The JLab Hall A experimental program at 12 GeV

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INT Workshop

Jefferson Laboratory upgrade to 12 GeV

Talk outline

- Hall A general overview
- Recent results and 6 GeV program
- The 12 GeV upgrade in Hall A
- Solenoidal detector
- Conclusion

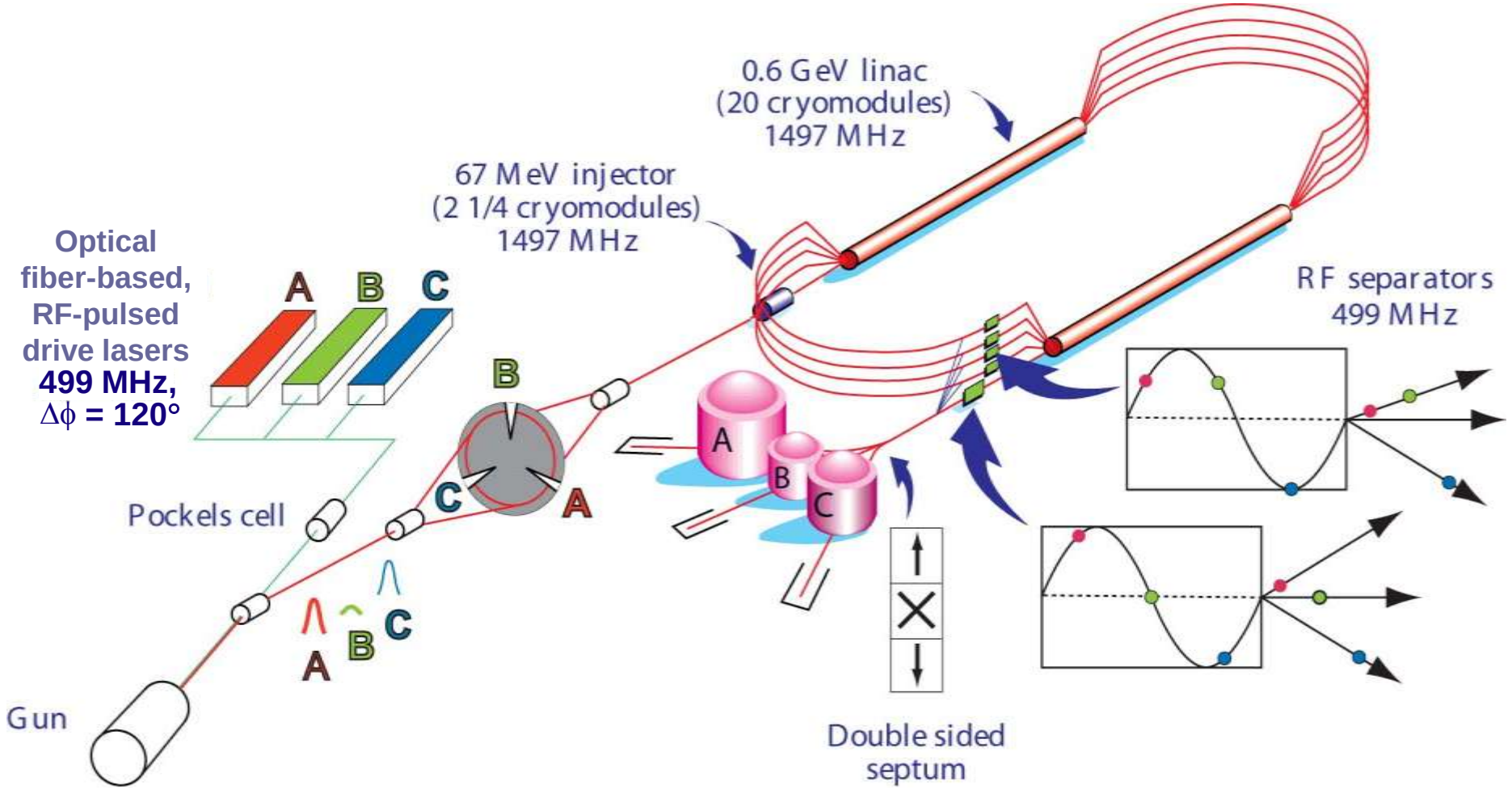
General overview of Hall A at Jefferson Laboratory

Hall A physics topics

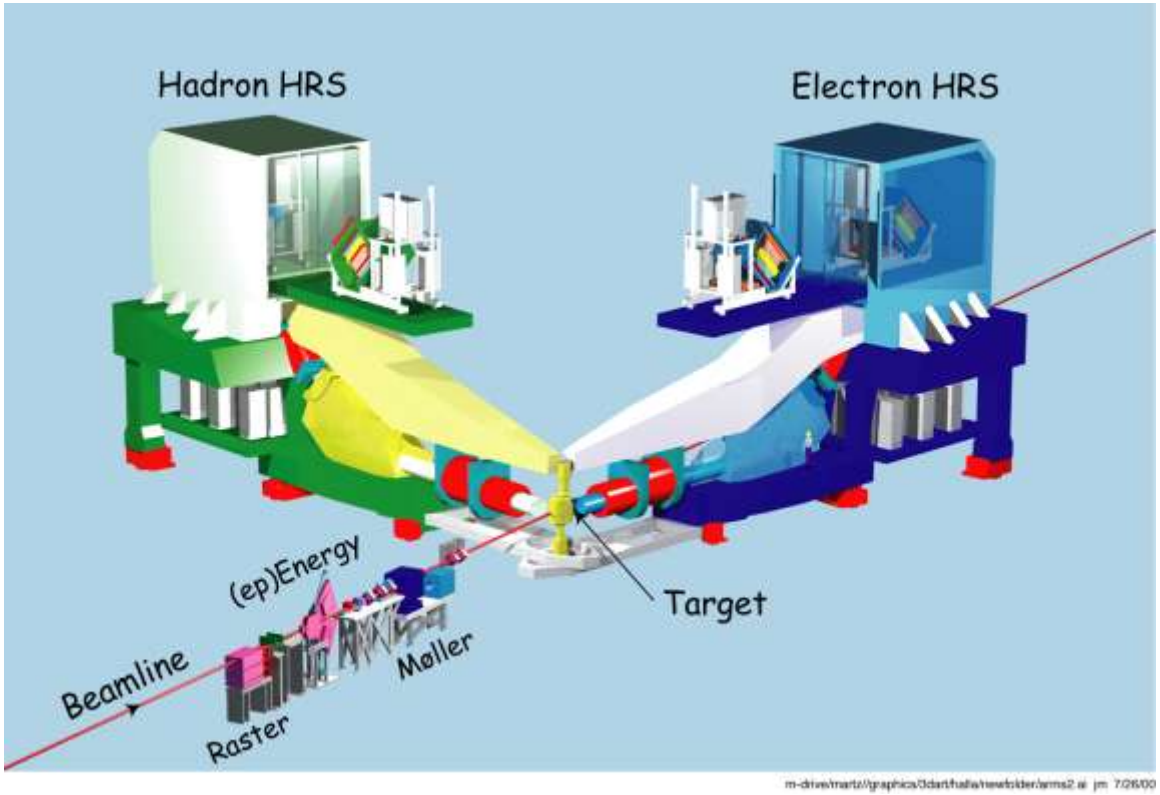
Study of nuclei at different scales dependending on momentum transfer

- Few-Body Systems and form factors
- The Structure of the Nucleus
- The Structure of the Nucleon

Continuous Electron Beam Accelerator Facility



Hall A spectrometers layout



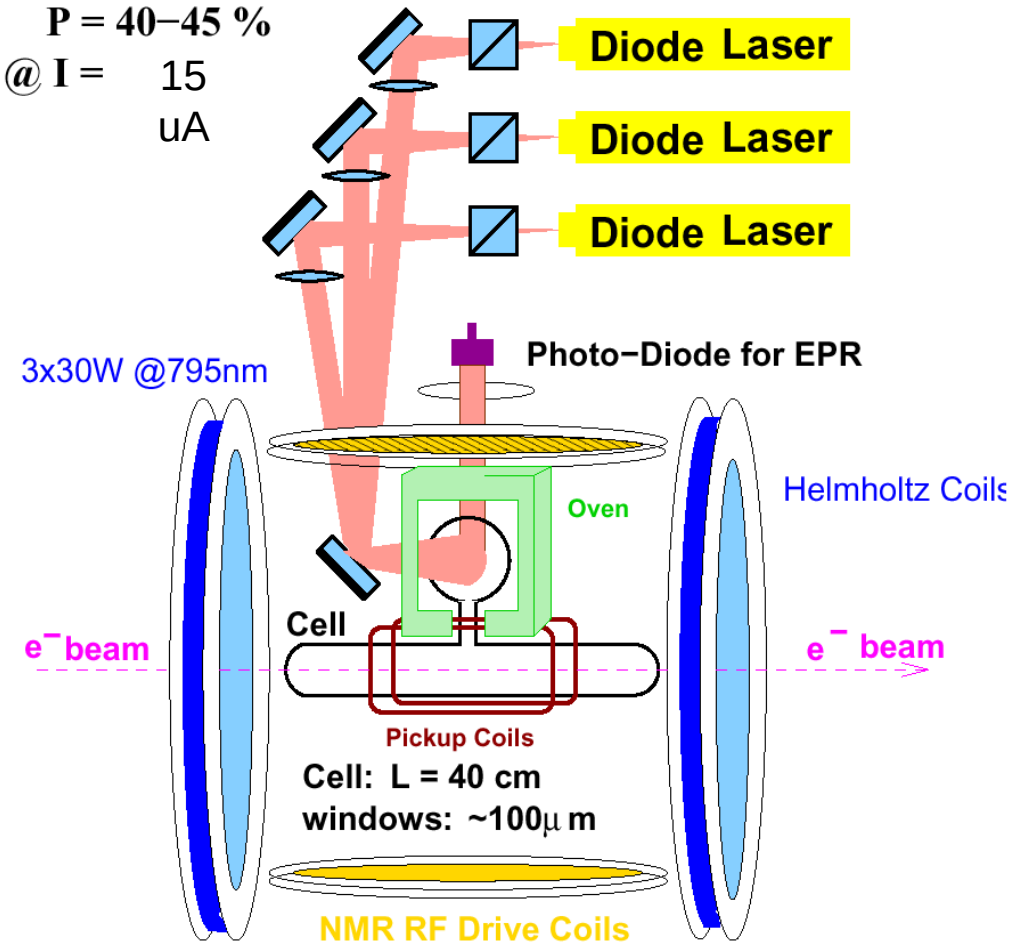
HRS Spectrometers	FWHM
Max. momentum	4.2 GeV/c
Momentum acceptance	± 4.5%
Momentum resolution	1.10^{-4}
Angular acceptance	6 msr
Angular resolution	1 mrad
Vertex acceptance	± 5 cm
Vertex reconstruction	1 mm

Focal-Plane Detectors

- Scintillator trigger
- MWDC tracking
- Pb-glass preshower/shower
- Focal plane polarimeter

- Gas Cherenkov
- Aerogel Cherenkovs
- Ring Imaging Cherenkov

Hall A polarized ^{3}He target

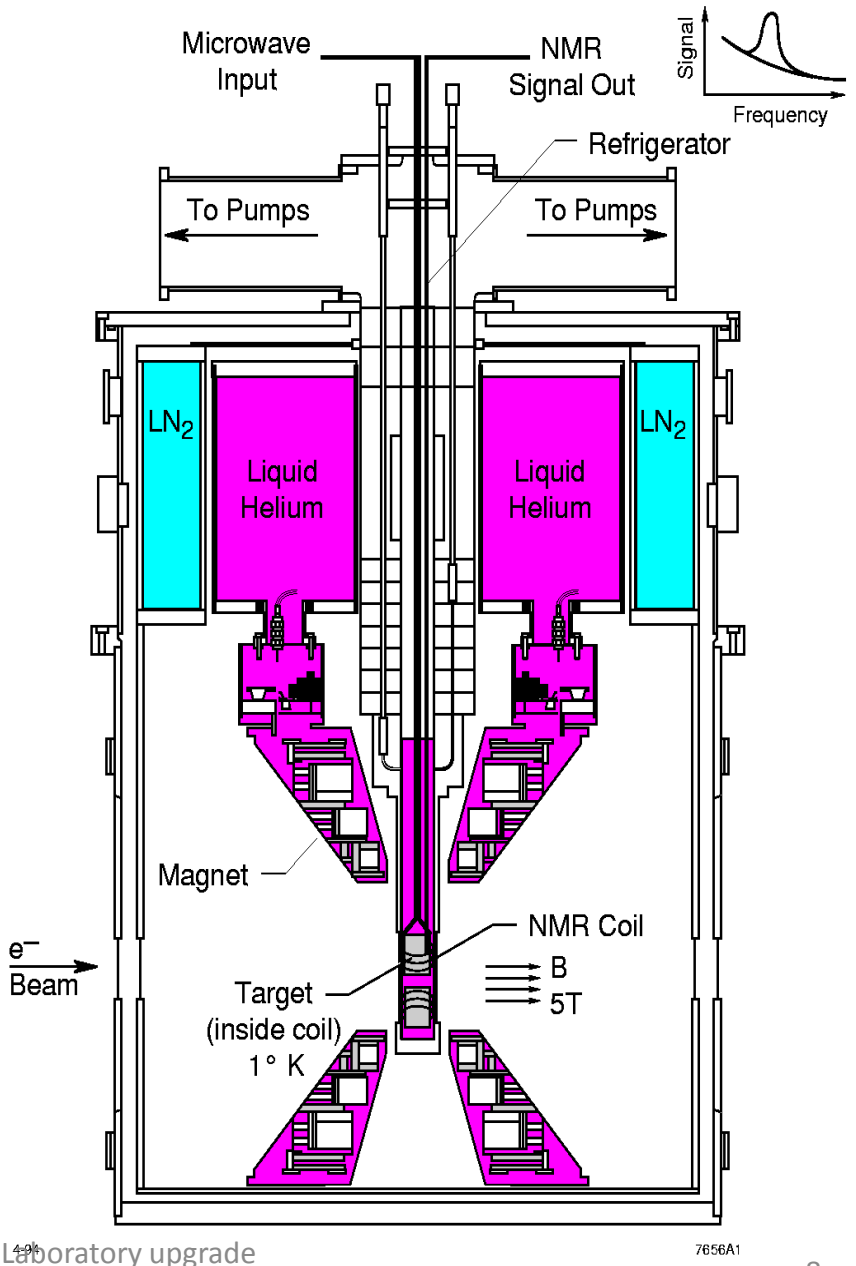


- ✓longitudinal, transverse and vertical
- ✓Luminosity=10^{36} (1/s) (highest in the world)
- ✓High in-beam polarization > 65%
- ✓Effective polarized neutron target
- ✓12 completed experiments
  1 are currently running
  6 approved with 12 GeV (A/C)

Hall B/C Polarized proton/deuteron target

- Polarized NH_3/ND_3 targets
- Dynamical Nuclear Polarization

- In-beam average polarization
  - 70-90% for p
  - 30-40% for d
- Luminosity up to ~ 10^{35} (Hall C)
  - ~ 10^{34} (Hall B)



Large acceptance detectors

- Big Bite
  - electron package
  - hadron package
- Neutron detectors
  - HAND
  - Big HAND
- Calorimeters
  - DVCS lead fluoride calorimeter
  - Big Cal

Recent results and upcoming 6 GeV experiments

Highlights of recent experiments

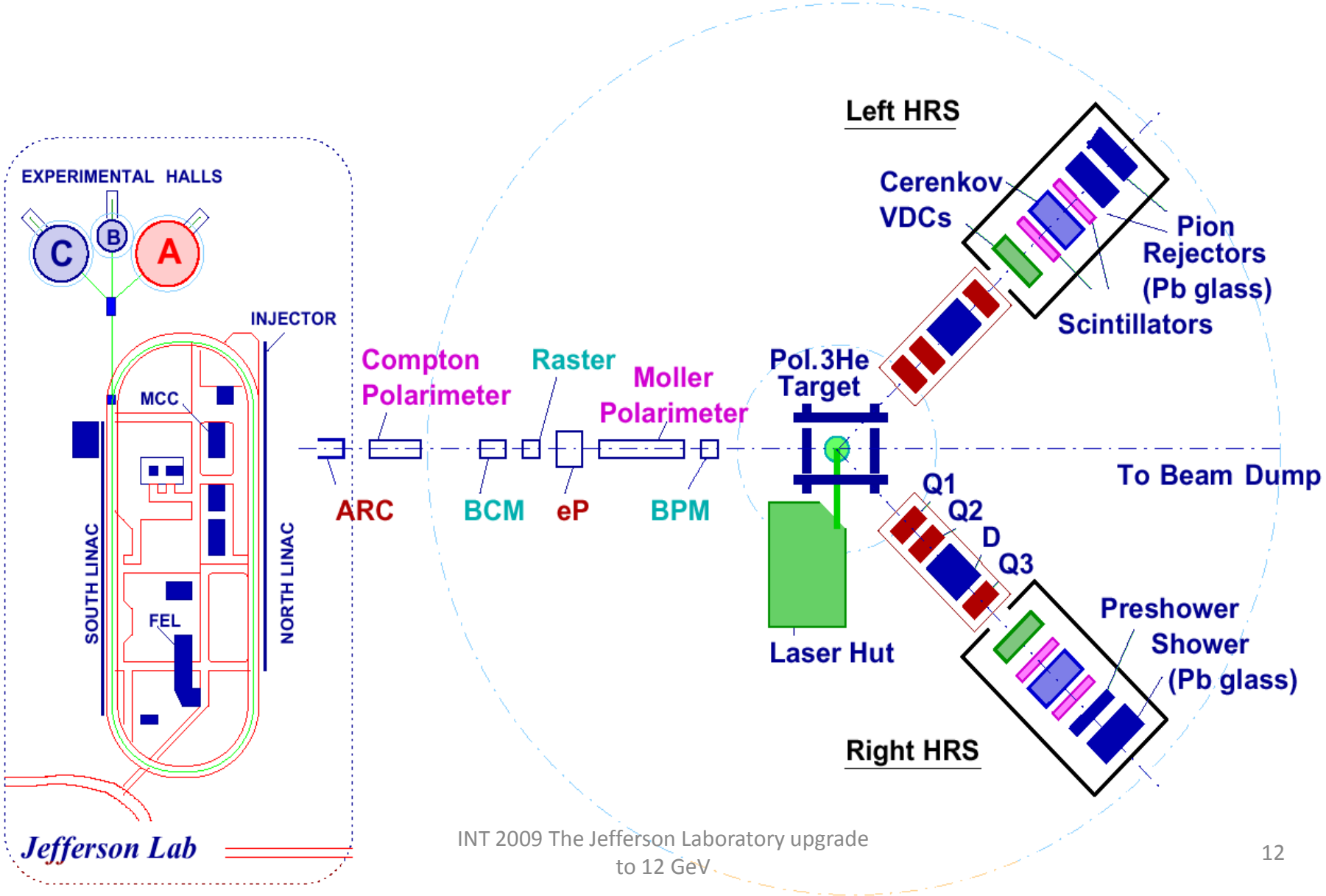
Selection of recent or upcoming experiments for different information on nuclei
Form factors and radius measurements

- Recent results
  - G_{ep} and G_{en} (Bogdan Wojtsekowski's talk)
  - **A_{1n}**
  - **Short Range Correlations**
  - **Deeply Virtual Scattering in Hall A**

- Recently completed
  - **Transversity**

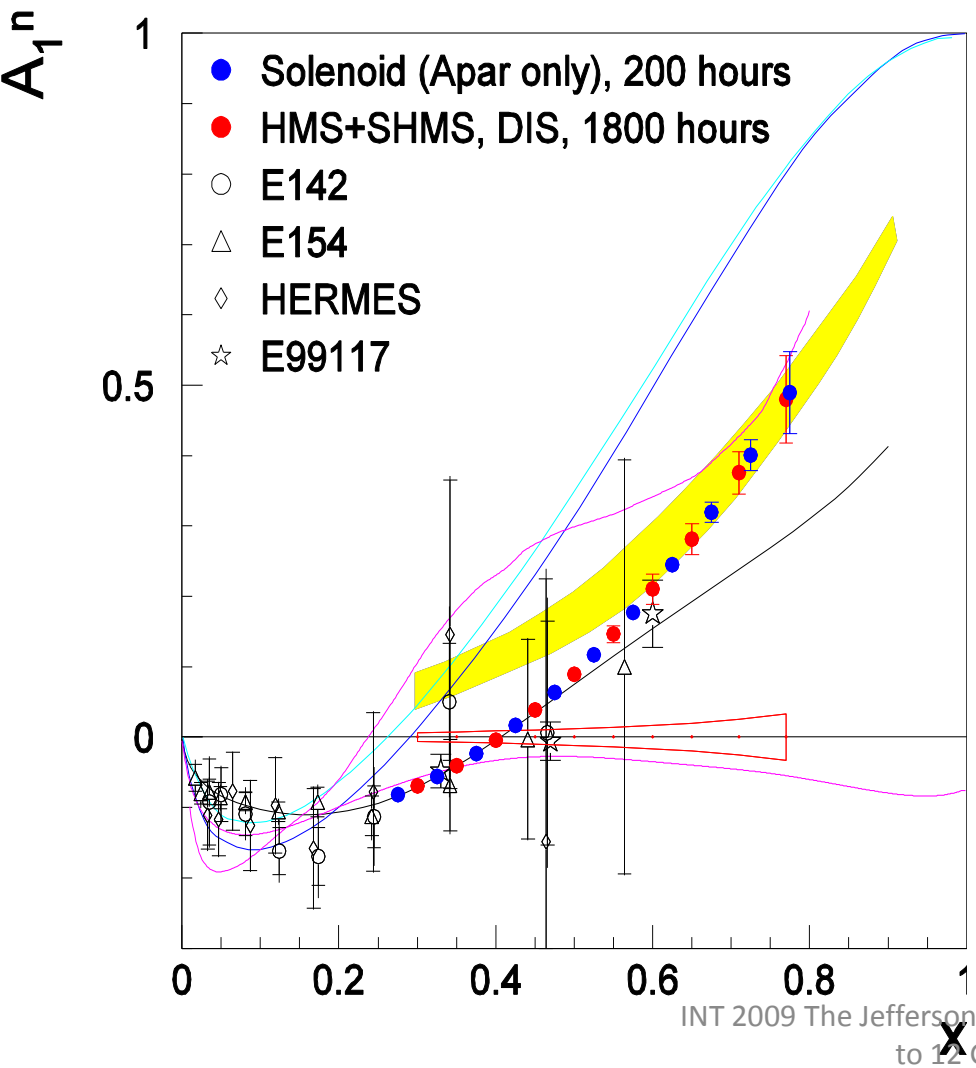
- Upcoming 6 GeV experiments
  - Happex III, **DIS Parity**, Lead Parity experiment PREX
  - DVCS
  - Short range correlation
  - g_{2p}
  - Hypernuclear

Jefferson Lab Hall A Experimental Setup for inclusive polarized n (^{3}He) Experiments

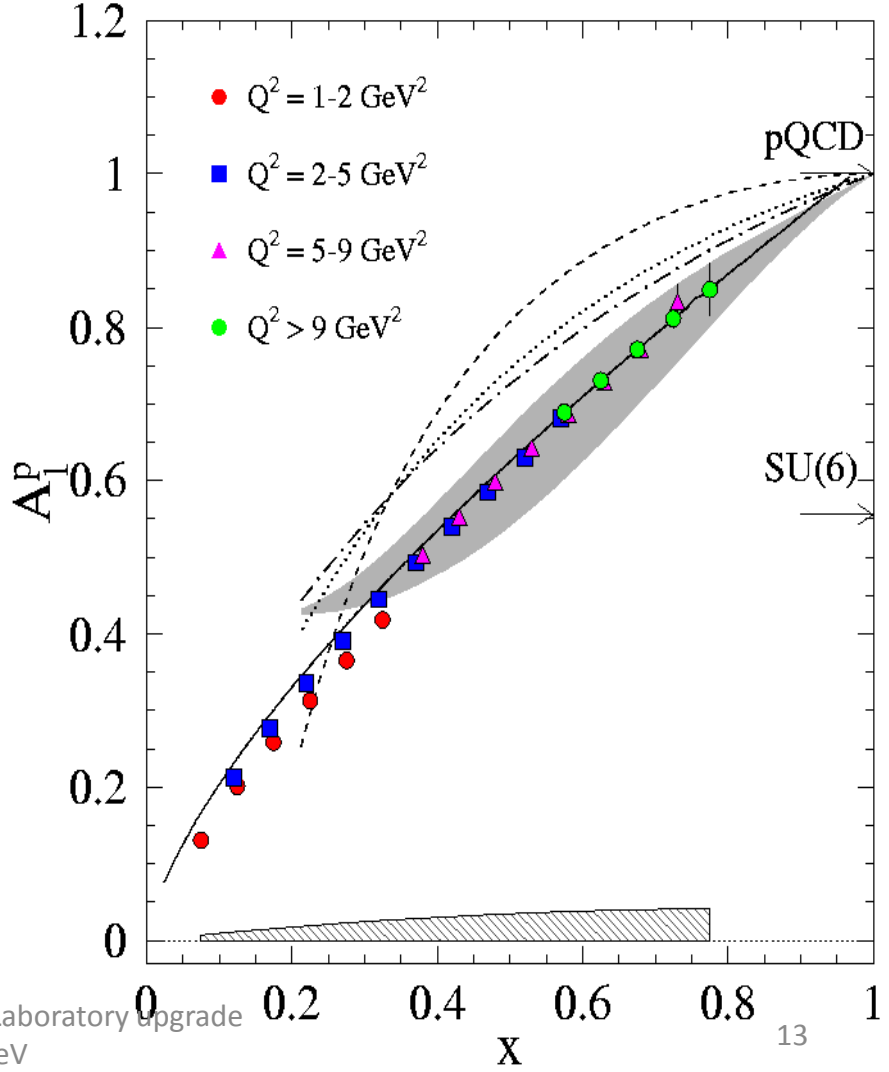


Projections for JLab at 11 GeV

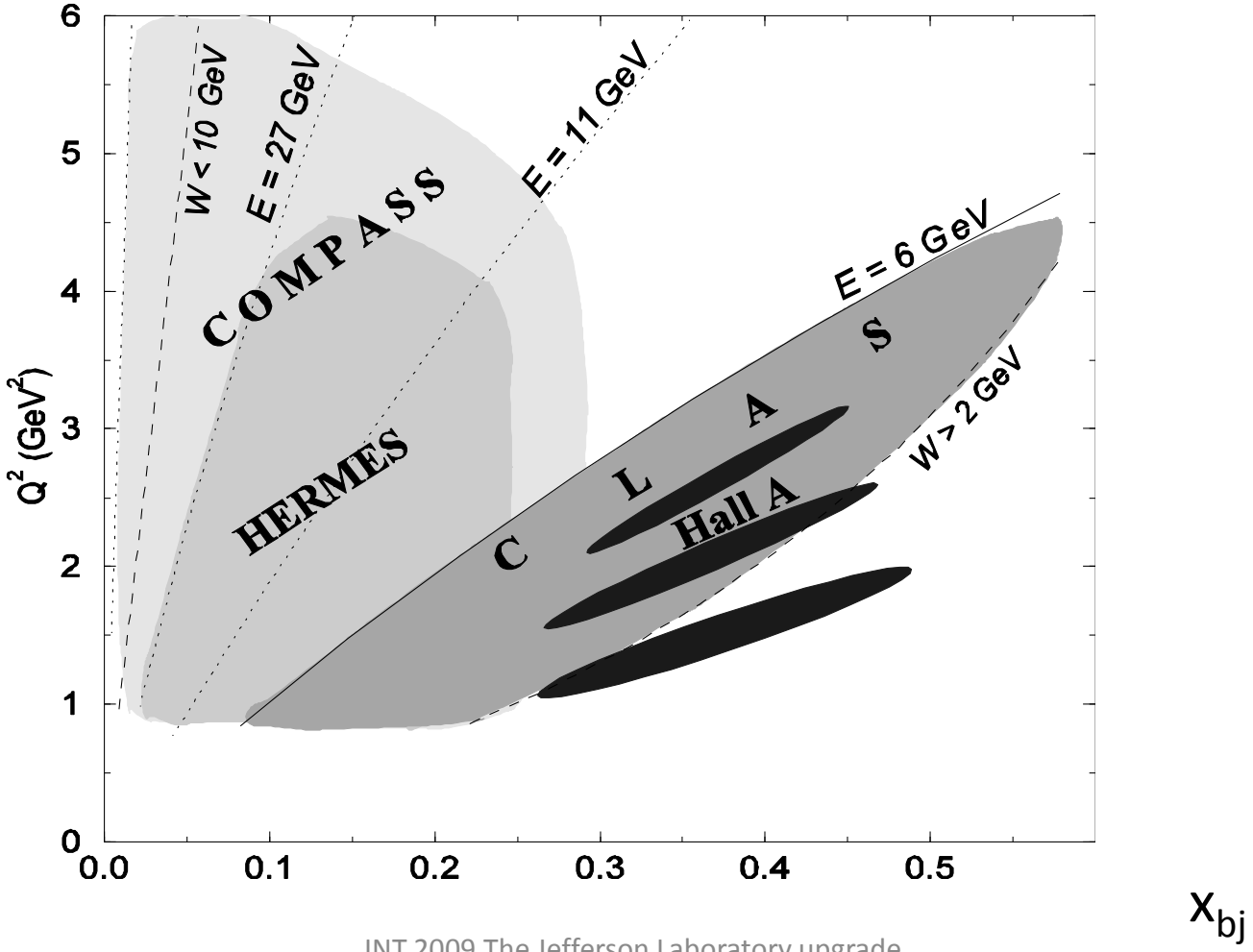
A_1^n at 11 GeV



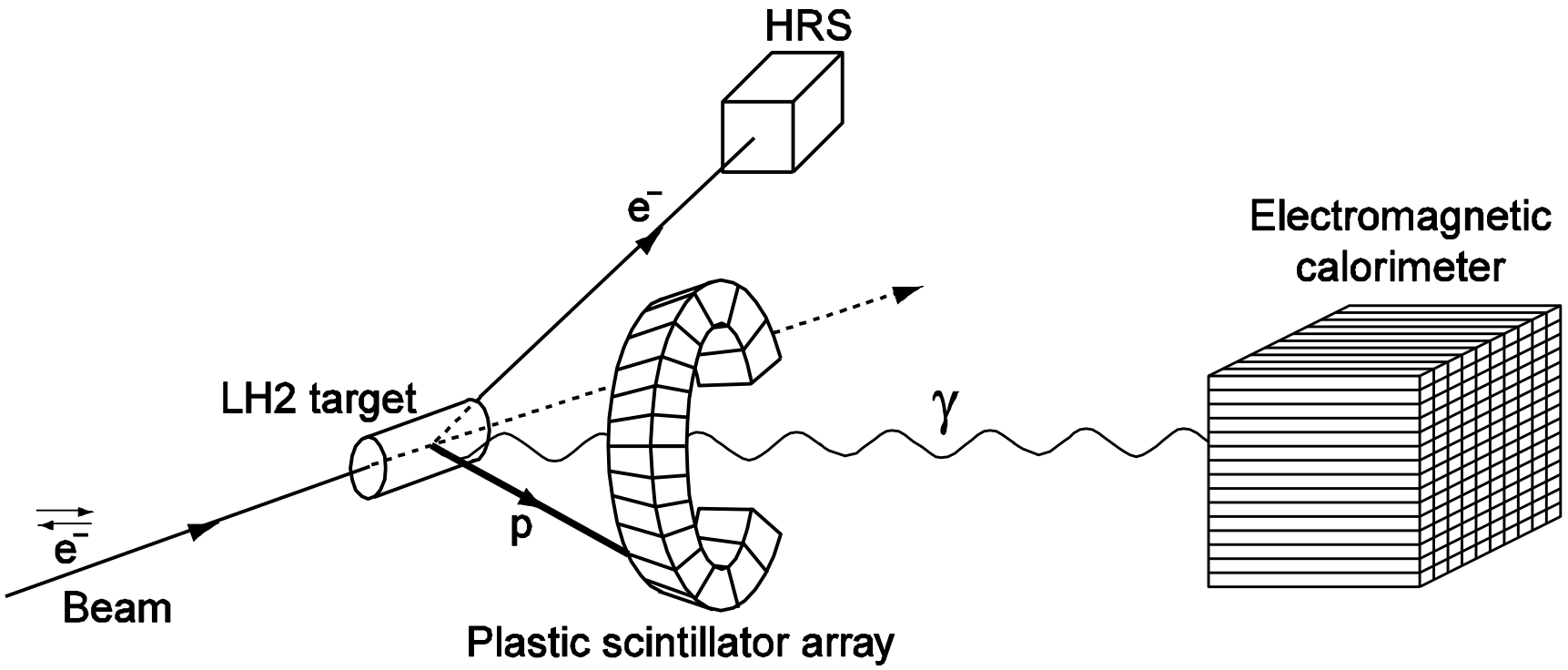
A_1^p at 11 GeV



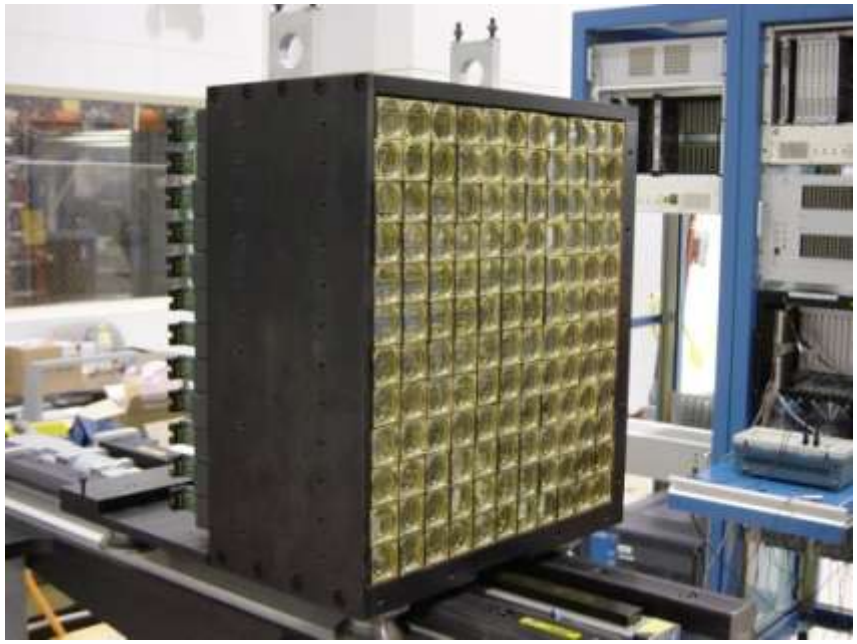
DVCS kinematical coverage



DVCS Experimental setup



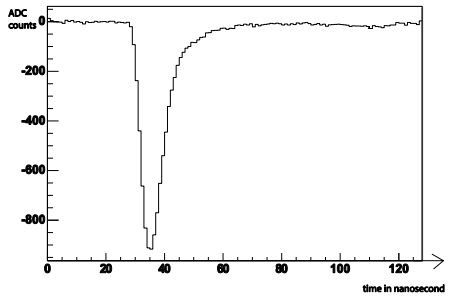
Electromagnetic calorimeter



11x12 = 132 blocks
3cmx3cmx18.6cm
110 cm from the target
1msr per block

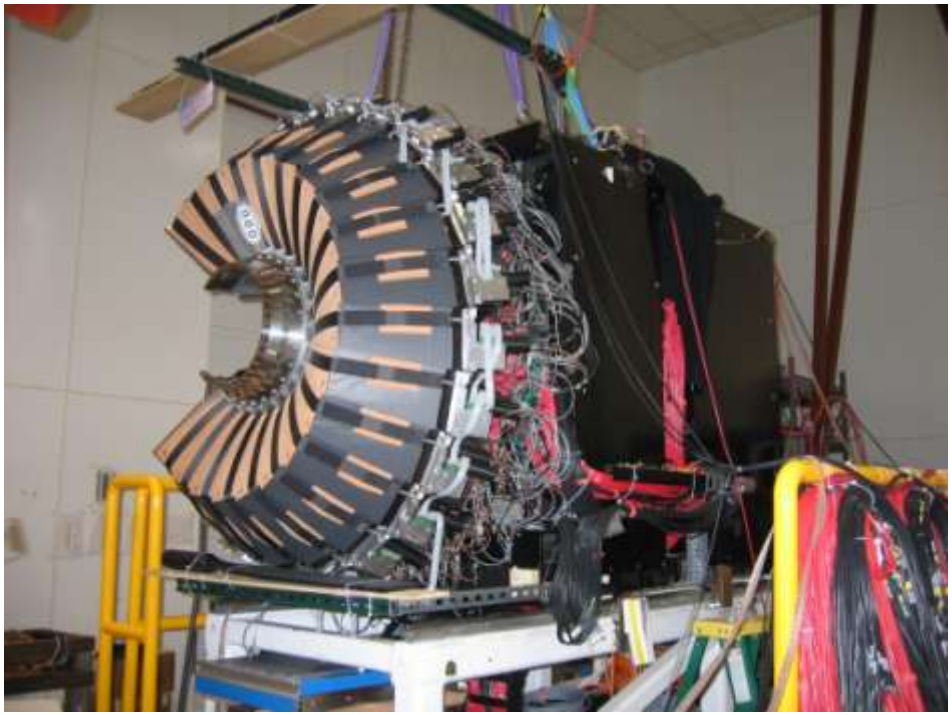
- Lead fluoride
  - Pure Cerenkov : not sensitive to charged hadronic background
  - density 7.77 g.cm^3
  - X_0=0.93 cm length=20X_0
    Molière radius = 2.2 cm
  - Good radiation hardness

- PMT R7700 Hamamatsu
  - 8 stages
  - Gain : 10^4
  - Rise time 2 ns
  - FWHM 6 ns



- 1 Photoelectron per MeV,
- Energy resolution 4 .2GeV : 2.4 %
- Position resolution: 2 mm

Proton Array



20x5 = 100 blocks
EJ-200 plastic scintillator

Azimutal coverage

270 degrees

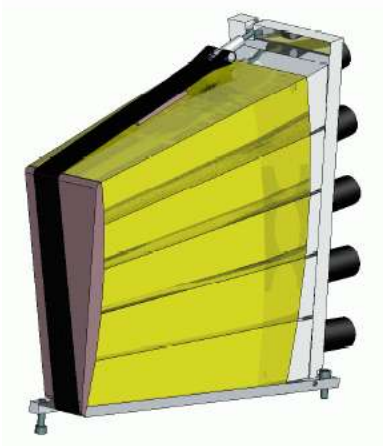
Polar coverage

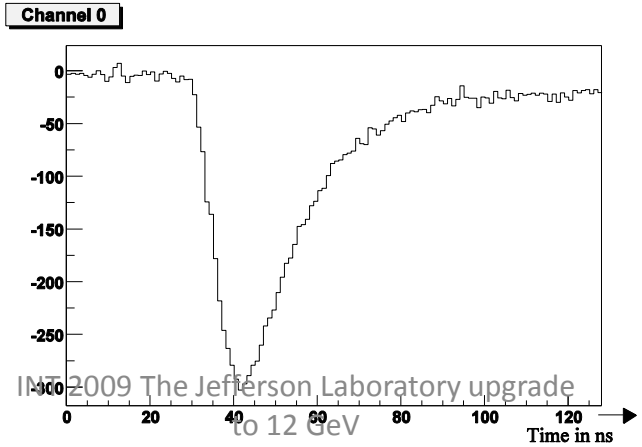
18 to 38 degrees

60 cm from the target

0.7 msrd module

Photonis XP2972





PMT signal from proton array XP2972

FWHM 20 ns

Rise time 7 ns

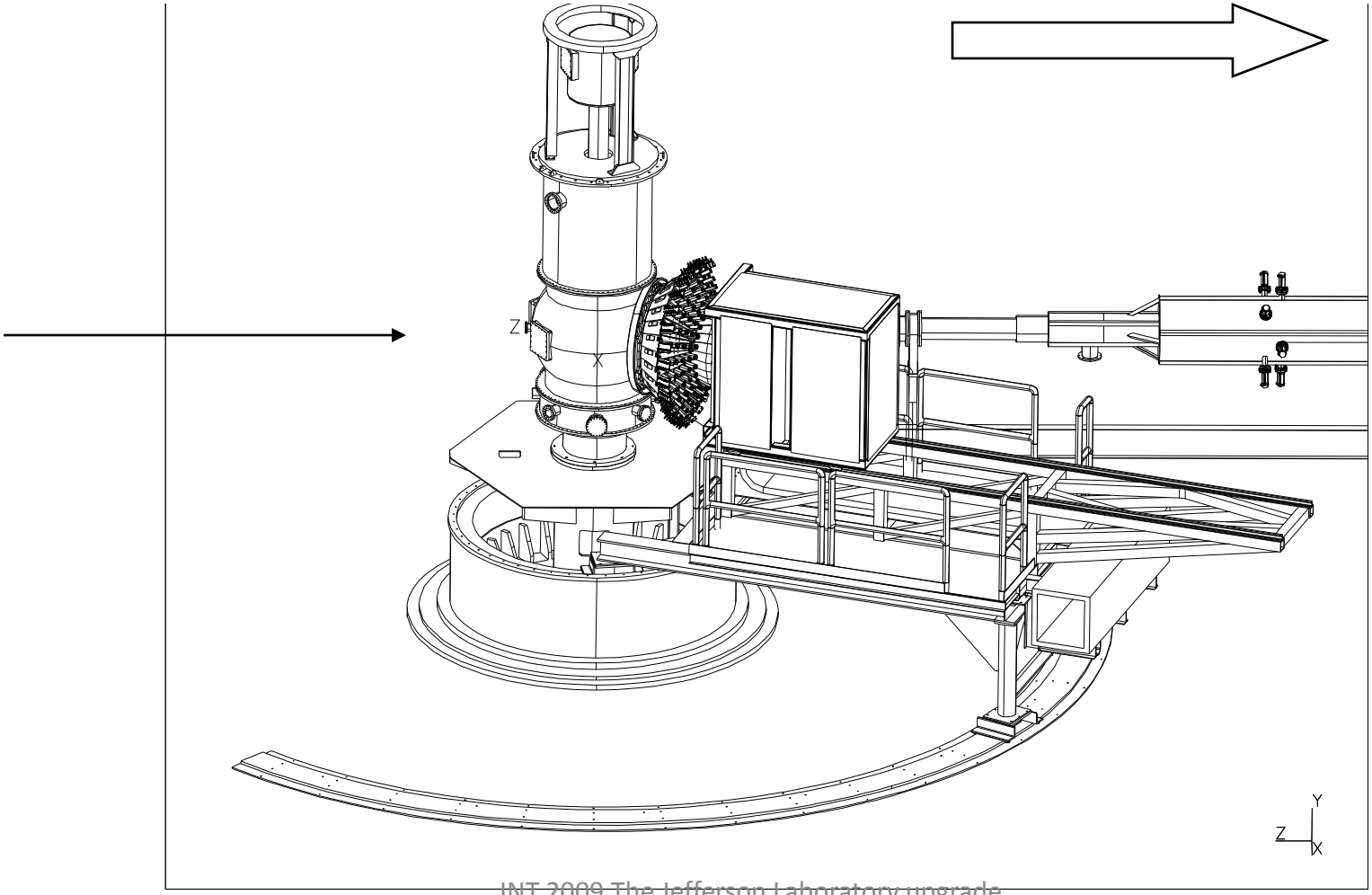
Cross sections measurement

Electron helicity dependent cross sections of photon electroproduction using Jefferson Laboratory polarized electron beam

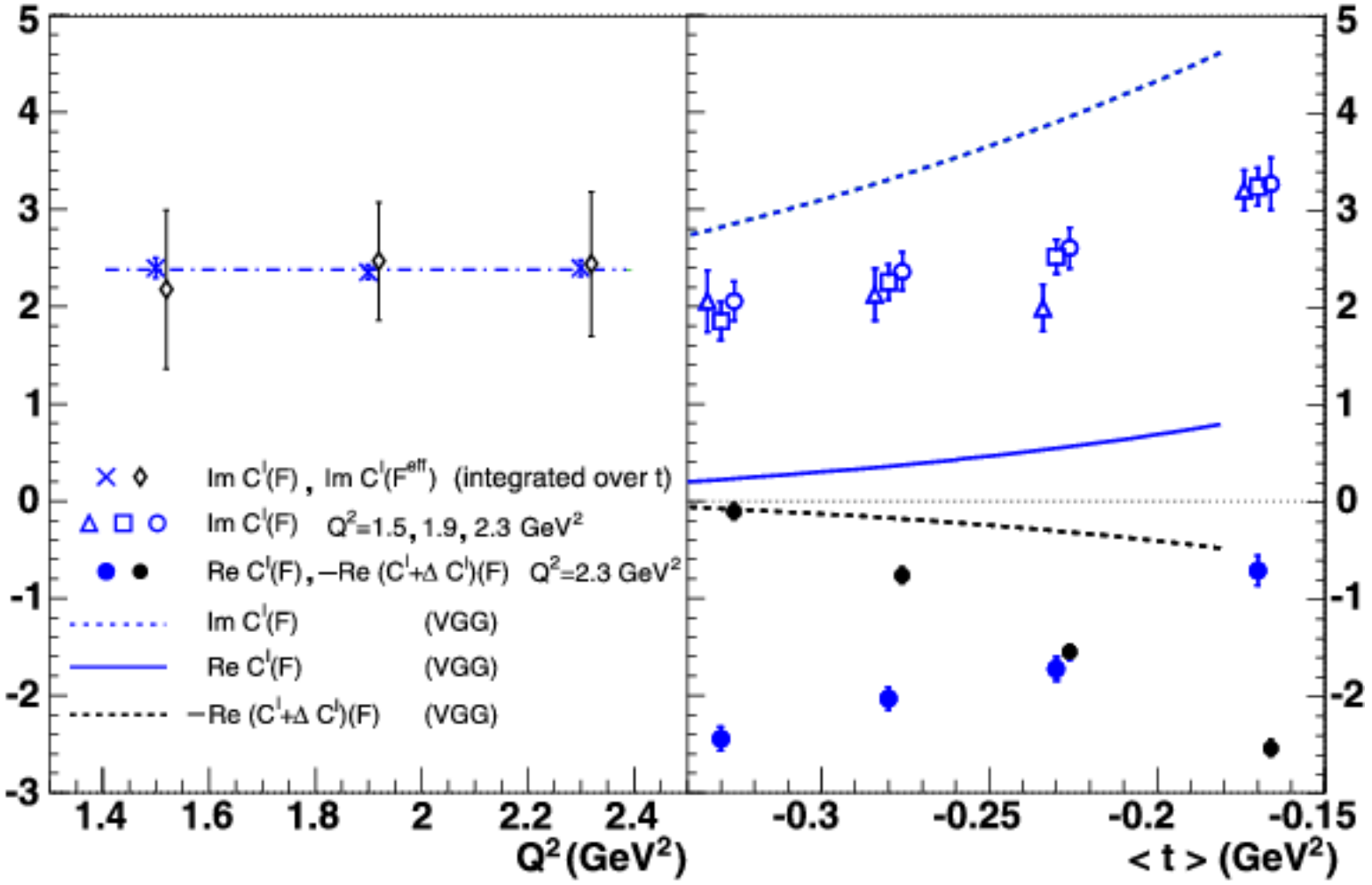
$$d^5\vec{\sigma} - d^5\overleftarrow{\sigma} \propto BH \cdot \mathrm{Im}(DVCS) + (\overrightarrow{DVCS}^2 - \overleftarrow{DVCS}^2)$$

$$d^5\vec{\sigma} + d^5\overleftarrow{\sigma} \propto BH^2 + \mathrm{Re}(BH \cdot DVCS) + DVCS^2$$

Final setup

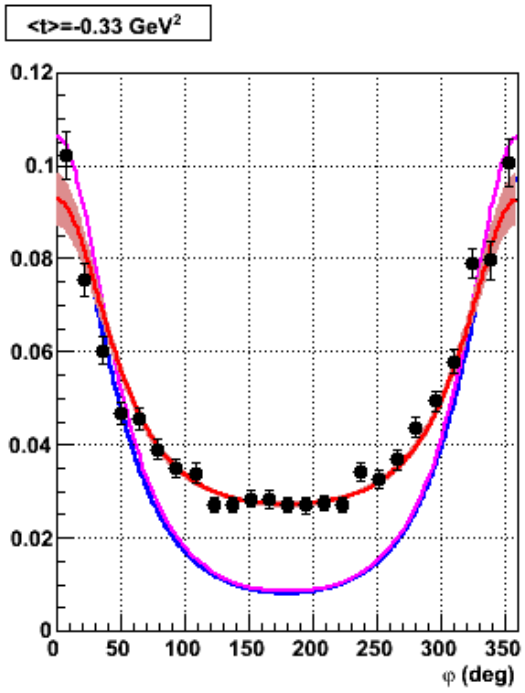


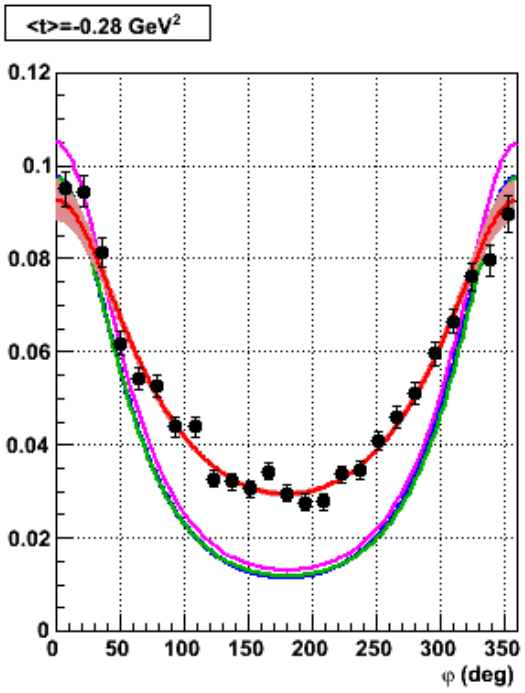
DVCS coefficients from difference of cross sections Q^2 dependence

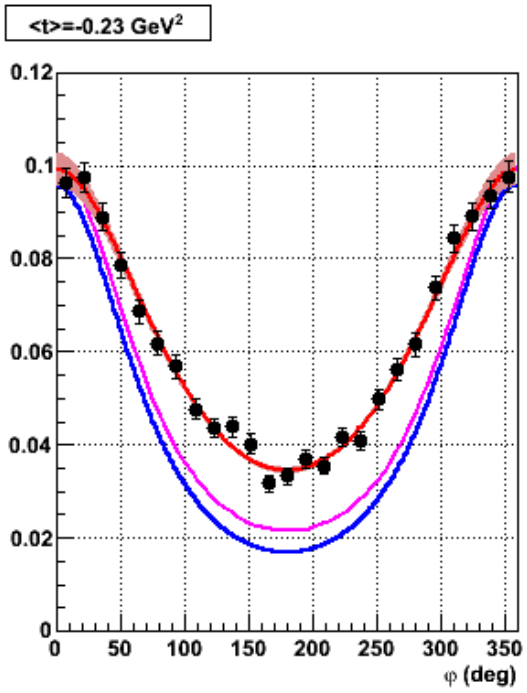


DVCS crosssection

$$\frac{d^4\sigma}{dx_B dQ^2 d\varphi\, dt} \quad [\mathrm{nb/GeV^4}]$$

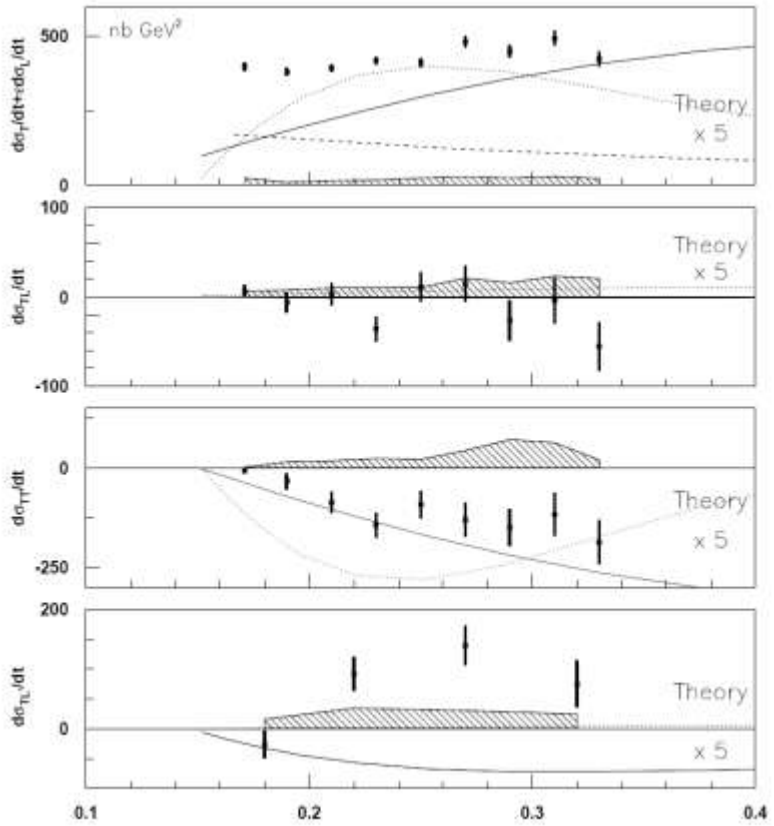






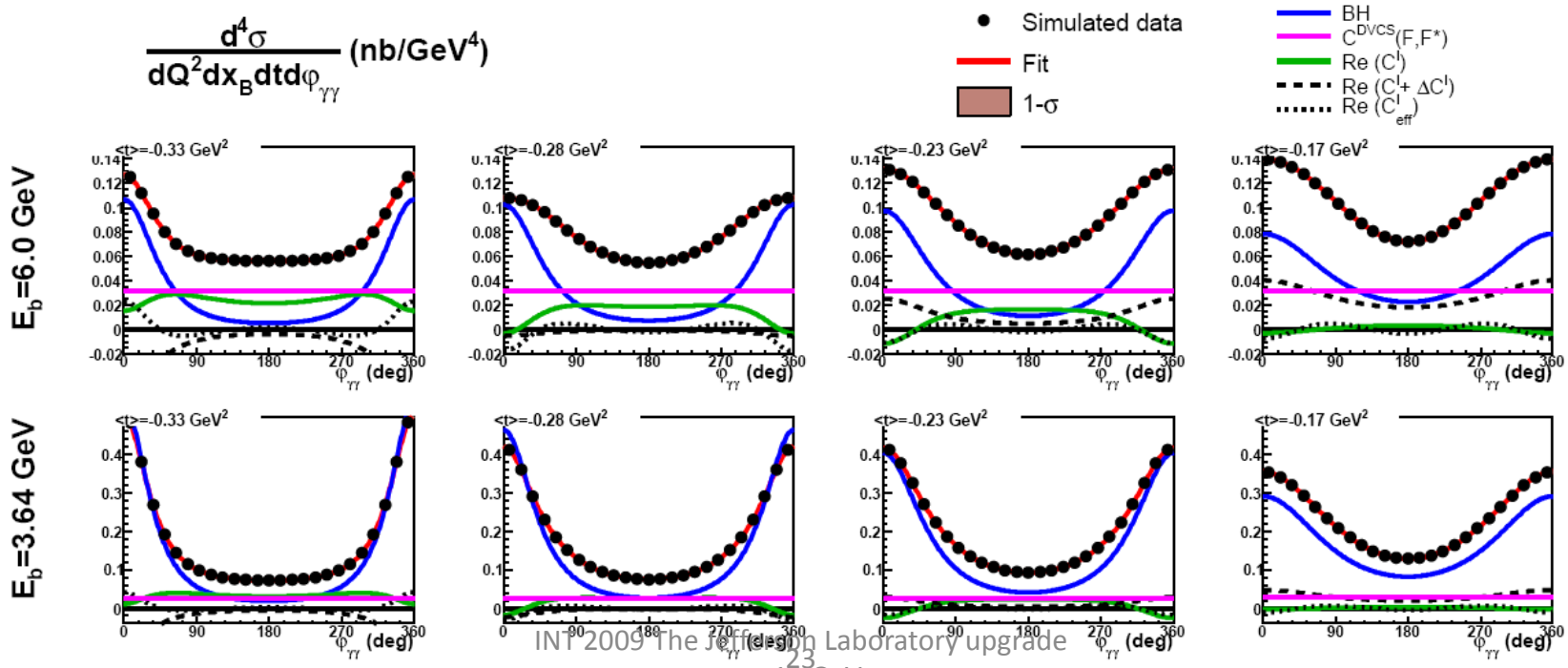
Cross sections π^0

$$\frac{d\sigma_\nu}{d\Omega_F dE_F d\Omega} = \frac{d\sigma_T}{d\Omega} + \varepsilon \frac{d\sigma_L}{d\Omega} + \sqrt{2\varepsilon(1+\varepsilon)} \frac{d\sigma_{LT}}{d\Omega} \cos\varphi + \varepsilon \frac{d\sigma_{TT}}{d\Omega} \cos 2\varphi + h\sqrt{2\varepsilon(1-\varepsilon)} \frac{d\sigma_{LT'}}{d\Omega} \sin\varphi$$



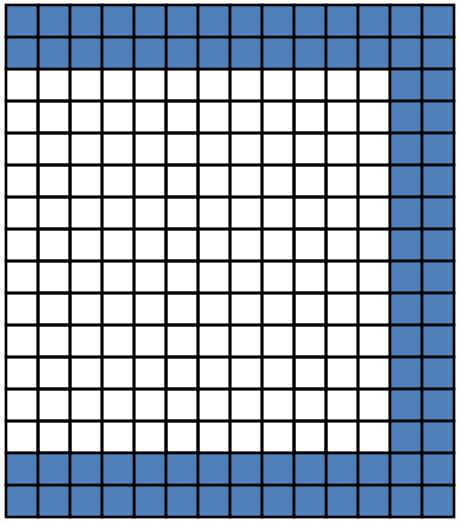
DVCS new 6 GeV experiment

- 6 GeV experiment tentatively for 2010
  - Study of the importance of the $DVCS^2$ compared to the interference term by varying the incident beam energy



DVCS new experimental setup

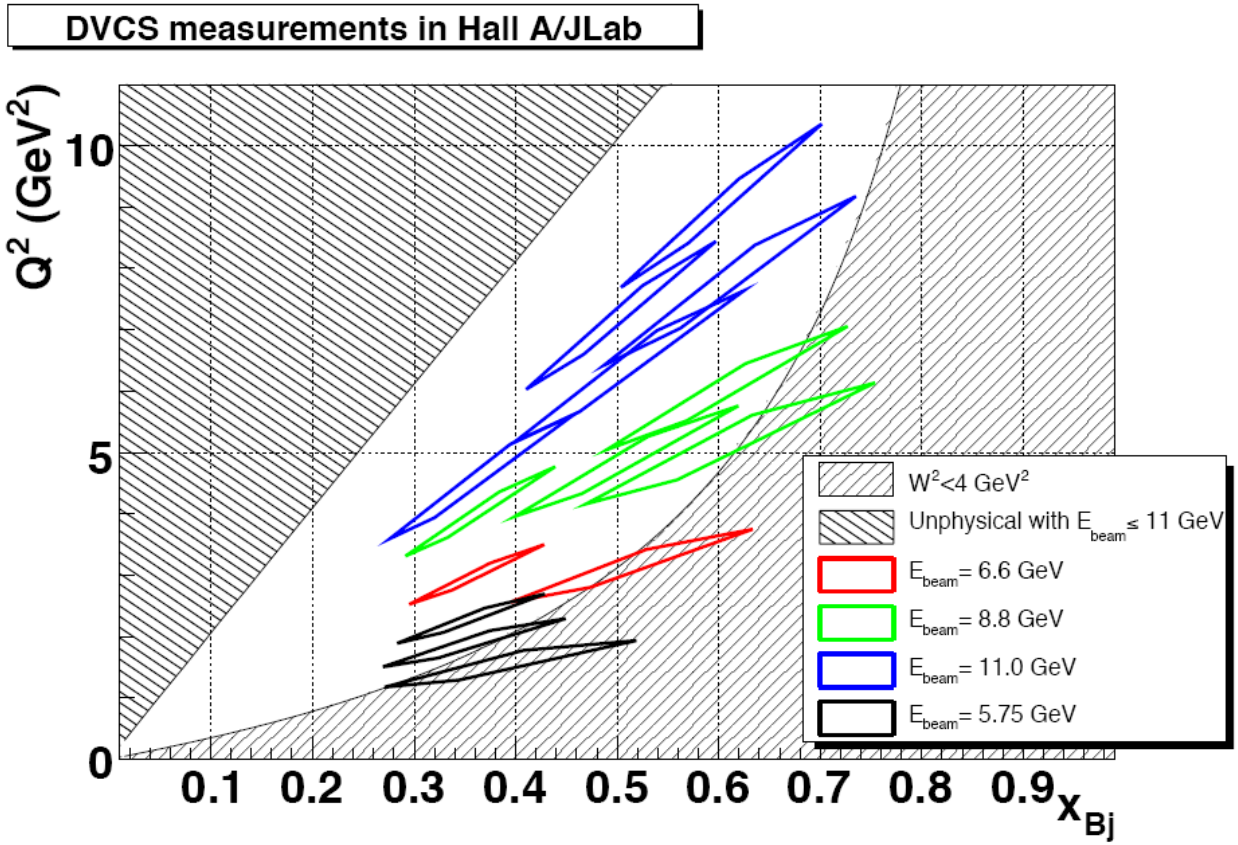
- Double arm experiment : proton array not needed
  - Increase acceptance
  - Increase in luminosity
- Calorimeter
  - Increased size of the calorimeter from 132 to 208 blocks for larger acceptance for the π^0 to match the DVCS acceptance



- Electronics
  - Improved trigger for optimal π^0 detection (many π^0 were cut by the high threshold for DVCS photons)
  - Data transfer improvement to accommodate lower threshold

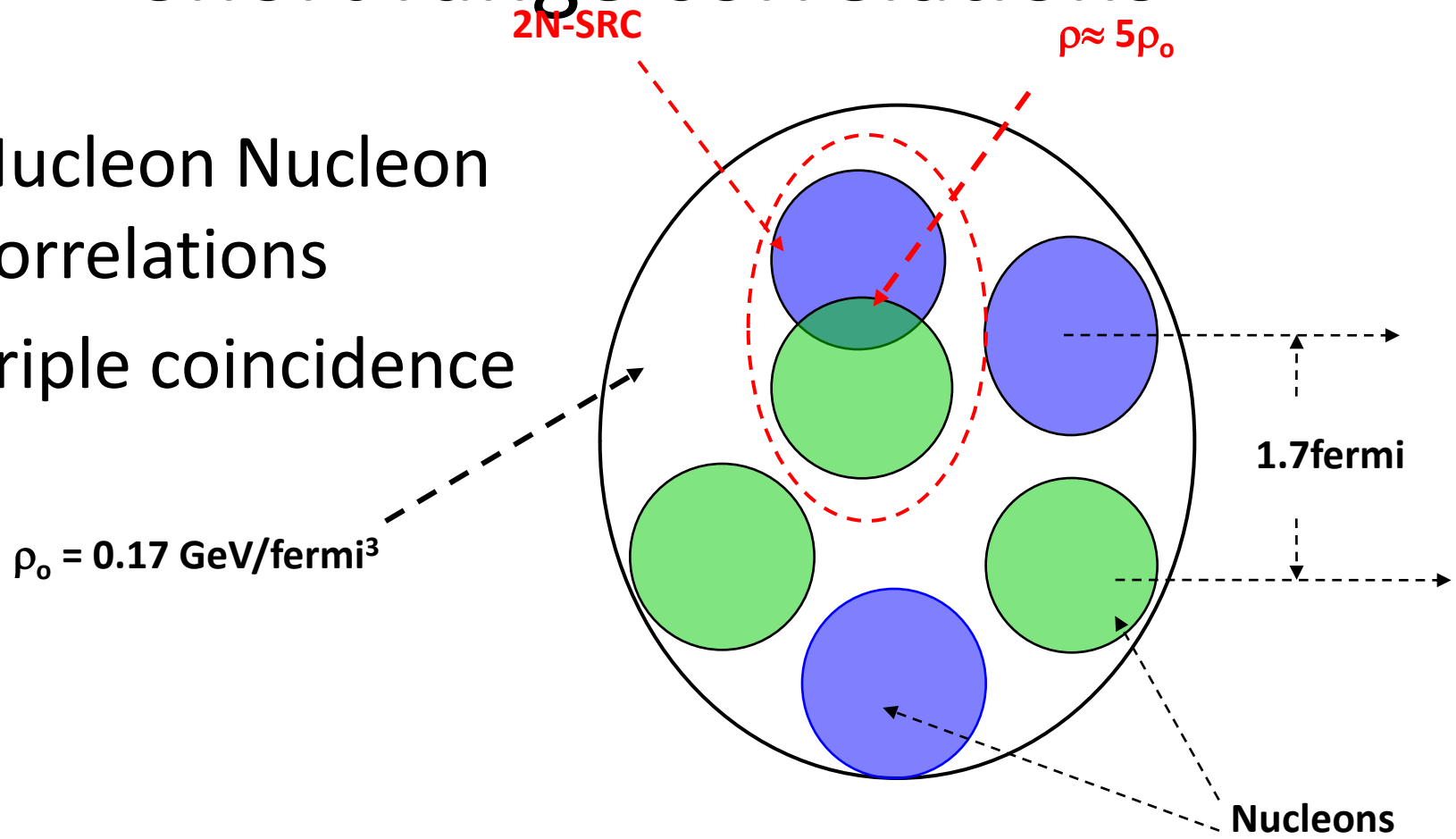
DVCS Kinematical coverage

- 12 GeV proposal



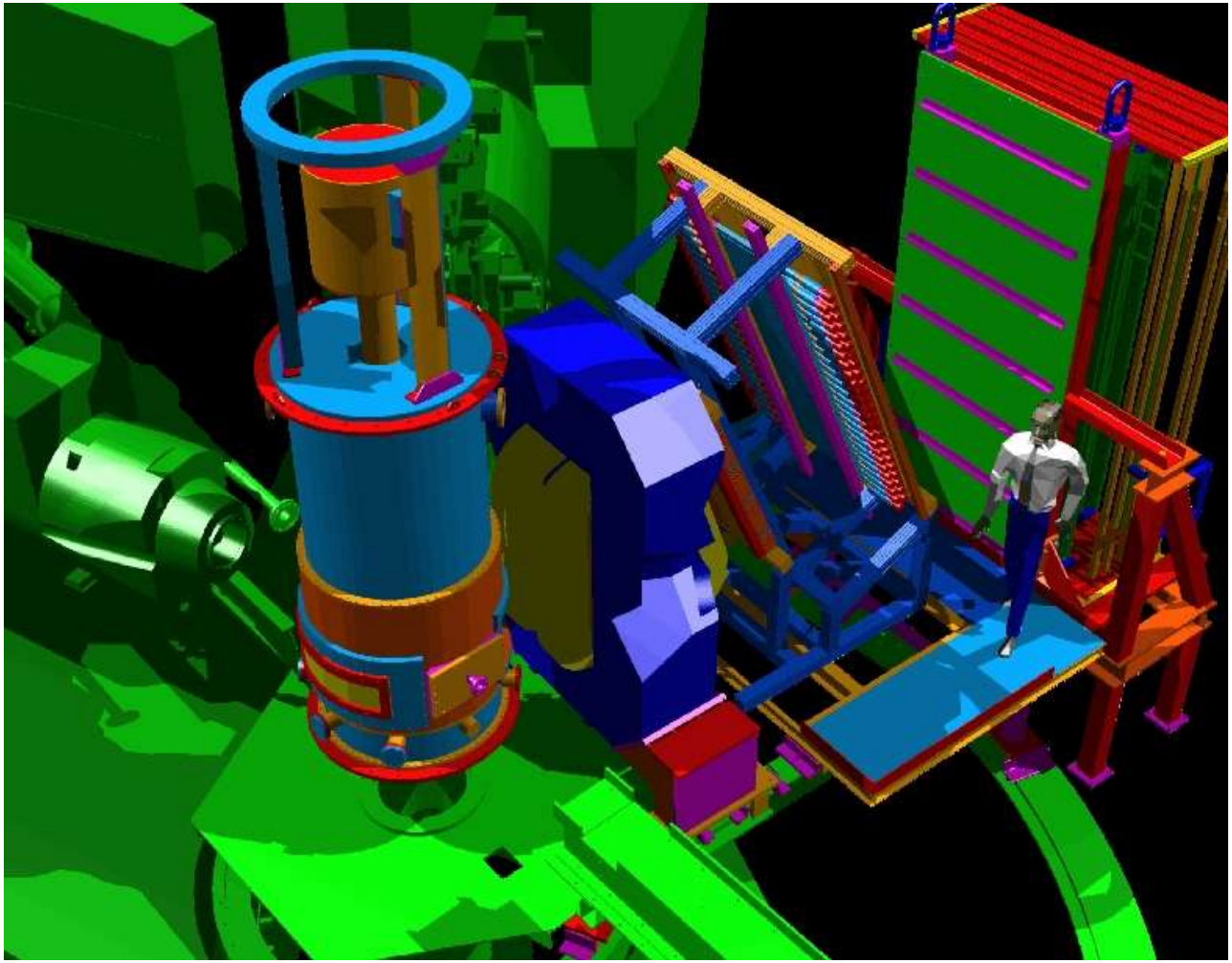
Short range correlations

- Nucleon Nucleon correlations
- Triple coincidence

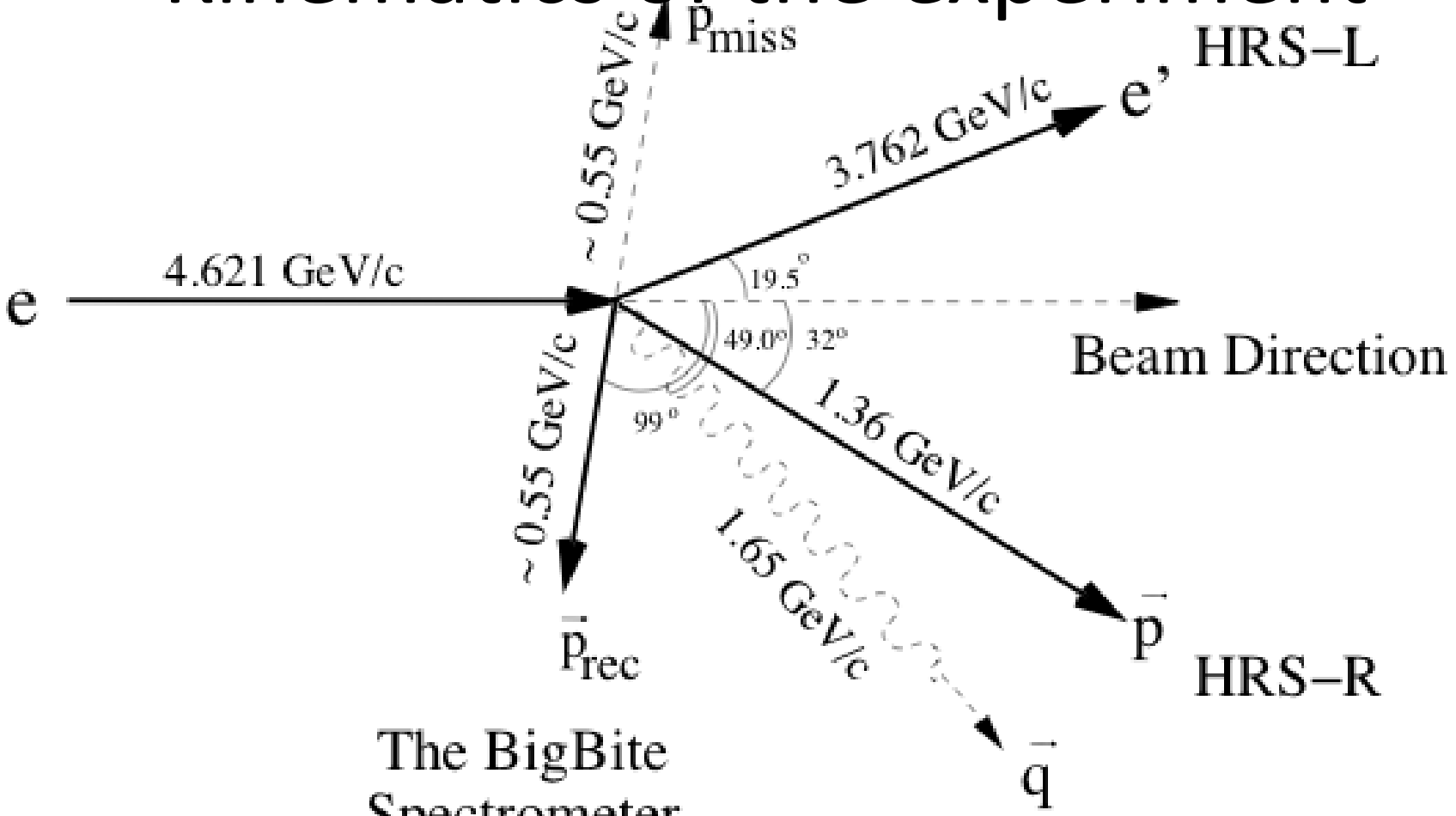


Courtesy of Douglas Higinbotham

Bigbite spectrometer and neutron detector



Kinematics of the experiment



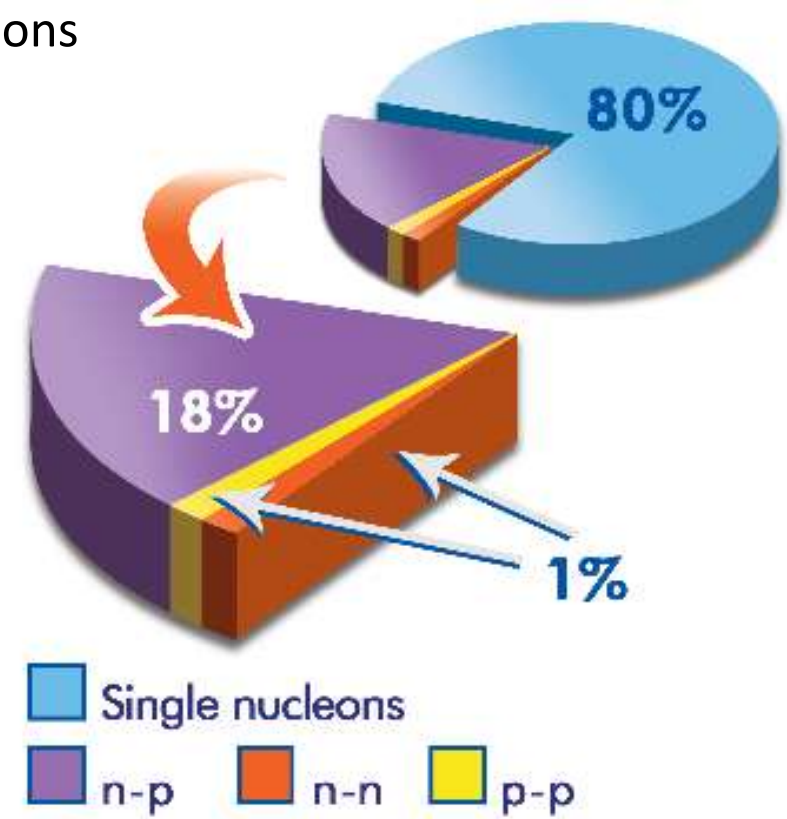
The BigBite Spectrometer

and

Neutron Detector

From the (e,e'), (e,e'p), and (e,e'pN) Results

- 80 +/- 5% single particles moving in an average potential
  - 60 – 70% independent single particle in a shell model potential
  - 10 – 20% shell model long range correlations
- 20 +/- 5% two-nucleon short-range correlations
  - 18% np pairs
  - 1% np pairs
  - 1% nn pairs (from isospin symmetry)
- Less than 1% multi-nucleon correlations



R. Shneor *et al*., Phys. Rev. Lett. **99** (2007)

R. Subedi *et al*., Science **320**, 1476 (2008), published online 29 May 2008 (0.1126/science.1156675).

The 12 GeV upgrade in Hall A

Hall A with 12 GeV Upgrade

- The base instrumentation will not be augmented, but beam line equipment (both polarimeters and switchyard magnets) will be upgraded to handle 11 GeV beam
- Even with their maximum momentum of 4 GeV/c both HRS spectrometers can be used to detect electrons at large energy transfer or hadrons
- BigBite spectrometer can be used up to 11 GeV
- This has resulted in submission of four proposals to the first PAC for 12 GeV:
  - Measuring A_1^n with BigBite and polarized ^{3}He target
  - Measuring d_2^n with BigBite and polarized ^{3}He target
  - Measuring DVCS beam asymmetry and absolute cross section with HRS-L and PbF_2 photon calorimeter
  - Measuring the d/u ratio up to $x \approx 0.85$ with ^{3}H/^{3}He targets and both HRS spectrometers
- Parity violation experiments

Physics

- http://hallaweb.jlab.org/12GeV/
- **Physics Program**
  - Inclusive Reactions
  - Semi-inclusive Reactions
  - Exclusive Reactions
  - Nuclear Medium
  - Charm Threshold Production
  - Deep Inelastic Parity

12 GeV proposed experiments

- Approved experiments
  - E12-06-114: DVCS
  - E12-06-122: A_{1n}
  - E12-07-108: G_{MP}
  - E12-07-109: G_{EP}/G_{MP}
  - E09-005: Moller
  - E09-016: G_{EN}
  - E09-019: G_{MN}
- Conditionally Approved
  - PR12-06-118: Tritium
  - PR09-012: Inclusive 3H 3He
  - PR09-018: SIDIS

12 GeV upgrade

- 2 large acceptance detectors projects
- Super Big Bigte Large Dipole
  - Form factors
  - Deep inelastic
- SoLID
  - PVDIS
  - semi inclusive

12 GeV upgrade

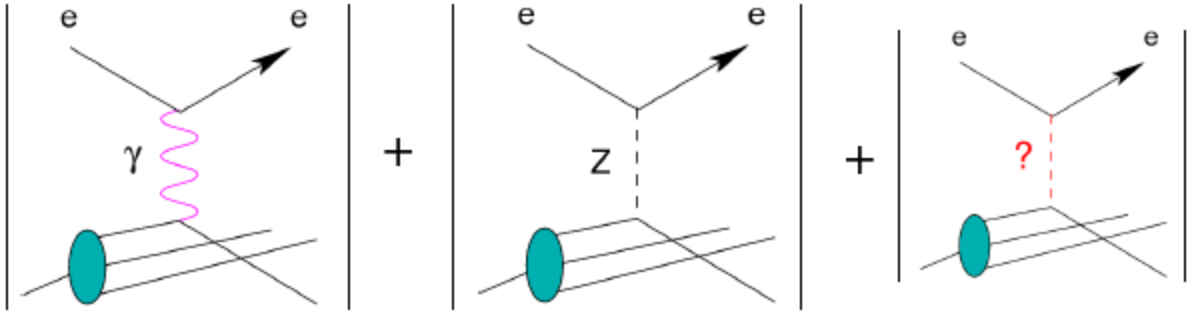
- Baseline equipment
  - HRS DAQ upgrade
  - Polarimeters upgrade to sub percent accuracy for 6 GeV program
    - Moeller
    - Compton
- New detectors
  - Super Big Bite
  - SoLID : solenoidal detector
  - Parity Moeller detector

The Solenoidal Large Intensity Device (SoLID) in Hall A

Solenoidal detector

- Solenoidal field well suitable to contain low energy background allowing high luminosity running
- System of baffles to eliminate photon background
- Large acceptance, high luminosity detector
  - Parity Violation DIS
  - Semi inclusive transversity
  - Other exclusive / semi inclusive reactions

PVDIS Asymmetries

$A_{PV} =$ 

- Deuterium:

$$A_d = (540\,ppm)Q^2 \frac{2C_{1u}[1+R_C(x)] - C_{1d}[1+R_S(x)] + Y(2C_{2u} - C_{2d})R_V(x)}{5 + R_S(x) + 4R_C(x)}$$

$$C_{1u} = g_A^e g_V^u = -\frac{1}{2} + \frac{4}{3}\sin^2(\theta_W) \qquad C_{2u} = g_V^e g_A^u = -\frac{1}{2} + 2\sin^2(\theta_W)$$

$$C_{1d} = g_A^e g_V^d = \frac{1}{2} - \frac{2}{3}\sin^2(\theta_W) \qquad C_{2d} = g_V^e g_A^d = \frac{1}{2} - 2\sin^2(\theta_W)$$

- Can extract $C_{1,2q}$ (and $\sin^2\theta_W$)– discover new physics beyond the SM
- Sensitive to: Z' searches, compositeness, leptoquarks
- Mass limit:

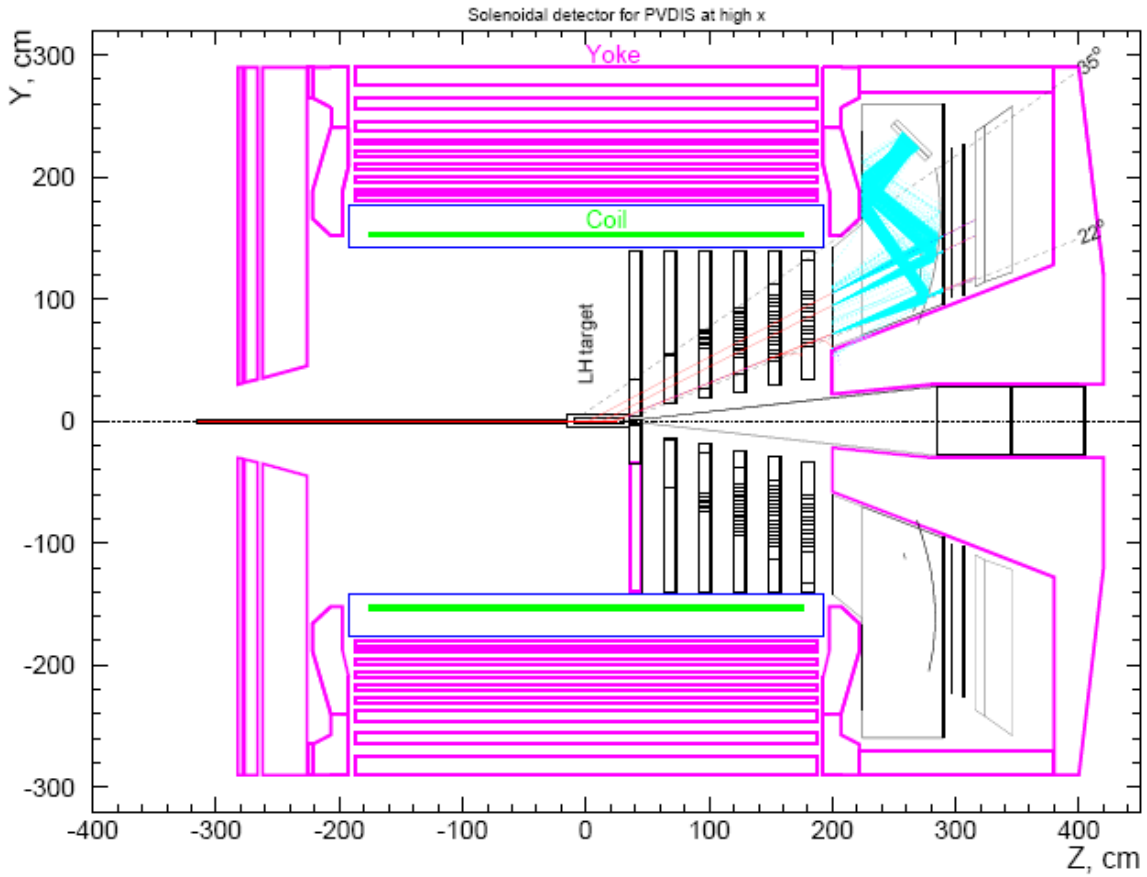
$$\Lambda/g \approx \frac{1}{\left[\sqrt{8}\,G_F\left|\Delta(2C_{2u} - C_{2d})\right|\right]^{1/2}} \approx 1.0\,\text{TeV}$$

X. Zheng, PAC33, January 2008

PVDIS

- Large solid angle
- High rate capability
- PID for electron pion discrimination
- 6 GeV experiment will be a benchmark for the PVDIS program at 12 GeV

PVDIS setup

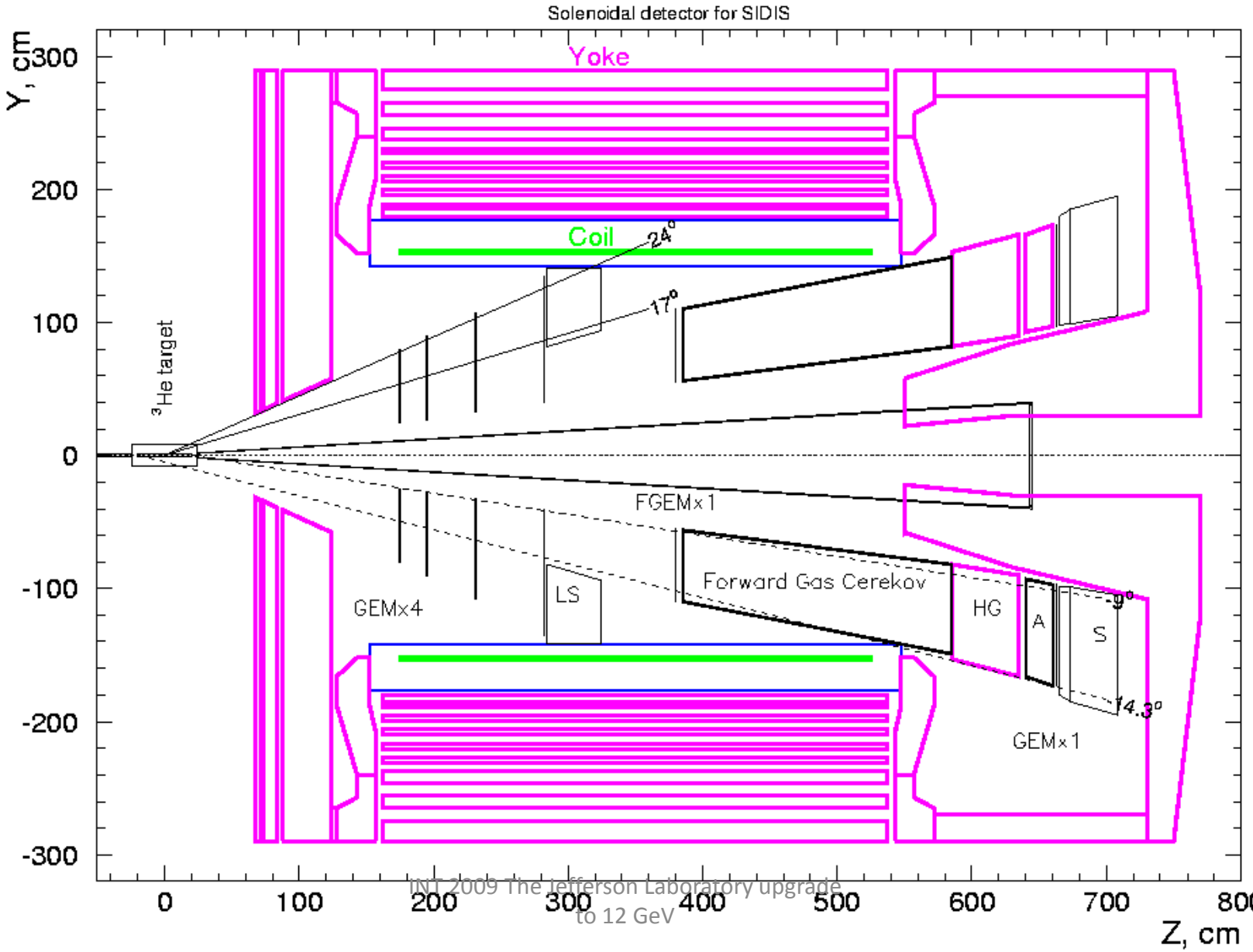

Solenoidal detector for PVDIS at high x
Yoke
Coil
LH target
35°
22°
Y, cm
Z, cm
300
200
100
0
-100
-200
-300
-400
-300
-200
-100
0
100
200
300
400

Transversity

- Large solid angle
- High rate capability
- PID for electron pion discrimination
- Similar requirements as PVDIS with polarized He3 target out from the magnetic field

Solenoid detector for SIDIS at 11 GeV

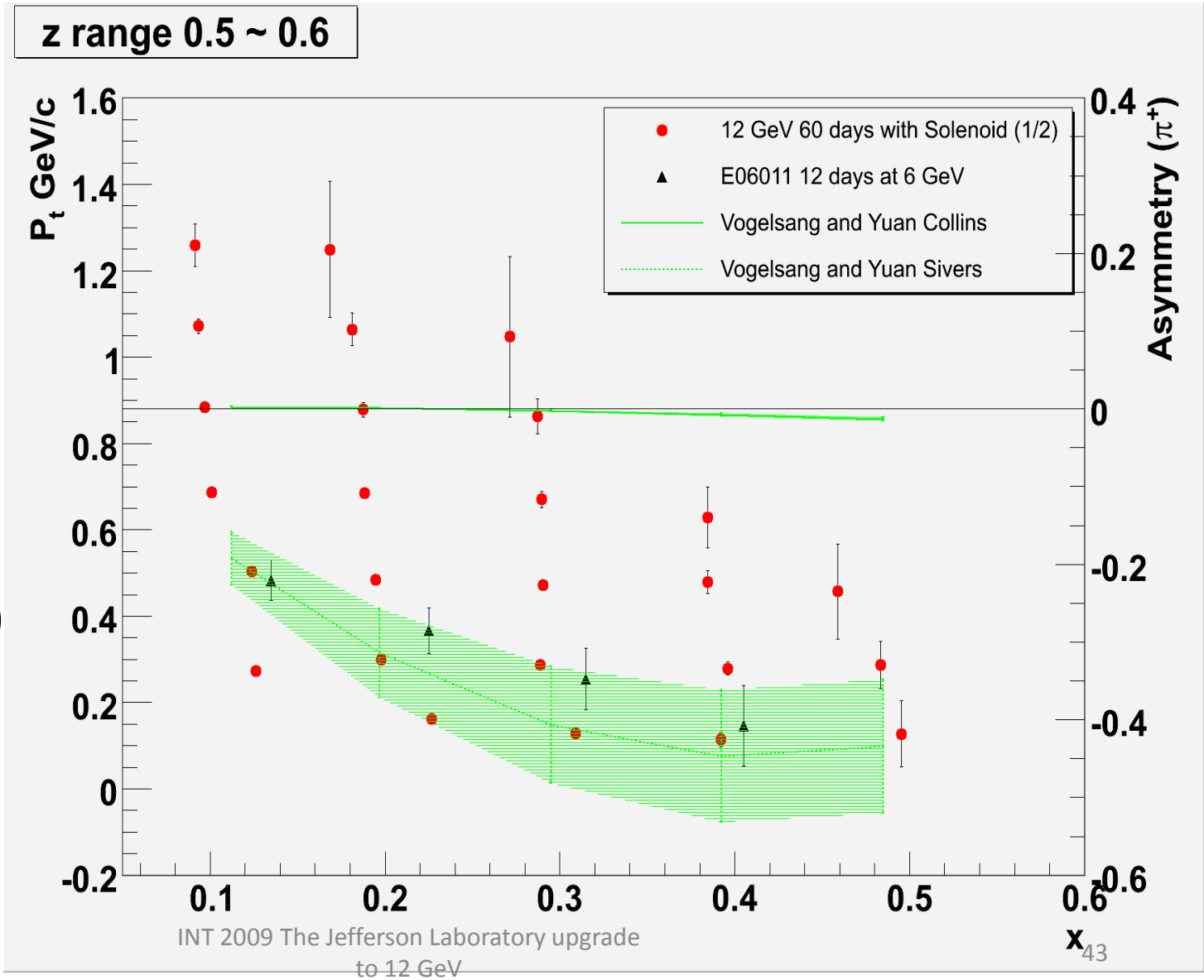
Proposed for PVDIS at 11 GeV



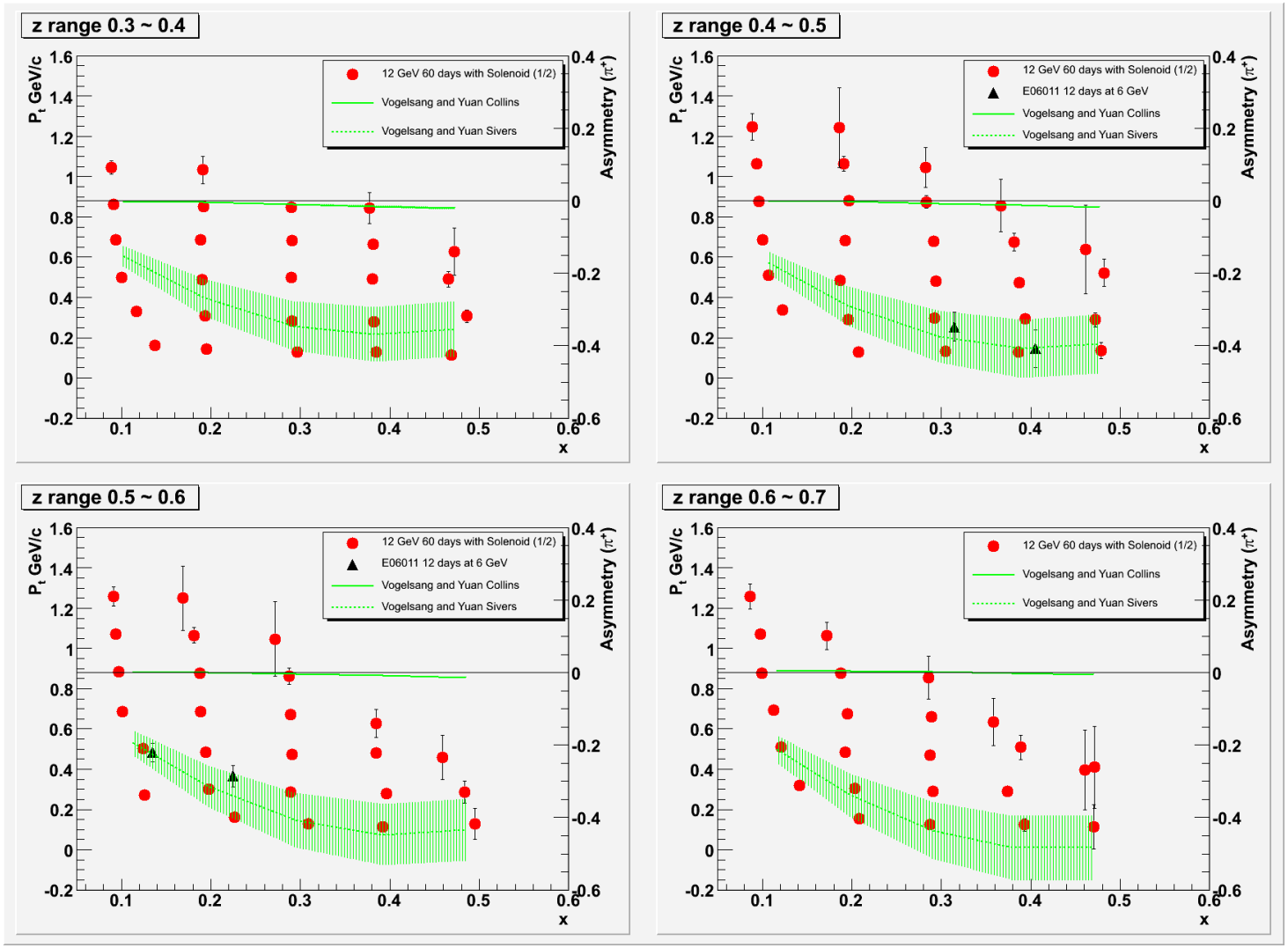
3-D Mapping of Collins/Siver Asymmetries at JLab 12 GeV

With A Large Acceptance Solenoid Detector

- Both π+ and π-
- For one z bin (0.5-0.6)
- Will obtain 4 z bins (0.3-0.7)
- Upgraded PID for K+ and K-



3-D Projections for Collins and Sivers Asymmetry (π^+)



- Unprecedented precision *3-d* mapping of SSA
  - Collins and Sivers
  - π^+, π^- and K^+, K^-
- Study factorization with *x* and *z*-dependences
- Study P_T dependence
- Combining with CLAS12 proton and world data
  - extract transversity and fragmentation functions for both *u* and *d* quarks
  - determine tensor charge
  - study TMDs for both valence and sea quarks
  - study quark orbital angular momentum
- Combining with world data, especially data from high energy facilities
  - study Q^2 evolution
- Global efforts (experimentalists and theorists), global analysis
  - much better understanding of 3-d nucleon structure and QCD

- Program on neutron spin structure with polarized ^{3}He and solenoid
  - **Polarized ^{3}He target**
    effective polarized neutron
    highest polarized luminosity: 10^{36}
  - **A solenoid with detector package (GEM, EM calorimeter+ Cherenkov**
    large acceptance: ~700 msr for polarized (without baffles)

  → high luminosity and large acceptance
  - **Inclusive DIS: improve by a factor of 10-100**

    A_1 at high-x: high precision

    d_2 at high Q^2: very high precision

    parity violating spin structure g_3/g_5 : first significant measurement
  - **SIDIS: improve by a factor of 100-1000**

    transversity and TMDs,

    spin-flavor decomposition (~2 orders improvement)
- Unpolarized luminosity: $5x10^{38}$, acceptance ~ 300 msr (with baffles)
  - **Parity-Violating DIS**
  - **Boer-Mulders function**

Other applications of the large acceptances devices

- More exclusive reactions ?
  - DVCS
  - Double DVCS
- Short range correlations ?

- Moeller experiment (next talk by Willem Van Oers)

Conclusion

- Rich program of physics from nuclear to quarks correlations
- Takes advantage of the broader kinematic range especially large x
- New large acceptance detectors available for exclusive, semi inclusive and inclusive studies
- Vast parity violation program (next talk by Willem Van Oers on Moeller in Hall A)