A_1^n Updates and Plans

Mingyu Chen
University of Virginia
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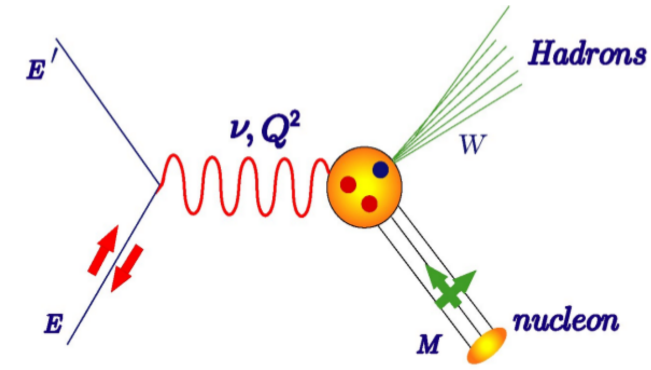
Outline:

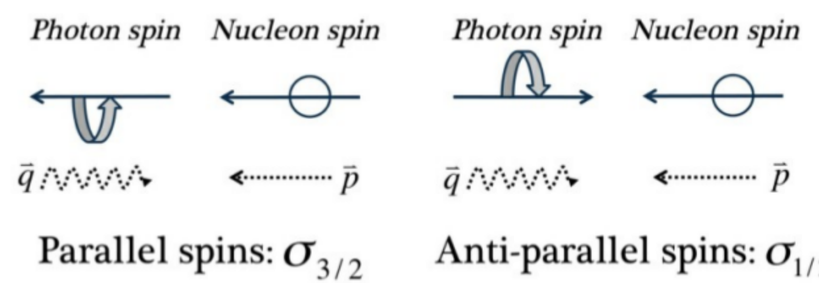
1. Introduction for A_1^n Experiment
2. Experimental Setup
3. Polarized ^{3}He Target
4. Kinematics and Expected Results
5. A_{el} Online Results

Longitudinal Virtual Photon Asymmetry A_1

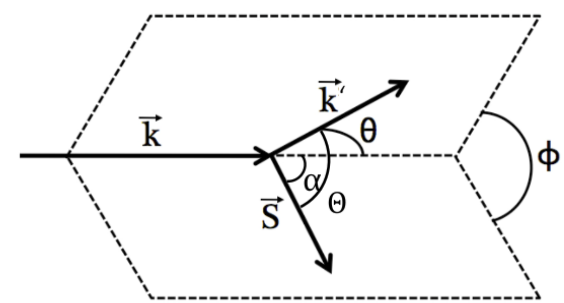
- $Q^2 =$ 4-momentum of virtual photon squared
- $\nu =$ Energy transfer
- $\theta =$ Scattering angle
- $x = \dfrac{Q^2}{2M\nu} =$ Fraction of nucleon momentum carried by the struck quark



$$A_1 = \frac{g_1 - \frac{(2Mx)^2}{Q^2} g_2}{F_1} = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}}$$



$$A_1 = \frac{1}{(E+E')D'}\left[(E - E'\cos\theta)A_{\parallel} - \frac{E'\sin\theta}{\cos\phi}A_{\perp}\right]$$



$$\boxed{A_{\parallel} = \frac{\sigma_{\downarrow\uparrow} - \sigma_{\uparrow\uparrow}}{\sigma_{\downarrow\uparrow} + \sigma_{\uparrow\uparrow}}}$$

$$\boxed{A_{\perp} = \frac{\sigma_{\downarrow\rightarrow} - \sigma_{\uparrow\rightarrow}}{\sigma_{\downarrow\rightarrow} + \sigma_{\uparrow\rightarrow}}}$$

$$\boxed{D' = \frac{(1-\epsilon)(2-y)}{y[1+\epsilon R]}}$$

- Angular kinematics for polarized electron scattering

Goals for A_1^n Experiment

- Precisely measure the neutron spin asymmetry A_1^n in the far valence domain ($0.61<x<0.77$) for the first time.
- Explore the Q^2 dependence of A_1^n with large x value.
- After combining with proton data (CLAS12), extract polarized to unpolarized parton distribution function (PDF) ratios $\Delta u/u$ ($\Delta d/d$) for large x region.
- Give more insights on understanding the spin structure of neutron.

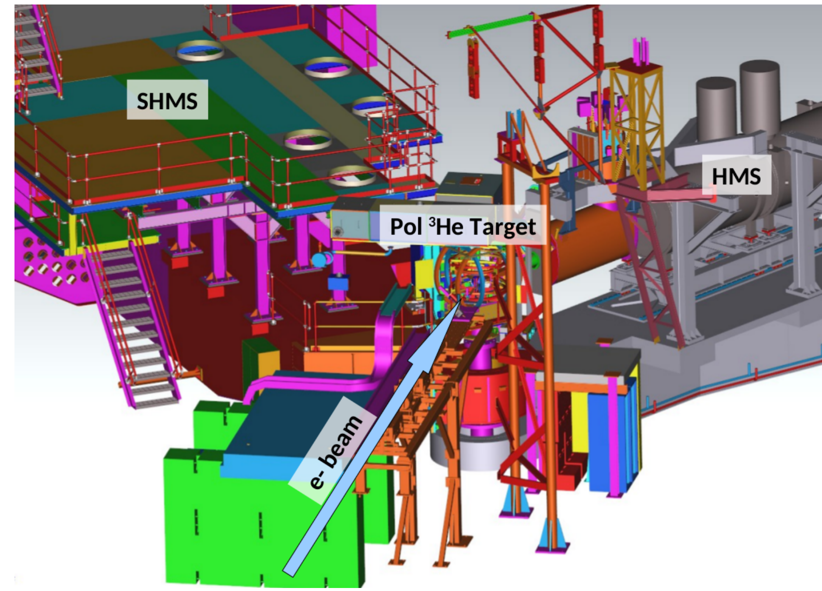
Experimental Setup

PhD students:
A1n: Mingyu Chen (UVa), Melanie Rehfuss (Temple U) Target: Chris Jantzi (UVa)

Detectors:

- High Momentum Spectrometer (HMS)
- Super HMS (SHMS)

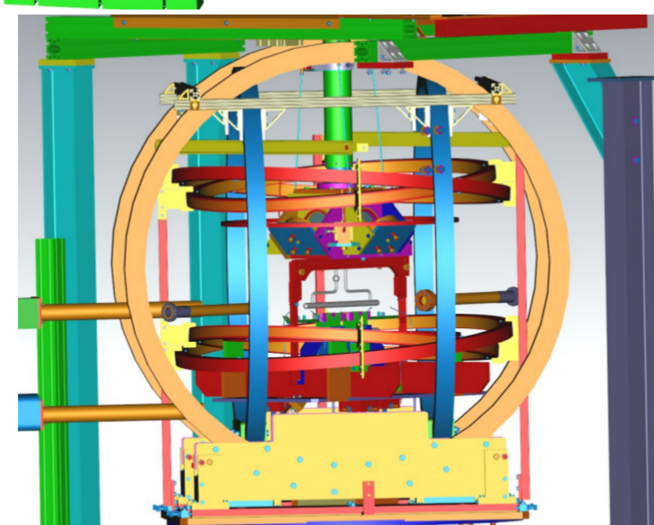
(Spokespeople: X. Zheng, G. Cates, JP Chen, Z-E Meziani)



Electron Beam:

- 1-pass (elastic, Δ(1232))
- 5-pass beam (DIS, resonance)
- Beam polarization: 85%

  (2% uncertainty by Moller Polarimeter)
- Circular beam raster with 2.5mm radius
- < 50 ppm charge asymmetry (average over ~ 1–2 hr run)



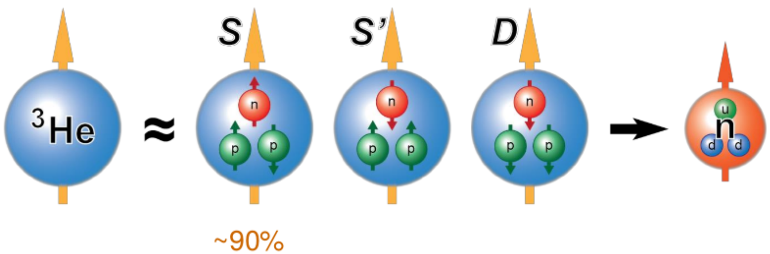
Polarized ^{3}He target:

- ^{3}He production cell (40cm)
- 55–60% polarization without beam
- 30 uA beam current

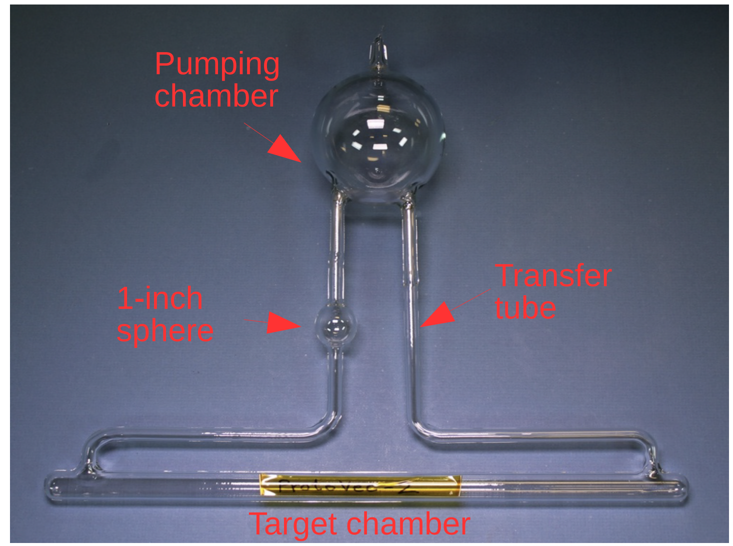
  (doubles performance compare to 6 GeV era)
- 3% uncertainty for polarimetry

Polarized ^{3}He Target

(see Junhao's talk for more info)



- Free Neutron mean life: 880.2 s
- Neutron carries the majority of the ^{3}He nucleus polarization

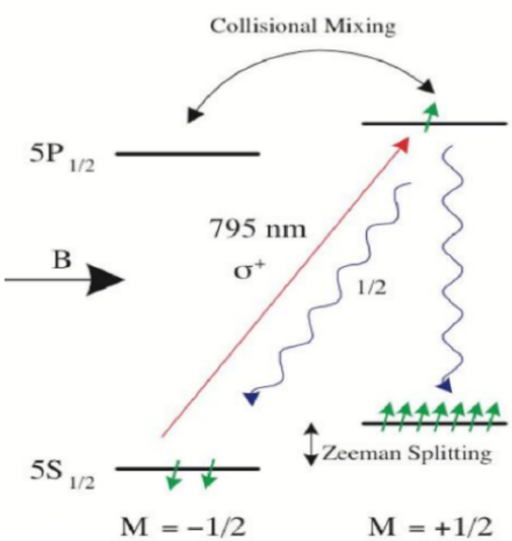


12 GeV era target cell performance:

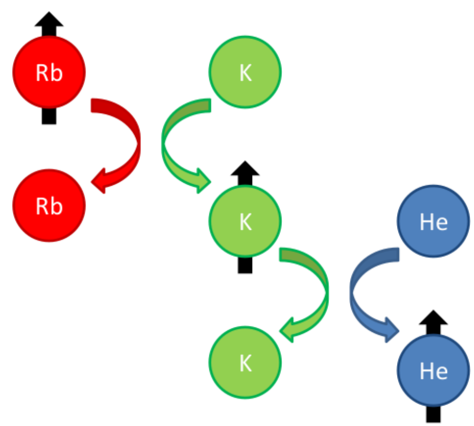
Beam Current: 30uA

Expected in beam polarization: 50%

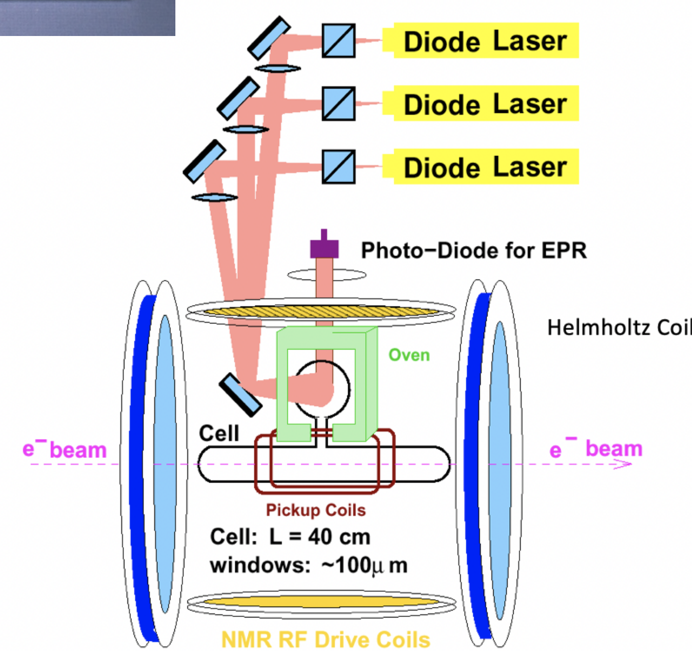
Luminosity: ~ 2.2x10^{36} cm^{-2}s^{-1}
Convection Cell



1. Optical Pumping



2. Spin Exchange



Kinematics and Beam time

Completed 1-pass commissioning

Kine	Spec	E_b GeV	E_p GeV	θ ($\circ$)	beam time (hours)
Δ(1232)	SHMS	2.183	-1.79736	8.5	4.0
Elastic	SHMS	2.183	-2.12860	8.5	8.0

Ongoing 5-pass

DIS production runs. Achieved ~18% of the charge goal for highest x setting.

Kine	Spec	E_b GeV	E_p GeV	θ ($\circ$)	e^- production (hours)	e^+ prod. (hours)	Tot. Time (hours)
DIS							
1	HMS	10.5	6.00	11.7	84.0	0.0	84.0
3	HMS	10.5	2.90	30.0	88.0	0.0	88.0
4	HMS	10.5	3.50	30.0	511.0	0.0	511.0
B	SHMS	10.5	3.40	30.0	511.0	4.0	515.0
C	SHMS	10.5	2.60	30.0	88.0	4.0	92.0
Resonances							
D	SHMS	10.5	6.90	11.0	84.0	0.0	84.0

- Longitudinal asymmetry of elastic scattering and transverse asymmetry of Δ(1232) are used to check $P_b P_t$ and other systematics.
- The SHMS setting B and HMS setting 4 are used to determine physics asymmetry of ^{3}He at high x, high Q^2.
- The SHMS setting C and HMS setting 3 are used to cover the medium x with high Q^2 region in order to improve previous 6 GeV results.
- HMS kine 1 measures the physics asymmetry of ^{3}He at low Q^2.
- SHMS kine D resonance measurements will provide data needed for radiative corrections.

Expected Values of ΔA_1^n for 5-pass Runs

x_{bj}	ΔA_1^n (stat.) Low Q^2	ΔA_1^n(stat.) High Q^2	ΔA_1^n(stat.) two Q^2 combined	ΔA_1^n(syst.)	ΔA_1^n(total.)
0.25	0.0027	0.0000	0.0027	0.0133	0.0136
0.30	0.0029	0.0000	0.0029	0.0130	0.0133
0.35	0.0038	0.0544	0.0038	0.0131	0.0137
0.40	0.0056	0.0243	0.0055	0.0135	0.0146
0.45	0.0094	0.0200	0.0085	0.0141	0.0165
0.50	0.0181	0.0191	0.0131	0.0149	0.0199
0.55	0.0606	0.0162	0.0156	0.0162	0.0225
0.60	0.0000	0.0145	0.0145	0.0179	0.0231
0.65	0.0000	0.0157	0.0157	0.0206	0.0260
0.71	0.0000	0.0186	0.0186	0.0257	0.0317
0.77	0.0000	0.0414	0.0414	0.0485	0.0638

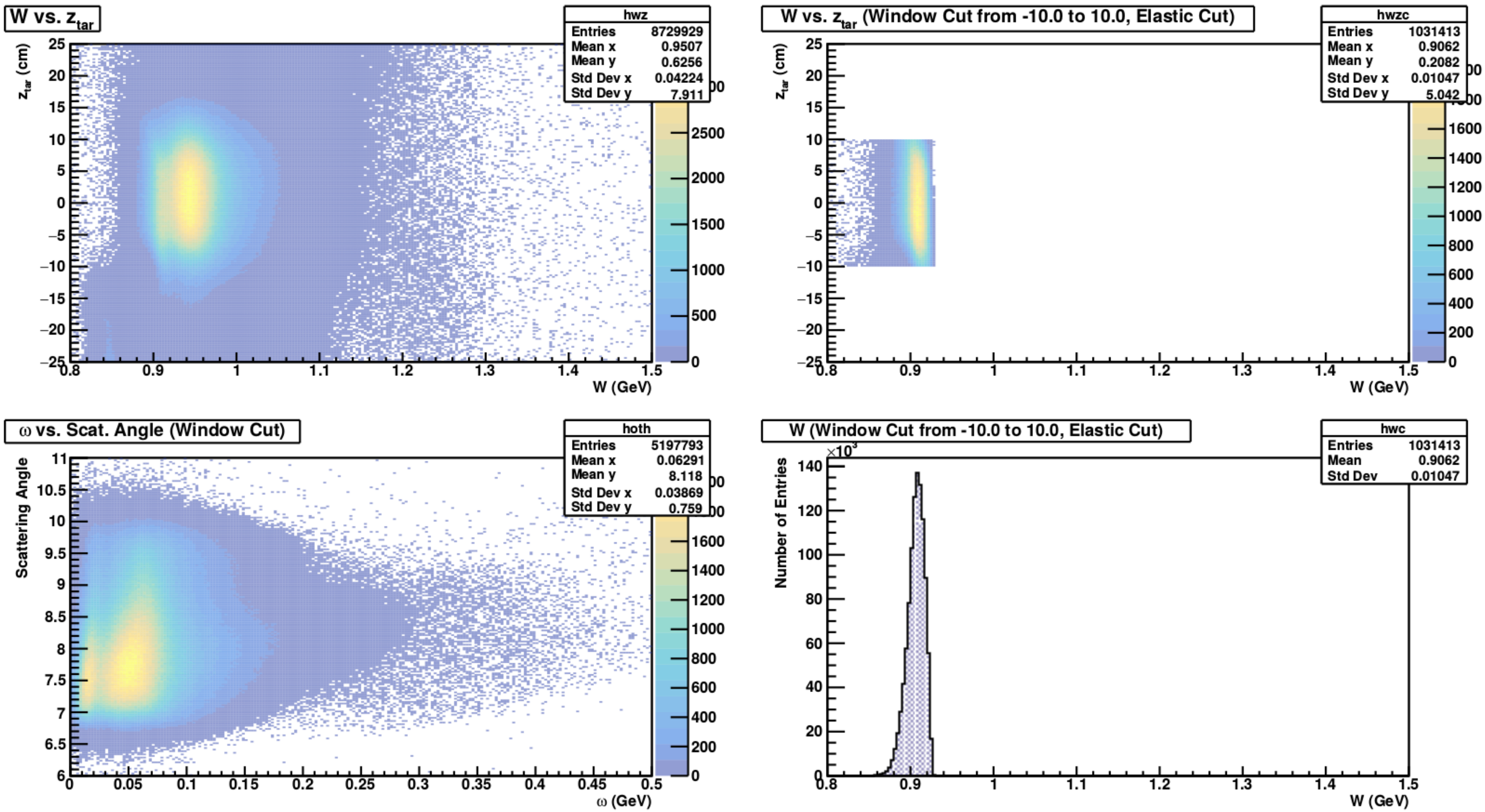
Table 1: Statistical and systematic uncertainties for DIS data at different x and Q^2

x_{bj}	ΔA_1^n (stat.)	ΔA_1^n(syst.)	ΔA_1^n(total.)
0.40	0.0335	0.0134	0.0361
0.45	0.0144	0.0138	0.0199
0.50	0.0121	0.0148	0.0191
0.55	0.0130	0.0156	0.0203
0.60	0.0134	0.0175	0.0220
0.65	0.0214	0.0222	0.0308
0.71	0.0271	0.0291	0.0398
0.77	0.0364	0.0376	0.0523
0.83	0.0212	0.0512	0.0555
0.89	0.0958	0.1083	0.1446

Table 2: Statistical and systematic uncertainties for Resonance data at different x and Q^2

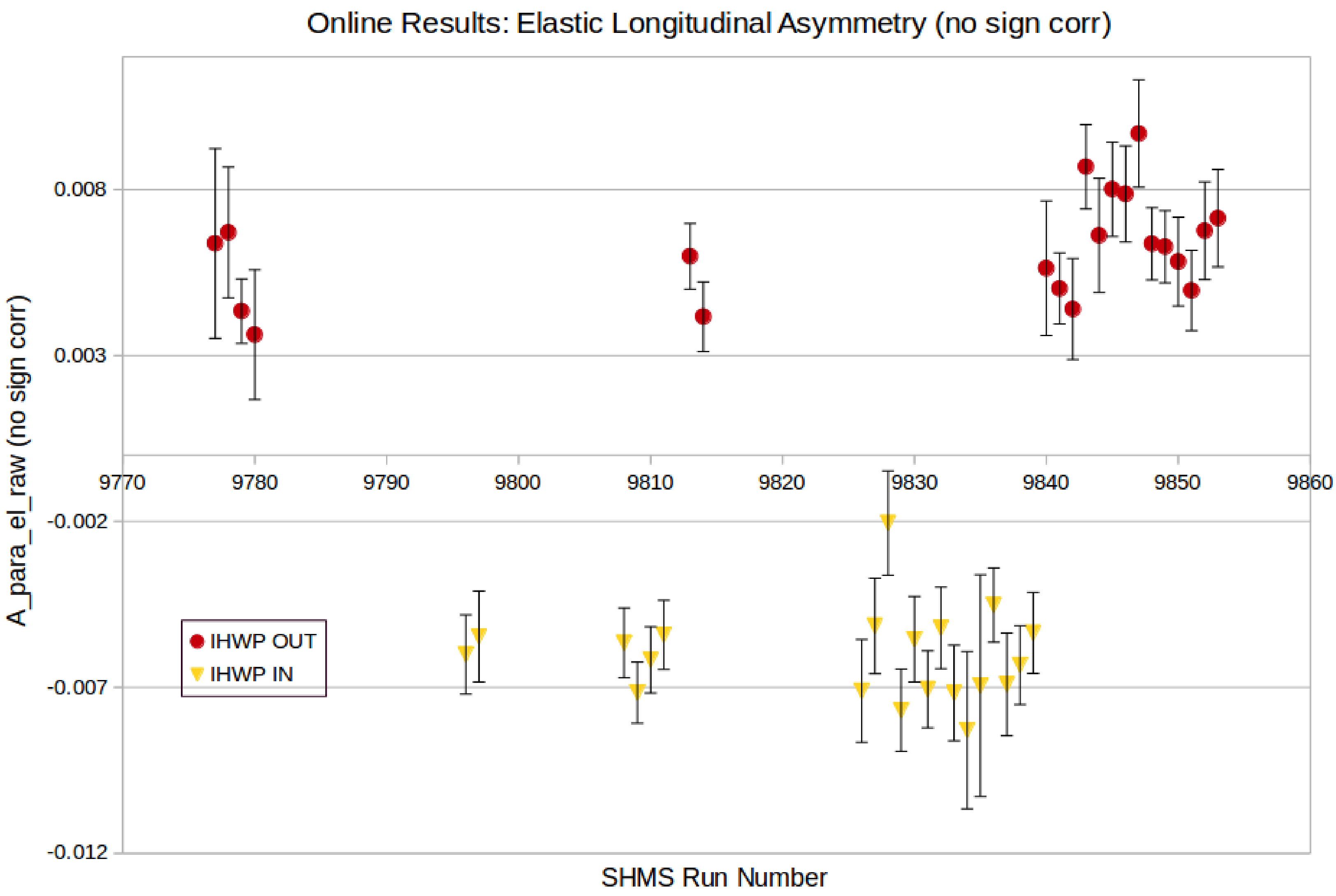
Typical Elastic Run Online Results

(count number of elastic events from SHMS)



A_{el} Online Results

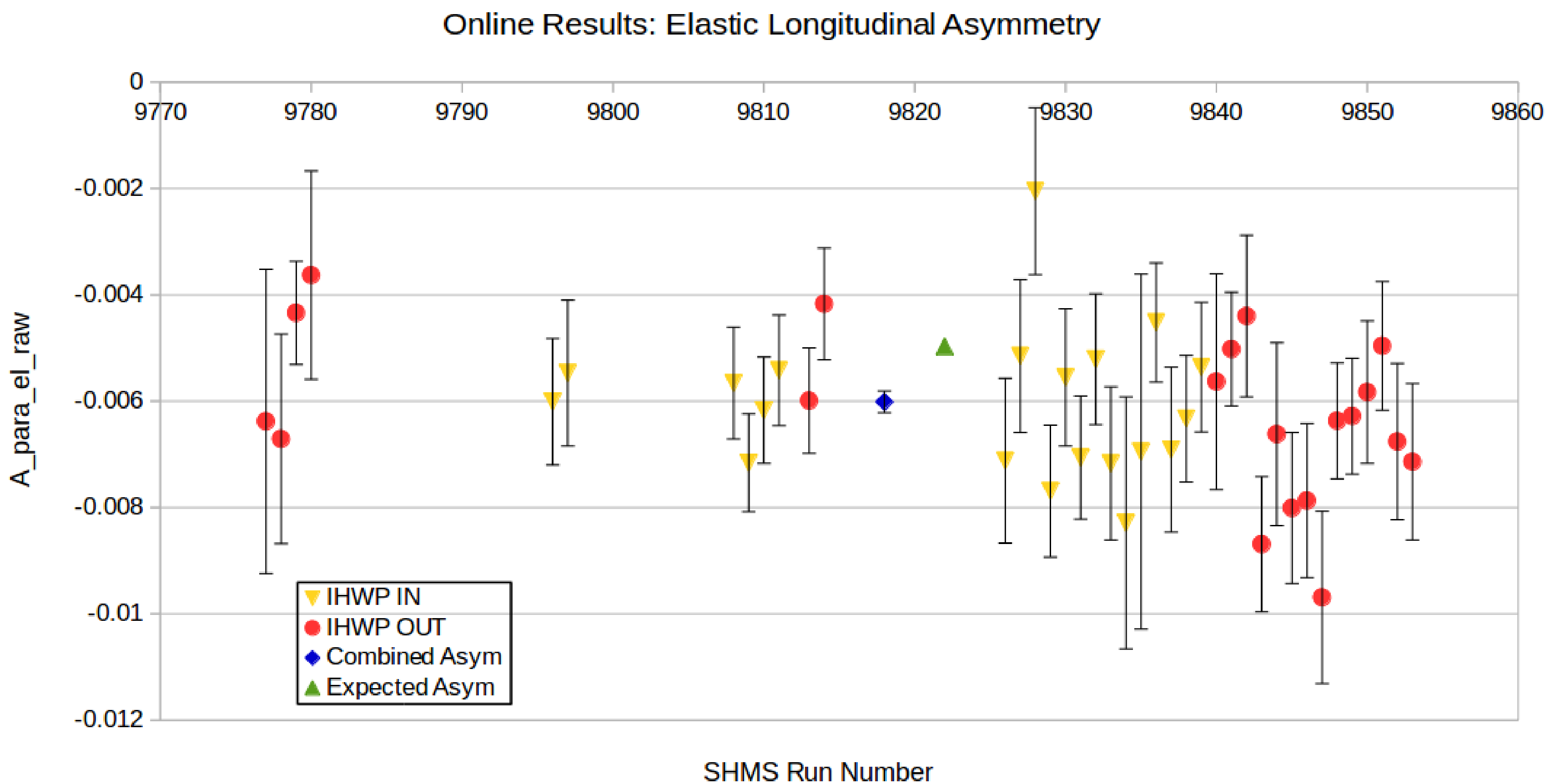
(no sign correction)



- Raw elastic asymmetry for all SHMS runs.

$$A_{raw} = \frac{N^+ - N^-}{N^+ + N^-}$$

A_{el} Online Results



- For “IHWP OUT”, multiply all asymmetries with sign=-1 to account IHWP flip.
- The combined asymmetry for SHMS runs is 0.60%, with uncertainty 0.020%. Then ΔA/A=3.4%.
- The expected physics asymmetry is 2.6%, if we use 85% P_b, 50% P_t, 0.9 f_{N2} and 0.457 f_{QE} to calculate the expected raw asymmetry be about 0.45%.

  (need further correction for QE asymmetry)

$$A_{physics} = \frac{A_{raw}}{P_b P_t f_{N2} f_{QE}}$$

Backup Slides

QE/el Ratio

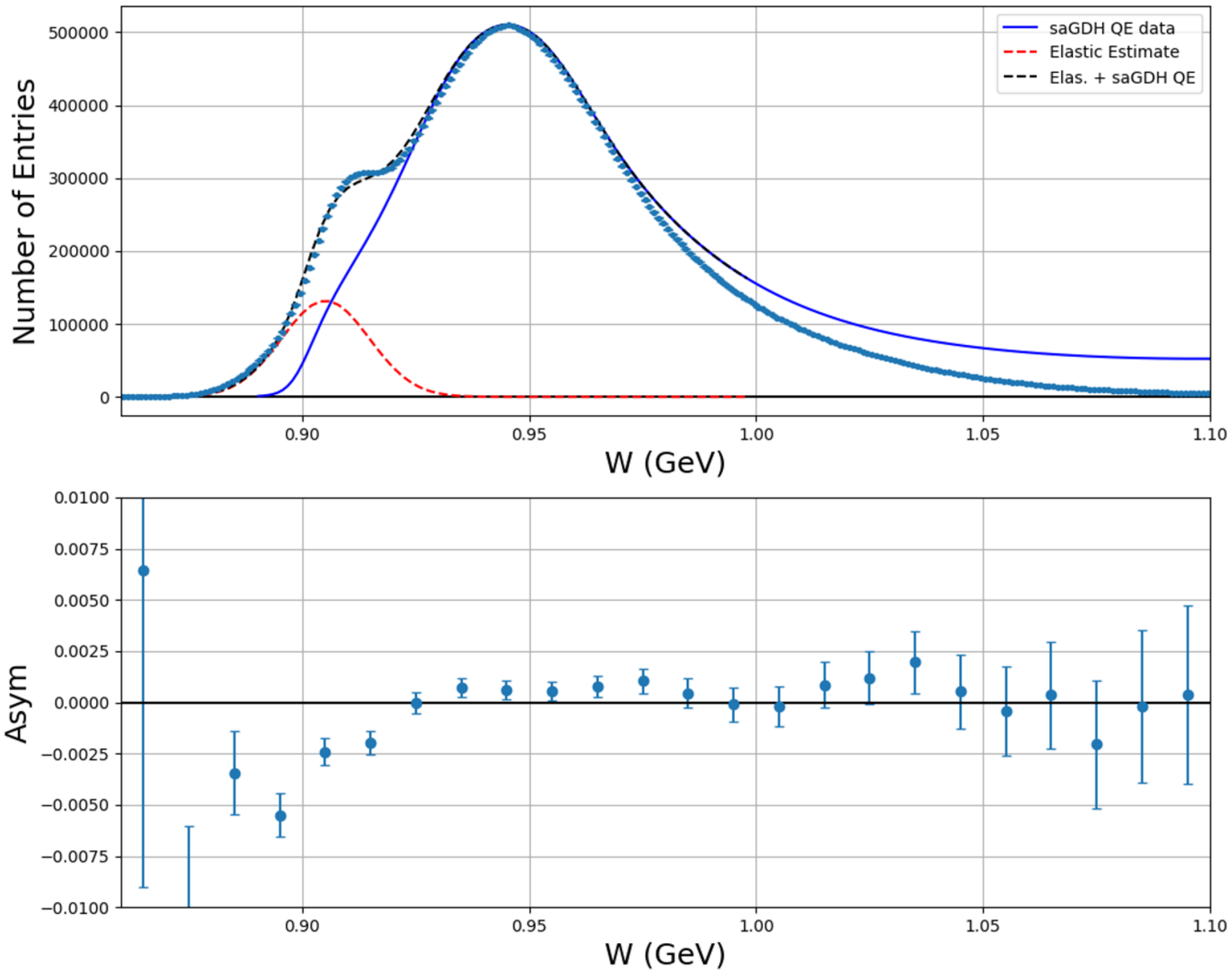
(Hclog from Chao Peng)

QE/el ratio estimation

- Used the saGDH data (2.2 GeV @ 9 degree) to estimate the Quasi-elastic contribution (with scale and shift)
- Subtract the saGDH data and fit it with a Gaussian peak
- With this estimation, the El/QE ratio at the peak (W = 0.905) is about 1.151
- The El/QE ratio within (0.87 < W < 0.92) is 0.841
- The El/QE ratio within 3 sigma of the el peak (0.884 < W < 0.926) is 0.562

- For El/QE ratio be 0.841, the QE dilution factor:

$$f_{QE} = \frac{0.841}{1.841} = 0.457$$



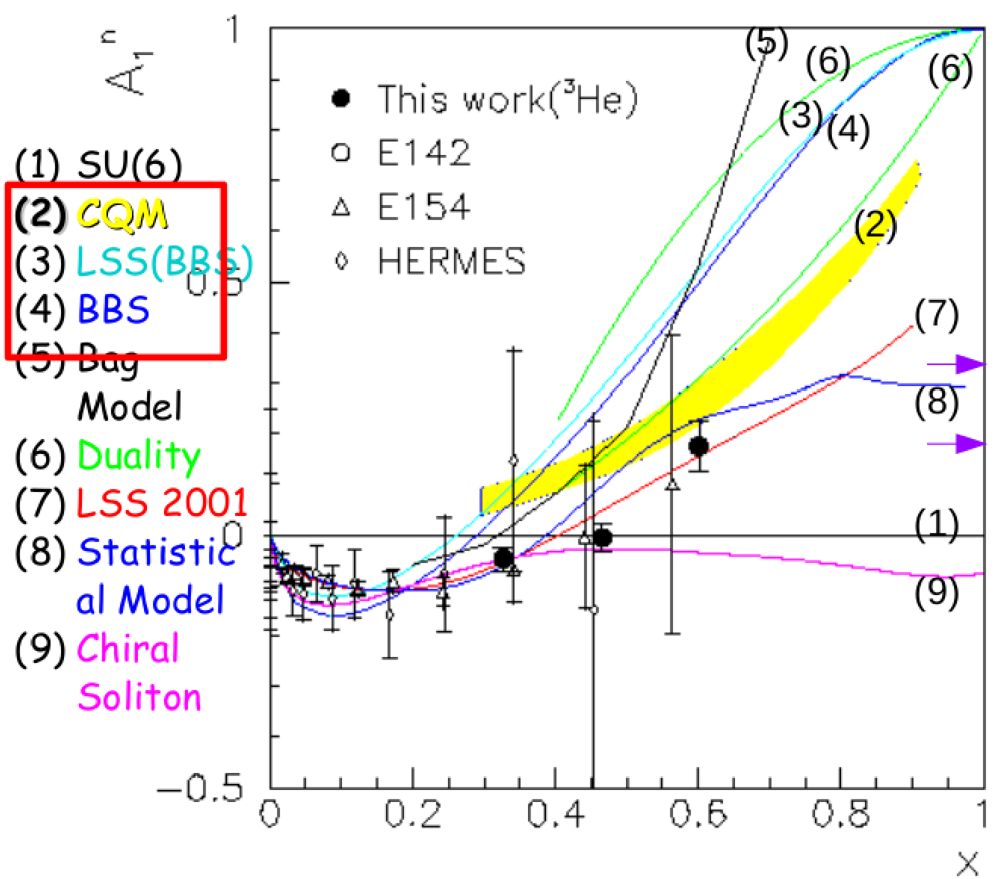
Predictions for A_1 and $\Delta q/q$ at Large x

- In the far valence domain, different models give different predictions.
- For pQCD and many other models, the far valence domain is the only place to make absolute predictions.

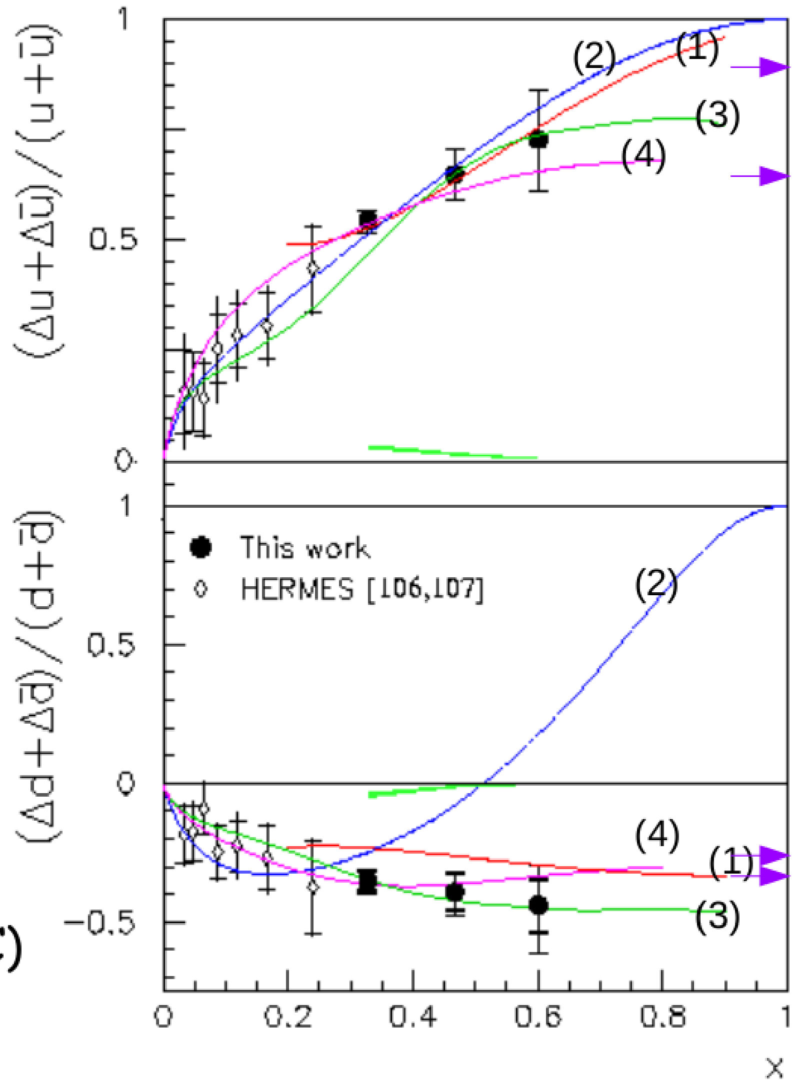
Model	F_2^n/F_2^p	d/u	Δ u/u	Δ d/d	A_1^n	A_1^p
SU(6) = SU3 flavor + SU2 spin	2/3	1/2	2/3	-1/3	0	5/9
Valence Quark + Hyperfine	1/4	0	1	-1/3	1	1
pQCD + HHC	3/7	1/5	1	1	1	1
DSE-1	0.49	0.28	0.65	-0.26	0.17	0.59
DSE-2	0.41	0.18	0.88	-0.33	0.34	0.88

- Predictions for x=1 value for various models.
  From Craig D. Robert et al.

Previous Results for A_1^n and PDF



(Deutron data not shown: E143, E155, SMC)



X. Zheng *et al.*, Phys. Rev. Lett. 92, 012004 (2004); Phys. Rev. C 70, 065207 (2004)

(1)CQM (2)LSS(BBS):pQCD+HHC (3)Statistical Model (4)LSS 2001