# Upcoming Experiments

Hall C Collaboration Meeting

January 9, 2003

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**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 $Q^2$…"

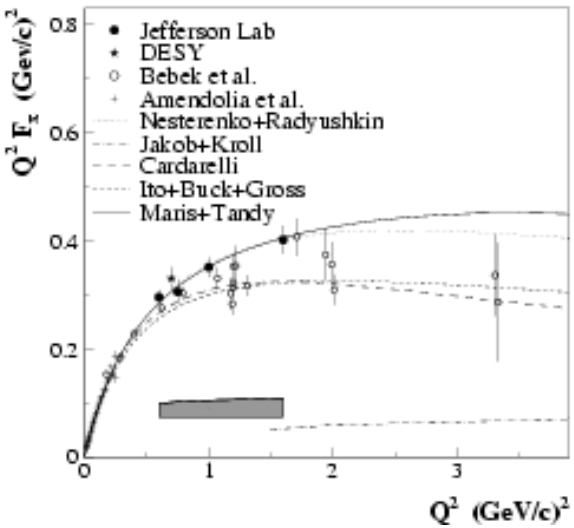
E01-104

# Scientific Motivation

- Asymptotic behavior is rigorously calculable in pQCD:

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

where $f_\pi$=133MeV is the $\pi^+$ decay constant

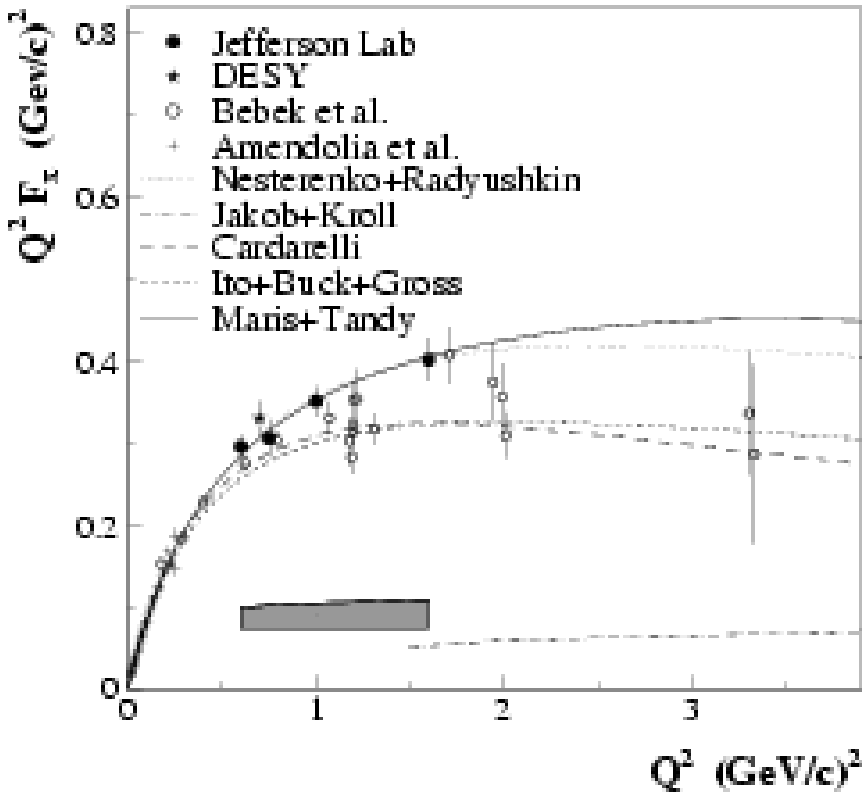



If we use this formula to calculate $F_\pi$ at low $Q^2$:

$Q^2$=1 GeV$^2$ then $Q^2F_\pi \approx 0.13$ (exp.: $\approx 0.4$)

E01-104

# Theoretical Calculations for $F_\pi$ at Low $Q^2$

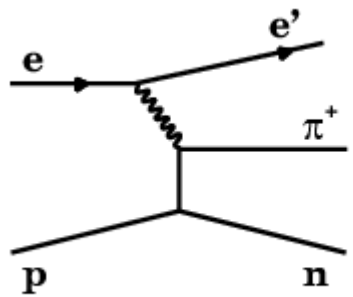



- pQCD
  - QCD sum rules
- Soft contributions
  - Constituent Quark Model (CQM)
  - Bethe – Salpeter Equation (BSE)

E01-104

# Previous Measurements

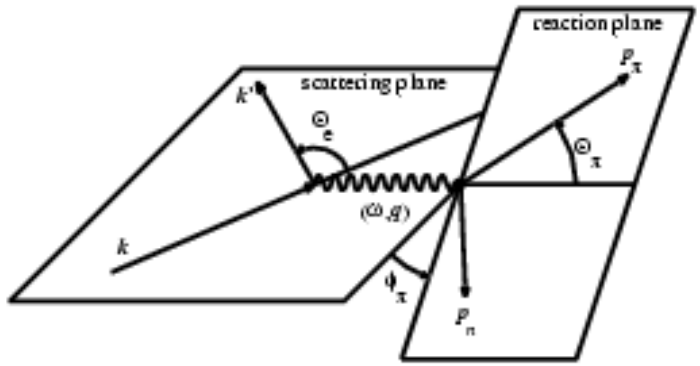
- Low $Q^2$ ($<0.28$ GeV$^2$):
  - scattering high-momentum pions off atomic electrons (CERN, Fermilab)
- Higher $Q^2$ can be reached in the reaction: $^1H(e,e'\pi^+)n$
  - **Quasi-elastic scattering of electron from virtual pion in proton (DESY, Cornell, JLab)**
  - previous data




E01-104

# Pion electroproduction

schematics for reaction




$$\frac{d^3\sigma}{dE'\,d\Omega_{e'}d\Omega_\pi} = \Gamma_V \frac{d^2\sigma}{dt\,d\phi}$$

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

$F_\pi$

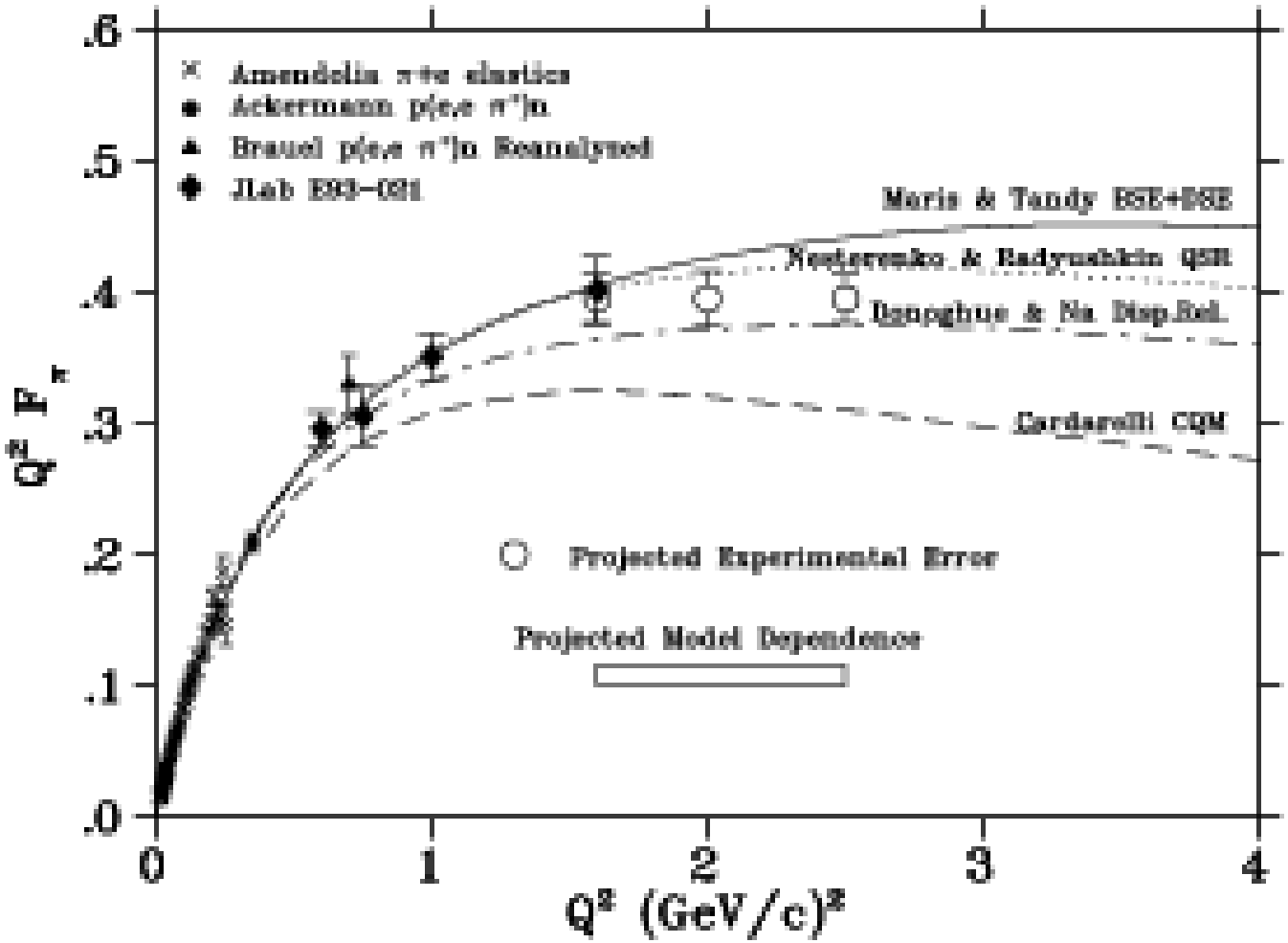
- φ dependence: $\sigma_{LT}$, $\sigma_{TT}$, and $\sigma_T+\varepsilon\sigma_L$
- Rosenbluth separation: $\sigma_T$ and $\sigma_L$

E01-104

# 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)

E01-104

# 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

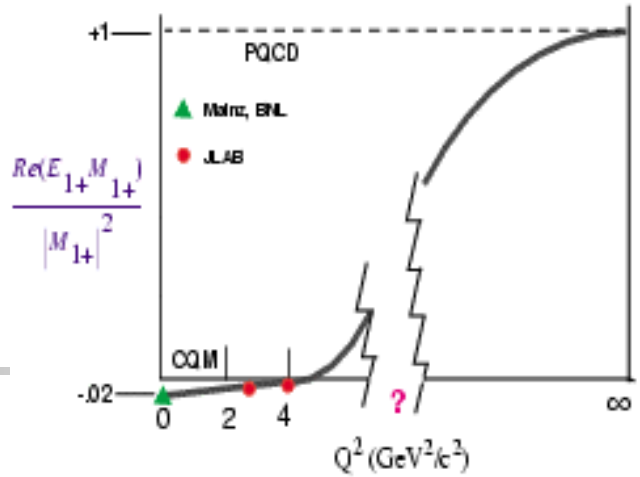
- Singles rates in HMS and SOS are well below detector capabilities (kHz)
- Particle Identification:
  - HMS: trigger *S1•S2* (3/4 scintillator arrays)
  - SOS: trigger *S1•S2•Electron*
  - TOF in HMS cannot be used for $p/\pi^+$ separation: use aerogel (n=1.030)
    - (see talk later today)

# Baryon Resonance Electroproduction at High Q2

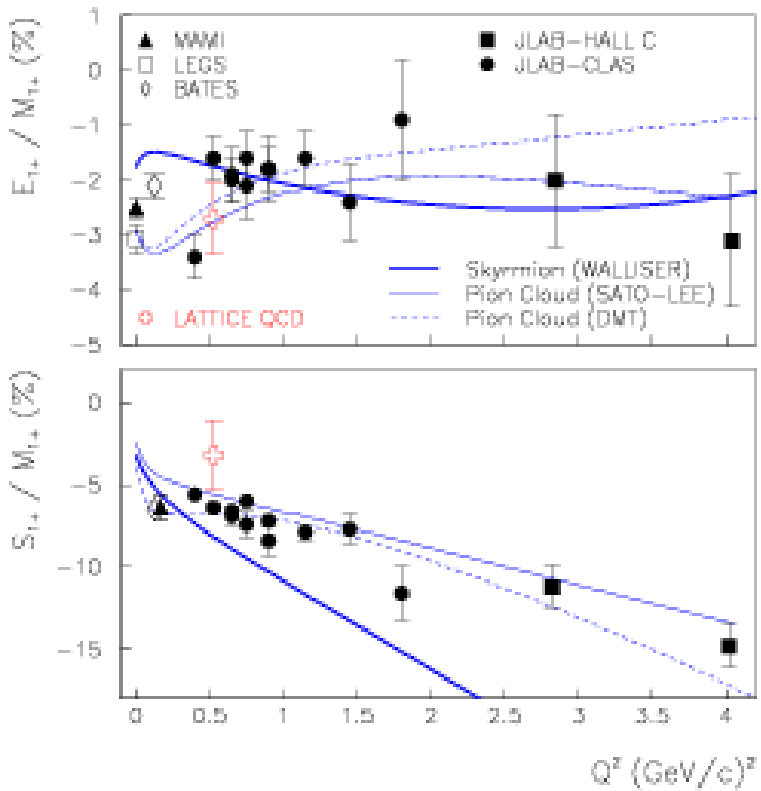
- Spokespersons: V. Frolov, V. Koubarovski, P. Stoler
- Scheduled to run between 4/29 and 6/18
- Extension of experiment E94-014
- "Study the evolution from low-to-high $Q^2$ physics and a search for definitive signals of the onset of hard perturbative reaction mechanisms"

E01-002

# Physics Motivation

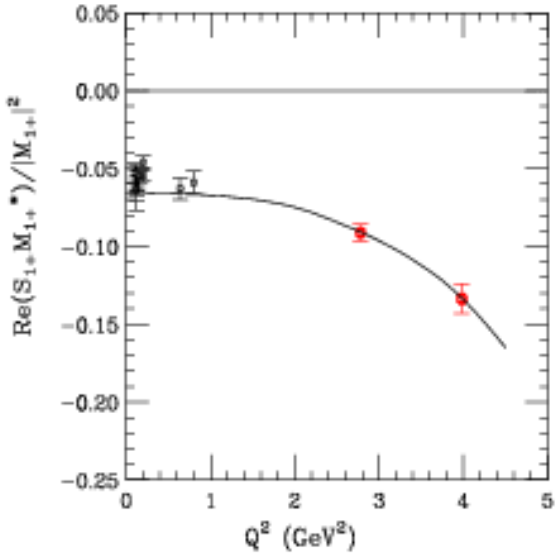



- The N→Δ transition form factors
  - Low $Q^2$ in CQM it is purely $M_{1+}$
  - Very high $Q^2$ in pQCD $E_{1+}/M_{1+} \rightarrow 1$
- Sensitive to possible deformation of the nucleon or the Δ(1232)




E01-002

Figure 4: The result of $S_{1+}/M_{1+}$ measurement of E94-014 at $Q^2 = 2.8$ and 4 GeV$^2/c^2$. At the lower $Q^2$ are recent data from Bates and Bonn. All data are the results of MAID [3] fits to the compiled recent world data. Fits using *dynamic models* [3, 10] yield somewhat different results.

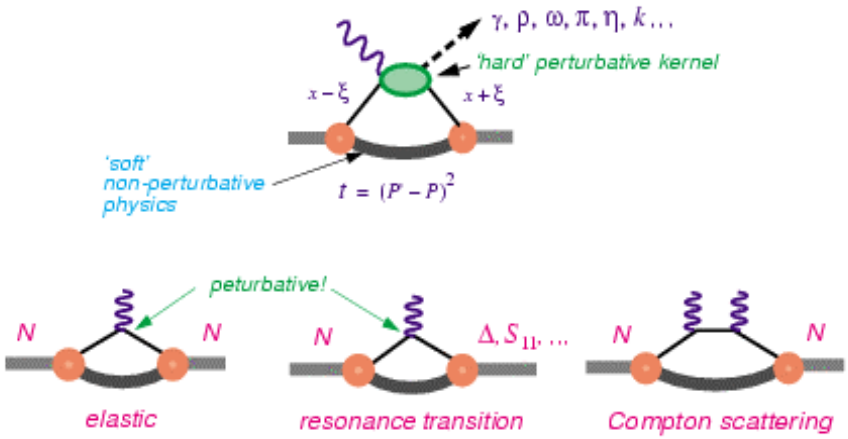



- The N→$S_{11}$(1535) transition form factors
  - $S_{11}$(1535) = lowest mass state with a $J^{\pi}$=1/2- with isospin ½: easier to model
  - Helicity conserving: Scaling in $Q^3A^p_{1/2}$ indicates transition from soft to hard processes
  - Can be isolated via the $\eta$ decay channel

E01-002

# 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




$$G_E^* = \int_{-1}^{+1} \sum_q H_E^q(\xi, x, t)\, dx$$

transition form factors

$$G_M^* = \int_{-1}^{+1} \sum_q H_M^q(\xi, x, t)\, dx$$

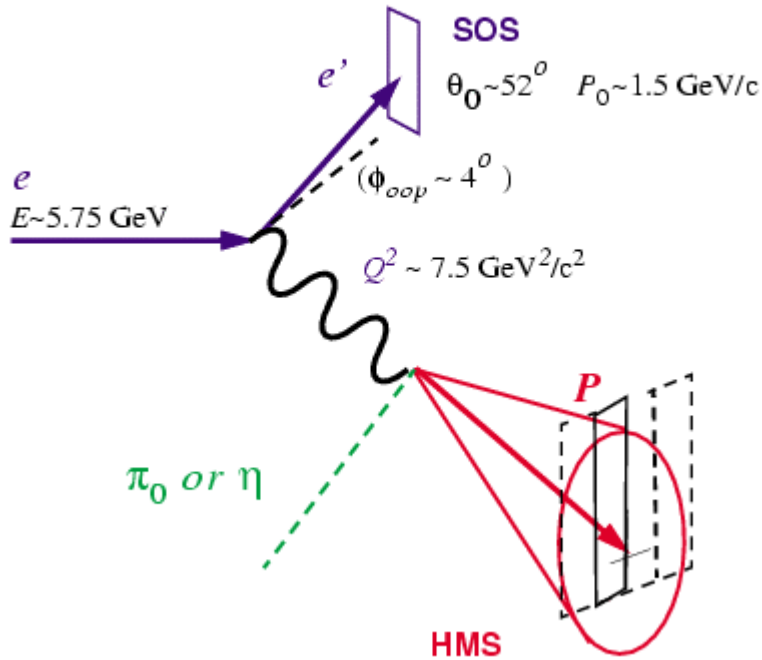
$H_M^q$ $H_E^q$ axial GPDs

# The Goal of E01-002

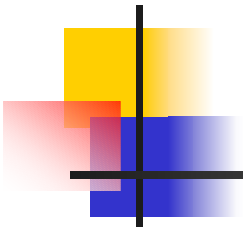
- Measure the reactions $p(e,e'p)\pi^0$ from the $\Delta(1232)$ and $p(e,e'p)\eta$ from the $S_{11}(1535)$ at $Q^2=7.5$ GeV$^2$
- Extract $E_{1+}$ /$M_{1+}$
- Projected uncertainty ?

# 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.




E01-002



- Targets:
  - 4cm H, empty (Al)
- Beam energy:
  - 5.496 GeV
- Beam current 100 μA
  - Standard Hall C beamline
  - Low profile beam pipe can be used
- Channel id.:
  - missing mass cuts

# The Duality Experiments

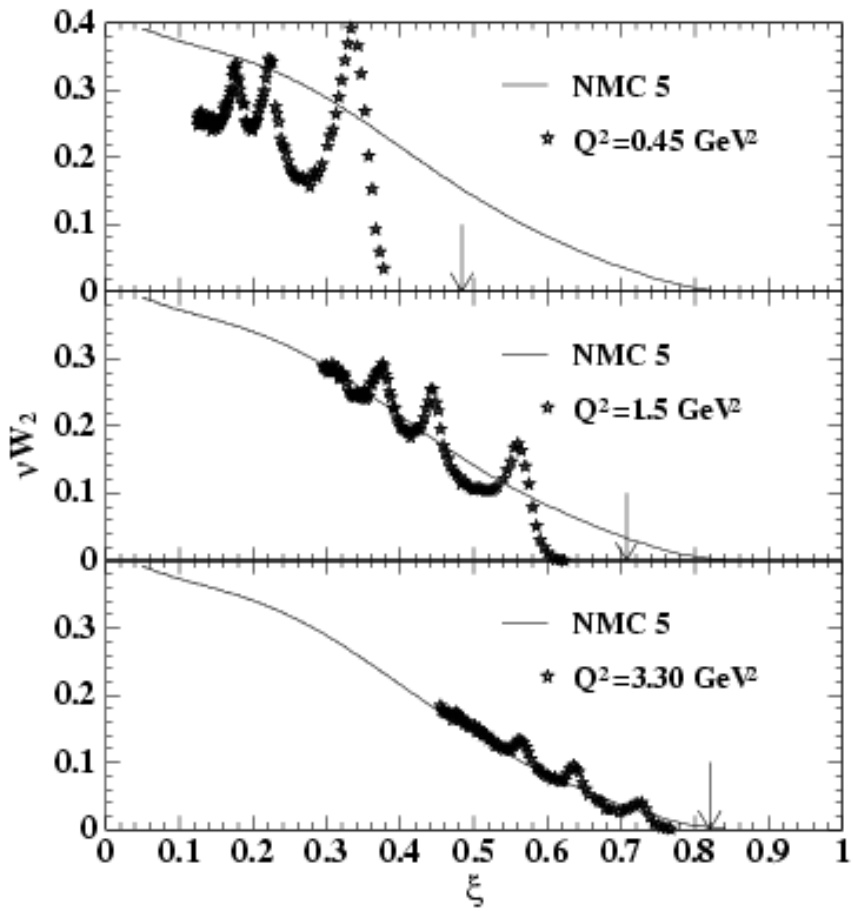
- **E00-002**: *"$F_2^N$ at Low $Q^2$"*
- **E00-116**: *"Duality at Intermediate $Q^2$"*
- **E00-108**: *"Duality in Meson Electroproduction"*

# 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

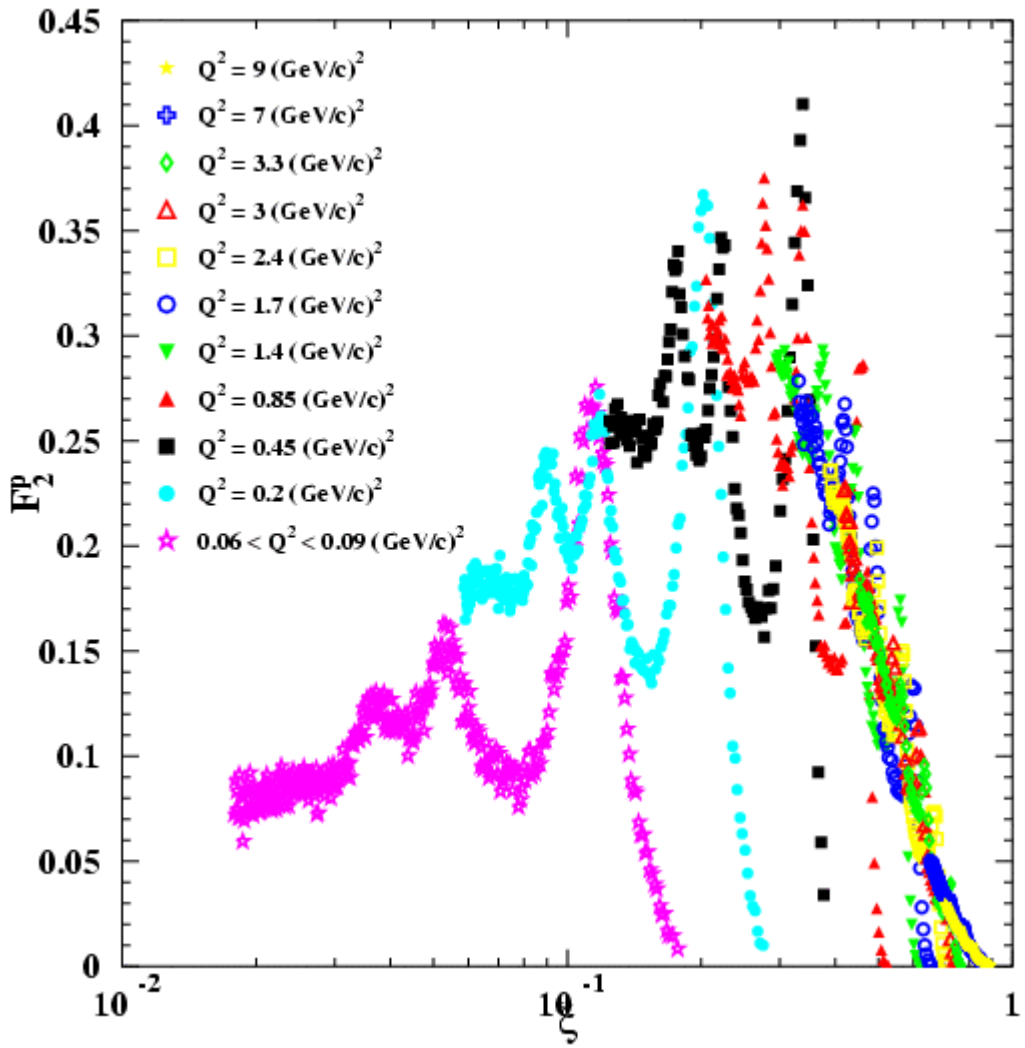
# Previous Results

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

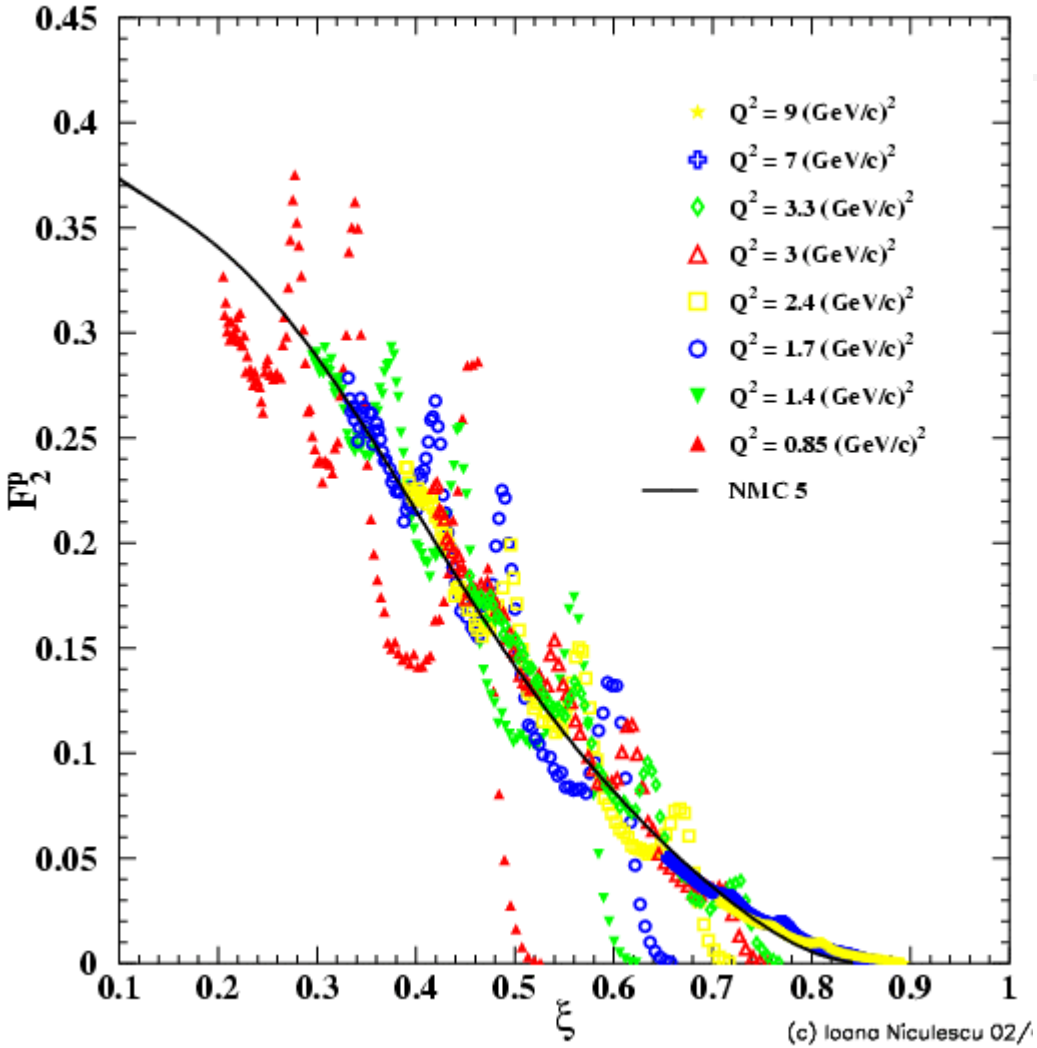


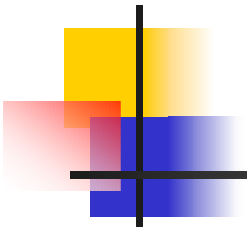
# Upcoming exp. will address:

- 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 $Q^2, W'^2 < 3$ GeV$^2$."

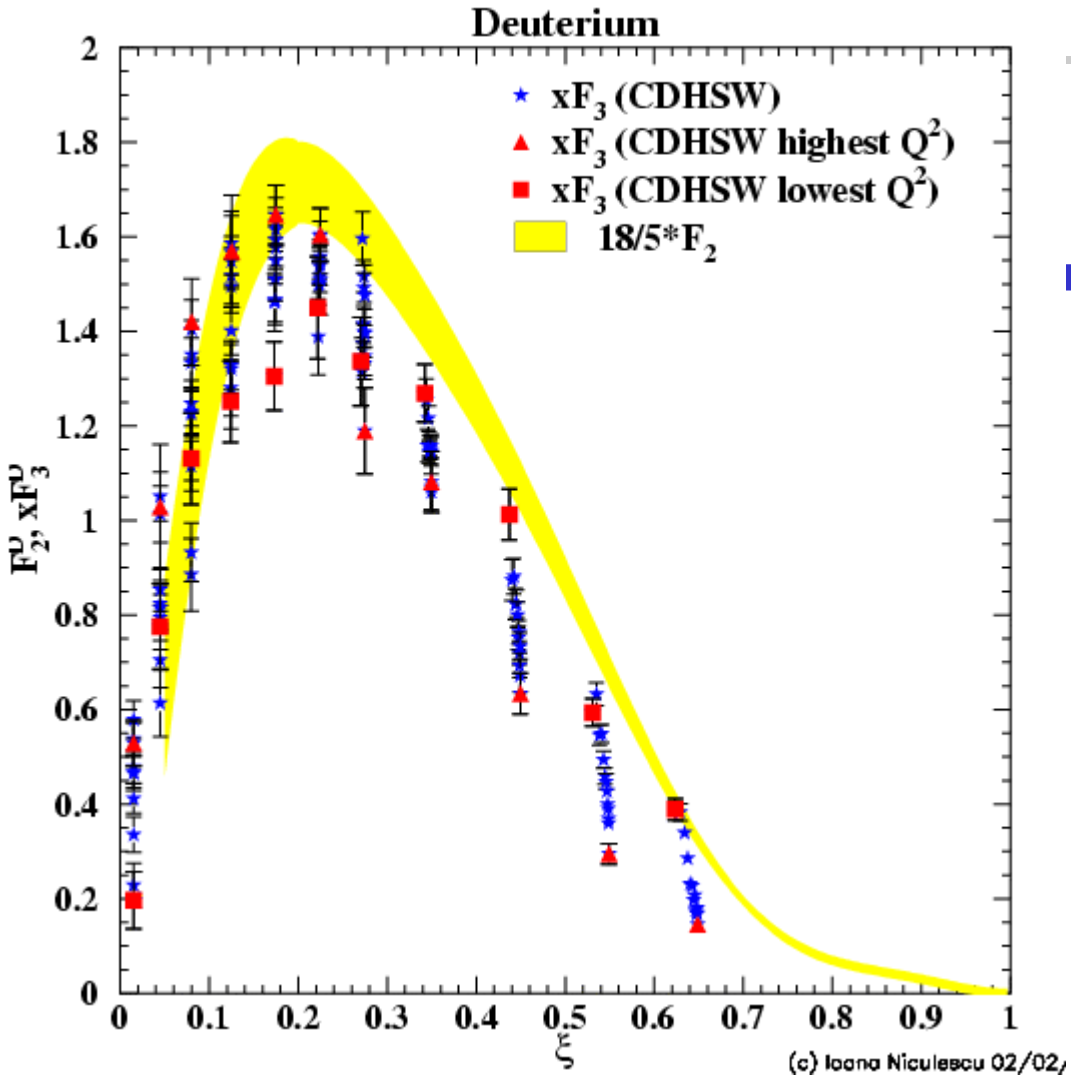
  (Isgur and Close, Phys.Lett. B509, 81,2001)

# $F_2^N$ 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"

E00-002

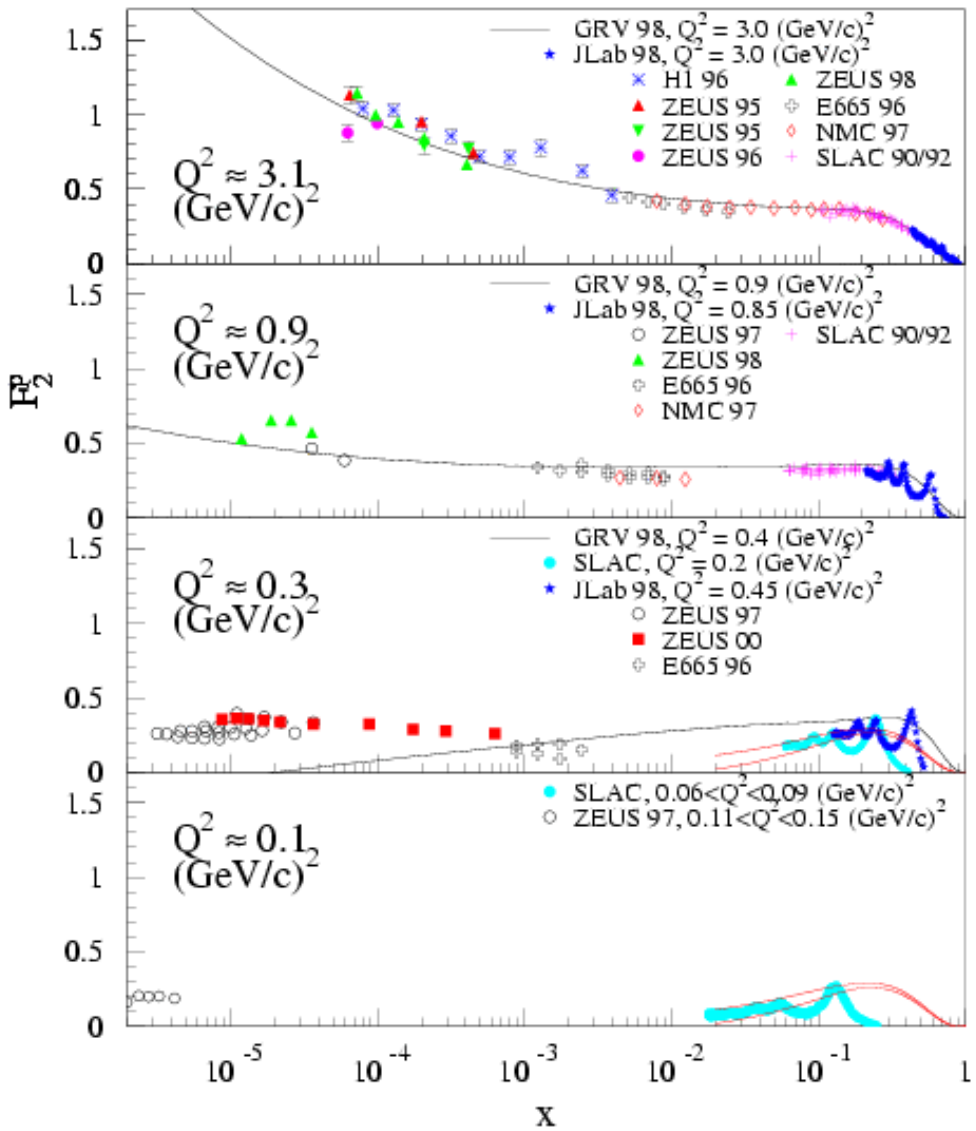
# Physics Motivation




- The Jlab scaling curve has similar shape to $xF_3$ (valence structure)

E00-002

- 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

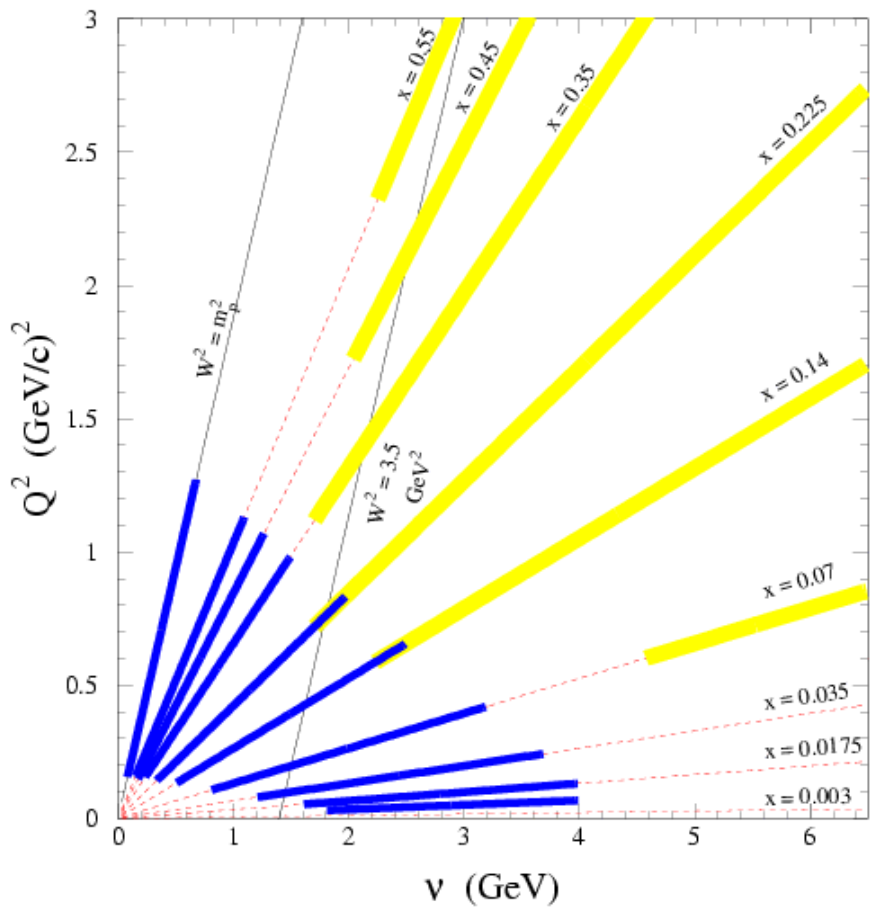


# The Experiment

- Single arm experiment (e- in HMS)
- HMS at forward angle $10.5^{o}$
  - 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 50$\mu$A

# The Goal of E00-002

- Measure cross section for reactions
  - H(e,e')
  - D(e,e')
- $0.03<Q^2<1.5$ GeV
- $0.007<x<1.$
- Uncertainty in cross section ~3%
- Extract $F_2$ for proton and deuteron

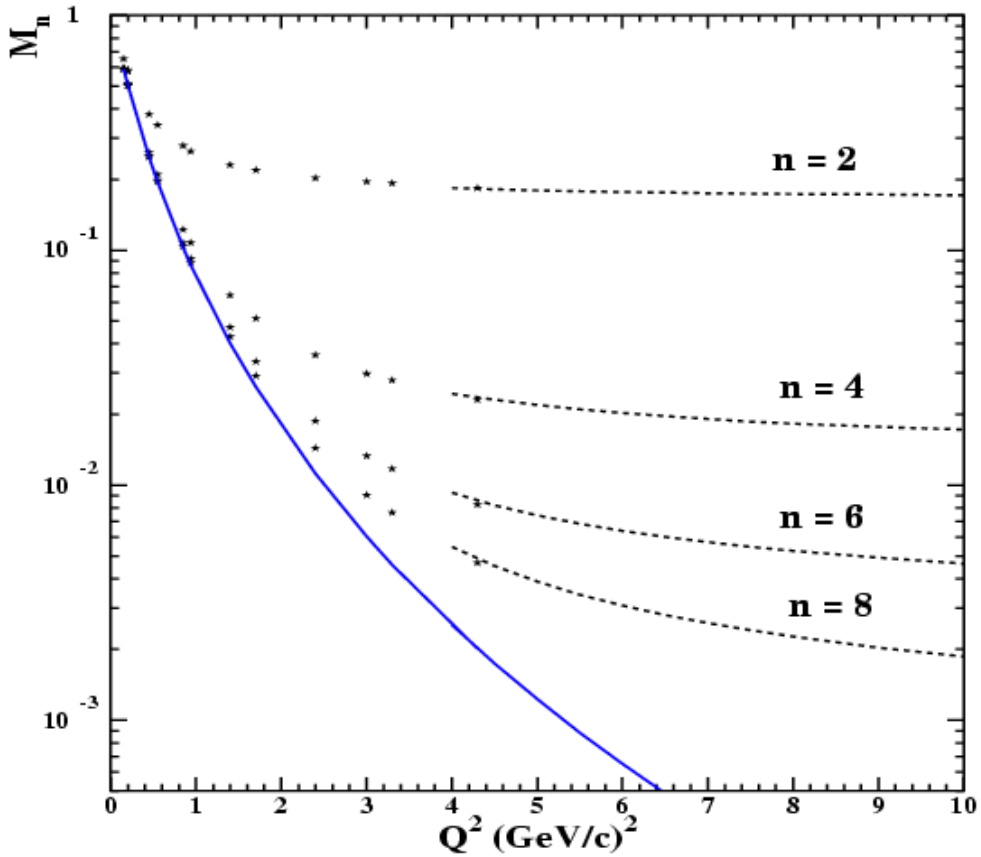



E00-002

# 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 ~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

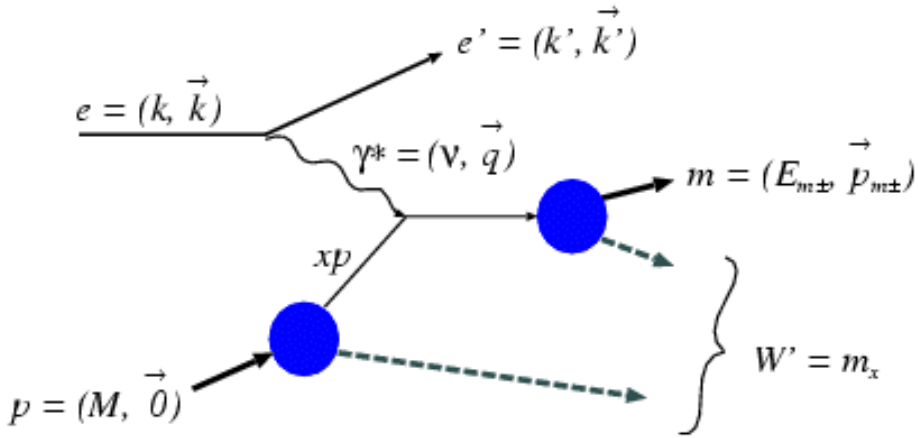
- Single arm experiment (e- in HMS and SOS)
- HMS used also to measure e+ rates
- Beam energy 5.496 GeV
- Targets:
  - 4 cm H, D, and empty target
- Beam current 50$\mu$A

# 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"

E00-108

# Kinematics




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

$z$ = **fraction of virtual photon energy taken away by meson**

$$W'^2 = W^2 - 2z\nu(m_p + \nu - |\vec{q}|\cos\vartheta_{qm})$$

# Physics Motivation

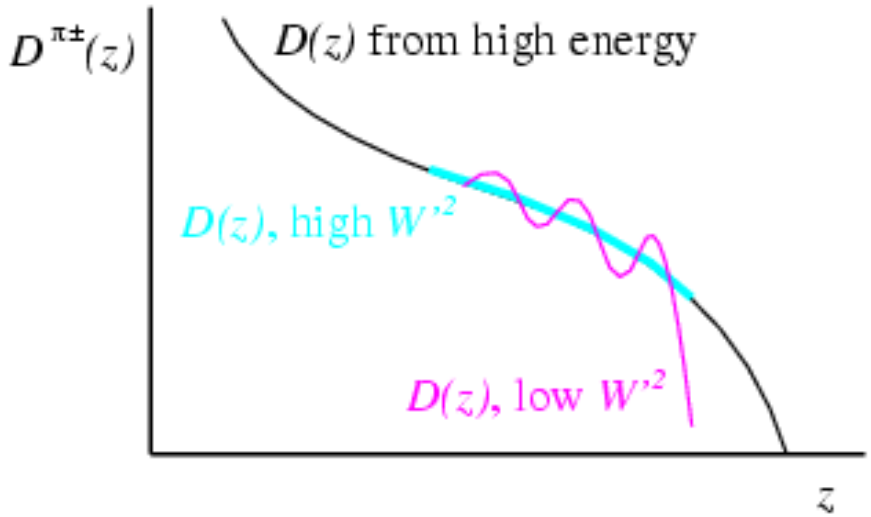
At high energies: factorization (pQCD)

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

quark hadronization

hard quark-photon interaction

If duality holds: *may see behavior consistent with factorization even at lower energies.*




Duality in meson electroproduction:

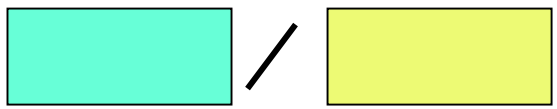
look for duality in *f(z)*

- Spectra in z at low $Q^2$ and W average to scaling curve (high $Q^2$ and W)?
- Q2 behavior of resonant bumps
- Relative strength of resonances/ background at different $Q^2$

# The Goal for E00-108

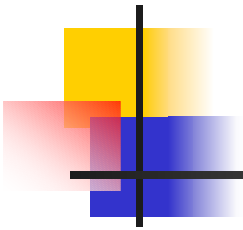
- Measure cross sections

$$\frac{d\sigma}{d\Omega_e dE_e d\Omega_m dp_m} \quad \text{and} \quad \frac{d\sigma}{d\Omega_e dE_e}$$

- $1.8<Q^2<6$ and $0.2<x<0.7$
- Extract $dN/dz \propto$  / 
- Statistical uncertainties ~ 1-2%
- Systematic uncertainties ~ 5-10%

# The Experiment

- Coincidence HMS (mesons)+SOS(e-)
- HMS at forward angle $10.5^{o}$
  - 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.