Analysis of the August 2004 NA48/2 Kabes Test Beam Data

Draft Version

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Peter Cooper, Massimiliano Fiorini, Hogan Nguyen, and Martin Wache

Introduction

In the summer of 2004, Augusto Ceccucci, on behalf of the NA48 collaboration, invited members of the CKM collaboration to take part in a test beam exercise to study the NA48/2 Kabes performance at high rate. It was recognized that the Kabes detector[1], built by the NA48/2 Saclay group, is a promising technology for future kaon experiments where beam tracking in a high rate environment is desired. Peter Cooper and Hogan Nguyen went to CERN and collaborated with Massimilliano Fiorini and Martin Wache.

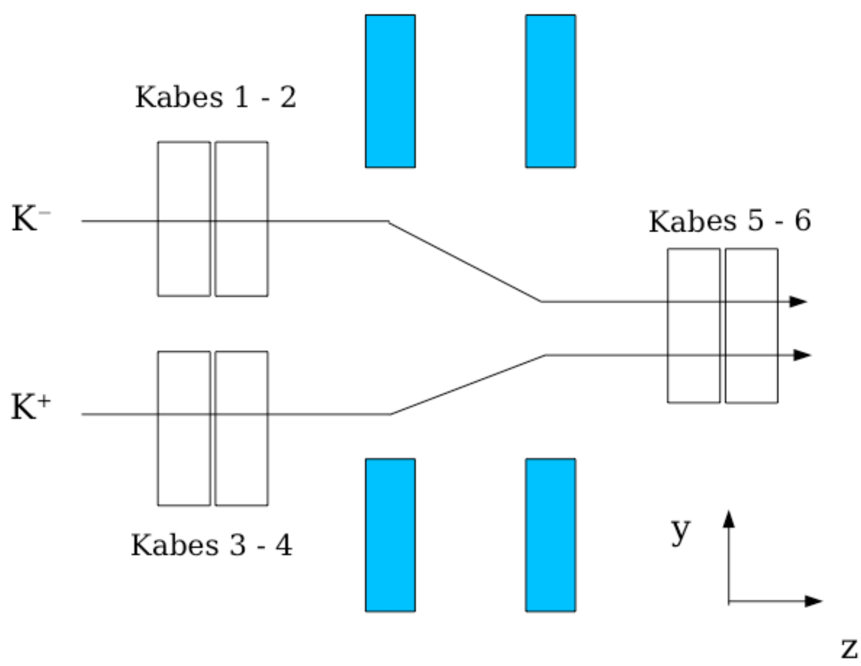


Figure 1: Kabes Layout

[1] Bernard Peyaud, Contribution to the VCI 2004 Conference.

The NA48/2 apparatus consisted of 6 Kabes chambers as shown in figure 1. Positively charged tracks traverse chambers 3, 4, 5, and 6. Negatively charged tracks traverse chambers 1, 2, 5, and 6. The upstream chambers are defined as chambers 1-4. The downstream ones are 5 and 6. The bend and drift views are in the *y* and *x* directions respectively. The drift directions for chambers 1-6 are respectively, $+x$, $-x$, $+x$, $-x$, $-x$, and $+x$. The micromegas gap is 50 μm for chambers 1-4. The gap for chambers 5 and 6, which was 50 μm during the NA48/2 program, was reduced to 25 μm for this test beam exercise. This gap change reduces the chamber time resolution and pulse width. There are 48 anode strips per chamber, and the signals were amplified, discriminated, and digitized with 1-nsec-resolution TDC's. The amplified signals of the central 8 strips of chambers 1,2, 5, and 6, were also sent to 500 MHz FADC's.

Chambers 1 and 2, 3 and 4, 5 and 6 form complementary pairs. In a complementary pair, a track will deposit charge on similar strip numbers. If the track is intime with the trigger, the sum of time of the hits from that track is a constant within resolution.

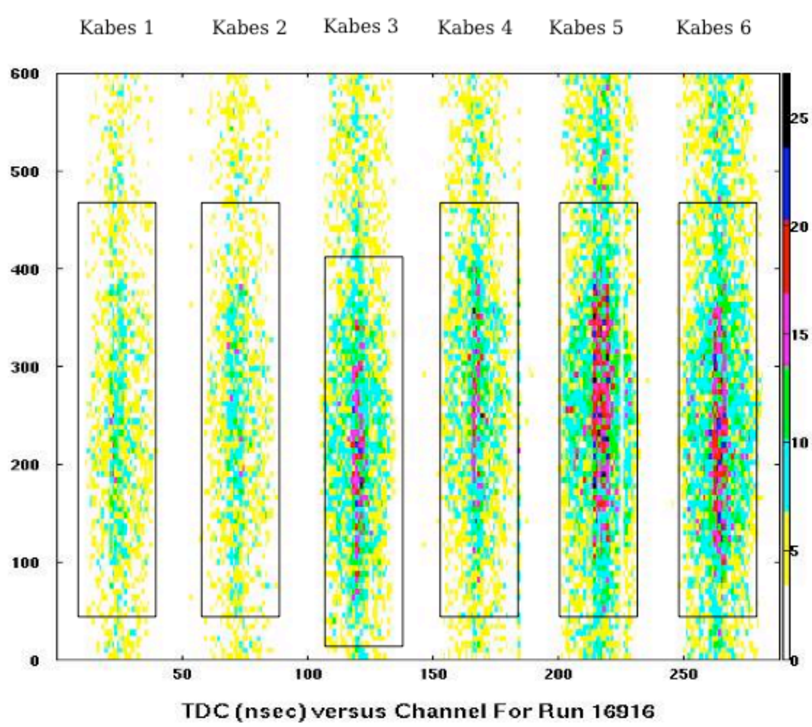


Figure 2: TDC hits versus channel number. Boxes denote intime hits.

The beam intensity varied from below the nominal NA48/2 intensity[2] to 9*x* the nominal intensity. During these runs, typically only one charged sign was present. The analysis presented here uses primarily the TDC information. With low and nominal intensity runs, we measure basic quantities such as chamber efficiencies, time resolution and the dependence on the pulse width, and strip multiplicity. We attempted to measure the same quantities for high intensity runs. This was not always possible, but we present some comparisons for low versus high rate runs.

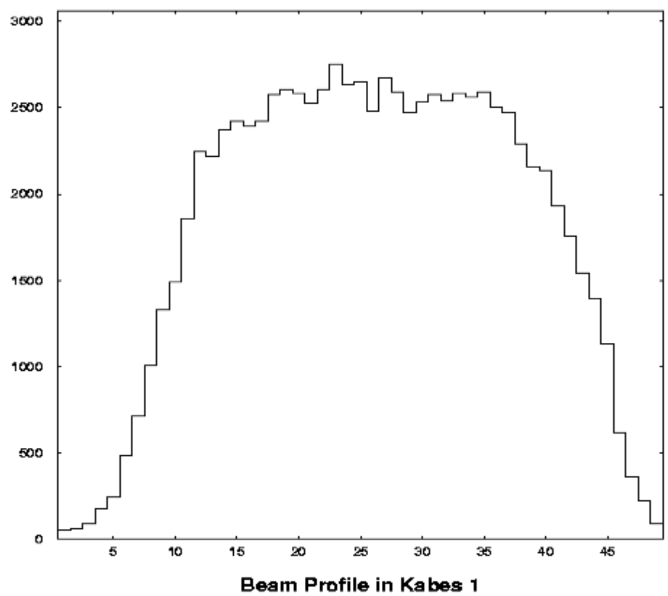


Figure 3: Beam Profile in Kabes 1. The anode strip pitch is 800 μm.

Raw Distributions

Figure 2 shows the leading edge TDC distributions for run 16916, which was at or below nominal intensity. The hit times are measured relative to an external timing signal that approximated the exact event time. The exact event time could be extracted from the hit time of the main NA48/2 scintillation counters. The boxes define the intime hits. Figure 3 shows the beam profile of intime hits in Kabes 1 where the strip pitch is 800 microns. The beam profile in the bend view is about 40 strips, or 3.2 centimeters wide.

[2] Nominal NA48/2 intensity is 20 MHz of charged particles through chambers 5 and 6.

A track will deposit charge on similar strips in complementary chambers (chambers 1&2, 3&4, and 5&6). If the track is intime, then the sum-of-time of its hits is a constant, within resolution. This is shown in figure 4, for the case of exactly 1 hit in each chamber of a complementary pair. As will be shown later, the resolution of the sum-of-time distribution depends on the pulse width, using the exact (rather than approximate) event time, and on calibration.

The track momentum is measured by the difference between the strip coordinates between the upstream and down stream chambers. Since this is an achromatic beam, the chamber geometry was aligned with the following anti-correlation: tracks that leave hits in strip *i* of the upstream chambers will tend to leave hits in strip 49-*i* of the downstream chambers.

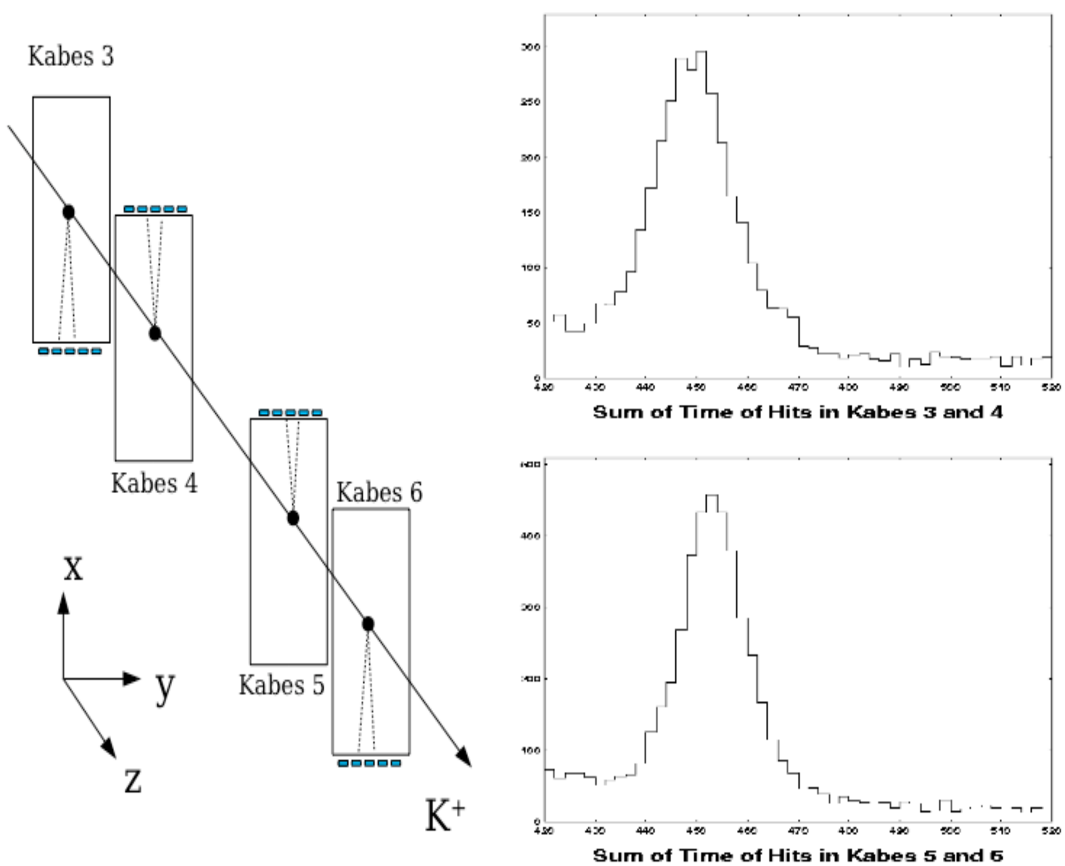


Figure 4: Sum-of-Time Pairs in Complementary Chambers. Good pairs are defined as being within 22 counts (~3σ) of the peak.

Pattern Recognition and Tracking Efficiency

To measure the track efficiency, in which a track traverses only 4 chambers, we identify a clean track using TDC hits in 3 chambers, and look for a TDC hit in the 4th chamber. The identification of a clean track in 3 chambers proceeds as follows:

- The presence of intime hits in all 3 chambers.
- 2 of the 3 chambers form a complementary pair. The hits on these chambers have identical strip coordinates, and the sum-of-time is consistent with a track.
- The drift time of the hit in the remaining chamber is consistent with the other hits. The strip coordinate is consistent with the expected achromatic beam.

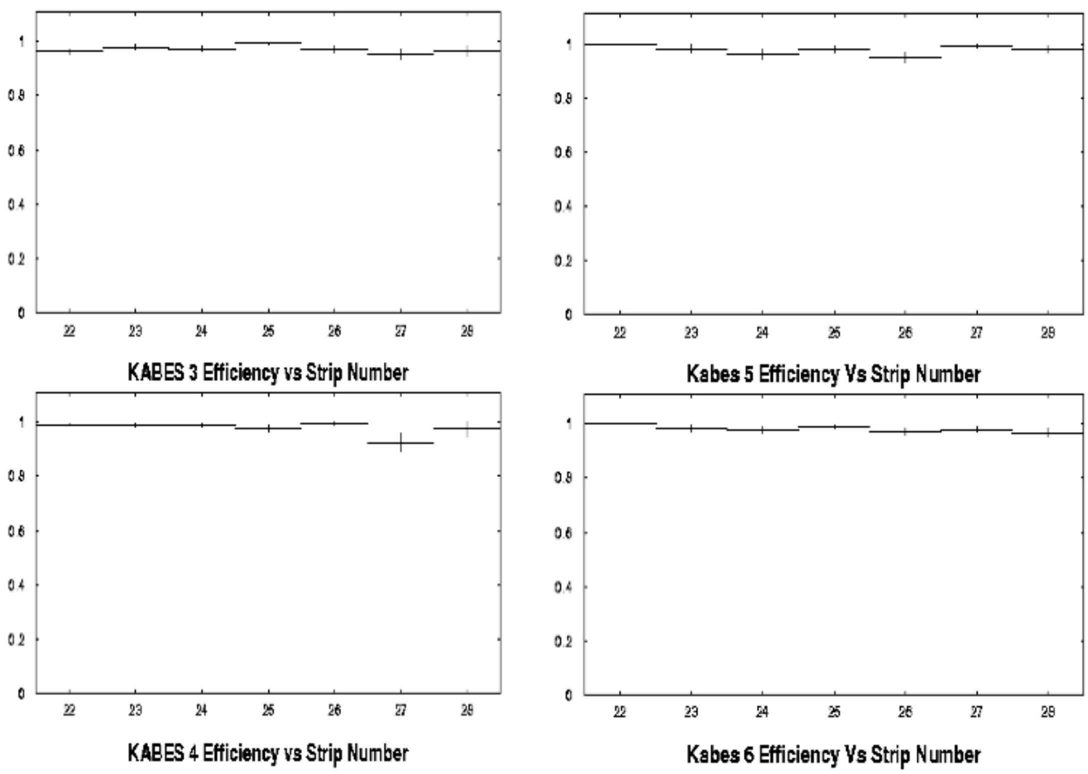


Figure 5: Hit efficiency versus strip number for 7 central strips.

After identify tracks with 3 chambers, the efficiency of the 4th chamber is measured as the presence of an intime TDC hit on the expected set of strips. This is shown in figure 5. The efficiency is above 95%. Chambers 5 and 6 have new 25 μm gap micromegas.

Chambers 3 and 4 have 50 μm gap micromegas that saw the full NA48/2 flux. This is estimated to be roughly 6.4 x 10^{12} particles.

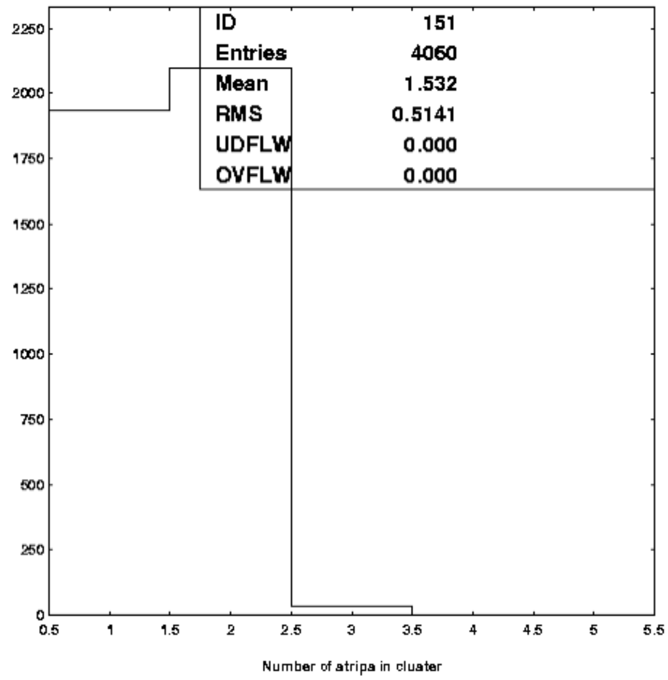


Figure 6: The cluster size parameter

Strip Multiplicity

An important parameter is the number of strips in a chamber that responds to the passage of a track (i.e. the cluster size parameter). To measure this parameter, we use tracks identified as having a good sum-of-time pair in both upstream and downstream chambers, and that the two sum-of-time pairs have strip numbers consistent with the achromatic beam. The cluster size is shown in figure 6.

Calibration

Before we can measure the intrinsic time resolution of a hit in Kabes, and measure the dependence on the pulse shape, the system needs to be calibrated to determine the various timing offsets. First, a sample of tracks in low rate data is selected relying solely on the strip coordinate information. Since the beam is achromatic, it has been arranged so that there is an anti-correlation between the strip coordinates of hits in the upstream and downstream chambers. For definiteness, the reader can refer to the event display of figure 7, in which we have transformed the latter strip coordinates *i* into 49-*i*.   The pattern recognition for a track is simply to look for strip hits in a row, and requiring that

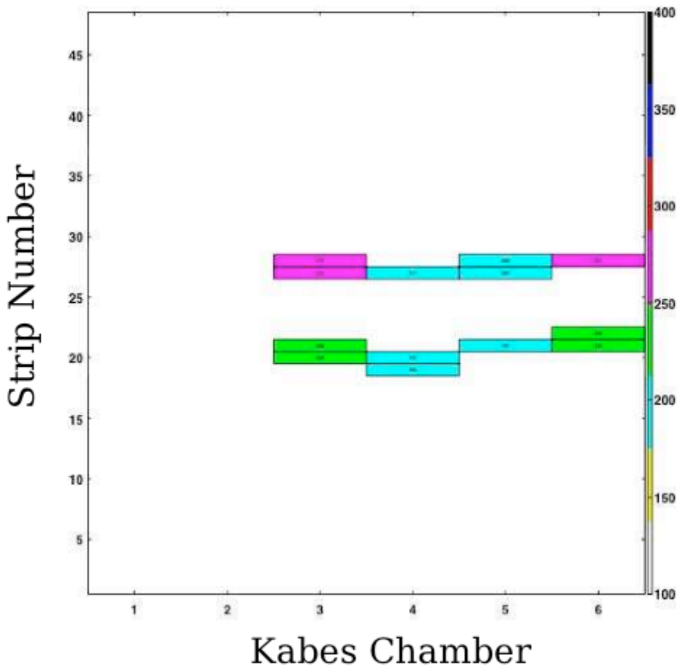


Figure 7: Display of two positive tracks traversing Kabes chambers 3, 4, 5 and 6. The strip numbering in Kabes 5 and 6 have been inverted (see text). The colors indicate TDC hit values. Note that tracks often leave two hits in a Kabes chamber (see figure 6).

there be no other hits on those strips. The timing calibration procedure is made possible by recognizing that track hits, whether or not they are intime with the trigger, obey the following constraints:

(1) If a track leaves hits on two adjacent strips in a chamber (doublets), the drift times should be similar.

(2) Hits belonging to the Kabes chambers that have the same drift direction (e.g. chambers 3 and 6), should differ by a fixed constant when averaged over all events. The fixed constant account for effects such as the time-of-flight between chambers and cable length differences. It can be set to zero. Event-by-event, the times in chambers 3 and 4 differ due to resolution and the variation in the track slope in the non-bendview. This averages to zero.

To illustrate item (1), figure 8 shows the difference in time between hits in a doublet versus strip number, which should average to zero. The variation is attributed to

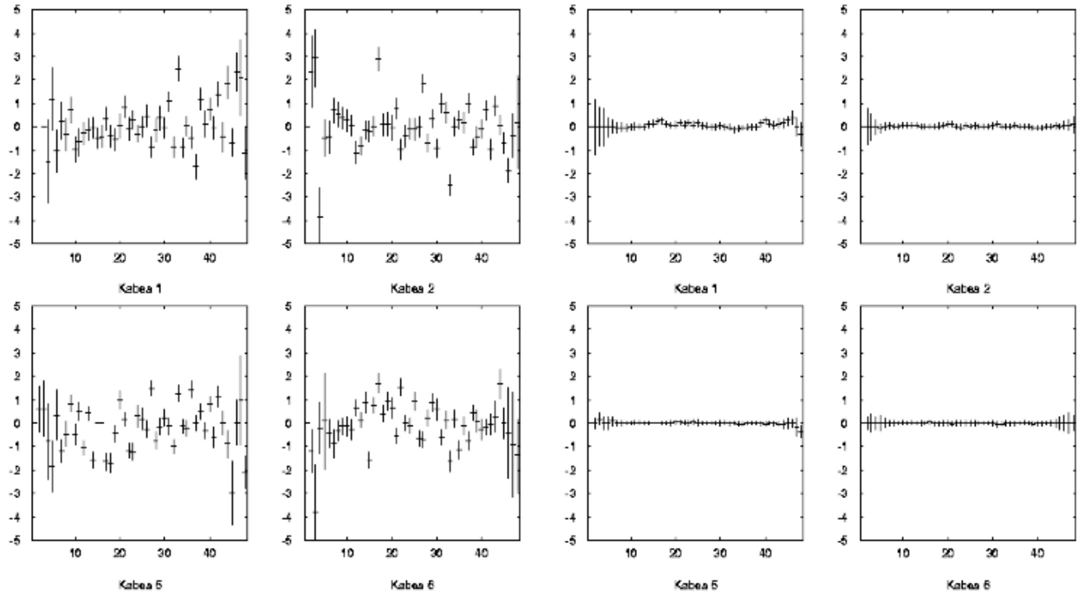


Figure 8: Difference in time between hits in a doublet versus strip number. Left (right) 4 histograms shows the quantity before (after) calibration.

electronics effects. The calibration consists of channel-dependent offsets to flatten out the variation.

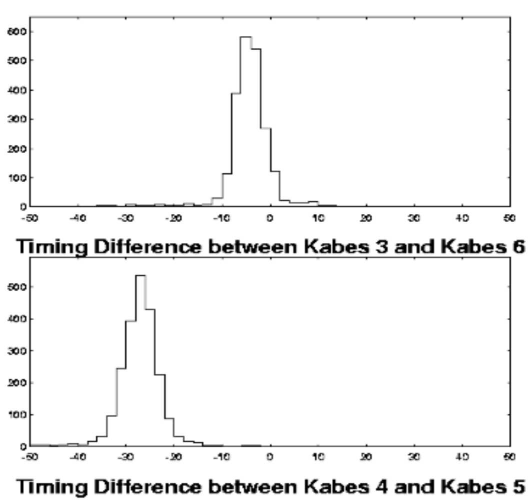


Figure 9: Timing difference between hits, associated to a track, in chambers of the same drift direction, showing the global offsets.

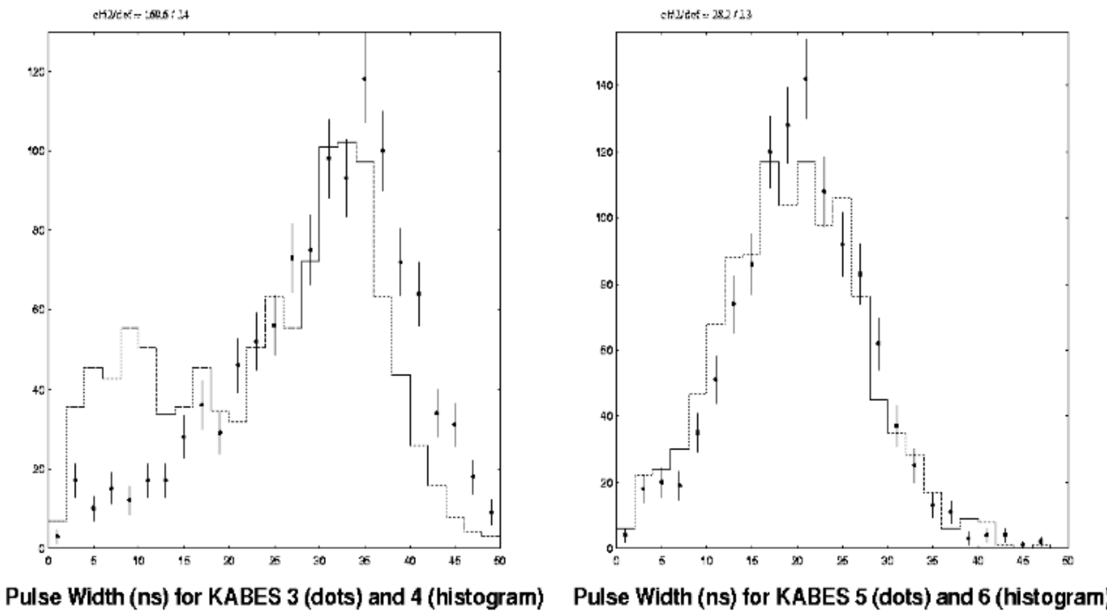


Figure 10

After correcting for channel-dependent effects, figure 9 shows the time difference between hits in chamber 3 and 6, and between hits in 4 and 5. The calibration is a chamber-dependent timing offsets, given by the means of the histograms in figure 9.

Time Resolution

After the calibration, we can now measure the time resolution σ(t) and the dependence on pulsewidth. The pulsewidth distributions are shown in figure 10 for Kabes 3, 4, 5, and 6. At low rate, the pulsewidth correlates nicely with pulse amplitude, in which large amplitude improves the timing resolution.

We calculate the time difference between hits in a doublet: t_1-t_2. We assume that:

(1) $\sigma(t_1-t_2) = \sigma(t_1) \oplus \sigma(t_2)$

(2) the function σ(t) depends only on the pulse width.

The extracted function σ(t) is shown in figure 11 as an exponential fit. We see a strong dependence on the pulse width for Kabes 3 and 4 (50 μm gap micromegas), where as the Kabes 5 and 6 (25 μm gap micromegas) has a rather consistent 1 nsec resolution. We can

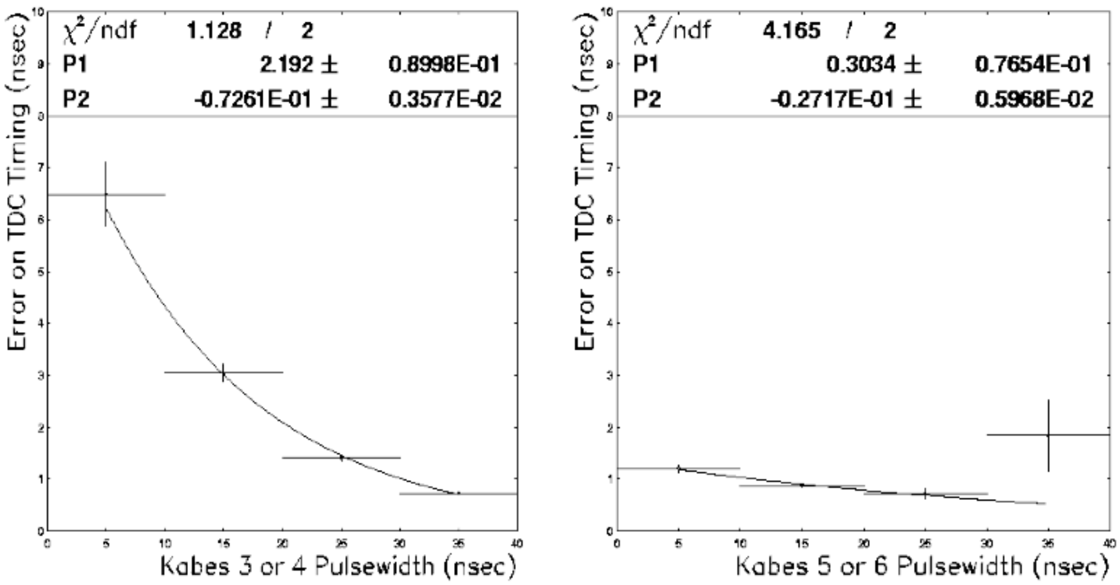


Figure 11

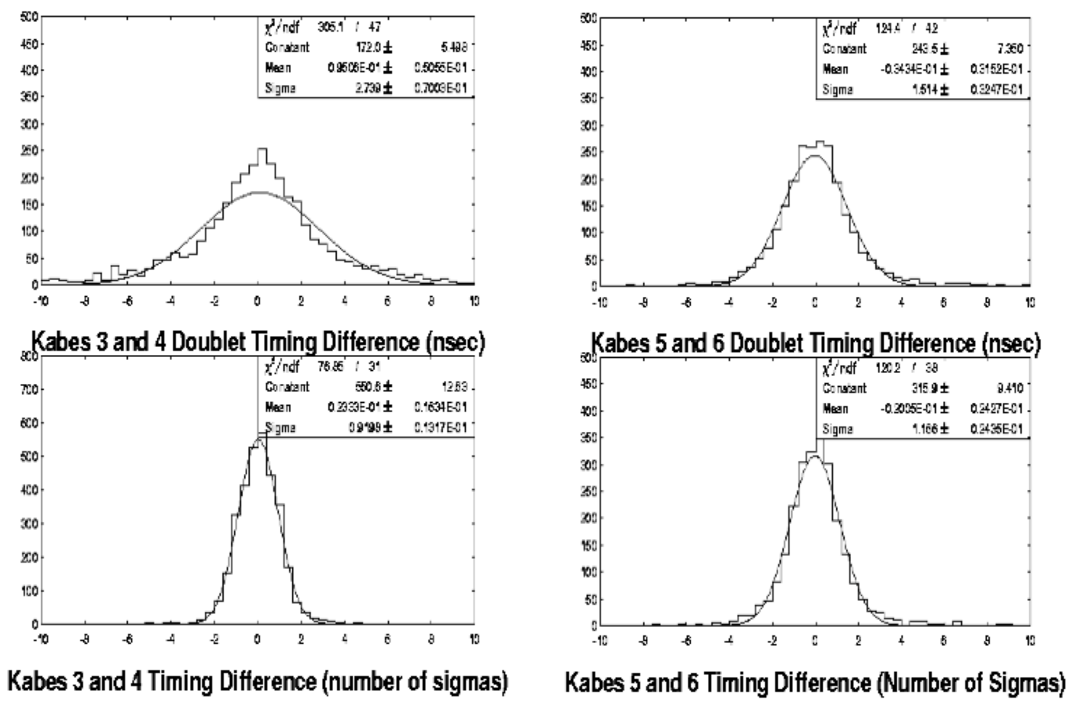


Figure 12: Top shows timing difference between hits in doublets. Bottom shows the quantity normalized to the expected variation.

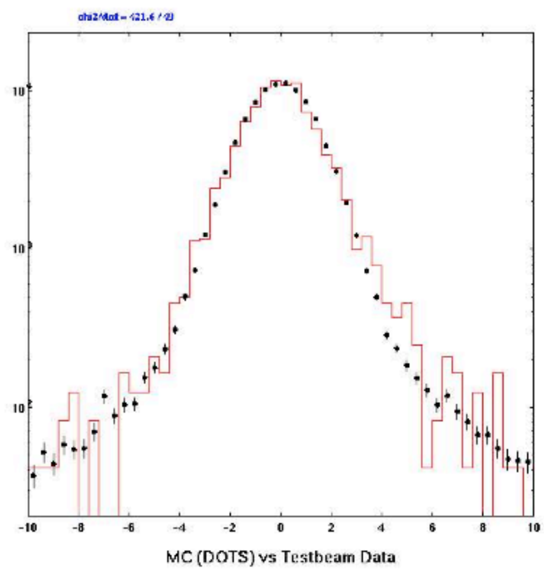
now reexamine the time difference of hits in a doublet, normalized by the expected variation (the pull distribution): $(t_1\text{-}t_2) / (\sigma(t_1) \oplus \sigma(t_2))$. This is shown in figure 12. The non-Gaussian tails are clearly present as shown in figure 13 for Kabes 5 and 6. The non-Gaussian tails in Kabes 5 and 6 are reasonably parameterized by a time resolution function consisting of 3 separate Gaussian functions.

Simulation of Non-gaussian time Resolution

σ_1 = 0.83 nsec $\quad$ σ_2 = 1.29 nsec $\quad$ σ_3=5.11 nsec

$w_1 = 605\sqrt{\sigma_1}$ $\quad$ $w_2=206\sqrt{\sigma_2}$ $\quad$ $w_3=13\sqrt{\sigma_3}$

Figure 13: Histogram shows the time difference (nsec) between hits in a doublet for Kabes 5 and 6.
The simulation (dots) is the individual hit time resolution parameterized by 3 Gaussian components.



Rate Comparison

A goal of the August 2004 test beam is to explore the Kabes behavior at high rate. At this time, only a few comparisons can be made. This section shows two comparisons between runs of different intensities: runs 16916 (166 KHz/strip), 16951 (hit 500 KHz/strip), 16955 (1MHz/strip), and 16959 (1.7 MHz/strip). Run 16951 was at nominal NA48/2 intensity, while run 16959 was 4.2*x* nominal intensity.

The first comparison is the pull distribution for doublets (figure 14), showing no significant rate dependence. The slightly larger non-Gaussian tail for run 16955 is consistent with more severe accidental effects in that run. Comparing the pull distributions is a very sensitive test of rate effect. However, our current requirement for identifying doublets is rather inefficient at high rate.

The second comparison is the beam profile between run 16951 and 16959 (figure 15), showing no significant difference. This test was not possible at the ultra-high rate runs since the beam optics was not fixed during the intensity scans.

Conclusion

In this document, we've shown basic Kabes distributions for the NA48/2 August 2004 test beam run. Distributions shown were the beam profile, time of intime hits, hit efficiencies, pulse width, and the cluster size. A simple TDC calibration scheme was presented, and we extracted a function to represent the time resolution of hits. The time resolution of Kabes 1-4 (50 μm gap micromegas) exhibited a strong dependence on pulse width. The time resolution of Kabes 5-6 (25 mm gap micromegas) is roughly 1 nsec and independent of the pulse width. Non-Gaussian timing tails were clearly observed.

A goal for this test beam run was to study the Kabes at high rate. We made comparisons of the time resolutions and beam profile. No strong rate dependence is seen in these distributions.

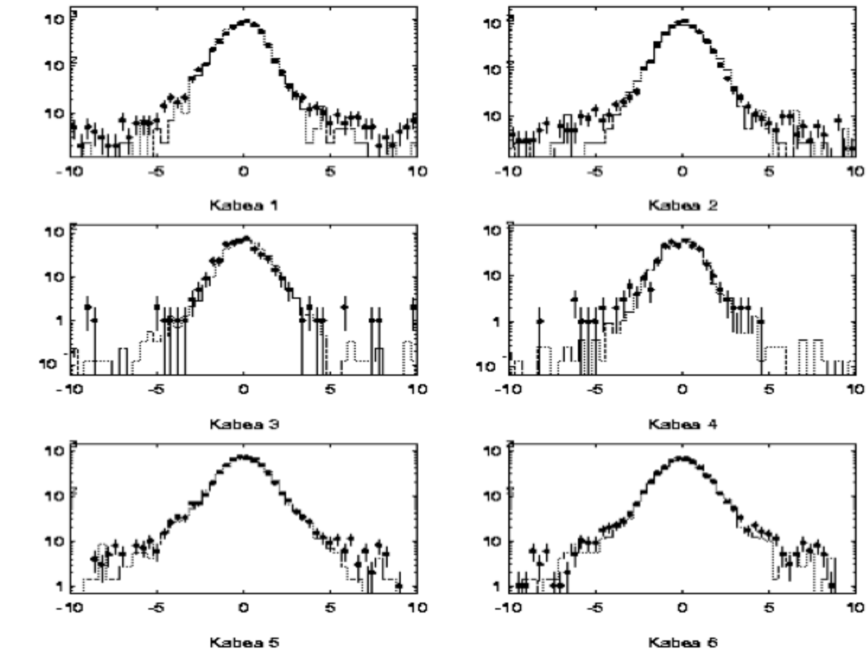


Figure 14: Pull distristributions for doublets. Dots (histrogram) show the quantity for run 16955 (16916).

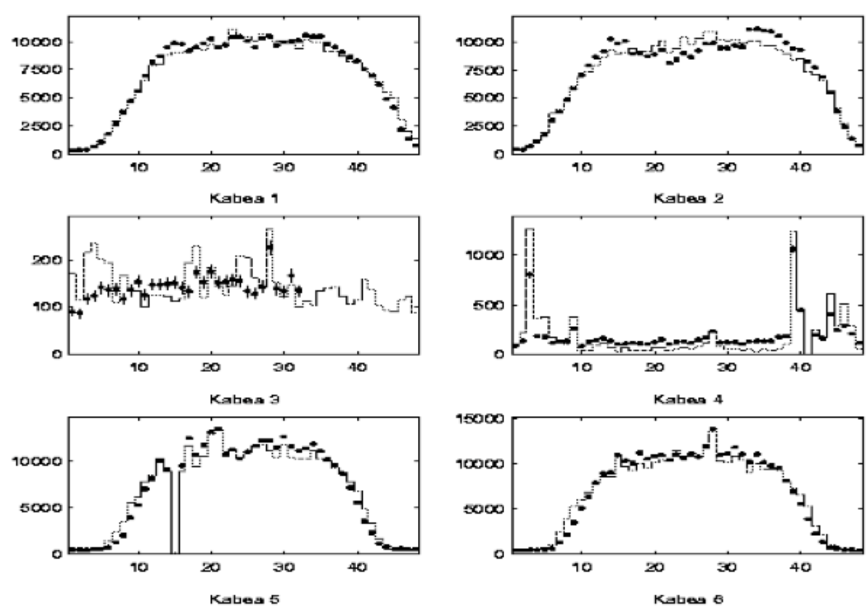


Figure 15: Hit distribution for runs 16959 (dots) and 16951 (histogram). The beam did not go through kabes 3 and 4. Run 16951 was at the nominal NA48/2 intensity. Run 16955 was at 4.2x nominal intensity.