Accelerator Department
Brookhaven National Laboratory
Associated Universities, Inc.
Upton, L.I., N.Y.

EP & S DIVISION TECHNICAL NOTE

No. 19

John Fox

September 12, 1968

# PRODUCTION OF MUONS BY PROTON SCRAPING IN THE SLOW EXTERNAL BEAM

Protons striking the walls of the SEB pipe produce secondary pions and K's which may result in muons at the end of the S pipe (S190). This background is important for two of the experiments being planned for this beam.[1,2] The secondaries from protons which strike relatively far upstream have long flight paths and are likely to decay somewhere along the pipe; however the secondaries and decay muons can be removed from the beam by collimators. Protons which strike close to the end of the pipe produce secondaries with short flight paths but if the decay occurs, the decay muons are likely to survive. It is not clear, therefore, where scraping does the most damage. This paper describes an attempt to calculate, by Monte Carlo methods, the number of muons that can be expected to survive to S190 for a given number of interacting protons as a function of the interaction point in the beam.

Program FLIGHT describes the interaction of a given number of protons and the subsequent history of the decay products. The initial momentum and angle distribution of $\pi$'s and K's is calculated in accordance with the Sanford-Wang empirical formula[3]. The secondary particle may do the following things: (1) Not decay (2) strike a collimator before decay (3) Decay into a muon with energy insufficient to penetrate the shield wall at the end of the S pipe hence making no contribution to background (4) Decay into an energetic muon which may (4a) strike a collimator (4b) be transported to the end of the S pipe, and contribute to muon background. In case the muon strikes

a collimator it will, in general, not be eliminated but will lose enough energy so that on arriving at the end of the S pipe it will not penetrate the shield wall. Muons which miss the target (2' x 3' ref[1]) are also considered to have been eliminated.

Although the principal contribution of muons is from $\pi$'s, the contribution from K's cannot be entirely neglected. The high energy K's are about 1% of the pions at production, and in a given decay length are 7.45 times more likely to decay; however, because of the larger transverse energy available the muons are more likely to be collimated and are more likely to be below the minimum energy. The contribution from $K \rightarrow \pi^o + \mu + \upsilon$ appears to be negligible, because of the small branching ratio and the fact that the $\mu$ is almost always below minimum energy.

The results of this calculation for the conditions of the experiment of Ref. 1 are described in Table 1. Here $P_{min}$ the minimum momentum required to penetrate the shield wall is 21.0 GeV/c. Momentum of the external proton beam is taken as 28.5 GeV/c. The fields in RQ1, RD1, RD2, SQ1, SQ2, SQ3, SQ4, SD1 and SD2 are those presently in use, (the so called 5 Quad solution). The transmitted muons, column 5, are the undesirable background which results from proton interactions.

Fig. 1 shows transmitted $\mu$'s as a function of production point. Fig. 2 shows the momentum spectrum of transmitted muons. The beam has the effect of hardening the muon spectrum so that the spectrum of muons from far upstream of S190 is less steeply falling for muons produced upstream in the SEB.

Distr: B3 Experimental

## References


1. R.K. Adair et al. BNL-Yale Proposal Experiment #388
2. J.H. Christianson et al. Columbia Experiment #420
3. J.R. Sanford and C.L. Wang AGS Internal Report JRS/CLW I,II May 1967

Figures

Fig. 1 Slow External Beam Apertures

Fig. 2 Muon Spectrum at S190 vs Production Point

K+E 10 X 10 TO THE CENTIMETER 46 1510
18 X 25 CM. MADE IN U.S.A.
KEUFFEL & ESSER CO.



Figure 1 Slow External Beam Apertures

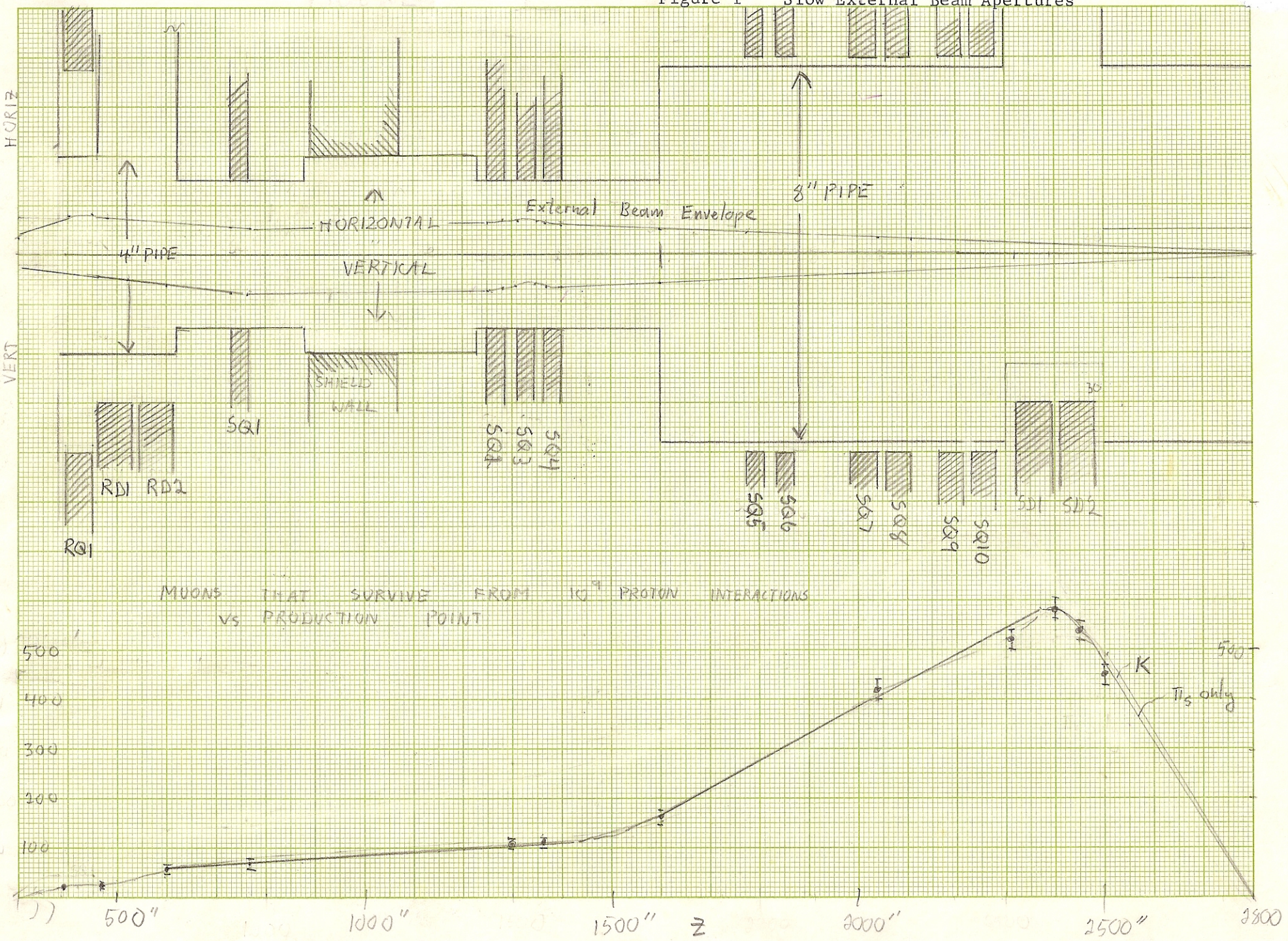

Figure 2

Muon Spectrum at S190 vs Production Point

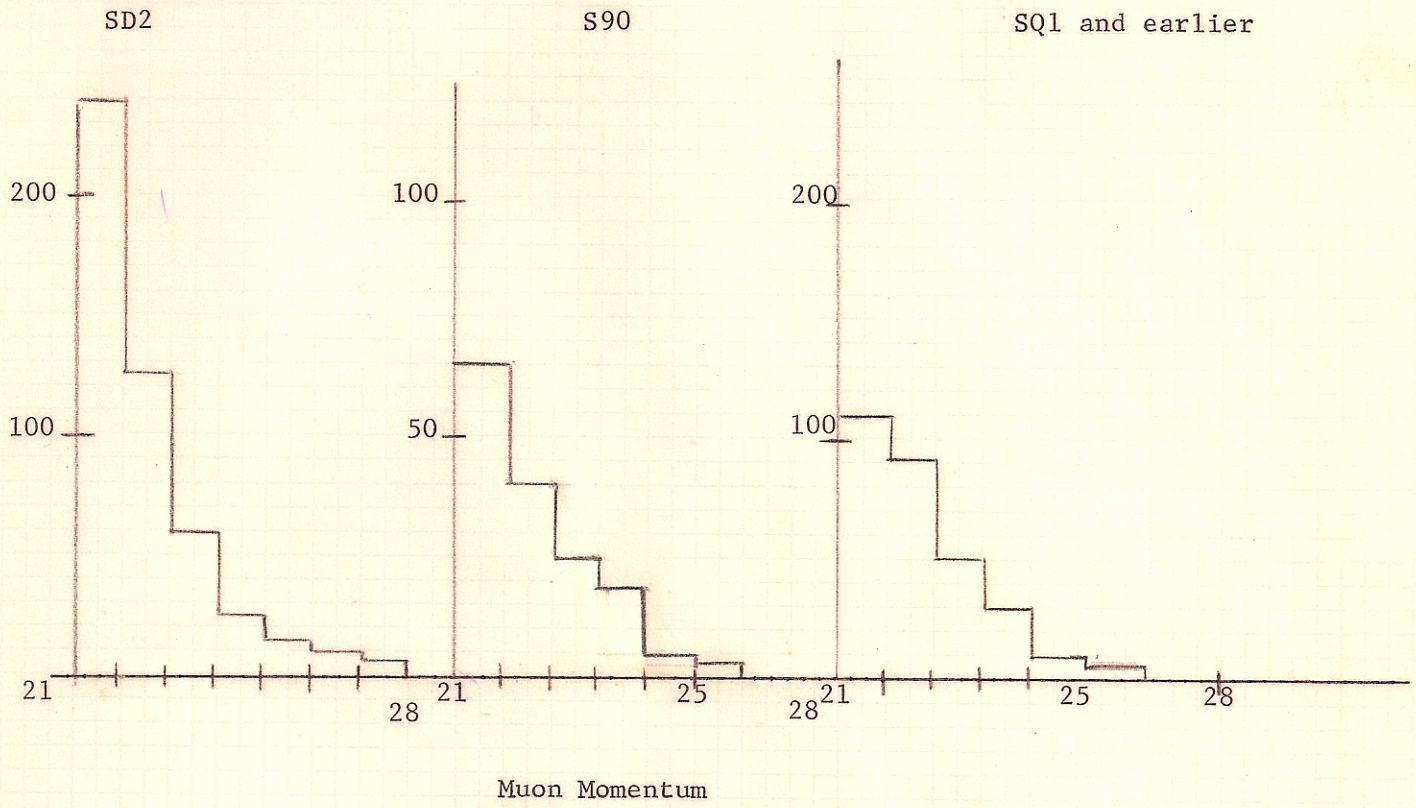

TABLE I

RESULTS OF CALCULATION

$P_o$ = 28.5 GeV/c  $P_{min}$ = 21.0 GeV/c

| Interaction Point | Decay Length to S190 | $10^9$ interacting protons give 419 519 pions > 21 GeV/c of which: | | | | |
|---|---|---|---|---|---|---|
| | | N1 Do not Decay | N2 Decay with $P_\mu$ < 21 | N3 Pions Collimated | N4 Muons Collimated | N5 Transmitted Muons |
| RQ1 | 2404 | 399 891 | 1765 | 17 474 | 366 | 23 |
| SQ1 | 2034 | 402 850 | 3507 | 12 356 | 728 | 78 |
| SQ3 | 1455 | 407 528 | 2461 | 9 003 | 406 | 121 |
| S90 | 1198 | 409 619 | 2584 | 6 787 | 373 | 156 |
| SD2 Exit | 317 | 416 877 | 2164 | 0 | 6 | 472 |

| | | $10^9$ interacting protons give 3878 $K^+$ > 21 GeV/c of which: | | | | |
|---|---|---|---|---|---|---|
| | | Do not decay | Decay with $P\mu$ < 21 | K's Collimated | Muons Collimated | Transmitted Muons |
| RQ1 | 2404 | 2676 | 135 | 1 061 | 6 | 0 |
| SQ1 | 2034 | 2832 | 291 | 746 | 9 | 0 |
| SQ3 | 1455 | 3097 | 202 | 571 | 7 | 1 |
| S90 | 1198 | 3223 | 214 | 430 | 8 | 3 |
| SD2 | 317 | 3694 | 172 | 0 | 0 | 12 |