Future Opportunities at CEBAF

Physics with CEBAF at 12 GeV and Future Opportunities
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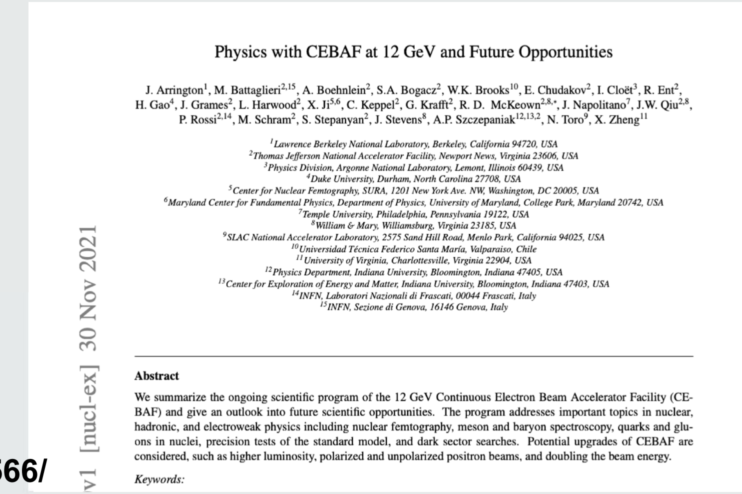
Physics with CEBAF at 12 GeV and Future Opportunities

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Abstract

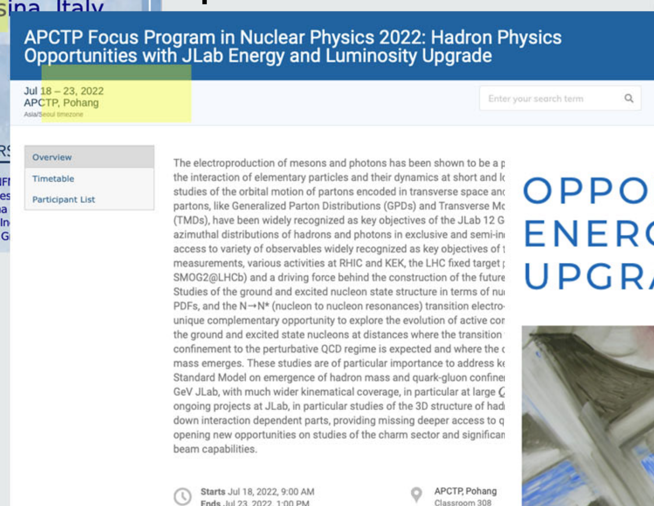
We summarize the ongoing scientific program of the 12 GeV Continuous Electron Beam Accelerator Facility (CEBAF) and give an outlook into future scientific opportunities. The program addresses important topics in nuclear, hadronic, and electroweak physics including nuclear femtography, meson and baryon 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:

v1 [nucl-ex] 30 Nov 2021

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

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



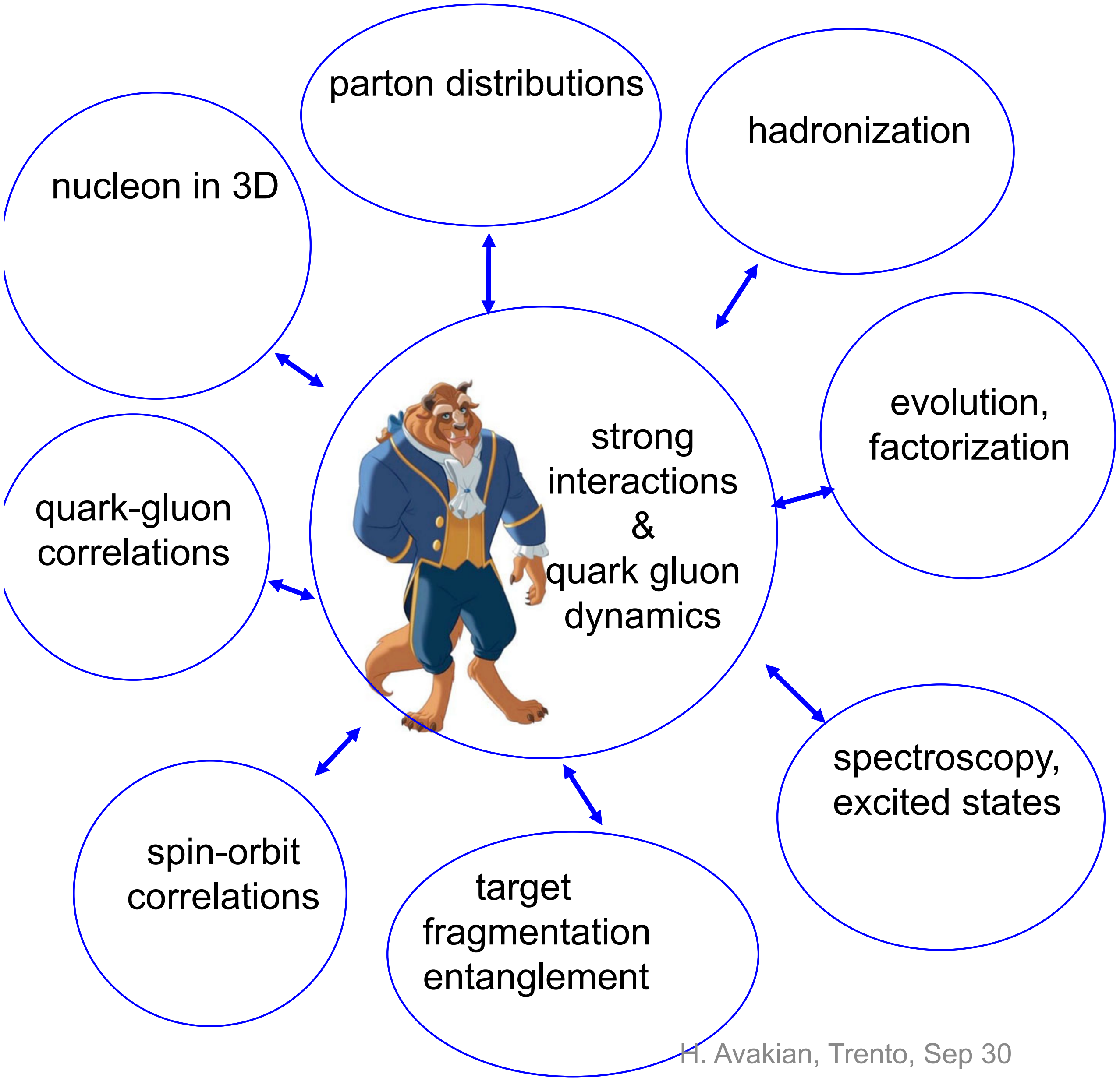
https://www.ectstar.eu/workshops/opportunities-with-jlab-energy-and-luminosity-upgrade/

More to come in next round!!!

OBJECTIVE:

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

QCD: from testing to understanding



<u>Testing stage:</u>
pQCD predictions, observables in the kinematics where theory predictions are easier to get (higher energies, 1D picture, leading twist, IMF)

<u>Understanding stage:</u>
non-perturbative QCD, observables in the real life kinematics where most of the data is available and interactions are strong (more complex observables revealing details of the dynamics,…)

Goals

- Identify key measurements that are not possible to access at 12 GeV
  - initially utilize largely existing or already-planned Hall equipment
  - leverage the unique capabilities of luminosity and precision possible at JLab in the EIC era

1. Identify the flagship measurements that can be done only with 20+ GeV and its science impact (Uniqueness)

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 (Enrichment)

3. Identify the measurements with 20+ GeV that can set the bridge between JLab12 and EIC (Complementarity)

Opportunities with JLab energy upgrade

Energy upgrade of JLab will provide access to

- wider phase space to access large momentum transfer and large transverse momenta of final state particles.
- full range of kinematics where the non-perturbative sea is expected to be significant
- near-threshold charmonium photoproduction will enable studies of the gluonic properties of the proton
- an extensive program at the intensity frontier will cover light and heavy quark hadron spectroscopy
- QCD in medium
- Physics beyond the standard model

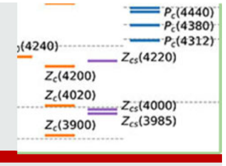
Proposal of a new project requires clear understanding of the current status
a) Identify problems we have in interpretation of what we already observed
Possible path to address (more or better quality data, improved analysis frameworks,..)
b) Identify new problems that can be addressed with new observables, new kinematics that can provide a critical input in understanding of the QCD dynamics

To produce a realistic and convincing physics program we should be able to simulate the observables, their physics and detector backgrounds, to claim understanding of observables and validate the interpretation

Request to participants: 1 slide addressing a) and/or b) with possible classification of observables of interest to 1-U, 2-E and 3-C

Support slides

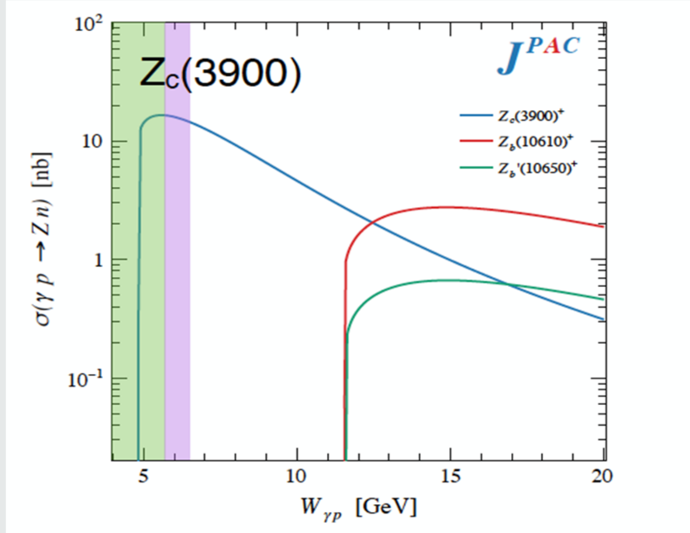
Hadron Spectroscopy

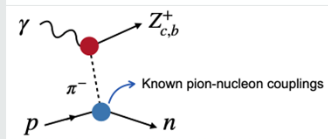


CEBAF @ 20+ GeV : XYZ states & other charmonia can be studied

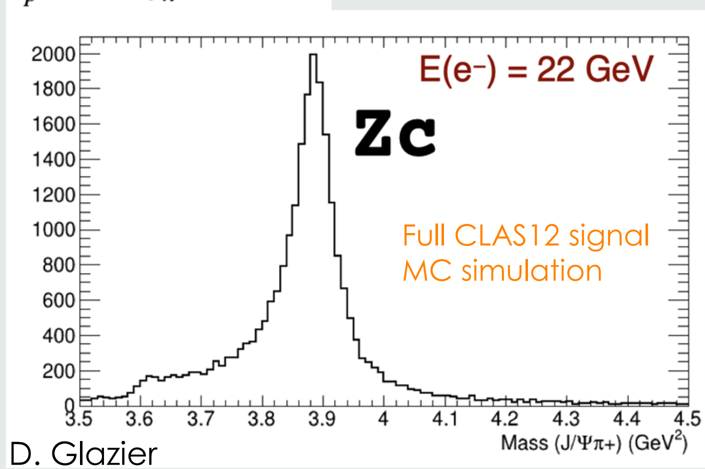
- Tetraquark candidates observed in B decays, e^+e^- colliders
- Significant theoretical interest and progress, but internal structure not yet understood
- **Never direcly produced** using photon/lepton beams

- **Photoproduction provides an alternative mechanisms to study such states**
- Initial simulations from GlueX and CLAS12 demonstrate the **capabilities of the existing detectors to measure these reactions**





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



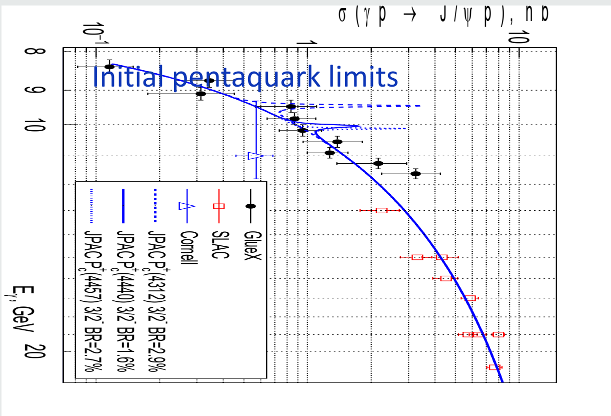
D. Glazier

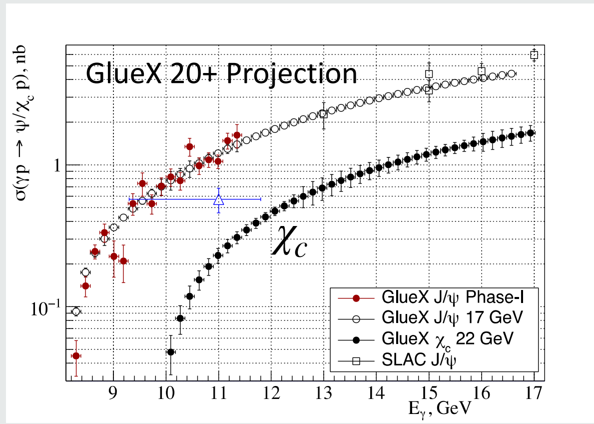
J/ψ and ψ' photoproduction

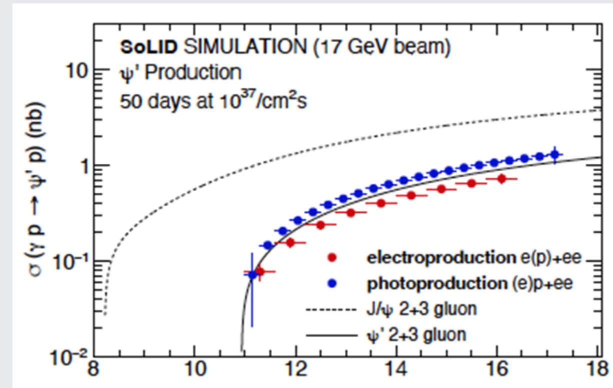
Golden processes to pin down:

a) existence/confirmation of pentaquark resonances

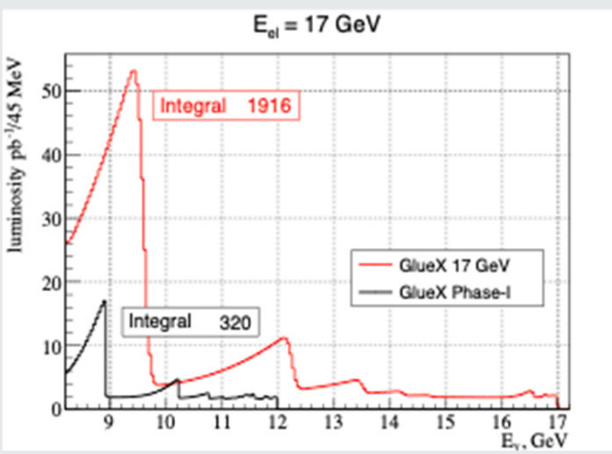
b) nucleon structure (mass, gluon distribution…)

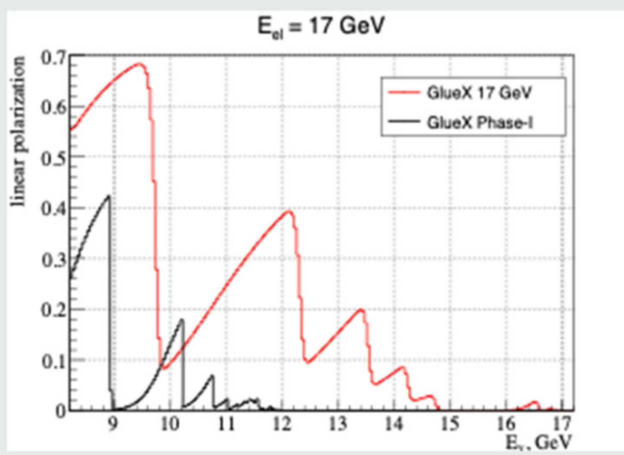


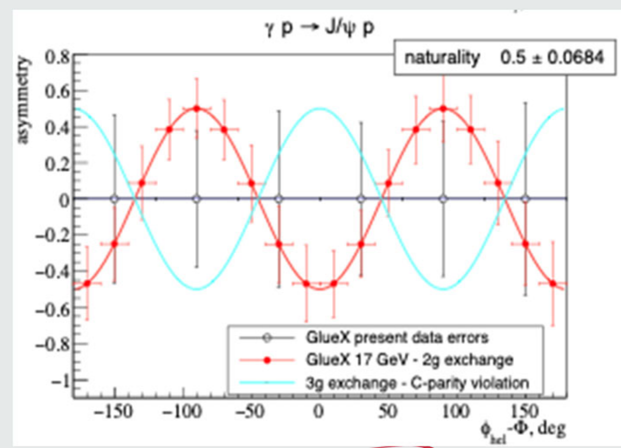




S. Joosten





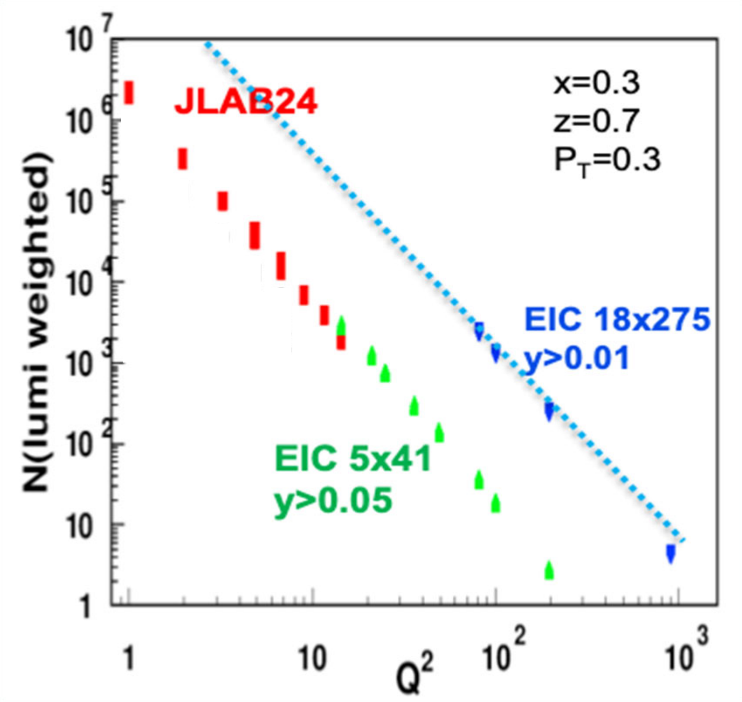


SIDIS at Large x

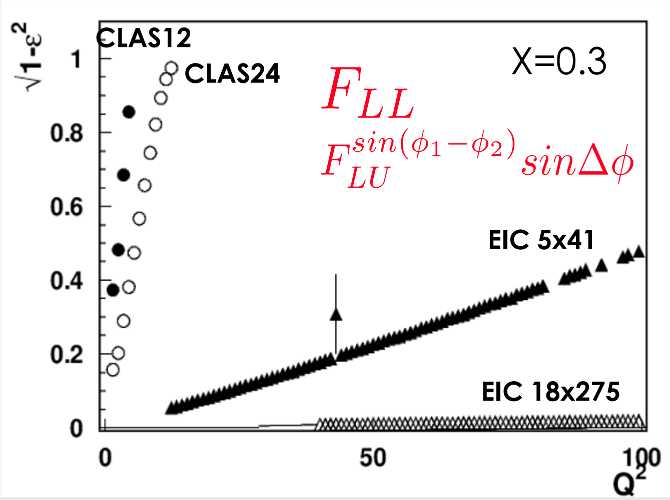
SIDIS at Large x : JLab domain!

- **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})**

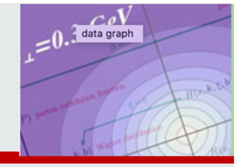
$$
\begin{aligned}
&\frac{d\sigma}{dx\, dy\, d\phi_S\, dz\, d\phi_h\, dP_{h\perp}^2} \\
&= \frac{\alpha^2}{x\, y\, Q^2} \frac{y^2}{2\,(1-\varepsilon)} \Bigg\{ F_{UU,T} + \varepsilon F_{UU,L} + \sqrt{2\,\varepsilon(1+\varepsilon)}\, \cos\phi_h\, F_{UU}^{\cos\phi_h} + \varepsilon \cos(2\phi_h)\, F_{UU}^{\cos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

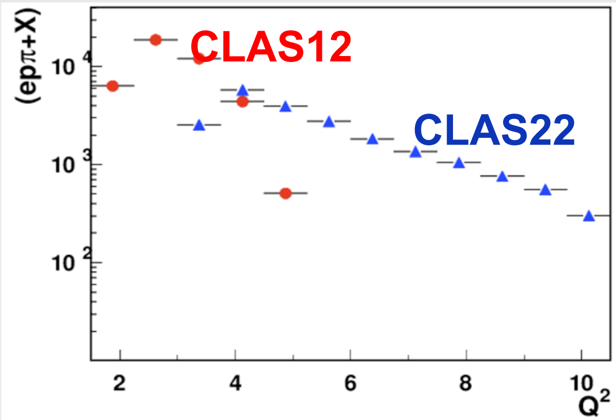


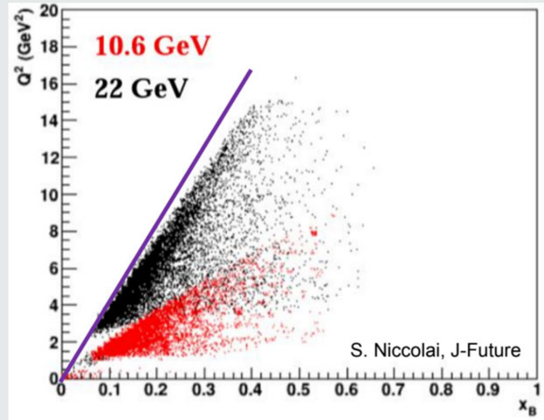
x-section from Bacchetta et al, 1703.10157

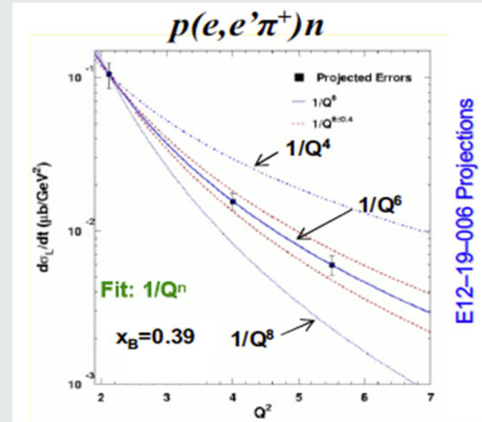


3D Imaging: Enhancement of Q^2 & P_T range

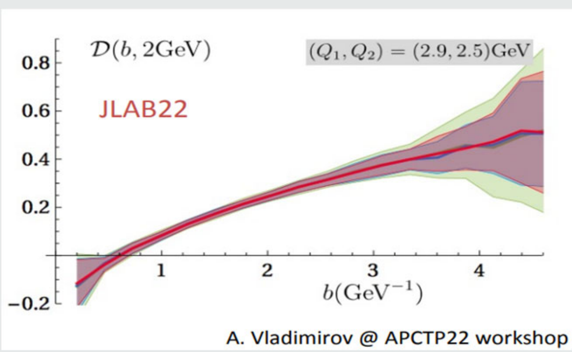


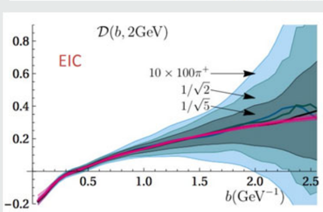




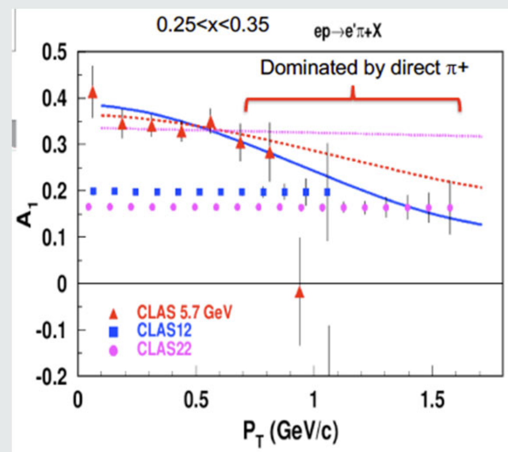


- Q^2 evolution studies possible, superior access to critical Collins-Soper (CS) kernel
- More cleanly separate pure twist-2 CFFs
- Significantly increase of the relevant Q^2 range for the Q^n scaling test – Not yet proven at 12 GeV





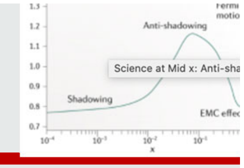
- JLab22 will provide measurements of CS kernel, critical for understanding the evolution properties, in most relevant range



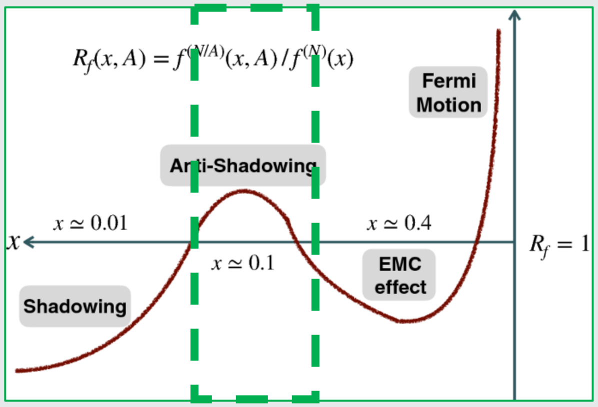
- Larger P_T range and high luminosity is the key for a better insight into the problem

Jefferson Lab

Anti-Shadowing



JLab at ~22 GeV is an anti-shadowing regime machine !



~22 GeV

- Region extremely interesting, near-equally dominated by valence quarks, sea-quarks, and gluons → many many models!!
- Anti-Shadowing is the least studied nuclear structure function effect exp.
  - flavor and spin dependence essentially uncharted
  - no tagged measurements

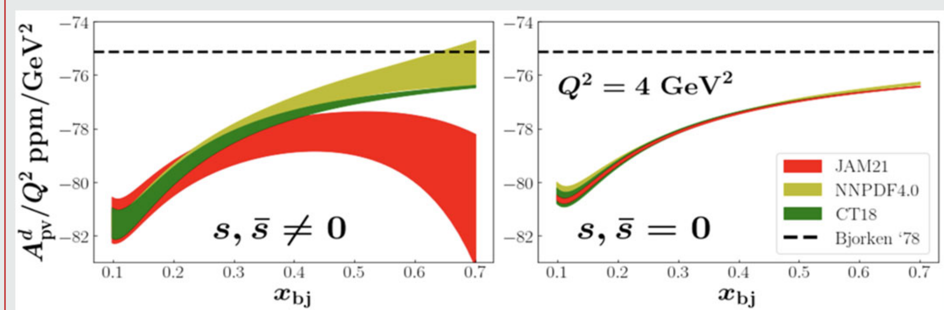
What is needed

- **High precision → high lu**
- **e-A (x, Q²) range**
- **Ability to ch... gets quickly,…**
- **Pol... apping across A, N, Z,**
- **N... tagging → links between nuclear dynamic & quark structure**

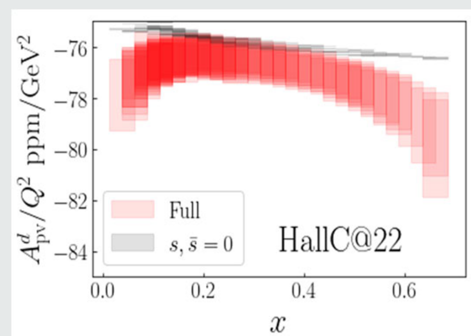
ALL Possible @ Jlab 22 GeV

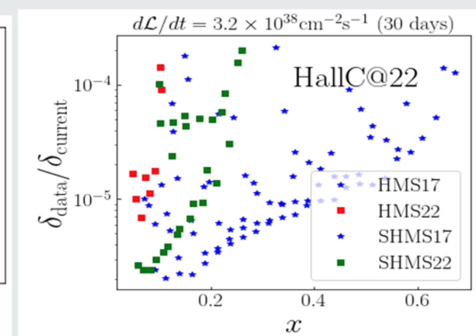
Impact on Strange Quark Puzzle

- **Parity-violating DIS allows for a large contribution of the strange. $F_2^{\gamma Z,p}$ is 5 times more sensitive to the strange**
  - **Precision extraction of $\sin^2\theta_W$**



- **Impact on A_{PV} of PVDIS:**





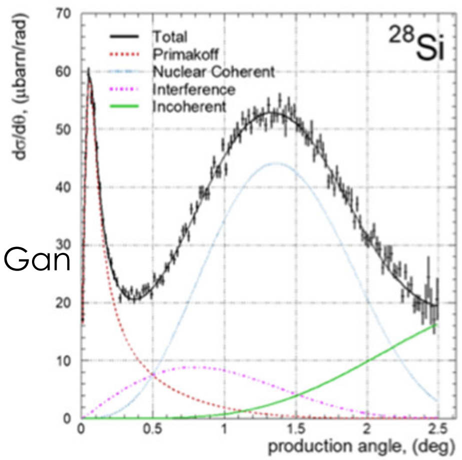
- **Projections with SoLID@22 GeV have significant impact as well**

Physics Beyond the Standard Model

Topic	Presenter	Highlight/Comment
SoLID PVDIS on deuteron	A. Emmert	Prelim. Study → reduced uncertainty in $\sin^2\theta_W$
BSM in PVDIS experiments	S. Mantry	e → μ study underway
Primakov effect experiments	L. Gan	γ + e → π +e, new gauge boson searches
BDX experiment	M. Spreafico	Prelim. Study → expanded reach
BSM with secondary beams	M. Bondi	Competitive with current hadron facilities

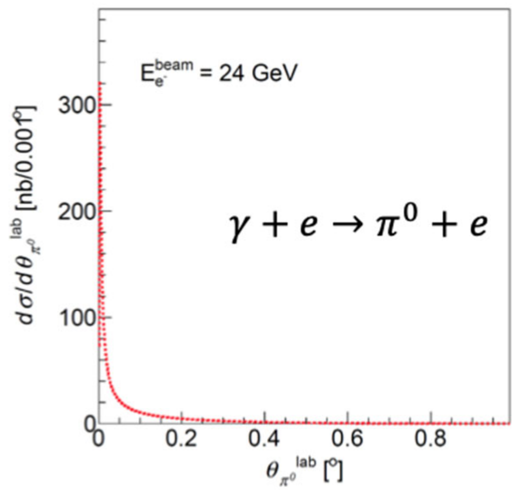
π^0 Primakoff production off an electron target: eliminate nuclear bkg

PrimEx-II: $\gamma + {}^{28}Si \rightarrow \pi^0 + {}^{28}Si$



L. Gan

Science 368, 506-509 (2020)



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