

Electron Spin Precession at CEBAF

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Abstract.

The nuclear physics experiments at the Thomas Jefferson National Accelerator Facility often require longitudinally polarized electrons to be simultaneously delivered to three experimental halls. The degree of longitudinal polarization to each hall varies as function of the accelerator settings, making it challenging in certain situations to deliver a high degree of longitudinal polarization to all the halls simultaneously. Normally, the degree of longitudinal polarization the halls receive is optimized by changing the initial spin direction at the beginning of the machine with a Wien filter. Herein, it is shown that it is possible to further improve the degree of longitudinal polarization for multiple experimental halls by redistributing the energy gain of the CEBAF linacs while keeping the total energy gain fixed.

Keywords: Polarized Electron, Spin Precession

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INTRODUCTION

Longitudinally polarized electron beams are produced at Jefferson Lab with a strained superlattice GaAs wafer and a DC photogun [1, 2]. These polarized electrons are required for a large fraction of the Jefferson Lab nuclear physics experiments; but the spin precession from the injector to the experimental halls is complicated by the fact that the accelerator runs with different total energies, different number of passes around the machine for different halls, and even with different bend angles into the various halls. In the past, once a beam energy was established, the only parameter that could be changed to manipulate the spin was the Wien angle at the beginning of the machine [3, 4]. If only one hall required polarization, by adjusting the Wien angle, that hall could receive the full injected longitudinal polarization. The challenge is to provide the highest possible longitudinal polarization simultaneously to multiple halls.

SPIN PRECESSION

In general, the spin precession, $\Delta\phi$, of an electron of fixed energy as it bends through a series of dipole magnets is given by:

$$\Delta\phi = \frac{E}{440.65\text{MeV}} \times \Delta\theta \quad (1)$$

where E is the energy of the electron and $\Delta\theta$ is the bend angle [5]. A simple example of CEBAF spin precession for first pass beam being hypothetically delivered to all three halls is shown in Fig. 1. In this example, the spin direction starts at the injector along the

velocity direction ends in the three end stations with angles of $2\phi + \beta$, 2ϕ , and $2\phi - \beta$ with respect to the velocity direction. For even this simple calculation, two different energies need to be taken into account as the electrons increase in energy for each pass through a linac. In the example, the spin precesses by ϕ to the midpoint of the arc and by then another ϕ as it completes its bend around the arc all with an energy $E_{north\ linac}$; but after passing through the south linac the precession needs to be calculated of an energy of $E_{north\ linac} + E_{south\ linac}$ and a bend angle of 37° , 0° , -37° bend for Hall A, B, or C, respectively. Since Jefferson Lab is a race track accelerator, the energies continue to increase for higher passes. Nevertheless, a simple series of precession calculations are sufficient to calculate the total precession to any given Hall and at given pass. In fact, this relation between the beam energy and the amount of precession has been used to help determine the beam energy at Jefferson Lab [6].

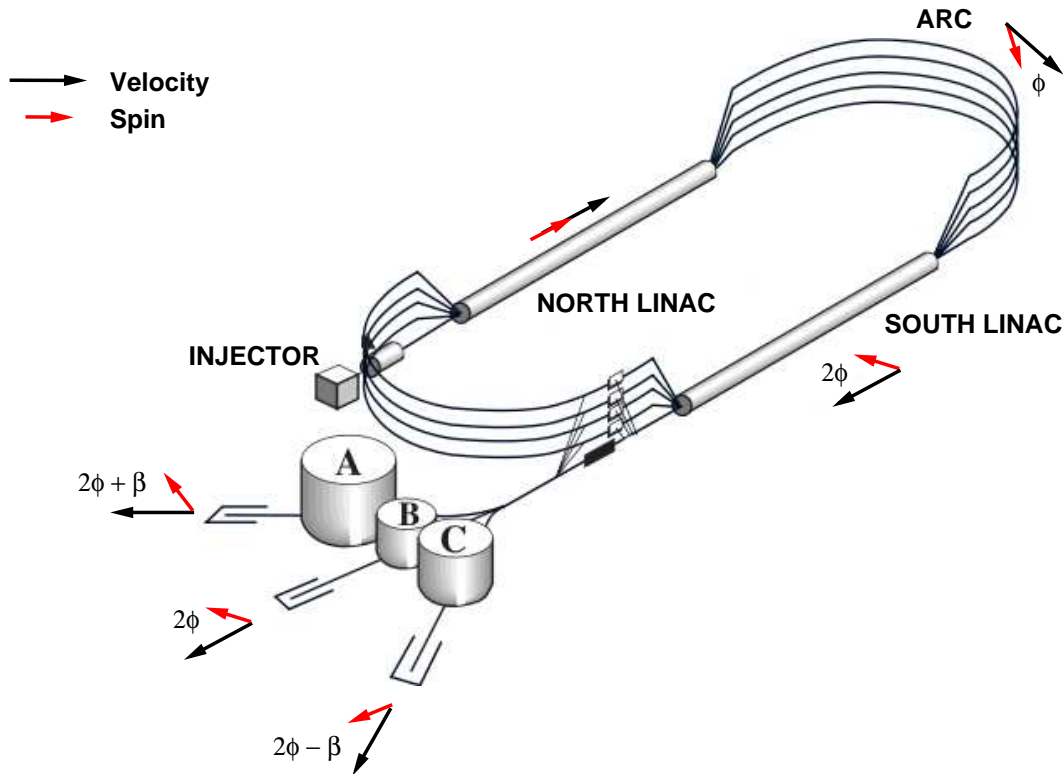


FIGURE 1. Shown is a simple example of spin precession in CEBAF. In this example first pass beam is being sent to all three halls. The velocity and spin directions start out parallel at the injector and continue parallel through the north linac. As the beam passes through the arc, spin precession causes the two vectors to start to point in different directions. By the time the beam has arrived at the three different end stations, the angle between the velocity and spin has taken the values of $2\phi + \beta$, 2ϕ , and $2\phi - \beta$, for Hall A, B, and C, respectively.

LINAC ENERGY IMBALANCING

In the summer of 2008, the CEBAF accelerator was running with only Hall C requiring high longitudinal polarization. The results of Moller measurements done in the halls

during this time along with curves showing the expected degree of longitudinal polarization as a function of Wien angle is shown in Fig. 2. For spin experiments that use only beam polarization, like the one that was running in Hall C, the figure of merit of the experiment is proportional to P^2 , the polarization square.

During the second half of this same run period, both Hall A & C required high polarization while Hall B required that the beam energy stay fixed. In the past, the Wien angle was the only parameter to change; but this would have only provided a P^2 of only 0.8 to Halls A & C and thus effectively caused a 10% reduction in beam time compared to the P^2 of 0.9 they were expecting. By running with imbalanced energy gains in the north and south linacs, the accelerator was able to precess the spin in such a way as to provide a P^2 of 0.9 to both Halls A & C while still maintaining the same total energy. The effect on the spin precession of the imbalancing is shown in Fig. 3 and summarized in Table 1.

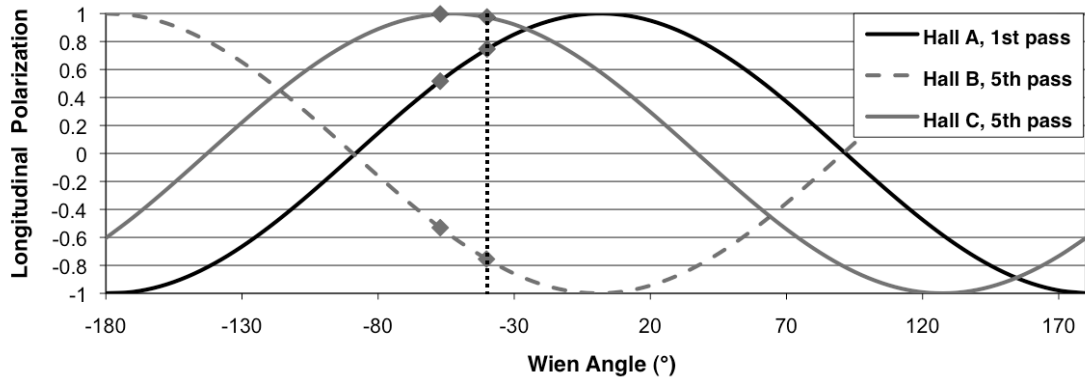


FIGURE 2. Shown is the degree of longitudinal polarization to the end stations for CEBAF setup with the injector set to 63.5 MeV and each of the linacs set to a gain of 565 MeV per pass. The points represent normalized Moller measurements done by the various Halls at different Wien settings. During this run period, in the summer of 2008, Hall C was the only experiment running which required the highest polarization. The dotted line indicates the Wien angle setting of -40° for this run period.

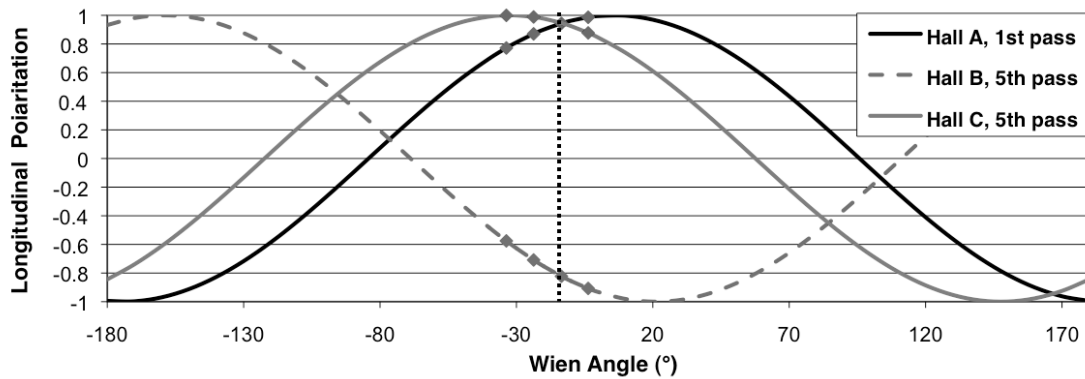


FIGURE 3. By reducing the north linac by 10 MeV and increasing the south linac by 10 MeV, we were able to deliver high polarization to both Hall's A & C for the second half of the summer 2008 run period while not changing the beam energy Hall B was receiving. The points represent normalized Moller measurements done by the various Halls at different Wien settings. The dotted line indicates the Wien angle setting of -13.5° that was used after the linacs were imbalanced.

TABLE 1. Shown are the conditions before and after imbalancing the CEBAF linacs. With Halls A and C both doing polarization transfer experiments, being able to keep both Halls at a polarization squared, P^2 , of 0.9 prevented an effective 10% reduction in beam time.

	Injector	North Linac	South Linac	P^2
Balanced	63.5 MeV	565 MeV	565 MeV	0.8
Unbalanced	63.5 MeV	555 MeV	575 MeV	0.9

Now that this method of optimizing the spin precession for multiple halls by imbalancing the energy gain of the accelerator's north and south linacs has been demonstrated, Jefferson Lab's accelerator division is determining its potential for future experiments. With two degrees of freedom, the Wien angle and linac imbalance, the physics experiments should receive, for the same beam energy, higher longitudinal polarization than was previously achievable.

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REFERENCES

1. C. Hernandez-Garcia, M. L. Stutzman, and P. G. O'Shea, *Phys. Today* **61N2**, 44–49 (2008).
2. C. K. Sinclair, et al., *Phys. Rev. ST Accel. Beams* **10**, 023501 (2007).
3. C. W. Leemann, D. R. Douglas, and G. A. Krafft, *Ann. Rev. Nucl. Part. Sci.* **51**, 413–450 (2001).
4. S. R. Mane, Y. M. Shatunov, and K. Yokoya, *Reports on Progress in Physics* **68**, 1997–2265 (2005).
5. B. W. Montague, *Phys. Rept.* **113**, 1–96 (1984).
6. J. M. Grames, et al., *Phys. Rev. ST Accel. Beams* **7**, 042802 (2004).