SciSi performance studies MUSE beam test December-2015

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Abstract

The results of the December-2015 MUSE beam test run studies of 2 mm thin Scintillators coupled to SiPMs (SciSi) are presented. The system resolution for pion identification for one bar of SciSi discriminated by a CFD is about 120/110/90 ps for a 12 mm bar with AvanSiD readout / 5 mm bar with AvanSiD readout / 5 mm bar with Hamamatsu readout SciSi bar. For two SciSi bars it is about 95 / 90 ps for 12 mm bar with AvanSiD readout / 5 mm bar with AvanSiD readout. The maximal detection efficiency for a SciSi bar is at least 99%. The 5 mm detectors were tested with up to about 1 MHz beam on them.

1. Introduction

Following the July-2015 PSI review committee suggestion Scintillators coupled to SiPMs[1] (SciSi) technology was studied, as an alternative to the MUSE Cerenkov detector - Scintillating Fiber arrays system.

A prototype of SciSi was assembled for the December-2015 MUSE test run, consisting of the following:

1. Two 12 mm wide bars, coupled on both ends to three AvanSiD[2] SiPMs, supplied with 90 V.
2. Two 5 mm wide bars, coupled on both ends to one AvanSiD[3] SiPM, supplied with 30 V.
3. One 5 mm wide bar, coupled on both ends to one Hamamatsu[4] SiPM, supplied with 68 V.

All scintillators were of EJ204 type, and 100 mm (length) × 2 mm (thickness).

The detectors were built in collaboration with and under the supervision of Dr. Alexey Stoykov of PSI, the expert in the technology, using his design. T. Rostomyan

[1] We denote Avalanche photo-diod as SiPM here.

[2] ASD-NUV3S-P-40

[3] ASD-NUV3S-P-40

[4] S12572-025C

was primarily responsible for assembly, with help from K. Deiters, T. Rauber, and M. Schwarz. The data presented in this report were collected in the PSI piM1 channel.

2. Timing resolution

To study the SciSi timing resolution, the signals were amplified using dedicated preAmplifiers designed and assembled by Dr. Alexey Stoykov at PSI, discriminated by a PSI Constant Fraction Discriminator (950-VME CFD) and read out using a CAEN v1290N TDC. The Time Of Flight (TOF) distribution from SciSi to a 5-cm thick, fast (σ 50 ps) scintillator (SA) 1 m downstream, was fitted to a Gaussian distribution, separately for each particle type. The width of these distributions (σ) are the reported system resolutions. PID was done using the RF time in the SA scintillator.

Fig. 1 and 2 show typical timing spectra for a single SciSi bar, and for two SciSi bars in coincidence. The system resolutions for a single SciSi bar are:

$$\sigma[\text{ps}] = \begin{cases} \pi \quad /\mu \quad /e & \\ 118.4(4)/112.1(8)/131.3(1) & \text{12 mm AvanSiD} \\ 110.3(4)/110.9(9)/144.1(6) & \text{5 mm AvanSiD} \\ 90.1(3)\ /89.5(6)\ /113.3(1.2) & \text{5 mm Hamamatsu,} \end{cases}$$

And for a two SciSi bars in coincidence:

$$\sigma[\text{ps}] = \begin{cases} \pi \quad /\mu \quad /e & \\ 94.9(3)/87.5(6)/111.3(9) & \text{12 mm AvanSiD} \\ 87.3(3)/84.1(7)/108.7(1.4) & \text{5 mm AvanSiD.} \end{cases}$$

The above reported uncertainties arise mainly from differences between paddles and runs. Note that the 5 mm Hamamatsu SiPM presents slightly better timing resolution than the AvanSiD: about 90 ps resolution for pion identification vs. 110 ps for the AvanSiD.

3. Detection efficiency

The detection efficiency of each SciSi bar was determined by counting the events using scalers. The study was performed as a function of discrimination threshold. Fig 3 shows the efficiency for all SciSi bars. Also shown are the efficiencies for the SciSi paddles with their HV set to the maximum allowed voltage (91.5 Volt for 12 mm AvanSiD, 30.5 Volt for 5 mm AvanSiD, and 69 Volt for 5 mm Hamamatsu).

4. High rate performance

To study SciSi high rate performance an efficiency measurement was setup for the 5 mm wide Hamamatsu bar, and the beam rate was increased. The measured detection efficiency remained at the level of 97.8(1)% up to a rate of 1 MHz on the SciSi bar.

5. Conclusions

The 5 mm wide SciSi basic features are as follows:

1. About 90 ps timing resolution for a single 5 mm bar coupled to Hamamatsu SiPMs, and from inference about 65 ps for two paddles (this was not tested due to lack of Hamamatsu SiPMs).

2. $>$ 99% detection efficiency.

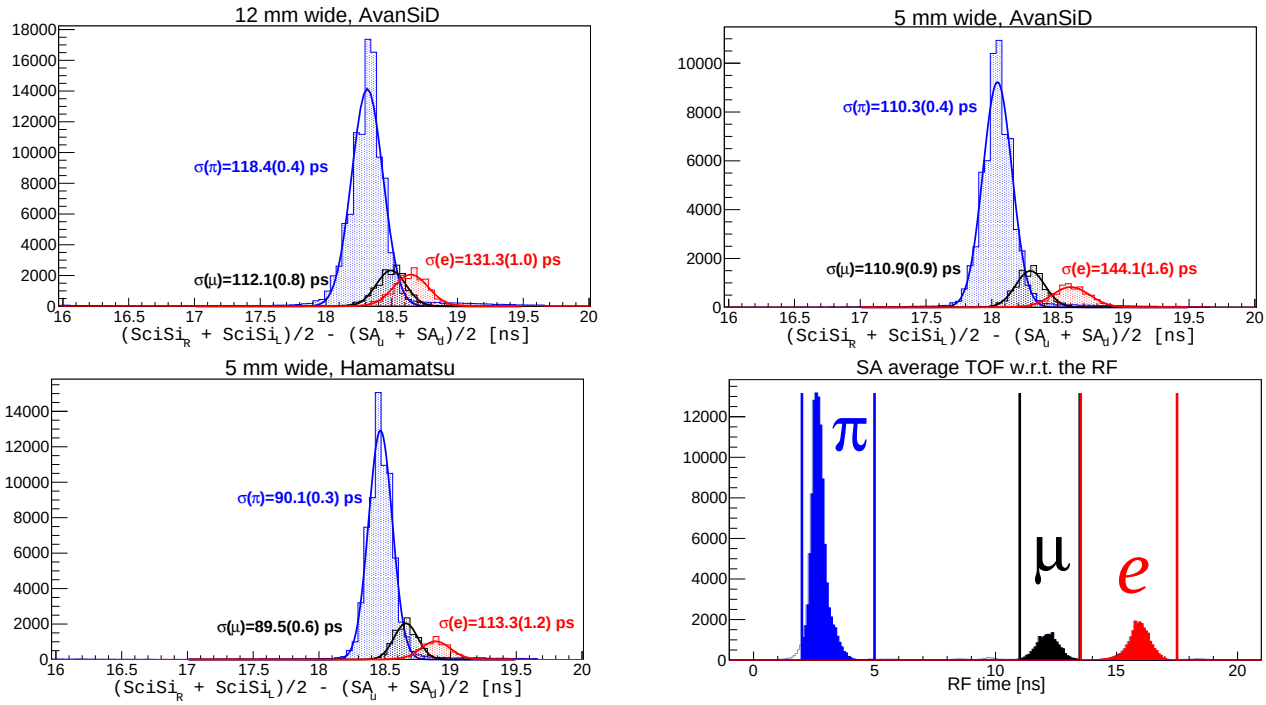

Figure 1: The average TOF from a SciSi paddle to the SA scintillator for π/ μ/e at 160 MeV/c. Top left: a 12 mm wide bar coupled to 3 AvanSiD SiPMs on both ends. Top right: a 5 mm wide paddle coupled to 1 AvanSiD SiPM. Bottom left: a 5 mm wide paddle coupled to 1 Hamamatsu SiPM. PID was done using TOF w.r.t. RF (bottom right). Data taken from run 5061 during Dec-2015 MUSE test run (160 MeV/c, beam trigger rate 1 kHz).

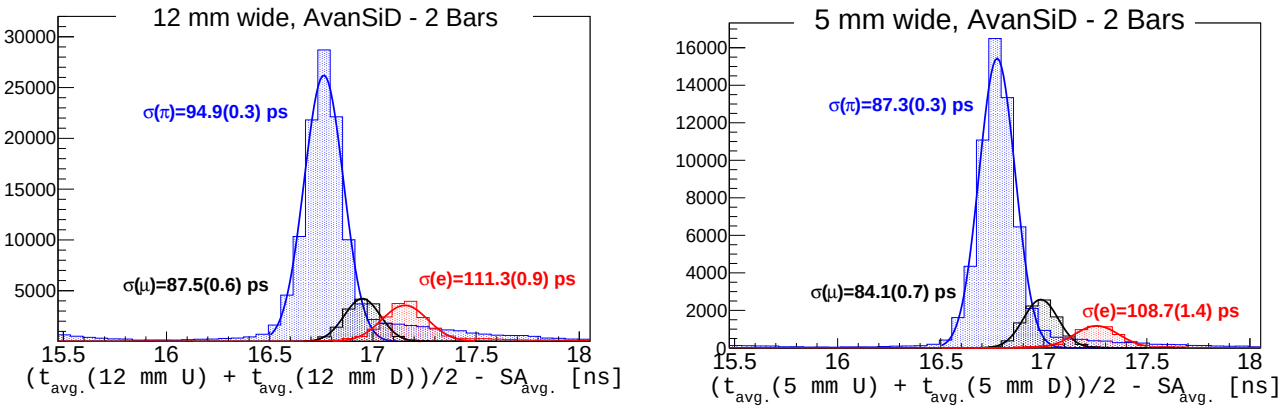

Figure 2: The average TOF for two SciSi paddles in coincidence w.r.t. the SA scintillator for π/ μ/e at 160 MeV/c. Left: two 12 mm wide paddles coupled to AvanSiD SiPMs. Right: two 5 mm wide paddles coupled to AvanSiD SiPMs. Data taken from run 5061 during Dec-2015 MUSE test run (160 MeV/c, beam trigger rate 1 kHz).

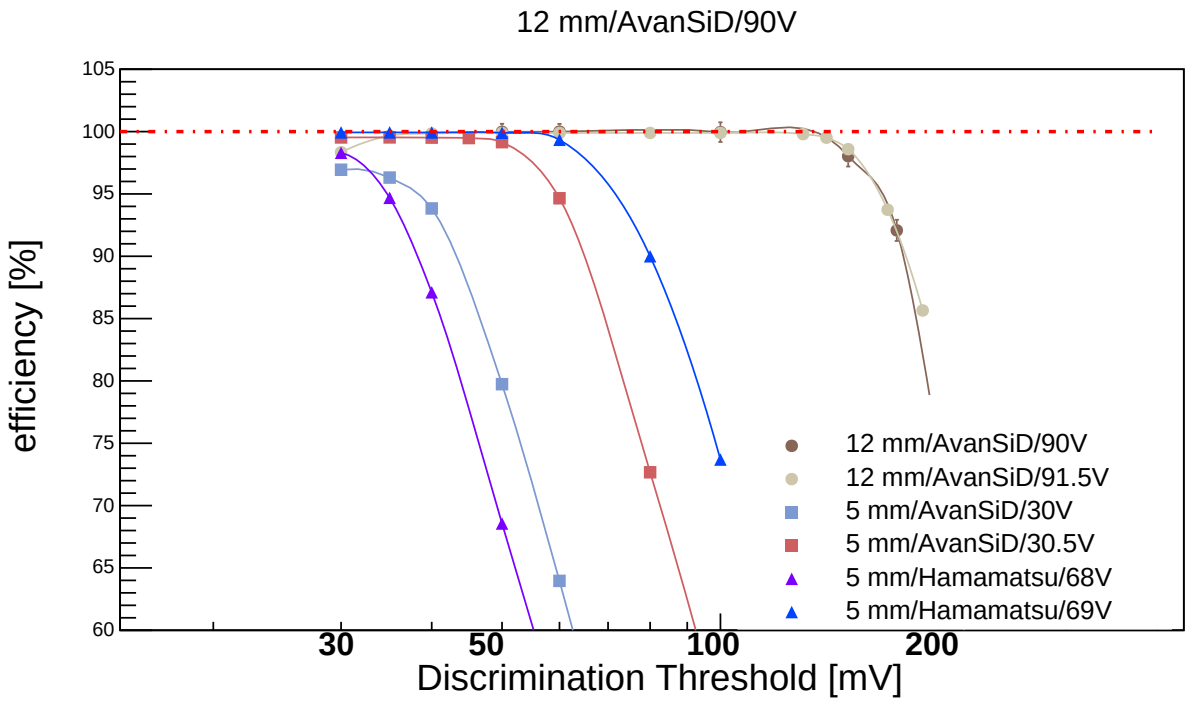

Figure 3: Efficiency as a function of discrimination threshold for all SciSi bars in their standard configuration, and when their voltage supply is increased to the maximal allowed limit.

3. No performance degradation up a rate of 1 MHz.

The timing characteristics of the SciSi are sufficient for MUSE both at the trigger level (replacing at least some of the SciFi planes), and at the analysis level (replacing the Cerenkov counter). We should discuss development and simulation of few planes of SciSi bars, and their correlation with the GEM for resolving ambiguities in multiple tracks events.