Recent performance results with the ATLAS Muon Spectrometer

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The ATLAS Muon Spectrometer (MS) is used to trigger on muons and reconstruct their tracks. It is composed of two sets of air-core superconducting toroidal magnets embedded in three layers of precision chambers and three layers of trigger chambers. Monitored Drift Tubes (MDT) and Cathode Strip Chambers (CSC) measure the bending coordinate (η) with a point resolution of respectively 80 and 60 μm. Resistive Plate Chambers (RPC) in the Barrel ($|\eta| < 1$) and Thin Gap Chambers (TGC) in the Endcap ($1 < |\eta| < 2.7$) also provide the second coordinate (ϕ) and the trigger signal (up to $|\eta| < 2.4$), with a point resolution around 1 cm.

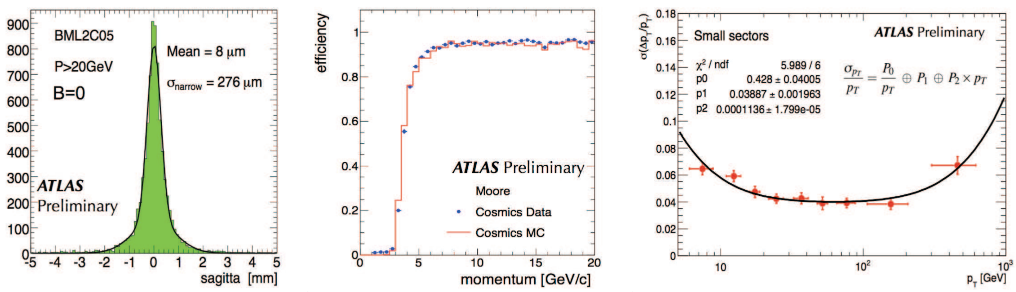
Different types of muon tracks can be reconstructed using different combinations of subdetectors. Stand-alone tracks are based only on MS hits. The MS hits are used to form local straight segments, which are combined to form a curved track. The track parameters are then extrapolated, accounting for energy loss in the calorimeters, to the Interaction Point. Combined tracks are formed by matching a stand-alone track with an Inner Detector (ID) track, improving the precisionon of the track parameters, especially at low momenta. Tagged tracks are built from extrapolated ID tracks by looking for either a segment in the MS or energy depositions compatible with an isolated muon in the calorimeters. They are designed to increase tracking efficiency for low momentum muons or muons traversing uninstrumented areas (cracks).

The first set of performance studies on which we report is based on a large sample of RPC-triggered cosmic-ray events crossing the MS Barrel, recorded in the fall of 2009. Of these events, 48 million were collected without a toroidal B-field. For 21 million events the B-field was at nominal value (with a field integral between 2 and 8 Tm) in order to study momentum resolution and tracking efficiency.

Chamber alignment and sagitta resolution are studied using cosmic-ray tracks collected without magnetic field. The segment sagitta is defined as the distance from the Middle-station segment to the straight line connecting the segments in the Inner and Outer stations. The segment sagitta distribution for each sector is fitted to a double Gaussian (see Fig. 1(a)). The mean of the narrow Gaussian is used for track-based alignment of the spectrometer, while the sigma corresponds to the sagitta resolution. The sagitta resolution is parametrized into two separate components: multiple scattering and intrinsic resolution, respectively dominating at high and low momenta. Using the solenoidal magnetic field of the Inner Detector to determine the momentum of the muon tracks, the intrinsic component of the sagitta resolution is isolated and found to be between 80 and 100 μm.

The hit residual distribution, track reconstruction efficiency and momentum resolution are studied using curved tracks collected with the solenoidal B-field at its nominal value, and are found to be very close to the design specifications for the MS. The hit residual is defined as the distance between a reconstructed track and the position (drift radius) of its individual hits. The residual distribution for stand-alone tracks crossing three MDT chambers is found to be 104 μm, consistent with the measured sagitta resolution. The efficiency of track reconstruction is obtained by calculating the fraction of ID cosmic-ray tracks which are also reconstructed in the MS. The reconstruction efficiency for stand-alone tracks crossing two or more MDT chambers matches with the cosmic simulation, averaging 95% (see Fig. 1(b)).

To measure the momentum resolution of the MS without requiring a comparison with the ID, the top and bottom sections of a cosmic-ray track traversing the whole detector are compared. The momentum resolution is the width of the fitted distribution of relative p_T differences ($\Delta p_T / p_T$) between the top and bottom halves of the track. Fitting the momentum resolution against the momentum of the tracks (see Fig. 1(c)) allows the extraction of its three components: energy loss correction (P_0), multiple scattering (P_1), and intrinsic resolution (P_2). Extrapolating the fitted function to 1 TeV momenta gives a resolution of $11 \pm 2\%$ for tracks crossing small MDT chambers and $25 \pm 2\%$ for tracks crossing large ones. The difference between small and large chambers is due to the difference in integrated magnetic field along the muon paths. The design goal for 1 TeV muon tracks is a p_T resolution of approximately 10%.



(a) (b) (c)

Figure 1: Performance results from a study of cosmic-ray tracks in the MS Barrel. A segment sagitta distribution (a), the reconstruction efficiency as a function of momentum for stand-alone tracks (b), and the p_T resolution as a function of p_T for small MDT sectors (c).

The second set of performance studies discussed here is for the most part based on the first 0.6 nb^{-1} of 7 TeV pp collisions triggered using the ATLAS Minimum Bias Trigger Scintillators. The hardware performance of the MS during these collision runs was good, with very low fractions of dead or noisy channels (0.3% for MDT, 1.5% for CSC, 2.7% for RPC, 1.2% for TGC), and the performance of the muon tracking chambers matches well our expectation from Monte-Carlo. Some basic distributions are shown, for both data and simulation, in figures 2(a) to 2(f). Here the Monte-Carlo is normalized to the number of events in the data. Using a larger dataset (6.4 nb^{-1}), the efficiency of the muon triggers relative to the tracking efficiency was measured by comparing triggered tracks with reconstructed tracks in the minimum-bias sample. The geometrical acceptance of the RPC trigger is around 80%, setting a limit for its relative efficiency, while the TGC efficiency reaches its plateau above 90% (see Figs. 2(g) and 2(h)).

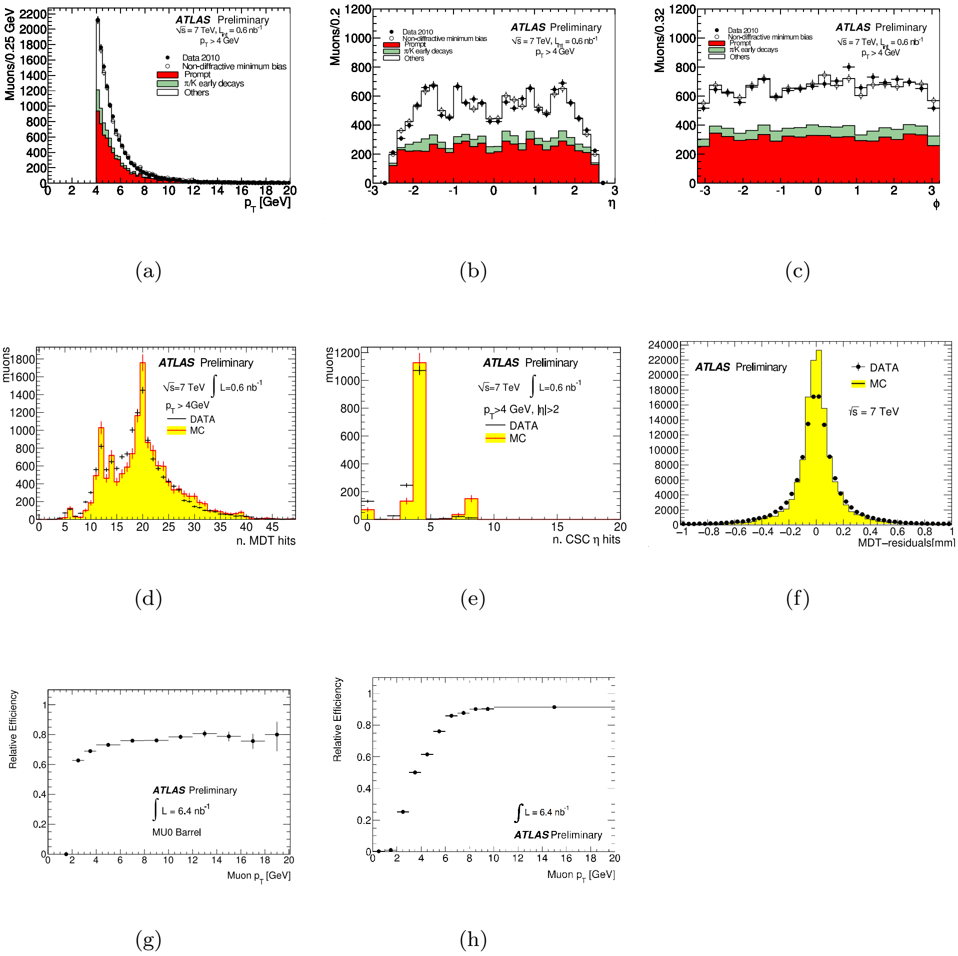


Figure 2: Basic distributions obtained from collision muons compared to simulation: track p_T (a), η (b), and ϕ (c), number of MDT (d) and CSC (e) hits per combined track match the Monte-Carlo prediction well. The two peaks in (d) correspond to tracks crossing two and three chambers, respectively. The hit residual distribution (f) is slightly wider in data than in the simulation due to an underestimation of the material in the MS. (g) and (h): RPC and TGC trigger efficiencies for the lowest trigger threshold (MU0) relative to combined tracks.

References

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