Measurement of light charged particle in the SAMURAI magnet gap with NINJA

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SAMURAI is a large-acceptance magnetic spectrometer aiming at coincidence measurements of charged particles and neutrons. SAMURAI has a standard detector setup for measuring heavy residual nuclei and neutrons, but it is practically impossible to measure more than three types of particles that have considerably different magnetic rigidities, such as neutrons, heavy residual nuclei, and protons. NINJA was designed to measure protons in their trajectory inside the SAMURAI vacuum chamber before they are incident on the side yoke of the dipole magnet.

NINJA consists of a 2-layer plastic scintillator with a thickness of 10 mm each and has a sensitive area of 1080×720 mm^2. Multi-pixel photon counters (MPPCs) located in the pole gap of the dipole magnet are used to count scintillation photons in a strong magnetic field.[1)] Signals from each MPPC are read by the VME-EASIROC frontend board,[2)] which equips an onboard TDC and voltage sensitive ADC.

The first online performance test of NINJA using protons and other fragments was performed at RIBF in 2015. Proton beams with energies of 110 MeV and 250 MeV generated by the fragmentation of a primary beam of ^{48}Ca irradiated NINJA. A particle identification (PID) test using NINJA for light fragments such as deuterons and ^{3}He produced at reactions between a secondary beam of ^{29}Ne and a liquid H_2 target was also performed.

In the present experiments, it was found that the data aquisition with the ADC remained to be developed. For the PID of light-charged ions, time over threshold (ToT) values were taken by the TDC instead of ADC. Figure 1 shows PID using the ToT value and the leading edge timing of a certain bar in the X layer measured by a plastic scintillator (F13 plastic) during the ^{29}Ne+H_2 run. One can clearly identify the proton, deuteron, ^{3}He, and ^{4}He by means of TOF-ΔE.

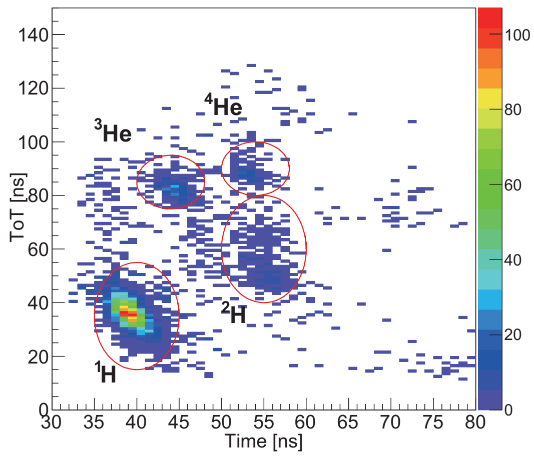

Fig. 1. Particle identification with NINJA. The horizontal axis represents the time of flight between F13 plastic and NINJA, and the vertical axis represents the ToT value for ΔE.

One can measure the X and Y positions of the light charged particle by taking the coincidence between the X layer and Y layer. Figure 2 shows the position of a 250-MeV proton beam measued by NINJA. Each pixel in Fig. 2 represents the coincidence of both layers. The peak position is consistent with a calculation of the proton trajectory.

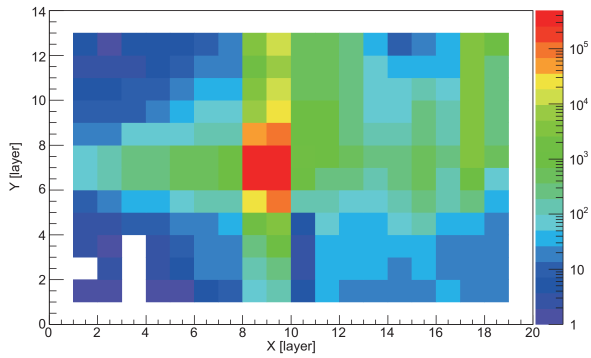

Fig. 2. Measured position of a proton beam with an energy of 250 MeV.

Currentry, VME-EASIROC used in the present experiments is being replaced by NIM-EASIROC aiming at the easier handling of bias supply and low noise. The performance with NIM-EASIROC is reported in Ref. 3. Further developments are in progress to incorporate NINJA into standard detectors of SAMURAI.

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References
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