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BEAM SWINGER OPTICS [A POSSIBLE METHOD FOR THE CASCADE TARGETTING]

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I, INTRODUCTION

It is very much important to utilize the finite-intensity primary protons to produce as much secondary particles as possible. For this purpose the primary beam sometimes irradiates two or much number of production targets in cascade. The problem is how to collect as much primary protons as possible at the downstream of the first production target passed. The solution is very simple and is to place the re-focussing beam optical elements (Q-magnets) as close as possible to the first production target. The primary factor which make the problem difficult is the deflection of the beam axis of the primary protons by the first bending magnet of the secondary beam channel, which is usually set over the primary beam axis in order to collect secondary particles at zero degree where the production rates of the most secondary particles have their maximum. Therefore the axis of the primary protons is deflected as a function of the secondary-beam momentum selected. Then the beam axis should be swung back to the ideal optical axis for the beam re-focussing Q-magnets. The traditional method of this beam-axis correction is to add three bending magnets at the downstream. The bending power of each correction magnet should be the same as the first bending magnet of the secondary beam line. Then the distance between the production target and the re-focussing elements becomes longer in order to put three extra bending magnets there. We must remember that the divergence of the primary beam becomes larger after the production target due to the multiple scattering in the target material. Then the gap of the beam-axis correction magnets and the bore of the re-focussing Q-magnets become large as a function of the distance from the target. We can not build the infinitely huge magnet with the infinitely high magnetic field. The real cascade targetting of two thick targets has, therefore, not yet succeeded in the world. The first target should be as small as possible to avoid emittance growth or, in some case, the zero degree production of the secondary particle was given up to avoid the beam-axis correction.

In the construction of the new counter experimental hall[1] of the KEK 12-GeV Proton Synchrotron (KEK-PS), we were forced to solve this cascade targetting problem. The site prepared for the new experimental hall is only 50m x 60m. In this limited area, two new secondary beam lines should be settled with sufficiently wide space for experiments. Both secondary lines required as much secondary beam intensity as possible. This request was, at that time, almost impossible to be satisfied as described above. Finally we could find a new idea for the cascade targetting with two thick targets. In this paper we summarize the new idea developed and employed for the successful cascade targetting of two thick targets in the new hall, as well as the first beam commissioning results.

II, BEAM SWINGER OPTICS

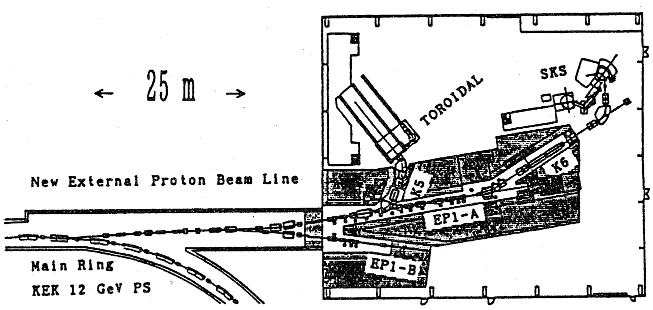

Fig. 1, Schematic illustration of the new counter experimental hall and beam lines at the KEK-PS.

Schematic illustrations of both the new hall and the beam lines are shown in Fig. 1. The primary proton beam can be switched in two directions, i.e., A and B. Two production targets are prepared in cascade on the beam line A. The upstream target provides secondary particles to the low momentum separated beam line, K5, and the downstream target is connected to the medium energy separated beam line, K6. The beam line B is open for future projects. The principle of our newly developed cascade targetting scheme is to bend the beam axis at the upstream of the production target instead of correcting the axis at the downstream. We will put extra two dipole magnets at the upstream of the target and the first bending magnet of the secondary beam line is used to swing back the beam axis to the ideal optical axis. The third small bending magnet will be placed at the crossing point of the beam axis on the ideal optical axis of re-focussing Q-magnets. This new scheme and the traditional scheme with three correction magnets at the downstream are illustrated in Fig. 2. the advantages of this new scheme are;

(1) The magnet gap of the upstream pre-bending magnets are relatively small compared to the traditional correction magnets because the beam emittance at the upstream of the target is always smaller than that at the downstream.

(2) The third bending magnet can be placed as near as possible when the physical dimensions are allowed. Then the distance between the target and the re-focussing elements is as close as possible.

The disadvantages of this new scheme is that we have to give up the real zero degree production of the secondary particles. The production angle is, however, changed to be only 2 or 3 degrees in the maximum. Then the loss of the secondary beam intensity is negligibly small. If the secondary beam channel is for the low momentum kaon beam, the maximum production angle is not zero degree and is at around 5 degrees[2]. In this case we may increase the secondary beam intensity by employing the new scheme. This is a reason why we set K5 beam channel at the upstream target. We named the new scheme "The Beam Swinger Optics, BSO".

III. OPERATION RESULTS OF THE BSO SYSTEM

The first beam was introduced to the new counter experimental hall of the KEK 12-GeV Proton Synchrotron (KEK-PS) in January, 1991. The beam tuning with the BSO system started a bit later from the first beam. Three bending magnets, BS1,2 and 3, as well as the first dipole magnet of the K5 beam channel, K5D1, were excited with suitable magnetic field strength, which satisfy the BSO condition. Initially the beam tuning was performed with low beam intensity. The tuning criteria is to find the best combination of BS1 and BS2 to maximize the secondary beam intensity with the fixed beam location at the BS3 entrance. The excitation of BS3 magnet is justified by the beam position monitor at the far downstream. The location of beam monitors used for the tuning of the BSO system is indicated in Fig. 3. Then the BSO parameters were finally established with the maximum intensity from the KEK-PS and with several momentum of K5. The collection factor of the primary beam intensity depends on the thickness of the production target. We can collect 100 % of initial beam with empty target and approximately 50 % with 6 cm Pt target which is the saturation length of the kaon production and is usually used for the experiment. Since the dissipation of primary beam in the 6 cm Pt target is estimated to be about 50 %, the collection efficiency is thought to reach approximately 100 %. The profile at the downstream is almost independent of the upstream-target thickness though the beam size at the intermediate position becomes twice. The beam profiles, collection coefficients etc. are summarized in the Table 1 with various thickness of the upstream target. The field strength of the re-focussing Q-magnets was not changed at the measurement.

IV. CONCLUSION

The Beam Swinger Optics, BSO, is newly invented to irradiate two thick production targets in cascade. The BSO scheme was employed at the new experimental hall of the KEK-PS and tested with 12 GeV proton beam. After the careful tuning of the BSO parameters, the beam collection rate reached approximately 100 % even with the thick upstream target. This fact means that we can use 150 % of primary beam compared to the pre-BSO era. It is the cheapest and the most efficient way to employ the BSO scheme in order to increase the effective beam intensity for the secondary particle production.

V. ACKNOWLEDGMENT

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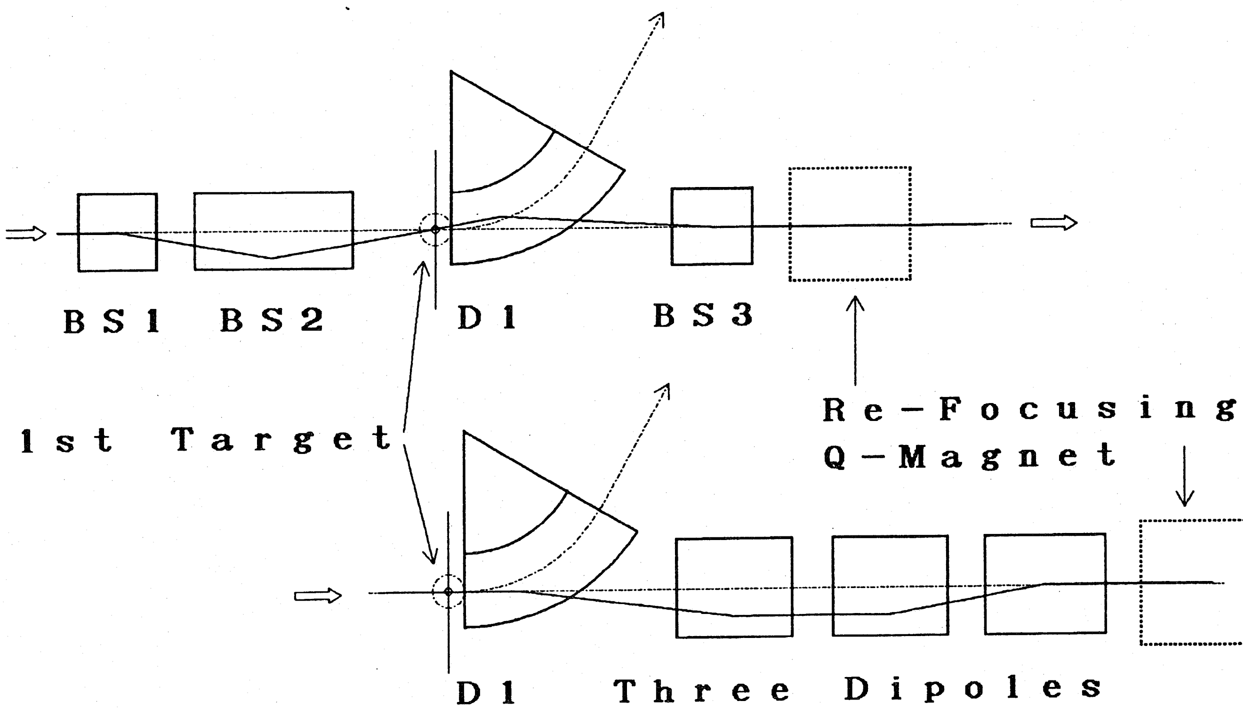

Fig. 2 The schematic illustration of the BSO and old-fashion method.

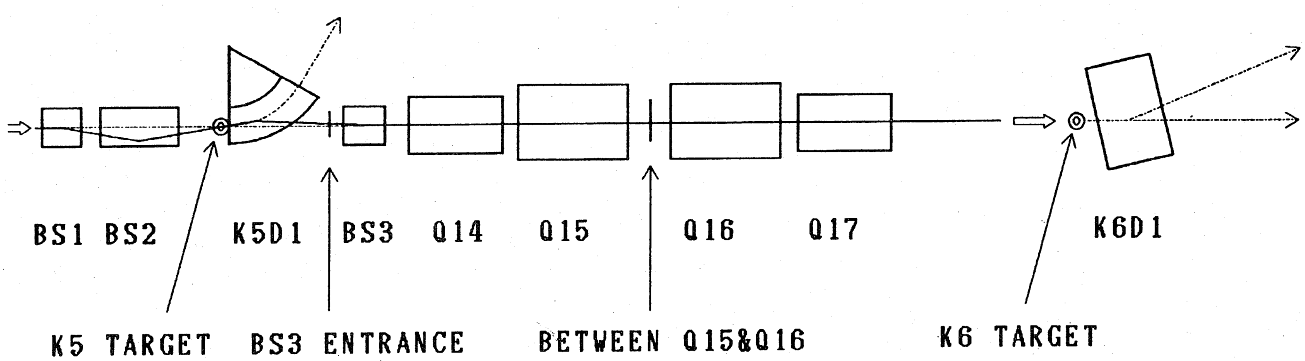

Fig. 3, Full scheme of the cascade targetting with BSO. Positions of the beam profile monitor used for the BSO tuning are also shown.

Table 1, Width and intensity of primary proton beam at around the BSO system and relative charged particle yield of K6 measured with various upstream (K5) targets. By tuning the field strength of the re-focussing Q-magnets, the relative yield at K6 can be improved up to 0.95 even for the 6 cm target.

K5 Target (Platinum)	Intensity ratio (K6/K5)	Beam Profile {X mm x Y mm, Full Width at 1/e of the Max.} (K5 Target)	(BS3 Entrance)	(Btwn Q15&Q16)	(K6 Target)	Relative Yield at K6
Empty	100 %	9.5 x 4.9	12.0 x 22.0	69.7 x 58.7	8.7 x 10.3	1.00
6 mm / x 20 mm·L	85 %	9.5 x 4.8	17.8 x 25.1	106.4 x 66.6	10.2 x 12.2	0.94
6 mm / x 40 mm·L	75 %	9.3 x 4.8	18.5 x 27.2	107.2 x 73.0	9.7 x 12.3	0.91
6 x 10 mm^2 x 60 mm·L	50 %	9.4 x 4.8	24.3 x 32.5	131.1 x 80.5	10.0 x 13.3	0.79