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KEK-PS E251 & E289 Collaboration

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Hyperon-Proton Scattering Experiments with a Scintillating Fiber Detector at KEK

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Hyperon-proton scattering has being studied at KEK in order to obtain a better understanding of the Baryon-Baryon interaction. A scintillating fiber (SCIFI) block detector has been used as a production target of hyperons as well as a hyperon scattering target on hydrogen. The pilot experiment (E251) for Σ^+p scattering has been completed, and the next experiment (E289) for Σ^+p, Σ^-p and Λp channels has finished its data taking and is now carrying out analysis.

1. INTRODUCTION

Nucleon-nucleon (NN) scattering was extensively studied in the 50's and 60's. The existence of a "hard-core" has definitely been verified by a phase-shift analysis, and the NN scattering data well described by one-boson exchange (OBE) models. An attempt has been made to understand the NN interaction within the framework of the strong interaction between the baryon octet. The OBE models have been extended to include the YN scattering data. The Nijmegen group took into account the flavor SU(3) symmetry [1] and the Bonn-Jülich group developed a model based on SU(6) symmetry [2]. The short-range repulsive force of the strong interaction was explained based on a more basic hierarchy, i.e., quarks and gluons. The quark-cluster model approach has been developed independently by groups from Tokyo, Tübingen and Kyoto-Niigata [3–5].

Although experimental studies of the hyperon-nucleon (YN) interaction will play an essential role for understanding the strong interaction, there is not much experimental data on YN scattering, especially in the momentum region below 1 GeV/c. The existing YN data are from bubble-chamber experiments in the 1960's [6]. The major difficulty of the YN scattering experiment arises from the short lifetime of hyperons. The production target of hyperons must serve as the scattering target of hydrogen. The detector must be capable of resolving a three-dimensional reaction sequence. Although a bubble chamber is also such a device, the data-taking rates are limited. We thus developed a SCIFI block detector as a live target to satisfy these requirements. A SCIFI detector may overcome any data-rate difficulties, and data are recorded directly as digital images, unlike in a bubble chamber. In this paper, the present status of the YN study with a SCIFI detector at KEK is described.

2. EXPERIMENT

The experiment was performed at the K2 beam line of the 12-GeV Proton Synchrotron at KEK. A separated π^+ or π^- beam was used to produce Σ^+'s, Λ's or Σ^-'s through the $(\pi^\pm, K^+)$ reaction, and subsequent scattering of hyperons was observed in a SCIFI target. Fig 1 shows a top view of the E289 experimental setup, which consists of the beam line, a spectrometer and the SCIFI target system. The system is similar to the E251 setup, which was also used in a previous H-dibaryon search experiment [7], except for the central angle (14°) of the spectrometer to the beam axis. At E289, the spectrometer was set at a finite angle in order to reduce the overlap of tracks of an outgoing K^+, a produced hyperon, its decay product(s) and a recoiled proton in the image data.

A $\pi^\pm$ beam of about 1.6 GeV/c and an intensity of 1~2×10^5 pions/spill (one spill is ~2 sec length with 0.25 Hz repetition) was focused on the target. The beam particle identification was performed by measuring the time-of-flight between the T1 and T2 scintillation counters, supplemented by a silica aerogel Čerenkov counter (BAC) and a gas Čerenkov counter (GC). The particle momentum and trajectory were measured by sets of drift chambers (BDC1~3) and multi-wire proportional chambers (BPC1~5).

The outgoing charged particles were momentum analyzed and detected with a spectrometer consisting of a dipole magnet (SP), multi-wire proportional chambers (PC1 and PC2), drift chambers (DC1, DC2 and DC3), an aerogel Čerenkov counter (FAC), a lucite Čerenkov counter (FLC) and a TOF hodoscope (FTOF). The FAC vetoed scattered pions. A coincidence matrix between the hodoscope (CH) in the entrance of the SP magnet and the FTOF counters was used for the first- and second-level trigger to provide approximate momentum information on the particle.

The scintillating fiber (SCIFI) target is a visual detector located at the focal point of the beam line. In E251, we used the same SCIFI block target and the image-intensifier tubes (I.I.T.) which were used in the previous H-search experiment. In E289, we made and assembled a larger target with smaller fibers for higher statistics and better spatial resolution. The characteristic parameters of SCIFI targets for E251 and E289 are listed in Table 1.

Table 1
Parameter list of SCIFI block detectors for E251 and E289

			E251	E289
Fibers used		KURARAY	SCSF81	SCSF78
Fiber cross section	[μm^2]		500×500	300×300
Target size	[cm^3]		8×8×10	10×10×20

SCSF78 has a 1.8-times higher light output at 30 cm length than does SCSF81. The E289 SCIFI block was assembled in two stages: first, 10 cm (width)×30 cm (length) flat fiber sheets were constructed using about 330 fibers for each sheet; the sheets were then stacked alternately in the vertical and horizontal directions. About 600 such sheets in total were used to form a target volume of 10 cm(U) × 10 cm(V)× 20 cm(Z). The space between the fiber sheets in each direction beyond the target volume created by stacking alternately was reduced at the readout arms, as shown in fig 2, in order to match the sensitive area of the I.I.T.'s, which amplify the output light from the target. Two chains of I.I.T.'s were used, one for the U-Z plane and the other for the V-Z plane.

Table 2
Structure of I.I.T. for E289

stage	I.I.T.	input/output dia.	gain	Q.E.	phosphor
1st	HAMAMATSU VP4440XP	100/25mmϕ	~10	19%	PS-5
2nd	DEP PP0030X	25/25mmϕ	6~10	14%	P46
3rd	PROXITRONIC BV2563McG	25/25mmϕ	~ 10^4	~10%	P20
Fiber Optic Taper		25/8.64mmϕ			
4th	GEOSPHAERA EBCCD	Magnification~1	~ 10^3	~10%	

A list of the components of the I.I.T. chain is given in Table 2. The input diameter of the 1st-stage I.I.T. is larger than that of E251 (80 mmϕ). We require a phosphor with a short decay time in order to reduce event overlapping. Thus, the PS-5 phosphor with a decay time of 1.4 μsec was used for the first stage, whereas the P24 phosphor (2.4 μsec) was used at E251.

The third stage of the I.I.T was gated by the first-level trigger formed by $\pi^{\pm}$'s in the beam vetoed by scattered pions. The rate of the first-level trigger was 150~170/spill for (π^+, K^+) and and 200~250/spill for (π^-, K^+) at $1.5\times10^5\pi^{\pm}$/spill. The fourth stage was gated by a second-level trigger, which we called a "mass trigger". The trigger was invoked within 15μsec from the occurrence of an event, and opened the gate of the fourth I.I.T. for 1 msec. The trigger was formed by the signal from the mass region of K^+'s in the "mass trigger" logic. The mass-trigger selection was determined by momentum information given by the combination of hit positions on CH and FTOF and the time-of-flight information between the T2 and FTOF counters obtained from the fast-encoding TDC modules. The trigger rate at this level was 10~14/spill for (π^+, K^+) and 5~8/spill for (π^-, K^+).

The photo-electron in this fourth stage bombarded the back-side of a CCD-chip containing 532 × 580 pixels, the effective area of which was 9.04 mm × 13.34 mm. The output signals from the CCD were digitized in real-time and recorded in CAMAC memory modules after data compression.

3. MILESTONE & PRESENT STATUS

3.1. E251

In KEK, a SCIFI detector was newly designed and developed as a live target for a H-dibaryon search experiment (E224). As a first trial of the application of this SCIFI detector to Σ^+p scattering, experiment E251 was approved, and started in July, 1991 with a slight modification of the E224 setup. Data acquisition was finished in January, 1993, and the result has been reported [8].

3.2. E289

After R&D work and preparation from 1993 to the summer of 1995, the beam time of E289 started in October, 1995, and finished in February, 1997. About 2×10^6 Σ^+'s and Λ's in total and $5\times10^5\Sigma^-$'s were accumulated by the (π^+, K^+) reaction and by the (π^-, K^+) reaction, respectively. A measurement of the magnetic field of the spectrometer and the calibration of an overall distortion of the SCIFI detector by X-ray was performed this March and April.

A raw image on the CCD suffers a distortion caused by the I.I.T. lens system and a stray magnetic field of the spectrometer. The position of each pixel in the real target was calibrated by placing a plate with holes on the opposite end of the SCIFI block and illuminating them with EL panels. This position calibration was performed with a two-dimensional spline fitting, as shown in Fig 3.

The proton-proton scattering was measured by the SCIFI detector for the system calibration. Proton beams of 750 MeV/c were incident on the SCIFI target, and image data were recorded for each proton beam. A preliminary result of the p-p differential cross section for image data selected by the eye-scanning procedure was obtained after kinematical constraints, such as the coplanarity condition and the momentum balance, as shown in Fig 4. The p-p differential cross section is known to be almost flat at about 3.5 mb/sr around this momentum region. This figure shows that the eye-scanning efficiency drops at angles less than 50 degrees. By using this pp data, we will estimate the efficiencies of the eye-scanning procedure and the automatic tracking program, as well as systematic errors, such as contaminations caused from pC quasi-elastic scatterings.

4. SUMMARY

After a long experimental silence since obtaining the bubble chamber data, E251 developed a new technique using scintillating fibers, and showed new data of Σ^+p elastic scattering. Its statistics, however, was still poor. E289 for $\Sigma^\pm$- and Λ-p scattering is now in analysis. Thus, this SCIFI technique provides a new opportunity for Yp scattering experiments. However, data-acquisition rates are limited by both the decay time of the phosphor in I.I.T. and by triggers. Further improvements or tests of a fast imaging device, such as the image-delay tube [9], might be required for experiments at BNL and the coming JHF. At BNL and JHF, measurements of polarization observables and Ξ^-p scattering will be attainable.

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REFERENCES

1. M. M. Nagels, Th. A. Rijken, and J. J. de Swart, *Phys. Rev. D***15**,2547 (1977);*Phys. Rev. D***20**,1633 (1979); P. M. M. Maessen, Th. A. Rijken, and J. J. de Swart, *Phys. Rev. C***40**,2226 (1989); Th. A. Rijken, and V. G. J. Stoks *Phys. Rev. C***54**,2851 (1996).
2. B. Holzenkamp, K. Holinde, and J. Speth,*Nucl. Phys.***A500**,485 (1989); A. Reuber, K. Holinde, and J. Speth,*Nucl. Phys.***A570**,543 (1994).
3. M. Oka and K. Yazaki, in *Quarks and Nuclei*, edited by W. Weise(World Scientific Publishing, 1984), p. 489; K. Yazaki,in *Perspectives of Meson Science*, edited by T. Yamazaki, K. Nakai, and K. Nagamine (Elsevier Science Publishers, 1992), p. 795.
4. U. Straub, Z. Y. Zhang, K. Bräuer, A. Faessler, S. B. Khadkikar, and G. Lübeck, *Nucl. Phys.***A483**,686 (1988);*Nucl. Phys.***A508**,385c (1990).
5. Y. Fujiwara, C. Nakamoto, and Y. Suzuki, *Prog. Theor. Phys.***94**,215 (1995); *Prog. Theor. Phys.***94**,353 (1995); *Phys. Rev. Lett.***76**,2242 (1996); *Phys. Rev. C***54**,2180 (1996).
6. R. Engelmann *et al.*,*Phys. Lett.***21**587 (1966); G. Alexander *et al.*,*Phys. Rev.***173**1452 (1968); B. Sechi-Zorn *et al.*,*Phys. Rev.***175**1735 (1968); G. R. Charlton *et al.*,*Phys. Lett.***32B**720 (1970); J. A. Kadyk *et al.*,*Nucl. Phys.***B27**13 (1971); F. Eisele *et al.*,*Phys. Lett.***37B**204 (1971); J. M. Hauptman *et al.*,*Nucl. Phys.***B125**29 (1977).
7. J. K. Ahn *et al.*,*Phys. Lett. B***378**,53 (1996);
8. Y. Goto, *Ph.D. thesis, Kyoto Univ.* (*Memoirs of the Faculty of Science, Kyoto University, (Series of Physics, Astrophysics, Geophysics and Chemistry)* Vol. **40-1**, 1 (1997)); J. K. Ahn *et al.*, submitted to *Phys. Rev. C*.
9. A. G. Berkovski *et al.*,*Nucl. Instr. and Meth.***A380**,537 (1996).

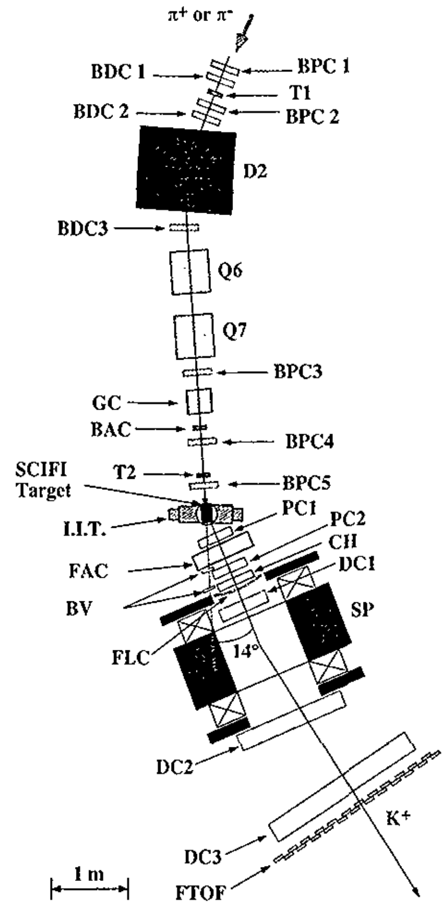

Figure 1. Top view of the E289 experimental setup.

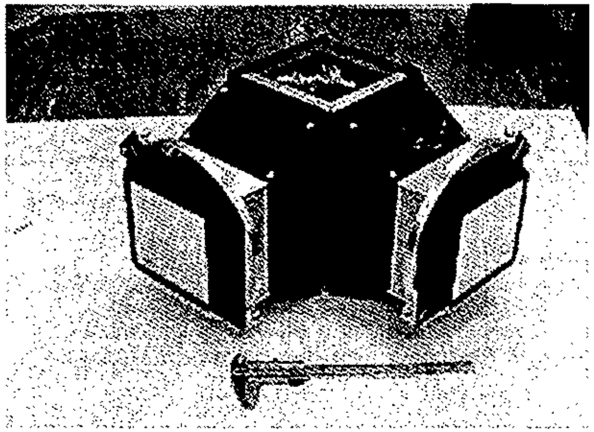

Figure 2. A photo of the E289 scintillating fiber block.

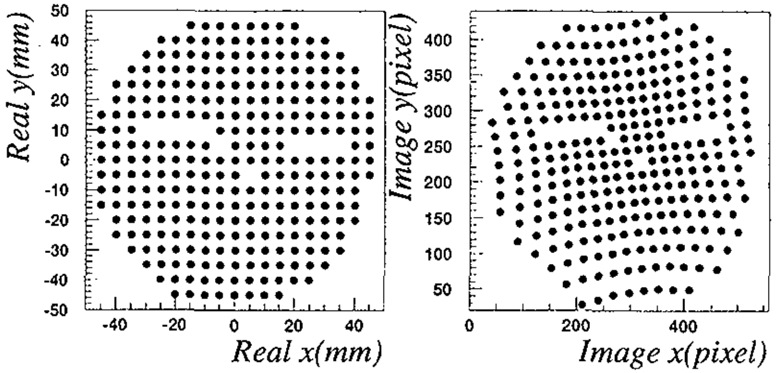

Figure 3. Position calibration of each pixel of CCD in the real target performed by a two-dimensional spline fitting. Left) calibrated image; Right) raw image.

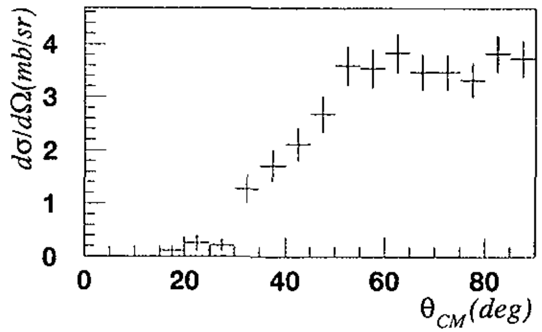

Figure 4. Preliminary result of pp elastic scattering by the SCIFI detector for system calibration. The vertical error-bars contain only statistical errors.