



Search for W' in Lepton+Missing E_T Final State With Early Data at ATLAS

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INTRODUCTION

Extensions of the SM gauge symmetries imply the existence of new heavy charged gauge boson generically denoted as W' . Assuming its SM-like couplings to fermion, and its decay to WZ suppressed, we evaluate the ATLAS discovery potential of such a boson in lepton (electron or muon) plus Missing E_T final state with early data at $\sqrt{s}=14$ TeV. The whole study presented is done within ATLAS CSC exercise [1].

Signal: $W' \rightarrow l\nu$ (τ included) generated with Pythia 6.4, p.d.f CTEQ6, higher order corrections $K=1.37$, evaluated with MC@NLO.

Background: reducible (tt and QCD multijet production), irreducible (SM $W \rightarrow l\nu$ production).

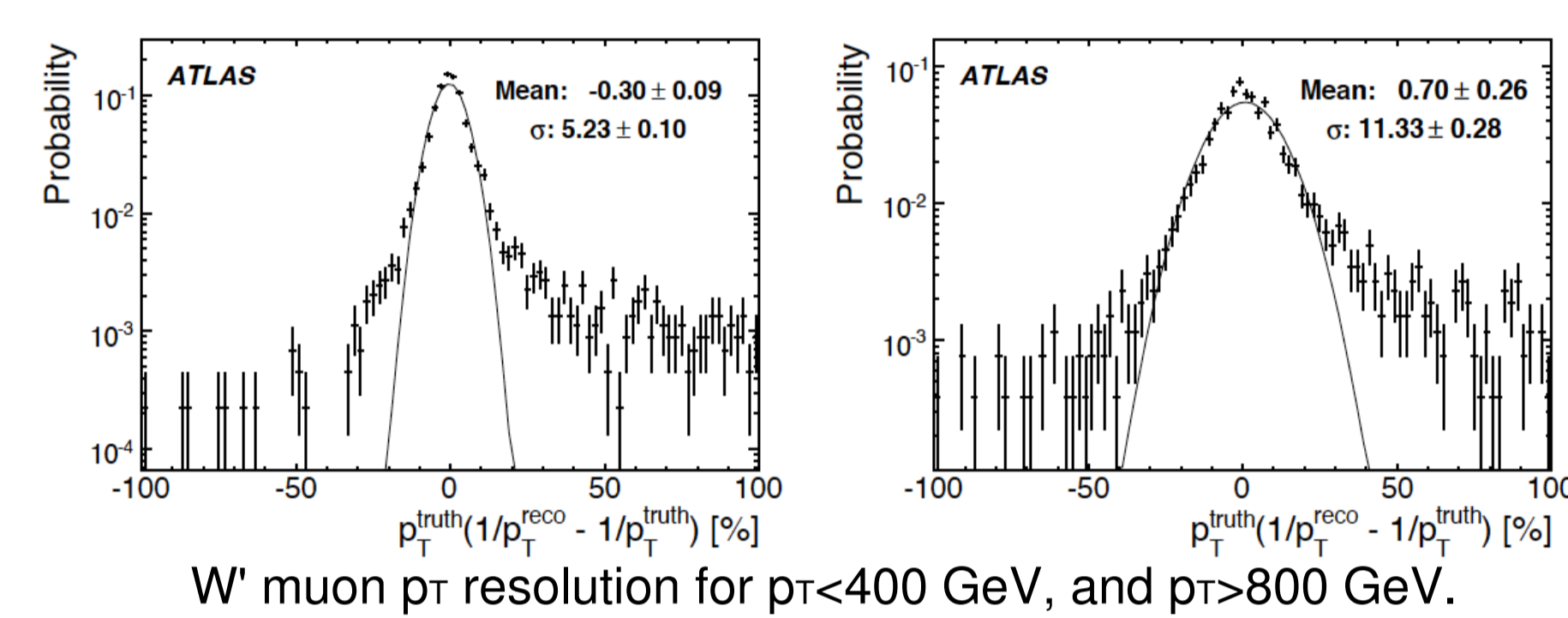
Generated signal and background events were passed through the full simulation of ATLAS detector which includes most recent realistic detector description, and complete simulation of the trigger chain.

Most stringent limit to W' mass is obtained with $D\phi$ collaboration: $m(W') > 1$ TeV @ 95% CL [2].

OBJECT RECONSTRUCTION AND TRIGGER

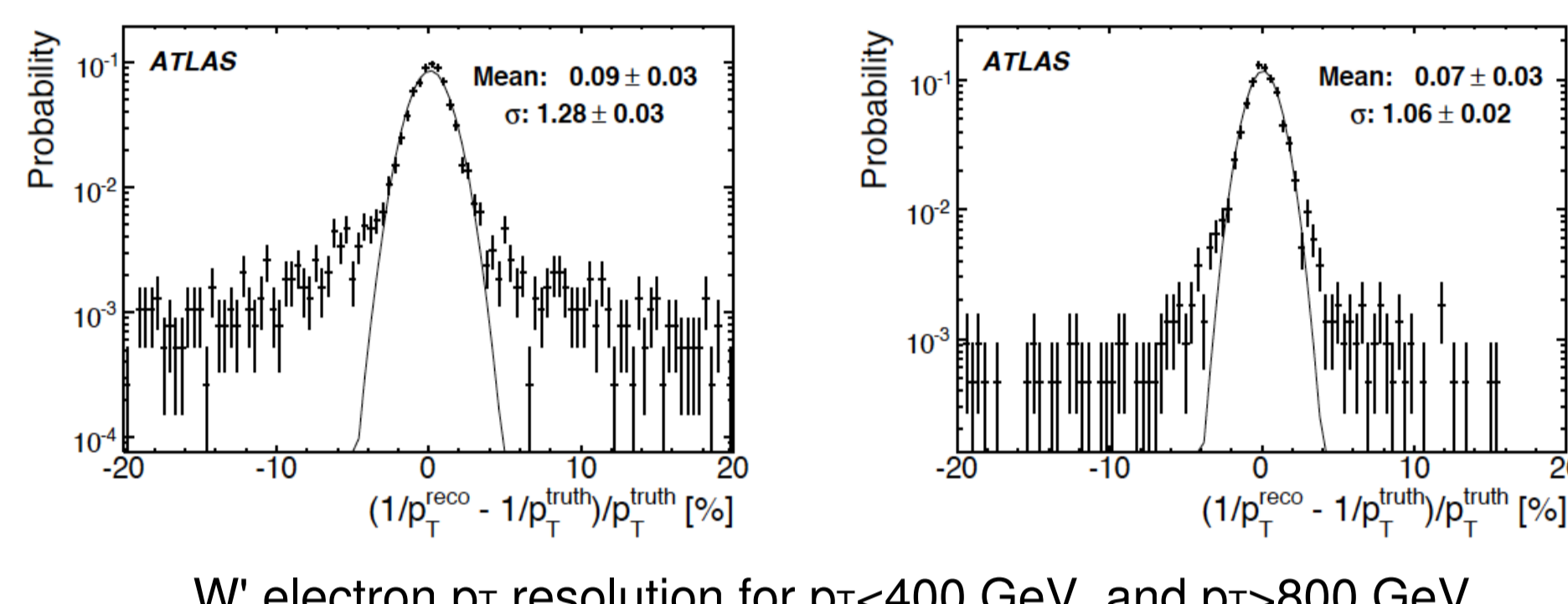
Muon reconstruction and performance

- **Combined muons** constructed by combining tracks found independently in the ID and MS.
- Muon resolution, p_T dependent, limited by detector characteristics, alignment, and calibration.
- Muon reconstruction efficiency $\sim 93\%$ (92%) for $m(W')=1$ TeV (2 TeV). Drop due to high p_T muon radiation. Efficiency loss in regions with poor detector coverage.
- Reduction of fake and badly reconstructed muons achieved by imposing quality cuts: match $\chi^2 < 100$, impact parameter in z-axis < 200 mm and significance in R/ϕ plane < 10 .



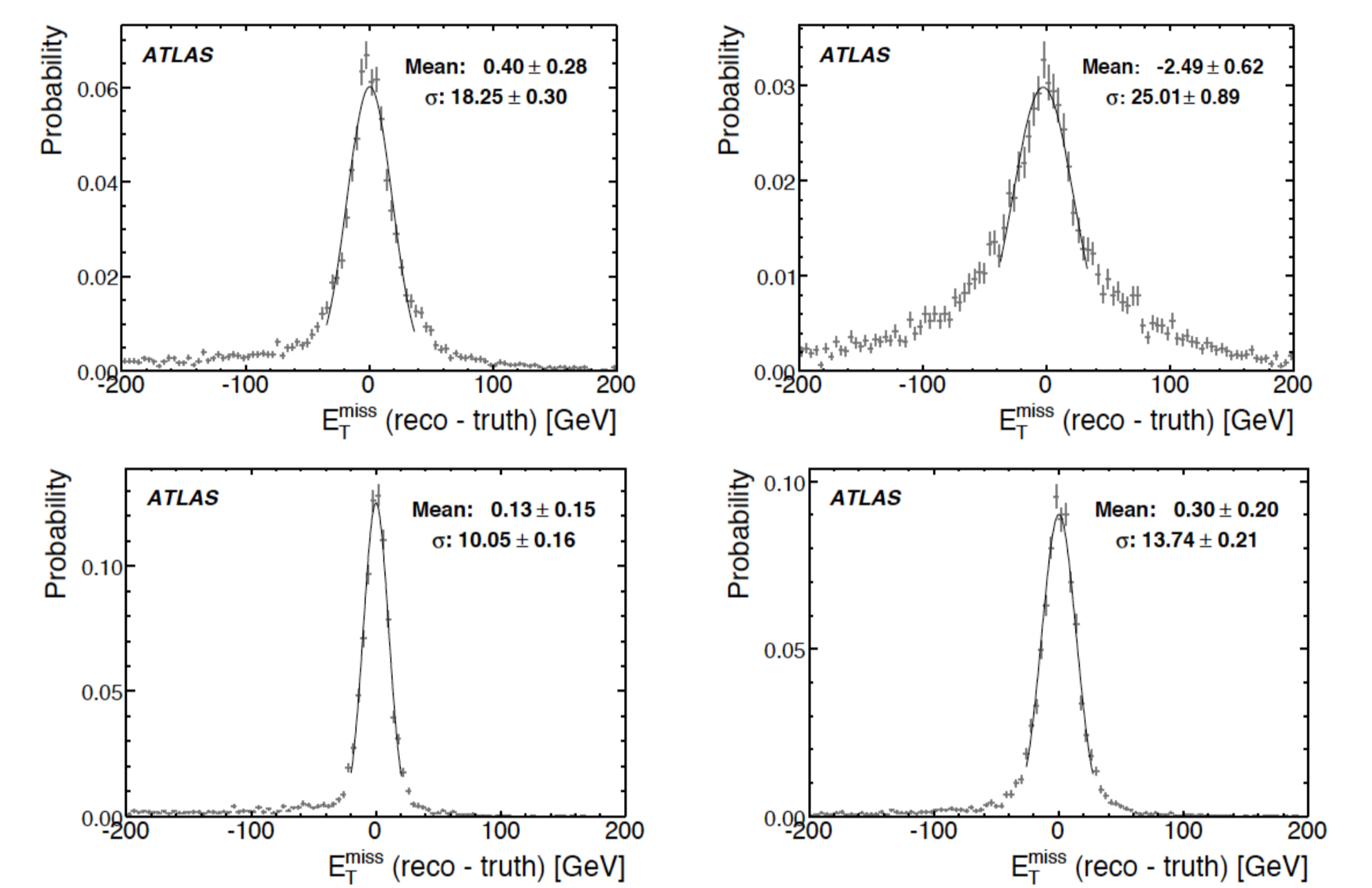
Electron reconstruction and identification

- Electron candidates are built from clusters of calorimeter cell with energy deposition, which are matched to an ID track.
- **"Medium"** quality cuts have been applied for electron identification. These cuts comprise cuts on hadronic leakage, shower-shape variables and the quality of track matched.
- Non Gaussian tails in electron p_T resolution are due to the amount of material in inner detector, and therefore η dependent.



Missing transverse energy reconstruction

- Missing E_T reconstruction is calculated from energy deposits in calorimeter cells that survive a noise suppression procedure. Cells are calibrated using global calibration. Corrections are applied for muon energy loss and cryostat. Muon p_T is from MS is added.
- **Refined calibration** of calorimeter cells is done by using the association of calorimeter cells with reconstructed objects.
- For higher W' mass value, non-Gaussian tails of the missing E_T resolution are more pronounced because of muon resolution degradation at high p_T .



Trigger

Electron trigger: L1 threshold with $E_T > 100$ GeV, efficiency = 98%, rate = 14 ± 1 Hz @ 10^{32} cm $^{-2}$ s $^{-1}$ (threshold higher than those defined in trigger menu). Loose requirement on L2 and EF further reduce the rate, with overall trigger efficiency of 90%.

Muon trigger: $p_T > 20$ GeV at each level, lower threshold due to lower fake rate. Efficiency (74%) is limited mainly by geometrical regions of muon spectrometer not covered by RPC chambers.

EVENT SELECTION

1) Preselection

- exactly 1 lepton, $p_T > 50$ GeV and $|\eta| < 2.5$;
- Missing $E_T > 50$ GeV.

2) Background rejection

Lepton track isolation:

$$\sum p_{\text{Tracks}} / p_{\text{Lepton}} < 0.05 \text{ in } 0.02 < \Delta R < 0.3$$

$$\Delta R = \sqrt{(\Delta \eta)^2 + (\Delta \phi)^2},$$

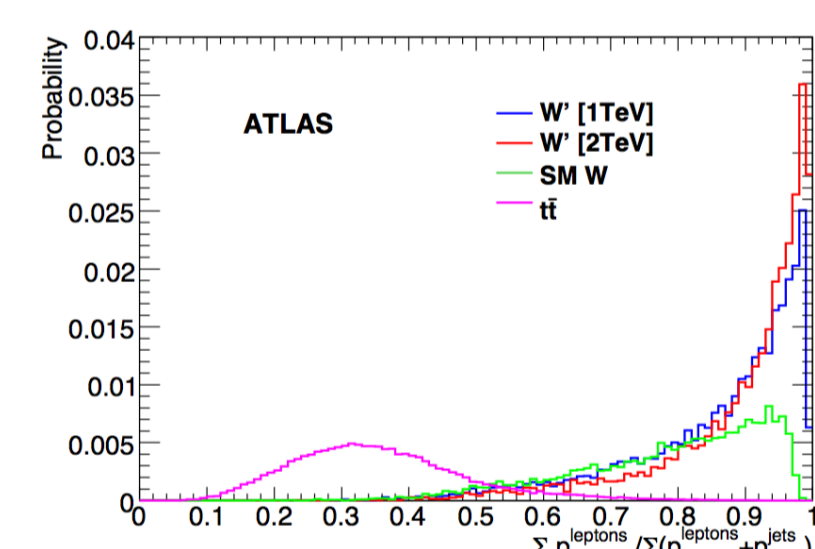
$$\Delta \eta = \eta_{\text{track}} - \eta_{\text{lepton}}, \quad \Delta \phi = \phi_{\text{track}} - \phi_{\text{lepton}}$$

Lepton fraction:

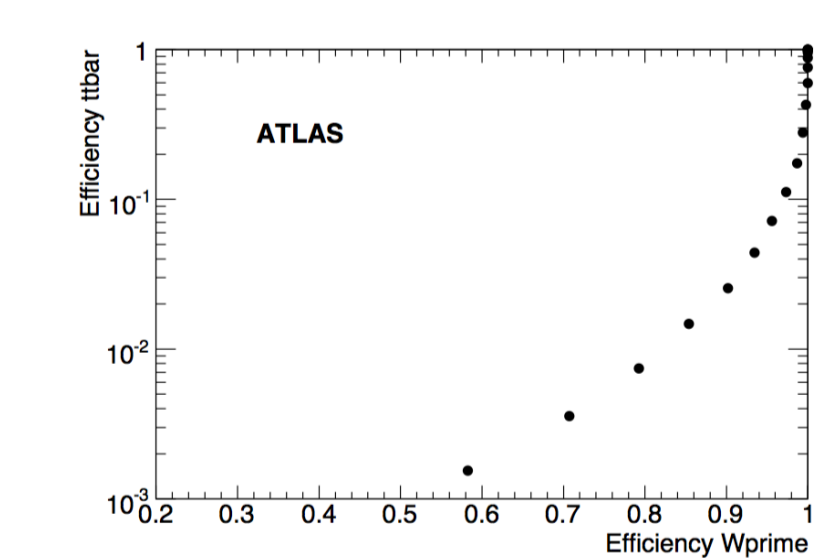
$$\sum p_T^{\text{leptons}} / (\sum p_T^{\text{leptons}} + \sum E_T) > 0.5$$

Transverse mass cut:

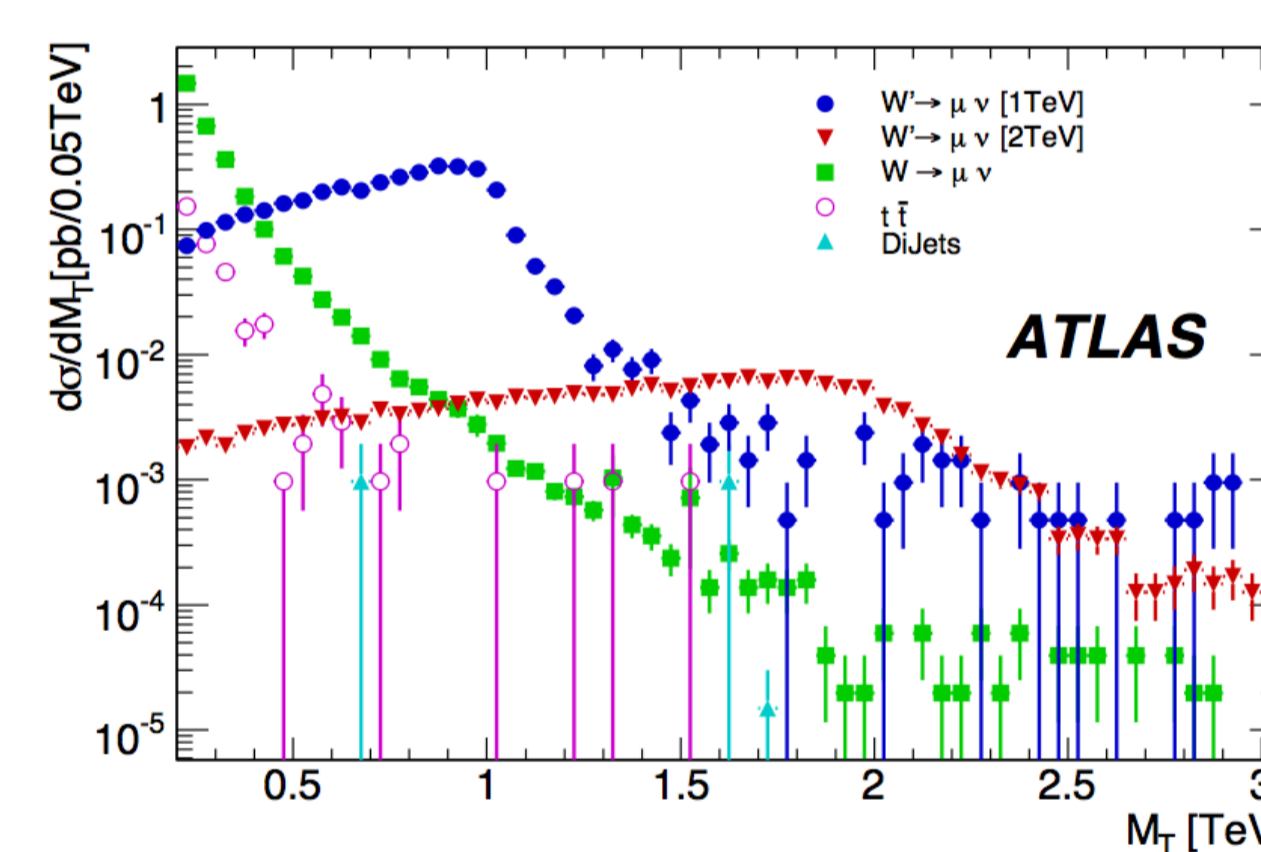
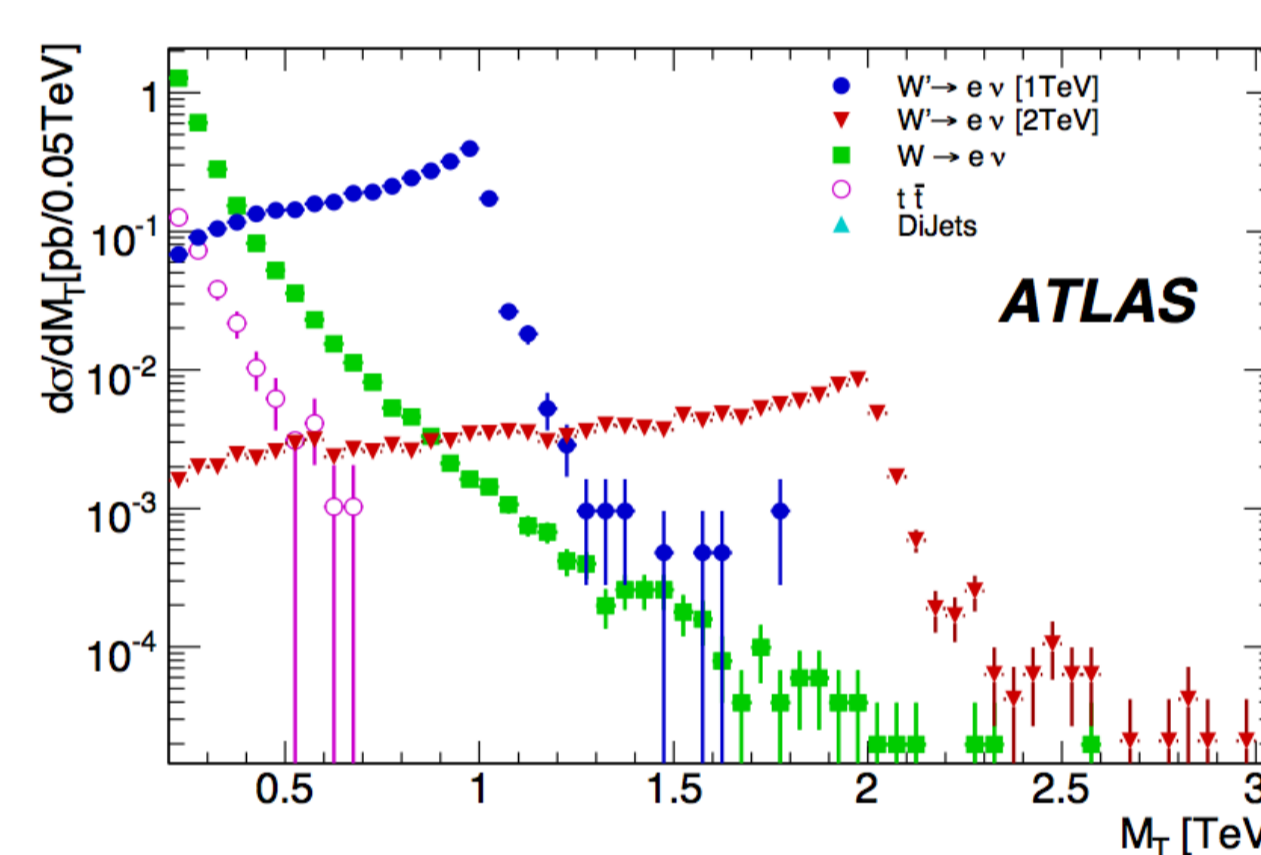
$$m_T = \sqrt{2p_T E_T^{\text{miss}} (1 - \cos \Delta \phi_{l, E_T^{\text{miss}}})} > 0.7 m(W')$$



Lepton fraction distribution in signal and background muon events.



Signal efficiency versus $t\bar{t}$ efficiency for different requirement values of the lepton fraction



Transverse mass distributions after lepton fraction cut.

Requirement	σ [pb]				
	W' (1 TeV)	W' (2 TeV)	W tail	$t\bar{t}$	Dijets[1-7]
(No requirement)	4.99	0.231	10.28	452	1.91×10^{10}
Preselection	3.67 ± 0.04	0.160 ± 0.002	6.80 ± 0.06	150.57 ± 0.40	$(13.6 \pm 0.2) \times 10^6$
$p_T > 50$ GeV	3.43 ± 0.04	0.150 ± 0.002	5.53 ± 0.05	51.13 ± 0.23	$(7.23 \pm 0.6) \times 10^3$
$E_T > 50$ GeV	3.40 ± 0.04	0.149 ± 0.002	5.19 ± 0.05	25.78 ± 0.16	45.33 ± 16.65
Isolation	3.36 ± 0.04	0.148 ± 0.002	5.01 ± 0.05	23.30 ± 0.16	0.65 ± 0.13
Lepton fraction	3.25 ± 0.04	0.145 ± 0.002	4.10 ± 0.04	0.50 ± 0.02	0
$m_T > 700$ GeV	1.86 ± 0.03		0.0317 ± 0.0008	0	0
$m_T > 1400$ GeV		0.0740 ± 0.001	0.0014 ± 0.0002	0	0

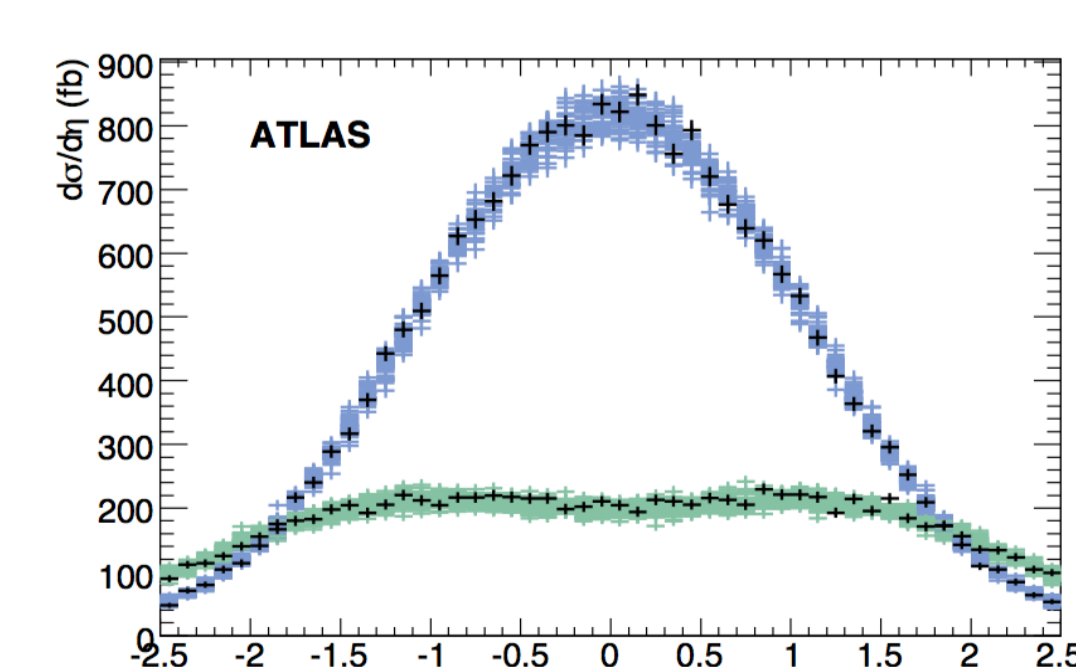
Table 4: Cross-section for signal and backgrounds after each requirement. Electron mode.

Requirement	σ [pb]				
	W' (1 TeV)	W' (2 TeV)	W tail	$t\bar{t}$	Dijets[1-7]
(No requirement)	4.99	0.231	10.28	452	1.91×10^{10}
Preselection	4.28 ± 0.05	0.199 ± 0.002	7.77 ± 0.06	205.30 ± 0.46	$(11.2 \pm 0.19) \times 10^6$
$p_T > 50$ GeV	4.03 ± 0.04	0.187 ± 0.002	6.40 ± 0.06	61.71 ± 0.25	$(1.24 \pm 0.26) \times 10^3$
$E_T > 50$ GeV	4.00 ± 0.04	0.186 ± 0.002	6.04 ± 0.05	31.34 ± 0.18	74.32 ± 23.28
Isolation	3.95 ± 0.04	0.185 ± 0.002	5.99 ± 0.05	28.70 ± 0.17	1.00 ± 0.82
Lepton fraction	3.81 ± 0.04	0.181 ± 0.002	4.85 ± 0.05	0.64 ± 0.03	$(1.96 \pm 1.38) \times 10^{-3}$
$m_T > 700$ GeV	2.20 ± 0.03		0.043 ± 0.002	0.007 ± 0.003	0.001 ± 0.001
$m_T > 1400$ GeV		0.094 ± 0.0001	0.0031 ± 0.0006	0.001 ± 0.001	0.001 ± 0.001

Table 5: Cross-section for signal and backgrounds after each requirement. Muon mode.

SYSTEMATIC UNCERTAINTIES

Theoretical uncertainties comprise higher order corrections and PDF uncertainties. NLO corrections were evaluated with MC@NLO/HERWIG, with width set to the one in Pythia. Small variation in scale, QED corrections partly included through PHOTOS for FSR. PDF systematics estimated through 40 error PDF of CTEQ6.1 corresponding to the 2 limits of each of 20 eigenvectors. Overall theoretical uncertainty is 8%.



Muon η distributions for W' and W^- $m(W')=1$ TeV for CTEQ6.1 p.d.f central value and 40 error sets.

Description of systematic	electrons		muons	
	$\delta\sigma_s$ [%]	$\delta\sigma_b$ [%]	$\delta\sigma_s$ [%]	$\delta\sigma_b$ [%]
lepton energy scale +	+0.8	+1.8	+1.2	+4.6
lepton energy scale -	-0.7	-2.1	-1.2	-4.4
lepton energy resolution	+0.1	+0.2	-1.0	+3.7
efficiency +	+1.0	+1.0	+5.	+5.
efficiency -	-1.0	-1.0	-5.	-5.
Jet energy scale +	+0.1	-0.2	-0.1	+0.1
Jet energy scale -	+0.1	-0.2	+0.1	+0.7
Jet energy resolution	+0.0	+0.1	-0.1	+0.3
Luminosity	$\pm 3.$		$\pm 3.$	

Table 9: Effect of the detector systematics in percentage for $m_{W'} = 1$ TeV.

Detector systematic uncertainties comprise lepton reconstruction efficiency, scale and resolution, as well as jet energy uncertainties and overall luminosity uncertainty.

CONCLUSION

The potential for the ATLAS experiment to reconstruct and identify the decay of heavy, charged gauge bosons with SM-like coupling to fermions, has been studied in a lepton and a neutrino decay mode. It has been shown that, even with integrated luminosity of 10 pb $^{-1}$ of data, it would be possible to discover this type of bosons should they exist not far from current experimental limit.

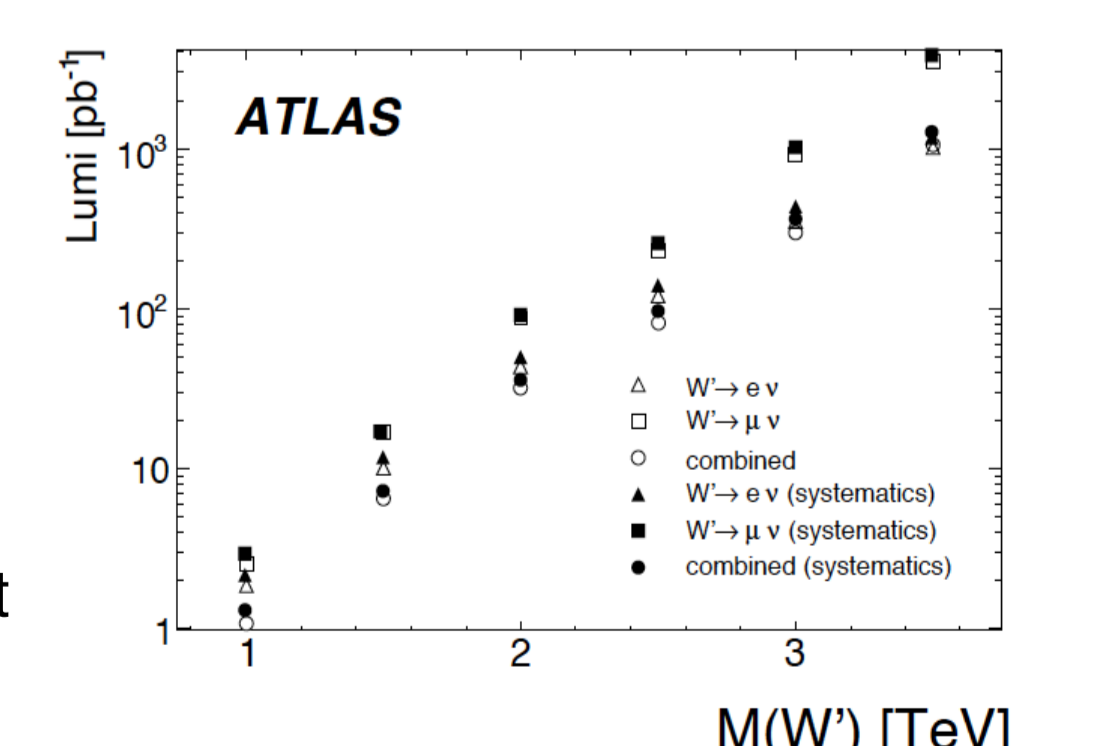
DISCOVERY POTENTIAL

The significance is obtained from the expected number of signal (s) and background events (b) according to formula

$$S = \sqrt{2((s+b) \ln(1+s/b) - s)},$$

which is a good approximation to the likelihood ratio based significance in the low statistics regime. Higher order corrections and systematic uncertainties were taken into account.

Alternatively the significance could be obtained taking into account the shape of the signal and background m_T distribution. This was done using the Fast Fourier Technique [3] which allows for analytical calculation of the experiment estimator distributions instead of generating a large number of pseudoexperiments. With this method the collected luminosity required for 5σ is reduced by 20-35% with respect to the values shown on the right plot.



Integrated luminosity needed for 5σ discovery, as a function of W' mass.

REFERENCES

- [1] ATLAS Collaboration, Expected Performance of the ATLAS Experiment, Detector, Trigger and Physics, CERN-OPEN-2008-020, Geneva, 2008, to appear.
- [2] V.M. Abazov *et al*, *Phys. Rev. Lett.*, **100** (2008) 031804.
- [3] H.Hu and J.Nielsen, arXiv:physics/9906010