Deuteron Photodisintegration and Asymptotic Scaling at 6-12 GeV

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Introduction

The energy dependence of the cross section for a two-body exclusive reaction is, according to QCD predictions, expected to follow the constituent counting rules [1]. This energy dependence is $d\sigma/dt = h(\theta^*)/s^{n-2}$, where s and t are the Mandelstam variables (the total energy and square of the momentum transfer in the s-channel) and n is the number of elementary fields in initial and final states. The angular dependence, $h(\theta^*)$, depends on the details of the reaction dynamics and carries no energy dependence at sufficiently high interaction energies. The onset of such scaling behavior with increasing energy may prove to be an indication that we are probing the transition regime, above which QCD degrees of freedom are applicable.

D(γ,p)n at Higher Energies

Measurements of the D(γ, p)n cross section [2, 3] carried out at currently available CEBAF energies have provided new data and further insight into the scaling observed in some kinematics. The previously observed s^{-11} scaling at $\theta^* = 90°$ continues to 4 GeV and more forward-angle data has begun to hint at the onset of scaling. It is clear that higher beam energies are needed if we are to fully map out the transition to the scaling regime. With CEBAF beam energies of 6 to 12 GeV, measurements of D(γ, p)n cross sections can be extended somewhat beyond the current data set, however, the very strong energy dependence of the the cross section will make going much beyond the lowest of these newly available energies very difficult.

The E96-003 experiment, which will measure D(γ, p)n cross sections at center of mass angles of 37 and 57° and beam energies between 4 and

5.5 GeV, is scheduled to run in early 1999. Using the Hall C HMS spectrometer, a 15 cm liquid deuterium target and 30 μA beam incident on a 6% copper bremsstrahlung radiator, count rates from the reaction of interest will be of order 0.1 Hz and lower. At these rates, statistical uncertainties of $\sim$ 15% can be reached at five kinematic settings in approximately 10 days total running time. Using an s^{-11} energy dependence to estimate the time required to continue these to 6 GeV indicate that a 15% measurement will require as much as a week for a single kinematic setting while measurements at 7 GeV would require on the order of a month. Such measurements would be further limited by the difficulties inherent in extracting such a small cross section from backgrounds. Therefore it seems that 6-7 GeV is a practical upper limit for measurements of the $\mathrm{D}(\gamma,\mathrm{p})\mathrm{n}$ cross section.

$^1\mathrm{H}(\gamma,\pi^+)\mathrm{n}$ at 6-12 GeV

Although cross sections falling like $1/s^{n-2}$ provide a constraint that is hard to beat, this does not rule out scaling studies with higher energy CEBAF beams. Reactions on protons have much more slowly falling cross sections than those on deuterons and have yet to be investigated thoroughly in the 6 to 12 GeV range. In particular, the energy dependence of the $^1\mathrm{H}(\gamma,\pi^+)\mathrm{n}$ cross section is expected to be s^{-7}. Data taken at SLAC in the 1970s [4] is seen to exhibit approximate s^{-7} scaling, as shown in Fig. 1. This data has often been cited as evidence of angle independence of scaling, however, fits to the data at different angles result in a range of scaling powers (n). The spread in powers is not as large as that seen in the $\mathrm{D}(\gamma,\mathrm{p})\mathrm{n}$ data, but the trend is similar. The angular dependence is especially interesting given that it may be possible to reproduce it with calculations using non-forward parton densities.

Compared to $\mathrm{D}(\gamma,\mathrm{p})\mathrm{n}$, measurements of the $^1\mathrm{H}(\gamma,\pi^+)\mathrm{n}$ cross section have practical advantages in addition to much larger count rates. In order to exclude backgrounds from $^1\mathrm{H}(\gamma,\pi^+)\mathrm{n}\pi^0$, only the highest energy part of the Bremsstrahlung spectrum can be used. In the $^1\mathrm{H}(\gamma,\pi^+)\mathrm{n}$ case, this background appears approximately 200 MeV below the bremsstrahlung end point, while in the most favorable $\mathrm{D}(\gamma,\mathrm{p})\mathrm{n}$ kinematics, a window only $\sim$ 100 MeV wide is available. A second important consideration in such measurements is particle identification. The primary background sources

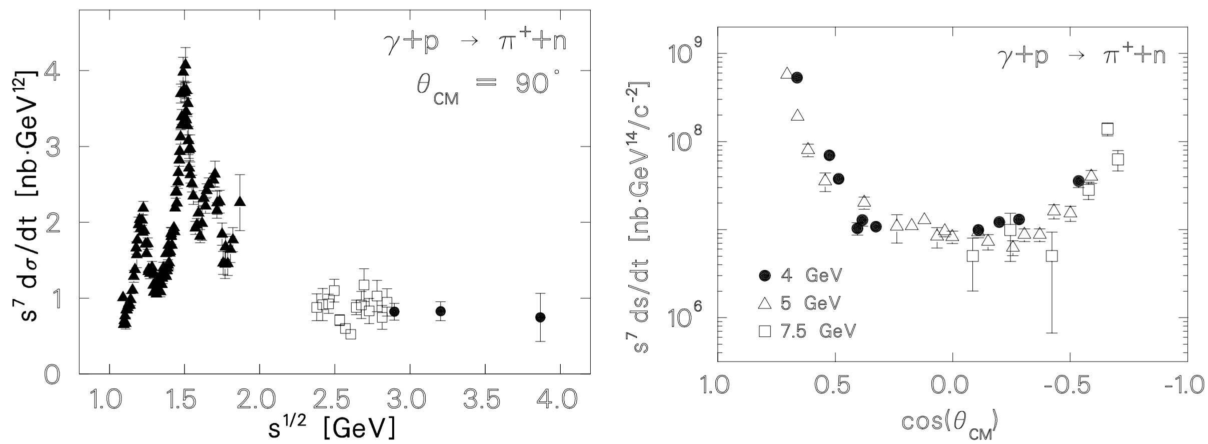

Figure 1: *Left:* $^1\mathrm{H}(\gamma,\pi^+)\mathrm{n}$ cross section at 90°. The three highest energy points are from Ref. 4. *Right:* Angular distributions from Ref. 4.

are expected to be from the ep→ep reaction. With C_4F_{10} in the HMS cerenkov detector, the pion threshold at ~2.8 GeV allows for good separation of π^+s from proton background. Although the cross section for π^0 photoproduction is known to be several times larger than for pi^+ photoproduction, these particle identification issues make the π^+ case more feasible. A more detailed estimate of anticipated background rates will need to be done to quantify this.

Kinematics are limited by the minimum forward angle, 10°, and maximum momentum, 7.5 GeV, of the HMS as shown in Fig. 2. With the proposed super HMS (SHMS) and 6-12 GeV beam energies, a large range of unexplored kinematics will open up. Preliminary count rate estimates indicate that, with a 10 μA beam, an 8 cm LH_2 target and the HMS spectrometer, a measurement of the cross section angular distribution can be made in less that a day at 6 GeV (the time is dominated by

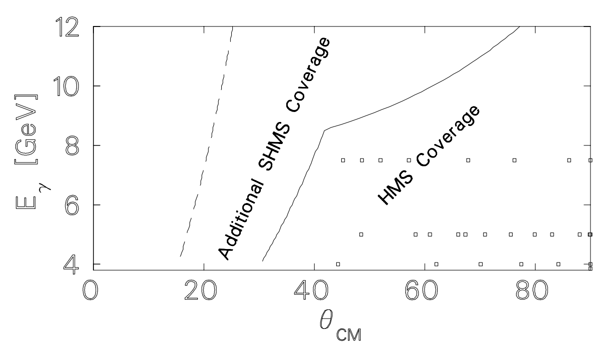

Figure 2: Accessible $^1\mathrm{H}(\gamma,\pi^+)\mathrm{n}$ kinematics. The points are from Ref. 4.

experimental overhead) and in approximately 2 days at 10 GeV. With a week or so of running time, several angular distributions can be measured, resulting in much improved statistical uncertainties in fits to s^{n-2} scaling.

Summary

Existing and scheduled measurements of the D(γ, p)n cross section will push the data set to the edge of practical kinematics for that reaction, even before beam energies of greater than 6 GeV are available. This is unfortunate as it is clear that this data set is just beginning to map out the transition to the s^{n-2} scaling regime. However, the existing Hall C equipment and current CEBAF beam energies can be used to study the ^{1}H(γ, π^+)n cross section. This cross section is quite accessible experimentally as well as theoretically. More careful count rate and background estimates are in progress and a proposal to carry out such measurements at 4-6 GeV is in preparation. As the CEBAF energy rises, and experimental equipment is upgraded, these measurements can be extended, taking full advantage of the available energy. This will allow us to compile a data set that is very likely to extend well into the scaling region. The insights provided are sure to be a valuable asset in our efforts to understand the transition to quark/gluon degrees of freedom.

References

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