Beam Commissioning at ESS

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Workshop on Testing and Commissioning
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Outline

• Beam commissioning overview
  – Planning
  – Configuration
  – Note on beam physics

• Summary
What I'm doing...

• Planning phase
  – Identify required activities with beam and their dependencies.
    • Primary focus is on beam physics related activities, e.g., RF cavity setting.
    • Also including hardware verifications with beam, e.g., diagnostics verifications.
  – Define a sequence of the activities based on the dependencies and priorities.
    • Have no authority to change the term allocated to a beam commissioning stage. (Only provide feedbacks to the integration, testing, and commissioning planner.)
  – Help to develop (or do develop) a procedure of each activity.
  – Maintain and update the plan.

• Execution phase
  – When the beam is available, determine conducted activities based on the plan and other conditions, e.g., availability of subsystems and personnel.
    • Availability of the beam itself is determined by the system owners and operations.
  – Help to conduct (or do conduct) each activity.
  – Is one of the primary stakeholders to permit (the shift leader) to use a new machine configuration and beam parameter envelope.
    • In the control room, the shift leader is in charge of these.
  – Maintain and update the plan.
Beam commissioning stages and schedule

- Focus now is on the ongoing ISrc-LEBT and the following NC linac stage.
- Schedule is driven by deliveries and installations of components. The sequence of beam commissioning activities is laid out to fit to the allocated time.
  - No contingency for unexpected interventions.
  - Every step has to be well prepared and executed as planned.
  - Possible to run out of time (e.g., before starting current ramp-up).
  - Doing better (e.g., including realistic contingency) is harder when the plan is not so stable.
- Beyond the ISrc-LEBT stage, we use internal and permanent beam stops and diagnostics devices. This allows us to come back to a state of the preceding stages.
  - The linac includes a thorough set of permanent diagnostics devices.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Energy [MeV]</th>
<th>Start date (old)</th>
<th>Start date (baseline)</th>
<th>Start date (update)</th>
<th>Duration [weeks]</th>
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<td>2018-06-28</td>
<td>2018-09-19</td>
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<td>ISrc - DTL4</td>
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Planning example of commissioning steps: ISrc-LEBT

- High-level plan and strategy, in terms of beam physics, has been presented in internal documents (e.g., ESS-0149990 for NC linac) as well as in conferences and workshops.
- Steps and sub-steps of the ISrc-LEBT stage has been maintained and updated in Jira.
- Steps and sub-steps of the ISrc-DTL1 stage has been developed in Jira.
- How to prepare for each sub-step is up to the responsible person.
Planning example of commissioning sub-steps: ISrc-LEBT

There is a page for each sub-step.
## Beam modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Current [mA]</th>
<th>Duration [µs]</th>
<th>Rep [Hz]</th>
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<td>Probe</td>
<td>~6</td>
<td>≤ 5</td>
<td>≤ 1</td>
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<td>Fast tuning</td>
<td>≤ 62.5</td>
<td>≤ 5</td>
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<td>Slow tuning</td>
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<td>Long pulse verification</td>
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<td>Production</td>
<td>≤ 62.5</td>
<td>2860</td>
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# Beam stops

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<th>Type</th>
<th>Availability</th>
<th>Tuning</th>
<th>Long-pulse</th>
<th>Production</th>
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<td>LEBT (inside tank)</td>
<td>FC</td>
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## Full list of diagnostics devices
(From the lattice synoptic viewer)

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<th>RFQ</th>
<th>MEBT</th>
<th>DTL</th>
<th>SPK</th>
<th>MBL</th>
<th>HBL</th>
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</table>
ISrc- LEBT commissioning configuration (Plan)
Running the real beam provides the best lesson, but we need to take balance.
— We should have had agreed on the minimal configuration, beforehand.

Only occasion to use an external stop and diagnostics. We could never come back to this configuration.

Only occasion, besides target, we can test the nominal beam parameters.
ISrc - MEBT, DTL1

- DTL2-3 not installed. DTL4 installed but not powered.
- DTL2 FC placed right after DTL1. (With shielding?)
- Temporary shield wall at DTL5.

ISrc - DTL4

- No change from the baseline.
• This configuration (FC shielding + wall) allows the NC linac beam and SC linac installation in parallel.

• Prompt dose limit:
  – 3 µSv/h (supervised area)
  – Averaged over 1 hour

• Limits in dose and FC itself are comparable. If either is missing, the beam very limited.

<table>
<thead>
<tr>
<th></th>
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<td>3.0E-3</td>
<td>6</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Contents of the table:

- **FC**: The configuration identifier.
- **Energy [MeV]**: The energy level in MeV.
- **Ave curr lim [µA]**: The average current limit in µA.
- **Probe lim [min/hour]**: The probe limit in minutes per hour.
- **Slow-tuning lim [min/hour]**: The slow-tuning limit in minutes per hour.
- **Fast-tuning lim [min/hour]**: The fast-tuning limit in minutes per hour.

**Diagram**: Courtesy of K Batkov

**Diagram Description**: The diagram visually represents the layout of the FC and DTL4 configurations, highlighting the areas where the limits are applied.
No special configuration after the NC linac commissioning

- The beam is stopped with internal beam stops, tuning dump, or target.
  - The tuning dump could bear with the 2.86 ms pulse but only at 1/30 Hz (12.5 kW).
- Only available number of cryomodules change over time.
Simple and or standard tuning

Standard linac/beamline tuning, requiring a dedicated application:

• Linear optics verification
  – Polarity check
  – Beam based alignment
  – Trajectory correction
• RF phase and amplitude setting
• Transverse matching with 3+ profile measurements

For beam transports and RFQ, many adjustments are done with a simple parameter(s) scan:

• LEBT
  – Iris verification
  – Chopper verification
• RFQ
  – Amplitude scan
  – Matching with LEBT solenoids scan
• MEBT
  – Chopper verification
  – Collimator positioning
• A2T (including dogleg)
  – Achromatic condition verification
  – Cross-over point verification
  – Raster verification

• Online beam physics application and diagnostics devices are keys to efficient beam commissioning.
• Further details on tuning were presented in the past conference, workshops, and reviews.
Could-be-challenging tuning
(Excluding operational challenges such as protection)

- ISrc optimization
  - Unlike H- machines, we need to balance the current and beam quality.
- Optics tuning of the non-periodic MEBT
- Twiss and emittance reconstruction with a quad or cavity scan
  - Space charge and beam loss require extra care.
- Matching at the frequency jump
  - Frequency jump at the SPK-MBL interface is the weakest point of our linac and requires a smooth matching. But, there is no nearly direct longitudinal measurement.
- Beam loss mitigation
  - We don't have the obvious beam loss cause of H- stripping.
Summary (and questions)

• Status of planning beam commissioning activities and their sequence:
  – For the ISrc-LEBT stage, the developed plan is being executed and also updated to adopt to situation.
  – For the NC linac stage, plan is being detailed.
  – For the SC linac stage (starting in ~2.5 years), due to a resource limitation, we only have very high-level plan (and studies).
  – **Is there a rule of thumb for contingency of the beam commissioning?**
  – **How detail we plan for each activity.**
    • Controlled document vs piece of code.

• The schedules of the stages beyond the ISrc-LEBT are aggressive but using internal and permanent beam stops and diagnostics allow to come back and repeat the process in any given point, later.
  – On the contrary, the ISrc-LEBT stage is unique.
  – **Comments/suggestions on this strategy?**
Backup
ISrc- LEBT operations configuration

- Solenoid 1 (Steerer 1)
- Chopper
- Collimator
- Solenoid 2 (Steerer 2)
- Iris
- FC
- Allison (H)
- Allison (V)
- Camera (H)
- Camera (V)
- Doppler
- Camera (H)
- Camera (V)
- BCM

Source extraction

Permanent tank

BCM
NC linac commissioning configuration (baseline)

**ISrc - MEBT, DTL1**

- DTL1-4 installed but only DTL1 powered.
- MEBT and DTL2 FCs at their nominal locations.
- Temporary shield wall + DTL4 FC with shielding at DTL5.

**ISrc - DTL4**

- DTL1-4 powered.
- MEBT and DTL2 FCs at their nominal locations.
- Temporary shield wall + DTL4 FC with shielding at DTL5.