A_1^n Experiment Overview

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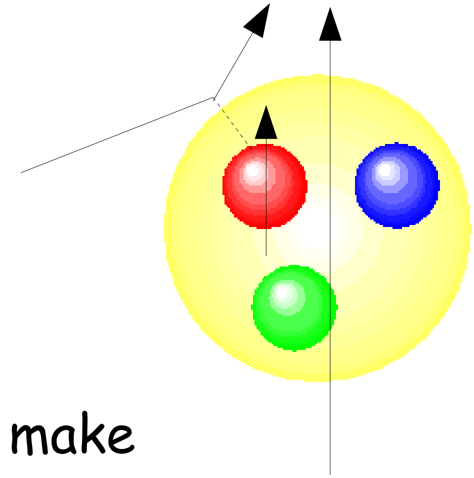
- Physics of A1n in the far-valence domain
- Experimental Requirements
- Kinematics and expected results

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



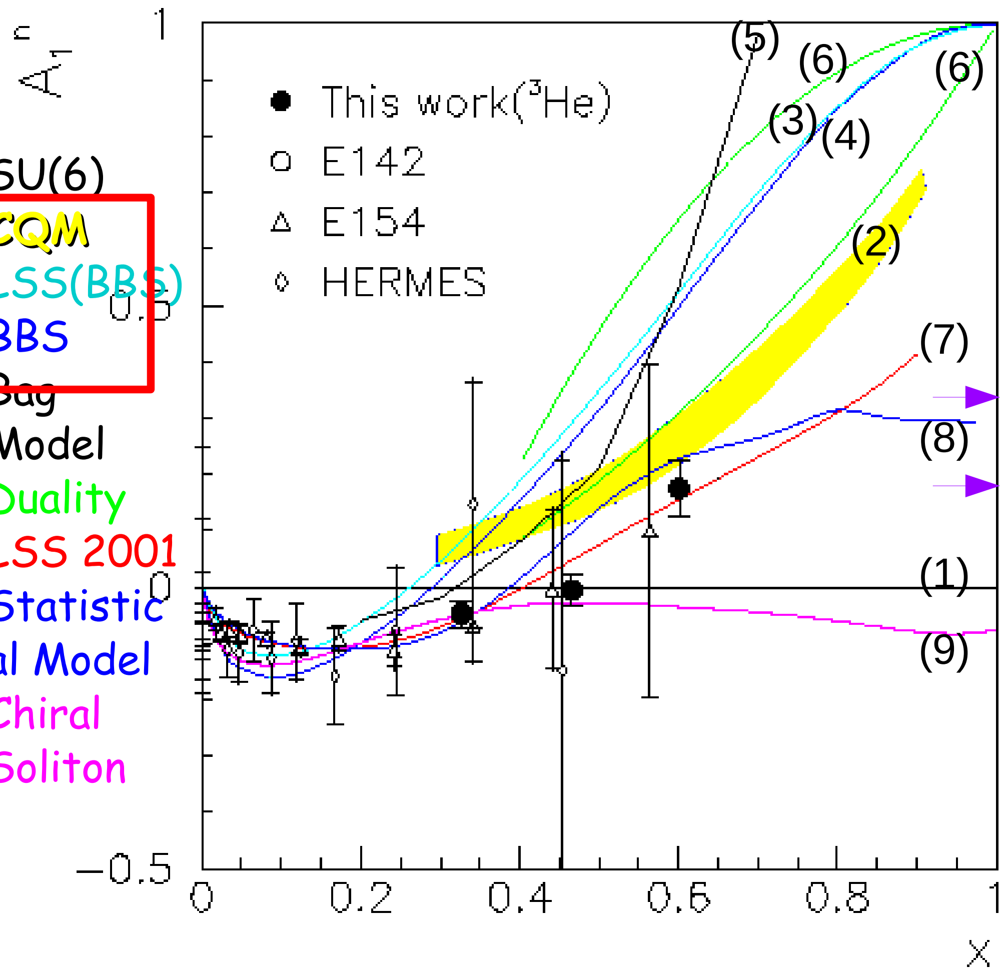
The far valence domain (x>0.5)

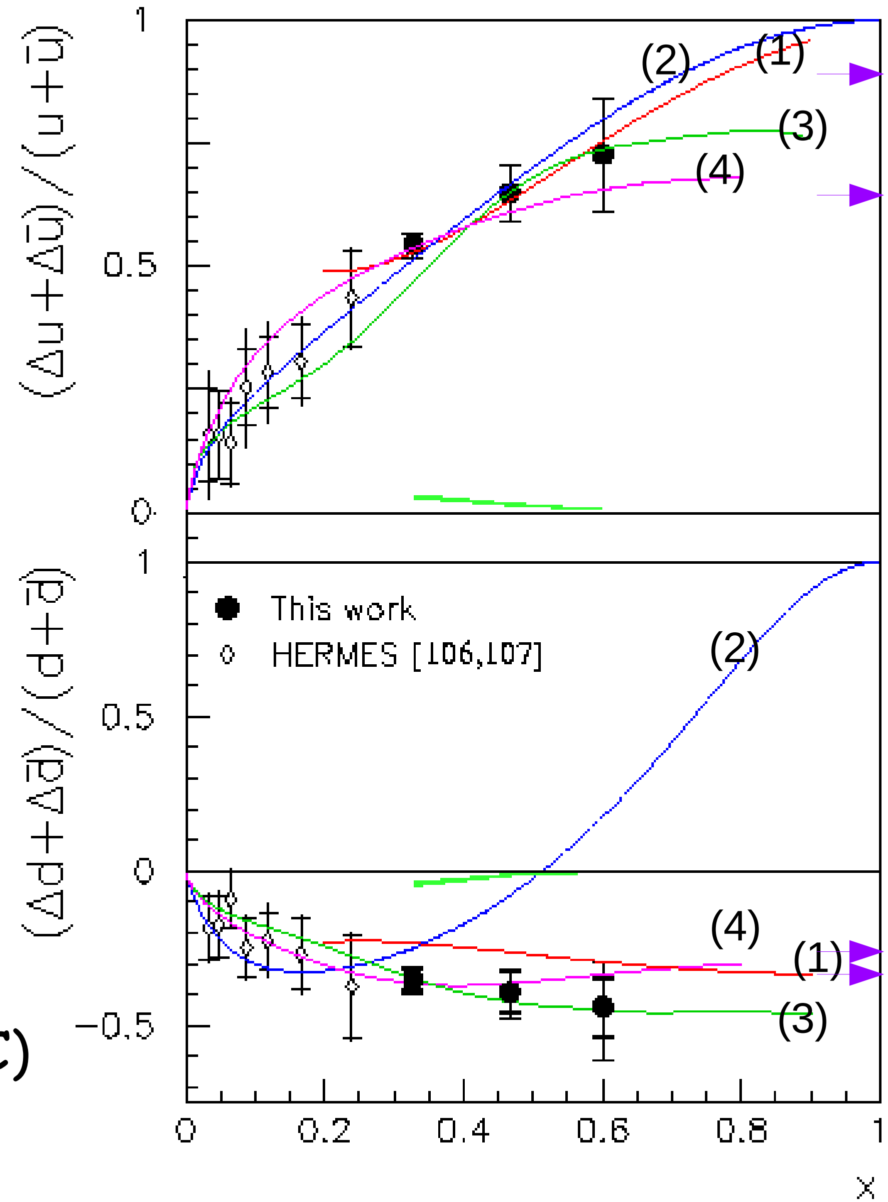
- is definitive of the hadrons
- is the only domain where QCD (and many other models) can make absolute predictions for structure functions

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

The 6 GeV Hall A Measurement (21 PAC days, 2001)

(1) SU(6)
(2) CQM
(3) LSS(BBS)
(4) BBS
(5) Bag Model
(6) Duality
(7) LSS 2001
(8) Statistical Model
(9) Chiral Soliton





(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

A1n Running Conditions

- First experiment to require polarized beam in Hall C after the upgrade: 85% requested, (minimum 80%), measured to 2%; transverse beam polarization < 1% desired.
- Beam size no larger than 300μm in σ, 200μm in σ desired.
- 11 GeV (min 10.5 GeV), 30 μA, beam trip goal: (6-10) per hour or less
- circular rastering of beam spot to a radius of 2.5 mm and "no hot spot", current ramping at (0.5-1.0) μA/sec on polarized target cell;
- changing beam IHWP status every 12 hours or at least half-way of each kinematics;
- beam charge asymmetry controlled to under 200ppm (average over each run);

- First time to use polarized 3He target in Hall C: Stage-I target upgrade: 12amg, 40cm, 30uA, Pt=(55-60)%; 3% polarimetry
- Both longitudinal and transverse spin configurations; spin direction known to ±0.5 degree desired and ±1.0 degree required; density known to 3% (2% from fill density and 2% from operating temperature).

- Q^2 known to 1% desired (Ebeam at the ±1E-3 level; spectrometer momentum to ±1E-3, angle to ±0.06 deg).
- PID performance: pion rejection > 10,000 desired by combining calorimeter and Cherenkov, > 5000 required, while keeping electron efficiency at 99% (desired) or 95% (min) each (worst case at SHMS momentum 2.25 GeV/c and HMS 2.82 GeV/c).

$A_1{}^n$ Kinematics and Production Beam Time (previous)

Kine	E_b (GeV)		θ (°)	E_p (GeV)	e^- production (hours)	e^+ prod. (hours)	Tot. Time (hours)
				DIS			
1	11.0	HMS	12.5	5.70	12	0	12
2	11.0	HMS	12.5	6.80	24	0	24
3	11.0	HMS	30.0	2.82	96	0	96
4	11.0	HMS	30.0	3.50	551	1	552
A	11.0	SHMS	12.5	5.80	36	0	36
B	11.0	SHMS	30.0	3.00	464	0	464
C	11.0	SHMS	30.0	2.25	88	0	88
				Resonances			
D	11.0	SHMS	12.5	7.50	96	0	96

both $A_{\parallel}$ and $A_{\perp}$

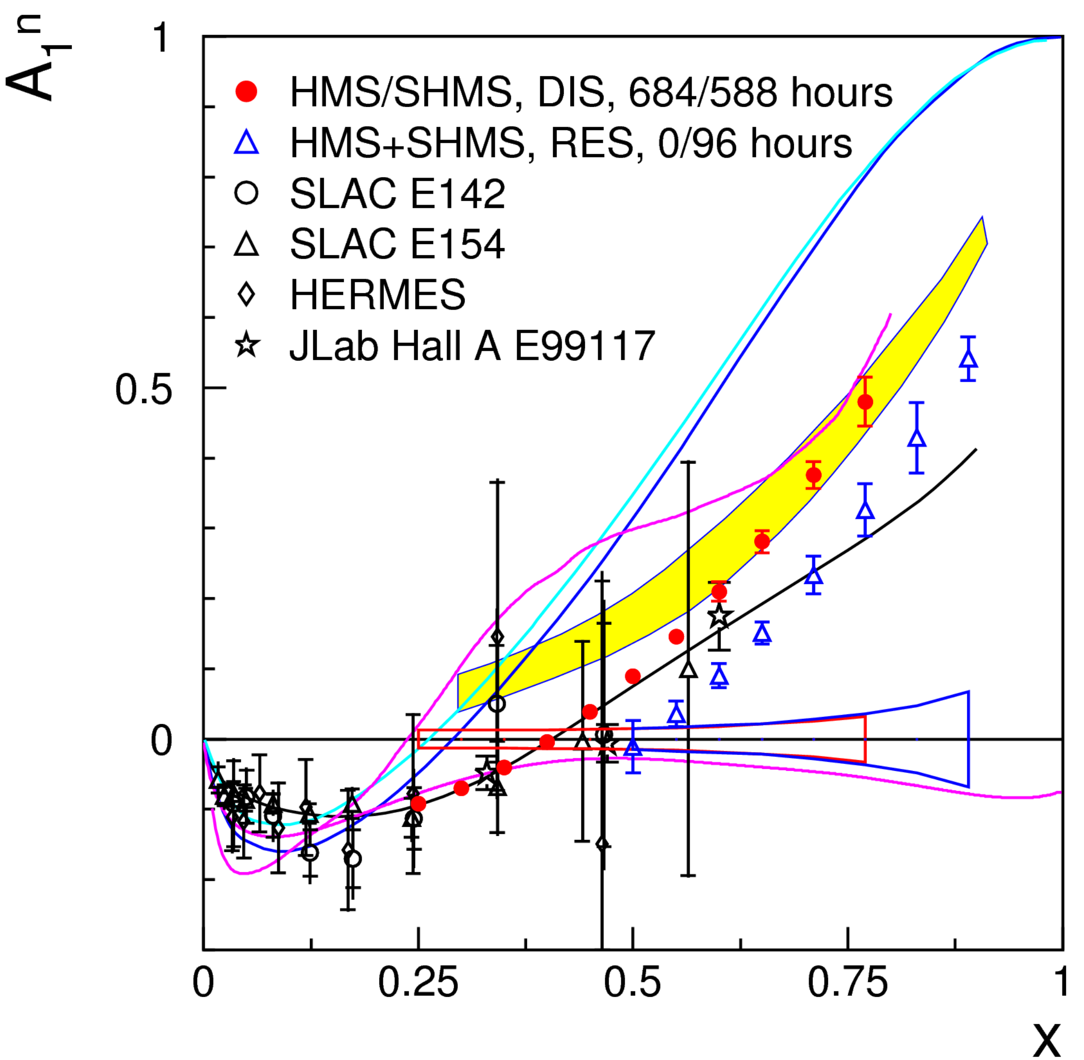
Kine	E_b GeV	E_p GeV	θ (°)	elastic x-sec (nb/sr)	elastic rate (Hz)	Asymmetry	Time (hours)
Elastic	2.200	2.160	12.5	106.986	1293.9	$A_{\parallel} = 0.0589$	11.2
$\Delta(1232)$	2.200	1.815	12.5	-	-	$A_{\perp} \sim$ a few %	6

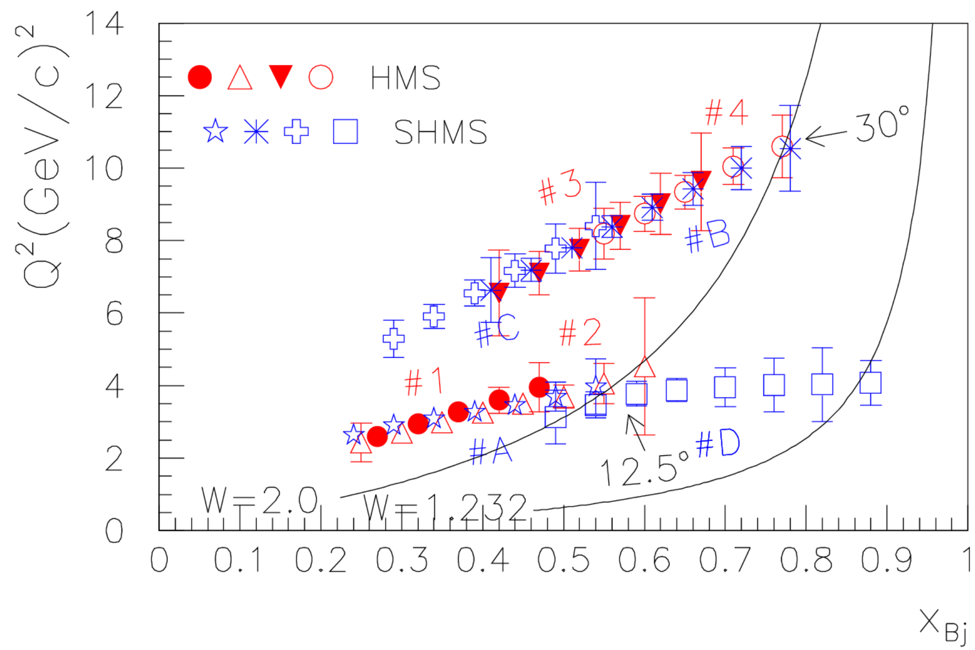
$A_{\parallel}$

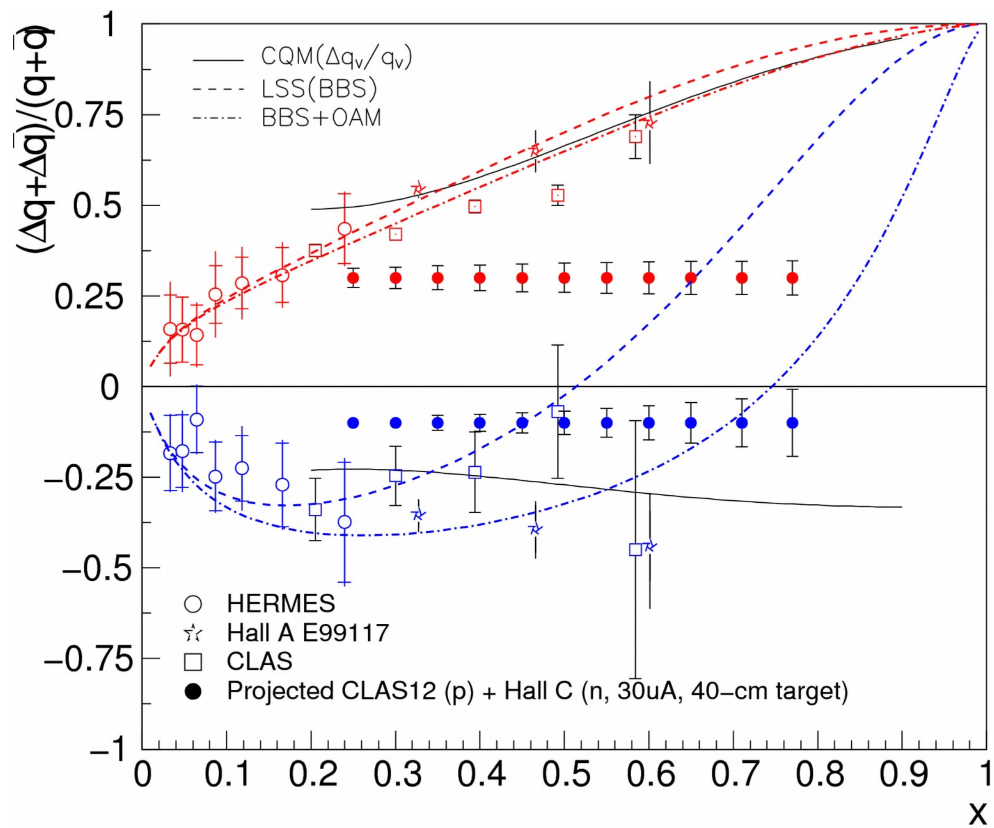
$A_{\perp}$

A_1^n Kinematics and Expected Results (approved 36 days)

30uA, 85% beam, 40cm, 60% target







A_1^n Kinematics and Production Beam Time (updated)

- Ebeam;
- same beam time for HMS vs. SHMS for the large angle running
- p0 setting optimized using latest simulations

Kine	E_b (GeV)		θ (°)	E_p (GeV)	e^- production (hours)	e^+ prod. (hours)	Tot. Time (hours)
				DIS			
1	11.0	HMS	12.5	5.70	12	0	12
2	11.0	HMS	12.5	6.80	24	0	24
3	11.0	HMS	30.0	2.82	96	0	96
4	11.0	HMS	30.0	3.50	551	1	552
A	11.0	SHMS	12.5	5.80	36	0	36
B	11.0	SHMS	30.0	3.00	464	0	464
C	11.0	SHMS	30.0	2.25	88	0	88
				Resonances			
D	11.0	SHMS	12.5	7.50	96	0	96

- Elastic/Delta (not shown here): Ebeam=2.05 GeV, no other change

Kine	Ebeam (GeV)	Spec	p0	θ0	e- production time (hours)	e+ (hours)
1	10.5	HMS	5.7	12.5	12.0	0.0
2	10.5	HMS	6.8	12.5	24.0	0.0
3	10.5	HMS	2.9	30.0	88.0	1.0
4	10.5	HMS	3.5	30.0	511.0	1.0
A	10.5	SHMS	5.8	12.5	36.0	0.0
B	10.5	SHMS	3.4	30.0	511.0	0.0
C	10.5	SHMS	2.4	30.0	88.0	0.0
D	10.5	SHMS	7.5	12.5	96.0	0.9

Backup Slides

ERR Status

- Review occurred on March 19^{th}, this year;
- weekly meeting since then to address the review comments/report, most time spent on target (beam) thermal stress calculation, target field gradient calculation, etc
- beam time request submitted by end of May;
- Plan to send reply to comments by end of this month.

Total Beam Time Allocation (ERR)

- Run-group A1n/d2n commissioning of the beamline, target, and spectrometers: 3 PAC days or 72 PAC hours (not including initial Moller commissioning)
- 1-pass elastic PbPt and Δ transverse asymmetries: 14 PAC hours (incl N2 runs);
- optics: 8 PAC hours;
- Moller: at least 3 measurements at 11 GeV (10 PAC hrs), one at 2.2 GeV (6 PAC hrs).
- beam pass change from 2.2 to 11 GeV: 8 PAC hours
- Production: DIS 636 PAC hours, RES 48 PAC hours (2-arms equivalent)
- Reference cell runs (N_2, ^3He, H_2 and empty): 12 PAC hours (2hr each at kine#1 and #2 or #A and #D, 4hr each at #3 and #4 or #B and #C)
- Configuration changes: 12x0.5 PAC hrs (angle or momentum or target spin directions), 8 PAC hrs polarity, 14 PAC hours total
- Target polarization measurements: 4% of production, 28 PAC hours total
- Total beam time: **36 PAC days**

A_1^n Uncertainties (ERR)

Table 3: Projected statistical and systematic uncertainties for DIS data at different x and Q^2. As a comparison, the 6 GeV result at $x = 0.61$ was $A_1^n = +0.175 \pm 0.048(\text{stat.})^{+0.026}_{-0.028}(\text{syst.})$. And the 2010 proposed values are $\Delta A_1^n(\text{stat.}) = 0.0288$ and $\Delta A_1^n(\text{total}) = 0.0446$.

x	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	0.0034	–	0.0034	0.0131	0.0135
0.30	0.0037	–	0.0037	0.0130	0.0135
0.35	0.0048	0.0157	0.0046	0.0129	0.0137
0.40	0.0062	0.0159	0.0058	0.0134	0.0146
0.45	0.0085	0.0123	0.0070	0.0138	0.0154
0.50	0.0124	0.0112	0.0083	0.0146	0.0168
0.55	–	0.0122	0.0107	0.0159	0.0192
0.60	–	0.0135	0.0134	0.0180	0.0224
0.65	–	0.0157	0.0157	0.0217	0.0268
0.71	–	0.0189	0.0189	0.0254	0.0316
0.77	–	0.0346	0.0346	0.0325	0.0475

Break-down of Uncertainties (ERR)

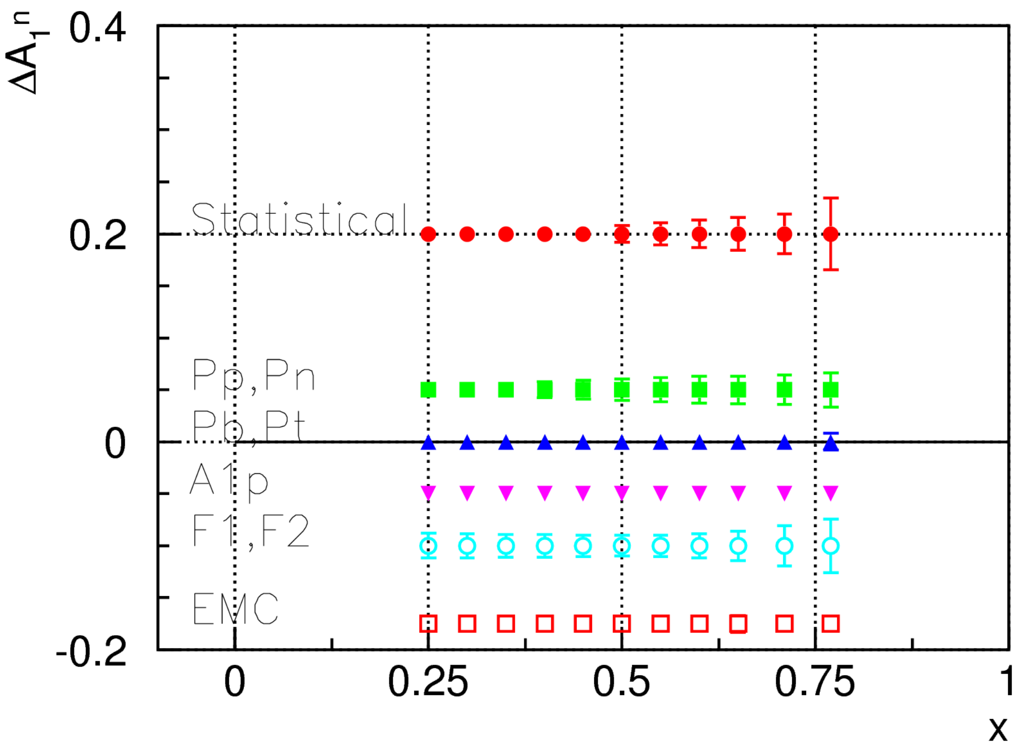


Table 4: Projected statistical and systematic uncertainties for resonance data at different x and Q^2. Resonance data will be taken at a scattering angle of 12.5° (same as the low Q^2 DIS data). The DIS fit for A_1 was used in the systematic uncertainty study.

x	ΔA_1^n(stat.)	ΔA_1^n(syst.)	ΔA_1^n(total)
0.55	0.0180	0.0171	0.0249
0.60	0.0171	0.0198	0.0261
0.65	0.0158	0.0215	0.0266
0.71	0.0269	0.0279	0.0388
0.77	0.0371	0.0362	0.0518
0.83	0.0505	0.0476	0.0694
0.89	0.0310	0.0678	0.0746

A_1^n Kinematics – x, W, and background estimation

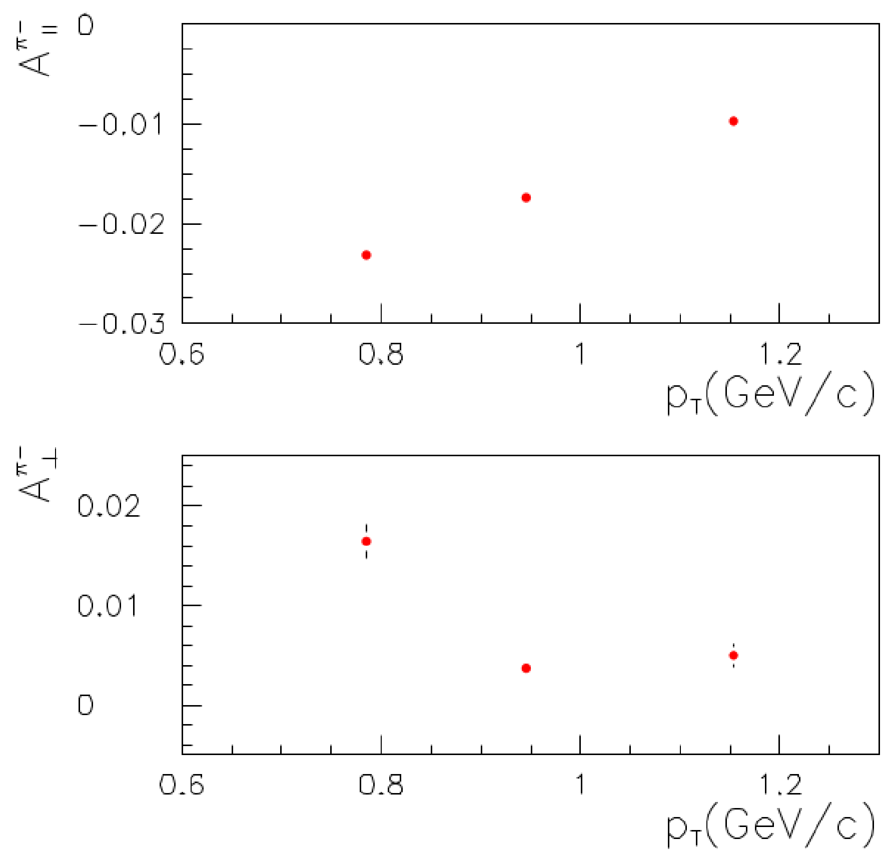
	Kine	E_b GeV	E_p GeV	θ (°)	(e,e') rate (Hz)	π^-/e	e^+/e^-	x (Q^2, in GeV^2) (W, in GeV) coverages
				DIS				
1	HMS	11.0	5.70	12.5	575.42	< 0.4	$< 0.1\%$	0.25-0.55 (2.59- 4.40) (2.1- 2.9)
2	HMS	11.0	6.80	12.5	426.14	< 0.2	$< 0.1\%$	0.25-0.60 (2.43- 4.53) (2.0- 2.9)
3	HMS	11.0	2.82	30.0	2.69	< 10.7	$< 0.1\%$	0.40-0.71 (6.55-10.19) (2.2- 3.3)
4	HMS	11.0	3.50	30.0	0.74	< 2.4	$< 0.1\%$	0.50-0.77 (7.72-10.60) (2.0- 2.9)
A	SHMS	11.0	5.80	12.5	701.73	< 0.5	$< 0.1\%$	0.25-0.60 (2.64- 4.42) (2.0- 3.0)
B	SHMS	11.0	3.00	30.0	2.70	< 12.2	$< 0.1\%$	0.40-0.77 (6.63-10.54) (2.0- 3.3)
C	SHMS	11.0	2.25	30.0	6.96	< 91.0	$< 0.1\%$	0.25-0.65 (4.71- 9.49) (2.4- 3.9)
				Resonances				
D	SHMS	11.0	7.50	12.5	104.79	–	–	0.50-1.00 (3.12- 4.45) (0.9- 2.0)

Size of Measured Asymmetries from 6 GeV

Table 6.1: ^{3}He results – $A_{\parallel}^{^3\mathrm{He}}$ and $A_{\perp}^{^3\mathrm{He}}$.

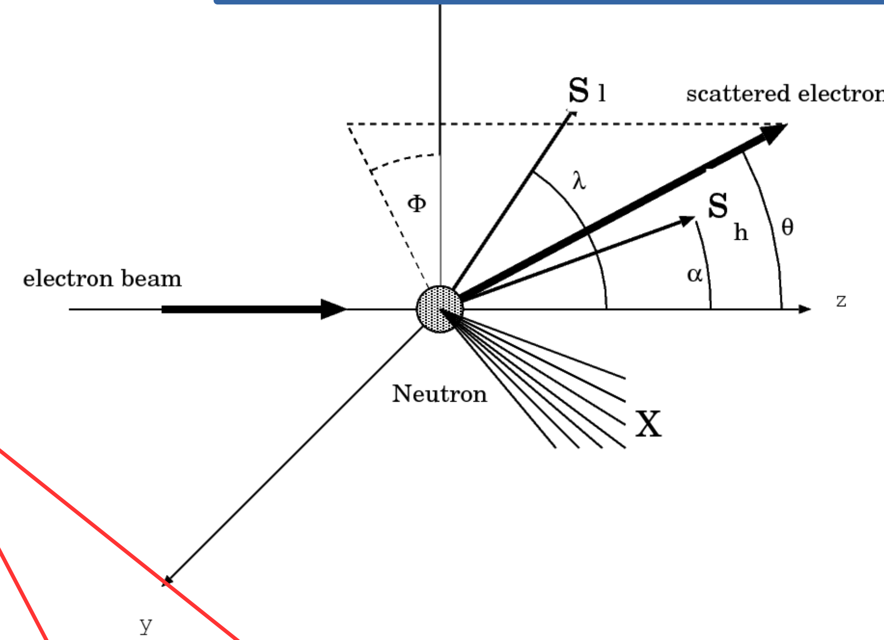
x	Q^2	$A_{\parallel}^{^3\mathrm{He}}\pm$stat.$\pm$sys.	$A_{\perp}^{^3\mathrm{He}}\pm$stat.$\pm$sys.
0.327	2.709	$-0.01397 \pm 0.00475 \pm 0.00071$	$-0.00216 \pm 0.00955 \pm 0.00011$
0.466	3.516	$-0.00722 \pm 0.00449 \pm 0.00036$	$0.01359 \pm 0.00790 \pm 0.00069$
0.601	4.833	$0.01036 \pm 0.00739 \pm 0.00052$	$-0.01173 \pm 0.01550 \pm 0.00059$

Figure 6-10: Pion asymmetry A^{π^-} results.



ref: E94010 tech note #6

Beam Transverse Polarization



transverse beam spin is suppressed by γe

$$A_{\parallel}^{Jlab} = \frac{\frac{d^2\sigma}{d\Omega dE'}^{\swarrow\Uparrow} - \frac{d^2\sigma}{d\Omega dE'}^{\nearrow\Uparrow}}{\frac{d^2\sigma}{d\Omega dE'}^{\swarrow\Uparrow} + \frac{d^2\sigma}{d\Omega dE'}^{\nearrow\Uparrow}}$$

$$= \frac{g_1[(2xy - \frac{Q^2(\nu + \frac{Q^2}{2E})}{2ME^2})\cos\lambda + \frac{E'\sin\theta(\nu + \frac{Q^2}{2E})}{ME}\frac{\sin\lambda}{\gamma_e}] - g_2\frac{xQ^2}{E^2}\cos\lambda}{xy^2F_1 + (1 - y - \frac{y^2\gamma^2}{4})F_2}$$

and the transverse asymmetry :

$$A_{\perp}^{Jlab} = \frac{\frac{d^2\sigma}{d\Omega dE'}^{\swarrow\Leftarrow} - \frac{d^2\sigma}{d\Omega dE'}^{\nearrow\Leftarrow}}{\frac{d^2\sigma}{d\Omega dE'}^{\swarrow\Leftarrow} + \frac{d^2\sigma}{d\Omega dE'}^{\nearrow\Leftarrow}}$$

$$= \frac{g_1[(2xy - \frac{E'^2\sin\theta^2}{ME})\frac{\sin\lambda}{\gamma_e} + \frac{Q^2E'\sin\theta}{2ME^2}\cos\lambda] + g_2[2xy\frac{\sin\lambda}{\gamma_e} + \cos\lambda\frac{2xE'\sin\theta}{E}]}{xy^2F_1 + (1 - y - \frac{y^2\gamma^2}{4})F_2}$$

Requirement on target angle

A1n analysis is dominated by $A_{||}$, which is less sensitive to the target field angle than Aperp:

$$\left(\frac{\Delta\sigma_{pol}}{\sigma_{pol}}\right)_{\alpha=0+\delta\alpha}=(\delta\alpha)\frac{E'\sin\theta}{\frac{g_1}{g_2}\left(yE+\frac{1}{2xM}\left[\nu-(E-E'\cos\theta)\right](E-E'\cos\theta)\right)+\left[yE-(E-E'\cos\theta)\right]}$$

$$\left(\frac{\Delta\sigma_{pol}}{\sigma_{pol}}\right)_{\alpha=\frac{\pi}{2}+\delta\alpha}=(\delta\alpha)\frac{\frac{g_1}{g_2}\left(2xyE-\frac{1}{M}\left[\nu-(E-E'\cos\theta)\right](E-E'\cos\theta)\right)+2xyE-2x(E-E'\cos\theta)}{2xE'\sin\theta}$$

Requirement on Q^2

- dilution – relative cross sections
- kinematic variables used to extract $A_{1,2}$ from measured asymmetries
- $F_{1,2}$ (p, n, 3He) used in nuclear corrections
- A_1^p, PDF (d/u) used in extracting $\Delta q/q$