Search for Dilepton and Lepton + MET resonances at high mass with ATLAS Experiment at LHC

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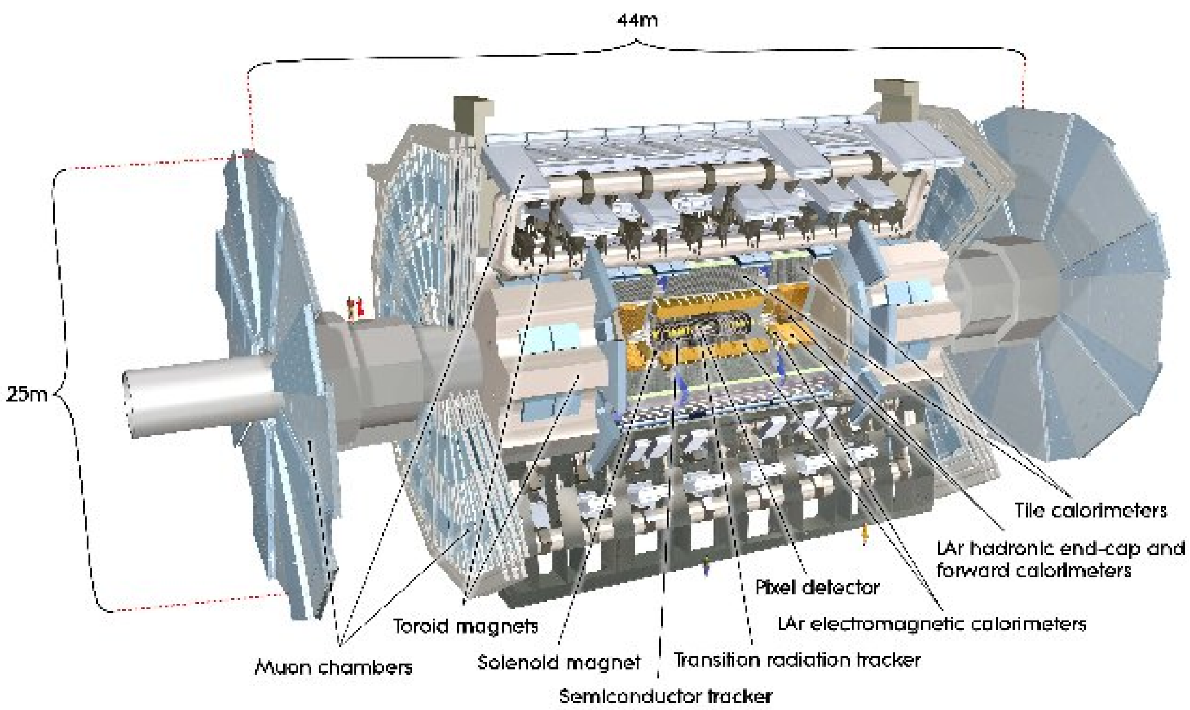
Motivation

- 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
  - Superstring-inspired E6 models
  - Extra-dimentions (Kaluza-Klein model)
  - etc...
- Z' and W' are the generic names of the new heavy gauge bosons introduced in those extensions
- ATLAS has studied the dilepton and lepton+MET signatures to search for this particles using 1.21fb-1 of integrated luminosity recorded this summer.

ATLAS Detector

- High energy electrons are detected by the LAr calorimeter, and identified using shower shapes, track matching, etc...
- Muons are detected by the Muon System, and their momenta obtained by a combination with the Inner Detector information



Lepton Resolution

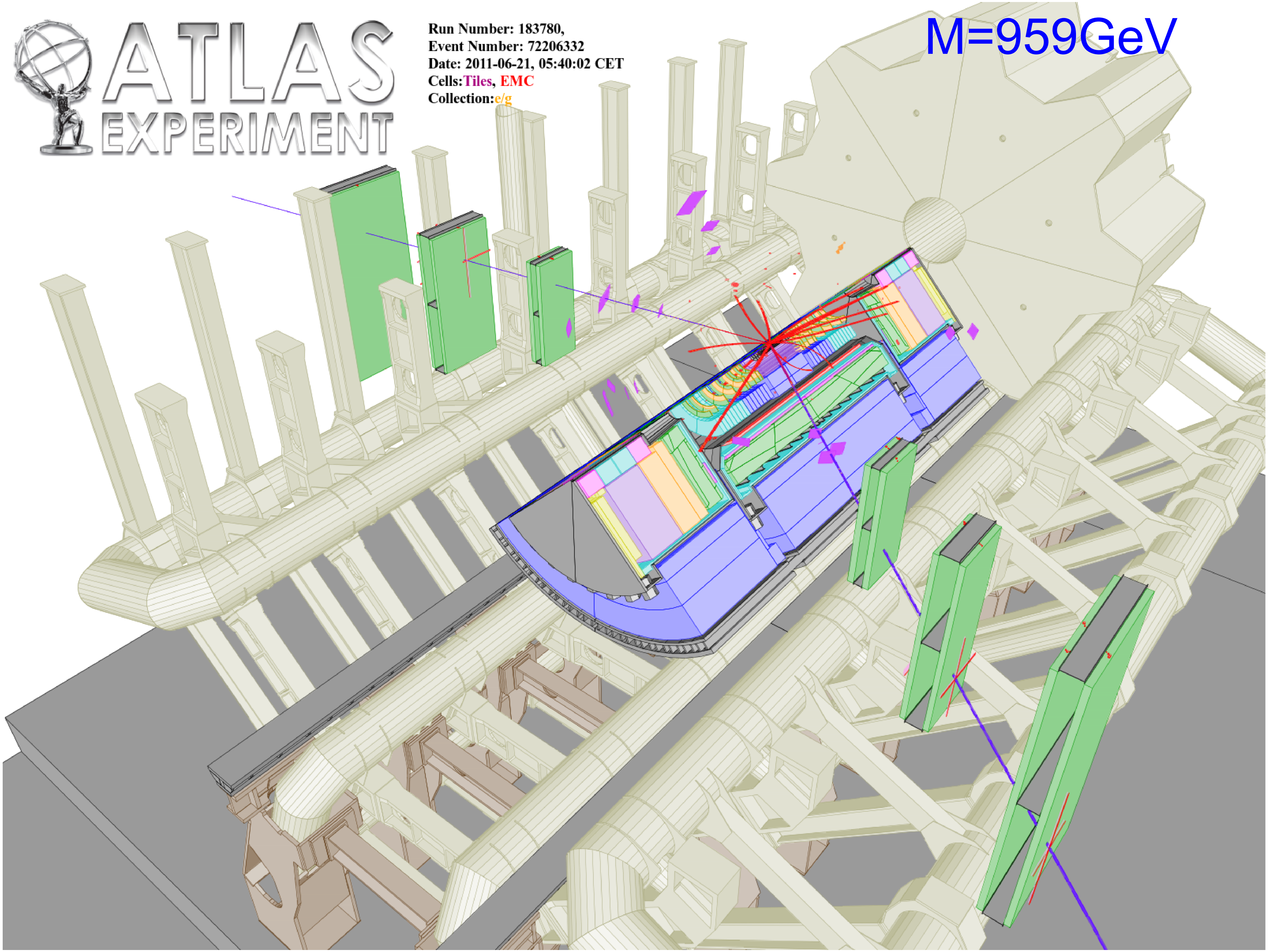
- Electrons
  - Isolated energy deposition in the calorimeter

$$\frac{\sigma(E)}{E}=\frac{k_1}{\sqrt{E}}+k_2$$

  - For high energy electrons, the resolution is dominated by constant term k_2 which is 1.2% in the barrel and 1.8% in the endcap
- Muons
  - At high p_T curvature resolution dominated by intrinsic/mis-aligment term S_2 which ranges from 0.15/TeV to 0.44/TeV (for η>2)

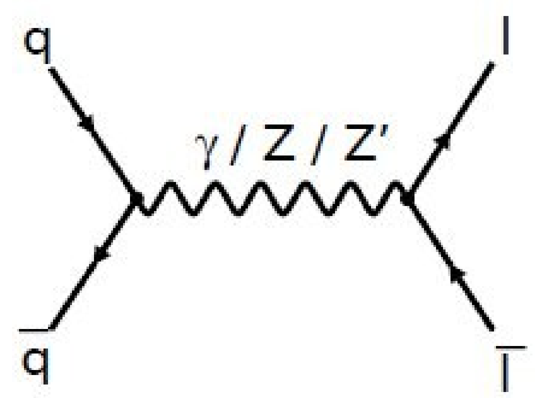
$$\frac{q}{p_T}\rightarrow\left(\frac{q}{p_T}\right)_{ini}+S_1\left(\frac{q}{p_T}\right)_{ini}+S_2$$

Dileptons final states



Introduction

- Z'(SSM) is a benchmark model with the same couplings constants as the usual W and Z.
- The neutral gauge boson are produced via the Drell-Yan process: pp$\rightarrow$Z'$\rightarrow$l+l- (l=e,μ), clean signature
- The differential cross-section for the lepton-pair production depends on:
  - Center of mass energy
  - Z' couplings
  - Z' invariant mass M, its rapidity y
  - The c.m angle $\theta*$
- If a Z' is discovered we will be able to measure:
  - Its mass, decay width
  - The total cross-section
  - Its spin and its branching ratios



J. L. Rosner, Phys. Rev. D35 (1986)

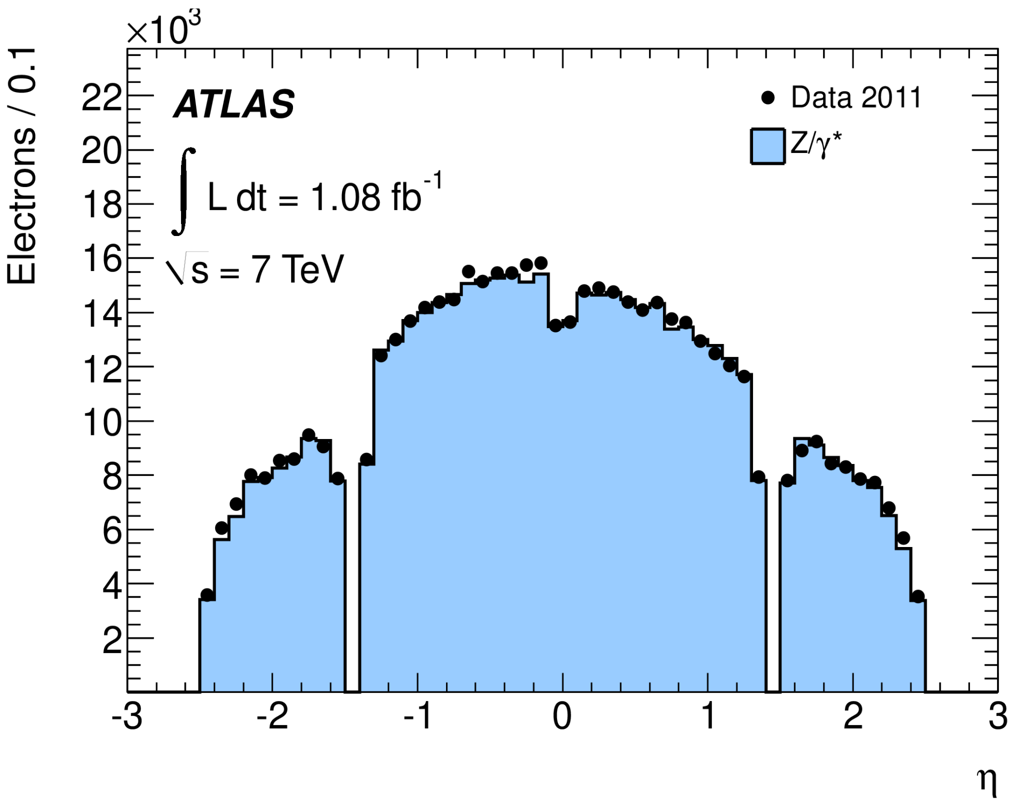
$$\frac{d\sigma}{dMdyd(\cos\theta^*)} = \frac{Mx_Ax_B}{48\pi}\Big[\sum_q [f_q^A(x_A)f_{\bar{q}}^B(x_B) + f_{\bar{q}}^A(x_A)f_q^B(x_B)]\,S_q(1+\cos^2\theta^*) + \sum_q [f_q^A(x_A)f_{\bar{q}}^B(x_B) - f_{\bar{q}}^A(x_A)f_q^B(x_B)]\,2A_q\cos\theta^*\Big]$$

- S_q and A_q symmetric and antisymmetric contributions to the cross-section in cos$\theta*$ ($\theta*$ is the c.m. angle between negative lepton with respect to the quark direction)
- f^A and f^B are parton densities depending on the momentum fractions of the quarks

Electron Selection

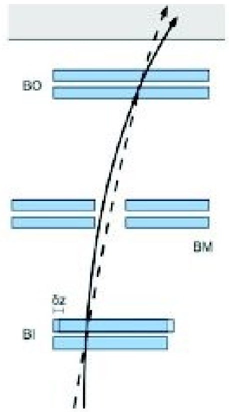
- EM clusters with E_T>25GeV,

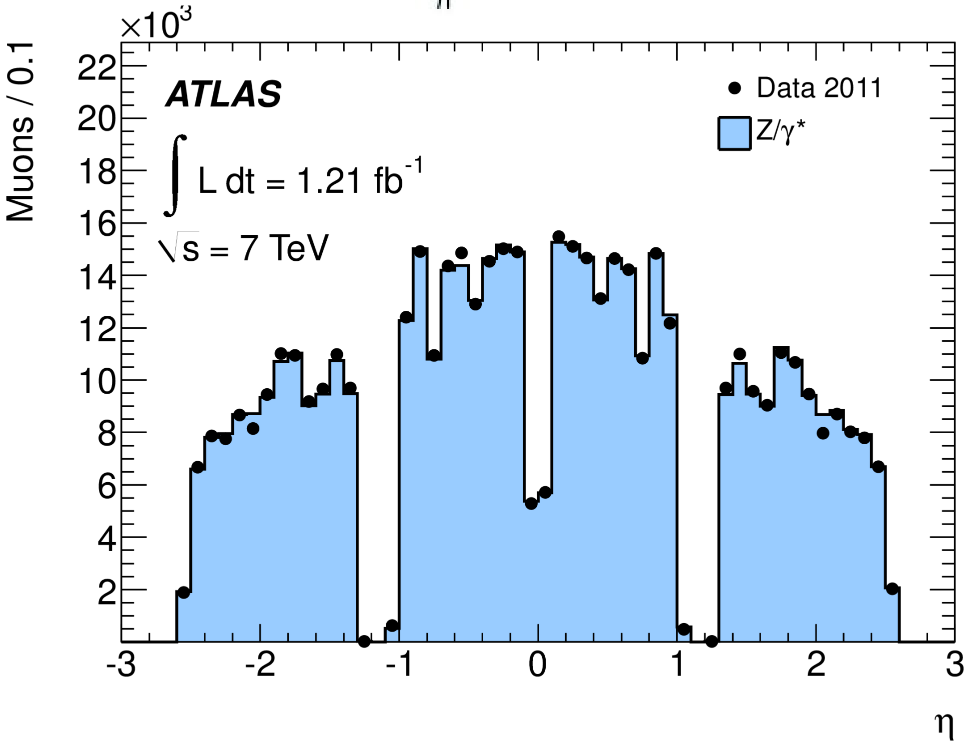
  $|\eta|$<2.47
- Criteria on the transverse shower shape, the longitudinal leakage into hadronic calorimeter
- Removal of transition region between barrel and endcap
- Association to an inner detector track
- Calorimeter isolation for leading electron<0.2 in cone DR of 0.2



Muon Selection

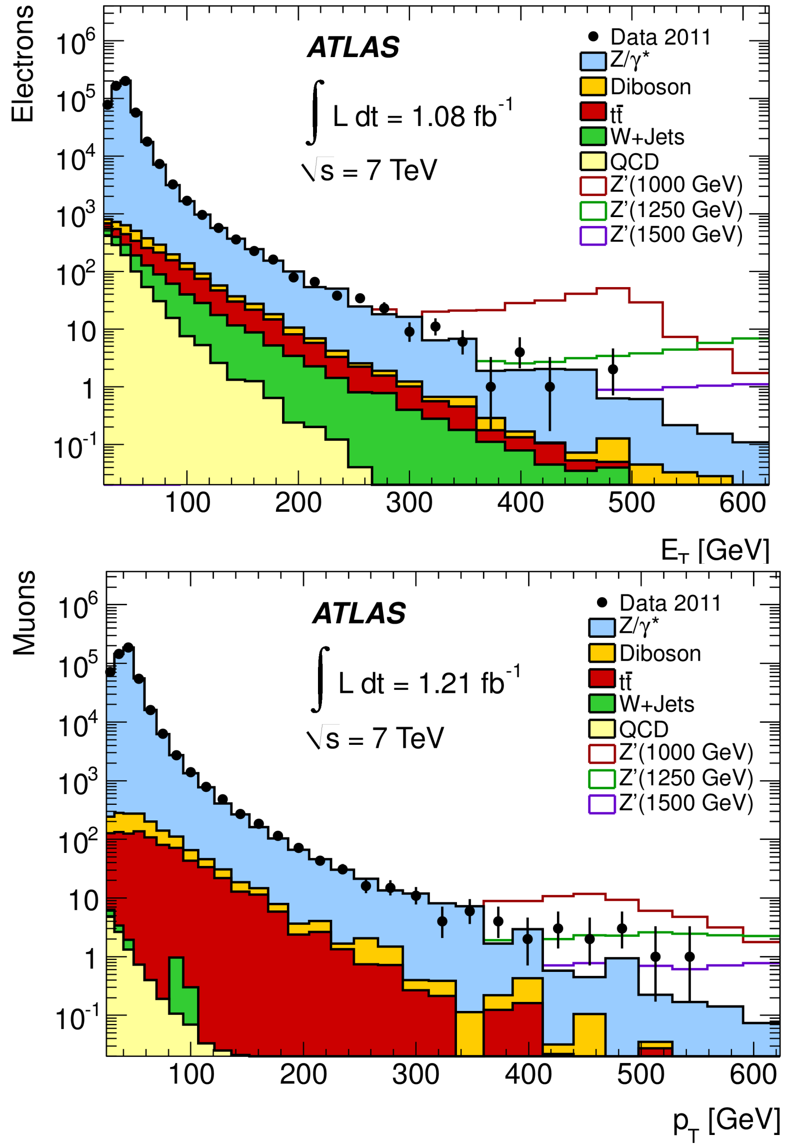
- Combined muons with $p_T > 25GeV$
- Hit requirements in ID and MS require 3 hits in all 3 muon stations to ensure optimal momentum resolution
- Impact parameter cuts: d0 and z0 wrt PV
- Muons opposite charge





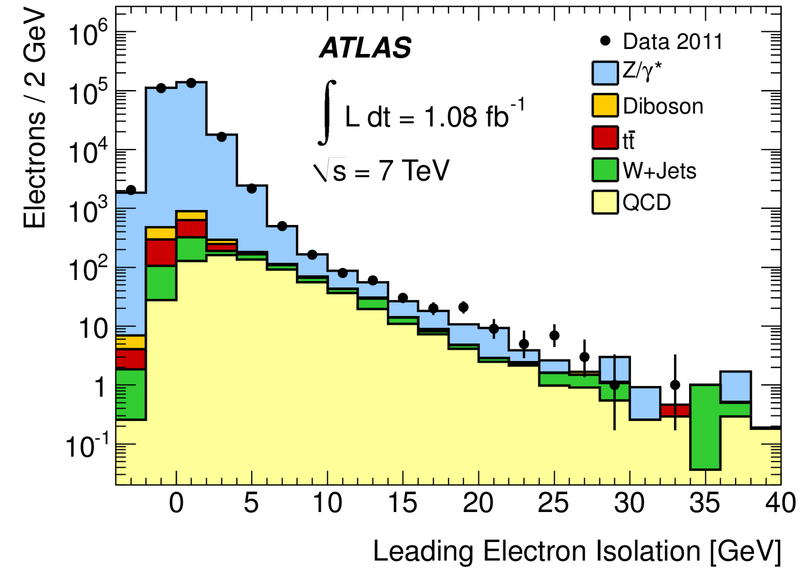
Signal and backgrounds

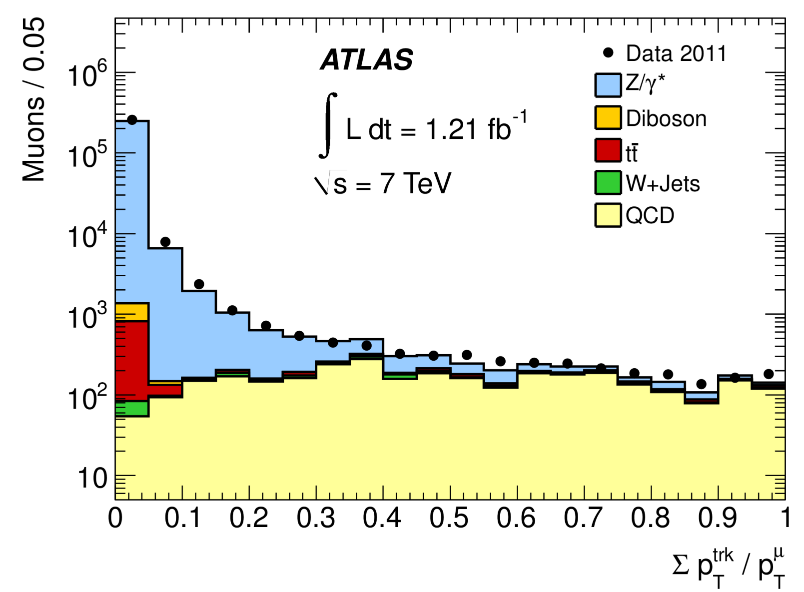
- Z' signal simulated using Pythia
- Backgrounds simulated used:
  - Pythia (Z/γ*)
  - Alpgen (W+jets)
  - Herwig (WW, WZ, ZZ)
  - MC@NLO (ttbar)
- Higher-order corrections MC cross-sections
- Data driven backgrounds:
  - QCD
  - Cosmics



QCD Backgrounds

- Sources for electron channel
  - Photon conversions
  - Semi-leptonic heavy quark decays
  - Hadrons faking electrons
- Methods estimation
  - Reverse electron identification
  - Isolation fit techniques
  - Fake rates from jet samples
- Source for the muon channel
  - Semi-leptonic deacays of b and c quarks
- Estimate from muon isolation variable
  - Found to be negligible





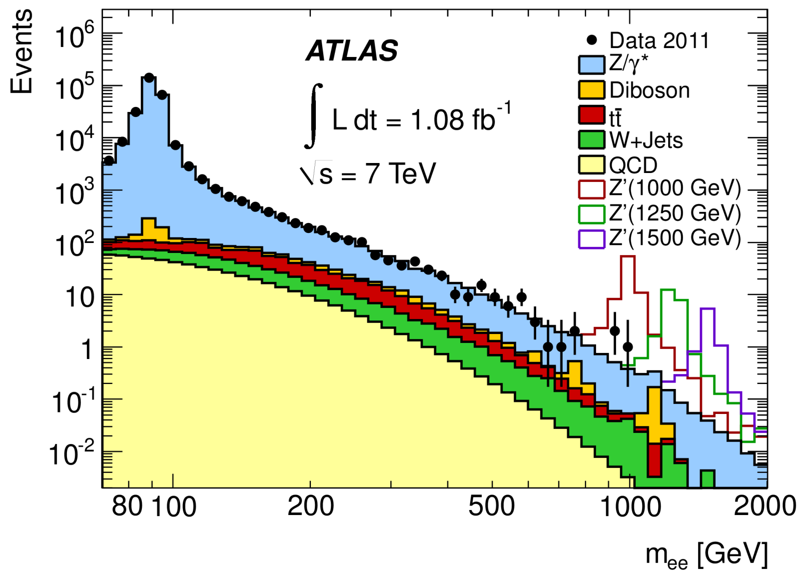
Drell-Yan Background

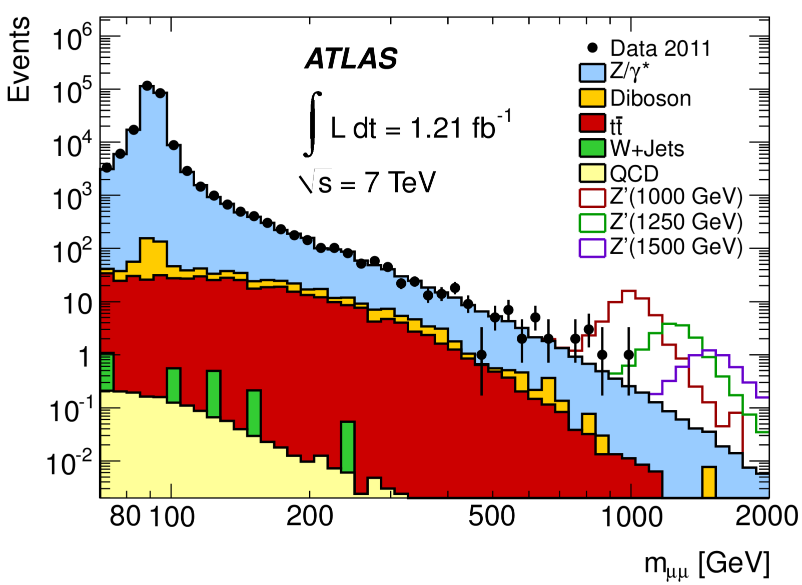
- Z/γ^* the irreducible background which dominates in the entire search region.
  - Using the Pythia with NNLO multiplicative the K-factor correction was predicted
  - This K-factor was applied to the signal
    - The PDFs uncertainties and higher-order corrections are the dominant uncertainties

$m_{e^+e^-}$ [GeV]	70-110	110-200	200-400	400-800	800-3000
DY	258482 ± 410	5449 ± 180	613 ± 26	53.8 ± 3.1	2.8 ± 0.1
$t\bar{t}$	218 ± 36	253 ± 10	82 ± 3	5.4 ± 0.3	0.1 ± 0.0
Diboson	368 ± 19	85 ± 5	29 ± 2	3.1 ± 0.5	0.3 ± 0.1
W+jets	150 ± 100	150 ± 26	43 ± 10	4.6 ± 1.8	0.2 ± 0.4
QCD	332 ± 59	191 ± 75	36 ± 29	1.8 ± 1.4	< 0.05
Total	259550 ± 510	6128 ± 200	803 ± 40	68.8 ± 3.9	3.4 ± 0.4
Data	259550	6117	808	65	3

$m_{\mu^+\mu^-}$ [GeV]	70-110	110-200	200-400	400-800	800-3000
DY	236319 ± 320	5171 ± 150	483 ± 22	40.3 ± 2.5	2.0 ± 0.3
$t\bar{t}$	193 ± 21	193 ± 20	63 ± 6	4.2 ± 0.4	0.1 ± 0.0
Diboson	307 ± 16	69 ± 5	25 ± 2	1.7 ± 0.5	< 0.05
W+jets	1 ± 1	1 ± 1	< 0.5	< 0.05	< 0.05
QCD	1 ± 1	< 0.5	< 0.5	< 0.05	< 0.05
Total	236821 ± 487	5434 ± 150	571 ± 23	46.1 ± 2.6	2.1 ± 0.3
Data	236821	5406	557	51	5

Dilepton invariant mass





- Normalization to the Z peak

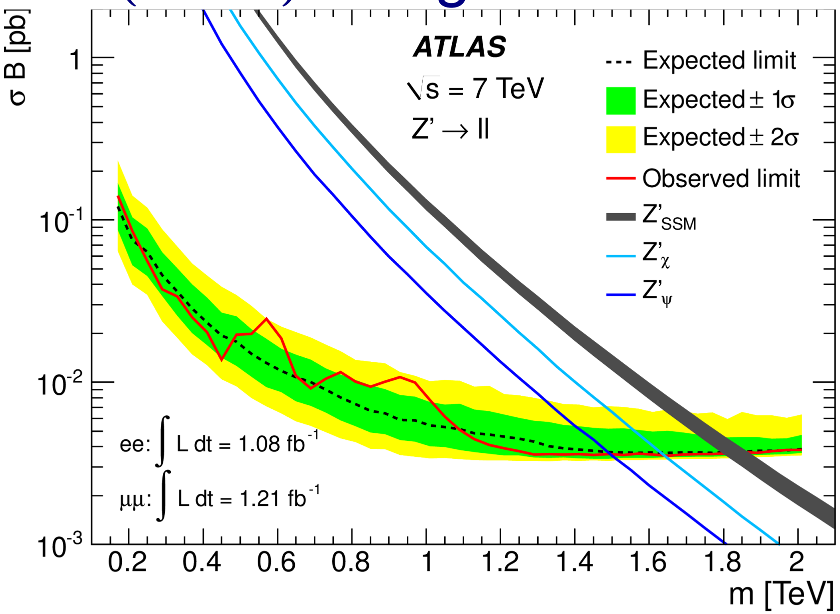
  $\sigma(Z')=\sigma(Z)*N(Z')/N(Z)*A(Z)/A(Z')$

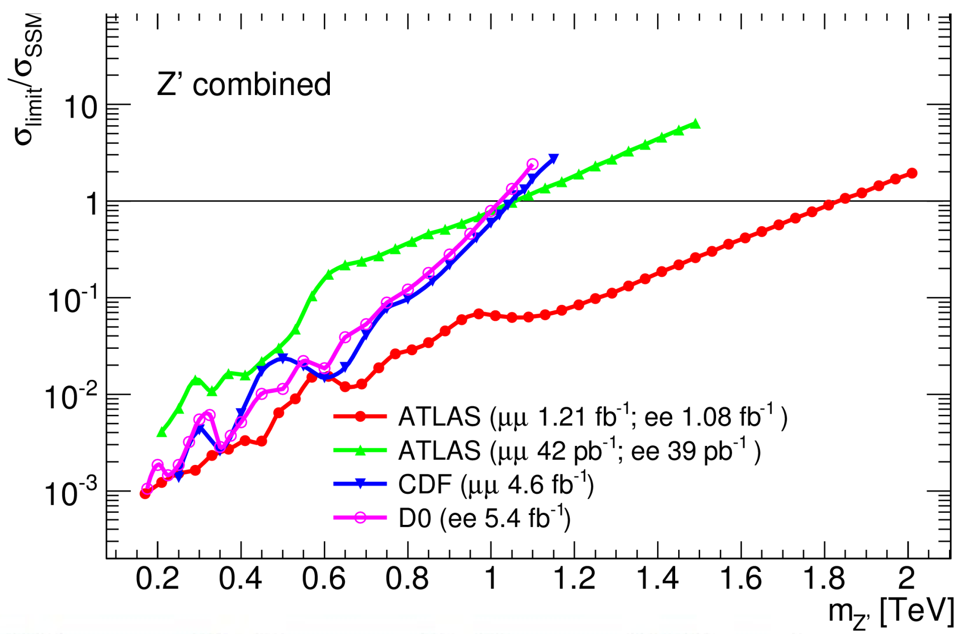
- No systematics were applied to the signal
- Resolution systemactics is negligible
- Remaining systematics

Source	dielectrons		dimuons	
	signal	background	signal	background
Normalization	5%	NA	5%	NA
PDFs/α_S	NA	10%	NA	10%
QCD K-factor	NA	3%	NA	3%
Weak K-factor	NA	4.5%	NA	4.5%
Trigger/Reconstruction	negligible	negligible	4.5%	4.5%
Total	5%	11%	7%	12%

Z' Limits

- Checking if there is a significant excess in the signal: p-value for electrons 54% and for muons: 24%
- Since there is not evidence, we obtained the 95%C.L limits on $\sigma * B(Z' \to ll)$ using the cross-section ratio Z/Z'

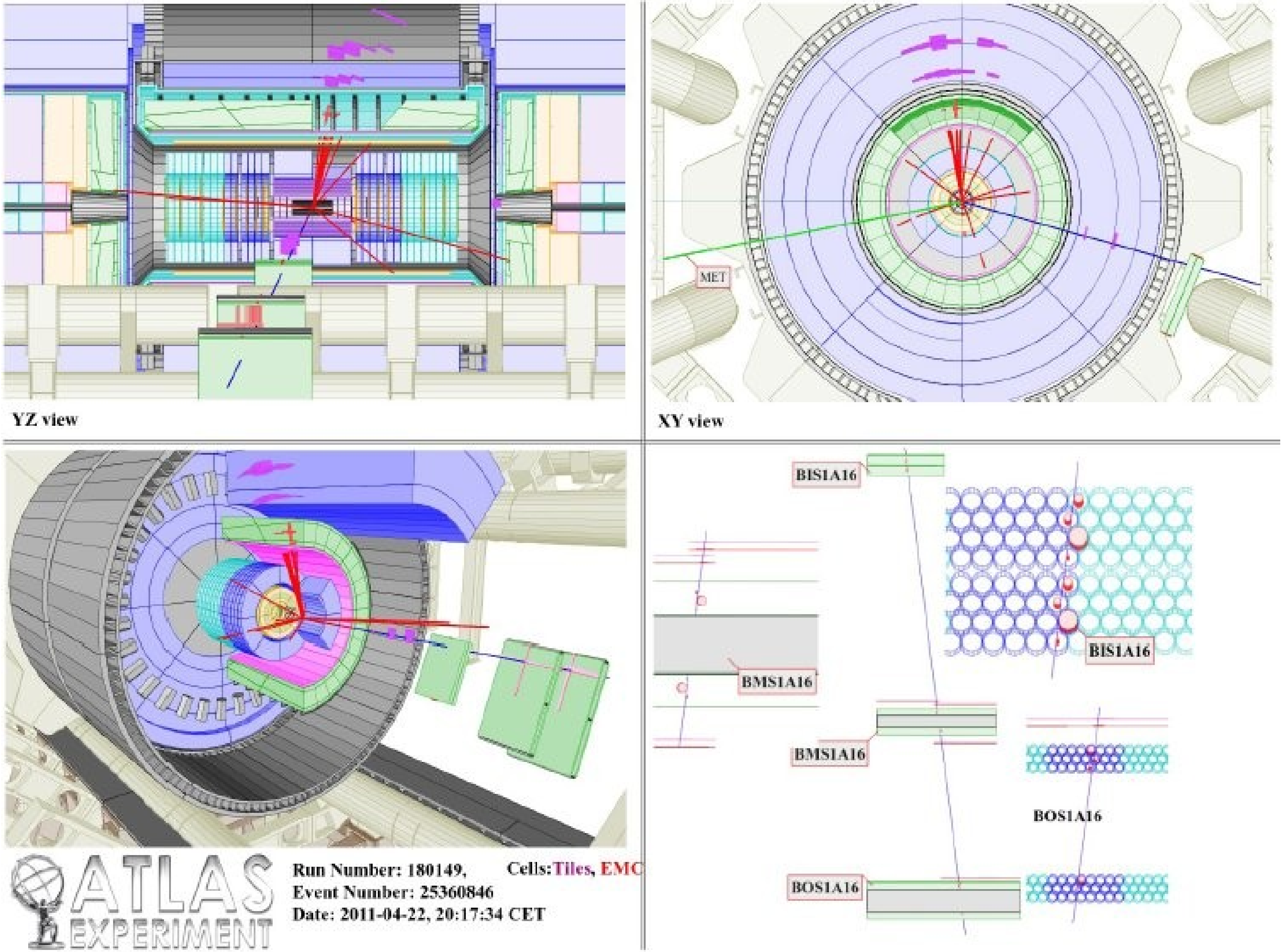




	E_6 Z' Models					
Model/Coupling	Z'_ψ	Z'_N	Z'_η	Z'_I	Z'_S	Z'_χ
Mass limit [TeV]	1.49	1.52	1.54	1.56	1.60	1.64

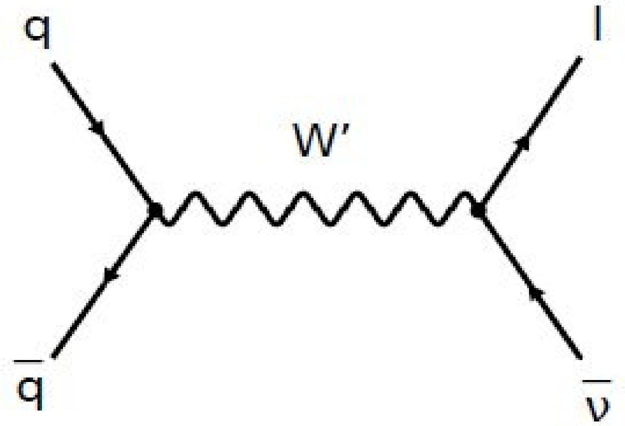
Model	e^+e^-	$\mu^+\mu^-$	$\ell^+\ell^-$
Z'_{SSM}	1.70 (1.70)	1.61 (1.61)	1.83 (1.83)

Lepton+MET final states



Introduction

- The heavy gauge charge common denoted by W', is the most easily searched for in a their decay to a charged lepton and neutrino.
- The differential cross-section for the W' depends on:
  - Center of mass energy
  - Its couplings, its mass
  - Its rapidity and the c.m angle $\theta*$
- The observation of the W' is based on the detection of an excess of a single lepton at high p_T above background, with a sharp upper edge (transverse mass)



T. G. Rizzo, JHEP 0705 (2007)

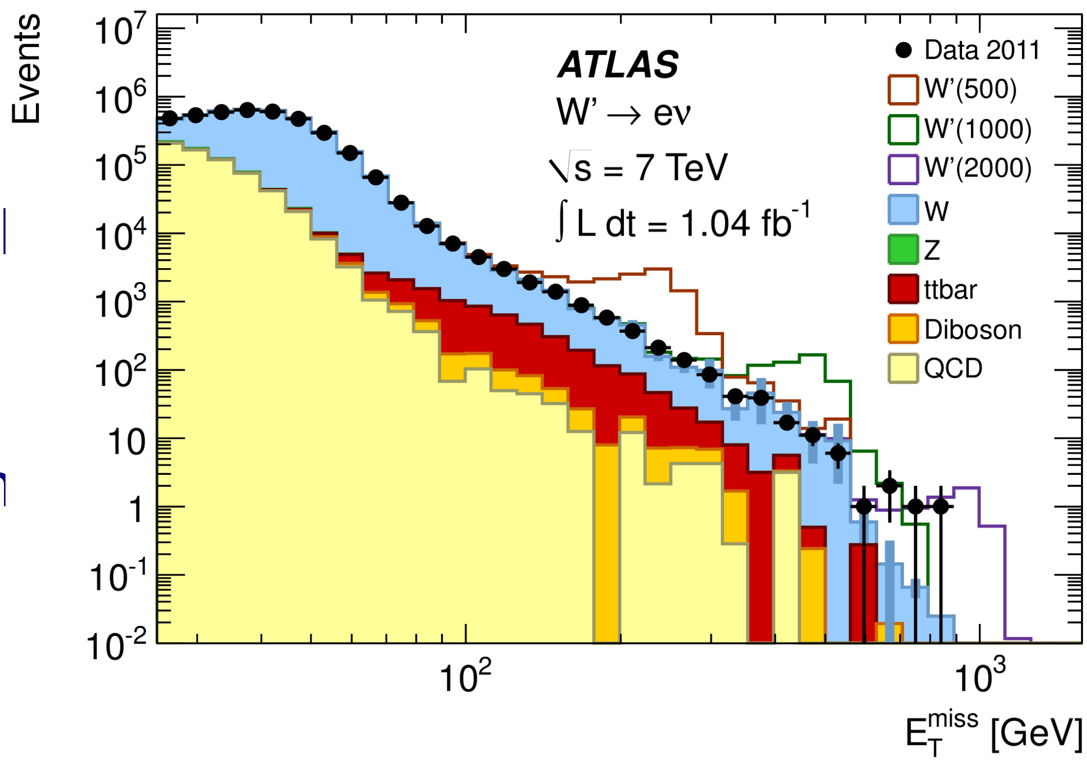
$$\frac{d\sigma}{d\tau\ dy\ dz} = K\ \frac{G_F^2 M_W^4}{48\pi} \sum_{qq'} |V_{qq'}|^2 \left[SG^+_{qq'}(1+z^2) + 2AG^-_{qq'} z \right]$$

- The coupling strengths for leptons and quarks, the helicity factors and the square of the total collision energy are implicitly in S and A
- $V_{qq'}$ is the CKM(unit) matrix; q(q') is a u(d)-type quark
- $G_{qq'}^{\pm}$ are the combinations of the parton distribution functions.
- z in the cosθ, the scattering angle in the c.m. frame defined as that between the incoming u-type quark and the outgoing neutrino.
- $\tau = M^2/s$, where M^2 lepton-pair invariant mass and $\sqrt{s}$=cme

Electron Selection

- EM clusters with E_T>25GeV,

  |η|<1.37 or 1.52<|η|<2.47
- Criteria on the transverse shower shape, the longitudinal leakage into hadronic calorimeter
- Calorimeter isolation for leadin electron<9GeV in cone DR of 0.4
- (MET or E_T^{miss})>25GeV and E_T^{miss}/E_T >0.6
- One electron per event.



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- Hit requirements in ID and MS require 3 hits in all 3 muon stations to ensure optimal momentum resolution

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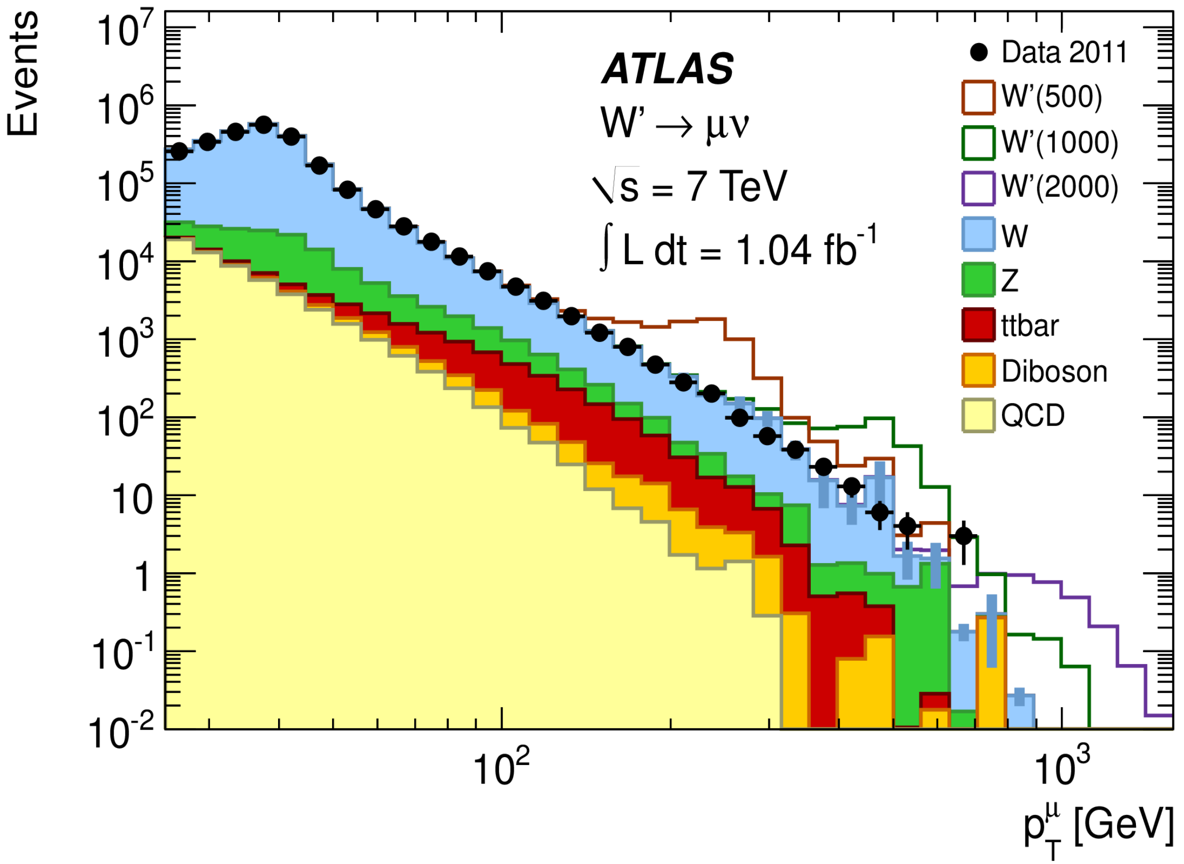
- One muon per event and E_T^{miss}>25GeV



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  - MC@NLO (ttbar)
- Higher-order corrections MC cross-sections
- Data driven backgrounds:
  - QCD
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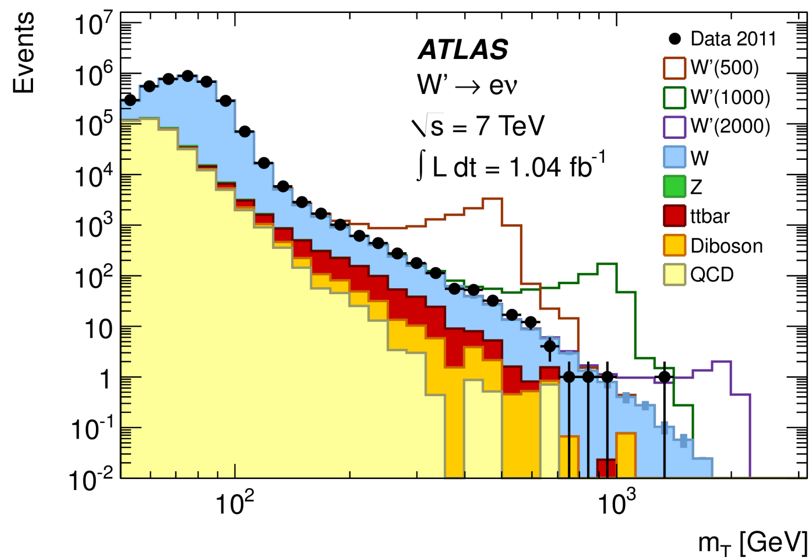
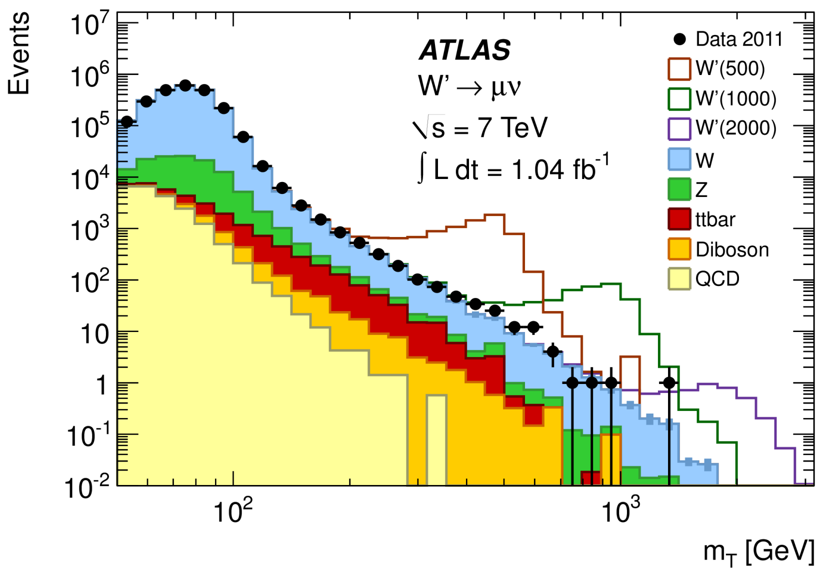
	$e\nu$		$\mu\nu$	
$W \to \ell\nu$	1.59	$\pm$ 0.13	1.36	$\pm$ 0.13
$Z \to \ell\ell$	0.00010	$\pm$ 0.00004	0.095	$\pm$ 0.005
diboson	0.08	$\pm$ 0.08	0.11	$\pm$ 0.08
$t\bar{t}$	0.08	$\pm$ 0.08	0	
QCD	0	${}^{+0.17}_{-0}$	0.01	${}^{+0.02}_{-0.01}$
Total	1.75	${}^{+0.24}_{-0.18}$	1.57	$\pm$ 0.15

Transverse mass





- Transverse mass definition

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

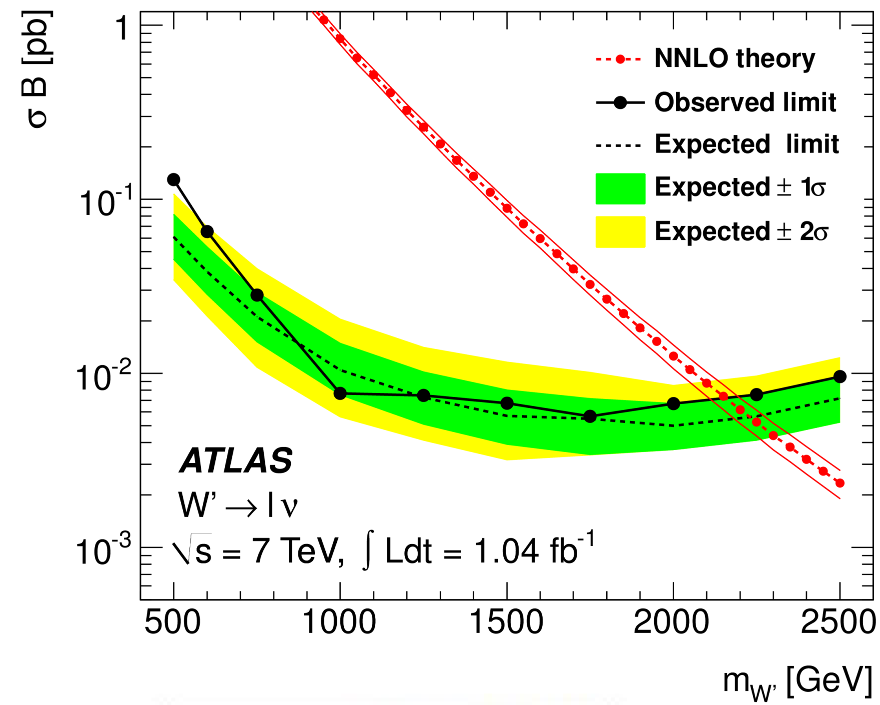
- Signal and background normalized using calculated cross-section and the integrated luminosity of data.

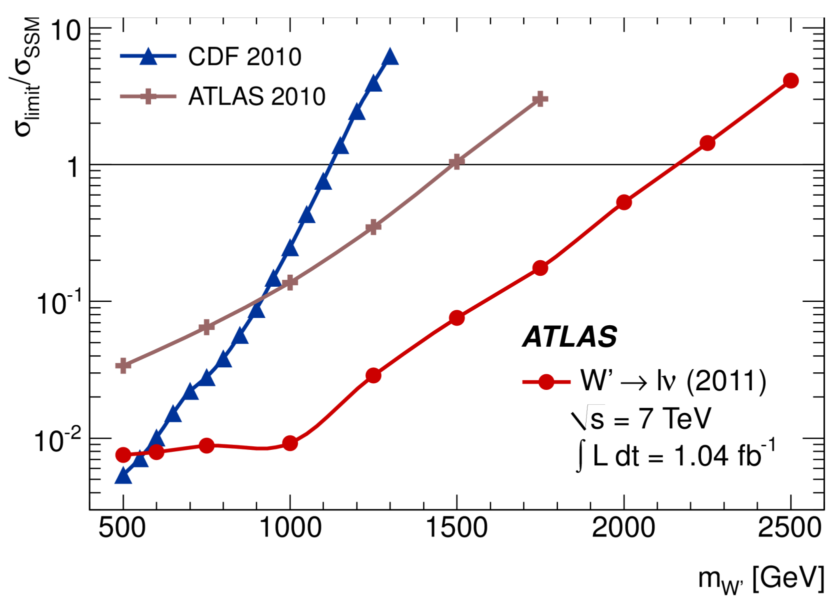
- Remaining Systematics

Source	ε_{sig} $e\nu$	ε_{sig} $\mu\nu$	N_{bg} $e\nu$	N_{bg} $\mu\nu$
Efficiency	2.7%	3.9%	2.7%	3.8%
Energy/momentum resolution	0.3%	2.3%	2.9%	0.6%
Energy/momentum scale	0.5%	1.3%	5.2%	3.0%
QCD background	-	-	10.0%	1.3%
Monte Carlo statistics	2.5%	3.1%	9.4%	9.9%
Cross section (shape/level)	3.0%	3.0%	9.5%	9.5%
All	4.7%	6.3%	18%	15%

W' Limits

- None of the observations for any mass in either channel or the combination has a significance above 3σ.
- 95%C.L exclusion limits on σ∗B(W'→lυ)





	$m_{W'}$ [TeV] Exp.	Obs.
$e\nu$	2.17	2.08
$\mu\nu$	2.08	1.98
both	2.23	2.15

Summary

- ATLAS published its latest results from these final states:
  - Dilepton:arXiv:1108.1582,
    accepted by Phys. Rev. Lett.
  - Lepton+MET: Phys.Lett. B, (2011)
    doi:10.1016/j.physletb.2011.09.093
- Exclusion limits at 95%C.L.:
  - $M(Z'_{SSM})<1.83\,TeV$
  - $M(W'_{SSM})<2.15\,TeV$
- ATLAS is still motivated to continue searching for high mass resonances