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Breakup cross section measurement in the ^{16}O+^{16}O system

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Abstract

We propose to measure the inclusive breakup cross section in the ^{16}O+^{16}O system in the energy range $E_{lab} = 80$ to 100 MeV. This experiment would indicate whether the origin of a sudden change in absorption around $E_{lab} = 90$ MeV which has recently been observed arises from breakup processes. If so, this would be the subject of a future exclusive measurements to isolate which channels are contributing.

1 Motivation

The study of nuclear rainbow phenomena (Airy structures in the elastic angular distributions [1]) as a function of incident energy, has highlighted the transparency of the interaction in the case of collisions involving the closed or semi closed shell nuclei : ^{12}C, ^{14}C, ^{15}N and ^{16}O. It has also enabled the longstanding ambiguities inherent in the analysis of heavy ion scattering used to extract interaction potentials to be removed, so that unique potentials can be obtained (see proposal "Rainbow effects in the scattering of ^{12}C+^{12}C" [7]).

The ^{16}O+^{16}O system, composed of doubly magic nuclei, is a good candidate to observe these phenomena, where the first excited states are quite high around 6 MeV, implying that there are few open channels [8]. In the higher energy regime ($E_{lab} \geq 10$ MeV/n), the measurements of accurate and extensive elastic scattering differential cross section obtained in the last couple of years by the Berlin [2] and Jaeri [3] groups have allowed the observation of strong refractive effects which in turn have permitted a better understanding of the interior part of the interaction potential. From this unique optical potentials have been extracted : strongly attractive (deep) with relatively weak absorption and the volume integrals for the real and imaginary part of the potentials show a smooth energy dependance (see figure 1). Complete angular distributions for the ^{16}O+^{16}O elastic channel recently obtained by the Strasbourg group [4] at bombarding energies between 5 and 10 MeV per nucleon have completed the existing data and allowed the evolution of the depth of the Nucleus-Nucleus potential to be followed from the higher energy ($E_{lab} \geq 10$ MeV/n) to the lower energy ($E_{lab} \leq 5$ MeV/n) regimes where data exist [5]. All these angular distributions can be fitted with a fixed deep real part with only the imaginary part varying with energy.

The data of the Strasbourg group [4] seem to indicate that there is an abrupt transition at around $E_{lab} \sim 90$ MeV in both the magnitude and shape of the imaginary potential (see figure 2). This coincides with the point at which the scattering changes rather dramatically in character from diffractive to refractive regimes. Presumably the change in absorption reflects a rather sudden change in the reactions occuring and which lead to loss of flux, however their origin is unknown. For example, is it a dynamical effect (new reaction processes occuring) or a structural effect (new channels opening) ? To address this, the evolution of the different competing breakup reaction processes must be measured accross this energy region. It is known that the fusion cross section saturates around $E_{lab} \sim 60$ MeV [6], so the variation in absorption is unlikely to arise from fusion processes. Alternate candidates include binary transfer, breakup or deep inelastic processes.

This proposal involves an investigation of the breakup yield to investigate whether it is the origin of the characteristic change in absorption . Parallel work to explore whether the binary transfer channels are responsible is likely to be the subject of future work by the Strasbourg group. We plan to maintain close contact in a joint exploration of this topic.

2 Proposed measurements

The dominant breakup channels in α conjugate systems such as ^{16}O+^{16}O involve α particles. The breakup process may be direct or a two-step, resonant process involving excitation of the ^{16}O nucleus followed by breakup to the ^{12}C+α channel. In this, the ^{12}C nucleus may itself be left in an excited state, leading to subsequent breakup into the three α channel. To isolate the relative contributions of the different mechanisms, and to identify which excitation energy regions are important, requires inclusive measurements in which all the fragments of the decay are detected and their energies and emission angles accurately measured. From these measurements it is possible to reconstruct the reaction kinematics to identify the excitation of the ^{16}O nucleus before breakup. We have a considerable expertise in such measurements and with MEGHA we have an ideal device with which to make measurements. However, such measurements are by their nature time-consuming, as the requirement to record many particles in the exit channels leads to a reduced efficiency and hence long running times. The reconstruction of the data is also rather complex and time-consuming.

Since it is not established at this point that the origin of the rather dramatic break in absorption lies in changes in the breakup reactions, it would not be appropriate to invest a large effort in such detailed, exclusive measurements. Rather, we propose a short series of inclusive measurements which would establish whether there is any change in the total α breakup channels as the beam energy is varied across 90 MeV. Such a measurement could be carried out with only one or two days of beamtime and provide data requiring only minimal analysis. However this would be sufficient to establish whether the origin of the change lies in the breakup channels and if it did, provide us with the information necessary to design a more detailed coincidence measurement which would explore what particular breakup channels were responsible.

The experimental setup would be identical to that used in a recent measurement at ANU in a joint experiment carried out with the Fusion-Fission group. This involved a measurement of the scattering yield in the ^{9}Be+^{208}Pb system, as part of a larger programme to understand the failure of conventional reaction model calculations in this loosely bound system. This is an important part of our interest in exotic nuclei, since most of these are loosely bound and our present inability to properly describe the sacttering of these systems will compromise our ability to extract reliable spectroscopic information on their structure. In the experiment, run last August, we used a setup of three position sensitive silicon detector telescopes in the 2m chamber. These enables us to identify the elastic transfer channels, and to record accurate angular distributions for the yields across the full angular range. Interestingly, and quite unexpectedly, the setup also provided some remarkable valuable breakup cross section data. Figure 3 shows an online spectrum of the α particles recorded in the telescopes. Superimposed on a falling tail is a clear, Gaussian shaped peak. The energy of the peak corresponds to α-particles with a velocity equal to the beam velocity and corresponds to those α-particles which result from breakup of the beam projectile. The continuum arises from α from other processes such as compound nucleus formation. By integrating the counts in the peak at each angle, the differential cross section for all α breakup channels is obtained. This can then be angle integrated to obtain the total breakup cross section. We have also exploited the same procedure to obtain breakup inclusive cross sections for ^{6}Li and ^{7}Li on ^{208}Pb [9].

Our proposal would be to use an identical setup to the system used at ANU last August, to record the inclusive α particle yield from the ^{16}O+^{16}O system. At a beam energy of 90 MeV the breakup α-particles energies would be peaked around 20 MeV. The telescopes comprise a 70 μm ΔE detector and an 500μm rear detector, which would be ideally suited to these energies. The setup has been used in the past and shown to work. The breakup yields are not known, indeed it is the determination of this that is the goal of the measurement, but we can expect them to be similar to those observed in others systems we have studied. Hence a reasonable estimate is around 100mb. Given a BeO target thickness of 20μg/cm^2 (with $\sim$ 8μg/cm^2 of oxygen) and a beam intensity of 20 enA, it should be possible to complete a full angular distribution at each energy in one shift of beam. We would like to record the inclusive yield at five energies across the 90 MeV region to be sure we can identify any characteristic change. We will also need a shift to check and calibrate the detectors, leading to a request for **2 days**. Based on the data from this measurement we should be in a situation to say whether changes in the breakup could be responsible for the change in absorption at 90 MeV. If this is established, then we would anticipate a future proposal to request time for a more detailed investigation using coincidence detection techniques.

The need to use a compound for the ^{16}O target does lead to the potential of breakup yield arising from the other elements in the target. It is likely that we will use a BeO target, since we have considerable experience in their production and use [10]. In this case breakup α-particles may arise from ^{16}O breakup on the Be nuclei in the target and the ^{12}C buildup. In this inclusive measurement it is not possible to separate these from those of the ^{16}O nuclei. However, the intention of this measurement is simply to establish whether or not the breakup process is responsible for the change in absorption at 90 MeV. In this respect, where we are looking for a change in the breakup yield across this energy region, the additional contribution from the other target nuclei and contaminant is not really a problem. If there is no change in the yield we know that the breakup is not the origin of the change. If there is a change then we can be fairly certain that it is the origin and follow this up with exclusive measurements where the other target contributions can be separated. There would exist the small possibility that a change could be observed in the breakup at 90 MeV which subsequently turned out to be from the Be or the ^{12}C deposite in the target, but we would have to proceed on the basis that nature would not be so perverse!

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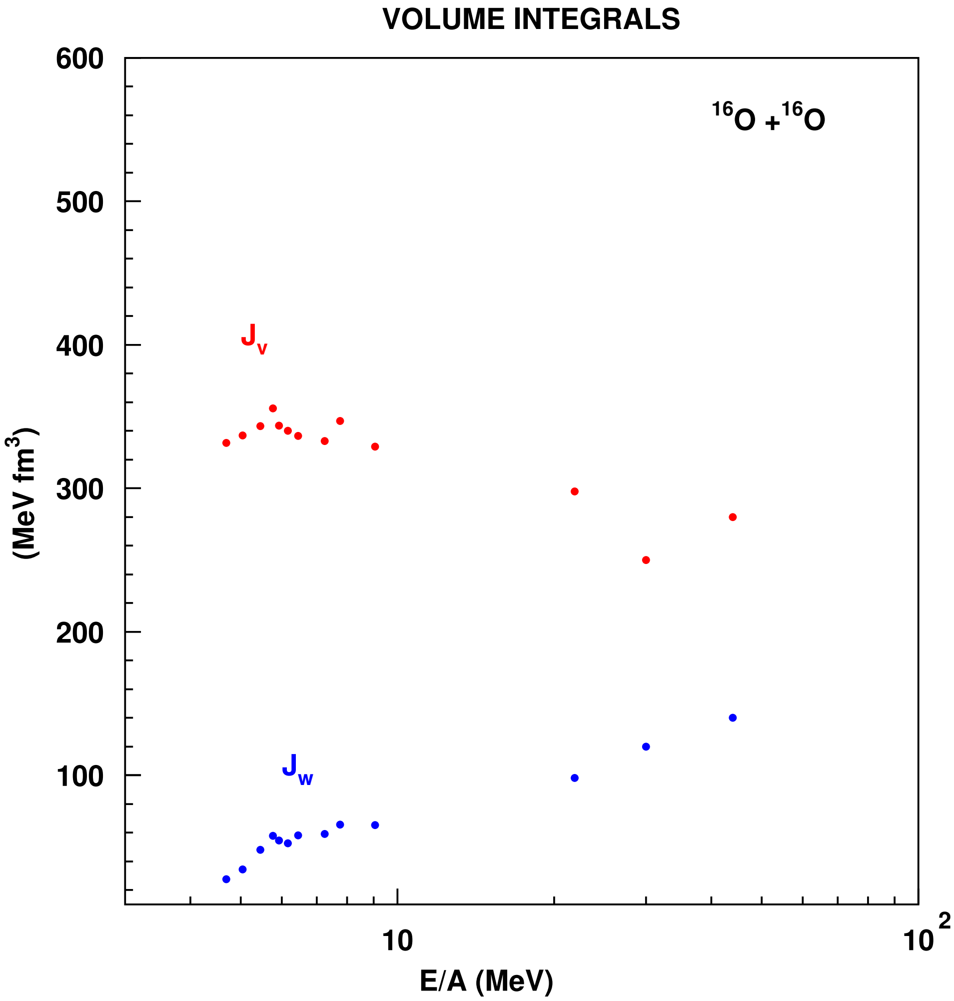

Figure 1: *Volume integrals of the real J_v and imaginary J_w part as a function of energy calculated for the ^{16}O+^{16}O system.*

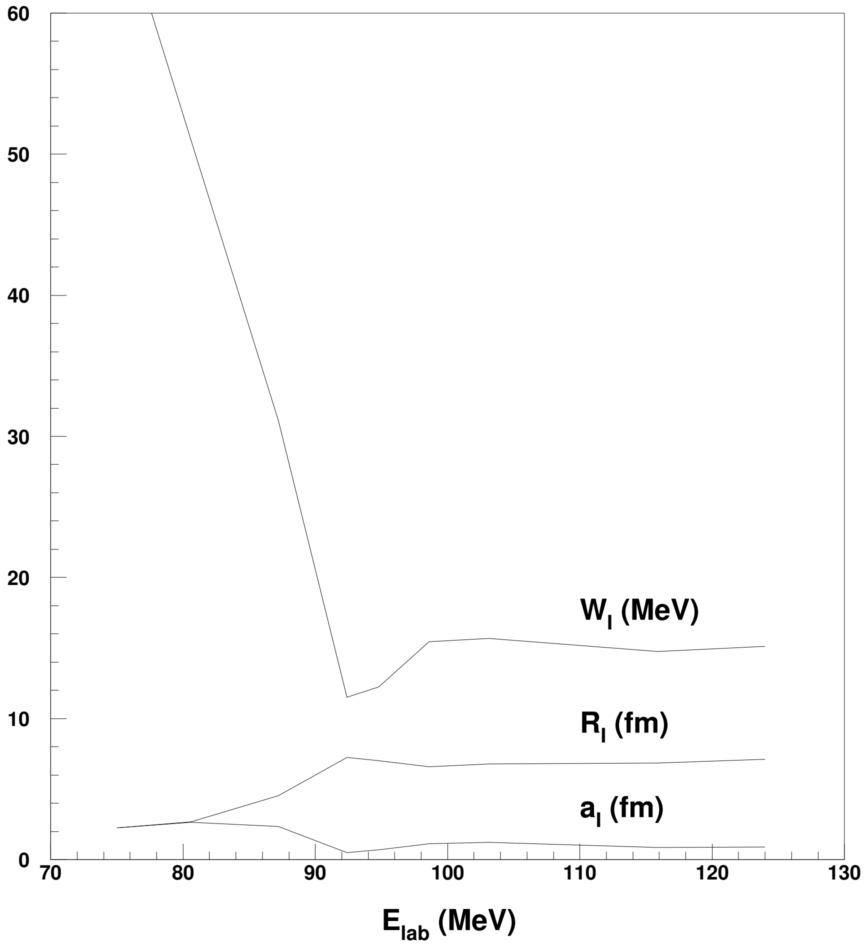

Figure 2: *The parameters of the imaginary part as a function of bombarding energy.*

Figure 3: *Online spectrum of the* α *particles recorded in the telescopes for the* ^9Be+^{208}Pb *experiment carried out at ANU.*