THE MAIN RING POLARIMETER AT KEK 12 GeV PS

Hikaru SATO, Shigenori HIRAMATSU, Takeshi TOYAMA* and Dai ARAKAWA
National Laboratory for High Energy Physics
Oho-machi, Tsukuba-gun, Ibaraki-ken, 305, Japan

Hiroshi SAKAMOTO
Tsukuba University
Sakura-mura, Niihari-gun, Ibaraki-ken, 305, Japan

Ken-ichi IMAI and Norio TAMURA
Kyoto University, Sakyo-ku, Kyoto, 606, Japan

ABSTRACT

An internal polarimeter was constructed to detect the beam polarization in KEK proton synchrotron (PS) from T_p = 500 MeV to 12 GeV. The polarimeter was installed in the main ring and successfully used for the measurement of the beam polarization at 500 MeV circulating beam. We describe the design and the performance of the polarimeter.

INTRODUCTION

Both the booster and the main ring of KEK PS are strong focusing synchrotrons and therefore strong depolarizing resonances are expected during acceleration[1,2]. Especially, the main ring has many depolarizing resonances. It is quite necessary to measure the beam polarization before and after each resonance during acceleration to tune the polarized beam through the depolarizing resonances with minimum polarization loss. For this purpose, an internal polarimeter is the best one. So the main ring internal polarimeter is installed in the straight section II-2F of the 12 GeV PS main ring. Hereafter we denote main ring polarimeter.

The design philosophy of the main ring polarimeter is as follows.

1) The polarimeter can be operated at any energy from 500 MeV to 12 GeV to study each resonance.
2) The absolute value of the beam polarization at low energy, especially at 500 MeV, can be measured with good accuracy.
3) For the tuning of the accelerator, the beam polarization should be measured in a short period.
4) To avoid the frequent access to the polarimeter which is located inside of the accelerator tunnel, the polarimeter must be reliable and easy to operate and free from maintenance.

To fulfill the above requirements, we constructed the main ring polarimeter which consists of a polyethylene string target and scintillation counter telescopes. The beam polarization can be obtained by measuring the left-right asymmetry of the proton-proton elastic scattering. At least at low energy, the separation from the proton-carbon reaction is expected to be good enough to use it as the absolute polarimeter.

At high energy, it is difficult to separate proton-proton elastic scattering from the background and the main ring polarimeter can be used as a relative polarimeter. But it has a great advantage to monitor the beam polarization before and after each resonance during acceleration.

We can control the main ring power supply to make a flat top at selected energy above 4.6 GeV. So the polarization can be measured with use of the debunched beam above 4.6 GeV. (The control system of the main ring power supply is under reconstruction to make a flat top from 500 MeV to 12 GeV.)

DESIGN AND CONSTRUCTION OF THE POLARIMETER

Polarimeter target system

A polarimeter target system consists of a scattering chamber and a target mechanism. The scattering chamber has two 100 μm thick SUS foil windows of 62 mm diameter for recoil protons from 57° to 83° of scattering angle. It has two visual glass windows of 30 mm diameter to look into the inside. The multiple scattering of recoil protons (∿ 80 MeV at $|t|$ = 0.15 $(GeV/c)^2$) by the SUS foil is estimated to 0.5° and the energy loss is about 5 MeV.

The target mechanism is mounted on a top plate of the scattering chamber. Figure 1 shows the target mechanism. It consists of two target frames which can be rotated by 90 degrees independently with two torque motors. The torque motors mounted in hermetic housing are cooled by water. The target is rotated to the scattering position at beginning of the flat top. Two target frames mount a 150 μm polyethylene string target and a 220 μm carbon fiber target, respectively. The target is burned out at the beam intensity of 1×10^{10} ppp within 30 seconds, if it is fixed. The target string can be automatically wound up in order to avoid the burn-out of the string due to the beam heating. However if the beam intensity is lower than 1×10^{9} ppp, the target string can be fixed.

The scattered proton in the forward direction passes through a 3 mm thick aluminum beam-pipe of 160 mm diameter connected to the scattering chamber. In order to minimize the multiple scattering by the pipe wall, we chose the aluminum pipe as thin as possible. It is less than 0.5° at the worst case.

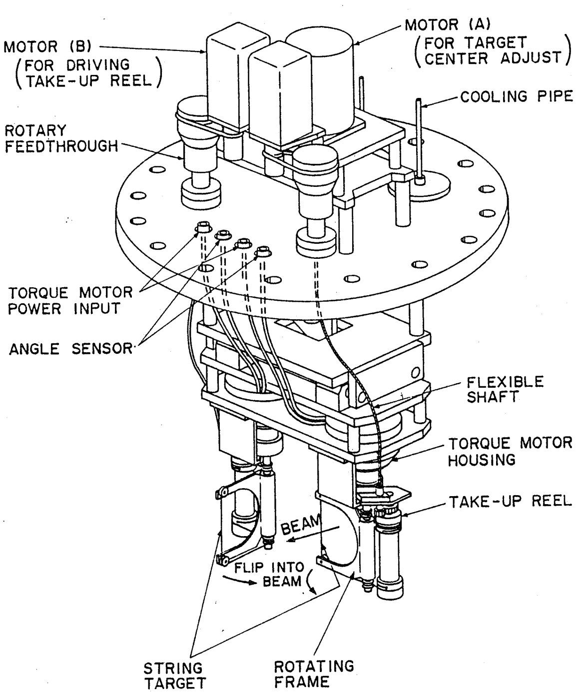

Fig. 1 Target mechanism of the main ring polarimeter.

* Graduate Student of Department of Physics, Faculty of Science
The University of Nagoya, Chikusa-ku, Nagoya, 464, Japan

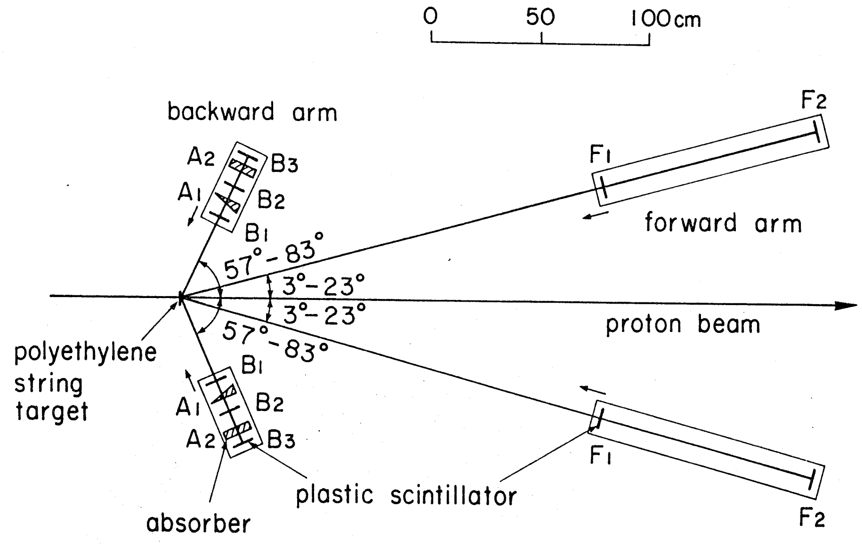

Fig. 2 Schematic of the counter telescope.

Turn table system and the counter telescope

Turn table system consists of two forward arms and two backward arms to detect the elastic scattering events by a coincidence method. The forward counter telescope consists of two scintillation counters. The backward one consists of three scintillation counters and two absorbers.

Figure 2 shows a schematic of the counter telescope. The 1000 mm long table which mount the two scintillation counters can slide on the 3000 mm long forward arm.

The forward counter telescope is pulled by a winding steel wire of which tension is kept to be constant by a draft spring to vary the position from the target. The distance between F2 and the target is variable from 900 mm to 3000 mm. The arm can be rotated from 0° to 23°, and the minimum detection angle is 3°.

The 200 mm long table which mounts the three scintillation counters and two absorbers can slide on the backward arm. Angle and position of the backward counter telescope are fed by the lead screw. The distance between B2 and the target is varied from 300 mm to 450 mm. The backward arm is rotated from 57° to 83°. To avoid the frequent access to the polarimeter in the accelerator tunnel, these can be driven by a remote controller from the center control of the accelerator.

The angle and the distance are monitored by a high precision potentiometer (0.1 %). The accuracy of the angle setting is less than 0.2°. The setting error of the turn table pivot to the beam center is less than 0.5 mm. All arms are leveled within 0.4 mm.

The sizes of counters are summarized as follows.

	Width	× Height	× Thickness (mm)
F1	20	× 80	× 5
F2	20	× 120	× 20
B1	40	× 180	× 3
B2	40	× 200	× 5
B3	50	× 250	× 5

All scintillators (NE110) are viewed by photo-multipliers (Hamamatsu R1398) of 28 mm diameter which have good time resolution. The transit time spread is less than 0.65 nsec. The F2 and B2 scintillators have two photomultipliers on both ends so that the vertical position of the detected particle can be measured by means of time difference between the two photomultiplier output signals. The position information can be used for the coplanarity measurement to identify the proton-proton elastic scattering. The proton-proton elastic scattering at $|t| \sim 0.15$ $(GeV/c)^2$ can be measured from $T_p = 0.5$ to 7 GeV by varying the angle and the position of counter telescopes. Above 7 GeV, measurement should be done in higher $|t|$ region than 0.15 $(GeV/c)^2$.

A wedge shape aluminum absorber A1 equalizes the recoil proton energy over the acceptance of B2. An aluminum absorber A2 is placed between B2 and B3 counter to reject pions and other high energy particles using B3 counter as a veto.

Fast logic and data taking

The block diagram of the fast logic is shown in Fig. 3. F2U and F2D denote two photomultiplier output signals from F2 counter. The scattered particles are defined by a coincidence of two forward counters (F1·F2U·F2D) and recoil ones are defined by a coincidence of B1 and B2 vetoed with B3 ($B1 \cdot B2U \cdot B2D \cdot \overline{B3}$). And then L(R) denotes the coincidence count corresponding to the left (right) forward scattered proton and right (left) backward scattered proton.

$$L,R = (F1 \cdot F2U \cdot F2D \cdot B1 \cdot B2U \cdot B2D \cdot \overline{B3}).$$

The rate of accidental coincidence is estimated by a delayed coincidence. The discriminator (LeCroy 825) which has two threshold levels for the good time resolution is employed for the F2 and B2 counters. The position of the detected particle in the F2 counter is obtained by the time difference (τ_F) between F2U and F2D signals. And τ_B is the time difference between B2U and B2D signals. Thus the correlation between the two time differences (τ_F and τ_B) gives the coplanarity of the event. These timing informations are read into a

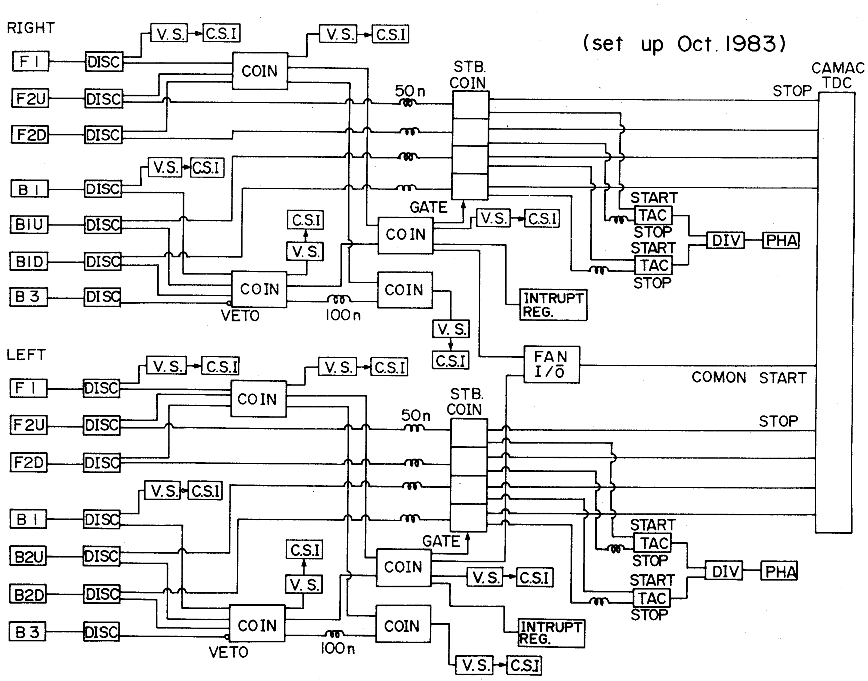

Fig. 3 Block diagram of the fast logic and data taking.

microcomputer (MINICOM-80ZB) through a CAMAC time to digital converter (TDC). The coplanarity plot of the events can be made by the on-line analysis to extract the elastic proton-proton scattering. The event rate (maximum 500 Hz) is limited by the dead time of CAMAC and computer system in this scheme. The other scheme is to use two time to analog converters (TAC) instead of CAMAC TDC and add two outputs from the TAC with appropriate attenuator to make the "coplanarity plot". In the second scheme the counting rate can be increased up to several tens kHz.

The scaler counts from various logic outputs are read into the microcomputer through a CAMAC scaler interface after acceleration cycle. The beam polarization P is given by

$$P = \frac{1}{A_y} \frac{L - R}{L + R} \quad ,$$

where A_y is the analyzing power.

The calculated value of the beam polarization transfered through CAMAC VIDEO RAM is displayed at the operator console of the central control room of the accelerator. The coincidence count (L or R) includes background events mainly due to quasi-elastic scattering from the carbon in the polyethylene target, and its analyzing power is lower than that of pure proton-proton elastic scattering.

SUMMARY AND TEST RESULTS WITH POLARIZED BEAM

We studied the depolarization in the 500 MeV booster synchrotron as the first step of polarized proton acceleration at KEK PS in October 1983.

We measured the polarization at 500 MeV in the main ring with the fixed target by coasting beam to investigate the strength of the depolarization in the booster synchrotron[3].

The single count event rate of B1 counter is ∿ 400/bunch and the coincidence event rate is ∿ 12/bunch at the beam intensity of 1 - 2 × 10^8 ppp. The scattered protons could be successfully measured without pile up.

Figure 4 shows the coplanarity plot obtained by TACs. It shows a left-right asymmetry of the coplanar events. FWHM of left and right coplanarity plot are 0.54 nsec and 0.59 nsec, respectively. Figure 5 shows a comparison of coplanarity plots from the polyethylene and the carbon target.

The contamination from carbon in the polyethylene is only a few percent. The systematic left-right asmmetry is checked by measuring with unpolarized beam. The asymmetry for the unpolarized beam is less than 0.2 %. The value of the analyzing power A_y is 0.42 ± 0.025 (T_p = 500 MeV, t = 0.15 $(GeV/c)^2$)[4]. The effective analyzing power including the contamination can be calibrated by the coplanarity measurement. At 500 MeV, as described below, most of the coincidence is coplanar events and the effective analyzing power is almost the same as the analyzing power of coplanar events.

Figure 6 shows the example of the polarization data vs. the excitation current of the vertical deflector which generates the vertical closed orbit distortion in the booster. The beam polarization is measured in a few minutes with ≦ 2 % statistical accuracy. More detail data are shown in ref. 5)

In summary, the beam polarization in the main ring was measured at 500 MeV by the main ring polarimeter. The high quality coplanarity plot of the proton-proton elastic scattering was obtained, and the absolute beam polarization was measured in a short period. It was quite useful to investigate the depolarizing resonances in the 500 MeV booster synchrotron.

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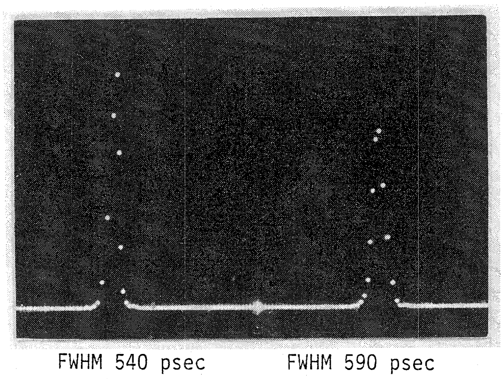

Fig. 4 Left-right asymmetry of the coplanarity plot.

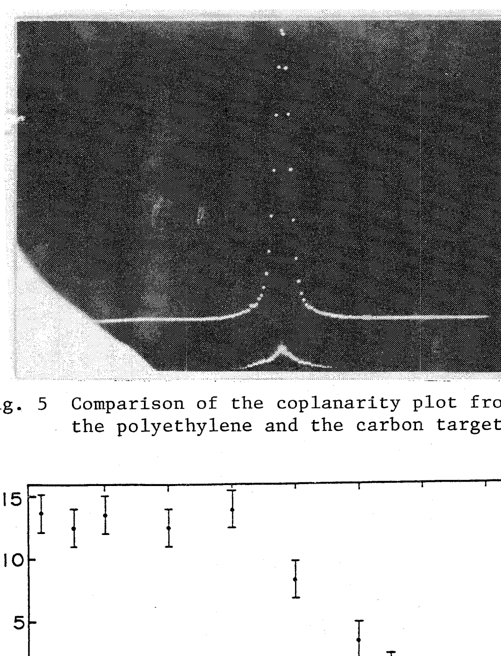

Fig. 5 Comparison of the coplanarity plot from the polyethylene and the carbon target.

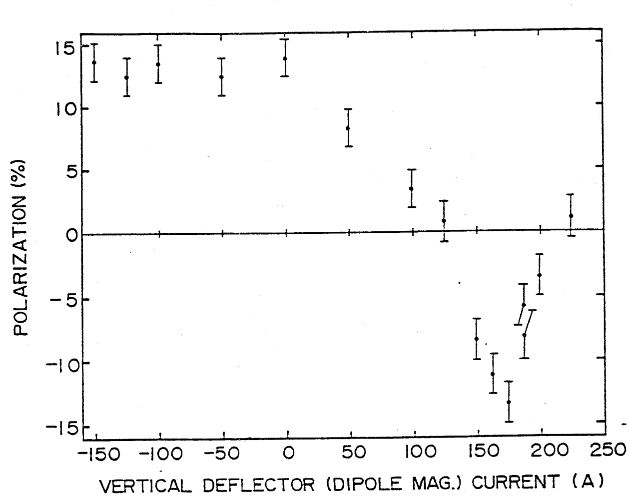

Fig. 6 Polarization date vs. the excitation current of the vertical deflector.