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A NEW APPROXIMATION FOR GLAUBER THEORY ON STRIPPING OF RELATIVISTIC DEUTERONS

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[illegible] forward protons from relativistic [illegible] with nuclei is computed from a Glauber [illegible] and [illegible]. In this note we appr[illegible] [illegible] proton-neutron scattering state (disintegrated [illegible] plane wave [illegible] the components of this plane wave [illegible] state vector. With no fitted parameters we [illegible] with data from the reaction $d + C^{12} \to p + X$ in the region corresponding to non-relativistic Fermi momenta in the forward direction. At more relativistic Fermi momenta, the model deviates more from the data, which can be due to incorrect choice of the short distance part of the deuteron wave function as well as off-shell effects in the deuteron.

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I. INTRODUCTION

The past years have seen abundant production of data on the break-up of relativistic heavy ions at Bevatron-Bevalac energies of 1-2 GeV per nucleon. Parallel thereto there has been considerable effort on understanding such fragmentation processes in terms of Glauber-theoretical ideas. In this paper we propose a new approximation for one particular such Ansatz by Bertocchi, Tékou, and Treleani (BTT) [1] on the stripping of neutrons from relativistic deuterons impinging on target nucleus A,

$$d + A \rightarrow p + X. \tag{1}$$

and calculate the cross section. We further discuss the region of validity of this model.

In conventional Glauber theory [2] the incoming particle striking a nucleus is treated as a plane wave with no internal structure. For reaction (1) the incoming and fragmented deuterons traversing across the nucleus correspond to this plane wave. The internal structure of the projectile is in [1] additionally accounted for by wave functions of the internal variables of the proton-neutron system. Furthermore, the authors BTT assume the complex phase shift χ_d of deuteron nucleus scattering to be the sum of the proton χ_p and neutron χ_n phase shifts. With these assumptions they set up the amplitudes (2a,b) below as their Ansatz.

Our main concern here will be the choice of the internal wave function for the proton-neutron system resulting from the deuteron disintegration. Obviously, a proton-neutron scattering state is the right choice, but very difficult to evaluate. In their approximation BTT use plane waves for each of the two nucleons. As emphasized by them,

the internal part of the product of plane waves has a non-vanishing overlap with the deuteron wave function. Consequently, using the plane waves in computing the amplitude, the authors also include a fraction of the elastic deuteron-nucleus scattering. This fraction is determined by the amount of overlap between the plane waves and the deuteron wave function. In the second paper [1b] BT discuss the severity of this approximation. They correct for their overestimate of the stripping cross section by a normalization factor for the plane waves. It is determined so as to reproduce the correct total stripping cross section, i.e. integrated over the proton momentum. Thus, they neglect the correlation to the momentum transfer dependence of the amplitude.

In the following discussion we will basically retain the plane wave formulation. However, our correction for the elastic d-A scattering has a more physical basis than the normalization factor for the plane waves: We construct an outgoing p-n state orthogonal to the deuteron state by subtracting from the plane wave its component parallel to the deuteron. This state is thus orthogonal to the deuteron. For simplicity in computation it is used only in that part of the cross section where the outgoing target nucleus is left in the ground state (coherent part). One argument justifying the latter is that the momentum transfer imparted to the excited or fragmented target nucleus in incoherent d-A scattering will probably also break up the deuteron. Thus the probability for "elastic" incoherent d-A scattering is small and therefore need not be corrected for.

The paper is organized as follows: In Section II we give a short review of the Ansatz of BTT and then calculate the formula for the stripping cross section with the orthogonalized p-n state. In Section III

we present the results of our approximation compared with fragmentation data from 1.05 and 2.1 GeV/N incoming deuteron beams on carbon target. We also touch upon a few questions relating to some basic assumptions and approximations in the model.

II. THE GLAUBER MULTIPLE SCATTERING MODEL

A.

The stripping cross section for reaction (1) is conveniently broken into two parts

$$\frac{d^3\sigma_{strip}}{d^3q_p} = \frac{d^3\sigma_{dis}}{d^3q_p} + \frac{d^3\sigma_{abs}}{d^3q_p}$$

corresponding to the reactions

$$d + A \rightarrow p + n + A' \qquad \text{disintegration} \qquad (1b)$$

$$d + A \rightarrow p + x + A',\ x \neq n \qquad \text{absorption of neutron.} \qquad (1c)$$

The amplitude for (1b) according to the assumptions discussed in section I is

$$F_{dis} = \frac{ik}{2\pi} \int d^2B\ e^{-i\vec{T}\cdot\vec{B}} \langle d'\langle A'|(1 - e^{i(\chi_p+\chi_n)})|A\rangle\ d\rangle. \qquad (2a)$$

Here $|A\rangle$ and $|d\rangle(|A'\rangle,\ |d'\rangle)$ are the internal states of the incoming nucleus and deuteron (outgoing nucleus and p-n system), $\vec{B}$ and $\vec{T}$ are impact parameter of incident deuteron and transverse momentum transferred to the total p-n system respectively. The incident deuteron momentum is given by k; χ_p, χ_n are the complex phase shifts of proton

and neutron. In Glauber's multiple scattering theory the phase shifts are given in terms of the profile functions Γ_p, Γ_n for elastic proton-nucleus and neutron-nucleus scattering:

$$e^{i(\chi_p+\chi_n)} = (1 - \Gamma_p(\vec{b}_p))(1 - \Gamma_n(\vec{b}_n)) \tag{3}$$

where $\vec{b}_p$ and $\vec{b}_n$ are the proton and neutron impact parameters respectively (i.e. $\vec{B} = (\vec{b}_p + \vec{b}_n)/2$). As is well known, the profile function is the two-dimensional Fourier transform of the scattering amplitude:

$$\Gamma(b) = \frac{1}{2\pi ik} \int d^2q_\perp e^{i\vec{q}_\perp \cdot \vec{b}} f(\vec{q}_\perp).$$

By analogy the amplitude for reaction (1c) is written

$$F_{abs} = \frac{ik}{2\pi} \int d^2B\ e^{-i\vec{\Gamma}\cdot\vec{B}} \langle d' \langle A' | (1 - \Gamma_p(\vec{b}_p))\ \Gamma_n^x(\vec{b}_n) | A \rangle d \rangle. \tag{2b}$$

Here Γ_n^x is the Fourier transform of the amplitude for $n + A \to x + A'$, $x \neq n$. The unity in $1 - \Gamma_n^x$ is missing due to the inelastic x-production. In (2b) $|d'\rangle = |p,x\rangle$.

B.

The processes included in the amplitudes (2) can be represented by the diagrams in Fig. 1a. The shaded blobs represent the full multiple scattering expansion of conventional Glauber theory for a structureless projectile. The following processes have not been included in (2):

a) Charge exchange as in Fig. 1b, where the converted neutron would be the detected proton. This contribution is very roughly a

factor of 5 to 10 less than elastic scattering at these energies [3].

b) Production of fast particles by the scattered proton, as in Fig. 1c. In section III.C we discuss where in the proton momentum spectrum this neglect might be justified.

c) Any possible resonance excitations are neglected.

C.

To compute the differential stripping cross section,

$$\frac{d^3\sigma_{strip}}{d^3q_p} \propto \int d^3q_n \sum_{A'} |F_{dis}|^2 + \sum_{x,A'} |F_{abs}|^2 , \tag{4}$$

we sum over the unobserved states A', x and n. The sum over A' is easy to perform via closure $\sum_{A'} |A'\rangle\langle A'| = 1$. For the sum and integrals over x and $\vec{q}_n$ one must specify the $|d'\rangle$ state. In ref. [1b], $|d'\rangle = |p,n\rangle = (\sqrt{C_d}/(2\pi)^{3/2}) e^{i\vec{f}\cdot\vec{r}}$ ($\vec{f} = (\vec{q}_p - \vec{q}_n)/2$ and $\vec{r} = \vec{r}_p - \vec{r}_n$ are the relative momentum and coordinate of proton and neutron) and similarly for $|p,x\rangle$. C_d is their normalization constant to correct for the elastic d-A scattering.

Here, setting $C_d = 1$, we follow BTT everywhere <u>but</u> for the <u>coherent disintegration</u> amplitude. For the latter case we write

$$|d'\rangle = |p,n\rangle = \frac{1}{(2\pi)^{3/2}} [e^{i\vec{f}\cdot\vec{r}} - (2\pi)^{3/2} \frac{\psi^*_{\vec{Q}'}(\vec{f})}{\sqrt{2E_p}} \psi_{\vec{Q}'}(\vec{r})] . \tag{5}$$

Here $\psi_{\vec{Q}'}(\vec{r})$ is the configuration-space internal wave function of a deuteron flying with momentum $\vec{Q}' = (\vec{k},\vec{T})$. Through Lorentz-contraction this internal wave function obviously depends on $\vec{Q}'$. Its overlap with the plane wave state

$$\frac{\phi_{\vec{Q}}(\vec{f})}{\sqrt{2E_p}} = \frac{1}{(2\pi)^{3/2}} \int d^3r\, e^{-i\vec{f}\cdot\vec{r}} \psi_{\vec{Q}}(\vec{r}) \tag{6}$$

is of course the deuteron wave function in momentum space. A factor of $\sqrt{2E_p}$ (E_p = energy of the proton bound in the deuteron) is extracted from the wave function, so that $|\phi_{Q'}(\vec{f})|^2$ is an invariant, i.e.

$$\int \frac{d^3q_p}{2E_p} |\phi_{\vec{Q}'}(\vec{f}=\vec{q}_p-\vec{Q}'/2)|^2 = 1 \tag{7}$$

for all $\vec{Q}'$, under the assumption that "bound" momenta have the same transformation laws as "free." Thus for a given $\vec{Q}'$ and $\vec{q}_p$ we can write

$$\phi_{\vec{Q}}(\vec{f}=\vec{q}_p-\vec{Q}'/2) = \phi_o(\vec{p}^2(\vec{q}_p,\vec{Q}')) \tag{8}$$

where $\vec{p}^2(\vec{q}_p,\vec{Q}')$ is the 3-momentum squared of the bound proton in the deuteron rest frame. The rest frame wave function ϕ_0 is assumed to depend only on the square of $\vec{p}$.

To approximate $\vec{p}^2$ we set the deuteron and proton on shell, as they are the detected in- and out-going particles, and the neutron off shell, with virtual mass squared τ. (We will come back to this approximation below.) Then in the lab frame we have

$$\tau \equiv (p_d - p_p)^2 = M_d^2 + m_p^2 - 2E_pE_d + 2\vec{Q}\cdot\vec{q}_p \tag{9}$$

In the deuteron rest frame:

$$\vec{p}^2(1_p,\vec{t}_p,\vec{Q}) = \vec{p}^2(\vec{q}_p,\vec{Q}) = [\frac{1}{2M_d}(M_d^2 + m_p^2 - \tau)]^2 - m_p^2 \tag{10}$$

$$=(1/M_d^2)\{[(M_d^2 + \vec{Q}^2)(m_p^2 + \vec{q}_p^2)]^{1/2} - \vec{Q}\cdot\vec{q}_p\}^2 - m_p^2$$

where l_p, $\vec{t}_p$ are longitudinal and transverse lab momenta of the proton. Equation (10) differs from the one used in ref.[1b], where deuteron and neutron are set on shell and proton off.

D.

To evaluate (4) we proceed as follows: For the coherent disintegration $F_{dis}(dA \to d'A)$ we use the full wave function (5); for all other contributions to (4) only the plane wave part of (5). Upon squaring $F_{dis}(dA \to d'A)$ we obtain first the square of the plane wave contribution only. That term combined with the other plane wave contributions in (4) is exactly the formula (2.10) of BT in ref. [1b] whose calculations we will not repeat here. Instead we elaborate on the correction terms of $|F_{dis}(dA \to d'A)|^2$: a mixed interference term and the square of elastic deuteron scattering. Combining the results of BT, their equation (2.10), with our two additional terms we obtain (setting $C_d = 1$, and with a slight change of notation):

$$\frac{d^3\sigma_{strip}}{d^3q_p} = \frac{|\phi_o(p^2(\vec{q}_p,\vec{Q}))|^2}{2E_p}\sigma_{N,A} + \int d^2t \frac{|\phi_o(p^2(l_p,-\vec{t},\vec{Q}))|^2}{2(m_p^2+l_p^2+\vec{t}^2)^{1/2}} \sigma^N_{N,A}(\vec{t}_p-\vec{t})$$

$$- 2\mathrm{Re}\left\{\frac{\phi_o^*(p^2(\vec{q}_p,\vec{Q}))}{\sqrt{2E_p}} \int d^2t \frac{\phi_o(p^2(l_p,-\vec{t},\vec{Q}))}{\sqrt{2}(m_p^2+l_p^2+\vec{t}^2)^{1/4}} \sigma^N_{N,A}(\vec{t}_p-\vec{t})\right\} + \tag{11}$$

$$\frac{1}{(2\pi)^2}\int d^2t_n \frac{|\phi_o(p^2(\vec{q}_p,\vec{Q}'=\vec{q}_p+\vec{q}_n))|^2}{2E_p} \left|\int d^2B' \, e^{-i\vec{T}\cdot\vec{B}'} \langle d \langle A |(1 - e^{i\chi_d(\vec{B}')})| A \rangle d\rangle\right|^2$$

$$- \frac{2}{(2\pi)^{3/2}} \mathrm{Re} \left\{ \int d^2t_n \int d^2B \, d^3r \, e^{-i\vec{T}\cdot\vec{B}} \, e^{-i\vec{f}\cdot\vec{r}} \, \psi_{\vec{Q}}(\vec{r}) \langle A|(1 - e^{i\chi_d(\vec{B})})|A\rangle \times \right.$$

$$\left. \times \frac{\phi_{\vec{Q}'}(\vec{f})}{\sqrt{2E_p}} \int d^2B' \, e^{i\vec{T}\cdot\vec{B}'} \langle d \langle A|(1 - e^{-i\chi_d(\vec{B}')})|A\rangle d\rangle \right\}$$

where we have explicitly shown the variables which the wave functions depend upon. (Note that $\vec{q}_p$, $\vec{Q} = (k, 0)$ are fixed.) Here the last two terms represent our correction for elastic d-A scattering. As usual in Glauber theory the outgoing longitudinal momentum of the projectile system is set (approximately) equal to the incoming one. Thus in the three-dimensional integration over the neutron momentum, the longitudinal part has trivially been accomplished using the δ-function $\delta(l_p + l_n - k)$. The wave functions with the argument $\vec{Q}$ in p^2 represent the incident deuteron; those with $\vec{Q}' = (k, \vec{T})$ the outgoing deuteron in elastic d-A scattering. $\sigma_{N,A}$ is the total and $\sigma^N_{N,A}(\vec{t}_N) = \frac{d^2\sigma(NA\to NX)}{d^2t_N}$ the differential nucleon-nucleus cross sections summed over all target nucleus states. In the first three terms the approximation $\Gamma = \Gamma_p = \Gamma_n = \Gamma^*$ has been used.

E.

To facilitate a numerical evaluation of (11) we need several simplifications: For ease of computation we presently use a Hulthén wave function with S-wave only. The cross section $\sigma^N_{N,A}(\vec{t}_N)$ will be parameterized as $(A_N/\pi)e^{-B_N\vec{t}_N^2}$, where A_N, B_N are obtained from empirical fits of $d\sigma/d|t| = A_n e^{-B_N|t|}$ (t = 4-momentum transfer squared) for small $|t|$ [4] . We further

identify the $\int d^2B'$ integrals in the last two terms with the elastic d-A amplitude (as in (2a) setting $|d'\rangle = |d\rangle$). In the approximation that that amplitude is purely imaginary, we substitute for the $\int d^2B'$ integral

$$\frac{2\pi}{k}\sqrt{\frac{d\sigma_{el}(dA)}{d\Omega}} = 2\pi\sqrt{\frac{\sigma_{d,A}^{2}}{16\pi^2}}\; e^{-B_d\vec{T}^2/2} = 2\sqrt{A_d\pi}\; e^{-B_d\vec{T}^2/2} \tag{12}$$

where A_d, B_d are again obtained from empirical fits [5].

Inserting (12) into (11), the elastic d-A scattering term becomes

$$\frac{A_d}{\pi}\int d^2t_n\,\frac{|\phi_o(p^2(\vec{q}_p,\vec{Q}'))|^2}{2E_p}\; e^{-B_d(\vec{t}_p+\vec{t}_n)^2}\,. \tag{13}$$

For the interference term we obtain, after inserting the real profile functions for the deuteron phase shift in the $\int d^2B$ integral:

$$\frac{2\sqrt{A_d}}{(2\pi)^3}\int d^2t_n\int d^2B\int d^3r\; e^{-i\vec{T}\cdot\vec{B}}\; e^{-i\vec{f}\cdot\vec{r}}\;\frac{\phi_{\vec{Q}'}(\vec{f})}{\sqrt{2E_p}}\,\psi_{\vec{Q}}(\vec{r})\; e^{-B_d(\vec{t}_p+\vec{t}_n)^2/2}\;\times$$
$$\times\{\langle A\,|\Gamma(b_p)|\,A\rangle + \langle A\,|\Gamma(b_n)|\,A\rangle - \langle A\,|\Gamma(b_p)\Gamma(b_n)|\,A\rangle\}\,. \tag{14}$$

Using now $d^2Bd^3r = d^2b_p d^2b_n dz$ and $\vec{T}\cdot\vec{B} + \vec{f}\cdot\vec{r} = \vec{t}_p\cdot\vec{b}_p + \vec{t}_n\cdot\vec{b}_n + (l_p - k/2)z$, we can identify the $\int d^2b_p$, $\int d^2b_n$ integrals with the respective elastic nucleon-A amplitudes, as above in (12) for the d-A case. To maximally utilize this parameterization we employ the so-called "coherent" approximation for the double scattering part of (14)

$$\langle A\,|\Gamma(b_p)\Gamma(b_n)\,|\,A\rangle \;\simeq\; \langle A\,|\Gamma(b_p)|\,A\rangle\langle A\,|\Gamma(b_n)|\,A\rangle,$$

thus neglecting correlations between the proton and neutron scatterings. Finally, using the Fourier transformation (6) to get rid of $\psi_{\vec{Q}}(\vec{r})$, (14)

becomes

$$\frac{2\sqrt{A_d A_N}}{\pi} \int d^2t_n \left[\left(\frac{\phi_o(p^2(\vec{q}_p,\vec{Q}'))}{\sqrt{2E_p}}\right)\left(\frac{\phi_o(p^2(1_p,-\vec{t}_n,\vec{Q}))}{(4(m_p^2+1_p^2+\vec{t}_n^{\,2}))^{1/4}}\right) + \right.$$

$$\left. + \left(\frac{\phi_o(p^2(\vec{q}_p,\vec{Q}))}{\sqrt{2E_p}}\right)\left(\frac{\phi_o(p^2(\vec{q}_p,\vec{Q}'))}{\sqrt{2E_p}}\right)\right] e^{-(B_d+B_N)(\vec{t}_p+\vec{t}_n)^2/2} \tag{15}$$

$$- \frac{A_N\sqrt{A_d}}{\pi^{5/2}} \int d^2t_n \int d^2f_\perp \left(\frac{\phi_o(p^2(\vec{q}_p,\vec{Q}'))}{\sqrt{2E_p}}\right)\left(\frac{\phi_o(p^2(1_p,\vec{f}_\perp,\vec{Q}))}{(4(m_p^2+1_p^2+\vec{f}_\perp^{\,2}))^{1/4}}\right) \times$$

$$\times\, e^{-B_N(\vec{t}_n+\vec{f}_\perp)^2/2}\; e^{-B_N(\vec{t}_p-\vec{f}_\perp)^2/2}\; e^{-B_d(\vec{t}_n+\vec{t}_p)^2/2}$$

Thus (13) and (15) inserted back into (11) gives our final stripping cross section formula.

III. RESULTS AND DISCUSSION

A.

To compare (11) with data for the reactions d + C → p + X at 1.05 and 2.1 GeV/N from the thesis of Papp [4], we used the Hulthén wave function parameters from Moravcsik's fit to the Gartenhaus function [5]:

$$\frac{\phi_o(p^2)}{\sqrt{2E_p}} = C_1[1/(p^2+\alpha^2) - 1/(p^2+\beta^2)], \quad E_p^2 = p^2+m_p^2$$

α = 45.7 MeV, β = 5.18 α and C_1 the normalization constant. For the nucleon-carbon and deuteron-carbon parameters we used A_N = 7.5 barns/(GeV/c)^2, B_N = 65 (GeV/c)$^{-2}$ [4], A_d = 20.278 barns/(GeV/c)^2, B_d = 103 (GeV/c)$^{-2}$,

and $\sigma_{N,A}$ = 380 mb [6] . In Figs. 2 and 3 the predictions (i.e. no fitted parameters) of the model, using Monte Carlo integrations, are compared with the data from Ref. [4] . The statistical uncertainties of the integrations are represented by the thickness of the curves. The inclusive proton spectra from other targets, Be and Pb, have also been measured [4] , only we are lacking the A_d,B_d parameters.

B.

The discrepancy in the high momentum tails is not unexpected, since we have only used a simple Hulthén wave function taken from non-relativistic nuclear physics. However, the wave function alone may not be the only culprit. There is at least one basic assumption of Glauber theory used here which in our mind may break down for momenta considerably above the peak: the approximation of setting the same particles on shell for all three diagrams in Fig. 1a. It is probably all right in those regions where both nucleons in the deuteron are close to the mass shell, namely close to the peak of the momentum spectrum. However, in our treatment, as the proton momentum grows, the neutron slips farther off shell. This is clearly wrong for the second diagram of Fig. 1a, where the spectator neutron, being a free particle, should be on shell (e.g. in our approximation of p, d on shell, $\sqrt{\tau}$ = .927 GeV at q_p = 3.2 GeV/c and .77 GeV at q_p = 4.35 GeV/c, both for 2.1 GeV/N beams). However, in the Glauber theory framework the diagrams of Fig. 1a are not computed individually and summed and squared. Instead, through closure, the squared sum of the diagrams is transformed to a sum of terms,

each of which no longer uniquely corresponds to one of the graphs, c.f. eq. (11). It is therefore not trivial to decide upon which particles to put off shell in the evaluation of those terms.

C.

As mentioned above, this model neglects the fast particle production depicted in Fig. 1c. Its corresponding positive term in the cross section would, very qualitatively, be a convolution of two probabilities: that of fast particle production and that of finding a proton in the deuteron with momentum $\vec{q} + \Delta\vec{q}$ prior to collision. Here $\vec{q}$ is the observed outgoing momentum and $\Delta\vec{q}$ (with $\Delta\vec{q}_{\parallel} > 0$) some finite momentum transfer due to production. Thus, the steepness of the spectra in Fig. 2 and 3 above the peaks, roughly indicative of the wave function squared, implies that a proton which originally had $\vec{q} + \Delta\vec{q}$ contributes negligibly to the spectrum at $\vec{q}$, compared with elastically scattered protons with momentum $\vec{q}$ prior to reaction.

D.

In Fig. 4 the predictions of the model, using the same parameters as above, are compared with preliminary data of L. Anderson [7] . Plotted is the invariant inclusive cross section vs. the transverse moment $\vec{t}_p$ of the proton at the peak of the longitudinal momentum spectrum in the lab frame. As mentioned above in II.D, the longitudinal momentum of the entire projectile is "conserved" in Glauber theory. However, for finite $\vec{t}_p$

there trivially is a longitudinal momentum transfer which is presently very difficult to include in the model. To circumvent this difficulty each data point plotted is the maximum value of $Ed^3\sigma/d^3p$ as a function of l_p at fixed $\vec{t}_p$. This maximum value was chosen for the model comparison since the calculated cross section at fixed $\vec{t}_p$ peaks in its l_p dependence at zero l_p-transfer.

The first point to note in Fig. 4 is the energy dependence of the data in terms of the hypothesis of limiting fragmentation (HLF) [8] . It says that the momentum distribution of a beam fragment in the projectile frame is independent of the incident energy. The data satisfy HLF, as well as the model (which here is only calculated at 2.1 GeV/N) provided the elastic scattering input parameters do.

Below $\vec{t}_p$ = .225 GeV/c the data lie systematically 25-30% below the curve. However, the model represents very well the structure of the data in this region. Above .225 GeV/c the model drops precipitously whereas the data continue roughly exponentially at least out to .600 GeV/c with a slope of ≈ 5.76 $(\mathrm{GeV/c})^{-1}$ [7] . This serious discrepancy would be remedied, at least partly, by including the <u>incoherent</u> contributions (i.e. excitation and break-up of the target) in the parameterizations of the p-nucleus and d-nucleus cross sections. This additional information will soon be available [7] .

E.

In Fig. 5 we show the predicted longitudinal momentum spectrum for both energies at 0°. The unrealistically sharp kinematical cutoff is

introduced by hand, being $\simeq 2.86$ GeV/c for the 1.05 GeV/N case and $\simeq 5.0$ GeV/c for 2.1 GeV/N deuterons. Thus, though not visible in Fig. 5, the higher energy trivially allows "measurement" of higher Fermi momenta. The corresponding data will soon be available.

A final remark to the difference between our correction method and that of BT [1b] : Taking the ratio of the plotted values in Fig. 5 to the "plane wave contribution" of eq. (11) at various momenta, we get values of .67 at the peak, dropping to .35 at $1_p = 4.6$ Gev/c (for the 2.1 GeV/N case). These are to be compared with the constant value of $_d = .54$ used in [1b]. In other words, the two correction methods predict different shapes of the momentum spectra.

F.

We point out that the first term of (11) contributes a significant - almost dominant - part of $d\sigma_{strip}/d^3q_p$. This term can be identified with the square of the first diagram in Fig. 1a, summed over A', x, and $\vec{q}_n$, i.e. with the process where the detected fragment is merely a "spectator" to the nuclear interaction.

IV. CONCLUDING REMARKS

From the observations above we find the region of best validity of the present evaluation of (2a, b) to be for longitudinal momenta above the peak and corresponding to non-relativistic protons in the deuteron rest frame, and for transverse momenta out to where incoherent

effects become important. The latter agreement could be extended to larger $\vec{t}_p$ by including also incoherent p-A scattering in the input parameters.

The model furthermore has several inherent shortcomings. The off-shell effects need to be treated correctly or arguments must be found as to why they are not important. The correct kinematics, such as the shift in peak position to smaller q_p with increasing $\vec{t}_p$ as well as the kinematic cutoff at the high q_p end must be introduced by hand in an ad hoc fashion. With a better understanding of these shortcomings one can use this model to extract more reliable information about the short distance part of the deuteron wave function.

We further stress that any models applied to deuteron stripping should always include the contributions where the detected fragment is a spectator as well as a participant of the interaction, as observed in III.F above.

In principle the same model could be employed to learn about single particle wave functions in e.g. ^{4}He projectiles. However, in the derivation of (11) the "equality" of the observed and nonobserved deuteron-fragments, i.e. $\Gamma_p^A = \Gamma_n^A$, proved very helpful. Thus, the direct extension of this method to α particles seems presently only possible for the momentum distribution of deuteron fragments from ^{4}He. The necessary d-A and ^{4}He-A cross section parameters will soon be available [7] . For p, ^{3}He, ^{3}H fragments of ^{4}He major modifications in the derivation would be needed, i.e. $\Gamma_p^A \neq \Gamma_{^3H}^A$, the ^{3}H-A total cross section is poorly known,

etc. This latter application has therefore not yet been seriously considered.

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FIGURE CAPTIONS

Fig. 1. a) Diagrams to illustrate mechanisms contributing to the amplitudes in (2a, b).

b) Charge exchange diagram, where the detected proton would be the one from $n + A \rightarrow p + A'$, not included in the model.

c) Fast particle production, also not included in the model.

Fig. 2. Comparison of the model prediction (i.e. no fitted parameters) with data from 1.05 GeV/nucleon deuterons on carbon target, taken from ref. [4].

Fig. 3. Same as Fig. 2, at 2.1 GeV/nucleon.

Fig. 4. The transverse momentum dependence at the peak of the longitudinal momentum dependence of the preliminary data of L. Anderson [7] at 1.05 and 2.1 GeV/N compared with the model prediction at 2.1 GeV/N. Typical error bars on the solid curve derive from the squared sum of the four independent variations in $Ed^3\sigma/d^3p$ resulting from varying the input parameters A_p, B_p, A_d, B_d by 10 %, one at a time.

Fig. 5. Predicted longitudinal momentum dependences at 0° for 1.05 and 2.1 GeV/N. Corresponding data will soon be available [7].

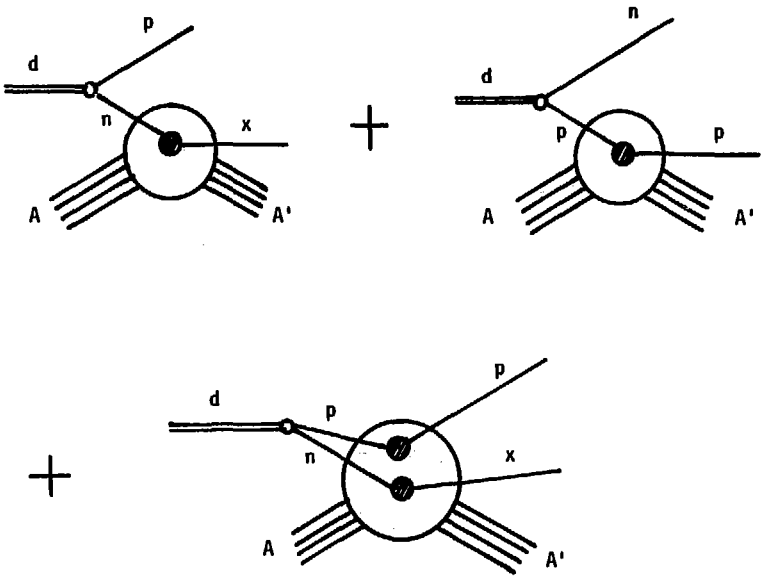

FIG. 1a

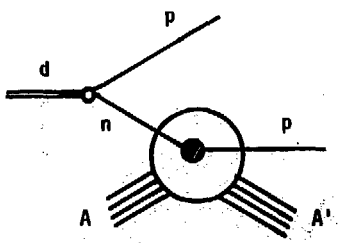

FIG. 1b

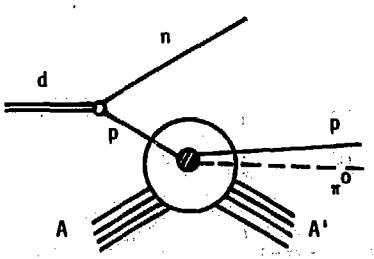

FIG. 1c

XBL 778-2584

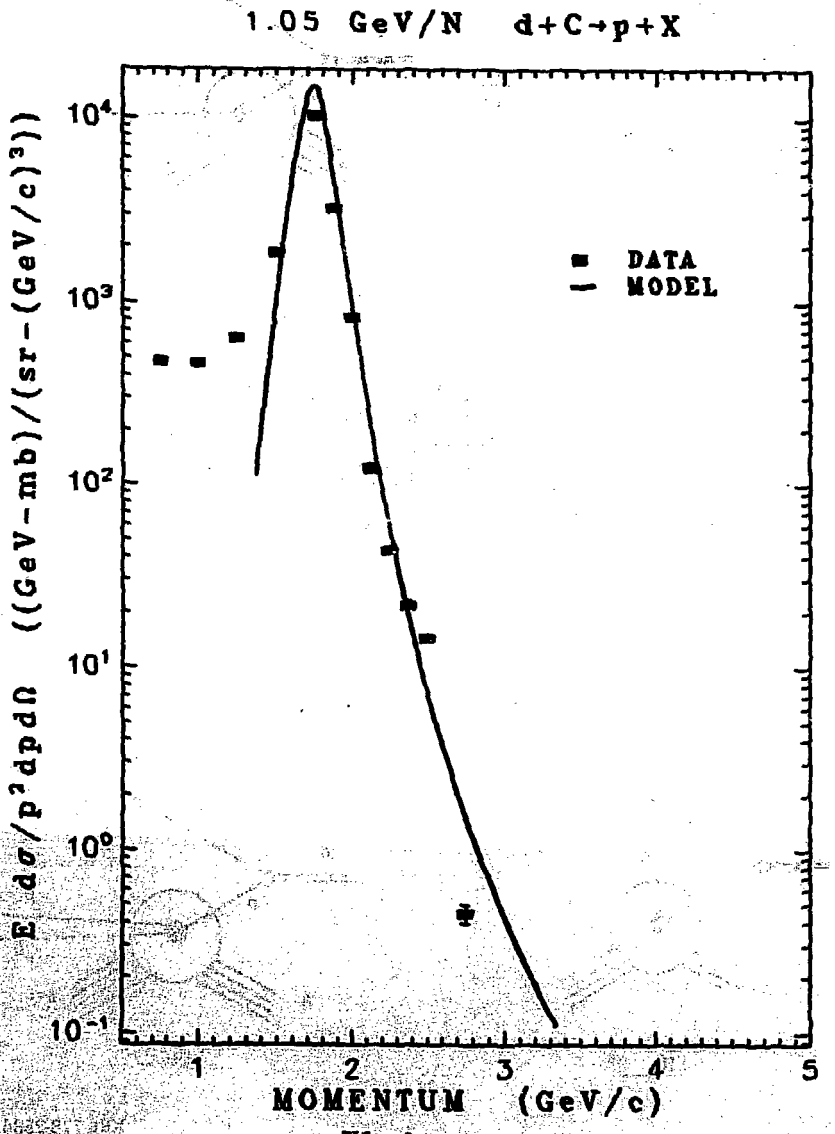

FIG. 2

XBL 778-1647

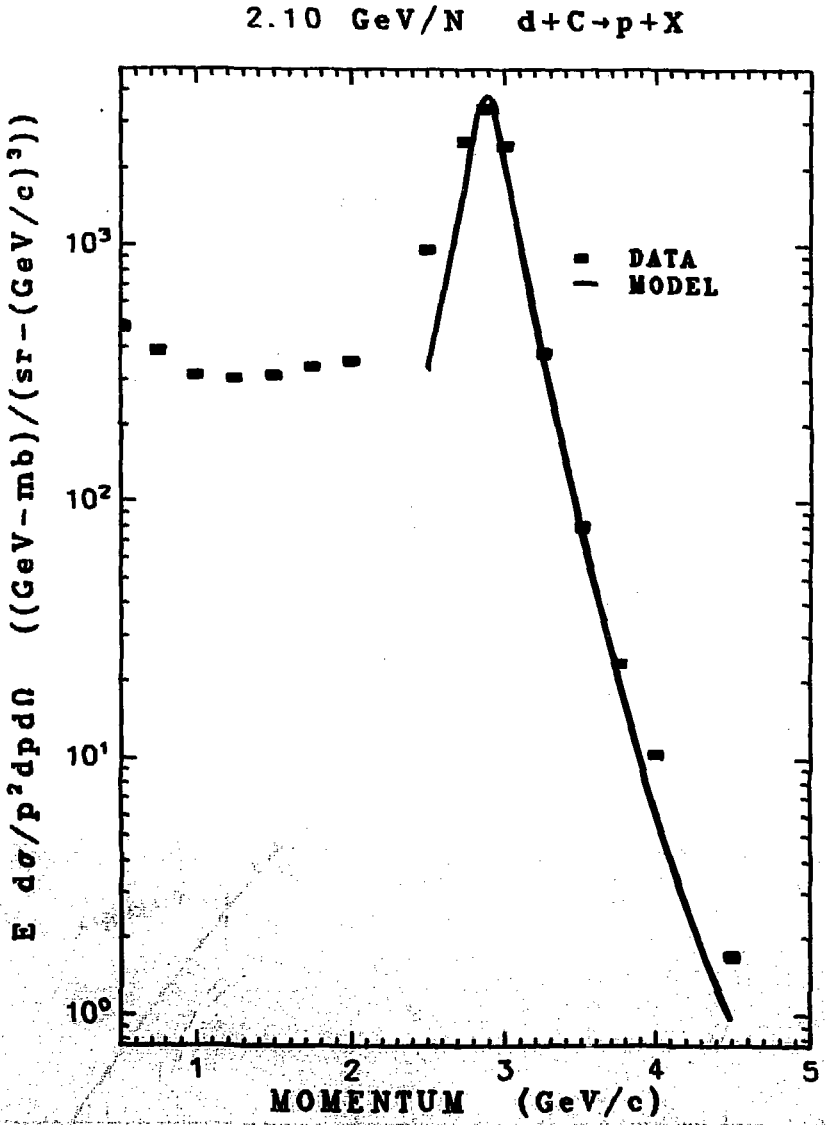

FIG. 3

XBL 778-1648

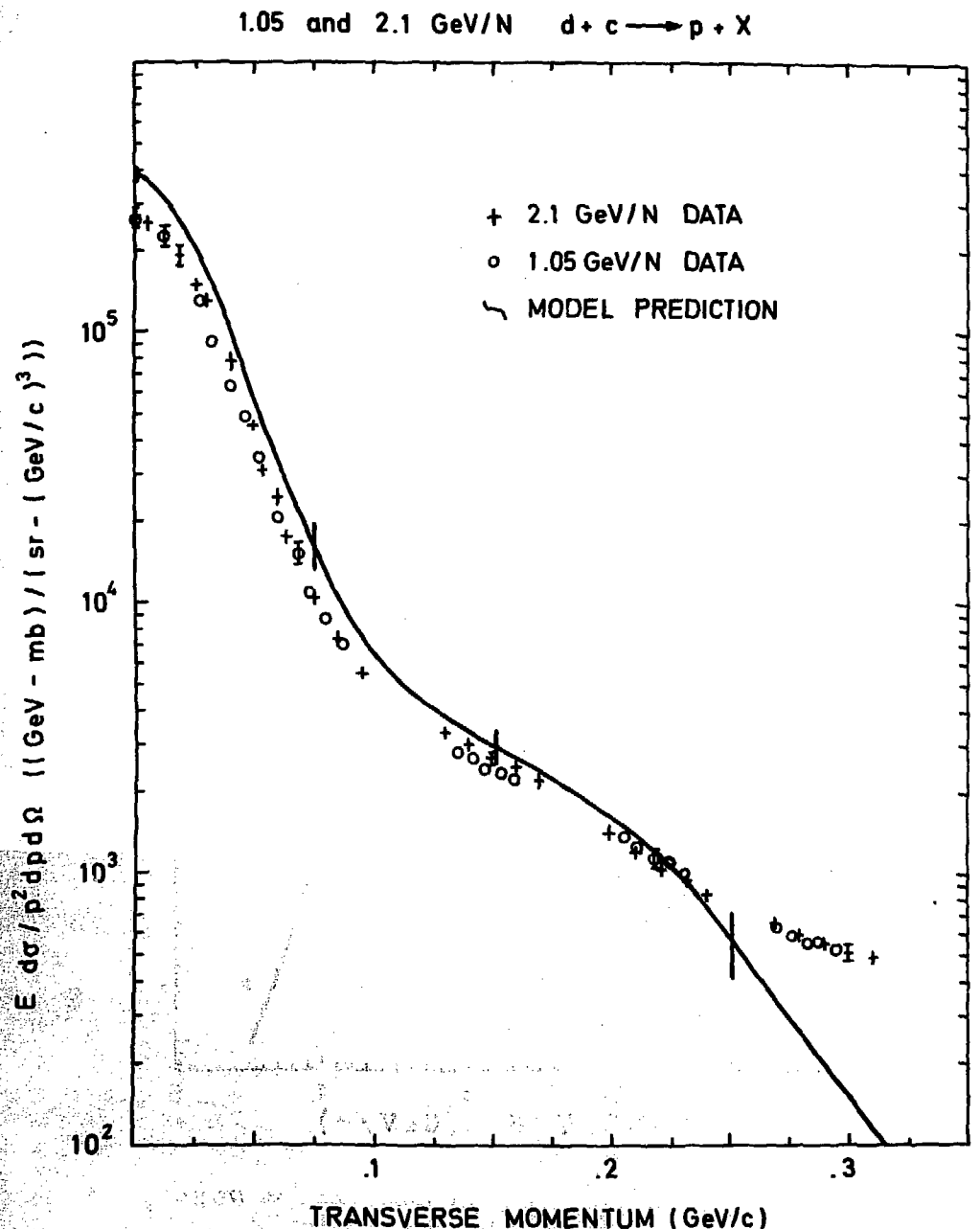
1.05 and 2.1 GeV/N d + c → p + X
+ 2.1 GeV/N DATA
o 1.05 GeV/N DATA
MODEL PREDICTION
E dσ / p² dp dΩ ((GeV - mb) / (sr - (GeV/c)³))
10⁵
10⁴
10³
10²
.1
.2
.3
TRANSVERSE MOMENTUM (GeV/c)

Fig. 4

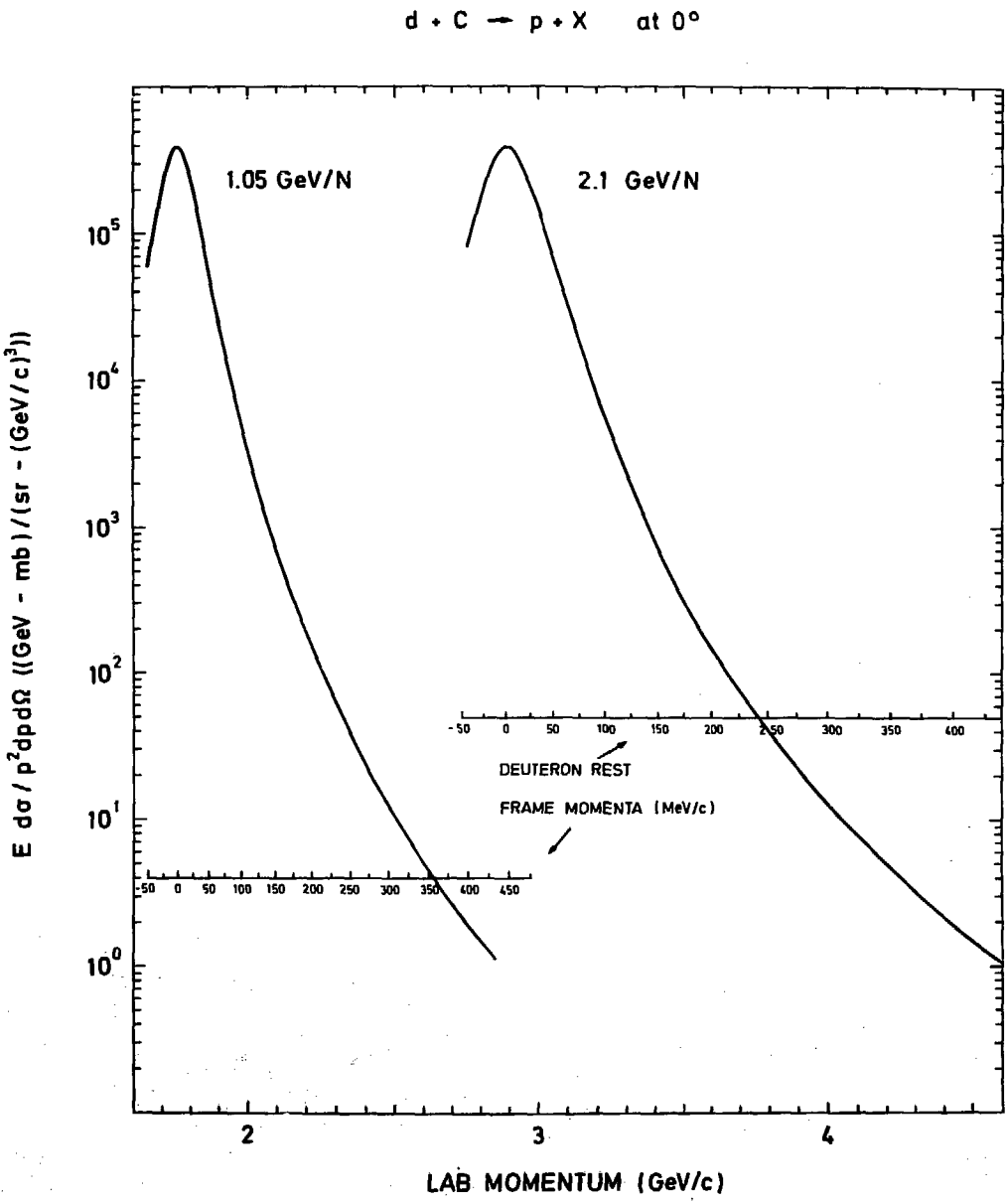
d + C → p + X at 0°
1.05 GeV/N
2.1 GeV/N
E dσ / p²dpdΩ ((GeV - mb)/(sr - (GeV/c)³))
10⁵
10⁴
10³
10²
10¹
10⁰
-50 0 50 100 150 200 250 300 350 400 450
-50 0 50 100 150 200 250 300 350 400
DEUTERON REST
FRAME MOMENTA (MeV/c)
2
3
4
LAB MOMENTUM (GeV/c)

Fig. 5