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Photon Reconstruction and Identification with the ATLAS Detector

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The understanding of the reconstruction of photons will be one of the key issues at the start-up of data-taking with the ATLAS experiment at the LHC in 2009. Large statistics of photons produced in association with jets are expected over a wide range of E_T, from 20 GeV to several hundred GeV. These will be used as an important in situ calibration tool for the jet energy scale. The energy measurement of unconverted photons is based on the electromagnetic calorimetry over the full relevant energy range (10 GeV to a few TeV). The electromagnetic calorimeter cluster algorithm starting from electronically calibrated calorimeter cells will be described. Local position and energy variations are corrected for. A refined calibration procedure, developed and validated over years of test-beam data-taking and analysis, strives to identify all sources of energy losses upstream of the calorimeter and outside the cluster and corrects for them one by one (using Monte-Carlo). Unconverted photons require a specific calibration depending on the conversion radius to reach the optimal linearity and resolution.

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1. Introduction

In order to acquire the full physics potential of the LHC, the ATLAS electromagnetic calorimeter must be able to identify photons and electrons at energies in the wide range of 5 GeV to 5 TeV. The reconstruction of an electromagnetic object begins in the calorimeter and the inner detector information determines whether the object is a photon - either converted or unconverted - or an electron. The photon identification method presented here is a cut-based method, which is one of several methods developed in ATLAS [1].

2. Photon/jet discrimination

The main source of high p_T isolated photons at the LHC comes from QCD processes, with di-jet events as the dominant background. The separation between the photons and the fake photons resulting from the jets, is based on their characteristic features. In the electromagnetic calorimeter photons are narrow objects well contained in the electromagnetic calorimeter, while fakes exhibits a broader profile and can deposit a substantial fraction of their energy in the hadronic calorimeter. Hadronic leakage and transverse shower variables, especially in the front layer with fine granularity along η, can therefore be used to efficiently reject jets.

At this stage of the identification process, the converted and unconverted photons are treated equally. A few of the selection variables for signal and background samples before cuts (vertical lines) are displayed in figures 1, 2 and 3 (for $|\eta| < 0.7$ and $20 < E_T < 30$ GeV).

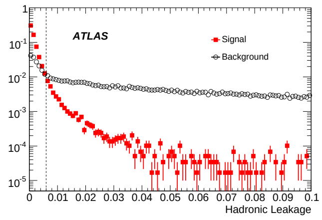

Figure 1: Ratio of transverse energy in the first layer of hadronic calorimeter to the transverse energy of the cluster.

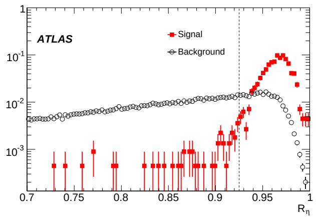

Figure 2: The fraction of energy in a cluster with a window of $\Delta\eta \times \Delta\phi = 3 \times 7$ cell with respect to a window of 7×7 cells.

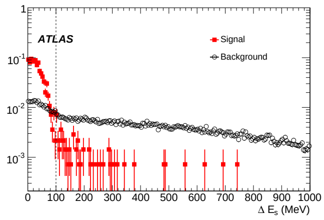

Figure 3: From the 1st layer of ECAL: Energy difference between the 2nd maximum and the minimum reconstructed energy between 1st and 2nd maximum in the strips.

3. Track isolation

After the calorimeter cuts are applied, the contamination of the signal from charged hadrons is significantly reduced. The remaining background is dominated by low track multiplicity jets containing high p_T π^0 mesons. In order to remove the resulting fake photons, track isolation is used (see figure 4). The variable is defined as the sum of the p_T of all tracks with $p_T > 1$ GeV within $\Delta R < 0.3$, where ΔR is the $\eta - \phi$ distance between the track position at the vertex and the cluster centroid. Track $p_T > 1$ GeV is imposed to minimize the effect of pile-up and underlying events. Tracks from photon conversions must obviously first be excluded from this variable, which is accomplished through additional selection requirements.

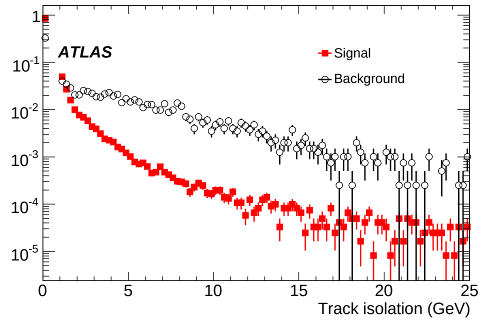

Figure 4: The distribution of the track isolation variable for true and fake photon candidates, after the calorimeter shower-shape cuts. An additional rejection of factor 1.5 to 2 is possible for a relatively small efficiency loss with a 4 GeV cut.

4. Photon identification performance

Table 1 summarizes the average efficiencies of the calorimeter and track isolation cuts, while figure 5 illustrates the fake rates (inverse of the rejection) as a function of pseudorapidiy for all jets with $E_T > 25$ GeV. There is a small increase for higher $\mid \eta \mid$ due to the increase in material in front of the calorimeter, which imposes slightly looser cuts to preserve a constant efficiency

Efficiency	ε (calorimeter cuts)	ε (track-isolation cuts)
Nominal geometry (no pile-up)	(87.6±0.2)%	(99.0±0.1)%
Nominal geometry (with pile-up)	(86.6±0.5)%	(98.0±0.2)%
Distorted geometry (with pile-up)	(83.6±0.2)%	(98.1±0.1)%

Table 1: Overall efficiency for photons from $H \rightarrow \gamma\gamma$ decays for three different simulation choices.

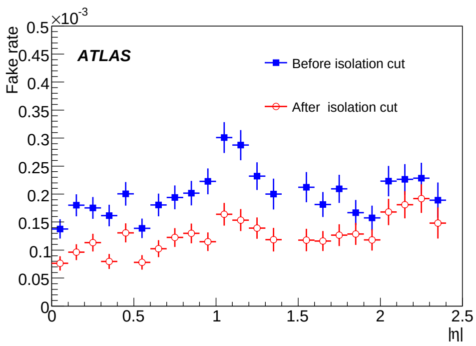

Figure 5: Fake-photon rate as a function of pseudorapidity in the filtered jet sample.

5. Conclusion

The performance of the ATLAS electromagnetic calorimeter and tracker have been extensively studied with simulation analysis and test beam data-taking. Recent cosmic rays have been used to validate the calorimeter shower shape used for identification.

Detailed Monte Carlo studies have shown that currently available photon identification are adequate for physics analysis in rejecting background while retaining photons with high efficiency. It is, however, of crucial importance to reevaluate the identification performance with beam-collision data.

References

[1] ATLAS Collaboration, *Expected Performance of the ATLAS Experiment, Detector, Trigger and Physics*, arXiv:0901.0512 [2009].

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