Upcoming Experiments

Hall C Collaboration Meeting
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Ioana Niculescu
JMU
Hall C Schedule for 2003

- **E00-002**: “$F_2^N$ at Low $Q^2$”
  4/11 – 4/25

- **E01-002**: “Baryon Resonance Electroproduction at High Momentum Transfer”
  4/29 – 6/18

- **E00-116**: “Duality at Intermediate $Q^2$”
  6/19 - 6/24

- **E01-104**: “The Charged Pion Form Factor”
  7/13 – 8/12

- **E00-108**: “Duality in Meson Electroproduction”
  6/25 – 7/01, 8/13 – 8/29
The Charged Pion Form Factor

- Spokespersons: H. Blok, G. Huber, D. Mack

- Scheduled to run between 7/11 and 8/12

- Extension of E93-021 to higher $Q^2$

- “Extending the range with reliable data to values of $Q^2$ beyond where they exist now is needed to delineate the role of hard versus soft contributions at intermediate $Q^2$...”
Scientific Motivation

- Asymptotic behavior is rigorously calculable in pQCD:

\[ F_\pi \rightarrow \frac{8\pi\alpha_s f_\pi^2}{Q^2} \]

where \( f_\pi = 133\text{MeV} \) is the \( \pi^+ \) decay constant

If we use this formula to calculate \( F_\pi \) at low \( Q^2 \):

\( Q^2 = 1 \text{ GeV}^2 \) then \( Q^2 F_\pi \approx 0.13 \) (exp.: \( \approx 0.4 \))
Theoretical Calculations for $F_\pi$ at Low $Q^2$

- pQCD
  - QCD sum rules
- Soft contributions
  - Constituent Quark Model (CQM)
  - Bethe – Salpeter Equation (BSE)
Previous Measurements

- Low $Q^2 (<0.28 \text{ GeV}^2)$:
  - scattering high-momentum pions off atomic electrons (CERN, Fermilab)

- Higher $Q^2$ can be reached in the reaction: $^1\text{H}(e,e'\pi^+)n$
  - Quasi-elastic scattering of electron from virtual pion in proton (DESY, Cornell, JLab)

- previous data
Pion electroproduction

\[ \frac{d^3 \sigma}{dE'd\Omega_e d\Omega_\pi} = \Gamma_V \frac{d^2 \sigma}{dt d\phi} \]

\[ 2\pi \frac{d^2 \sigma}{dt d\phi} = \varepsilon \frac{d\sigma_L}{dt} + \frac{d\sigma_T}{dt} + \sqrt{2\varepsilon(\varepsilon+1)} \frac{d\sigma_{LT}}{dt} \cos \phi + \varepsilon \frac{d\sigma_{TT}}{dt} \cos 2\phi \]

- \( \phi \) dependence: \( \sigma_{LT}, \sigma_{TT}, \) and \( \sigma_T + \varepsilon \sigma_L \)
- Rosenbluth separation: \( \sigma_T \) and \( \sigma_L \)
Goals for Experiment E01-104

- Measure $F_\pi$ up to $Q^2=2.5$ GeV$^2$
  - (true L/T separation)
- Measure $F_\pi$ at higher $W$ (2.2 GeV)
  - (closer to pion pole, above resonance region)
- Some info on $W$ dependence of cross section.
- Expected uncertainty:
  - In cross section: 3.3%
  - In $F_\pi$: 5% (without model uncertainty)
Projected measurements: $Q^2=1.6$ and $2.5$ GeV
The Experiment

- Coincidence HMS (pions) + SOS (e-)
- L/T separation: 2 $E_{beam}$ for each $Q^2$
  - 3.772, 4.702, 4.210, 5.248 GeV
- SOS momentum $< 1.76$ GeV/c
  - (saturation effects)
  - Full set of optical calibration measurements (sieve slit data, elastic electron-proton scattering)
- HMS momentum $< 3.4$ GeV/c
  - Check matrix elements (sieve slit data @ this $p$)
- HMS angle 10.5°
  - Need low-profile beam pipe (see talk later today)
Target and Beam

- Targets:
  - 4 cm H and D targets (test t-channel dominance of $\sigma_L$)
  - Quintar (for optics studies)
  - “empty target” (to subtract end-cap events)

- Beam current 75 $\mu$A
  - Standard Hall C beamline hardware
  - Super-harps
  - RF cavities+Unser
  - Beam energy measurements

E01-104
Singles rates in HMS and SOS are well below detector capabilities (kHz)

Particle Identification:

- HMS: trigger $S1\bullet S2$ (3/4 scintillator arrays)
- SOS: trigger $S1\bullet S2\bullet Electron$
- TOF in HMS cannot be used for $p/\pi^+$ separation: use aerogel ($n=1.030$)
  - (see talk later today)
Baryon Resonance Electroproduction at High Q2

- **Spokespersons:** V. Frolov, V. Koubarovski, P. Stoler

- Scheduled to run between 4/29 and 6/18

- Extension of experiment E94-014

- “Study the evolution from low-to-high $Q^2$ physics and a search for definitive signals of the onset of hard perturbative reaction mechanisms”
Physics Motivation

- The $N \rightarrow \Delta$ transition form factors
  - Low $Q^2$ in CQM it is purely $M_{1+}$
  - Very high $Q^2$ in pQCD $E_{1+}/M_{1+} \rightarrow 1$
- Sensitive to possible deformation of the nucleon or the $\Delta(1232)$
The $N \rightarrow S_{11}(1535)$ transition form factors

- $S_{11}(1535) =$ lowest mass state with a $J^\pi=1/2^-$ with isospin $1/2$: easier to model
- Helicity conserving: Scaling in $Q^3A^p_{1/2}$ indicates transition from soft to hard processes
- Can be isolated via the $\eta$ decay channel
Baryon resonances and GPDs

- Form factor measurements at high t:
  - sensitive to hard parton-parton correlations
  - Related to transverse distributions of parton spin and momentum in baryon

\[
G_E^* = \int \sum_{-1}^{+1} H_E^q(\xi, x, t) \, dx
\]

\[
G_M^* = \int \sum_{-1}^{+1} H_M^q(\xi, x, t) \, dx
\]

transition form factors

\[
H_M^q \quad H_E^q
\]
axial GPDs
The Goal of E01-002

- Measure the reactions $p(e,e'p)\pi^0$ from the $\Delta(1232)$ and $p(e,e'p)\eta$ from the $S_{11}(1535)$ at $Q^2=7.5$ GeV$^2$
- Extract $E_{1+}/M_{1+}$
- Projected uncertainty ?
The Experiment

- Coincidence SOS (e-) and HMS (p)
  - SOS momentum
    - = 1.6 GeV/c
  - HMS momentum
    - < 5.1 GeV/c
  - HMS $p$ and $\theta$ will vary to cover the resonance decay cone and proton momentum range.

$E_0 \approx 5.75 \text{ GeV}$

$Q^2 \approx 7.5 \text{ GeV}^2/c^2$

$\theta_0 \approx 52^\circ$, $p_0 \approx 1.5 \text{ GeV}/c$
Targets:
- 4cm H, empty (Al)

Beam energy:
- 5.496 GeV

Beam current 100 $\mu$A
- Standard Hall C beamline
- Low profile beam pipe can be used

Channel id.:
- missing mass cuts
The Duality Experiments

- **E00-002**: "$F_2^N$ at Low $Q^2$"
- **E00-116**: "Duality at Intermediate $Q^2$"
- **E00-108**: "Duality in Meson Electroproduction"
Brief Intro to Bloom-Gilman Duality

- Inclusive electron – proton and electron – deuteron scattering

- Resonances (low $W$ and $Q^2$) average to DIS scaling curve (high $W$ and $Q^2$)

- pQCD explanation (OPE): higher twists terms mostly cancel (small) when averaging over resonances
Previous Results

- Jlab results indicate BG duality holds over a broader kinematic range.
- Local BG duality holds down to $Q^2 \approx 0.5 \text{ GeV}^2$. 

![Graph showing Jlab results indicating BG duality over a broader kinematic range.]
Upcoming exp. will address:
Low $Q^2$ duality in inclusive electron-nucleon scattering
Intermediate $Q^2$, large $x$ duality
Duality in semi-inclusive scattering (meson electroproduction)

First attempt to study duality in non-inclusive measurements

"... one may expect factorization and approximate duality at small $Q^2, W'^2 < 3 \text{ GeV}^2$."

F$_2^N$ at Low Q$^2$

- **Spokespersons**: C. Keppel, I. Niculescu

- Run between 4/11 and 4/25

- “Extend the measurements of proton and neutron structure functions to low Q$^2$ and moderately low x”
Physics Motivation

The Jlab scaling curve has similar shape to $xF_3$ (valence structure)
- Measure $F_2$ (p and n) in the region where it drops off
- Study quark-hadron duality
- Study $F_2$ at low $Q^2$ as a function of $x$
The Experiment

- Single arm experiment (e- in HMS)
- HMS at forward angle 10.5°
  - Requires a low-profile beam pipe
- SOS used for auxiliary scans and luminosity monitoring
- Beam energies:
  - 2.298, 3.322, and 4.409 GeV
- Targets:
  - 4 cm H, D, and empty target
- Beam current between 10 and 50μA
The Goal of E00-002

- Measure cross section for reactions
  - $H(e,e')$
  - $D(e,e')$
- $0.03 < Q^2 < 1.5 \text{ GeV}$
- $0.007 < x < 1.$
- Uncertainty in cross section $\sim 3\%$
- Extract $F_2$ for proton and deuteron
Duality at Intermediate Q2

- **Spokesperson**: C. Keppel

- Run between 6/19 - 6/24

- “proposed measurements will help answering the question of the nature of power corrections in hard processes as fundamental components in understanding the transition between pQCD and non-pQCD”
Physics Motivation

Cornwall-Norton moments

\[ M_n(Q^2) = \int x^{n-2} F(x, Q^2) dx \]

Twist expansion

\[ M_n(Q^2) = A_n(Q^2) + \sum_k \left( \frac{nM_0^2}{Q^2} \right)^k B_{n,k}(Q^2) \]
The Goal of E00-116

- Measure inclusive $H(e,e')$ and $D(e,e')$ cross section in the resonance region
- $4.0 < Q^2 < 7.0$ GeV
- Uncertainty in cross section $\sim 3\%$
- Extract $F_2$ for proton and deuteron
- Data can be used to extract $F_2^n/F_2^p$ at large $x$
The Experiment

- Single arm experiment (e- in HMS and SOS)
- HMS used also to measure e+ rates
- Beam energy **5.496 GeV**
- Targets:
  - 4 cm H, D, and empty target
- Beam current **50µA**
Duality in Meson Electroproduction

- **Spokespersons:** R. Ent, H. Mkrtchyan, G. Niculescu

- Will run between
  - 6/25 – 7/01 and 8/13 – 8/29 (best effort basis)

- “Explore the extent to which the electroproduction of mesons exhibits the same dual behavior between resonance region scattering and scaling region”
Kinematics

\[ z = \frac{(p \cdot m)}{(p \cdot \gamma^*)} \]

\( z = \text{fraction of virtual photon energy taken away by meson} \)

\[ W'^2 = W^2 - 2z \nu (m_p + \nu - |\vec{q}| \cos \theta_{qm}) \]
Physics Motivation

At high energies: factorization (pQCD)

\[ \sigma \propto f(z)g(x, Q^2) \]

quark hadronization  hard quark-photon interaction

If duality holds: *may see behavior consistent with factorization even at lower energies.*
Duality in meson electroproduction: look for duality in $f(z)$

- Spectra in $z$ at low $Q^2$ and $W$ average to scaling curve (high $Q^2$ and $W$)?

- $Q^2$ behavior of resonant bumps

- Relative strength of resonances/background at different $Q^2$
The Goal for E00-108

- Measure cross sections
  \[ \frac{d\sigma}{d\Omega_e dE_e d\Omega_m dp_m} \]

- 1.8\( < Q^2 < 6 \) and 0.2\( < x < 0.7 \)

- Extract \( dN/dz \propto \)

- Statistical uncertainties \( \sim 1-2\% \)
- Systematic uncertainties \( \sim 5-10\% \)

E00-108
The Experiment

- Coincidence HMS (mesons) + SOS(e-)
- HMS at forward angle 10.5°
  - Requires a low-profile beam pipe
- HMS momentum > 2GeV/c
  - Avoid pion-nucleon FSI
- Targets:
  - 4cm H, D, and empty target
- Beam energy:
  - 5.496 GeV (June) and 5.248 GeV (August)
- Beam current:
  - 50µA
Particle id.:

- Pion/proton separation (HMS): gas Cerenkov
  - Need 1.4 atm. $C_4F_{10}$ (would 1 atm work?)
- Kaon/proton separation (HMS): aerogel ($n=1.015$)
  - (for status see talk later today)
Summary

- 5 experiments scheduled between April and August 2003
- Use standard Hall C equipment (HMS, SOS, beam line instrumentation)
- Use H, D, and Al (empty) targets + optics target
- Need low – profile beam pipe
- 2 need aerogel in HMS for PID.