A TECHNIQUE TO IMPROVE THE QUALITY OF EXPERIMENTAL DATA USING AN UNANALYSED CYCLOTRON BEAM

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A two parameter (energy and time) list mode data have been taken for $^{12}C(\alpha,\alpha')$ reactions at $E_\alpha = 65.0 MeV$ for several scattering angles ranging from 8^0 to 20^0. It has been demonstrated that a proper choice of the time gate on the alpha beam time structure during the off-line analysis considerably reduces the unwanted background events in the inelastic spectrum. Good quality angular distribution data are obtained for the elastic and inelastic scattering reactions agreeing beautifully with the theoretical DWBA angular distributions obtained using the programme DWUCK4. This technique is particularly useful in the absence of an analysing magnet. From the quality of the fit we conclude that the rf gated spectra can be reliably used for estimation of angular distributions of weak excitations in inelastic scattering.

1 Introduction

In the study of weakly excited states in (α,α') reactions we aim to obtain a clean spectrum, free of unwanted background, with good line shapes for the various peaks. The unwanted background in the spectrum originates, mostly, from the quality of the incident beam. Scattering from various beam defining slits contributes significantly to this background, particularly, at the forward angles. The time and the momentum profiles of the incident beam determine the line shape and the resolution of the peaks observed in the solid state detector. The high intensity beam line at 20^0 of Variable Energy Cyclotron (VEC) at Calcutta delivers unanalyzed beam for nuclear reaction studies in a $90 cm$ scattering chamber.

In an earlier study it has been shown [1] that by improving the time profile of the beam by optimizing the central region parameters and the geometry of the ion source slit, extremely good quality inelastic scattering spectra can be obtained. However, optimization of the central region parameters of the cyclotron to achieve good quality beam is a time consuming process. Further, the beam quality thus obtained may deteriorate over a long period of time due to instabilities in various cyclotron parameters. For these reasons in most of the reaction work, the normal machine settings are used at VEC. The time profile of the beam delivered in this situation is found to contain multiple structures resulting in deterioration of the quality of the analysed spectra. Also, due to scattering from the various slit systems contributing significantly to the background, the measurements of angular ditributions of weak inelastic peaks become difficult. In the present work good quality spectra in a typical inelastic scattering experiment $^{12}C(\alpha,\alpha')$ is obtained at $E_\alpha = 65.0 MeV$ by recording the time information of the scattering events along with their energy information. Analysis of such time gated spectra is shown to yield good angular distribution data even for weak inelastic peaks. This technique is particularly useful when there is no analysing magnet in the beam line for improving the energy resolution.

2 Experimental Technique

The details of the alpha-rf electronic set-up have already been described in reference [1]. Instead of recording the energy spectra with a pre-selected time gate as was done earlier [1], in the present experiment the enregy and time spectra are recorded in two ADC's in a two parameter mode, event by event and are analysed off-line. Carbon target having a thickness of 350 mg/cm and surface barrier particle detectors have been used in the experiment.

Since a long flight path is needed to discriminate the unwanted slit scattered events by time of flight, all the beam defining slits in the scattering chamber and the beamline in the experimental cave are removed. A $2mm \times 2mm$ slit $10m$ upstream from the target is only retained in the cyclotron vault. Data have been taken at an incident energy $E_\alpha = 65.0MeV$ for scattering angles $\theta_{lab} = 8^0, 10^0, 12^0, 14^0, 16^0, 18^0$ and 20^0 . A monitor detector placed at $\theta_{lab} = 50^0$ also recorded the spectra for each run.

3 Results and Discussion

Extreme care has been taken in the off-line sorting of the list-mode data. The stability of the time structure of the alpha beam has been examined by sorting the total alpha-rf time spectra block-by-block.

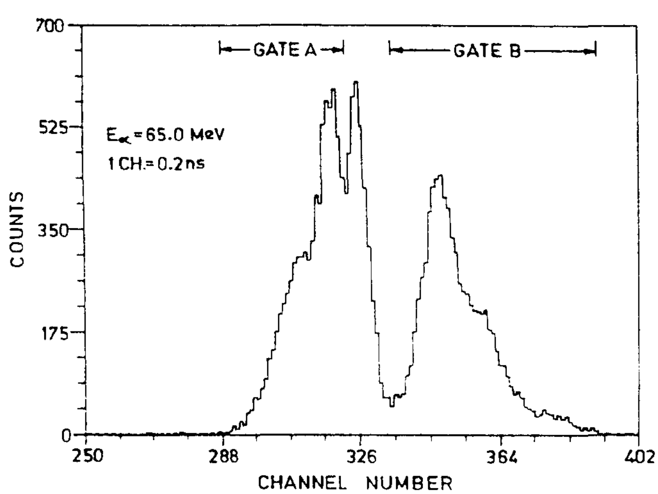

Figure 1: Time structure of the alpha beam ($E_\alpha = 65.0MeV$) obtained by gating the time ADC with the elastic peak in the energy ADC at $\theta_{lab} = 18^0$.

A few blocks of data, where the time structure is shifted by more than 5 channels in the time ADC (corresponding to about $1ns$), have been excluded in the final analysis presented here.

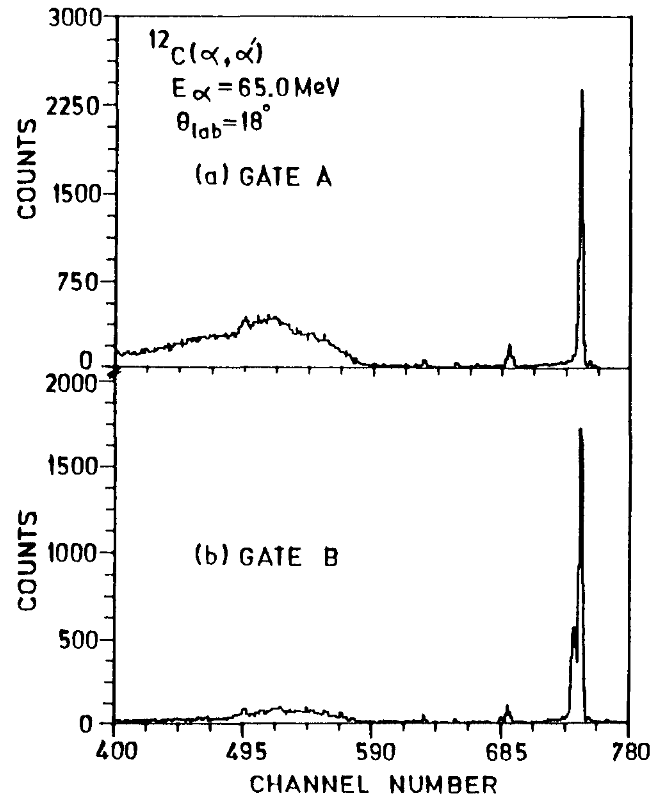

Figure 2: Alpha energy spectra ($E_\alpha = 65.0MeV$) for two settings of time gates a) GATE A and b) GATE B in the time ADC (as shown in Fig.1).

In Fig.1 the time spectrum of the alpha beam is shown. This time spectrum has been obtained by gating the time ADC with the elastic peak in the energy ADC at $\theta_{lab} = 18^0$. The multiple structure of the alpha beam is clearly visible in Fig.1 and arises, primarily, from the multiturn extraction nature of the cyclotron as a result of mixing and overlapping of the coherent and incoherent radial betatron oscillations in the neighbouring orbits at the extraction radius. Broadly, the beam time structure is composed of two parts each of about $3.5ns$ width. However, substructures with time widths of $1.2ns$ are also present. We believe that this type of time structure of the beam originates, in addition to the overlapping of betatron oscillations, from magnet trim coil current instability resulting in beam phase fluctuations. The time structure as shown in Fig.1 is not unique and for different settings of the central region parameters of the cyclotron, as well as the beam optics parameters, the time structure of the beam may vary.

Setting two time gates in the time ADC, GATE A and GATE B, as shown in Fig.1 the alpha energy spectra on the energy ADC are projected from the list mode data. These energy projections are shown in Fig.2. While GATE A gives an excellent inelastic spectrum, the quality of the spectrum obtained from Gate B is rather poor. One notices here (Gate B) double peaks in the elastic and inelastic excitations. A comparison of these with the singles spectra (not gated by rf) indicates that the background is considerably reduced in both GATE A and GATE B spectra. Fig.2 clearly establishes that the cause of the peak shape distortion is due to the second part (GATE B) of the time spectrum.

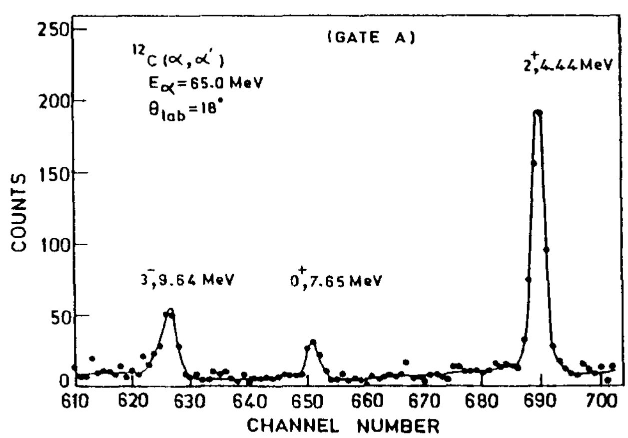

Figure 3: The inelastic excitation regions (4 to $10 MeV$) from Fig.2 (GATE A) are shown expanded.

To show the quality of the GATE A spectrum, the inelastic excitation regions are shown expanded in Fig.3. The overall constant background over the large excitation region of 4 to $10 MeV$ in $^{12}C(\alpha,\alpha')$ inelastic scattering is ideally suited for the differential cross-section measurements of weak excitations.

The angular distributions of the rf gated elastic and the 2^+, 0^+ and 3^- inelastic excitations in ^{12}C are shown in Fig.4 along with the theoretical DWBA angular distributions obtained using the program DWUCK 4 [2]. From the quality of the fit we conclude that the rf gated spectra can be reliably used for estimation of angular distributions of weak excitations in inelastic scattering.

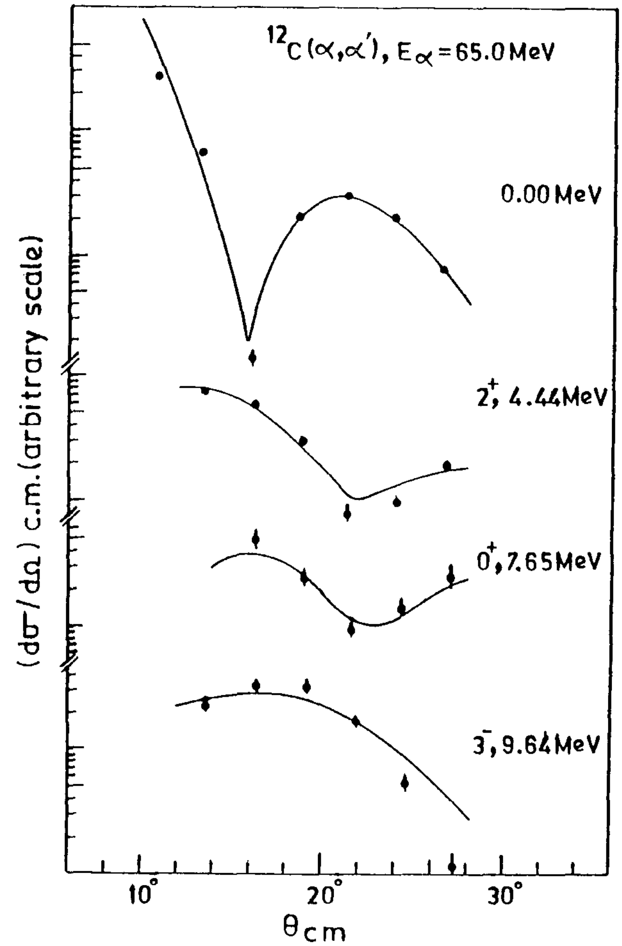

Figure 4:Experimental angular distributions of the rf gated elastic and 2^+, 0^+ and 3^- inelastic excitations. The solid lines are the theoretical DWBA angular distributions obtained using the program DWUCK4.

Acknowledgement: The authors acknowledge with thanks the co-operation of Prof. P. Mukherjee and Dr S.K. dutta. They are also thankful to the cyclotron operation crew for their help in carrying out this work.

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