Study of High Energy Particle Background in Hypernuclear γ-ray Spectroscopy with π^+ Induced Reaction on ^{89}Y and ^{12}C targets

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A π^+ induced reaction used in hypernuclear experiments is characterized by its large probability to produce a Λ hyperon bound nucleus. At KEK, high resolution γ-ray spectroscopy with the Ge-detector array HYPERBALL has been successfully performed for $^7_\Lambda$Li in a ^{7}Li$(\pi^+, K^+)^7_\Lambda$Li reaction at 1.05 GeV/c by Tamura *et al.* [1]. A similar experiment for medium heavy nuclei with $A \sim 90$ has been also proposed at GSI to investigate inner shell transitions[2]. Gamma-ray spectroscopy with Ge detectors is difficult because of high energy particle background in the Ge detectors, causing large dead time due to saturation of the preamplifiers. The problem was solved by the HYPERBALL collaboration by using transistor-reset preamplifers [1]. However, the nature of the background has not been well understood.

At the pion beam facility at GSI, we produced a secondary π^+ beam from a primary ^{12}C beams at 2 GeV/u on a Be production target, Secondary beams with 0.929 GeV/c ($B\rho = 3.094$ T·m) and 1.131 GeV/c ($B\rho = 3.766$ T·m) of π^+ momentum were transfered to Cave C. Two different experimental targets, ^{89}Y with 1.25 cm diameter and 3 cm thickness and ^{12}C with 2 cm diameter and 6 cm thickness were used at each momentum. Since there is no separator in the beam line, other secondary particles in particular ^{1}H, ^{2}H, ^{3}H and ^{3}He were also delivered to the experimental target. Time-Of-Flight (TOF) was measured for the beam particles by using two plastic scintillators with 5 mm thickness separated by 2.2 m. Figure 1 shows the separation among the beam particles at $B\rho = 3.766$ T·m. The beam distribution was measured by a position-sensitive Si strip detector with 0.47 mm strip width to be $\sigma_x = 7.3$ and $\sigma_y = 8.9$ mm. Particles produced in the experimental targets, ^{89}Y and ^{12}C, were measured by a BaF_2 detector at 90° surrounded by 6 NaI detectors. The BaF_2 detector is hexagonally shaped and is 14 cm long with an inscribed circle radius of 4.34 cm. The NaI detectors are also hexagonal and are 20 cm long with an inscribed circle radius of 2.94 cm. A plastic scintillator with 9 mm thickness was placed in front of the BaF_2 detector. The distance of the BaF_2 to the target center was 15 cm. Particle identification was performed by pulse shape analyses with information on the plastic scintillator and NaI detectors. Spectra of π^+, protons, high energy γ-rays from π^0 decay, high energy neutrons, electrons, heavy ions, and low energy neutral particles, which are mainly low energy γ-rays and neutrons ($E < 30$ MeV), from the target were obtained for each kind of projectile by using cuts in TOF and the beam position. Table 1 shows preliminary results for the yield of observed particles by π^+ and proton beams on the ^{89}Y target with more than 10 MeV energy deposition in BaF_2 normalized to the beam intensity at the experimental target at 1.131 GeV/c. We have observed significant particle background with the π^+ beam hitting the ^{89}Y target at 90° and we preliminary conclude that the rate of produced particles in the target can be explained by nucleon resonances. For proton beams as shown in the table, we observed less particles from the target, and we observed almost no particles with the other beam particles.

The results of the measurement show that the proposed hypernuclear γ-spectroscopy with two VEGA Ge detectors at 3 cm from the target center [3] could be performed with a necessary π^+ beam intensity of 5×10^5 per second.

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References

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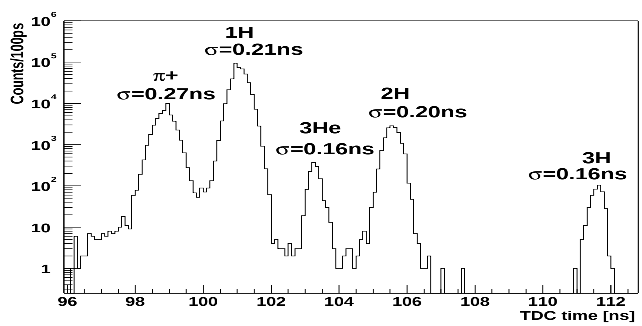

Figure 1: TOF for the beam particles measured by two plastic TOF scintillators at $B\rho = 3.766$ T·m.

Table 1: Preliminary results of particle measurement for energy deposit > 10 MeV in BaF_2 with π^+ and proton beams at 1.131 GeV/c on the ^{89}Y target. The numbers are normalized to the total intensity of the beams hitting the target.

Particles	π^+ beam	Proton beam
π^+	$4(3) \times 10^{-4}$	$< 2 \times 10^{-6}$
Proton	$10(4) \times 10^{-4}$	$8(1) \times 10^{-4}$
High energy γ-ray	$4(3) \times 10^{-4}$	$5(3) \times 10^{-5}$
Electron	$1(1) \times 10^{-4}$	$3(2) \times 10^{-5}$
Low energy neutral particles ($E < 30$ MeV)	$7(3) \times 10^{-4}$	$16(5) \times 10^{-5}$