

SoLID update

Ching Him Leung

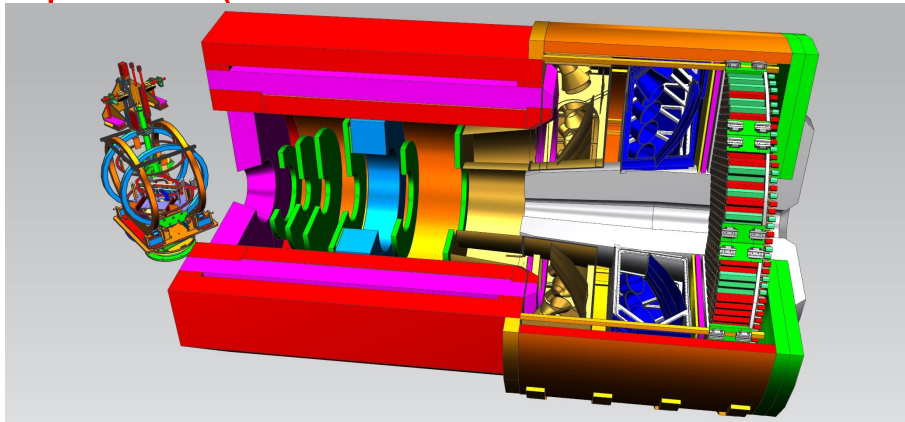
Jefferson Lab

June 25 2026



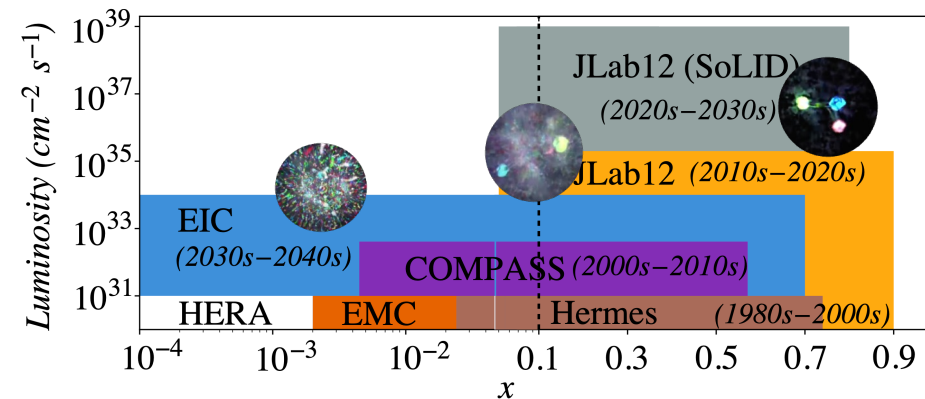
Solenoidal Large Intensity Device (SoLID) with JLab 12-GeV Enables QCD at the Intensity Frontier

- Nucleon spin, mass and BSM search experiments. Precision measurements of small cross sections and asymmetries. Critical: **high luminosity (10^{37} - 10^{39} $\text{cm}^{-2}\text{s}^{-1}$)** and **large acceptance (at least 100 times better than existing facility in terms of Figure of Merit)**



• Solenoidal Large Intensity Device (SoLID)

- Precision 3D imaging of the nucleon in the valence region (GPDs, TMDs). Unique, critical to NP science mission but complementary to EIC.
- Exploring the origin of the proton mass and confining color forces. Mass and scalar energy distributions in the proton. Unique, critical to NP science, but complementary to EIC.
- Search beyond the Standard Model of Particle Physics. Unique and complementary to MOLLER

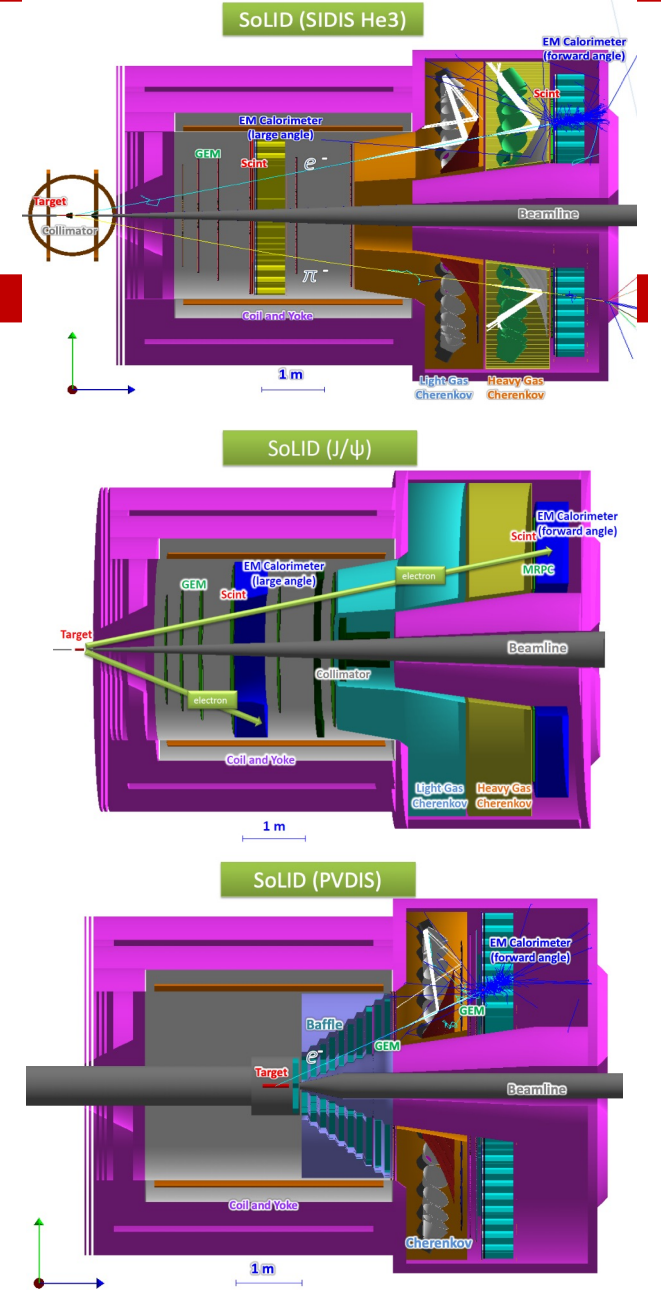


• Luminosity Frontier in the Valence Region

- DOE/JLab supported pre-R&D activities on cutting-edge technologies.
- Enhanced credibility of the design with greatly reduced cost/schedule risks
- Scientific excellence and students training ground with a growing impactful science portfolio



Approved SoLID Experiments

- A) SIDIS: (3)** Transversely Polarized ^3He (n): Transversity Sivers, Pretzosity TMDs
 Longitudinally Polarized ^3He (n): Worm-gear TMDs
 Transversely Polarized Proton: Transversity, Sivers, Pretzosity TMDs
- B) Threshold J/ψ :** **Rating A** Gluon Field, Proton Mass, Gluon Radius
- C) Parity: PVDIS:** **Rating A** Test Standard Model & Nucleon Structure
- Beam Normal SSA** **Rating A-** 2-photon Effects
PVEMC **Conditional Approval** Isospin EMC Effects
- D) DDVCS:** **Rating A (C1 Conditional)** GPDs
- E) Run group experiments (8) approved for GPDs, TMDs, and Spin**

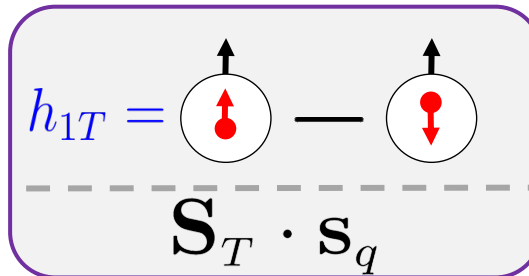


TMDs – confined motion inside the nucleon

Transversely Polarized Nucleon TMDs

 Nucleon Spin
 Quark Spin

Transversity

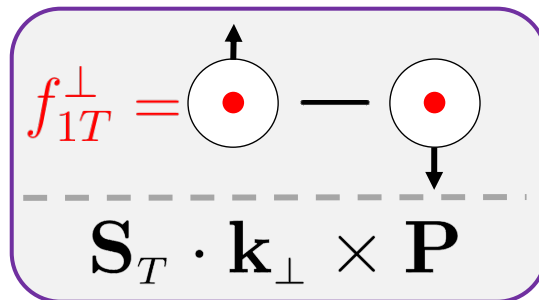


Relevant Vectors

\mathbf{S}_T : Nucleon Spin
 \mathbf{s}_q : Quark Spin
 \mathbf{k}_\perp : Quark Transverse Momentum
 \mathbf{P} : Virtual photon 3-momentum (defines z-direction)

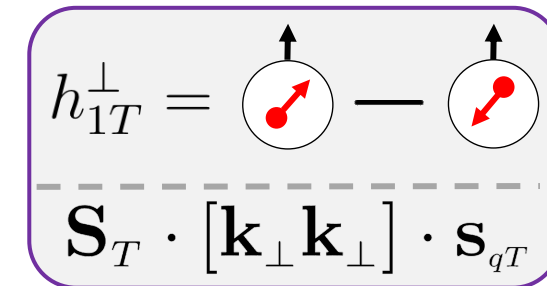
- h_{1T} (h_1) = g_1 (no relativity)
- h_{1T} → tensor charge (lattice QCD calculations)
- Connected to nucleon beta decay and EDM

Sivers



- Nucleon spin - quark orbital angular momentum (OAM) correlation – zero if no OAM (model dependence)

Pretzelosity



- Interference between components with OAM difference of 2 units (i.e., s-d, p-p) (model dependence)
- Signature for relativistic effect

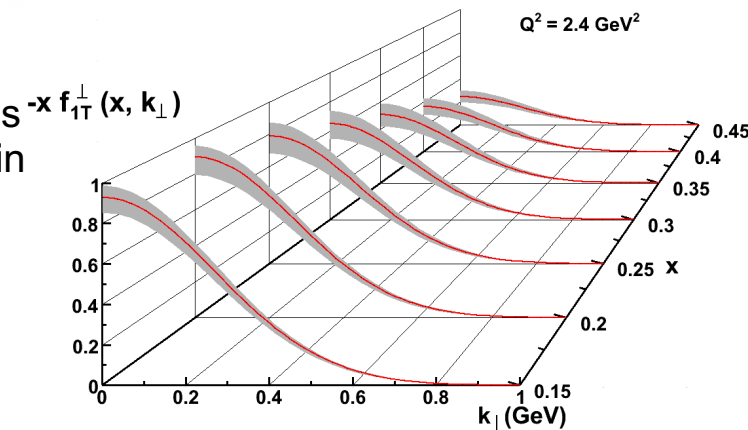
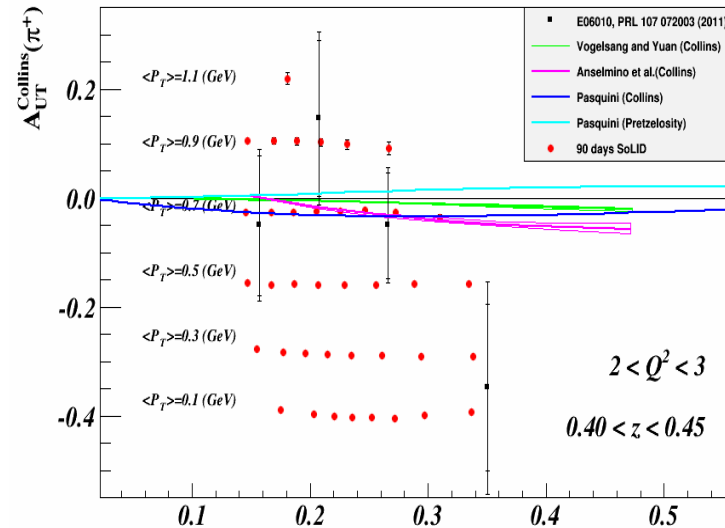
SoLID-SIDIS: Precision Mapping in Multi-Dimension

- SoLID-SIDIS program: Large acceptance, Full azimuthal coverage + High luminosity
- 4-D mapping of asymmetries with precision
- Constrain models and forms of TMDs, Tensor charge, ...
- Lattice QCD, QCD dynamics

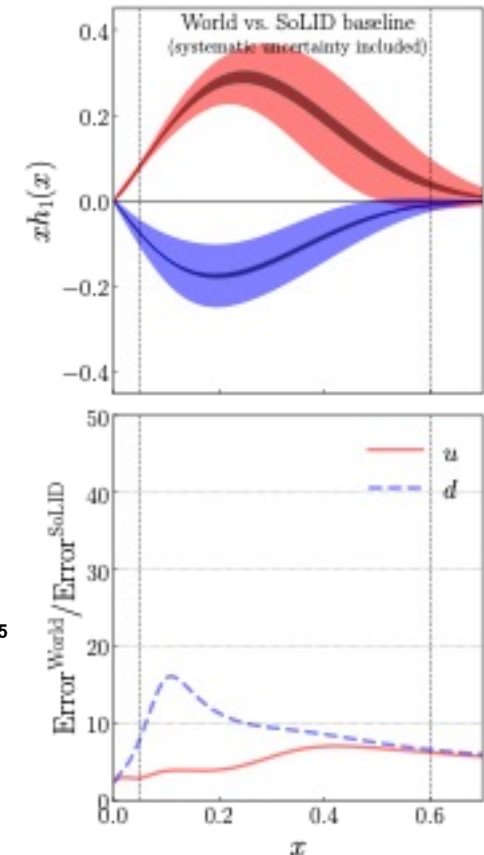
4-D binning for the first time!

- More than 1400 bins in x , Q^2 , P_T and z for 11/8.8 GeV beam.

- **Sivers:** Confined quark motion
- Quantum correlations between nucleon spin and quark motion
- QCD dynamics



Transversity



SoLID Impact on Tensor Charge

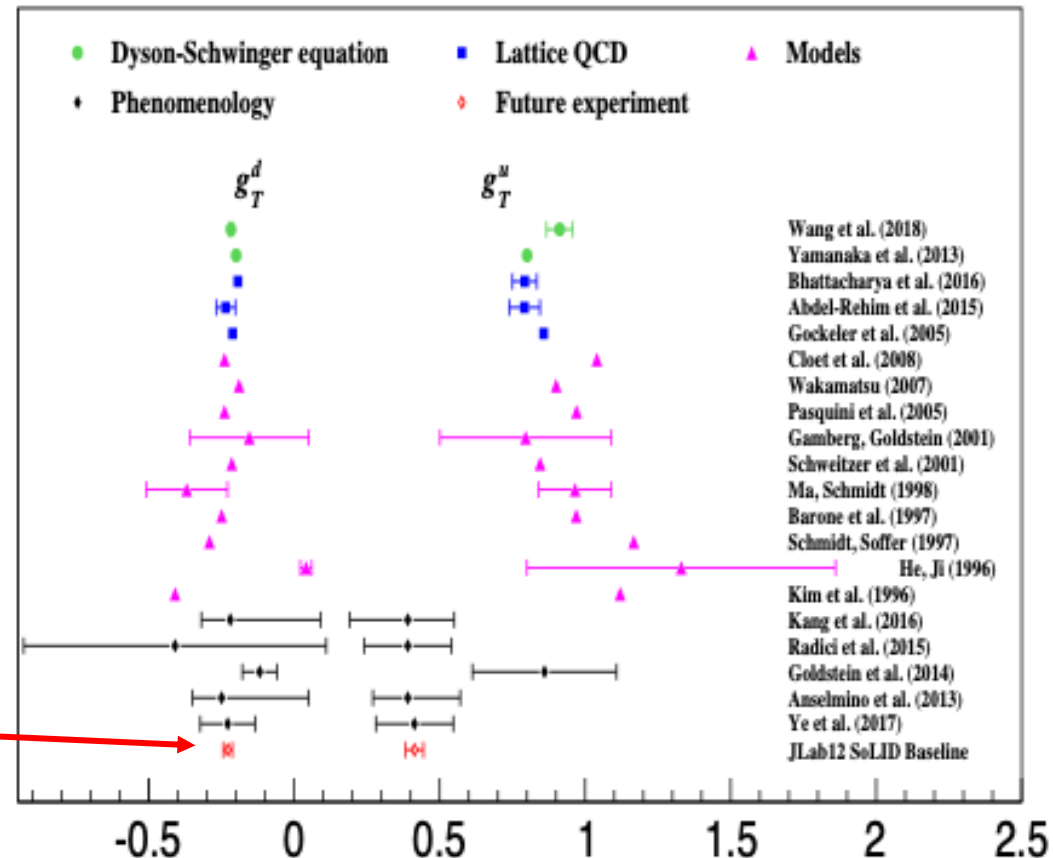
Definition

$$\langle P, S | \bar{\psi}_q i\sigma^{\mu\nu} \psi_q | P, S \rangle = g_T^q \bar{u}(P, S) i\sigma^{\mu\nu} u(P, S) \quad g_T^q = \int_0^1 [h_1^q(x) - h_1^{\bar{q}}(x)] dx$$

- A fundamental QCD quantity: matrix element of local operators.
- Moment of transversity distribution
- Valence quark dominant.
- Precision calculations available from lattice QCD.
- Probe new physics combined with EDMs

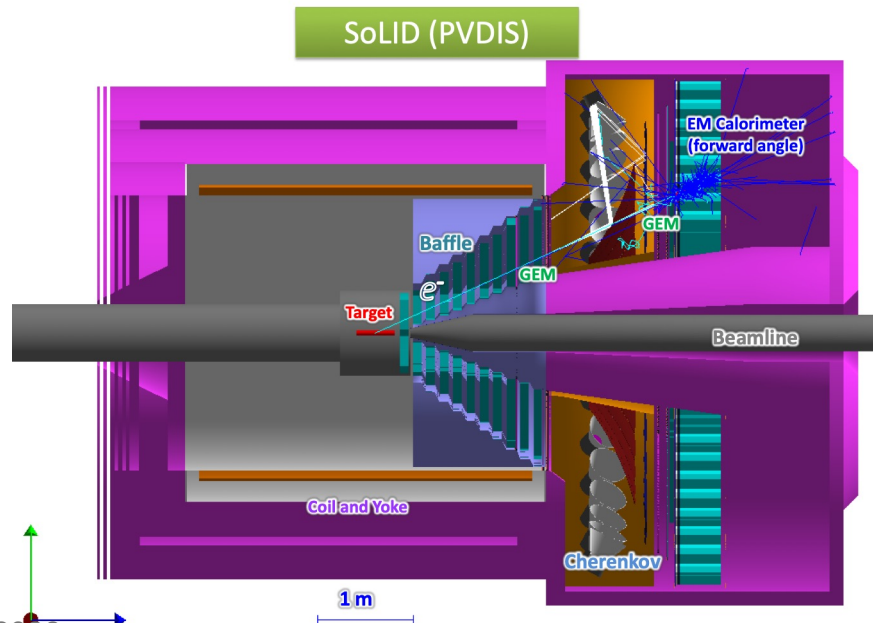
$$d_n = g_T^d d_u + g_T^u d_d + g_T^s d_s$$

SoLID Projections

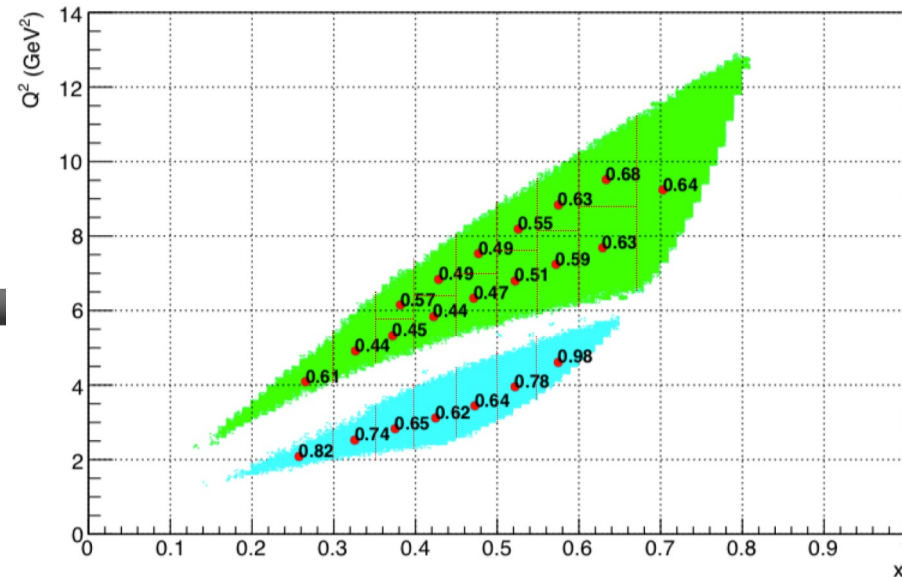


SoLID-PVDIS

- **SoLID@JLab: Extraordinary opportunity to do the ultimate PVDIS measurement**
 - **Strategy: sub-1% precision over broad kinematic range: sensitive Standard Model test *and* detailed study of hadronic structure contributions**

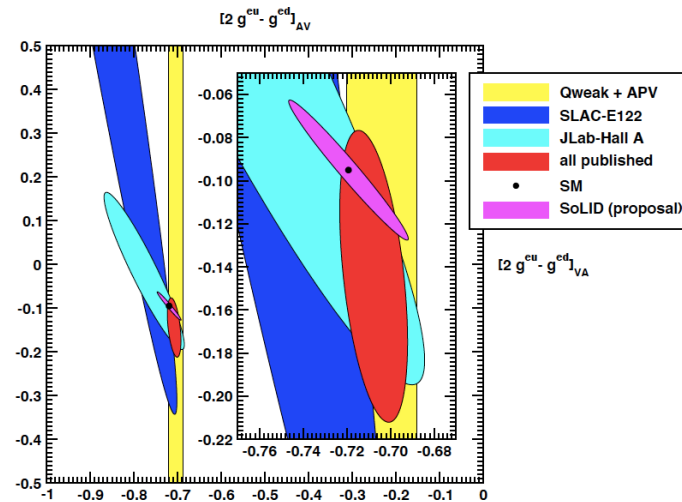


PVDIS Asymmetry Uncertainty (%)



SoLID-PVDIS: Precision Test of Standard Model

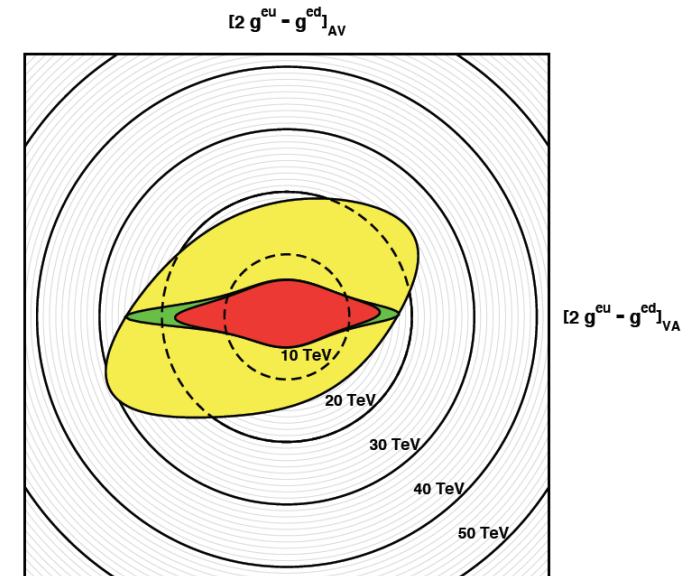
SoLID makes a unique contribution to the SMEFT program.
Improvement in couplings



Unique sensitivity to

- lepto-phobic Z' , dark boson Z_d
- Also provides precision study of
- charge symmetry violation
- high-twist effects
- d/u at high-x

Improvement in energy reach for electron-nucleon couplings



- Published data
- Published data + P2
- Published data + P2 + SoLID

Structure Function Ratio d/u for the Proton

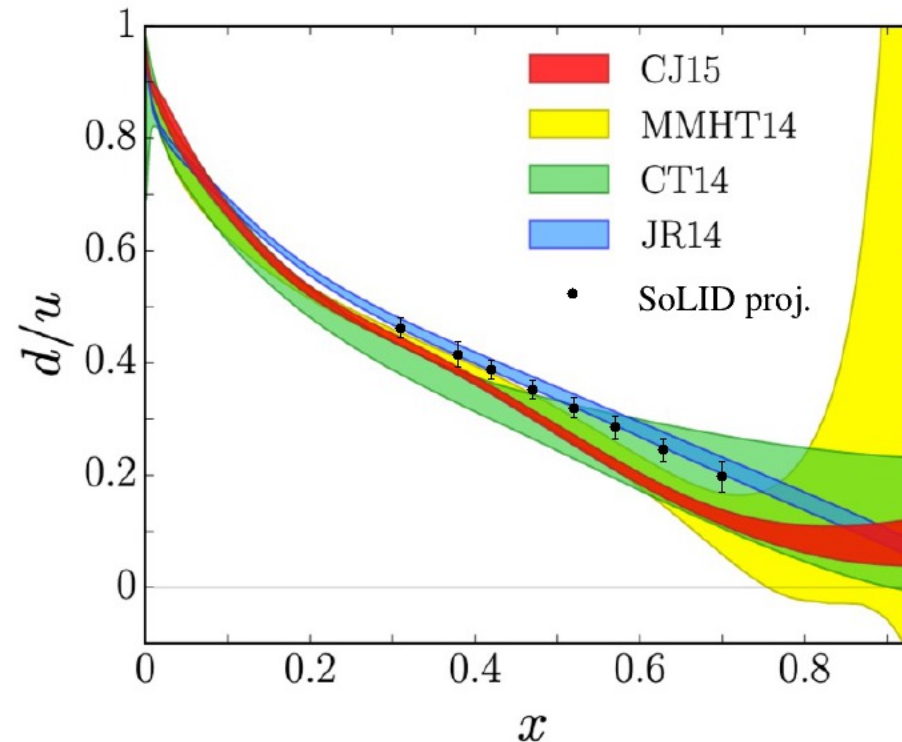
$$A_{PV} = \frac{G_F Q^2}{\sqrt{2}\pi\alpha} [a(x) + f(y)b(x)]$$

PVDIS is complementary to the rest of the JLab d/u program.
PVDIS has no nuclear effects

Additional observables provided by PVDIS (both p and d) can help determination of strangeness PDF.

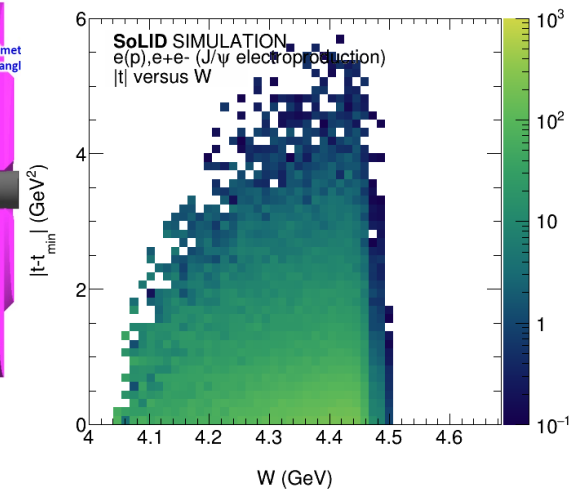
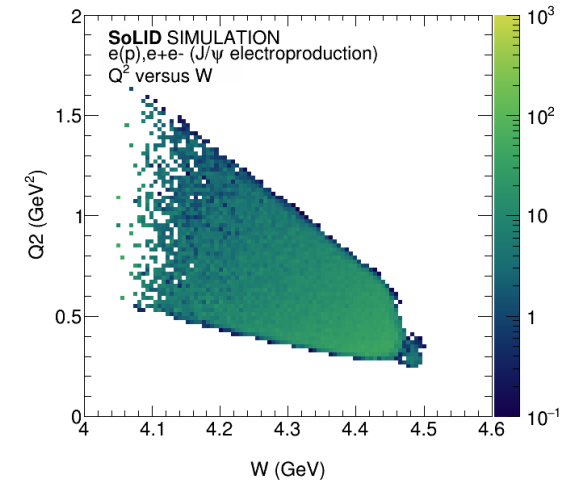
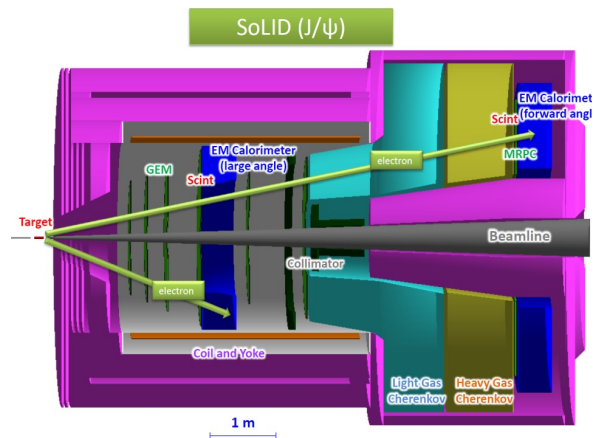
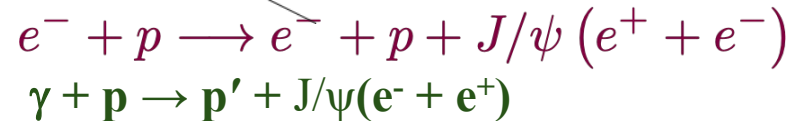
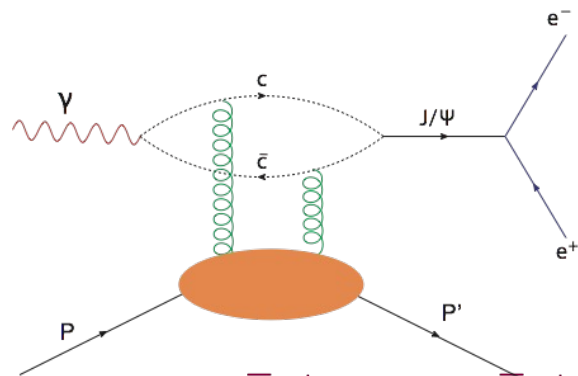
$$A_{PVDIS}^p(x) \approx \frac{u(x) + 0.91d(x)}{u(x) + 0.25d(x)}$$

Phys. Rev. D 87 (2013) 094012



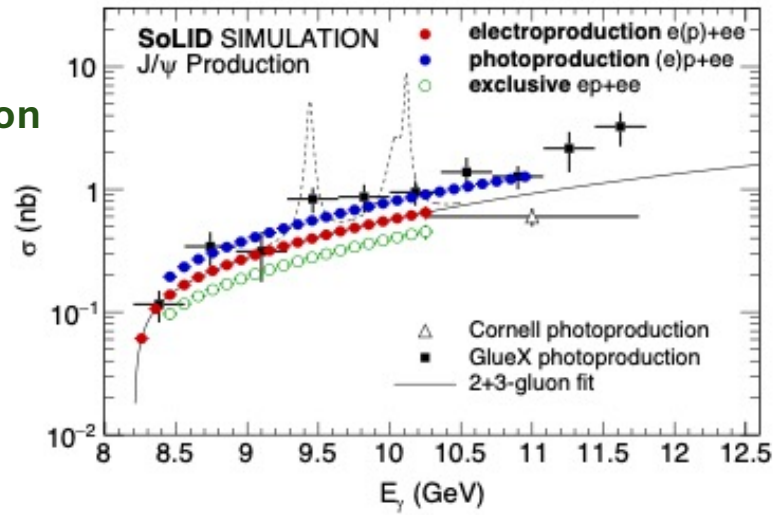
SoLID-J/ ψ : Experiment E12-12-006

- 50 days of $3 \mu\text{A}$ beam on a 15 cm long LH_2 target at $1 \times 10^{37} \text{ cm}^{-2} \text{ s}^{-1}$
- 10 more days include calibration/background run
- SoLID configuration overall compatible with SIDIS
 - **Electroproduction trigger:** 3-fold coincidence of e, e^-e^+
 - **Photoproduction trigger:** 3-fold coincidence of p, e^-e^+
 - **Additional trigger:** 4-fold coincidence of ep, e^-e^+
 - And (inclusive) 2-fold coincidence e^+e^-

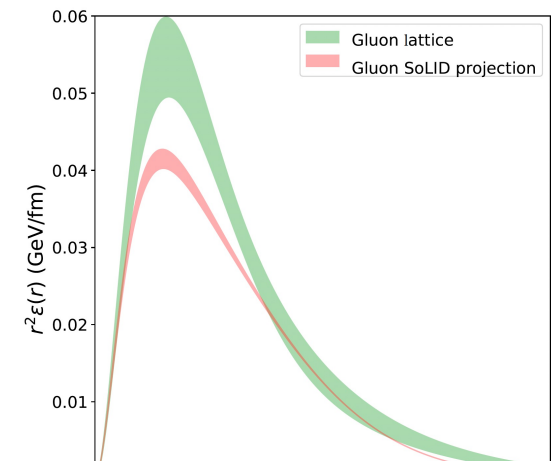


SoLID-J/ ψ : Gluon Field, Radius and Proton Mass

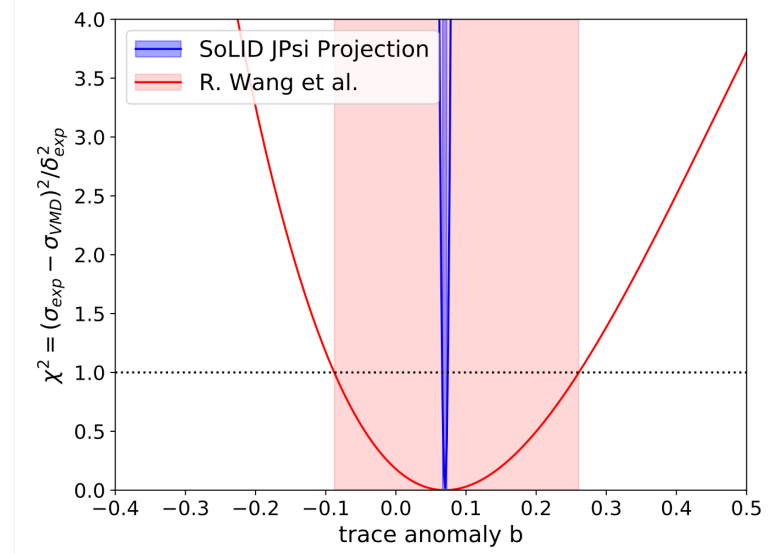
SoLID precision projection



Gluon Radius



Gluon (trace anomaly) contribution to proton mass



S. Joosten, Z.E. Meziani, PoS 308 (2017)

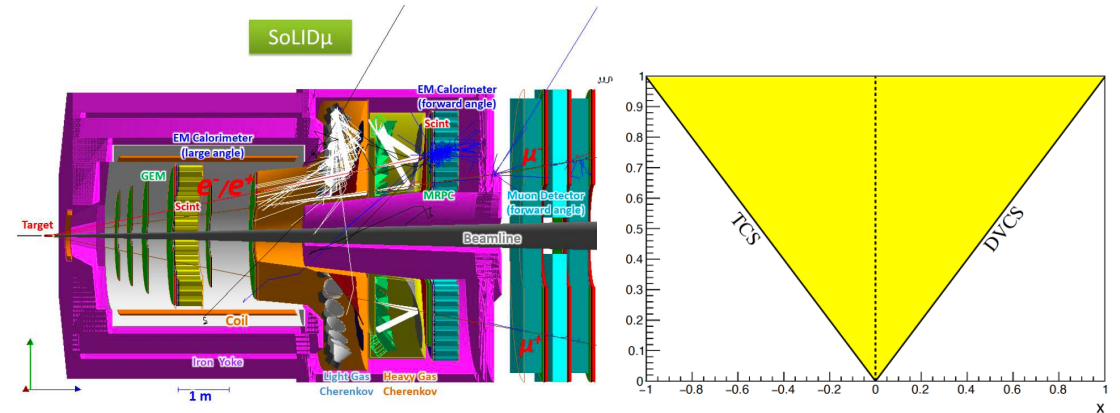
Gryniuk, Joosten, Meziani, and Vanderhaeghen, PRD 102, 014016 (2020) (for update)

GlueX on J/ ψ Ali et al., PRL 123, 072001(2019)

M. Boer, et al., arXiv: hep-ph2512.15064 (2025)

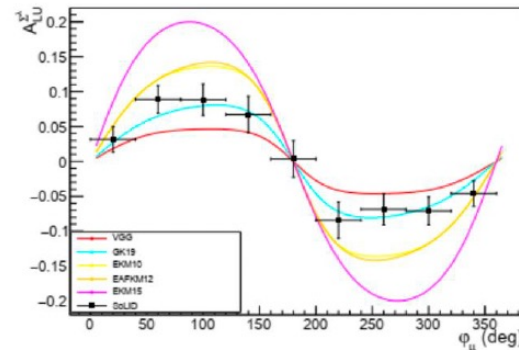
SoLID-GPD Program: DDVCS and more

- DDVCS with SoLID μ (SoLID+muon detector): C1 approval with A rating
 - (another DDVCS proposal with μ CLAS12: C1 approved with A rating)
- Deep Exclusive Meson Production: approved run-group experiment
- TCS (Time-like Compton Scattering): approved run-group experiment

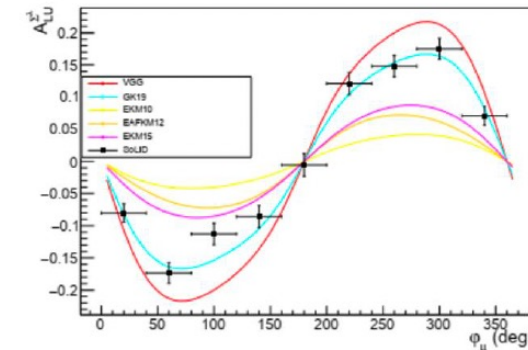


Double Deeply Virtual Compton Scattering (PR12-25-010)

- C1 Conditionally approved with A rating
- First ever DDVCS to access the full kinematic space for extracting GPDs
- A breakthrough physics program (from PAC53 closeout)



DVCS-like region

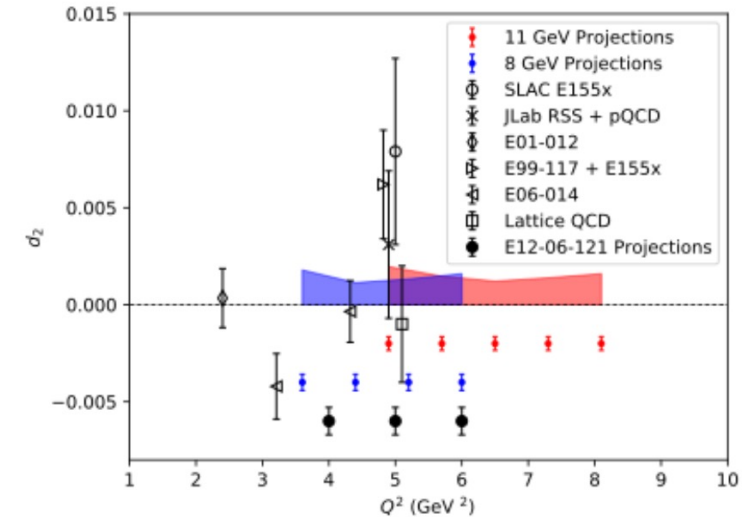
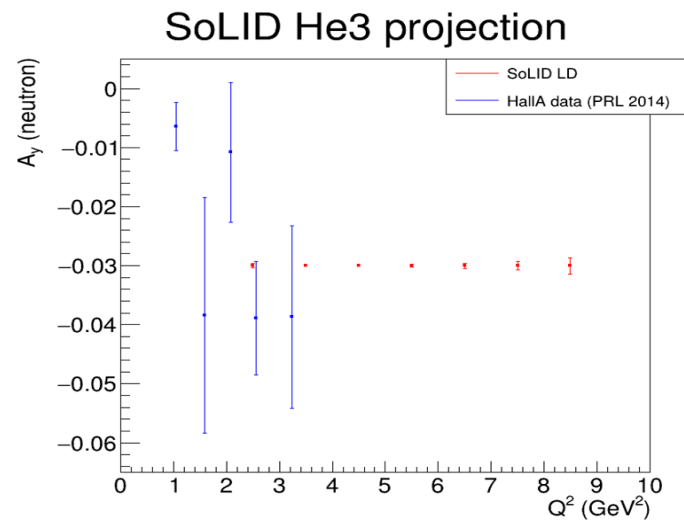


TCS-like region

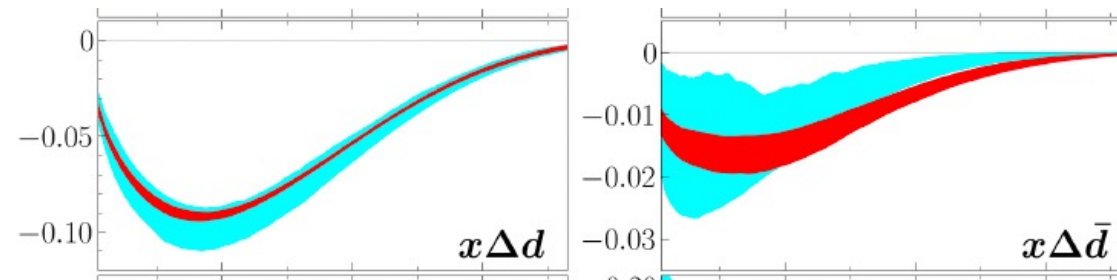
SoLID-Spin: Run-Group Experiments

- Approved experiments

- Run-group experiment d_2^n
- Run-group experiment A_y^n projections, in comparison with world data (Phys. Rev. Lett. **113**, 022502 (2014))
- Run-group experiment polarized Sea/PDFs



Δd and $\Delta \bar{d}$ with polarized ^3He
World fit and SoLID impact by JAM group



Pre-R&D Progress

- Early Pre-R&D by user groups
 - Pre-R&D on all subsystems led to the pCDR
 - Beam tests on GEMs, ECal, Cherenkovs and MRPC to verify design
- JLab supported pre-R&D
 - Magnet refurbishment/testing and DAQ
- DOE funded, JLab supported pre-R&D activities (2020-now)
 - High luminosity beam test with focus on Cherenkov performance (2020-2023)
 - High luminosity beam test with focus on Ecal, PID (2023-2025)
 - Pre-R&D on Tracking and Trigger Electronics/Readout system
- Beam Testing activities during Run 2026 in Hall C
 - Focus on tracking detector and readout with full set of prototype detectors
 - GEMs as baseline design, new options: micro-RWell, micro-RGroove
- Current and planned pre-R&D on cutting-edge technologies
 - Submitted White Paper for MPGD ASIC development
 - Streaming readout, self-driving detector
 - AI/ML proposals for Genesis Mission

Light/Heavy Gas Cherenkov Beam test

Performance of photosensors in a high-rate environment for gas Cherenkov detectors

C. Peng,^a J. Xie,^{a,*} S. Joosten,^a Z.-E. Meziani,^a M. Jones,^b E. Kaczanowicz,^c M. Rehfuss,^c N. Sparveris,^c M. Paolone,^d M. Foley,^e M. Minot^e and M. Popecki^e

- Photosensor and readout: two beam tests (2018, 2020) to study two types of photosensors performance under high background rate
 - Baseline design: 64-pixel photosensors, arranged as 3×3 or 4×4 modules per sector.
 - **Hamamatsu H12700 MaPMTs** Good performance demonstrated. Require magnetic shielding.
 - **Pixelated LAPPDs** Better magnetic-field tolerance. Comparable Cherenkov detection performance demonstrated in 2020 beam test.
- Canada CFI funds got approved for the HGC manufacturing, agreement with Jlab waiting for DOE approval

Performance of a coarsely pixelated LAPPD photosensor for the SoLID gas Cherenkov detectors

J. Xie,^{a,*} C. Peng,^a S. Joosten,^a Z.-E. Meziani,^a A. Camsonne,^b M. Jones,^b S. Malace,^b E. Kaczanowicz,^c M. Rehfuss,^c N. Sparveris,^c M. Paolone,^d M. Foley,^e M. Minot,^e M. Popecki^e and Z.W. Zhao^f

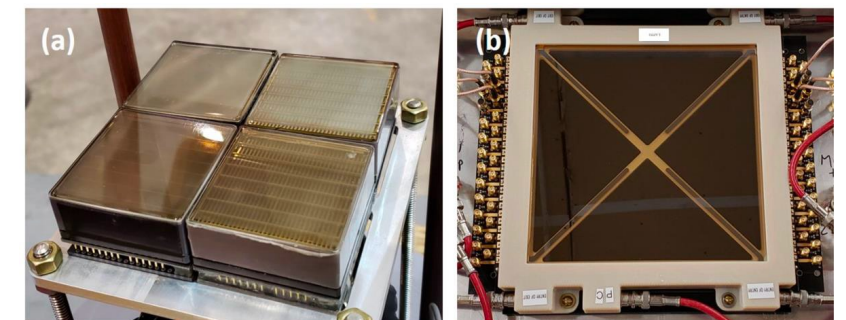
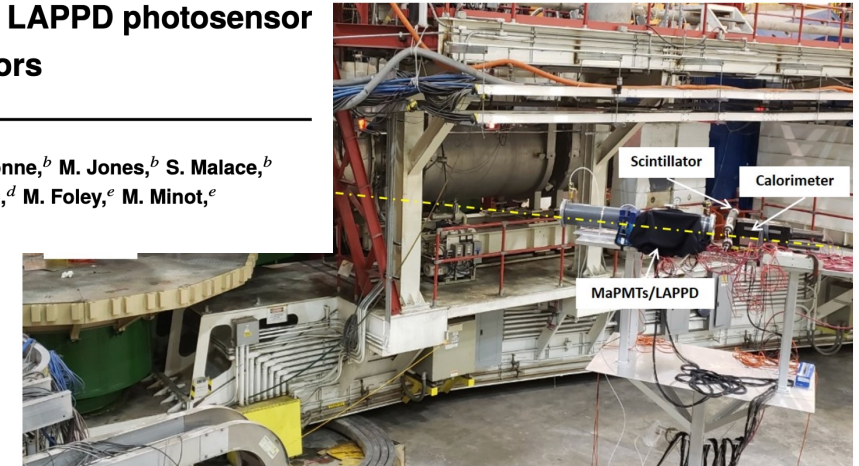


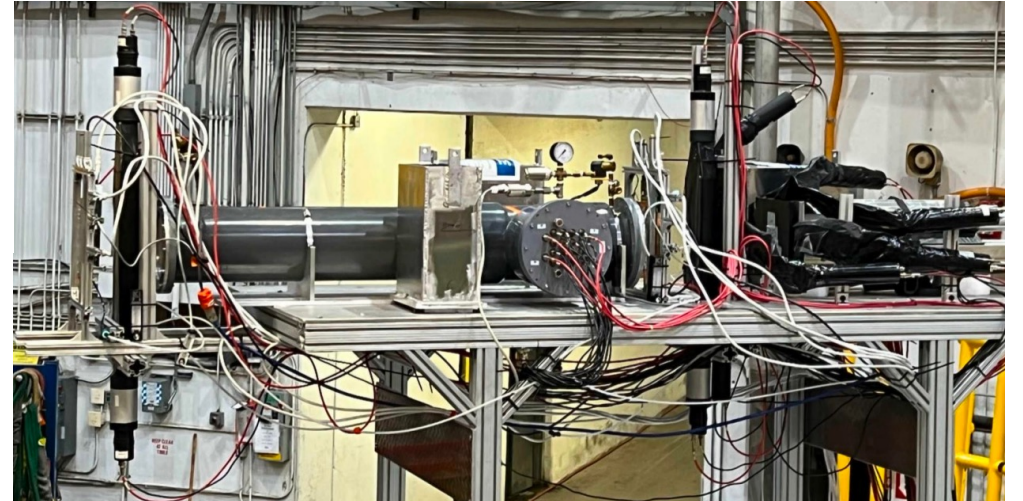
Figure 2. (a) $10 \times 10 \text{ cm}^2$ p-terphenyl coated MaPMT array, and (b) $20 \times 20 \text{ cm}^2$ LAPPD.

ECAL and LASPD Beam test

Electromagnetic Calorimeter Performance In a High Rate Environment for the SoLID Physics Program

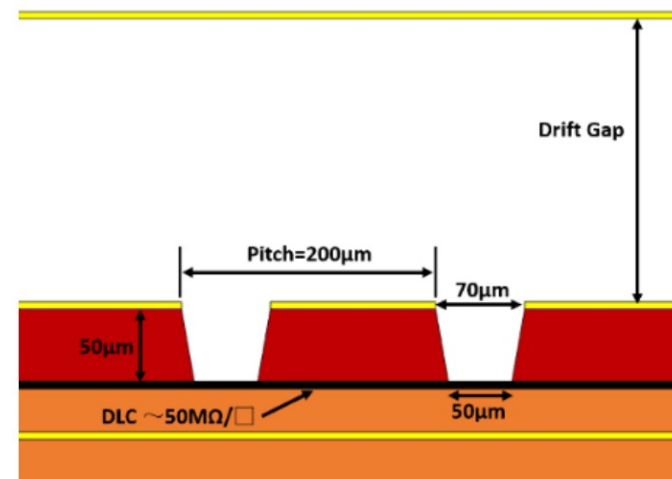
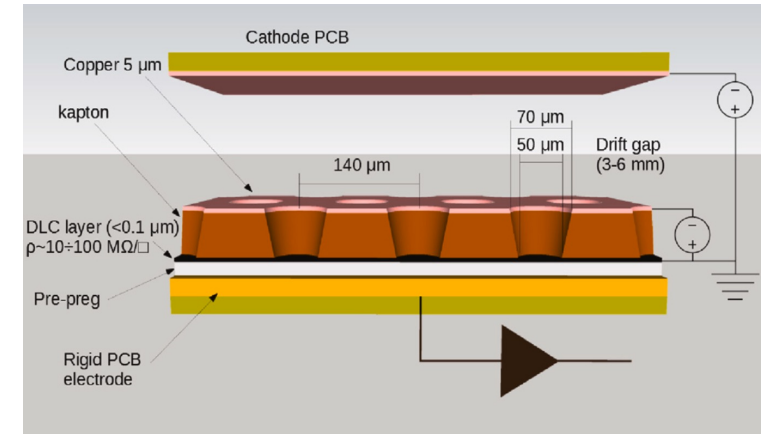
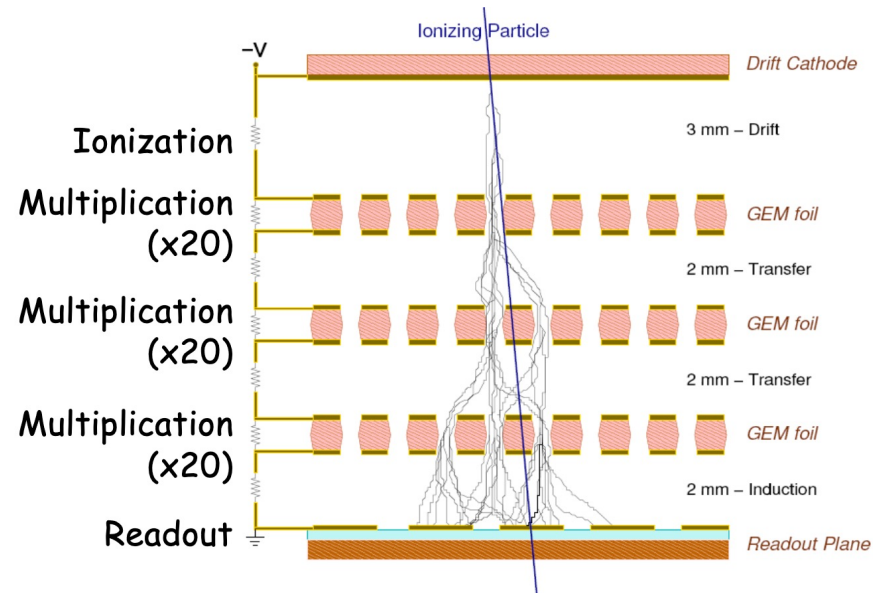
H. Atac,¹ X. Bai,² A. Camsonne,³ J. Caylor,⁴ J.-P. Chen,³ C. Feng,⁵ H. Gao,⁶ C. Hedinger,² T. Holmstrom,⁷ D. Liu,⁵ Y. Liu,⁵ N. Liyanage,² M. Lowry,² Z.-E. Meziani,⁸ B. Moffit,³ M. Nycz,² S. Opatrny,² C. Peng,⁸ M. Paolone,⁹ M. Rafi,² B. Raydo,³ P. A. Souder,⁴ N. Sparveris,¹ H. Sun,⁵ Y. Tian,⁴ Y. Tian,¹⁰ R. Trotta,² Z. Ye,¹¹ D.W. Upton,² J. Zhang,² Z.-W. Zhao,⁶ and X. Zheng²

- Test of ECAL and LASPD during the 2022 beam test
- Demonstrate PID with AI/ML
- PMT base redesign needed to address gain shift at high rate
- Other to do:
 - MaPMT readout of Preshower testing
 - MCP-PMT readout of LASPD



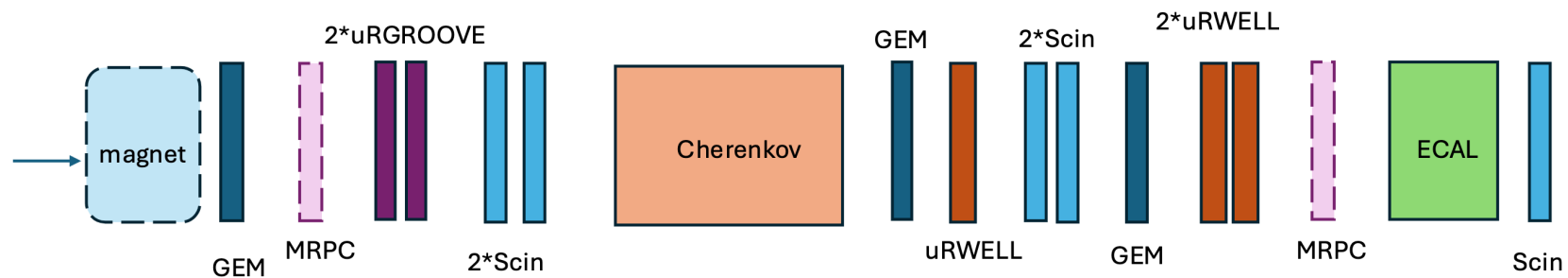
2026 Beam test in Hall C

- The goal is to evaluate the performance of tracking with GEMs, uRwell, uRGROOVE in high rate conditions



2026 Beam test in Hall C

- Detector installation at large angle is complete
- Detector commissioning in progress
- Plan to move the detector setup to small angle (15deg) in August
- Also planned to evaluate the performance of the VMM prototype board in beam



Path Forward for SoLID

- Given the challenging funding situation
 - DOE is unlikely to start large project in the next few years
- Collaboration plans to pursue staged construction approach
 - Initially build the components required for one experiment
 - Will limit the cost to what Jlab can support
 - Progressively expand and enhance the detector
 - Iteratively secure additional funding opportunities
- Currently plan to start with the J/ψ program
 - Magnet, ECal, trackers, Cherenkov?
 - Partial coverage
 - Evaluate options with impacts and costs to form a plan

Summary

- SoLID is at the intensity frontier with JLab 12 GeV upgrade
 - Rich and highly rated physics programs: PVDIS, SIDIS, near-threshold J/ψ
 - Many other experiments in development
- Beam tests
 - Demonstrated the feasibility of key detector subsystems in a high-rate environment
 - Evaluating new detector designs and front-end electronics as they become available
- Developing plan to start the SoLID physics program with a subset of the detectors