Beam dynamics studies for the definition of the MEBT-3 beam line section (MYRRHA)

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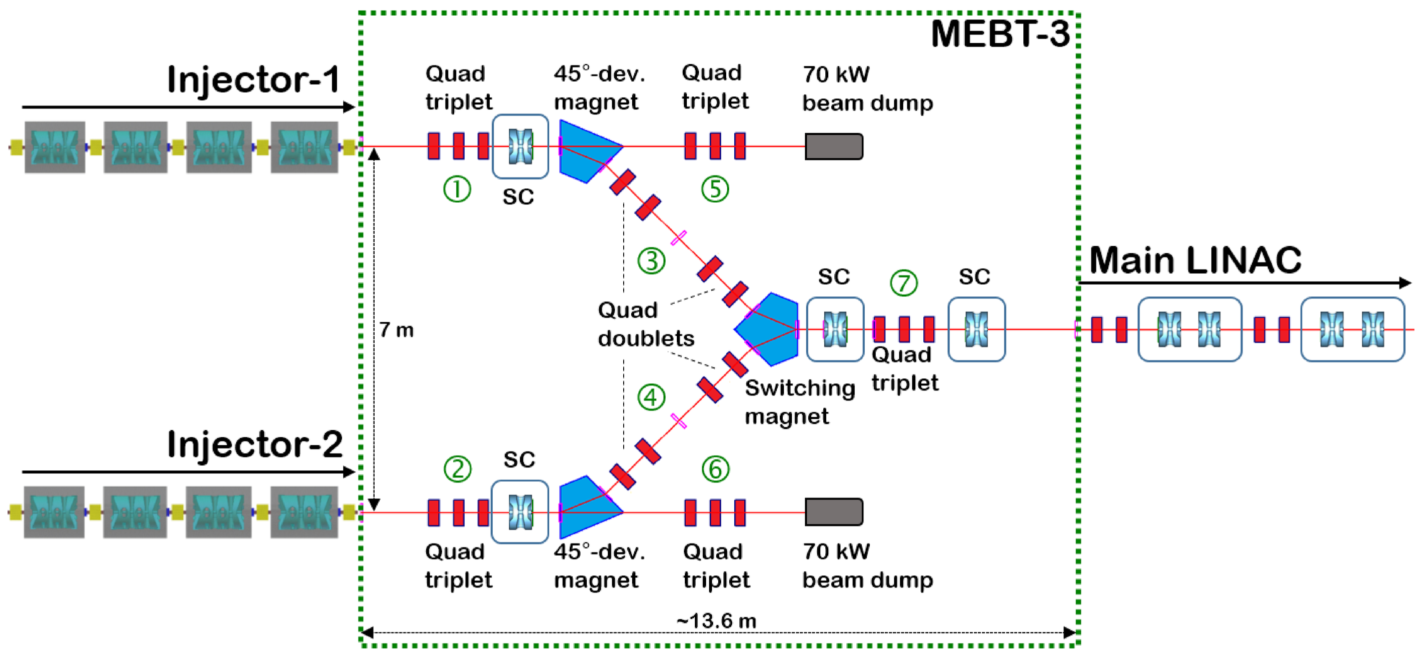
Medium Energy Beam Transport (MEBT-3) section of MYRRHA

The main purpose of the MEBT-3 section of the MYRRHA accelerator is to connect the two injectors lines to the main LINAC with the possibility to switch quickly between the injector lines in case of a failure of the operating one. The fast switching between the injectors increases the reliability of the accelerator operation. The reference scenario of injector reconfiguration and line switching has been defined [1] with the maximal time for the procedure being within 3 seconds.

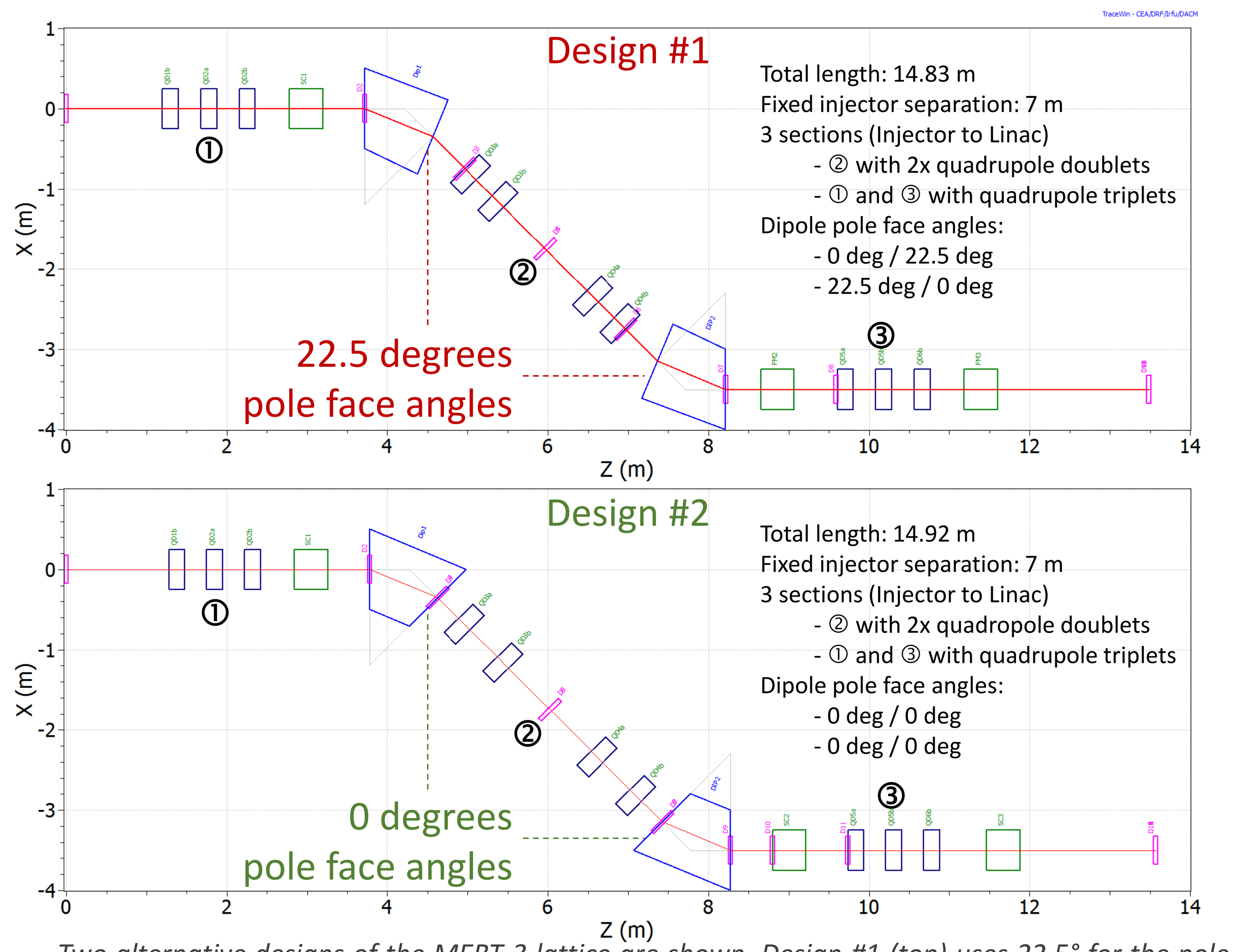


The MEBT-3 section between the two injectors and the main LINAC (dashed green line). It is divided into seven parts separated by two 45°-deviation magnets and a switching dipole connecting the two injectors to the LINAC section.

Lattice design of the MEBT-3 section defined by beam dynamics simulations

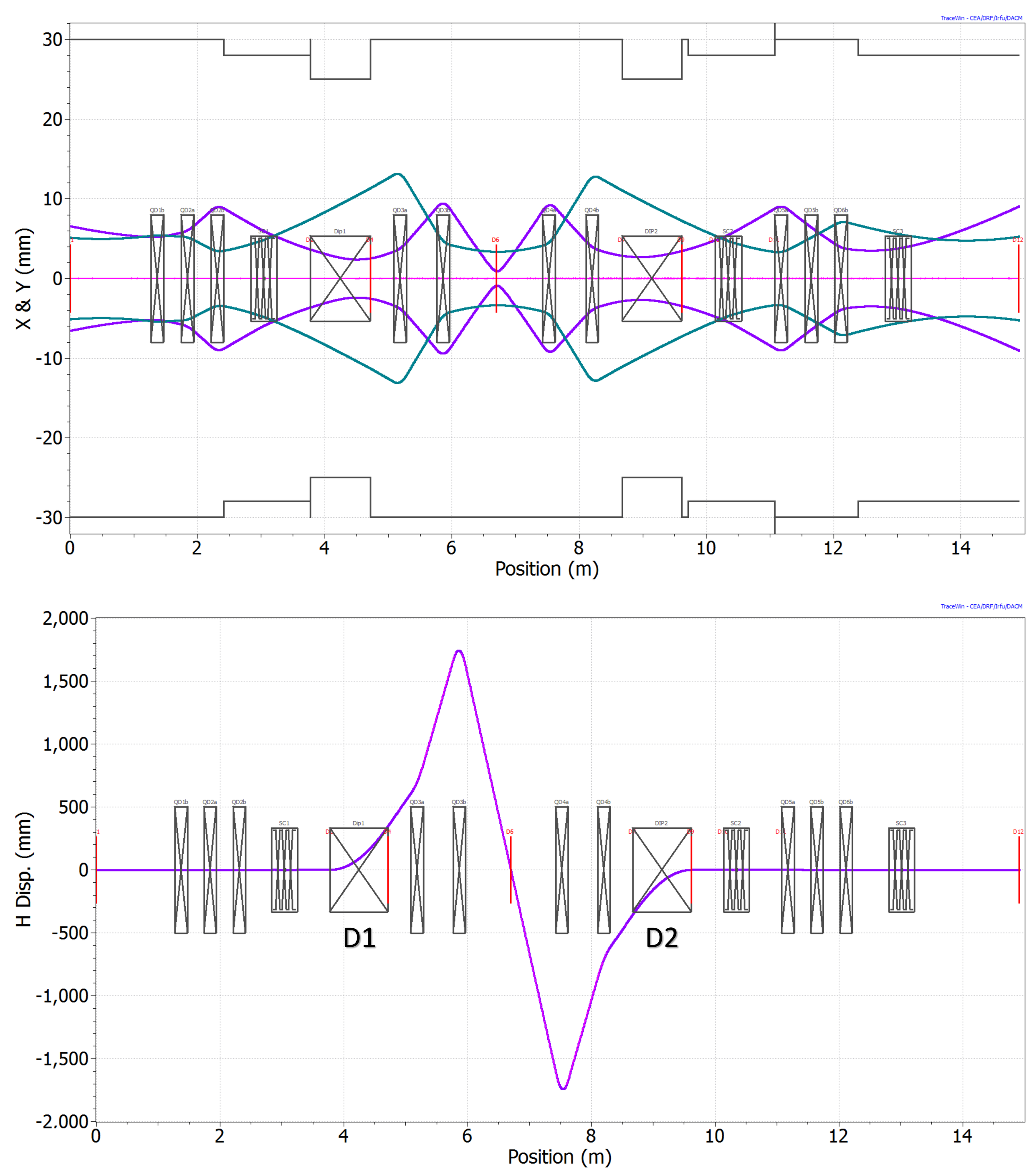
The conceptual design of the MEBT-3 was obtained by using beam dynamics simulations. The initial lattice was adapted from [1]. The simulations were done with the code TraceWin [2], which allows defining the beams either as envelopes based on the initial beam properties (energy, current, Twiss parameters, emittance, etc.) or directly as particle distributions obtained by simulations on the injectors design [3]. A similar distribution was obtained for the purpose of beam matching at the entrance of the main LINAC.

Two alternative lattice designs of the MEBT-3 were considered in the simulations. Both designs fulfill the desired goals defined in the TraceWin simulations.



Two alternative designs of the MEBT-3 lattice are shown. Design #1 (top) uses 22.5° for the pole face angles in section ②, whereas Design #2 (bottom) has straight pole faces.

Requirements for defining the MEBT-3 design and envelopes along the beam line



The top panel shows ±3σ envelopes in the two transverse directions (purple - horizontal plane, green - vertical). The bottom is showing the dispersion being compensated after the switching dipole and satisfying the double achromaticity condition.

The design and tuning of the MEBT-3 section satisfies the following criteria:

- *Beam matching*
- *Beam losses*
- *Double achromaticity*
- *Emittance growth*
- *Energy preservation and synchronous phase*

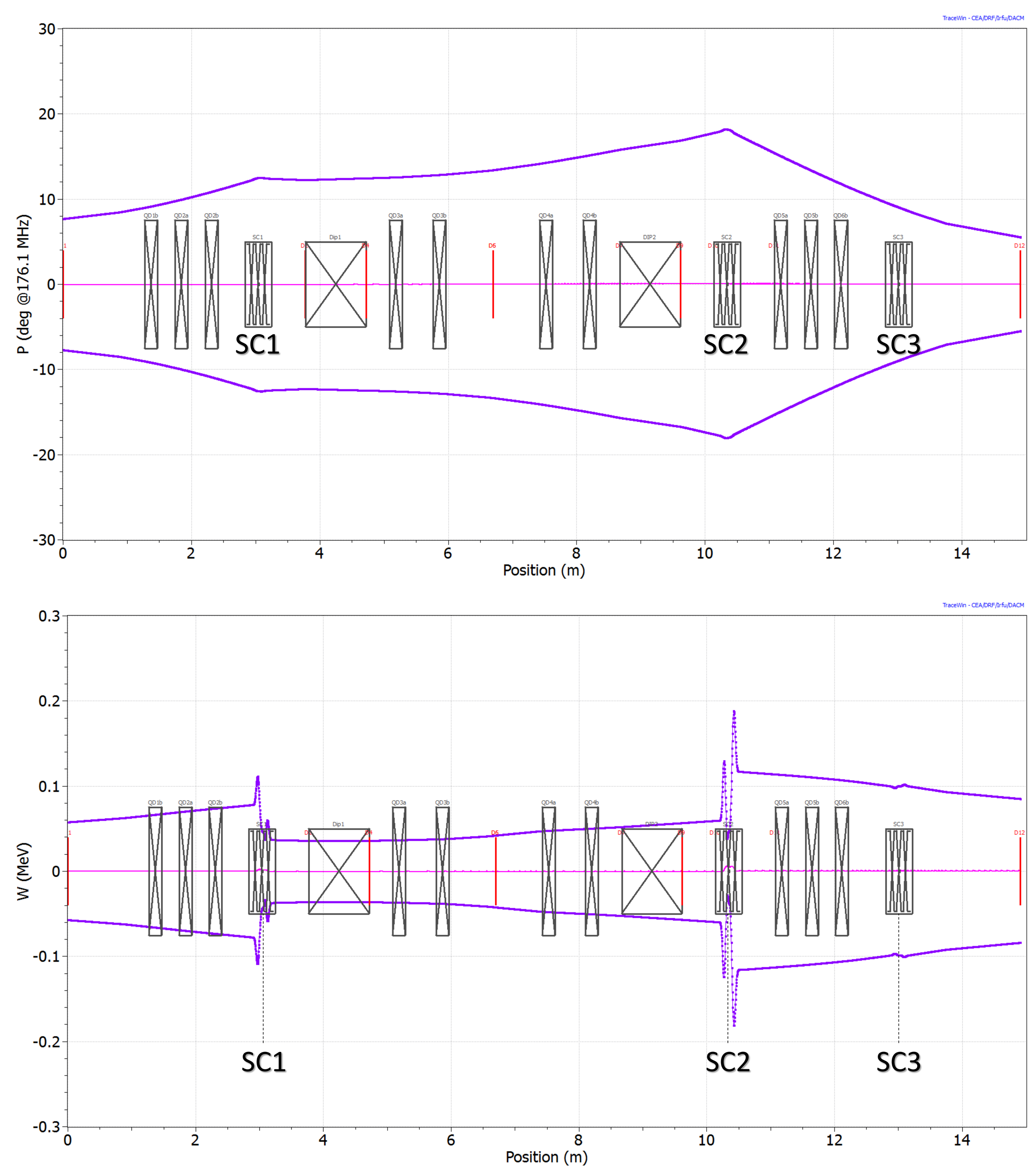
The MEBT-3 section will have diagnostics for tuning and control of the stable operation. A system of collimators will be used to protect the downstream lines in case of failures. The lattice and tuning optimization was done using a beam definition at the entrance obtained by Twiss parameters.

Main properties of MEBT-3

Beam energy	16.6446 MeV
Beam current	4 mA
Max. transverse size	12 mm (±3σ)
Double chromaticity	
Active cavities	SC1 and SC2
Recovery cavity	SC3
Non-accelerating section	
Synchronous phase	

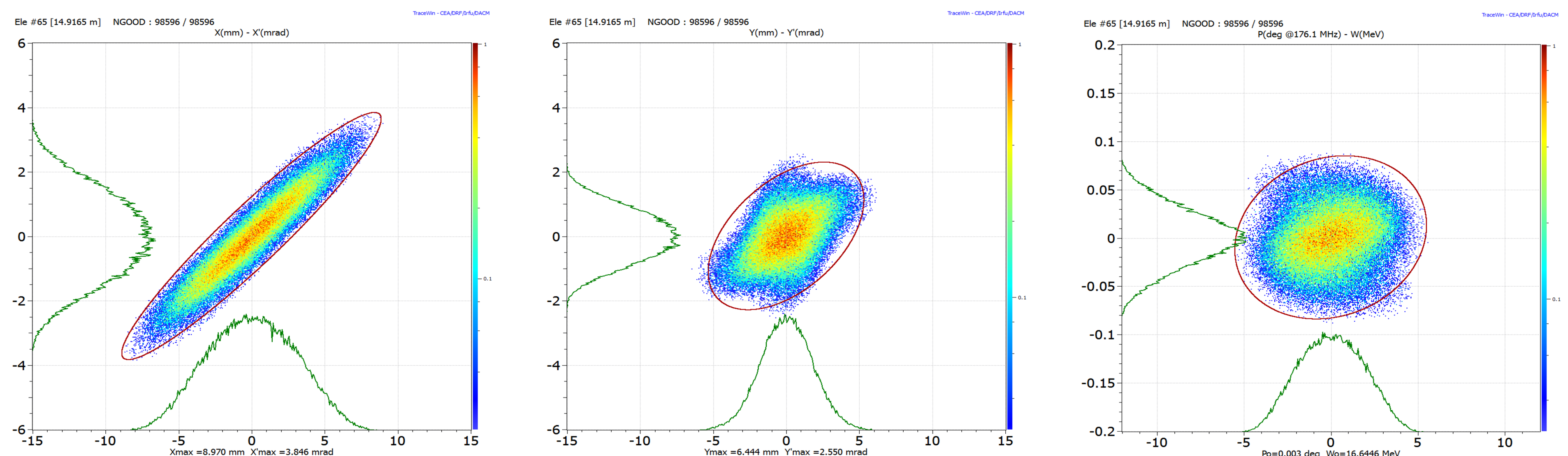
Transverse envelopes

Longitudinal envelopes

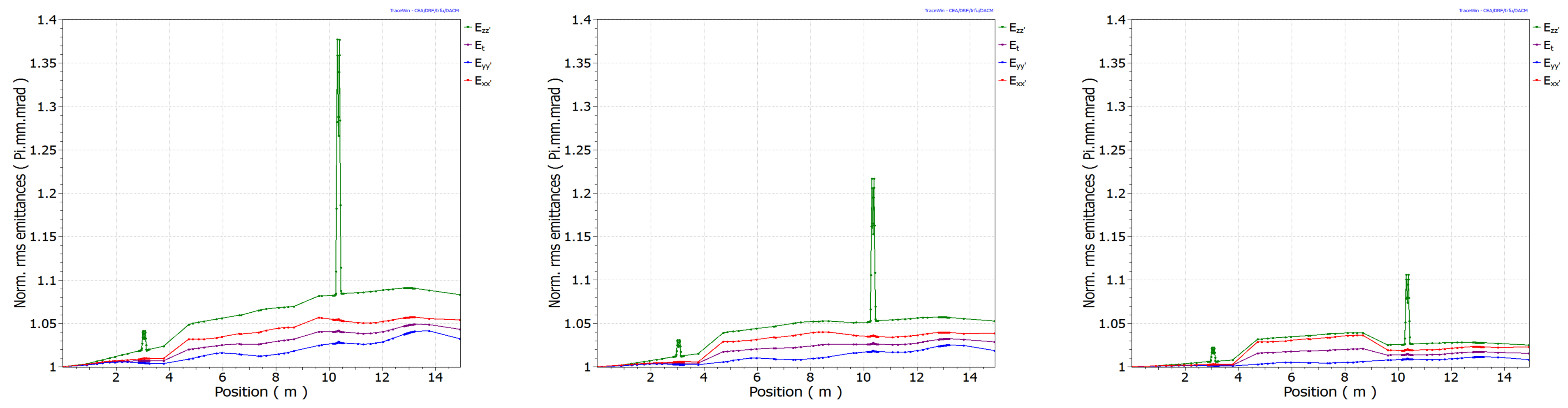


Longitudinal ±3σ envelopes along the MEBT-3 section. The phase and the energy spread are shown in the top and the bottom panels respectfully.

Beam matching at the end of the MEBT-3 and emittance growth along the beam line



The three panels show proton distributions at the exit of the MEBT-3 line in the horizontal (left), vertical (center), and longitudinal (right) directions. The mismatch compared to the desired distributions at the entrance of the main LINAC is smaller than 0.12% in all directions. The red ellipses correspond to an emittance of 9 rms.



The three panels show the change of emittance in the three planes along the MEBT-3 for three different beam currents (4 mA, 3 mA, and 2 mA). Red and blue lines correspond to transverse emittances – horizontal and vertical, respectfully. Green lines correspond to longitudinal emittance.

Comparison of the results obtained for the two designs

	Design #1, 0/22.5 deg, 22.5/0 deg				Design #2, no pole face angles			
	env.	PARTRAM			env.	PARTRAM		
beam current	4 mA	4 mA	3 mA	2 mA	4 mA	4 mA	3 mA	2 mA
Max env. x [mm]	9.3	9.1	9.8	10.5	9.3	9.2	9.5	10.0
Max env. y [mm]	13.1	13.0	12.8	12.7	11.4	11.6	11.4	11.3
$\Delta\varepsilon_x$ [%]	4.6	5.4	3.9	2.3	5.7	5.0	3.5	2.0
$\Delta\varepsilon_y$ [%]	0.0	3.2	1.9	0.8	0.0	3.2	2.4	1.3
$\Delta\varepsilon_z$ [%]	4.1	8.3	5.3	2.5	5.0	8.2	5.2	2.5
Mismatch x [%]	0.14	0.11	8.56	18.25	0.01	0.10	6.30	14.10
Mismatch y [%]	0.23	0.12	0.70	3.24	0.10	0.24	1.53	4.19
Mismatch z [%]	0.01	0.00	12.69	27.75	0.00	0.01	12.42	27.35

The differences in the simulation results using Design #1 and Design #2 are listed. The main difference is the larger maximal vertical envelope in the case of Design #2 due to the lack of a vertical focusing effect in the case of straight pole faces. As expected emittance growth is smaller at lower beam currents. Since all the results presented here were obtained for tuning optimizations at 4 mA beam current, there are large mismatches at lower current values.

References

[1] J.-L. Biarrotte, D. Uriot, H. Klein, H. Podlech, D. Maeder, R. Tiede, C. Zhang, D. Vandeplassche, "Design fine-tuning & beam simulation codes benchmarking," *MAX DELIVERABLE 1.2*, 2013

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