Overview of CLAS Physics

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Florida State University
Tallahassee, FL

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Outline

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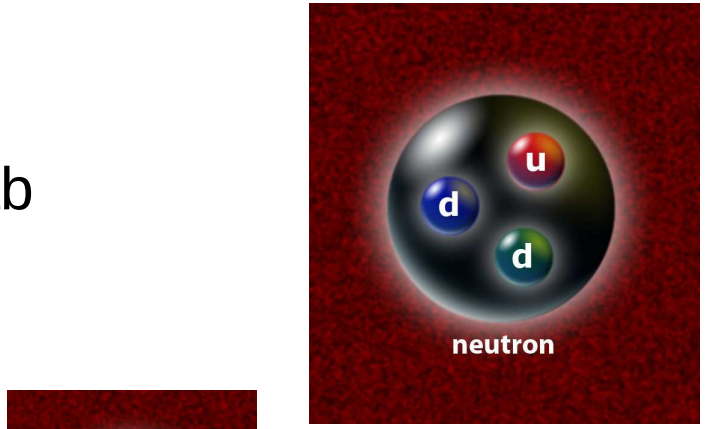

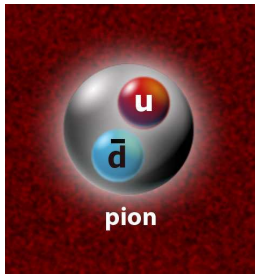

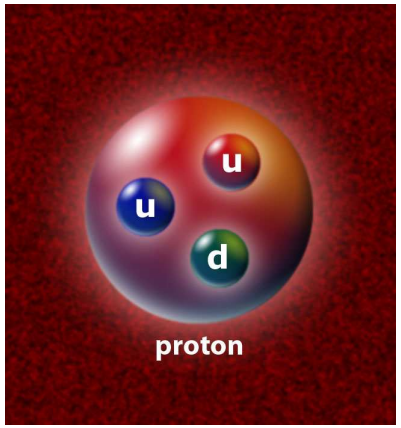

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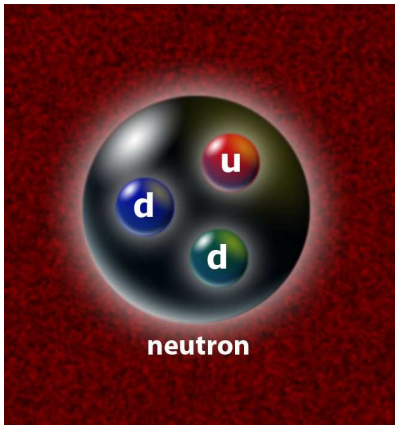
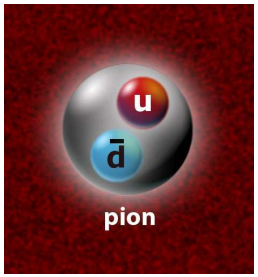
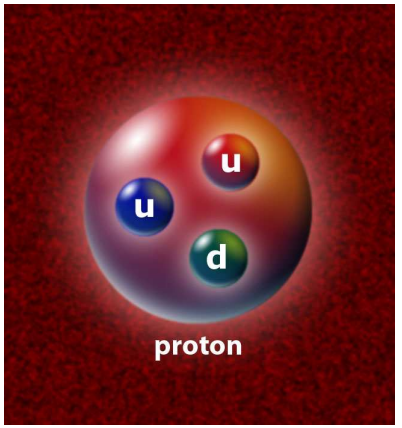




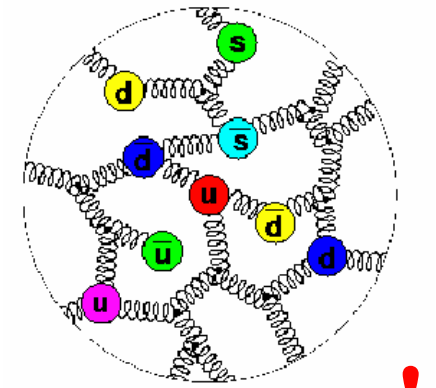


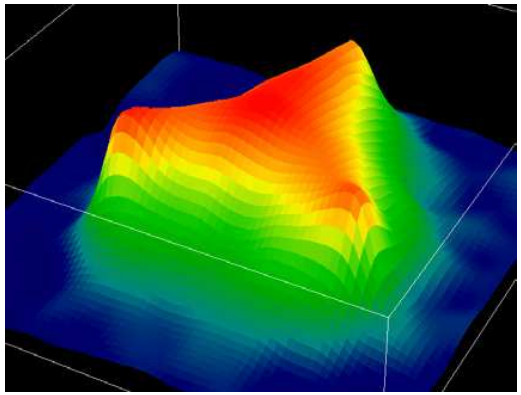
Physics with the CLAS Detector

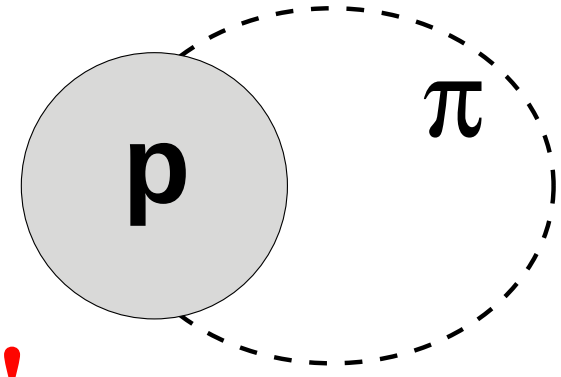
Wide range of experiments covering mostly

- Meson spectroscopy
  - ➜ P. Eugenio, Tuesday: 10h20
- N^* Program (baryon spectroscopy, transition form factors)
  - ➜ M. Williams, K. Park, V.C., this session
- Nucleon structure (through)
  - Elastic scattering
  - Deep inelastic scattering
    - ➜ S. Niccolai (GPD's), Monday: 14h00
- Nuclear transparency and nucleon correlations in nuclei

$\ll 0.1$fm | 0.1 – 1.0 fm | > 1.0 fm







pQCD
q, g, $q\bar{q}$

? ! ↔ ? !

Models
Quarks and Gluons
as Quasiparticles

? ! ↔ ! ?

ChPT
Nucleon and
Mesons

1. What are the relevant degrees of freedom?
2. What are the corresponding effective interactions responsible for hadronic phenomena?

One of the main goals of CLAS ...

Search for *missing* resonances

Quark models predict many more baryons than have been observed

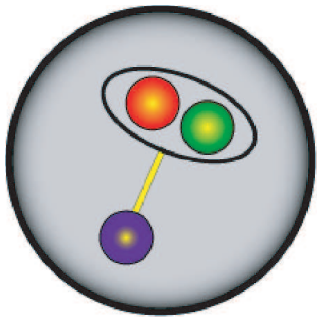
	****	***	**	*
N Spectrum	11	3	6	2
Δ Spectrum	7	3	6	6

$\Rightarrow$ according to PDG
(Phys. Rev. **D66** (2002) 010001)

$\Rightarrow$ little known
(many open questions left)

Possible solutions:

1. Quark-diquark structure



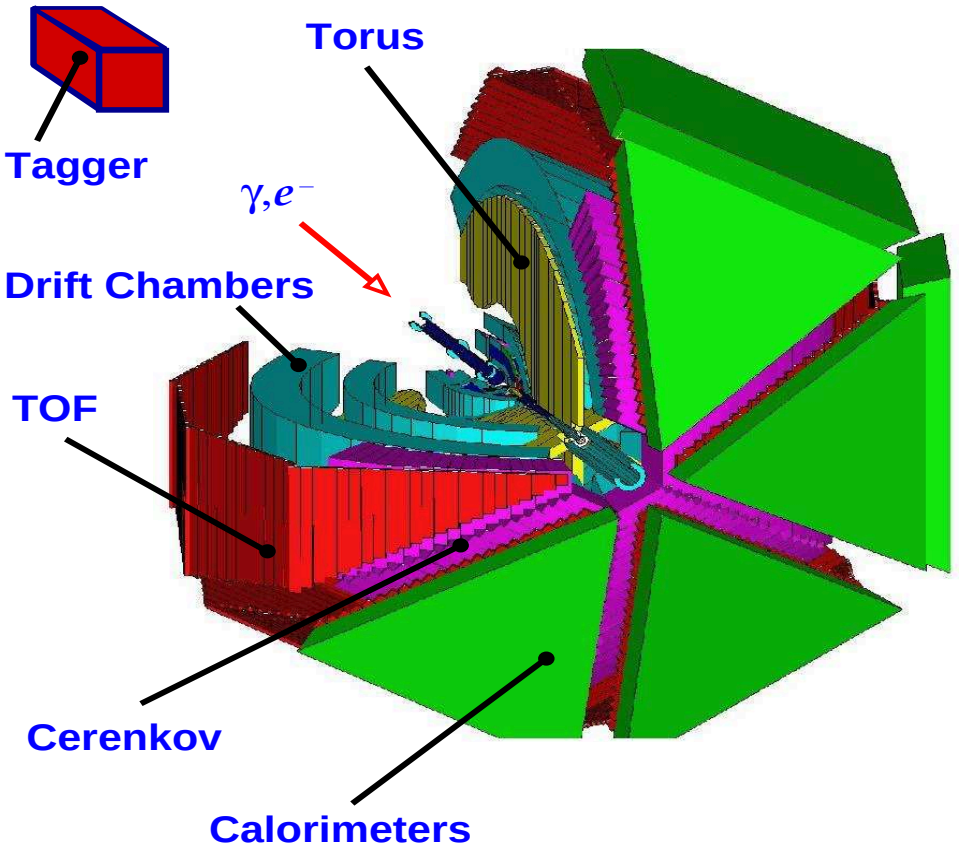
one of the internal degrees of freedom is frozen

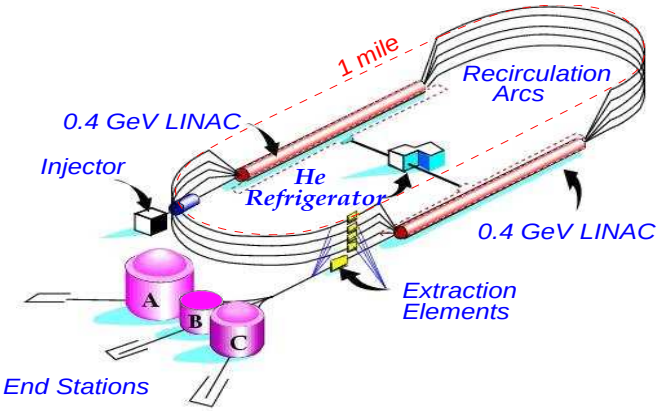
2. Have not been observed, yet

Nearly all existing data result from πN scattering experiments

➜ If the missing resonances did not couple to Nπ, they would not have been discovered!!

CLAS Spectrometer





CHARACTERISTICS:

Electron Coverage: $\theta : 15\text{–}50^{o}$

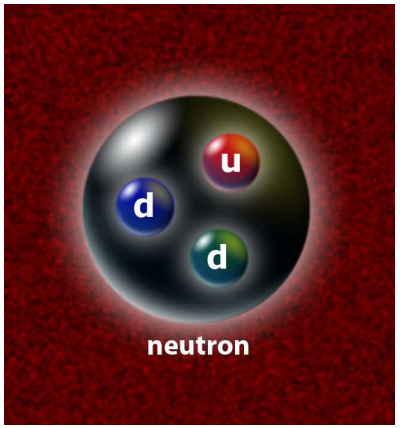
Hadron Coverage:

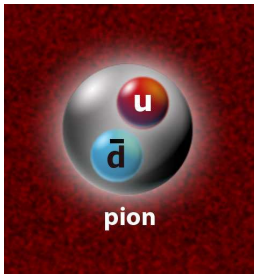
$\theta : 15\text{–}140^{o}$, $\phi : 80\%\ 2\pi$

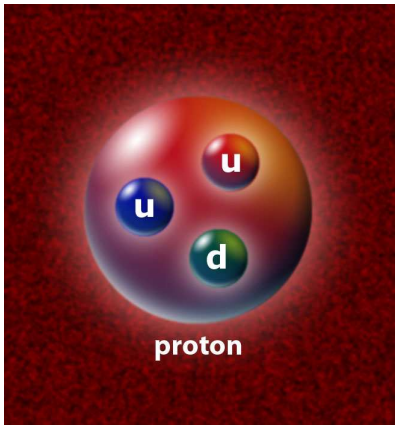
Resolution : $\Delta p/p \sim 1\text{–}2\%$
$\Delta\theta, \Delta\phi \sim 2\ mrad$

$$\mathcal{L} = 1 \times 10^{34}\ cm^{-2} sec^{-1}$$
$$\mathcal{F}_{\gamma} = 1 \times 10^{7}/s$$

Outline





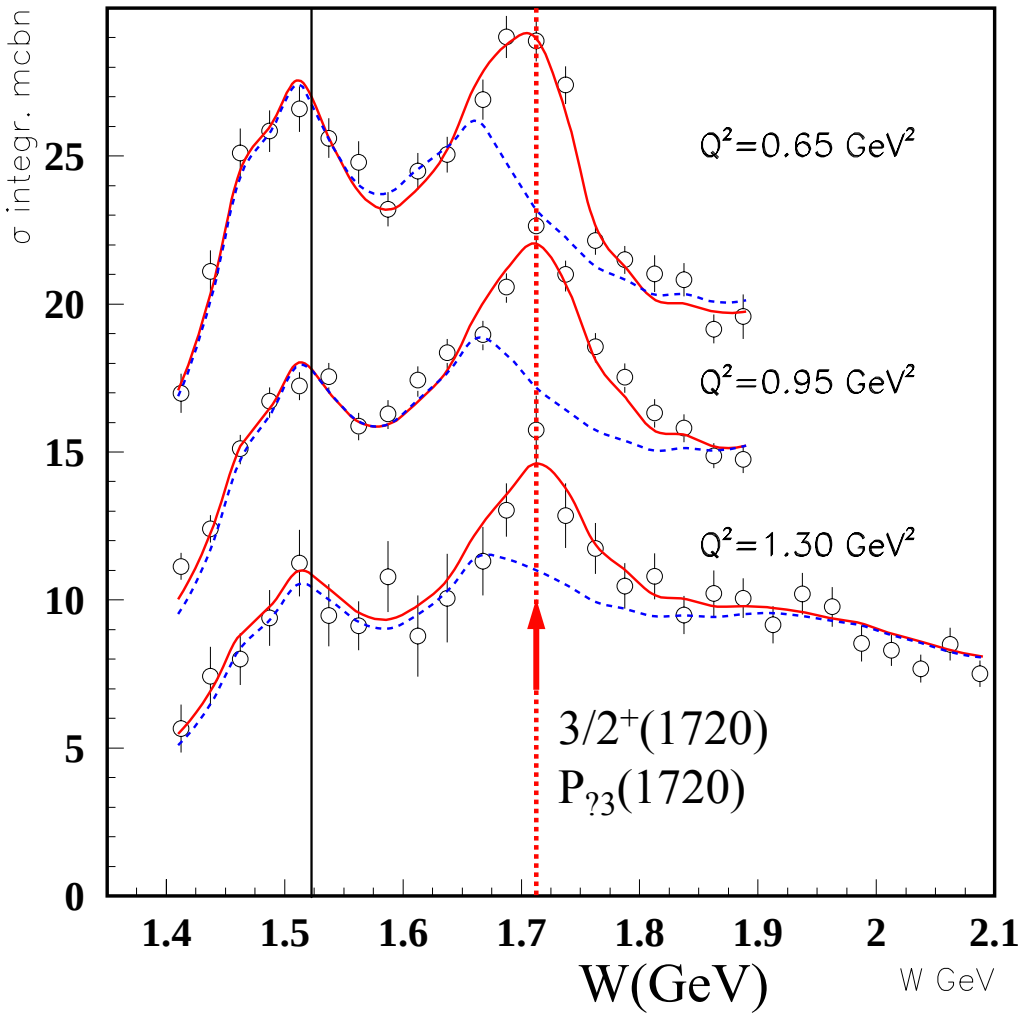


The Excited Baryon Program at JLab

The excited baryon program has two main components:

- Establish the systematics of the spectrum
  - ➜ Provides information on the nature of effective degrees of freedom in strong QCD
- Probe resonance transitions at different distance scales (electron beams are ideal to measure transition form factors)
  - ➜ Provides information on the confining forces of the 3-quark system

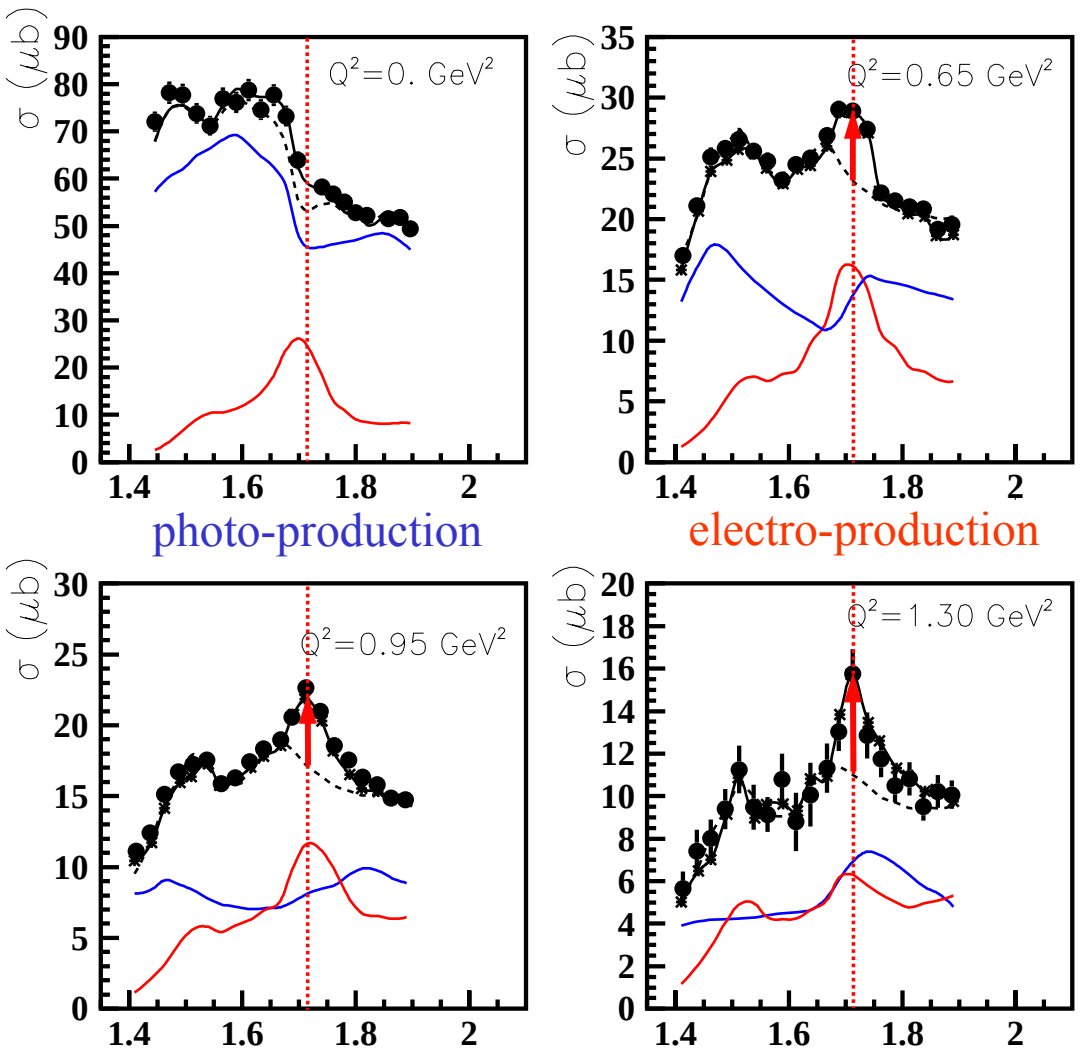
Resonances in $\gamma^{(*)}p \rightarrow p\pi^+\pi^-$



- 2π channel sensitive to N*'s heavier than 1.4 GeV
- Provides complementary information to the 1π channel
- Many higher lying N*'s decay preferably to $N\pi\pi$ final states via intermediate states

Solid curves are from fits using the recent JM06 model with and without a new ?(1720)$P_{?3}$ state

Resonances in $\gamma^{(*)}p \rightarrow p\pi^+\pi^-$



- Background
- Resonances

Combined analysis of preliminary real (M. Bellis) and also published virtual photon data (M. Ripani):

Fit needs both the candidate ?(1720)$P_{?3}$ and the N(1720)P_{13} state.

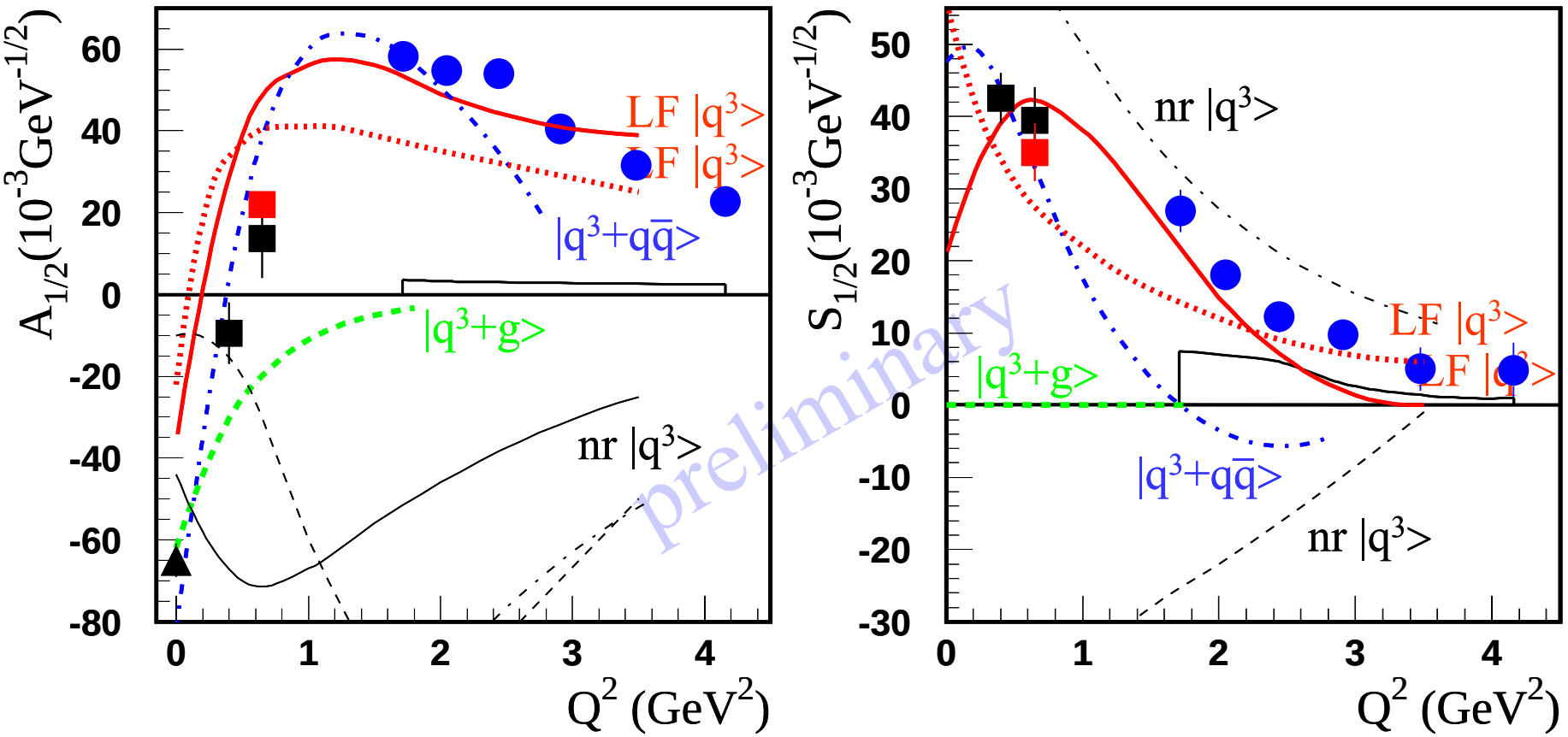
Authors claim that combined fit of various single differential cross sections allowed to establish all significant mechanisms.

Reasonable Description of $N\pi/N\pi\pi$ Electroproduction

The CLAS-Collaboration phenomenological models (UIM/DR/JM) reproduce reasonably well comprehensive CLAS/world data on all observables in $N\pi/N\pi\pi$ electroproduction:

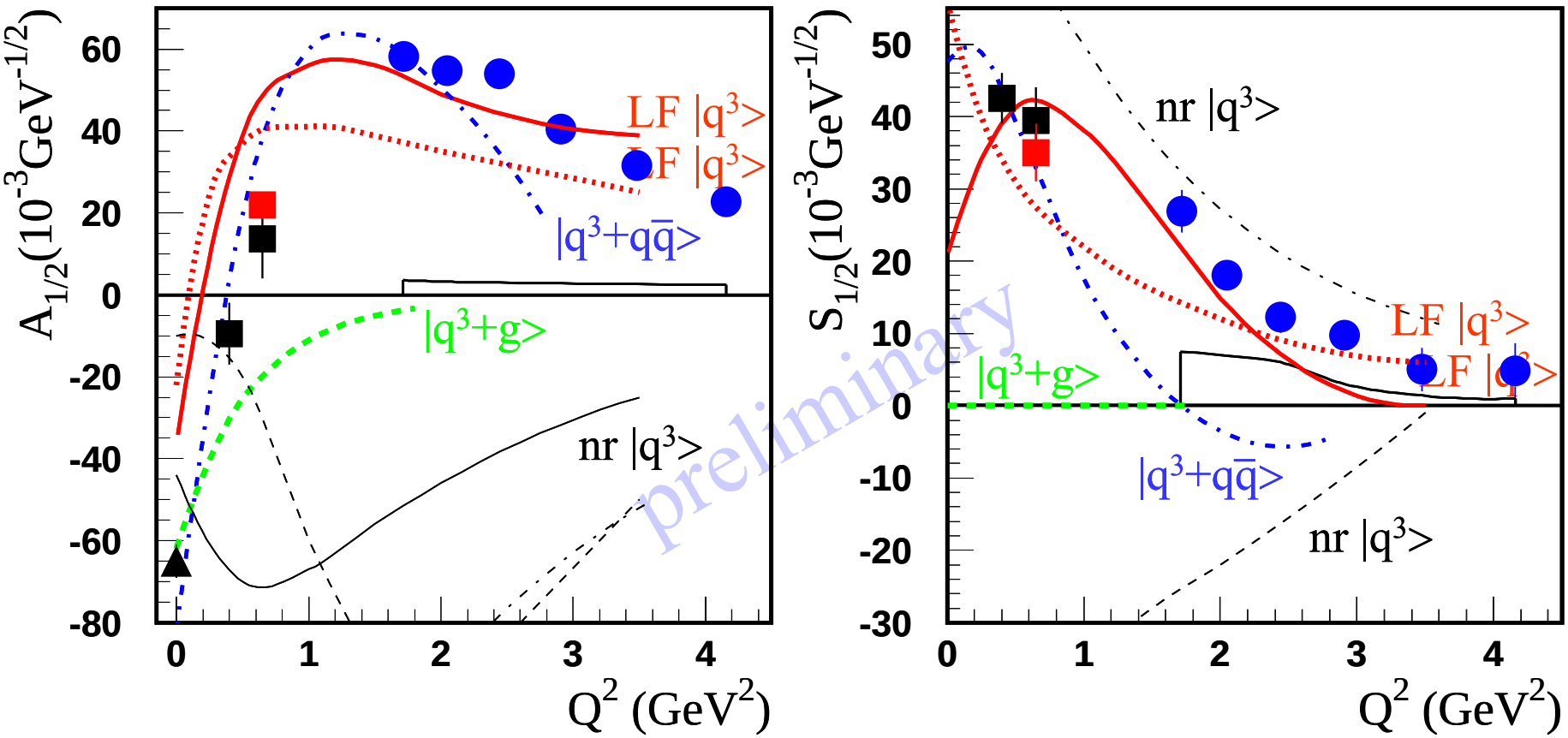
- Isobars used in $N\pi\pi$ electroproduction
  1. All well-established $N^* \to \pi^- \Delta^{++}$ decays + $3/2^+(1720)$
  2. All well-established $N^* \to \rho\pi$ decays + $3/2^+(1720)$
  3. Observed for the first time in CLAS data:
     $\pi^+ D^0_{13}(1520)$, $\pi^+ F^0_{15}(1685)$, and $\pi^- P^{++}_{33}(1640)$
- Models can be used to evaluate N^* electrocouplings
  ➜ Information on contributing mechanisms will be used by EBAC for N^* studies in advanced coupled channel analysis (Julia-Diaz, Lee, Phys. Rev. C**76**, 065201 (2007))

Roper Electro-Coupling Amplitudes $A_{1/2}$, $S_{1/2}$



Is Roper a 3-quark state?

Roper Electro-Coupling Amplitudes $A_{1/2}$, $S_{1/2}$

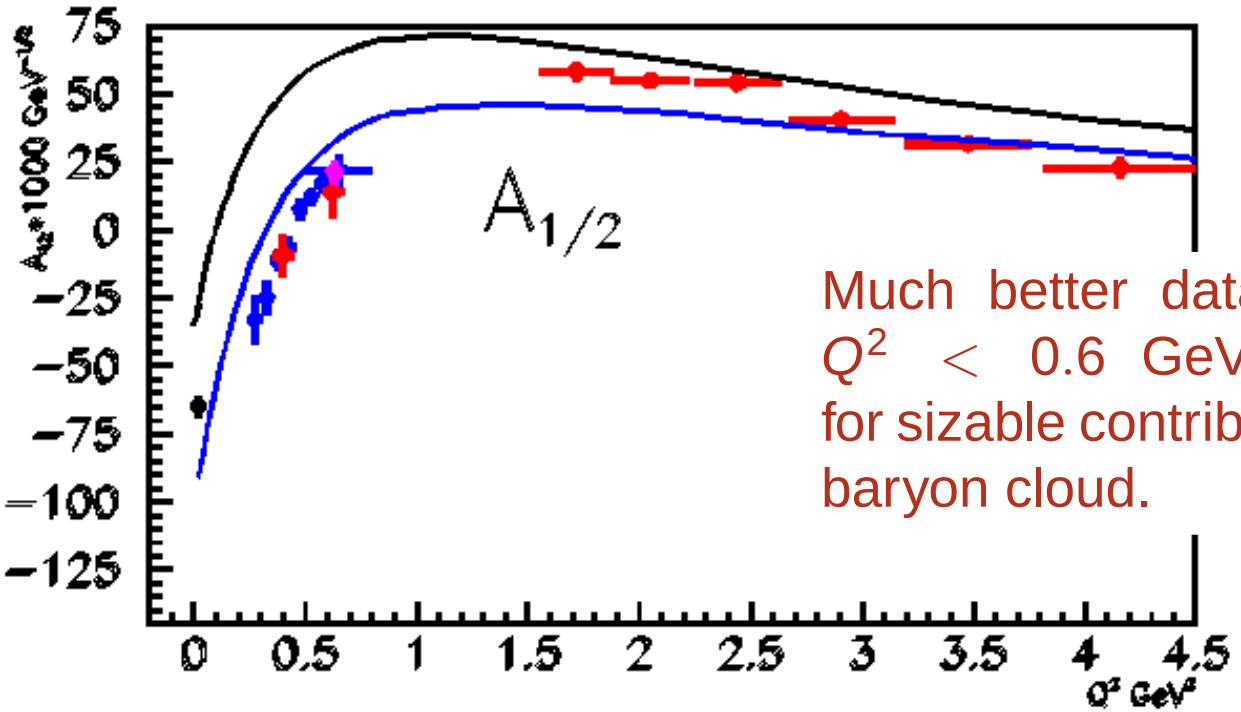


Is Roper a 3-quark state? Hybrid (glue) nature ruled out.

Roper Electro-Coupling Amplitudes $A_{1/2}$

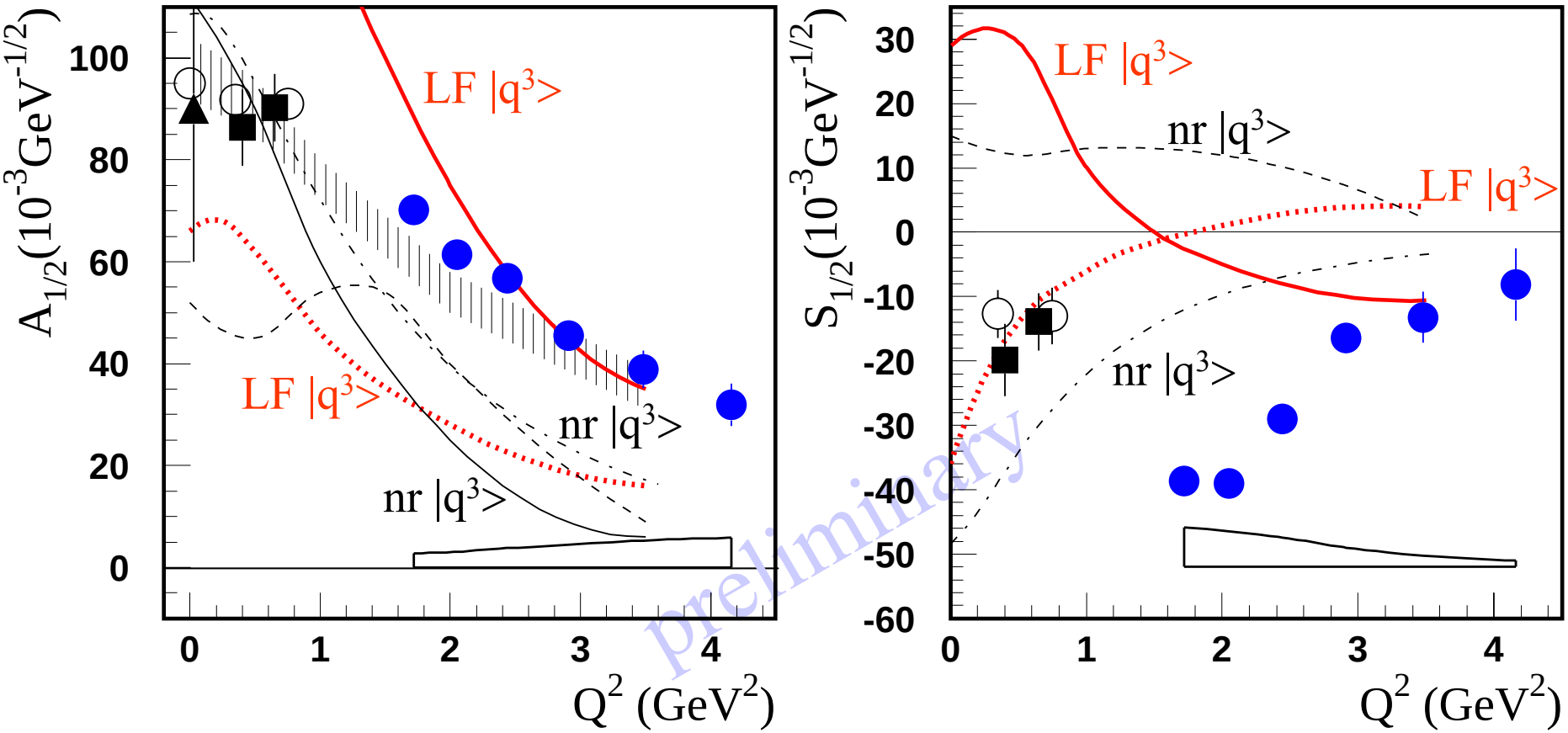
- Bare electrocouplings (from I. Aznauryan)
- Dressed electrocouplings (accounting for only Nπ in dressing)

(B.Julia-Diaz, T-S.H.Lee, et.al, Phys. Rev. C**77**, 045205 (2008))



Much better data (description) at $Q^2 < 0.6$ GeV^2 offer evidence for sizable contribution from meson-baryon cloud.

$S_{11}(1535)$ Electro-Coupling Amplitudes $A_{1/2}$, $S_{1/2}$



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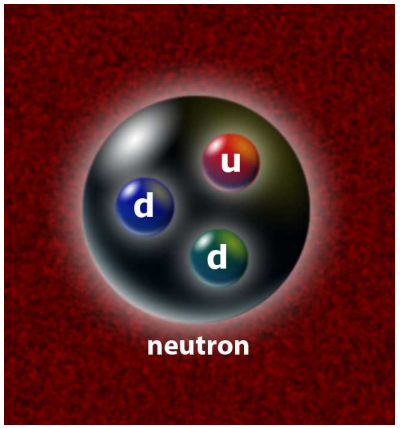
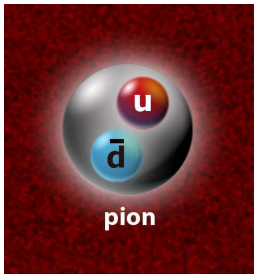
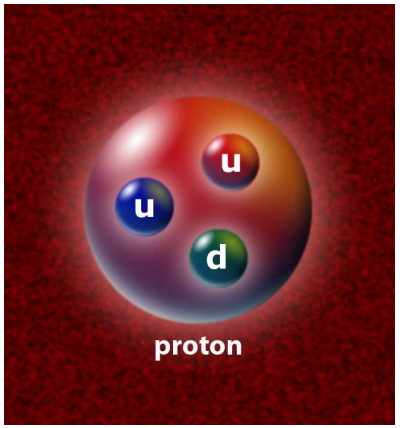
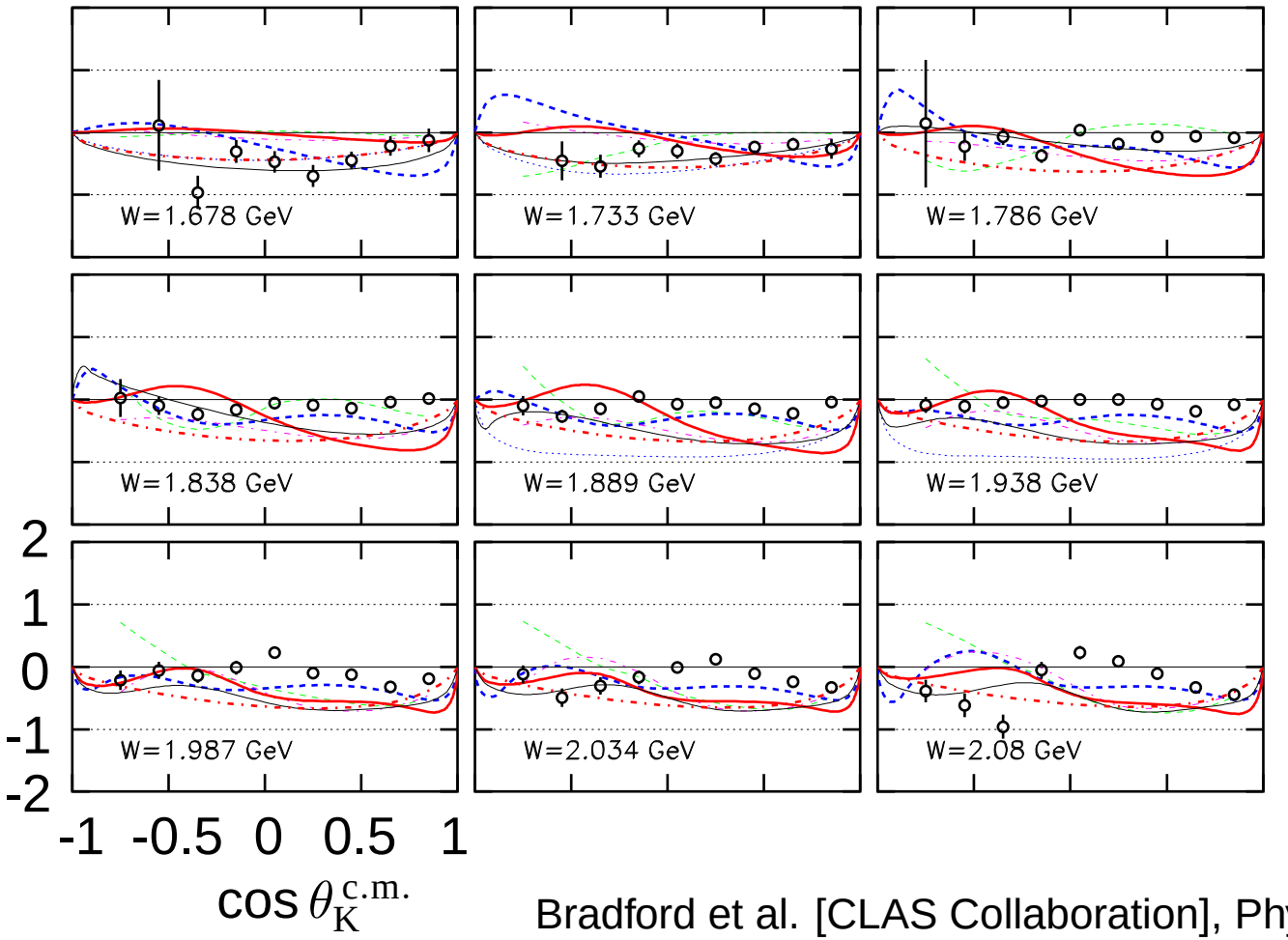






C_x (and C_z) in Hyperon Photoproduction



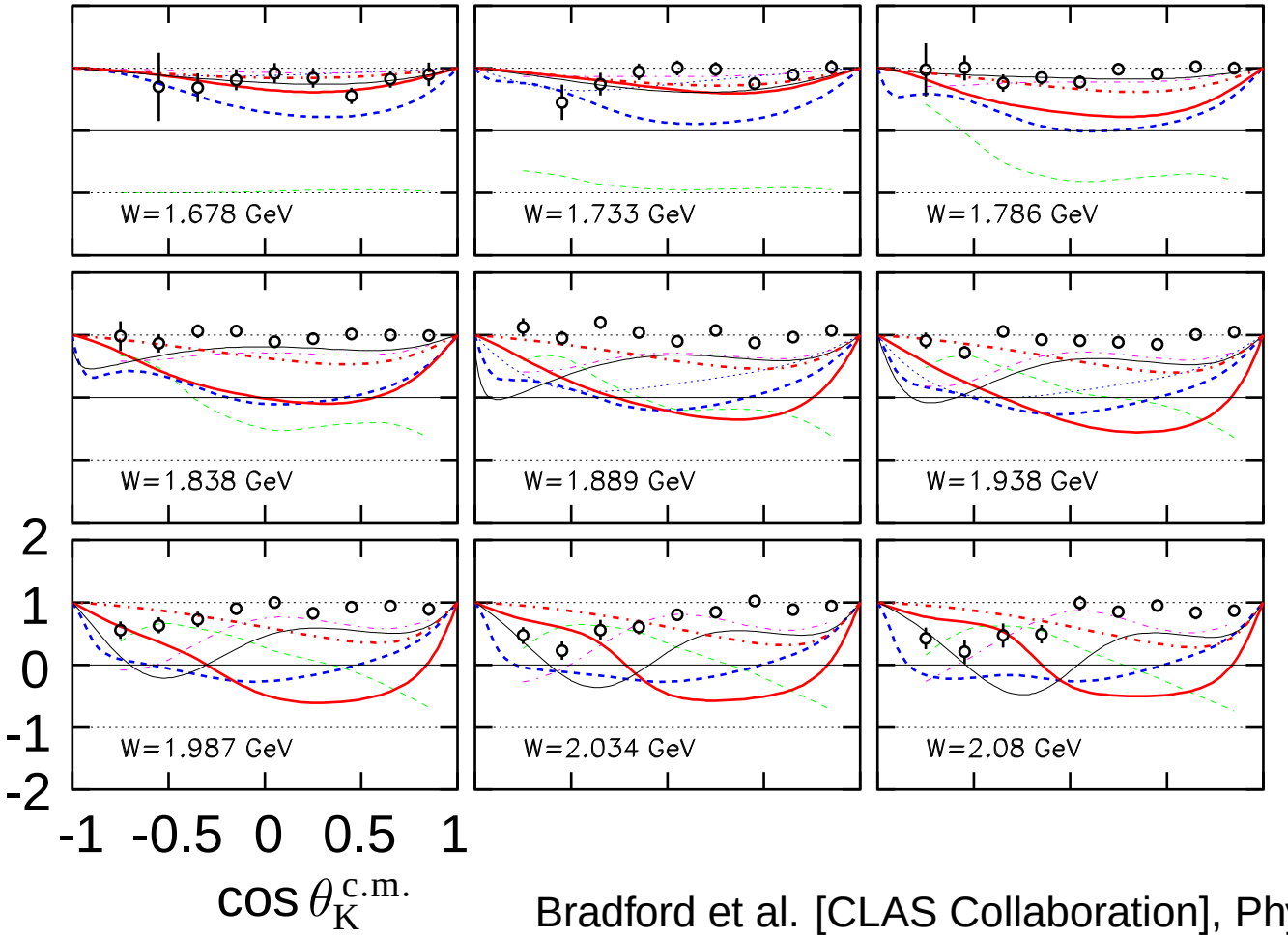
$\vec{\gamma}\mathrm{p} \rightarrow \mathrm{K}^{+} + \vec{\Lambda}$

Circularly-polarized beam

C_x/C_z characterize polarization transfer from beam to recoiling hyperon

Bradford et al. [CLAS Collaboration], Phys. Rev. C **75**, 035205 (2007)

(C_x and) C_z in Hyperon Photoproduction

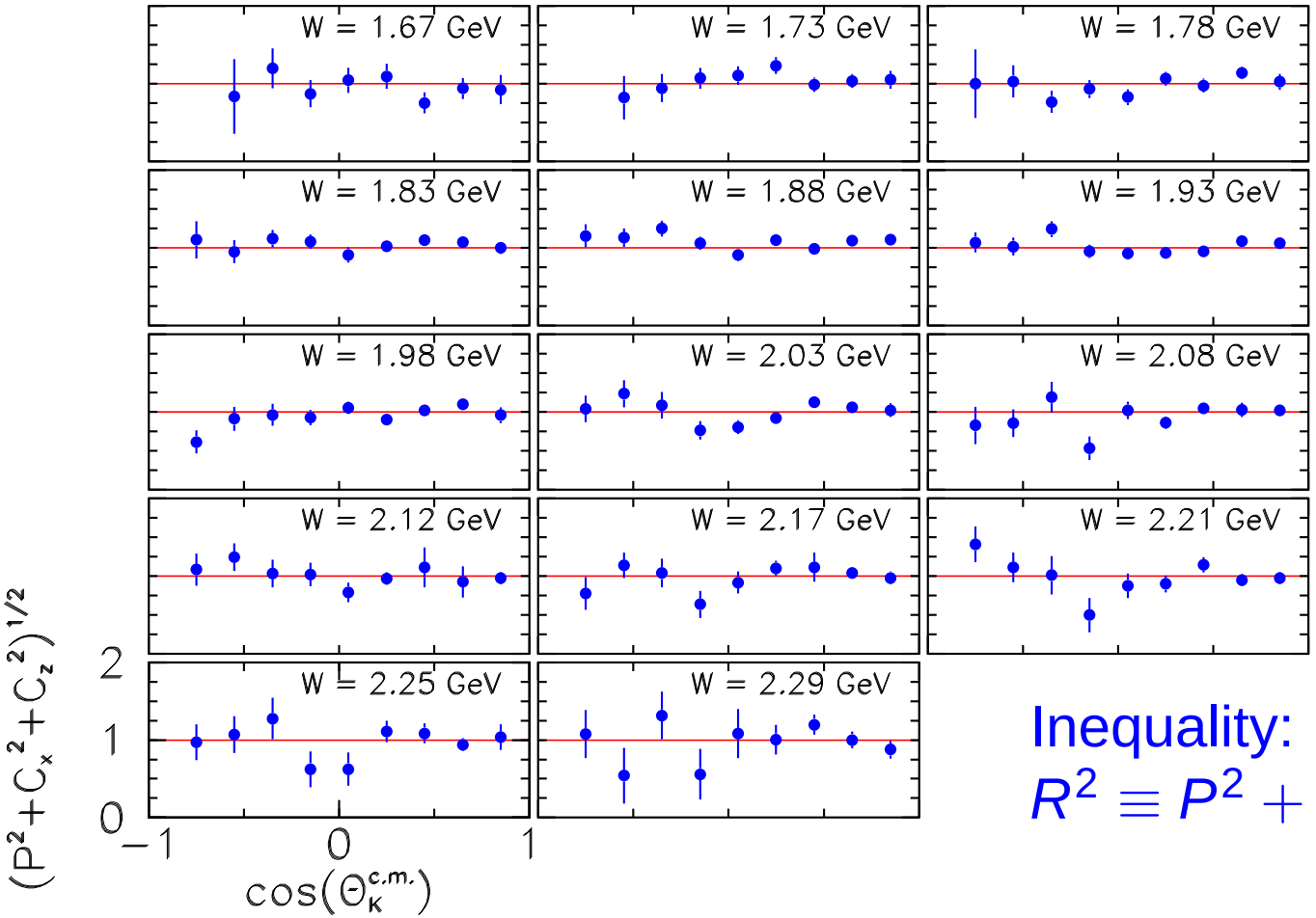


Circularly-polarized beam

Possible relation:
$C_z \approx C_x + 1$

Bradford et al. [CLAS Collaboration], Phys. Rev. C **75**, 035205 (2007)

C_x and C_z in Hyperon Photoproduction



Conclusion:

Λ hyperons appear 100 % spin polarized.

Kinematically not required, unknown origin!

Inequality:

$$R^2 \equiv P^2 + C_x^2 + C_z^2 \leq 1$$

The CLAS Polarization Program

The Double-Polarization Program (FROST) at JLab:

- E 02-112 $\Rightarrow$ *Photoproduction of Hyperons* ($K^+\Lambda$ (Σ^0), $K^0\Sigma^+$)
- E 03-105 $\Rightarrow$ $\pi^0 p$, $\pi^+ n$ *Photoproduction*
  E 04-102
- E 05-012 $\Rightarrow$ η *Photoproduction*
- E 06-013 $\Rightarrow$ $\pi^+\pi^-$ Photoproduction

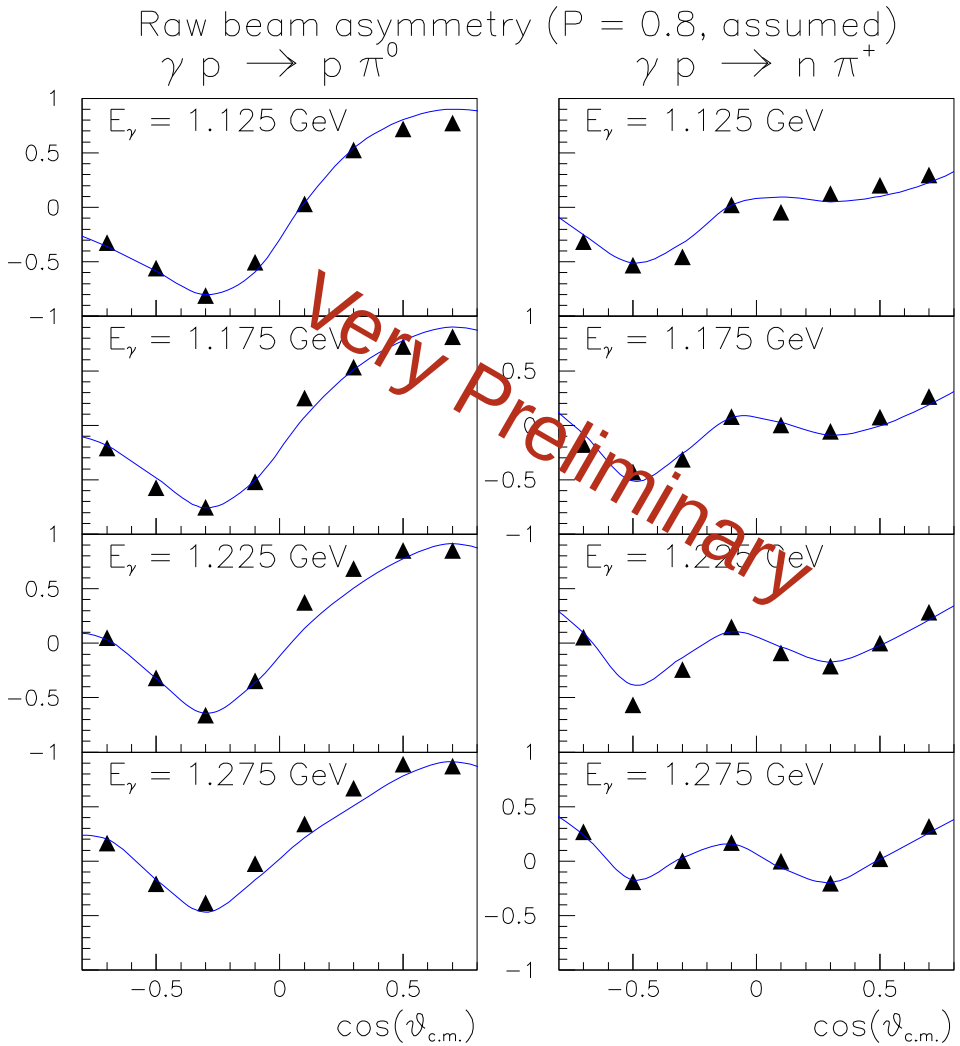
The Polarized Deuterium-Target Program (HD-Ice target from BNL):

- E 06-101 $\Rightarrow$ $\gamma n \rightarrow \pi^- p$, $\pi^+\pi^- n$, $K\ Y$ ($K^0\Lambda$, $K^0\Sigma^0$, $K^+\Sigma^-$)

Polarized photon beams on unpolarized targets:

- g1, g8 $\Rightarrow$ Reactions on Hydrogen (✓)
- g13 $\Rightarrow$ Reactions on Deuterium (✓)

Linearly-Polarized Beam at JLab: g8b Run Group



- Many channels being analyzed:
- High statistics > 10 billion events
- High photon polarization from 1.3 – 2.1 GeV

⇐ Preliminary analysis of $\gamma p \to N\pi$ (Mike Dugger ASU)

- P_γ estimated at 0.8
- — SAID prediction
- Data with statistical errors (no systematic)

g13

Summary

- Polarized photons
  - 1.1 - 2.3 GeV (linear)
  - 0.4 - 2.5 GeV (circular)
- Deuterium target
- $5 \cdot 10^{10}$ events

Status

- Data collected Nov 2006 – Jun 2007
- Calibration soon complete
- At least 7 PhD theses in progress

N^* Physics: $\gamma n \rightarrow N^* \rightarrow \ldots$

$K^0 \Lambda$, $K^0 \Sigma^0$, $K^+ \Sigma^-$, $K^{0*} \Lambda$, $K^+ \Sigma(1385)^-$

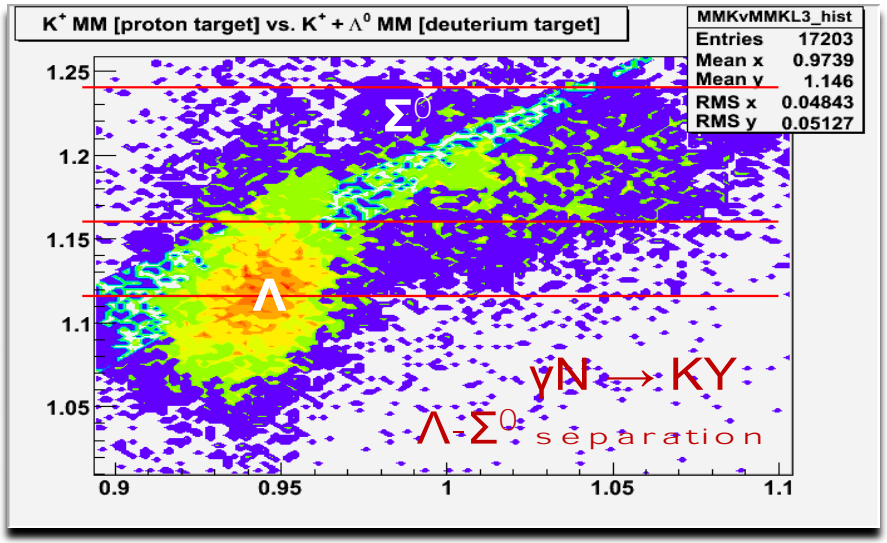
$\pi^- p$, $\pi^- \pi^0 p$, ωp

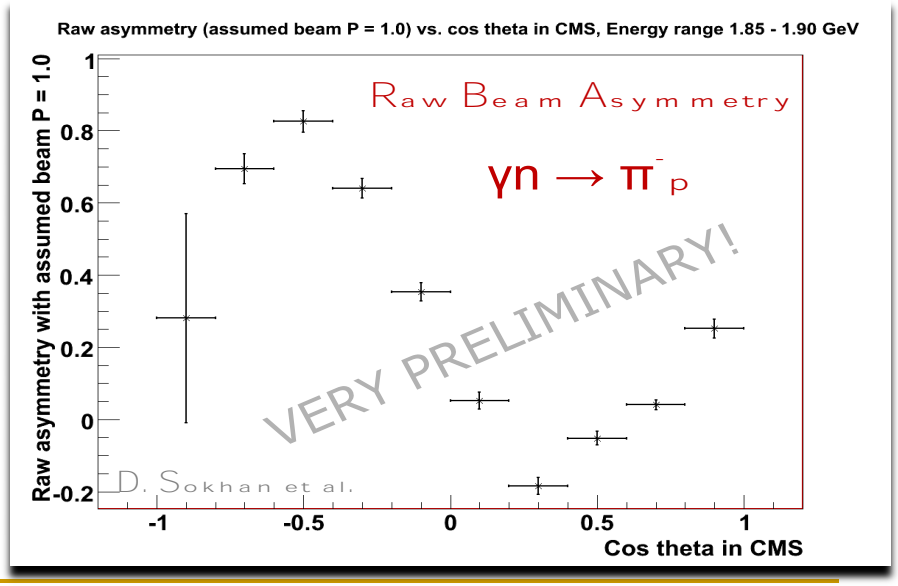
Nuclear effects, YN interactions, pQCD:

$\gamma d \rightarrow \ldots$

$\pi^- p p$, $K^+ \Lambda p$, $K^0 \Lambda p$, $K^0 \Sigma^0 p$, Φn

$\pi^0 d$, ηd, ωd, ρd, $\eta' p n$, $p n$





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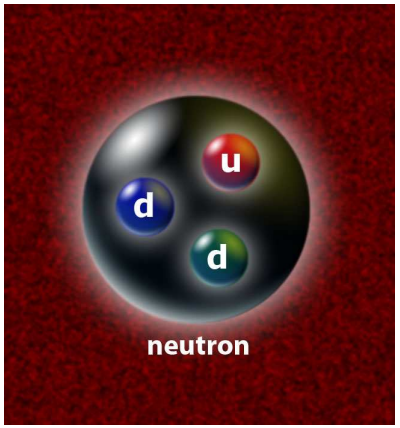

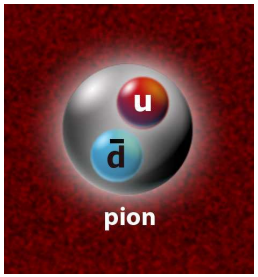

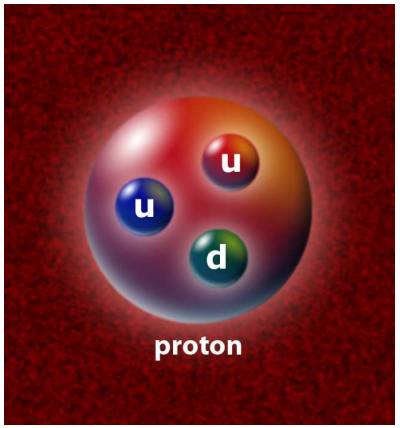

Summary and Outlook

Successful Excited-Baryon (Meson) Program using CLAS

- Improved statistics for previous measurements
- $P_{11}(1440)$, $D_{13}(1520)$, $S_{11}(1535)$ electrocouplings determined from CLAS data for the first time at $0.2 < Q^2 < 4.5$ GeV^2
- New data has revealed some hints for new N* resonances

Double-Polarization Program

- Complete determination of KΛ amplitude
- Almost complete sets for Nπ, Nη, N$\pi\pi$, ...

FROST completed with longitudinal target polarization

➜ Program on transversely-polarized target in 2009

HD program scheduled to run in 2010