Calibration of the ATLAS Muon Spectrometer Precision Chambers for Initial LHC Beam Collisions

Haijun Yang

University of Michigan, Ann Arbor
on behalf of the ATLAS Collaboration

ATL-MUON-SLIDE-2010-091
27 May 2010

2th Topical Seminar on Innovative Particle
and Radiation Detectors (IPRD10), Siena, Italy
June 7-10, 2010

Outline

- ATLAS Muon Spectrometer
- Muon calibration constants for muon reconstruction
- Determine muon drift tube timing offsets (T_0) using beam splash events
- Determine time-to-space (RT) function using gas monitor chambers
- Validation of the calibration constants
- Conclusion

ATLAS Detector

ATLAS Muon Spectrometer

1) Subsystem

- **MDT** chambers are used for precisely measurement, with $< 100 \mu\text{m}$ precision; Barrel: BI, BM, BO; Endcap: EI, EM, EO
- **CSC** chambers exist in high- η ($|\eta| > 2.0$) region of the innermost station to cope with high rate measurement
- Trigger chambers: **TGCs** and **RPCs** (second coordinate measurement)
- Coverage $|\eta| < 2.7$

- 2) The momentum resolution is typically $\sim 3\%$ over most of the p_T ranges; at $p_T = 1 \text{ TeV}$ it is expected to be 10%.
(error dominated by calibration and chamber alignment)

Muon MDT Calibration Constants

- MDT time offset (T0s) for each tube; initially, for each MDT chamber
- MDT response function (RT) & MDT resolution function

Drift Time Spectrum

RT function curve

Single Proton Beam in ATLAS (Nov. 2009)

- Beam “splash” events with closed collimators
 - Beam 1 from ATLAS A side
 - Beam 2 from ATLAS C side
- All detector components were getting hits → Occupancy ~100%

Beam Splash Events

Beam intensity: $\sim 2 \times 10^9$ protons/bunch

MDT chamber occupancy $\sim 95\%$

Recorded hits in projections of ATLAS Detector

Beam Splash, Nov. Runs 140370/477/536

Find Time Offset From Beam Splashes

- 1) Use combined beam splash runs:
 - 35 events for beam1 ($A \rightarrow C$)
 - 59 events for beam2 ($C \rightarrow A$)
- 2) Analyze time spectra from Beam1 and Beam2 separately
- 3) Use moving average to smooth spectrum & find peak
- 4) Raw T0 is taken as TDC time for the bin which has 5% magnitude of the peak

Beam splash MDT TDC Spectra

Geometric Correction for Collision

(Calculate T0 from Beam Splash Raw T0)

Geometric correction:

$$\Delta T = (BO - BD) / c \text{ (c=speed of light)}$$

$$T0_{\text{raw}} = BD / c - \text{CTP}$$

$$T0 = BO / c - \text{CTP}$$

$$T0 = T0_{\text{raw}} + \Delta T$$

Compare T0's from Beam1 & Beam 2

T0 Difference (ns)	# of Chambers	Percentage
< 5	698	62.77%
< 10	888	79.86%
< 20	1029	92.54%
> 20	83	7.46%

Comparison T0's obtained in Nov. 2009 and in Feb. 2010 Using Beam Splash Events

2010 Beam Splash T0s are systematically ~100ns smaller than 2009
Beam splash T0s → due to LHC trigger 4 ticks shift (100ns)

Determine RT Using Gas Monitor Chamber

P= 3 bar with standard MDT gas mixture: 93% Ar, 7% CO₂

Monitor Max. Drift time

Max. drift time has large variation which is sensitive to RT. It is determined by fit the TDC spectrum. Update RT every day.

$T_{\max}$ vs. Pressure, Temperature

RT for each MDT chamber is corrected by Pressure and Temperature

MS Segment Reconstruction

(with calibration constants)

Using the time offset (T0s) and RT to determine the drift distance (circles) of each hit for track fitting

Validation of Muon Calibration Constants

- Using beam collision muons to validate the T0s obtained from beam splash events.

~14 ns global offset of T0
from beam splash events

MDT Hit resolution ~ 142 μm

Validation of Muon Calibration Constants

Using beam collision muons to validate the T0s obtained from the beam splash events and RT function using gas monitor chamber.

MDT Segment resolution ~ 90 μm

Segment residual vs drift radius

Validation with 2010 collision data, both residual distribution and residual vs. drift distance plots show that the calibration constants are accurate

Segment Track Fit Residuals

MDT segment track fit resolution $\sim 90 \mu\text{m}$

Validation using $J/\psi \rightarrow \mu^+\mu^-$ Mass Spectra from 7 TeV Data

$J/\psi \rightarrow \mu^+\mu^-$ mass spectra can determine muon momentum or energy scale at low Pt region.

Event are selected with at least one muon reconstructed by both inner tracker and MS.

mass = 3.103 ± 0.004 GeV
resolution = 46 ± 3 MeV

It indicates that the initial muon calibration constants are valid.

Conclusions

- ATLAS Muon MDT Calibration constants time-offset (T0's) have been determined by using beam splash events with an accuracy ~ 3 ns.
- The universal MDT RT function has been determined by the gas monitor chamber. This function has been used in muon reconstruction with temperature and pressure corrections for each MDT chamber.
- Using the muon tracks from the initial LHC beam collisions, the MDT calibration constants have been validated $\rightarrow$ the tracking residual $\sigma \sim 90 \mu\text{m}$.