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Determination of Direct Reaction Contribution by Reducing the Cross Section Fluctuation Data to the Polarization-like Ones

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The normalized variance (NV) of the differential cross section (CS) equals [1)]

$$(\langle\sigma^2\rangle - \langle\sigma\rangle^2)/\langle\sigma\rangle^2 = (1 - y_d^2)/N \,, \tag{1}$$

where $y_d = \sigma_d/\langle\sigma\rangle$ is the contribution of direct reaction CS σ_d into summarized energy-averaged CS $\langle\sigma\rangle = \sigma_d + \langle\sigma_{fl}\rangle$ with $\langle\sigma_{fl}\rangle$ being the average fluctuating CS and N being the number of independent channels. The formula (1) reflects the well-known problem: The NV of the CS gives only the relation between y_d and N but does not allow to determine each quantity separately. Probability distribution (PD) of the CS also is practically not sensible to y_d and N values for the NV of CS (1) being fixed. In this contribution a method is proposed for the determination of both y_d and N values.

Suppose we have the excitation function $\sigma(E)$ for nuclear reaction of the arbitrary spin structure $S_1+S_2\rightarrow S_3+S_4$ and let $\sigma(E)$ be measured with the high energy resolution $\Delta E \ll \gamma$, where γ is the energy coherence length [1)]. Let us take for each value of $\sigma(E)$ the energy-shifted one $\sigma(E+e)$ with $e \gg \gamma$. Then $\sigma(E)$ and $\sigma(E+e)$ are uncorrelated random functions. Now turn from $\sigma(E)$ and $\sigma(E+e)$ to the new variables

$$s(E) = \sigma(E) + \sigma(E+e) \,, \qquad r(E) = (\sigma(E) - \sigma(E+e))/s(E) \,. \tag{2}$$

Taking into account the stationarity of the random process $\sigma(E)$ and using the PD of the CS [1)] it is easy to obtain the simultaneous PD of $y(E) = s(E)/\langle s\rangle$ and $r(E)$

$$\begin{aligned} F_{2N}(r,y) = {} & 2N^2(1-y_d)^{-2}y_d^{1-N}y^N\exp(-2N(y_d+y)/(1-y_d))(1-r^2)^{(N-1)/2} \\ & I_{N-1}(2Ny_d^{1/2}y^{1/2}(1+r)^{1/2}/(1-y_d))I_{N-1}(2Ny_d^{1/2}y^{1/2}(1-r)^{1/2}/(1-y_d)) \,, \end{aligned} \tag{3}$$

where $I_{N-1}(x)$ stands for the Bessel function of an imaginary argument. Using (3) we can investigate the statistical correlation (SC) between y and r. The simple analysis shows that for the NV of the CS being fixed the greater y_d the stronger this correlation (Fig.1). Hence the study of SC between y and r do makes possible the unique determination of both y_d and N.

To test the SC method we use $^{28}Si(\vec{p},p)$ data at E_p=12-18 MeV, ϑ=160° with ΔE_p=50 keV energy steps [2)]. Using of the polarized beam in this case results in the one-channel situation, N=1 for the partial CS

$\sigma \pm \sigma A$ (A is the analyzing power (AP)). Hence, from (1) it is easy to determine the y_d value for both partial CS. The results of SC analysis after trend-reducing by averaging over 650 keV interval [2] are shown in Fig.2. The ability of method proposed to increase the initial statistics was used in the histograms derivation. Namely, the sets of s and r were taken which differed by energy shifts $e \lesssim 1$ MeV. The values of e have been chosen from the condition of uncorrelation between $\sigma(E) \pm \sigma(E)A(E)$ and $\sigma(E+e) \pm \sigma(E+e)A(E+e)$ on the 10% level of statistical accuracy.

The possibility to determine y_d and N values arises due to the reduction of CS fluctuation data to polarization-like ones. Indeed, the analysis proposed is analogous to the investigation of SC between AP and CS for the reaction of $\overrightarrow{1/2}+J_1 \rightarrow J_2+J_3$ type [3] with direct reaction AP being zero. Here s(E) takes part of the CS and r(E) corresponds to the AP. At the same time the analysis [3] is based principally on the uncorrelation condition of compound-nucleus phases, which does not hold in the presence of direct reactions [4]. The method proposed above is more general. Indeed, the compound-nucleus phase correlations naturally effect $\langle \sigma_{fl} \rangle$ and hence y_d and N values, but it is expected that their influence on the PD of the CS and simultaneous PD (3) is negligible. Note as a conclusion that investigation of the stability of the PD and correlations between s and r under the variation of an interval e can be used for the identification of the intermediate structure in nuclear reactions.

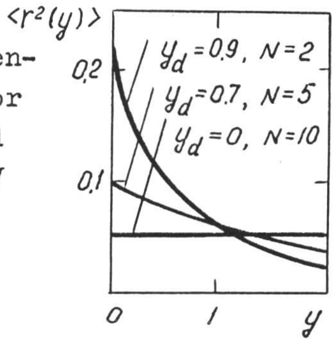

Fig.1. Correlation dependences $\langle r^2(y) \rangle$ for different y_d and N values with NV of the CS being fixed and equal to 0.1.

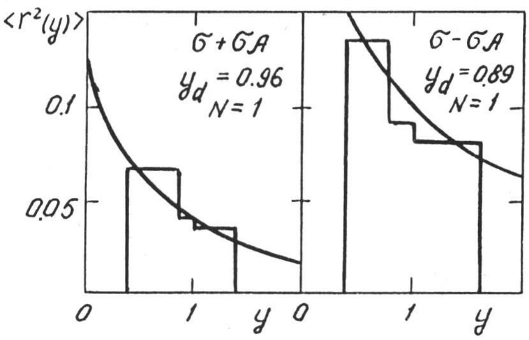

Fig.2. Experimental (histograms) and theoretical correlation dependences $\langle r^2(y) \rangle$ for $^{28}Si(\vec{p},p)$ scattering.

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