ISTITUTO NAZIONALE DI FISICA NUCLEARE
Laboratori Nazionali di Frascati

LNF-84/36

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Estratto da:
Phys. Letters 139B, 263 (1984)

Servizio Documentazione
dei Laboratori Nazionali di Frascati
Cas. Postale 13 - Frascati (Roma)

# ELASTIC SCATTERING OF α PARTICLES ON LIGHT NUCLEI AT $P_\alpha$ = 7 GeV/c

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Received 22 September 1983

Elastic scattering differential cross sections of α particles have been measured at $P_\alpha$ = 7.0 GeV/c (T/N = 1.05 GeV) on $^1$H, $^2$H, $^3$He and $^4$He target up to a momentum transfer of ~4 (GeV/c)$^2$. A preliminary interpretation of the data is given in the framework of the Glauber theory.

In high energy nucleus–nucleus collisions many nucleons can interact mutually. The structure of multiple scattering is richer as compared to proton–nucleus collisions. It is thus expected that certain features of nuclear structure, e.g. short range dynamical correlations [1], may be enhanced in the elastic collision where both target and projectile are composite. The αα elastic scattering measurements [2] that we performed a few years ago have been interpreted in the framework of the Glauber theory extended to nucleus–nucleus interactions [3] by several authors [4,5]. Viollier and Turtschi [5] deduced from these data a clear effect due to nuclear correlations at momentum transfer $t \leqslant 0.4$ (GeV/c)$^2$. However, the expected contribution of multiple scattering terms would become relatively more important at higher momentum transfer.

In this perspective, we measured at Saclay's synchrotron Saturne II a set of four elastic scattering differential cross sections for α$^4$He, α$^3$He, αd and αp reactions at the maximum available α energy of 4.2 GeV and over a broad range of $t$ values. We note that data on the scattering of the same particle on light targets ($1 \leqslant A \leqslant 4$) in identical experimental conditions can isolate contributions of multinucleon collision terms appearing in the Glauber theory. These contributions are also expected to be appreciable at high momentum transfer [3].

The experimental apparatus has been described elsewhere [6] and can be summarized as follows. The extracted α beam of 7.0 GeV/c and ~$10^{11}$ ppp was focused on one of the liquid $^4$He, $^3$He, $^2$H and $^1$H targets, 3.8 cm long, alternatively brought on the beam line by a remotely controlled sleeve motor. The beam position at the target was set within ~1 mm and ~1 mrad using beam profile detectors. The scattered particles were steered to the entrance of the double focusing SPES IV spectrometer. Two scintillator hodoscopes, 16 m apart at the intermediate and final images, allowed the identification of secondary particles by combined measurements of time of flight and energy loss. Each detector of the final hodoscope covered a 0.2% momentum interval, and the average momentum of the elastic peaks was measured with an accuracy ~$10^{-3}$ over a 7% momentum range. The beam intensity was continuously monitored by three plastic scintillator telescopes, two of them viewing a thin mylar film upstream the target, and one viewing the interaction region at a fixed angle. The absolute calibration of these monitors, which were stable to better than 1%, was provided by activity measurement from $^{12}$C(α, x)$^{11}$C reaction. The overall un-

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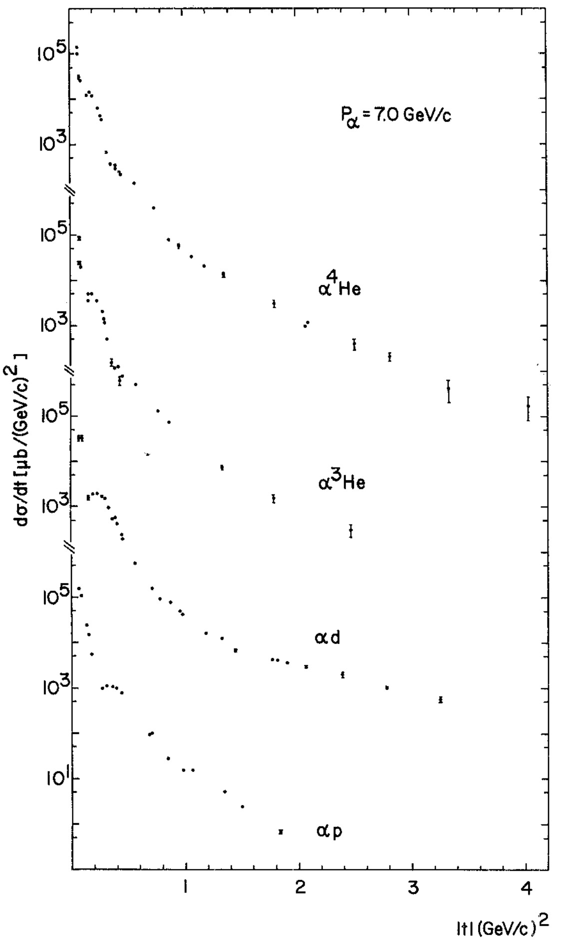


Fig. 1. Differential cross section for $\alpha^4$He, $\alpha^3$He, αd and αp as a function of $|t|$.

certainty on the absolute beam calibration led to a systematic error on the cross section of ±10%. The experimental results are presented in fig. 1 as a function of the momentum transfer $t$ [‡1]. Quoted errors result from the combination of the statistical error and the estimated uncertainty in the subtraction from the elastic peak of the quasi elastic and double scattering contribution. The explored $t$ interval ranges from ~0.07 (GeV/$c$)$^2$ to ~4 (GeV/$c$)$^2$, while the cross sections fall from the barn to the nanobarn level. The cross sections exhibit a clean diffraction pattern followed, at high momentum transfer, by an apparently structureless slowly decreasing tail. The first minimum is well defined, while next ones are rather filled. The αp reaction, for which data already exist [7], has been measured essentially to provide a test for the consistency between different measurements. Some discrepancy in normalization seems to exist between our αp data and those of ref. [7].

This behaviour is compared with the calculation of Czyz and Maximon [3] performed at 7.0 GeV/$c$ with suitable parameters [8–11]. This model, in which the full multiple scattering series is evaluated, is a

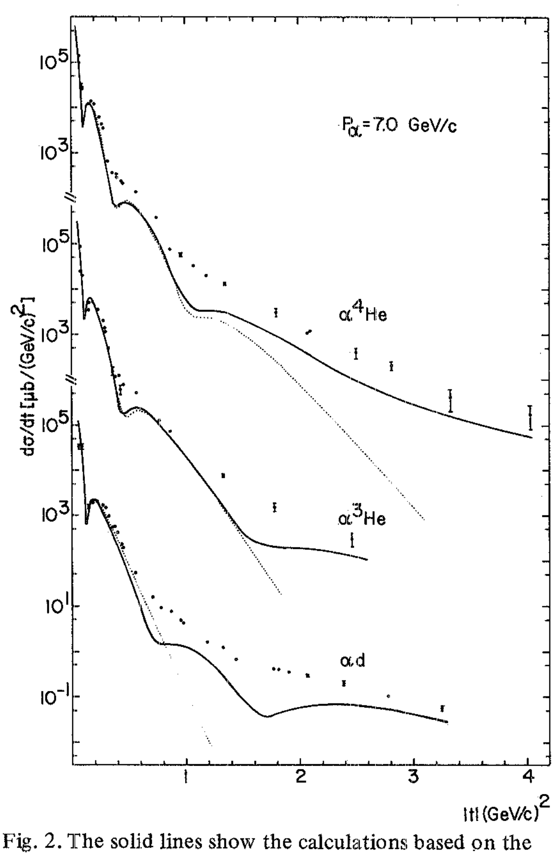


Fig. 2. The solid lines show the calculations based on the Czyz and Maximon model [3] using gaussian densities for the ground state wave function together with the usal radii: 1.37 fm for $^4$He [8], 1.65 fm for $^3$He [9] and 1.8 fm for d [10]; and using the following values for the NN interaction parameters [11]: $\sigma_{pp}$ = 47 mb, $a_{pp}$ = 5.9 (GeV/$c$)$^2$, $\beta_{pp}$ = −0.20, and $\sigma_{pn}$ = 47 mb, $a_{pn}$ = 4.2 (GeV/$c$)$^2$, $\beta$ = −0.42. The dotted lines are the calculations with the rigid projectile approximation using the same wave functions as above and an αp scattering amplitude described in the text.

‡1 Data tables are available upon request from ER54, LNS, CEN, Saclay or INFN, Laboratori Nazionali di Frascati.

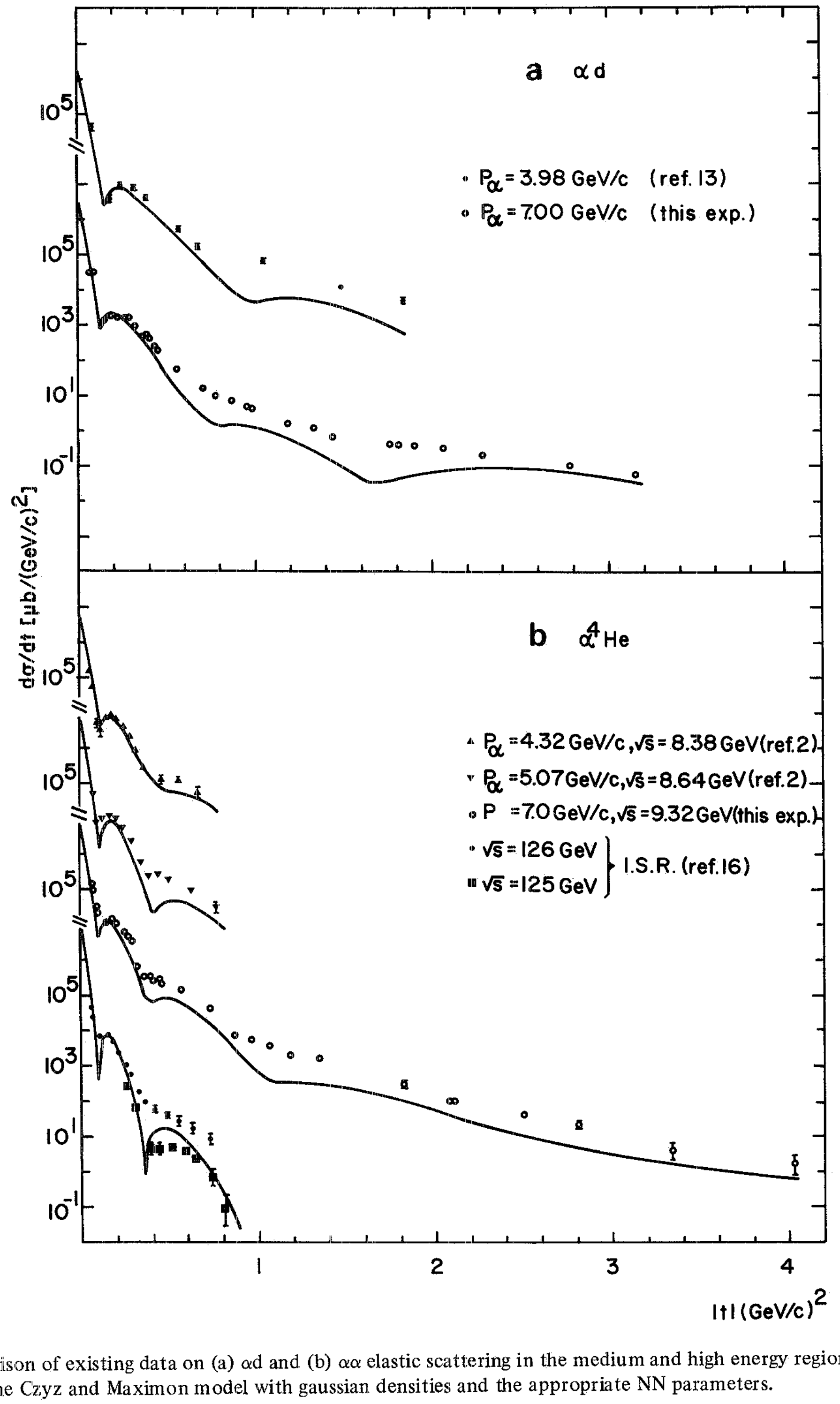


Fig. 3. Comparison of existing data on (a) αd and (b) αα elastic scattering in the medium and high energy region. Data are confronted with the Czyz and Maximon model with gaussian densities and the appropriate NN parameters.

powerful tool for the microscopic investigation of the interaction. The results of this calculation are reported as a continuous line in fig. 2. The general trends of the data are fairly well reproduced for all targets, and the positions of the minima are correctly accounted for.

A model which is easier to handle and which has already been used by Viollier and Turtschi [5] in the analysis of our previous $\alpha\alpha$ measurements [2], assumes the incident $\alpha$ to be an elementary particle (the rigid projectile approximation [12]), and derives the expressions for the $\alpha^4$He, $\alpha^3$He and $\alpha$d cross sections in terms of the $\alpha$p elastic amplitude. We obtained this amplitude from the presently measured $\alpha$p data, using for the optical point the total cross section given by Palevsky et al. [13]. The calculation gives the dotted curves of fig. 2, and, at low momentum transfer, also fits the observed structures.

In fig. 3a the present $\alpha$d measurement is compared with our previous results at 3.98 GeV/$c$ [14]. We note that the behaviour of the available data is similar for both momenta, and also that beyond the second minimum the slope at 7.0 GeV/$c$ is close to that observed by Whipple et al. [15] for dd elastic scattering at 5.75 GeV/$c$. In fig. 3b we compare our $\alpha\alpha$ elastic scattering data at 4.32 GeV/$c$ ($\sqrt{s}$ = 8.38 GeV) [2], 5.07 GeV/$c$ ($\sqrt{s}$ = 8.64 GeV) [2] and 7.0 GeV/$c$ ($\sqrt{s}$ = 9.32 GeV) with measurements at ISR for $\sqrt{s}$ = 125 GeV [16] and $\sqrt{s}$ = 126 GeV [16]. The main difference is that for $t \geqslant 0.1$ GeV$^2/c^2$ the differential cross section at $\sqrt{s}$ = 125 and 126 GeV is significantly smaller than at lower energy. This difference increases rapidly for increasing $t$.

To summarize, we have measured $\alpha$–light nuclei elastic scattering at $P_\alpha$ = 7.0 GeV/$c$, over a momentum range extending up to 4 GeV$^2/c^2$. For $t \geqslant 1$ GeV$^2/c^2$ the rigid projectile model, which can be considered the most straight-forward application of the Glauber theory to nucleus–nucleus scattering, fails to reproduce both the experimental data and the complete evaluation of multiple scattering. Thus the domain of large $t$ in nucleus–nucleus scattering may provide interesting information on nuclear structure, not available in the proton–nucleus scattering. The Czyz–Maximon model, while more successful than the rigid projectile model in reproducing data at large $t$, nevertheless leaves room for further theoretical improvement. For instance, one can use improved nuclear densities with nucleon–nucleon correlations, with eventual inclusion of non-eikonal propagation [17] and/or inelastic shadowing [18].

We thank Professor E. Etim and Professor A. Małecki for many enlightning discussions. We also thank Mr. P. Guillouet and G. Simonneau for their skillful assistance during runs and the Saturne crew for providing us with a good beam of $\alpha$ particles. The participation of Dr. G. Bizard during the early phase of data taking is gratefully acknowledged.

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