TRIUMF Experiment E614
TN-26
Muon Trigger Scintillator

M.A. Quraan, J. A. Macdonald and J.M. Poutissou
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1 Introduction

Due to the strict requirement on material thickness, a thin scintillator has to be used as a muon trigger for E614. On the other hand, since the detector is enclosed in a high magnetic field region, the signal would have to be transported outside this region before coupling to a photomultiplier tube (PMT). A thin scintillator-fiber combination was therefore suggested as a possible muon trigger.

2 Setup

The scintillator used in this test was $250\mu m$ thick by $25mm$ diameter Bicron (BC408). A Bicron fiber (BCF99-AA) double-clad wavelength shifter $1mm$ in diameter was wrapped around the scintillator as shown in figure 1. The fiber was heated before bending to ensure uniform bending and to avoid kinks that may result in the loss of light output. The ends of the fiber extended approximately $1m$ away from the scintillator and were coupled to two Hamamatsu R580 PMTs using optical grease. The fiber has an attenuation length of $\sim 4m$.

The scintillator was then placed in the beam $\sim 1cm$ away from a $\sim 1cm$ diameter collimator. The collimator ensured that the beam did not hit the fiber directly. Two scintillators $2.8mm$ thick were placed directly behind the thin scintillator to provide a trigger and beam diagnostic.

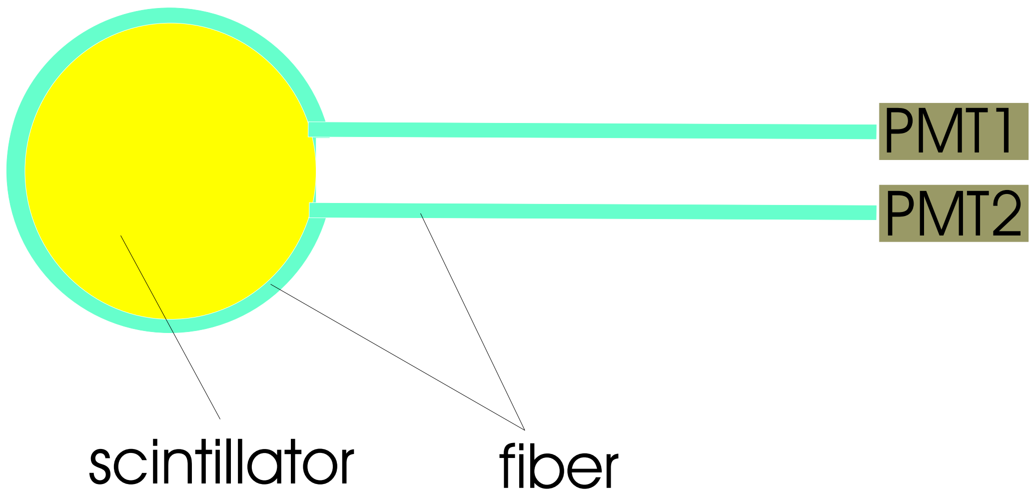

Figure 1: A schematic view of the scintillator-fiber coupling.

3 Beam Tests

The M11 beamline was run at a momentum of $220MeV/c$, to provide protons with a kinetic energy of $25.6MeV$. At this energy, protons deposit about $20MeV \cdot cm^{-2}/g$, an amount which is similar to that which muons deposit at a momentum of $29.7MeV/c$ (surface muons). The beam also contained (background) pions and positrons. At this momentum, pions have a kinetic energy of $120MeV$ and deposit about $3MeV \cdot cm^{-2}/g$.

The two ends of the fiber were labeled S3 and S4. The scintillator right behind the thin scintillator was labeled S2, as shown in figure 2, and the most downstream scintillator was labeled S1. Scintillator S2 provided the trigger signal as well as a gate for the ADCs and a start signal for the TDCs. Each end of the fiber, S3 and S4, were sent to an ADC and a TDC, and the RF time of flight was also recorded. Signals from S2 and S1 were sent to an ADC.

Figure 3 shows the raw ADC spectra from each end of the fiber, figure 4 shows the raw ADC spectra from scintillators S1 and S2, and figure 5 shows the raw TDC spectrum of the RF time of flight (TOF) for three time cycles. The latter spectrum suggests the presence of (at least) two kinds of particles in the beam where the larger of the two peaks corresponds mainly to protons (the structure in the large peak is a feature that is often seen in the cyclotron). To test this hypothesis, a cut was imposed on the S2 ADC spectrum

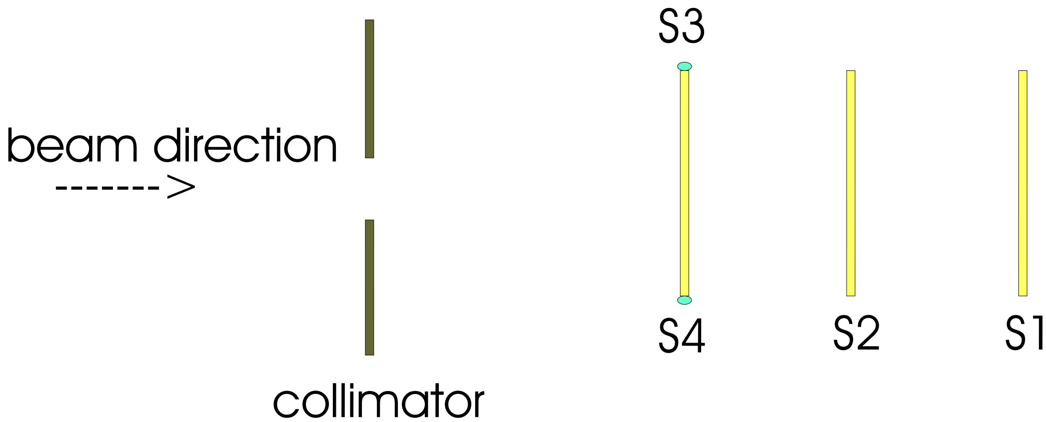

Figure 2: A schematic view of the experimental setup.

to allow only particles with $ADC > 150$ channels. This resulted in the RF TOF spectrum shown in figure 6. Figure 7 shows the ADC spectrum from one end of the fiber (S3) corresponding to the same cut. Both spectra verify that the second peak in the S2 ADC spectra ($ADC > 150$ channels) correspond to protons, which in turn correspond to the larger of the two peaks in the RF TOF spectrum.

The bottom histogram in figure 4 suggests that most particles do not have enough energy to make it all the way to scintillator S1. This is likely to be the case for most protons, whereas the minimum ionizing positrons and pions will punch through both S2 and S1. A cut requiring no signal in S1 will, therefore, get rid of most of these minimum ionizing particles and improve our selection criteria. Figure 8 shows the ADC spectra from each end of the fiber with two cuts: the first requiring no signal in S1 ($ADC < 20$ channels), and the second requiring a large signal in S2 ($ADC > 150$ channels). These cuts reduce the number of particles with a small ADC value, verifying that they indeed correspond to minimum ionizing particles.

As a final test, a cut was imposed where the S3 ADC spectrum was plotted requiring only small signals in S4 ($ADC < 50$ channels), to establish whether small signals in S4 correspond to large signals in S3 (and vice versa). This resulted in figure 9, suggesting that this correlation does not exist since most of the small signals in the S3 ADC spectrum correspond to small signals in the S4 ADC spectrum. Figure 10 shows the TDC time from one end of the fiber S3, relative to the trigger scintillator S2. The TDC spectrum from the other end of the fiber is similar. The width of this spectrum results from the convoluted time resolution of S3 and S2, and results in a σ of approximately $2ns$. Assuming the resolutions of S2 and S3 are equal, the resolution of each scintillator is about $1.4ns$.

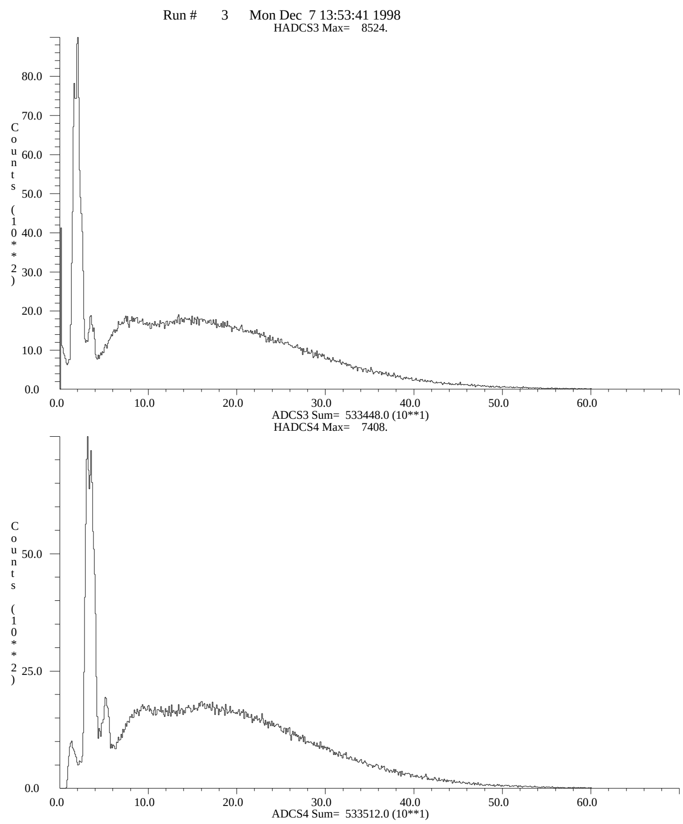

Figure 3: Raw ADC spectra from each end of the fiber..

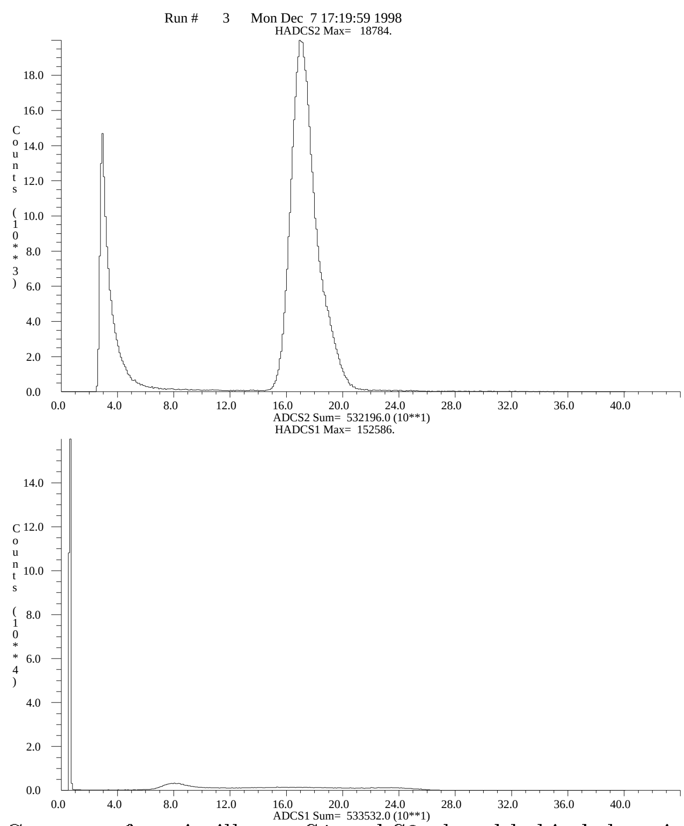

Figure 4: Raw ADC spectra for scintillators S1 and S2 placed behind the scintillator-fiber assembly.

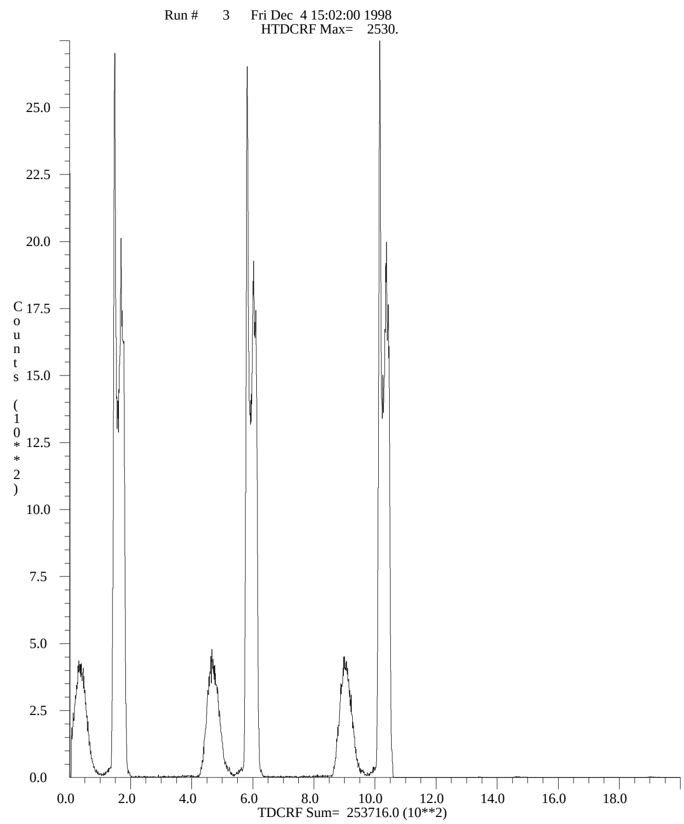

Figure 5: Raw RF time of flight.

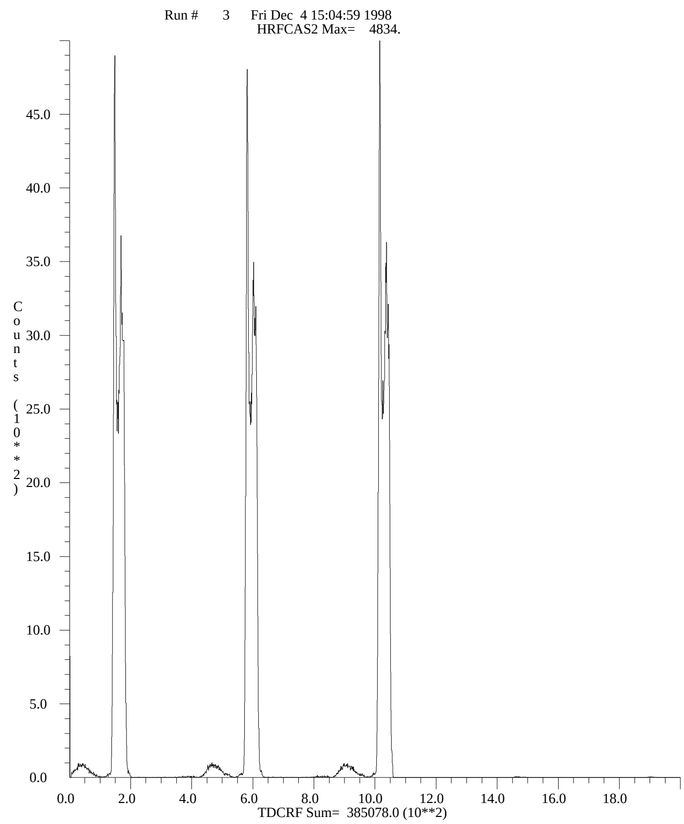

Figure 6: RF time of flight requiring a large signal in S2.

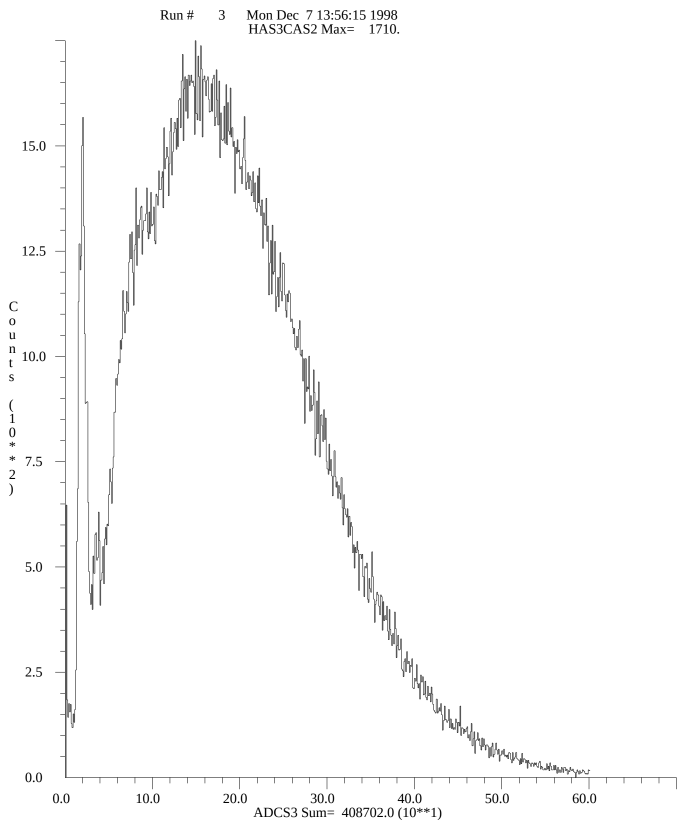

Figure 7: ADC spectrum from one end of the fiber requiring a large signal in S2.

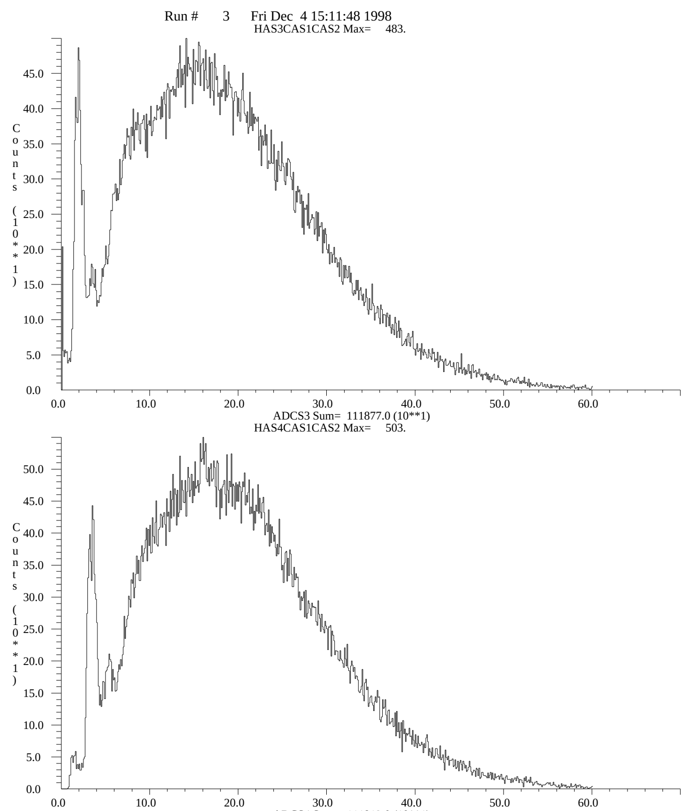

Figure 8: ADC spectra from each end of the fiber requiring no signal in S1 and a large signal in S2.

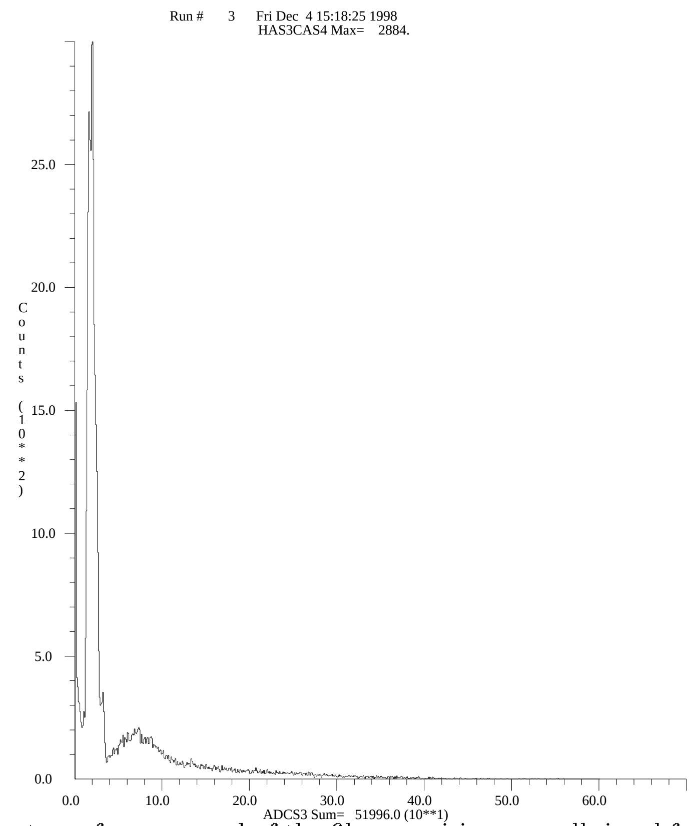

Figure 9: ADC spectrum from one end of the fiber requiring a small signal from the other end of the fiber.

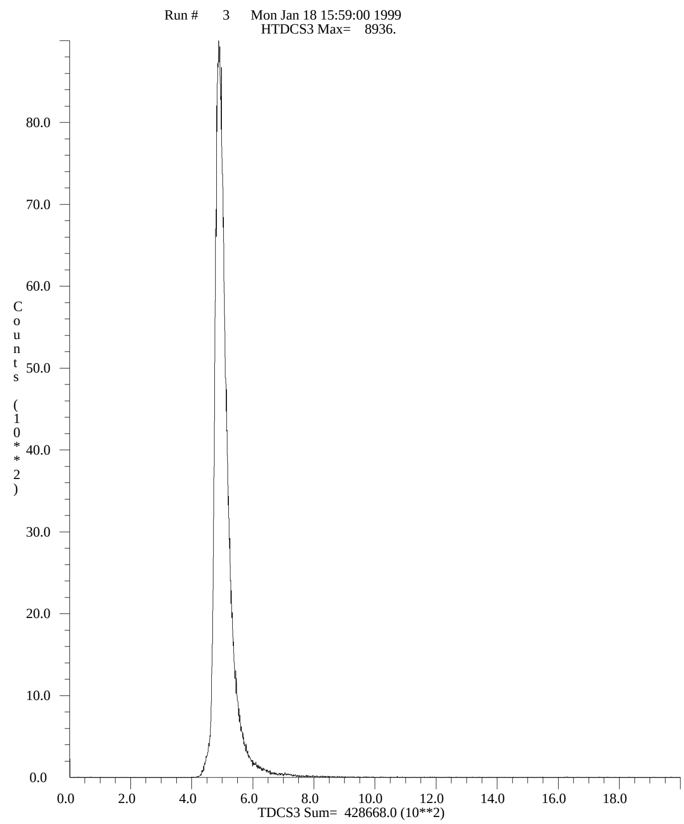

Figure 10: TDC spectrum from one end of the fiber (S3) relative to the trigger scintillator (S2).

4 Conclusions

This test has shown that a thin scintillator ($250\mu m$) coupled to a $1mm$ diameter fiber and properly assembled have good light collection efficiency for particles depositing energies around $20MeV \cdot cm^{-2}/g$. The time resolution of this assembly is less than $2ns$. This scintillator-fiber combination would be adequate as a muon trigger for E614.

Further testing will be performed in the future. Methods to improve the coupling of the fiber to both the scintillator and the PMTs will be investigated, as well as tests of the light collection efficiency with different fiber lengths.