

What SoLID aims to reveal about QCD

Michael Nycz

For the SoLID Collaboration

JLUO Satellite Meeting at APS

03/18/2026



Acknowledgement: Thanks to Jian-Ping Chen, Haiyan Gao, Zein-Eddine Meziani, Paul Souder, Xiaochao Zheng and many other SoLID collaborators.

Talks at APS

Mechanical structure of the pion and nucleon

Adam Freese (presenter)

 Save to my schedule

 Add to calendar

Mechanical or gravitational form factors—which can be inferred by hard exclusive $2 \rightarrow 3$ reactions such as deeply virtual Compton scattering—encode the way that energy, momentum and spin are distributed in a hadron, and how they flow through it. The momentum flux densities in particular are commonly interpreted as characterizing mechanical stresses (such as pressure, tension and shear), and through the Cauchy momentum equation they provide a means of mapping out the force felt by sub-components of a composite system. In this talk, I discuss the basic formalism of mechanical form factors—including their definition and how to convert them into densities through Fourier transforms—and the rationale behind the mechanical stress interpretation of them. I also show how de Broglie-Bohm pilot wave theory can be used to draw a sharper picture of how these stresses operate.

Extracting the weak mixing angle at intermediate Q^2

Michael Nycz (presenter)

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Over the next several years, a number of experiments will perform precision measurements, comparable to those made near the Z pole, of the weak mixing angle, a fundamental parameter of the Standard Model, at intermediate Q^2 values. I will discuss planned parity-violating deep inelastic scattering (PVDIS) experiments with the solenoidal large acceptance (SoLID) at Jefferson Lab as well as with the future Electron Ion Collider (EIC), which can provide new insights into the nucleon structure searched for Beyond-the-Standard Model (BSM) physics at intermediate Q^2 values. I will briefly outline the capabilities of electroweak physics with the ePIC detector and highlight the impact of measuring the weak-mixing angle at moderate Q^2 values.

Study of Nuclear TMDs in SIDIS with CLAS12 at Jefferson Lab

Suman Shrestha (presenter), Nikos Sparveris, Raphael Dupre, Hamza Atac



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 Add to calendar

Transverse momentum dependent parton distributions (TMDs) describe how quarks and gluons move not only along the direction of motion but also in the transverse direction, revealing its three-dimensional momentum structure. While TMDs have been extensively studied in nucleons, we extend this framework to nuclear targets using Semi-Inclusive Deep Inelastic Scattering (SIDIS) with the CLAS12 detector at Jefferson Lab (Fall 2023). A 10.5 GeV polarized electron beam was used on deuterium (LD2) and solid C, Cu, and Sn targets to study nuclear effects on parton dynamics. We present a preliminary analysis of the data using on multiplicity ratios, transverse momentum broadening, and unpolarized azimuthal moments ($\cos \phi$, $\cos 2\phi$) to probe nuclear modifications to parton propagation and transverse momentum distributions.

Experimental Overview of the Proton's Gluonic Gravitational Form Factors

Pierre Chatagnon (presenter)

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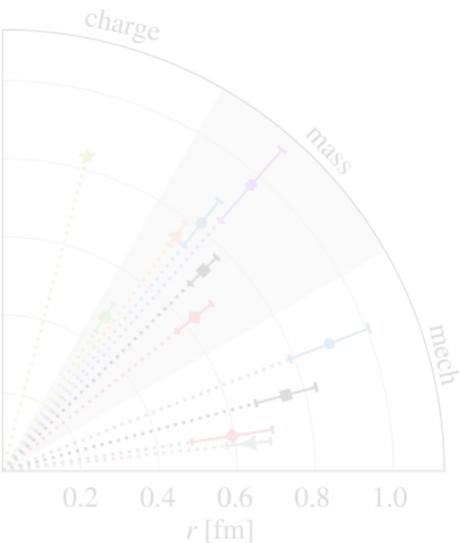
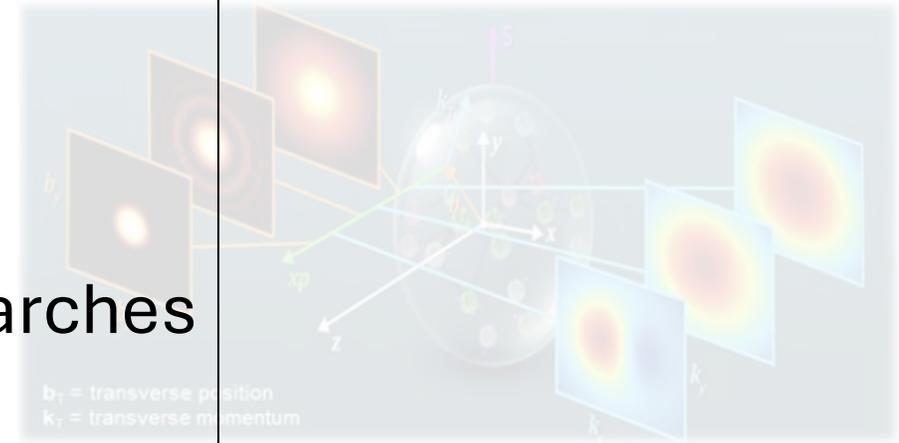
Understanding the proton's fundamental properties, particularly the origin of its spin and mass, is one of the central questions of hadronic physics. Gravitational Form Factors (GFFs), have recently been the focus of an intense theoretical and experimental effort worldwide, because they provide insights into the nucleon's spin structure, mass distribution and internal force dynamics.

This talk will provide an overview of the current and upcoming experimental programs aimed at measuring the proton's gluon GFFs. Recent results from Jefferson Lab experiments, including GlueX, J/ψ -007 and CLAS12 will be highlighted, with a focus on exclusive vector-meson production measurements. In particular, the differential cross section of the photoproduction of J/ψ off the proton has been identified as a key observable to access the gluon content off the proton and especially its gluon GFFs.

Finally, this talk will discuss the expected impact of future measurements at Jefferson Lab, especially with the proposed μ CLAS12 and SoLID experiments, and at the future Electron Ion Collider.

Intensity Frontier

- 3D imaging of the nucleon
- Nucleon spin
- Gravitational Form Factors
- Beyond-the-Standard Model Searches



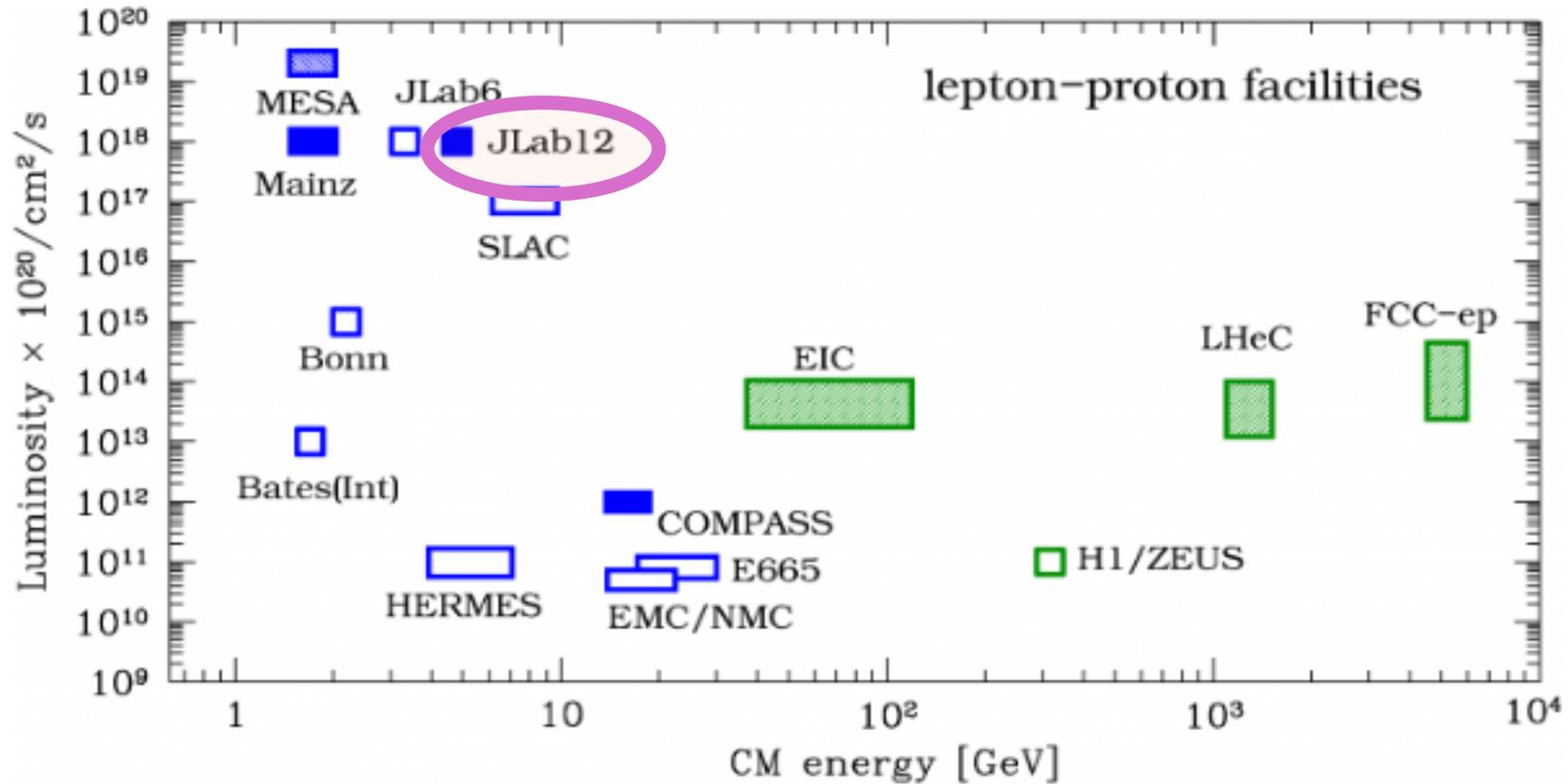
Standard Model of Elementary Particles



- Small Asymmetries
- Small Cross Sections
- Multidimensional Binning

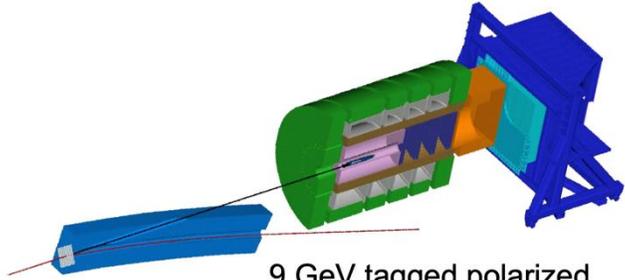
Intensity Frontier

$\mathcal{L}(\text{max}): 10^{39} \text{ cm}^{-2} \text{ s}^{-1}$
Polarization: 85%



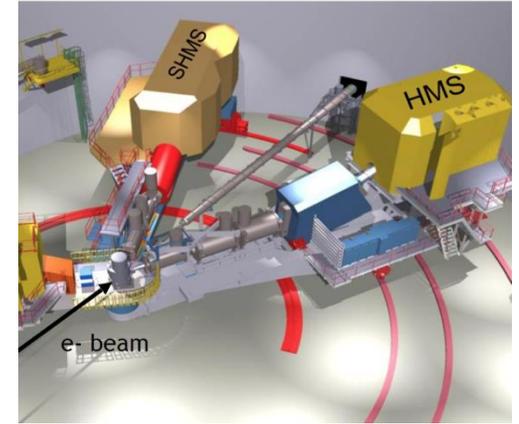
Jefferson Lab

Hall D



9 GeV tagged polarized photons and a 4π hermetic detector

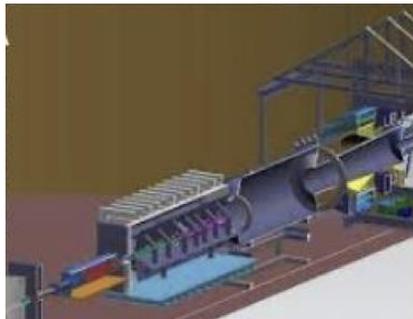
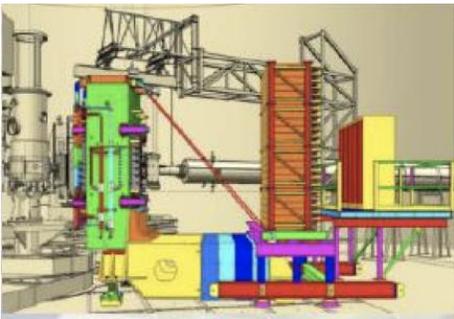
Hall C



Hall B

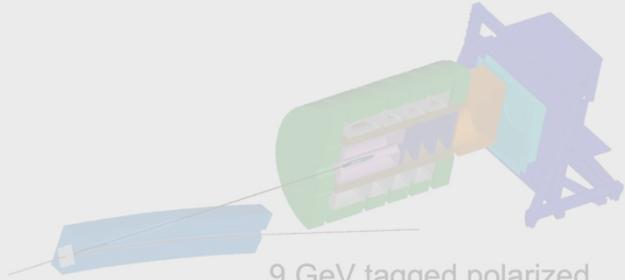


Hall A



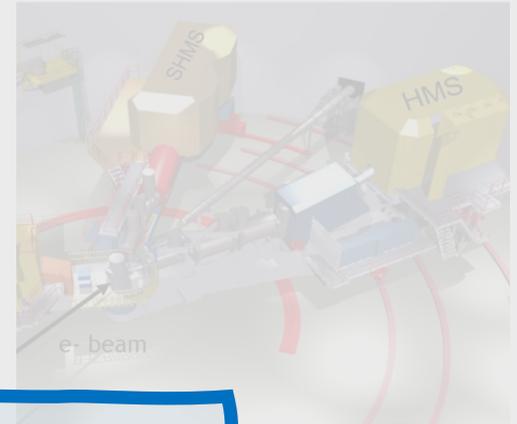
Jefferson Lab

Hall D



9 GeV tagged polarized photons and a 4π hermetic detector

Hall C



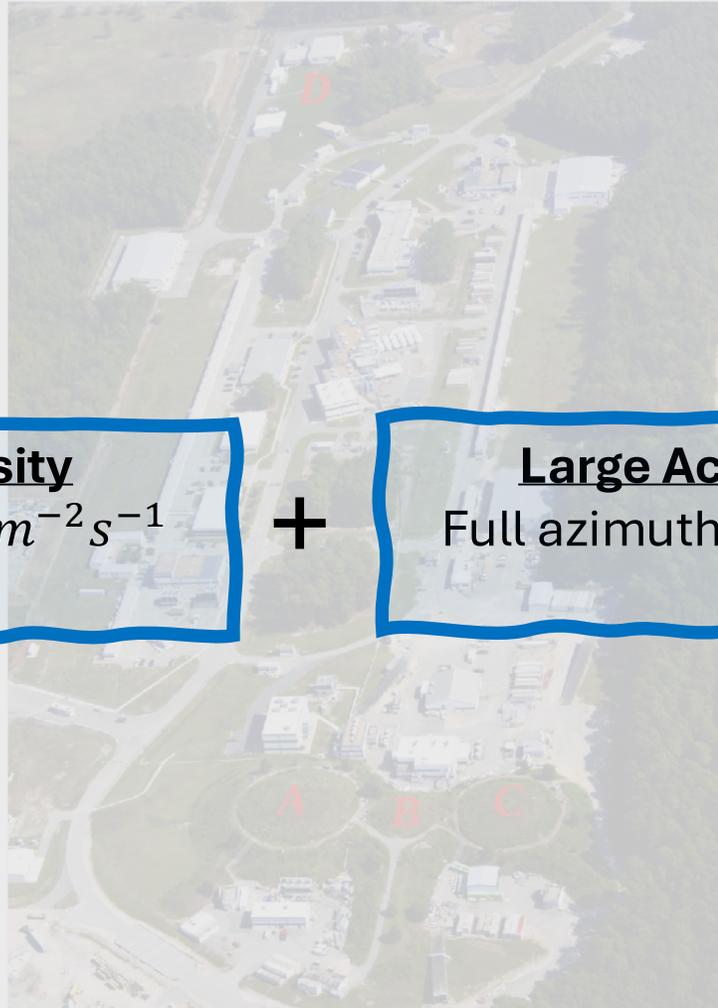
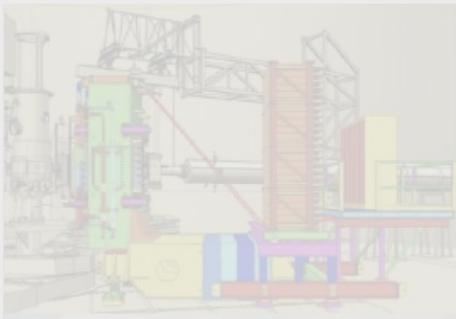
e⁻ beam

High Luminosity
 $L \sim 10^{37} - 10^{39} \text{ cm}^{-2} \text{ s}^{-1}$

+

Large Acceptance
Full azimuthal ϕ coverage

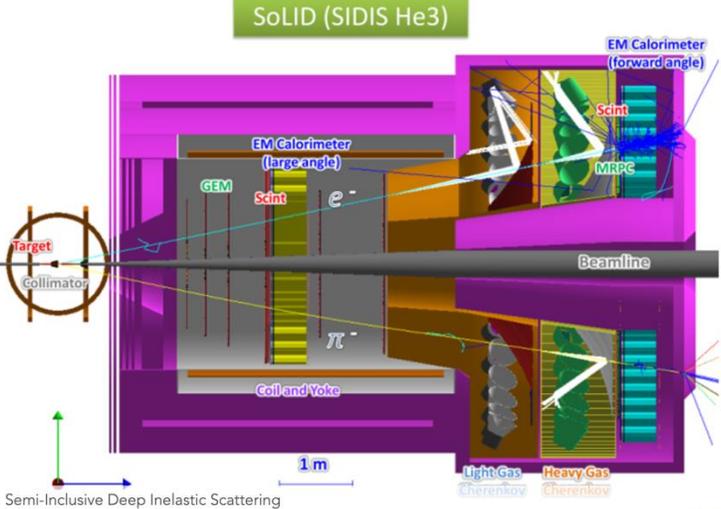
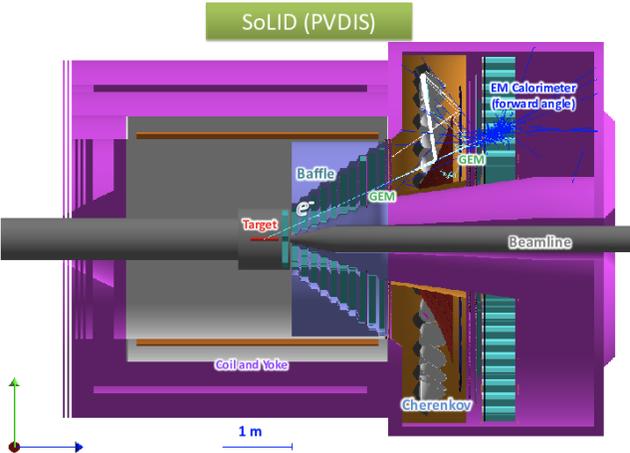
Hall A



Hall B



SoLID (Solenoidal Large Intensity Device)



High Luminosity
 $L \sim 10^{37} - 10^{39} \text{ cm}^{-2} \text{ s}^{-1}$
 [>100x CLAS12] [>1000x EIC]

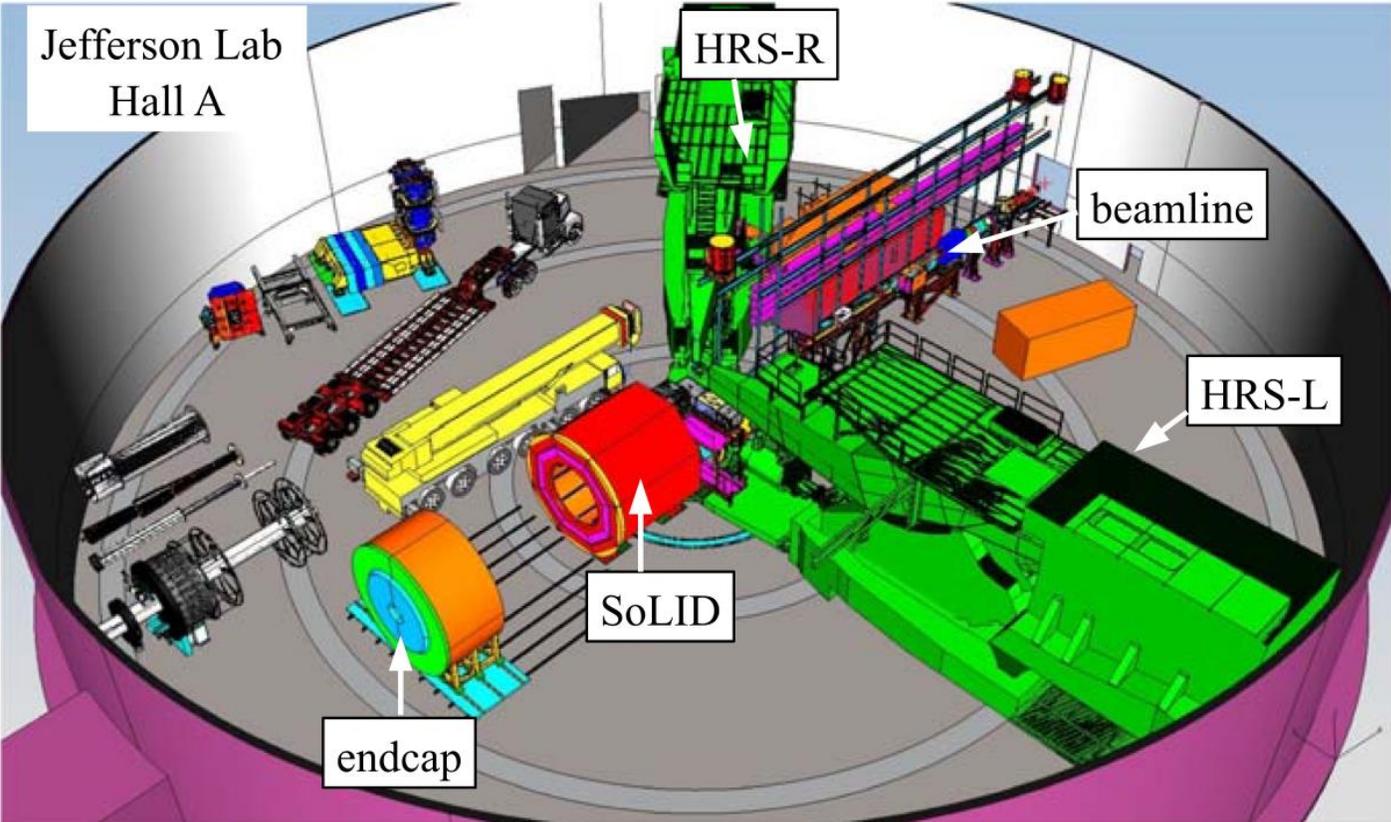
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Large Acceptance
 Full azimuthal ϕ coverage

Fully utilize Jlab 12 GeV Upgrade

- Precision 3D imaging of the nucleon in the valence quark region
- Beyond Standard Model searches
- Exploring the origin of the proton mass and gluonic force in the non-perturbative regime

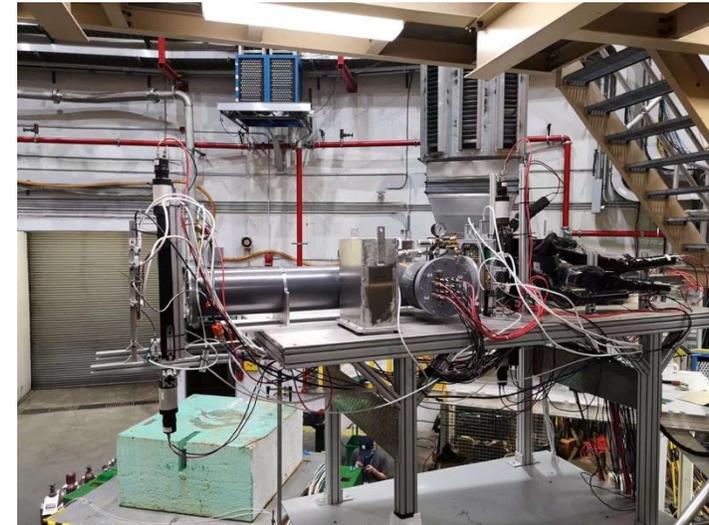
SoLID (Solenoidal Large Intensity Device): Hall A



CLEO-II Magnet in Test Lab

SoLID Detectors

- GEMs (Gas Electron Multipliers)
 - Cherenkov counters (LG and HG)
 - Advanced photon detectors
 - Shashlik EM calorimeters
 - Baffles (PVDIS)
 - Reduce photon
 - LASPD (Scintillator Pad)
 - Photon rejection
- SoLID detector technology has been tested thoroughly
 - Pre R&D beam tests to test to ensure
 - Upcoming tracking beam test in Hall C



SoLID Experimental Program

SIDIS



PVDIS



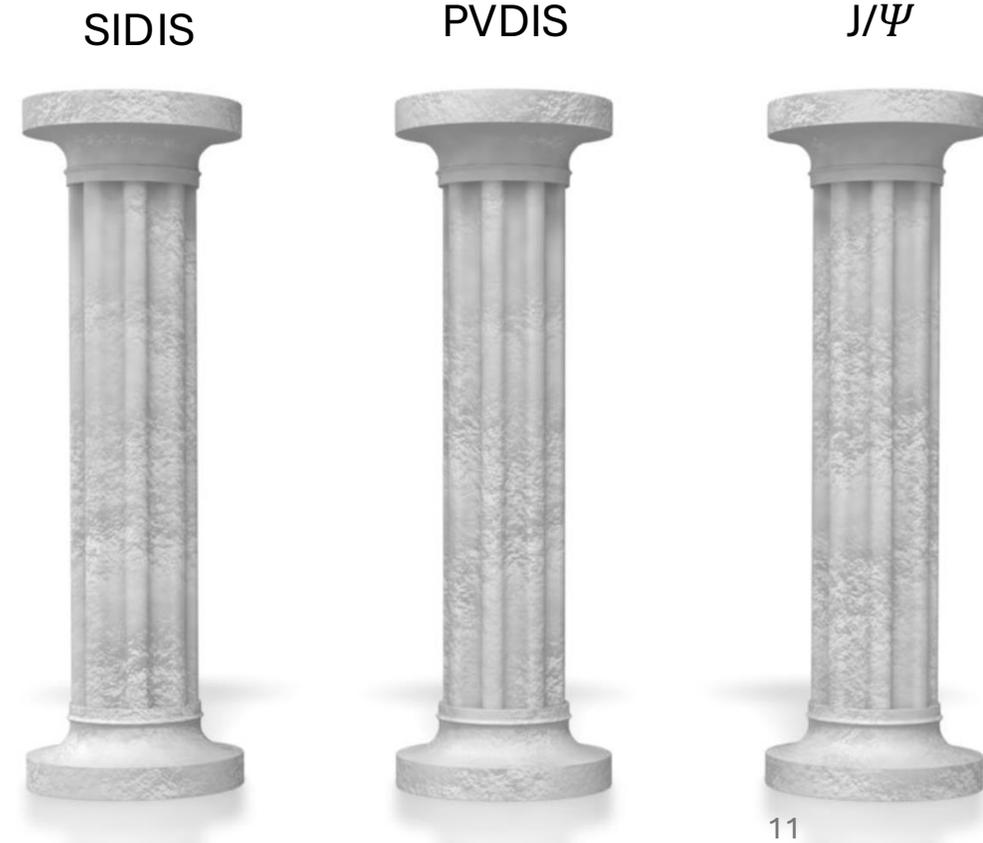
J/ψ



SoLID Experimental Program

Established Physics Program

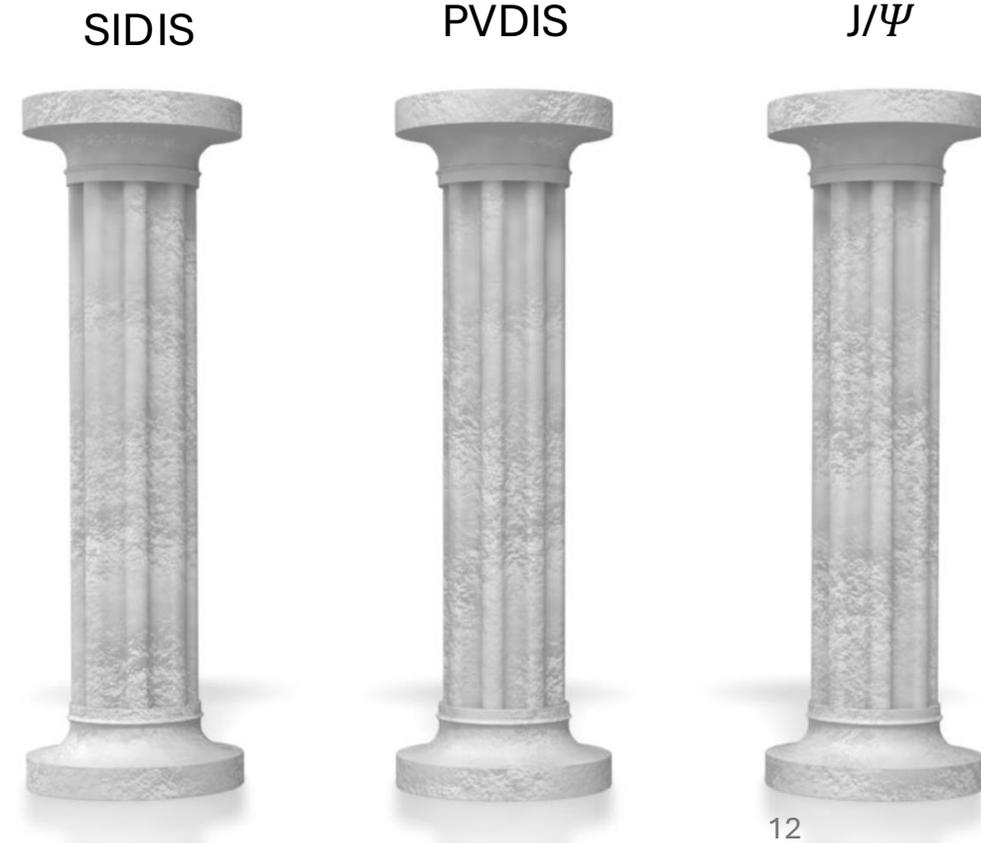
- ❑ SIDIS
 - SIDIS with Transversely Polarized ^3He (E12-10-006)
 - SIDIS with Longitudinally Polarized ^3He (E12-11-007)
 - SIDIS with Transversely Polarized Proton (E12-11-108)
- ❑ PVDIS
 - PVDIS (E12-10-007)
- ❑ J/ψ
 - J/ψ (E12-12-006)
- ❑ 6 Approved Run Group Experiments
 - SIDIS Dihadron with Transversely Polarized ^3He
 - SIDIS in Kaon Production with Transversely Polarized ^1H & ^3He
 - Target SSA Measurements in DIS with Transversely Polarized ^1H & ^3He
 - Measurement of Deep Exclusive π^- Production using a Transversely Polarized ^3He
 - TCS with circular polarized beam and unpolarized LH2 target



SoLID Experimental Program

Evolving Physics Program

- ❑ SIDIS
 - SIDIS with Transversely Polarized ^3He (E12-10-006): A rating
 - SIDIS with Longitudinally Polarized ^3He (E12-11-007): A rating
 - SIDIS with Transversely Polarized Proton (E12-11-108): A rating
- ❑ PVDIS
 - PVDIS (E12-10-007): A rating
 - **BNSSA (E12-22-004): A- rating**
 - **PVEMC (E12-22-002): C2**
- ❑ J/ψ 6 A rated and 1 A- rated experiments
 - J/ψ (E12-12-006): A rating
- ❑ GPD
 - Double DVCS (DDVCS): A rating
- ❑ 6 Approved Run Group Experiments
 - SIDIS Dihadron with Transversely Polarized ^1H
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SoLID Experimental Program

Evolving Physics Program

☐ SIDIS

- SIDIS with Transversely Polarized ^3He (E12-10-006): A rating
- SIDIS with Longitudinally Polarized ^3He (E12-11-007): A rating
- SIDIS with Transversely Polarized Proton (E12-11-108): A rating

☐ PVDIS

- PVDIS (E12-10-007): A rating
- **BNSSA (E12-22-004): A- rating**
- **PVEMC (E12-22-002): C2**

☐ J/ψ

- J/ψ (E12-12-006): A rating

6 A rated and 1 A- rated experiments

☐ GPD

- Double DVCS (DDVCS): A rating

☐ 6 Approved Run Group Experiments

- SIDIS Dihadron with Transversely Polarized ^1H
- SIDIS in Kaon Production with Transversely Polarized Proton & ^3He
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- Measurement of Deep Exclusive π^- Production using a Transversely Polarized ^3He
- TCS with circular polarized beam and unpolarized LH2 target

SIDIS



PVDIS

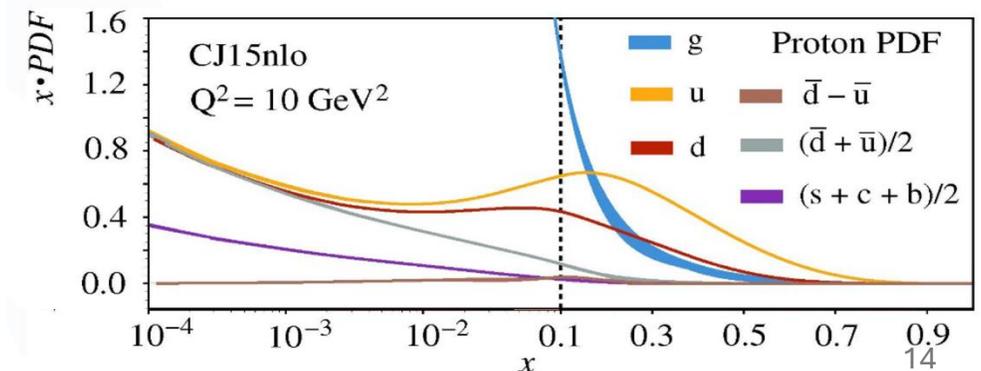
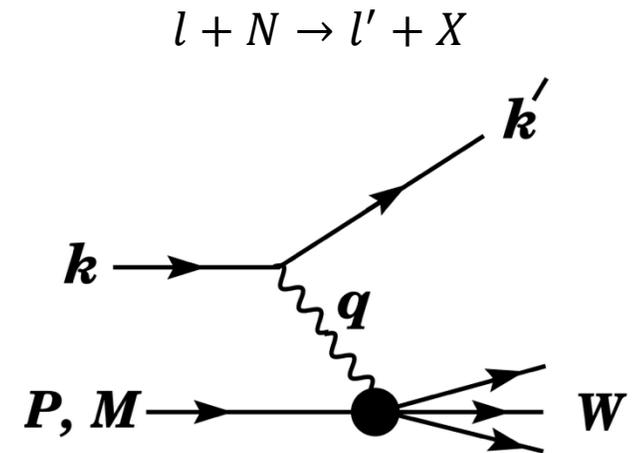


J/ψ



SoLID Experimental Program: SIDIS

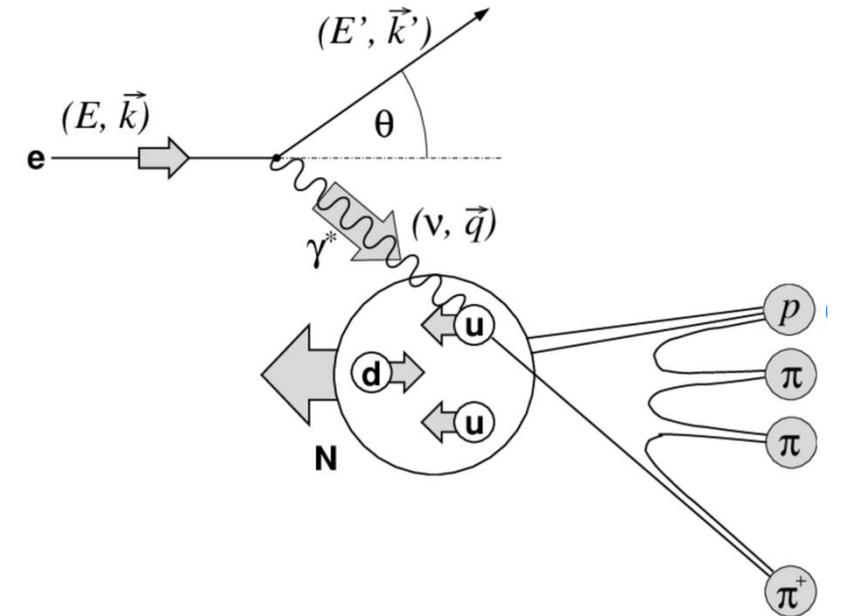
- Decades of DIS experiments have given us a precise one-dimensional picture of the nucleon in terms of PDFs that depend only on x
 - This integrates over the transverse motion of partons.
- The nucleon is a three-dimensional object



SoLID Experimental Program: SIDIS

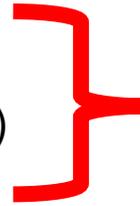
- Semi-inclusive Deep Inelastic Scattering
 - Access transverse structure through TMDs
 - Partonic motion and spatial distributions in transverse direction

$$\begin{aligned}
 \frac{d\sigma}{dx dy d\psi dz d\phi_h dP_{h\perp}^2} = & \frac{\alpha^2}{xyQ^2} \frac{y^2}{2(1-\varepsilon)} \left(1 + \frac{\gamma^2}{2x}\right) \left\{ F_{UU,T} + \varepsilon F_{UU,L} + \sqrt{2\varepsilon(1+\varepsilon)} \cos\phi_h F_{UU}^{\cos\phi_h} \right. \\
 & + \varepsilon \cos(2\phi_h) F_{UU}^{\cos 2\phi_h} + \lambda_e \sqrt{2\varepsilon(1-\varepsilon)} \sin\phi_h F_{LU}^{\sin\phi_h} \\
 & + S_{\parallel} \left[\sqrt{2\varepsilon(1+\varepsilon)} \sin\phi_h F_{UL}^{\sin\phi_h} + \varepsilon \sin(2\phi_h) F_{UL}^{\sin 2\phi_h} \right] \\
 & + S_{\parallel} \lambda_e \left[\sqrt{1-\varepsilon^2} F_{LL} + \sqrt{2\varepsilon(1-\varepsilon)} \cos\phi_h F_{LL}^{\cos\phi_h} \right] \\
 & + |S_{\perp}| \left[\sin(\phi_h - \phi_S) \left(F_{UT,T}^{\sin(\phi_h - \phi_S)} + \varepsilon F_{UT,L}^{\sin(\phi_h - \phi_S)} \right) \right. \\
 & + \varepsilon \sin(\phi_h + \phi_S) F_{UT}^{\sin(\phi_h + \phi_S)} + \varepsilon \sin(3\phi_h - \phi_S) F_{UT}^{\sin(3\phi_h - \phi_S)} \\
 & \left. + \sqrt{2\varepsilon(1+\varepsilon)} \sin\phi_S F_{UT}^{\sin\phi_S} + \sqrt{2\varepsilon(1+\varepsilon)} \sin(2\phi_h - \phi_S) F_{UT}^{\sin(2\phi_h - \phi_S)} \right] \\
 & + |S_{\perp}| \lambda_e \left[\sqrt{1-\varepsilon^2} \cos(\phi_h - \phi_S) F_{LT}^{\cos(\phi_h - \phi_S)} + \sqrt{2\varepsilon(1-\varepsilon)} \cos\phi_S F_{LT}^{\cos\phi_S} \right. \\
 & \left. + \sqrt{2\varepsilon(1-\varepsilon)} \cos(2\phi_h - \phi_S) F_{LT}^{\cos(2\phi_h - \phi_S)} \right] \left. \right\}, \quad (
 \end{aligned}$$



SoLID Experimental Program: SIDIS

SIDIS with Transversely Polarized ^3He (E12-10-006)
 SIDIS with Transversely Polarized Proton (E12-11-108)



Transversity, Sivers, & Pretzlosity TMDs

Target Single Spin Asymmetries (unpolarized e^- and \perp polarized target)

$$A_{UT}(\phi_h, \phi_s) = \frac{1}{P_{t,\text{pol}}} \frac{N^\uparrow - N^\downarrow}{N^\uparrow + N^\downarrow}$$

$$= A_{UT}^{\text{Collins}} \sin(\phi_h + \phi_s) + A_{UT}^{\text{Pretzlosity}} \sin(3\phi_h - \phi_s) + A_{UT}^{\text{Sivers}} \sin(\phi_h - \phi_s)$$

$$A_{UT}^{\text{Collins}} \propto h_1 \otimes H_1^\perp$$

$$A_{UT}^{\text{Pretzlosity}} \propto h_{1T}^\perp \otimes H_1^\perp$$

$$A_{UT}^{\text{Sivers}} \propto f_{1T}^\perp \otimes D_1$$

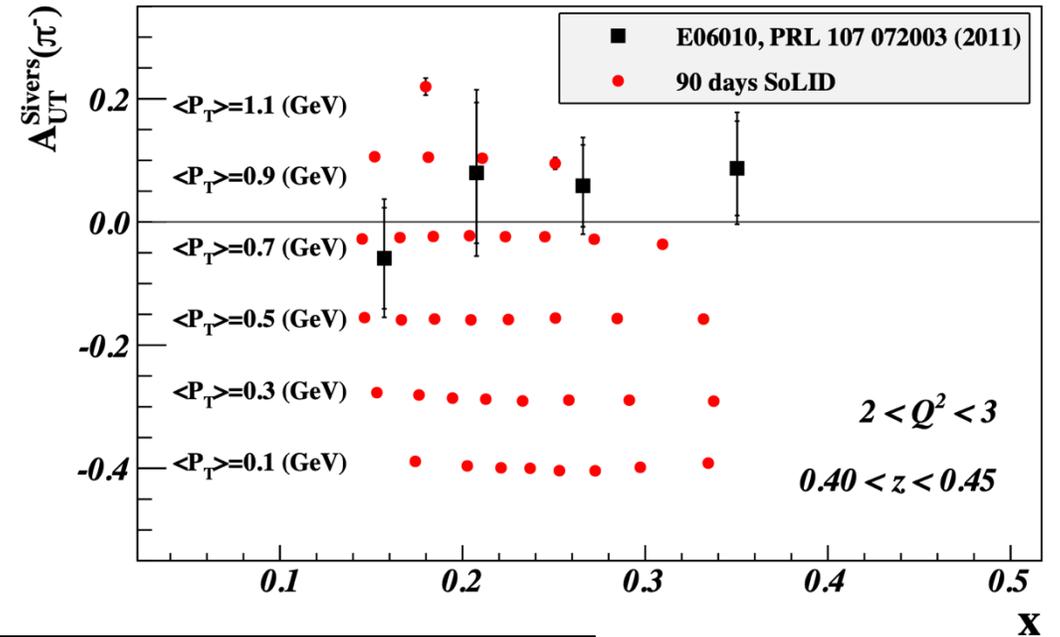
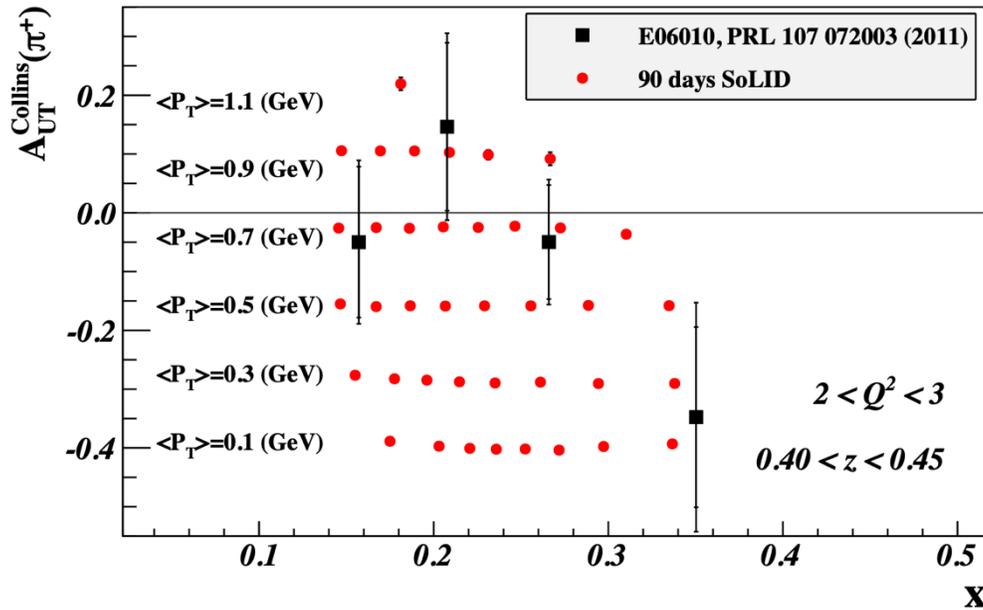
Leading Twist TMDs

: Nucleon Spin : Quark Spin

		Quark polarization		
		Un-Polarized (U)	Longitudinally Polarized (L)	Transversely Polarized (T)
Nucleon Polarization	U	$f_1 = \odot$		$h_1^\perp = \uparrow - \downarrow$ Boer-Mulder
	L		$g_1 = \rightarrow - \leftarrow$ Helicity	$h_{1L}^\perp = \rightarrow - \leftarrow$ Worm gear
	T	$f_{1T}^\perp = \uparrow - \downarrow$ Sivers	$g_{1T}^\perp = \rightarrow - \leftarrow$ Worm gear	$h_{1T}^\perp = \uparrow - \downarrow$ Transversity $h_{1T}^\perp = \rightarrow - \leftarrow$ Pretzlosity

At leading twist there are 8 TMDs

SoLID Experimental Program: E12-10-006



- 4-D Mapping of asymmetries with precision!
- Binning - $\Delta z = 0.05$, $\Delta P_T = 0.2$ GeV, $\Delta Q^2 = 1$ GeV²
 - more than **1400** bins in $(x, Q^2, P_T, \& z)$
- Constrain models and forms of TMDs, Tensor charge

SoLID Experimental Program

Evolving Physics Program

SIDIS

- SIDIS with Transversely Polarized ^3He (E12-10-006): A rating
- SIDIS with Longitudinally Polarized ^3He (E12-11-007): A rating
- SIDIS with Transversely Polarized Proton (E12-11-108): A rating

PVDIS

- PVDIS (E12-10-007): A rating
- **BNSSA (E12-22-004): A- rating**
- **PVEMC (E12-22-002): C2**

J/ψ

- J/ψ (E12-12-006): A rating

GPD

- Double DVCS (DDVCS): A rating

6 Approved Run Group Experiments

- SIDIS Dihadron with Transversely Polarized ^1H
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6 A rated and 1 A- rated experiments

SIDIS



PVDIS

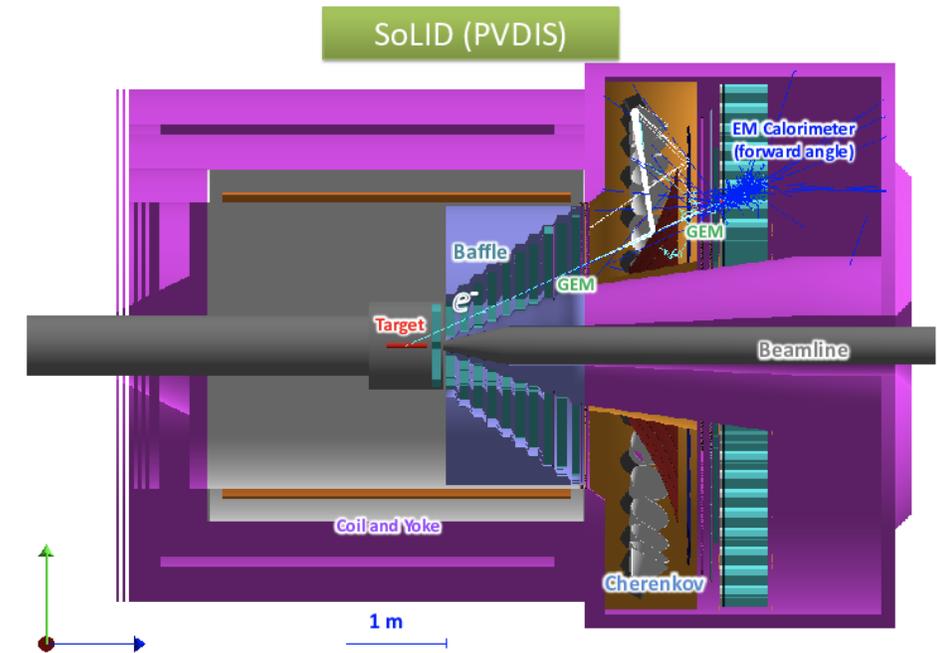


J/ψ



SoLID Parity Violation DIS Program

- **Parity Violating** DIS on Isoscalar Deuteron
 - Precision determination of electroweak parameters
 - Beyond-the-Standard Model (BSM) physics search
 - Search for CSV at quark level
 - Search for quark-quark higher twist effects
- **Parity Violating** DIS on Proton Target
 - Hadronic physics \rightarrow d/u measurement
- **Parity Violating** EMC Effect
 - Isospin dependence of the EMC effect by the use of neutron-rich isotopes
- Beam-Normal Single Spin Asymmetry using SoLID **PVDIS Configurations**

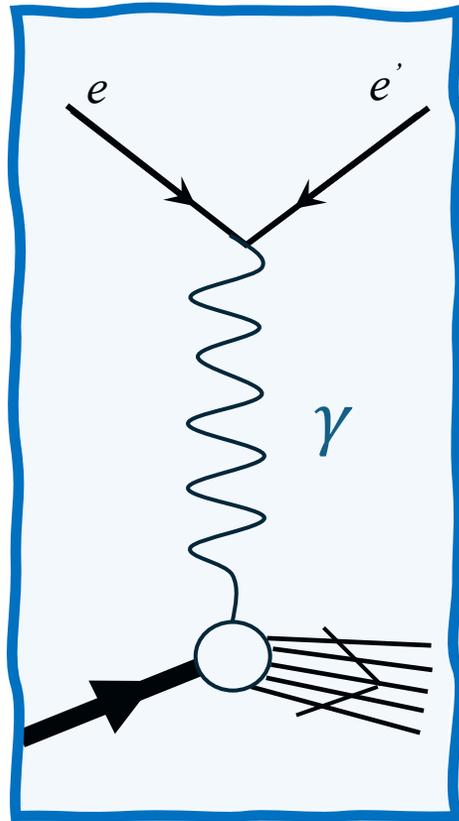


- High luminosity
 - $L \sim 10^{37} - 10^{39} \text{ cm}^{-2} \text{ s}^{-1}$
- Large acceptance + full azimuthal coverage

Parity Violation DIS

EM Interaction

Parity conserving



Parity Violation DIS

PHYSICAL REVIEW

VOLUME 104, NUMBER 1

OCTOBER 1, 1956

Question of Parity Conservation in Weak Interactions*

T. D. LEE, *Columbia University, New York, New York*

AND

C. N. YANG,† *Brookhaven National Laboratory, Upton, New York*

(Received June 22, 1956)

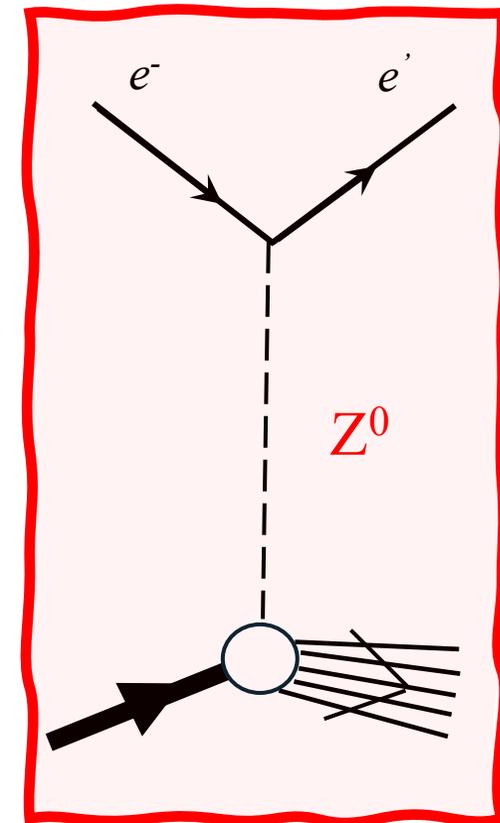
The question of parity conservation in β decays and in hyperon and meson decays is examined. Possible experiments are suggested which might test parity conservation in these interactions.

Experimental Confirmation

- Chien-Shiung Wu: **1957**
 - β decay of [cobalt-60](#): ${}^{60}\text{Co} \rightarrow {}^{60}\text{Ni} + e^- + \bar{\nu}_e$
 - Placed in magnetic field + cooled
- Spin of ${}^{60}\text{Co}$ aligned with magnetic field
- Electrons emitted preferentially in direction opposite nuclear spin

Weak Interaction

Parity violating

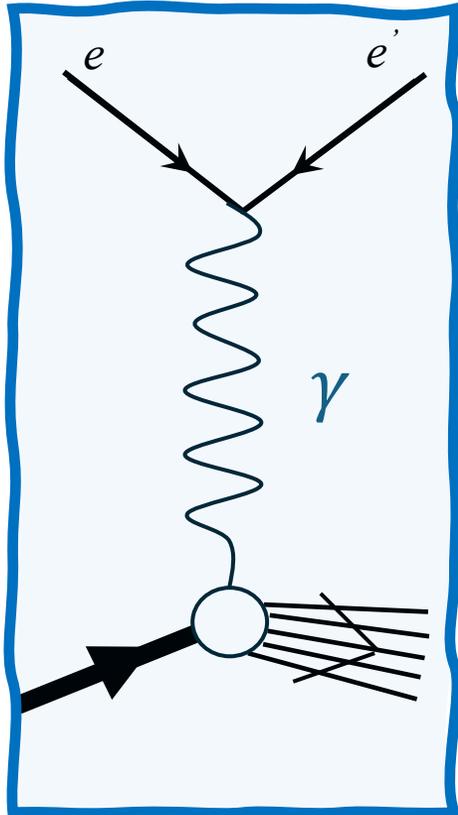


SLAC E1122

EM interaction

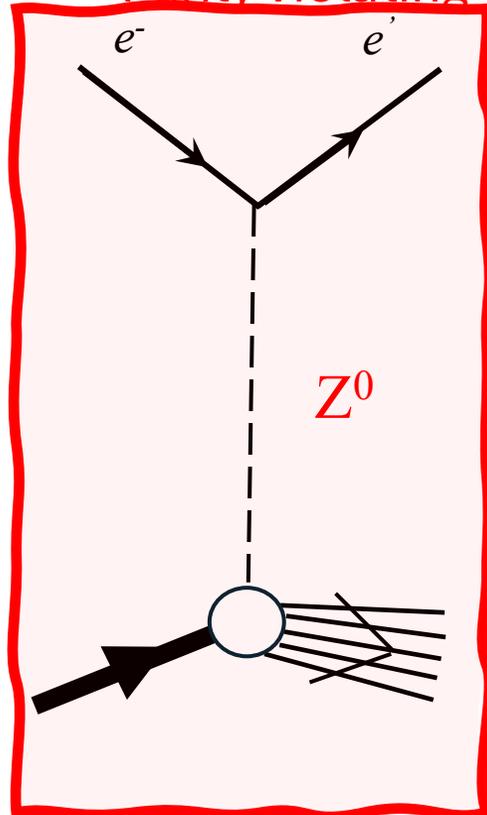
Weak Interaction

Parity conserving



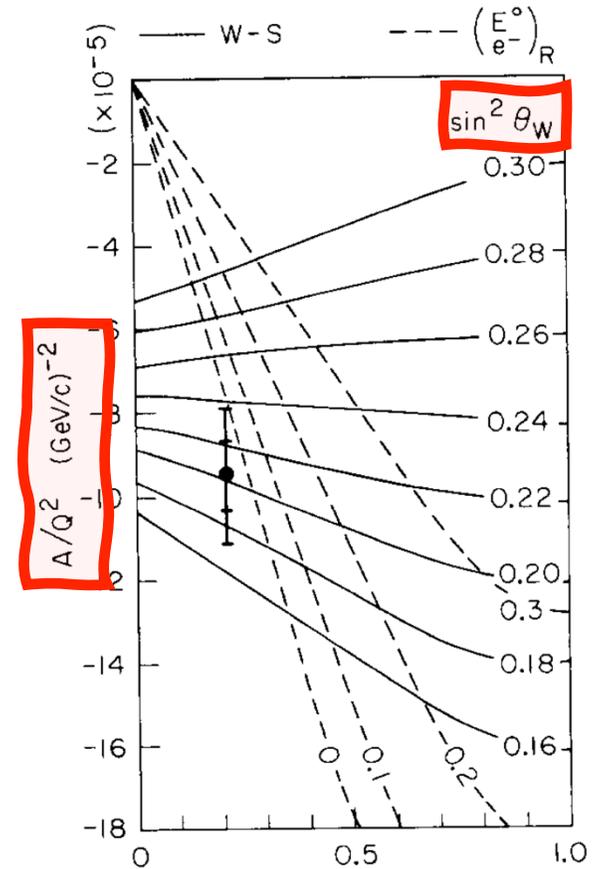
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Parity violating



$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

DEUTERIUM TARGET



Comparison of results with $SU(2) \times U(1)$ theories

1. Weinberg-Salam (solid line)
2. Hybrid (dashed line)

1979 Nobel Prize (Glashow, Salam, Weinberg) "Unification of the weak & electromagnetic forces"

Parity Violation DIS

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

In DIS regime, the asymmetry can be expressed as:

$$A_{PV} = -\frac{G_F Q^2}{4\sqrt{2}\pi\alpha} [a_1(x) + a_3(x)Y]$$

$$a_1(x) = 2g_A^e \frac{F_1^{\gamma Z}}{F_1^\gamma}, \quad a_3(x) = g_V^e \frac{F_3^{\gamma Z}}{F_1^\gamma}, \quad Y = \frac{1-(1-y)^2}{1-(1+y)^2}$$

$$F_1^\gamma(x, Q^2) = \frac{1}{2} \sum Q_{q_i}^2 [q_i(x, Q^2) + \bar{q}_i(x, Q^2)],$$

$$F_1^{\gamma Z}(x, Q^2) = \sum Q_{q_i} g_V^i [q_i(x, Q^2) + \bar{q}_i(x, Q^2)],$$

$$F_3^{\gamma Z}(x, Q^2) = 2 \sum Q_{q_i} g_A^i [q_i(x, Q^2) - \bar{q}_i(x, Q^2)]$$

vector and axial coupling of the electron or quark of flavor i

- $g_{AV}^{eu} = 2g_A^e g_V^u = -\frac{1}{2} + \frac{4}{3} \sin^2 \theta_W$
- $g_{VA}^{eu} = 2g_V^e g_A^u = -\frac{1}{2} - 2 \sin^2 \theta_W$
- $g_{AV}^{ed} = 2g_A^e g_V^d \approx -\frac{1}{2} + \frac{2}{3} \sin^2 \theta_W$
- $g_{VA}^{ed} = 2g_V^e g_A^d \approx \frac{1}{2} - 2 \sin^2 \theta_W$

1. PVDIS Asymmetry is sensitive to both g_{VA}^{eq} and g_{AV}^{eq}
2. PVES (elastic) Asymmetry only sensitive to g_{AV}^{eq}

PVDIS Isoscalar Deuteron

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

In DIS regime, the asymmetry can be expressed as:

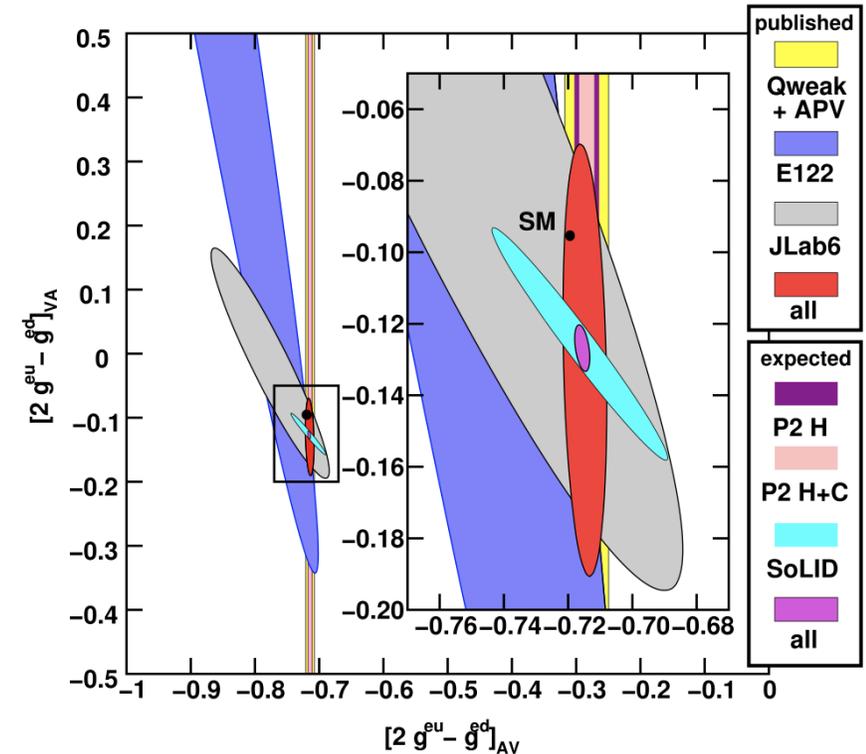
$$A_{PV} = -\frac{G_F Q^2}{4\sqrt{2}\pi\alpha} [a_1(x) + a_3(x)Y]$$

For an Isoscalar Deuteron Target, A_{PV} reduces to

$A_{PV,(d)}$ at high x

1. Independent of pdfs, x & W
2. Well-defined SM prediction for Q^2 & y

$$A_{PV,(d)}^{SM} = \frac{3G_F Q^2}{10\sqrt{2}\pi\alpha} [(2g_{AV}^{eu} - g_{AV}^{ed}) + R_V Y (2g_{VA}^{eu} - g_{VA}^{ed})]$$



Simultaneous fit of $(2g_{AV}^{eu} - g_{AV}^{ed})$ and $(2g_{VA}^{eu} - g_{VA}^{ed})$

SoLID Experimental Program: Near Threshold J/ψ

Evolving Physics Program

SIDIS

- SIDIS with Transversely Polarized ^3He (E12-10-006): A rating
- SIDIS with Longitudinally Polarized ^3He (E12-11-007): A rating
- SIDIS with Transversely Polarized Proton (E12-11-108): A rating

PVDIS

- PVDIS (E12-10-007): A rating
- **BNSSA (E12-22-004): A- rating**
- **PVEMC (E12-22-002): C2**

J/ψ

- J/ψ (E12-12-006): A rating

GPD

- Double DVCS (DDVCS): A rating

6 Approved Run Group Experiments

- SIDIS Dihadron with Transversely Polarized ^1H
- SIDIS in Kaon Production with Transversely Polarized Proton & ^3He
- Target SSA Measurements in DIS with Transversely Polarized ^1H & ^3He
- Measurement of Deep Exclusive π^- Production using a Transversely Polarized ^3He
- TCS with circular polarized beam and unpolarized LH2 target

6 A rated and 1 A- rated experiments

SIDIS

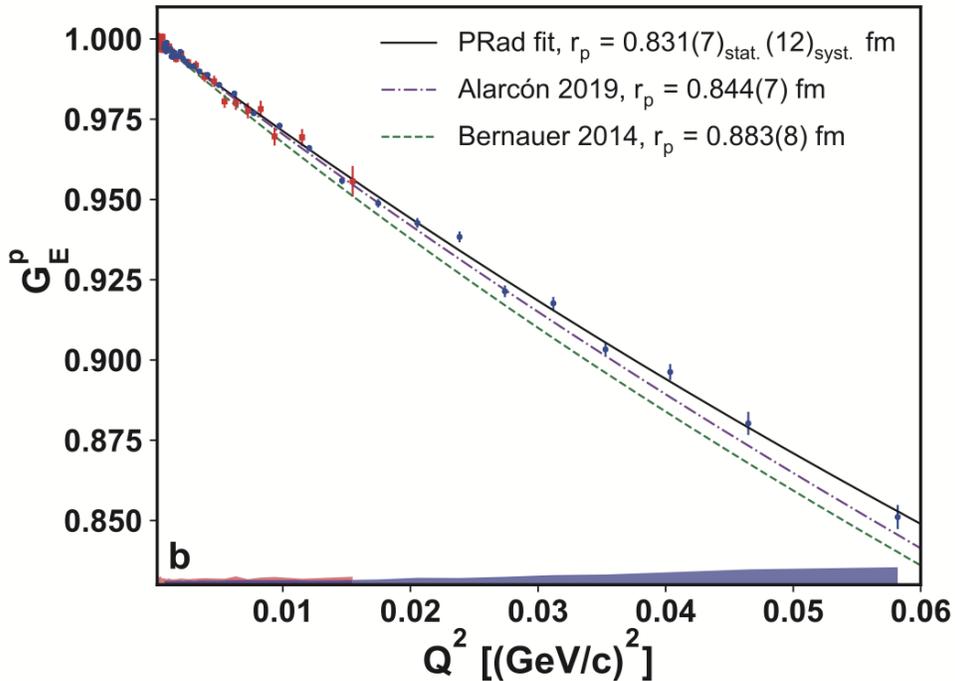
PVDIS

J/ψ

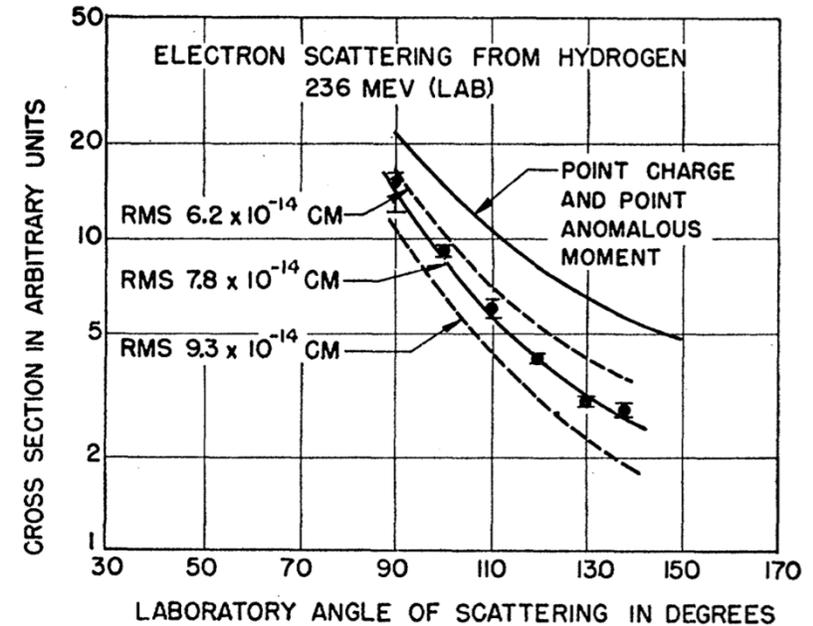


SoLID Experimental Program: Structure of the Proton

$$\sigma = \sigma_{NS} \left\{ F_1^2 + \frac{q^2}{4M^2} [2(F_1 + \mu F_2)^2 \tan^2(\theta/2) + \mu^2 F_2^2] \right\}$$



$$\langle r_E^2 \rangle = - \frac{6}{G_E(0)} \left. \frac{dG_E}{dQ^2} \right|_{Q^2=0}$$



SoLID Experimental Program: Near Threshold J/psi

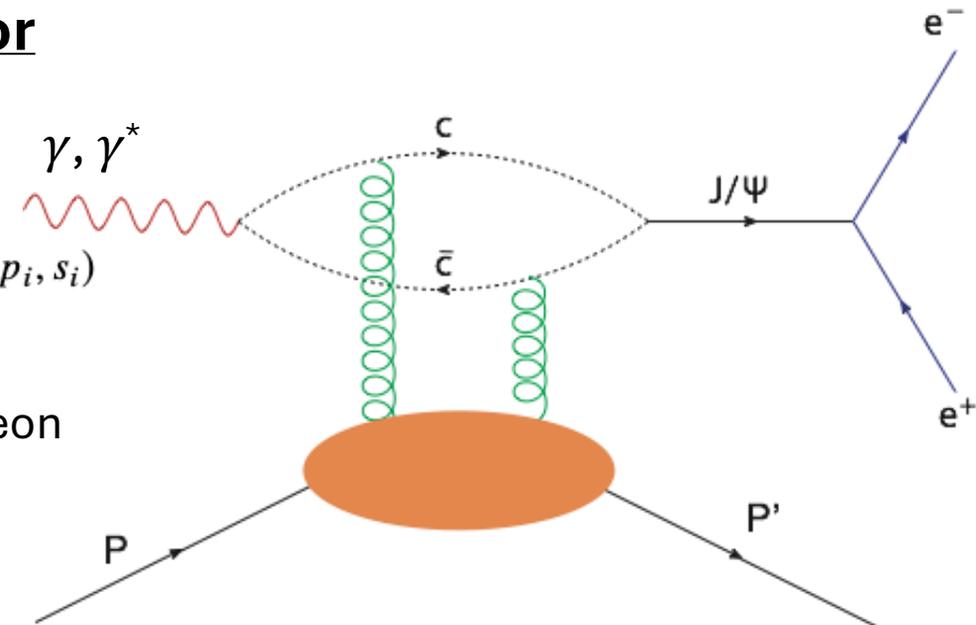
Structure of the Proton

Gravitational Form Factors

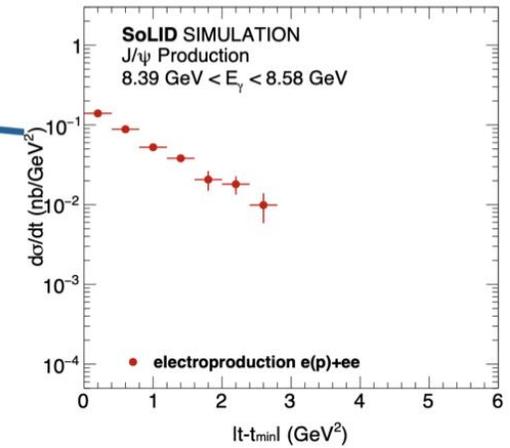
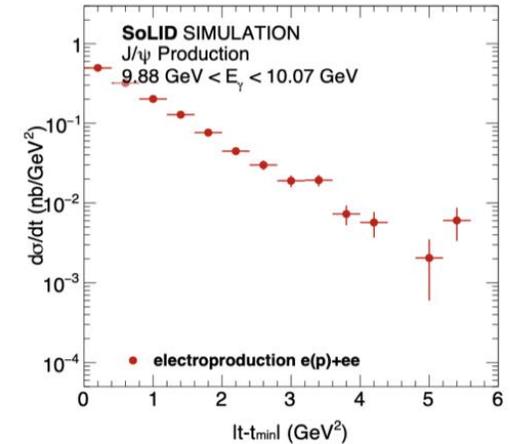
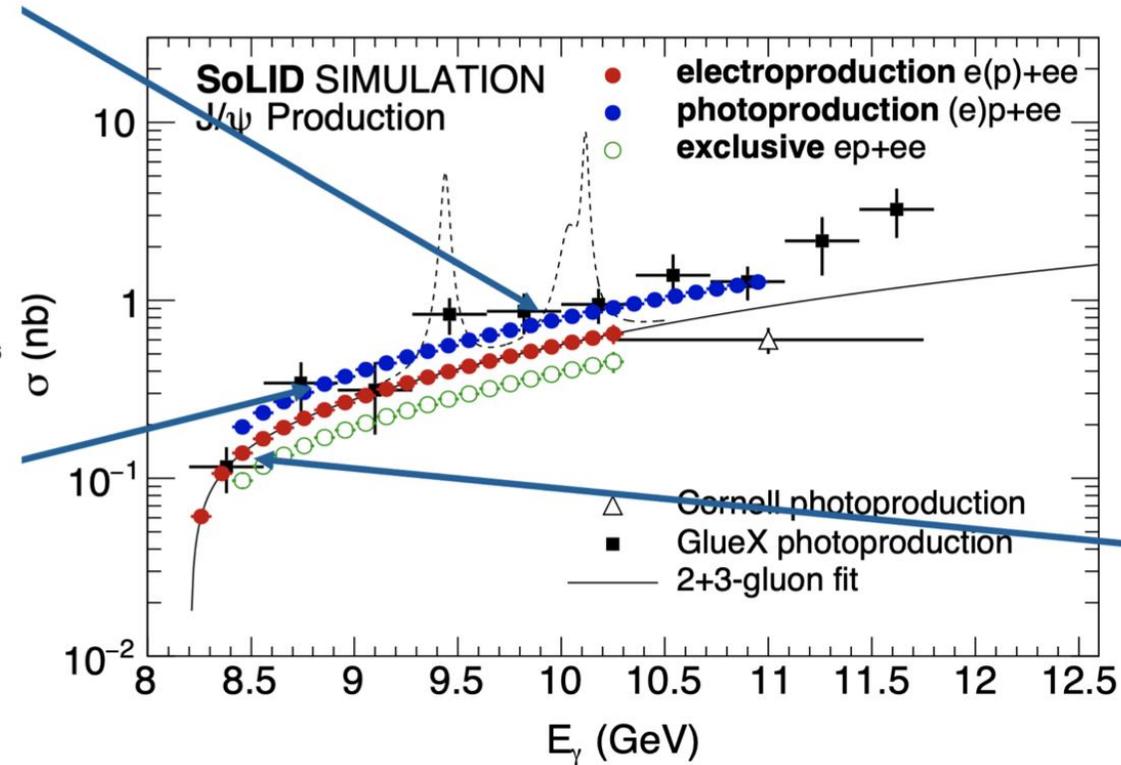
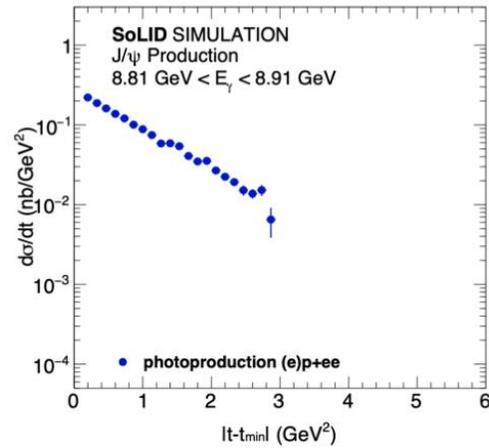
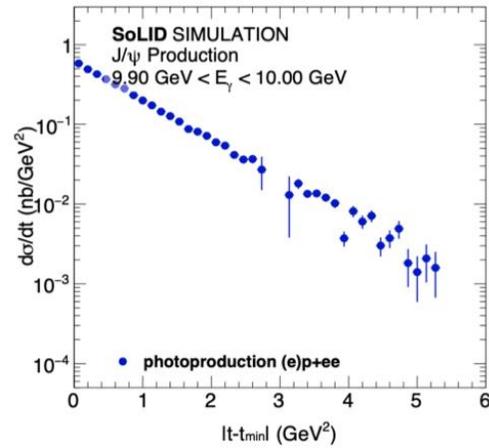
Matrix element of the QCD energy-momentum tensor

$$\langle p_f, s_f | T_{q,g}^{\mu,\nu}(0) | p_i, s_i \rangle = \bar{u}(p_f, s_f) \left(A_{q,g}(t) \gamma^{\{\mu} P^{\nu\}} + B_{q,g} \frac{iP^{\{\mu} \sigma^{\nu\}\rho} \Delta_\rho}{2M_N} + C_{g,q} \frac{\Delta^\mu \Delta^\nu - g^{\mu\nu} \Delta^2}{M_N} + \bar{C}_{q,g}(t) M_N g^{\mu,\nu} \right) u(p_i, s_i)$$

$A_{q,g}(t), B_{q,g}(t), C_{q,g}(t),$ and $\bar{C}_{q,g}(t)$ are the quark and gluon GFFs of the nucleon



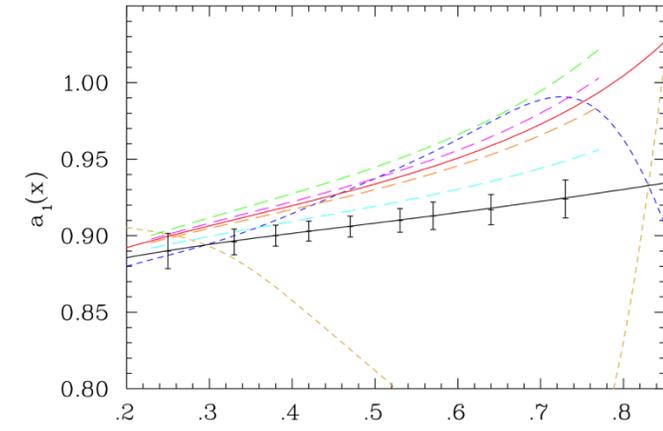
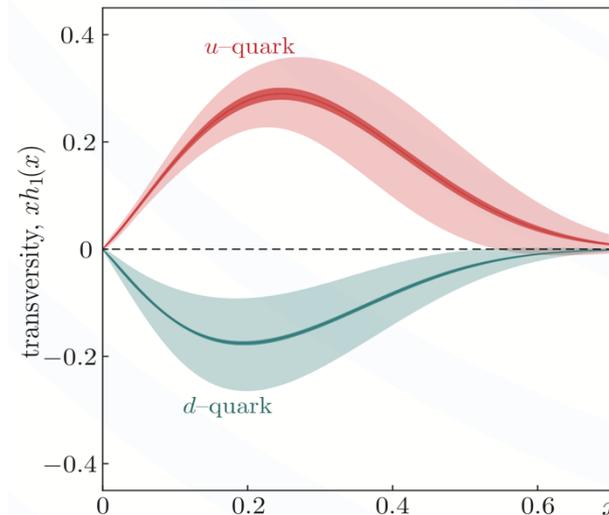
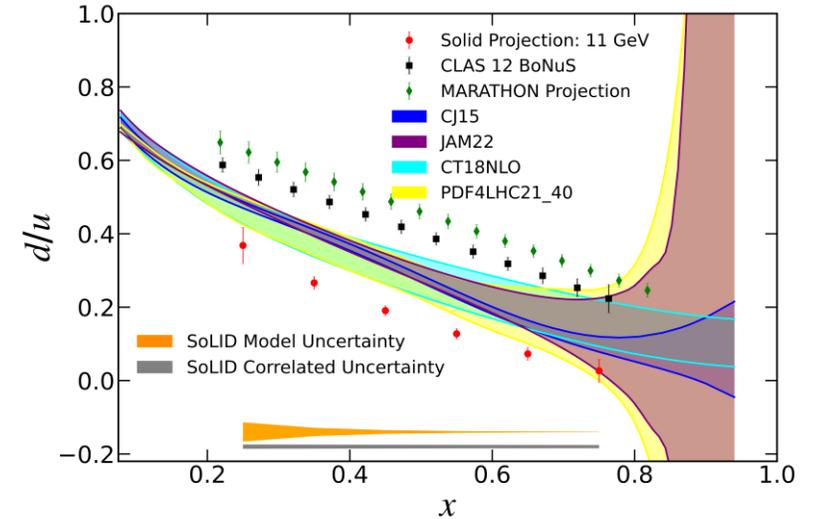
SoLID Experimental Program: Near Threshold J/ψ



Precision at high t critical constrain extrapolation uncertainties

Summary and Conclusion

- SoLID: A **large acceptance** device which can handle **very high luminosity** to allow full exploitation of JLab 12 GeV potential
- SoLID has a rich and vibrant science program
- 7 SoLID experiments approved by PAC
 - high rating (6 A, 1 A-)
- 2023: Long Range Plan, SoLID highlighted, one of the recommendations
- 2024: Facility Review: Ready to Launch



Thank You

SoLID PVDIS: Deuteron

Title: Precision Measurement of Parity-Violation in Deep Inelastic Scattering over a Broad Kinematic Range

Spokespersons: P. Souder (contact), X. Zheng, P. E. Reimer

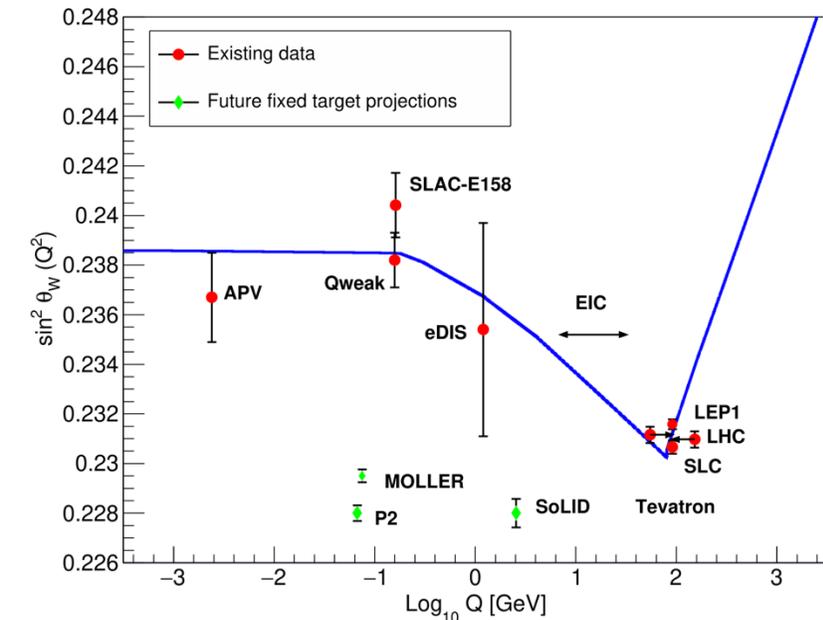
- Dominant uncertainties: experimental systematics

Polarimetry	0.4
Q^2	0.2
Radiative Corrections	0.2
Event Reconstruction	0.2

- Able to measure A_{PV} to sub-percent level precision

$$A_{PV}^{\text{data}} = A_{PV,(d)}^{\text{SM}} \left(1 + \frac{\beta_{\text{HT}}}{(1-x)^3 Q^2} + \beta_{\text{CSV}} x^2 \right),$$

$\longrightarrow \sin^2 \theta_w(Q^2)$



Parity Violation DIS

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

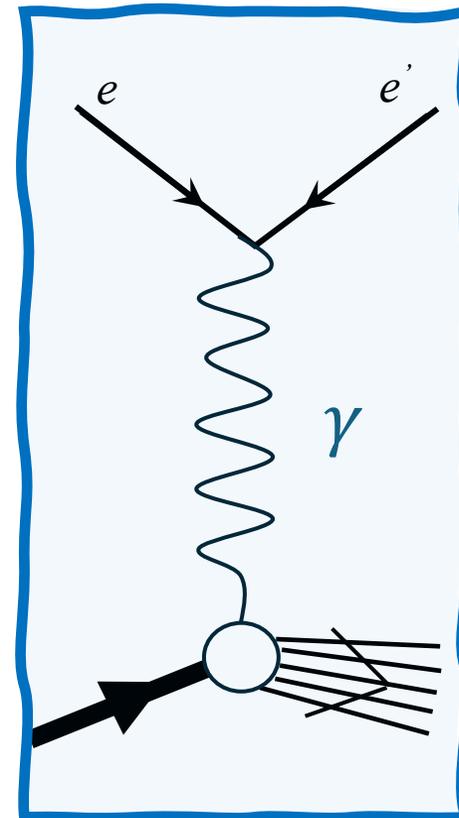
A_{PV} is due to the interference between electromagnetic and weak interaction

$$\sigma_R \propto |M_{EM} + M_Z^R|^2$$

$$\sigma_L \propto |M_{EM} + M_Z^L|^2$$

$$A_{PV} \sim \frac{M_Z^R - M_Z^L}{M_{EM}}$$

EM Interaction
Parity conserving



Weak Interaction
Parity violating

