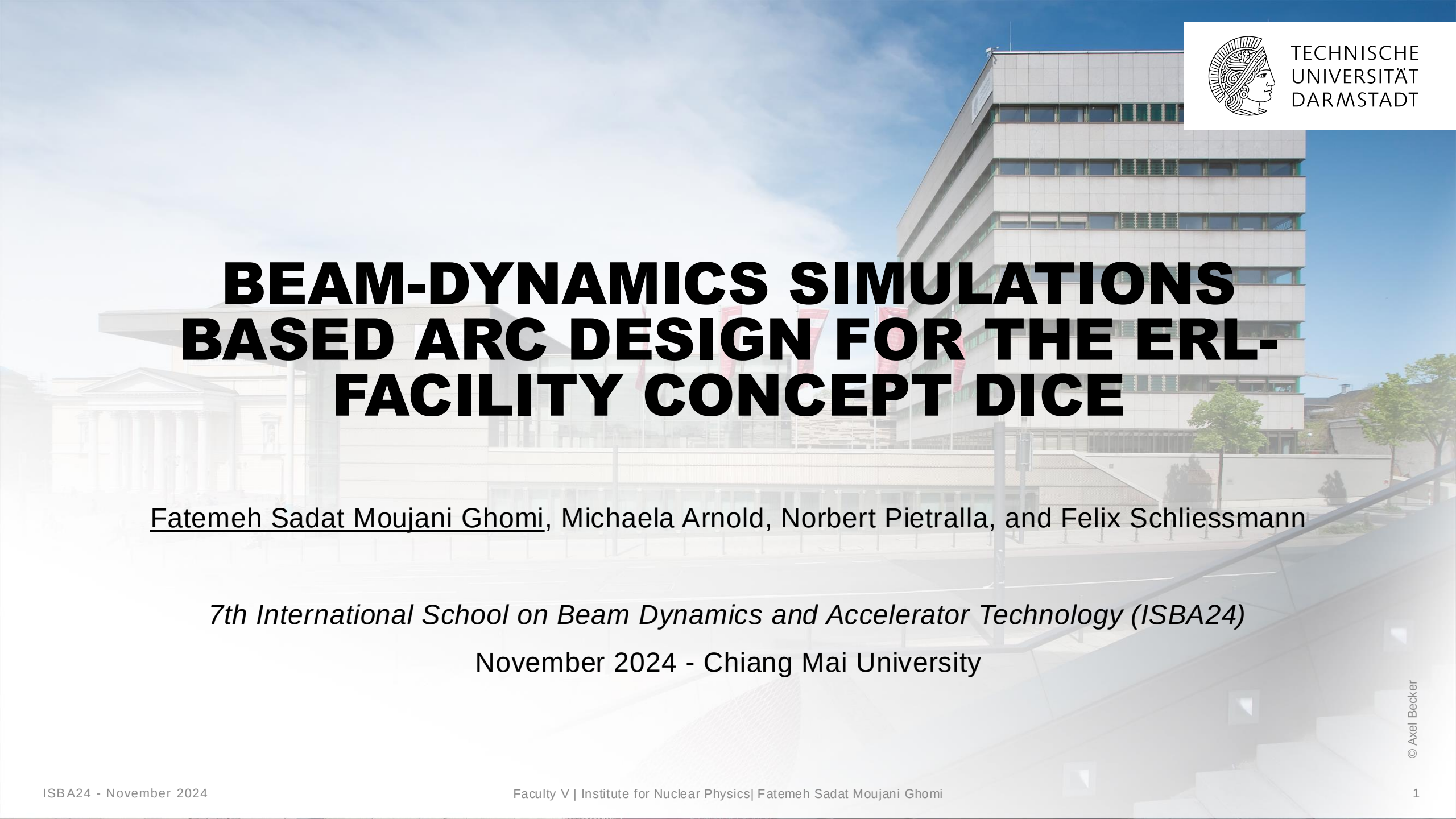

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BEAM-DYNAMICS SIMULATIONS BASED ARC DESIGN FOR THE ERL-FACILITY CONCEPT DICE

Fatemeh Sadat Moujani Ghomi, Michaela Arnold, Norbert Pietralla, and Felix Schliessmann

7th International School on Beam Dynamics and Accelerator Technology (ISBA24)

November 2024 - Chiang Mai University

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MOTIVATION

LHeC:
50 GeV and 20 mA ~> **1** GW of beam power

Increasing demand on beam power

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Sustainable solution

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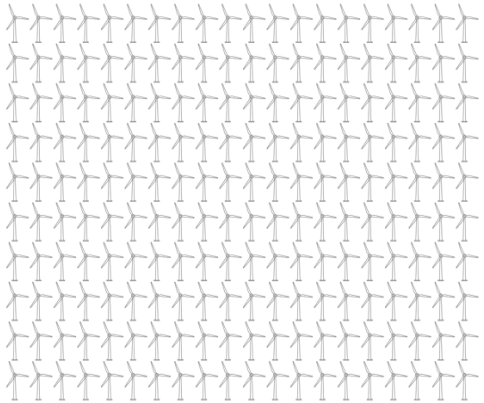
Sustainable solution

Using a sustainable source of energy

200 – 500 on-shore wind turbines
(1 on-shore wind turbine ~ 2-5 MW)



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Using a sustainable source of energy

200 – 500 on-shore wind turbines
(1 on-shore wind turbine ~ 2-5 MW)

Designing a sustainable facility

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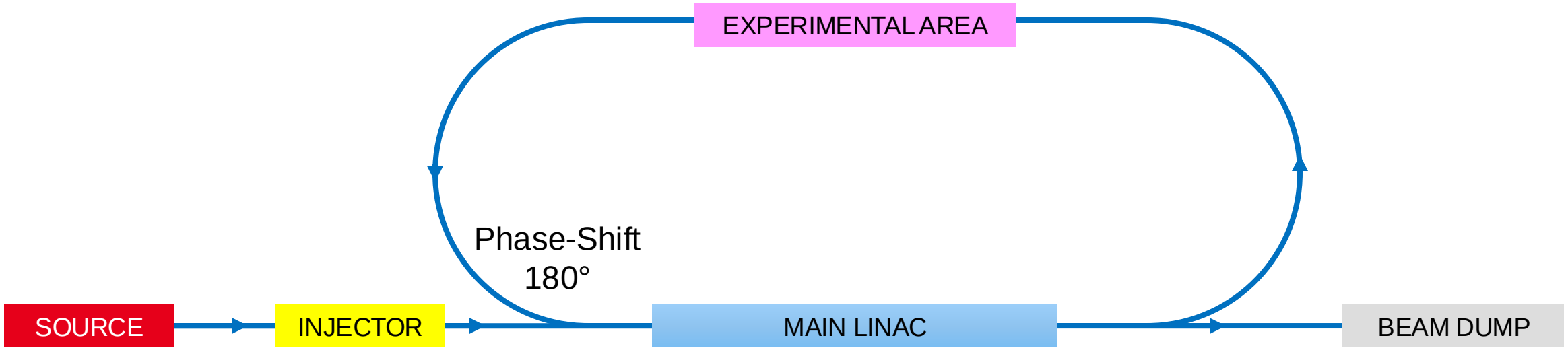
LINEAR ACCELERATORS (LINACS)

- Conventional LINAC

Adapted from J. D'Hondt, https://indico.ijclab.in2p3.fr/event/9817/

LINEAR ACCELERATORS (LINACS)

- Energy Recovery LINAC (ERL)



Adapted from J. D'Hondt, https://indico.ijclab.in2p3.fr/event/9817/

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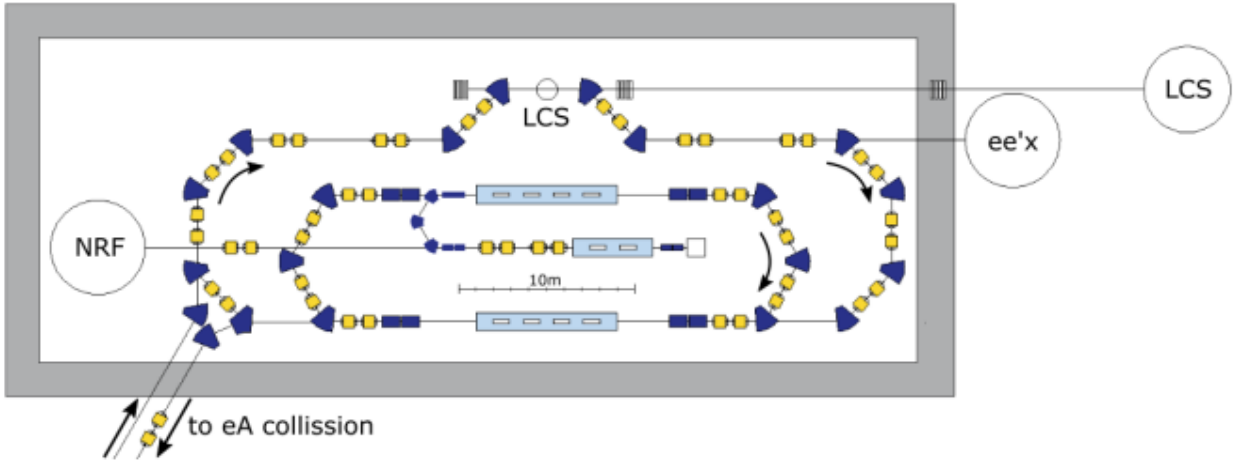
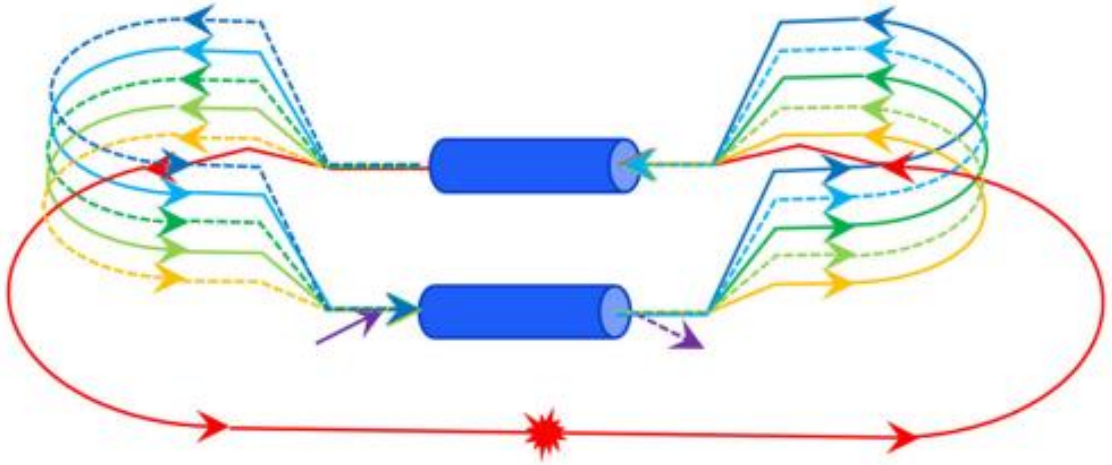
DUAL LINAC ERL

A POSSIBLE DESIGN FOR THE DARMSTADT INDIVIDUALLY RECIRCULATING ERL (DICE) CONCEPT



First sketch of the DICE Accelerator;
Arnold, M., *DICE*, In preparation



Dual Linac ERL: Possible DICE Design
G. Pérez Segurana et al., Phys. Rev. Accel. Beams **25**, 021003 (2022)

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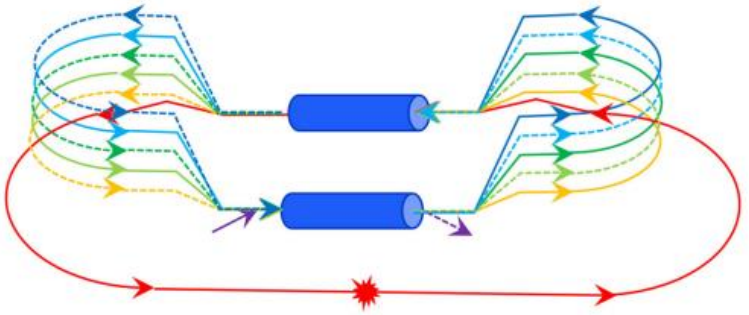
GOALS



- Design: two vertical dog-legs and a total horizontal bend of 180°.
- Ideally adaptable to all arcs in the DICE structure.
- Tunability of the dispersion terms.
- Focus of this work: $l = x_5(s) = \sum_{j=1}^{6} R_{5j}(s)x_j(0) + \sum_{k=1}^{6}\sum_{j=1}^{k} T_{5jk}(s)x_j(0)x_k(0)$
- Goal: Maximum range around zero for R_{56} and T_{566},

while $R_{16} = R_{26} = R_{36} = R_{46} = T_{166} = T_{266} = T_{366} = T_{466} = 0$.

Longitudinal dispersion terms:
1. First-order: R_{56}
2. Second-order: T_{566}

$$\vec{x}(s) = \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{pmatrix} = \begin{pmatrix} x \\ x' \\ y \\ y' \\ l \\ \delta \end{pmatrix} = \begin{pmatrix} \text{horizontal position deviation} \\ \text{horizontal directional ...} \\ \text{vertical position ...} \\ \text{vertical directional ...} \\ \text{longitudinal ...} \\ \text{relative momentum ...} \end{pmatrix} \rightarrow \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{pmatrix}_f = \begin{pmatrix} R_{11} & R_{12} & R_{13} & R_{14} & R_{15} & R_{16} \\ R_{21} & R_{22} & R_{23} & R_{24} & R_{25} & R_{26} \\ R_{31} & R_{32} & R_{33} & R_{34} & R_{35} & R_{36} \\ R_{41} & R_{42} & R_{43} & R_{44} & R_{45} & R_{46} \\ R_{51} & R_{52} & R_{53} & R_{54} & R_{55} & R_{56} \\ R_{61} & R_{62} & R_{63} & R_{64} & R_{65} & R_{66} \end{pmatrix} \cdot \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{pmatrix}_i$$

DESIGN AND SIMULATIONS

- Used simulation tool: ELEGANT.
- Design: horizontal lattice and dog-leg.
- The full lattice is designed mirror-symmetrically.
- The simulation process included three types of files:
  1. Lattice.lte
  2. Optimize.ele
  3. Track.ele
- Initial parameters:

initial momentum	$p_0 = 187\ mc \approx 95.6$ MeV/c (kinetic energy $E_{\text{kin}} \approx 95$ MeV)
normalized emittance in both x- and y-plane	$\epsilon_{\text{n},x} = \epsilon_{\text{n},y} = 2$ mm·mrad
RMS bunch length	$\sigma_l = 1$ mm

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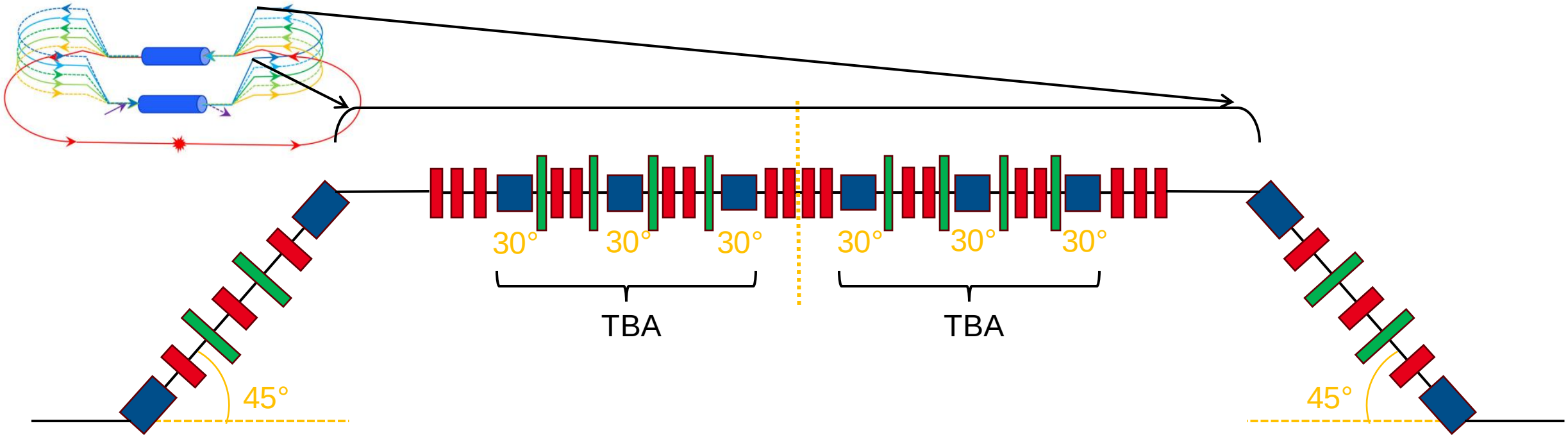
SUGGESTED FULL LATTICE DESIGN:



- Dipole magnet
- Quadrupole magnet
- Sextupole magnet

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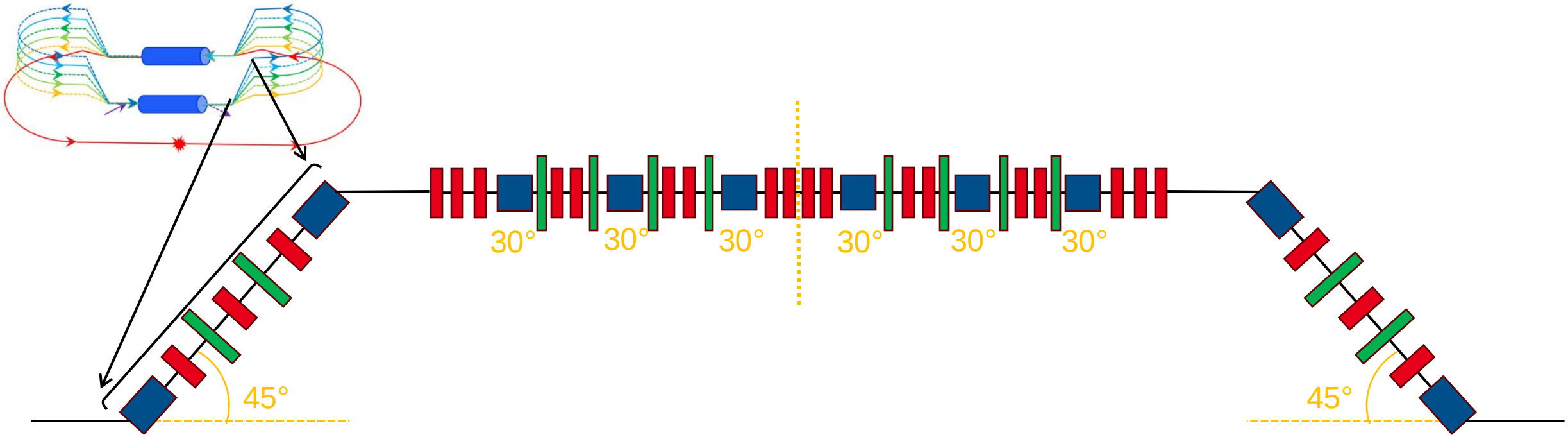
SUGGESTED FULL LATTICE DESIGN:



- Dipole magnet
- Quadrupole magnet
- Sextupole magnet

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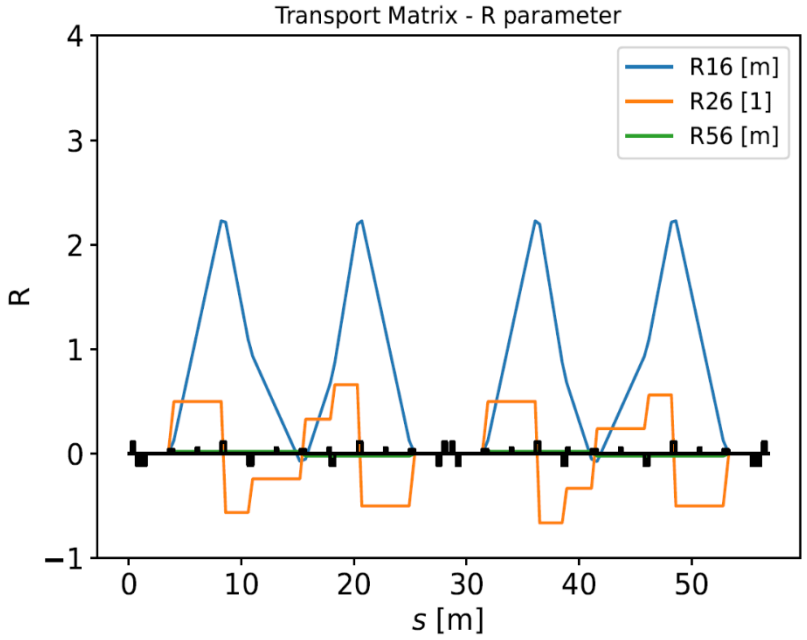
OBSERVATIONS AND RESULTS

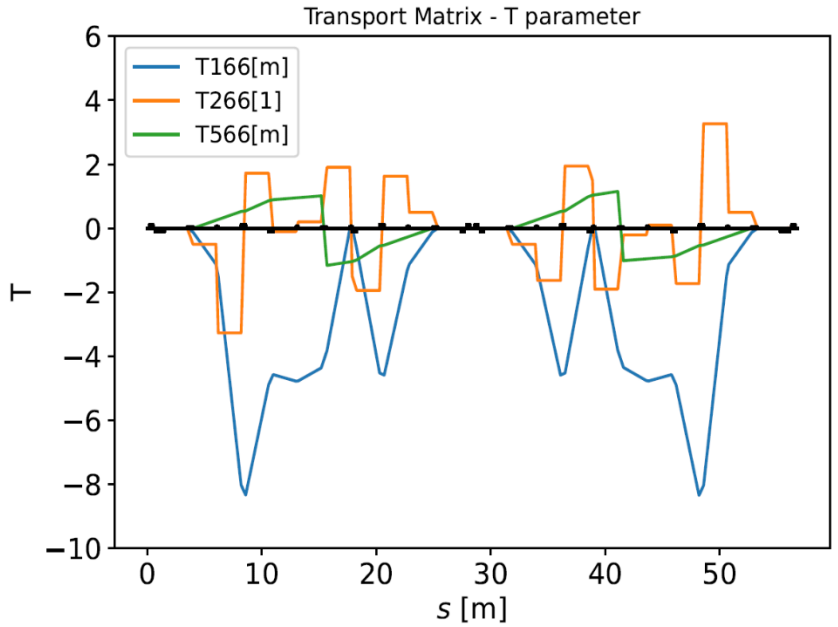
- Horizontal lattice approx. 55 m.
- Optimization parameters:

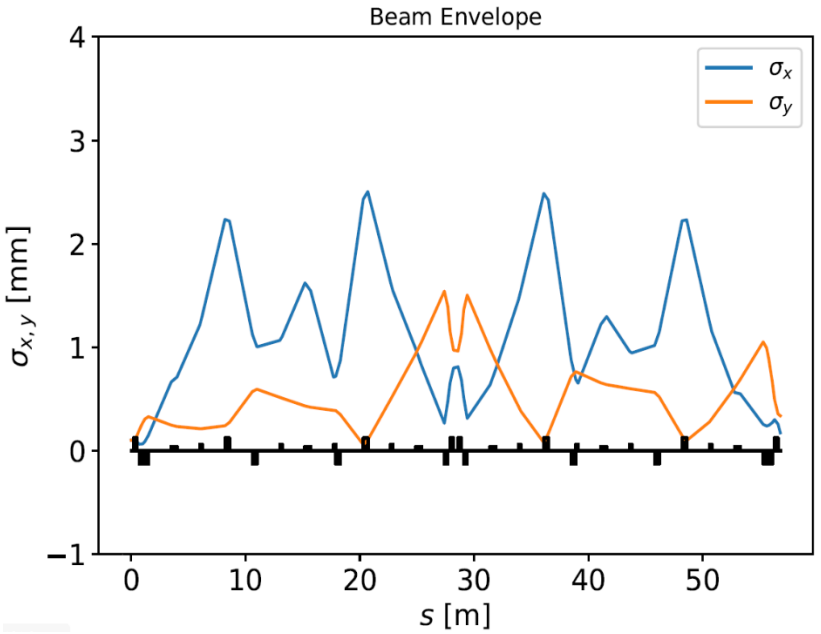
$$R_{16} = R_{26} = R_{36} = R_{46} = T_{166} = T_{266} = T_{366} = T_{466} = 0$$

$$R_{56} = 0 \text{ , } T_{566} = 0$$

Longitudinal dispersion terms:
1. First-order: R_{56}
2. Second-order: T_{566}







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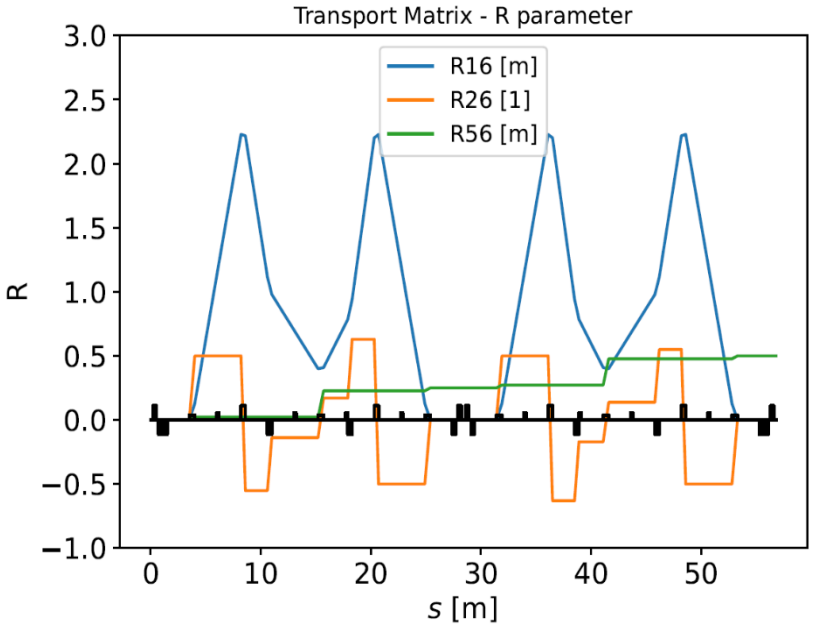
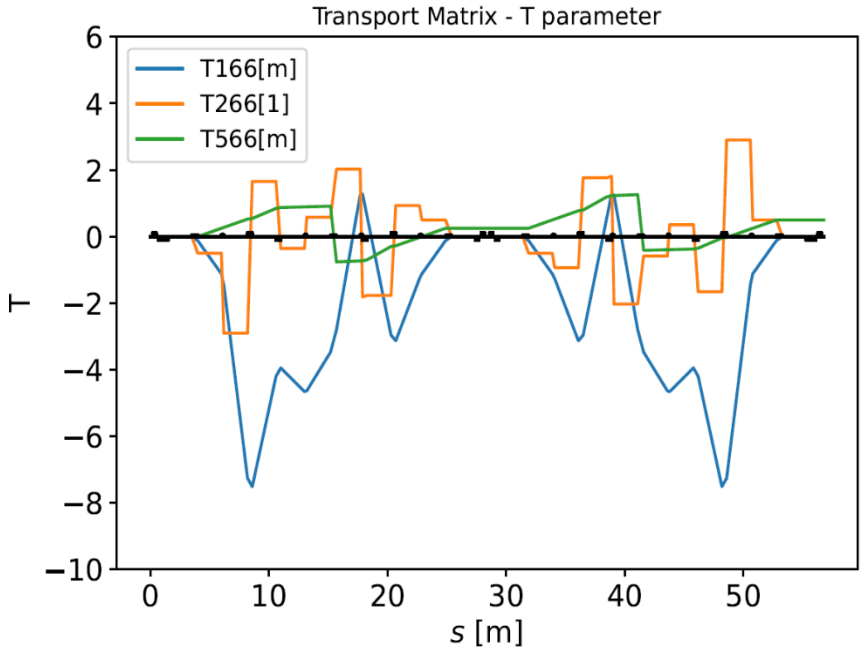
OBSERVATIONS AND RESULTS

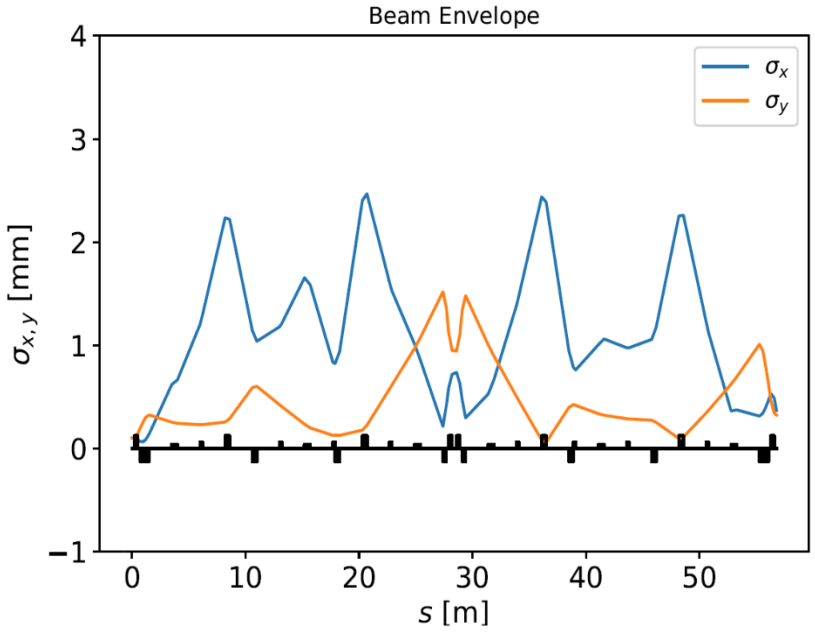
- Optimization parameters:

$$R_{16} = R_{26} = R_{36} = R_{46} = T_{166} = T_{266} = T_{366} = T_{466} = 0$$

$$R_{56} = +0.5\ \text{m}\ ,\ T_{566} = +0.5\ \text{m}$$







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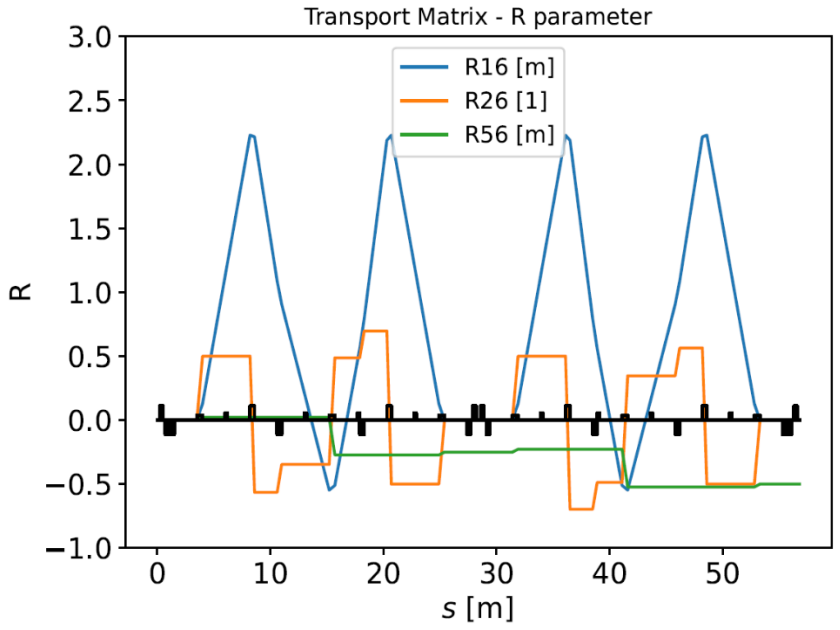
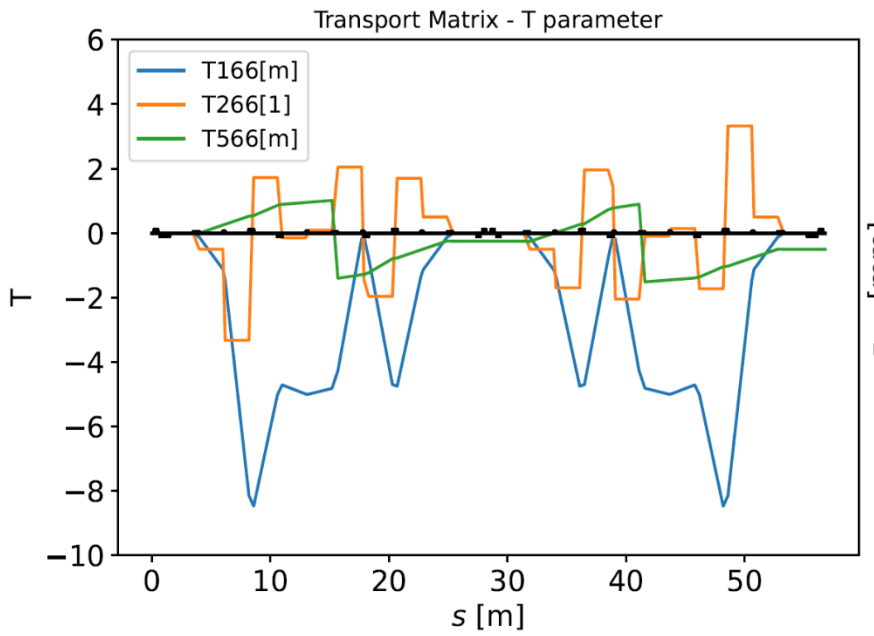
OBSERVATIONS AND RESULTS

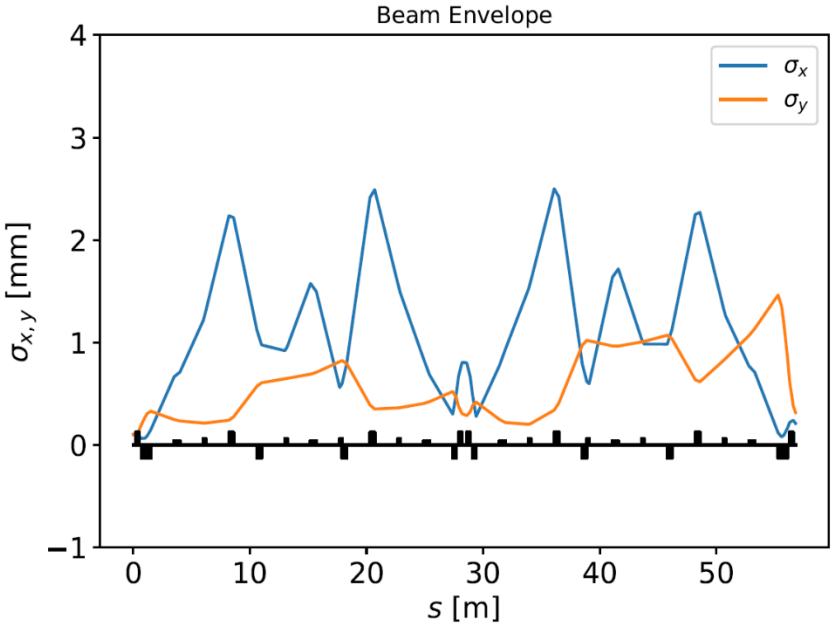
- Optimization parameters:

$$R_{16} = R_{26} = R_{36} = R_{46} = T_{166} = T_{266} = T_{366} = T_{466} = 0$$

$$R_{56} = -0.5\ \text{m}\ ,\ T_{566} = -0.5\ \text{m}$$







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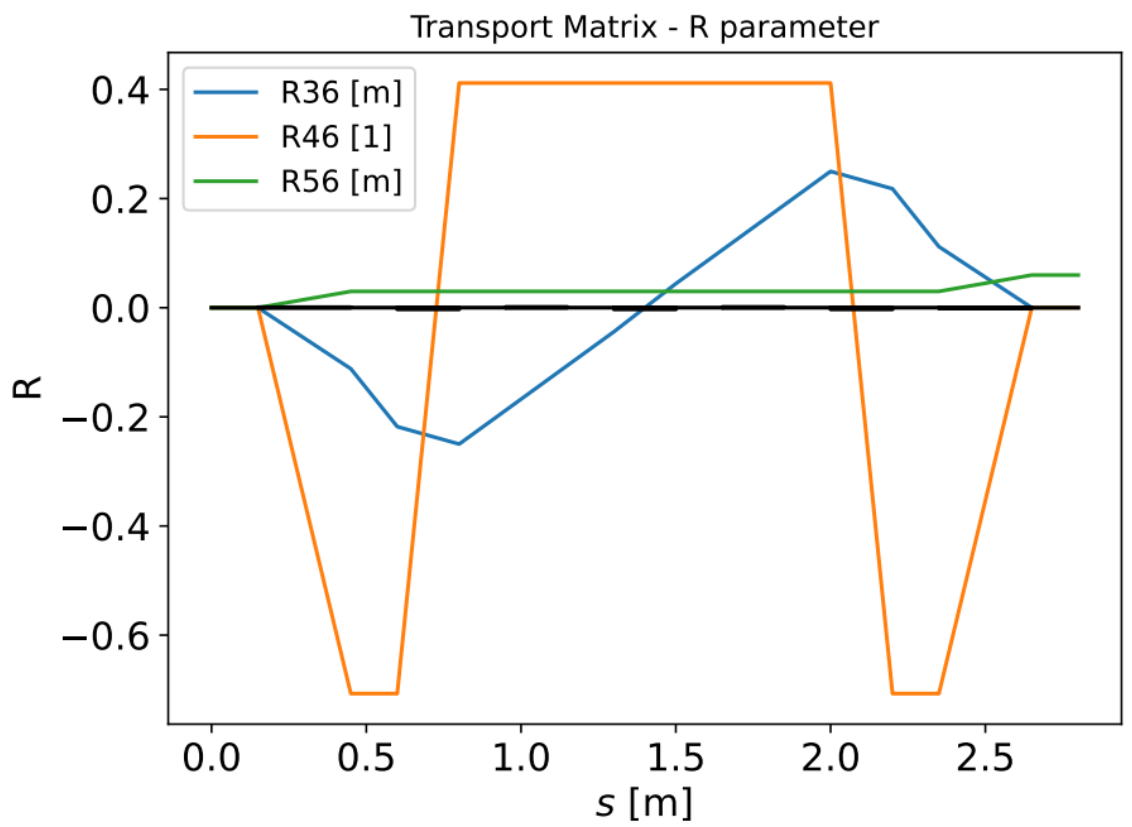
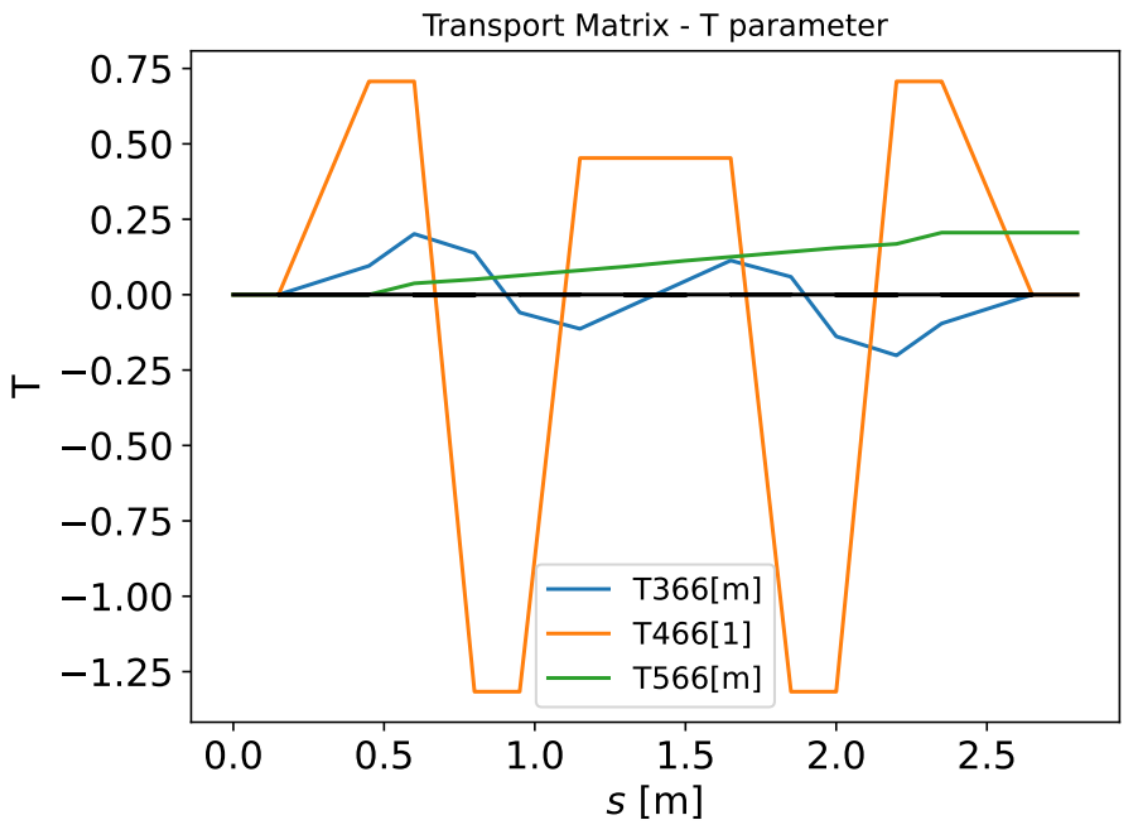
OBSERVATIONS AND RESULTS

- Dog-legs approx. 3 m.
- Optimization parameters: $R_{36} = R_{46} = T_{366} = T_{466} = 0$





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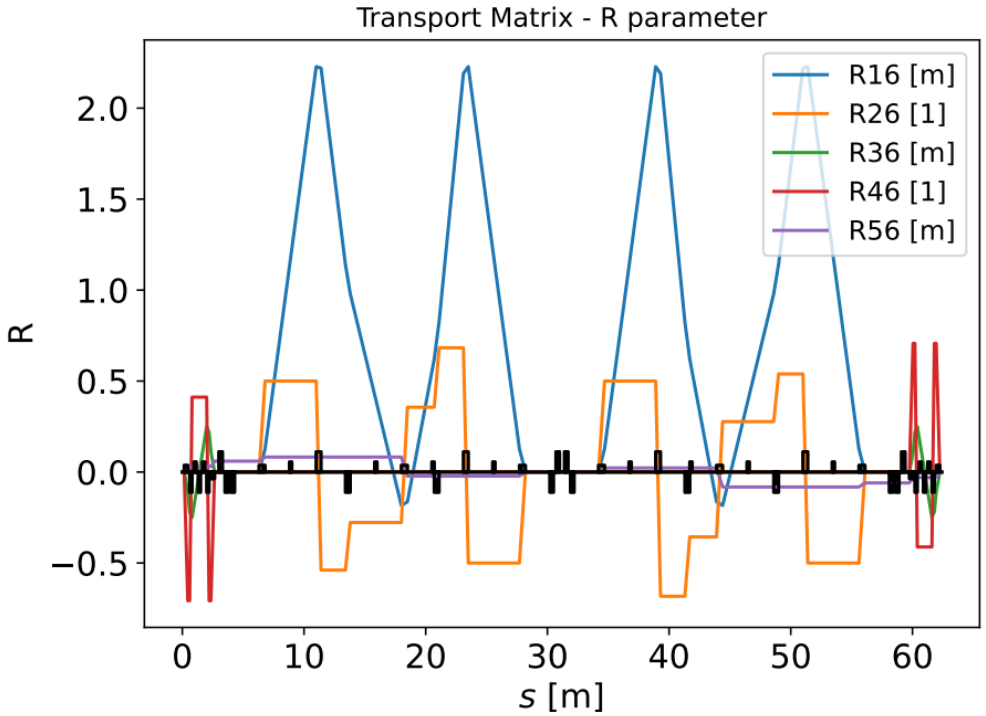
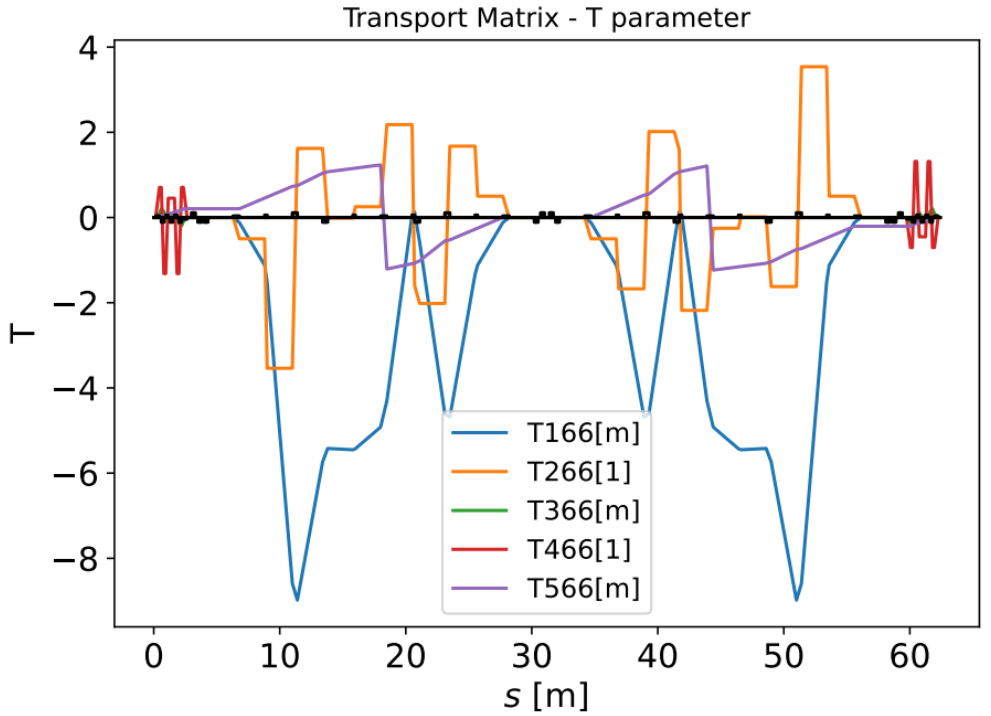
OBSERVATIONS AND RESULTS

- Full lattice approx. 60 m.
- Optimization parameters:

$$R_{16} = R_{26} = R_{36} = R_{46} = T_{166} = T_{266} = T_{366} = T_{466} = 0$$

$$R_{56} = 0 \ , \ T_{566} = 0$$





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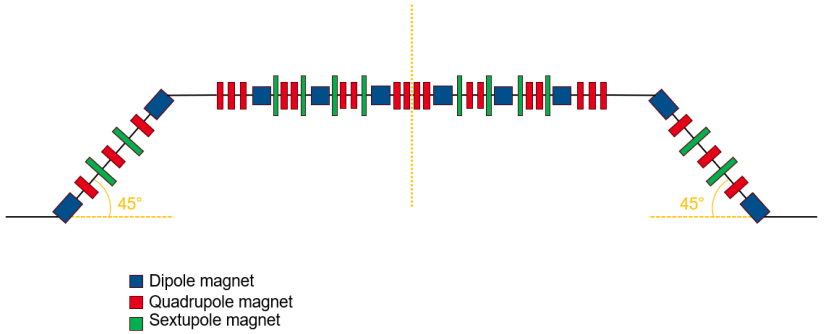
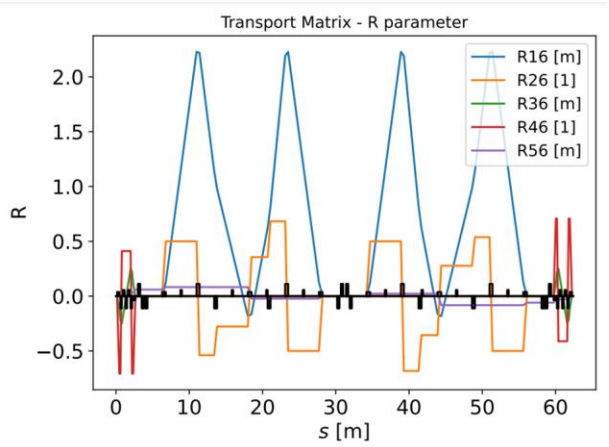
CONCLUSION AND OUTLOOK

- Tunability for both R56 and T566 has been shown with the suggested lattice.
- A maximum freedom range of 1 m, from −0.5 m to 0.5 m, has been obtained for R56. The same range has been obtained for T566.
- The beam envelope has been found to be around a maximum of 2.5 mm in the horizontal lattice.
- Outlook: Reducing the arc length and optimizing the beam size.





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THANK YOU!