**Commissioning of Injector Upgrade II**

This is a beam-based commissioning plan for phase II of the injector upgrade: raising the photocathode gun high voltage from 130 kV to 200 kV; replacing the existing capture and the quarter cryo module with the booster cryo module. This plan covers the steps to commission the new beamline components and establishes the physics quality electron beam in the injector. The estimated time needed is 122.0 hours or about 15.3 shifts. If we run two shifts per day we would need about 8 days and this is beam-on time. Given the fact that after an extended accelerator down or a beamline upgrade we would usually have some hardware and software issues during the restoration of beam or commissioning of the new beamline, and that we may also need to repeat some procedures, I would say we need about three to four weeks to finish the commissioning and setup of the injector.

**Prerequisites**

1. The hot checkout of the injector from the gun to the inline dump (ILD) is complete and the injector is ready for beam operations.
2. A QE scan has been done.
3. The laser spot has been moved to a good location.

Note: The ratio of beam momenta with the gun biased at 200 kV and 130 kV is 1.277.

**Procedure steps**

The steps are not necessarily executed in the order as listed based on availability of the machine.

**Restore beam to FCup 1 with gun biased at 130 kV----------------------------------------------------------8.0 hrs.**

1. Load the injector settings of all the beamline components using a good saved file from the last run (March 2023).
2. Cycle all the solenoids from the gun to FCup 1.
3. Cycle the Wien magnets. Reset the HWien to the same angle as in the save so the Wien HV would be set properly.
4. Set MFA0I05 to zero. Set MFX0I05 and MFX0I06 to the values recommended by Injector Group/CASA. If those settings are for 200 keV beam operations. Scale down the settings by a factor of 1.277 for 130 keV beam operations. Cycle them.
5. Make sure the prebuncher and chopper are on.
6. If the gun is on and gun HV is not at 130 kV, turn off the gun HV.
7. Set the gun HV trip window for 130 kV operations.
8. Turn on the gun and set the gun HV to 130 kV.
9. Thread beam to Fcup, and then to Fcup 1 using the relative BPMs. Since the laser spot is different now the first two relative BPMs would be different from the saved values. Also the relative BPMs between the chopper and FCup 1 would be different due to installation of the booster.
10. Beam center all the solenoids from the gun to FCup 1.
11. Turn off the prebuncher and chopper.
12. Re-establish beam to FCup 1.
13. Turn off the HWien magnet and the Wien high voltage. Cycle the HWien magnet.
14. Re-establish beam to FCup 1.
15. Turn off beam.
16. Turn off the gun HV.

**Establish beam to FCup 1 with gun biased at 200 kV---------------------------------------------------------6.0 hrs.**

1. Set the gun HV trip window for 200 kV operations.
2. Turn on the gun and set the gun HV to 200 kV.
3. Scale up all the magnet settings (including MDR1I02) from the gun to FCup 1 by a factor of 1.277, or load in the settings recommended by Injector Group/CASA.
4. The Wien magnets are off at this point (step 13). Will set it up at a later time.
5. Thread beam to FCup. Refine the setting for MDR1I02.
6. Thread beam to FCup 1.
7. Check and make sure all the solenoids are beam centered.
8. Turn off beam.

**Set up chopper with gun biased at 200 kV-----------------------------------------------------------------------8.0 hrs.**

1. Turn on the chopper and scale up the chopper gsets by a factor of 1.277.
2. Set up the chopper. Does the chopper work well with the gun biased at 200 kV. Log any findings.
3. Turn off beam.

**Set up prebuncher with gun biased at 200 kV------------------------------------------------------------------3.0 hrs.**

1. The prebuncher’s gset is 3.0, and its CRFP 26.35 W for 130 keV beam operations. Raise the prebuncher’s gset so that the CRFP would increase by a factor of 1.277 for 200 keV beam operations. The prebuncher’s gset will need fine adjustments.
2. Set up the buncher amplitude and phase.
3. Verify the prebuncher works for all four beams on ITV0I04
4. Does prebuncher work well with the gun biased at 200 kV? Log the findings.
5. Turn off beam.

**Set up beam to 1D dump with gun biased at 200 kV---------------------------------------------------------4.0 hrs.**

1. MBO0I06 current is -230.3 mA for 130 keV beam operations. Scale up the current by a factor of 1.277 for 200 keV beam operations.
2. Turn off the buncher.
3. Thread beam to ITV1D00B
4. Turn off beam.

**Set up buncher** **with gun biased at 200 kV----------------------------------------------------------------------5.0 hrs.**

1. Set MFX0I05 and MFX0I06 to the values recommended by CASA/Injector Group and cycle them.
2. The buncher’s gset is 6.5, and its CRFP is 26.43 W for 130 keV beam operations. Raise the buncher’s gset so that its CRFP would increase by a factor of 1.277 for 200 keV beam operations. The buncher’s gset may need some fine adjustment later.
3. Set buncher’s phase to zero crossing.
4. Does buncher work well with the gun biased at 200 kV? Log the findings.
5. Turn off beam.
6. Set MBO0I06 to the straight ahead mode and cycle the magnet.

**Thread beam through booster cryo module and to Fcup 2-------------------------------------------------8.0 hrs.**

1. Set MFX0I07 to the value recommended by Injector Group/CASA and cycle it.
2. Scale up the settings of the quads between the booster and Fcup 2 by a factor of 1.277. Or load in the values recommended by Injector Group/CASA/eDT. The final settings would be from the match.
3. Make sure the booster cryo module is on. Set the 2-cell cavity gradient to 2.5 mV/m, the 7-cell cavity 7.5 MV/m. These settings would raise the beam momentum to ~6.3 MeV/c.
4. Thread beam through IPM0I07B.
5. Thread beam through the booster using ITV0L01. Adjust the cavity phases to get the best beam spot on ITV0L01: beam center the cavities; the beam spot should be close to round; make the beam spot as bright as possible with the same incoming beam current.
6. Thread beam to FCup 2.
7. Beam center the quads between the booster and FCup 2.
8. Turn off beam.

**Phase the booster and set up the booster energy------------------------------------------------------------4.0 hrs.**

1. Set MDL0L02 to the setting for 2D line.
2. Thread beam to ITV2D00
3. Phase the booster using the Bunch length Setup script.
4. Set the booster gset to get the beam momentum to 6.3 MeV/c.
5. Turn off beam.

**Evaluation of booster-------------------------------------------------------------------------------------------------24.0 hrs.**

1. Set MDL0L02 to the straight ahead mode and cycle it.
2. Verify beam to Fcup 2 is good.
3. Measure beam emittances upstream and downstream booster using qsUtility.
4. Measure beam x/y coupling induced by the booster
5. Measure beam deflection caused by the booster.
6. Document beam image on ITV0L01. The beam spot on ITV0L01 was round and at 7 o’clock position prior to installation of the booster. ITV0L01 might be different now due to the installation of the booster.
7. Turn off beam.

**Beam to 4D dump-------------------------------------------------------------------------------------------------------8.0 hrs.**

1. Load the magnet settings for 0L and 0R regions using eDT for the desired injector energy.
2. Cycle all the quadrupoles between the booster and ILD, and chicane dipoles.
3. LEMi the injector for the desired energy.
4. Thread beam to ITV4D00.
5. Phase RF0L03 and 0L04.
6. Set the injector to the desired energy.
7. Turn off beam.
8. Put MBF0L06 to the straight ahead mode.

**Beam to ILD-------------------------------------------------------------------------------------------------------------4.0 hrs.**

1. Thread beam to ILD.
2. Do an aperture check in the chicane region.
3. Check collinearity of all four beams.
4. Calibrate the injector orbit lock.
5. Run orbit lock and energy lock to make sure they work.
6. Turn off beam.

**Fine tuning--------------------------------------------------------------------------------------------------------------40.0 hrs.**

1. Go through the above steps to make sure the setup is good. Pay attention to the setup for prebuncher, chopper, buncher and booster.
2. Measure the beam bunch length in 5 MeV region using the bunch length scrip.
3. Measure the beam bunch length in the 4D line using the back phasing technique.
4. Set up the Wien for the physics program.
5. Perform an injector-to-NL match.
6. Establish high current (as high as allowed) CW beam to ILD.
7. Park high current CW beam to ILD for 10 minutes with the orbit and energy locks on.
8. Do an Allsave with zero pos.
9. Turn off beam.
10. Update the injector alarms.
11. Update BNOM for the injector BEM.

**Procedure Complete**