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Performance of Track and Vertex Reconstruction and b-Tagging Studies with ATLAS in pp Collisions at $\sqrt{s}$ = 7 TeV

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First 7 TeV proton-proton collisions produced by the Large Hadron Collider (LHC) at CERN have been recorded by the ATLAS experiment. The ability to accurately and efficiently reconstruct the trajectories of charged particles produced in these collisions as well as their origin, the primary event vertex, is a critical component in many analyses. This note presents the track and vertex reconstruction performance of the ATLAS tracking system, as well as first results from b-tagging algorithms, used to identify b-quark jets. These algorithms take advantage of displaced tracks or displaced vertices caused by the long-lived decay of a b-hadron via the weak force. The precise trajectory measurement of charged particle tracks is therefore one of the crucial ingredients to b-tagging algorithms. The distributions of the corresponding observables - track impact parameters and secondary vertices - were measured in pp collisions at $\sqrt{s}$ = 7 TeV, and compared to the predictions from Pythia Monte Carlo simulation. b-tagging is an important tool for various physics programs of the ATLAS experiment.

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1. The ATLAS detector

The ATLAS experiment is one of the four main experiments at the Large Hadron Collider (LHC) in Geneva, Switzerland. The LHC is a proton-proton collider running at 7 TeV centre-of-mass-energy since March 2010. ATLAS is designed as a general purpose detector and is sensitive to a large number of Standard Model and new physics signatures. The ATLAS Inner Detector is a high-precision tracking detector. It is contained within a solenoidal magnetic field of 2 T and consists of three sub-detectors: the Pixel detector and the Semi-Conductor Tracker (SCT) at inner radii (starting from 50.5 mm) and the Transition-Radiation-Tracker (TRT) at larger radii (spanning up to 1 m) [1]. The Pixel and SCT detectors use semi-conductor technology and have an excellent resolution down to 10 μm. The TRT consists of straw tubes and improves the momentum resolution significantly.

The analyses presented in this note are based on a sample of pp collisions at $\sqrt{s} = 7$ TeV collected between March and June 2010 using an integrated luminosity between 0.4 nb^{-1} and 15 nb^{-1}. Only data collected during stable beam periods in which the silicon systems were operated at full depletion voltage are used. Events are required to have a reconstructed primary vertex with at least 10 tracks, while events with one or more additional reconstructed primary vertices with more than 4 tracks are removed from the sample to reduce the influence of pile-up.

2. Primary vertex reconstruction

The reconstruction of primary vertices in ATLAS is done in two steps: first the primary vertex finding algorithm, dedicated to identify vertex candidates and associate reconstructed tracks to them, and then the vertex fitting algorithm, dedicated to reconstruct the vertex position and its corresponding error matrix [2]. The primary vertex resolution can be estimated by randomly splitting the tracks associated to it in two, fitting these two sets of tracks to two independent vertices and using their separation to get an estimate of the intrinsic resolution of the primary vertex. The results of this measurement are presented in Figure 1. The resolution of the primary vertex depends strongly on the number of fitted tracks in the vertex and has been measured to be 40 μm in x- and 60 μm in z-direction for a typical number of 50 tracks per vertex.

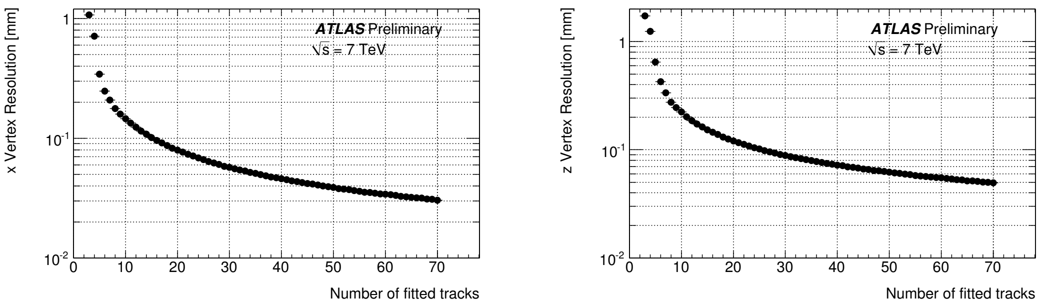

Figure 1: Resolution of the primary vertex reconstruction for the x- (left) and z-component (right).

3. Transverse impact parameter resolution

The knowledge of the impact parameter resolution is crucial for the correct understanding of the b-tagging algorithms and their performance and has been studied in [3]. Figure 2 (left) shows the measured transverse impact parameter distribution for tracks passig the b-tagging cuts, which require amongst other cuts at least one hit in the inner-most pixel layer. The transverse impact parameter is expressed at the point of closest approach in the transverse plane to the reconstructed primary event vertex. The core of the distribution for experimental data agrees very well with predictions from Pythia Monte Carlo simulation [4], whereas some discrepancies are visible in the tails. The measured track resolution can be understood as the intrinsic impact parameter resolution convolved with the uncertainty of the reconstructed primary vertex. The intrinsic track resolution can be deconvolved in an iterative procedure and its result is shown in Figure 2 (right). The deconvolution procedure is explained elsewhere [3]. It can be seen that for small values of transverse momentum p_T the agreement between unfolded and true resolution as obtained from Pythia Monte Carlo truth agrees very well, larger discrepancies are visible towards larger values of p_T. These discrepancies are dominated by remaining misalignments in the ATLAS Inner Detector.

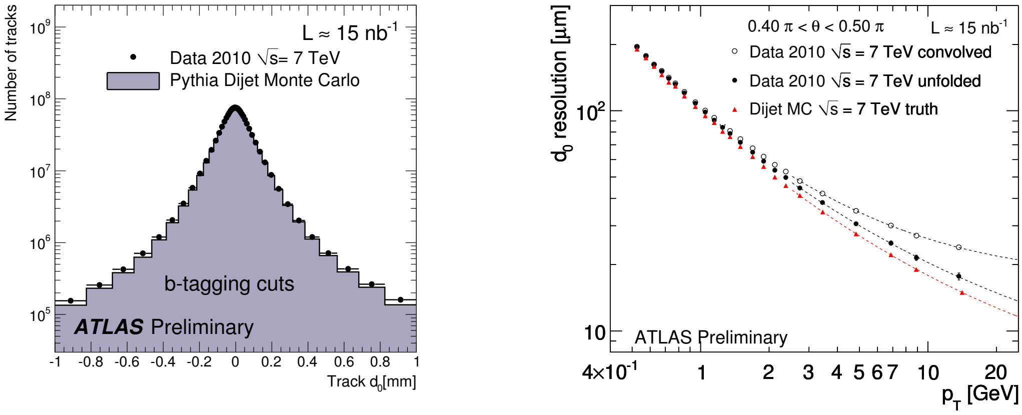

Figure 2: Transverse impact parameter distribution as measured directly (left) and its resolution in the central barrel versus p_T as unfolded compared to Pythia Monte Carlo truth resolution (right).

4. b-tagging studies with first collisions at $\sqrt{s}$ = 7 TeV

The identification of jets originating from b-quarks is an important part of the LHC physics program. In precision measurements in the top quark sector as well as in the search for the Higgs boson and new phenomena, the suppression of background processes containing predominantly light-flavour jets using b-tagging is of great use. Two b-tagging algorithms used for early data analyses will be presented in the following.

4.1 The jet probability tagging algorithm

The jet probability tagging algorithm [5] uses the signed impact parameter significance $Sd_0 = d_0/\sigma(d_0)$, where the sign is defined using the jet direction and tends to be positive for tracks from

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c- or *b*-hadrons and equally distributed for light jets. For each selected track in a calorimeter jet with $Sd_0 > 0$ the probability that this track originates from the primary vertex is measured. For this a dedicated resolution function R is used, which is determined seperately from experimental and simulated data. The probability P_{Jet} is the combination of all individual track probabilities and denotes the probability that the jet does not contain any decay products from *b*-hadrons. The resulting jet probability is shown in Figure 3 (left) for experimental data compared to Pythia Monte Carlo simulation. The same result, but shown as the distribution of $-\log_{10}(P_{Jet})$ is shown on the right. The simulation describes relatively well the experimental data. The expected features related to the jet flavour are visible on the simulated curves: the distribution of P_{Jet} for the prompt jet component is flat, and the heavy flavour component is localized at very low values of P_{Jet}.

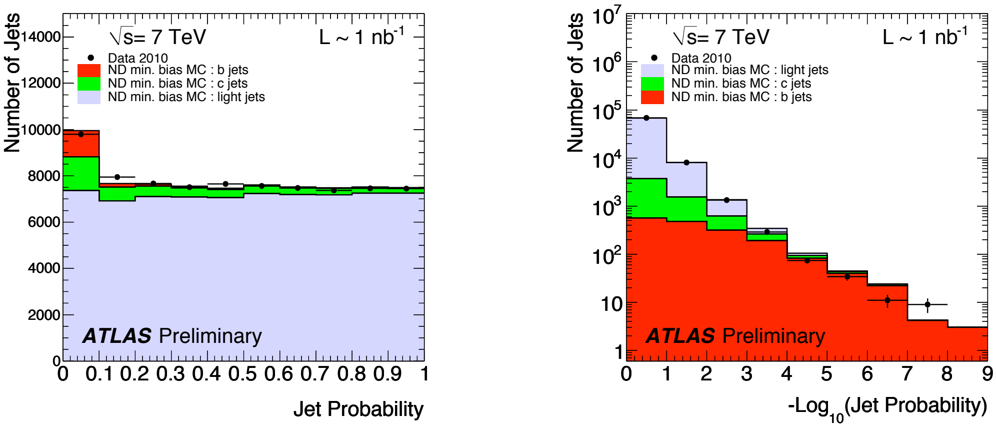

Figure 3: Probability P_{Jet} that the jet does not contain any decay products from long-lived particles (left) and its $-\log_{10}(P_{Jet})$ (right).

4.2 The secondary vertex tagging algorithm SV0

The SV0 tagging algorithm [6] is a lifetime-based *b*-tagging algorithm which explicitly reconstructs an inclusive secondary vertex from tracks associated to a jet. The discriminating variable of this tagging algorithm between heavy-flavour contribution and light jets is the signed decay length significance $L/\sigma(L)$ of the reconstructed secondary vertex. Figure 4 (left) shows the signed decay length significance for all reconstructed secondary vertices. The shape of the distribution is well modelled by the simulation, both in the low decay length significance region which is dominated by background from *c*- and light jets and in the large decay length significance region where the sample is dominated by *b*-jets. The right plot in the same figure shows the invariant mass M_{vtx} of the tracks associated to the reconstructed secondary vertices with positive decay length significance $L/\sigma(L) > 0$. The agreement between data and simulation is generally good, with an excess of data events in the low-mass region.

5. Conclusions

Studies of the performance of the track and vertex reconstruction as well as *b*-tagging algorithms using the ATLAS detector with proton-proton collisions at $\sqrt{s} = 7$ TeV have been presented.

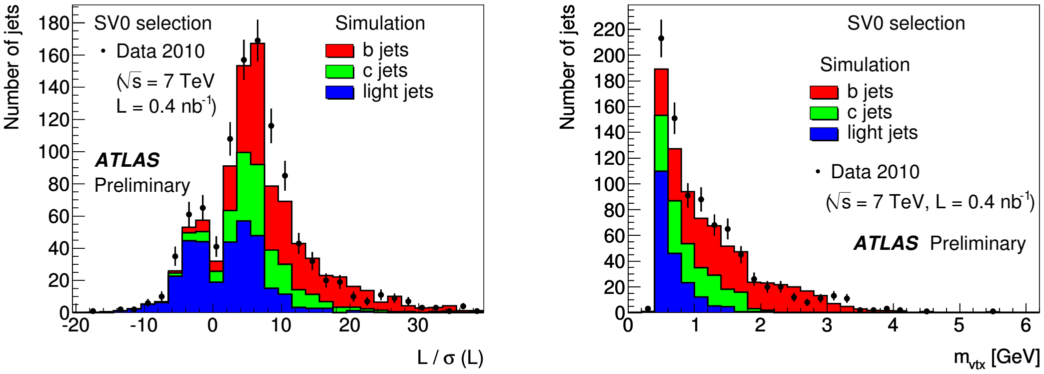

Figure 4: Signed decay length signigicance (left) and invariant mass M_{vtx} of the tracks associated to the reconstructed secondary vertices with positive decay length significance (right).

Overall the agreement between experimental data and Pythia Monte Carlo simulation is very good. This puts ATLAS in a position where its track and vertex reconstruction can be used reliably as inputs to many physics analyses. One very important tool relying on a good understanding of both the track and vertex reconstruction is *b*-tagging. Its good performance in the first collisions enables physics groups in ATLAS to use this powerful tool already in the first year of LHC running.

Acknowledgements

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