Preliminary Beam Parameter Specifications for the Qweak Experiment

From: R. Carlini
To: D. Skopik
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This is our response to the request for a preliminary beam parameter specification sheet for the Qweak. We would like feedback on the feasibility of or requirements and also guidance on which items can be better defined from the accelerator perspective. Our preliminary estimate of the beam property requirements are summarized in Table 1. For each beam property, we list requirements in the categories defined below.

Table 1: Preliminary estimate of beam property specifications for Qweak. Definition of the various categories can be found in the text.

Beam Property	Nominal value	Maximum deviation from nominal (DC)	Maximum noise at the helicity reversal frequency	Maximum noise at all other frequencies	Maximum allowed run-averaged helicity-correlation
Energy (average)	1.165 GeV	1×10^{-4}	1×10^{-5}	1×10^{-4}	1×10^{-8}
Energy Spread (1 σ)	$\sigma_E/E < 5 \times 10^{-5}$	$\sigma_E/E < 5 \times 10^{-5}$			
CW average current	180 μA	± 5%	< 70 ppm	< 0.1%	< 0.1 ppm
Position at Qweak target	"0"	± 0.1 mm	± 28 μm	< 100 μm	< 20 nm
Angle at Qweak target	"0"	60 microrad	< 0.3 millirad	< .02 millirad	< 100 nrad
Angular divergence at target	$\sigma_{X'}, \sigma_{y'} < 100 \mu r$	+- 10%			
rms size (unrastered) at target	< 150 μm	± 25%	< 10 μm	< 0.1 mm	< 2.6 μm
Polarization	> 80%				
Beam halo at Qweak target	$< 1 \times 10^{-6}$ outside of 3 mm radius				

Categories:

1. Nominal value: This is the usual desired central value of the beam property.

2. Maximum deviation from nominal (DC): This is how far the DC (averaged over several seconds; ie. EPICS update timescale) central value of the beam property can drift from the nominal value before corrective action is required.

3. Maximum noise at the helicity reversal frequency: Operationally, we integrate the signal from any given beam property over a 33 msec time period. Then we form differences between two successive 33 msec integration periods. The standard deviation of the distribution of those differences is what we refer to as the "noise at the helicity reversal frequency". It needs to be kept small enough so that we can measure helicity-correlated position differences and current asymmetries accurately enough to do feedback.

4. Maximum noise at all other frequencies: This is the upper limit on the random noise in a given beam property at frequencies other than the helicity reversal frequency. (for example, 60 Hz noise and higher harmonics)

5. Maximum allowed run-averaged helicity-correlation: This refers to the maximum value of the helicity-correlated difference (or asymmetry) that can be tolerated in that beam property after averaging over the entire 2000 hour run. This assumes that injector-based helicity-correlated feedback systems will be in place to achieve these values.

<u>Other considerations</u>

1. Basic beam tune: The tune should be achromatic at the target (<1mm/% dispersion) with large enough dispersion (35 mm/%) at the center of the Hall C arc to make an accurate relative energy measurement.

2. Raster pattern: The raster for Qweak is likely to be very similar if not identical to the system developed by Chen Yan for the G^0 experiment. The current specifications call for a square pattern with raster frequencies of fx=25 kHz and fy=25.02 kHz. The maximum length per side of the square is 4 mm.

3. Helicity-defining Pockels cell: The laser arrangement should be set up so that the Hall C beam is on the center of the Pockels cell, and the Pockels cell should be adjusted to provide the maximum possible circular polarization for the Hall C beam.

4. Rotateable half-wave plate: The rotateable half-wave plate should be set to the value that minimizes the Hall C current asymmetry when no other helicity-correlated feedback systems are turned on.

5. Stability of electron beam polarization: As is well known, there have been issues associated with measuring the electron beam polarization at different beam currents. These arise from the way the laser beams are combined and leakage currents from one hall to another. Whether any such issues will exist for the Qweak 499Mhz time structure is unclear at this point. It will be important to assess the situation when we have beam to determine if there is any situation like this that will compromise our experiment's ability to determine the beam polarization with a relative precision of ±1%.

6. Cross-talk with other halls: There are two possible categories of cross-talk of other hall's beams into the Hall C beam:

   a. Current leakage: We want the contribution of the summed beam currents from other hall's beams to be less than 1% of the Hall C beam current.

   b. "Helicity-correlated" leakage: It has been observed during HAPPEX running in 1999 that a helicity-correlated intensity in another hall's beam can induce helicity-correlated energy and position differences in their beam. The exact origin of this was not determined, but the solution is to have helicity-correlated feedback controls on the other hall's lasers. This will need to be done to the extent that it is necessary to satisfy the helicity-correlation specifications in Table 1.

7. Helicity-correlated feedback systems: For helicity-correlated feedback systems at the polarized injector, we prefer that each laser beam have separate helicity-correlated feedback controls. We prefer that devices that are common to all laser beams (the helicity-defining Pockels cell and the rotateable half-wave plate) not have active feedback on them, and they should only occasionally be adjusted while keeping to the guidelines in points 2 and 3.

8. Fast energy and position locks: We would like the fast energy and position lock systems to be in operation for the Hall C beam.

9. Beam position and angle modulation: We will be using air core steering coils in the Hall C beamline upstream of the arc to modulate the beam position and angle at the Qweak target. This type of modulation was done during both HAPPEX runs and is under development for G^0, so the protocols for safety have been thought out before, and we will follow them. The frequency for runs of this type has not yet been determined, but it could be as often as once per hour.

10. Beam energy modulation: This system was in use during HAPPEX (and has been requested during G^0 running) to modulate the beam energy by varying a cavity in the South Linac. This affects the other hall beams, as well, but it was done routinely during HAPPEX running. The frequency for runs of this type has not yet been determined; but it could be as often as once per hour.

Betatron match: While this is still an area of active development, we request that the accelerator tune be “betatron-matched” as well as the current accelerator instrumentation allows. We are interested in this because of the adiabatic damping effect that can suppress helicity-correlated position differences in the experimental hall. Our main diagnostic for this is the comparison between the sizes of helicity-correlated position differences in the experimental hall versus the 5 MeV region of the injector. We will be able to monitor this ratio continuously when we are running. It will be useful to see if there is a correlation between this diagnostic and the accelerator measurements of the Courant-Snyder parameters.

11. Kinematic damping will be needed during Qweak production running to reduce helicity correlated beam position related systematics. More study is needed to quantify our actual requirements. Hopefully, much will be learned from the upcoming HAPPEX and G^0 runs.

Polarized Source Issues for the Qweak Experiment

The Qweak experiment requires high average current with high polarization. Beam polarization has consistently been greater than 70 percent for the past few years at Jlab. Recent modification of photocathode cleaning techniques have produced a modest increase in polarization. Users report beam polarization in the upper 70's. It is anticipated that the Source Group will continue to work to improve polarization with the goal of routinely providing polarization greater than 80 percent. New photocathode samples from Bandwidth Semiconductor (formerly Spire Corporation) and from Prof. Mamaev's group at the State Technical University, St. Petersburg are being tested at the Injector Test Stand at Jlab. Over the next few years, the source group has indicated that they expect to meet their goal of routine delivery of beam with polarization greater than 80 percent. The source group recommends restricting the combined maximum current to other users during Qweak to less than ~50µA. This will keep the total extracted gun current for all users to approximately 350µA, a level not drastically greater than what we have successfully demonstrated (we have extracted ~250 µA for weeks during simultaneous delivery to the Gen experiment in Hall C and Gep experiment in Hall A). It is worth noting that successful delivery of 200µA to Hall C will necessitate a better understanding of beam optics at the injector and possibly, other portions of the accelerator. The most production current delivered to a single user during a physics experiment has been ~140µA.

The dominant Polarized Source issue associated with this requirement is photocathode lifetime. Based on past experience, JLab photo-guns should be able to deliver 200μA average current with 499 MHz pulse repetition rate to Hall C for ~1 week, at which point the photocathode QE will have degraded and the laser spot will need to be moved to a fresh location on the photocathode surface. The laser spot diameter is approximately 0.5mm and the photocathode active area is 5mm. Past experience indicates this provides roughly 5 photocathode locations, therefore we hope to expect ~5 weeks of uninterrupted beam time for Qweak. After delivering beam from all available photocathode locations, subsequent high current operation will require heating and reactivating the photocathode. This process takes ~8 hours and completely restores the photocathode QE. This task can be accomplished during a scheduled accelerator shutdown. Following reactivation, one can expect another 5 weeks of beam delivery. The source group will use a mode locked Ti-Sapphire laser from the vendor TimeBandwidth Products to drive the photocathode. This laser has been ordered, they expect delivery January, 2003. The source group will commission this laser during the Hall A HAPPEX~II experiment Spring, 2003. Should the commercial laser prove unacceptable for use at the photoinjector, a homebuilt mode locked Ti-Sapphire laser can be used for Qweak. A version of the homebuilt laser was used for the high current, high polarization Gen experiment at Hall C. It has since been improved and the source group expects to test it at the photo-injector winter, 2002.

Reduced Duty Factor Modes of Operation Required for Calibration

Specifically, low average current with unpolarized beam. These setups fall into several general categories as discussed below. These running conditions are for periodic calibration runs to DC performed every few weeks and lasting only several shifts. "Parity quality" beam is not required as these are background and Q^2 acceptance measurements.

<u>G0 Beam Microstructure</u>

The existing G0 laser can be made available to provide Qweak with reduced duty factor beam suitable for calibration runs with the following parameters; beam with rf micropulses spaced 32 nsec apart (16th subharmonic of the standard 499 MHz repetition rate, or 31.1875 MHz) and average current from nA's to a few μAs, no beam polarization required. If Qweak must routinely take beam with the G^0 time structure, the Source Group may pursue a diode-laser based system in an effort to save space on the laser table. Diode lasers with 31 MHz pulse repetition rate are low power devices but they may provide nA beam current suitable for this application.

<u>Short Macropulse Mode with rf Microstructure</u>

Qweak will also require a macropulse beam that contains 499 MHz microstructure for routine calibration runs. The beam parameters are; a macropulse duration of approximately 50 to 100 ns with repetition rate variable between 100 kHz and 1 MHz, an average current of a few nA and no polarization requirement. This is a new beam time structure for Jlab and some development is required. The Source Group envisions a gain switched diode laser to create the 499 MHz microstructure and a pulsed DC bias to create this calibration macropulse structure. The Source Group is confident this can be accomplished.

<u>Control of Helicity Correlated Beam Residuals</u>

Control of helicity correlated residuals will be accomplished in a manner similar to that used for the G0 and HAPPEX2 parity violation experiments. Every effort will be made to minimize the free-running beam asymmetries (e.g., properly aligned Pockels cell, rotating half-wave plate downstream of the pockel cell oriented to provide small helicity correlated asymmetries for all Users). Hall C will own and control independent optical elements to provide feedback to minimize helicity correlated charge and position asymmetry (low voltage IA pockel cell for charge asymmetry control and pzt mirror for position asymmetry control).