PROCEEDINGS OF SCIENCE

First observation of electrons in the ATLAS detector

Jana Kraus on behalf of the ATLAS Collaboration*
University of Bonn
E-mail: j.kraus@physik.uni-bonn.de

The special topology of cosmic ray events traversing all subdetectors offers the unique opportunity to investigate the combined performance of ATLAS in identifying and reconstructing particles before first collisions. The study of high-energy delta electrons in cosmic ray data, produced by cosmic muons through ionisation of the inner detector material, is described.
A method of separating knock-on electrons from the large background of muon bremsstrahlung is presented accounting for the special nature of cosmic ray events and utilizing the ATLAS tools to identify electrons with their characteristic properties. The resulting sample of 32 delta electrons out of 3.5 million cosmic ray events with a high-level trigger track candidate in the inner detector barrel has for the first time allowed the observation and investigation of electrons in ATLAS.

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*Speaker.

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1. Introduction

Electrons are important final state particles in many processes of the Standard Model and of new physics which will potentially be discovered at the LHC. Since the cross sections of these processes are rather small in comparison to the large QCD background, an efficient and clean extraction of these particles needs to be assured.
The reprocessing of a large amount of cosmic ray data in December 2008 allowed the commissioning of the ATLAS subdetectors before first collisions with cosmic rays, for more details see [1]. It also offered for the first time the opportunity to investigate the performance of the ATLAS detector in finding and identifying electrons.

2. Extraction of high-energy delta electrons in cosmic ray data

Electrons in cosmic ray events can be produced by the interaction of the incoming muons with the inner detector material. In rare cases the high-energy delta electrons can reach the calorimeter and are reconstructed in ATLAS. The electron electromagnetic clusters are required to have a transverse energy of at least 3 GeV with a loose track match in ϕ in the lower detector hemisphere. A process leading to the reconstruction of a fake electron candidate is muon bremsstrahlung where the photon shower in the calorimeter is matched to the inner detector track of the cosmic muon.
The basis for the investigation of electrons in cosmic ray data is a sample of 3.5 million cosmic ray events which all feature a track in the inner detector barrel. Among these, about 11000 electron candidates can be found [2]. The candidates are divided into two categories according to their signature in the detector: One sample consists of events which feature only one inner detector track, they are therefore supposed to consist mainly of the background bremsstrahlung candidates. The second sample contains events which feature at least two inner detector tracks and are therefore assumed to result from ionisation processes. The events of these categories are required to fulfill medium electron cuts for a first suppression of background [3]: An electron-compatible shape of the shower in the first two calorimeter layers, a good matching of track and cluster in ϕ and a minimal number of hits in the Transition Radiation Tracker (TRT) is required. The standard cut set is adjusted to the special topology of cosmic ray events which often feature TRT-only tracks and therefore lack precision track hits and an accurate polar angle information. After these cuts 1229 candidates remain in the bremsstrahlung sample and 85 candidates in the ionisation sample.
Two independent variables are investigated which are most powerful to extract a signal from real electrons: The ratio of cluster energy and track momentum (E/p) should be approximately one for electrons which leave their total energy in the electromagnetic calorimeter and much smaller for muon bremsstrahlung events. The fraction of high-threshold hits with respect to the total number of TRT hits on tracks (HT-TRT ratio), which indicates the emission of transition radiation, should be larger for electrons than for muons. The two-dimensional distribution of these variables for the medium candidates in both samples can be seen in Figure 1. As expected for background, only a very small fraction of events (19 of 1229) pass these cuts. In contrast to that, a much larger fraction of events survive the cuts (36 of 85) in the ionisation sample, and a clear signal of electrons with E/p$\approx$1 and a high fraction of high-threshold TR hits can be observed. These events are interpreted as high-energy delta electrons produced by muon ionisation.

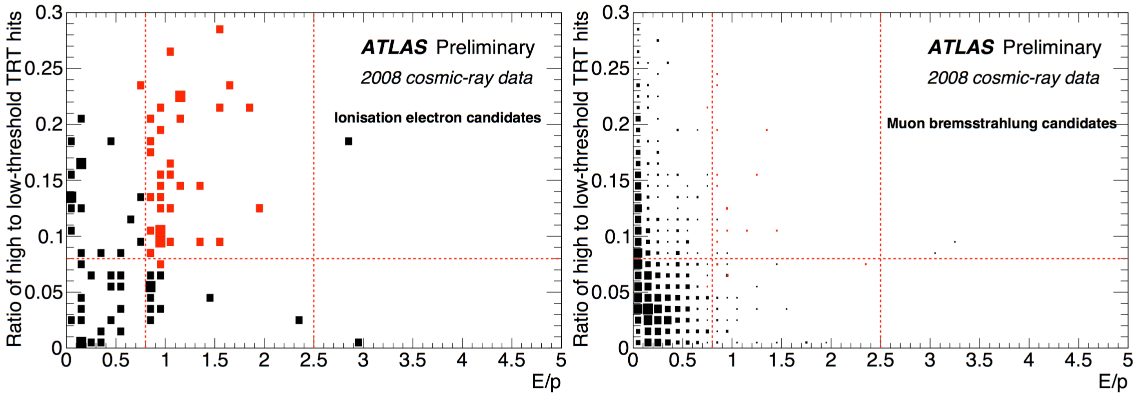

Figure 1: Fraction of high-threshold TR hits vs. E/p for all medium candidates. The red boxes mark the electron candidates which in addition satisfy the cuts indicated by the lines.

In order to estimate the background contained in the final sample, a two-dimensional binned maximum likelihood fit is performed on the HT-TRT ratio vs. E/p distribution (Figure 1) excluding the signal candidates. The shape of the distribution is obtained from the bremsstrahlung sample, and the fit is performed on the ionisation sample. The integral of the obtained fit-function over the signal region yields a background contamination of (8.7 $\pm$ 3.1) events. The two distributions and respective fit projections can be seen in Figure 2. For the HT-TRT ratio distribution (left) a clear

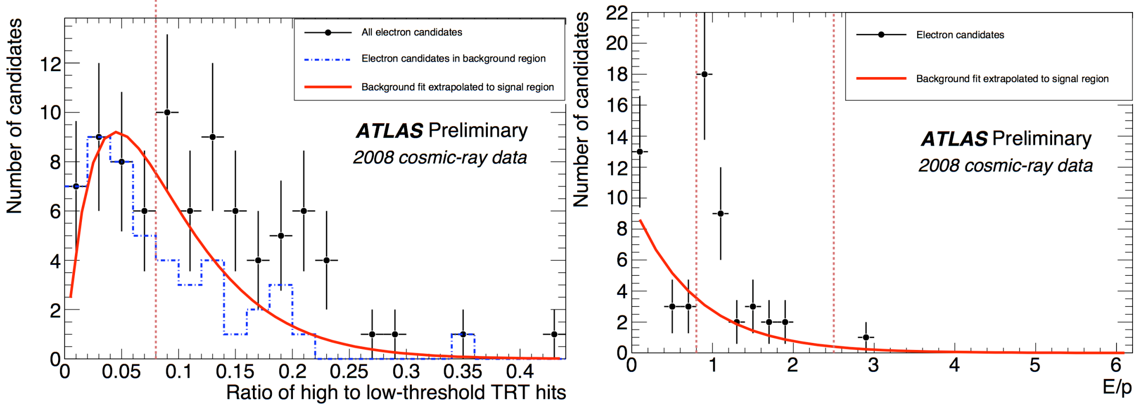

Figure 2: Distribution of the fraction of high-threshold TR hits (left) and E/p (right) for the ionisation candidates and the respective projection of the two-dimensional background fit.

excess of the signal events at larger values in comparison to the background events can be observed. For the E/p distribution (right) the cut on the HT-TRT ratio has already been applied. One can see a clear accumulation of signal electron events around one above the background, as expected.
The event display of a typical delta electron candidate is shown in Figure 3.

3. Data - Monte Carlo comparison of shower shapes

The lateral and longitudinal shower shapes of the 32 delta electron candidates which remain after the removal of four positively charged candidates are compared to a simulated projective electron sample with $E_T = 5$ GeV and $|\eta| < 0.8$. Two examples can be seen in Figure 4. The shower profiles are in good agreement with the Monte Carlo sample.

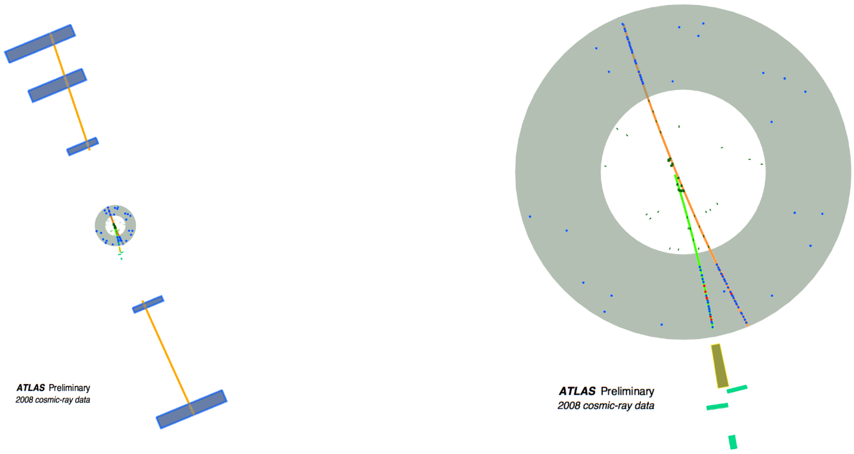

Figure 3: Event display of a typical delta electron in full (left) and zoomed (right) view. The incoming and outgoing muon track (orange) in three top and two bottom muon stations (blue) and the inner detector (grey) is displayed. The additional track of the produced electron in the inner detector (green) and the electromagnetic calorimeter cluster (light green) including the cells (dark green) which were used to build the cluster can be seen clearly in the zoomed view.

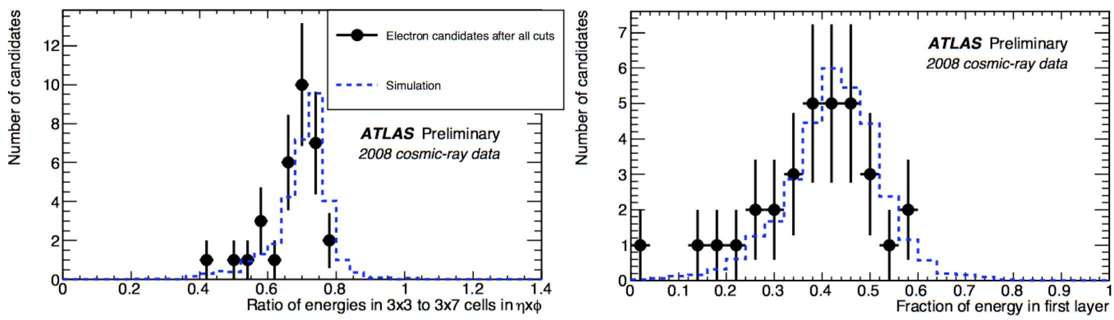

Figure 4: Data - Monte Carlo comparison of lateral (left) and longitudinal (right) shower profiles for the 32 final delta electrons.

4. Summary

The first observation of electrons in cosmic ray data demonstrates both the excellent commissioning of the calorimeter and of the inner detector with efficient transition radiation, and it allows to build confidence that early electrons will be successfully reconstructed and identified in ATLAS during the upcoming collision data-taking phase.

References

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[2] J. Kraus, *Measurement of electron production from cosmic rays in the ATLAS detector*, diploma thesis, January 2010, Bonn-IR-2010-01, in preparation.

[3] The ATLAS Collaboration, *Expected Performance of the ATLAS Experiment, Detector, Trigger and Physics*, (2008), CERN-OPEN-2008-020.