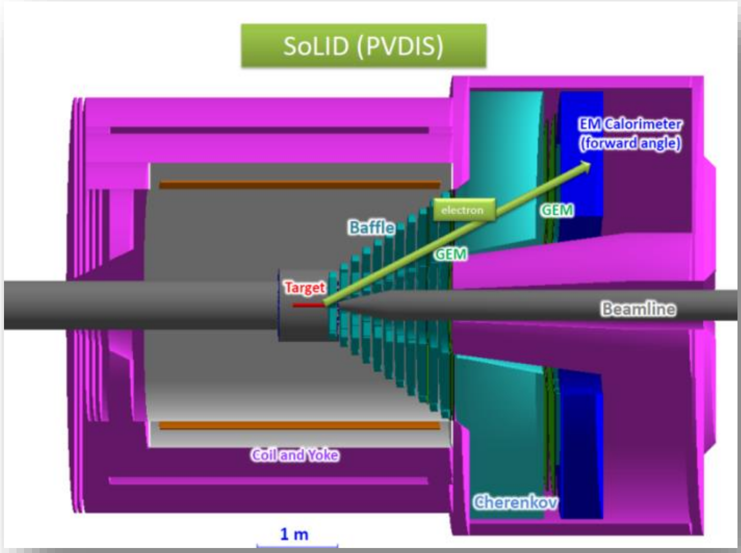
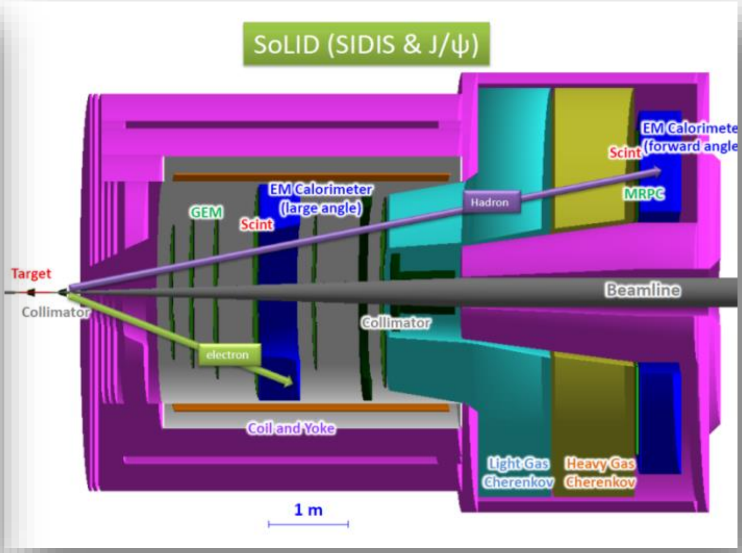
Update from SoLID

(Solenoidal Large Intensity Device)





Zhihong Ye

Duke University & SoLID Collaboration

Hall-A Winter Meeting

10/09/2014

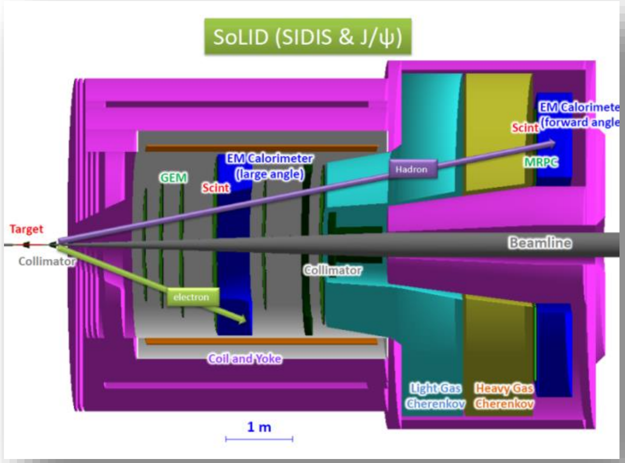
Outline

- Phyiscs Overview:
  - SIDIS,
  - PVDIS,
  - J/Psi
- SoLID Overview
  - Magnet
  - Detectors
  - Triggers&DAQ
  - Simulation and Software
- Summary

Physics Overview

- Semi-Inclusive Deep Inelastic Scattering (SIDIS):
  - → Transversely Polarized 3He, E12-10-006 (90 days, A),
  - → Longitudinally Polarized 3He, E12-11-007 (35 days, A),
  - → Transversely Polarized Proton, E12-11-108 (120 days, A),
  - → Two new bonus runs: Ay and Di-Hadron,
  - → And can be more ...
- Parity Violation Deep Inelastic Scattering (PVDIS):
  - → PVDIS with LH2 and LD2, E12-10-007 (169 days, A)
  - → proposing new experiments, e.g. EMC with Cacium
- J/ψ :
  - → Near Threshold Electroproduction of J/ψ at 11 GeV, E12-12-006 (60 days, A-)
- More ...

SIDIS



- **Semi-Inclusive Deep Inelastic Scattering:**

→SIDIS: 4-D (x, pt, Q2, z) probe of nucleon transverse momentum distribution (TMD)

Leading-Twist TMD PDFs

Nucleon Polarization	Quark polarization: Unpolarized (U)	Quark polarization: Longitudinally Polarized (L)	Quark polarization: Transversely Polarized (T)
U	$f_1 =$		$h_1^{\perp} =$ − Boer-Mulders
L		$g_1 =$ − Helicity	$h_{1L}^{\perp} =$ − Worm Gear
T	$f_{1T}^{\perp} =$ − Sivers	$g_{1T} =$ − Worm Gear	$h_1 =$ − Collins/Transversity $h_{1T}^{\perp} =$ − Pretzelosity

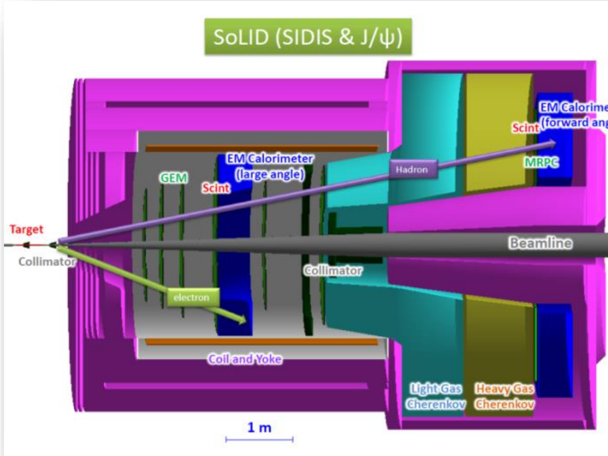
Nucleon Spin *Quark Spin*

SIDIS

◆ **Semi-Inclusive Deep Inelastic Scattering:**

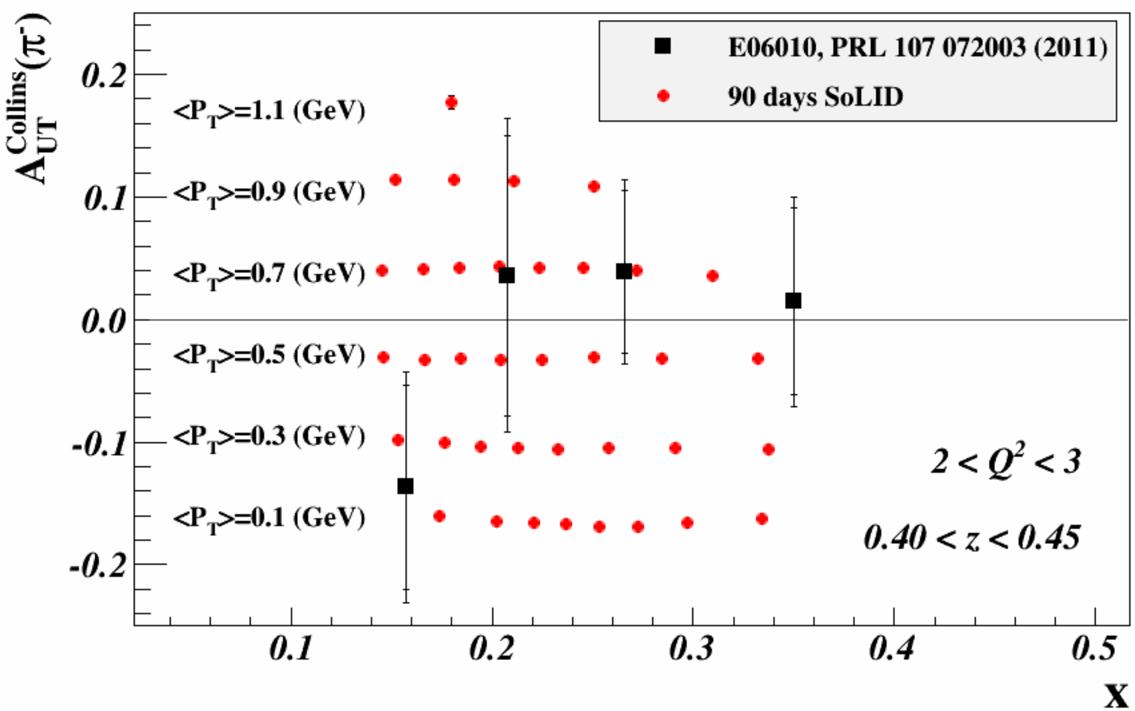
→SIDIS: 4-D (x, pt, Q2, z) probe of nucleon transverse momentum distribution (TMD)

→ SoLID-SIDIS studies TMDs with extensive coverage, and high resolutions



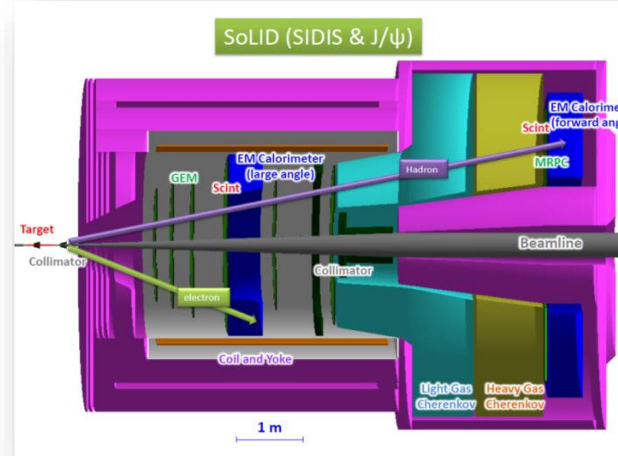
(48 Q-z bins)

0.3 < z < 0.7
1.0 < Q < 8.0
0.0 < pt < 1.2
0.1 < x < 0.7



SIDIS

◆ Semi-Inclusive Deep Inelastic Scattering:

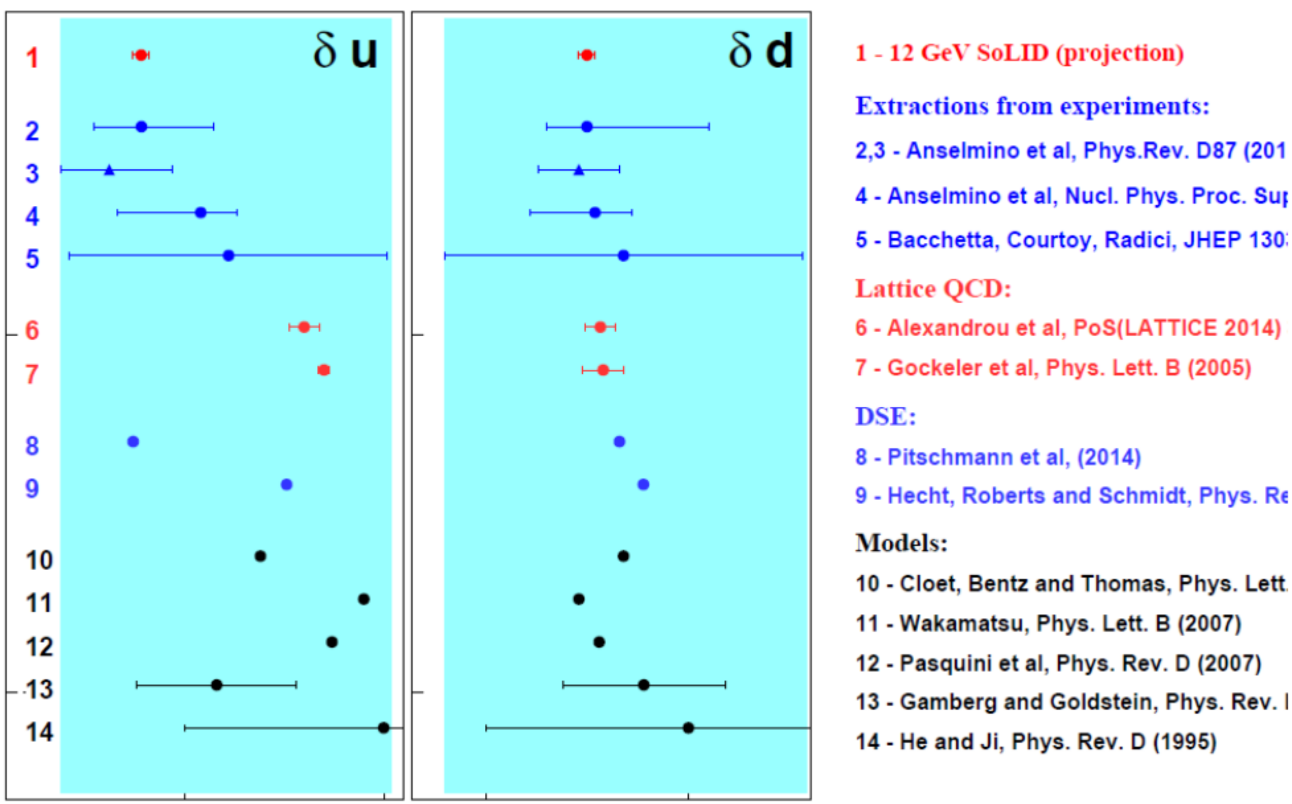


→SIDIS: 4-D (x, pt, Q2, z) probe of nucleon transverse momentum distribution (TMD)

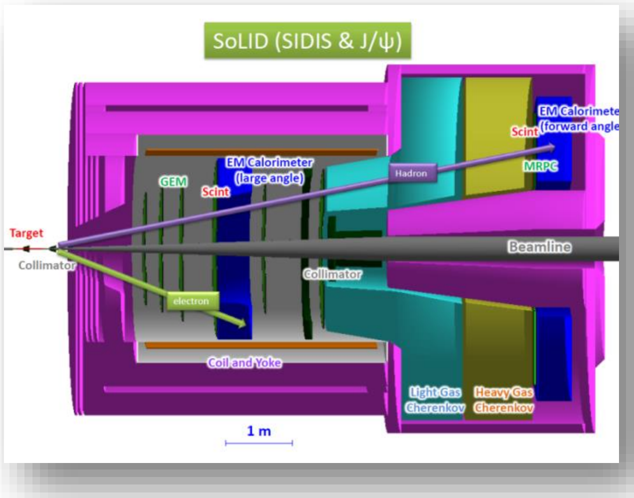
→ SoLID-SIDIS studies TMDs with extensive coverage, and high resolutions

→ Determine the tensor charge of d & u

$$\delta q^a = \int_0^1 [h_{1T}^a(x) - h_{1T}^{\bar{a}}(x)]dx$$



SIDIS



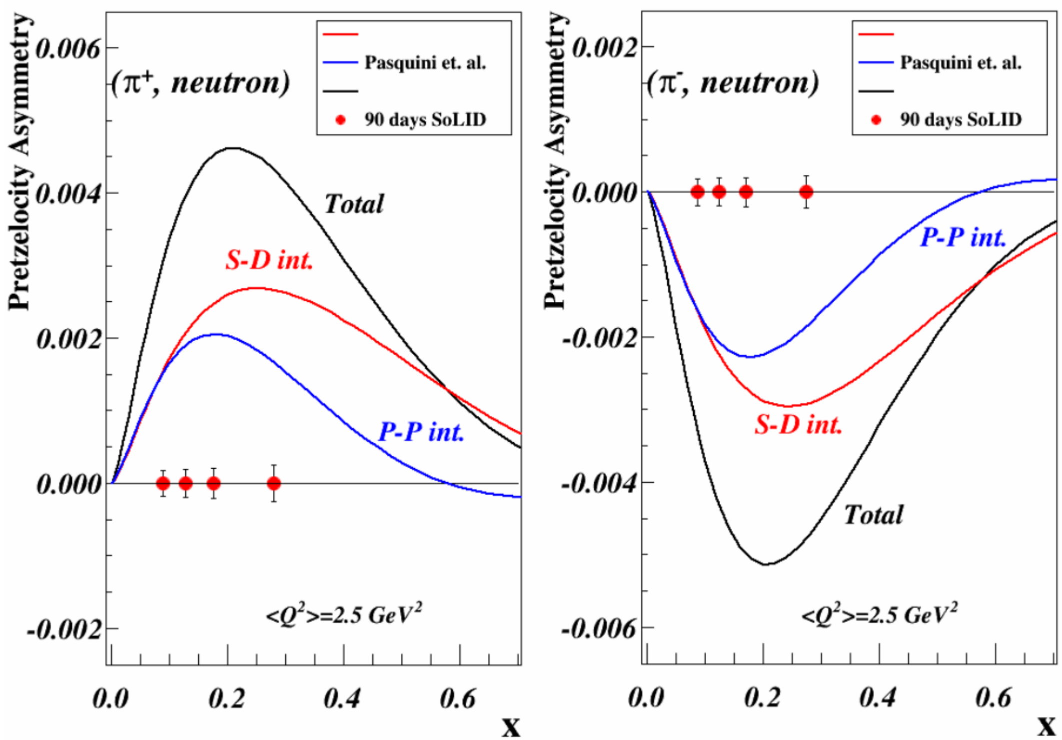
- **Semi-Inclusive Deep Inelastic Scattering:**

→SIDIS: 4-D (x, pt, Q2, z) probe of nucleon transverse momentum distribution (TMD)

→ SoLID-SIDIS studies TMDs with extensive coverage, and high resolutions

→ Determine the tensor charge of d & u

→ Access the orbital angular momentum (OAM) of quarks and gluons with transverse n/p

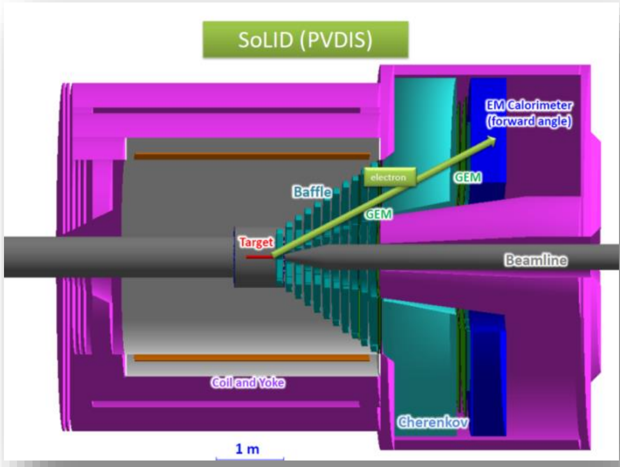


Nucleon Spin Puzzle:

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma(\mu) + L_q(\mu) + J_g(\mu)$$

- No direct model-independent relation to the OAM in Spin Sum-Rule.
- Pretzelosity: access info of $\triangle$L=2 (S-D or P-P interference)

PVDIS

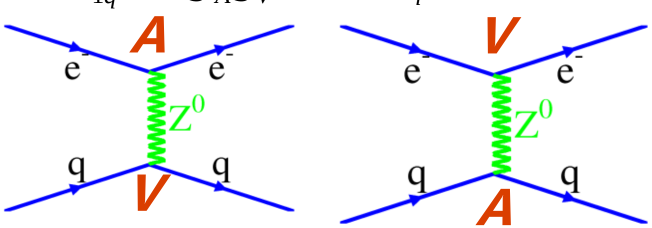


- **P**arity **V**iolation **D**eep **I**nelastic **S**cattering:

→ Measure the asymmetry between left- and right-handed electron scatterings which can access:

- ✓ QCD: nucleon structure, charge asymmetry, high twist, EMC …
- ✓ Electro-Weak
- ✓ New physics in NP and HEP (TeV-scale probe …)
- ✓ More …

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



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

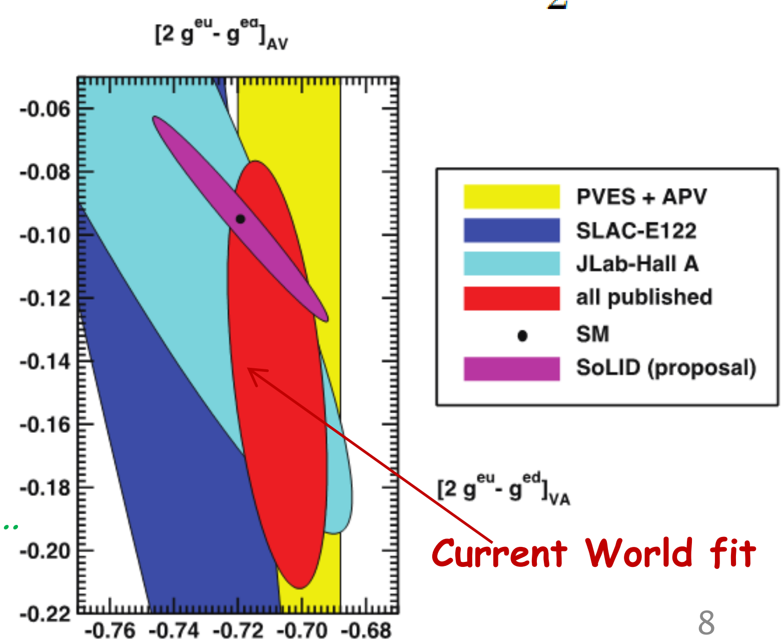
$$a_1(x) = \frac{6}{5}(2C_{1u} - C_{1d})\left(1 + \frac{2s^+}{u^+ + d^+}\right),$$

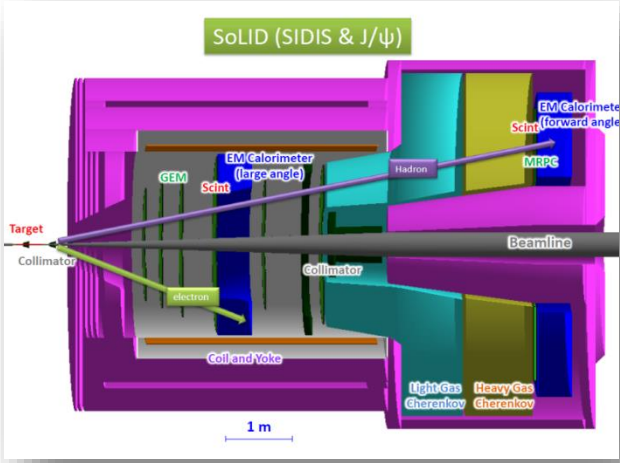
$$a_3(x) = \frac{6}{5}(2C_{2u} - C_{2d})\left(\frac{u^+ - d^+}{u^+ + d^+}\right) + \ldots$$

HT, New physics …

Standard Model:

$$g_{VA}^{eu} = C_{2u} = g_{VA}^{ed} = -C_{2d} = \frac{1}{2} - 2\sin^2\theta_W$$



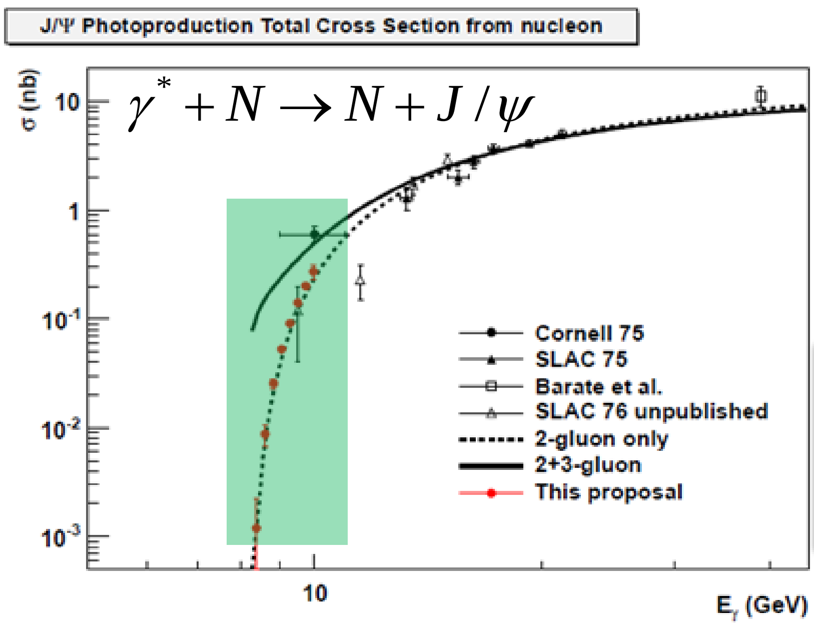


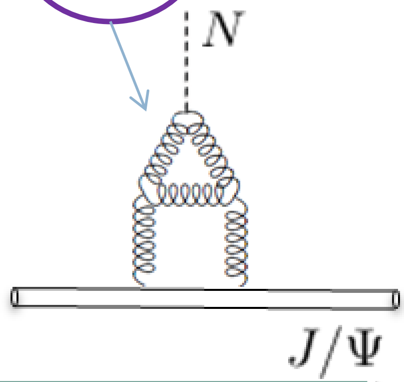
J/ψ

◆ Near Threshold Electroproduction of J/ψ

→ Probes strong gluonic interaction between two color neutral objects J/ψ and nucleon near threshold:

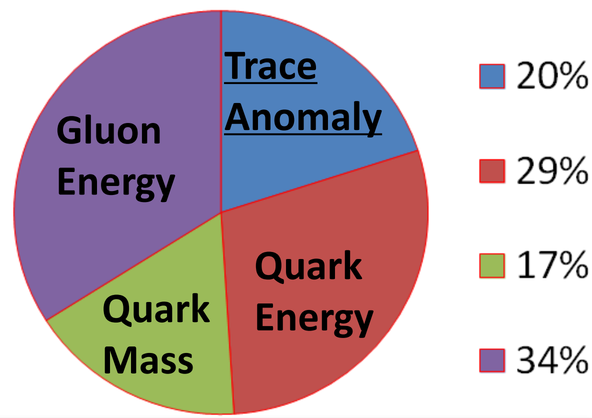
$$M_N = \left\langle N \middle| \sum_{u,d,s} m_q q\bar{q} + \frac{\beta(g)}{2g} G^{\alpha\beta\gamma} G^{\gamma}_{\alpha\beta} \middle| N \right\rangle$$





Multiple gluon exchange may cause enhancement near threshold

Proton Mass Budget



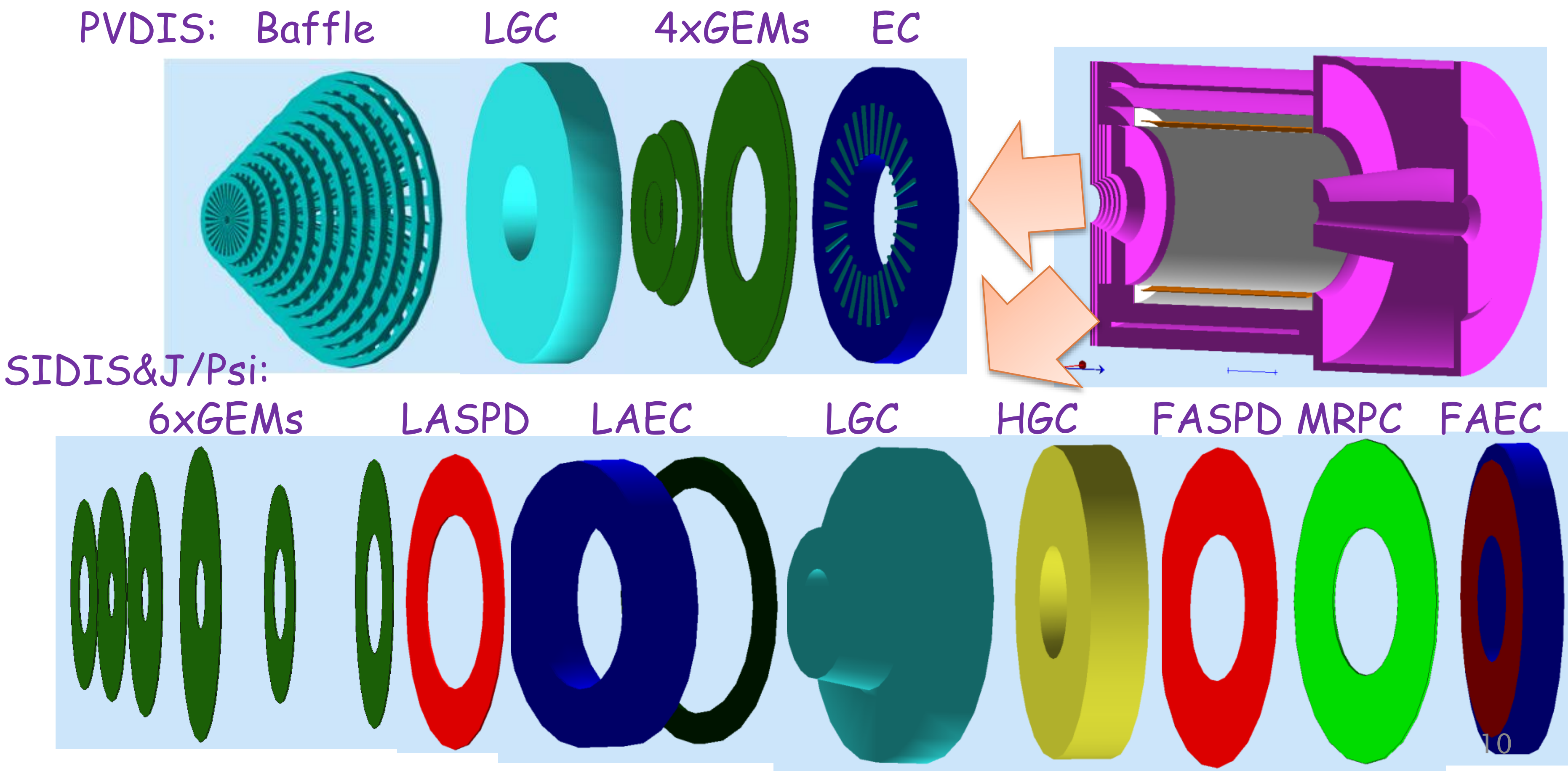
Trace anomaly of QCD energy momentum tensor plays an essential part in proton mass budget

→ Models relate J/ψ production near threshold to trace anomaly and proton mass budget

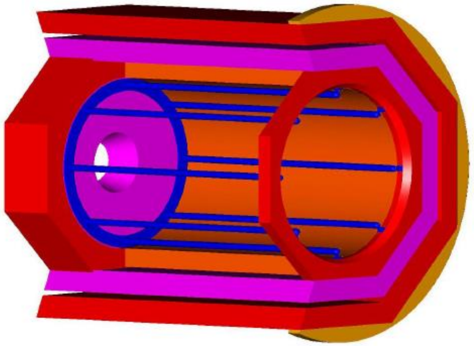
(D. Kharzeev et al Eur.Phys.J. C9 459 (1999), A. Sibirtsev et al. Phys. Rev., D71:076005 (2005))

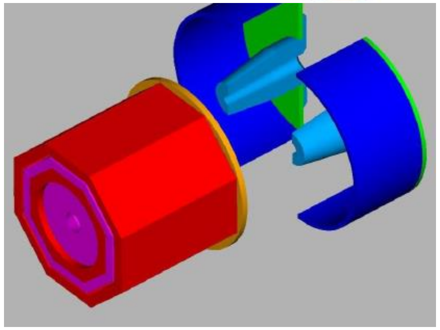
SoLID Overview

- High Intensity ($10^{37} \sim 10^{39}$ $cm^{-2}s^{-1}$) and Large Acceptance
- Take advantage of new developed detector techniques, fast electronics and data acquisition.
- Sophesticated MC simulation and analysis software developments



Magnet





- **CLEO-II Solenoid Magnet:** from Cornell Univ.

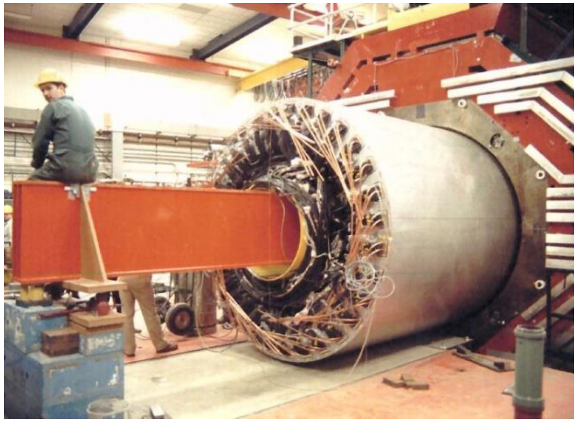
Goals:

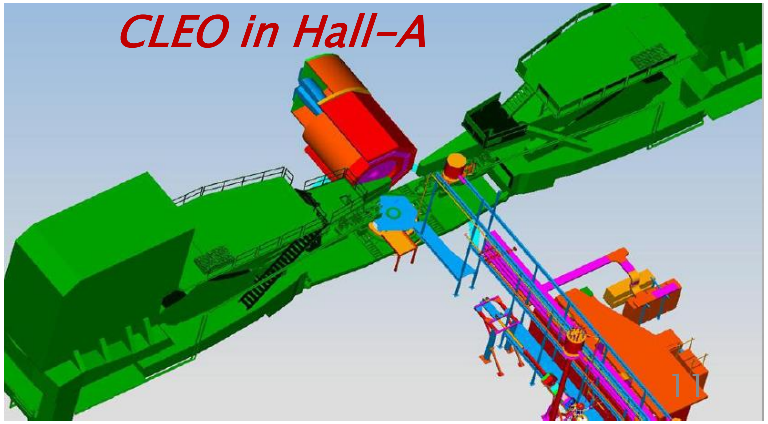
→Acceptance: Φ: 2π, θ: 8°-24° (SIDIS), 22°-35° (PVDIS),
P: 1.0 – 7.0 GeV/c,
→ Resolution: δP/P ~ 2% (requires 0.1 mm tracking resolution)
→ Fringe field at the front end < 5 Gaus

Status:

→ CLEO-II magnet formally repqested and agreed in 2013:
Built in 1989 and operated until 2008, uniform central field at 1.5 T,
Inner radius 2.9 m, coil radius 3.1 m and coil length 3.5 m
→ Site visit in 2014, disasembly in 2015 and plan transportation in 2017
→ Design of supporting structures and mounting system at JLab

CLEO at Cornell



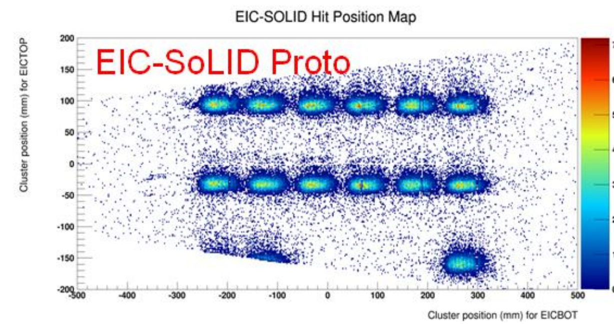


CLEO in Hall-A

Detectors

◆ **GEM:** by UVa and Chinese collaborators

Goals: →5 planes (PVDIS) and 6 planes (SIDIS/JPsi), area~37 m^2 (165K outputs),
→work in high rate and high radiation environment.
→tracking eff.>90%, radius resolution ~ 0.1 mm,



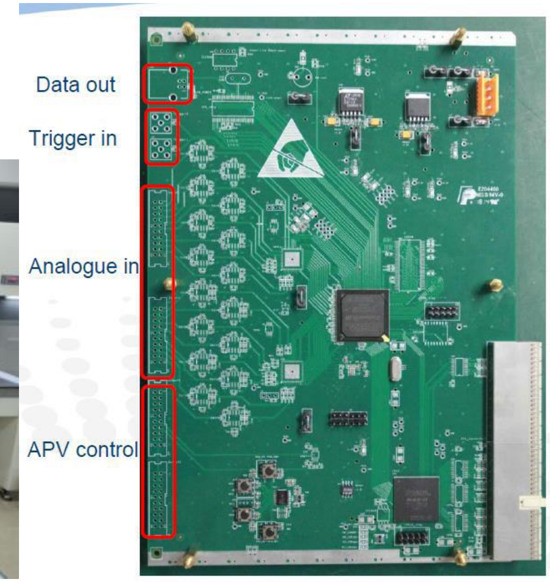
Status:

- UVa: First full size prototype assembled, and beam test at Fermi Lab Oct 2013

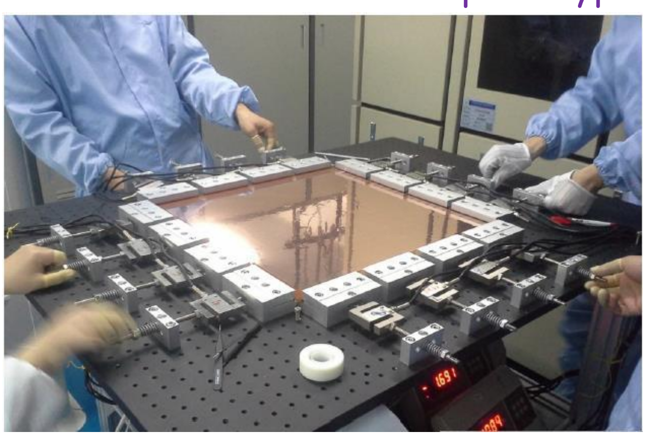
- China: CIAE/USTC/Tsinghua/LZU)

✓ 30x30 cm prototype constructed and readout tested, and now moving to 100cmx50cm construction
✓ Gem foil production facility under development at CIAE
✓ Continue on read-out electronics desgin and test

Test board for APV25



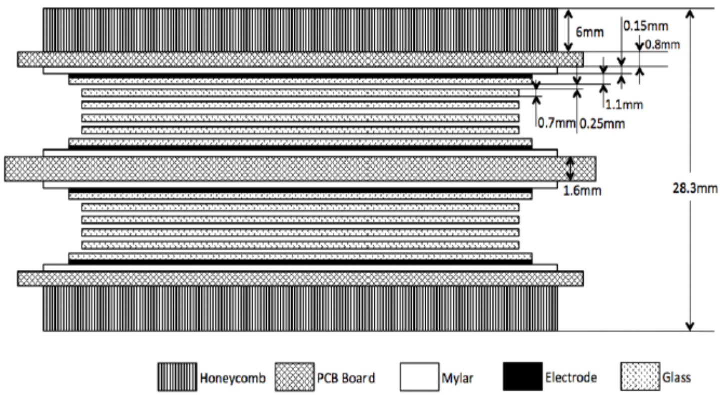
30cmx30cm GEM prototype



100cmx50cm GEM foil

Detectors

◆ **Multi-gap Resistive Plate Chamber:** by Tsinghua, Duke and Rutgers

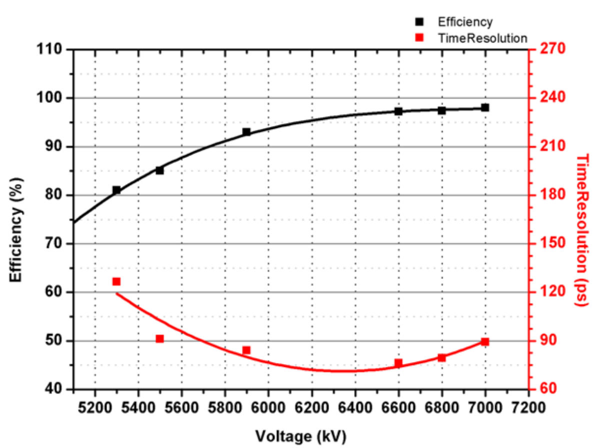


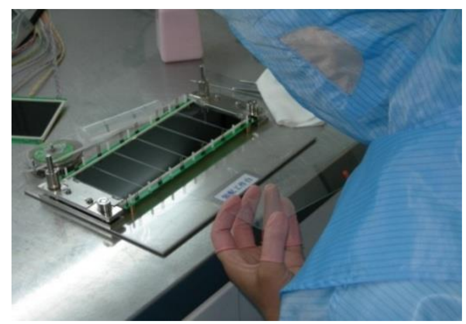
Goals:

→ For SIDIS/JPsi only, between FASPD and FAEC
→ 50 super-modules, each contains 3 modules, 1650 strips and 3300 output channels.
→ Timing resolution < 100ps
→ Works at high rate up to 10 KHz/cm2
→ Photon suppression > 10:1
→ π/k separation up to 2.5GeV/c

Status:

→ Prototype Developed at Tsinghua
→ Beam test at Hall-A in 2012
→ New facility for mass production
→ Read-out electronics design



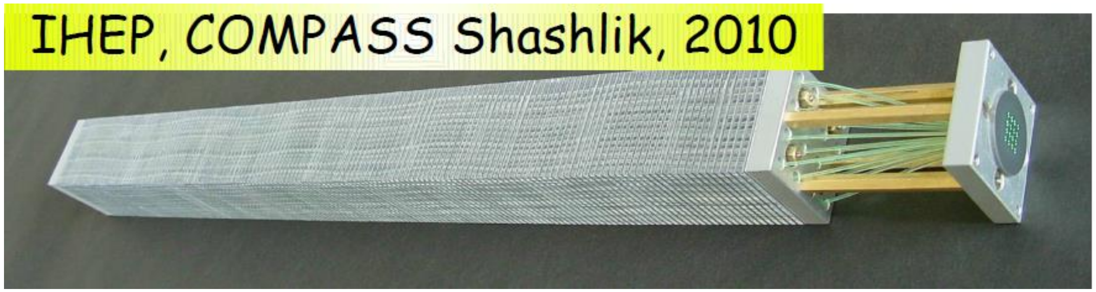


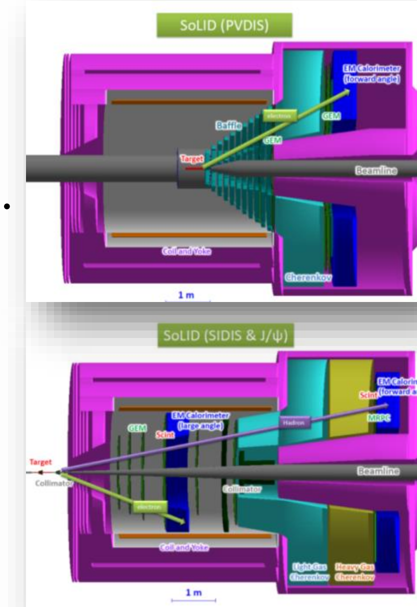
Pre-Amp

Tsinghua-FPGA TDC

Detectors

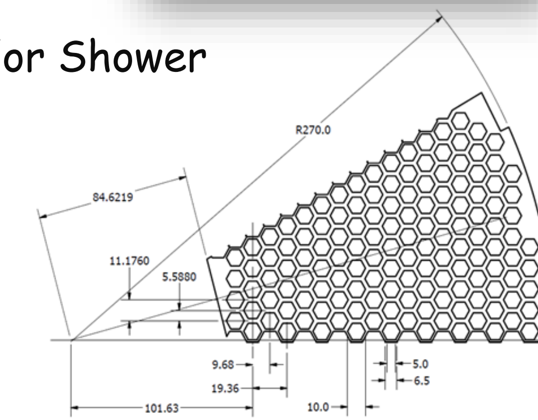
◆ **Electromagnetic Calorimeters (EC):** by UVa, W&M, ANL ...





Goals:

→ Shashlyk sampling calorimeters
→ 1800 modules (2 R.L.) for PreShower, 1800 modules (18 R.L) for Shower
→ Modules re-arranged for PDVIS<->SIDIS
→ electron eff.>90%, E-Resolution~10%/√E,
  π suppresion > 50:1
→ Rad. Hard (<20% descreasing after 400K Rad)



	θ (deg)	z (cm)	R(cm)	P (GeV/c)	Max π/e	Area (m^2)
PVDIS FAEC	22 - 35	(320,380)	(110,265)	2.3 - 6	~200	~ 18.3
SIDIS FAEC	7.5 - 14.85	(417,475)	(98,230)	1 - 7	~200	~ 13.6
SIDIS LAEC	16.3 - 24	(-65,-5)	(83,140)	3-6	~20	~ 4.0

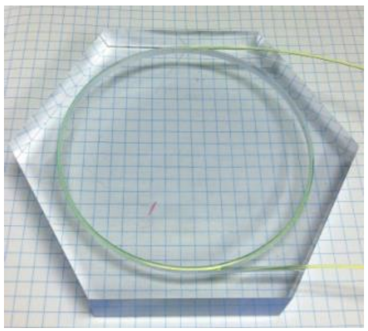
Detectors

◆ **Electromagnetic Calorimeters (EC):** continue …

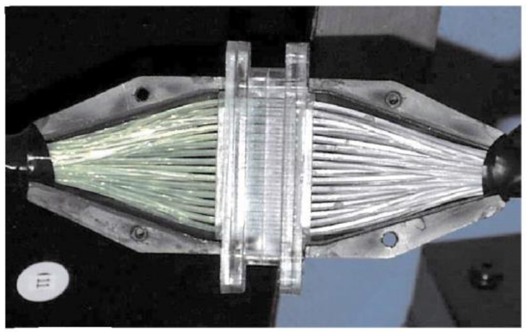
Status:

→ Sophesticated Geant Simulation
→ Active Pre-R&D at UVa and Jlab
→ Sample&PMT tests and Pre-Amp design

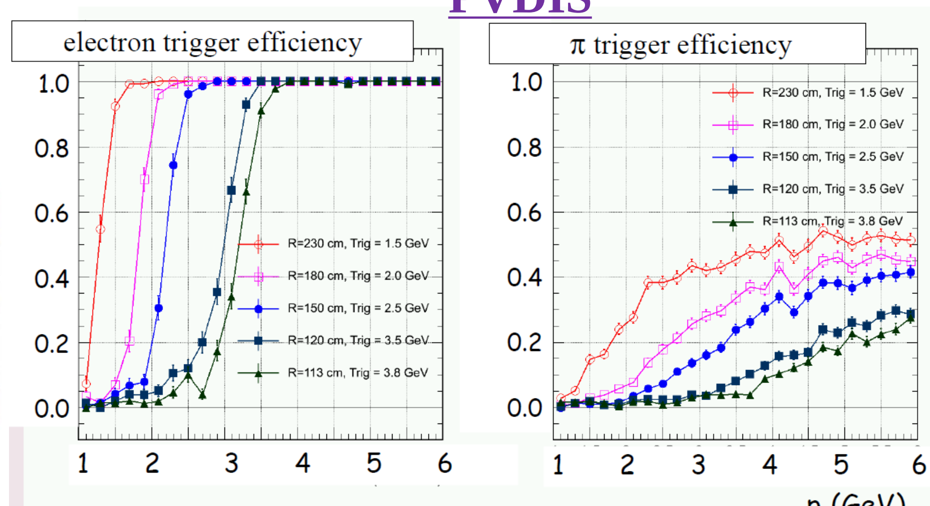
PreShower module



Fiber connectors

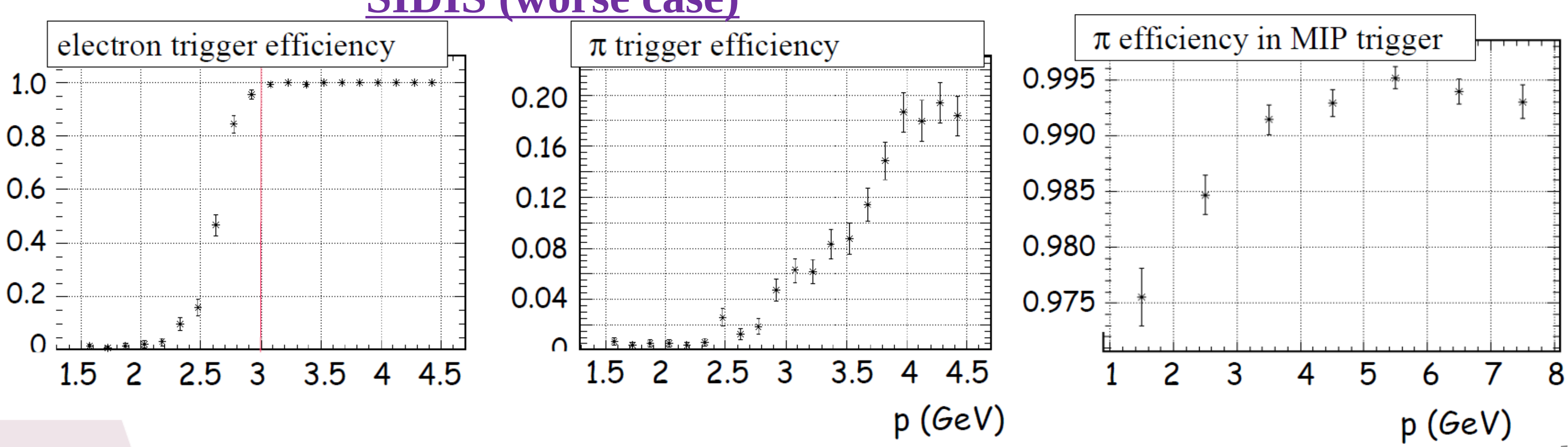


PVDIS



preserve DIS electron of x>0.35

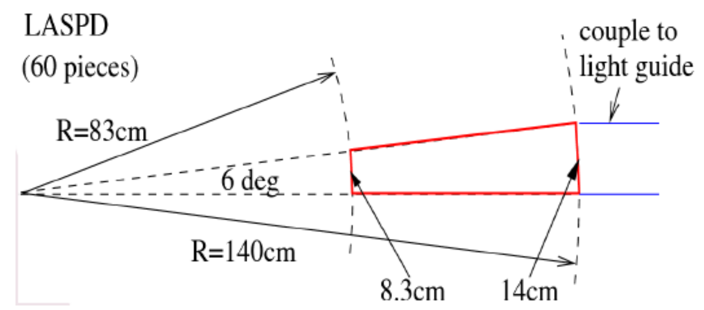
SIDIS (worse case)



threshold: 2.6 GeV → 3 GeV momentum

Detectors

◆ **Scintillating Pedal Detectors (SPD):** by UVa and Duke ...



Goals:

→ For SIDIS/JPsi only

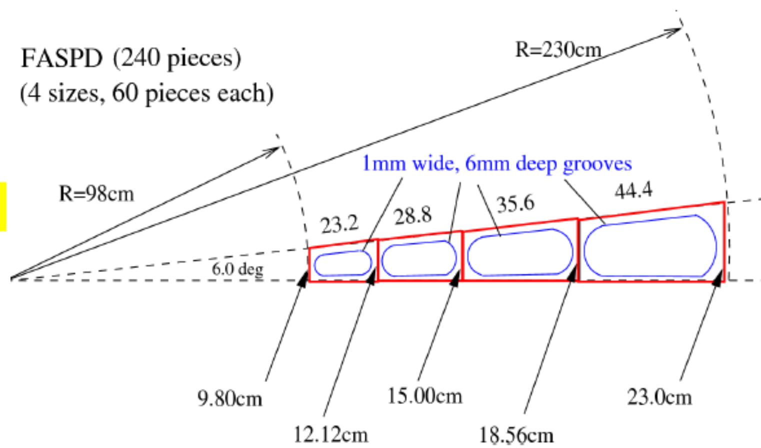
→ Two planes (in front of LAEC and FAEC):
LASPD: 60 modules, 5 mm or thicker, photon rej. 10:1
FASPD: 60 modules x 4 radius, photon rej. 5:1

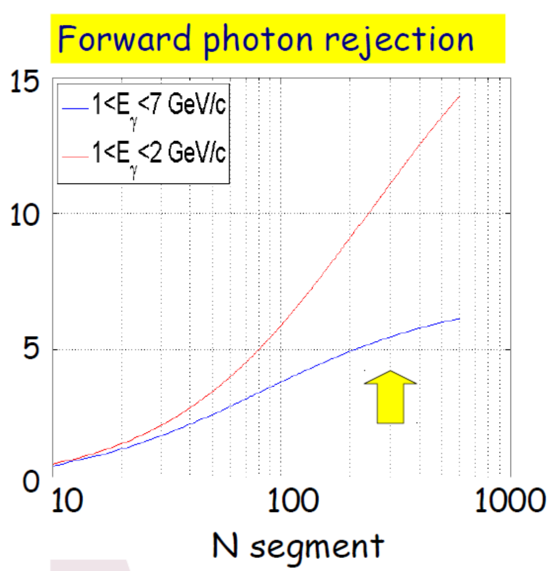
→ LASPD timing resolution < 150ps

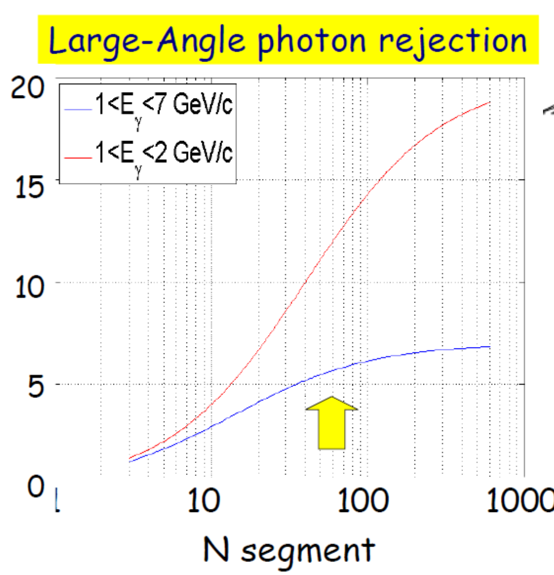
Status:

→ Design and Simulation

→ Pre-R&D at UVa and JLab







Triggers&DAQ

◆ Triggers:

→ Estimation based on sophesticated Geant simulation and well-tone physics models

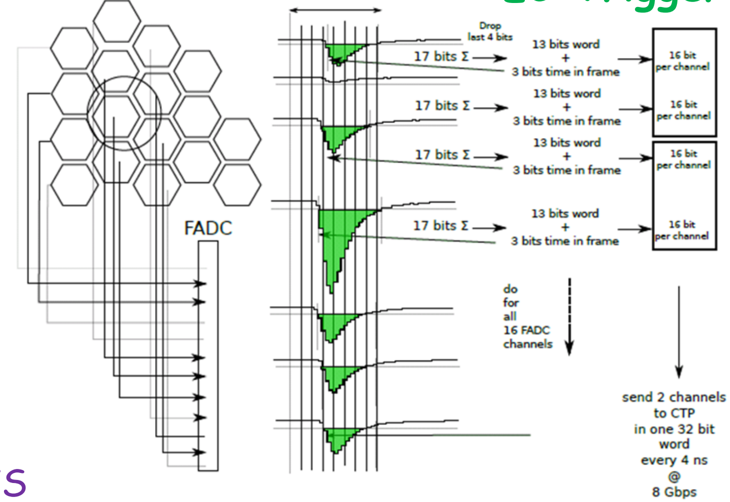
→ PVDIS: LGC+EC provide electron triggers, 27 KHz/sector, 30 sectors

→ SIDIS: Coincident trigger between electrons and hardrons within a 30 ns window:

LASPD+LAEC provide electron triggers, 25 KHz
LGC+FASPD+MRPC+FAEC provide electron trigger, 129 KHz
FASPD+MRPC+FAEC provide hardron trigger, 14 MHz

} 66 KHz + 6 KHz (eDIS)

EC Trigger



◆ Read-Out and Data Aquisition System:

→ Use fast electronics to handle the high rates (FADC, APV25, VETROC, etc.)

→ Read out EC clusters to reduce background

→ Current design can take the trigger rates
60 KHz per sector for PVDIS, and 100 KHz overall for SIDIS

→ Use Level-3 to further reduce the events size

→ Learn new developments from others (e.g. Hall-D)

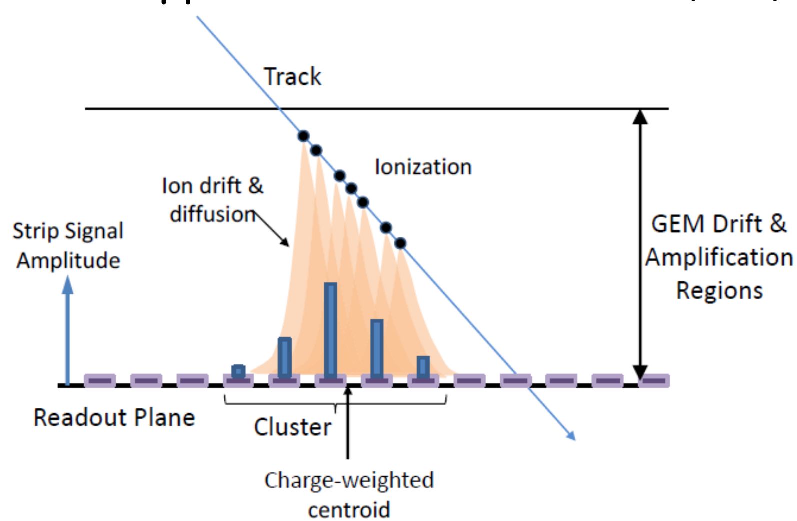
Simulation&Software

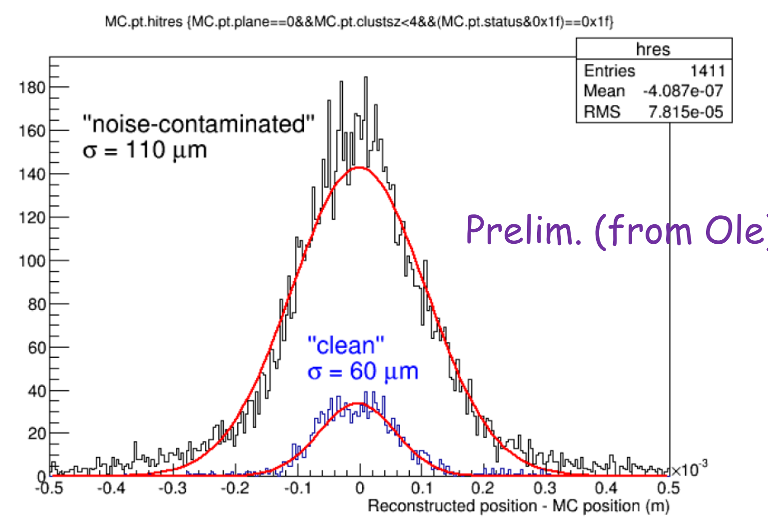
◆ GEMC:

- SoLID full setup in GEMC (Geant4) with realistic materials
- EM background produced from 11GeV e- on targets with the physics models in Geant4
- Hadron background, generated from event generators (Wiser fit) on both target and target windows, then passed into GEMC

◆ GEM Tracking Reconstruction:

- Can reconstruct charged particles traveling in the strong magnetic filed
- Need fast processing time for high rates with backgrounds
- Two approaches: Tree Search (Ole), Progressive Tracking (Weizhi Xiong, Duke)





Summary

◆ Highly rated experiments with exciting physics topics

◆ Take advantage of latest detector and electronics techniques

◆ Active MC simulation, software deveoptments and Pre-CDR & Prototyping

◆ A strong and still expending collaboration:

200+ physicists, 50+ institutions and significant international contributions ...

Timeline:

◆CLEO-II magnet has been requested and will be transported in 2017

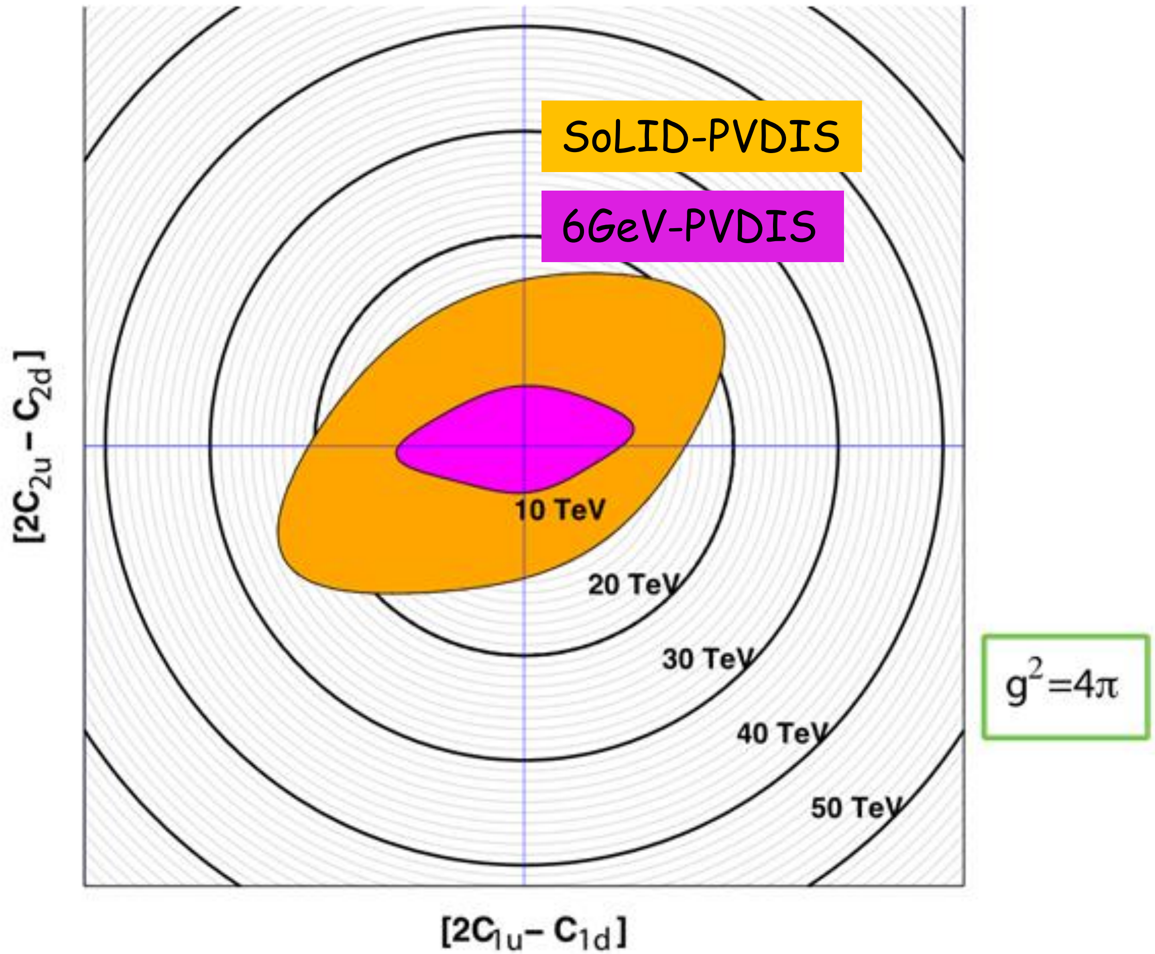
◆ Pre-conceptial Design Report has been submitted in July 2014

◆ White-papers submited for QCD and Symmetry town-meetings in 2014 (LRP), many talks& semenars, and received very positive feekbacks.

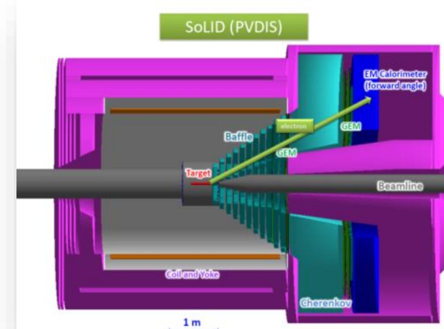
◆ Ready for the director review

Backup Slides

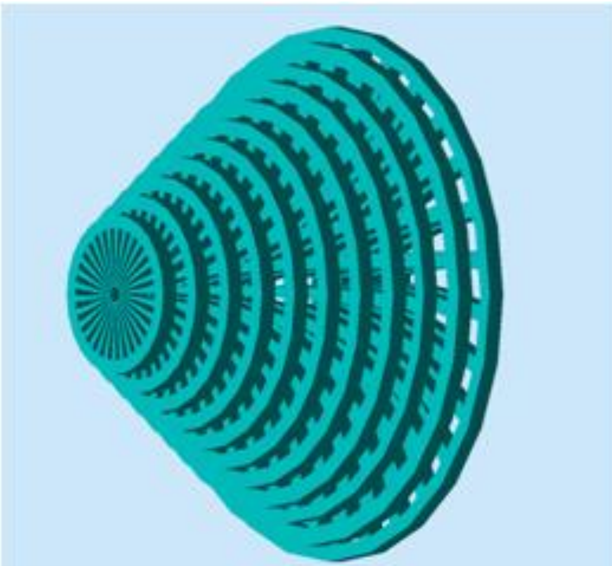
Power of SoLID-PVDIS



Baffle



◆ **PVDIS Baffle:**



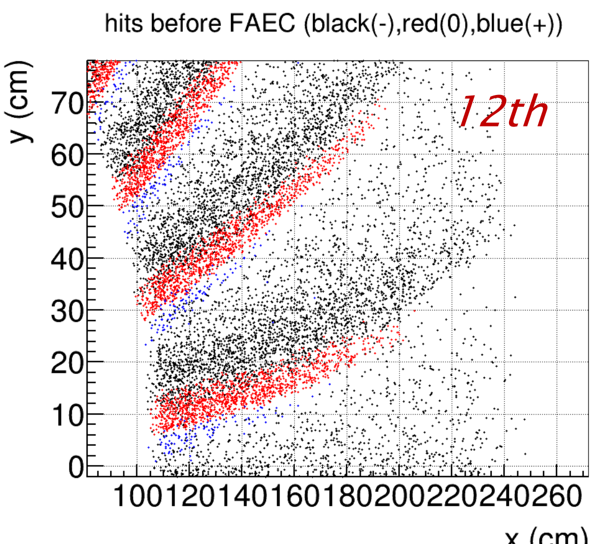
Goals:

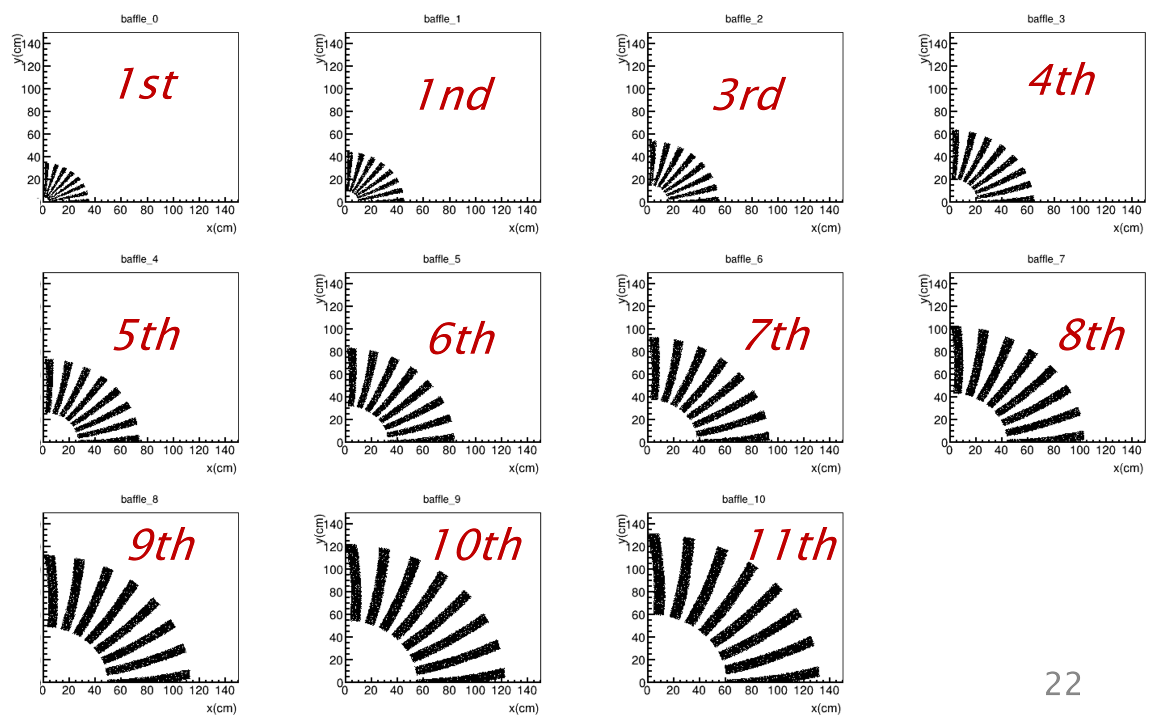
→ For PVDIS only

→ 11 layers of 9cm thick lead and one layer of 5cm lead

→ Right after the target to block photons, pions and secondary particles.

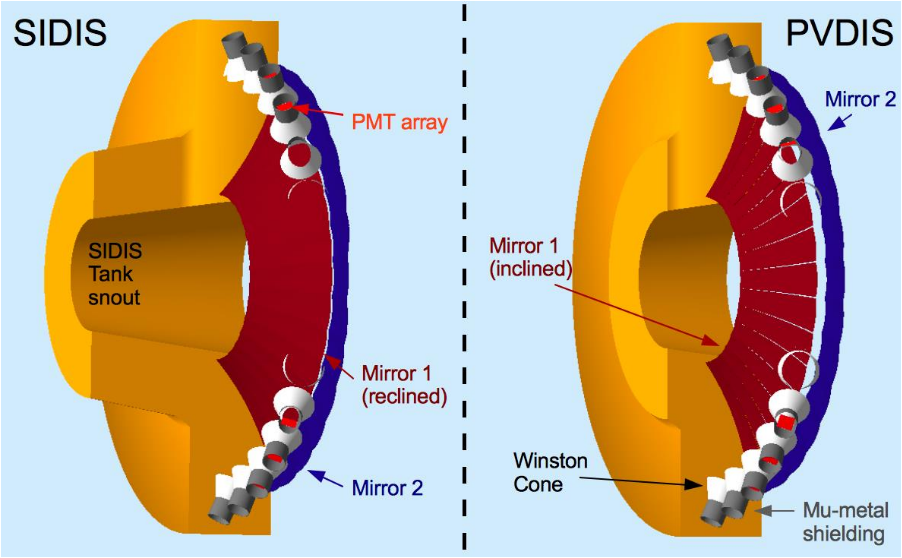
→ Follow charge particle bending in the field, preserve the same azimuthal slice and block line of sight.





Detectors

◆ Light Gas Cherenkov Counter (LGC): by Temple University

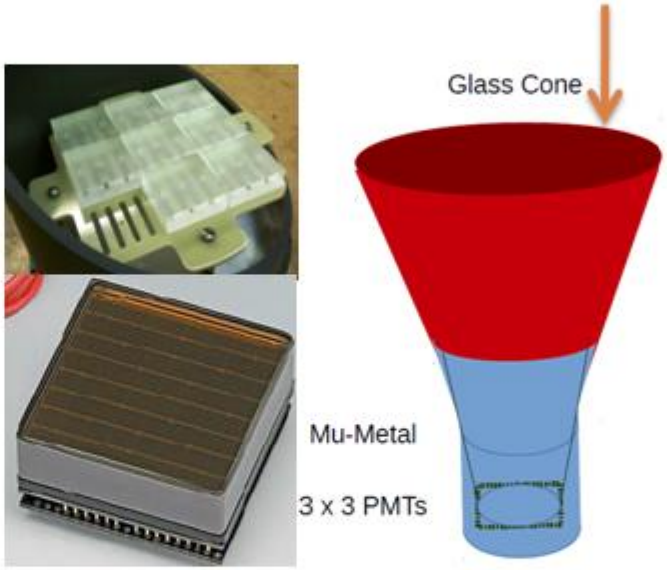


Goals:

→2 m C02 (SIDIS/Jpsi), 1 atm
→1 m C4F8O (65%)+N2 (35%) (PVDIS), 1 atm
→30 sectors, 60 mirrors, 270 PMTs, Area~$20m^2$
→N.P.E>10, eff.>90%, π suppresion > 500:1
→Work at 200G field (100G after shielding)

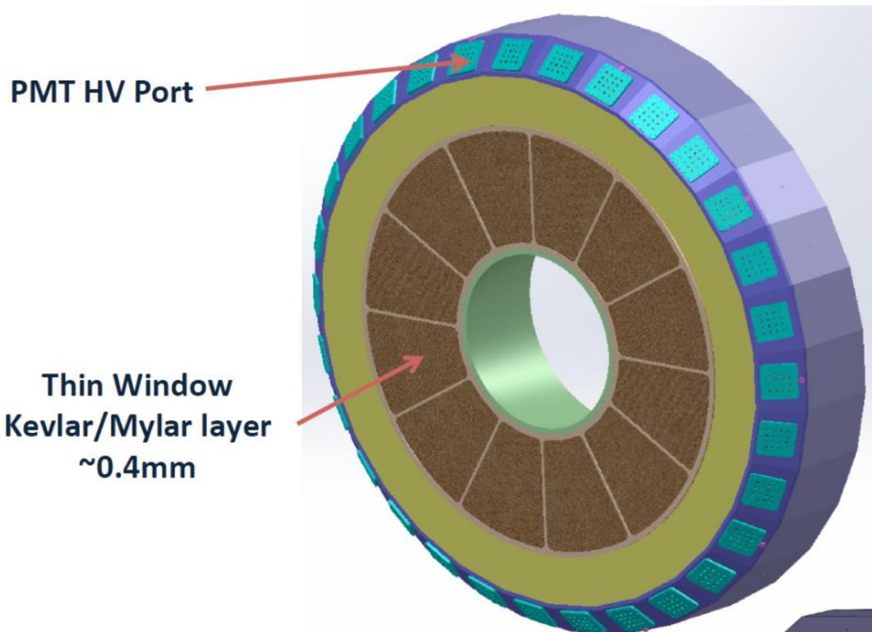
Status:

→ Support Structure and Mounting Design
→ u-metal Shielding design
→ Pre-R&D ongoing at Temple



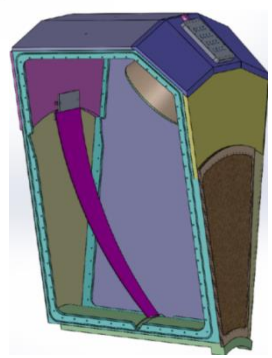
Detectors

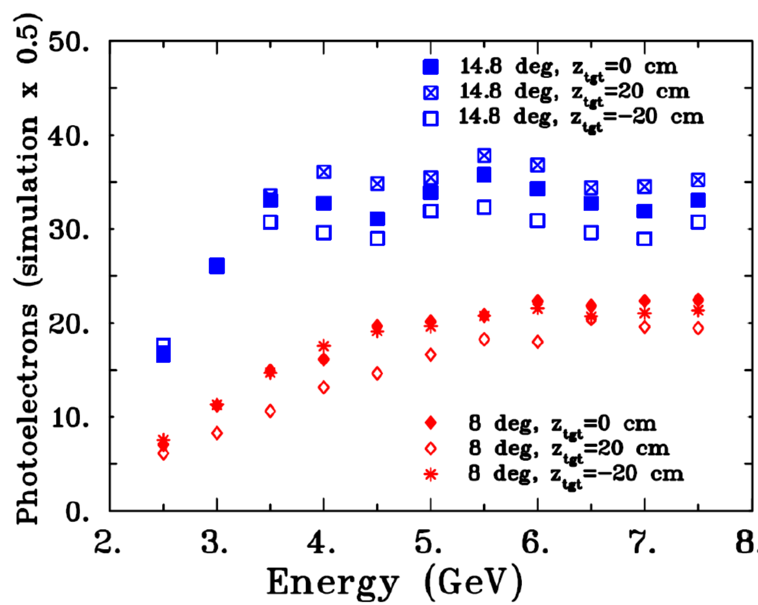
- **Heavy Gas Cherenkov Counter (HGC):** by Duke University



Goals:

→for SIDIS only
→1 m C4F8O at 1.5 atm
→30 mirrors, 480 PMTs, area~20 m^2
→N.P.E>10, eff.>90%, Kaon suppresion > 10:1,
→Work at 200G field (100G after shielding)

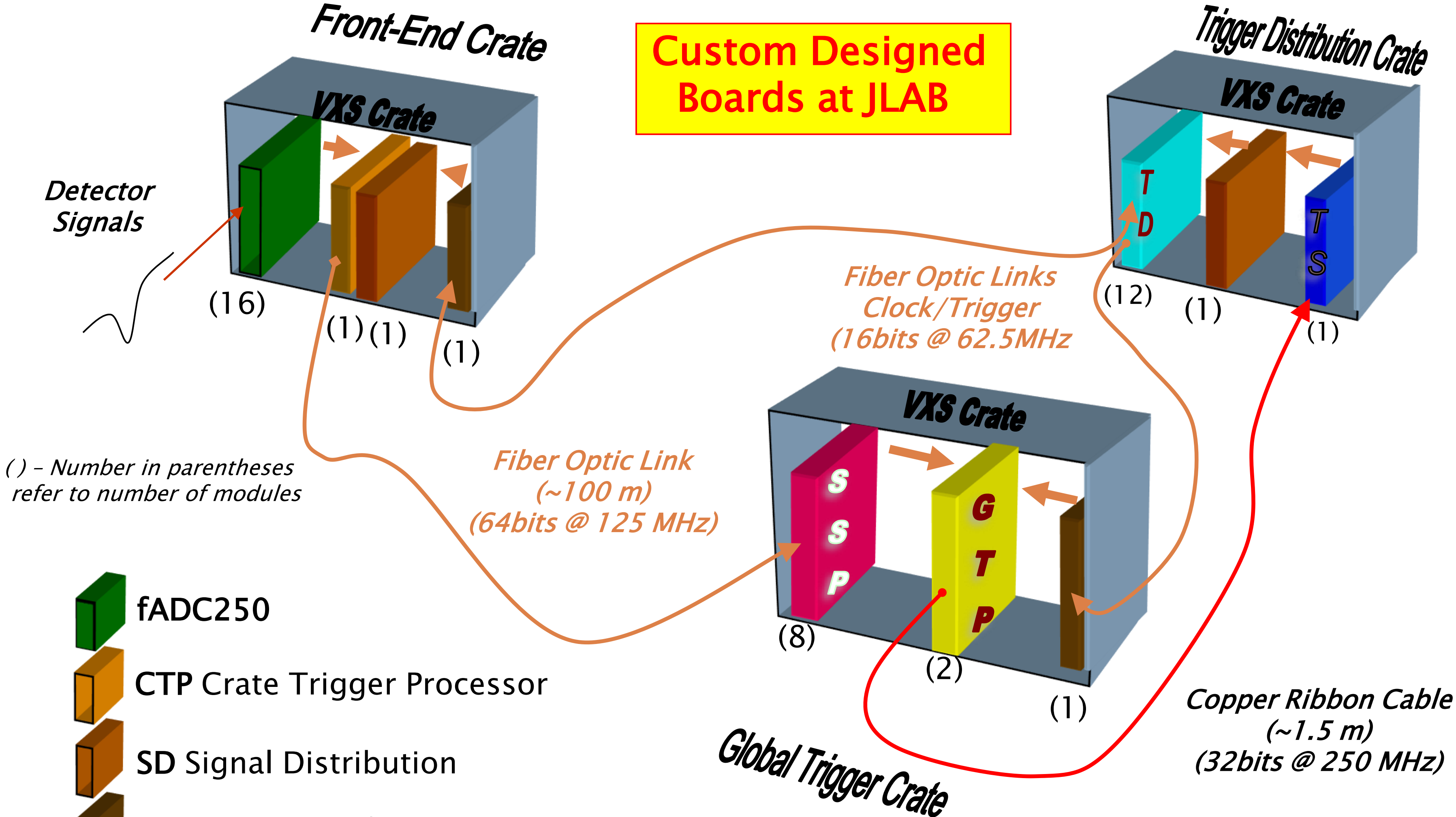




Status:

→ Optimize the design with MC
→ Designs of Support Structure, Mounting, Shielding, etc.
→ Magnet field test with MaPMT H8500 (S. Malance, JINST 8 P09004,2013) and H12700
→ Prototype-Test will happen at Duke soon

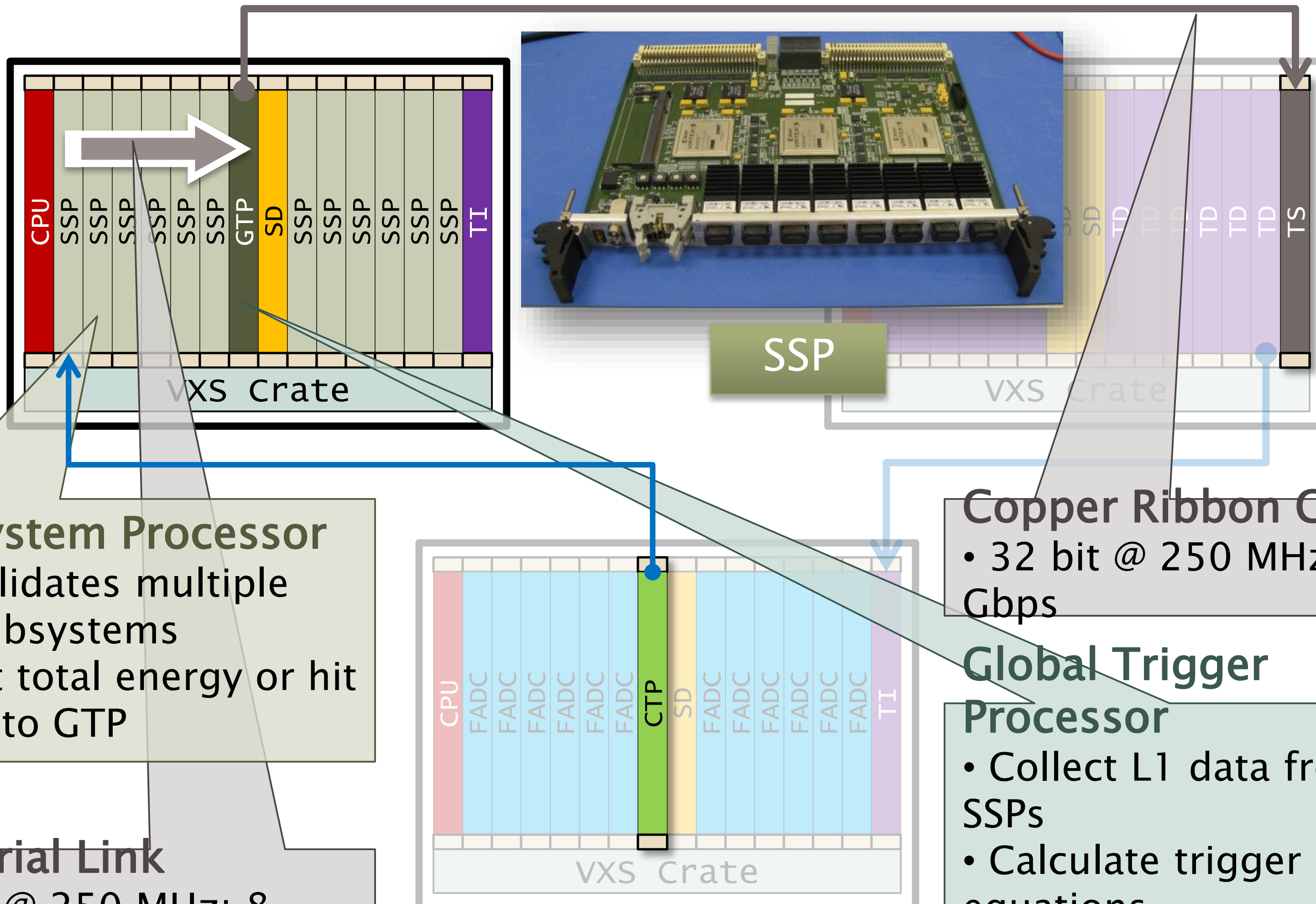
Level-1 Trigger Electronics



Pipelined detector readout electronics: fADC

- Trigger Latency ~ 3 µs

L1 Trigger Diagram



Sub-System Processor
- Consolidates multiple crate subsystems
- Report total energy or hit pattern to GTP

VXS Serial Link
- 32 bit @ 250 MHz: 8 Gbps

Copper Ribbon Cable
- 32 bit @ 250 MHz: 8 Gbps

Global Trigger Processor
- Collect L1 data from SSPs
- Calculate trigger equations
- Transfer 32 bit trigger pattern to TS