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Drift Tube Linac Tanks 4-6 and Coupled Cavity Linac Modules 1-3 Beam Commissioning Plan

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by

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1. INTRODUCTION

This document presents the beam commissioning plan for the Drift Tube Linac tanks four through six and Coupled Cavity Linac modules one through three of the SNS linear accelerator. The accelerator system for this commissioning run consists of the Front-End Systems (FES), Drift Tube Linac Tanks 1,2,3,4,5, and 6 (DTL1-6), Coupled Cavity Linac Modules 1,2,3 (CCL1-3) and a temporary beam stop. The FES and DTL1-3 were previously commissioned with beam.

1.1 SYSTEM LAYOUT AND CONFIGURATION

1.1.1 Drift Tube Linac Tank 4-6 and CCL modules 1-3

The DTL Tanks 4-6 and CCL modules 1-3 system for this commissioning run are shown in Figure 1. A shielding enclosure surrounds the DTL, CCL and temporary beam stop. The Front-End Systems and DTL1-3 hardware are identical to that which was commissioned at ORNL earlier. DTL tanks 4-6, and CCL modules 1-3 and the temporary beam stop are new hardware which will be commissioned with beam for the first time. (CCL4 is installed and will be used for beam transport but will not be commissioned as an accelerating device) .The basic parameters for DTL tanks 4-6 and CCL modules 1-3 are given in Table 1. The DTL tanks 4-6 and CCL modules 1-3 output beam parameters are summarized in Table 2. This table shows both the design parameters, where applicable, and the performance goal that we would like to achieve during beam commissioning.

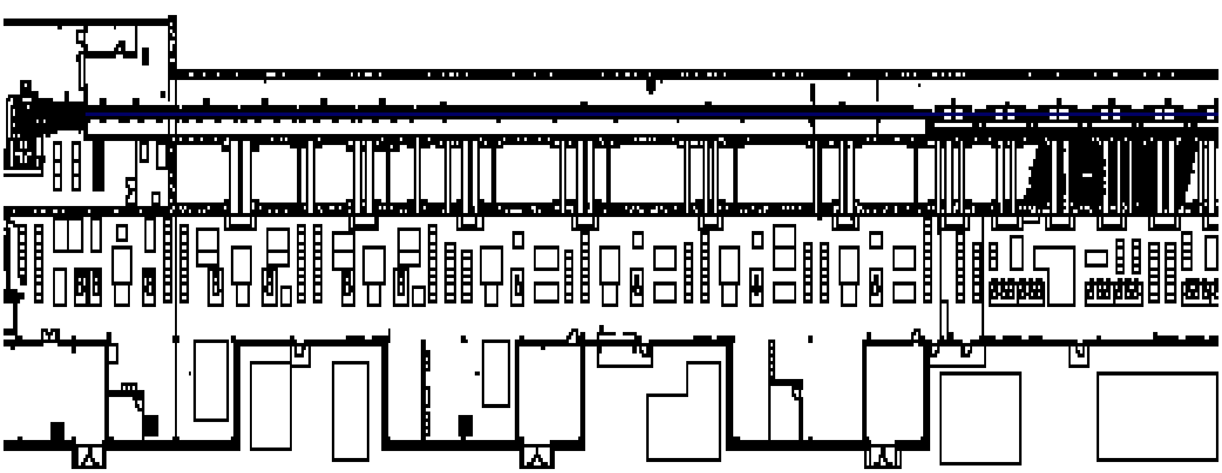

Figure 1. Layout of DTL tanks 4-6, CCL modules 1-3 and the beam stop for beam commissioning.

Table 1a. Drift Tube Linac Tank 4 Design Parameters	
Resonant Frequency	402.5 MHz
Bore radius	12.5 mm
Tank Length	6.411m (between inside end walls)
Number of cells	28
Energy Gain	16.77 MeV
Stored Energy	22.2 J
Synchronous phase	-25°
Average E_0T	2.9 MV/m
Shunt Impedance ZT^2	41.91 MΩ/m
Unloaded Quality Factor (design/measured)	42492/48118
External Quality Factor (design/measured)	29812/36875
Peak RF Structure Power	1140 kW
Focusing structure	FFODDO
Focusing period	6 βλ
Table 1b. Drift Tube Linac Tank 5 Design Parameters	
Resonant Frequency	402.5 MHz
Bore radius	12.5 mm
Tank Length	6.294m (between inside end walls)
Number of cells	24
Energy Gain	15.98 MeV
Stored Energy	22.1 J
Synchronous phase	-25°
Average E_0T	2.89 MV/m
Shunt Impedance ZT^2	40.83 MΩ/m
Unloaded Quality Factor (design/measured)	43429/48088
External Quality Factor (design/measured)	29981/37654
Peak RF Structure Power	1160 kW
Focusing structure	FFODDO
Focusing period	6 βλ
Table 1c. Drift Tube Linac Tank 6 Design Parameters	
Resonant Frequency	402.5 MHz
Bore radius	12.5 mm
Tank Length	6.341m (between inside end walls)
Number of cells	22
Energy Gain	14.31 MeV
Stored Energy	21.5 J
Synchronous phase	-28° to -49°
Average E_0T	2.78 MV/m
Shunt Impedance ZT^2	39.03 MΩ/m
Unloaded Quality Factor (design/measured)	43316/48139
External Quality Factor (design/measured)	30863/36056
Peak RF Structure Power	1130kW
Focusing structure	FFODDO
Focusing period	6 βλ

Table 1d. Coupled Cavity Linac Module 1 Design Parameters	
Resonant Frequency	805 MHz
Bore radius	15 mm
Tank Length	11.839m
Number of cells	96 in 12 segments
Energy Gain	20.33 MeV
Stored Energy	6.63 J
Synchronous phase	-30°
Average E_0T	1.983 MV/m
Shunt Impedance ZT^2	21.89MΩ/m
Unloaded Quality Factor (design/measured)	16310/18000
External Quality Factor (design/measured)	12309/11583
Peak RF Structure Power	1930 kW
Focusing structure	FODO
Focusing period	13 βλ

Table 1e. Coupled Cavity Linac Module 2 Design Parameters	
Resonant Frequency	805 MHz
Bore radius	15 mm
Tank Length	12.946m
Number of cells	96 in 12 segments
Energy Gain	23.979MeV
Stored Energy	8.23J
Synchronous phase	-30°
Average E_0T	2.139 MV/m
Shunt Impedance ZT^2	24 MΩ/m
Unloaded Quality Factor (design/measured)	17418/18700
External Quality Factor (design/measured)	13089/14626
Peak RF Structure Power	2300 kW
Focusing structure	FODO
Focusing period	13 βλ

Table 1f. Coupled Cavity Linac Module 3 Design Parameters	
Resonant Frequency	805 MHz
Bore radius	15 mm
Tank Length	14.001m (between inside end walls)
Number of cells	96 in 12 segments
Energy Gain	26.074 MeV
Stored Energy	21.84 J
Synchronous phase	-29.5° (average)
Average E_0T	2.14 MV/m
Shunt Impedance ZT^2	25.71 MΩ/m
Unloaded Quality Factor (design/measured)	18.432/19332
External Quality Factor (design/measured)	13.597/16029
Peak RF Structure Power	2380kW
Focusing structure	FODO
Focusing period	13 βλ

Table 2a. DTL tank 4 output beam parameters		
Parameter	Design Value	Performance Goal
Input Energy [MeV]	39.7652	39.77 ± 0.03*
Output Energy [MeV]	56.5364	56.54± 0.03*
Peak Macropulse Current [mA]	38	> 38
Beam pulse length [msec]	1.0	<.05
Repetition Rate [Hz]	60	<1
Duty Factor [%]	6	<.005
Chopped Beam Gap [%]	32	32
Transverse jitter and variation within a pulse [mm]	N/A	< 0.1
Energy jitter and variation within a pulse [MeV]	N/A	< 0.03*
Phase jitter and variation within a pulse [deg]	N/A	< 2.0
Tank 4 Beamloss	< 7 W	< 4% (measurable loss threshold)

Table 2b. DTL tank 5 output beam parameters		
Parameter	Design Value	Performance Goal
Input Energy [MeV]	56.5364	56.54± 0.03*
Output Energy [MeV]	72.5208	72.52± 0.03*
Peak Macropulse Current [mA]	38	> 38
Beam pulse length [msec]	1.0	<.05
Repetition Rate [Hz]	60	<1
Duty Factor [%]	6	<.005
Chopped Beam Gap [%]	32	32
Transverse jitter and variation within a pulse [mm]	N/A	< 0.1
Energy jitter and variation within a pulse [MeV]	N/A	< 0.03*
Phase jitter and variation within a pulse [deg]	N/A	< 2.0
Tank 5 Beamloss	< 7 W	< 4% (measurable loss threshold)

Table 2c. DTL tank 6 output beam parameters		
Parameter	Design Value	Performance Goal
Input Energy [MeV]	72.5208	72.52± 0.03*
Output Energy [MeV]	86.8277	86.83± 0.03*
Peak Macropulse Current [mA]	38	> 38
Beam pulse length [msec]	1.0	<.05
Repetition Rate [Hz]	60	<1
Duty Factor [%]	6	<.005
Chopped Beam Gap [%]	32	32
Transverse jitter and variation within a pulse [mm]	N/A	< 0.1
Energy jitter and variation within a pulse [MeV]	N/A	< 0.05*
Phase jitter and variation within a pulse [deg]	N/A	< 2.0
Tank 6 Beamloss	< 7 W	< 4% (measurable loss threshold)

*Limited by measurement accuracy

Table 2d. CCL module 1 output beam parameters

Parameter	Design Value	Performance Goal
Input Energy [MeV]	86.8277	86.83± 0.03[*]
Output Energy [MeV]	107.1613	107.16± 0.03[*]
Peak Macropulse Current [mA]	38	> 38
Beam pulse length [msec]	1.0	<.05
Repetition Rate [Hz]	60	<1
Duty Factor [%]	6	<.005
Chopped Beam Gap [%]	32	32
Transverse jitter and variation within a pulse [mm]	N/A	< 0.1
Energy jitter and variation within a pulse [MeV]	N/A	< 0.03[*]
Phase jitter and variation within a pulse [deg]	N/A	< 2.0
Module 1 Beamloss	< 12 W	< 4% (measurable loss threshold)

Table 2e. CCL module 2 output beam parameters

Parameter	Design Value	Performance Goal
Input Energy [MeV]	107.1613	107.16± 0.03[*]
Output Energy [MeV]	131.1402	131.14± 0.03[*]
Peak Macropulse Current [mA]	38	> 38
Beam pulse length [msec]	1.0	<.05
Repetition Rate [Hz]	60	<1
Duty Factor [%]	6	<.005
Chopped Beam Gap [%]	32	32
Transverse jitter and variation within a pulse [mm]	N/A	< 0.1
Energy jitter and variation within a pulse [MeV]	N/A	< 0.03[*]
Phase jitter and variation within a pulse [deg]	N/A	< 2.0
Module 2 Beamloss	< 13 W	< 4% (measurable loss threshold)

Table 2f. CCL module 3 output beam parameters

Parameter	Design Value	Performance Goal
Input Energy [MeV]	131.1402	131.14± 0.03[*]
Output Energy [MeV]	157.2143	157.21± 0.03[*]
Peak Macropulse Current [mA]	38	> 38
Beam pulse length [msec]	1.0	<.005
Repetition Rate [Hz]	60	<1
Duty Factor [%]	6	<.005
Chopped Beam Gap [%]	32	32
Transverse jitter and variation within a pulse [mm]	N/A	< 0.1
Energy jitter and variation within a pulse [MeV]	N/A	< 0.05[*]
Phase jitter and variation within a pulse [deg]	N/A	< 2.0
Module 3 Beamloss	< 14 W	< 4% (measurable loss threshold)

1.1.2 Beam stops

There are eight beam stops or intercepting absorbers which will be used in this commissioning run. The first is located in the anti-chopper box in the MEBT. This beam stop, constructed of carbon-carbon composite material, is electrically isolated and provides a current signal. The next six intercepting absorbers are energy degrader/faraday cup (ED/FC) diagnostic systems located at the end of each DTL tank. They consist of a carbon (1-3) or copper (4-6) energy degrader and isolated beam absorber, which provide accelerated beam current signals. A temporary copper absorber is located at the end of the CCL4 and also provides current readout capability. The maximum beam parameters for safe operation of each beam stop are given in Table 3.

Table 3. Beam power capability for beam stops and intercepting absorbers

	Beam current** (mA)	Pulse length (μs)	Repetition Rate (Hz)	Average Power (W)	Single Pulse Energy (J)
MEBT Beam Stop*	40	50	3	15	5
EDFC-1	40	50	2	30	15
EDFC-2	20	50	1	23	23
EDFC-3	20	50	2	80	40
EDFC-4	18	50	2	100	50
EDFC-5	18	50	2	130	65
EDFC-6	30	50	1	130	130
Temporary beam stop	26	200	2	1630	815

*No active cooling
** Average over pulse

1.1.3 Diagnostic Systems

The front-end systems' diagnostic suite is the same that was used in the previous commissioning runs. There are no diagnostic systems in DTL tank 1 proper. Tanks 2-6 each have a pair of beam position and phase monitors (BPM) inside the drift tubes. A diagnostics beam box, which includes a wire scanner (WS), energy degrader/faraday cup (ED/FC) system and transformer type beam current monitor (BCM), is located after all DTL tanks. Theh CCL system has 10 BPMs, 9 wire scanners, 1 BCM and 3 Beam Shape Monitors (BSM) distributed over 4 modules as described in Table 4. There is an additional BCM and wire scanner installed between the exit of the CCL module 4 and the temporary beam stop. Operational limitations of the interceptive diagnostic devices are summarized in Table 5. The Machine Protection System (MPS) ensures that these devices can be operated only in the appropriate machine mode to avoid damage to the devices.

Table 4. Diagnostics locations in CCL

CCL module	BPM	WS	BSM	BCM
Module #1	3	4	3	1
Module #2	2	2	0	0
Module #3	2	2	0	0
Module #4	3	2	0	0

Table 5. Beam power capabilities of the diagnostic systems*			
System	Peak Current (mA)	Maximum Pulse Length (μs)	Maximum Repetition Rate (Hz)
MEBT Wire Scanners	50	50	5
MEBT Aperture	38	50	30
DTL and CCL Wire Scanners	38	50	5

*Longer pulse lengths are acceptable at lower peak current, such that the product of current and pulse length is maintained within the value shown in the table.

1.2 COMMISSIONING GOALS

The primary beam commissioning goals are the following:

- Bring DTL tanks 4-6, CCL segments1-3 and all associated sub-systems into beam operation
- Characterize the primary beam parameters and achieve the beam performance goals outlined in Table 2
- Develop and validate procedures which will be used for tuning during operations
- Characterize the beam performance versus tuning variables, and
- Measure losses consistent with the measurable loss limit.

If time permits we would like to accomplish several secondary goals, namely

- Measure pulse-to-pulse jitter in beam parameters
- Test the LEBT chopper systems, and
- Measure transmission of the chopped beam.

1.3 COMMISSIONING BEAMS

Since the LEBT chopper systems will be commissioned later in the commissioning run, we plan to use unchopped beam for the bulk of the commissioning studies. The beams will be consistent with the beam-handling capabilities of the diagnostics systems in use at the time.

1.3.1 Peak Current

We plan to perform the bulk of the commissioning studies with a 20 mA peak current beam. This is a current with which we have much experience in the previous runs and which is readily and routinely achievable from the ion source and front-end systems. At the end of the commissioning run we will attempt to increase the peak current to the nominal 38 mA to obtain a set of beam parameter measurements and design current. We may occasionally insert the current limiting aperture to perform other studies at low current, and may during the 38 mA run, drop the peak current to 20 mA for certain studies and operations.

1.3.2 Pulse Length

The pulse length will be set typically by the limitations of the diagnostic system and beam stop in use at the time. For initial injection into the new DTL tanks and CCL modules, we will use a pulse length less than 20 μsec until we are assured that the beam transmission to the beam stop is adequate. The rest of the commissioning measurements will be carried out at less than 50 μsec pulse length, consistent with beam stop limitations. The MPS pulse width key will be always in the 50 μsec position to prevent accidental run at larger pulse width.

1.3.3 Repetition Rate

The entire commissioning program will be carried out at low repetition rate, equal or less than 1 Hz. "Beam on demand" mode will be used whenever it's possible and appropriate in order to minimize activation of the hardware by the high energy beam. A single beam pulse is accelerated upon request in this mode.

2. BEAM OPTICS

2.1 NOMINAL OPTICS

The nominal beam envelopes are shown in Figures 3 and 4 for 20 mA operation and 38 mA operation, respectively. The nominal MEBT rebunchers and quadrupoles settings are given in Table 5. Rebuncher phases will be set using proper tuning algorithms with beam. Nominal amplitude and phase settings for the DTL and CCL cavities will be found using proper tuning algorithms with beam. The nominal CCL quadrupoles settings are given in Table 6. It should be noted that nominal settings of the CCL quadrupoles will provide lossless beam transport to the temporary beam stop independent of amplitude or phase settings of the DTL6 and CCL1-3.

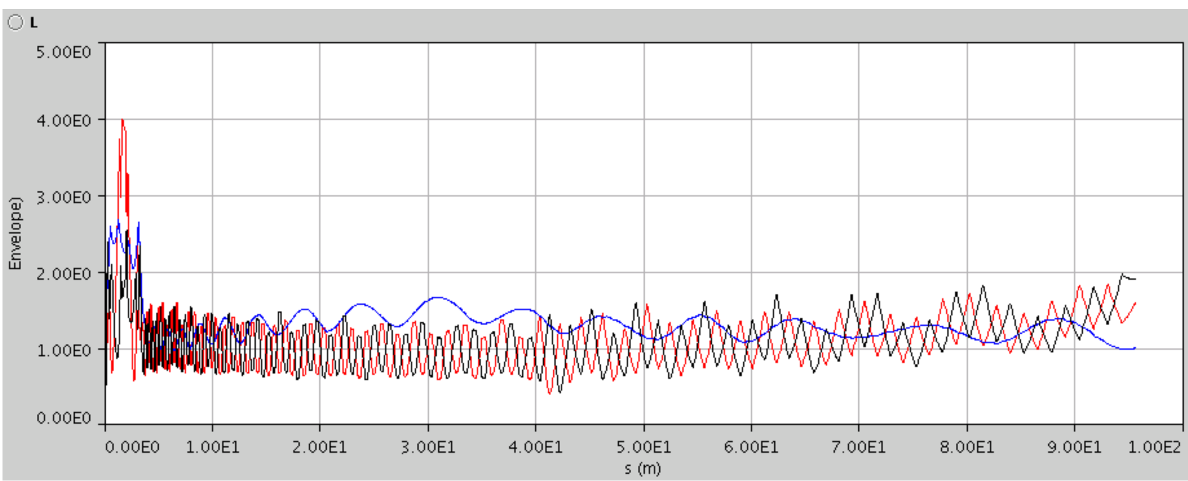

Figure 3. On-line model beam envelope profiles for 20mA operation.

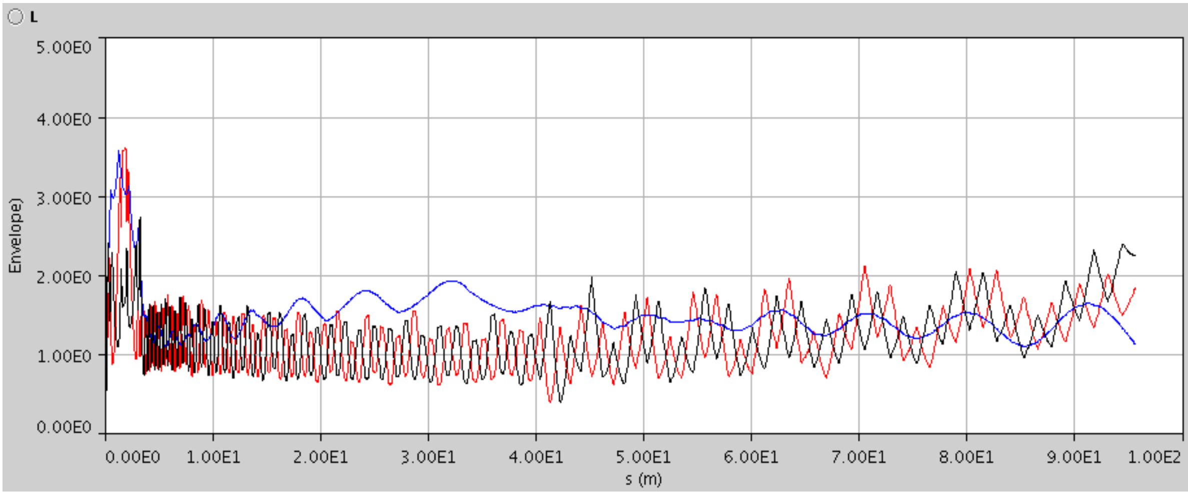

Figure 4. On-line model beam envelope profiles for 38mA operation.

Table 5. MEBT quadrupole and rebuncher setpoints		
QH01 [T/m]	-34.64	
QV02 [T/m]	36.81	
QH03 [T/m]	-28.33	
QV04 [T/m]	16.12	
QH05 [T/m]	-17.00	
QV06 [T/m]	26.20	
QH07 [T/m]	-11.70	
QH08 [T/m]	-11.70	
QV09 [T/m]	26.20	
QH10 [T/m]	-17.00	
QV11 [T/m]	16.72	
	38mA	20mA
QH12 [T/m]	-25.96	-29.39
QV13 [T/m]	27.58	26.95
QH14 [T/m]	-18.51	-13.6
Rebuncher 1 [kV]	75	
Rebuncher 2 [kV]	45	
Rebuncher 3 [kV]	46	
Rebuncher 4 [kV]	90	

Table 5. CCL quadrupoles setpoints			
Magnet	G [T/m]	(PS#) I[A]	I shunt [A]
QH00	-32.61	(1) -436.09	N/A
QV101	31.34	(2) 320.49	N/A
QH102	-32.51	(3) -332.14	N/A
QV103	29.67	(4) 303.13	N/A
QH104	-26.64	(5) 273	0.8

QV105	26.38	(5) 273	3.5
QH106	-26.11	(5) 273	6.2
QV107	25.84	(5) 273	9.0
QH108	-25.57	(5) 273	11.8
QV109	25.29	(5) 273	14.7
QH110	-25.01	(5) 273	17.5
QV111	24.73	(5) 273	20.4
QH112	-24.45	(6) 251	1.2
QV201	24.18	(6) 251	4.0
QH202	-23.90	(6) 251	6.8
QV203	23.63	(6) 251	9.6
QH204	-23.36	(6) 251	12.4
QV205	23.09	(6) 251	15.1
QH206	-22.82	(6) 251	17.9
QV207	22.55	(6) 251	20.6
QH208	-22.29	(7) 229	1.3
QV209	22.02	(7) 229	4.0
QH210	-21.76	(7) 229	6.7
QV211	21.50	(7) 229	9.4
QH212	-21.24	(7) 229	12.0
QV301	20.98	(7) 229	14.7
QH302	-20.72	(7) 229	17.3
QV303	20.47	(7) 229	19.9
QH304	-20.21	(8) 207	0.5
QV305	19.92	(8) 207	3.4
QH306	-19.64	(8) 207	6.3
QV307	19.36	(8) 207	9.2
QH308	-19.08	(8) 207	12.1
QV309	18.80	(8) 207	15.0
QH310	-18.52	(8) 207	17.8
QV311	18.24	(8) 207	20.7
QH312	-17.96	(9) 184	0.5
QV401	17.69	(9) 184	3.3
QH402	17.41	(9) 184	6.1
QV403	17.14	(9) 184	8.9
QH404	-16.87	(9) 184	11.6
QV405	16.60	(9) 184	14.4
QH406	-16.33	(9) 184	17.1
QV407	16.06	(9) 184	19.9
QH408	-15.80	(10) 161.4	N/A
QV409	15.53	(11) 158.7	N/A
QH410	-13.88	(12) 141.8	N/A
QV411	9.057	(13) 92.54	N/A

3. COMMISSIONING TASKS

The list of commissioning tasks and the beam parameters required for each task are contained in Appendix A. The commissioning proceeds along the following broad outline. First, the Ion Source, RFQ and MEBT beams are prepared. The emphasis at this point is on reliable 20-25 mA source operation, rather than attempting to push the peak current. Once the MEBT beam is brought to the MEBT beam stop, the necessary measurements and tuning operatings are performed. This work is carried out in major tasks 1-2. In task 3, the MEBT beam stop is removed and a low-current, short pulse beam is transported through the remainder of the MEBT with the DTL RF off, in order to properly tune the last rebunchers and correct the latter portion of the MEBT trajectory. In this stage the beam that enters tank 1 is lost on the last several drift tubes. In task 4, tank 1 is powered and this low-current, short-pulse beam is transported to the DTL1 EDFC beam stop and transmission through tank 1 is optimized. In task 5, EDFC 1 is taken out and beam is accelerated through the DTL tank 2 to the EDFC 2 and transmission through tank 2 is optimized. In task 6, EDFC 2 is taken out and beam is accelerated through the DTL tank 3 to the EDFC 3 and transmission through tank 3 is optimized. Acceptance and phase scans are used to establish DTL amplitude and phase set points during these tasks. The corresponding software was commissioned during the previous runs. In task 7, EDFC 3 is taken out and beam is accelerated through the DTL tank 4 to the EDFC 3. Tank 3 set point tuning software is commissioned and transmission through tank 3 is optimized. In task 8, EDFC 4 is taken out and beam is accelerated through the DTL tank 5 to the EDFC 5. Tank 5 set point tuning software is commissioned and transmission through tank 5 is optimized. In task 9, EDFC 5 is taken out and beam is accelerated through the DTL tank 6 to the EDFC 6. Tank 6 set point tuning software is commissioned and transmission through tank 6 is optimized. Finally in Task 10 EDFC 6 is retracted and the temporary beam stop is commissioned. In task 11, characterization of the DTL RF system performance is carried out, fault studies are performed, transmission through the DTL is tuned and absolute energy measurements after each tank are performed. In task 12 the beam is accelerated in the CCL module 1. Module 1 set point tuning software is commissioned and transmission through module 1 is optimized. In task 13 beam is accelerated in CCL module 2. Module 2 set point tuning software is commissioned and transmission through module 2 is optimized. In task 13 beam is accelerated in the CCL module 3. Module 3 set point tuning software is commissioned and transmission through module 3 is optimized. Finally, the peak beam current is increased to 38mA and all systems are tuned for maximum transmission at nominal current.

The remainder of this section presents the detailed instructions for carrying out the individual commissioning tasks.

3.1 ION SOURCE AND RFQ STARTUP

3.1.1 Ion Source startup and cesiation

Follow the ion source startup procedure to produce a 20-25 mA beam.

3.1.2 MPS and timing checkout

Perform MPS system and timing system checkout without beam.

3.1.3 Establish beam through RFQ

Insert the MEBT beamstop. Restore the nominal MEBT settings from the previous run. Set the MPS mode to 50 microseconds, the ion source pulse width to 100 microseconds and the repetition rate to 1 Hz.

Make sure that the RF power for Tank 1 is turned off. Observe the MEBT beam stop and BCM01 signals. Set the RFQ forward power to last run optimal set point and observe the current signals.

3.1.4 LEBT optimization

With beam safely transported to the beam stop, optimize the LEBT settings by observing the BCM01 signal. Measure the RFQ output beam intensity vs. source voltage and LEBT steering. Take an IS saveset at nominal conditions.

3.1.5 Measure RFQ transmission vs. excitation

With source and LEBT optimized for 50 usec, 20 mA, 1 Hz operation, record the BCM01 and beam stop current vs. RFQ forward power in the range 400 kW to 750 kW in 20 kW steps. Be sure to record both feedforward setpoint and forward power readback. Compare to previous measurements obtained from the front-end startup, and set RFQ power appropriately for maximum transmission. Take an IS/RFQ saveset at nominal conditions.

3.1.6 Iterate LEBT optimization and RFQ transmission

With RFQ at nominal power, retune LEBT for maximum transmission and maximum peak current on the MEBT beamstop. Take a saveset.

3.2 TUNE BEAM TRANSPORT TO MEBT BEAM STOP

3.2.1 Check out MEBT BPMS #1-4

Generate 20 mA, 50 microsecond, 1 Hz beam. Observe beam position signals on BPMs 1-4. Adjust BPM timing as necessary. Tune correctors to verify change in beam position on MEBT BPMs.

3.2.2 Set phase of Rebunchers #1-3

With rebunchers set at nominal amplitude, check that the rebuncher LLRF phase and amplitude control loops are working properly. Verify that phase readback tracks command and that amplitude isn't affected and vice versa. Adjust feedback controls as necessary to achieve stable control. Use the MEBT Rebuncher Phase Scan program to find the bunching phase of Rebunchers 1-3. When finished, take a MEBT saveset. Note: Rebuncher 4 will be set in section 3.3.

3.2.3 Trajectory correction up to beam stop

Correct the MEBT trajectory using horizontal and vertical correctors. The trajectory error should be reduced below 1 mm. Record in the logbook the MEBT trajectory for LEBT steerers and MEBT correctors off, for LEBT steerers powered for optimum transmission and MEBT correctors off, and the corrected trajectory and the resulting corrector settings. Record a saveset.

3.2.4 Check out Wire Scanners #1-3

Record beam profiles with wire scanners 1-3 to exercise the systems. Provide beam as necessary for the Diagnostics Group commissioning of the wire scanners.

3.2.5 Beam Envelope measurements and correction up to beam stop

Measure the beam profiles up to the beam stop. Compare with the MEBT model. Derive RFQ output Twiss parameters from the model. Adjust quadrupole strengths as necessary to correct the beam envelopes. Record a saveset.

3.3 BEAM TRANSPORT THROUGH MEBT

3.3.1 Check out BPMs 5 and 6

Make sure MEBT gate valve to DTL Tank 1 is open. Remove MEBT beam stop and observe beam signals on BPMs 5 and 6 in MEBT.

3.3.2 Set rebuncher 3 phase and amplitude

Perform phase scan of rebunchers 3 and 4 using the MEBT phase scan application. Calibrate the rebuncher voltage. Record the calibration constants and set rebunchers at bunching phase and nominal amplitude. Record a savest.

3.3.3 Correct MEBT trajectory

Correct the MEBT trajectory at BPMs 5 and 6 if necessary. Maintain trajectory error less than 1 mm.

3.3.4 Perform phase scan of rebuncher 4

Using the MEBT phase scan application perform phase scan of rebuncher 4 and set at bunching phase. Record a saveset.

3.4 BEAM TRANSPORT THROUGH DTL1 TO EDFC 1

3.4.1 Transport beam to EDFC 1 Beam stop

Summon an RCT to verify shielding. Put Energy Degrader/Faraday Cup signal on the CR scope. Turn on RF to DTL Tank 1 and set at nominal amplitude from the previous run. Adjust DTL1 phase to see signal on scope traces. Tune DTL1 phase and amplitude, MEBT correctors, etc. to maximize FC signal.

3.4.2 Commission Faraday Cup

Provide beam for Diagnostics Group verification of Faraday Cup signal. Have the RCT verify the shielding performance with beam transported to the beamstop.

3.4.3 Perform Acceptance Scan

Using 2-D DTL acceptance scan application find optimal phase and amplitude set point

3.4.4 Tune for maximum transmission

Using EDFC 1 beamstop signal maximize the transmission through DTL tank1 and. Tune DTL1 phase and amplitude, MEBT correctors, matching quads, MEBT rebunchers. Record a DTL+MEBT saveset for optimum conditions.

3.5 BBEAM TRANSPORT THROUGH DTL2 TO EDFC2

3.5.1 Transport beam to EDFC 2 Beam stop

Summon an RCT to verify shielding. Put Energy Degrader/Faraday Cup #2 signal on the CR scope. Turn on RF to DTL Tank 2 and set to nominal design RF power. Retract EDFC1. Adjust DTL2 phase to see signal on scope traces. Tune DTL2 phase and amplitude, MEBT correctors, etc. to maximize FC signal.

3.5.2 Commission Faraday Cup

Provide beam for Diagnostics Group verification of Faraday Cup signal. Have the RCT verify the shielding performance with beam transported to the beamstop.

3.5.3 Perform Acceptance Scan

Using 2-D DTL acceptance scan application find optimal phase and amplitude set point

3.5.4 Tune for maximum transmission

Using EDFC2 beamstop signal maximize the transmission through DTL tank 2. Tune DTL1,2 phase and amplitude, MEBT correctors, matching quads, MEBT rebunchers. Record a DTL1,2+MEBT saveset for optimum conditions.

3.6 BEAM TRANSPORT THROUGH DTL3 TO EDFC3

3.6.1 Transport beam to EDFC 3 Beam stop

Summon an RCT to verify shielding. Put Energy Degrader/Faraday Cup #3 signal on the CR scope. Turn on RF to DTL Tank 3 and set to nominal design RF power. Retract EDFC2. Adjust DTL3 phase to see signal on scope traces. Tune DTL3 phase and amplitude, MEBT correctors, etc. to maximize FC signal.

3.6.2 Commission Faraday Cup

Provide beam for Diagnostics Group verification of Faraday Cup signal. Have the RCT verify the shielding performance with beam transported to the beamstop.

3.6.3 Perform Acceptance Scan

Using 2-D DTL acceptance scan application find optimal phase and amplitude set point

3.6.4 Tune for maximum transmission

Using EDFC 3 beamstop signal maximize the transmission through DTL tank 3. Tune DTL1,2,3 phase and amplitude, MEBT correctors, matching quads, MEBT rebunchers. Record a DTL1,2,3+MEBT saveset for optimum conditions.

3.7 BEAM TRANSPORT THROUGH DTL4 TO EDFC4

3.7.1 Transport beam to EDFC 4 Beam stop

Summon an RCT to verify shielding. Put the Energy Degrader/Faraday Cup #4 signal on the CR scope. Turn on RF to DTL Tank 4 and set to nominal design RF power. Retract EDFC3. Adjust DTL4 phase to see signal on scope traces. Tune DTL4 phase and amplitude, MEBT correctors, etc. to maximize FC signal.

3.7.2 Commission Faraday Cup

Provide beam for Diagnostics Group verification of Faraday Cup signal. Have the RCT verify the shielding performance with beam transported to the beamstop.

3.7.3 Commission Energy Degrader / Faraday Cup software

Provide beam for commissioning of the EDFC scan software. Test the 2-D DTL acceptance scan application.

3.7.4 Perform Acceptance Scan

Using 2-D DTL acceptance scan application find optimal phase and amplitude set point

3.7.5 Check out and adjust neutron detectors and loss monitors.

Observe neutron signals from beamstop on the neutron detectors. Record the signals in the logbook. Observe the loss monitor signals and exercise the beamloss display software.

3.7.6 Tune for maximum transmission

Using EDFC 4 beamstop signal maximize the transmission through DTL tank 4. Tune DTL1,2,3,4 phase and amplitude, MEBT correctors, matching quads, MEBT rebunchers. Record a DTL1,2,3,4+MEBT saveset for optimum conditions.

3.7.7 Commission BPMs in DTL4

Provide beam for Diagnostics Group verification of Beam Position and Phase Monitor signal.

3.7.8 Commission EDMs in DTL4

Commission EDMs. Tweak EDMs set points to reach maximum transmission through the DTL tank4.

3.7.9 Commission WS in DTL3

Provide beam for Diagnostics Group verification of wire scanner signal

3.7.10 Commission BCMs in DTL4

Provide beam for Diagnostics Group verification of Beam Current Monitor signal.

3.8 BEAM TRANSPORT THROUGH DTL5 TO EDFC5

3.8.1 Transport beam to EDFC 5 Beam stop

Summon an RCT to verify shielding. Put the Energy Degrader/Faraday Cup #5 signal on the CR scope. Turn on RF to DTL Tank 5 and set to nominal design RF power. Retract EDFC4. Adjust DTL5 phase to see signal on scope traces. Tune DTL5 phase and amplitude, MEBT correctors, etc. to maximize FC signal.

3.8.2 Commission Faraday Cup

Provide beam for Diagnostics Group verification of Faraday Cup signal. Have the RCT verify the shielding performance with beam transported to the beamstop.

3.8.3 Commission Energy Degrader / Faraday Cup software

Provide beam for commissioning of the EDFC scan software. Test the 2-D DTL acceptance scan application.

3.8.4 Perform Acceptance Scan

Using 2-D DTL acceptance scan application find optimal phase and amplitude set point

3.8.5 Check out and adjust neutron detectors and loss monitors.

Observe neutron signals from beamstop on the neutron detectors. Record the signals in the logbook. Observe the loss monitor signals and exercise the beamloss display software.

3.8.6 Tune for maximum transmission

Using EDFC 5 beamstop signal maximize the transmission through DTL tank 5. Tune DTL1,2,3,4 phase and amplitude, MEBT correctors, matching quads, MEBT rebunchers. Record a DTL1,2,3,4,5+MEBT saveset for optimum conditions.

3.8.7 Commission BPMs in DTL5

Provide beam for Diagnostics Group verification of Beam Position and Phase Monitor signal.

3.8.8 Commission EDMs in DTL5

Commission EDMs. Tweak EDMs set points to reach maximum transmission through the DTL tank5.

3.8.9 Commission WS in DTL4

Provide beam for Diagnostics Group verification of wire scanner signal

3.9 BEAM TRANSPORT THROUGH DTL6 TO EDFC6

3.9.1 Transport beam to EDFC6

Summon an RCT to verify shielding. Put the Energy Degrader/Faraday Cup #5 signal on the CR scope. Turn on RF to DTL Tank 6 and set to nominal design RF power. Retract EDFC5. Adjust DTL6 phase to see signal on scope traces. Tune DTL6 phase and amplitude, MEBT correctors, etc. to maximize FC signal.

3.9.2 Commission Faraday Cup

Provide beam for Diagnostics Group verification of Faraday Cup signal. Have the RCT verify the shielding performance with beam transported to the beamstop.

3.9.3 Commission Energy Degrader / Faraday Cup software

Provide beam for commissioning of the EDFC scan software. Test the 2-D DTL acceptance scan application.

3.9.4 Perform Acceptance Scan

Using 2-D DTL acceptance scan application find optimal phase and amplitude set point

3.9.5 Check out and adjust neutron detectors and loss monitors.

Observe neutron signals from beamstop on the neutron detectors. Record the signals in the logbook. Observe the loss monitor signals and exercise the beamloss display software.

3.9.6 Tune for maximum transmission

Using EDFC 6 beamstop signal maximize the transmission through DTL tank 6. Tune DTL1,2,3,4,5,6 phase and amplitude, MEBT correctors, matching quads, MEBT rebunchers. Record a DTL1,2,3,4,5,6+MEBT saveset for optimum conditions.

3.9.7 Commission BPMs in DTL6

Provide beam for Diagnostics Group verification of Beam Position and Phase Monitor signal.

3.9.8 Commission EDMs in DTL6

Commission EDMs. Tweak EDMs set points to reach maximum transmission through the DTL tank6.

3.9.9 Commission WS in DTL5

Provide beam for Diagnostics Group verification of wire scanner signal

3.9.10 Commission BCMs in DTL6

Provide beam for Diagnostics Group verification of Beam Current Monitor signal.

3.10 OTHER DTL MEASUREMENTS

3.10.1 LLRF characterization

Provide beam for RF group checkout of LLRF system with beam. Verify amplitude and phase loop stability and control with beam.

3.10.2 Time of flight measurement for output energy

At final RF setpoint, perform Time-of-Flight measurements using DTL2 BPMs to determine DTL1 output beam energy. Perform Time-of-Flight measurements using DTL3 BPMs to determine DTL2 output beam energy. Perform Time-of-Flight measurements using DTL4 BPMs to determine DTL3 output beam energy. Perform Time-of-Flight measurements using DTL5 BPMs to determine DTL4 output beam energy. Perform Time-of-Flight measurements using DTL6 BPMs to determine DTL5 output beam energy.

3.10.3 Fault Study

Perform Fault study in accordance with Fault study plan.

3.11 BEAM TRANSPORT THROUGH CCL TO BEAM STOP

3.11.1 Transport beam to Beam stop using manual transverse correction

Summon an RCT to verify shielding. Put the Beam Stop signal on the CR scope. Retract EDFC6. Adjust CCL1-4 correctors to maximize FC signal.

3.11.2 Commission BPMs in CCL

Provide beam for Diagnostics Group verification of Beam Position and Phase Monitor signal.

3.11.3 Commission Wire scanners in CCL

Provide beam for Diagnostics Group verification of Wire Scanner signal.

3.11.4 Commission BSMs in CCL1

Provide beam for Diagnostics Group verification of Beam Shape monitor signals.

3.11.5 Check out and adjust neutron detectors and loss monitors.

Observe neutron signals from beamstop on the neutron detectors. Record the signals in the logbook. Observe the loss monitor signals and exercise the beamloss display software.

3.11.6 Tune for maximum transmission

Using BPM and beam stop signal maximize the transmission through DTL and CCL. Tune DTL1,2,3,4,5,6 phase and amplitude, MEBT correctors, matching quads, MEBT rebunchers. Record a DTL1,2,3,4,5,6+MEBT saveset for optimum conditions.

3.11.7 Commission BCMs after CCL4

Provide beam for Diagnostics Group verification of Beam Position and Phase Monitor signal.

3.12 BEAM ACCELERATION THROUGH CCL1

3.12.1 Accelerate beam in CCL1

Summon an RCT to verify shielding. Put RF power in CCL1. Adjust module 1 RF phase while observing forward power signal on LLRF screen. Maximize beam loading.

3.12.2 Perform delta-T scan and tune amplitude and phase

Run the delta-T phase scan XAL data application. Use the Labview analysis code to analyze scan results to obtain phase and amplitude setpoints.

3.12.3 Test "signature matching" procedure

Run the PASTA XAL phase and amplitude scan program and compare to model predictions to obtain the input energy error, and amplitude and phase setpoint errors.

3.12.4 Perform TOF energy measurements after CCL1

Perform Time-of-Flight measurements using CCL2 BPMs to determine CCL1 output beam energy.

3.12.5 Tune for maximum transmission and acceleration

Using beam stop signal maximize the transmission through CCL. Tune DTL1,2,3,4,5,6,CCL1 phase and amplitude, MEBT correctors, matching quads, MEBT rebunchers. Record a DTL1,2,3,4,5,6,CCL1 +MEBT saveset for optimum conditions.

3.12.6 Measure Bunch length using BSMs

Commission the Bunch Shape Monitors with beam. Deliver beam for diagnostics group to commission BSMs. Measure the beam profile and longitudinal halo with BSMs. Measure beam profile vs. RF setpoints.

3.12.7 Measure beam profile using Wire scanners

Measure the horizontal and vertical beam profiles and compare with online model predictions.

3.12.8 Estimate losses using loss monitors

Record loss monitor signals versus tuning parameters, including RF setpoints and MEBT/DTL transverse matching.

3.13 BEAM ACCELERATION THROUGH CCL2

3.13.1 Accelerate beam in CCL2

Summon an RCT to verify shielding. Put RF power in CCL2. Adjust module 2 RF phase while observing forward power signal on LLRF screen. Maximize beam loading.

3.13.2 Perform delta-T scan and tune amplitude and phase

Run the delta-T phase scan XAL data application. Use the Labview analysis code to analyze scan results to obtain phase and amplitude setpoints.

3.13.3 Test "signature matching" procedure

Run the PASTA XAL phase and amplitude scan program and compare to model predictions to obtain the input energy error, and amplitude and phase setpoint errors.

3.13.4 Perform TOF energy measurements after CCL2

Perform Time-of-Flight measurements using CCL3 BPMs to determine CCL2 output beam energy.

3.13.5 Tune for maximum transmission and acceleration

Using beam stop signal maximize the transmission through CCL. Tune DTL1,2,3,4,5,6,CCL1,2 phase and amplitude, MEBT correctors, matching quads, MEBT rebunchers. Record a DTL1,2,3,4,5,6,CCL1,2 +MEBT saveset for optimum conditions.

3.13.6 Measure beam profile using Wire scanners

Measure the horizontal and vertical beam profiles and compare with online model predictions.

3.13.7 Estimate losses using loss monitors

Record loss monitor signals versus tuning parameters, including RF setpoints and MEBT/DTL transverse matching.

3.14 BEAM ACCELERATION THROUGH CCL3

3.14.1 Accelerate beam in CCL3

Summon an RCT to verify shielding. Put RF power in CCL3. Adjust module 3 RF phase while observing forward power signal on LLRF screen. Maximize beam loading.

3.14.2 Perform delta-T scan and tune amplitude and phase

Run the delta-T phase scan XAL data application. Use the Labview analysis code to analyze scan results to obtain phase and amplitude setpoints.

3.14.3 Test "signature matching" procedure

Run the PASTA XAL phase and amplitude scan program and compare to model predictions to obtain the input energy error, and amplitude and phase setpoint errors.

3.14.4 Perform TOF energy measurements after CCL3

Perform Time-of-Flight measurements using CCL4 BPMs to determine CCL3 output beam energy.

3.14.5 Tune for maximum transmission and acceleration

Using beam stop signal maximize the transmission through CCL. Tune DTL1,2,3,4,5,6,CCL1,2,3 phase and amplitude, MEBT correctors, matching quads, MEBT rebunchers. Record a DTL1,2,3,4,5,6,CCL1,2,3 +MEBT saveset for optimum conditions.

3.14.6 Measure beam profile using Wire scanners

Measure the horizontal and vertical beam profiles and compare with online model predictions.

3.14.7 Estimate losses using loss monitors

Record loss monitor signals versus tuning parameters, including RF setpoints and MEBT/DTL transverse matching.

3.15 BEAM STUDY

3.15.1 Commission MEBT emittance scanner

Provide beam for Diagnostics Group to commission MEBT emittance scanner.

3.15.2 Characterize LLRF system performace

Provide beam for RF group checkout of LLRF system with beam. Verify amplitude and phase loop stability and control with beam.

3.15.3Test LEBT chopper system

Insert MEBT beamstop. Set LEBT chopper system for operation at 2 kV. Tune beam of pulse length less than 50 microseconds and repetition rate less than 2 Hz. Observe beam signal on MEBT BPM02 using an oscilloscope. Load chopper waveform from chopper control screen and operate the chopper. Record scope display demonstrating chopper performance.

3.15.4 Commission MEBT emittance laser wire

Provide beam for Diagnostics Group to commission MEBT laser wire.

3.15.5 Test new commissioning software

Provide beam for testing and tweaking new commissioning software.

3.15.6 Characterize BPM performance

Record BPM position and phase histograms to measure combined beam+BPM position jitter.

3.15.7 Characterize Wire scanners performance

Measure beam profiles as functions of the DC bias to determine the optimum bias on each WS.

3.15.8 Characterize Beam Loss Measurement system performance

Measure the beam loss monitor response with “localized” beam losses achieved by mismatching and mistuning.

3.15.9 MEBT scraper experiment

Insert MEBT scraper. Measure emittance using MEBT emittance scanner, profiles using all wire scanners, and losses in the DTL and CCL vs. scraper position.

3.15.10 “Round optics” experiment

Load MEBT quad settings corresponding to the “round optics”. Measure emittance using MEBT emittance scanner, profiles using all wire scanners, and losses in the DTL and CCL.

3.15.11 Measure losses vs. transverse mismatch between DTL/CCL

Vary transverse matching conditions using first two quadrupoles in the CCL1. Record beam losses.

3.15.12 Measure losses vs. longitudinal mismatch between DTL/CCL

Vary longitudinal matching conditions using DTL6 RF amplitude. Record beam losses.

3.15.13 Measure beam stability/jitter from FE to beam stop

Record sets of >1000 beam pulses from all BPMs. Record data sets while varying single parameters, including, MEBT steerer strength, MEBT Rebuncher phases, and DTL phase and amplitude for later observation of beam modes.

3.15.14 Ring BPM test unchopped/chopped

Provide chopped and unchopped beam for Diagnostics Group to test the ring BPM electronics.

3.11.15 Radiological measurements

Provide beam for Radiological experiments in the CCL area.

3.11.16 Nominal peak beam current test

Insert MEBT beam stop. Increase ion source current to 38mA at BCM02. Optimize MEBT settings for the nominal current. Retract MEBT beam stop. Optimize transmission through DTL and CCL. Saveset optimal set points. Perform emittance, WS and BSM measurements.

APPENDIX A. DTL TANK FOUR THROUGH SIX AND CCL MODULES ONE THROUGH THREE BEAM COMMISSIONING TASKS

	TASK	Duration (shifts)	Peak Current (mA)	Pulse Width (usec)	Rep Rate (Hz)	Beam Power (kW)	Beam stop	Priority	Spec. software	Beam Energy [MeV]	Macro Duty
1	**Ion Source and RFQ Startup**	3	20	50	2	0.005					
1.1	Ion source start up and cesiation (20 mA)	0.5					MEBT			2.5	0.5
1.2	MPS/timing checkout	0.5					MEBT			2.5	0.5
1.3	Establish beam through RFQ	0.5					MEBT			2.5	0.5
1.4	LEBT optimization	0.5					MEBT			2.5	0.5
1.5	Measure RFQ transmission vs. excitation	0.5					MEBT			2.5	0.5
1.6	Iterate LEBT optimization/RFQ transmission	0.5					MEBT			2.5	0.5
2	**Beam transport to MEBT beam stop**	2.5	20	50	2	0.005					
2.1	BPMs #1-4 checkout	0.5					MEBT			2.5	0.5
2.2	Phase set of rebunchers ##1-3	0.5					MEBT		1	2.5	0.5
2.3	Trajectory correction up to beam stop	0.5					MEBT			2.5	0.5
2.4	Wire scanners ##1-3 checkout and adjustment	0.5					MEBT			2.5	0.5
2.5	Beam envelope measurements and correction up to beam stop	0.5					MEBT		2	2.5	0.5
3	**Beam transport through MEBT (DTL1 is open)**	2	20	50	1	0.0025					
3.1	BPMs ## 5,6 checkout	0.5					EDFC -1			2.5	0.5
3.2	Set rebuncher 3 phase and amplitude	0.5					EDFC -1		1	2.5	0.5
3.3	Correct MEBT trajectory	0.5					EDFC -1			2.5	0.5
3.4	Perform phase scan of rebuncher 4	0.5					EDFC -1		1	2.5	0.5
4	**Beam transport through DTL1 to EDFC1**	2	20	50	1	0.0075					
4.1	Transport beam to beamstop EDFC1	0.5					EDFC -1			7.5	0.5
4.2	Check out Energy Degrader/Faraday Cup #1	0.5					EDFC -1			7.5	0.5
4.3	Perform Acceptance Scan with Energy Degrader/Faraday Cup	0.5					EDFC -1		3	7.5	0.5
4.4	Tune for maximum transmission	0.5					EDFC -1			7.5	0.5
5	**Beam transport through DTL2 to EDFC2**	2	20	50	1	0.023					
5.1	Transport beam to beamstop EDFC2	0.5					EDFC-2			23	0.5
5.2	Check out Energy Degrader/Faraday Cup #2	0.5					EDFC-2			23	0.5
5.3	Perform Acceptance Scan with Energy Degrader/Faraday Cup	0.5					EDFC-2		3	23	0.5
5.4	Tune for maximum transmission	0.5					EDFC-2			23	0.5
6	**Beam transport through DTL3 to EDFC3**	2	20	50	1	0.04					
6.1	Transport beam to beamstop EDFC3 (aperture scan)	0.5					EDFC-3			40	0.5
6.2	Check out Energy Degrader/Faraday Cup #3	0.5					EDFC-3			40	0.5
6.3	Perform Acceptance Scan with Energy Degrader/Faraday Cup	0.5					EDFC-3		3	40	0.5
6.4	Tune for maximum transmission	0.5					EDFC-3			40	0.5
7	**Beam transport through DTL4 to EDFC4**	5.5	20	50	1	0.057					
7.1	Transport beam to beamstop EDFC4 (aperture scan)	0.5					EDFC-4			57	0.5
7.2	Commission Energy Degrader/Faraday Cup #4	0.5					EDFC-4			57	0.5
7.3	Commission ED/FC #4 software	0.5					EDFC-4			57	0.5
7.4	Perform Acceptance Scan with Energy Degrader/Faraday Cup	0.5					EDFC-4		3	57	0.5

7.5	Adjust neutron detectors and loss monitors	0.5					EDFC-4			57	0.5
7.6	Tune for maximum transmission	0.5					EDFC-4			57	0.5
7.7	Commission BPMs in DTL4	1	20	50	1	0.04	EDFC-4			57	0.5
7.8	Commission EDMs in DTL4	0.5	20	50	1	0.04	EDFC-4			57	0.5
7.9	Commission WS in DTL3	0.5	20	50	1	0.04	EDFC-4			57	0.5
7.10	Commission BCMs in DTL4	0.5	20	50	1	0.04	EDFC-4			57	0.5
8	**Beam transport through DTL5 to EDFC5**	5	20	50	1	0.073					
8.1	Transport beam to beamstop EDFC5 (aperture scan)	0.5					EDFC-5			73	0.5
8.2	Commission Energy Degrader/Faraday Cup #5	0.5					EDFC-5			73	0.5
8.3	Commission ED/FC #5 software	0.5					EDFC-5			73	0.5
8.4	Perform Acceptance Scan with Energy Degrader/Faraday Cup	0.5					EDFC-5	3		73	0.5
8.5	Adjust neutron detectors and loss monitors	0.5					EDFC-5			73	0.5
8.6	Tune for maximum transmission	0.5					EDFC-5			73	0.5
8.7	Commission BPMs in DTL5	1					TBS			73	0.5
8.8	Commission EDMs in DTL5	0.5					TBS			73	0.5
8.9	Commission WS in DTL4	0.5					TBS			73	0.5
9	**Beam transport through DTL6 to EDFC-CCL**	5.5	20	50	1	0.086					
9.1	Transport beam to beamstop EDFC-CCL (aperture scan)	0.5					EDFC-6			87	0.5
9.2	Commission Energy Degrader/Faraday Cup - CCL	0.5					EDFC-6			87	0.5
9.3	Commission ED/FC -CCL software	0.5					EDFC-6			87	0.5
9.4	Perform Acceptance Scan with Energy Degrader/Faraday Cup	0.5					EDFC-6	3		87	0.5
9.5	Adjust neutron detectors and loss monitors	0.5					TBS			87	0.5
9.6	Tune for maximum transmission	0.5					TBS			87	0.5
9.7	Commission BPMs in DTL6	1					TBS			87	0.5
9.8	Commission EDMs in DTL6	0.5					TBS			87	0.5
9.9	Commission WS in DTL5	0.5					TBS			87	0.5
9.10	Commission BCM in DTL6	0.5					TBS			87	0.5
10	**Other DTL Measurements**	5	20	50	1	0.086					
10.1	LLRF characterization	1					TBS			87	0.5
10.2	TOF energy measurement after DTL1, DTL2, DTL3,DTL4,DTL5,DTL6	1					var		var		0.5
10.3	Fault study	1					var		var		0.5
10.4	DTL1-6 tweak tuning	2					TBS			87	0.5
11	**Beam transport through CCL to beam stop (no CCL RF)**	8.5	20	50	1	0.086					
11.1	Transport beam to beam stop using manual transverse correction	0.5					TBS			87	0.5
11.2	Commission BPMs in CCL1,2,3	2					TBS			87	0.5
11.3	Comission Wire scanners in CCL1,2,3	2					TBS			87	0.5
11.4	Commission BSMs in CCL1,2,3	2					TBS			87	0.5
11.5	Adjust neutron detectors and loss monitors	1					TBS			87	0.5
11.6	Tune for maximum transmission using BPMs and loss monitors	0.5					TBS			87	0.5
11.7	Commission BCM after CCL4	0.5					TBS			87	0.5
12	**Beam acceleartion through CCL module 1**	5.5	20	50	1	0.107					
12.1	Accelerate beam in CCl1	0.5								107	0.5
12.2	Perform delta-T scan and tune amplitude and phase	1					TBS			107	0.25

12.3	Test "signature matching" procedure	0.5					TBS	107	0.5
12.4	Perform TOF energy measurements after CCL1	0.5					TBS	107	0.5
12.5	Tune for maximum transmission and acceleration	0.5					TBS	107	0.5
12.6	Measure bunch length using BSMs	1					TBS	107	0.5
12.7	Measure beam profiles using Wire scanners	1					TBS	107	0.5
12.8	Estimate losses using loss monitors	0.5					TBS	107	0.25
13	**Beam acceleartion through CCL module 2**	4.5	20	50	1	0.133			
13.1	Accelerate beam in CCl2	0.5					TBS	131	0.5
13.2	Perform delta-T scan and tune amplitude and phase	1					TBS	131	0.25
13.3	Test "signature matching" procedure	0.5					TBS	131	0.5
13.4	Perform TOF energy measurements after CCL2	0.5					TBS	131	0.5
13.5	Tune for maximum transmission and acceleration	0.5					TBS	131	0.5
13.6	Measure beam profiles using Wire scanners	1					TBS	131	0.5
13.7	Estimate losses using loss monitors	0.5					TBS	131	0.25
14	**Beam acceleartion through CCL module 3**	5	20	50	1	0.16			
14.1	Accelerate beam in CCl3	0.5					TBS	157	0.5
14.2	Perform delta-T scan and tune amplitude and phase	1					TBS	157	0.25
14.3	Test "signature matching" procedure	0.5					TBS	157	0.5
14.4	Perform TOF energy measurements after CCL3	0.5					TBS	157	0.5
14.5	Tune for maximum transmission and acceleration	0.5					TBS	157	0.5
14.6	Measure beam profiles using Wire scanners	1					TBS	157	0.5
14.7	Estimate losses using loss monitors	1					TBS	157	0.25
15	**Beam study FE through CCL module 3**	20	20	50	1	0.16			
15.1	Commission MEBT emittance scanner	2					MEBT	2.5	0.5
15.2	Characterize LLRF system performace	1	38	50	1	0.32	TBS	157	0.25
15.3	Test LEBT chopper	1					MEBT	2.5	0.5
15.4	Commissioning MEBT "laser wire"	2					MEBT	2.5	0.5
15.5	Test new commissioning software	1					var	var	
15.6	Characterize BPMs performace	2					TBS	157	0.25
15.7	Characterize Wire scanners performace	2					TBS	157	0.25
15.8	Characterize beam loss system performace	2					TBS	157	0.25
15.9	MEBT scraper experiment	1	38	50	1	0.32	TBS	157	0.25
15.10	"Round optics" experiment	1	38	50	1	0.32	TBS	157	0.25
15.11	Measure losses vs. transverse mismatch between DTL/CCL	1	38	50	1	0.32	TBS	157	0.5
15.12	Measure losses vs. longitudinal mismatch between DTL/CCL	1	38	50	1	0.32	TBS	157	0.5
15.13	Measure beam stability/jitter from FE to beam stop	0.5					TBS	157	0.5
15.14	Ring BPM test unchopped/chopper	0.5					TBS	157	0
15.15	Radiological measurements	1					TBS	157	0.5
15.16	Nominal peak current beam transmission	1	38	50	1	0.32	TBS	157	0.25

Total Shifts	78
Total Days	26.0