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NUCLEAR STRUCTURE MEASUREMENTS WITH THE BROOKHAVEN COSMOTRON*

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MASTER

About a year ago the Brookhaven group undertook a study of the Brookhaven Cosmotron to determine whether the energy resolution and energy stability of the machine were adequate for nuclear structure measurements. Figure 1 shows some of the characteristics of the Cosmotron and the results of the preliminary measurements. The internal beam intensity is around 5×10^{11} protons per pulse. We can extract 20 to 30% of that giving about 10^{11} external protons per pulse. The time average current with a 2.5 sec rep. rate is 8 nA and the beam spill length is 100 to 200 milliseconds. The energy range can be varied from 500 MeV to 3 BeV. In our preliminary experiments a year ago we determined the beam energy spread to be less than 3 MeV and the long-term beam stability to be better than 1.5 MeV. This latter measurement extended over an 18 hour period and included shutting the RF off, the magnetic field off, and starting up again. With these encouraging results we decided to build a large spectrometer system which

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would allow us to do elastic and inelastic scattering and (p,2p) measurement at 1 BeV incident energy. In this project we were joined by groups from Rice University, Maryland, and Los Alamos.

Figure 2 shows the experimental setup. The beam exits from the Cosmotron through the external shims, passes through a quadrupole triplet, and is then bent 12 degrees to reduce the background created when the beam passed through the Cosmotron exit window. A series of three bending magnets, two on railroad tracks, is then used to change the angle at which the beam strikes the target. The second quadrupole triplet, also on tracks, is used to obtain the desired beam spot at the target. The distance from the shims to the target is of the order of 100 feet. We have a fixed spectrometer which is located at 20 degrees with respect to the zero degree beam line, and a moving spectrometer which can be rotated between 50 and 90 degrees with respect to the zero degree beam line. The magnet associated with this spectrometer is on railroad tracks so it is easily moved. The scattering angle into the fixed spectrometer can be varied from -5 degrees to 40 degrees. Consequently the scattering angle of the second spectrometer can be varied over the range 30 to 110 degrees. The angle between the two spectrometers is variable between 70 and 110 degrees. To get the energy resolution and the large solid angles required to do large momentum transfer measurements, we are using a magnetic spectrometer in conjunction with wire spark chamber hodoscopes as shown in Figure 3. S1 and S2 are our trigger scintillation counters. There are four horizontal hodoscopes before the magnets and four after the magnets. In our high resolution work the bending angle is

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mainly determined by planes P3, P4, P5, and P6. The other planes are used for redundancy. That is, they are used to guarantee that the sparks in hodoscopes 3-6 are located at the point at which the particle passed. It is this redundancy which is very important in reducing accidental counts and allows one to do very low cross section measurements.

Figure 4 is a picture of the hodoscopes as they are set up in the spectrometer. We have to use helium bags to reduce the multiple coulomb scattering which is the largest source of energy smearing in our system. Figure 5 shows a close-up of a hodoscope, 18 in. long by 6 in. high; the wires are 50 mils apart. Each wire is threaded through a magnetic core and after each event we read out all the cores that have flipped. This information is stored in a buffer memory. We can spark the hodoscopes about 100 times per beam pulse. Between beam pulses we dump the data from the buffer memory onto magnetic tape and simultaneously dump it into the Merlin computer. The computer analyzes the data and presents us with an on-line display so that we can determine whether or not the experiment is running properly.

Now just to show you that we really have started taking some data on this experiment the next few figures show some preliminary spectra. The momentum spectrum shown in Figure 6 was obtained by putting the 1 BeV beam from the Cosmotron right through the spectrometer. The points are .8 MeV apart and the full width at half maximum is 5 MeV. This width is almost entirely due to multiple coulomb scattering in the planes. We are nearing

completion of a set of planes 1/10 as thick as the ones we used to take this data, and which will give a multiple coulomb scattering contribution to the energy resolution of less than 1 MeV. We are confident that it is possible to obtain a total resolution between 1 and 2 MeV for a single spectrometer. Figure 7 shows the scattering of 1 BeV protons from water at 9.3 degrees. You can see the ground state and the first excited state of oxygen. The rather large peak is p,p elastic scattering from the hydrogen in the water. The background rate, that is, the target-out to target-in ratio, is only a few percent and offers no problems. In Figure 8 we show the scattering of 1 BeV protons from carbon at 9.3 degrees. Again, you can see the separation of the elastic and first excited states. With our new planes we expect that this separation will improve substantially. The rather large bump is quasi-elastic scattering. To get some preliminary numbers we also ran carbon at 40 degrees which corresponds to a momentum transfer of a little over 1 BeV/c. At this angle we are measuring a cross section of a few microbarns. The background was still only a few percent. Even more important the accidental coincidence rate was less than a fraction of 1%. This is mainly due to the fact that the planes have such a high rejection ratio for accidental events.

I think you can see that this equipment can be quite useful for investigating nuclear structure.

Figure Captions

- Fig. 1: Characteristics of the Cosmotron and results of preliminary measurements.
- 2: Experimental setup - Cosmotron external beam III.
- 3: High resolution spectrometer.
- 4: Equipment view showing first four hodoscopes of the spectrometer.
- 5: Closeup of 18" x 6" hodoscope.
- 6: Momentum spectrum of the 1 BeV external proton beam from the Brookhaven Cosmotron.
- 7: Scattering of 1 BeV protons from H_2O at 9.3° (lab).
- 8: Scattering of 1 BeV protons from graphite at 9.3° (lab).

COSMOTRON CHARACTERISTICS

Internal Beam Intensity	$\sim 5 \times 10^{11}$ protons/pulse
External Beam Intensity	$\sim 10^{11}$ protons/pulse
Time Average Current (2.5 sec. rep. rate)	~ 8 nanoamps
Beam Spill Length	100 - 200 millisec.
Energy Range	500 MeV - 3 BeV
Beam Energy Spread	Less than 3 MeV
Long-term Beam Stability	Better than 1.5 MeV over an 18-hour period

FIGURE 1

COSMOTRON EXTERNAL BEAM III NUCLEAR STRUCTURE STUDIES

FIGURE 2

HIGH RESOLUTION SPECTROMETER

FIGURE 3

FIGURE 4

FIGURE 5

Momentum spectrum of the 1 BeV external proton
beam from the Brookhaven Cosmotron.

FIGURE 6

Scattering of 1 BeV Protons
from H_2O at 9.3° (lab). Each
data point is separated by
0.83 MeV. The left-hand group
is elastic scattering from O^{16} ,
the near-by group from the O^{16}
states at ~ 6 MeV. The strong,
right-hand group is mostly
elastic p-p scattering and
some quasi-elastic scattering.

FIGURE 7

FIGURE 8