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OFFICE MEMORANDUM

TO : Distribution

DATE: November 20, 1973

FROM : R. L. Hutson RLH

SUBJECT : Some Comparisons of Biomedical Pion Channel Performance when Tuned for Pion Tissue Range = 10 cm and Range = 25 cm

SYMBOL : MP-3

Introduction

This memo summarizes for two cases several factors which determine the pion channel performance. The cases are:

Case 1 - E_π = 53 MeV, Range in tissue = 10 cm

Case 2 - E_π = 95 MeV, Range in tissue = 25 cm

Total Flux

Definitions:

F - a number proportional to the total energy delivered to tissue by star products.

$F = \sigma f_1 f_w f_2 D$ where the factors of the product are defined below

σ - proportional to the pion production cross section.

f_1 - fraction surviving decay between the target and the wedge.

f_w - fraction surviving passage through the wedge.

f_2 - fraction surviving decay between the wedge and the end of the channel

D - a number proportional to the star energy delivered to tissue per pion incident at the tissue surface.

All these quantities are tabulated below. The initial assumptions are that an 800-MeV proton beam is incident on a carbon target.

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S_p: another effect which contributes to the momentum spread of the beam as it leaves the wedge is that, because of the divergence of the beam, all rays passing through a given point in the midplane of the wedge do not have the same path length in the wedge. Define S_p to be the rms contribution to the momentum spread due to this effect.

S_{strag}: Finally there is energy straggling in the wedge. This contribution is denoted as S_{strag}.

S_{strag} = 0.408% at 95 MeV.

S_{strag} = 0.690% at 53 MeV.

S_{tot}: $S_{tot} = (S_w^2 + S_{scat}^2 + S_p^2 + S_{strag}^2)^{1/2}$

Results

Results of the PIFLUX studies are tabulated below. All numbers are effective rms momentum spreads in % $\Delta P/P_o$. Two cases, one with air in the channel up to the wedge and another with helium in the channel, were considered. The total rms % momentum spread of the pion beam leaving the wedge is given in the last two columns.

E_π(MeV)	S_w	S_{scat}(air)	S_{scat}(He)	S_p	S_{strag}	S_{tot}(air)	S_{tot}(He)
53	0.317	1.83	0.460	0.313	0.690	2.01	0.941
95	0.317	1.15	0.289	0.313	0.408	1.30	0.670

Effective rms Range Distribution

Combine the effect of the rms momentum spread of the beam with the range straggling in tissue to get σ, the rms variation in the depth distribution of stopping pions for the various cases outlined in the table above.

$\sigma_{RS}(95)$ = (rms range straggling at E_π = 95 MeV) = 0.53 cm

$\sigma_{RS}(53)$ = (rms range straggling at E_π = 53 MeV) = 0.23 cm

D(95) = (derivative of mean range with respect to percentage change in momentum at E_π = 95 MeV) = 0.57 cm/%

D(53) = (the same derivative at E_π = 53 MeV) = 0.27 cm/%

$\sigma_D = [\ _{RS}^2 + (D \times S_{tot})^2]^{1/2}$

(MeV)	σ with air in channel to wedge (cm)	σ with helium in channel to wedge (cm)
53	0.59	0.34
95	0.97	0.85

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