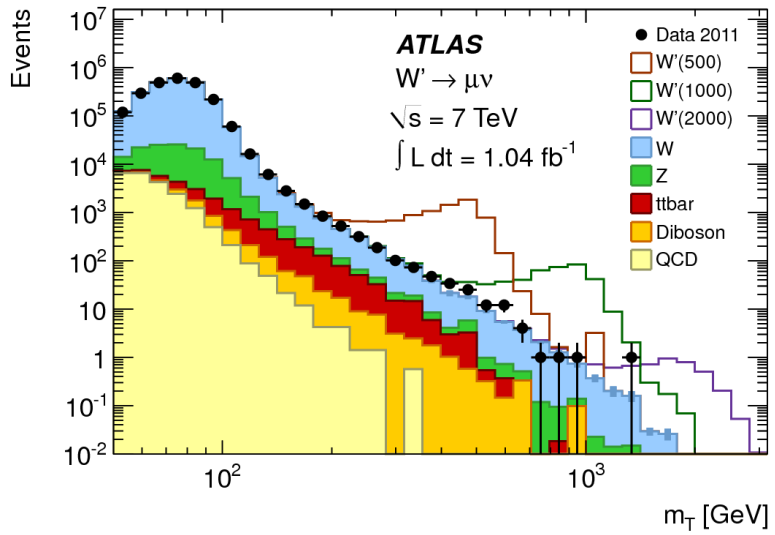


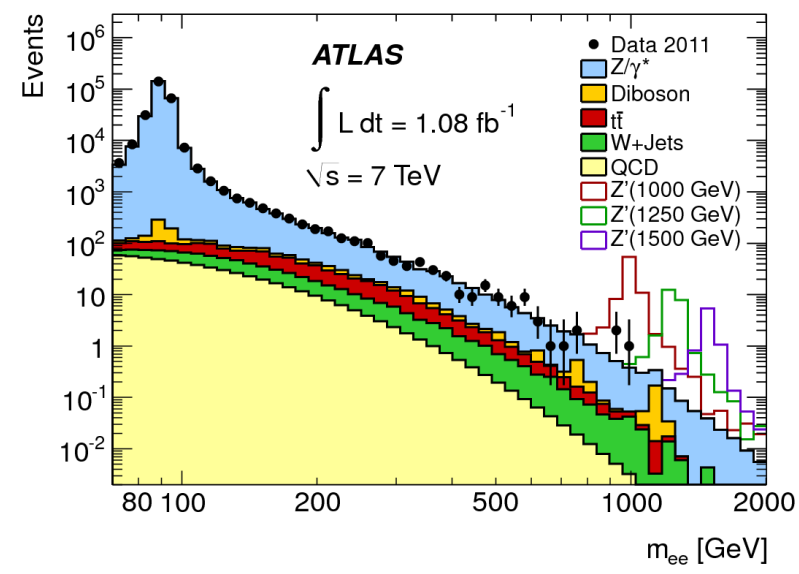


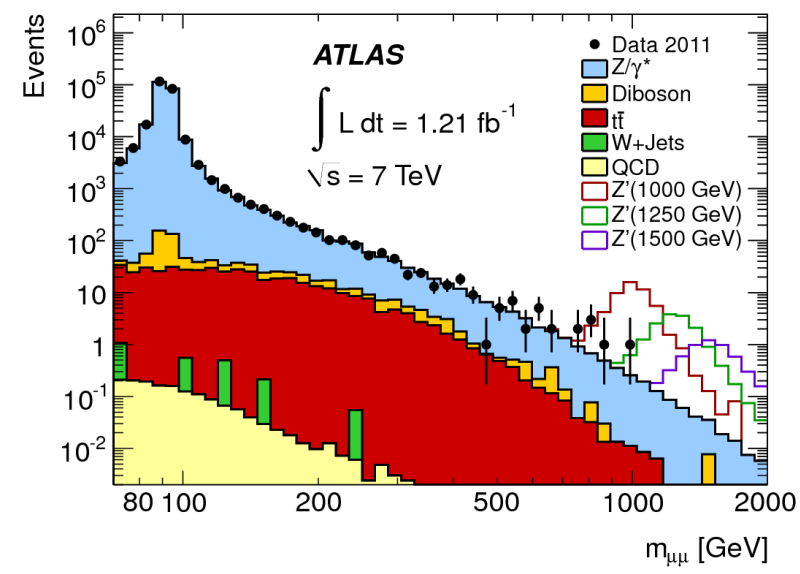


Mass distributions









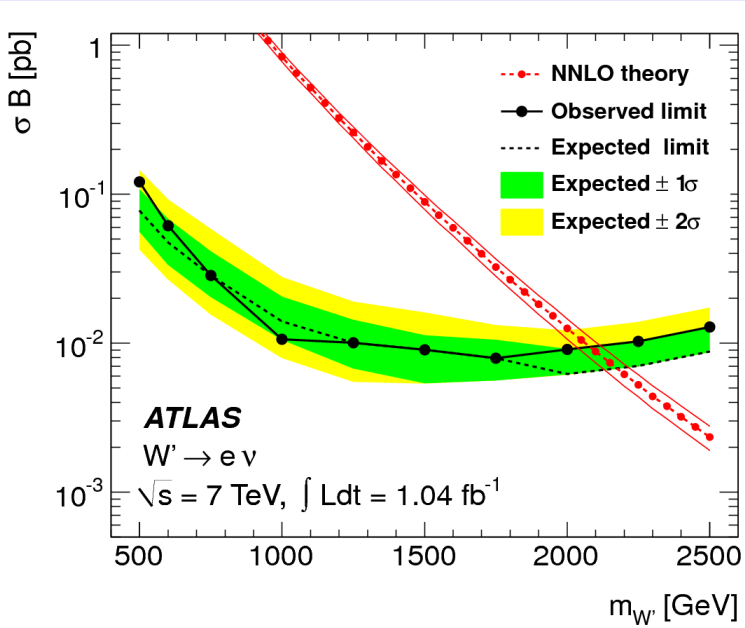
Limit setting

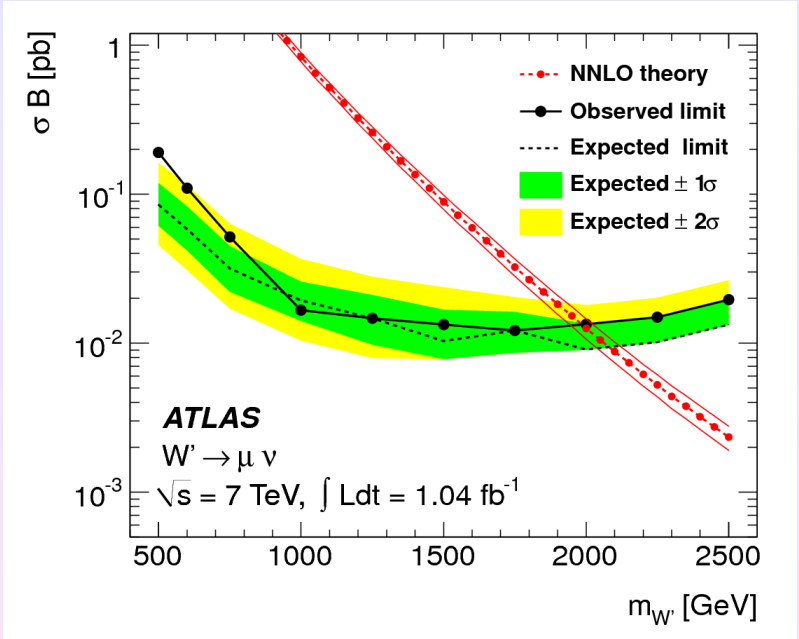
- As no excess of events is observed at high transverse mass or high invariant mass, 95% CL limits are placed on the cross sections (times branching fractions) of hypothetical new particles
- The limits on cross sections are calculated using a Bayesian approach with a flat prior on the cross section for all non-negative cross sections
- The cross section limits are converted into mass limits assuming certain specified models

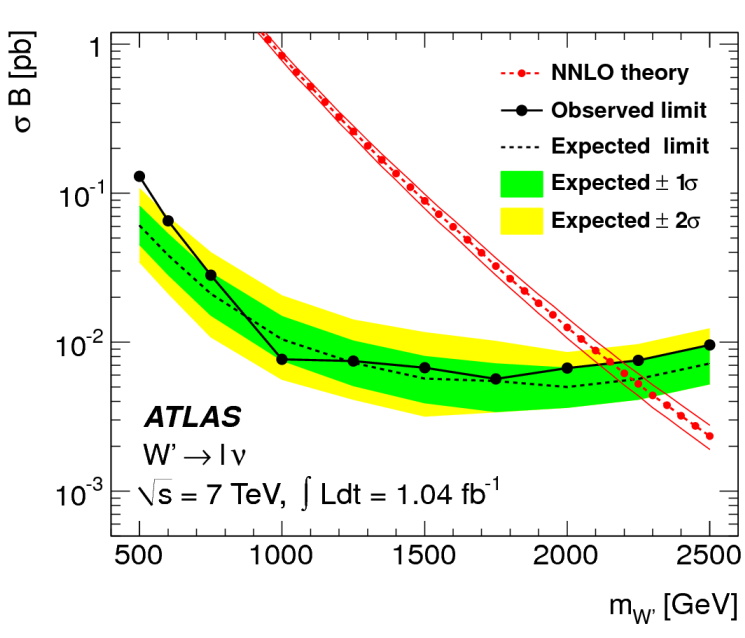
The limit on the cross section times branching fraction is $(\sigma B)_{\text{upper}}$ where:

$$\int_0^{(\sigma B)_{\text{upper}}} P_{\text{posterior}}(\sigma B)\, d(\sigma B) = 0.95$$

Limits - W' search

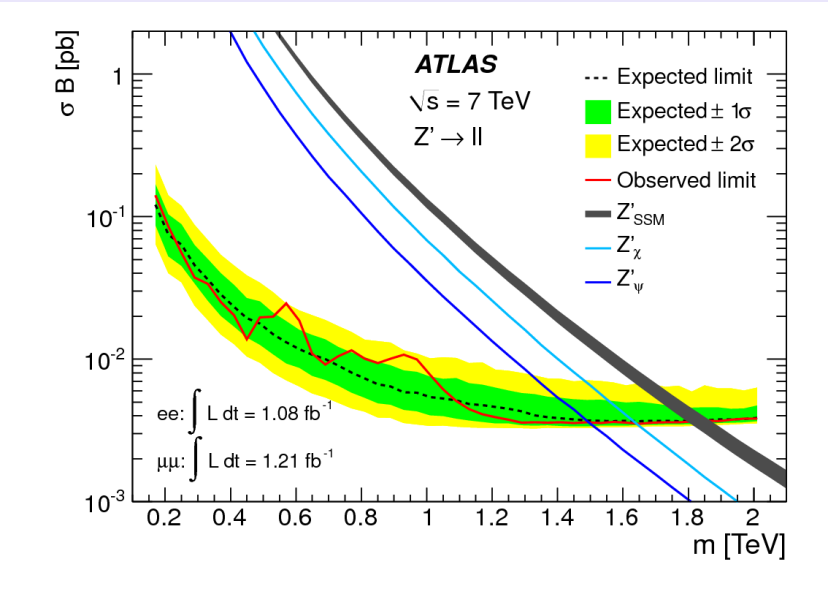


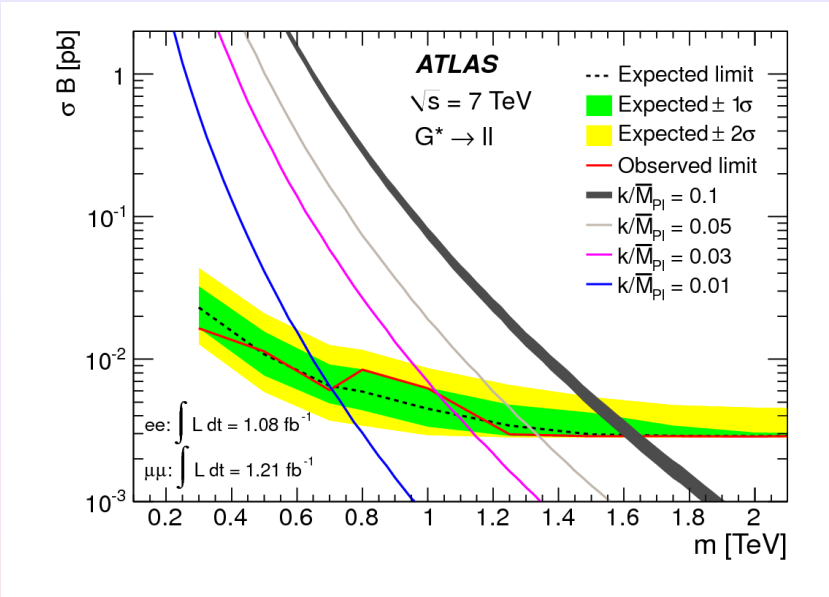




- Using the combination of the electron and muon channels, a mass limit $m_{W'} > 2.15\,\mathrm{TeV}$ is obtained at 95% CL for the Sequential Standard Model W'

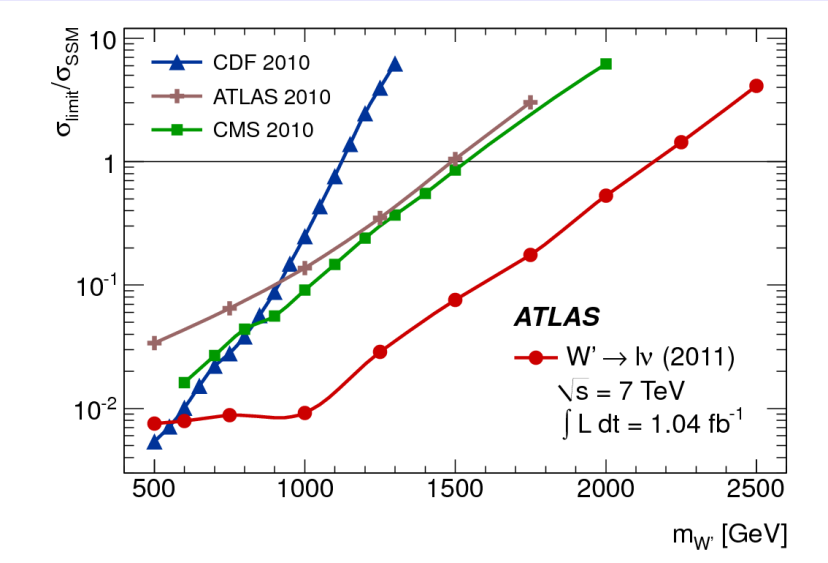
Limits - Z'/G^* search

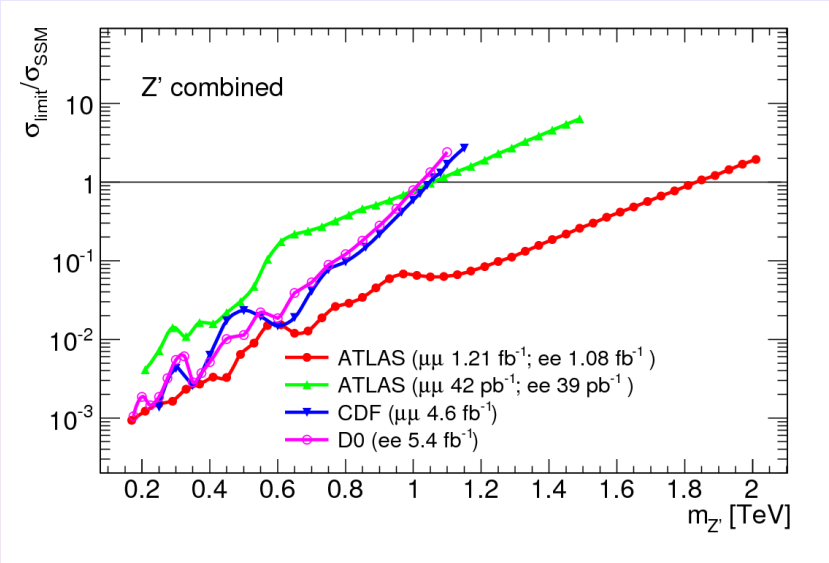




- $m_{Z'} > 1.83\,\mathrm{TeV}$ for the Sequential Standard Model Z'
- $m_{Z'} > 1.49 - 1.64\,\mathrm{TeV}$ for E_6 motivated Z' bosons
- $m_{G^*} > 0.71 - 1.63\,\mathrm{TeV}$ for Randall-Sundrum gravitons with $k/\overline{M}_{\mathrm{Pl}} \in [0.01, 0.1]$

Limits - comparisons to other experiments





- ATLAS has by far surpassed the Tevatron experiments in terms of mass reach for both W' and Z'
- The ATLAS limits with $1\,\mathrm{fb}^{-1}$ are better than Tevatron limits all the way down to around $600\,\mathrm{GeV}$ mass for both W' and Z' searches
- The CMS results for 2011 data were not public when these plots were produced, and are therefore not included
- CMS presented mass limits $m_{W'} > 2.27\,\mathrm{TeV}$ and $m_{Z'} > 1.94\,\mathrm{TeV}$ for SSM gauge bosons at 95% CL with 2011 data

Conclusions

- The ATLAS detector has been used to search for dilepton and lepton-neutrino resonances using about $1\,\mathrm{fb}^{-1}$ of proton-proton data at $\sqrt{s} = 7\,\mathrm{TeV}$
- No excess of events is observed at high dilepton invariant mass or high lepton-neutrino transverse mass
- Limits are placed on the cross sections times branching fractions of hypothetical new particles
- The sequential standard model W' and Z' gauge bosons are excluded for masses $m_{W'} < 2.15\,\mathrm{TeV}$ and $m_{Z'} < 1.83\,\mathrm{TeV}$ using the electron and muon channels in combination
- Mass limits between $1.49\,\mathrm{TeV}$ and $1.64\,\mathrm{TeV}$ are obtained for E_6 motivated neutral gauge bosons
- Mass limits between $0.71\,\mathrm{TeV}$ and $1.63\,\mathrm{TeV}$ are obtained for Randall-Sundrum gravitons with $k/\overline{M}_{\mathrm{Pl}} \in [0.01, 0.1]$