ELASTIC $p-{}^4$He SCATTERING AT INTERMEDIATE ENERGIES

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Effects of nonnucleonic degrees of freedom in nuclei for small transferred momenta give small corrections to the common nuclear physics predictions. So before studying these effects an accurate calculation of amplitudes of the considered processes should be done in the common nuclear physics framework. This paper is devoted to the description of the elastic $p - {}^4$He scattering in terms of the NN amplitudes obtained in the recent phase shift analysis [1] and realistic wave functions [2]. The ratio of the experimental differential cross section obtained in [3] to the calculated one in the Glauber theory is shown in fig.1. For the energy 991 *MeV* (890 *MeV*) the nuclear wave function calculated in [2] with the Eikemeier-Hackenbroich (SSC/A) potential was used. In both cases the S- and D-components of the wave functions, five pp and pn invariant amplitudes were taken into account. In spite of the good description of the experimental charge form factor the discrepancy between the $p - {}^4$He data [3] and the calculated cross section increases with an increasing of the transferred momentum q and becomes about 15—20% for $-t = q^2 = 0.08\ (GeV/c)^2$.

This discrepancy can not be explained by ordinary corrections to the Glauber approximation as one can see from fig.2. The solid curve shows the differential cross section. The long-dashed line represents the ratio of the differential cross section, calculated with the Fresnel correction, to the one calculated in the Glauber theory. The dash-dotted curve shows the Δ-isobar contribution to the $p - {}^4$He scattering. The short-dashed line represents the ratio of the cross section calculated with the Fresnel and Δ-isobar excitation corrections to the cross section calculated in the framework of the Glauber theory. It is easy to see that for $|t| \leq 0.1\ (GeV/c)^2$ the contribution of the corrections under discussion is smaller than 3%. The statement is likely to be true for nonadiabatic effects too [4].

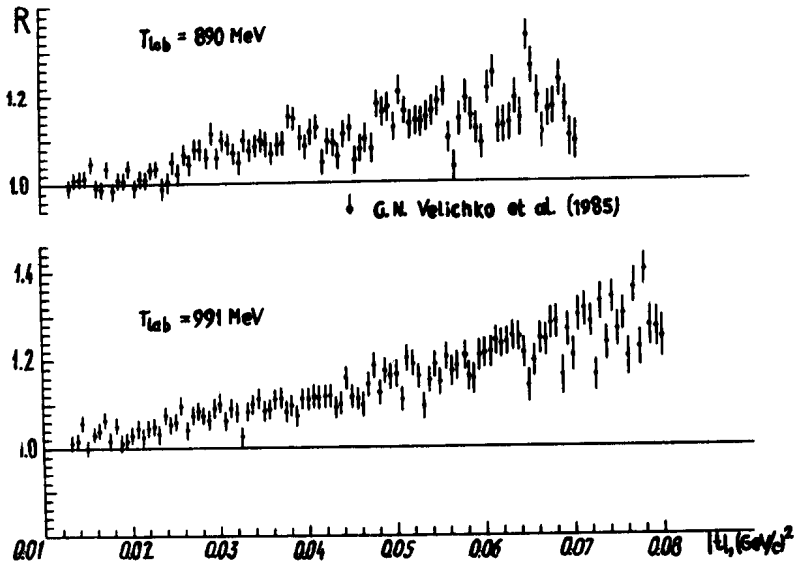
R
T_{lab} = 890 MeV
1.2
1.0
G.N. Velichko et al. (1985)
1.4
T_{lab} = 991 MeV
1.2
1.0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
|t|, (GeV/c)²

Fig.1

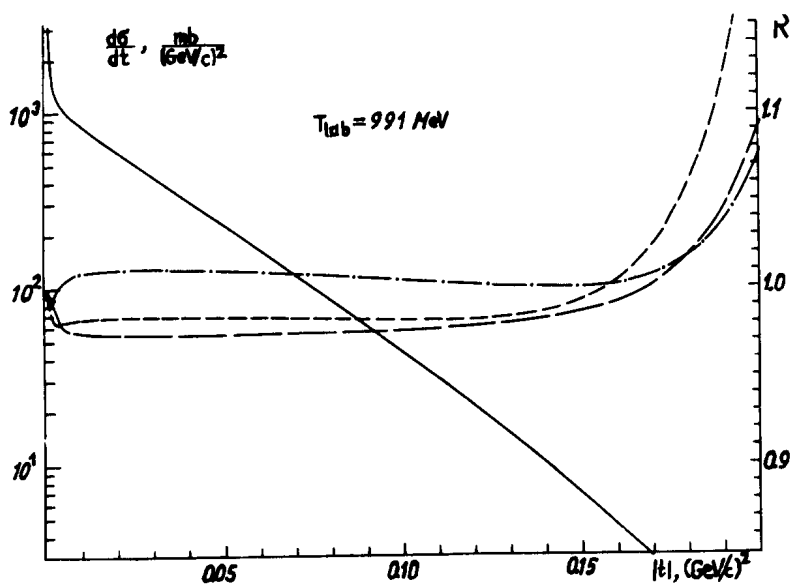
$\frac{d\sigma}{dt}$, $\frac{mb}{(GeV/c)^2}$
R
T_{lab} = 991 MeV
10^3
10^2
10^1
1.1
1.0
0.9
0.05
0.10
0.15
|t|, (GeV/c)²

Fig.2

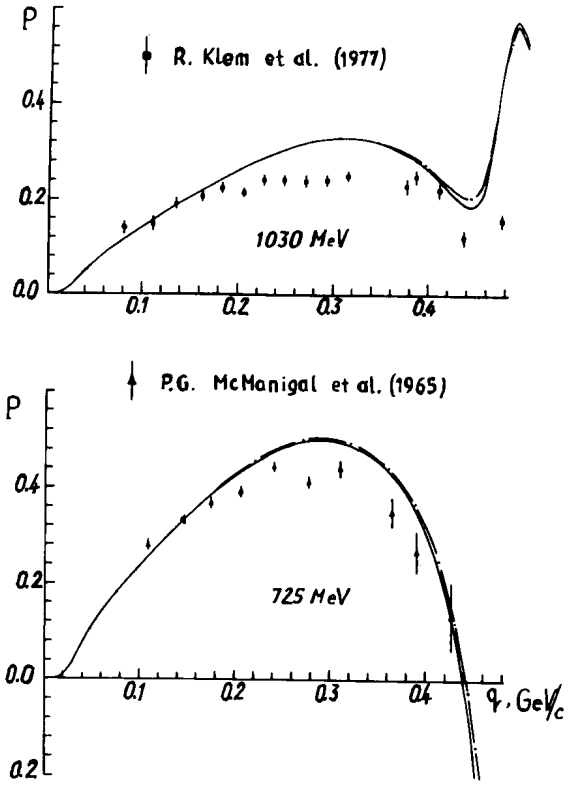
P
R. Klem et al. (1977)
0.4
0.2
1030 MeV
0.0
0.1
0.2
0.3
0.4
P.G. McManigal et al. (1965)
P
0.4
0.2
725 MeV
0.0
0.1
0.2
0.3
0.4
q, GeV/c
0.2

Fig.3

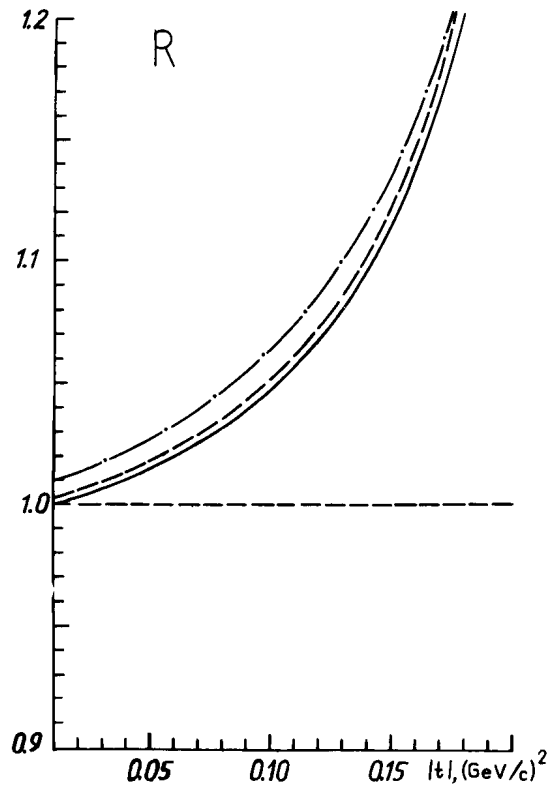
1.2
R
1.1
1.0
0.9
0.05
0.10
0.15
|t|,(GeV/c)²

Fig.4

Let us briefly discuss the question if the NN amplitudes [1] are adequate enough to describe the $p - {}^4\mathrm{H}$ scattering data. The most crucial point is a spin-dependent part of the NN amplitude. The ratio $R = |H/G|^2$ (G and H are the scalar and spin-orbital $p-{}^4\mathrm{He}$ amplitudes) shows a contribution to the cross section of the spin-orbital NN amplitude C. R is smaller than 15% for $t = 0.08\ GeV/c)^2$ at energies 695, 890 and 991 MeV. If one considers the discrepancy shown in fig.1 as a result of a shortcoming of C then one has to suppose that the shortcoming is about 50-100%. But this explanation contradicts a satisfactory description of the experimental polarization [5,6] shown in fig.3. The solid curves show results of calculations with the EH wave function and the dash-dotted lines are calculated with the SSC/A wave function.

The importance of the D-wave component contribution to the differential cross section is illustrated in fig.4 where the ratio $R = \frac{d\sigma}{dt}(S + D)/\frac{d\sigma}{dt}(S)$ is shown. The dash-dotted, dashed and solid curves are calculated at energies 695, 890 and 991 MeV respectively with the EH wave function of ${}^4\mathrm{He}$. The D-wave admixture in the EH wave function is equal to 10.2% (7.3% for the SSC/A wave function case). The D-wave component contribution improves a description of the data but the improvement is smaller than 5% at $-t = 0.08\ (GeV/c)^2$ so the correction under discussion can not remove the discrepancy shown in fig.1.

The $p - {}^4\mathrm{He}$ scattering amplitudes for small t are not very sensitive to parameters of the nucleus (except its radius which was taken equal to the experimental value) so the improvement of the nuclear wave function will not appreciably decrease the discrepancy under discussion. It may mean that a gap for new physics really exists and nonnucleonic degrees of freedom can be studied in the hadron scattering from nuclei at intermediate and high energies.

References

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