UITF Ops Review, March 18, 2016

In attendance: T. Satogata, M. Spata, F. Hannon, H. Fanning, A. Hutton, R. Kazimi, H. Areti, J. Hasnknecht, J. Grames, A. Bogacz, A. Hofler, A. Sandorfi, Xiangdong Wei, C. Hanretty

Absent: A. Freyberger, G. Krafft

Summary of Findings

**Will UITF work?** The overall consensus was Yes, it will work, but with the following concerns:

1. HDIce anticipates that target polarization can be maintained only for nA or sub-nA beam current. Currently, only cavity-style BPMs can “see” such beam, and we can’t use these types of BPMs at UITF (too costly, and not enough space). So technology must be developed to see nA or sub-nA beam.
   1. Trent Allison and John Musson are considering modifications to the existing stripline BPM technology to improve our low current beam monitoring capability. Firmware can be modified to employ a “lockin amplifier” style detection scheme. We hope these ideas can be tested at Hall D soon.
   2. We have also proposed a beam macropulse structure, with a brief “high current” macropulse that can be detected by existing stripline BPMs, but of sufficiently short duration, such that it does not depolarize the HDIce target.
   3. Finally, we will obtain two or more toroid-winding style BPMs from Juelich, with reported detection capability to 200pA.
   4. Is it possible to install an electrically isolated thin window (could be upstream of their radiation baffle) that could be used as a relative current monitor calibrated against a BCM?
2. It is important to uniformly “paint” the HDIce target with beam, and to avoid sending beam to the walls of the target or other parts of the in-beam cryostat. Team HDIce has been using G4Beamline to model MeV beam interactions through the HDIce target and the in-beam cryostat. These simulations indicate that a specific beam energy of 7.86 MeV provides clean transport through the HDice target and the in-beam cryostat. However, deviation from this specific beam energy by as little as 100 keV can be detrimental. Some reservations were expressed related to the accuracy of the simulation, and whether “real life” provides more complications, e.g., how well is the magnetic field of the holding solenoid known? How well does G4Beamline simulate beam interaction with the upstream radiation baffle? Several people commented that energy spread could exceed 100 keV. And of course we don’t know if the ¼ cryomodule (new or old) can provide 7.86 MeV beam energy, because we will be using available (i.e., weak) klystrons.
   1. We expect to install a “beam good” monitor. If beam position deviates from optimium, it strikes an aperture that generates x-rays that are detected with a beam loss monitor, and this will trigger an FSD trip that closes the laser shutter
   2. The G4Beamline model of HDIce is being used to define relatively fine details of the beam, however, it’s not connected to the refined beam model distributions.
   3. G4Beamline model should include a solenoid field that is demonstrated to be realistic.
3. Related to the energy spread on the beam, a slit inside the chicane could be employed to reduce energy spread and perhaps also serve as a “beam good” diagnostic.
4. There was some acknowledgement that posted beam specifications for UITF are somewhat arbitrary, and more related to specifications expected at CEBAF using GeV beam. In particular, the halo specification of 10-4. We will strive to meet the specifications, but MeV beam and GeV beam are very different. Certainly, for detecting halo at 10-4 level, we will need PMTs to detect beam as the wire scans across. Keeping beam from hitting anything but the target material is the toughest beam requirement. Are the Specifications indicative of beam at the radiation baffle or at the target? We will need a harp downstream of the in-beam cryostat to know that we have met the specifications.
5. We will “set up” the beam in Tune Mode at 8uA. Can we feel confident that beam optics are the same at 1nA? Harps will be available to compare beam in Tune Mode and nA CW – this should give us confidence that we know beam specifications while operating CW at nA or sub-nA current. And we can consider enabling viewer insertion when delivering nA CW beam. And there’s the CEBAF precedent, setting up the injector in Tune Mode and then delivering nA beam to Hall B.
6. The tragedy would be to get a bad result at UITF due to MeV optics, whereas the HDIce improvements made to date would be effective at GeV beam energy

**What is driving the schedule?**

There are three A-rated experiments hoping to use the HDIce target at Hall B. These experiments could be scheduled within the next three years, based on favorable testing at UITF

**How does UITF differ from the CEBAF injector?**

The UITF beamline shares many features of the CEBAF injector. We believe it is sufficiently similar as to provide a realistic commissioning ground for the new ¼ cryomodule, in adnvace of installation at CEBAF. And once we augment radiation shielding, we expect to operate UITF at currents that will be useful for testing new diagnostics, making polarized positrons and conducting the Bubble Chamber experiment.

We anticipate two UITF configurations: during the first ~ 3 years we will employ a configuration using a 200 kV photogun and the new ¼ cryomodule with SRF capture section and one 7-cell accelerating cavity. Then, after the new ¼ cyromodule gets installed at CEBAF, we will use a 350 kV gun and the old ¼ cryomodule (the one pulled from CEBAF).

Key beamline elements include:

* 200 kV photogun and then later, a 350 kV photogun
* Y-chamber to allow photocathode illumination at normal incidence
* Wien filter to orient the polarization transverse to the beam direction
* Chopper cavities with variable slit located at the midplane
* Buncher cavity
* keV spectrometer line
* SRF ¼ cryomodule (new, and then old)
* MeV beamline with a sufficient number of quadrupole magnets
* MeV spectrometer beamline
* We envision installing a polarimeter in the out years

Space is limited at UITF - there is not enough room along the beamline to install a prebuncher or second Wien filter needed to construct a 4 spin flipper.

Joe Grames has performed an assessment of magnets. For the most part, present day CEBAF style solenoids will provide sufficient focusing of 200kV beam, and then later, 350 kV beam. Only the 15 degree dipole magnet and the Wien filter dipole magnet will need to be upgraded to accommodate higher energy beam. The Wien filter will also need new vacuum feedthroughs to bias the capacitor plates at higher voltage. The 1497 MHz chopper cavities should be able to operate with 200kV beam (75 W rf power), and then later, with 350 kV beam (200 W rf power). These old cavities have been tested to 200 W, the power level needed to displace 350 kV beam by 1.5 cm at the midplane. At MeV beam energy, Panofsky-style quads will provide sufficient control of the beam envelope. Steering magnets for MeV beam need to be procured or manufactured (there are some Haimson coils, but of insufficient quantity).

The “free” buncher cavity from the LERF sets the maximum bunch repetition rate at UITF to 750 MHz. Lower repetition rates, subharmonic to 750 MHz, can be employed for higher bunch charge operation. If and when the free LERF buncher is needed at the LERF, we can use the 1497 MHz buncher (and klystron) that gets pulled.

The UITF drive laser will be similar to CEBAF drive lasers, providing ~ 35 ps optical pulses (FWHM) at 780 nm, the wavelength required for generating highly polarized beam. The laser will be located inside a clean room, with light delivered to the Cave via fiber optic transmission line. A small outrigger table will hold the pockel cell and steering mirrors.

At kV beam energies, we can deliver very high average current beams to a fixed dump upstream of the ¼ cryomodule, in the keV spectrometer line. Lifetime tests will be performed at millampere currents.

At MeV energy, the thickness of the Cave2 concrete walls and ceiling limits the maxmum allowable CW beam current to 100 nA. Additional concrete shielding can be installed to permit 100uA beam delivery at 10 MeV, and of course we will pursue this, to ensure that we properly commission the new ¼ cryomodule prior to installation at CEBAF.

**UITF Optics modeling**

Modeling of UITF beam optics has been performed by Alicia Hofler using GPT, Joe Grames using Elegant, and Alex Bogacz using Optim. Overall, good agreement between models, although space charge has not been considered yet. This is OK for HDIce operation, but will need to be investigated to thoroughly evaluate the performance of the new ¼ cryomodule at 100uA.

Concerns expressed per individual:

Joe Grames:

* + buncher relatively far from the ¼ CM
  + some magnets insufficiently powerful, especially for 350kV beam (chopper solenoids, steering magnets, Wien dipole, 15 degree dipole)
  + Presently no budget for chopper amplifiers (especially, 200 W amplifiers needed for 350 kV beam)
  + MeV steering magnets
  + Beamline downstream of IBC is presently ill-defined
  + Are we using accurate modeling information for the new ¼ cryomodule?

Alex Bogacz:

* Wien filter – Recommended to center between MFB2K02 and MFA3K01 lenses. Move Wien filter ~ 20 cm away from gun
* Buncher – Recommended to center between MFA3K03 and MFA4K03 lenses. Move buncher ~ 20 cm away from gun
* Recommended to add a pair of skew quads between MFA4K03 lens and ¼Cryo to control coupling and to rotate the dispersion into the vertical plane
* Alex modeled 350 kV beam – the group recommends that Alex also model 200kV beam and compare results

Alicia Hofler:

* A genetic algorithm was employed to optimize the UITF layout, using GPT
* A more realistic model should include the 15o dipole, RF choppers, MeV line, apertures, and more macro-particles
* Consider performing optimizations with 15o dipole and RF choppers
* Optimizations needed for 100 μA, including space charge, to support ¼ cryomodule commissioning

Additional comments:

* Alex found 80um RMS and I found 200um RMS, because we optimized differently. His solution may allow using only QJ quads whereas mine required two QD quads. Alex provided me his quad values and optimization strategy, which I will reproduce in Elegant.
* Alex suggested the Optim solenoid model is better than the Elegant solenoid model; this won’t change whether the solenoids work but the exact operating value.
* The Wien filter is not included yet.
* Alicia demonstrated the energy spread is achievable; we will need to understand trade-off between operating with “best” e.g. 1E-4 spread or “sufficient” 1E-3 spread
* We need to ALL get on same page with initial conditions by gun and THEN understand how well models agree or disagree, first in the keV section and then in the MeV section; the HDIce model should be incorporated
* The UITF modelers should be meeting every two weeks to work through a well defined punchlist; this should include the HDIce model

**Global Issues**

As much as possible, CEBAF-compatible systems and software will be used. This means UITF will be composed of many CEBAF spares, items that can be pulled from UITF when needed at CEBAF. We hope that most UITF software is simply a copy of CEBAF software.

We will employ UED: the UITF Element Database

The next UITF review will be an Internal Safety Review, focused on Machine Protection and Personnel Protection

From Andy

Q.Will UITF Work, item (2):  
     The statement is perhaps a bit too strong. Our simulations tell us that 7.86 MeV puts a node on the front face of the HD, which gives the best chance of using the raster to uniformly “paint the target” and spread out the damage. A 100 keV shift from that is not necessarily a disaster; but it’s not optimum. Adjustments can be made; we can change the magnetic field, although to minimize depolarization our preference is to keep it as high as possible. The key thing is to have a useful diagnostic so we can model what is going on inside the IBC. Our modeling indicates that the position of the beam on a HARP after the IBC (without a target) would give us that, provided the energy spread isn’t too big. From my perspective, it’s the energy spread that’s of the greater concern.  
  
•   What is driving the schedule:  
     To get the perspective right: Pac 39 assigned the three transverse polarization experiments with HDice an “A” scientific rating; PAC 41 ranked them as having the “highest impact” for the Hall B physics program.   
  
•   UITF Optics:  
     Several people mentioned (moaned even) about the limitations of space along the beam line. I wonder if backing off from the goal of maintaining all possible options to manipulate the beam polarization might free up useful space.  While measuring a helicity asymmetry could in principle provide a valuable independent method of monitoring the target polarization, we haven’t yet figured out a practical way of doing that, given the optics limitations. It certainly won’t be used in the first round of tests. Is there real estate along the beam line that could be put to better use?

Hi Joe,

We can do diagnostic tests without a target and without the radiation baffle; eg. measuring beam profiles, etc. But when the radiation baffle is rotated out, the temperature of the mixing chamber, which is the heat-sink for the target, will rise to about 600 mK just due to the thermal load of 300 K radiation. If an HD target is attached to the mixing chamber with the Rad baffle open, its temperature would rise to 600 mK, which is just fine UNTIL an electron beam hits. The beam will un-pair the 1s electrons of the HD in its path, and at 600 mK the single electrons left behind will not be polarized - THAT's the problem. We need to maintain a low temperature to keep the residual molecular electrons polarized so that they do not depolarize the HD. At 600 mK the depolarization rate could easily be 100 times faster, and it would not be clear how to connect such UITF measurements with expected performance in the Hall.

Andy



