Experiment E99-117 Run Plan

Xiaochao Zheng, xiaochao@jlab.org

June 09, 2001

http://hallaweb.jlab.org/physics/experiments/he3/A1n/runplan.ps.gz

Contents

1 The E99-117 Experiment

1.1 Overview

The experiment E99-117 was proposed to measure the neutron spin asymmetry A_1^n in inclusive deep inelastic electron scattering at 6 GeV for three kinematics: $0.33 < x < 0.61$ at $2.7 < Q^2 < 4.9(GeV/c)^2$. Available models give different predictions for the high x behavior of A_1^n, most of which predict that A_1^n to be large and positive as $x \to 1$. While all existing data do not yet exhibit this behavior for $x < 0.4$, this measurement should clarify the high x behavior of A_1^n and therefore will provide nontrivial experimental support for understanding spin structure of the nucleon.

The experiment will use an 80% polarized electron beam with current 15 μA and the beam energy 6 GeV. The target is polarized ^{3}He gas cell. Typical target pressure is 10 atm and polarization is 40%. During measurement the target will be polarized either parallel or perpendicular to the electron beam, such that A_1^n can be extracted from the measured asymmetries $A_{||}$ and $A_\perp$. The two Hall-A high resolution spectrometers will be used in a single mode independent of each other.

The major goal of this run plan is to allocate beam time to different kinematics and different polarization such that the statistical error of each kinematics is minimized to the same level. Electron rates are estimated in section 2, as well as pion and positron backgrounds. Positron runs are found to be necessary. In section 3 all commissionings and other measurements are listed. Finally the overall run plan is summarized in section 4.

1.2 Cross sections and asymmetries

The measured raw asymmetries Δ are the physicl asymmetries A_{phy} diluted by the beam polarization P_b, the target polarziation P_t, and the dilution factor f due to the fact that we are using ^{3}He instead of neutron target.:

$$A_{phy} = \frac{\Delta}{P_b P_t f}$$

Then the target asymmetry $A_1^{^3\mathrm{He}}$ can be extracted from the measured asymmetries $A_\perp$ and $A_{||}$ as:

$$A_1 = \frac{1}{D(1+\eta\xi)} A_{||} - \frac{\eta}{d(1+\eta\xi)} A_\perp \tag{1}$$

where $A_{||}$ is the asymmetry when the beam polarization is parallel and antiparallel to the target polarization: $A_{||} = \frac{\sigma^{\uparrow\downarrow}-\sigma^{\uparrow\uparrow}}{\sigma^{\uparrow\downarrow}+\sigma^{\uparrow\uparrow}}$. And $A_\perp$ is the asymmetry when the beam polarization is transverse to the target polarization: $A_\perp = \frac{\sigma^{\downarrow\leftarrow}-\sigma^{\uparrow\leftarrow}}{\sigma^{\downarrow\leftarrow}+\sigma^{\uparrow\leftarrow}}$.

Other variables are kinematics dependent, except $R = \sigma_L/\sigma_T = \frac{1+\gamma^2}{2x}\frac{F_2}{F_1} - 1$. D is the depolarization factor $D = \frac{1-\epsilon E'/E}{1+\epsilon R}$.

1.3 Statistical errors and optimization

The statistical error of the asymmetries are:

$$\Delta A_1^2 = (\frac{1}{P_t P_b f})^2 [(\frac{1}{D(1+\eta\xi)}\Delta A_{||})^2 + (\frac{\eta}{d(1+\eta\xi)}A_{\perp})^2]$$

The statistical error of $A_{||}$ and $A_{\perp}$ can be obtained from:

$$\Delta A_{||} = \sqrt{\frac{1-A_{||}^2}{N_{||}}} \sim \frac{1}{\sqrt{N_{||}}} \qquad \Delta A_{\perp} = \sqrt{\frac{1-A_{\perp}^2}{N_{\perp}}} \sim \frac{1}{\sqrt{N_{\perp}}}$$

where $N_{||}$ ($N_{\perp}$) is the number of scattered electrons when the beam polarization is parallel or antiparallel (perpendicular) to the target polarization. They can be estimated from the cross section of inclusive deep inelastic electron scattering, as shown in section 3.

The error of A_1 for each kinematics can be written as:

$$\Delta A_1^2 = \alpha^2 \Delta A_{||}^2 + \beta^2 \Delta A_{\perp}^2$$

To minimize ΔA_1 we need $t_{||} = \frac{\alpha}{\beta} t_{\perp}$.

1.4 From ^{3}He to neutron

In the deep inelastic region an effective neutron spin structure function can be extracted to first order from that of ^{3}He if only S, S' and D states of the ^{3}He wave function are included:

$$\begin{aligned} \tilde{g_1^n} &= \frac{1}{\rho_n}(g_1^{^3\mathrm{He}} - 2\rho_p g_1^p) \\ \tilde{A_1^n} &= \frac{W_1^{^3\mathrm{He}}}{W_1^n}\frac{1}{\rho_n}(A_1^{^3\mathrm{He}} - 2\frac{W_1^p}{W_1^{^3\mathrm{He}}}\rho_p A_1^p) \end{aligned} \tag{2}$$

where $\tilde{g_1^n}$, g_1^p and $g_1^{^3\mathrm{He}}$ are the spin structure functions of an effective free neutron, a free proton and ^{3}He, respectively. $\rho_n = (87 \pm 2)\%$ and $\rho_p = (-2.7 \pm 0.3)\%$ are the polarization values of the neutron and proton in ^{3}He due to the S, S' and D states of the wave function.

An easier way to estimate A_1^n from $A_1^{^3\mathrm{He}}$ is: $A_1^n = 3A_1^{^3\mathrm{He}}$, e.g., the dilution factor is about 3.

2 Kinematics, Rates and Schedule

2.1 Kinematics

First the three kinematics and related variables are shown in Table 1.

Table 1: Kinematics of E99-117

Beam energy = 5.7 GeV, 25cm ^{3}He target

kine #	x	θ_e	p_e (GeV/c)	ν (GeV)	Q^2 (GeV^2)	ϵ	W^2 (GeV/c^2)
1	0.610	45°	1.45	4.25	4.858	0.382	3.985
2	0.475	35°	1.72	3.98	3.546	0.479	4.800
3	0.331	35°	1.32	4.38	2.721	0.385	6.375

2.2 Estimation of rates and backgrounds

There are several different parameterizations for e^-, π and e^+ simulations. However, they include different mechanisms so give different yields at the kinematics of E99-117. Test runs have been done in August 2000, the result (e/π, e^+/e^- ratios and cross sections) have been compared to simulations and the best parameterization has been choosed for the simulation of E99-117. For details please refer to Appendix A.

With average beam current $15\mu A$, polarization 80%, target polarization 40%, spectrometer momentum acceptance $\frac{\Delta p}{p} = \pm 4.0\%$ and solid angle acceptance 4.9 msr with open collimater (or 3.9 msr with 6 msr collimator) , the rates have been estimated by whitlow's fit. e/π and e^+/e^- ratios have also been estimated and are shown in Table 5.

Table 2: Simulation of rates and e/π, e^+/e^- ratios for E99-117

kine #	x	$(\frac{d^2\sigma}{d\Omega dE'})_{e^-}$ (nb/GeV-sr)	rate (s^{-1})	π^-/e^-	e^+/e^-
1	0.610	0.8749	0.1410	∼10	∼ 0.2%
2	0.475	4.0528	0.9522	∼20	∼ 0.5%
3	0.331	7.1019	1.2805	∼100	∼ 3%

2.3 Run time optimization

The statistical error is minimized for all kinematics to the same level. If the total time of data taking is t_{tot}, then the time for each kinematics and each polarization are shown in Table 3.

Table 3: Run time optimization for E99-117

kine #	x	α	β	$t_{\|\|}/t_{tot}$	$t_{\perp}/t_{tot}$
1	0.610	2.5554	0.5628	0.5385	0.1186
2	0.475	3.4869	0.8017	0.1497	0.03442
3	0.331	3.9670	0.6503	0.1364	0.02235

The total beam time (effective) is about 20 days, optimized data taking time and statistical error for each kinematics are shown in Tabel 4.

Table 4: Data taking run time optimization of E99-117

kine #	$t_{\|\|}$ (hours)	$t_{\perp}$ (hours)	6msr collimator				open collimator	
			$N_{\|\|}$	$N_{\perp}$	$\Delta A_1^{^3\text{He}}$ (f = 0.95)	ΔA_1^n	$\Delta A_1^{^3\text{He}}$ (f = 0.95)	ΔA_1^n
1	258.50	56.94	131258	28910	2.56%	7.68%	2.24%	6.72%
2	71.86	16.52	246329	56633	2.56%	7.68%	2.24%	6.72%
3	65.45	10.73	301727	49460	2.56%	7.68%	2.24%	6.72%

$\star$ The error of asymmetry is $\Delta A_1^{^3\text{He}} = \frac{1}{\sqrt{N}}/(P_b P_t f) = 0.7792\%/(0.8 \times 0.4 \times 0.95) = 2.56\%$;

2.4 Experiment Schedule

Table 5: Experiment Schedule

From	To	Hall-A Status	E99-117	Time (days)
06/01/01	06/02/01	1.198 GeV/15μA/pol	Commission	2
06/03/01	06/05/01	5.734 GeV/15μA/pol	x=0.61 $\perp$	3
06/06/01	06/18/01	5.734 GeV/15μA/pol	x=0.61 $\|\|$	14
06/19/01	06/19/01	5.734 GeV/15μA/pol	x=0.33 $\|\|$ e^+	0.2
(06/19/01)	(06/19/01)	5.734 GeV/15μA/pol	(x=0.48 $\|\|$ e^+)	(0.2)
06/19/01	06/20/01	5.734 GeV/15μA/pol	x=0.33 $\perp$	0.8+0.3$\star$
06/20/01	06/24/01	5.734 GeV/15μA/pol	x=0.33 $\|\|$	4.6+0.3
06/25/01	06/30/01	5.734 GeV/15μA/pol	x=0.48 $\|\|$	5.1+0.2
06/30/01	07/01/01	5.734 GeV/15μA/pol	x=0.48 $\perp$	1.2+0.2
07/02/01	07/08/01	Holiday		5
07/09/01	07/12/01	Maintenance	target tests	4
07/13/01	07/14/01	5.734 GeV/15μA/pol	x=0.61 $\perp$	1.5
07/14/01	07/19/01	5.734 GeV/15μA/pol	x=0.61 $\|\|$	5.5

$\star$ there is one extra day added due to hall schedule change and is unevenly distributed between two lower x kinematics such that better statistic error can be achieved at lowest x point, where A_1^n is expected to be small.

3 Commissioning

Survey

One survey before commissioning, for spectrometer angle at 20°, beamline girder and target.

Beam Tuning
Should be done through Compton Chicane;

OTR Measurement
One OTR (O??? Transition Radiation) measurement should be down right after beam tuning to obtain beam profile, 30 minutes;

Compton Set-up
Hopefully will take less than 8 hours;

BPM Calibration
Check BeO target position, one set of BPM/Harp measurement, 1 hour;

Charge asymmetry measurement
One should be done during commissioning, 1∼2 hour(s);

Moller measurement
One should be done during commissioning, (first one) 3 hours;

Mott measurement
One should be done during commissioning, 1 hour;

Beam energy measurements - ep and ARC
One ep(2E-4) measurement, 1 hours;
One ARC (full, 2E-4) measurement, 1 hour;
ARC (bdl, 2E-3) measurement does not take extra beam time.

Detector Check-out
Should be done parasitically to the Compton setup, BPM, Moller, and beam energy measurement, use optics target;

Optics runs
With sieve slits in, ^{12}C target, no raster, beam current $5\mu A$, elastic, 5 minutes, or total number of events no less than 28K;
With sieve slits in, ^{12}C target, no raster, beam current $5\mu A$, quasi-elastic, 5 minutes, or total number of events no less than 20K;
With open collimator, ^{12}C target, raster on, beam current $25\mu A$, quasi-elastic, to check false asymmetry, 1 hour;

Acceptance runs
With open collimator, ^{12}C target, raster on, beam current $25\mu A$, do a momentum scan at elastic P_0, $(1\pm0.02)P_0$ and $(1\pm0.04)P_0$. Run 5 minutes for each point, or total number of events no less than 20K for each point;

Elastic Runs – for asymmetry and xsection
Polarized ^{3}He target, parallel polarization, open collimator, raster on (4mm diameter), 13.3 hours, number of events in elastic peak no less than 1.8M, or total number of events no less than 2.5M. Polarization of the beam and the target needs to be reversed half way.

To reverse the polarization of the beam and the target, the following procedure needs to be followed:

- Take 2.5 hours data with target holding field at present direction (either 0° or 180°, target half-wave plate(s) out;
- Call MCC to reverse the beam polarization, take 2.5 hours data;
- Rotate target holding field by 180°, put target half-wave plate(s) in, take 2.5 hours data;
- Call MCC to reverse the beam polarization, take 2.5 hours data;

Delta Asymmetry Runs – determine sign of transverse asymmetry

Polarized ^{3}He target, transverse asymmetry, open collimator, raster on (4mm diameter), 0.5 hour, number of events in delta resonance peak no less than 120K. (Polarization of the beam and the target needs to be reversed half way?)

Reference Cell Runs

The following runs should be with open collimator, raster on (4mm diameter), beam current $15\mu A$.

For each pressure curve, should measure 4 points at 2.5, 5.0, 7.5 and 10.0 atm. To save ^{3}He gas, ^{3}He should be the last one to be measured.

Using N_2, measure pressure curve at elastic, For each pressure, take 2 minutes data or total number of events in elastic peak no less than 20K. Changing pressure takes 5 minutes so the total time will be 0.5 hour;

One run using N_2, measure false asymmetry at quasi-elastic; 20 minutes or total number of events in elastic peak no less than 25M;

(optional) One run using ^{4}He, measure cross section at elastic, for normalization; 2 minutes or total number of events in elastic peak no less than 20K;

Using ^{3}He, measure pressure curve at elastic, and check normalization; Take 8 minutes data at 2.5 atm, 4 minutes at 5.0 atm, 3 minutes at 7.5 atm and 2 minutes at 10.0 atm, respectively. Or for each pressure total number of events in elastic peak should be no less than 20K. Changing pressure takes 5 minutes so the total time will be 40 minutes;

Compton measurement

Will continuously run compton polarimeter during the experiment.

BCM calibration – optional

One BCM calibration takes 2 hours. However, one full BCM calibration has been done at the beginning of April (2 hours and Hall-A only, 100 μA). So we probablly do not need to do BCM calibration during E99-117.

4 Data Taking and Special Runs

Data Taking Runs

Should run for parallel and perpendicular polarization for each kinematics, with open collimator, raster on, beam current 15 μA. For parallel kinematics, (target is in longitudinal polarization), polarization of the beam and the target needs to be reversed half way.

To reverse the polarization of the beam and the target, the following procedure needs to be followed:

- Take 1/4 data with target holding field at current direction, e.g., 0° or 180° for parallel, target half-wave plate(s) out;
- Call MCC to reverse the beam polarization, take 1/4 data;
- Rotate target holding field by 180°, put target half-wave plate(s) in, take 1/4 data;
- Call MCC to reverse the beam polarization, take 1/4 data;

For perpendicular kinematics, because there is no half waveplate for tranverse lasers, target polarization cannot be reversed. For the current quater waveplates setting, holding field should always be 270○. Never rotate field to 90°. **Optics runs**

For each kinematics, take 15 minutes of ^{12}C data with open collimators, no raster.

Acceptance runs

At kinematics x=0.33, do a momentum scan at $(1\pm0.02)P_0$=1.2936 and 1.3464 (GeV/c) with open collimator. ^{12}C target, raster on, beam current $25\mu A$. Run 1.6 hours (2.7 hours), and total number of events (both e^- and π^- no less than 0.7M for each point;

Reference Cell Runs

For each kinematics, do one run using N_2, and one run using ^3He, with open collimators and raster on;

Momentum and angle changes

30 minutes for each momentum and angle change;

Target polarization measurement

Should do one NMR and one EPR measurement every 4 hours during the run, each will take about 20 minutes.

(Optional) Do continuous EPR monitoring every 4 hours, between two EPR/NMR measurements. Typically one continuous EPR monitoring takes 0.5 minutes, must be done with field feedback system on. More NMR, EPR measurements and other target tests need to be done during maintenance.

Target polarization change

Typically it takes 10 minutes to rotate the target polarization from perpendicular to parallel direction (and vice versa).

Other Special Runs

Moller: 1 hour, should be done
every 5 days;
after every spot change;
after every down time (maintenance or holiday);

Compton: continuous running during the experiment;

Beam energy measurement: 1 hour (ep) + 1 hour (ARC), should be done
at the beginning of data taking (6 GeV);
after every down time (maintenance or holiday);

BPM calibration: $\sim$ 5 minutes
Should check BeO target position and do BPM/harp once everyday.

OTR Measurement: 30 minutes Should be done once a day.

Survey

Before commissioning, do one survey at 20°;
On 06/19/01, do one survey at 45° during 4 hours' weekly maintainance, then change spectrometer momentum (polarity) and spectrometer angle to 35°;
On 07/13/01, do one survey at 35°;
Then change spectrometer angle to 45°, do another survey;
On 07/19/01 (end of run), do one survey at 45°.

5 Run Plan

5.1 Commissioning

Beam energy 1.198 GeV, 15 μA, $\theta_L = \theta_R = 20°$, $p_L = p_R = p$.

Pressure curve for reference cells should be measured at 4 points with 2.5, 5.0, 7.5 and 10.0 atm, respectively.

Cross sections are measured to the level of 1%, ^{3}He elasitic asymmetry is measured to the level of 3%, reference cell ^{3}He false asymmetry is measured to 2×10^{-4}.

For ^{12}C elastic run, at 20° the rate will be about 250 Hz at 5μA, the HRS momentum should be shifted higher (from 1.1903 to 1.200) to reduce the contribution from QE peak within the acceptance.

Compton measurement will be continuously running during the experiment.

5.2 Data Taking

Beam energy 5.734 GeV, 15 μA.

Based on the result of online analysis for $x = 0.33$ e^+ run, will decide whether $x = 0.48$ e^+ run is necessary or not.

5.3 Target Operational Limits

- For $^3\vec{\mathrm{He}}$ target, everytime when rotating the holding field by 180°, put (take) the half-wave plate(s) in (out), and vice versa.

Table 6: E99-117 Commissioning

Date	Task	Target	I_{beam} (μA)	p(GeV/c)	Time	Note
	Beam Tuning			(1.1903)	$\sim$16	through Compton Chicane
06/01	OTR				0.5	
	Compton Set-up				$\sim$8	check beam profile
	BPM/Harp	BeO			1	Det checking start
	Charge asym				1$\sim$2	
	Moller	^{12}C			3	using optics target
	Mott	?			0.5	
	ep	^{12}C			1	
	ARC	^{12}C			1	Det checking end
	Optics	^{12}C	25	el, 1.1903	0.1	raster on, open collimator
	Optics	^{12}C	5	el, 1.1903	0.1	raster off, sieve slits in
	Optics	^{12}C	5	QE, 1.112	0.1	raster off, sieve slits in
	False asym	^{12}C	25	QE, 1.112	1.0	raster on, open collimator
06/02	Elastic	$^3\vec{\mathrm{He}}_{\parallel}$	15	el, 1.168	13.3	check asym, σ, raster on, open collimator
	Delta resonance	$^3\vec{\mathrm{He}}_{\perp}$	5	Δ, 0.796	0.5	check transverse asym sign, raster on, open collimator
	Reference cell	r.N_2	15	el,1.1914	0.5	pressure curve, f, raster on, open collimator
		r.N_2	15	el,1.1914	0.4	check false asym, raster on, open collimator
		r.^{4}He	15	el, 1.175	0.1	for normalization, raster on, open collimator
		r.^{3}He	15	el, 1.168	1.0	pressure curve, (norm.), raster on, open collimator
		r.^{3}He	15	QE, 1.112	0.4	check false asym, raster on, open collimator

A Simulation for Data Taking Runs and Test Run Results

There are several codes available for estimating electron rates and backgrounds for inelastic electron scattering. However, they are based on different mechanisms and give out different results for the kinematics of E99-117. The pion background is predicted to be high, which will be the crucial point of the following data analysis. Positron background is also predicted to be nontrivial and positron runs are necessary.

To further pin down the event rates, testruns have been done in August of 2000 and the results were compared to different codes. The final rates are results from whitlow for electron, rosetail for elastic tail, and from wiser for pion and positron, plus a correction factor obtained from the testruns.

Table 7: E99-117 Data Taking

From	To	E99-117	$S_{^3\vec{\mathrm{He}}}$	$\theta_L = \theta_R$	$p_L = p_R$ (GeV/c)
06/03/01	06/05/01	x=0.61	transverse	45°	-1.455
06/06/01	06/18/01	x=0.61	parallel	45°	-1.455
06/19/01	06/19/01	x=0.33	parallel	35°	+1.320
(06/19/01)	(06/19/01)	(x=0.48)	(parallel)	(35°)	(+1.720)
06/19/01	06/20/01	x=0.33	transverse	35°	-1.320
06/20/01	06/24/01	x=0.33	parallel	35°	-1.320
06/25/01	06/30/01	x=0.48	parallel	35°	-1.720
06/30/01	07/01/01	x=0.48	transverse	35°	-1.720
07/02/01	07/08/01	Holiday	tests		
07/09/01	07/12/01	Maintenance	tests		
07/13/01	07/14/01	x=0.61	transverse	45°	-1.455
07/14/01	07/19/01	x=0.61	parallel	45°	-1.455

Table 8: Target Operational Limits I_{beam} (μA)

Target	raster on	raster off
BeO	25	5
^{12}C	50	50
$^3\vec{\mathrm{He}}$	15	never
Ref. cells	15	never

A.1 Programs electron scattering, pion electroproduction and positron yield

The codes that will be used are:

- ⋆ qfs (epc) – e^- (π^-) cross section near resonance region[1]
- ⋆ whitlow (wiser) – e^- (π^-) cross section in deep inelastic region [2]([3])
- ⋆ rosetail – (e, e') elastic tail
- ⋆ pos_epc, pos_wiser – e^+ cross section

For positron yield only one reaction channel has been included for calculating e^+ cross section: $\pi^0 \to e^+e^-$. The code pos_epc was first developed by J.P.Chen based on SLAC data and epc code for yield of π^0. Code pos_wiser was developed by using the same reaction channel, but using wiser's fit for yield of π^0.

[1] J. W. Lightbody, Jr., J. S. O'Connell, **Computers in Physics**, May/June (1988);
[2] L. W. Whitlow, **SLAC-Report-357**, (1990);
[3] D. E. Wiser, **Ph.D. thesis**, Univ. of Wisconsin, (1977);
[4] Mo and Tsai,**Rev. Mod. Phys.**, **41**, 205 (1969);
[5] Stein, et. al. **Phys. Rev. D**,**12**, 1884 (1975).

A.2 Test run results

Kinematics: Beam energy = 5.650 GeV, $\theta_e = 45°$
Target: 4 cm LH2 for electron runs, 15 cm LH2 for positron runs

Results of e^-, π^- and e^+ cross sections (nb/GeV-sr) are shown in Table 9.

Table 9: Test run result for E99-117

p_e(GeV/c)	1.5	0.9	0.55
π^- (epc)	12.01	705.2	5405.3
π^- (epcv)	0.00	0.000	0.000
(wiser)	2.98	204.4	1607.1
π^-(data)	3.2	150	890
e^-(qfs)	0.499	1.684	3.844
(Whitlow)	0.305	1.324	2.219
(rosetail)	0.011	0.251	1.521
e^-(data)	0.166	1.062	3.924
e^+(epc)	0.0022	0.0038	0.0074
(wiser)	0.011	1.001	11.2
e^+(data)	0.0006	0.17	2.03

⋆ The internal radiation length used in wiser's fit is: 2.7%
⋆ The radiation length used in rosetail is:
for 4cm liquid H_2 target
before interaction: 2.8 mil Al + 4 cm/2 LH2 = 0.08% + 0.23%= 0.31%
after interaction: 4 cm/2 LH2 + 7 mil Al/$\sin\theta$ + 16mil Al + 20 cm Air + 7 mil Kapton
= 0.23% + 1.01% = 1.24%

For pion yields we compare data with wiser and epc code for pion, while for e^- we compare data with (whitlow+rosetail) and (qfs+rosetail). From the comparison we can see that wiser gives better result for π cross section (thougth there is an overestimation). For e^- cross section whitlow's fit is better. For positron yield, though much better than pos_epc, there is an overestimation in code pos_wiser. We expect that this is because we didn't include the angular distribution of $\pi^0 \to e^+ + e^-$. This overestimation will be corrected by a reasonable factor (about 6).

A.3 Estimation of electron, pion and positron rates

Results of calculations are listed in Table 10.
⋆ The radiation length for 25 cm ^{3}He target is:
before interaction:
10 mil Be + 10 mil Al + 0.012 mm Pyrex + 20 cm Air + 25 cm/2 ^{3}He (10atm) = 0.3574%
after interaction:
25 cm/2 ^{3}He (10atm) + 10 mil Al + 1.4 mm Pyrex + 20 cm Air + 7 mil Kapton + 4 mil Ti = 1.673%

Table 10: Simulation for E99-117

kine #	1	2	3
p_e(GeV/c)	1.455	1.72	1.32
θ_e	45°	35°	35°
π^-(epc)	55.6	92.6	749.8
π^-(epcv)	259.1	234.6	291.0
π^-(wiser)	4.520	11.96	98.42
e^-(qfs)	1.700	6.274	9.759
e^-(whitlow)	0.875	4.053	7.102
e^-(rosetail)	0.012	0.043	0.195
e^-(rosetail, new window)	0.013	0.043	0.026
e^+(epc)	0.0047	0.0057	0.0086
e^+(wiser)	0.0158	0.114	1.11
π^-/e^-(estimation)	∼10	∼20	∼100
e^+/e^-(estimation)	$\sim 0.2\%$	$\sim 0.5\%$	$\sim 3\%$

B Simulation for Commissioning Runs

In this section, the cross section, rate, required total number of events, and the estimated beam time for reference cell runs during commissioning are presented. The beam energy is 1.198 GeV. At an angle of 20° the (reference) cell windows will be within acceptance and its contribution is estimated using: $\sigma_{\mathrm{GE180}} = \sigma_{^3He} \times \frac{2\times d_{\mathrm{GE180}}}{25\mathrm{cm}} \times \frac{\rho_{\mathrm{GE180}}}{\rho^3He}(\frac{Z_{\mathrm{GE180}}}{Z_{^3He}})^2$. Elastic scattering from window has a cross section of $32.6 \times \sigma^3He$ at 10atm, which gives a rate of 22.1 kHz with beam current $15\mu A$. For quasi-elastic window gives $12.6 \times \sigma^3He$ at 10atm. During commissioning prescale factors should be set properly such that the high rate from window will not kill DAQ. In on-line analysis windows need to be cut off (in y_{tgt}) to make sure if enough data has been collected.

- N_2 pressure curve, elastic:

  N_2 elastic (Mott) cross section is $\frac{d\sigma}{d\Omega} = 228.56\mu b/sr$. With beam current $15\mu A$ and N_2 pressure 1 atm the rate is 132KHz, which exceed the upper limit of data aquisition system (2KHz). Because of the contribution from cell windows the real rate from N_2 is a little less than 2KHz. For measuring pressure curve we would like to have 20K events for each point so the error will be at 1% level. So we need approximately 20K/2K/2.5 atm=4 seconds for 2.5 atm point and even less for higher pressure. Rate is not a problem but need to pay attention to the prescale factors such that the event rate is lower than the DAQ limit.

- N_2 false asymmetry, elastic:

  We would like to have false asymmetry $\Delta A \sim 2\times10^{-4}$, e.g., 2.5×10^7 events are needed. At elastic peak this corresponds to 25M/132KHz=3 minutes. With beam effiency 60%, also taking into account the fact that we are using Mott cross section to estimate rate, about 10 minutes (one run) is needed for N_2 false asymmetry measurement.

- ^{3}He pressure curve, elastic:

  ^{3}He elastic cross section is $\frac{d\sigma}{d\Omega} = 1.908 \times 10^{-5}\text{fm}^2/\text{sr}$. With beam current $15\mu A$ and ^{3}He pressure 1 atm the rate is 50Hz. The quasi-elastic peak will also partially fall into the spectrometer acceptance, the ratio of quasi-elastic events vs. elastic events is about 0.4. If windows contribute 22KHz then with prescale factor ~ 12 the real rate coming from ^{3}He elastic is about 4Hz/atm. For each pressure the quasi-elastic event rate, time needed for 10 K events and the total time (with beam efficiency 60% and an extra 5 minutes to change pressure) are shown in table B:

^{3}He pressure (atm)	rate(Hz)	time for 20K events	total time
2.5	10	17 min	17+5 min
5.0	21	8 min	8+5 min
7.5	31	6 min	6+5 min
10.0	42	4 min	4+5 min

  So we will need about 1 hour to complete the measurement for reference cell ^{3}He pressure curve. For each point events within elastic peak should be no less than 10K.

- ^{4}He elastic cross section:

  ^{4}He elastic cross section is $\frac{d\sigma}{d\Omega} = 2.75 \times 10^{-5}\text{fm}^2/\text{sr}$. With beam current $15\mu A$ and ^{4}He pressure 10 atm the rate is 800Hz. With a prescale factor of 12 due to window contribution the real rate coming from ^{4}He elastic is 66.7 Hz/atm. To obtain 20 K events about 5 minutes will be needed. So we will need 9 minutes (with efficiency 60%) for this measurement. Events within elastic peak should be no less than 20K.

- ^{12}C elastic cross section (optics):

  ^{12}C elastic cross section is $\frac{d\sigma}{d\Omega} = 3.2 \times 10^{-5}\text{fm}^2/\text{sr}$. Event rate will be 60Hz with beam current $5\mu A$, 108 mg/cm^2 ^{12}C target (density 2 g/cm^3, thickness 0.5mm) and sieve slits in (which will reduce the acceptance by 10^2). To obtain 10 K events about 3 minutes will be needed. So we will need 5 minutes (with efficiency 60%) for this measurement.

- ^{12}C quasi-elastic cross section (optics):

  ^{12}C quasi-elastic cross section is $\frac{d\sigma}{d\Omega} = 6.6 \times 10^{-4}\text{fm}^2/\text{sr}$. With beam current $5\mu A$, 108 mg/cm^2 ^{12}C target and sieve slits in the rate is 1.2 KHz. We would like to have 5 minutes on this measurement.

- ^{12}C quasi-elastic, check false asymmetry:

The cross section is shown above. Without collimater the rate is 120 KHz. To check asymmetry at a level of 2×10^{-4} we need $2.5{\times}10^7$ events so we need 25M/120K = 3.5 minutes, or total beam time 6 minutes (with efficiency 60%) for this measurement.

- $^3\vec{\mathrm{He}}$ asymmetry, elastic:

$^3\vec{\mathrm{He}}$ elastic asymmetry, with target spin parallel to beam, is estimated to be 0.0877. With dilusion factor $f = 0.9$, beam polarization 80% and target polarization 40% the raw asymmetry is $A_{raw} = fAP_bP_t = 0.0253$. If an error of 3% is needed then the total number of events will be
$N = (\frac{1}{\Delta A_{raw}})^2 = (\frac{1}{A_{raw}3\%})^2 = 2.3 \times 10^6$. With beam current 15 μA, typical $^3\vec{\mathrm{He}}$ cell pressure 10 atm, prescale factor 12, $^3\vec{\mathrm{He}}$ elastic rate is 40 Hz. Contribution from quasi-elastic scattering is about 0.4 times elastic rate. With both arms taking data simutaneouly we need effective beam time $2.3 \times 10^6/(40 \times 2) = 57508\mathrm{sec}/2 = 8\mathrm{hours}$, or total time $8/0.6 \approx 13.3$ hours for $^3\vec{\mathrm{He}}$ asymmetry measurement. Number of events within elastic peak is no less than 2.3M. Total number of events from both elastic and quasi-elastic is 3.22 M.

Since rate of elastic scattering from windows is high compared to the rate coming from $^3\vec{\mathrm{He}}$ elastic, the first run for $^3\vec{\mathrm{He}}$ asymmetry will be analyzed on-line so as to check if it is possible to suppress window contribution by shifting the central momentum of HRSs lower. By doing this quasi-elastic scattering from windows still come into acceptance and $^3\vec{\mathrm{He}}$ elastic will also be suppressed by a factor of 1.33.

- $^3\vec{\mathrm{He}}$ transverse asymmetry, Δ resonance:

Momentum setting for Δ resonance at 1.198 GeV and 20° is 0.796 GeV/c. Total cross section (by QFS) is 8.693μb/GeV-sr, contribution from Δ resonance is 6.121μb/GeV-sr. With beam current 5 μA, typical $^3\vec{\mathrm{He}}$ cell pressure 10 atm, total rate is 6.541 KHz (4.605 KHz from Δ resonance), which exceeds DAQ limit. Also take into consideration windows, we assume a prescale factor of 12 is needed. Then the rate is about 2KHz/12=160 Hz.
Δ resonance asymmetry is about 0.02. With dilusion factor $f = 0.9$, beam polarization 80% and target polarization 40% the raw asymmetry is $A_{raw} = fAP_bP_t = 0.00576$. If we need to measure asymmetry 2σ away from zero to determine sign, then the total number of events will be
$N = (\frac{1}{\Delta A_{raw}})^2 = (\frac{1}{A_{raw}50\%})^2 = 1.2 \times 10^5$. With $^3\vec{\mathrm{He}}$ rate 160 Hz, one arm taking data, we need effective beam time $1.2 \times 10^5/160/0.6 = 750\mathrm{sec} = 13\mathrm{min}$, or total time $13\mathrm{min}/0.6 \approx 0.5$ hours for $^3\vec{\mathrm{He}}$ asymmetry measurement. Number of events within Δ resonance peak is no less than 120K.