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Requirements for Beam–Synched Signals for G^0

Introduction

The G^0 experiment requires two beam-synched timing signals, which are to be supplied by JLab. These are known as CLK (nominally 499 MHz) and Y_0 (nominally 31.1875 MHz). These are to be used in measuring time-of-flight of protons from the G^0 target to the scintillation detectors. The timing signals are therefore required to be referenced to the time of beam arrival at the target area rather than times related to injection or acceleration.

The Y_0 signal is to be used as a reference by both the French and North American versions of time-encoding electronics instrumenting the G^0 detectors. The CLK is to be used in generating a gated clock pulse train to clock the North American version of the electronics. Since the gate is based on Y_0, stability of the CLK signal relative to Y_0 is essential.

An unacceptable false asymmetry could result from a very small helicity-correlated offset between beam arrival and the Y_0 timing signal. For this reason the Y_0 is to be phase-shifted to reflect the actual beam arrival time with a stabilization time which is comparable to the helicity-reversal time and small compared to the time between helicity reversals.

Specifications

1) The most critical parameter is the helicity-correlated shift in the Y_0 or CLK relative to actual beam arrival. This shift should average to less than 10 fs over the duration of a 40 day run. This sets the limit on sensitivity to helicity-correlated parameters of the beam, which are expected to be limited to the following helicity-correlated shifts:

Current	1 ppm
Position	20 nm
Angle	2 nr
Size	2 μm (shift in unrastered beam size)
Energy	2.5×10^{-8}

2) The Y_0 signal must be phase-matched to the actual beam arrival, not just to a harmonic such as 499 MHz or 1497 MHz. This is to avoid a situation in which the time between

actual beam arrival and Y_0 is subject to discreet jumps, especially after the beam has been off. The box should lock in automatically, without need for human intervention.

3) The integration time used in locking into the beam arrival should not be much greater than ~30μs so the system can track helicity-correlated beam arrival time changes in a time scale which is comparable to the 500 μs helicity-reversal time and much less than the 33 ms period of a helicity macropulse.

4) The jitter of the timing signals is to be less than 100 ps, preferably substantially less.

5) Since timing pulse trains will be made by gating CLK with a gate based on Y_0, it is necessary that the relative timing of these two signals not change by more than 50 ps even if the time of each undergoes a large excursion.

6) The signals should stay accurately synched to the beam even if the beam current is as low as 10 μA, preferably even lower.

7) When the beam intensity is too low to lock-in upon (or the beam is off) the CLK and Y_0 signals should still be generated at or near the nominal frequencies and they should still not have relative timing changes of more that 50 ps with respect to each other. A logic signal from the box should indicate whether it is attempting to synchronize to the beam signal or has gone into 'safe' mode, generating stable signals which are not synched to the beam.

8) Additional signals from the box should indicate the actual value of the phase-shifts which are being used to track beam arrival and the integrated phase difference (error) signal which indicates how much additional phase shift is needed.

9) The Y_0 and CLK signals are to be provided in differential ECL form (to plug into a LEMO hermaphroditic connector type EPL.0S.302.HLN). Both CLK and Y_0 should be 'square waves', meaning that leading edges and trailing edges should be equally spaced and should be reasonably sharp.

10) Long term drift (due to temperature change of cables, etc.) should not cause more than a 0.25 ns shift in the time offset between Y_0 and the signals from the protons striking the G^0 detectors.

11) Extensive testing is needed before beam comes on. The box should be available by mid-June, that the latest, to allow tests to carried out by the collaboration.

Implementation

Point 1 is untested. Sensitivity to position is expected to be minimized by synchronizing to signals derived from the sum of all four strips of a BPM (or 1499 MHz from a BCM cavity?) The task will be simplified if the BCM signal can be made available. An estimated 120 dB of isolation can be provided to avoid affecting the BCM signal going to the experiment.

High gain amplification and clamping of the signal are intended to reduce sensitivity to current variation. We are in the process of analyzing data to see whether an apparent shift in Y_0 time (relative to the master oscillator) as a function of beam current is also reflected in the proton signal. Even if it does not reflect a true change in beam arrival time with beam current, a walk of <1 ns / 40 μA would be within spec.

Point 2 has been successfully achieved by the first version of the box except that a phase offset had to be set manually. Simply extending the range of automatic adjustment of the phase may correct this except that care must be taken that the system cannot get stuck at one extreme of phase adjustment while trying to reach a phase which is almost 360° away, near the other end of the phase adjustment range.

Point 3 has been achieved and exceeded. Increasing the integration time to 30 to 50 μs may give more stable operation at low beam current.

Points 4 and 5 have probably been achieved but were difficult for us to confirm when the signals could not drive our electronics.

Point 6 has been achieved and exceeded. We would be happy to have synchronization for even lower beam current (down to 1 μA) but it is not the highest priority.

For point 7 we discussed the use of digital phase shifts which would allow the phase shift to be held at a safe value when the beam intensity is becoming too low to track. The phase shift would cease to try to track the beam whenever the beam current (or beam monitor signal strength) fell below a pre-determined threshold. This threshold would be set high enough so that the locked values of phase shifts would be reliable values. Ideally the threshold would be remotely adjustable with a known calibration.

The signals in point 8 should be DC levels which can be fed to an ADC (through a high impedance) or into a VCO. The details of which signals are needed should still be finalized.

Point 9 will be achieved by boards being developed by the Jlab electronics group (under Chris Cuevas) which will include front-end amplification of the incoming R.F. signals.

Point 10 remains an open question. Temperature shifts in the heliax cables carrying the R.F. signals from the hall are expected to be negligible, which may not match the behavior of the cables carrying the detector signals.