Jefferson Lab

Single Spin Asymmetry (SSA) in $^3\vec{He}$(e, e')

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College of William and Mary

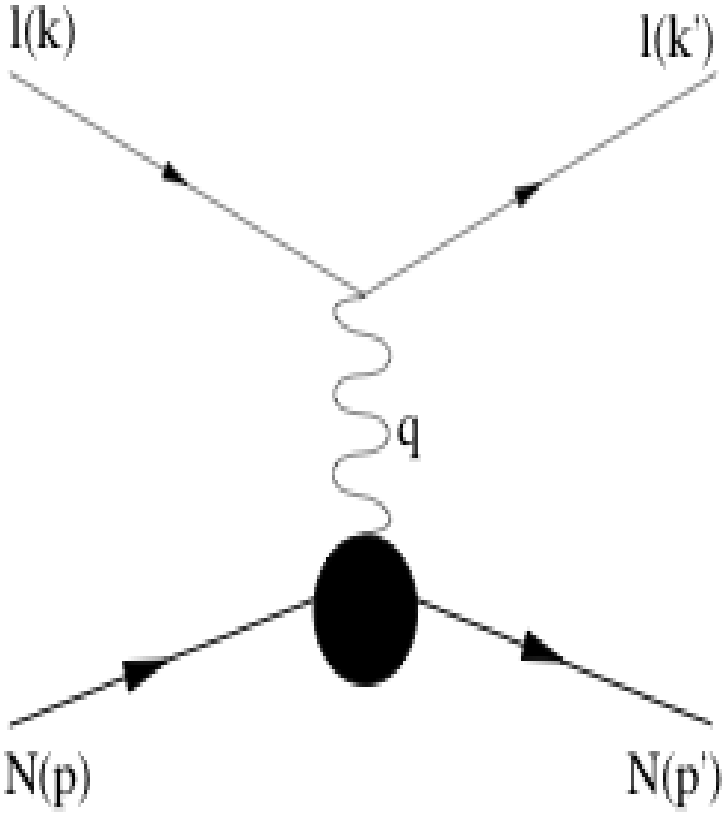
For the Hall-A collaboration at Jefferson Lab

- Quasi-Elastic ^{3}He(e, e')
- Deep-Inelastic ^{3}He(e, e') { Joe katich, Ph.D. thesis }

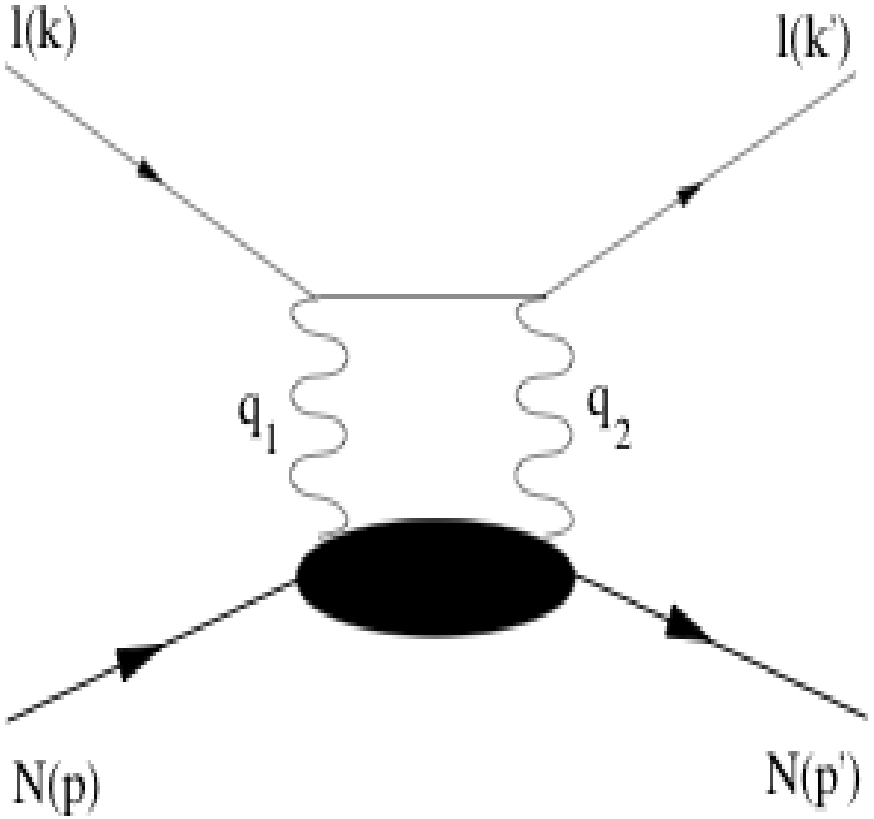
OUTLINE

- Physics Motivation
- Experimental setups
- Data analysis
- Results and future experiments

Born scattering and beyond

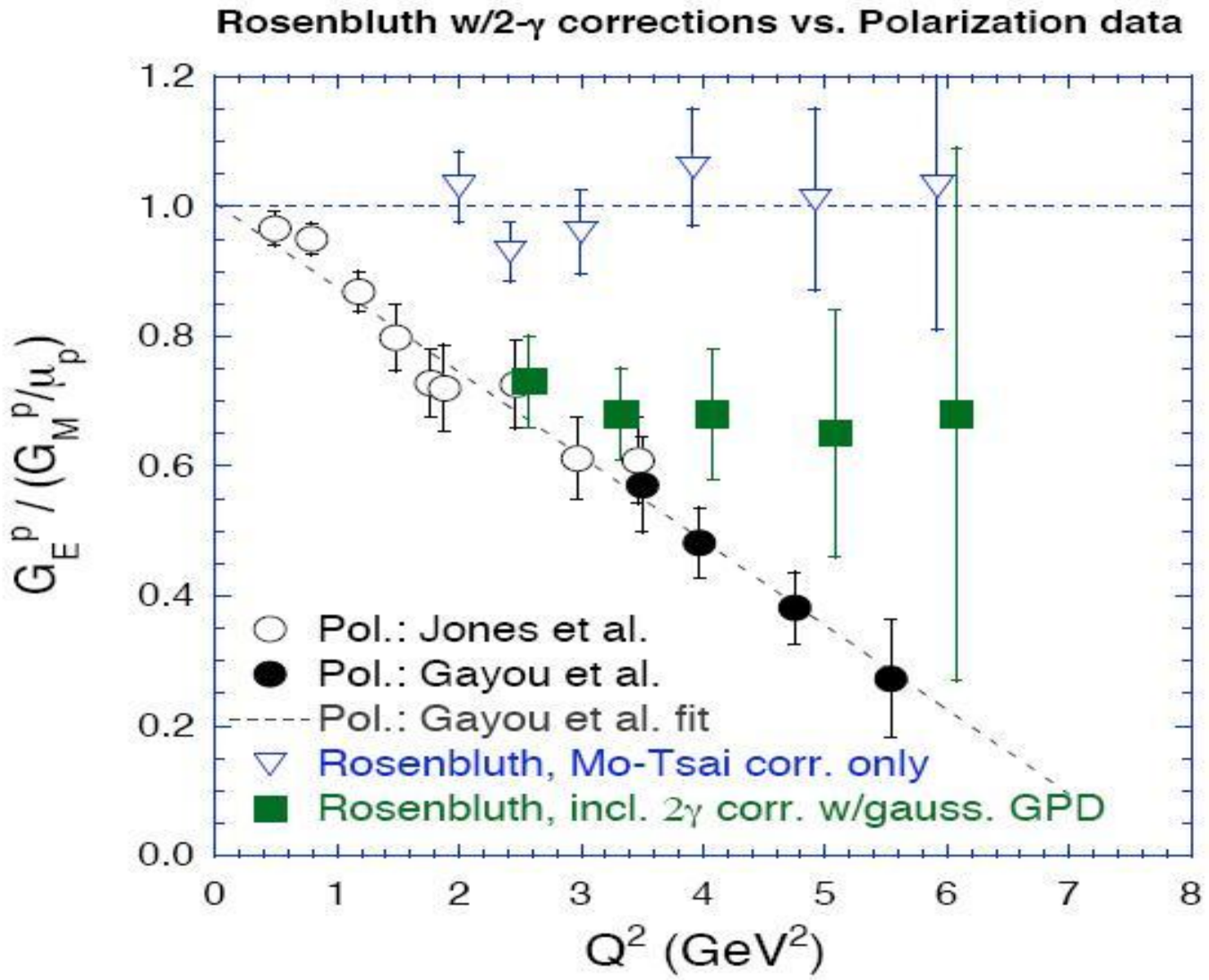


Born scattering



Initiative “radiative ” correction

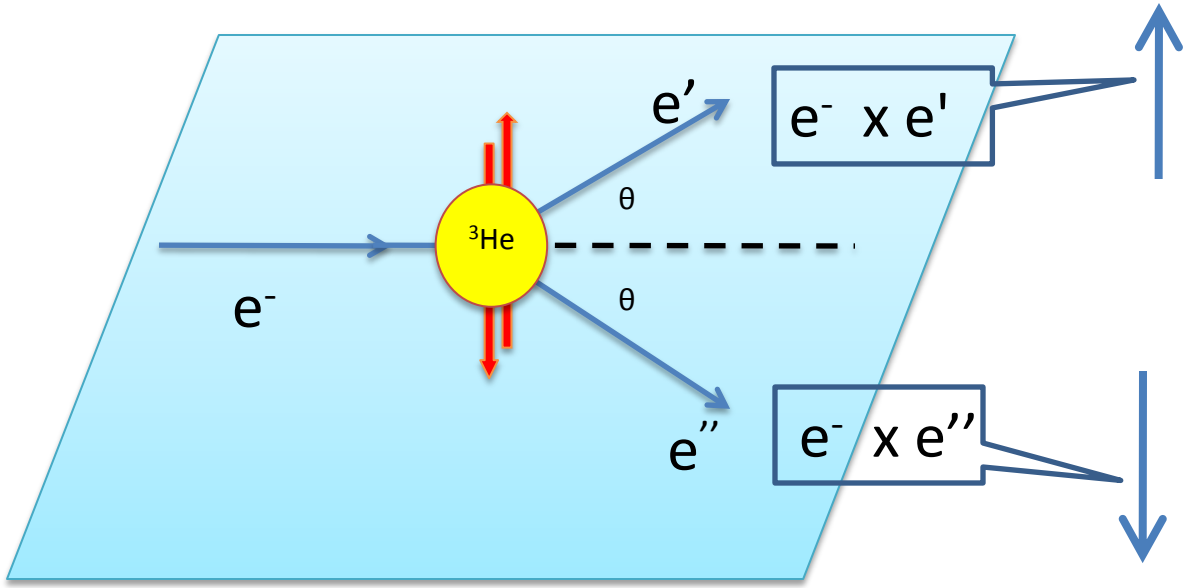
G_E^p / G_M^p data



A. Afanasev et al. Phys. Rev. D 72, 013008 (2005)

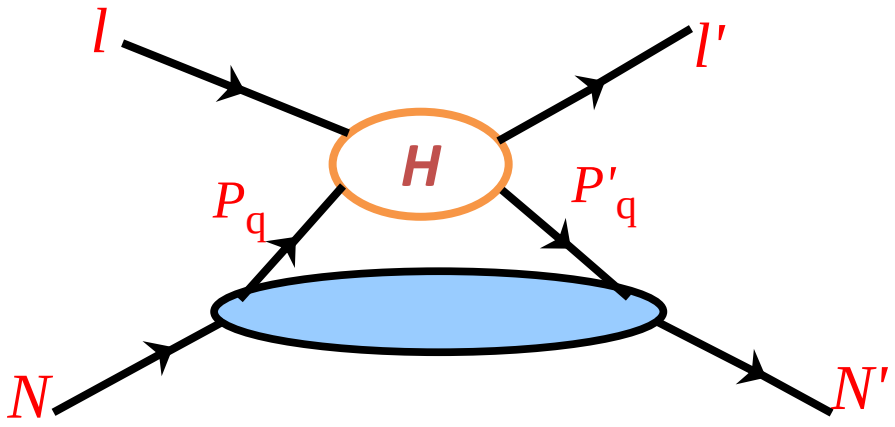
Target Single-Spin Asymmetry

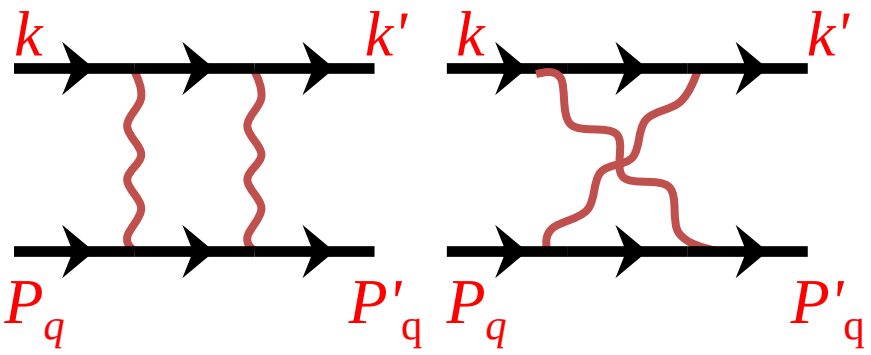
$$A_y = \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}}$$



- $A_y^{Born} = 0$ using Time-Reversal Invariance
- $A_y \neq 0$ due to imaginary part of $1\gamma \otimes 2\gamma$ interference

Connection with Generalized Parton Distributions (GPDs)





- Assume scattering described by handbag diagram with box and crossed diagrams for 2γ exchange at hard vertex H.
- Evaluation of 2γ box diagram involves full nucleon response to doubly virtual compton scattering. Elastic intermediate contribution well-known. Calculate inelastic response using GPDs.
  (P.A.M. Guichon etc. , Phys. Rev. Lett. 91, 142303 (2003))

Connection with GPDs (con't)

Y.-C. Chen, A. Afanasev, S. J. Brodsky, C. E. Carlson and M. Vanderhaeghen, PRL **93** (2004) 122301

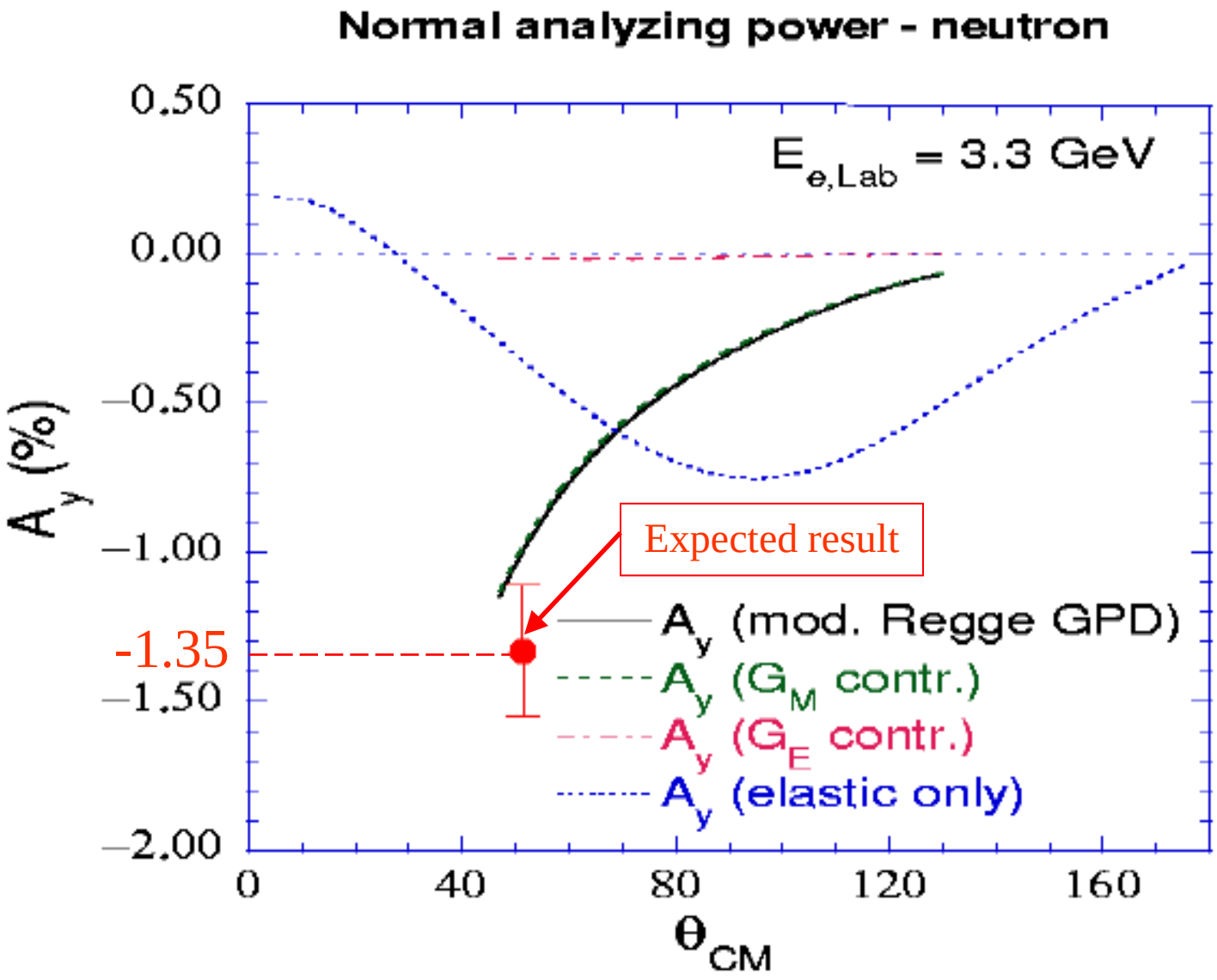
$$A_y = \sqrt{\frac{2\,\varepsilon\,(1+\varepsilon)}{\tau}}\;\frac{1}{\sigma_R}\left\{-G_M\,\mathcal{I}m\,(B) + G_E\,\mathcal{I}m\,(A)\right\}$$

$$A = \int_{-1}^{1}\frac{dx}{x}\tilde{K}\sum_q e_q^2\left[H^q(x,0,t) + E^q(x,0,t)\right]$$

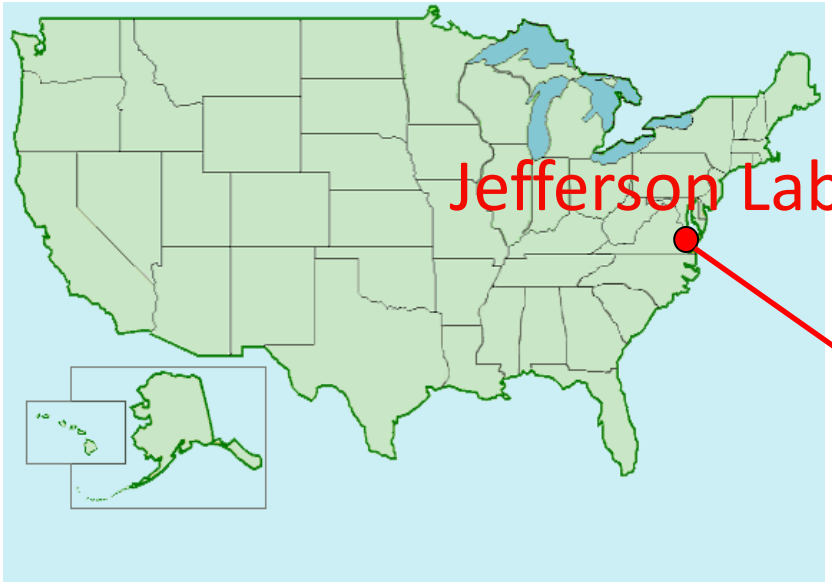
$$B = \int_{-1}^{1}\frac{dx}{x}\tilde{K}'\sum_q e_q^2\left[H^q(x,0,t) - \tau E^q(x,0,t)\right]$$

- *Im*(*A*) and *Im*(*B*) are non-zero through 2γ contribution.
- Measuring neutron A_y provides new constrain on specific GPD moment.

Theoretical prediction

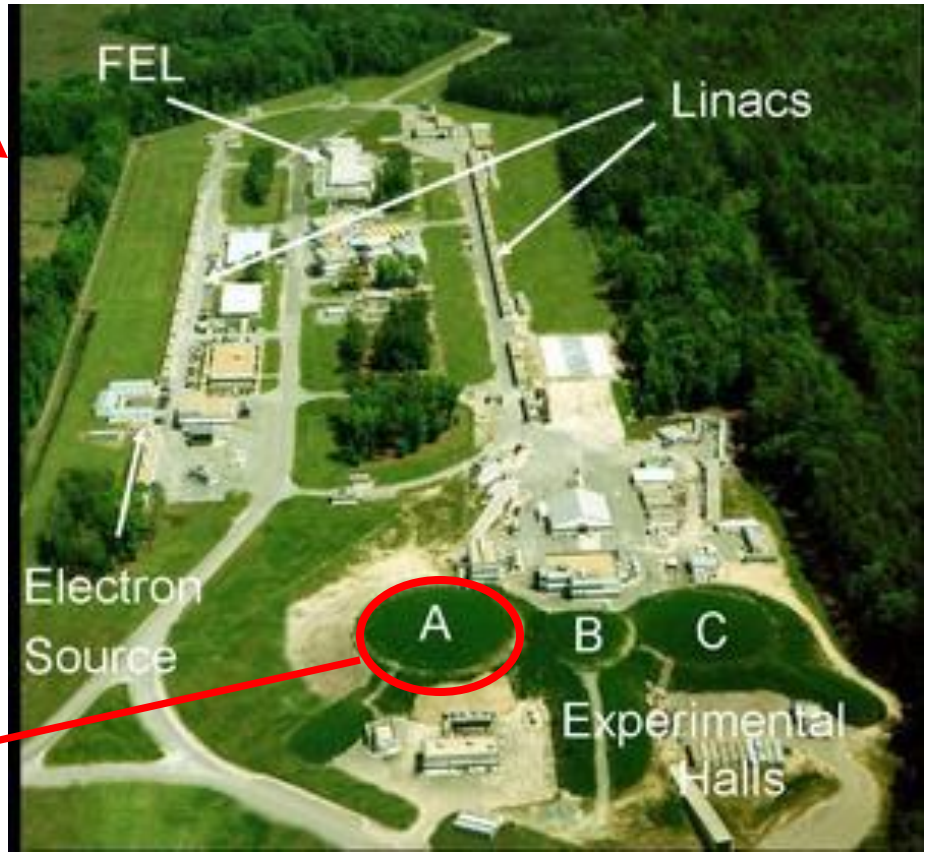


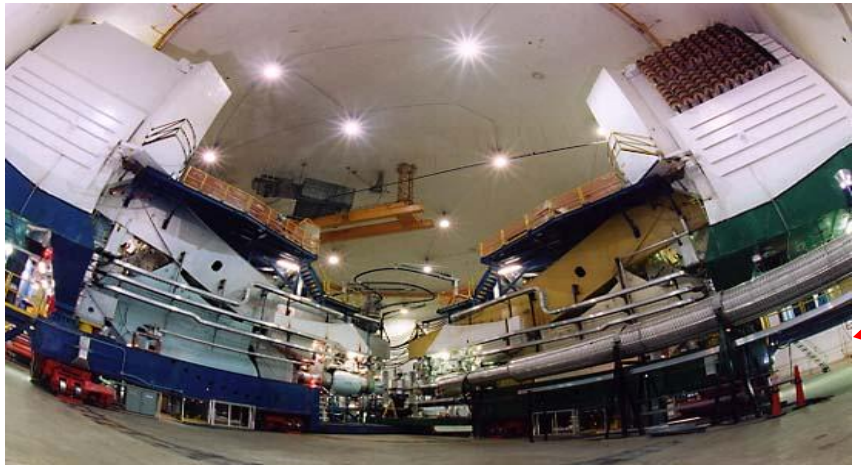
Facility at Jefferson Lab



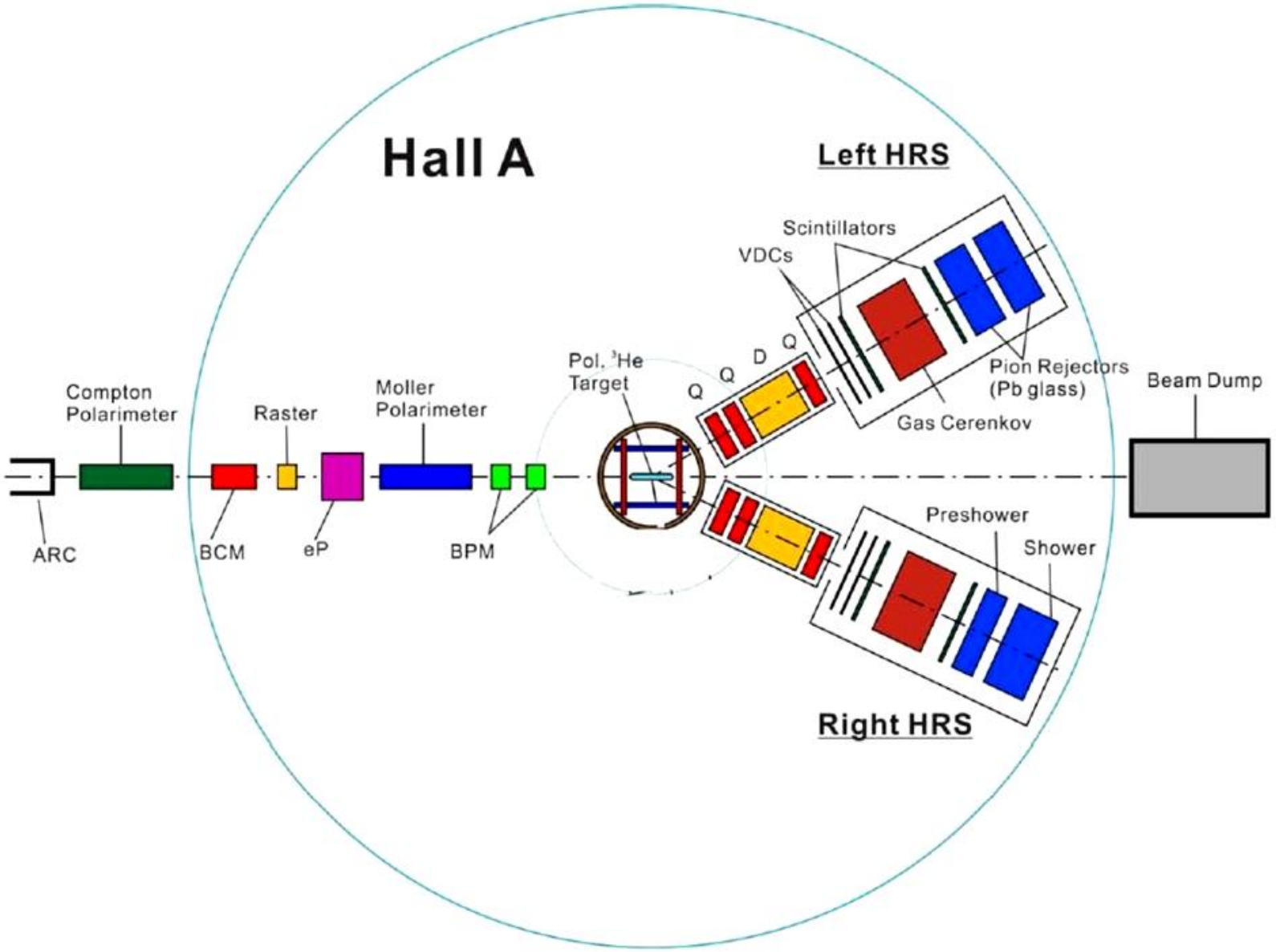
E_{max} ~ 6 GeV

I_{max} ~ 200μA

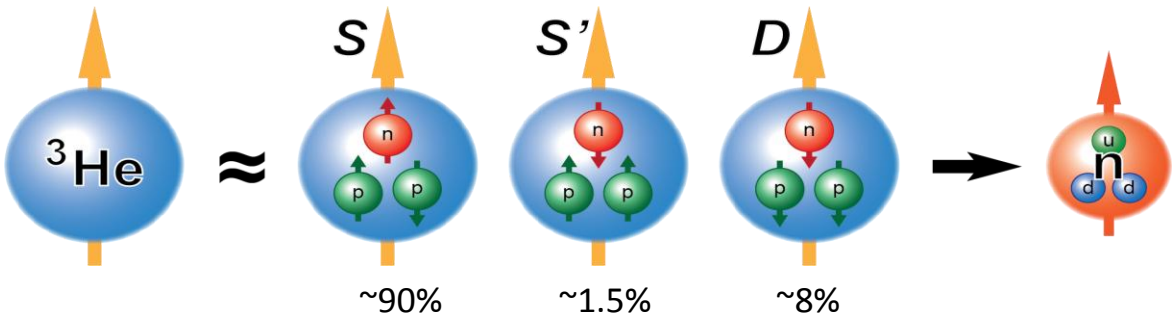


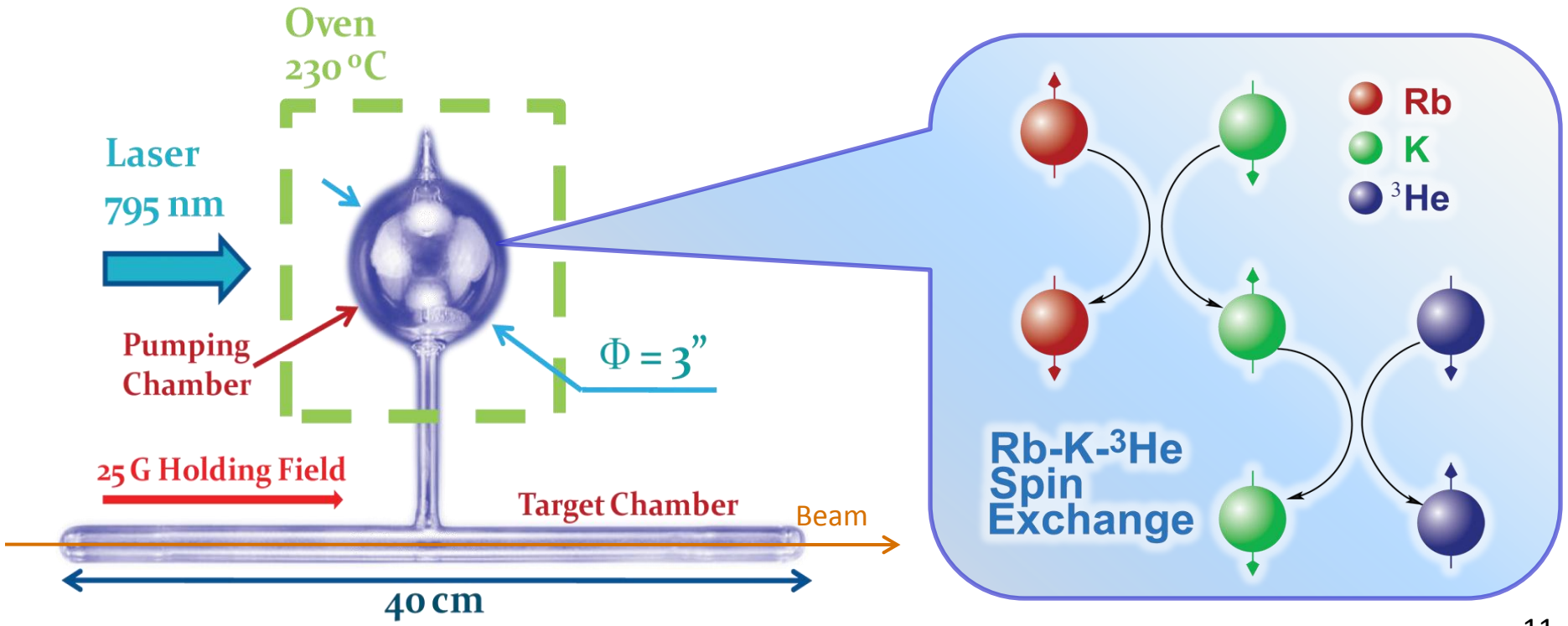


Experimental setups



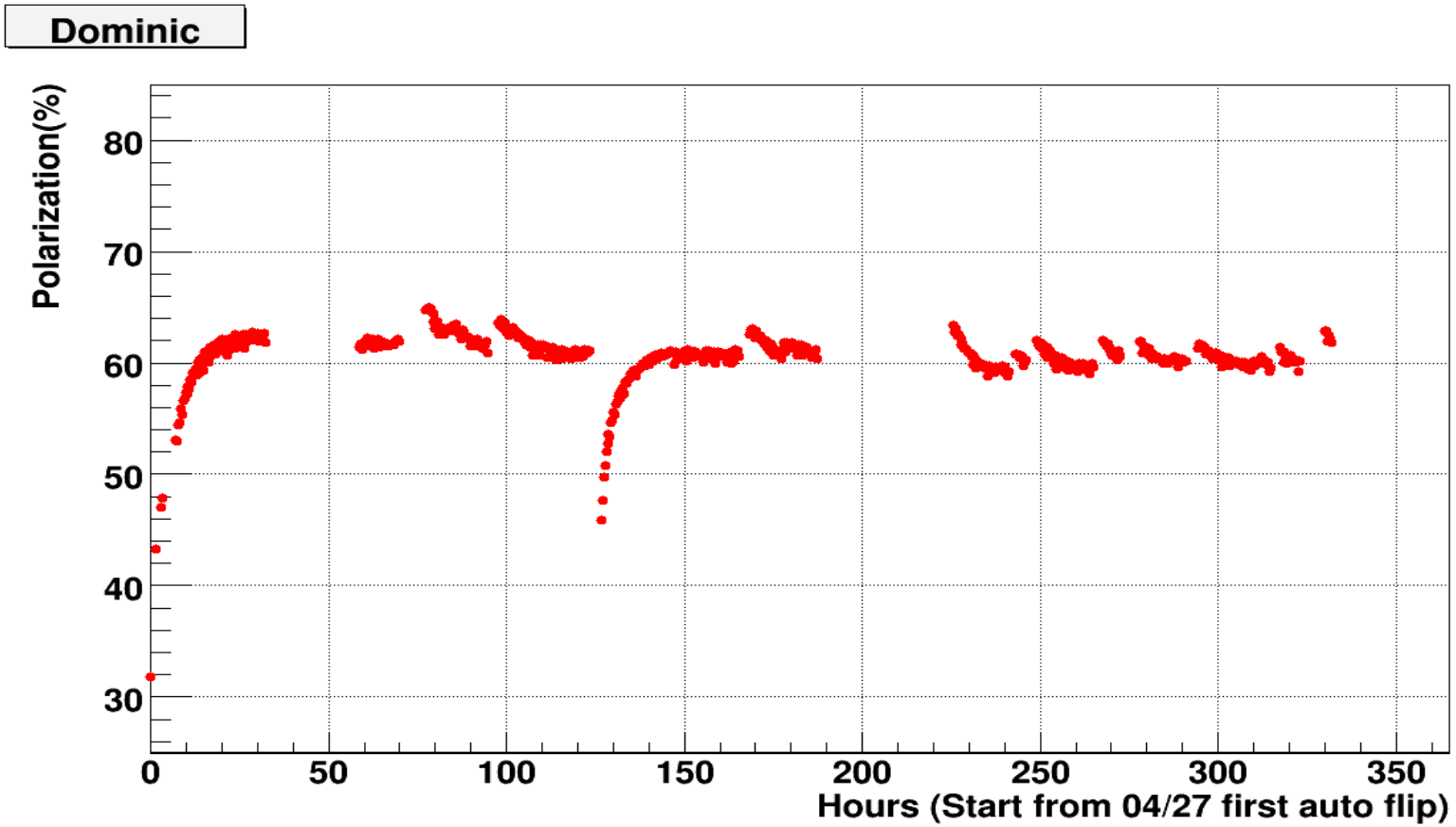
Polarized ^{3}He target





Performance of ^{3}He target

- High luminosity: $L(n) = 10^{36}$ cm^{-2} s^{-1}
- Record high 60~ 65% polarization in beam with automatic spin flip / 20 minitues

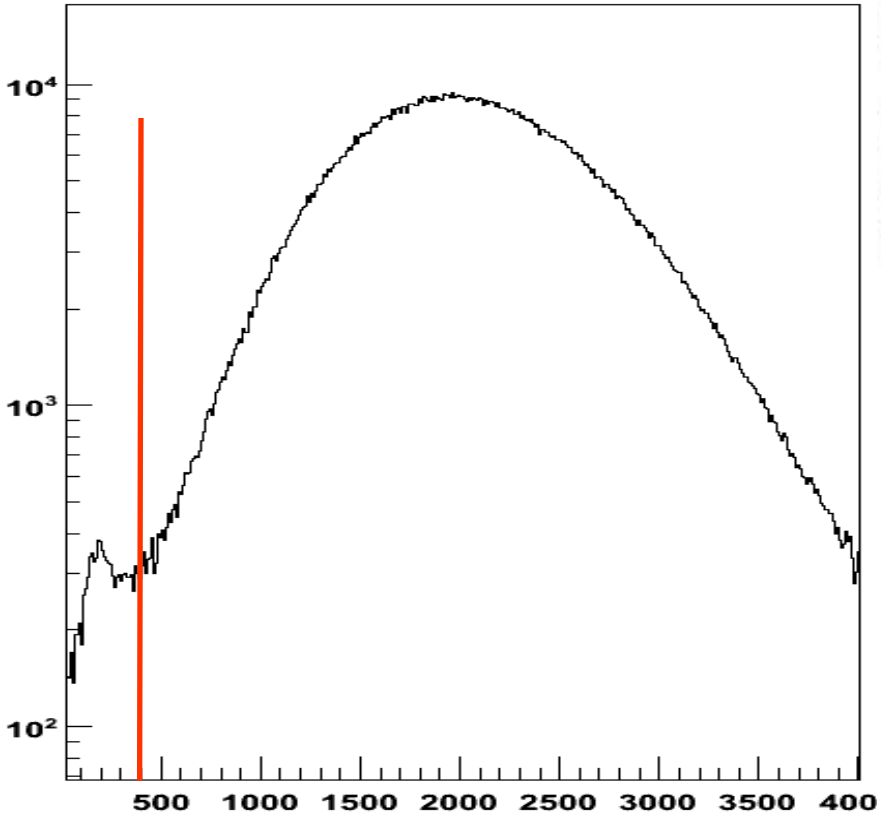


Quasi-Elastic (QE) Ay Kinematics

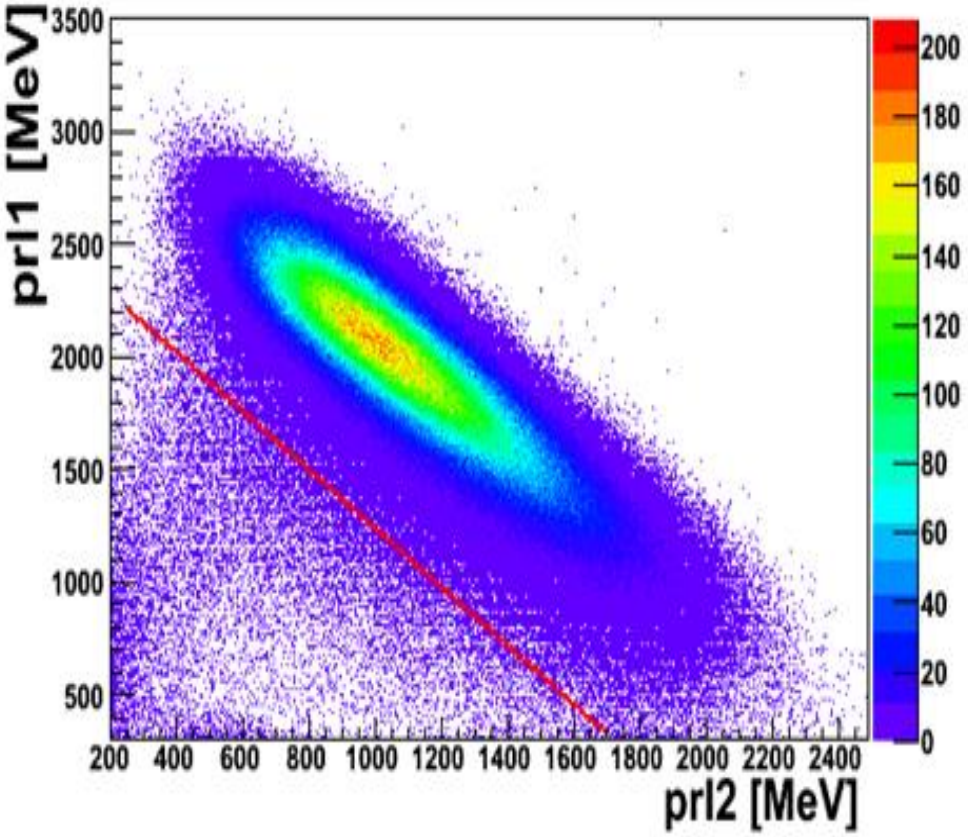
- This QE A_y experiment (E05-015) was run from April 26th to May 12th in 2009
- The Kinematics of this QE A_y experiment:

E_0 [GeV]	E' [GeV]	θ_{lab} [Deg]	Q^2 [GeV]^2	$\|q\|$ [GeV]	θ_q [Deg]
1.25	1.22	17	0.13	0.359	71
2.43	2.18	17	0.46	0.681	62
3.61	3.09	17	0.98	0.988	54

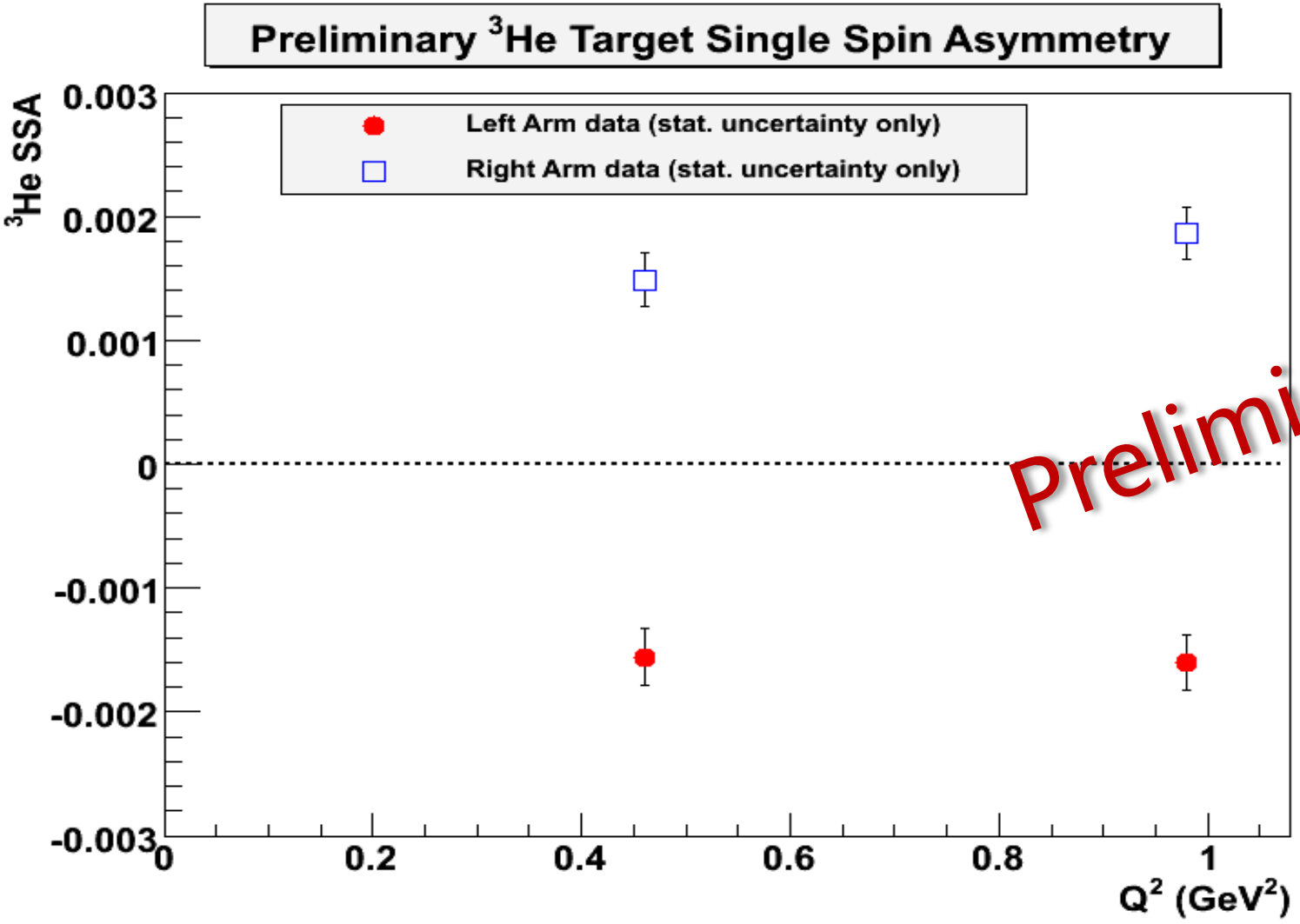
Particle Identification



Gas Cerenkov (ADCs)



Prelim. Results at (Q^2 = 0.46 and 0.98 GeV^2)



Topic 2: What about A_y for N(e,e') in DIS?

- The formalism remains the same:
  A_y=0 for 1-photon exchange

- For DIS, one assumes that the scattering is dominated by two photon exchange with a single quark.

- For non-interacting quarks, A_y=0 for two-photon exchange

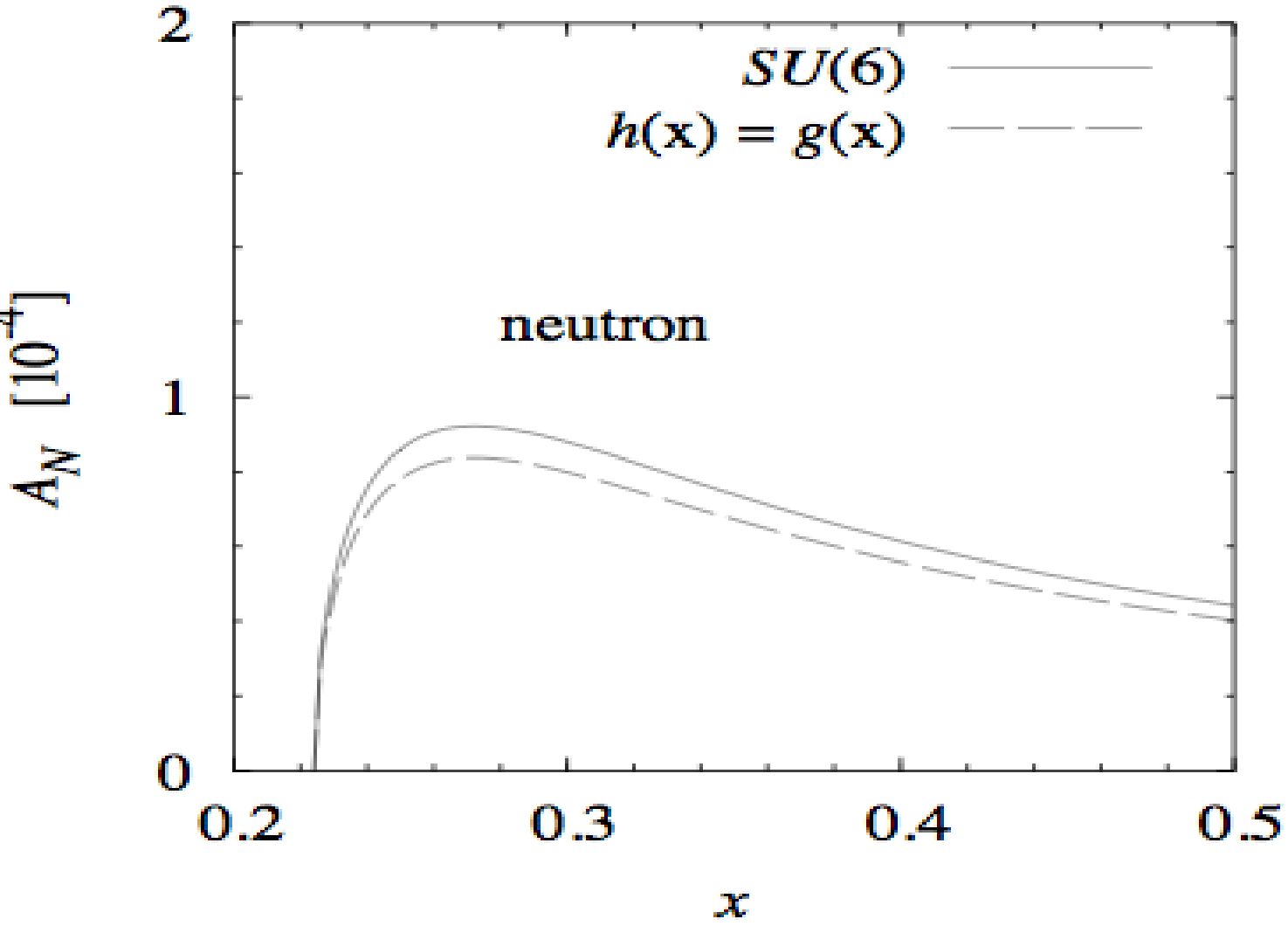
- Afanasev, Strikman, Weiss (**Phys.Rev.D77:014028,2008)** predict $A_y \sim 10^{-4}$ using a model based on the quark transversity distribution.

- This means *the SSA should change by two orders of magnitude from DIS to QE kinematics.* This is a direct study of the "transition" from hadron-like to parton-like behavior.

- This was measured in Hall A during the transversity experiment E06-010, using the BigBite Spectrometer in singles mode.

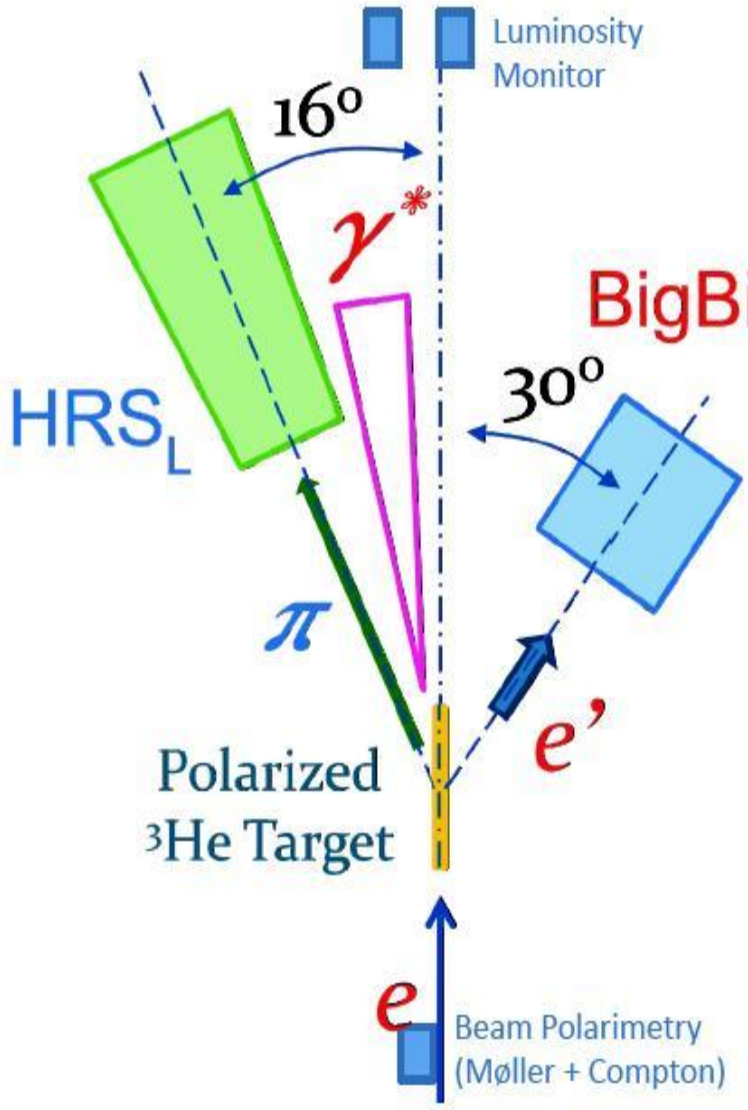
- Joe Katich-WM graduate thesis student

Prediction for DIS A_y



Afanasev, Strikman, Weiss (**Phys.Rev.D77:014028,2008)**

E06-010 Experiment

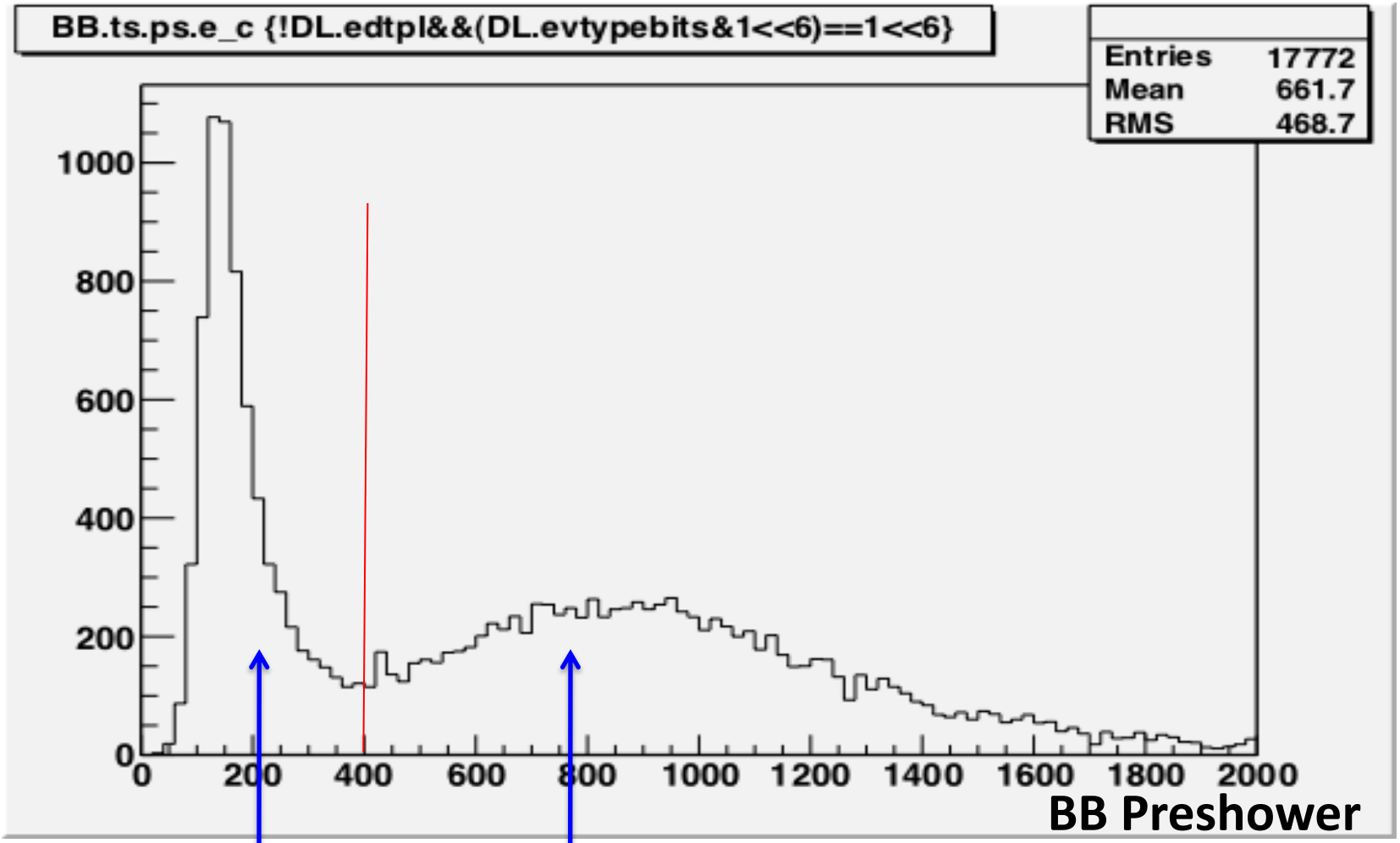


Measure ^{3}He(e,e') SSA using BB and LHRS in singles mode.

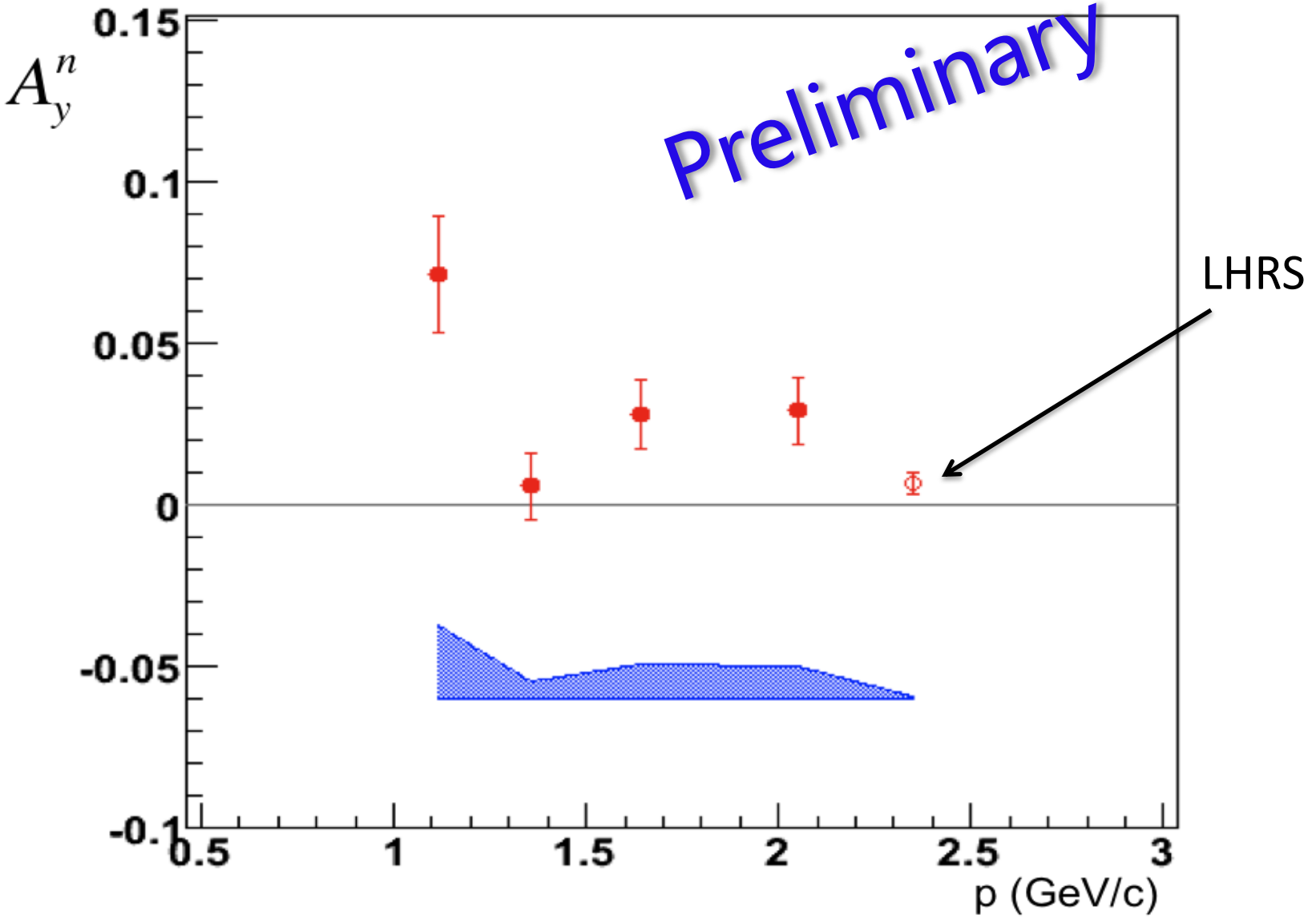
E=5.89 GeV

	LHRS	BB			
		1	2	3	4
θ (deg)	16.00	29.60	29.60	29.50	28.80
θ (rad)	0.28	0.52	0.52	0.51	0.50
E (GeV)	5.89	5.89	5.89	5.89	5.89
E' (GeV)	2.35	1.12	1.36	1.65	2.05
ν (GeV)	3.54	4.78	4.53	4.25	3.84
Q^2 (GeV^2)	1.07	1.71	2.09	2.51	2.99
W^2 (GeV^2)	6.45	8.13	7.30	6.33	5.09
X	0.16	0.19	0.25	0.32	0.42

Electron Identification

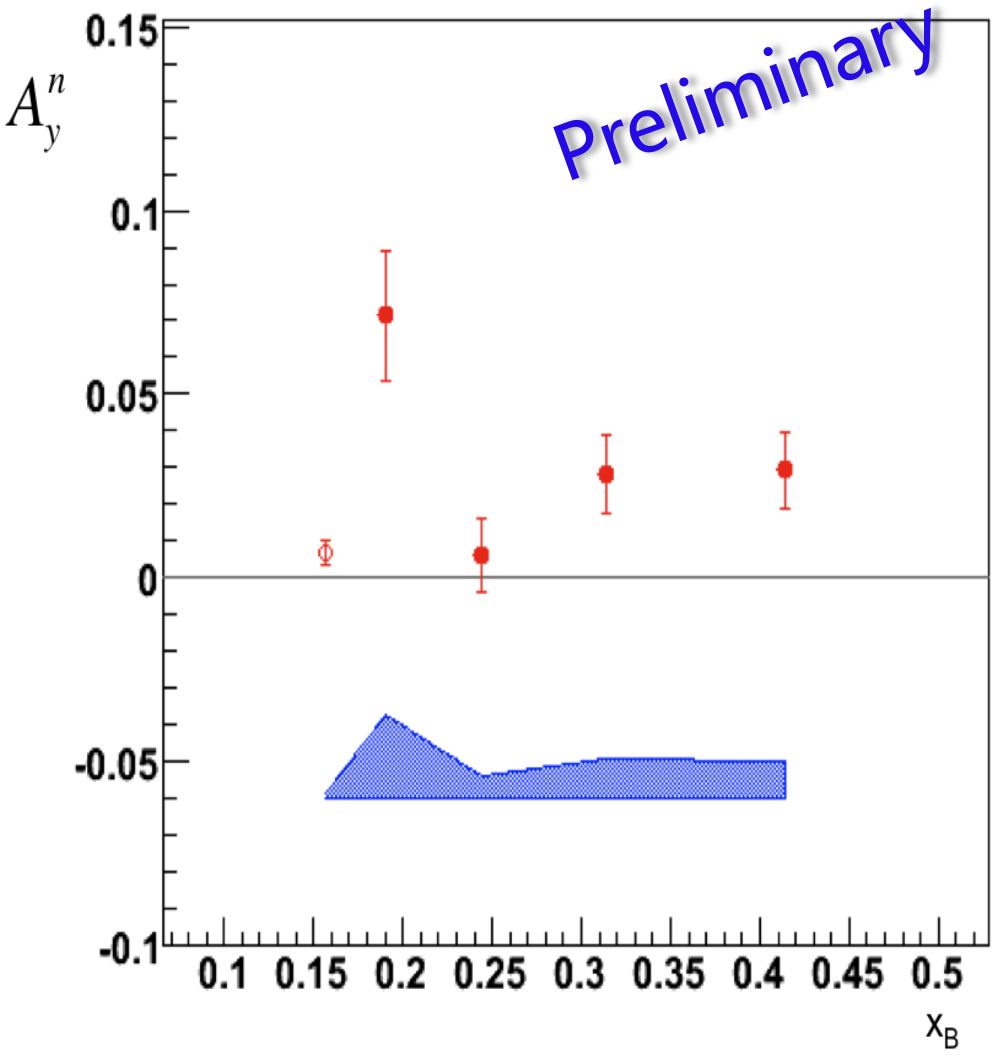


Prelim. results for DIS A_y

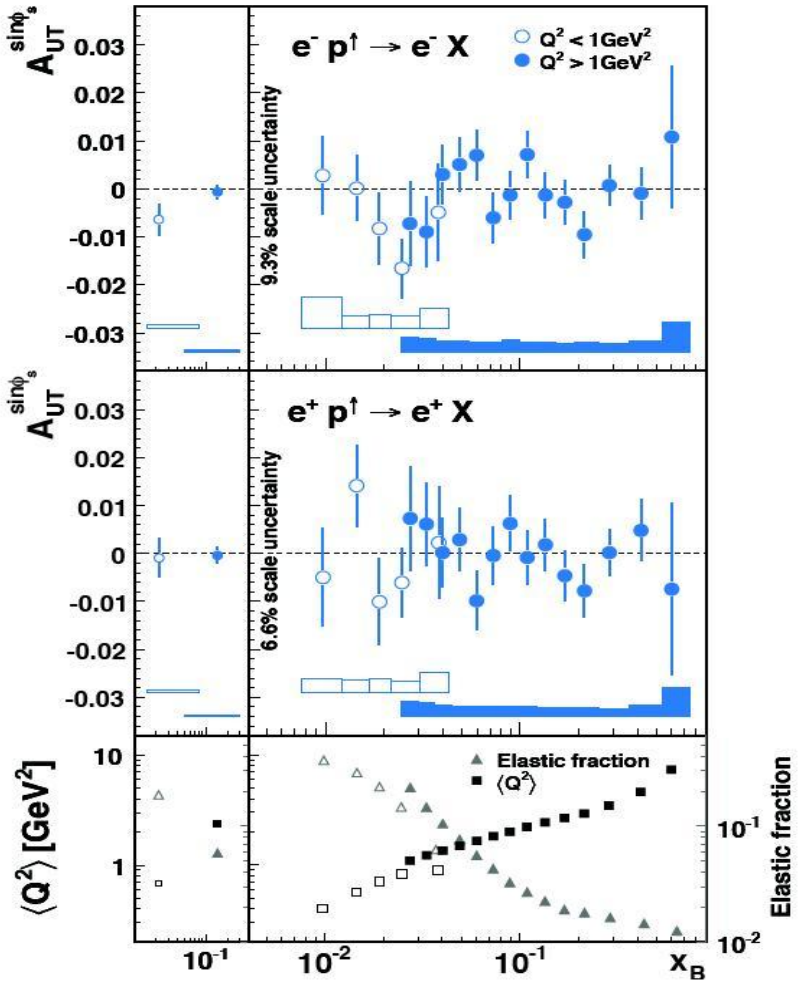


Results for n and p

Prelim. Jlab Neutron

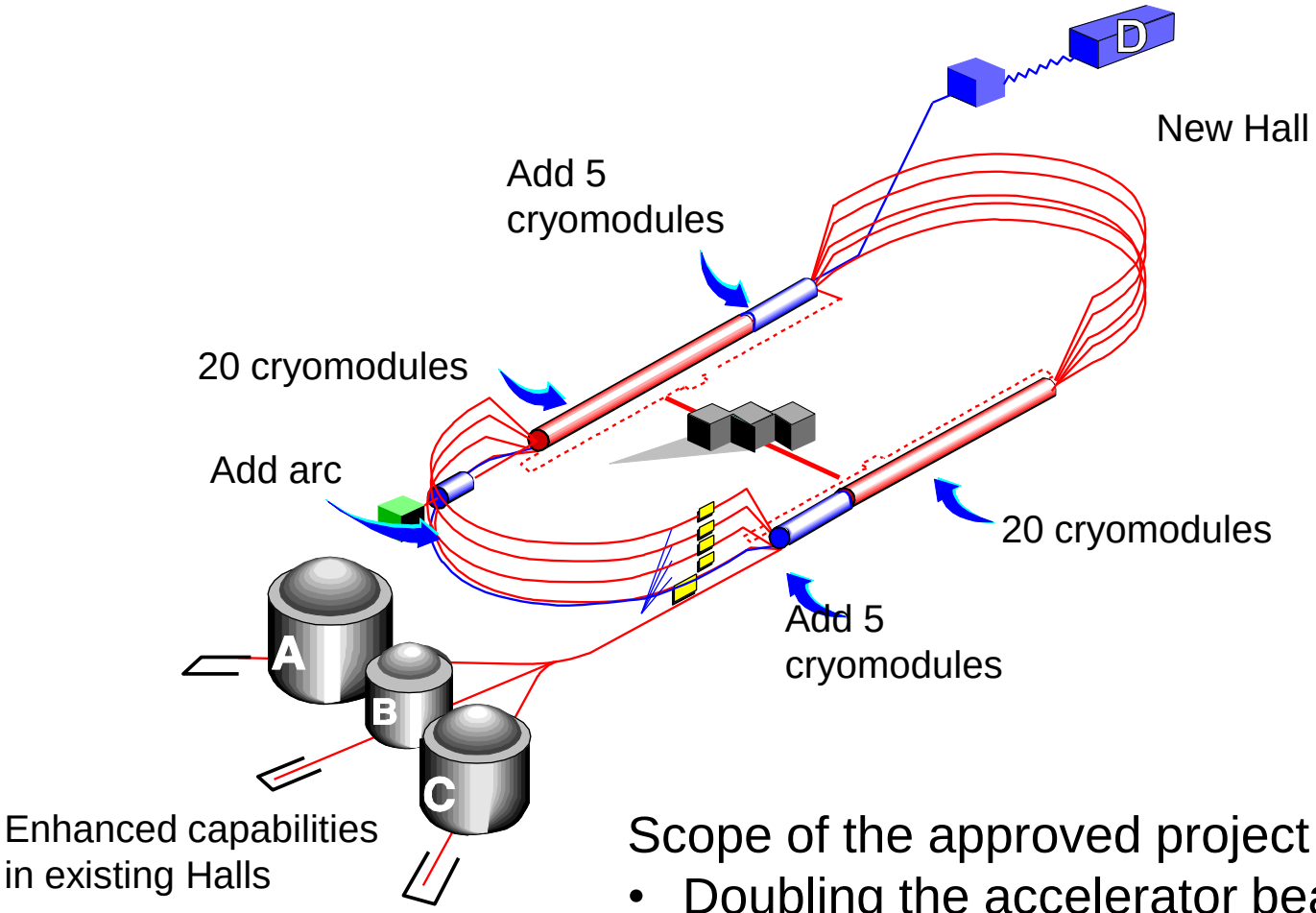


HERMES Proton



A. Airapetian et al.
Phys. Lett. B 682, 351 (2010)

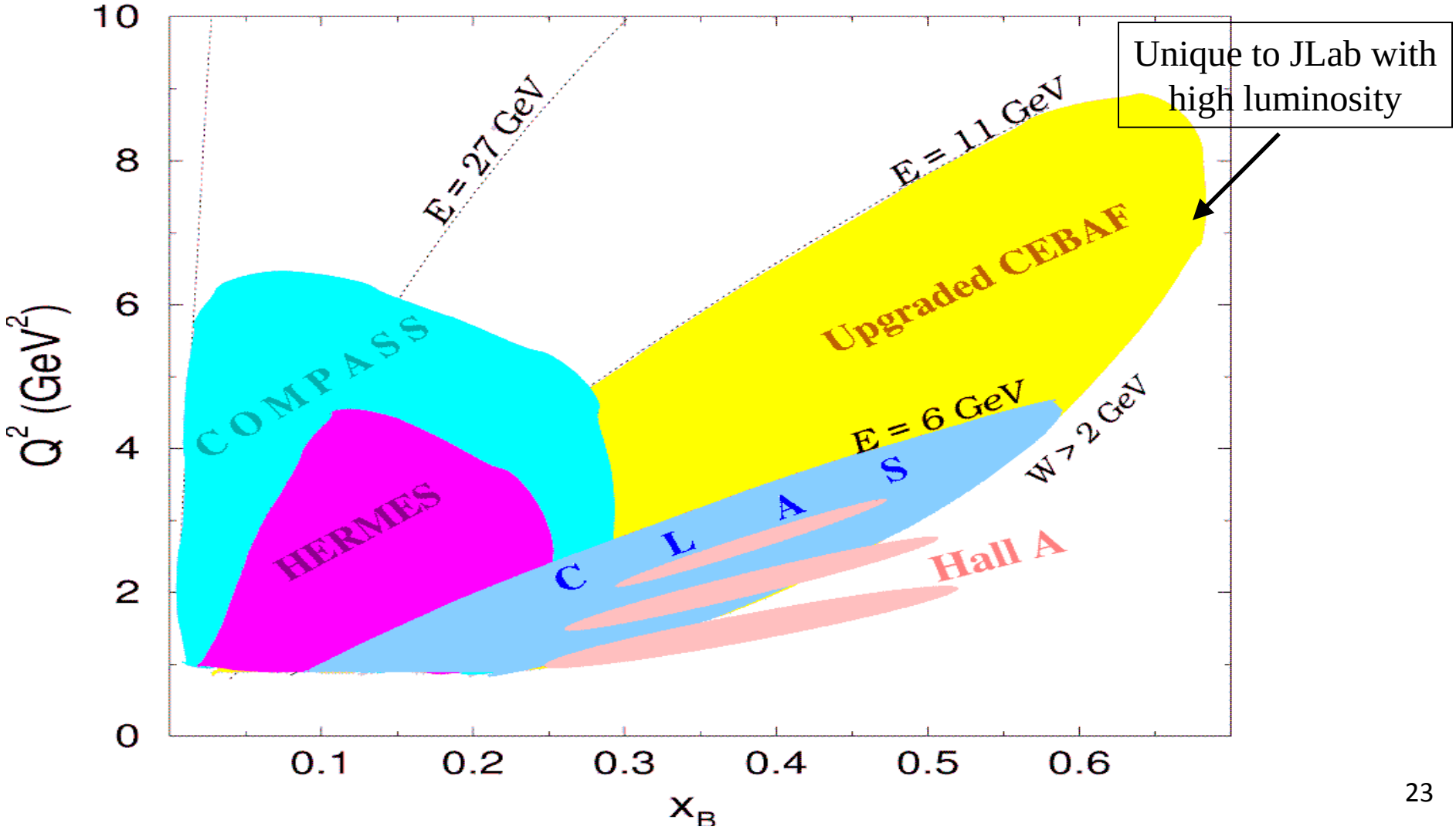
JLab 12 GeV upgrade



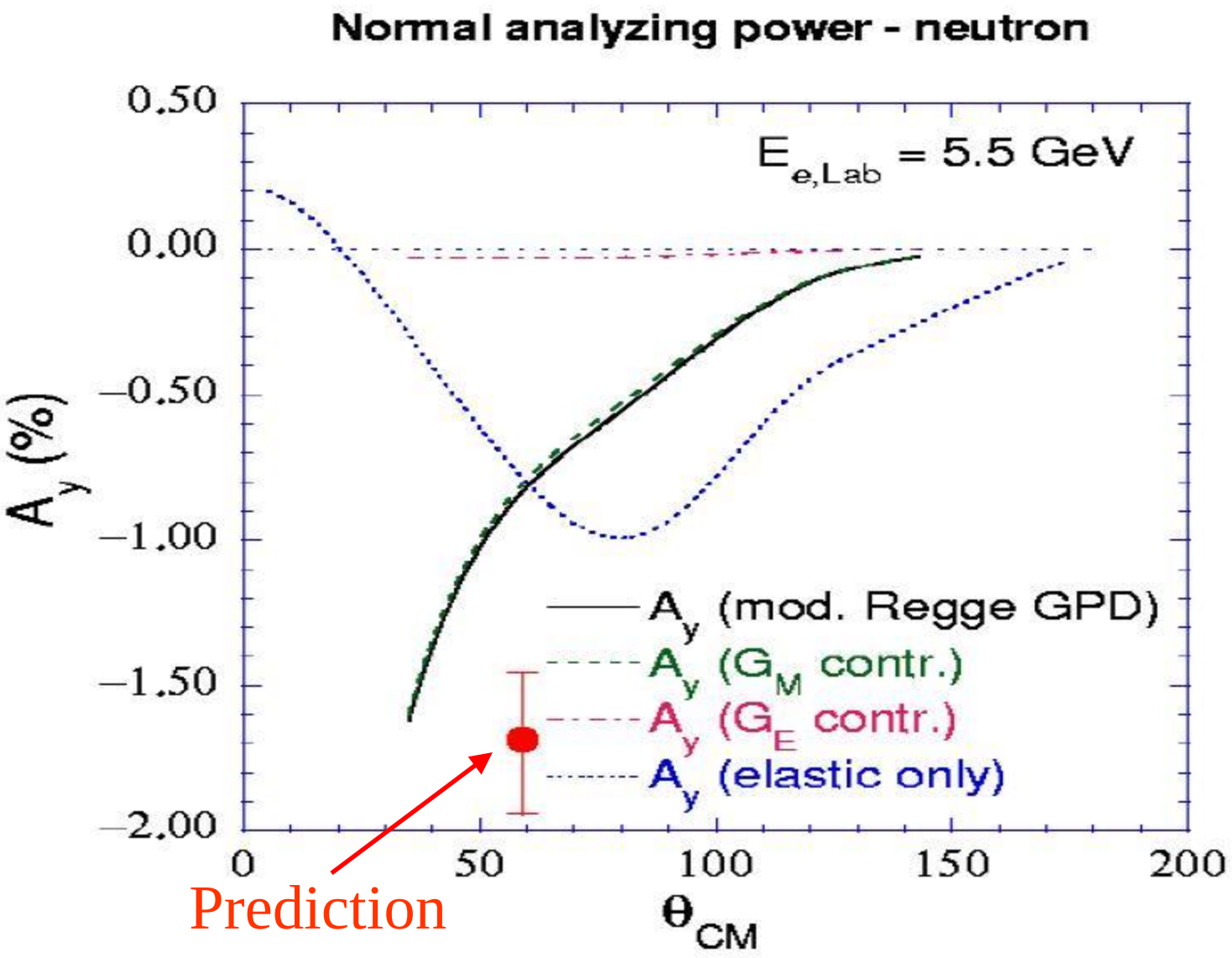
Scope of the approved project includes:

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

Kinematics Coverage of the 12 GeV Upgrade



Prediction for higher Q^2



Summary

- Preliminary raw SSA at $Q^2 = 0.46$ and $0.98\ GeV^2$ is clearly non-zero and consistent between L-arm and R-arm data with the opposite sign.
- Raw SSA at $Q^2 = 0.13\ GeV^2$ and the systematic uncertainty study for raw asymmetry are ongoing and will be released soon.
- Two new proposals to probe the two-photon exchange at higher Q^2 with JLab 12 GeV update are in progress. (Quasi-Elastic and Deep-Inelastic on $^3He(e, e')$, led by B. Zhao and V. Sulkosky.)

Cross-check from Ellie ($Q^2 = 0.98\ GeV^2$)