COMMISSIONING OF THE BEAM SWEEPING DIPOLE MAGNET

J.J. Kruse, A. Galonsky, C. Snow, J. Wang

Some time ago, a kinematically complete measurement was made of the coulomb dissociation of ^{11}Li[1]. The ^{11}Li were electromagnetically excited in the coulomb field of a target lead nucleus, and decayed into ^{9}Li and two neutrons. The energies and angles of all three final state particles were measured, and the excitation energy could be calculated event-by-event. These measurements allowed us to map out the coulomb excitation function. The experiment proved successful, but before expanding the program to study other neutron halo nuclei, several upgrades were made in the experimental apparatus. The small array of neutron detectors used in the first experiment were replaced by the Neutron Walls[2]. In addition, the fragment detection telescope was replaced by a Beam Sweeping Dipole and a new array of fragment detectors.

In the first experiment, the energy and the angle of each ^{9}Li fragment was measured by a three element charged particle telescope placed directly behind the target. The first element was a double sided silicon strip detector which was 300 μm thick. The strips on the detector provided a measurement of the fragment's angle, while the energy lost in the detector was used for particle identification in a $\Delta E - E$ plot. The second element of the telescope was a 300 μm silicon PIN diode which provided additional ΔE information. Finally, the fragments were stopped in a CsI detector which measured the remaining energy of each particle. Unfortunately, only approximately one percent of the ^{11}Li particles reacted in the target, while a similar number were dissociated in the detector array. Many of the events produced in the array were indistinguishable from real target events, and so a large percentage of the beam time was used with no target in place to measure the magnitude of this effect. A dominant contribution to the width of our decay energy measurements was provided by the thickness (0.598 g/cm^2) of the lead target, but to use a thinner target would cause our data to be overwhelmed by events originating in the detector stack. These problems provided the motivation for the development of a Beam Sweeping Dipole Magnet.

In the new configuration, the target is placed at the entrance of the Beam Sweeping Dipole. In the case of a dissociation event in the target, the fragment is swept through an angle of approximately 20 degrees before stopping in a detector array. The neutrons produced in the target travel straight through the field and arrive at the Neutron Walls, which are centered at zero degrees. All unreacted beam particles leaving the target are also swept through an angle and are stopped by the charged particle detector array. Neutrons produced in the array by the dissociation of halo nuclei are largely forward focused, and so any dissociation events which occur when the beam stops in the detector array will produce neutrons which can be shielded from the Neutron Walls. This apparatus prevents the detection of coincidence neutrons from dissociation in the detector array, and so a thinner target may be used in an effective manner. With this equipment, decay energy resolution is enhanced, and beam-time is used more efficiently.

The magnet is a former beamline dipole from the Bevalac at Lawrence Berkeley Laboratory. It is a room temperature C-shaped magnet whose pole faces measure 13x24 in^2. When we received the magnet, the vertical gap between the pole faces measured 6 inches but has been enlarged to 7.5 inches to increase the vertical opening angle for fragments and neutrons to leave the magnet. The field has been mapped in several planes, and in the midplane the peak field is more than 1.5 tesla. At full field strength, a ^{6}Li entering the magnet with an energy of 25 MeV/A is deflected through more than 20 degrees.

The target ladder is located four inches upstream from the opening of the magnet. Six inches downstream from the target, two inches inside the magnet, are located a pair of double sided silicon strip detectors. They are placed side by side, to cover an active area of 2 x 4 in^2. The silicon detectors measure the angles of charged particle fragments produced in the target, as well as ΔE measurements for particle identification. While they are located at zero degrees, and can contribute to the total dissociation yield in the experiment, they are only 250 μm thick, and so the number of events produced in the silicon is small, even in comparison to the thinner targets used in our latest experiments. Seventy inches downstream from the target, at the exit of the magnet, is an array of plastic scintillator bars which completely stop the charged fragments and measure their energies. The array consists of 16 vertical scintillator bars 16 inches long. Each bar is 2 cm thick and 4 cm wide and has a two inch photomultiplier tube (PMT) glued to each end. The bars are inside the vacuum chamber, but the resistor chain for the PMT bases is outside the vacuum to avoid gain shifts from over heating of the resistors. Any other gain shifts are monitored throughout the experiment by use of a pulsed LED system on the PMT faces. In addition to measurement of the fragments' energies, the PMT's on the scintillator array provide a reference for neutron time-of-flight measurements. Because the magnetic field is mapped, the flight path for each fragment is calculable. With the energy measurement made by the scintillators the transit time for each fragment between the target and the detectors can be calculated and added to the neutron time of flight. Neutrons produced in the target travel straight through the magnetic field and leave the vacuum chamber through a light weight aluminum Hex-cell material, which provides minimal scattering of the neutrons on their way to the Neutron Walls.

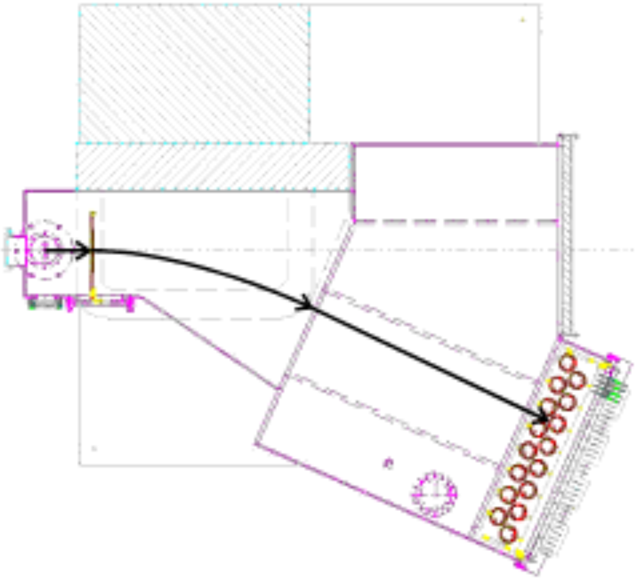

Figure 1: CAD drawing of the Beam Sweeping Dipole and vacuum chamber. The beam enters from the left and strikes the target located in the circular flange at left. The hatched region at top left represents the return yoke of the dipole and the dotted rectangles show the outlines of the coils. The strip detectors are located between the coils at left, and the phototubes for the scintillator array are shown at bottom right. The hatched region at top right represents the Hex-cell plate through which neutrons will pass on their way to the Neutron Walls. The dark trajectory through the magnet represents the path of a 22 MeV/A ^{9}Li into the scintillator bars.

The Neutron Wall / Beam Sweeping Dipole apparatus was commissioned in the summer of 1996. Since that time, it has been used in seven experiments, with approved proposals to complete two more. Measurements include the coulomb dissociation of ^{6}He, ^{8}He, and ^{11}Li, as well as measurement of the cross section for the astrophysical ^{14}C(n,γ)^{15}C reaction.

In the ^{11}Li measurement, the scintillator bar array showed an energy resolution of better than 3% FWHM for measurements of 20 MeV/A ^{9}Li fragments. The thickness of the lead target was reduced from 0.598g/cm^{2} used in the first experiment to 0.376 g/cm^{2}. Even with the substantially thinner target, less than 20% of the coincidence events measured were created in the zero degree silicon detector. In addition to the lead target, a 0.240g/cm^{2} aluminum target was used, so that, assuming a similar reaction cross section in aluminum and silicon, the contribution from the silicon detector was measured quickly and its effects were subtracted from the lead spectra. The addition of 2in of brass shielding behind the scintillator bars but inside the vacuum chamber and 12in of steel shielding outside the chamber has virtually eliminated the detection of coincidence neutrons created by unreacted beam particles stopping in the scintillators.

References

1. "Electromagnetic excitation of ^{11}Li," D. Sackett, K. Ieki, A. Galonsky, C.A. Bertulani, H. Esbensen, J.J. Kruse, W.G. Lynch, D.J. Morrissey, N.A. Orr, B.M. Sherrill, H. Schulz, A. Sustich, J.A. Winger, F. Deák, Á. Horváth, Á. Kiss, Z. Seres, J.J. Kolata, R.E. Warner, D.L. Humphrey, *Physical Review C **48***, 11, 1993.
2. "A Large-Area, Position-Sensitive Neutron Detector with Neutron/γ-ray Discrimination Capabilities," P.D. Zecher, A. Galonsky, J.J. Kruse, S.J. Gaff, J. Ottarson, J. Wang, F. Deák, Á. Horváth, Á. Kiss, Z. Seres, K. Ieki, Y. Iwata, Hugo Schelin, *Nuclear Instruments & Methods in Physics Research A*, **401**, 329, 1997.