Fermilab

TM-1144
7190.621
2250.000
October 1982

The Double Proton Beam for E-621

by

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For experiment 621 we plan to modify the transport system of the Proton-center beam to create two side-by-side proton beams separated by two inches. This Technical Memo describes how we plan to do this, and the results we hope to attain.

The aim of E-621 is to study CP-violation in the decay $K_S^o \rightarrow \pi^+\pi^-\pi^o$, by comparing the proper time decay distribution of a mixed K_s and K_L beam with that of a pure K_L beam. One of the two proton beams will strike a target at the entrance of the Hyperon magnet. Those K_s^o and K_L^o mesons that pass through a hole in the collimator inside the Hyperon magnet will form the mixed beam. The pure K_L^o beam will be formed when the second proton beam strikes a second target 30 meters upstream of the Hyperon magnet. A second hole in the collimator inside the Hyperon magnet will define a beam of K_L^o mesons that come from the upstream target. Figure 1 illustrates this geometry. In order to detect the decays of these mesons with the smallest systematic errors we need to have the two targets being struck simultaneously, each by one of the proton beams. To equalize the acceptance for the two beams we would frequently alternate the targets from beam to beam, always having one target in each beam.

The thirty meter drift space in between the two targets takes up two-thirds of the space in the Proton-center pretarget area. The remaining space will just hold six EPB dipole magnets. They will be used to bend the beam 8 mradians east to direct it into the p-center pit extension.

A new enclosure, 120 feet long, will be built 88 feet upstream of the pretarget area. This enclosure will hold Lambertson magnets to split the beams and quadrupole magnets to focus them. A doublet of six 4Q120 magnets will be needed to focus on the downstream target. Two two-way Lambertson magnets will be used to give the two inch separation. These Lambertsons will have their septa horizontal and bend in the horizontal plane.

To reduce the muon flux created when protons strike the septa of the Lambertson magnets, we will place one more two-way Lambertson magnet in Enclosure H, the place where the three proton lab beams are created. This Lambertson will have its septum vertical, and will bend in the vertical plane, creating two beams whose centers are separated by about 1½ inches when they reach the new focussing enclosure. Muons made in Enclosure H should not be a problem for the experiment. The 500 meter lever arm between the two enclosures means that the field integral of this Lambertson need be only 2 k Gauss meters, so it could be quite a small magnet.

Figure 2 is a plan view of the E621 beam transport system.

To study beam sizes and shapes produced by this set of magnets, I used a Monte Carlo program that generated individual protons and tracked them through the transport system. The basic inputs were the known sizes of the Proton-center beam in Enclosure H and in the pretarget area: standard deviations of .25 cm and 1.3 cm respectively. Protons were generated according to phase space ellipses (in x versus θ_x, and y versus θ_y) that preserved these beam sizes. The results were quite insensitive to the details of this generation. A simplified map of the magnetic field of the 4Q120 quadrupole was used that had about 1% deviations from the ideal.

To test the program I simulated the 400 GeV/c beam used for E619 this past spring. The E619 beam was brought to a focus of full width ∿1 mm horizontally and ∿2 mm vertically. The program predicted 1.0 and 1.5 mm, reproducing the data well.

Using the same beam sizes and divergence (of about 26 micro radians) I then generated an 800 GeV/c beam for E621 and studied the transport system of Figure 2. Figures 3-5 show some of the results. Fig. 3 shows the cross-section of the beam as it enters the focussing enclosure. The upper beam is the one that was bent by the Lambertson in Enclosure H. The shadow of that magnet's septum has been washed out by the beam's divergence. The split provided by that magnet has cleaned up the beam center to the extent that only 3% of the beam hits the septa of the Lambertson magnets in the focussing enclosure. This figure shows two beams of approximately equal intensity, produced by centering the Lambertson's septum on the beam in Enclosure H. By moving the Lambertson horizontally a few mm, more of the beam will go on one side of the septum than the other, creating two beams of unequal intensity. An offset of about 4 mm is required to get the 10:1 ratio of beam intensities needed for the experiment.

Figure 4 shows the vertical profile of the beams as they enter the pretarget area. Here they encounter the most restrictive aperture, the 1 5/8 pole piece separation of an EPB dipole magnet. This distance is indicated on the figure, showing that the beam just fits.

Figure 5 is a cross section of the beam at the location of the upstream target. It shows that the two beams are distinct at this point, with almost two inches between their centers. The upstream target would have to move from beam to beam so that one of its edges would be located along the vertical line drawn on the figure.

At the focus at the downstream target, the beam size is 1.5 mm horizontally by 2.2 mm vertically. The quadrupoles used to focus the beam for E621 will be located about twice as far from the focus, as were the quadrupoles that were used for E619. Hence one would expect an image size twice as great. It turns out to be only 50% larger because of the higher beam energy at which we will run E621.

In conclusion, I have described the design of the beam transport system to make the double proton beam to be used for

E621, and sketched some of the characteristics of that beam. I would like to acknowledge the help of J. Butler, K. Stanfield, and R. Stefansky in doing this work.

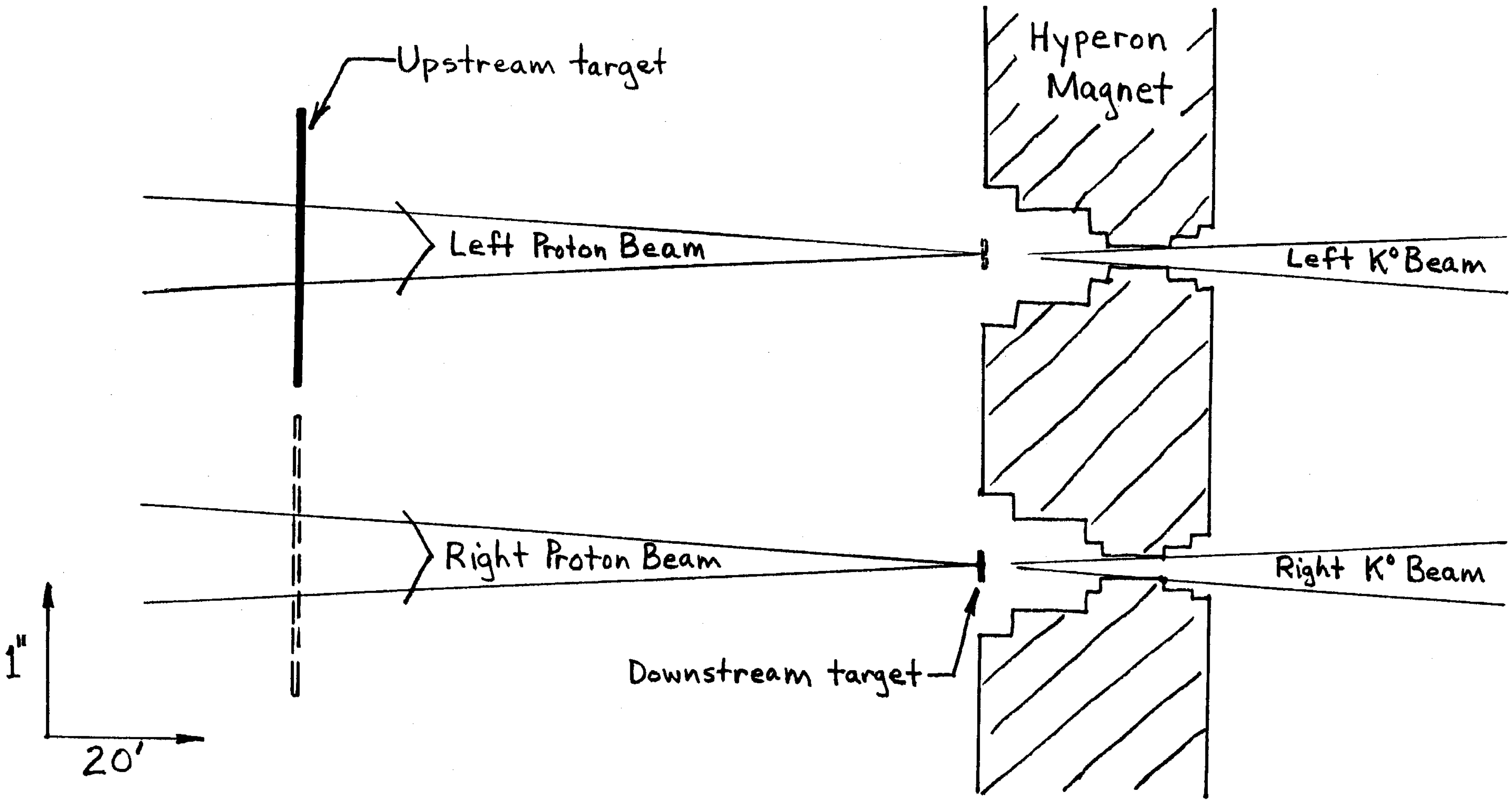

FIGURE 1. TARGETING GEOMETRY

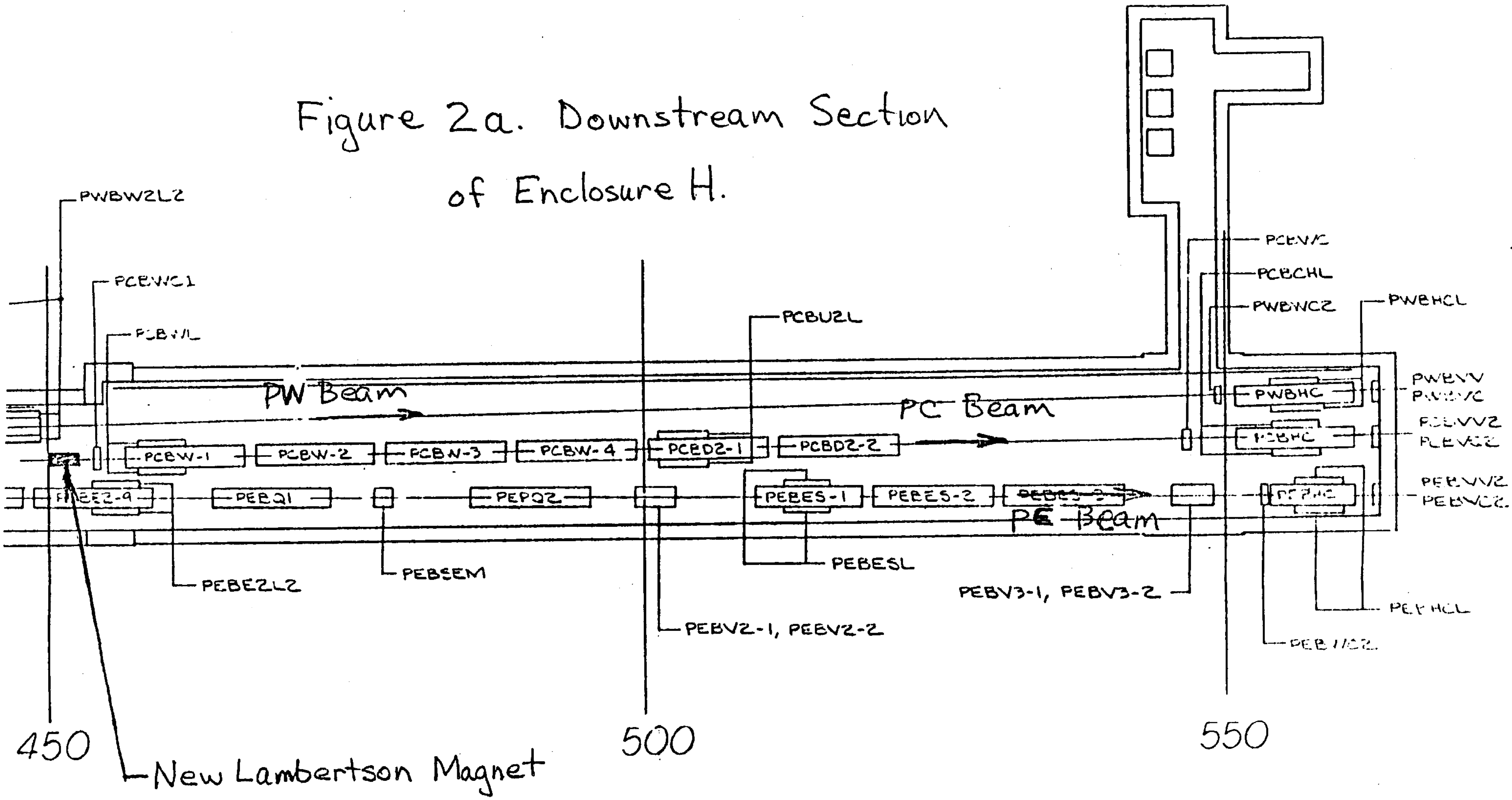

Figure 2a. Downstream Section of Enclosure H.

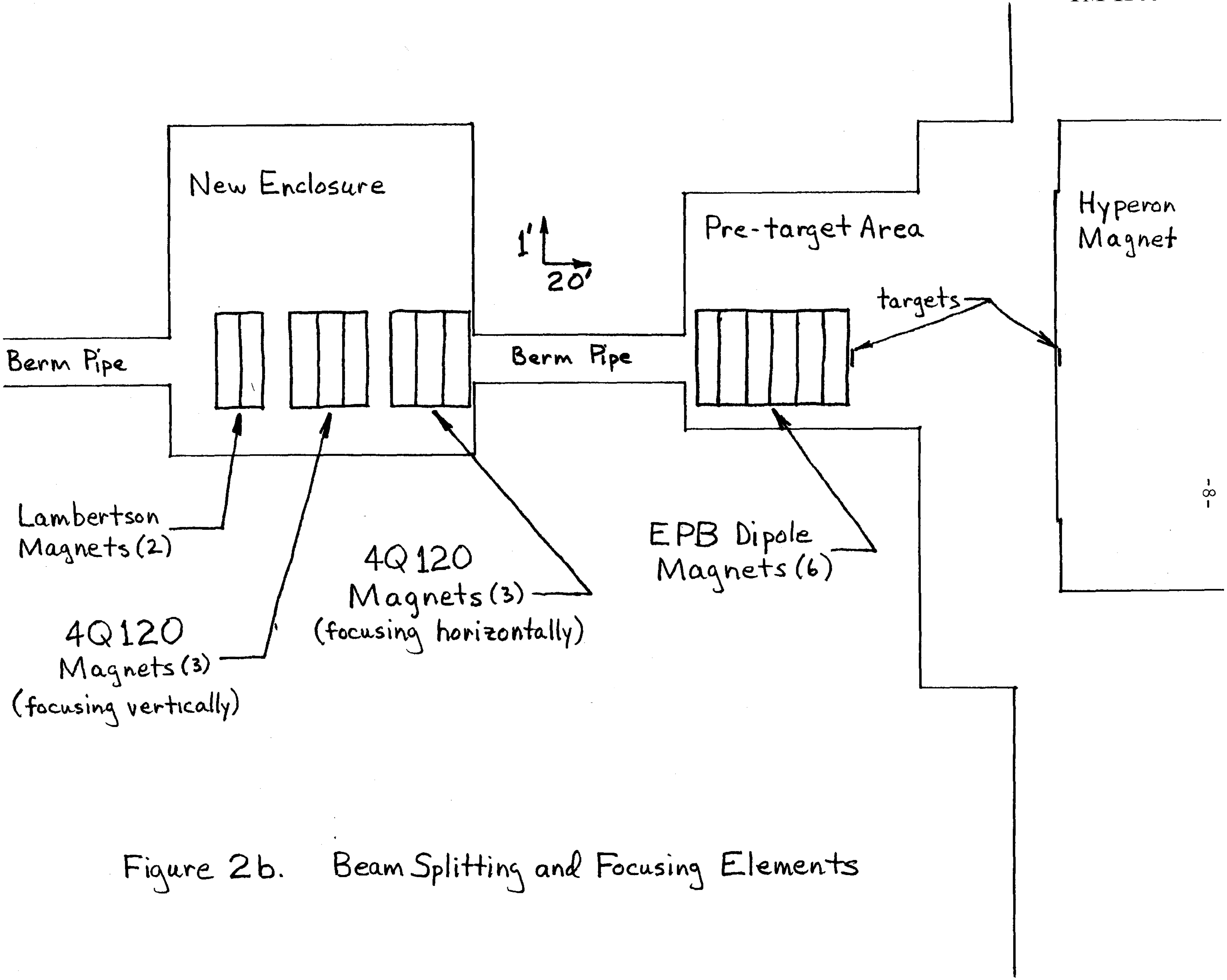

Figure 2b. Beam Splitting and Focusing Elements

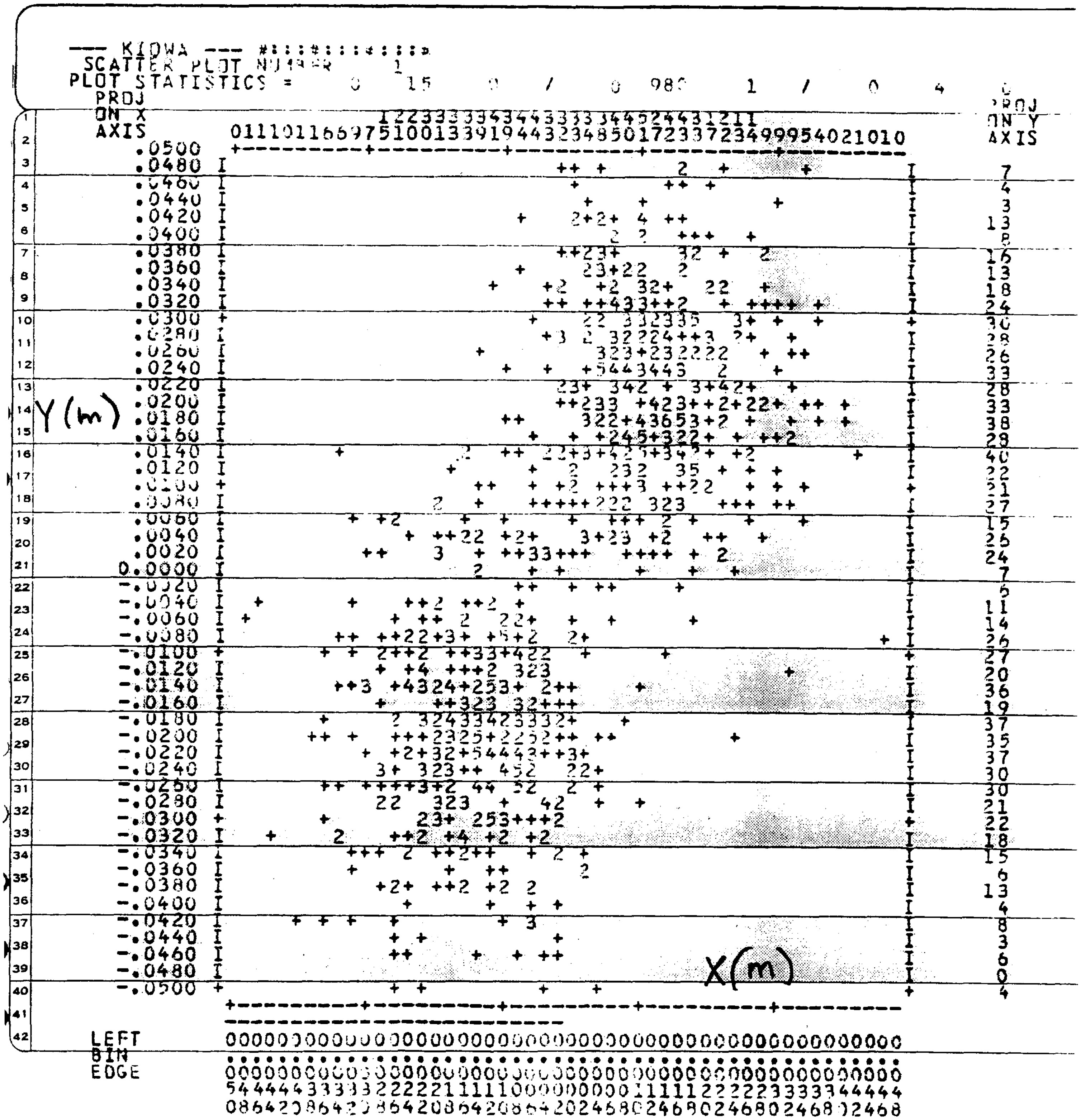

Figure 3. Beam Cross-Section at Focusing Enclosure

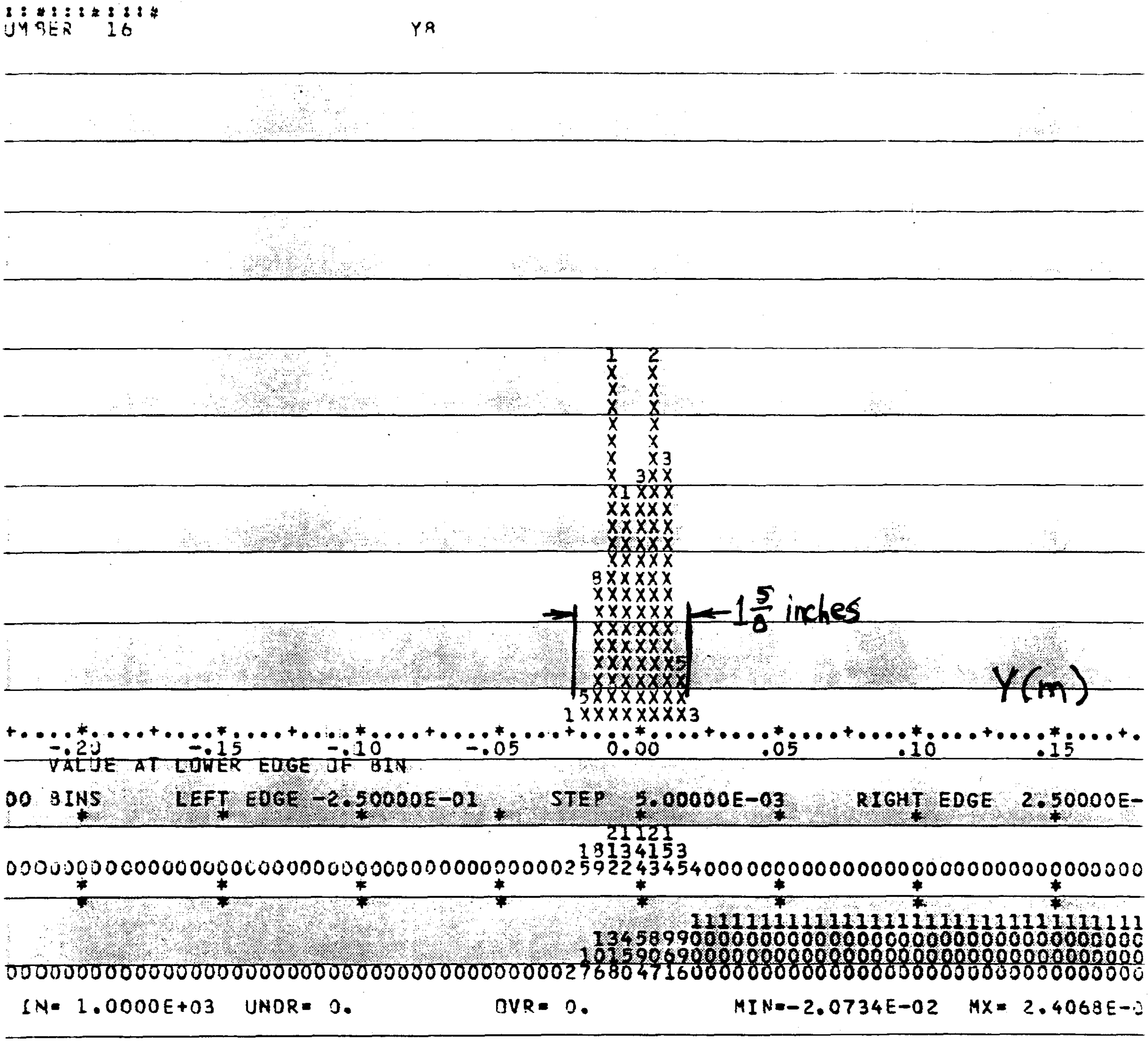

Figure 4. Beam Vertical Profile Entering Pre-target Area

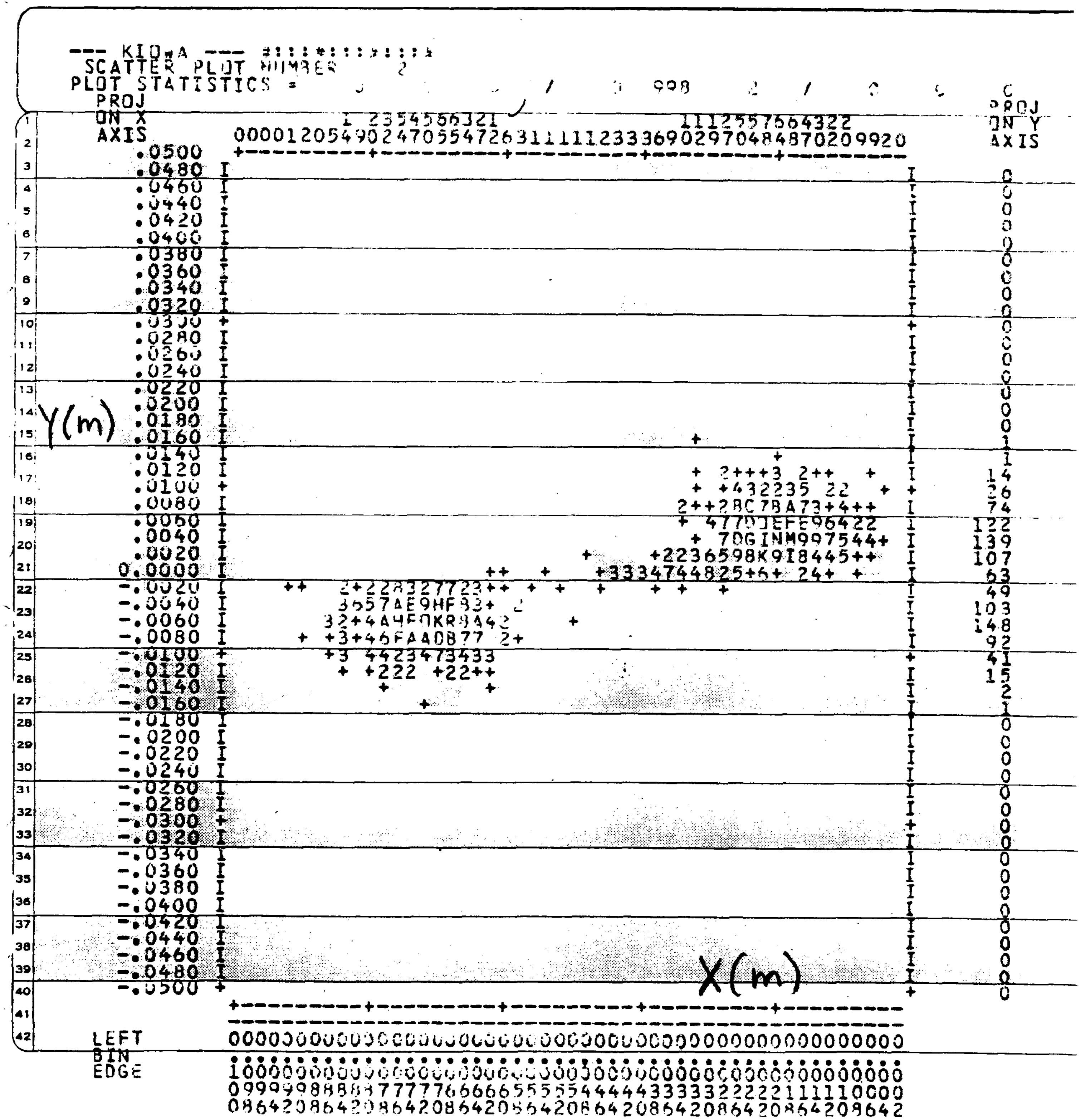

Figure 5. Beam Cross Section at Upstream Target