A_1^n Overview and Running Conditions

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1.What are the running conditions for both experiments? Please state clearly the maximum current being used and the target dimensions.

2.What is the operational status/performance requirements of the equipmentneeded by the experiments. Precisely:

a) 3He target – Provide the targets configuration needed, performance requirements and status.

A_1^n Experiment Overview

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- First approved in 2006, re-approved in 2010 for 36 PAC days, rated A and with high impact;
- Will be the first time/experiment requiring the use of polarized beam in Hall C after the 12 GeV upgrade;
- Will be the first time/experiment using the polarized ^3He target in Hall C, stage-I target upgrade performance expected: density 12 amg, 40cm long target cell, 30 uA beam current, (55-60)% in-beam polarization (mostly longitudinal, 3% NMR+EPR+pNMR polarimetry);
- Production: Inclusive electron scattering in DIS and resonance region with longitudinally polarized 11 GeV electron beam;
- Supporting measurements: reference cell ^3He, N_2 and H_2 rates, positron rate, elastic scattering and Delta asymmetry and optics (2.2 GeV beam).

History of Running Conditions Used in A_1^n Proposals

1) 2006 proposal: 15uA, 40cm, Pt=55% – best 6 GeV target performance.

– ΔA_1^n=±0.071 (stat) ± 0.032 (syst) at x=0.77, requested 53 PAC days

2) 2010 update:

a) GEN-II became a possible 12 GeV reality – 60uA, 60cm, Pt=60% ("stage-II" upgrade).

b) SHMS design changed:

Year	p range (GeV/c)	θ range	$\Delta p/p$	solid angle (msr)	y_{targ} (cm)
2006 design	2.0-10.4	$5.5° - 30°$	(-15.0%,25.0%)	3.8	30
2010 (current) design	2.0-11	$5.5° - 40°$	(-10.0%,22.0%)	5.0	30

c) resonance settings added

d) rates estimated using the smaller value of PDF (MRST, CTEQ) and NMC F2 fits.

proposed: ΔA_1^n=±0.029 (stat) ± 0.034 (syst) at x=0.77, total 36 PAC days (approved)

3) 2014-2018:

a) Stage-II upgrade will cost significant time, effort, and modification of existing JLab target. Stage-I upgrade becomes a more realistic option: 30uA, 40cm, Pt=(55-60)%

b) full SHMS simulation became available. Also used Hall C F2 and R code for rates.

– we keep the same 36 PAC day beam time and adjusted the kinematics slightly to maximize the outcome at x=0.77: ΔA_1^n=±0.035 (stat) ± 0.033 (syst)

Performance Requirements

- Polarized beam polarization 85% requested, (minimum 80%), measured to 2% using Moller; Moller measurement once every 7-10 days (and at least at each energy and at each Wien angle change); transverse beam polarization < 1% desired.
- Beam size no larger than 300μm in σ, 200μm in σ desired.
- 11 GeV, 30 μA, beam trip goal: (6-10) per hour
- circular rastering of beam spot to a radius of 2.5 mm and "no hot spot", current ramping at (1) μA-step/(2 sec) on polarized target cell – heat stress calculation underway;
- changing beam IHWP status every 12 hours or at least half-way of each production kinematics;
- beam charge asymmetry controlled to under 200ppm (average over each run);

- 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).

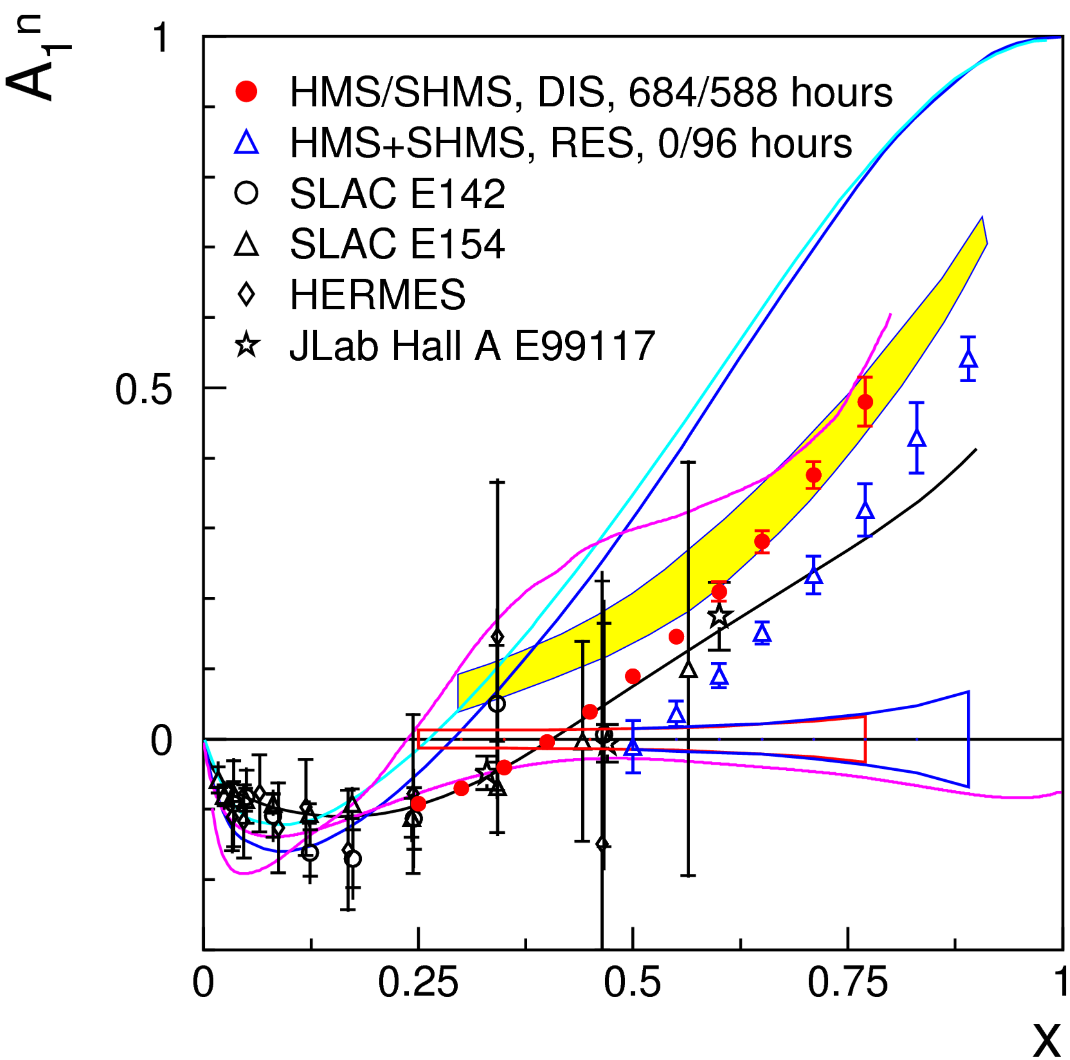
A_1^n Kinematics and Production Beam Time

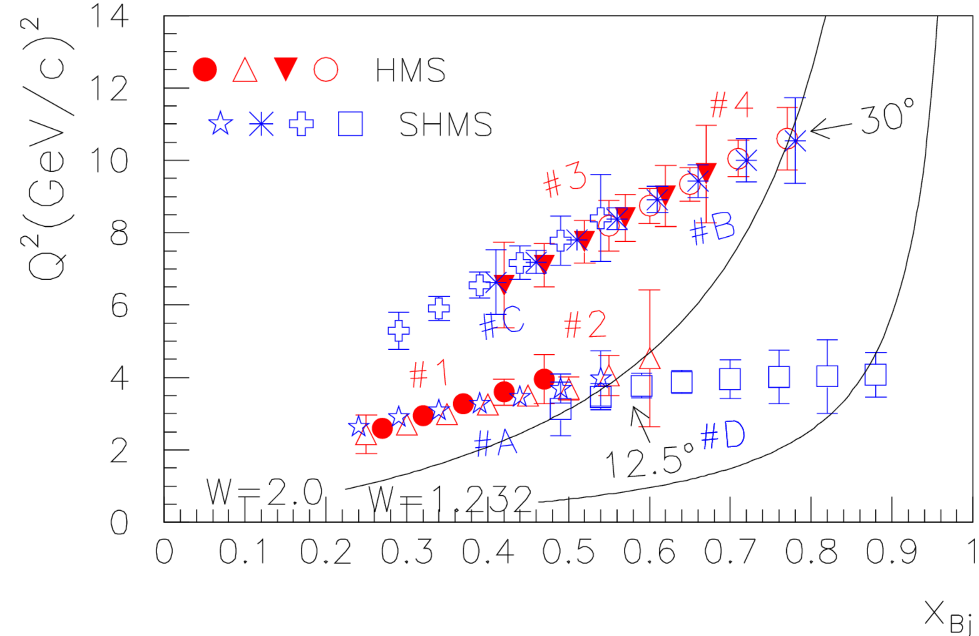
Kine	E_b (GeV)		θ (°)	E_p (GeV)	e^- production (hours)	e^+ prod. (hours)	Tot. Time (hours)
				DIS			
1	11.0	HMS	12.5	5.70	12	0	12
2	11.0	HMS	12.5	6.80	24	0	24
3	11.0	HMS	30.0	2.82	96	0	96
4	11.0	HMS	30.0	3.50	551	1	552
A	11.0	SHMS	12.5	5.80	36	0	36
B	11.0	SHMS	30.0	3.00	464	0	464
C	11.0	SHMS	30.0	2.25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

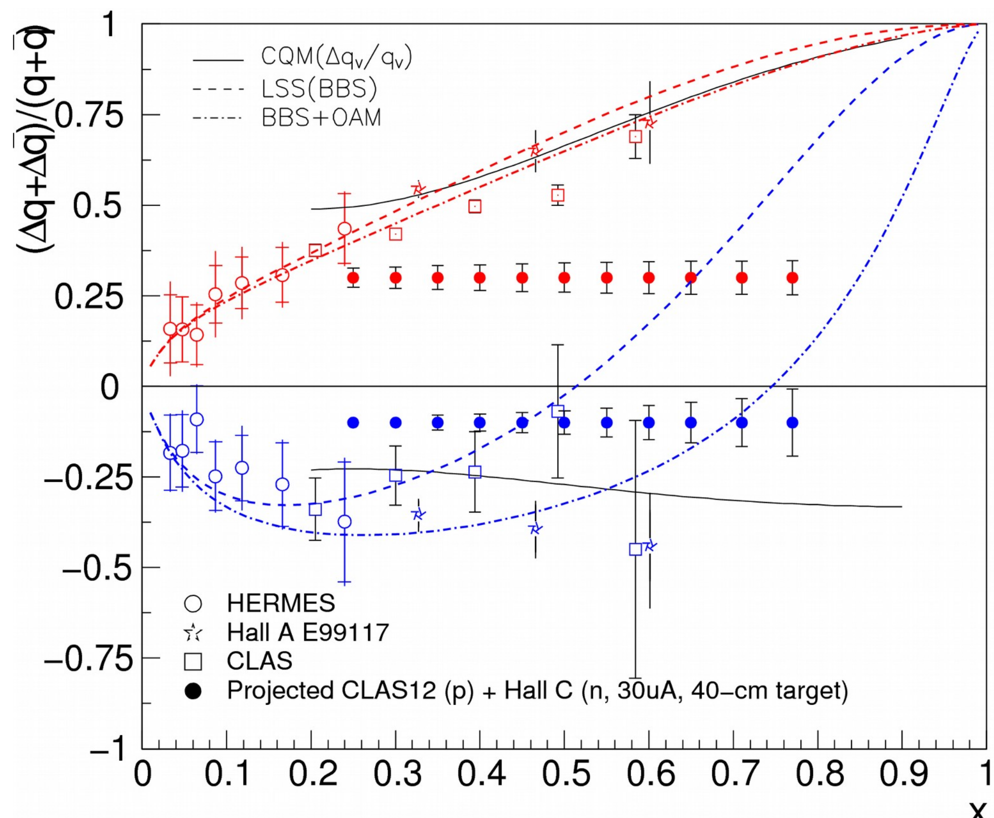
Kine	E_b GeV	E_p GeV	θ (°)	elastic x-sec (nb/sr)	elastic rate (Hz)	Asymmetry	Time (hours)
Elastic	2.200	2.160	12.5	106.986	1293.9	$A_{\parallel} = 0.0589$	11.2
$\Delta(1232)$	2.200	1.815	12.5	-	-	$A_{\perp} \sim$ a few %	6

A_1^n Kinematics and Expected Results

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







Total Beam Time Allocation (not a run plan)

- 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 and ^3He, and H2): 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**

Backup Slides

A_1^n Uncertainties

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

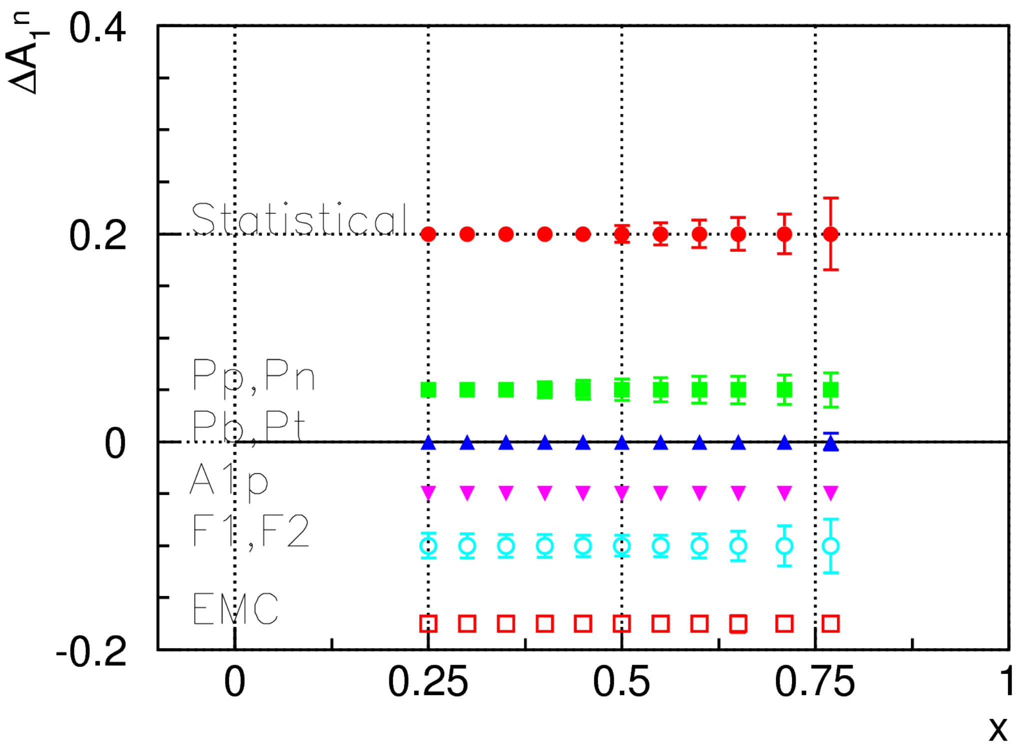


Table 4: Projected statistical and systematic uncertainties for resonance data at different x and Q^2. Resonance data will be taken at a scattering angle of 12.5° (same as the low Q^2 DIS data). The DIS fit for A_1 was used in the systematic uncertainty study.

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

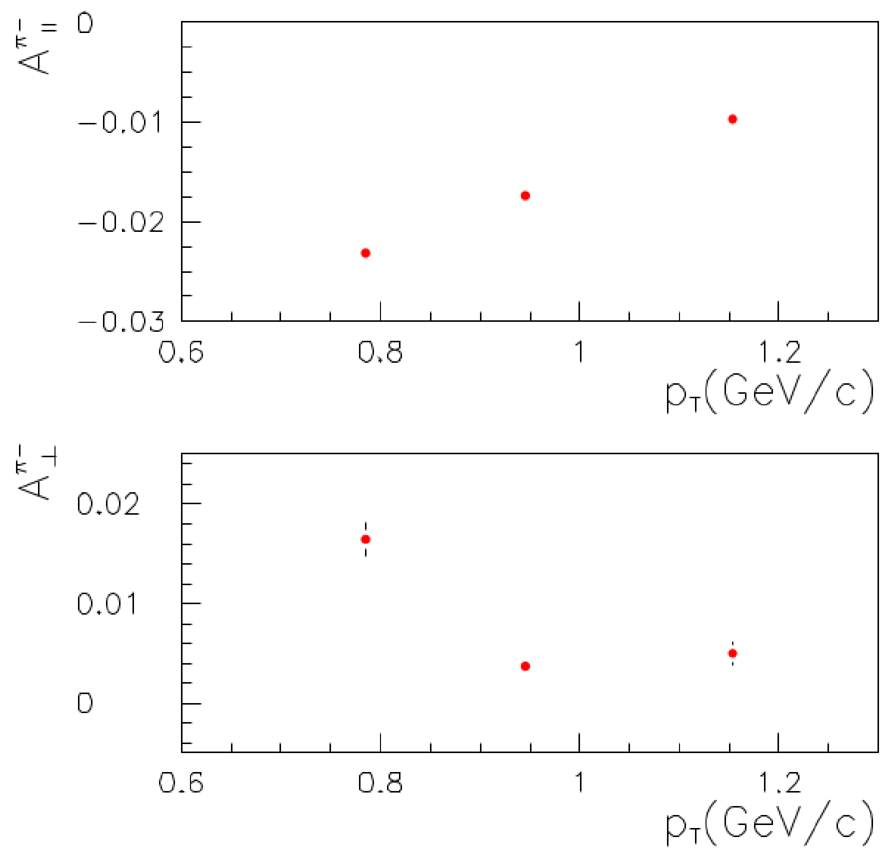
Kine		E_b GeV	E_p GeV	θ (°)	(e,e') rate (Hz)	π^-/e	e^+/e^-	x (Q^2, in GeV^2) (W, in GeV) coverages
DIS								
1	HMS	11.0	5.70	12.5	575.42	< 0.4	$< 0.1\%$	0.25-0.55 (2.59- 4.40) (2.1- 2.9)
2	HMS	11.0	6.80	12.5	426.14	< 0.2	$< 0.1\%$	0.25-0.60 (2.43- 4.53) (2.0- 2.9)
3	HMS	11.0	2.82	30.0	2.69	< 10.7	$< 0.1\%$	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

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

x	Q^2	$A_{\vert\vert}^{^3\text{He}}$±stat.±sys.	$A_{\perp}^{^3\text{He}}$±stat.±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	$0.01036 \pm 0.00739 \pm 0.00052$	$-0.01173 \pm 0.01550 \pm 0.00059$

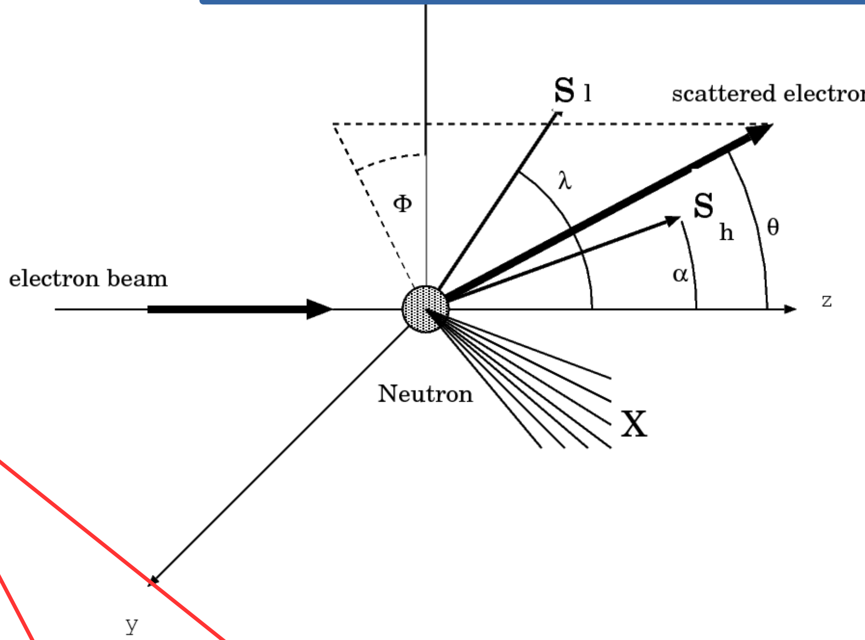
Figure 6-10: Pion asymmetry A^{π^-} results.



Beam Transverse Polarization

ref: E94010 tech note #6

transverse beam spin is suppressed by γ_e



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

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

and the transverse asymmetry :

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

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

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 $\Delta q/q$