Experiments for Studies on Neutron-Rich Hypernuclei

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We J-PARC E10 collaboration attempt to perform an experiment for the studies on properties of the neutron-rich hypernuclei those are not studied well yet [1]. The neutron-rich hypernuclei have many interesting features as follows:

- exotic structures with the large neutron/proton ratios
- possible large contributions of the ΛNN three-body interaction to the nuclear structures thorough the ΛN-ΣN mixing [2]
- links to the ordinary neutron-rich nuclei [3] and the matter properties in the core of neutron stars [4]

The studies require the copious production of the neutron-rich hypernuclei and the precise measurement of the hypernuclear structures. The requirements can be achieved at the same time by spectroscopic studies with the double charge-exchange (DCX) reaction, the (π^-, K^+) reaction, with a high-intensity pion beam line and a large acceptance magnetic spectrometer with a good energy resolution [5, 6]. The minimum requirements on the performances of the accelerator, the secondary meson beam line and the kaon spectrometer system are as follows:

1. flexibility of the beam spill length in the beam acceleration and the slow beam extraction
2. stability of the beam intensity during the slow beam extraction
3. beam intensity of 1.2 GeV/c pions higher than 10^7 particle/spill at the experimental target
4. spectrometer acceptance close to 100 msr for 0.8 GeV/c Kaons
5. spectrometer energy resolution close to 2 MeV (FWHM) for 0.8 GeV/c Kaons

The requirements from 1 to 4 relate on the yield of the production of the hypernuclei. The yield is considerably small due to the tiny cross section of the DCX reaction, roughly 10 nb/sr, which is about 1/1000 of that of the non charge-exchange reaction, so we need the high duty factor and the high beam intensity.

We believe such beam line and spectrometer will be available at the K1.8 beam line of the Nuclear and Particle Physics Facility at J-PARC within a few years. So, as the 1st step of the studies on the neutron-rich hypernuclei, we are planning to produce the ${}^{6}_{\Lambda}\mathrm{H}$ and ${}^{9}_{\Lambda}\mathrm{He}$ hypernuclei by the ${}^{6}\mathrm{Li}(\pi^-, K^+){}^{6}_{\Lambda}\mathrm{H}$ and the ${}^{9}\mathrm{Be}(\pi^-, K^+){}^{9}_{\Lambda}\mathrm{He}$

reactions, respectively. The measurements can be accomplished by minor modifications of the detector system in the K1.8 beam line with ordinary techniques.

For the future extension of the studies on the neutron-rich hypernuclei, we have to improve and develop the beam line and the spectrometer system. Current maximum pion beam intensity, roughly 10^7 pion/spill, is not limited by the primary proton beam intensity from the accelerator, but by the maximum count rates of the beam line tracking detectors. An update of the beam line tracking detectors with the GEM (Gas Electron Multiplier) technique may improve the maximum beam intensity over 10^7 pion/spill. The development of the GEM based tracking chamber is proceeding under the collaboration of Osaka University and Osaka Electro-Communication University.

A breakthrough may be possible by the High-Intensity and High-Resolution (HIHR) beam line and spectrometer system presented by Noumi in this workshop [7, 8]. Thanks to the dispersion matching technique, the HIHR beam line and spectrometer system has no tracking detectors in the beam line in keeping excelent energy resolution, and we can have the pion beam with the intensity close to 10^9 pion/spill. The HIHR beam line is ideal also for the study of the neutron-rich hypernuclei. So, we hope the HIHR beam line and spectrometer system will be developed and constructed as a part of the 2nd construction plan of J-PARC at the Nuclear and Particle Physics Facility.

References

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