

## UITF Commissioning Plan

Version 4

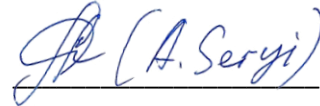
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### Approvals:



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UITF Facility Manager



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Accelerator Division AD

### Pre-commissioning Tasks:

QCM cooldown to 2K: schedule the cool down of the QCM at least two days in advance of UITF commissioning, coordinating activities with Cryo and SRF. CTF piping must be reconfigured, restoring LN2 flow to the QCM shield line and sending LHe to UITF instead of the CMTF. Staff from the SRF Institute check insulating vacuum using a turbo pump cart, and oversees cooldown from RT to 4K, and from 4 to 2K.

Hot Check Out: one week in advance of commissioning, using the System Readiness tool or via direct communication with group leaders/system owners. Document the status of each:

- a) UITF Operator to verify “good” vacuum of the UITF beamline from the photogun to the waist-height beam dumps IDLM601 and IDLM703 (valves on either side of the QCM CLOSED). “Good” vacuum corresponds to all ion pumps registering current < 100 nA (typical)
- b) SRF to verify functionality of the QCM (insulating vacuum, waveguide vacuum, beamline vacuum)
- c) RF group to verify functionality of high power RF to QCM and buncher, proper functionality of water skids
- d) RF group to verify functionality of the Yao cavity time of flight system
- e) I&C to verify functionality of components for the entire keV beamline and through the MeV regions up to M7 (the “waist height” beamline). I&C components include viewers, valves, ion pumps, BPMs, harps, current monitoring at cups, dumps and apertures
- f) DC power to verify functionality of magnets: for the entire keV beamline through the MeV regions up to M7
- g) High Level Applications: Ditherer, viewer image fitting tool, StepNGraph, archiver, allsave, UITF electronic logbook, JELI, alarm handler, chime, LivePlot
- h) Software functionality and the accuracy of UED is implied in the above list
- i) UITF Facility Manager to verify accuracy of the UITF Quick Reference Guide ([https://wiki.jlab.org/ciswiki/images/6/6b/UITF\\_quick\\_reference\\_rev.7.1.pdf](https://wiki.jlab.org/ciswiki/images/6/6b/UITF_quick_reference_rev.7.1.pdf))

### Beam Authorization: days in advance of commissioning

- a) Verify Credited Controls:
  - Radiation Control Department inspects/verifies that all required moveable radiation shielding is in place and with proper labels (periodic inspection required, results posed to UITFLog and documented using the Beam Authorization Tool)
  - Safety System Group verifies PSS Access Controls and ODH monitoring systems (periodic certification required)
  - FM&L inspects/verifies that all permanent radiation shielding is in place (periodic inspection required, results posed to UITFLog and documented using the Beam Authorization Tool)
  - UITF Facility Manager verifies facility configuration: ODH vent barrier in place, lead shielding in place at trenches, dumps and cups as prescribed by RCD
- b) Lab Management (Accelerator Associate Director/Lab Director) approves the UITF Commissioning Plan
- c) UITF Facility Manager authorizes MeV beam delivery to the Cave2 waist-height beam dumps IDLM601 and IDLM703

### **Commissioning Strategy:**

The keV beamline has been operated and deemed functional, including the chopper system that can be used to control the electron bunchlength at the QCM, albeit impacting beam current

The buncher can be commissioned in advance of UITF MeV beam commissioning. Use the keV spectrometer to find the buncher “zero-crossings” and to set the buncher amplitude (nominal 40 W, per simulation). Alternatively, use the harmonically-resonant “Brock” cavity to measure bunchlength versus buncher RF amplitude. Extrapolate the results to determine the buncher power needed to set longitudinal waist at the QCM 2-cell cavity.

The biggest challenges associated with commissioning the UITF accelerator is finding (for the first time) the proper rf phases of the 2 and 7-cell cavities of the QCM, and the buncher amplitude that properly sets the electron bunch length at the QCM 2-cell cavity

Initial attempts to thread beam through the MeV beamline will be performed using Viewers and Viewer Limited Beam, corresponding to ~ 10 nA average beam current. But viewers are spaced relatively far apart. Tune Mode beam and BPMs can be used if finding beam on viewers proves difficult. There are more BPMs than viewers and BPMs can “see” beam over the entire 1.5” beampipe diameter, so BPMs could be more useful than viewers for initial beam steering.

First, attempt to “float” 200 keV beam through the QCM (QCM cavities NOT energized), and transport beam all the way to the MeV beam dumps. Adjust quads to obtain tight beams on viewers. If successful delivering 200 keV beam to the MeV dumps (or if not successful), then increase beam energy...

Increase the beam energy by first energizing only the QCM 2-cell capture cavity powered to provide 500 keV beam – adjust 2-cell cavity phase to “crest” the 2-cell and adjust 2-cell gradient to obtain 500 keV beam as determined using the MeV spectrometer dipole magnet, MDLM601.

With the 2-cell capture cavity energized, now energize the 7-cell, setting gradient to obtain 1 MeV beam, steer beam to the spectrometer dump and adjust quads to obtain tight beam images on viewers. Crest the 7-cell, and adjust power incrementally until 5 MeV and then 10 MeV beam is obtained.

As an alternative to the spectrometer techniques described above, a Yao cavity “time-of-flight” measurement system can be used to quickly set the buncher rf phase and amplitude and the QCM cavity phases. The Yao cavity is installed on the beamline and the RF group is now in the process of building related electronics to implement the time-of-flight technique (predicted availability September, 2019).

The steps 1 – 9 below assume no Yao cavity time-of-flight system available. Steps 10 – 12 describe commissioning steps using the Yao cavity technique to set the RF amplitude and phase of the buncher cavity, and the RF phases of the QCM cavities.

After beam is delivered to the MeV spectrometer dump, measure beam quality. The buncher phase and amplitude can be optimized to provide the best beam quality as determined by harp scans used to measure emittance and energy spread.

### **Procedure:**

#### **With UITF enclosure OPEN**

Step 1: Use dipole field maps and Elegant to create a table of expected settings for dipole magnet MDLM601 leading to the MeV spectrometer beamline, the four quad magnets (MQJM501, MQJM502, MQJM503, and MQJM504) and the RF amplitudes for the buncher, 2 and 7-cell cavities, for each of the following beam energies: 200 keV, 500 keV, 1 MeV, 5 MeV and 10 MeV. (see Table at bottom of document)

Step 2: Having obtained permission to commission the UITF accelerator, remove the lock from the upstream QCM valve, permitting opening of this valve via epics control

Step 3: check the functionality of the Machine Protection System vacuum/valve interlock. Open all valves from the dumps to the photogun. Using EPICS, set the ion pump current trip level to a value below the actual vacuum level, verify that all vacuum valves automatically close.

Step 4: set the current-limit on the Glassman HV power supply to 12 uA using GUN HV EPICS control screen (intended maximum CW current is 10 uA, but gun high voltage power supply current readback can be “noisy”. Setting the current limit to 12 uA prevent nuisance trips)

Step 5: conduct the Pre-ops checklist (below) and described in the MeV OSP, log results

Step 5: Sweep UITF enclosure, lockup and set PSS to RUN mode

#### **With UITF in RUN mode:**

Step 1: load UITF All-Save XYZ and deliver keV beam delivery to Faraday Cup 2, IFYK403 immediately upstream of the QCM. Viewer Limited beam, with the chopper cavities powered at nominal values and properly phased. The chopper slit retracted.

Step 2: set the buncher phase and amplitude using the keV spectrometer beamline (technically, this can be done in advance of UITF commissioning):

- a) With the choppers energized and properly phased, and with the laser phase set to provide 200 keV beam centered on the chopper viewer, insert the chopper master slit to pass nominal 100 ps bunches to the buncher. This corresponds to the largest opening of the UITF chopper slit “arrowhead”
- b) Adjust dipole MDIK402 to send the 200 keV Viewer Limited beam to the keV spectrometer dump viewer, ITVK501. Record the centroid position of the beam on the viewer.
- c) Set the buncher amplitude/forward power to 40 W which is the expected operating power for beam delivery to the QCM
- d) Adjust the buncher phase to re-establish beam on the viewer, at the same centroid location as noted above. You have found one of the two zero-crossings.
- e) Add or subtract 180 degrees to the buncher zero-crossing phase identified above, to find the other zero crossing. Switch back and forth between the two zero crossing phases while observing the beam center on the spectrometer viewer. The beam center should not change on the viewer. If it does, adjust the zero crossing phase by plus or minus 2 degrees and repeat. Stop when adjustment less than 2 degrees is required. (Note: at this point there is an ambiguity as to which zero crossing provides the desired bunching phase. It will be decided later)
- f) Subtract 90 degrees from the buncher phase to operate “on crest”, and adjust the MDIK402 dipole setting to recover beam on the viewer, with beam centroid in the location determined in step (b). Compare the dipole setting with the original value to determine the energy boost provided by the buncher. Adjust the buncher amplitude to obtain 15 kV energy difference between Buncher OFF and Buncher ON/crested. 15 kV is the required buncher voltage predicted by simulation, to set the proper bunchlength at the QCM 2-cell cavity.
- g) Alternatively, measure the electron bunchlength versus buncher power, using the harmonically resonant Brock cavity bunchlength monitor. The cavity has limited bandwidth and can only resolve 30 ps bunches and longer, whereas a ~ 1 ps bunch is required at the 2-cell cavity. Extrapolate results to infer the required buncher amplitude to obtain 1 ps bunches, and then reduce the buncher amplitude by the ratio of distances, (buncher to Brock cavity)/(buncher to 2-cell cavity). Compare these results to that obtained in Step 2f, and the expected buncher power of 40 W, log the results.

Step 3: set MeV steering magnets to Zero integrated field ( $Bdl = 0$ ), set the four quad magnets (MQJM501, MQJM502, MQJM503, and MQJM504) to expected values for 200 keV beam

Step 4a: with the buncher cavity OFF and the chopper cavities ON, “float” 200 keV beam through the QCM (no RF applied to the 2 or 7-cell cavities inside the QCM), steer beam to viewer ITVM402. This should be easy, this viewer is immediately downstream of the QCM, and then attempt to deliver 200 keV beam all the way to the waist height MeV beam dump IDLM601. Steer beam onto viewers ITVM504 and ITVM601, adjust the four quads empirically to obtain small round beam at viewers. Perform an “all save” and log results.

Step 4b: now “float” 200 keV beam to the MeV spectrometer dump IDLM703. Begin by setting dipole magnet MDLM601 to the expected value for 200 keV beam. There is little uncertainty in beam energy for this step – the beam energy is equal to the gun bias voltage, which is well known, and dipole magnet MDLM601 was accurately mapped. Therefore, only adjustments to steering magnet should be required to see beam on dump viewer ITVM703. Perform an “all save” and log results.

Step 5: Viewers are spaced relatively far apart, it could be difficult to deliver beam to the MeV dumps IDLM601 and IDLM703 using only viewers. It is permissible to go to “Tune Mode” using BPMs to assist steering the “soft” 200 keV beam to the dumps:

- Insert the keV Faraday Cup IFYK403 and adjust the laser attenuator to obtain 100 nA in Tune Mode (this corresponds to 8uA macropulse, considered safe for hardware)
- Remove the keV Faraday Cup IFYK403 to send beam through the QCM. Steer beam up/down/left/right looking for BPM signals, working sequentially downstream from the QCM to the waist height beam dumps, IDLM601 and IDLM703.
- After obtaining BPM signals, insert viewers, adjust quads to obtain round beam images, log the results
- Perform an “all save” and log results

Step 6: Commissioning process “break point” - This is the first in a series of commissioning process “break points” to assess machine and personnel protection systems. Break points are scheduled at beam energies 200 keV, 500 keV, 1 MeV, 5 MeV and 10 MeV:

- a) Set the laser attenuator to provide 100 nA average current while in Tune Mode, measured at keV Faraday Cup IFYK403 (there are no ItoV amps at UITF, 100 nA average current corresponds to 8 uA of “machine safe” Tune Mode beam)
- b) Send this Tune Mode beam to Faraday Cup 3 (IFYM401), and to the straight-ahead dump IDLM601, and then the spectrometer dump ILDM703
- c) In sequential order, use steering magnets near BLMs ILMM401, ILMM601 and ILMM701 to intentionally steer beam into the beam pipe wall near these BLMs, working together with SSG to adjust BLM sensitivity to trip OFF beam. It is preferable to steer beam into the beam pipe using Tune Mode where there is little concern for venting the beamline, but CW current up to 1 uA maybe be employed for brief periods (< 1 minute).
- d) Note increased pressure near adjacent ion pumps, and whether valves CLOSE if ion pump current > 100 nA. Stop to troubleshoot if valves do NOT close when ion pump current exceeds the trip limit.
- e) Work with RCD to measure radiation levels inside and outside the UITF enclosure by delivering beam to Faraday Cup 3 (IFYM401), which is intentionally unshielded for this test. Faraday Cup 3 is the first cup downstream of the QCM and adjacent to the control room. Measure radiation levels by intentionally steering the beam into the beamline vacuum chamber wall, in Tune Mode and low current CW mode (~ 1 uA), in the vicinity of the waist height dumps located near the labyrinth exit, which represents a potential weak point in terms of radiation shielding.
- f) Log results

Step 7: Deliver 500 keV beam to the straight-ahead dump IDLM601, and then the spectrometer dump ILDM703 spectrometer dump, using the QCM 2-cell capture section. If 200 keV beam was successfully

delivered to the MeV beam dumps, this process should proceed relatively easily/quickly because magnet values can be sensibly scaled. However, if 200 keV beam delivery to the MeV beam dumps was unsuccessful, this step could take more time, finding beam on viewers and/or BPMs for the first time:

- a) With beam to the spectrometer dump viewer ITVM703, turn ON the buncher at the design amplitude found earlier and verify the two zero crossing phases (centroid of beam spot does not move on viewer, buncher ON and OFF)
- b) Turn OFF the buncher
- c) Turn ON the 2-cell at a low RF gradient setting, 0.26 MV/m, which corresponds to 10% of the design operating gradient, adjust dipole magnet MDLM601 to center beam on the spectrometer dump viewer ITVM703
- d) Swing the phase of the 2-cell from zero to 360 degrees and observe the beam motion on the spectrometer viewer ITVM703. If the beam motion is too small, increase the RF amplitude delivered to the QCM 2-cell cavity to obtain beam motion comparable to the size of the view screen.
- e) Find the two zero crossings of the 2-cell cavity following a similar procedure outlined for the buncher, document these phases (centroid of beam spot does not move on viewer, 2-cell RF ON and OFF)
- f) Turn ON the buncher and the 2-cell, setting both to zero crossing – there are four combinations. Choose the combination that gives the shortest horizontal beam size at the spectrometer viewer.
- g) Now that the correct zero crossing phases are found for both buncher and the 2-cell cavity, find the crest phase of the 2-cell cavity by adding or subtracting 90 degrees. Choose the phase that provides the highest beam energy at the spectrometer (beam appearing on the right-most position on viewer)
- h) Set the quad magnets MQJM501, MQJM502, MQJM503, and MQJM504 to the expected settings for 500 keV beam, set the 2-cell cavity gradient to 2.6 MV/m, set dipole magnet to MDLM601 the expected value for 500 keV beam. Steer beam to the dump viewer ITVM703. “Crest” the 2-cell by adjusting the 2-cell cavity rf-phase. The cavity is crested when the beam has moved to the right-side of the viewer, and can move no further to the right, subtending the smallest deflection angle, corresponding to beam of highest energy. If the dipole magnet setting was adjusted in order to find beam on the viewer, restore the dipole setting to the expected 500 keV value, while fine tuning the 2-cell rf amplitude until beam is centered on the viewer.
- i) At this point, the buncher can be energized. Vary the buncher amplitude (and phase) while looking at beam on the spectrometer dump viewer: adjust buncher amplitude to improve the quality of the beam image (e.g., minimize beam tail)
- j) Harp scans can be performed, for energy spread and emittance measurements (these measurements can be omitted in favor of turning ON the QCM 7-cell cavity to make MeV beam). Perform an “all save” and log results
- k) **Commissioning Process “break point”**. Work with SSG and RCD to evaluate BLM functionality and shielding effectiveness as described in Step 6 above.

Step 8: Deliver MeV beam to the ILDM703 spectrometer dump using the QCM 7-cell cavity:

- a) Set the quad magnets MQJM501, MQJM502, MQJM503, and MQJM504 to expected settings for 1 MeV beam
- b) Set the 7-cell RF gradient to the expected operating value (0.7 MV/m) and steer beam to viewers. BPMs can be used to steer beam using Tune Mode, if necessary
- c) Steer beam to the straight-ahead dump IDLM601, and then steer beam to the spectrometer dump viewer by energizing the dipole magnet MDLM601 (it will be easier and easier to set the dipole magnet strength, by virtue of scaling previous values obtained for lower beam energy)
- d) Once beam is established on the dump viewer ITVM703, “crest” the 7-cell by adjusting the 7-cell cavity rf-phase. The cavity is crested when the beam has moved to the right-side of the viewer, and can move no further to the right, subtending the smallest deflection angle, corresponding to beam of highest energy. Compare the dipole current to the expected setting for 1 MeV beam.
- e) At this point, buncher and 2-cell settings can be adjusted while looking at beam on the spectrometer dump viewer to improve the quality of the beam image (e.g., minimize beam tail). Perform harp measurements to evaluate energy spread and beam emittance.
- f) Perform an “all save” and log results
- g) **Commissioning Process “break point”**. Work with SSG and RCD to evaluate BLM functionality and shielding effectiveness as described in Step 6 above.

Step 9: Increase beam energy incrementally to 5 MeV and then 10 MeV, by increasing the RF power applied to the QCM 7-cell

- a) Repeat Step 8 for higher beam energies, 5 MeV and then 10 MeV. This should be relatively quick/easy – increasing the current supplied to the dipole magnet MDLM601 as the rf amplitude to the 7-cell cavity is increased incrementally, while maintaining beam on the spectrometer dump viewer ITVM703, requiring only small adjustments to steering and quad magnets along the way. Settings for the 7-cell cavity gradient are 6.4 and 13.6 MV/m, for 5 and 10 MeV beam, respectively. These gradient settings are below the onset of field emission.
- b) Perform an “all save” at each beam energy and log results

**Process when the Yao cavity time-of-flight system is available:**

Former JLab staff member C. G. Yao devised a method to measure the electron bunch length at the CEBAF injector using a small pillbox cavity that resonates at 6 GHz, which is the 4<sup>th</sup> harmonic of CEBAF accelerating cavity frequency. In normal practice, determining the electron bunchlength is not the motivation for using this cavity, rather the Yao-bunchlength measurement technique is mostly employed to set rf phases of the injector rf bunching and accelerating cavities. Specifically, Yao cavities are used to find zero-crossing phases of rf-elements, and to determine longitudinal beam waists, via the “time-of-flight” technique. The technique is described in publications, and a brief description is given here.

At UITF, the Yao cavity technique will be employed to find the phases for zero-crossing (i.e., the bunching phases) of the 2 and 7-cell cavities in the QCM. Once the zero-crossing phases are obtained for the 2 and 7-cell cavities, 90 degrees will be added to these values to obtain phases for on-crest acceleration. In addition, the Yao cavity will validate the buncher settings found using the keV

spectrometer beamline, in particular the buncher amplitude that provides a longitudinal waist at the QCM 2-cell cavity.

Basic approach: The drive-laser rf phase is varied to slew the electron bunch across a narrow slit that resides between the UITF rf-deflector cavities (i.e., the UITF “chopper”). In this way, the head, the middle, and the tail of the electron bunch can be delivered to a Yao cavity located downstream of rf components that need to be set properly. The phase of the signal excited within the Yao cavity is compared to a stable/constant reference phase. When the rf phase of the cavity in question is set properly (i.e., for zero crossing), the arrival times of the different portions of the electron bunch that pass through the narrow chopper slit are identical, and the phase of the signal from the Yao cavity will appear as a constant value while the drive-laser rf phase is varied.

As mentioned above, the biggest challenges associated with commissioning the UITF accelerator is finding (for the first time) the proper rf phases of the 2 and 7-cell cavities of the QCM, and the buncher amplitude that provides the desired electron bunch length at the QCM 2-cell cavity. The Yao cavity and Faraday Cup 3 are positioned near the output of the QCM and as a result, it will be fairly easy to deliver beam to through the Yao cavity at all of the beam energies described above, even for 200 keV beam which is considered “soft”.

### **Procedure continued:**

Step 10: Find the buncher rf amplitude that provides minimum bunchlength at the QCM 2-cell rf cavity

- a) In Tune Mode.....after using the 200 keV spectrometer to find the buncher zero-crossing, deliver beam through the Yao cavity ICBM401 and to Faraday Cup 3 IFYM401.
- b) Implement the Yao cavity software which varies the drive laser rf-phase and provides epics readback of the Yao cavity signal.
- c) With buncher amplitude set to 10 W (~ 25% of design value), verify that the zero-crossing phase determined using the 200 keV spectrometer beamline yields a Yao cavity signal with minimal variation when the drive laser rf phase is varied.
- d) Slowly increase the buncher rf amplitude to further minimize the variation in the Yao cavity signal, and then observe the signal grow as buncher rf amplitude is increased further. The rf amplitude that provides minimum variation corresponds to the setting that provides a minimum bunchlength at the location of the Yao cavity.
- e) To set the bunchlength minimum at the QCM2-cell cavity (which is the objective of this step), increase the amplitude of the buncher rf by the ratio of distances: (buncher to yao cavity)/(buncher cavity to the center of the 2-cell), which corresponds to factor 2.26. Compare this value to the expected value of 40W and log the results.

Step 11: Find the crest phase for the QCM 2-cell cavity

- a) Turn OFF the buncher. Deliver 200 keV beam to Faraday Cup 3.
- b) Set the 2-cell rf gradient to 10% of expected operating gradient, 0.26 MV/m.
- c) While noting the signal from the yao cavity, adjust the 2-cell phase to minimize the variation in the signal, corresponding to zero-crossing phase. The amplitude of the 2-cell rf can be increased if necessary, to provide a more definitive Yao cavity signal.



d) Now add 90 degrees to the 2-cell rf phase for on-crest operation.

Step 12: Find the crest phase for the QCM 7-cell cavity

- a) Turn OFF the buncher but leave the QCM 2-cell cavity powered at nominal settings to provide 500 keV beam to the QCM 7-cell cavity
- b) Repeat Step 11 above for the 7-cell cavity.....

After completing these Yao cavity measurements, the buncher amplitude should now be relatively close to the intended operational value, and the 2 and 7-cell cavity phases corresponding to on-crest operation will be known to within a few degrees. It should now be fairly easy to deliver MeV beam to the MeV beam dumps. Start at Step 8 above, to fine tune rf settings using the MeV spectrometer line.

### **Commissioning Plan Pre-Ops Check List:**

Verify shielding credited controls in-place per RCD specifications

Check status of the helium vent barrier grating, in-place with RCD locks

Check status of the Rapid Access monitor in the UITF control room: test button, all lights illuminated, no harmful radiation present

Set Gun HV power supply current limit to 12 uA using EPICS controls

Remove the lock from the ball valve used to provide compressed air to the valve immediately upstream of the QCM (VBVM101), and open the valve

Verify RCD signage in place:

- at both doorways
- "high radiation area" postings in place at cave 2 roof boundary.
- flip the signs at the access stair to Cave1 rooftop, to display RCA posting

Verify functioning PSS beacons

Table 1 from the UITF ARR Plan:

Jefferson Lab will conduct the ARR under the conditions shown below in *Table 1 - Operating Parameters for Commissioning and Operations*.

**Table 1 - Operating Parameters for Commissioning and Operations**

ARR Phase	Beam Termination	Beam Mode	Beam Current (nanoA)	Beam Energy (keV)
Commissioning	Beam in the injector up to but not including the QCM	CW	1.0E+05	200
	Beam to post-QCM cup and dumps	Tune-Mode*	1.0E+02	10,000
	“beam spill tests**” with RCD	CW	Up to 1.0E+4	10,000
Operations	Beam in the injector up to but not including the QCM	CW	1.5E+07	200
	Beam to post-QCM cup and dumps	CW	1.0E+05	10,000

\*Tune-Mode beam is ensured by one hardware and one administrative method.

Acceptable Hardware Methods:

- 1) beam current monitors set to trip on CW
- 2) current limit on the gun high voltage power supply

Acceptable Administrative Methods:

- 1) button for CW disabled in software
- 2) posted operator instructions and trained operators

\*\* “spill tests” with RCD representing less than 10% of total commissioning time

**Elegant settings for MeV dipole, quads and keV solenoids (elegant units, will convert to current)**

Cases	Start			Exit Gun		Exit 2-Cell		Exit 7-Cell	
	End			IDLM 601	IDLM703	IDLM 601	IDLM703	IDLM 601	IDLM703
Simulated Beam Parameters	Energy	MeV		0.200		0.500		7.000	
	Momentum	MeV/c		0.494		0.872		7.494	
	Twiss Source	n/a		GPT – Gun		GPT – Booster		GPT – Booster	
	Norm Hor Emit	Mm-mrad		0.36900		0.500		0.550	
	Norm Ver Emit	Mm-mrad		0.36900		0.300		0.350	
	Beta Hor	Meter		1.34500		7.000		10.000	
	Beta Ver	Meter		1.34500		7.000		10.000	
	Alpha Hor	1/Rad		-2.93000		-2.500		5.000	
	Alpha Ver	1/Rad		-2.93000		-1.000		5.000	
	dp/p	#		5.00E-05		3.70E-04		3.70E-04	
	ds	sec		5.00E-11		1.00E-12		4.00E-13	
Elegant	ELEGANT OPTIMIZATION RESULTS ARE LISTED BELOW (unhighlighted values are standard demonstrated setup)								
	ELEMENT	TYPE	PARAM						
Standard 200keV Beam line	MFH1K01	SOLE	KS	11.000	11.000	11.000	11.000	11.000	11.000
	MFB2K02	SOLE	KS	13.400	13.400	13.400	13.400	13.400	13.400
	MFA3K01A	SOLE	KS	12.700	12.700	12.700	12.700	12.700	12.700
	MFA3K01B	SOLE	KS	-12.700	-12.700	-12.700	-12.700	-12.700	-12.700
	MFD3K02AA	SOLE	KS	11.980	11.980	11.980	11.980	11.980	11.980
	MFD3K02AB	SOLE	KS	-11.980	-11.980	-11.980	-11.980	-11.980	-11.980
	MFD3K02BA	SOLE	KS	11.980	11.980	11.980	11.980	11.980	11.980
MFD3K02BB	SOLE	KS	-11.980	-11.980	-11.980	-11.980	-11.980	-11.980	
Matching 200 keV Solenoids	MFA3K03A	SOLE	KS	-8.000	-8.000	-12.000	-12.000	-12.000	-12.000
	MFA3K03B	SOLE	KS	8.000	8.000	12.000	12.000	12.000	12.000
	MFA4K03A	SOLE	KS	-4.500	-4.500	-11.000	-11.000	-11.000	-11.000
	MFA4K03B	SOLE	KS	4.500	4.500	11.000	11.000	11.000	11.000
MatchingQuads	MQJM501	QUAD	K1	2.778	4.979	-1.854	-2.564	3.248	1.195
	MQJM502	QUAD	K1	-2.399	-8.805	1.178	0.389	3.858	-2.044
	MQJM503	QUAD	K1	-2.263	4.726	0.674	0.947	1.110	-8.359
	MQJM504	QUAD	K1	2.295	-0.720	0.885	1.013	-6.446	7.342
Dipole	MDLM601	CSBEND	ANGLE	0.000	-30.000	0	-30.000	0.000	-30.000
MeVSpectrometer	MQJ7M01	QUAD	K1	Not Applicable	Tuning knob	Not Applicable	Tuning knob	Not Applicable	Tuning knob
	MQJ7M02	QUAD	K1		Tuning knob		Tuning knob		Tuning knob