Poster Session - CERN, 22/23 February 2017

ATLAS Electron Identification for the HL-LHC

1. Overview

Over the next decade the LHC will receive substantial upgrades; increasing its luminosity by around a factor of 10, allowing it to collect 3000 fb^{-1} of data per interaction point over its lifetime. This will increase the pileup to up to 200, making particle identification much more challenging. In preparation, the ATLAS detector will also be upgraded. Electron identification has been optimised for this new environment, and tested for various pileup scenarios.

2. The HL-LHC

Around 2025, the LHC will undergo upgrades which will increase its ultimate instantaneous luminosity to 7.5x10^{34}cm^{-2}s^{-1}. These upgrades are made possible primarily by advances in superconducting magnet and cavity technologies. The HL-LHC is expected to deliver of 3000 fb^{-1} of data per interaction point by the end of its lifetime. However, this is expected to increase the pileup to up to 200 inelastic proton-proton interactions per bunch crossing, meaning there will be around 5 times more activity in the detector during collisions, making it more challenging to identify particles. To cope with these new, more demanding conditions, the LHC experiments will upgrade their detectors.

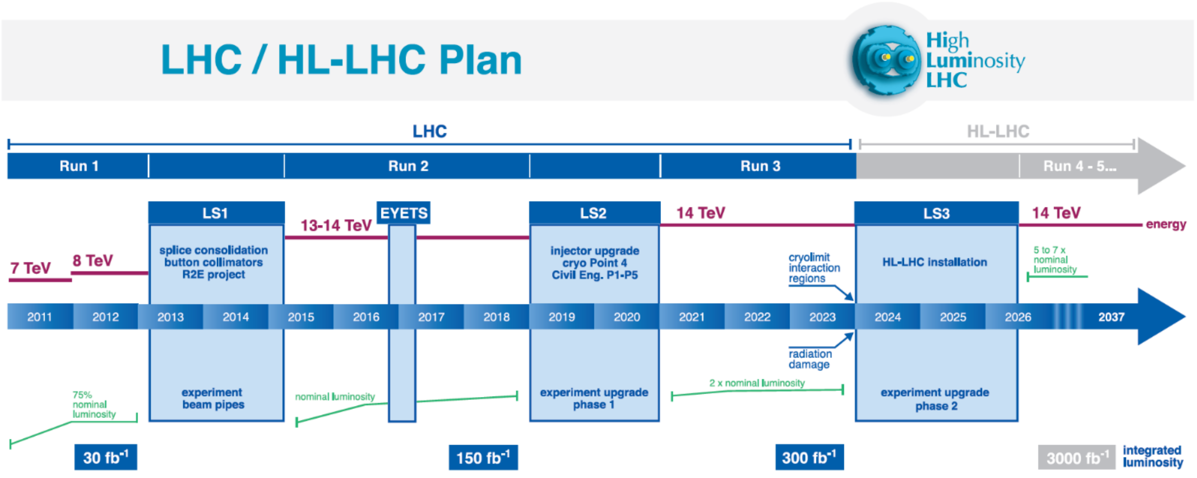

Figure 1: Timeline of the HL-LHC Upgrade Program [1]

3. ATLAS Upgrades for the HL-LHC

The increased interaction rate of the HL-LHC will place new demands on the radiation hardness, and pileup robustness of the ATLAS detector. To deal with this, the calorimeters, muon spectrometers and triggers will be upgraded, while the Inner Detector will be replaced with a new all-silicon ITk. These upgrades are expected to more than compensate for the increased pileup. With the greater luminosity ATLAS will aim to: Make more precise measurements of the Higgs boson mass, spin, couplings, and observe its rare decays; either discover, or exclude natural scenarios of Supersymmetry; search for exotic gauge bosons; and probe for quark and lepton substructure, to name but a few physics goals.

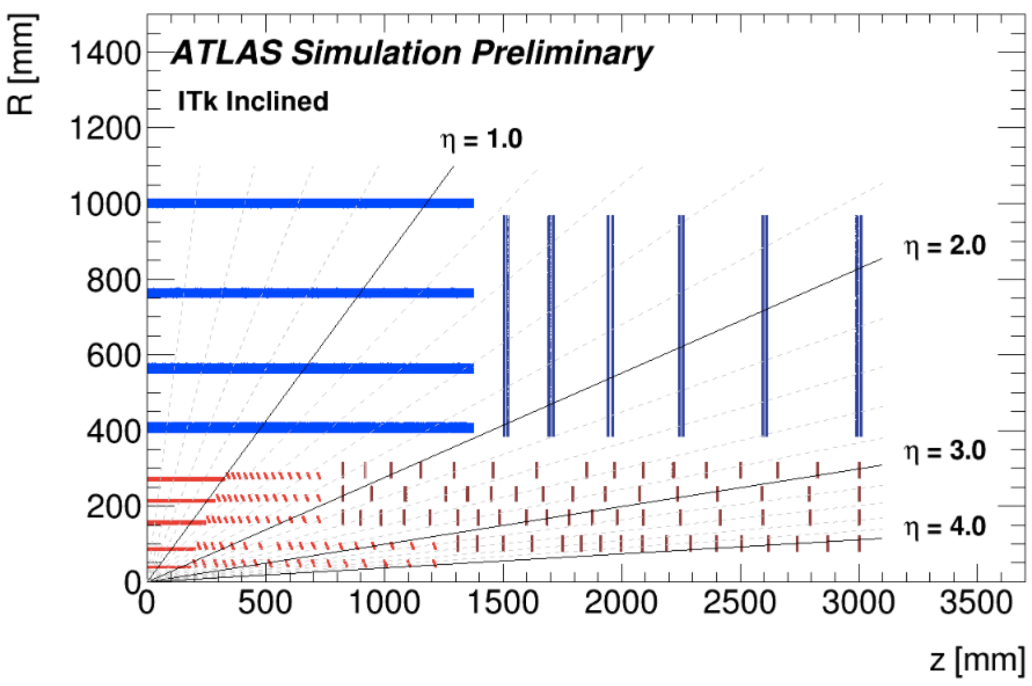

Figure 2: ATLAS ITk (Inclined) Layout [2]

4. Electron Identification at ATLAS

Electron candidates are reconstructed by matching a track in the Inner Detector to a cluster in the electromagnetic calorimeter. Subsequently, a series of tracking and calorimetric requirements are applied to identify it as an electron. The main background to electrons is hadronic jets faking electrons. Pre-identification requirements are applied to ensure the identification variables are well defined. Three identification categories (Loose, Medium and Tight) achieve different levels of efficiency and background rejection. The selection is optimised in bins of E_T and $|\eta|$. We currently use information from our transition radiation tracker, but this will not be available at the HL-LHC.

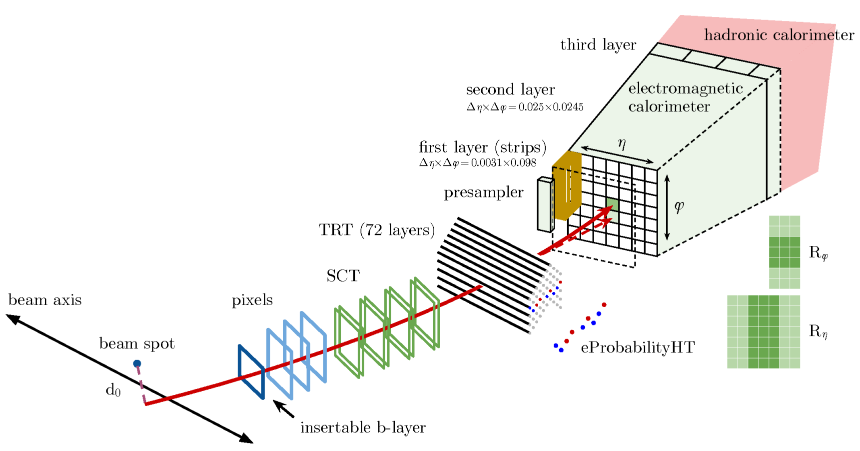

Figure 3: Electron Reconstruction at ATLAS [3]

5. ATLAS HL-LHC Electron Identification Methods

Z → ee and dijet Monte-Carlo are used to perform the study. An identification menu with three efficiency working points, defined in terms of uncorrelated, highly discriminant variables [4] has been designed following the approach in Ref. [5], described in Section 4, using simulated samples with pileup 200. This menu was then evaluated on samples of pileup 80, 140 and 200. The variables are listed in Table 1.

Type	Description	Name
ITk	Number of hits in the innermost pixel layer	n_{BL}
	Number of hits in the pixel detector	n_{Pix}
	Number of hits in the silicon detector	n_{Si}
	Number of hits in the 2nd innermost pixel layer	n_{2nd}
	Transverse impact parameter of the track to the beam-spot	d_0/σ_{d_0}
Strip layer of EM Calorimeter	Ratio of energy in the strip layer to energy in the whole ECal	f1
	Shower width $\sqrt{(\Sigma E_i(i-i_{max})^2)/(\Sigma E_i)}$, where i runs over all strips in a window of $\Delta\eta \times \Delta\phi \approx 0.0625 \times 0.2$, where i_{max} is the index of the highest-energy strip	W_{stot1}
	Ratio of the energy difference between the largest and second largest energy deposits in the cluster, divided by their sum	E_{Ratio}
Matching	$\lvert\Delta\eta\rvert$ between the cluster position in the strip layer and the extrapolated track	$\lvert\Delta\eta_1\rvert$
Middle layer of EM calorimeter	Lateral shower width, $\sqrt{(\Sigma E_i\eta_i^2)/(\Sigma E_i) - ((\Sigma E_i\eta_i)/(\Sigma E_i))^2}$, where the sum is calculated within a window of 3×5 cells	$w_{\eta 2}$
	Ratio of the energy in $\eta \times \phi$ of 3×7 cells and 7×7 cells, centred on the energy cluster	R_η
	Ratio of the energy in $\eta \times \phi$ of 3×3 cells and 3×7 cells, centred on the energy cluster	R_ϕ
Back layer	Ratio of the energy in the back layer to the total energy in the ECal	f3
Hadronic leakage	Ratio of E_T in the hadronic calorimeter to E_T of the EM cluster (used over the range $0.8 < \lvert\eta\rvert < 1.37$)	R_{had}
	Ratio of E_T in the first layer of the hadronic calorimeter to E_T of the EM cluster (used over the range $\lvert\eta\rvert < 0.8$ and $\lvert\eta\rvert > 1.37$)	R_{had1}

Table 1: Electron Identification Variables

6. Expected Electron Performance

The efficiency of the electron reconstruction, consisting of the electromagnetic cluster reconstruction, the cluster-track matching, and the track-quality requirements, are evaluated for each pile-up working point [6]. It has been found that the cluster reconstruction efficiency is approximately 0.995, the track matching efficiency is approximately 0.97, and the efficiency of the track-quality requirements is approximately 0.99, irrespective of pile-up. The efficiencies, as well as the probabilities of a hadronic jet or conversion being mis-identified as an electron (relative to candidates passing the track-quality requirements) were calculated for the three efficiency working points, and the three pileup scenarios considered, and as shown below, is not expected to deteriorate significantly. The electron resolution was also calculated in the barrel and end-caps, and is shown below. The probability of a generator-level hadronic jet faking a Tight electron at pileup 200 is (2.5±0.4)x10^{-4}. The charge mis-identification rate of Medium electrons at pileup 200 is (2.6±0.2)x10^{-3}, and is roughly constant with pileup.

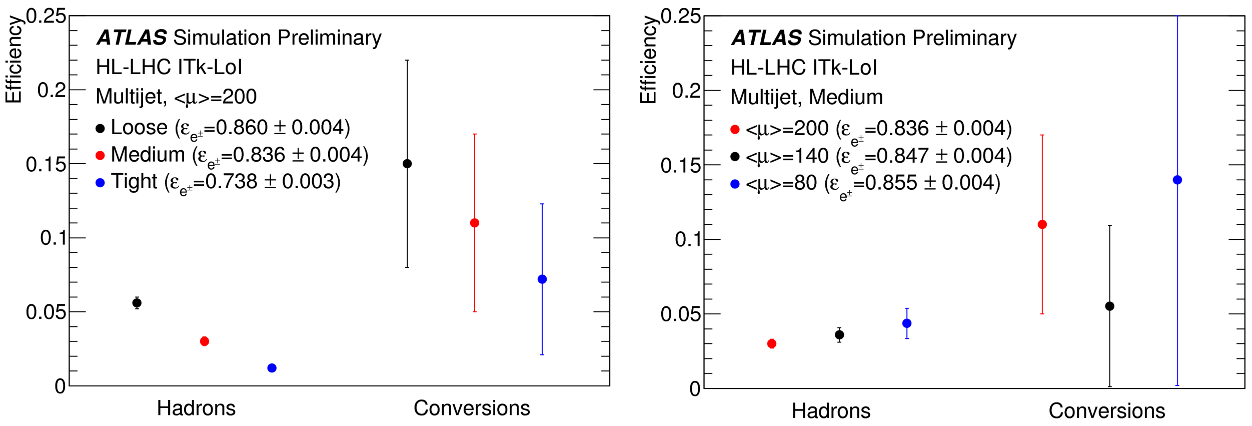

Figure 4: Background fake probabilities for different efficiency working points, and different pileup [6]

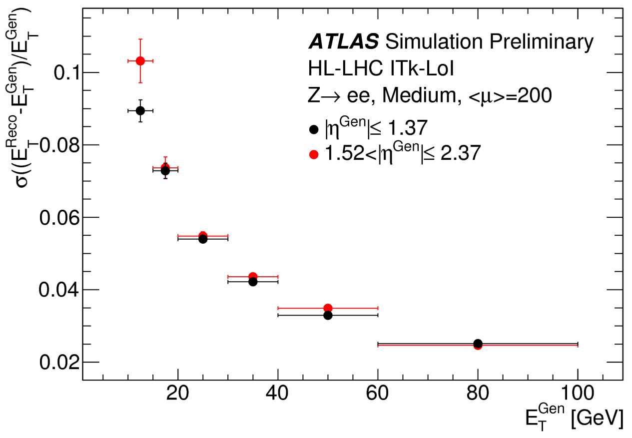

Figure 5: Electron Resolution vs generator-level transverse energy, in the barrel and end-caps [6]

7. Summary

- By around 2025, the HL-LHC is expected to be operational, which will mean a factor of 10 increase in the luminosity, increasing pileup and the radiation rate.
- This will place demands on the pileup robustness of the detectors and identification procedures.
- ATLAS will undergo major upgrades, including a full replacement of the Inner Detector.
- Post-upgrade, ATLAS is expected to be able to achieve a jet fake probability (relative to generator-level) of (2.5±0.4)x10^{-4} for an efficiency of approximately 0.78.
- These results suggest that we can expect performance at the HL-LHC, which is at least compatible with our current performance [7].

References

1. The ATLAS Collaboration ; CERN. Geneva. The LHC experiments Committee ; LHCC, "ATLAS Phase-II Upgrade Scoping Document", CERN-LHCC-2015-020 ; LHCC-G-166, (2015).
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3. The ATLAS Collaboration, "Electron efficiency measurements with the ATLAS detector using the 2015 LHC proton-proton collision data", ATLAS-CONF-2016-024, (2016).
4. The ATLAS Collaboration, "Expected electron performance in the ATLAS experiment", ATL-PHYS-PUB-2011-006, (2011).
5. The ATLAS Collaboration, "Electron reconstruction and identification efficiency measurements with the ATLAS detector using the 2011 LHC proton-proton collision data", Eur. Phys. J. C 74 2941, (2014).
6. The ATLAS Collaboration, "Expected performance for an upgraded ATLAS detector at High-Luminosity LHC", ATL-PHYS-PUB-2016-026 (2016).
7. The ATLAS Collaboration, "Electron efficiency measurements with the ATLAS detector using 2012 LHC proton-proton collision data", CERN-EP-2016-262 (2016).

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