Phase Space Tomography Diagnostics at the PITZ facility

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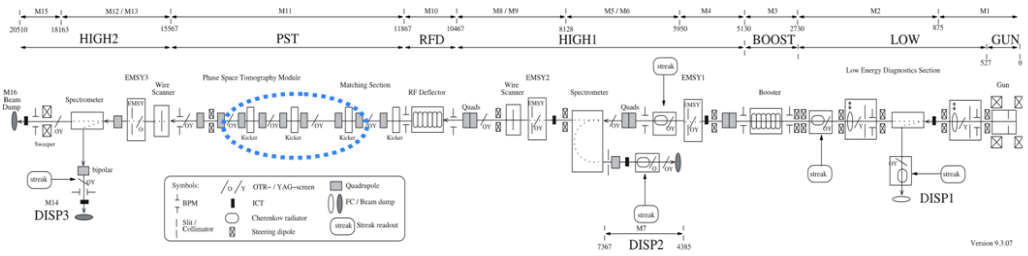
The transverse density distribution of an electron beam has to be studied in order to optimise the performance of the photo injector and reach the requirements for SASE FELs. For that purpose the PITZ beamline will be equipped with a tomography module consisting of four observation screens and three intermediate FODO cells.

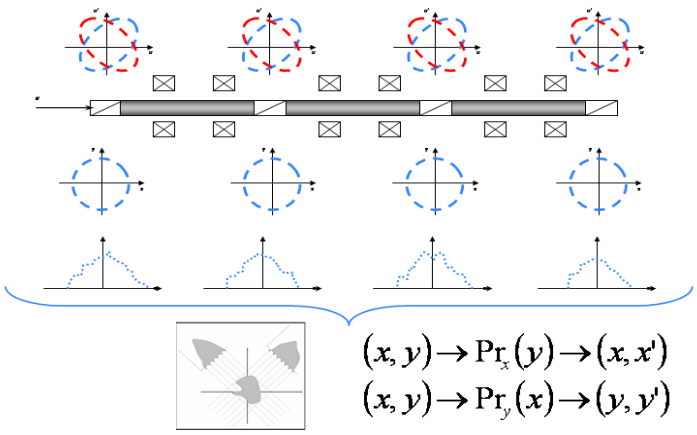
Electron beam momentum 15 - 40MeV/c

Bunch charge 1nC

Goal normalised transverse emittance 0.9π mm mrad



Multi-screen measurement principle

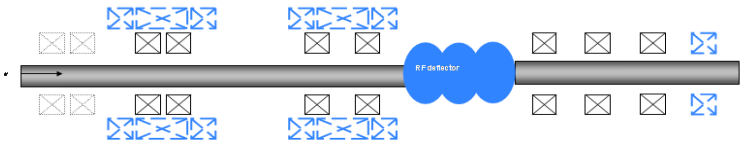


$$(x,y)\rightarrow \mathrm{Pr}_x(y)\rightarrow (x,x')$$
$$(x,y)\rightarrow \mathrm{Pr}_y(x)\rightarrow (y,y')$$

Requirements

- Periodic solution for particles' trajectories inside the FODO lattice
  - Phase advance $\varphi_{x,y} = 45°$
    - Delivers the smallest emittance measurements error using four screens
  - Equal beam size on screens
    - The reconstruction is based on the assumption that the particles' motion can be described completely by first order transport matrices

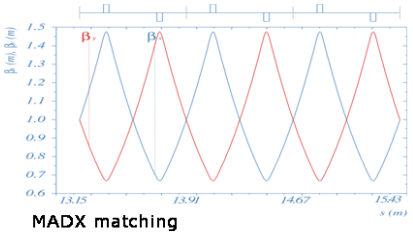
=> A matching section is required to deliver the necessary beam size and slope on the first screen



Standard setup

Setup for round beam

Matching into the tomography section – space charge compensation



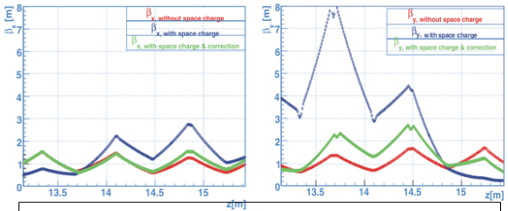
MADX matching

Ideal case of zero current

p = 32MeV/c

ε_N = 0.97π mm mrad

- Correction is energy dependent
- Space charge dominated beam for the full energy range
- Use always more than one quadrupole magnet to compensate for the RMS size increase in both transverse planes



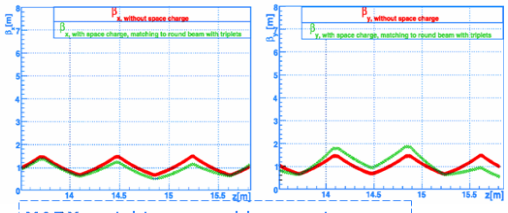
ASTRA/TRACE matching, standard setup

- Find Correcting Coefficient for each quadrupole:

$$CC_i = \frac{K^* \times L^*_{sc}}{R^{2***}}$$

- $CC_{i,(i+1)}$= max{CC_i, $CC_{(i+1)}$}
- Find quadrupole strength k_i corrected with CC, which delivers smallest Δ w.r.t. the one without space charge

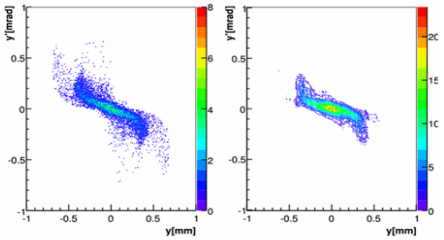
$$\Delta = \min\left\{\sqrt{\Delta^2_{slope} + \Delta^2_{size}}\right\}$$



MADX matching, round beam setup

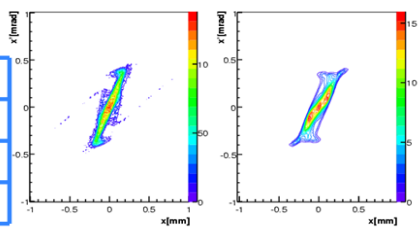
- Using triplets to focus both transverse planes simultaneously
- Focus the beam to a round one in front of the last four quadrupoles
- Good match in both transverse planes

Phase space tomography reconstruction from simulated data



	σ_x	$\sigma_{x'}$	$\varepsilon_{x,norm}$
Original	0.26	-0.03	1.21
Reconstructed	0.24	-0.03	1.18
Disagreement (%)	7.7	-	2.6

Simulated (left) and reconstructed (right) from matching setup (1)



	σ_x	$\sigma_{x'}$	$\varepsilon_{x,norm}$
Original	0.143	0.023	1.27
Reconstructed	0.155	0.0241	1.07
Disagreement (%)	8.4	4.3	4.8

Simulated (left) and reconstructed (right) from matching setup (2)

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