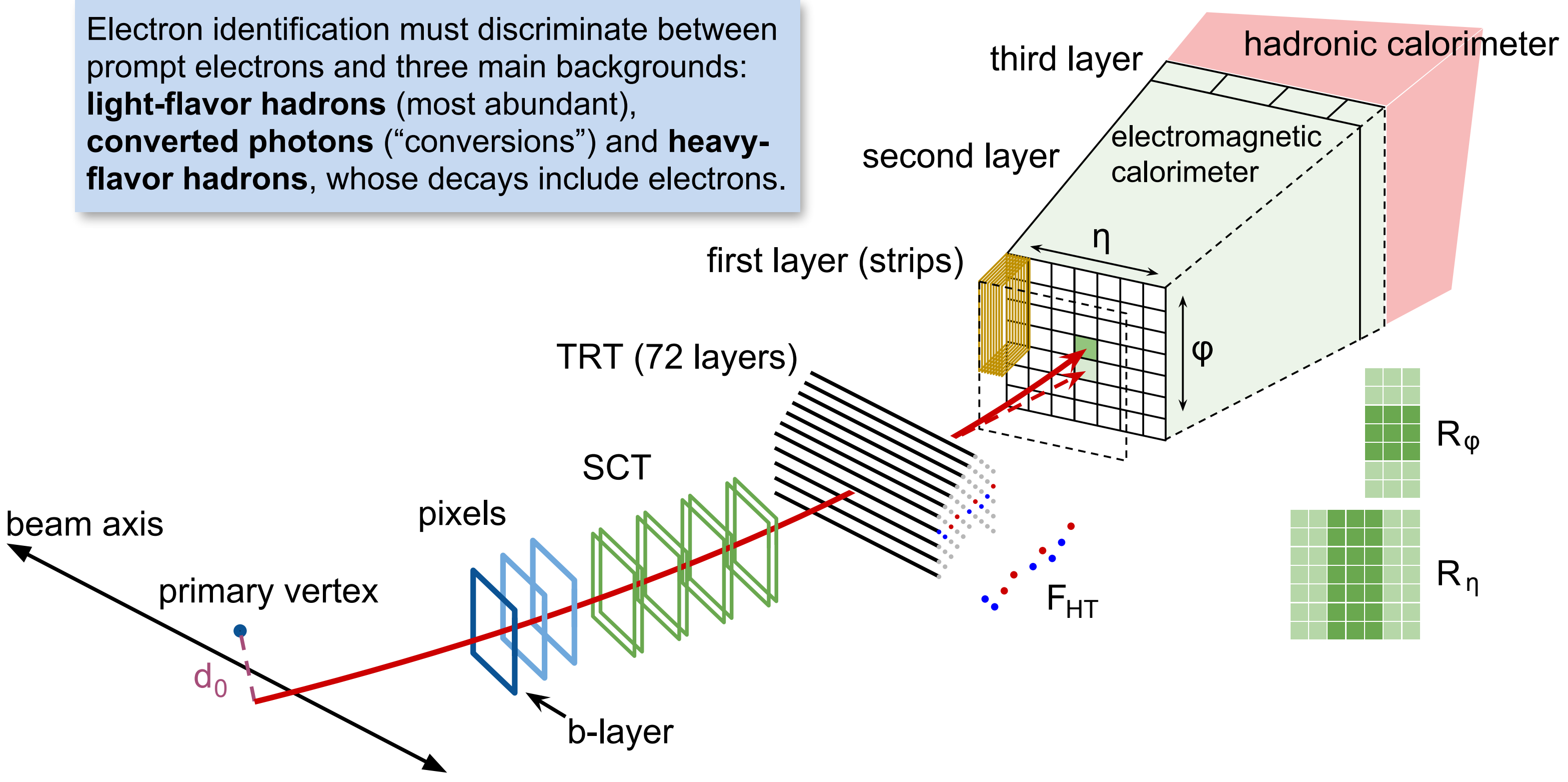
Electron Identification and Efficiency Measurements in 2012

Introduction: The ATLAS Experiment requires efficient discrimination of electrons from backgrounds as a vital part of its physics program. Electron identification is achieved using Inner Detector and Electromagnetic Calorimeter quantities.

Electron efficiency measurements and uncertainties are needed for cross section measurements and searches. Electron efficiencies in the detector are measured and data-Monte Carlo correction factors are produced using in-situ methods with electrons from Z→ee and J/Ψ→ee resonances.

Electron Identification

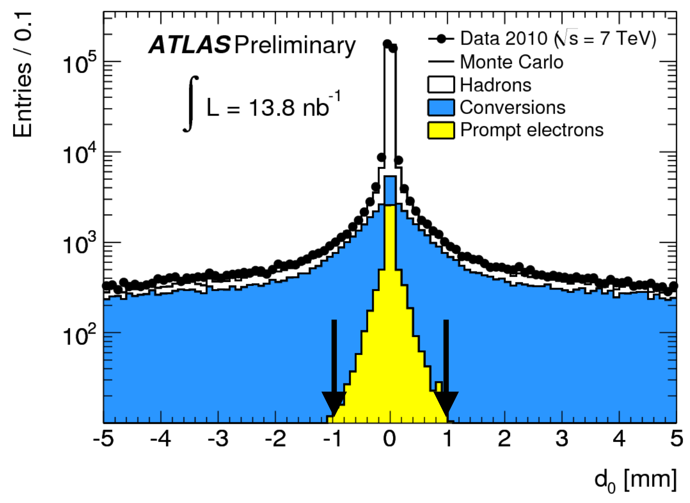
Electron identification must discriminate between prompt electrons and three main backgrounds: **light-flavor hadrons** (most abundant), **converted photons** ("conversions") and **heavy-flavor hadrons**, whose decays include electrons.



Electron identification uses **tracking**, **calorimeter**, and **track-calo matching** variables.

- **Track quality cuts** including number of b-layer hits, pixel+SCT hits and TRT hits
- **F_{HT}**: TRT ratio of high-threshold to low-threshold hits, indicating electron transition radiation
- **Track parameters**: e.g. **d_0**, distance of closest approach to primary vertex
- **Calorimeter shower shapes**: energy ratios of cell clusters and layers, and lateral widths
- **R_{Had}**, energy deposited in the hadronic calorimeter, divided by the cluster electromagnetic energy
- **Track-calorimeter matching**: distances between the extrapolated track and the electromagnetic cluster (**Δφ** and **Δη**)

Cut-based Identification method
- Simplest and most robust electron identification technique
- Rectangular cuts are applied to discriminating distributions to reject background.
- Used in 2011 and 2012 data-taking periods
- Re-optimized in 2012 to account for harsher pileup conditions
- Cut-based 2015 menus in preparation, with relaxed cuts on pileup-dependent variables



An illustration of the d_0 variable for electrons, conversions and hadrons. The tight cut is indicated with arrows.

Likelihood-based Identification method
- Developed for 2012 data-taking period
- Constructed by creating probability distribution functions (pdfs) for signal and background distributions
- Form discriminant based on the products of the pdfs evaluated for a given electron with variable values $\vec{x}$:

$$d_{\mathcal{L}} = \frac{\mathcal{L}_S}{\mathcal{L}_S + \mathcal{L}_B} \quad \text{with} \quad \mathcal{L}_S(\vec{x}) = \prod_{i=1}^{n} P_{s,i}(x_i)$$

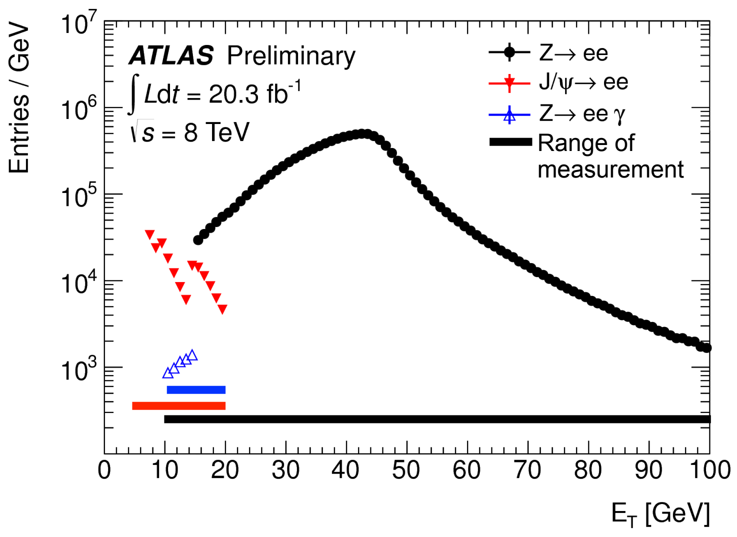
- Cut on the discriminant d_L applied to define the selection
- Designed to have the same signal efficiency as the 2012 cut-based menu, with better background rejection (see table).
- Prepared for use offline and in the trigger in 2015.

	Electron Efficiency in data	Background Efficiency (MC)
Medium Cuts	88.1 ± 0.2%	1.11 ± 0.02%
Tight LH	87.8 ± 0.3%	0.51 ± 0.01%

Electron Efficiency Measurements

Efficiencies are studied in data using the **tag and probe method**:
- Use Z→ee and J/Ψ→ee events
- Events collected using single-electron triggers
- Strict identification requirements on the triggered electron ("tag")
- No requirement on the second "probe" electron
- Probe is unbiased source of electrons for efficiency measurements

Measurements performed in bins of E_T and η



Number of probe electrons passing tight cuts. The bars below show the range of each method.

The total electron efficiency:

$$\epsilon_{\text{total}} = \epsilon_{\text{reconstruction}} \times \epsilon_{\text{identification}} \times \epsilon_{\text{trigger}}$$

- **Reconstructed electron**: electromagnetic cluster matched to a track passing basic tracking cuts
  - Measured with Z→ee events, for E_T>15 GeV electrons
- **Identified electron:** passes cut-based or likelihood selection
  - High-E_T electrons measured using Z→ee methods
  - Low-E_T electrons: J/Ψ→ee, Z→ee and Z→eeγ (where the final state radiates a photon)

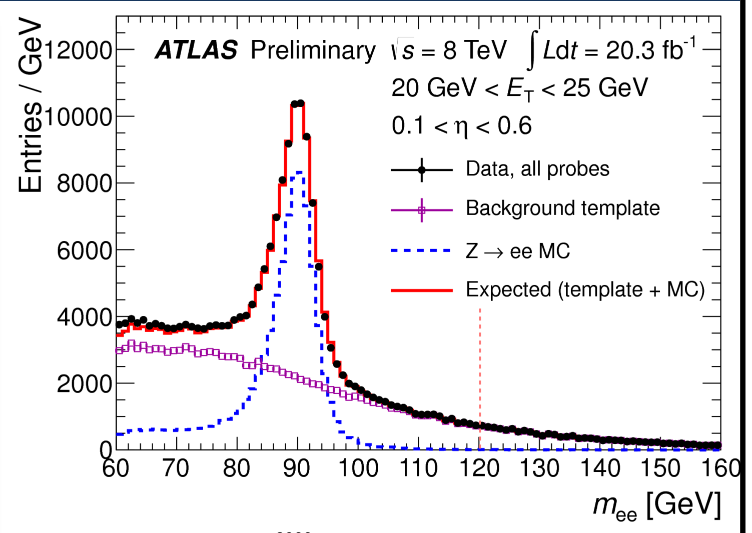
Efficiency Methods using Zee Events: Mass and Isolation Methods

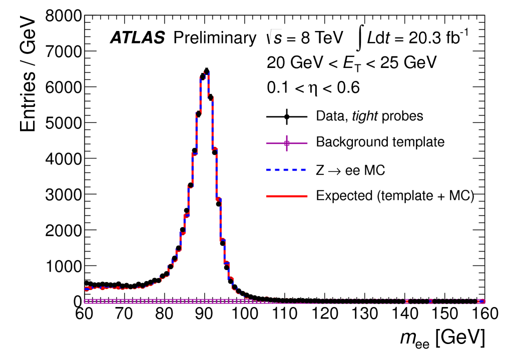
Select electron pairs with an invariant mass in a window around m_{ee}=90 GeV.

Background estimated using a **template method**.
- Tag and probe method is applied, but an identification menu or set of cuts is reversed
- Take background shape from this sample
- Normalized to a background-dominated region

Two methods used to measure efficiencies with different discriminating variables:
- **m_{ee}** and **calorimeter isolation**

Main uncertainty in both methods is background estimation at the probe level via templates.





Top plot: all probes in the m_{ee} discriminant. Bottom: probes after applying tight cuts.

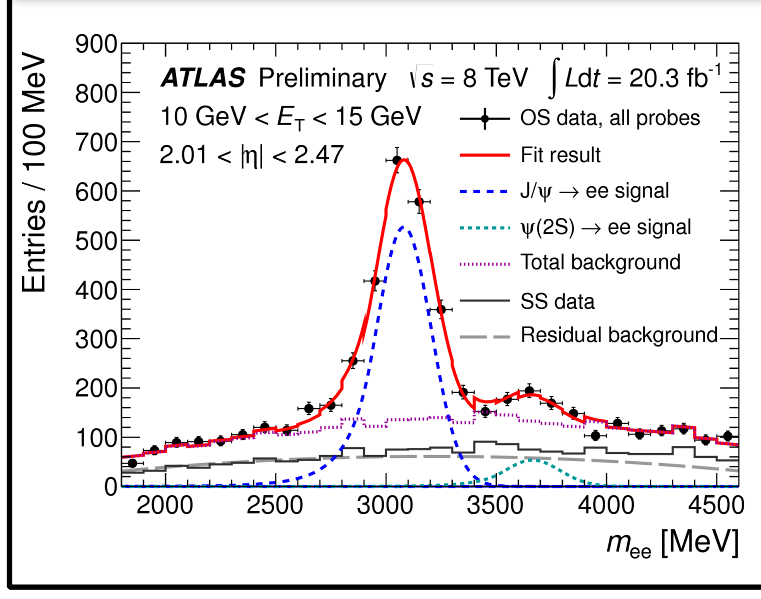
Efficiency Methods using J/Ψ Events

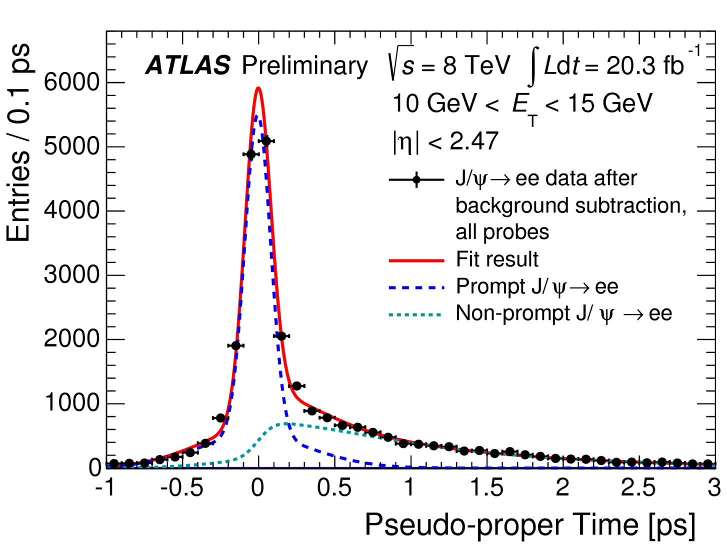
J/Ψ decays have **prompt** and **non-prompt** contributions.
- Pseudo-proper time discriminates between the two

Pseudo-proper Time:

$$\tau = \frac{L_{xy} \cdot m_{\mathrm{PDG}}^{J/\psi}}{p_{\mathrm{T}}^{J/\psi}}$$

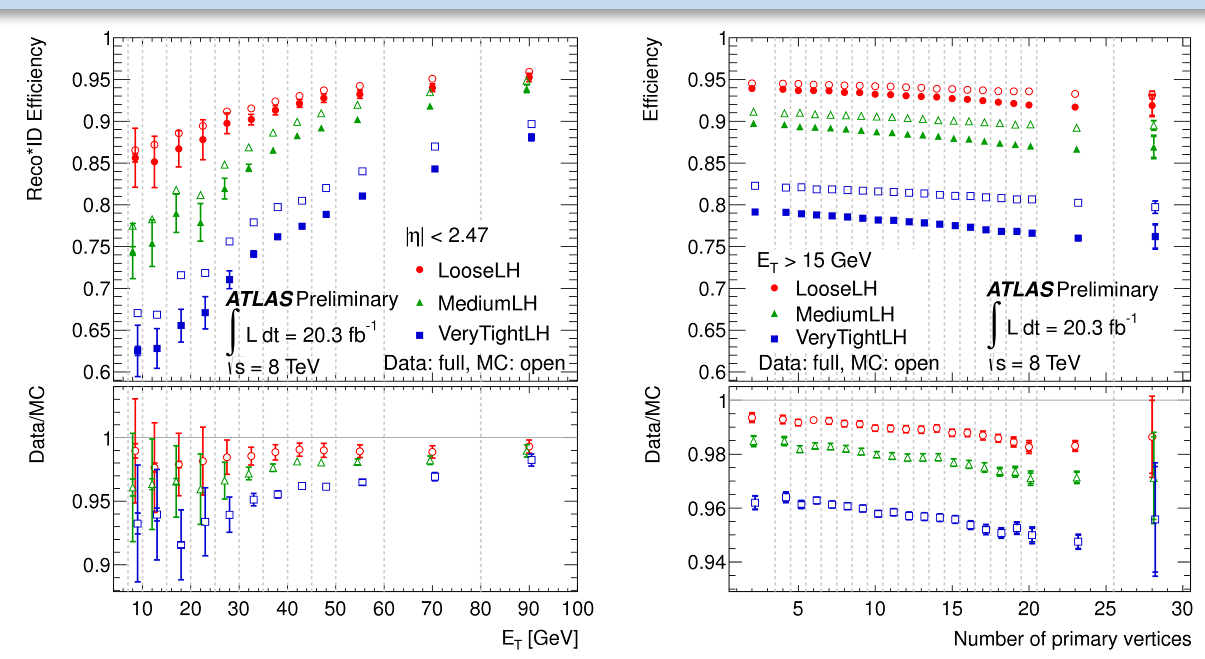
Two J/Ψ Efficiency Methods to measure prompt, isolated electrons:
- Cut out events with large pseudo-proper time
- Fit pseudo-proper time to find prompt and non-prompt contributions





Efficiency Measurement Results

Identification measurements from Z→ee, Z→eeγ and J/Ψ→ee are combined using a global χ^2 fit which correlates systematic uncertainties between bins of E_T and η for a given method.



Efficiency measurements as a function of E_T (left) and number of primary vertices (right). Data-MC correction factors are shown in the ratio plots below.

Reference material: The ATLAS Collaboration, Electron efficiency measurements with the ATLAS detector using the 2012 LHC proton-proton collision data (ATLAS-CONF-2014-032)
The ATLAS Collaboration, Observation of inclusive electrons in the ATLAS experiment at √s=7 TeV (ATLAS-CONF-2010-073)

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