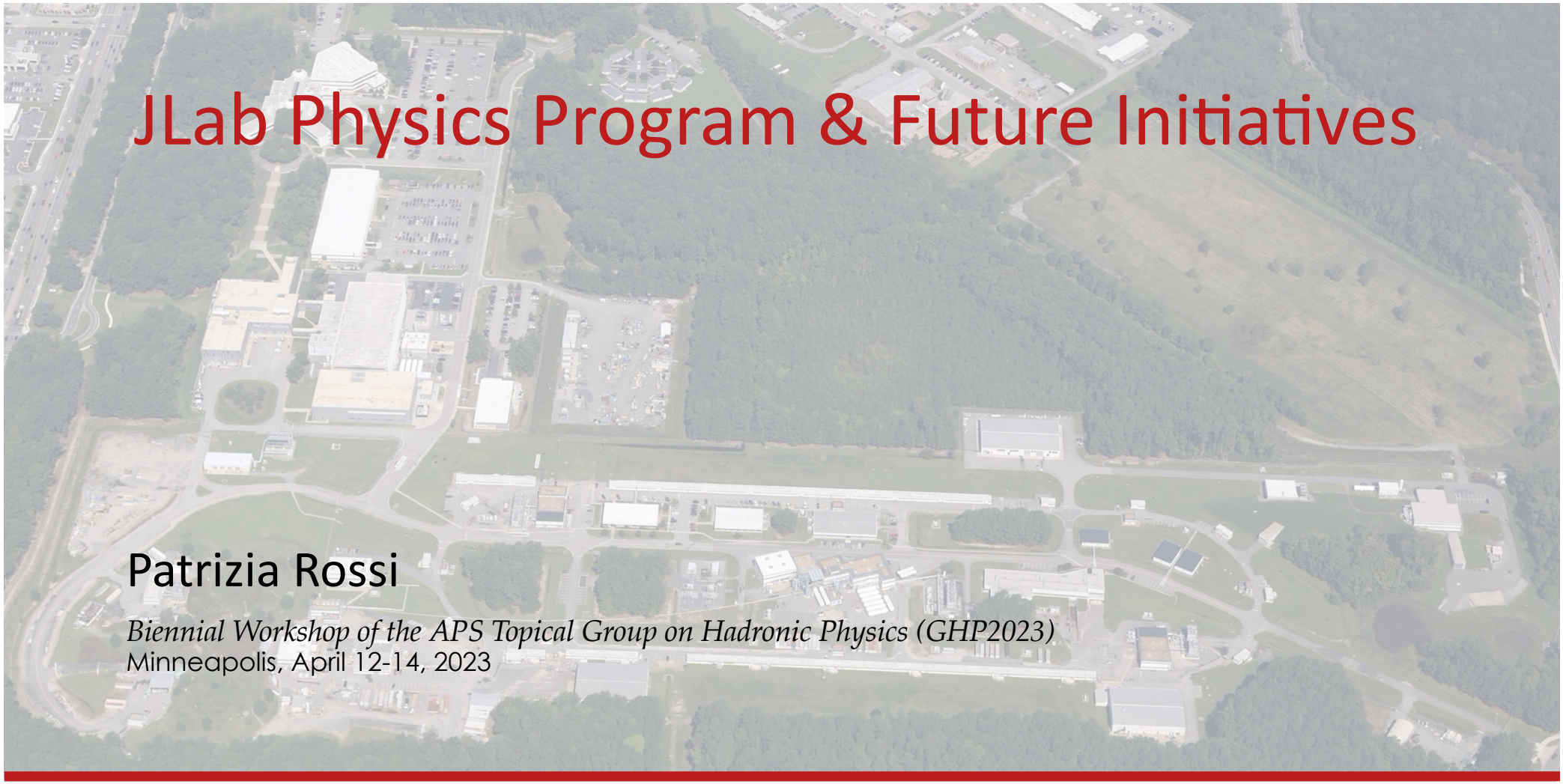
# JLab Physics Program & Future Initiatives



Patrizia Rossi

*Biennial Workshop of the APS Topical Group on Hadronic Physics (GHP2023)*
Minneapolis, April 12-14, 2023

TJNAF is managed by Jefferson Science Associates for the US Department of Energy

Jefferson Lab
Thomas Jefferson National Accelerator Facility

# Talk Outline

*The 12 GeV Nuclear Physics Program*

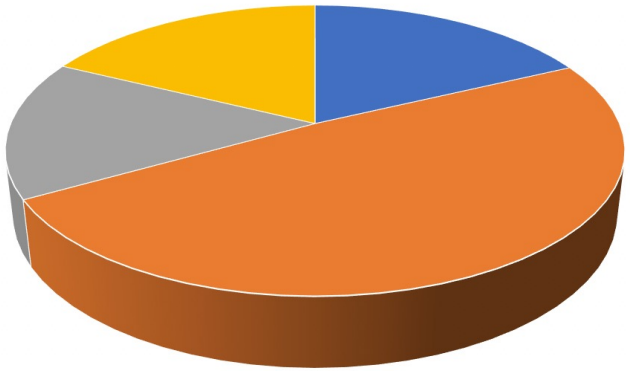
- Some highlights of published results and current running program (with apologies to all I couldn't include!)
- Near & longer-term physics program

*Look to the future*

- CEBAF energy upgrade
- Positron beam

# Jefferson Lab and CEBAF


Approved 12 GeV program by PAC days



- Probe the structure of matter

  Complex **non-pQCD** problem which demands different approaches and measurements to access multiple observables

- Discover evidence for physics beyond the standard model

**Hadron Spectra**

**1D-3D Nucleon Structure**

**Hadrons & Cold Nuclear Matter**

**Test of SM & Fundamental Sym.**



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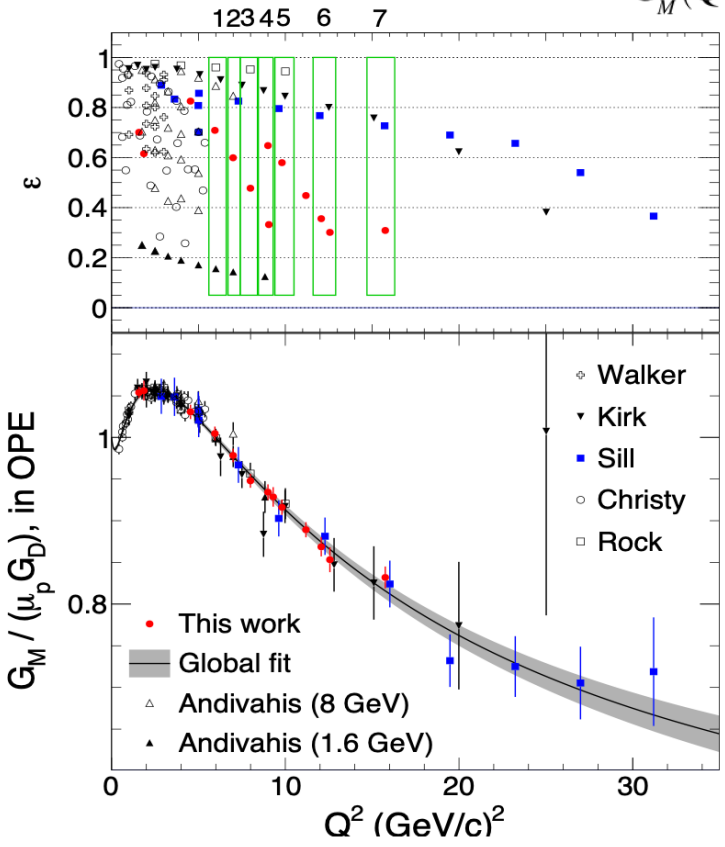
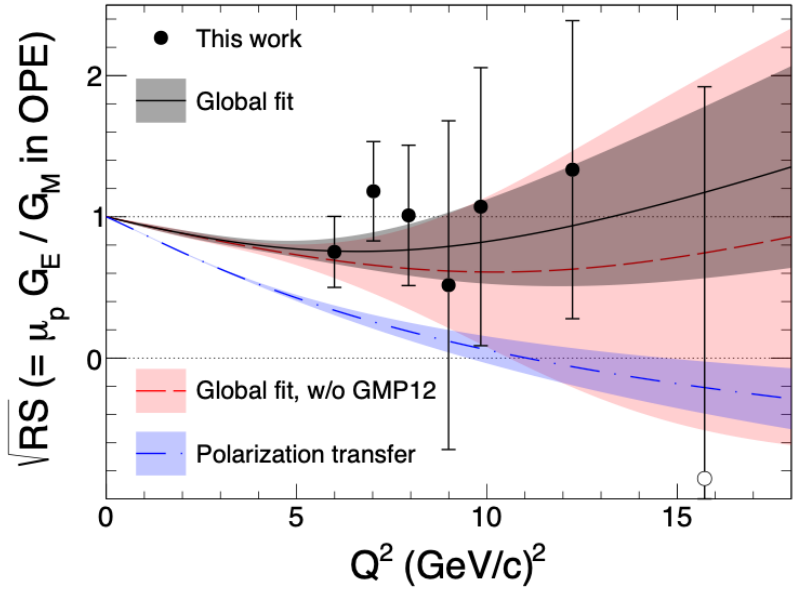
# 2-γ Effects in Elastic e-p Scattering in Hall A

**E12-07-108**

$$\sigma_R = \tau\, G_M^2(Q^2) + \varepsilon\, G_E^2(Q^2) = \sigma_T + \varepsilon\, \sigma_L$$
$$= G_M^2(Q^2)(\tau + \varepsilon\, RS(Q^2)/\mu_p^2),$$




Signature of a dominant contribution of TPE to the value of the Rosenbluth slope at $Q^2$ up to 15 (GeV/c)$^2$

Phys. Rev. Lett. **128**, 102002



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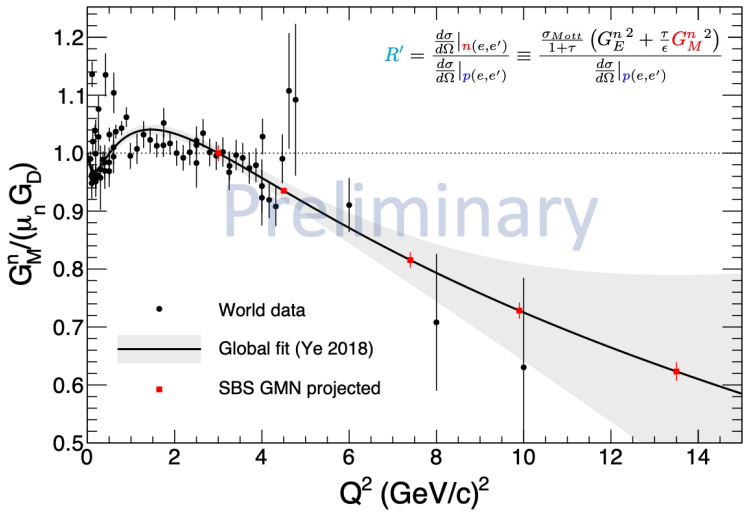
# Hall A SBS Program: unprecedented access to **all nucleon FFs** at high $Q^2$

***SBS-$G_M^n$*** *exp. successfully completed in 2/ 2022* ***(E12-09-019)***




- Precision of the highest $Q^2$ data point (13.5 (GeV/c)$^2$) is expected to stay unmatched for years to come

***Neutron two-photon exchange (nTPE) (E12-20-010)***

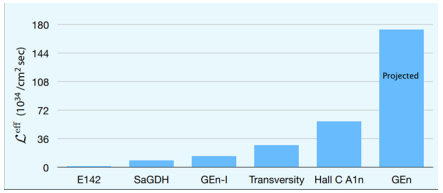
- Two measurements at same $Q^2$, 2 values of ε

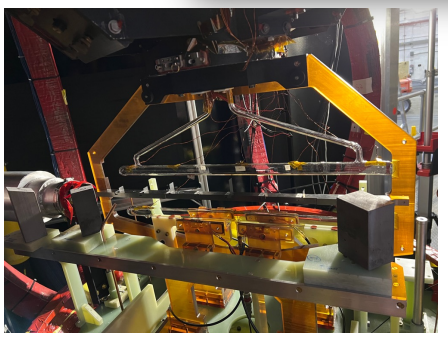
Preliminary results from both exps expected by Summer 2023

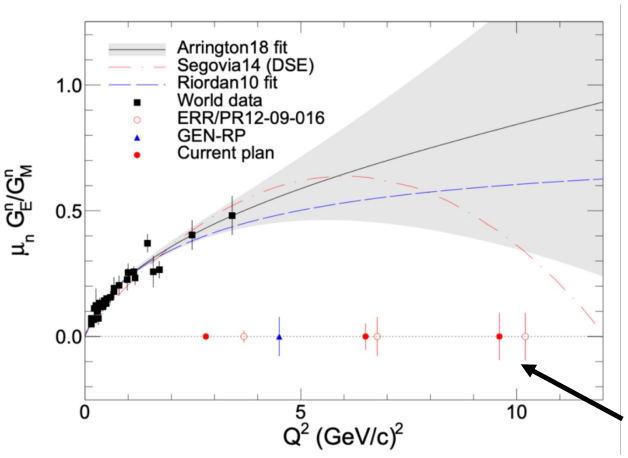
***SBS-$G_E^n$*** *exp. started 10/2022* ***(E12-09-016)***

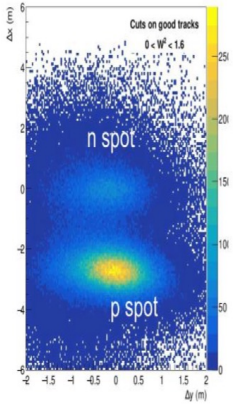
- use double polarization to measure $\frac{G_E^n}{G_M^n}$
- Polarized $^3$He target – highest $\mathcal{L}$ to date!
  - First time 60 cm long target
  - 42 – 50% target polarization

$$A_N = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} = \frac{\Delta}{\Sigma}$$
$$A_N = -\frac{2\sqrt{\tau(\tau+1)}\tan(\theta/2)\frac{G_E^n}{G_M^n}\sin\theta^*\cos\phi^*}{\left(\frac{G_E^n}{G_M^n}\right)^2 + \tau + 2\tau(1+\tau)\tan^2(\theta/2))} - \frac{2\tau\sqrt{1+\tau+(1+\tau)^2\tan^2(\theta/2)}\tan(\theta/2)\cos\theta^*}{\left(\frac{G_E^n}{G_M^n}\right)^2 + \tau + 2\tau(1+\tau)\tan^2(\theta/2))}$$





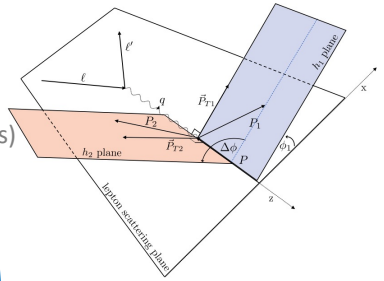

**Running 6 more weeks after SAD2023**

# Hall B provides **First-ever** Measurements

## Observation of Correlations between Spin and Transverse Momenta in Back-to-Back Dihadron production at CLAS12

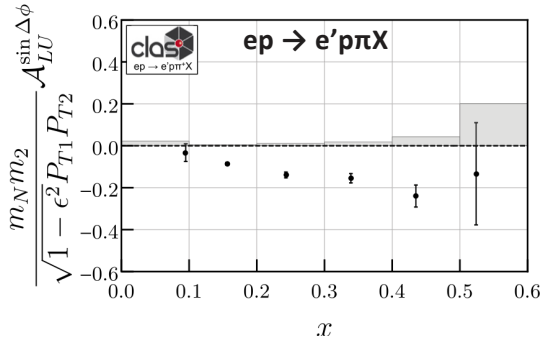
H. Avakian et al. (CLAS Collaboration)
Phys. Rev. Lett. 130, 022501 (2023)

Two hadrons in opposite hemispheres ( current and target-fragm. regions)




- Direct access to leading twist **Fracture Functions** which gives conditional probability to eject a longitudinally polarized quark with the additional hadron in the target fragment

$$\mathcal{A}_{LU} = -\sqrt{1-\epsilon^2}\,\frac{|\vec{P}_{T1}||\vec{P}_{T2}|}{m_N m_2}\,\frac{\mathcal{C}[w_5 \hat{l}_1^{\perp h} D_1]}{\mathcal{C}[\hat{u}_1 D_1]}\sin\Delta\phi$$

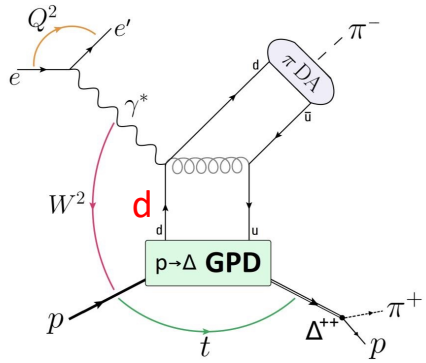


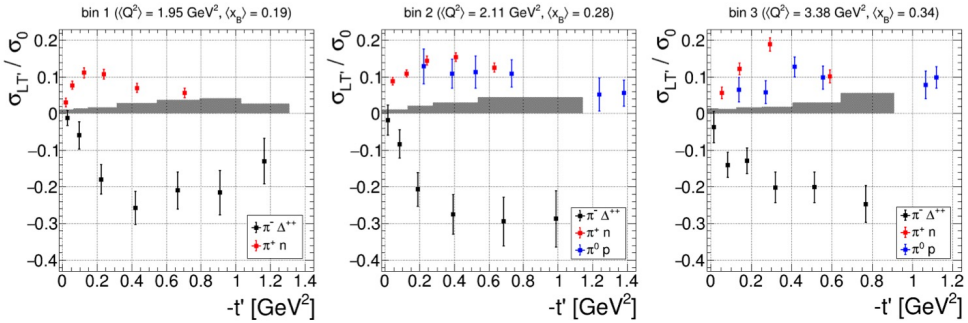

$A_{LU}$ increases with x → correlation of final-state hadrons most significant in the valence quark region

## First measurement of hard exclusive $\pi^-\Delta^{++}$ electro-production BSA off protons

S.. Diehl et al. (CLAS Collaboration)
arXiv:2303.11762 [hep-ex]

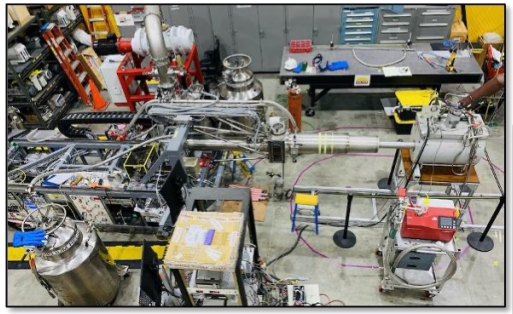
- Provides access to p-Δ transition GPDs
- Provides access to the d-quark content of the nucleon



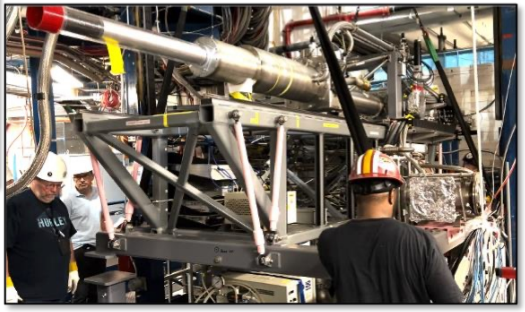

BSA clearly negative and ~ 2 times larger than for the hard exclusive $\pi^+/\pi^0$ production → Polarized u quarks ($\pi^+ n$, $\pi^0 p$) has positive asymmetry, d quarks ($\pi^-\Delta^{++}$) negative asymmetry

# RG-C: a Comprehensive Program w Longitudinally Polarized $NH_3$, $ND_3$ targets in Hall B

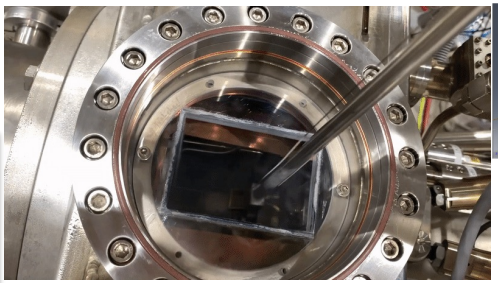


Testing in Target Lab, March 2022

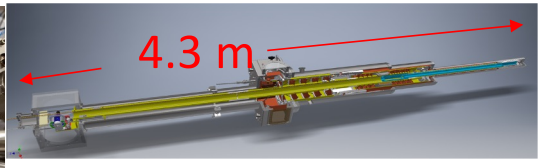
Protons and deuterons ($NH_3$ & $ND_3$) dynamically polarized at 1 K and 5 T

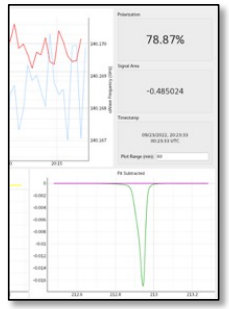


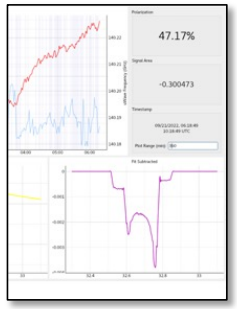
Installation in Hall B, June 2022

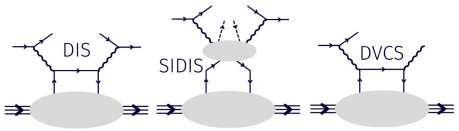


Rapid exchange of target samples



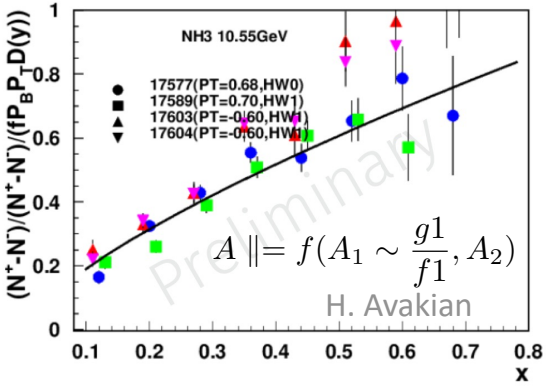



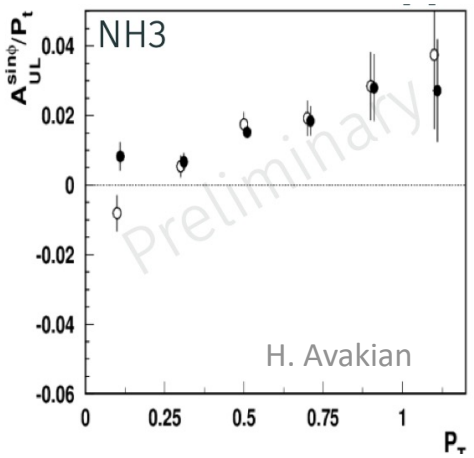




- Longitudinally pol. $NH_3$ and $ND_3$ targets
- 10.5 GeV highly-polarized e- beam

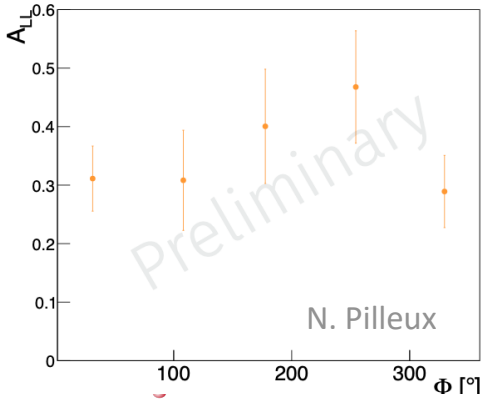
**DIS:** spin structure of the nucleon at high x




**SIDIS eπ⁺X**: TMD-3D imaging, spin orbit correlations




**pDVCS:** $\Re(\widetilde{\mathcal{H}}_p)$, $\Re(\mathcal{H}_p)$, $\Re(\mathcal{H}_n)$ GPD

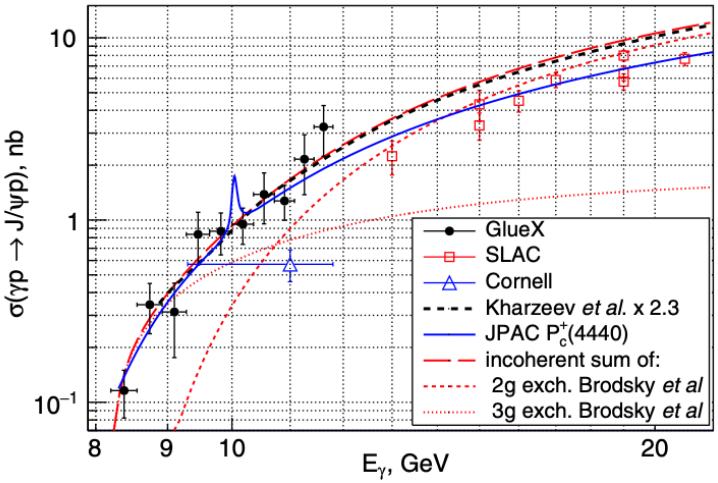


# J/ψ Photoproduction at threshold

## Hall D - GlueX

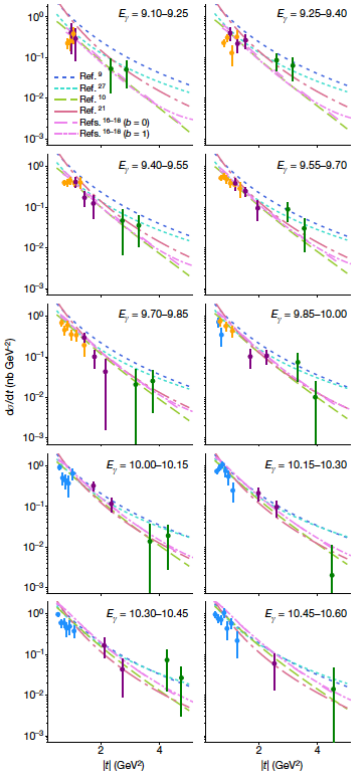
- Two-gluon exchange model doesn't reproduce σ
- **no evidence of 5quark** → model-dependent U.L. on on the branching fraction of the LHCb $P_c^+$ states

Phys. Rev. Lett. 123, 072001 (2019)




## Hall C (E12-16-007)

- measured 5x more statistics → set more stringent limit on $\sigma(\gamma p \to P_c \to J/\psi p)$
- Data used to determine the **gluonic gravitational form factors of the proton**

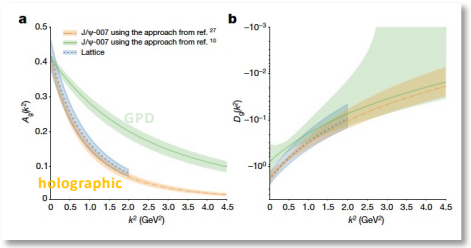


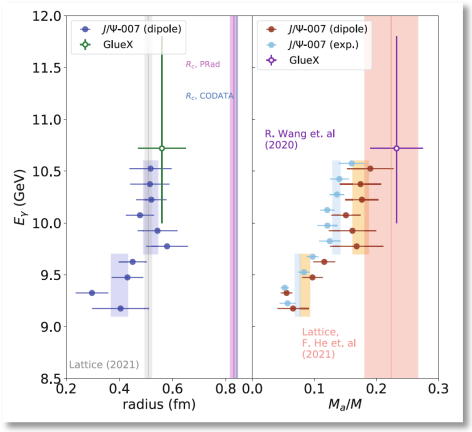

- Simultaneously fit of the **J/ψ dσ/dt** with the holographic and the GPD approaches to extract the gluonic gravitation form factors A(k) and D(k).

$$\langle r_m^2 \rangle_g = 6\frac{1}{A_g(0)}\frac{dA_g(t)}{dt}\Big|_{t\to 0} - 6\frac{1}{A_g(0)}\frac{C_g(0)}{M_N^2}$$

$$\langle r_s^2 \rangle_g = 6\frac{1}{A_g(0)}\frac{dA_g(t)}{dt}\Big|_{t\to 0} - 18\frac{1}{A_g(0)}\frac{C_g(0)}{M_N^2}$$

- **Mass Radius smaller than charge radius**




Nature volume 615, pages 813–816 (2023).



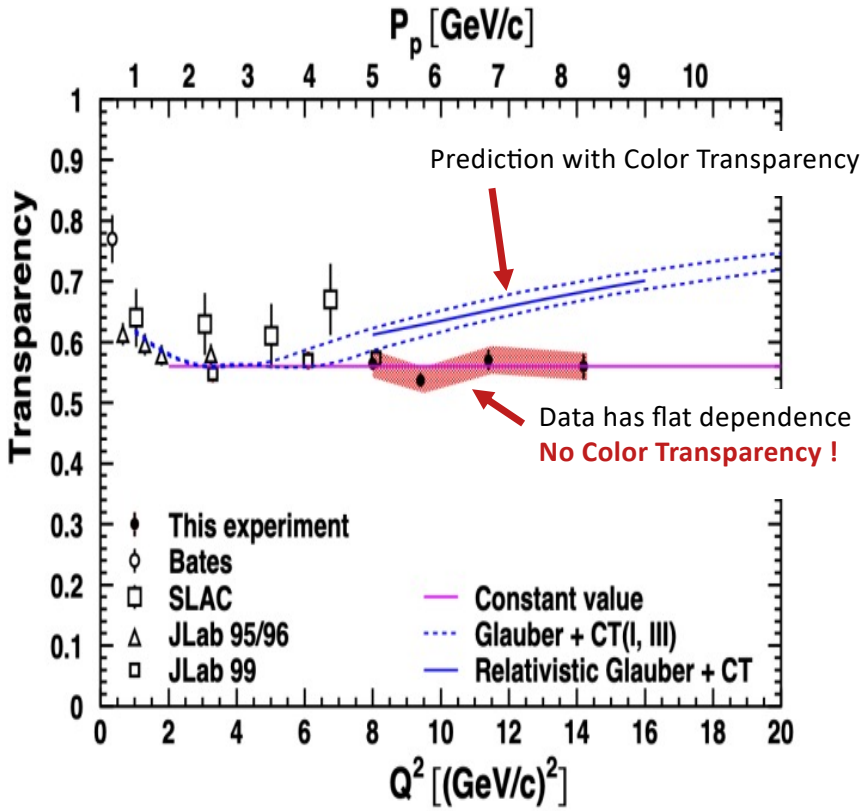
Talk by Shivangi Prasad

Jefferson Lab

# New nuclear data challenge theory – Hall C

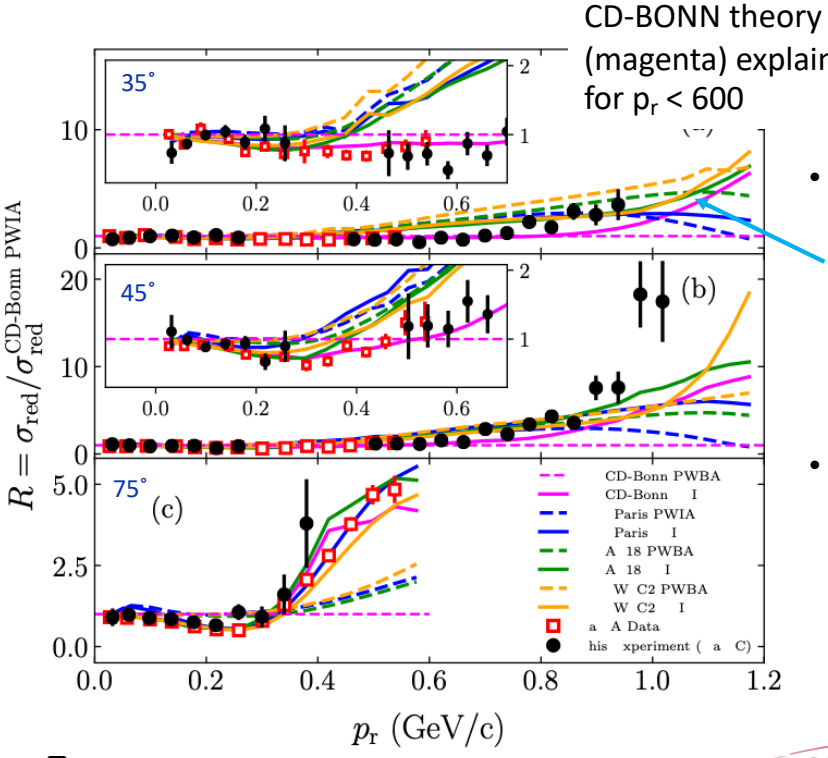
## Ruling out color transparency in quasi-elastic $^{12}C(e,e'p)$ up to $Q^2$ of 14.2 $(GeV/c)^2$

Phys. Rev. Lett. 126, 082301




## Probing the Deuteron at Very Large Internal Momenta

Phys. Rev. Lett. 125, 262501 (2020)




- None of the calculations, including the CD-BONN theory, can explain data for $p_r > 0.6$
- Completed experiment to explore if trend continues to $p_r > 1.1$



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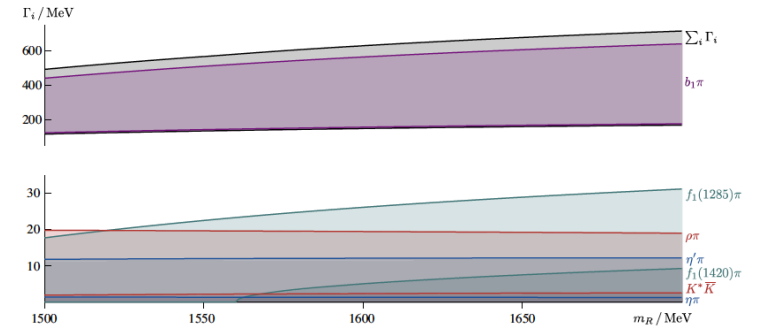
# Search for Hybrid Mesons at GlueX

**Focus on $\pi_1$ (1600)**

- Set upper limit on photoproduction x-section
- Perform partial wave analyses on $\eta\pi$ and $\eta'\pi$ to confirm COMPASS data

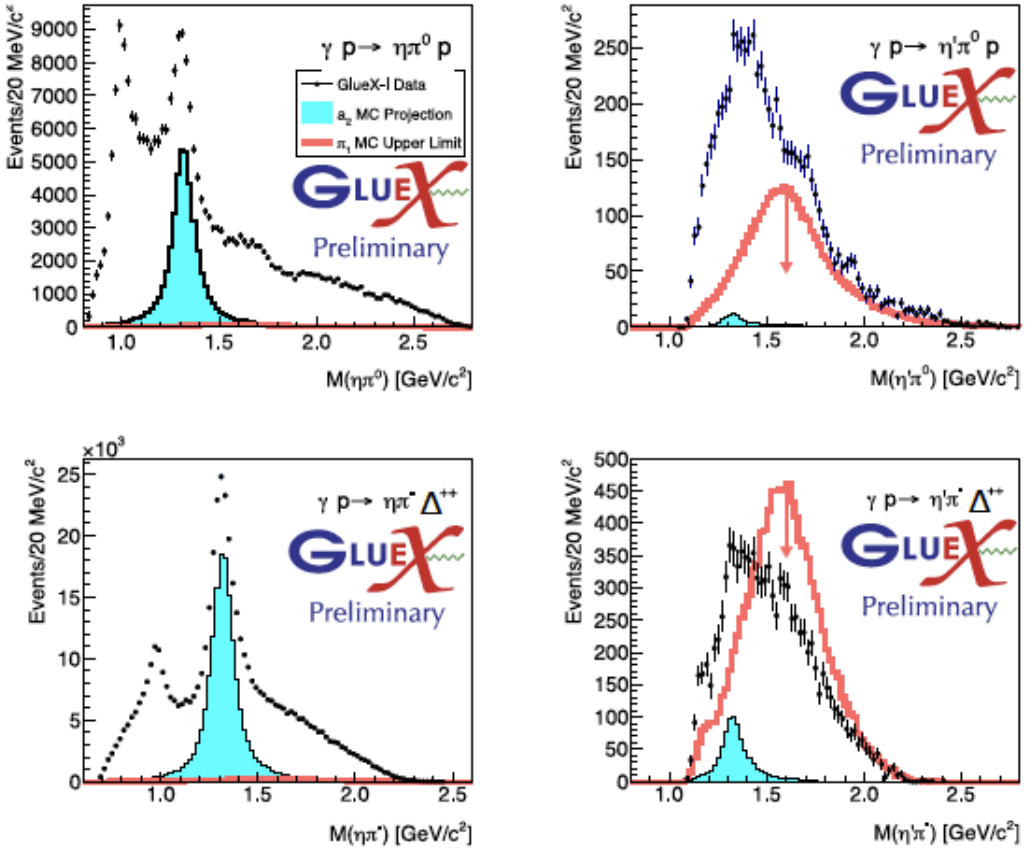
$\pi_1$ Branching Fractions from Lattice QCD
(PRD 103 054502, 2021)




the $\pi_1 \rightarrow b_1\pi \rightarrow \omega\pi\pi$ decay channel is used to set an upper limit on photoproduction, setting the scale of possible contributions in $\eta\pi$ and $\eta'\pi$

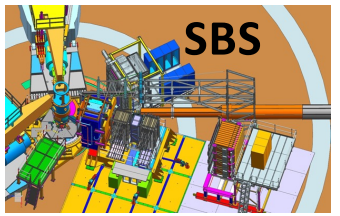
Talk by W. Imoehl

**$\pi_1$ Upper Limit - Projections to $\eta\pi$ and $\eta'\pi$**



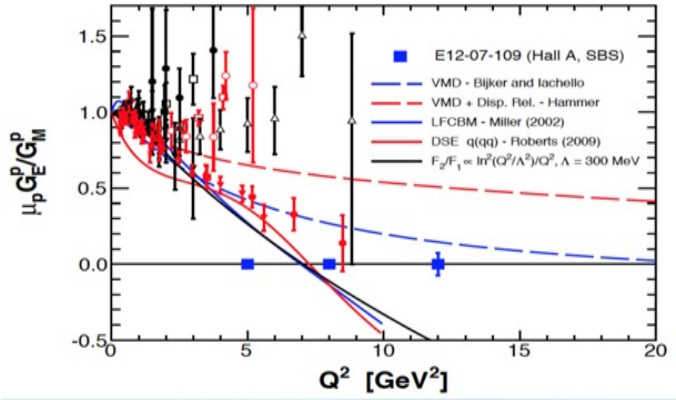

- $\pi_1$ not a large fraction of $\eta\pi$
- $\pi_1$ could saturate $\eta'\pi^-$ distribution

# Hall A Preparing for the Future: SBS ➔ MOLLER ➔SoLID



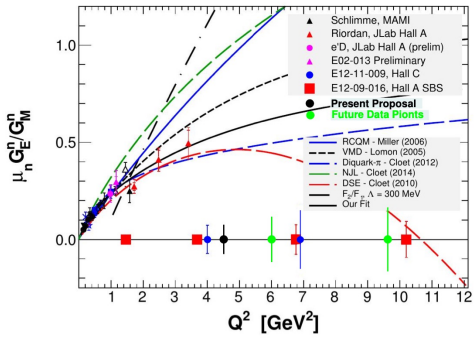

### E12-07-109

- Measurement of the ratio $G_E^p / G_M^p$ in a wide range of momentum transfer $Q^2$ using the **polarization transfer method**
- **SBS $G_E^p / G_M^p$** exp. currently scheduled - Installation start in Fall 2023




### E12-17-004

- Measurement of the ratio $G_E^n / G_M^n$ using the **two-recoil polarization technique** of a polarized beam on an unpolarized $LD_2$ target
  - Change-exchange np→pn (copper analyzer)
  - Conventional np-np (plastic analyzer)
- **SBS $G_E^n / G_M^n$** exp. currently scheduled after **$G_E^p / G_M^p$**




- Approved SBS SIDIS (TMDs), TDIS (meson structure) exps. ?



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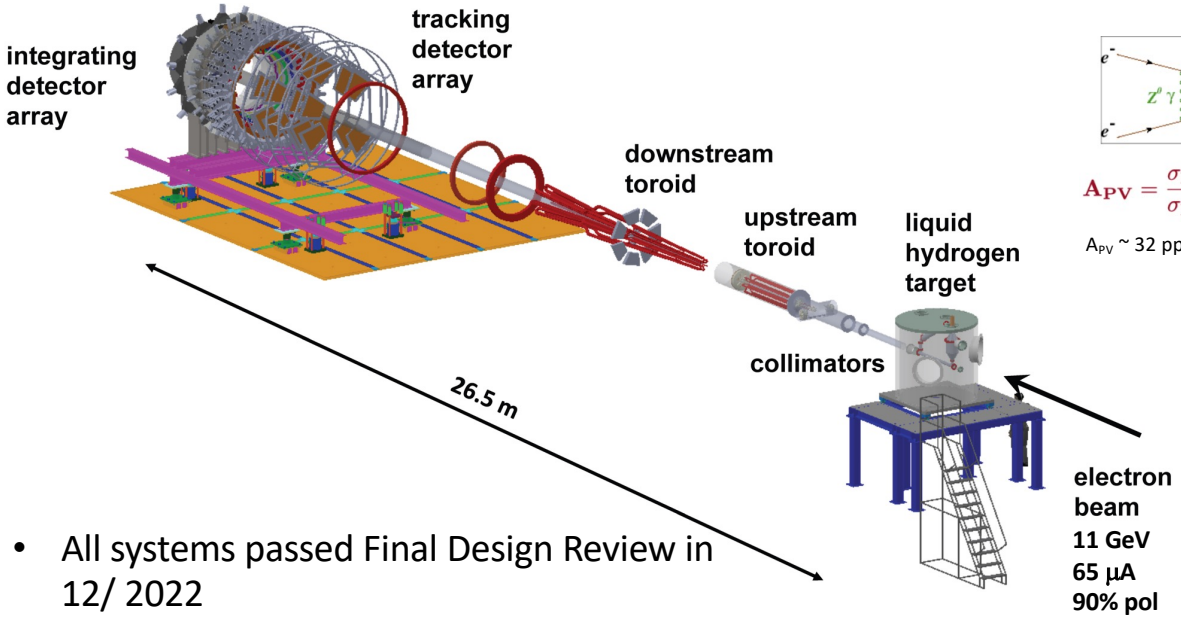
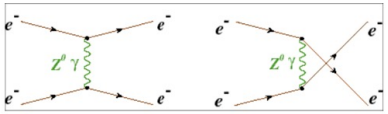
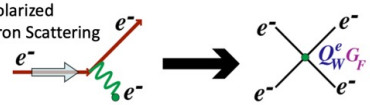
# MOLLER: World-leading Measurement of e-e PV



Fixed Target Polarized Electron-Electron Scattering

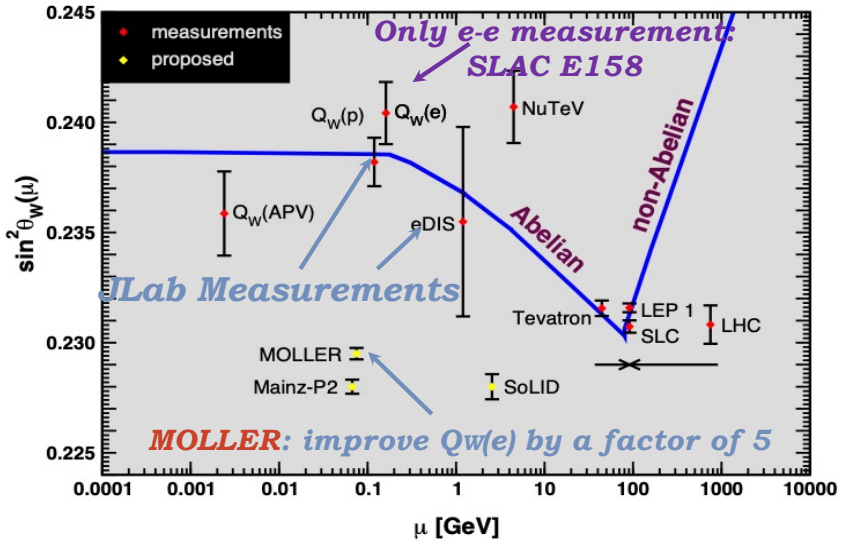


$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} = -mE\frac{G_F}{\sqrt{2}\pi\alpha}\frac{16\sin^2\Theta}{(3+\cos^2\Theta)^2}Q_W^e$$

$$Q_W^e = 1 - 4\sin^2\theta_W \sim 0.075$$

$A_{PV}$ ~ 32 ppb $\delta(A_{PV})$ ~0.8 ppb

$\delta(Q^e_w)$ = ±2.1% (stat) ± 1.1% (syst.)




- All systems passed Final Design Review in 12/ 2022
- Nearly all of the needed funding has been appropriated
- Achieved CD-3A, Approve Long Lead Procurements, in March 2023
- On track for CD-2/3, Start of Construction, in late CY2023
- On track to be ready for installation by Q1FY25



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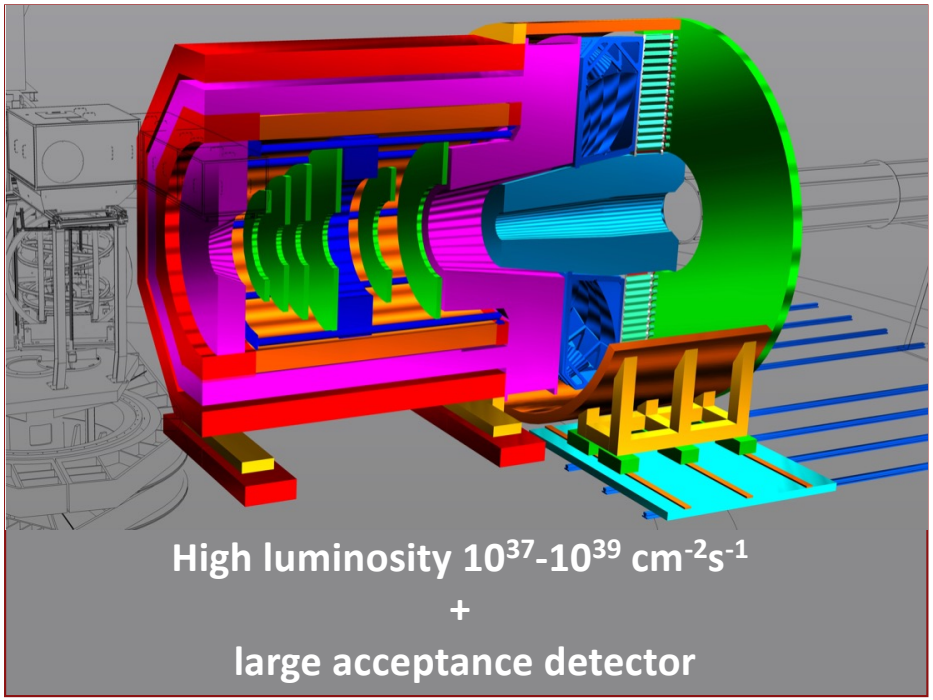
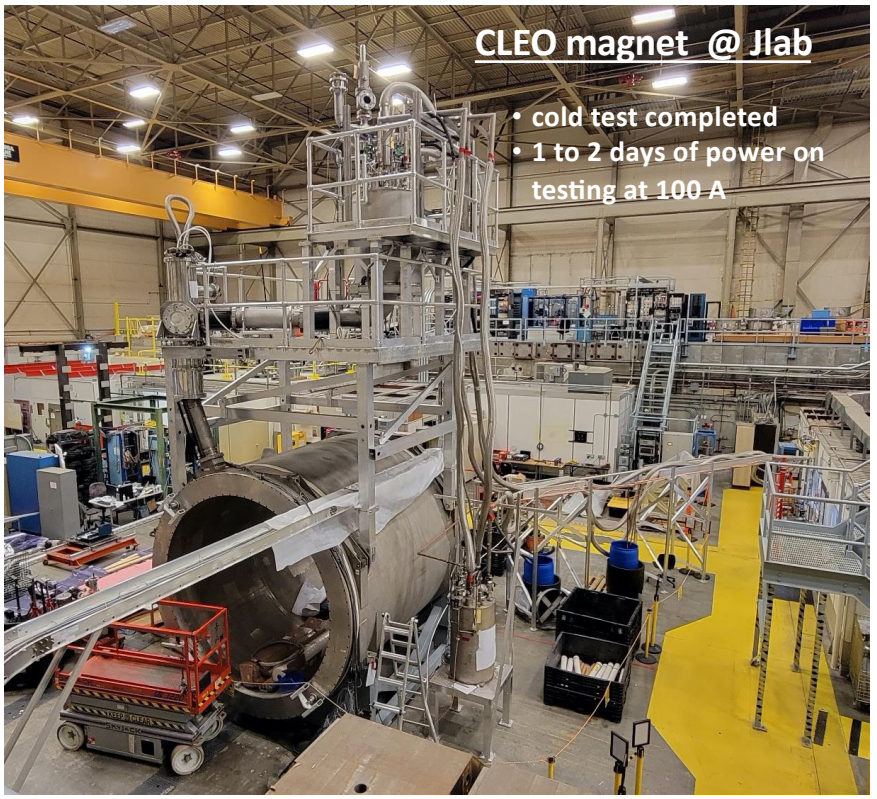
# Solenoidal Large Intensity Device (SoLID)



**High luminosity $10^{37}$-$10^{39}$ $cm^{-2}s^{-1}$**
**+**
**large acceptance detector**




- Precision 3D momentum imaging in the valence quark region
- BSM searches complementary to Moller
- Exploring the origin of the proton mass and gluonic force in the non-perturbative regime

**SoLID Awaiting Science Review Report**



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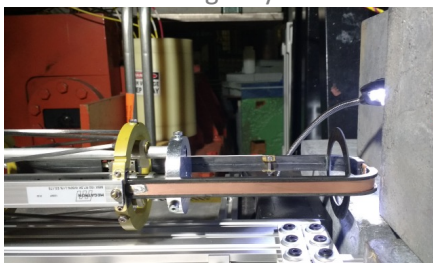
# Hall B: Nuclear Experiments

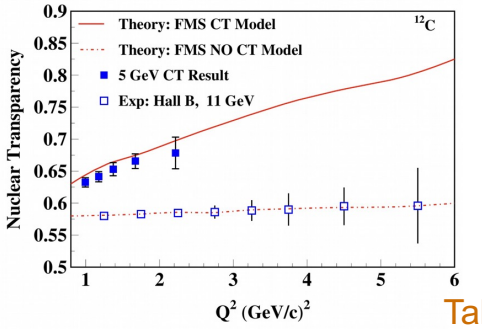
**Suite of experiments using nuclear targets: D, C, Al, Sn, Cu, Pb**

July 2023-Nov 2024

- Study of Color Transparency in Exclusive Vector Meson Electro-production off Nuclei
- Quark Propagation and Hadron Formation
- A Low Energy Recoil Tracker (ALERT): A comprehensive program to study the partonic nuclei & nuclear effects

new Double-Target system



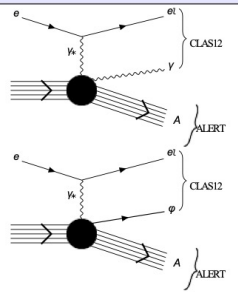



Talk by L. El Fassi

**Coherent Processes on $^4$He**

- $^4$He($e, e' ^4$He $\gamma$)
- $^4$He($e, e' ^4$He $\varphi$)

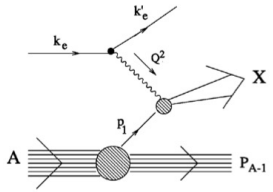
Explores the partonic structure of $^4$He




**DIS on $^4$He and $^2$H : Tagged EMC Effect**

- $^4$He($e, e'+^3$H)X (proton DIS)
- $^4$He($e, e'+^3$He)X (neutron DIS)
- $^2$H($e, e'$ + $p$)X (neutron DIS)

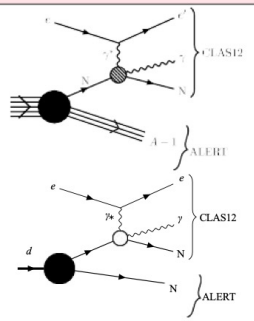
Test FSI and rescaling models



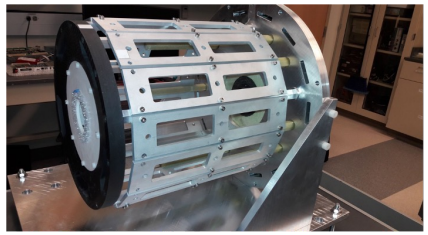

**Incoherent processes on $^4$He and $^2$H**

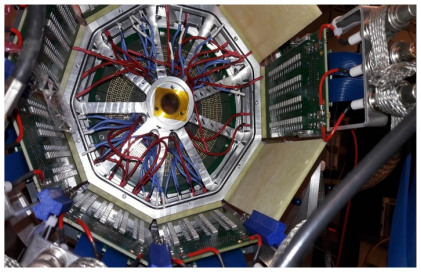
- $^4$He($e, e'\gamma$ $p+^3$H)
- $^4$He($e, e'\gamma$ $+^3$He)$n$
- $^2$H($e, e'\gamma$ + $p$)$n$

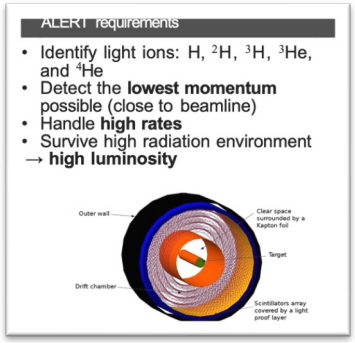
Identify medium modified nucleons




Upstream with electronics view








Jefferson Lab

# Hall C Neutral Particle Spectrometer (NPS) Program

**$e^-$ beam**

E12-13-010 - E12-06-114 - E12-13-007

- Exclusive Deeply Virtual Compton **on proton**
- SIDIS p(e,e',$p^0$) cross section.
  Map the transverse momentum dependence.

E12-22-006

- Exclusive Deeply Virtual Compton **on deuteron**
  Subtract the proton data from deuteron data to get neutron

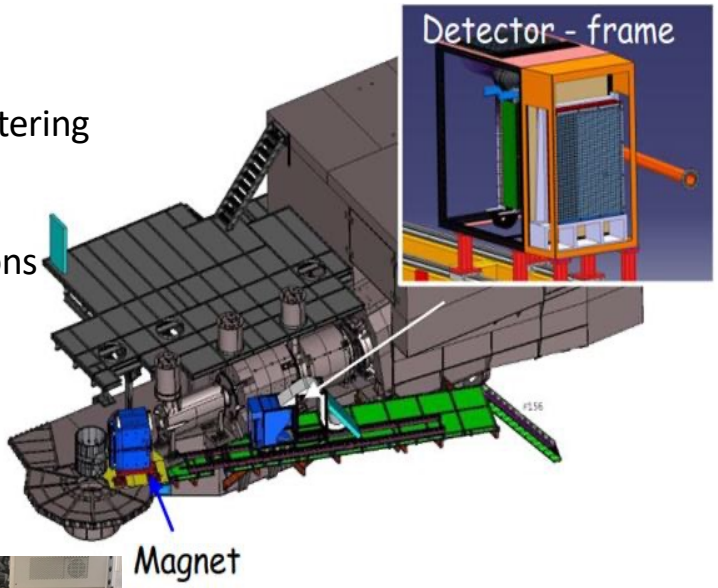
**$\gamma$ beam**

E12-14-003

- Wide-angle Compton Scattering

E12-14-005

- Wide Angle Exclusive Photoproduction of $\pi^0$ mesons




Being Installed -Start program in July 2023

Miktat Imre and Carlos Domingues installing PMT/bases assemblies

**Neutral Particle Spectrometer (NPS) : Magnet with calorimeter**

- 1080 Lead-Tungstate blocks in Calorimeter to detect $\gamma$ & $\pi^0$
- NPS attached to SHMS carriage to allow easy angle change. The calorimeter is on rails. Remove the SHMS HB magnet

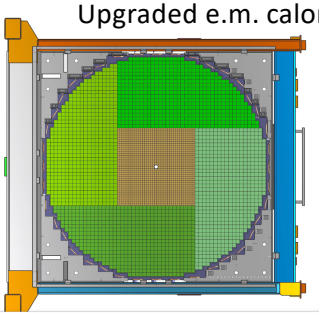
# Hall D: GlueX-II – JEF - KLF

**Jefferson Lab Eta Factory (JEF):** a unique probe for QCD and BSM physics

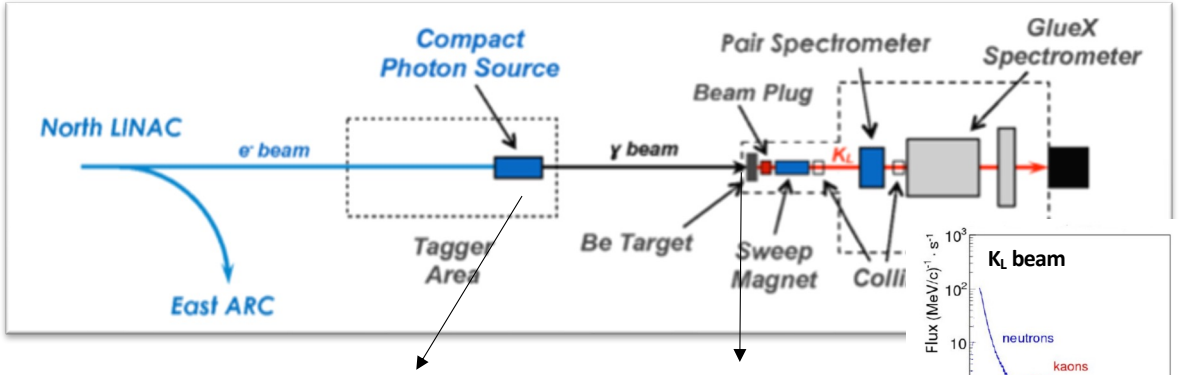
- Probe a leptophobic dark B-boson in 140-550 MeV range via $\eta \rightarrow B\gamma \rightarrow \pi^0\gamma\gamma$
- Directly constrain CVPC new physics via $\eta \rightarrow 3\gamma$
- Test the role of scalar dynamics in ChPT through $\eta \rightarrow \pi^0\gamma\gamma$
- A clean determination of the light quark mass ratio via $\eta \rightarrow 3\pi$

Start Program in 2024

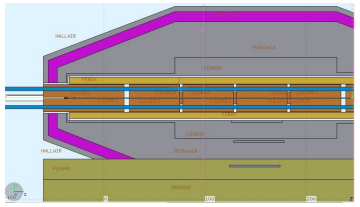
Upgraded e.m. calorimeter in preparation



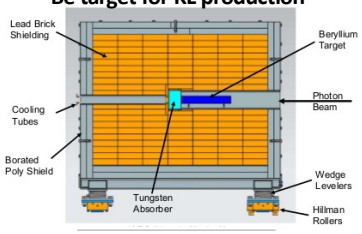
## K-long Facility: Spectroscopy in $K_{LONG}$ beam

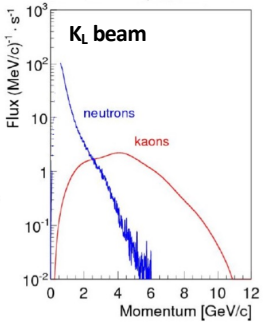



Compton Photon Source (CPS) design development



Be target for KL production



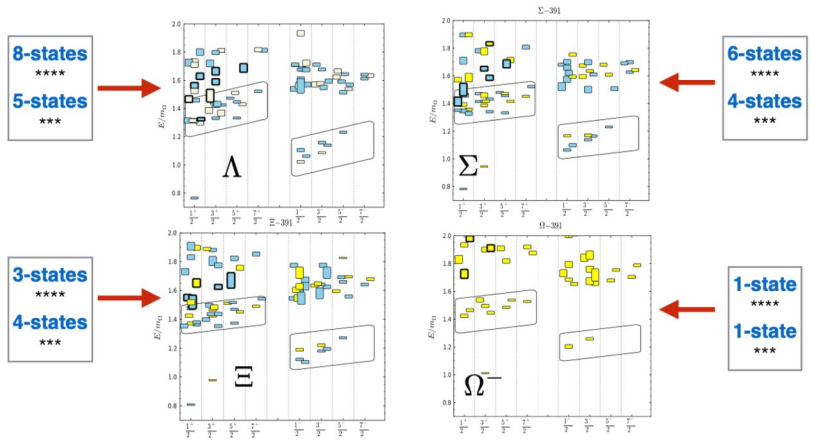

$N(K_L)/sec \sim 10^4$

Tentative schedule for installation 2026



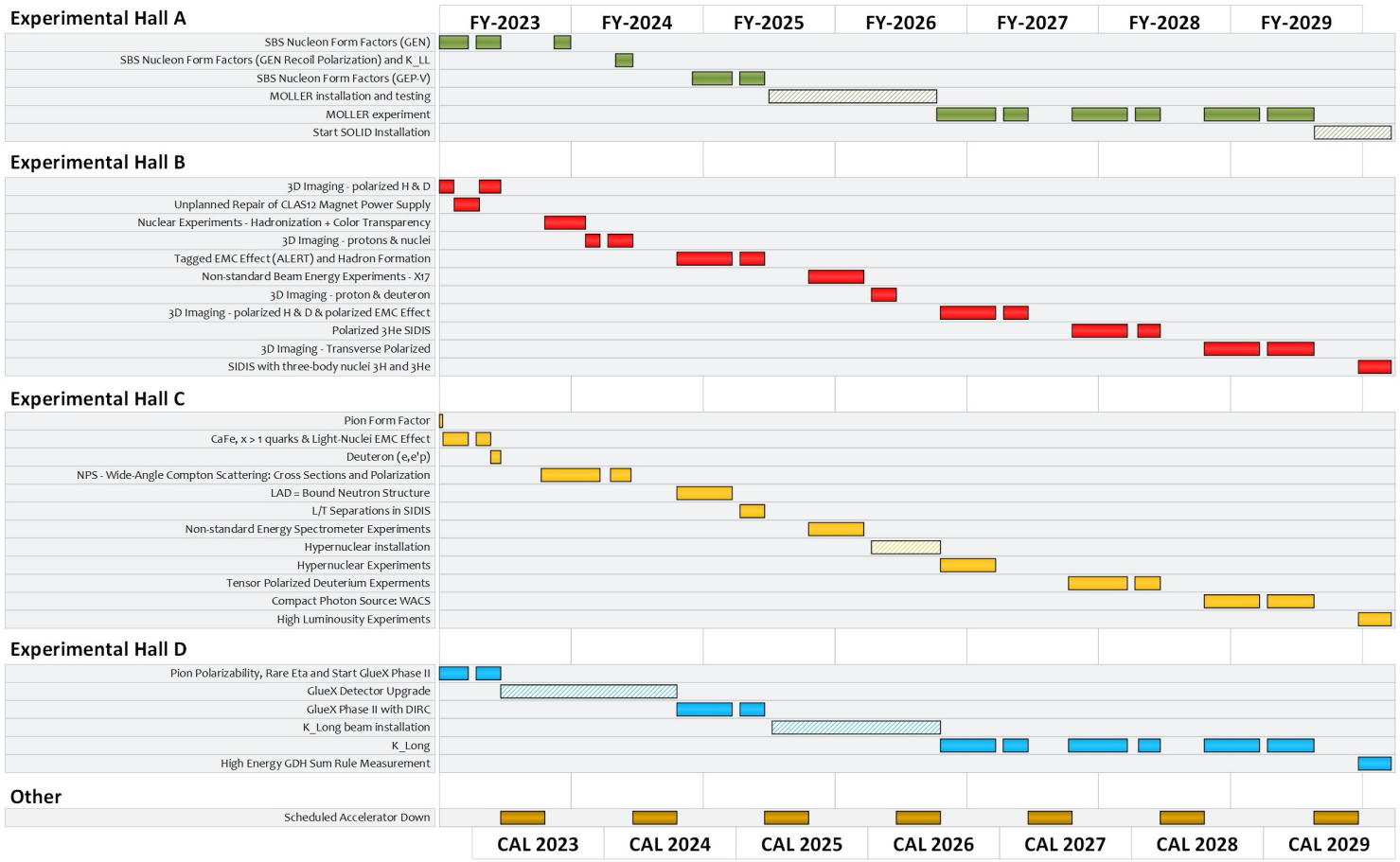
## Hyperon Spectroscopy

*LQCD in addition to already known states predicts many more including hybrids (thick bordered)*




Edwards, Mathur, Richards and Wallace, Phys. Rev. D 87, 054506 (2013)

# Extended Experimental Schedule/Draft




- **SoLID installation could start ~mid-FY29**
- **86% complete in FY29 without SoLID, 70% complete with SoLID** (assuming optimal running operation)

…not including new proposals

- **A new NPES schedule is about to be released**
  - **Schedule to March 2025**
  - **Assumes 33 weeks of physics running annually**

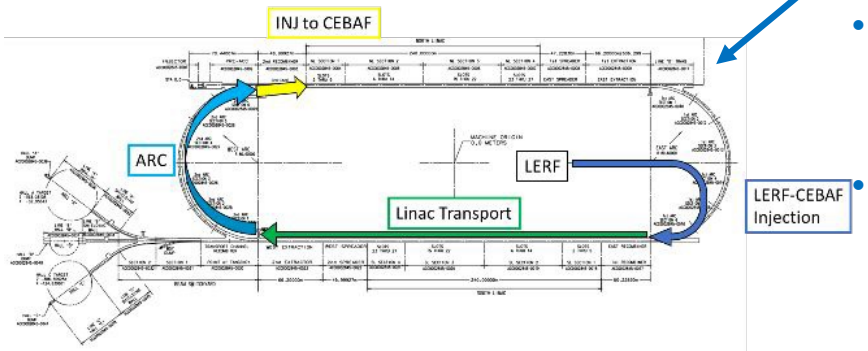


Jefferson Lab

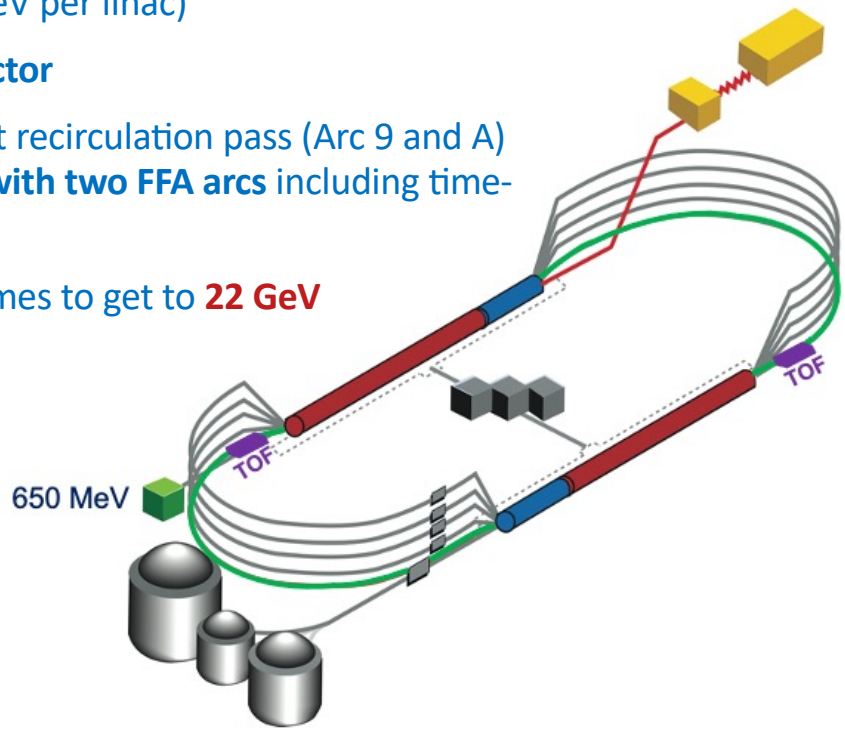
# Feasible, Cost effective, Innovative Path from $e^+$ to 22 GeV

Capitalize on recent science insights and US-led accelerator science and technology innovations to develop a **staged program at the luminosity frontier**

- CEBAF @ 22 GeV
- Positron beam

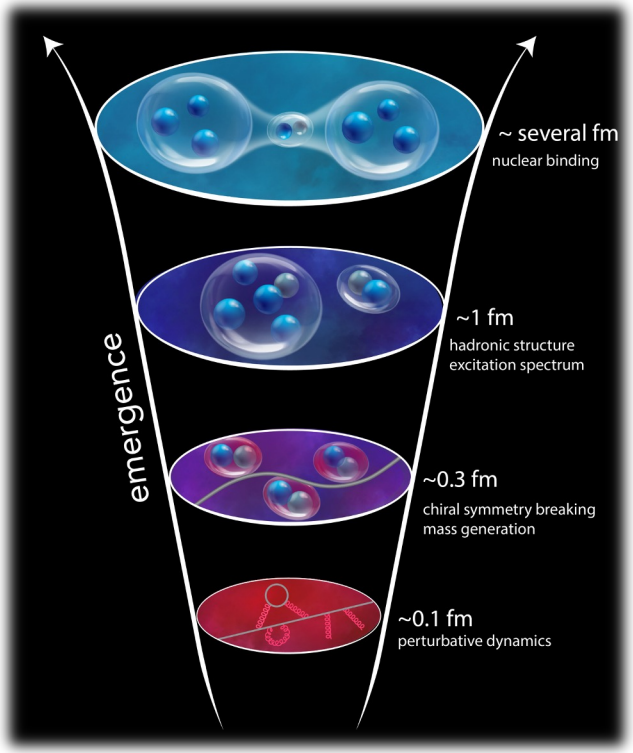



- Starting with 12 GeV CEBAF
- NO new SRF (1.1 GeV per linac)
- **New 650 MeV injector**
- Remove the highest recirculation pass (Arc 9 and A) and **replace them with two FFA arcs** including time-of-flight chicane
- Recirculate 4.5+6times to get to **22 GeV**




- **Positrons (e+) in the LERF with transport to CEBAF**
- Injection energy upgrade for 650 MeV Electron (e-) in LERF

# Why CEBAF @ 22 GeV?




## Emergence of hadron structure

Complex non-pQCD problem which demands different approaches and measurements to access multiple observables

**What a 22 GeV upgrade will bring:**

- **some important thresholds would be crossed → charm, nuclear distances, in fundamental symmetries, etc..**
- **An energy window which sits between JLab @ 12 GeV and EIC**
  **→ test and validation of our theory from lower to higher energy**

- **A rich physics program is under development, leveraging on existing or already-planned infrastructure and on the uniqueness of CEBAF HIGH LUMINOSITY**

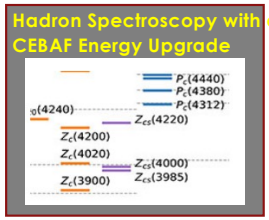
# Science Case for an Energy Upgrade

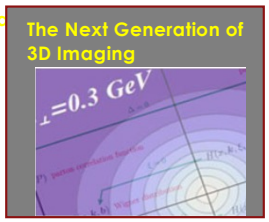
## International Workshops

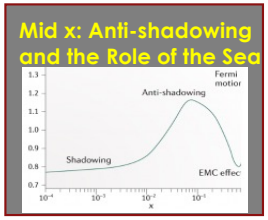
March-Sep 2022

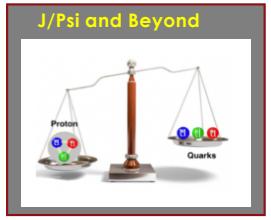

## Summer Series @ Jlab

Jun-Aug 2022





## Science at the Luminosity Frontier: JLab at 22 Gev

January 23-25, 2023


- **Physics case summarized in a short document sent to the LRP writing committee**
- **Longer document is in preparation**
  - **It will be circulated within the community**
  - **Goal is to post it on (ArXiv) by the end of May**

APS April Meeting 2023
Apr 15 & 16, 2023

**B15/K16 Mini-Symposium: Opportunities with Jlab Upgrades in Energy, Luminosity and a Positron Beam**

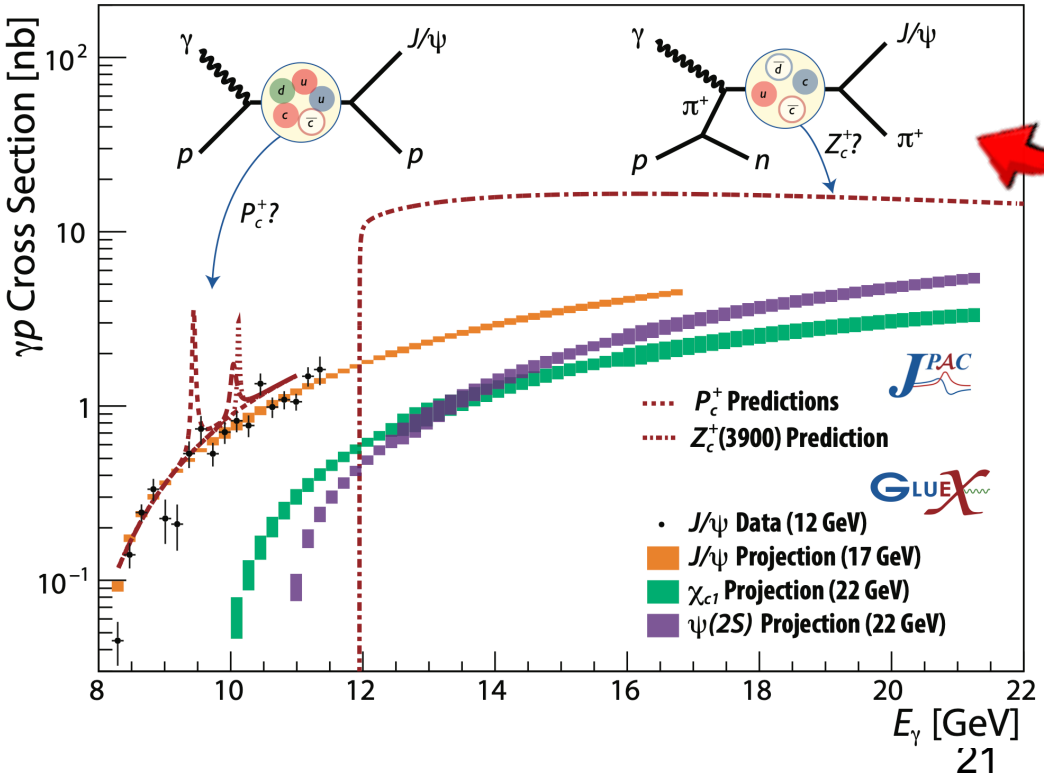
Jefferson Lab

# Spectroscopy of Exotic States with $c\bar{c}$

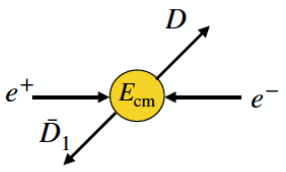
**Photoproduction of hadrons with charm quarks: new tool for discovery in QCD**

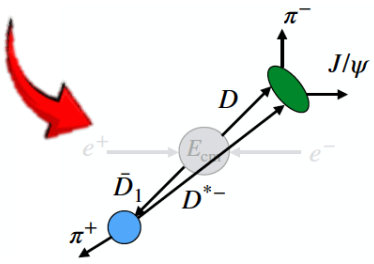
➜ potentially decisive information about the **nature of some 5-quark and 4-quark** candidates

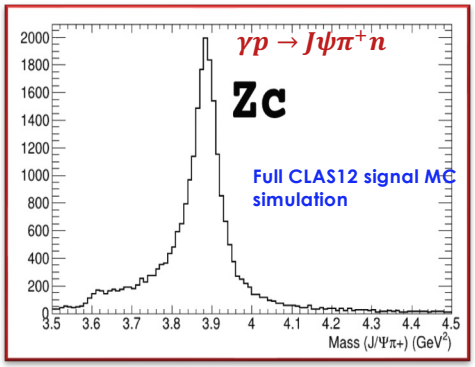
➜ a unique method to probe the **structure of the proton**




- Never direcly produced using γ/lepton beam
- Direct probe of the $Z_c \to J/\psi\pi$ coupling without rescattering effects




Simulations from GlueX & CLAS12 with existing detectors

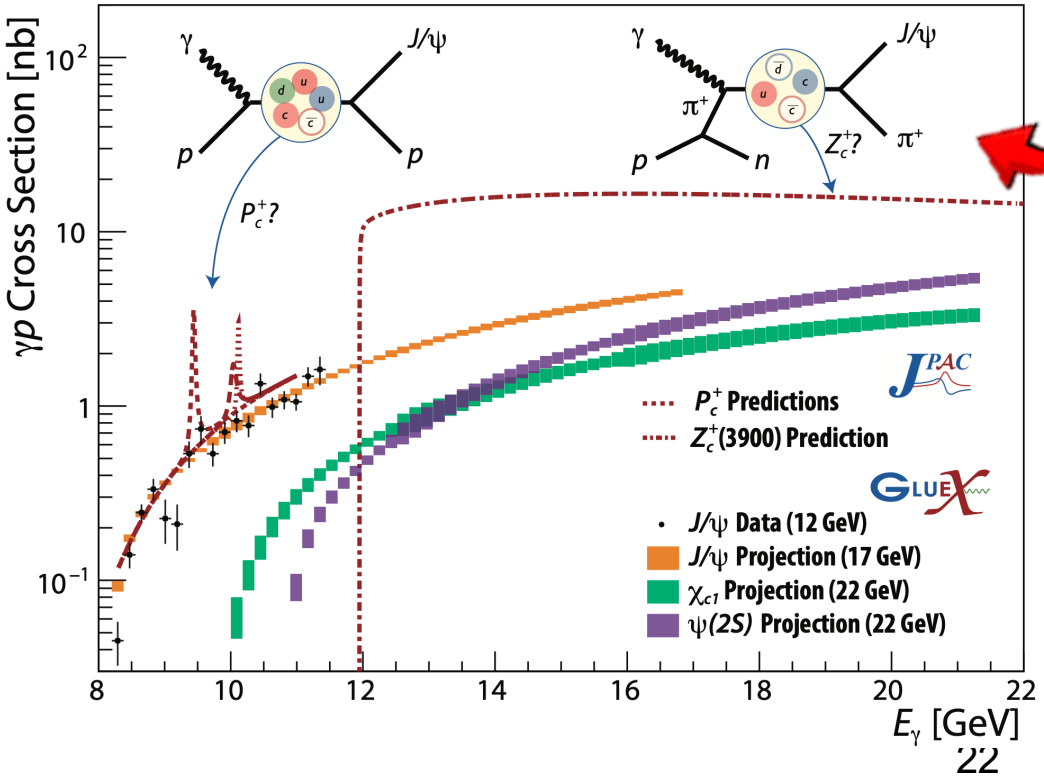
Jefferson Lab

# Spectroscopy of Exotic States with $c\bar{c}$

**Photoproduction of hadrons with charm quarks: new tool for discovery in QCD**

➜ potentially decisive information about the **nature of some 5-quark and 4-quark** candidates

➜ a unique method to probe the **structure of the proton**

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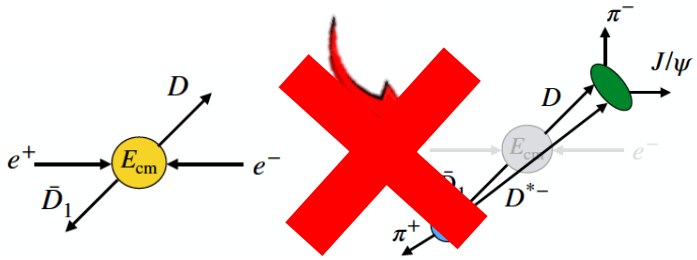


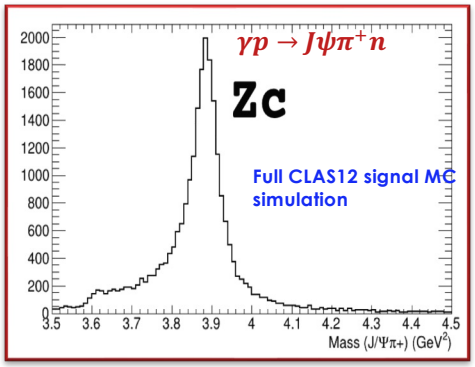


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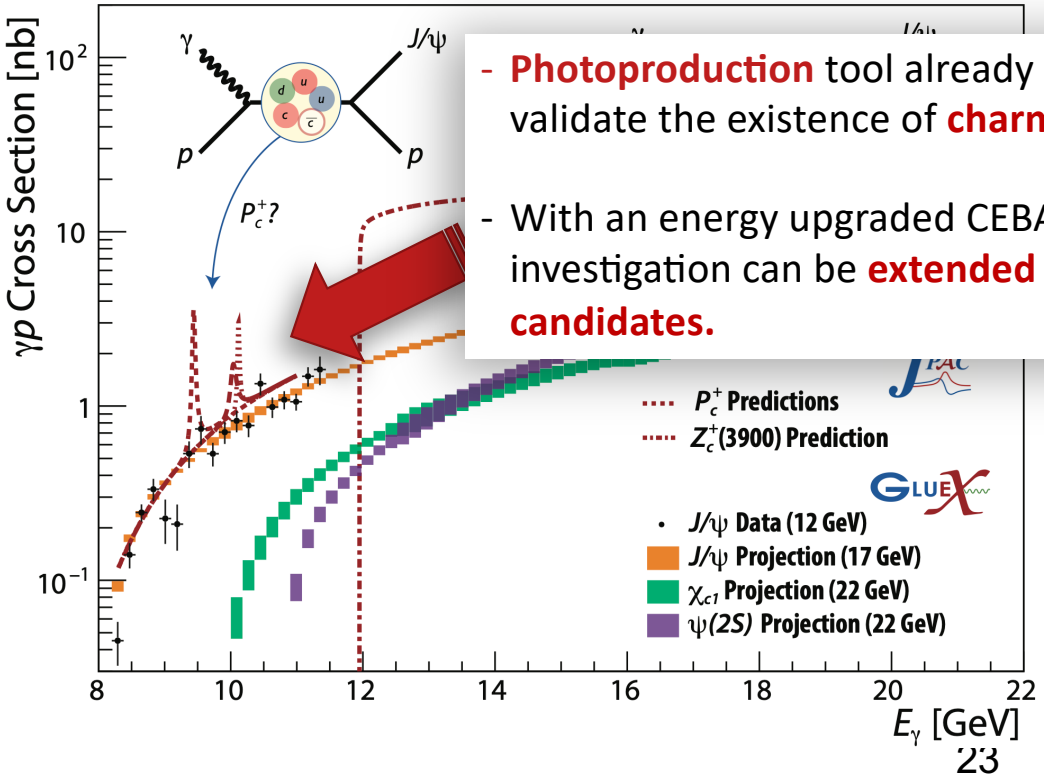
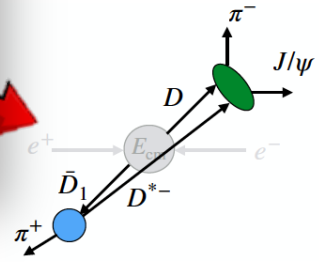


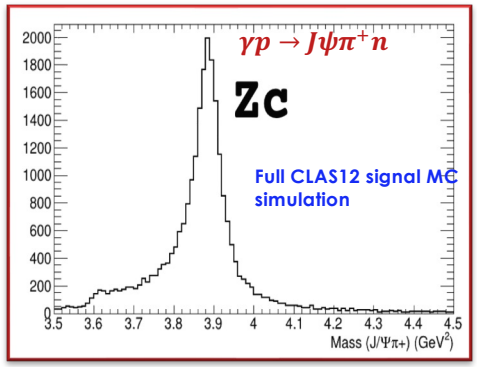

- **Photoproduction** tool already used at 12 GeV to validate the existence of **charmed pentaquark**.

- With an energy upgraded CEBAF, this line of investigation can be **extended to other exotic candidates.**

- Never direcly produced using γ/lepton beam

$c \to J/\psi\pi$ coupling without




Simulations from GlueX & CLAS12 with existing detectors



Jefferson Lab

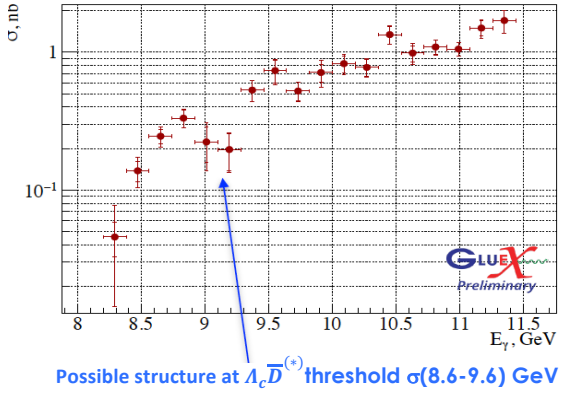
# J/ψ photoproduction near threshold

**Used to study important aspects of the gluon structure of the proton**

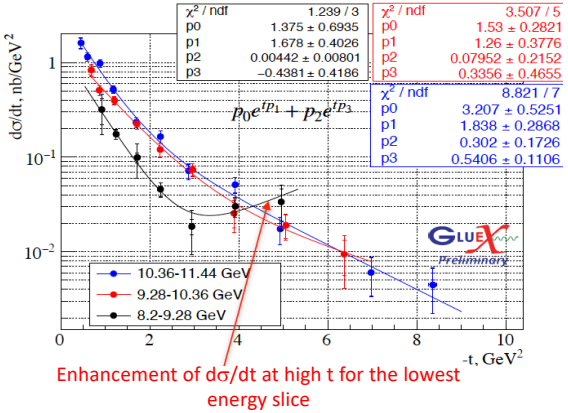
- **gluon GPD**
- **mass radius of the proton,**
- **anomalous contribution to the proton mass**.

..based on some assumptions (mainly 2-g exchange)

**GlueX final results to be submitted to PRC**




Possible structure at $\Lambda_c\bar{D}^{(*)}$ threshold σ(8.6-9.6) GeV

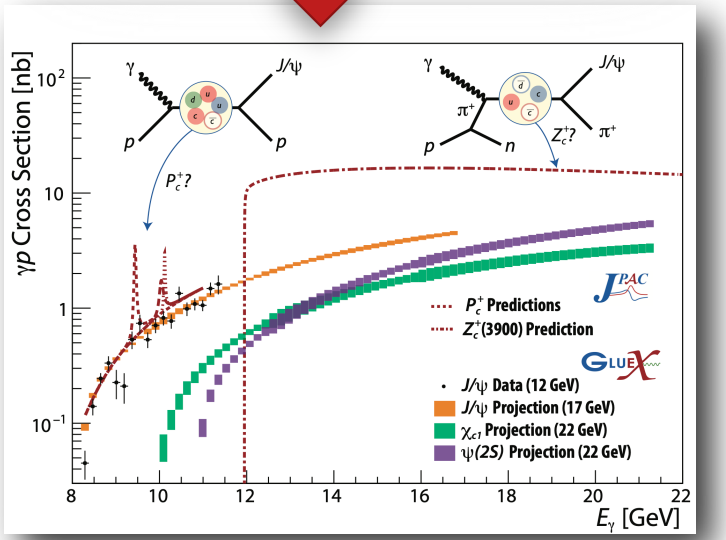



Enhancement of dσ/dt at high t for the lowest energy slice

- **CANNOT be explained by t-channel (GLUON EXCHANGE) alone**
- Can have contribution from open-charm exchange to both $\sigma$ and $d\sigma/dt$ at high t

Talk by L. Pentchev

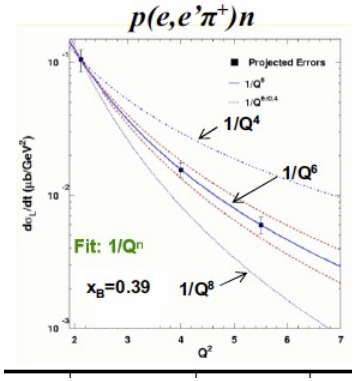
**Need precise measurements to develop accurate theoretical models to understand the mechanism! POSSIBLE with GlueX at 17+ GeV**

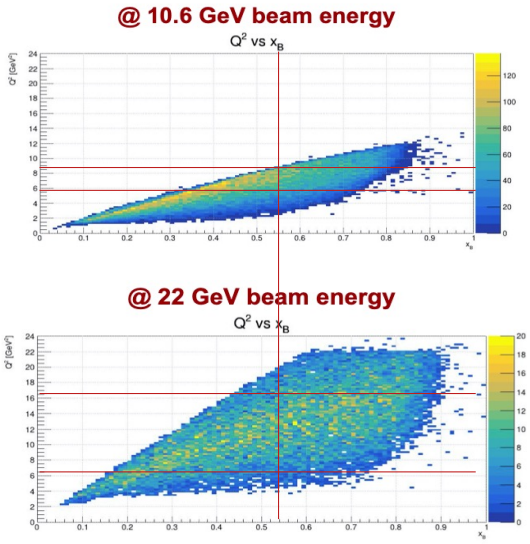




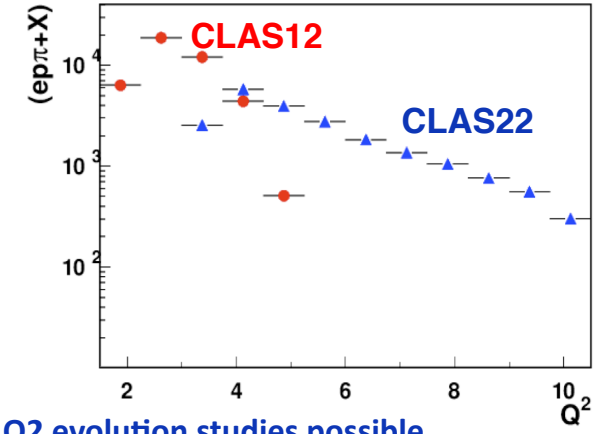

Jefferson Lab

# 3D Structure of the Nucleon

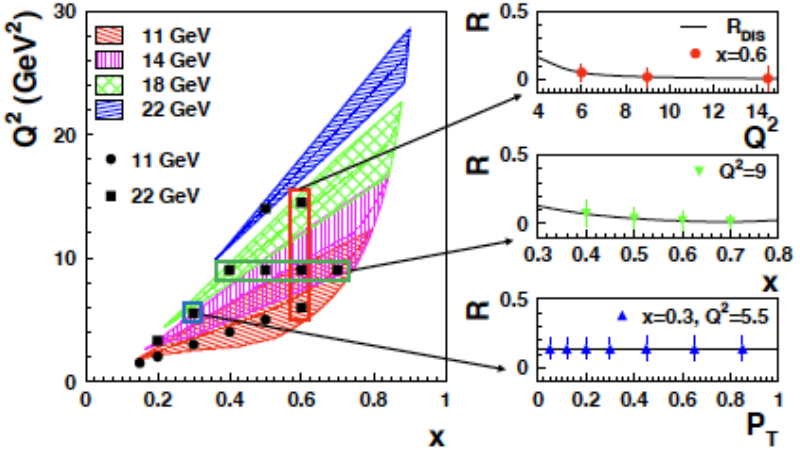



- The relevant $Q^2$ range for the $Q^n$ scaling test (GPD formalism) significantly increase with 18/22 GeV beam




- Q2 evolution studies possible
  - QCD predicts only the $Q^2$ dep.
  - Leading/sub-leading contributions




b

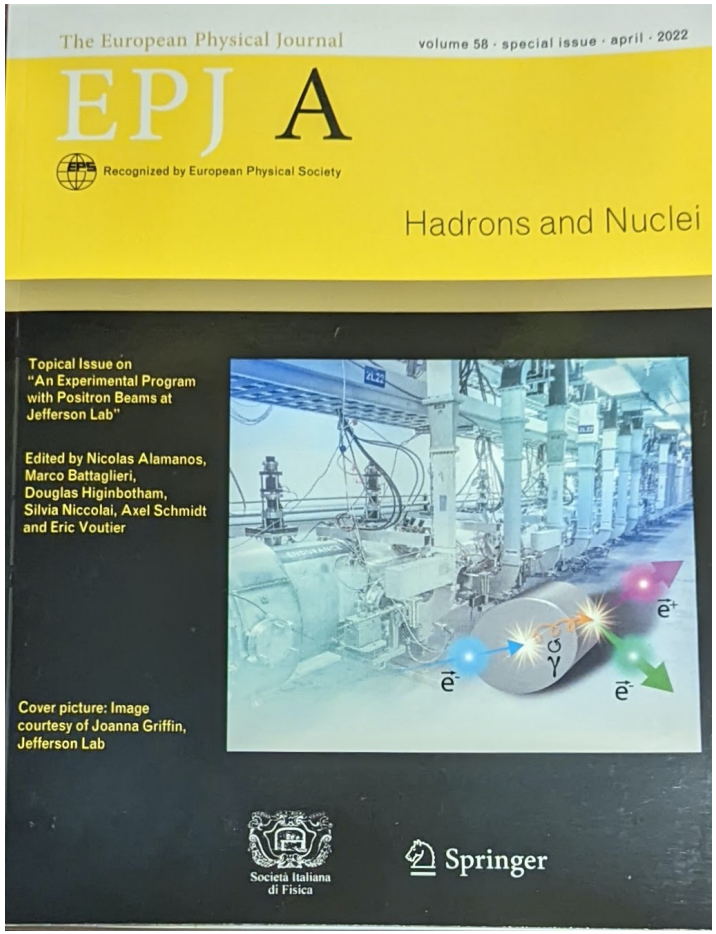
**A combined 11 and 22 GeV SIDIS program**

- will provide a unique determination of the ratio of longitudinal to transverse photon SIDIS cross sections essential to properly understand SIDIS multiplicities, Sivers and Collins effects,…

# Positron Program White Paper

| Experiment Label (EPJ A) | Short Name | Measurement Configuration Hall | Detector | Target | Polarity | Beam Parameters $p$ (GeV/$c$) | $P$ (%) | $I$ ($\mu$A) | Time (d) | PAC Grade |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | ***Two Photon Exchange Physics*** | | | | | | | |
| 57:144 | $H(e,e'p)$ | B | CLAS12$^{+}$ | $H_2$ | $+/-_s$ | 2.2/3.3/4.4/6.6 | 0 | 0.060 | 53 | |
| 57:188 | $H(\vec{e},e'\vec{p})$ | A | ECAL/SBS | $H_2$ | $+/-_p$ | 2.2/4.4 | 60 | 0.200 | 121 | |
| 57:199 | $r_p$ | B | PRad-II | $H_2$ | + | 0.7/1.4/2.1 | 0 | 0.070 | 40 | |
| | $r_d$ | | | $D_2$ | | 1.1/2.2 | | 0.010 | 39 | |
| 57:213 | $\vec{H}(e,e'p)$ | A | BB/SBS | $N\vec{H}_3$ | $+/-_s$ | 2.2/4.4/6.6 | 0 | 0.100 | 20 | |
| 57:290 | $H(e,e'p)$ | A | HRS/BB/SBS | $H_2$ | $+/-_s$ | 2.2/4.4 | 0 | 1.000 | 14 | |
| 57:319 | SupRos | A | HRS | $H_2$ | $+/-_p$ | 0.6–11.0 | 0 | 2.000 | 35 | |
| 58:36 | $A(e,e')A$ | A | HRS | He | $+/-_p$ | 2.2 | 0 | 1.000 | 38 | |
| | | | ***Nuclear Structure Physics*** | | | | | | | |
| 57:186 | p-DVCS | B | CLAS12 | $H_2$ | $+/-_s$ | 2.2/10.6 | 60 | 0.045 | 100 | C2 |
| 57:226 | n-DVCS | B | CLAS12 | $D_2$ | $+/-_s$ | 11.0 | 60 | 0.060 | 80 | |
| 57:240 | p-DDVCS | A | SoLID$^{\mu}$ | $H_2$ | $+/-_s$ | 11.0 | (30) | 3.000 | 100 | |
| 57:273 | He-DVCS | B | CLAS12/ALERT | $^4$He | $+/-_s$ | 11.0 | 60 | | | |
| 57:300 | p-DVCS | C | SHMS/NPS | $H_2$ | + | 6.6/8.8/11.0 | 0 | 5.000 | 77 | C2 |
| 57:311 | DIS | A/C | HRS/HMS/SHMS | | $+/-_s$ | 11.0 | | | | |
| 57:316 | VCS | C | HMS/SHMS | $H_2$ | $+/-_s$ | | 60 | | | |
| | | | ***Beyond the Standard Model Physics*** | | | | | | | |
| 57:173 | $C_{3q}$ | A | SoLID | $D_2$ | $+/-_s$ | 6.6/11.0 | (30) | 3.000 | 104 | D |
| 57:253 | LDM | B | PADME | C | + | 11.0 | 0 | 0.100 | 180 | |
| | | | ECAL/HCAL | $PbW0_4$ | | | | | 120 | |
| 57:315 | CLFV | A | SoLID$^{\mu}$ | $H_2$ | + | 11.0 | | | | |
| | | | | | | | | **Total (d)** | **1121** | |

CLAS12$^{+}$ $\equiv$ CLAS12 implemented with an Electromagnetic Calorimeter in the Central Detector
SoLID$^{\mu}$ $\equiv$ SoLID complemented with a muon detector
+ Secondary positron beam
$-_s$ Secondary electron beam
$-_p$ Primary electron beam
(30) Do not require polarization but would take advantage if available at the required beam intensity




Talk by D. Higinbotham



https://doi.org/10.1140/epja/s10050-022-00699-6

# Conclusions

- The 12 GeV era is going strong
  - More than 1/3 of experiments have been completed
  - High-profile results are emerging from the program

- CEBAF's approved program extends into 2030s (assuming ~30 weeks OPS/year)
  - 86% complete in FY29 without SoLID
  - 70% complete with SoLID

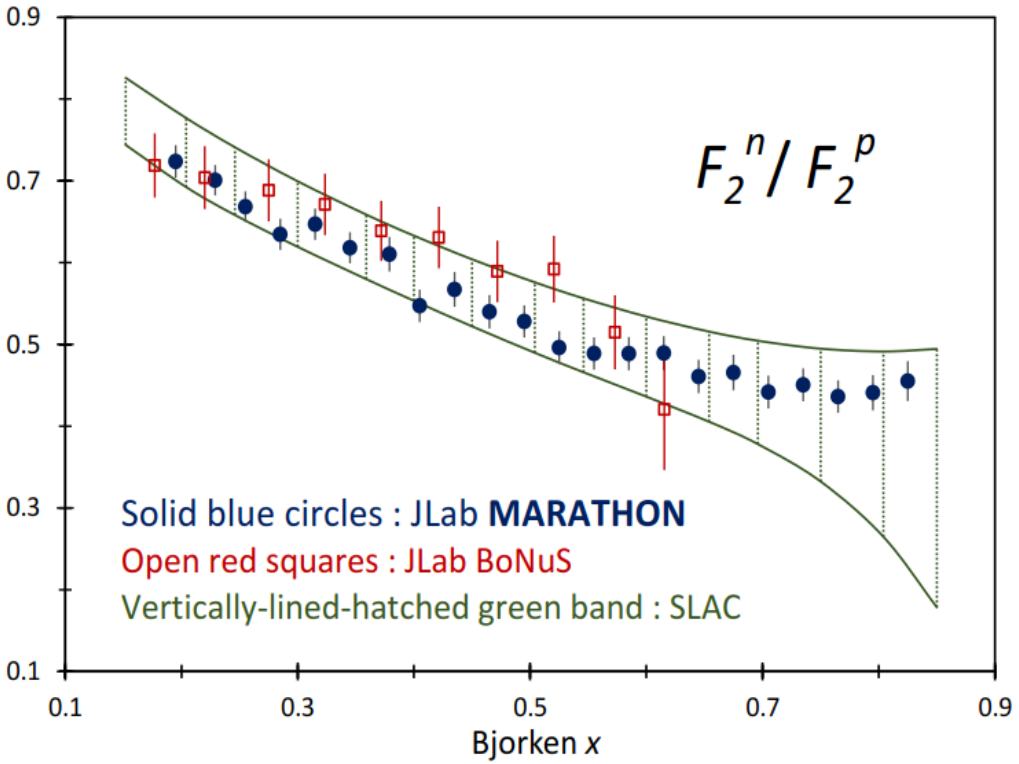
- CEBAF will remain a critical facility for fixed target electron scattering at high luminosity
  - Laying the groundwork for an exciting role for CEBAF in the EIC era
    - CEBAF @ 22 GeV
    - Positron Beam

- A rich physics program for "Future CEBAF" is under development, leveraging on existing or already-planned infrastructure and on the uniqueness of CEBAF HIGH LUMINOSITY

# Backup Slides

# PDF at large x : $F_2^n/F_2^p$

## New generation of experiments at JLab focused on high x




**MARATHON (Hall A)**

**Minimizes bias from nuclear effects by measuring $^3He/^3H$ ratios**

Phys. Rev. Lett. 128, 132003 (2022)

**BONUS (Hall B)**

**Minimizes bias from nuclear effects by using fixed target tagged DIS**

Some publishable results expected by end of Summer or early Fall of 2023

**E12-10-002 (Hall C)**

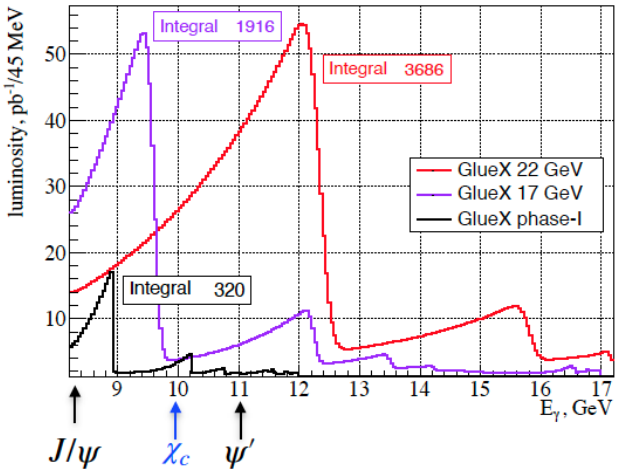
**wide x range (from 0.2 to 1) with small statistical and systematic uncertainties**

**$F_2^n/F_2^p$ predicted by models**

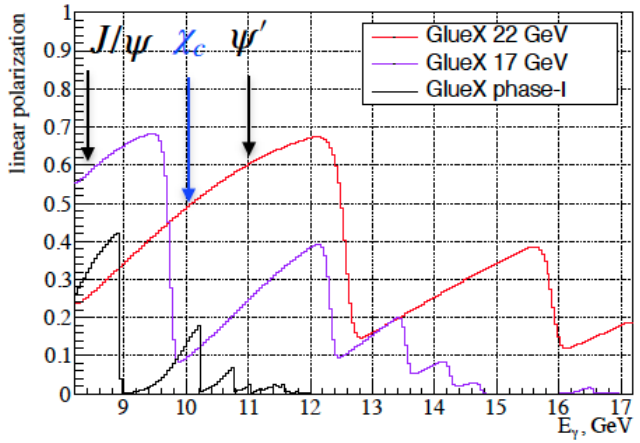
| Model | $F_2^n/F_2^p$ |
|---|---|
| SU(6) | 2/3 |
| NJL | 0.43 |
| DSE-1 | 0.49 |
| CQM | 0.25 |
| pQCD | 3/7 |

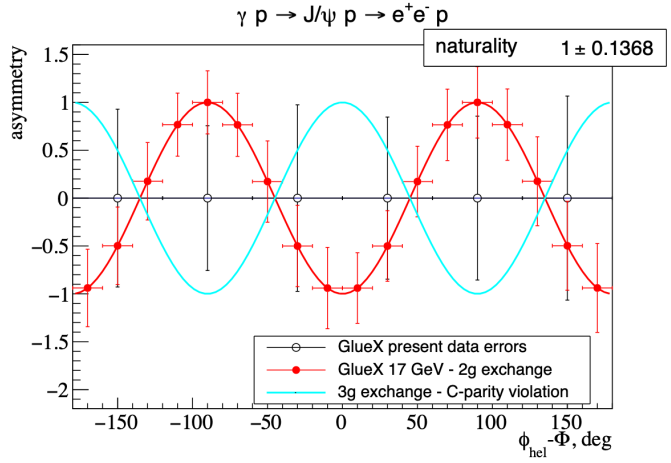
# J/ψ photo-production and other charmonium states in Hall D

## hiaher fluxes




## Increased γ linear polarization






Jefferson Lab