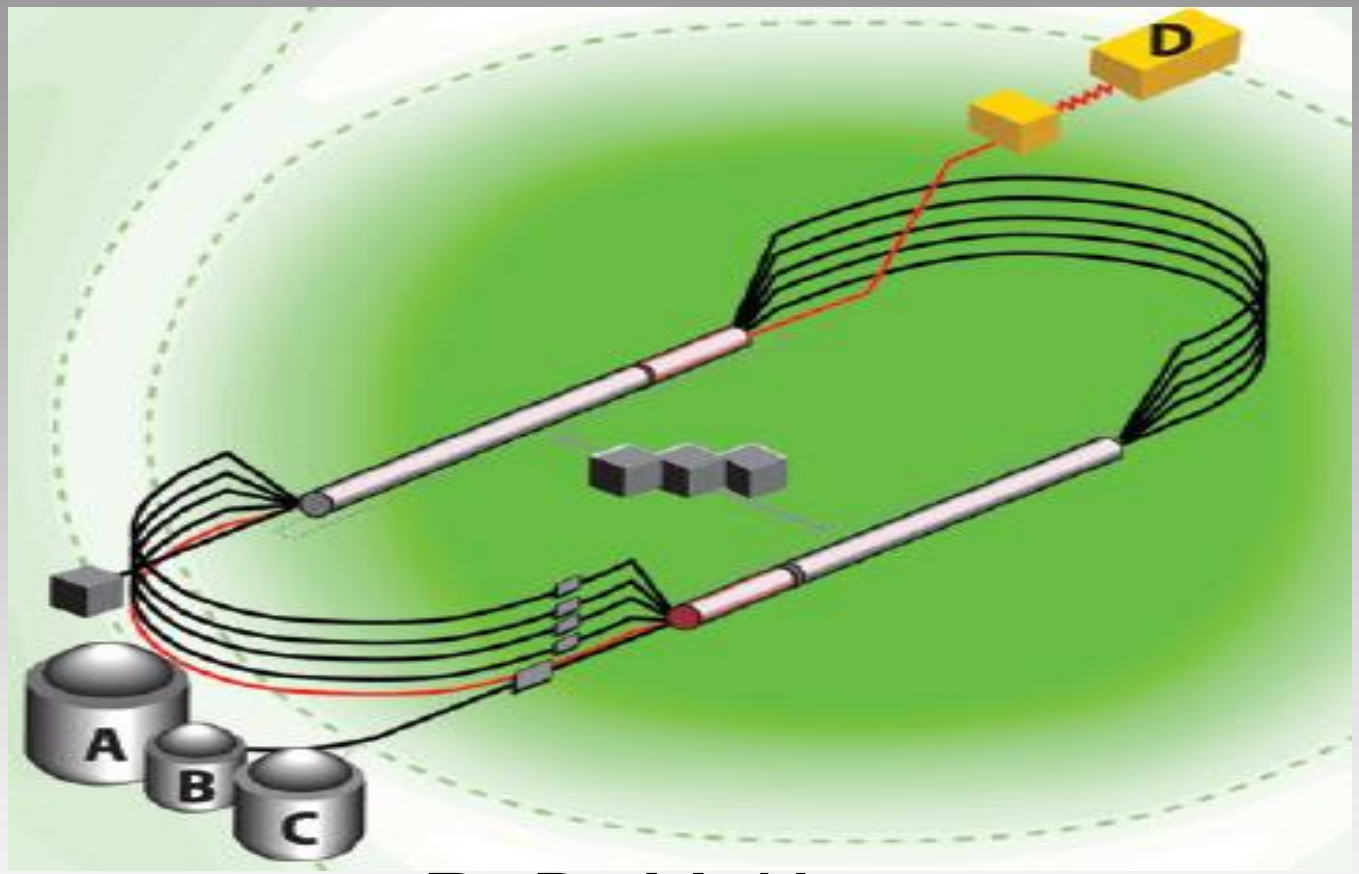
The Jlab 12 GeV Upgrade



R. D. McKeown

Jefferson Lab

College of William and Mary

12 GeV Science Program

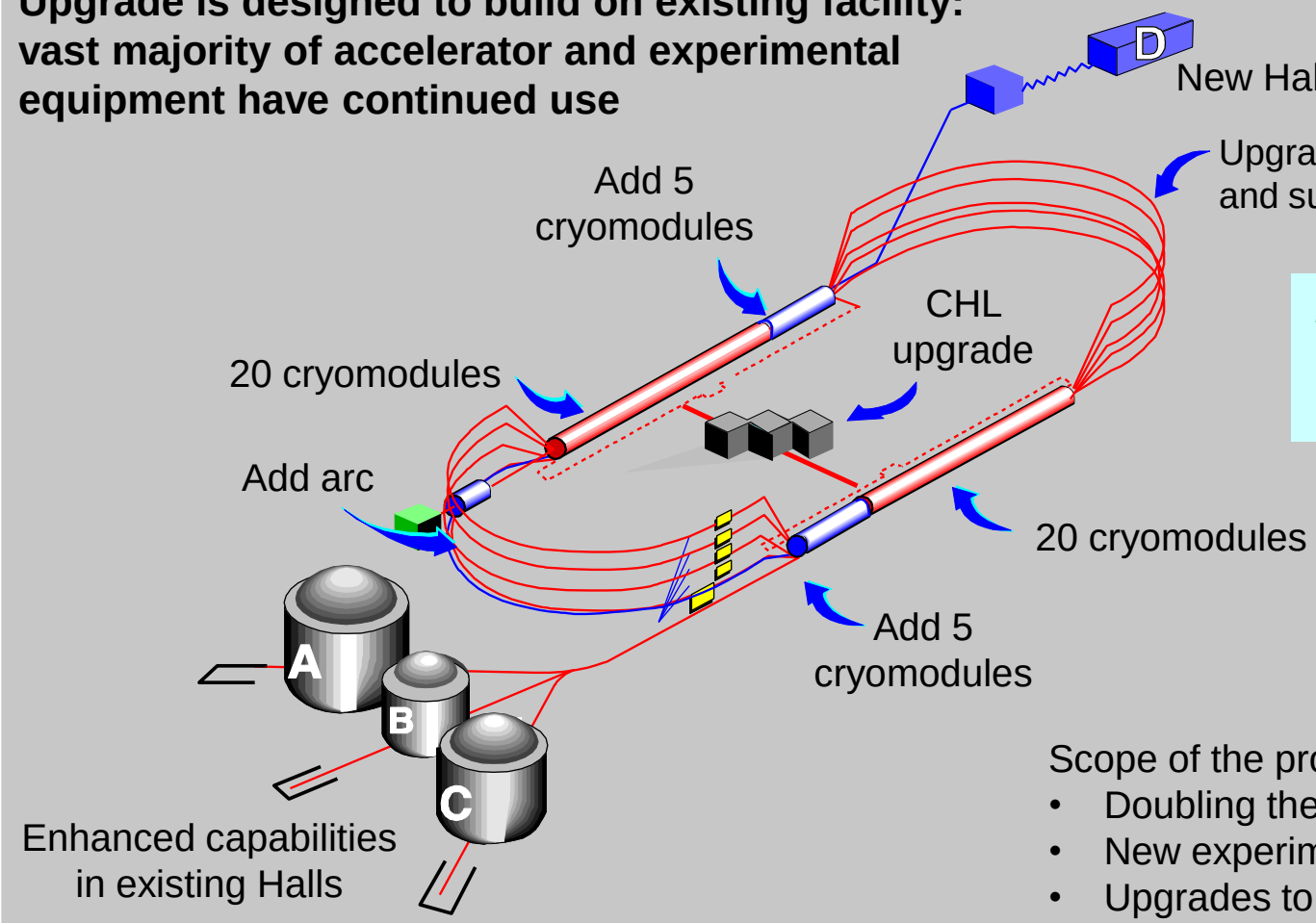
- The physical origins of quark confinement (GlueX, meson and baryon spectroscopy)
- The spin and flavor structure of the proton and neutron (PDF's, GPD's, TMD's…)
- The quark structure of nuclei
- Probe potential new physics through high precision tests of the Standard Model

- 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

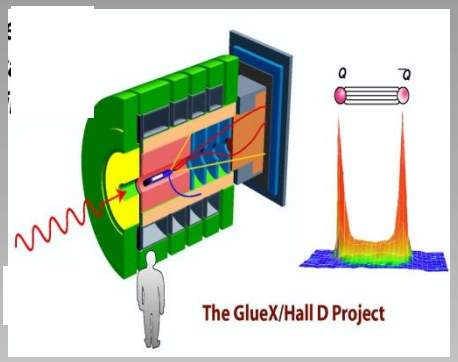


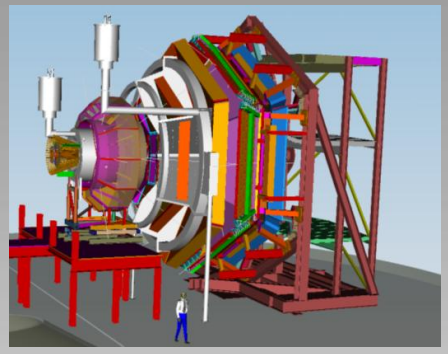
Maintain capability to deliver lower pass beam energies: 2.2, 4.4, 6.6….

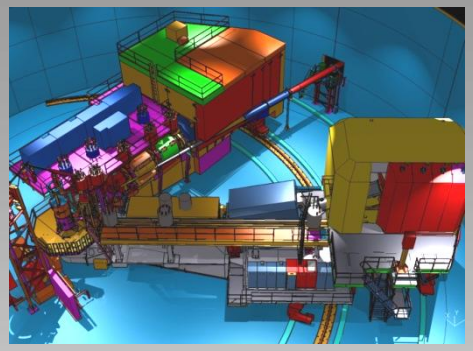
Scope of the project includes:

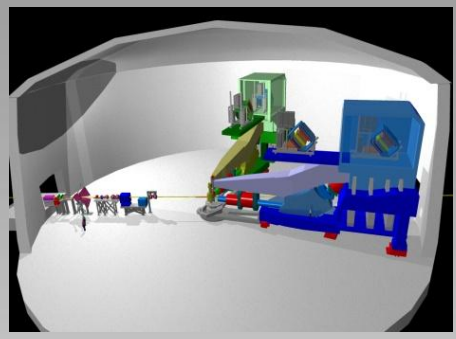
- Doubling the accelerator beam energy
- New experimental Hall and beamline
- Upgrades to existing Experimental Halls

Overview of Technical Performance Requirements





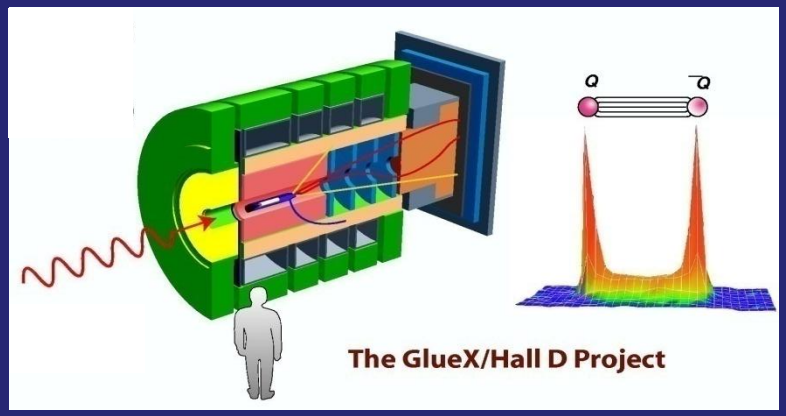


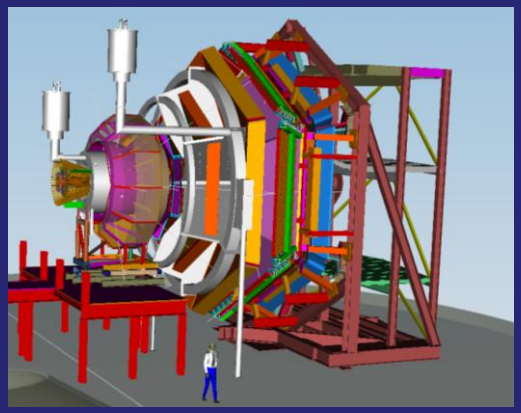


Hall D	Hall B	Hall C	Hall A
excellent hermeticity	luminosity 10×10^{34}	energy reach	installation space
polarized photons	hermeticity	precision	
E_γ~8.5-9 GeV	11 GeV beamline		
10^8 photons/s	target flexibility		
good momentum/angle resolution		excellent momentum resolution	
high multiplicity reconstruction		luminosity up to 10^{38}	
particle ID			

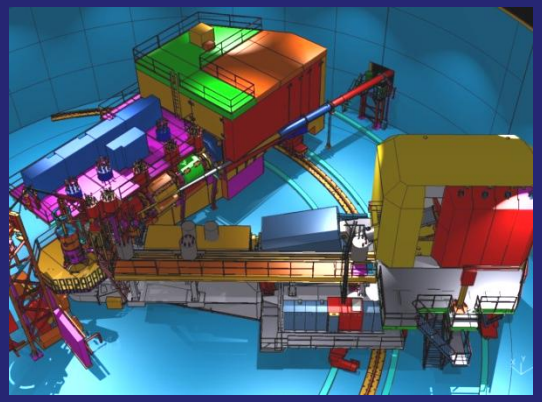
12 GeV Scientific Capabilities

Hall D – exploring origin of confinement by studying exotic mesons

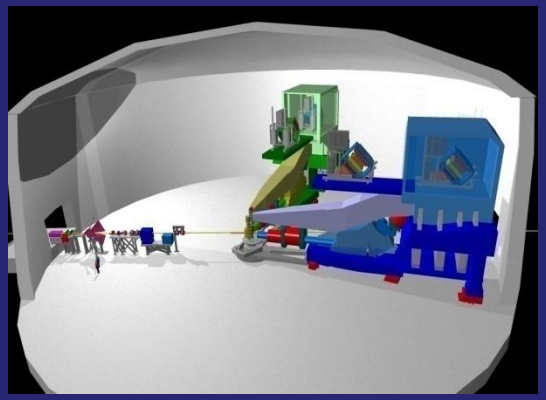




Hall B – understanding nucleon structure via generalized parton distributions

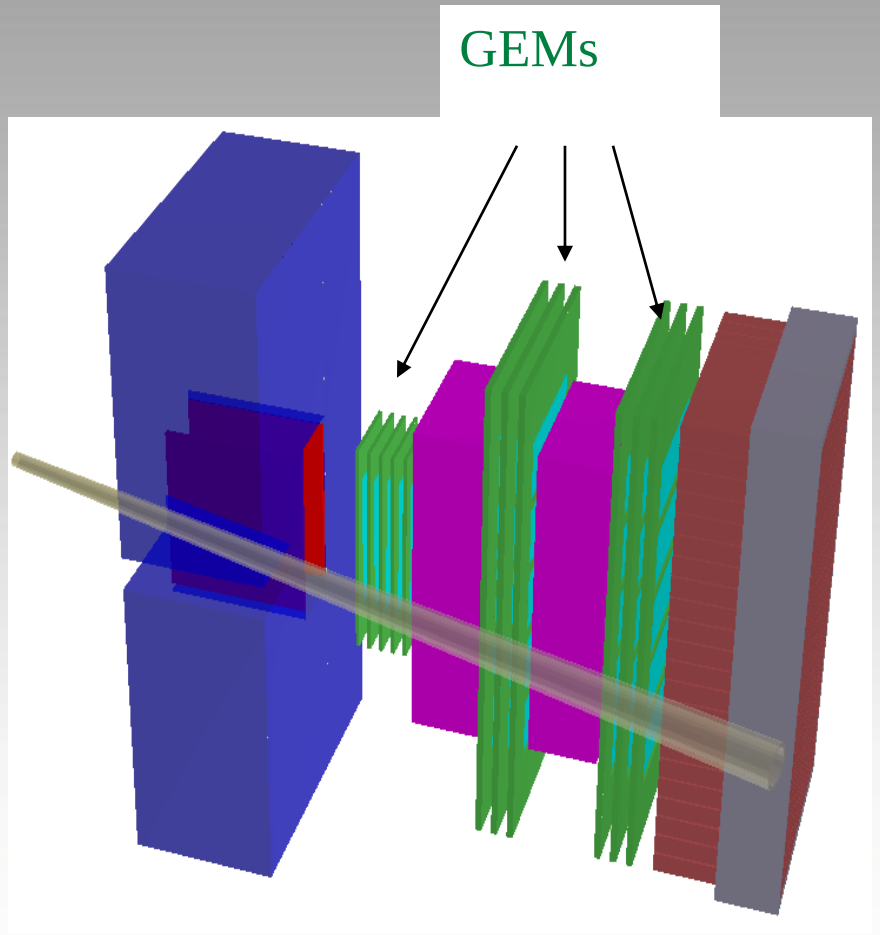


Hall C – precision determination of valence quark properties in nucleons and nuclei



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

Hall A

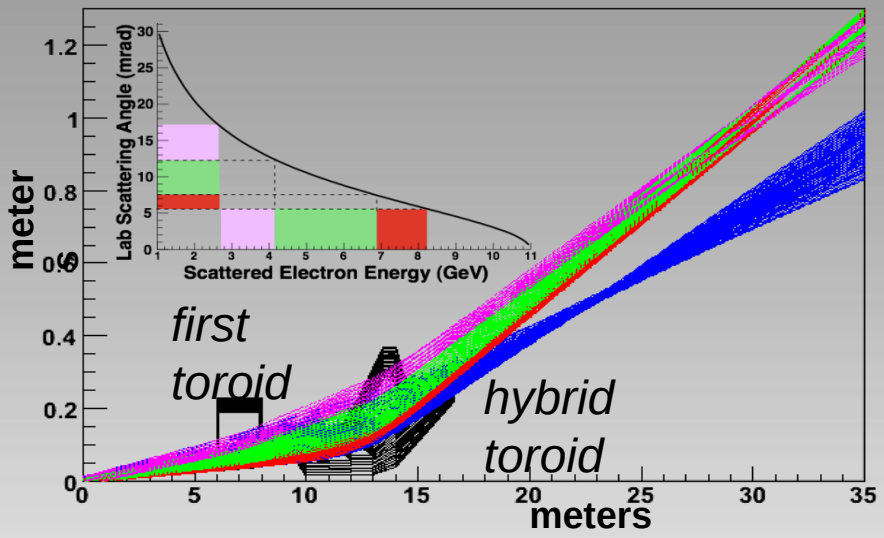


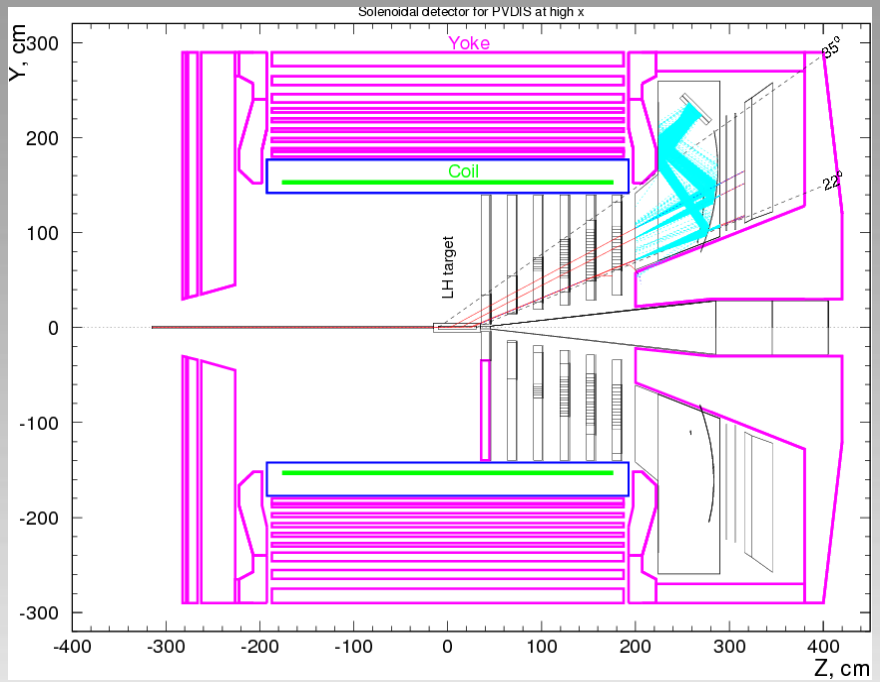
Super Bigbite project:

- large dipole magnet
- GEM trackers (~100,000 channels)
- hadron and EM calorimeter
- Trigger and DAQ

operating in open geometry at a luminosity of 10^{38} $cm^{-2}s^{-1}$

Hall A (Additional Equipment Required)





PV Moller Scattering:

- Precision test of SM
- Custom Toroidal Spectrometer
- 5kw LH Target

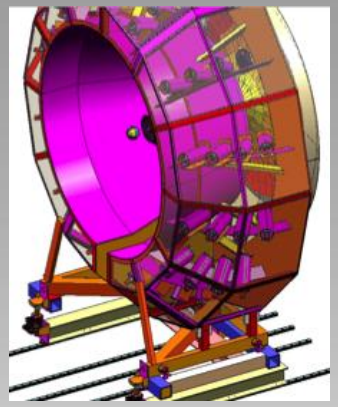
SOLID:

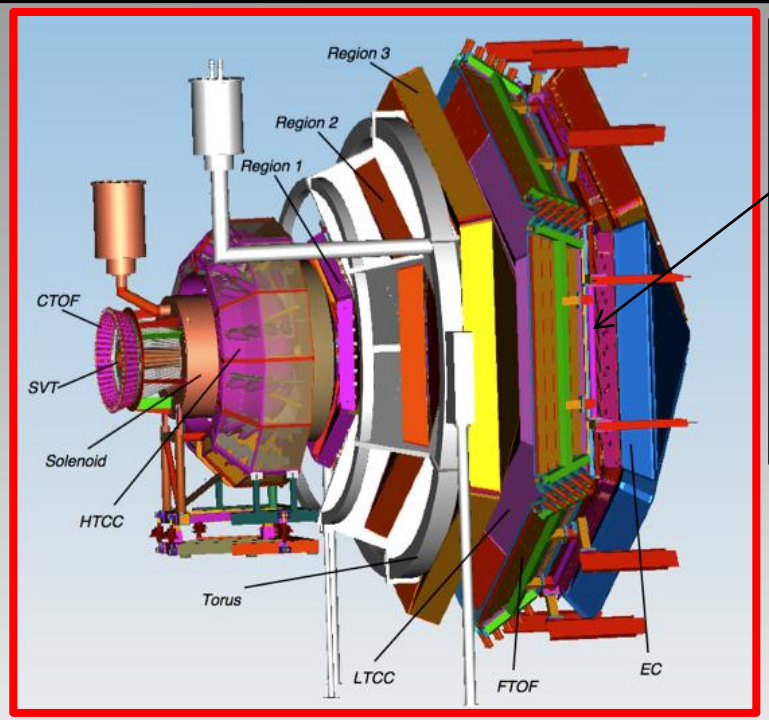
- High Luminosity on LD2 and LH2
- Better than 1% errors for small bins
- Large Q^2 coverage
- x-range 0.25-0.75
- $W^2 > 4$ GeV^2

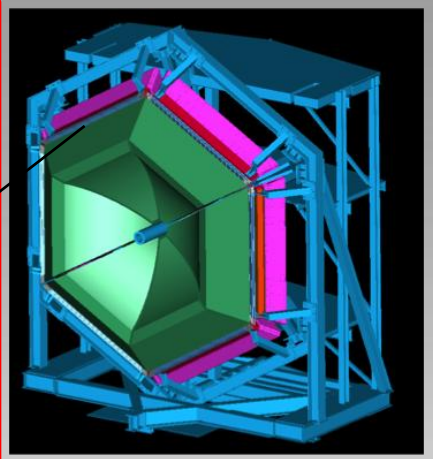
Hall B

CLAS12

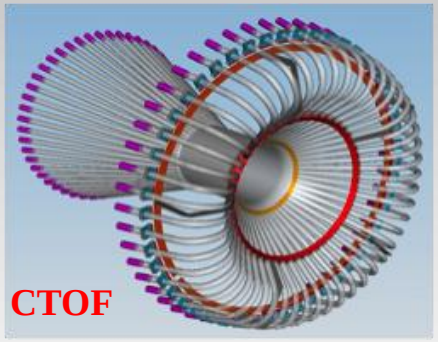
HTCC



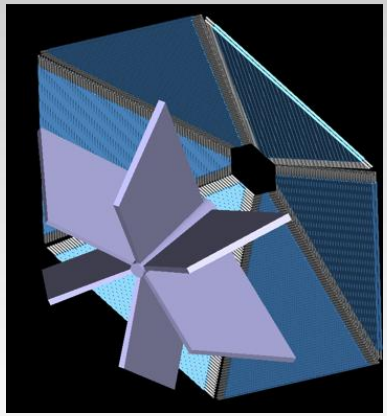




PCAL

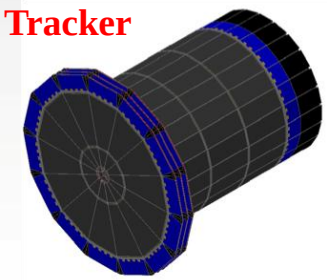


CTOF

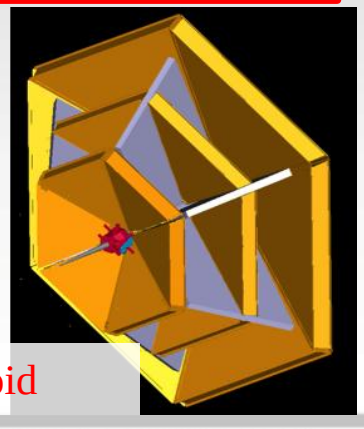


FTOF

Silicon Tracker



Solenoid &Toroid



Drift Chambers R1, R2, R3

Hall C

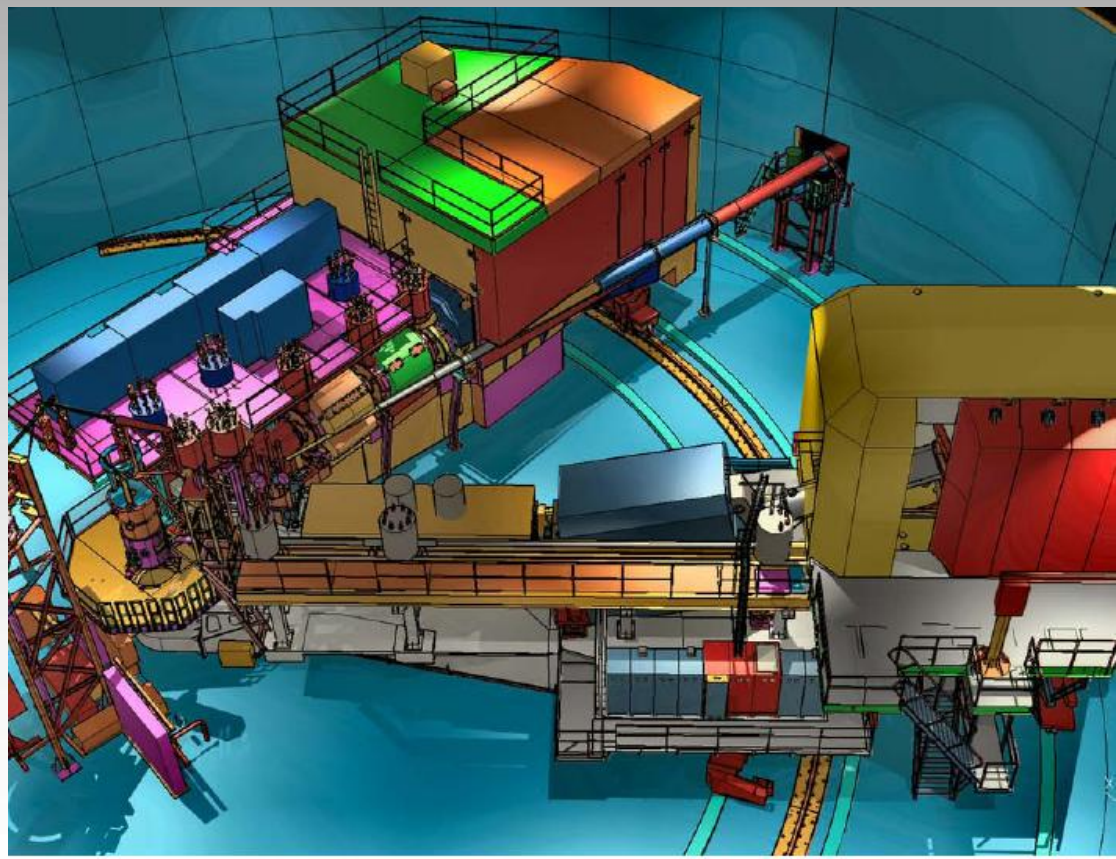
- **New Super High Momentum Spectrometer (SHMS)**

Horiz. Bender, 3 Quads + Dipole
P →11 GeV/c
dP/P 0.5 –1.0x10^{-3}
Acceptance: 5msr, 30%
5.5°< θ< 40°

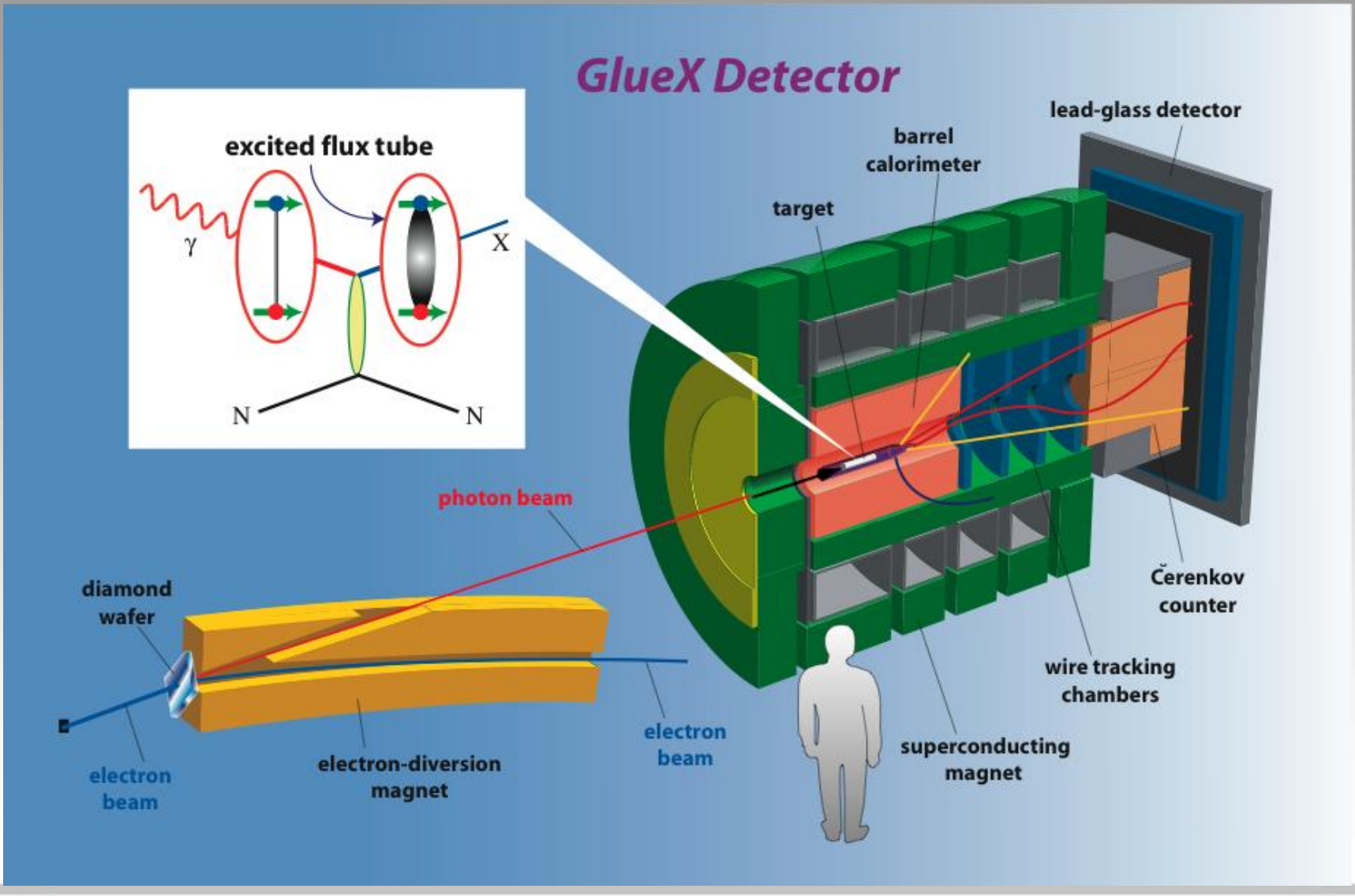
- **High Momentum Spectrometer (HMS)**

P →7.5 GeV/c
ΔP/P = 0.5 –1.0x10^{-3}
Acceptance: 6.5msr, 18%
10.5°< θ< 90°

- **Minimum opening angle: 17°**



Hall D


GlueX Detector
excited flux tube
γ
X
N
N
lead-glass detector
barrel calorimeter
target
photon beam
diamond wafer
Čerenkov counter
wire tracking chambers
electron beam
electron-diversion magnet
electron beam
superconducting magnet

Quantum Numbers of Hybrid Mesons

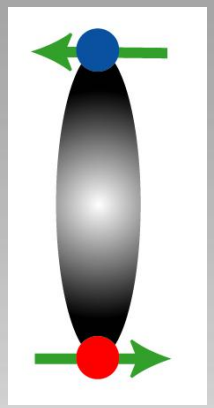
Quarks ⊕ **Excited Flux Tube** → **Hybrid Meson**

$S = 0$

$L = 0$

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

like π, K



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

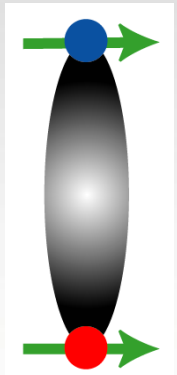
$$J^{PC} = \begin{cases} 1^{--} \\ 1^{++} \end{cases}$$

$S = 1$

$L = 0$

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

like γ, ρ



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

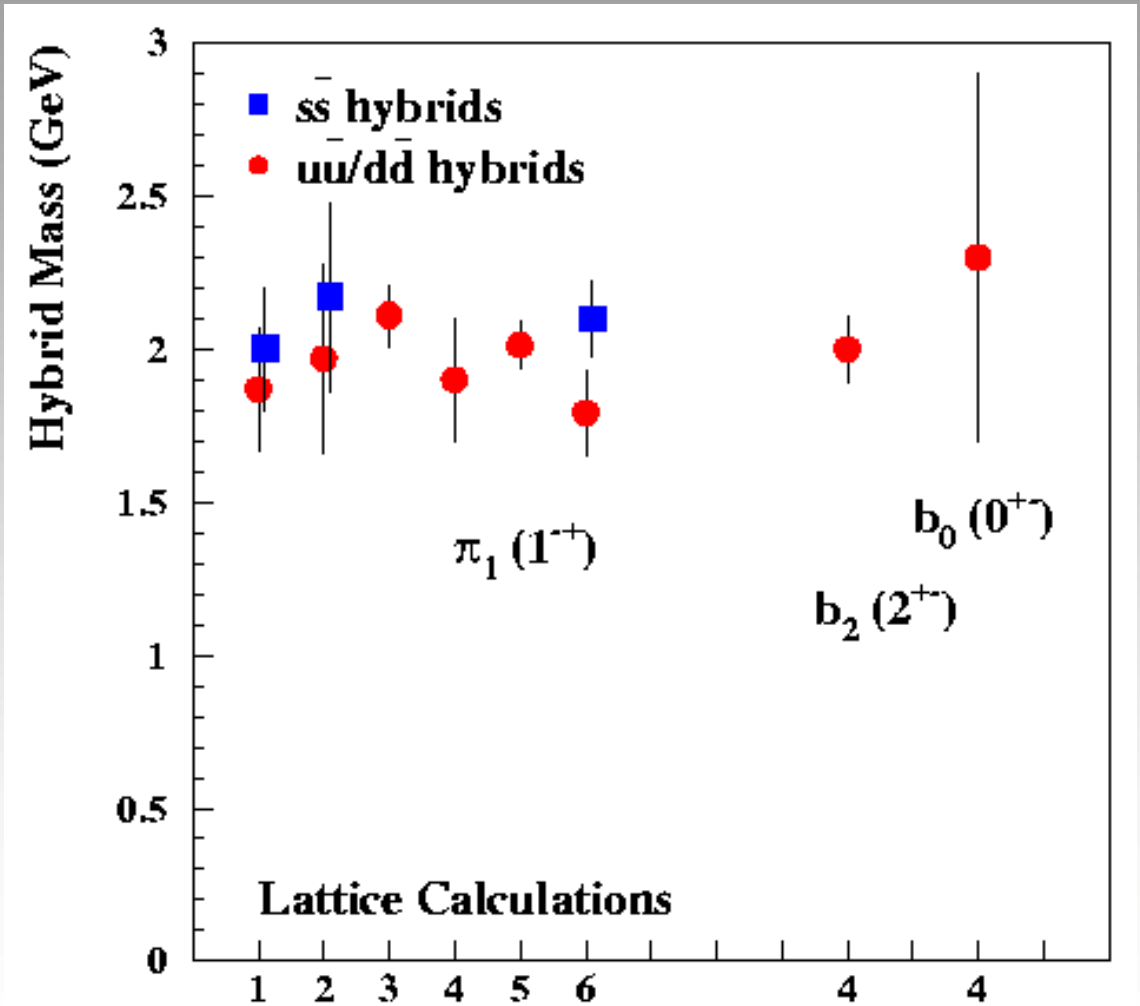
Exotic

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

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



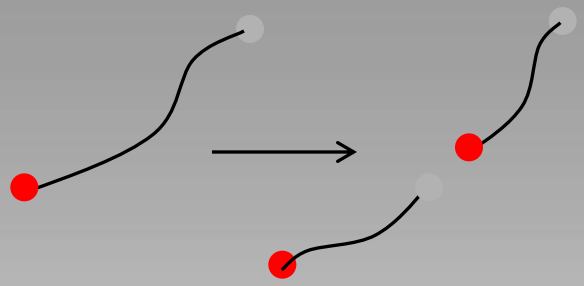
Lattice

1^{-+} 1.9 GeV

2^{+-} 2.1 GeV

0^{+-} 2.3 GeV

Decay of Exotic Mesons



Possible daughters:

a,b,h,f,...

$\pi,\rho,\eta,\omega,...$

The angular momentum in the flux tube stays in one of the daughter mesons (L=1) and (L=0) meson, e.g:

flux tube L=1 quark L=1

Example: $\pi_1 \rightarrow b_1\pi$

$\hookrightarrow \omega\pi \rightarrow (3\pi)\pi$

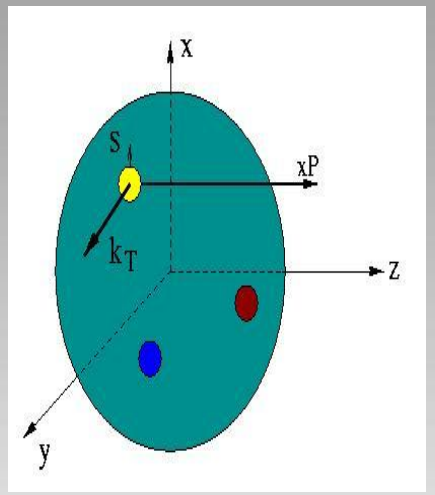
or $\omega\pi \rightarrow (\pi\gamma)\pi$

simple decay modes such as $\eta\pi,\rho\pi$, ... are suppressed.

Unified View of Nucleon Structure

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

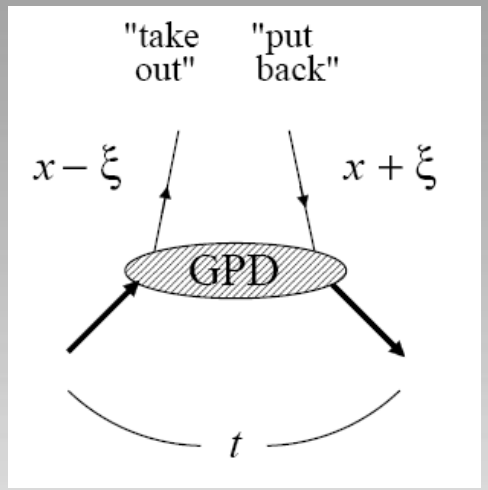
6D Des.



$d^3\boldsymbol{r}$ $d^2k_T\,dr_z$

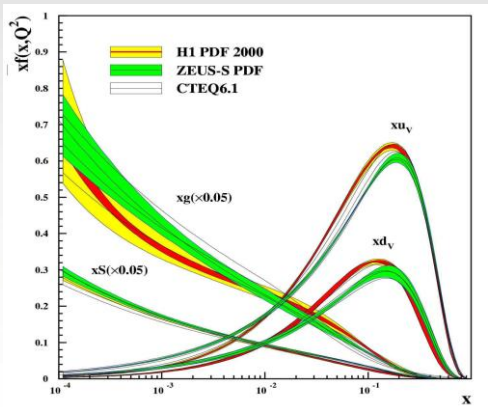
TMD PDFs
$f_1^u(x,k_T)$, .. $h_1^u(x,k_T)$

GPDs/IPDs



3D imaging

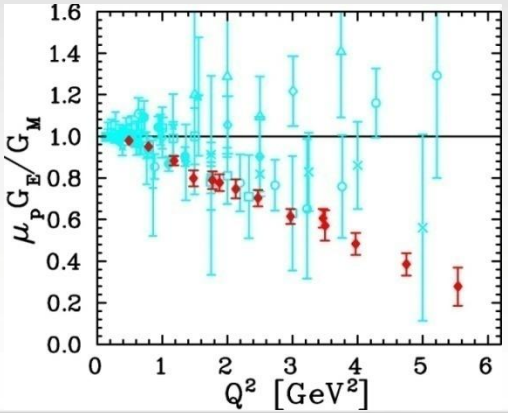
d^2k_T d^2r_T dx & Fourier Transformation



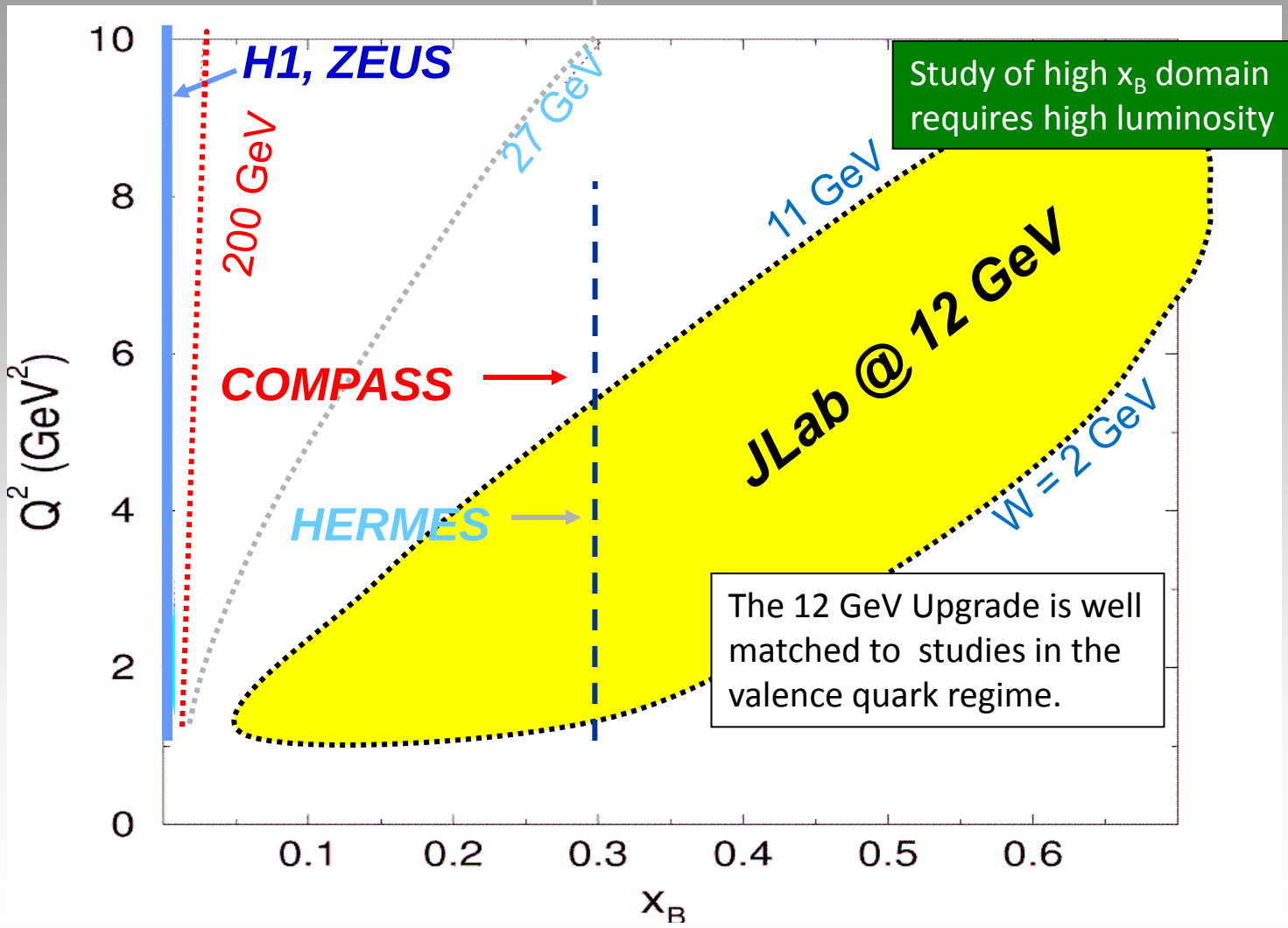
PDFs
$f_1^u(x)$, .. $h_1^u(x)$

1D

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



Kinematics Coverage of the 12 GeV Upgrade

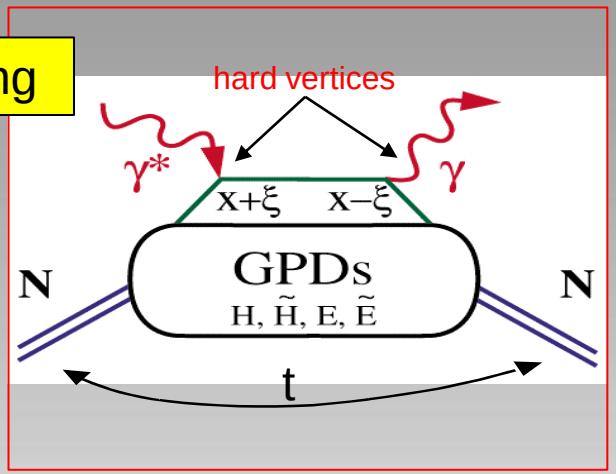


Extraction of GPD's

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:

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

$\Rightarrow H(\xi,t)$

Unpolarized beam, longitudinal target:

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

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

Unpolarized beam, transverse target:

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

$\Rightarrow E(\xi,t)$

DVCS beam asymmetry at 12 GeV

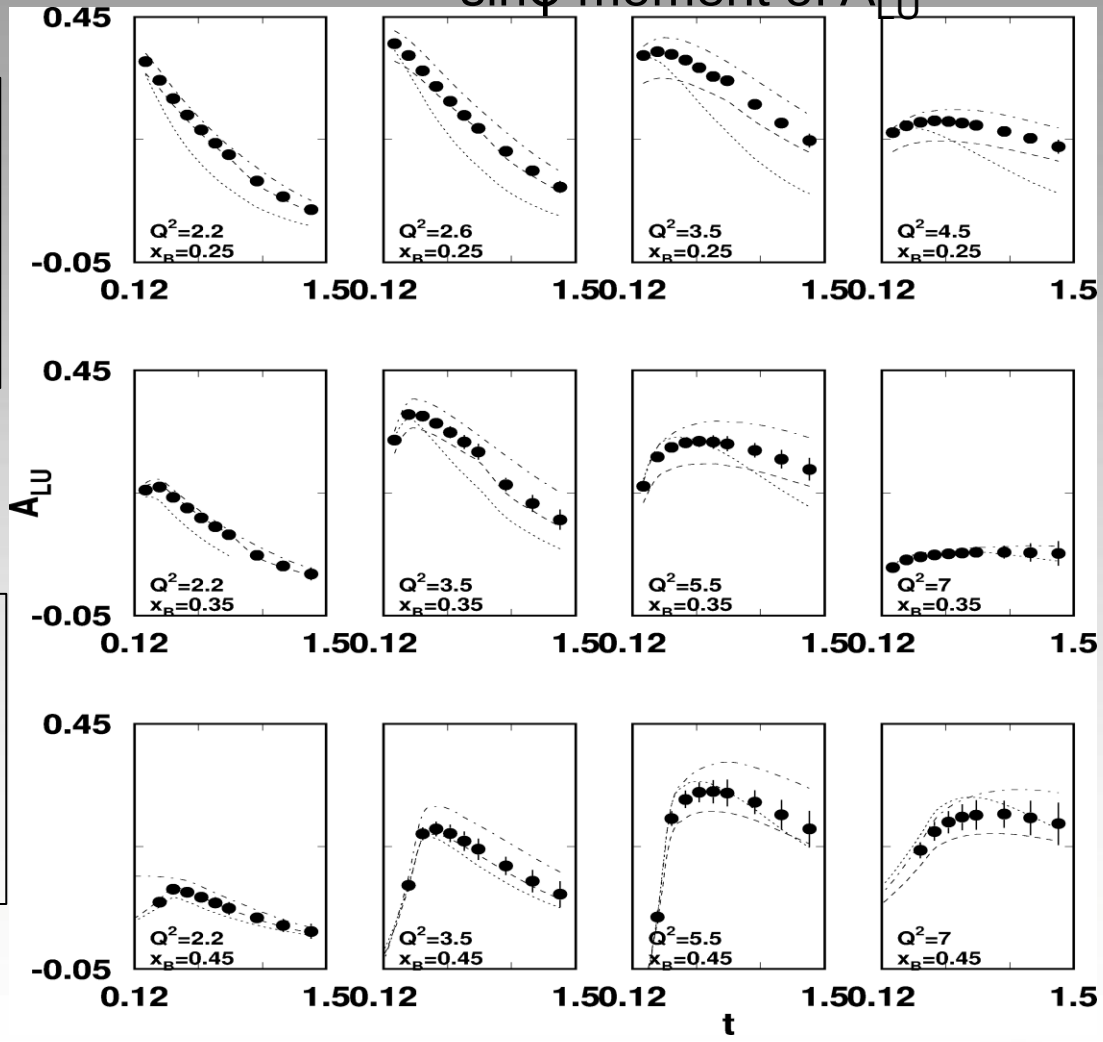
CLAS12

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

$$\vec{e}p \longrightarrow epγ$$

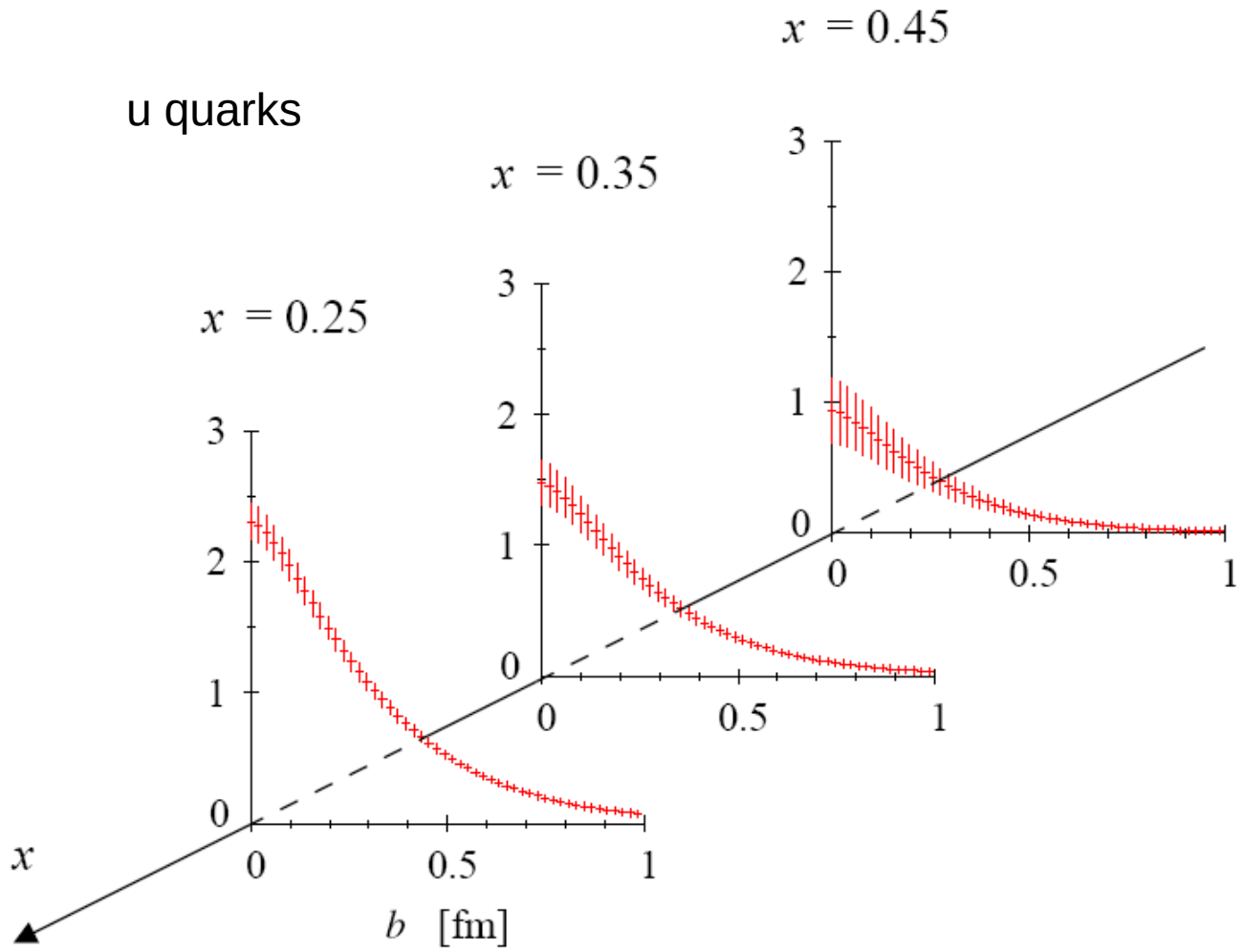
High luminosity and large acceptance allows wide coverage
in $Q^2 < 8$ GeV^2, $x_B < 0.65$, and $t < 1.5$GeV^2

sinφ moment of A_{LU}



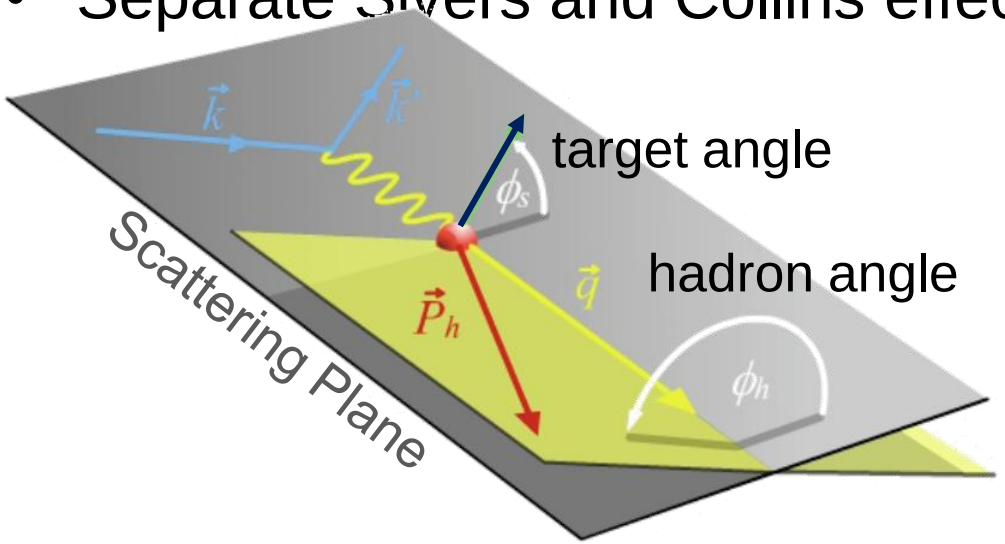
DVCS at 12 GeV

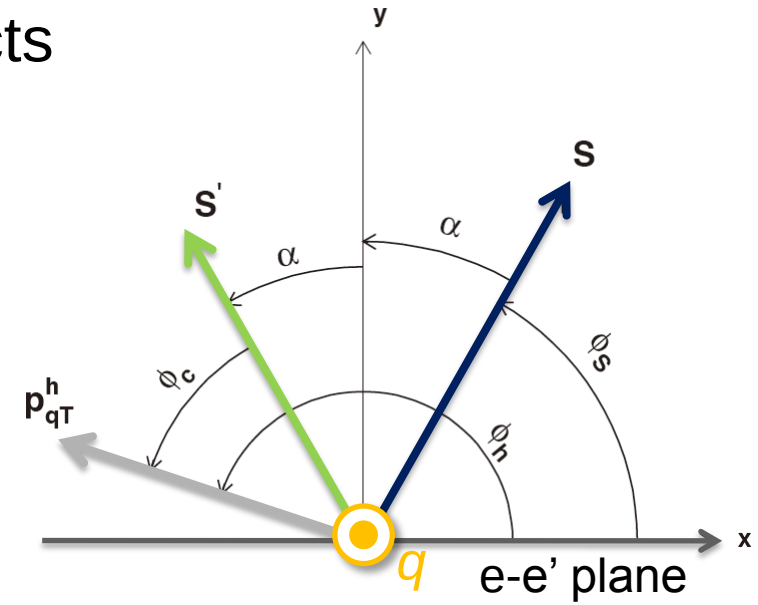
CLAS12



SIDIS Electroproduction of Pions

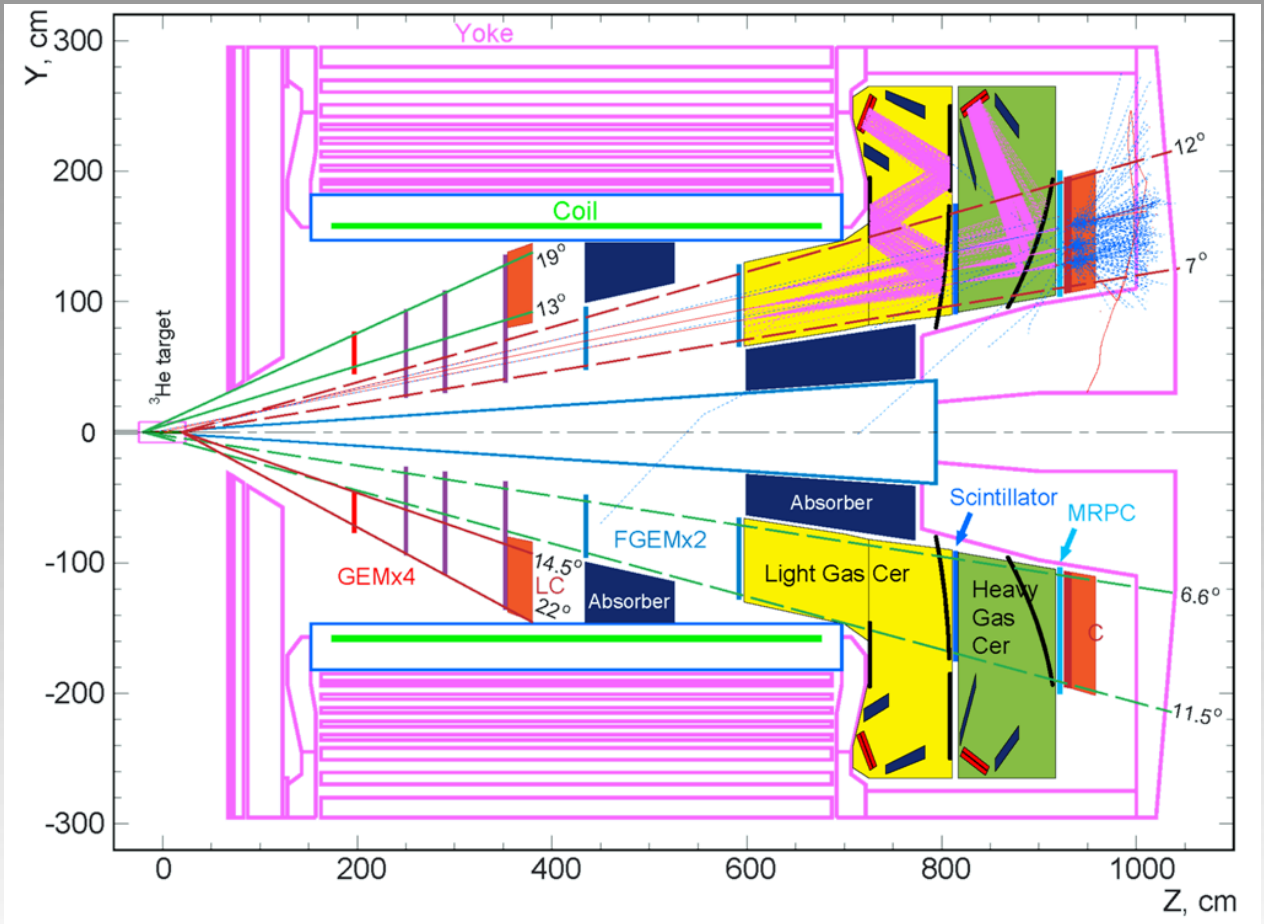
- Separate Sivers and Collins effects





- **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

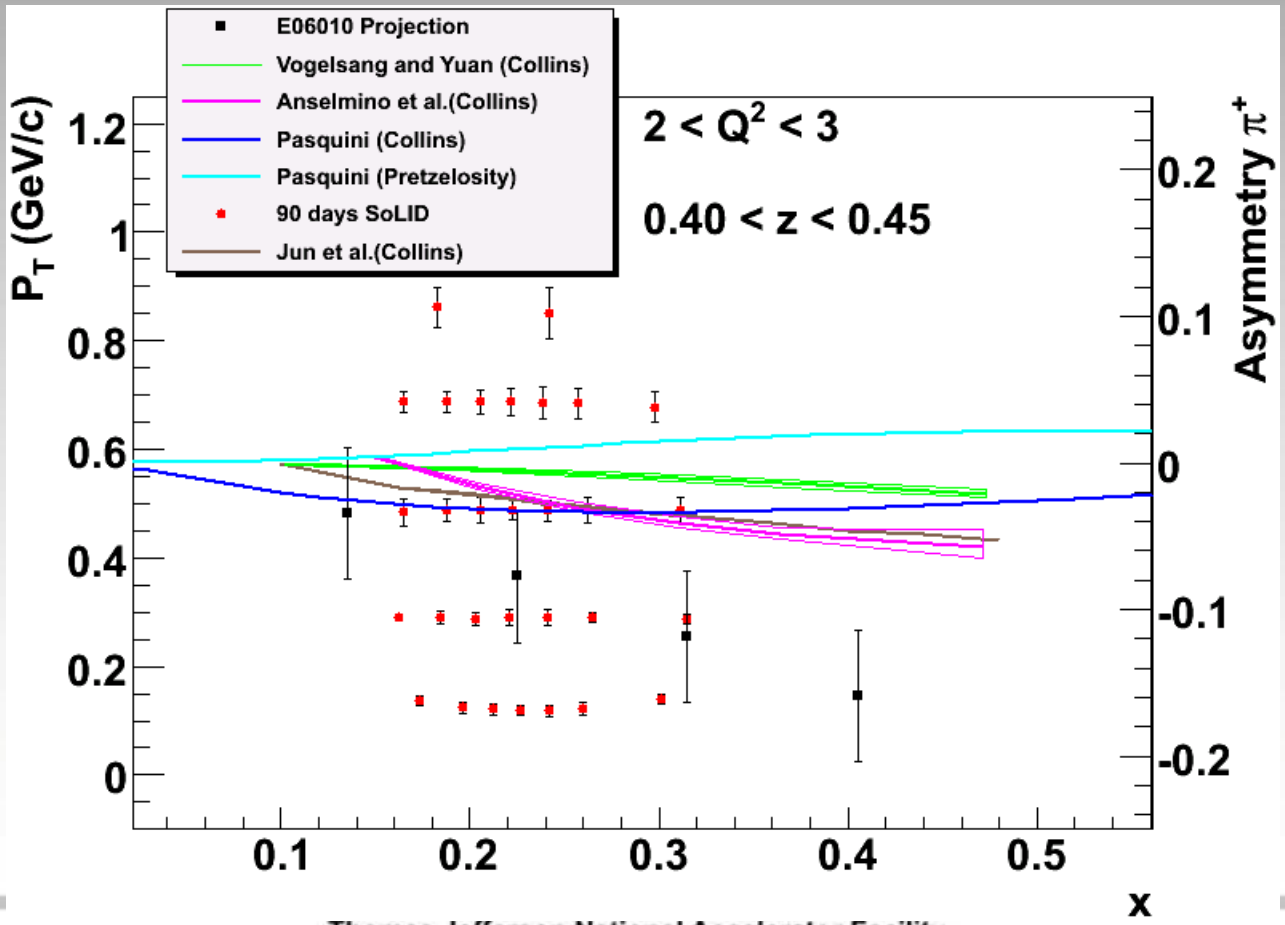


SIDIS SSAs depend on 4 variables (x, Q^2, z and P_T)

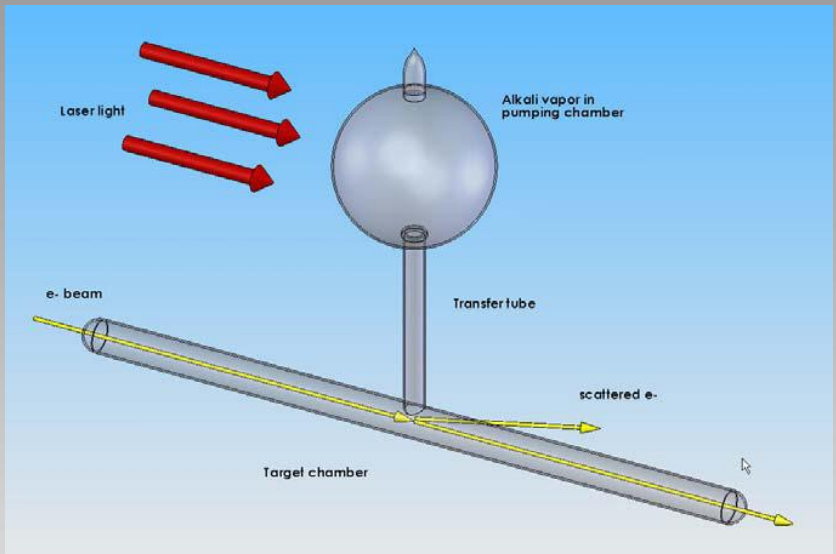
Large angular coverage and precision measurement of asymmetries in 4-D phase space are essential.

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^- .

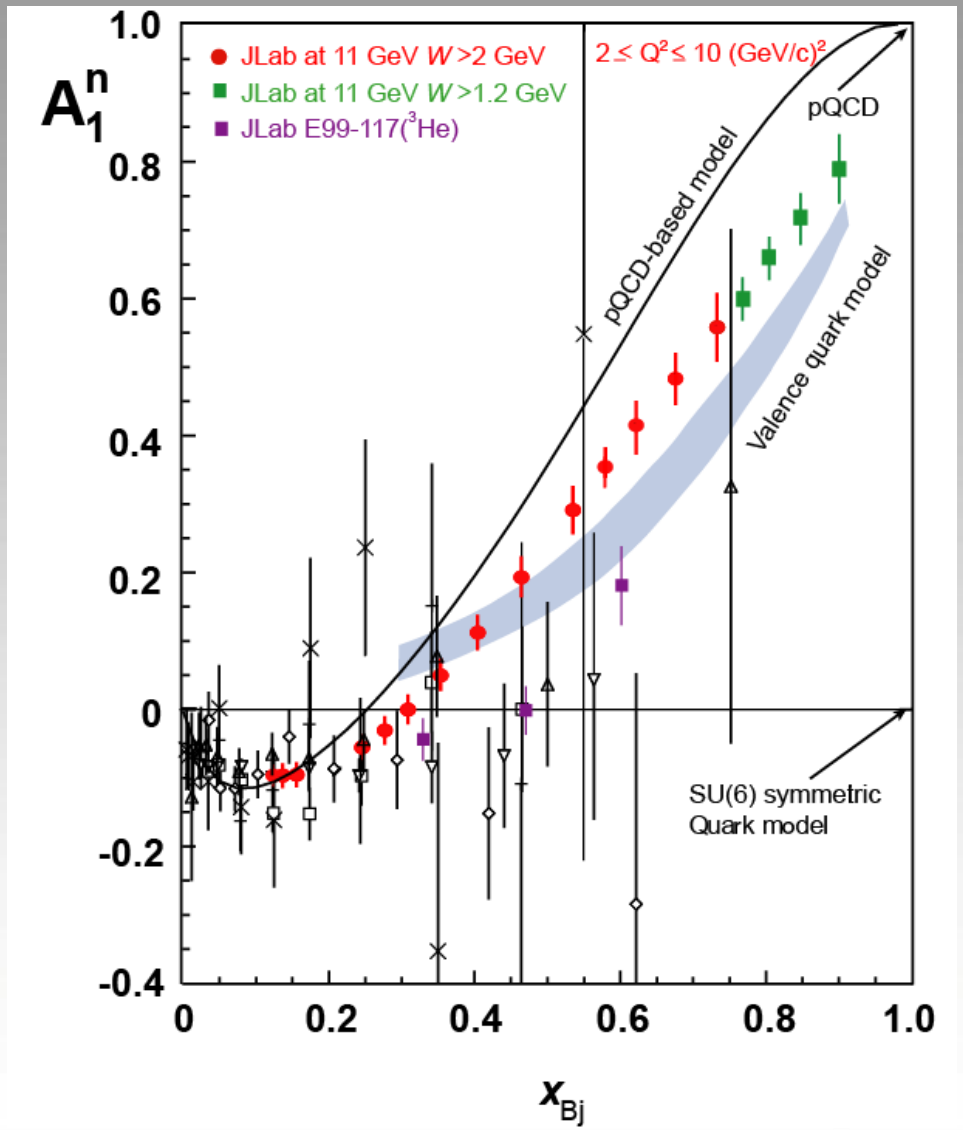


High x spin dependent DIS



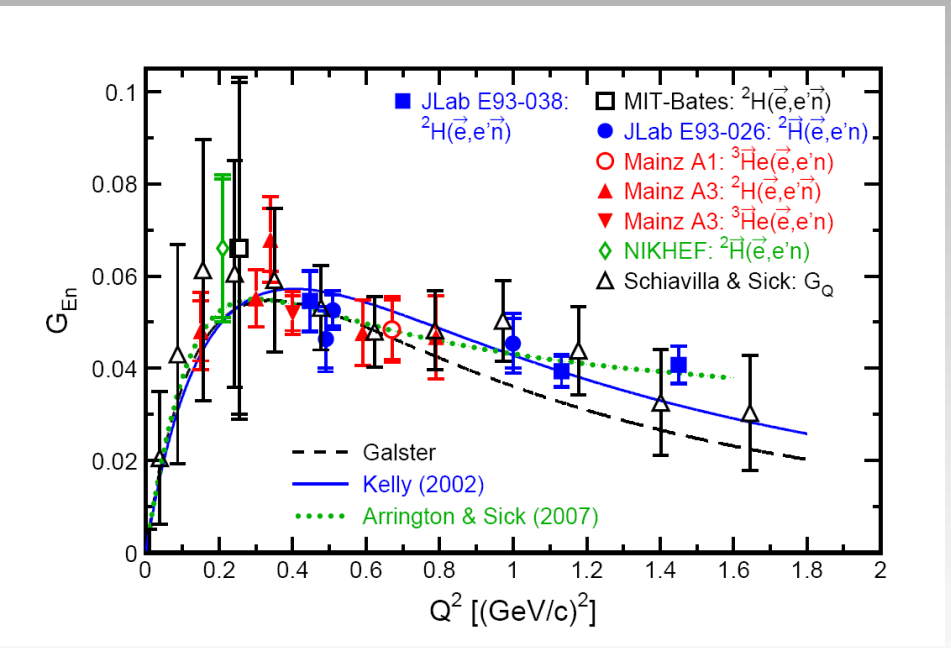
REQUIRES:

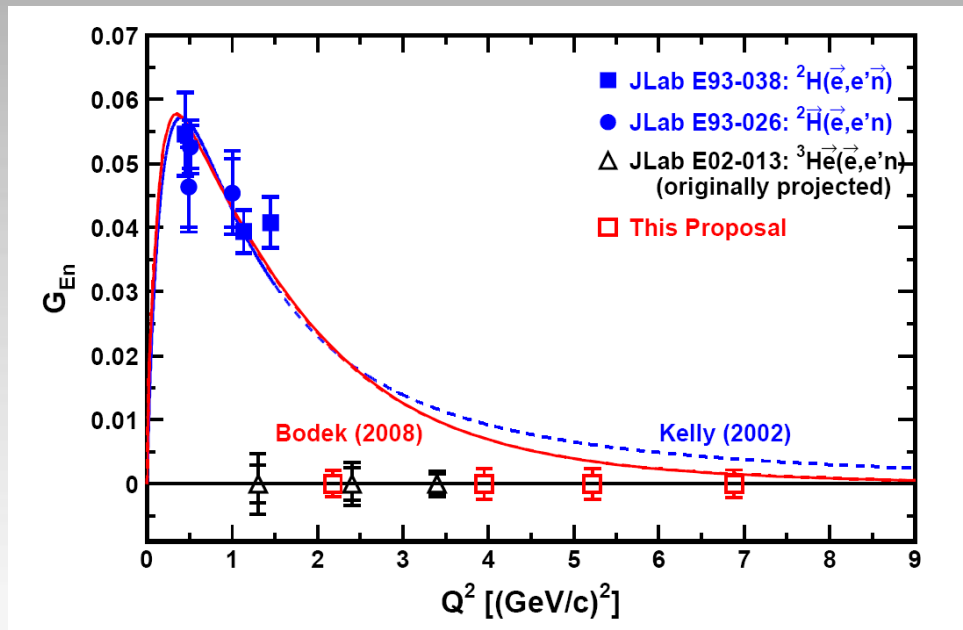
- High beam polarization
- High electron current
- High target polarization
- Large solid angle spectrometers



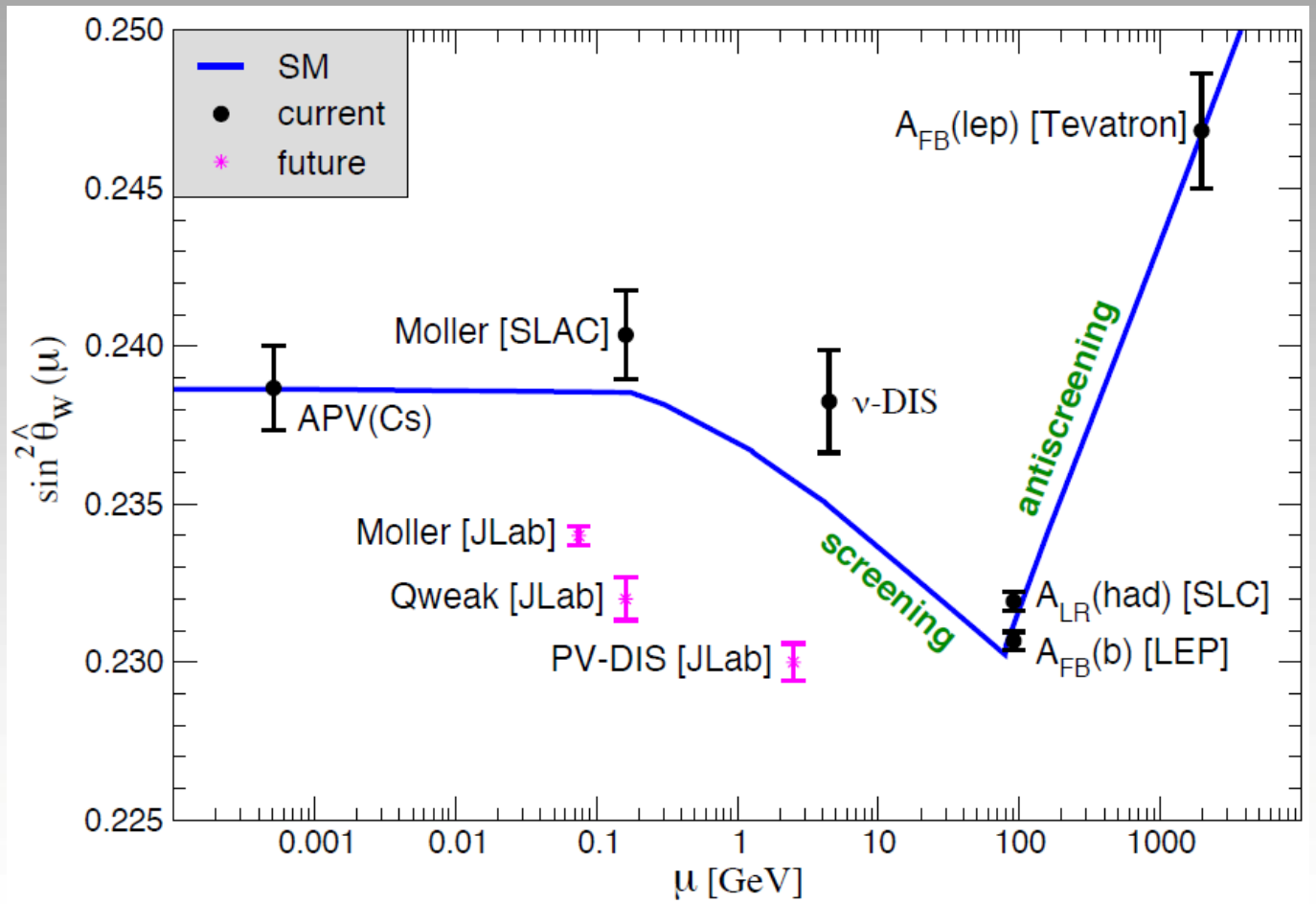
G_E^n – Hall C @ 12 GeV

$^2H(\vec{e}, e'\vec{n})^1H$ via Recoil Polarimetry

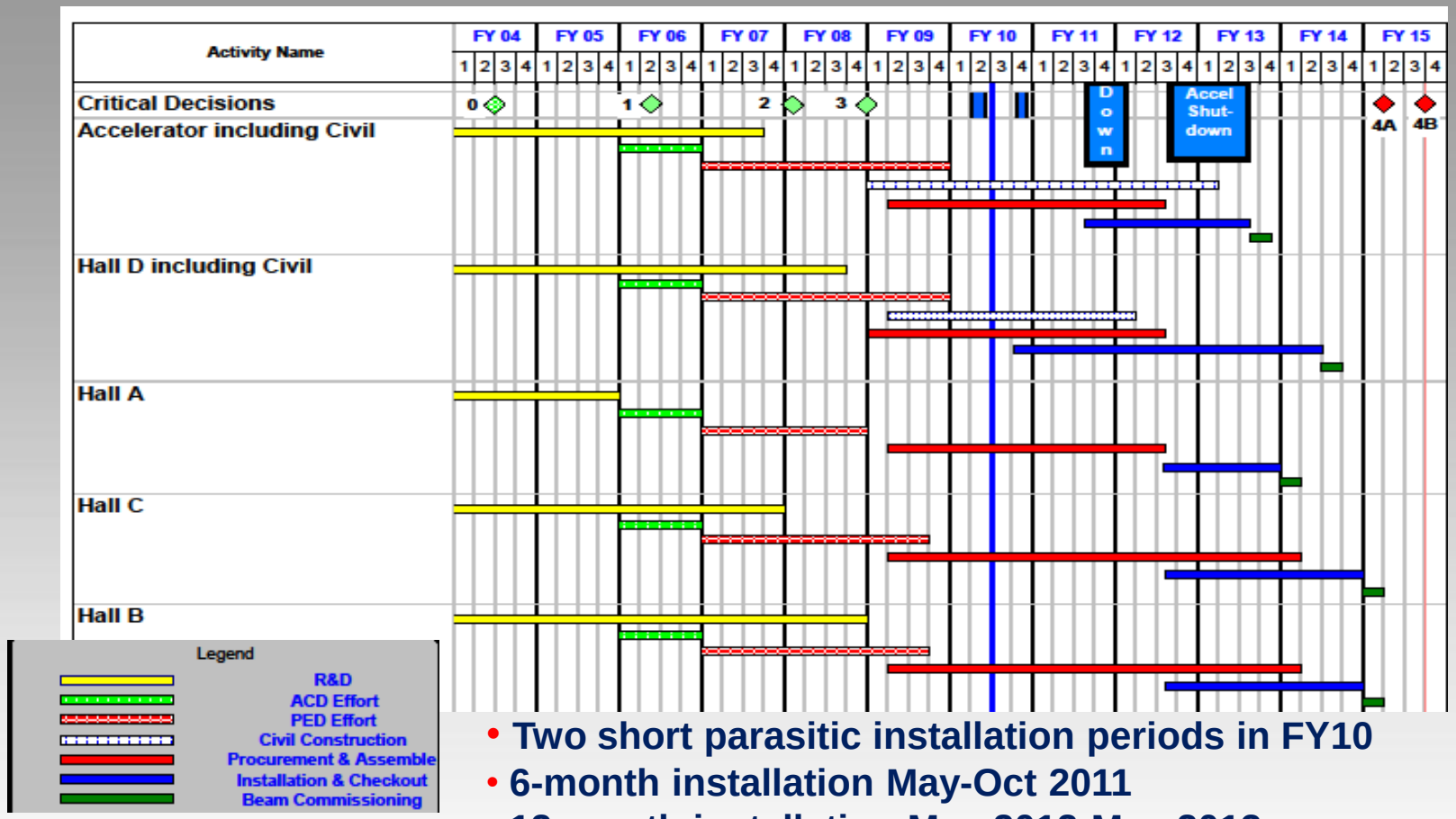




Future PV Program



12 GeV Upgrade Schedule



- Two short parasitic installation periods in FY10
- 6-month installation May-Oct 2011
- 12-month installation May 2012-May 2013
- Hall A commissioning start October 2013
- Hall D commissioning start April 2014
- Halls B and C commissioning start October 2014
- Project Completion June 2015

12 GeV Construction

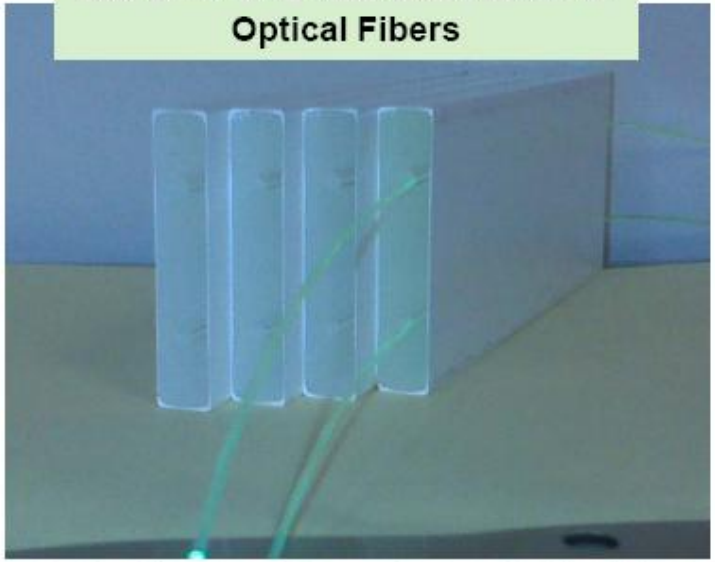
- **Accelerator: Major Procurements (>$500K) nearly complete**
  - **beam transport magnets ; helium refrigerator ; power supplies; etc…**

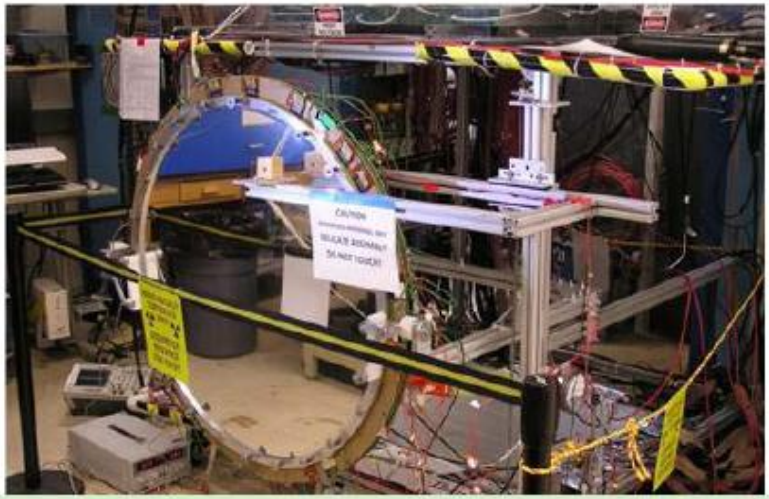
4m Dipole Magnet at JLab

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

Physics Equipment Construction

Hall B – PCAL Test Extrusions w/ Optical Fibers



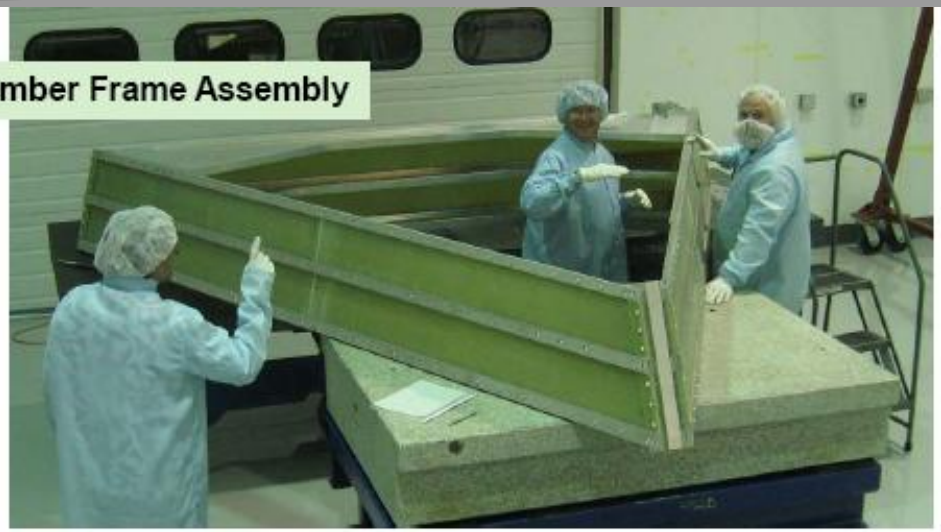


Hall D – Forward Drift Chamber in Test Stand

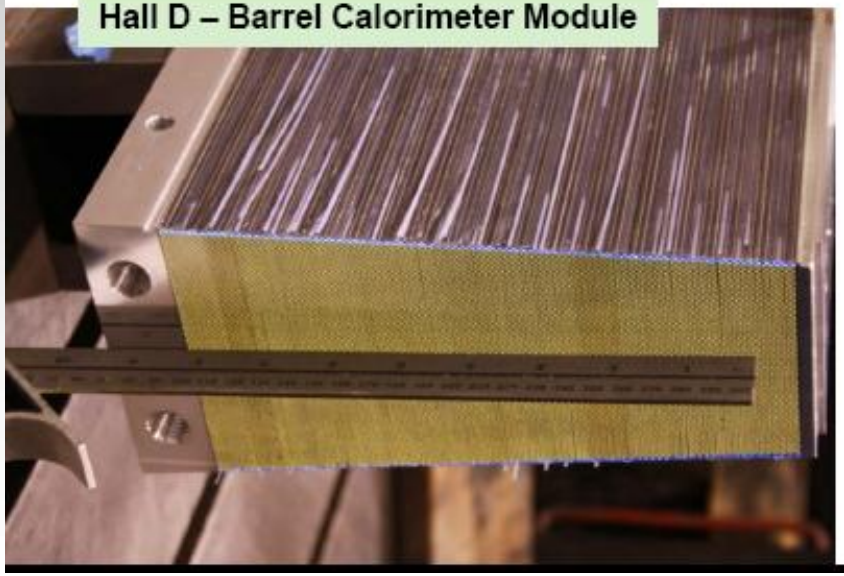
Hall C Superconducting Magnet Q1 Coil

Physics Equipment Construction

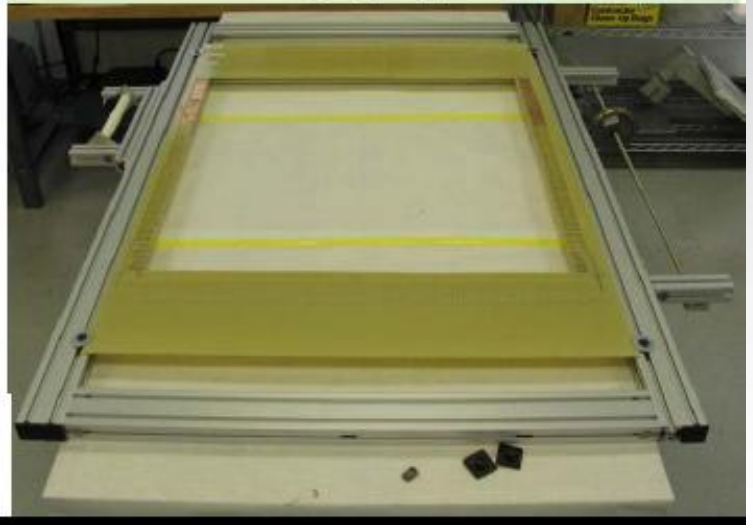
Hall B – Region II Drift Chamber Frame Assembly



Hall D – Barrel Calorimeter Module



Hall C – Wire Stringing Jig for Drift Chamber



Civil Construction: Hall D Complex 2009-2010

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, Collaborators, Contributions($,€,¥...) welcome!

Thanks:

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