A Muon Identification and Combined Reconstruction Procedure for the ATLAS Detector at the LHC at CERN

Theodota Lagouri

Aristotle University of Thessaloniki

&

the MUID/Moore group

2003 IEEE-NSS-MIC

Portland, Oregon, 19-25 October 2003

Outline

- The ATLAS Detector
- Muon Combined Reconstruction method
- Performance on single μ
- Performance on physics channels $Z \rightarrow \mu\mu$,
 $H \rightarrow 4\mu$
- Conclusions

The ATLAS Detector

- General purpose apparatus
- Length of 46 m, diameter of 22 m
- Onion shell structure, two endcaps and one barrel
- Inner tracker, calorimeters, muon spectrometer
- Inner tracker contained in a solenoid (max 2 T), muon spectrometer in a toroid (air core, max 3.9 T for barrel, 4.1 T for endcap)

The Muon Spectrometer

16 sectors in ϕ (small and large)
Instrumented with trigger and precision chambers

Muon bending

- $|\eta| < 1$ from barrel toroid
- $1.4 < |\eta| < 2.7$ from two endcap magnet
- $1.0 < |\eta| < 1.4$ transition region

Design performances

- $\Delta p_t/p_t \approx \text{few \%}$ up to 100 GeV/c
- $\Delta p_t/p_t \approx 10\%$ for 1 TeV/c

Traversing Atlas a μ is detected in

2 high precision tracking systems:
Inner Detector and Muon Spectrometer

EM and hadronic Calorimeters

Muon Spectrometer: best at higher p_T

Calorimeters: E loss $> 3\text{GeV}$

Inner Detector: best at lower p_T

Muon Reconstruction

- **Moore** (Muon Object Oriented REconstruction)
 - reconstruction in the MuonSpectrometer
- **MuonIdentification**
 - Muon combined reconstruction and identification
 - Divided in two parts :
 - MuidStandAlone:
 - Back tracking of the MOORE tracks to the interaction point
 - Muid Comb:
 - Combination of the muon and the inner detector tracks
- Both work in ATHENA (= the ATLAS reconstruction framework)

Muon Spectrometer Strategy for Pattern Recognition

- Software MOORE (Muon Object Oriented REconstruction)
- Identification of regions of activity in the ϕ -projection and RZ-projection
- Reconstruction of local straight track segments in the bending plane using the MDT hits
- Track segment combination
- Track fit
 - Multiple scattering and energy loss in the dead matters of the Muon System taken into account
 - track parameters ($a_0, z_0, \phi, \cot\theta, 1./pt$) are expressed at the first measured point.

MDT multilayer

Muon Combined Reconstruction Strategy

- MuonIdentification (MUID)
- Backtracking from Muon System down to beam region
 - multiple scattering parameterised as scattering planes in calorimeters
 - energy loss from truth, or from Calo Reconstruction, or from parametrization as function of (η, p)
 - Refit: muon track parameters expressed at vertex
- Muon/ID tracks matching with a χ^2 cut-off
 - χ^2 based on track covariance matrices and on the difference in track parameters
- Combined track fit

Moore Architecture

- ✱ Pattern recognition is divided in several steps.
- ✱ Each step is driven by an Athena top-algorithm
- ✱ Algorithms indepent, imply less dependencies, code more maintainable, modular, easier to develop new reconstruction approaches

Basic idea:
Separation of the
algorithmic classes
from data objects

Algorithms

MooAlgs

MooMakePhiSegments

MooMakeRZSegments

MooMakeRoads

MooMakeiPatTracks

MooStatistics

MooMakeNtuples

Moore Objects

RPC/TGC digits

PhiSegments

MDT digits

CrudeRZSegments

MooRoads

MooiPatTracks

Ntuples

MUID Architecture

Single μ performances

Efficiency vs p_T

Rather good agreement with
Physics TDR results

- Plateau efficiency $\sim 95\%$
- Low efficiencies @ low p_T
 - Only μ with $E > 3-4$ GeV reach the Spectrometer
 - Few measurements
 - Multiple scattering and magnetic field effects are dominant $\rightarrow$ pattern recognition more difficult
- Combined efficiency @ high p_T
 - Pattern recognition perturbed by possible em shower accompanying high p_T muons

1/Pt Resolution vs Pt

- The Inner Detector measurements dominate the combined transverse momentum below 10 GeV/c
- The Muon System dominate at high p_T

Efficiency vs η

- Loss at low η due to the Muon Spectrometer central crack
- 2nd coordinate of CSC missing in simulation $\rightarrow$ low efficiency at $|\eta| > 2$
- Tracking in the high inhomogeneous field in the transition region $\rightarrow$ low efficiency in the range $1 < |\eta| < 1.5$ for low pt muons

Uniform efficiency vs phi

$Z \rightarrow \mu\mu$

5000 events

Backtracking $\rightarrow$
mass correction

Combination $\rightarrow$
mass resolution
improvement

Phy TDR $\sigma = 2.5 \text{ GeV}$

H → 4μ

- H → 4μ (with m_H = 130 GeV)
~ 10 K evt.

Reconstruction with Muon Spectrometer Standalone
(Moore + MUID Standalone)

Combined Reconstruction
(Moore + MUID + iPat)

Without Z constraint

Phy TDR $\sigma = 2.7 \text{ GeV}$

Without Z constraint

Phy TDR $\sigma = 1.6 \text{ GeV}$

Conclusions

- Muon reconstruction at ATLAS is very challenging
 - Muon System very large and complex → extrapolation uncertainties
 - Rather inhomogeneous Magnetic Field
 - Precise propagation required
 - Problems at low pt
 - High level of background
 - OO software for ATLAS muon Reconstruction has been developed
 - For standalone Muon Spectrometer reconstruction (Moore)
 - For muon combined reconstruction (Muid)
 - Performances have been tested
 - For single μ
 - For physics channels
- Alternative tracking methods to be inserted in Moore (e.g. Kalman Filter) and optimize efficiency for low energy muons (use of muon signal in TileCal) are under development