ATLAS Tracking Results from the first Collision data-taking Period

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The first collision data taking period with stable beam conditions at the LHC at $\sqrt{s} = 900$ GeV in December 2009 provided stringent tests of the ATLAS track reconstruction. The detailed understanding of the performance of the track and vertex reconstruction chains has been an integral component of the first charged particle distribution measurements in proton-proton collisions published by the ATLAS collaboration. The very good description of the data by the ATLAS Monte Carlo simulation for track quantities and the reconstruction of weakly decaying particles is shown.

1 Introduction

The data shown here was taken during the stable LHC[1] running periods between December 6 and 15 2009, when the ATLAS tracking detectors[2] were in full operational mode and the magnetic field of the solenoid was on. Approximately half a million events were collected by requiring a hit on either side of the minimum bias trigger scintillators. To reduce the contribution from beam backgrounds, a reconstructed primary vertex was required. The understanding of the detector in terms of e.g. material budget or inactive modules is important for performance studies and physics analyses. Therefore the observed LHC and detector conditions including inactive modules and channels were used in the Monte Carlo (MC) simulation.

2 Track Reconstruction Performance in the Inner Detector

The main reconstruction sequence in the inner detector is an inside-out track reconstruction chain. Track candidates are formed from space points in the silicon detector, which consists of the innermost pixel detector which is inside a silicon microstrip detector (SCT). These track candidates are then extended into the transition radiation tracker (TRT) that provides additional particle identification. A loose track selection was chosen: tracks within a pseudorapidity[a] range of $|\eta| < 2.5$, a reconstructed transverse momentum p_{T} greater than 500 MeV, and with a minimum of 7 hits in the silicon detector were selected. Additional requirements, such as a maximum number of holes and shared hits on a track are applied in the pattern recognition. There is a very good description of the data by the ATLAS MC simulation. Figure 1 illustrates this by comparing the number of associated pixel hits per selected track. The number of holes — i.e. expected hits not associated to a track — is an even stronger test of the pattern recognition performance and is shown for the SCT detector. A more complete performance study for the inner detector track reconstruction using the same track selection can be found elsewhere[3].

[a]Pseudorapidity is defined as $\eta = -\ln\tan(\theta/2)$

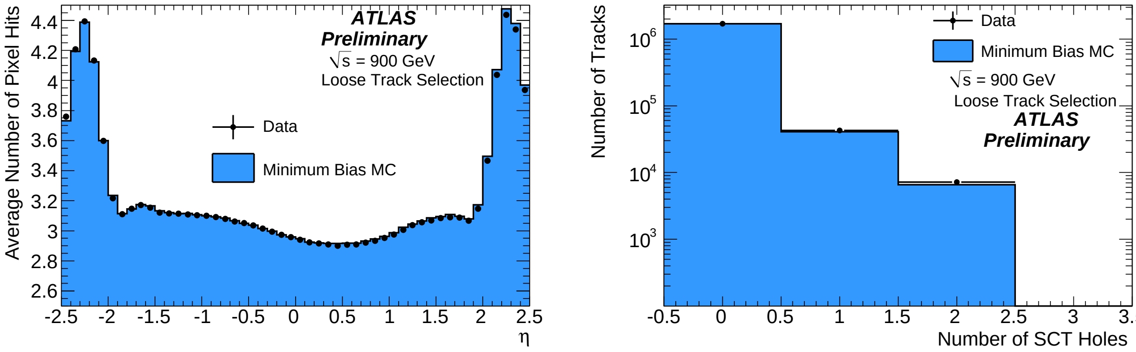

Figure 1: Left: Average number of pixel hits per selected track as a function of pseudorapdity. The distributions are shown for both simulation and data. The structure is mainly influenced by the inactive modules that have been also masked in the digitisation process of the simulation samples to reproduce the run conditions. Right: Total number of SCT holes on a track.

Figure 2 (left) shows the transverse impact parameter distribution of tracks with respect to the primary vertex in linear and logarithmic scale. The difference in the core distribution is due to module misalignment in data. The agreement in the tails indicates that both the secondary production rate and the material budget in the simulation are in good agreement with data. The high quality track reconstruction allowed track-based alignment algorithm to achieve residual distributions close to those of a perfectly aligned detector (see Fig. 2, right).

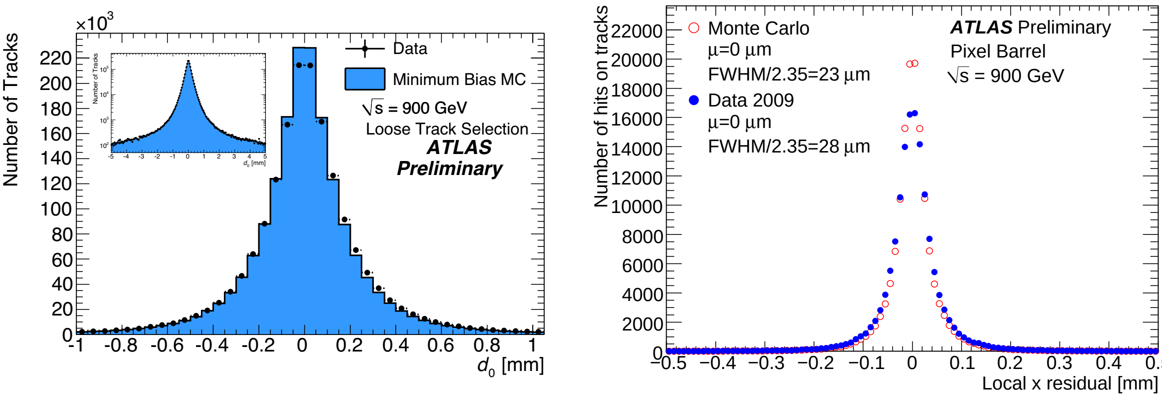

Figure 2: Left: Transverse impact parameter distributions d_0 in linear and logarithmic scale in Monte Carlo and data. The impact parameter is expressed with respect to the reconstructed vertex. Right: The unbiased pixel barrel residual in the local x coordinate after track-based alignment using the 2009 dataset.

3 Primary Vertex and Beam Spot Reconstruction

The interaction point of the proton-proton collision is reconstructed on an event by event basis by a dedicated primary vertex reconstruction algorithm. The efficiency of reconstructing a primary vertex has been determined from data and is close to 100% for events with more than 2 reconstructed tracks[4]. The primary vertices are used to measure the luminous region (beam spot) of the LHC inside the ATLAS detector. This is done for every whole run but also every 2 luminosity blocks[b] to be able to monitor any drifting or widening of the beam spot during

[b] A luminosity block is a defined data-taking time interval.

a run. Figure 3 shows the reconstructed vertex position in one transverse component and the estimated beam spot position and its stability throughout a data-taking run.

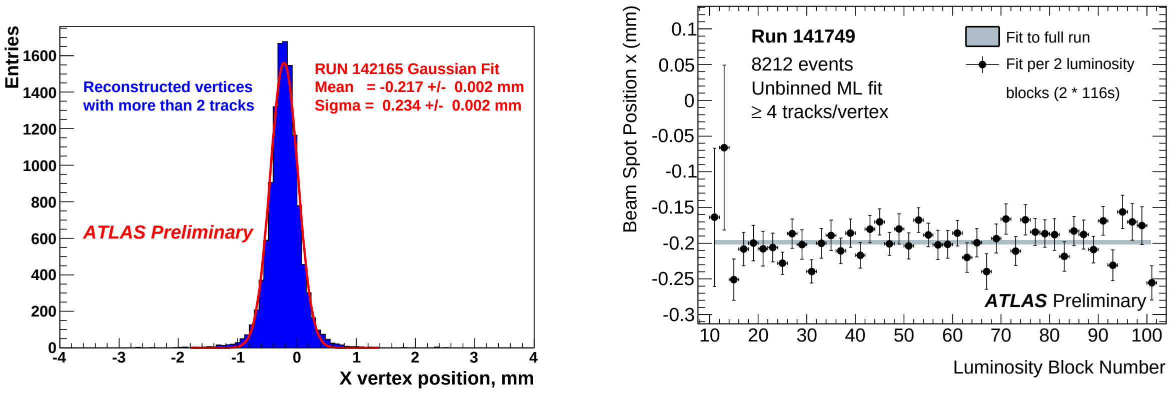

Figure 3: Left: The reconstructed primary vertex position in the transverse coordinate x for a single run. Right: Stability of the beam spot position as a function of luminosity block for a single run.

4 Electron Reconstruction and Photon Conversions

A unique element of the ATLAS inner detector is the TRT detector. It provides electron-pion separation using transition radiation (TR). TR is emitted by a particle traversing materials with strongly differing dielectric constants and is proportional to the Lorentz factor $\gamma = E/m$ of the particle. Figure 4 (left) shows the probability of a high threshold hit induced by transition radiation in the TRT end-cap. Electron candidates with $\gamma > 10^3$ were selected for this study from reconstructed photon conversions into electron-positron pairs. The estimation of the rate of photon conversions is a very powerful approach to estimate the material budget of the detector from data. There is a good agreement between the MC prediction and data within the limited statistics[5].

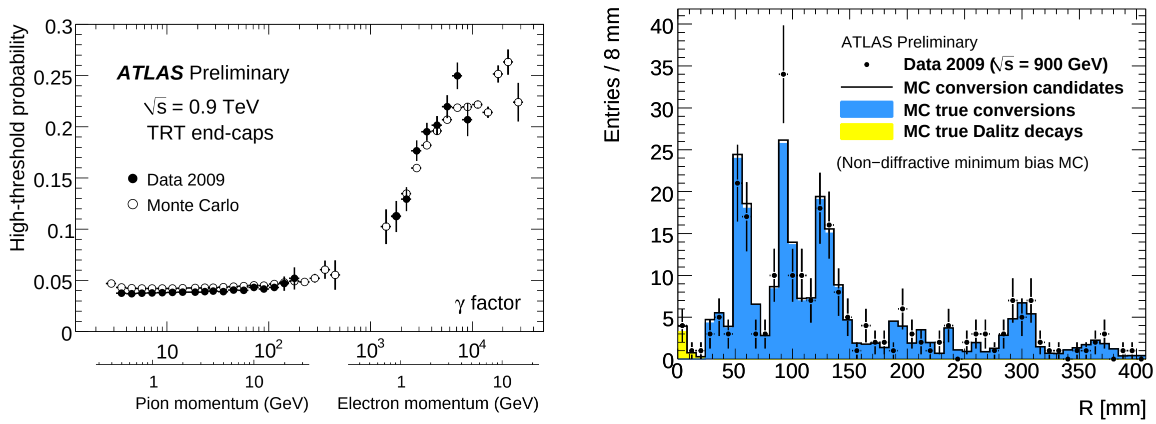

Figure 4: Left: The probability of a TRT high-threshold (HT) hit as a function of the Lorentz factor $\gamma = E/m$ for the TRT end-caps. Right: Distribution of photon conversion radii in the Silicon tracker volume comparing data and MC.

5 Weakly Decaying Particles

Secondary vertex reconstruction was used to identify decay products from weakly decaying particles, such as K_S and Λ. Figure 5 shows the invariant mass distribution of vertices reconstructed from two tracks of opposite charge. The flight direction of the K_S candidate was required to be compatible with the location of the reconstructed primary vertex. No mass constraint was applied during the vertex fit and the invariant mass is calculated by assuming that both tracks are pions. Data and MC show a very good agreement of both the fitted K_S mass and the width. The invariant mass distribution of K_S can been used to provide a constraint on the detector material. Underestimating the ionisation energy loss correction in the track fit shifts the mean of the reconstructed K_S mass. A global scale offset causes the reconstructed K_S mass to depend on the decay radius of the K_S because the decay products traverse different lengths of excess material. Figure 5 (right) compares the fitted K_S mass in data and in MC samples with an excess of 10% and 20% of extra material to MC samples with nominal material in the ID. The presented study[6] shows a disagreement of data with the 10 (20)% excess material MC.

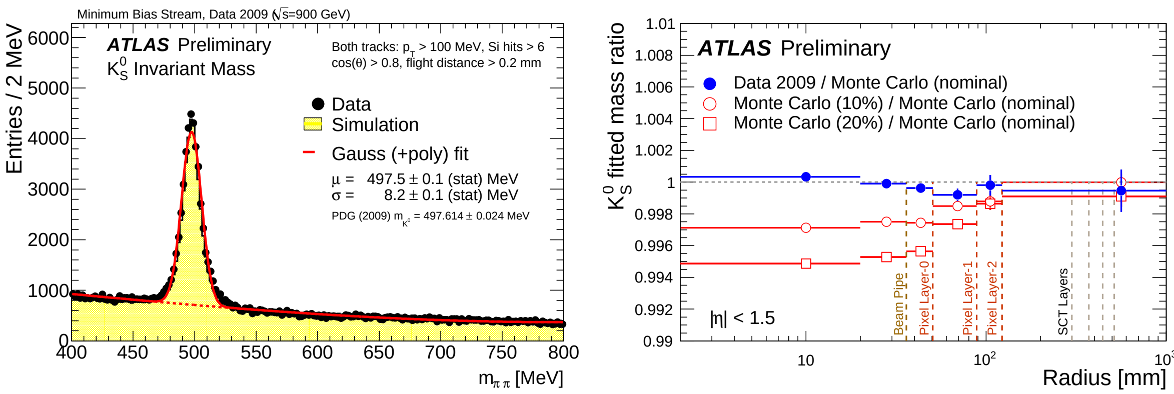

Figure 5: Left: Invariant mass distribution of vertices formed from two tracks of opposite charge, only statistical errors are shown. Right: Ratio of fitted K_S mass in bins of decay radii to the value obtained with the nominal ATLAS MC simulation. Data is compared to MC simulation with the material budget enhanced by 10 and 20 %.

6 Conclusion

The first data-taking period at $\sqrt{s} = 900$ GeV demonstrated excellent performance of the ATLAS tracking system. Close to 98 % of all channels in the inner detector were active and provided stable data taking conditions. The ATLAS Monte Carlo simulation describes the data to a very high level of accuracy. First estimates of the potential deficits in the description of the inner detector material budget were obtained from both photon conversions and the fitted K_S mass. This indicates a good level of agreement between the detector and its simulation model.

References

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2. The ATLAS Collaboration, JINST 3 S08003 (2008).
3. The ATLAS Collaboration, ATLAS-CONF-2010-011.
4. The ATLAS Collaboration, Phys. Lett. B 688, Issue 1 (2010).
5. The ATLAS Collaboration, ATLAS-CONF-2010-007.
6. The ATLAS Collaboration, ATLAS-CONF-2010-019.