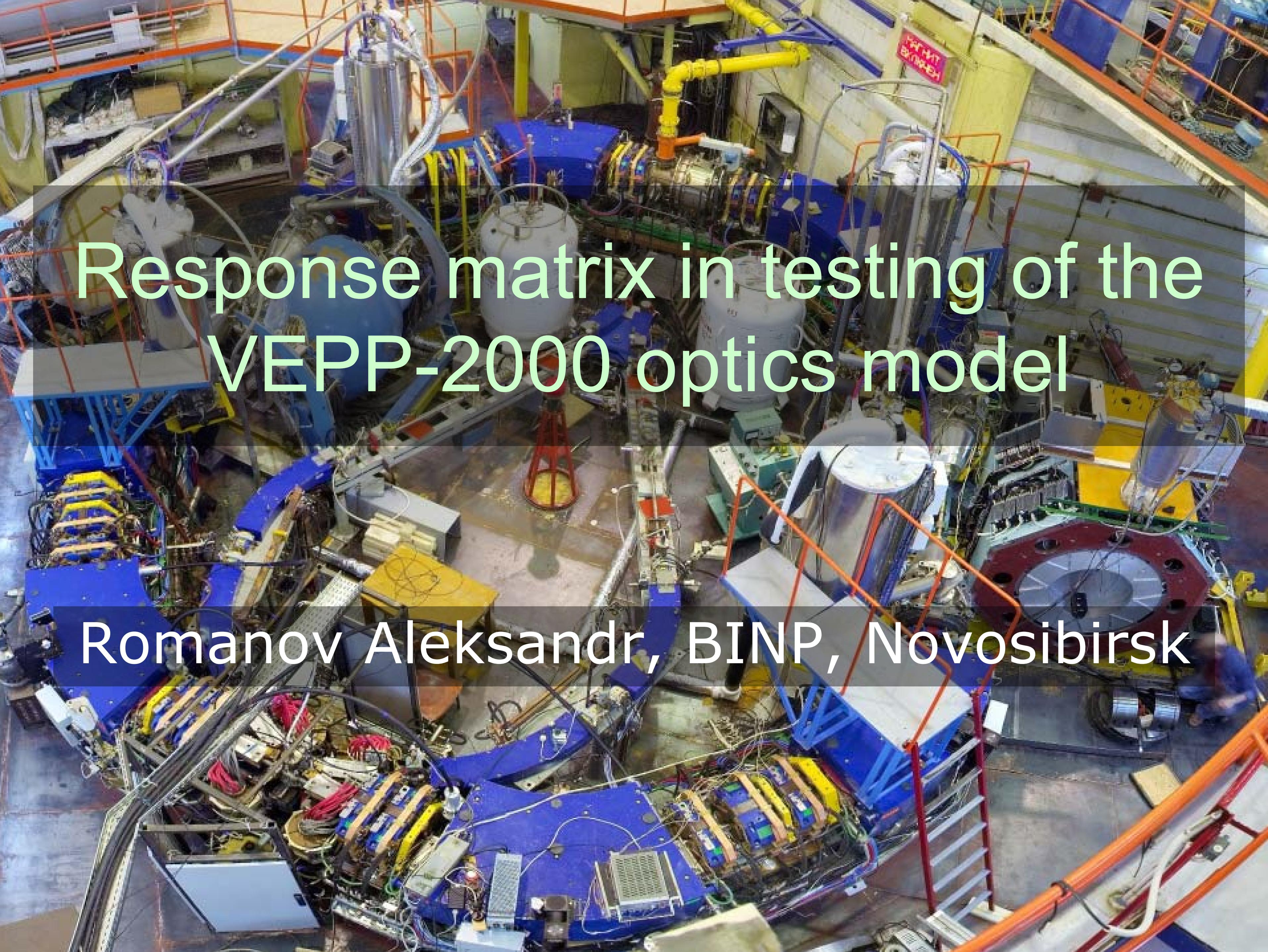

Response matrix in testing of the VEPP-2000 optics model

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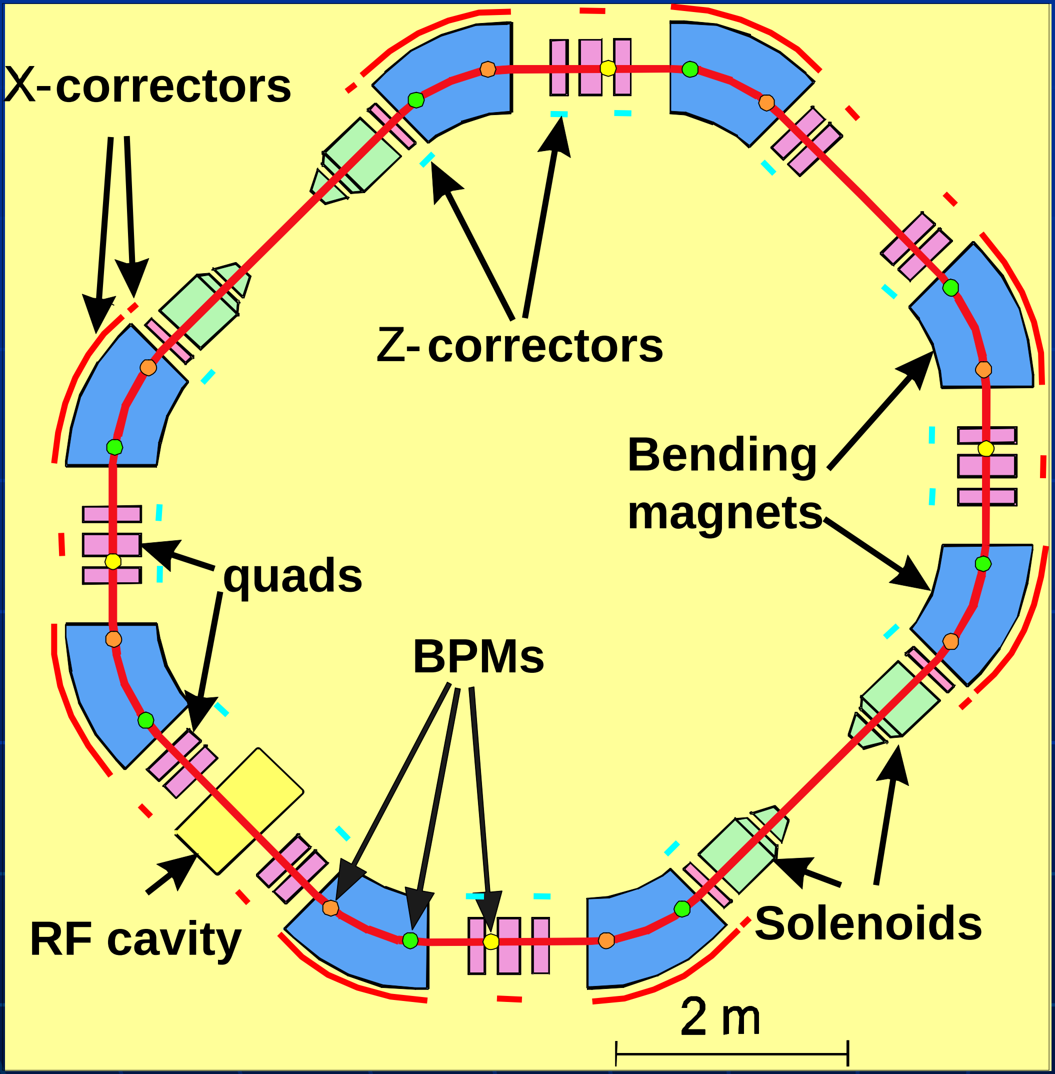
Main goals

Precise tunining of the VEPP-2000 lattice to the project parameters

- Orbit correction
  - OC relative to the quads
  - OC in the solenoids of the final focus
  - Reduce current in the correctors
- Lattice optimisation
  - Optical functions symmetry
  - Dispersion correction
  - Interraction region

BPM and correction systems on VEPP-2000



e+ CCD	8
e- CCD	8
pickups	4

X-correctors	8	dipoles
	12	quads
Z-correctors	16	quads

quads	12+12
solenoids	4 (x3)
skew-quads	12
mechanical shifts	∞

Orbit correction

- Measure orbit displacements relative to the magnetic centers of quads
    - Measure CO shift in BPMs from quad gradient variation
    - Determine CO shifts using least squares method

$$F(\lambda)=\sum_{BPM}\frac{(x_{\exp}-\lambda x_{\text{model}})^2}{\sigma_{\exp}^2};\;\; F(\lambda\pm\Delta\lambda)=2F_{\min};\;\; \Delta x_{orb}=\Delta\lambda\,\Delta l_{\text{model}}$$

- Determine set of corrector currents needed for optimal correction of measured distortions

$$\Delta\vec{X}_{err}=M_{model}\Delta\vec{I}_{corr};\qquad \Delta\vec{I}_{corr}=(M_{model})^{-1}_{SVD}\vec{X}_{err};$$

$$\Delta\vec{I}_{corr}=(M_{model}/(\vec{\sigma}_{\exp}+S))^{-1}_{SVD}(\vec{X}/(\vec{\sigma}_{\exp}+S))$$

Optimization of the currents in orbit correctors

- Determine CO variation caused by selected group of correctors
- Search for optimal set of the correctors strengths that follows current CO variation with minimal influence
    - In case of strong corrections it is necessary to precisely know the model of the ring

Lattice correction

To find lattice errors one should minimize difference between experimental and theoretical set of parameters V_k, by varying selected properties p_n. As V_k one can choose any value that can be measured and predicted, for example:

- CO response in BPMs on dipole correctors
- Tunes
- Dispersion

By inverting the rectangular matrix $\partial V_k/\partial p_n$ with help of SVD one can find parameters that describe the experimental data better:

$$\Delta V_k = \frac{\partial V_k}{\partial p_n}\Delta p_n; \; V_{k0} + \Delta V_k = 0 \;\Rightarrow\; \Delta p_n = -\left(\frac{\partial V_k}{\partial p_n}\right)^{-1}_{SVD} V_{k0}$$

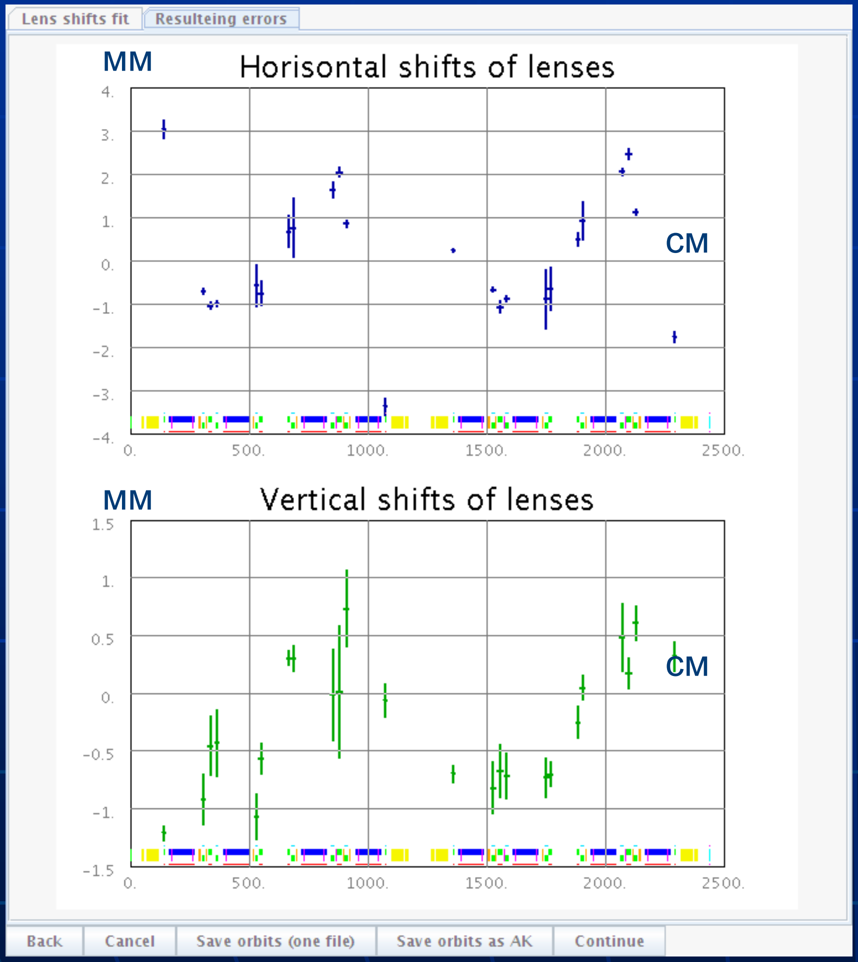
Sixdsimulation

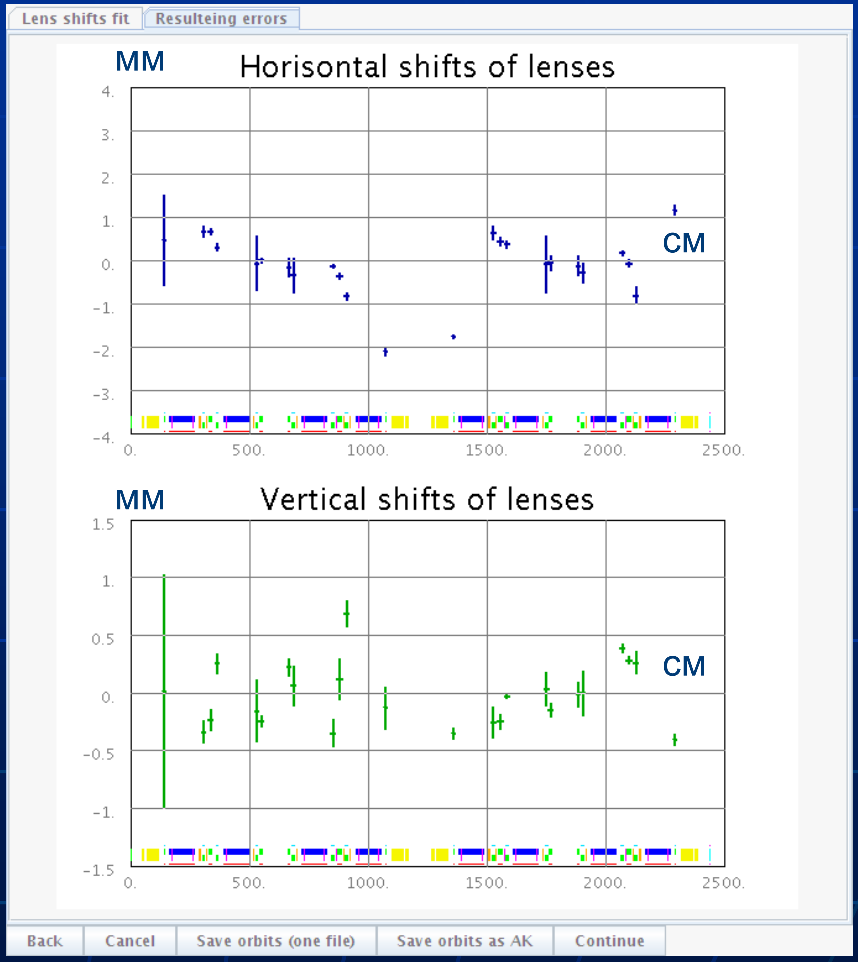
- Program has graphical interface
- Program calculates lattice parameters in 6 dimensions with coupling
- Main goals of the program:
  - Calculation of the basic linear lattice parameters of the circular accelerators
  - Automated CO correction relative to the magnetic centers of the quads
  - Automated lattice correction
  - Automated optimization of the currents in the correctors
  - Other…

Sixdsimulation

- Means that can be used for CO correction:
  - Horizontal correctors
  - Vertical correctors
  - Mechanical shifts of quads and solenoids
- Means that can be used for linear lattice correction:
  - Gradients of magnetic field in:
    - Quads
    - Skew-quads
    - Magnets
  - Lengths of the elements
  - Rotations of the elements:
    - Quads
    - Skew-quads
    - Correctors
    - BPMs
  - Strengths of solenoids
  - Calibrations:
    - Correctors
    - BPMs
  - There is possibility to group set of parameters for dependent variation

Example of the CO correction



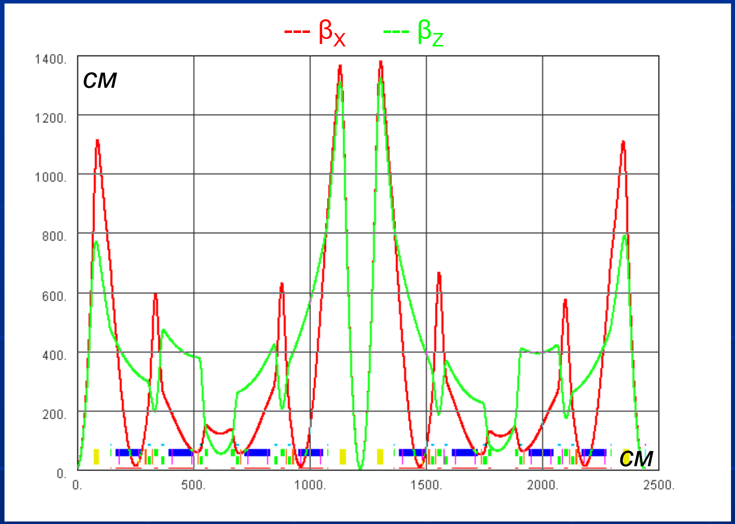


Example of the optimization of currents in the correctors

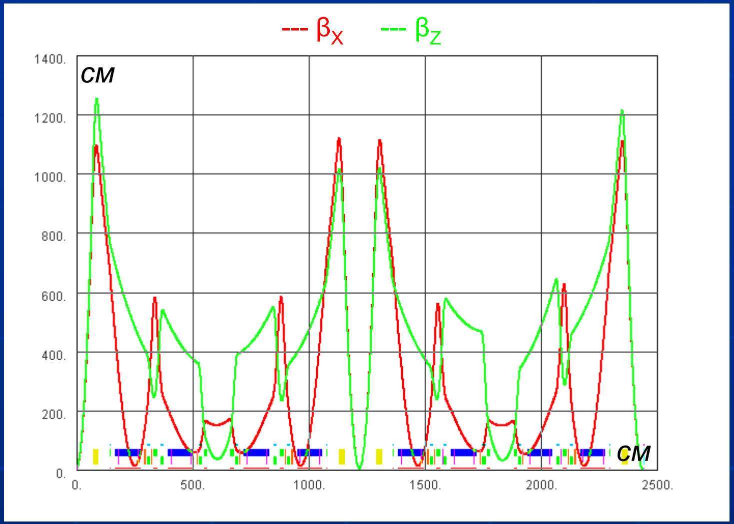
	ΣI^2	$\Sigma\|I\|$	$\Sigma\|I\|/N_{corr}$
Before optimisation	17.6 A^2	18.8 A	0.52 A
After optimisation	6.1 A^2	8.1 A	0.22 A
After orbit correction	5.1 A^2	10.2 A	0.28 A

Example of the lattice correction

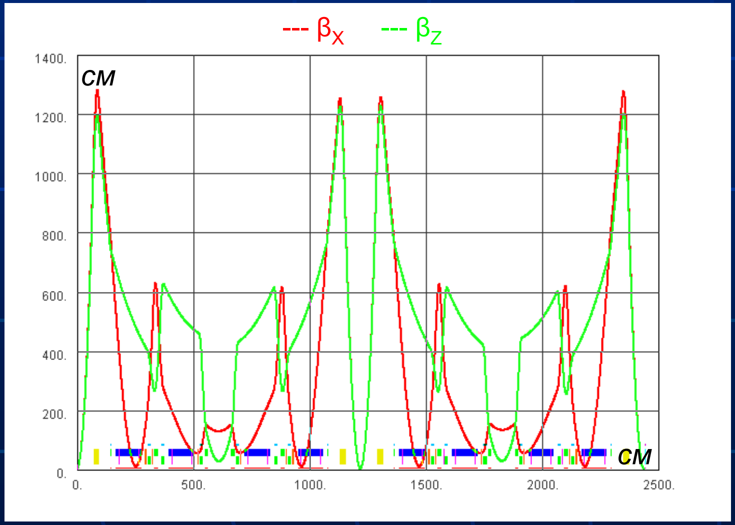
$\Sigma\|I\|$
105.4
$\Sigma\|I\|/N_{quads}$
4,4



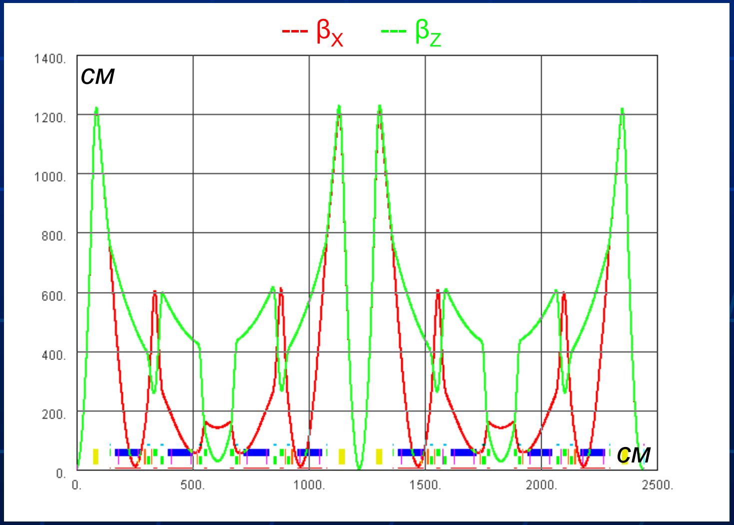
$\Sigma\|I\|$
59.8
$\Sigma\|I\|/N_{quads}$
2.5



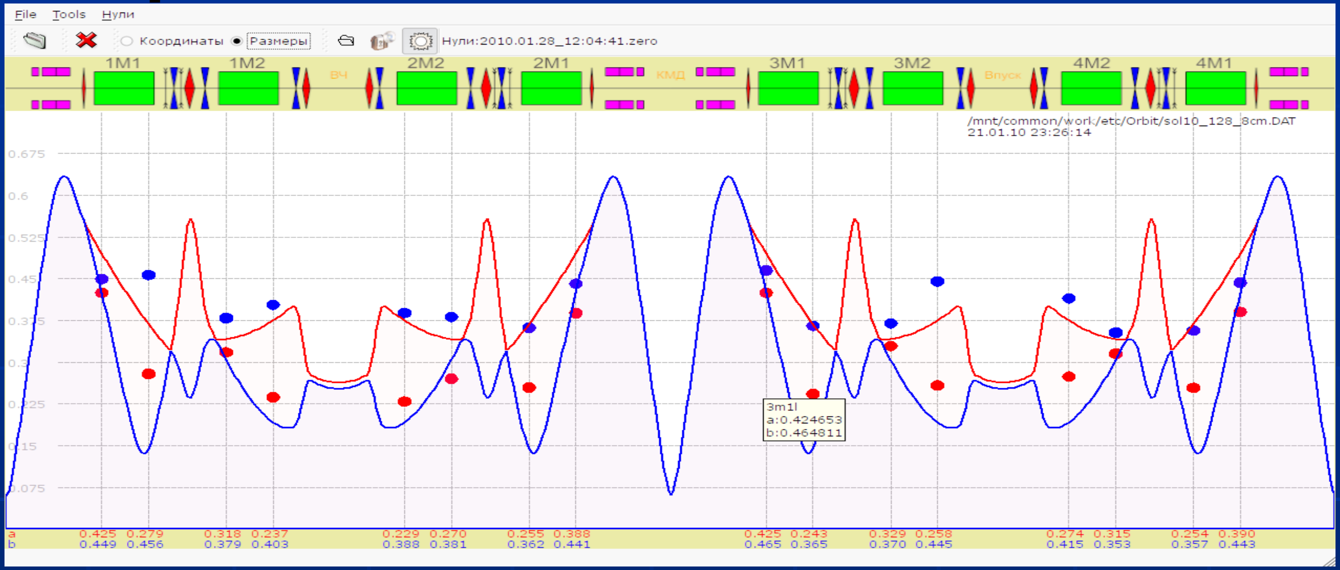
$\Sigma\|I\|$
17.4
$\Sigma\|I\|/N_{quads}$
0.7

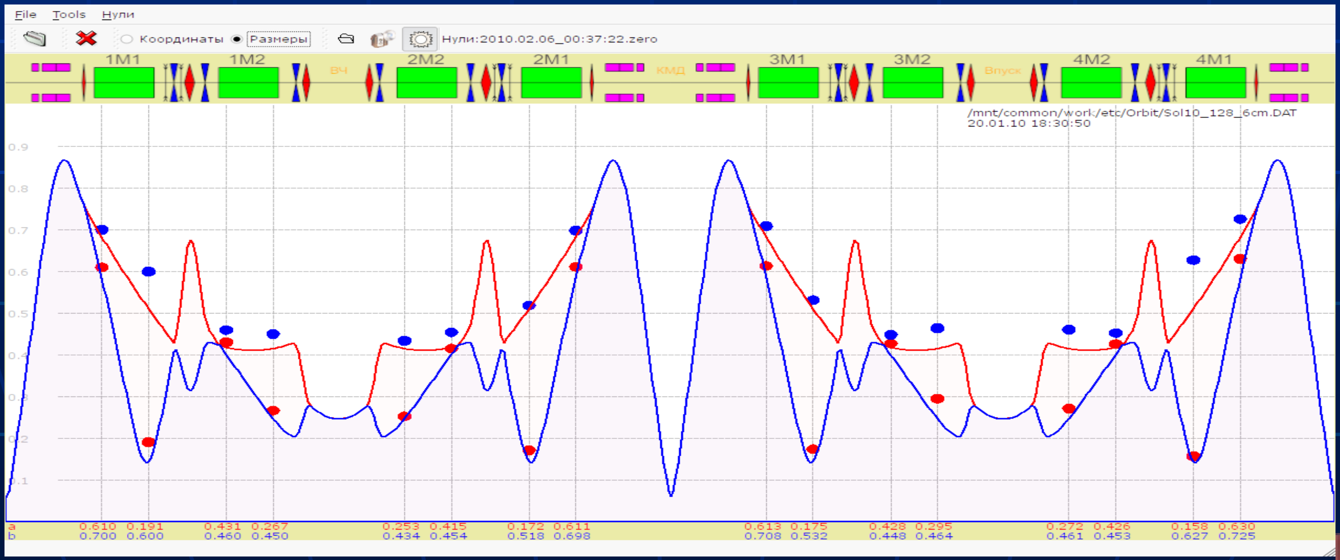


$\Sigma\|I\|$
3.6
$\Sigma\|I\|/N_{quads}$
0.15



Example of the lattice correction





Conclusion

Automation was performed for:

- CO correction
- Linear lattice correction
- Correctors strengths optimization