RCNP EXPERIMENT E

PROPOSAL FOR EXPERIMENT AT RCNP

2 July 2016

TITLE:

Test of a scintillating fiber target for the hypernuclear spectroscopy

SPOKESPERSON:

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RUNNING TIME:	Installation time without beam	3 days
	Beam commissioning	1 days
	Data runs	1 days
BEAM LINE:		Ring : WS course
BEAM REQUIREMENTS:	Type of particle	unpolarized p
	Beam energy	392 MeV
	Beam intensity	$\leq 5 \times 10^3$ pps
	Other requirements	energy resolution ~100 keV
		halo-free, small emittance

BUDGET:	Vacuum feedthrough	100,000 yen
	Travel expense	200,000 yen

SAFETY CONTROLLED ITEMS:

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Test of a scintillating fiber target for the hypernuclear spectroscopy

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SUMMARY OF THE PROPOSAL

A spectroscopy experiment of Ξ hypernucleus through the ^{12}C(K^-, K^+) reaction is planned to carry out in the J-PARC E05 experiment. For this experiment, a scintillating fiber bundle with a thickness of $\sim$10 cm is under development as a production target. The substantial thickness of the carbon in the fiber will provide enough yields of the hypernuclear states, and the light yield in the fiber will be utilized to correct an energy loss of the K^- and K^+ in the target, which deteriorates an energy resolution crucially.

We propose a test experiment using proton beam at 392 MeV to evaluate the response of scintillating fibers for energy loss of the hadron beams. The energy loss should be measured by spectrometer with an energy resolution of a few tens of keV to compare with the QDC information from the fiber system. This measurement can be realized only with the high resolution spectrometer Grand Raiden and relatively high energy proton beams available only in RCNP.

DETAILED DESCRIPTION OF PROPOSED RESEARCH

1 MOTIVATION

A spectroscopy experiment of Ξ hypernucleus through the ^{12}C(K^-, K^+) reaction is planned to carry out in the J-PARC E05 experiment. In this experiment, the bound state peaks of not only the Ξ hypernucleus and also $\Lambda\Lambda$ hypernucleus are expected to be observed as peaks for the first time. The information of the peak positions and widths are quite unique for investigating the baryon-baryon interaction in the strangeness $= -2$ system.

Since the production cross section of the bound state is expected to be very small, $\sim$60 nb/sr, it is desired to use substantially thick target to carry out the experiment with enough statistics. About ten g/cm^2-thick target will be required to perform the experiment in the reasonable run time with the current K^- beam intensity at the J-PARC.

On the other hand, an energy resolution should be better than 2 MeV including the spectrometer resolution of about 1 MeV, in order to observe peak structures of the hypernuclei precisely. With such a thick target, an energy resolution should deteriorate by more than a few MeV because of the energy loss straggling in the target. In that case, it becomes difficult to separate peak structures and measure the peak widths. Thus, we need to develop a target system with enough thickness keeping a good energy resolution.

For this purpose, a scintillating fiber target is under design. Figure 1 shows a concept of the fiber target. The carbon and hydrogen in the fiber bundle are used for the production of hypernuclei and hyperons (as a calibration source), respectively. As for the resolution, a correlation between the energy loss and light yield in the fiber due to the passage of K^- and K^+ is expected to enable us to correct the momenta of them. The target system should measure the energy loss through the light yield as a QDC information event by event, and the energy resolution will keep improved even if a large straggling exists.

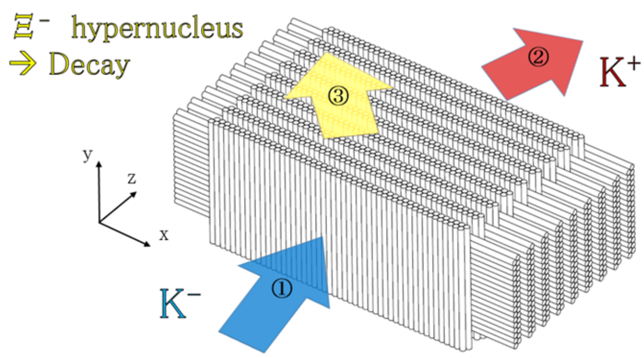

Figure 1: Schematic drawings of the fiber target.

The spread of total energy loss in the target will be around 3–4 MeV, and ∼10 percent of energy resolution is required for the target system. It is very important to evaluate the energy resolution of scintillating fiber and read out system, and to prove the priciple of this measurement.

2 EXPERIMENTAL PROCEDURE

We will measure a relationship between energy loss in a scintillating fiber and the number of photons emitted in it. The test is performed at WS course. A proton beam at 392 MeV accelerated by AVF and Ring Cyclotrons bombards a fiber placed at the center of the scattering chamber. Since a trajectory of the scattered proton by multiple Coulomb scattering is almost straightforward, Grand Raiden spectrometer is set at 0 degrees. Figure 4 shows Grand Raiden spectrometer in plan view. The primary beam or the scattered protons are deflected by the spectrometer, and then their momenta are measured in focal plane detectors. Coincidences between the fiber and the detectors allow event-by-event measurement of energy loss in the fiber, and therefore the relationship is obtained.

Figure 2 shows a simulation result of the energy loss in a fiber. The mean value is estimated at about 0.7 MeV, so the loss must be determined with an accuracy of 30 keV. Dispersion matching with a stable halo-free beam is required in this experiment. In a previous study, an achieved energy resolution was $\Delta E = 17$ keV (FWHM) in a spectroscopy of ^{48}Ca with (p, p') reaction at $E_p = 295$ MeV [1] (see Figure 3). Hence this proposed high-resolution measurement is feasible.

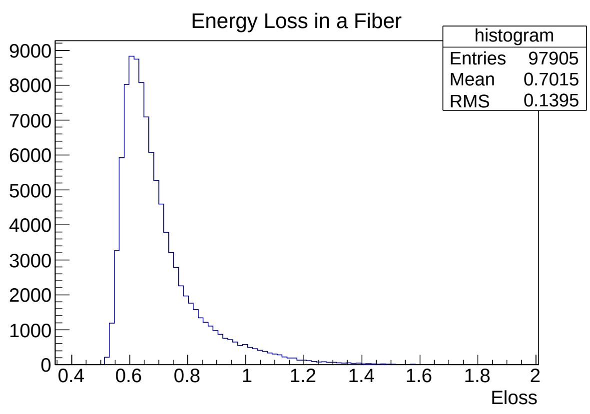

Figure 2: Simulation of the energy loss of proton in a scintillating fiber.

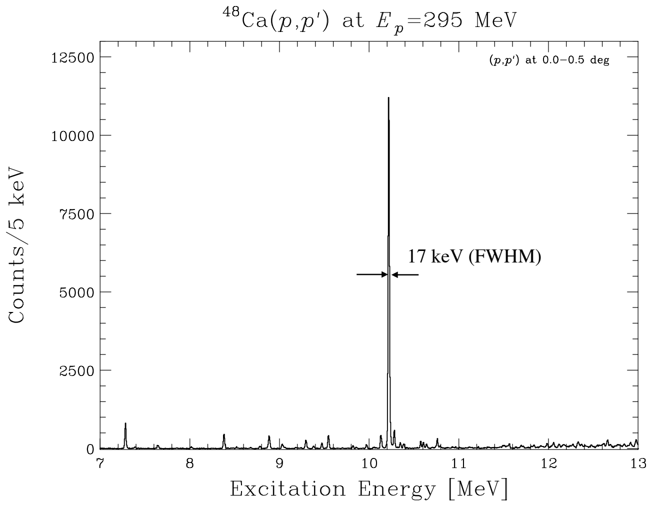

Figure 3: The achieved energy resolution in ^{48}Ca(p, p') reaction was 17 keV (FWHM).

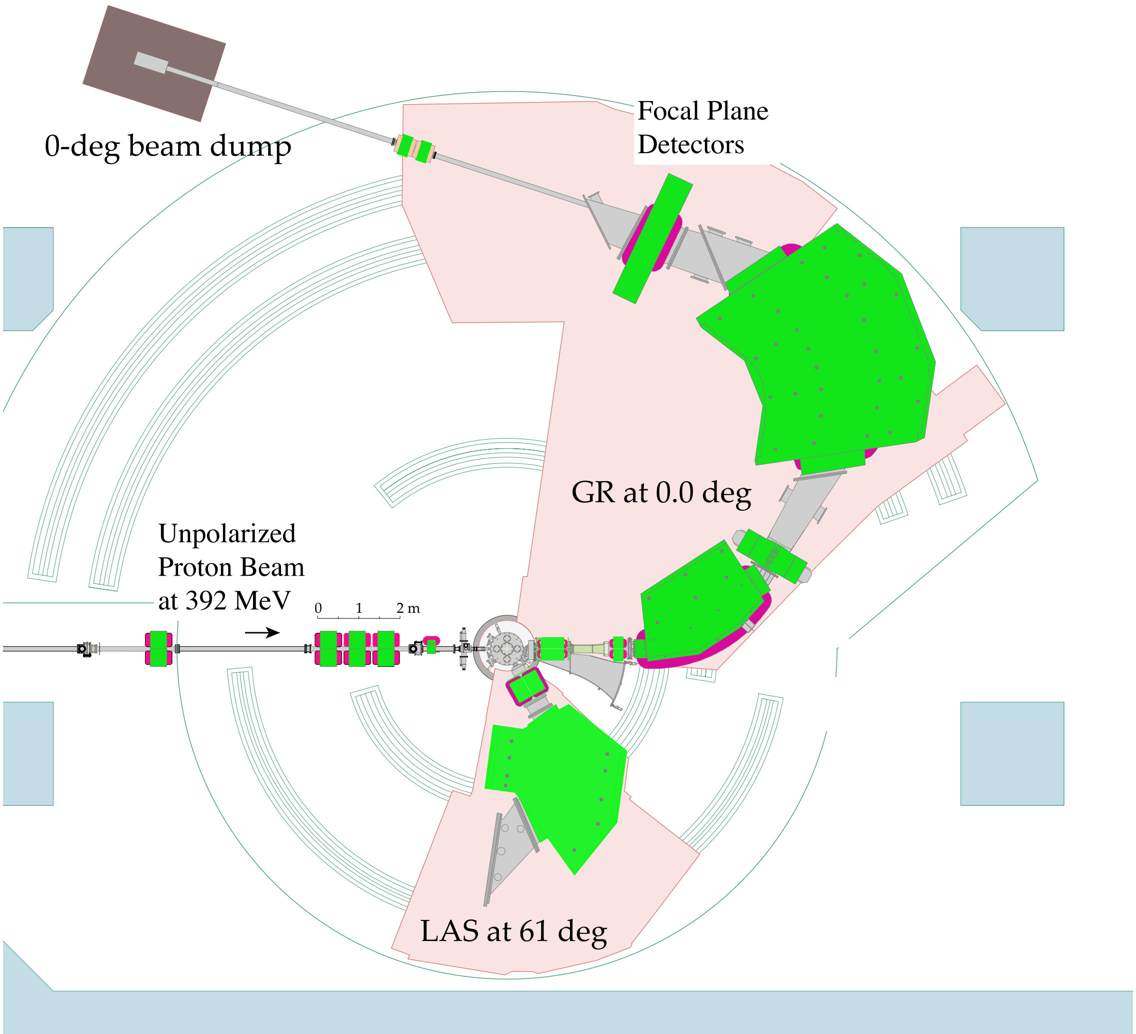

Figure 4: Grand Raiden spectrometer in plan view. Not only scattered protons but a primary beam are detected at the focal plane.

2.1 Target

We use a several kinds of fibers as a target with a length of 20 cm. A remotely controlled target ladder enables us to survey a position dependence of a fiber. The fibers are changed by means of breaking vacuum in the scattering chamber. Both sides of the fiber are mounted on MPPCs. Then the readout devices are controlled and the signals are digitalized by EASIROC modules.

3 Beam time estimation

To obtain a position dependence of fibers, we scan each fiber choosing 5 positions, starting from the center in a step of 4 cm. Since a trigger rate of this experiment is 5000 Hz, the DAQ efficiency is almost 100%. Although we consider time to change fiber positions and tune gains of MPPCs, 30 minutes allow us to get a sufficient number of events.

Moreover, we perform the test of at least 3 kinds of fibers to evaluate performance of fibers and 4 each of these fibers to measure individual specificity of fibers. It takes about 1.5 hours to change fibers because we must break vacuum in the scattering chamber to change them.

From the above, we need $0.5 \times 12 + 1.5 \times 11 = 22.5$ hours beam time for data runs and it takes about 24 hours to tune beam condition as we require. Therefore, we conclude that this experiment requires 2 days beam time.

References

[1] A. Tamii et al., Nuclear Physics A 788 (2007) 53c–60c