Helicity Control Requests from the G^0 Experiment

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August 20, 2001

Abstract

This document describes the helicity control and timing scheme that is desired by the G^0 collaboration for its experimental runs. These conclusions were arrived at by a subset of G^0 collaborators, and they are more fully described in ref. [1]. The first section discusses the two main differences between our proposed scheme and the current one. The second section gives a detailed description of all the signals we need. The third section contains a more detailed justification of why we prefer this new scheme.

1 Main differences between G^0 scheme and current scheme

The G^0 preference for helicity control and timing differs in two significant ways from the current scheme:

1. It generates a fixed integration period (1/30 sec) with continuous phase slip relative to the power line cycle instead of the current "line-locked" scheme.
2. It generates a "quartet" of helicity states instead of the current pairs of helicity states.

These differences are described in more detail below. The impact on (non-parity) experiments in Hall A and B should be minimal. The signals referred to below are diagrammed in Figure 1.

1. Helicity flip timing: Currently the helicity flips occur at the transitions of the "30 Hz clock signal" (the G^0 analogue of this signal will be referred to as MPS - macro-pulse trigger). Currently this signal is generated in a line-locked fashion and the pulse period is $2T_{line}$, where T_{line} is the period of the power line cycle. Experiments currently use some fraction of this period (typically 1 msec out of 33.3 msec) for data readout and to allow time for the Pockels cell to settle. So the actual data-taking interval is shorter than $2T_{line}$, and the cancellation of 60 Hz noise is not as exact as it could be. We propose to lengthen this period to guarantee an interval over which 60 Hz noise will cancel exactly. The signal would consist of a LOW period of length T_{settle} and a HIGH period of length T_{stable}. The T_{settle} interval exists primarily to allow the Pockels cell time to stabilize. It is also the time when experiments read out their data. This time should be adjustable at the polarized source, and

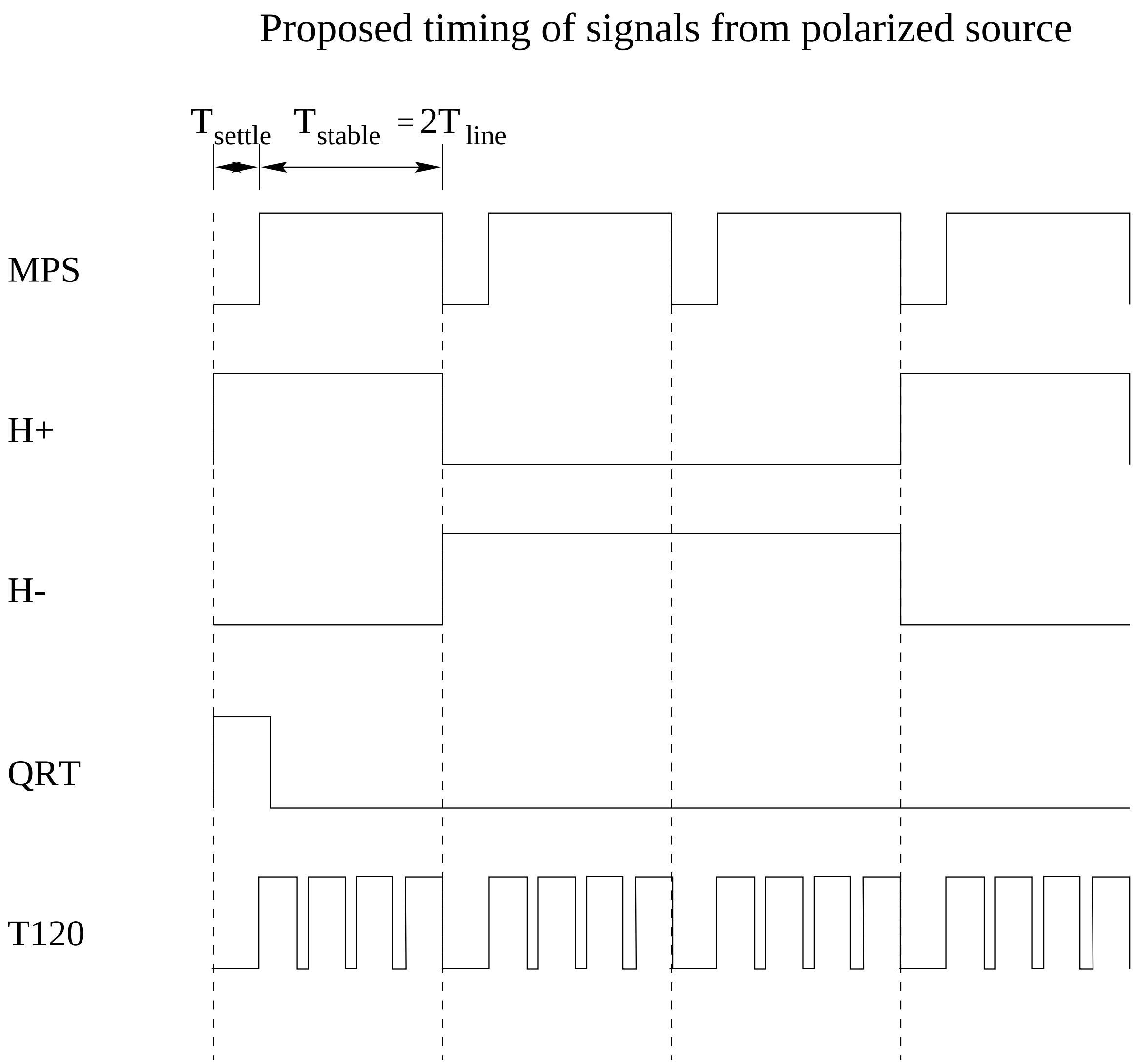

Figure 1: Proposed polarized source signal timing for G0. See text for details.

a typical value of it might be 200 μsec. The T_{stable} interval is the period when the Pockels cell is considered stable, and also the period when the experiments take data (the "integration period"). We desire that **THIS** interval (and not the full interval) be equal to $2T_{line}$. This allows nearly perfect cancellation of the 60 Hz power line noise over the actual data-taking interval, which is not possible in the present scheme. In principle, one could determine the period $2T_{line}$ from two periods of the instantaneous line voltage period. However, this period is relatively stable with typical variations from 16.658 msec to 16.675 msec (1/60 Hz = 16.667 msec). Thus, we believe the simplest thing is to set $2T_{line}$ = 1/30 sec = 33.333 ms exactly by use of a stable quartz oscillator.

We believe this scheme offers the following advantages over the current one:

(a) Nearly exact cancellation of 60 Hz noise over the **data-taking integration**

period

(b) Continuous phase slip relative to the line voltage; this allows all phases of the 60 Hz line to be sampled rather than remaining locked to a single phase as is done currently

These advantages are discussed further in Section 3.

Hall A and B can continue to receive the same clock signal that they always have. It will just come at a slightly different frequency.

2. Helicity signal sequence: Currently the helicity signals are generated in "pairs", with the first one being chosen pseudo-randomly and the next being the complement ($+ -$ or $- +$). We prefer that the helicity be generated in quartets: $+ - - +$ or $- + + -$, where the first member of the quartet is chosen pseudo-randomly. The advantage of the quartet sequence is that it provides exact cancellation of linear drifts over the timescale of the sequence. The pair sequence requires averaging over other pairs for cancellation of linear drifts.

   We also would like for the helicity information to be sent to the counting house building in the "delayed reporting" mode. This has been the routine mode for HAPPEX running, so the halls are equipped to deal with it.

   The impact on the other halls of quartets versus pairs is relatively minor. Halls could still form their asymmetries as pairs, since there are two proper pairs in every quartet. The only modification that may be necessary is for halls that use a "predictor algorithm" in their replay code to predict what the helicity should be (rather than wait the eight cycles to get the delayed information). For quartets, this algorithm would have to be modified since the pseudo-random generation algorithm would be different.

2 Detailed description of G^0 helicity control and timing scheme signals

This section describes each signal that we would like to receive from the polarized source helicity control box. The relative timing of the signals is shown in Figure 1.

1. MPS (macro-pulse trigger): This is the analog to the current "30 Hz clock signal". As described in detail in section 1, we would like this signal to consist of a LOW period of length T_{settle} and a HIGH period of length T_{stable}. The T_{settle} interval should be adjustable at the polarized source, and a typical value of it might be 200 μsec. The T_{stable} interval should be set to be 33.333 ms exactly with a stable quartz oscillator.

2. H+/H-: Helicity state (H+) and its complement (H-). These signals should transition at the instant the Pockels cell is set to a new state. These should be reported to

the experiment in "delayed reporting mode" (delayed by a preset number of 30 Hz pulses) as is done currently. We prefer that the helicity be generated in quartets: + - - + or - + + -, where the first member of a quartet is generated pseudo-randomly.

3. QRT(quartet trigger): This signal defines when a new random sequence of four helicity states has started. The pattern is either + - - + or - + + -.

4. T120: This is a signal at 120 Hz that is generated at 4 times the MPS (30 Hz) frequency. It should subdivide the MPS HIGH period into 4, so that the experiment can take data at 4 times the normal rate. This will be used to measure the 60 Hz noise contribution to the experiment.

3 Justification for the G^0 preferences

The G^0 preference for helicity control and timing differs in two significant ways from the current scheme:

1. It generates a fixed integration period (1/30 sec) with continuous phase slip relative to the power line cycle instead of the current "line-locked" scheme.

2. It generates a "quartet" of helicity states instead of the current pairs of helicity states.

In this section, we discuss what we believe to be the advantages of the above recommendations.

First, we discuss the clock rate. Currently, the clock is generated in a "line-locked" scheme driven by zero-crossings of the 60 Hz power cycle. Most experiments allow some time of this period (about 1 msec) for data-readout and Pockels cell stablization. So about 32.3 msec out of 33.3 msec remains for data-taking. Thus the 60 Hz noise is not exactly canceled over the data-taking interval. Due to the line-locked scheme, all data-taking intervals integrate over the same phase of the line voltage. So, even though the line noise is not canceled exactly over a single data-taking interval, it should cancel when the data is combined in helicity pulse pairs. This is true provided that the 60 Hz noise has no component that is helicity-correlated (see below).

In the scheme G^0 prefers, the data-taking interval is enforced to be exactly 1/30 second in length. Thus, 60 Hz noise is nearly exactly canceled over the data-taking period. Then there is a wait interval (about 200 μsec) for Pockels cell stabilization and data readout. The combination of these two results in a true clock rate of 29.82 Hz. Thus, the phase of this fixed clock will slip continuously with respect to the power line phase. In fact, all phases of the power line will be sampled every eight seconds. We consider this to be an important advantage over the current "line-locked" scheme. While it is certainly likely that the measured experimental asymmetry is independent of the line phase, it is far preferable to have the data to prove it. In the scheme proposed here, any experiment can track their asymmetry versus line phase, provided they implement electronics to detect the phase of the polarized source flip relative to the line frequency.

Summarizing, we see the advantages of this scheme over the current scheme as:

1. This scheme provides for nearly exact cancellation of 60 Hz noise over the duration of a single data-taking interval. The “nearly” comes from the fact that the line frequency can vary from 60 Hz, but those variations are typically at the $\pm 0.05\%$ level.

2. This scheme insures a continuous phase slip of the beginning of the data-taking interval relative to the line frequency. Thus, it provides more information than the current scheme - namely, the ability to check whether or not the experimental asymmetry depends upon the line phase.

It is worth considering how some other labs and experiments have dealt with this issue. Pulsed machines (SLAC at 120 Hz and MIT-Bates at 600 Hz) sample uniformly over the 60 Hz cycle by definition. The most demanding parity violation experiments done to date are the proton-proton experiments done at CW machines. Such experiments at SIN[2] and TRIUMF[3] both chose the technique of fixed integration interval with continuous phase slip. Both of these experiments determine the asymmetry to a level of 2×10^{-8}. This is an order of magnitude smaller than the HAPPEXI and G^0 precision, but comparable to the desired precision of many of the second generation JLAB parity experiments.

We can construct a simple false asymmetry scenario that would be detected in the proposed scheme but missed in the current scheme. Imagine that the Pockels cell positive high voltage supply had a 60 cycle noise component, while the negative power supply had none. The laser beam properties are dependent on the Pockels cell high voltage, and therefore so are the electron beam properties. This could potentially cause some electron beam property to have 60 cycle noise in one helicity state that is different from the other (helicity-correlated 60 Hz noise). If the experimentally detected signal is sensitive to this beam property, then the experiment would pick up a false asymmetry if 60 Hz noise is not being canceled precisely. In the scenario where one continously phase slips, this would be evident as an asymmetry that varies with power line phase, and it would be suppressed when averaging over all phases. In the line-locked scheme, there would not be enough information to catch this false asymmetry and it would not be suppressed since the data is all taken at a fixed phase.

Our second recommendation that is different from the current scheme is the request for helicity sequences in quartets rather than pairs. We would like the helicity sequences to be + - - + or - + + -. The asymmetry would be formed as (1+4)-(2+3). The current scheme defines the helicity sequence in pairs: + - or - +. The advantage of the quartet sequence is that it provides exact cancellation of linear drifts over the timescale of the sequence. The pair sequence requires averaging over other pairs for cancellation.

Finally, we discuss how this affects other users. For the clock signal, other users could be sent a copy of the clock signal that looks the same as the clock signal they get now, except the frequency would be different. So, unless they were relying on that particular frequency, things could remain the same for them. For the helicity information, users could still form their asymmetries in pairs if they choose. The one change is that the predictor algorithms that they use to recover the true helicity from the delayed helicity information would have to be modified.

References

[1] "Report of G^0 120 Hz Task Force," Stephen Pate *et al.*, G^0 Internal Report 99-049, 8-December-1999.

[2] R. Balzer *et al.*, Phys. Rev. C **30**, (1984) 1409.

[3] W.D. Ramsey, private communication