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Muon g-2 Note No. 449

Title: **Dependence of the Pion Flux in the E821 Beamline on the Target Length**

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Dependence of the Pion Flux in the E821 Beamline on the Target Length

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In this note I study the dependence of the pion flux in the E821 beamline on the target length. The angular acceptance of Q1/Q2 after the target is ±32mrad (H) and ±60mrad (V) from the Design Report. Fig. 1 shows the production spectra from ref. 1 dN/dΩdp (π^+ per interacting proton - steradian - GeV/c) for 24 GeV proton interactions on a thin Nickel target.

Fig. 1. Production spectra from ref. 1 for a thin Ni target.

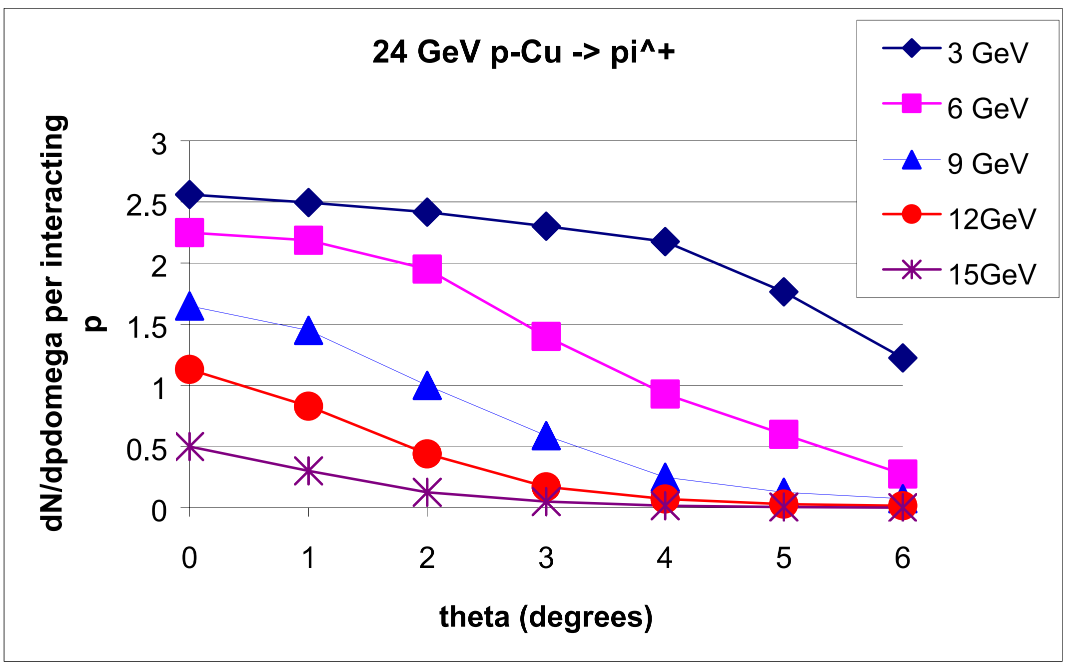


Table 1 gives the interaction and radiation lengths from the PDG for ≈24 GeV p-Ni interactions. The program is to start with protons hitting the target, take a small step (0.1 X_0 for my program), multiple scatter the proton trajectory, and then see if the proton interacts inelastically or elastically. If it interacts inelastically, then generate a π^+ as parameterized by ref. 1. The function, which gives reasonable agreement with Fig. 1 is:

$$\frac{dN}{dp_L dp_T} \propto \; e^{-p_T^2/2(350\,MeV/c)^2} \; e^{-p_L^2/2(8.4\,GeV/c)^2} \quad (1)$$

Table 1. Inelastic interaction length λ_I, total interaction length (elastic plus inelastic) λ_T, and radiation length X_0 for p-Ni interactions at 24 GeV. The E821 target is 15.4cm Ni.

	p-Ni
λ_I	15.1 cm
λ_T	9.6 cm
X_0	1.4 cm

Next, step the produced π^+ by 0.1 X_0. If the π^+ interacts inelastically, then generate another π^+ with

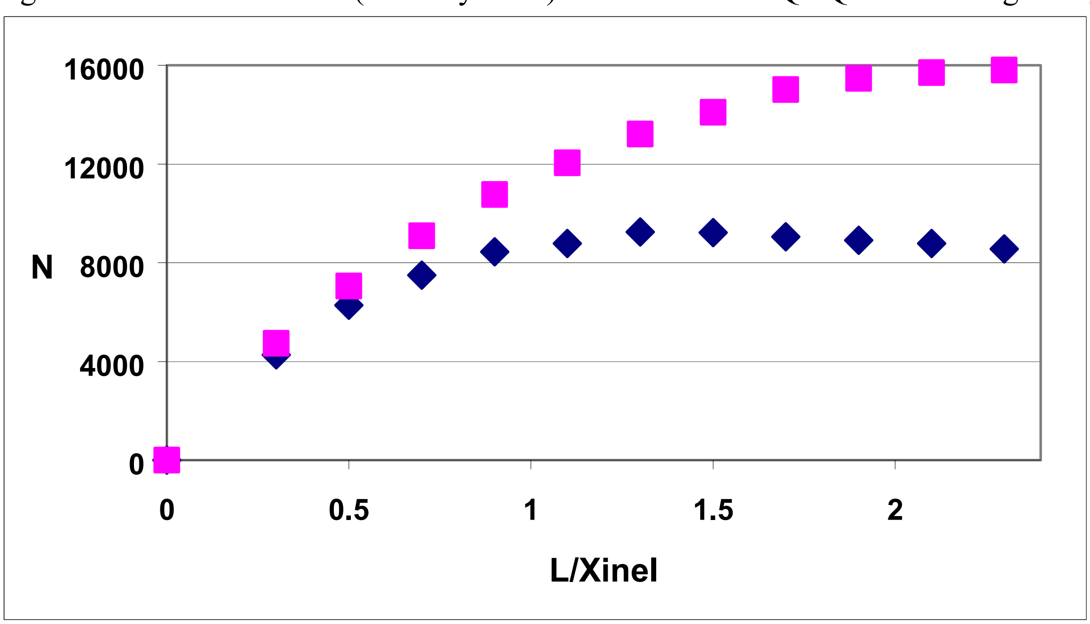
$$\frac{dN}{dp_L dp_T} \propto e^{-p_T^2/2(350\,MeV/c)^2} \qquad (2)$$

The program generates the second π^+ with longitudinal momentum randomly between 0.4 and 1.0 times the original π^+ longitudinal momentum ($0.4 < x < 1.0$, where x is the Feynman variable). This gives a reasonable description of the leading particle effect [2]. The additional non-leading particle production of π^+ from produced $K^\pm$, $\pi^\pm$, etc. does not contribute importantly to $\geq$ 3 GeV π^+. Elastic scattering [2] of both protons and pions is parameterized as:

$$\frac{dN}{dp_T} \propto e^{-p_T^2/2(350\,MeV/c)^2}$$

with the longitudinal momentum unchanged (high energy approximation). The relative rate of 3 GeV/c pions as a function of target length with and without scatterings is shown in Fig. 2 as diamonds and squares, respectively.

Fig. 2. Number of 3GeV π^+ (arbitrary scale) within the E821 Q1/Q2 $\Delta\Omega$ vs. target length.

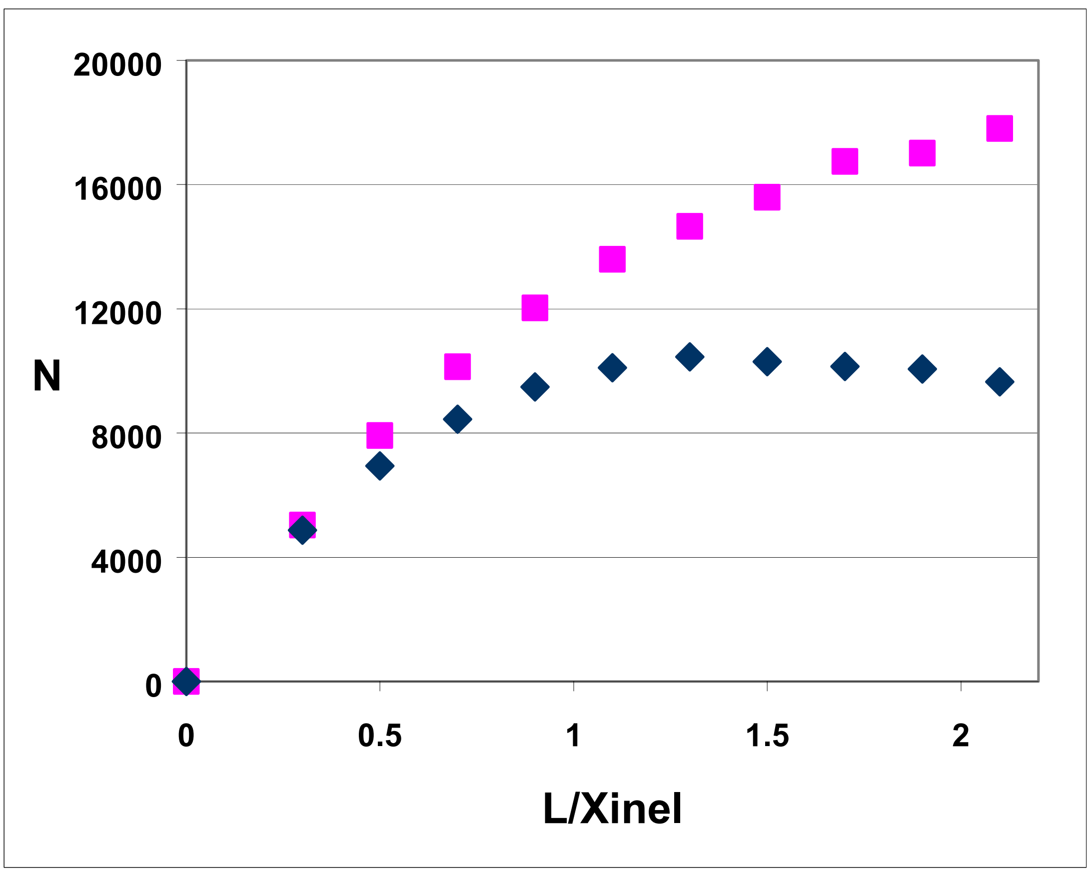


The π-p cross-sections are about 2/3 of the p-p cross-sections at 24 GeV. However, the π heavy nuclei cross-sections are closer to the p - heavy nuclei cross-sections due to nuclear shadowing. I simply take them to be the same in my program. Although this study could be done much more accurately with a real GEANT simulation, it doesn't look like there is any large gain in pion flux from making the E821 target longer: more pions are created, but many then scatter out of the beamline acceptance.

Appendix I

Recently there has been interest in a 5.2 GeV π^+ beam. The same simulation program was used. As shown in Fig. 1, $dN/dpd\Omega$ is lower at 5.2 GeV compared to 3.1 GeV. However, $dp = (dp/p)\times p$ is 1.7 times larger for the same dp/p. My program finds 10% more flux at 5.2 GeV compared to 3.1 GeV into the same dp/p (see Fig. 3). Note that the Q1/Q2 B field must be increased by a factor of 1.7 to retain the same $\Delta\Omega$ as at 3.1 GeV. Without increasing the Q1/Q2 magnetic field, the pion flux at 5.2 GeV is 66% of that at 3.1 GeV for the same dp/p, from my simulation program.

Fig. 3. Number of 5.2GeV π^+ within ±32mrad (H) and ±60mrad (V) vs. target length (arbitrary vertical scale, but same as Fig. 2). Squares and diamonds are without and with scatterings, respectively.



References

1. H. Grote, R. Hagedorn, J. Ranft, "Atlas of Particle Production Spectra", CERN December, 1970.

2. W.M. Morse et al., Phys. Rev. D15, 66 (1977), for example.