Advanced injector – possible specs

Jay Benesch 10 Sept 2015

Physics requirements

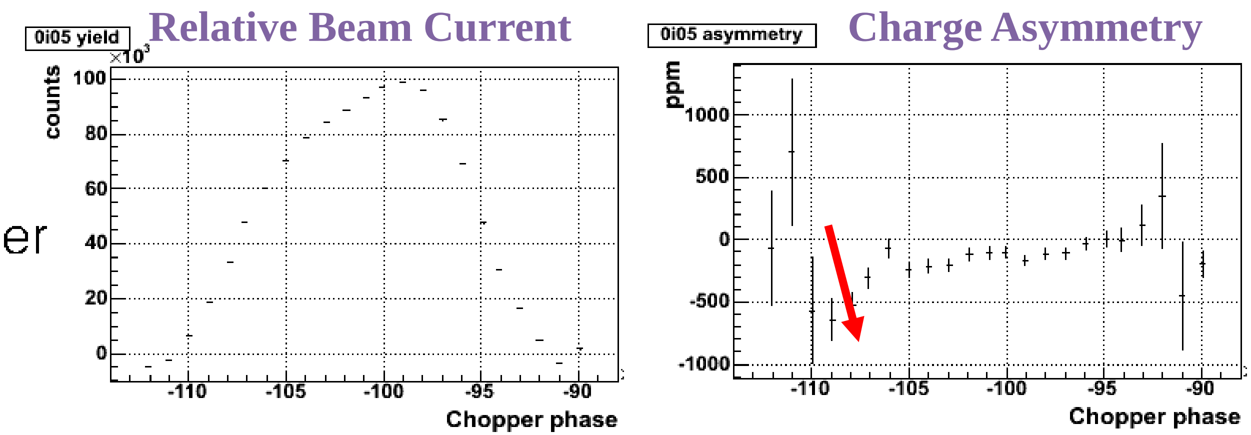
- Parity violating electron scattering (PVES) experiments will be running the majority of the time in hall A
- The most stringent of these is MOLLER. For funding it needs to convince DOE/NSF/etc. that 1.1% systematic error on 28 ppb asymmetry is possible, aka 300 pp trillion. This is more than an order of magnitude tighter than Qweak beam achieved. It is known that helicity correlated (HC) beam property variation and halo with large HC asymmetry start in injector. *(MOLLER technical feasibility review ~May 2016)*
- The FY2016 injector experiment needs 0.1% energy accuracy. This will require a lot of work given environmental magnetic fields. Follow-on experiments with similar requirements are likely if this one provides valuable information.
- Four chopper slits would be nice.

How Could This Happen? (Mark Pitt slide)

Why did the "beam halo" develop helicity-correlated beam properties (charge and position) that were significantly larger than the "core" beam? [PRL 23 ppb]

Study at end of run in injector region: narrow down chopper slits from their usual wide open setting to explore helicity-correlated charge as a function of longitudinal position in the beam bunch.

After chopper



Charge asymmetry is much larger at lagging temporal edge than in core of beam.

Very different helicity-correlated beam properties in the leading/trailing edges of the electron beam bunch can potentially translate into large helicity-correlated beam properties in the beam halo observed in the experimental hall.

Matt Poelker 8/31 email re desirability of parallel injectors

1) we could deliver 100% long polarization to two halls simultaneously because each gun/beamline has wien filters.

2) the parity folks could monitor HC beam properties directly from gun. No other superimposed beams from gun to merger point. This is a big deal: what they see at gun would in principle be directly related to what arrives at hall.

3) apertures at injector are good for non-parity users, they can keep them. Apertures are bad for parity users, the new line could eliminate them, hopefully even the chopper.

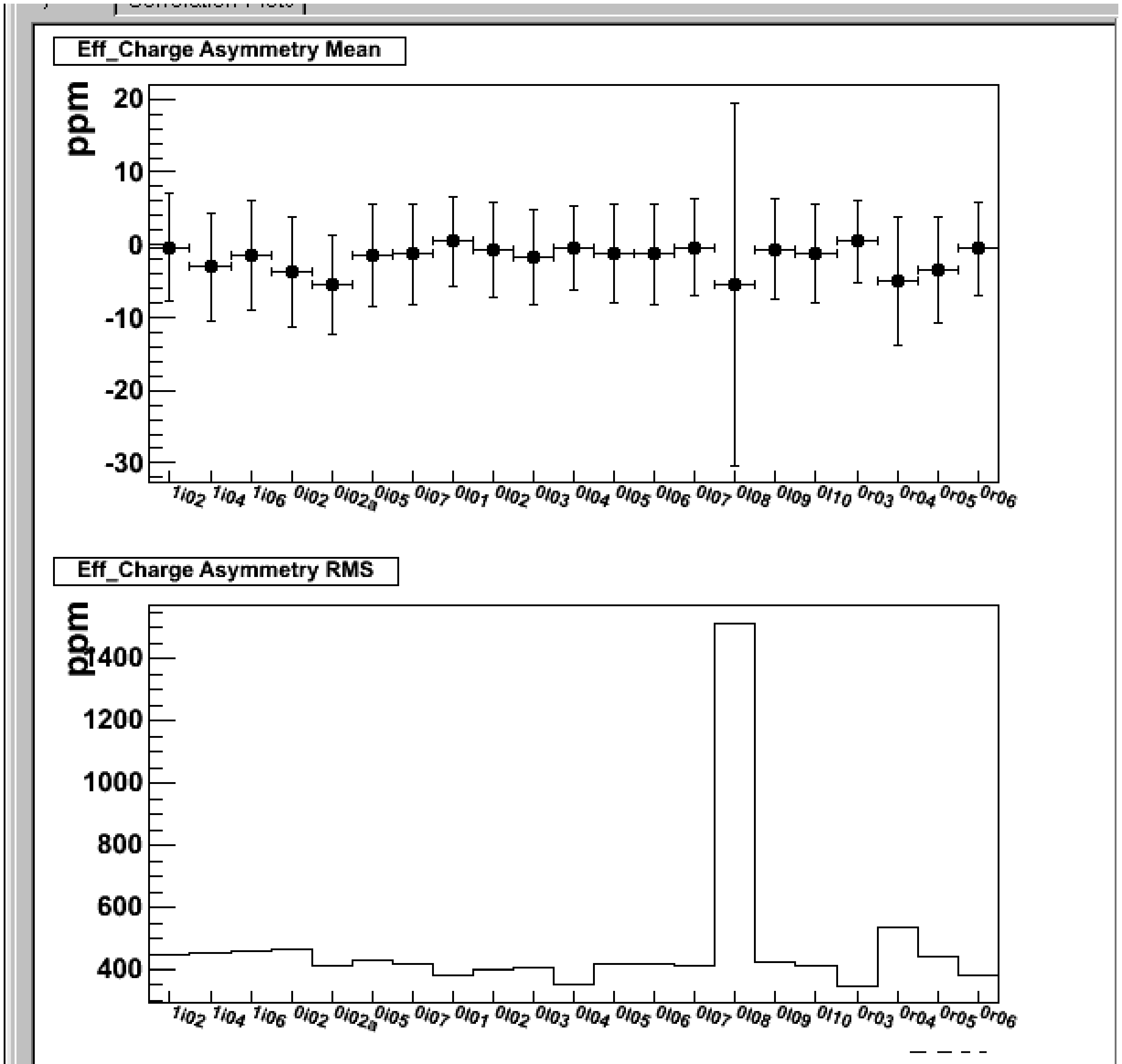
4) MOLLER gets the "clean up polarizer" on laser table they so frequently and desperately ask for. A clean up polarizer helps us achieve 100% circular polarization, which results in zero helicity correlated beam asymmetries. We can't easily use a clean up polarizer with multiple lasers, at least not the way we combine laser beam today.

Of course there are disadvantages associated with two injectors, we will need to list them too.

Possible specifications

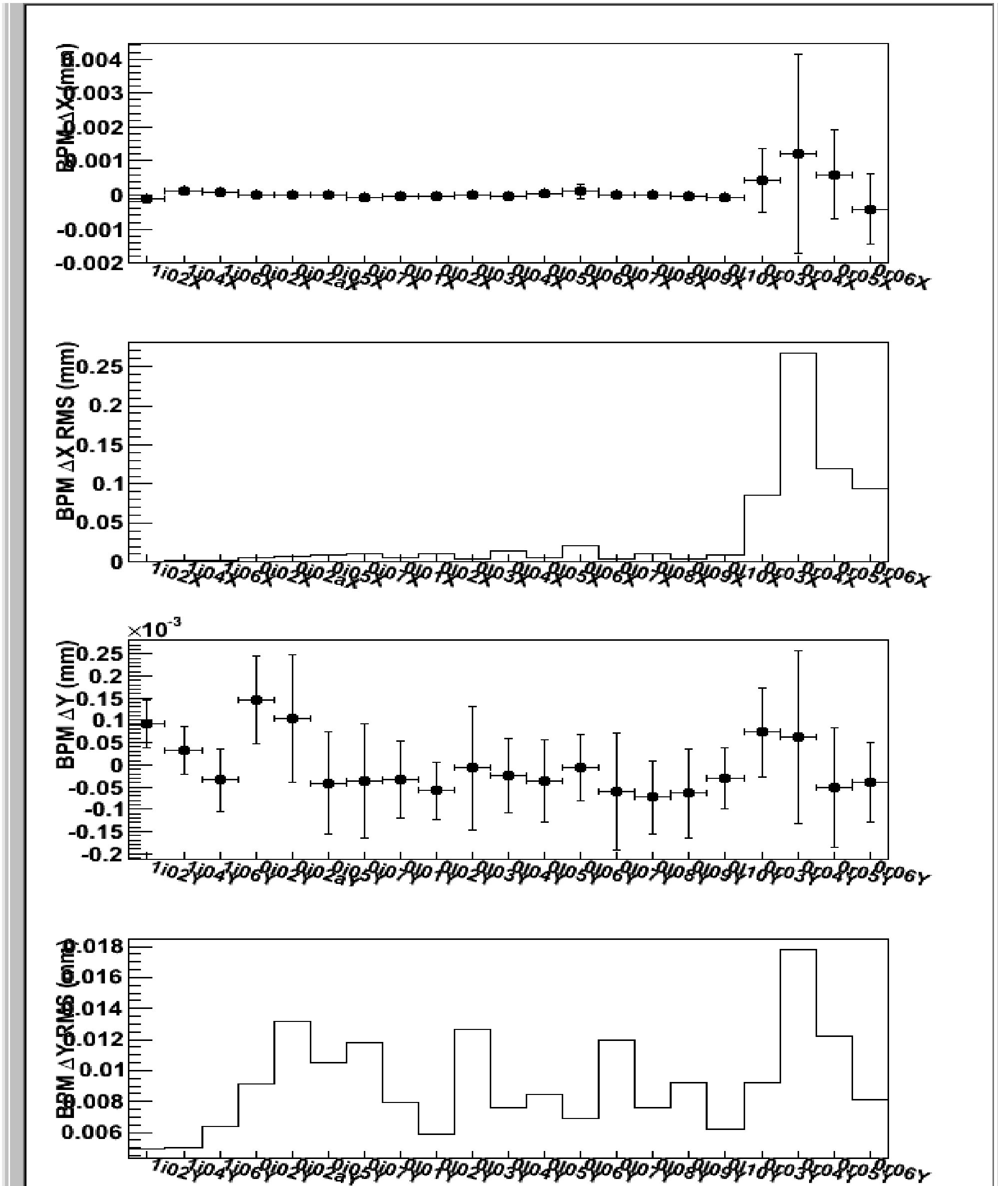
- I forwarded Bob's email with last meeting's presentations and minutes to Paschke, Pitt, Michaels, Dalton, Cates, Suleiman asking for input.
- The links and numbers below were in my email.
- I received a response from Kent 9/9, which I present after the elog images.

https://logbooks.jlab.org/entry/1574301



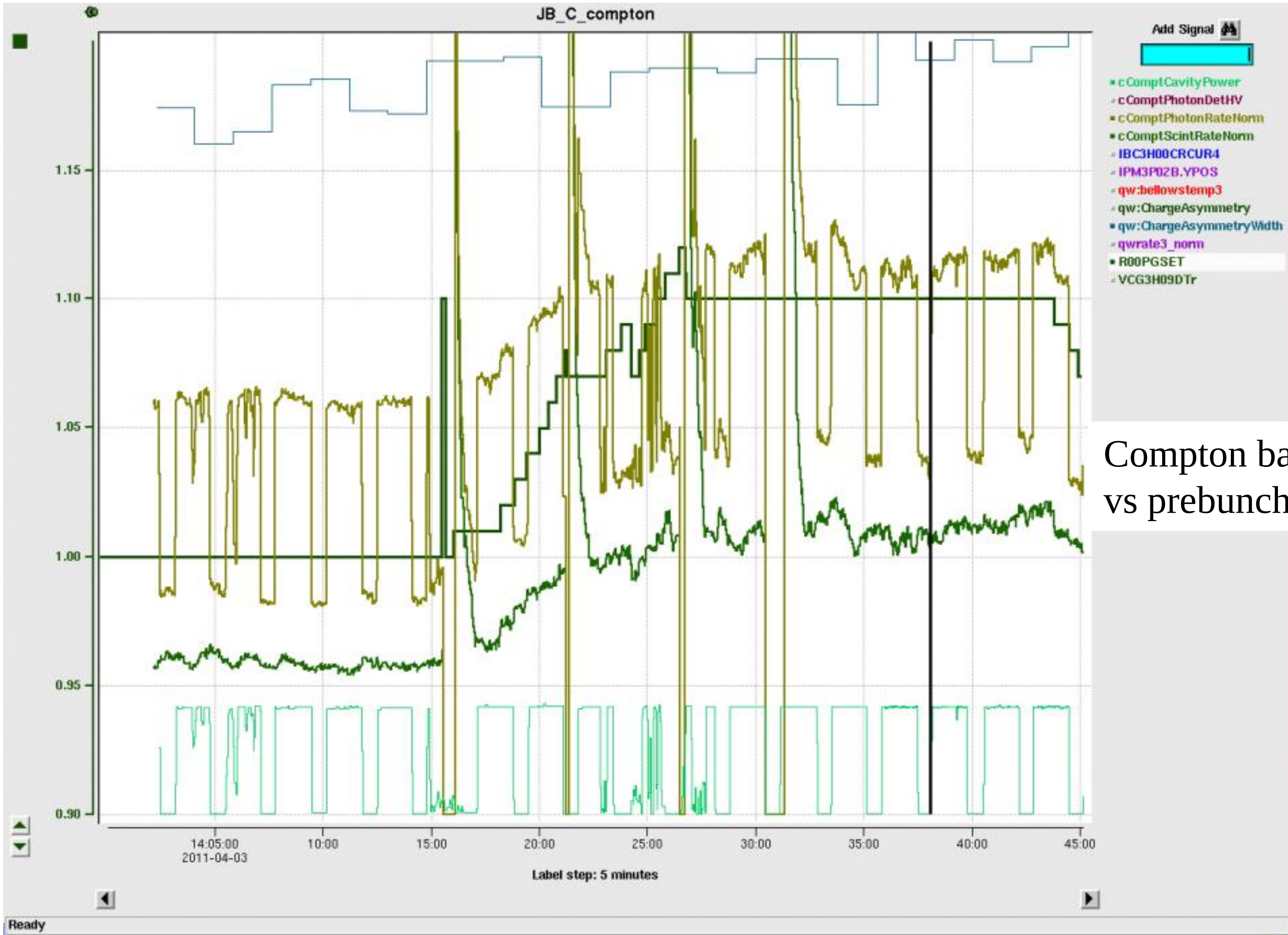
Proposed specs 8/29:
|Mean| < 1 ppm
RMS < 100 ppm
Integrated over 20 minutes (~10^6 pairs)

https://logbooks.jlab.org/entry/1574301



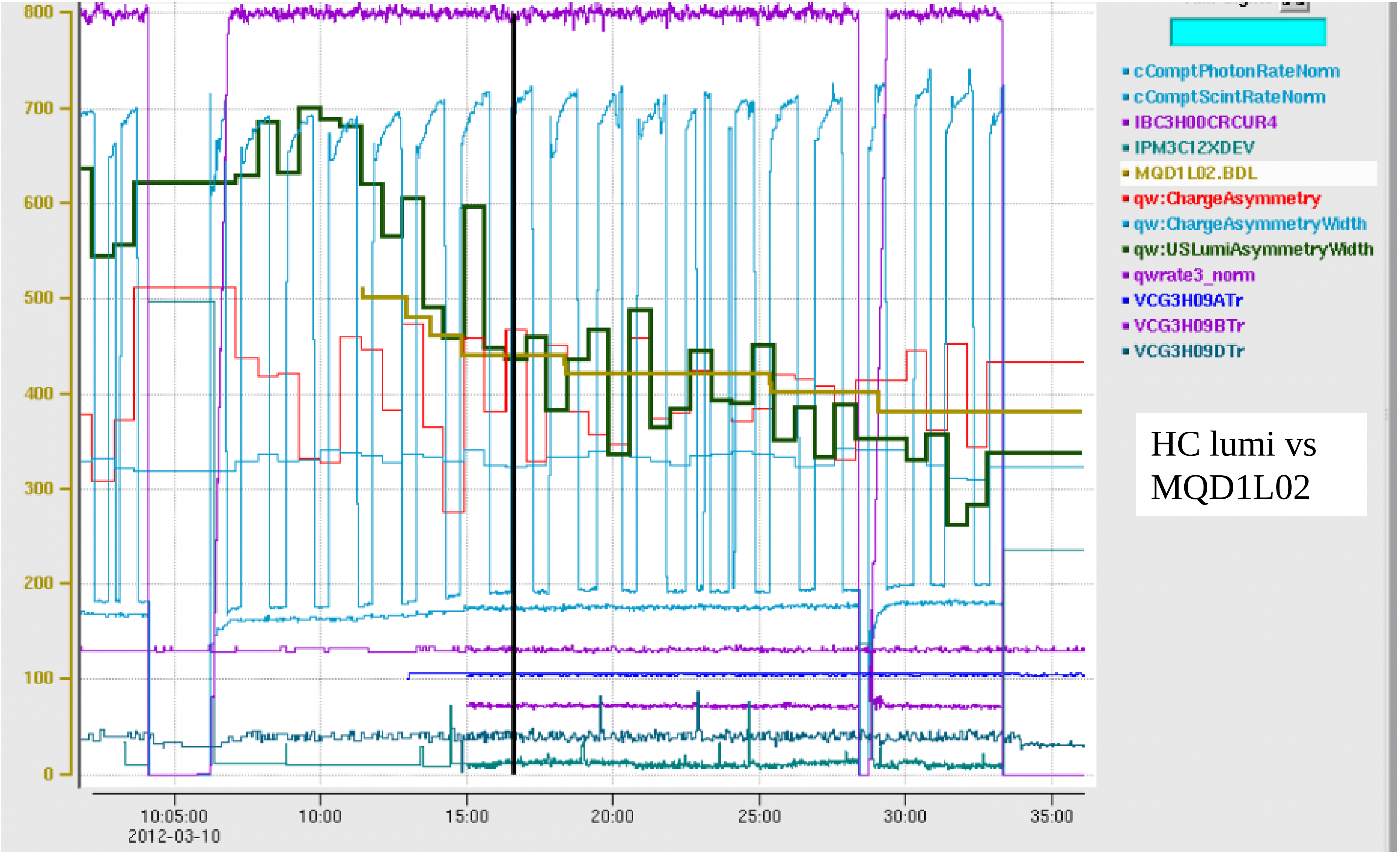
Proposed specs 8/29:
Abs(BPM position mean)<200nm
BPM position RMS < 10 μm
Integrated over 20 minutes (~10^6 pairs)

https://logbooks.jlab.org/entry/1577489



Compton background vs prebuncher

https://logbooks.jlab.org/entry/1690478



HC lumi vs MQD1L02

Kent Paschke 9/9/2015 email (pt 1)

We've discussed this a bit, and tried to refine the bullet points we would use to describe our requirements. Please consider this attempt as a first draft - comments are welcome, and we will certainly need to further develop and refine this list.

First, a bit of a "motherhood" statement of purpose: although the exact impact of any particular request can be difficult to quantify, the overarching goal is to optimize the beam delivery for minimization of helicity-correlated changes. The changes of concern can be in the current, position, or size/halo of the beam. A separate matter, still important but not generally as difficult at JLab, is keeping the "noise" or "jitter" of the measurable quantities of the beam (current, position) to be small enough to allow for precise measurement. Any goal for jitter (usually applied as an RMS on a difference or asymmetry distribution) must be referenced to a specific reversal frequency - MOLLER plans to run with a reversal frequency of 2 kHz, so we suggest that as the benchmark here.

The MOLLER collaboration has identified to primary equipment upgrades of interest: the higher voltage gun (to improve cathode lifetime and beam transport) and removal of pre-buncher from the double-wein (both to improve the simplicity of the spin-rotation and to avoid changing halo characteristics by coupling transverse position to longitudinal or energy parameters). Many of the other suggested changes are also expected to be of significant benefit, and we're glad these are being considered, but we want to make sure that those two priorities aren't left behind! Here is my attempt to remake the bulleted list you presented. There aren't numbers for each bullet point, and I welcome suggestions at how to make these goals more concrete. Here I've attempted to organize by topics (number bullets) and specific goals (letter bullets).

Kent Paschke 9/9/2015 email (pt 2)

1) transmission: the helicity-correlated properties are controlled at the photocathode of the polarized source. To avoid creating or exacerbating helicity-correlated asymmetries, we seek to optimize transmission through the injector. This includes the effect of interception on apertures or in the chopper.

a) changes in the charge asymmetry central value should be less than approximately 10 ppm throughout the injector

b) jitter in the charge asymmetry, measured at the helicity reversal frequency of 2 kHz, should not change by more than about 10% throughout the injector.

2) Noise, or jitter: much of the jitter in the beam charge and position appears to be generated at the cathode, perhaps by instability in the cathode or laser spot. Differential clipping in the injector can enhance this noise.

c) charge jitter in the injector should be <1000 ppm, measured at 2 kHz reversal.

d) position jitter in the injector should be sufficiently small to allow <47 micron RMS of the position difference, measured at 2 kHZ reversal frequency in the experimental hall. (This number comes from the MOLLER proposal, and may be tweaked slightly in the future. We don't expect either of these jitter goals to be in any way a difficult constraint to meet, as they are larger than what we typically observed in previous experiments.)

Kent Paschke 9/9/2015 email (pt 3)

3) Adiabatic damping: although the polarized source will be configured to minimize helicity-correlated changes in the beam, it will be necessary to realize the benefit of adiabatic damping of the beam phase space.

e) coupling of beam phase space should be sufficient to allow a significant fraction of the theoretical maximum of the adiabatic phase space to be expressed as a reduction of transverse, helicity correlated beam differences.

4) Halo: open geometry spectrometers can be sensitive to excess beam halo, with aperture scattering or non-uniform beam monitor response creating potential false asymmetries. Qweak, in particular, appeared to have a problem with significant halo that had a large, helicity-correlated asymmetry.

f) Minimize the halo or tail in the beam phase space (including the longitudinal or energy tail)

g) Minimize the helicity-correlation of the charge and distribution of any halo or tail.

h) Backgrounds in the Compton polarimeter (both the photon detector and electron detector) are one important measure - these backgrounds need to be kept sufficiently low to allow precision polarimetry.

Kent Paschke 9/9/2015 email (pt 4)

5) Spin Manipulation: MOLLER requires frequent spin reversal from spin manipulation in the injector.

i) robust operation and calibration to support efficient reconfiguration of reversed spin states.

j) beam parameters (including halo, to the extent measured) should be the same before and after reversal. Measurements can include helicity-correlated position differences, position difference jitter, beam spot size, and halo measurements after reversal.

h) configuration of the spin manipulator should avoid coupling transverse position and longitudinal phase space parameters (i.e. removal of prebuncher from middle of 2-wien spin manipulator).

6) High-voltage electron gun. The operation of a >200keV photocathode is expected to be a significant help to achieving the above goals.

Kent Paschke 9/9/2015 email (pt 5)

To comment on another line in your email:

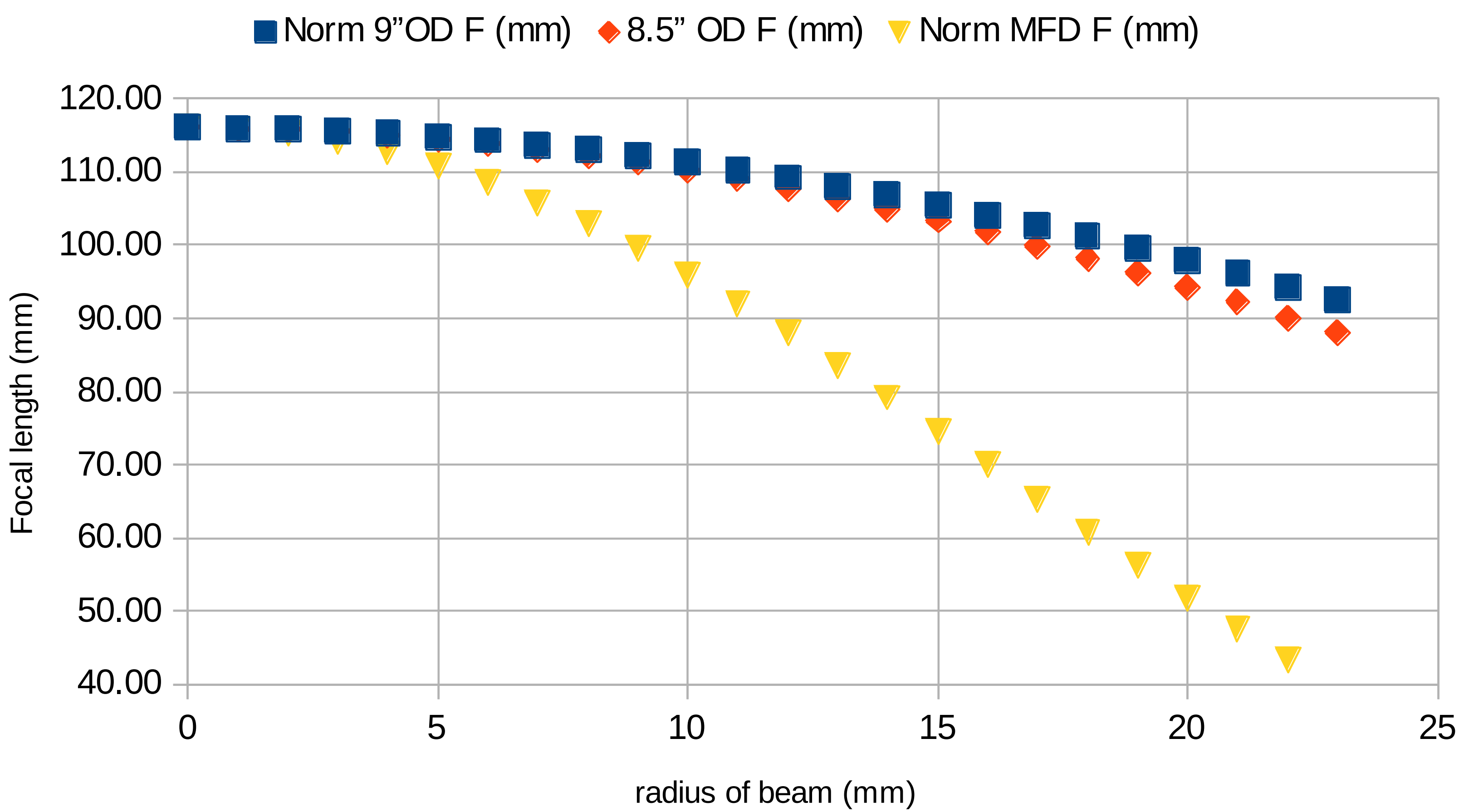
> I advocated starting a "green field" design effort to finish before the MOLLER review...

It isn’t at all clear that the MOLLER review should be a deadline on this planning process. The fact that planning is underway, and the major thrust of the upgrade is known, is probably sufficient. This upgrade process may be part of a dependency for the MOLLER project, but I don’t believe there is any realistic path for it to be part of the MOLLER project, and while the progress will be reviewed with MOLLER, the details will not receive the same level of scrutiny as the project topics.

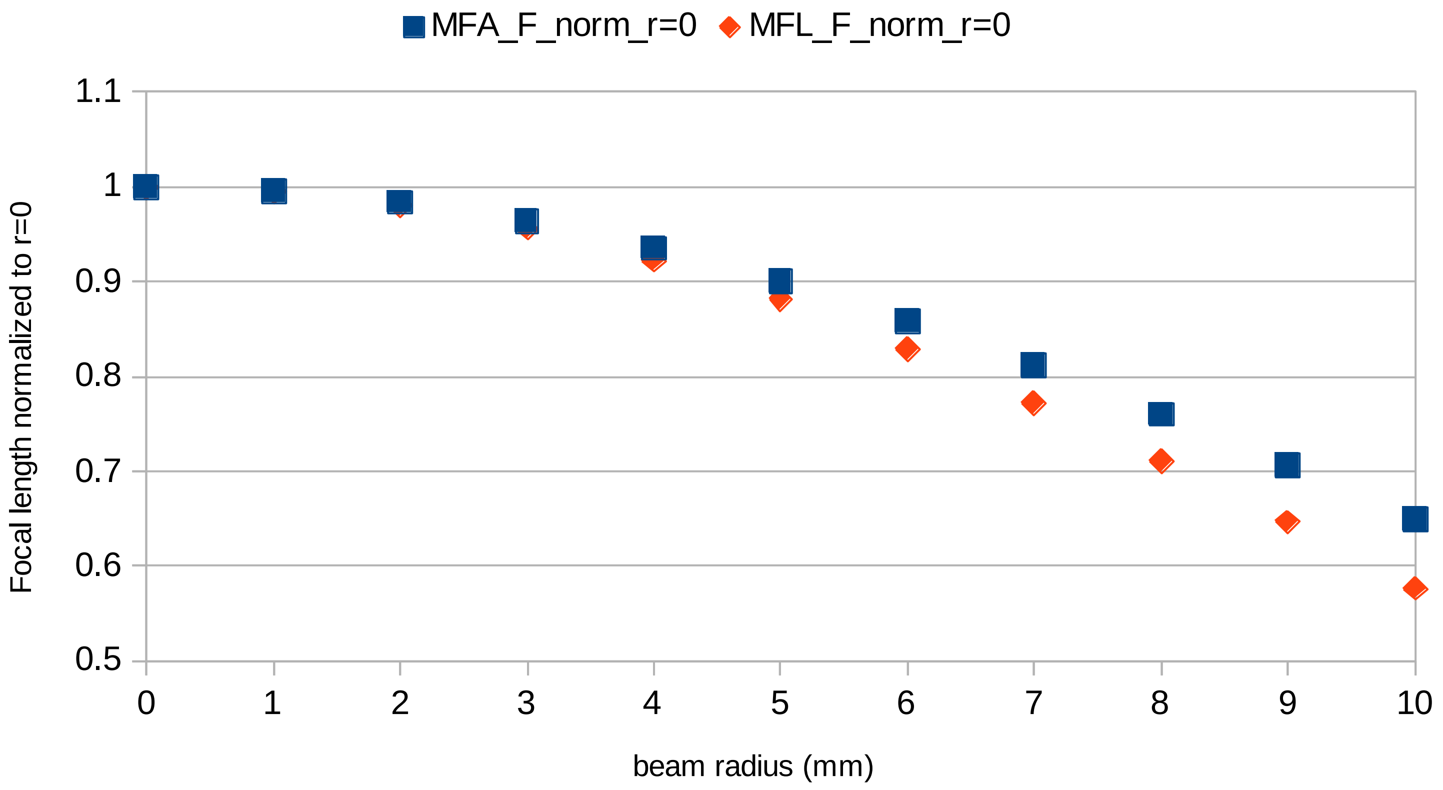
Ok, I think that is the most important topics. I do have some thoughts on pros and cons of the “green field” design (including some concern about the loss of the chopper in the parallel line), but perhaps I can send those later, to keep this focused on the larger design goals from the PV point of view.

Backup

Chopper solenoid



Other solenoids



Focal lengths for solenoids with nominally centered beam, normalized at r=0

Wien focusing

- Trajectories of 125 rays through Wien provided to T. Satogata to determine first order transport.
- This should determine whether existing air core quads (QU, QW) will suffice or iron-core options are needed.