N* Structure Studies from KY Electroproduction at CLAS22

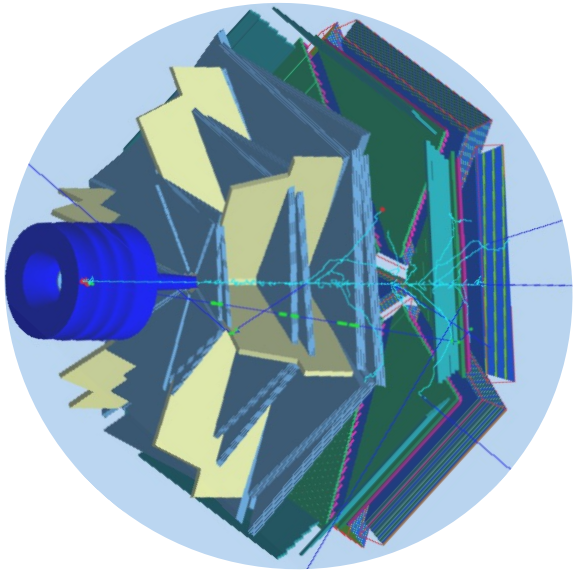
Insights into EHM with an Energy-Upgraded CEBAF

Daniel S. Carman
Jefferson Laboratory

Outline:

- CLAS/CLAS12 N* Program
- KY Electroproduction Studies
- Prospects for N* Studies at 22 GeV
- Summary / Concluding Remarks

Hall B N* Program Overview

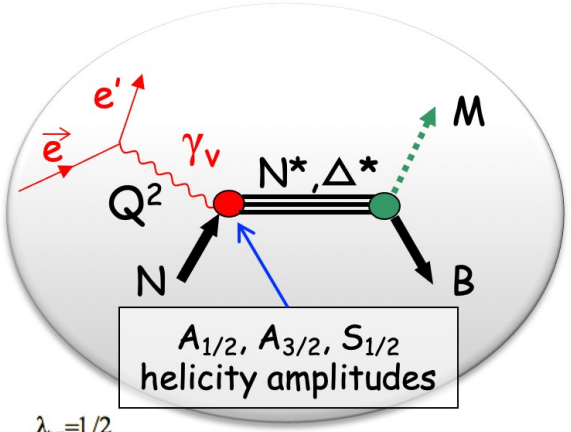


The N* program is one of the key physics foundations of Hall B

- CLAS & CLAS12 were designed to study exclusive reaction channels over a broad kinematic range:

  πN, ωN, ϕN, ηN, $\eta' N$, $\pi\pi N$, KY, K^*Y, KY^*

- Program designed to explore the *spectrum* and *structure* of N* states
  - probe underlying degrees of freedom via studies of the Q^2 evolution of their electroexcitation amplitudes
  - these N* amplitudes do not depend on decay channel but different final states have different hadronic decay parameters + backgrounds

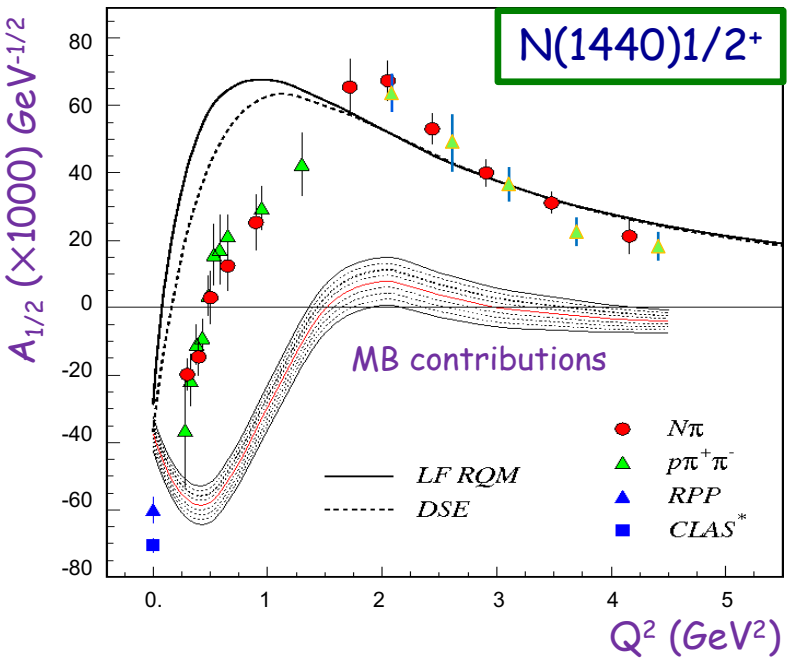


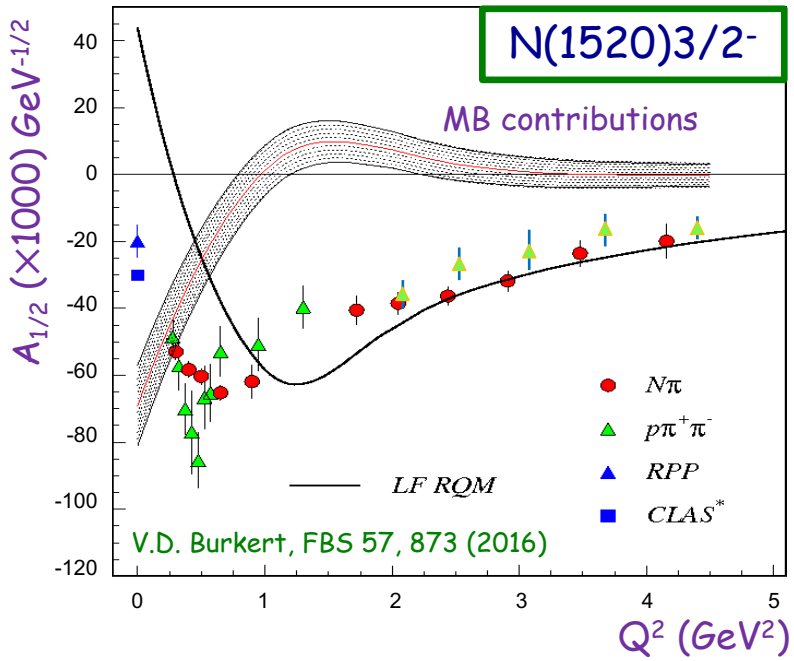
$A_{1/2}$, $A_{3/2}$ – transverse

$S_{1/2}$ – longitudinal

Measurements with CLAS22 to $Q^2 \sim 30$ GeV^2 would allow for exploration of the emergence of hadron mass and provide insight into how the dominant part of hadron mass emerges from QCD

CLAS N* Electrocouplings



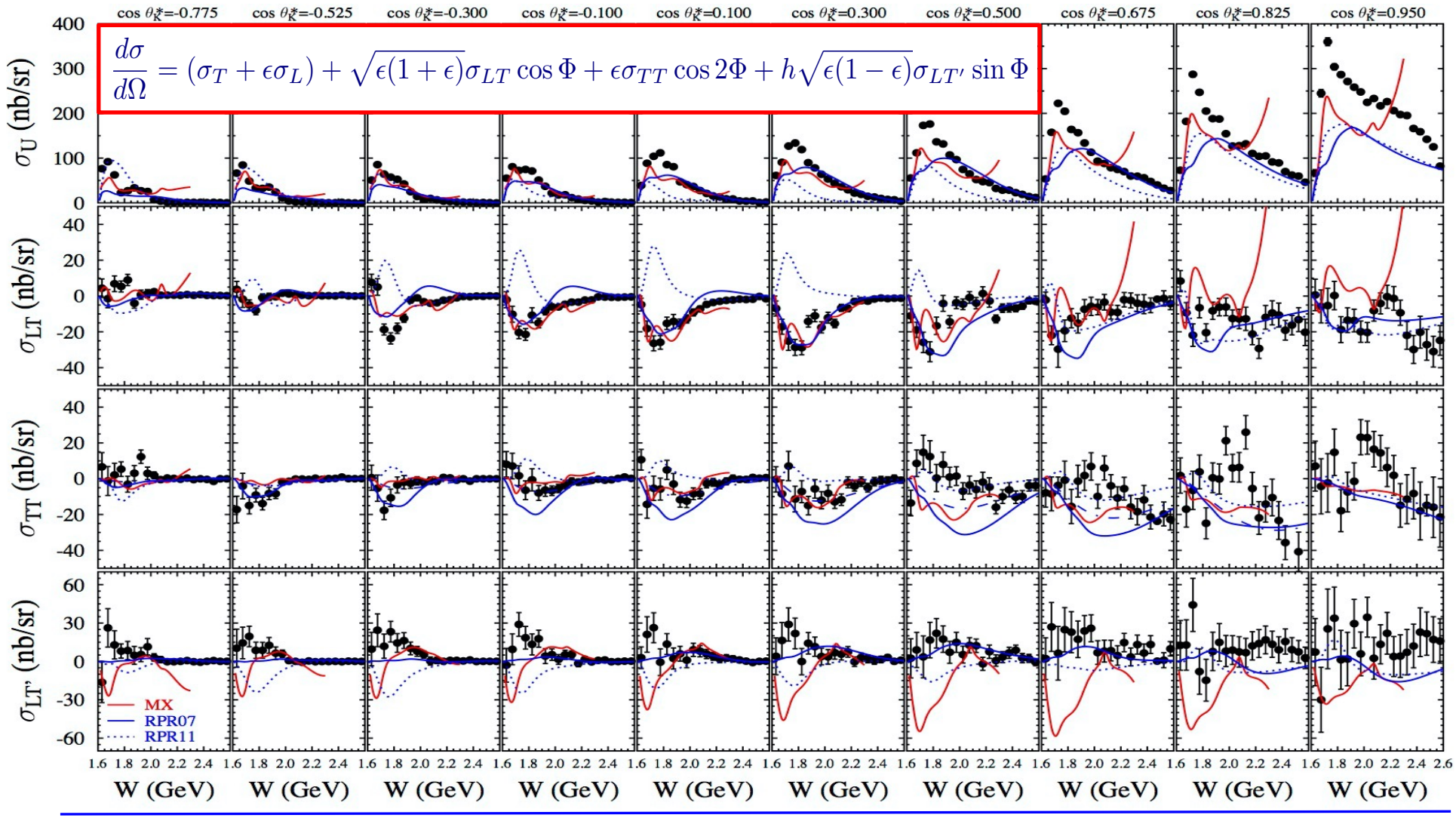


CLAS Electrocoupling Extraction	
Reaction Channel	N*, Δ* States
$\pi^0 p$, $\pi^+ n$	Δ(1232)3/2+, N(1440)1/2+, N(1520)3/2-, N(1535)1/2-
$\pi^+ n$	N(1675)5/2+, N(1680)5/2+, N(1710)1/2+
ηp	N(1535)1/2-
$\pi^+\pi^- p$	N(1440)1/2+, N(1520)3/2- Δ(1620)1/2-, N(1650)1/2-, N(1680)5/2+, Δ(1700)3/2-, N(1720)3/2+, N'(1720)3/2+

- Good agreement of the extracted N* electrocouplings from πN and ππN:
  - Compelling evidence for the reliability of the results
  - Channels have very different mechanisms for the non-resonant background
  - Results of independent analyses of different final states are crucial to understand the model systematics

Coupling to πN is small for many higher-lying states – electrocouplings from the KY channels are necessary to compare against the ππN channel as an independent validation

CLAS $K^+\Lambda$ Electroproduction Data



- CLAS KY electroproduction results dominate the world data
- Statistics comparable to CLAS ππN
- No available reaction model can be used as extraction tool for KY electrocouplings

This CLAS dataset can be used to define the required statistics for a viable CLAS22 experiment

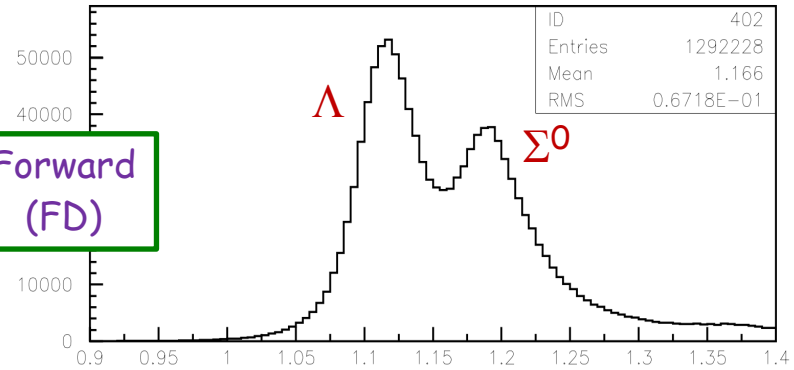
E = 5.5 GeV, W: thr – 2.6 GeV, Q^2 = 1.80, 2.60, 3.45 GeV^2

D.S. Carman et al., PRC 87, 025204 (2013)

CLAS12/CLAS22 Resolution Function

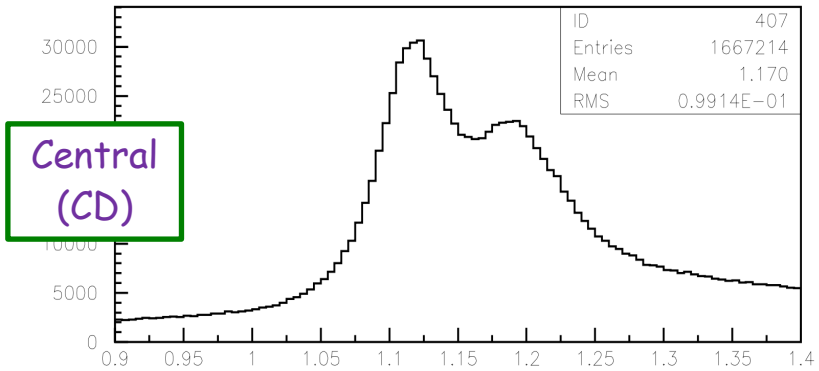
CLAS12 data @ 6.5 GeV

Forward (FD)

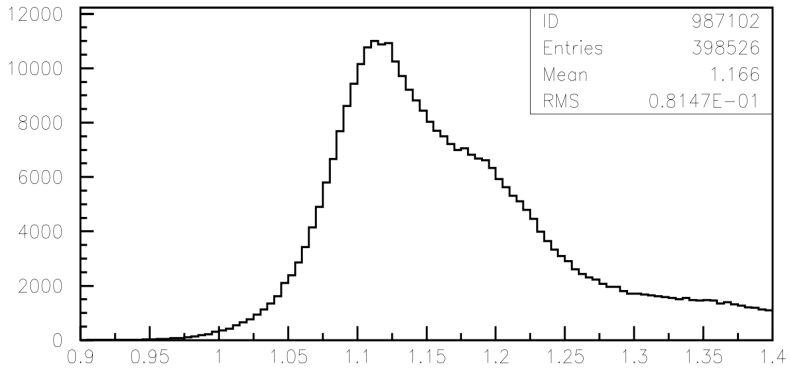


RG-K

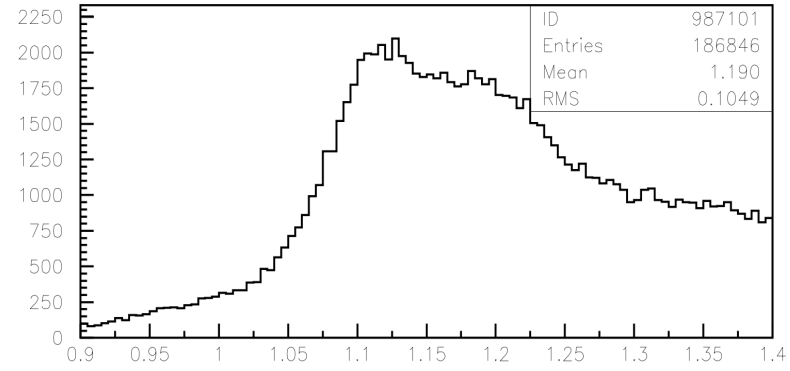
Central (CD)



CLAS12 data @ 10.6 GeV

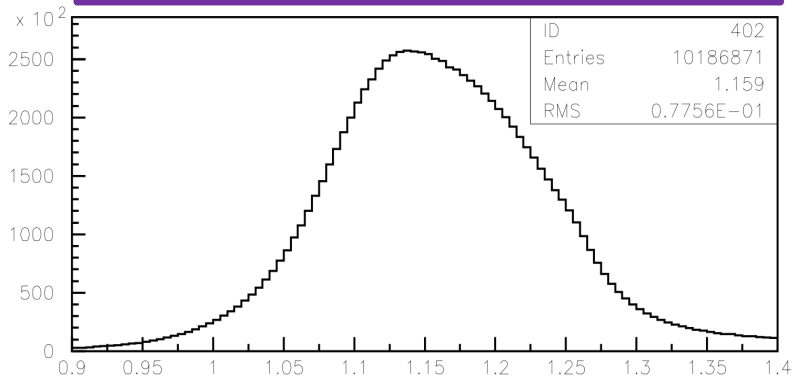


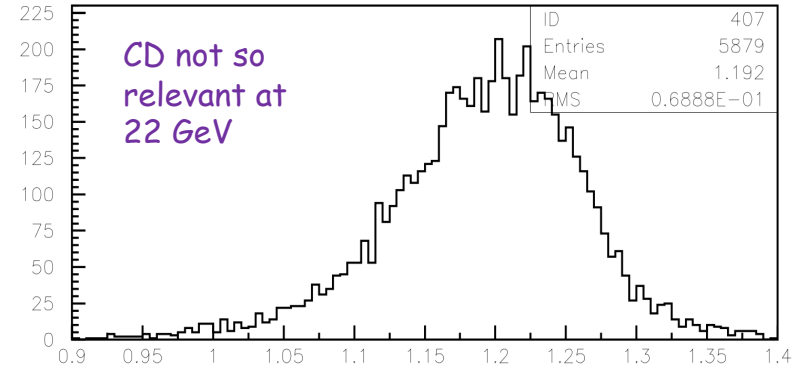
RG-A



m_Λ=1.1157 GeV/c², m_Σ =1.1926 GeV/c²

CLAS22 MC @ 22 GeV





Momentum resolution of CLAS12 (*"pass-1" cooking*) is limited by:

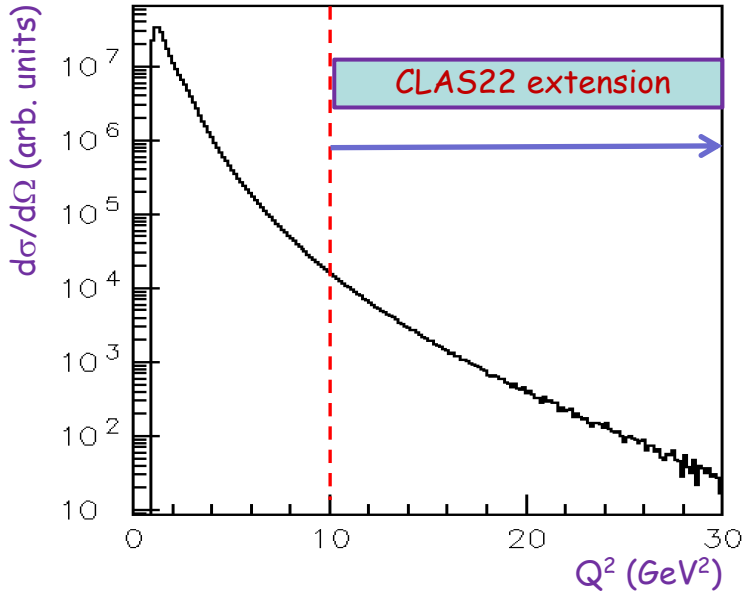
- Tracker alignment
- Torus field map
- Track reconstruction
- DC calibration
- Momentum corrections
- DC HV settings

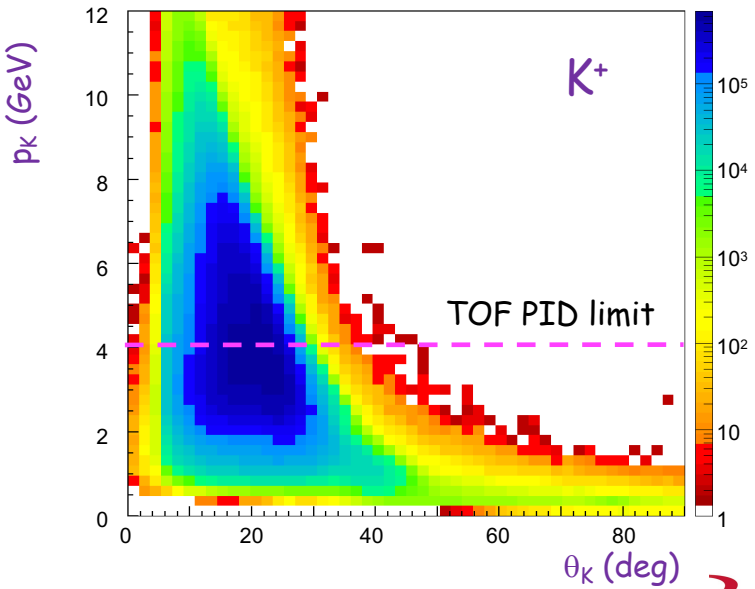
Δp/p= 1% (present) vs. 0.3% (proposals)

Biggest issue with CLAS22:

require improvements in FD charged particle momentum resolution

CLAS22 K^+Y Simulation Studies





- The electroproduction cross section for exclusive meson production reaction falls off rapidly vs. Q^2

  → Over the range of Q^2 accessible at E_b=22 GeV, the cross section drops by *~6 orders of magnitude!*

This drives the necessary luminosity: $\mathcal{L} \gtrapprox$ 2-5 x 10^{35} $cm^{-2}s^{-1}$

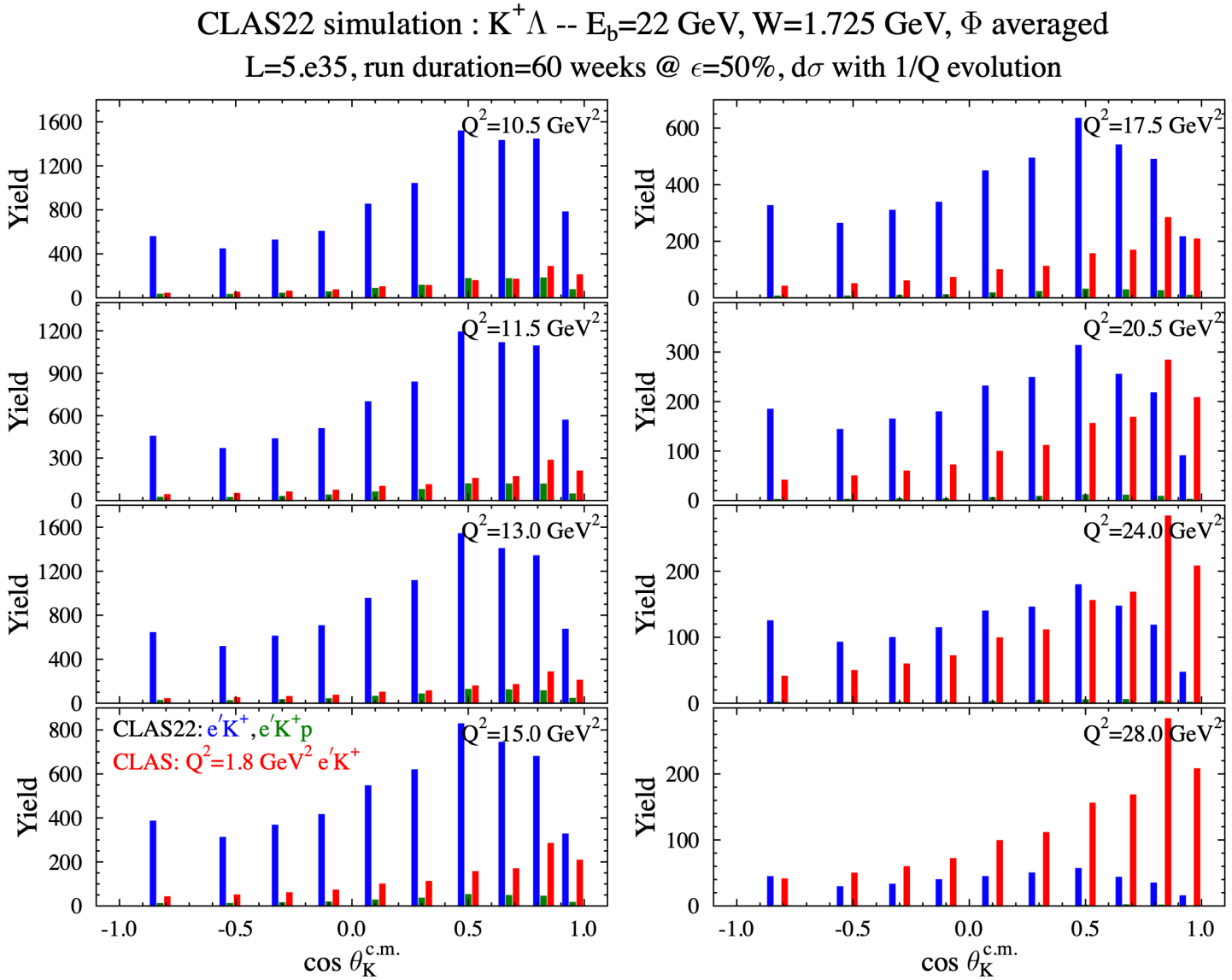
Note: The two-body acceptance for CLAS22 is ~5-10% for $e'h^+$ and ~1-2% for $e'h_1^+h_2^+$ with unchanged CLAS12 configuration

- Now starting to explore what can be done with CLAS12 to improve tracking efficiency, vertexing, PID, shielding, detector response, …

  - AI tracking finding + "de-noising"
  - Tracking system upgrade (μRWell)
  - L3 trigger/streaming readout
  - DC HV optimization
  - FTOF shielding
  - PID with RICH

CLAS12 luminosity upgrade in progress

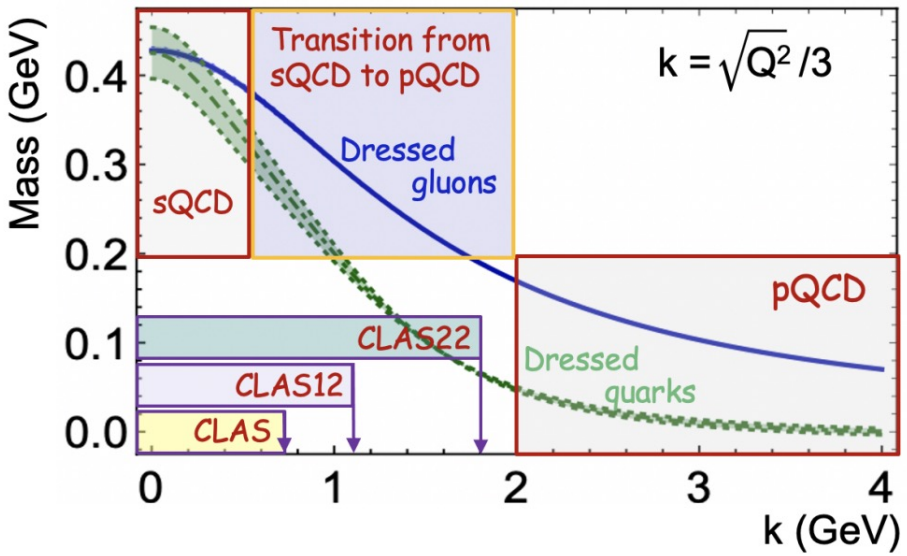
CLAS22 K^+Y Rate Studies



Good news:

In a reasonable running scenario, count rates for K^+Y are sufficient to cover up to ~25 GeV^2

(with some caveats …)



Summary / Concluding Remarks

- The study of N* states is one of the key foundations of the CLAS & CLAS12 physics programs:
  - CLAS has provided a huge amount of data up to $Q^2 \sim 5$ GeV^2
  - CLAS12 is extending these studies to $Q^2 \sim 10$ GeV^2
  - Studies of KY final states are an important aspect of the program
- A CLAS22 N* program would provide a culmination to this work:
  - The physics motivations are being developed to provide the most compelling case
  - An N* experimental program with CLAS22 will be challenging:
    - Need to push to *luminosity* $\mathcal{L} > 2\times10^{35}$ cm^{-2}s^{-1} - provide statistics to $Q^2 \sim 30$ GeV^2
    - Need to address detector *momentum resolution* - especially for a viable KY program

The capability to measure exclusive reactions to $Q^2 \sim 30$ GeV^2 with large-acceptance CLAS22 detector would make *JLab @ 22 GeV the ultimate QCD machine* to fully explore hadron generation in the strong QCD regime.