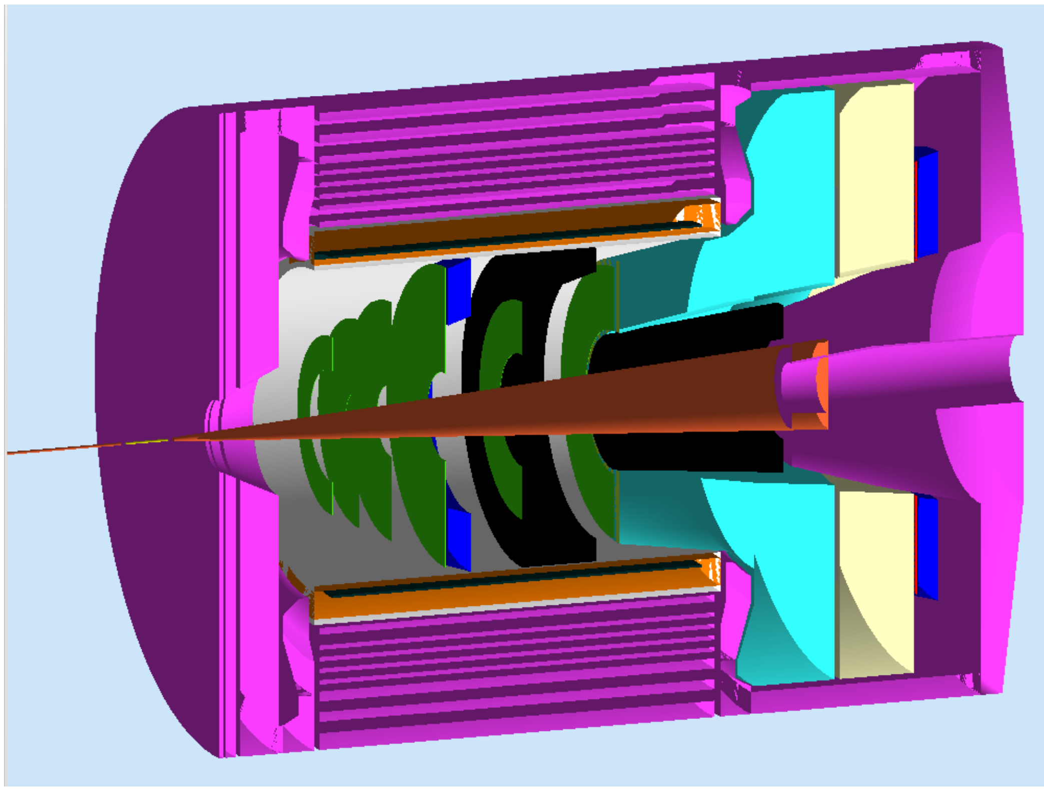
Summary of Requirements and Special Considerations



Xin Qian

KRL

Caltech

SoLID-Spin (SSA + DSA on n)

- We measure asymmetries (a few 10^{-4} → a few 10^{-2})
- Total statistical precision $<10^{-5}$, Systematic: ~ 6% x A

Keys of SoLID:

Large Acceptance + High Luminosity →
4-D mapping of asymmetries
→ Tensor charge, TMDs …
→Lattice QCD, QCD Dynamics, Models.

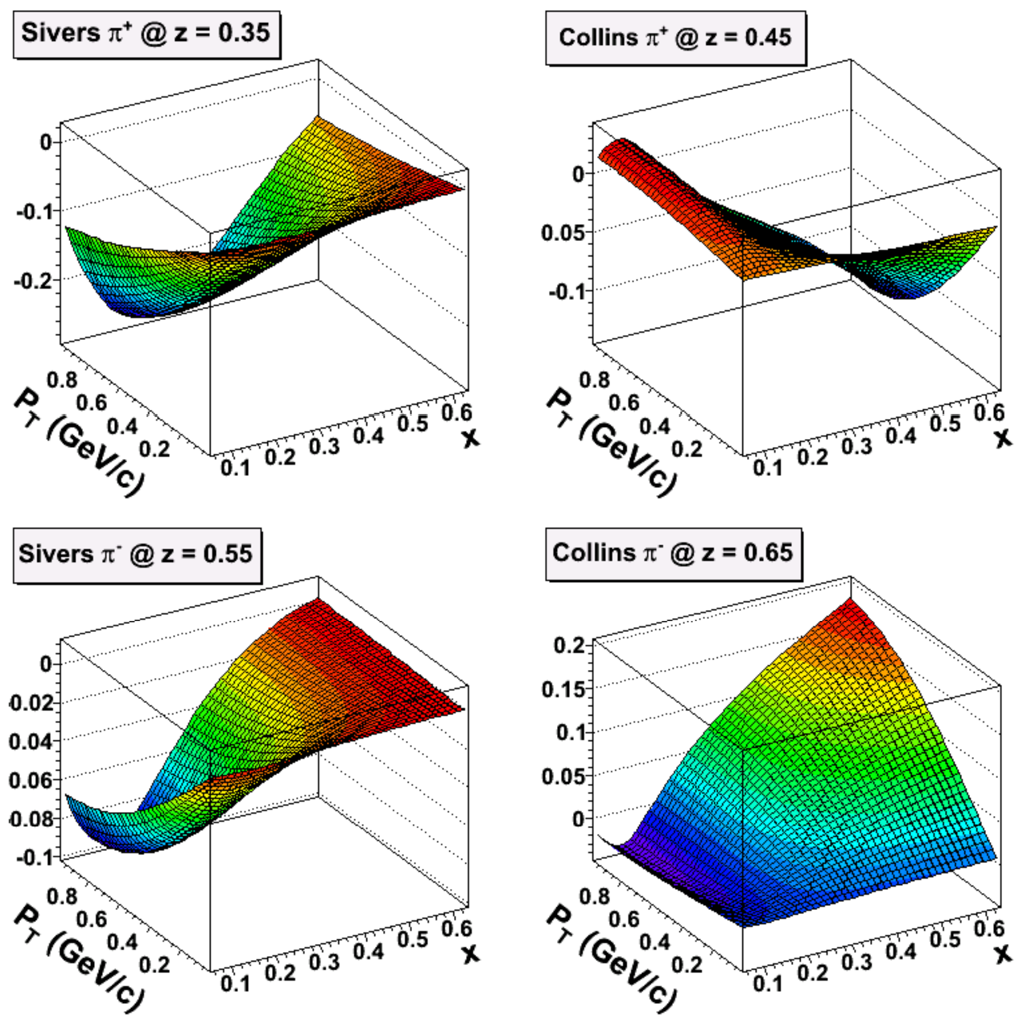
Experimental Side:

Full Azimuthal Angular Coverage
→ Double Cancellation in Asymmetries (both acceptance and luminosity fluctuation)

+ Fast Spin Flip for SSA
→Control False Asymmetry

Challenges:

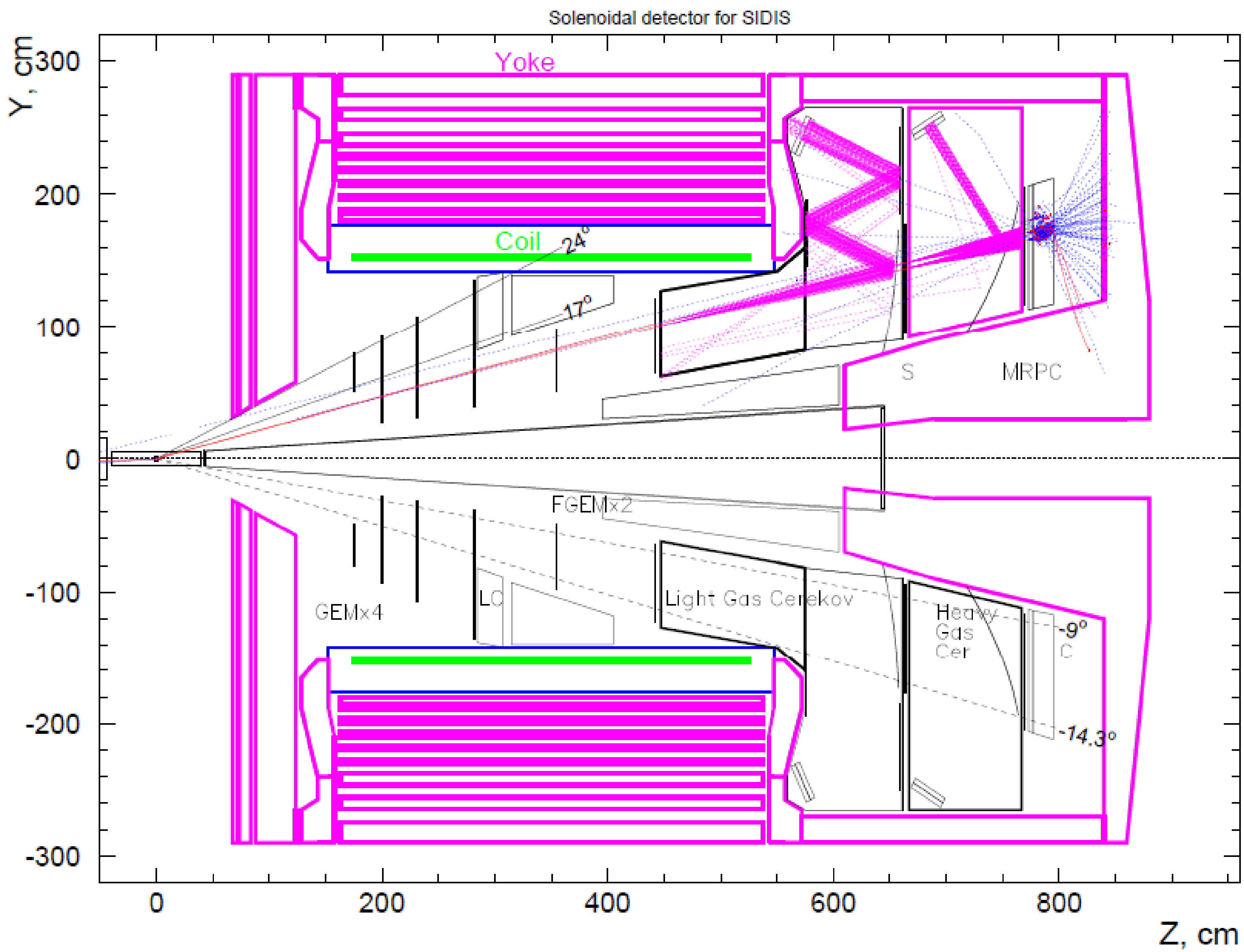
→ Detectors Performance in high luminosity environment (GEM…)
→ Fast DAQ (Hall D Standard, Other Halls)



Requirement of SIDIS

- Kinematics Coverage:
  - **0.05 ~ 0.6 in x (valence)**
  - **0.3 ~ 0.7 in z (factorization region)**
  - **P_T up to ~ 1 GeV (TMD Physics)**
  - **Fixed target → Q^2 coverage 1-8 GeV^2 (~ 2 GeV^2 in ΔQ^2 at fixed x)**
- Luminoisity:
  - **Unpolarized ~ 10^{37} $N/cm^2/s$**
- Polarized ^3He Target:
  - **~ 60% higher polarization**
  - **Fast spin flip (<20 mins)**
- Electron PID:
  - **<1% Pion contamination (asymmetry point of view)**
- Pion PID:
  - **<1% Kaons and Protons**
  - **<1% electron contamination**
- Optics of Reconstruction:
  - **< a few % in δP/P.**
  - **< a few mr in polar angle.**
  - **< a few 10s mr in azimuthal angle**
  - **~ a few cm vertex resolution**
  - **Similar precision required.**
  - **A factor of 2-3 better already achieved in MC.**
- DAQ:
  - **~ 3kHz Physics Coincidence**
  - ~ 200 kHz Single electron
  - ~ 50 kHz Coincidence
  - **Limits: 300 MB/s to tape.**

Conceptual Design with BaBar



Special Considerations

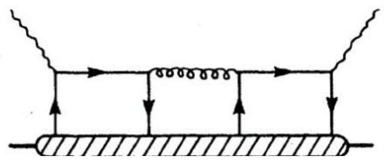
- Uniformity:
  - E.g. Design of Detector Support Structure to minimize holes in acceptance (especially in azimuthal angle)
- Background in Detectors
- Radiation:
  - Design of Detector front end electronics and calorimeter
    - Minimize radiation damage
    - Maximize radiation hardness of design.
- Multiple New Detectors:
  - Need dedicated time to commission detectors and system integration.
  - Multiple/Staged beam tests needed for detector R&D.
  - Detailed Integration Plan.
- Mechanical Design:
  - Compact
  - Detector maintenance
  - Cable layout
  - Switch plan among different configurations:
    - Transverse vs. Longitudinal
    - SIDIS vs. PVDIS
  - Strong Engineering Support
- Procedure to quick establishment of detector performance.
  - Position of Tracking detectors
  - Energy response in Calorimeter
  - Background/Gain in Gas Cerenkov.
  - Physics asymmetry in single hadron, and zero PV will help in this.

Motivation for PVDIS

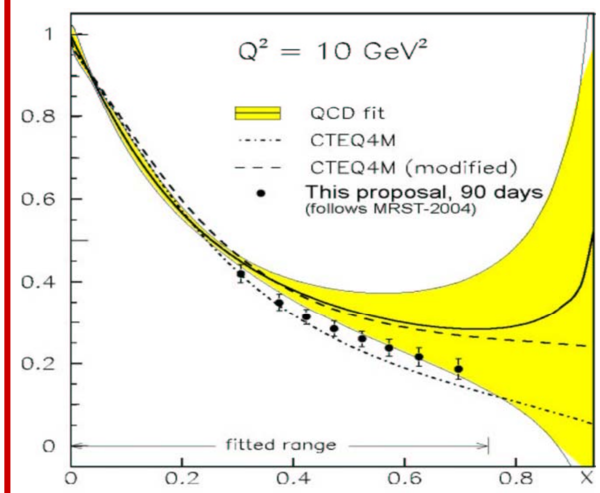
Standard Model

$$b(x) = \frac{\sum_i C_{2i} Q_i f_i^-(x)}{\sum_i Q_i^2 f_i^+(x)}$$

Di-quarks in the nucleon (Q^2 Dependence)



d/u for Hydrogen



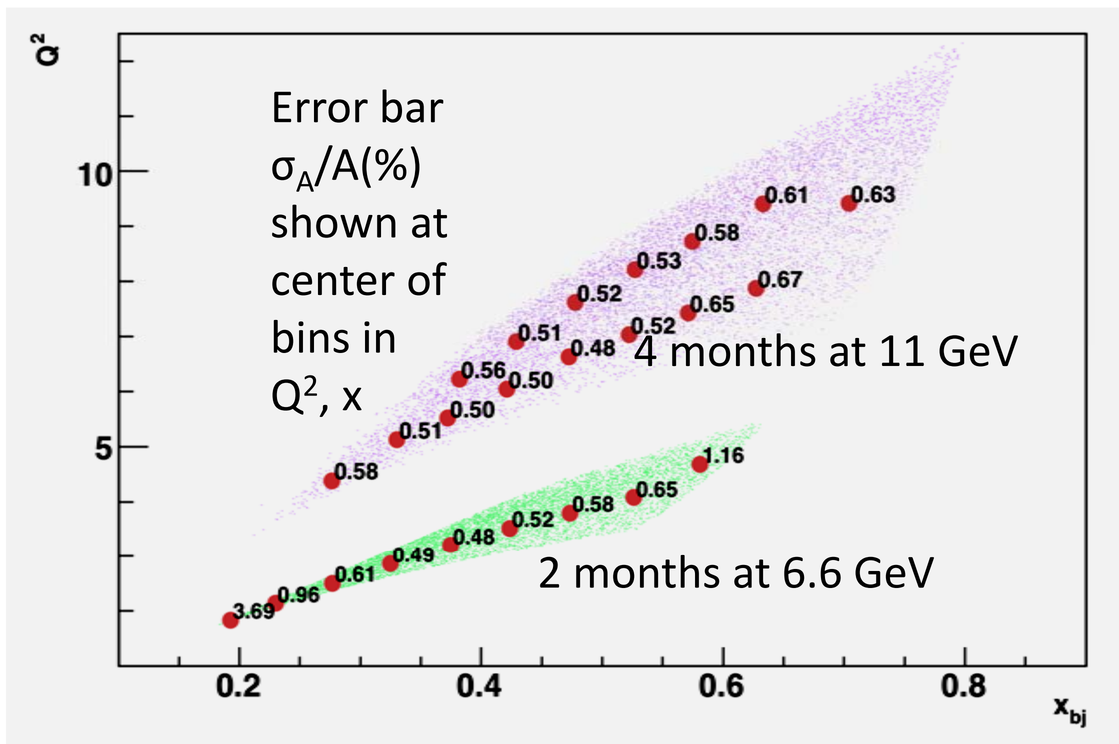
CSV at Quark Level

$$\delta u(x) = u^p(x) - d^n(x)$$

$$\delta d(x) = d^p(x) - u^n(x)$$

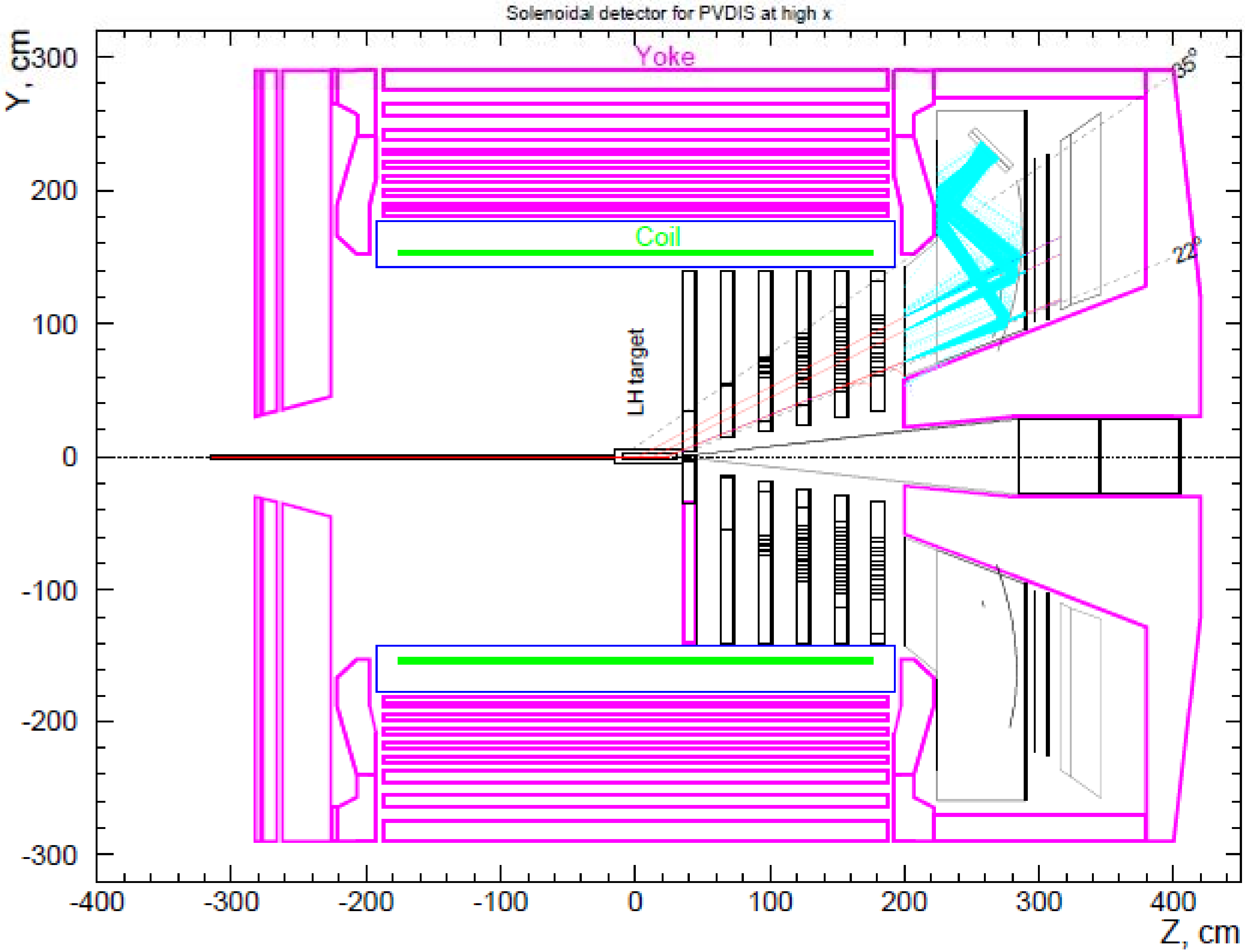
$$R_{CSV} = \frac{\delta A_{PV}(x)}{A_{PV}(x)} = 0.28\,\frac{\delta u(x) - \delta d(x)}{u(x) + d(x)}$$

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



Summary of Requirement

- 0.5% precision over broad kinematics range.
  - Beam Polarimetry (Paschke)
  - Control false asymmetries in PID/Tracking.
- New Cryotarget Design (Chen)
  - Challenges in mechanical engineering.
  - Control of false asymmetry.
- High luminosity 10^{39} N/cm^2/s
  - Sieve to block direct photons
    - Effectively reduce luminosities on detectors.
  - Background in Cerenkov.
  - Radiation dose in Calorimeter.
    - Similar to SIDIS requirement
- Electron PID:
  - < ~1% Pion contamination
  - Gas Cerenkov + E&M Calorimeter for < 3.0 GeV
  - Calorimeter alone for high Momentum
  - GEM for tracking
- 30 sectors, each employs an independent DAQ system.
  - Simpler design than SIDIS.
  - < 10 kHz per sector
- Require L3 farm and online tracking.
  - Proof-of-principle of tracking was achieved.
    - 2.5 kHz per sector @ 1 CPU @ 3.0 GHz.


Solenoidal detector for PVDIS at high x
Yoke
Coil
LH target
35°
22°
Y, cm
Z, cm
300
200
100
0
-100
-200
-300
-400
-300
-200
-100
0
100
200
300
400

Special Considerations

- Q^2 Determination
  - Elastic scattering Need Mont Carlo
  - 4.4 + 6.6 GeV?
  - How clean are the peaks?
  - How can they be centered? (not symmetric)
- Sieve Slits (Optics)
  - Run with lower B and B=0
  - Rotate one or more baffles to get straight path
  - Install slit with holes to calibrate angles
- Pile-up and Dead Time
  - Dither Intensity: $\sim 10^{-2}$
  - Empirically measure all effects.
  - Reduce Acceptance and vary Intensity by 20%
  - Correct for density variation
- Calibrate BCM
  - Solid target
  - Linear Luminosity Monitor
- Other considerations similar to that of SIDIS: Mechanical Design

Conceptual Design (I)

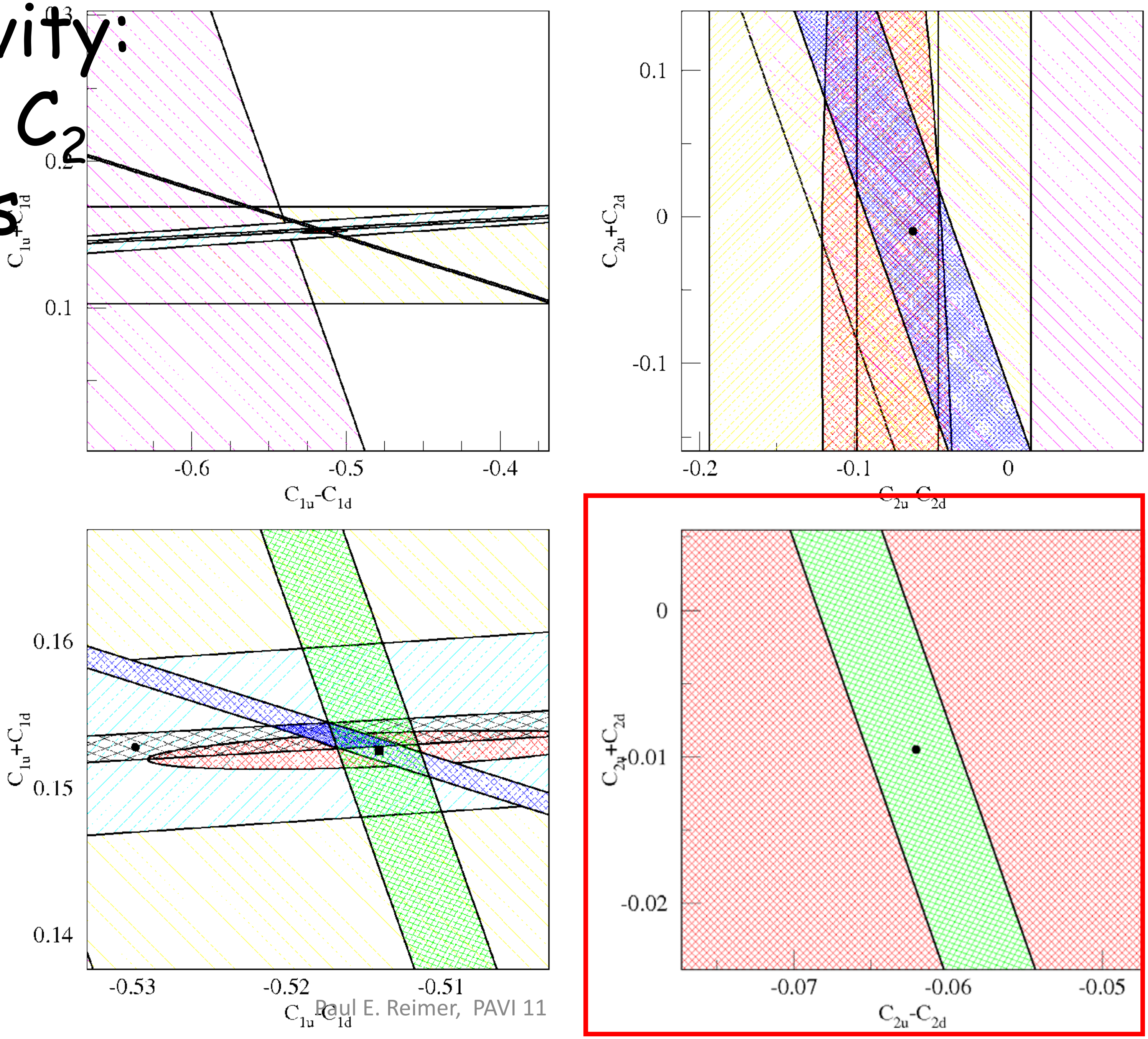
- Kinematics Coverage:
  - Preference of Magnet
  - Limited by SoLID geometry
  - Data taking at 8.8 GeV for radiative corrections and expand Q^2 coverage.
- Luminoisity:
  - Requirement on GEMs, Cerenkov.
  - Radiation dose on E&M Calorimeter and front end electronics.
  - Requirement on DAQ system.
- Polarized ^{3}He Target:
  - Achieved performance assumed for this experiment
  - Magnetic field shielding design and correction coils are keys for performances.
  - Possibly benefits from new techniques developed for earlier 12 GeV experiments
- Electron PID:
  - Combination of E&M calorimeter + Gas Cerenkov (shared equipments with PVDIS)
  - Advantage of coincidence measurement in SIDIS (additional Pion suppression)
- Pion PID:
  - *Gas Cerenkov + E&M Calorimeter to suppress electron.*
  - *TOF (MRPC) at low momentum to suppress kaons/protons*
  - *Heavy Gas Cerenkov to suppress kaons in high momentum.*

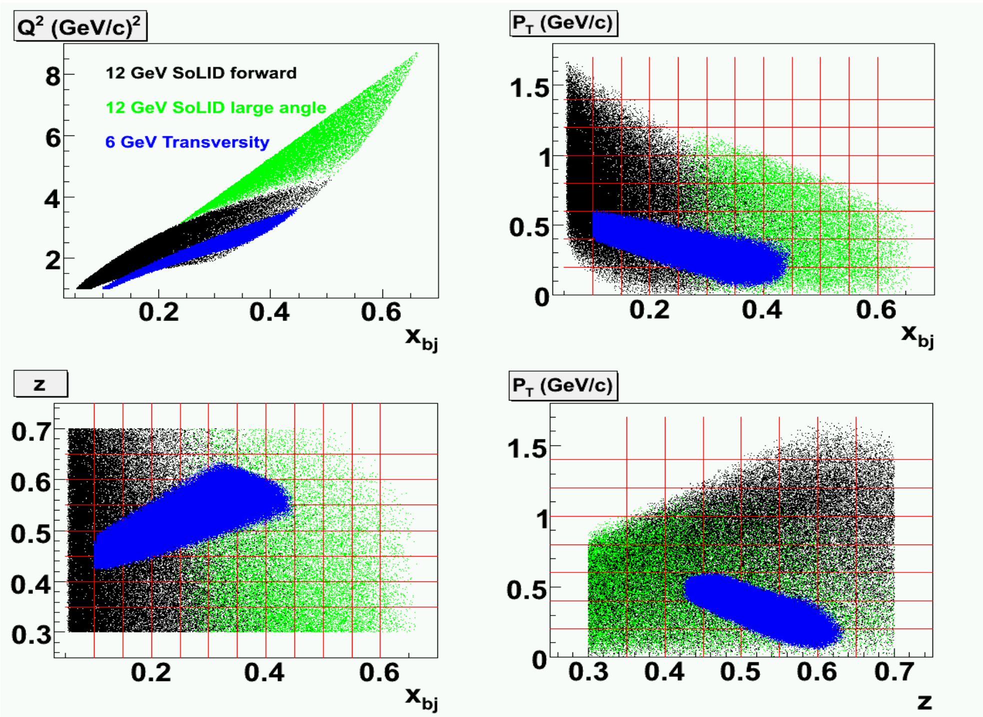
Conceptual Design (II)

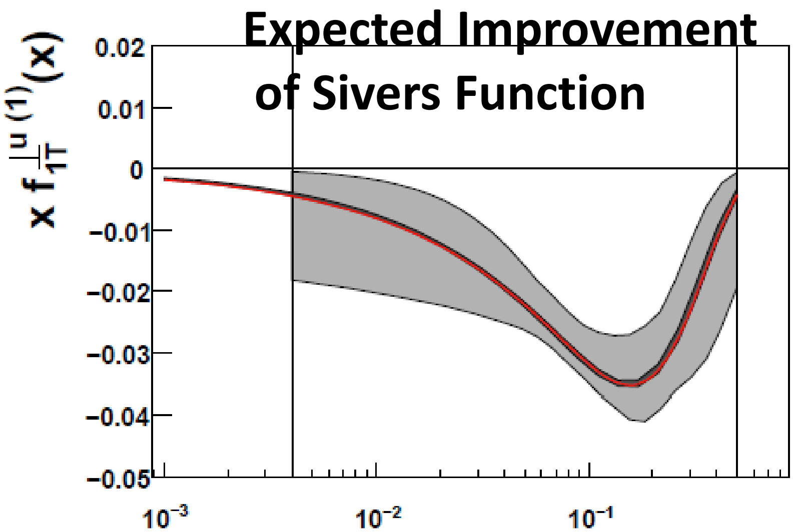
- Optics of Reconstruction:
  - Already demonstrated in MC, 200 um resolution in GEM leads to resolution performance.
    - ~ 1% in $\delta P/P$
    - < 6 mr in azimuthal angle
    - < 0.5 mr in polar angle
    - ~ 1 cm vertex resolution
- Calibration Plan:
  - 2.2, 4.4 and 6.6 GeV beam
  - Multi-Carbon Foils for Vertex.
  - Elastic Hydrogen for momentum.
  - Sieve Slit for angles.
  - Varying strength of SoLID magnetic field. (e.g. No Field Run + Survey …)
  - **Very experienced team in optics calibration.**
- DAQ:
  - JLab customized pipeline technology.
  - Fast Tracking:
    - Demonstrated tracking in expected experimental environment.
    - Already achieved 1 kHz per 3.0 GHz CPU.
    - **Plenty of room to improve**
      e.g. Multi-thread + Sectors + Algorithm Improvement (e.g. GPUs)
- Additional Goals to be studied:
  - Neutral Pion Identification (Limited by E&M calorimeter granularity)
  - Two Hadron SIDIS (multiplicity at high W + acceptance)
    - Complemantary Transversity Measurement

Sensitivity: C_1 and C_2 Plots

World's data







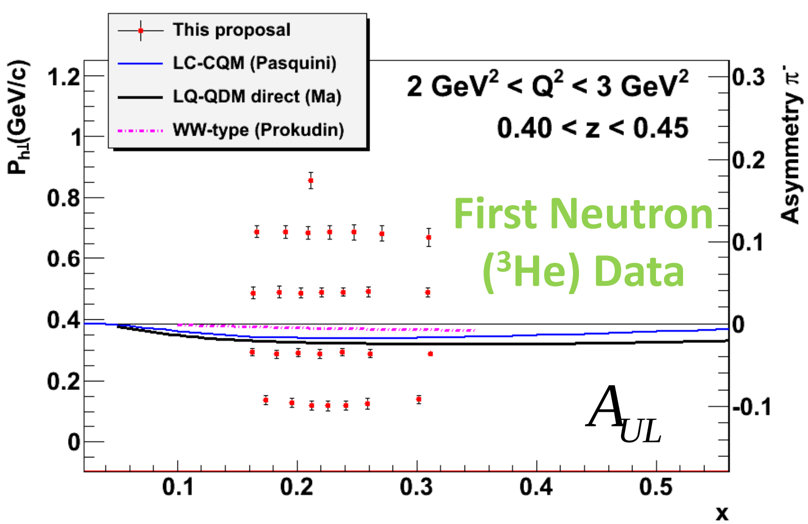
$$A_{UT}^{Collins} \propto \langle \sin(\phi_h + \phi_s) \rangle \propto h_{1T} \otimes^{x} H_1^{\perp}$$

$$A_{UT}^{Sivers} \propto \langle \sin(\phi_h - \phi_s) \rangle \propto f_{1T}^{\perp} \otimes D_1$$

<10% d quark tensor charge Collins Effect

Sys.: 0.1% (abs.) + ~6% (rel.) + Nuclear Effect/FSI

50 days @ 11 GeV + 22 days @ 8.8 GeV (Coverage + RC) + 10 days on H/D (Dilution, FSI, Mechanism) + 8 days on calibration of new device + 35 days with longitudinal target spin



These data will provide ultimate precision mapping of Neutron SSA/DSA in the valence region at low Q^2!

Example projections of Neutron A_{UL} moments, 1/48 bins in z vs. Q^2.