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A muon identification and combined reconstruction procedure for the ATLAS detector at the LHC using the (MUONBOY, STACO, MuTag) reconstruction packages

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Abstract

A robust muon identification and high momentum measurement accuracy is crucial to fully exploit the physics potential that will be accessible with the ATLAS experiment at the LHC at CERN.

In this paper an overview of the muon reconstruction software is given and performance results from detailed Geant4-based simulations are presented.

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Keywords: ATLAS; Muon spectrometer; Reconstruction; Combined reconstruction

1. Introduction

Muon identification and high momentum measurement accuracy is crucial to fully exploit the physics potential that will be accessible with the ATLAS experiment at the LHC. The muon energy of physics interest ranges in a large interval from few GeV, where the *B*-physics studies dominate the physics program, up to the highest values that could indicate the presence of new physics. The muon detection system of the ATLAS detector is characterized by two high precision tracking systems, namely the Inner Detector and the Muon Spectrometer plus a thick calorimeter that ensures a safe hadron absorption filtering with high purity muons with energy above 3 GeV.

In order to combine the muon tracks reconstructed in the Inner Detector and the Muon Spectrometer the Muon Identification (MUONBOY, STACO, MuTag) software package have been developed. The purpose of these packages is to associate segments and tracks found in the Muon Spectrometer with the corresponding Inner Detector track and calorimeter information in order to identify muons at their production vertex with optimum parameter resolution. The performances of these packages from detailed Geant4-based simulations, real data from the Combined Test Beam and cosmic ray events from the recent detector commissioning period have been evaluated.

2. Muon reconstruction in ATLAS

The MUONBOY program was developed to cope with the challenging task of muon reconstruction in the ATLAS detector. The specificities of the experiment environment are: the large muon system size (44 m length and 22 m Ø) implies higher extrapolation uncertainties; the open air-core toroid that leads to a rather inhomogeneous magnetic field affects the measurement for events with low transversed momentum (p_T), and finally the precision chambers that can measure only the coordinate giving the bending direction with an accuracy of 80 μm, while the second coordinate is given by trigger chambers with an accuracy of 1cm. A high level of physics background is also expected.

The strategy of the pattern recognition algorithm, described below, can be summarized in four main steps: (1) identifications of ‘regions of activity’ (ROA) in the muon system, through the trigger chambers; (2)

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reconstruction of 'local straight track segments' in each muon station of these ROA; (3) combination of track segments of different muon stations to form muon track candidates; (4) global track fit of the muon track candidates through the full system.

Another relevant task of the reconstruction is to perform backtracking from Muon System down to beam region. This procedure requires an accurate knowledge of the amount and the nature of the material traversed by muon trajectory in such a way to correctly account for energy losses of the muons along the track. Muon momentum is corrected using an energy loss parameterization. A second method that will be implemented in future can use the energy measured in the traversed cells of the calorimeters. This second method is foreseen, however, only for high p_T muons, having a higher probability of catastrophic energy loss. More details about Muon System design and performance can be found in Ref. [1].

3. Combined muon reconstruction

Muon tracks are also reconstructed in the Inner Detector. The combination of the measurements made in the Muon System with the ones from the Inner Detector improves the momentum resolution in the range $6 < p_T < 100\,\text{GeV}/c$. The matching of the muon track reconstructed independently in the Inner Detector and in the Muon System allows the rejection of muons from secondary interactions as well as the ones from π/K decays in flight. In order to combine the tracks reconstructed in the Inner Detector and the Muon System, the STACO program applies a strategy based on the statistical combination of the two independent measurements using the parameters of the reconstructed tracks and their covariance matrices. Details of the method can be found in Ref. [2]. The reconstruction and combination efficiencies and the p_T

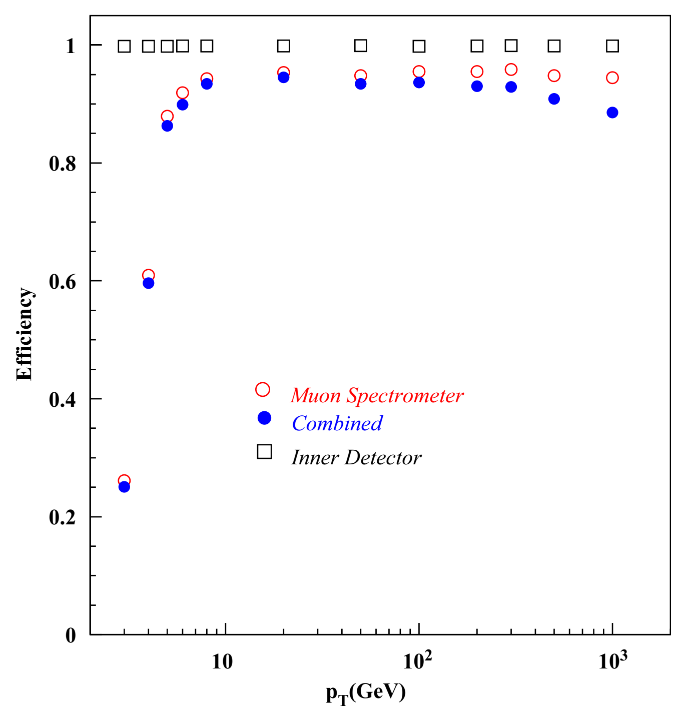

Fig. 2. Efficiency of track reconstruction in the Muon System and in the Inner Detector, using the STACO procedure, as a function of p_T.

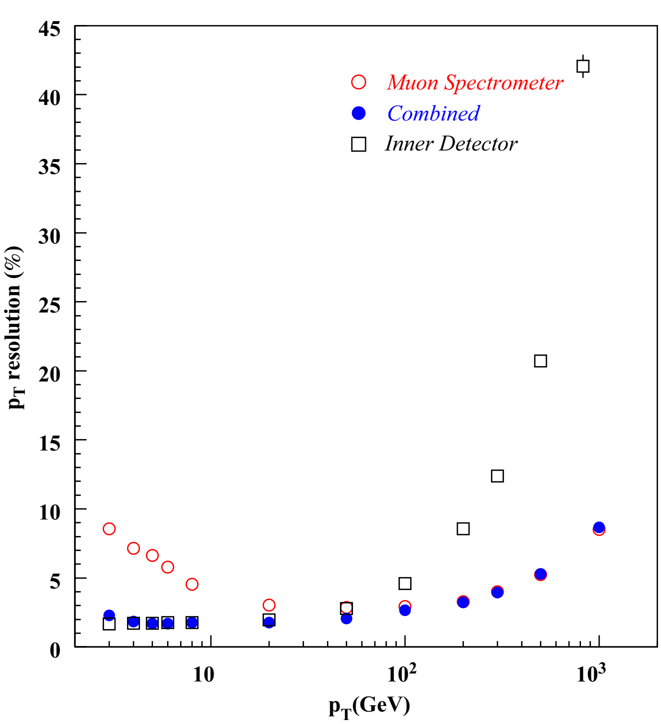

Fig. 1. p_T resolution of track reconstruction in the Muon System and in the Inner Detector, using the STACO procedure, as a function of p_T.

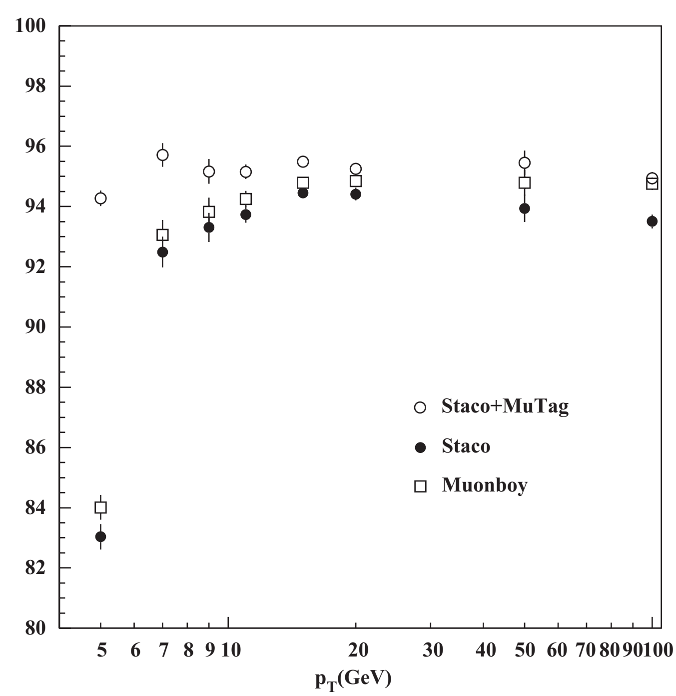

Fig. 3. Efficiency of track reconstruction using MUONBOY, STACO and MuTag as a function of p_T.

resolution are presented in Figs. 1 and 2 for the full p_T range. These results are obtained from detailed Geant4-based simulations.The efficiency of the muon reconstruction decreases very rapidly with decreasing p_T because accurate tracking of low p_T muons in highly inhomogeneous magnetic field is delicate and requires a dedicated algorithm. Furthermore as p_T decreases, the energy lost by the muons inside the calorimeters becomes comparable to their energy, specially in the barrel region. The MuTag algorithm has been developed to tag low p_T muons. The principle is to start from the Inner Detector tracks, extrapolate them to the inner station of the Muon System, and try to match them with a segment reconstructed in these stations not yet associated with a combined track. Other cuts on the segment quality are applied. Fig. 3 shows the MuTag efficiency as a function of p_T. MuTag could improve muon identification up to 96% in the momentum range $5 < p_T < 1000\,\mathrm{GeV}$.

The MUONBOY, STACO and MuTag packages run in the official ATLAS software and their performances results from detailed Geant4-based simulations have been presented.

References

[1] ATLAS Muon TDR, CERN/LHCC/97-22.
[2] ATLAS Detector and Physics Performance TDR, CERN/LHCC/99-14.