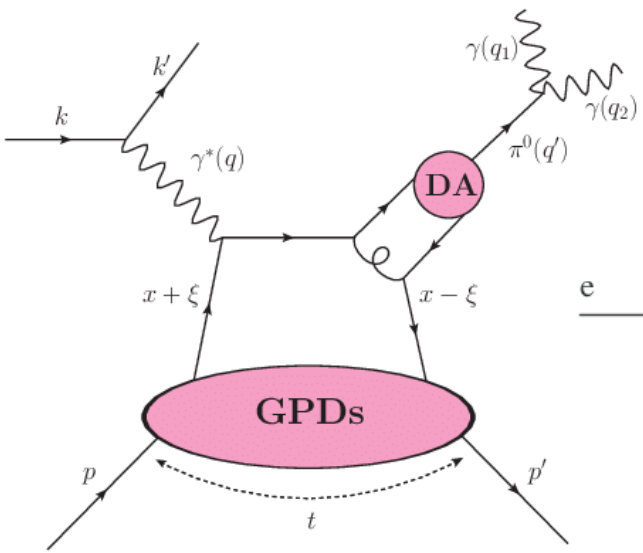
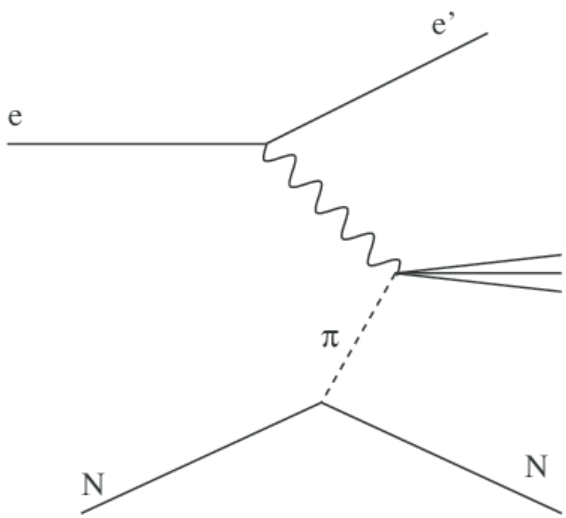
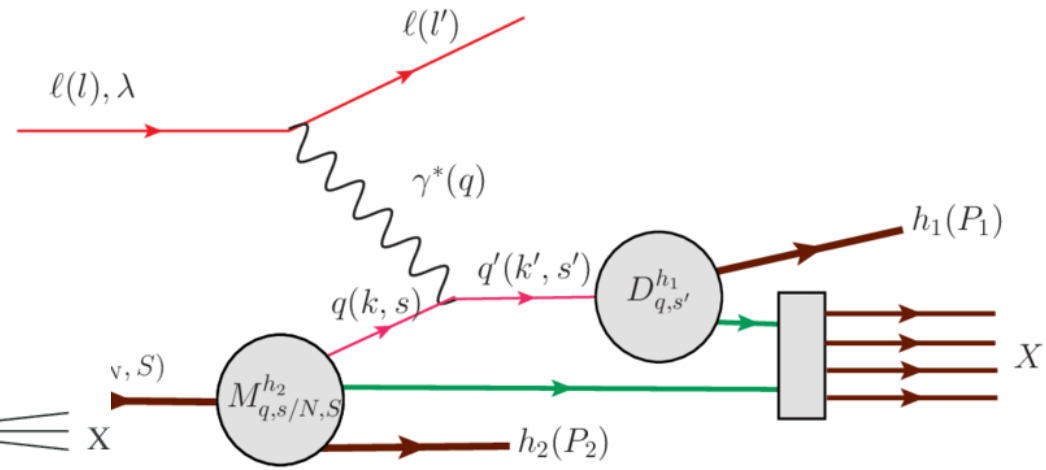
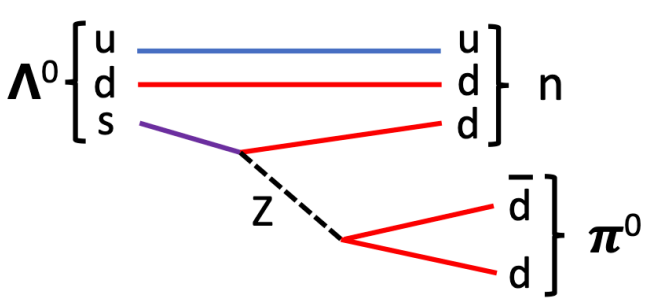
Precision Physics at the Luminosity Frontier

Edward R. Kinney, University of Colorado at Boulder
On behalf of the **Hall C Futures Task Force**









- Overview and Focus
- Physics Goals
- Tools
- Soapbox
- Summary

Preliminaries

- Thanks to Arun Tadepalli (and implicitly Tanja Horn) for sharing their slides from previous talks at Hall A/C Collaboration meetings (posted at pages for June 2021 and January 2022)
- Thanks to the Hall C Task Force for allowing me to join the discussion and learn from them!
- My apologies in advance to the Hall C Task Force for any mis-statements or misrepresentations I may make; they are my mistakes, not yours!
- Thanks to Dave Mack and Thia Keppel for pushing us to think and speak clearly about the future opportunities in Hall C
- I will not attempt to review the entire body of work, see the previous talks and the draft white paper for details.
- Talks to the working group are posted at https://hallcweb.jlab.org/wiki/index.php/Hall_C_Futures

The Hall C Futures Task Force

Chairs: Cynthia Keppel, Steve Wood, Mark Jones,Dave Mack

Jay Benesch (JLab)
V. Berdnikov (CUA)
P. Brindza (JLab)
S. Covrig Dusa (JLab)
Eric Christy (Hampton U.)
Dipangkar Dutta (Mississippi State U.)
David Gaskell (JLab)
T. Gogami (Kyoto U)
J.M. Grames (Jlab)
David Hamilton (U.Glasgow)
D. Higinbotham(JLab)
Or Hen (MIT)
Tanja Horn (CUA)
Garth Huber (U. Regina)
C. Keith (JLab)
Ed Kinney (U. Colorado)
Wenliang Li (W&M)
Nilanga Liyanage (UVa)
Ellie Long (New Hampshire)
B. Metzger (Jlab)
Carlos Munoz-Camacho (IJCLab-Orsay)
S.N. Nakamura (Tohoku U)
Brad Sawatzky (JLab)
Karl Slifer (New Hampshire)
Holly Szumila-Vance (JLab)
Arun Tadepalli (JLab)
Bogdan Wojtsekhowski (JLab)
+ Your name!

Futures Task Force Overview

- First Meeting of Hall C Futures Task Force convened February 2021 by Thia Keppel
- Charged to think about the future of measurements in Hall C beyond presently approved experiments into the EIC era
- Focus on strengths and complementarity of experiments in Hall C relative to other Jefferson Lab halls and the EIC
- Develop a white paper to express these ideas to the wider nuclear physics community
- We've been meeting bi-weekly/weekly ever since! Hope to complete our white paper soon!

Outline of White Paper

- Focus on basic questions about QCD and Hadrons
- Questions guide us to measurements!
- Hall C is at the high luminosity frontier, measuring small cross sections and performing longitudinal/transverse separations are our bread and butter
- Existing equipment and future conceptual ideas described
- A sampling of future measurements are described showing the breadth of the program
- How positrons and higher beam energy augment the program at 12 GeV

Strong Hall C Capabilities

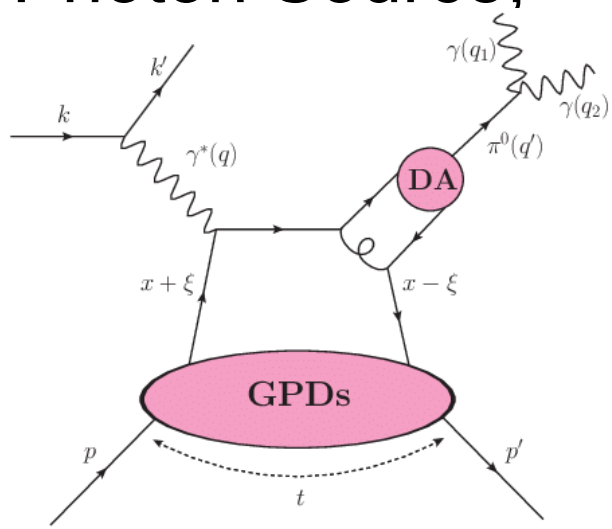
- Hall C is at the high luminosity frontier, precisely measuring small cross sections and performing longitudinal/transverse separations are our bread and butter
- The ability to rapidly switch between different targets can greatly reduce systematic uncertainties, and a wider choice of nuclei is possible
- Do not fail to appreciate the ability to set a spectrometer at a precise angle; alignment of large collider detectors takes years (e.g. JLUO talk of A. Kotwal!)
- High luminosity measurements with polarized beams and targets are well established capabilities.
- Flexibility to change experimental layout (spectrometers, calorimeters, compact photon source) allows for optimized measurements with precision

Future Science at Hall C -1-

Question: What is the spatial distribution of quarks inside the nucleon and nuclei?

Measurements: Elastic and hard exclusive process cross-sections, Parity Violating DIS

Requirements: High luminosity, excellent resolution, polarized beam and targets, Compact Photon Source, positrons

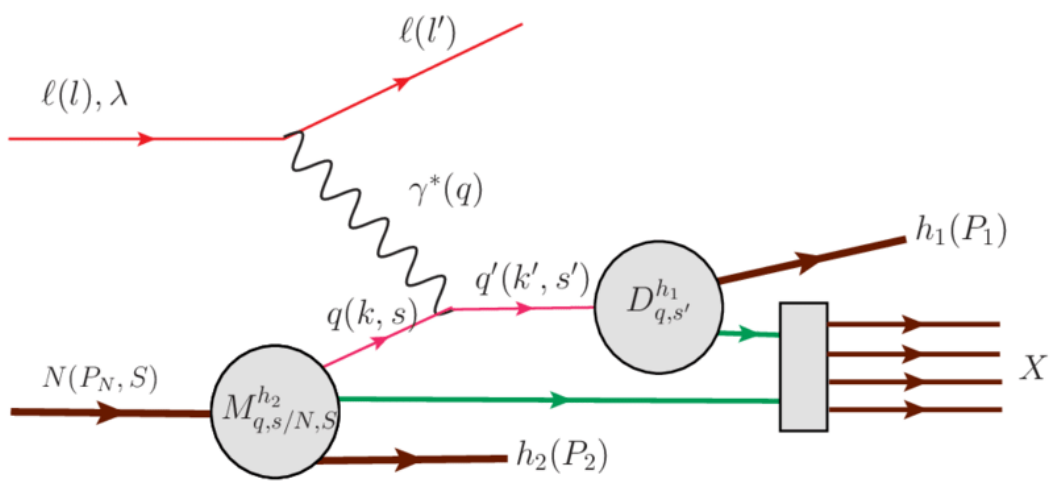


Future Science at Hall C -2-

Question: What is the quark structure of nucleons and nuclei in momentum space?

Measurements: Inclusive and semi-inclusive cross-sections

Requirements: L-T separations, good resolution



Future Science at Hall C -3-

Question: How does the spin of the nucleon arise from the spin of quarks and their orbital angular momenta?

Measurements: Structure functions g_2 and b_1

Requirements: Transverse and tensor polarized targets

Question: What is the nature of confinement/hadronization?

Measurements: (e,e'p) cross-sections, A_{LT}, SIDIS fragmentation functions, Hyperon decays

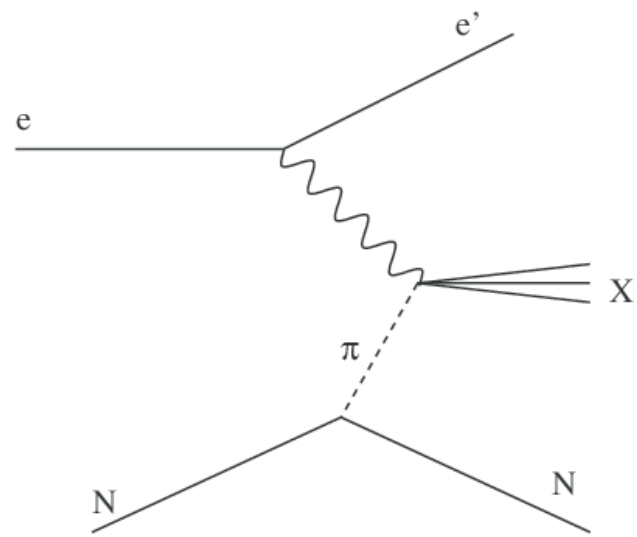
Requirements: Polarized beams, Focal Plane Polarimeter, low energy hadron detection, triple coincidence

Future Science at Hall C -4-

Question: What is the origin of hadronic mass?

Measurements: Pion structure function via Sullivan process; π+, K+ form factors

Requirements: Low-energy forward hadron detection; L-T separation, high momentum hadron detection at very forward angle

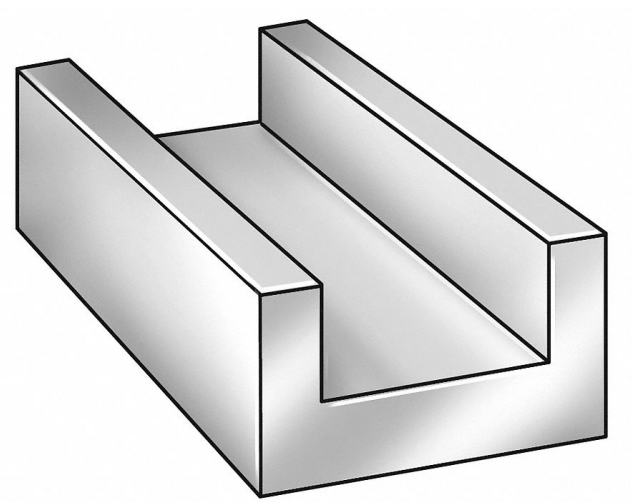


Future Science at Hall C -5-

Question: Where does the hard/soft QCD factorization regime begin?

Measurements: Factorization tests in both t- and u$-channel hard exclusive processes

Requirements: L-T separation, high momentum hadron detection at very forward and backward angles

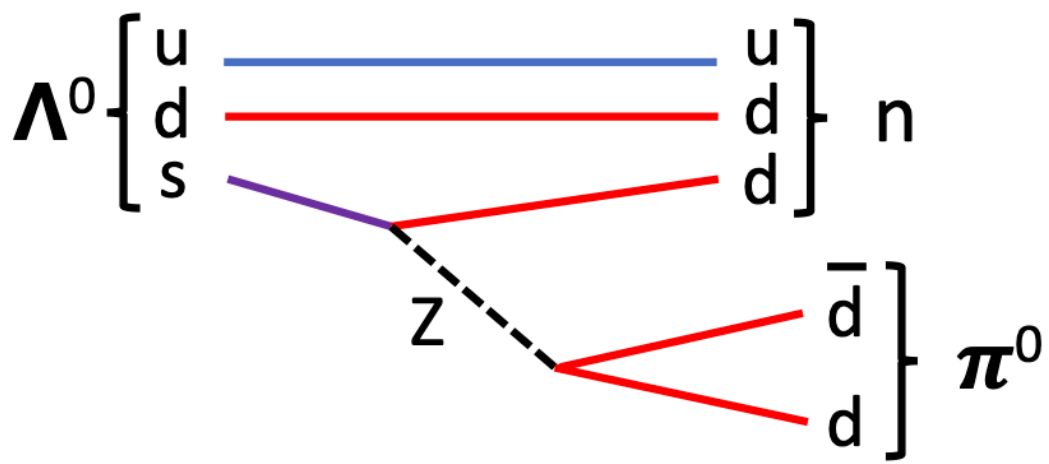


Future Science at Hall C -6-

Question: What is the nature of the strong/nuclear force?

Measurements: Hyper-nuclear cross-sections, Short range correlations, Hyperon decays

Requirements: HMS, SHMS, NPS, polarized beam, backwards detection, triple coincidence



The Soapbox

- As the timescales for new facilities has expanded and the complexity of systems have developed, our students have less exposure to the “setup” phase of an accelerator based experiment.

- While designing/testing/building a detector at home institutions is a wonderful and effective learning tool, it is not a substitute for the experience of bringing fully instrumented spectrometers into reliable operation.

- Automation often brings us reliable, stable operation, but it also can rob us of a deeper understanding of our apparatus

- As described in the white paper, the Hall C program is now and will be in the future, one in which new experiments with very different components are being assembled, commissioned and operated.

- We should highlight this fantastic learning opportunity for our students and postdocs as part of the strengths of Hall C!

Summary

- The task force is in final stages of producing a white paper describing a future physics program at Hall C
- The general capabilities of the Hall allow a broad program already at 12 GeV; the focus is on precise measurements of small cross sections and the ability to perform longitudinal/transverse separations.
- The flexibility of the hall provides for frequently changing arrays of experimental equipment, with many opportunities for training future generations of students and postdocs
- The availability of a positron beam would open new areas of exploration, while an increase in beam energy would enhance our ability to explore higher Q^2 and larger photon-hadron CM energy (W)

Hall C: High Precision at the Luminosity Frontier

SHMS, HMS, CPS, NPS, HCAL, ECAL etc. versatility of new equipment

High Precision polarimetry

Student/postdoc Learning

+ AI/Machine learning

High Precision measurements of small cross sections

Space for new installations