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NEW STATISTICAL FUNCTION
FOR THE ANGULAR DISTRIBUTION
OF EVAPORATION RESIDUES PRODUCED
BY HEAVY IONS

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The problem of the angular distribution of evaporation residues (EVR) with heavy-ions reaction has been studying for many years^[1]. However, the interest on this problem increased during the last years due to the development of new electromagnetic separators for the study of the evaporation residues from heavy-ion induced fusion-evaporation reactions ^[2-7]. The angular distribution is important for separators because the acceptance of the separator during the study of determined reaction, depends on the widths of the angular distribution of the EVR recoiled out from the target.

For thick targets the angular distribution depends fundamentally on the multiple scattering of the EVRs by the nuclei of the target. But, for thin targets (when the target thickness much less than the average range of EVRs in this target), the neutron evaporation can play an important role as well.

Experimentally, the angular distribution $R_{\text{xp}}(\theta_i)$ is known to be determined by counting the number of nuclei impinging on some disks whose radii are defined by

the expression $L \cdot \sin(\theta_i)$, where L is the distance from the target to the disk and θ_i is a certain mean angle (expressed in degrees here) between the central trajectory of the beam and the direction of the central circle inside the disk "i" . In this case , the number of counts in each disk will depend on the angle (through $\sin(\theta_i)$) and on certain other function of θ .

Using the function $R_{\text{exp}}(\theta_i)$, we can determine the experimental mean squared angle $\langle \theta^2 \rangle_{\text{exp}}$ by the expression :

$$\langle \theta^2 \rangle_{\text{exp}} = \sum \theta_i^2 * R_{\text{exp}}(\theta_i) \quad (1)$$

It is well known that the parameter $\langle \theta^2 \rangle$ is very important because , under the assumption of isotropic neutron evaporation , it is possible to obtain an expression which establishes a relation between this value and some parameters of the studied reaction . In a first approximation , this relation takes the form :

$$\langle \theta^2 \rangle = 2 * X * E_n / (3 * A_b * E_b) \quad (2)$$

where X is the number of emitted neutrons , E_n is the mean energy of these neutrons, A_b and E_b are the mass number and the laboratory bombarding energy of the projectiles respectively . Usually^[8] the function $R(\theta)$ is modelled using a Gaussian function combined with the function $\sin(\theta)$. Nevertheless , with this combination one can not obtain a mean square value of θ corresponding to the experimental one because , for the normal distribution , the mean square value coincides with the variance . This detail explains the discrepancy in the expression of the $\langle \theta^2 \rangle$ that is observed in some works ^[9,10].

We have found a new statistical function which describes the experimental results in a natural form and gives a better concordance between the experimental and cal-

culated values .This function is determined only by one parameter , namely, the $\langle \theta^2 \rangle$ value :

$$R(\theta) = 360/(\pi * \langle \theta^2 \rangle) * \sin(\theta) * e^{-\theta^2 / \langle \theta^2 \rangle} \quad (3)$$

The function $R(\theta)$ satisfies the following conditions :

$$\int_0^{90} R(\theta) * d\theta = 1 \quad (4)$$

$$\langle \theta^2 \rangle = \int \theta^2 * R(\theta) * d\theta \quad (5)$$

The integral is taken to 90° however , since under generally encountered experimental conditions , the function $R(\theta)$ goes rapidly down to zero for values of θ taken three or four times of the value $\sqrt{\langle \theta^2 \rangle}$.

For illustrating how the function $R(\theta)$ works , in figs.1-4 we compare some experimental results obtained for the angular distributions of the nuclei after evaporation of X neutrons ^[9,11] with the calculated distribution involving the experimental parameter $\langle \theta^2 \rangle_{\text{exp}}$.

Represented in figs.1-3 are angular distributions of the residual nuclei ^{149g}Tb and $^{149,151}\text{Dy}$ produced by the reactions^[9] :

In the figures the experimental results (crosses) are compared with the calculated ones (solid lines) obtained by using the function $R(\theta)$.

In fig 4 the experimental^[11] angular distribution of the nuclei with atomic number $A=125$ obtained from the reaction $^{\text{nat}}\text{Ag} + ^{22}\text{Ne}$ are compared with the calculated

Fig.1

Fig.2

Fig.3

Fig.4

distributions using the Gaussian distribution (point-dashed)^[11] and using the function $R(\theta)$ (solid line) .

We stress there is no fitting of any kind , but only the calculation of angular distributions using the function $R(\theta)$ with experimental parameters $\langle \theta_i^2 \rangle_{\text{exp}}$.

The function $R(\theta)$ is very simple and it describes the process in a natural form . Nevertheless the origin of the coefficient $(360/\pi)$ is not quit clear yet . But , in any case , it was very nice to find it .

The function $R(\theta)$ is particularly useful to describing angular distributions when in the experiment are detected all the particles arriving under the angle θ . It is very useful also for the evaluation of the acceptance of collecting the EVR of determined heavy ion induced reaction , using electromagnetic separators .

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Новая статистическая функция для углового распределения продуктов испарения в реакциях с тяжелыми ионами

Получена новая статистическая функция для моделирования углового распределения продуктов испарения в реакциях с тяжелыми ионами. Результаты расчетов сравниваются с данными экспериментов.

Работа выполнена в Лаборатории ядерных реакций ОИЯИ.

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Rigol J.

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New Statistical Function for the Angular Distribution of Evaporation Residues Produced by Heavy Ions

A new statistical function has been found for modelling the angular distribution of evaporation residues produced by heavy ions. Experimental results are compared with the calculated ones.

The investigation has been performed at the Laboratory of Nuclear Reactions, JINR.

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