DEVELOPMENT OF THIN PLASTIC SCINTILLATION COUNTER FOR LOW ENERGY MUON EXPERIMENT AT MuSIC

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Abstract:

MuSIC is a highly intense muon facility which was constructed at RCNP, Osaka University and officially operated since 2009. MuSIC was equipped with a superconducting solenoid at the pion capture system a muon yield up to 10^8 muons /sec is available. The thin counters with dimension of 30 mm x 380 mm x 0.5 mm has been developed for low energy muon experiment at the MuSIC 5th beam test. Each counter was attached with a wavelength shifting fiber (WLS) and MPPC for readout. Several tests and experiments were done in order to achieve best position resolution with thin plastic scintillation counter for medium energy muon experiment.

1. INTRODUCTION

MuSIC facility at RCNP, Osaka University can yield about 10^8 muons per sec and which equivalent to the highest intensity in the world, and a broad field of muon science can be carried out with the muon beam provided by the MuSIC. The MuSIC consists of two systems which are a pion capture system and muon transport system which officially operated since 2010 [1-3]. A 0.4kW proton beam produced by a cyclotron is injected on a graphite target in the pion capture section. The pions yield will be transport by the muon transport solenoid of 2 Tesla solenoidal magnetic fields. In addition, the dipole field may provides charge and momentum selection of the muon beam.

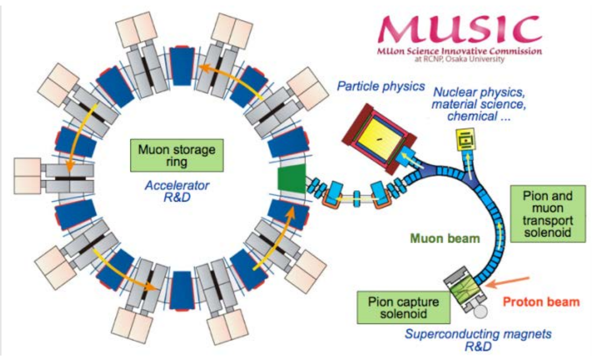

Figure 1: Schematic layout of MuSIC

MuSIC provides variety of muon experiments such as muon lifetime measurement and muonic X-ray measurement. From the first until 4th beam test, these two measurements were taken using the medium energy muon. In the 5th beam test last June, muon energy and spatial distribution was measured. The muon beam in MuSIC is a DC muon source; we hardly get the timing information for the muon arrival time from the accelerator system such as RF timing. The trigger counter was essential to obtain the time information and location information during the MuSIC experiments. Due to low energy muons stopped on a target, the thin plastic scintillation counters were used as the trigger counter in order to avoid low energy muons to stop on the scintillators before hit the target.

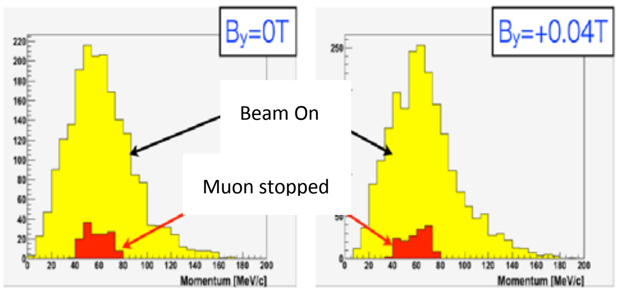

Figure 2: Momentum distribution in MuSIC 4th beam test

The main purpose of this detector is to make a trigger timing signal for the stopping muons. The detector is located upstream from the stopping target. Another thick plastic counter is placed downstream from the target, and is used as a Veto counter. Using signal from both counter, trigger signals are made for muons stopped in the target. The trigger signal is work as start timing for the muon lifetime measurement, and provides gates to ADC modules for muonic X-ray measurements.

Since the solenoid was equipped with strong magnetic field, MPPC was used as readout. MPPC have many features which may challenge the capability and sensitivity of PMT [4]. Even though the size and its active area of MPPCs are so small compared to PMTs, it is able to detect photon signals separately [4, 5].

The aim of this study is to measure the rate of hit of particle, number of light yield for each MPPC attached in the counter and also the measurement of muon lifetime using the designed thin plastic scintillation counter. The combination of MPPC with Wavelength Shifting (WLS) fiber may enhance the capability of both components to detect particle.

2. EXPERIMENTAL PROCEDURE

The end of solenoid exits at MuSIC was about 40cm in diameter. The thin plastic scintillation counters were designed to cover the exits. In this study, we develop the thin scintillation counter with the dimension of 380mm x 30mm x 0.5mm. The counter was attached with the wavelength shifting fiber at the centre of the thin plastic scintillator and the readout was Hamamatsu MPPC S10362-13-050C.

Light yields are measured with three different location of WLS fiber before deciding the suitable counter for the MuSIC; centre, side and edges (Refer to Figure 3(a), 3(b) and 3(c). 2 MPPCs are attached at the end of the fiber. The number of photon yield at each MPPC will be recorded and compare for the selection of MuSIC beam time detector. The ^{241}Am source was used during the experiment. All plastic scintillators were wrapped with 2µm aluminized mylar to enhance the light yield propagation of the fiber towards the MPPC readout.

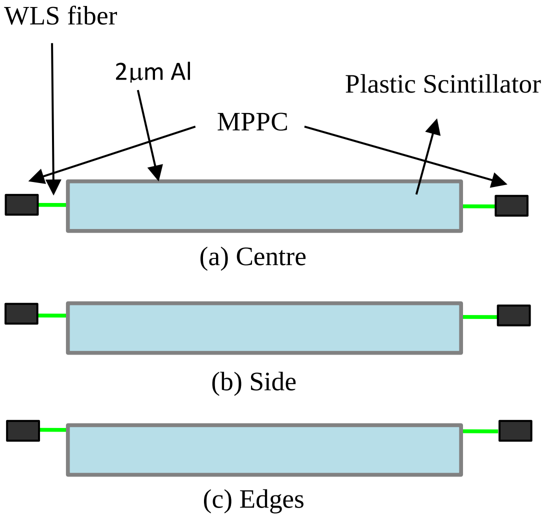

Figure 2: Three Configuration of tested thin

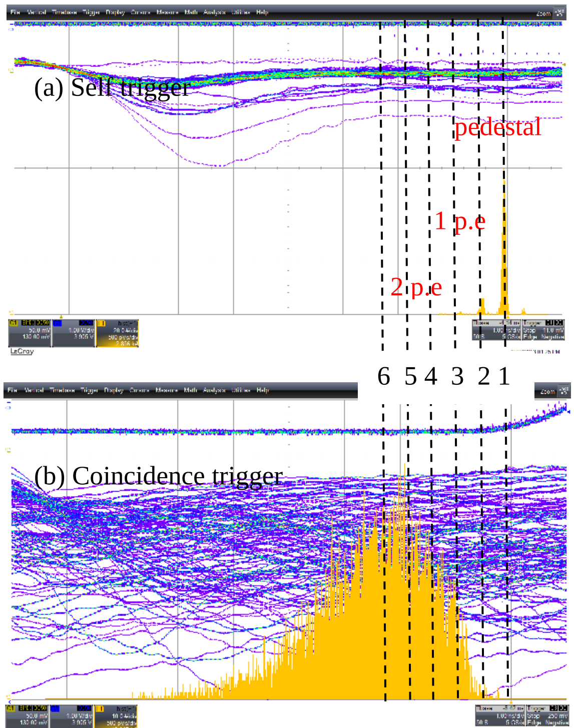

Figure 3: Signal from MPPC

The chosen configuration for MuSIC 5th beamtest was finally check and the total muon yield at each MPPC was calculated. During the beam test, a set of 8 thin plastic scintillation counters was used. This detector was mainly used to determine muon lifetime with few metal targets, the momentum distribution of muon also will be determined.

A trigger is made with coincidence of two MPPC. MPPC signal with NIM module and observed with LeCroy waverunner oscilloscope.

3. DETECTOR PERFORMANCE

The MPPC has single photon counting detection, each photon detected by MPPC will represent by photopeak respectively.

Table 1 below summarizes the rate of event per second at every 2.5p.e threshold for three assigned configurations. Dark current rate and source rate was then compared to choose the suitable configuration. The centre and side configurations recorded almost same events rate, however the event for edges was slightly different from these two. This might due to poor connection of fiber and plastic scintillator causing the event counted by opposite MPPC is not evenly distributed. The centre configuration was chosen among all due to good photon yield, large signal to noise ratio compare to other configurations and also easy fabrications steps.

Figure 3(a) shows the self trigger signal of MPPC and figure 3(b) shows the coincidence signal from MPPC with ^{241}Am for centre configuration. The dotted line represents the gain of the MPPC. We can estimate that the average light yield detected at centre configuration was about 6 photons.

Table 1: Rate of events for MPPC

Source	MPPC	V_{op} (V)	Dark current @1.5pe, I_{ref} (kHz)	Rate@2.5pe, I_{obs} (kHz)		
				Center	Side	Edges
No	TJ5359	71.37	57.9	15.0	15.0	8.9
	TJ5362	71.38	56.7	12.3	12.1	36.5
^{241}Am	TJ5359	71.37	57.9	32.3	18.8	16.3
	TJ5362	71.38	56.7	21.2	16.5	55.3

4. BEAMTEST PERFORMANCE

Eight sets of center configuration were then fabricated and the light yields for all MPPC were measured. Figure 4 was the thin plastic scintillation counter for MuSIC beamtest. The same type of MPPC was used for all counters. The ^{241}Am source was placed at the center of the plastic scintillator. The gain was set to each MPPC so that the signal can be clearly separated from the pedestal.

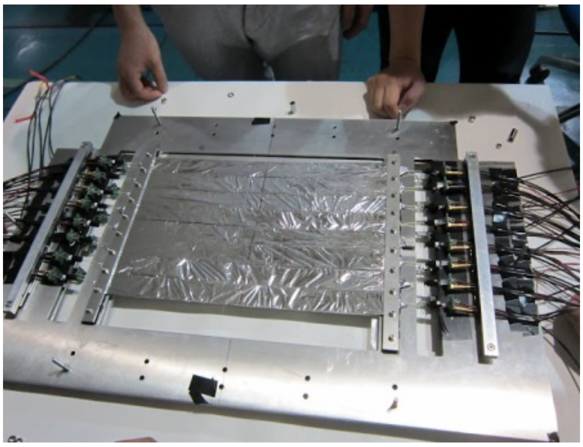

Figure 4: Thin Plastic Scintillation counter for MuSIC

The MPPC signal during the beamtest can be observe by VME module. Figure 5 shows the signal of MPPC, a black curve represents the raw ADC signal of MPPC and the red curve represents the ADC signal over threshold. We can clearly see the separation between pedestal and muon signal with the thin plastic scintillators.

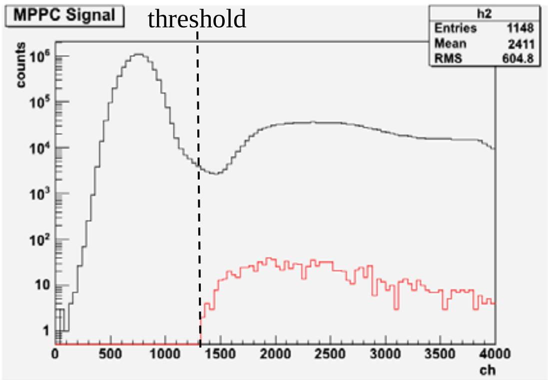

Figure 5: ADC Signal of MPPC during beam test

5. CONCLUSION

In this study, we quantitatively compared the rate of event on three different configurations of thin plastic scintillation counter. We also employed a coincidence technique which effectively rejected dark noise produced by each MPPC. We found that the position of WLS fiber and the MPPC readout do affect the event rate at each MPPC and the coincidences of two opposite MPPC effectively reduce the dark count.

We can conclude that the average number of photon yield at each MPPC was about 6 photons. The separation between photopeak also can be clearly distinguished with this thin counter by offline and online beam experiment.

References

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