Baryon Resonance Electroproduction at High Q^2 in Hall C.

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In this note I will briefly outline the rationale for a program of measurement of baryon transition form factors in Hall C as support for the construction of a new high quality spectrometer.

One of the unique capabilities of JLAB will be to make detailed studies of exclusive reactions at higher momentum transfers than ever before possible. The measurement of baryon transition amplitudes from the real photon point to the highest Q^2 available will play an important role in these studies. The physics issues for high momentum transfer exclusive reactions, and specifically for baryon transition amplitudes have been widely discussed at this workshop,[1]. In short the issues concern which degrees of freedom are appropriate to describe exclusive reactions, and particularly baryon transitions, at experimentally accessible momentum transfers, and how are models at low, medium and high Q^2 related? Quark models appear to work well at the low Q^2 limit, and it is widely believed that valance pQCD will be valid in the limit of high Q^2. The physics between these two extremes appears to be more difficult, and it is one of JLAB's most important goals to understand the physics of this domain. There have been recent [2][4] developments toward a QCD quark-parton description of exclusive reactions in terms of *non-forward parton distributions* (NFPD), which have the potential for a general basis in this JLAB dominated domain. With respect to baryon transition amplitudes the various models for exclusive reactions make very definite predictions [3][1][5].

There will be a major program at JLAB of studying baryon transition amplitudes out to the highest Q^2 possible. Hall C has a central role to play. This has already been demonstrated by the successful completion of JLAB experiment 94014, which measured the $\Delta(1232)$[6] and $S_{11}(1535)$ amplitudes via the π^0 and η decay channels, respectively, up to $Q^2 = 4$ G.

There are about 20 resonances below $W2 = \mathrm{GeV}^2/\mathrm{c}^2$, and they are overlapping. To separate individual resonances and their contributing electromagnetic multipoles requires angular distribution measurements of the resonance decay channels. In addition to isolating resonances and separating their multipoles, exclusive angular distributions will yield a great deal of reduction of the non-resonant background through the selection of decay channel and decay angle kinematic space. Also, the decay channels in all charge states and decay channel multipolarities, and polarization and non-polarization measurements, are necessary to reduce isospin and non-resonant background ambiguities.

Hall C's unique niche is to measure neutral meson electroproduction. For the single meson decay channel measuring only one of the decay hadrons com-

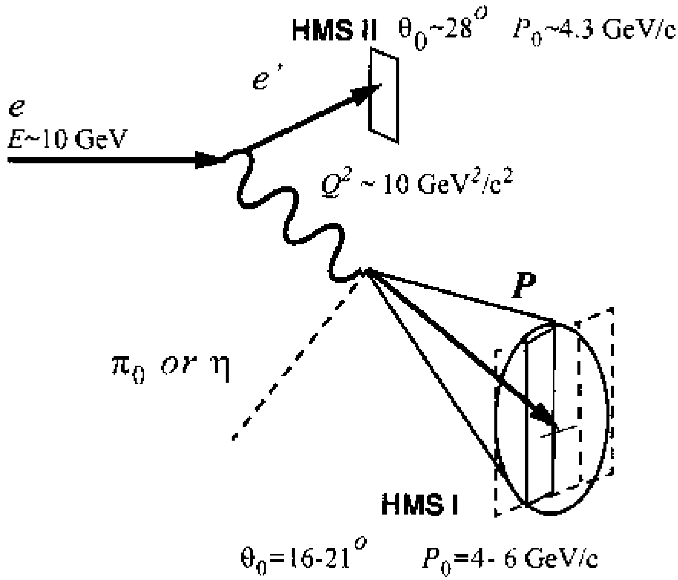

Figure 1: Schematic overview of the experiments $p(e,e'p)\pi^0$ and $p(e,e'p)\eta$ with an electron beam energy 10 GeV and Q^2 = 10 GeV^2/c^2. The kinematic requirements for the spectrometers are also indicated.

pletely determines the kinematics of the entire reaction, including the other undetected hadron. An important property of high Q^2 reactions which hall C can take advantage of is that the hadronic reaction products are boosted into a narrow cone relative to the momentum transfer, so that large c.m. angular acceptances in θ and ϕ can be obtained with relatively modest angular acceptance spectrometers. This is especially true for the recoil protons in single neutral meson production, ie. in the reactions $p(e,e'p)\pi^0$, and $p(e,e'p)\eta$. The protons emerge in a narrow cone around the momentum transfer $\vec{q}$. For example, if we consider π^0 production at the delta peak, $W = 1232$ MeV, at $Q^2 = 10$ GeV^2/c^2 the cone angle in the lab corresponding to 4π in the c.m. is 2.7° (47 mr). For $\eta's$ at the peak of the $S_{11}(1535)$ resonance the angle is 2.5° (43 mr). Thus, with modest solid angle acceptance spectrometers one can obtain almost all of the decay proton cone, and then select the π^0 and η channels by reconstructing their missing mass. The schematic setup for such an experiment is illustrated in Figure 1.

In experiment 94014 the HMS detected the protons with momenta up to about 3.5 GeV/c, and the SOS detected the scattered electrons with a momentum about 1.5 GeV/c. At much higher Q^2 (eg. ~ 10 GeV^2/c^2), the SOS must be replaced by a new spectrometer, call it HMS II. At these increased Q^2 *both* spectrometers must have high maximum momentum capabilities. In addition *both* must have excellent resolution, as well as acceptance in large solid angle.

The momentum and angular resolutions must be excellent because the lab momentum and angular resolution will be greatly magnified in converting the narrow cone in the lab into 4π c.m. The missing mass resolution is limited

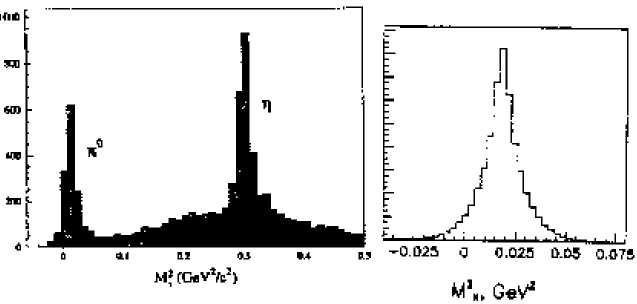

Figure 2: Missing mass for the reaction $p(e,e'p)X$. a: for a typical setting at $Q^2 = 4$ GeV^2/c^2 obtained on JLAB exp. 94014. b: result of Monte-Carlo simulation for $p(e,e'p)\pi^0$ at $W = 1.235$ GeV, at $Q^2 = 10$ GeV^2/c^2 using spectrometers HMS and a new spectrometer; HMS II.

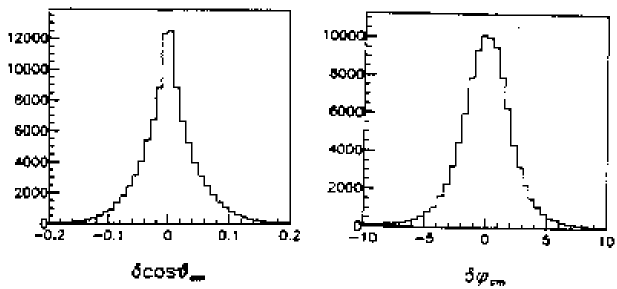

Figure 3: Monte-Carlo simulation for the missing mass and angular resolution in the c.m. for the reaction $p(e,e'p)\pi^0$ $Q^2 = 10$ GeV^2/c^2 and $W = 1.232$ GeV, with HMS and a new spectrometer HMS II.

by the spectrometer resolution, and becomes progressively worse at higher Q^2. Figure 2. shows the missing mass resolution obtained in a typical setting for experiment 94014 at $Q^2 = 4$ GeV^2/c^2. It is very clean and there is essentially no contamination from the elastic radiative processes. The main contributor to the missing mass resolution in Figure mm is from the poor angular resolution of the SOS spectrometer. At $Q^2 = 10$ GeV^2/c^2 the missing mass resolution would be poorer such that there will be a larger contamination from elastic radiative processes. In Figure 3. I also show the Monte Carlo generated missing mass resolution which would be expected at $Q^2 = 10$ GeV^2/c^2 using two spectrometers with the properties of HMS II identical to the existing HMS I. Figure res shows that the simulated c.m. angular resolution also remains very good.

Large solid angle acceptance is important because the cross sections for resonance production, as for any exclusive reaction, are decreasing rapidly with increasing high momentum transfer. With spectrometers HMS I and HMS II the Monte Carlo generated angular acceptance in the c.m. is essentially 4π.

The table below gives the conditions which would hypothetically be submitted in a PAC proposal, some of the particulars, including spectrometer resolution and acceptances needed carry out the experiment. In generating the Monte Carlo simulation for the experiment cross sections at $Q^2 = 10\ \mathrm{GeV}^2/c^2$ were extrapolated from the results of experiment 94014. One can see that in 30 days one can perform a high quality experiment. The thing that makes it all possible is the unique Hall C capability including high luminosity coupled with high quality high momentum spectrometers.

E_{beam}	I_{max}	Target	beam time	proton detector	electron detector
10 GeV	100 μA	4cm LH	30 days	HMS I	HMS II

Assumptions:

- $L = 1 \times 10^{38}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- $\Delta E_p \Delta\Omega_p = \Delta E_e \Delta\Omega_e = 0.03\ \mathrm{GeV} \times 0.7\ \mathrm{msr}$
- Resolutions $\delta p/p \approx 1 \times 10^{-3}$ $\delta\theta = \delta\varphi = 1\,\mathrm{mr}$

-10 settings for proton arm

-Overall acceptance (MC) = 0.93

- $\dfrac{d\sigma}{d\Omega_p}^* = 2.5\ \mu b \left(\dfrac{G_D(4)}{G_D(10)}\right) f(Q^2)$

- $\dot{n} \approx 5 \times 10^{-2}$ ev/sec $\approx 1 \times 10^4$ ev/ 600 hrs

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