$pn \to p\Lambda$ reaction and its feasibility

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The non-mesonic decay of hypernuclei is believed to be the two body weak decay process $\Lambda N \to NN$, then it is a different category of weak decay, which happens only in finite baryon density, from the free decay of the Λ particle [1]. Based on the meson exchange model with the $\Lambda N\pi$ coupling studied through the mesonic decay of hypernuclei, one can explore the direct weak process by the ΛNNN coupling as deviations from the simple meson exchange model. On the other hand, explanations of the observables of the non-mesonic decay of hypernuclei is not unique or measured physical quantity has large ambiguity due to the inter-nuclear cascade process after the weak decay of hypernuclei.

To exclude the ambiguity and to make a complementary measurement to the non-mesonic weak decay of hypernuclei, a measurement of the inverse reaction $pn \to p\Lambda$ at a threshold energy region is proposed. The measurement is relatively free from the inter-nuclear cascade because p+N collisions in the initial state lower the energy of the proton and the proton with the lower energy does not contribute to the Λ creation. The Λ particle in the final state enables a polarization measurement by its weak decay asymmetry, and polarized proton may be combined with the polarization measurement to investigate the spin dependent property of the weak interaction. *A challenge in the $pn \to p\Lambda$ reaction measurement is the small cross section of the reaction,* $10^{-39} cm^2$.

The $pn \to p\Lambda$ reaction measurement is proposed at the Ring Cyclotron of the Research Center for Nuclear Physics (RCNP), Osaka University. The highest energy of proton beam available at the Ring Cyclotron is 416 MeV and is in the threshold energy region of the $pn \to p\Lambda$ reaction (threshold energy is E_p=368MeV). The measurement of the reaction is based on a simultaneous detection of a proton and π^- pair from a Λ decay:

$$p + n \to p + \Lambda$$

$$\Lambda \to p + \pi^-$$

An estimation of yield tells one can get about 45 events/30 days with 300 nA proton beam, 1 cm Be target and overall detection efficiency of 5 %. So, the main issue of the measurement is the discrimination of background events from strong processes. The main background of proton is coming from the quasi-elastic scattering of proton by the target and a typical cross section of the process is 25 mb. The main π^- background comes from the quasi-free pion production process, $pn \to pp\pi^-$. A typical cross section of the process is 30 μb. Both processes are highly stronger than the $pn \to p\Lambda$ process, 10^{13} and 10^{10} for proton and π^-.

A collimator made of heavy metal which fully stops protons with the beam energy and other charged particles is proposed to discriminate events which have reaction vertexes in the target and to accept only the proton and π^- pair from Λ particle which has decay vertex out of the target. To achieve reasonable single counting rate at the outside of the collimator,

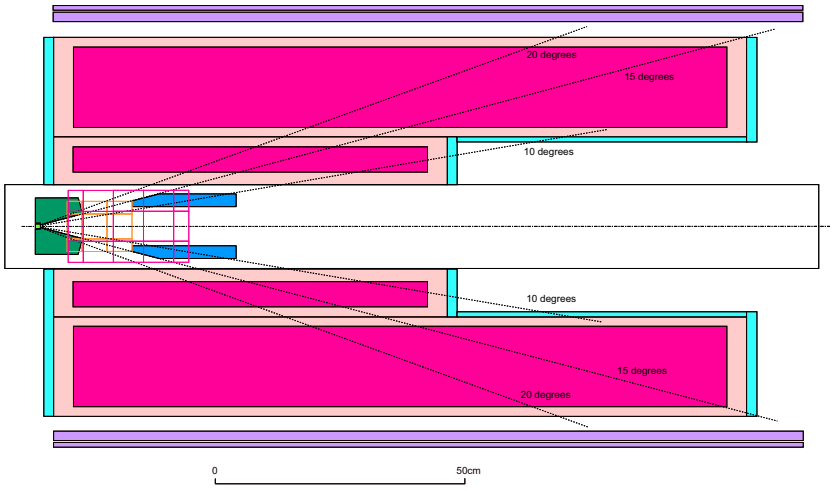

Figure 1: Conceptual design of the experimental setup. The collimator covers the target to stop all charged particles from the target for the laboratory angle down to 15 degrees. The SSD system (shown with wire frames) is installed in the most inner part of the setup to reconstruct the Λ decay vertex. The CDC covers about 2π radian acceptance. To avoid CDC hits by charged particles from the target, an absorber made of heavy metal is installed at forward angle. Counters are surrounding the CDC for trigger purpose.

about 10^4 reduction of charged particles from the target, which corresponds to about 1 μb in cross section, is needed. Monte Carlo (MC) studies of the collimator based on GEANT is in progress. Importance of hardness of the detectors against neutral particles (mainly neutrons and gamma rays) is realized from the studies since energetic protons create low energy neutral particles in the collimator. A test experiment was carried out at the Ring Cyclotron of RCNP with a collimator prototype made of W-alloy, and about 10^2 reduction of charged particles was obtained. Some optimization are needed to increase the reduction rate up to 10^4 with the help of the MC studies.

For the determination of the vertex point of the proton and π^- pair and further discrimination of the background processes, a Silicon Strip Detector (SSD) system at the most inner layer of the experimental setup is in designing [2]. A Central Drift Chamber (CDC) system is in preparation for a large angular coverage (about 2π rad) and a measurement of proton and pion momenta to reconstruct Λ invariant mass. A conceptual design of the experimental setup is shown in Fig.1.

References

[1] For more detail on the non-mesonic decay process, please refer theoretical talks in this workshop.

[2] See also the report by Y. Shimizu on the SSD design in this workshop.