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KEK Preprint 97-228
December 1997
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H. NOUMI

Sw 9828

*Presented at
the International Conference on Hypernuclear and Strange Particle Physics (HYP97),
BNL, U.S.A., October 13 - 18, 1997.*

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High intensity pion beam line at JHF

H. Noumi^a

^aPhysics Division III, High Energy Accelerator Research Organization,
1-1, Oho, Tsukuba, Ibaraki 305-0801, Japan

A high-intensity, high-resolution pion beam line has been proposed for the Japan Hadron Facility. An intensity of 10^9 and a momentum resolution of 10^{-4} will be available. High-resolution, high-statistics, and high-sensitivity spectroscopic studies of hypernuclei will be possible.

1. INTRODUCTION

The Japan Hadron Facility (JHF) will provide research facilities that the hypernuclear physicists in the world have been desiring for a long time. The main proton synchrotron will deliver a high-power beam of 50 GeV and 10 μ A. High-intensity, high-quality kaon and pion beam lines will be constructed. Particularly, by taking advantage of the low-emittance primary beam (4.1π mm·mrad) [1], a *High-Intensity, High-Resolution GeV-Pion Beam Line* can be designed.

In this article, a proposal for a high-intensity pion beam line at JHF is presented. The beam line will provide a pion intensity as high as 10^9 per second and a momentum resolution as good as 10^{-4} , which are respectively 1000-times more and 10-times better than those realized at K6 of the KEK 12-GeV PS [2]. Utilizing the beam line, next-generation hypernuclear studies with high precision will be possible, where high resolution, high statistics, and high sensitivity will be key issues.

2. HIGH INTENSITY PION BEAM LINE

A layout of the proposed beam line is illustrated in Figure 1, together with a kaon spectrometer, which is described later. The beam line consists of two halves. The first half is for separating pions from the other secondary particles with an electrostatic separator. The pion beam is achromatically focused at the mass slit (MS). Since no tracking devices are available, due to the high counting rate, the beam momentum must be determined by measuring the reaction point where the beam position is strongly correlated with its momentum. Therefore, the second half is for making the beam dispersive vertically at the final focus point (FF) where the experimental target will be placed. The dispersion and vertical magnification at FF are to be $\sim 10\text{cm}/\%$ and -0.4 , respectively. Sextupole magnets are used to eliminate the dominant second-order aberrations. A momentum resolution of 10^{-4} can be achieved when the source size at the production target (PP) is smaller than 2.5mm, which will be easily realized owing to the low-emittance primary beam.

Figure 1. High-intensity, high-resolution pion beam line and kaon spectrometer.

The total length and acceptance of the beam line are 35m and $4\text{msr}\cdot\%$. According to the Sanford-Wang formula [3], the π^+ intensity is estimated to be more than 10^9 per second with a platinum production target 6cm long.

One of the key issues for utilizing the above-mentioned beam line is to measure the hypernuclear excitation spectra with high resolution. For this purpose, the kaon spectrometer will be required to have the same order of magnitude in terms of resolution as that of the beam line. The kaon spectrometer shown in Figure 1 meets this requirement.

The specifications of the pion beam line and kaon spectrometer in ion optics are summarized in Table 1. The pion beam line has a horizontal magnification of about 0.8 and makes a sharp and waist image at FF. Taking advantage of this, the bending plane of the kaon spectrometer is placed horizontally. Measuring the horizontal and vertical profile (position and divergence with respect to the central orbit) at the focal plane of the spectrometer, one can derive the scattering angle and momentum of scattered kaon and the beam momentum, respectively. There is no need at all to place tracking devices at the entrance of the spectrometer. This makes a measurement at a forward angle easy, where the cross section becomes large in most of hypernuclear states.

The present kaon spectrometer is obviously optimized for the resolution, compromising with the acceptance and kaon survival rate. The specifications of the kaon spectrometer should be changed if necessary. The resolution, acceptance, maximum central momentum, total length, cost, and so on, will have to fit the experimental requests.

Table 1

Specifications of the pion beam line and kaon spectrometer. ^{a)} Corrections for higher order aberrations are required.

	π Beam Line	K Spectrometer
Max. Central Momentum(GeV/c)	1.5	1.5
Total Length(m)	34.738	12.4
Horizontal Acceptance(mrad)	± 50	± 100
Vertical Acceptance(mrad)	± 10	± 40
Momentum acceptance(%)	± 1	± 5
Horizontal Magnification	-0.409	-3.084
Vertical Magnification	0.773	-0.851
Dispersion(cm/%)	10.614	8.327
Momentum Resolution($\Delta P/P$)	10^{-4}	10^{-4} ^{a)}

3. HIGH-PRECISION HYPERNUCLEAR SPECTROSCOPY

At the present beam line facility, the hypernuclear structure can be investigated with an energy resolution as good as 300 keV. Figure 1 shows the simulated excitation energy spectra produced via the (π^+, K^+) reactions on ${}^7_\Lambda\text{Li}$ and ${}^{90}_\Lambda\text{Zr}$. We will be able to see the fine structure of not only the low-lying states but also the highly excited states. It is very

Figure 2. Simulated excitation energy spectra for ${}^7_\Lambda\text{Li}$ (left) and ${}^{90}_\Lambda\text{Zr}$ (right).

advantageous that the production rate of these states is still sufficiently high owing to high-intensity beam, even though we use a very thin target in order to keep the energy-straggling effect negligible. Thus, systematic measurements on the hypernuclear structure

will be proceeded efficiently. The spin-isospin structure of the YN interaction and details concerning the mean field potential of the hypernucleus could be studied.

The high-intensity pion beam allows us to carry out hypernuclear decay spectroscopy with high precision. Particularly, the hypernuclear weak-decay mechanism has yet to be revealed. Nonmesonic decay is a unique process in hypernuclei and provides invaluable information on the weak YN interaction. Partial decay widths of nonmesonic decays reflect the spin-isospin structure of the weak YN interaction, and have so far been observed in limited hypernuclei and limited statistics. There exists a discrepancy between theory and experiment. However, the experimental data seem to have a large uncertainty since contributions from the final state interaction and many body decay are still unclear. Recently, the asymmetry of nonmesonic decay has been measured [4], which gives the interference term of the parity-violating amplitude with the parity-conserving one. A further accumulation of data with better quality is necessary.

In this beam line, the differential decay widths ($d\Gamma/dE$ and $d\Gamma/d\theta$, energy and angular distributions) in addition to Γ can be measured very precisely, based on high statistics. Our primitive understanding of the decay mechanism will be improved.

Mesonic weak decay, particularly in heavy hypernuclei, is sensitive to pion propagation in the nucleus, which reflects the dynamics of hadrons in the nuclear medium. Exotic decay, such as positive pion emission, is interesting since it is sensitive to the $\Lambda\Sigma$ mixing effect. The sensitivity for the branching ratios of these decays will be as high as 10^{-3} in the present beam line.

The hypernuclear magnetic moment is quite sensitive to the details of the hyperon-nucleon interaction in the nuclear medium. Particularly, the isospin dependence is interesting since it would reflect the structure of the exchange current, *e.g.*, the contributions of kaon exchange and/or Σ excitation [5]. It has been an ambitious dream to measure the hypernuclear magnetic moment. This dream may come true at the present facility.

4. SUMMARY

The production rate of hypernuclei is expected to drastically increase at JHF; a so-called hypernuclear factory will be established. Based on this, we will be able to carry out hypernuclear spectroscopic studies with high precision, where high resolution, high statistics, and high sensitivity will be key issues. It will be a pleasure if the proposed beam line facility is realized.

REFERENCES

1. JHF Project Office, Proposal for Japan Hadron Facility, KEK Report 97-3.
2. The K6-SKS spectrometer system has realized about 50 events of the $^{12}\text{C}(\text{g.s.})$ production per hour with a graphite target $1.8\text{g}/\text{cm}^2$ thick.
3. J. R. Sanford and C. L. Wang, BNL 11279 and BNL 11479 (1967); C. L. Wang, Phys. Rev. Lett., **25**, 1068 (1970).
4. S. Ajimura *et al.*, Phys. Lett., **B282** (1992)293.
5. M. Oka, Exchange current contributions to hypernuclear magnetic moments, contribution to this conference; K. Saito, M. Oka, and T. Suzuki, Exchange currents for hypernuclear magnetic moments, TIT/HEP-368/NP, 1997.