that can be rejected by pulse-shape discrimination.

Similarly, energetic electrons scattered into the detector due to gamma-ray interactions in the material supporting and enclosing the detector may be discriminated against since they pass through the surface of the detector where the collecting field may be small.

Fabri, Gatti, and Svelto[5] have observed the presence of a slow time constant in α-particle-induced pulses from silicon surface-barrier detectors cooled to low temperatures. They have attributed this effect to trapping since the effect is temperature dependent. In our measurements the integration time for charge collection was 1 μsec so that the pulses would have been degraded if a very long time constant was present in the current pulse due to trapping.

To summarize, it has been shown that the technique of pulse-shape discrimination can improve the high-energy gamma-ray spectra from lithium-drifted germanium detectors by reducing the background while still maintaining the intrinsic efficiency for the $(E_\gamma - 2m_0c^2)$ peaks. An investigation of the processes giving rise to pulse-shape differences in these detectors would be desirable.

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CROSS-SECTION FLUCTUATIONS IN THE $Mn^{55}(p,\alpha)Cr^{52}$ REACTION*

H. K. Vonach
Argonne National Laboratory, Argonne, Illinois

and

A. Katsanos and J. R. Huizenga
Argonne National Laboratory, Argonne, Illinois
and Department of Chemistry, University of Chicago, Chicago, Illinois

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Most measurements of statistical fluctuations in the cross sections of various nuclear reactions have been made with light target nuclei, $A < 40$.[1-7] In this Letter we wish to report similar measurements for the ground and first two excited states produced in the $Mn^{55}(p,\alpha)Cr^{52}$ reaction. Target nuclei of larger A are advantageous for fluctuation measurements because they more adequately meet the requirements necessary for the applicability of the theory of Ericson[8] and others.[9] However, due to the decrease in the width of the compound states, Γ, with increasing A, the possible distortion in the results introduced by the experimental energy resolution must be carefully investigated.[10]

Excitation functions of the ground state (0^+), 1.43-MeV first-excited state (2^+), and the 2.37-MeV second-excited state (4^+) in Cr^{52} were measured for $Mn^{55}(p,\alpha)Cr^{52}$ reaction. The differential cross sections were measured at 90°, 130°, 150°, and 170° in 5-keV steps with protons accelerated by the Argonne tandem Van de Graaff in the energy range 9.5 to 9.9 MeV. A manganese target of 50 $\mu g/cm^2$ thickness, prepared by vacuum evaporation onto a 100-$\mu g/cm^2$ carbon foil, was used in the experiment. The energy loss of the beam due to the target is less than 2 keV. The energy resolution of the proton beam from the Van de Graaff is not precisely known. However, from the narrowest peak observed in our excitation functions and magnetic spectrometer measurements of the linewidths resulting from proton scattering, we estimate the tandem energy resolution to be less than 5 keV. The reaction particles were identified with surface-barrier solid-state detectors which subtended an angle of 7° in the reaction plane. In order to discriminate against protons, the detectors were biased to just stop the ground-state α particles.

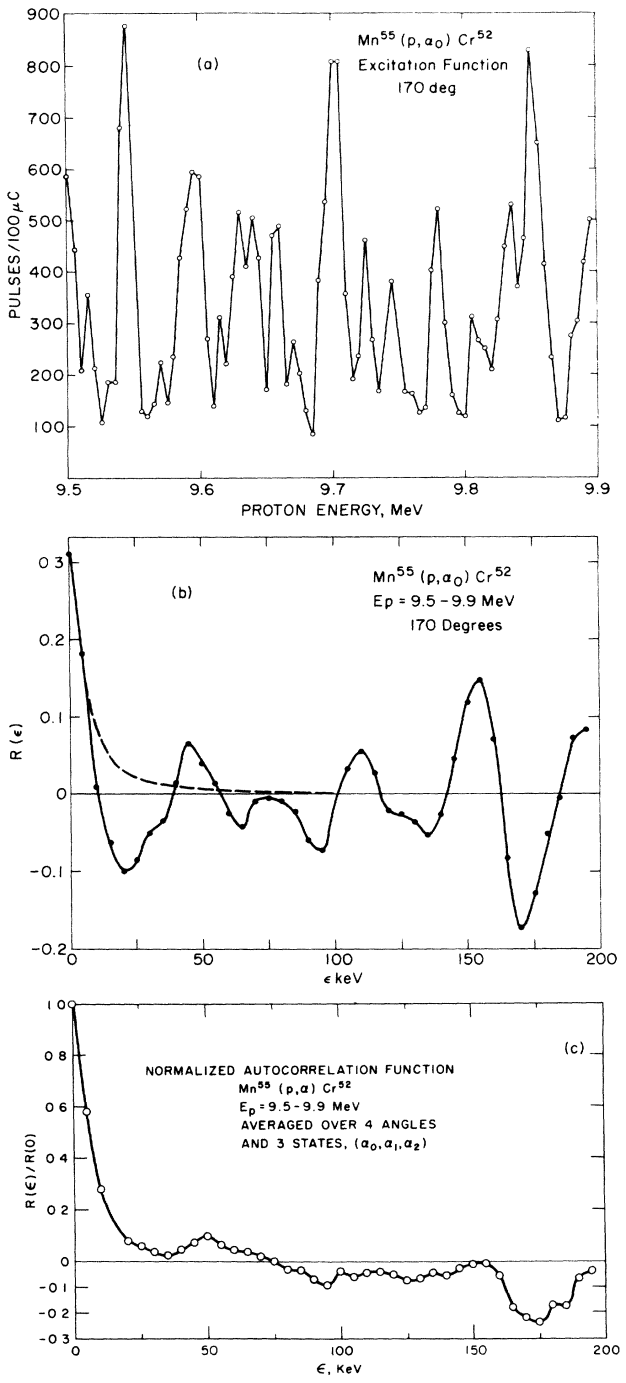

FIG. 1. (a) Excitation function for the $Mn^{55}(p, \alpha_0)Cr^{52}$ reaction. (b) Autocorrelation function for data displayed in (a). The values of $R(\epsilon)$ are calculated as a function of ϵ by Eq. (1) and these values displayed as solid circles. The dashed line is a theoretical Lorentzian line with $\Gamma = 6$ keV. (c) Normalized autocorrelation function where this function is the average of 12 normalized $[R(0) = 1]$ autocorrelation functions derived from the excitation functions for three states (each at four angles) in the $Mn^{55}(p, \alpha)Cr^{52}$ reaction.

A typical excitation function is displayed in Fig. 1(a). Sufficient counts were collected for each α group at every angle and energy to insure that the counting statistics contribute less than 10% to the measured mean-square fluctuations. In most cases the contribution of counting statistics was much less.

Estimates of the ratio of the level width to spacing, Γ/D, in the compound nucleus Fe^{56} by Eq. (A3.4) of reference 8 show this quantity to exceed 50 at our excitation energies of about 20 MeV, even though one allows for rather wide variations in the necessary parameters. Hence, we analyzed our excitation functions in terms of the statistical fluctuations of Ericson.[8] The autocorrelation function defined by

$$R(\epsilon) = \langle [\sigma(E) - \langle\sigma\rangle][\sigma(E+\epsilon) - \langle\sigma\rangle]\rangle / \langle\sigma\rangle^2 \qquad (1)$$

was calculated for each of the 12 excitation functions. Comparisons of these autocorrelation functions with the corresponding theoretical expression,

$$R(\epsilon) = R(0)\Gamma^2/(\Gamma^2 + \epsilon^2), \qquad (2)$$

gave values of the two characteristic parameters of the Ericson theory, $R(0)$ and Γ, where $R(0)$ is equal to

$$R(0) = (\langle\sigma^2\rangle - \langle\sigma\rangle^2)/\langle\sigma\rangle^2, \qquad (3)$$

and Γ is the characteristic width of the compound states.

The autocorrelation function deduced from the excitation function of Fig. 1(a) is shown in Fig. 1(b) along with a theoretical curve calculated from Eq. (2). The most striking difference between the experimental and theoretical correlation functions is the sizable fluctuation about zero in the experimental curve for large ϵ. This results from the fact that experimental data represent a finite energy interval, whereas Eq. (2) is derived by averaging over an infinite energy interval. The statistical nature of these fluctuations becomes apparent by comparing the correlation functions displayed in Figs. 1(b) and 1 (c). The data in Fig. 1(c) represent an average of 12 autocorrelation functions (three states and four angles). The data were normalized to unity at $\epsilon = 0$ before averaging. The fluctuations at large ϵ are considerably damped in the average correlation function as expected.

The mean-square fluctuation of the oscillations in an autocorrelation function of finite energy interval has been calculated recently by Gibbs and Monahan.[11] For $\epsilon > 2\Gamma$, he obtained an expression which for our particular case, where

$\Delta E \gg \Gamma$, can be reduced to

$$\langle R^2(\epsilon)[(\Delta E-\epsilon)/\Delta E]\rangle \cong R^2(0)(\pi/2)(\Gamma/\Delta E), \quad (4)$$

where ΔE is the energy interval investigated. For each correlation function we have computed the average of the quantity $R^2(\epsilon)[(\Delta E-\epsilon)/\Delta E]$ for ϵ values ranging between 20 and 200 keV, and from this average we have calculated Γ by Eq. (4).

Errors in the fluctuation parameters of Table I arise from experimental energy resolution and finite number of data points associated with the finite energy interval. Since little quantitative information is available on the latter effect, we intend to study it more thoroughly with Monte Carlo calculations by the method of Brink and Stephen.[12] The effect of experimental resolution on the parameters of Table I has been investigated. Resolutions of $\Delta = 10$, 15, 20, and 30 keV were simulated by averaging 2, 3, 4, and 6 of the original cross-section values and recalculating $R(0)$, Γ_1, and Γ_2 for all excitation functions. The dependence of the latter quantities (averaged over all 12 excitation functions) on Δ are shown in Figs. 2(a) and 2(b). From qualitative extrapolations of the curves in Fig. 2 to $\Delta = 0$, we estimate that the values of $R(0)$ in Table I should be increased by $15 \pm 10\%$ and the values of Γ_1 and Γ_2 decreased by $20 \pm 10\%$ in order to correct for the resolution effect.

The above two methods of determining Γ give results which agree remarkably well on the average. A third method[9] of estimating Γ from the number of peaks in the excitation function per unit energy gives values of Γ which are about a factor of 2 higher than methods 1 and 2. However, method 3 is expected to overestimate Γ if

Table I. Fluctuation parameters derived from excitation functions of the $Mn^{55}(p,\alpha)Cr^{52}$ reaction. The data were taken in 5-keV steps over the proton energy range 9.5 to 9.9 MeV which corresponds to a compound nucleus excitation energy range of 19.6 to 20.0 MeV.

State	Spin	Angle	$R(0)$[a]	N_{exp}[b]	Γ_1 (keV)[c]	Γ_2 (keV)[d]
Ground	0^+	90	0.115	17	7.5	6.7
		130	0.081	25	6.5	3.7
		150	0.143	14	7.0	5.7
		170	0.310	6	6.0	7.3
$E1$	2^+	90	0.027	74	6.5	6.6
		130	0.023	87	7.0	8.3
		150	0.022	91	4.5	3.6
		170	0.086	23	6.5	2.2
$E2$	4^+	90	0.046	43	10.0	5.0
		130	0.016	125	5.0	5.7
		150	0.033	61	8.5	8.6
		170	0.104	19	6.5	3.4
			Average		6.8	5.6

[a] $R(0)$ = mean-square fluctuation at $\epsilon = 0$ calculated from Eq. (3).

[b] $N_{exp} = 2/R(0)$ = number of degrees of freedom. This notation has been used frequently to characterize the amplitude of the fluctuation.

[c] Γ_1 = width of compound states deduced from the half-width of the autocorrelation function.

[d] Γ_2 = width of compound states determined from Eq. (4).

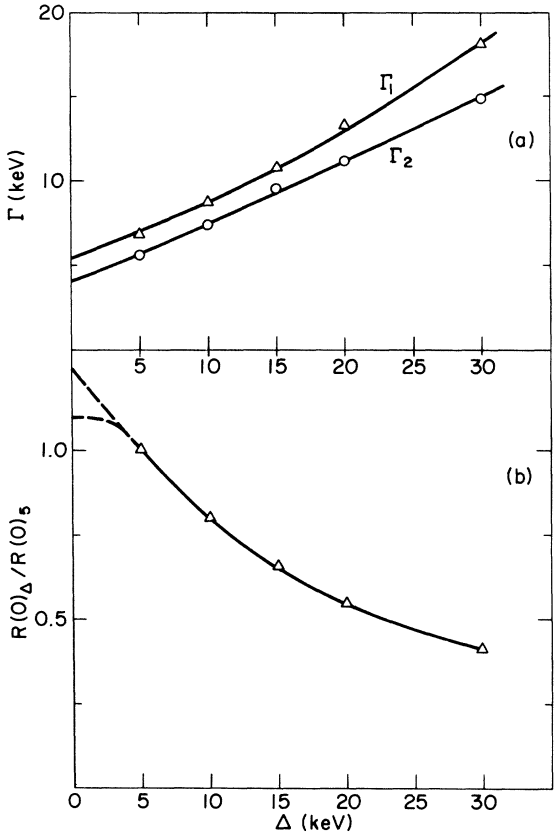

FIG. 2. Dependence of observed fluctuation parameters on energy resolution. Each parameter is derived from an average of 12 parameters each of which is deduced from a separate excitation function. The results at $\Delta = 5$ are calculated from all the experiment data which were taken at 5-keV energy invervals. The results at $\Delta = 10$, 15, 20, and 30 are calculated by averaging 2, 3, 4, and 6 of the original cross-section values. (a) Increase of apparent width Γ as a function of energy resolution. (b) Decrease of apparent fluctuation amplitude with energy resolution.

either the energy resolution or the magnitude of the energy steps approach Γ.

The fluctuation amplitude $R(0)$ for all states is much larger at 170° than at other angles, and the ground-state (0^+) fluctuation amplitude at each angle is much larger than the corresponding value for each of the excited states. Both of these experimental observations are in agreement with theory.[13] More quantitative comparisons of $R(0)$ and Γ with statistical theory and the results of all the various cross correlations will be published elsewhere.

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EFFECT OF ABSORPTIVE CHANNELS ON THE ONE-PARTICLE EXCHANGE MODEL

A. Dar

Department of Nuclear Physics, Weizmann Institute of Science, Rehovoth, Israel

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The purpose of this note is to point out to the remarkable agreement with experimental angular distributions obtained for many peripheral elementary particle reactions by using a simple model incorporating strong absorption of low partial waves into the one-particle exchange (OPE) model.

The predominance of small momentum transfers in two-body and quasi two-body high-energy reactions suggests a theoretical interpretation in terms of peripheral models like the OPE model.[1] However, while the OPE model successfully describes the polarization of the emitted unstable particles,[2] the predicted absolute cross sections are higher than experiment by an order of magnitude,[3] and the experimental angular distributions deviate markedly from theory in the sense that the observed production process seems to be too peripheral. The customary modification of the OPE model is the inclusion of form factors,[4] but the required momentum-transfer dependence of these form factors has been shown[5] to be so violent that comparison of theory with experiment is almost reduced to "empirical curve fitting."

Strong absorption in the other interacting channels can be expected to modify the predictions of the OPE model appreciably in the proper direction.[6,7] The absolute cross section is reduced and the angular distribution is modified by diffraction effects to give a narrower forward peak and possibly secondary maxima and minima. The absorption has been taken into account quantitatively by cutting out the low partial waves[7] from the Born amplitude with no form factors. An impact parameter (Fourier-Bessel) expansion of the Born amplitude has been used, rather than a partial-wave expansion, and a sharp cutoff (step function) has been used at a radius R which is varied to fit the experimental data.[8] There is only a single free parameter, the cutoff radius R, in the model, if the absolute cross sections and the relevant coupling constants are known. In all cases the particle assumed to be