Upgrade of proton detector NINJA

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The detector NINJA[1,2] is a plastic scintillator array positioned inside the SAMURAI gap chamber to measure protons that cannot to exit the gap chamber with the standard SAMURAI setup. NINJA is composed an X-layer and a Y-layer. The X- and Y-layers consist of 18 slots with dimensions of 60(w)× 720(l)mm^2× 10(t)mm^t and 12 slots with 60(w)× 1100(l)^2×10(t)mm^t, respectively. The X-layer is located 5 cm upstream of the Y-layer. Scintillation light signals from the plastic are transported to the MPPC through a wave-length-shifter rod in the scintillator. The details of the NINJA can be found in Ref. 2.

This report describes the upgrade of the readout circuits and the performance of NINJA. The readout circuit of NINJA was earlier the VME-EASIROC[3], witch was utilized to digitize the signals from NINJA. VME-EASIROC supplies HV to MPPC. Since we determined that the connection of the external HV supplier was the major noise source, the readout circuit has been changed to NIM-EASIROC,[4] which has an internal HV supplier. Since NIM-EASIROC is not equipped with an internal TDC, the V1190A TDC was used (as an external TDC) to accept the leading and trading edges of signals.

The timing resolution and the detection efficiency of NINJA for protons were evaluated by using the projectile-like protons produced in the ^{1}H(^{6}He,X) reaction in the SAMURAI13 experiment[5]. The detection efficiency ε of the X-layer was evaluated as $N(X\cap Y)/N(Y)$, where $N(X\cap Y)$ represents the number of events occurring at both the X- and Y-layers, and N(Y) the event firing the Y-layer. The Y-layer efficiency ε^Y was evaluated as $N(X\cap Y)/N(X)$. The efficiency of NINJA for protons was evaluated to be 98% for both layers.

The timing resolution was evaluated by using the time difference between the X- and Y-layers, since the distance between the two layers is small (50mm). Figure 1 shows the spectrum of time difference between the X- and Y-layers. One channel in the X-axis corresponds to 100 ps in this case. The red curve indicates the result of fitting using a Gaussian distribution. The resultant sigma of the Gaussian is 6.5 ch, corresponding to 650 ps. Assuming that the time resolutions the X- and Y-layers are identical, the time resolution of NINJA is estimated to be 460 ps. This resolution is mostly governed by one of the EASIROC circuits[3,4], and it can be further improved sightly vis correcting of the walk effect and adjusting the fine offsets of the individual TDC channels. NINJA is currently ready to be employed as the SAMURAI standard detector. It will be used to detect protons emitted from reactions of proton-rich unstable-nuclei beams, for example, for the study of exotic decay channels such as a d-bar (singlet s state of the p+n system) decay from excited states of nuclei. The momentum reconstruction of protons will be performed by combining NINJA with a drift chamber that is currently being developed, which will be positioned immediately in front of NINJA.

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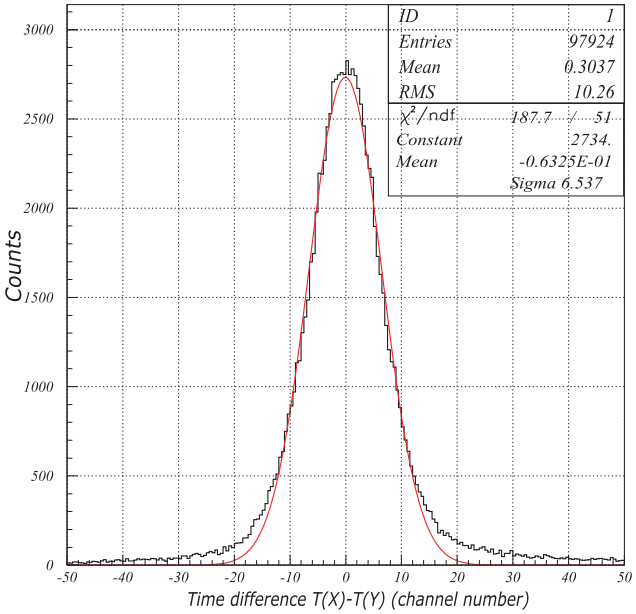

Fig. 1. Spectrum of time difference between X- and Y-layers of NINJA.

References
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