CH/PROP/ANU/99/07
Proposal for beam time at the Australian National University

The use of neutron channel selection in the study of cluster structure in light nuclei.

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Abstract

The study of cluster structure in light nuclei with MEGHA can be enhanced by the inclusion of a neutron detector in the event. A neutron counter , MEGHADON, is already under construction. Three days are requested for the setup and testing of the first module.

Introduction

Many alpha-conjugate light nuclei can be well described by the alpha cluster model [1] , where the individual clusters are assumed as tightly bound sub-structures which retain some semblance of their alpha particle identity, and occupy a fairly localised position in phase space - the classic example is ^{8}Be. When additional nucleons are added to such nuclei , these nucleons must occupy delocalised shell model orbits within the two-centre potential created by the core clusters; and the states can be predicted using the two centre shell model [2,3]. The nuclei ^{9}Be and ^{9}B are well understood within this framework, and both nuclei can be considered as nuclear analogues of atomic molecules with the additional neutron/proton providing the stability for the ^{8}Be core. The states in the (^{8}Be + 2N) isobars ^{10}Be and ^{10}B near 6MeV of excitation, just above the $\alpha+\alpha+2n$ and $\alpha+\alpha+d$ decay thresholds have also been described by two-centre orbits [3].

In proposal CH/PROP/ANU/99/06 , we plan to study the $^{(}$ $\alpha+3N+\alpha$) systems, investigating the cluster structure of the T=1/2 and T=3/2 isobaric states in ^{11}B and ^{11}C using a modification of the MEGHA array to detect and identify the breakup fragments (p,d, t, ^{3}He, ^{4}He and heavy ions) using the reactions

^{7}Li (^{9}Be, ^{11}B - > $\alpha + \alpha$ +t or ^{10}Be +p $)^{5}$He (Q=+6.19MeV) [1]
and ^{16}O (^{9}Be, ^{11}C - > ^{10}B +p or $\alpha+\alpha$ ^{3}He) ^{14}C (Q=-7.06MeV) [2]

The analogue T= 3/2 states in ^{11} Be are considered as (α+ 3n + α) molecular structures, with the three neutrons binding the ^{8}Be core. With the exception of the T=3/2, J= $1/2^{+}$ intruder ground state and the J=$1/2^{-}$ (0.32MeV) state, all the low lying states which are analogues of those in ^{11}B are unstable to the emission of one or more neutrons. We propose to investigate the cluster structure of these states using the reactions

$^{7}Li(^{9}Be, ^{11}Be)^{5}Li$ (Q= -5.6MeV) [3]
or $^{9}Be(^{9}Be, ^{11}Be)^{7}Be$ (Q=-13.25MeV) [4]

with a variety of decay paths open for ^{11}Be:-

^{10}Be +n ; Q = -0.504MeV
^{9}Be + n+n; Q = - 7.32MeV
^{8}Be + n+n+n Q= - 8.98 MeV
$^{4}He + ^{6}He$ + n Q= -7.91MeV [5]

Other breakup channels involving isotopes of lithium and hydrogen have Q values larger than -15MeV.

For all these reaction we can identify the charged particles in coincidence but the detection of a neutron is essential to enhance our selectivity, and unambiguously identify the cluster structure of the states in ^{11}Be, particularly those above E_x = 7.9MeV.

MEGHADON - the MEGHA Detector Of Neutrons

The design study of a neutron detector module which would replace one of the heavy ion telescope modules in the back wall of the MEGHA array was commenced in May 1998. The engineering and design effort has been supplied by the support group at CCLRC, Daresbury, and the final detailed drawings are in preparation. The basic structure is based on the considerable experience of the Daresbury engineers in completing the neutron wall for the EUROBALL project, and the same 'salt-bath' alloy welding technique will be used to construct the MEGHADON module.

Fig.1 shows a plan of the construction; the tapered front section which fits into the back wall of the MEGHA array is divided by internal partitions into four volumes of liquid scintillator each of about 900 cm^3; each volume is provided with a miniature stainless steel expansion bellows on the backplate to provide for temperature changes. Each volume has a glass window viewed by a fast 3-inch photomultiplier tube (Philips XP4312B) which is coupled by a 'self-wetting' gel pad. Each tube has an individual mu-metal shield (M5153) and a transistorized voltage divider base (VD123K) within a custom designed canister adapted from the EUROBALL design.

The final design drawings are expected in January 1999, and construction is expected to be complete by April 1999.

Any study of exotic light nuclei implies those nuclei which are mostly neutron rich, and the study of their cluster structures will inevitably require the measurement of decays into neutron channels. Without the selectivity of an instrument such as MEGHADON, we cannot hope to eliminate the large backgrounds which are present in our events selected by the identities of the charged particles. We therefore see MEGHADON as an essential tool to extend our measurements of clustering in light nuclei.

Beam time request at ANU

The inclusion of a neutron counter into the MEGHA data acquisition at ANU poses some technical difficulties which we need to explore. In order to distinguish gamma rays from neutrons within the MEGHADON, we plan to use (initially) some dedicated 'LINK system' modules which perform pulse shape discrimination using the 'two gates' technique. These modules will provide us with a signal denoting 'gamma' or 'neutron' and a pulse height corresponding to the energy deposited in the counter; and five of the 'Link' modules are available at Birmingham. We need to include this information in the event by reading into CAMAC modules.

However, this strategy does not supply the energy of the neutron, only its identity, and time of flight signals using the pulsed beam at ANU would be necessary to obtain the neutron energy. Since most of the neutrons will have kinetic energies of <20MeV (v=0.2c) , the resolution for the neutron energy at R=600mm will be better than 10% for a 1ns time resolution from the pulsed beam.

We are asking for a period of **three days** for the initial testing of the MEGHADON module. The experimental measurements will be made using a beam of about 30nA of ^{9}Be at about 60MeV. Assuming cross sections for two-neutron transfer of the order of 1mb sr^{-1}, and lithium oxide or beryllium targets of about 200μg cm^{-2} at 60cm, about 50 neutrons per second would be incident upon the MEGHADON module. The simulated neutron detection efficiency of MEGHADON varies from ~ 40% at 1MeV to about 25% at 20MeV, so these rates will be ideal for testing the module. Overall coincidence detection efficiencies of 2% -6% can be achieved with optimum placement of the charged particle detectors.

Day 1 would be required to explore the working parameters of the individual counter volumes, including optimising the voltages on the PM tubes, and getting signals into the MEGHA data acquisition system.
Day 2 would be required to optimize the gating parameters of the LINK modules to achieve optimum separation of neutron and gamma events, and attempting to incorporate the time of flight information in our event pattern.
Day 3 would be required to incorporate both the neutron counter and the charged particle array within the MEGHA event readout, and attempt some preliminary physics measurements.

Thus, we request a total of <u>3 days</u> of beam time for these measurements.

References:

[1] M Freer & A C Merchant J.Phys. G. 23 (1997) 261-323
[2] W Von Oertzen Z.Phys. A354 (1996) 37
[3] W Von Oertzen, Z. Phys. A357 (1997) 355
[4] M Freer et al. CH/PROP/ANU/99/06