Linac4 commissioning

Transverse emittance measurement strategy

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Linac4 Layout

- A new 160 MeV $H^-$ ion linac, injector of PS Booster.
Linac4 present status

- H- source presently under commissioning.
- RFQ delivered, RF bead-pulls performed.
- DTL, Tank1 assembled.
- First CCDTL modules delivered in October.
- PIMS modules ready from next year.
- Tunnel ready for machine installation.
Linac4 commissioning plans

- Commissioning will start next year and will be divided into 6 stages
  - Stage 1: 3MeV test stand. Commissioning of the source, LEBT, RFQ and MEBT in the PS south hall.
  - Stage 2: Re-commissioning of the 3MeV line in the tunnel.
  - Stage 3: First DTL tank (12 MeV).
  - Stage 4: DTL tank 2&3 (50 MeV).
  - Stage 5: CCDTL (100 MeV).
  - Stage 6: PIMS (160 MeV).
Commissioning Planning

- **3 and 12 MeV** from mid 2013
- **50 MeV** from 2014
- **100 MeV** mid 2014
- **160 MeV** 2015
- **160 MeV tests and reliability run** 2015-16
Emittance measurement

- Low energies, up to 12 MeV
  - Low penetration depth
  - Low activation
  - Use of an emittance-meter: Slit-Grid

- High energies, 30, 50, 100 and 160 MeV
  - Three monitor method
  - Space charge to be taken into account...
The « Forward Method »

- 1\textsuperscript{st} step: No space charge included, the classical 3 monitor method

\[
\sigma = \begin{pmatrix} x_m^2 & x'_m x'_m \\ x'_m x_m & x'_m^2 \end{pmatrix} = \varepsilon \begin{pmatrix} \beta & -\alpha \\ -\alpha & \gamma \end{pmatrix} \\
R = \begin{pmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{pmatrix} \quad \sigma(L) = R \cdot \sigma(0) \cdot R^T
\]

\[
x_{\text{monitor}1} = \sigma_{11}(1) = R_{11}^2(1)\varepsilon\beta - 2R_{11}(1)R_{22}(1)\varepsilon\alpha + R_{12}^2(1)\varepsilon\gamma
\]

\[
x_{\text{monitor}2} = \sigma_{11}(2) = R_{11}^2(2)\varepsilon\beta - 2R_{11}(2)R_{22}(2)\varepsilon\alpha + R_{12}^2(2)\varepsilon\gamma
\]

\[
x_{\text{monitor}3} = \sigma_{11}(3) = R_{11}^2(3)\varepsilon\beta - 2R_{11}(3)R_{22}(3)\varepsilon\alpha + R_{12}^2(3)\varepsilon\gamma
\]
The « Forward Method »

- 1st step: No space charge included, the classical 3 monitor method

@ DTL output, 50 MeV.
The « Forward Method »

- 1st step: No space charge included, the classical 3 monitor method

@ DTL output, 50 MeV.
The « Forward Method »

- 1st step: No space charge included, the classical 3 monitor method

@ DTL output, 50 MeV.

Need to include space charge forces in the calculation !!!
The « Forward Method »

• 2\textsuperscript{nd} step, Including space charge, iterative process with particle tracking code.

• Generate a beam distribution file for a multiparticle tracking code, with parameters found at step 1.
• Assume a longitudinal distribution (simulations and BSM).
• Launch a series of statistical runs of the measurement line by varying the beam input transverse parameters ($\alpha$, $\beta$, $\epsilon$) at each run.
• At each run, simulated beam size at the monitor locations is compared to measured values to get a convergence criteria.
The « Forward Method »

- DTL emittance reconstruction at 50 MeV.

<table>
<thead>
<tr>
<th>Twiss parameters</th>
<th>From beam distribution</th>
<th>3 monitors method No space charge</th>
<th>Forward method</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha_x )</td>
<td>-5.51</td>
<td>-3.67</td>
<td>-5.61</td>
</tr>
<tr>
<td>( \beta_x ) (mm/mrad)</td>
<td>4.38</td>
<td>2.22</td>
<td>4.57</td>
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<tr>
<td>( \epsilon_x ) Norm. rms. (mm.mrad)</td>
<td>0.28</td>
<td>0.30</td>
<td>0.29</td>
</tr>
<tr>
<td>( \alpha_y )</td>
<td>2.77</td>
<td>1.03</td>
<td>2.95</td>
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<tr>
<td>( \beta_y ) (mm/mrad)</td>
<td>1.69</td>
<td>0.66</td>
<td>1.78</td>
</tr>
<tr>
<td>( \epsilon_y ) Norm. rms. (mm.mrad)</td>
<td>0.29</td>
<td>0.32</td>
<td>0.29</td>
</tr>
</tbody>
</table>
Summary

- We have developed and validated a method for the transverse emittance reconstruction in a space charge dominated regime that we will apply during the Linac4 commissioning.

- The method is based on multiparticle tracking codes and its key point is the generation of the beam distribution in the 3 phase spaces.

- Constraints are:
  - 3 monitor measurement conditions.
  - Knowledge of the longitudinal plane distribution.
  - Choice of the transverse distribution types.