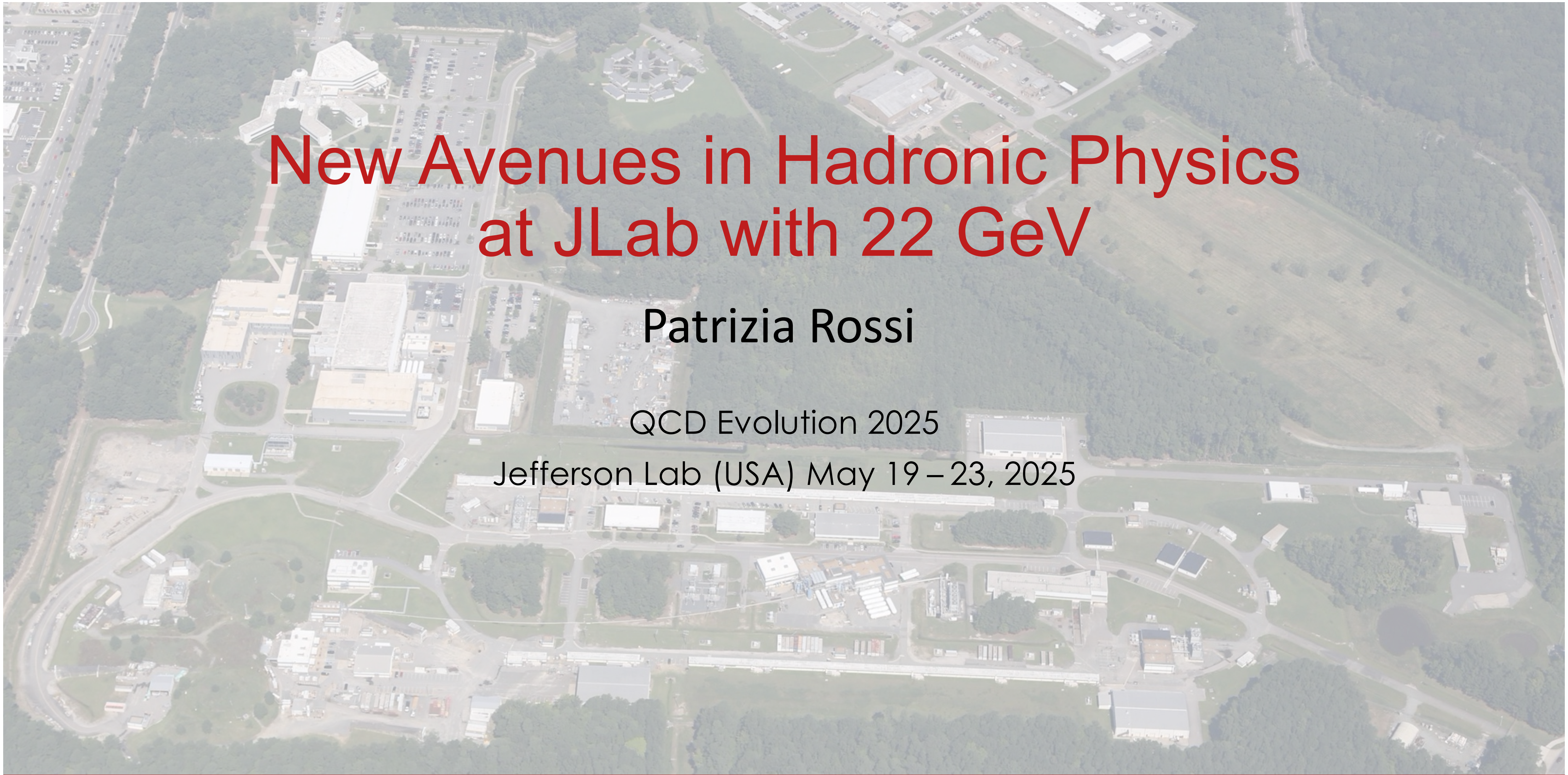
New Avenues in Hadronic Physics at JLab with 22 GeV

Patrizia Rossi

QCD Evolution 2025

Jefferson Lab (USA) May 19 – 23, 2025



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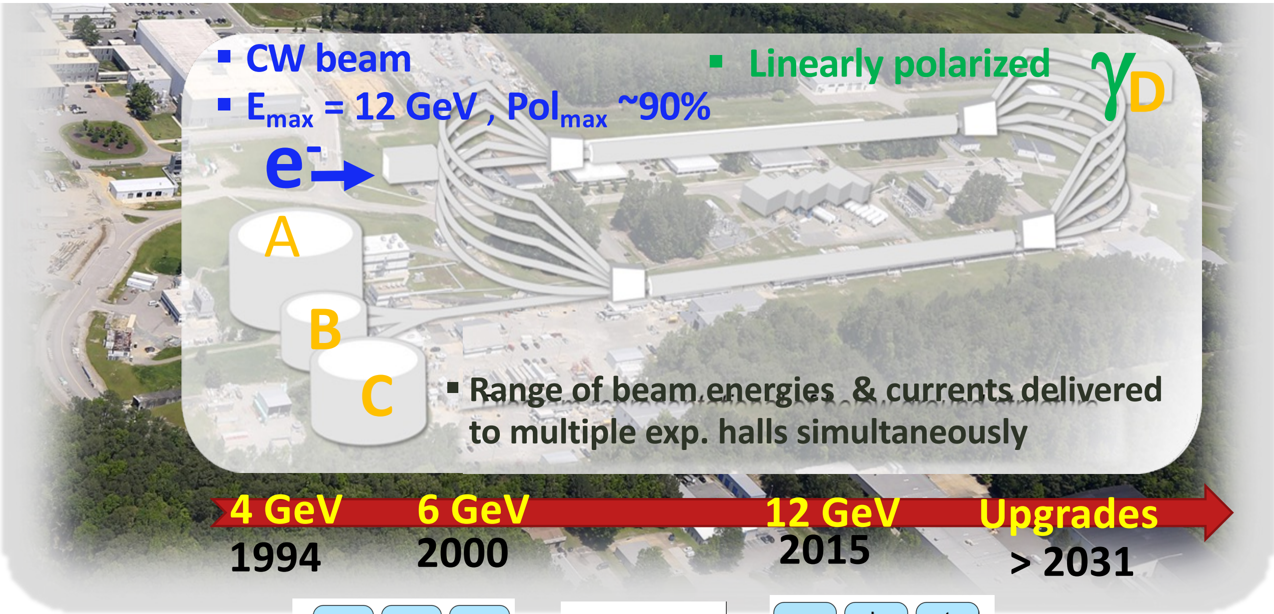
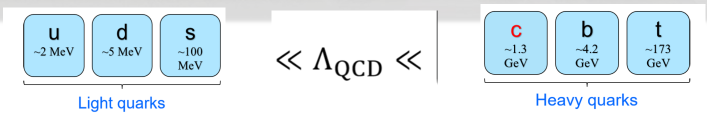
Jefferson Lab - a Cornerstone of Modern Hadron Physics Research





A Facility at the LUMINOSITY Frontier
(up to 10^{39} cm^{-2} s^{-1})

World-Class Electron Beam
CEBAF provides a high-quality, 12 GeV continuous electron beam with::
- High Intensity
- High Polarization

Unique Experimental Facilities
CEBAF supports 4 cutting-edge experimental halls with:
- State-of-the-art detectors
- Versatile experimental setups
- Detection of multiparticle in the Final State

Impactful Research
CEBAF has a history of groundbreaking discoveries

- A NEW territory to explore
- A BETTER insight into our current program
- A BRIDGE between JLab @ 12 GeV and EIC

CEBAF @ 22 GeV
Positron Beam @ 12 GeV

The 22 GeV Physics Program

EPJ A

Hadrons and Nuclei

White Paper
***Eur.Phys.J.A* 60 (2024) 9, 173**

2023 Impact factor **2.6**

10 most recent | All issues | Topical Collections | Reviews | Letters | Viewpoints & Perspectives | Code Papers

Eur. Phys. J. A (2024) **60**: 173
https://doi.org/10.1140/epja/s10050-024-01282-x

Review

~ 450 authors

Strong interaction physics at the luminosity frontier with 22 GeV electrons at Jefferson Lab

A. Accardi[1], P. Achenbach[2], D. Adhikari[3], A. Afanasev[4], C. S. Akondi[5], N. Akopov[6], M. Albaladejo[7], H. Albataineh[8], M. Albrecht[2], B. Almeida-Zamora[9], M. Amaryan[10], D. Androić[11], W. Armstrong[12], D. S. Armstrong[13], M. Arratia[14], J. Arrington[15], A. Asaturyan[16], A. Austregesilo[2], H. Avakian[2], T. Averett[13], C. Ayerbe Gayoso[13], A. Bacchetta[17], A. B. Balantekin[18], N. Baltzell[2], L. Barion[19], P. C. Barry[2], A. Bashir[2,20], M. Battaglieri[21], V. Bellini[22], I. Belov[21], O. Benhar[23], B. Benkel[24], F. Benmokhtar[25], W. Bentz[26], V. Bertone[27], H. Bhatt[28], A. Bianconi[29], L. Bibrzycki[30], R. Bijker[31], D. Binosi[32], D. Biswas[3], M. Boër[3], W. Boeglin[33], S. A. Bogacz[2], M. Boglione[34], M. Bondí[22], E. E. Boos[35], P. Bosted[13], G. Bozzi[36], E. J. Brash[37], R. A. Briceño[38], P. D. Brindza[10], W. J. Briscoe[4], S. J. Brodsky[39], W. K. Brooks[24,40,41], V. D. Burkert[2], A. Camsonne[2], T. Cao[2], L. S. Cardman[2], D. S. Carman[2], M. Carpinelli[42], G. D. Cates[43], J. Caylor[2], A. Celentano[21], F. G. Celiberto[44], M. Cerutti[17], L. Chang[45], P. Chatagnon[2], C. Chen[46,47], J.-P. Chen[2], T. Chetry[33], A. Christopher[1], E. Christy[2], E. Chudakov[2], E. Cisbani[23], I. C. Cloët[12], J. J. Cobos-Martinez[48], E. O.

- Hadron Spectroscopy
- Partonic Structure and Spin
- Hadronization and Transverse Momentum
- Spatial Structure, Mechanical Properties, Emergent Hadron Mass
- Hadron-Quark Transition and Nuclear Dynamics at Extreme Conditions
- QCD Confinement and Fundamental Symmetries

The 22 GeV Physics Program

A new document outlining the progress of the scientific case will be available soon

Goal 1: recent developments since the white paper

- Changes in the overarching goals or focus since the white paper
- Progress made in understanding either the discovery potential or anticipated (statistical and systematic) precision of key observables
- New thrusts or topics in this broad area that would benefit from 22 GeV data that are not featured in the white paper (or topics in the white paper for which it has become evident that 22 GeV data will not add significant scientific value)

Goal 2: future plans

- Most critical simulation exercises needed to understand sensitivity
- Most important theoretical issues to address
- Key results from 12 GeV data needed to help solidify the science case for 22 GeV

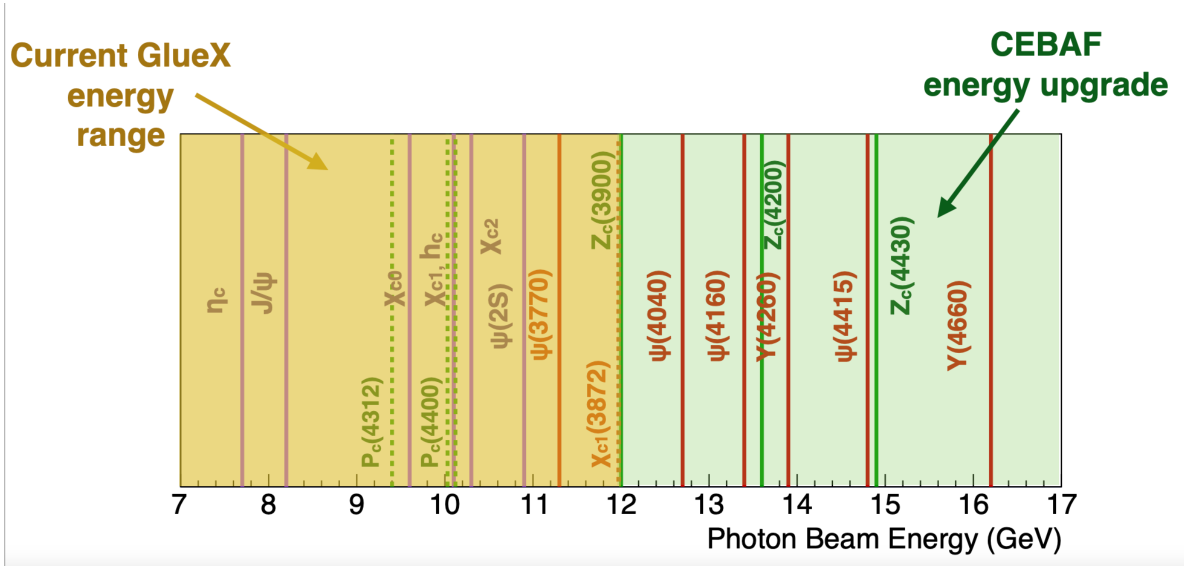
Goal 3: the global landscape

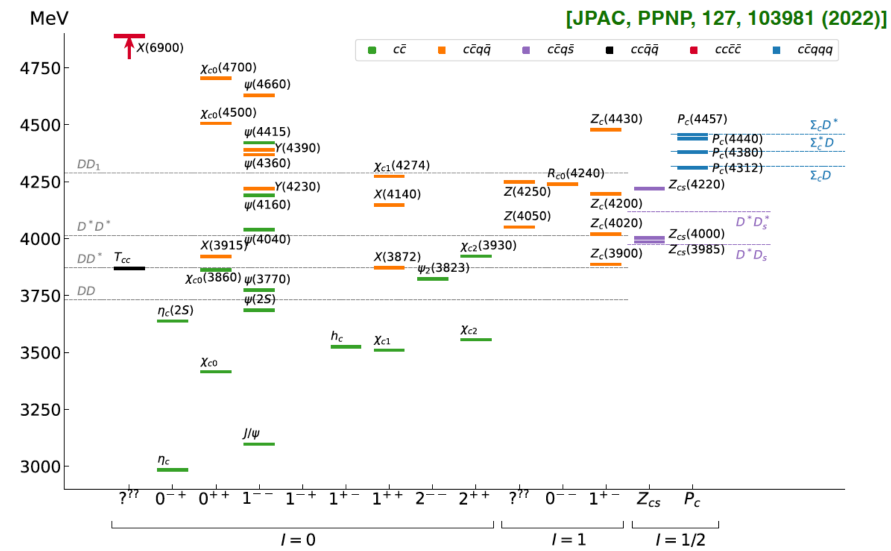
- How is the 22 GeV program anticipated to remain unique in its capabilities into the future (over the next 10-15)?

Next workshop planned for spring/summer 2026

22 GeV: A New Window into the World of XYZ States

This program suits perfect the 22 GeV upgrade: Thresholds for XYZ states open just above 12 GeV





- Many non-$q\bar{q}$ candidate states observed in in B decays, e⁺e- colliders
- No XYZ state uncontroversially seen so far (tetraquark, molecule, virtual state, triangle singularity, … ?)
- Crucial to confirm these states in other production processes

→ never directly produced using γ/lepton beam → free from re-scattering mechanisms

Jefferson Lab

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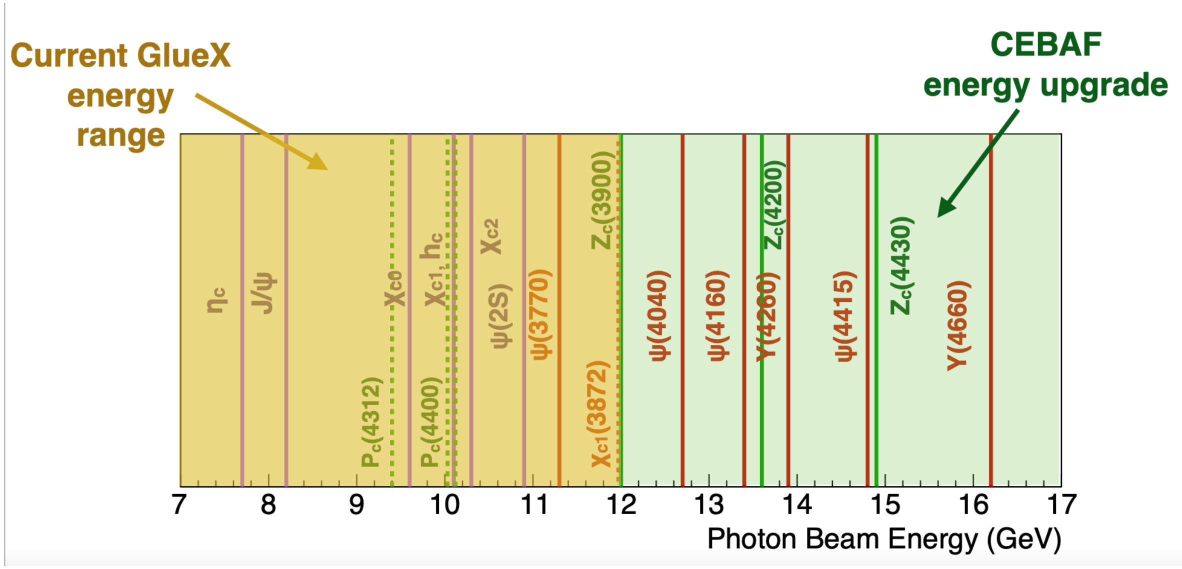

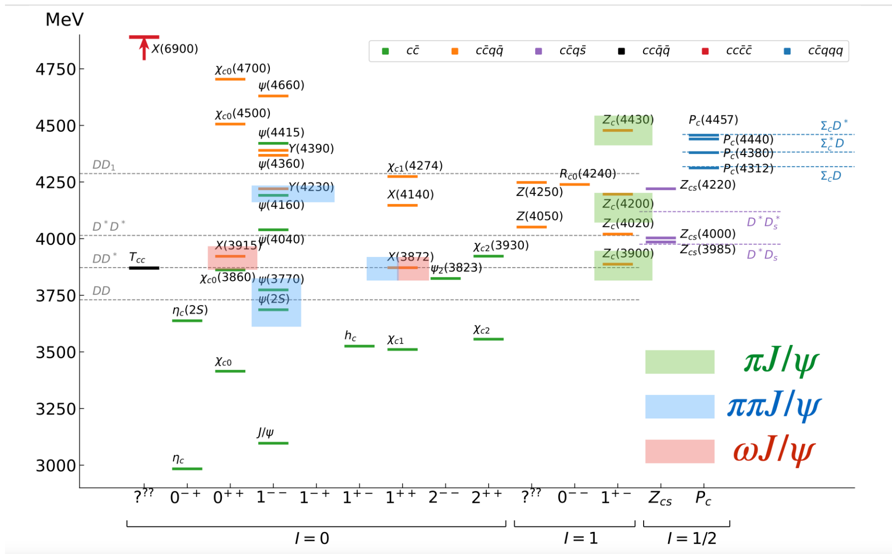

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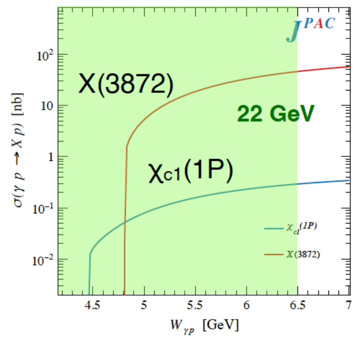
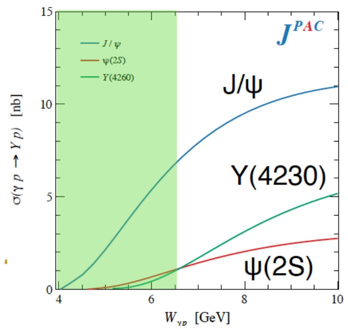
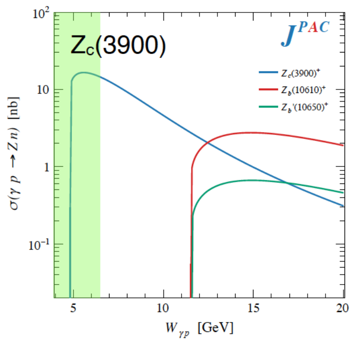
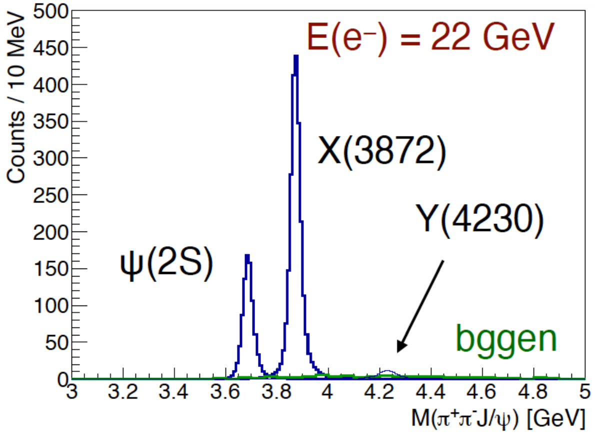






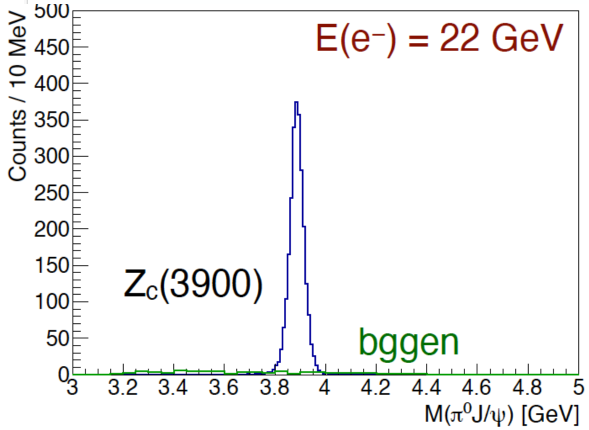
- JPAC predictions using fixed-spin exchanges near threshold
  (PRD 102, 114010 (2020) arXiv:2209.05882)
- GlueX can test models by measuring χ_{c1}(1P), ψ(2S) production

γp → J/ψ$\pi^+\pi^-$p, J/ψ → e^+e^-



Br(X,Y→ $\pi^+\pi^-$J/ψ) = 5%
1 year@500 pb−1 :
N(ψ(2S)) = 900, N(X(3872)) = 2300, N(Y(4260)) = 120

γp → J/ψπ^0p, J/ψ → e^+e^-



Br(Z0→ π^0J/ψ) = 5%
1 year @ 500 pb−1:
N[Zc(3900), J/ψπ^0] = 2500

- Simulations for $\gamma p \rightarrow Z^-_c \Delta^{++} \rightarrow (J/\psi\pi^-)(p\pi^+)$ is underway, expecting similar rates!
- Next steps:
  - Develop reasonable non-resonant background models to include in the MC (COMPASS data can be used for guidance)
  - Evaluate the contribution of open charm channels

With GlueX-III baseline (1 fb−1/year): All numbers doubled

Jefferson Lab

Nucleon Structure: JLab Advantages

IDEAL PLACE TO CARRY OUT IMAGING STUDIES in the non-perturbative region

High Luminosity + High Polarized beam and target + High Resolutions State-of-the-art detectors + Versatile experimental setup + Multiparticles FS detection

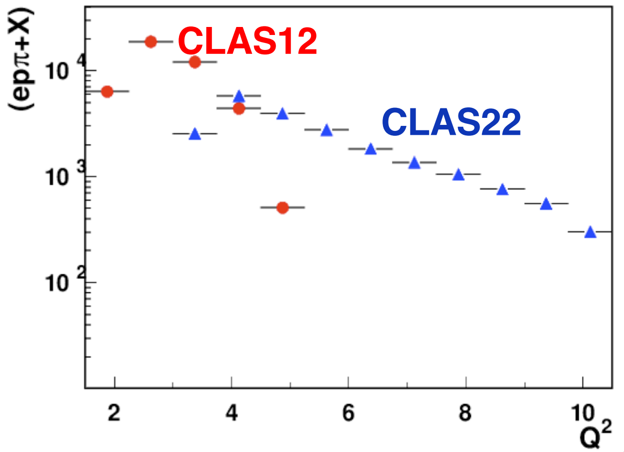
JLab @ 22 GeV will enable several advancements, including:

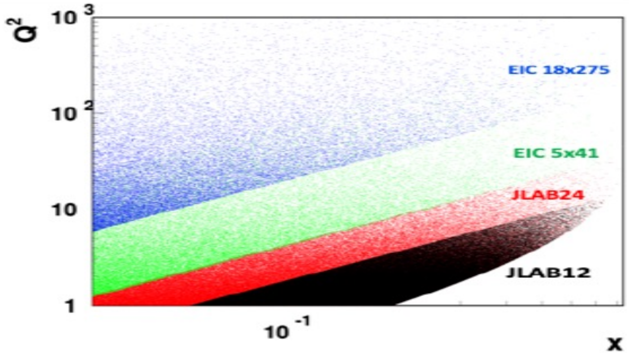
1. **Multidimensional** studies of the evolution of 3D observables **with the energy scale (Q^2)**

2. A unique opportunity to **measure γ^*_L and γ^*_T** contributions to observables **at higher Q^2**

3. A unique opportunity to evaluate the **contribution of various processes** (i.e. longitudinal ρ,..) **at higher Q^2**

All critical aspects for a deeper and better understanding of our current measurements, future measurements at EIC and ultimately the nucleon internal structure !





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Talk on Evolution studies by H. Avakian

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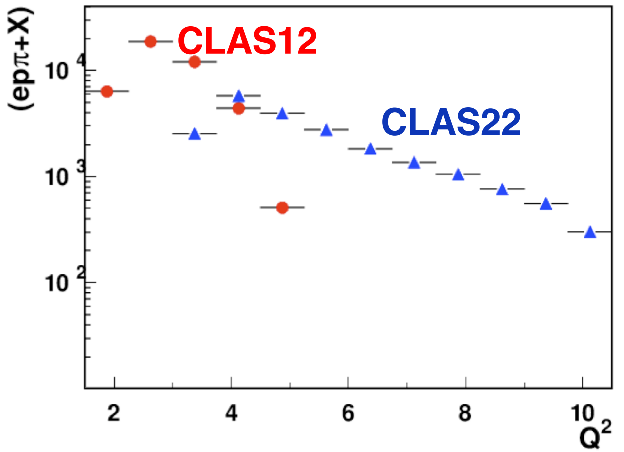
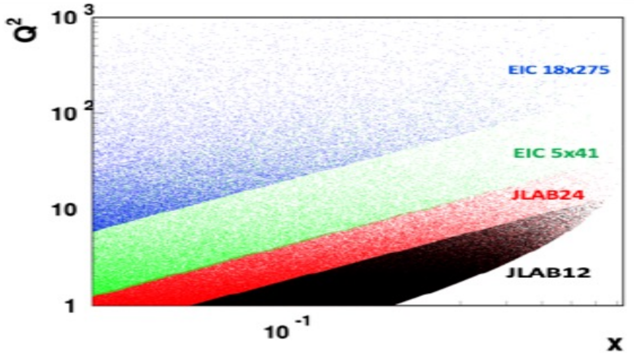




SIDIS Cross Section

$\nu = E - E'$

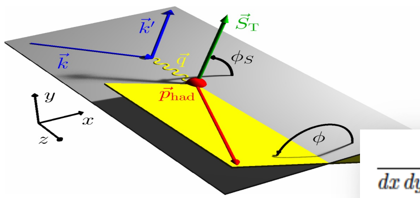
$Q^2 = 4EE' \sin(\theta/2)$

$x = Q^2 / 2M\nu$

$z = E_h / \nu$

$y = \frac{\nu}{E}$

$\mathbf{P_T = z k_T + k_T}$



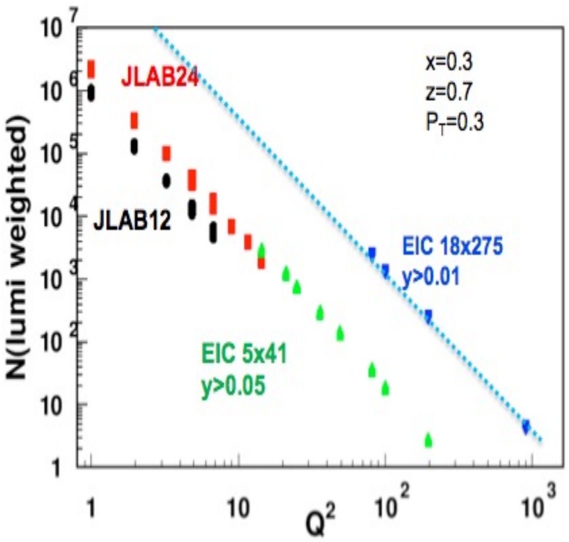
X-section for $\mathbf{eN \rightarrow e'hX}$

$$\mathbf{F_{ij}(x, Q^2, z, P_T, \phi, \phi_S) = TMD \otimes FF}$$

$$\frac{d\sigma}{dx\,dy\,d\phi_S\,dz\,d\phi_h\,dP_{h\perp}^2} = \frac{\alpha^2}{x\,y\,Q^2}\frac{y^2}{2(1-\varepsilon)}\Big\{F_{UU,T} + \varepsilon F_{UU,L} + \sqrt{2\varepsilon(1+\varepsilon)}\cos\phi_h\,F_{UU}^{\cos\phi_h} + \varepsilon\cos(2\phi_h)\,F_{UU}^{\cos 2\phi_h}$$
$$+ \lambda_e\sqrt{2\varepsilon(1-\varepsilon)}\sin\phi_h\,F_{LU}^{\sin\phi_h} + S_L\Big[\sqrt{2\varepsilon(1+\varepsilon)}\sin\phi_h\,F_{UL}^{\sin\phi_h} + \varepsilon\sin(2\phi_h)\,F_{UL}^{\sin 2\phi_h}\Big]$$
$$+ S_L\lambda_e\Big[\sqrt{1-\varepsilon^2}\,F_{LL} + \sqrt{2\varepsilon(1-\varepsilon)}\cos\phi_h\,F_{LL}^{\cos\phi_h}\Big]$$
$$+ S_T\Big[\sin(\phi_h-\phi_S)\Big(F_{UT,T}^{\sin(\phi_h-\phi_S)} + \varepsilon F_{UT,L}^{\sin(\phi_h-\phi_S)}\Big) + \varepsilon\sin(\phi_h+\phi_S)\,F_{UT}^{\sin(\phi_h+\phi_S)}$$
$$+ \varepsilon\sin(3\phi_h-\phi_S)\,F_{UT}^{\sin(3\phi_h-\phi_S)} + \sqrt{2\varepsilon(1+\varepsilon)}\sin\phi_S\,F_{UT}^{\sin\phi_S}$$
$$+ \sqrt{2\varepsilon(1+\varepsilon)}\sin(2\phi_h-\phi_S)\,F_{UT}^{\sin(2\phi_h-\phi_S)}\Big] + S_T\lambda_e\Big[\sqrt{1-\varepsilon^2}\cos(\phi_h-\phi_S)\,F_{LT}^{\cos(\phi_h-\phi_S)}$$
$$+ \sqrt{2\varepsilon(1-\varepsilon)}\cos\phi_S\,F_{LT}^{\cos\phi_S} + \sqrt{2\varepsilon(1-\varepsilon)}\cos(2\phi_h-\phi_S)\,F_{LT}^{\cos(2\phi_h-\phi_S)}\Big]\Big\}$$

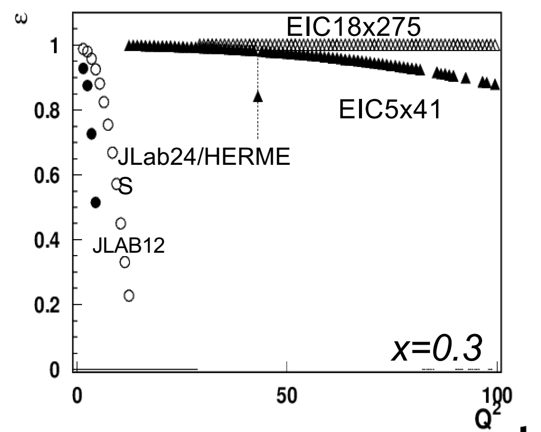
- Measurements of correlations of spin and transverse momenta provides direct access to details of QCD dynamics
- Full decomposition of SFs is needed to underlying the 3D PDFs

- At higher energies (EIC), observables surviving the e→1 limit (F_{UU}, F_{UL}, Transversely pol. F_{UT})



- Combination of statistics and depolarization factors defines measurable SFs
- At large x fixed target experiments are sensitive to ALL Structure Functions

ε=ratio of longitudinal and transverse photon flux



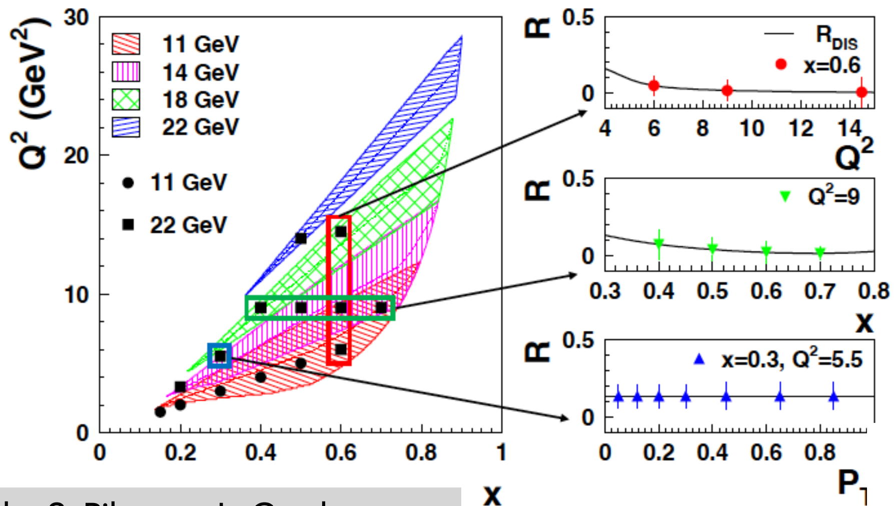
σ_L / σ_T : CRITICAL for SIDIS & Exclusive Measurements

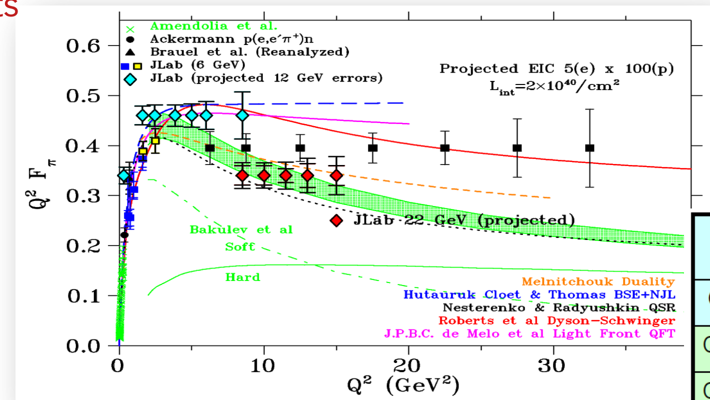
- Measurements of $F_{UU,T}$ and Sivers requires *separation*, evaluation of γ^*_L

$$\frac{d\sigma}{dx\,dy\,d\phi_S\,dz\,d\phi_h\,dP_{h\perp}^2} = \frac{\alpha^2}{x\,y\,Q^2}\frac{y^2}{2\,(1-\varepsilon)}\Big\{F_{UU,T}+\varepsilon F_{UU,L}+\sqrt{2\,\varepsilon(1+\varepsilon)}\cos\phi_h\,F_{UU}^{\cos\phi_h}+\varepsilon\cos(2\phi_h)\,F_{UU}^{\cos 2\phi_h}$$
$$+\lambda_e\sqrt{2\,\varepsilon(1-\varepsilon)}\sin\phi_h\,F_{LU}^{\sin\phi_h}+S_L\Big[\sqrt{2\,\varepsilon(1+\varepsilon)}\sin\phi_h\,F_{UL}^{\sin\phi_h}+\varepsilon\sin(2\phi_h)\,F_{UL}^{\sin 2\phi_h}\Big]$$
$$+S_L\,\lambda_e\Big[\sqrt{1-\varepsilon^2}\,F_{LL}+\sqrt{2\,\varepsilon(1-\varepsilon)}\cos\phi_h\,F_{LL}^{\cos\phi_h}\Big]$$
$$+S_T\Big[\sin(\phi_h-\phi_S)\Big(F_{UT,T}^{\sin(\phi_h-\phi_S)}+\varepsilon\,F_{UT,L}^{\sin(\phi_h-\phi_S)}\Big)+\varepsilon\sin(\phi_h+\phi_S)\,F_{UT}^{\sin(\phi_h+\phi_S)}$$

- By neglecting the contribution of γ^*_L, can introduce biases in **TMD extractions and factorization studies** limiting the depth and accuracy of our understanding of spin-dependent QCD effects

$$\frac{d\sigma_L}{dt} \propto \frac{-tQ^2}{(t-m_\pi^2)} g_{\pi NN}^2(t)\,F_\pi^2(Q^2,t)$$





$\Delta(d\sigma_L/dt)$ magnified by $1/\Delta\varepsilon$

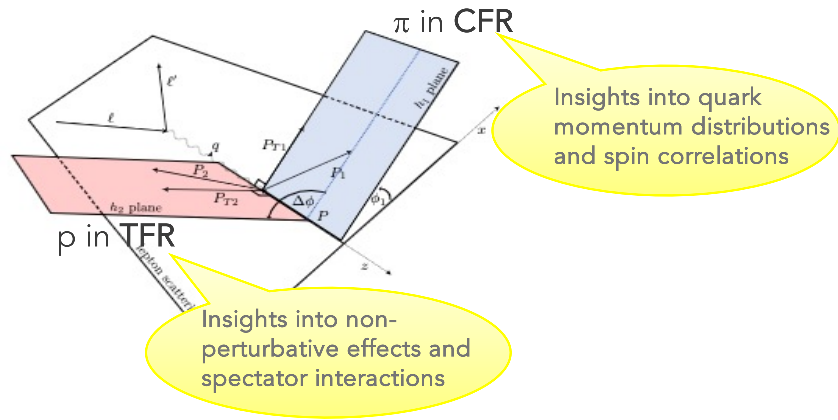
	10.6 GeV	18.0 GeV	Improvement in $\delta F_\pi/F_\pi$
Q^2=8.5	$\Delta\varepsilon$=0.22	$\Delta\varepsilon$=0.40	17.9%→4.6%
Q^2=10.0	New high quality F_π data		
Q^2=11.5	Larger F_π extraction uncertainty due to higher $-t_{min}$		

JLab will remain the ONLY source of quality L–T separated data!

Talk by S. Piloneta, L. Gamberg

B2B Production – Leading Twist Fracture Functions…and more

Back-to-Back SIDIS (B2B): A powerful **dual lens**, for a complete picture of the nucleon's internal structure



$$\sigma_{LU} = -\frac{P_{T1}P_{T2}}{m_N m_2} F_{k1}^{\hat{l}_1^{\perp h}\cdot D_1} \sin(\Delta\phi),$$

$$\sigma_{UL} = -\frac{P_{T1}P_{T2}}{m_N m_2} F_{k1}^{\hat{u}_{1L}^{\perp h}\cdot D_1} \sin(\Delta\phi)$$

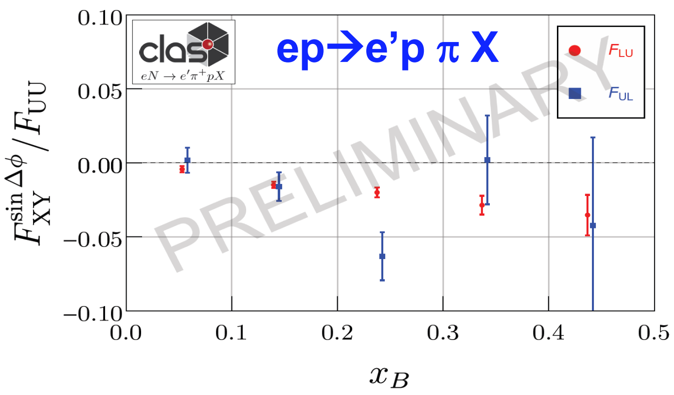
F_k= Fracture Function Fragmentation Funtion

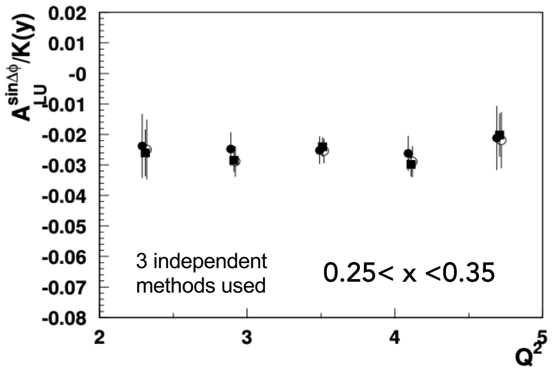
Fracture Functions:
describe conditional probabilities to produce a hadron of certain type in a target fragmentation for a given flavor of struck quark

Leading Twist Fracture Function:

N/q	U	L	T
U	$\hat{u}_1$	$\hat{l}_1^{\perp h}$	$\hat{t}_1^h, \hat{t}_1^{\perp}$
L	$\hat{u}_{1L}^{\perp h}$	$\hat{l}_{1L}$	$\hat{t}_{1L}^h, \hat{t}_{1L}^{\perp}$
T	$\hat{u}_{1T}^h, \hat{u}_{1T}^{\perp}$	$\hat{l}_{1T}^h, \hat{l}_{1T}^{\perp}$	$\hat{t}_{1T}, \hat{t}_{1T}^{hh}, \hat{t}_{1T}^{\perp\perp}, \hat{t}_{1T}^{\perp h}$

A. Kotzinian et al, arXiv:1107.2292





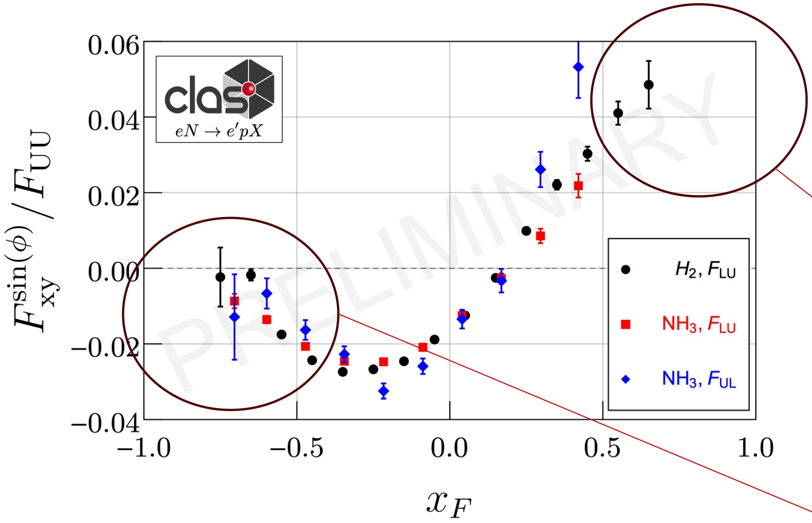
No Q^2 dependence for F_{LU}
→ Leading Twist

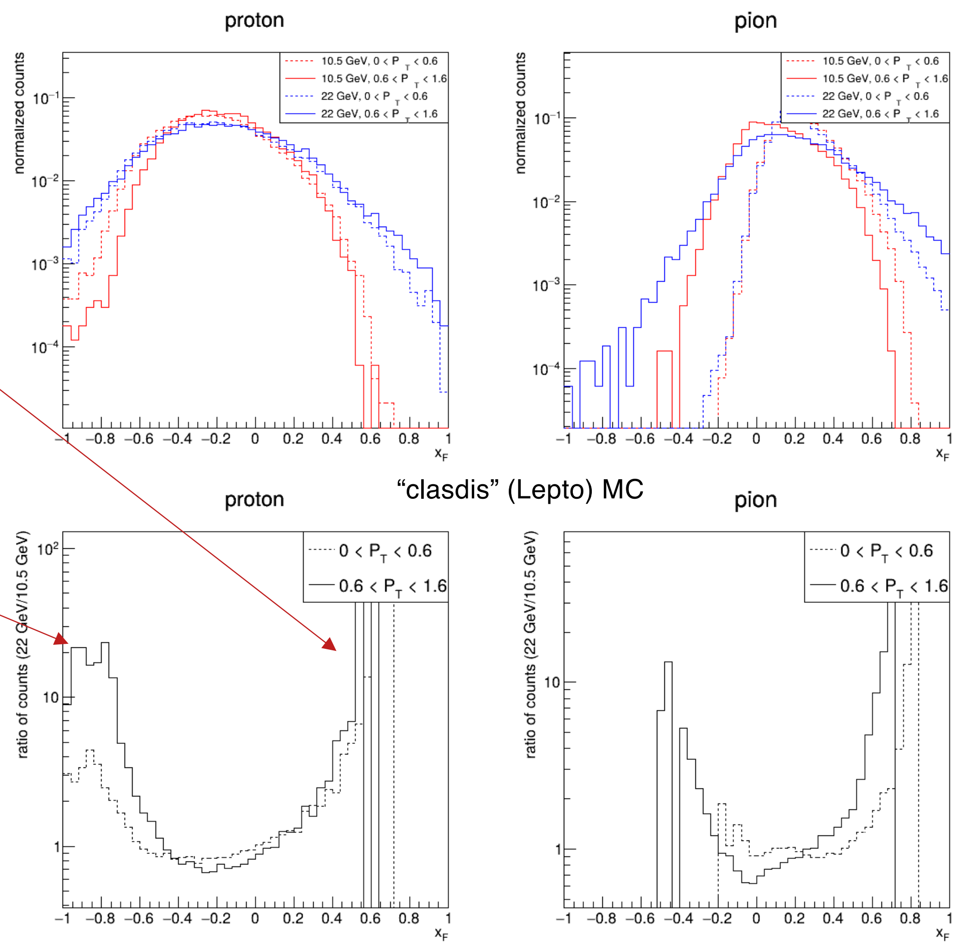
Detection of proton in the TFR allows:

- Reduces contamination from exclusive processes: The presence of diffractive **ρ** mesons can distort the interpretation of SIDIS observables, particularly in low transverse momentum (p_T) regions.
- Improves factorization validity: SIDIS relies on a leading-twist factorization framework, which can be violated if exclusive vector meson contributions are not properly accounted for.

See Talk by H. Avakian

B2B Increased Phase Space at 22 GeV





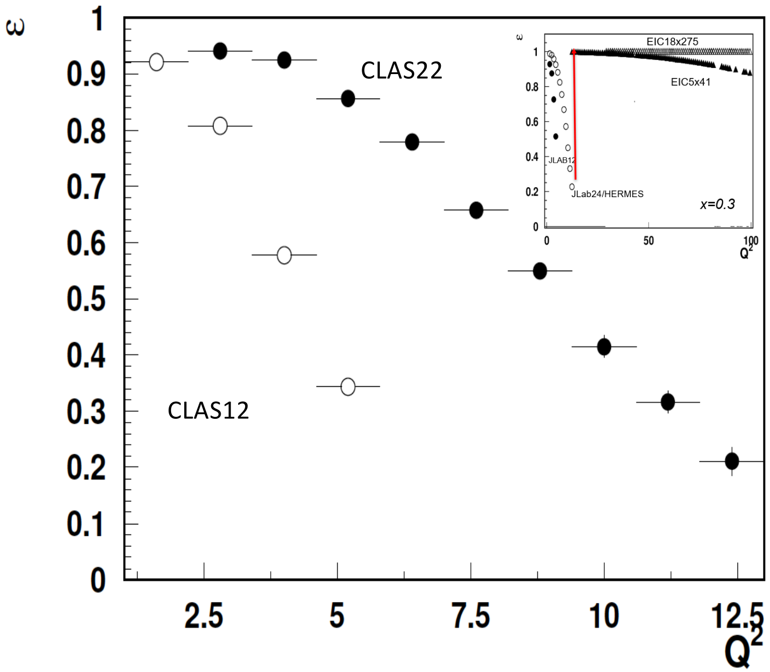
At 22 GeV there is over an order of magnitude more data at the highest and lowest x_F, particularly at higher P_T:

1. Allow for the exploration of the full range of x_F from -1 to 1.
2. Significantly more statistics for protons at the smallest –t values.
3. Extension of pions to significantly negative x_F.

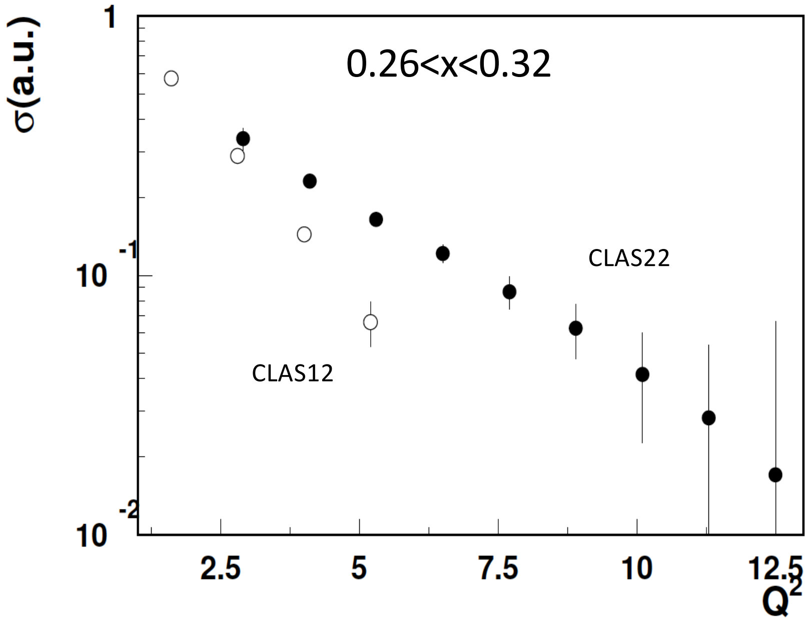
1. K.B. Chen et al., JHEP 05 (2024) 298 (2024), [hep-ph] 2402.15112
2. X. Tong, CPHI2024

Courtesy T. Hayward

Exclusive ρ^0: extending the Q^2 with JLab22



Longitudinal photon contributions
kinematically enhanced at higher energies



Courtesy H. Avakian

$$\gamma_L^* \to \rho_L \propto 1$$

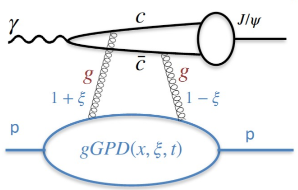
$$\gamma_T^* \to \rho_L \propto \sqrt{-t}/Q$$

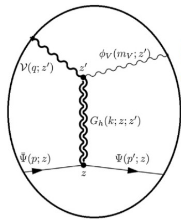
- Beam SSA provides important info on production of longitudinal ρ from transverse photons
- Range in Q^2 increases significantly with 22 GeV upgrade, allowing detailed studies at beyond 10 GeV^2 and providing a bridge to EIC

Threshold Charmonium Photoproduction

Charmonium photoproduction near threshold has been used to probe the gluonic structure of the nucleon

- Two theoretical approaches have been used with very different domains of validity
  - **GPD → requires high |t| and works for hard processes** – the reaction is expected to be dominated by two-gluon exchange. As the two gluons can mimic graviton-like exchange, the gluonic GPD in turn can be related to the gluon Gravitational Form Factors (gGFFs)
  - **Holographic → valid for soft processes** - works in the limit of high coupling constant that depend only on the momentum transfer t.





1) $\boldsymbol{(d\sigma/dt)_{\gamma p\to J/\psi p} = F(E\gamma)\xi^{-4}[G_0(t)+\xi^2 G_2(t)] + ..}$

GPD analysis by Guo, Ji, Yuan PRD 109 (2024)

Leading terms in $G_0(t)$, $G_2(t)$, $H_0(t)$, $H_2(t)$ contain gGFFs $A_g(t)$, $B_g(t)$, $C_g(t)$

2) $\boldsymbol{(d\sigma/dt)_{\gamma p\to J/\psi p} = N(E\gamma)[H_0(t)+\eta^2 H_2(t)] + ..}$

Holographic analysis by Mamo and Zahed PRD 106 (2022), PRD, PRD 101 (2020), Hatta and Yang PRD 98 (2018)

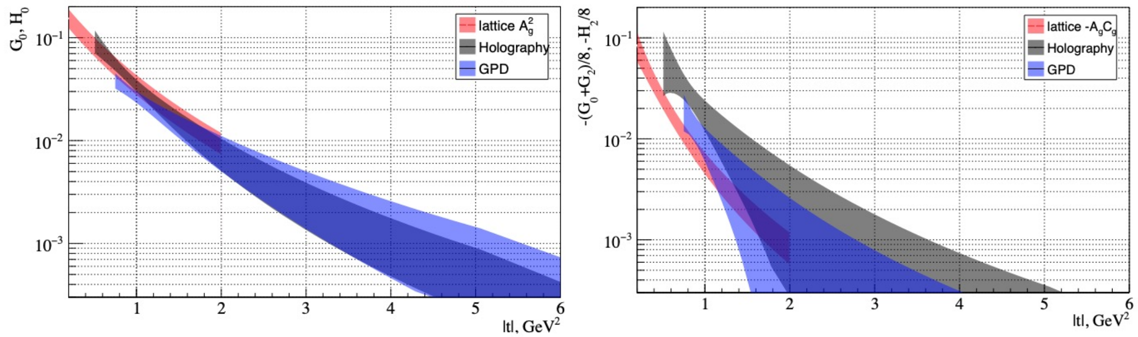
- Gluon gravitational form factors (gGFFs) via Rosenbluth separation technique
  - Assuming 1) or 2) extracted the gGFFs kinematically from the data and found they are energy independent

  - In leading-term approximation (and neglecting B_g):

    $G_0(t) = H_0(t) = A^2_g(t)$

    $G_0(t) + G_2(t) = H_2(t) = 8C_g(t)Ag(t)$

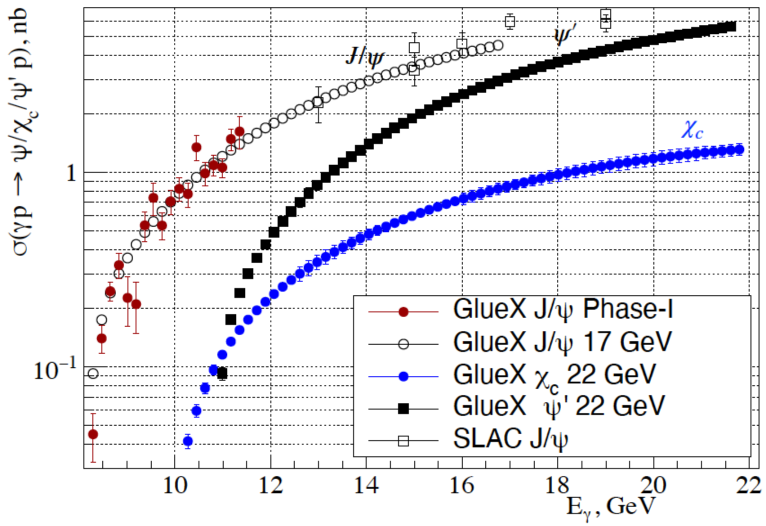
  - General agreement in the extracted FFs using two diametric theories, each with specific corrections very different in nature (higher moments, , …) and agreement with lattice

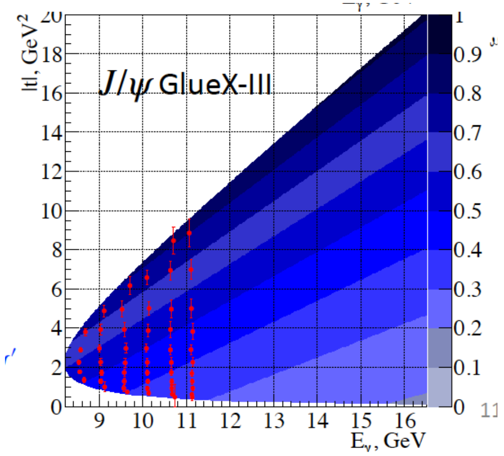


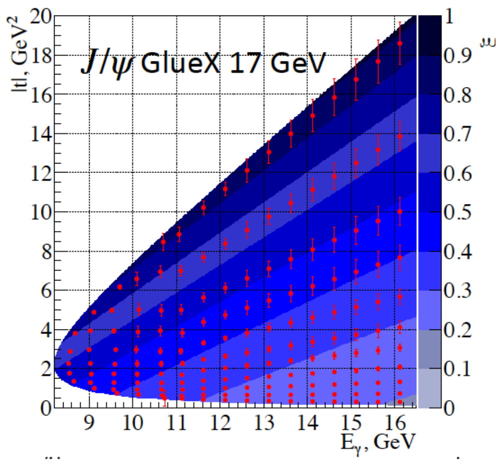
L. Pentchev, E. Chudakov arXiv:2404.18776v2

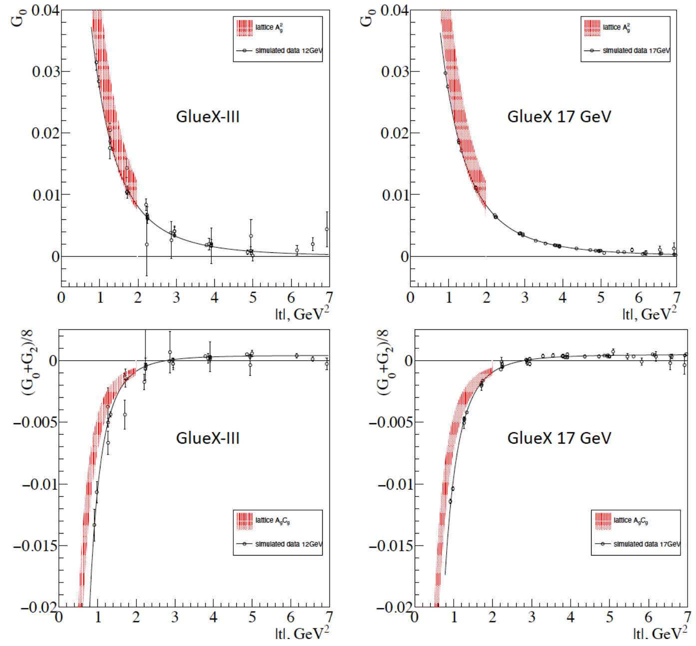
More precise relation to the gluon properties of the proton requires comprehensive experimental and theoretical studies to better understand the reaction mechanism.

Threshold J/Ψ Photoproduction at 22 GeV

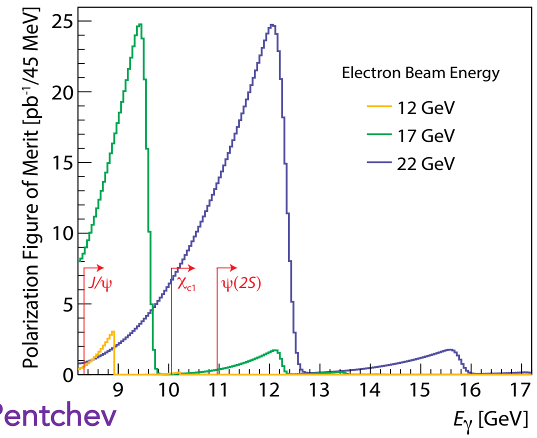








- Anticipated results for the extracted gFFs



- JLab22 projections for Polarization FoM

Jlab22 projections for 100 PAC days: 80k J/ψ, 8K χc, 18k ψ'

Courtesy L. Pentchev

Jefferson Lab

"Charmed" Studies at 22 GeV

	GlueX 22GeV	Solid 22GeV	EIC
J/ψ photoproduction	✓	✓ Aceptance limitations for E_γ>12 GeV	?
J/ψ electroproduction	✗	✓ unique up to Q^2 = 8 GeV^2	?
χ_c photoproduction	✓ unique	✗	?
ψ(2S) photoproduction	✓	✓ Acceptance limitations for E_γ>16 GeV	?
ψ(2S) electroproduction	✗	✓ up to Q^2 = 1.5 GeV^2	?
J/ψ, χ_c, ψ(2S) linear polarization	✓ unique	✗	✗
Υ	✗	✗	✓ unique

Courtesy L. Pentchev

- GlueX has linear polarization and almost full acceptance for multi-particle final states (including photons) - unique in polarization measurements and χ_c states.
- SoLID has very high luminosity, relatively wide acceptance, capable of reaching high values in electroproduction (unique).
- EIC energies much above charmonia thresholds, detection is questionable, however very suitable for studying production at threshold.

CEBAF energy upgrade adds new dimensions:

- Threshold production of higher-mass charmonium states (with different quantum numbers) ψ(2S) (SoLID, GlueX), χ_c(GlueX)
- Threshold charmonium electroproduction at high Q^2 (SoLID)
- Polarization measurements with high FoM (GlueX)
- Studies of open-charm production, that is supposed to dominate with increasing the energy

Measurements of α_s with JLab@22 GeV

It is the most important quantity of QCD, key parameter of the SM, but (by far) the least known fundamental coupling: $\Delta\alpha_s/\alpha_s \simeq 10^{-2}$

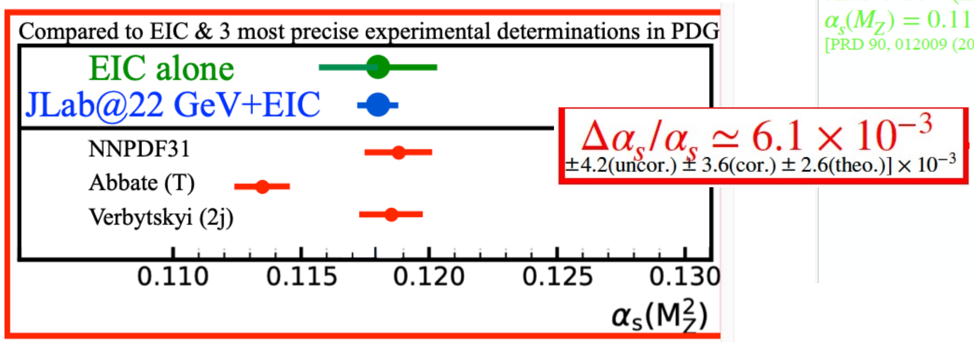
- Large efforts ongoing to reduce $\Delta\alpha_s/\alpha_s$
- No "silver bullet" experiment can perfectly determine $\alpha_s \Rightarrow$ Strategy: combine many independent measurements

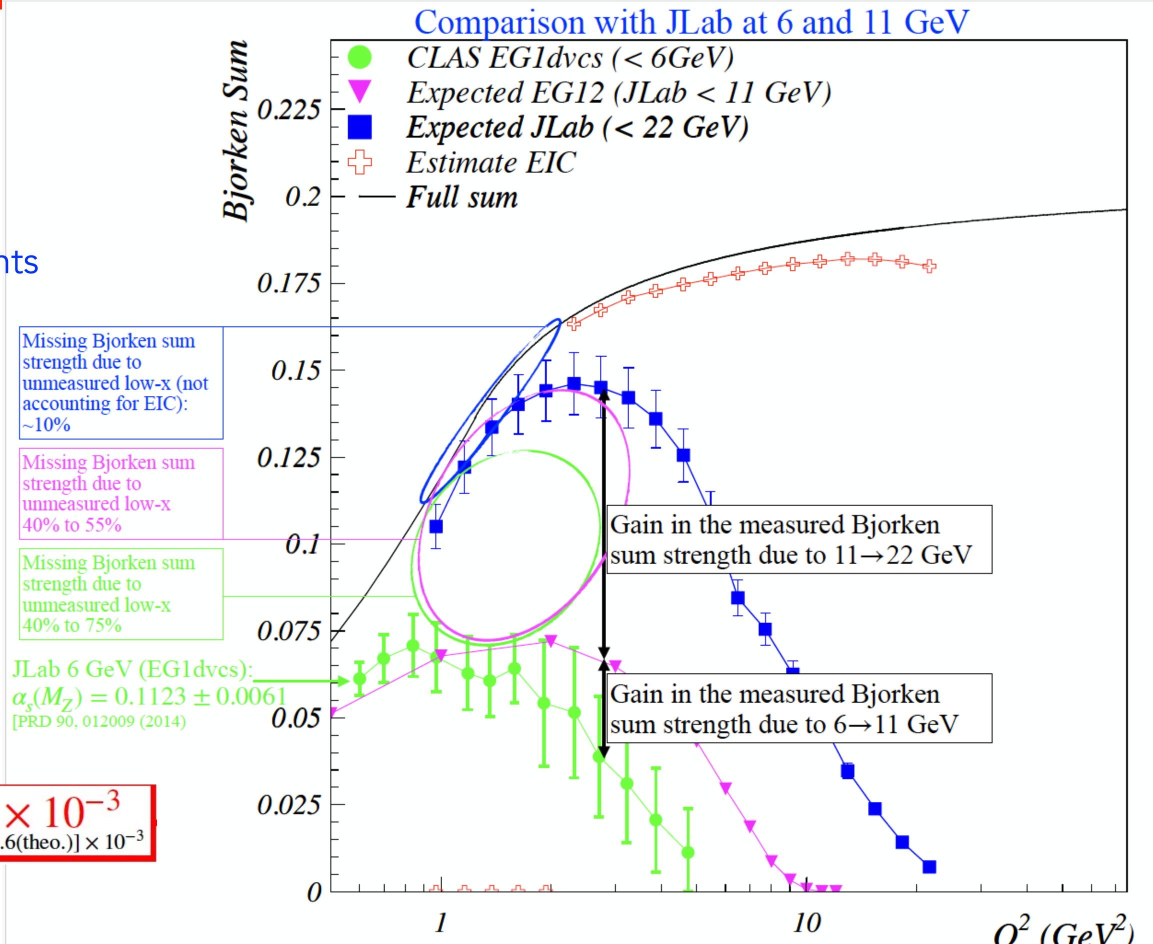
Good prospects of measuring precisely α_s *(Mz)* at JLab@22 GeV with Bjorken sum rule:

Bjorken sum rule: $\Gamma_1^{p-n}(Q^2) \equiv \int g_1^{p-n}(x, Q^2)dx = \frac{1}{6} g_A \left[1 - \frac{\alpha_s}{\pi} \cdots \right]$

Q^2-dependence of $\Gamma^{p-n}(Q^2)$ provides α_s.

Uncertainties from pQCD truncation and Higher-Twists remain small



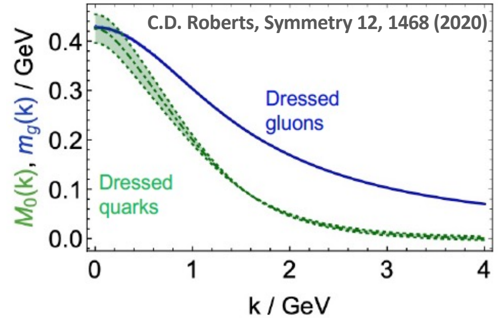


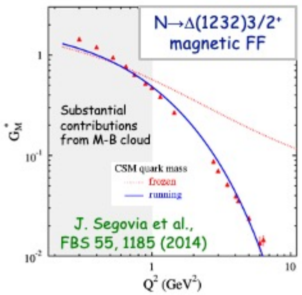
Courtesy A. Deur

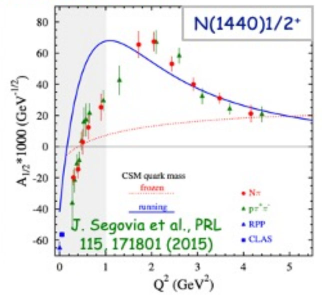
Jefferson Lab

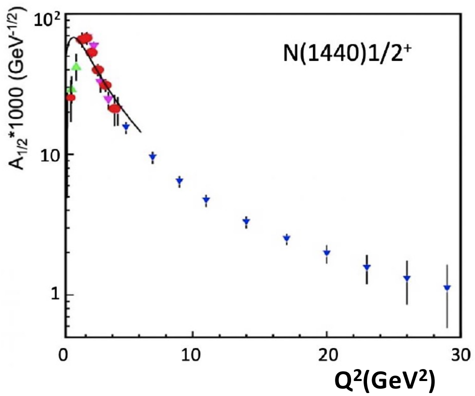
Probing Bound Three-Quark Exitations

- The N* program in Hall B is uniquely positioned to explore nucleon resonance structure with high-precision, providing unparalleled access **to γ_vNN* electrocouplings.**
- The **γ_v**NN* electrocouplings are directly linked to Emergent Hadron Mass (EHM), with the Schwinger-Dyson equations (DSEs) describing how quarks and gluons dynamically acquire momentum-dependent masses.
- The Continuum Schwinger Function Methods (CSMs) built upon the DSEs, successfully described N* electrocoupling for nucleon resonances of different structure, π and N FFs.
- These successes demonstrate the capability of gaining insight into EHM from the experimental results on the **Q^2-evolution of the electrocouplings**.

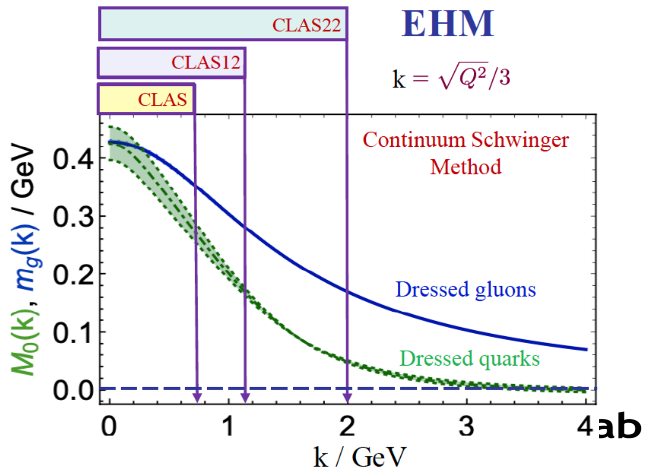








	Q^2-coverage of electrocouplings	Range of quark momenta k	Fraction of dressed quark mass at $k<k_{max}$
CLAS	< 5 GeV²	< 0.8 GeV	30%
CLAS12	< 12 GeV²	< 1.2 GeV	50%
CLAS22	< 35 GeV²	< 2.0 GeV	90%



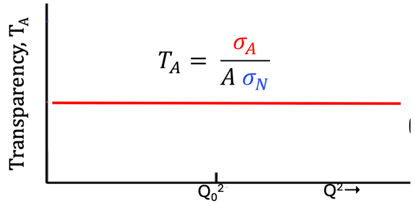
- ✓ Beam energy 22 GeV
- ✓ Nearly 4π acceptance
- ✓ High luminosity detector
- ✓ High momentum resolution
- ✓ Studies of exclusive reactions

On-going studies:

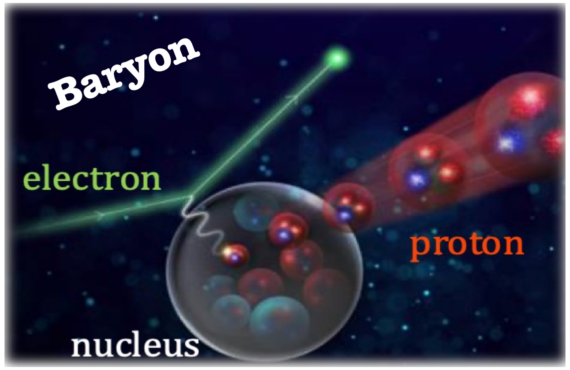
- Acceptance calculation improved with increased precision in the TWOPEG event generator
- Resolution for 10.6 GeV experiment (Fall 2018, is comparable to resolution for 22 GeV simulation

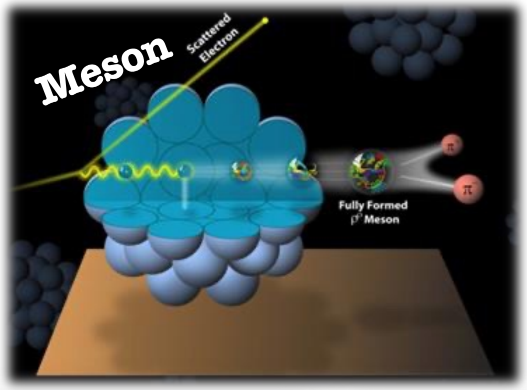
These measurements can be uniquely done at JLab

Color Transparency



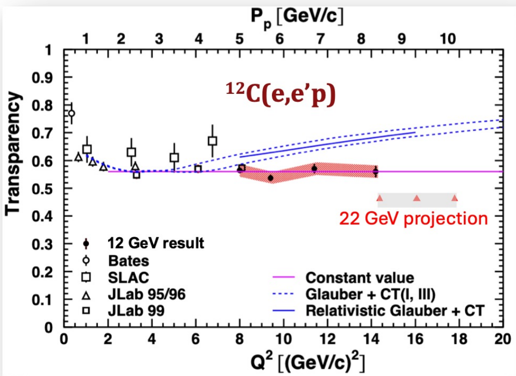
- Transparency is the probability that the struck hadron emerges from the nucleus without being deflected or absorbed
- Onset of CT indicates where quark-gluon degrees of freedom become relevant

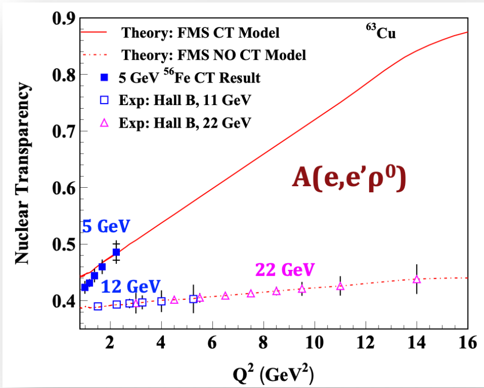


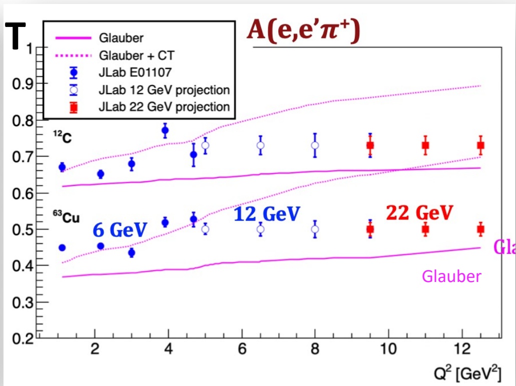


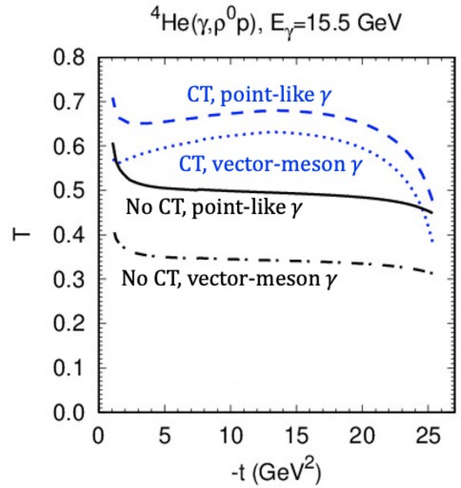
- New approaches have been developed to explore CT in different kinematics and reaction mechanisms that could increase the sensitivity for observing its onset, especially for protons.

Photoproduction in Hall D at 22 GeV

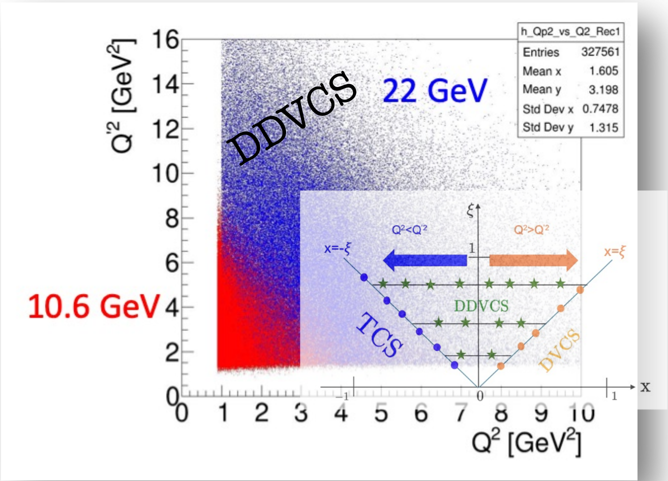


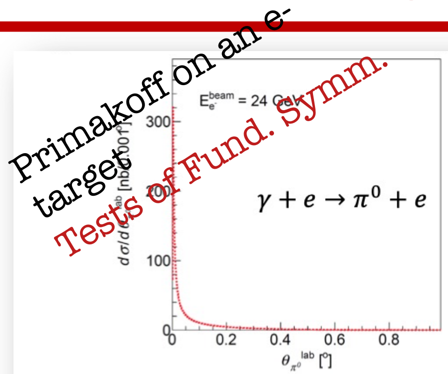




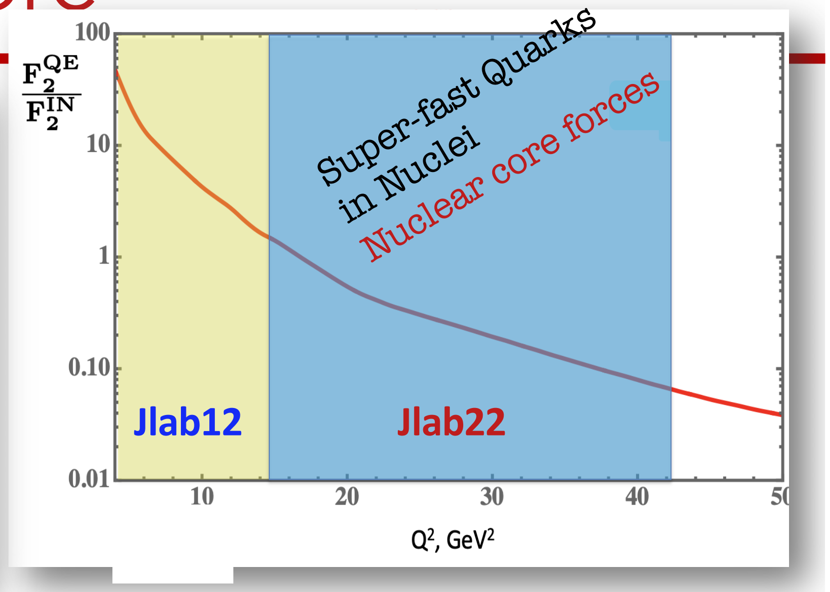


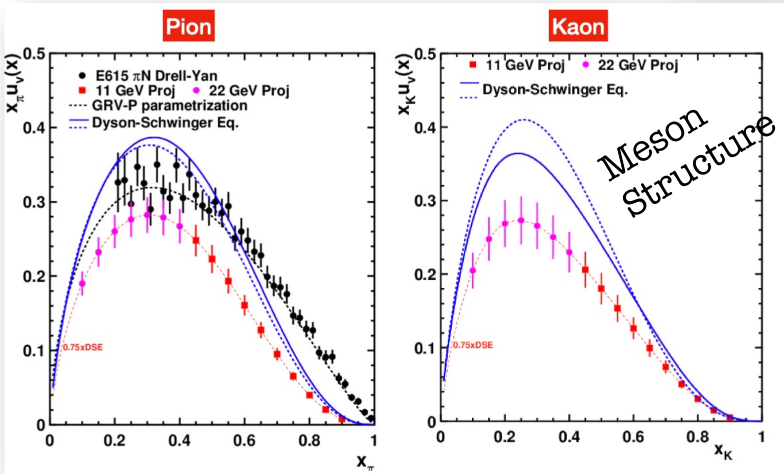
…And Many More

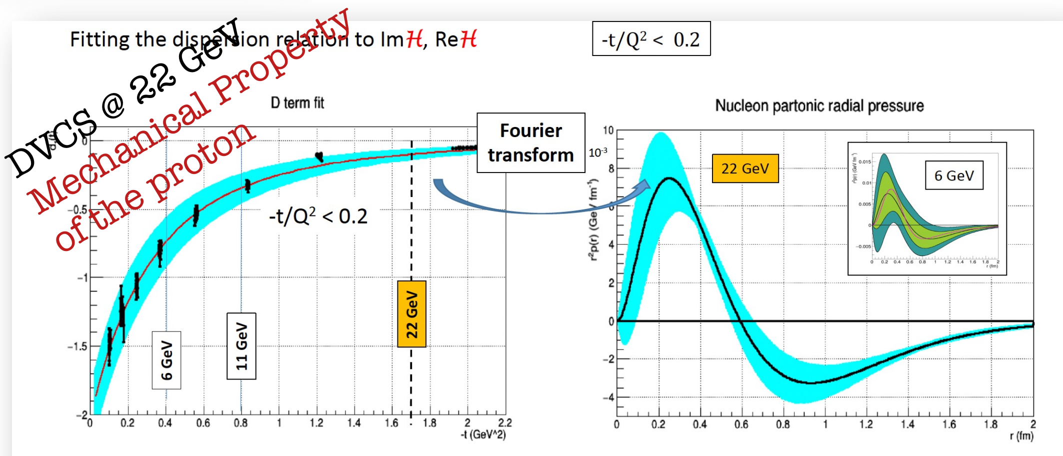




Measurement	Reaction	E_{th} (GeV)
$\Gamma(\pi^0 \to \gamma\gamma)$	$\gamma + e \to \pi^0 + e$	18.0
$F(\pi^0 \to \gamma^*\gamma)$	$e + e \to \pi^0 + e + e$	18.1

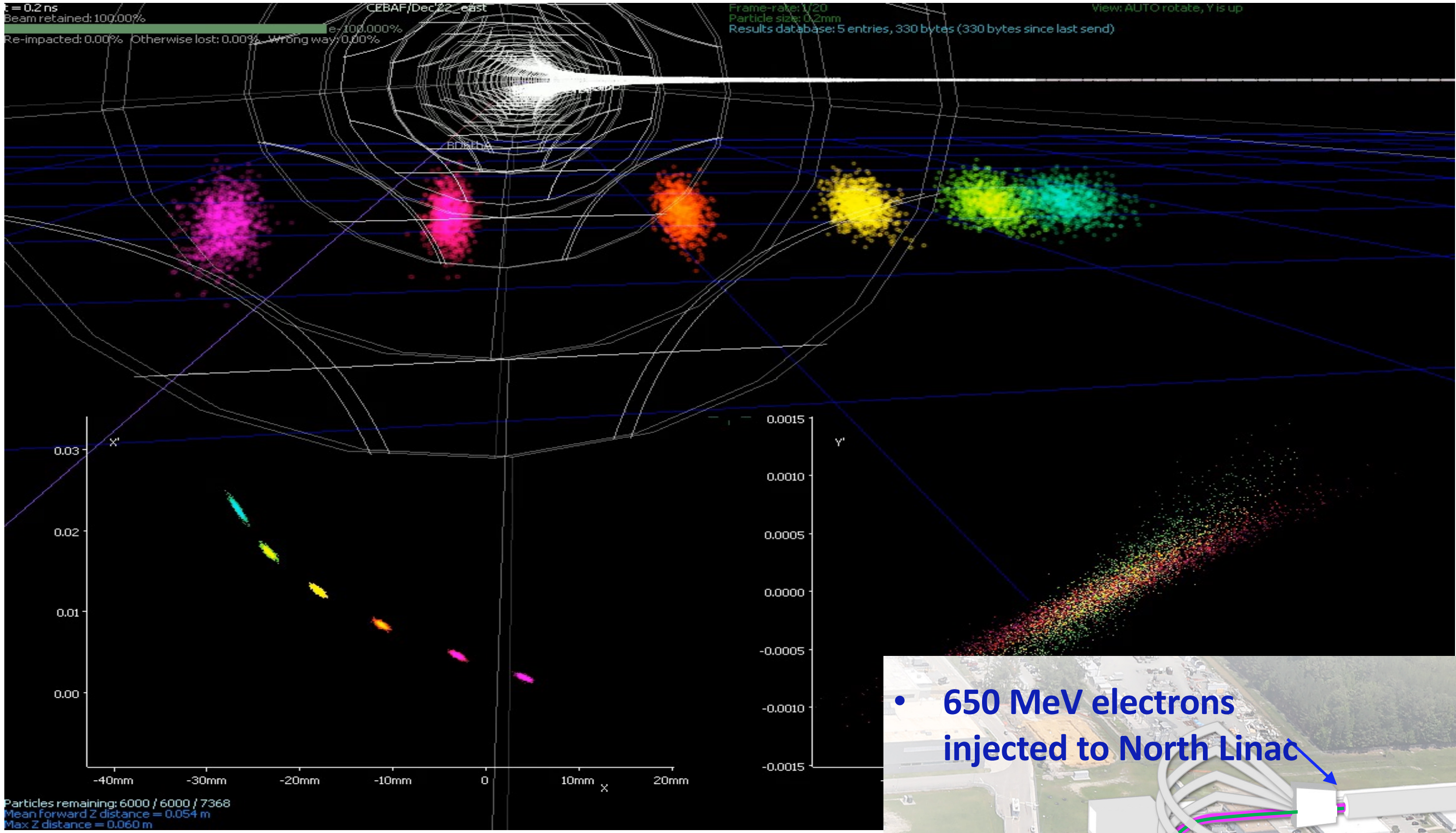


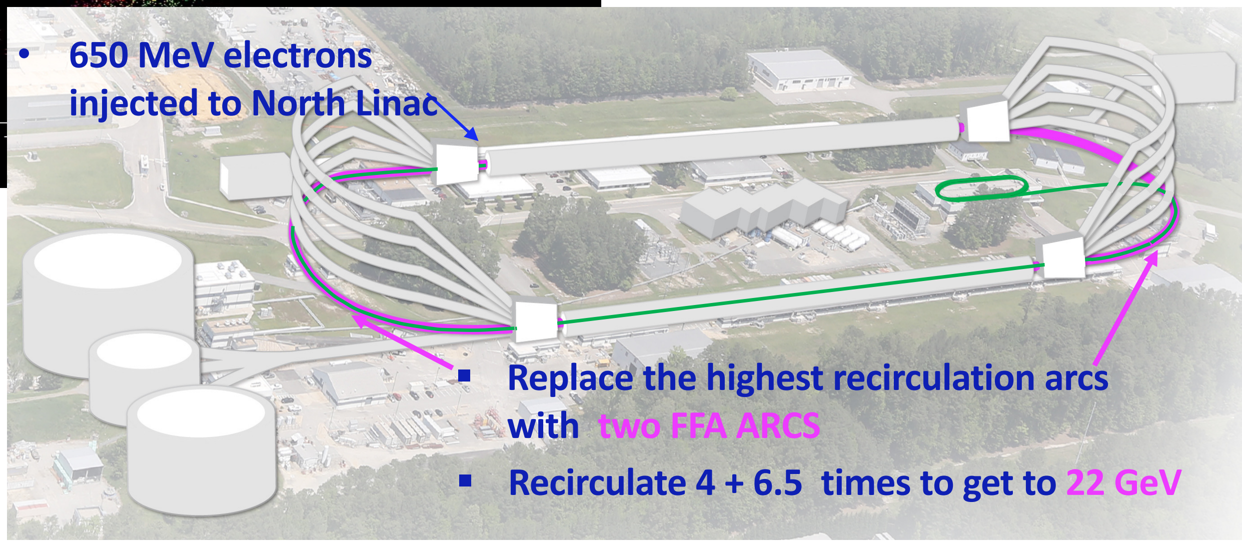




22 GeV will cover a large range in -t and may discover existence of pressure domains.

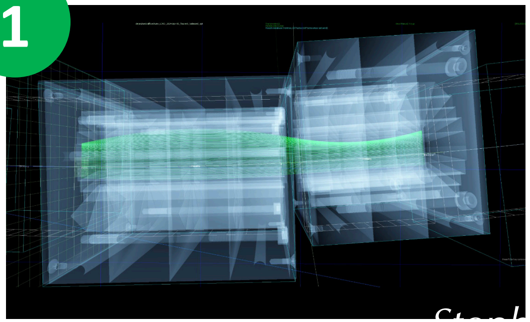
CEBAF FFA Upgrade





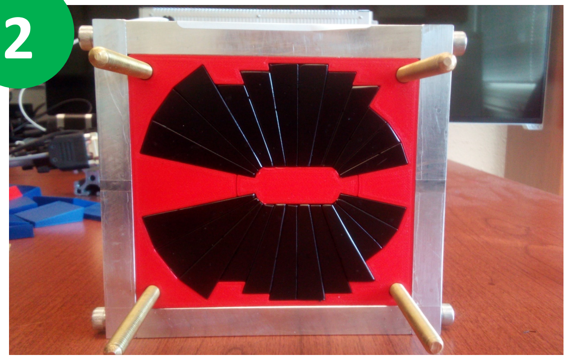
22 GeV Upgrade – Baseline under Study

1



- Imported a vendor's magnet mechanical design and overlaid it on the beam orbits to make sure there is **clearance**

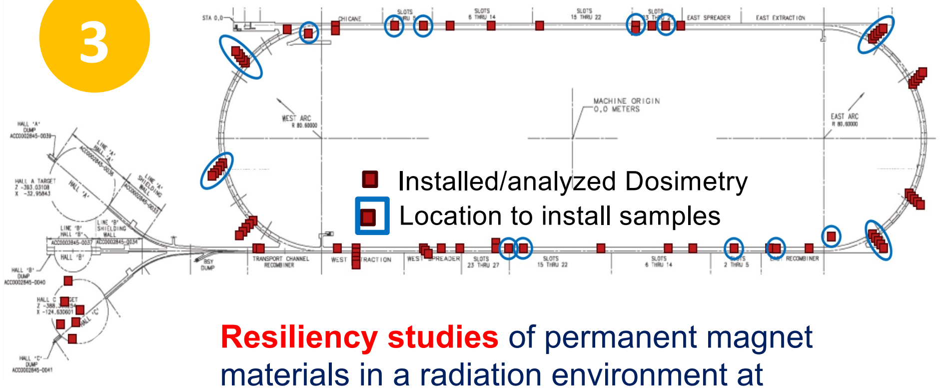
2



- Prototype open-midplane BF magnet successfully built and evaluated for **mechanical integrity**
- >1.5 Tesla measured in good field region
- Field accuracy of 10^{-3}

Installation map in CEBAF – 30 installation locations of varying dose and radiation type (gamma vs. neutron)

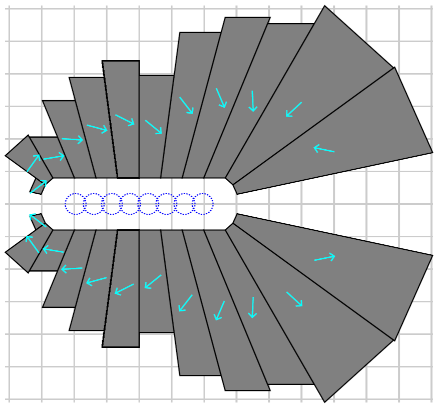
3



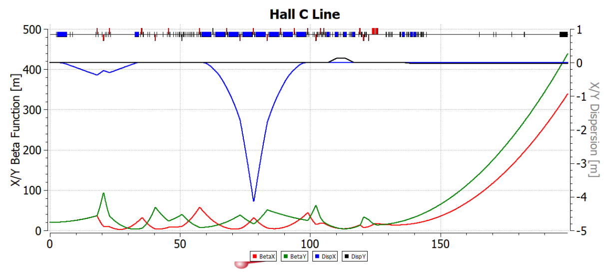
Resiliency studies of permanent magnet materials in a radiation environment at CEBAF resembling their intended operational one **(LDRD project started Oct. 1, 2023)**

4

Construction of a full-length permanent magnet (LoI to DOE)



Hall C - possible location of the **Test**



Path Forward

- Jefferson Lab continues to work with the community to articulate the scientific case for an increase in the max electron beam energy from 12 GeV to 22 GeV

- **Goal:** *strong* placement in the next Long Range Plan

Working backwards…

- Assume LRP every seven years, so look to 2029 town meetings
- **Prepare a strong TDR for ~2028, excellent physics case**
- Enable accelerator to make a major splash with technology demonstration in ~2027
- **Earlier pTDR prepared in ~2026**
  - Capture the critical questions that must be answered
  - Workshops and meetings to prepare
  - A small study group (11 people) from Jab management, Physics, Accelerator and Theory Divisions, and 3 representatives of the user community, meets monthly
- Laboratory to continue communication with funding agencies in parallel

Conclusions and Outlook

- Jefferson Lab offers an exceptional environment for exploring QCD in the non-perturbative regime, combining high luminosity with state-of-the-art experimental facilities.

- Upgrading CEBAF to 22 GeV will allow researchers to cross key energy thresholds and expand the phase space, opening a new window between Jefferson Lab at 12 GeV and the EIC. This intermediate range offers a unique opportunity to explore non-perturbative QCD dynamics with unprecedented precision.

- A strong scientific case for this upgrade is emerging and actively being developed. It is supported by JLab management, staff and user community.

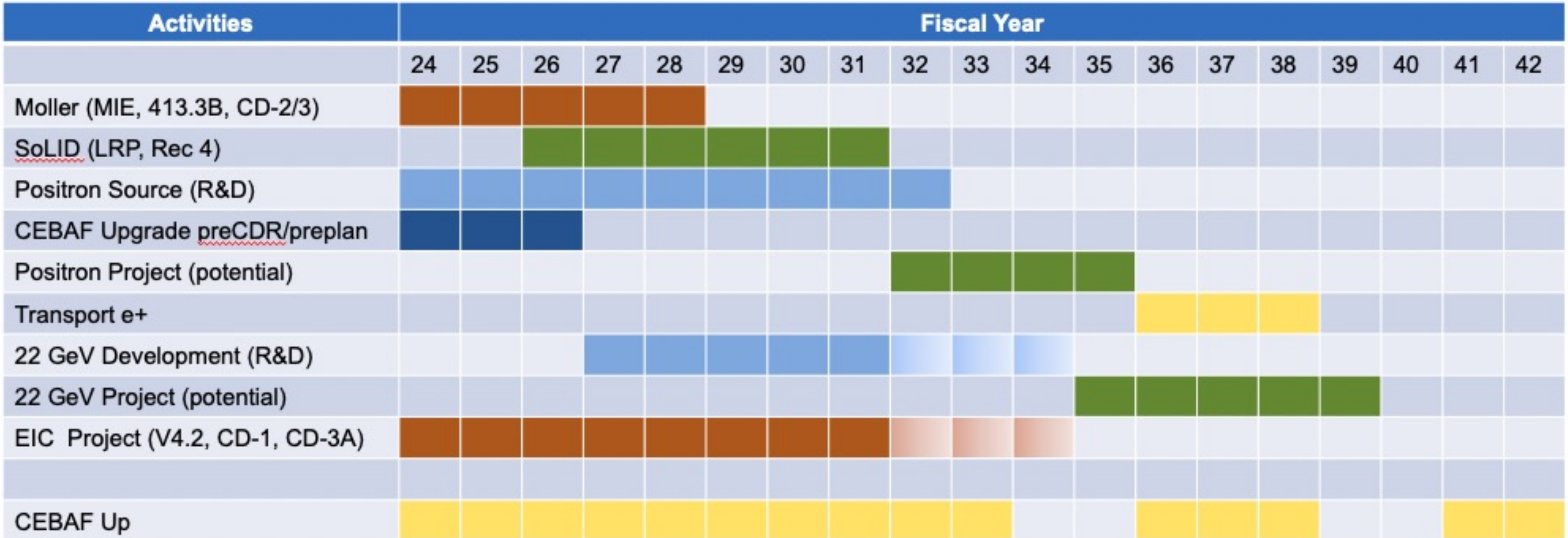
- It is an exciting accelerator opportunity – nearly double the energy with no new cryomodules!

- The goal is to secure a strong position in the next Long Range Plan.

Backup Slides

Notional CEBAF and EIC Efforts on One Chart

- Accelerator team has worked up an early schedule and cost estimate
  – Schedule assumptions based on a notional timing of when funds might be available (near EIC ramp down based on EIC V3 profile)
  – For completeness, Moller and SoLID (part of 12 GeV program) are shown; positron source dev shown
- EIC Project is shown



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