Measurement of the inclusive electron cross-section in proton-proton collisions at √s = 7 GeV with the ATLAS detector

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The Cross Section Measurement

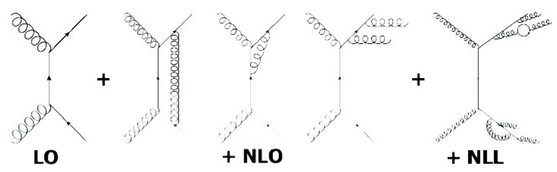
The inclusive electron differential cross section is defined by :

$$\frac{\Delta\sigma}{\Delta p_T} = \left(\frac{N^{Q\to e}}{\epsilon_{trigger} \cdot \int \mathcal{L} dt} - \sigma^{W/Z/\gamma^*}_{accepted} \right) \cdot \frac{C_{migration}}{\epsilon_{reco+ID}} \cdot \frac{1}{\Gamma_{bin}}$$

- i : index of the bin of width Γ
- N_{sig} : number of signal electrons with reconstructed pT in the i - bin
- $\mathcal{L}$: instantaneous luminosity
- $\epsilon_{trigger}$: trigger efficiency
- $\epsilon_{(reco+Id)}$: combined reconstruction and identification efficiency
- $C_{migration}$: bin migration correction factor

The measurement is compared to the FONLL theoretical predictions:

$$\frac{d\sigma^{\ell}}{dp_T} = \frac{d\sigma^{Q}}{d\hat{p}_T} \otimes D^{Q\to H_Q} \otimes g^{H_Q\to\ell}$$

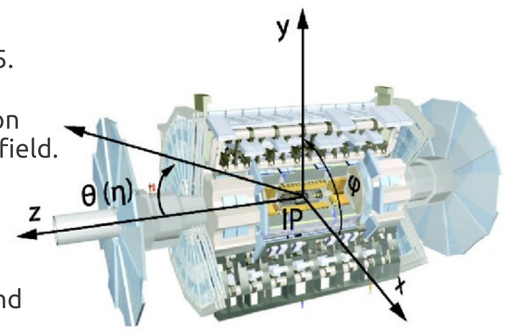


- Heavy quark (Q) production cross section evaluated at the NLO+NLL calculations ;
- Fragmentation function evaluated from LEP data in the same framework ;
- Decay of heavy hadrons to leptons extracted from *B*-factories data .

The ATLAS detector

Two main components of the ATLAS detector are used for this analysis:

- **Inner Detector** (ID): precise track measurement within |η| < 2.5. Composed by pixel detectors, silicon microstrips (SCT) and a Transition Radiation Tracker (TRT), immersed in a 2T magnetic field. The TRT provide a good electron – hadron discrimination.
- The **Electromagnetic calorimeter** (EM): within |η| < 2.5 is provided by the barrel and end-cap lead/Liquid Argon (LAr) sampling calorimeters. These calorimeters are segmented into 4 longitudinal layers and have a fine lateral granularity.

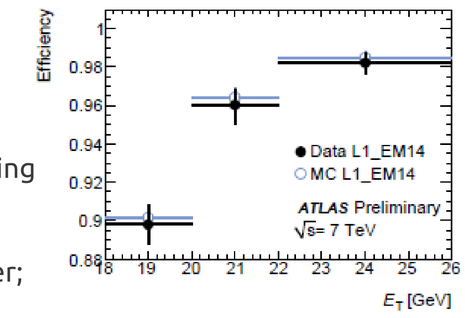


The analysis is based on a data sample collected at √s = 7 TeV during April - August 2011.
The total integrated luminosity of the sample is 1.3 pb^{-1}

Trigger Requirement and efficiency

Trigger event selection :

- Only hardware-based first level (L1) calorimeter trigger selecting EM cluster within |η| < 2.5 to minimize the biases for non-isolated electrons;
- Four EM cluster energy thresholds increasing with the instantaneous luminosity;
- Bulk of the integrated luminosity (76%) obtained using the higher-threshold trigger;



Trigger efficiency :

Lower threshold trigger : measured using a very inclusive minimum bias trigger based on hit information in the Minimum Bias Trigger Scintillator.

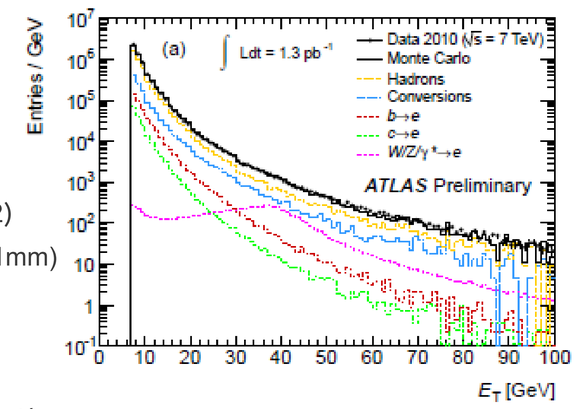
Higher threshold trigger : measured within respect to a lower trigger threshold.

The trigger efficiency is measured to be between 92.1% and 100.0% .
Systematic uncertainty (< 1.8%) assigned from a comparison with the efficiency computed with simulated heavy-quark electrons.

Reconstruction and Identification

Signal selection criteria :

- Collision vertex with > 2 tracks
- Cluster E_T threshold (7 to 18 GeV) depending on the trigger chain
- |η| < 2.0 (excluding 1.37 < |η| < 1.52)
- Transverse impact parameter (d_0 < 1mm)
- Number of ID hits ;
- Track quality ;
- Track-cluster matching ;
- Fraction of the energy deposited on the first EM sampling .



The identification criteria are designed to select non isolated signal electrons against hadronic and conversion backgrounds.

Signal from:

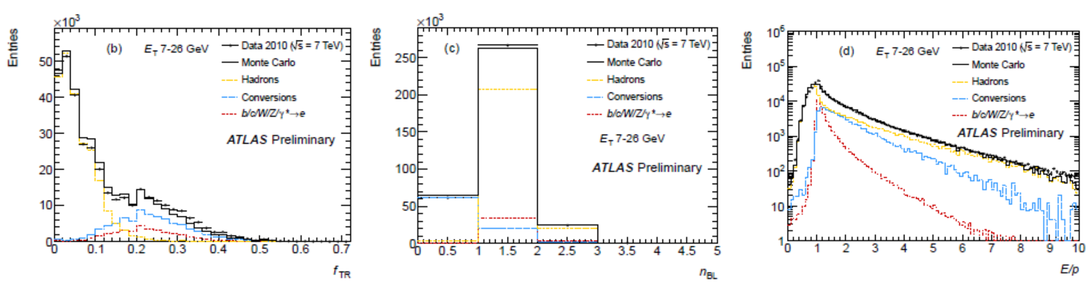
- B and D meson decays
- Drell Yan process
- W/ Z in high ET region

Background from :

- Photon conversions (~20 %)
- Hadronic fakes (~70 %)

The signal fraction is extracted from data using a binned likelihood technique based on three discriminating variables:

- Fraction of high threshold TRT hits out of all hits on track (**TRfrac**) ;
- Number of hits on the pixel B-layer (**nBL**) ;
- Ratio of the measured energy of the EM cluster and the track momentum (**E/p**) .



The analysis is restricted to the 7 - 26 GeV E_T region to keep the fraction of electrons from heavy flavour meson decays dominant within respect to isolated electrons from W and Z decays.

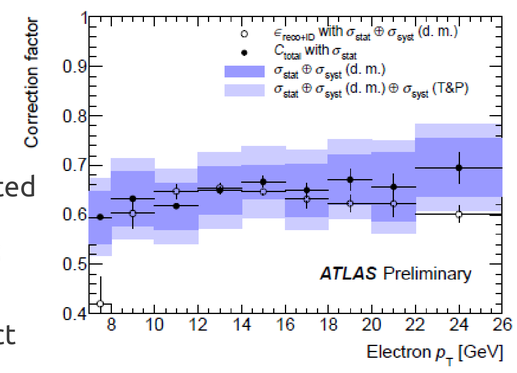
Efficiency measurement and correction factor

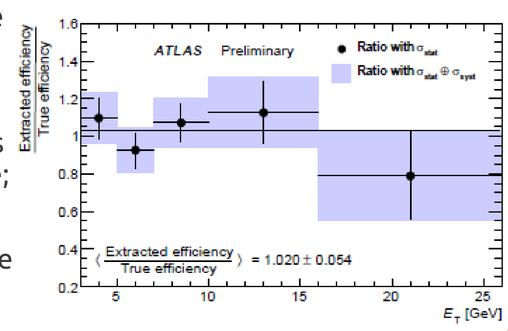
The overall efficiency and migration correction factor (C_{total}) is determined from PYTHIA simulated samples of heavy-flavours electrons;

The systematic uncertainties are estimated by the difference expected using 5% increase of amount of material in the ID;

The efficiency of the electron identification cuts is compared to a direct measurement on data using a Tag and Probe (T&P) technique : enriched sample of heavy quark pair events, with both quarks decaying into an electron were selected. The signal extraction before and after the identification cuts is done using a binned likelihood technique;

An additional uncertainty is assigned by comparing the measured efficiency to the one expected in simulation .





Production cross section and theoretical predictions

The differential cross-section is extracted using a bin-by-bin unfolding method.

The theoretical prediction for the accepted electron cross-section of W/Z/γ* decays (based on PYTHIA expectation) are subtracted before applying the correction factor, applicable only for heavy-flavours electrons.

Statistical uncertainty originates from the signal extraction procedure.

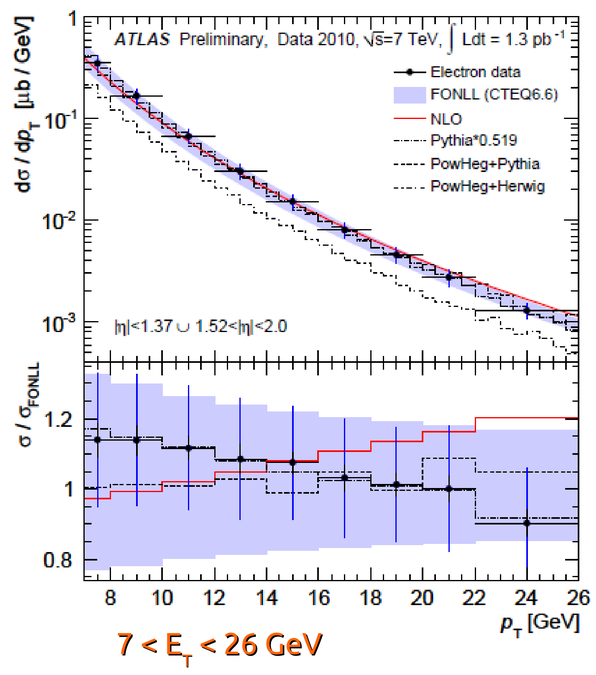
Source of systematic uncertainty	Cross-section uncertainty (%)
Possible bias in signal extraction	8
Mis-modelling of discriminating variables	8
Statistical uncertainty on pdfs for signal extraction	0.8–2.5
Efficiency dependence from T&P	5
Material uncertainty on $\epsilon_{(reco+ID)_i} / C_{migration_i}$	5–10
Statistical uncertainty on $\epsilon_{(reco+ID)_i} / C_{migration_i}$	0.4–3.5
Energy scale uncertainty	1.5
Trigger efficiency (stat.+syst.)	< 2
Accepted Drell-Yan cross-section (stat.+syst.)	< 1
Total	15–17

The measured integrated cross-section over the considered E_T and η acceptance is:

$$\sigma^{e}_{HF} = 0.946 \pm 0.020(stat.) \pm 0.146(syst.) \pm 0.032(lumi.)\ \mu b$$

Measurement is compared to several theoretical predictions :

- **FONLL calculation:** measurement is fully compatible within the prediction uncertainty band;
- **NLO expectations:** obtained from the FONLL program excluding the NLL resummation in the hard-process calculation. The contribution of the NLL terms starts to be visible in the high pT region ;
- **NLO prediction with POWHEG + PYTHIA :** agreement with the FONLL predictions ;
- **NLO prediction with POWHEG +HERWIG :** significantly lower cross-section ;
- **Standalone PYTHIA :** good description of the p_T- dependence but the cross-section is a factor two higher .



7 < E_T < 26 GeV
|η| < 1.37 and 1.52 < |η| < 2.0