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Argonne, Illinois 60439

SPLITTING OF THE ZGS POLARIZED PROTON BEAM
TO TWO BEAMS UTILIZING A COMMON FRONT STAGE*

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Accelerator Research Facilities

Accelerator Report

ACC-2

ABSTRACT

A septum magnet produced a double source for a beam transport. At the first image, another septum magnet allowed the two beams to enter separate transports for two different experiments.

*Work supported by the U. S. Energy Research and Development Administration.

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A septum magnet produced a double source for a beam transport. At the first image, another septum magnet allowed the two beams to enter separate transports for two different experiments.

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During a recent operating period (April-May/1977) of the Argonne Zero Gradient Synchrotron (ZGS) for polarized proton research, a special technique of beam splitting and subsequent transport was utilized to permit simultaneous operation of two beams which, heretofore, could only operate singly. Thus the utility of the ZGS was boosted 33% by delivering beam to four experiments simultaneously, instead of three as would have been possible during this period. The two beams are denoted 22A and 22B, and lie at the end of the external proton beam #1 (EPB I) channel. Both beams had been approved for experiments utilizing 6 GeV/c polarized protons.¹ Beam 22A would be utilized to provide $\sim 10^5$ protons/pulse for an experiment² utilizing the ANL-U. of Illinois Streamer Chamber facility. In addition, continued data taking was required in Beam 22B, as part of a program to measure the proton-proton elastic scattering amplitudes using 6 GeV/c polarized protons;³ in this case, fluxes of 2×10^6 protons/pulse were required for the experiment which uses a polarized proton target (PPT III).

Beams 22A and 22B are each two-stage secondary beams; however, they share a common first-stage (and intermediate focus). Figure 1(a) shows an optical layout of the first stage in the horizontal plane. The magnets SB1, SB2, and SB3 are septum magnets, while B1 and the "cube" are rectangular bending magnets. During normal unpolarized operation a beam of 12.3 GeV/c protons is transported from the ZGS down EPB I, and focussed upon a copper target located in the center of the cube. Under these conditions the cube is not powered, and SB3 is removed. Beam 22 then becomes a conventional two-stage secondary beam. Then beam can be delivered into either the 22A or 22B channels.

To utilize Beam 22A or 22B for primary polarized protons, the cube magnet is adjusted to bend the protons 1.5° into SB1. To define a "clean

source", the primary beam is focussed at the center of a 0.6 m long hole collimator located 2.44 m upstream of the cube center [at the origin O of the xz coordinate system depicted in Fig. 1(a)]. Simultaneous operation of Beams 22A and 22B became possible by utilizing a two-holed collimator as a source, and a septum magnet SB3. Referring to Fig. 1(a), the two sources were located at $x = 0$ and $x = x_d$. Down at the intermediate focus ($z = 20.3$ m), the images were inverted with horizontal centroids separated by a distance Mx_d , where M is the horizontal magnification. The protons arising from the source at $x = x_d$ entered the field region of SB3 and were bent right another 6.5° into a new Beam 22B channel.⁴ Similarly, the protons emerging on axis (at $x = 0$) passed undeflected to the beam left side of SB3, and into the Beam 22A channel. The required strengths of quadrupoles Q1 and Q2 were determined using the program TRANSPORT.⁵ The horizontal magnification M was calculated to be -2.55, while the horizontal divergence angle (x') at the image is given by

$$x' \text{ (mrad)} = -2.84x_0 - 0.39x'_0 \quad (1)$$

where x_0 represents the half-source width (in cm) and x'_0 is the initial horizontal angular beam divergence.

As indicated above, the sources for Beams 22A and 22B were defined at the collimator with the two hole centers separated by the distance x_d . Accordingly, two separate incident beams were focussed on these holes at the entrance to the collimator. Figure 1(b) shows how the two incident beams were produced: A thin (~ 0.2 cm) septum magnet (X21SSB1) located 38.75 m upstream of the collimator center was used to split the incident proton beam into two portions;⁶ the quadrupole doublet X12Q9-X12Q10 then focussed the two beams onto the holes of the Beam 22 collimator. Increasing the bending strength ($\int \vec{B} \cdot d\vec{l}$) of X21SSB1 increased the horizontal separation between the two focussed beams at the collimator entrance.

Flux sharing between the two beams was performed by motor driving X21SSB1 in the $\pm x$ direction [see Fig. 1(b).]; of course, we could also vary the relative fluxes in Beams 22A and 22B by changing the respective physical hole diameters in the collimator.

During the entire operating period, we utilized a 2.54 cm spacing between hole centers ($\equiv x_d$) at the Beam 22 collimator. This spacing required a 3 mr bend in X21SSB1. A typical horizontal profile of the two incident beams (just before the collimator) is shown in Fig. 2(a), which displays the readout of an integrating multiwire proportional chamber system with 2 mm wire spacing. The peak widths are both ~ 1.25 cm FWHM, with centers separated by ~ 15 wires or 3.0 cm; better transmissions were, in fact, obtained with the left-hand beam converging toward the EPB I line, in opposition to the "ideal" case of the parallel spacing displayed in Fig. 1(b).⁷ As shown in Fig. 2(a), we have split a larger fraction of beam to the left. Next we show in Fig. 2(b) the horizontal profile of the two beams arriving at the intermediate focus in Beam 22. In this case, the integrating proportional wire chamber had 4 mm wire spacing, the scope trace was inverted, and the hole diameters were identical in the source collimator ($x_o = 0.3175$ cm). As is evident in Fig. 2(b), the optical images have been indeed inverted with the more intense beam now on the right. The peaks are separated by ~ 16 wires or ~ 6.4 cm, in perfect agreement with the expected value of 6.48 cm ($\equiv Mx_d$). Moreover, the image widths are ~ 4 wires FWHM or 1.6 cm, in close agreement with the expected first-order size of 1.62 cm ($\equiv 2Mx_o$).

Normal data taking proceeded with collimator source holes $x_o = 0.3175$ cm, and $x_o = 0.635$ cm, respectively, for the beams transported to Beams 22A and 22B. These conditions together with selective apportioning of particle

flux upstream with magnet X21SSB1, resulted in a successful operation of both experiments simultaneously. That is, Beam 22A delivered $\sim 10^5$ 6 GeV/c protons/pulse to the streamer chamber experiment,² and Beam 22B transported typically 2×10^6 protons/pulse to the polarized proton target experiment.³ Final beam conditions (e. g., small spot size and divergence) were excellent in both cases.

Many people contributed to the successful operation of this run. We thank Dr. J. Watson for suggestions and Dr. R. Klem for the initial design of Beam 22. We acknowledge the aid of personnel from the two experiments: (i) Centre de Recherches Nucléaires de Strasbourg, and the in-house Streamer Chamber group (in 22A); (ii) The in-house PPT group (in 22B). C. Brzegowy and D. Gacek are thanked for engineering support. The personnel of the Experiment Planning and Operations Group, too numerous to name, are acknowledged. Lastly we thank the EPB I tuners D. Bohringer, D. Hulet, and R. Wilson for their painstaking efforts in keeping the two beams accurately steered at the entrance to the Beam 22 collimator.

REFERENCES AND FOOTNOTES

1. For a discussion of polarized proton acceleration in the ZGS, see, e.g., T. Khoe et al., Particle Accelerators 6, 213 (1975).
2. H. Braun, A. Fridman, J. P. Gerber, G. Maurer, C. Voltolini, and L. Massonnet, Proposal to Study Coherent $p^4\text{He}$ Interactions at 9 GeV/c by Means of the ANL Streamer Chamber, ZGS Proposal E-351 (1972).
3. See, e.g., I. P. Auer, A. Beretvas, E. Colton, H. Halpern, D. Hill, K. Nield, H. Spinka, D. Underwood, Y. Watanabe, and A. Yokosawa, Measurement of the Observable (L, S; O, N) at 6 GeV/c, ZGS Proposal E-431 (1977).
4. The SB3 septum magnet nominally has a 11.2 cm vertical gap; we had to shim the magnet down to a 4.0 cm gap in order to produce a 6.5° bend for 6 GeV/c protons ($\int \vec{B} \cdot d\vec{l} = 22.69$ kG-meters). Special step shims were epoxied to the top and bottom pole plates on the septum side in order to maintain a linear falloff of $\int \vec{B} \cdot d\vec{l}$ with x in the region traversed by the beam. The field gradient was about 0.268 kG/cm (horizontally defocussing), and was compensated for by the downstream quadrupoles in Beam 22B.
5. K. L. Brown, D. C. Carey, Ch. Iselin, and F. Rothacker, CERN 73-16 (1973).
6. Little beam was lost on the X21SSB1 septum. The horizontal beam width was 4.0 cm FWHM at that point.
7. This running condition caused little difficulty in practice. The beam separation at SB3 is still $Mx_d = (-2.55)(2.54) = -6.48$ cm. Referring to Eq. (1), we see that the entrance angle at SB3 is changed somewhat due to a nonzero value for x'_0 (~ -2 mr); for $x_0 = 0.635$ cm the value of x' is slightly changed from -1.8 mr to -1.0 mr.

FIGURE CAPTIONS

Fig. 1(a) Horizontal plane optical layout of the common first stage of Beams 22A and 22B.

(b) Horizontal plane optical layout of the upstream magnets in EPB I. The mechanism for producing split focussed beams is displayed.

Fig. 2(a) A typical horizontal plane beam profile at the entrance to the two-holed collimator in Beam 22. Wire spacing is 2 mm.

(b) A horizontal plane beam profile at the intermediate focus in Beam 22; wire spacing is 4 mm. The beam flux on the left proceeds to Beam 22A, while the particles on the right are bent into Beam 22B by magnet SB3.

Figure 1

Figure 2