JLab at 22 GeV

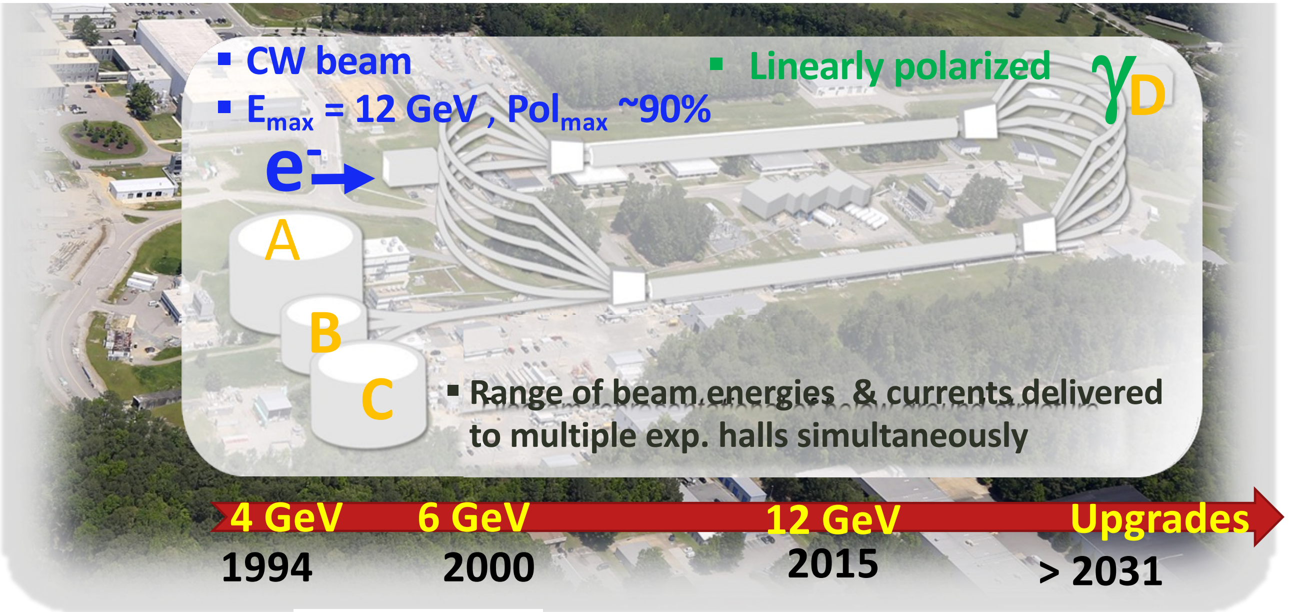
Patrizia Rossi

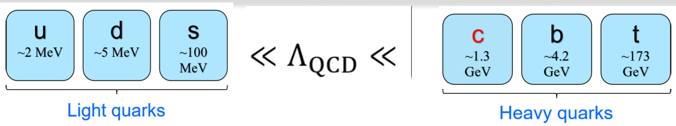
Hall A/C Collaboration Meeting

Jefferson Lab, July 15-16, 2024

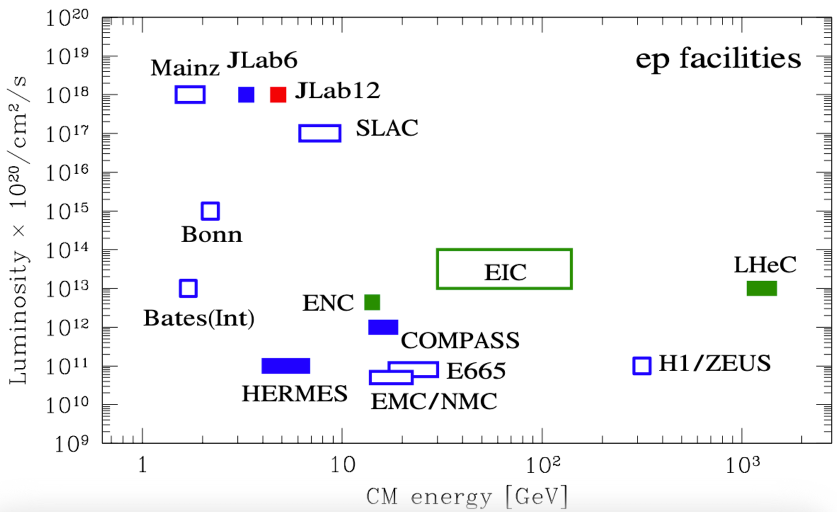
Jefferson Lab
Thomas Jefferson National Accelerator Facility

Jefferson Lab: The Intensity Frontier





Fixed target experiments at the "luminosity frontier"
(up to 10^{39} e-N /cm^2/ s)



- **12 GeV scientific era is going strong**
  - High-profile results emerging from 12 GeV program
  - At least a decade of running in the future
- Looking toward exciting future scientific opportunities that could be obtained through cost-effective upgrades

CEBAF @ 22 GeV

Positron Beam @ 12 GeV

Prepare for the Future…

- The community did a lot of work (science workshops, accelerator studies, cost estimating, profile development,…) to quickly prepare for the NSAC Long Range Plan
  - Critical just to be mentioned favorably!

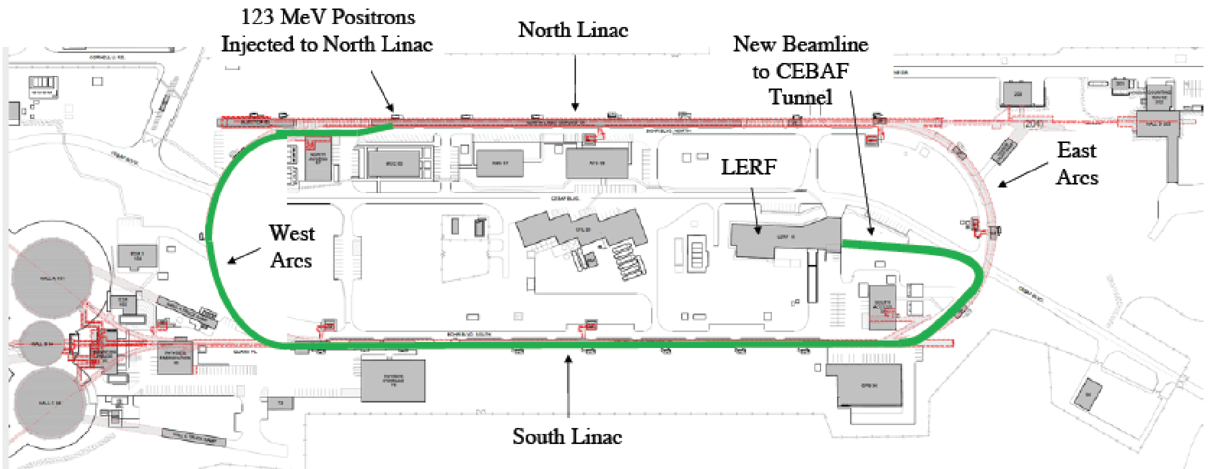
To investigate the other XYZP states, higher beam energy is required; the tetraquark candidate Zc states would be copiously produced at a high-luminosity, fixed-target electron machine operating above 20 GeV

"The staged upgrade plan for CEBAF foresees...[]…an energy upgrade of CEBAF to more than 20 GeV. Recently, the Cornell Brookhaven Electron Test Accelerator (CBETA) facility demonstrated eight-pass recirculation of an electron beam with energy recovery employing arcs of fixed-field alternating gradient magnets. This exciting new technology could enable a cost-effective method to double the energy of CEBAF, allowing wider kinematic reach for nucleon femtography studies in the existing tunnels and with no new cryomodules required."

CEBAF Phased Upgrade

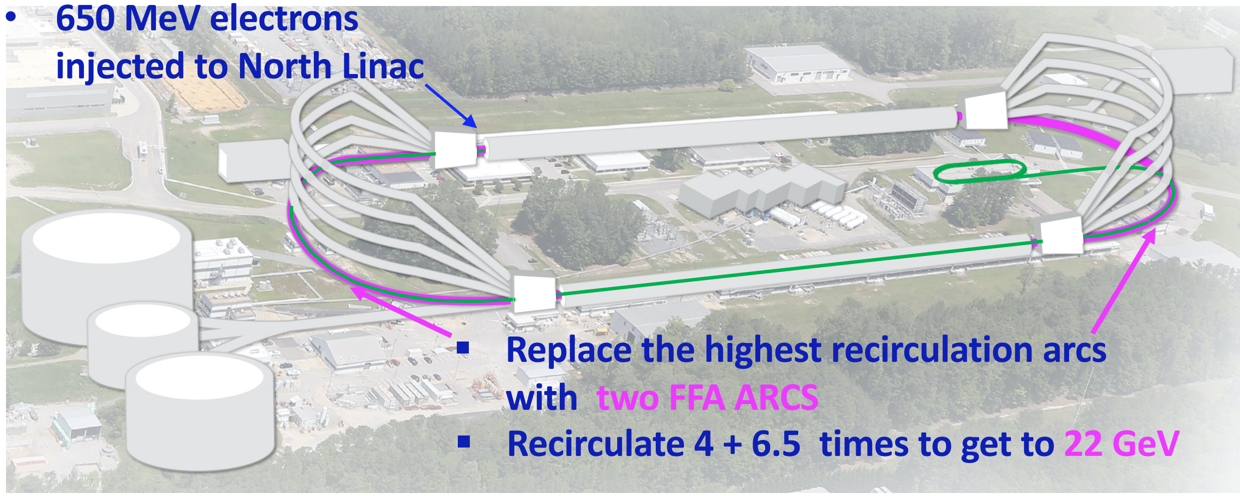
Phase 1:

- New injector (123 MeV e^+ & 650 MeV e^-) in a former FEL ("LERF")
- Polarized positrons transported to CEBAF (proposed 12 GeV science program)



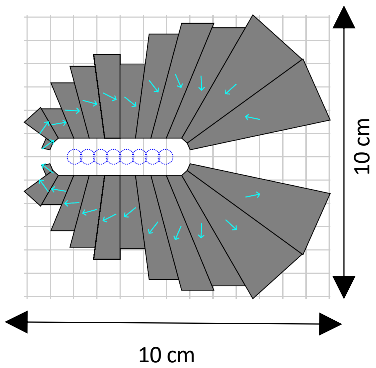
Phase 2:

- Recirculating injector energy upgrade to 650 MeV electrons
- Replace one set of arcs on each side with new FFA permanent magnet arcs to upgrade to 22 GeV – no new RF needed! No new cryomodules needed!

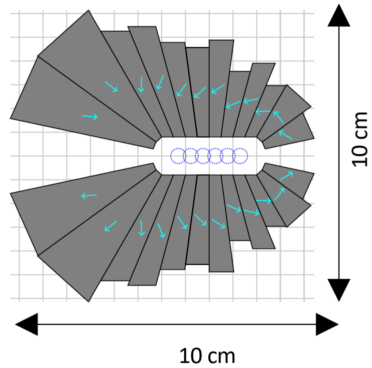


CEBAF FFA Upgrade – Baseline under Study

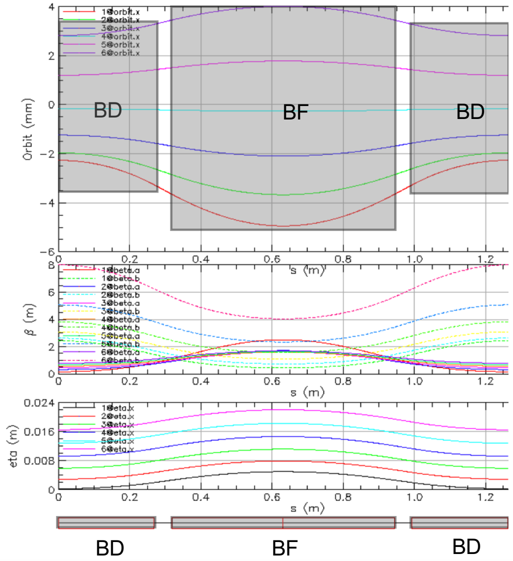
- Large momentum acceptance FFA (Fixed Field, Alternating Gradient) cell is configured with combined function permanent magnets capable of transporting multiple energy beams through the same string of magnets (six beams with energies spanning a factor of two)
- Arc composed of 75 cells, Lcell = 3.15 m

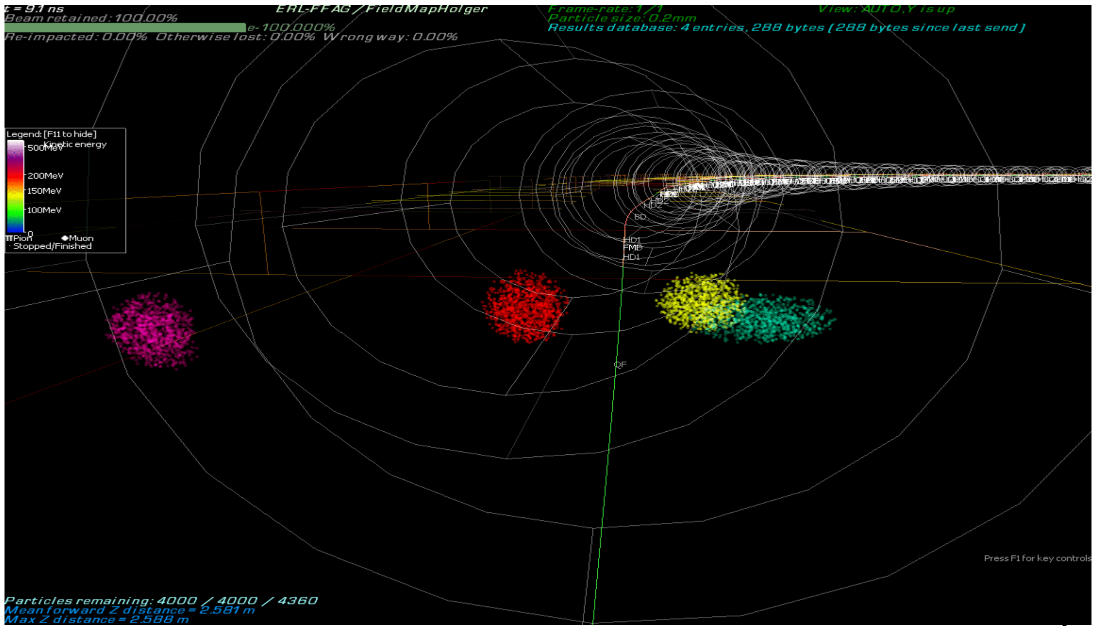


Focusing Magnet BF L_{QF}= 1.67 m

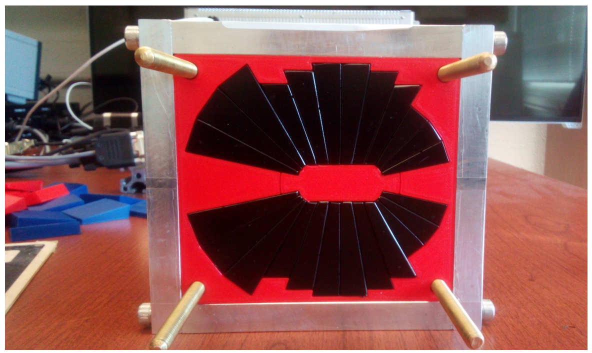


Defocusing Magnet BD L_{BD}= 1.24 m





- Novel permanent magnets, CBETA.-like used for power and cost savings



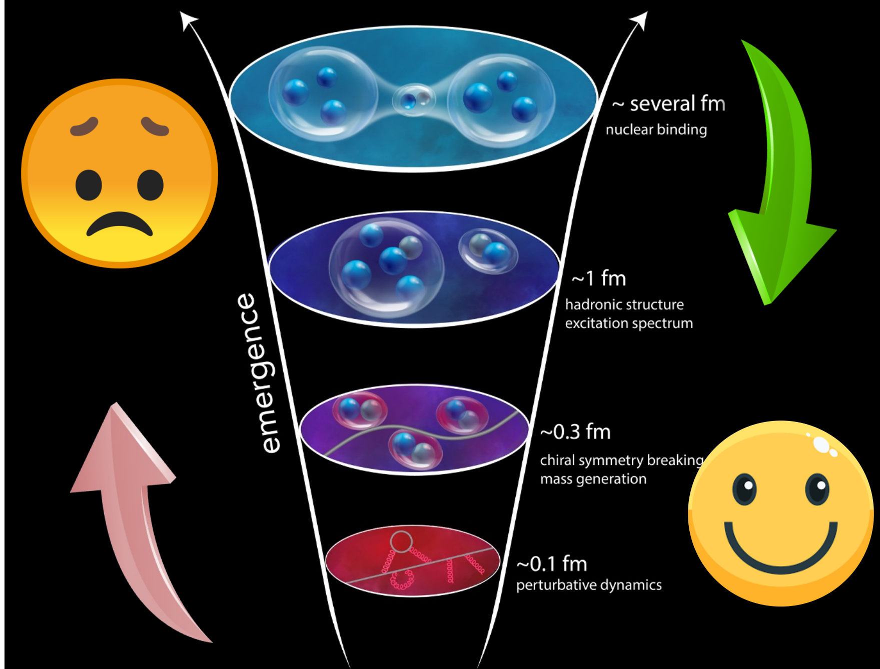
FFA@CEBAF Collaboration

- A prototype open midplane BF magnet was built and evaluated for mechanical integrity
- Magnetic measurement confirmed a robust design with >1.5 Tesla in good field region, 10^{-3} field accuracy
- Testing magnetic materials for radiation resilience at CEBAF - LDRD project started Oct. 1, 2023

22 GeV – Near Term Strategy

- Accelerator design focus for the next few years should be:
  - Developing a pre-conceptual design for FFA racetrack to reach 22 GeV
  - Complete design of FFA arcs and transitions to linacs
  - Design extraction system for all FFA passes to Halls A, B, C, D
  - Study SR emittance and polarization effects
  - Design 650 MeV recirculating injector
- Technical design focus for the next few years should be:
  - Testing resilience of permanent magnets in CEBAF beam environment
  - Testing performance of an FFA FODO cell with multi GeV beams at CEBAF
  - Designing and prototyping beam separation components (splitter, septa, RF cavities)

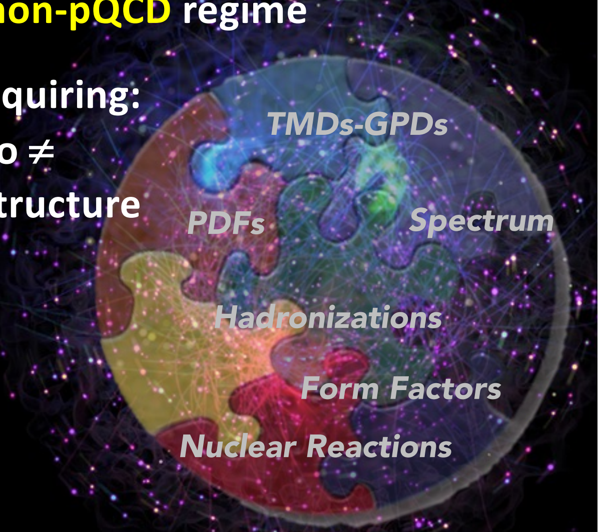
Emergent Phenomena in QCD



How does this arise from QCD?

- A detailed understanding of the way QCD generates protons, neutrons, and other strongly interacting hadrons remains elusive
  → JLab's mission: study the emergence of hadronic structure & the quarks and gluons dynamics in the non-pQCD regime
- Complex and multi-faced problem requiring:
  - Multiple observables sensitive to ≠ characteristics of the hadronic structure
  - Precise measurements

  ⟶ HIGH LUMINOSITY

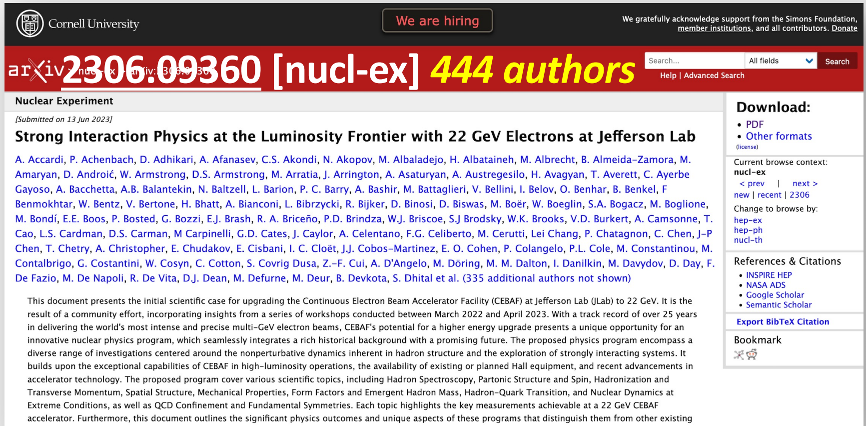


How can a 22 GeV upgrade help?

- A NEW territory to explore → $c\bar{c}$ states in large quantities and with additional light quarks d.o.f.
- A BETTER insight into our current program → Enhancement of the phase space
- A BRIDGE between JLab @ 12 GeV and EIC → Low to high energy theory validation with high precision

The INITIAL Physics case with 22 GeV

- Developed through a series of workshops started in summer 2022
- A white paper has been written and accepted for publication by EPJA


Cornell University

We are hiring

We gratefully acknowledge support from the Simons Foundation, member institutions, and all contributors. Donate

arXiv:2306.09360 [nucl-ex] **444 authors**

Nuclear Experiment

[Submitted on 13 Jun 2023]

Strong Interaction Physics at the Luminosity Frontier with 22 GeV Electrons at Jefferson Lab

A. Accardi, P. Achenbach, D. Adhikari, A. Afanasev, C.S. Akondi, N. Akopov, M. Albaladejo, H. Albataineh, M. Albrecht, B. Almeida-Zamora, M. Amaryan, D. Androić, W. Armstrong, D.S. Armstrong, M. Arratia, J. Arrington, A. Asaturyan, A. Austregesilo, H. Avagyan, T. Averett, C. Ayerbe Gayoso, A. Bacchetta, A.B. Balantekin, N. Baltzell, L. Barion, P. C. Barry, A. Bashir, M. Battaglieri, V. Bellini, I. Belov, O. Benhar, B. Benkel, F. Benmokhtar, W. Bentz, V. Bertone, H. Bhatt, A. Bianconi, L. Bibrzycki, R. Bijker, D. Binosi, D. Biswas, M. Boër, W. Boeglin, S.A. Bogacz, M. Boglione, M. Bondí, E.E. Boos, P. Bosted, G. Bozzi, E.J. Brash, R. A. Briceño, P.D. Brindza, W.J. Briscoe, S.J Brodsky, W.K. Brooks, V.D. Burkert, A. Camsonne, T. Cao, L.S. Cardman, D.S. Carman, M Carpinelli, G.D. Cates, J. Caylor, A. Celentano, F.G. Celiberto, M. Cerutti, Lei Chang, P. Chatagnon, C. Chen, J-P Chen, T. Chetry, A. Christopher, E. Chudakov, E. Cisbani, I. C. Cloët, J.J. Cobos-Martinez, E. O. Cohen, P. Colangelo, P.L. Cole, M. Constantinou, M. Contalbrigo, G. Costantini, W. Cosyn, C. Cotton, S. Covrig Dusa, Z.-F. Cui, A. D'Angelo, M. Döring, M. M. Dalton, I. Danilkin, M. Davydov, D. Day, F. De Fazio, M. De Napoli, R. De Vita, D.J. Dean, M. Defurne, M. Deur, B. Devkota, S. Dhital et al. (335 additional authors not shown)

This document presents the initial scientific case for upgrading the Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Lab (JLab) to 22 GeV. It is the result of a community effort, incorporating insights from a series of workshops conducted between March 2022 and April 2023. With a track record of over 25 years in delivering the world's most intense and precise multi-GeV electron beams, CEBAF's potential for a higher energy upgrade presents a unique opportunity for an innovative nuclear physics program, which seamlessly integrates a rich historical background with a promising future. The proposed physics program encompass a diverse range of investigations centered around the nonperturbative dynamics inherent in hadron structure and the exploration of strongly interacting systems. It builds upon the exceptional capabilities of CEBAF in high-luminosity operations, the availability of existing or planned Hall equipment, and recent advancements in accelerator technology. The proposed program cover various scientific topics, including Hadron Spectroscopy, Partonic Structure and Spin, Hadronization and Transverse Momentum, Spatial Structure, Mechanical Properties, Form Factors and Emergent Hadron Mass, Hadron-Quark Transition, and Nuclear Dynamics at Extreme Conditions, as well as QCD Confinement and Fundamental Symmetries. Each topic highlights the key measurements achievable at a 22 GeV CEBAF accelerator. Furthermore, this document outlines the significant physics outcomes and unique aspects of these programs that distinguish them from other existing

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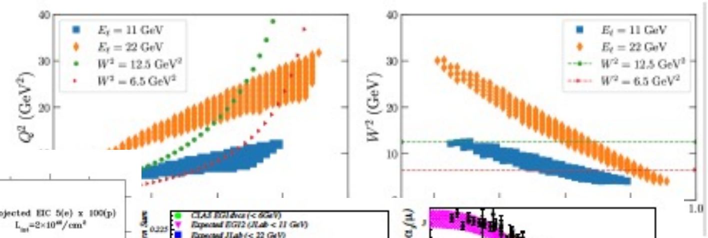
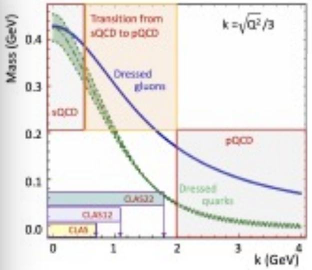
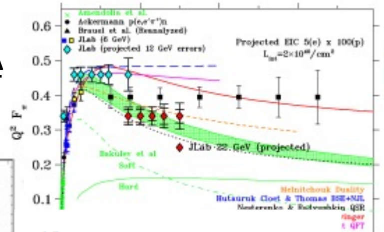
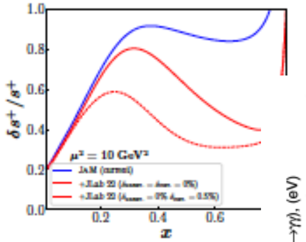
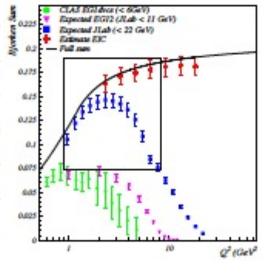
- Hadron Spectroscopy
- Partonic Structure and Spin
- Hadronization and Transverse Momentum
- Spatial Structure, Mechanical Properties, Emergent Hadron Mass
- Hadron-Quark Transition and Nuclear Dynamics at Extreme Conditions
- QCD Confinement and Fundamental Symmetries

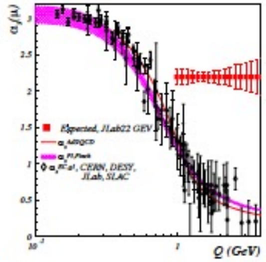


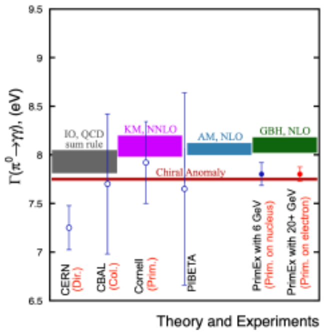


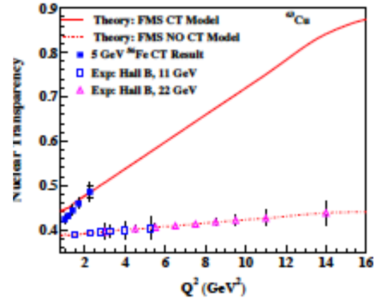












This meeting

13:00	**Jlab at 22 GeV** Speaker: Patrizzia Rossi
13:30	**Nuclear dynamics (SRC, superfast quarks, etc)** Speaker: Wim Cosyn (Florida International University)
14:00	**SIDIS at 22 GeV** Speaker: Ed Kinney
14:30	**Pion/Kaon LT** Speaker: Garth Huber

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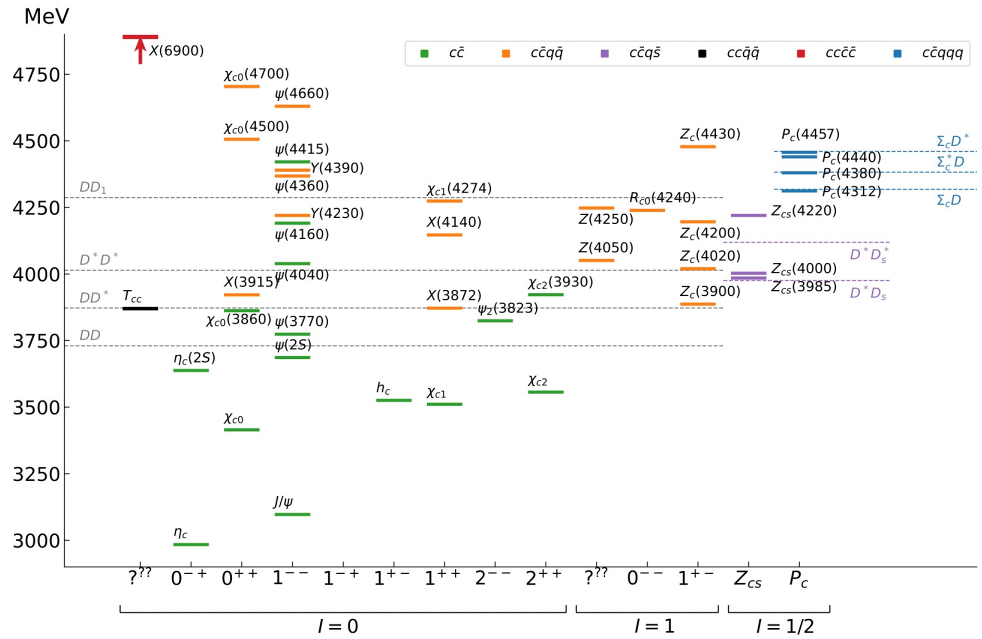
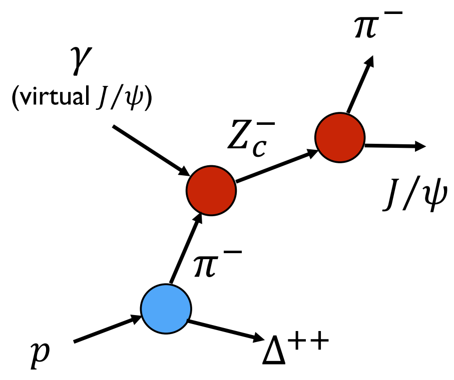
Photoproduction of Hadrons with Charm Quarks

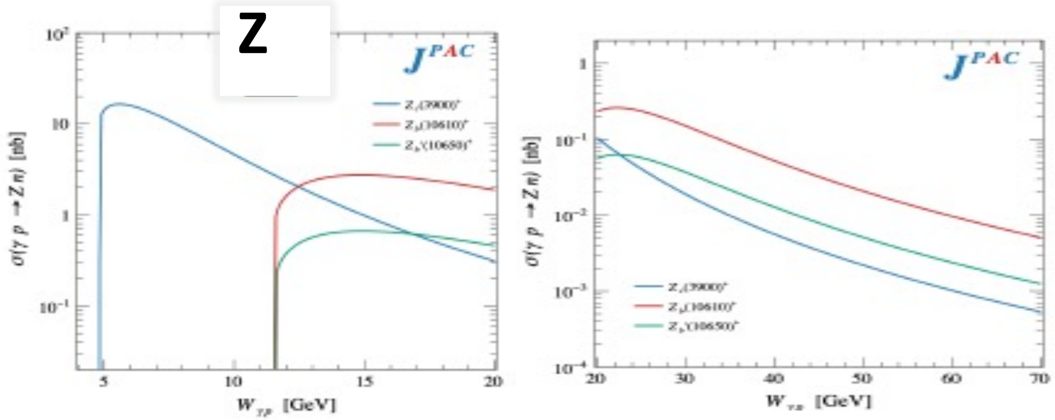
Potentially decisive information about the **nature of some 5-quark and 4-quark (XYZ)** candidates



JPAC Collaboration, arXiv:2112.13436

Direct (photon) probe of the $Z_c \to J/\psi\pi$ coupling without rescattering effects provides unique complementary data to constrain interpretation of e^+e^- and B decays data.



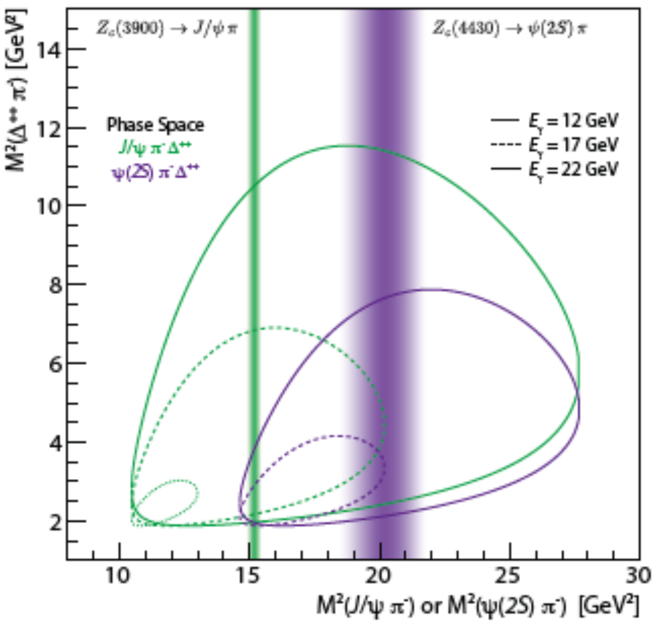


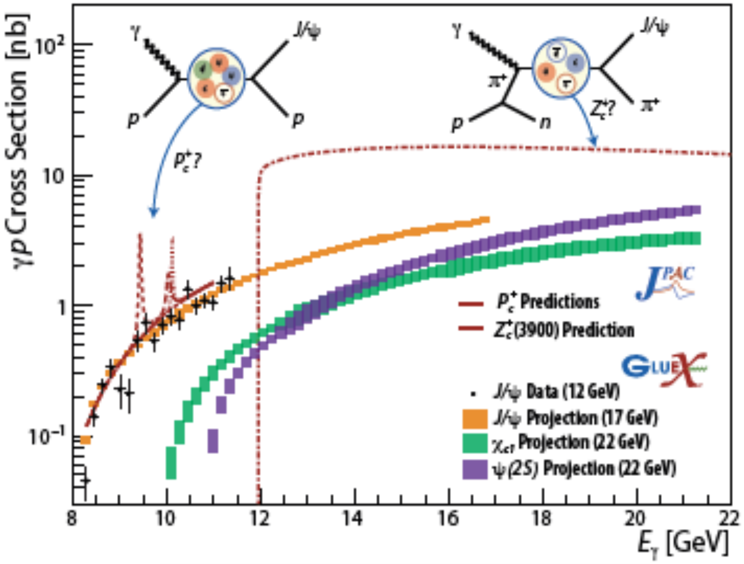
These predictions suggest that the extraction of exotics at JLab 22 is a possibility (XZ searches might be better at JLab 22, Y searches better at EIC

- **Many "XYZ" states observed in B decays, e⁺e- colliders**
- **No XYZ state uncontroversially seen so far**
- **Never direcly produced using γ/lepton beam**

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

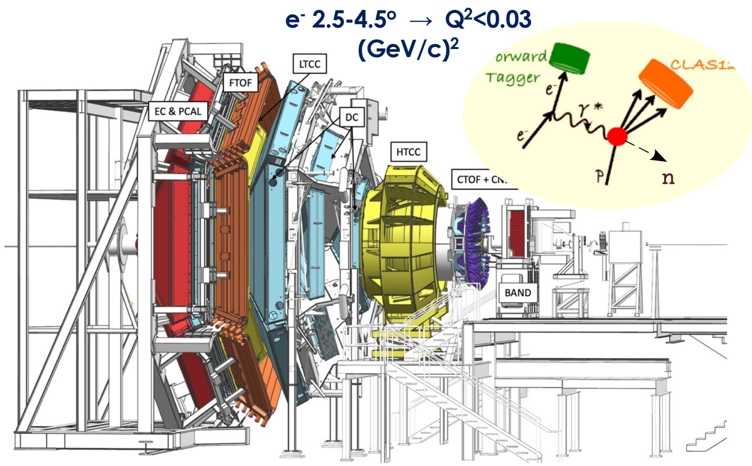
GlueX-Hall D

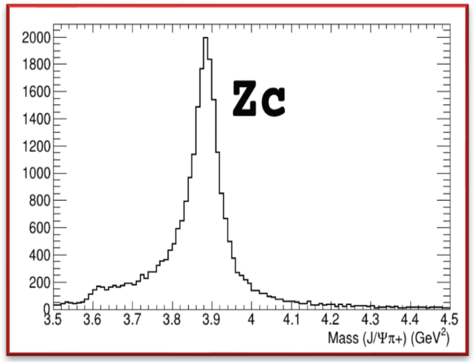




- **Photoproduction** used to validate the existence of **charmed 5quark**.
- With energy upgrade the investigation can be **extended to other exotic candidates.**

CLAS12-Hall B





- Zc(3900) → J/ψ π
- Zc(4430) → ψ(2S) π

- **Q^2 evolution** of any new state

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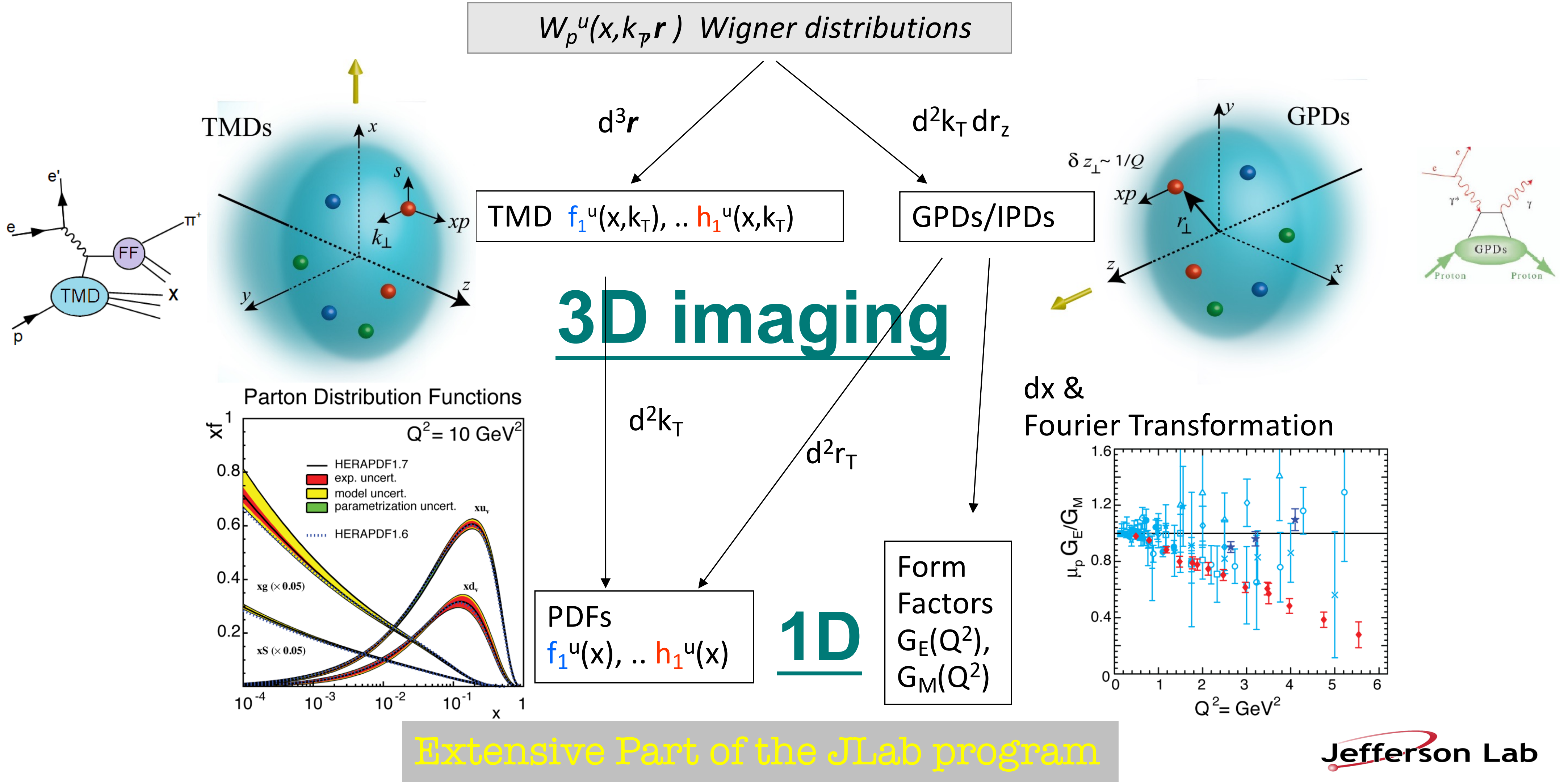
Unified View of Nucleon Structure



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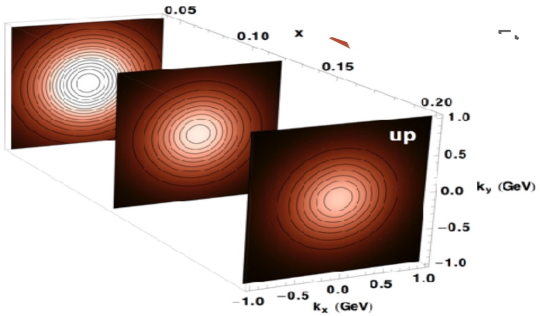
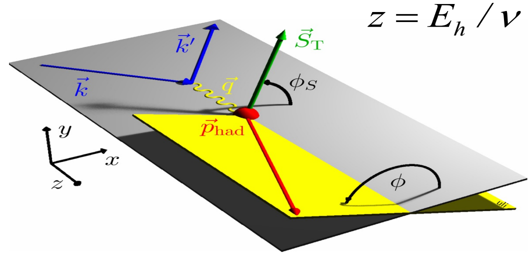
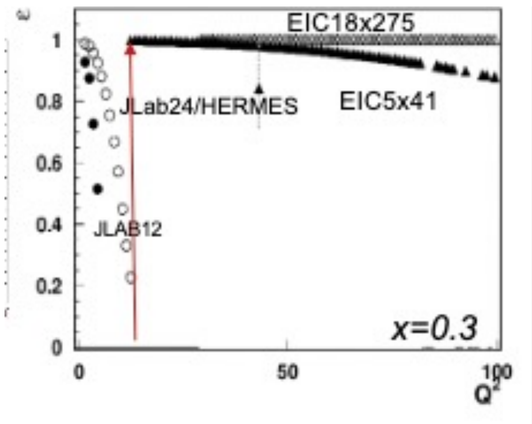
Nucleon 3D in Momentum Space (TMD)

$x = Q^2/2M\nu \quad \nu = E - E' \quad Q^2 = 4EE'\sin(\theta/2)$

$z = E_h/\nu$







$\sigma = f(x, Q^2, z, P_T)$

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

- **At large x fixed target experiments are sensitive to ALL Structure Functions**
- Measurements of $F_{UU,T}$ and Sivers requires separation, evaluation of **longitudinal photon !**

Hall C crucial for these studies

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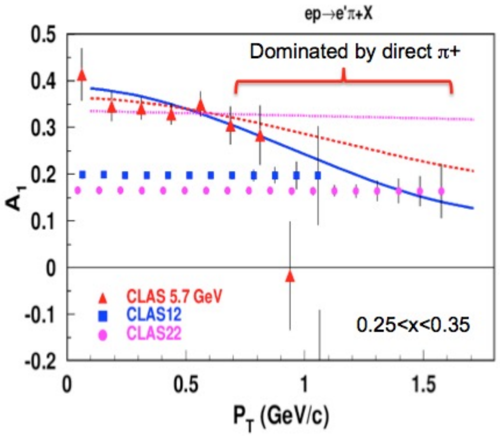
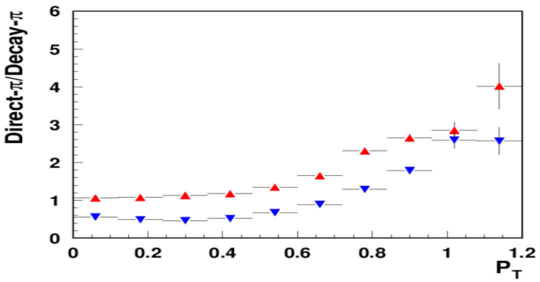
Nucleon 3D in Momentum Space (cont'd)



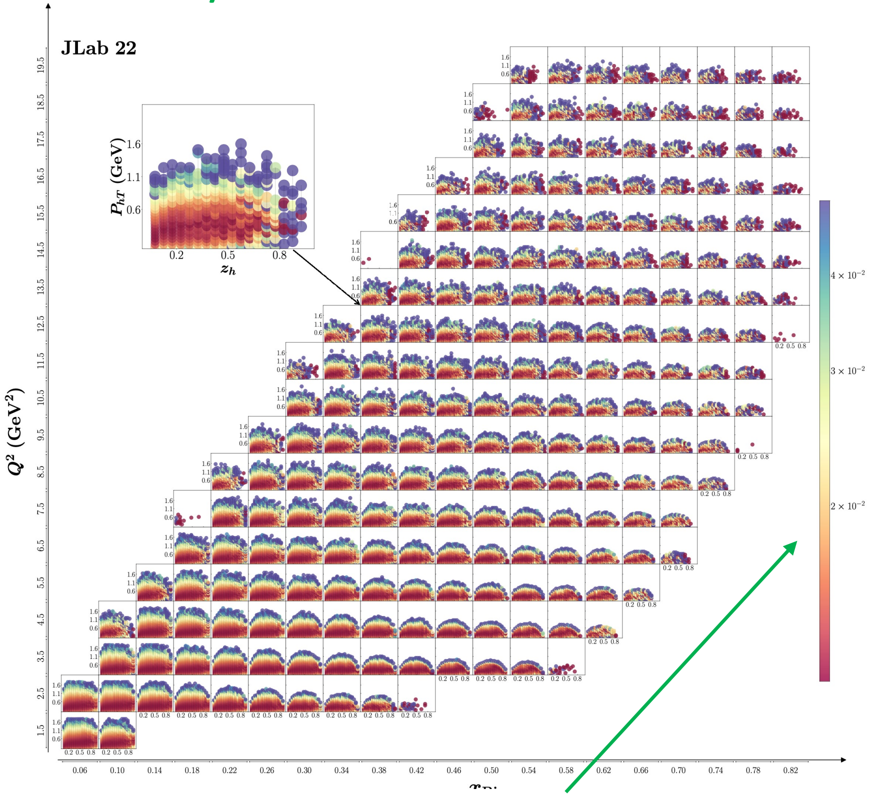
- Large P_T accessible with CLAS12



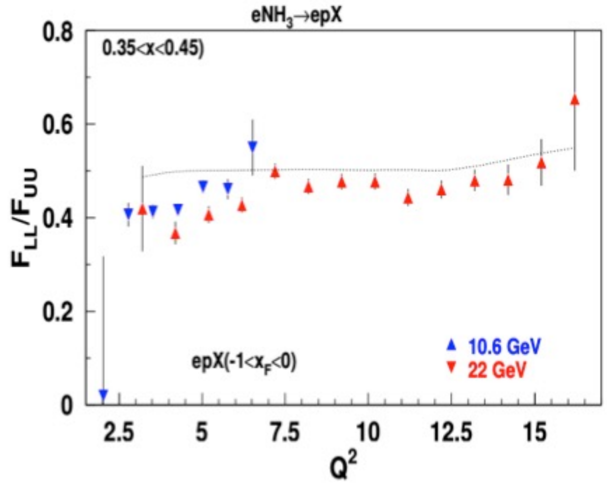
- For low P_T the impact of rho can be critical

Crucial Hall C & Hall B complementary studies

Projections for 100 days of running with L= 10^{35} $cm^{-2}s{-1}$ using the existing CLAS12 simulation/reconstruction chain



Expected uncertainties for SIDIS cross sections in 4D bins



- Q^2 evolution studies possible, allowing:
  - Studies of evolution properties
  - Disentangle leading/sub-leading contributions
  - Validate/test the phenomenology

Study Group

- We are just at the beginning of a lengthy process which includes physics and technical planning, and we want to maintain momentum toward a major facility upgrade of CEBAF.
- White Papers for both the positron and the higher energy programs are available.
- A small study group (11 people from JLab Management, Physics Division, Accelerator Division, Users) for the science and technology of both the 12 GeV positrons, and the 22 GeV energy upgrade has been set up. We may expand the group as needed to meet that end goal.
- The study group meets monthly to both plan for the upgrade and to report on progress toward it.
  - **Understand community/science requirements for the positron beam (e.g., polarizability, energy, intensity, fast switching between e+ and e- beams) and translating those into source requirements and machine operations requirements.**
  - **Define a roadmap for development of the technology for the positrons and for the 22 GeV beams.**
  - **Define the R&D path needed to fill gaps in our capability to reach polarized positrons and 22 GeV beams.**
  - **Report on progress of the group in defining our path forward (JSA board, S&T Mission Committee, DOE/NP)**
- **The ultimate outcome of this group would be the preCDR**
- **Meeting with Allison Lung on July 22nd to have her guidance on how to proceed with the preCDR**

22 GeV Open Discussion

https://wiki.jlab.org/jlab22/index.php/22_GeV_Open_Discussion

- The goal of the 22 GeV Open Discussion meetings are to discuss and **refine the scientific case for the 22 GeV upgrade**. These discussion are likely to build on the ideas in the 22 GeV White Paper but are also a good place to bring new ideas.
- Eventually we will need to lay out the most compelling scientific arguments for the 22 GeV upgrade in order to secure the support of the community and ultimately the funding agencies. Therefore, we want to raise and examine all potential criticisms in advance in order to strengthen the scientific case. **We anticipate these discussions to motivate additional studies or simulations needed demonstrate the impact of various measurements.**

Meeting Agendas (biweekly meetings)

- June 17, 2024: Volker Burkert: Quark pressure and shear stress in the proton at 22 GeV
- July 1, 2024: Lubomir Pentchev: Threshold J/ψ production and proton gravitational form factors
- July 15, 2024: Stepan Stepanyan: Double Deeply Virtual Compton Scattering (DDVCS) at 22 GeV
- July 29, 2024: Garth Huber: Pion and Kaon form factors with JLab at 22 GeV
- August 12, 2024: Viktor Mokeev: Charting emergence of the N* structure and hadron mass in experiments of 22 GeV era

22 GeV Open Discussion

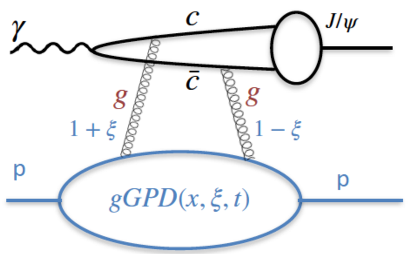
Guidance for Speakers

- The goal for speakers should be to provoke discussion from the group which has broad scientific interests in nuclear physics as well as being composed of both theorists and experimentalists.
- Aim for 15 minutes of presentation followed by discussion. This should be 3-5 slides maximum. Additional backup slides can be included for anticipated questions. The goal is to get the discussion started.
- Focus on three things for each measurement:
  - the broader context and motivation for this particular measurement
  - a description of what is being measured and the anticipated precision or sensitivity
  - the importance of 22 GeV electrons
- It may be helpful to think about broad questions in the context of the scientific method like
  - What falsifiable hypothesis is being tested by the measurement?
  - What precision is required to draw a conclusion from the result?
  - Do the results lead to an understanding of nature that is predictive in some way?
  - Based on the result what predictions can be tested with future measurements?
- **As an expert you know the uncertainties, weak points, or challenges in the scientific arguments. Raise them in the discussion, and together we can strengthen the case or identify areas where additional study is needed.**

Threshold Charmonium Photoproduction

Used to access the gluonic contribution to the mechanical properties of the proton

GPD



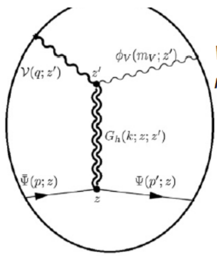
- Compton-like amplitudes $\mathscr{H}_{gC}(\xi,t)$, $\mathscr{E}_{gC}(\xi,t)$ and form-factors as in DVCS
- In contracts: threshold kinematics is very different: at high momentum transfer t and skewness ξ (hard process):

$$\left(\frac{d\sigma}{dt}\right)_{\gamma p\to J/\psi p} = F(E_\gamma)\xi^{-4}[G_0(t)+\xi^2 G_2(t)] + \ldots$$

- Leading terms in $G_0(t)$ and $G_2(t)$ contain gGFFs $A_g(t), B_g(t), C_g(t)$
- Absolute calculations, but require knowledge of gGFFs

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

Holographic Approach



Witten diagram representation

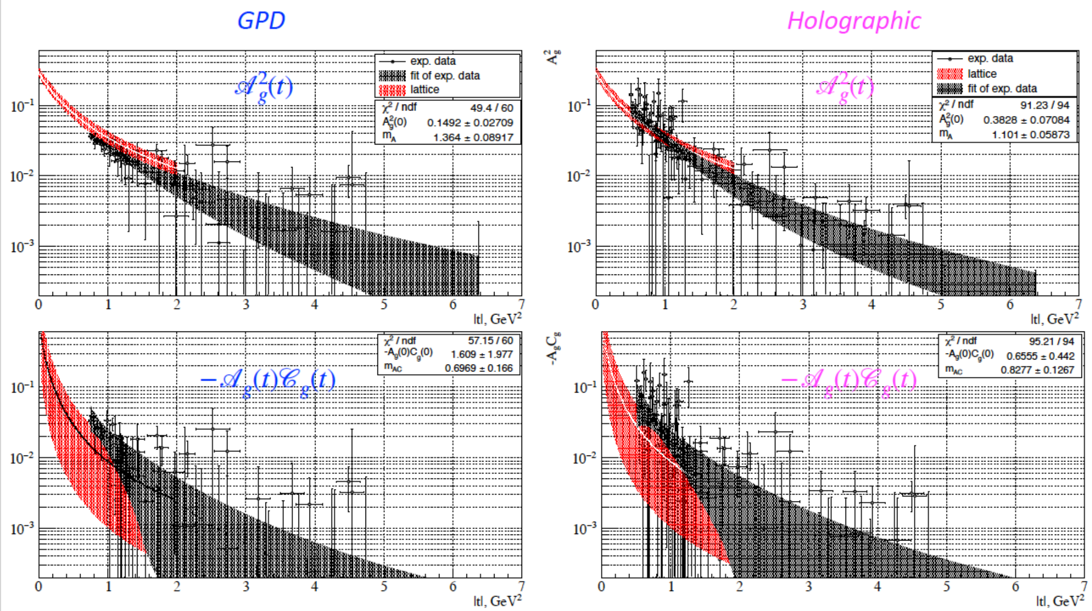
- Using gauge/string correspondence
- In the double limit of large N_c and strong gauge coupling (soft process):

$$\left(\frac{d\sigma}{dt}\right)_{\gamma p\to J/\psi p} = H(E_\gamma)[A_g^2(t) + \eta^2 8A_g(t)C_g(t)] + \ldots$$

- Approximate theory, requires $1/N_c$ corrections
- Relative calculations ($H(E_\gamma)$ normalized to GlueX total cross-sections), but predicts $A_g(t)$ and $C_g(t)$ shapes from Regge trajectories

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

Gluonic Form Factors - data vs lattice



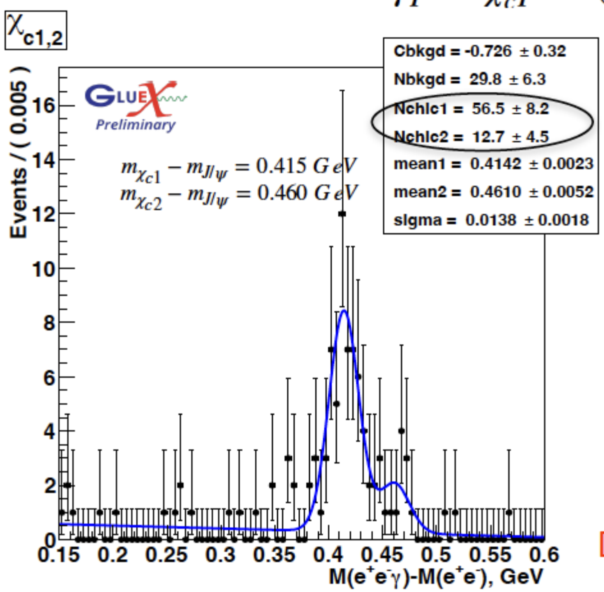
Extraction of gluonic form factors from JLab J/Ψ data (GlueX + Hall C) cannot distinguish between two diametric theories, each with specific corrections (higher moments, 1/Nc)

L. Pentchev

Higher-mass Charmonium States at Threshold

$$\gamma p \rightarrow \chi_c p \rightarrow (J/\psi\gamma)\, p \rightarrow (e^+e^-\gamma)\, p$$

L. Pentchev

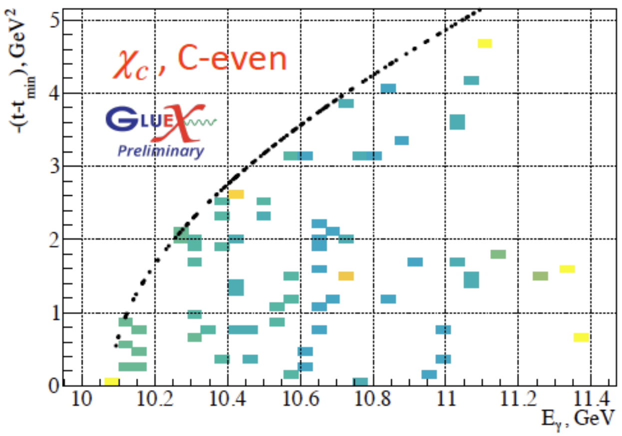


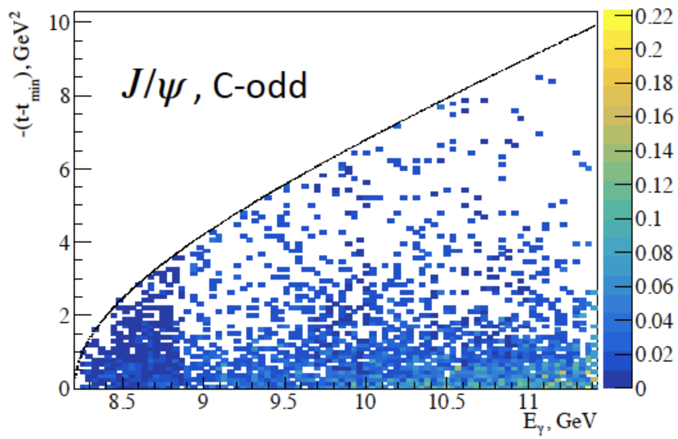
$\chi_{c1}(3511)$ and $\chi_{c2}(3556)$, 1^{++} and 2^{++},
$E_\gamma^{thr} = 10.1$ GeV

- First ever evidence for photoproduction of C-even charmonium
- Studying χ_c states - complementary to J/ψ in understanding reaction mechanism near threshold

Study of χ_c, Ψ ', and J/Ψ states provide complementary information to understand the reaction mechanism near threshold

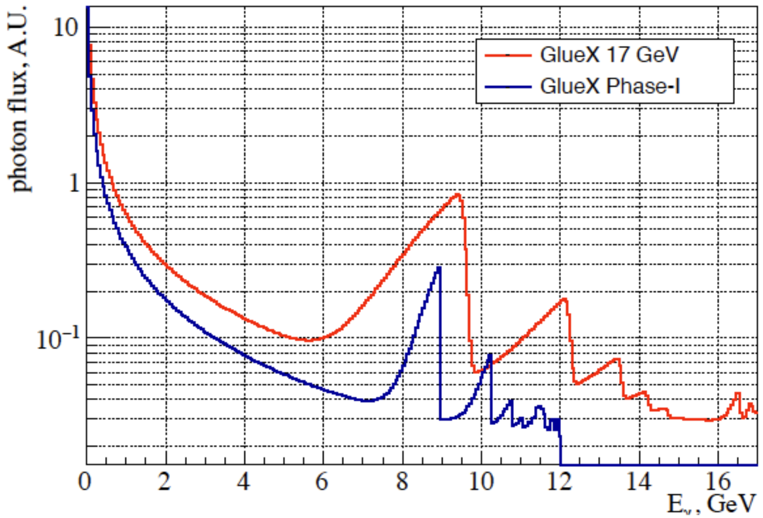
Dramatic difference: χ_c distribution in (E_γ, t) vs J/ψ



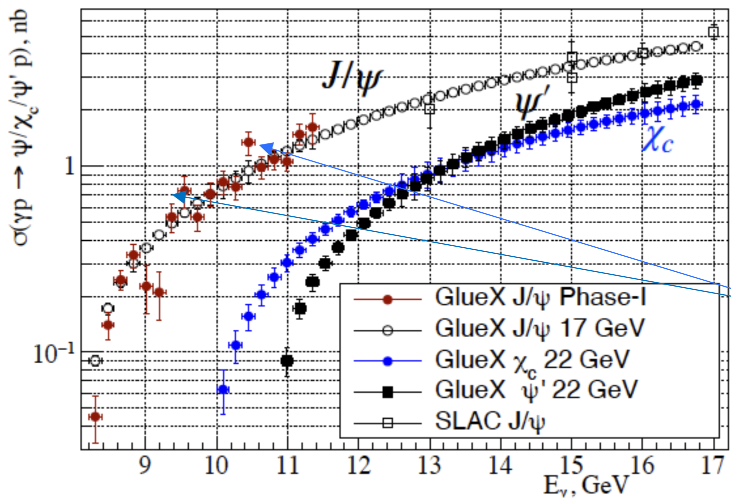


Threshold Charmonium Photoproduction at 22 GeV era

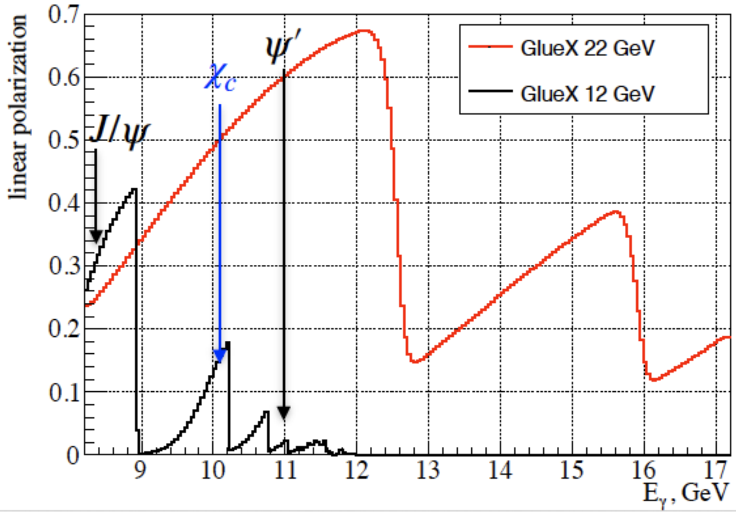
L. Pentchev



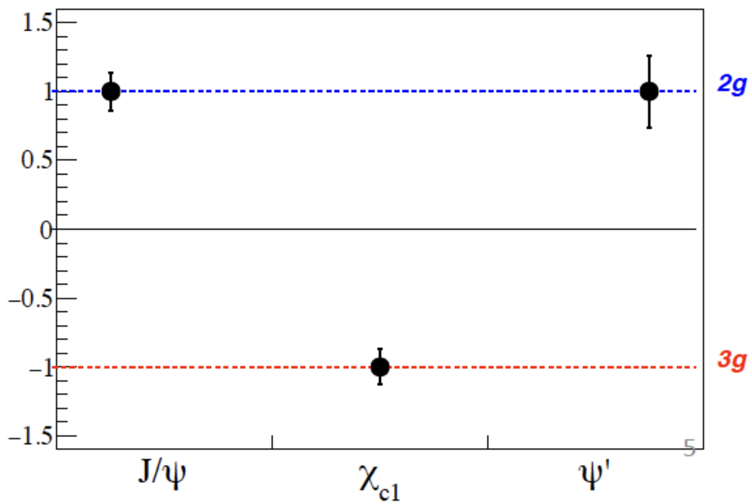
E_{el} = 22 GeV

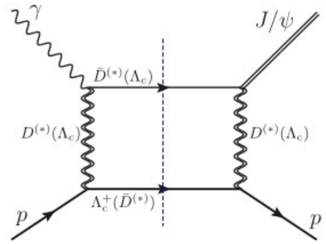


Possible structure at $\Lambda_c\overline{D}^{(*)}$ threshold σ(8.6-9.6) GeV



naturality $\times (-1)^J = P$





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Next Step

- Comparisons of different programs/facilities need to be laid out in detail: GlueX (at 17 GeV, 22 GeV), GlueX phase-III upgrade, SOLID in Hall A, CLAS12, CLAS22, EIC. These comparisons should be quantitative and define the unique aspects of each program (energy range, polarization, flux, Q^2 range, acceptance, etc). Pros/cons (or strengths/weaknesses) of the different programs/facilities should be compared and contrasted.

- What impact do open charm channels have on interpreting the J/Ψ+p final state? Can contributions from channels like D(*)Λc be disentangled from t-channel J/Ψ production? What about non-resonant production mechanisms? How do these contributing channels affect comparisons with theory?

Closing the loop on virtual Compton scattering

S. Stepanyan

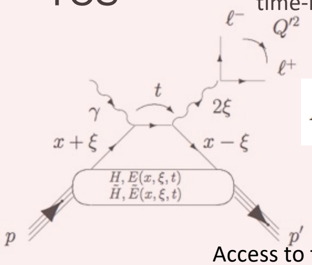
- GPDs, accessible in hard exclusive reactions (DVCS, TCS, DVMP), describe the correlation of quark/antiquark transverse spatial and longitudinal momentum, the quark angular momentum distributions.
- Extracting information on GPDs from experimental observables is not straightforward and is a two-step process
  a. The exp. observables (asym. & x-sections in DVCS/TCS) are parametrized by complex-valued CFFs:
  b. Infer nformation on GPDs from CFFs, is challenging. One of the GPD variables, x, is integrated out of the CFFs

JLAB Flagship program – accessing GPDs through measurements of beam/target asymmetries and the cross sections of Compton processes (TCS and DVCS)

First experimental measurement with CLAS12 PRL 127, 262501 (2021)

TCS

Hard scale is defined by time-like photons



$$Re\ \mathcal{H}(\xi,t) = PV \int_{-1}^{1} dx\, C^{-}(\xi,x) H(x,\xi,t)$$

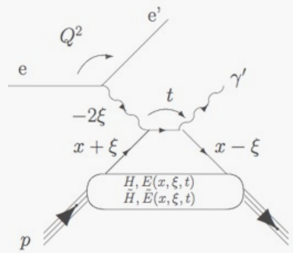
$$Im\ \mathcal{H}(\xi,t) = i\pi H(\xi,\xi,t)$$

Access to the Re-part of the Compton amplitude

Started in 2001, PRL 87, 182002.
Now is the flagship physics program

DVCS

Hard scale is defined by space-like photon

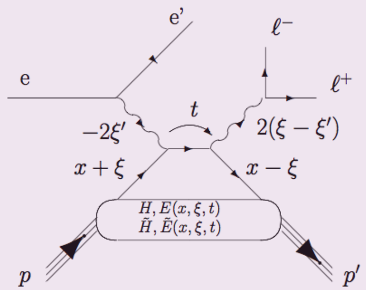


Jefferson Lab at the luminosity frontier is the only place in the world DDVCS can be measured!

μCLAS12 in Hall B and SoLID in Hall A are the two proposed facilities capable of carrying out such measurements.

DDVCS

Both space-like and time-like photons can set the hard scale



$$\int_{-1}^{+1} dx \frac{H(x,\xi,t)}{x-(2\xi'-\xi)+i\epsilon} + \ldots$$

$$H(2\xi'-\xi,\xi,t) + H(-(2\xi'-\xi),\xi,t)$$

σ-DDVCS is three orders of magnitude smaller than σ-DVCS

Jefferson Lab

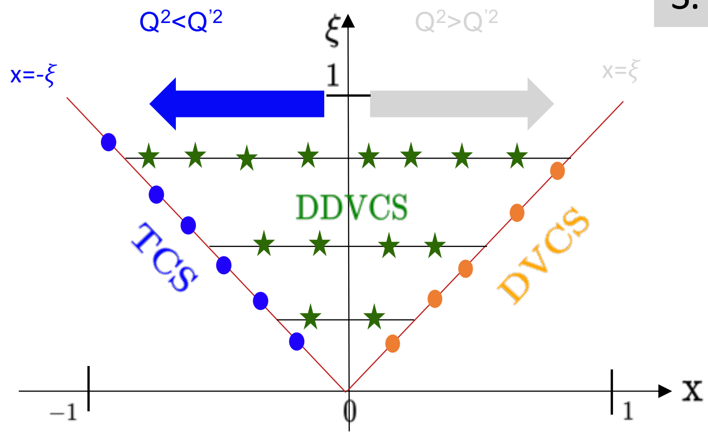
CFFs and GPDs in Virtual Compton Scattering

S. Stepanyan

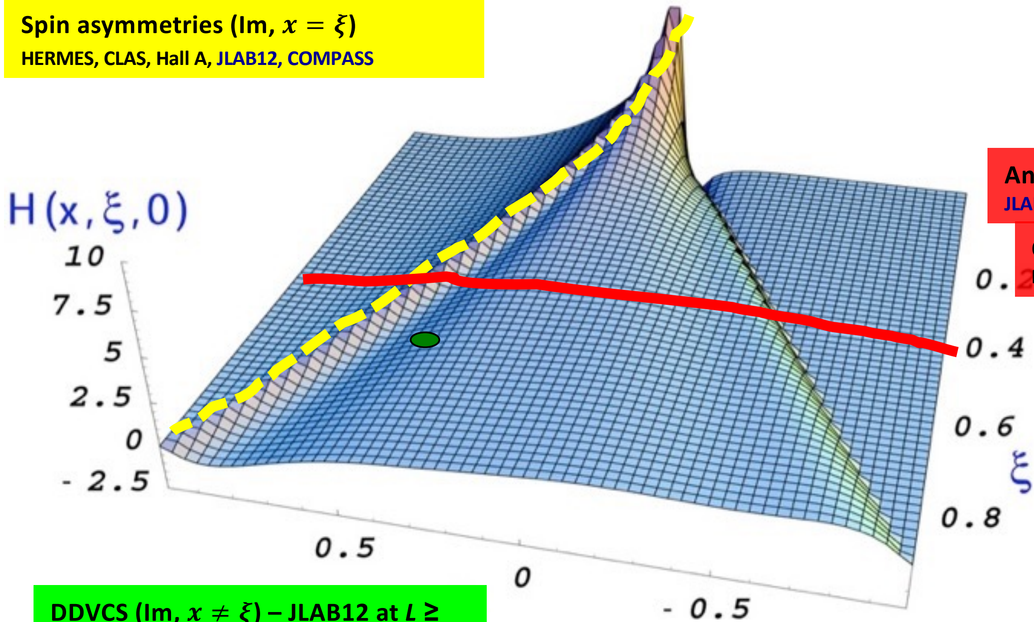
$$\mathcal{T}_{DVCS} \sim CFF\ \mathcal{H}(\xi,t) \propto i\pi[H(\xi,\xi,t) - H(\xi,\xi,t)] + P\int_{-1}^{+1} dx\left(\frac{1}{x-\xi} \pm \frac{1}{x+\xi}\right)[H(x,\xi,t) \mp H(x,\xi,t)]$$

(the same for TCS)

$$\mathcal{T}_{DDVCS} \sim CFF\ \mathcal{H}(\xi,\xi',t) \propto i\pi[H(2\xi'-\xi,\xi,t) - H(-2\xi'+\xi,\xi,t)] + P\int_{-1}^{+1} dx\left(\frac{1}{x-(2\xi'-\xi)} \pm \frac{1}{x+(2\xi'-\xi)}\right)[H(x,\xi,t) \mp H(x,\xi,t)]$$



Spin asymmetries (Im, $x = \xi$)
HERMES, CLAS, Hall A, JLAB12, COMPASS



Angular asymmetry in TCS (|Re|)
JLAB12

Charge asymmetry in DVCS (|Re|)
HERMES, COMPASS, JLAB12

DVCS Cross sections (|Re|²) H1,
Hall A, JLAB12, COMPASS

DDVCS (Im, $x \neq \xi$) – JLAB12 at $L \geq 10^{37}$ cm^{-2} sec^{-1}

Re part of CFFs provides a direct measurement of the D-term and access to the mechanical properties of the proton

High luminosity CLAS12 for DDVCS

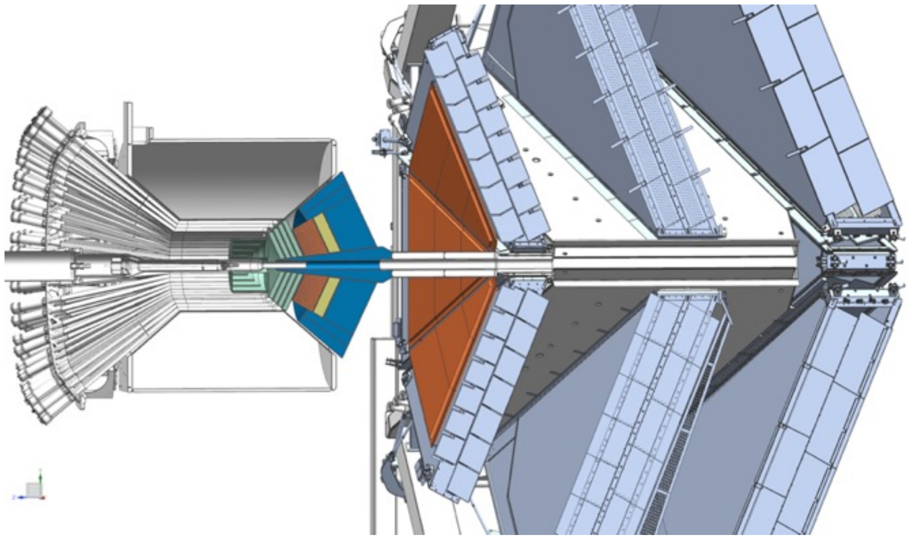
S. Stepanyan

Challenge to measure DDVCS:

a) The cross section is three orders of magnitude smaller than that of DVCS.
b) Ambiguities and anti-symmetrization issues with the decay leptons of the outgoing virtual photon and the incoming-scattered lepton.

Di-muon electroproduction, using upgraded CLAS12, will overcome these challenges.

μCLAS12



A concept first introduced in LOI12-16-004

Detector capable of measuring

$$ep \rightarrow e'p'\mu^{+}\mu^{-} \;\; @ \; L > 10^{37} cm^{-2} sec^{-1}$$

A simple concept:

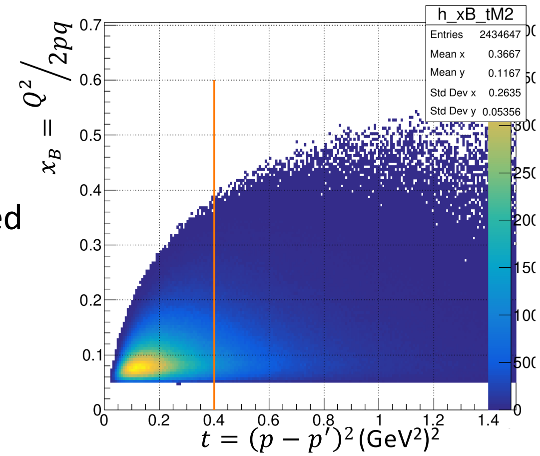
- Remove HTCC and block the CLAS12 forward with a W-shield and $PbWO_4$ calorimeter to prevent flooding of DC by EM background;
- Scattered electrons will be detected in the calorimeter, while the shield will work as a pion filter, as most charged pions will shower and will not reach the forward tracking system;
- Remove CVT, instead use a high rate MPGDs for the central and forward (in front of the calorimeter) tracking.

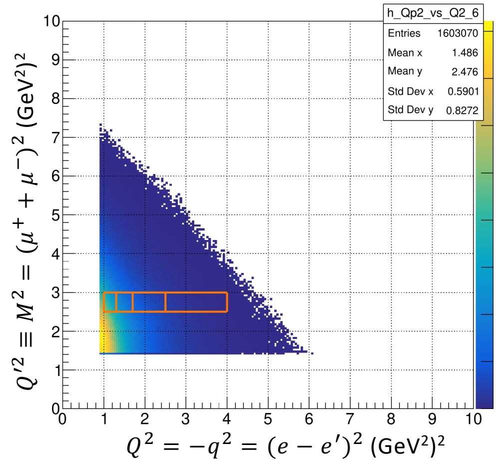
Kinematical coverage at 11 GeV

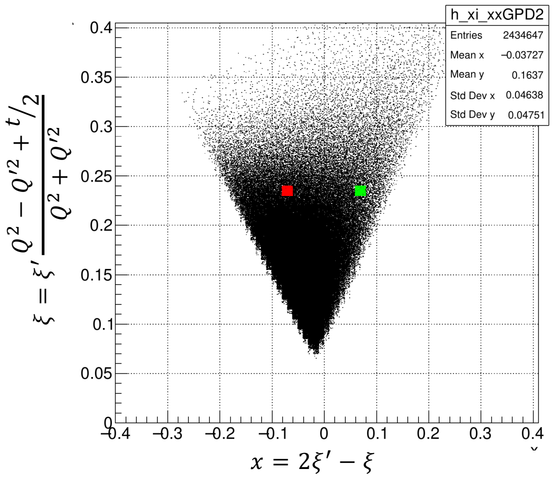
S. Stepanyan

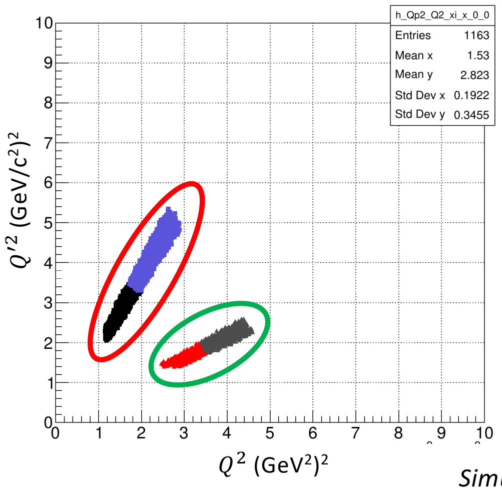
$$ep \rightarrow e'p'\mu^+\mu^-$$

- GRAPE event generator, BH only.
- The whole region is measured simultaneously.
- At 11 GeV, the interesting region is $Q'^2 > 2$ (GeV/c²)².









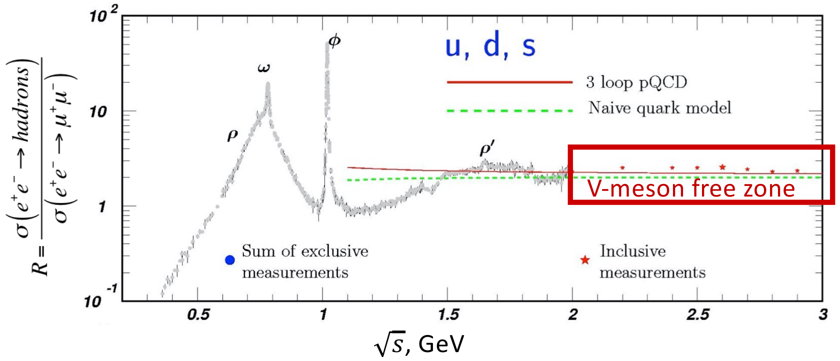
$$x_B = \frac{Q^2}{2pq} \qquad \xi' = \frac{Q^2 + Q'^2}{2Q^2/x_B - Q^2 - Q'^2 + t}$$

- ξ - x bin fixes the ratio Q'^2/Q^2 while their values are unconstrained.
- For each ξ - x bin asymmetry can be measured at different Q'^2 and Q^2, can be a scaling test for GPDs.

Simulations from R. Paremuzyan

DDVCS at 22 GeV

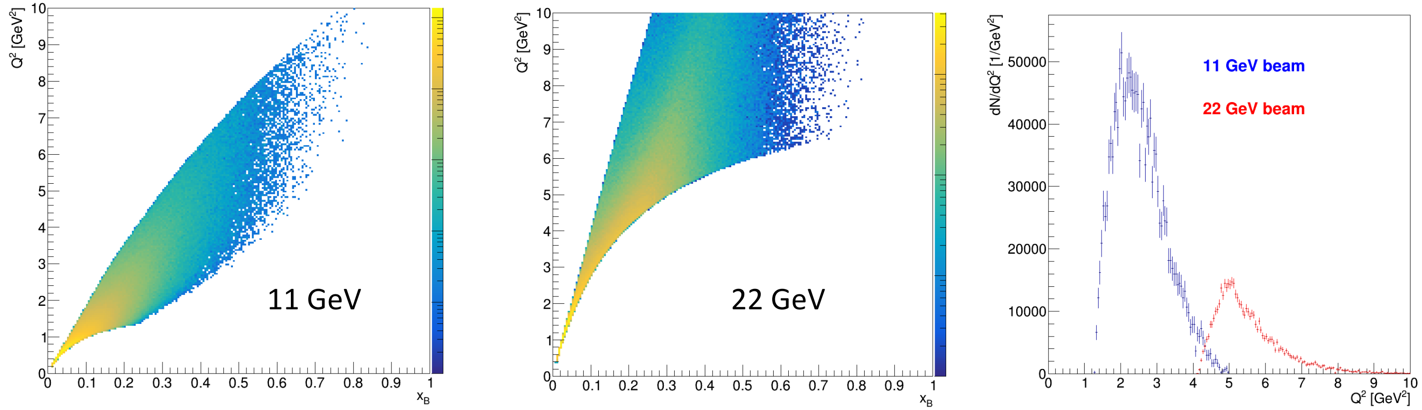
S. Stepanyan



Expand measurements in spacelike, $Q^2 > Q'^2$, and timelike, $Q^2 < Q'^2$, regimes to the resonance free region $Q'^2 > 4$ (GeV/c²)²

$\mu CLAS12$ will perform with higher energy beams.

$ep \to e'p'\mu^+\mu^-$



Simulations from R. Paremuzyan

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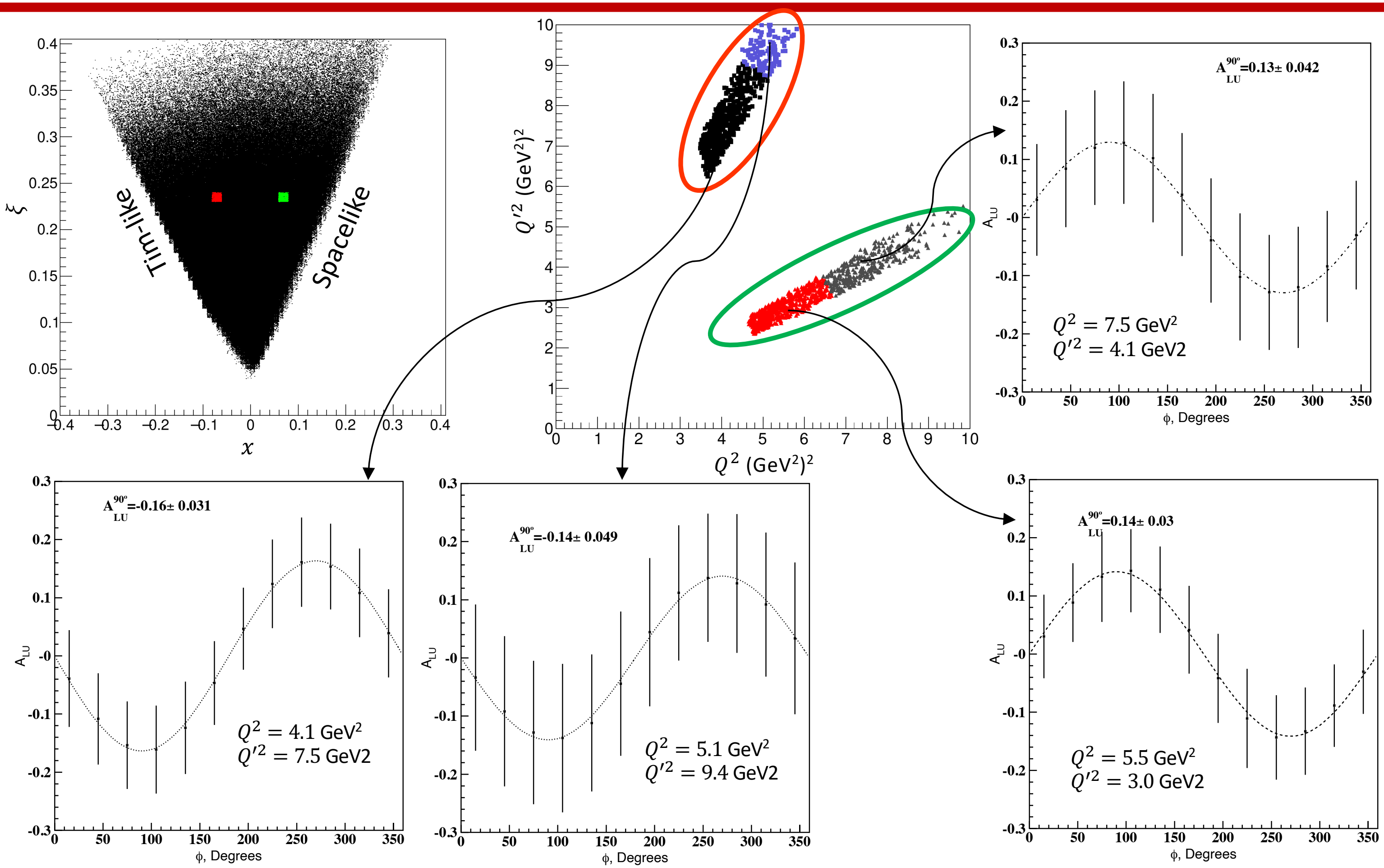
Projections: BSA 200 days @ $10^{37} cm^{-2} sec^{-1}$

S. Stepanyan



Simulations from R. Paremuzyan

Statistics is from GRAPE, asymmetries is from VGG

22 GeV Upgrade: Next Workshop

The workshop will focus on the continuing development of the scientific case for a 22 GeV upgrade to CEBAF at Jefferson Lab.

As highlighted in the 2023 US Long Range Plan for Nuclear Science:

> *"Recently, the Cornell Brookhaven Electron Test Accelerator (CBETA) facility demonstrated eight-pass recirculation of an electron beam with energy recovery employing arcs of fixed-field alternating gradient magnets. This exciting new technology could enable a cost-effective method to double the energy of CEBAF…"*
>
> *The 22 GeV energy upgrade "…will allow access to a new sector of hadron spectroscopy and offer an unprecedented view of the complex nucleon structure in the valence region, one not accessible at other machines."*

This workshop will showcase the continued staff and user community efforts to develop increasingly realistic projections for experiments that would become possible with an energy upgrade that maintains the world-leading luminosity of CEBAF. This is the second edition in a series with the previous workshop being in January 2023 at Jefferson Lab.

A committee of conveners will assemble an agenda of both invited and contributed talks that span the interests of the user community. The participation of young researchers interested in the field is very much encouraged.

Registration and abstract submission will open on 1st September 2024 from this web site.

Jefferson Lab

Conclusions and Outlook

- The CEBAF uniqueness to run experiments at the luminosity frontier provides a powerful tool to understand the structure and dynamics of the strong interaction in the non-pQCD regime
- A CEBAF energy upgrade to 22 GeV is presently under technical development
- With CEBAF at higher energy some important thresholds would be crossed and an energy window which sits between JLab @ 11 GeV and EIC would be available. This, together with CEBAF uniqueness to run electron scattering experiment at the luminosity frontier can provide a unique insight into the non-pQCD dynamics
- A strong science case for the upgrades is emerging – come join the fun!