Beam dynamic optimization and rebuncher for the FRANZ project

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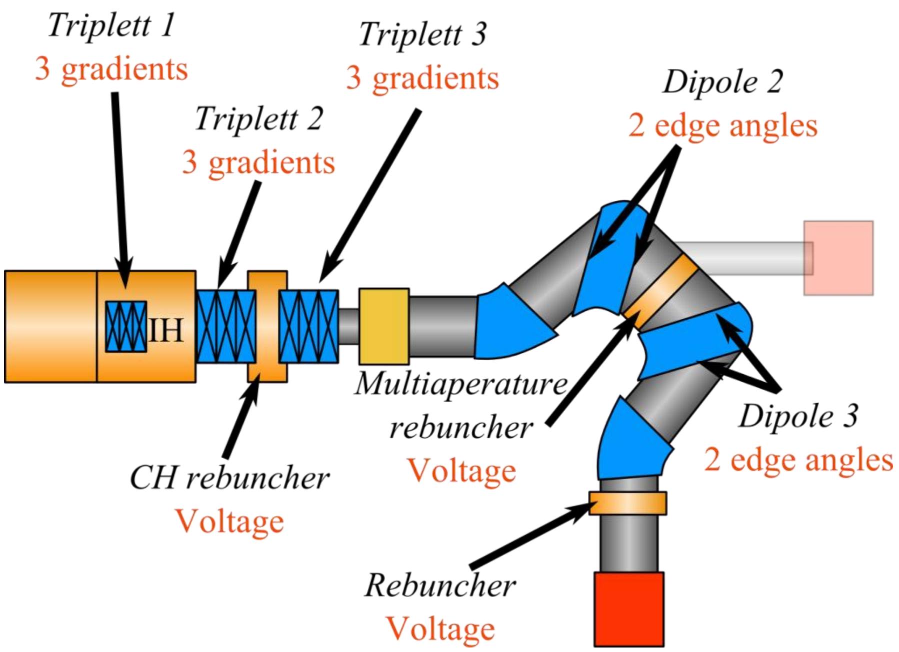
Overlook

- Beam dynamics optimization
  - The FRANZ bunch compressor
  - Optimization Strategy
    - Particle Swarm Optimization
    - Trajectory optimization
- Rebuncher
  - Multiaperture rebuncher
  - Rebuncher in front of the target
- Outlook

Beam dynamics in the FRANZ bunchcompressor

- 3 Triplets provide transversal focussing in the linac
- Transversal focussing in the bunch compressor works via edge and weak focussing
- Two rebunchers are needed for longitudinal focussing

$\longrightarrow$ *16 parameters* for linac and one trajectory



Why use automatic optimization?

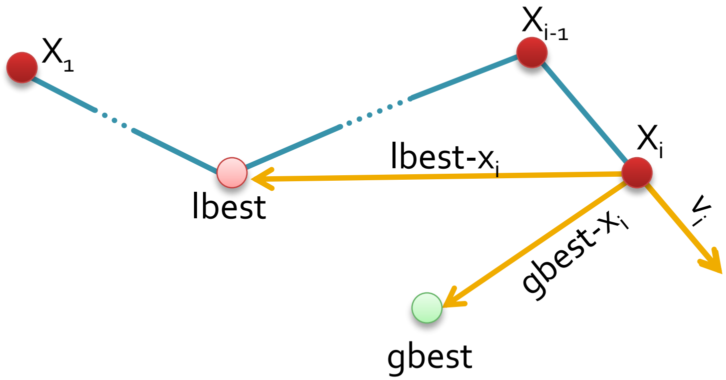
- Can linac and bunch compressor be optimized seperately?
  - No, bunch compressor performance is highly dependant on the input particle distribution
- A computer can try out solutions considerably faster than a human being.
  - Problem: Evaluating every possible combination in 16 dimensions is not an option
  - Solution: Use “smart” algorithm

Particle Swarm Optimization

- N points in *search space* (e.g in $\mathbb{R}^{16}$) with
  - position r
  - velocity v
  - a memory – they remember the best position on their way
- Initialize r and v with random values
- Iterate:

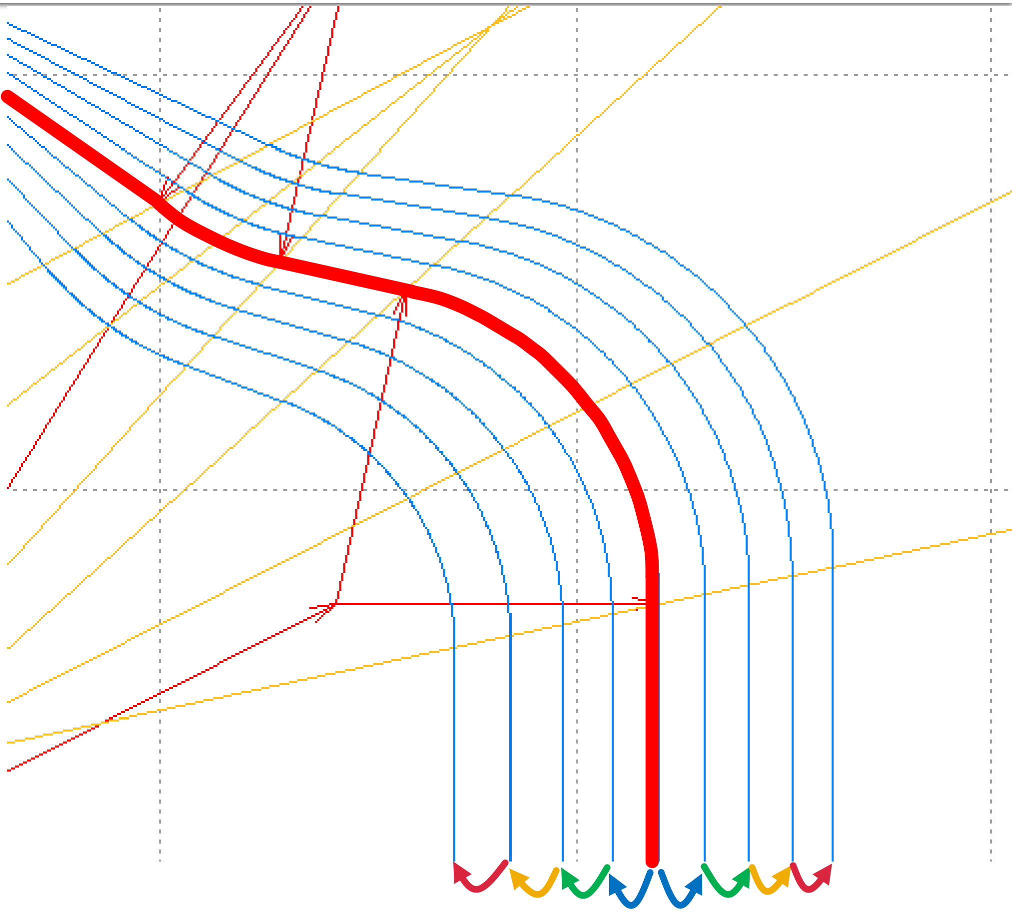
$$\vec{v}_{i+1} = \omega \vec{v}_i + c_1 \underline{A} \cdot \left(l\vec{best} - \vec{x}_i \right) + c_2 \underline{B} \cdot \left(g\vec{best} - \vec{x}_i \right)$$

$$\vec{x}_{i+1} = \vec{x}_i + \vec{v}_{i+1}$$



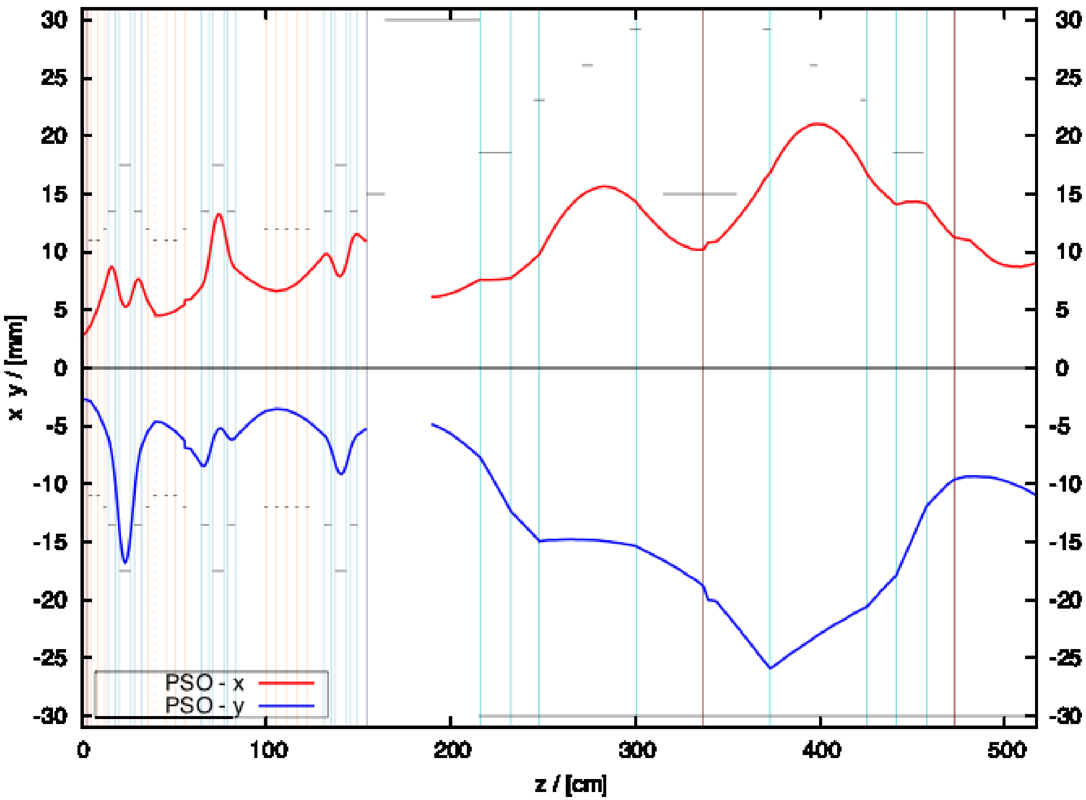
Optimization strategy

- Optimize one trajectory using a *global* optimization algorithm (like PSO)
- Repeat for adjacent trajectories:
  - Use solution for neighbouring trajectory as a starting point for a local optimization algorithm



Particle Swarm Optimization

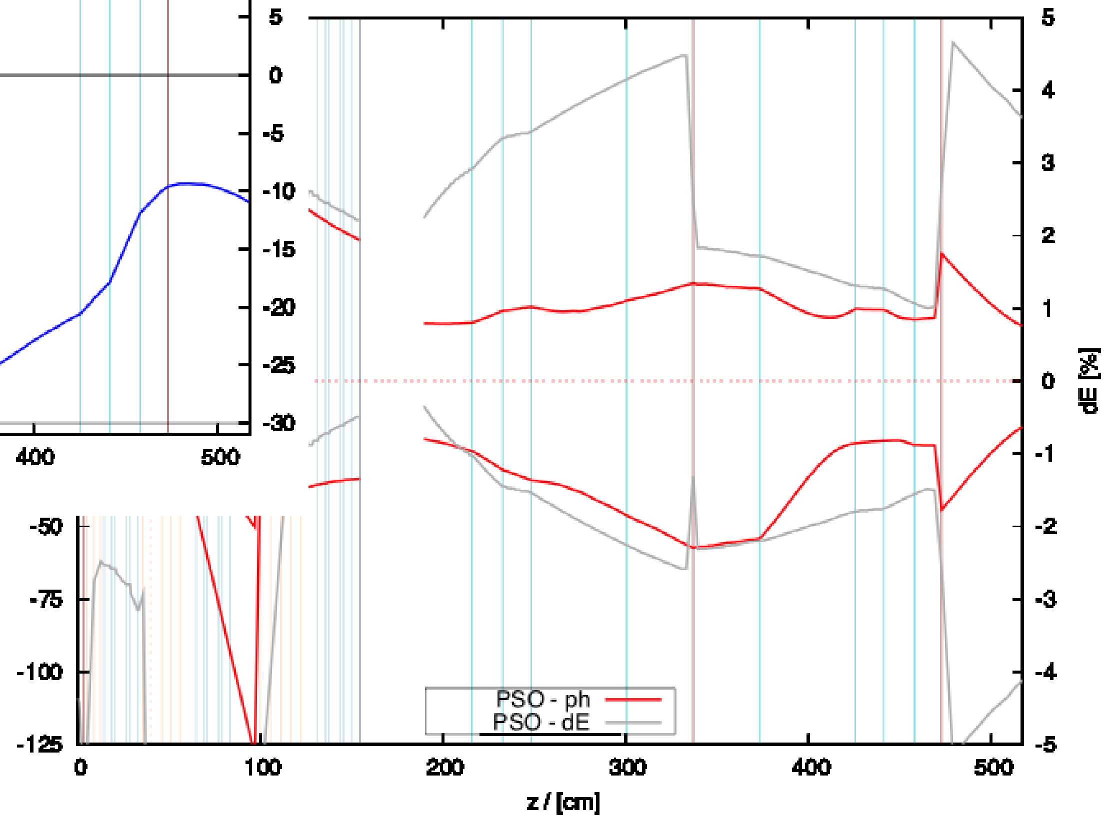
A possible setting



Beam spot on target (95%):

x: ± **9.1 mm** y: ± **11.2 mm**

Pulse length: **0.53 ns**



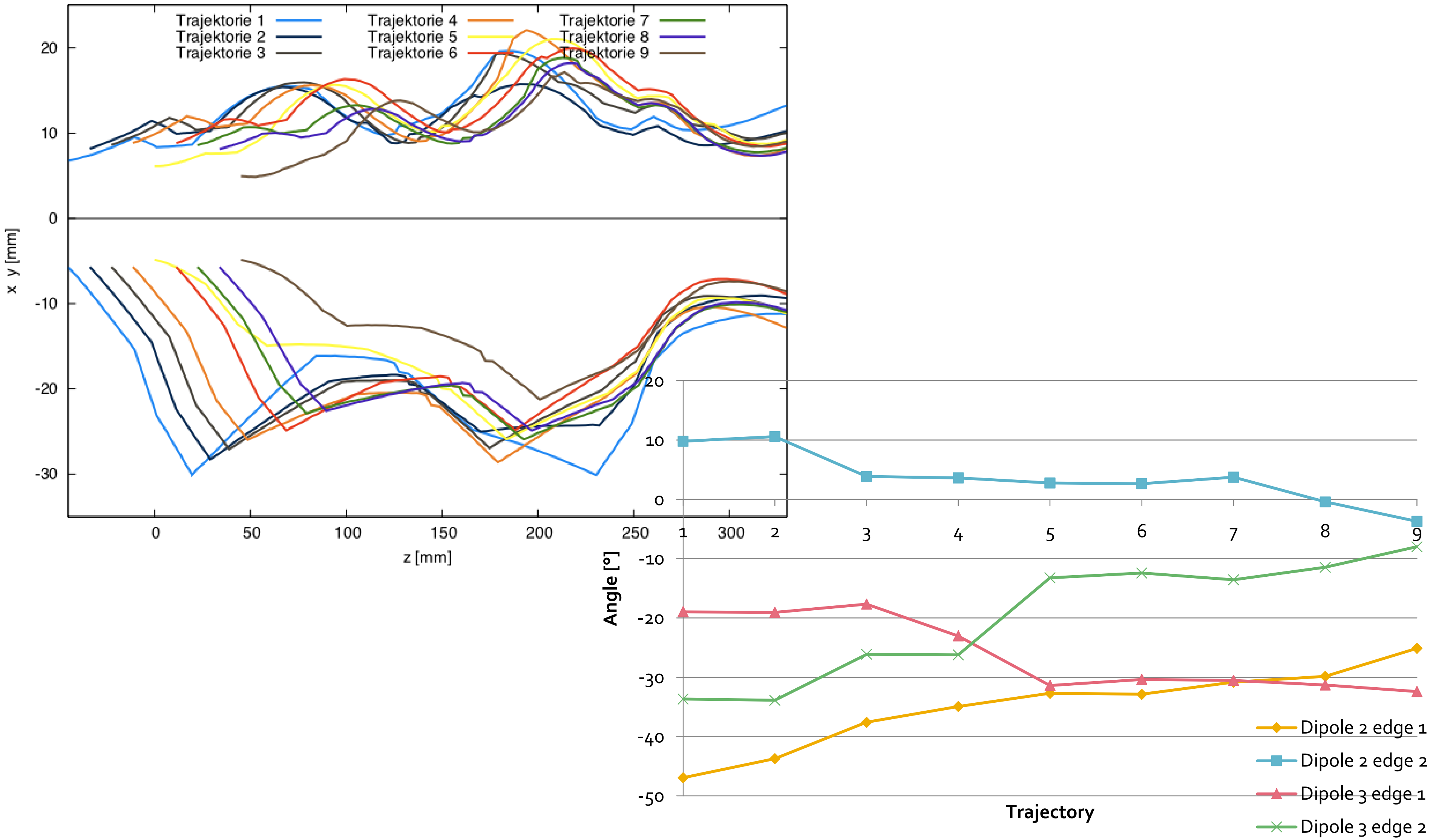
Beam spot on target (rms):

x: **5.2 mm** y: ± **5.3 mm**

Pulse length: **140 ps**

Trajectory optimization

First results

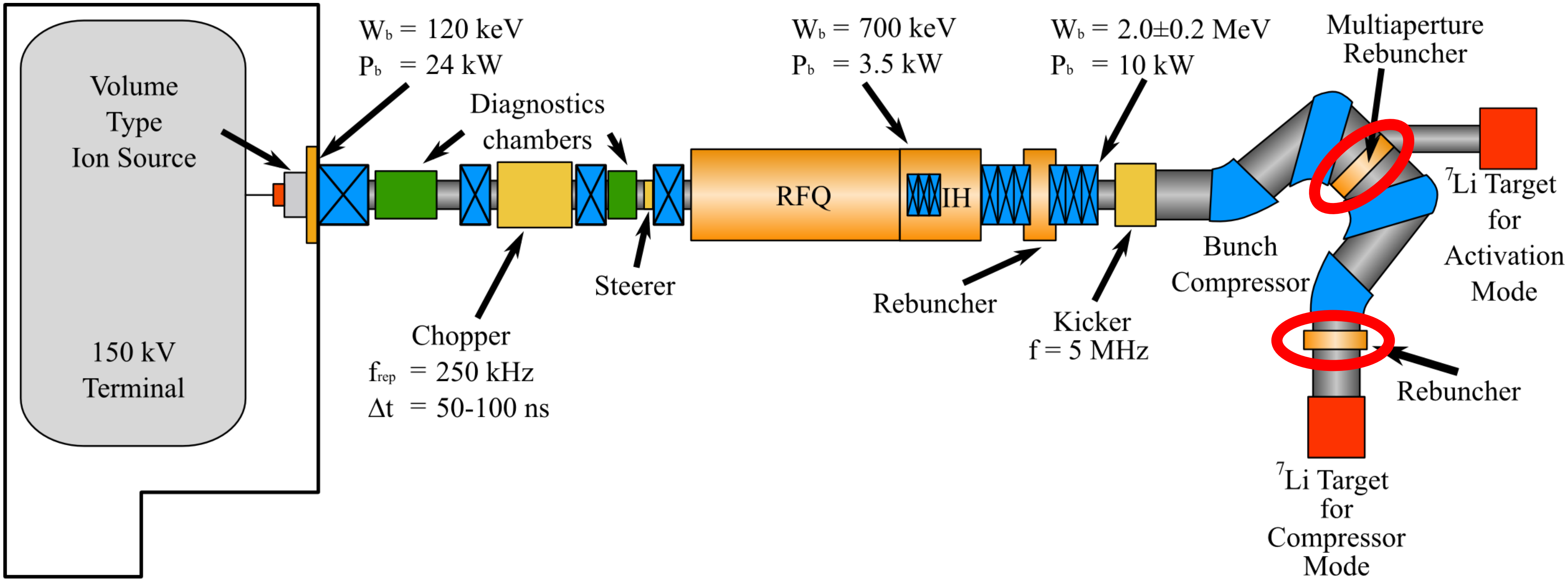


Trajectory optimization

First results

- Broyden–Fletcher–Goldfarb–Shanno-algorithm from the Gnu Scientific Library was used
- First results:
  - On the transverse plane the longest trajectory is hard to optimize, longitudinally the shorter trajectories are more difficult
    - Optimize on outer trajectories instead of the central one
  - Parameters as well as results don't differ much between trajectories

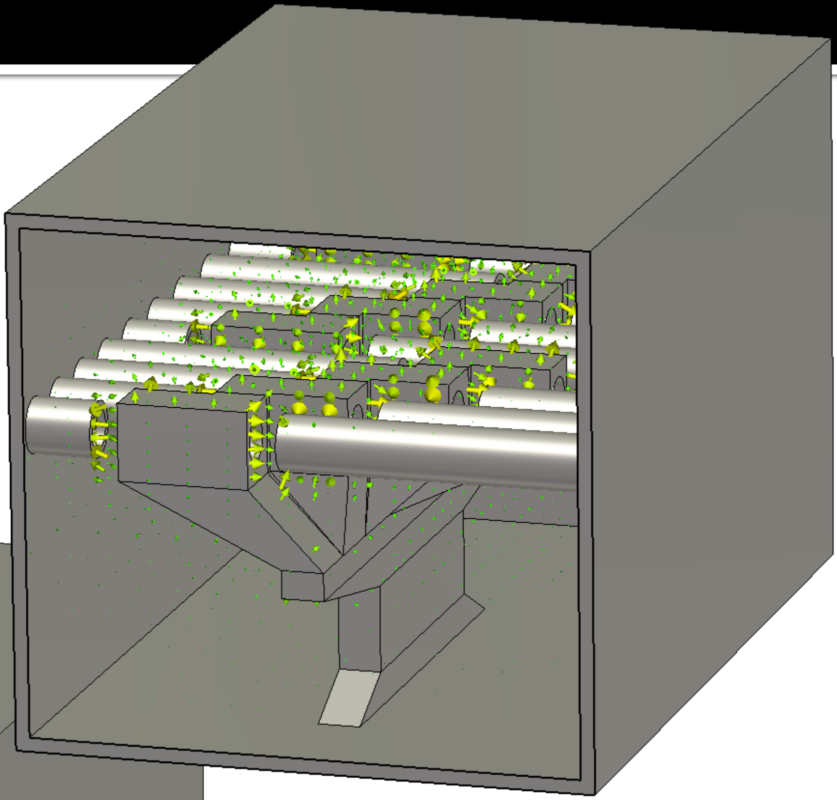
Rebuncher

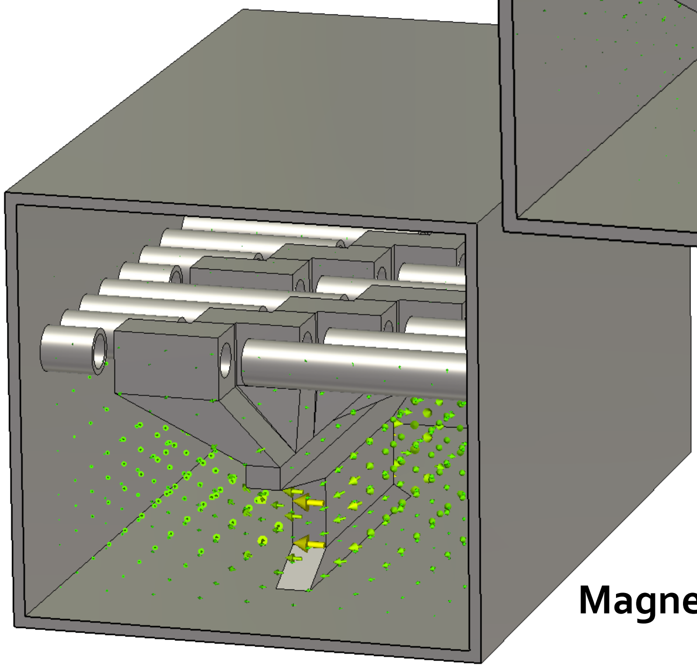


Volume
Type
Ion Source
150 kV
Terminal
W_b = 120 keV
P_b = 24 kW
Diagnostics
chambers
Chopper
f_rep = 250 kHz
Δt = 50-100 ns
Steerer
W_b = 700 keV
P_b = 3.5 kW
RFQ
IH
Rebuncher
W_b = 2.0±0.2 MeV
P_b = 10 kW
Kicker
f = 5 MHz
Multiaperture
Rebuncher
Bunch
Compressor
7Li Target
for
Activation
Mode
Rebuncher
7Li Target
for
Compressor
Mode

Multiaperture rebuncher

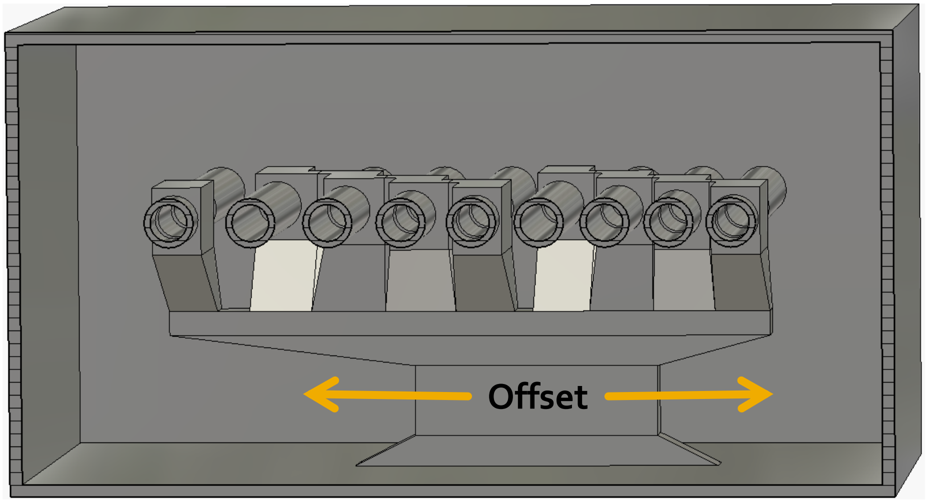
- Properties
  - Due to the transit time difference between trajectories the gaps are offset
  - 87,5 MHz
  - λ/4 resonator


Electric field

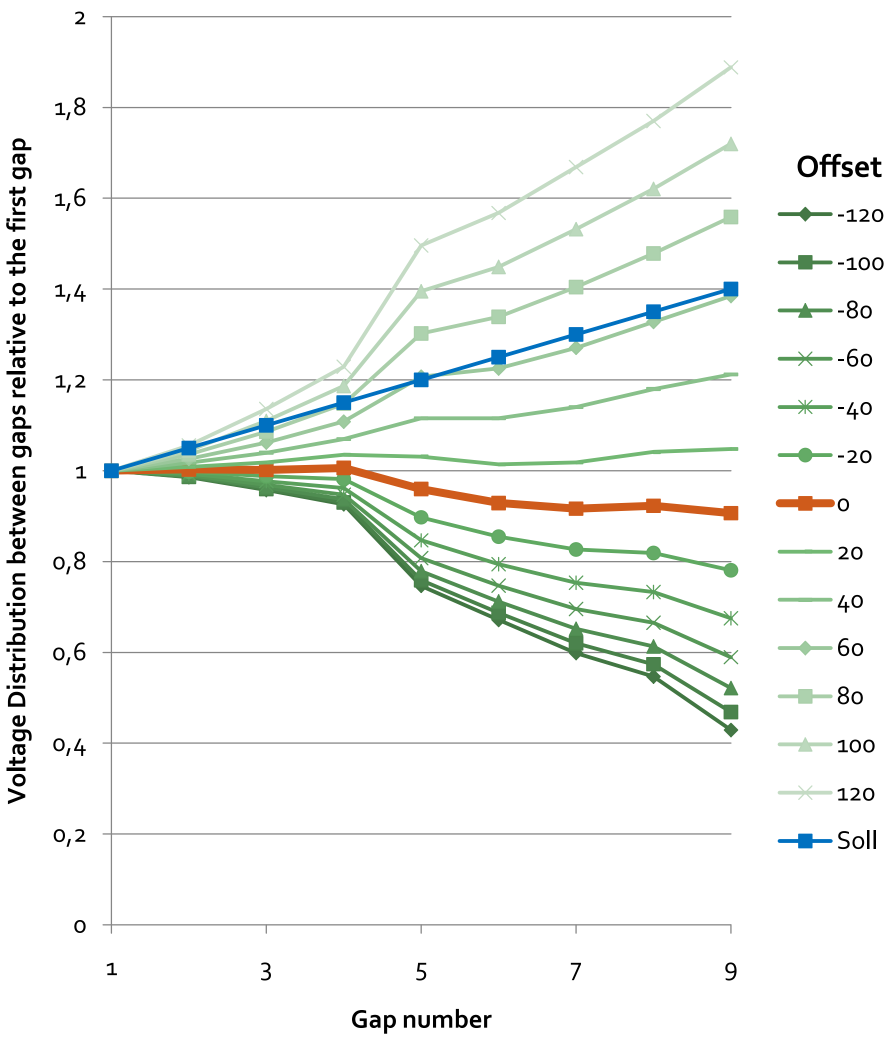

Magnetic field

Multiaperture rebuncher

Voltage distribution

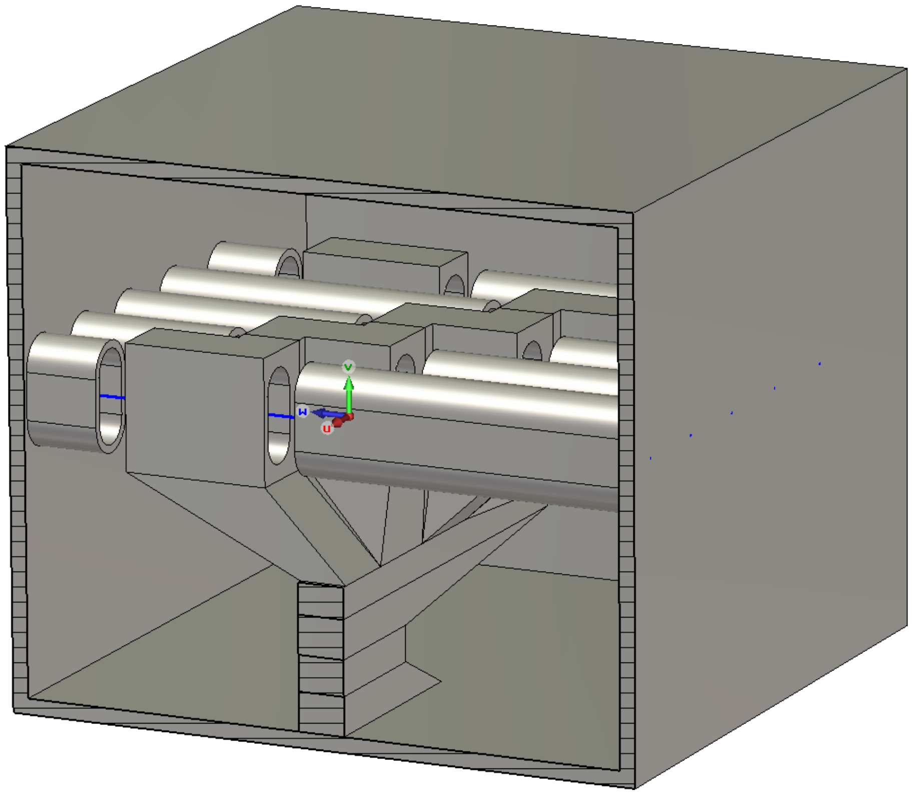


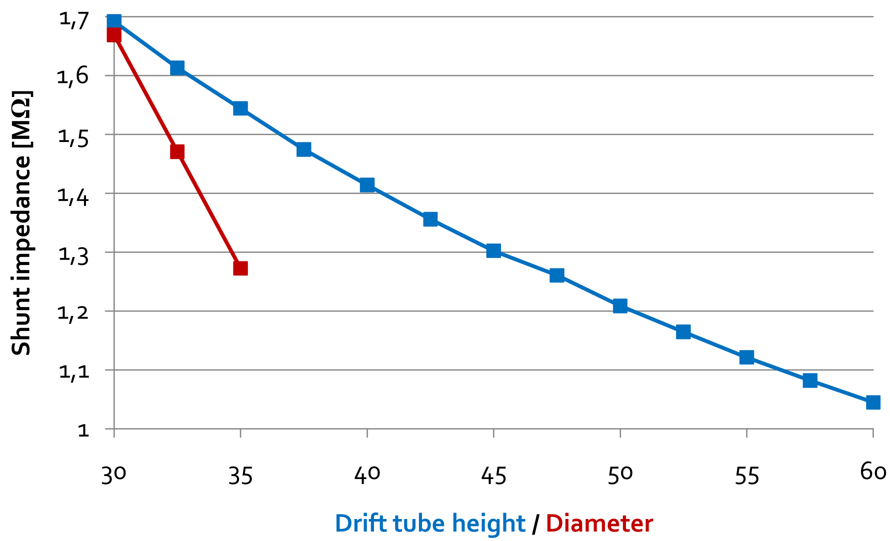
- Homogenous voltage distribution:
  - 2 cm Offset
- Distribution from optimization:
  - 6,4 cm Offset
- Practically no change (< 500W) in power dissipation

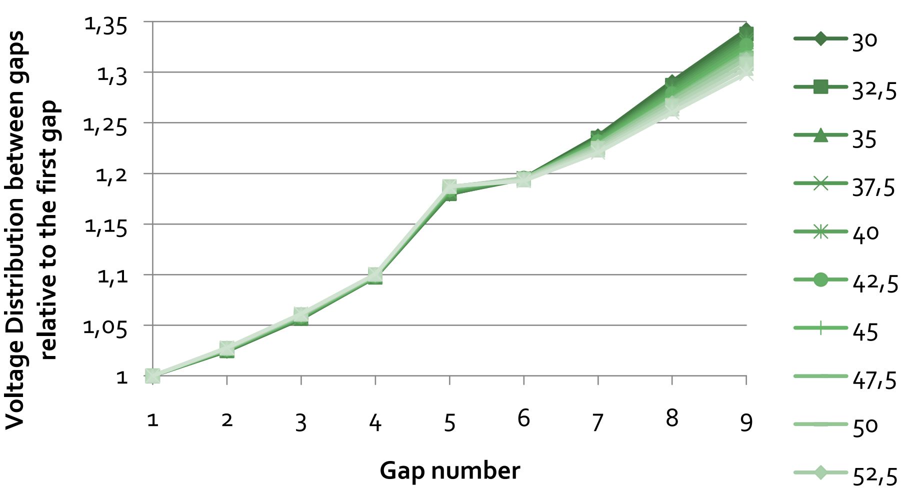


Multiaperture rebuncher

Drift tube size and geometry





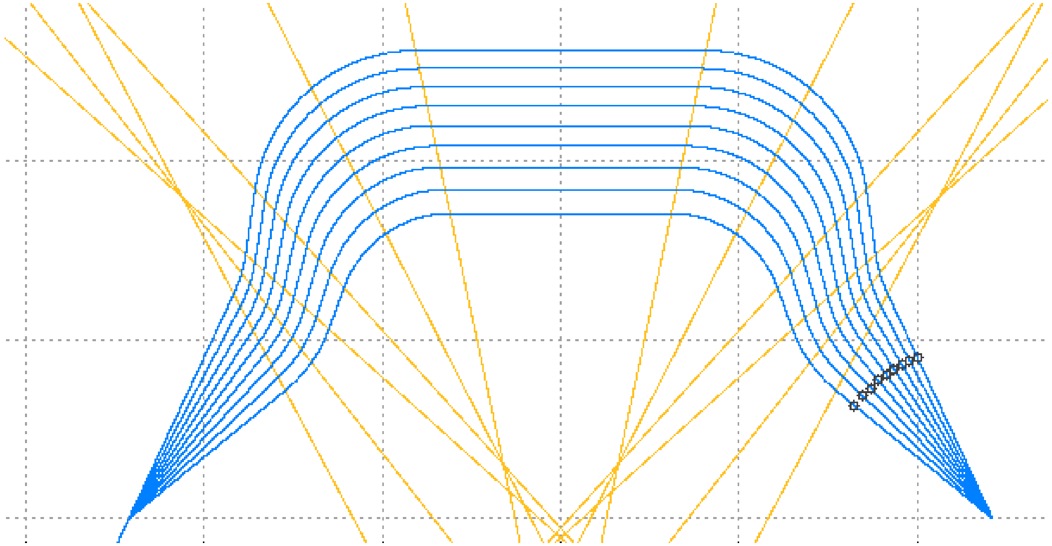


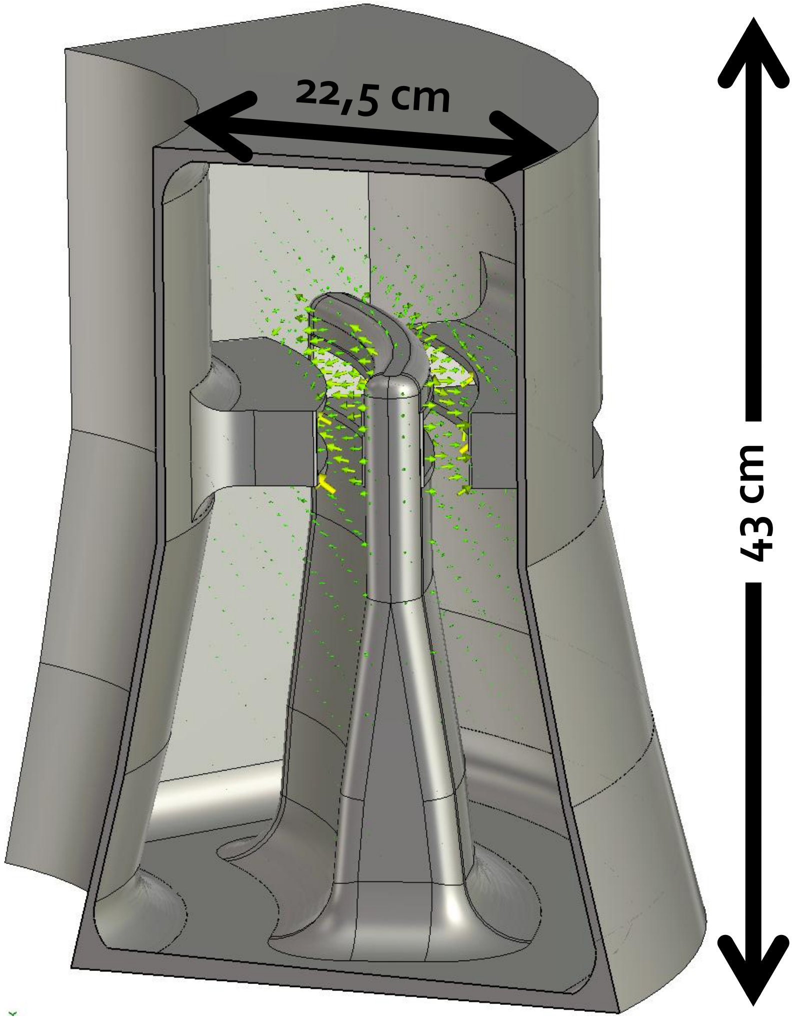
Power dissipation with 45 mm drift tube height @ 120kV: ~11 kW

Rebuncher in front of the target

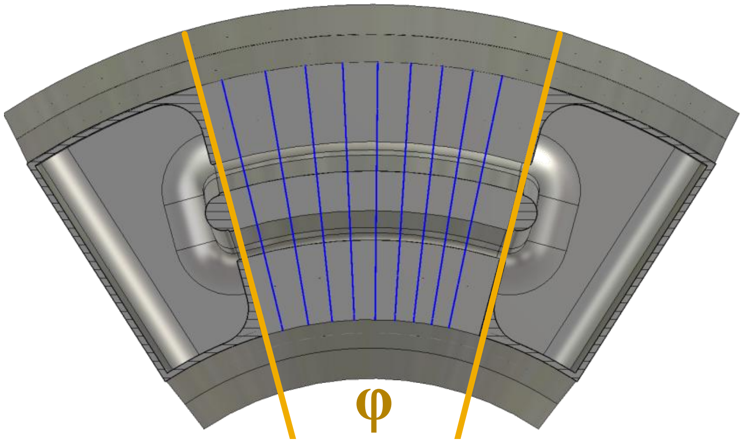
- Final focus on the target
- Energy variation after the bunch compressor

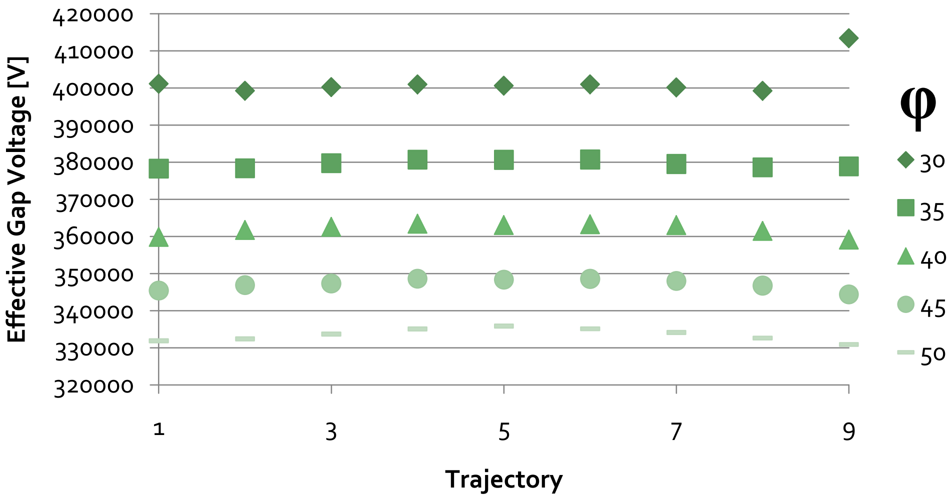
- 175 MHz

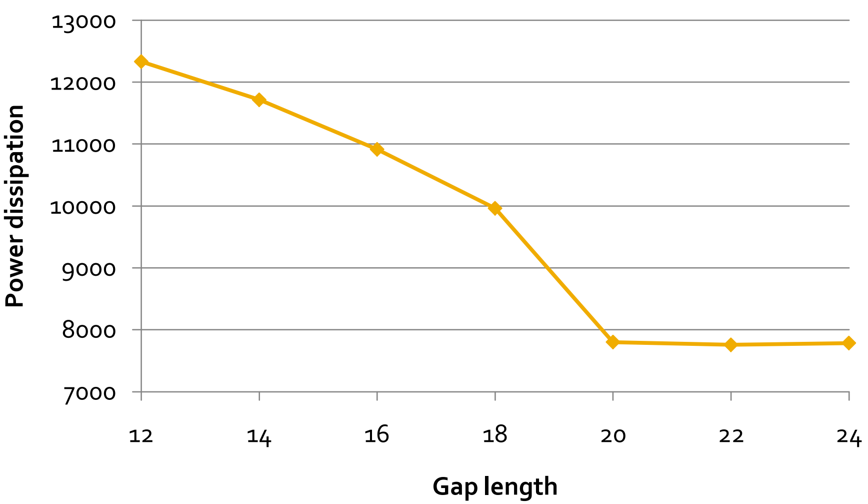




Rebuncher in front of the target







→ ~7,7 kW for 120kV

Outlook

- Multiple bunch compressor optimization runs
  - With different edge focussing strengths
  - Using first / last trajectory as a reference
- Further optimization of the rebuncher cavities
- Beam dynamics for the rebunchers using realistic fields

Thank you for your attention!