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Calibration Study on a Prototype of the Muon Telescope Detector at STAR of RHIC

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Calibration Study on a Prototype of the Muon Telescope Detector at STAR of RHIC

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Abstract

Calibration Study on a Prototype of the Muon Telescope Detector at STAR of RHIC

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A prototype of the Muon Telescope Detector (MTD) was installed at STAR (Solenoidal Tracker at RHIC) during run year 2007. While the cosmic and beam tests showed a ~ 60 - 70 ps timing resolution for MTD, the actual performance in Au + Au collisions at STAR was found ~300 ps. In run year 10 STAR implemented a new electronics system for MTD and a cosmic ray trigger to study the performance of its several subsystems. With the cosmic ray data, this study shows that the timing resolution of MTD can reach 99 ps after a full calibration.

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A prototype of the Muon Telescope Detector (MTD) was installed at STAR (Solenoidal Tracker at RHIC) during run year 2007. While the cosmic and beam tests showed a ~ 60 - 70 ps timing resolution for MTD, the actual performance in Au + Au collisions at STAR was found ~300 ps [2]. One reason for this is that the electronics used for the MTD in run year 2007 and 2008 is for generic trigger purpose, rather than specifically designed for precise time measurement needed for MTD. Another reason is that there are a lot of hadron backgrounds in physical collisions due to the interactions between the outgoing particles after collisions and the detector materials [2].

In run year 10 STAR implemented a cosmic ray trigger to study the performance of its several subsystems, including TPC, MTD, TOF etc. Because the cosmic rays are primarily muons, we were able to get rid of the hadron background from material interactions in the MTD analysis, as seen in previous studies with data from physical collisions. Also the cosmic ray data offers us significant amount of muon tracks with pt > 2 GeV/c, and these high momentum particles have less interaction with the materials than the lower momentum particles therefore we can calculate the tracking information more precisely.

The experiment setup is as follows: A sketch of the whole STAR detector is shown in Fig. 1. TPC, the Time Projection Chamber, is the main tracking detector with inner and outer field cage radii of 50 cm and 200 cm respectively from the axis of the STAR detector. Its length is 4m along the beam axis and the azimuth and pseudo-rapidity coverages are 2pi and |eta| < 1.8 respectively. It provides us the paths and momenta for the outgoing particles as well as the ionization energy loss (dE/dx), which can be used for particle identification. Outside the TPC is the TOF (Time-Of-Flight) detector based on the Multi-gap Resistive Plate Chambers (MRPC) technology, which covers 2pi in azimuth and |eta| < 1 in pseudo-rapidity and has an outer radius of ~ 220cm from the STAR detector axis. This detector was fully installed in 2010 and its < 100 ps timing resolution enables us to extend particle identification to pt ~ 3 GeV/c for p and pbar. A full barrel electromagnetic calorimeter (BEMC) is outside TOF with a full azimuth coverage and |eta| < 1 pseudo-rapidity coverage. The solenoidal magnetic field in TPC is provided by the magnetic coils and the flux returns via a roughly cylindrical magnet steel barrel consisting of 30 flux return bars, 4 end rings and 2 poletips. The flux return bars are 6.85 m long and 60 cm thick with a 363 cm outer radius. The cross-section is trapezoidal and the width at the outer radius is 57 cm.

Since RUN 9 p+p 200 GeV period a new prototype of MTD has been installed outside the STAR magnet steels at a radius ~ 400 cm from the STAR detector center and used to take data at STAR. It is one tray with 3 long MRPC modules and each module has 6 strips. The design of an MRPC module prototype can be seen in Fig. 2 and [2]. There are two read-outs for each strip, from the east side and west side respectively. This prototype utilized the same electronics as that for TOF in order to achieve a better timing resolution than that from trigger electronics.

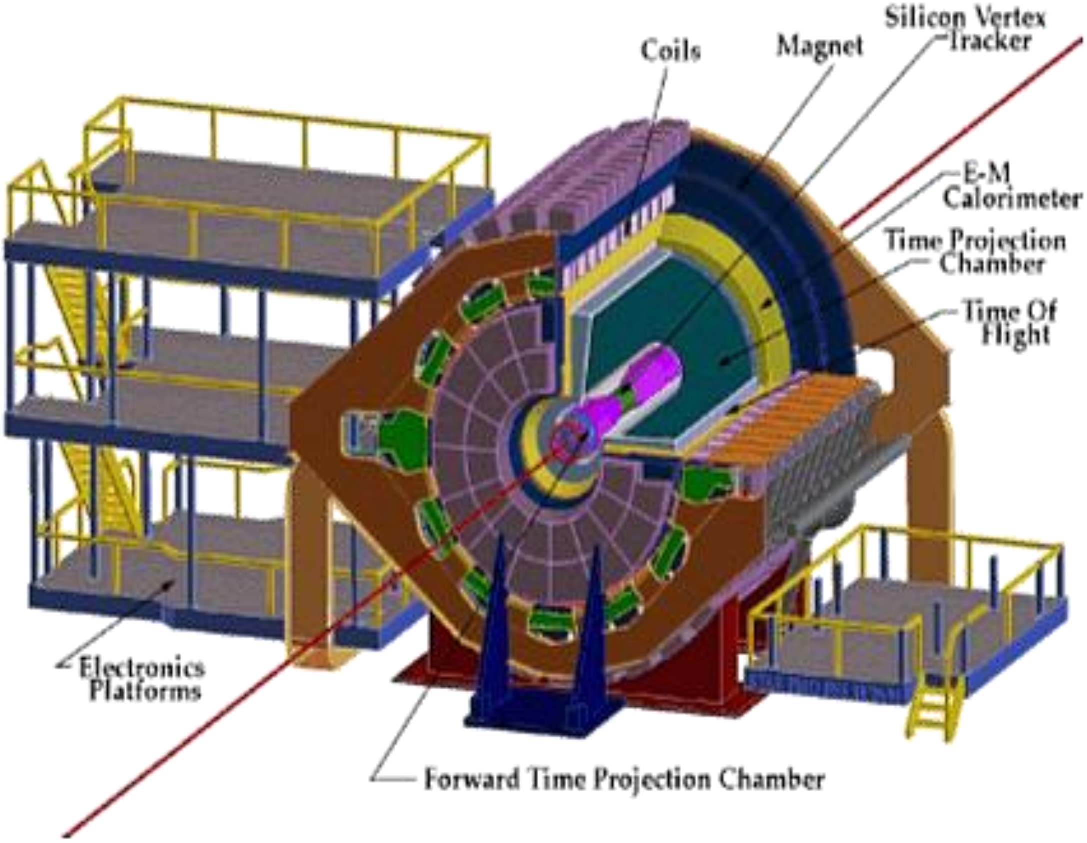

Fig. 1 Perspective view of the STAR detector, with a cutaway for viewing inner detector systems. The trigger barrel, shown in this figure, was fully replaced by the TOF detector in year 2009. The figure is taken from the STAR website and can also be found in [1].

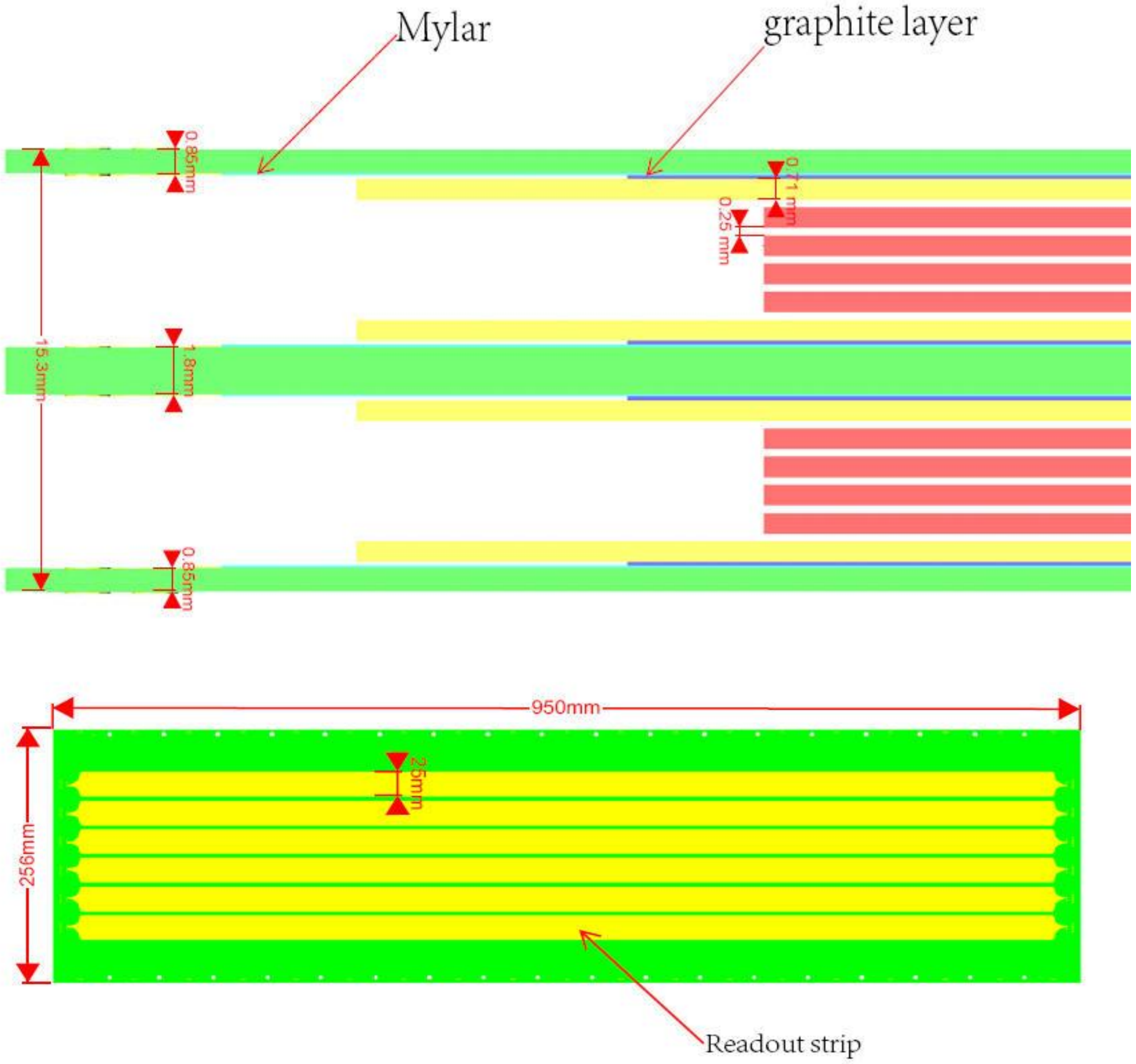

Fig. 2 Side view and top view of an LMRPC module prototype

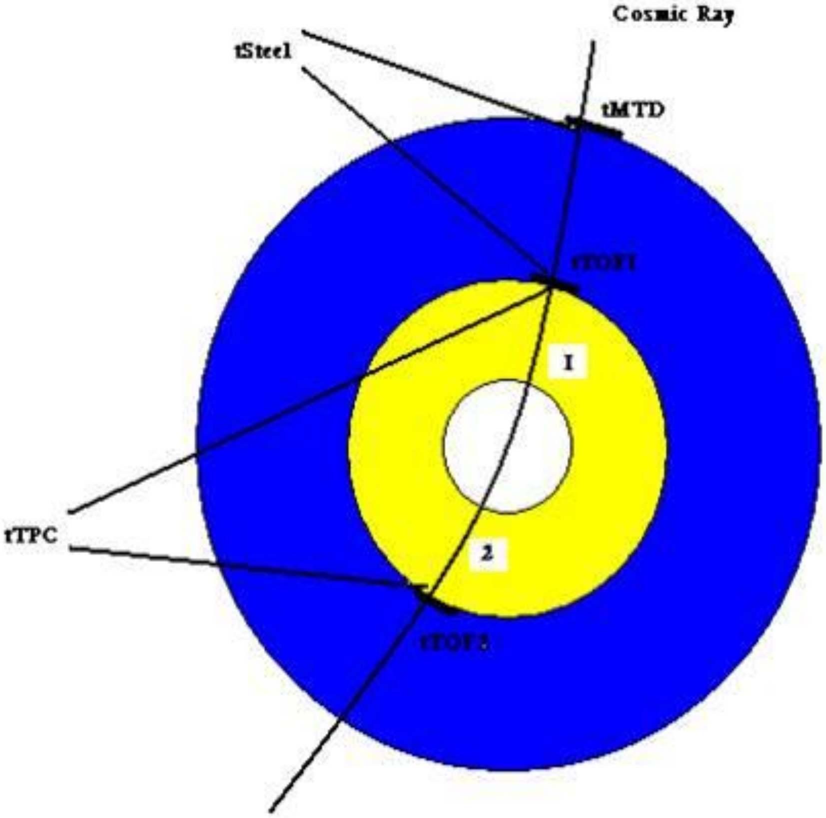

Fig. 3 A sketch of a cosmic ray event in the STAR detector

The data we used are from cosmic ray triggered events in run year 10 Au+Au 11 GeV production runs. With the global tracks from these events, first we do the track matching by 3 steps. The matching between 2 halves of a muon track in TPC requires nHitsFit >14, |eta| < 1.5 and p > 1 GeV/c for each half and |p1-p2|/p1 < 0.27, where p1 and p2 are the momenta for the two halves. Fig. 4 shows the histogram for the quantity |p1-p2|/p1. The next step is raw matching for the TPC tracks. The requirements are nFitPoints >= 25, Pt >= 2.0 GeV/c, TpcZ < (0.0+zMargin) && TpcZ > (-mrpcLength-zMargin), TpcPhi > 0.419 && TpcPhi < 0.628, where Z is the position along the beam pipe and an MTD strip, TpcZ and TpcPhi are extrapolated Z and Phi values for a track from TPC and zMargin = 100 cm. Finally we do the matching between the TPC tracks and the MTD hits, requiring |TpcZ-MtdZ| < 6 cm and |TpcPhi-MtdPhi| < 0.2. MtdZ is from the timing difference between 2 ends of a strip and MtdPhi is from the center of the fired MTD strip. The position resolutions along Z and Phi directions after matching are 2.5 cm and 0.006 rad respectively, as shown in Fig. 5 and Fig. 6. The energy loss as a function of momentum after matching is shown in Fig. 7 and a clear muon band can be seen.

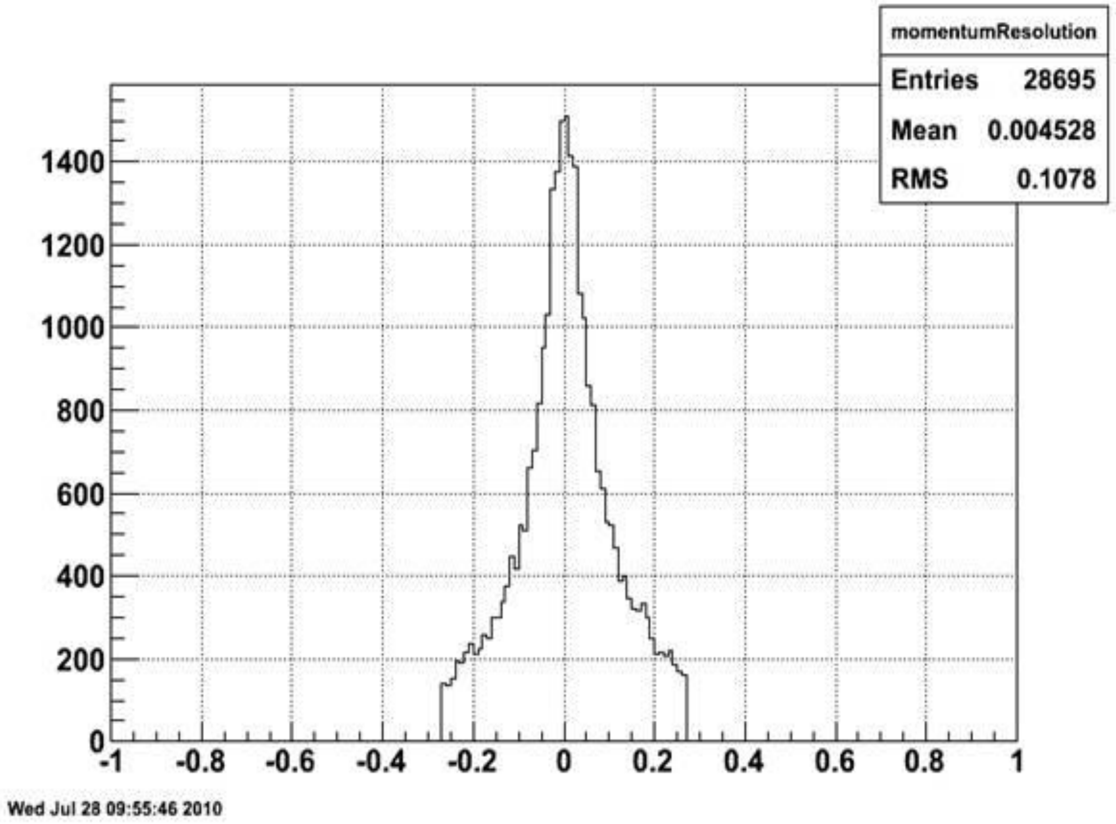

Fig. 4 The momentum difference between the 2 halves of a cosmic ray in the STAR TPC

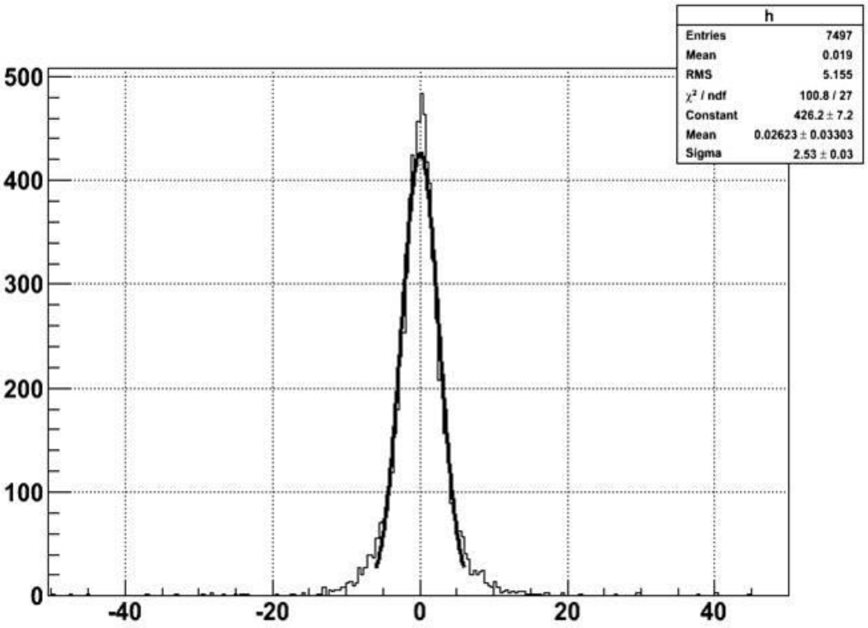

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Fig. 5 The position resolution along Z direction

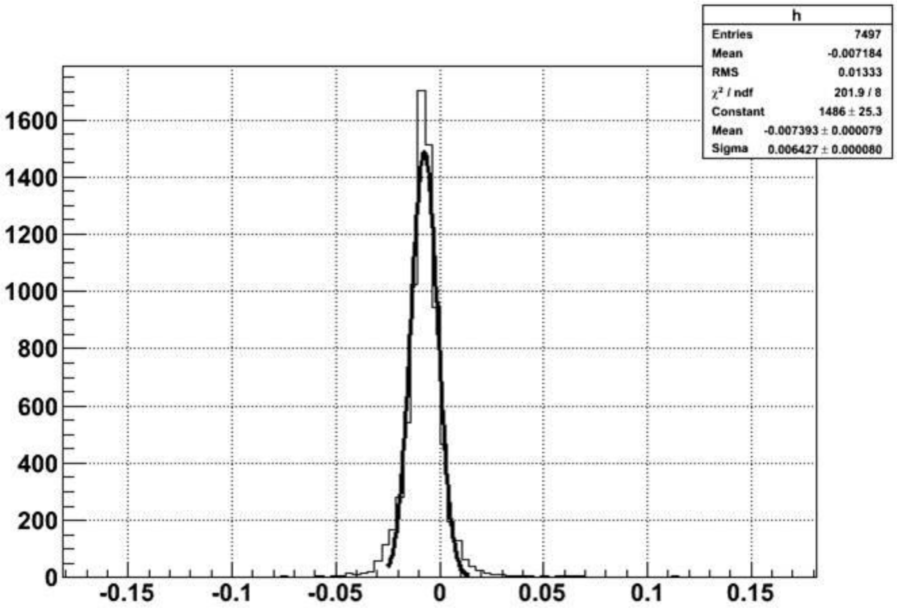

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Fig. 6 The position resolution along Phi direction

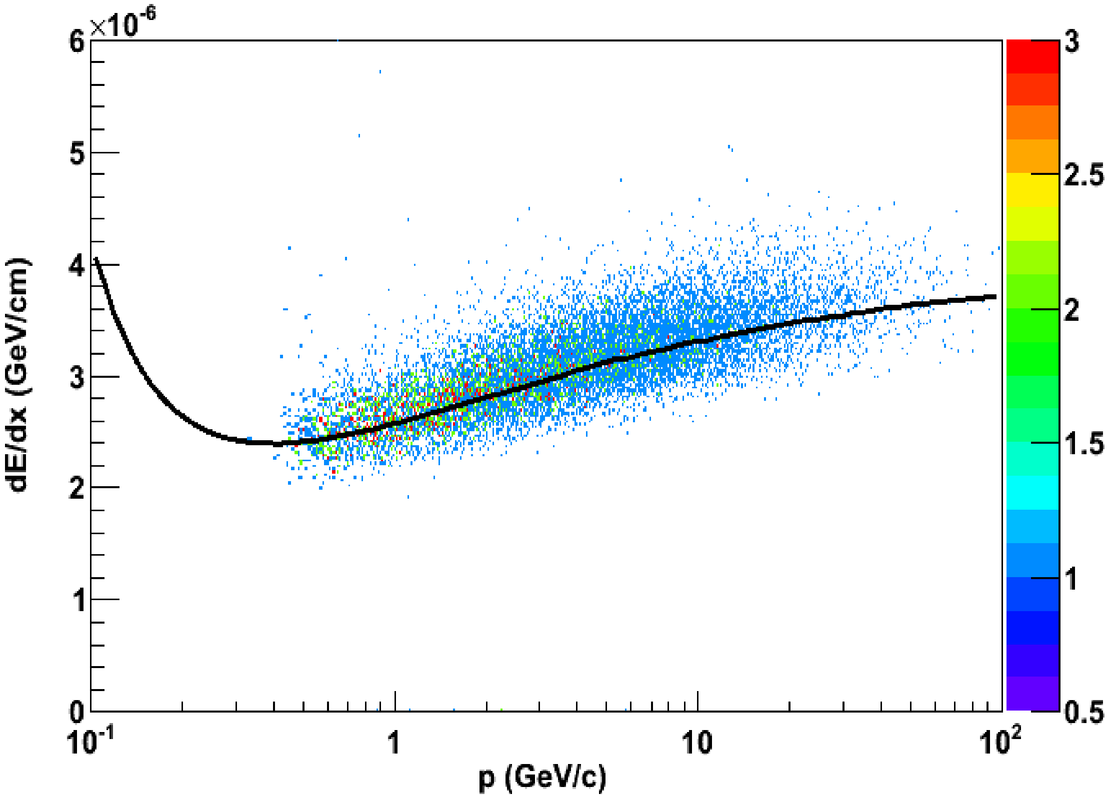

Fig. 7 Energy loss in TPC as a function of momentum

To measure the time of flight in the STAR detector for a cosmic ray muon, we need a start time from MTD (tMTD) and a stop time from TOF (tTOF1 and tTOF2). tMTD is calculated by averaging the times from two ends of a strip so that it does not depend on the hit position on the MTD strip. tTOF1 and tTOF2 are calibrated times associated with TOF hits due to the cosmic ray muons. Then we evaluate the quantity deltaT0 = tTOF2-tTOF1-tTPC to investigate the TOF timing resolution, where tTPC is the calculated time of flight between two TOF trays 1 and 2 with the path length and momentum information from TPC. The histogram is shown in Fig. 8 and the timing resolution is 92.9 ps/sqrt(2) ~ 66 ps, which is close to the result in another TOF intrinsic timing resolution study [3]. The time difference between TOF+MTD measured time and TPC measured time is deltaT = (tTOF2-tTPC+tTOF1)/2-tMTD-tSteel, where tSteel is the time of flight from MTD to TOF, also calculated with TPC information. The deltaT histograms are then filled strip by strip.

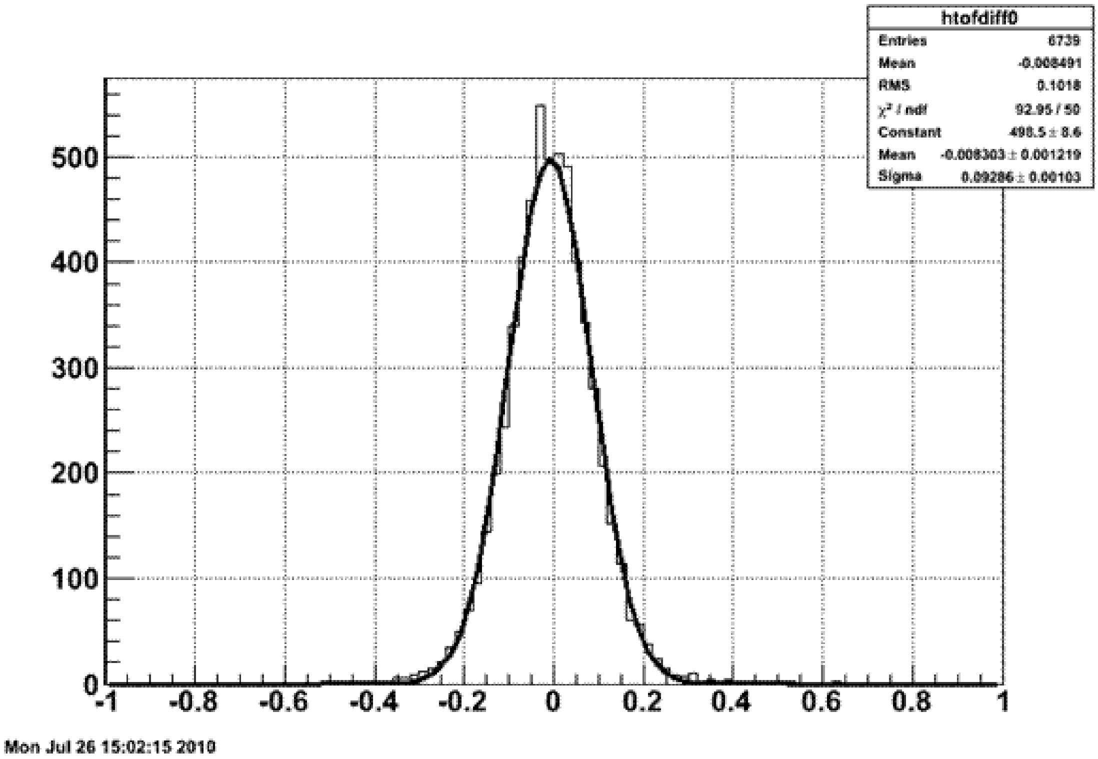

Fig. 8 TOF timing resolution

The calibration is done by 3 steps. First, we did a T0 offset correction for each strip. Basically we fitted the deltaT histograms with a Gaussian function and subtracted the obtained mean value from tMtd. The fitting plots are shown in Fig. 9:

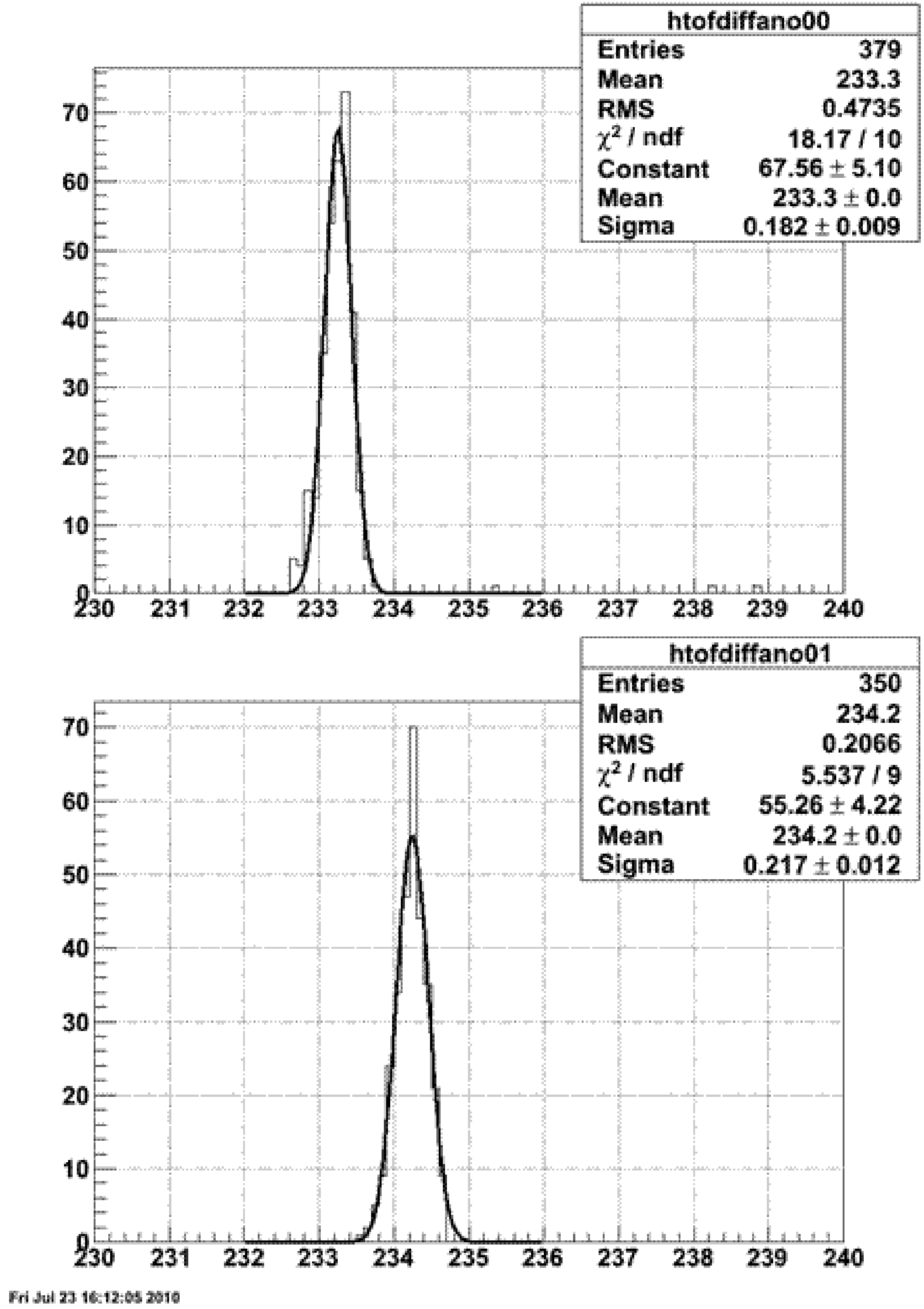

Fig. 9 The first T0 offset correction

Secondly, we combined all channels and plotted deltaT (after T0 calibration) versus averageTOT=sqrt(totMtdEast*totMtdWest). The slewing correction curve is obtained by a 4th order polynomial function fitting the Gaussian mean deltaTs for all averageTOT bins. Then the slewing correction is done by subtracting the function value from tMtd according to its averageTOT value. The slewing correction curve is shown in Fig. 10:

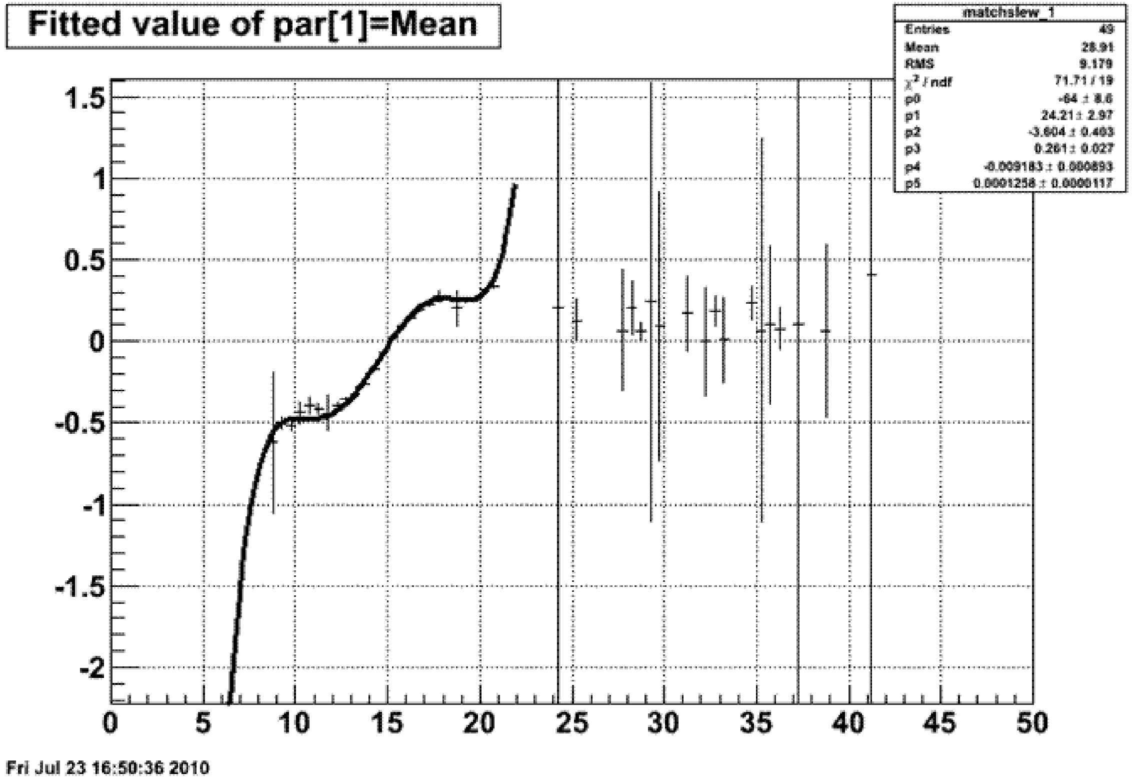

Fig. 10 The slewing correction

A second T0 correction is done thereafter due to the observed T0 shift after the slewing correction and the plots are shown in Fig. 11:

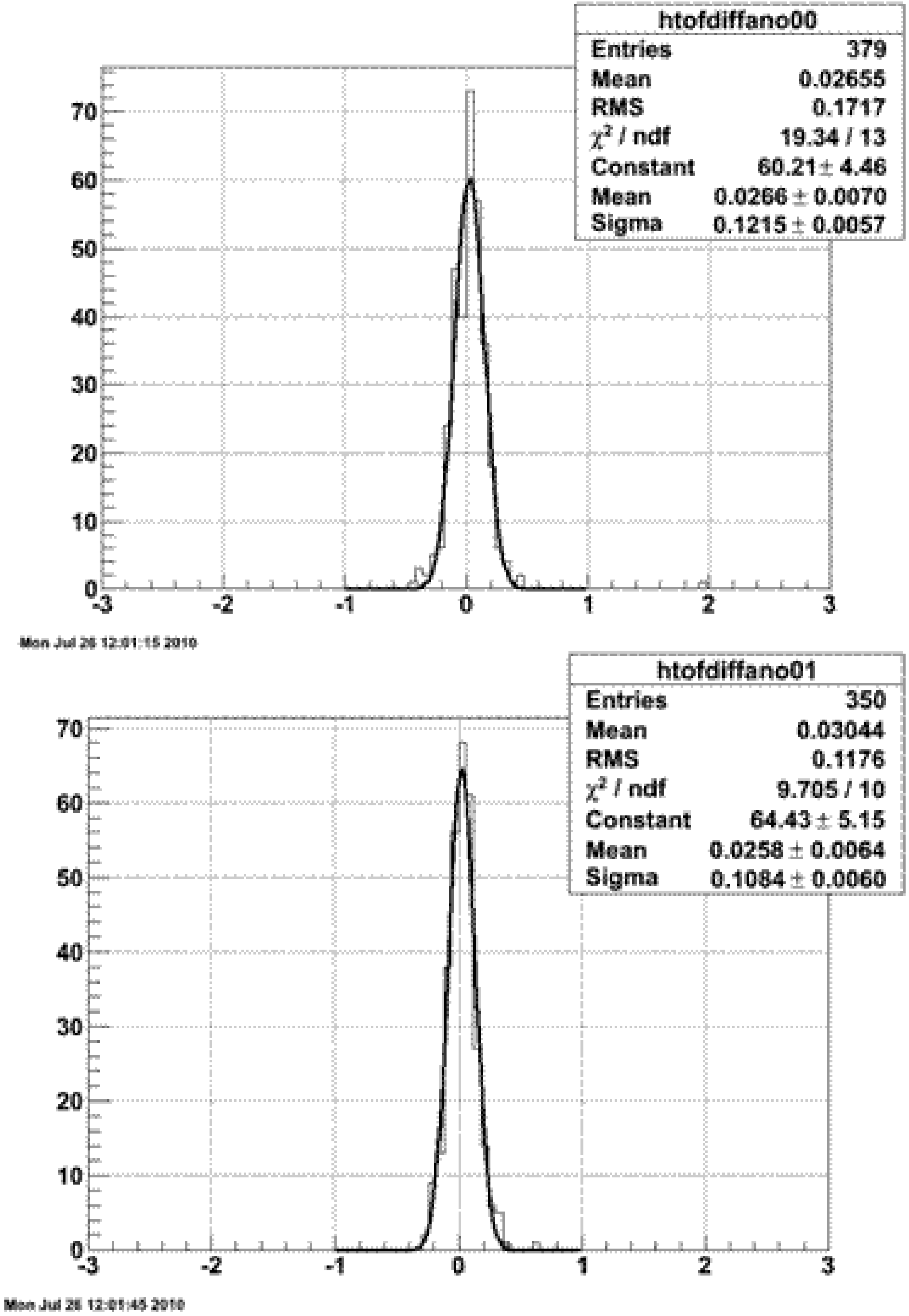

Fig. 11 The second T0 offset correction

Combining all strips and doing a single Gaussian fit to the deltaT histogram gives a final MTD+TOF timing resolution ~109 ps as shown in Fig. 12. This means the timing resolution for MTD alone is 99 ps.

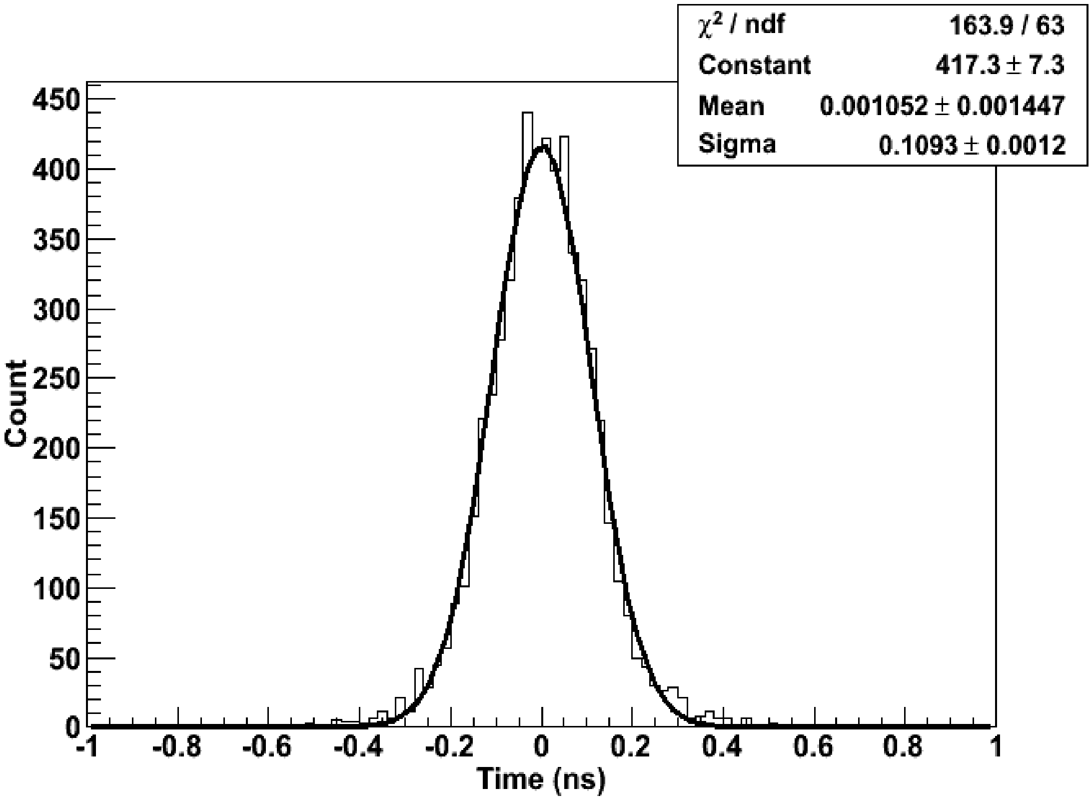

Fig. 12 The timing resolution for the MTD+TOF system

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Vita

Liang Li was born in Qingdao, Shandong, China. After completing his work at No.1 High School of Jimo, Jimo, Qingdao, Shandong, China, in 2002, he entered University of Science and Technology of China in Hefei, Anhui, China and received the degree of Bachelor of Natural Science there in 2006. In August 2007, he entered the Graduate School at the University of Texas at Austin.

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