fits of the folding model with no density dependence. Using the obvious relation $Ar_m^2 = Zr_p^2 + Nr_n^2$ and the value[1] $r_p(^{48}\mathrm{Ca}) = 3.386$ fm one obtains $r_n(^{48}\mathrm{Ca}) - r_p(^{48}\mathrm{Ca}) = 0.17 \pm 0.10$ fm.

Table II compares the present results with previous ones, all of which were obtained using simple analytic functions for the nuclear-matter distribution. If the uncertainties obtained in the present work are typical of the uncertainties that should have been quoted for previous results, then all seemingly conflicting results are in agreement with each other.

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Model-Independent Determination of the Compound-Elastic Enhancement Factor in a Polarized-Proton Fluctuation Experiment

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An unambiguous and model-independent separation of direct and compound elastic cross section was performed by a simultaneous fluctuation analysis of the cross section and the analyzing power for the reaction $^{30}\mathrm{Si}(p_{\mathrm{pol}}, p_0)^{30}\mathrm{Si}$. The compound elastic cross section was calculated by means of Hauser-Feshbach theory without any adjustable parameters. Comparison of experiment with the calculation results in a compound-elastic enhancement factor of 2.09 ± 0.14 for this strong-absorption, many-channel case.

In this Letter we report definitive experimental evidence for a factor-of-2 enhancement of the compound elastic cross section (σ^{CE}) over the Hauser-Feshbach[1] cross section (σ^{HF}) in a reaction with many strongly absorbing channels. This so-called compound-elastic enhancement factor $W_{\alpha\alpha} = \sigma^{\mathrm{CE}}/\sigma^{\mathrm{HF}}$ has been the subject of considerable theoretical efforts.[2-6] In the many-channel, strong-absorption limit most theorists now agree that $W_{\alpha\alpha}$ should be two irrespective of the number of direct reaction channels. Previous attempts to determine $W_{\alpha\alpha}$ experimentally have been performed only with unpolarized protons yielding a large model-dependent error.[7] In the best of these experiments Ernst, Harney, and Kotajima[7] have confirmed the effect of channel self-correlation ($W_{\alpha\alpha} > 1$) but their values of $W_{\alpha\alpha}$ ranged from 1.6 to 3.5. Thus a clear statement about the validity of the underlying compound-nucleus theories was not possible. Since the enhancement factors derived from these theories are widely used,[8,9] it is important to have a much more critical test.

A model-independent separation of σ^{CE} and σ^{DI} (DI indicating the direct part of the cross section), necessary for an accurate determination of $W_{\alpha\alpha}$, can be performed by measuring both the differential cross section σ and the analyzing power $A(\theta)$ either in an energy-averaged experiment[10] or in an Ericson fluctuation experiment[11] on a spin-0 target nucleus. We have used both methods: First we have applied the method of Henneck and Graw,[11] where a combination of the normalized variances of σ and σA yields the relative direct contribution y_D to the reaction without any assumption about the effective number of spin channels N_{eff}. We then checked the consistency of this method by describing the extracted σ^{DI} with the optical potential obtained by fitting the artifically energy-averaged observable $\langle \sigma(\theta) A(\theta) \rangle$ which contains no compound-nucleus contribution.[10] A target nucleus $^{30}\mathrm{Si}$ was chosen because in the energy region of interest ($E_p = 9.8$ MeV) all final levels of the competing (p,p'), (p,n), and (p,α) compound-nucleus reactions were known and therefore the Hauser-Feshbach cross section σ^{HF} could be calculated explicitly without the introduction of free parameters. Finally, $W_{\alpha\alpha}$ was calculated as the ratio $\sigma^{\mathrm{CE}}/\sigma^{\mathrm{HF}}$.

The experiment was performed with the polarized proton beam of the Erlangen Lamb-shift source and the 6-MV *EN* tandem accelerator. The excitation functions from 8.5 to 10.7 MeV were measured in 20-keV steps simultaneously for all angles between 50° and 170° at 10° intervals; the beam polarization ($\overline{P} = 0.66$) was continuously monitored with a ^{4}He polarimeter behind the Faraday cup. The solid angle of the detectors was 0.2 msr and the energy resolution due to the target and the beam was determined to be 4.5 keV. A portion of the excitation function was measured twice as a reliability test and the deviations from the first measurement were at all angles less than 5% in σ and less than 3% in A. More experimental details and the excitation functions of σ and σA may be found in Wangler[12a] and a forthcoming paper.[12b]

The relative direct part of the cross section, $Y_D = \sigma^{\mathrm{DI}}/\langle\sigma\rangle$, was determined from a combination of the normalized "polarized" and "unpolarized" variance[11]:

$$Q(\sigma,\sigma A) = [R(\sigma) + R(\sigma A)]\langle\sigma\rangle^{-2} = 1 - Y_D^2 \tag{1}$$

with $R(x) \equiv \langle x^2\rangle - \langle x\rangle^2$. This expression yields Y_D alone, whereas the other well-known methods[13] applied to the unpolarized fluctuating cross section determine a combination of N_{eff} and Y_D. The trend reduction for the cross-section excitation functions was performed by dividing each point by local sliding energy average, while for σA the sliding average was subtracted according to Ref. 11. Corrections for the effects of trend reduction, finite range of data, counting statistics, and the experimental energy resolution were applied for both the σ and σA excitation functions.[12] The compound elastic cross section $\sigma^{\mathrm{CE}}(\theta)$ shown in Fig. 1 was obtained from the Y_D values and the artificially averaged differential cross section $\langle\sigma(\theta)\rangle$:

$$\sigma^{\mathrm{CE}}(\theta) = \langle\sigma(\theta)\rangle[1 - Y_D(\theta)]. \tag{2}$$

Data below 9 MeV were excluded from the present analysis because of the occurrence of an intermediate structure. It should be mentioned that the use of Y_D values, obtained from the un-

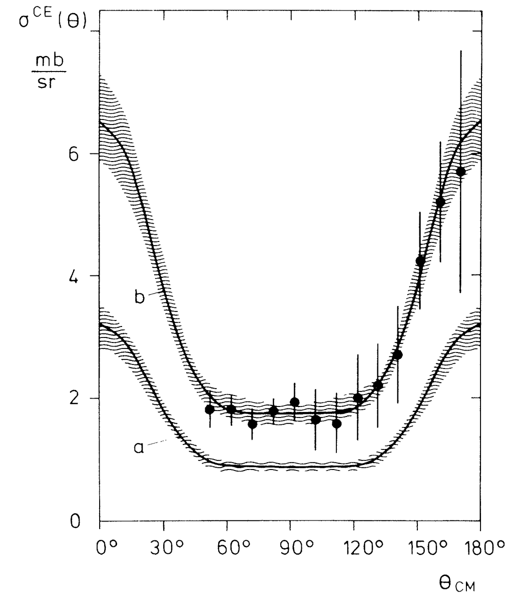

FIG. 1. Angular distribution of σ^{CE} with theoretical curves due to the Hauser-Feshbach theory (curve *a*) and due to a formalism suggested by Hofmann *et al.* (curve *b*).

polarized cross section alone (with the assumption of $N_{\mathrm{eff}} = 2$ and 1 for $\theta_{\mathrm{lab}} \leq 160°$ and $\theta_{\mathrm{lab}} = 170°$, respectively) results in a much more fluctuating angular distribution of $\sigma^{\mathrm{CE}}(\theta)$ than the use of the Y_D values from Eq. (1).

Finally the experimental $\sigma^{\mathrm{CE}}(\theta)$ must be compared with the theoretical $\sigma^{\mathrm{HF}}(\theta)$ to extract the enhancement factor $W_{\alpha\alpha}$. For this calculation the optical potentials of the possible exit channels (p, n, α) were the only input parameters, since all final levels were known. The calculated compound elastic cross section turned out to be most sensitive to the imaginary part of the proton optical potential. To reduce the ambiguities due to the optical model, the proton potential was fixed by a fit to $\langle\sigma(\theta)A(\theta)\rangle$. This potential also describes $\sigma^{\mathrm{DI}}(\theta)$, obtained by subtracting the previously determined $\sigma^{\mathrm{CE}}(\theta)$ from the energy-averaged differential cross section $\langle\sigma(\theta)\rangle$, thus giving a further confirmation for the adopted extraction method of $\sigma^{\mathrm{CE}}(\theta)$. Figure 2 shows the angular distributions of $\sigma^{\mathrm{DI}}(\theta)$ and $\langle\sigma(\theta)A(\theta)\rangle$ at the mean energy 9.84 MeV compared with optical-model calculations. The dashed and the dash-dotted curve are calculations with the global-optical-potential sets of Perey[14] and Rosen,[15] respectively. Both calculations underestimate the polarization effect in the 80° and 160° region. The full curve shows the best fit, where compared to the

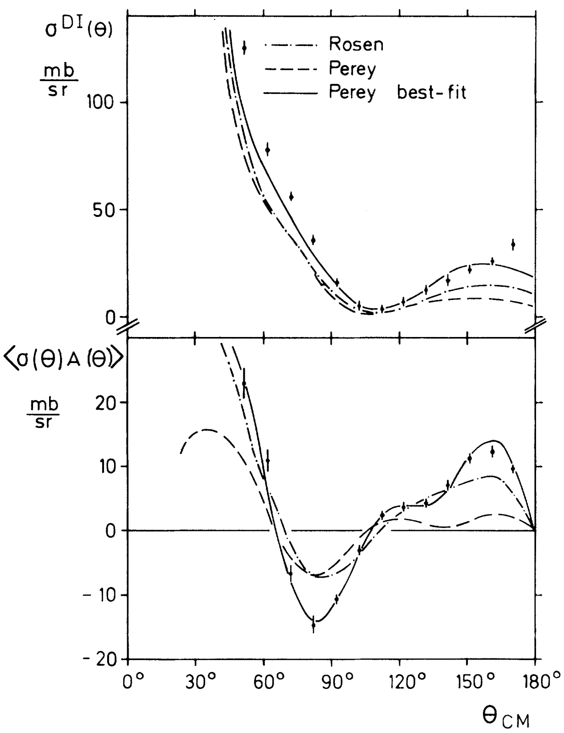

FIG. 2. Angular distributions of the direct elastic observables $\sigma^{DI} = \langle\sigma\rangle - \sigma^{CE}$ and $\langle\sigma A\rangle$ with optical-model curves at the mean energy $E_p = 9.84$ MeV.

Perey set only the imaginary part has been changed ($W_D = 6.4$ MeV, $r_I = 1.37$ fm, $a_I = 0.44$ fm). This potential was used for the calculation of the proton transmission coefficients; the influence of large variations of the neutron and of the α potential on the calculated compound elastic cross section was shown to be less than 5% and therefore potential sets from the literature[16,17] were used. Figure 1 shows the angular distribution of the compound elastic cross section with theoretical curves due to the original Hauser-Feshbach theory[1] (curve *a*) and due to the formalism of Hofmann *et al.*[6] (curve *b*). The solid lines are calculated with the best-fit proton potential and the shaded areas show the influence of changes in the proton potential to such an extend that the χ^2 of the elastic scattering worsens by about 50%.

The experimental curve is best described by the formalism of Hofmann *et al.*,[6] which was developed for the general case, i.e., for both weak and strong absorption. The compound-elastic enhancement factor $W_{\alpha\alpha}$ is given by $\langle\sigma_{\mathrm{expt}}{}^{\mathrm{CE}}(\theta)/\sigma^{\mathrm{HF}}(\theta)\rangle$ with the average over all angles. From this experiment we obtained $W_{\alpha\alpha} = 2.09 \pm 0.14$. This result is consistent with the predictions of different approaches for the many-channel, strong-absorption limit.

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