Communications

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Coulomb-nuclear interference for the ^{58}Ni(^{14}N,^{14}N′) reaction*

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Interference between Coulomb and nuclear excitation has been observed for excitation of the first 2^+ state of ^{58}Ni by inelastic scattering of ^{14}N. For classical impact parameters corresponding to "grazing collisions" the interference is strongly destructive, indicating a predominantly real nuclear form factor.

[NUCLEAR REACTIONS ^{58}Ni(^{14}N, ^{14}N), $E=30-48$ MeV; measured $\sigma(E)$ for g.s., first 2^+ state at $\theta_{\text{lab}}=59°$. ^{58}Ni(^{14}N, ^{14}N), $E=41$ MeV; measured $\sigma(\theta)$ for g.s., first 2^+ state. Enriched target.]

Heavy-ion inelastic-scattering experiments[1-7] have revealed destructive Coulomb-nuclear interference analogous to, but substantially stronger than, that observed for (α,α') reactions.[8-11] This destructive interference can be attributed to the dominance of the real part of the optical potential; the form factor for nuclear excitation, which in the collective model is the first-order term of a Taylor-series expansion of the optical potential, is therefore also mainly real. Thus, in the collective model, Coulomb-nuclear interference is very sensitive to the optical potential, particularly to its phase. We have measured the inelastic scattering from ^{58}Ni of ^{14}N, an odd-odd spin-one nucleus, as a means of qualitatively determining if the ^{14}N optical potential differs substantially from that of other heavy ions.

The ^{14}N beam, produced in a lithium-exchange duoplasmatron ion source, was accelerated by the Rutgers-Bell FN tandem. Beams of up to 100 nA (6^+ charge state) were focused on a 99.95%-enriched, 100-μg/cm^2, self-supporting, electroplated ^{58}Ni target. The beam was stopped in a Faraday cup and the intensity monitored by a detector placed at 20° relative to the incident beam direction; at this angle the elastic-scattering cross section is Rutherford for all energies (30–48 MeV) for which measurements were made. ^{14}N ions scattered in a particular charge state through an angle θ were observed on the image surface of a split-pole spectrograph using a position-sensitive proportional counter[12] with a thin (.013 mm) aluminized Mylar entrance window. The angular acceptance of the spectrograph was approximately 5°, corresponding to a solid angle of 3.34 msr. Energy resolution of 200–300 keV was easily achieved. Energy and angular dependence of relative charge-state populations were monitored by measurement of the elastic scattering by a second monitor placed below the spectrograph aperture; this detector moved with the spectrograph and the angle below the spectrograph was sufficiently small so that the scattering angle is essentially also equal to θ. The charge state population for the elastic scattering was observed to be dependent on both the incident energy and the scattering angle. It has been assumed that the charge state populations for elastic and inelastic ($Q=-1.45$ MeV) scattering are equal, thereby possibly introducing a small error (<10%) in the absolute normalization of the inelastic scattering cross sections.

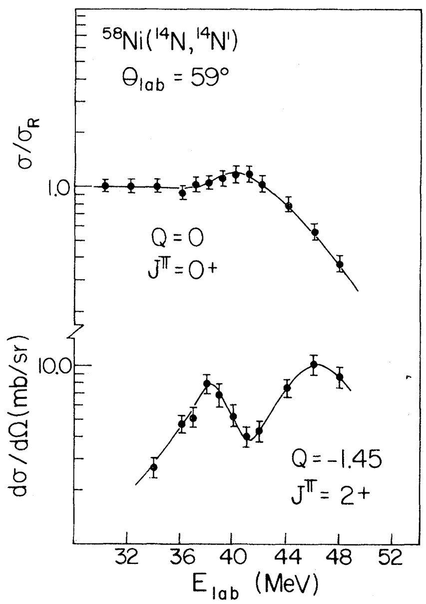

FIG. 1. Results for excitation function measurements. The lines are drawn to guide the eye.

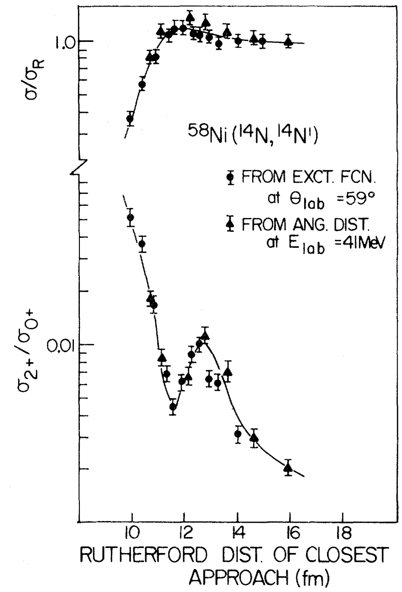

FIG. 3. All data plotted as a function of the Rutherford distance of closest approach as defined in the text. The lines are drawn to guide the eye.

The experimental results are shown in Figs. 1–3. It should be noted that the maximum interference occurs in the region of "grazing collisions," i.e., where the elastic scattering cross section begins to deviate from the pure Rutherford value.

Figure 1 shows the results for an excitation function of the elastic and inelastic ($Q = -1.45$ MeV, $J^{\pi} = 2^{+}$) scattering of ^{14}N from ^{58}Ni measured at a laboratory angle of 59°, approximately 70° in the center-of-mass system. At this angle a grazing collision is seen to occur in the vicinity of $E_{lab} = 41$ MeV. The dip in the inelastic cross section at this energy is indicative of the destructive interference.

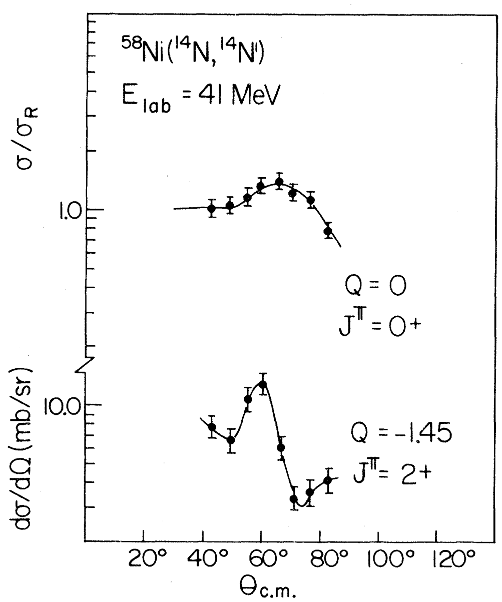

FIG. 2. Results for angular distribution measurements. The lines are drawn to guide the eye.

The results for angular distribution measurements at $E_{lab} = 41$ MeV are shown in Fig. 2. Again the destructive interference at approximately 70° center-of-mass scattering angle is apparent.

Finally, in Fig. 3 the equivalence of the two types of experiments is shown by representing the inelastic data as the ratio of excitation probabilities ($\sigma_{2^+}/\sigma_{0^+}$) and plotting this as a function of the classical Rutherford distance of closest approach, defined as

$$d = \frac{0.72 Z_1 Z_2}{E_{lab}} \, \frac{A_1 + A_2}{A_2} \left[1 + \csc\left(\tfrac{1}{2}\theta_{c.m.}\right)\right],$$

where 1 and 2 refer to the projectile and the target, respectively. Results from the two experiments are essentially identical. Here a grazing collision is seen to correspond to a classical projectile-target separation of approximately 11.5 fm.

The results of this experiment are qualitatively identical to the results of inelastic scattering of other heavy ions. One can therefore expect the optical potential for ^{14}N to closely resemble that for neighboring heavy ions which have been more extensively studied, e.g., ^{16}O. This conclusion is supported by recent optical model studies[13] of elastic scattering of ^{14}N, but conclusive comparisons of heavy-ion optical potentials are very difficult to make due to the ambiguities in the optical potentials.

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