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E-Linac Beam Commissioning Plan

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Author(s): **T. Planche**

	Name:	**Signature:**
Author:	**T. Planche**	
Reviewed By:	**R. Baartman**	
	Y. Bylinskii	
	S. Koscielniak	
Approved By:	**R. Laxdal**	**APPROVAL RECORD**

History of Changes

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1	2014-09-24	First release: ELBT only	T. Planche
2	2014-09-30	EMBT added	T. Planche
3	2015-08-28	Re-writing of the document following release (DRAFT) #3 of the e-Linac Commissioning Plan [1] It covers all beam lines up to EHDT	T. Planche
3	2016-01-11	Incorporated above changes	T. Planche

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Contents

1 Introduction **4**
1.1 Purpose 4

2 System to be commissioned **4**

3 Commissioning team **4**

4 Pre-requisite **5**

5 Acceptance criteria **5**

6 Record of commissioning **5**

7 Safety **5**

8 Procedures for low beam power commissioning **5**
8.1 Steerers 6
8.2 Dipoles 6
8.3 Solenoids 6
8.4 Quadrupoles 7
8.5 Measure beam energy 7
8.6 Establish a low power tune 8
8.7 Phase an accelerating rf cavity 8
8.8 Rf buncher and rf deflector 9

9 Procedures for commissioning higher beam power **9**

1 Introduction

This document is the plan for the electron beam commissioning; the present plan follows the directives of the E-linac Commissioning Plan [1].

1.1 Purpose

The beam commissioning follows directly the equipment commissioning [2]. The purpose of beam commissioning is to:

1. achieving and verifying acceptance criteria listed in section 5;
2. characterize optical elements with the beam;
3. set up tunes for the different sections of beam line, including envelope matching and trajectory correction.

2 System to be commissioned

The system to be commissioned is the e-linac and its ability to overall produce, transport and accelerate the electron beam. The e-linac is subdivided into sections; the release of the present document covers the sections: ELBT, ELBD, EINJ, EMBT, EMBD, EACA, EABT, EABD, EACB, EHAT, and EHDT.

3 Commissioning team

The commissioning team is composed of:

- Shane Koscielniak: Head of commissioning team;
- Marco Marchetto: Equipment commissioning coordinator;
- Thomas Planche: Beam commissioning coordinator;

and their delegates:

- Rick Baartman,
- Youri Bylinski,
- Yi-Nong Rao,

and other delegates as may be appointed. Responsibilities are defined in the e-Linac Commissioning Plan [1].

4 Pre-requisite

Equipment commissioning shall be completed over a given section of beam line before starting to commission the beam over this section; the detail of what is requered for each individual section is given in the E-linac Prerequisites Tracking Tool [2].

5 Acceptance criteria

- Confirm that the beam energy out of EGUN (300 keV).
- Confirm acceleration through SRF cavities (10 MeV per 9-cells module).
- Establish a low loss tune (transmission $\geq$95%, loss $\leq$ 5 W/m).
- Each of these is the cumulant of lower level verifications of the basic function of optical elements, transverse and longitudinal diagnostics, and controls interface, etc. The essential low-level verifications are performed step-by-step following procedures given in section 8.

6 Record of commissioning

The electron beam commissioning will proceed in seven stages (see section 3.2 of [1]) Upon execution of each sub-section, a new release of the Beam Commissioning Report will be produced.

7 Safety

All members of the commissioning team shall conform to sections 2.5, 4 and 5.2 of the e-Linac Commissioning Plan [1].

8 Procedures for low beam power commissioning

This section lists the procedures that shall be followed to:

- test with the beam each individual steering and optics device (following the sequence in which they appear along the beam line);
- measure beam properties at lower average power and low peak current.
- establish a well-understood high-transmission low-power tune.

Before turning ON the EGUN, set EGUN:HC to the optimum setting for field compensation determined during the e-Linac Equipment Commissioning. Note: this setting will be different with the cyclotron main magnet ON or OFF.

For commissioning up to 30 MeV set the e-gun to:

- EGUN:CHT = 100 V
- Repetition rate = 1 k Hz
- Duty factor = 0.5%
- E-gun grid RF amplitudes set so that peak current is lower than 100 μA.

8.1 Steerers

Steerers are also referred to as correction benders (CB). They are used to keep the beam as close as possible to the reference beam axis. Along the e-linac, all steerers are magnetic benders.

1. Confirm using at least one downstream monitor (either beam position monitor (BPM), view screen, of wire scanner) that a positive current deflects the beam to the left (looking downstream) for X-steerers, and to the top for Y-steerers.
2. Record the amount of displacement measured for at least three current settings.

8.2 Dipoles

Dipoles are also referred to as magnetic benders (MB). Their role is to deflect the reference beam axis.

1. Confirm using at least one downstream monitor (either beam position monitor (BPM), view screen, of wire scanner) that a positive current deflects the beam to the left.
2. For dipoles that are at the intersection between two segments of beam line, confirm that the beam goes through the dipole with minimal deflection when it is off and degaussed.

8.3 Solenoids

Solenoids are transverse focusing elements used in the low energy sections ELBT and ELBD.

1. Insert a view screen downstream of the solenoid and obtain an image of the beam on this screen.

2. Check polarity: an increase in excitation current (with positive polarity) should rotate the beam counter-clockwise on the view screen.

3. Use beam optics graphical user interface elinacOptGUI to find conditions (setting of upstream solenoid, and choice of the view screen to insert) to form a beam waist on a view screen.

4. Adjust the solenoid setting to achieve minimal beam size on the screen. Record setting.

5. Adjust steering so that a change in excitation current of ~20% has minimal impact on beam position measured by downstream BPMs and/or view screens. This will help establishing a tune later on.

8.4 Quadrupoles

Like solenoids, quadrupoles are transverse focusing elements. They are used in all beam lines downstream of EINJ.

1. Insert a view screen downstream of the quadrupole and obtain an image of the beam on this screen.

2. Check polarity: a positive polarity should have an horizontally focusing (and vertically defocussing) effect on the beam. This can be tested looking at changes in spot size on the view screen.

3. Use elinacOptGUI to find conditions (setting of upstream quad., and choice of the view screen to insert) to form an horizontal (or a vertical) waist on a view screen.

4. Adjust the quadrupole setting to achieve minimal horizontal (or vertical) beam size on the screen. Record setting.

5. Adjust steering so that a change in excitation current of ~20% has minimal impact on beam position measured by downstream BPMs and/or view screens. This will help establishing a tune later on.

8.5 Measure beam energy

Beam energy is measured using deflection through an analyzer dipole.

1. Set the analyzer dipole to its theoretical setting for the estimated beam energy (find theoretical setting using this link).

2. Set focusing elements to the corresponding theoretical tune (given by elinacOptGUI).

3. Vary the dipole until to the beam is seen on the Faraday cup at the end of the analyzed line.
4. Centre beam horizontally on Faraday cup using dipole. Record dipole setting. Use this link to find out the corresponding beam energy.

8.6 Establish a low power tune

A tune is an ensemble of set point values for steering and optical elements to achieve goals such as: transporting the beam with minimal loss, matching to downstream beam lines, achieving maximum momentum resolution at a given location, etc...

1. Set focusing elements to a theoretical tune (given by elinacOptGUI) corresponding to the estimated beam energy.
2. Measure beam energy (follow section 8.5).
3. Re-set focusing elements to a theoretical tune corresponding to the measured energy (if different from the estimated one).
4. Use steerers to centre the beam as much as possible on BMPs.
5. Insert view screens (one at a time) and record beam centering and beam size (horizontal and vertical).
6. Compare the values of beam size with theory (elinacOptGUI). Resolve discrepancies (if any) by exercising individual optical elements.
7. Measure transmission through the section of beam line using two Faraday cups.

8.7 Phase an accelerating rf cavity

The optimum rf phase is defined, at this stage, as the phase that maximizes the energy gain. To phase an accelerating cavity:

1. set the cavity to a given gradient (approximately known from the commissioning of the cryomodule without beam);
2. prepare downstream analyzing leg for energy measurement (see section 8.5);
3. measure energy of the accelerating beam;
4. vary the rf phase to maximize the beam energy;
5. repeat the previous two steps until optimum phase is found.

8.8 Rf buncher and rf deflector

Unlike other elements, these two rf devices are tested with beam only after a tune has been established for the ELBD line.

- Set ELBD to the high energy resolution tune (given by elinacOptGUI).
- Insert ELBD:VS1, and centre beam spot on it.
- Turn on the rf buncher, vary its phase until beam size is minimized (in the 'momentum' direction) on ELBD:VS1; record this phase.
- Vary the buncher phase further: another minimum of beam size should be observer about 180° away from the first one; record this phase.
- Turn on the rf deflector, vary its phase until beam size is maximized (in 'time' direction, which should be orthogonal to the 'momentum' direction) on the ELBD:VS1; record this phase.
- Vary the rf deflector phase further: another maximum of beam size should be observer about 180° away from the first one; record this phase.

9 Procedures for commissioning higher beam power

Procedures given in this section will be applied to the sub-sections of elinac as outlined in e-Linac Commissioning Plan [1], sections 11 and 12. These procedure will be provided in a future release of the present document.

References

[1] S. Koscielniak, e-Linac Commissioning Plan P0104, Document-108335, Internal report, TRIUMF, June 2015.

[2] M. Marchetto, E-linac Prerequisites Tracking Tool Document-109600, Internal report, TRIUMF, August 2015.