SECONDARY TARGET STATION NO. 2

B. C. Barish
California Institute of Technology

G. Bingham, J. MacLachlan, and R. Mobley
National Accelerator Laboratory

D. Berley and H. Foelsche
Brookhaven National Laboratory

G. Conforto
University of Chicago

L. Hand and D. H. White
Cornell University

R. March and D. D. Reeder
University of Wisconsin

K. Terwilliger
University of Michigan

and

R. Zdanis
Johns Hopkins University

ABSTRACT

The layout of a set of beams is described. The yields, beam characteristics, and some of the motivations that lead us to this proposal are discussed.

It has become traditional for a group of people to propose a design for a target station at each summer study. In trying to compare these designs, it is important to understand the underlying considerations that lead to the combinations of beams selected. The station we describe we think of as the first to be constructed. It should then be general enough in the beams that it has to offer that it can encompass the experimental program three years hence. Moreover, we expect that this area will remain relatively untouched for many years.

The design is influenced by the demands that have been made by the experiments that have been fashionable at this summer study, but a real attempt has been made to incorporate the ideas and attitudes of previous summer studies. Of course, trying to predict all the demands that experimenters might make of this facility is impossible, but some of the general criteria that have appeared are:

1. High resolution in momentum and angle for at least one secondary beam
2. High intensity in some beams without the requirements of 1
3. Enriched beams of K's and $\bar{p}$ of useful intensity
4. The ability to alter the polarity and beam momentum at a particular experiment over a wide range.

We comment now on each of these items:

1. There is a class of experiments that achieve selectivity with a single-arm spectrometer. They rely on the relationship between the momenta of the incident and scattered particles. To appreciate the precision required, notice that the momentum difference between elastic scattering of a pion and scattering with Δ production at the nucleon in the target is:

$$\Delta p \approx \frac{m_\Delta^2 - m_p^2}{2m_p} = 350\ \mathrm{MeV/c}\ \text{for the}\ \Delta(1238).$$

If we are serious about an experiment at 100 BeV/c incident momentum, then the momentum resolution must be of the order of 0.1%. This requirement implies a large linear dispersion at the first horizontal focus. The 2.5-mrad beam is designed to do this. The first quadrupole distance is such that the acceptance of the beam transport system, neglecting the momentum dispersion, is about 1 mm · mrad assuming a proton target spot of 1 mm in diameter. The horizontal width of a 10-cm thick target at 2.5 mrad is 0.25 mm--an acceptable number. Many of the experiments that have been suggested use the small emittance, and some experiments try to improve on it with hodoscopes in the beam, a difficult problem at the higher intensities that can be achieved. The point of this observation is that there exists, in our judgment, a need for beams of good emittance even at some cost in intensity. This beam is also capable of transporting diffracted protons, and apart from the direct use of the extracted protons, it seems suitable in intensity (2×10^{10} for 3×10^{12} interacting protons) for first attempts at producing both charged and neutral hyperon beams. This is commented on in one of the following reports.

The beam at 7.5 mrad is also of "high" quality, and if we restrict the momentum to 80 GeV/c then the finite production angle only loses a factor of six over zero angle, at the highest momenta. This beam also meets the high resolution requirements.

2. A number of experiments have been suggested which require a high intensity of pions to produce secondary beams of K^0's without a large neutron contamination. Similarly, the production of an electron beam by conversion of the photons from π^0 decay requires a beam with optics typical of that used in the beam at 3.5 mrad. The

wide momentum acceptance of this beam produces a high flux of pions when narrow momentum definition is unnecessary. D. Meyer and A. Krisch suggest this kind of beam, and while we recognize the note of caution stressed by Meyer, we feel that this beam produces particles of purity (K^o) and quantity (high energy electrons, pions) not available before. We should try to cope with the attendant problems at an early stage. Apart from the K^o and electron experiments, wide-angle scattering of pions may well be feasible with this beam, as well as deeply inelastic production experiments not requiring fine momentum resolution. In the event that W's are produced more copiously by mesons than protons, this beam may offer a particularly clean method for a W search. This beam is also proposed to transport 200 GeV/c protons, thus giving the choice of putting the initial hyperon beam at the end of this beam.

3. The rf separated beam (20-40 GeV/c kaons) is designed to use presently available rf components. Although we are attracted by the lure of superconducting cavities, we felt that since separation can be achieved by brute force, it was interesting to demonstrate the feasibility of this approach. The popularity of these enriched beams where they exist is such that we assign this beam a high priority.

4. Much of the emphasis in strong interactions at the present time rests on the measurement of the energy dependence of various reactions. This being the case, we imagine that experimenters will expect flexibility in setting the momentum of the beam into their apparatus. It is this consideration as well as the freedom to select polarity at will that has led us to leave out the dispersing magnet at the target proposed by Frauenfelder and Wenzel.[1,2] This is a first target station, and we expect the experimental demands to be diverse. The nature of survey experiments at these higher energies convinces us to choose flexibility over the increased flux offered by the dispersing magnet. We appreciate the attraction of the scheme, which in a more settled target station probably has great merit. Our feeling, however, was to set it aside.

It is important that we understand the magnitude of the gain that zero-mrad production yields over the angles we have chosen. Table I has approximate comparisons according to Awschalom and White.

We find ourselves enthusiastic about providing more than one experimental setup in the beams that are described. The 2.5-mrad beam has a switch at the expense of few components and the spatial separation of the two experimental areas that are served seems adequate. The 3.5-mrad beam is more difficult, and here we have sketched series use of the beam as one possibility. Even in these beams where we have not explicitly provided for alternate use, we believe that the investment in equipment is worthwhile.

Standard Magnets

In designing these beams, we have chosen quadrupoles and bending magnets similar to those proposed in the Danby-Good[3] report (FN-145). They are sketched in Fig. 1. In our conversations with Stekly, we were informed that these sizes represented sensible dimensions for super-ferric magnets. These dimensions apply to the super-ferric version. The gain inherent in reducing the size of the conductor from copper to superconductor is offset somewhat by the space needed to incorporate the dewar. One difference between these magnets and the Danby-Good recommendations is the 3-in. vertical aperture for the dipoles. This dimension became more appropriate as the beam design progressed.

The Hot Box and Hadron Shield

We have drawn a box designed to enclose the hadron shield with its collimating beam holes that is approximately 10 meters long. The idea behind this is that the very active shield can then be removed for maintenance of the upstream focusing elements. Further study is required, but we felt intuitively that a separation at this distance between a box intended to enclose the hadron shield and shielding and protection for the magnets seemed desirable. Perhaps a compromise between the railway concept of Maschke for the hadron box, together with the overhead accessibility of the Nezrick proposal in the area of the magnets is the best. This seems primarily an engineering problem, and we merely observe that if we do not use a dispersing magnet then active elements and passive shield divide naturally at this distance. We also point out that if the hot box extends upstream of our present target location, the dispersing magnet can be accommodated by moving the target upstream.

Individual contributions follow this introduction detailing our understanding of the yields and optics of the various beams. We offer this study as our example of a versatile station. We realize that more beams of useful energy and intensity can be made at wider angles than we have set our lines. They should be made if experimental demand for them is demonstrated. At the very least, we feel that simple test beams are very important to the construction of many of the experiments that have been described. Figure 2 is an assembly drawing of this station.

CONTRIBUTIONS FROM THE 1969 SUMMER STUDY

1. D. Reeder and J. MacLachlan, High Quality Unseparated Beams, SS-41.
2. B. C. Barish, A 3.5-Mrad High Intensity Beam, SS-30.
3. R. A. Zdanis, A Neutron-Free K_L^o Beam, SS-29.
4. L. Hand, Electron Proton Beam at NAL, SS-49.
5. H. Foelsche, RF Separated Beam of Long Duty Cycle (20-50 GeV/c), SS-26.

6. R. A. Zdanis, Long-Lived Neutral Beams, SS-46.
7. D. Berley, G. Bingham, and G. Conforto, A Hyperon Beam in Target Area 2, SS-20.
8. R. H. March, A Short-Lived Neutral Beam, SS-3.
9. K. M. Terwilliger, Comments on Areas for Experiments with the Primary Extracted Proton Beam, SS-22.
10. J. MacLachlan, Comments on the Use of Superconducting Beam Transport Magnets, SS-66.

REFERENCES

[1]H. Frauenfelder and W. A. Wenzel, Target Stations with High Beam Multiplicity, National Accelerator Laboratory 1968 Summer Study Report B.7-68-108, Vol. II, p. 291.

[2]W. A. Wenzel, NAL General Purpose Target Station, National Accelerator Laboratory 1969 Summer Study Report SS-150, Vol. I.

[3]G. Danby and M. L. Good, Quads and Bending Magnets for NAL, National Accelerator Laboratory FN-145, May 7, 1968.

Table I. 200-BeV Protons on Pb.

Angle mrad	Particle	Momentum BeV/c	Gain To 0 mrad
2.5	π^-	100	1.3
7.5	π^-	50	2.0
2.5	K^+	100	1.5
7.5	K^+	50	2.0
2.5	π^+	100	1.3
7.5	π^+	50	2.2
2.5	K^-	100	1.4
7.5	K^-	50	1.5
15	K^-	30	2.0
15	K^+	30	2.0

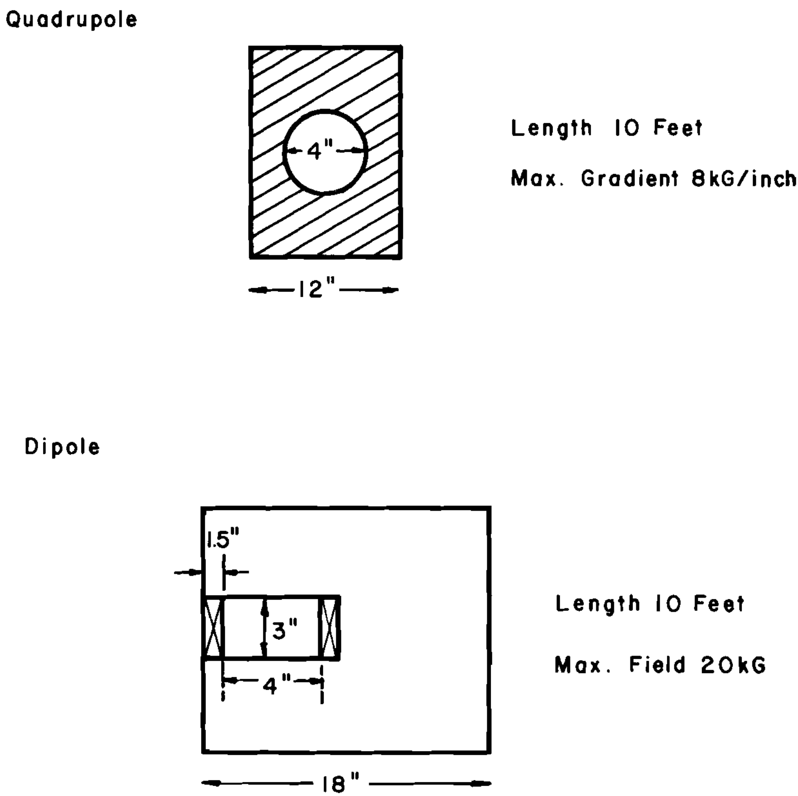

Fig. 1. Sizes of "standard" beam transport components.

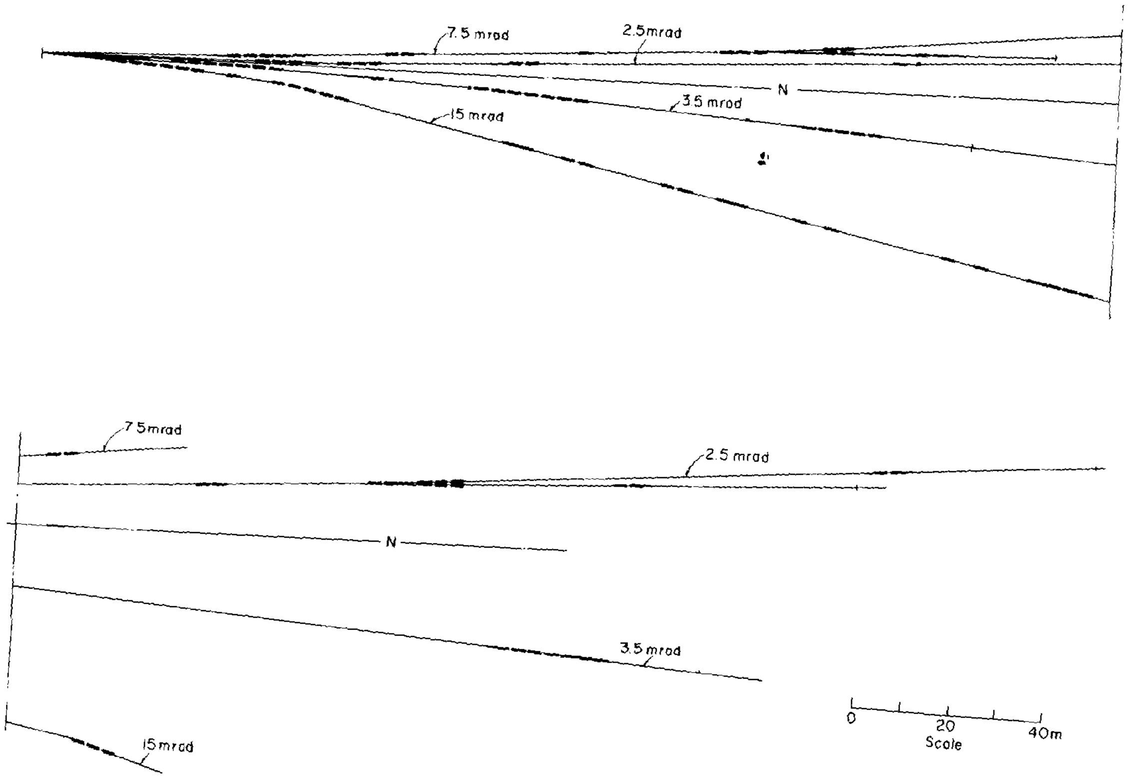

Fig. 2. Above: Target and first part of proposed multibeam layout. Below: Continuation of beams.