SINGLE PASS COLLIDER MEMO

SLAC-CN--300

DE25 012006

AUTHOR: W. R. NELSON and
R. A. SHORE

DATE: 5/17/85

REPLACES CN#

TITLE: PI-DECAY MUONS FROM THE SLC POSITRON SOURCE

SUMMARY

This note extends the calculations presented in CN-295 (Ref. 1) by taking into account the photoproduction of pions in the SLC positron target with subsequent decay into μ ons. By taking into account the probability of pion interaction in the target/wave guide/solenoid complex versus decay in drift regions, we have concluded that this source of muons will not significantly contribute to the overall levels presented in the previous note (e.g., see Figure 2).

PION PRODUCTION MODEL

In Figure 1 we present an extension of the parameterization given in the SLAC Users Handbook (Ref. 2) for the yield of pions from a 0.3 radiation length Be target. Referring to the Users Handbook, the yield from a 6.0 radiation length Ta target is obtained as follows:

$$Y(1.0 \text{ Be}) = 4.5 Y(0.3 \text{ Be}) \quad (\text{Fig. 20, p. C.2-32})$$

$$Y(1.0 \text{ Ta}) = Y(1.0 \text{ Be}) \left(\frac{A_{\text{Be}}}{A_{\text{Ta}}} \right)^{0.8} \quad (\text{p. C.2-9})$$

$$(\text{with } A_{\text{Be}} = 9.0, A_{\text{Ta}} = 180.9)$$

$$Y(6.0 \text{ Ta}) = 2.5 Y(1.0 \text{ Ta}) \quad (\text{Fig. C.3-2, p. C.3-13})$$

The result is that $Y(6.0 \text{ Ta}) = Y(0.3 \text{ Be})$ so that Figure 1 can be used directly to obtain the differential yield of positive or negative pions ($\text{GeV}/c^{-1} \text{ sr}^{-1} \text{ elec}^{-1}$) produced in the SLC positron target as a function of the square of the transverse momentum.

MASTER

Work supported by DOE Contract No: DE-AC03-76SF00515

JW

PI-MU DECAY MODEL

The differential muon fluence ($\text{cm}^{-2} \text{GeV}^{-1} \text{elec}^{-1}$) from pion decay can be obtained from

$$\frac{d\phi(\theta, E)}{dE} = \frac{2}{R^2} \int_E^{E/a} dE_\pi P_d(E_\pi) \frac{1}{P_\pi(1-a)} \frac{d^2 n_\pi(\theta_\pi, E_\pi)}{d\Omega_\pi dp_\pi}$$

where E, E_π = total energy of muon, pion (GeV),

P_π = momentum of pion (GeV/c),

$a = (m/m_\pi)^2$,

m, m_π = rest mass of muon, pion (GeV),

θ, θ_π = laboratory angles of muon, pion,

R = source-to-detector distance (cm),

P_d = probability of pion decay versus interaction,

and where the last factor in the integral is the pion yield obtained from Figure 1.

The probability of decay versus interaction in a series of n -slabs of different materials (including air spaces) can be determined from

$$P_d = \lambda_d \left\{ \frac{1}{\Lambda_1} (1 - e^{-\Lambda_1 t_1}) + \frac{1}{\Lambda_2} (1 - e^{-\Lambda_2 t_2}) e^{-\Lambda_1 t_1} \right. \\ \left. + \frac{1}{\Lambda_3} (1 - e^{-\Lambda_3 t_3}) e^{-(\Lambda_1 t_1 + \Lambda_2 t_2)} + \dots \right. \\ \left. \dots + \frac{1}{\Lambda_m} (1 - e^{-\Lambda_m t_m}) e^{-(\Lambda_1 t_1 + \Lambda_2 t_2 + \dots + \Lambda_{m-1} t_{m-1})} \right\}$$

where $\Lambda_j = \lambda_j + \lambda_d$

λ_d = decay constant = $m_\pi / c \gamma p_\pi$ (cm^{-1}),

$c \gamma$ = 780.4 cm,

λ_j = interaction constant for j th-slab = $1/L_j$ (cm^{-1}),

t_j = j th-slab thickness (cm),

and where L_j is the interaction mean free path for hadrons in the j th-slab material [Note: $L=15.1(\text{Cu})$, $16.8(\text{Fe})$, $10.9(\text{Ta})$, and $69800(\text{air})$ from Ref. 3].

APPLICATION TO POSITRON TARGET COMPLEX AT 2/3 TAKEOFF TUNNEL

Lines corresponding to 3 and 5 degrees were traced on a life-size drawing (obtained from Bennett Smith) of the target/wave guide/solenoid complex). The various slab thicknesses were obtained for input into the P_d equation above. Since most of the high energy pions are produced in the first radiation length of the target, we took the first slab as the remaining 5 radiation lengths of Ta (using the 16.9 g/cu.cm density of the actual Ta90W10 target). The final slab was assumed to be air starting at the exit point of the solenoid. Since this calculation must apply to detector locations at the SLAC boundary, we assumed that the length of this last slab was 1000 feet (Note: this assumption caused a negligible effect to the final answer due to the fact that most of the pions interact before they can get out of the target complex).

The differential muon fluence thus obtained was used as a source in the muon transport model described in CN-295. Turning the multiple scattering "off" and "on" had a small, but noticeable, effect on the resultant fluence for small shield thickness (i.e., a few meters). However, we took the conservative approach for the results presented here and simply did not allow the muons to multiple scatter in the shield.

In Figure 2 we show the pion decay results as compared with the Bethe-Heitler component presented in CN-295. Since the dose rates are at least an order of magnitude smaller, we conclude that muons from pi-decay will not change the conclusions reached in CN-295 (under the assumption that the target/wave guide/solenoid remains essentially as depicted in the drawing used for the present calculations).

REFERENCES

1. W. R. Nelson and R. C. McCall, "Additional Muon Calculations for the SLC Positron Source", CN-295 (23 April 1985).
2. SLAC Users Handbook (1971).
3. Particle Properties Data Booklet (April 1984).

FIG. 14--The π^+ yield from a 0.3 r.l. Be target divided by $\ln (E_0/p + 1.5)$ with $E_0 = 18 \text{ GeV}$ and $\delta = 1.5 \text{ GeV}$. Q is the transverse momentum = $p \sin \theta$. [taken from SLAC Users Handbook]

MUON DOSE RATE VS. SHIELD THICKNESS

3° comparison of π/μ vs. Bethe-Heitler

5° comparison of π/μ vs. Bethe-Heitler

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.