Recent results and future measurements for few body problems in Hall A

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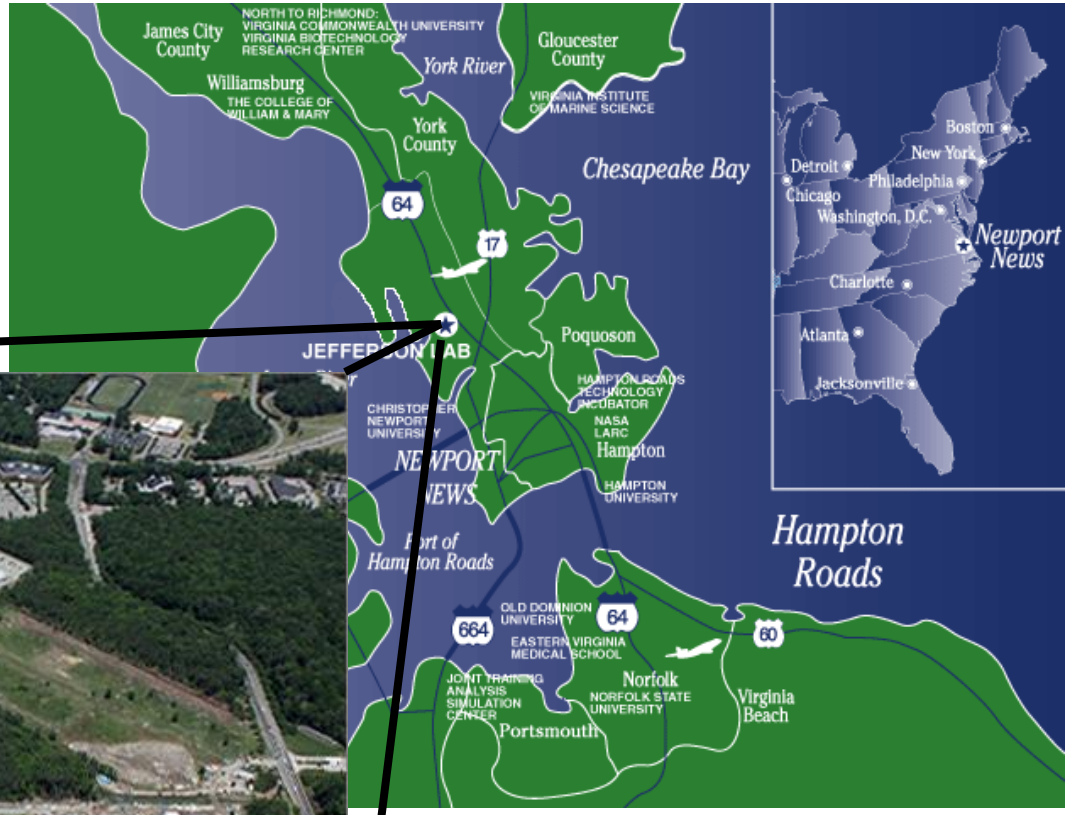
Hall A
Jefferson Laboratory
Asian Pacific Few Body Conference
August 26th 2011

Outline

- Jefferson Laboratory - Hall A experimental Hall
- Recent results
  - Short Range Correlation (Higginbotham)
  - Parity results (Michaels / Paschke)
  - He3 transversity result (Qian, Averett, Chen)
- 12 GeV upgrade
  - SoLID
  - Super BigBite
- Conclusion

Jefferson Laboratory

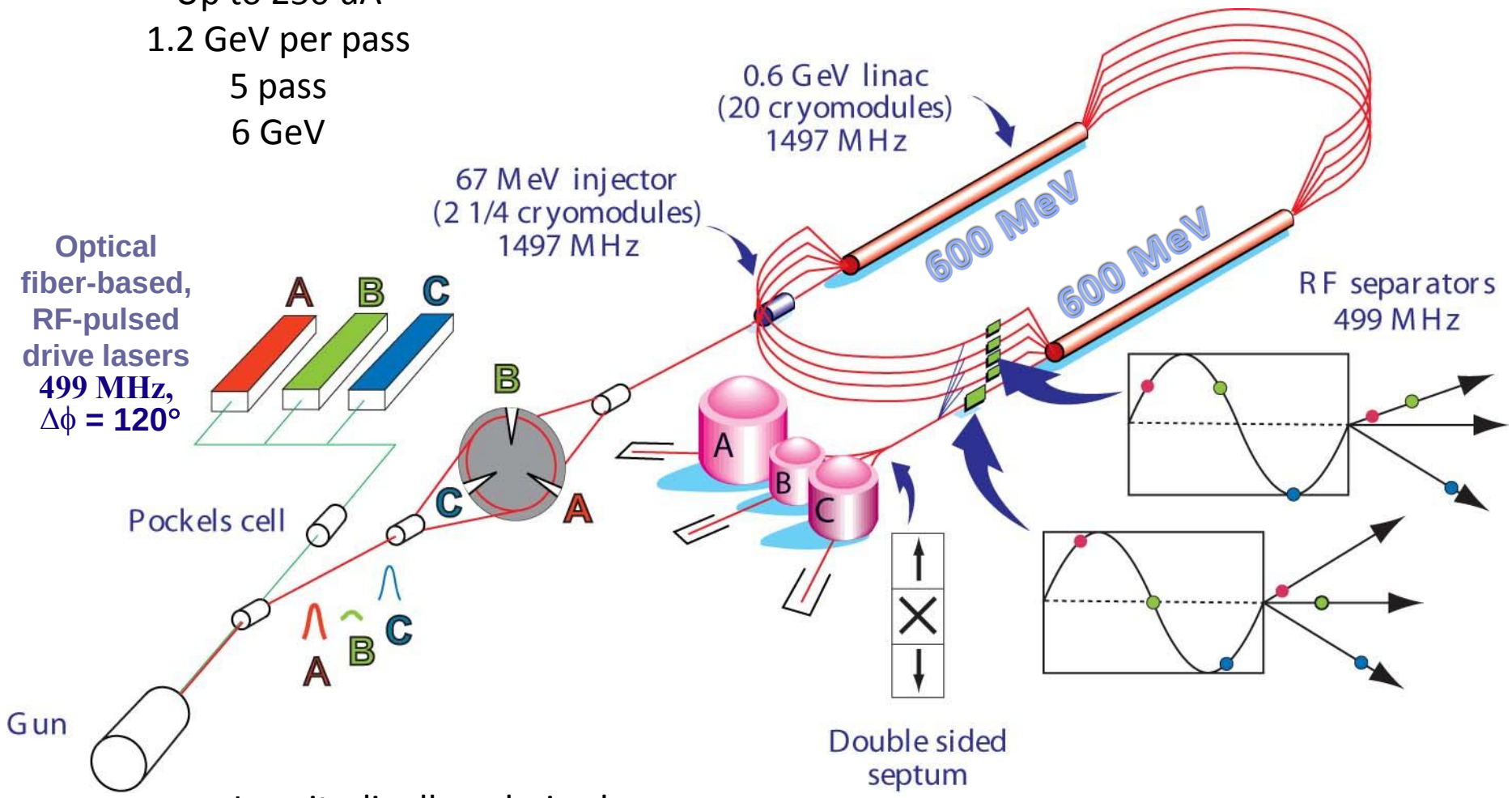
Newport News
Virginia
USA



2 superconducting LINACs
5 ARCs
3 experimental Halls

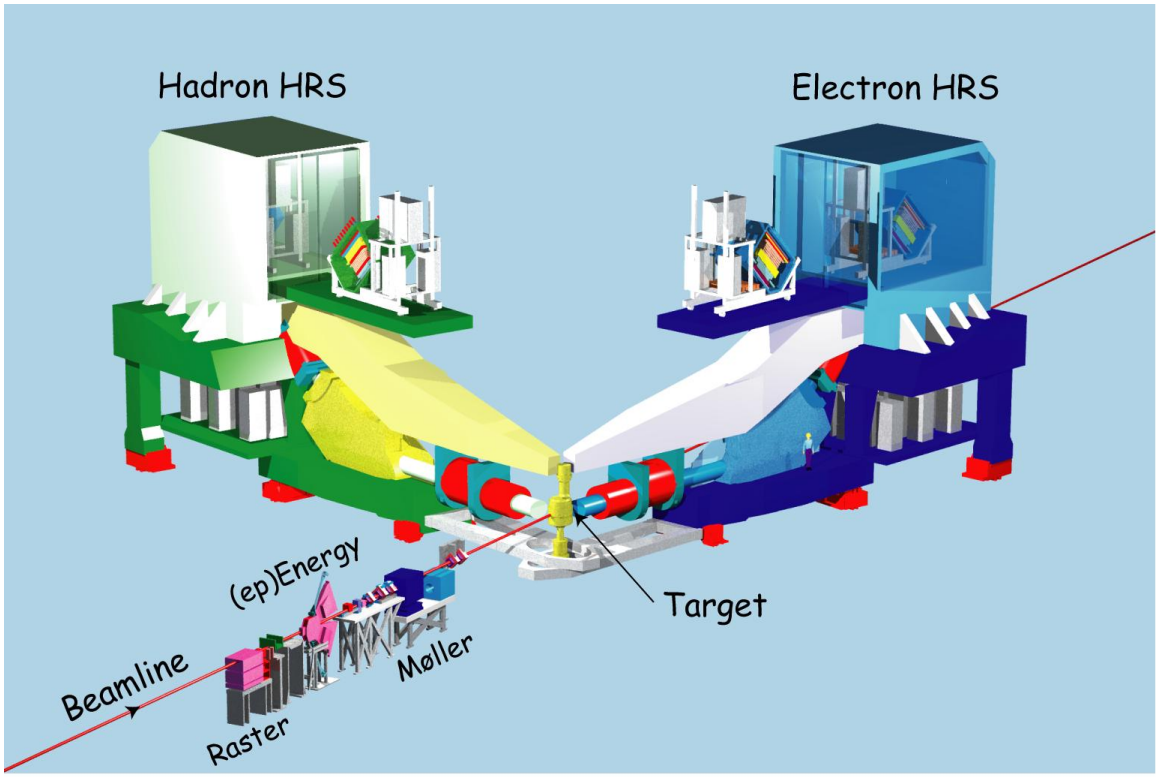
Continuous Electron Beam Accelerator Facility

Up to 250 uA
1.2 GeV per pass
5 pass
6 GeV



Longitudinally polarized
electrons up to 85 %

Hall A Infrastructure



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
- Gas Cherenkov
- Aerogel Cherenkovs
- Ring Imaging CHerenkov

Auxiliary Instrumentation

- Møller Polarimeter
- Compton Polarimeter
- Polarized ^{3}He Target
- Cryo-target
- BigBite spectrometer
- Large on-floor detector arrays for neutrons and photons

Hall A equipment

- Standard experiment using one or two HRS
- Larger acceptance using BigBite Spectrometer
- Additional detector : Neutron detectors, calorimeters
- Targets :
  - Cryogenic unpolarized: H,D,He3,He4
  - Polarized He3
  - Solid targets : from B to Pb
  - Polarized NH3

Hall A Physics

- Nuclear : Medium effects, short range correlations, Hypernuclear spectroscopy
- Form Factors : on proton and polarized neutron (He3, H rosenbluth and polarization transfer)
- Nucleon structure : Deep inelastic, Semi – inclusive and exclusive measurements (DVCS, SIDIS)
- Parity measurements : HAPPEX, PREX, PVDIS
- APEX : A’ boson search (Dark matter)

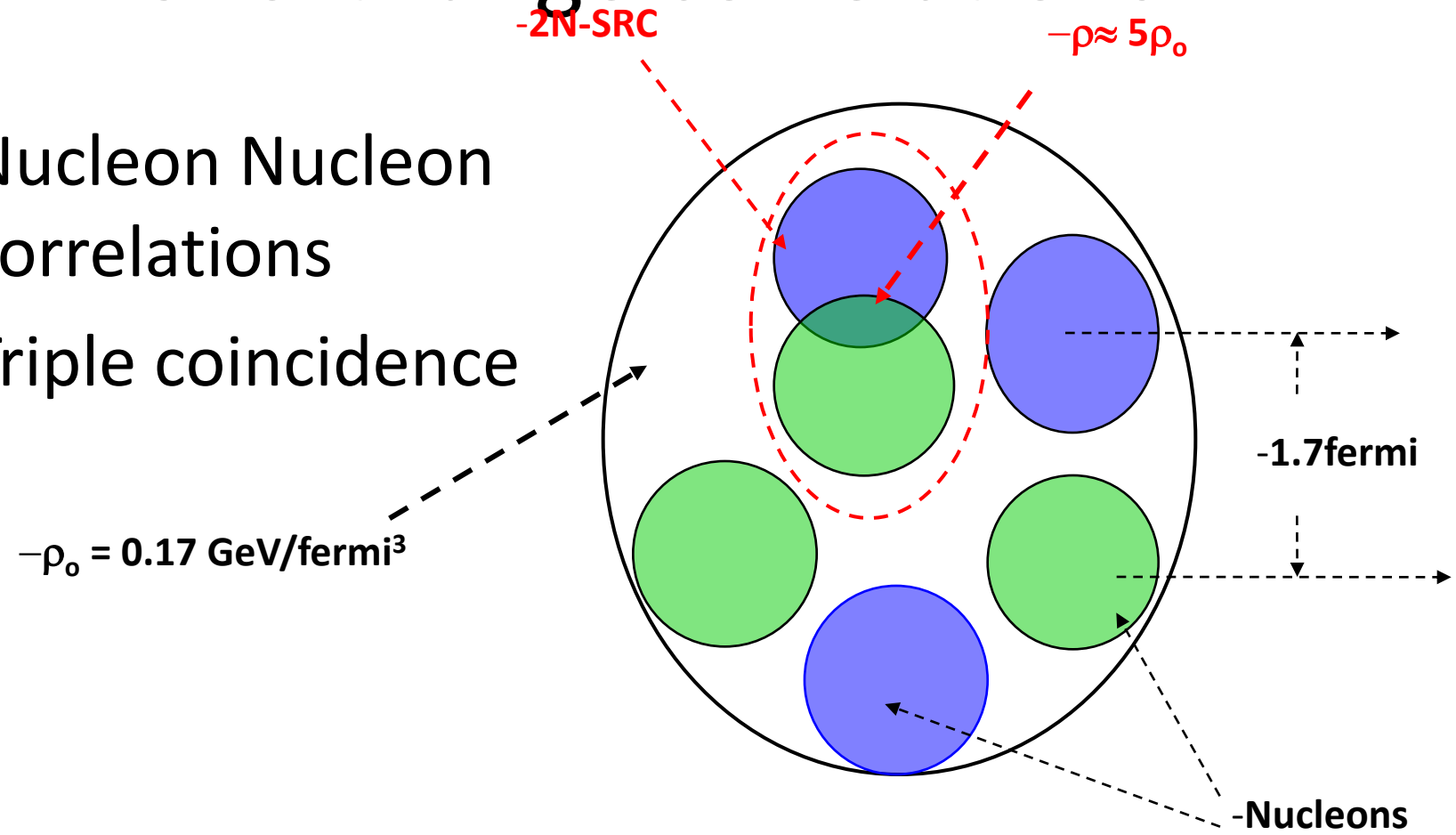
Experiments in Hall A

- 2005 : SRC I, HAPPEX II
- 2006 : GEn, LEDEX, He3/He4 form factors
- 2007 : Lead ee'p, Coulomb Sum Rule
- 2008 : He3 family : transversity,Ay Quasielastic Ay DIS, ee'D
- 2009 : HAPPEX III , PVDIS
- 2010 : PREX,APEX test run,DVCS2
- 2011 : SRC II, x>2 (inclusive SRC) , g2p,He4 ee'p

Recent results

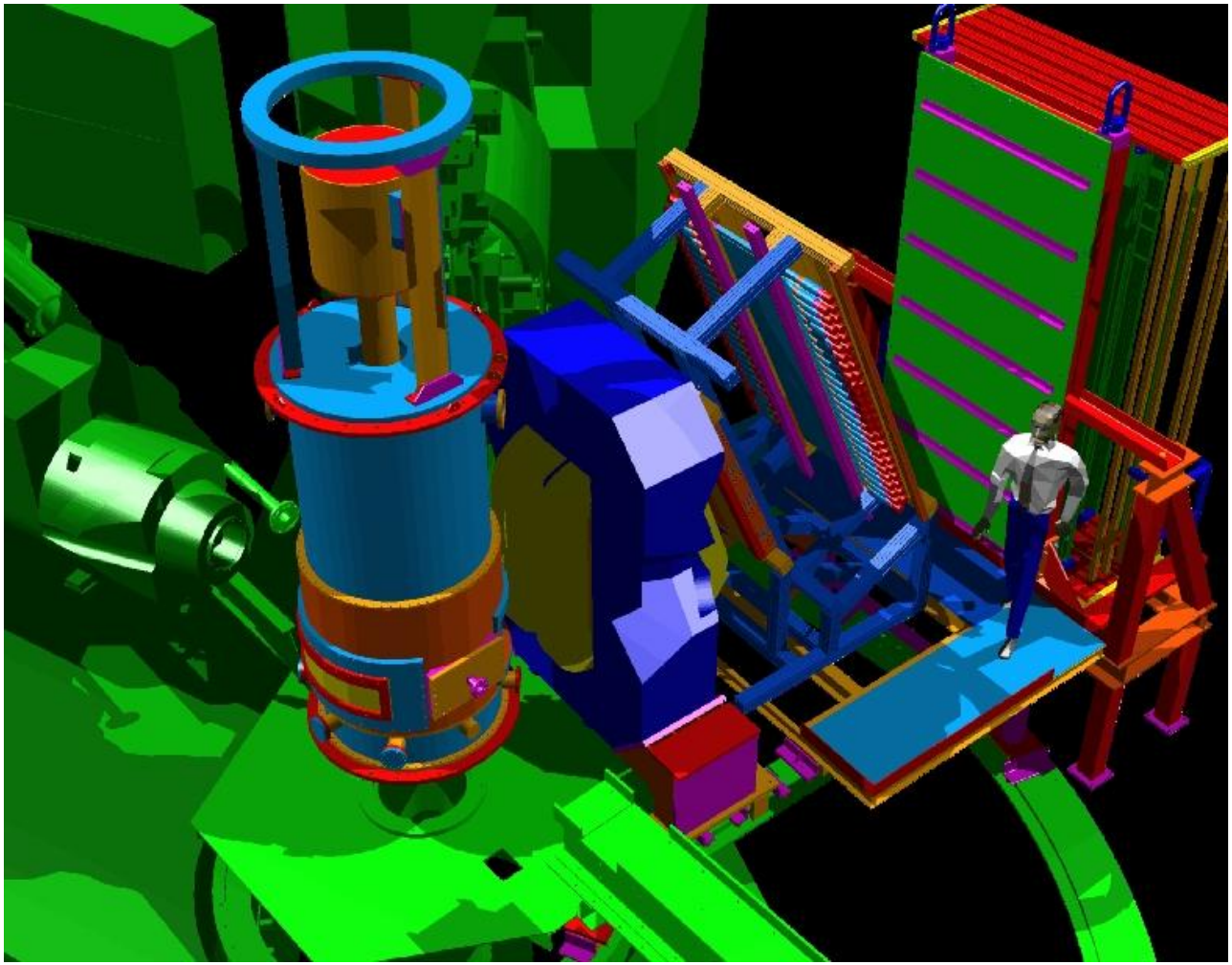
Short range correlations

- Nucleon Nucleon correlations
- Triple coincidence

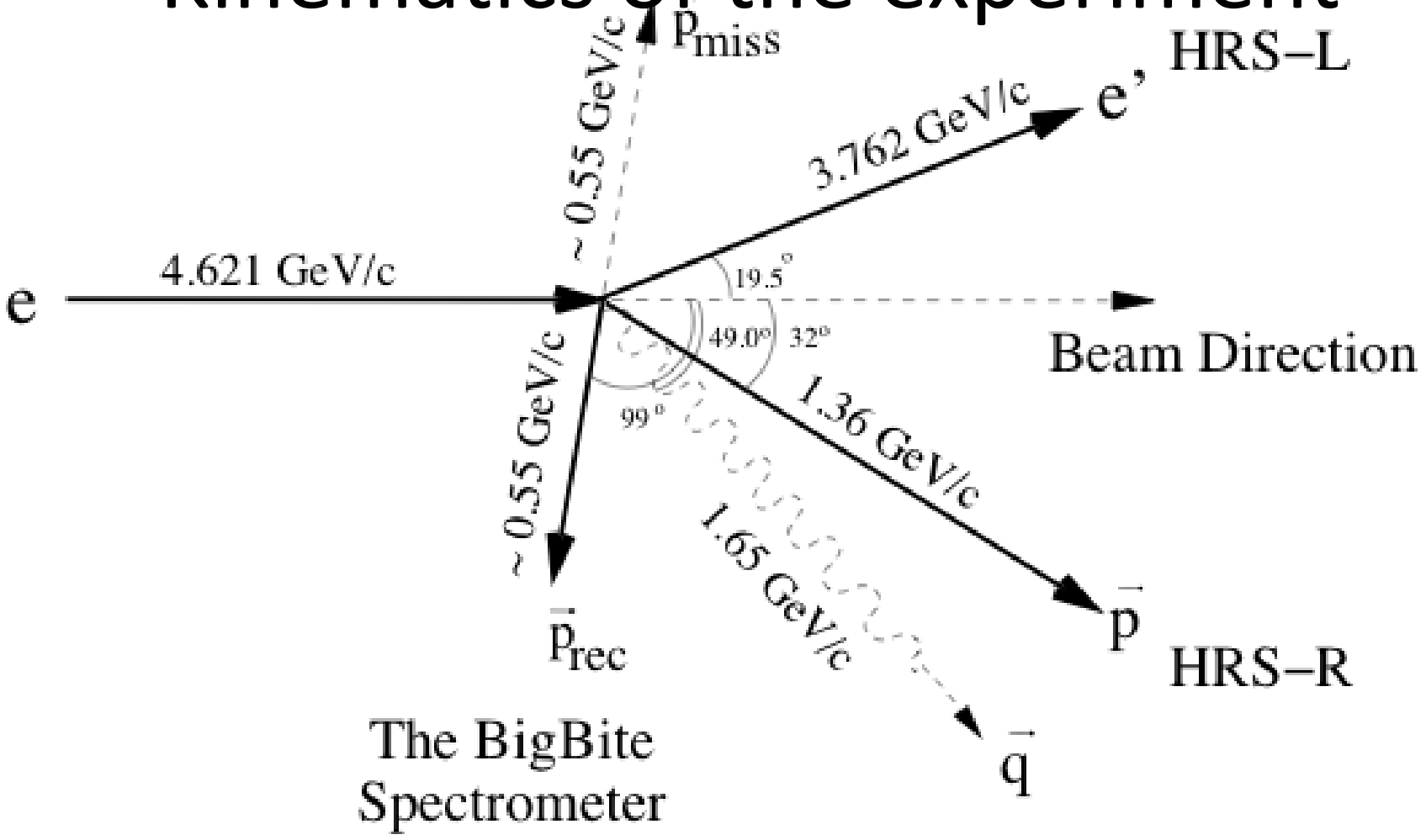


Courtesy of Douglas Higinbotham

Bigbite spectrometer and neutron detector



Kinematics of the experiment



The BigBite Spectrometer

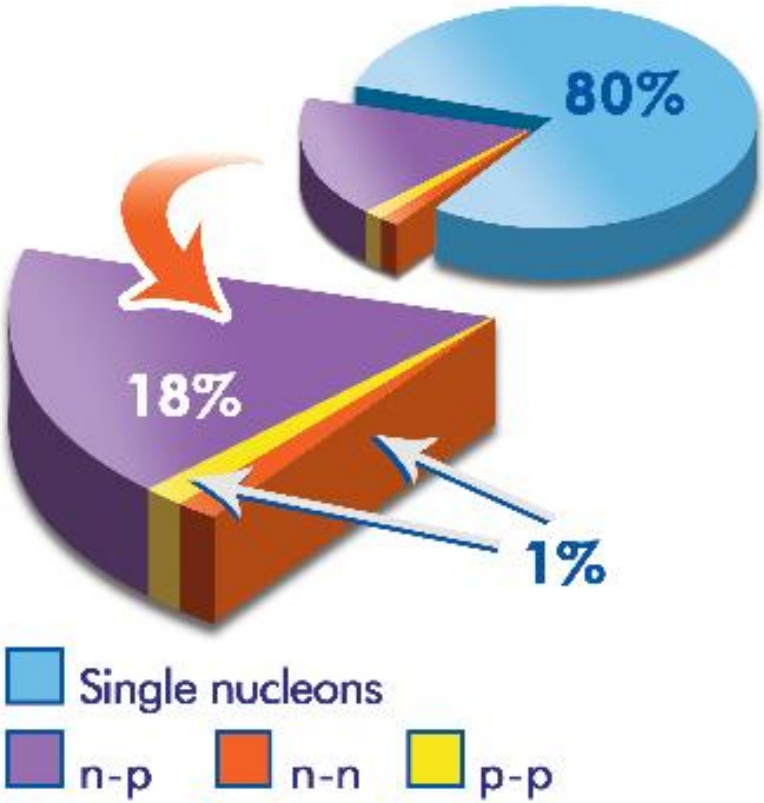
-and

-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

- More on the SRC during the dedicated part of the workshop

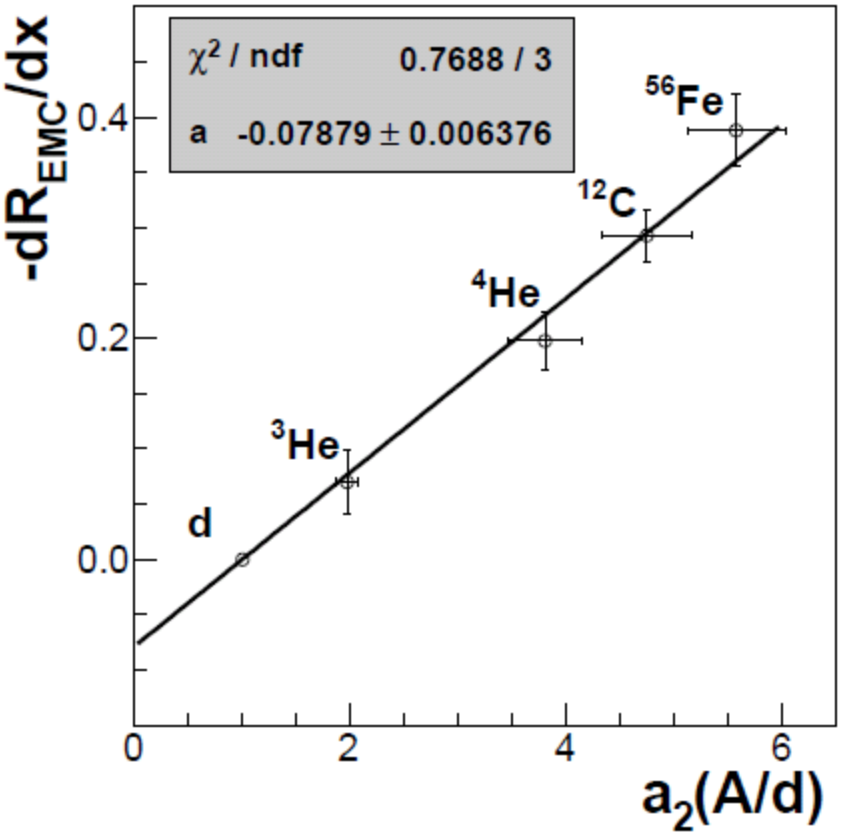


-R. Shneor *et al*., Phys. Rev. Lett. **99** (2007)

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

Short range correlation and EMC

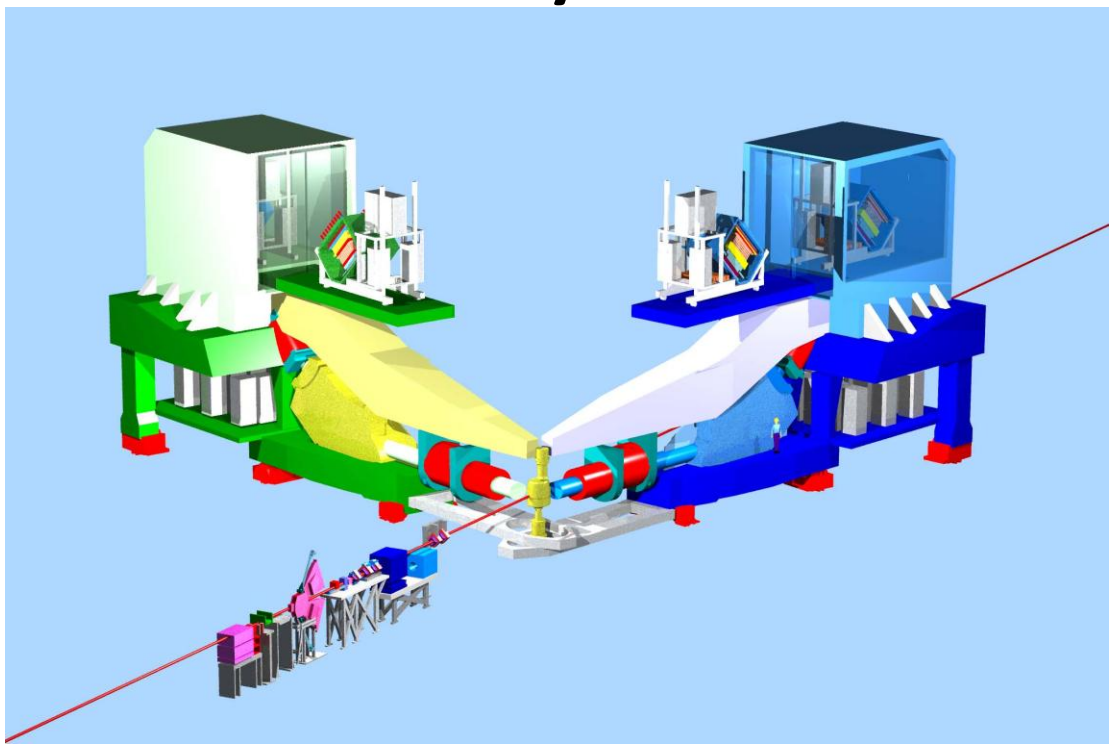
- **Linear correlation of EMC slope and SRC**
- **R_{EMC}** ratio of deep inelastic cross section in nuclei A to deuterium
- a2(A/d) ratio of SRC to deuterium



arXiv:1009.5666v4

Phys.Rev.Lett.106:052301,2011

Parity violation in Hall A



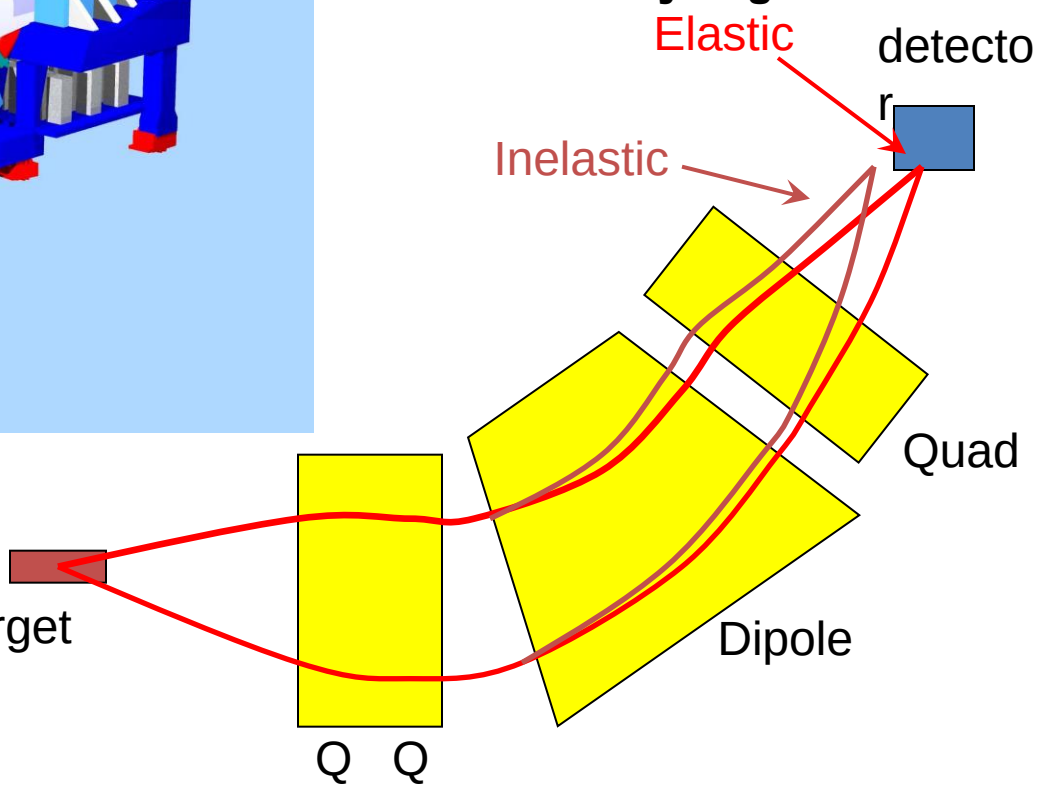
Left-Right symmetry to control transverse polarization systematic

Integrated measurement

Spectrometer Concept: Resolve Elastic

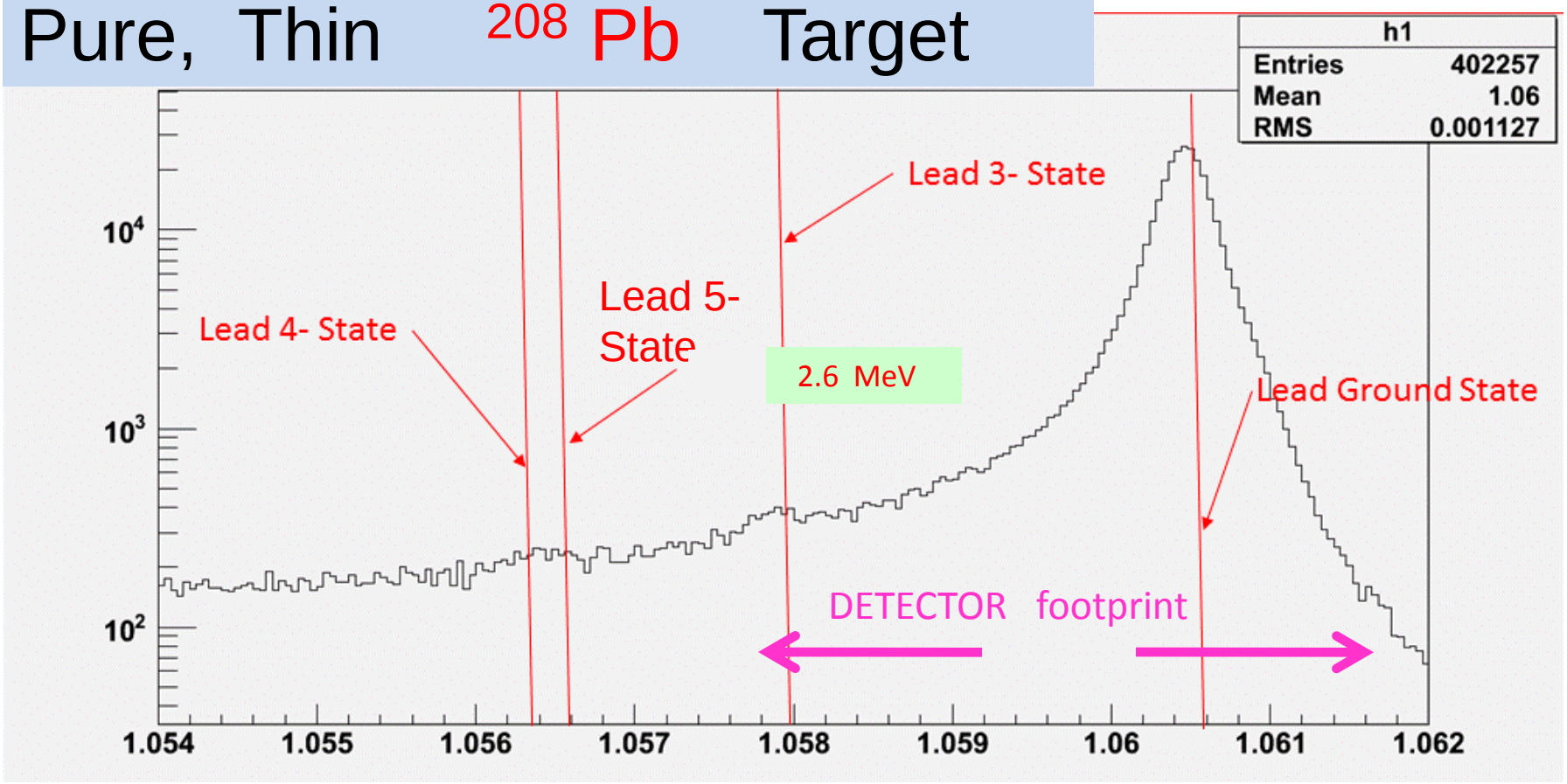
1st excited state Pb 2.6 MeV

Or Hydrogen

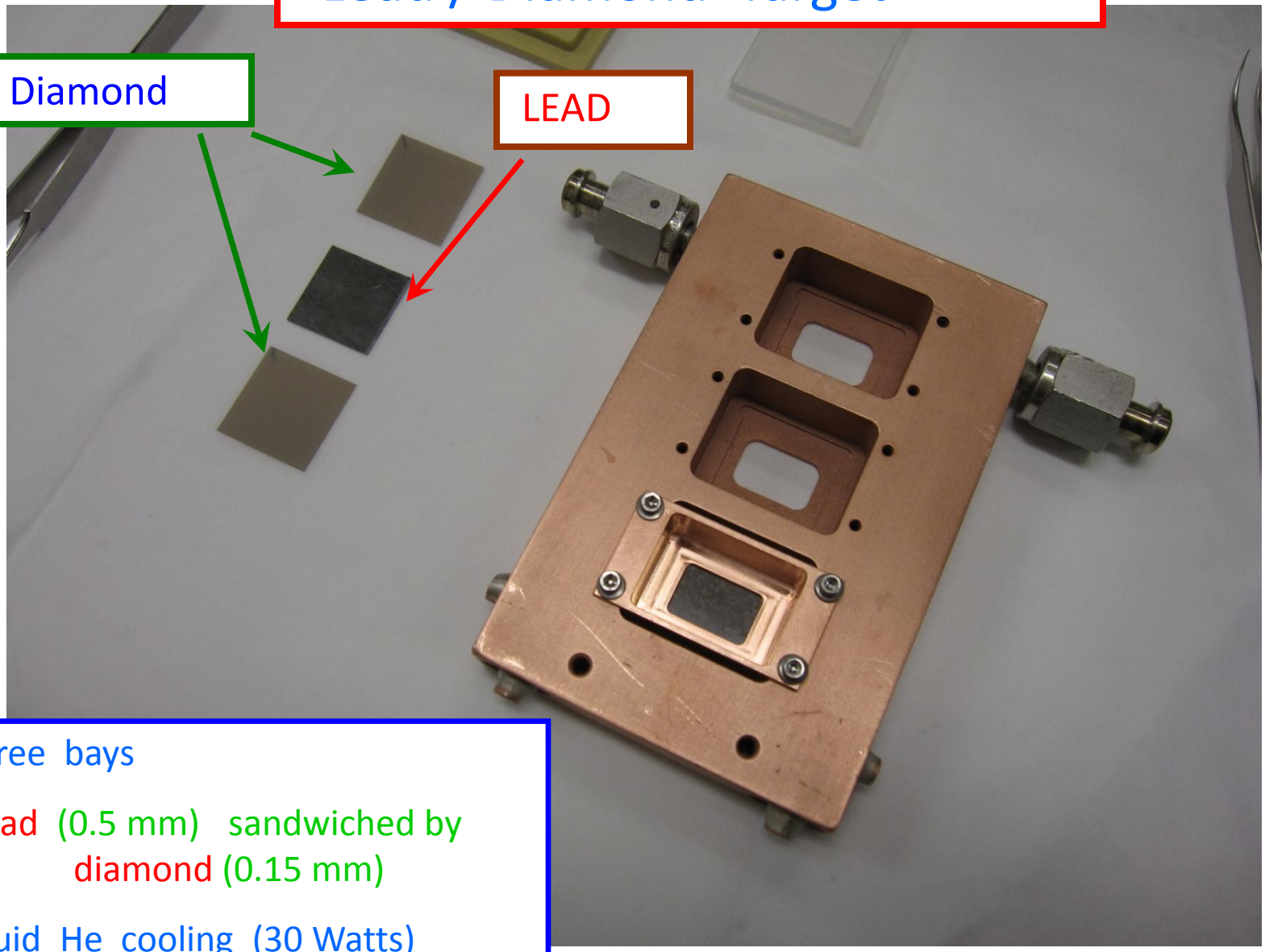


High Resolution Spectrometers

Pure, Thin ^{208}Pb Target



Lead / Diamond Target



- Three bays
- Lead (0.5 mm) sandwiched by diamond (0.15 mm)
- Liquid He cooling (30 Watts)

PARITY VIOLATION RESULTS

PREX Physics Result

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} =$$

$$0.6571 \pm 0.0604(stat) \pm 0.0130(syst)$$

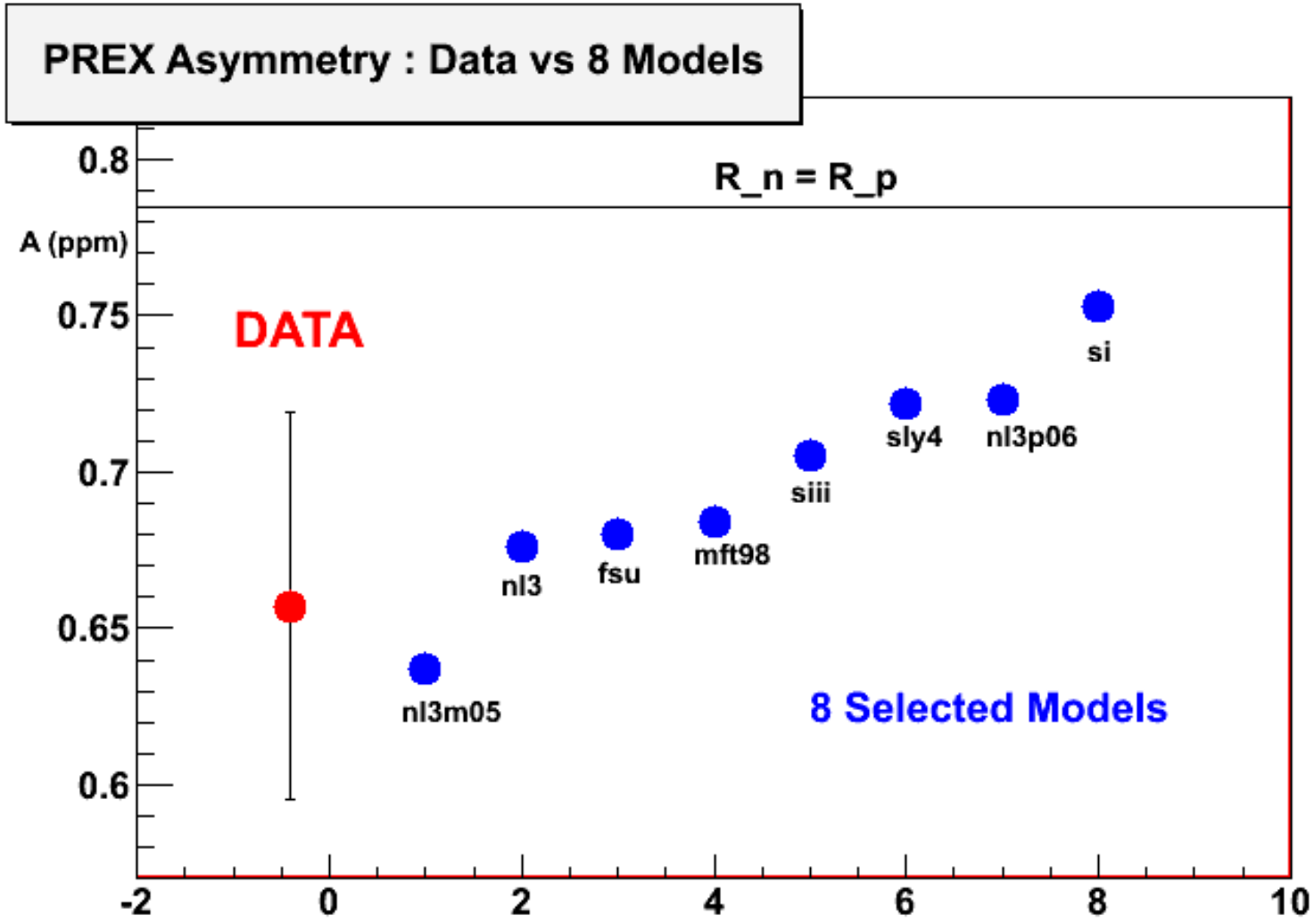
ppm 9.2 % 2.0 %

at $Q^2 = 0.00906$ GeV^2

→ Statistics limited (9%)

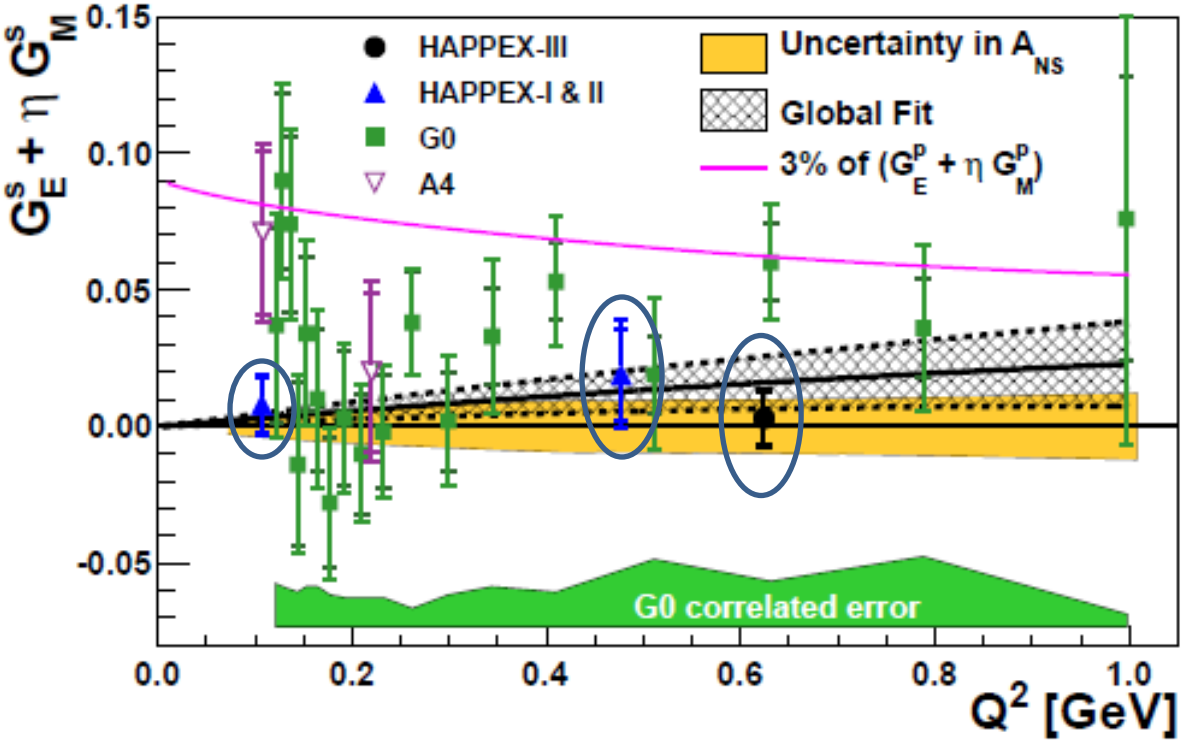
→ Systematic error goal achieved ! (2%)

PARITY VIOLATION RESULTS



Parity violation results

- HAPPEX III result



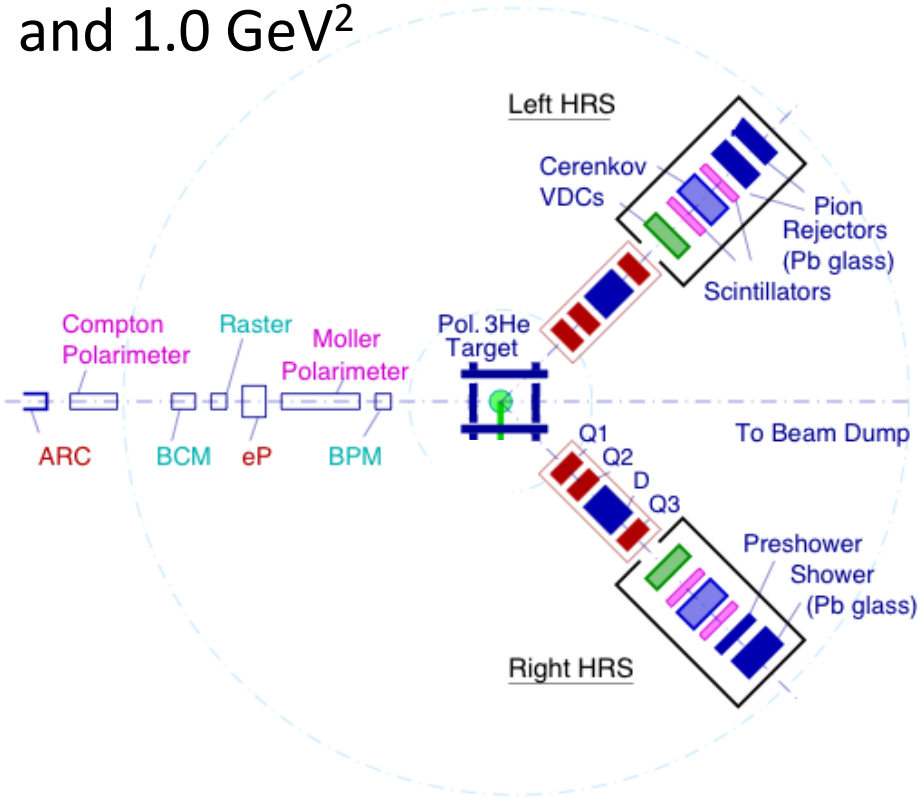
•Strong constraint of the strange quarks contribution in the proton

•[arXiv:1107.0913]

He3 results

Experimental Design

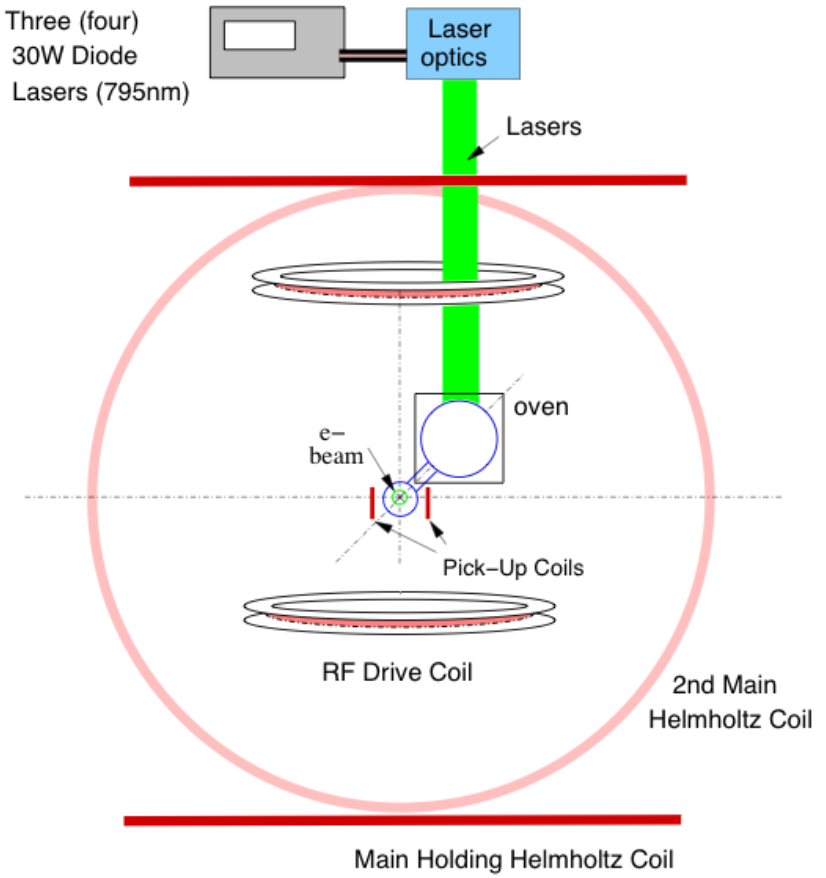
- Use two symmetric spectrometers for singles electron detection. Jefferson Lab Hall A HRS spectrometers.
- Vertically polarized ^{3}He target.
- Measurements at Q^2=0.1, 0.5 and 1.0 GeV^2
  - Test GPD calculation
  - Study Q^2 dependence
  - Parton to hadron transition

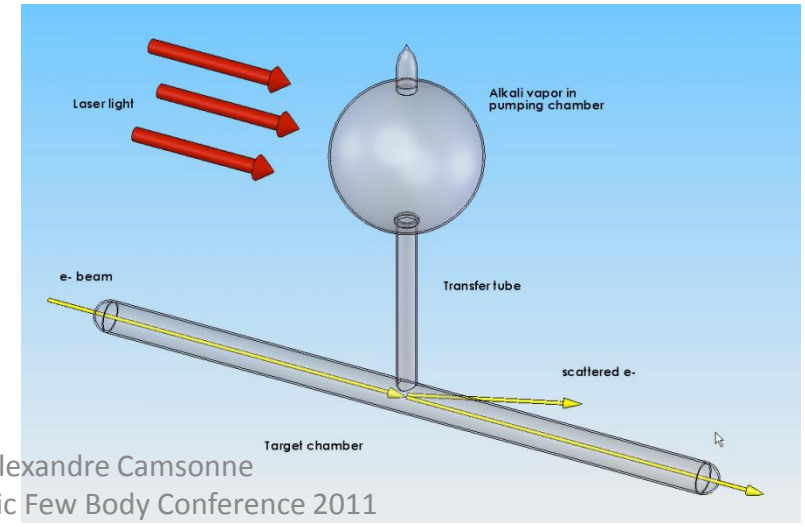


Hall A polarized ^{3}He target

W&M, UVa, JLab

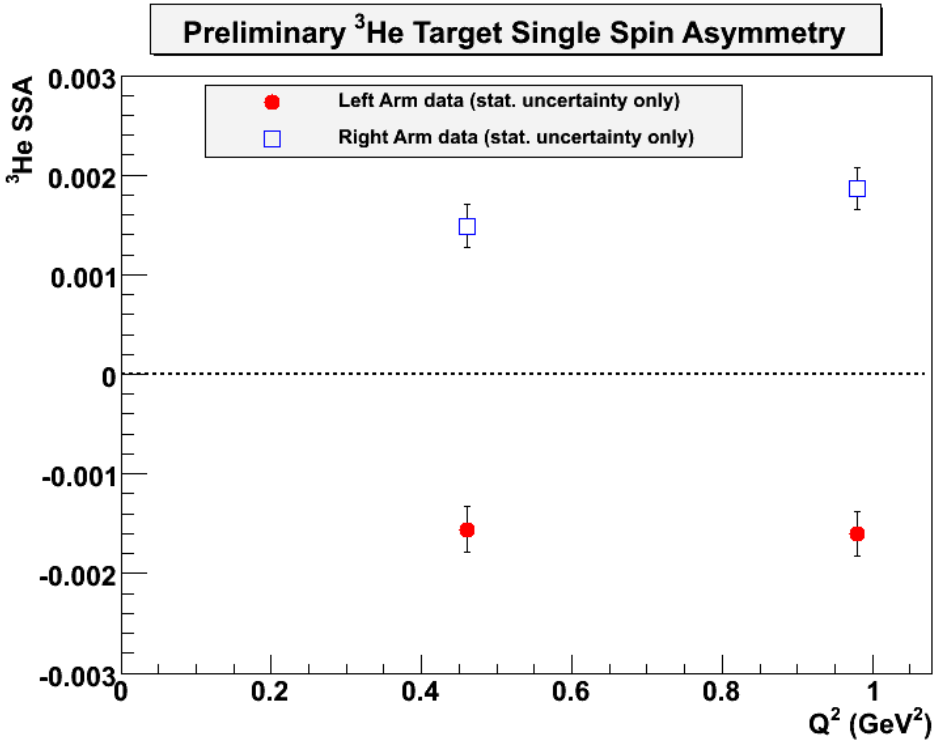
- Effective polarized neutron target
- Spin Exchange Optical Pumping (SEOP) technology
- New Innovations:
- 5:1 ratio of K:Rb for high efficiency optical pumping and spin exchange.
- Spectrally narrowed diode lasers
- With 15uA beam, $\langle P_{targ} \rangle \sim 65\%$
- Luminosity $L \sim 10^{36}$ /cm^2/s



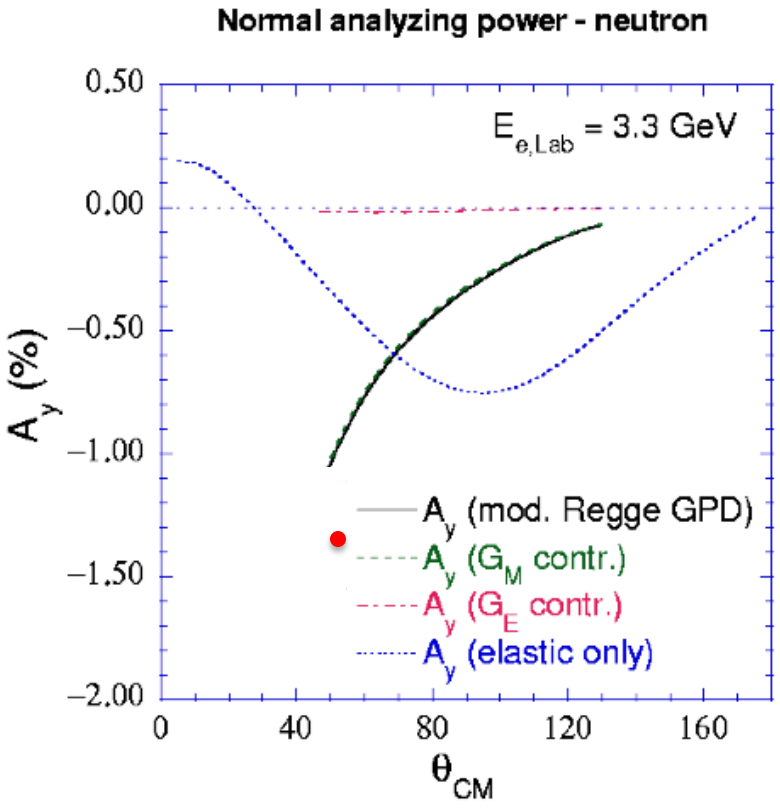


Preliminary Ay ^{3}He results at Q^2=0.5 and 1.0 GeV^2

^{3}He(e,e') A_y^{3He}



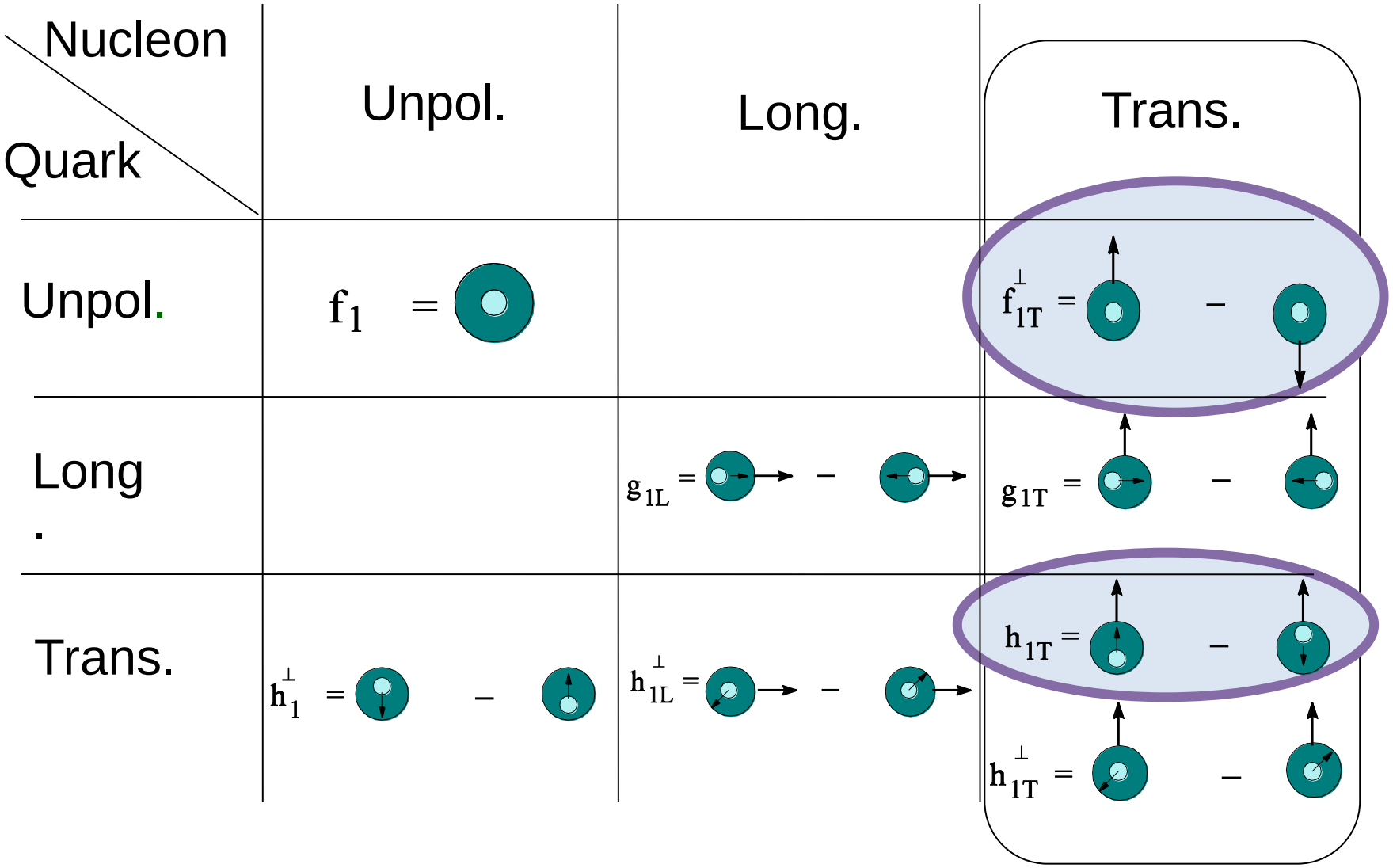
Prediction below is for Q^2= 1 GeV^2
Carlson et al.--Neutron



Data above is for helium-3, no correction to extract neutron results.

Analysis by Bo Zhao—College of W&M

Transversity "Leading-Twist" *TMD* Quark Distributions

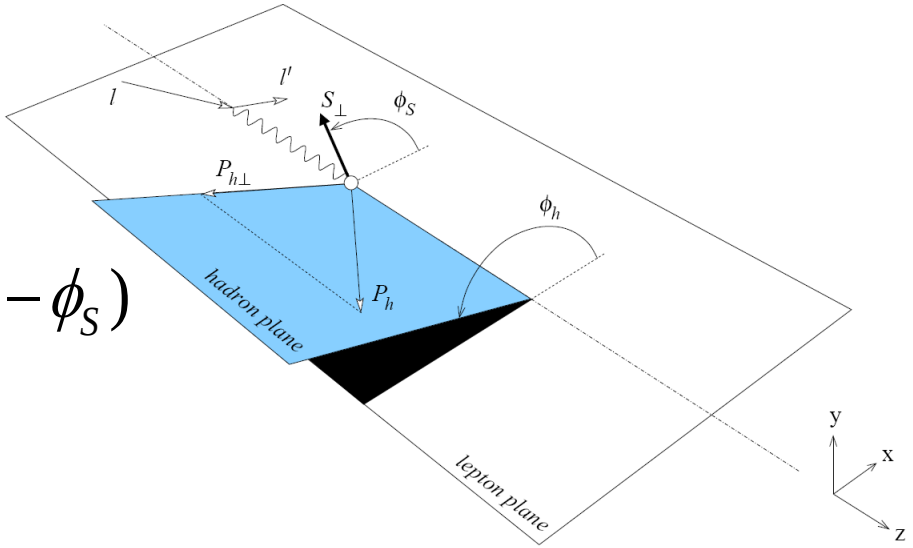


Separation of Collins, Sivers and pretzelocity effects through angular dependence in SIDIS

$$A_{UT}(\varphi_h^l, \varphi_S^l) = \frac{1}{P}\frac{N^{\uparrow} - N^{\downarrow}}{N^{\uparrow} + N^{\downarrow}}$$

$$= A_{UT}^{Collins} \sin(\phi_h + \phi_S) + A_{UT}^{Sivers} \sin(\phi_h - \phi_S)$$

$$+ A_{UT}^{Pretzelosity} \sin(3\phi_h - \phi_S)$$

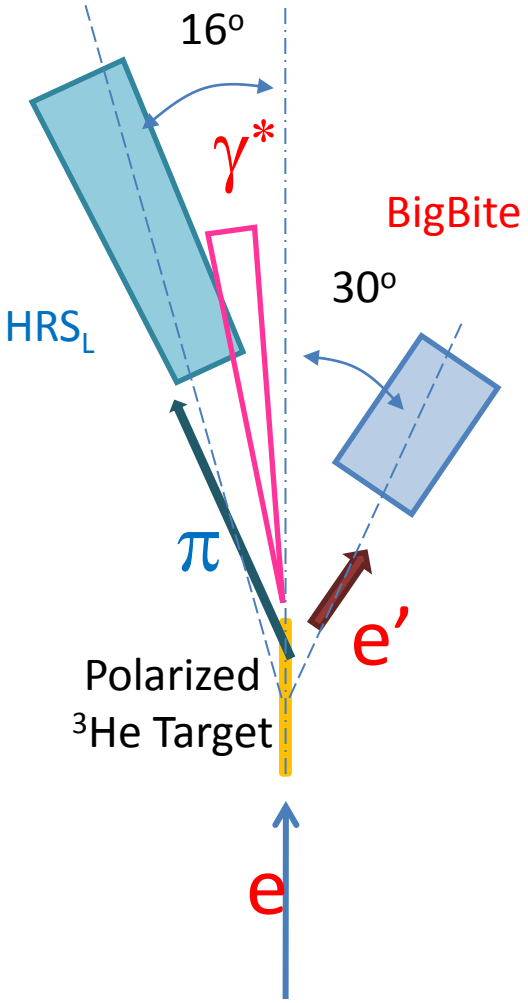


$$A_{UT}^{Collins} \propto \langle \sin(\phi_h + \phi_S) \rangle_{UT} \propto h_1 \otimes H_1^{\perp}$$

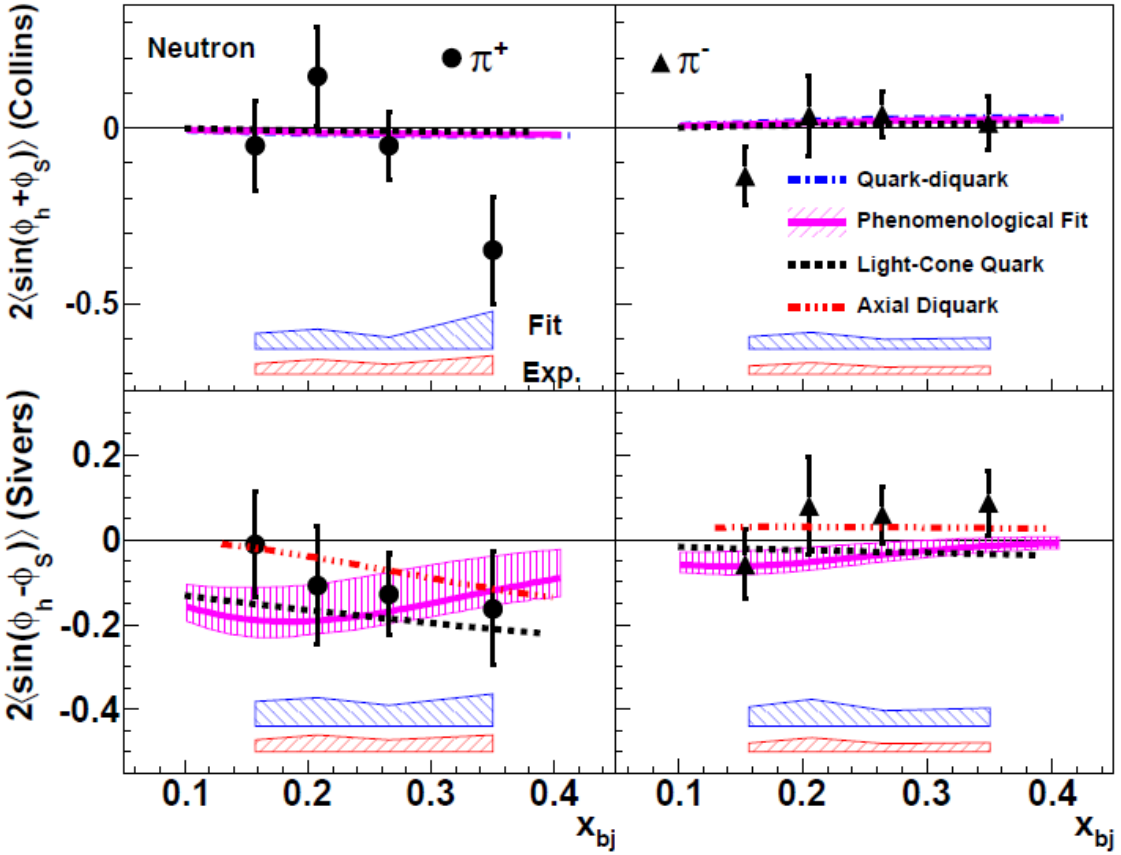
$$A_{UT}^{Sivers} \propto \langle \sin(\phi_h - \phi_S) \rangle_{UT} \propto f_{1T}^{\perp} \otimes D_1$$

$$A_{UT}^{Pretzelosity} \propto \langle \sin(3\phi_h - \phi_S) \rangle_{UT} \propto h_{1T}^{\perp} \otimes H_1^{\perp}$$

E06-010: Single Target-Spin Asymmetry in Semi-Inclusive $n^{\uparrow}(e, e'\pi^{+/-})$ Reaction on a Transversely Polarized ^{3}He Target



First measurement on the neutron

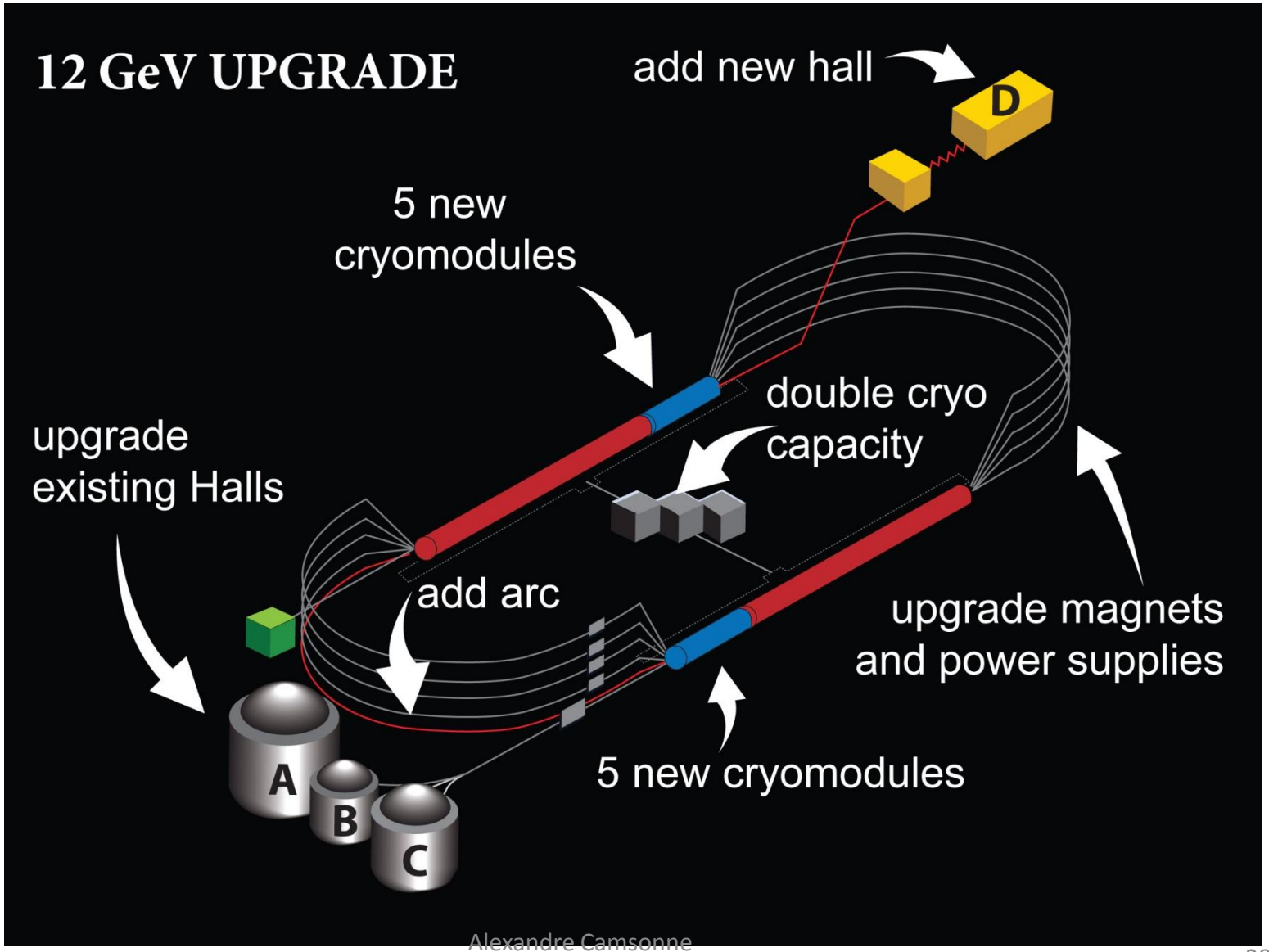


arXiv:1106.0363
Accepted by PRL

More results to come

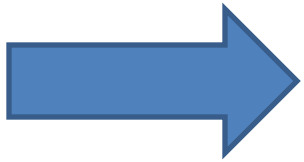
- Being Analyzed
  - Lead ee'p
  - He4/He3 elastic form factor
  - Coulomb Sum Rule
- To be submitted :
  - APEX, Ay
- Just taken
  - SRC, DVCS, x>2 on Ca^{40}
- To be taken before 12 GeV
  - g_{2p}

12 GeV Upgrade



Continuation of Hall A physics at 12 GeV

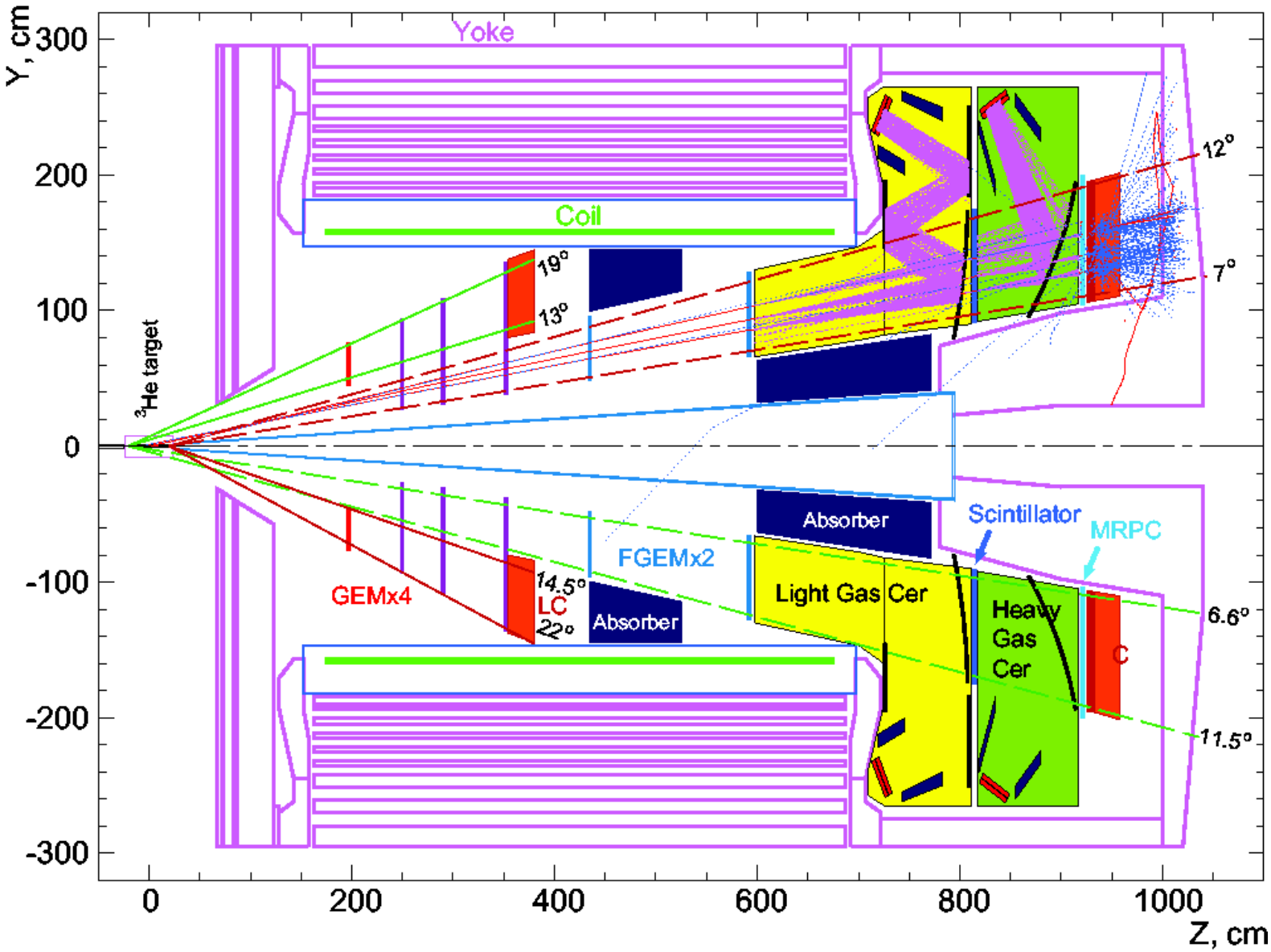
- Physics with larger kinematical coverage
  - Inclusive
  - Form factors
  - Semi-inclusive
  - Hypernuclear (HKS in Hall A)



- Larger Q^2
- Large x

- New non baseline equipment
  - Solenoidal Large Intensity Device SoLID
  - SuperBigBite

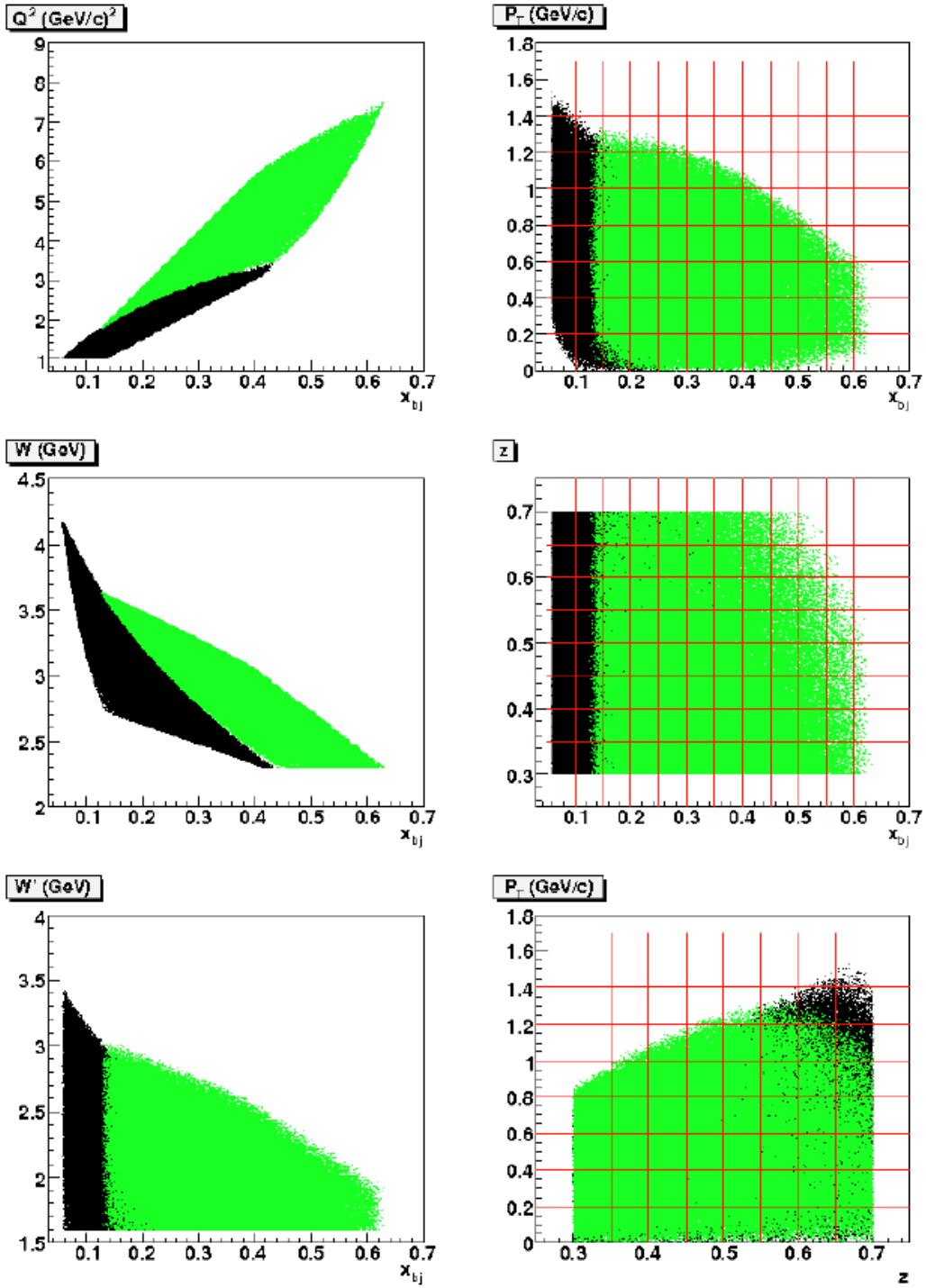
Solenoid Detector for 11 GeV SIDIS



This study done with CDF magnet. Earlier study with BaBar

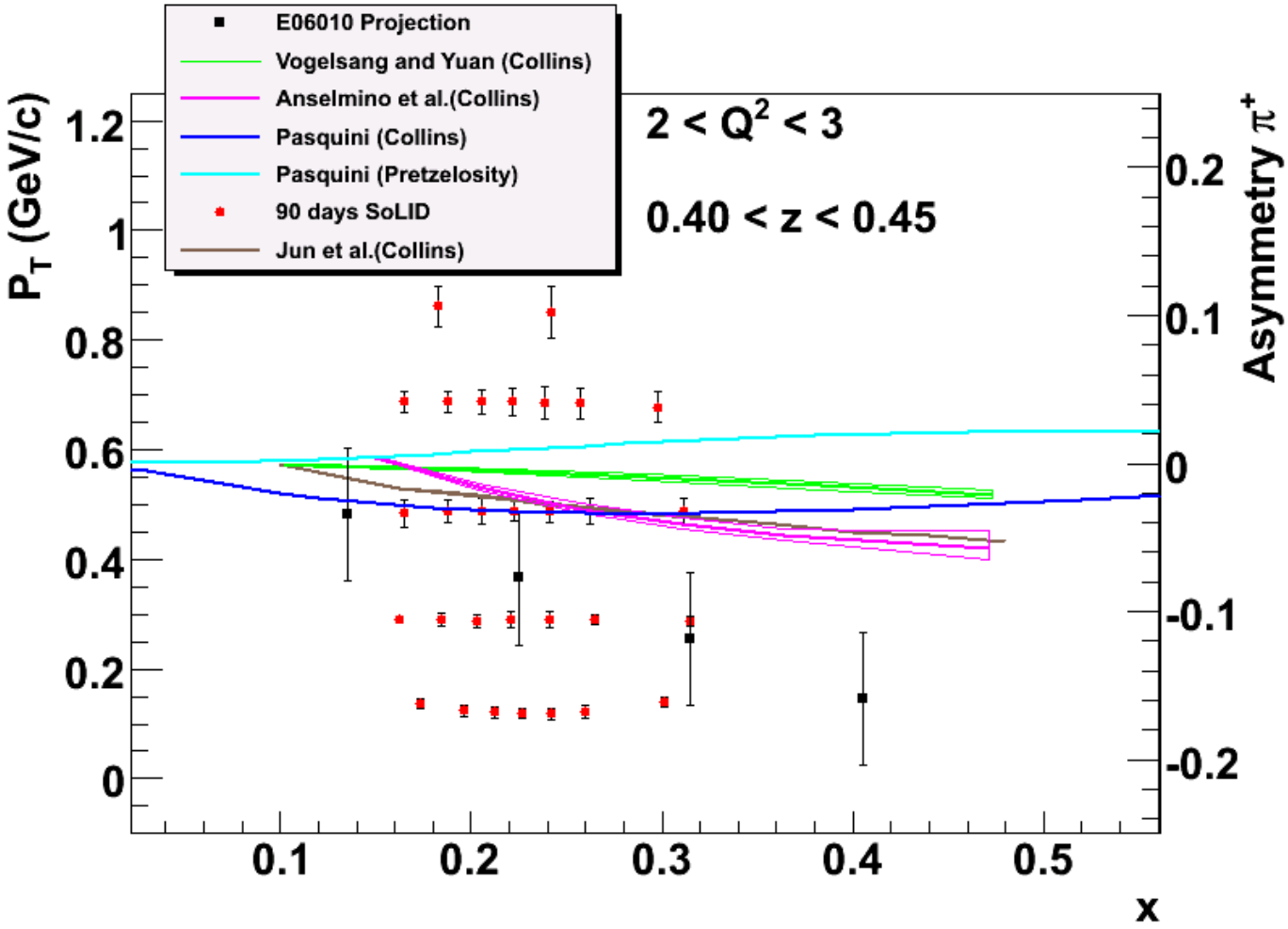
Kinematic Coverage

- Precision 4-D (x, Q^2, p_T and z) mapping of Collins, Sivers and pretzelosity.
- **Coverage with 11 GeV beam shown here**
  - Black: forward angle
  - **Green: large angle**
- x_B: 0.1 ~ 0.6
- P_T: 0 ~ 1.5 GeV/c
- W: 2.3 ~ 4 GeV
- z: 0.3 ~ 0.7
- M_m: 1.6~ 3.3 GeV

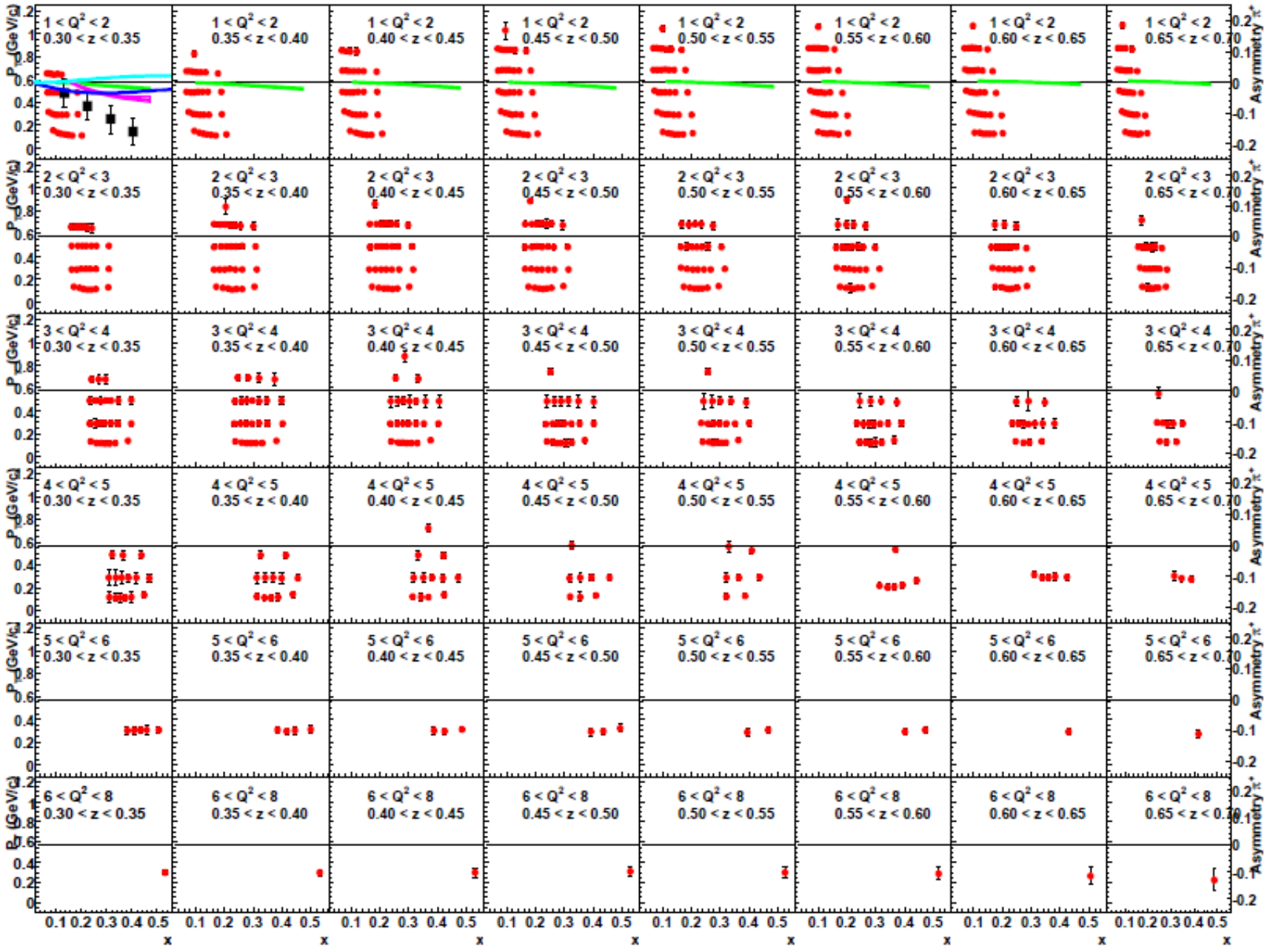


Projected Data

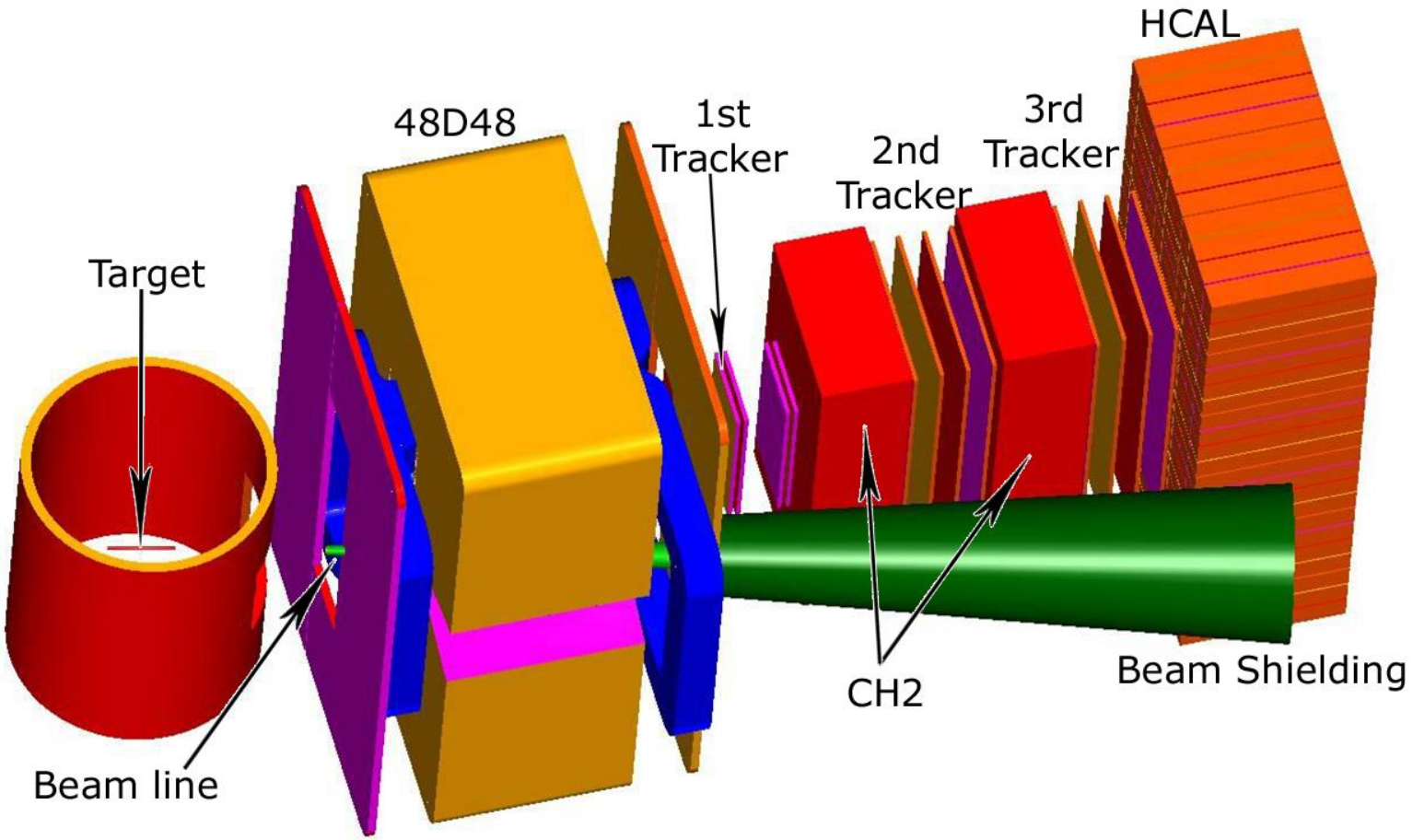
- Total 1400 bins in x, Pt and z for 11/8.8 GeV beam.
- z ranges from 0.3 ~ 0.7, only a sub-range of 11/8.8 GeV shown here.



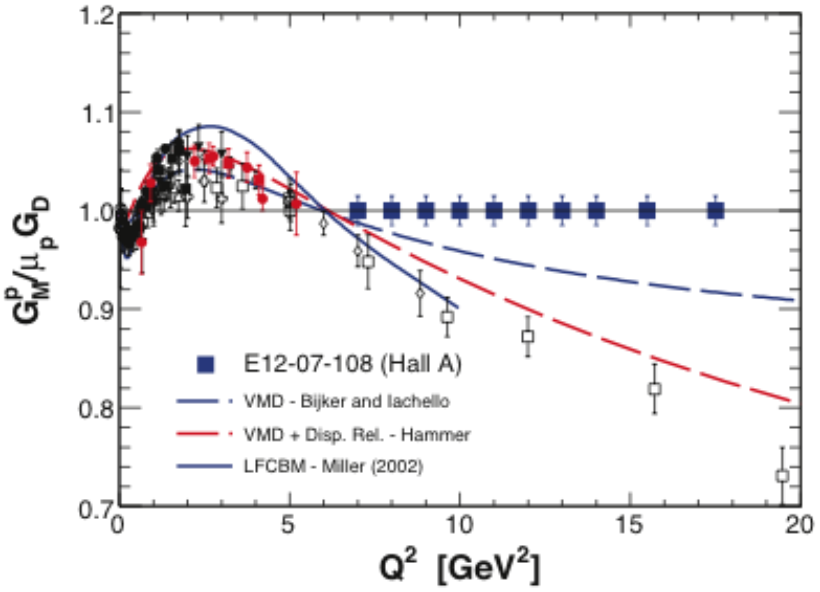
Power of SOLID

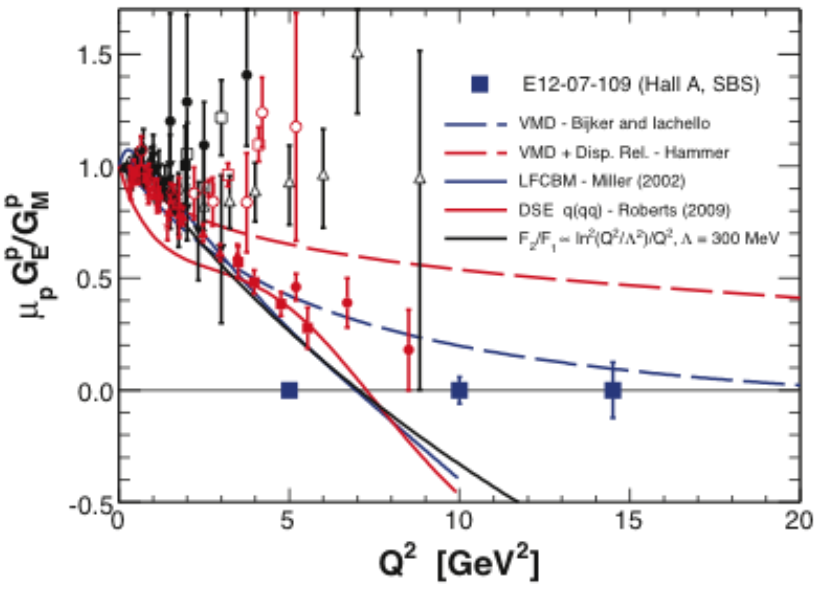


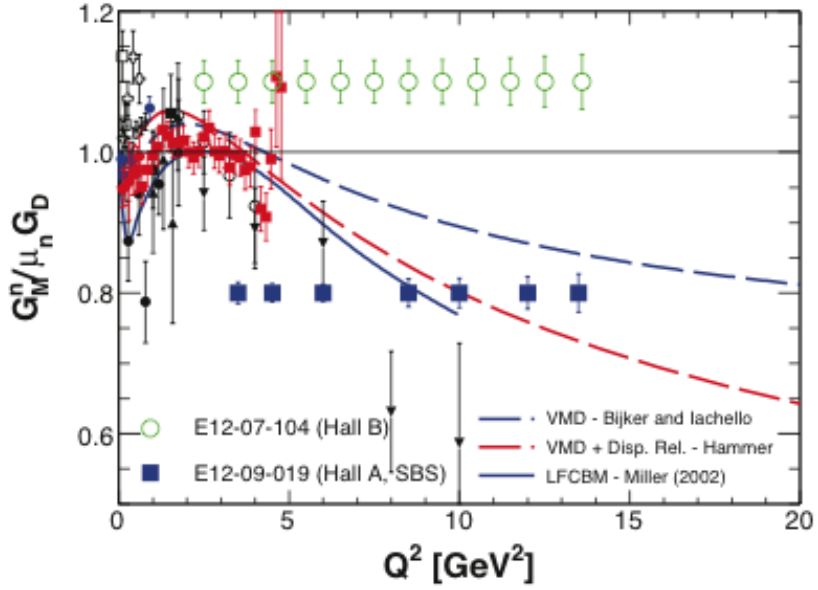
SuperBigBite G_{ep} setup

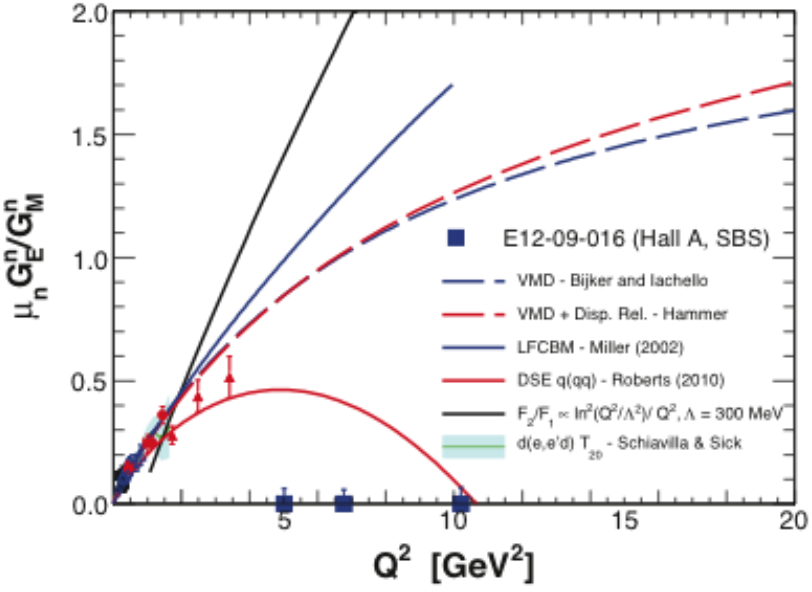


Projected EMFF data with SBS @ 12 GeV



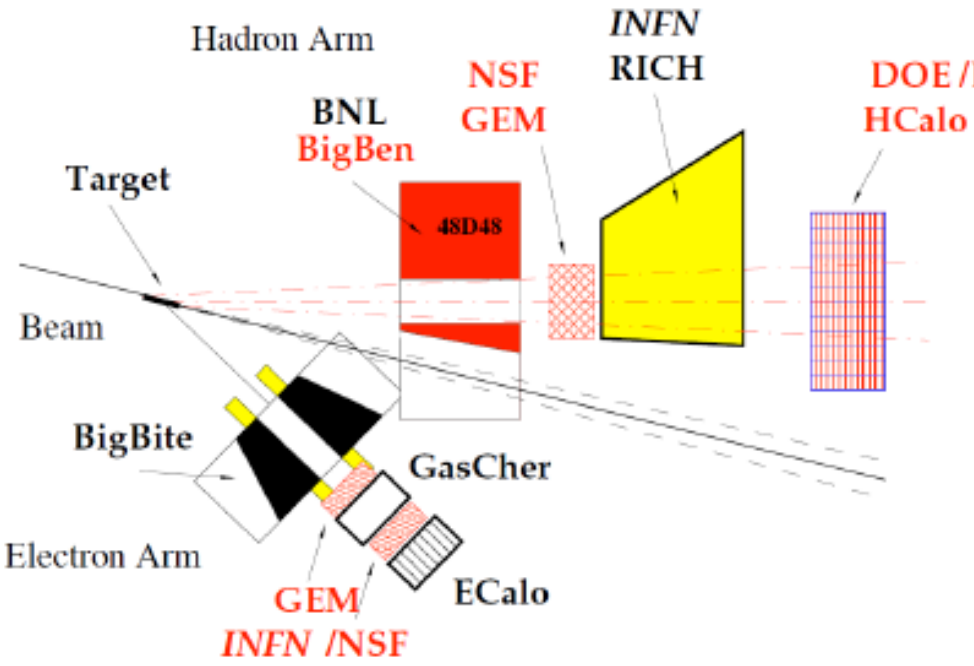






Super BigBite

$e + {}^3He^{\uparrow} \rightarrow e' + \pi(K)^{\pm} + X$



BB: e-arm at 30°
Ω = 45 msr
GEM Tracker
Gas Cherenkov
Shower
⇐ GMn/PR-09-019
SBS: h-arm at 14°
Ω = 50 msr
GEM tracker
excellent PID / RICH
Hadron CALO

Beam: 50 μA, E=8.8 and 11 GeV (80% long. Pol.)
Target: 65% polarized 3He ⇐ GEn(2)/PR-09-016
⇨ Luminosity: 1.4×10^{37} $cm^{-2}s^{-1}$, 0.05 sr

Event rate: ~10^4×HERMES
60 days of production
expected stat. accuracy:
1/10 of proton HERMES

Super BigBite Physics

Detector configurations in SBS program

	Front GEM	Polar GEM	Had Calo	Elec Calo	Big Ben	Big Bite	RICH a/gas	BB Calo	preShower (HERMES)
GEP	X	X	X	X	X				
GEN	X(BB)	X(BB)	X		X	X		X	
GMN	X(BB)	X(BB)	X		X	X		X	
A1n+	X (BB)	X	X		X	X	X,gas	X	X
T:u/d	X (BB)	X	X		X	X	X,gas	X	X
SIDIS+	X (BB)	X	X		X	X	X,a	X	
D(e,e'p)	X (BB)	X	X		X	X	*X,a	X	
SRC	X (BB)	X	X		X	X			
e,e'ϕ	X (BB)	X	X		X	X	X,a	X	
$A(Q^2)$	X (BB)	X	X		X	X	X,gas	X	

Conclusion

- Wide array of measurements relevant to Few Body Physics in Hall A
- Large projects for 12 GeV
  - SoLID
  - SuperBigBite
- New proposals or involvement on current experiments welcomed !