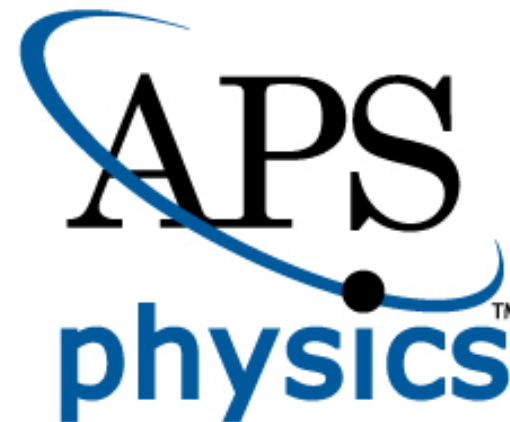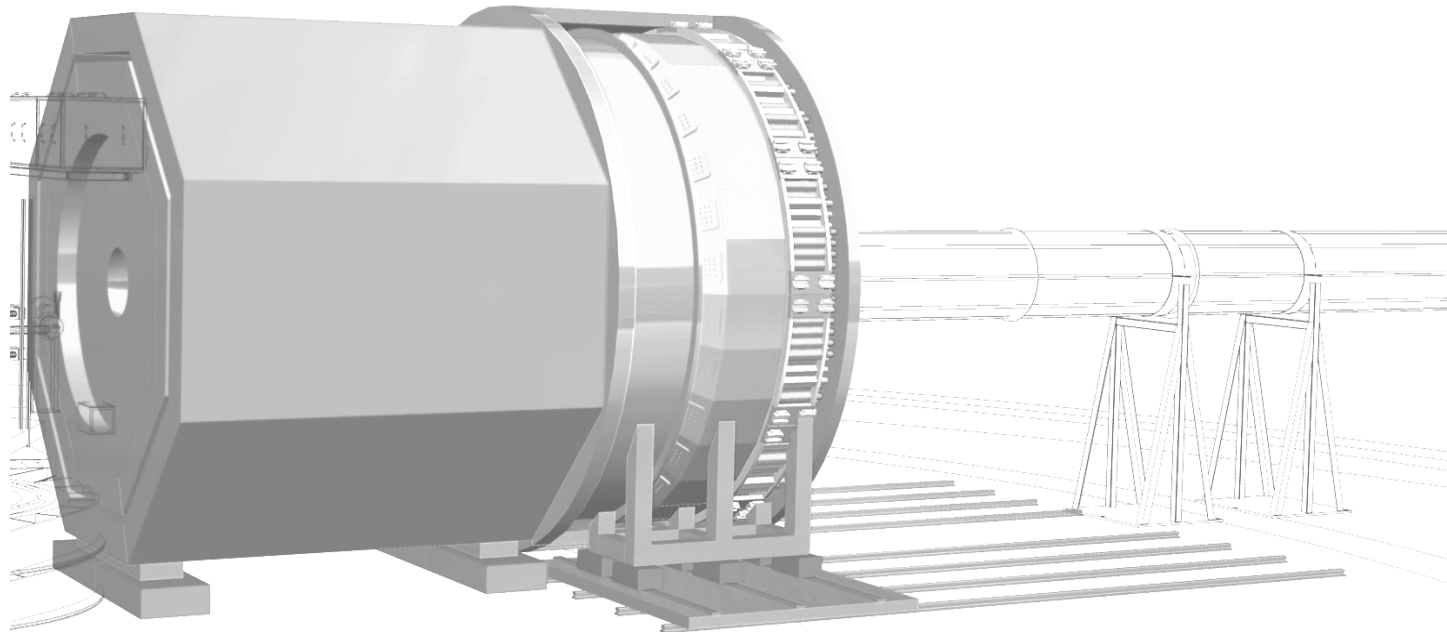# Parity Violating Deep Inelastic Scattering with SoLID at JLab

- Weizhi Xiong

- Syracuse University

- for the SoLID Collaboration

- APS April Meeting 2021

- April 18th 2021

Outline

- Physics motivation

- SoLID detector for PVDIS

- Status of the SoLID program

- Summary

Parity Violating Deep Inelastic Scattering (PVDIS)

EW neutral current interaction

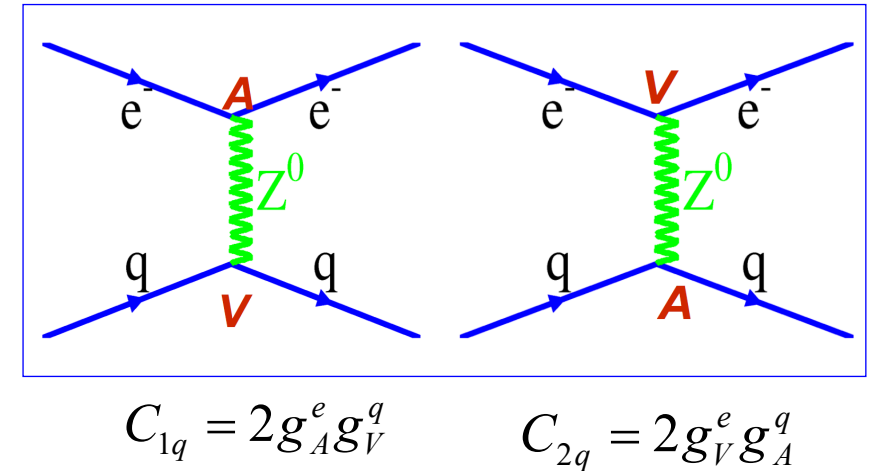$$C_{1q} = 2g_A^e g_V^q \qquad C_{2q} = 2g_V^e g_A^q$$

- Search for new interactions beyond the Standard Model
- Precision tool to study Hadron Physics
- PVES Lagrangian:

$$\mathcal{L}^{PV} = \frac{G_F}{\sqrt{2}}[\bar{e}\gamma^\mu\gamma_5 e(C_{1u}\bar{u}\gamma_\mu u + C_{1d}\bar{d}\gamma_\mu d)$$

$$+\bar{e}\gamma^\mu e(C_{2u}\bar{u}\gamma_\mu\gamma_5 u + C_{2d}\bar{d}\gamma_\mu\gamma_5 d)$$

- At tree level:

$$
\begin{aligned}
C_{1u} &= -\frac{1}{2}+\frac{4}{3}\sin^2\theta_W &\approx& -0.19 \\
C_{1d} &= \frac{1}{2}-\frac{2}{3}\sin^2\theta_W &\approx& 0.35 \\
C_{2u} &= -\frac{1}{2}+2\sin^2\theta_W &\approx& -0.04 \\
C_{2d} &= \frac{1}{2}-2\sin^2\theta_W &\approx& 0.04
\end{aligned}
$$

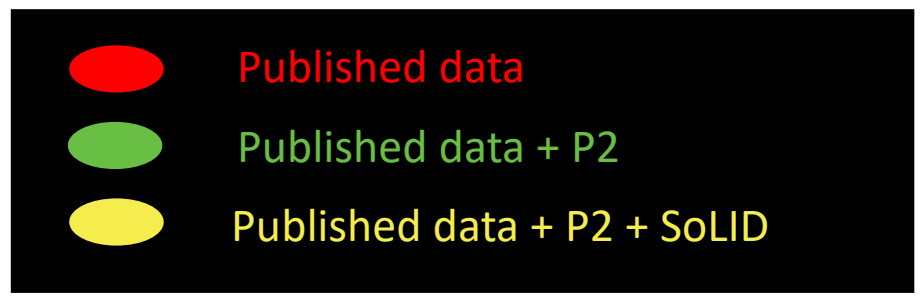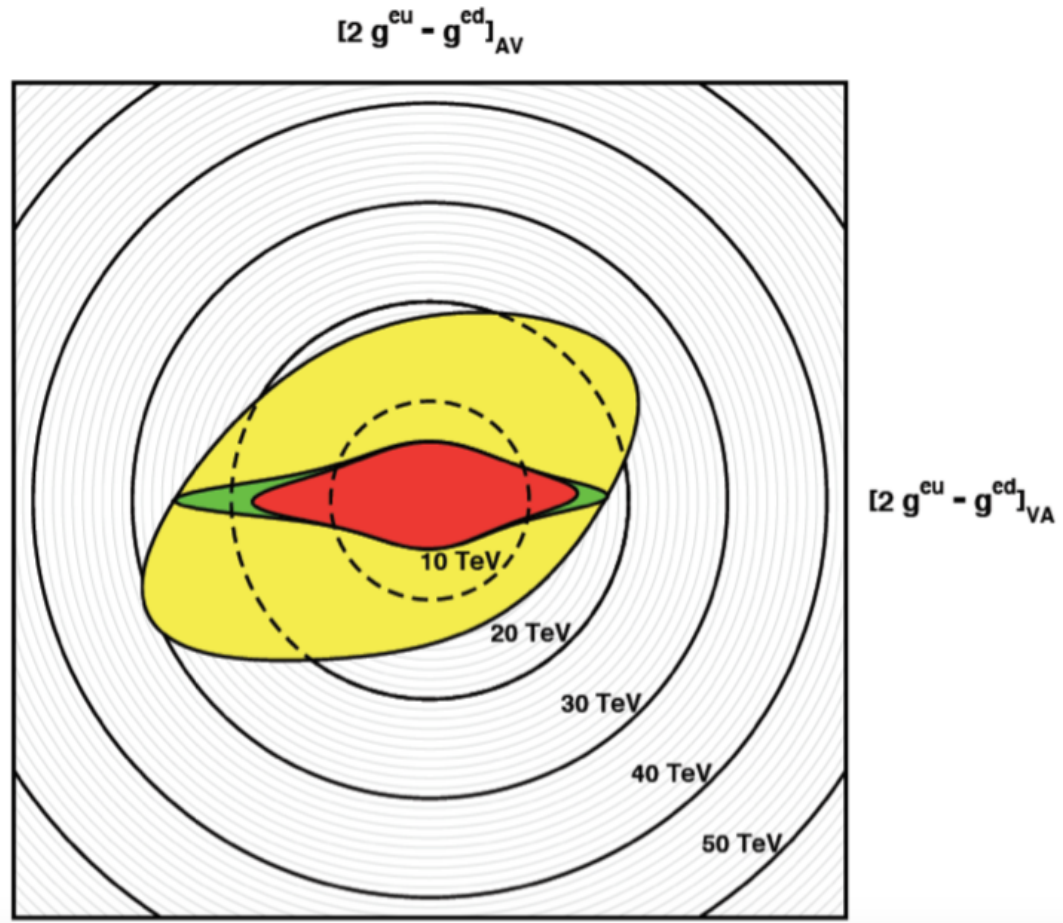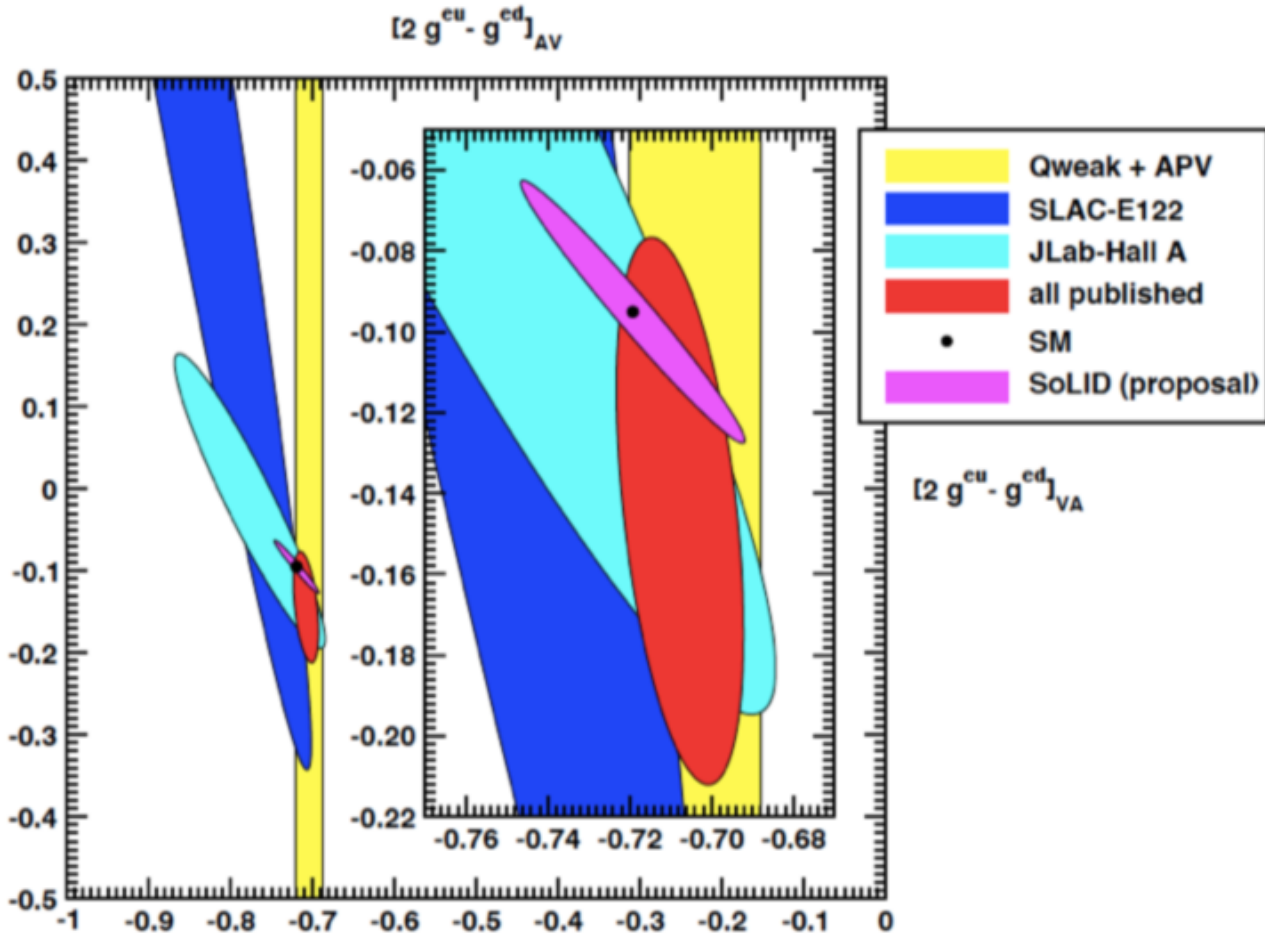PV elastic e-p
Atomic PV

PVDIS

- Parity violating asymmetry:

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

$$\approx -\frac{G_F Q^2}{4\sqrt{2}\pi\alpha}\left[a_1(x) + a_3(x)\frac{1-(1-y)^2}{1+(1-y)^2}\right]$$

- With deuteron target and in the valence quark region:

$$a_1 = \frac{6}{5}(2C_{1u} - C_{1d}) \qquad a_3 = \frac{6}{5}(2C_{2u} - C_{2d})$$

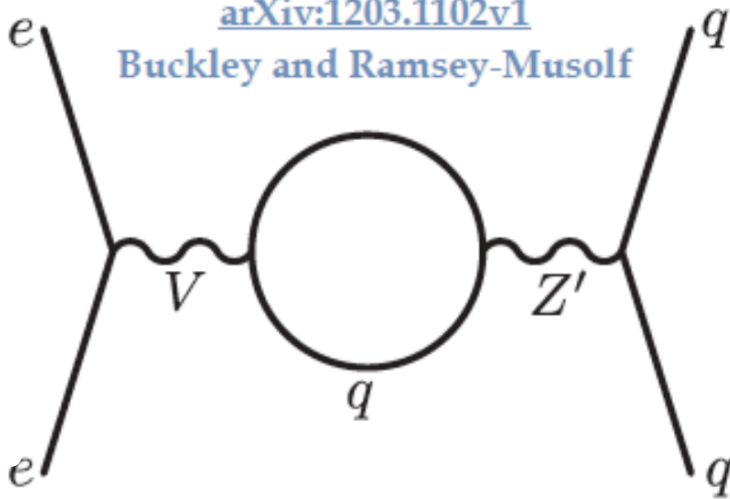# Projected Results on Coupling constants

Improvement in couplings

New Physics beyond the Standard Model

Leptophobic Z'
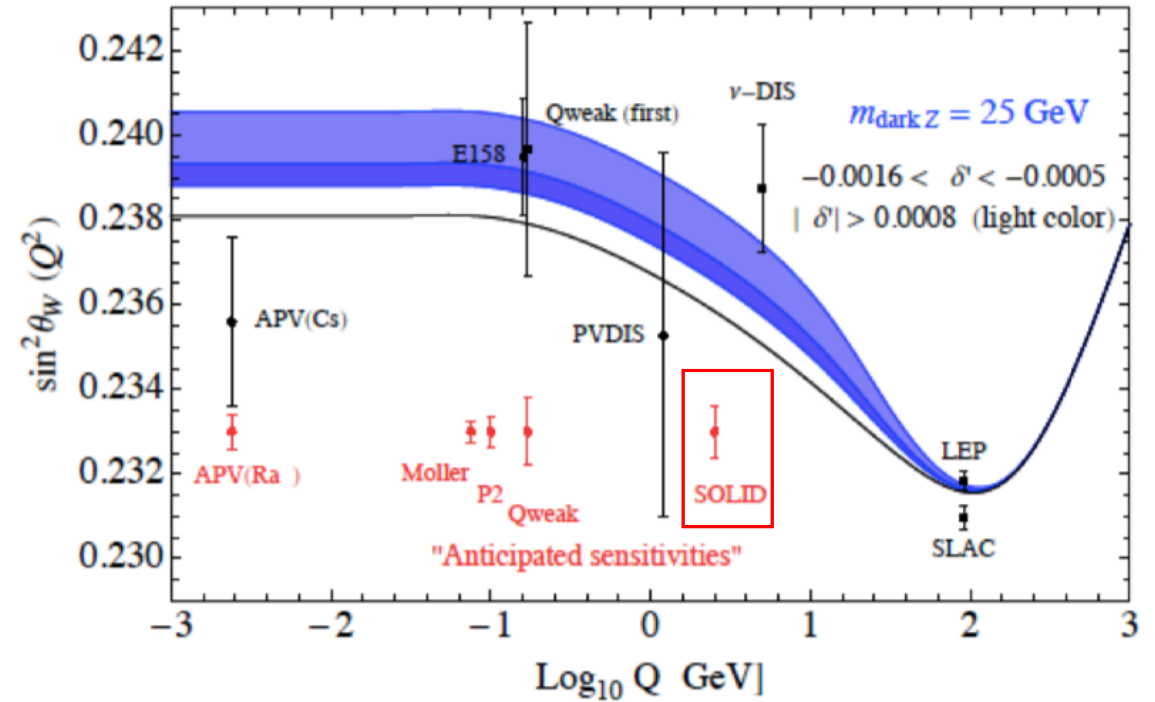

arXiv:1203.1102v1
Buckley and Ramsey-Musolf

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

Dark boson Z_d and $\sin^2\theta_W$

- *Davoudiasl, et al. Phys.Rev.D 92 (2015) 5, 055005*

Hadronic Physics with PVDIS

- Precision tool to study hadronic physics
- Sensitive to partonic Charge Symmetry Violation (CSV) at large x
- Clean probe to study Higher-Twist (HT) effects from *q-q* correlations
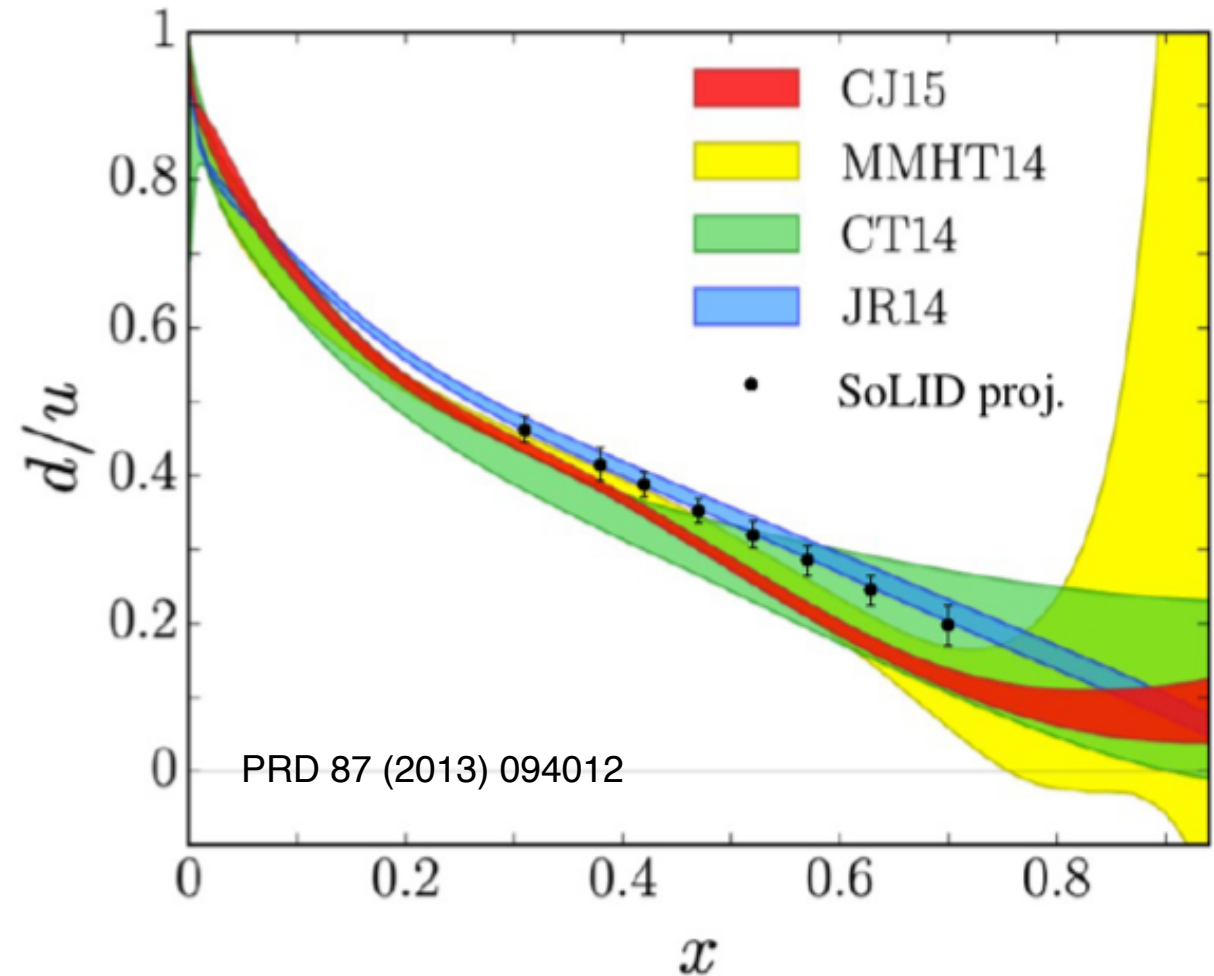- Board kinematic coverage allows clean separation of different physics
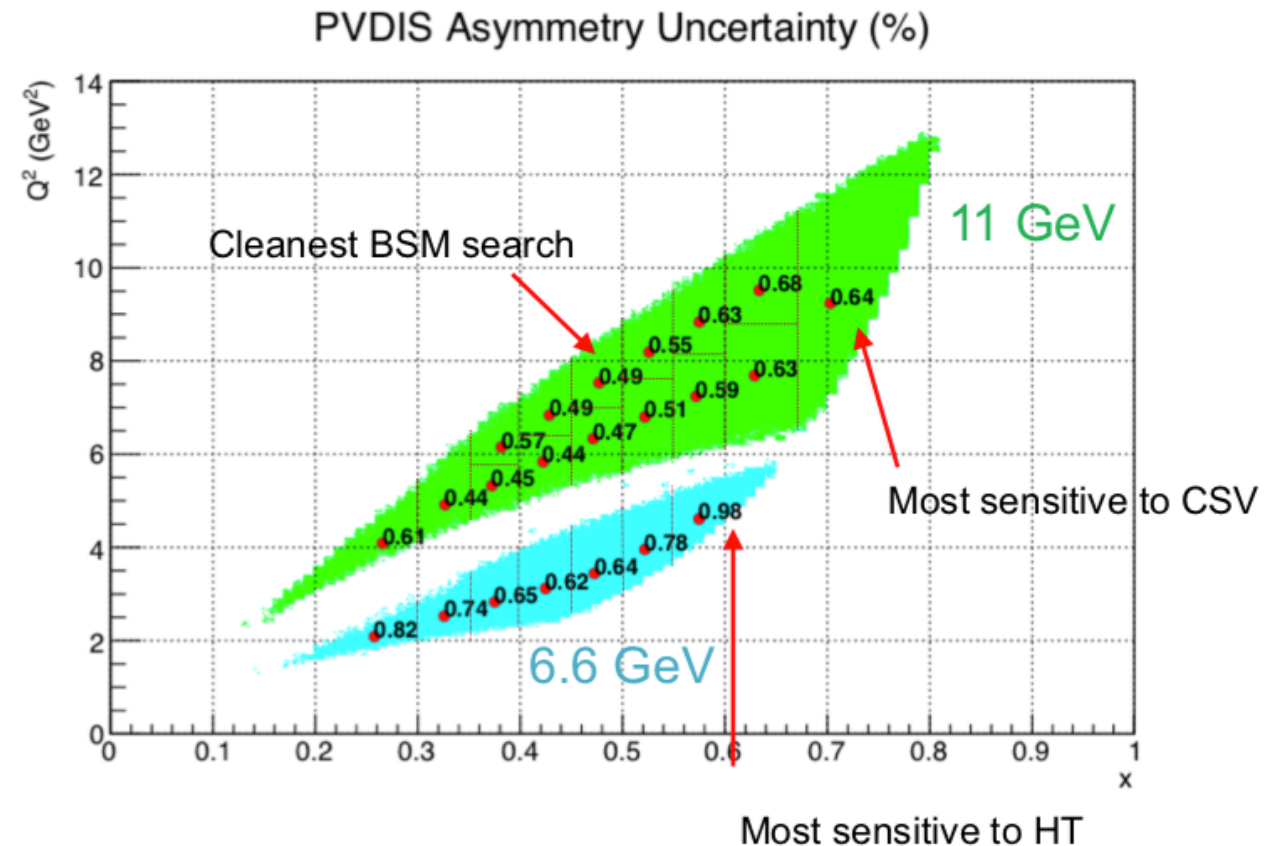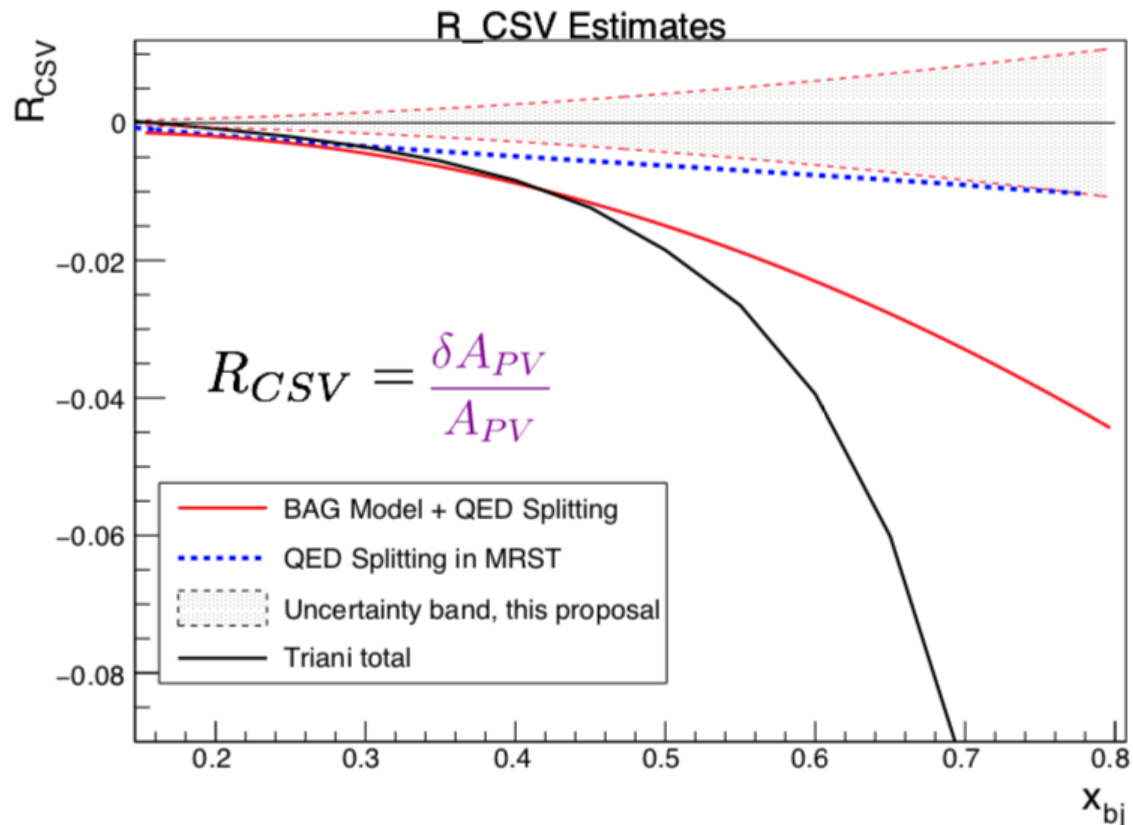
d/u PDF Ratio with Proton Target at High x

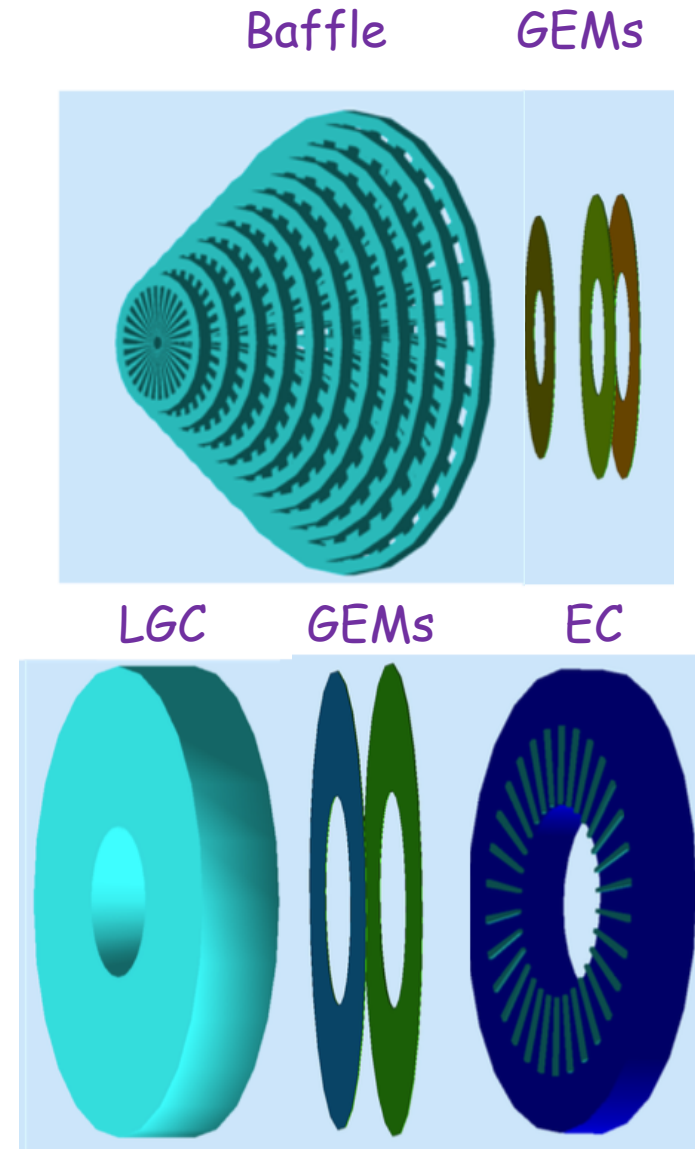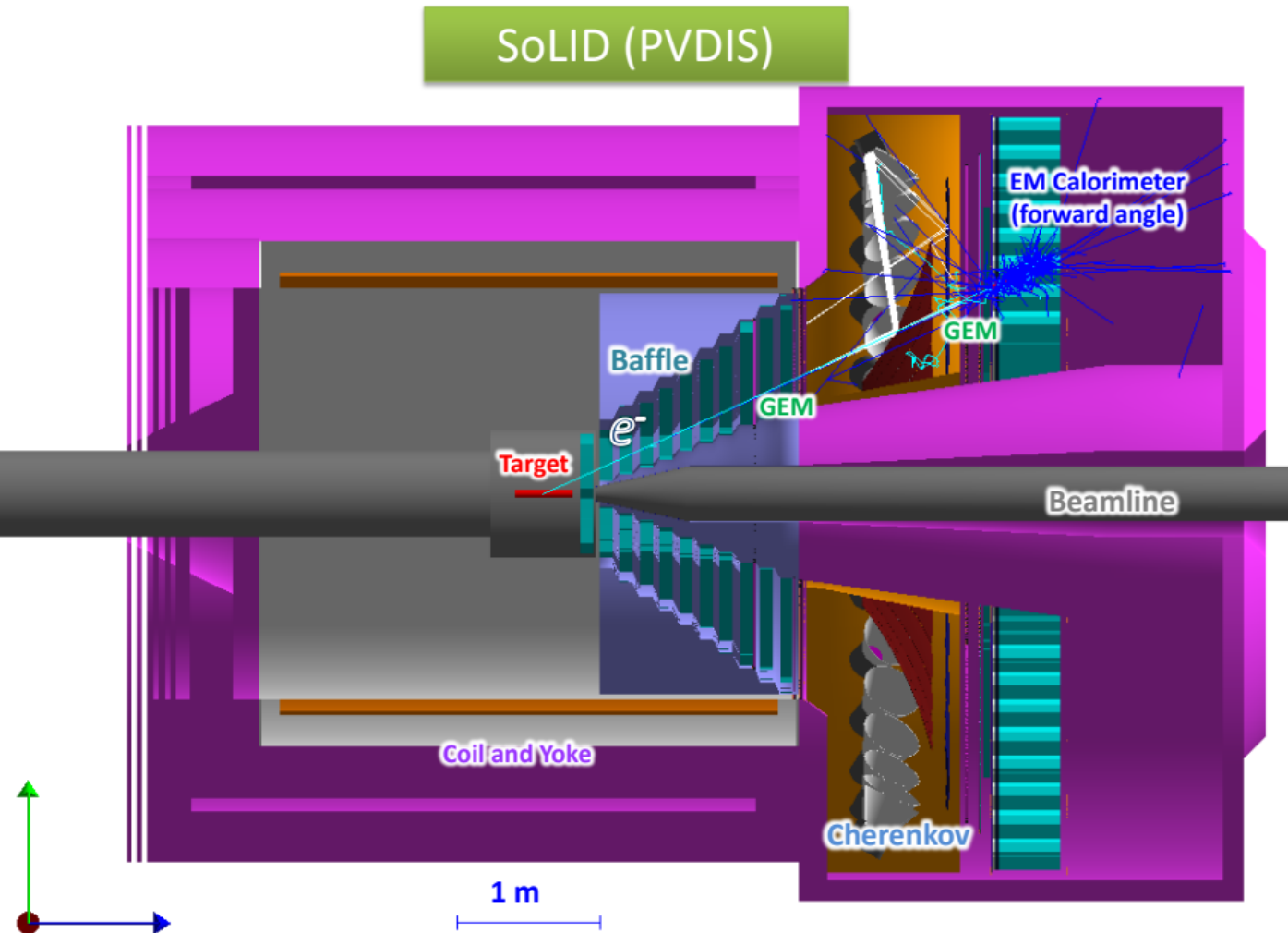- With proton target, PVDIS can measure d/u PDF ratio

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

- PVDIS has no nuclear effect
- Complementary to the rest of the JLab d/u programs

PRD 87 (2013) 094012

SoLID Apparatus – PVDIS Configuration

- SoLID spectrometer: large acceptance and can handle very high luminosity (10^{37} to 10^{39} cm^{-2}s^{-1})

SoLID (PVDIS)

EM Calorimeter (forward angle)

Baffle

GEM

e^-

Target

Beamline
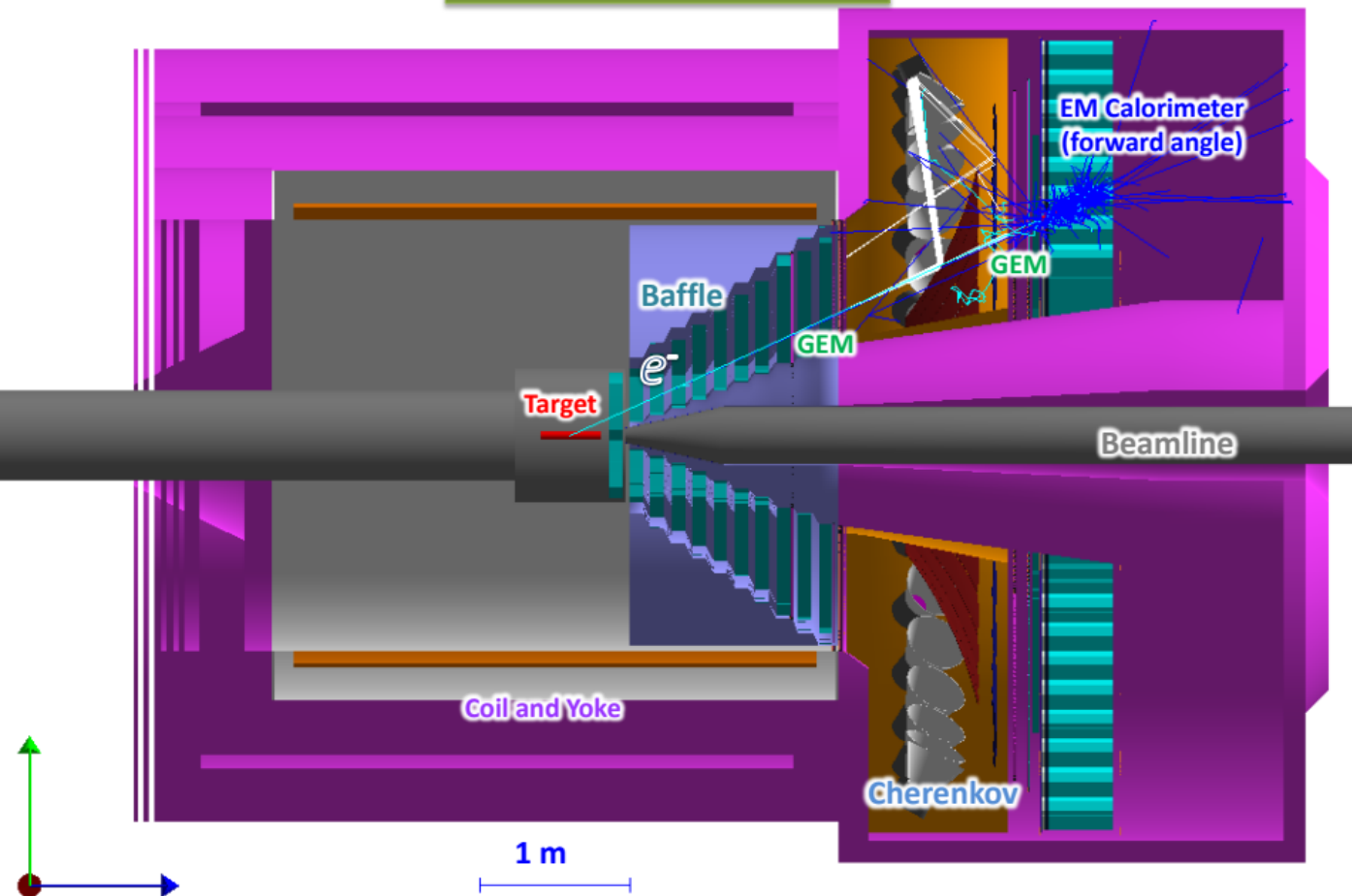
Coil and Yoke

Cherenkov

1 m

Baffle   GEMs

LGC   GEMs   EC

SoLID Apparatus – PVDIS Configuration

- SoLID spectrometer: large acceptance and can handle very high luminosity (10^{37} to 10^{39} cm^{-2}s^{-1})
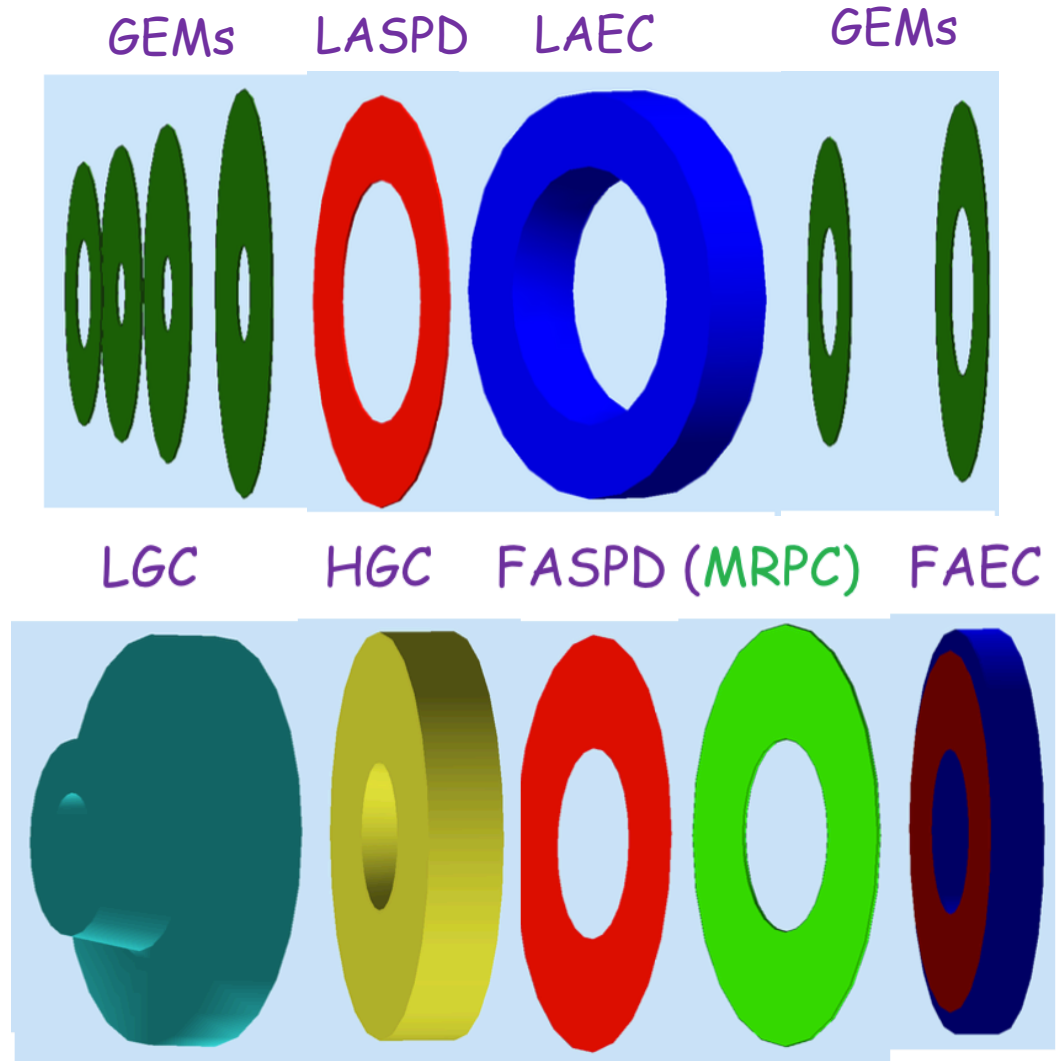

- SoLID-PVDIS detector configuration
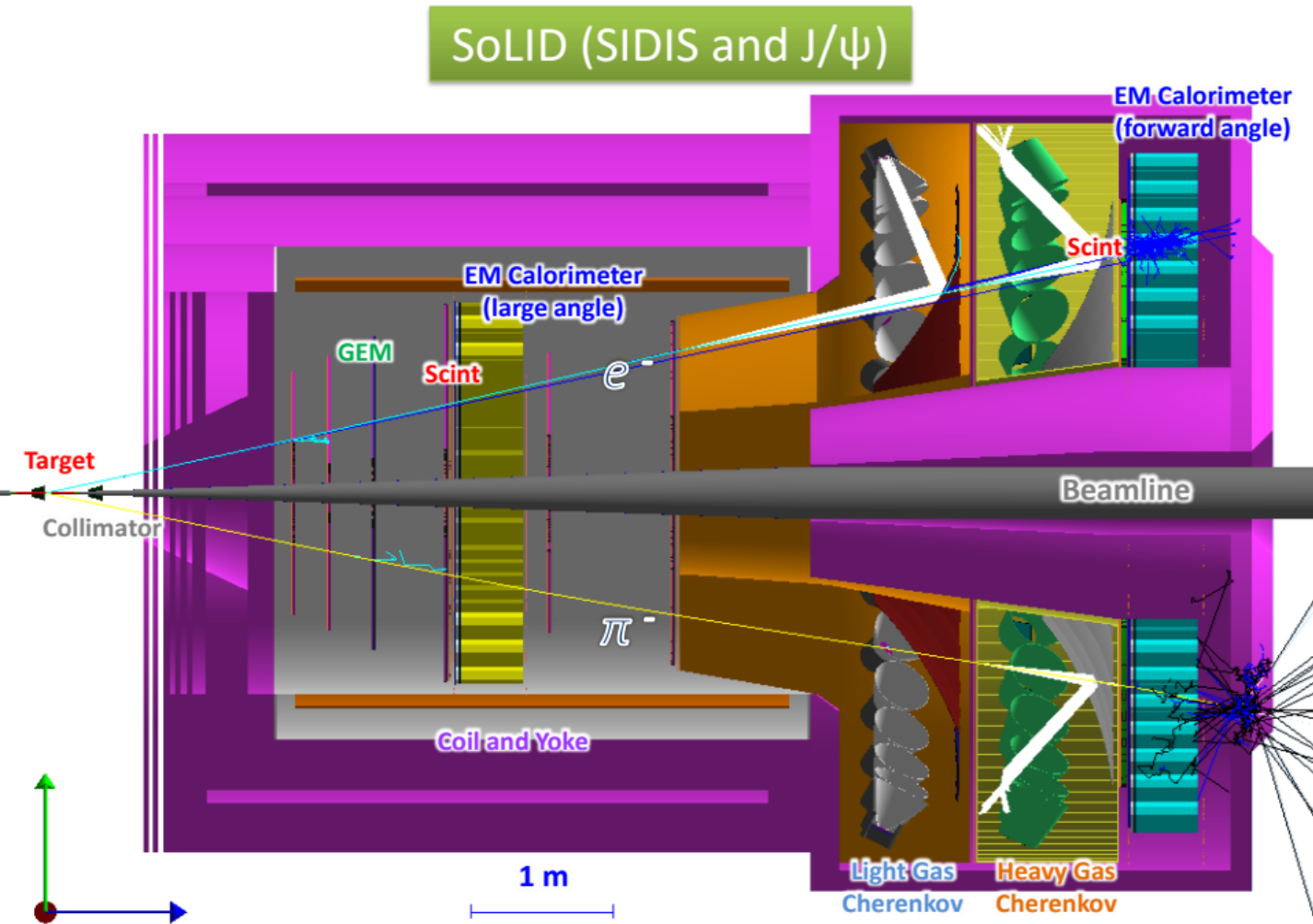
  - 2 GeV^2 < Q^2 < 10 GeV^2
  - 0.3 < $x_{Bjorken}$ < 0.7
  - Scattering angle ~22° to ~35°
  - Acceptance ~ 40%
  - Luminosity ~ 10^{39} cm^{-2}s^{-1}
  - Momentum resolution ~ 2%
  - Polar angle resolution ~ 1mrad

SoLID Apparatus – SIDIS and J/ψ Configuration

- Many detector elements will be shared with SoLID-SIDIS and J/ψ Configuration

SoLID-PVDIS Status

- Magnet: CLEO-II arrived at JLab, currently being cold-tested
- Simulation: Geant4 simulation with realistic background, tracking reconstruction with GEM digitization
- Baffle: Shape and material optimized
- GEM: full size GEM prototyped constructed and tested
- LGC: Pre-R&D beam test completed, data analysis ongoing
- ECal: prototype modules beam tested at Fermi Lab
- DAQ: pre-R&D ongoing, including VMM3, FADC fast readout and deadtime…

- Completed 3rd JLab Directors' Review in Feb. 2021
- Completed DOE Science Review in March 2021

Summary

- PVDIS on deuteron: sensitive to C_{2q} weak coupling constants, precision test of SM, precision study of charge symmetry violation and higher twist

- PVDIS on proton: clean measurement of d/u pdf ratio at high-x without nuclear correction

- The SoLID PVDIS apparatus will also be used for extensive physics programs of SIDIS and J/ψ

- DOE science review completed in March 2021

- Continue R&D on subsystems