Jefferson Laboratory 12 GeV Upgrade

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Acknowledgements

This talk was compiled from the work of many others. In particular I have liberally used transparencies from talks presented by my colleagues at Jefferson Laboratory and others from whom they in turn have “borrowed”.

I would like to thank the organizers and the people from Lanzhou for their welcome and hospitality.

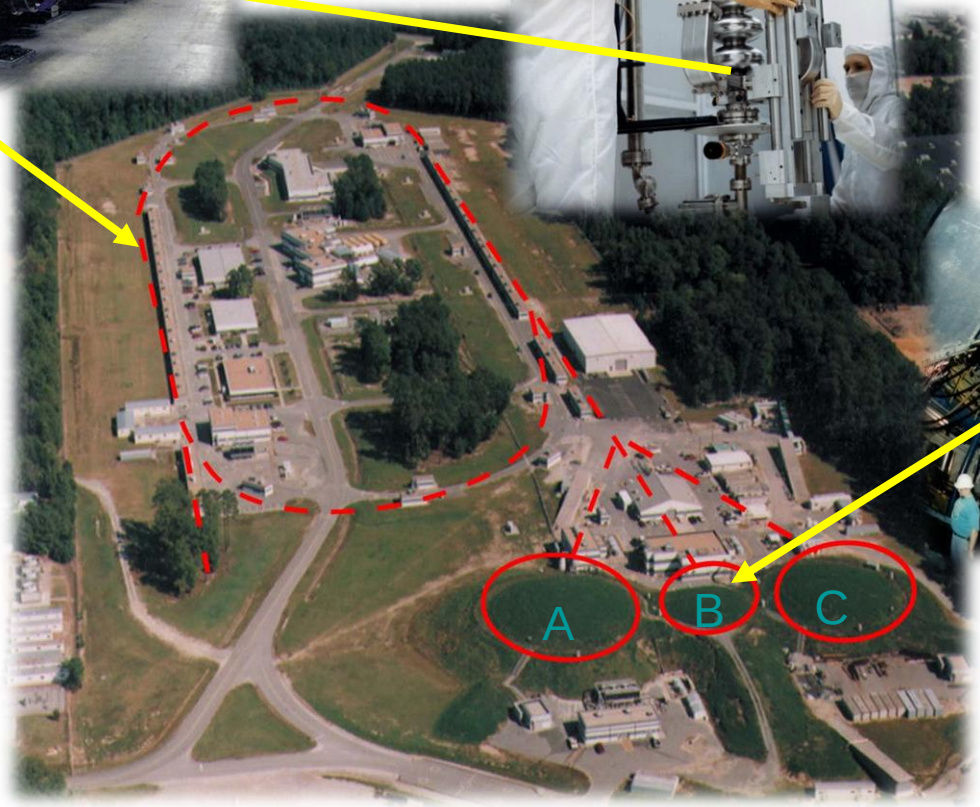
The Talk

- Introduction
- Jefferson Laboratory – CEBAF and Upgrade
- Experiments and Physics in 12 GeV Era
- Project Status
- Conclusion

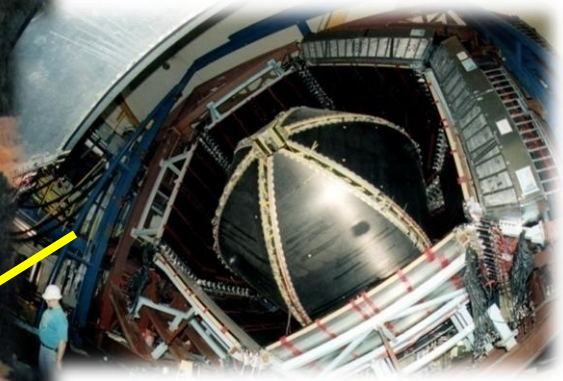
Jefferson Lab

Cryomodules in the accelerator tunnel

Superconducting radiofrequency (SRF) cavities undergo vertical testing.

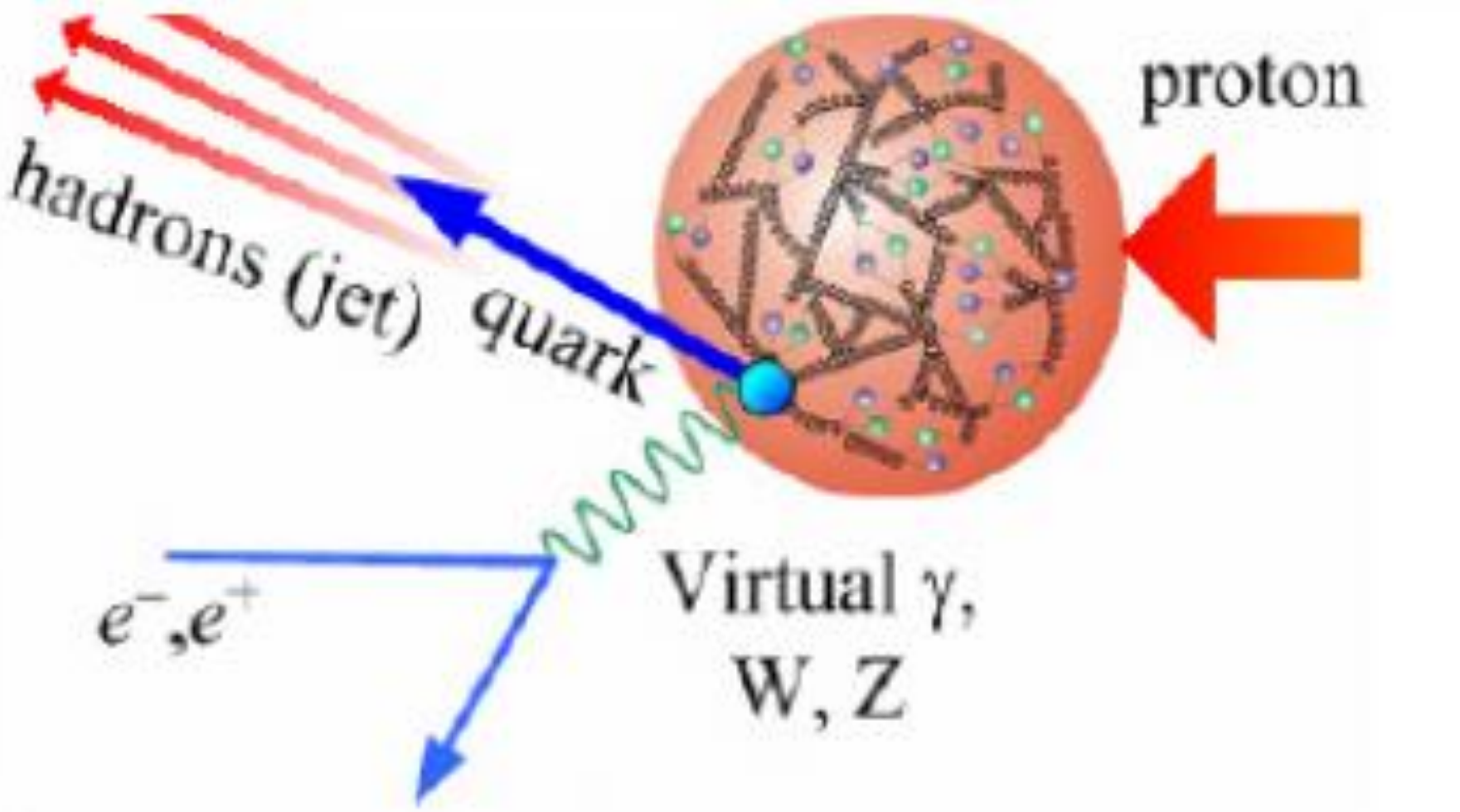


An aerial view of the recirculating linear accelerator and 3 experimental halls.

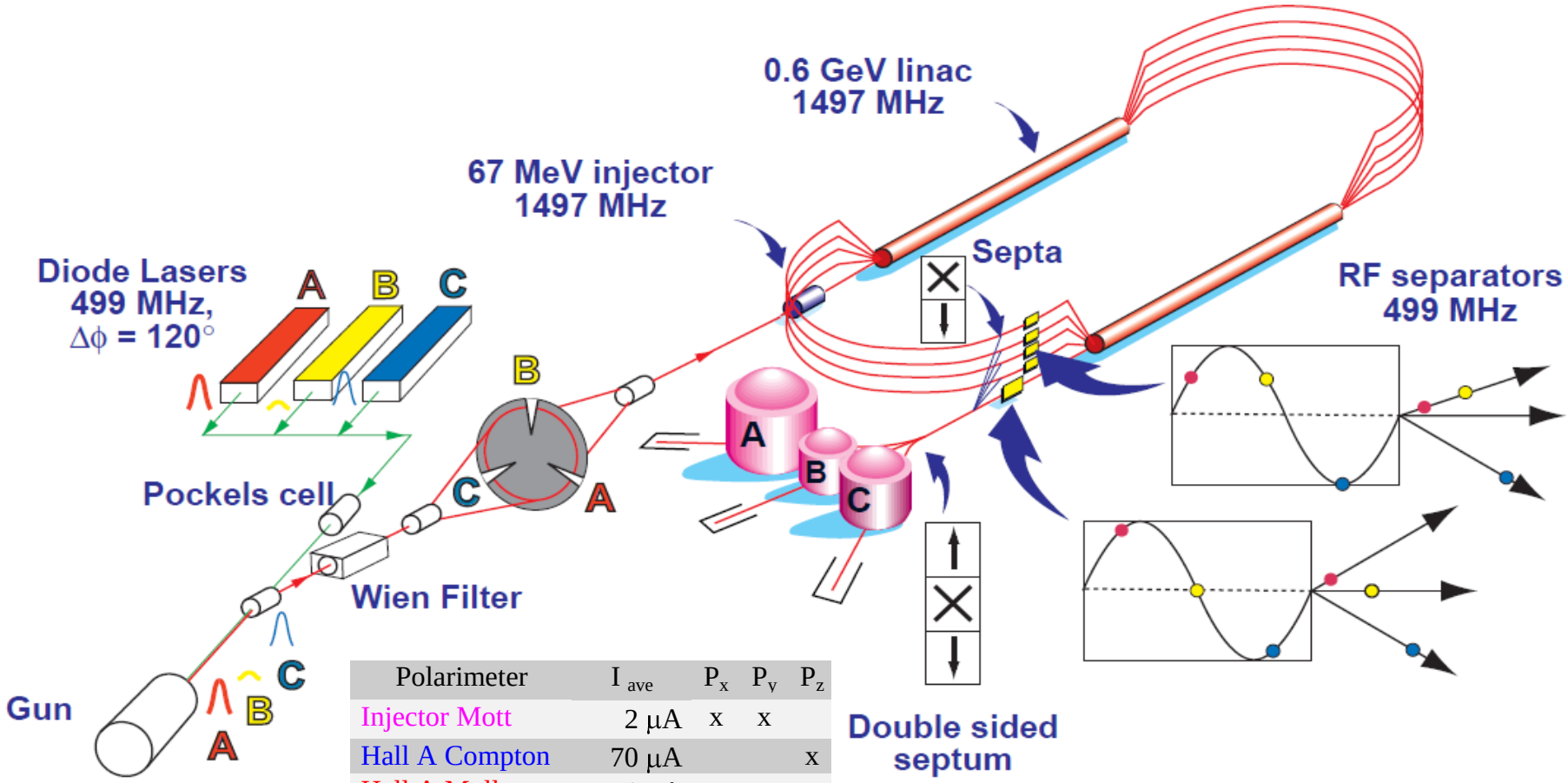


CEBAF Large Acceptance Spectrometer (CLAS) in Hall B

Electron Scattering: A picture



Spin, Current, and Beam Delivery @CEBAF



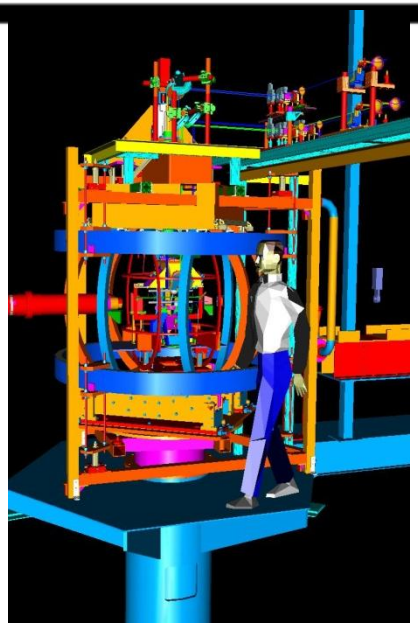
Polarimeter	I_{ave}	P_x	P_y	P_z
Injector Mott	2 μA	x	x	
Hall A Compton	70 μA			x
Hall A Moller	1 μA	x		x
Hall B Moller	10 nA		x	x
Hall C Moller	1 μA			x

Under development
<0.5% Atomic Beam Polarimeter (Hall A)
<1% Compton Polarimeter (Hall C)

Polarized Targets at Jefferson Lab

Hall A: $^3\vec{He}$

G_E^n, SSAs
Transversity



Hall B: eg1

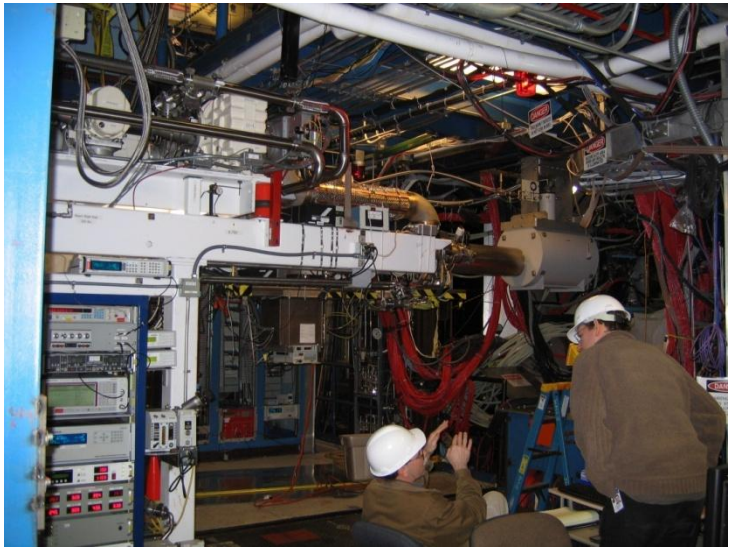
Dynamically polarized NH_3 ND_3,

Q^2 evolution of Nucleon Spin Structure, DVCS

Hall B: FROST

Frozen Spin Target, Butanol

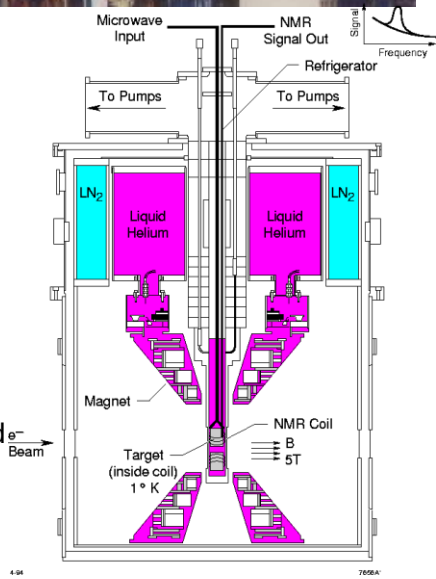
"Missing" N* Search.



Hall C:

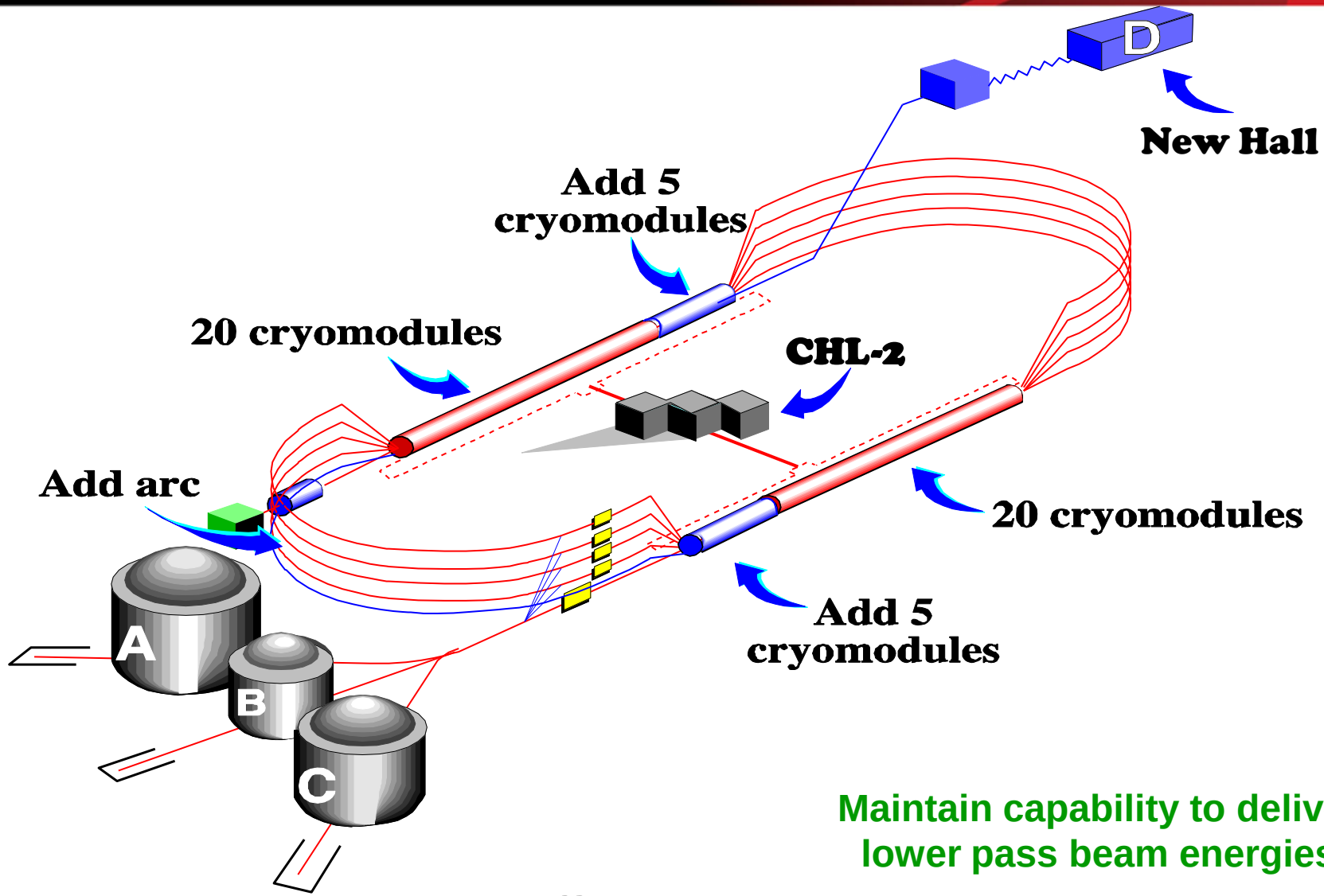
Dynamically polarized, NH_3 ND_3

G_E^n, SANE, g_1^p, g_1^d



HDIce from BNL under development: Polarized neutron target for N* expts.

12 GeV Upgrade



Enhanced capabilities in existing Halls

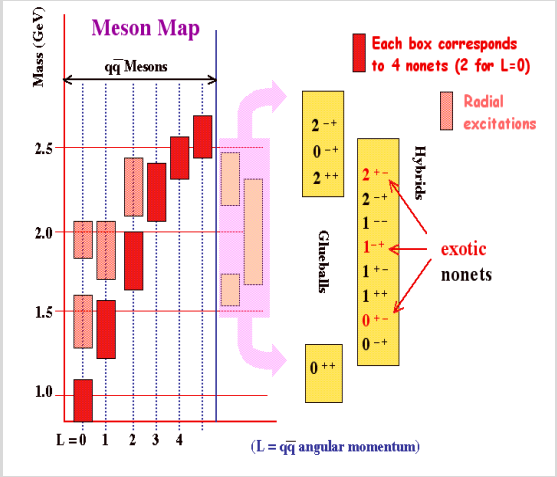
Maintain capability to deliver lower pass beam energies

12 GeV Upgrade

Exciting new scientific opportunities – continue world leadership

- **Discover the spectrum and properties of exotic mesons in mass range 1.5-2.6 GeV** in order to explore the physical origins of quark confinement

- **Define the spin and flavor structure of the nucleon in the valence region**, hence test theories of di-quarks, pQCD….



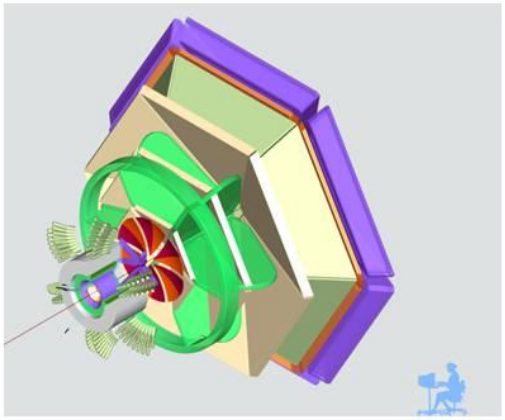
- Determine the orbital angular momentum carried by up and down quarks and **explore potential of Generalized Parton Distributions for tomographic imaging**

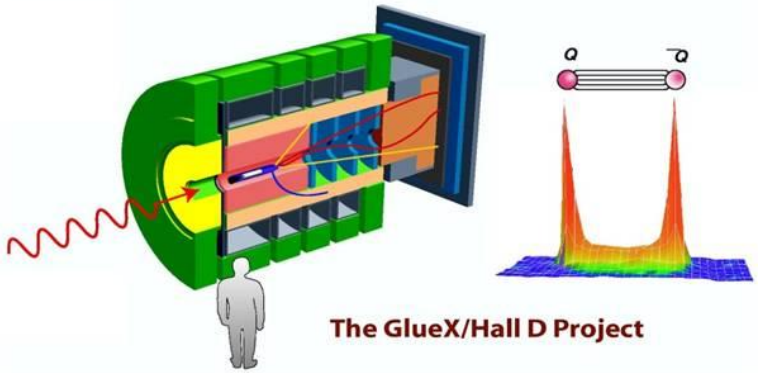
- Exploit the unique capabilities of CEBAF at 12 GeV **to explore the structure of nuclei at the level of quarks and gluons** – understand the EMC effect

- **Probe potential new physics** (beyond the Standard Model) through precise test of evolution of $\sin^2 \theta_W$ from Z-pole

Four Halls

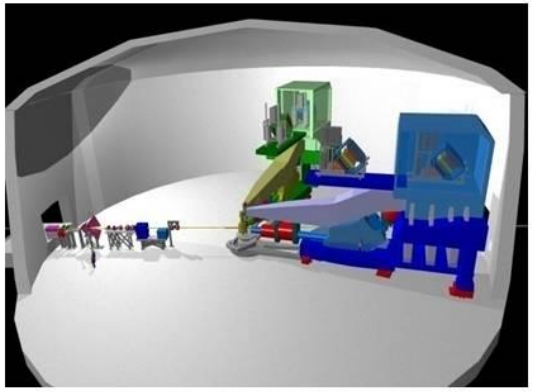
Hall D – exploring origin of confinement by studying exotic mesons

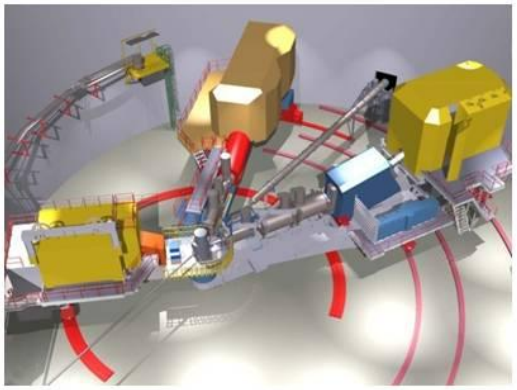




Hall B – understanding nucleon structure via generalized parton distributions

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

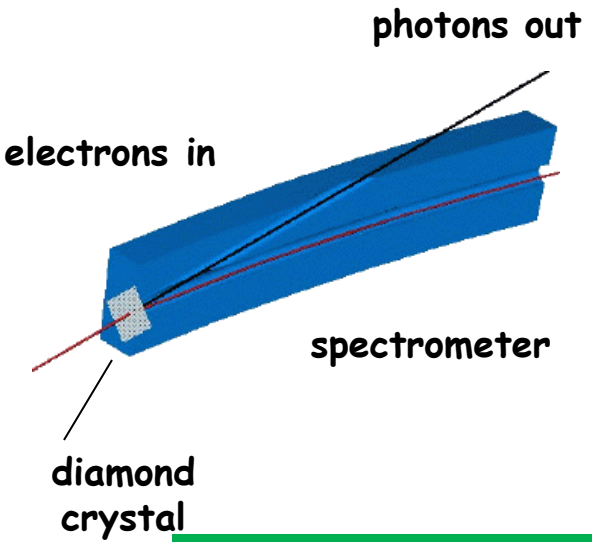


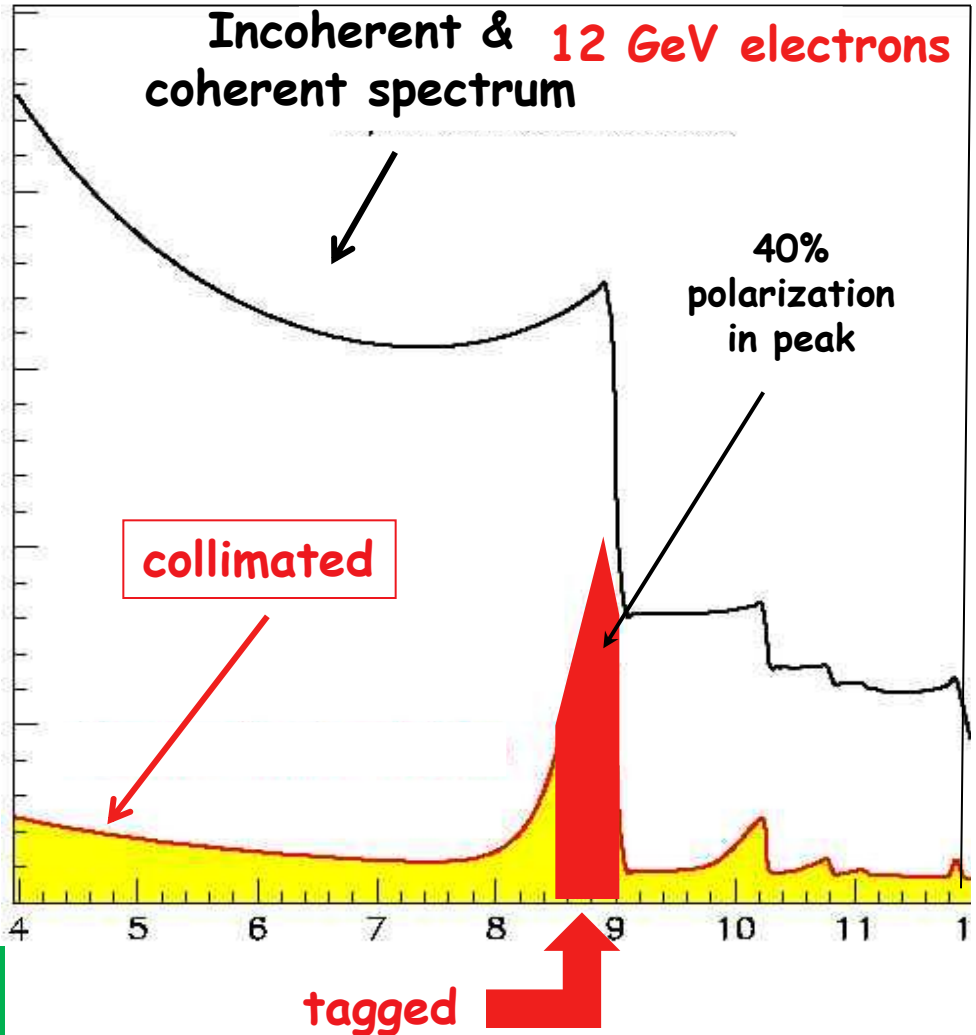


Hall A – short range correlations, form factors, hyper-nuclear physics, future new experiments

Gluex uses Coherent Bremsstrahlung

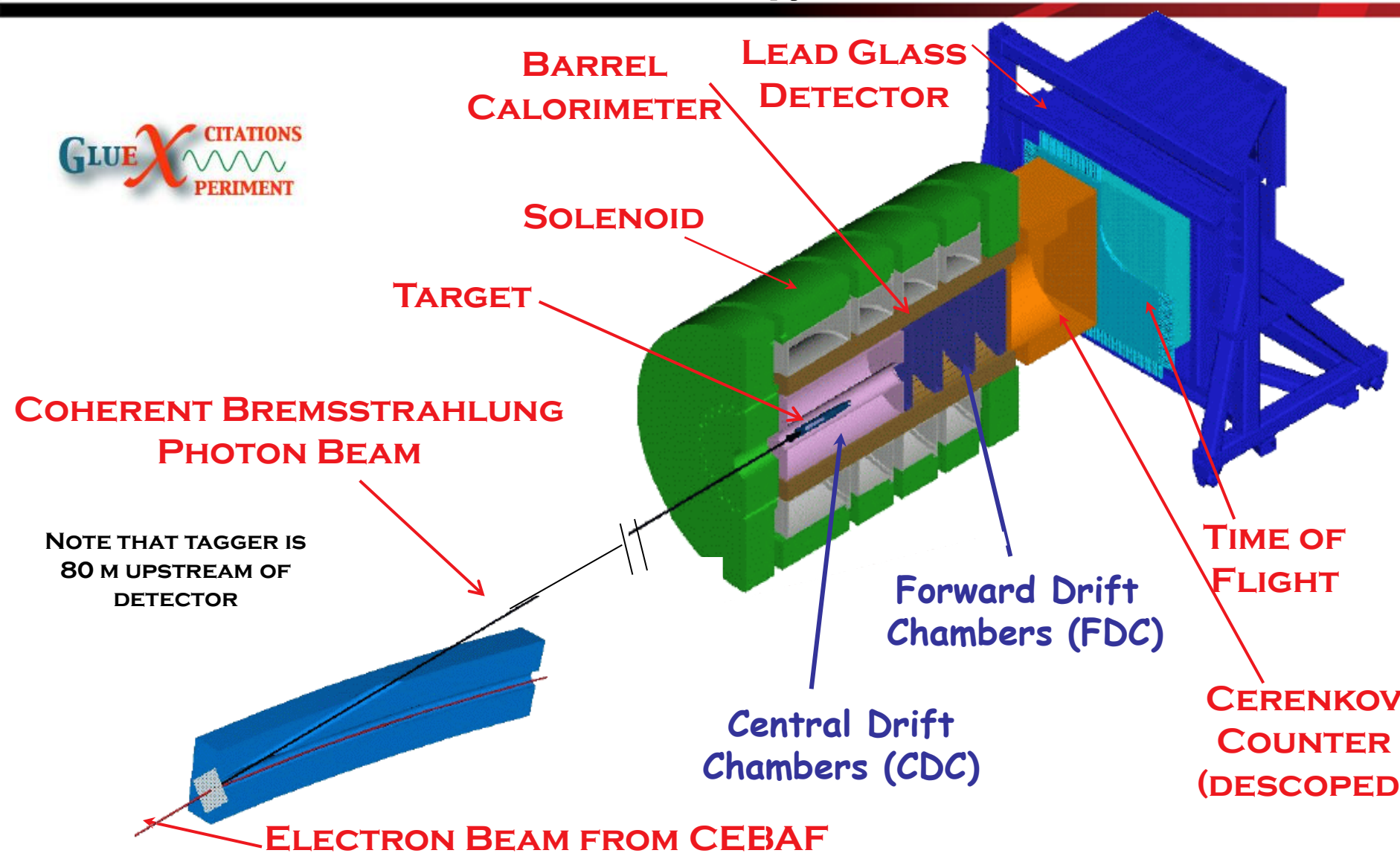
This technique provides requisite energy, flux and polarization



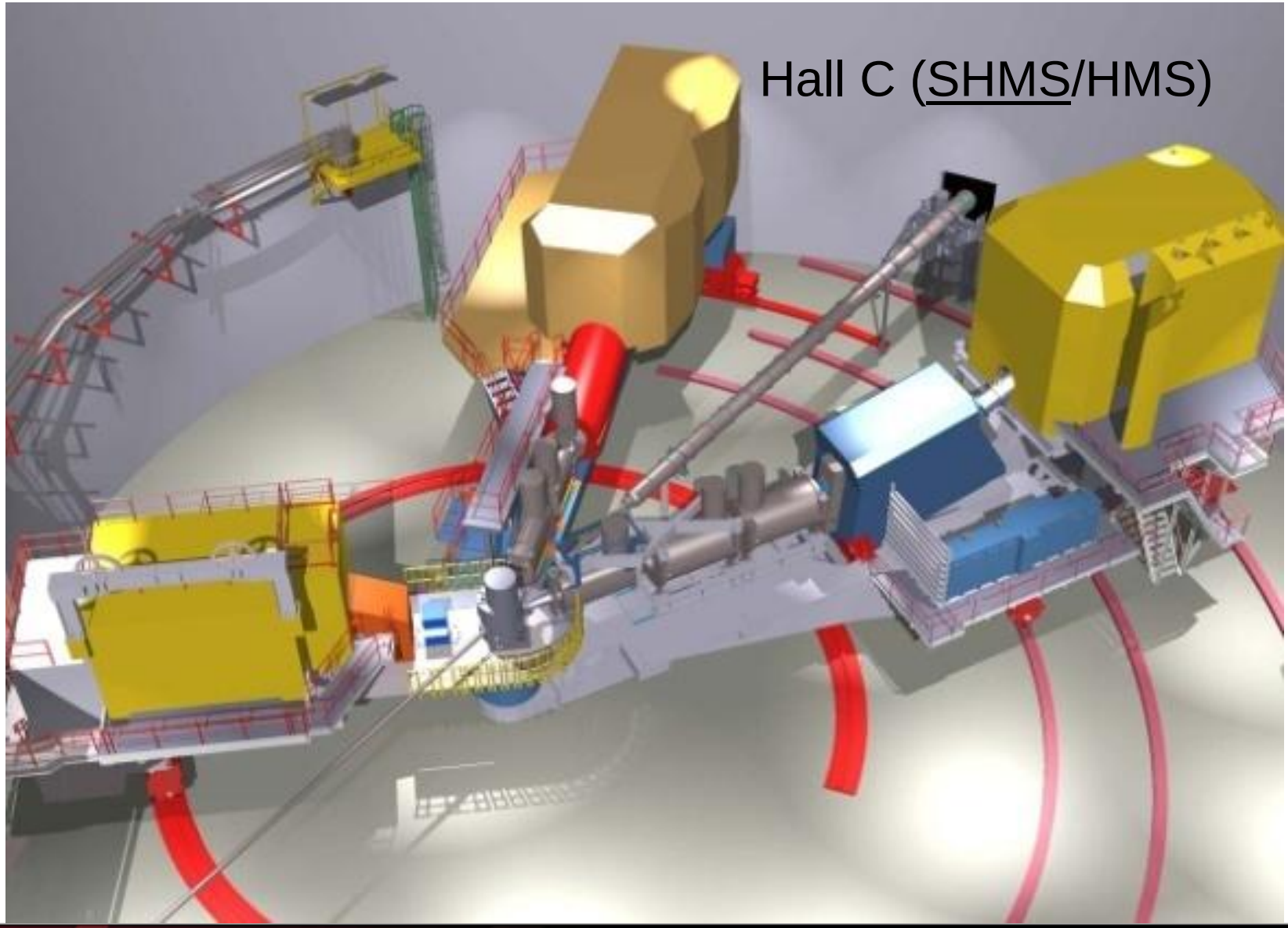


Good "acceptance" up to M ~ 2.5 GeV

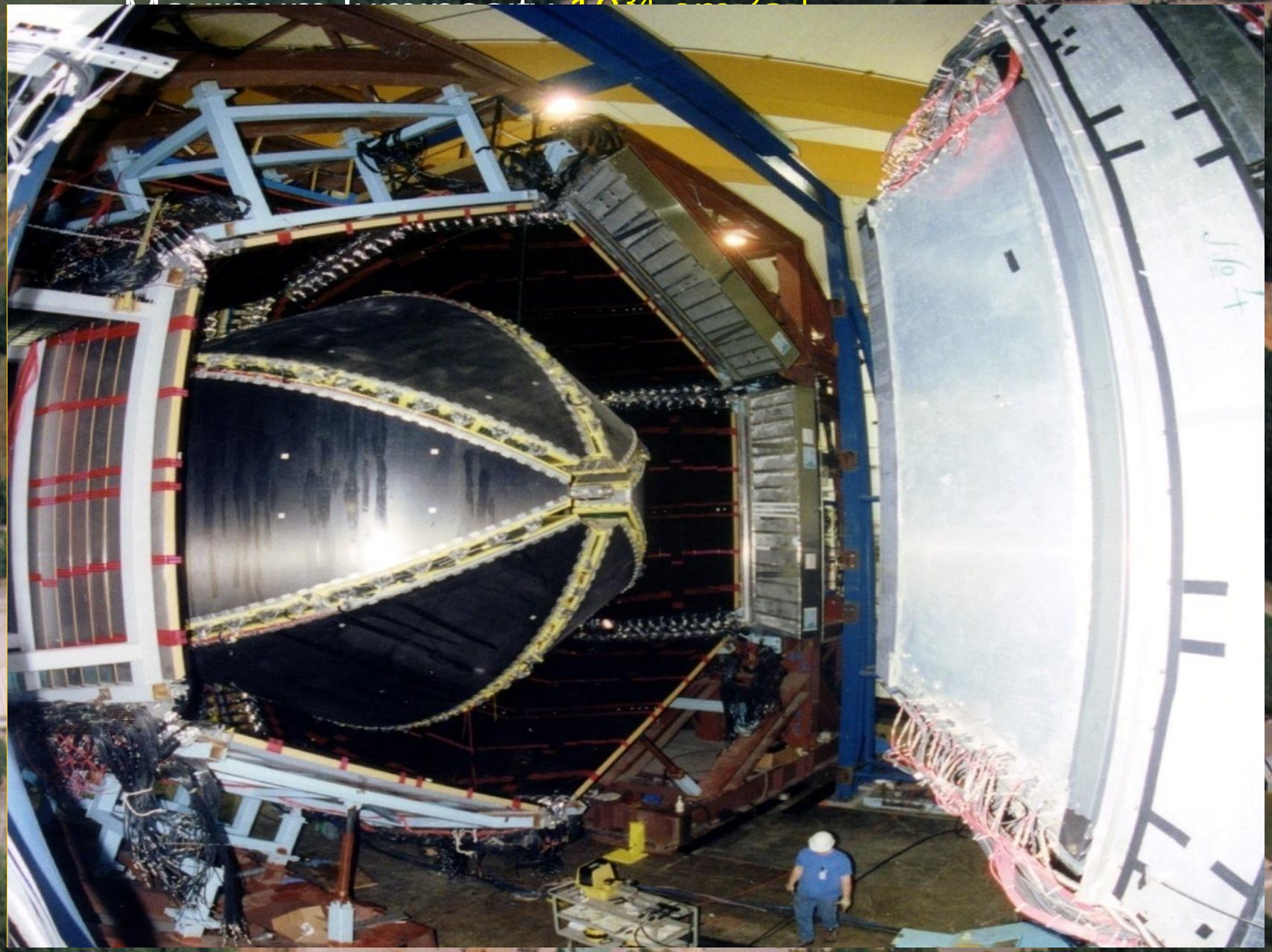
Gluex


Barrel Calorimeter
Lead Glass Detector
Solenoid
Target
Coherent Bremsstrahlung Photon Beam
Note that tagger is 80 m upstream of detector
Time of Flight
Forward Drift Chambers (FDC)
Cerenkov Counter (descoped)
Central Drift Chambers (CDC)
Electron Beam from CEBAF

Hall C Precision Spectrometers



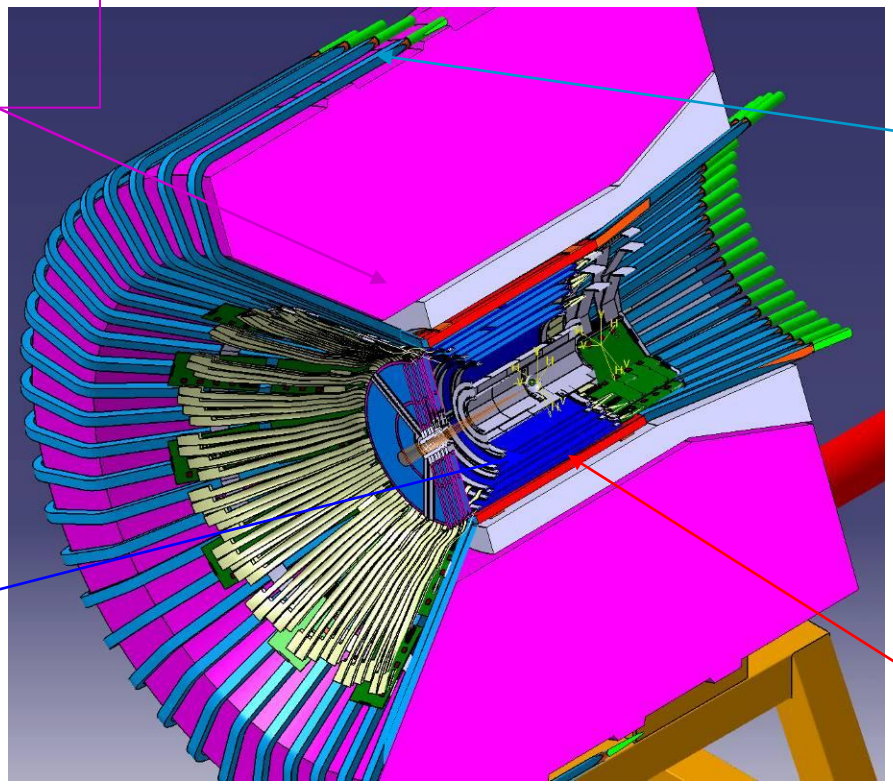
Hall B: The CEBAF Large Acceptance Spectrometer (*CLAS*)



CLAS12 Central Detector

European collaboration:
INFN Frascati,
INFN Genova,
U. Glasgow
LPSC Grenoble
IPN Orsay,
CEA-Irfu Saclay

Solénoïde 5 T:
Saclay?



Light guides TOF
IN2P3/Glasgow

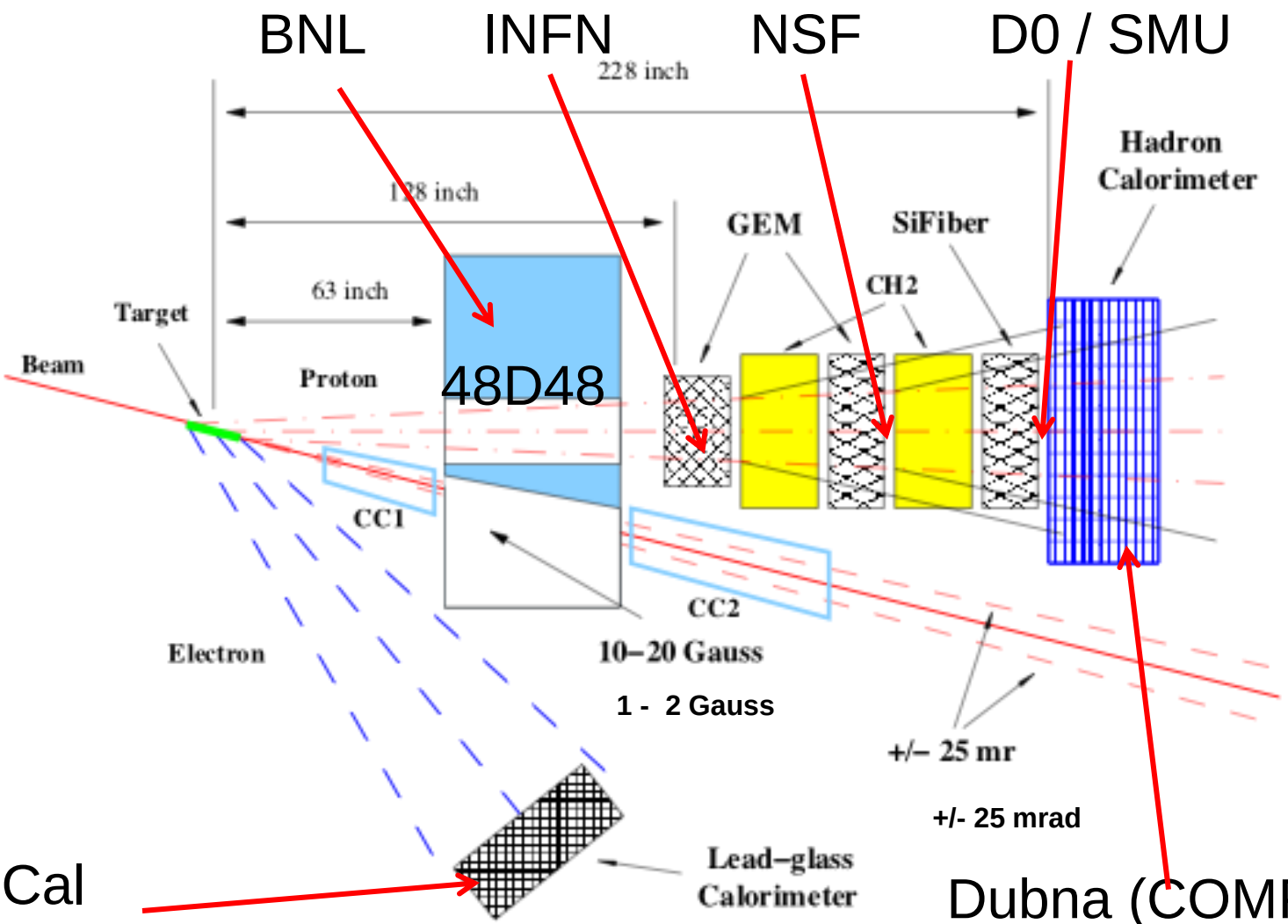
Central
Tracker:
Si JLab
MM Saclay

Neutron
counters

IN2P3/INFN

(All subsystems under R&D or conceptual phase)

Super BigBite Spectrometer



QCD

Confinement

Large Distance
Low Energy

Strong QCD

Spectroscopy

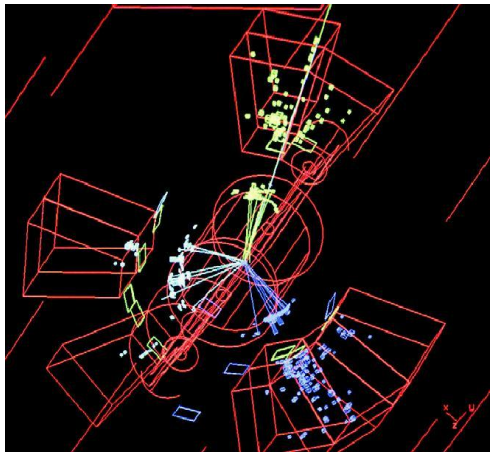
Gluonic
Degrees of Freedom
Missing

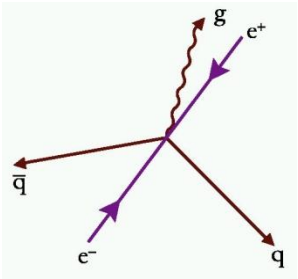
Asymptotic Freedom

Small Distance
High Energy

Perturbative QCD

High Energy Scattering

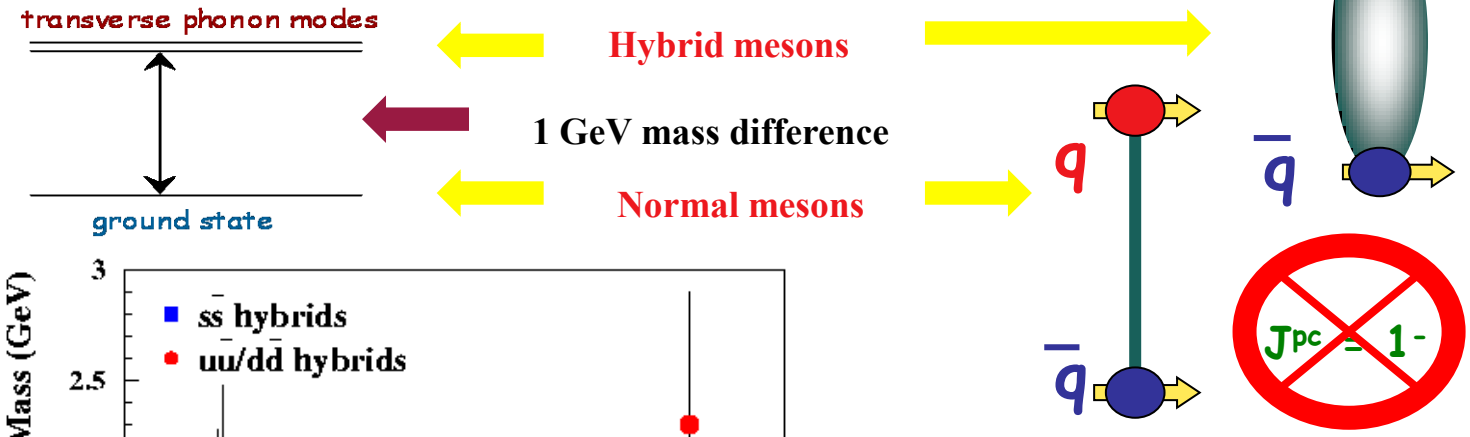


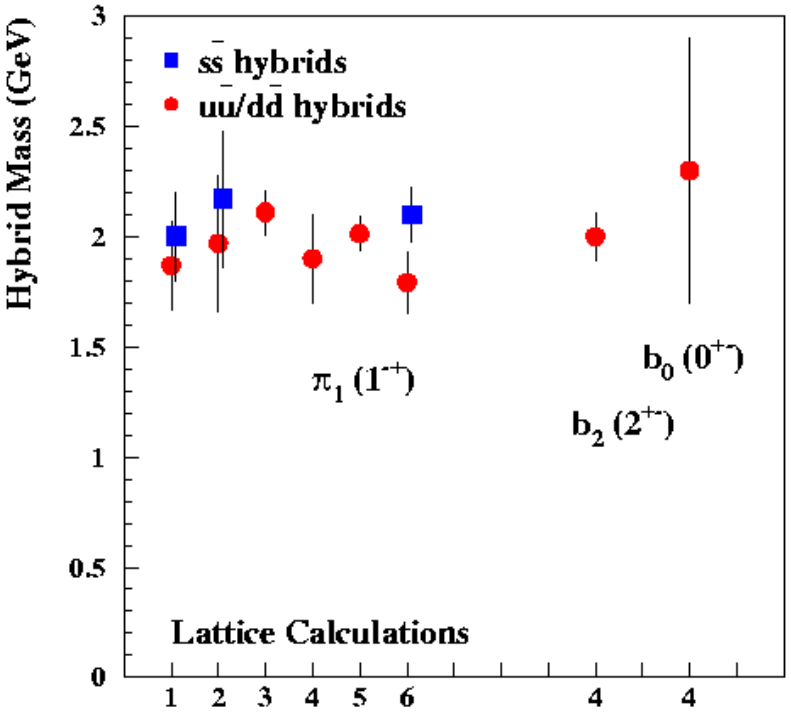


Gluon
Jets
Observed

Gluex : Search for Hybrid Mesons

Hybrid mesons and mass predictions





Lattice

1^{-+} 1.9 GeV

2^{+-} 2.1 GeV

0^{+-} 2.3 GeV

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

Gluex: Finding the Exotic Wave

$\gamma \rightarrow$ V(ector Meson) S = 1 (Double-blind M. C. exercise)

An exotic wave ($J^{PC} = 1^{-+}$) was generated at level of 2.5 % with 7 other waves. Events were smeared, accepted, passed to PWA fitter.

$$X(\text{exotic}) \rightarrow \rho\pi \rightarrow 3\pi$$

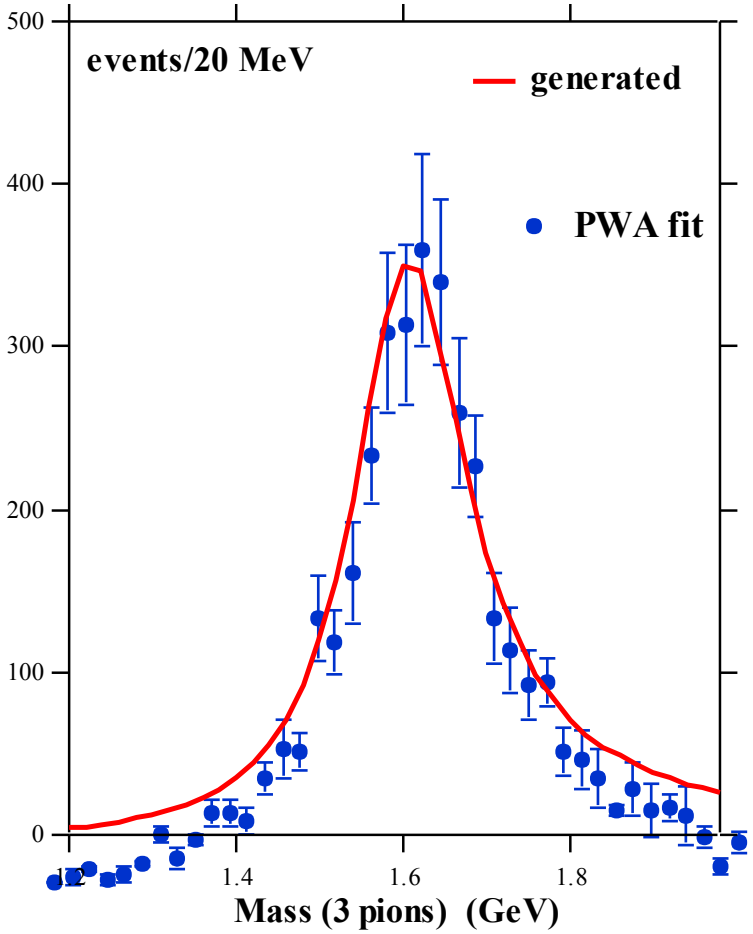
Mass

Input: 1600 MeV
Output: 1598 +/- 3 MeV

Width

Input: 170 MeV
Output: 173 +/- 11 MeV

Statistics shown here correspond to a few days of running.



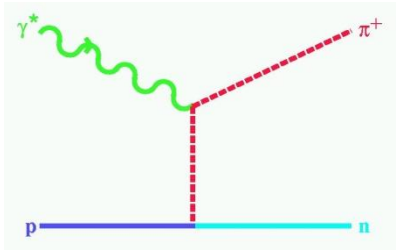
Charged Pion Electromagnetic Form Factor

Where does the dynamics of the q-q interaction make a transition from the strong (confinement) to the perturbative (QED-like) QCD regime?

- It will occur earliest in the simplest systems
  → the pion form factor $F_\pi(Q^2)$ provides our best chance to determine the relevant distance scale experimentally

To measure $F_\pi(Q^2)$:

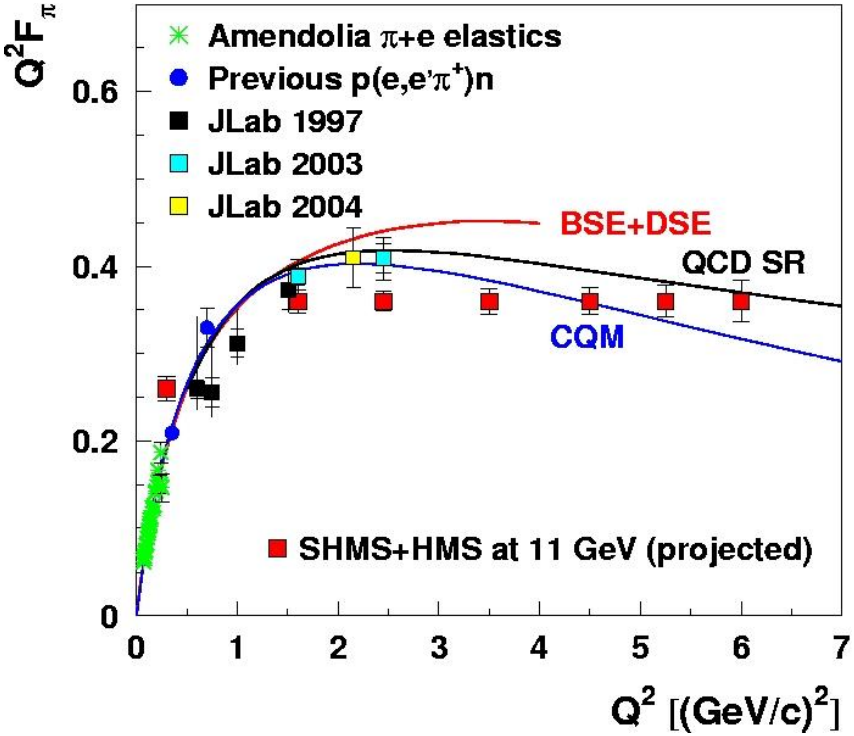
- At low Q^2 (< 0.3 $(GeV/c)^2$): use π + e scattering → R_{rms} = 0.66 fm
- At higher Q^2: use $^1H(e,e'\pi^+)n$



Scatter from a virtual pion in the proton and 1) extrapolate to the pion pole
→ large uncertainty
2) use a realistic pion electroproduction model

- In asymptotic region, $F_\pi \to 8\pi\alpha_s f_\pi^2 Q^{-2}$

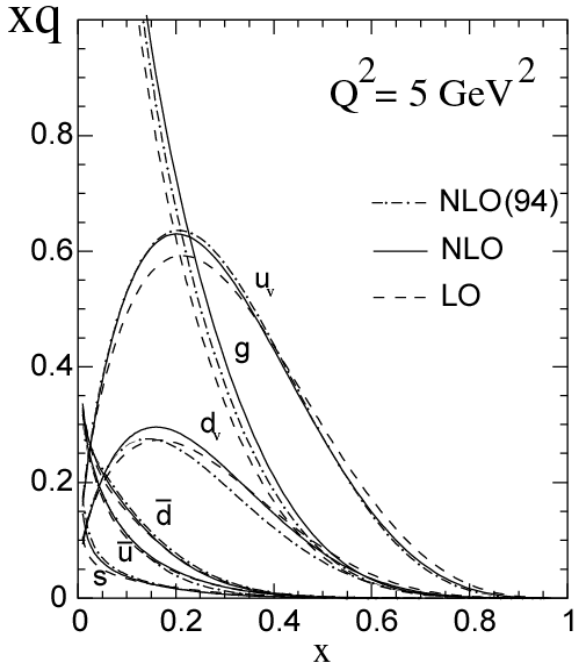
Hall C Experiment



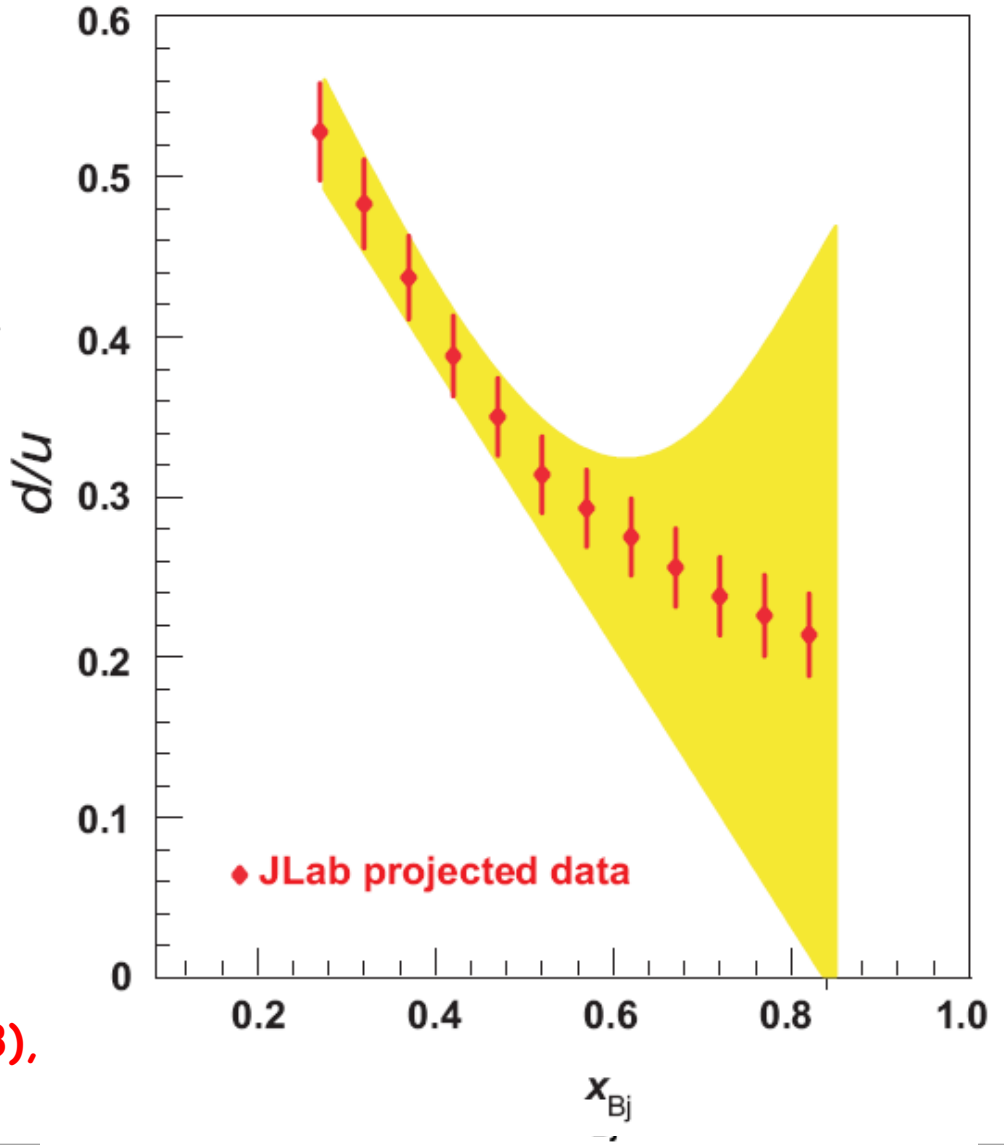
Measuring High-x Structure Functions with 12 GeV in Hall A

REQUIRES:

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

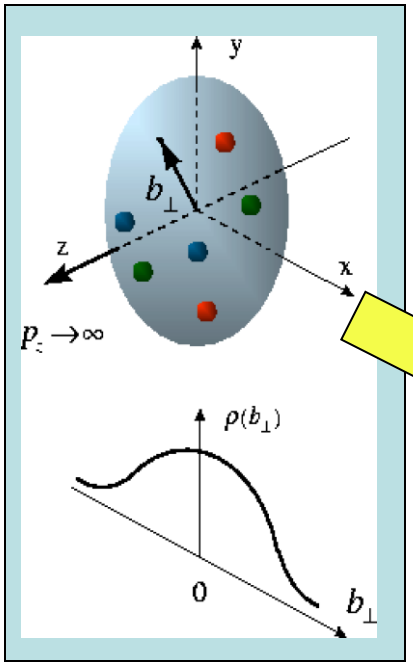


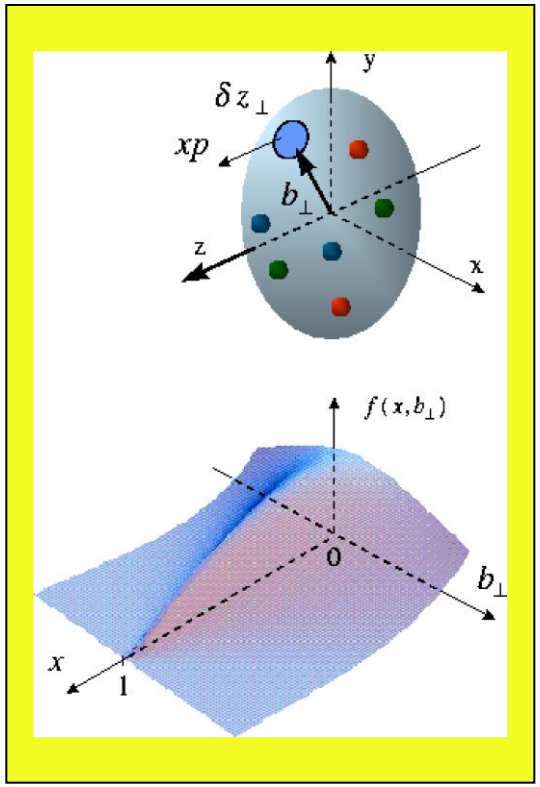
12 GeV will access the regime (x > 0.3), where valence quarks dominate

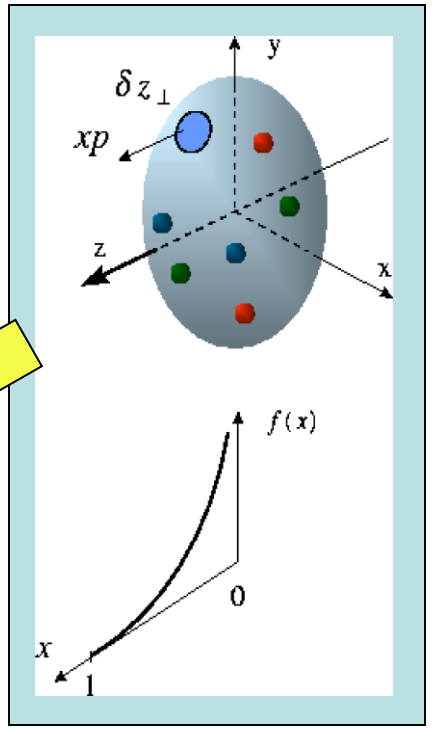


Generalized Parton Distributions (GPDs)

X. Ji, D. Mueller, A. Radyushkin (1994-1997)





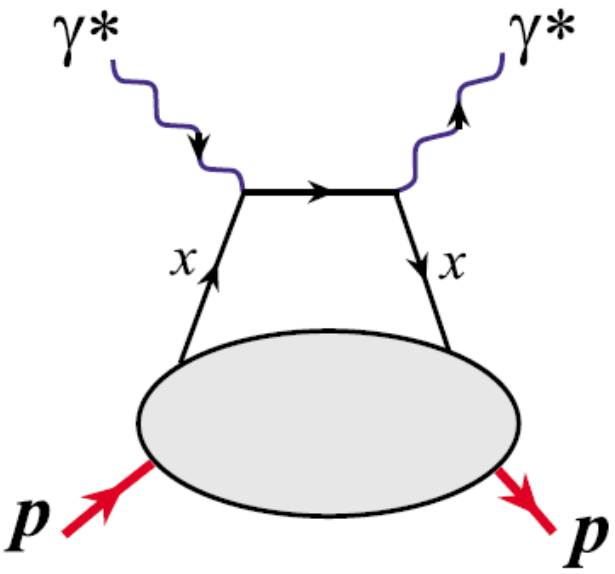


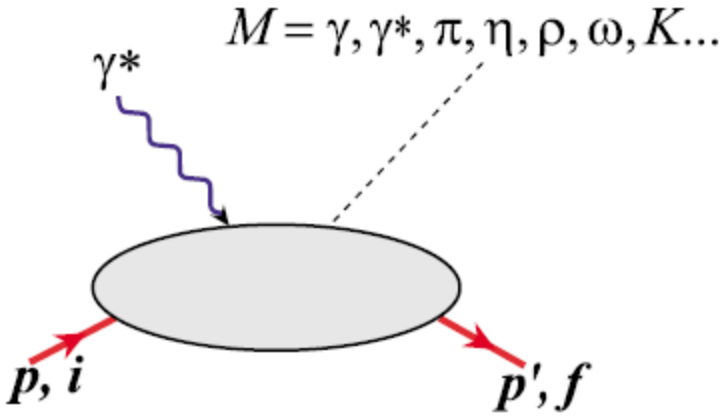
Proton form factors, transverse charge & current densities

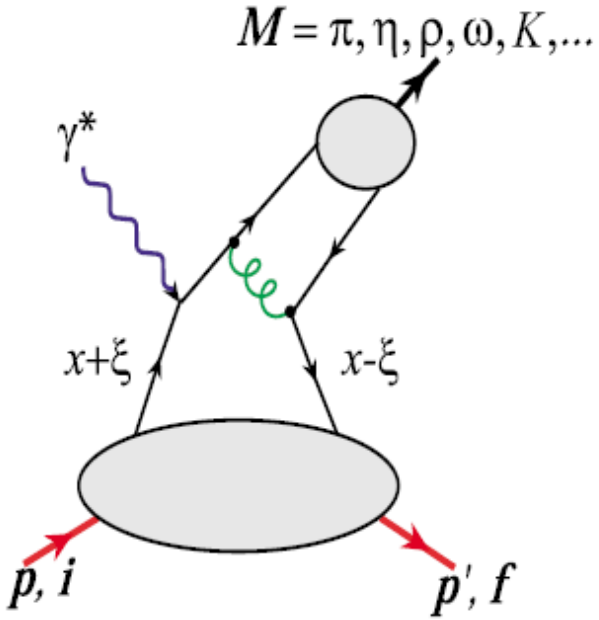
Correlated quark momentum and helicity distributions in transverse space - GPDs

Structure functions, quark longitudinal momentum & helicity distributions

Deep Inelastic and Deep Exclusive Scattering







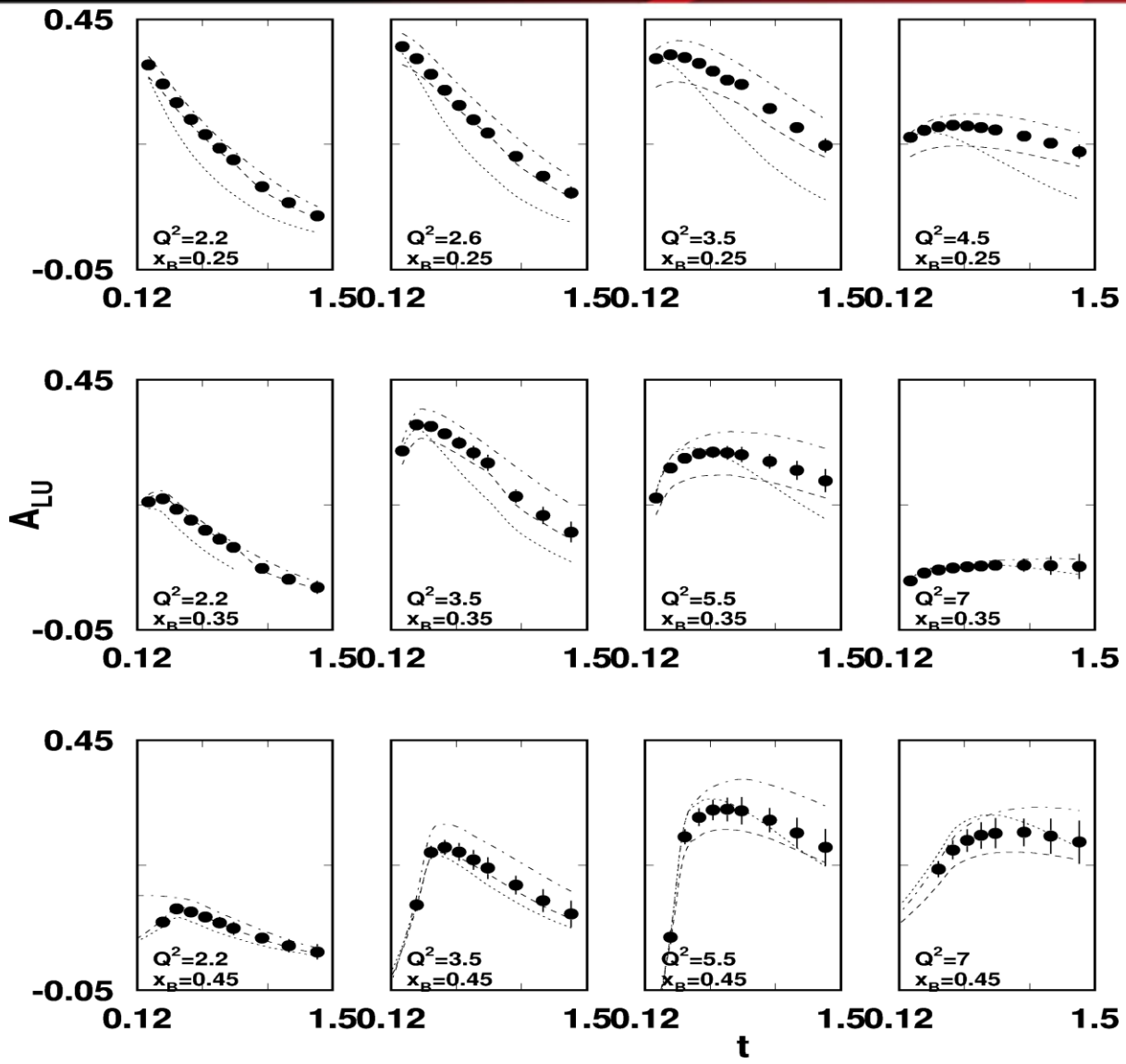
CLAS12 - DVCS/BH Beam Asymmetry

$\vec{e}\,p \longrightarrow epγ$

E = 11 GeV

Selected Kinematics

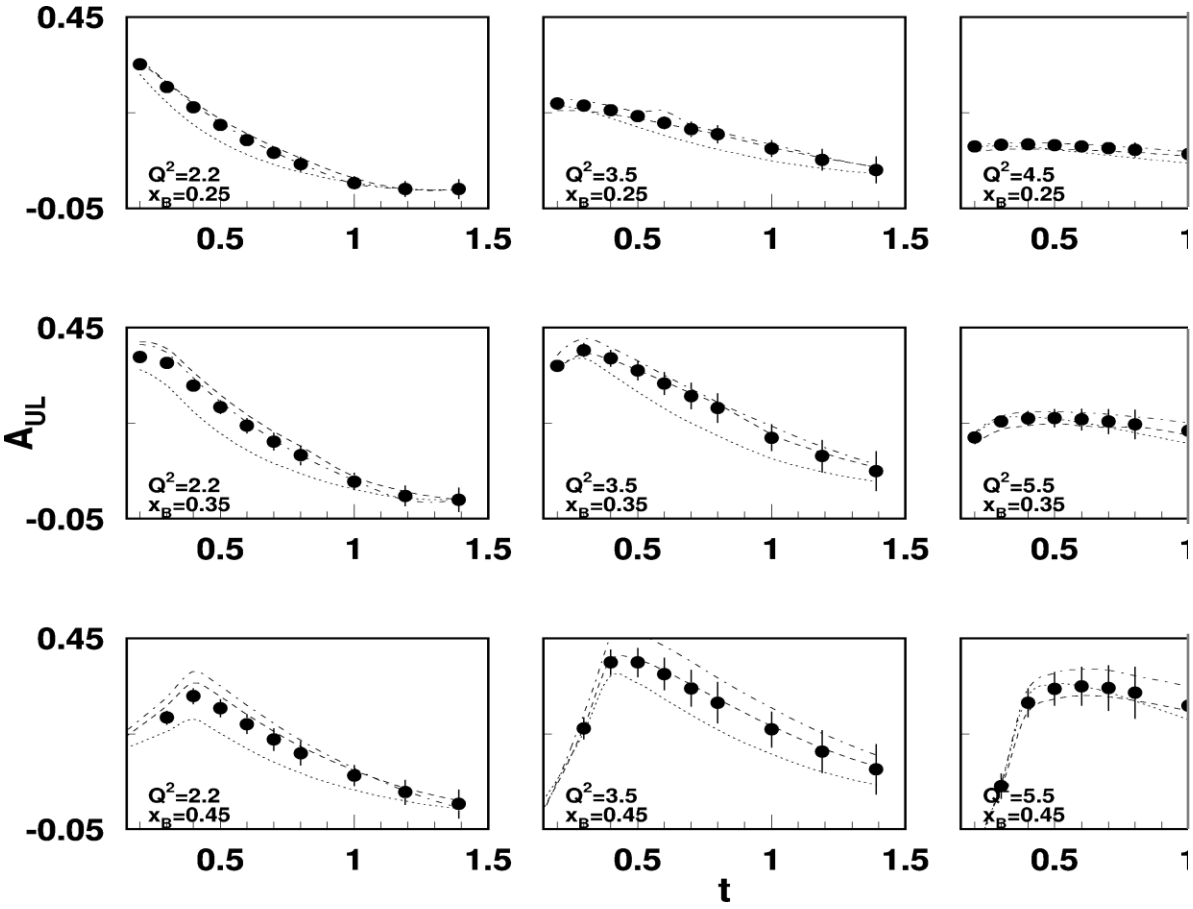
L = $2x10^{35}$
T = 2000 hrs
ΔQ^2 = 1 GeV^2
Δx = 0.05



CLAS12 - DVCS/BH Target Asymmetry

$\vec{e}\,\vec{p} \longrightarrow ep\gamma$

E = 11 GeV

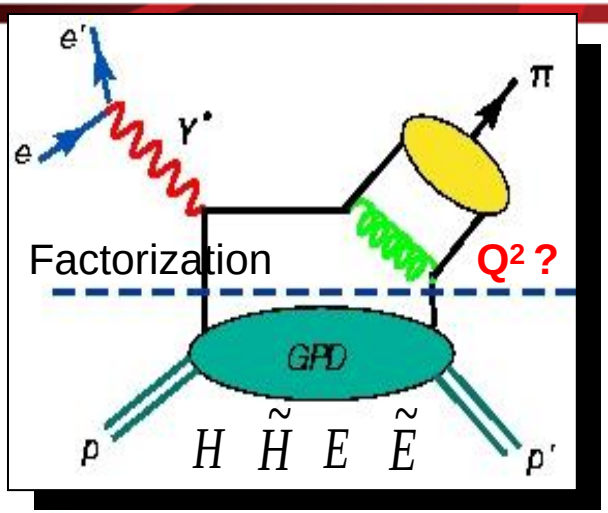


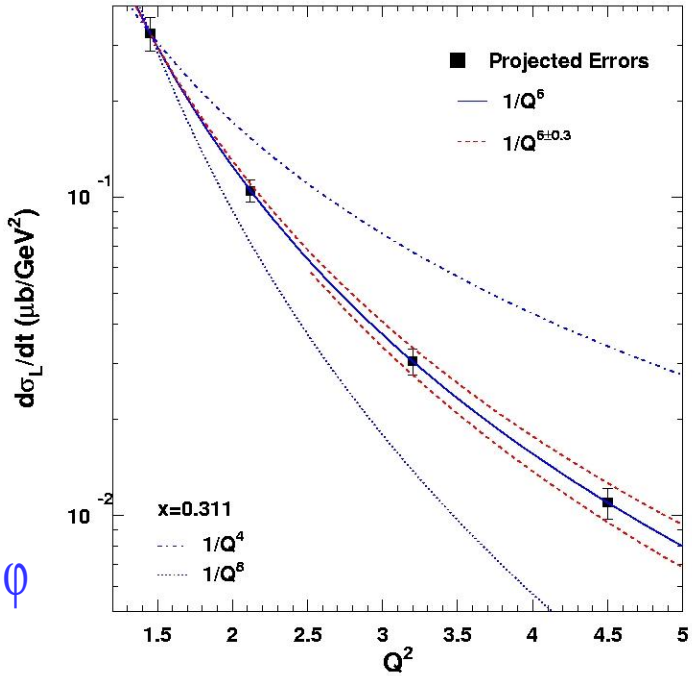
L = $2x10^{35}$
T = 2000 hrs
$\Delta Q^2 = 1 GeV^2$
$\Delta x = 0.05$

Selected Kinematics

Tests of the Handbag Dominance in Hall C

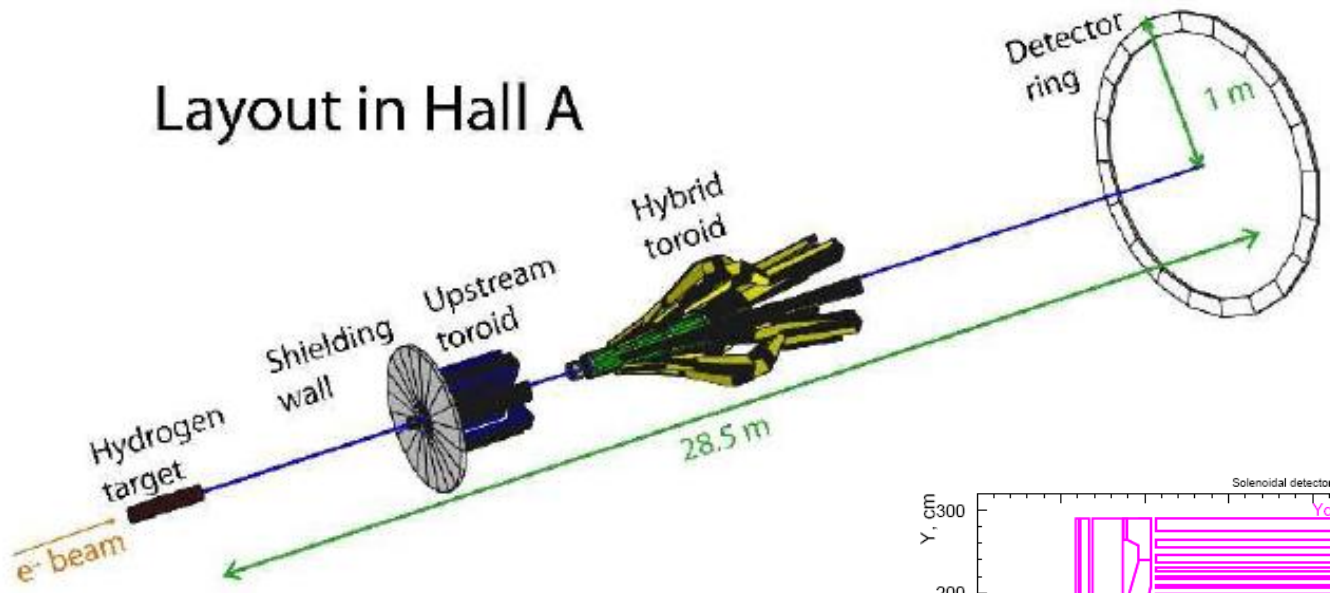
- To study the combined spatial and momentum distributions, need to measure GPDs
  - But must demonstrate that the conditions for factorization apply!
- One of the most stringent tests of factorization is the Q^2 dependence of the π electroproduction cross section
  - **σ_L scales to leading order as Q^{-6}**
  - σ_T scales as Q^{-8}
  - As Q^2 becomes large: $\sigma_L >> \sigma_T$
- Factorization theorems for meson electroproduction have been proven rigorously only for longitudinal photons
  [Collins, Frankfurt, Strikman, 1997]



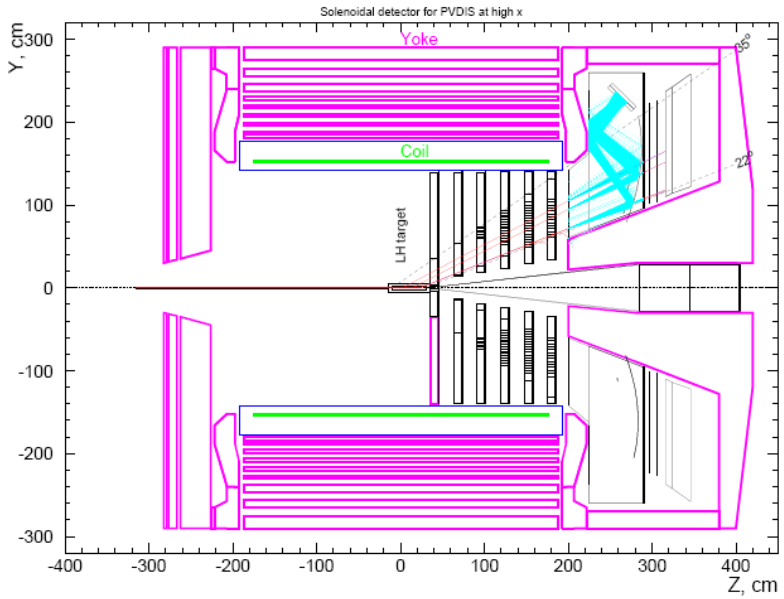


$$2\pi\frac{d\sigma}{dtd\varphi}=\frac{d\sigma_T}{dt}+\varepsilon\frac{d\sigma_L}{dt}+\sqrt{2\varepsilon(1+\varepsilon)}\frac{d\sigma_{LT}}{dt}\cos\varphi+\varepsilon\frac{d\sigma_{TT}}{dt}\cos 2\varphi$$

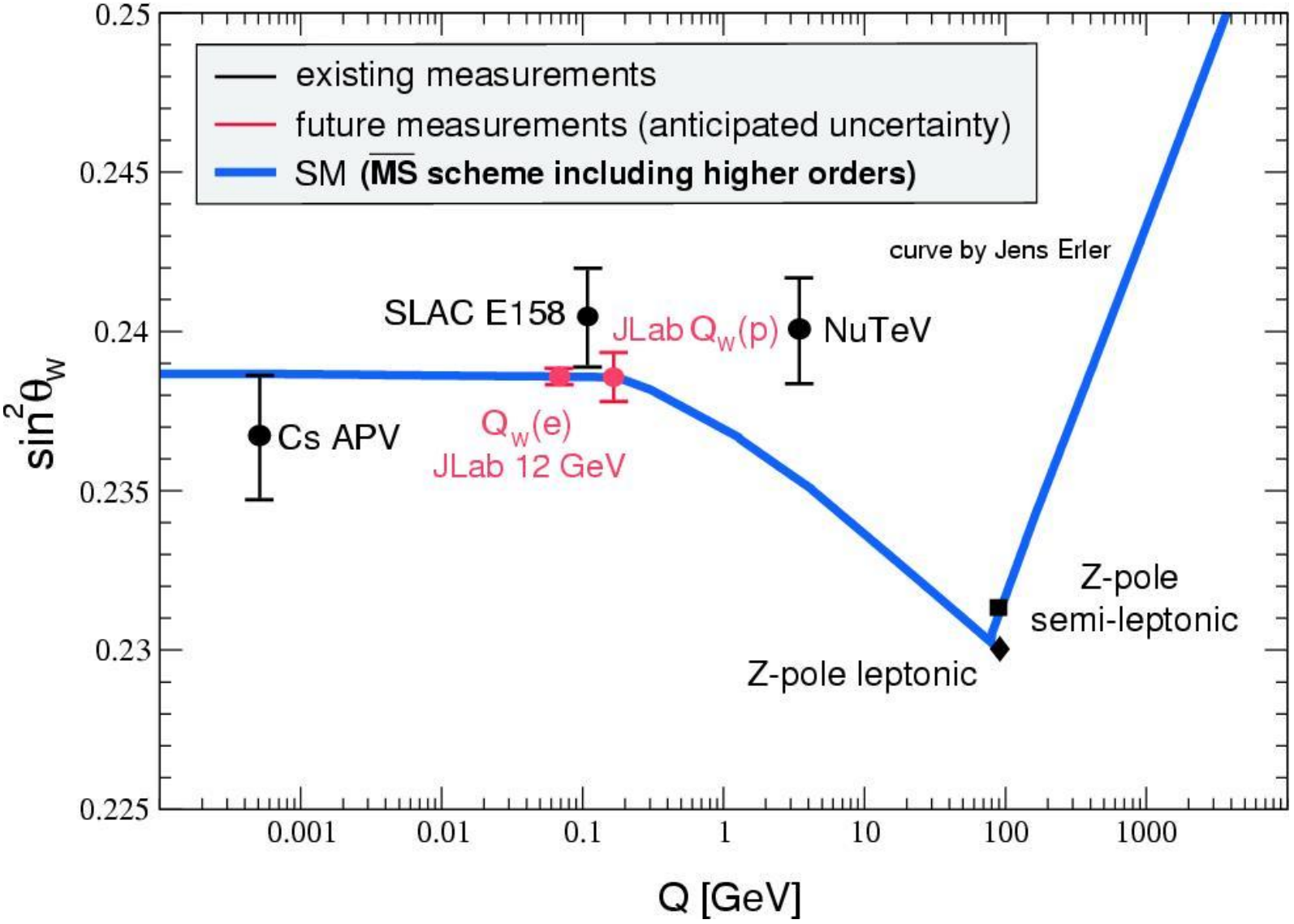
Møller & Deep Inelastic Scattering Parity Violation



- Dedicated Møller Experiment with toroids
- SoLID general purpose deep inelastic parity violating experiment with solenoid
  - Semi-Inclusive Program?



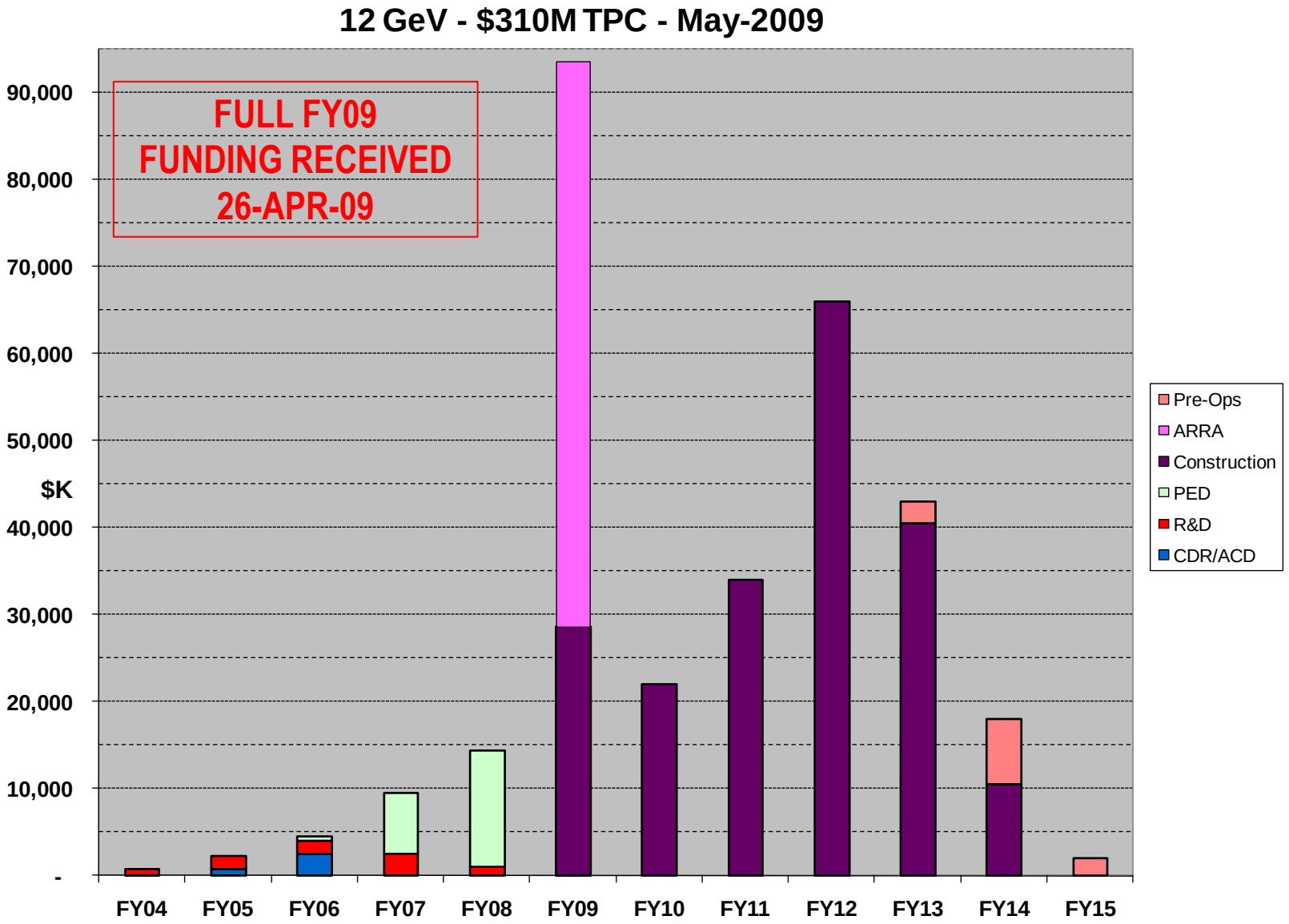
$\sin^2\theta_W$


existing measurements
future measurements (anticipated uncertainty)
SM (MS scheme including higher orders)
curve by Jens Erler
SLAC E158
JLab $Q_W(p)$
NuTeV
Cs APV
$Q_W(e)$
JLab 12 GeV
Z-pole
semi-leptonic
Z-pole leptonic
$\sin^2\theta_W$
Q [GeV]
0.25
0.245
0.24
0.235
0.23
0.225
0.001
0.01
0.1
1
10
100
1000

12 GeV Upgrade Project Milestones

Level and Number	Milestone Description	Baseline	Projected	Actual
1-1	CD-0 (Approve Mission Need)	Mar-04		Mar-04
1-2	CD-1 (Approve Preliminary Baseline Range)	Feb-06		Feb-06
1-3	CD-2 (Approve Performance Baseline)	Dec-07		Nov-07
1-4	CD-3 (Approve Start of Construction)	Sep-08		Sept-08
1-5	CD-4A (Approve *Accelerator* Project Completion and Start of Operations	Dec-14	Dec-14	
1-6	CD-4B (Approve *Experimental Equipment* Project Completion and Start of Operations)	Jun-15	Jun-15	
2-05	Design Review of Superconducting Magnets	Jul-08		May-08
2-14	Design of Conventional Facilities Completed	Sep-08		Sep-08
2-06	Award First Superconducting Magnet Contract	Jul-09		Jul-09
2-15	Ready for Equipment - CHL Addition (RFE)	Sep-10	Sep-10	
2-16	Ready for Equipment - Hall-D (RFE)	Oct-10	Oct-10	
2-10	Start Hall-D Installation	Nov-10	Nov-10	
2-01	Klystron Mass Production Authorization	Jun-11	Jun-11	

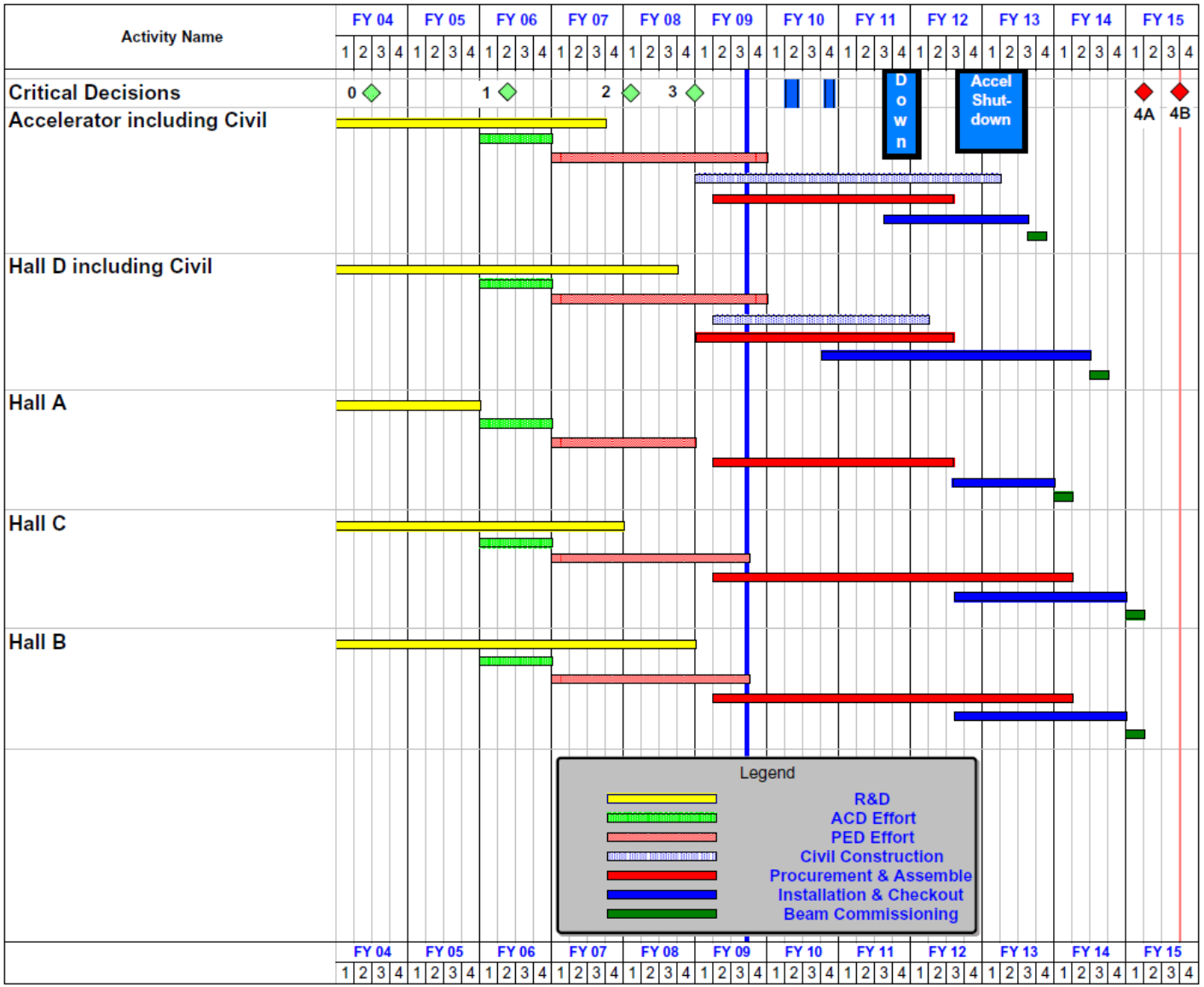
12 GeV - $310M TPC – May-2009



FY09 & 10 Major Procurement Effort

- 34 of 43 Major Procurements being worked - **~$75M Phased**
  - 31 Specifications complete and signed
  - 29 Solicitations issued
  - 25 Bids received - **~$65M**
    - 11 Awarded - **~$35M**
      - Hall D Barrel Cal Fibers
      - Civil CHL, Hall D, Hall D CM
      - SRF Waveguides, Nb, Cavity
      - Klystrons
      - 4m Dipole **(1st Stimulus)**, Conventional Quads
      - Hall C Q1
    - 2 Additional Vendor selected **~$10M**
      - CHL Coldbox
      - SRF Vacuum Valves **(at DOE)**

12 GeV SCHEDULE



Exploring the Nature of Matter

12 GeV Upgrade Project