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E-linac Beam Commissioning Plan

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History of Changes

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1	2014-09-24	First release: ELBT only.	Thomas Planche
2	2014-10-01	Second release: EMBT added.	Thomas Planche

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1 Introduction

This document is the detailed plan for the electron beam commissioning; the present plan follows the directives of the E-linac Commissioning Plan (ECP) (document-108335).
First release of this document (109780) corresponds to the phase IC-1:"Injector Commissioning Part 1 the GUN, ELBT and ELBD are commissioned up to 1kW c.w. at 300keV", and is consistent with the goals of Section 9.1 and procedure of Section 9.3 of the ECP.

1.1 Purpose

The beam commissioning follows directly the equipment commissioning (document-109600).
The purpose of this stage of beam commissioning is twofold:
(1) to verify the basic properties of the beam;
(2) to verify that the different beam line components can be used together to achieve basic beam diagnostics (measurement of beam current, position, size, and energy), beam transport (steering and focusing), and acceleration.

1.2 Referenced documents

- E-linac commissioning Plan: document-108335;
- E-linac Equipment Commissioning Plan: document-109600.

2 System to be commissioned

The system to be commissioned is made of four major subsystems:

- the electron beam,
- beam diagnostics elements,
- beam lines steering and focusing elements,
- accelerator cryomodules (excluding cryogenic aspect).

The beam diagnostics elements comprise:

- Faraday cups,
- rf shields,
- view screens,
- wire scanners,
- collimator (ELBT:COL0) and slits (ELBD:LPM0)
- beam position monitors (BPM),
- the rf deflector (ELBD:DEFL).

The beam lines steering and focusing elements comprise:

- Helmholtz coils,
- correction benders (also called steerers),
- dipole benders,
- solenoids,
- quadrupoles,
- rf buncher (realizing longitudinal focusing).

There are three accelerator cryomodules:

- EINJ,
- EACA,
- EACB.

3 Commissioning team

The commissioning team is composed of:

- Rick Baartman: Head of commissioning team;
- Marco Marchetto: Equipment commissioning coordinator;
- Thomas Planche: Beam commissioning coordinator;

and their delegates:

- Iouri Bylinski,
- Yi-Nong Rao
- Yu-Chiu Chao,
- Shane Koscielniak.

3.1 Overall responsibility

According to the E-linac commissioning plan (paragraph 5.2.2) the overall responsibility for the commissioning plan lies with the head of the commissioning team.

3.2 Specific responsibility

According to the E-linac commissioning plan (paragraph 5.2.4) the responsibility for the beam commissioning plan and its execution lies with the beam commissioning coordinator.

4 Pre-requisite

See and verify Sections 4.2.3 and 4.2.4 of the ECP.

The equipment commissioning of a given section of the E-linac must be completed before starting beam commissioning over this section. The equipment commissioning must in particular include a record of the test of machine safety interlock system.

It is the responsibility of the beam commissioning coordinator to verify that an equipment commissioning record exists before starting beam commissioning. The existence of this document is confirmed by writing the released document number on the related table.

5 Acceptance criteria

The high level acceptance criteria in Phase IC-1 are to:

- Establish a (low loss) beam tune in the ELBT straight section
- Establish a (law loss) beam tune in the ELBD analyzing section
- Confirm beam longitudinal manipulation by the buncher and deflector.

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 and reported in Tables.

6 Record of commissioning

The Commissioning Plan is a list of successive steps presented in the form of multiple tables (Table 2 and 4); the acceptance criterion is successful fulfillment of a series of related tests. As the Plan is executed, each outcome is recorded in the related table. The Commissioning Report will contain the exact same tables with the 'outcome' column filled in. The Commissioning Report may also include additional relevant information (such as measured values, graphs, pictures, report of unexpected events, etc) acquired during commissioning.

Upon execution of the Plan for first section, a Report will be produced as first release. Subsequent releases of the same document will be produced in accordance with the completion of the equipment commissioning of other sections.

7 Safety

7.1 Personal safety

To prevent exposure to prompt ionizing radiations, the E-hall shall always be evacuated and the locked-up prior to turning on the electron beam.

7.2 Machine safety

Basic machine safety interlocks tested during the equipment commissioning shall be operational during the beam commissioning.

8 Commissioning plan

The following paragraphs contain the commissioning plan grouped by beam line sections.

8.1 ELBT commissioning plan

Before turning the beam ON to start ELBT beam commissioning it must be check that the beam line is ready to receive the electron beam. For this purpose every item listed is Table 1 shall be checked.

Table 1. ELBT ready for beam check list.

Device	Setting	Checked
EGUN:CHT	100 V	
Repetition rate	1 kHz	
Duty factor	0.5 %	
RF amplitudes	enough to produce 0.2 mA peak current	
All correction bender	set at 0A unless otherwise specified	
ELBT:HC	Enough to produce +3G	
EGUN:SOL1	+2.54 A	
EGUN:XCB0	0 A	
EGUN:YCB0	-0.09 A	
EGUN:FC1	IN set at 5mA gain	
ELBT buncher	Buncher detuned	
ELBT:SOL1	+3.15 A	
ELBD:MB0	Degaussed and 0 A	
ELBT:SOL2	+3.38 A	
ELBT:FC2	Locked IN set at 5mA gain	

Successive steps of the ELBT beam commissioning are listed in Table 2. Columns of Table 2 contain, from left to right: the subsystem to be commissioned, the functionality we want to verify, measured values (when applicable) and other possible outcomes, and whether or not the device satisfies its acceptance criteria.

Table 2. ELBT beam commissioning plan.

Device	Verification	Outcome	Accepted?
EGUN:FC1	Device note menu contains all necessary instructions to operate this diagnostics.		
	Can read beam peak current.		
EGUN:RFSH1	Device note menu contains all necessary instructions to operate this diagnostics.		
	Raw signal proportional to peak current.		
EGUN:VS1	Device note menu contains all necessary instructions to operate this diagnostics.		
	Beam off: calibrate size using calibration screen.		
	Beam seen on view screen.		
Set EGUN:SOL1 to 0 A			
EGUN:HC	Device note menu present and writable.		
	Centre beam horizontally on EGUN:VS1 using EGUN:HC.		
EGUN:XCB0	Device note menu present and writable.		
	+0.2 A moves beam on EGUN:VS1 horizontally to the left by ~6.5 mm.		
	-0.2 A moves beam on EGUN:VS1 horizontally to the right by ~6.5 mm.		
EGUN:YCB0	Device note menu present and writable.		

	+0.2 A moves beam on EGUN:VS1 vertically up by ~5.2 mm.		
	-0.2 A moves beam on EGUN:VS1 vertically down by ~5.2 mm.		
	Centre beam vertically on EGUN:VS1 using EGUN:YCB0.		
EGUN:BPM1	Device note menu contains all necessary instructions to operate this diagnostics.		
	Can read beam peak current.		
	Change EGUN:XCB0 by +0.1 A: beam moves beam horizontally by +3.9 mm.		
	Change EGUN:YCB0 by +0.1 A: beam moves beam vertically by +3.2 mm.		
EGUN:SOL1	Device note menu present and writable.		
	Minimum beam size on EGUN:VS1 around 2.98A.		
EGUN:SOL1 now set back to 2.54 A			
ELBT:VS0	Device note menu contains all necessary instructions to operate this diagnostics.		
	Beam off: calibrate size using calibration screen.		
	Beam seen on view screen		
ELBT:RFSH0	Device note menu contains all necessary instructions to operate this diagnostics.		
	Raw signal proportional to		

	peak current.		
EGUN:XCB1	Device note menu present and writable.		
	Positive current moves beam horizontally to the left on ELBT:VS0.		
	Negative current moves beam horizontally to the right on ELBT:VS0.		
EGUN:YCB1	Device note menu present and writable.		
	Positive current moves beam vertically up on ELBT:VS0.		
	Negative current moves beam vertically down on ELBT:VS0		
ELBT:XCB0	Device note menu present and writable.		
	+1 A moves beam on ELBT:VS0 vertically up by ~1.9 mm.		
	-1 A moves beam on ELBT:VS0 vertically down by ~1.9 mm.		
ELBT:YCB0	Device note menu present and writable.		
	+1 A moves beam on ELBT:VS0 horizontally to the left by ~1.9 mm		
	-1 A moves beam on ELBT:VS0 horizontally to the right by ~1.9 mm.		
ELBT:BPM0	Device note menu contains all necessary instructions to operate this diagnostics.		
	Can read beam peak current.		

	Change ELBT:XCB0 by +1 A: beam moves beam horizontally by +3.1 mm.		
	Change ELBT:XCB0 by -1 A: beam moves beam horizontally by -3.1 mm		
	Change ELBT:YCB0 by +1 A: beam moves beam vertically by +3.1 mm.		
	Change ELBT:YCB0 by -1 A: beam moves beam vertically by -3.1 mm.		
ELBT:FC2	Device note menu contains all necessary instructions to operate this diagnostics.		
	Can read beam peak current.		
With beam OFF: remove ELBT:FC2 and insert ELBT:VS2 EGUN:SOL1 at 2.54 A, ELBT:SOL1 at 1.7 A and ELBT:SOL2 OFF			
ELBT:VS2	Device note menu contains all necessary instructions to operate this diagnostics.		
	Beam off: calibrate size using calibration screen.		
	Beam seen on view screen.		
EMBD:MB0 (OFF and degaussed)	Device note menu present and writable.		
	Beam within 5 mm of the ELBT:VS2 center with only EGUN:XYCB0 and EGUN:XYCB1 used as steerers.		
	Beam round on ELBT:VS2		
ELBT:SOL1	Device note menu present and writable.		

	Minimum beam size on ELBT:VS2 at 2.2 A.		
ELBT:XCB1A	Device note menu present and writable.		
	+0.2 A moves beam on ELBT:VS2 vertically up by ~2.1 mm.		
	-0.2 A moves beam on ELBT:VS2 vertically down by ~2.1 mm.		
ELBT:YCB1A	Device note menu present and writable.		
	+0.2 A moves beam on ELBT:VS2 horizontally to the left by ~2.1 mm.		
	-0.2 A moves beam on ELBT:VS2 horizontally to the right by ~2.1 mm.		
EGUN:SOL1 at 2.54 A, ELBT:SOL1 at 1.19 A and ELBT:SOL2 at 1.88 A			
ELBT:SOL2	Device note menu present and writable.		
	Minimum beam size on ELBT:VS2 at 3.9 A.		

8.2 EMBT commissioning plan

This part of the plan is based on the assumption that EINJ provides to EMBT an 10 MeV electron beam.

Before injecting beam into the EINJ it must be check that the beam line is ready to receive the electron beam. For this purpose every item listed is Table 3 shall be checked.

Table 3. EMBT ready for beam check list.

Device	Setting	Checked
EGUN:CHT	100 V	
Repetition rate	1 kHz	
Duty factor	0.1 %	
RF amplitudes	Enough to produce 0.2 mA peak current	
All correction bender	Set at 0A unless otherwise specified	
ELBT:HC	Enough to produce +3G	
EMBT:HC	Enough to produce +2.3G	
EGUN:SOL1	+2.48 A	
EGUN:YCB0	-0.08 A	
EGUN:FC1	IN set at 5mA gain	
ELBT:RFSH0	IN	
ELBT buncher	Set to inject bunched beam into EINJ	
ELBT:SOL1	+1.52 A	
ELBD:MB0	Degaussed and 0 A	
ELBT:SOL2	+0.07 A	
ELBT:FC2	IN	
EMBT:Q1	-0.16 A	
EMBT:Q2	+0.52 A	
EMBT:Q3	-0.17 A	
EMBT:MB0	23.15 A	
EMBT:Q4	1.75 A	
EMBT:Q5	-1.12 A	
EMBT:MB5A	23.15 A	

EMBT:Q5B	+1.12	
EMBT:MB5C	-25.00	
EMBT:Q6	-1.32	
EMBT:Q7	+1.50	
EMBT:FC6	Locked in and set at 5 mA gain	

Successive steps of the EMBT beam commissioning are listed in Table 4. Columns of Table 4 contain, from left to right: the subsystem to be commissioned, the functionality we want to verify, measured values (when applicable) and other possible outcomes, and whether or not the device satisfies its acceptance criteria.

Table 4. EMBT beam commissioning plan.

Device	Verification	Outcome	Accepted?
EMBT:VS0	Device note menu contains all necessary instructions to operate this diagnostics.		
	Beam off: calibrate size using calibration screen.		
	Beam seen on view screen.		
EMBT:XCB0	Device note menu present and writable.		
	Positive current moves beam to the left on ELBT:VS0.		
	Negative current moves beam to the right on ELBT:VS0.		
EMBT:YCB0	Device note menu present and writable.		
	Positive current moves beam vertically up on ELBT:VS0.		
	Negative current moves beam vertically down on ELBT:VS0.		

EMBT:BPM0	Device note menu contains all necessary instructions to operate this diagnostics.		
	Can read beam peak current.		
	It is still unclear to me how to use steering to check this particular BPM (because it is right after EINJ)		
EMBT:VS4	Device note menu contains all necessary instructions to operate this diagnostics.		
	Beam off: calibrate size using calibration screen.		
	Beam seen on view screen.		
Set EMBT:Q1 and EMBT:Q2 to 0A			
EMBT:BPM2	Device note menu contains all necessary instructions to operate this diagnostics.		
	Can read beam peak current.		
	Change EMBT:XCB0 by +0.1 A: beam moves beam to the left.		
	Change EMBT:XCB0 by -0.1 A: beam moves beam to the right.		
	Change EMBT:YCB0 by +0.1 A: beam moves beam up.		

	Change EMBT:YCB0 by -0.1 A: beam moves beam down.		
EMBT:XCB1	Device note menu present and writable.		
	Positive current moves beam to the left on ELBT:BPM2.		
	Negative current moves beam to the right on ELBT:BPM2.		
EMBT:YCB1	Device note menu present and writable.		
	Positive current moves beam vertically up on ELBT:BPM2.		
	Negative current moves beam vertically down on ELBT:BPM2.		
Set back EMBT:Q1 and EMBT:Q2 to nominal currents			
EMBT:Q1	Device note menu present and writable.		
	Find current which minimizes horizontal beam size on EMBT:VS4.		
	Find current which minimizes vertical beam size on EMBT:VS4.		
EMBT:Q2	Device note menu present and writable.		
	Find current which minimizes horizontal beam size on EMBT:VS4.		
	Find current which minimizes vertical beam size on EMBT:VS4.		
EMBT:Q3	Device note menu present and writable.		

	Find current which minimizes horizontal beam size on EMBT:VS4.		
	Find current which minimizes vertical beam size on EMBT:VS4.		
EMBT:Q4	Device note menu present and writable.		
	Find current which minimizes horizontal beam size on EMBT:VS4.		
	Find current which minimizes vertical beam size on EMBT:VS4.		
Set EMBT:Q4 and EMBT:Q5 to 0 A			
EMBT:XCB3	Device note menu present and writable.		
	Positive current moves beam to the left on ELBT:VS4.		
	Negative current moves beam to the right on ELBT:VS4.		
EMBT:YCB3	Device note menu present and writable.		
	Positive current moves beam vertically up on ELBT:VS4.		
	Negative current moves beam vertically down on ELBT:VS4.		
EMBT:BPM4	Device note menu contains all necessary instructions to operate this diagnostics.		
	Can read beam peak current.		
	Change EMBT:XCB3 by +0.1 A: beam moves		

	beam to the left.		
	Change EMBT:XCB3 by -0.1 A: beam moves beam to the right.		
	Change EMBT:YCB3 by +0.1 A: beam moves beam up.		
	Change EMBT:YCB3 by -0.1 A: beam moves beam down.		
Set back EMBT:Q4 and EMBT:Q5 to nominal currents			
EMBT:VS5B	Device note menu contains all necessary instructions to operate this diagnostics.		
	Beam off: calibrate size using calibration screen.		
	Beam seen on view screen.		
EMBT:XCB4	Device note menu present and writable.		
	Positive current moves beam to the left on ELBT:VS5B.		
	Negative current moves beam to the right on ELBT:VS5B.		
EMBT:YCB4	Device note menu present and writable.		
	Positive current moves beam vertically up on ELBT:VS5B.		
	Negative current moves beam vertically down on ELBT:VS5B.		
EMBT:MB5A	Device note menu present and writable.		
	Beam seen on EMBT:VS5B with an		

	excitation current of 21.00A		
EMBT:XCB5A	Device note menu present and writable.		
	Positive current moves beam to the left on ELBT:VS5B.		
	Negative current moves beam to the right on ELBT:VS5B.		
EMBT:YCB5A	Device note menu present and writable.		
	Positive current moves beam vertically up on ELBT:VS5B.		
	Negative current moves beam vertically down on ELBT:VS5B.		
EMBT:Q5	Device note menu present and writable.		
	Find current which minimizes horizontal beam size on EMBT:VS5A.		
	Find current which minimizes vertical beam size on EMBT:VS5A.		
Set EMBT:Q5 to 0A			
EMBT:BPM5B	Device note menu contains all necessary instructions to operate this diagnostics.		
	Can read beam peak current.		
	Change EMBT:XCB5A by +0.1 A: beam moves beam to the left.		
	Change EMBT:XCB5A by -0.1 A: beam moves		

	beam to the right.		
	Change EMBT:YCB5A by +0.1 A: beam moves beam up.		
	Change EMBT:YCB5A by -0.1 A: beam moves beam down.		
Set back EMBT:Q5 to its nominal current			
EMBT:VS6	Device note menu contains all necessary instructions to operate this diagnostics.		
	Beam off: calibrate size using calibration screen.		
	Beam seen on view screen.		
Set EMBT:Q6 and EMBT:Q7 to 0A			
EMBT:XCB5B	Device note menu present and writable.		
	Positive current moves beam to the left on ELBT:VS6.		
	Negative current moves beam to the right on ELBT:VS6.		
EMBT:YCB5B	Device note menu present and writable.		
	Positive current moves beam vertically up on ELBT:VS6.		
	Negative current moves beam vertically down on ELBT:VS6.		
EMBT:XCB5B2	Device note menu present and writable.		
	Positive current moves beam to the left on ELBT:VS6.		

	Negative current moves beam to the right on ELBT:VS6.		
EMBT:YCB5B2	Device note menu present and writable.		
	Positive current moves beam vertically up on ELBT:VS6.		
	Negative current moves beam vertically down on ELBT:VS6.		
EMBT:MB5C	Device note menu present and writable.		
	Beam seen on EMBT:VS6 with an excitation current of 21.00A		
EMBT:XCB5C	Device note menu present and writable.		
	Positive current moves beam to the left on ELBT:VS6.		
	Negative current moves beam to the right on ELBT:VS6.		
EMBT:YCB5C	Device note menu present and writable.		
	Positive current moves beam vertically up on ELBT:VS6.		
	Negative current moves beam vertically down on ELBT:VS6.		
EMBT:BPM5C	Device note menu contains all necessary instructions to operate this diagnostics.		
	Can read beam peak current.		

	Change EMBT:XCB5C by +0.1 A: beam moves beam to the left.		
	Change EMBT:XCB5C by -0.1 A: beam moves beam to the right.		
	Change EMBT:YCB5C by +0.1 A: beam moves beam up.		
	Change EMBT:YCB5C by -0.1 A: beam moves beam down.		
EMBT:BPM7	Device note menu contains all necessary instructions to operate this diagnostics.		
	Can read beam peak current.		
	Change EMBT:XCB5C by +0.1 A: beam moves beam to the left.		
	Change EMBT:XCB5C by -0.1 A: beam moves beam to the right.		
	Change EMBT:YCB5C by +0.1 A: beam moves beam up.		
	Change EMBT:YCB5C by -0.1 A: beam moves beam down.		
EMBT:Q6	Device note menu present and writable.		
	Find current which minimizes horizontal beam size on EMBT:VS6.		
	Find current which minimizes vertical beam size on EMBT:VS6.		
EMBT:Q7	Device note menu present		

	and writable.		
	I am not sure how to check the focusing effect of this quad.		