on SU(3) theory.

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INELASTIC SCATTERING OF NEGATIVE PIONS FROM DEUTERONS AT 5.53 GeV/c *

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The differential cross sections for the total scattering and the inelastic scattering of negative pions by deuterium for 5.53-GeV/c incident pion momentum have been measured over the squared four-momentum transfer interval from ~0.3 (GeV/c)^2 to ~1.0 (GeV/c)^2. The results are compared with calculations based upon the impulse approximation and the Glauber approximation.

We have measured the differential cross section for the inelastic scattering of 5.53-GeV/c negative pions by deuterons. Previous experiments on pion-deuteron inelastic scattering have been concerned either with total cross sections or with angular distributions for incident momenta less than 1.0 GeV/c.[1] The theoretical analyses of these total cross-section data are based upon the Glauber high-energy approximation where both the single and double interaction effects have been taken into account.[2] The low-energy pion-deuteron differential cross sections were analyzed using the impulse approximation with limited success. In this note we shall compare our measured differential cross section with the impulse approximation and the Glauber approximation.

The experiment was performed at Argonne National Laboratory in the 17° beam of the zero-gradient synchrotron. The beam transport system determined the momentum of the pions to ±1% with an intensity of 2×10^5 pions/pulse for 580-msec pulses repeated at the rate of 1000 pulses/h. The beam angular divergence was ±5 mrad horizontally and ±3 mrad vertically at the 2.31-in. liquid-deuterium target. The liquid deuterium was maintained at a vapor pressure of 1 atm with a density of 0.1625 ± 0.002 g/cm^3. Beam pions were counted by a series of four scintillation counters with the last counter defining the beam size to be $\frac{3}{4}$ in. by $\frac{3}{4}$ in. The scattered pions were detected in a single-arm spectrometer consisting of a bending magnet, two scintillation counter arrays, and a single scintillation counter behind the first array to determine the azimuthal acceptance. The 1.0-in. width of an element in the first array determined the polar angular acceptance. A scintillation counter was placed downstream from the target to veto beam pions that did not interact with the target. The criteria for a good event were a count in the beam counters, a count in the azimuthal counter, a count in an element of the first array in coincidence with a count in a corresponding element of the second array, and no count in the veto counter. The desired events were then stored in a multichannel analyzer.

The background was determined by scattering in a carbon target and in an empty target. The ratio of background to desired event rate was found to vary from 40 to 76% depending upon the scattering angle. Corrections were applied to the data for electronic deadtime effects due to the veto counter, for muon and electron contamination of the pion beam, for nuclear absorption of the scattered pion in the liquid deuterium and the counter materials, for scattered pion decay, for impurities in the liquid-deuterium target, and for attenuation of the pion beam. The total scattering differential cross section is given in

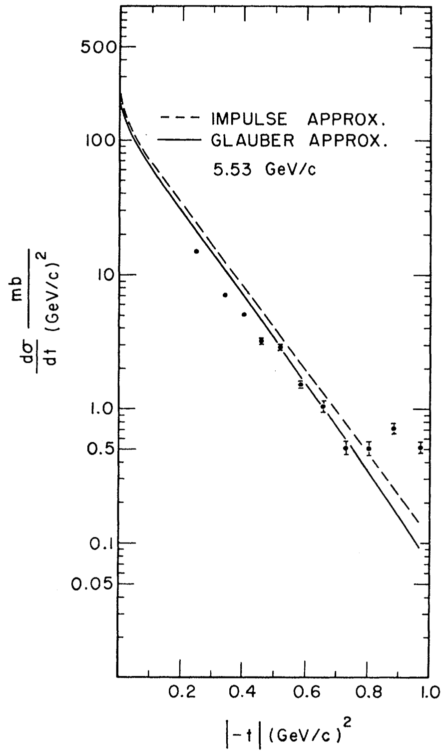

FIG. 1. Total scattering differential cross section for the negative pion on deuteron to yield a negative pion and any other final state (missing mass).

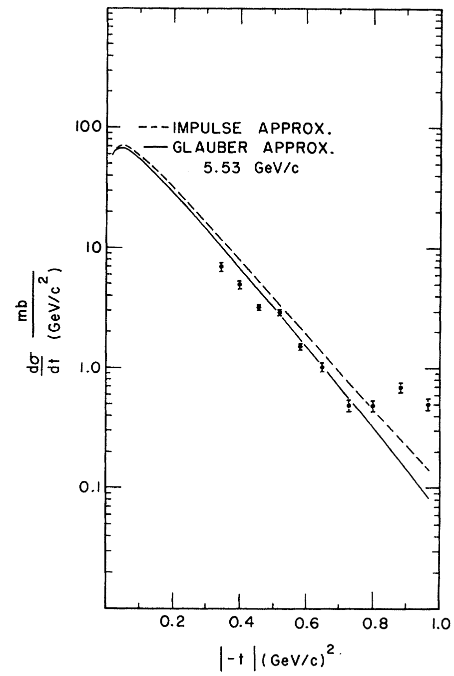

FIG. 2. Inelastic scattering differential cross section for negative pion on deuteron. The solid curve is the Glauber approximation and the dashed curve is the impulse approximation explained in the text.

Fig. 1. The error bars shown are associated with statistical errors only. The normalization uncertainty is ±12%. The inelastic differential cross section was determined by subtracting the elastic differential cross section of Fellinger et al.[3] from the total scattering differential cross section. In Fig. 2 the differential cross section for the inelastic scattering of negative pions from deuterium is shown.

Using the closure approximation to sum over a complete set of final deuteron states, the Glauber high-energy approximation predicts the unpolarized total scattering differential cross section (nonabsorptive) to be[3,4]

$$\left(\frac{d\sigma}{d\Omega}\right)_{\mathrm{sc}}=\tfrac{1}{3}\sum_{m',m}\Big\{|f_n(\vec q)|^2+|f_p(\vec q)|^2+2S_{m',m}(\vec q)\,\mathrm{Re}[f_n(\vec q)f_p^*(\vec q)]-\frac{1}{\pi k}\mathrm{Im}f^*(\vec q)\int S_{m',m}(\vec q\,'-\tfrac{1}{2}\vec q)\langle f_nf_p\rangle\,d^2\vec q\,'$$
$$-\frac{1}{\pi k}\mathrm{Im}f_p^*(\vec q)\int S_{m',m}(\vec q\,'+\tfrac{1}{2}\vec q)\langle f_nf_p\rangle\,d^2\vec q\,'+\frac{1}{(2\pi k)^2}\int d\vec r\,|\psi(r)|^2\Big|\int d^2\vec q\,'e^{i\vec q\,'\cdot\vec s}\langle f_nf_p\rangle\Big|^2\Big\},$$

where $S_{m',m}=\langle\psi_{m'}|e^{i\vec q\cdot\vec r}|\psi_m\rangle$ are the form factors of the deuteron ${}^3S_1+{}^3D_1$ ground state, ψ is the deuteron wave function, m and m' are the initial and final projections, respectively, of the deuteron spin, f_p and f_n are the pion-proton and pion-neutron elastic scattering amplitudes, respectively, $\vec s$ is the projection of the neutron-proton relative coordinate ($\vec r$) onto the plane perpendicular to the incident pion momentum, and k is the incident momentum. The $\langle f_nf_p\rangle$ is an operator in the composite isospin space of the pion and the target nucleons given by[5]

$$\langle f_nf_p\rangle=f_n(\tfrac{1}{2}\vec q+\vec q\,')f_p(\tfrac{1}{2}\vec q-\vec q\,')-\tfrac{1}{4}[f_n(\tfrac{1}{2}\vec q+\vec q\,')-f_p(\tfrac{1}{2}\vec q+\vec q\,')][f_n(\tfrac{1}{2}\vec q-\vec q\,')-f_p(\tfrac{1}{2}\vec q-\vec q\,')].$$

The elastic scattering differential cross section is given in the Glauber approximation by

$$\left(\frac{d\sigma}{d\Omega}\right)_{\mathrm{el}}=\tfrac{1}{3}\sum_{m',m}\Big[S_{m',m}{}^2(\tfrac{1}{2}\vec q)\{|f_n(\vec q)|^2+|f_p(\vec q)|^2+2\,\mathrm{Re}[f_n(\vec q)f_p^*(\vec q)]\}$$
$$-\frac{1}{\pi k}S_{m',m}(\tfrac{1}{2}\vec q)\,\mathrm{Im}\{[f_n^*(\vec q)+f_p^*(\vec q)]\int S_{m',m}(\vec q\,')\langle f_nf_p\rangle d^2\vec q\,'\}+\frac{1}{(2\pi k)^2}\Big|\int S_{m',m}(\vec q\,')\langle f_nf_p\rangle d^2\vec q\,'\Big|^2\Big].$$

The inelastic differential cross section is then given by $(d\sigma/d\Omega)_{\rm inel} = (d\sigma/d\Omega)_{\rm sc} - (d\sigma/d\Omega)_{\rm el}$. The inelastic differential cross section given by the above calculations considers only the breakup process and does not take into account production and absorption processes.

The pion-nucleon elastic amplitudes at high momenta in the forward direction may be represented by

$$f_N(q) = \frac{k\sigma_N}{4\pi}[i + \alpha_N(t)]\left(\frac{1+\alpha_N^2(0)}{1+\alpha_N^2(t)}\right)^{1/2} \exp(\tfrac{1}{2}A_N t), \quad N = n \text{ or } p, \quad t = -q^2,$$

where σ_N is the total pion-nucleon cross section, $\alpha_N(t)$ is the ratio of the real part to the imaginary part of the scattering amplitude, and A_N is the slope of an exponential fit to the pion-nucleon differential cross sections. By charge symmetry the π^-n parameters may be replaced by the π^+p parameters which are available from experimental data. In the calculations we have taken $\alpha_N(t) = \alpha_N(0)$ where the $\alpha_p(0)$ and $\alpha_n(0)$ have been obtained from Barashenkov.[6] The total pion-nucleon cross sections were measured by Citron *et al.*,[7] and the diffraction slopes were fitted by Lasinski, Levi Setti, and Predazzi.[8] The Hamada-Johnston deuteron wave function was used to determine the form factors.[9] In the theoretical calculations there are no free parameters.

In Figs. 1 and 2 the solid curves are the result of the calculations using the Glauber approximation. The impulse approximation is given by the first three terms of the Glauber expressions for the differential cross section; these are the terms which do not contain an integration over the form factors. The results for the impulse approximation are given by the dashed curves. Inclusion of the double-scattering effects via the Glauber approximation is shown to give a more reasonable interpretation of our data for four-momentum transfers $|-t| < 0.7$ (GeV/c)^2 than the impulse approximation.

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