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1

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Θ_{rel}'S BEHAVIOUR IN THE P+T $\rightarrow$ A_i+A_{j-k} $\rightarrow$ $A_1+A_2+A_3$ REACTION

P. D'Agostino, A. D'Arrigo, G. Fazio, G. Giardina, A. Italiano and A. Taccone
Dipartimento di Fisica dell'Universita', Messina and Istituto Nazionale di Fisica Nucleare, Gruppo Collegato di Messina, Salita Sperone 31 Vill. S. Agata 98166 Messina, Italy
R. Palamara
Istituto di Tecnologia dell'Universita', Via Diana 5, 89125 Reggio Calabria, Italy

ABSTRACT - In this work we observe the trend of the θ_{rel} angle versus the curvilinear abscissa s obtained in the analysis of the bidimensional spectra coming from the P+T $\rightarrow$ A_i+A_{j-k} $\rightarrow$ $A_1+A_2+A_3$ reaction. The slope of the θ_{rel}(s) functions in the kinematical region of interest are determined for the d+^{7}Li$\rightarrow\alpha+\alpha$+n and ^{3}He+^{6}Li$\rightarrow\alpha+\alpha$+p reactions at different incident energies and detection geometries.

In some recent papers$^{1-5)}$ we investigated the possible modification of the resonance parameters in a two-body channel in presence of a third particle in three-body reactions in the final state. We noticed that the apparent E_x and Γ dependence on incident energy, detection geometry and the used reaction is, on the other hand, almost certainly due to:

I) interference effects;

II) data analysis method;

III) low resolving time of the coincidence circuit;

IV) trend of the LS→CMS transformation Jacobians.

In this work we shall study another possible uncertainty which can occur when the spectroscopic parameters are extracted from bidimensional spectra obtained in reactions like $P+T \rightarrow A_i+A_{j-k} \rightarrow A_1+A_2+A_3$. As is well known, when this is the case, in order to analyze any bidimensional spectrum, one must project it onto some curve of the underlying plane. The kinematical locus reaction appears to be the most appropriate one. As a matter of fact, contrarily to what occurs when projecting onto a different curve, the projection onto the kinematical locus guarantees that the spectra are free from false peaks. It also allows a weighted distribution of the data on the curve and by an appropriate choice of the distribution function (Lorentzian form), automatically deconvolves the data from the widening effects arising from the finite resolving power of the detecting system. The result is a distribution of events on the central kinematical curve which ought to be a good approximation of the true one.

Now, the best way to treat the above event distributions is to transfer them in the relative coordinate system (RCS), by using the proper transformation Jacobians J_{i-jk}. So[5] the E_{j-k}, θ_{i-jk} and θ_{rel} continuous functions can be built along the rectified kinematical curve, versus the curvilinear abscissa s, in all possible hypotheses: i) the first emitted A_i particle goes to the detector placed at θ_1 angle, ii) the first emitted A_i particle goes to the detector placed at θ_2 angle; iii) the first emitted A_i particle does not go to any detector recording a coincidence between A_j and A_k coming from the resonating system $A_{j-k} \rightarrow A_j+A_k$ decay. Here E_{j-k} is the relative energy of the j-k system, θ_{i-jk} is the angle that $\mathbf{p}_{i-jk}$ momentum makes with the beam direction and the θ_{rel} is the angle that the $\mathbf{p}_{j-k}$ momentum makes with $-\mathbf{p}_{i-jk}$ in the relative coordinate system.

In this paper we want to study the trend of θ_{rel} angles on the kinematical curve to observe the $\Delta\theta_{rel}$ corresponding to the Δs where the resonating system A_{j-k} energy spectrum of our concern falls, in the three hypotheses as assumed in points i), ii) and iii). We study this aspect bearing in mind the angular correlation $[d^3\sigma/dE_{j-k}d\Omega_{i-jk}d\Omega_{rel}$ versus $\theta_{rel}]$ of the above resonance in order to observe the gradient of the differential cross section in the $\Delta\theta_{rel}$ interval of our interest. This result informs us about the possibility of extracting the E_x and Γ values in a correct way from the above spectrum. The extreme cases are: a) $d^3\sigma/dE_{j-k}d\Omega_{i-jk}d\Omega_{rel}$ = constant, b) $d^3\sigma/dE_{j-k}d\Omega_{i-jk}d\Omega_{rel}$ having a large slope. Case a) is the best one for extracting, by a fit, the spectroscopic parameters from the spectrum; case b), on the contrary, is not appropriate. $\Delta\theta_{rel}=\pm5°$ is generally the maximum uncertainty allowed to extract the above parameters in a correct way.

In figs. 1, 2, 3 and 4 θ_{rel} for the $d+{}^7Li\rightarrow\alpha+\alpha+n$ and ${}^3He+{}^6Li\rightarrow\alpha+\alpha+p$ reactions at different energies and detection geometries are reported versus curvilinear abscissa s. Each figure contains three $\theta_{rel}(s)$ functions as the detection hypotheses described in i), ii) and iii).

More in detail, figs. 1 and 2 show the above trends for the $d+{}^7Li$ reaction at E(d)=7 MeV when the detectors record only $\alpha\alpha$ coincidences. We suppose the two detectors to be placed at $\theta_1=80°$, $\theta_2=54°$ and at $\theta_1=80°$, $\theta_2=72°$, on the opposite side with respect to the beam, for the two figures, respectively. In these cases dashed (hypothesis i)) and dotted (hypothesis ii)) curves are associated to the possible ${}^5He$ state formation as intermediate nuclei [${}^7Li(d,\alpha){}^5He(\alpha)n$ process]; the continuous one (hypothesis iii)) is instead associated to the possible ${}^8Be$ state formation as intermediate nuclei [${}^7Li(d,n){}^8Be(\alpha)\alpha$ process].

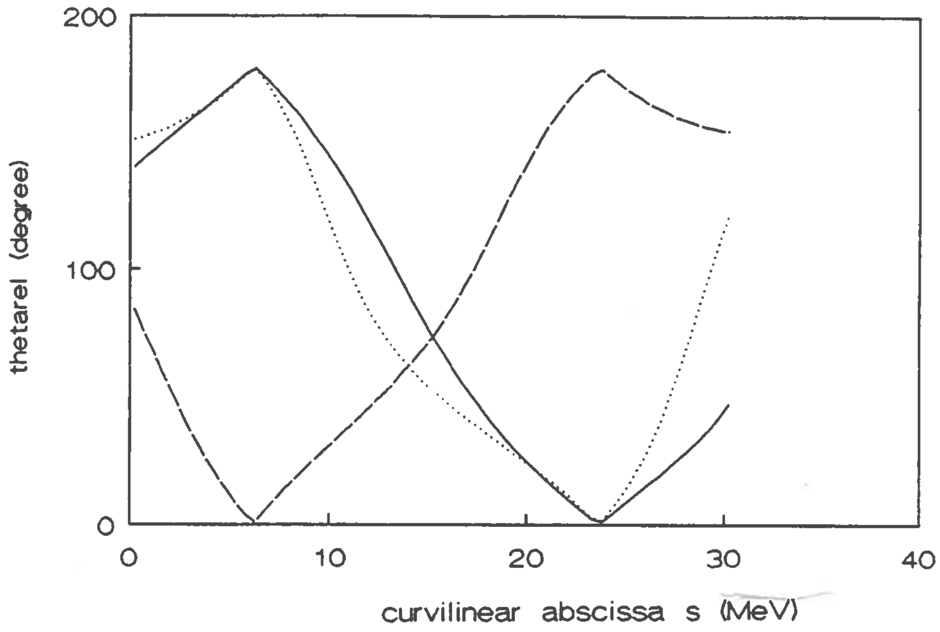

Fig.1 θ_{rel} angles versus s for the $d+{}^7Li\rightarrow\alpha+\alpha+n$ reaction at E(d)=7 MeV, $\theta_1=80°$ and $\theta_2=54°$. For the meaning of the dashed, dotted and continuous lines see text.

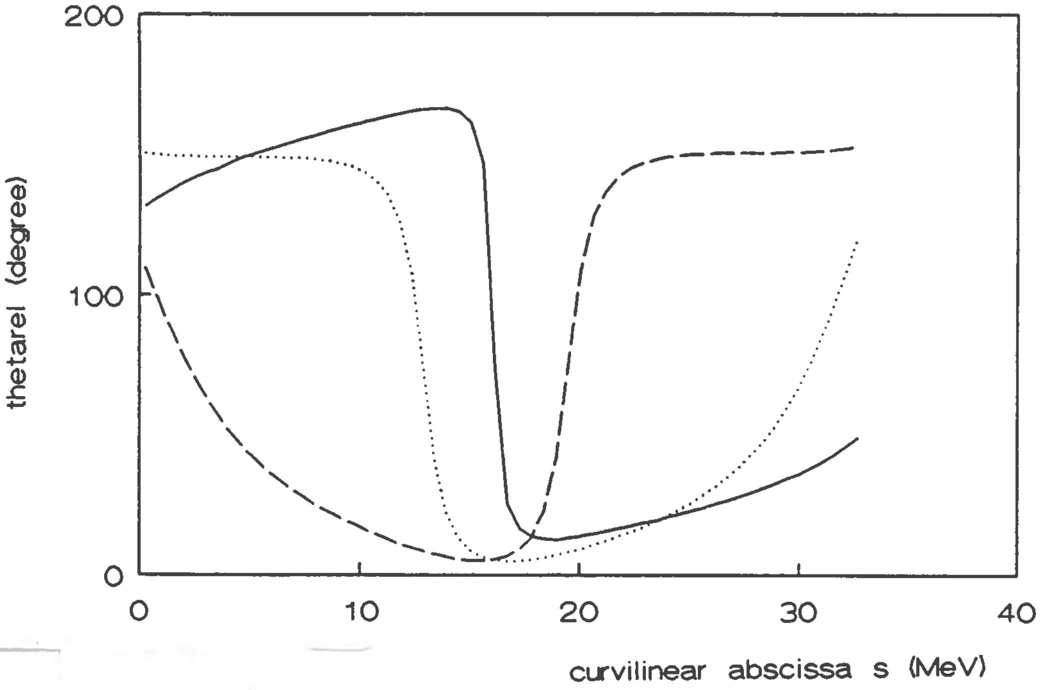

Fig.2 Same as Fig. 1 but with θ_2=72°.

As one can see, in some regions of the central part of the kinematical curve (for instance in fig. 2) the θ_{rel} slope is very high: $|d\theta_{rel}/ds| \approx$ 19.7, 40. and 22.6 degree/MeV for the hypotheses of the above i), ii) and iii) points, respectively. Now, an eventual ^{5}He or ^{5}Be short-lived state contribution falling exactly in this kinematical region could be inappropriate for extracting the spectroscopic parameters of the above state. In fact, this state would extend on a **Δs**, on the curvilinear abscissa, corresponding to a $\Delta\theta_{rel}$ of several tenths of degrees between a $(\theta_{rel})_{min}$ and a $(\theta_{rel})_{max}$. If in this angular interval the $d^3\sigma/dE_{j-k}d\Omega_{i-jk}d\Omega_{rel}$ shows a high slope, one gets a deformed spectrum which is not therefore suitable, to extract the spectroscopic parameters of our concern by a fitting procedure.

Figs. 3 and 4 show the θ_{rel}'s, calculated for the $\alpha\alpha$ coincidences and

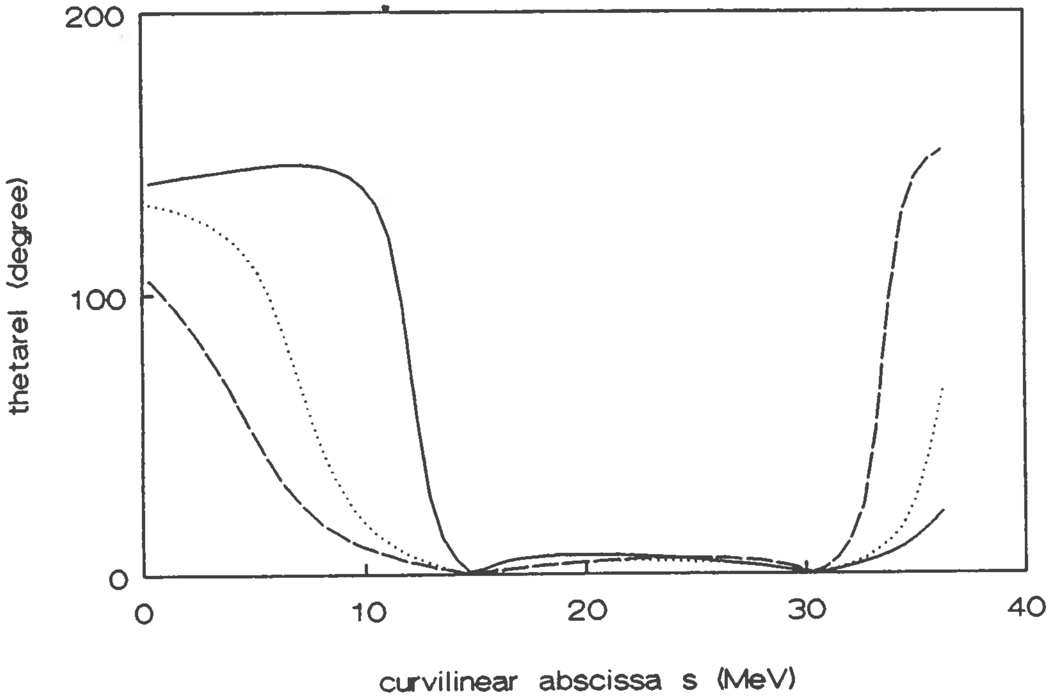

Fig.3 Same as Fig. 1 but for the $^3He+^6Li \rightarrow \alpha+\alpha+p$ reaction, $E(^3He)=13$ MeV, $\theta_1=55°$ and $\theta_2=90°$.

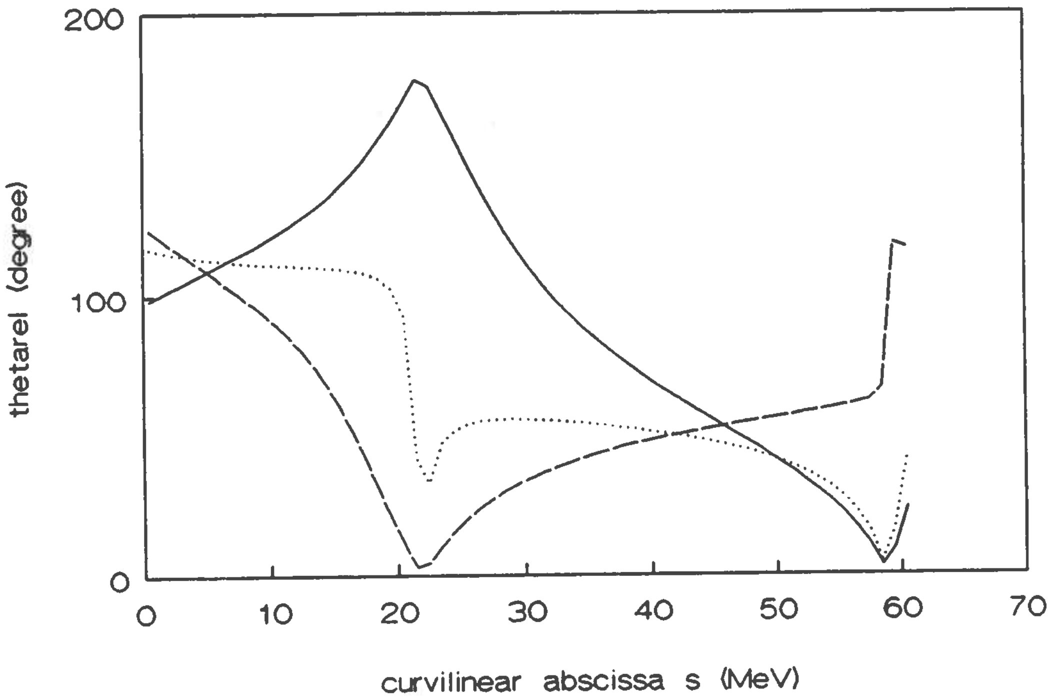

Fig.4 Same as Fig. 3 but with $E(^3He)=25$ MeV, $\theta_1=25°$ and $\theta_2=75°$.

versus curvilinear abscissa, for the $^{3}He+^{6}Li\rightarrow\alpha+\alpha+p$ reaction at 13 and 25 MeV incident energies, respectively. The detection geometries associated to the two figures are, respectively, $\theta_1=55°$, $\theta_2=90°$ and $\theta_1=25°$, $\theta_2=75°$ with the two detectors placed on the opposite side with respect to the beam. Here there are two processes in competition [$^{6}Li(^{3}He,\alpha)^{5}Li(\alpha)p$ and $^{6}Li(^{3}He,p)^{8}Be(\alpha)\alpha$] too, which can lead to the ^{5}Li and ^{8}Be state formation.

As one can see, both figures contain kinematical regions where the θ_{rel} slope is very high, while in the central region θ_{rel} changes slowly (15÷30 MeV in fig. 3, 30÷55 in fig. 4). For instance, from fig.3 we get the following maximum values $|d\theta_{rel}/ds|\simeq$ 27.2, 28.6 and 10.8 degree/MeV for the detection hypotheses described in i), ii) and iii), respectively. Therefore all considerations previously made in extracting E_x and Γ parameters can also be applied here, while if the resonance of our interest falls in regions in which θ_{rel} changes slowly, the extraction of the spectroscopic parameters E_x and Γ is very good.

Bearing all this in mind, we can conclude that peculiar θ_{rel} trends on the kinematical locus as well as the interference effects, the data analysis method, the low resolving time of the coincidence circuit and the trend of the LS→CMS transformation Jacobians can be sources of uncertainty. Now, to avoid the eventual effects arising from the θ_{rel} trends which would deform the energy spectra, one has to study, spectrum by spectrum, the $\theta_{rel}(s)$ trend to decide, successively, from the $d^3\sigma/dE_{j-k}d\Omega_{i-jk}d\Omega_{rel}$ trend, in the above angle variability region, if the spectrum can be used for extracting the spectroscopic parameters of the state of our concern.

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