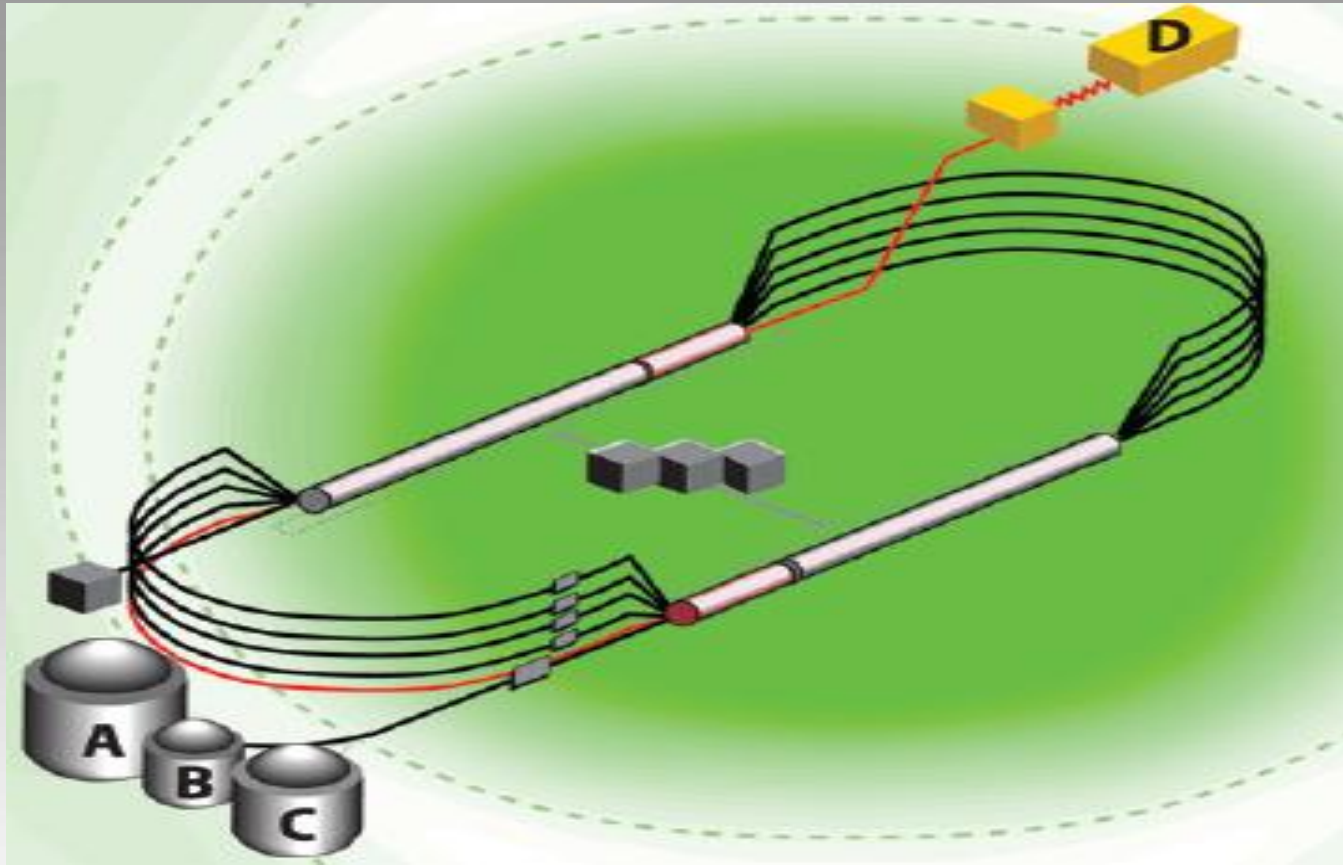


The Jlab 12 GeV Upgrade



R. D. McKeown
Jefferson Lab
College of William and Mary

12 GeV Science Program

- The physical origins of quark confinement (GlueX, meson and baryon spectroscopy)
- The spin and flavor structure of the proton and neutron (PDF's, GPD's, TMD's...)
- The quark structure of nuclei
- Probe potential new physics through high precision tests of the Standard Model

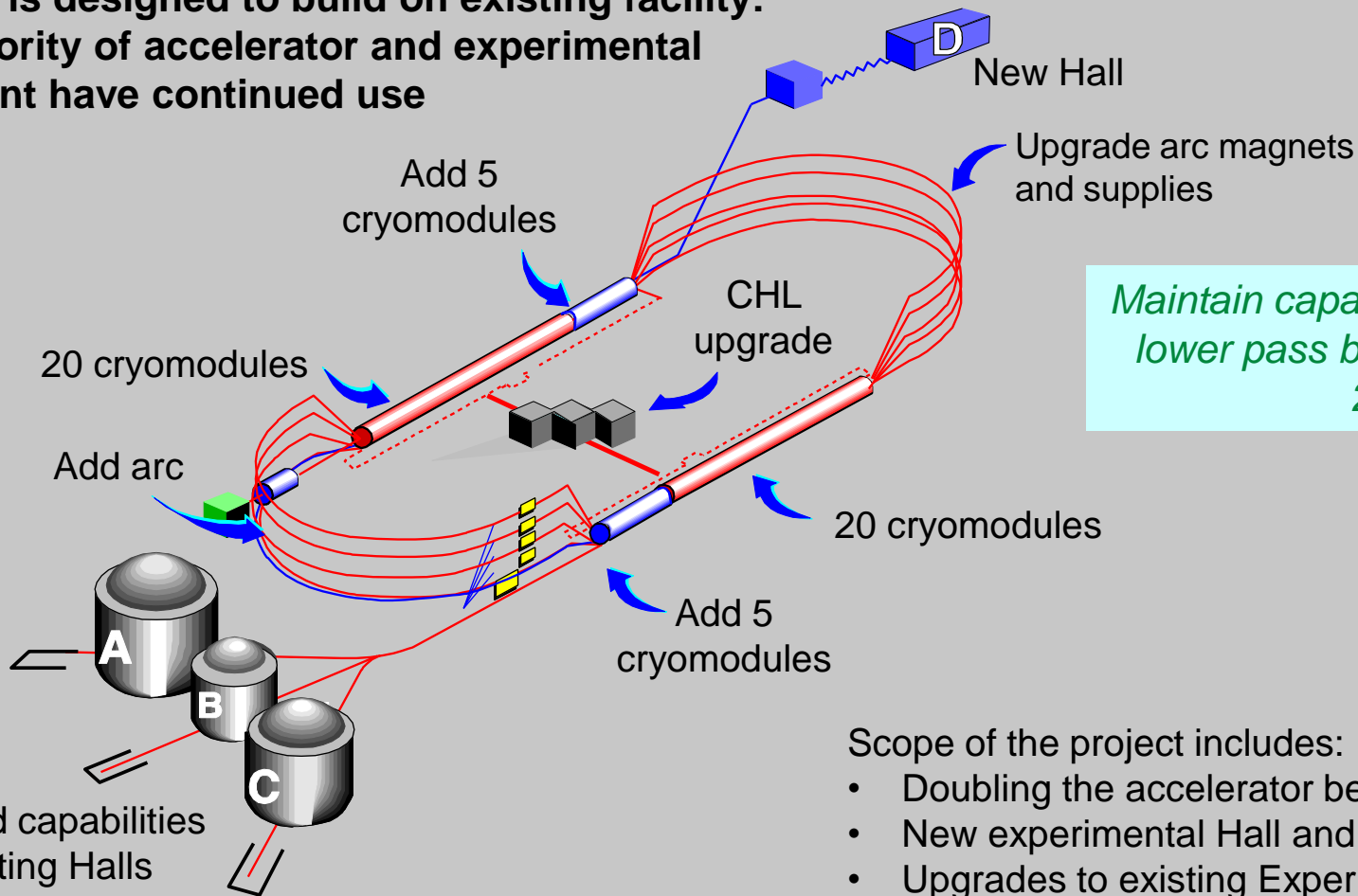
- Defining the Science Program:

- Four Reviews: Program Advisory Committees (PAC) 30, 32, 34, 35
- 2006 through 2010
- Results: *32 experiments approved ; 13 conditionally approved*
- PAC36 scheduled August 2010: continue rankings

Exciting slate of experiments for 4 Halls planned for initial five years of operation!

12 GeV Upgrade Project

Upgrade is designed to build on existing facility:
vast majority of accelerator and experimental
equipment have continued use

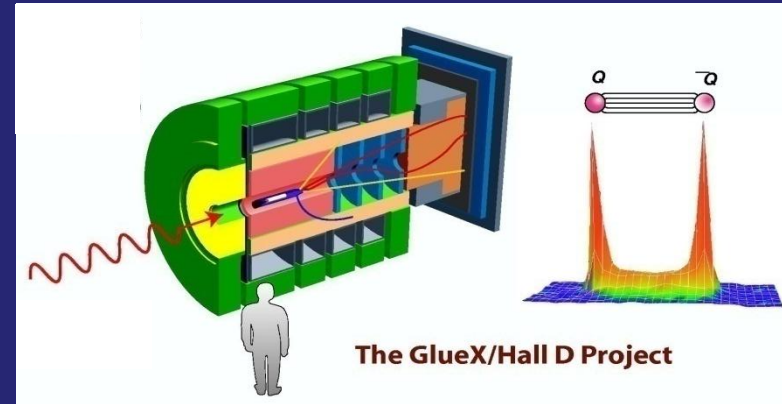
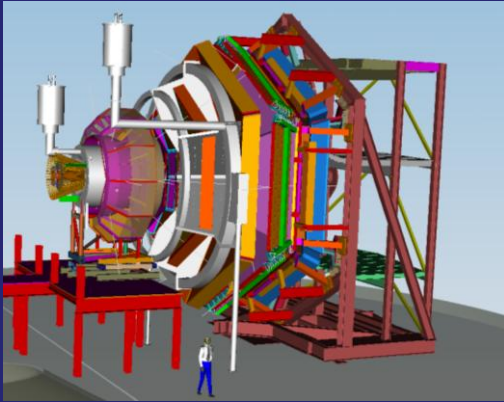


Scope of the project includes:

- Doubling the accelerator beam energy
- New experimental Hall and beamline
- Upgrades to existing Experimental Halls

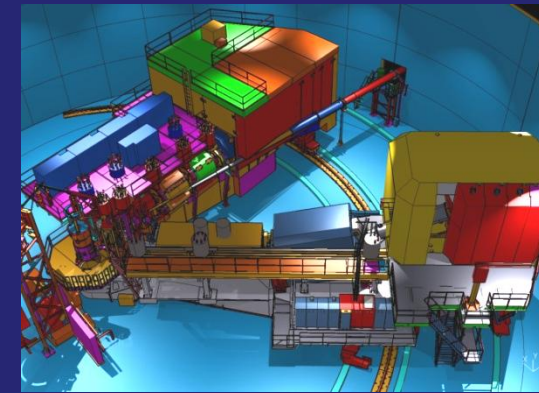
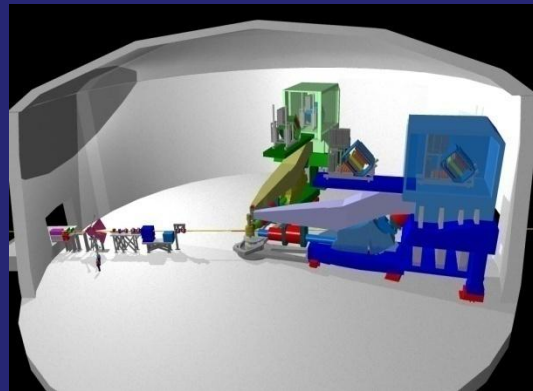
12 GeV Scientific Capabilities

Hall D – exploring origin of **confinement** by studying **exotic mesons**



Hall B – understanding **nucleon structure** via **generalized parton distributions**

Hall C – precision determination of **valence quark properties** in nucleons and nuclei



Hall A – short range correlations, form factors, hyper-nuclear physics, future **new experiments (e.g. PV and Moller)**

Quantum Numbers of Hybrid Mesons

Quarks



Excited
Flux Tube



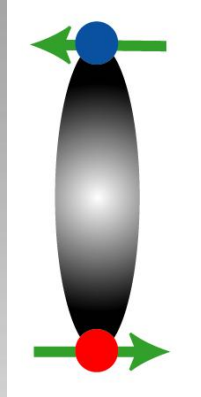
Hybrid Meson

$$S = 0$$

$$L = 0$$

$$J^{PC} = 0^{-+}$$

like π, K



$$J^{PC} = \begin{cases} 1^{+-} \\ 1^{-+} \end{cases}$$

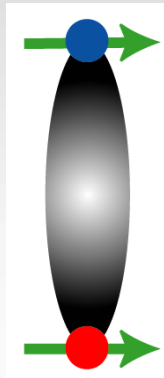
$$J^{PC} = \begin{cases} 1^{--} \\ 1^{++} \end{cases}$$

$$S = 1$$

$$L = 0$$

$$J^{PC} = 1^{--}$$

like γ, ρ



$$J^{PC} = \begin{cases} 1^{+-} \\ 1^{-+} \end{cases}$$

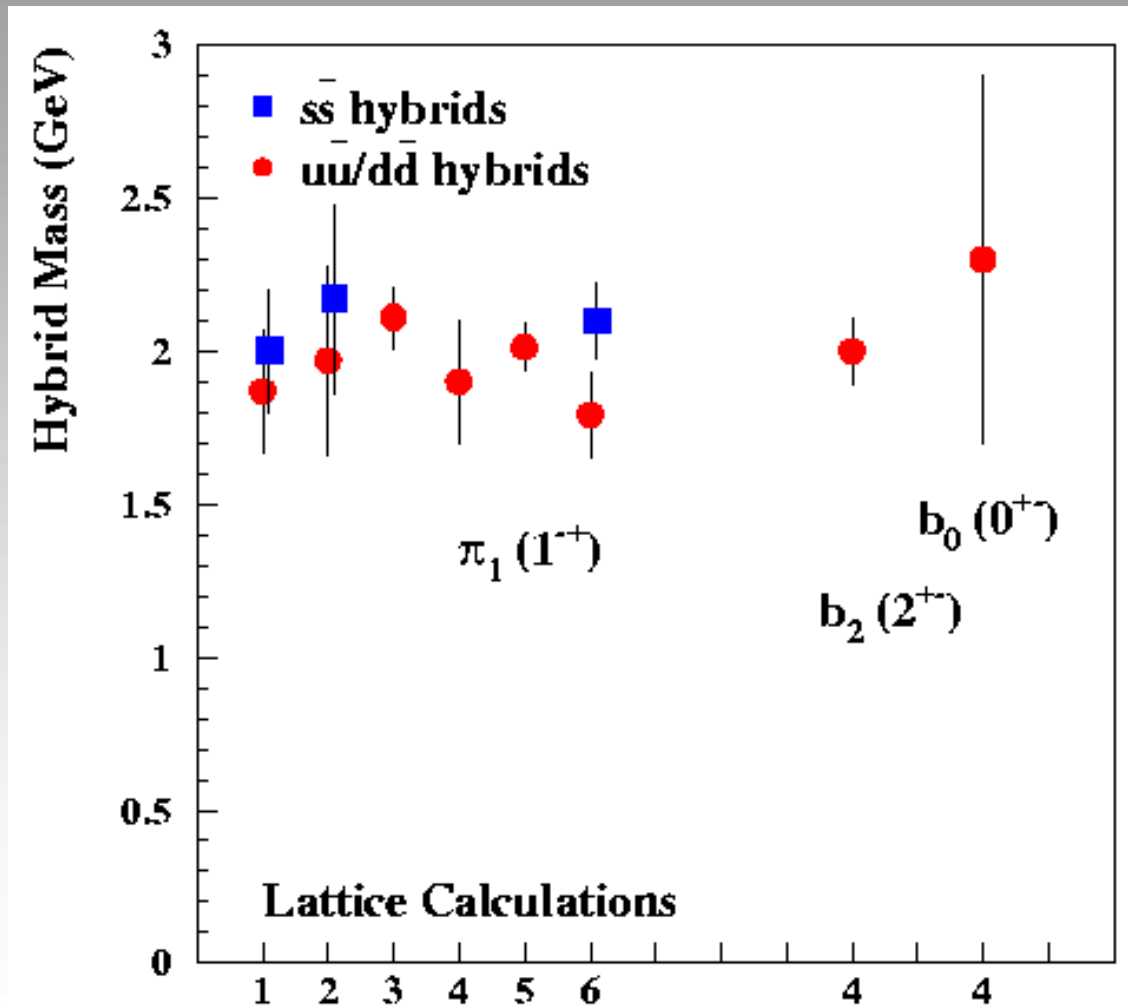
Exotic

$$J^{PC} = \begin{cases} 0^{-+} & 1^{-+} & 2^{-+} \\ 0^{+-} & 1^{+-} & 2^{+-} \end{cases}$$

Flux tube excitation (and parallel quark spins) lead to exotic J^{PC}

Mass Predictions

Lowest mass expected to be $\pi_1(1^{+-})$ at 1.9 ± 0.2 GeV



Lattice

1^{+-} 1.9 GeV

2^{+-} 2.1 GeV

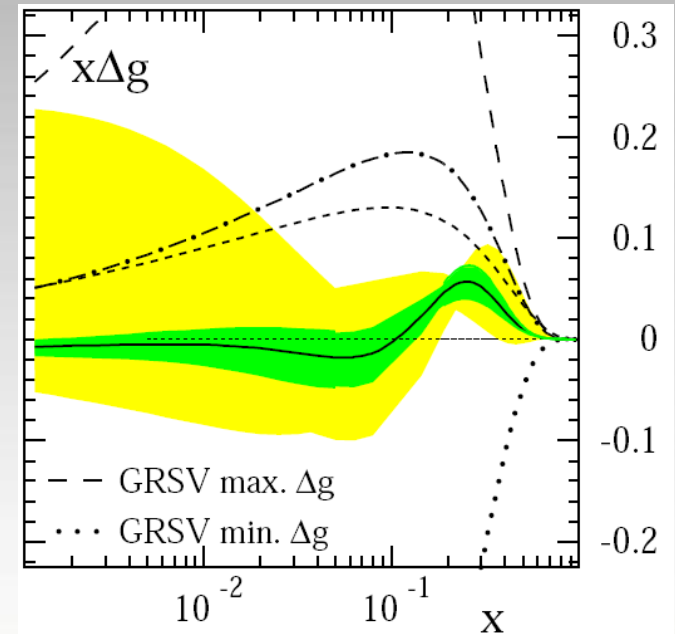
0^{+-} 2.3 GeV

Proton Spin Puzzle

$$\frac{1}{2} = \frac{1}{2} \Delta \Sigma + \Delta G(Q^2) + L_q(Q^2) + L_g(Q^2)$$

[X. Ji, 1997]

- DIS $\rightarrow \Delta \Sigma \cong 0.25$
- RHIC + DIS $\rightarrow \Delta g \ll 1$
- $\rightarrow L_q$



D. de Florian et al., PRL 101 (2008) 072001

Unified View of Nucleon Structure

$W_p^u(x, k_T, \mathbf{r})$ Wigner distributions

6D Dist.

$d^3\mathbf{r}$

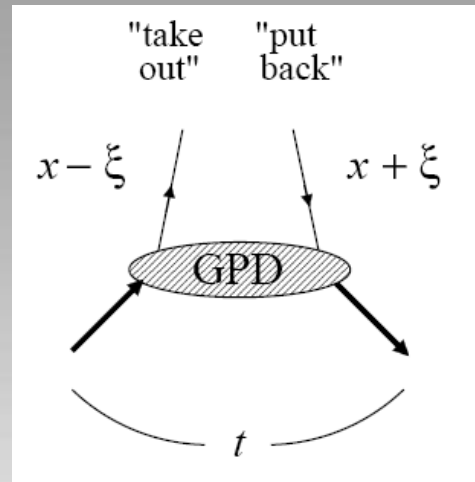
$d^2k_T dr_z$

TMD PDFs

$f_1^u(x, k_T), \dots, h_1^u(x, k_T)$

GPDs/IPDs

3D imaging



d^2k_T

d^2r_T

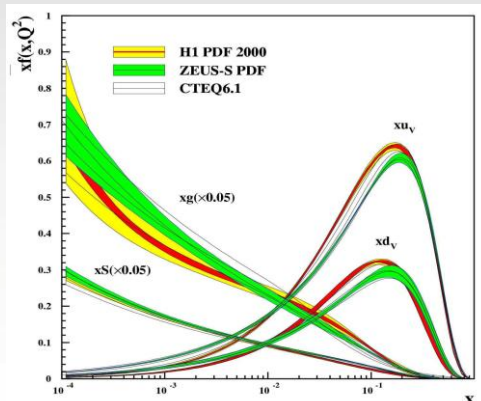
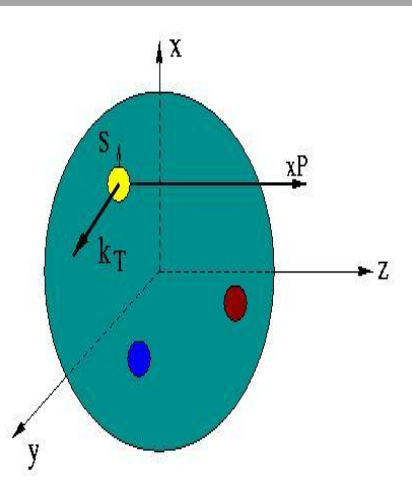
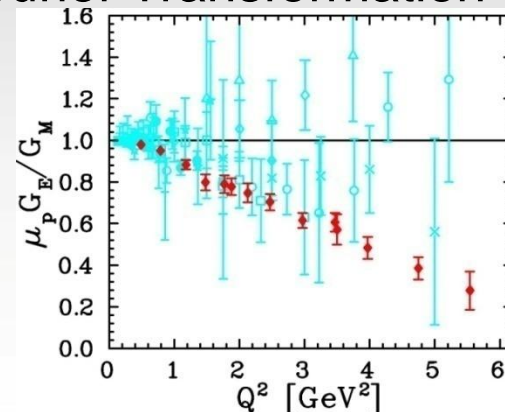
dx & Fourier Transformation

PDFs

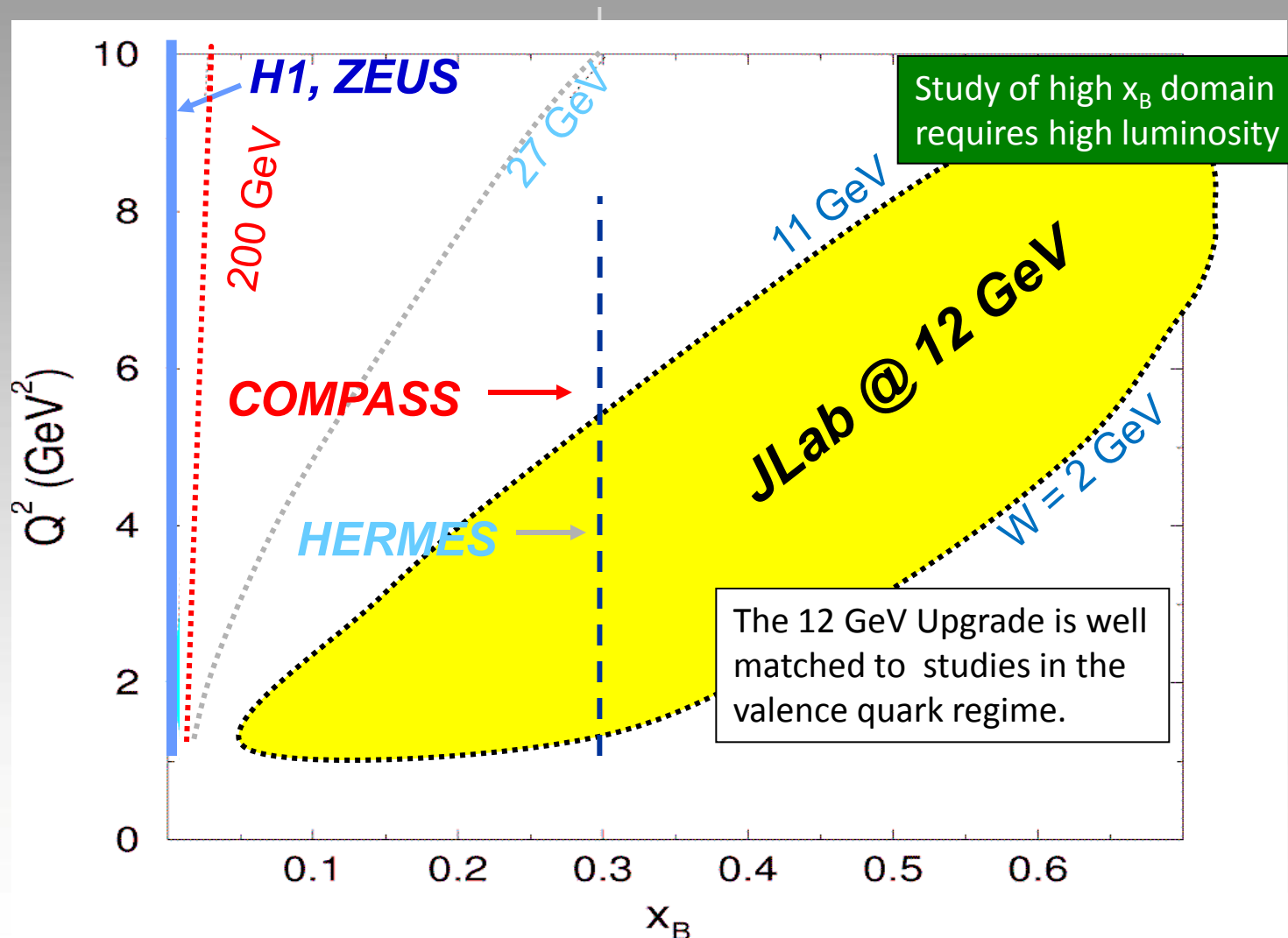
$f_1^u(x), \dots, h_1^u(x)$

1D

Form Factors
 $G_E(Q^2),$
 $G_M(Q^2)$



Kinematics Coverage of the 12 GeV Upgrade

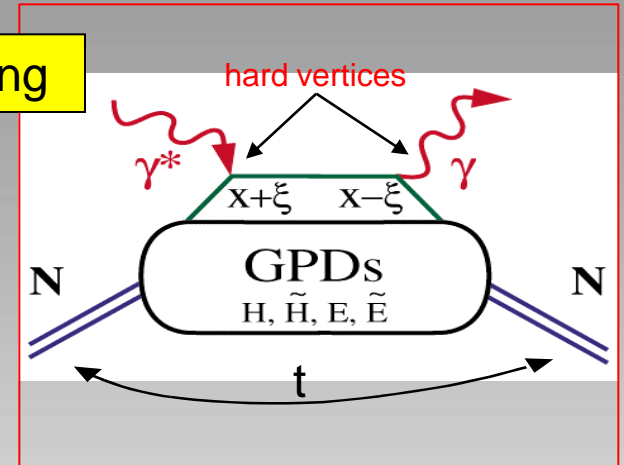


Extraction of GPD's

Cleanest process: Deeply Virtual Compton Scattering

$$A = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = \frac{\Delta\sigma}{2\sigma}$$

$$\xi = X_B / (2 - X_B)$$



Polarized beam, unpolarized target:

$$\Delta\sigma_{LU} \sim \sin\phi \{F_1 H + \xi(F_1 + F_2) \tilde{H} + kF_2 E\} d\phi$$

$$H(\xi, t)$$

Unpolarized beam, longitudinal target:

$$\Delta\sigma_{UL} \sim \sin\phi \{F_1 \tilde{H} + \xi(F_1 + F_2) (H + \xi/(1+\xi) E)\} d\phi$$

$$\tilde{H}(\xi, t)$$

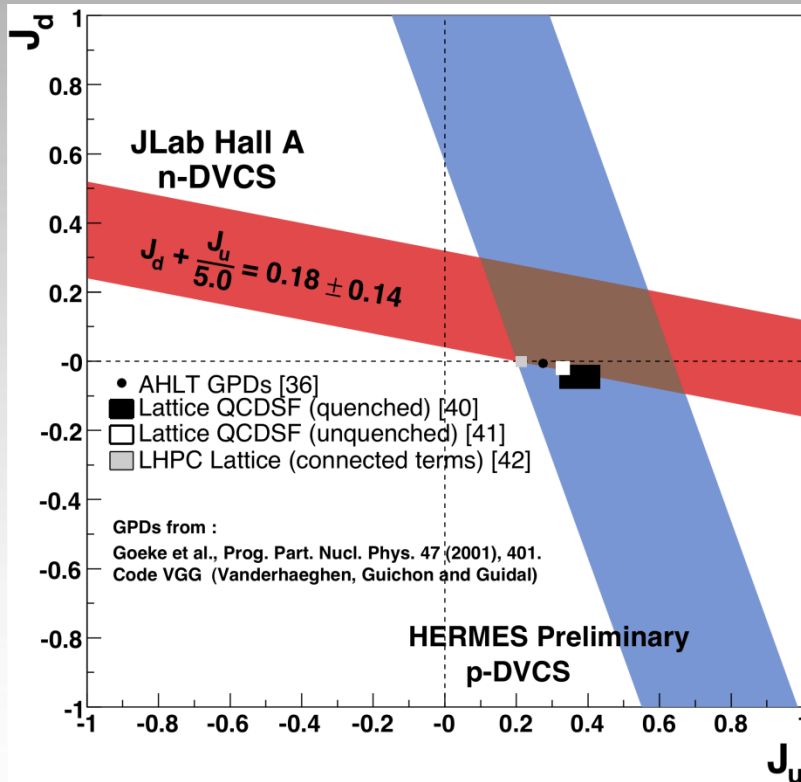
Unpolarized beam, transverse target:

$$\Delta\sigma_{UT} \sim \sin\phi \{k(F_2 H - F_1 E)\} d\phi$$

$$E(\xi, t)$$

Quark Angular Momentum

$$J^q(t) = \int_{-1}^{+1} dx x [H^q(x, \xi, t) + E^q(x, \xi, t)]$$

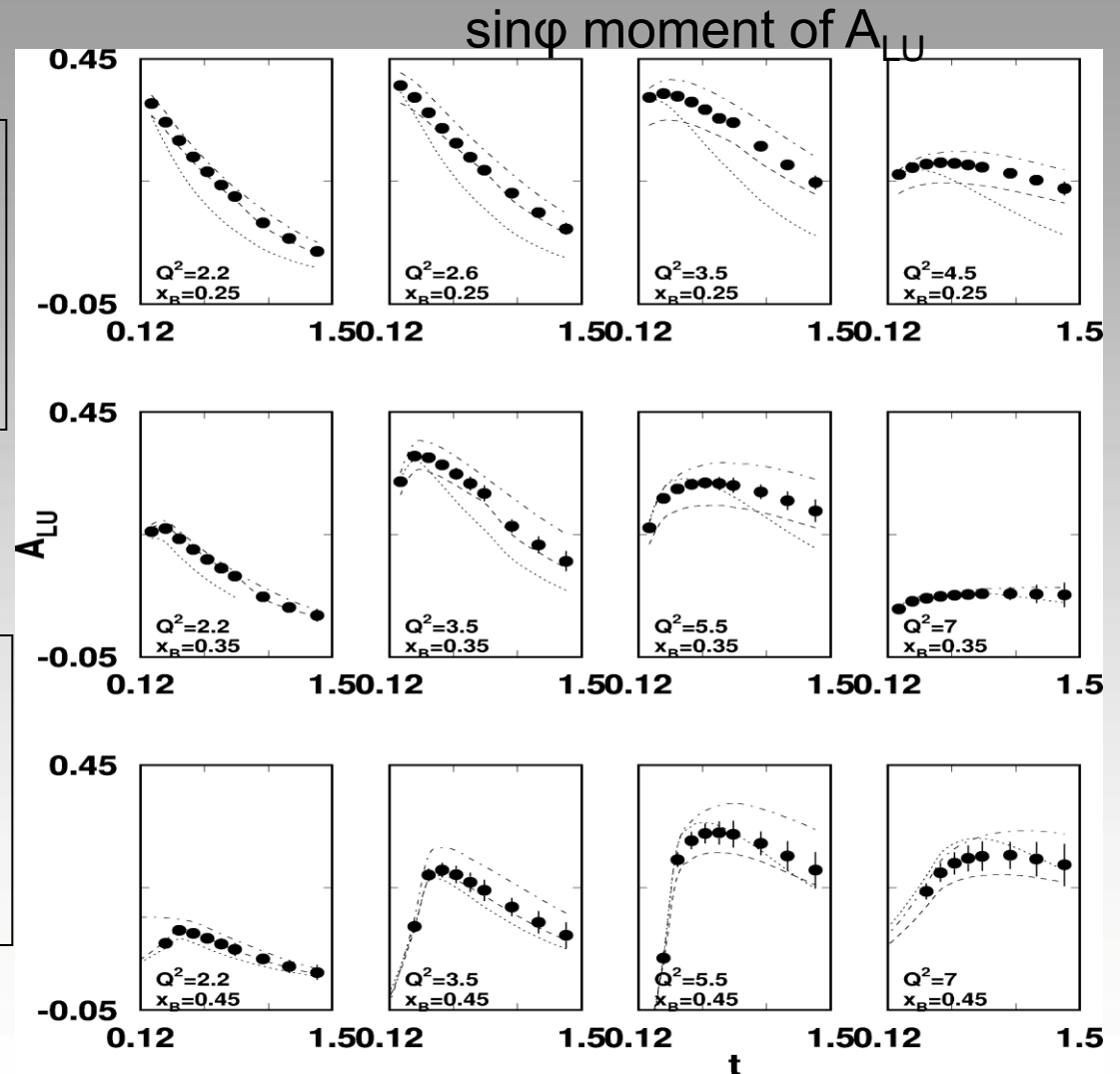


→ **Access to quark
orbital angular
momentum**

Experimental DVCS program **E12-06-119** was approved for the 12 GeV upgrade using polarized beam and polarized targets.

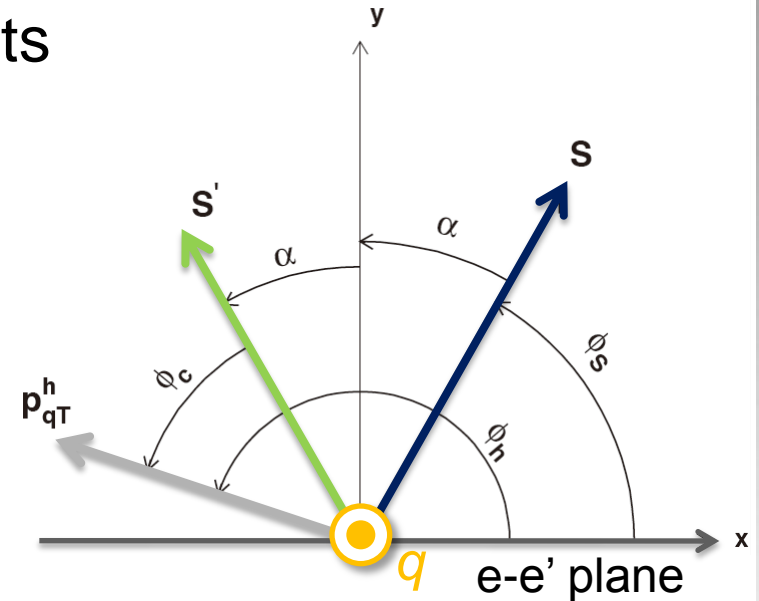
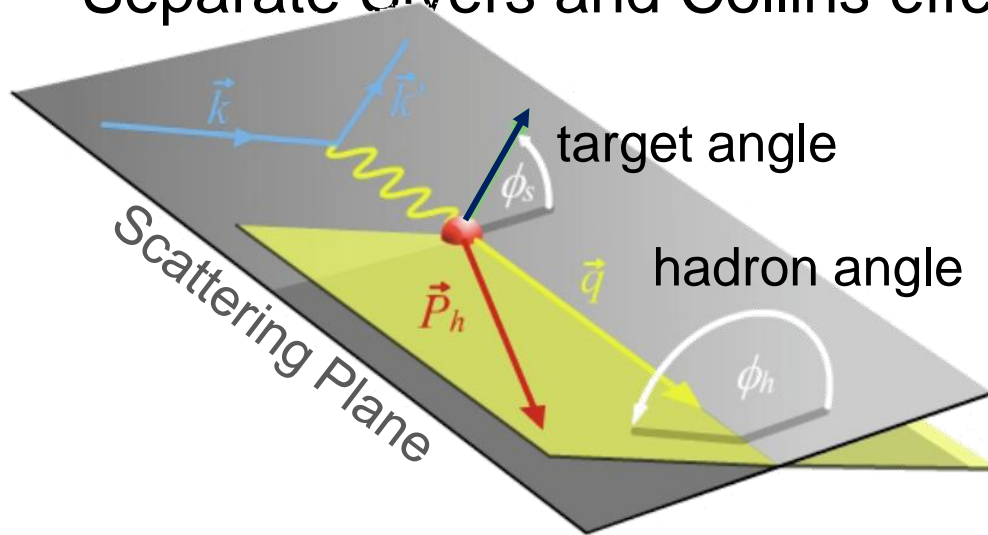


High luminosity and large acceptance allows wide coverage in $Q^2 < 8 \text{ GeV}^2$, $x_B < 0.65$, and $t < 1.5 \text{ GeV}^2$



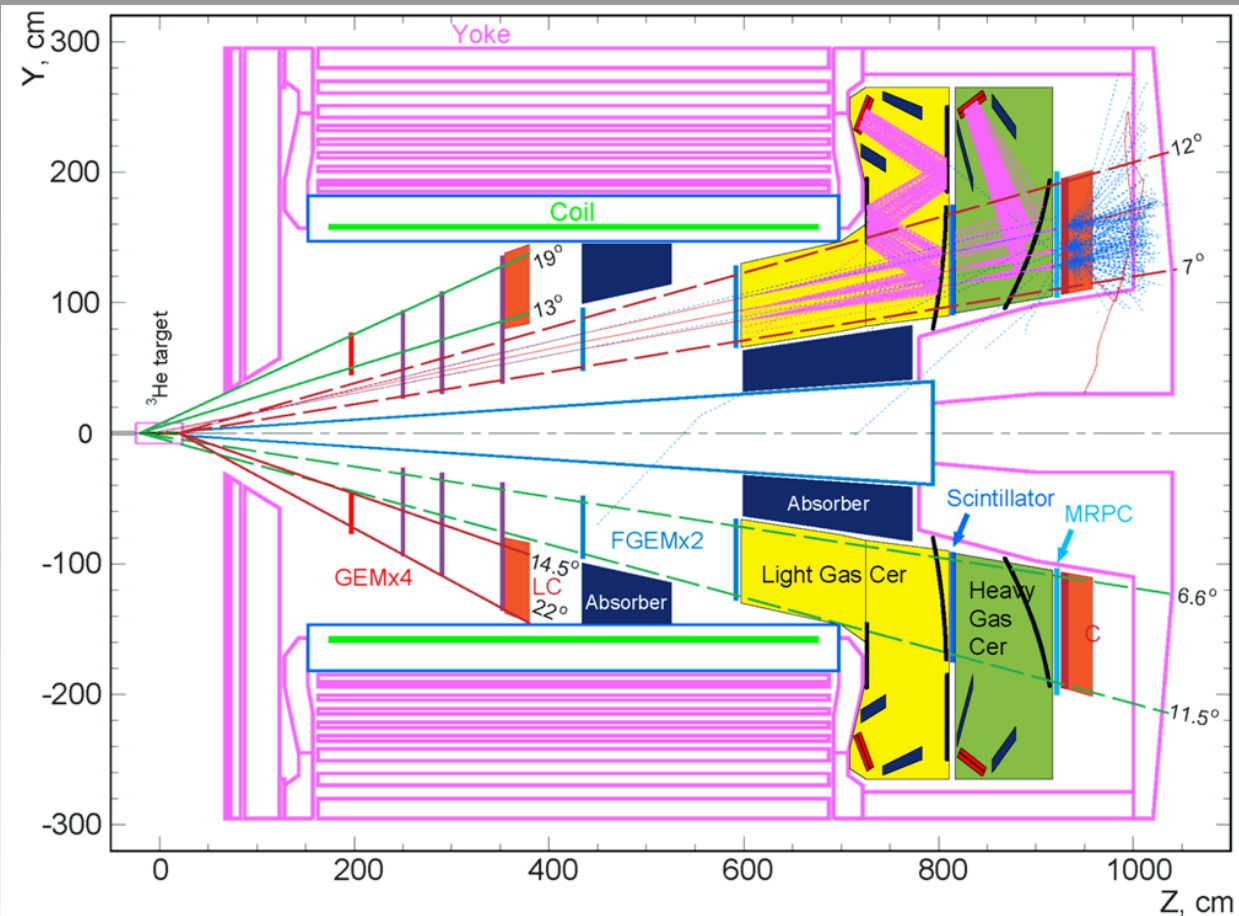
SIDIS Electroproduction of Pions

- Separate Sivers and Collins effects



- Sivers** angle, effect in distribution function:
 - $(\phi_h - \phi_s)$ = angle of hadron relative to *initial* quark spin
- Collins** angle, effect in fragmentation function:
 - $(\phi_h + \phi_s) = \pi + (\phi_h - \phi_{s'})$ = angle of hadron relative to *final* quark spin

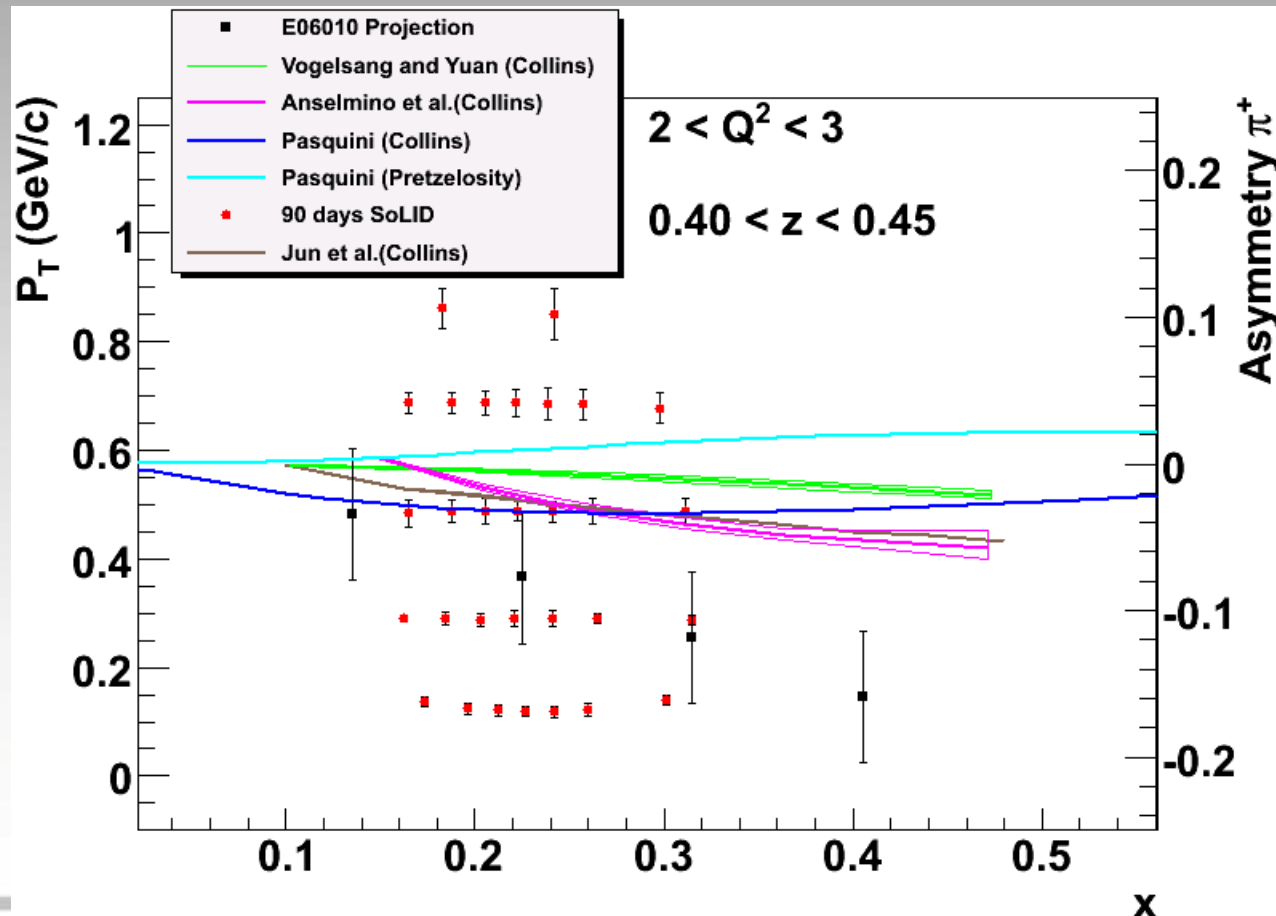
A Solenoid Spectrometer for SIDIS



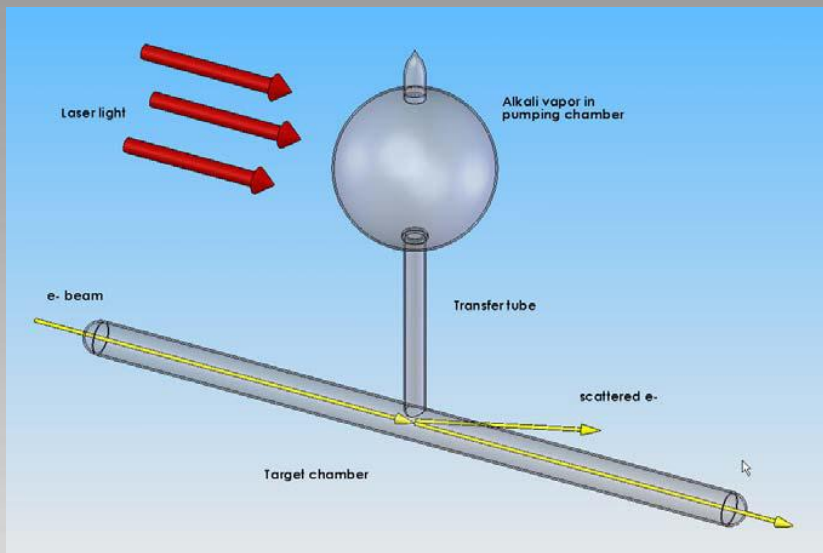
SIDIS SSAs depend on 4 variables (x , Q^2 , z and P_T)
Large angular coverage and precision measurement of asymmetries in 4-D phase space are essential.

Hall A Transversity Projected Data

- Total 1400 bins in x , Q^2 , P_T and z for 11/8.8 GeV beam.
- z ranges from 0.3 ~ 0.7, only **one z and Q^2 bin** of 11/8.8 GeV is shown here. π^+ projections are shown, similar to the π^- .

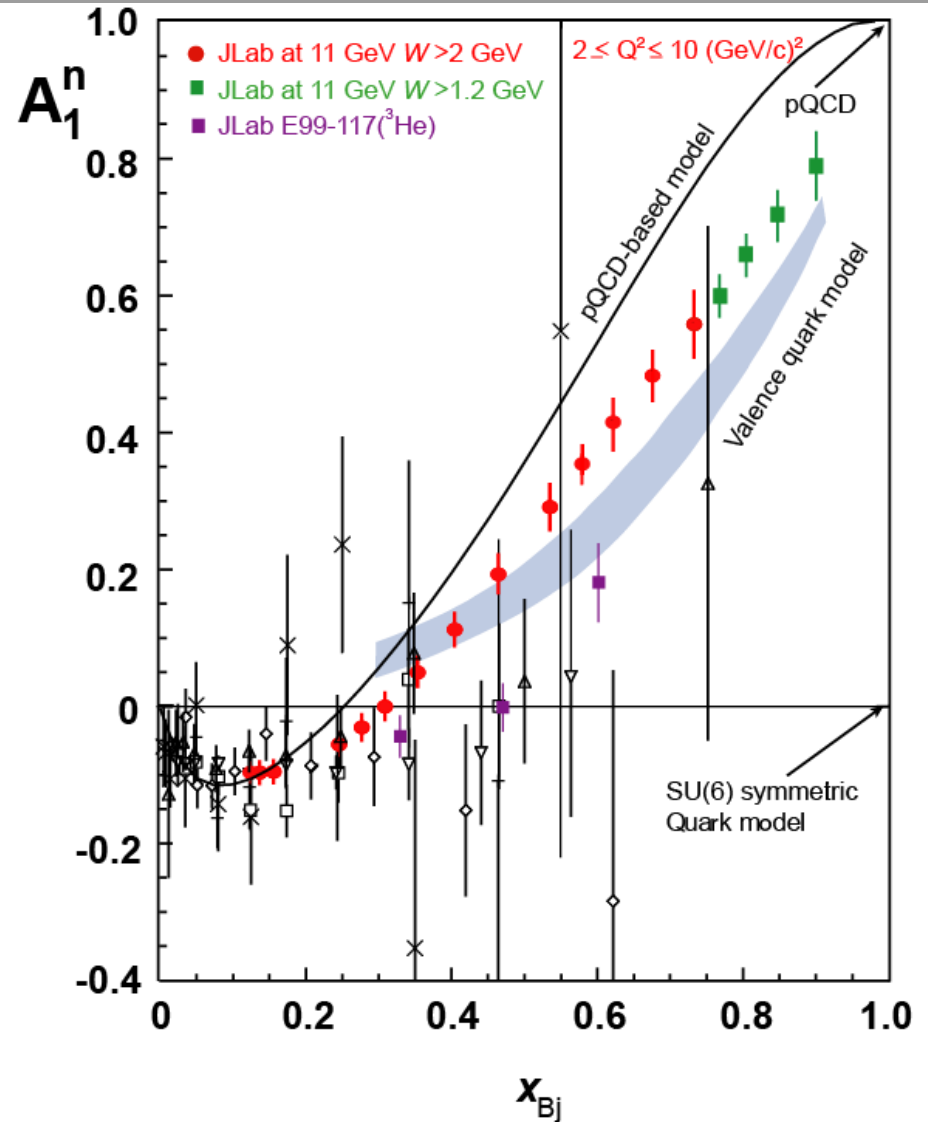


High x spin dependent DIS

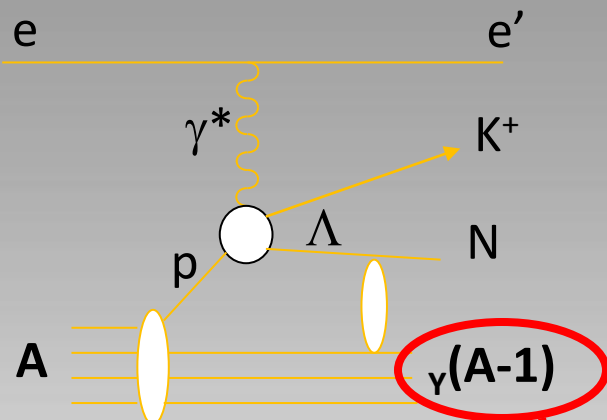


REQUIRES:

- High beam polarization
- High electron current
- High target polarization
- Large solid angle spectrometers

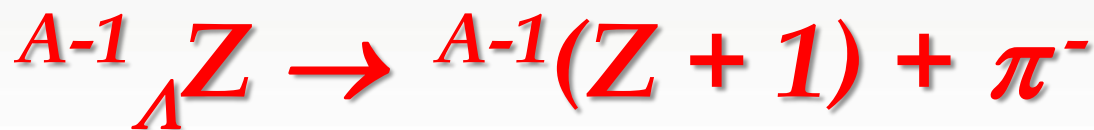
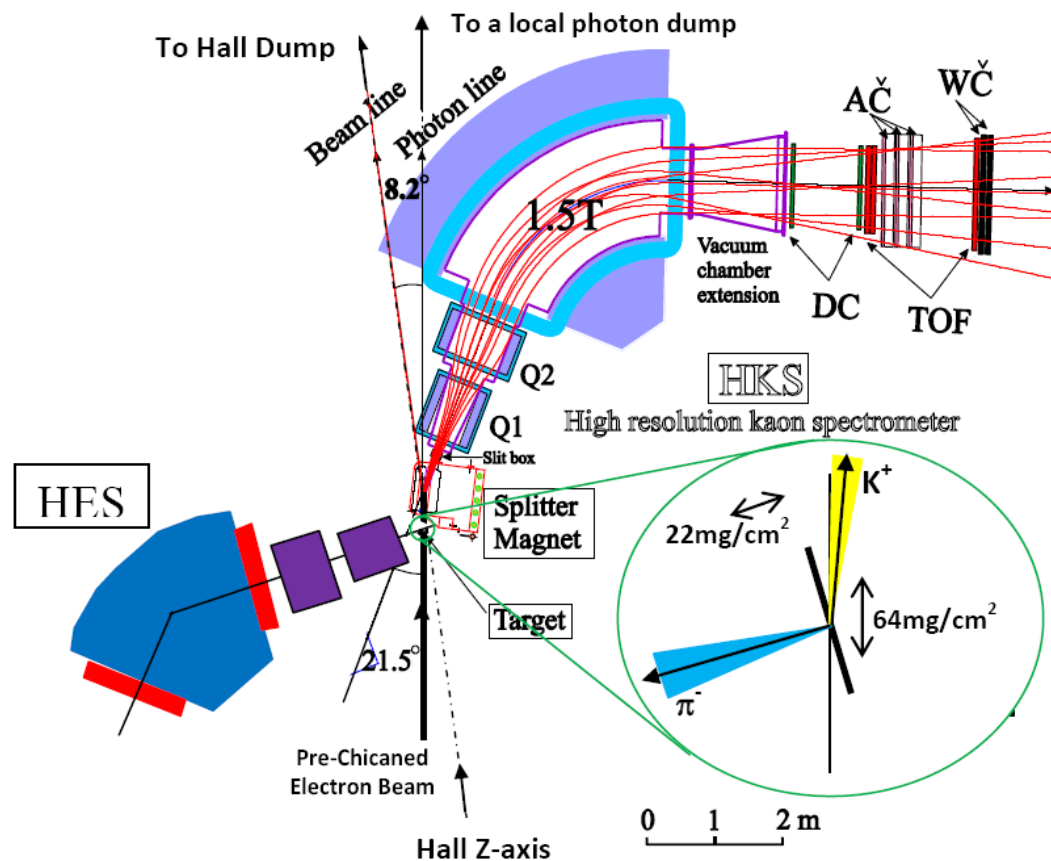


Hypernuclear Physics

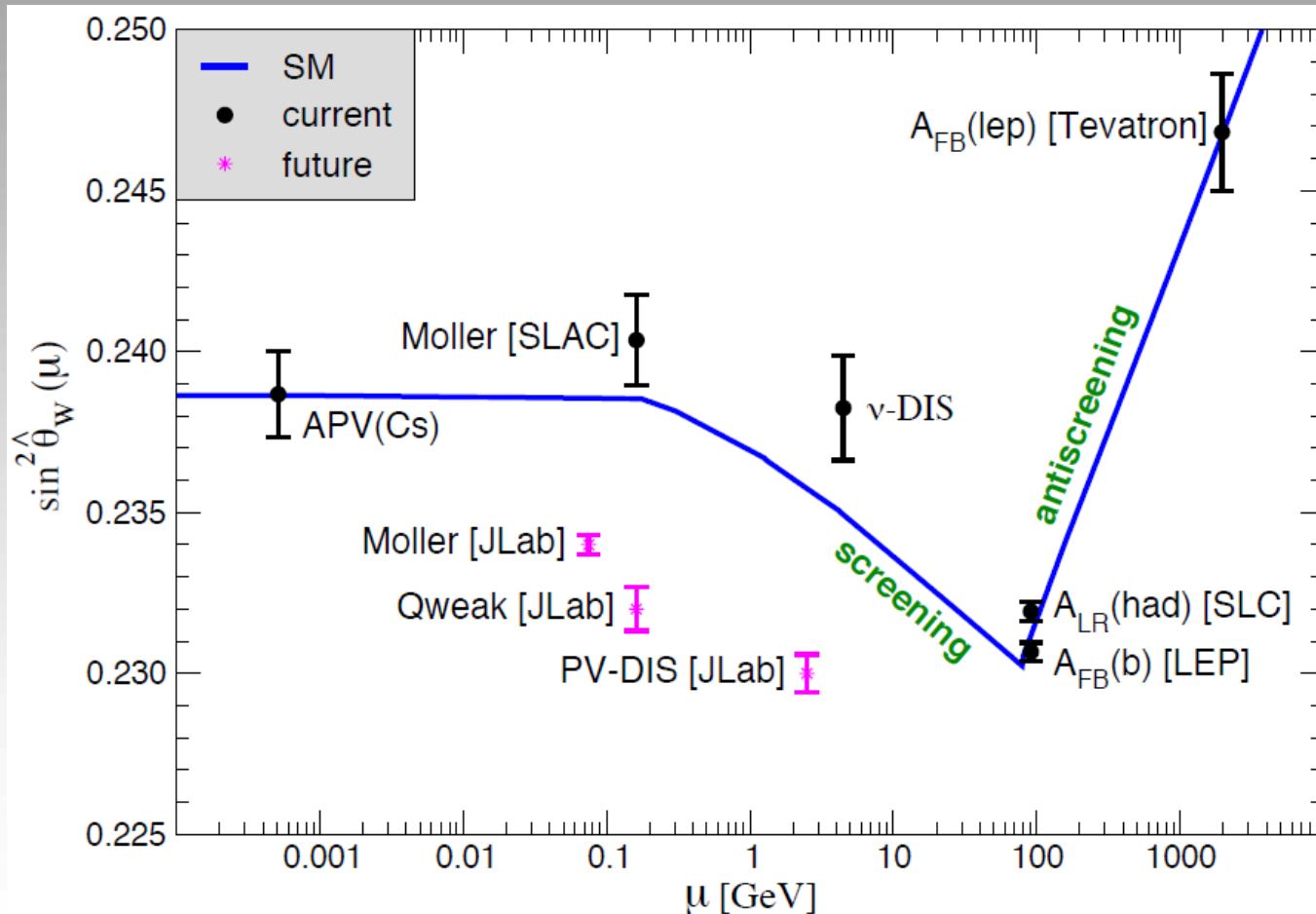


Measure 2-body decay

- High resolution
- High yield



Future PV Program



12 GeV Construction

- Accelerator: Major Procurements (>\$500K) nearly complete
 - beam transport magnets ; helium refrigerator ; power supplies; etc...

4m Dipole Magnet at JLab

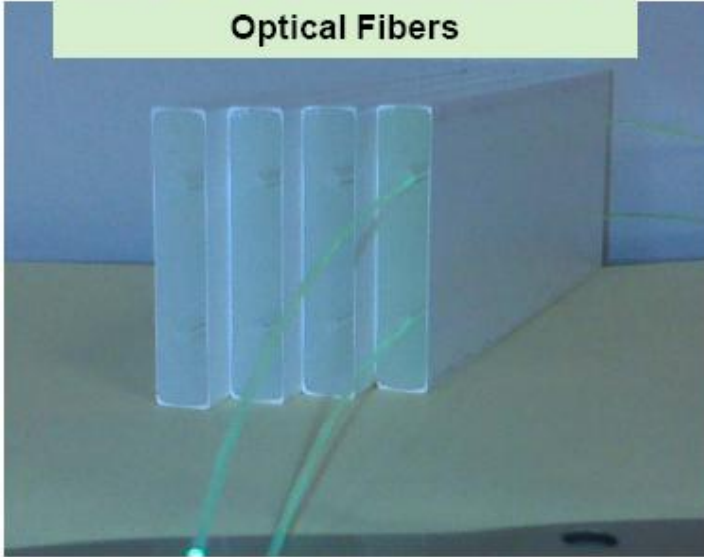


Beam Transport Quadrupole Magnets (50 of 114 total) at JLab

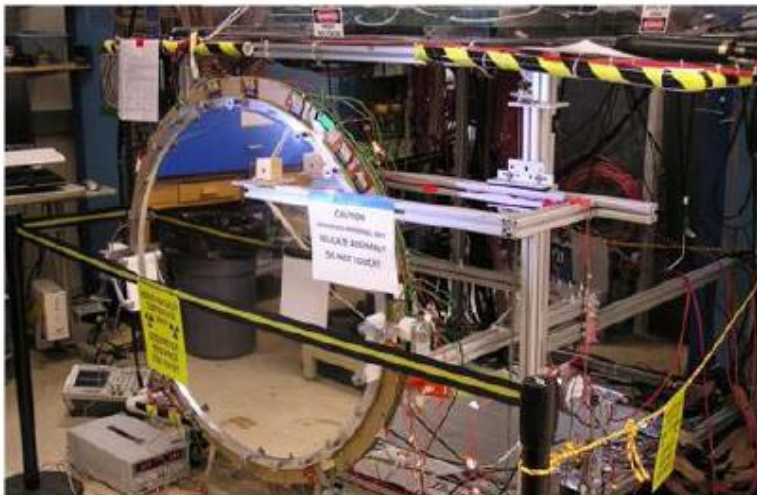
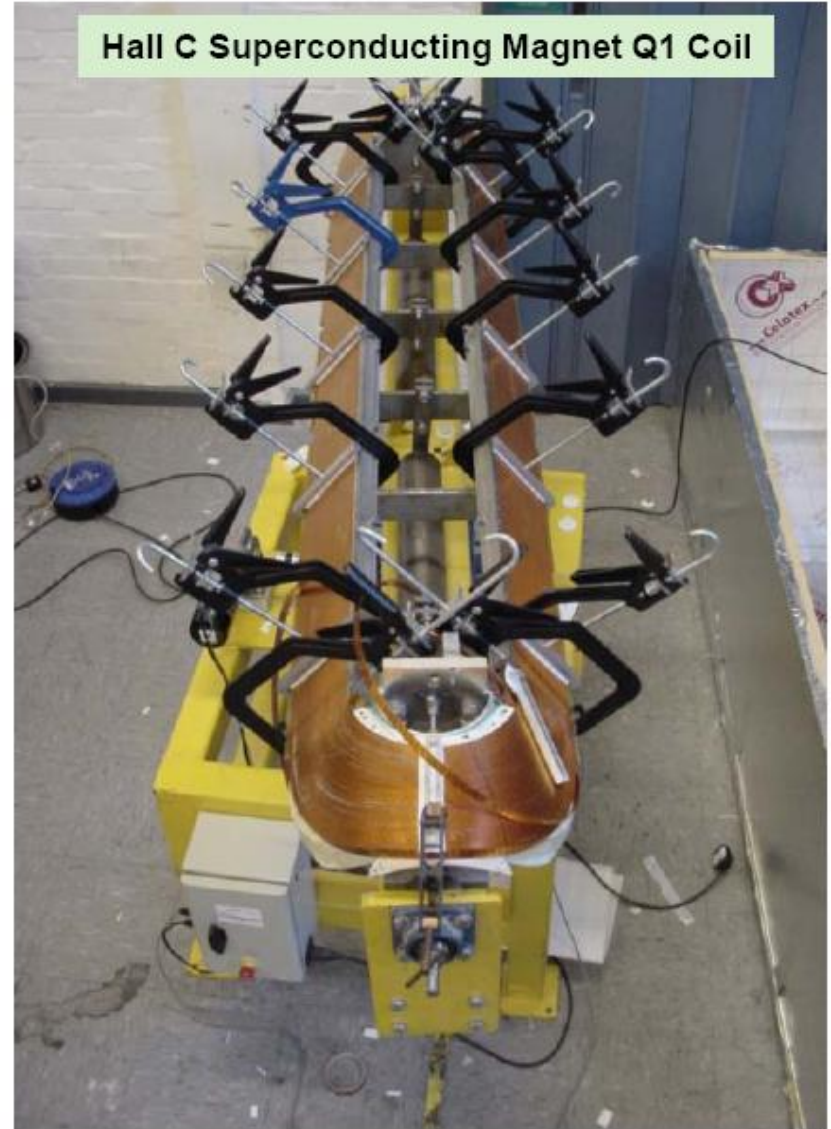


Physics Equipment Construction

Hall B – PCAL Test Extrusions w/
Optical Fibers



Hall C Superconducting Magnet Q1 Coil



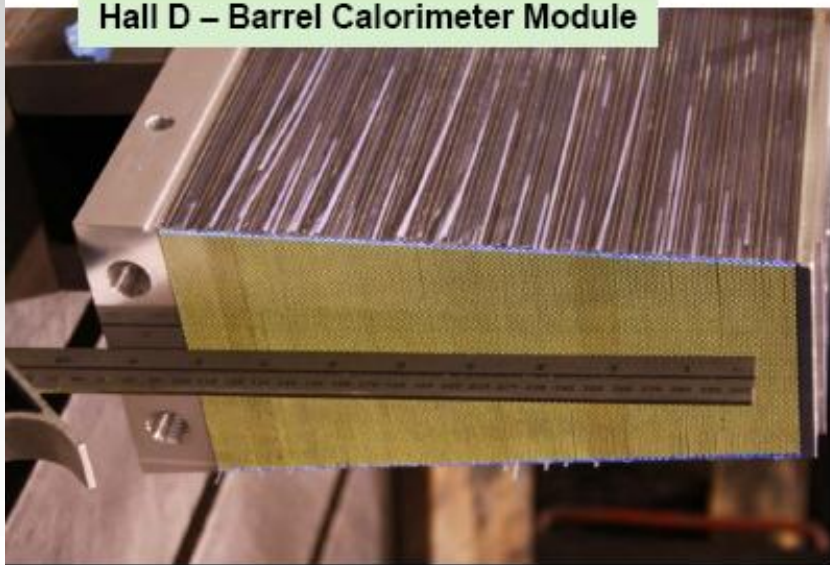
Hall D – Forward Drift Chamber in Test Stand

Physics Equipment Construction

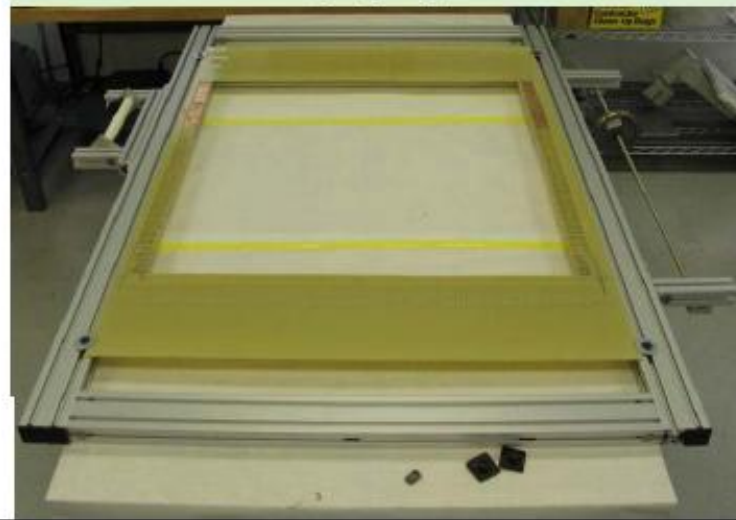
Hall B – Region II Drift Chamber Frame Assembly



Hall D – Barrel Calorimeter Module



Hall C – Wire Stringing Jig for Drift Chamber



Excavation – Sept 2009



Nor'easter – Nov 2009



Civil Construction: Hall D Complex 2009-2010

Floor Slab – Jan 2010



Walls - June 2010



Jlab 12 GeV Upgrade

An exciting scientific opportunity

- Explore the physical origins of quark confinement (GlueX)
- New access to the spin and flavor structure of the proton and neutron
- Reveal the quark/gluon structure of nuclei
- Probe potential new physics through high precision tests of the Standard Model

Strong User community involvement

- NSF MRI and NSERC funding to universities for detector elements
- Strong international collaborations
- 32 PAC-approved experiments

Accel-Civil-Physics scope leverages the existing facility

Construction is well underway !

- Accelerator nearing completion on major procurements; hardware arriving
- Detector assembly ramping up
- Civil construction on track

New Proposals and collaborations are welcome