ESR Compton Polarimeter Requirements

Introduction:

The Compton polarimeter in the electron storage ring (ESR) must be designed to meet the needs of both the accelerator (to provide timely feedback on the beam performance) and the experiment (high precision). In addition, integration of the polarimeter with the accelerator beamline will be crucial to the performance of the device, so points of interface must be clearly documented.

General Requirements:

The Compton Polarimeter must be designed to accomplish the following:

1. Measure the polarization of each electron bunch. This implies that the system (both laser and detectors) must have sufficient time resolution to clearly separate the 10 ns spaced bunches at 5 and 10 GeV. The timing constraints are less stringent at 18 GeV (40 ns). In addition, the measurement time must be shorter than the bunch lifetime in the ring. At 18 GeV, this is about 1 minute.
2. The polarimeter must achieve a combined statistical and systematic uncertainty of 1% or better.
3. The polarimeter must have the capability to measure the longitudinal and transverse components of the polarization. At the planned location of the polarimeter (upstream of IP6), there will be both longitudinal and horizontal components of the polarization. While the vertical component should be zero, it would be prudent to have the ability to measure this directly as well.

Laser Requirements:

1. The laser repetition rate should be the same as the electron beam bunch frequency (i.e. 100 MHz and 25 MHz) to allow easy identification of the sampled electron bunch. The ideal system would be easily configurable for a range of bunch frequencies. In addition, it would be desirable to have the ability to sample one and only one bunch in the ring - this would require a laser repetition rate of about 78 kHz - this frequency is low enough that it could be accomplished with an AOM or other similar device.
2. The preferred wavelength of the laser is 532 nm (green).
3. The pulsewidth should be comparable to the electron beam pulsewidth (~ 20 ps).
4. The laser spot size should be able to be focused to ~100 um to allow sampling of the polarization across the profile of the electron beam. This likely results in the requirement that the laser produce diffraction limited beams (M^2=1) to avoid unduly large laser spot sizes at the vacuum chamber entrance and exit windows.
5. The laser system must provide sufficient power to yield about 1 backscattered photon per bunch crossing. The average power required for this rate is about 5-10 W.
6. The system must include appropriate optics for laser polarization setup and monitoring. Note that making use of the “backreflection” technique required to eliminate uncertainties due to vacuum window birefringence will require a mirror in the vacuum can that can be inserted during laser alignment.

Electron Detector Requirements:

1. The detector time response must be fast enough to allow measurement of the polarization bunch-by-bunch, i.e., <= 10 ns.
2. The detector should be radiation hard. The nominal rate of scattered electrons on the detector is expected to be on the order of 100 MHz. At this rate the expected dose is XX rad/hour.
3. The detector size is dictated by the requirement to detect scattered electrons from the kinematic endpoint to the (longitudinal) asymmetry zero-crossing. This will be largest at 18 GeV and requires a detector covering a span of about 6 cm horizontally. The electrons have a relatively small vertical distribution, so a detector on the order of a few mm in the vertical direction is adequate. (This is based on old layout - needs to be updated)
4. The detector segmentation is driven by the desire to have at least 30 bins when fitting the Compton asymmetry spectrum. The distance between asymmetry zero-crossing and kinematic endpoint is smallest at 5 GeV (12 mm), so a strip pitch of 400 um (in the horizontal direction) is required. (This is based on the old layout - needs to be updated)
5. Since the position of the Compton endpoint and asymmetry zero-crossing change with beam energy, the detector must be remotely movable.

Photon Detector Requirements:

Note that the photon detector consists of two components: A calorimeter to measure the total energy of the backscattered photon, and position sensitive (strip or pad) detectors to measure spatial dependence of the transverse polarization.

1. As with the electron detector, the time response must be fast enough to allow measurement of the polarization bunch-by-bunch, i.e., <= 10 ns.
2. The detector must be at least XX meters from the Compton interaction point to allow measurement of the transverse polarization. (Simple studies I did a while ago suggest that 100 um position resolution is adequate to robustly fit the transverse asymmetry, even allowing the offset to float, at a distance of 25 m).
3. Both the position sensitive detector and calorimeter should be radiation hard. The estimated dose in the calorimeter is ~ 10 Mrad/year, just from the backscattered photons alone.
4. The segmentation of the position sensitive detectors will depend on the distance of the detector from the Compton IP. At 25 m, a detector pitch of 100 um allows robust measurement of the transverse asymmetry. (should be studied/checked)
5. The transverse size of the calorimeter is dictated by the size of the backscattered photon cone at 5 GeV. At 25 m, 4 x 4 cm will contain the backscattered photons. The detector should be at least 20 cm long to effectively determine the photon energy..
6. The longitudinal polarization measurement depends on the calorimeter resolution. Higher resolution allows more precise determination of the low-energy threshold, reducing the systematic uncertainty.
7. A collimator will be required in front of the detector system to help mitigate backgrounds. The size of the collimator will again depend on the detector position.

Key Accelerator Interface Points:

1. Windows will be required to allow the Compton laser to enter and exit the electron beamline. In the present layout, the entrance window will be downstream of Q12_EF5 and the exit window upstream of QF14_EF5. The window will need to be AR coated for the appropriate laser wavelength, and will need to have a diameter of about 1 inch to avoid shape-distorting effects on the laser beam.
2. A mirror that can be moved into and out of the laser path will be required in the electron beam vacuum chamber (needed for polarization setup). The location of this mirror is not critical, but must be able to be aligned from outside the vacuum chamber.
3. The electron beampipe between Q12EF_5 and Q11EF_5 must be large enough to accommodate the full spectrum of the Compton scattered electrons. At 18 GeV, the Compton endpoint will be about 8.5 cm from the nominal electron beam path. (This is based on the old layout - needs to be updated)
4. A Roman pot (with a separate vacuum) will likely be required to protect the electron detector from the wakefield power deposited. Estimates performed as part of eRD15 suggest this could be 500-800 W.
5. The backscattered photons will not fit within the nominal quadrupole apertures for all quads aside from the first after dipole D2EF_5. Space in the vicinity of the quad coils will be required to allow the photons to proceed unimpeded to the photon detector. (It would be nice to specify the location and sizes here)
6. The exit window for the backscattered photons should be designed keeping in mind the large amount of synchrotron radiation at that point. (should specify size and location of window)