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Informal Report

CHOICE OF TARGET FOR NARROW-BAND (DICHROMATIC) NEUTRINO BEAM

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We find that a 5-6" long Cu target should be used for the target of the N.B. neutrino beam.

Introduction

The horns for the narrow-band neutrino beam of Baltay/Kalbfleisch (AGS 589/639) in the U line to the 7 foot bubble chamber at BNL are under construction. The optical arrangement for this two horn beam is point target to point (hadron momentum focus) to parallel (into decay space). Conical collimators at the focus select the hadron momentum which produces the dichromatic neutrino beam. 10GeV/c hadrons will produce 4 GeV pion neutrinos and 10GeV kaon neutrinos into the solid angle subtended by the detectors.

The depth of focus of the first horn is 4-6 inches. In order to obtain the highest yield possible, a short target is required (≤ 6 inches). Al is not suitable; either Cu or Pt could be used; the higher density of Pt might be desirable. The B target station was equipped with five targets 2", 4" and 6" heavimet (W), 2" Al and 2" Cu. A short test was conducted there (March 4, 1975). Other targets (4" and 6" each Al and Cu) have been prepared but have not yet been installed due to the high radiation levels present at the B target.

General Considerations

The interaction rate of the incident beam in a target will increase linearly with the length at first. The yield of secondaries will not keep

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up with the increased yield due to absorption (interaction of the secondaries). Assume that the incident and secondary particles' effective mean characteristic length, L , is the same; this assumption is a reasonable approximation above 10GeV/c for $\pi^\pm$, $K^\pm$ and proton. Then the yield out of the target (production and reabsorption) from interactions at a depth x into a target of length l is

$$dN = e^{-\left(\frac{x}{L}\right)} \frac{dx}{L} e^{-\left(\frac{l-x}{L}\right)} = e^{-\left(\frac{l}{L}\right)} \frac{dx}{L} = \text{uniform} \quad (1)$$

for forward production in a target of largish transverse dimensions. For a target of thin transverse dimensions, large angle particles leaking out of the sides would give a larger yield owing to smaller reabsorption ($e^{-\left(\frac{l-x}{L}\right)}$ would be replaced by $e^{-\frac{x}{L}}$ where x is the mean distance traversed by the secondaries before leaking out the sides). Integrating $x=0, l$ gives us the total yield

$$N(l) = \frac{l}{L} e^{-\left(\frac{l}{L}\right)} \quad (2)$$

which peaks at $(l/L) = 1$. However, for $(l/L) \sim 0.7$, the yield is 90% of peak and creates a minimum of other secondaries which will normally be unwanted (e.g., creates background).

Now the characteristic L is expected to be the absorption Length L_a , which corresponds to the inelastic cross-section of the incident or secondary particles with the target nuclei. The interaction length L_1 , which includes the elastic scattering, is expected to be too short. In fact, L appears to be somewhat longer than L_a as we shall see. The crucial point to be found out experimentally is whether the peak yield is e^{-1} as given by $(l/L) = 1$

in eqn. (2). It turns out that the heavier elements are less efficient. This is presumably due to subsequent interactions in the interacting nucleus due to its high effective thickness.

The L_1 and L_a for Al, Cu and W are (Particle Data Group Tables)

<u>Al</u>	<u>Cu</u>	<u>W</u>
Li: 25.5 cm (10.0 in.)	9.3 cm (3.7 in.)	5.6 cm (2.2 in.)
La: 37.2 cm (14.6 in.)	14.8 cm (5.8 in.)	10.3 cm (4.1 in.)

The Cal-Tech. Results for Al

At Fermilab, experiment 21 (Barish/Sculli), in the neutrino lab, measured the yields of 120 GeV positives from the interactions of 300 GeV protons in Al targets of lengths $l = 1, 6, 12$ and 18 inches. These targets are of large transverse dimensions, and the production angles are less than 3 mr. The results are given in the thesis of Tom Humphrey. We show as Fig. 1 his figure "9.12". He obtains a best fit L of 17.8 inches. We show in addition to his best fit curve, represented by eqn. (2) additional curves, using $L = L_1$ and L_a respectively. His best fit $L = 17.8$ is $\sim 1.2 L_a$.

The Current B Target Results (March 4, 1975)

With the help of Weisberg, Grannis and Good of AGS-650, some personnel from the MPS, and the AGS operations crew, yields from the B target were measured. The primary target (#1), 4" heavimet (W) had been tuned previously. The proton intensity was stable pulse to pulse (about 2×10^{12} on B target). The five targets can be interchanged on a pulse by pulse basis from the control room. The targets are mounted on a rotating head; all targets should come in the same position. We did not retune or steer the protons during these measurements. Retuning could only increase the yields from targets 2 through 5; we will assume that the measured yields are "tuned."

Figure 9.12 Dependence of yields on target thickness

{ T. Humphreys } Fig. 1 (Aluminium)
{ Thier (Cal-Tech) }

The yields (a) from the MPS $\check{C}$ monitor (highest singles, and triples), (b) of 3.9 GeV/c $\bar{p}$ at 6° in the MPS beam (SHA $\bar{p}$), (c) from the ION chamber of Penn-SUNY measuring 15 GeV/c p (and π^+) at 0° , and (d) from the BSEC ion chamber in the B beam upstream of the target were recorded. The Penn monitor had failed. The MPS $\check{C}$ monitor was useless except as an "ionization level" (using highest singles) since it was 30-50% accidentals due to AGS RF structure persisting about halfway into the flattop at the time of the measurements (the $\check{C}$ monitor should be at least 4-fold, probably 5). The proton intensity on target was about 2×10^{12} per pulse giving a BSEC of ~ 4400 . The 3.9 GeV/c $\bar{p}$ @ 6° and the 15 GeV/c p (and π^+ , $p/\pi + \sim 3$) at 0° and the MPS singles monitor all essentially tracked one another as the targets were changed. The yields are given in the following table:

	Tgt#	ION/BSEC	SHA $\bar{p}$ /pulse *	$\check{C}$ Singles/pulse
2"W (heavimet)	2	.0080	1860	400k
4"W	1	.0150	5200	1200k
6"W	5	.0147	5230	1350k
2" Al	4	.0077	1920	385k
2" Cu	3	.0126	4420	1020k

* Slit mostly closed.

The yields from W versus length l (arbitrarily normalized to e^{-1} at the peak) are shown in Fig. 2 along with three curves representing Eqn. (2) for three $L = L_1, L_a$ and $1.2 L_a$ as in Fig. 1. We see that $L = 1.2 L_a$ gives a reasonable representation of the data; a possibly higher yield from "tuning" on the 2" W target might give $L \text{ best} < 1.2 L_a$.

- 4a -

Thus we see that $L \sim 1.2 L_a$ in eqn. (2) gives a yield versus L that agrees with the data (Fig. 1 and 2). We show in Fig. 3 the data of table 2 for Al, Cu and W along with curves using $L \sim 1.2 L_a$. The data are normalized as in Fig. 2. The Al and Cu curve is normalized so as to average the two data points. We see that Cu (or Al) gives 1.7 times as much yield as W (or more if "tuning" increases the yields). Thus a 5" Cu target is indicated for the narrow band beam. An optimum Al target would be too long for the depth of focus; a W target would have reduced yield ($\sim 60\%$). Since a large cone of angles is accepted by this first horn, some particles will escape from the sides of the thin (~ 0.2 " dia.) target; thus a slightly longer (6" Cu) target can be used.

Possible Further Tests

L. Repeta, at my request, has made additional targets, 4" and 6" of Al and Cu. The 4" and 6" Cu targets could replace the 2" Al and 6" W and the above tests be rerun (maybe this summer 1975). One could arrange an hour of time so that each target could be "tuned" for maximum yield. This would insure that there would be no uncertainty left in the measurements. We would then have the (relative) yields versus lengths for three materials Al (E-21 Fermilab), Cu and W. One could also contemplate a measurement of the "absolute" yield, i.e. peak value of ae^{-1} , $a \leq 1$ ($a = 1$ for hydrogen by definition).

-5a-

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