PREDICTING INCLUSIVE ELECTROPION AND NUCLEON CROSS SECTIONS FOR HIGH PARTICLE MOMENTA

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Abstract

A parametrization of yields of pions and nucleons by monoenergetic photons on nucleons above the resonance region is used to predict the bremsstrahlung and electroproduction cross sections on nuclei.

INTRODUCTION

In ref. 1 a delta resonance model was used to predict the doubly differential cross section for producing low momentum pion (< 0.5 GeV/c) resulting from the inclusive reaction

$$A + \gamma \longrightarrow \pi + \text{anything} \qquad (1)$$

where γ represent a real or virtual photon. The model fails for higher momentum pions where nonresonant, multiple-pion production from nucleons becomes dominant. We present here a model based on parametrization of the pion and nucleon yield data for GeV bremsstrahlung on the nucleon.

BREMSSTRAHLUNG YIELDS

The code GPC of ref. 1 has been modified for pions and nucleons above 0.5 GeV/c by the addition of a subroutine (S2PI) that accounts for multiple pion production and the associated recoiling nucleon. The cross section $d^2\sigma(\gamma_b, x)/d\Omega_x\, dp_x$, where $x=\pi$ or N, is computed directly in the lab system using parametrizations[2] of the invariant differential cross sections. For pions

$$\sigma_{Wiser} = E_\pi \frac{d^3\sigma}{d^3 p_\pi} = \left(a_1 + \frac{a_2}{s^{1/2}} \right) \left[1 - x_R + \frac{a_3{}^2}{s} \right]^{a_4} \exp(a_5 M_L) \exp(a_6 p_T{}^2/E_\pi) \tag{2}$$

and for nucleons

$$E_N \frac{d^3\sigma}{d^3 p_N} = \left(a_1 + \frac{a_2}{s^{1/2}} \right) \left[1 - x_R + \frac{a_3{}^2}{s} \right]^{a_4} \exp(a_5 M_L) \ (1 + |u|)^{-(a_6 + a_7 s)} \tag{3}$$

where ω is the photon energy, p_x and E_x are the momentum and total energy of the particle at angle θ and $p_T = p_x \sin\theta$.

The parameters a_n are from fits to charged pion and proton yields from hydrogen with bremsstrahlung end-point energies in the range 5-19 GeV, particle momenta in the range 1-8 GeV/c, and particle angles that varied the transverse momenta in the range p_T = 0.5-2.25 GeV/c. We assume isospin symmetry to parametrize the yields from neutrons. The parameters for π^0 are taken to be the same as $p(\gamma, \pi^+)$. The quantities s,u are the Mandelstam variables ($s = 2\omega M + M^2$, $u = M^2 - 2ME_x + m_x{}^2$) and x_R is the ratio of the cm particle momentum to cm photon momentum (the ratio is computed using a Lorentz transformation from the lab system). The longitudinal mass is given by $M_L{}^2 = p_T{}^2 + m_x{}^2$. The form of the parametrization is motivated by quark-parton models of the nucleon. The main sensitivity for pion production lies in the approximate scaling of the invariant cross section with transverse momentum.

The lab cross section for monoenergetic photons we need is

$$\frac{d^2\sigma(\gamma,x)}{d\Omega_x \; dp_x} = p^2{}_x \frac{d^3\sigma}{d^3 p_x} \tag{4}$$

The bremsstrahlung cross section per equivalent quanta, Q, is then

$$\frac{d^2\sigma(\gamma_b,x)}{Q \; d\Omega_x \; dp_x} = \int_{\omega_{thr}}^{k} \frac{d^2\sigma(\gamma,x)}{d\Omega_x \; dp_x} \frac{d\omega}{\omega} \tag{5}$$

where k is the end-point energy and ω_{thr} is the threshold energy for the process. An important difference between the one-pion final state in the delta model and the two or more pions in the final state in the present model is that only one photon energy contributes to the former while a range of photon energies contributes to the latter.

The thresholds for $p(\gamma,\pi^+)X$, $n(\gamma,\pi^-)X$, $N(\gamma,\pi^0)X$, and any $N(\gamma,N)X$ reaction are taken as the lab photon energy to produce one pion at the observed momentum from a free nucleon. The thresholds for $p(\gamma,\pi^-)X$ and $n(\gamma,\pi^+)X$ are taken as the lab photon energy to produce two pions (one of which has the observed momentum and the other has zero momentum) from the nucleon.

ELECTROPRODUCTION YIELDS

The code EPC of ref. 1 has been modified to switch from the one-pion delta model to the multiple-pion model for pion and nucleon momenta greater than 0.5 GeV/c. The electroproduction cross section is given by virtual photon theory as described in ref. 1,

$$\frac{d^2\sigma(e,x)}{d\Omega_x\ dp_x} = \int_{\omega_{thr}}^{E} \frac{N_e(k,\omega)}{\omega} \frac{d^2\sigma(\gamma,x)}{d\Omega_x\ dp_x}\, d\omega . \qquad (6)$$

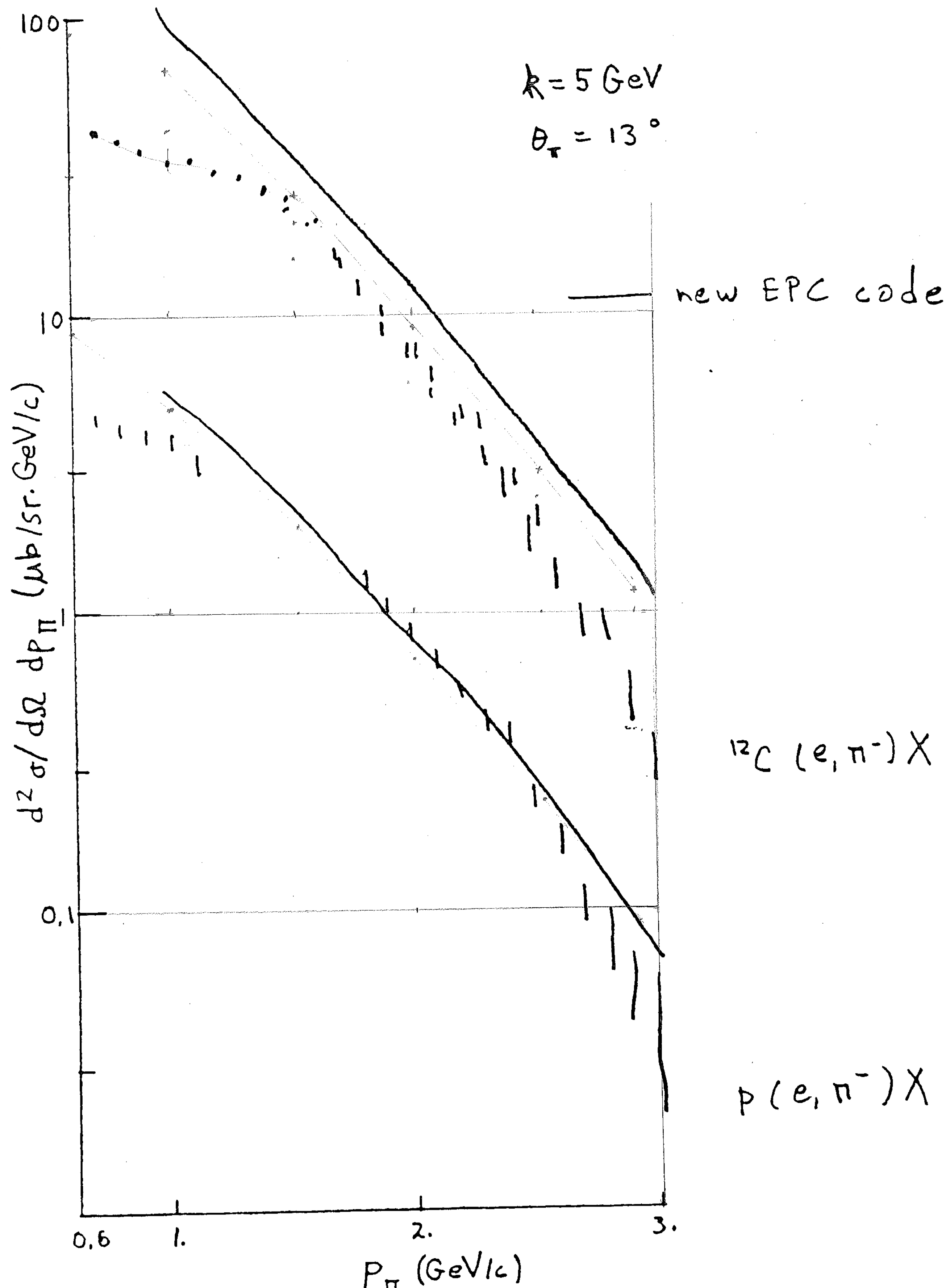
RESULTS

Fig. 1 shows a comparison of (e,π-) spectra predicted by the present model and data at 13 degrees from hydrogen and carbon targets. The agreement is close to the factor of two we set as our goal at lower particle momenta.

REFERENCES

1. J.W. Lightbody, Jr. and J.S. O'Connell, Computers in Physics, May/June, 1988.

2. D.E. Wiser, Ph.D. thesis, University of Wisconsin, 1977. Thanks to Richard Milner for bringing this reference to my attention.


k = 5 GeV
θ_π = 13°
new EPC code
$^{12}C(e,\pi^-)X$
$p(e,\pi^-)X$
100
10
0.1
$d^2\sigma/d\Omega\, dp_\pi$ (μb/sr. GeV/c)
0.6
1.
2.
3.
P_π (GeV/c)