Karlsruhe Institute of Technology

ANKA

Response Matrices - Measurements and Fits

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Outline

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- LOCO - Linear optics from closed orbits
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The orbit response matrix

- The orbit response matrix (RM) can be calculated or measured directly on the accelerator.

- The RM element M_{ij} describes the beam motion x_i at the i^{th} beam position monitor (BPM) in response of a dipole kick θ_j from the j^{th} corrector magnet (CM):

$$x_i = M_{ij}\theta_j$$

- Each element of the RM is also an R_{12} element of the transport matrix:

$$\begin{pmatrix} x \\ x' \end{pmatrix}_{final} = \begin{pmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{pmatrix} \cdot \begin{pmatrix} x \\ x' \end{pmatrix}_{inital}$$

LOCO - Linear optics from closed orbits

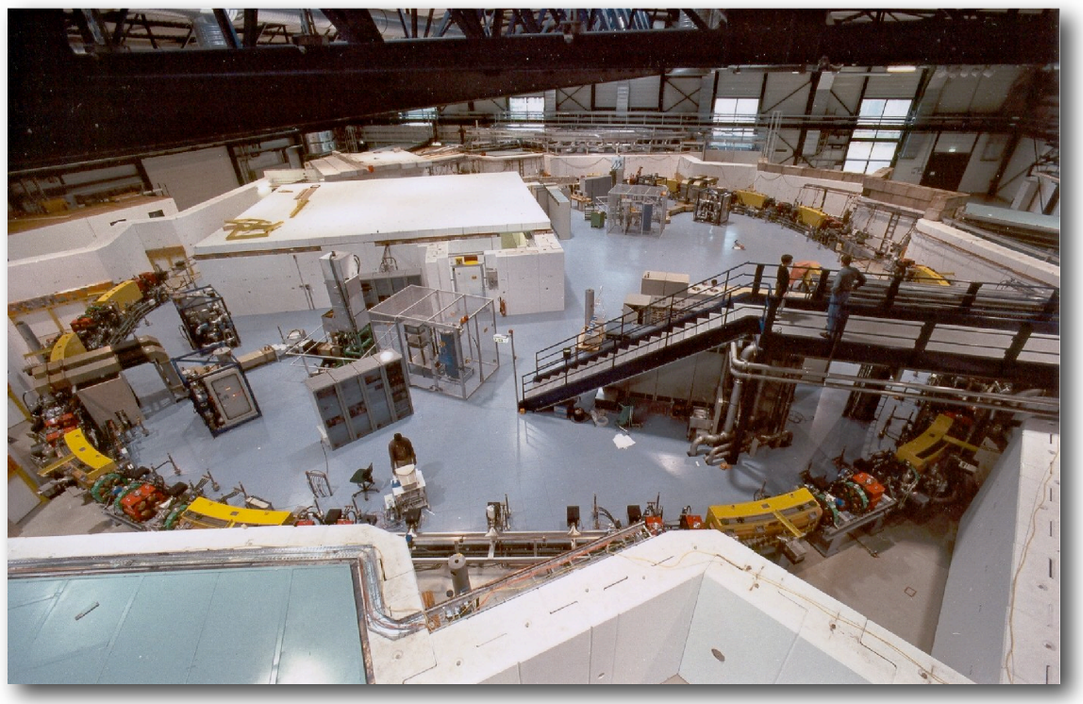
- LOCO is written in Matlab and can be used in addition to the Accelerator Toolbox (AT).
- The code estimates the actual linear optics of the ring for a given measured RM.
- To find the best fitting model, the χ^2-difference between the measured data and the model is minimized:

$$\chi^2 = \sum_{i,j} \frac{(M_{mod,ij} - M_{meas,ij})^2}{\sigma_i^2}$$

- The standart parameters varied when fitting are: quadrupole gradients, BPM and CM gains, BPM and CM coupling
- For the fit, the nonquadratic RM must be inverted.
  → Single value decomposition (SVD) is used.

Measurements at ANKA

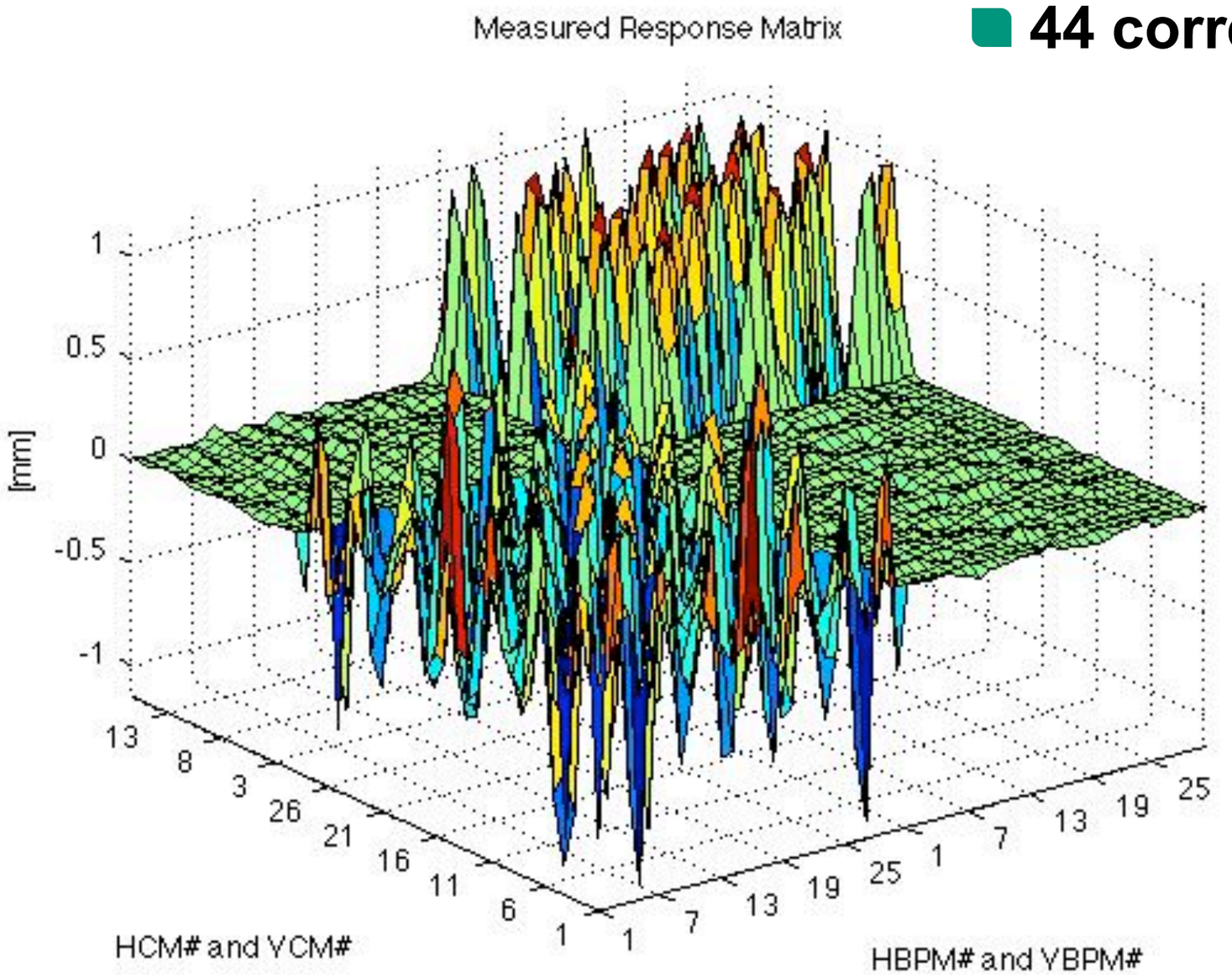
- Low alpha optics:
  - 1.3 GeV beam energy
  - changing the optics in steps to reduce the momentum compaction factor α
  - decrease the bunch length → „squeeze“



- for each squeeze step:
  - store the orbit difference for each CM kick → RM
  - measure the dispersion as an additional column for the RM
  - measure the chromaticity and the tunes

Measurements at ANKA

- 60 beam position monitors (BPM)
- 44 corrector magnets (CM)

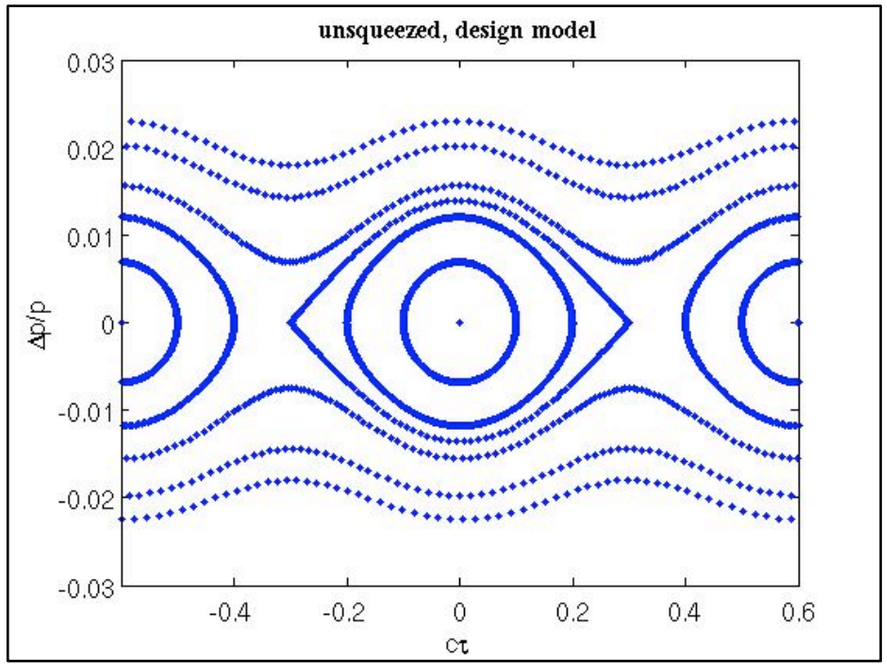


- low coupling
- periodic behaviour

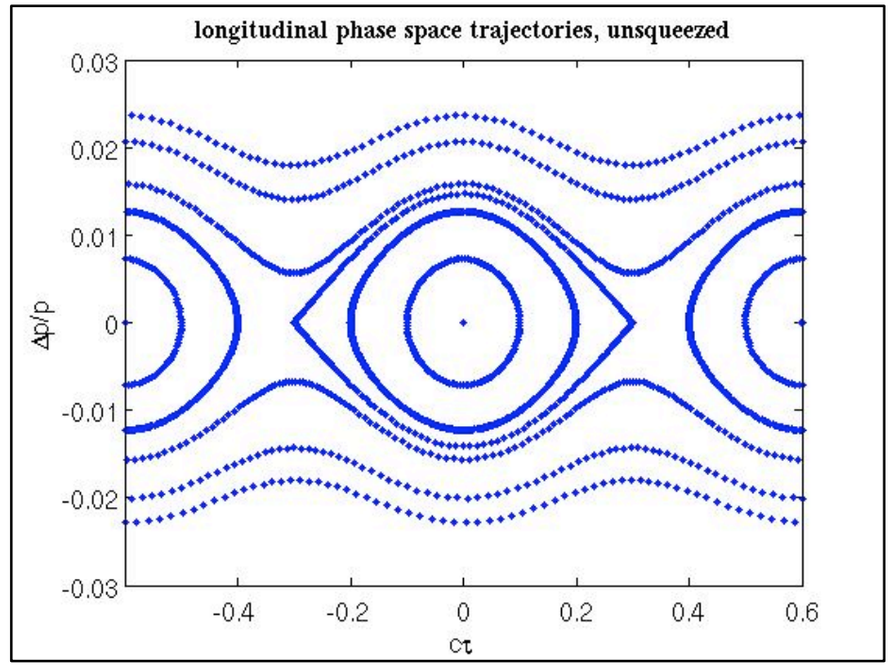
Measurement and LOCO setup

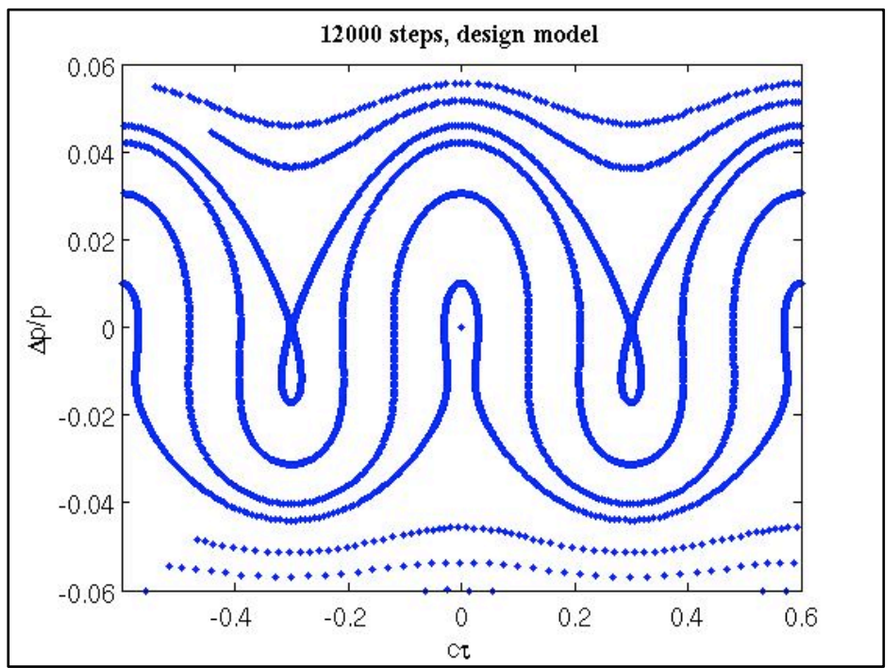
RM calculator	linear, last two iterations full
	constant path length
Coupling	no BPM coupling
Energy shift	no energy shift at the CM
Dispersion	fit horizontal dispersion (cavities off)
Singular values	remove outlier above threshold
RM measurement method	one way
Algorithm	Levenberg-Marquard
Sextupoles	stay turned on, orbit offset is small
Dipoles	no K-values, no fringe fields included

First results - Phase space trajectories

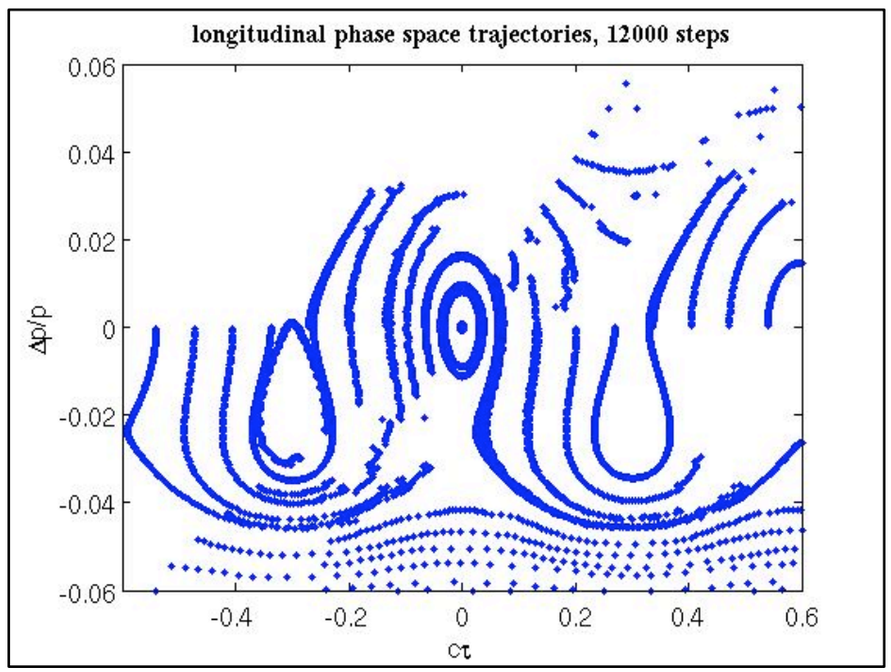


unsqueezed
← design / fitted →
$\alpha_{model} = 8.5 \times 10^{-3}$

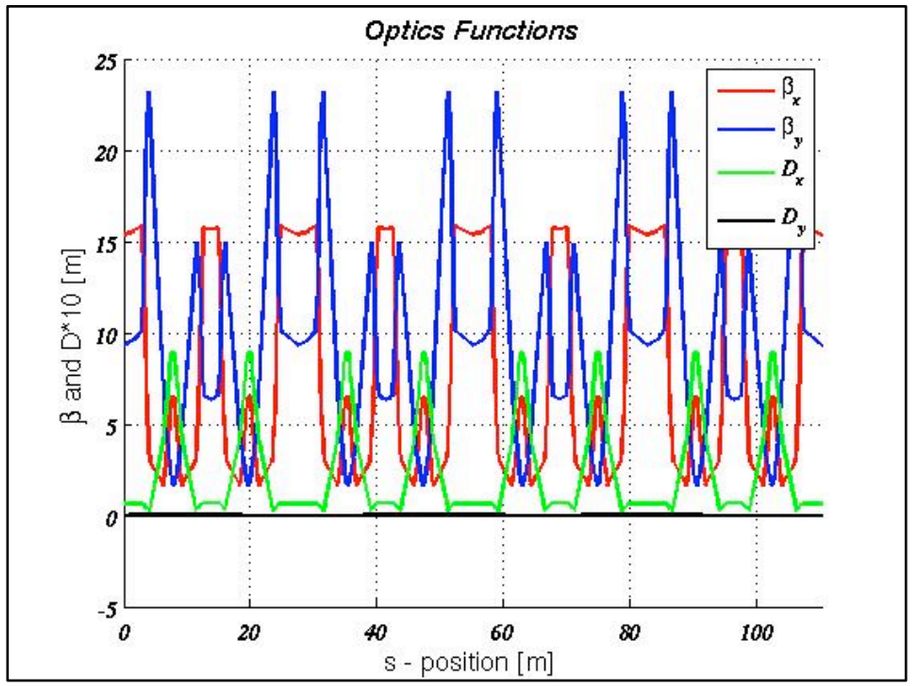




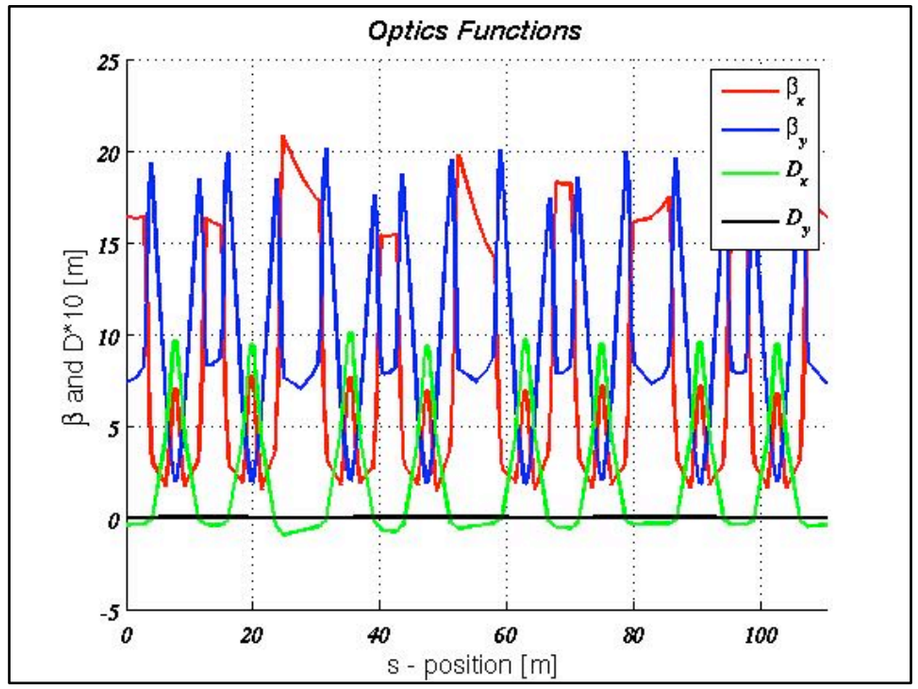
12000 steps
← design / fitted →
$\alpha_{model} = 2.6 \times 10^{-4}$

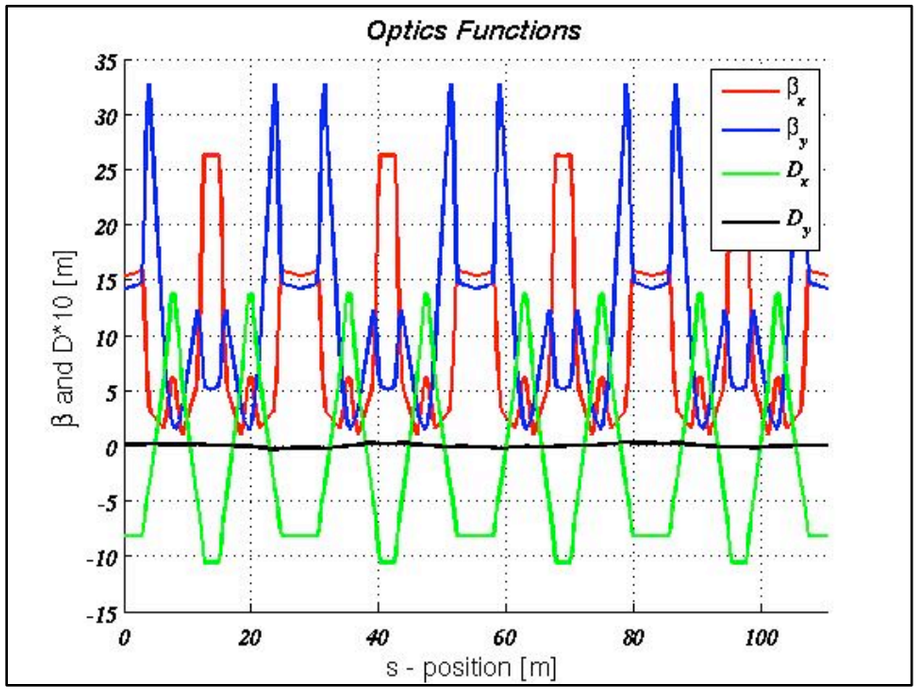


First results - The optics functions

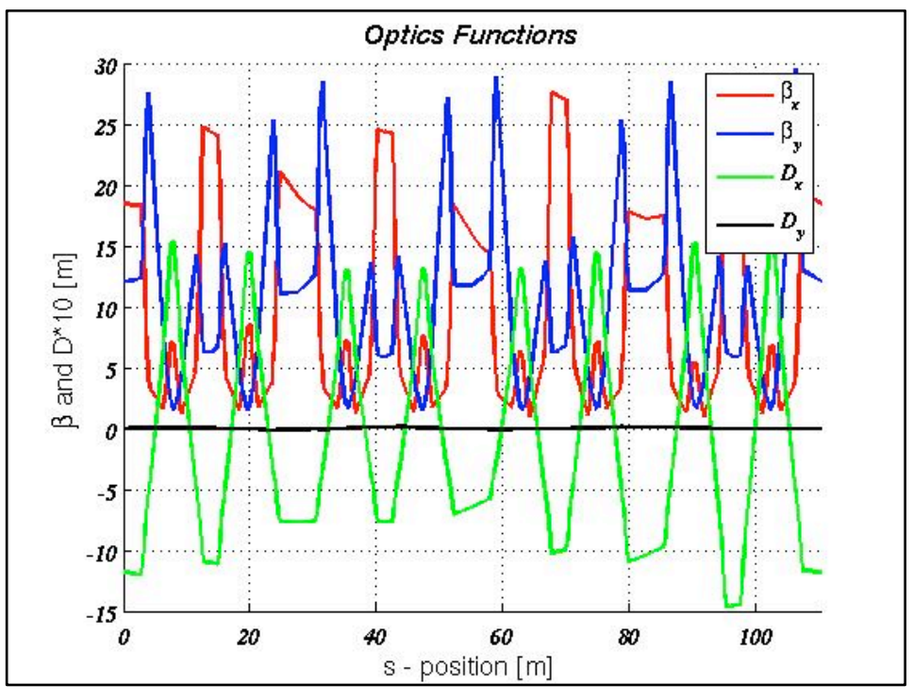


unsqueezed
← design / fitted →





12000 steps
← design / fitted →



First results - Momentum compaction factor and synchrotron frequency

- **Momentum compaction factor α_c and synchrotron frequency f_s are related as follows:**

$$f_s = f_{rev}\sqrt{\frac{h\alpha_c}{2\pi E}\sqrt{e^2V_{RF}^2 - U_0 + k}}$$

$$f_{s,meas} = f_{rev}\sqrt{\frac{h\alpha_{c,mod}}{2\pi E}\cdot C}$$

- **The bunch length can be estimated from f_s.**

- **By comparing the results of the optics of six squeeze steps, the constant C could be determined:**

$$C = (867 \pm 11)eV$$

- **$\rightarrow$ The expected bunch length of a new model can be calculated.**

Outlook

- **Improve the existing models:**
  - **Migrate models to MAD**
  - **Vary quadrupole strength to match betatron tunes exactly**
  - **Vary sextupole strength to match chromaticity**
  - **Ad the true orbit**

- **Analysis of the models:**
  - **Calculate the tune footprint / Systematic search for resonances**

- **Application:**
  - **Optimize existing ramping curves**
  - **Develop new models...**