Experimental Requirements

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Thanks inputs from Jian-Ping, Bob Michael, Paul and Haiyan.

Physics Program of SoLID

- **Parity Violation DIS**: Quark Axial charge, Charge Symmetry Violation …
  - Inclusive DIS

$$\vec{e} + N \rightarrow e' + X$$

- **SoLID-Spin**: Nucleon Spin, Tensor Charge, TMD, Quark OAM …
  - Semi-inclusive Deep Inelastic Scattering (SIDIS)

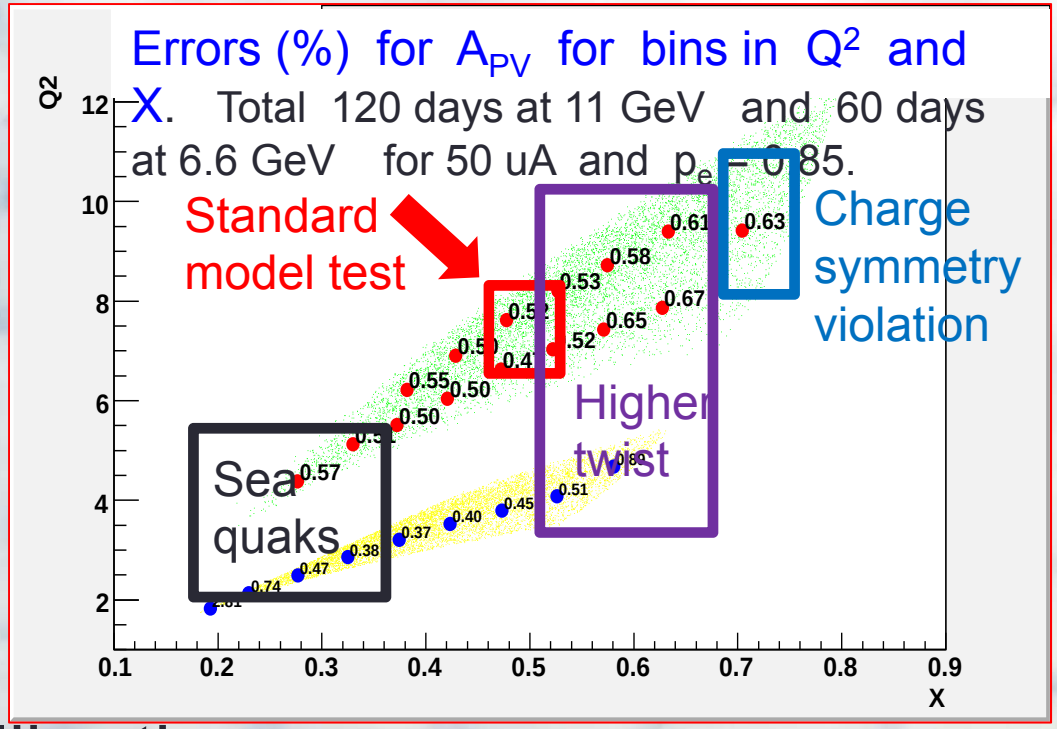
$$e + \vec{N} \rightarrow e' + \pi^{\pm} + X$$

- **SoLID-J/ψ**: Nucleon Mass, Non-perturbative gluons
  - Exclusive Process

$$e + p \rightarrow e' + J/\psi + p$$

Requirement of PVDIS

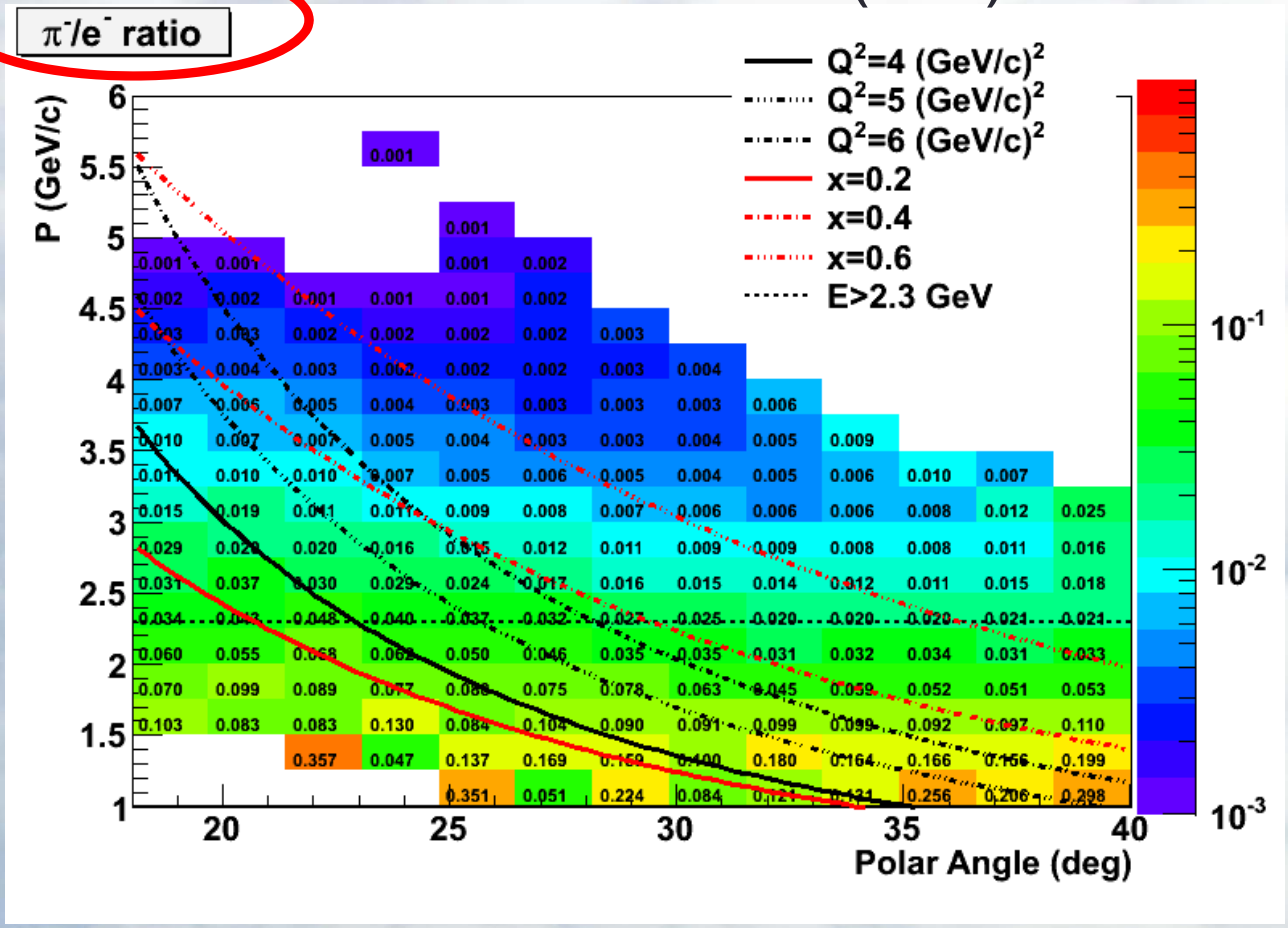
- Large scattering angle, x-range 0.25→0.75, W>2.0 GeV, factor of 2 in Q^2 range for each x
- **~5x10^{38} N/cm^2/s** at 11 GeV to reach better than 1% error in each bin → Radiation hardness
- **10^{-3}** uncertainty in pion contamination
- DAQ: ~ 15 kHz per sector → 450 kHz in total.
- Precision polarimetry **0.4%**
- Precise kinematics calibration



Concerns raised by Paul

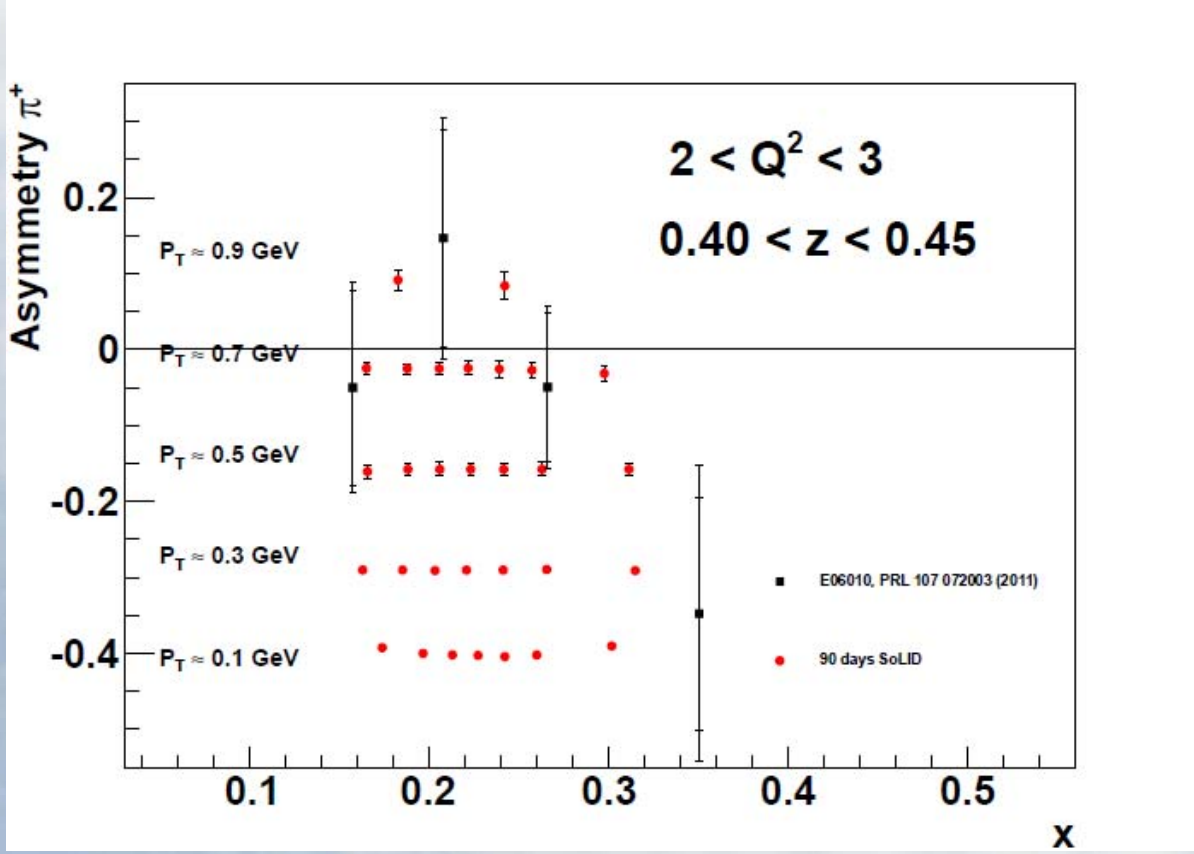
- HERMES calorimeter paper:
  - Resolution
  - Achieved pion rejection
- What is the rate dependence in pion rejection factor?
- What is the effect of pile-up?
- Radiation load on detectors:
  - How much power is deposited at various angle and on various elements?

Preliminary Combination of E&M calorimeter and Gas Cerenkov (GC)



- More realistic estimation in GC, multi-variable-analysis in E&M calorimeter to further reduce π/e ratio
- Need measurement of pion asymmetry

Projections on Collins Asymmetry (90 Days)



Collins 1/48 bins 4-D Mapping of Asymmetries

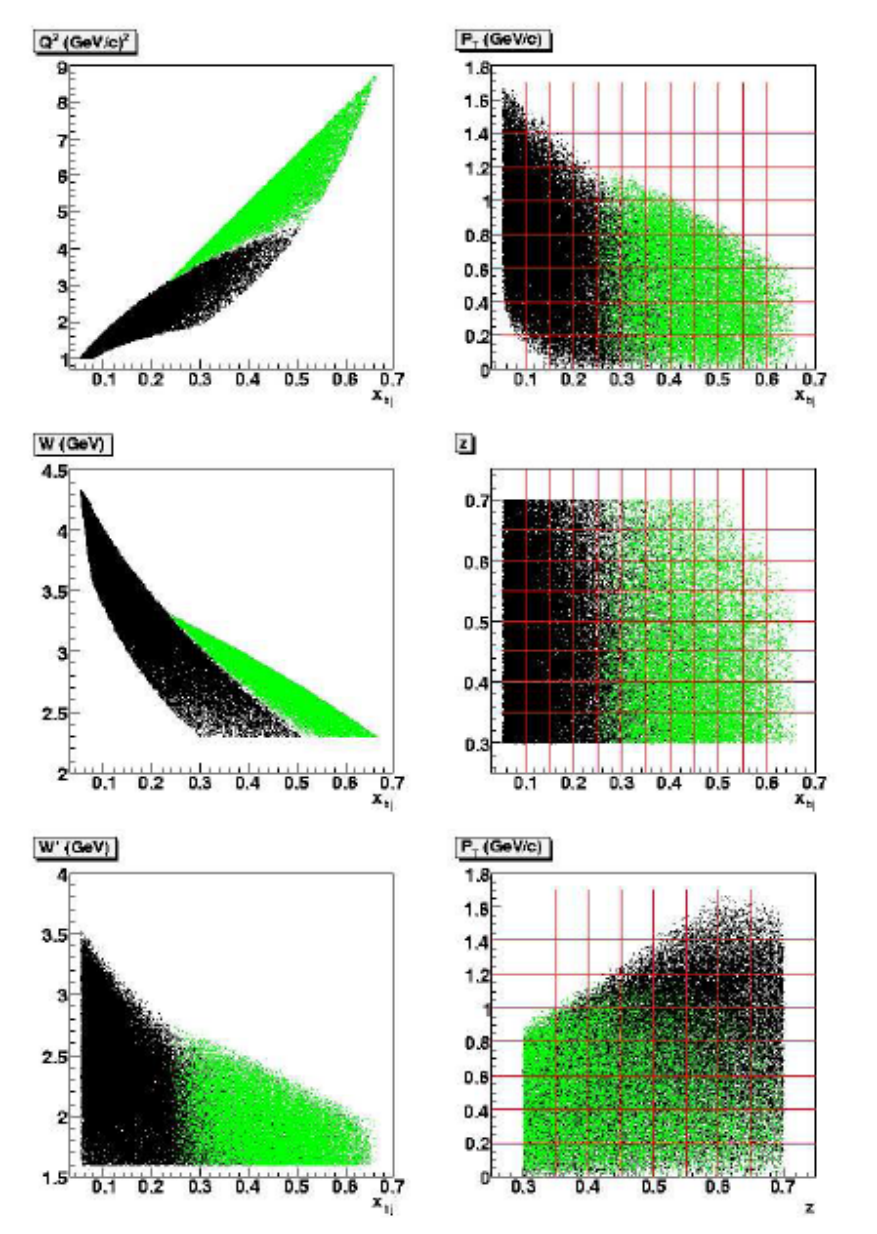
Similar for Sivers, DSA of 3He, less requirement for proton

Goal: <10% Tensor Charge, for each bin, we require **<0.2% stat.** on neutron → <3e-4 on raw asymmetry

6% relative sys. + ~0.1% absolute sys. (neutron)

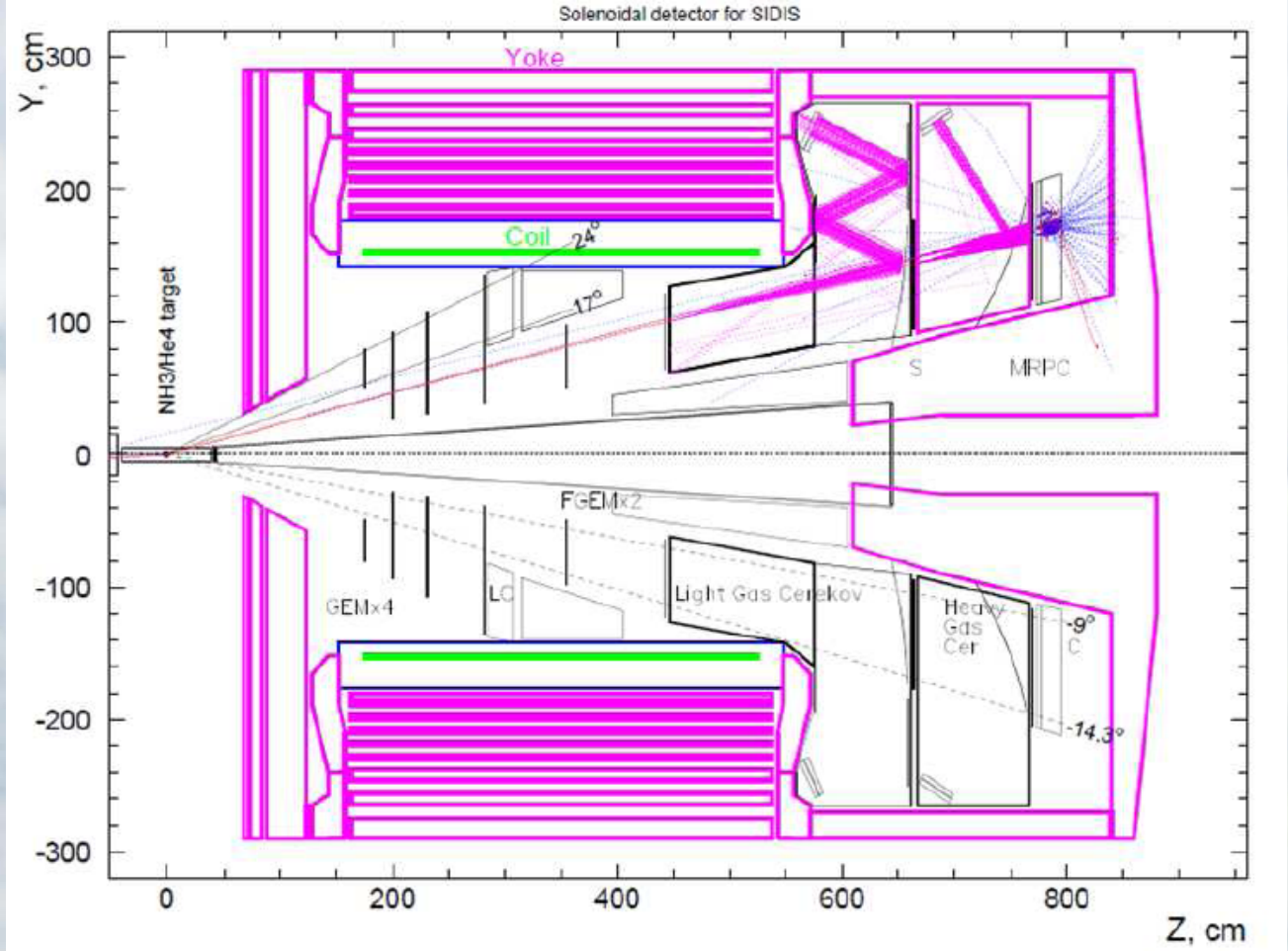
Requirement of SIDIS

- 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)**
- Polarized ^{3}He Target:
  - **Unpolarized ~ 10^{37} N/cm^2/s**
  - **~ 60% higher polarization**
  - **Fast spin flip (<20 mins)**
- Polarized NH3 Target:
  - Unpolarized ~ **10^{36} N/cm^2/s**
  - **~70% higher polarization with spin flip**



Requirement of SIDIS

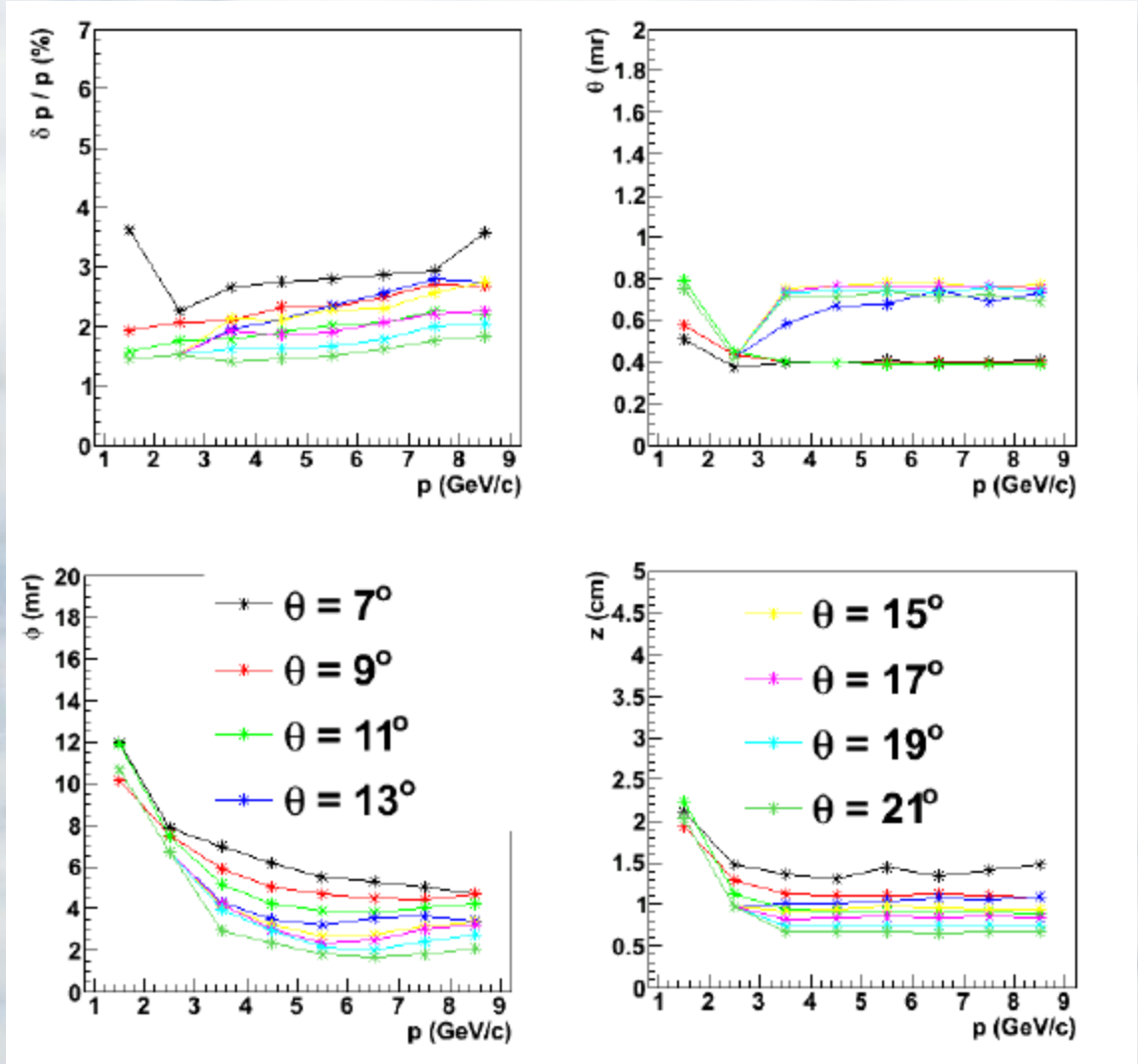
- DAQ:
  - **~ 3kHz Physics Coincidence**
  - ~ 100 kHz Single electron
  - ~ 60 kHz Coincidence
  - **Limits: 300 MB/s to tape.**
- Electron PID:
  - **<1% Pion contamination (asymmetry point of view)**



- Pion PID:
  - **<1% Kaons and Protons**
  - **<1% electron contamination**

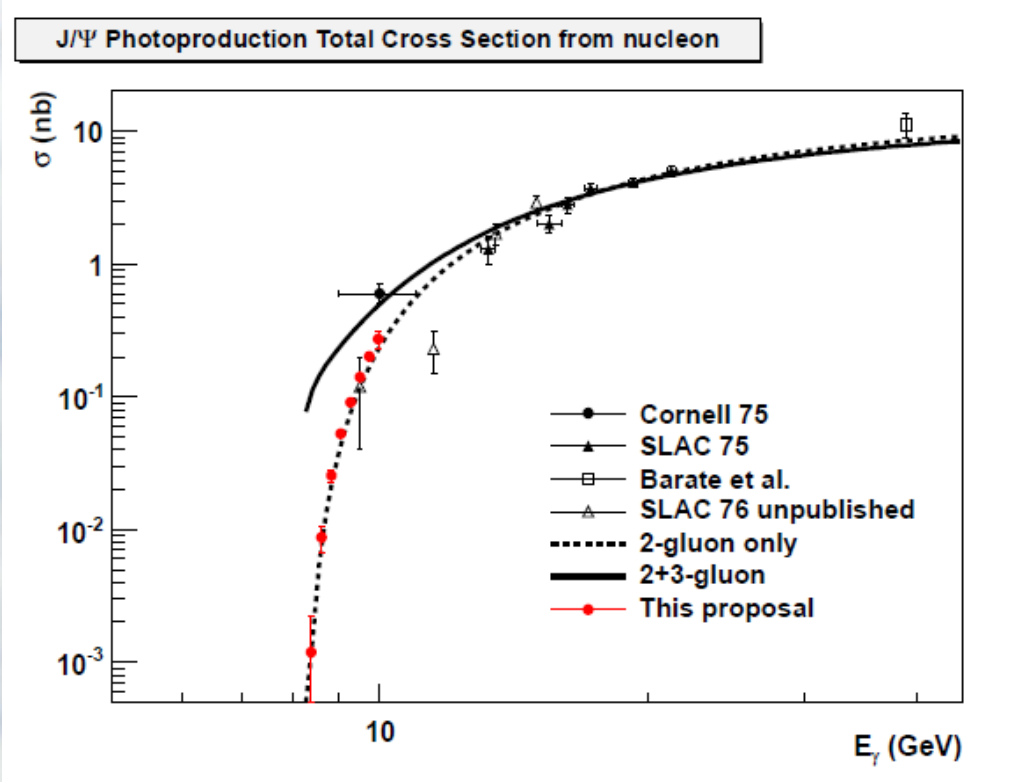
Requirement of SIDIS

- Optics of Reconstruction:
  - **< a few % in δP/P.**
  - **< 1 mr in polar angle.**
  - **< 10 mr in azimuthal angle**
  - **~ 1-2 cm vertex resolution**
  - **Similar precision required**
  - **MC results supported a factor of 2-3 better performance**



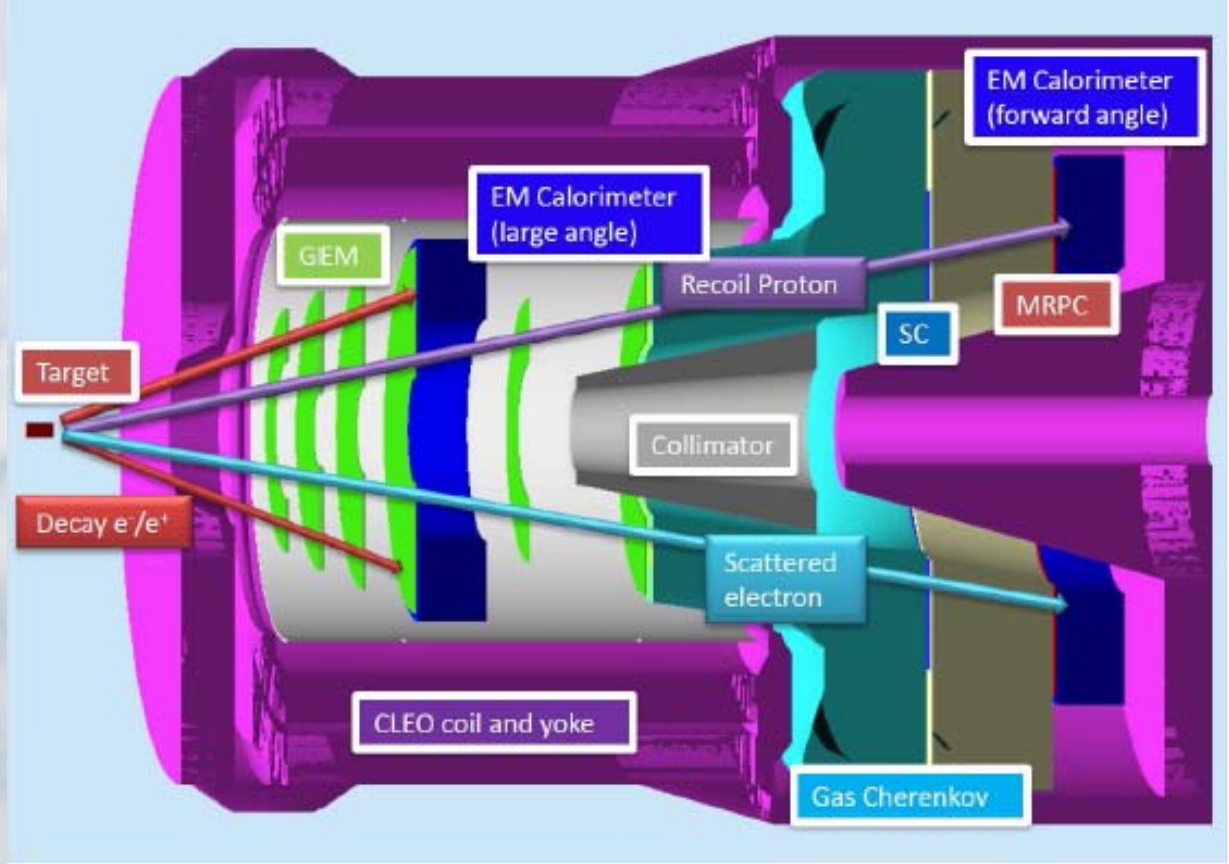
Projection of SoLID-J/ψ

- 4-fold coincidence:
  - 2g-only: **0.68 k** events
  - 2g + 3g: **2.9 k** events
- 3-fold no proton:
  - 2g-only: **2.1 k** events
  - 2g+3g: **8.08 k** events
- Goal: **<10%** Cross section measurement



Requirement of J/ψ

- 11 GeV + 15 cm Proton Target
- Luminosity: >= **10^{37} N/cm^2/s**
- DAQ: **Triple Coincidence Trigger**
  - scattered electron, decay electron and decay positron from J/ψ ~ 3 kHz



- PID: E&M calorimeter for decay e^-/e^+ additional gas Cerenkov for scattered e^- MRPC-TOF for recoil proton

Cross Section Validation (Leptonic+Photon)

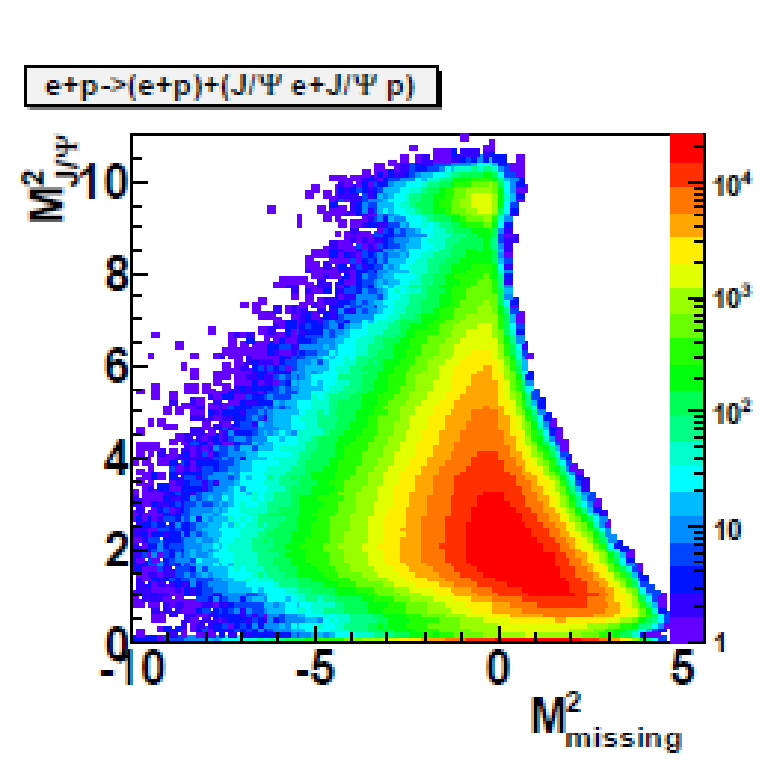
$$e + p \rightarrow e' + V(e^- + e^+) + p$$

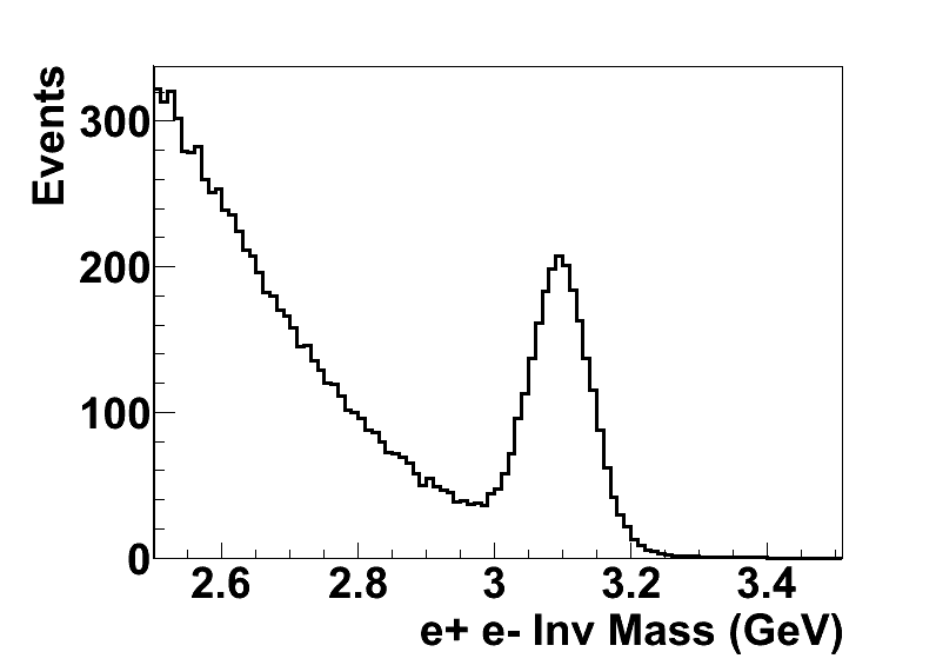
	Bethe-Heitler	ω	ρ	φ	η
Xs	**0.1 ub**	**1ub**	**1ub**	**50 nb**	**10 ub**
Decay Channel and BR	**e^+e^-** **1.0**	**e^+e^-** **7.3e-5**	**e^+e^-** **4.71e-5**	**e^+e^-** **2.97e-4**	**Γγ** **0.39**
Compared to Jpsi	**>10**	**X2**	**x1**	**X0.5**	**Large**
SoLID capability	**good**	**good**	**good**	**good**	**good**

Other Channels: SIDIS channel, e+p elastic for optics calibration, Exclusive Channel (neutral pions, Omega and Rho) also missing mass technique.

Requirement of J/ψ

- Detector resolution: $\delta P/P<2\%$, $\delta\theta\sim0.6$mr $\delta\varphi\sim6$mr, and $\delta z_{vertex}\sim1$cm essential for background reduction





	PVDIS	SIDIS	J/ψ
Luminosity (N/cm^2/)	~5x10^{38} → Radiation Hardness + Baffle design + pileup	<=10^{37} Sheet of flames in proton-SIDIS	More than10^{37} →detector requirement
PID	10^{-3} uncertainty in pion contamination → GC + E&M	MRPC + HG → π E&M + LC → e	MRPC→Proton
Detector Resolution/Calibration	Q^2	Angular and momentum	Absolute momentum
Polarimetry	0.4% in beam polarization	>60% 3He >70% NH3 spin flip & yoke design	N/A
DAQ	~30x15 kHz total trigger rate	~100 kHz trigger rate, GEM pad readout?	Triple coincidence
Online Farm → Tracking/optics	Essential to reduce file size	Essential to keep coincidence	Important at higher luminosity
Systematic uncertainty	<0.5% relative	Abs. 1e-3 (neutron) + 6% relative	<10% Xs measurement

Detector Requirement

- E&M calorimeter: **~100:1** Pion rejection
- Light Gas Cerenkov **~1000:1** Pion rejection
- GEM position resolution: **~ 100 um** (10 degree readout)
  - GEM pad readout in trigger?
- Heavy Gas Cerenkov: **>10:1** Kaon rejection
- MRPC TOF: **80 ps** timing resolution

Color Legend: PVDIS, SIDIS, J/ψ

- Magnetic field: → ~2% momentum resolution
- Yoke design: force limit on coils

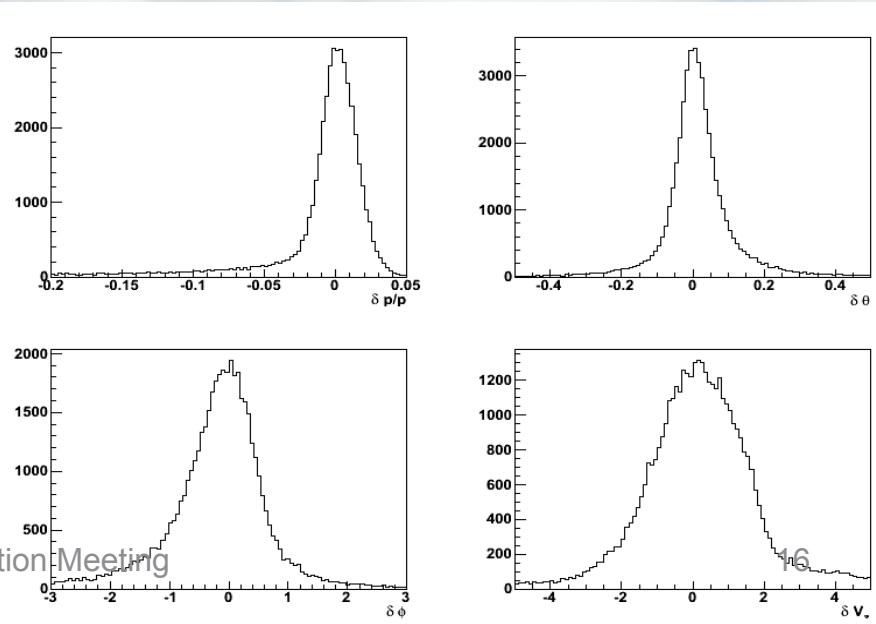
Starting Model of Optics

$$BqR = P_T$$

$$R \cdot \theta \sim P_T$$

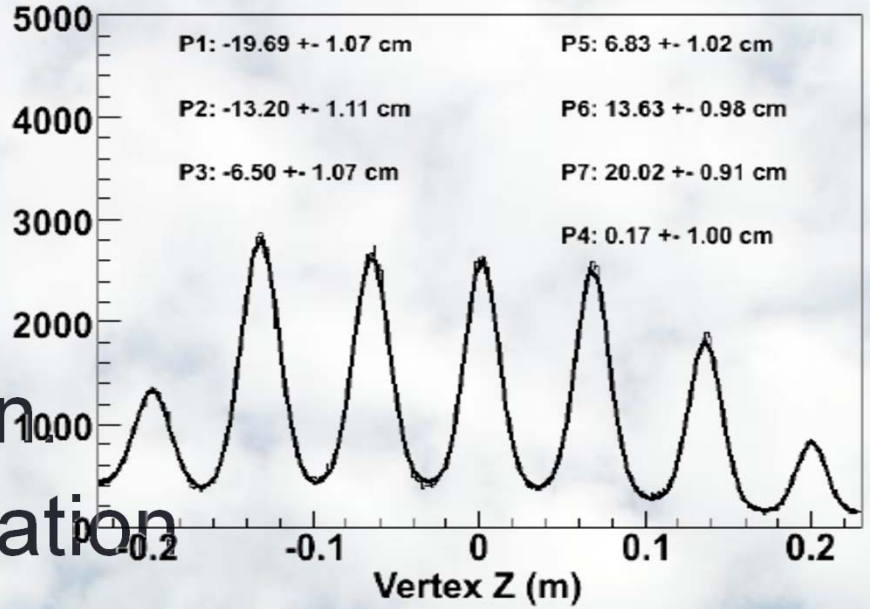
$$z \sim P_L$$

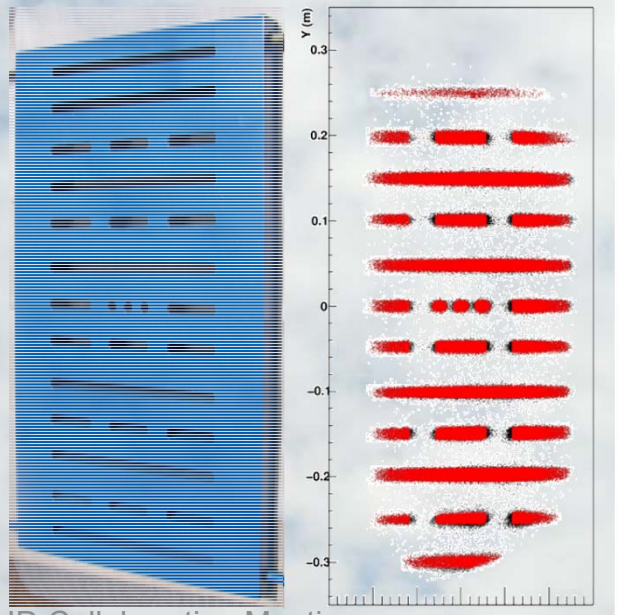
- Along z, the trajectory is a circle.
- With Radius R, and distance along z
  - One can get P_T/P_L -> polar angle
  - Combine R and magnetic field, one can get P_T -> P
  - Azimuthal angle can be determined at the point when the particles enter magnetic field + theta angle
  - Vertex can be determined by unfolding the trajectory + polar angle + hit positions.
- With MC, we can do optics (input/output known)



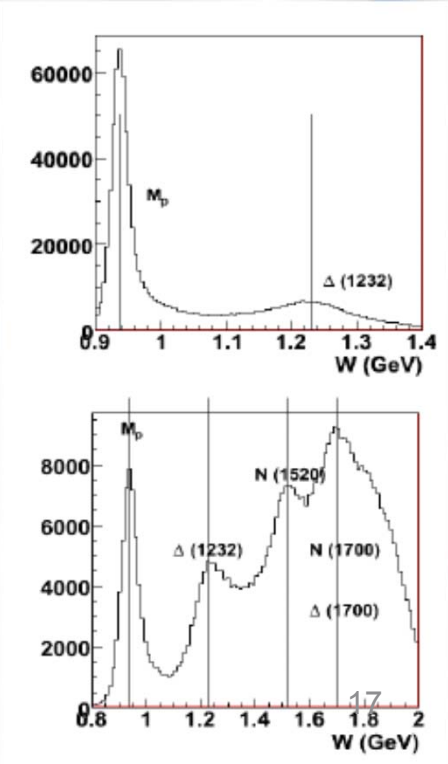
Initial Idea

- Similar to BigBite: Multi-Carbon foils for vertex reconstruction
- Sieve for angular calibration
- e-p elastic scattering for momentum calibration at 1 and 2 pass.
- Need lower mag. field setting for SoLID
- Other ideas?





BigBite Sieve Slit



Optics Working Plan

- Current Optics Model is good for director review etc.
- Future working plan includes:
  - Design the **detailed optics working plan** (beam energies/current, beam time, target, settings, and checks)
  - Generate **simulated data** to demonstrate optics reconstruction according to optics working plan.
  - We MUST achieve this before data taking, since tracking needs this information as input (online).

System Integration

- Electron ID: Light Gas Cerenkov + E&M calorimeter (PVDIS)
- Pion ID: Heavy Gas Cerenkov + MRPC (SIDIS)

- Yoke Design + Target/phase space (SIDIS + J/ψ)

- DAQ + online farm with tracking ability
  - Fast GEM calibration, also calorimeter calibration
  - Quick optics calibration, essential input to tracking

- Detector reconfiguration between PVDIS and SIDIS+J/ψ
- Detector reconfiguration for proton-SIDIS due to sheet of flames