Spin Dance 2000

Author(s): J. Grames for the Spin Dance 2000 collaboration (grames@jlab.org)

Date Submitted: June 26, 2000

Description of Experiment

A spin dance refers to the series of beam polarization measurements where the only parameter varied is the orientation of the beam polarization. The set of measurements yields the measurable component of the beam polarization at the polarimeter. By modeling and fitting the data, the amplitude of the sinusoid reflects the analyzing power of the polarimeter, and the phase reflects (with respect to another measurement) the precession of the beam polarization.

The purpose of this experiment is to perform a spin dance using the five laboratory polarimeters in a unique configuration to address the following issues:

- simultaneous intercomparison of the five polarimeters using a single test beam
- comparison of spin-based energy measurement with Hall A arc method
- measurement of polarimeter systematics (current intensity dependence, measurement of unpolarized beam, longitudinal versus transverse polarization sensitivity, operation at 5.65 GeV)

Request for Experiment

The beamtime request for the experiment is 6 shifts spanning July 10-11, 2000 during the scheduled facility development period. All equipment for the experiment is baseline laboratory equipment and all technical support is like that for routine operation of the equipment. The usual conduct of operations and safety documents for which baseline equipment of the accelerator and end stations is used is all that is required. No additional laboratory computing support is necessary. The strength in planning this experiment lay in the distributed responsibility for each portion of the required baseline equipment, listed here:

Baseline Equipment	*Contact*
Injector	Charlie Sinclair
Polarized Source	Matt Poelker
Injector Mott	Michael Steigerwald
Hall A Compton	Joe Mitchell
Hall A Moller	Eugene Chudakov
Hall B Moller	Arne Freyberger
Hall C Moller	Howard Fenker
Injector Energy	Reza Kazimi
Hall A Arc Energy	Douglas Higinbotham
Accelerator	Michael Tiefenback

The staff required for the experiment are the Operations crew, injector, and polarimeter support. These have been coordinated and a list of names is given later.

Beam and Accelerator Requirements

High polarization beam (~75%) is required for all portions of the experiment, except in the case where the beam polarization will be modified to be zero for a polarimeter systematics test. The beam current requested is typically low (<20uA), except for the case of the Compton polarimeter which requires higher beam current (~80 uA) because of the relatively smaller cross-section. The energy/pass for the experiment is requested to be at the present value of 1.118 GeV. The accelerator configuration requested is for fifth pass beam delivery to all end stations. There are different beam separation methods available to be both effective and efficient in our approach, and these are discussed in more detail later. In summary, the beam parameters for the planned measurements are outlined here:

Measurement	*Current*	*Energy*	*Polarization*
Injector Energy	<5 uA	<65 MeV	none
Injector Mott	<20 uA	5 MeV	high/none
Hall A Compton	<100 uA	5.65 GeV	high/none
Hall A Moller	<5 uA	5.65 GeV	high/none
Hall B Moller	<10 nA	5.65 GeV	high/none
Hall C Moller	<10 uA	5.65 GeV	high/none
Hall A Arc Energy	<5 uA	5.65 GeV	none

We reiterate that the operation of the devices (targets, cryogenics, high voltage, lasers) are all performed as baseline equipment without any additional considerations.

Description and Use of Baseline Equipment

Polarized Source

The present high polarization photocathode will be used. A re-activation is planned by injector staff for the July maintainence preceding the facility development period to restore the quantum efficiency for both the spin dance and subsequent Physics Program.

Laser System

Only the Hall A diode laser will be used. This ensures that both the laser wavelength, and subsequent beam polarization, destined for each end station is identical. This is a strength of simplicity for this type of measurement which is not often afforded. For one approach the laser will be driven in a DC mode. Overall laser intensity can be adjusted by the use of an attenuator, but beam structure and intensity are determined by the injector chopping apertures.

This method is suitable for delivering lower average beam current (most of the beam is lost at the chopping apertures). A strength of this method is that there is no time dependence of the beam polarization. In the second approach the laser will be driven at 1497 MHz. This improves the gain of the laser and concentrates the beam current within the acceptance of the chopping apertures, providing for the higher beam current intensities required by the Compton polarimeter. Switching the laser rf between DC and 1497 MHz is accomplished by a software control.

Helicity Reversal

The beam helicity reversal will be set for 30 Hz in a pseudo-random mode. Controls for adjusting the reversal rate (to 1 Hz) and mode (regular reversal) are readily accessible.

Depolarizer

An optical element capable of depolarizing the laser beam, and thus the electron beam, will be installed on a remotely controlled insertable actuator during the July maintainence. This device will be used to deliver unpolarized beam without making any changes to the helicity reversal system.

Following the spin dance an access will be required to ensure that this optic cannot be accidentally inserted during the subsequent Physics Program.

Orienting the Beam Polarization

The beam polarization orientation will be set by the Wien filter following the polarized source. This device can orient the beam polarization in excess of +/- 100 degrees about the nominal longitudinal polarization direction. Software for control of the Wien filter and beam transport at this device are part of standard operations.

Energy/Pass

To reiterate, no change in beam energy is required for this experiment.

Injector Energy Measurement

The injector beam energy will be measured by use of the “45 MeV injector spectrometer method” (“45 MeV” does not refer to the energy of the beam, but the historical name for the spectrometer magnet). Measurement of the injector beam energy is important in the analysis and for determining the uncertainty of the spin-based energy measurements. The measurement has an uncertainty of 7e-4. A final beam test plan (conducted by injector personnel during the July maintainence period) is planned and a procedure will be ready prior to the spin dance. The expert for this system (Reza Kazimi) will perform the measurement.

Accelerator Configuration

The accelerator configuration will be fifth pass. Beam will either be transported to the injector Mott polarimeter or to the end stations. Because higher average current (~80uA) at fifth pass is required for the Compton polarimeter beam loading effects were considered as a possible source for increased linac cavity trip rates. However, we have demonstrated operation of the accelerator at 105 uA at fourth pass for Hall A Physics at this same energy, which is equivalent to the demand of ~85 uA required at fifth pass for the spin dance request. Further, the 6

GeV setup for August, 2000 includes increasing the available power (HPA tap setpoints) to each linac by ~200kW. The setpoints for the NL are scheduled for an increase during the July maintainence prior to the spin dance benefiting us the additional *headroom*.

Beam Extraction

Three types are needed. 1. Beam extraction to the Mott polarimeter is performed by automatic software control. 2. Beam extraction to the end station Moller polarimeters will be performed by three hall rf separation. 3. Beam extraction for the Compton polarimeter requires that at least two of the three electron bunches (A, B, C) reach the Hall A end station to maintain the higher average current (~80uA). The simplest technique is to use magnetic dipole extraction which diverts all three bunches to the end station for measurement (the current intensity is adjusted at the injector). Another approach is to use rf separation to extract two bunches to Hall A and one bunch to Hall C. At issue is whether there is enough rf separator power available for this mode of extraction, which will be determined prior to the spin dance. All methods are standard extraction techniques for Operations.

Injector Mott Polarimeter

The polarimeter is ready. Software controls are in place to transport the beam quickly between the accelerator and the polarimeter. On-line analysis software is ready. A testplan to calibrate the Wien filter against the Mott polarimeter is planned by injector personnel during the July maintainence prior to the spin dance.

Staff to execute: Michael Steigerwald, Reza Kazimi, Joe Grames

Hall A Compton Polarimeter

The polarimeter is ready. Setup of the polarimeter with a low background signal is an important factor. Arun Saha, Mike Spata, and Ron Lauze are documenting the most effective method for the Compton polarimeter setup and will pass this information to the Operations crew prior to the spin dance in the form of a procedure.

Staff to execute: Joe Mitchell, N*Delta Compton group

Hall A Moller Polarimeter

The polarimeter is ready. On-line analysis software is ready. A preliminary test to check that the polarimeter dipole magnet operates reliably at 5.65 GeV was successful.

Staff to execute: Eugene Chudakov, TBD

Hall B Moller Polarimeter

The polarimeter is ready. On-line analysis software was recently ported to the Hall B Moller computers to provide quick preliminary results.

Staff to execute: Brain Raue (expert), Rakhsha Nasseripour (expert in trainaing), Renee Hutchins, K. Joo, Vipuli Dharmawardane, R. Suleiman

Hall C Moller Polarimeter

The polarimeter is not ready yet. This device is being brought on-line and in parallel with the present Hall C installation. The LHe cryogenic transfer line necessary to cool the superconducting target magnet is an issue, however, it continues to be on schedule for a July 5 cooldown. The polarimeter detectors and target controls have been checked and are ready. Progress is on-going and continues through the July maintainence. Although it is a consuming task to bring the polarimeter on-line for the spin dance it appears to be on schedule. Whether all of the tasks will converge on time is not yet clear. In the event that this polarimeter is not functional by the start of the spin dance the experiment can continue with the four polarimeters. There is some loss of information in the less precise method for extracting the beam energy from the spin precession, however, the intercomparison of the remaining four polarimeters does not suffer, except in that they are not intercompared with the Hall C Moller.

Staff to execute: Beni Zihlmann, Marko Zeier, Sam Danagoulian

Hall A Arc Energy Measurement

The system is ready.

Staff to execute: Douglas Higinbotham

Proposed Run Plan (48 hours)

The experiment contains 5 parts.

1. Setup (3)
2. Polarimeter checkout (8.5)
3. Energy measurements (1.5)
4. Spin dance (33)
5. Unpolarized beam delivery (2)

Setup (3 hours)

This is time required to setup the accelerator or determine setpoints to be used later. Note that moving between setups, once obtained and saved, requires about 15 minutes.

Time	*Task**
0.5 hour	Set initial Wien angle + injector checkout
0.5 hour	Configure for 5th pass
1.0 hour	A_2/C_1 rf or A_3 magnetic separation (TBD)
1.0 hour	$A_1/B_1/C_1$ rf separation

*The notation X_Y means send Y bunches to Hall X.

Polarimeter Checkout (8.5 hours)

The checkout period assumes ~75% beam polarization and attempts to accommodate specific start-up tests and polarimeter systematics measurements requested by each polarimeter group. The task list indicates the Wien and laser rf mode used, the resultant beam polarization given to the end station for the testing, and the tests to be performed. This particular arrangement of tasks accommodates each end station with at least 40% additional time.

Time	*Task*
2.5 hr	**Injector** Wien = -10 deg Laser rf = *OFF* **Hall A Moller (-75%)** 120 min @ 0.1, 0.5, 1, 2 uA current scan **Hall B Moller (+41%)** 40 min @ 2nA for PMT response 60 min @ 1, 2, 3, 4, 5, ... nA for accidentals study 120 min @ max current for target systematics **Hall C Moller (+32%)** Setup Electronics Checkout (1.5 h) Start Quad Scans (1h)
3.0 hr	**Injector** Wien = -65 deg Laser rf = *OFF* **Hall A Compton (-41%)** Setup beam through chicane (max 4 hours) **Hall B Moller (+75%)** Remainder of tests from previous section **Hall C Moller (-37%)** Collimator Setup (1 h) Asymmetry Studies (1 h) Position Sensitivity Studies (1 h)
3.0 hr	**Injector** Wien = +55 deg Laser rf = *OFF, but finally ON for Compton checkout* **Hall A Compton (-34%)** Setup beam through chicane (max 4 hours) **Hall B Moller (-39%)** No beam or more testing? **Hall C Moller (+75%)** Current Scan (1.5 h)

Energy Measurements (1.5 hours)

1 hour is allocated for one Hall A arc energy measurement
30 minutes is allocated for the injector energy measurement.

Spin Dance (33 hours)

A main issue for planning the spin dance is selecting a good set of polarization orientations to adequately describe a sinusoid with good amplitude and phase information from each polarimeter.

The amplitude is best determined by selecting setpoints which orient the beam polarization near the maximum in the asymmetry at the polarimeter (transverse for Mott, longitudinal for Moller and Compton). The phase is best determined by selecting setpoints which orient the beam polarization near the zero of the asymmetry at the polarimeter, where the rate of change of asymmetry with polarization orientation is greatest.

At the proposed energy/pass and accelerator configuration the polarimeters measure the maximum polarization at the following Wien setpoints:

Polarimeter	$Wien_{max}$
Injector Mott	-90 deg
Hall A Compton/Moller	-8 deg
Hall B Moller	-67 deg
Hall C Moller	+55 deg

Their zero crossings are then located at +/- 90 degrees. As can be deduced from this information, and discussed at length in preparing this proposal, is that a fairly broad spacing of Wien setpoints is required to gather all of the desired information.

Two types of setups determined to collect the polarization information are described in the next section. Type II is the most elaborate and collects information for all five polarimeters and requires 4.22 hours per data point. Type III is essentially Type II, but without the Compton polarimeter measurement and required configuration change. Type III reduces the required time to 2.03 hours per data point.

The preference is to select 4 measurements of Type II (4 * 4.22 hours = 16.88 hours) to collect amplitude and phase information for the Compton polarimeter and then 8 measurements of Type III (8 * 2.03 hours = 16.24 hours) to complete the sinusoid for the remaining polarimeters. The total time requested for the spin dance is therefore 33.12 hours.

Description of Type I, II, and III for Determining Wien Setpoints

The most effective procedure for obtaining data at many Wien setpoints with different beam delivery configurations (2 or 3 hall) is the one which has the least overhead due to making changes. Additionally, there are two methods for comparing the effect of laser rf on versus off, which are described here:

Type I: The Hall A Moller and Compton are mutually exclusive measurements. The Hall C Moller runs simultaneously with the Compton replacing the need for a second Hall A

Moller run at this Wien setpoint (w/ laser rf on). *Not possible if Hall C Moller is not available*.

Type II: Hall A Moller performed in DC mode and with laser rf on for comparison with Compton polarimeter data. *In any event, the Hall C Moller can also make this comparison too if it is available.*

Type III: The Hall A Compton measurement is excluded and therefore the Compton DAQ time and setup time are unnecessary.

The sequential order for tasks for each type of measurement is shown in the table here:

Task	*Type I (min)*	*Type II (min)*	*Type III (min)*
Wien set + injector setup	15	15	15
Mott setup + measure	30	30	30
Setup $A_1/B_1/C_1$ rf separation	15	15	15
3 Moller measurement w/ laser rf OFF	45	45	45
Setup A_2/C_1 rf separation	15	15	0
Compton + Moller(s) w/ laser rf ON	45	90	0
Wien set + injector setup	15	15	15
Compton + Moller(s) w/ laser rf ON	45	90	0
Setup $A_1/B_1/C_1$ rf separation	15	15	0
3 Moller measurement w/ laser rf OFF	45	45	45
Mott setup + measure	30	30	30
Total	5.25 h	6.75 h	3.25 h
Time per point = Total/2	**2.62 h**	**3.38 h**	**1.62 h**
REALISTIC (25% overhead added)	**3.28 h**	**4.22 h**	**2.03 h**

Unpolarized Beam Delivery (2 hours)

Finally, a period of time will be used to deliver unpolarized beam to the polarimeters for systematic checkout. This period does not necessarily fall last in the program and will be inserted at the most opportune point of the final run plan.

Spin Based Energy Measurement

There are two methods to calculate the beam energy based on the polarization measurements from this experiment. Each has it’s own merit and is useful for comparing with alternative energy measurement techniques.

Technique I: Calculate the beam energy based on the total precession within the accelerator. This total precession is determined by measuring the phase difference between the injector Mott polarimeter and any of the end station polarimeters. At this accelerator configuration the beam polarization precesses nearly 11,000 degrees before reaching Hall A, therefore, the "moment arm" is quite good. However, one then contends with systematic uncertainties associated with the accelerator. The relevant uncertainties are the injector energy, the bend angles of the beam in the recirculation and transport arcs, the equality of the gradient between the NL and SL, and how well the phase can be measured between two polarimeters, given their systematic uncertainties. The result of having "poor", "good", or "great" knowledge of these uncertainties is shown in the following table:

	poor	*good*	*great*
Number of Passes	5	5	5
Mott-Hall A Precession (deg)	11000	11000	11000
Injector Uncertainty (dE/E)	7e-4	7e-4	7e-4
Linac Imbalance (MeV)	18	6	2
Bend Angles (deg)	0.05	0.01	0.002
Phase Advance Resolution (deg)	4	2	1
Beam Energy (dE/E)	1.7e-3	5.9e-4	2.1e-4

There is presently a testplan in place by the Optics group aimed at leveling the linac imbalance, however, whether it will be performed (successfully) prior to the spin dance is uncertain. There is an effort to measure the bend angles of the accelerator (east arc, west arc, transport arc), which can be done at least as well as "good". Obtaining 2 degree resolution between the polarimeters is challenging, however, it is within our reach to do the "good" energy measurement. It may in fact lead to the correct approach to do the "great" energy measurement.

Technique II: Calculate the beam energy based on the difference in precession between two end stations. The merit of this technique is that only the uncertainty in physical constants, the bend angle between two end stations, and how well the phase can be measured between two polarimeters is required. The disadvantage is that the net precession moment arm is only about 962 degrees between Halls A and C for this accelerator configuration, and half of that if the Hall C Moller polarimeter is not functional. For comparison with the above table using relevant values is given for this technique:

	poor	*good*	*great*
Hall A - Hall C Precession (deg)	962	962	962
Bend Angles (deg)	0.05	0.01	0.002
Phase Advance Resolution (deg)	4	2	1
Beam Energy (dE/E)	4e-3	2.1e-3	1.0e-3

So, although the second technique is less precise, it does provide and independent spin-based energy method for comparison with other methods.

Punchlist

Finally, included here is a summary of the tasks and testplans which are in progress:

System	*Priority*	*Task*
Injector Energy	Medium	Procedure required
Injector Energy	High	Beam test during July maint.
Injector Mott	Low	Wien calibration during July maint.
Hall A Compton	High	Procedure required
Hall A Moller	Medium	Shift personnel not yet determined
Accelerator (beam loading)	Low	Increase NL power during July maint.
Accelerator (rf separator)	High	Determines rf or dipole A/C extraction
Hall C Moller	High	LHe cooldown of solenoid magnet
Hall C Moller	High	Beam dump work complete
Hall C Moller	High	Temporary beamline installed
Hall C Moller	High	DAQ + Controls fully operational