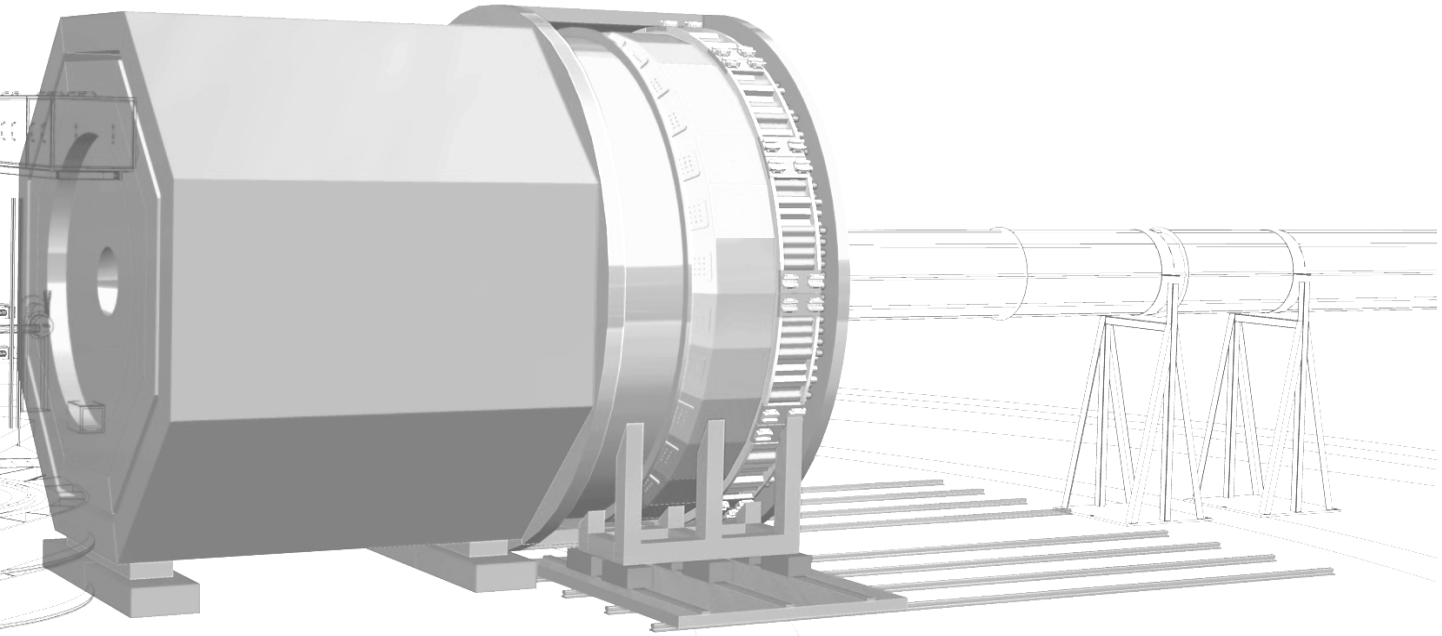


Current Status of SoLID

Weizhi Xiong
Syracuse University

01/22/2021

Hall A collaboration meeting

SOLENOIDAL LARGE INTENSITY DEVICE

Outline

- Physics reach of SoLID
- The SoLID spectrometer
- Status of SoLID program
- Summary

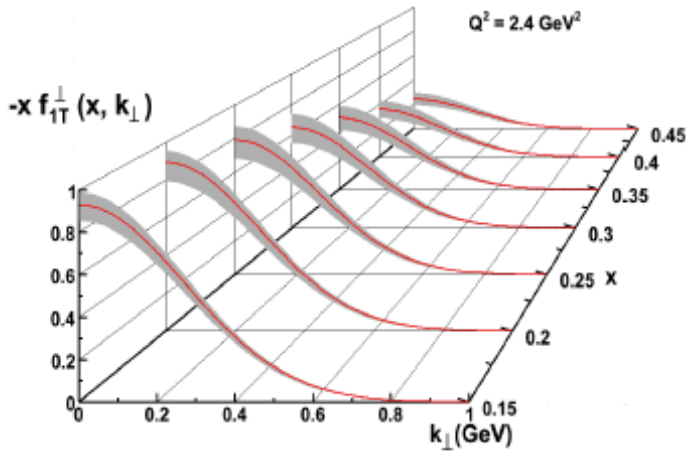
SOLENOIDAL LARGE INTENSITY DEVICE

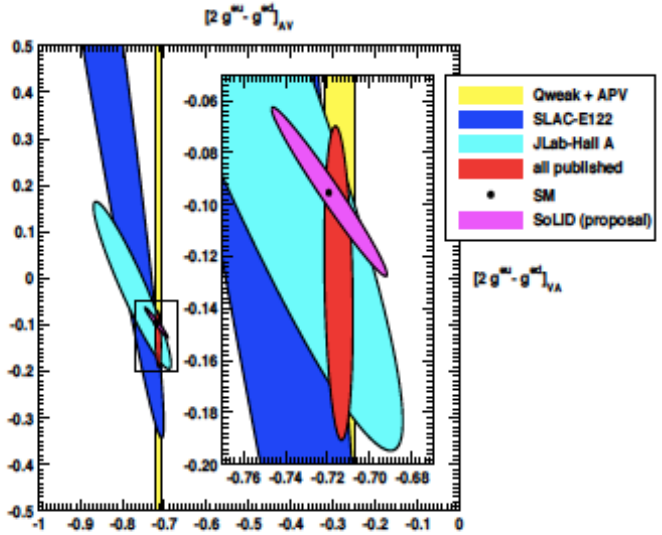
SoLID Physics Overview

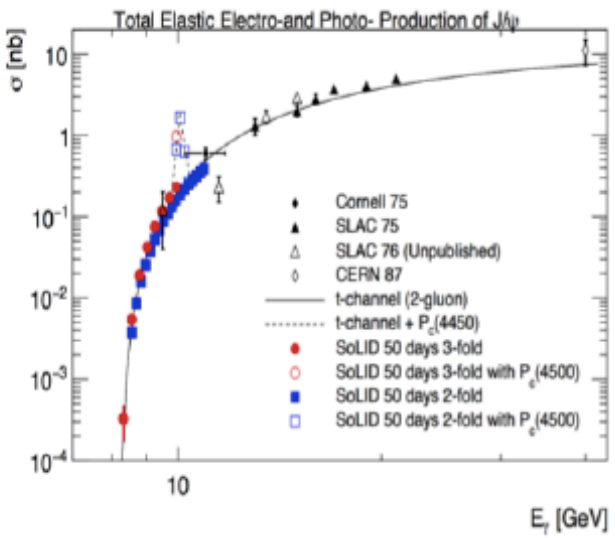
- **Full exploitation of JLab 12 GeV Upgrade to maximize scientific return**

A Large Acceptance Detector AND Can Handle High Luminosity (10^{37}-10^{39})

- SIDIS - reaching ultimate precision for tomography of the nucleon (E12-10-006, E12-11-007, E12-11-108)
- PVDIS in high-x region - providing sensitivity to new physics at 10-20 TeV (E12-10-007)
- Threshold J/ψ - probing strong color fields in the nucleon and the origin of its mass (trace anomaly) (E12-12-006)







- **2015 LRP recommendation IV**

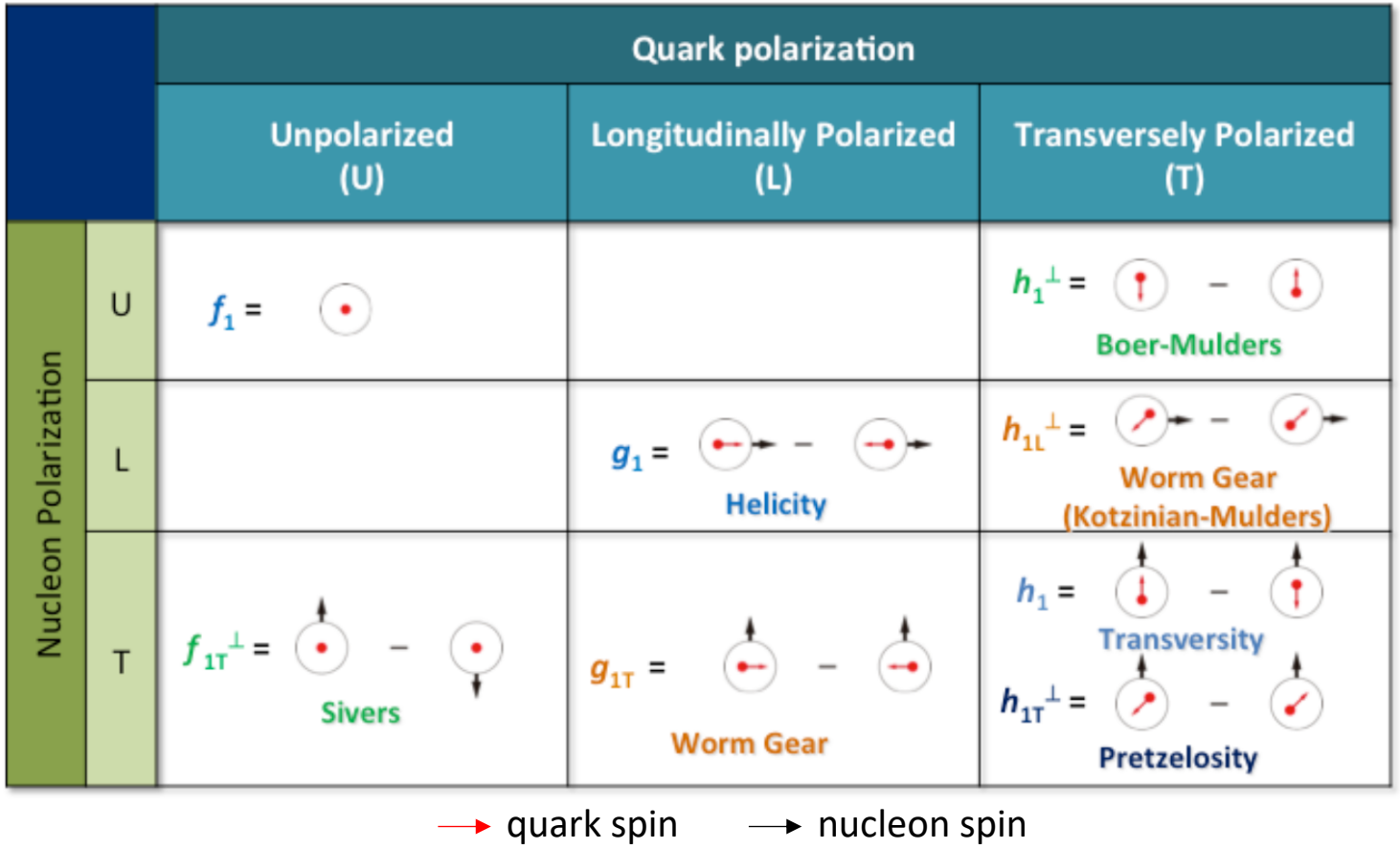
- We recommend increasing investment in small-scale and mid-scale projects and initiatives that enable forefront research at universities and laboratories – **SoLID – mid-scale project**

SoLID-SIDIS Program

- Semi-Inclusive Deep Inelastic Scattering
  1. Study 3-D nucleon transverse momentum dependent parton distributions (TMDs)
  2. Extraction the tensor charge for *d* and *u*
  3. Provide information on quark orbital angular momentum and QCD dynamics

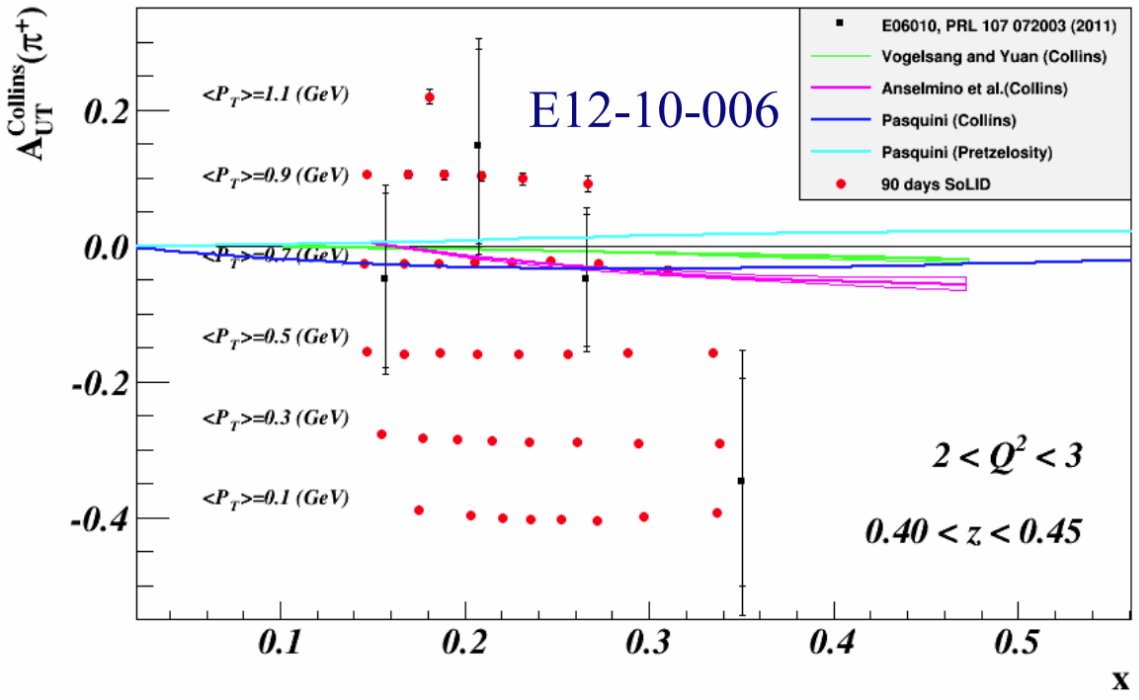
- Three experiments with A rating:
  - ^{3}He target with both transverse and longitudinal polarizations
  - NH_3 target with transverse polarization

- Measuring TMDs through single and double spin asymmetries



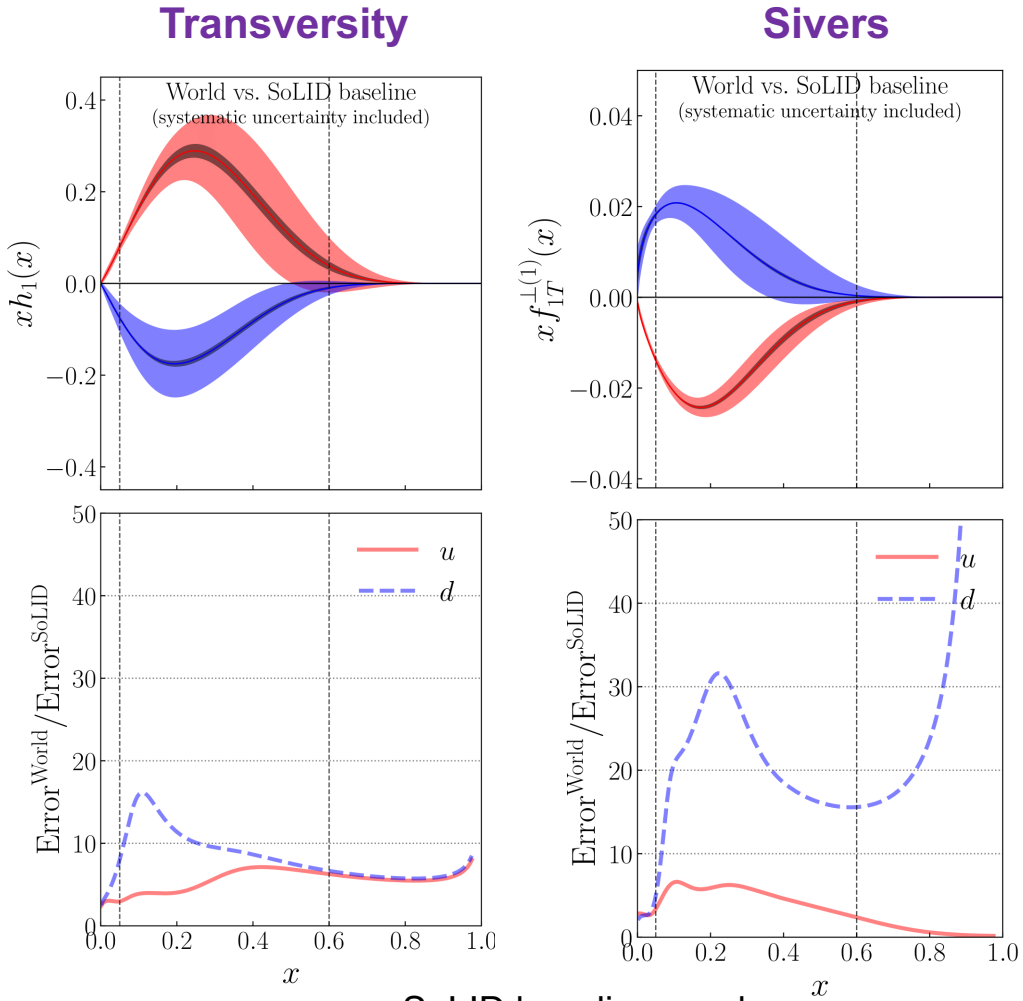
SoLID-SIDIS Impact on TMDs

Comparison of SoLID projection with JLab-6GeV data



- In total 1400 bins in *x*, Q^2, P_T and *z*
- Fit Collins and Sivers asymmetries in SIDIS and e^+e^- annihilation
- Both stat. and syst. errors included

Comparison with world data (HERMES, COMPASS, JLab-6GeV)



SoLID baseline used

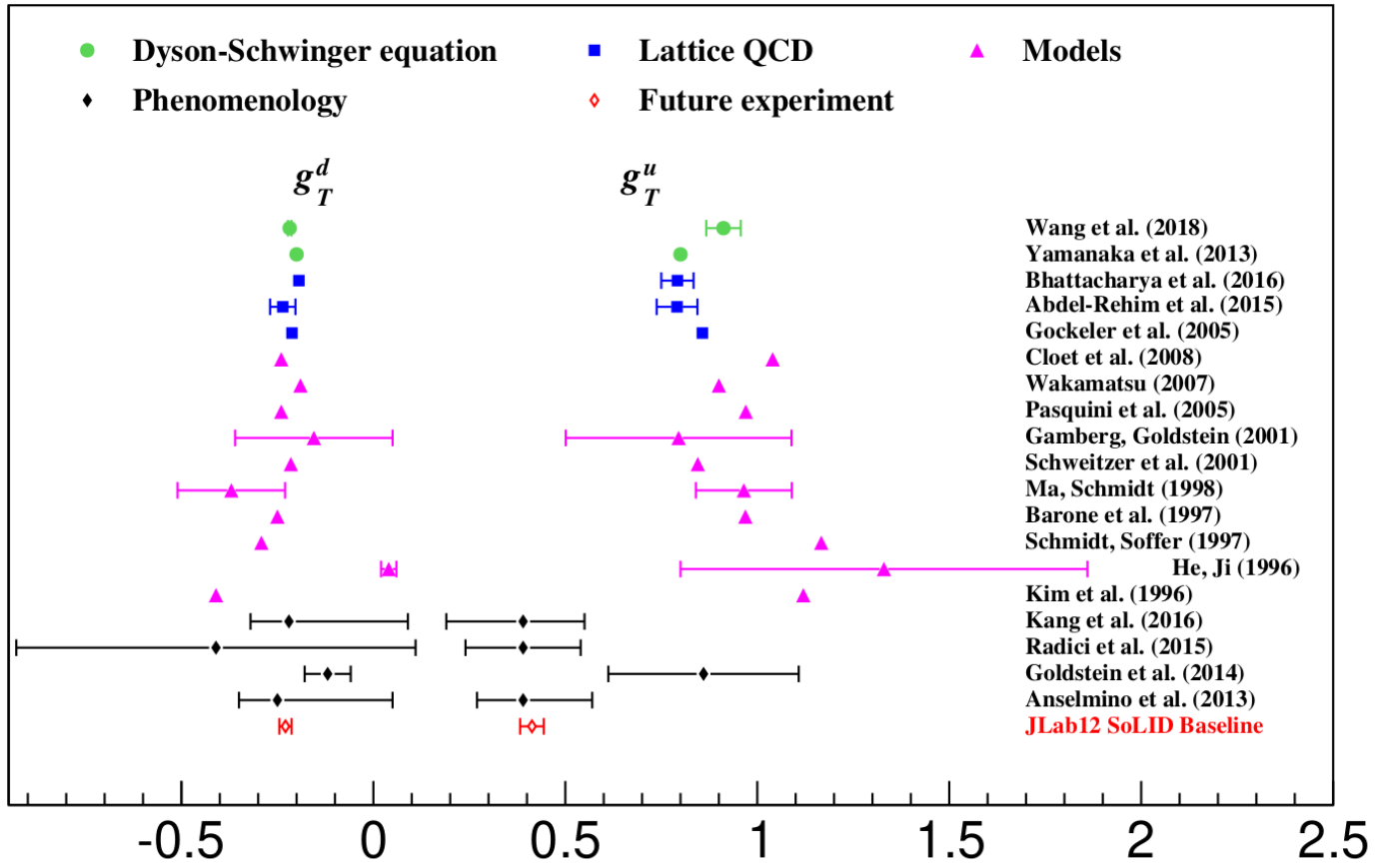
Refs: Z. Ye et al, Phys. Lett. B 767, 91 (2017);
D'Alesio et al., Phys. Lett. B 803 (2020)135347

SoLID-SIDIS Impact on Tensor Charge

Tensor charge

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

- A fundamental QCD quantity: matrix element of local operators.
- Moment of the transversity distribution: valence quark dominant.
- Calculable in lattice QCD.

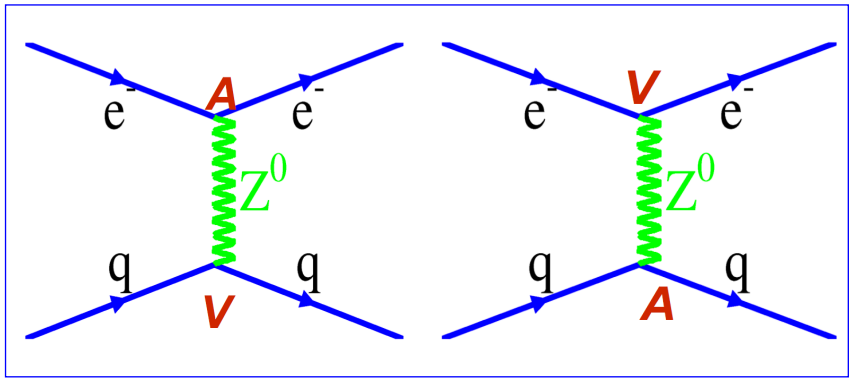


SoLID-PVDIS Program

- Parity Violation -Deep Inelastic Scattering:

- Search for new interactions beyond the Standard Model
- Precision tool to study Hadron Physics:
  1. Sensitive to Partonic Charge Symmetry violation (CSV) at the quark level
  2. Clean probe to study Higher-Twist effects from q-q correlations
- Measure the d/u ratio for the proton at high x

EW neutral current interaction



$$C_{1q} = 2g_A^e g_V^q \qquad C_{2q} = 2g_V^e g_A^q$$

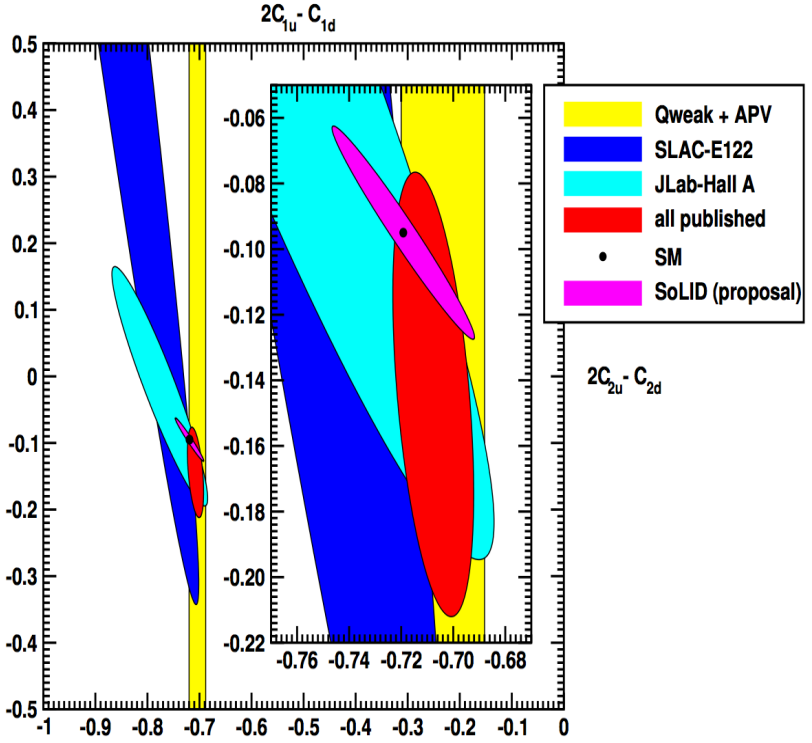
$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} = -\left(\frac{G_F Q^2}{4\sqrt{2}\pi\alpha}\right)(Y_1 a_1 + Y_3 a_3)$$

$$a_1(x) = \frac{6}{5}(2C_{1u} - C_{1d})\left(1 + \frac{2s^+}{u^+ + d^+}\right),$$

PV elastic e-p scattering, Atomic parity violation

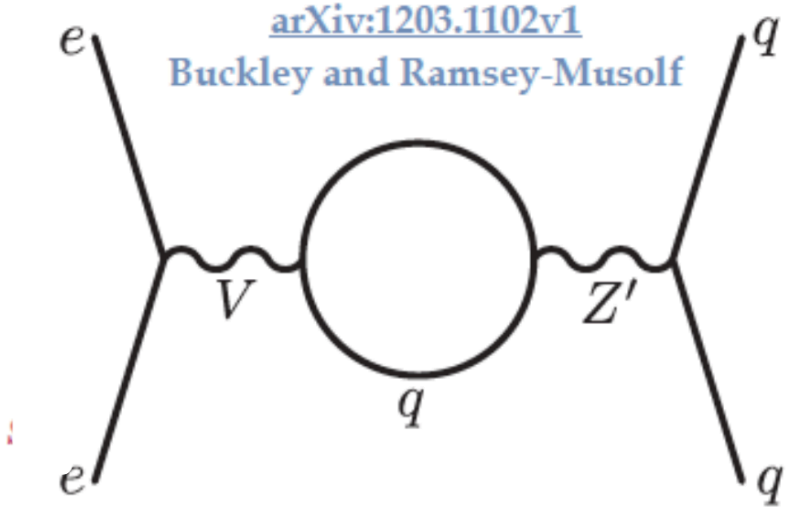
$$a_3(x) = \frac{6}{5}(2C_{2u} - C_{2d})\left(\frac{u^+ - d^+}{u^+ + d^+}\right) + \ldots$$

PV deep inelastic scattering (PVDIS) New physics



SoLID-PVDIS Program

Leptophobic Z'



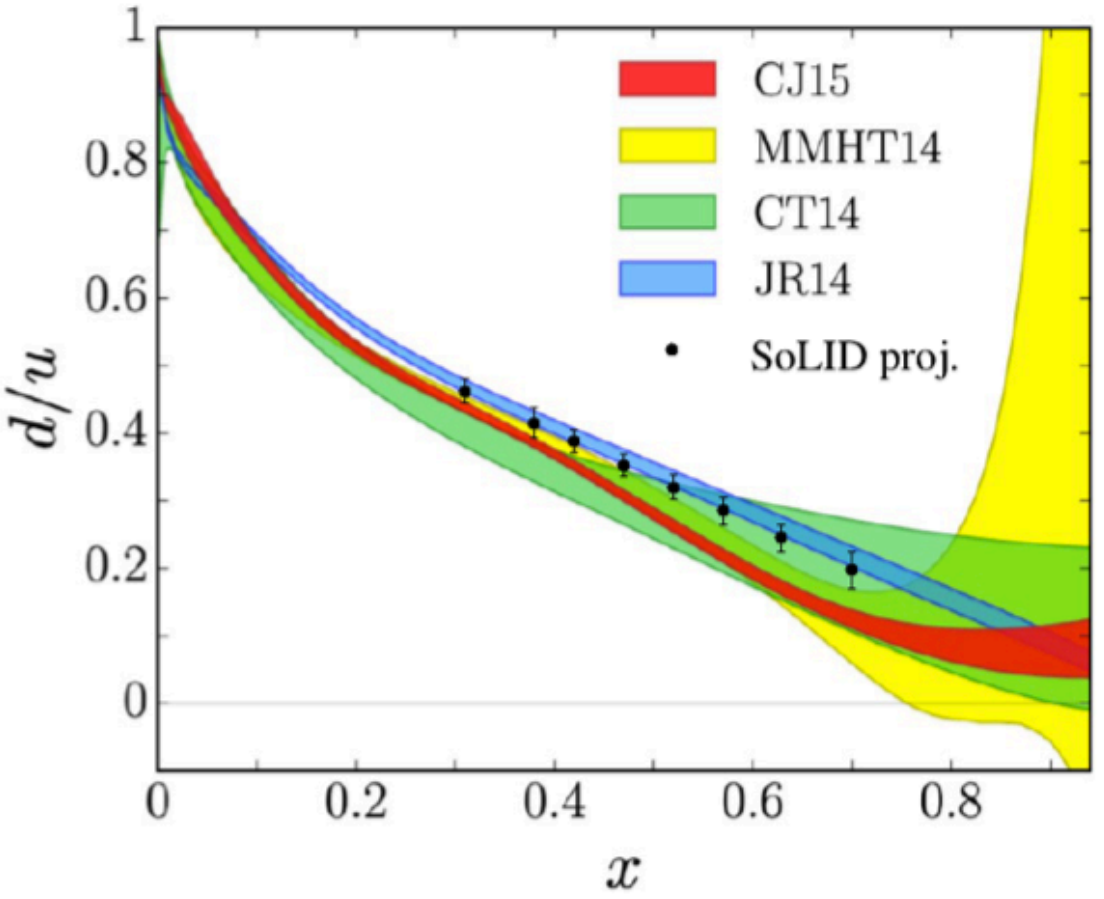
SOLID can improve sensitivity:
100-200 GeV range

Since electron vertex must be vector, the Z' cannot couple to the C_{1q}'s if there is no electron coupling: can only affect C_{2q}'s

- Hard to see low mass leptophobic Z's at the LHC

Measure the d/u ratio for the proton at high x

$$a_1^p(x) = \left[\frac{12C_{1u}u(x) - 6C_{1d}d(x)}{4u(x) + d(x)}\right] \sim \left[\frac{u(x) + 0.912d(x)}{u(x) + 0.25d(x)}\right]$$



PRD 87 (2013) 094012

SoLID-J/ψ Program

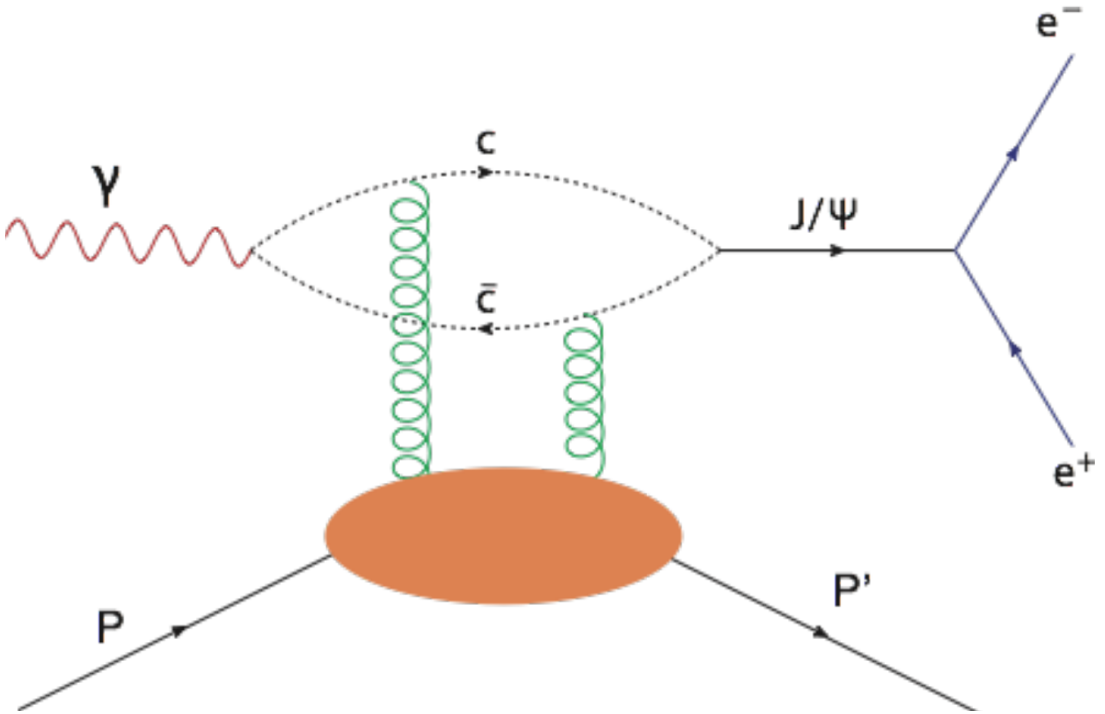
- Electro- and photo-production of Charmonium near threshold

$$ep \rightarrow e'p'\mathrm{J}/\psi(e^-e^+)$$

$$\gamma p \rightarrow p'\mathrm{J}/\psi(e^-e^+)$$

- Real part contains the QCD trace anomaly
  - Important to understand the origin of proton mass

- Probing strong color field in the nucleon
  - Color Van der Waals force?
  - Bound states of charmonium-nuclei?
  - Pentaquarks existence?



Trace Anomaly

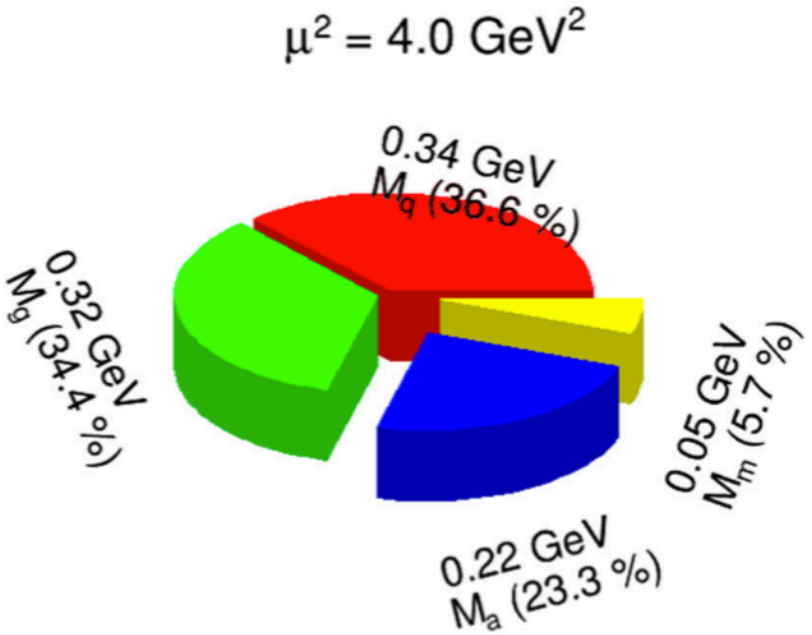
- Ji's mass decomposition: $M_N = M_q + M_m + M_g + M_a$

Quarks kinetic and potential energy $M_q = \frac{3}{4}\left(a - \frac{b}{1+\gamma_m}\right) M_N$

Gluons kinetic and potential energy $M_g = \frac{3}{4}(1-a) M_N$

Quarks masses $M_m = \frac{4+\gamma_m}{4(1+\gamma_m)} M_N$

Trace anomaly $M_a = \frac{1}{4}(1-b) M_N$



R. Wang, X. Chen and J. Evslin
EPJC 80, no.6 507 (2020)

- Access the trace anomaly using VMD and photo-production J/ψ cross section:

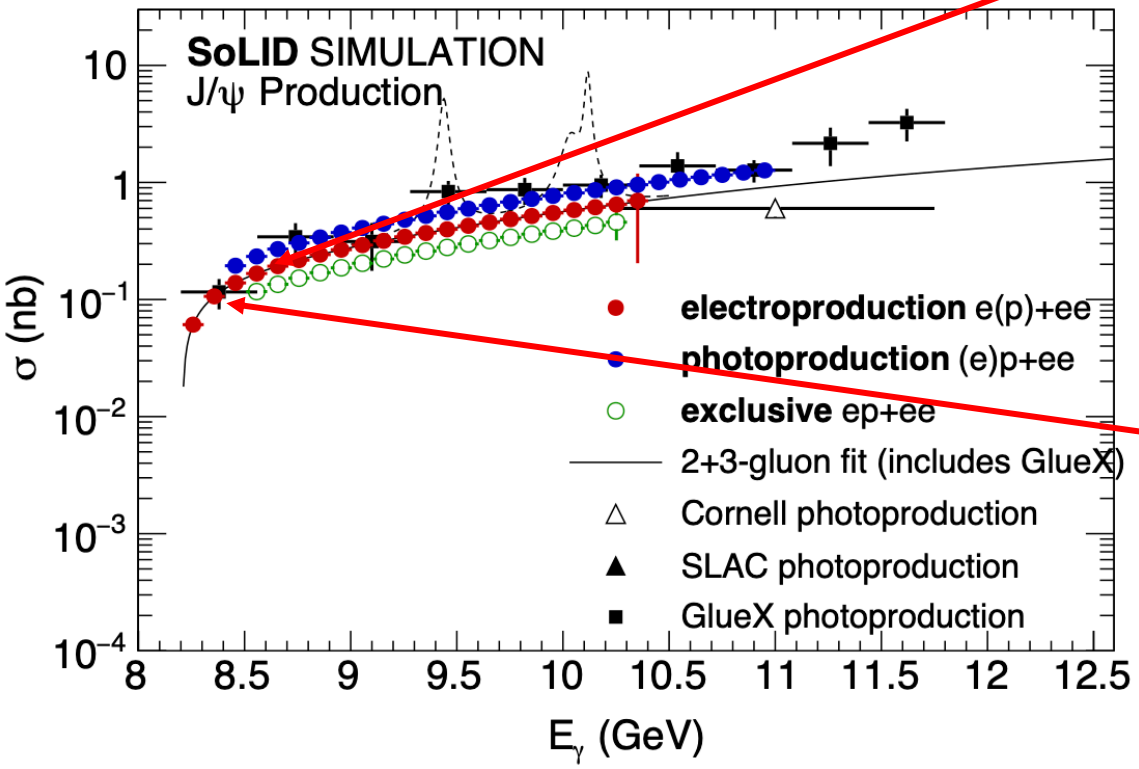
$$\left.\frac{d\sigma_{\gamma N \to J/\Psi N}}{dt}\right|_{t=0} = \frac{3\Gamma(J/\Psi \to e^+e^-)}{\alpha m_{J/\psi}} \left(\frac{k_{J/\Psi N}}{k_{\gamma N}}\right)^2 \left.\frac{d\sigma_{J/\Psi N \to J/\Psi N}}{dt}\right|_{t=0}$$

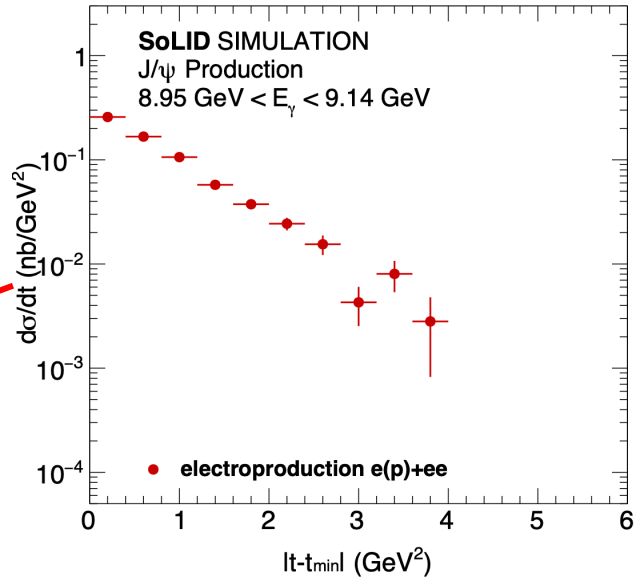
$$\left.\frac{d\sigma_{J/\Psi N \to J/\Psi N}}{dt}\right|_{t=0} = \frac{1}{64\pi} \frac{1}{m_{J/\Psi}^2(\lambda^2 - m_N^2)} |F_{J/\Psi N}|^2$$

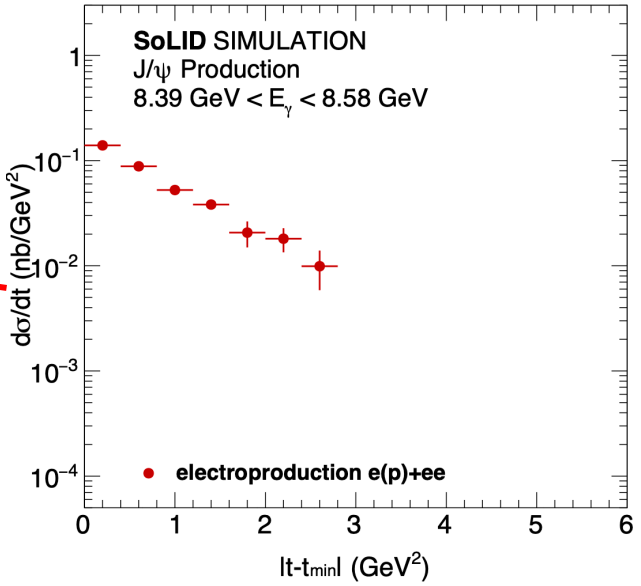
$$F_{J/\Psi N} \simeq r_0^3 d_2 \frac{2\pi^2}{27} 2M_N^2 (1-b)$$

SoLID J/ψ Projections

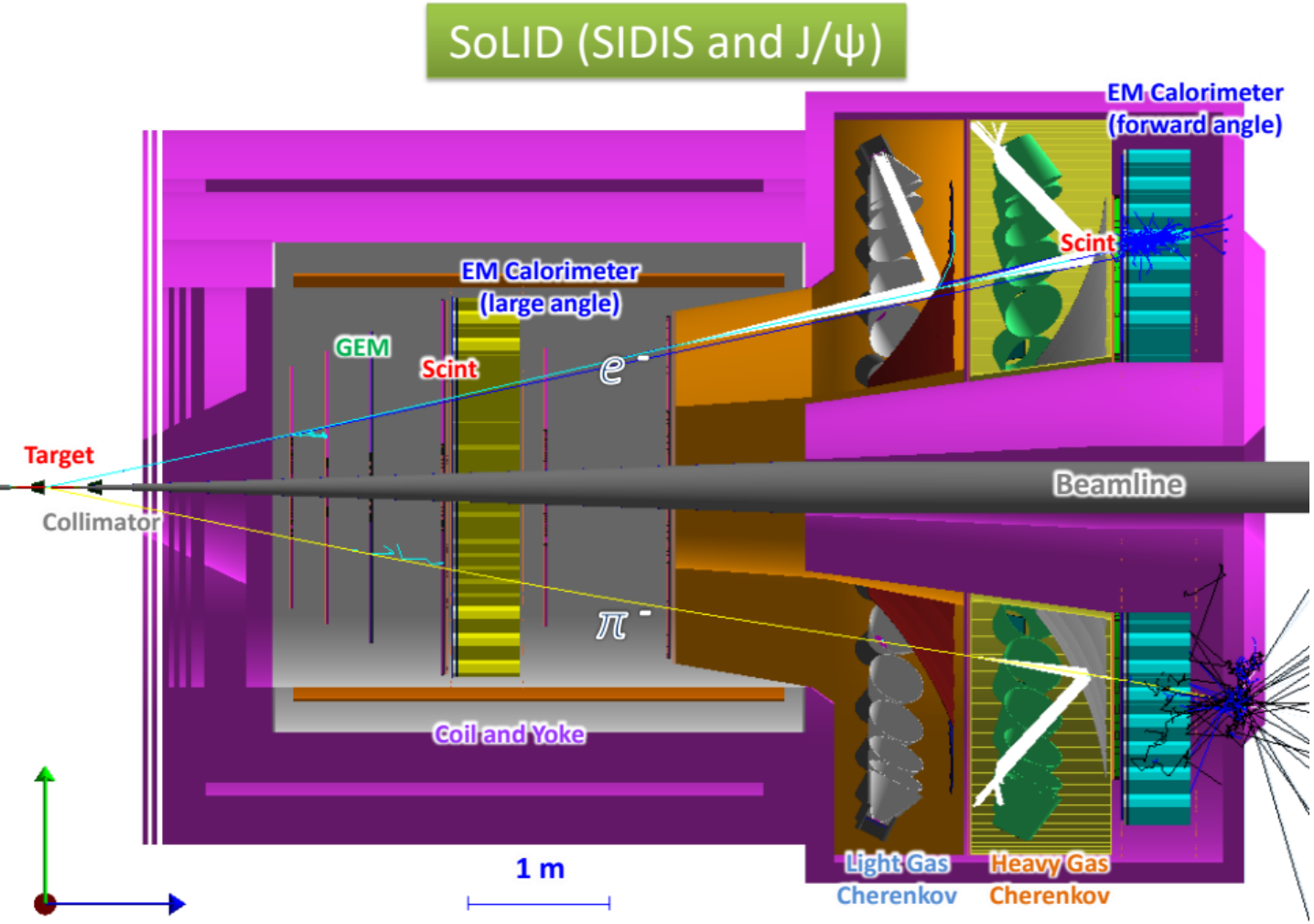
- SoLID provides
  - High Intensity, large acceptance
  - Precise t-distribution for each photon energy bin
- Projection on trace anomaly:
  - Wang el at: $M_a = 23.3\% \pm 4.25\%$
  - SoLID J/ψ: $M_a = 23.3\% \pm 0.08\%$

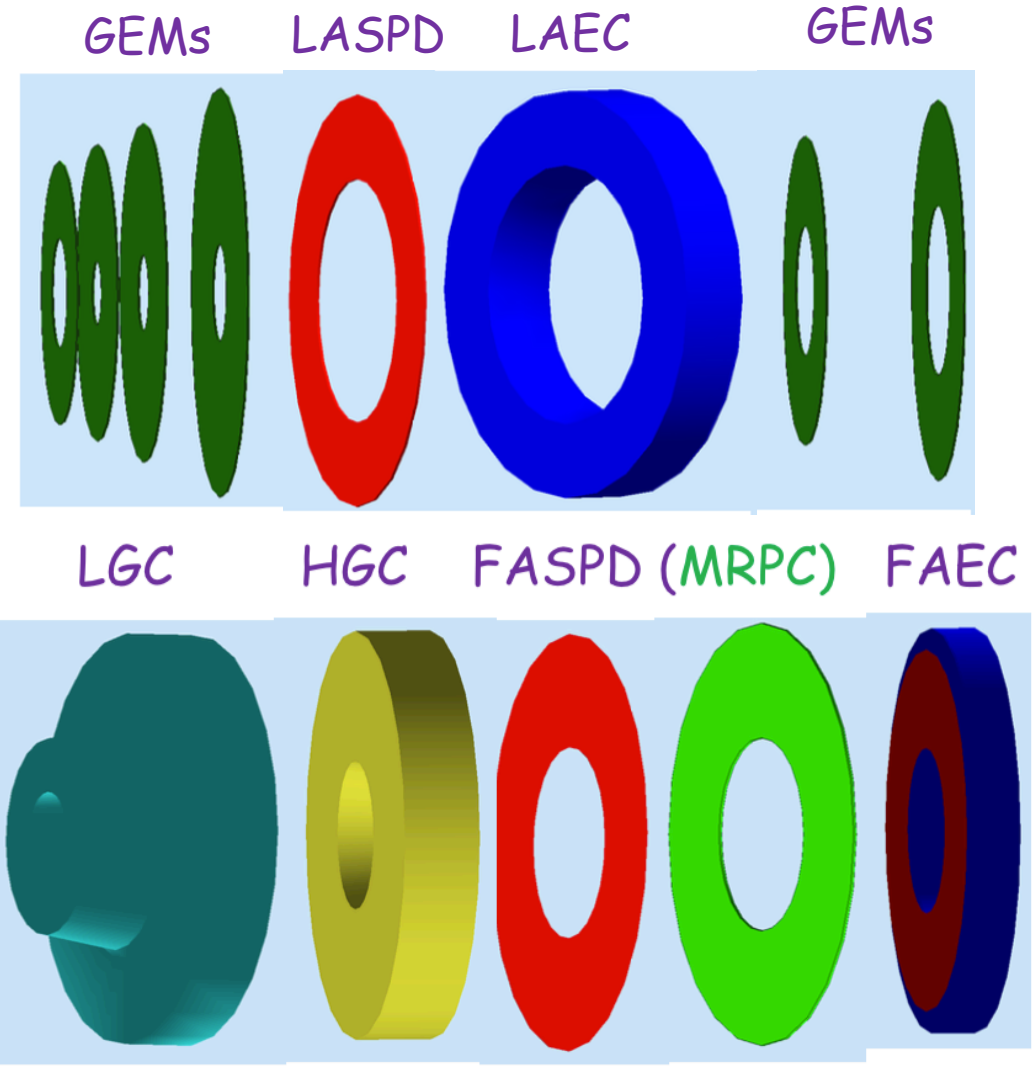




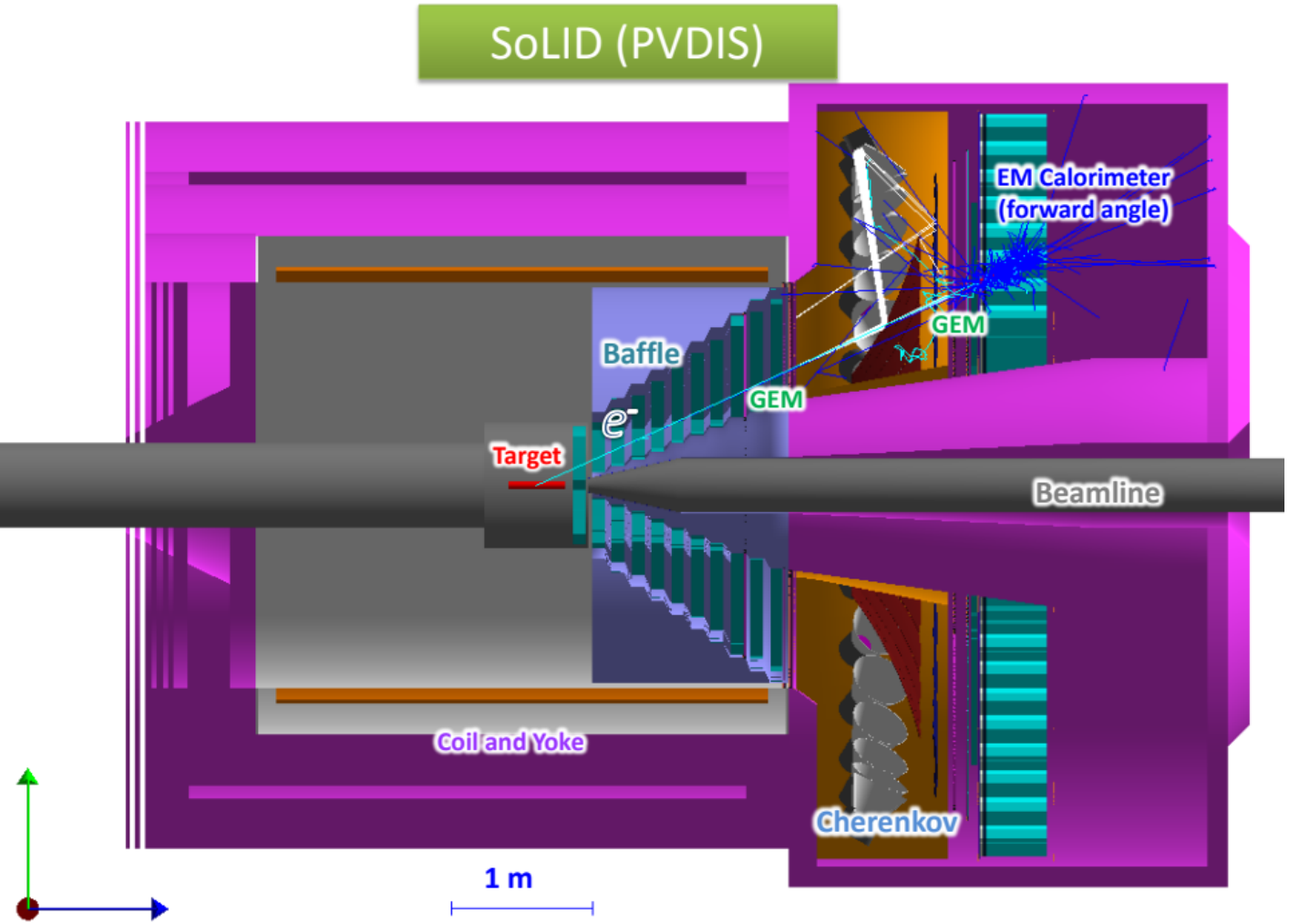


SoLID Apparatus – SIDIS and J/ψ Configuration

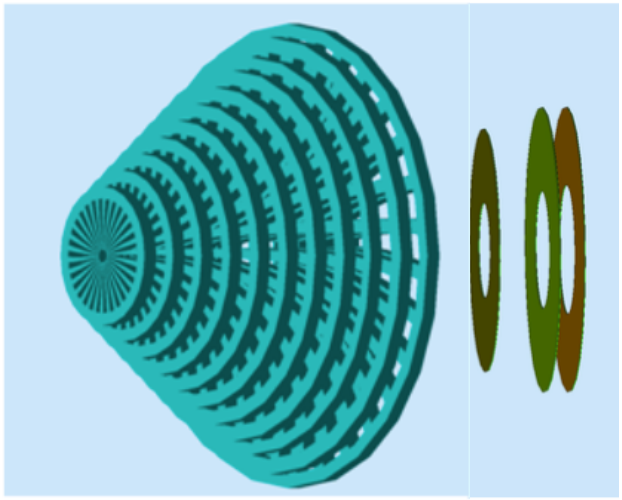




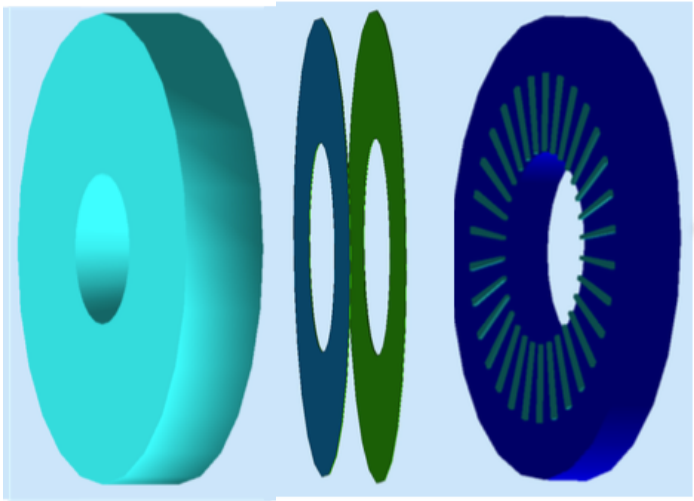
SoLID Apparatus – PVDIS Configuration



Baffle GEMs



LGC GEMs EC



Timeline

- Since 2010: **Five SoLID experiments approved by PAC with high rating**
  3 SIDIS with polarized ^{3}He/p target, 1 PVDIS, 1 threshold J/ψ
  Six additional run-group experiments approved
  SoLID collaboration, with JLab support, has been continuously working on pre-conceptual design and pre-R&D

- 2013: CLEO-II magnet requested, agreed, arrived at JLab 2016,
- **2014: pCDR submitted to JLab with cost estimation**
- **2015: 1st Director's Review: positive with many recommendations**

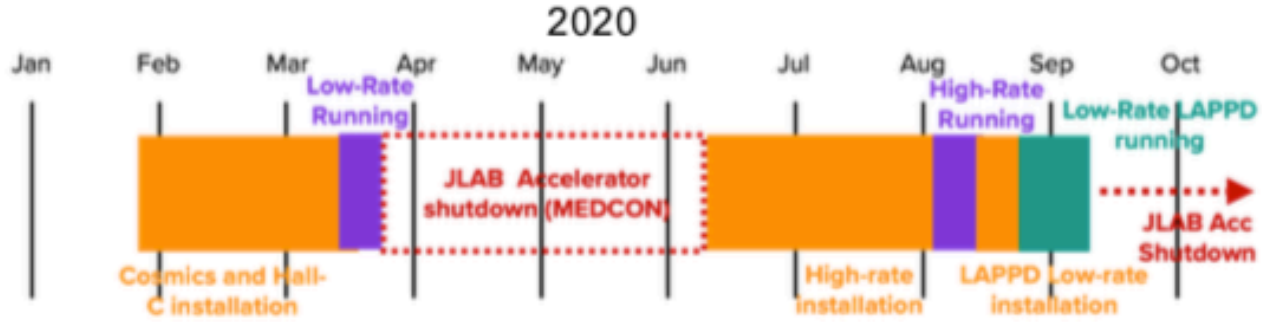
- 2017: Updated pCDR submitted to JLab with responses to the recommendations
- 2018: DOE NP visit and discussion: → update cost estimation
- **1/2019: Updated pCDR (new cost estimation) submitted to JLab**
- **9/2019: 2nd Director's Review: successful with only few recommendations**
- Late 2019: Pre-R&D plan approved, funding started 2/2020
- **2/2020: SoLID MIE (with updated pCDR) Submission to DOE**

- 3/2021: SoLID DOE science review (scheduled)

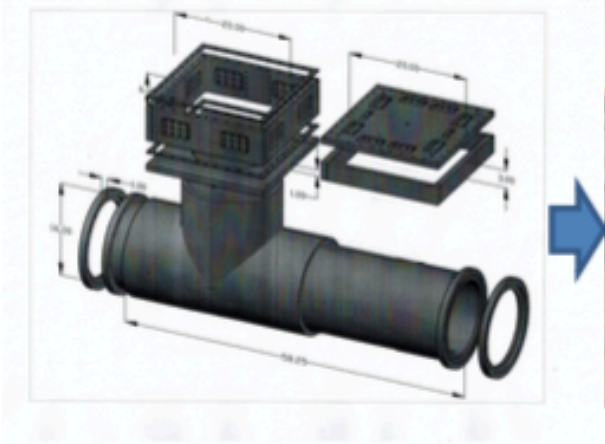
Cherenkov Tests

- **Prototyping Cherenkov detector** was designed and construction was completed at Temple in winter of 2019.
- In early 2020, **Cosmic testing** was performed at the ESB and initial **data was collected** in Hall-C before MEDCON shutdown.
- Additional **high-rate data was collected** in the fall of 2020.

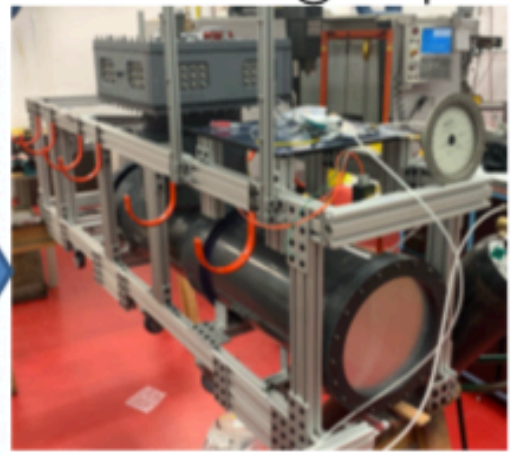
Preliminary data analysis shows the prototype works well in high-rate environment



Design



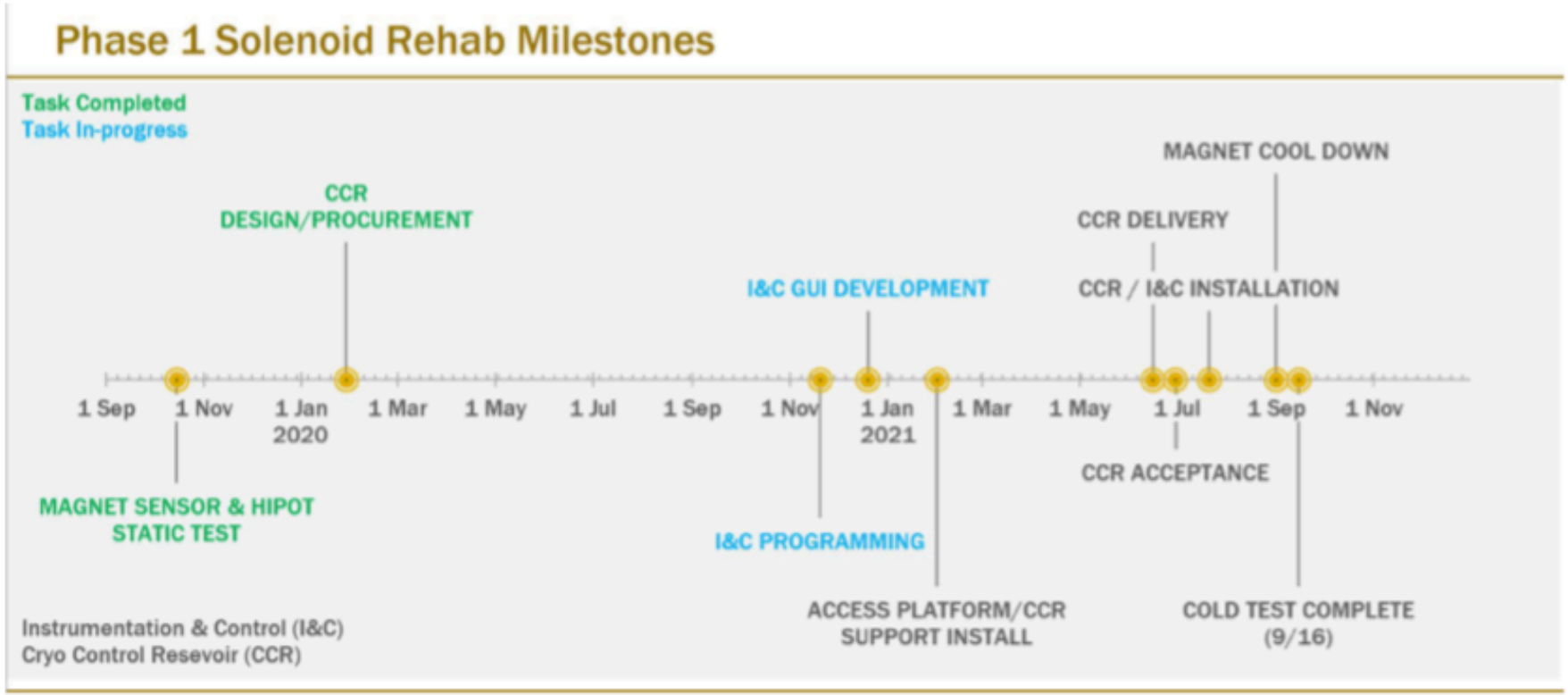
Construction @ Temple U

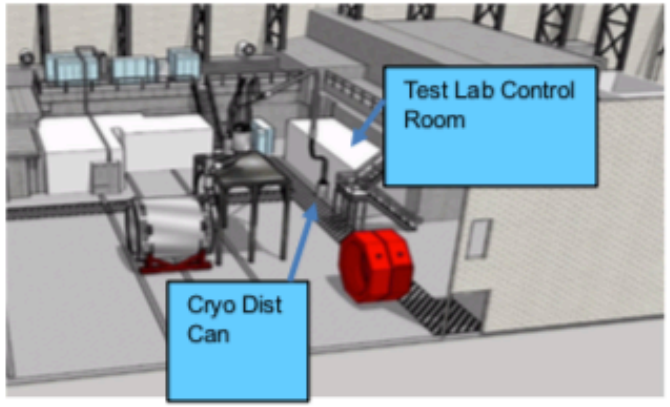


Cosmic Testing @ ESB

Parasitic running @ Hall-C

Magnet Cold Test





- Solenoid rehab will confirm condition of the magnet
- Provide risk reduction to the project
- Improve magnet cost estimate
- Estimated completion 16 Sept 2021

DAQ Tests and Others

- DAQ pre-R&D:
  1. GEM VMM3 testing in high background
  2. GEM APV25 trigger rate with SBS electronics
  3. Gas Cherenkov readout and trigger with FADC and MAROC
  4. FADC fast readout and deadtime measurement for PVDIS
  5. Time of flight sampling chip

- Other on-going activities:
  1. Beam test for Shashlyk ECal modules at Fermi Lab (Jan. 13 – 27 2021)
  2. MRPC development: reaching ~20 ps time resolution at high rate
  3. Simulation and VMM3 digitization

Summary

- SoLID: A **large acceptance** device which can handle **very high luminosity** to allow full exploitation of JLab12 potential
  - ➢ pushing the limit of the luminosity frontier

- After a decade of hard work, we have **a mature pre-conceptual design with expected performance to meet the challenging requirements for the three major science programs**

- SoLID benefited greatly from the previous Director's Reviews
- Technical risks are assessed and addressed in the pre-R&D activities.
- Cost and schedule have been evaluated multiple times

- Science review scheduled in **March 2021**

SoLID Wiki page: https://solid.jlab.org/wiki/index.php/Main_Page