6) A. Heavy ion orbiting and Regge poles

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Heavy ion orbiting is one of the phenomena found over the years to occur in special case of elastic scattering, well understood semi-classically, but not well documented by specific examples. The anomalous large-angle scattering of α-particles at moderate energies from elements throughout the periodic table has been a subject of considerable experimental study and has evoked a wide range of novel theoretical explanations [1, 2]. The conventional nuclear optical potential can explain much, if not all, of the anomalous scattering. The dominant physical parameter determining back-angle scattering is the strength, W, of the imaginary part of the optical potential. Lowering of W by a modest factor of two or three lead to changes in back-angle scattering by several orders of magnitude. This effect was dubbed in literature improperly as incomplete absorption. This severe sensitivity of back-angle scattering to the imaginary strength of the optical potential was explained as a sudden emergence of the giant resonances of the high-partial-wave strength functions, as W decreases[3]. A more popular explanation is the interference between the wave reflected at the internal angular momentum barrier with the wave reflected at the nuclear radius.

B. Imaginary part of the ^{9}C-^{9}Be single-folded optical potential

Single folded potentials for heavy ion reactions were proposed half a century ago and soon rejected as a useful method on the basis that the phenomenological nucleon-target potential used as a starting ingredient contains many-body correlations in an average way that lead to a nonphysical normalization $N_V \approx 2$. We show that it is possible to build a single-folded light nucleus-^{9}Be imaginary optical potential which is more accurate than a double-folded optical potential. By comparing to experimental reaction cross sections, we showed for ^{8}B, ^{8}Li, and ^{8}C projectiles, that a very good agreement between theory and data could be obtained with such a bare potential, at all but the lowest energies where a small semimicroscopic surface term is added to the single-folded potential to take into account projectile breakup. In this paper we extend this study to the case of ^{9}C projectiles and assess the sensitivity to the projectile density used. We then obtained the modulus of the nucleus-nucleus S matrix and parametrize it in terms of a strong-absorption radius R_s and finally extracted the phenomenological energy dependence of this radius. This approach could be the basis for a systematic study of optical potentials for light exotic nuclei scattering on light targets and/or parametrizations of the S matrix. Furthermore our study will serve to make a quantitative assessment of the description of the core-target part of knockout reactions, in particular their localization in terms of impact parameters. ^{9}Be is chosen as a target in breakup reactions at intermediate energies since it behaves as a perfect black disk (it has no bound excited states) and thus the stripping component of the breakup cross section is maximized. We remind that the elastic breakup or diffraction dissociation component is more difficult to describe theoretically. Also the Coulomb dissociation is small for this target. Light exotic nuclei have been studied extensively in the last 30 years and their structure was first enlightened from measurements of the total reaction cross sections analyzed in terms of the Glauber model. This lead automatically to calculations of imaginary parts of the nucleus-nucleus optical potential in the folding model. Such a procedure, although very simple, is questionable because the folding model is first order in the nucleon-nucleon interaction, while the Feshbach imaginary potential is second order for a real nucleon-nucleon interaction. Furthermore for light projectiles on light targets, the optical model itself has to be handled with great care. Recently we have argued that using two very successful n-^{9}Be optical potentials and microscopic projectile densities, such as the ab initio VMC (Variational MonteCarlo), it is possible to build a single-folded light nucleus-9Be optical potential which is more accurate than a double-folded optical potential thus overcoming the difficulties discussed above. This is because the n-^{9}Be optical potentials have strong surface terms in common for both the real and the imaginary parts which represent deformation effects, giant resonance excitations, and the breakup channels of the target. On the other hand, ab initio VMC [4,5] or other microscopic densities for the projectile would not contain enough information to reproduce the breakup channels of the projectile. By comparing to experimental reaction cross sections, we showed in Ref. [6], that for the cases of ^{8}B, ^{8}Li, and ^{8}C projectiles, a very good agreement between theory and data could be obtained by adding, at the lower energies, a small surface term to the singlefolded potential. In this paper we extend the study to the case of ^{9}C projectiles, compare to results obtained with the JLM potential, and assess the sensitivity of the result to the projectile density used. We obtain then the nucleus-nucleus S matrix, SNN, and parametrize $|SNN|^2$ in terms of a strong-absorption radius and finally extract the phenomenological energy dependence of the parameter R_s. Our results could have interesting implications in knockout formalisms as well. ^{9}Be is one of the ideal black-disk targets because it does not have bound excited states and for this reason it has been chosen in the majority of cases in which breakup of the projectile or total reaction cross sections have been studied. It has strong breakup channels itself but indeed these are taken into account by the n-^{9}Be optical potentials [7] we have developed which are able to reproduce at the same time the total, elastic, reaction cross sections and all available elastic scattering angular distributions. On the other hand, one of the motivations for paying particular attention to ^{9}C as a projectile, is in nuclear astrophysics [8]: the current knowledge of the rate of the ^{8}B (p, γ)^{9}C reaction in stellar conditions is contradictory at best and there is little hope to resolve this, now or in in the future, by means other than by indirect methods such as for example the ANC from the breakup $^{9}C \rightarrow {}^{8}B+p$. This reaction gives a possible path to the hot pp chain pp-IV at high temperatures and away from it toward a rapid α process at high temperatures and densities and therefore it is important in understanding nucleosynthesis in supermassive hot stars in the early universe, including the possible of bypassing the 3 α process. The correct description of the breakup reaction implies a precise knowledge of the various optical potentials and the corresponding S matrices at intermediate energies in the ^{9}C-target, ^{8}B-target, and p-target channels. Another motivation is two-proton radioactivity which has been studied recently by the HiRA collaboration [9-12]. They have applied nucleon removal to situations in which the remaining core is beyond the drip line, such as ^{8}C, unbound by one or more protons, and whose excitation-energy spectrum can be obtained by the invariant-mass method. By gating on the ground-state peak, core parallel-momentum distributions and total knockout cross sections have been obtained similar to previous studies with well-bound cores. In addition for each projectile, knock out to final bound states has also been obtained in several cases.

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