Electron efficiency measurement at low energies with J/ψ in ATLAS

Timothée Theveneaux-Pelzer (tpelzer@lpnhe.in2p3.fr) on behalf of the ATLAS collaboration

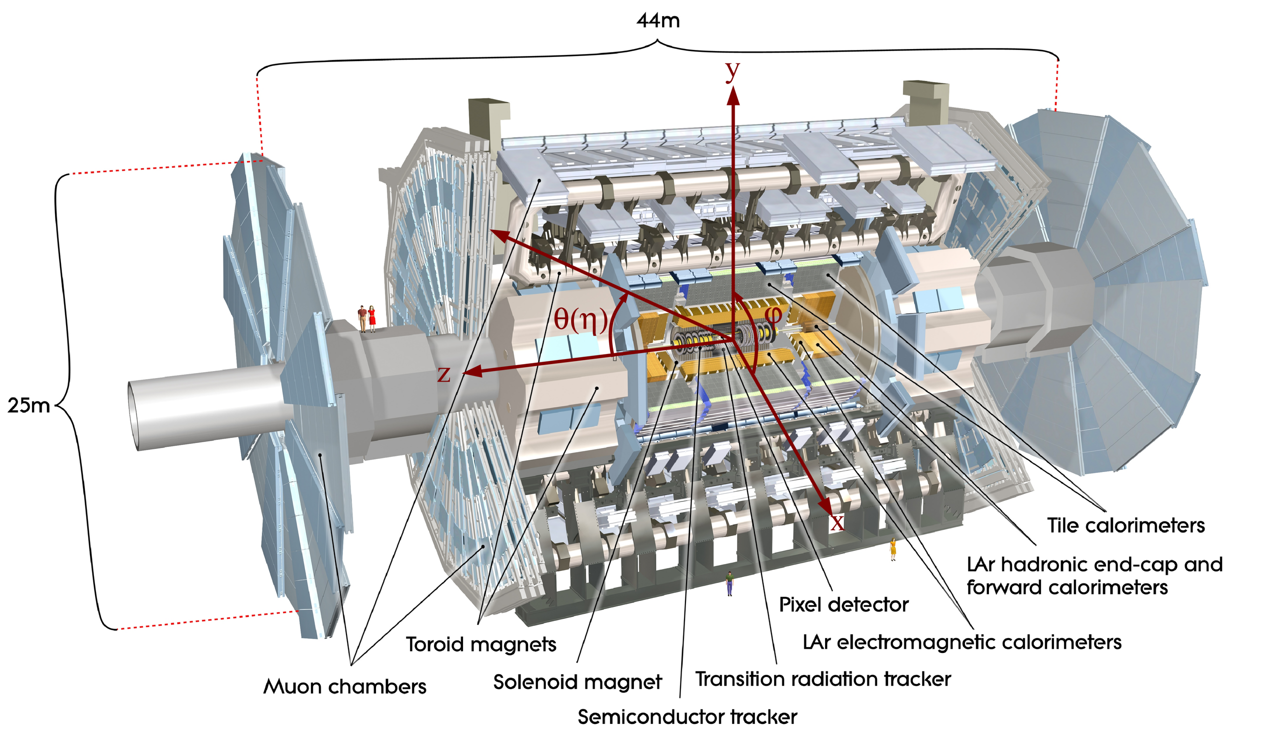
International Europhysics Conference on High Energy Physics - Grenoble, France, July 21-27 2011

Purpose of the study

Any physics measurement with electrons in final state needs to take into account efficiencies related to the electron selection. The identification efficiency is the ratio of the number of true electrons passing the identification criteria over the number of true reconstructed electrons. It was measured with 40 pb^{-1} of 2010 pp collision data at $\sqrt{s} = 7$ TeV, with a tag-and-probe method applied to $J/\psi \to ee$ events for low energy electrons. The J/ψ is one of the few "standard candles" that are used to calibrate the ATLAS detector and measure the electron performances.

The ATLAS detector

The ATLAS detector is made of several sub-detectors with a cylindrical geometry to cover the full acceptance. The two main sub-systems used in the reconstruction and identification of electrons are the inner tracker and the electromagnetic (EM) calorimeter.

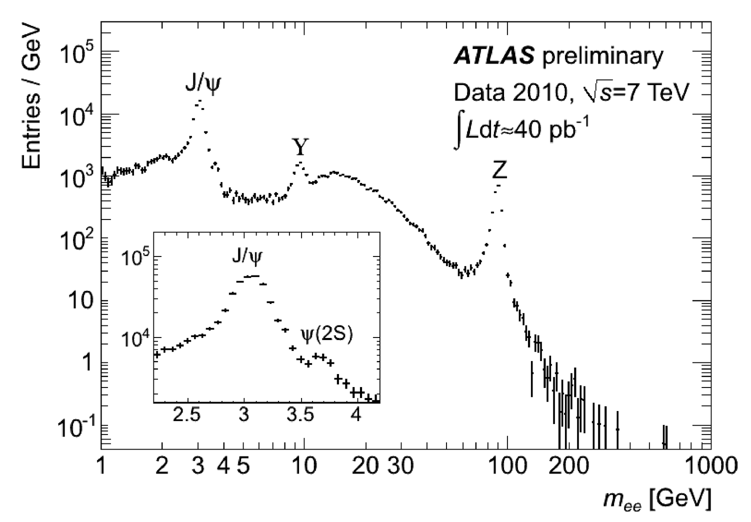


Sketch of the ATLAS detector. The coordinate system is shown. The pseudo-rapidity is defined as $\eta = -ln(tan(\theta/2))$.

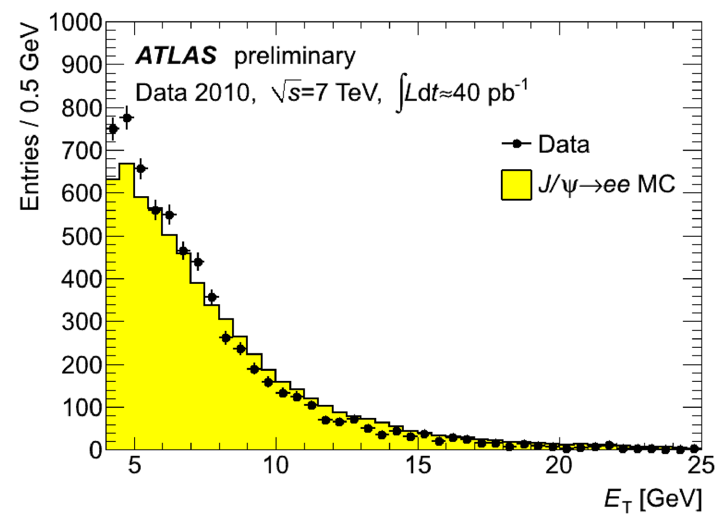
The inner detector is immersed in a 2 T solenoidal magnetic field and provides tracking information in the precision measurement pseudo-rapidity range ($|\eta| < 2.47$) of the EM calorimeter. It is made of a pixel silicon detector (for precise measurement of vertex position), a silicon micro-strips detector (Semi Conductor Tracker, SCT), and of a Transition Radiation Tracker (TRT) also used for electron identification.
The lead/liquid argon (LAr) sampling EM calorimeter is divided into a barrel part ($|\eta| < 1.475$) and two end-caps ($1.375 < |\eta| < 3.2$). Over the region covered by the tracking acceptance it is segmented in three layers in depth, in addition of a thin LAr presampler with coarse granularity in the $|\eta| \lesssim 1.8$ region.

Electron sources in pp collisions

The J/ψ is the most abundant source of isolated electrons in ATLAS. $J/\psi \to ee$ decays give electrons with lower transverse energy (E_T) than $Z \to ee$ decays, allowing to measure identification efficiencies of the standard cuts at lower energy. In 2010, efficiencies were measured with a tag-and-probe method, using $Z \to ee$ decays for electrons with 20 GeV $< E_T <$ 50 GeV and using $J/\psi \to ee$ decays for electrons with 4 GeV $< E_T <$ 20 GeV. In addition, electrons from $W \to e\nu$ decays were used to measure efficiencies in the 15 GeV$< E_T <$ 50 GeV region.



(a) Reconstructed dielectron mass distribution of electron candidate pairs passing the tight identification cuts for events selected by low E_T threshold dielectron triggers.



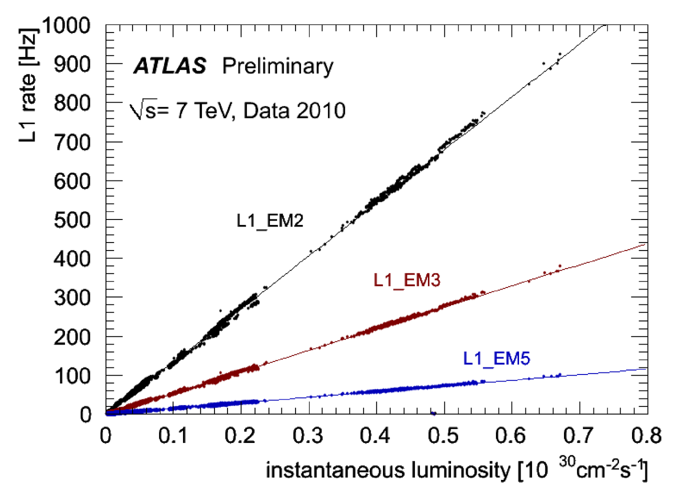
(b) Transverse energy spectrum, compared between data and MC, for the selected electron probes passing tight identification cuts for the $J/\psi \to ee$ channel.

Electron trigger, reconstruction and identification

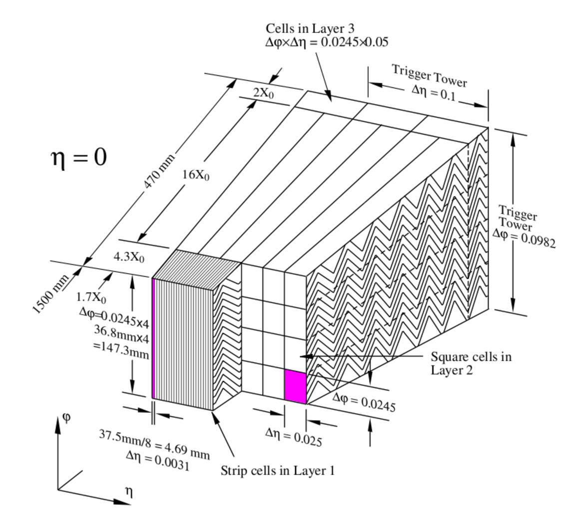
Events are selected with a three level trigger, reducing the data acquisition rate to ~ 300 Hz:

- L1: selection of regions of interest in the calorimeters and muon chambers with E_T above a threshold
- L2: fast reconstruction and refinement of the selection using the tracker and the full detector granularity
- EF: full reconstruction and standard identification criteria applied to objects selected by L2

In 2010, the luminosity delivered by the LHC increased almost exponentially. To keep the data recording rate within the processing capabilities, a fraction of the data selected by some high rate triggers is not recorded, and the rejection rate (prescale) of each trigger increases with instantaneous luminosity. For electron efficiency measurement, $J/\psi \to ee$ events were selected using a set of low E_T single electron triggers with thresholds between 5 and 10 GeV. Towards the end of 2010, these triggers had to be heavily pre-scaled and another trigger was used, requiring a second electromagnetic cluster with $E_T >$ 4 GeV.



(a) Observed rates for primary e/γ triggers at L1, before pre-scaling (PS).

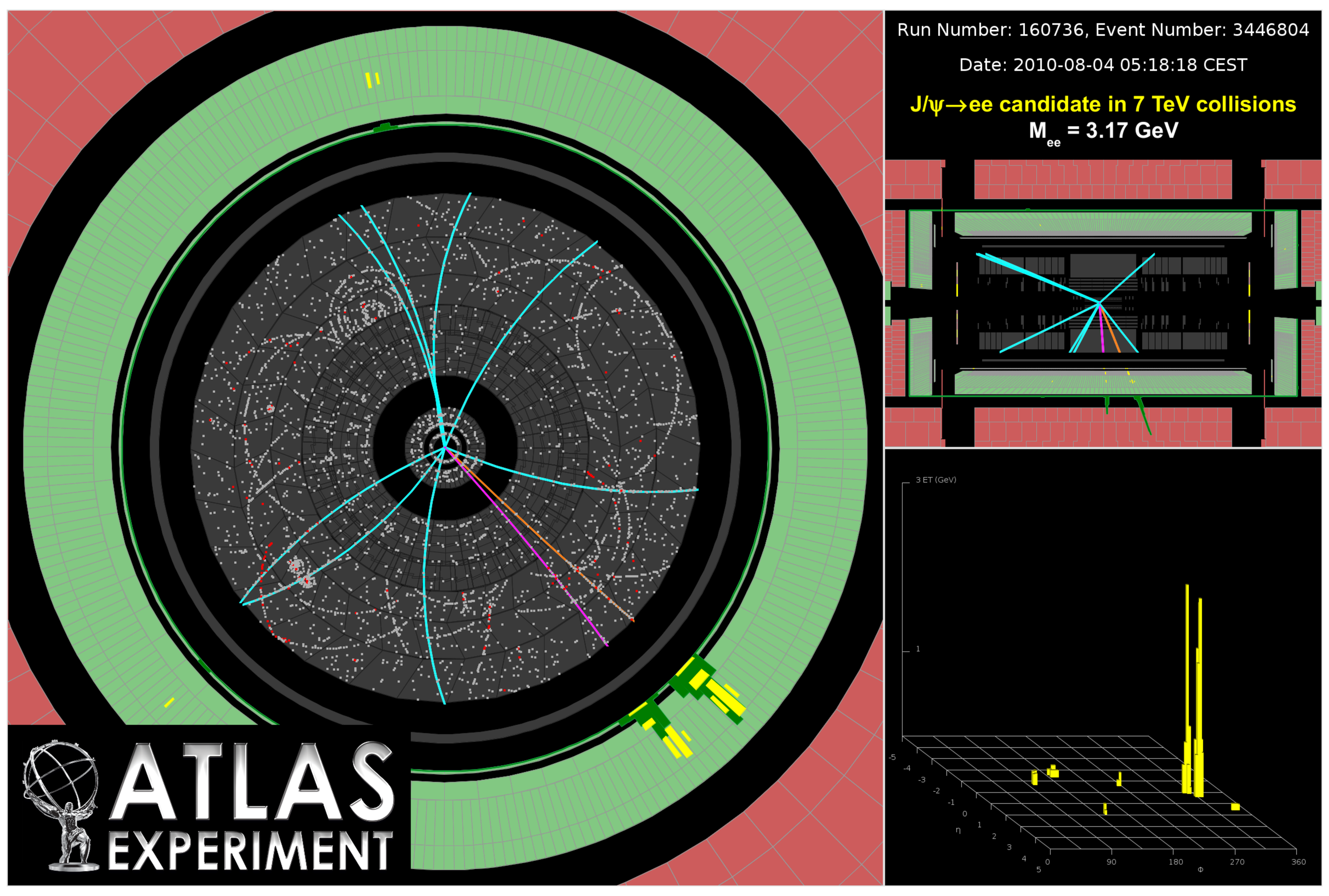


(b) Sketch of a EM calorimeter barrel module. The granularity in η and ϕ of the cells and of the trigger towers is shown.

The electron reconstruction begins with the creation of seed energy clusters in the EM calorimeter with significant energy. In the standard "sliding window" algorithm, seed clusters are a fixed-size rectangular window with $E_T >$ 2.5 GeV. Electrons are reconstructed from these clusters if there is a suitable match with a track of $p_T >$ 0.5 GeV.
The standard electron identification in ATLAS relies on rectangular cuts on a set of variables. Reference sets of cuts have been defined which have progressively stronger jet rejection factor and decreasing efficiency:

- medium: cuts on hadronic leakage, lateral shower shapes in the first and second samplings, on track quality variables and on track matching variables
- tight: cuts on TRT variables, tighter cuts on track quality and track matching, in addition to medium cuts

Event Display of a $J/\psi \to ee$ candidate

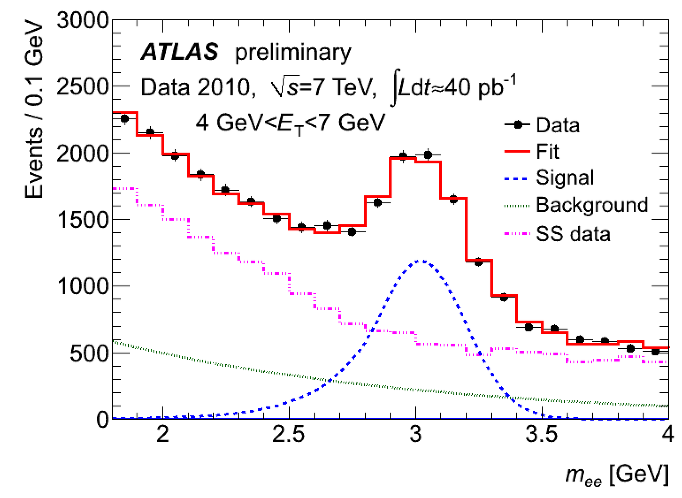


Event display of a candidate for a $J/\psi \to ee$ decay. The two reconstructed electrons have opposite charge and both satisfy the tight identification criteria.

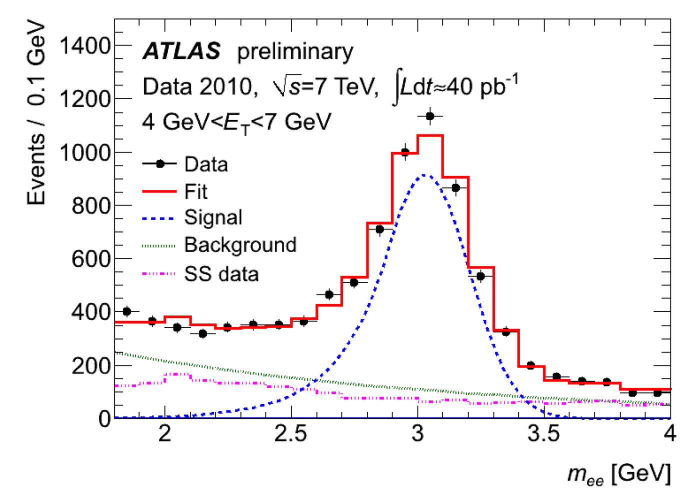
$E_T(e^+) = 7.53$ GeV
$\eta(e^+) = 0.080$
$\phi(e^+) =$ -0.835
$E_T(e^-) = 12.44$ GeV
$\eta(e^-) = 0.400$
$\phi(e^-) =$ -0.767
$M(ee) = 3.17$ GeV
$P_T(ee) =$ 19.96 GeV

The tag-and-probe method applied to $J/\psi \to ee$ events

A set of $J/\psi \to ee$ event candidates was selected, by applying identification cuts (typically tight requirements) on one electron - the tag - but not on the other one - the probe - of each event. The selected probes - about 6000 in 2010 pp collision data - provide a sample of unbiased electrons, on which any selection cut can then be applied to measure its efficiency.



(a) All probes, 4 GeV $< E_T <$ 7 GeV



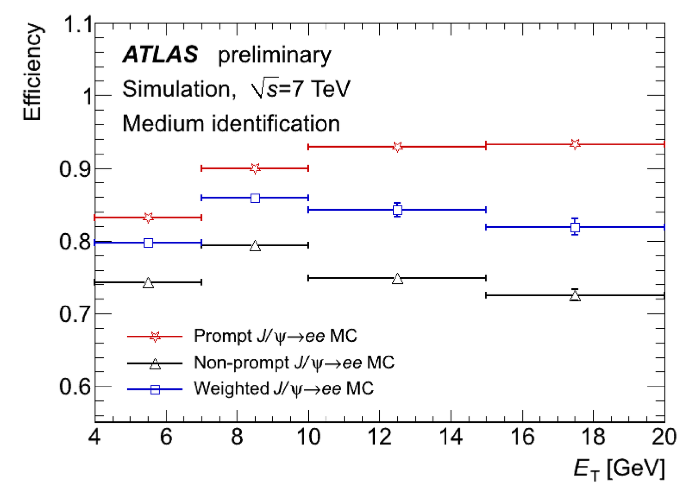
(b) Medium probes, 4 GeV $< E_T <$ 7 GeV

Distributions of the dielectron invariant mass of $J/\psi \to ee$ candidate events before applying electron identification cuts (a) and after Medium cuts (b) on the probes, for probes in the 4-7 GeV E_T range.

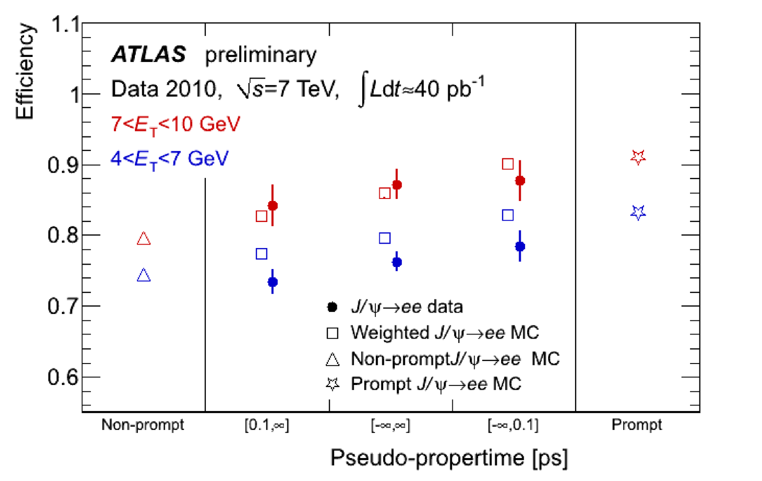
To subtract the background contamination of the probe sample, the invariant mass of the tag and the probe is used as a discriminating variable. For each bin of E_T and η, a fit of the invariant mass is performed, typically between 1.8 and 4 GeV. The signal contribution is modelled by a Breit-Wigner distribution convoluted with a Crystal-Ball function. The background contribution is modelled by a data-driven component based on the spectrum of same-sign electron pairs - describing the shape of random combinations of fake or real electrons - in addition to a decreasing exponential component. This method allowed to extract the efficiencies in 4 E_T bins and in 8 η bins, given the available statistics in 2010.

Prompt and non-prompt J/ψ

The selected electron probes sample is a mix of isolated and non-isolated electrons from prompt and non-prompt J/ψ decays. Their fraction depends on E_T. These samples can be discriminated by using the pseudo-propertime of the J/ψ candidate, defined as: $\tau_0 = \frac{L_{xy}.M}{p_T.c}$ where L_{xy} is the distance between the primary vertex and the extrapolated common vertex of the two electrons in the transverse plane, M (p_T) is the reconstructed mass (transverse momentum) of the J/ψ candidate, and c the speed of light.



(a) Medium efficiency vs. E_T predicted by prompt and non-prompt $J/\psi \to ee$ MC simulation, and after weighting the two samples according to the measured non-prompt fraction measured by ATLAS using $J/\psi \to \mu\mu$ events.

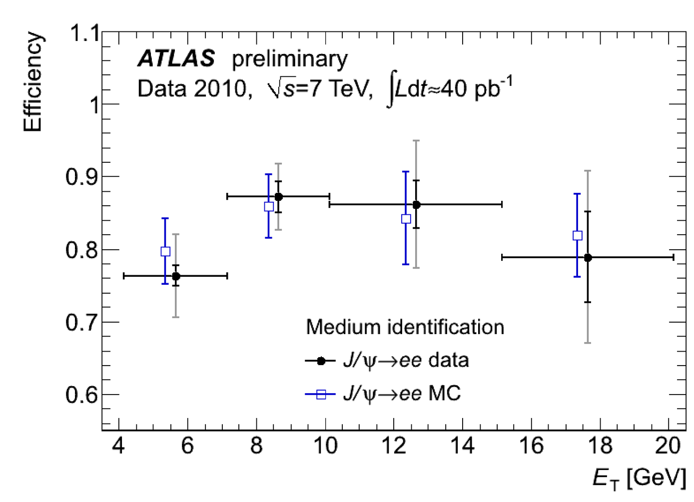


(b) Medium efficiency for $4 < E_T < 7$ GeV (lower points) and $7 < E_T < 10$ GeV (higher points) measured from data and predicted by MC for different ranges of pseudo-proper time, and predicted by pure prompt and non-prompt J/ψ MC samples.

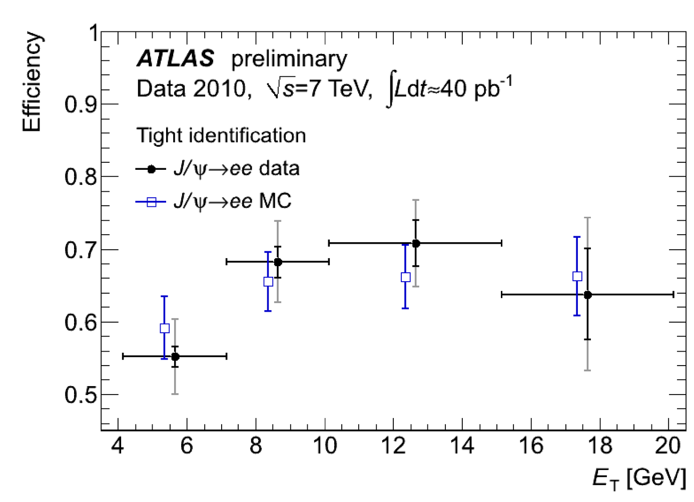
The efficiencies increase by several percent as the fraction of non-prompt decays decreases. The data shows the same trend but more statistics will be needed to measure clearly the variation of the efficiency with the fraction of decays from prompt J/ψ production in the data, and ultimately to separate the two samples.

Results

The E_T dependence of the efficiencies is in good agreement between data and MC. The shape can be attributed to the combination of the increasing contribution of non-isolated electrons from non-prompt J/ψ (for which the efficiency decreases with E_T and is significantly lower at all E_T than for electrons from prompt J/ψ) and to the rapidly improving efficiency for electrons from prompt J/ψ as E_T increases in this low-E_T range.



(a) Medium efficiency vs. E_T



(b) Tight efficiency vs. E_T

Efficiencies measured from $J/\psi \to ee$ events and predicted by MC for medium (a) and tight (b) identification as a function of E_T. For data, the total (outer bars) and the statistical (inner bars) uncertainties are shown. For MC the total uncertainties are shown.

Reference

[1] G. Aad *et al.* [ATLAS Collaboration], "Electron performance measurements with the ATLAS detector using the 2010 LHC proton-proton collision data" *to be submitted to Eur. Phys. J. C*