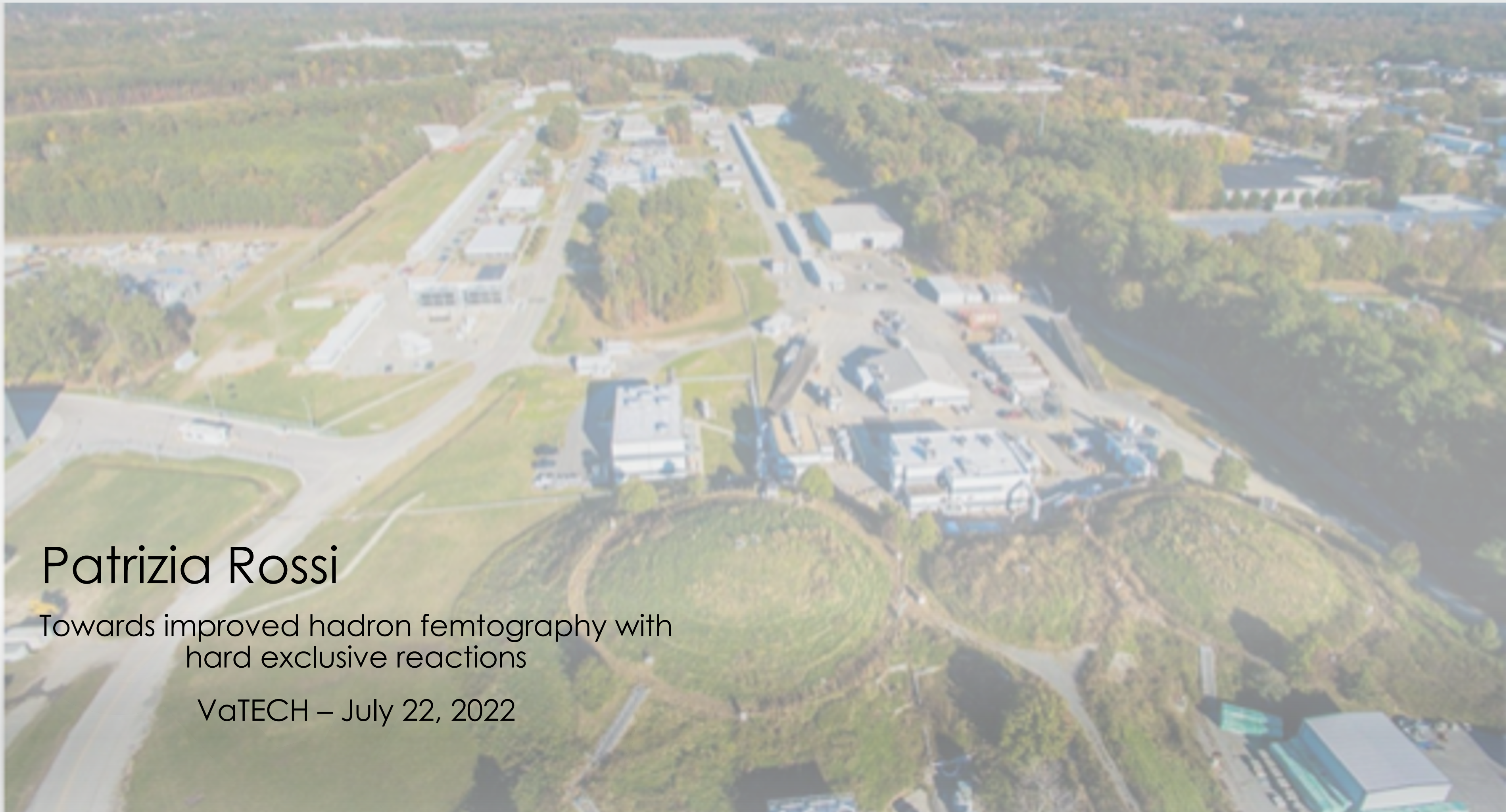
Jefferson Lab at 20+ GeV



Patrizia Rossi

Towards improved hadron femtography with hard exclusive reactions

VaTECH – July 22, 2022

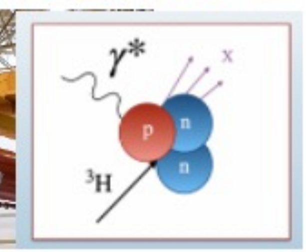
Introduction

Stuart's summary talk at the DOE S&T review July 19-21, 2022

- Jefferson Lab is in a very strong position with an exciting vision for the future
- Our priorities are clear:
  - Ensuring that the 12 GeV scientific program is successful in all facets
  - Moving EIC forward aggressively
  - Exploring the long-term scientific opportunities at CEBAF
  - Stewarding best-in-class accelerator technology in support of DOE mission
  - Diversifying Jefferson Lab's scientific mission with a significant role in Advanced Computing







We are delivering on our Nuclear Physics mission, as we chart a course for the Jefferson Lab of the future

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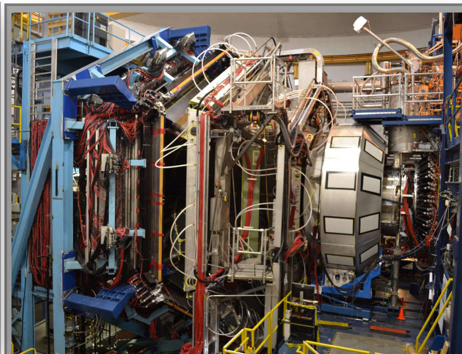
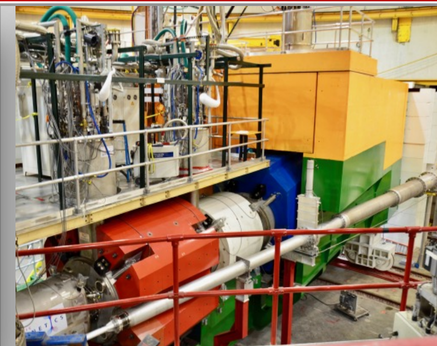
Today and Tomorrow

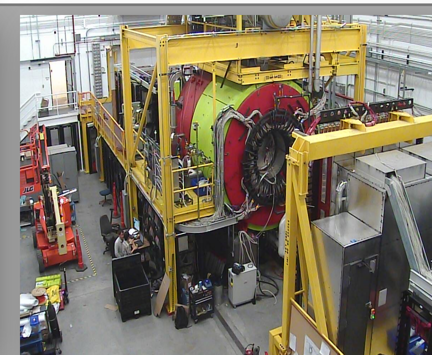
Hall A: SBS & BB



Hall B: CLAS12



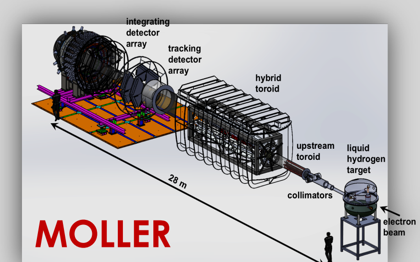
Hall C: HMS-SHMS

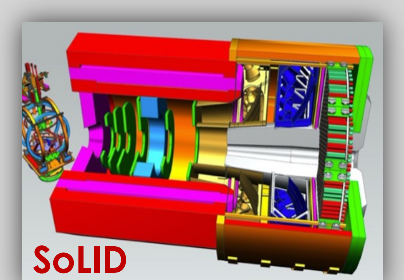


Hall D: GlueX

The 12 GeV Experimental Program is in full swing

33 Experiments completed out of 86 approved





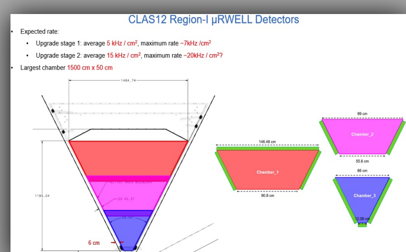
Luminosity Upgrade

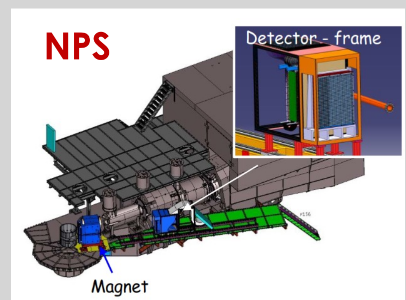
Stage -1: $2\times10^{35}cm^{-2}\,s^{-1}$

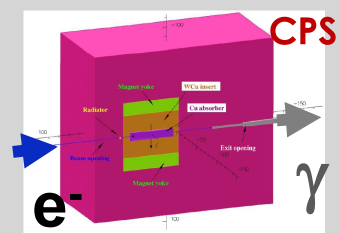
3 years

Stage -2: > $10^{37}cm^{-2}\,s^{-1}$

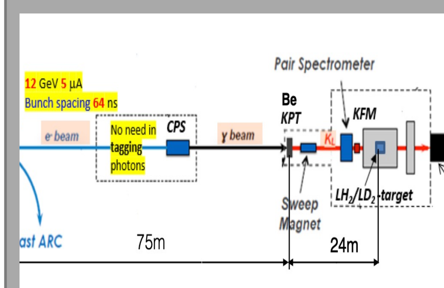
7-10 years





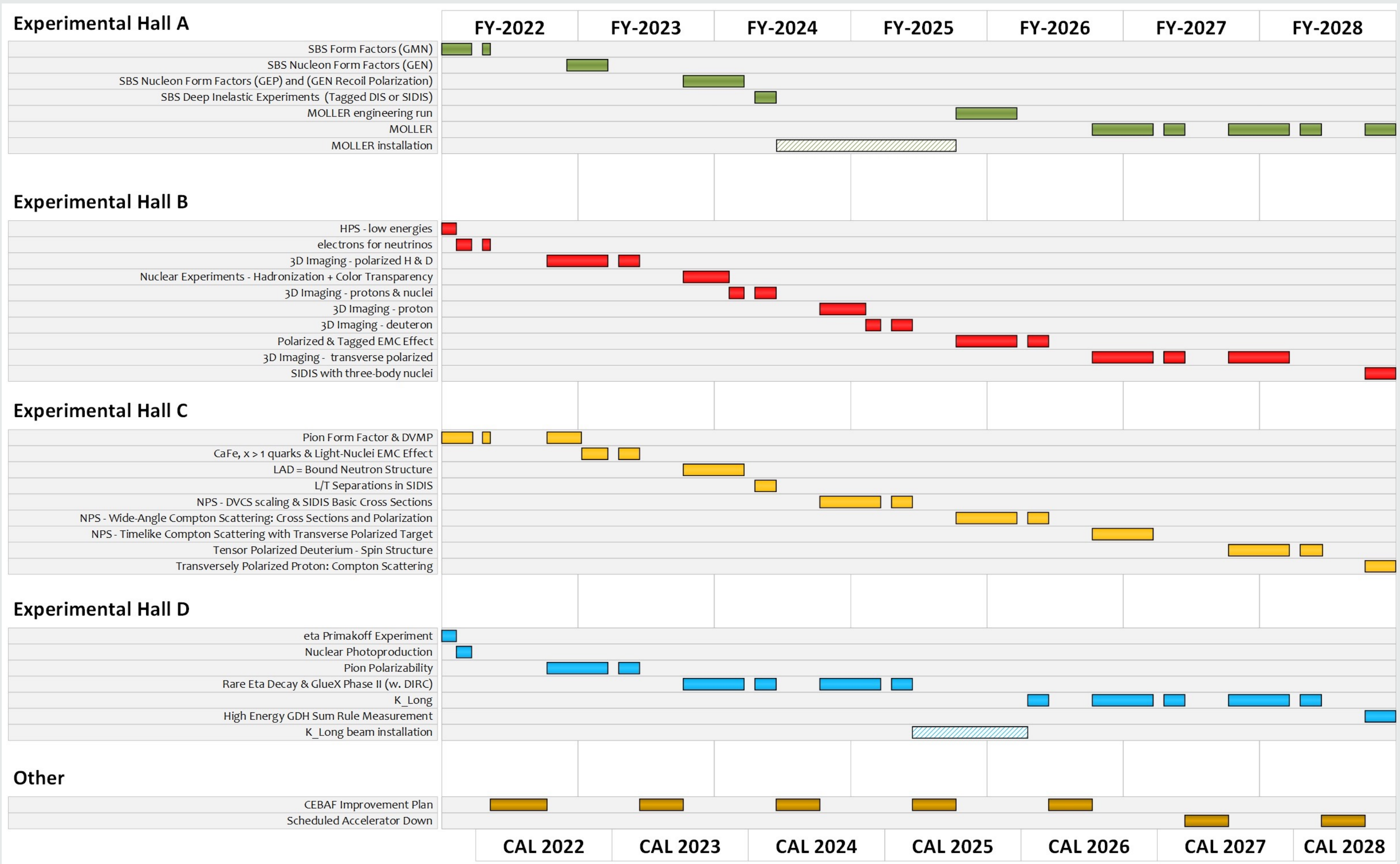


KLF



Jefferson Lab

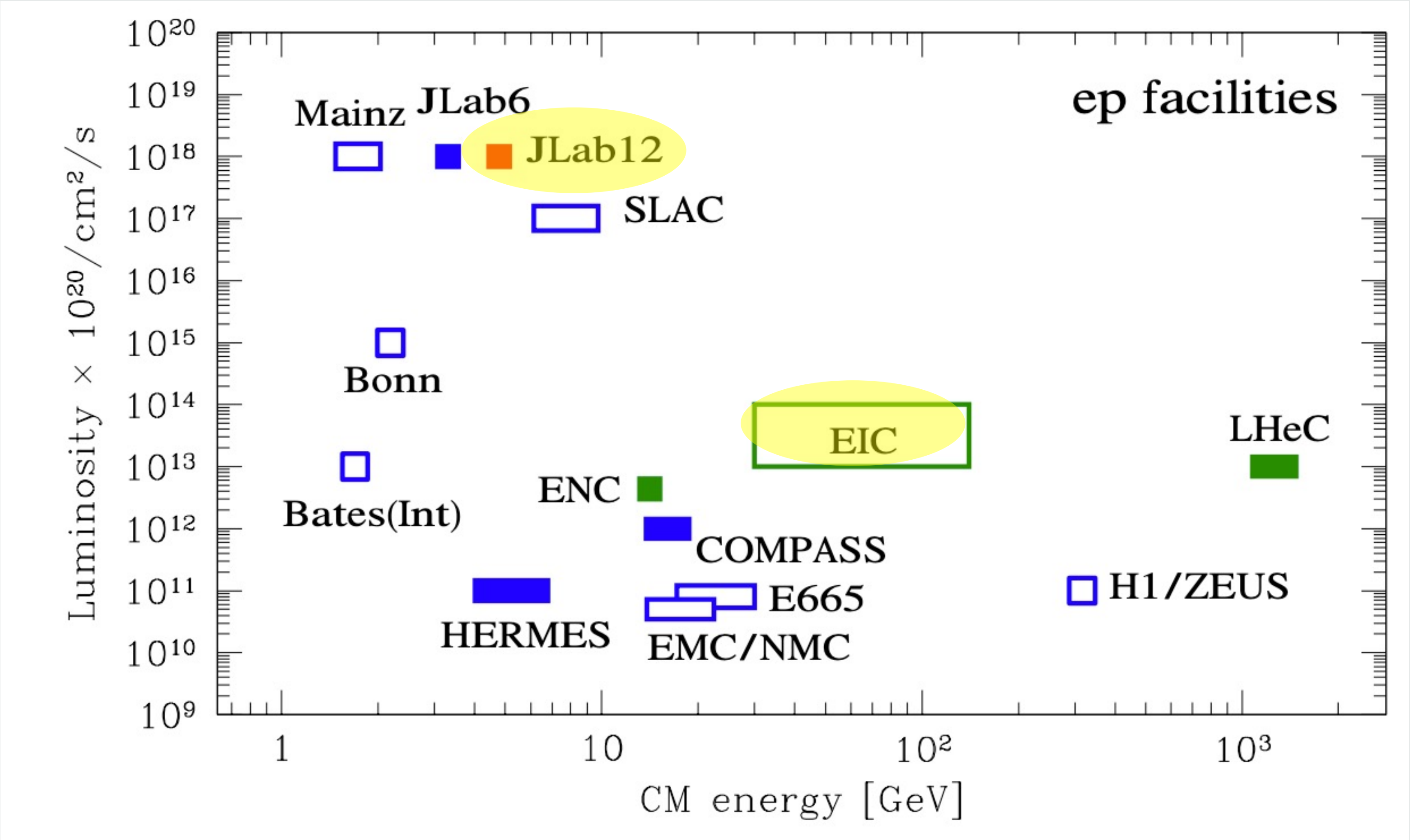
Experimental Schedule – Planning Ahead



~8 years at ~30 weeks/year

Jefferson Lab

Uniqueness of CEBAF



CEBAF has a unique program with fixed targets at the **luminosity frontier** and in the **x valence region**

Several Initiatives

Accepted to Progress in Particle and Nuclear Physics

arXiv:2112.00060v1 [nucl-ex] 30 Nov 2021

Physics with CEBAF at 12 GeV and Future Opportunities

J. Arrington[1], M. Battaglieri[2,15], A. Boehnlein[2], S.A. Bogacz[2], W.K. Brooks[10], E. Chudakov[2], I. Cloët[3], R. Ent[2], H. Gao[4], J. Grames[2], L. Harwood[2], X. Ji[5,6], C. Keppel[2], G. Krafft[2], R. D. McKeown[2,8,*], J. Napolitano[7], J.W. Qiu[2,8], P. Rossi[2,14], M. Schram[2], S. Stepanyan[2], J. Stevens[8], A.P. Szczepaniak[12,13,2], N. Toro[9], X. Zheng[11]

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Abstract

We summarize the ongoing scientific program of the 12 GeV Continuous Electron Beam Accelerator Facility (CEBAF) and give an outlook into future scientific opportunities. The program addresses important topics in nuclear, hadronic, and electroweak physics including nuclear femtography, meson and baryon spectroscopy, quarks and gluons in nuclei, precision tests of the standard model, and dark sector searches. Potential upgrades of CEBAF are considered, such as higher luminosity, polarized and unpolarized positron beams, and doubling the beam energy.

Keywords:

Contents

*Corresponding author, *email address:* bmck@jlab.org

Preprint submitted to Progress in Particle and Nuclear Physics *December 2, 2021*

- Update 2012 white paper
  - 12 GeV program accomplishments
  - Planned program approved by PAC
  - Future opportunities: high luminosity, positron beam, higher energy
- Discussions for future opportunities at CEBAF (high luminosity, higher energy, positron beam) have been initiated during collaboration meetings and also in dedicated round table meetings

Very Active Community

https://indico.jlab.org/event/520/

Objective of the workshops is to gather theorists and experimentalists to discuss the physics opportunities and technical options for each of the possible upgrade scenarios: luminosity, energy, positron

OPPORTUNITIES WITH JLAB ENERGY AND LUMINOSITY UPGRADE

26 September 2022 — 30 September 2022

ECT* - Villa Tambosi

Strada delle Tabarelle, 286

Trento - Italy

https://www.ectstar.eu/workshops/opportunities-with-jlab-energy-and-luminosity-upgrade/

APCTP Focus Program in Nuclear Physics 2022: Hadron Physics Opportunities with JLab Energy and Luminosity Upgrade

Jul 18 – 23, 2022
APCTP, Pohang
Asia/Seoul timezone

Enter your search term

- Overview
- Timetable
- Participant List

The electroproduction of mesons and photons has been shown to be a powerful tool for studies of the interaction of elementary particles and their dynamics at short and long distances. In particular, studies of the orbital motion of partons encoded in transverse space and momentum distributions of partons, like Generalized Parton Distributions (GPDs) and Transverse Momentum Distributions (TMDs), have been widely recognized as key objectives of the JLab 12 GeV program. Studies of azimuthal distributions of hadrons and photons in exclusive and semi-inclusive DIS (SIDIS) provide access to variety of observables widely recognized as key objectives of the COMPASS measurements, various activities at RHIC and KEK, the LHC fixed target projects (LHC spin, SMOG2@LHCb) and a driving force behind the construction of the future Electron Ion Collider (EIC). Studies of the ground and excited nucleon state structure in terms of nucleon elastic form factors, PDFs, and the N→N* (nucleon to nucleon resonances) transition electro-excitation amplitudes offer a unique complementary opportunity to explore the evolution of active components in the structure of the ground and excited state nucleons at distances where the transition from quark-gluon confinement to the perturbative QCD regime is expected and where the dominant part of hadron mass emerges. These studies are of particular importance to address key open problems of the Standard Model on emergence of hadron mass and quark-gluon confinement. The upgraded to 24 GeV JLab, with much wider kinematical coverage, in particular at large Q^2, will be crucial to extend all ongoing projects at JLab, in particular studies of the 3D structure of hadrons and hadronization, pin down interaction dependent parts, providing missing deeper access to quark- gluon dynamics and opening new opportunities on studies of the charm sector and significant improvement in secondary

https://indico.knu.ac.kr/event/566/

Organizers

Harutyun Avagyan (Jefferson Lab, Newport News/US)
avakian@jlab.org
John Arrington (Lawrence Berkeley National Laboratory, Berkeley/US)
JArrington@lbl.gov
Alessandro Bacchetta (Pavia University, Pavia/I)
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hen@mit.edu
Xiangdong Ji (University of Maryland (UMD), College Park/US)
xji@umd.edu
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kyungseon.joo@uconn.edu
Xiaochao Zheng (University of Virginia (UVa), Charlottesville/US)
xiaochao@jlab.org

Jefferson Lab

Looking at the Future

https://www.jlab.org/conference/hews22#

View | New draft | Revisions

HIGH ENERGY WORKSHOP SERIES 2022

We are pleased to announce an upcoming series of summer workshops being organized jointly between the laboratory and the Jefferson Lab Users Organization (JLUO) to probe the science that would be opened up by a higher energy electron beam (~20-24 GeV) at Jefferson Lab. We are particularly interested in identifying key measurements that are not possible to access at 12 GeV, that initially utilize largely existing or already-planned Hall equipment, and that leverage the unique capabilities of luminosity and precision possible at Jefferson Lab in the EIC era.

HIGH ENERGY WORKSHOP SERIES 2022

- **5 workshop series**

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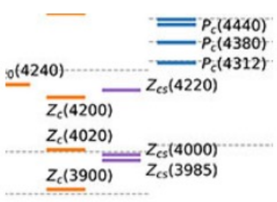

Hadron Spectroscopy with a CEBAF Energy Upgrade

June 16 & 17

Marco Battaglieri, Sean Dobbs, Derek Glazier, Alessandro Pilloni, Justin Stevens, Adam Szczepaniak

Recent observations in heavy-quark spectroscopy have provided numerous candidates for hadronic resonances which are exotic in nature, the so-called XYZ and Pc states. With a CEBAF energy upgrade to 20-24 GeV these states and other charmonia may be studied in photoproduction and electroproduction measurements at JLab. This workshop aims to identify the key measurements made possible by such an upgrade, utilizing recent theoretical models for production and evaluating the detector performance requirements.

- **5 workshop series**

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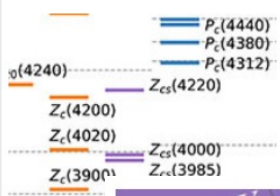

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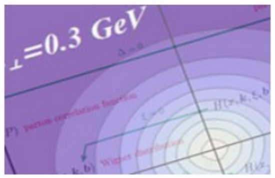

The Next Generation of 3D Imaging

July 7 & 8

Harut Avagyan, Carlos Munoz Camacho, Jian-Ping Chen, Xiangdong Ji, Jianwei Qiu, Patrizia Rossi

Studies of azimuthal distributions of hadrons and photons in exclusive and semi-inclusive Deep Inelastic Scattering measurements, providing access to a variety of observables helping to elucidate the way the properties of the proton emerge dynamically from strong interactions, are recognized as key objectives of the JLab 12 GeV program, and driving force behind the construction of the future Electron Ion Collider (EIC). Jefferson Lab 12-GeV data already have remarkably higher precision at large parton fractional momenta x compared to the existing data and will be the main source of information on non-perturbative QCD in next decade. The major limitations in studies of the nucleon structure at JLab12 are the limited coverage of the kinematical region, where the non-perturbative sea is significant, and the limited phase space in accessing large momentum transfer and large transverse momenta of final state particles due to relatively low energy in the photon-nucleon CM system. These issues can be overcome by a JLab upgrade to 24 GeV.
The focus of this workshop will be threefold:
(1) Identify the flagship measurements that can be done only with 20+ GeV. **(2)** Identify the flagship measurements with 20+ GeV that can extend and improve the 11 GeV measurements, helping the physics interpretation through multidimensional bins in extended kinematics. **(3)** Identify the measurements with 20+ GeV that can set the bridge between JLab12 and EIC (complementarity)

- **5 workshop series**

Jefferson Lab

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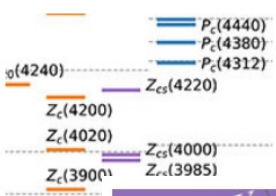

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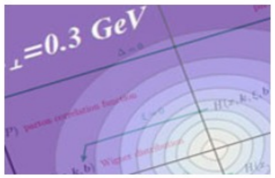

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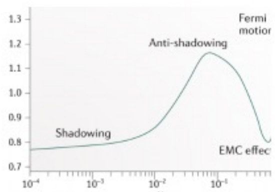

Science at Mid x: Anti-shadowing and the Role of the Sea

July 22,23

John Arrington, Mark Dalton, Thia Keppel, Wally Melnitchouk, Jianwei Qiu

An upgrade of CEBAF at Jefferson Lab beyond 20 GeV will open up key science that is not possible to access at 12 GeV. One kinematic regime where this is most possible is in the "middle" Bjorken x regime around x~0.1, where the available momentum transfers at 12 GeV have heretofore limited or prevented several exciting measurements. Here, for example, the long-standing mystery of anti-shadowing may now be probed for the first time in decades. The strange sea may now be measured with minimal theoretical bias using parity-violating electron scattering. More generally, the interplay of the valence and sea regimes may be better disentangled. Novel tagged measurements may provide access to meson structure and the role of mesons in nuclei. All of these measurements leverage the unique capabilities of luminosity and precision possible at Jefferson Lab in the EIC era. This workshop seeks to enhance our knowledge of these topics and broadly identify exciting new science opened up in this middle x regime via experiments that initially utilize largely existing or already-planned Hall equipment.

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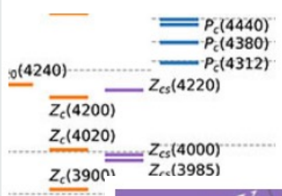

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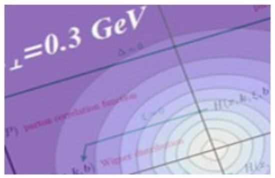

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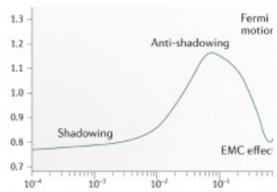

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Physics Beyond the Standard Model

August 1

Marco Battaglieri, Bob McKeown, Xiaochao Zheng

Possibilities for testing the Standard Model and searching for new physics beyond the Standard Model enabled by 20-24 GeV electron beams at CEBAF will be discussed. There will be opportunities for presentations and discussions where new ideas can be brought forward.

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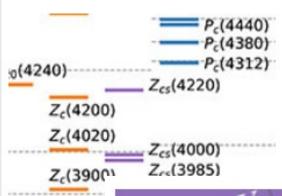

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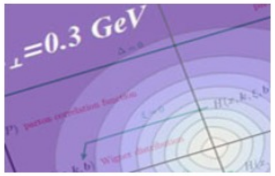

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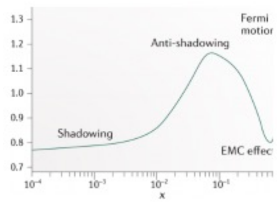

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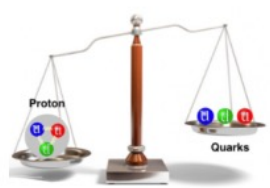

J/Psi and Beyond

August 16 & 17 9am - 1pm

Ed Brash, Ian Cloet, Zein-Eddine Meziani, Jianwei Qiu

Measurements of J/psi near threshold with high statistics, for both electro and photoproduction at JLab with 12 GeV beam, has created tremendous interest ir the community. A CEBAF energy increase (to ~24 GeV) will allow us to ask new questions and provide opportunities for addressing long-standing puzzles in nuclear and particle physics, thus enhancing the physics output of all four experimental halls, using existing (Halls B, C, and D) and future (SoLID in Hall A) equipment. This focused one-day workshop aims to **(1)** identify the key new measurements which could be made possible via an energy increase, and **(2)** specify the corresponding new questions that could be answered and the outstanding puzzles that could be addressed. For example, what is the impact of Psi(2S) data near and above its threshold in exploring the size change of the probe through a comparison with the threshold J/psi production data? With the enhanced Q lever-arm in J/psi electro-production that comes with higher energy beam, do we expect an improvement in probing the trace anomaly (which is central to the origin of proton mass)? Does having the J/psi produced precisely, especially with 19-20 GeV beam, help to address the tension that currently exi between JLab data and SLAC data from 40 years ago?

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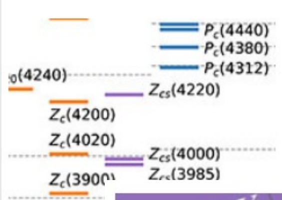

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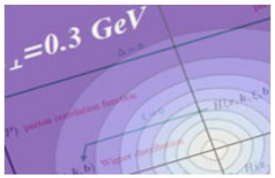

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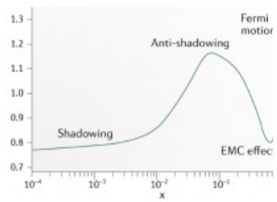

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Possibilities for testing the Standard Model and searching for new physics beyond the Standard Model enabled by 20-24 GeV electron beams at CEBAF will be discussed. There will be opportunities for presentations and discussions where new ideas can be brought forward.

J/Psi and Beyond

August 16 & 17 9am - 1pm

Ed Brash, Ian Cloet, Zein-Eddine Meziani, Jianwei Qiu

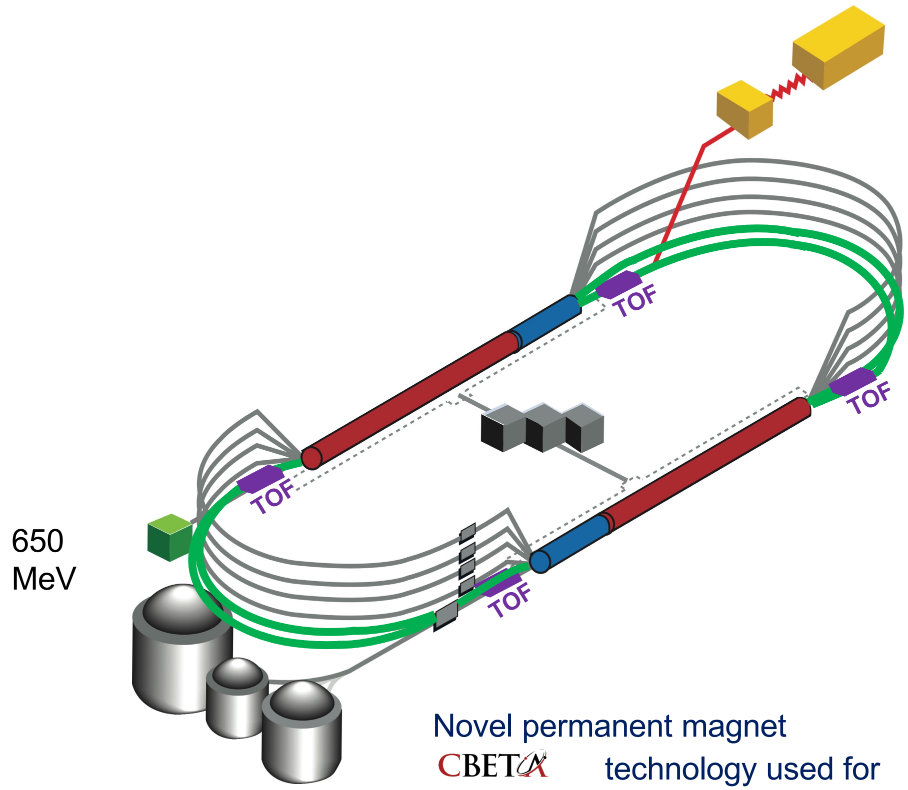
Measurements of J/psi near threshold with high statistics, for both electro and photoproduction at JLab with 12 GeV beam, has created tremendous interest in the community. A CEBAF energy increase (to ~24 GeV) will allow us to ask new questions and provide opportunities for addressing long-standing puzzles in nuclear and particle physics, thus enhancing the physics output of all four experimental halls, using existing (Halls B, C, and D) and future (SoLID in Hall A) equipment. This focused one-day workshop aims to **(1)** identify the key new measurements which could be made possible via an energy increase, and **(2)** specify the corresponding new questions that could be answered and the outstanding puzzles that could be addressed. For example, what is the impact of Psi(2S) data near and above its threshold in exploring the size change of the probe through a comparison with the threshold J/psi production data? With the enhanced Q lever-arm in J/psi electro-production that comes with higher energy beam, do we expect an improvement in probing the trace anomaly (which is central to the origin of proton mass)? Does having the J/psi produced precisely, especially with 19-20 GeV beam, help to address the tension that currently exi[sts] between JLab data and SLAC data from 40 years ago?

- **Short (~1-2 page) summaries of highlight science will contribute towards a white paper**

CEBAF FFA Upgrade – ‘Currently under Study’

- Starting with 12 GeV CEBAF as a baseline
- NO new SRF (1.1 GeV per linac)
- New 650 MeV recirculating injector
- Remove the highest recirculation pass (Arc 9 & A) and replace them with two FFA arcs including time-of-flight chicanes
- Recirculate 4 + 4 times to get to about 18 GeV
- Install a second pair of FFA arcs ‘on the floor’ below Arc 9 & A
- Recirculate 3 times to get to about 24 GeV

Pass Arithmetic: **5** -1 + 4 + 3 = **11**

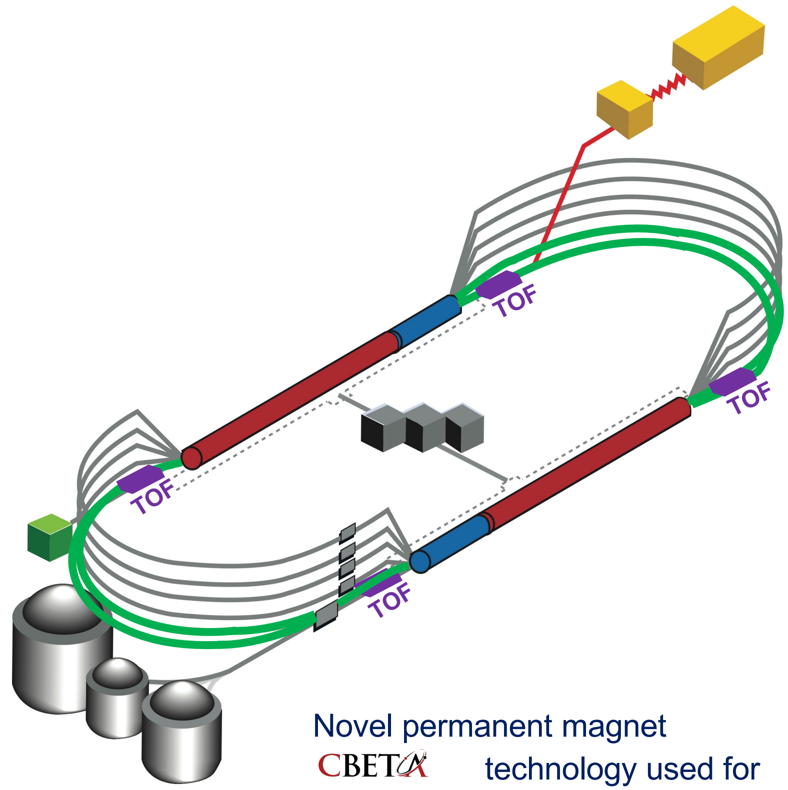


Novel permanent magnet CBETA technology used for power and cost savings

Courtesy Alex Bogacz

CEBAF FFA Upgrade – 'Currently under Study'

- Starting with 12 GeV CEBAF as a baseline
- NO new SRF (1.1 GeV per linac)
- New 650 MeV recirculating injector
- Remove the highest recirculation pass (Arc 9 & A) and replace them with two FFA arcs including time-of-flight chicanes
- Recirculate 4 + 6 times to get to about 22 GeV



Novel permanent magnet CBETA technology used for power and cost savings

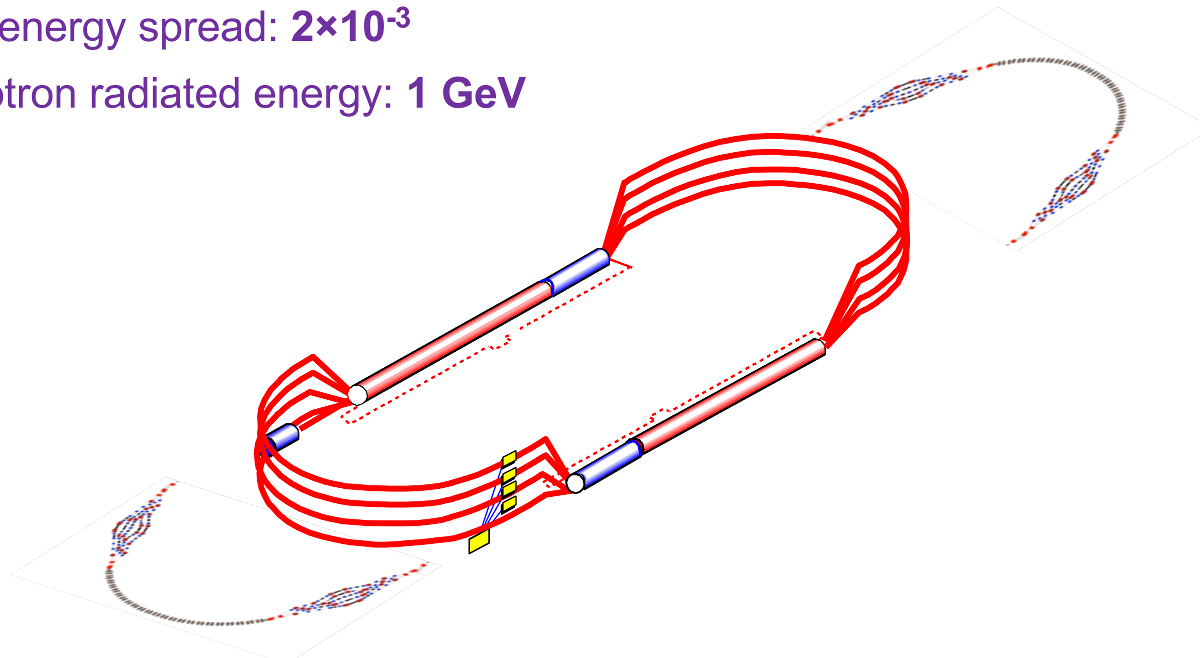
Pass Arithmetic: **5** -1 + 6 = **10**

Courtesy Alex Bogacz

FFA CEBAF with CBETA-like Arcs

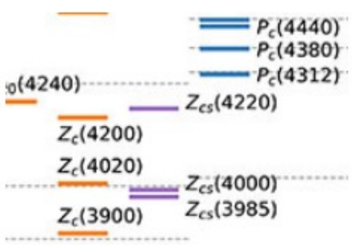
Synchrotron Radiation impact on beam quality

- Net transverse emittance dilution (normalized): **60 mm mrad** at 23 GeV, β = 20 m $\rightarrow$ σ = 150 microns
- Net natural energy spread: **2×10^{-3}**
- Net synchrotron radiated energy: **1 GeV**



Courtesy Alex Bogacz

Hadron Spectroscopy



Hadron Spectroscopy with a CEBAF Energy Upgrade

June 16 & 17

Marco Battaglieri, Sean Dobbs, Derek Glazier, Alessandro Pilloni, Justin Stevens, Adam Szczepaniak

Recent observations in heavy-quark spectroscopy have provided numerous candidates for hadronic resonances which are exotic in nature, the so-called XYZ and Pc states. With a CEBAF energy upgrade to 20-24 GeV these states and other charmonia may be studied in photoproduction and electroproduction measurements at JLab. This workshop aims to identify the key measurements made possible by such an upgrade, utilizing recent theoretical models for production and evaluating the detector performance requirements.

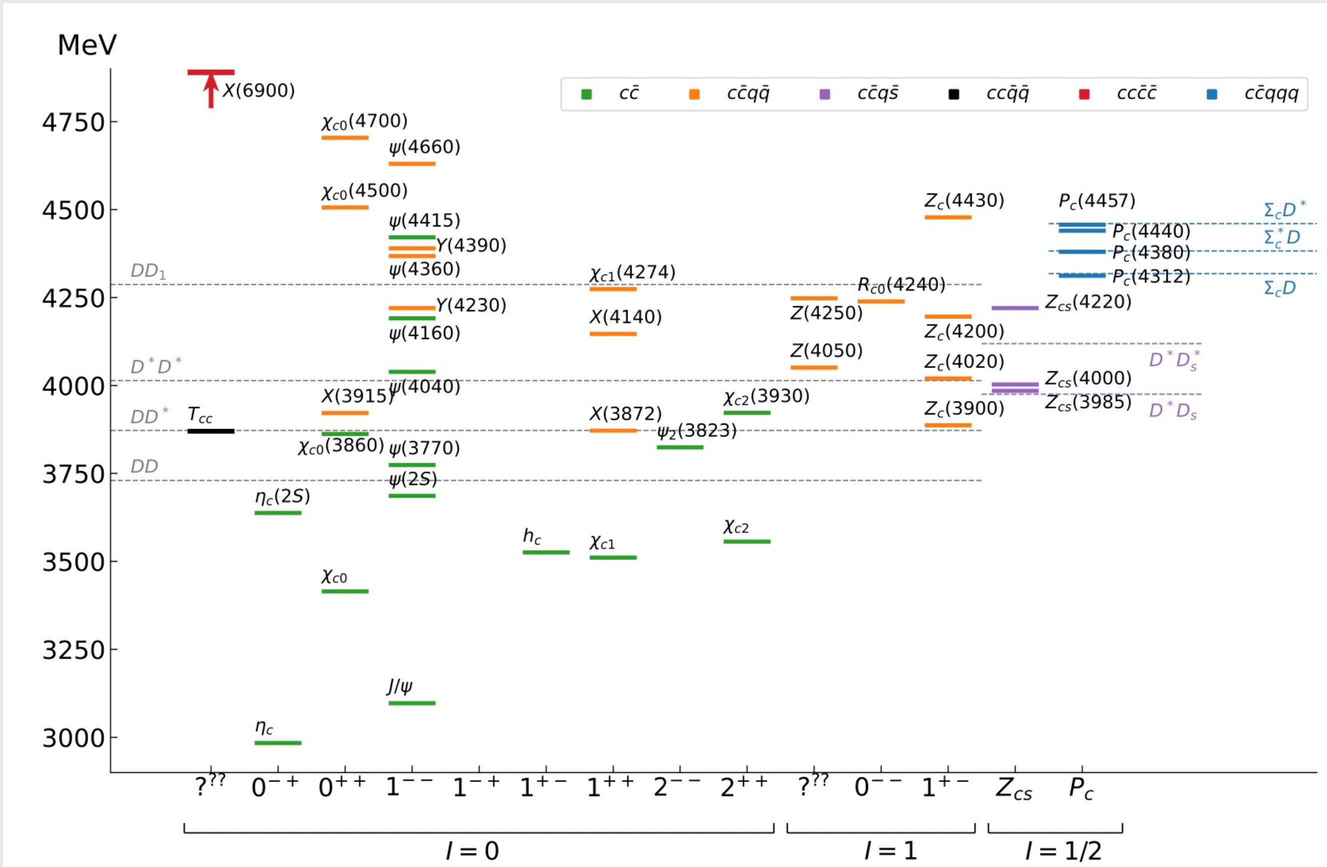
Thu 16/6

09:00	**Introduction to Workshop Series**	*David Dean*	*JLab F326, Hybrid*	09:00 - 09:10
	Accelerator perspective: FFA design	*Alex Bogacz*	*JLab F326, Hybrid*	09:10 - 09:30
	HEP perspective: Snowmass Spectroscopy Overview	*Richard Lebed*	*JLab F326, Hybrid*	09:30 - 10:00
10:00	**Coffee Break**		*JLab F326, Hybrid*	10:00 - 10:30
	Production of XYZP states at lepton-proton facilities	*Feng-Kun Guo*	*JLab F326, Hybrid*	10:30 - 11:05
11:00	**Theory of XYZ electro- and photo-production from JPAC**	*Vincent Mathieu*	*JLab F326, Hybrid*	11:05 - 11:40
	Discussion		*JLab F326, Hybrid*	11:40 - 12:30
12:00				

Fri 17/6

09:00	**CLAS baryon spectroscopy and structure**	*Daniel Carman*	*JLab F326, Hybrid*	09:00 - 09:35
	Charmonium spectroscopy with CLAS	*Derek Glazier*	*JLab F326, Hybrid*	09:35 - 10:10
10:00	**Coffee Break**		*JLab F326, Hybrid*	10:10 - 10:40
	Charmonium spectroscopy with GlueX	*Sean Dobbs*	*JLab F326, Hybrid*	10:40 - 11:15
11:00	**Discussion and White Paper planning**		*JLab F326, Hybrid*	11:15 - 12:30
12:00				

Hadron Spectroscopy

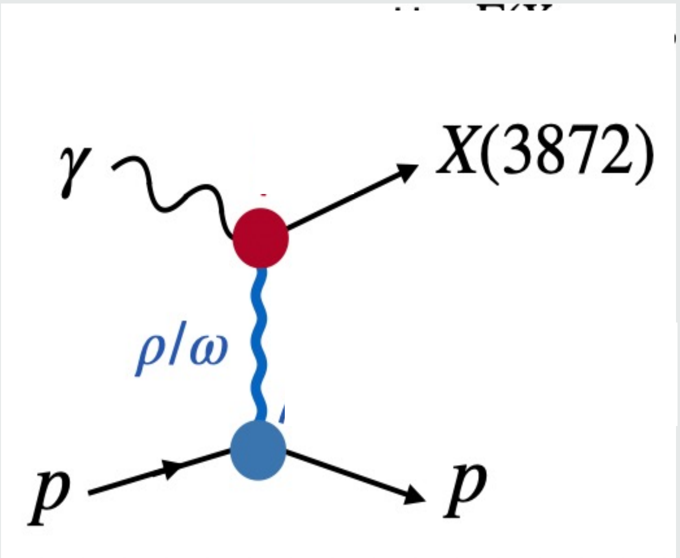


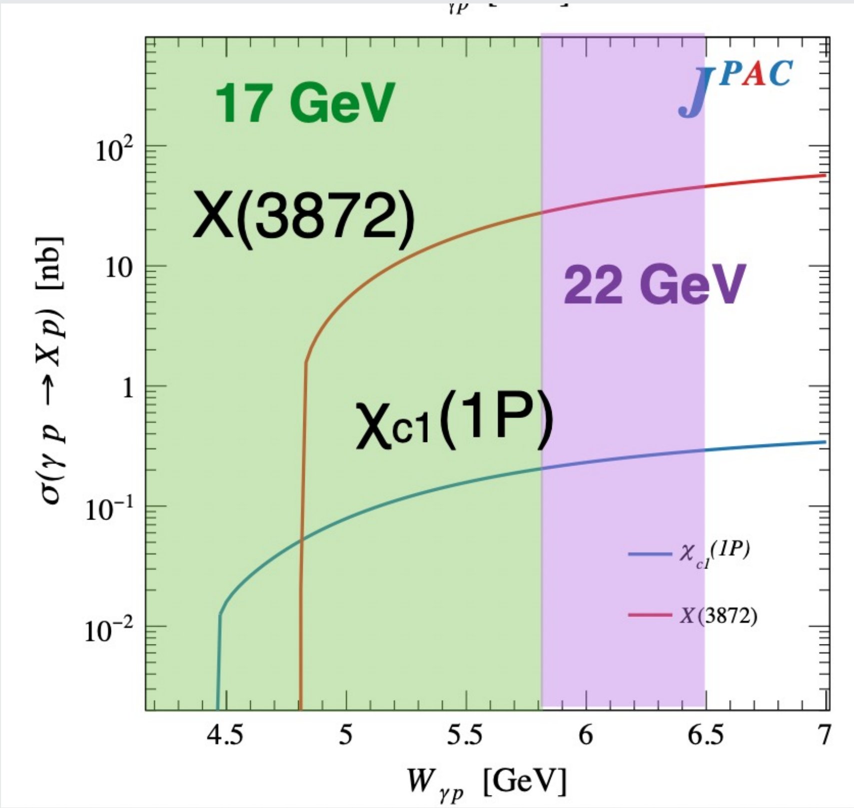
P. A. Zyla, et al., Review of Particle Physics, PTEP 2020 (8) (2020) 083C01

- **Many new charmonium states observed, so-called "XYZ states," in B decays, e+e- colliders, etc.**
- **Significant theoretical interest and progress, but internal structure not understood**

Hadron Spectroscopy

- **Photoproduction provides an alternative mechanisms to study such states**
- **Predictions from JPAC indicate these are accessible at an upgraded CEBAF with Ee = 17 or 22 GeV**

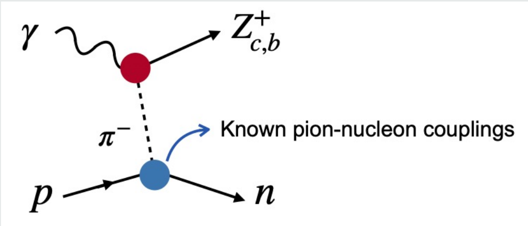




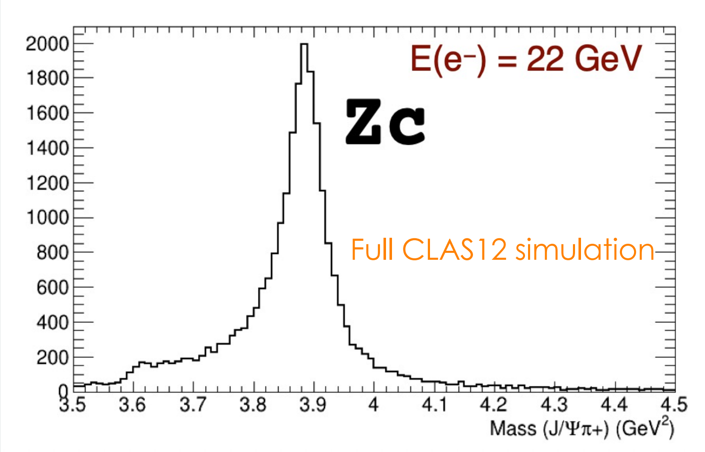
S. Dobbs, P. Pauli

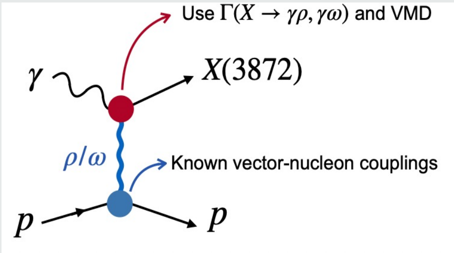
Hadron Spectroscopy

- **Initial simulations from GlueX and CLAS12 demonstrate the capabilities of the existing detectors to measure these reactions**
- **Upgraded CEBAF energy ideally situated for near-threshold photo production of X and Z**
- **Electroproduction of N* resonances with increased Q^2 range will explore emergence of hadron mass**

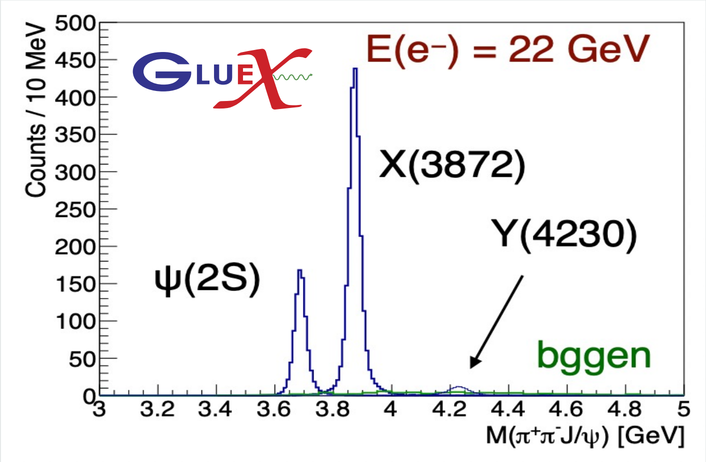


$$\gamma p \rightarrow J\psi\pi^+ n$$





$$\gamma p \rightarrow J\psi\pi^+\pi^- p$$



The Next Generation of 3D Imaging

The Next Generation of 3D Imaging

July 7 & 8

Harut Avagyan, Carlos Munoz Camacho, Jian-Ping Chen, Xiangdong Ji, Jianwei Qiu, Patrizia Rossi

Studies of azimuthal distributions of hadrons and photons in exclusive and semi-inclusive Deep Inelastic Scattering measurements, providing access to a variety of observables helping to elucidate the way the properties of the proton emerge dynamically from strong interactions, are recognized as key objectives of the JLab 12 GeV program, and driving force behind the construction of the future Electron Ion Collider (EIC). Jefferson Lab 12-GeV data already have remarkably higher precision at large parton fractional momenta x compared to the existing data and will be the main source of information on non-perturbative QCD in next decade. The major limitations in studies of the nucleon structure at JLab12 are the limited coverage of the kinematical region, where the non-perturbative sea is significant, and the limited phase space in accessing large momentum transfer and large transverse momenta of final state particles due to relatively low energy in the photon-nucleon CM system. These issues can be overcome by a JLab upgrade to 24 GeV.

The focus of this workshop will be threefold:

(1) Identify the flagship measurements that can be done only with 20+ GeV. **(2)** Identify the flagship measurements with 20+ GeV that can extend and improve the 11 GeV measurements, helping the physics interpretation through multidimensional bins in extended kinematics. **(3)** Identify the measurements with 20+ GeV that can set the bridge between JLab12 and EIC (complementarity)

GPD

Thu 7/7

09:00	Introduction to the workshop	Dr David Dean	CC F324-325, Hybrid	09:00 - 09:05
	SOLID simulations for 20+ GeV	Marie BOER	CC F324-325, Hybrid	09:10 - 09:25
	CLAS12 simulations for 20+ GeV (CANCELLED)	Francois-Xavier Girod	CC F324-325, Hybrid	09:30 - 09:45
10:00	Exclusive meson production program with CLAS12 at 20+ GeV	Andrey Kim	CC F324-325, Hybrid	09:50 - 10:05
	Meson production in Hall C at 20+ GeV	Garth Huber	CC F324-325, Hybrid	10:10 - 10:25
	Discussion		CC F324-325, Hybrid	10:30 - 11:00
11:00	Coffee break		CC F324-325, Hybrid	11:00 - 11:30
	3D structure from 20+ GeV	simonetta liuti	CC F324-325, Hybrid	11:30 - 11:45
12:00	Fitting Compton Form factors	Kyle Shiells	CC F324-325, Hybrid	11:50 - 12:05
	GUMP global analysis	Yuxun Guo	CC F324-325, Hybrid	12:10 - 12:25
	Discussions and additional presentations		CC F324-325, Hybrid	12:30 - 13:00
13:00				

SIDIS

Fri 8/7

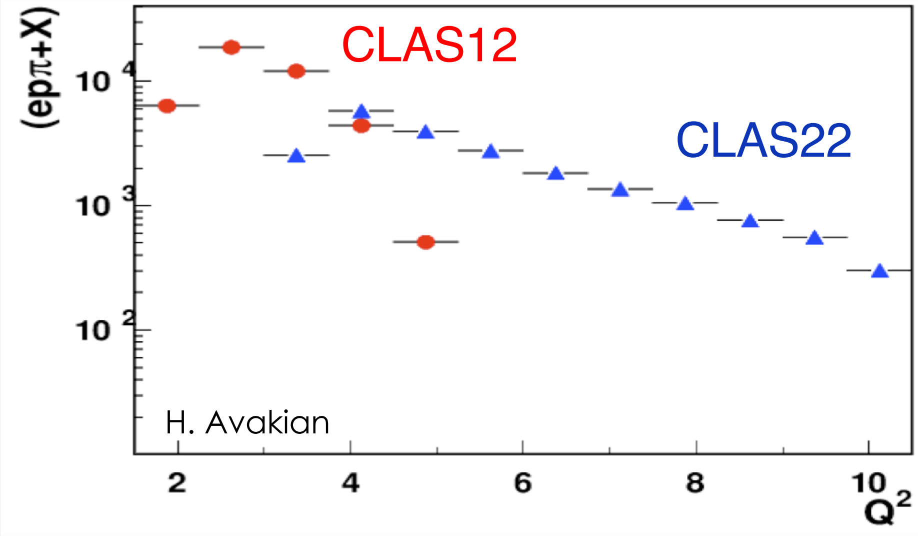
09:00	JLab 20 + GeV Upgrade	Alex Bogacz	CC F324-325, Hybrid	09:00 - 09:10
	Discussion		CC F324-325, Hybrid	09:10 - 09:15
	Why 20+ GeV for SIDIS/TMDs ?	Alessandro Bacchetta	CC F324-325, Hybrid	09:15 - 09:30
	Discussion		CC F324-325, Hybrid	09:30 - 09:40
	What can be done at 20+ GeV for SIDIS/TMDs ?	Nobuo Sato	CC F324-325, Hybrid	09:40 - 09:55
10:00	Discussion		CC F324-325, Hybrid	09:55 - 10:05
	How the 20+GeV SIDIS/TMDs can encounter LQCD?	Yong Zhao	CC F324-325, Hybrid	10:05 - 10:15
	Discussion		CC F324-325, Hybrid	10:15 - 10:20
	Break		CC F324-325, Hybrid	10:20 - 10:50
11:00	CLAS20+ simulation/projections	Harut Avakian	CC F324-325, Hybrid	10:50 - 11:05
	Discussion		CC F324-325, Hybrid	11:05 - 11:15
	SoLID simulation/projections	Vlad Khachatryan	CC F324-325, Hybrid	11:15 - 11:30
	Dscussion		CC F324-325, Hybrid	11:30 - 11:40
	What Hall C can do with 20+ GeV?	Dave Gaskell	CC F324-325, Hybrid	11:40 - 11:50
12:00	Discussion		CC F324-325, Hybrid	11:50 - 12:50
	Summary	Jianwei Qiu	CC F324-325, Hybrid	12:50 - 13:00
13:00				

Enhancement of the Q^2 range - SIDIS

- **Allow studies of evolution properties**
  QCD predicts only the Q^2-dependence of 3D PDFs !!

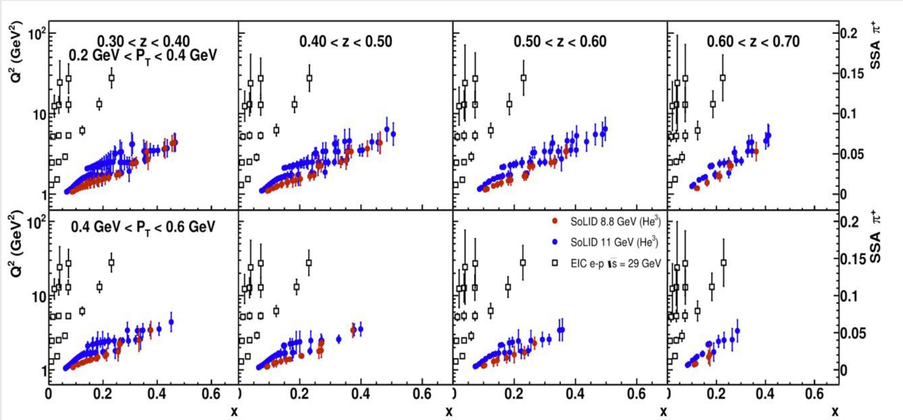
- **The theory is supposed to work better**

- **Fill the gap with EIC**



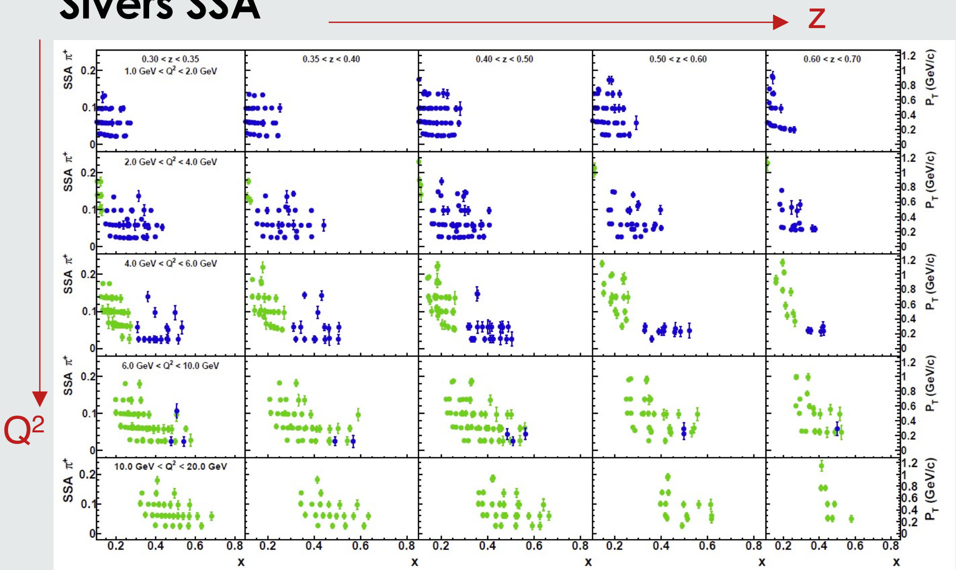
SoLID

A_{UT}



V. Khachatryan

Sivers SSA

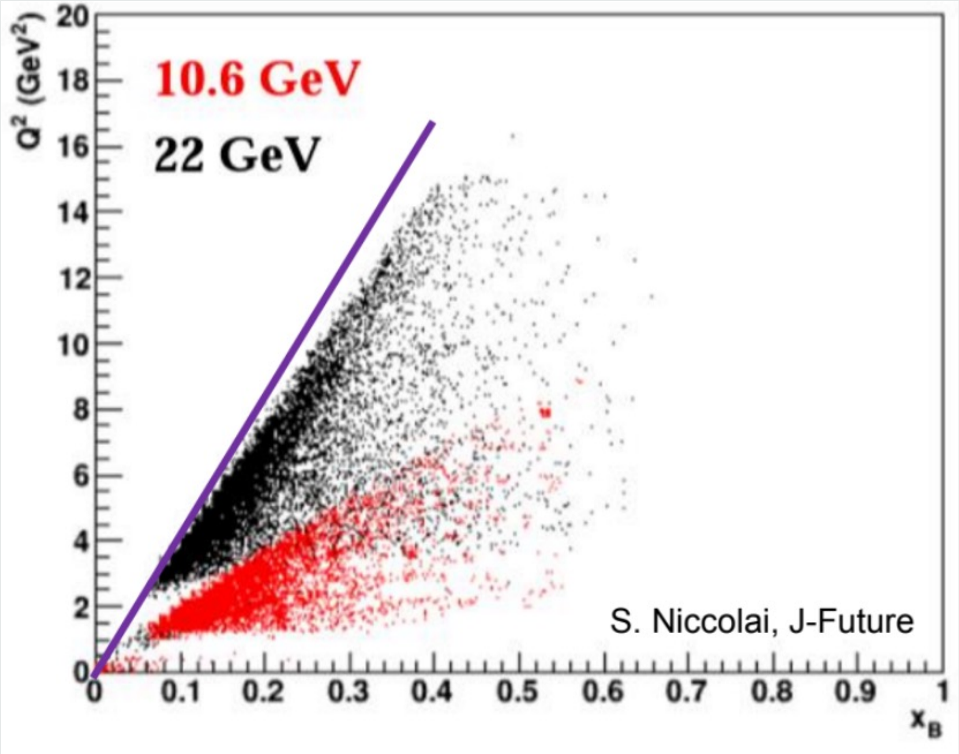


3He: 24 GeV -100 days 12 GeV -69 days

Enhancement of the Q^2 range - GPD

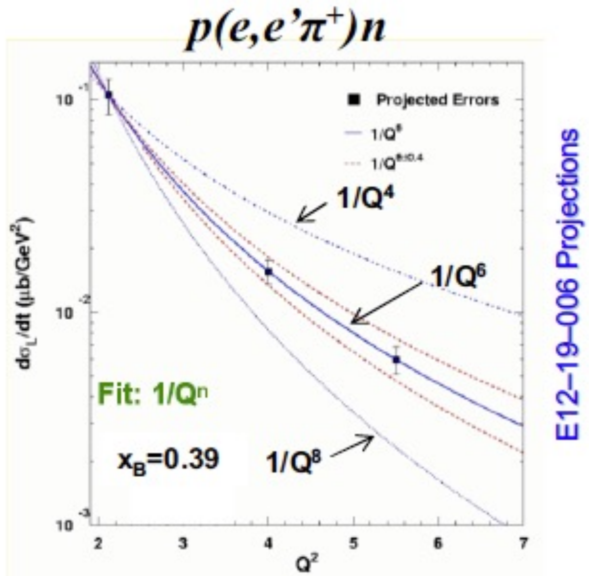
- **Higher Q^2 reach will significantly enhance the 3D imaging exclusive program**

  - The higher reach allows one to more cleanly separate pure twist-2 CFFs with suppressed higher twist (3) contributions
  - Evolution effects in GPDs may be studied more fully at the higher Q^2 as well



Enhancement of the Q^2 range - DVMP

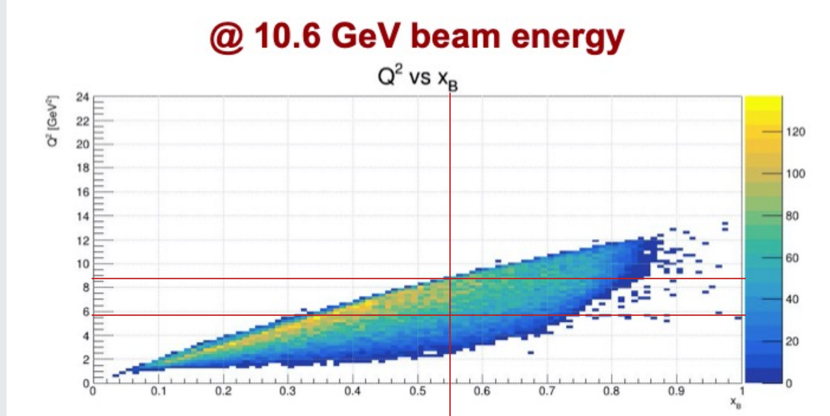
Hall C – HMS-SHMS

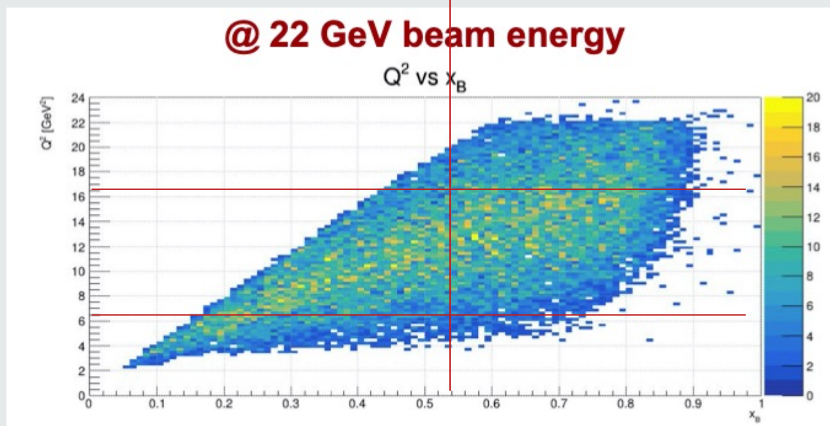


x	Q^2 (GeV²)	W (GeV)	$-t_{min}$ (GeV²)
0.31	1.45–3.65	2.02–3.07	0.12
	1.45–6.5	2.02–3.89	
0.39	2.12–6.0	2.05–3.19	0.21
	2.12–8.2	2.05–3.67	
0.55	3.85–8.5	2.02–2.79	0.55
	3.85–11.5	2.02–3.23	

G. Huber

Hall B – CLAS12



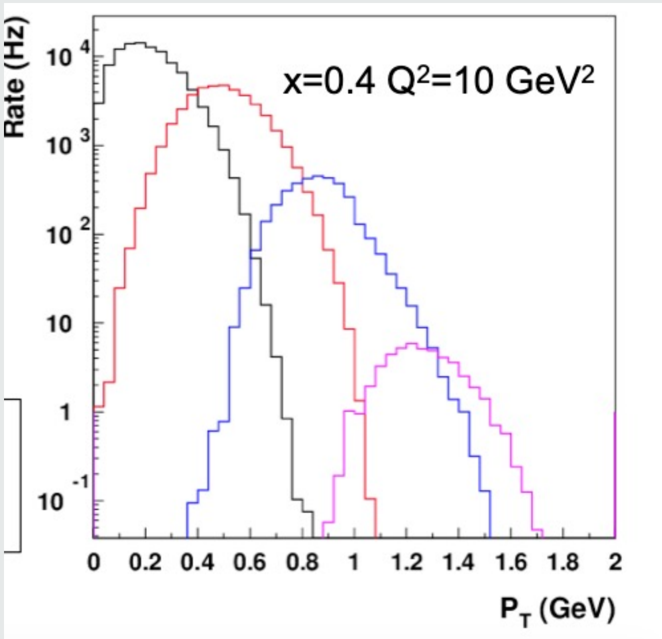


A. Kim

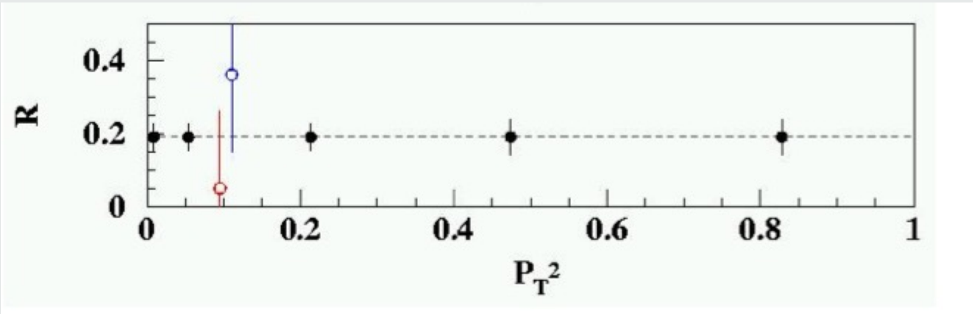
The <u>relevant</u> Q^2 range for the Q^n scaling test significantly icrease with 18/22 GeV beam

σ_L/σ_T in Hall C

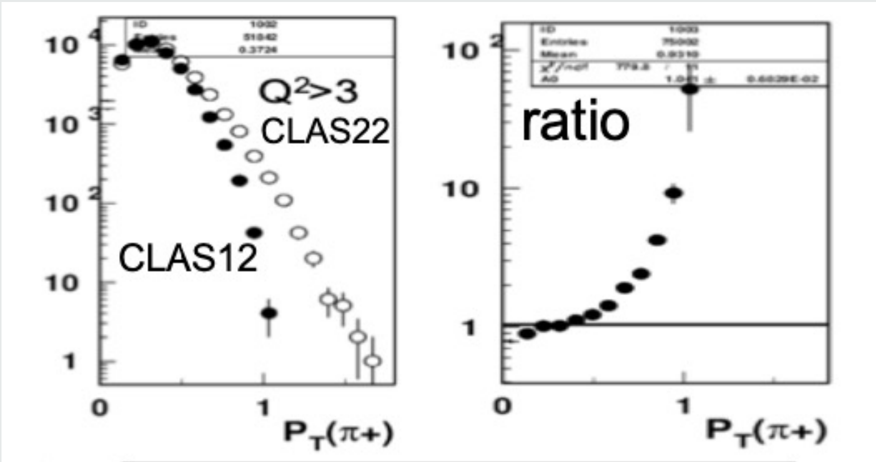
$$\frac{d\sigma}{dx\,dy\,dz\,dp_T^2\,d\phi} = \frac{\alpha^2}{xyQ^2}\frac{y^2}{2(1-\epsilon)}\left[F_T + \epsilon F_L + \sqrt{2\epsilon(1+\epsilon)}\cos\phi F_{LT} + \epsilon\cos 2\phi F_{TT}\right]$$



D. Gaskell



Relative rate

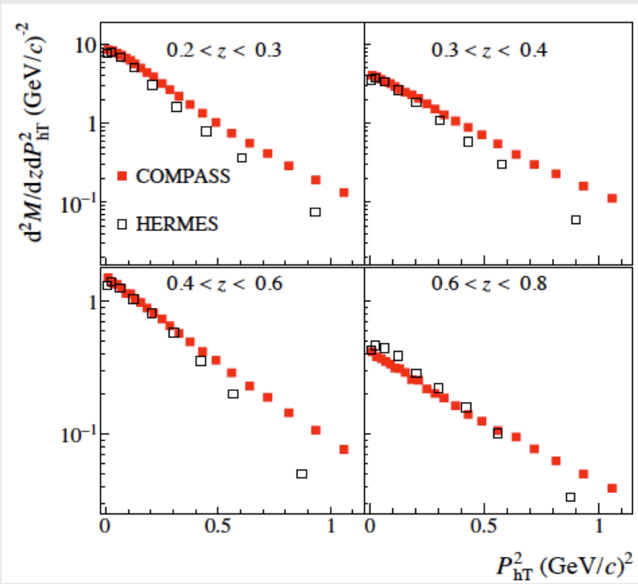


H. Avakian

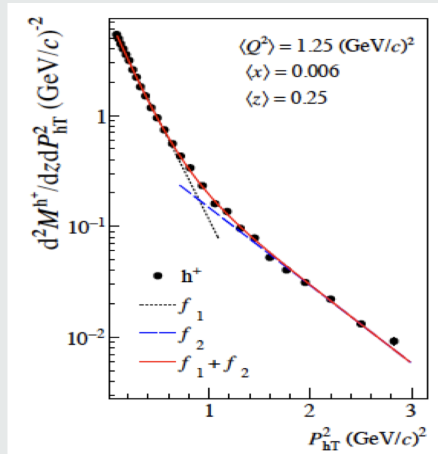
Measurement of R with high precision is crucial to validate the ratio σ_L/σ_T in SIDIS and critical for understanding the systematic for phenomenology.
An energy upgrade can extende the study of R up to significantly higher P_T

Jefferson Lab

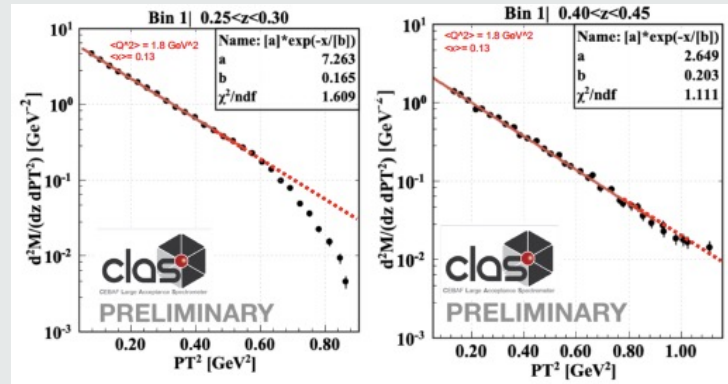
Enhancement of the P_T range



TMDs universal, so what is the origin of the differences observed ?



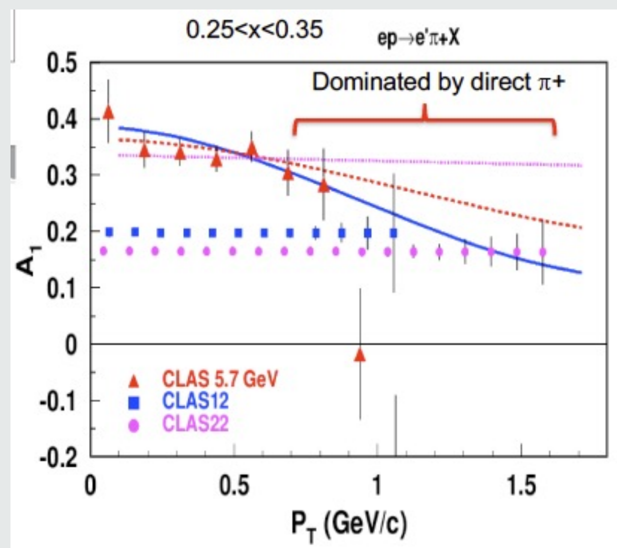
What is the origin of the "high" P_T (0.8-1.8) tail?
Perturbative/non perturbative contributions?



- **For some kinematic regions, at low z, the high P_T distribution appear suppressed: there is no enough energy in the system to produce hadron with high P_T (phase space effect).**

- **JLab: not enough energy to produce large P_T**
- **HERMES: not enough luminosity to access large P_T**

Larger P_T range and high luminosity is the key for a better insight into the problem



H. Avakian

Jefferson Lab

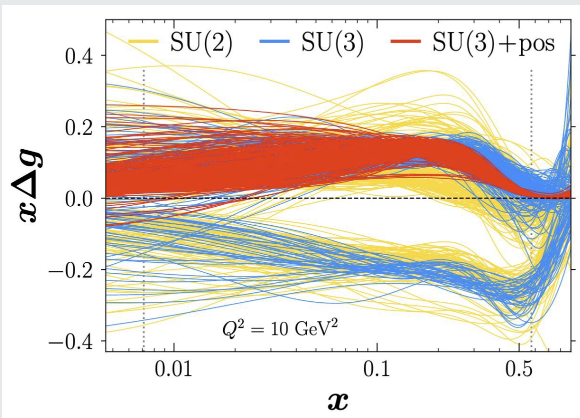
Accessing gluon polarization

Gluon polarization is still elusive in the valence region

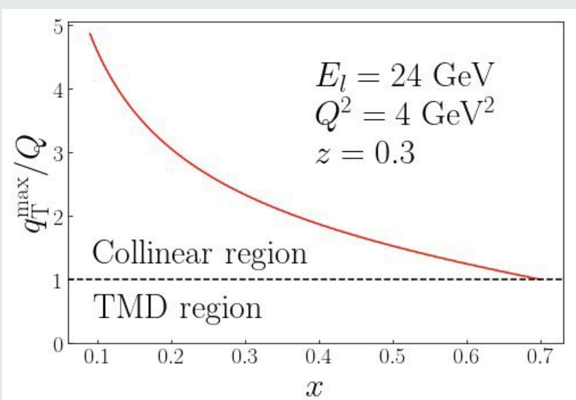
How well do we know the gluon polarization in the proton?

Y. Zhou,[1,2,3,4,5] N. Sato,[5] and W. Melnitchouk[5]

arXiv:2201.02075v2

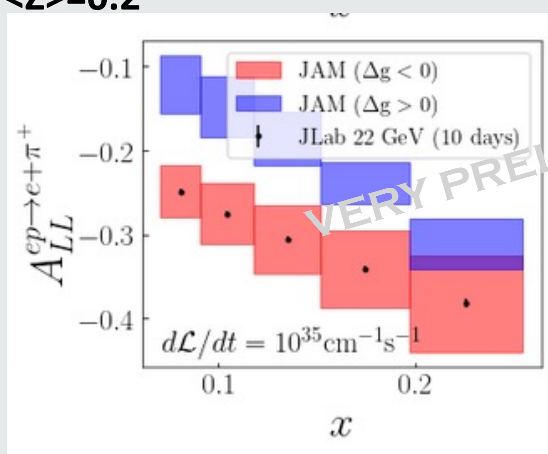


- **First simultaneous global QCD analysis of spin-averaged and spin-dependent PDFs (JAM Coll.), including single jet production data from unpolarized and polarized hadron collisions (STAR&PHENIX)**
- **Polarized jet data cannot discriminate between >0 & <0 solutions**
- **In the large P_T region: solid theoretical framework based on the collinear factorization -> observables pol./unpol. can be written as convolution of collinear pdf and fragmentation function.**

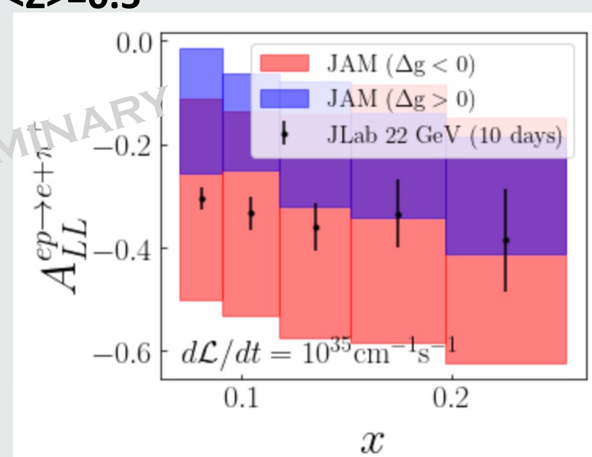


For 0.1<x<0.3 there is phase space with large P_T

<Z>=0.2



<Z>=0.5

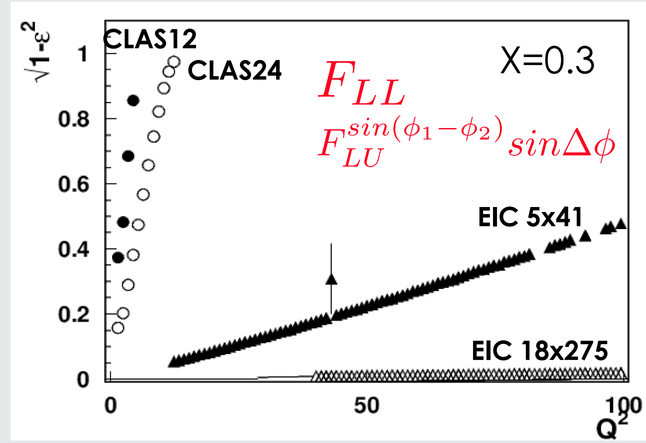


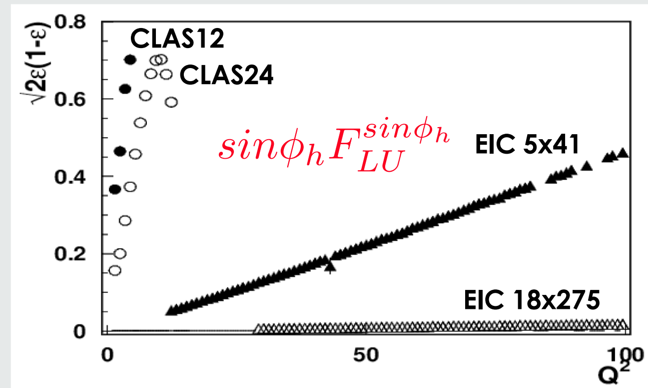
N. Sato

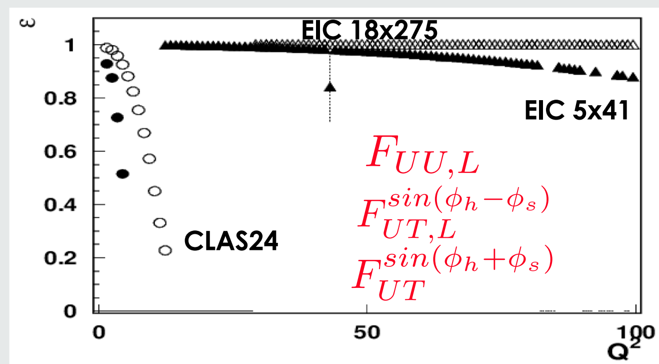
- **theory and exp are working together**

Kinematic Suppression at Large x

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







- **At large x fixed target experiments are sensitive to all Structure Functions**
- **For EIC, observables surviving the $\varepsilon\to 1$ limit (F_{UU}, F_{UL}, Transversely pol. F_{UT})**

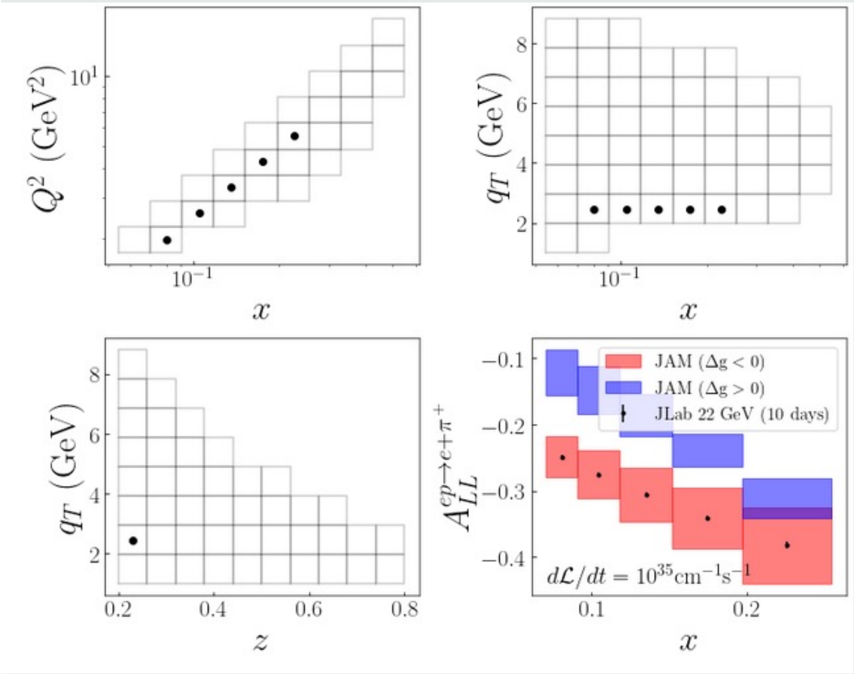
H.Avakian/A. Bacchetta

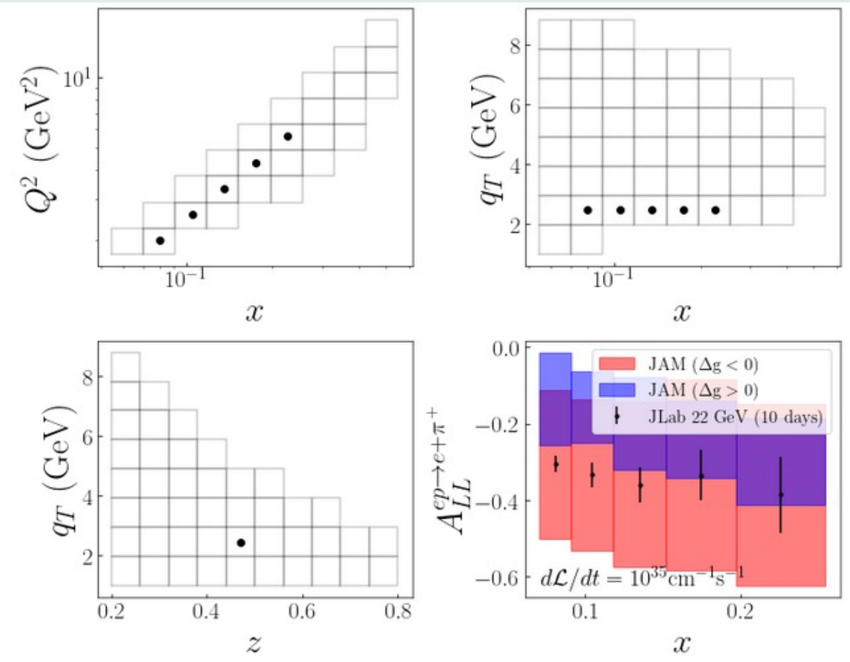
Conclusions

- CEBAF is **THE home** of high luminosity experiments and will remain the prime facility for fixed target electron scattering at very high luminosity also in the EIC era.
- We need to expand the time horizon of Jlab's scientific program beyond 2030. Ideas have been developing on extending CEBAF energy, luminosity and accelerating positrons.
- Staff and users are active and engaged.
- The laboratory and the Jefferson Lab Users Organization has organized a series of one-day workshops on "JLab at Higher Energies" to build a science case in preparation for the Long-Range Plan.
- The workshops aim to develop compelling physics arguments for energy upgrade - utilizing largely existing or already-planned Hall equipment - and are looking for:
  - Unique science in luminosity and precision frontier
  - New avenues and key science questions accessible with E>20 GeV electron beams
  - Complementarity with EIC

Backup Slides

Gluon Polarization





Energy Loss, Emittance Dilution (4-pass CEBAF)

	E [GeV]	Fill factor	ρ [m]	ΔE [MeV]	<H> [m]	$\Delta\varepsilon_N^{arc}[m\ rad]$	$\Delta\varepsilon_N[m\ rad]$	$\Delta^{arc}\sigma_{\Delta E/E}$	$\Delta\sigma_{\Delta E/E}$
arc 1	1.7	0.063	5.1	0	1.8E-01	2.4E-08	2.4E-08	6.3E-06	6.3E-06
arc 2	2.8	0.127	10.2	0	1.8E-01	1.1E-07	1.4E-07	1.1E-05	1.7E-05
arc 3	3.9	0.126	10.2	1	1.8E-01	8.0E-07	9.4E-07	2.4E-05	4.1E-05
arc 4	5.0	0.253	20.4	1	1.8E-01	8.7E-07	1.8E-06	2.2E-05	6.3E-05
arc 5	6.1	0.253	20.4	3	1.8E-01	1.4E-06	3.2E-06	3.6E-05	1.0E-04
arc 6	7.2	0.253	20.4	6	9.0E-02	3.8E-06	7.0E-06	5.5E-05	1.5E-04
arc 7	8.3	0.379	30.6	7	9.0E-02	3.9E-06	1.1E-05	5.2E-05	2.1E-04
arc 8	9.4	0.379	30.6	11	9.0E-02	8.2E-06	1.9E-05	7.0E-05	2.8E-04

Geometric Arc Radius [m]	80.6

$$\Delta E = \frac{2\pi}{3} r_0\ mc^2\ \frac{\gamma^4}{\rho}$$

$$\Delta\epsilon_N = \frac{2\pi}{3} C_q r_0 < H > \frac{\gamma^6}{\rho^2},$$

$$\frac{\Delta\epsilon_E^2}{E^2} = \frac{2\pi}{3} C_q r_0\ \frac{\gamma^5}{\rho^2},$$

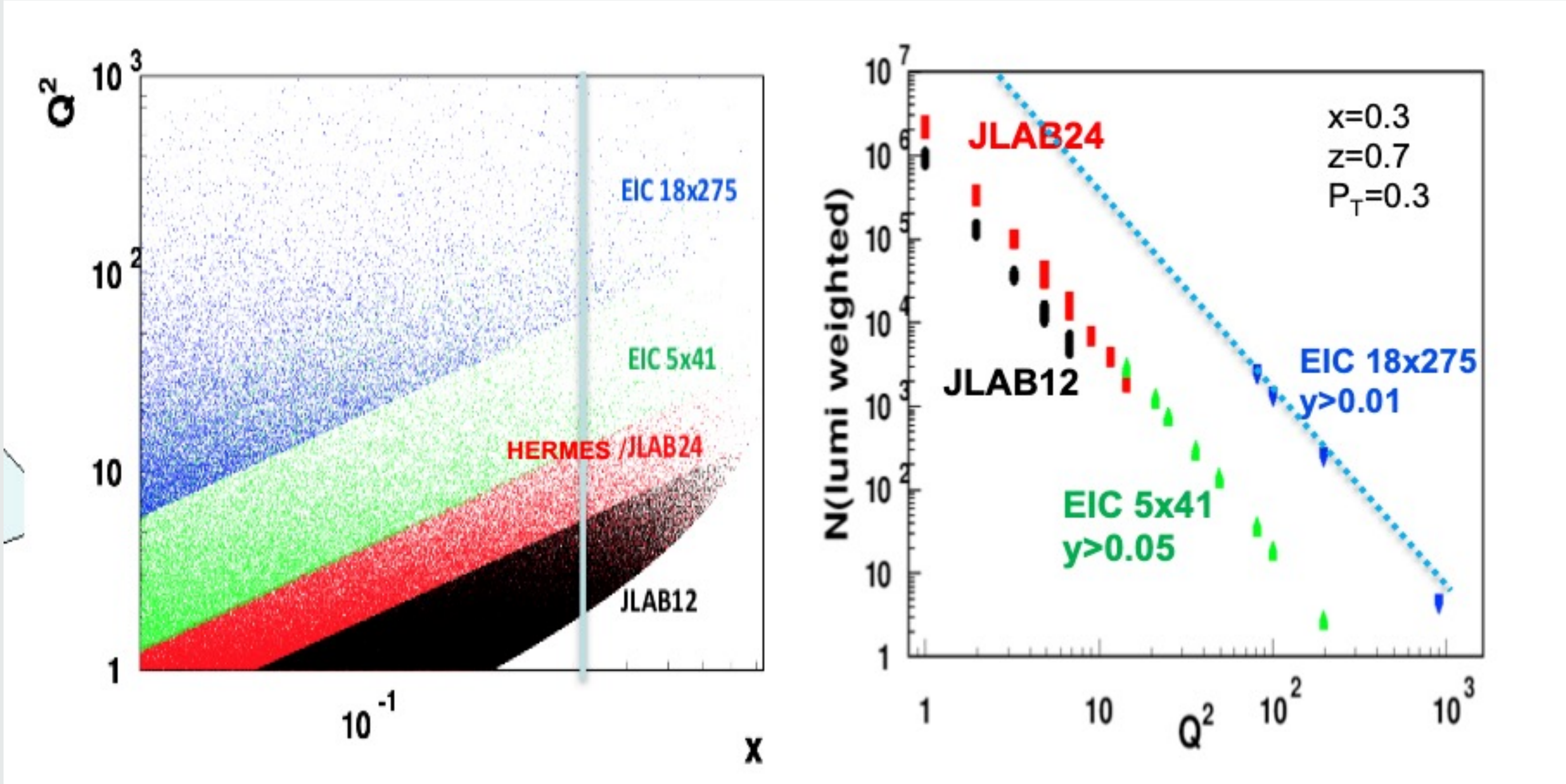
$$H_x = \gamma_x D_x^2 + 2\alpha_x D_x D_x^{'} + \beta_x D_x^{'2} \qquad C_q = \frac{55}{32\sqrt{3}} \frac{\hbar}{mc}$$

Energy loss, Emittance Dilution (7-pass FFAs)

	E [GeV]	Fill factor	ρ [m]	ΔE [MeV]	<H> [m]	$\Delta\varepsilon_N^{arc}[m\ rad]$	$\Delta\varepsilon_N[m\ rad]$	$\Delta^{arc}\sigma_{\Delta E/E}$	$\Delta\sigma_{\Delta E/E}$
FFA 9	10.43	0.876	70.6	7	4.0E-03	1.3E-07	1.9E-05	4.0E-05	3.2E-04
FFA 10	11.51	0.876	70.6	11	4.0E-03	2.4E-07	1.9E-05	5.1E-05	3.7E-04
FFA 11	12.59	0.876	70.6	16	4.0E-03	4.1E-07	2.0E-05	6.4E-05	4.3E-04
FFA 12	13.67	0.876	70.6	22	4.0E-03	6.6E-07	2.1E-05	7.9E-05	5.1E-04
FFA 13	14.73	0.876	70.6	30	4.0E-03	1.0E-06	2.2E-05	9.5E-05	6.1E-04
FFA 14	15.80	0.876	70.6	39	4.0E-03	1.6E-06	2.3E-05	1.1E-04	7.2E-04
FFA 15	16.85	0.876	70.6	50	4.0E-03	2.3E-06	2.5E-05	1.3E-04	8.5E-04
FFA 16	17.89	0.876	70.6	64	4.0E-03	3.3E-06	2.9E-05	1.5E-04	1.0E-03
FFA 17	18.91	0.876	70.6	80	4.0E-03	4.7E-06	3.3E-05	1.8E-04	1.2E-03
FFA 18	19.92	0.876	70.6	99	4.0E-03	6.4E-06	4.0E-05	2.0E-04	1.4E-03
FFA 19	20.91	0.876	70.6	120	4.0E-03	8.5E-06	4.8E-05	2.3E-04	1.6E-03
FFA 20	21.88	0.876	70.6	144	4.0E-03	1.1E-05	6.0E-05	2.6E-04	1.9E-03
FFA 21	22.83	0.876	70.6	170	4.0E-03	1.4E-05	7.4E-05	2.8E-04	2.2E-03
FFA 22	23.75	0.876	70.6	199	4.0E-03	1.8E-05	9.2E-05	3.1E-04	2.5E-03

Final Energy [GeV]	24.6
Total Energy Loss [MeV]	1080

3D Imaging



Jefferson Lab