

# QCD and electroweak physics with ATLAS

Deywis Moreno

on behalf of the ATLAS Collaboration.

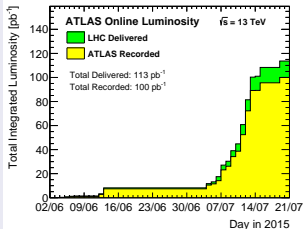
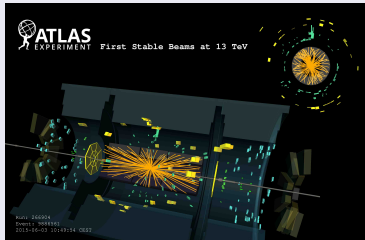
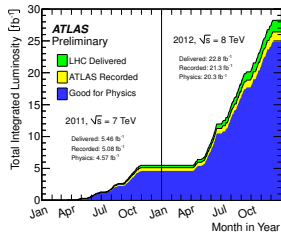
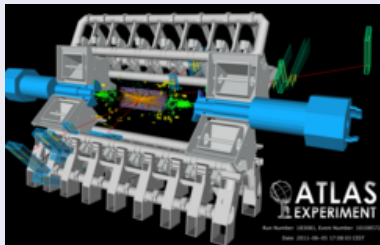
07.08.2015



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- Multibosons physics
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# ATLAS overview

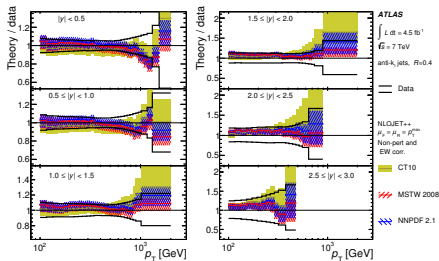
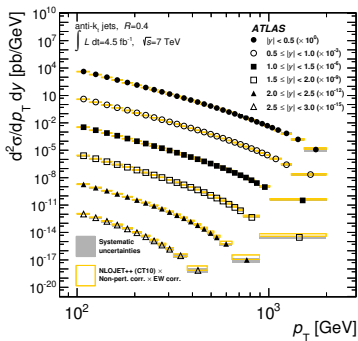


<http://twiki.cern.ch/twiki/bin/view/AtlasPublic>

<http://twiki.cern.ch/twiki/bin/view/AtlasPublic>

## Inclusive jet cross-section at 7 TeV (JHEP02(2015)153)

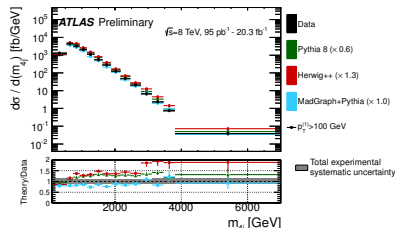
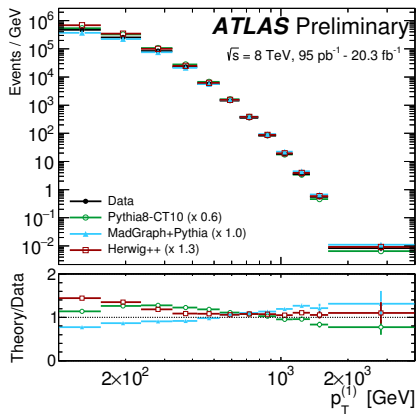
- 1 Test of the the validity of pQCD
- 2 Measurement of the double-differential inclusive cross-section as a function of  $p_T$  of the jets and rapidity  $y$
- 3 Jets with  $p_T > 100$  GeV and  $|y| < 3$ . Two radii 0.4 and 0.6



Predictions Sys. lower than measurement at low-rapidity

## Four jets production cross-section at 8 TeV (CERN-PH-EP-2015-181)

- 1 Various differential cross-sections of events with 4-Jets are calculated
- 2 Test of QCD up to  $H_t \approx 5$  TeV
- 3 Momentum, mass and angular variables were studied

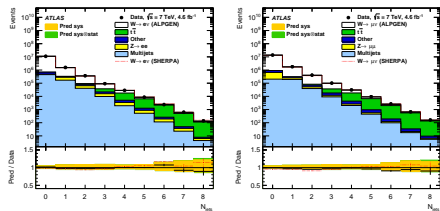


All LO generator show a slope in the momentum of leading  $p_T$   
HERWIG++ predicts more events at high  $m_{4j}$

## W+ jets production cross-section at 7 TeV (Eur. Phys. J. C (2015) 75:82)

- 1 Jet production measured up to  $p_T$  1 TeV and jet multiplicities up to 7
- 2 Fully leptonic final states ( $e/\mu$ )

- 1 Differential cross-section compared with theory predictions at LO/NLO
- 2 NP and QED corrections are applied.

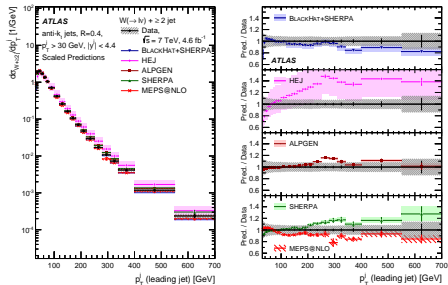
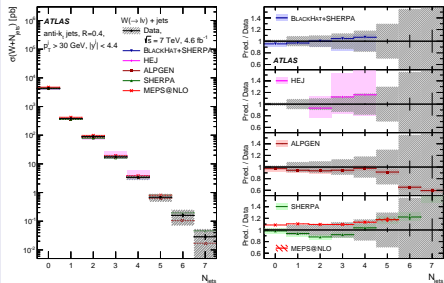


## Applied selections

- 1 Lepton  $p_T > 25$  GeV . Electrons(Muons)  $|\eta| < 2.47(2.4)$
- 2 Missing  $E_t > 25$  GeV
- 3 Jet  $p_T > 30$  GeV. Jets  $|\eta| < 4.4$

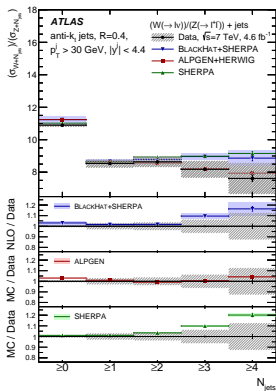
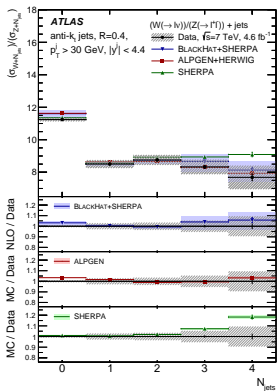
## W+ jets production cross-section at 7 TeV. (Eur. Phys. J. C (2015) 75:82)

- 1 Overall good agreement with predictions is found
- 2 However some differential cross-section distributions are not fully described by the predictions



## Measurement of the R+jets (the ratio of W+jets / Z+jets) at 7 TeV (Eur. Phys. J. C (2014) 74: 3168)

- 1 Inclusive and differential cross-section ratios for massive bosons decaying in  $e/\mu$  in association with jets
- 2 Some experimental uncertainties and NP QCD effects (hadronization and MPI) reduced in ratio

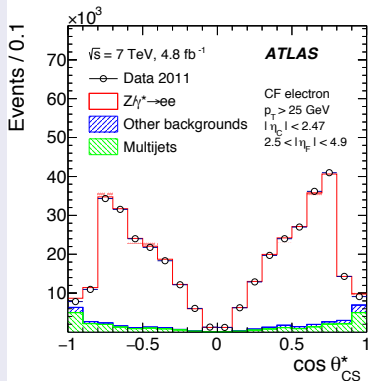
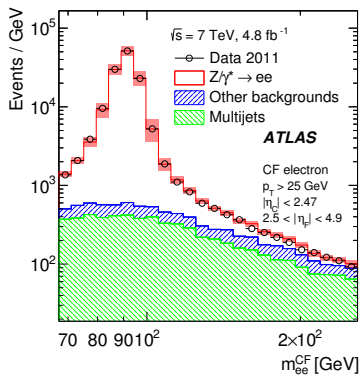


- 1 Comparison with NLO pQCD
- 2 Improved over previous measurements due to more statistics in events up to 4 jets multiplicities



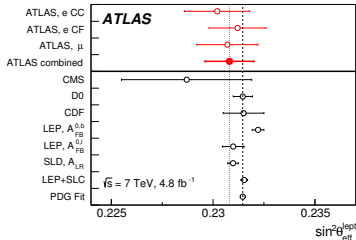
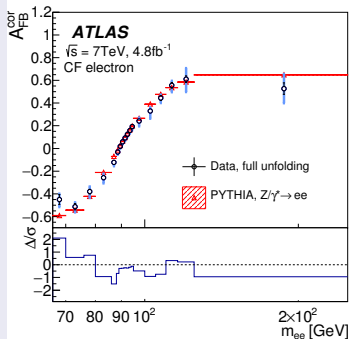
## Measurement of the forward-backward asymmetry ( $A_{FB}$ ) of lepton pair production at 7 TeV (arXiv:1503.03709v1)

- Measurement of  $A_{FB} = \frac{N_{\cos \Theta_{CS}^* \geq 0} - N_{\cos \Theta_{CS}^* < 0}}{N_{\cos \Theta_{CS}^* \geq 0} + N_{\cos \Theta_{CS}^* < 0}}$  as function of  $m_{\ell\ell}$
- Forward electrons are used in order to access high Z/ $\gamma$  rapidity regions



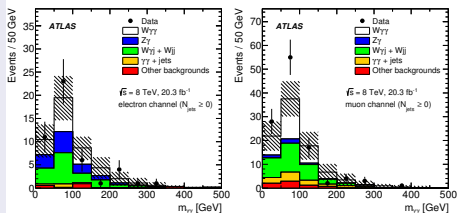
## Measurement of the forward-backward asymmetry ( $A_{FB}$ ) of lepton pair production at 7 TeV (arXiv:1503.03709v1)

- 1 Extraction of the weak mixing angle ( $\sin^2 \Theta_{eff}^{lept}$ )
- 2  $\sin^2 \Theta_{eff}^{lept} = 0.2308 \pm 0.005(stat.) \pm 0.0006(syst.) \pm 0.0009$   
in agreement with PDG value



## Evidence of the $W\gamma\gamma$ production at 8 TeV (Phys. Rev. Lett. 115, 031802 (2015))

- 1 Cross-section measured in fully leptonic ( $e/\mu$ ) channels for inclusive ( $N_{jet} \geq 0$ ) and exclusive ( $N_{jet} = 0$ ) regions
- 2 First evidence of  $W\gamma\gamma$  with  $3\sigma$  significance

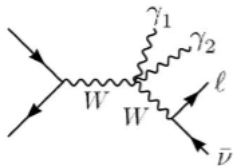


	$\sigma^{\text{fid}}$ [fb]	$\sigma^{\text{MCFM}}$ [fb]
Inclusive ( $N_{jet} \geq 0$ )		
$\mu\nu\gamma\gamma$	$7.1^{+1.3}_{-1.2}$ (stat.) $\pm 1.5$ (syst.) $\pm 0.2$ (lumi.)	$2.90 \pm 0.16$
$e\nu\gamma\gamma$	$4.3^{+1.8}_{-1.6}$ (stat.) $\pm 1.9$ (syst.) $\pm 0.2$ (lumi.)	
$\ell\nu\gamma\gamma$	$6.1^{+1.1}_{-1.0}$ (stat.) $\pm 1.2$ (syst.) $\pm 0.2$ (lumi.)	
Exclusive ( $N_{jet} = 0$ )		
$\mu\nu\gamma\gamma$	$3.5 \pm 0.9$ (stat.) $^{+1.1}_{-1.0}$ (syst.) $\pm 0.1$ (lumi.)	$1.88 \pm 0.20$
$e\nu\gamma\gamma$	$1.9^{+1.4}_{-1.1}$ (stat.) $^{+1.0}_{-1.2}$ (syst.) $\pm 0.1$ (lumi.)	
$\ell\nu\gamma\gamma$	$2.9^{+0.8}_{-0.7}$ (stat.) $^{+1.0}_{-0.9}$ (syst.) $\pm 0.1$ (lumi.)	

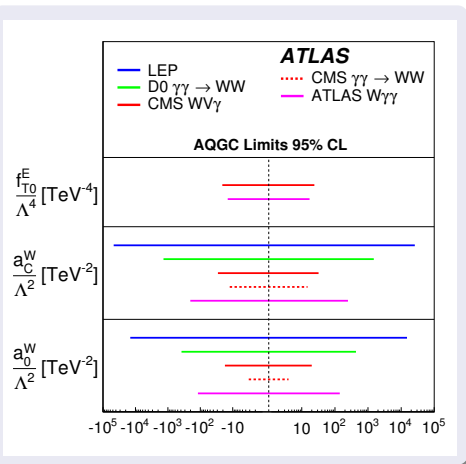
	Electron channel		Muon channel	
	$N_{jet} \geq 0$		$N_{jet} = 0$	
$W\gamma\gamma + W_{jj}$	$15.3 \pm 4.8$ (stat.) $\pm 5.3$ (syst.)	$30.5 \pm 7.7$ (stat.) $\pm 6.8$ (syst.)	$5.8 \pm 2.1$ (stat.) $\pm 2.0$ (syst.)	$14.4 \pm 4.9$ (stat.) $\pm 4.9$ (syst.)
$\gamma\gamma + jets$	$1.5 \pm 0.6$ (stat.) $\pm 1.0$ (syst.)	$11.0 \pm 4.0$ (stat.) $\pm 4.9$ (syst.)	$0.2 \pm 0.2$ (stat.) $\pm 0.2$ (syst.)	$6.1 \pm 3.5$ (stat.) $\pm 3.1$ (syst.)
$Z\gamma$	$11.2 \pm 1.1$ (stat.)	$3.9 \pm 0.2$ (stat.)	$2.4 \pm 0.5$ (stat.)	$2.8 \pm 0.2$ (stat.)
Other backgrounds	$2.2 \pm 0.6$ (stat.)	$6.7 \pm 2.0$ (stat.)	$0.3 \pm 0.1$ (stat.)	$1.1 \pm 0.3$ (stat.)
Total background	$30.2 \pm 5.0$ (stat.) $\pm 5.4$ (syst.)	$52.1 \pm 8.9$ (stat.) $\pm 8.4$ (syst.)	$8.7 \pm 2.2$ (stat.) $\pm 2.0$ (syst.)	$24.4 \pm 6.0$ (stat.) $\pm 5.8$ (syst.)
Data	47	110	15	53

## Evidence of the $W\gamma\gamma$ production at 8 TeV (Phys. Rev. Lett. 115, 031802 (2015))

- 1 First triboson aQGC limits of high dimension operator determined in jet exclusive region and  $m_{\gamma\gamma} > 300$  GeV



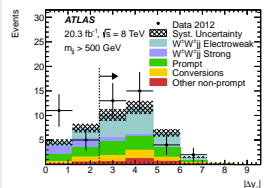
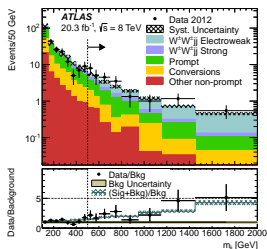
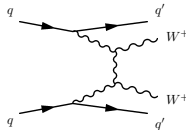
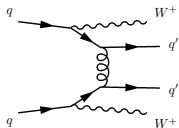
Limits are set at 95% C.L. on aQGC parameters, in particular improving the limit on  $f_{T_0}/\Lambda^4$



# Multiboson physics

First evidence of Vector Boson Scattering (VBS) in  $W^\pm W^\pm jj$  final state at 8 TeV (Phys. Rev. Lett. 113, 141803)

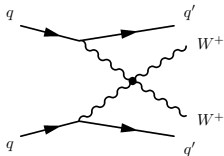
- 1 Measurement of the same sign  $W^\pm W^\pm$  scattering in  $(e/\mu)$  states
- 2 Signal using VBS topology selection:  $|\Delta Y_{jj}| > 2.4$  and  $m_{jj} > 500$  GeV



# Multibosons physics

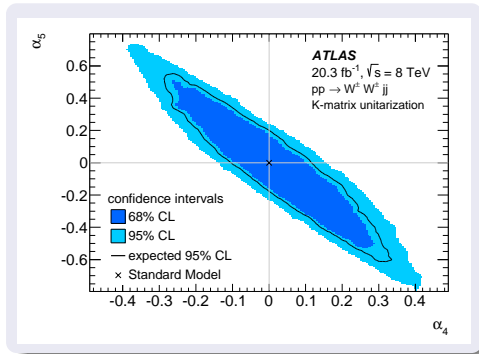
First evidence of Vector Boson Scattering in  $W^\pm W^\pm jj$  final state at 8 TeV  
(Phys. Rev. Lett. 113, 141803)

- 1 A total of 34 candidates found in VBS region
- 2 Measured cross-section in agreement with theory prediction



aQGC of  $WWWW$

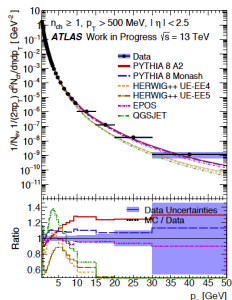
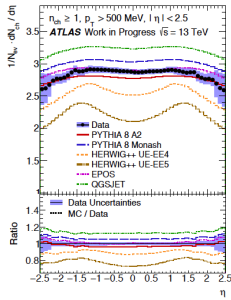
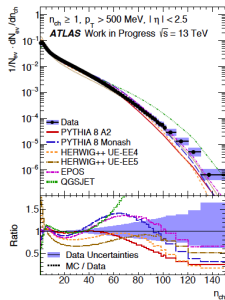
- 1 Measurement of the aQGC of  $WWWW$
- 2 First 2-D limits of high dimension operators  $\alpha_4/\alpha_5$



# Bonustrack: Some 13 TeV analysis

## Charged particle multiplicities in $pp$ interactions at 13 TeV (ATLAS-CONF-2015-028)

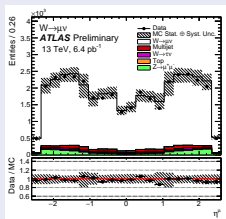
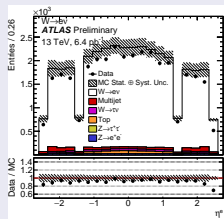
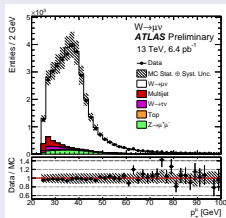
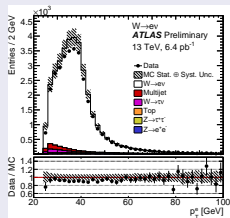
- 1 Charged particles multiplicities at 13 TeV selected with a special minBias trigger are studied
- 2 A dataset corresponding to  $169 \mu\text{b}^{-1}$  is analysed



# Bonustrack: Some 13 TeV analysis

## Kinematic distributions of $W \rightarrow l\nu$ and $Z \rightarrow \ell\ell$ (ATL-PHYS-PUB-2015-021)

- 1 Analysed data sample corresponds to  $6.4 \text{ pb}^{-1}$
- 2 A total of 33200  $W \rightarrow e\nu$  and 36400  $W \rightarrow \mu\nu$  events selected

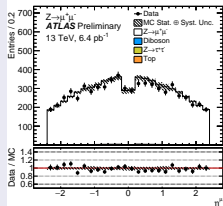
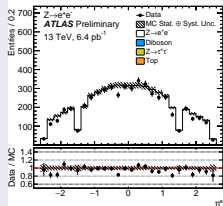
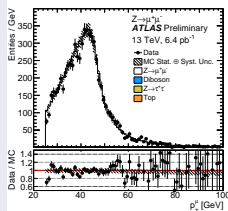
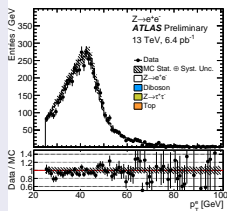




# Bonustrack: Some 13 TeV analysis

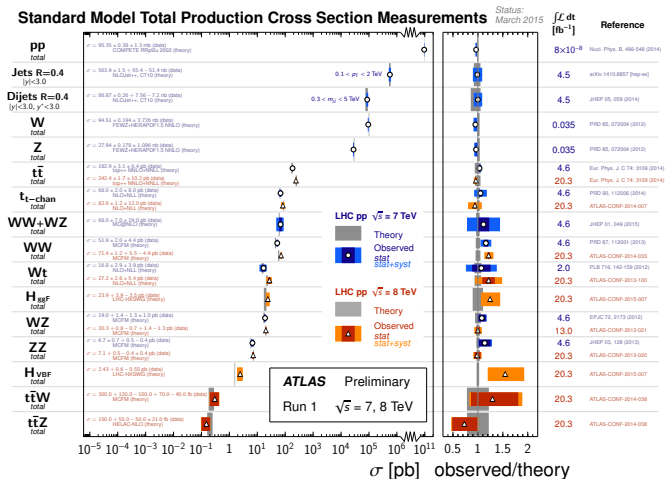
Kinematic distributions of  $W \rightarrow l\nu$  and  $Z \rightarrow ll$  (ATL-PHYS-PUB-2015-021)

- 1 Analysed data sample correspond to  $6.4 \text{ pb}^{-1}$
- 2 A total of 2590  $Z \rightarrow e^+e^-$  and 3350  $Z \rightarrow \mu^+\mu^-$  events selected



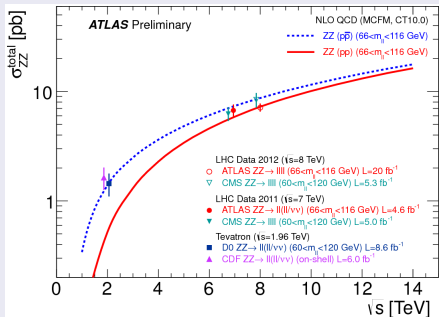
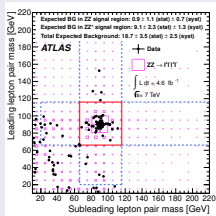
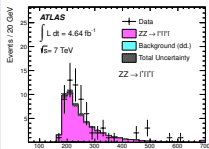
# Summary

- 1 Some of the most recent ATLAS results at  $\sqrt{s} = 7$  TeV, 8 TeV, 13 TeV were shown.
- 2 Presented cross-sections for different processes are in general in agreement with theoretical expectations.



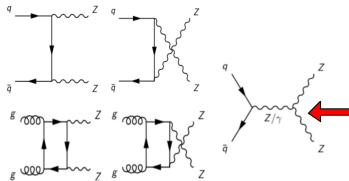
## Measurement of the $ZZ$ production cross section at 7 TeV. (JHEP03(2013)128)

- 1 Production cross section of the  $ZZ$  in  $4\ell$  and  $2\ell\nu\nu$  channels.
- 2 On-shell  $Z$  pairs were studied.
- 3 Good agreement of the cross-section with MC predictions.

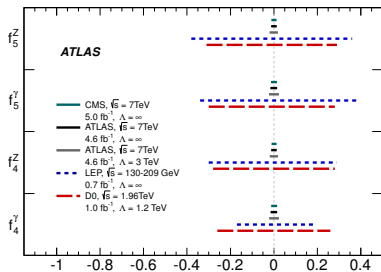


## Measurement of the $ZZ$ production cross section at 7 TeV (JHEP03(2013)128)

- 1 Limits to the aTGCs are calculated
- 2 Calculated limits more stringent than previous calculated limits

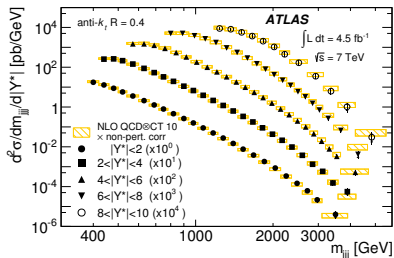


$ZZ$  production diagrams

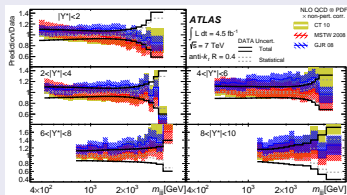


## Three jets production cross-section at 7 TeV (Eur. Phys. J. C (2015) 75)

- 1 Measurement of the double-differential inclusive cross-section as a function of  $m_{jjj}$  of the jets and rapidity separation  $Y^*$ .
- 2 Jets with  $p_T > 150$  GeV,  $p_T > 100$  GeV and  $p_T > 50$  GeV
- 3 Comparison with NLO predictions corrected and NP effects

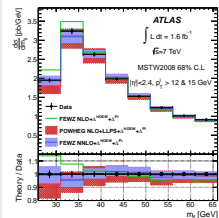
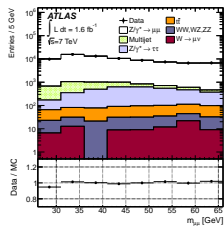
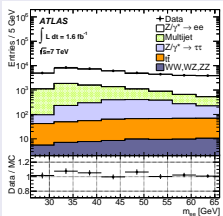


$$Y^* = |y_1 - y_2| + |y_2 - y_3| + |y_2 - y_3|$$





## Low mass Drell-Yan at 7 TeV (JHEP 06 (2014) 112)



## Measurement of the differential production cross-section of $Z$ in association with $b$ -jets at 7 TeV (JHEP10(2014)141)

