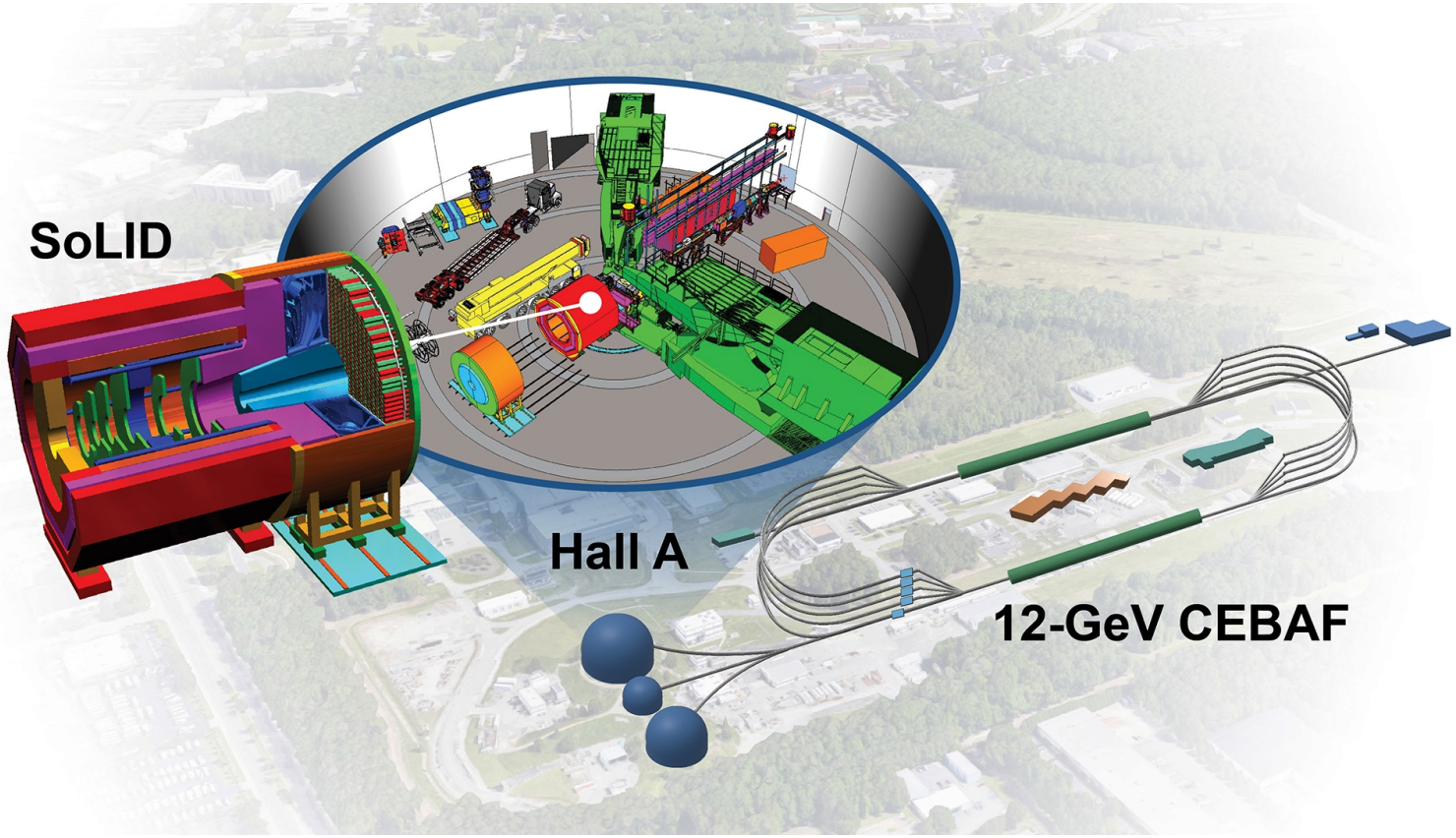
# SoLID Physics Overview




Hall A Winter
Collaboration Meeting

January 21-22, 2026

SoLID
SOLENOIDAL LARGE INTENSITY DEVICE

Xiaochao Zheng

University of Virginia

(for the SoLID Collaboration)

solid.jlab.org

2022 SoLID white paper:
https://arxiv.org/abs/2209.13357
(J.Phys.G 50 (2023) 11, 110501)

# Experimental Frontier of QCD Studies

Proton's 1D structure after four decades of study

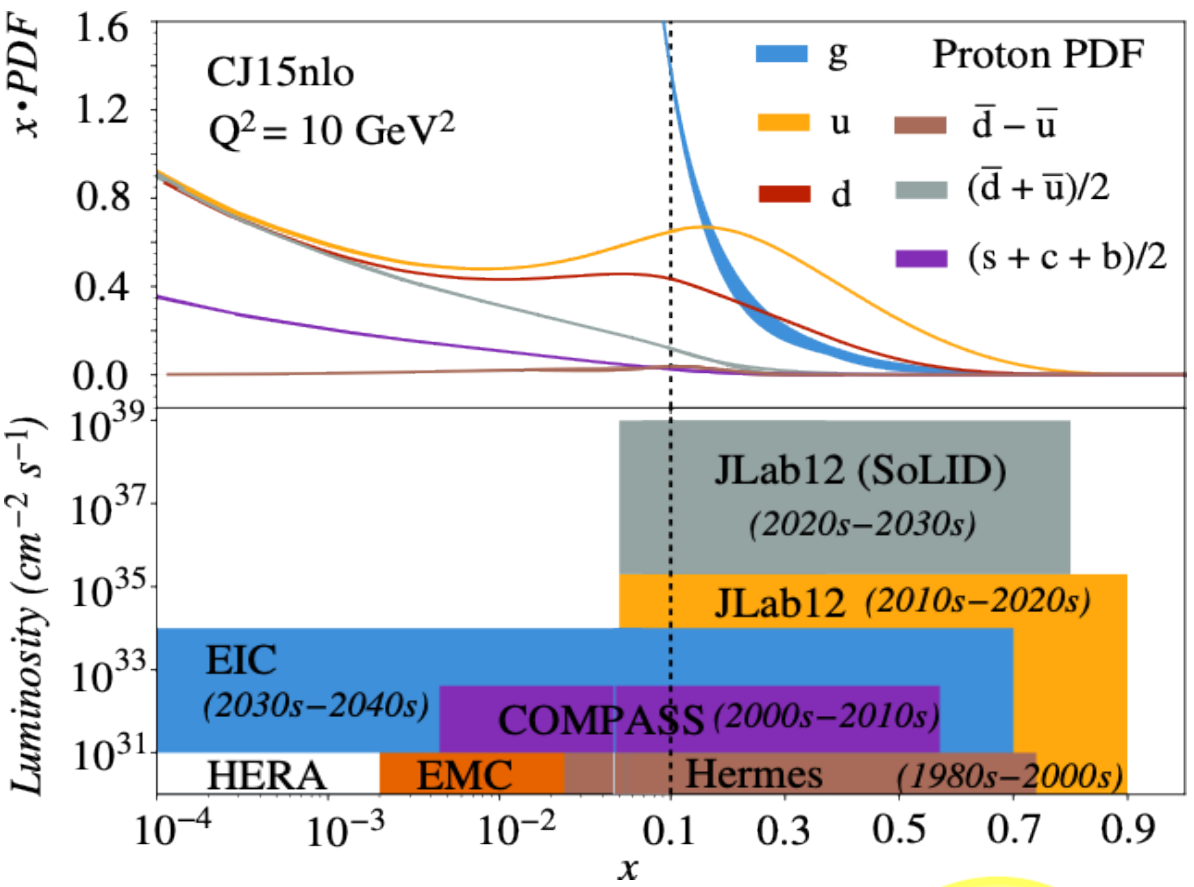
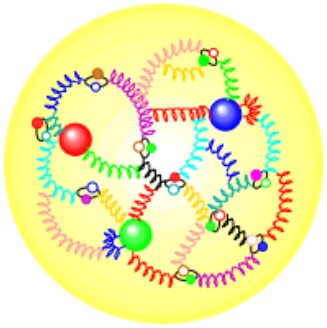
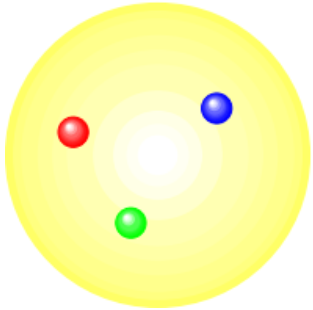



Figure from JLab12 GeV WP, J. Arrington et al., Prog. Part. Nucl. Phys. 127 (2022) 103985, adapted for the SoLID 2022 WP.





Haiyan Gao (Duke), Zein-Eddine Meziani (ANL)

https://www.innovationnewsnetwork.com/quantum-chromodynamics-at-the-intensity-frontier-with-a-precision-microscope/52920/

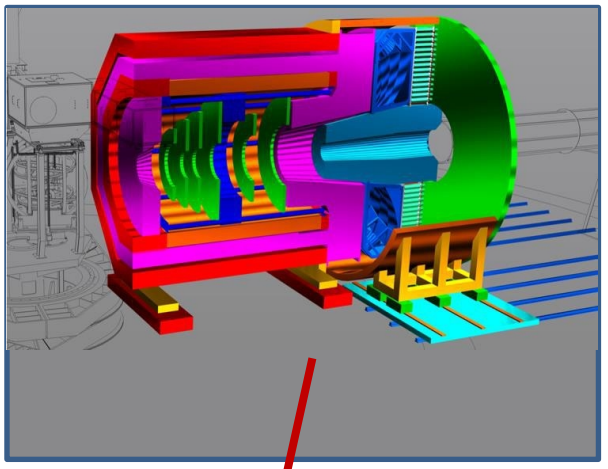
# SoLID as the Next-Generation Spectrometer

SoLID ***maximize*** the science return of the 12-GeV CEBAF upgrade. It will measure small cross sections and asymmetries with high or meaningful precision by combining:

**High Luminosity**
$10^{37\text{-}39}$ /(cm$^2$·s)
[ >100x CLAS12 ][ >1000x EIC ]

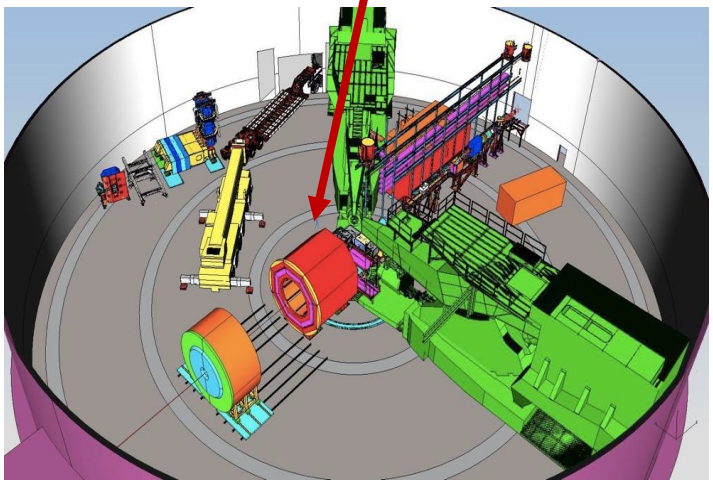
+

**Large Acceptance**
Full azimuthal $\phi$ coverage



Three pillars of the SoLID Science program:

- Imaging the proton **spin** from 1D (PDF) to 3D or more in SIDIS
- J/Psi threshold studies to probe the proton **mass** and gluonic field
- High precision PVDIS and test of the **electroweak** Standard Model



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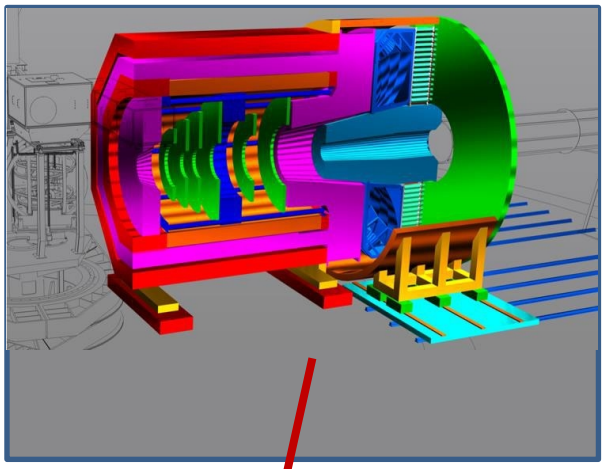

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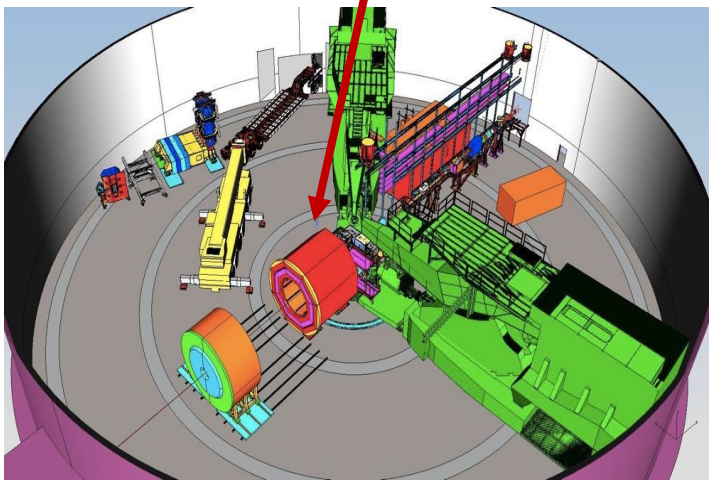
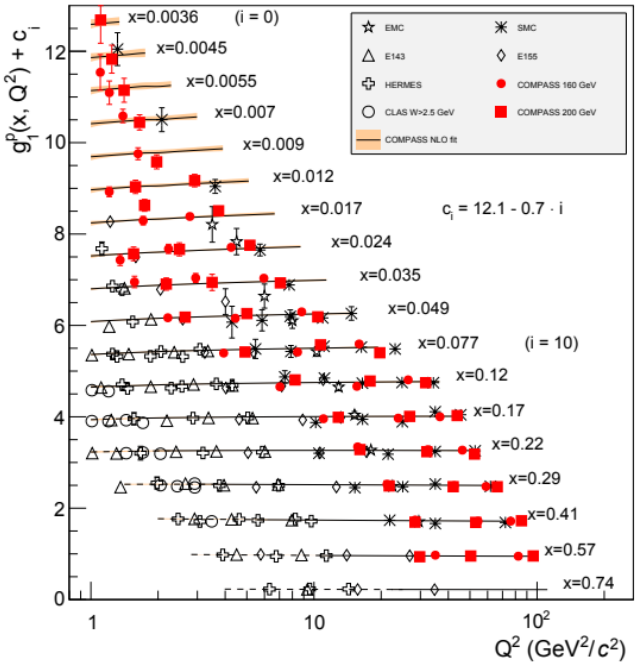
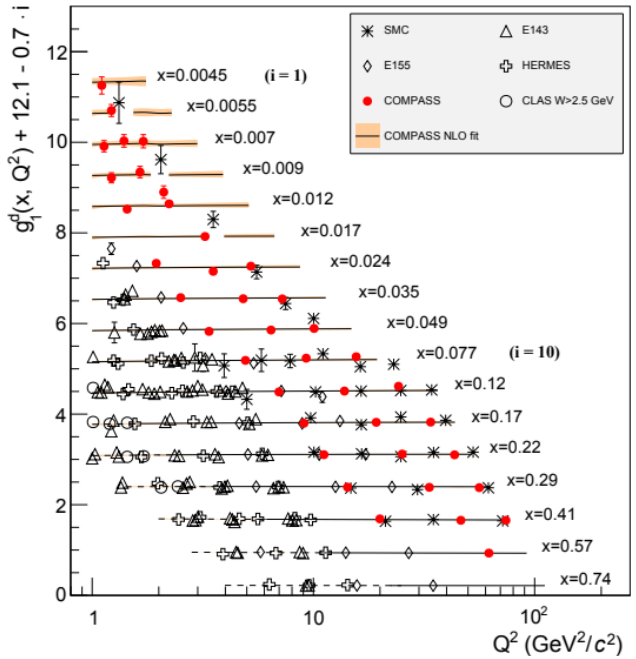


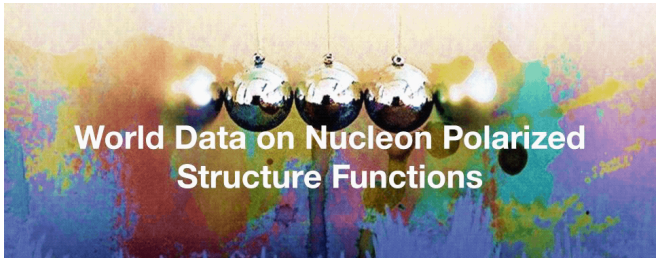
SoLID will measure processes never measured before:

- New observables: Beam-normal single-spin asymmetry (SSA) in DIS
- Deep exclusive processes – DDVCS, etc.
-

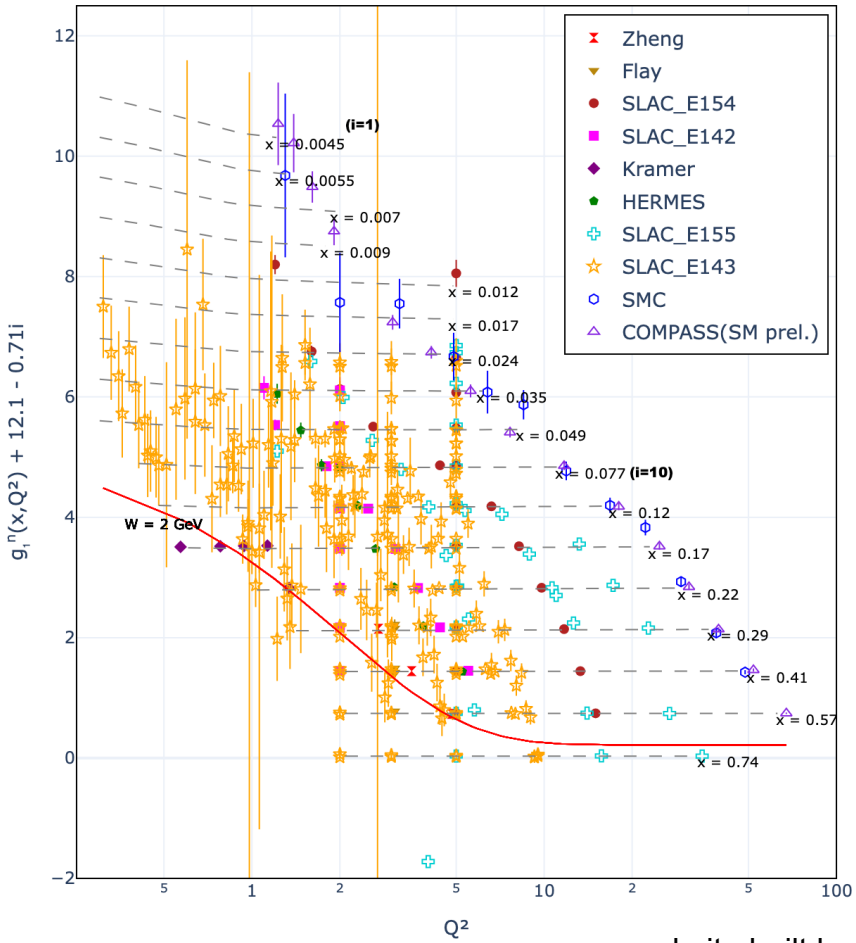
# SIDIS and TMDs – Nuclear Spin Structure from 1D to 3D




$g_1^n(x,Q^2)$ vs $Q^2$




website built by Scarlett Morse (UVA):
https://qnz3gx.github.io/sim.github.io/

# SIDIS and TMDs – Nuclear Spin Structure from 1D to 3D

Generalized parton distribution (GPD)

Transverse momentum dependent parton distribution (TMD)

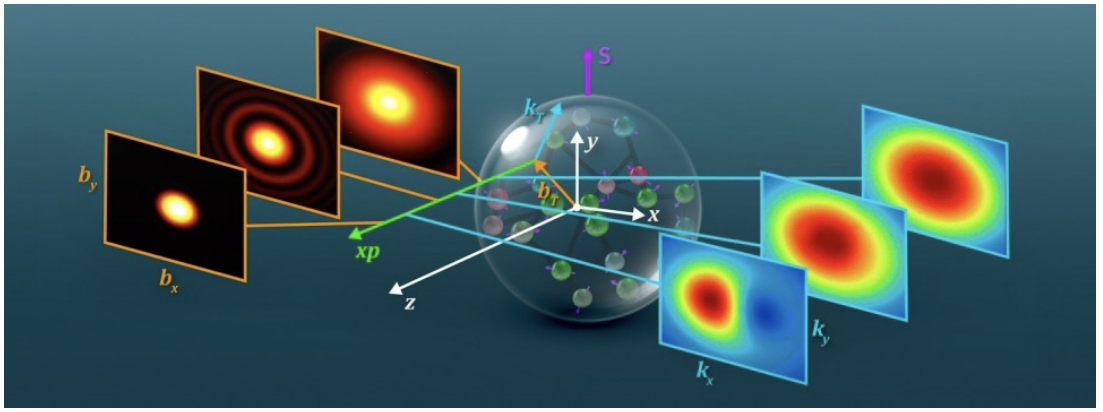
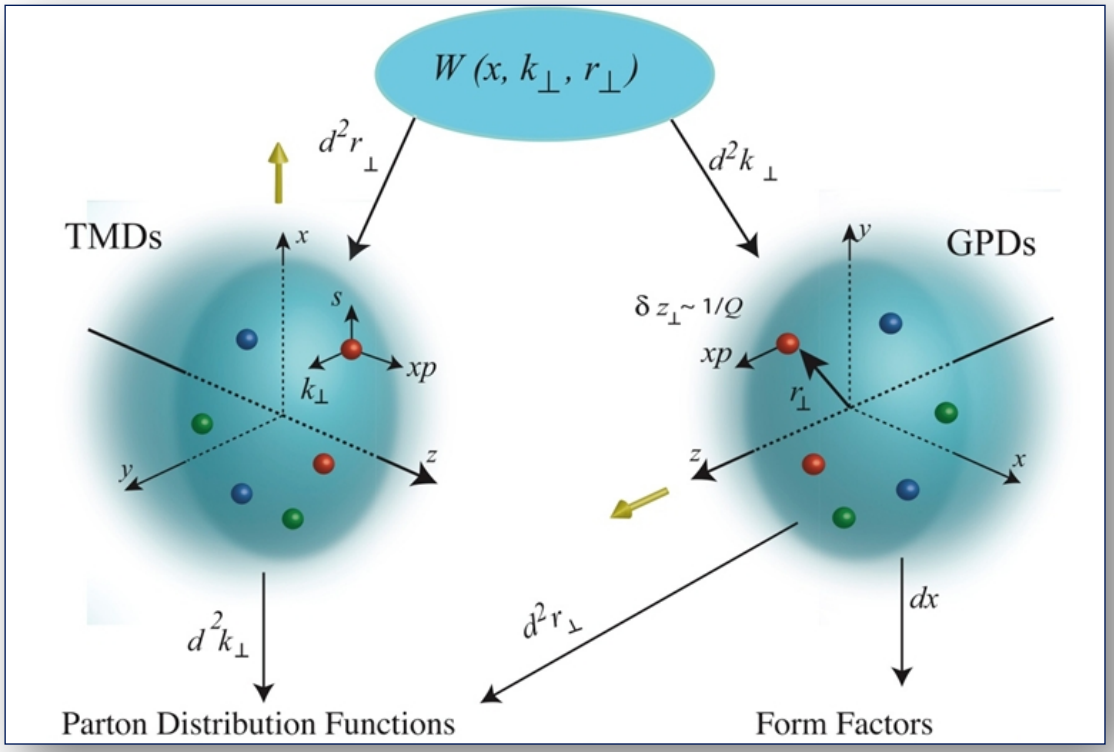



Image from 2023 NSAC LRP




Wigner distributions:
X.D. Ji, PRL91, 062001 (2003);
Belitsky, Ji, Yuan, PRD69,074014 (2004)

Image from J. Dudek et al.,
EPJA 48,187 (2012)

# SIDIS and TMDs – Nuclear Spin Structure in 3D

$$\vec{p}\left(e,e'\pi^{\pm}\right)X$$

$$^{3}\vec{He}\left(e,e'\pi^{\pm}\right)X$$

– hadron in final state "tags" transverse motion of quarks inside the proton/neutron

Leading Twist TMDs

: Nucleon Spin  : Quark Spin

| Nucleon Polarization | Quark polarization: Un-Polarized (U) | Longitudinally Polarized (L) | Transversely Polarized (T) |
|---|---|---|---|
| U | $f_1$ = | | $h_1^{\perp}$ = Boer-Mulder |
| L | | $g_1$ = Helicity | $h_{1L}^{\perp}$ = Worm gear |
| T | $f_{1T}^{\perp}$ = Sivers | $g_{1T}^{\perp}$ = Worm gear | $h_{1T}$ = Transversity; $h_{1T}^{\perp}$ = Pretzelosity |

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

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

$A_{UT}^{\text{Collins}} \propto h_1 \otimes H_1^{\perp}$ ← Collins fragmentation function from $e^+e^-$ collisions

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

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

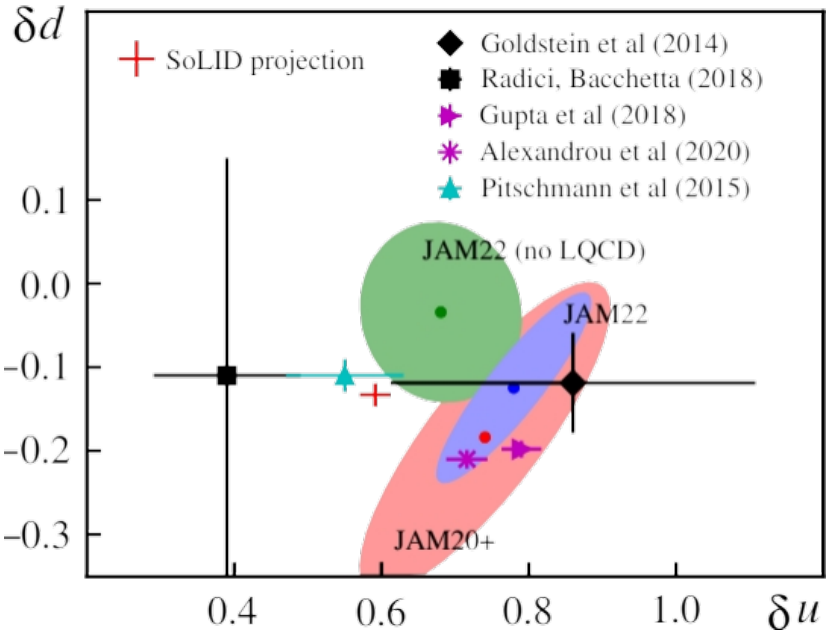
slide material from H. Gao

Good momentum and angular resolutions **in 4-D binning** over the kinematic variables (x, z, $Q^2$, $P_T$)

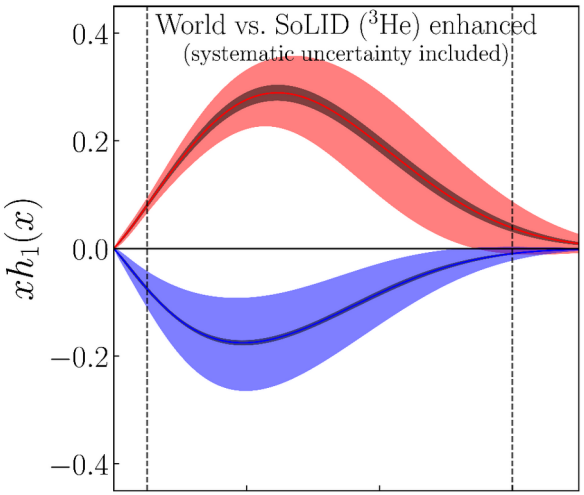
# SoLID for JLab Hall A – SIDIS and TMDs

## Compare SoLID 3He with World Data

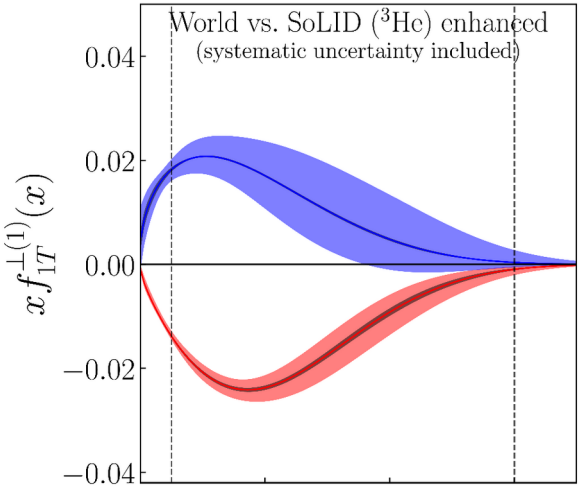
- Fit Collins and Sivers asymmetries in SIDIS and e+e- annihilation
- World data from HERMES, COMPASS
- e+e- data from BELLE, BABAR, and BESIII
- Monte Carlo method is applied
- Including both systematic and statistical uncertainties




### Transversity




### Sivers




SoLID enhanced = SoLID approved by the PAC

also see Z. Ye et al., Phys. Lett. B767 (2017) 91-98

## Nucleon tensor charge

- Nucleon tensor charge as important as its other static properties – electric charge, mass, spin
- chiral-odd, unique for quarks, no mixing with gluons

$$g_T^q = \int_0^1 \left[h_1^q(x) - h_1^{\bar{q}}(x)\right] dx.$$

# SIDIS Primary and RunGroup Proposals

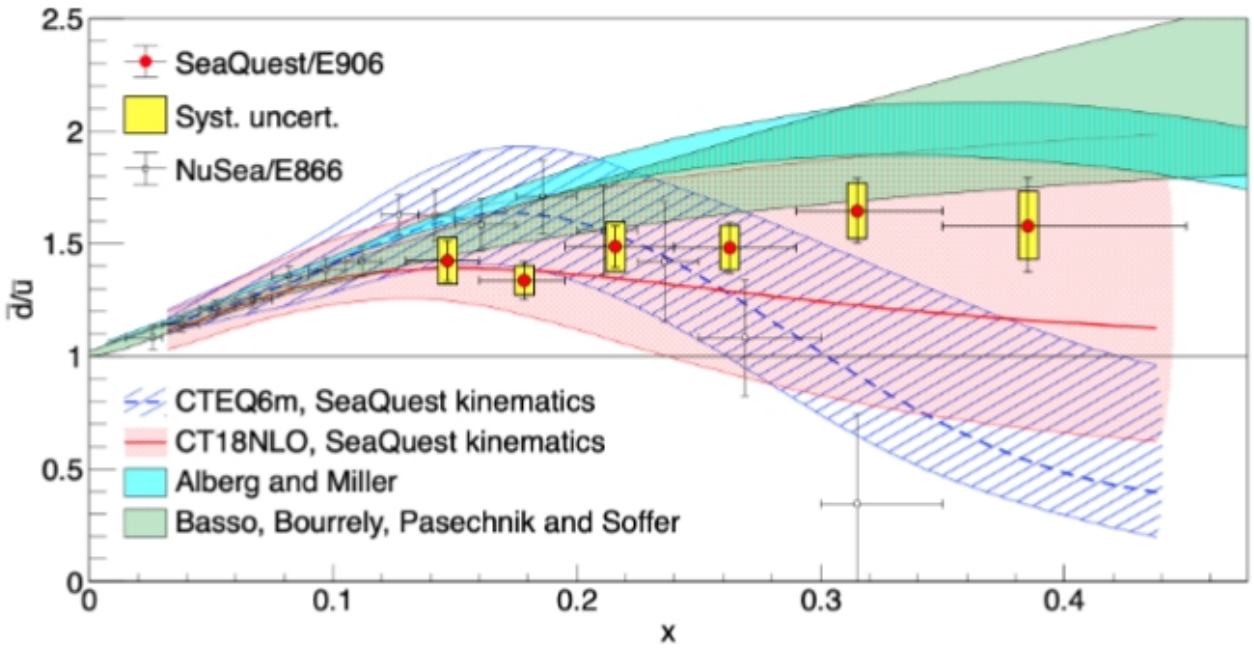
**E12-10-006:** Single Spin Asymmetries on Transversely Polarized $^3$He @ 90 days
**Rating A** Spokespersons: J.P. Chen, H. Gao (contact), J.C. Peng, X. Qian

**E12-11-007:** Single and Double Spin Asymmetries on Longitudinally Polarized $^3$He @ 35 days
**Rating A** Spokespersons: J.P. Chen (contact), J. Huang, W.B. Yan

**E12-11-108:** Single Spin Asymmetries on Transversely Polarized Proton @ 120 days
**Rating A** Spokespersons: J.P. Chen, H. Gao (contact), X.M. Li, Z.-E. Meziani

- SIDIS Dihadron with Transversely Polarized $^3$He
  - J.-P. Chen, A. Courtoy, H. Gao, A. W. Thomas, Z. Xiao, J. Zhang (E12-10-006A)
- SIDIS in Kaon Production with Transversely Polarized $^3$He
  - T. Liu, S. Park, Z. Ye, Y. Wang, Z.W. Zhao (E12-10-006D)
- Ay with Transversely Polarized $^3$He
  - T. Averett, A. Camsonne, N. Liyanage (E12-10-006A)
- $g_2^n$ and $d_2^n$ with Transversely and Longitudinally Polarized $^3$He
  - C. Peng, Y. Tian (E12-10-006E)
- Deep exclusive Production with Transversely Polarized $^3$He
  - Z. Ahmed, G. Huber, Z. Ye (E12-10-006B)
- Timelike Compton TCS circular polarized beam and unpolarized LH2 target
  - M. Boer, P. Nadel-Turonski, J. Zhang, Z. Zhao (E12-12-006A)
- Measurement of the Unpolarized SIDIS Cross Section from a $^3$He Target with SoLID
  - U. D'Alesio, M. Cerutti, H. Gao, S. Jia, V. Khachatryan, Y. Tian (E12-11-007B/E12-10-006F)
- Studying the Light Sea Quark Asymmetry with Longitudinally Polarized 3He
  - in progress

# SIDIS Primary and RunGroup Proposals




$^3$He @ 90 days
X. Qian

lly Polarized $^3$He @ 35 days

Proton @ 120 days
E. Meziani

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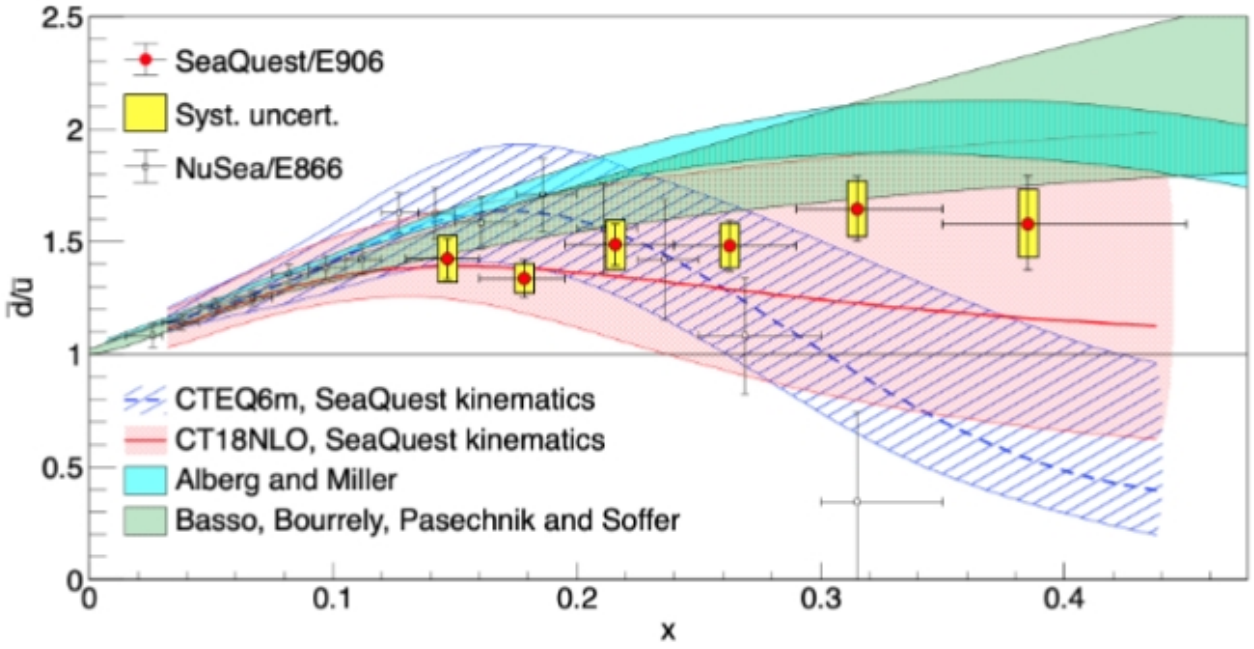
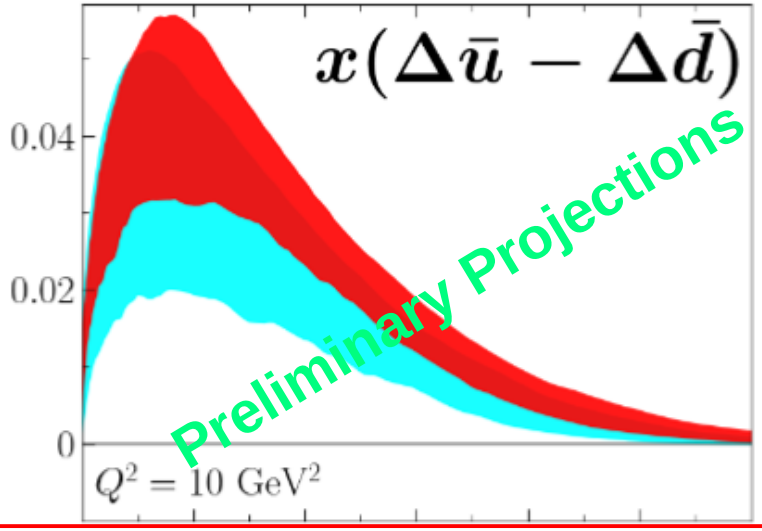
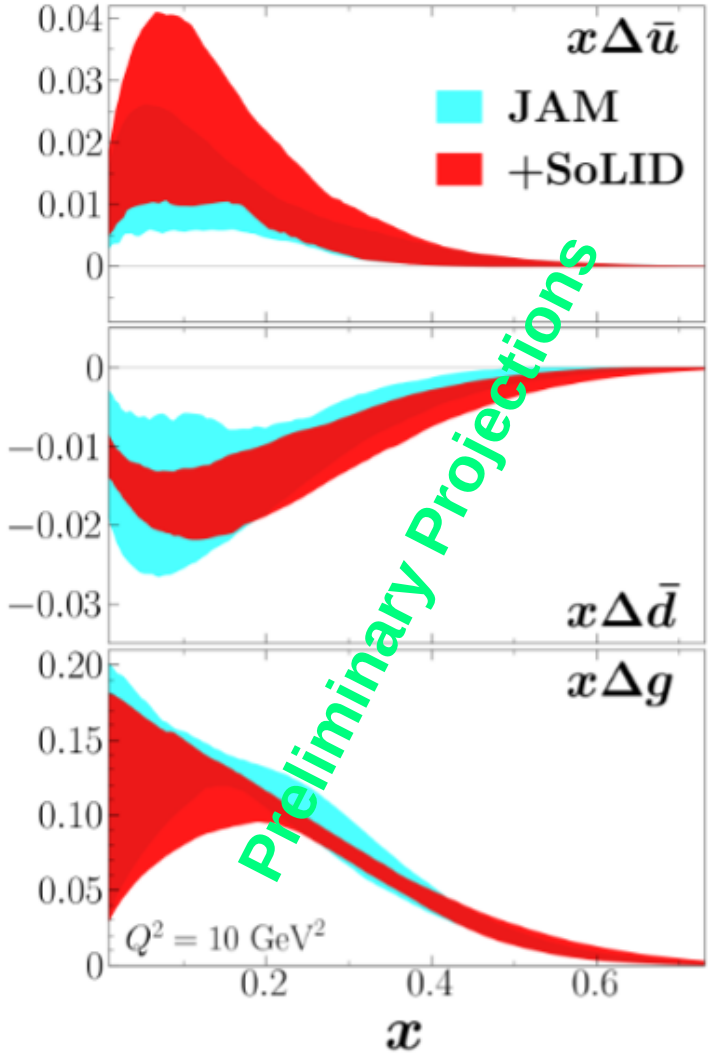
# SIDIS Primary and RunGroup Proposals




- Studying the Light Sea Quark Asymmetry with Longitudinally Polarized 3He
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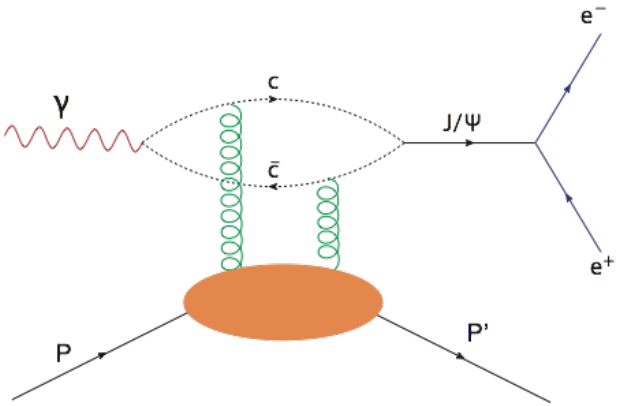
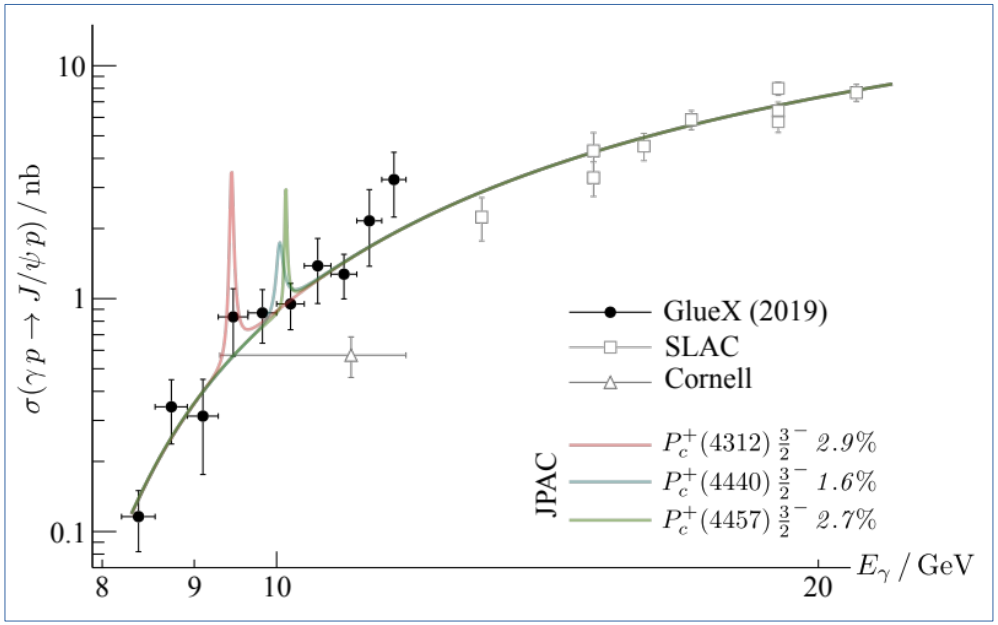
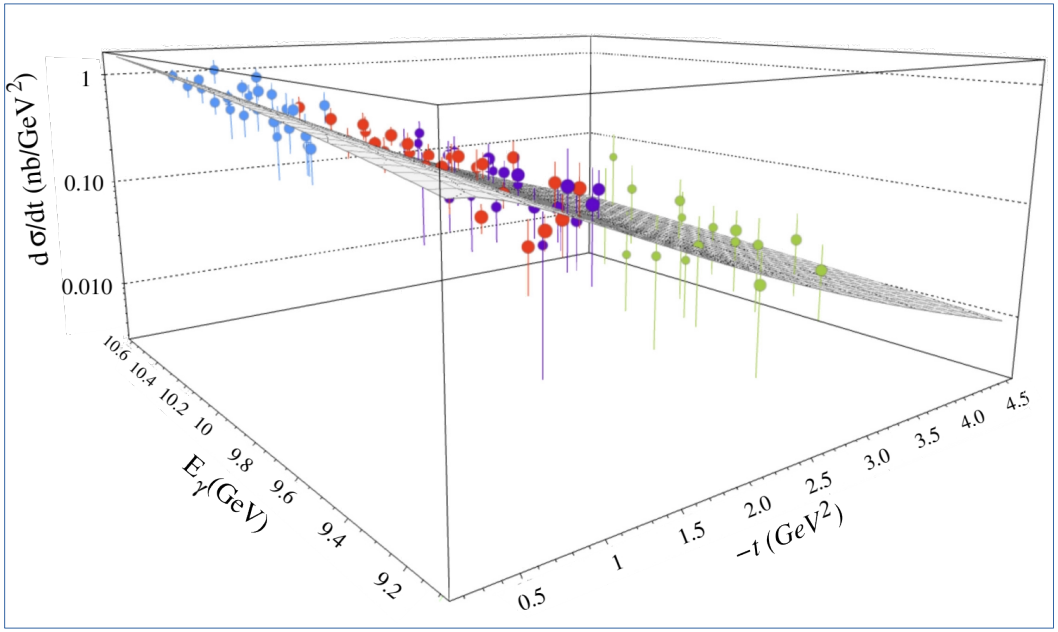
# SoLID for JLab Hall A – J/Psi Threshold Production

- Origin of the proton mass – a prominent topic in contemporary hadronic physics
- Quarkonium production near threshold uniquely sensitive to the non-perturbative gluonic structure of the proton
- Existing measurement by GlueX and Hall C J/psi E12-16-007, probing gluonic gravitational form factors (GFF) of the proton




GlueX: A. Ali *et al.*, Phys. Rev. Lett. 123, 072001(2019)

E12-16-007 see: B. Duran et al., Nature 615, 813-816 (2023)

Figure provided by S. Joosten, see QCD white paper, P. Achenbach et al., Nucl.Phys.A 1047 (2024) 122874

# SoLID for JLab Hall A – J/Psi Threshold Production

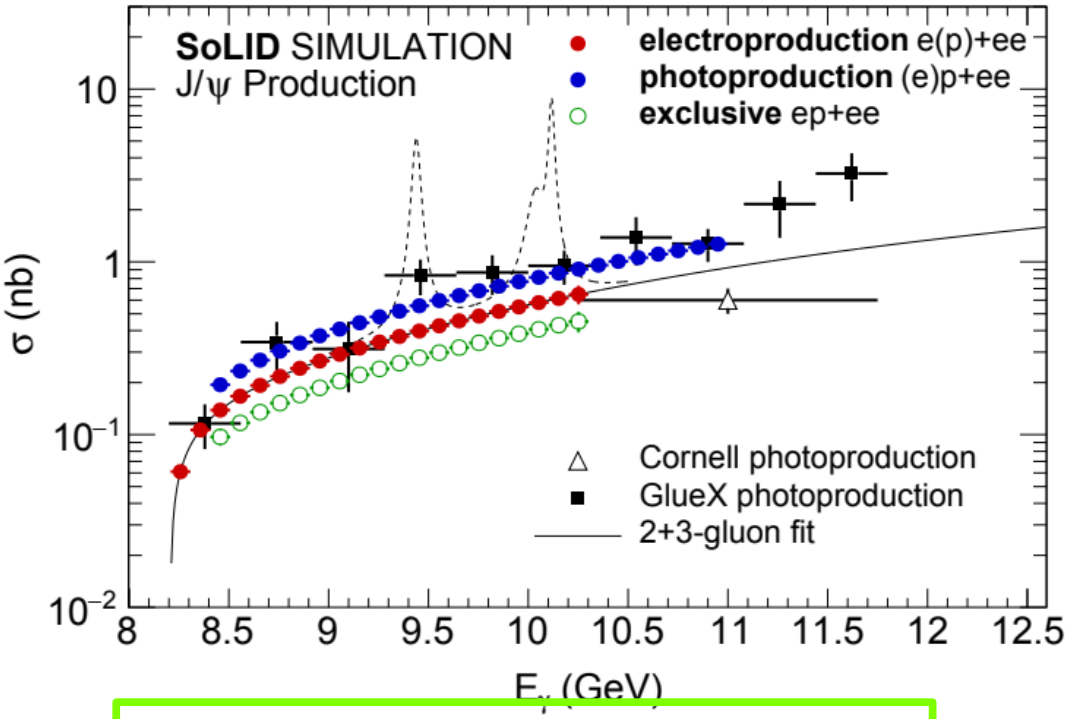
50 (+10) days of 3uA beam on a 15-cm LH2 target

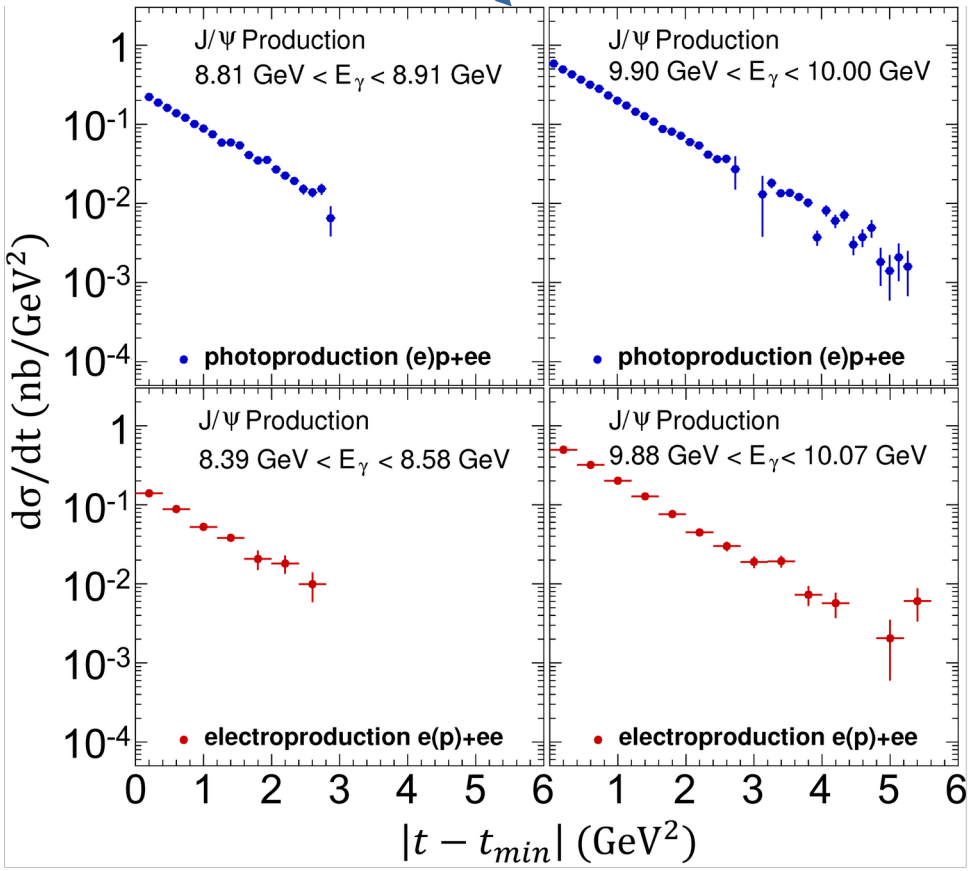
$1 \times 10^{37} \mathrm{cm}^{-2}\mathrm{s}^{-1}$

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

- Electroproduction trigger: e, e-e+
- Photoproduction trigger: p, e-e+
- additional 4-fold coin trigger: ep,e-e+
- and (inclusive) 2-fold coin trigger: e+e-

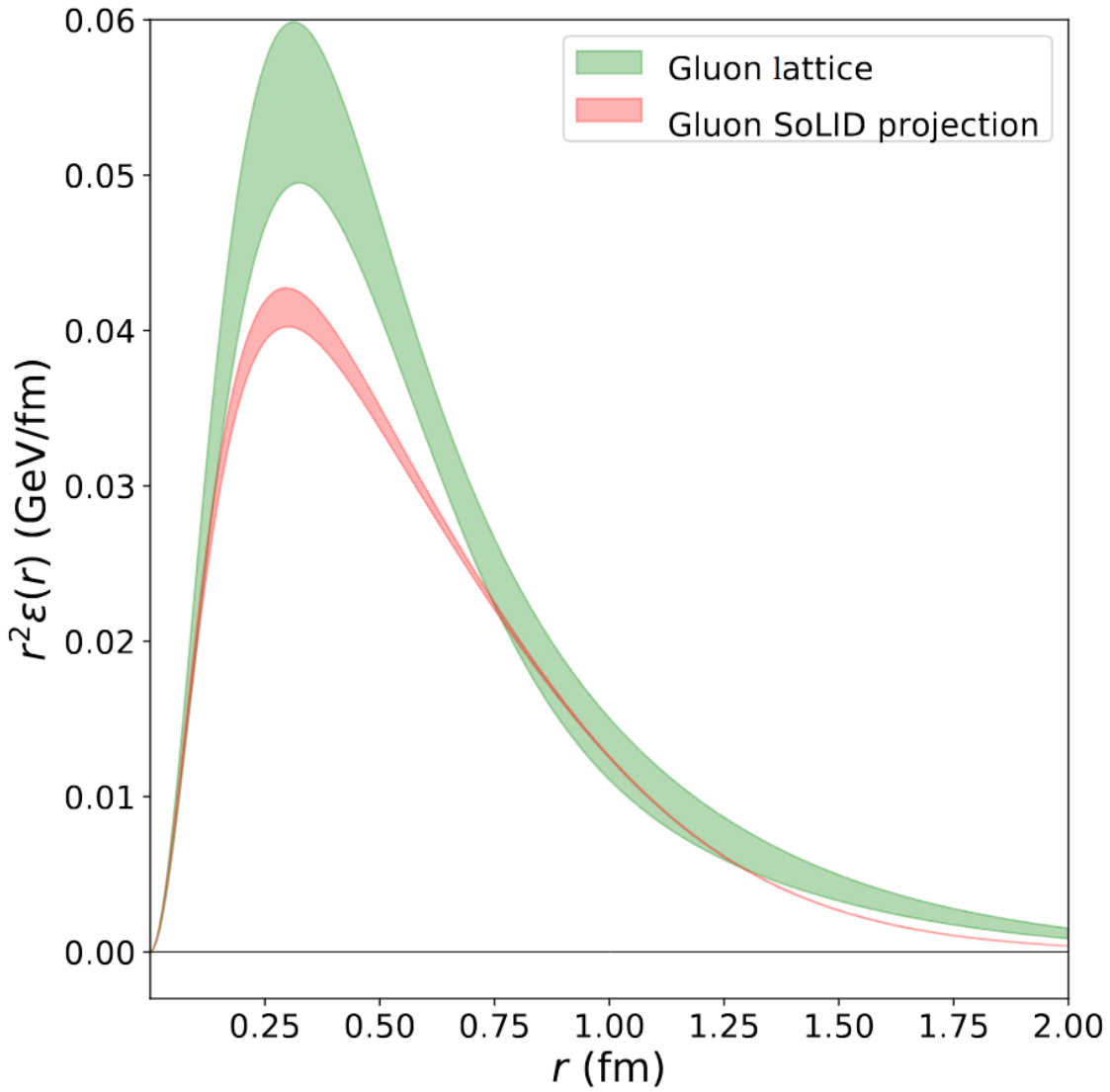
- SoLID allows for study of J/psi production in more than 1D;
- Each graph corresponds to one point on the left




Figures from SoLID 2022 WP

# SoLID for JLab Hall A – J/Psi Threshold Production




- Extraction of the gluon mass density from simulated precision data of SoLID.
- A similar impact can be shown for the scalar density.

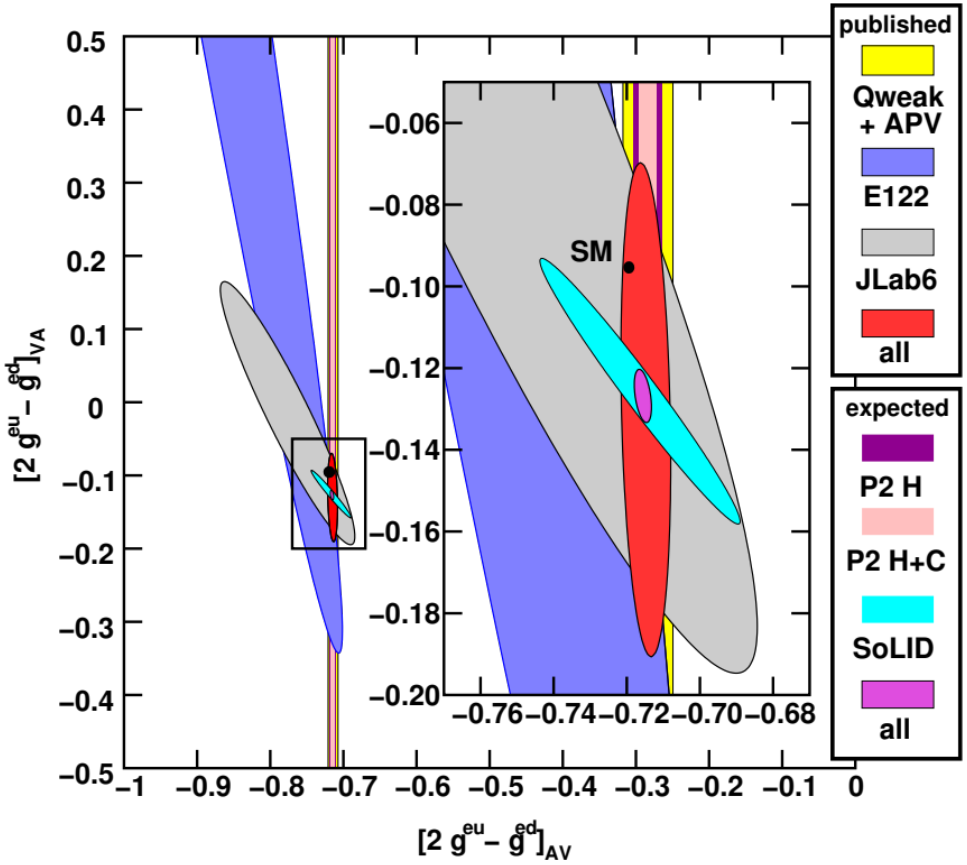
GPD white paper: M. Boer, A. Camsonne, M. Constantinou, et al., arXiv:2512.15064

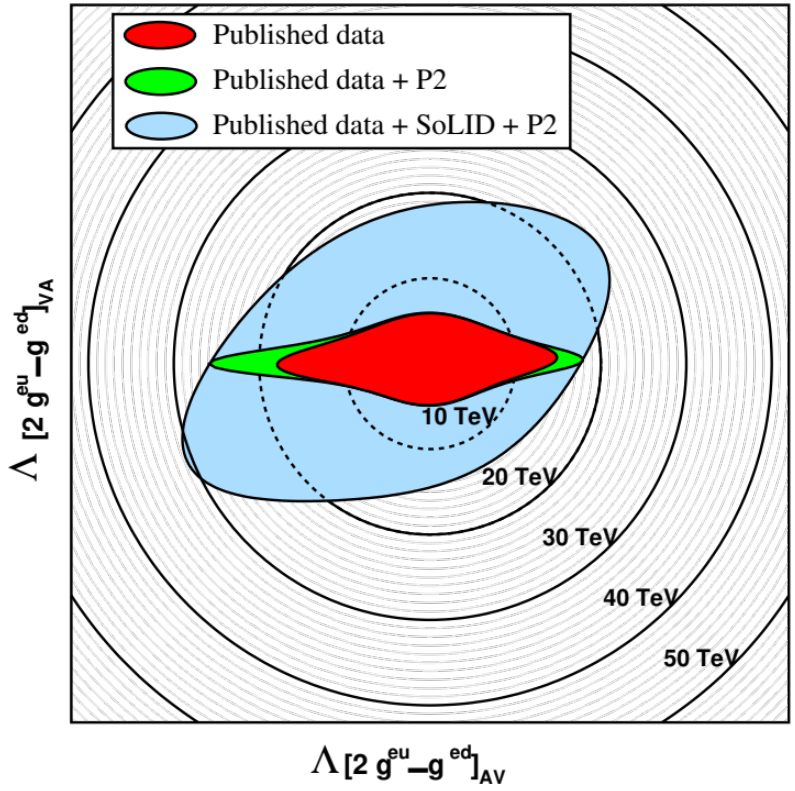
# SoLID for JLab Hall A – Parity-Violating DIS

- BSM Physics has large phase space, precision measurements would point the way
- PVDIS deuteron measurement access effective electron-quark couplings

$$\mathcal{L}_{\rm NC}^{eq} = \frac{1}{2v^2}\left(\bar{e}\gamma^\mu\gamma^5 e\sum_{q=u,d} g_{AV}^{eq}\bar{q}\gamma_\mu q + \bar{e}\gamma^\mu e\sum_{q=u,d} g_{VA}^{eq}\bar{q}\gamma_\mu\gamma^5 q\right)$$

$$A_{RL,d}^{\rm DIS} \approx \frac{3}{20\pi\alpha}\frac{Q^2}{v^2}\left[(2g_{AV}^{eu} - g_{AV}^{ed}) + (2g_{VA}^{eu} - g_{VA}^{ed})\frac{1-(1-y)^2}{1+(1-y)^2}\right]$$



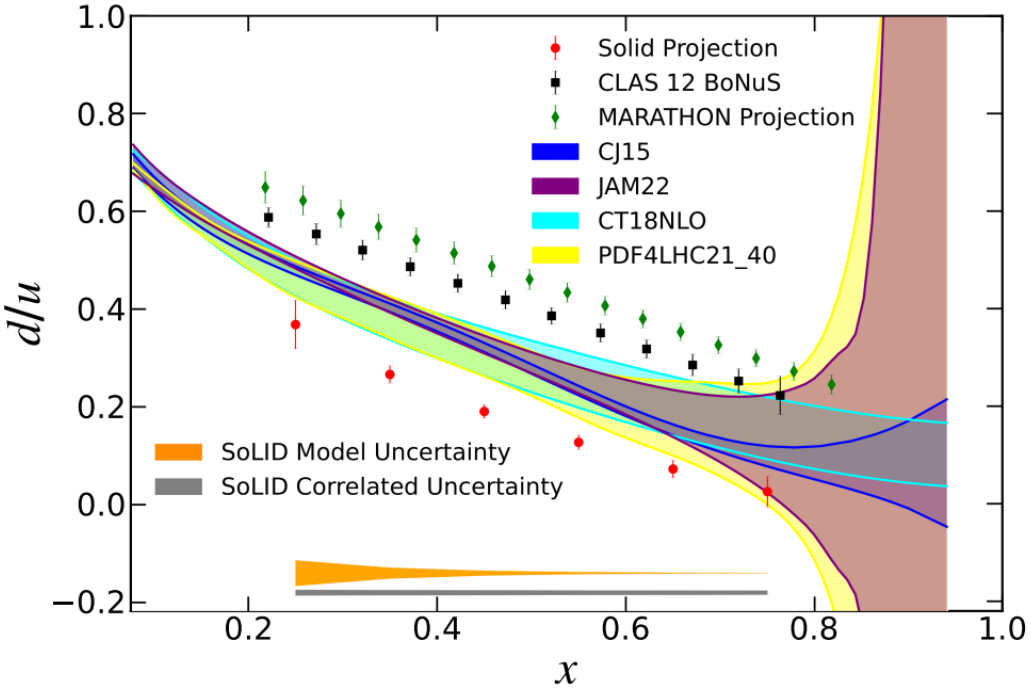




$$\frac{G_F}{\sqrt{2}}g_{ij} \rightarrow \frac{G_F}{\sqrt{2}}g_{ij} + \eta_{ij}^q\frac{4\pi}{(\Lambda_{ij}^q)^2}$$

# SoLID for JLab Hall A – Parity-Violating DIS

- PVDIS proton measurement access PDF d/u at high x, without the need of nuclear model

$$A_{RL,p}^{\mathrm{DIS}} \approx \frac{1}{4\pi\alpha}\frac{Q^2}{v^2}\left[\frac{12\,g_{AV}^{eu} - 6\,g_{AV}^{ed}\,d/u}{4 + d/u}\right]$$




Figures from SoLID 2022 WP

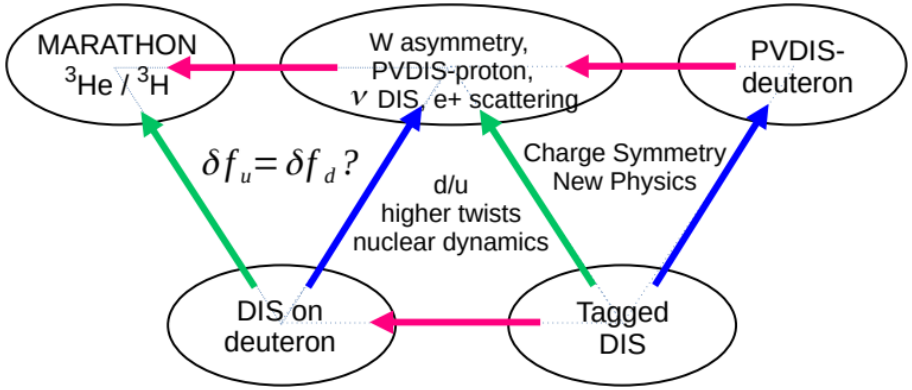
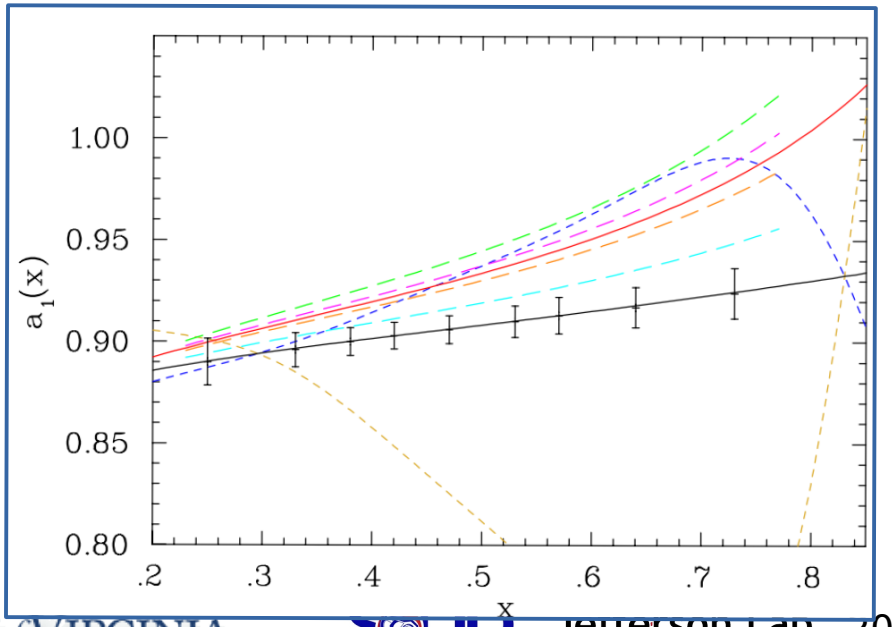



Figure from A. Accardi,
INT workshop on PVDIS at JLab 12 GeV (2022)

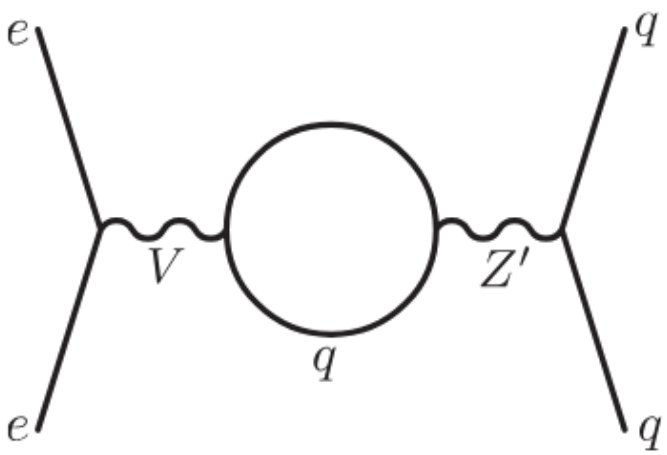
- PVDIS $^{48}$Ca access flavor dependence of EMC effect

$$a_1 \simeq \frac{9}{5} - 4\sin^2\theta_W - \frac{12}{25}\frac{u_A^+ - d_A^+}{u_A^+ + d_A^+}$$



# New Physics Examples from PVDIS – Dark Sector

- Leptophobic Z's: since the photon is only V, Z' needs to be A, thus only affect the VA (C2q) term in Apv




Babu, Kolda and March-Russell, Phys.Rev. D 54 (1996) 4635–4647, [hep-ph/9603212].

Gonzalez-Alonso, Ramsey-Musolf, Phys. Rev. D 87 (2013) 5, 055013 [arXiv:1211.4581].

Buckley, Ramsey-Musolf, Phys. Lett. B 712 (2012)261-265 [ arXiv:1203.1102].

- Dark photons: shift both C1q and C2q.

Thomas, Wang, Williams, Phys. Rev. Lett. 129 (2022) 1, 011807 [arXiv:2201.06760]

$$C_{1q} = C_{1q}^{Z} + \frac{Q^2 + M_Z^2}{Q^2 + M_{A_D}^2} C_{1q}^{A_D} = C_{1q}^{\mathrm{SM}}(1 + R_{1q})$$

$$C_{2q} = C_{2q}^{Z} + \frac{Q^2 + M_Z^2}{Q^2 + M_{A_D}^2} C_{2q}^{A_D} = C_{2q}^{\mathrm{SM}}(1 + R_{2q})$$

# New Physics Examples from PVDIS – Strong PV

- Parity violation in Strong Interaction

QCD Lagrangian is assumed to be invariant under parity transformation. What implications could the presence of strong P-violation cause to inclusive DIS?

Parton model interpretation:

$$F_3^{(\gamma)}(x_B, Q^2) = 0,$$

$$F_3^{(\gamma Z)}(x_B, Q^2) = \frac{1}{\sqrt{1+R^2}} \sum_q 2 e_q g_A^q f_1^{(q-\bar{q})},$$

$$F_3^{(Z)}(x_B, Q^2) = \frac{1}{\sqrt{1+R^2}} \sum_q 2 g_V^q g_A^q f_1^{(q-\bar{q})},$$

slide material from Matteo Cerutti, SoLID June 2023 collaboration meeting

Bacchetta, Cerutti, Manna, Radici, XZ PLB 849 (2024) 138455

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- Parity violation in Strong Interaction

QCD Lagrangian is assumed to be invariant under parity transformation. What implications could the presence of strong P-violation cause to inclusive DIS?

Parton model interpretation:

$$F_3^{(\gamma)}(x_B, Q^2) = 0,$$

$$F_3^{(\gamma Z)}(x_B, Q^2) = \frac{1}{\sqrt{1+R^2}} \sum_q 2 e_q g_A^q f_1^{(q-\bar{q})},$$

$$F_3^{(Z)}(x_B, Q^2) = \frac{1}{\sqrt{1+R^2}} \sum_q 2 g_V^q g_A^q f_1^{(q-\bar{q})},$$

Additional contributions due to new PV parton distributions

$$\Delta F_3^{(\gamma)}(x_B, Q^2) = -\frac{1}{\sqrt{1+R^2}} \sum_q e_q^2 g_1^{\mathrm{PV}(q+\bar{q})},$$

$$\Delta F_3^{(\gamma Z)}(x_B, Q^2) = -\frac{1}{\sqrt{1+R^2}} \sum_q 2 e_q g_V^q g_1^{\mathrm{PV}(q+\bar{q})},$$

$$\Delta F_3^{(Z)}(x_B, Q^2) = -\frac{1}{\sqrt{1+R^2}} \sum_q (g_V^{q2} + g_A^{q2}) g_1^{\mathrm{PV}(q+\bar{q})}$$

slide material from Matteo Cerutti, SoLID June 2023 collaboration meeting

Bacchetta, Cerutti, Manna, Radici, XZ PLB 849 (2024) 138455

# New Physics Examples from PVDIS – Strong PV

- Parity violation in Strong Interaction

QCD Lagrangian is assumed to be invariant under parity transformation. What implications could the presence of strong P-violation cause to inclusive DIS?

Parton model interpretation:

Additional contributions due to new PV parton distributions

Quark Polarization

| Nucleon Pol. | U | L | T |
|---|---|---|---|
| U | $f_1(x)$ | $g_1^{PV}(x)$ | |
| L | | $g_1(x)$ | |
| T | | | $h_1(x)$ |

**How do we look for it?**

slide material from Matteo Cerutti, SoLID June 2023 collaboration meeting

Bacchetta, Cerutti, Manna, Radici, XZ PLB 849 (2024) 138455

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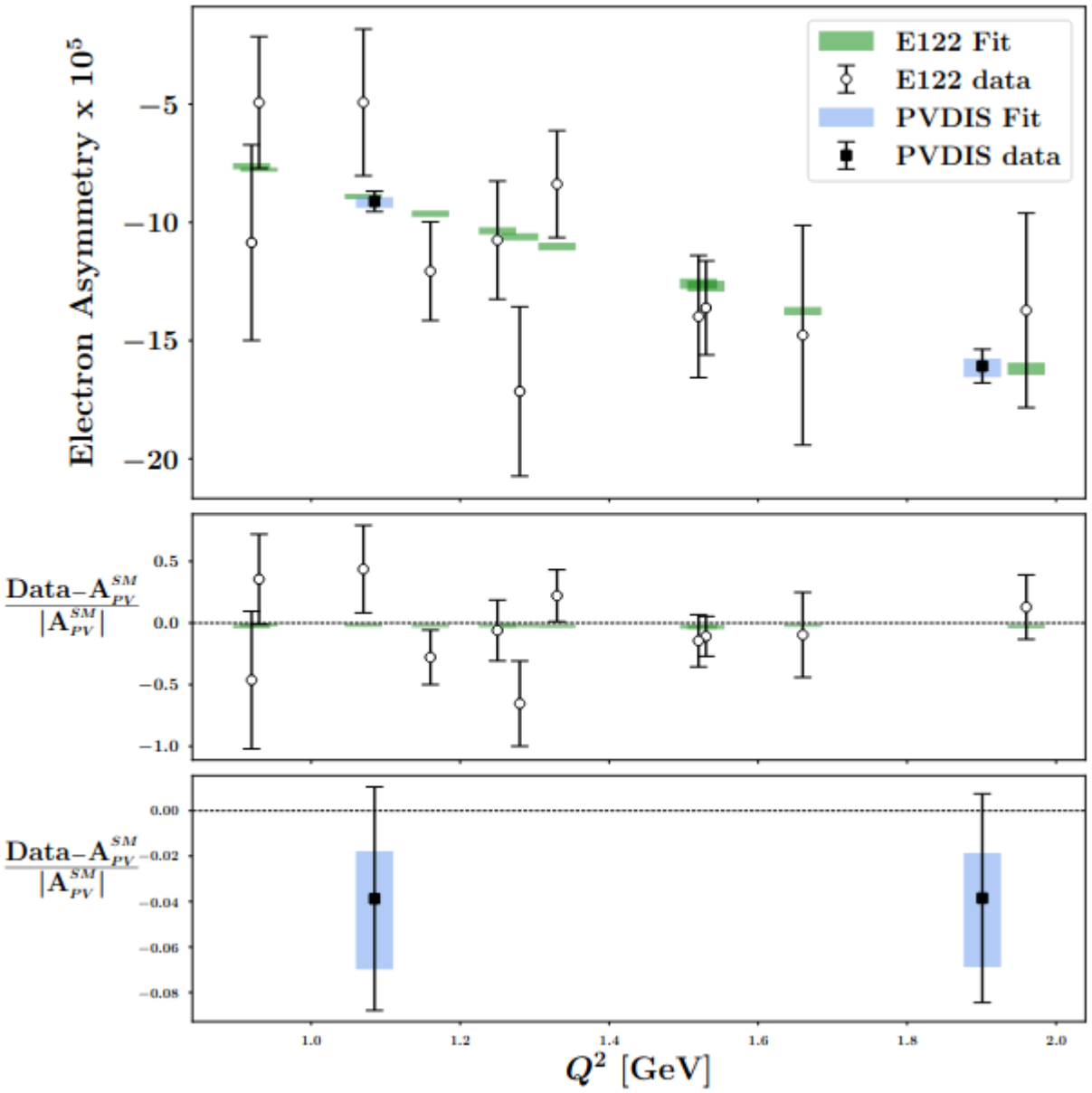
**How do we look for it?** Originally we thought we needed positrons. After a couple of months, we realized we can simply use PVDIS Asymmetry!

$$A_{\mathrm{PV}} \equiv \frac{d\sigma(\lambda=1)-d\sigma(\lambda=-1)}{d\sigma(\lambda=1)+d\sigma(\lambda=-1)} \quad \text{with} \quad g_1^{\mathrm{PV}}(x) = \alpha\, g_1(x)$$

# New Physics Examples from PVDIS – Strong PV




$$g_1^{\mathrm{PV}}(x) = \alpha\ g_1(x)$$

Baseline:

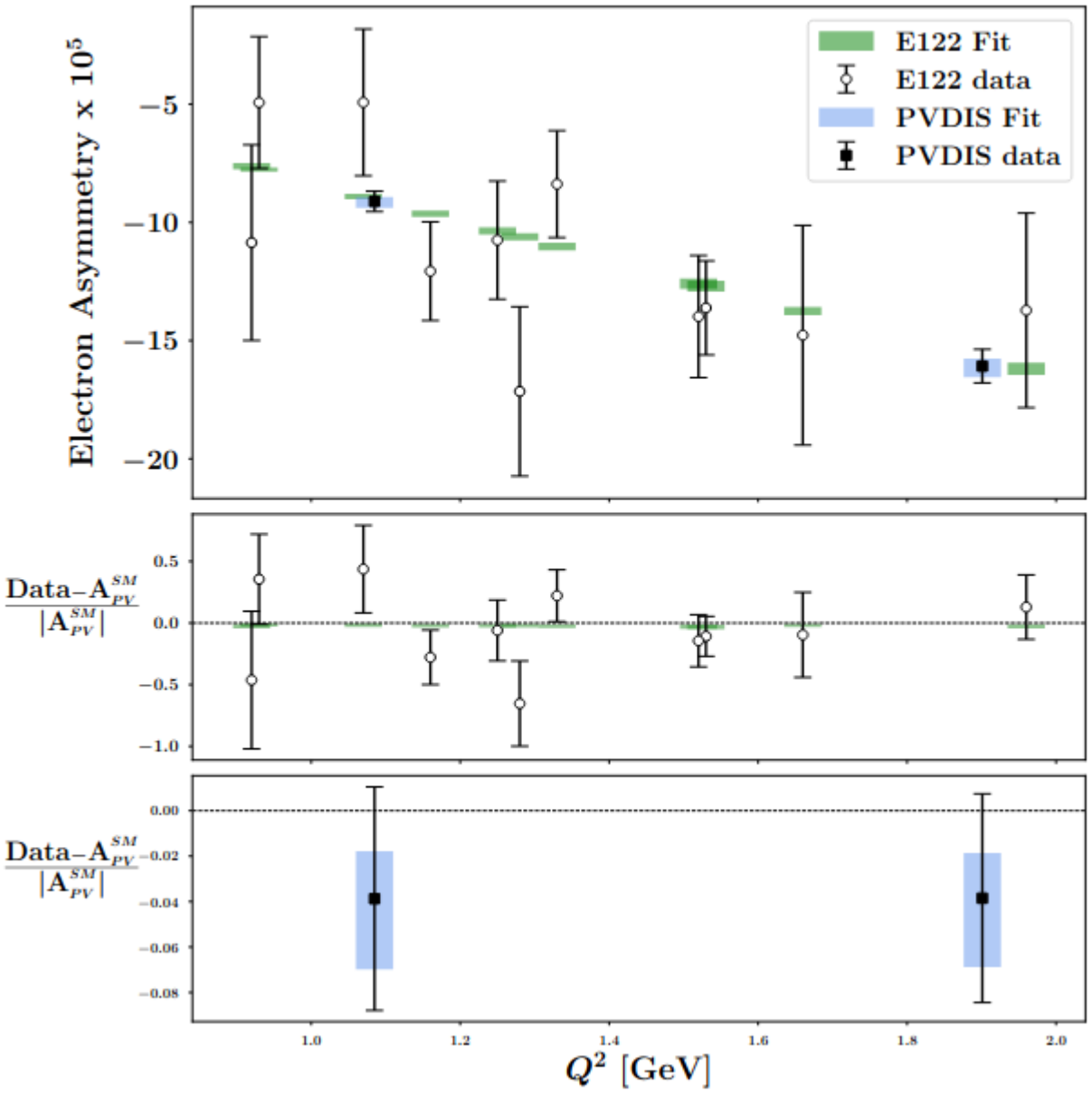
$$\alpha = (-1.01 \pm 0.66) \times 10^{-4}$$

If true, this would indicate there are more left-handed than right-handed quarks in an unpolarized nucleon, i.e. that parity symmetry is slightly broken in the structure of the nucleon.

slide material from Matteo Cerutti, SoLID June 2023 collaboration meeting

Bacchetta, Cerutti, Manna, Radici, XZ PLB 849 (2024) 138455

# New Physics Examples from PVDIS – Strong PV




$$g_1^{\mathrm{PV}}(x) = \alpha\ g_1(x)$$

Baseline:

$$\alpha = (-1.01 \pm 0.66) \times 10^{-4}$$

With SoLID (d):

$$\alpha = (-1.01 \pm 0.21) \times 10^{-4}$$

With SoLID (p):

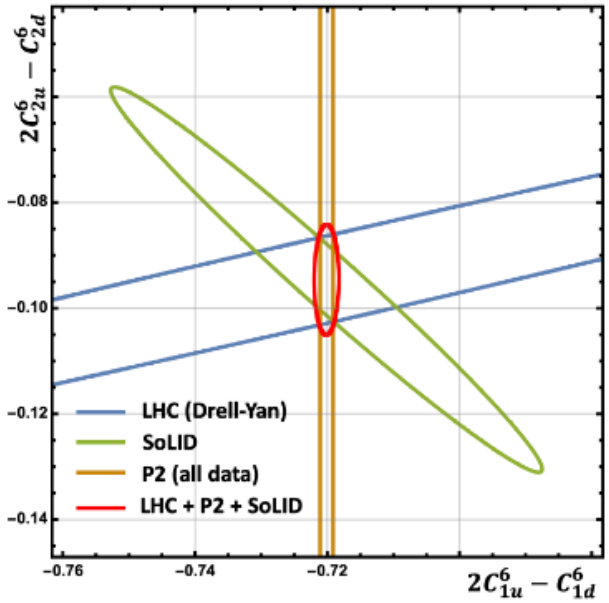
$$\alpha = (-1.01 \pm 0.15) \times 10^{-4}$$

slide material from Matteo Cerutti, SoLID June 2023 collaboration meeting

Bacchetta, Cerutti, Manna, Radici, XZ PLB 849 (2024) 138455

# New Physics Examples from PVDIS – SMEFT

SMEFT – Standard Model Effective Field Theory – The SMEFT basis often used in global fit analysis to constrain new physics beyond the electroweak scale:




$$\mathcal{L} = \mathcal{L}_{SM} + \frac{1}{\Lambda^2}\sum_i C_i^6 \mathcal{O}_{6,i} + \frac{1}{\Lambda^4}\sum_i C_i^8 \mathcal{O}_{8,i} + \ldots,$$

- PVES and Drell-Yan at the LHC are sensitive to different combinations of the SMEFT Wilson coefficients

slide material from Sonny Mantry, SoLID June 2023 collaboration meeting

Boughezal, Petriello, Wiegand, PRD 104 (2021) 1, 016005, https://inspirehep.net/literature/1857564

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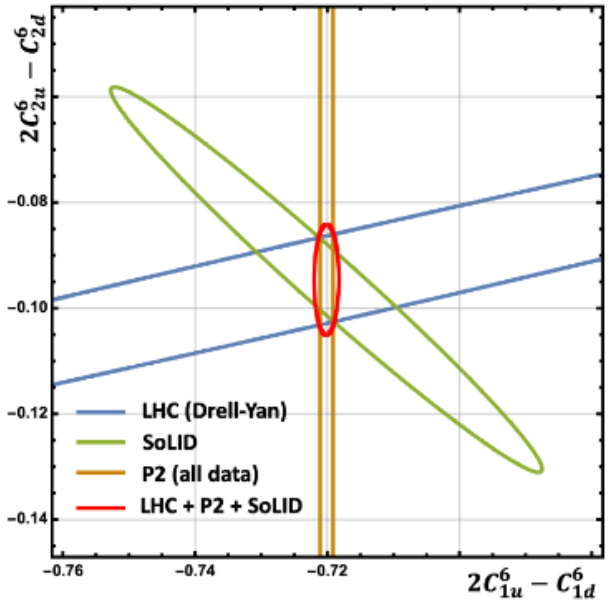
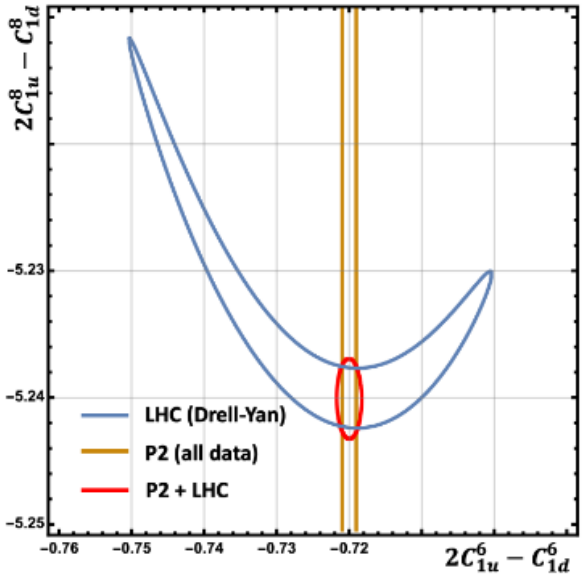
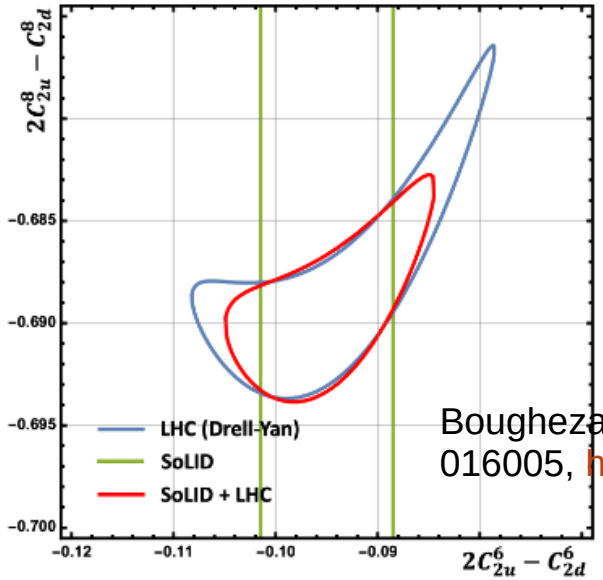



$$\mathcal{L} = \mathcal{L}_{SM} + \frac{1}{\Lambda^2}\sum_i C_i^6 \mathcal{O}_{6,i} + \frac{1}{\Lambda^4}\sum_i C_i^8 \mathcal{O}_{8,i} + \ldots,$$

- PVES and Drell-Yan at the LHC are sensitive to different combinations of the SMEFT Wilson coefficients
  - The high energy of the LHC makes it difficult to separate dim-6 and dim-8 operators.
  - Low energy PVES will help to disentangle dim-6 vs dim-8.



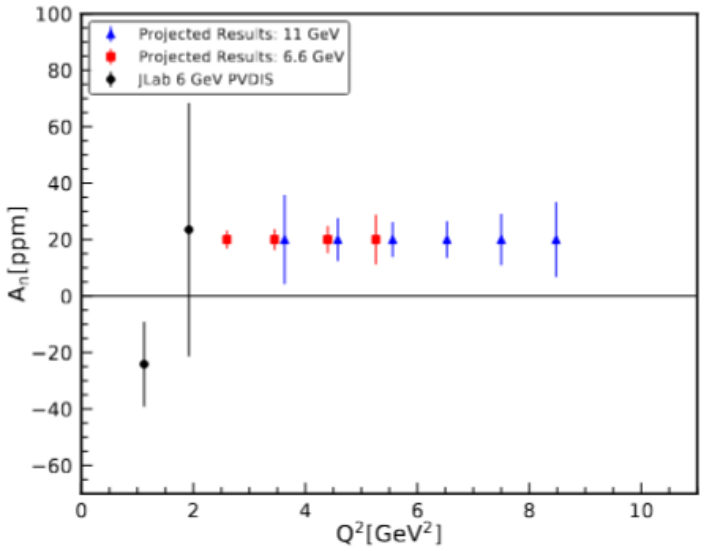

slide material from Sonny Mantry, SoLID June 2023 collaboration meeting

Boughezal, Petriello, Wiegand, PRD 104 (2021) 1, 016005, https://inspirehep.net/literature/1857564

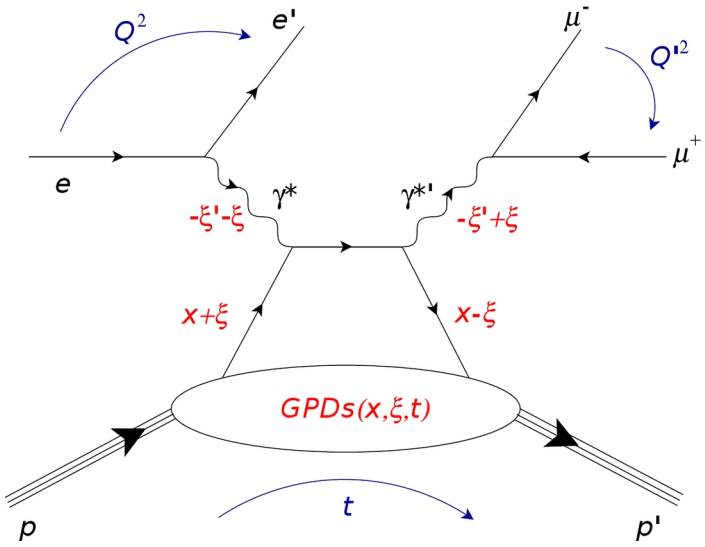
# BNSSA and DDVCS

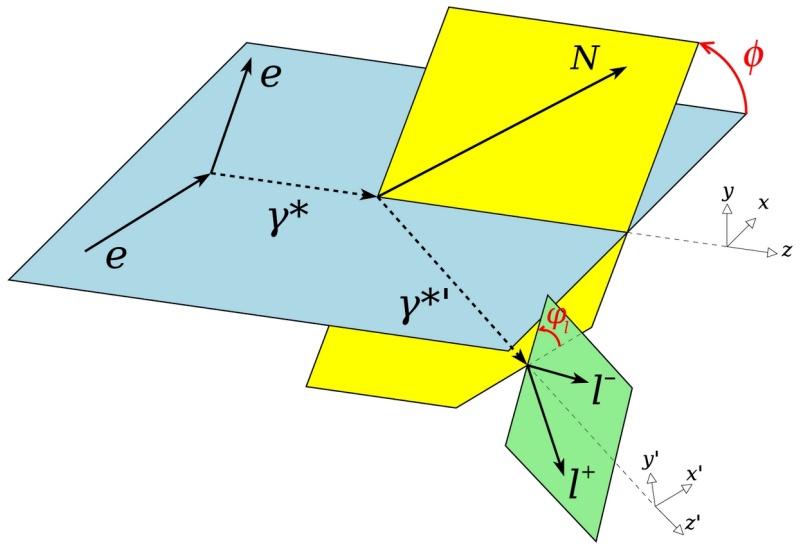
- Beam Normal Single Spin Asymmetry (E12-22-004)
  - Approved with A- rating
  - Investigate the effect of two-photon exchange in DIS
  - Q2 dependence of the asymmetry

$$A_{\text{raw}} = \frac{1}{P_b} \frac{N^{\uparrow}(\phi) - N^{\downarrow}(\phi)}{N^{\uparrow}(\phi) + N^{\downarrow}(\phi)}$$



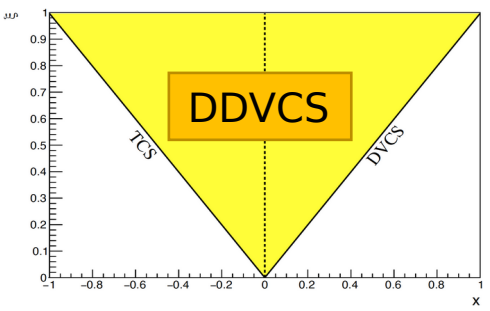

- Double Deeply Virtual Compton Scattering (C12-25-010)

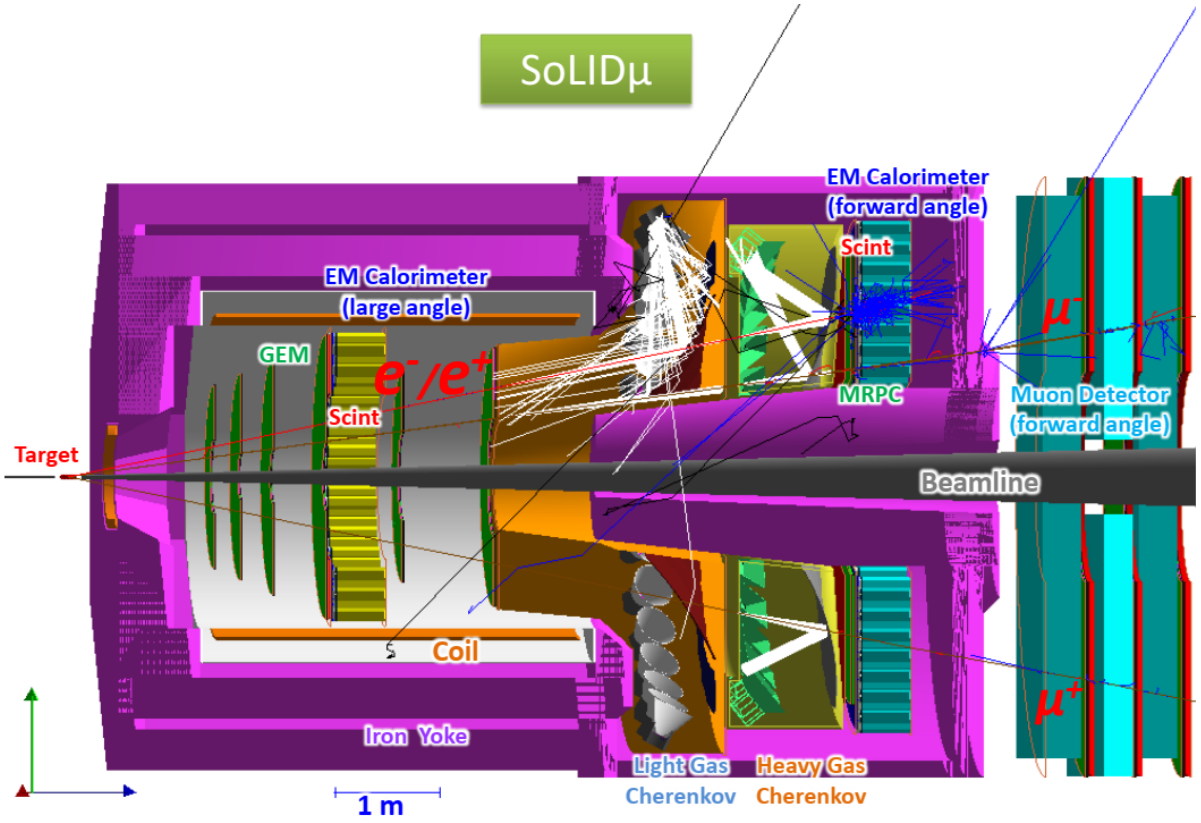


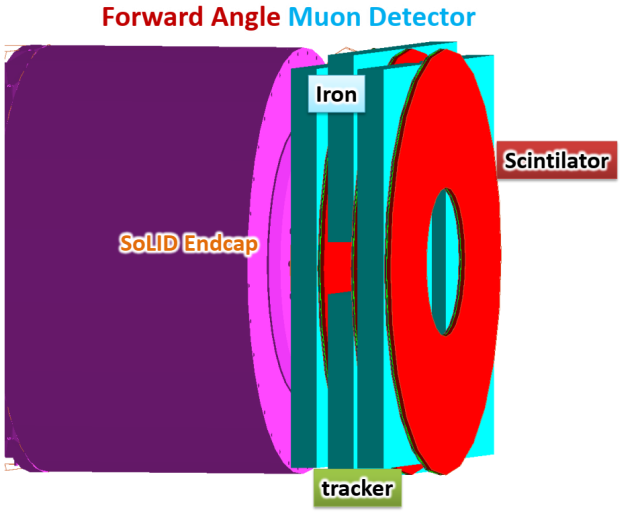



# SoLID for JLab Hall A – DDVCS

- DDVCS explores wide off-axis kinematic region of GPDs, beyond DVCS and TCS. The exclusive reaction has small crosssection and thus needs high luminosity and large acceptance.
- The SoLID apparatus completed with muon detectors at forward angle, enables DDVCS measurements with both polarized electron and positron beams at 11GeV.



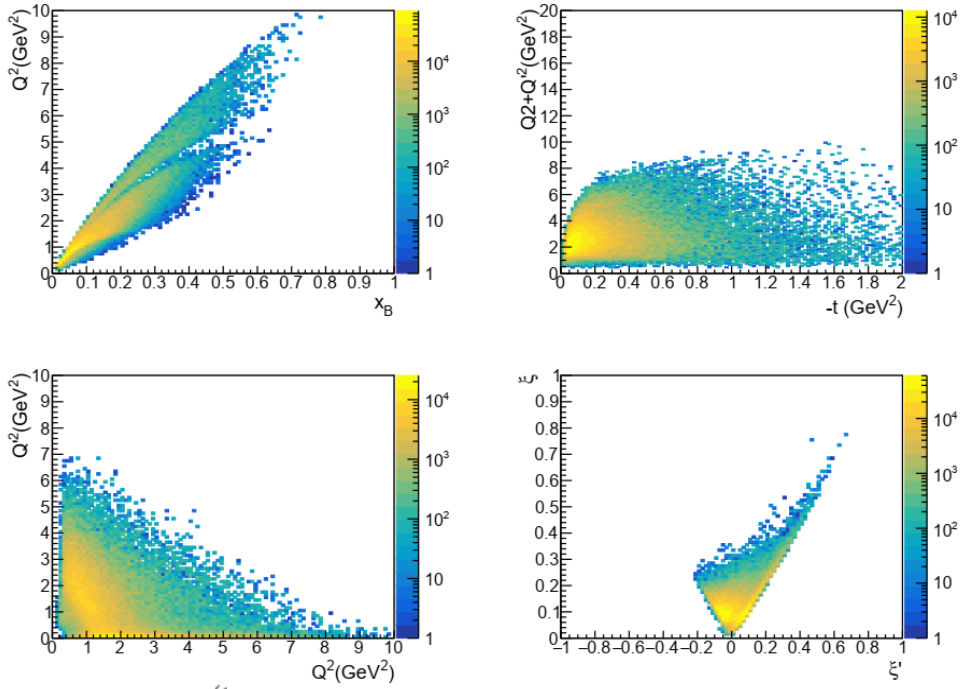

3 layers of iron+tracker+scintillator

Juan-Sebastian Alvarado, Xinzhan Bai, Marie Boer, Alexandre Camsonne, Eric Voutier, Zhiwen Zhao

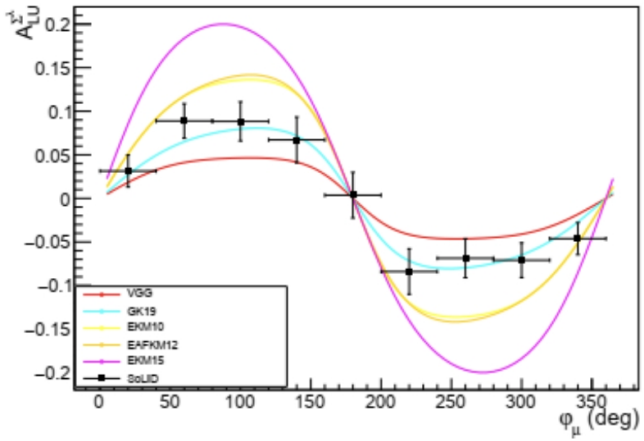
# SoLID for JLab Hall A – DDVCS

- Circularly polarized e- beam and LH2 target, 100 PAC days
- First time measurement on the BSA sign change between the two regions over a broad kinematic range
- **First time access to GPD** as inputs to GPD models and global fitting
- C1 Conditionally approved with A rating
- A **breakthrough physics program** (from PAC53 closeout)

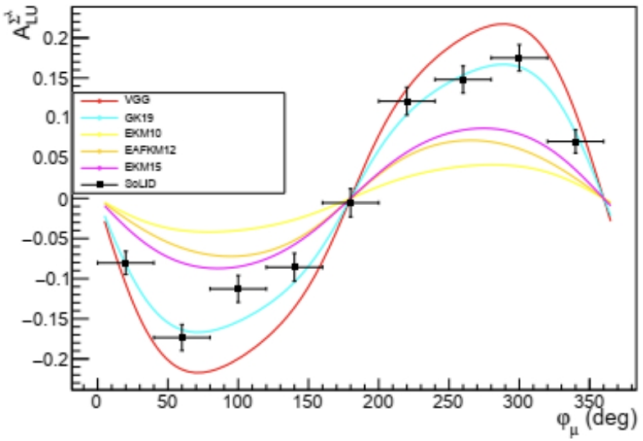
*coverage*




$$A_{LU}^{\Sigma^\lambda}(\varphi_\mu) = \lambda \frac{d^5\Sigma^+ - d^5\Sigma^-}{d^5\Sigma^+ + d^5\Sigma^-} = \frac{\lambda\, d^5\widetilde{\Sigma}_{\mathcal{I}_2}}{d^5\Sigma_{BH_1} + d^5\Sigma_{BH_2} + d^5\Sigma_{BH_{12}} + d^5\Sigma_{DDVCS} + d^5\Sigma_{\mathcal{I}_1} + d^5\Sigma_{\mathcal{I}_2}}(\xi$$




DVCS-like region




TCS-like region

PAC report: "*A C1 review by the Lab should be conducted at an appropriate time when the SoLID spectrometer may be functioning with the parameters required for this experiment*"

# More Ideas – 2024

**SoLID Science Workshop 2024**

June 17-20, 2024

Argonne National Lab, Lemont, IL

- AUT single-inclusive pion: https://arxiv.org/pdf/2401.02391 - see Fig. 3 for JLab12 predictions for neutron target
- ALT single-inclusive pion: https://arxiv.org/pdf/2210.14334 - see Fig. 5 for JLab12 predictions for neutron target

## 5 Workshop Dinner Discussions

In the spirit of the workshop, a number of experimentalists sat down at the dinner table and asked the following question to a number of theorists: "what measurements should we plan to do in the next couple of years, that are important (for advancing the field)?". After some prodding with beer, a dozen ideas were discussed, and could be recalled the next day. These ideas are listed as follows:

*Daniael Pitonyak:*

1. Measurements of $A_{LL}$,
2. Measurement $F_{1L}$ – electron beam on longitudinally polarized target
3. Single pion production $en^{\uparrow} \to \pi + X$ (need high $P_T$) asymmetries $A_{LT}$, $A_{UT}$ [See predictions in [], SoLID rungroup proposal].

*Leonard :*

4. TMD of pions [new proposal]
5. TMD of a scalar (double-magic) target such as $^4$He or $^{16}$O. The SIDIS process could be the simplest to study. [Existing ALERT experiment or new CLAS12 proposal]

*Hatta:*

6. $J/\psi$ electroproduction;

*Matteo:*

7. $C_{3q}$ and $F_3^{\gamma Z}$ ! [PAC49 proposal, deferred]
8. SIDIS on nucleus [new proposal, maybe look into the approved polarized-EMC experiment?]

*Marco:*

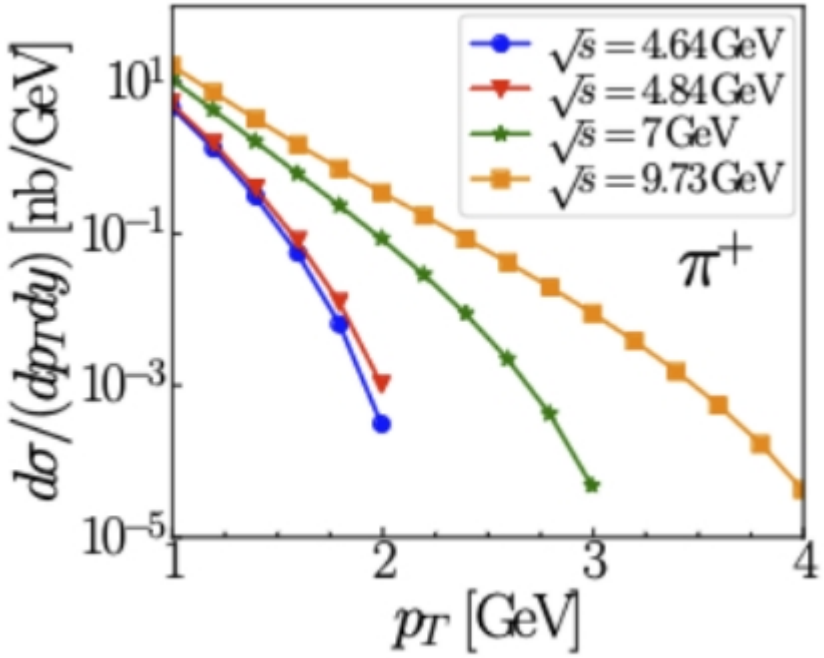
9. Anything BSM, such as PV SIDIS or neutrino SIDIS; [new proposal]

*Xiaochao:*

10. Spin asymmetries [run group proposal]

# More Ideas – 2025

- Traditionally considered a major background in DIS, single pion production in ep collision can **carry significant physics implication** on its own.
- By comparing inclusive pion cross section with calculations based on lepton distributions and fragmentation functions (see Fig), we can study how many of the pions in DIS are actually from fragmentation of the parton, and **that would be a pre-requisite of interpretation of SIDIS data**, particularly at JLab energies.
- If indeed the pions produced are mostly from non-prompt effects such as **vector meson** (e.g. ρ) decay, we need to at least understand them before interpreting SIDIS data using fragmentation alone.



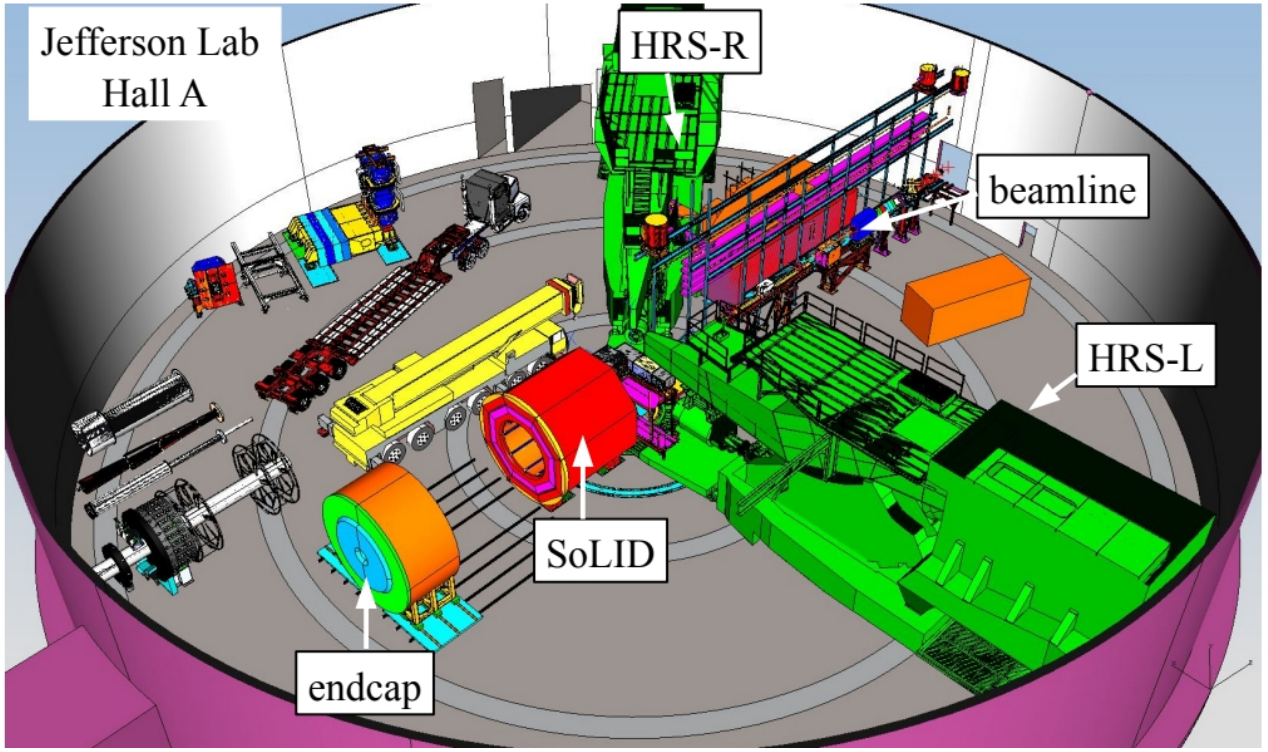

**See Jianwei Qiu's talk,** Inclusive Pion Production in Lepton-Hadron Collision – Prerequisite for understanding SIDIS data with current factorization formalism

**SoLID Collaboration Meeting, July 7-8, 2025**

https://indico.jlab.org/event/948/contributions/17185/attachments/12994/20883/SoLID2025July_Qiu.pdf

# More Ideas ?

- SoLID is the next generation spectrometer for fixed-target experiments
- with SoLID, many existing experiments can be measured to higher precision and in more dimension
- I would urge everyone discussing new ideas, particularly with theory groups, to design and carry out experiments never imagined possible before



# NSAC 2023 LRP Town Meetings – QCD

https://indico.mit.edu/event/538/
https://arxiv.org/abs/2303.02579

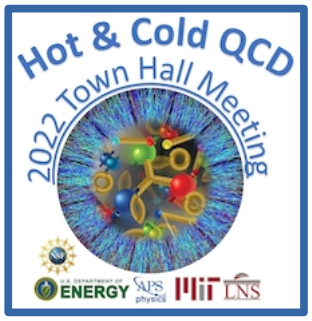
**Recommendation 1: Capitalizing on past investments** *(Yes: 335; No: 3; No Answer: 4)*

The highest priority for QCD research is to maintain U.S. world leadership in nuclear science for the next decade by capitalizing on past investments. Maintaining this leadership also requires recruitment and retention of a diverse and equitable workforce.

**We recommend support for a healthy base theory program, full operation of the CEBAF 12-GeV and RHIC facilities, and maintaining U.S. leadership within the LHC heavy-ion program, along with other running facilities, including the valuable university-based laboratories, and the scientists involved in all these efforts.**

This includes the following, unordered, programs:

- The 12-GeV CEBAF hosts a forefront program of using electrons to unfold the quark and gluon structure of visible matter and probe the Standard Model. We recommend executing the CEBAF 12-GeV program at full capability and capitalizing on the full intensity potential of CEBAF by the construction and deployment of the Solenoidal Large Intensity Device (SoLID).
- The RHIC facility revolutionized our understanding of QCD, as well as the spin structure of the nucleon. To successfully conclude the RHIC science mission, it is essential to complete the sPHENIX science program as highlighted in the 2015 LRP, the concurrent STAR data taking with forward upgrade, and the full data analysis from all RHIC experiments.
- The LHC facility maintains leadership in the (heavy ion) energy frontier and hosts a program of using heavy-ion collisions to probe QCD at the highest temperature and/or energy scales. We recommend the support of continued U.S. leadership across the heavy ion LHC program.
- Theoretical nuclear physics is essential for establishing new scientific directions, and meeting the challenges and realizing the full scientific potential of current and future experiments. We recommend increased investment in the base program and expansion of topical programs in nuclear theory.

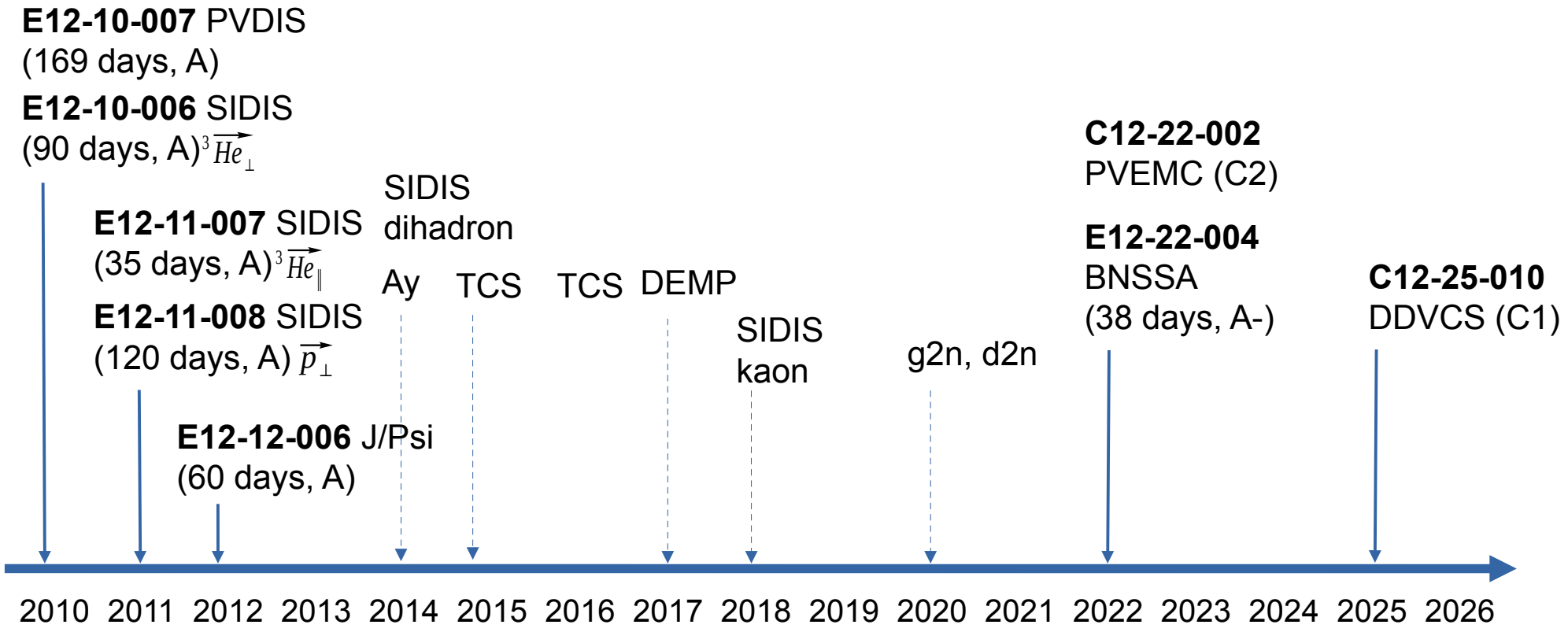


# Summary and Outlook

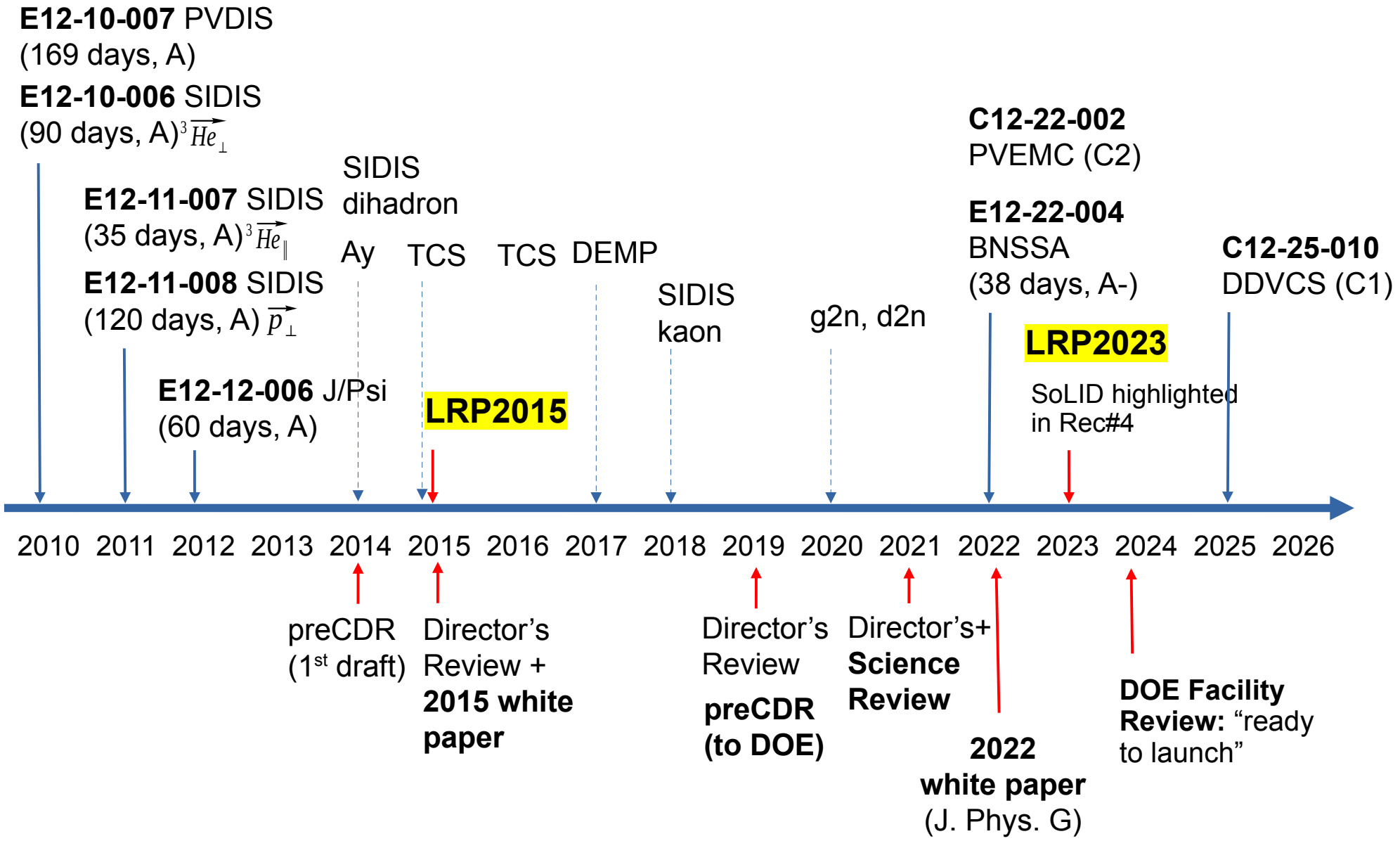
- SoLID will fully capitalize on the 12 GeV CEBAF at the intensity frontier, allowing precision studies of a number of modern topics central to hadronic physics and test of the SM:
  - *SIDIS, J/psi, PVDIS, DDVCS, BNSSA, … …*
  - ***unique physics program*** *that cannot be done by other existing facilities and the EIC*
- The SoLID collaboration, currently consists of 270+ collaborators from 70+ institutions (13 countries), worked tirelessly on the physics program and conceptual design since the early 2010's.
- SoLID is of high priority and is ready to launch:
  - successful first magnet cold test at JLab
  - DOE-funded/JLab-supported pre-R&D activities on Cherenkov, GEM readout, and ECal beam tests recently completed, AI/ML potential being developed
  - ***Tracking detector beam test and readout in preparation***
  - Timely realization of SoLID is essential for the US nuclear science program

# Back up Slides

# SoLID Timeline



# SoLID Timeline



# NSAC 2023 LRP Town Meetings – FSNN

https://indico.phy.ornl.gov/event/209/

2) **We recommend increased investments in targeted initiatives with unique sensitivity to violation of time reversal invariance, interactions beyond the Standard Model, and the neutrino masses.**

We highlight the most compelling scientific opportunities:

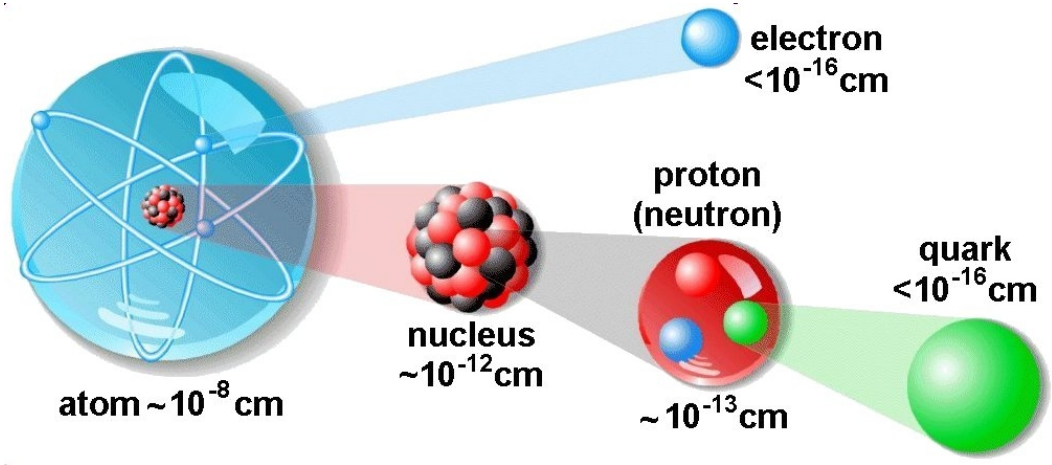
a. The expeditious **completion** of high-impact experimental campaigns, including the nEDM@SNS, the world's most ambitious search for the neutron electric dipole moment (EDM); and MOLLER@JLab, planning the most precise low energy measurement of a purely leptonic weak neutral current interaction

b. Realizing the full potential of the existing experimental program to address recent questions surrounding CKM unitarity, substantially improve constraints on CP violation, and extend the precision frontier's capability to discover BSM physics.

c. Support of R&D efforts targeting emerging opportunities with demonstrated scientific cases. These include the next generation measurements of the absolute neutrino mass (Project 8), lepton flavor universality in the weak interactions (PIONEER) search for new neutral current interactions (SoLID) as well as EDM searches enabled by FRIB.

# Experimental Frontier of QCD Studies


- How does QCD generate the spectrum and structure of conventional and exotic hadrons?
- How do the mass and spin of the nucleon emerge from the quarks and gluons inside and their dynamics?
- How are the pressure and shear forces distributed inside the nucleon?
- How does the quark–gluon structure of the nucleon change when bound in a nucleus?
- How are hadrons formed from quarks and gluons produced in high-energy collisions?



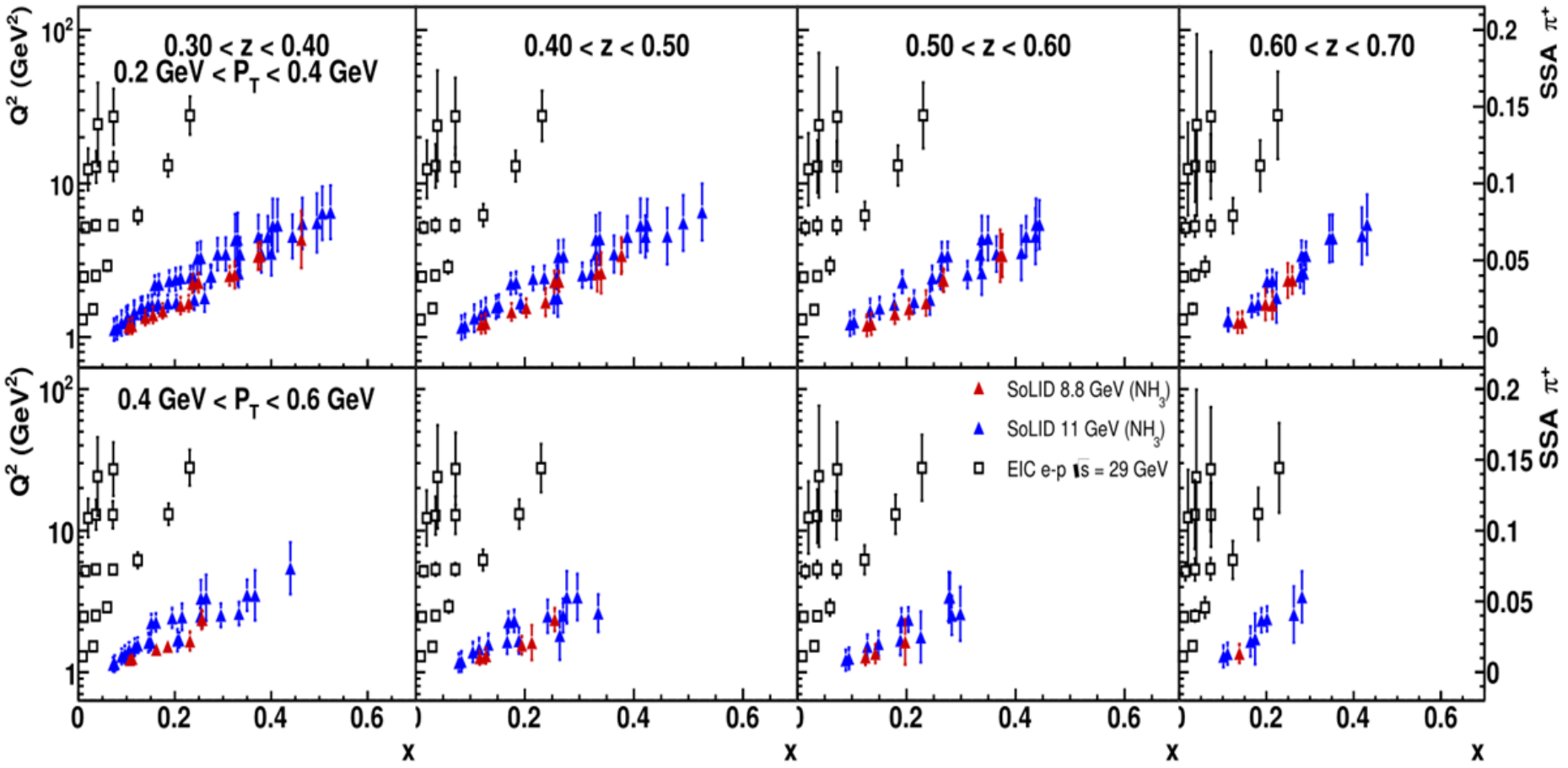

https://science.osti.gov/-/media/np/nsac/pdf/202310/NSAC-LRP-2023-v12.pdf

https://arxiv.org/abs/2303.02579

# SoLID for JLab Hall A – SIDIS and TMDs

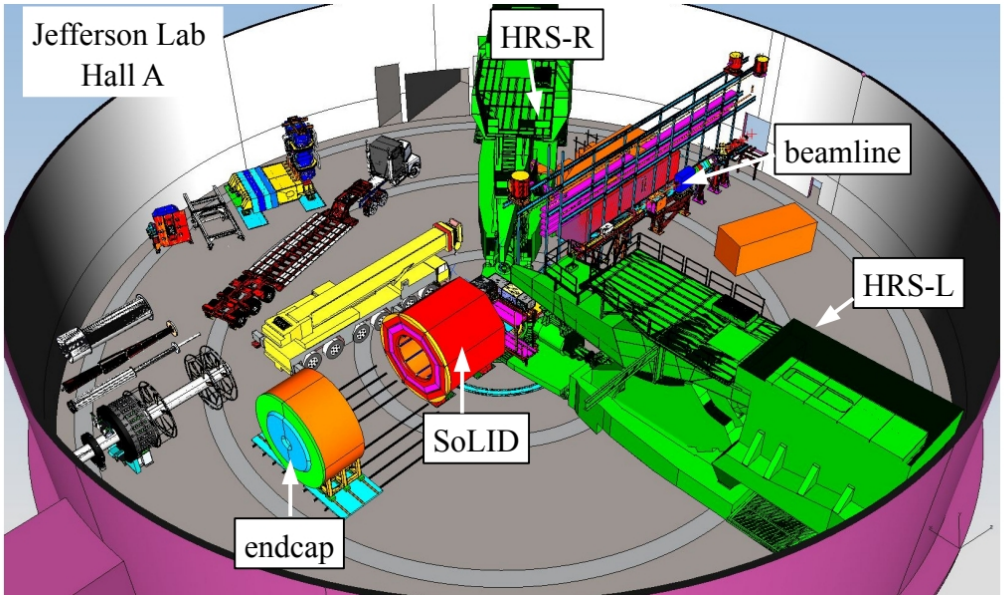
Example: E12-10-006 (SIDIS on Transversely Polarized 3He)

- SoLID SIDIS projections of $A_{UT}$ in various 4-D bins at 11/8.8 GeV beam energies
- Projections at EIC kinematics for the same observable at 29 GeV CM energy
- SoLID and EIC synergistic towards each other, by covering different x and $Q^2$ ranges

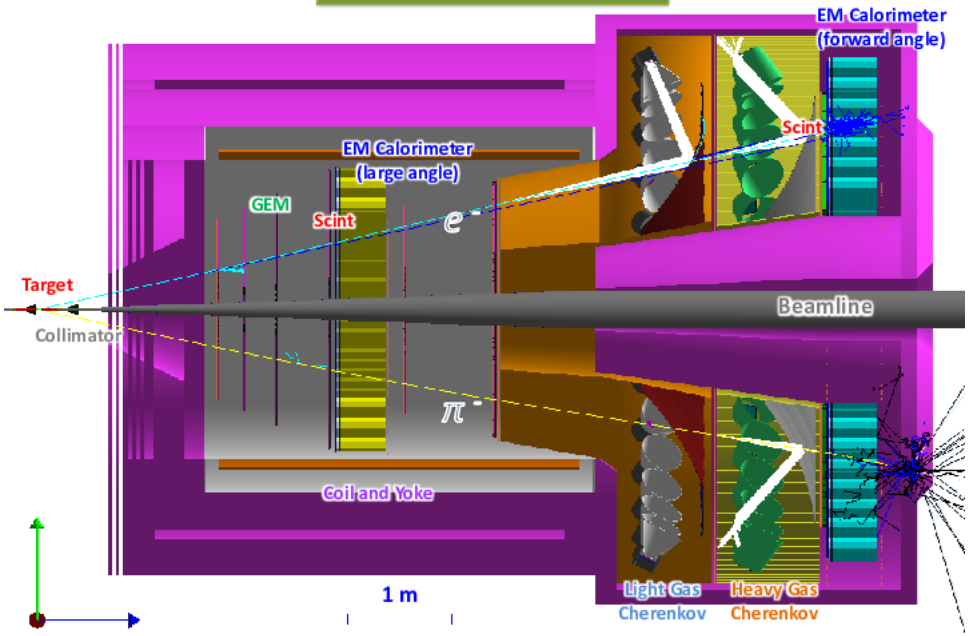



Slide provided by V. Khachatryan, PAC50 talk

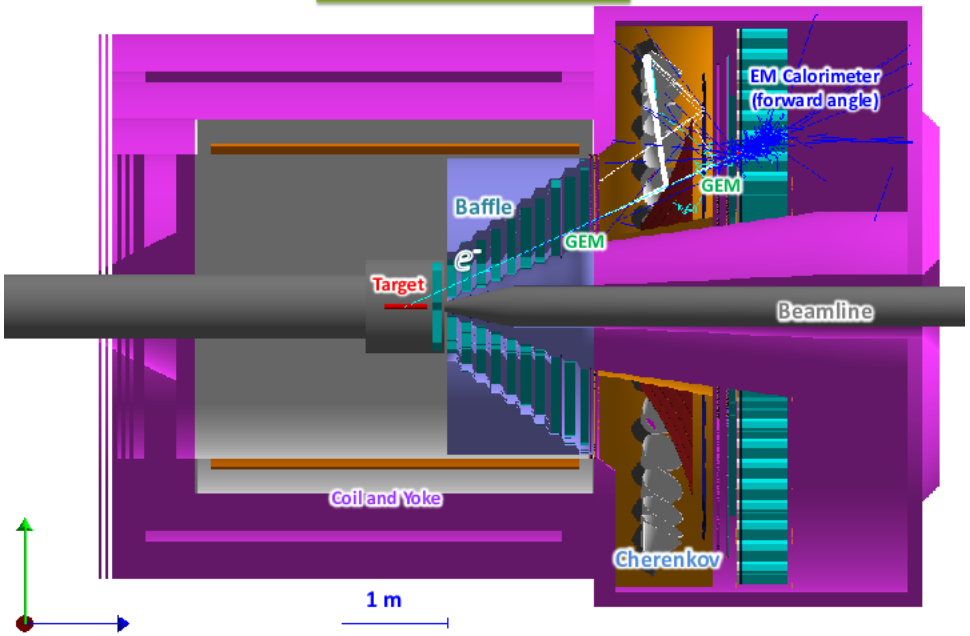
# Configurations



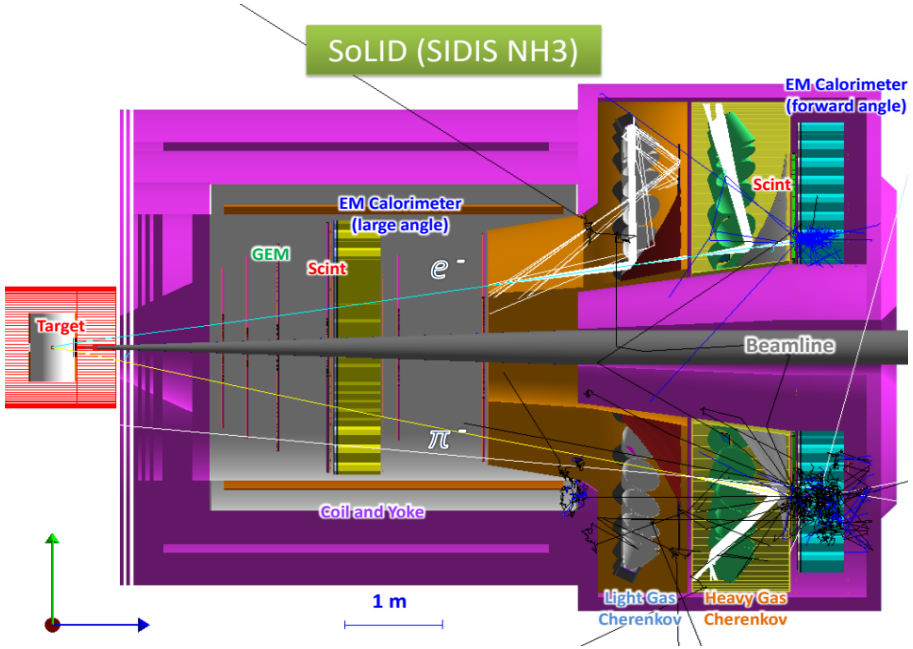

SoLID (SIDIS and J/ψ)

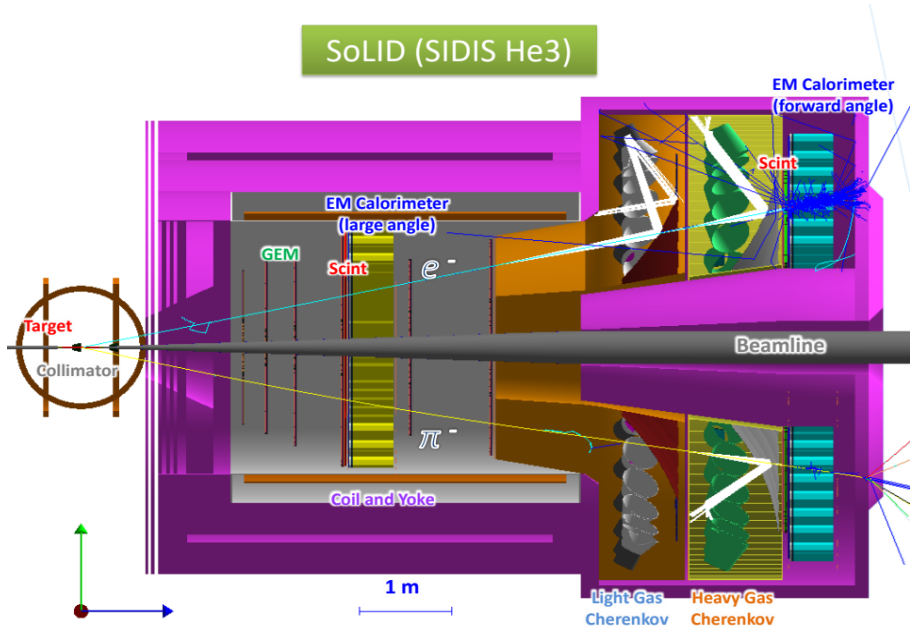



SoLID (PVDIS)



# SIDIS Configurations



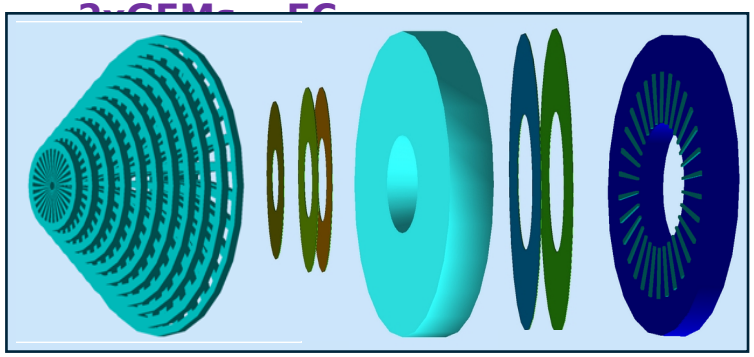




- **SoLID: Total 1400 bins in x, $Q^2$, $P_T$ and z for 11/8.8 GeV beam**

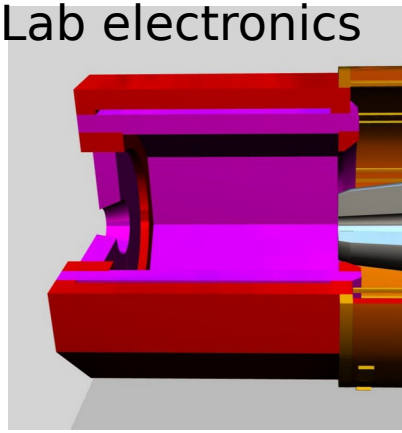
# Outline

**PVDIS**

Baffle 3xGEMS LGC

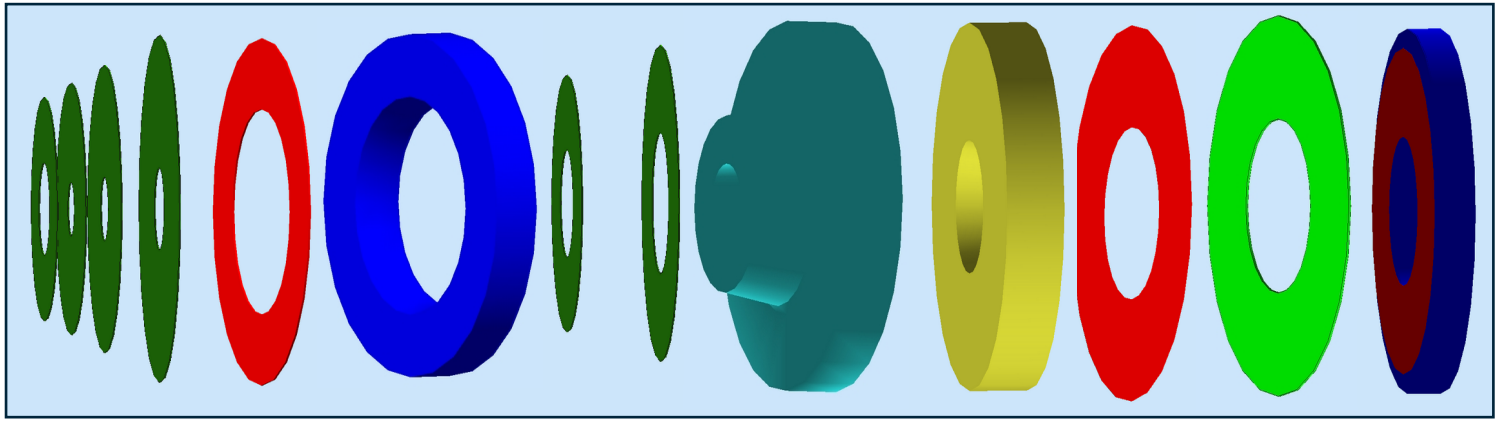


Uses full capability of JLab electronics



**SIDIS-J/**

4xGEMs LASPD LAEC 2xGEMs LGC
HGC FASPD (MRPC) FAEC



**Pre-R&D items: LGC, HGC, GEM's, EC, DAQ/Electronics, Magnet**