Detection Efficiency Simulation of binary breakup detected in Double Sided Strips Detector and its generalization

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Presently the Double Sided Silicon Strip Detectors (DSSDs) are commonly used for measuring the charged particle spectra in the accelerator based nuclear reaction studies. Due to large area coverage and segmentation of the DSSD, measurement quality has improved mainly because of large angle coverage and reduced angular bites. The DSSDs are useful particularly in the coincident measurements of breakup products to identify the breakup channel, reconstruct the decaying state (or invariant mass) of the nuclei [1].

Nuclei like ^{8}Be which even at ground state breakup in two alpha particles with .094 MeV energy release. The two alphas are detected in coincidence and their measured velocities are used for reconstructing the energy and the decaying state of ^{8}Be. Similarly, the weakly bound nuclei ^{6}Li, ^{7}Li breakup to α+d and α+t with energy release $\boldsymbol{Q} = \boldsymbol{E_x}$-1.475, $\boldsymbol{E_x}$-2.467 MeV respectively, where $\boldsymbol{E_x}$ is the excitation energy of the decaying state.

The coincidence detection efficiency [2] is generally computed by Monte Carlo Simulation of the experimental conditions to analyze the data in detail. Here, we are reporting the simulation of breakup channels and detection of its products in coincidence by square DSSDs to get the coincident detection efficiency. The present work for the first time brings out the generalization of the simulated detection efficiency to be applicable to different breakup channels, ***Q,*** detector size, distance and strips separation. The universal nature of the efficiency plot is useful in general for researchers in this field.

Simulation Procedure

Consider a breakup **A→B**+**C**, i.e., decaying nuclei **A** breaks up in two nuclei **B** & **C** with mass $\boldsymbol{m_1}$ & $\boldsymbol{m_2}$ respectively with an energy release ***Q***. In general the lifetime of a breakup state is ≤ 10^{-16} sec, the decay occur near the point where it is formed, i.e., at the target itself. If the initial kinetic energy of **A** is ***E*,** the maximum cone angle of the breakup as shown in Fig.1, can be given by:

$$\boldsymbol{\theta_b = \theta_1 + \theta_2}$$

where, $\boldsymbol{\theta_1}=\sin^{-1}(\boldsymbol{m_2Q/m_1E})^{½}$, $\boldsymbol{\theta_2}=\sin^{-1}(\boldsymbol{m_1Q/m_2E})^{½}$.

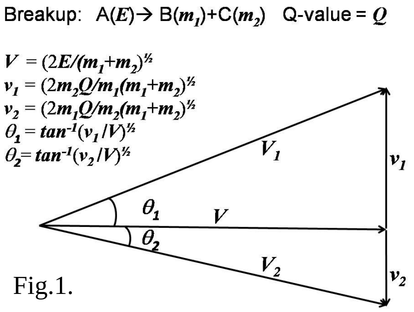


Fig.1.

The geometry of a square DSSD with sides 2***s*** can be defined with the following parameters. $\boldsymbol{N_s}$ = the number of horizontal and vertical strips, ***w*** = strips width, $\boldsymbol{w_d}$ = dead width between the two strips. So pitch can be given by $\boldsymbol{p} = \boldsymbol{w}+\boldsymbol{w_d}$, and $2\boldsymbol{s} = \boldsymbol{pN_s}-\boldsymbol{w_d}$. If the detector is kept at a distance ***d*** from the target, the angular acceptance in x & y direction and the solid angle subtended by it can be given as:

$$\boldsymbol{\Omega_D} = 4\tan^{-1}[\boldsymbol{s^2/d\,(2s^2 + d^2)^{½}}]$$
$$\boldsymbol{\theta_D} = 2\tan^{-1}(\boldsymbol{s/d})$$

For the initial stage of the simulation we chose $\boldsymbol{Q}$ = 0.94 MeV, $\boldsymbol{m_1} = \boldsymbol{m_2}$ = 4 amu, $\boldsymbol{N_s}$ = 16, ***w*** = 3.1 mm, $\boldsymbol{w_d}$ = 0.0 mm and ***d*** = 140 mm. Later we chose different values for these parameters and compare with the universal efficiency plot.

We used 1 million trials for each chosen energy ***E*** emitted out in a cone to cover the DSSD full area with equal probability. We considered isotropic breakup **A→B**+**C** in centre of mass frame and randomly selected the breakup direction **θ**, **ϕ** for $\mathbf{v_1}$ & **π -θ, ϕ +π** for $\mathbf{v_2}$ for each trial. The velocity vector of products **B** & **C** in the lab frame $\mathbf{V_1}$ & $\mathbf{V_2}$ were constructed and their Intersection Points (IP) of the two vectors with the detector plane were determined. A trial was considered unsuccessful under the following conditions: (***i***) any of the two IP lies out of the detector boundary, (***ii***) any of the two IP lies on the dead area separating the adjacent strips, (***iii***) both IP are found to lie on a single horizontal strip **AND** a single vertical strip. Due to some reason some researchers use the stricter form of the last condition namely: (***iii****) the event are rejected in which two IP are found to lie on a single horizontal strip **OR** a single vertical strip. Higher rejection due to condition (***iii****) the detection efficiency reduces. We simulated and presenting the efficiency under both conditions separately. The factor of successful detection trial was normalized to the detector solid angle $\boldsymbol{\Omega_D}$. The detection efficiency **ε** in terms of percentage of the detector solid angle $\boldsymbol{\Omega_D}$ is plotted against the angle ration $\boldsymbol{\theta_b/\theta_D}$ for various $\boldsymbol{m_1{:}m_2}$ ratio and $\boldsymbol{w_d/w}$ as shown in Fig.2. One can notice in the figure that rejection condition (***iii*** or ***iii****) start dominating for small value of $\boldsymbol{\theta_b/\theta_D}$ as a result the efficiency reduces irrespective of relatively larger $\boldsymbol{\theta_D}$. To generalize the plot against $\boldsymbol{w_d}$, the dead width of separation, the plotted efficiency is divided by a factor given by **η** = $\{N_s w/(N_s w+(N_s\text{-}0.5)w_d)\}^4$. The factor **η** is essentially obtained from the ratio of active to full region over the linear dimension of the detector. Note that for any $\boldsymbol{N_s}$ with $\boldsymbol{w_d}$ =0, **η** = 1. For $\boldsymbol{N_s}$ =16, $\boldsymbol{w}$ = 3.0 with $\boldsymbol{w_d}$ = 0.1, 0.3, the factor **η** = 0.88, 0.69 respectively.

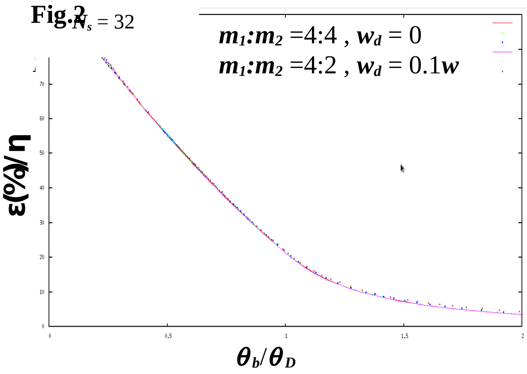
The universality of plot nature can be observed in Fig.2. For unrealistic cases such as large $\boldsymbol{w_d}$ >0.1$\boldsymbol{w}$, and $\boldsymbol{d}$ smaller than ~$\boldsymbol{3s}$ the simulation is found to deviate from the universal plot towards lower efficiency. The simulation for DSSD with $\boldsymbol{N_s}$=32 is also carried out and shown in the figure. As expected the rejection condition (***iii*** or ***iii****) for DSSD with higher number of strips start dominating at smaller value of $\boldsymbol{\theta_b/\theta_D}$.

Conclusions

Present work brings out the generalization of the coincident detection efficiency of the breakup products. The generalized plot is found to be quite linear in the useful region of $\boldsymbol{\theta_b/\theta_D}$ ranging from 0.15 to 1. For researcher using DSSD for breakup studies, the generalized plot is useful in getting the detection efficiency for their experimental setup.

As stated earlier the angular distribution of the decaying nucleus or the angular distribution of the breakup reaction have not been considered in the simulation. Although the energy loss of the decaying nuclei, or its breakup products in the target are not included in the simulation, the effect due to it on the efficiency will be negligible as long as the particles are detected in the DSSD. The detector threshold is also not included in the simulation, so wherever needed a proper correction has to be made to the efficiency obtained from the plot. The detection efficiency corresponding to events with $\boldsymbol{E \le Q}$, will be small and a single DSSD may not be a good option for breakup detection.

Fig.2



We would like to acknowledge the valuable discussion and suggestions by D.R. Chakrabarty and V.M. Datar in this work.

References

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