

DECAY OF HIGHLY EXCITED NUCLEI

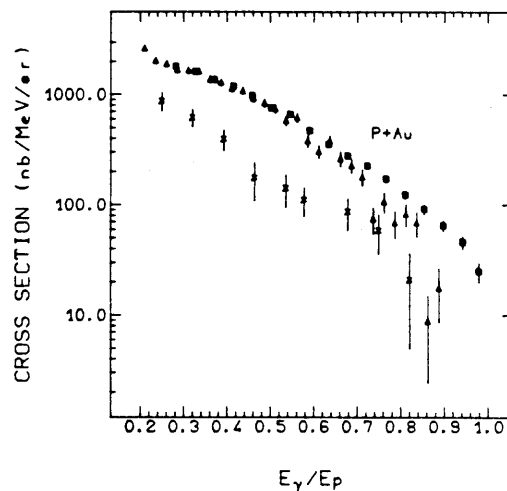
HIGH ENERGY GAMMA RAY PRODUCTION FROM PROTON INDUCED REACTIONS ON D, C, Zn, Pb AT INCIDENT ENERGIES OF 104, 145, AND 195 MeV

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High energy photon emission from heavy ion collisions has been the subject of much study recently.¹⁻⁶ However much of the experimental effort was devoted to studying the emission from intermediate and heavy systems and little emphasis was placed on gamma ray emission from light systems. In fact there have only been two new measurements of proton-nucleus bremsstrahlung within the last 20 years. The first measurement was made by Edgington and Rose⁷ in 1966. More recent measurements were made by Kwato Njock *et al.*⁸ and by Pinston *et al.*⁹ Edgington and Rose studied bremsstrahlung from proton-nucleus collisions at $E_p = 140$ MeV. The measurement was made with a large lead glass detector. They studied bremsstrahlung from targets ranging from deuterium to lead. These measurements were thought to be correct until 1988 when Kwato Njock *et al.* measured proton-nucleus bremsstrahlung at an incident energy $E_p = 72$ MeV. They found that the total cross section measured by Edgington and Rose was low compared to their value by a factor of 2-3. Later Pinston *et al.* made similar measurements at $E_p = 168$ and 200 MeV and found similar results to the $E_p = 72$ MeV data. The results of these two recent measurements are compared to the data of Edgington and Rose in Fig. 1. The plot is the double differential cross section versus the measured gamma ray energy divided by the incident proton energy. The use of this reduced variable, E_γ/E_p , allows the comparison of the three data sets which are at different beam energies. Figure 1 demon-

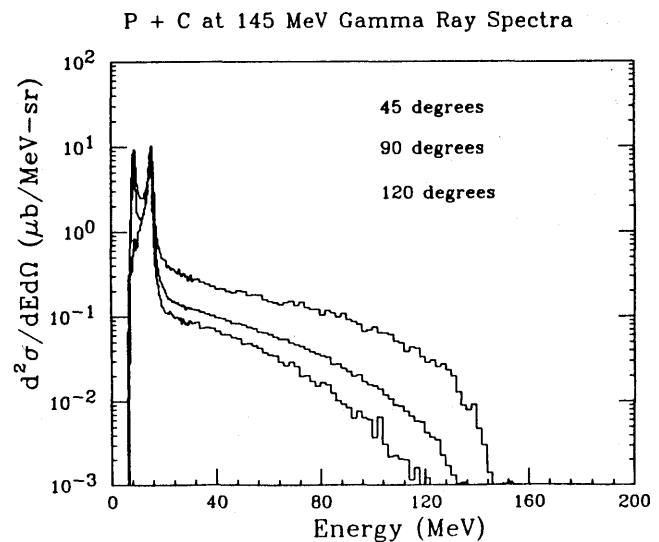
Figure 1. Comparison of the measured spectra of Edgington and Rose⁷ to the data of Kwato Njock *et al.*⁸ and Pinston *et al.*⁹ (See text).



strates that both the data of Kwato Njock *et al.* and Pinston *et al.* are a factor of 2-3 times larger than the data of Edgington and Rose and that there is consistency between the data sets of Kwato Njock *et al.* and Pinston *et al.* even though they differ in incident proton energy by about a factor of 2. It should be noted that these two measurements were made with the same detector set up, a large NaI crystal as a calorimeter and a BaF₂ crystal as the converter for the incident gamma ray. The use of the BaF₂ converter gave the detector set up better time resolution than using the NaI crystal alone.

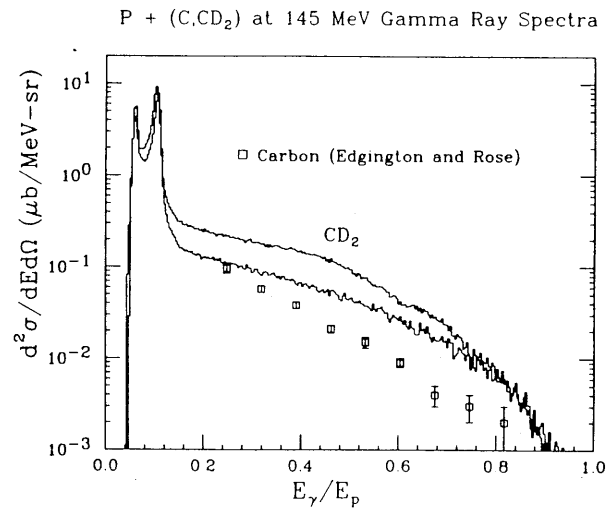
In the experiment reported here we studied proton-nucleus bremsstrahlung at incident energies of $E_p = 104, 145$ and 195 MeV on targets of C, Zn, Pb, CD₂. The measurements were made at the Indiana University Cyclotron Facility with two 5" x 9" BaF₂ crystals at angles of 45°, 60°, 90°, 120°, and 135° in the laboratory. The BaF₂ crystals were collimated to a diameter of 8.9 cm and were placed 75 cm from the target. Between the target and the crystal a polyethelene absorber bar was placed to reduce the background from charged particles. Prompt neutrons from the target were also reduced by the polyethelene bar but the main reduction for neutrons was made by using the time-of-flight of the particles relative to the cyclotron RF. The crystals were also surrounded by a 2.54 cm thick plastic scintillator anti-coincidence shield which was used to reject cosmic rays as well as charged particles from the target. The targets were all self-supporting foils and ranged in thicknesses from 25 mg/cm² for the Pb target to 51 mg/cm² for the CD₂ target. Figure 2 shows the energy spectra for the carbon target for $E_p=145$ at 45°, 90° and 120° in the

Figure 2. The measured energy spectra for high energy gamma rays from the reaction $p + C$ at 145 MeV.



laboratory. The spectra show the expected forward peaked angular distribution in the laboratory. The spectra are an exponential shape which is also expected. We detected photons out to nearly the maximum energy available for both the $E_p = 104$ and 145 MeV data. The comparison to the data of Edgington and Rose is shown in Fig. 3 for the C target data at $E_p = 145$ MeV. Although this analysis is in the preliminary stages, there is clearly a discrepancy regarding the magnitude of the cross section measured by Edgington and Rose. By comparing the total cross section for gamma rays above 40 MeV in the nucleon-nucleon center-of-mass, the value of the cross section reported here is roughly 2-3 times greater than the number reported by Edgington and Rose. This is consistent with the measurements by Kwato Njock *et al.* and Pinston *et al.*

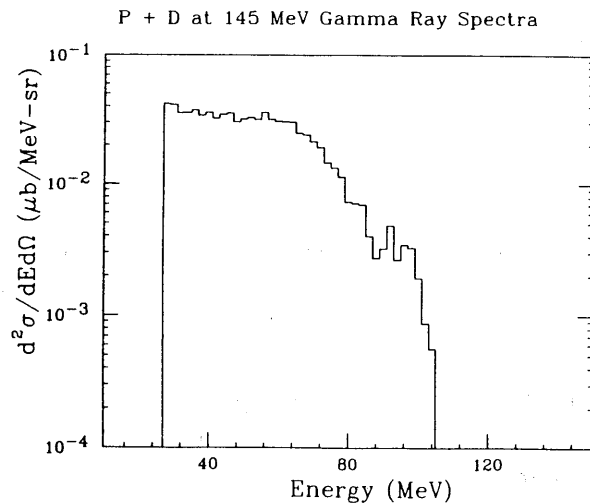
Figure 3. Comparison of the measured spectra for high energy gamma rays from a C target and a CD₂ target at E_p=145 MeV at 90° in the laboratory. Also shown is a comparison to the data of Edgington and Rose at E_p=140 MeV.



In the measurement of the system p + CD₂ we will be able to extract the p + d bremsstrahlung cross section at incident proton energies of 145 and 195 MeV. This can be done by subtracting the C contribution to the spectra by normalizing the two spectra using the 15.1 MeV gamma ray transition in C. The CD₂ is compared to the C spectra in Fig. 3 at 90° in the laboratory for E_p=145 MeV. The 15.1 MeV state is easily identified in both spectra. The extracted spectra p + d is also shown in Fig. 4.

In summary we have made a series of measurements to check the data of Edgington and Rose and we confirm that the discrepancy reported by Pinston *et al.* and Kwato Njock *et al.* is correct. The final values for the magnitude of this discrepancy are currently under analysis.

Figure 4. The measured spectra for p + d at an incident energy of 145 MeV. The spectra was derived from a subtraction of the C contribution of p + CD₂ target. (See text for details).



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SEARCH FOR MULTIFRAGMENTATION NEAR THRESHOLD
IN THE $^3\text{He} + \text{Ag}$ REACTION

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Coincidence measurements of intermediate mass fragment ($3 \leq Z \lesssim 15$) production from the $^3\text{He} + {}^{nat}\text{Ag}$ system at 900 MeV and 3600 MeV have been made at the SATURNE II accelerator in Saclay, France. These measurements are a followup on previous inclusive measurements¹ of this system that extended the existing data² from threshold through the proposed onset of multifragmentation.

Inclusive measurements indicate that the IMF formation mechanism undergoes a change between 900 MeV and 1.8 GeV.¹ This is evidenced by (1) a large increase in the overall cross section; (2) a flattening and then saturation of the high-energy tails of the energy spectra, accompanied by a broadening and a shift to lower energies of the Coulomb peak, and (3) a saturation of the fragment charge distribution.

The experimental setup included 36 detector telescopes covering about 20% of 4π . Thirty-two detectors were gas ion chamber (GIC)/500 μm silicon μstrip $\Delta E/E$ telescopes capable of detecting fragments from $Z=3-15$ with good energy resolution. The remaining four detectors were GIC/220 μm silicon μstrip /(300 μm or 500 μm) silicon μstrip /scintillator logarithmic telescopes capable of detecting light charged particles as well as IMFs. Several different scintillators were used in an attempt to determine which would be most suitable for future work: these included CsI, BGO, and orange plastic, with the resulting light detected by photodiodes in all cases.