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A SIMPLIFIED CYCLOTRON BEAM SNOUT

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ABSTRACT

A simple snouting arrangement for a cyclotron beam is described. The beam is brought out from the fringing field of the magnet through an iron snout which reduces the field sufficiently to straighten out the beam path. A method of collimating to produce a fairly homogeneous beam is shown and some preliminary results are presented.

A SIMPLIFIED CYCLOTRON BEAM SNOUT

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In order that certain physical experiments can be performed using the external beam of a cyclotron, it is frequently necessary to bring the beam to a point some distance from the magent. Various methods are employed to achieve this with the primary requirement being to bend the beam out of the fringing magnetic field. Some cyclotrons are designed in such a way that the beam is directed away from the magnet so that the extraction problem is quite simple.[1] Others require a steering magnet of some kind which can also be used to focus the beam. The situation with the 60-inch Cyclotron in Crocker Laboratory at Berkeley is such that the installation of a steering magnet would limit the space available for other types of experiments near the cyclotron and would reduce the versatility of the instrument. Thus, the problem was approached from still another direction, that of providing sufficient shielding of the beam from the magnetic field to bring it out past the magnet yoke.

Fundamentally, the beam path had to be essentially straightened out at the standard target position. To do this, an iron snout was designed to reduce the field along the beam axis to as low a value as possible without introducing a perturbation in the field that would affect the circulating beam.[2]

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1. P. Gerald Kruger et al., Rev. Sci. Inst. 15, 333 (1944).

2. The basic design for the snout was suggested by Dr. W. M. Powell

Figure 1 shows the basic design of the snout. To avoid disturbing the field, it was necessary to keep the snout dimensions small enough so that a large amout of iron was not necessary. The field at the entrance of the snout is in the neighborhood of 9,000 oersteds and it falls off to zero at about six feet from the target. It was assumed that the iron to be used would withstand a flux of the order of 18,000 gauss without too much leakage due to stauration. Therefore, the dimensions of the snout were made such that the half-width of the opening was of the order to twice the thickness of the iron on top and bottom (i.e., b = 2a) as shown in Figure 1. Then it would be expected that, of the flux that would normally pass through the portion of the gap without the snout, a major portion would be essentially by-passed through the iron reducing the field within the snout to a low value. By holding the snout to these dimensions, the amout of iron necessary and, hence, the distortion of the field, could be kept to a minimum.

The beam dimensions at the entrance of the snout are 1/4 inch by approximately 1-1/4 inches. The snout dimensions were accordingly set at 1/2 inch x 1-1/4 inch inside with 5/16 inch of iron top and bottom and 1-1/2 inches on each side. Measurements with a portable fluxmeter indicated the field within the snout was reduced to approximately 800 oersteds. To allow for an expected spreading of the beam as it passes down the snout, the clearance for the beam was increased by tapering the snout to a cross section of 1-1/2 inches x 3 inches at the exit end, a distance of approximately five feet. Since the field falls off rapidly with distance along the snout, the dimensions for shielding are only critical near the input end in the high field. Hence, the tapering of the snout

would presumably not affect its shielding properties. Figure 2 is a plan view of the cyclotron and the beam snout showing the extension tube which is used to bring the beam outside the water shielding tanks. With this extension tube, the beam is brought to a point approximately 17 feet from the standard external target position. The "Iron Target Snout Extension" shown in the figure is a separate section extending into the existing target chamber. The addition of this short section moved the beam at the end of the extension tube approximately three feet away from the magnet. In Figure 3 the iron snout and the positioning structure to hold it in the magnetic field are shown with a nuclear scattering chamber[3] set up for an experiment.

For the work with the scattering chamber, the beam was collimated to a dimension of 1/2 inch x 3/4 inch at the exit of the snout and approximately 0.50 microampere of molecular hydrogen was obtained for 20 microamperes input. The beam through the scattering chamber was collimated further to a 3/16 inch diameter and was of the order of 10^{-8} amperes.

In an attempt to obtain a monoenergetic external beam, an internal collimating slit was set up recently on the standard cyclotron probe. The slit was located at a point about midway between the deflector and the entrance to the snout as shown in Figure 2. By selecting a 1/8 inch portion of the beam at that point, a more homogeneous beam was directed down the snout. The beam was found to spread from a dimension of approximately 1/4 inch high by 1/8 inch wide to approximately 1/2 inch by 1/4 inch at the end of the iron snout and only slightly larger at the end of the extension snout. The magnitude of beam available with this arrangement was 1 to 2 microamperes for 25 to 30 microamperes on the probe slits

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3. J. C. Allred, L. Rosen, F. K. Tallmadge and J. H. Williams, Rev. Sci. Inst. 22, 191 (1951)

and with no measurable beam striking the iron or brass snouts.

Figure 4 shows the results of a measurement of the range of the deuteron beam in aluminum taken at the end of the extension tube.[4] The ratio of beam passing through the absorber into a Faraday cup to the total beam (cup plus absorber) is plotted against the thickness of aluminum in mg/cm^2. Plotted in the same figure are the range distribution curve (differential range curve) and the calculated range distribution due to straggling in the absorber for a monoenergetic beam. The latter was assumed to be a gaussian distribution; the distorted distribution given by Lewis[5] would have been negligibly different. The value for the mean square fluctuation in range was calculated to be 11.3 $(mg/cm^2)^2$ for 20 Mev deuterons. Comparison of these two curves can be taken qualitatively to indicate that the energy distribution consists of a fairly sharp peak with a low energy tail. The calculated distribution was adjusted to the experimental curve so that the mean values approximately coincided. The skew shape of the upper portion of the experimental curve is probably due to instrumental difficulties. Because of this it is not possible to determine the actual energy distribution in the beam. It would appear, however, that the energy spread is less than one percent. Further measurements will be made to determine this. Also, further work on the collimation of the beam and the alignment of the snout may eliminate some of the low energy tail. From the experimental curves, the most probable range would appear to be between 336.5 and 337.8 mg/cm^2 (20.1 Mev); the extrapolated range appears to be 341 mg/cm^2 (20.2 Mev); the mean range from the differential range curve is 336 mg/cm^2 (20.0 Mev).

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4. This measurement was made by J. W. Hadley and M. L. Stevenson.

5. H. W. Lewis, Phys. Rev. 85, 20 (1952)

The development of this snouting system has been a group project resulting from the contribution and work of the design, mechanical maintenance and the operational staff of the 60-inch Cyclotron in Crocker Laboratory.

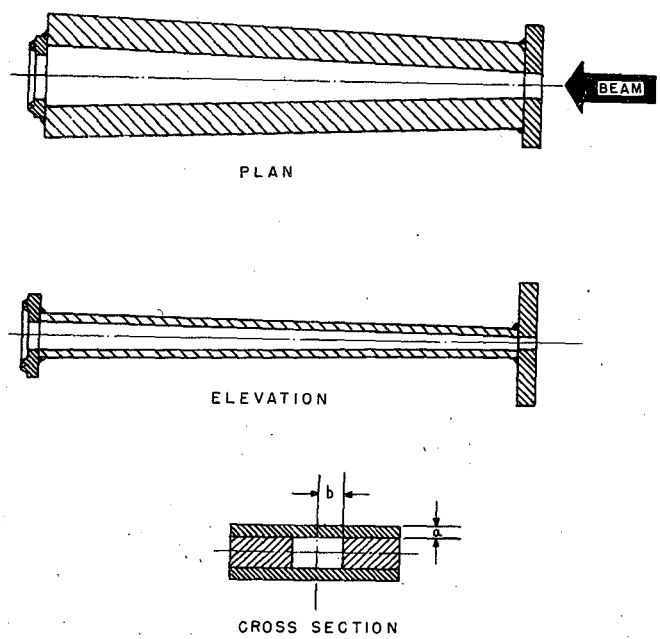

Figure 1

Basic design of iron beam snout.

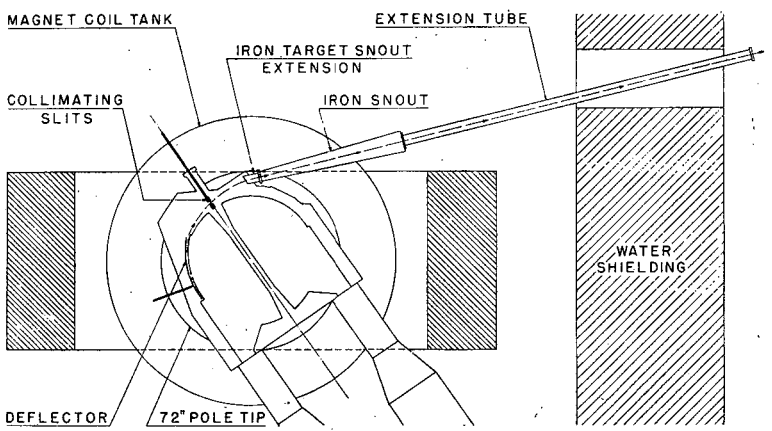

Figure 2.

Cyclotron and snout arrangement.

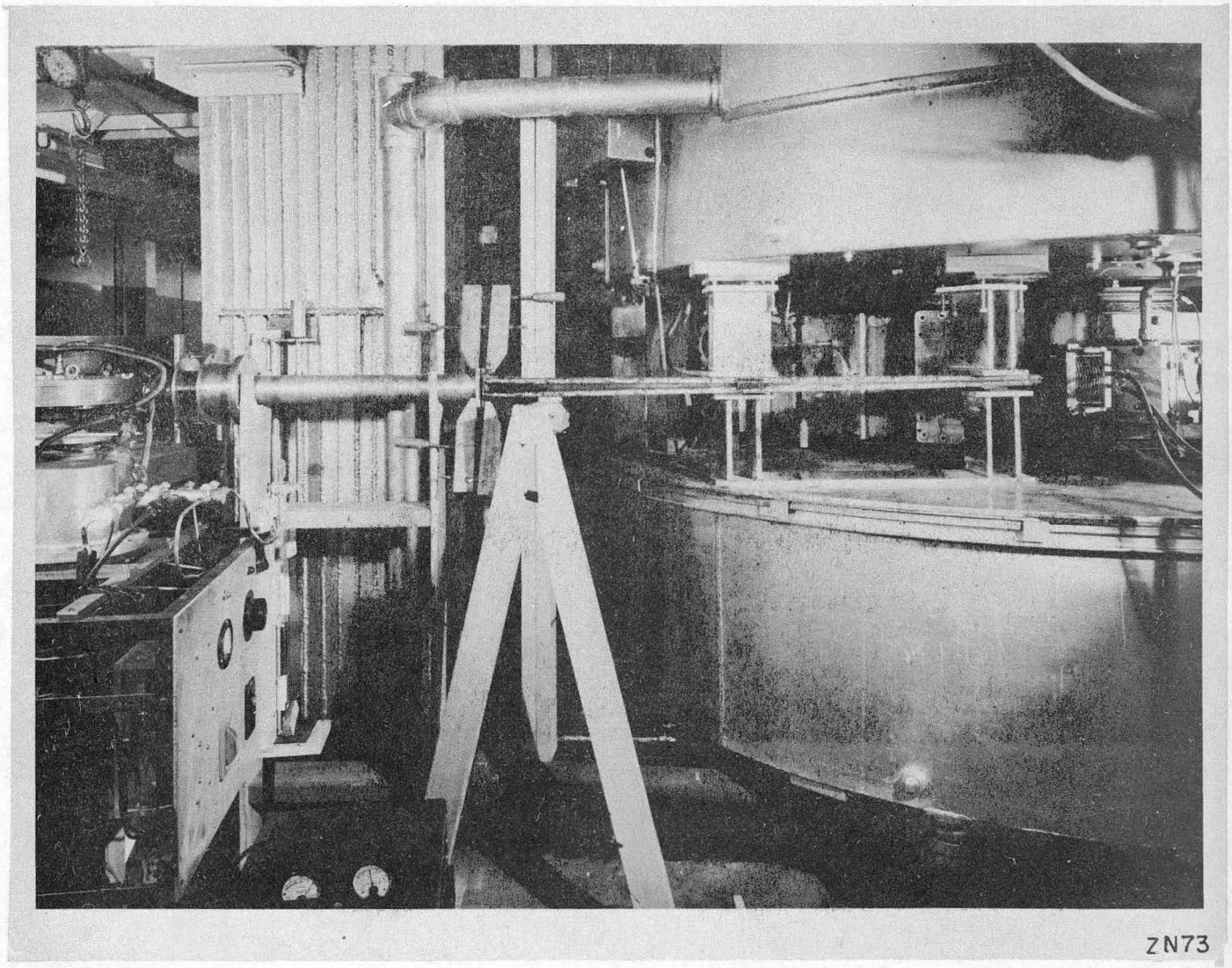

Figure 3.

Beam snout and cyclotron showing positioning structure in magnetic field. A nuclear scattering chamber is shown attached to the snout.

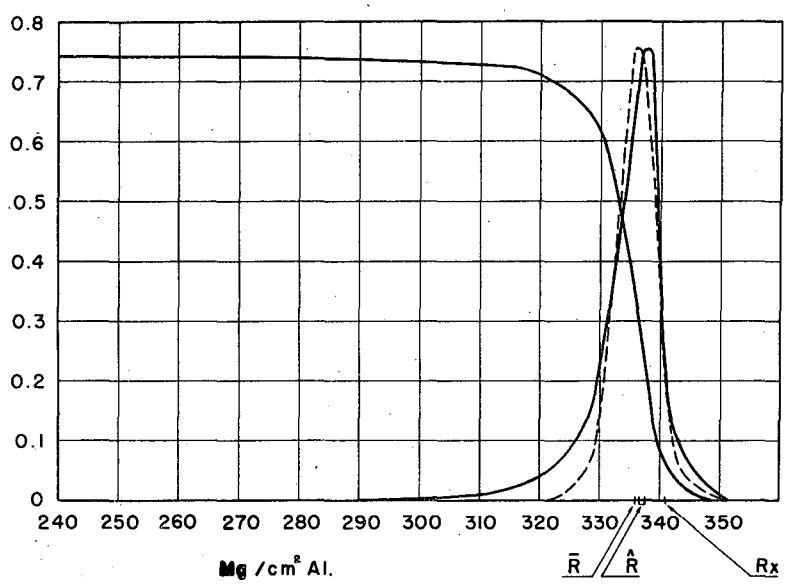

Figure 4.

Absorption curve of deuteron beam in aluminum. Solid curves are the experimental integral and differential range curves. Dashed curve is the calculated range distribution for a monoenergetic 20 Mev deuteron beam. Ordinate for differentail curves has been divided by factor of ten.