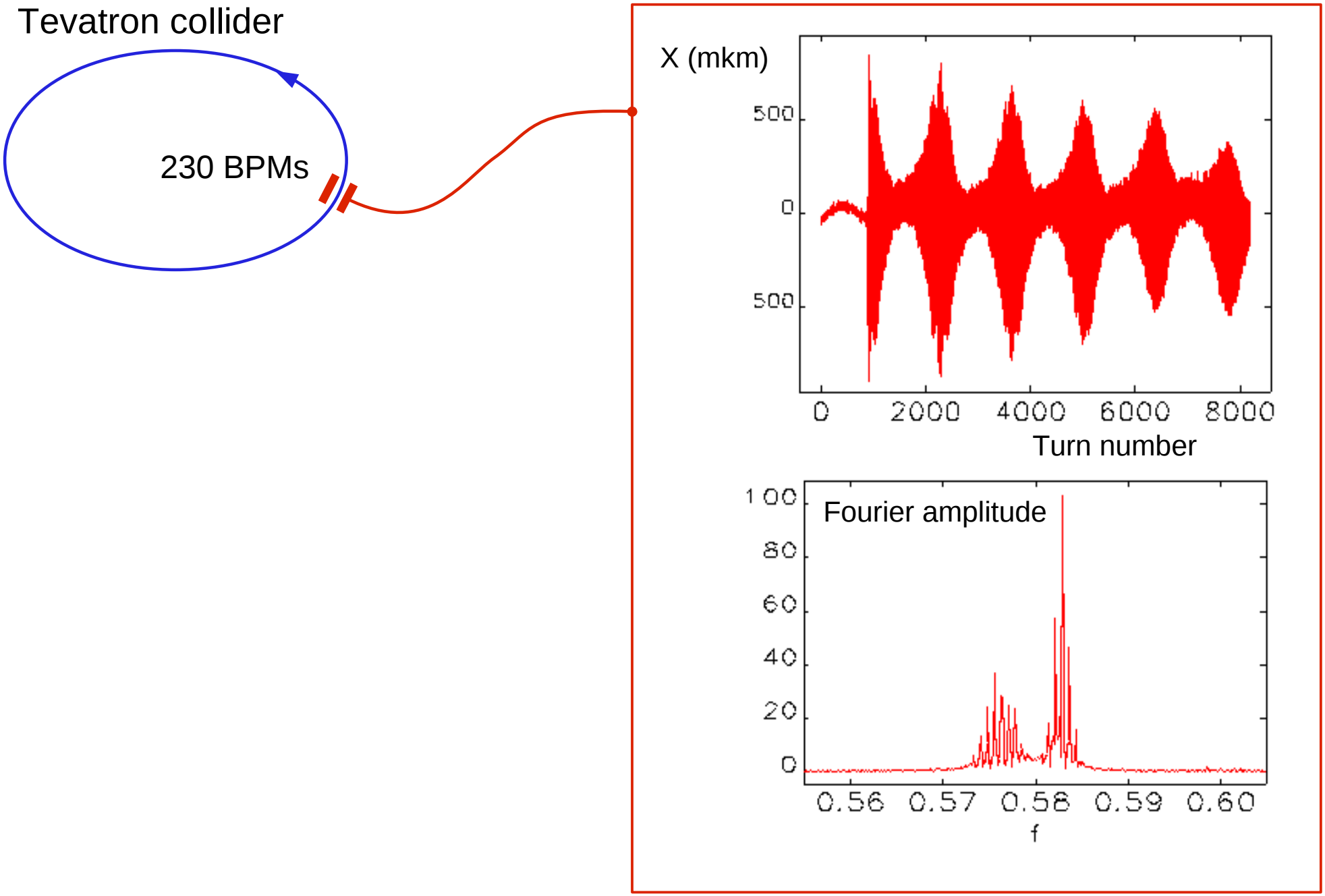
Model-Independent Analysis of Beam Position Monitor Measurements

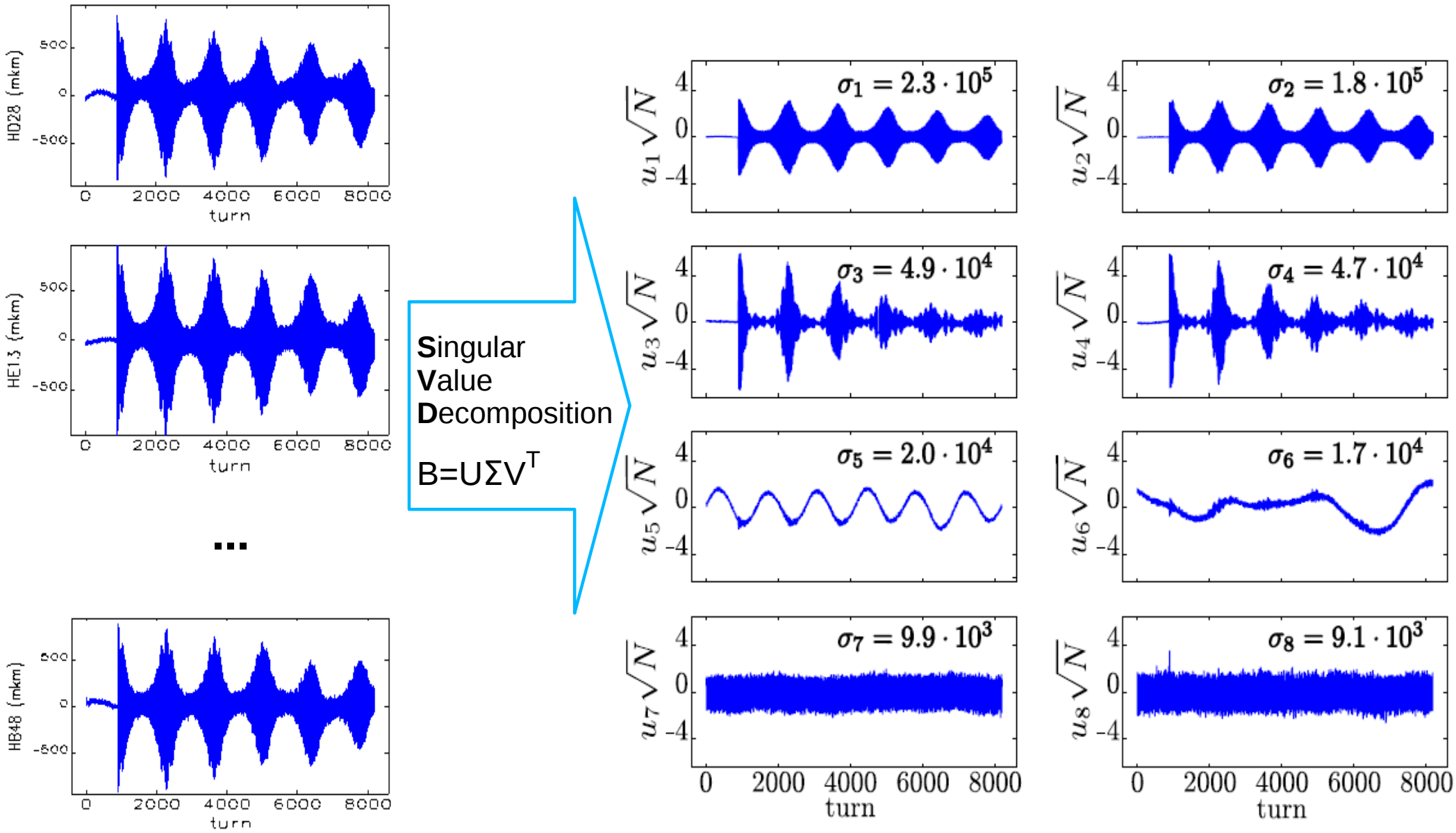
Alexey Petrenko, BINP, Novosibirsk, Russia

Turn-by-turn BPM signal after beam is kicked with a horizontal kicker

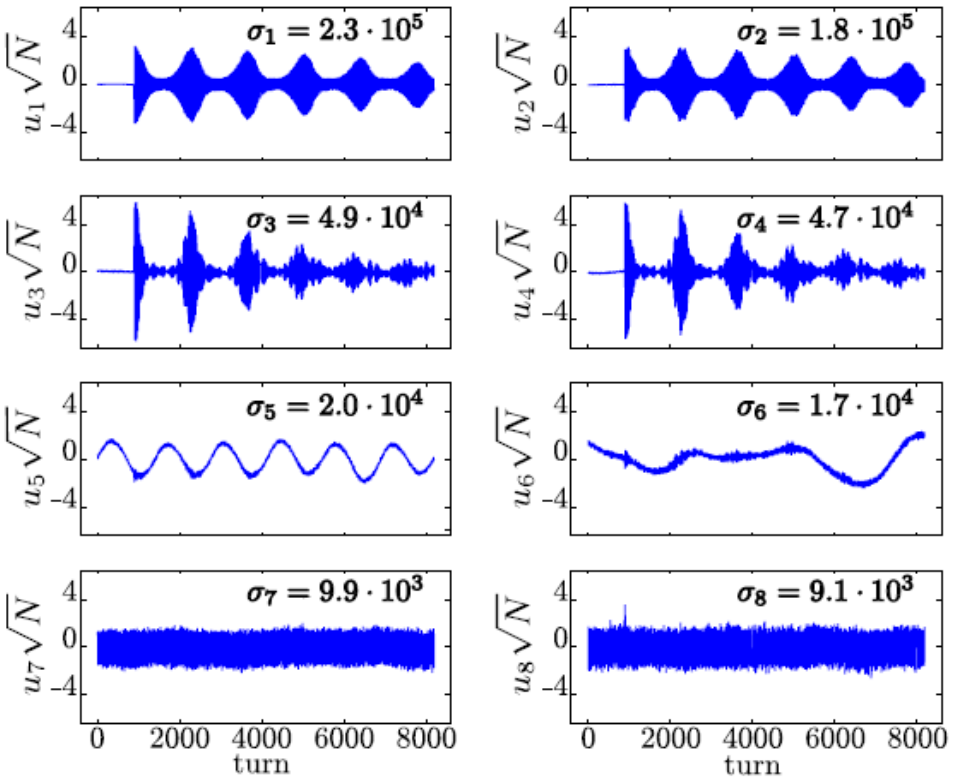


Model-Independent Analysis of BPM signals

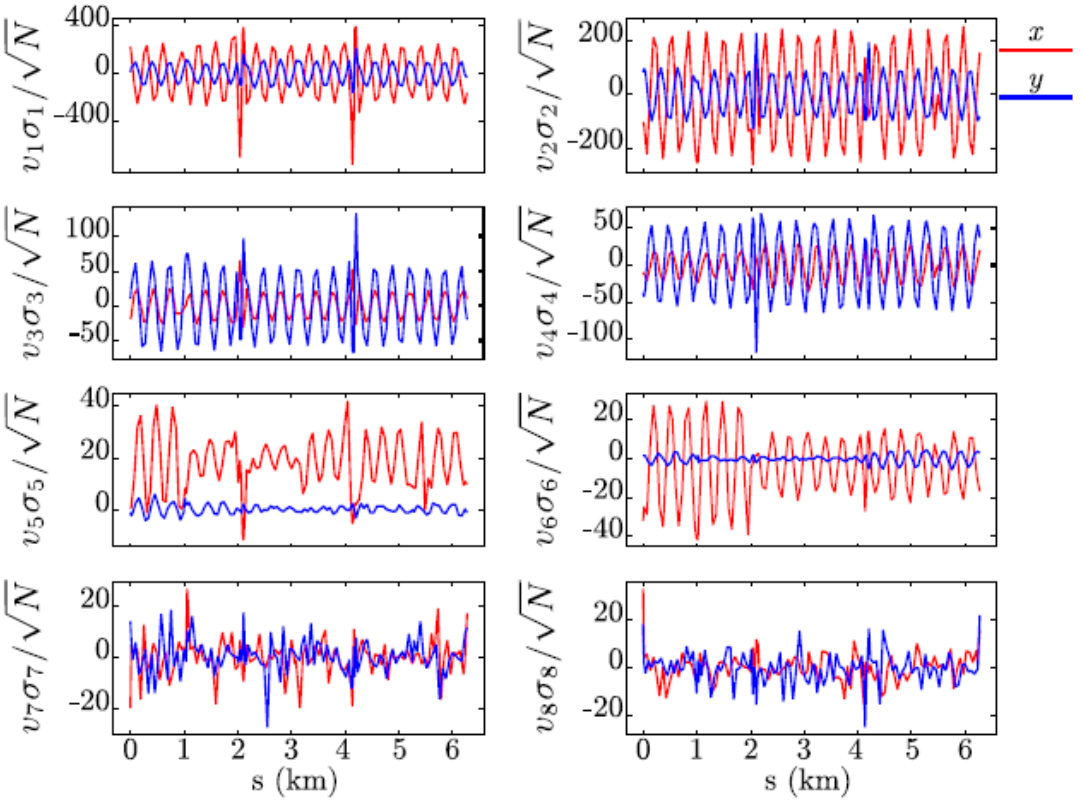
Signal from each BPM is represented as a linear combination of a small number of mutually independent (orthogonal) components:



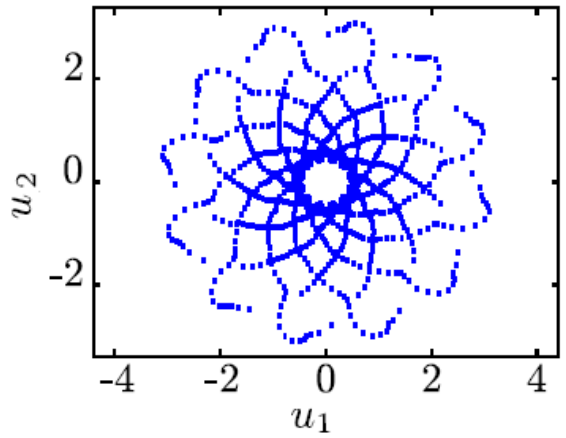
Temporal modes
(mutually independent components)



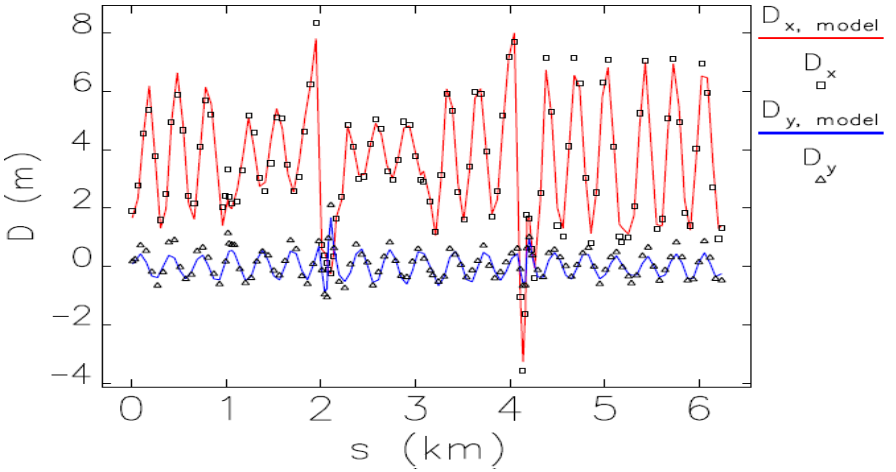
Spatial modes
(amplitude of temporal mode vs BPM position)



Beam centroid trace in phase space:



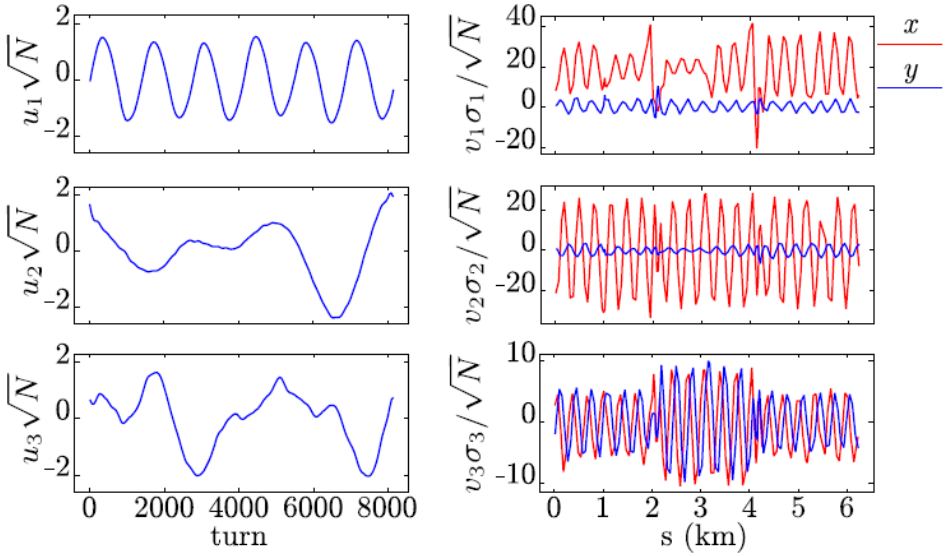
Lattice functions:



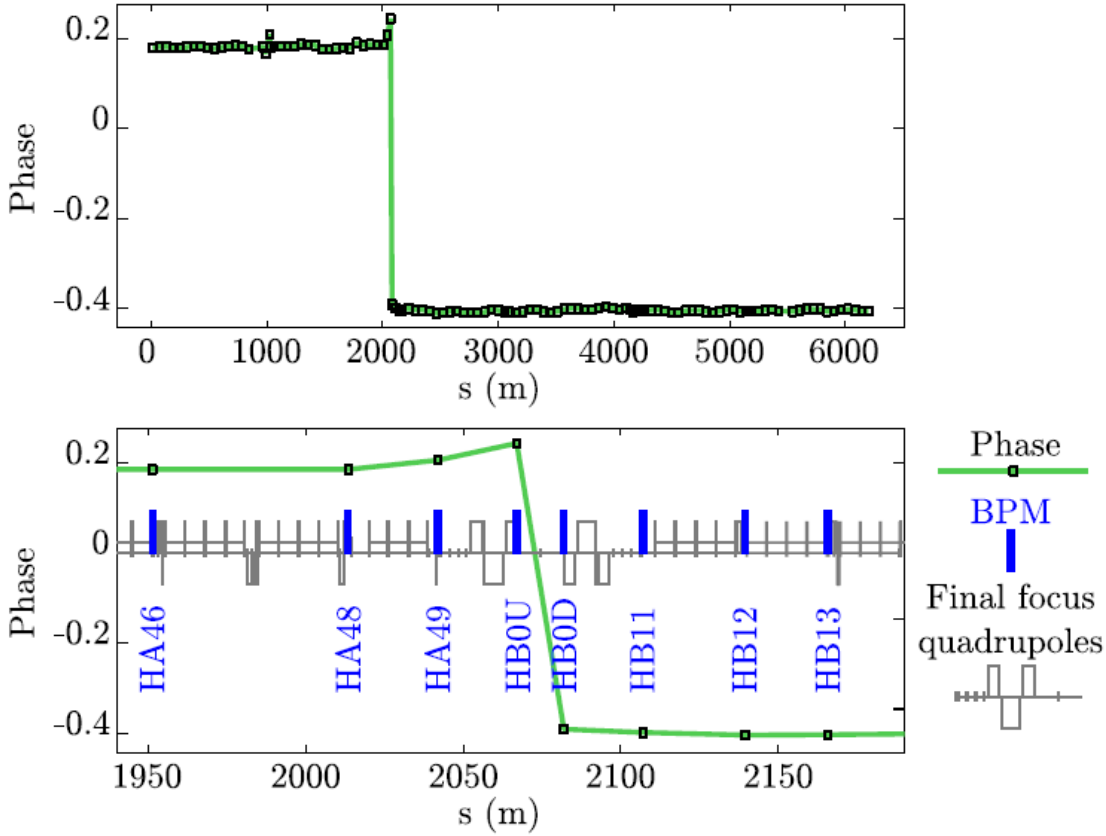
Horizontal and vertical dispersion function

Finding the source of some modes

Slow modes (after low-pass Fourier filter)



"Betatron" phase of mode 2 (vibrational mode)



At any pair of (horizontal) BPMs any spatial mode can be represented as a linear combination of two independent orbits:

$$\begin{cases} v_{\mathrm{vibr}}(s_1) = C_1 v_{\mathrm{b1}}(s_1) + C_2 v_{\mathrm{b2}}(s_1) \\ v_{\mathrm{vibr}}(s_2) = C_1 v_{\mathrm{b1}}(s_2) + C_2 v_{\mathrm{b2}}(s_2) \end{cases}$$

tan(Phase) = C_1/C_2

Elements of transport matrix between BPMs

Using any 4 linearly independent orbits (e. g. spatial modes of betatron oscillations) it is possible to calculate some of the transport matrix elements between BPMs:

$$(x_1^a x_2^b - x_2^a x_1^b)/Q_{12} + (x_3^a x_4^b - x_4^a x_3^b)/Q_{34} = \mathcal{R}_{12}^{ab}$$

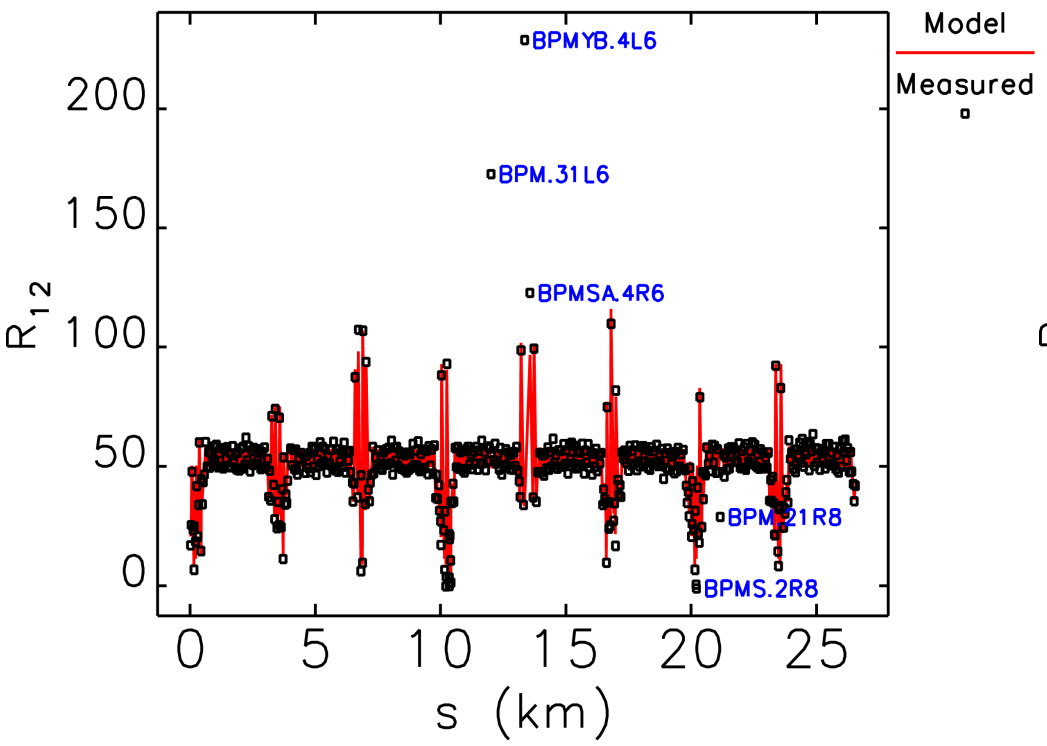
$$(x_1^a y_2^b - x_2^a y_1^b)/Q_{12} + (x_3^a y_4^b - x_4^a y_3^b)/Q_{34} = \mathcal{R}_{32}^{ab}$$

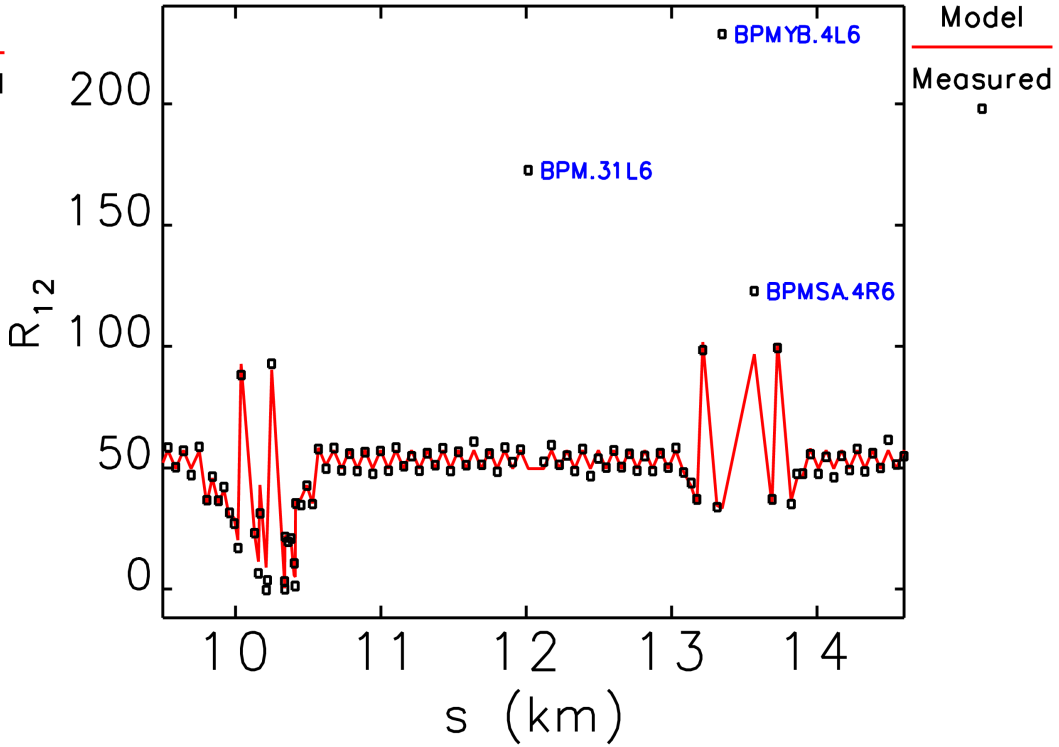
$$(y_1^a x_2^b - y_2^a x_1^b)/Q_{12} + (y_3^a x_4^b - y_4^a x_3^b)/Q_{34} = \mathcal{R}_{14}^{ab}$$

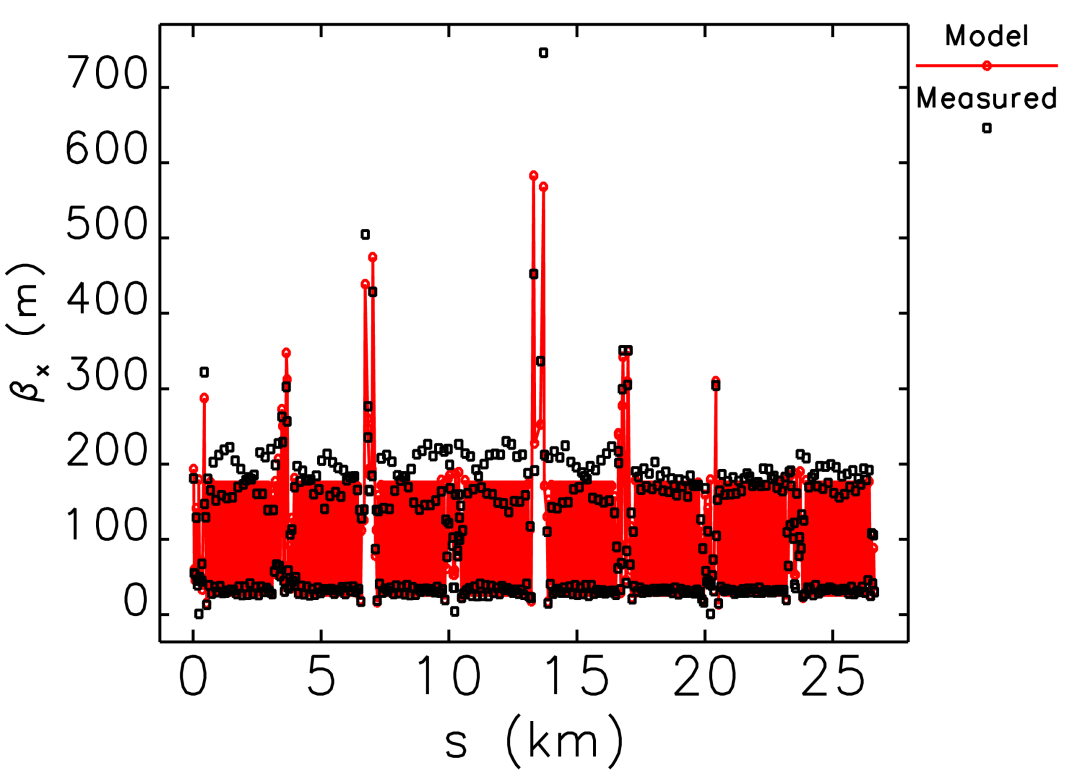
$$(y_1^a y_2^b - y_2^a y_1^b)/Q_{12} + (y_3^a y_4^b - y_4^a y_3^b)/Q_{34} = \mathcal{R}_{34}^{ab}$$

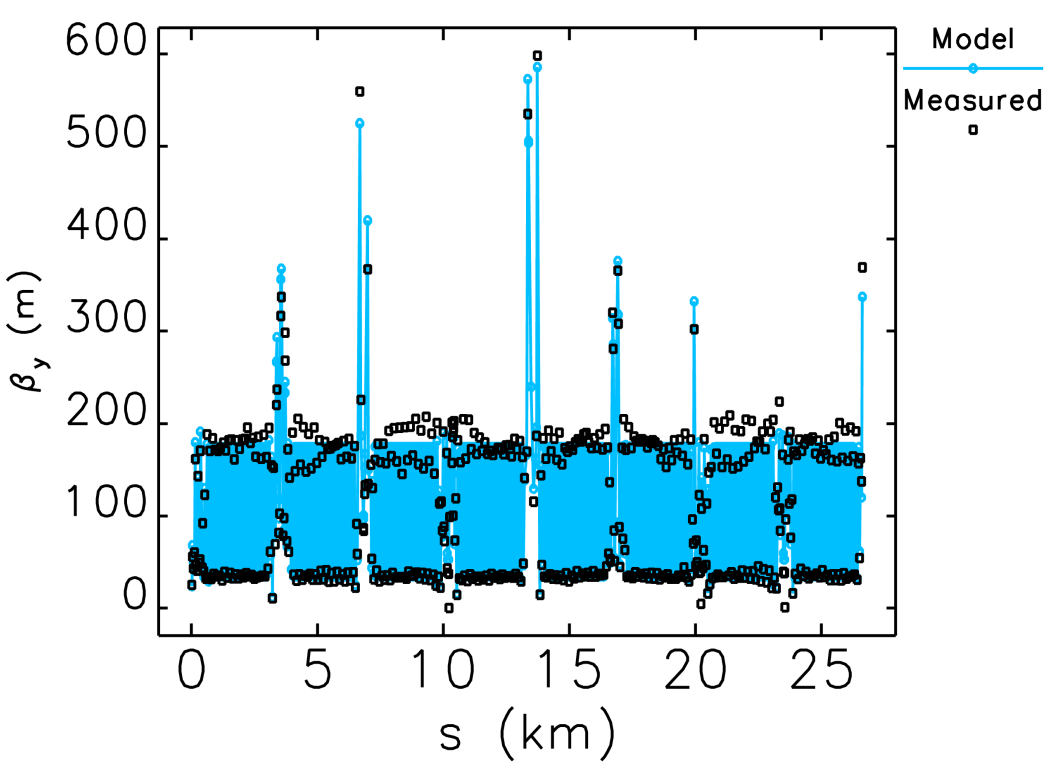
J. Irwin and Y. T. Yan, "*Beamline Model Verification Using Model Independent Analysis*", Proceedings of EPAC 2000, Vienna, Austria.

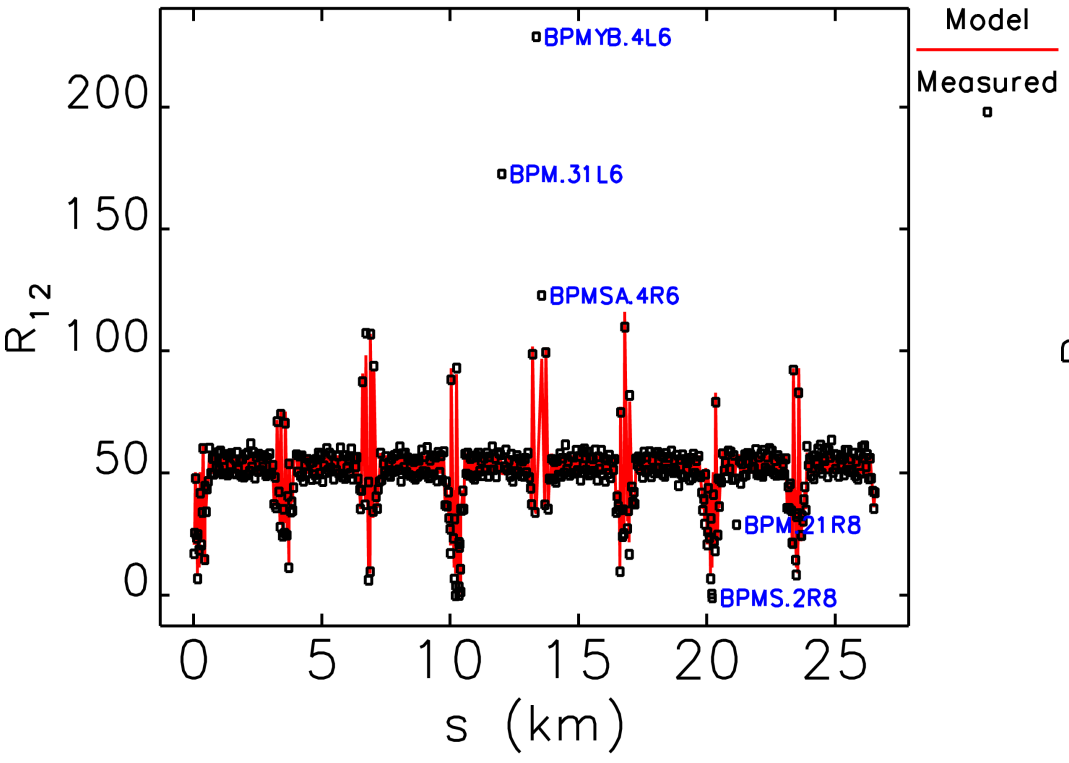
R_{12} calculated from turn-by-turn measurements (courtesy R. Miyamoto) at the LHC:

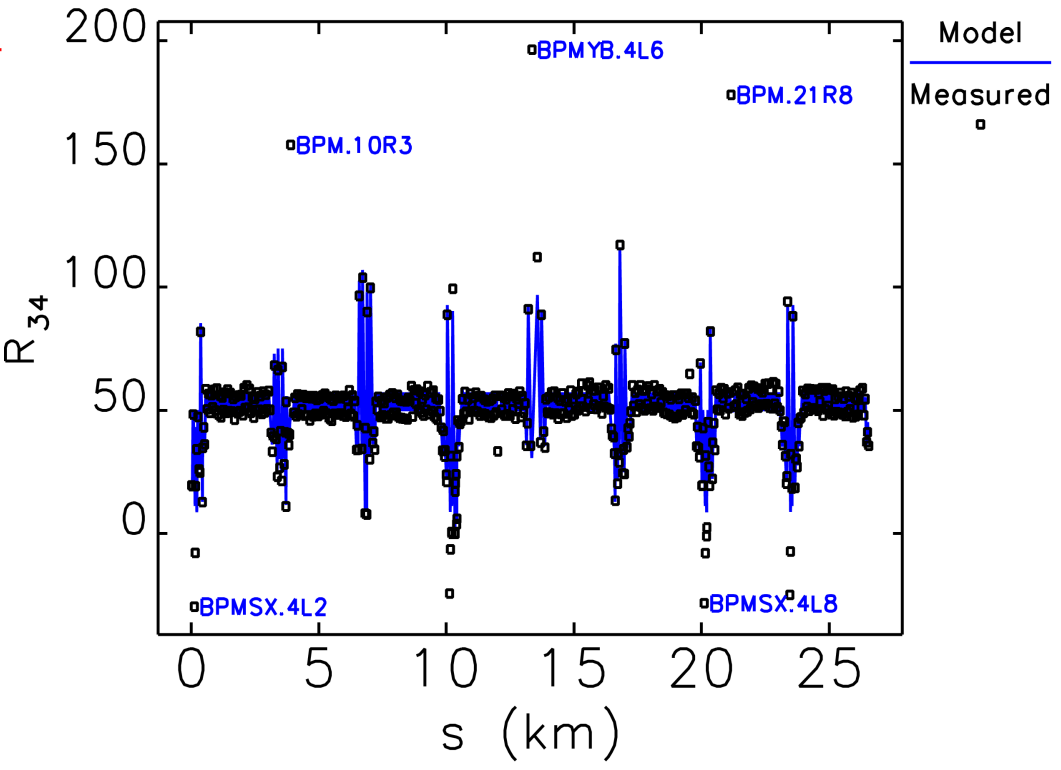





Model
Measured
β_x (m)
s (km)


Model
Measured
β_y (m)
s (km)


Model
Measured
BPMYB.4L6
BPM.31L6
BPMSA.4R6
BPM.21R8
BPMS.2R8
R_{12}
s (km)


Model
Measured
BPMYB.4L6
BPM.21R8
BPM.10R3
BPMSX.4L2
BPMSX.4L8
R_{34}
s (km)

Thank you for your attention!

In case you want to try the described techniques in your accelerator, I'll be glad to share my software or explain the details:
petrenko@ngs.ru