MEASUREMENT OF THE ELECTRON RECONSTRUCTION AND IDENTIFICATION EFFICIENCIES IN ATLAS

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Isolated, high-energy electrons constitute a very clean signature at hadron collider experiments. For final states of many Standard Model processes, as well as for physics beyond the Standard Model, electrons are key signature. A precise knowledge of the efficiency to correctly reconstruct and identify these electrons is thus important. In this contribution the measurement of these efficiencies is described. It is performed with a tag-and-probe method using Z and J/ψ decays to electrons in pp collisions recorded in 2012 at $\sqrt{s} = 8$ TeV, corresponding to an integrated luminosity of $L = 20.3\,\mathrm{fb}^{-1}$. The combination of the measurements results in identification efficiencies determined with an accuracy of the order of one percent and better for electrons with a transverse energy of $E_\mathrm{T} > 30$ GeV.

1 Introduction

The reconstruction and identification of isolated electrons plays a critical role in physics analyses at the ATLAS experiment[1]. Many physics processes of interest have signatures involving one or more isolated electrons. In order to quote detector independent physics results, measurements have to be corrected for the efficiencies to correctly reconstruct and identify electrons and therefore a precise knowledge of these efficiencies is needed. Electrons have been used in Standard Model measurements, the Higgs boson discovery and searches for physics beyond the Standard Model.

The measurements of the efficiencies for electrons with a pseudo-rapidity of $|\eta| < 2.47$, described here, are performed on the full dataset corresponding to an integrated luminosity of $L = 20.3\,\mathrm{fb}^{-1}$ of pp collisions recorded in 2012 at $\sqrt{s} = 8$ TeV. The methods have already been used in 2010[2] and 2011[3] and have been adjusted to the 2012 conditions.

2 Electron Reconstruction and Identification

The electron reconstruction and identification in the ATLAS experiment uses a combination of signatures of the silicon tracking detectors, of the transition radiation tracker and the finely segmented sampling calorimeter. Electrons are reconstructed and identified from energy deposits in the electromagnetic calorimeter that are then matched to a track in the inner detector. The electron reconstruction is optimised to reconstruct electrons with a high efficiency.

One of several sets of identification (ID) criteria is applied in order to reject background from physics objects that mistakenly are reconstructed as electrons. Four sets of identification criteria, based on rectangular cuts, and three sets of identification criteria, based on a multivariate analysis technique (MVA), are implemented. These rely on shower shape, track and track-to-cluster-matching variables.

3 Efficiency Measurements

In order to perform a precise measurement a clean source of electrons is required. These are selected from $J/\psi \to ee$ and $Z \to ee$ decays using a tag-and-probe technique, i.e. events are selected by putting strict criteria on event properties and on one of the decay electrons, no requirements are made on the other electron. The probe electrons are thus unbiased and can be used to measure the efficiency of the reconstruction and ID criteria. Since the identification criteria are optimised in bins of transverse energy E_T and pseudo-rapidity η the measurement is performed double-differentially in these variables. The sample obtained this way is largely contaminated with background, mainly hadronic jets that are misidentified as electrons. Background subtraction techniques are used, as explained below. They use templates, enriched in background processes by reverting single identification criteria and isolation requirements.

3.1 Electron Reconstruction Efficiencies

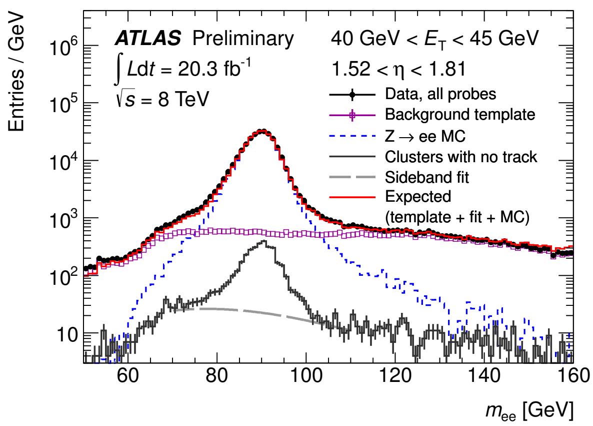


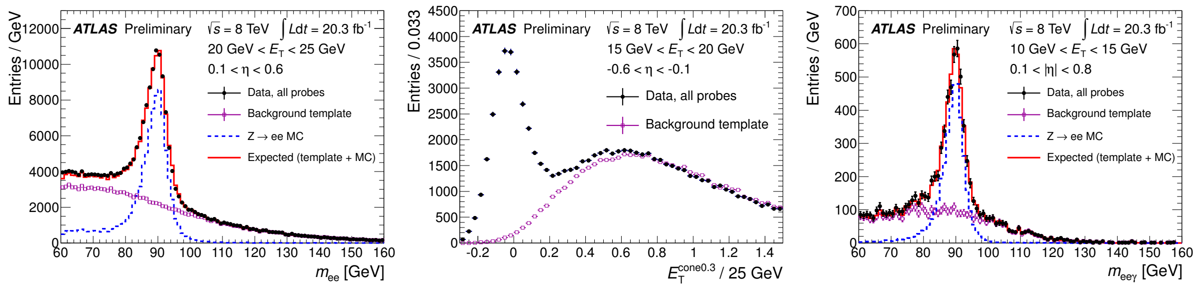
Figure 1: Illustration of the background subtraction technique used for the measurement of electron reconstruction efficiencies[5].

The efficiency of the electron cluster reconstruction is measured on simulated events only and found to be $> 99\%$ efficient for electrons with a transverse energy of $E_T > 15$ GeV. It reaches an efficiency of $> 99.9\%$ at $E_T > 45$ GeV. In data the efficiency of the track reconstruction and the track-to-cluster-matching is measured. The background subtraction technique is illustrated in Fig. 1 and based on the invariant mass distribution of the tag-and-probe pair. A side-band subtraction in the high invariant mass region is used with background templates constructed from data. Contributions from electrons without a matched track are estimated from fitting a polynomial in the side-bands of all clusters without a matched track.

3.2 Electron Identification Efficiencies

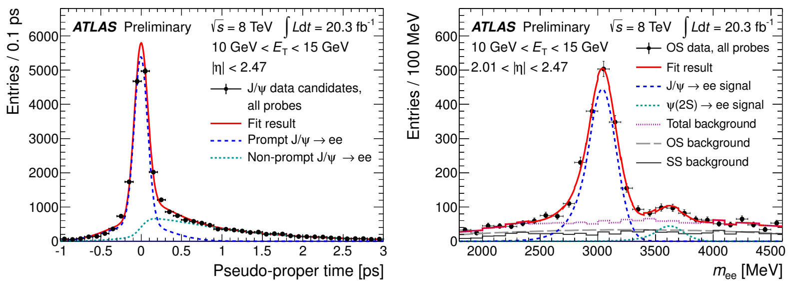
The efficiencies of the electron identification are measured $J/\psi \to ee$ decays in the transverse momentum range of $7 < E_T < 20$ GeV and from $Z \to ee$ decays in the range $E_T > 10$ GeV.

Two background subtraction techniques are implemented for $Z \to ee$ events. They are based on the invariant mass of the tag-and-probe pair or the calorimeter isolation E_T^{cone}. Both are used for electrons with a transverse momentum of $E_T > 15$ GeV. Background templates are normalised to data in the high invariant mass and high isolation region, respectively, and subtracted in the signal region.



(a) (b) (c)

Figure 2: Illustration of the background subtraction technique used for the measurement of electron identification efficiencies on $Z \rightarrow ee$ decays. The mass-based background subtraction technique (a), the calorimeter isolation based method (b) and the mass-based method in combination with $Z \rightarrow ee\gamma$ decays (c) are shown[5].



(a) (b)

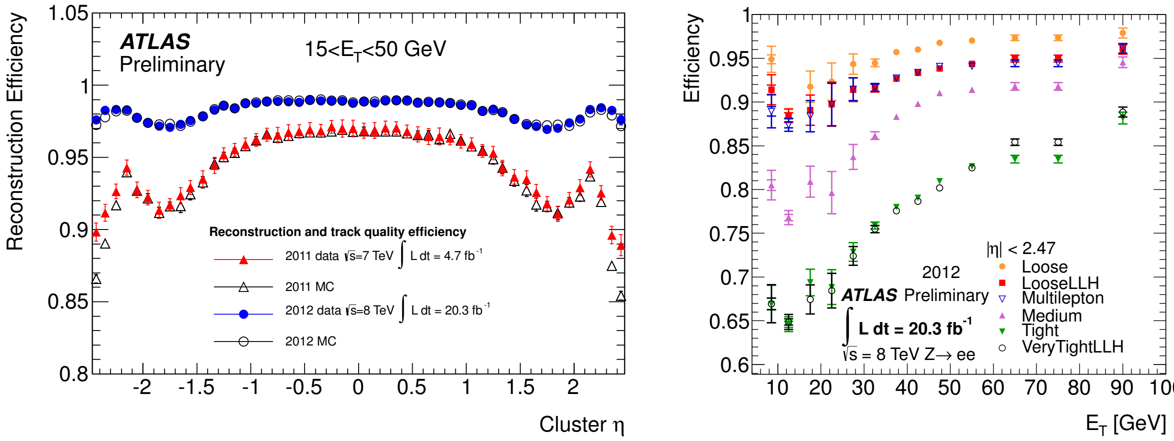
Figure 3: Illustration of the background subtraction technique used for the measurement of electron identification efficiencies in $J/\psi \rightarrow ee$ decays. The distribution of the pseudo-proper-time τ (a) and the invariant mass-based background subtraction fit (b) are shown[5].

To probe lower transverse momenta, radiative $Z \rightarrow ee$ decays are selected where the probe electron lost part of its energy due to QED final-state radiation (FSR). The invariant mass is reconstructed from three objects, the two electrons and the FSR photon. This allows for a significant reduction of the background as can be seen from the comparison of Figs. 2a and 2c. Even though the transverse energies of the probe electrons are higher by about $E_{\mathrm{T}} \sim 10$ GeV for the former samples, implying a smaller background contamination due to the steeply falling E_{T} distribution for the backgrounds, the amount of background is lower for the latter.

To probe electrons with even lower transverse energies, $J/\psi \rightarrow ee$ decays are used. In pp collisions J/ψs are produced in Drell-Yan processes or in decays of heavy flavour quarks, mainly b-hadron decays. Both sources exhibit different efficiencies since non-prompt electrons are less isolated. The measured life-time τ is used to differentiate between prompt and non-prompt decays. The distribution is shown in Fig. 3a. The measurement of efficiencies is performed with two methods, considering only short life-time events or extracting the prompt-fraction from a fit to the life-time. Both methods are using fits in the invariant mass distribution to estimate the J/ψ component. Signal and background distributions are parametrized as shown in Fig. 3b.

4 Results

The electron reconstruction efficiencies are shown in Fig. 4a as a function of pseudo-rapidity η for electrons with a transverse energy of $15 < E_{\mathrm{T}} < 50$ GeV. The electron reconstruction is



(a) (b)

Figure 4: Electron reconstruction efficiencies as a function of pseudo-rapidity η for electrons with a transverse energy of $15 < E_{\mathrm{T}} < 50$ GeV (a)[4]. Efficiencies are shown for the reconstruction algorithms used in 2011 and 2012 for data and simulation. Electron Identification Efficiency as a function of transverse energy E_{T} shown for electrons from $Z \to ee$ decays (b)[4]. Shown are different cut-based identification criteria Multi-lepton, Loose, Medium and Tight as well as likelihood-based criteria LooseLLH and VeryTightLLH.

$> 97\%$ efficient and well modelled in simulation. The reconstruction algorithm was improved in 2012 to explicitly allow for bremsstrahlung in the electron track reconstruction and yields efficiencies up to 5% higher than in 2011.

In general, the efficiencies are not considered to be process independent. For combination of the individual measurements of the identification efficiencies data/MC scale-factors are calculated. These are combined using a χ^2 minimisation. The combined scale-factors can then be applied to the MC simulation of a process of choice to obtain efficiencies for the identification of electrons of the respective physics process. This is done for $Z \to ee$ events, as shown in Fig. 4b. Typical efficiencies of the identification criteria range from 68% to 92% for electrons with a transverse energy of $E_{\mathrm{T}} \sim 25$ GeV. The efficiency to identify electrons is known with a precision of better than $\frac{\Delta\epsilon}{\epsilon} < 5\%$ and $\frac{\Delta\epsilon}{\epsilon} < 1\%$ for electrons with a transverse energy of $7 < E_{\mathrm{T}} < 30$ GeV and $E_{\mathrm{T}} > 30$ GeV, respectively.

References

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