SNS 104020000-PN0001-R00

Drift Tube Linac (DTL) Tank 1-3 Beam Commissioning Plan

A U.S. Department of Energy Multilaboratory Project

SPALLATION NEUTRON SOURCE

Argonne National Laboratory • Brookhaven National Laboratory • Thomas Jefferson National Accelerator Facility • Lawrence Berkeley National Laboratory • Los Alamos National Laboratory • Oak Ridge National Laboratory

SNS

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by

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1. INTRODUCTION

This document presents the beam commissioning plan for the Drift Tube Linac tanks 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 and 3 (DTL1-3) and a temporary beam stop. FES and DTL1 were commissioned in autumn 2003 up to nominal operational parameters.

1.1 SYSTEM LAYOUT AND CONFIGURATION

1.1.1 Drift Tube Linac Tank 1-3

The DTL Tank 1-3 system for this commissioning run is shown in Figure 1. A shielding enclosure surrounds DTL tank 1, tank 2 and tank 3 with temporary beam stop. The Front-End Systems hardware is identical to that which was commissioned at ORNL last year. The Drift Tube Linac Tank 1 has two drift tubes replaced with the new ones. DTL2, DTL3 and temporary beam stop are new hardware which will be commissioned with beam for the first time. The basic parameters for DTL tanks 1-3 are given in Table 1. The DTL tanks 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.

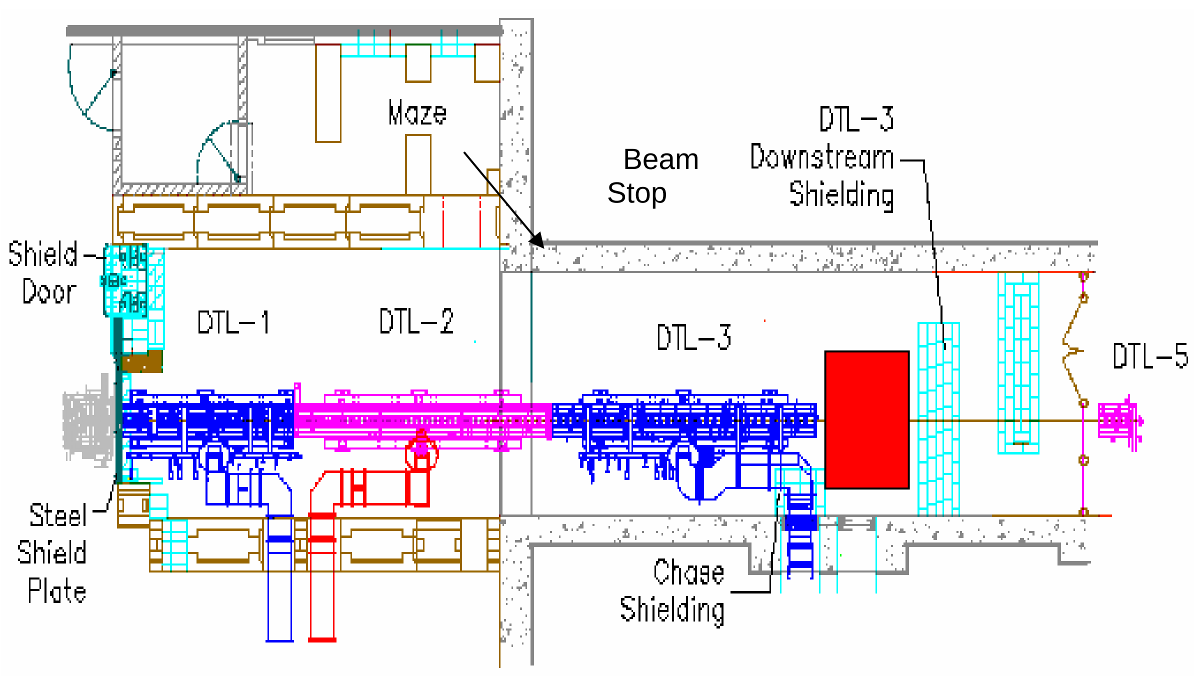

Figure 1. Layout of DTL tanks 1-3 and the beam stop for beam commissioning.

Table 1a. Drift Tube Linac Tank 1 Design Parameters

Resonant Frequency	402.5 MHz
Bore radius	12.5 mm
Tank Length	4.152m (between inside end walls)
Number of cells	60
Energy Gain	5.023 MeV
Stored Energy	4.78 J
Synchronous phase	-45° to -28°
Average E_0T	1.518 MV/m
Shunt Impedance ZT^2	28.22 MΩ/m
Unloaded Quality Factor (design/measured)	35891/40211
External Quality Factor (design/measured)	23554/17313
Peak RF Structure Power	339 kW
Focusing structure	FFODDO
Focusing period	6 βλ
Table 1b. Drift Tube Linac Tank 2 Design Parameters	
Resonant Frequency	402.5 MHz
Bore radius	12.5 mm
Tank Length	6.063m (between inside end walls)
Number of cells	48
Energy Gain	15.362 MeV
Stored Energy	16.51 J
Synchronous phase	-25°
Average E_0T	2.810 MV/m
Shunt Impedance ZT^2	45.25 MΩ/m
Unloaded Quality Factor (design/measured)	40074/40000
External Quality Factor (design/measured)	26480/25000
Peak RF Structure Power	1058 kW
Focusing structure	FFODDO
Focusing period	6 βλ
Table 1c. Drift Tube Linac Tank 3 Design Parameters	
Resonant Frequency	402.5 MHz
Bore radius	12.5 mm
Tank Length	6.324m (between inside end walls)
Number of cells	34
Energy Gain	16.880 MeV
Stored Energy	21.84 J
Synchronous phase	-25°
Average E_0T	2.966 MV/m
Shunt Impedance ZT^2	43.54 MΩ/m
Unloaded Quality Factor (design/measured)	43237/48279
External Quality Factor (design/measured)	29468/27697
Peak RF Structure Power	1277kW
Focusing structure	FFODDO
Focusing period	6 βλ

Table 2a. DTL tank 1 output beam parameters

Parameter	Design Value	Performance Goal
Input Energy [MeV]	2.50	2.50 ± 0.10[*]
Output Energy [MeV]	7.52	7.52 ± 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 1 Beamloss	< 4 W	< 4% (measurable loss threshold)

Table 2b. DTL tank 2 output beam parameters

Parameter	Design Value	Performance Goal
Input Energy [MeV]	7.52	7.52 ± 0.03[*]
Output Energy [MeV]	22.89	22.89 ± 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 1 Beamloss	< 4 W	< 4% (measurable loss threshold)

Table 2c. DTL tank 3 output beam parameters

Parameter	Design Value	Performance Goal
Input Energy [MeV]	22.89	22.89 ± 0.03[*]
Output Energy [MeV]	39.77	39.77 ± 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
Tank 1 Beamloss	< 4 W	< 4% (measurable loss threshold)

[*]Limited by measurement accuracy

1.1.2 Beam stops

There are five beam stops 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 second, third and fourth beam stops are energy degrader/faraday cup (ED/FC) diagnostic systems located at the end of each DTL tank. They consist of a carbon energy degrader and isolated beam absorber, which provide accelerated beam current signal. Temporary copper absorber is located at the end of the DTL3 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 for DTL tank 1 commissioning

	Beam current** (mA)	Pulse length (μs)	Repetition Rate (Hz)	Average Power (W)	Single Pulse Energy (J)
MEBT Beam Stop*	40	50	1	5	5
EDFC-1	20	50	1	7.5	7.5
EDFC-2	18	50	1	20	20
EDFC-3	20	50	1	40	40
Temporary beam stop	26	50	20	1040	52

*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 and 3 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 Tank 1, Tank2 and Tank3. The layout of diagnostics devices is shown in Figure 2. Operational limitations of the interceptive diagnostic devices are summarized in Table 4. The Machine Protection System (MPS) ensures that these devices can be operated only in the appropriate machine mode to avoid damage to the devices.

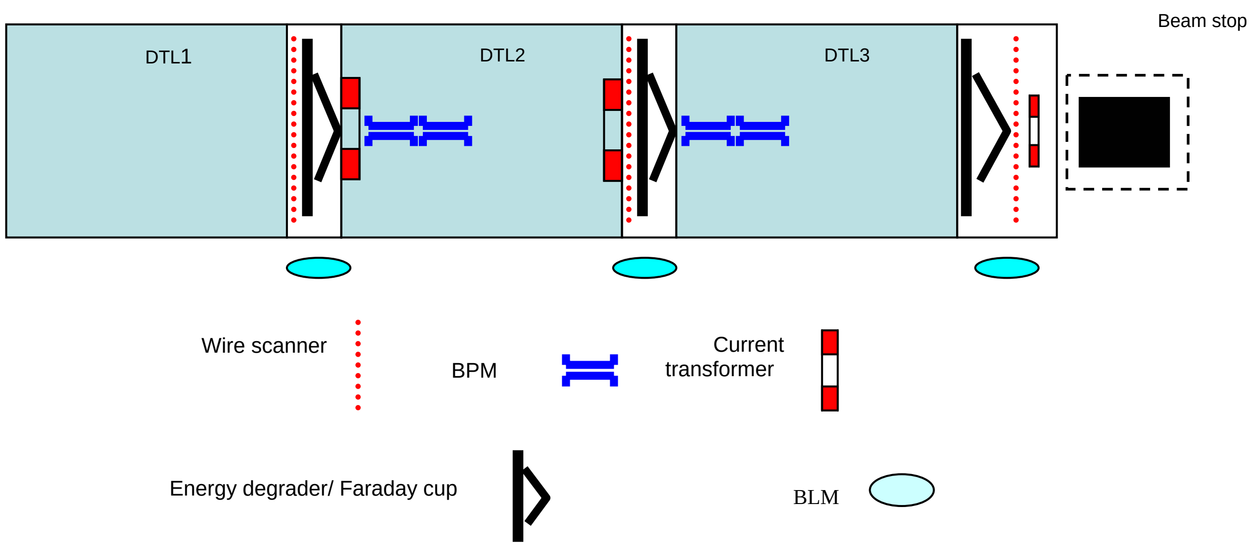

Figure 2. Layout of diagnostic devices for DTL1-3 Commissioning.

Table 4. Beam capabilities of 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-1-3 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 tank 1,2,3 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 subsequent portions of the SNS linac
- 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 commission in three phases with beams of three different peak currents. For initial injection into DTL tanks 2 and 3 we plan to insert the current-limiting aperture in the D-box to limit the peak current to less than 5 mA. Once we are assured of good transmission to the corresponding beam stop we will remove the aperture and 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 MEBT 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 DTL1-3 output beam parameter measurements. 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 DTL, 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. MPS pulse width key will be always in 50 μsec position to prevent accidental run at larger pulse width.

1.3.3 Repetition Rate

All of the 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 high energy beam. 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 rebuncher and quadrupole settings are given in Table 5.

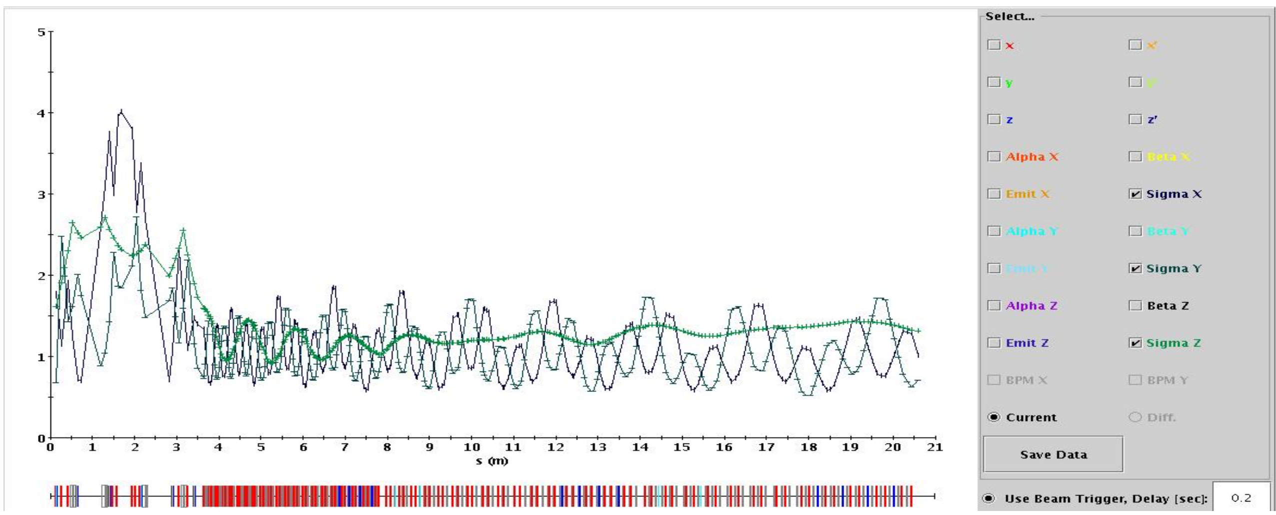

Figure 3. On-line model beam envelope profiles for 20mA operation.

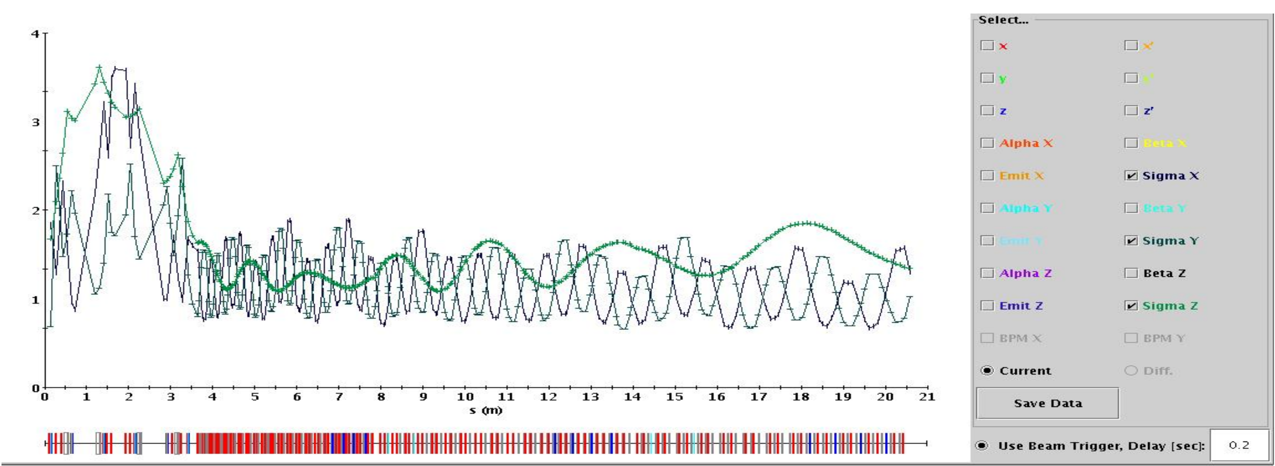

Figure 4. On-line model beam envelope profiles for 38mA operation.

Table 5. MEBT quadrupole and rebuncher setpoints for 20 mA and 38 mA operation		
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	
Rebuncher 1 [kV]	75.00	
Rebuncher 2 [kV]	45.00	
	20 mA	**38 mA**
QV11 [T/m]	17.31	16.72
QH12 [T/m]	-29.39	-25.96
QV13 [T/m]	26.95	27.58
QH14 [T/m]	-13.60	-18.50
Rebuncher 3 [kV]	46	46
Rebuncher 4 [kV]	90	90

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. Loss monitors are commissioned 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. Tank 2 set point tuning software is commissioned 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. Tank 3 set point tuning software is commissioned and transmission through tank 3 is optimized. Finally EDFC 3 is retracted and temporary beam stop is commissioned. Transmission through FES and DTL1-3 is measured using BCMs. In task 7, characterization of the RF system performance is carried out, various fault studies are performed with low-current beams to verify the loss predictions, LEBT chopper is tested and various high level tuning algorithms are checked out. Finally 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 RFQ conditioning

Condition the RFQ following the RFQ conditioning procedure.

3.1.3 MPS and timing checkout

Perform MPS system and timing system checkout without beam.

3.1.4 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.

3.1.5 BCM1 checkout and adjustment

Provide beam for Diagnostics Group verification of BCM01 operation. Compare BCM01 and beam stop signals to ensure good transmission.

3.1.6 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.

3.1.7 Commission integrating current measurement for BCM01

Provide beam for Diagnostics Group commissioning of integrating current measurement of BCM01. Incorporate into the MPS system and test the MPS shutoff function by increasing the integrated current and verifying that the MPS shuts off the beam.

3.1.8 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.

3.1.9 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 Commission 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 Commission 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 Commission 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 Check out Energy Degrader /Faraday Cup #1 software

3.4.4 Performe Acceptance Scan

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

3.4.5 Commission 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.

3.4.6 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.

3.4.7 Commission Electromagnetic Dipole Magnets in the DTL1

Commission EDMs. Tweak EDMs set points to reach maximum transmission through the DTL tank1.

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 Check out Energy Degrader /Faraday Cup #2 software

3.5.4 Performe Acceptance Scan

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

3.5.5 Commission 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.

3.5.6 Tune for maximum transmission

Using EDFC 2 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.

3.5.7 Commission BCMs in the DTL2

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

3.5.8 Commission BPMs in the DTL2

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

3.5.9 Commission Electromagnetic Dipole Magnets in the DTL2

Commission EDMs. Tweak EDMs set points to reach maximum transmission through the DTL tank 2.

3.5.10 Commission wire scanner after DTL1

Provide beam for Diagnostics Group verification of wire scanner signal.

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 Check out Energy Degrader /Faraday Cup #3 software

3.6.4 Performe Acceptance Scan

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

3.6.5 Commission 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.

3.6.6 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.

3.6.7 Commission temporary beam stop

Retract EDFC3 and commission temporary beam stop. Have the RCT verify the shielding performance with beam transported to the temporary beam stop.

3.6.8 Commission BPMs in the DTL3

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

3.6.9 Commission Electromagnetic Dipole Magnets in the DTL3

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

3.6.10 Commission wire scanner after DTL2

Provide beam for Diagnostics Group verification of wire scanner signal.

3.7 OTHER MEASUREMENTS

3.7.1 Verify amplitude and phase stability and control with beam

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

3.7.2 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.

3.7.3 Test 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 BCM02. Load chopper waveform from chopper control screen and operate the chopper. Record scope display demonstrating chopper performance.

3.7.4 RFQ output Twiss parameters study

Measure the beam profiles using the MEBT wire-scanners. Repeat for several quad settings. Check the beam size against the model. Resolve for optimal input Twiss parameters.

3.7.5 Fault study

Perform Fault study in accordance with Fault study plan.

3.7.6 Phase scan algorithm study

Check out phase scan software. Compare predicted set points with previously found.

3.7.7 Trajectory correction and matrix response measuremnts

Check out automated trajectory correction software. Perform matrix response measurements in the MEBT. Compare results with the model.

3.7.8 Phase scan “signature matching” algorithm study

Check out “phase scan signature matching” software. Compare predicted set points with previously found.

3.7.9 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 DTL1-3. Saveset optimal set points.

APPENDIX A. DTL TANK 1 THROUGH 3 BEAM COMMISSIONING TASKS

	TASK	Duration (shifts)	Peak Current (mA)	Pulse Width (usec)	Rep Rate (Hz)	Beam Power (kW)	Beam stop	Priority	Spec. software
1	**Ion Source and RFQ Startup**	4.5	20	50	1	0.0025	MEBT		
1.1	Ion source start up and cesiation (20 mA)	0.5							
1.2	RFQ conditioning	0.5							
1.3	MPS/timing checkout	0.5							
1.4	Establish beam through RFQ	0.5							
1.5	BCM1 checkout and adjustment	0.5							
1.6	LEBT optimization	0.5							
1.7	Commission integrating current measurement on BCM01	0.5							
1.8	Measure RFQ transmission vs. excitation	0.5							
1.9	Iterate LEBT optimization/RFQ transmission	0.5							
2	**Beam transport to MEBT beam stop**	3.2	20	50	1	0.0025	MEBT		
2.1	BPMs #1-4 checkout and adjustment	1							
2.2	Phase set of rebunchers ##1-3	0.5							1
2.3	Trajectory correction up to beam stop	0.2							
2.4	Wire scanners ##1-3 checkout and adjustment	0.5							
2.5	Beam envelope measurements and correction up to beam stop	1							2
3	**Beam transport through MEBT (DTL1 is open)**	0.8	20	50	1	0.0025	DTL1		
3.1	BPMs ## 5,6 checkout and adjustment	0.2							
3.2	Set rebuncher 3 phase and amplitude	0.2							1
3.3	Correct MEBT trajectory	0.2							
3.4	Perform phase scan of rebuncher 4	0.2							1
4	**Beam transport through DTL1 to EDFC1**	4	20	50	1	0.0075	EDFC1		
4.1	Transport beam to beamstop EDFC1	0.5							
4.2	Check out Energy Degrader/Faraday Cup #1	0.5							
4.3	Check out ED/FC #1 software	0.5							
4.4	Perform Acceptance Scan with Energy Degrader/Faraday Cup	0.5							3
4.5	Commission Neutron detectors and loss monitors	1							
4.6	Tune for maximum transmission	0.5							
4.7	Commission EDMs in DTL1	0.5							
5	**Beam transport through DTL2 to EDFC2**	6	20	50	1	0.023	EDFC2		
5.1	Transport beam to beamstop EDFC2	1							
5.2	Commission Energy Degrader/Faraday Cup #2	0.5							
5.3	Commission ED/FC #1 software	0.5							
5.4	Perform Acceptance Scan with Energy Degrader/Faraday Cup	0.5							3
5.5	Adjust neutron detectors and loss monitors	0.5							

5.6	Tune for maximum transmission	0.5						
5.7	Commission BCMs in DTL2	0.5						
5.8	Commission BPMs in DTL2	1						
5.9	Commission EDMs in DTL2	0.5						
5.10	Commission WS in DTL1	0.5						
6	**Beam transport through DTL3 to EDFC3**	6	20	50	1	0.04	EDFC3	
6.1	Transport beam to beamstop EDFC3 (aperture scan)	1						
6.2	Commission Energy Degrader/Faraday Cup #3	0.5						
6.3	Commission ED/FC #3 software	0.5						
6.4	Perform Acceptance Scan with Energy Degrader/Faraday Cup	0.5						3
6.5	Adjust neutron detectors and loss monitors	0.5						
6.6	Tune for maximum transmission	0.5						
6.7	Commission temporary beam stop	0.5	20	50	1	0.04	TBS	
6.8	Commission BPMs in DTL3	1	20	50	1	0.04	TBS	
6.9	Commission EDMs in DTL3	0.5	20	50	1	0.04	TBS	
6.10	Commission WS in DTL2	0.5	20	50	1	0.04	TBS	
7	**Other Measurements**	8.5	20	50	1	0.04	EDFC3	
7.1	LLRF characterization	1						
7.2	TOF energy measurement after DTL1, DTL2	1						
7.3	LEBT chopper test	1					MEBT BS	
7.4	RFQ output Twiss parameters study	1					MEBT BS	2
7.5	Fault study	1					TBS	
7.6	Phase scan algorithm study	1						4
7.7	Trajectory corr. and matrix response study	1						5
7.8	Phase scan signature matching study	1						6
7.9	Nominal peak beam current test	0.5	38	50	1	0.076	TBS	
	Total Shifts	33						
	Total Days	11						

Specialized software

1 MEBT rebunchers software (XAL)
2 On line model (XAL, MATLAB)
3 DTL acceptance scan (XAL)
4 Phase scan software (MATLAB)
5 Trajectory correction soft (XAL)
6 Phase scan signature matching software (MATLAB)?