E94-010 simulation and run plan optimization

A. DEUR. deurpam@cebaf.gov

09/08/1998

Contents

1 Introduction

The goal of this work is to provide tools to make and to optimize the run plan for the E94-010 experiment or other ^{3}He polarized target experiments. We did this work keeping in mind we could need to change quickly the run plan to adapt the experiment to some unexpected changes. Optimizing the run plan means to share properly the E94-010 allocated time between the different tasks in order to maximize the kinematic domain covered by the experiment and to minimize the asymmetry statistical errors.

We will first describe the way E94-010 will run and the different tasks one has to perform. Then, after having presented the codes used to simulate the experiment, we will give a recipe on how to get quickly a new optimized run plan. Finally we will propose a first run plan for the E94010 experiment.

2 The E94-010 experiment

2.1 Overview

The experiment E94-010 is the first experiment using the new ^{3}He polarized target built at Jefferson Lab. Thanks to the Pauli exclusion principle an ^{3}He target can be considered as a neutron target, up to small corrections. E94-010 goal is to measure the asymmetry $\mathrm{A_1}^n(v, Q^2)$ and the spin structure function $\mathrm{g_1}^n$ at low Q^2 ($0.020<Q^2<3.3$ GeV^2) in order to make a connection between the GDH and the Bjorken sum rule. We also plan to measure the absolute polarized cross sections. The experiment will take place from the 09/25/98 to the 12/24/98. Assuming run time efficiency 50 % efficiency, the usable time is 35.5 days. The experiment will use both detector arms of Hall A. The hadron spectrometer will be used as an electron detector. We will asume the same detection efficiency for the two arms even if we know that the "hadron" arm efficiency will be slightly lower. The main difference between the two arms is the hadron arm cannot run up to E_p= 3 GeV. Four different energies will be used (1. 044, 2.032, 3.020 and 4.008 GeV) at 3 different angles (15, 25 and 35^0) with a beam current between 3 and 10 μA.

2.2 Asymmetries

The experimental measured asymmetries ("raw" asymmetries) are the physical asymmetries diluted by the beam and the target polarization and by the fact we are scattering on ^{3}He instead of a neutron target. The raw asymetry Δ is related to the physical asymmetry A_1 by:

$A_1 = \frac{1}{P_b P_t f}\Delta$

where P_b is the beam polarization, P_t is the target polarization and f the dilution factor.

The expression of A_1 is, taking the beam polarisation parallel to the incoming electron momentum[1]:

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

where $A_{\parallel}$ is the asymmetry when the beam polarization is parallel and antiparallel to the target polarization:

$A_{\parallel} = \frac{\sigma^{\uparrow\downarrow} - \sigma^{\uparrow\uparrow}}{\sigma^{\uparrow\downarrow} + \sigma^{\uparrow\uparrow}}$, $\sigma^{\uparrow\uparrow}$ being the cross section when the beam and the target polarization are parallel and $\sigma^{\uparrow\downarrow}$ the cross section when the beam and the target polarization are transverse.

$A_{\perp}$ is the asymmetry when the beam and the target polarization are transverse.

$A_{\perp} = \frac{\sigma^{\downarrow\leftarrow} - \sigma^{\uparrow\leftarrow}}{\sigma^{\downarrow\leftarrow} + \sigma^{\uparrow\leftarrow}}$

The other factors are:

$D = \frac{1-\epsilon E'/E}{1+\epsilon R}$

$d = D\sqrt{\frac{2\epsilon}{1+\epsilon}}$

$\eta = \frac{\epsilon\sqrt{Q^2}}{E-\epsilon E'}$

$\epsilon = \frac{1}{1+2(1+\gamma^2)tan^2(\theta/2)}$

$Q^2 = -q^2 = 2EE'(1-cos\theta)$

$x = \frac{Q^2}{2M\nu}$

$R = \frac{1+\gamma^2}{2x}\frac{F_2}{F_1} - 1$ where the F_i are the unpolarized structure functions of the neutron.

2.3 Statistical errors

The statistical error on the asymmetries are thus:

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

we get the statistical error $\Delta A \|$ from the relation:

$\Delta A_{\parallel} = \sqrt{\frac{1-A_{\parallel}^2}{N_{\parallel}}} \simeq \frac{1}{\sqrt{N_{\parallel}}}$ where $N_{\parallel}$ is the number of scattered electrons when the beam polarization is parallele or antiparallele to the target polarization.

The asymmetry is expected to be small ($A_1 \simeq 10^{-3}$) we have:

$rate_{\perp} \simeq rate_{\parallel} = rate$

The number of events N is:

$N = rate \times t \times bin$

where the rate is given by a simulation, t is the time spent on the configuration (parallel, antiparallel or transverse) and *bin* is the energy difference between two calculated rates in the simulation. The total rate for one setting is the sum off each bin over one setting. The number of bins is given by $(\frac{\Delta P}{P} P_{setting})/(bin)$ where $\frac{\Delta P}{P}$ is the spectrometer momentum acceptance.

[1]This not true for E94010 because of some constraints. See subsection 2.5. However the structure of the codes remains the same and we will begin with this simple case.

2.4 Optimization

The experiment, at fixed energy and scattered angle has different spectrometer magnet settings. For each setting we will do two runs to get $A_\parallel$ and $A_\perp$. In order to minimize the statistical error on the asymmetry A_1 we have to share properly the time between the two runs.

If we write the error on asymmetry as following:
$\Delta A_1^2 = \alpha^2 \Delta A_\parallel^2 + \beta^2 \Delta A_\perp^2$
derivating with respect of $N_\parallel$ and minimizing yield the minimizing condition:
$t_\parallel = \frac{\alpha}{\beta} t_\perp$

Where $t_\parallel$ is the time spent on the "longitudinal" run and $t_\perp$ the time for the "transverse" run.

We have two options in the code (oprun.f or transoprun.f) providing the optimized times. The first option gives the time to spend on each run to achieve a given error. The second option provides, given a specific time, the way to share it to minimize the error. We add the constraint that all the run times should be greater than 30 min. We will come back later on the use of the different codes.

2.5 Modified expression of the asymmetries

The accelerator will not provide a purely longitudinal beam polarization. It will have a transverse component that complicates the asymmetry formula (cf. ref [1] and [7]). The formula expression remains the same however defined with new variables:
$A_1' = \frac{1}{D'(1+\eta'\xi')} A_\parallel^{JLab} - \frac{\eta'}{d'(1+n'\xi')} A_\perp^{JLab}$
where the new variables are defined in [1].

The code transoprun.f gives the optimized run plan using these variable.

The angle between the incident electron elicity and its momentum is given by the accelerator people.

2.6 Data acquisition limitation

The limiting rate for Hall A data acquisition is 2 kHz. We have taken this constraint into account in oprun.f. However the experimental rates are below this limit.

3 Tasks

In order to run an experiment one has to spend time on several tasks. They are listed below with their estimated time.

3.1 Runs

We have to perform two runs (longitudinal and transverse) for each setting.

- We have also to do reference cell runs to see the effects of the cell windows. We assume one hour for these runs and one reference cell run for each different angle and energy.

- Some false events are due to the $\gamma \rightarrow e^+e^-$ photoconversion.The simulation, provided by the code positron.f (Jian-Ping Chen), shows that, in the worst case (E=4.008 GeV, E_p=3.400 GeV, θ=35^0) the e^+/e^- ratio is 0.6 %. This implies we do not need to schedule positron runs.

- Some elastic runs will be done in order to check the spectrometer acceptance. These runs will be done at 1.719 GeV, 15.5^0. The elastic cross section for ^{3}He is 6.87497 10^{-2} microbarns/sr.

3.2 Momentum changes

For each angle and energy we want to get the asymmetry on a wide kinematics range. Therefore we have to change the magnet setting in the two spectrometers. We have assumed 30 min for each momentum change (both arm are changed in the same time).

We have also to change the settings and to reverse the magnet polarity to do the e^+e^- runs.

3.3 Angle changes

30 min was assumed for the spectrometers angle changes. We plan to begin the experiement at 15^o to avoid time loss .

3.4 BCM calibrations

We will perform absolut cross section measurements and thus we need to know precisely the beam current. We can assume 20 min for each BCM calibration. We can also try to avoid this time loss by proceeding during magnet setting changes or angle changes if there is nobody in the Hall. A BCM calibration will be done each 24 hours.

3.5 Moller Commissioning

A commissioning of the Moller polarimeter will be done at the beginning of the experiment (4-8 hours).

3.6 Moller measurement

A beam polarization measurement will be done at each begining and end of a new energy (1/2 hours).

3.7 Target polarization change

We estimate to 15 min maximum the time needed to switch from the parallel target polarization to the perpendicular one (and *vice versa*).

4 Electron scattering and π^- electroproduction rates, R factor and dilution factor

4.1 epc and qfs codes

The counting rates are computed using some modified codes qfs.f and epc.f from ref [2]. epc.f provides the cross-section for an electron scattered on a nucleus (here a ^{3}He nucleus). The kinematic region is from the quasi elastic peak to the deep inelastic scattering region. qfs.f gives the electroproduction of a particle (here a π^-) on the same kinematic region.

The epc derivated codes are used to modelize the experimental counting rates and the dilution factor f. The qfs derivated codes are used to compute the π^- backround to allow the computation of false events triggered by δ-electrons ref [3].

The variable R is given by the code R1990.f from SLAC [4].

The codes were checked by hands or by comparison to Zein-Eddine Meziani codes.

4.2 Input file

All the codes share the same input file, called "input". It is important to know the structure of this file since we could modify it for each run plan modification. In this file **all the energies should be in MeV and the angles in degree.** A typical input line is:

1 2. 1 PI- 4008. 1845. 1999. 20. 15. 1922. 80. 6.2574 6.2574 2009. 2163. 10.

The meaning is the following:

- Kinematic number (arbitrary)
- N of the scattering nucleus (1)
- Z of the scattering nucleus (2)
- electroproduced particle (PI-)
- incoming electron energy
- outgoing electron lower energy
- outgoing electron higher energy
- bin width

- scattering angle
- outgoing electron energy
- fermi momentum (80 MeV)
- nucleon separation energy (6.2574 MeV)
- delta separation energy (6.2574 MeV)
- lower virtual photon energy
- higher virtual photon energy
- beam current.

The code generating this file is named table.f. It gives only a draft of the input file and one has to add the desired corrections by hand. The kinematic domain covered begins at a chosen value from the elastic peak. 17 settings are computed covering all the kinematic regions. One has to remove the unwanted settings or shifts some of them.

The angle between the incoming electron momentun and its helicity is provided by the accelerator (see subsection 2.5).

5 Parameters

We use the following assumptions for the asymmetry computation:

- The target polarization is 40 %
- The beam polarization is 70 %
- The dilution factor is 0.25
- The accelerator efficiency will be assumed to be 50 %
- the HRS acceptance is taken at ±4.0 %
- the HRS angular acceptance is 3.9 mSr. This correspond to the acceptance when the collimator is **in**. (for collimator out the acceptance is 5.3)
- the nucleon and delta energy separation are 6.3 MeV (ref [5])
- the Helium 3 fermi momentum is 80 MeV
- the target thickness is $8{\times}10^{-21}$ cm^{-2} for 40 cm lengh. The lengh seen by the spectrometer at 90^0 is 10 cm.

6 Electrons-positrons runs

The code positron.f, written by J-P Chen, computes the electron production rate from the reaction $\pi^0 \rightarrow \gamma\gamma \rightarrow e^+e^-$ [6]. The e^- producted providing false events. If this rate is significant it will be done some runs with the hadron arm magnets in "hadron" configuration to measure the e^+ rate (thus the e^- rate).

7 Manual to get an optimized run plan

The steps one has to follow to get a optimized run plan are listed below. All the files are in the directory ~deurpam/runplan. **For HP machines, the codes have to be compiled with the -K option.**

- generate a input file ("named input") by running the code table.f
- modify by hand the file by removing the last unwanted magnet settings
- open PAW or PAW++
- run domain.f to get a plot of the kinematic domain covered by the settings. The horizontal axis is the bjorken variable x_{bj} while the vertical is Q^2.
- run the kumac domain.kumac to plot the result of domain.f
- run epc_count.f to get the π^- rates
- run qfsrad_count.f to get the electron rates. It provides the files for the kumacs.
- run the kumac kineα.kumac with α going from 1 to 9. (If we have more than 9 kinematics one has to create more kumacs and to modify the epc qfs codes). The kumac should give the plot of the pions and electron rates and the different kinematic domains covered by each magnet settings (the horizontal solid black lines)
- print the results of the kumac runs using print.kumac. It generates a printing file called print.ps. Use them to remove some of the settings when the rate is smooth in order to gain time
- generate an input file again and rerun epc_count.f , qfsrad_count.f and the kumacs
- run qfsrad2_count.f to get input file for oprun.f or transoprun.f
- run oprun.f to get the optimized run times (file oprun.dat). The file set.dat is also generated and contains the description, in term of kinematic variables, of each setting. If you want the optimized run plan in the case of a non purely longitudinal beam polarization (see subsection 2.5) skip this step for the next one

- run transoprun.f to get the optimized run plan in the case of a non purely longitudinal beam polarization (gives the file transoprun.dat). The output file transet.dat contains the description, in term of kinematic variables, of each setting

If one wants to compute the electron-positron counting rate one has to follow the steps:

- run pi0.f to get the input files (inpos.dat and pi0xα.inp where α is the kinematic number) for positron.f
- run positron.f to have the positron counting rate. The output files are posα.dat and poswα.dat
- run the kumac positron.kumac to have the results plotted

8 Codes and kumacs

the following section lists the codes and kumacs availables in the ˜deurpam/runplan directory and their purpose.

curset.f gives the fields to set in the HRSs dipoles and the currents to set in the quadrupoles. The results are stored in the file curset.dat. The code takes care of the case that the hadron arm cannot run up to $E_p = 3$ GeV.

domain.f computes the kinematic domain of the experiment. it Uses the file "input" as an input and returns the files qdomain.dat and xdomain.dat.

domain.kumac plot the files qdomain.dat versus xdomain.dat

elastic.f. Computes the virtual photon energy for elastic scattering.

epc_count.f gives the π^-counting rates. There is an option to average the rate on the spectrometer acceptance. The kumac kineα.kumac plot the results (one could have to change the plot scale and the title of the kumac).

epc_e94010.f gives the π^- cross sections. The kumacs kineα.kumac plot the results (one has to change the plot scale and choose the cross section plotting option of the kumacs).

f.kumac Plot the dilution factor

kineα.kumac (α is the kinematic number) plots the result of the epc and qfs codes.

oprun.f gives the way to share the time between the longitudinal and transverse runs. the beam polarization has to be purely longitudinal. The minimum time for a run is 30 min. the output file is oprun.dat. Generates another file (tps.dat) containing the time we have to spend on each bins in order to compute the error bars on each bins.

positron.f gives the electron-positron counting rate.

positron.kumac plots the result of positron.f

qfs_e94010.f gives the scattering electron-helium cross sections without radiative corrections.

qfsrad_e94010.f gives the electron-helium cross sections with radiative corrections. One has to compile it on SUN.

qfsrad_count.f gives the electron counting rates with radiative corrections. One has to use it on SUN.

qfsrad2_count.f gives the input file for oprun.f and transoprun.f . One has to use it on SUN.

randf.f gives the R and f factors. *(not working yet for $Q^2 < 0.3$ GeV^2)*

transoprun.f gives the way to share the time between the longitudinal and transverse runs. the beam polarization could have a transvers component.

varkin.f computes W^2, x, ν and Q^2 knowing the incoming and outcoming electron energy and the scattering angle.

Note. The codes are working for a maximun of ten differents kinematics. One has to modify them if one want to run them for more.

9 Run plan

9.1 oprun.dat

the file oprun.dat presents the run plan as below. The kinematic variable values for each magnet setting can be found in the file set.dat.

Inputs: bin= 0.0200 GeV. Target pol.= 0.4 beam pol.= 0.7 dilution factor = 0.2

moller comissioning 8 hours
BCM calibration (20 min) each 24 hours -> 21.3 hours
Target pol meas (15 min) each shift -> 53.25 hours
Ref cell run 1 hour each energy change -> 4 hours

E	Q^2	rate	dA1	Tpar	Tperp	Ttot	Npar	Nperp
1.044	0.070	2000.0	0.011	1.2	0.5	1.7	8837819.	3600000.
1.044	0.064	1004.5	0.030	0.6	0.6	1.2	2258630.	2004507.
1.044	0.060	1054.7	0.030	0.6	0.5	1.1	2240310.	1898375.
1.044	0.055	1213.7	0.024	0.7	0.5	1.2	3076275.	2184658.
1.044	0.051	952.8	0.023	0.8	0.5	1.3	2889720.	1714958.
1.044	0.047	887.8	0.021	1.0	0.5	1.5	3167184.	1598007.
1.044	0.043	682.6	0.020	1.1	0.5	1.6	2814155.	1228768.

1.044	0.040	547.4	0.020	1.3	0.5	1.8	2568634.	985273.
1.044	0.037	475.3	0.019	1.5	0.5	2.0	2506615.	855585.
1.044	0.034	222.9	0.025	1.6	0.5	2.1	1307681.	401291.
1.044	0.031	214.9	0.023	1.8	0.5	2.3	1390176.	386861.
1.044	0.029	215.1	0.021	2.0	0.5	2.5	1523534.	387188.
1.044	0.027	220.9	0.019	2.1	0.5	2.6	1702794.	397562.
1.044	0.025	228.9	0.017	2.3	0.5	2.8	1910865.	411951.
1.044	0.023	236.1	0.016	2.5	0.5	3.0	2125986.	425021.
1.044	0.021	241.7	0.014	2.7	0.5	3.2	2337856.	435107.
1.044	0.019	246.9	0.013	2.9	0.5	3.4	2557719.	444482.

angle 15 degree
momentum change 8.5 hours
angle change 0.5 hours
moller measurment 1 hour
total time is 35.4 hours, tot. par. time: 26.8 tot. perp. time: 8.6

E	Q^2	rate	dA1	Tpar	Tperp	Ttot	Npar	Nperp
1.044	0.188	575.0	0.009	2.2	0.5	2.7	4559991.	1034928.
1.044	0.173	128.6	0.030	1.7	0.9	2.6	795444.	400176.
1.044	0.160	79.6	0.030	3.2	2.2	5.4	926008.	624691.
1.044	0.148	105.9	0.030	2.4	1.8	4.2	933591.	667316.
1.044	0.136	93.1	0.030	2.7	1.9	4.6	906460.	621927.
1.044	0.126	110.0	0.030	2.2	1.4	3.6	865613.	548890.
1.044	0.116	92.1	0.030	2.5	1.4	3.9	818458.	473660.
1.044	0.107	72.6	0.030	2.9	1.6	4.5	769623.	405619.
1.044	0.099	61.7	0.030	3.3	1.6	4.8	722050.	347261.
1.044	0.091	28.7	0.030	6.6	2.9	9.5	677368.	298326.
1.044	0.084	27.5	0.030	6.4	2.6	9.0	636518.	257826.
1.044	0.078	27.8	0.030	6.0	2.2	8.2	599524.	224207.
1.044	0.072	28.9	0.030	5.4	1.9	7.3	566413.	196331.
1.044	0.066	30.5	0.030	4.9	1.6	6.5	536817.	173034.
1.044	0.061	32.0	0.030	4.4	1.3	5.8	510495.	153507.
1.044	0.057	32.9	0.030	4.1	1.2	5.3	487166.	137079.
1.044	0.052	33.5	0.030	3.9	1.0	4.9	466265.	123024.

angle 25 degree
momentum change 8.5 hours
angle change 0.5 hours
moller measurment 1 hour
total time is 92.7 hours, tot. par. time: 64.9 tot. perp. time: 27.8

E	Q^2	rate	dA1	Tpar	Tperp	Ttot	Npar	Nperp
2.032	0.263	2000.0	0.013	1.1	0.5	1.6	7616996.	3600000.
2.032	0.242	506.2	0.030	1.2	1.1	2.3	2230724.	2001713.
2.032	0.224	784.8	0.030	0.8	0.6	1.4	2130023.	1779934.
2.032	0.207	521.6	0.030	1.0	0.7	1.7	1910446.	1334568.
2.032	0.191	371.1	0.030	1.2	0.7	2.0	1660447.	970515.
2.032	0.176	387.9	0.030	1.0	0.5	1.5	1431129.	712225.
2.032	0.163	303.5	0.030	1.2	0.5	1.7	1266662.	546323.

2.032	0.150	256.6	0.028	1.3	0.5	1.8	1216995.	461841.
2.032	0.138	179.4	0.030	1.5	0.5	2.0	955655.	322995.
2.032	0.118	169.3	0.025	1.8	0.5	2.3	1104420.	304760.
2.032	0.101	102.5	0.027	2.2	0.5	2.7	796146.	184516.
2.032	0.086	99.8	0.024	2.5	0.5	3.0	904652.	179678.
2.032	0.073	102.9	0.020	2.9	0.5	3.4	1072407.	185288.

angle 15 degree
momentum change 6.5 hours
angle change 0.5 hours
moller measurment 1 hour
total time is 27.3 hours, tot. par. time: 19.7 tot. perp. time: 7.7

E	Q^2	rate	dA1	Tpar	Tperp	Ttot	Npar	Nperp
2.032	0.671	25.8	0.030	7.7	3.4	11.1	718589.	312493.
2.032	0.619	35.8	0.030	7.0	4.5	11.6	905984.	583574.
2.032	0.572	25.7	0.030	10.0	7.2	17.2	928181.	662243.
2.032	0.528	31.1	0.030	8.1	5.6	13.7	902296.	629069.
2.032	0.487	23.4	0.030	10.2	6.6	16.8	859990.	557741.
2.032	0.450	20.7	0.030	10.9	6.5	17.4	810912.	480879.
2.032	0.415	25.8	0.030	8.2	4.4	12.6	760481.	410707.
2.032	0.383	24.7	0.030	8.0	3.9	12.0	711974.	350641.
2.032	0.354	17.7	0.030	10.5	4.7	15.2	667060.	300578.
2.032	0.326	18.3	0.030	9.5	3.9	13.5	626388.	259266.
2.032	0.301	18.7	0.030	8.8	3.3	12.1	590086.	225291.
2.032	0.278	12.2	0.030	12.7	4.5	17.2	557787.	197176.
2.032	0.257	11.8	0.030	12.4	4.1	16.5	529146.	173804.
2.032	0.237	11.7	0.030	12.0	3.7	15.7	503724.	154225.
2.032	0.219	11.7	0.030	11.4	3.3	14.7	481183.	137742.
2.032	0.202	11.9	0.030	10.8	2.9	13.6	461074.	123707.
2.032	0.186	6.1	0.030	20.3	5.1	25.5	443123.	111691.

angle 25 degree
momentum change 8.5 hours
angle change 0.5 hours
moller measurment 1 hour
total time is 256.2 hours, tot. par. time: 178.6 tot. perp. time: 77.7

E	Q^2	rate	dA1	Tpar	Tperp	Ttot	Npar	Nperp
3.020	0.574	1153.1	0.020	0.9	0.5	1.4	3694084.	2075658.
3.020	0.530	689.2	0.030	0.9	0.8	1.7	2220710.	2008780.
3.020	0.489	945.4	0.030	0.6	0.5	1.1	2088920.	1709776.
3.020	0.452	646.2	0.030	0.8	0.5	1.3	1854175.	1265518.
3.020	0.417	776.5	0.024	0.9	0.5	1.4	2442865.	1397724.
3.020	0.385	606.1	0.024	1.0	0.5	1.5	2233925.	1091016.
3.020	0.355	510.7	0.022	1.2	0.5	1.7	2167605.	919342.
3.020	0.328	452.0	0.021	1.3	0.5	1.8	2176890.	813666.
3.020	0.280	332.1	0.019	1.7	0.5	2.2	1990631.	597808.
3.020	0.238	254.0	0.018	2.0	0.5	2.5	1833277.	457250.
3.020	0.203	189.6	0.018	2.4	0.5	2.9	1609692.	341300.

3.020	0.173	195.1	0.016	2.7	0.5	3.2	1915803.	351222.

angle 15 degree
momentum change 6.0 hours
angle change 0.5 hours
moller measurment 1 hour
total time is 22.7 hours, tot. par. time: 16.4 tot. perp. time: 6.4

E	Q^2	rate	dA1	Tpar	Tperp	Ttot	Npar	Nperp
3.020	1.367	8.1	0.034	24.3	15.7	40.0	704673.	454584.
3.020	1.262	16.6	0.035	11.7	8.3	20.0	697675.	497854.
3.020	1.165	22.6	0.031	10.6	7.4	18.0	861484.	600392.
3.020	1.075	22.3	0.030	10.6	6.9	17.5	853567.	553248.
3.020	0.993	34.8	0.030	6.3	3.7	10.0	786563.	466153.
3.020	0.916	32.8	0.030	6.5	3.5	10.0	767630.	414274.
3.020	0.846	30.9	0.031	6.0	3.0	9.0	670067.	329768.
3.020	0.781	31.1	0.030	5.9	2.6	8.5	655376.	295104.
3.020	0.721	31.0	0.030	5.7	2.3	8.0	631182.	261094.
3.020	0.614	25.9	0.030	5.9	2.1	8.0	551603.	194874.
3.020	0.523	20.5	0.030	6.5	2.0	8.5	481050.	147211.
3.020	0.446	22.0	0.031	5.5	1.5	7.0	437039.	117200.
3.020	0.380	15.8	0.030	7.3	1.7	9.0	413480.	98060.

angle 25 degree
momentum change 6.5 hours
angle change 0.5 hours
moller measurment 1 hour
total time is 173.5 hours, tot. par. time: 112.8 tot. perp. time: 60.7

E	Q^2	rate	dA1	Tpar	Tperp	Ttot	Npar	Nperp
4.008	0.972	287.2	0.030	2.1	1.7	3.8	2171676.	1786030.
4.008	0.897	301.9	0.030	2.0	1.8	3.8	2168824.	1910532.
4.008	0.828	333.7	0.030	1.6	1.2	2.9	1969294.	1474123.
4.008	0.765	416.9	0.030	1.1	0.7	1.9	1714040.	1068973.
4.008	0.706	393.7	0.030	1.0	0.5	1.6	1470665.	775638.
4.008	0.651	332.0	0.029	1.1	0.5	1.6	1315581.	597564.
4.008	0.601	278.0	0.028	1.3	0.5	1.8	1258825.	500376.
4.008	0.555	269.9	0.025	1.4	0.5	1.9	1378261.	485847.
4.008	0.473	200.6	0.023	1.7	0.5	2.2	1262838.	361086.
4.008	0.403	160.3	0.022	2.1	0.5	2.6	1207132.	288548.
4.008	0.343	162.4	0.019	2.4	0.5	2.9	1432062.	292382.
4.008	0.293	135.3	0.018	2.8	0.5	3.3	1374142.	243465.

angle 15 degree
momentum change 6.0 hours
angle change 0.5 hours
moller measurment 1 hour
total time is 30.3 hours, tot. par. time: 20.8 tot. perp. time: 9.5

E	Q^2	rate	dA1	Tpar	Tperp	Ttot	Npar	Nperp
4.008	2.169	3.0	0.036	58.3	41.7	100.0	637725.	455636.
4.008	2.002	5.0	0.035	35.6	24.4	60.0	646475.	442050.

4.008	1.848	8.0	0.033	24.5	15.5	40.0	708025.	446939.
4.008	1.706	14.3	0.030	15.2	8.8	24.0	785763.	452549.
4.008	1.575	16.6	0.030	12.1	6.4	18.5	725648.	380620.
4.008	1.454	16.2	0.030	11.8	5.7	17.5	688583.	329649.
4.008	1.342	17.5	0.030	10.1	4.4	14.5	636518.	279144.
4.008	1.239	16.1	0.030	10.3	4.2	14.5	598885.	241581.
4.008	1.143	17.1	0.030	9.1	3.4	12.5	560738.	208897.
4.008	0.974	15.7	0.030	9.1	2.9	12.0	512445.	164604.
4.008	0.830	13.7	0.030	9.3	2.6	11.9	458376.	128534.
4.008	0.707	11.3	0.030	10.4	2.6	13.0	423051.	104604.
4.008	0.603	12.6	0.030	8.6	1.9	10.5	389044.	85509.

angle 25 degree
momentum change 6.5 hours
angle change 0.5 hours
moller measurment 1 hour
total time is 348.9 hours, tot. par. time: 224.6 tot. perp. time: 124.3

E	Q^2	rate	dA1	Tpar	Tperp	Ttot	Npar	Nperp
4.008	3.182	0.2	0.069	126.8	73.2	200.0	104810.	60461.
4.008	2.937	0.6	0.068	51.6	28.4	80.0	104602.	57554.
4.008	2.711	1.1	0.051	46.0	24.0	70.0	179043.	93126.
4.008	2.310	2.1	0.046	27.4	12.6	40.0	202822.	93276.
4.008	1.969	2.4	0.047	21.3	8.7	30.0	181796.	73784.
4.008	1.677	2.4	0.049	18.4	6.6	25.0	156943.	56422.
4.008	1.429	2.1	0.049	18.9	6.1	25.0	144534.	46265.
4.008	1.218	2.5	0.049	15.5	4.5	20.0	141266.	40464.
4.008	1.038	1.9	0.048	19.9	5.1	25.0	139158.	35837.
4.008	0.884	2.3	0.048	16.2	3.8	20.0	132942.	30903.

angle 35 degree
momentum change 5.0 hours
angle change 0.5 hours
moller measurment 1 hour
total time is 535.0 Tot. par. time 362.2 tot. perp time is 172.8

total time to switch target pol. : 250.2

total time for the experiment:1684.0

9.2 run summary

energy (GeV)	1.719	4.230	3.020	4.996	1.044	1.044	2.032	2.032	4.996	(3.020)
Angle	15.5	15.5	15.5	15.5	15.5	23	23	15.5	23	23
Spec. Setting	13	11	12	11	15	14	15	12	8	11
Current μA	3	10	10	10	3	10	10	3	10	10
Long. e^- run hours	129.	225.4	93.2	334.5	72.2	75.	109.5	34.8	144.	143.
trans. e^- run	55.	139.6	45.8	209.5	29.8	36.	49.5	16.2	56.	88.
positron run	/	/	/	/	/	/	/	/	/	/
ΔA_1in %	<1.	<1.	<1.	<1.	<1.5	<2.3	<2.4	<2.3	<2.7	<3.
Elastic run	1	1	1	1	1	1	1	1	1	1
Moment. change	6.5	5.5	6	5.5	7.5	7	7.5	6	4	5.5
Angle change	/	/	/	/	.5	/	.5	.5	/	/
Ref cell run 4h										
Moller meas.	1	1	1	1	1	1	1	1	1	1
Moller comm. 8h										
BCM cal. 21h										
Tar. pol. change 40h										
total run (h)	184	365	139	544	102	111	159	51	200	231
total run (day)	7.7	15.2	5.8	22.7	4.25	4.6	6.6	2.1	8.3	9.6

Total time 2255.6 hours (93.4 days)

References

[1] Sebastien Incerti, Enkeleida Lakuriqi and Feng Xiong, E94-010 TN #06 : " The Effect of the Transverse Component of the Electron Beam Polarization on Experimental Asymmetries", 08/21/1998.

[2] Lightbody, O'Connell. Modeling single arm electron scatering and nucleon production from nuclei by GeV electrons. Computers in Physics, May/June 1988.

[3] A.Deur. JLAB technical note 98-028.

[4] L.W.Whitlow, SLAC-Report-357, Ph.D. Thesis, Stanford University, March 1990.

[5] American Institut of Physics Handbook. Mac Graw Hill.

[6] Jian-Ping Chen. The longitudinal and transverse response functions in ^{56}Fe(e,e') at Q^2 near 1 $(GeV/C)^2$. PhD Thesis, University of Virginia. May 1990.

[7] Feng Xiong E94-010 TN #05 : "Spin Transport Effect at TJNAF" 08/18/1998