Status of TOF Section in Performance Paper

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Outline of the section

- Introduction
- Calibration Method
- Reconstruction
- Performance

- Goal is to have 3.5-4 pages

Overall Status

- 1st 3 parts populated with text
- Not really readable
- A few content-related issues

Outline

- Introduction
- Calibration Method
- Reconstruction
- Performance

Introduction

Outline

- **Introduction**
- Calibration Method
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- Should be a short paragraph or two reminding the purpose of the system and outlining what will be described in the following subsections
- Do we need more detailed description of the hardware?
- There is some description in the NIM paper: "The design and commissioning of the MICE upstream time-of-flight system" NIMA 615 (2010) 14-26
- Current text is relatively detailed

1.1 Introduction

Three time-of-flight detectors (TOF0, TOF1, TOF2) have been built and installed at RAL in 2008 and 2009 to measure the position and the time of crossing particles. TOF0 and TOF1 [?], [?], [?] are placed upstream of the cooling channel, and TOF2 [?] is downstream of the channel, mounted in front of the KL, as shown in Fig. ??. The time of flight between two TOF stations provides particle identification information and can also be used for momentum measurement. TOF1 served most of the time also as an experimental trigger. They have smoothly operated during the so-called Step I and Step IV [?], [?] running periods of the MICE experiment and were essential for all the measurements done.

The good performances of the TOF detectors, over an extended period of time, has enabled the MICE experiment to characterize fully its muon beams during Step I data-taking, by measuring their emittance [?] and assessing their pion contamination [?].

Each TOF station is made of two planes of fast 1" thick scintillator counters along X/Y directions (to increase measurement redundancy) read out at both edges by R4998 Hamamatsu fast photomultiplier tubes[1]. R4998 PMTs have been delivered by Hamamatsu in assemblies (H6533MOD) that include the PMT tube, the voltage divider chain and a 1 mm thick μ-metal shield, extending 30 mm beyond the photocathode surface. TheTo increase the count rate stability active dividers were used, instead of conventional resistive ones. A

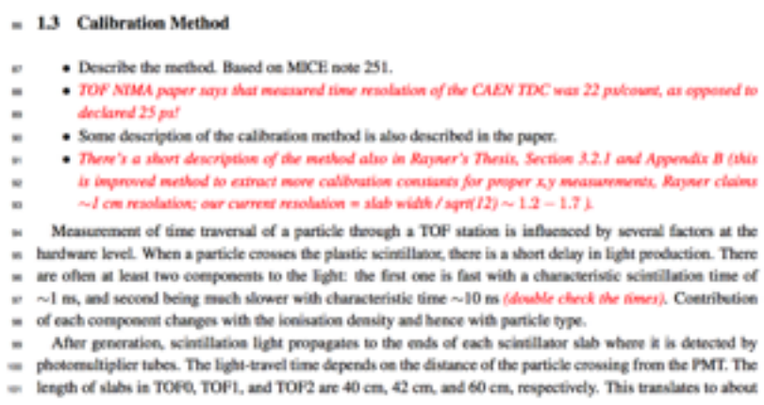
[1] one-inch linear focused PMTs with 10 stages, typical gain G~5.7×10^6 at -2250 V and B=0 T, rise time 0.7 ns, transit time spread (TTS) ~160 ps

Calibration

Outline

- Introduction
- **Calibration Method**
- Reconstruction
- Performance

- Should describe how we calibrated TOF-s time-wise
  - Should be reasonably detailed but not too much
  - Difficult to do as the method is relatively complex
- Current text:
  - collection of thoughts pasted in
  - divided into four parts
    - overview
    - time walk
    - trigger signal delay
    - individual PMT signal delay, a.k.a T0



1.3 Calibration Method

- Describe the method. Based on MICE note 251.
- *TOF NIMA paper says that measured time resolution of the CAEN TDC was 22 ps/count, as opposed to declared 25 ps!*
- Some description of the calibration method is also described in the paper.
- *There's a short description of the method also in Rayner's Thesis, Section 3.2.1 and Appendix B (this is improved method to extract more calibration constants for proper x,y measurements, Rayner claims ~1 cm resolution; our current resolution = slab width / sqrt(12) ~ 1.2 – 1.7).*

Measurement of time traversal of a particle through a TOF station is influenced by several factors at the hardware level. When a particle crosses the plastic scintillator, there is a short delay in light production. There are often at least two components to the light: the first one is fast with a characteristic scintillation time of ~1 ns, and second being much slower with characteristic time ~10 ns *(double check the times)*. Contribution of each component changes with the ionisation density and hence with particle type.

After generation, scintillation light propagates to the ends of each scintillator slab where it is detected by photomultiplier tubes. The light-travel time depends on the distance of the particle crossing from the PMT. The length of slabs in TOF0, TOF1, and TOF2 are 40 cm, 42 cm, and 60 cm, respectively. This translates to about

Reconstruction

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- Should describe how we reconstruct space points
- Should be brief and comprehensible
- Main points:
  - time is an average of 4 PMTs
  - space point created by matching 2 crossing slabs

1.4 Reconstruction

- slab hits - must have PMT over threshold on both sides
- only first recorded hits in the readout (per trigger) are considered
- times corrected for TW, TrigT and T0
- corrected slab time is the average of corrected times of each PMT
- "Space Point" (SP) is created for each combination of 2 cross slabs where the corrected slab times fall within *3 ns*.
- coordinate of the SP is placed in the middle of the station along the beam axis (where the two slab planes touch each other) and in the center of the slabs in the transverse direction.
- the time of the SP is the average of the slab times of the slabs it was reconstructed from.

Recorded signals in all PMT channels are processed in the following way. First, signals in opposite PMTs of a slab are paired. Recorded times are corrected for time walk, channel delay T0, and for the delay of the trigger signal. This requires that the trigger pixel in TOF1 station is determined.

Pixel area where the particle crossed the station is searched by attempting to match all possible combinations of slab signals in each plane. Transverse slabs are matched if their corrected times fall within a 4-ns window. A space point is then created with spatial coordinates centered at centre of the pixel in the transversal direction and middle of the station in the longitudinal direction. Time of the space point is calculated as an average of the times of each slab.

Performance

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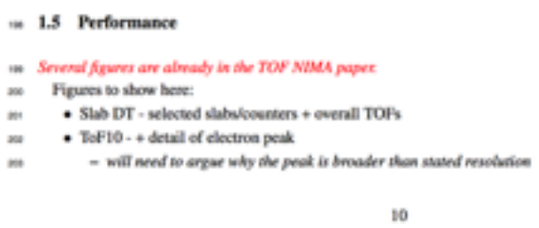

1.5 Performance

Several figures are already in the TOF NIMA paper.

Figures to show here:

- Slab DT - selected slabs/counters + overall TOFs
- ToF10 - + detail of electron peak
  - *will need to argue why the peak is broader than stated resolution*

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- Should describe how well the system performs
- Main points:
  - performance within each TOF station - Slab DT
  - performance of relative t-o-f measurement - position and RMS of electron peak
  - space-point creation efficiency/purity
  - ideally: crossing particle detection/reconstruction efficiency - will not happen

Outstanding Issues - I

- Systematic uncertainties
  - of time measurement of each TOF
  - relative measurement (some systematic errors are correlated)
- Don’t have final plots
  - final calibrations have not been checked through out all data taking periods
  - data has not been re-calibrated

Outstanding Issues - II

- Concern about precision of CAEN TDC boards
  - claimed nominal 25 ps/LSB
  - NIMA paper* says 22 ps/LSB was observed in one of tested boards
  - Maurizio said he would look into that after mid-September

* NIMA 615 (2010) 14-26

General Issues

- Usage of MICE's lingo: pixel, space point, slab, TOF
- How do we state spatial resolution of TOFs?
  - 1/2 width of a slab
  - or $1/\sqrt{12}$
- What will be the text formatting? How much can I expect the text to shrink?