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First Tests of the Timing Resolution of Microchannel-Plate Photomultipliers Viewing Čerenkov Radiation

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Abstract

We have tested the time resolution of Hamamatsu R3809U microchannel-plate photomultipliers using Čerenkov light emitted in a quartz window due to electrons from a Sr^{90} source. The time difference of two devices was observed to have resolution $\sigma = 55$ ps, corresponding to a resolution of each device of $\sigma = 39$ ps. This result is broader than the claimed capability of $\sigma = 15$ ps for Hamamatsu R3809U's, and is likely dominated by our use of an Ortec constant-fraction discriminator.

1 Introduction

Recently we have proposed a time-of-flight system based on microchannel-plate photomultipliers (MCP-PMT's) that view Čerenkov light in quartz fibers [1, 2]. If the fibers are arranged in hoops of radius ~ 1 m concentric with the beams at an e^+e^- B factory, the system could provide 4-σ π/K separation at all momenta.

Recently we have procured two Hamamatsu R3809U-02 MCP-PMT's to begin tests of our concept. Hamamatsu has kindly loaned us a third MCP-PMT that was optimized for performance at lower than typical gain, as is best for long device life.

2 Quantum Efficiency

We first determined the quantum efficiency *vs.* wavelength of these devices by comparing them against a Hamamatsu R1220 calibrated photomultiplier and an NIST calibrated photodiode using the procedure discussed in sec. 4.1 of ref. [1]. The results were very close to those provided by Hamamatsu with each MCP-PMT, namely that the Q.E. at 300 nm is about 5% for MCP-PMT's with a thin aluminum-oxide layer over the entrance to the microchannel plate, and 10% for the version without that layer.

3 Time Resolution

Next we studied the timing performance of two of the MCP-PMT's with the setup shown in Fig. 1. A Sr^{90} source (β's with 2.0-MeV endpoint) emitted electrons into a 3-mm-thick quartz window. The electrons emit Čerenkov radiation whose angular distribution is poorly defined due to multiple scattering and variation in the electron energy. The two MCP-PMT's under test were oriented to accept Čerenkov photons at angles of 45° to the direction of the electron's motion. Since quartz has index 1.46, this observation angle corresponds to the Čerenkov angle for electrons of $\beta = 0.8$, K.E. = 310 keV, which lies well within the β-spectrum of Sr^{90}. Note that the time-of-flight of the Čerenkov photons accepted by the MCP-PMT's is insensitive to the possible variation in Čerenkov angle in the apparatus.

The MCP-PMT's were operated at 3.0 kV, and their outputs fed to an Ortec model 935 constant-fraction discriminator and then on to the start and stop inputs of a Canberra model 2145 time-to-amplitude convertor. The output of the TAC was digitized with a Ortec ACE8k multichannel analyzer. The system was calibrated to have 2.4 ps/channel.

The results from two runs are shown in Fig. 2. The joint timing distribution of the two MCP-PMT's had $\sigma = 55$ ps, so each tube had a time resolution of $\sigma = 39$ ps (assuming the same resolution for each device).

While this result is already excellent, the observed time resolution is poorer than the value of $\sigma \approx 15$ ps reported by Hamamatsu. The discrepancy could well be due to our use of the Ortec 935 constant-fraction discriminator, whose resolution is stated to be limited to 25 ps for pulses 10-ns (or greater) in width. Ortec advises us that we should expect worse performance for narrower input pulses. Since the MCP-PMT's give pulses less than 1 ns wide these are not well matched to the Ortec discriminator.

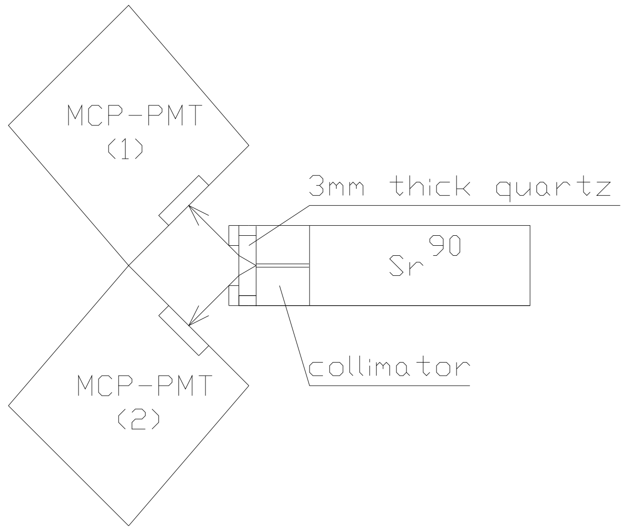

Figure 1: Setup to measure the time resolution of a pair of Hamamatsu R3809U MCP-PMT's.

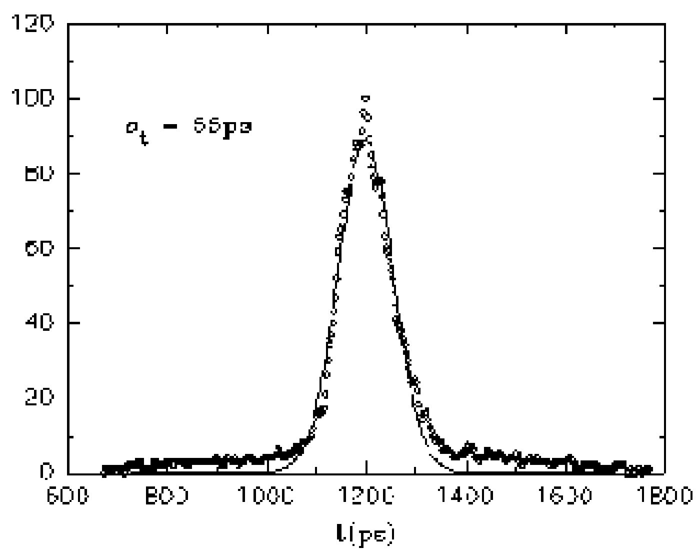

Figure 2: The time resolution of two Hamamatsu R3809U MCP-PMT's as determined with the setup shown in Fig. 1. The joint distribution was observed to have $\sigma = 55$ ps, corresponding to $\sigma = 39$ ps for each MCP-PMT.

4 Future Beam Tests

We have the opportunity to study the MCP-PMT's further in a 1-4 GeV hadron beam at KEK during the first week of July 1994. We may be able to get additional time in the BNL test beam later in July. In these tests two MCP-PMT's will be coupled to the ends of a 10-cm-long and 100-cm-long quartz rod, 1 cm in diameter. These test will more closely simulate the desired geometry of the proposed system of quartz fibers. The 100-cm-long rod should permit a demonstration of π/K separation, since the time-of-flight difference for Čerenkov light due to 2-GeV π's and K's normally incident on quartz is 173 ps.

References

[1] Z. Cheng *et al.*, *Hadron Identification for B Physics*, Princeton/HEP/94-01 (March 22, 1994).

[2] Z. Cheng, C. Lu and K.T. McDonald, *A Time-of-Flight System with Full Coverage for an e^+e^- B Factory Based on Čerenkov Light Viewed by Microchannel-Plate Photomultipliers*, Princeton/HEP/94-07 (May 6, 1994).