Z->ee cross-section measurement in pp collisions at √s = 7 TeV with the ATLAS detector

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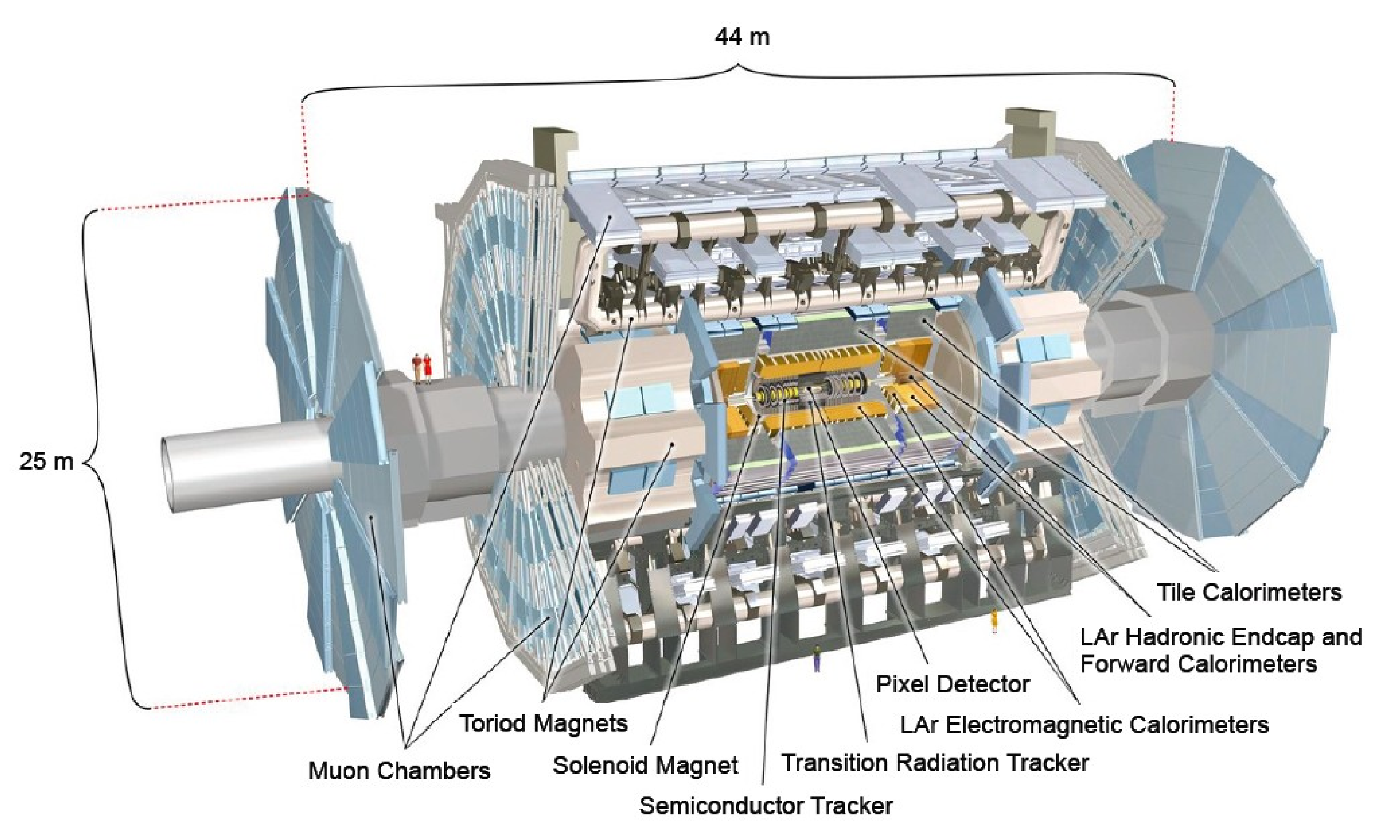
Electrons identification and reconstruction in ATLAS

•In order to achieve the LHC physics potential, the ATLAS electromagnetic calorimeter (EM) must be able to reconstruct electrons in a wide energy range [5 GeV, 5 TeV]. The liquid Argon (LAr) based calorimeter is divided into one barrel ($|\eta| < 1.475$) and two end-cap components ($1.375 < |\eta| < 3.2$, EMEC). It uses an accordion geometry to ensure fast and uniform response and fine segmentation for optimum identification and reconstruction of electrons and photons. The Forward Calorimeter (Fcal) covers the range $3.2 < |\eta| < 4.9$ and also uses Liquid Argon as active material. It consists of three modules in each end-cap: the first, made of copper, is optimised for electromagnetic measurement, while the other two, made of tungsten, measure primarily the energy of hadronic interactions.

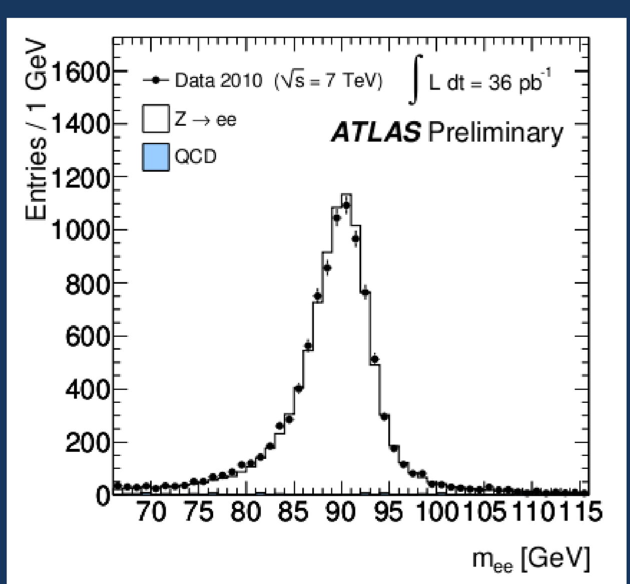
•Electrons and photons are triggered in the range $|\eta| < 2.5$, where the EM calorimeter has a fine segmentation in both lateral and longitudinal directions of the shower. The trigger also uses information of the inner detector (ID) which provides precise track reconstruction in the same pseudorapidity range. An electron seed is defined as a cluster in the second layer of the EM with $E_T > 2.5$ GeV. The closest matching track, if any, in a window of $\Delta\eta \times \Delta\Phi = 0.05 \times 0.1$ at the middle calorimeter layer is associated to the cluster to define an electron candidate. Three levels of purity of the candidates are defined at reconstruction level: *loose*, *medium*, and *tight* electrons, based on increasing requirements both on cluster-shape variables, hadronic leakage variables, track quality and matching and energy-to-momentum ratio. For forward region ($|\eta| > 2.5$), electron candidates are defined as reconstructed clusters with $E_T > 5$ GeV, their direction is defined as the barycentre of the cluster and the energy is the measured cluster energy.

•The analysis presented uses the data taken by the ATLAS detector in the year 2010 with proton beam energies of $E_p = 3.5$ TeV. For the Z/γ* cross section in the electron channel a total integrated luminosity of 36.2 pb^{-1} was used.

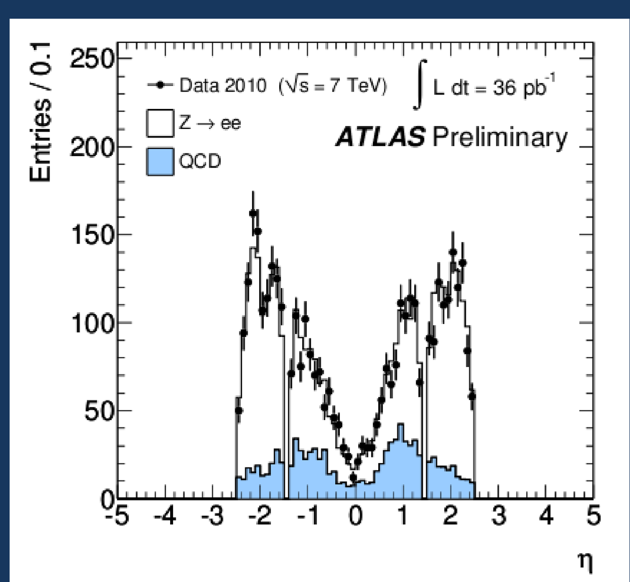
The ATLAS Detector



Z selection in the central region



Invariant mass distribution of central Z->ee candidates



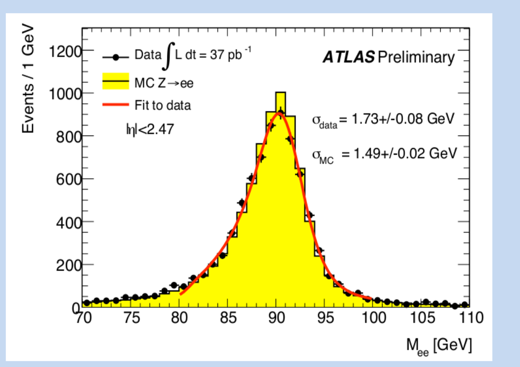
Pseudorapidity of central Z->ee candidates

Events are required to have at least one primary vertex formed by at least 3 tracks. After trigger requirements (L1_EM_14 or EF_e15_medium) two electrons are required to be reconstructed passing the "medium" identification criteria with $E_T > 20$ GeV and $|\eta| < 2.47$ excluding the transition region. Their charges have to be opposite, and the invariant mass of the $e^+ e^-$ pair has to be within the mass interval between 66 and 116 GeV .

The identification efficiency for electrons is determined using the tag-and-probe method and using the "*medium*" identification criteria. The MC efficiency is adjusted by about -2.5 % to match the data, with an estimated uncertainty of 1 %. The "*tight*" criteria instead, are more efficient in the data compared to the MC by about 2 % with an uncertainty of ~ 1.5 %.

Concerning the electron reconstruction efficiency, determined again using tag-and-probe method, results for data and simulation are found to be consistent within the assigned relative systematic uncertainty of ± 1.5 %.

Finally the energy scale and resolution correction have been determined constraining the measured $Z \to ee$ line shape to the one predicted by the simulation. For the central region the linearity and re-solution are in addition con-trolled using $J/\psi \to ee$ events.

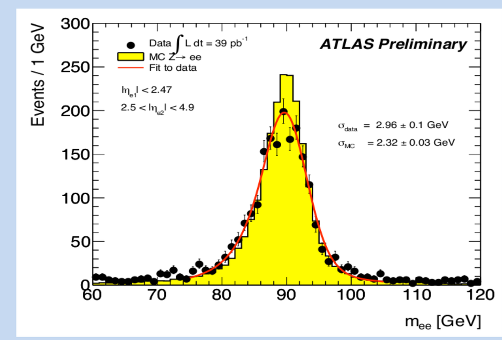


The calibrated Z->ee invariant mass (central region)

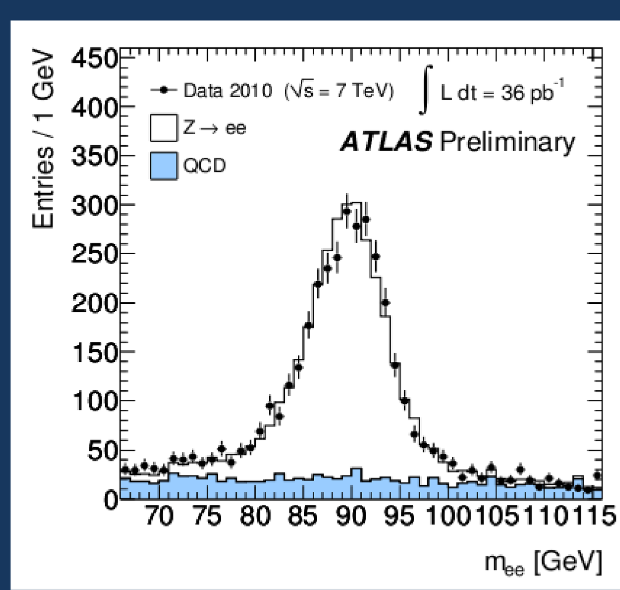
Z selection in the forward region

For the Z selection in an extended range of rapidity, a central electron passing the "tight" criteria is required while a second electron with $E_T > 20$ GeV has to be reconstructed in the forward region, $2.5 \le |\eta_e| \le 4.9$. Its transverse energy is determined from the calorimeter cluster energy and position. As the forward region is not covered by the tracking system, no charge can be measured and the identification has to rely on calorimeter cluster shapes only.

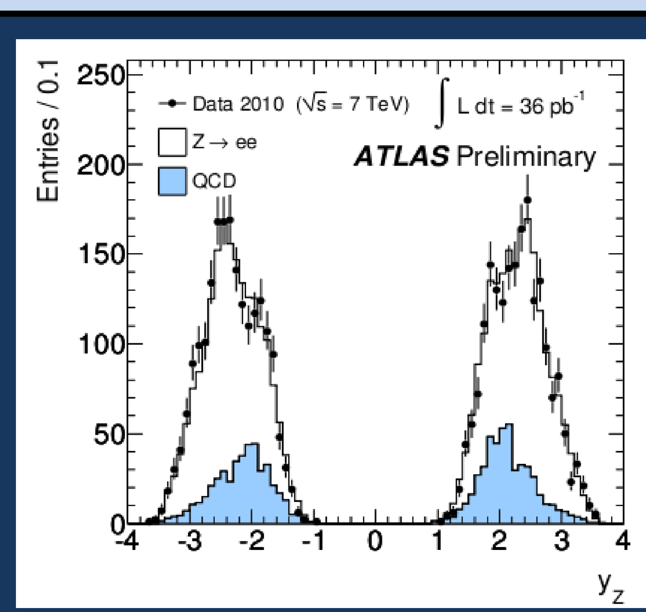
The electron reconstruction efficiency is close to 100 % and is assumed from MC. The identification efficiency is determined with the tag-and-probe method distinguishing two forward electron rapidity bins corresponding to the inner wheel of the EMEC and the FCal. The simulation overestimates the efficiency by 11.5 % and 3.5 % in this two bins and is adjusted accordingly.



The calibrated Z->ee invariant mass (forward region)



Invariant mass distribution of forward Z->ee candidates



Rapidity of forward Z->ee candidates

Z->ee cross section measurement

Analysis procedure

The total Z cross section is measured using the formula reported in (1), where:

– N is the number of candidate events measured in data,

– B is the number of estimated background events,

– L_{int} is the integrated luminosity corresponding to the run selections and the trigger employed,

– A_Z and C_Z are factorised acceptances.

C_Z is corrected for any discrepancy in recostruction and trigger efficiences between data and MC, while A_Z is introduced to extrapolate the measurement of $\sigma_{fid} = \sigma_{tot} / A_Z$ to the full kinematic region.

$$\sigma_{tot} = \sigma_Z \times BR(Z \to ll) = \frac{N - B}{A_Z \cdot C_Z \cdot L_{int}} \quad (1)$$

The QCD + elctroweak processes background contributions, both for central and forward $Z \to ee$ analysis, are estimated from data by fitting the invariant mass distribution of the final selection.

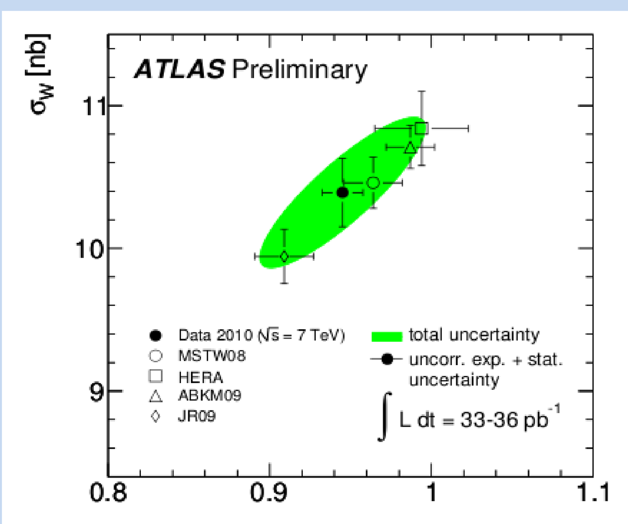
The table below shows the values of parameters for Z cross-section calculation in the electron channel in the 2010 data taking.

	N	B	C_z	A_z
Central Z	9721	217 ± 31	0.606 ± 0.021	0.445 ± 0.018
Forward Z	4000	1099 ± 128	0.448 ± 0.039	0.198 ± 0.008

Cross section value and uncertainties

	$\sigma^{fid}_{Z/\gamma^*} \cdot BR(Z/\gamma^* \to ee)$ [nb], $66 < m_{ee} < 116$ GeV
Z/γ^* Central	$0.433 \pm 0.004(sta) \pm 0.016(sys) \pm 0.015(lum)$
Z/γ^* Forward	$0.179 \pm 0.004(sta) \pm 0.017(sys) \pm 0.006(lum)$
	$\sigma^{tot}_{Z/\gamma^*} \cdot BR(Z/\gamma^* \to ee)$ [nb], $66 < m_{ee} < 116$ GeV
Z/γ^* Central	$0.972 \pm 0.010(sta) \pm 0.034(sys) \pm 0.033(lum) \pm 0.038(acc)$
Z/γ^* Forward	$0.903 \pm 0.022(sta) \pm 0.087(sys) \pm 0.031(lum) \pm 0.035(acc)$

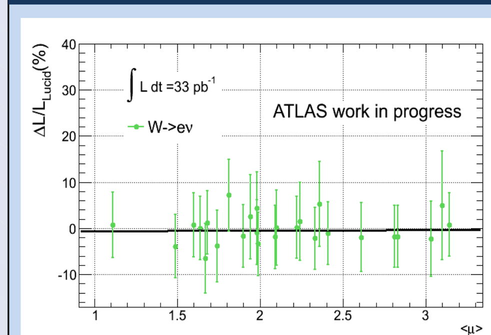
The table above shows the total and fiducial cross-sections times leptonic branching ratio, in *nb*, for *Z/γ** production in the electron dacay channel. The uncertainties denote statistical (sta) and experimental systematic (syst) errors, the acceptance (acc) errors and the luminosity induced errors (lum).

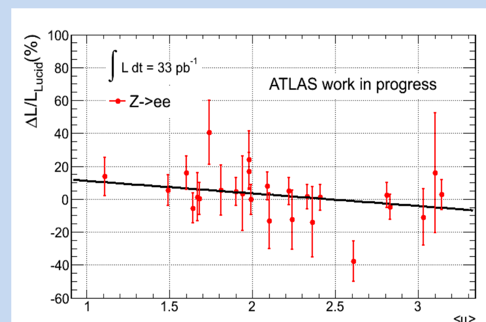


Measured and predicted Z (x-axis) and W (y-axis) cross section for electron and muon channels combined. The ellipse projections correspond to one standard deviation uncertainty of the measured cross section.

Final results agree very well with theory.

Luminosity monitoring using W/Z





Relative Luminosity (L) difference (%) between L measured by the official ATLAS luminometer (LUCID) and the L obteined using W (left) and Z (right) selection (see formula 2) as a function of the average number of interaction per bunch crossing (μ). The fit with a first order polynomial function results in values for the P1 parameters compatible with 0, confirming the perfect understanding of μ-dependence in the LUCID measurement.

W and Z bosons selections can be also used to monitor luminosity and to cross check the measurement of the dedicated luminosity detectors (see above plots).

Luminosity using physics channels (W/Z decay) can be measured using the following formula:

$$L = N_{(W/Z)} / (\varepsilon * \sigma^{(W/Z)}_{theo}) \quad (2)$$

$\sigma^{W}_{theo} = 10.46 \pm 0.52$ nb

$\sigma^{Z}_{theo} = 0.99 \pm 0.05$ nb

where $N_{(W/Z)}$ is the number of W/Z candidates background subtracted, $\sigma^{(W/Z)}_{theo}$ is the theoretical value of cross section and ε is the efficiency of the selection.

The total integrated luminosity (for 2010 ATLAS data taking) calculated using W->enu and Z->ee is respectively 1.3 % higher and 2.0 % lower wrt to the one measured by LUCID and in good agreement within statistical + systematic errors.

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