

# $A_1^n$ Overview and Running Conditions

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(spokespeople: Gordon Cates, Jianping Chen, Zein-Eddine Meziani, Xiaochao Zheng)

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 equipment needed by the experiments. Precisely:

a)  $^3\text{He}$  target - Provide the targets configuration needed, performance requirements and status.

# A<sub>1</sub><sup>n</sup> 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 <sup>3</sup>He 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 <sup>3</sup>He, N<sub>2</sub> and H<sub>2</sub> rates, positron rate, elastic scattering and Delta asymmetry and optics (2.2 GeV beam).

# Performance Requirements

- Polarized beam polarization 85% requested, (minimum 80%), measured to 2% using Moller; Moller measurement once every 7-10 days (at least at each energy and at each Wien angle change); transverse beam asymmetry < 1% desired.
- Beam size no larger than 300um in sigma
- 11 GeV, 30 uA, 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)  $\mu\text{A}$ -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  $\pm 0.5$  degree desired and  $\pm 1.0$  degree required; density known to 3% (2% from fill density and 2% from operating temperature).
- $Q^2$  known to 1% desired (Ebeam at the  $\pm 1\text{E-}3$  level; spectrometer momentum to  $\pm 1\text{E-}3$ , angle to  $\pm 0.06$  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)		$\theta$ ( $^\circ$ )	$E_p$ (GeV)	$e^-$ production (hours)	$e^+$ prod. (hours)	Tot. Time (hours)
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## 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

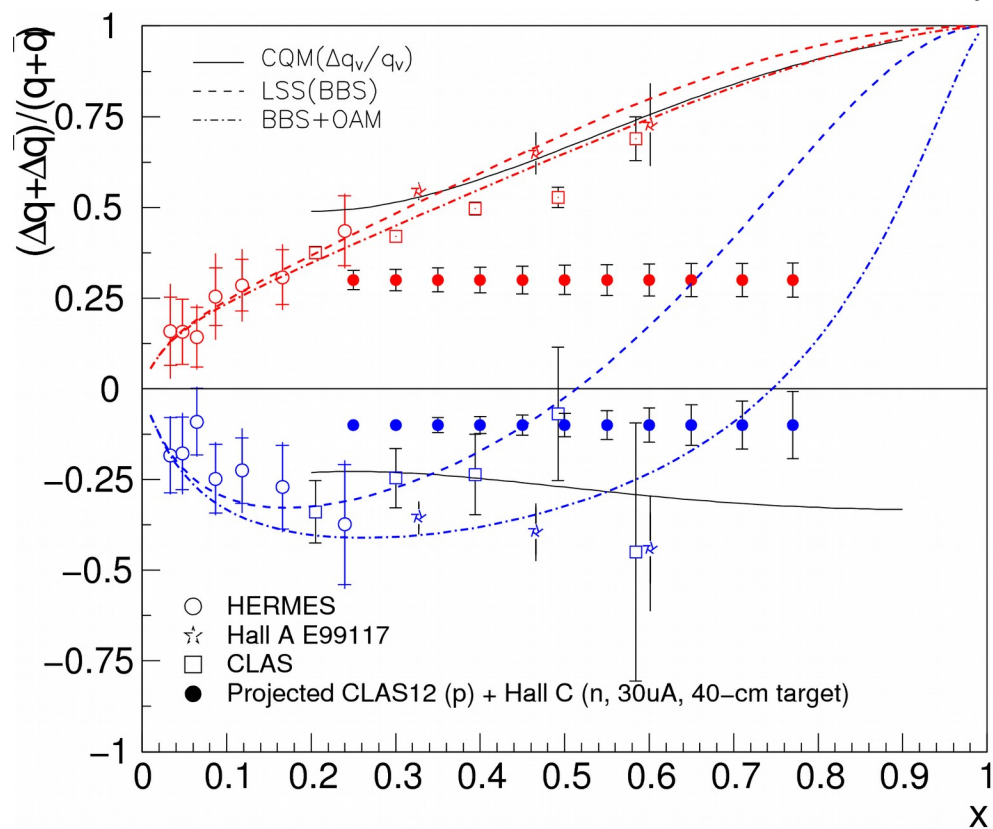
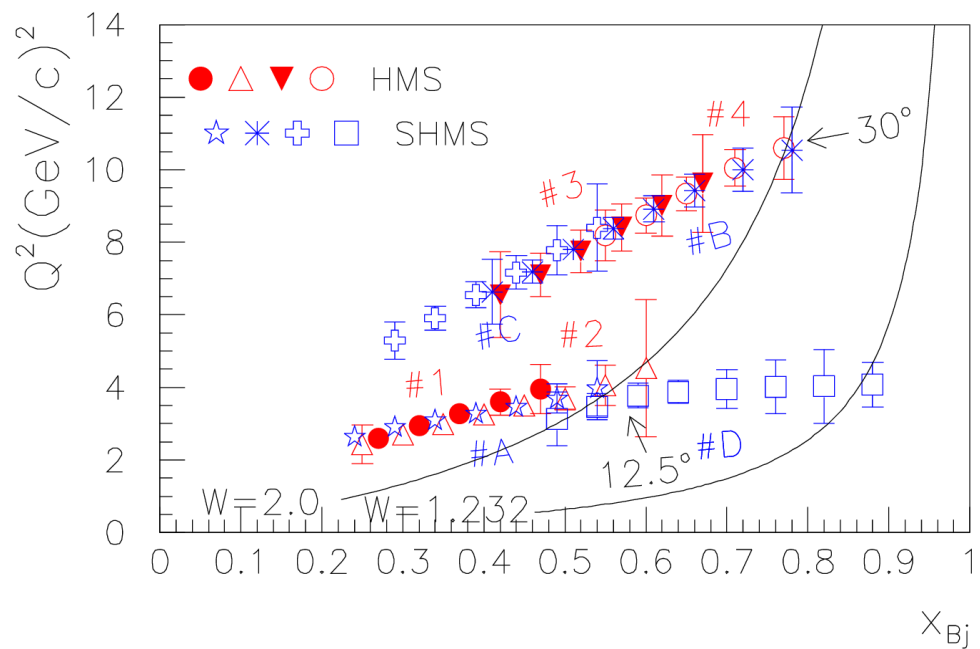
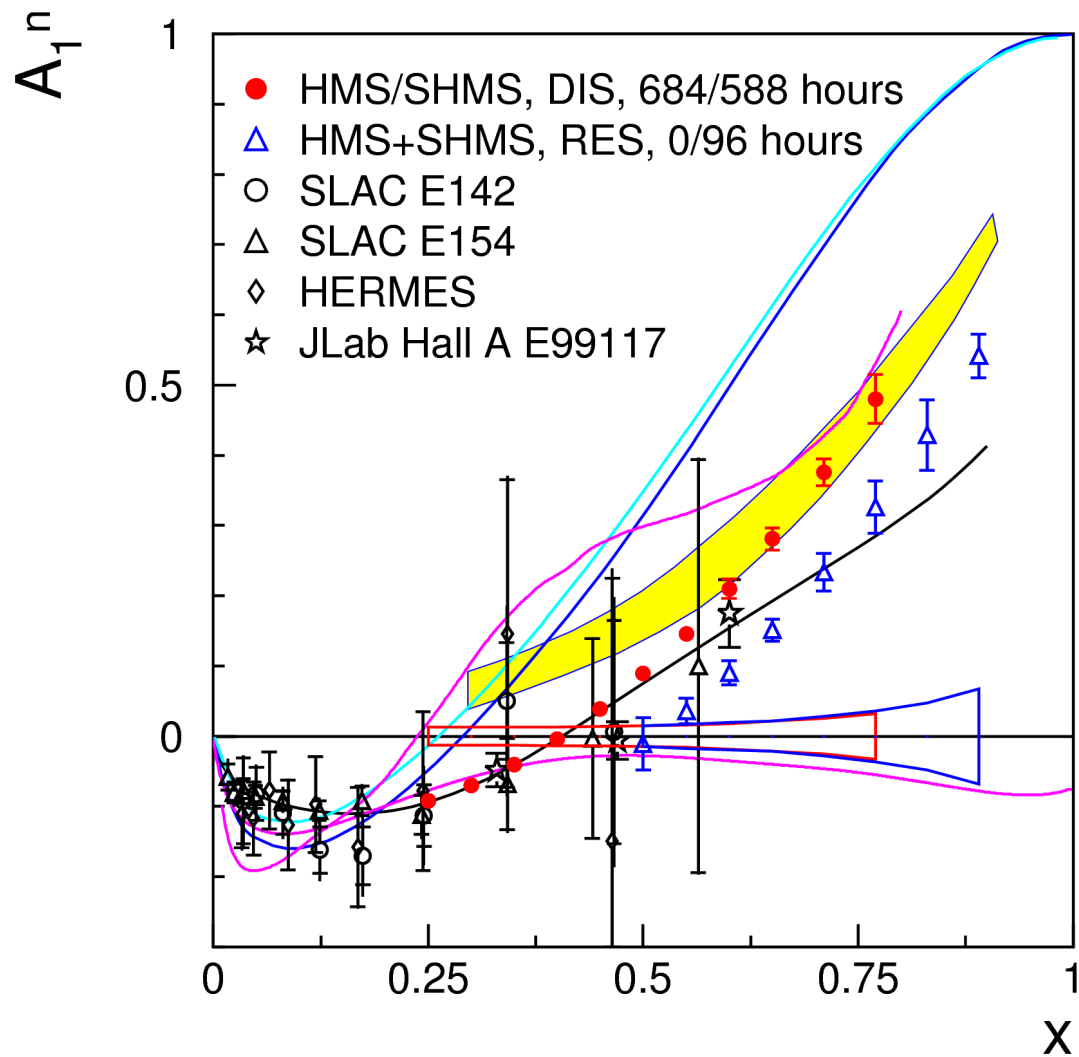
## Resonances

D	11.0	SHMS	12.5	7.50	96	0	96
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Kine	$E_b$ GeV	$E_p$ GeV	$\theta$ ( $^\circ$ )	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

- 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  $\Delta$  transverse asymmetries: **14 PAC hours** (incl N2 runs);
- optics: **8 PAC hours**;
- Moller: 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<sub>2</sub> and <sup>3</sup>He, and H<sub>2</sub>): **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  $A_1^n = +0.175 \pm 0.048(\text{stat.})_{-0.028}^{+0.026}(\text{syst.})$ . And the 2010 proposed values are  $\Delta A_1^n(\text{stat.}) = 0.0288$  and  $\Delta A_1^n(\text{total}) = 0.0446$ .

$x$	$\Delta A_1^n(\text{stat.})$ low $Q^2$	$\Delta A_1^n(\text{stat.})$ high $Q^2$	$\Delta A_1^n(\text{stat.})$ two $Q^2$ combined	$\Delta A_1^n(\text{syst.})$	$\Delta A_1^n(\text{total})$
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



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  $12.5^\circ$  (same as the low  $Q^2$  DIS data). The DIS fit for  $A_1$  was used in the systematic uncertainty study.

$x$	$\Delta A_1^n(\text{stat.})$	$\Delta A_1^n(\text{syst.})$	$\Delta A_1^n(\text{total})$
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

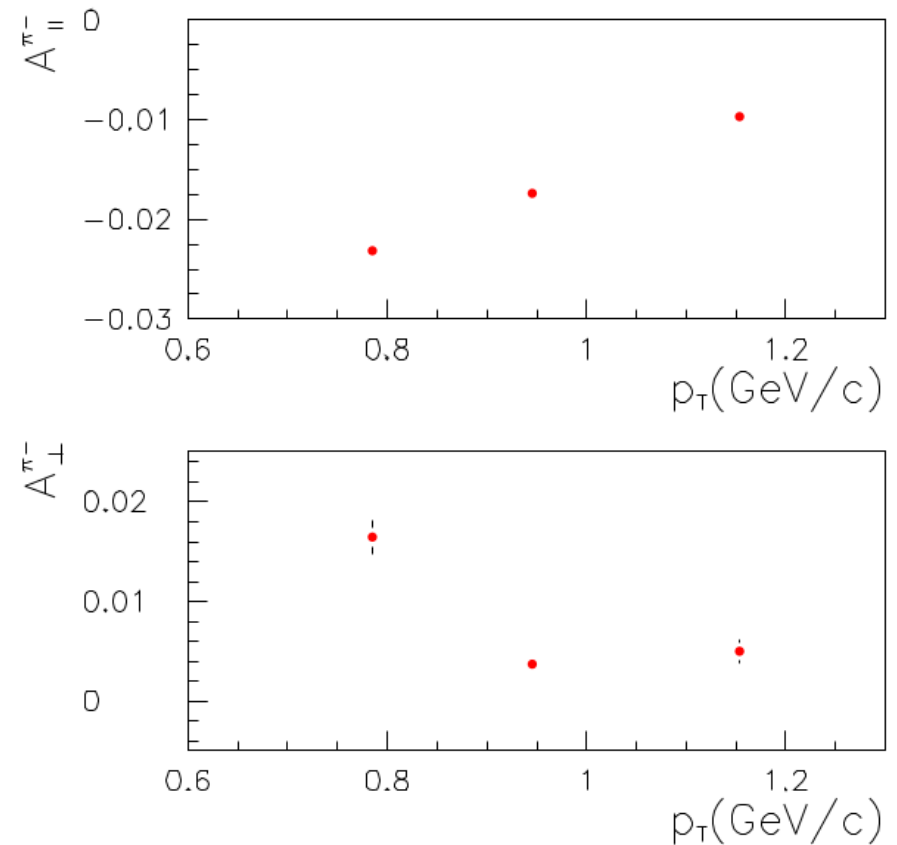
Kine		$E_b$ GeV	$E_p$ GeV	$\theta$ ( $^\circ$ )	$(e, e')$ rate (Hz)	$\pi^-/e$	$e^+/e^-$	$x$ ( $Q^2$ , in GeV $^2$ ) ( $W$ , in GeV) coverages
<b>DIS</b>								
1	HMS	11.0	5.70	12.5	575.42	< 0.4	< 0.1%	0.25-0.55 ( 2.59- 4.40) ( 2.1- 2.9)
2	HMS	11.0	6.80	12.5	426.14	< 0.2	< 0.1%	0.25-0.60 ( 2.43- 4.53) ( 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)
<b>Resonances</b>								
D	SHMS	11.0	7.50	12.5	104.79	—	—	0.50-1.00 ( 3.12- 4.45) ( 0.9- 2.0)

# Pion background and PID

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

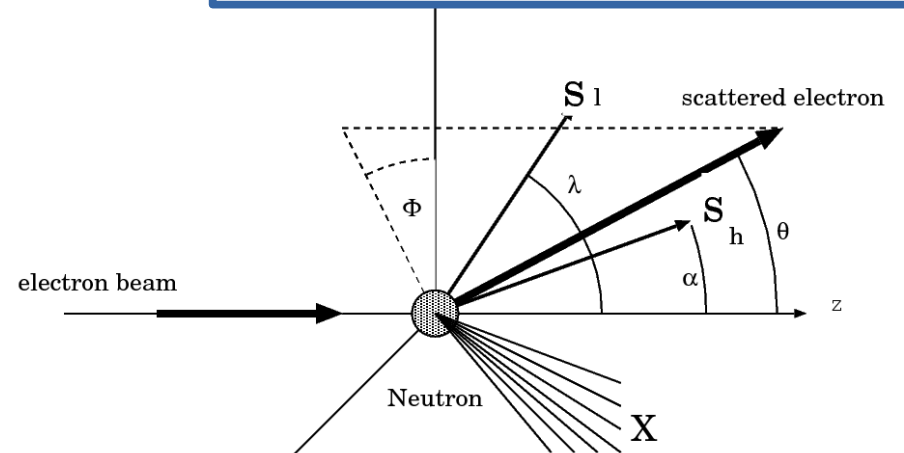
$x$	$Q^2$	$A_{\parallel}^{3\text{He}} \pm \text{stat.} \pm \text{sys.}$	$A_{\perp}^{3\text{He}} \pm \text{stat.} \pm \text{sys.}$
0.327	2.709	$-0.01397 \pm 0.00475 \pm 0.00071$	$-0.00216 \pm 0.00955 \pm 0.00011$
0.466	3.516	$-0.00722 \pm 0.00449 \pm 0.00036$	$0.01359 \pm 0.00790 \pm 0.00069$
0.601	4.833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

Figure 6-10: Pion asymmetry  $A^{\pi^-}$  results.



# Beam Transverse Polarization

transverse beam spin is suppressed by  $\gamma_e$



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

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

and the transverse asymmetry :

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

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

# Requirement on target angle

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

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

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

# Requirement on $Q^2$

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