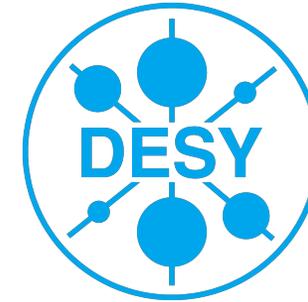


# OCELOT orbit correction and optimizer

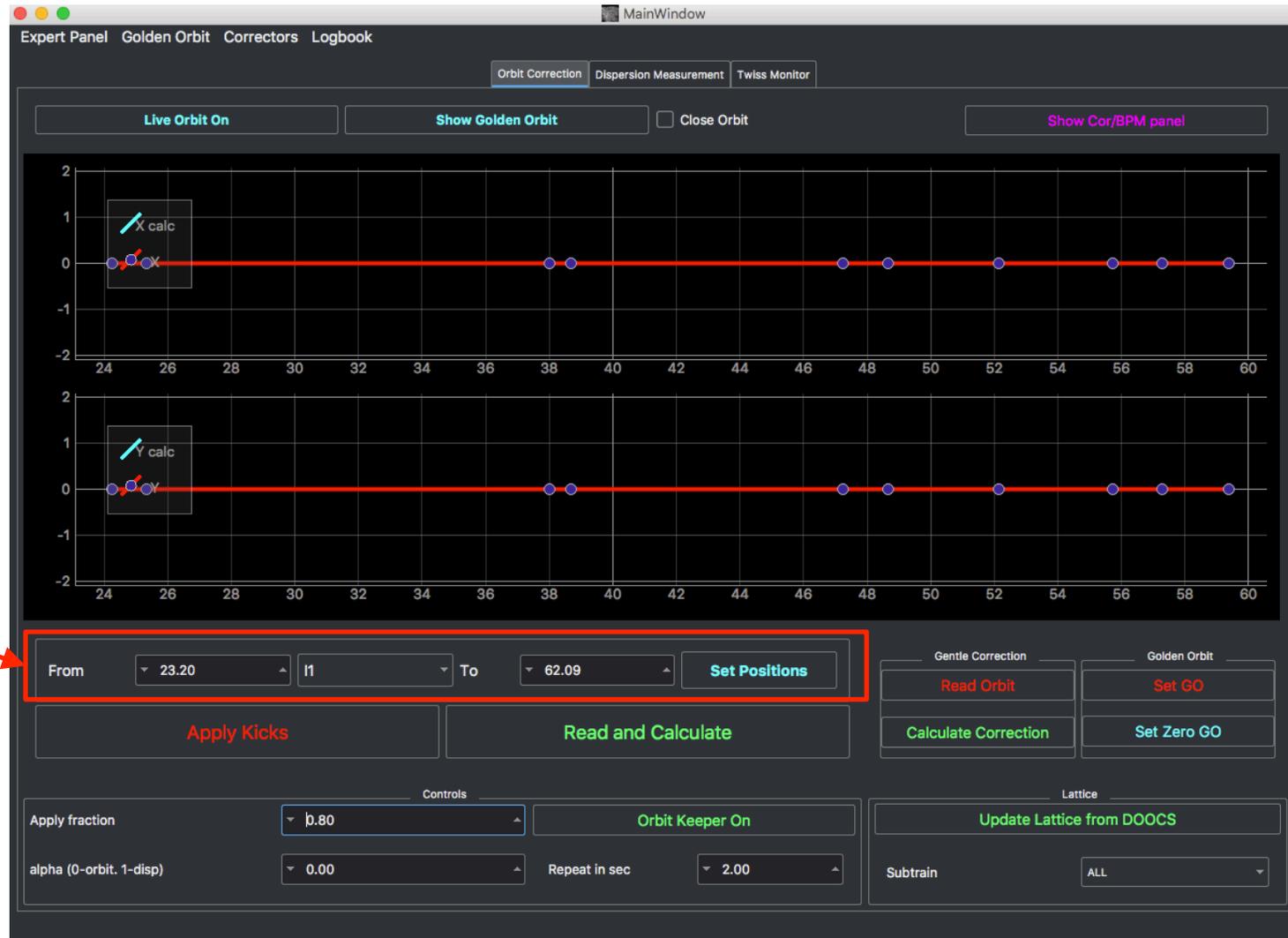


Sergey Tomin

# Outline

- OCELOT orbit correction tool
  - Orbit correction
    - ▶ Dispersion measurement
    - ▶ Twiss Monitor
    - ▶ Golden Orbit Adviser
  - Adaptive Feedback
  
- OCELOT Optimizer
  - Dispersion minimization
  - SASE optimization

# Orbit Correction Tool



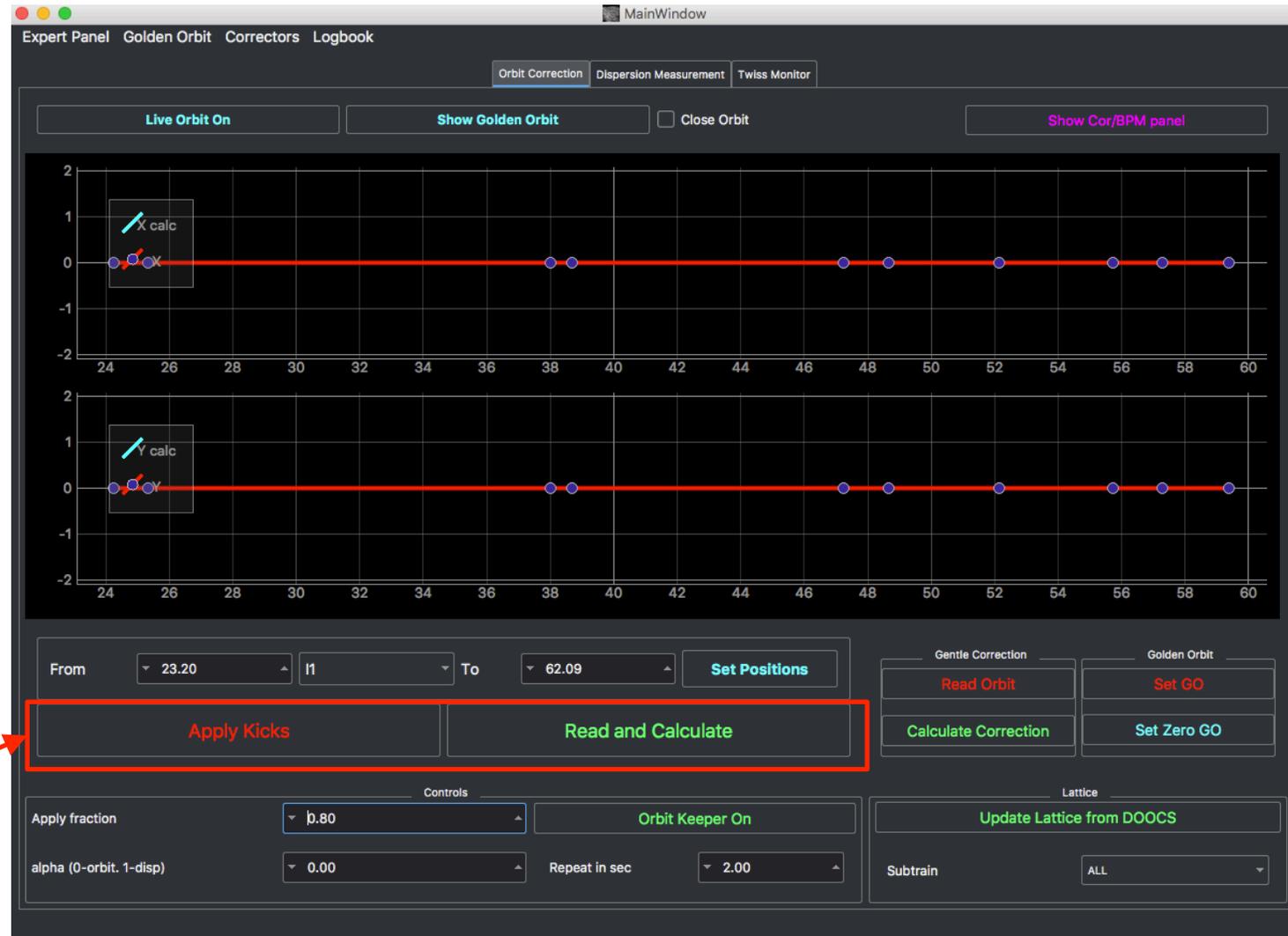
Choice of the accelerator section



# Orbit Correction Tool

Choice of the accelerator section

# Orbit Correction Tool



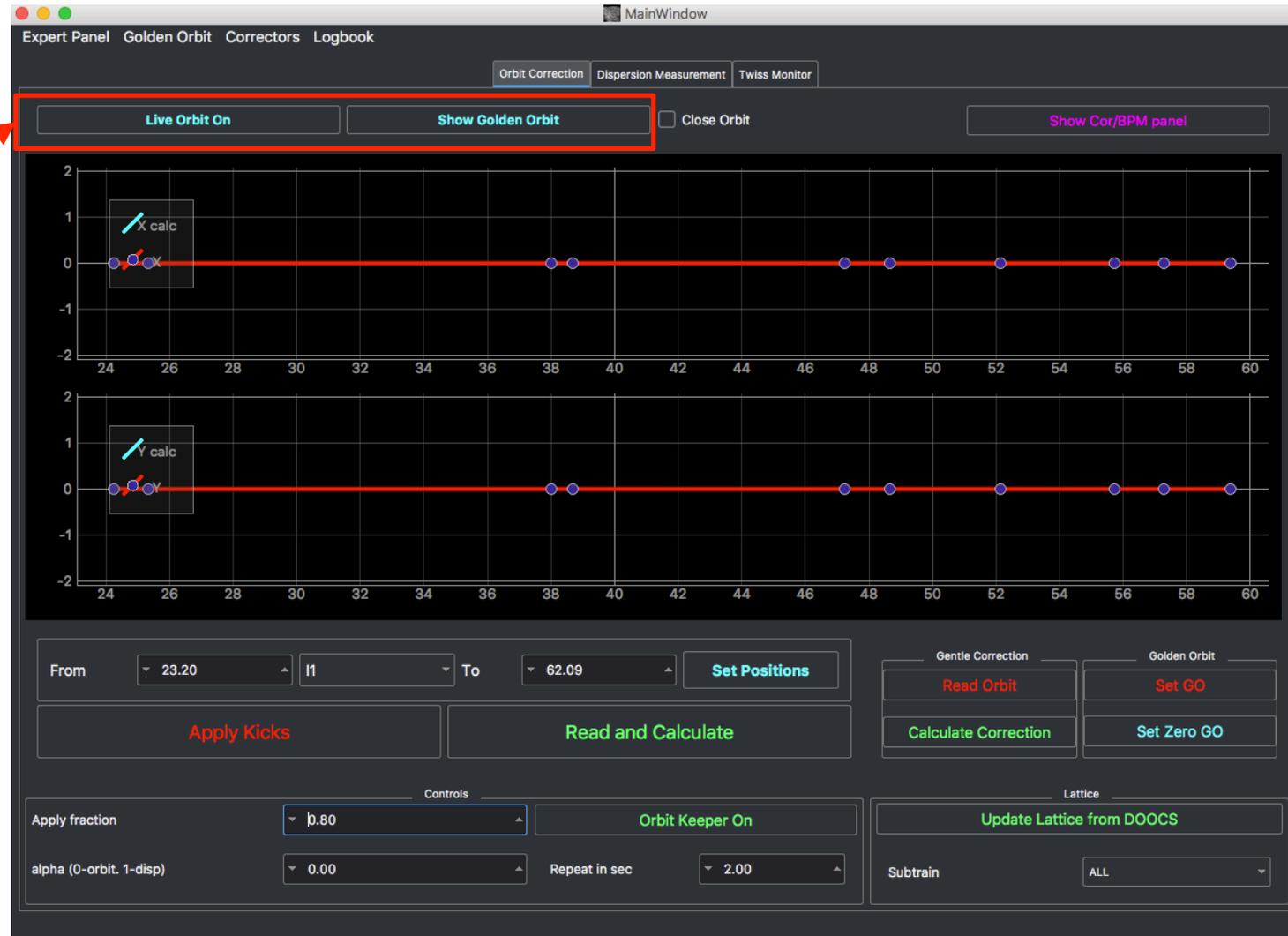
Normal operation (w/o switching the beam off):  
Read and calculate,  
Apply Kicks



# Orbit Correction Tool

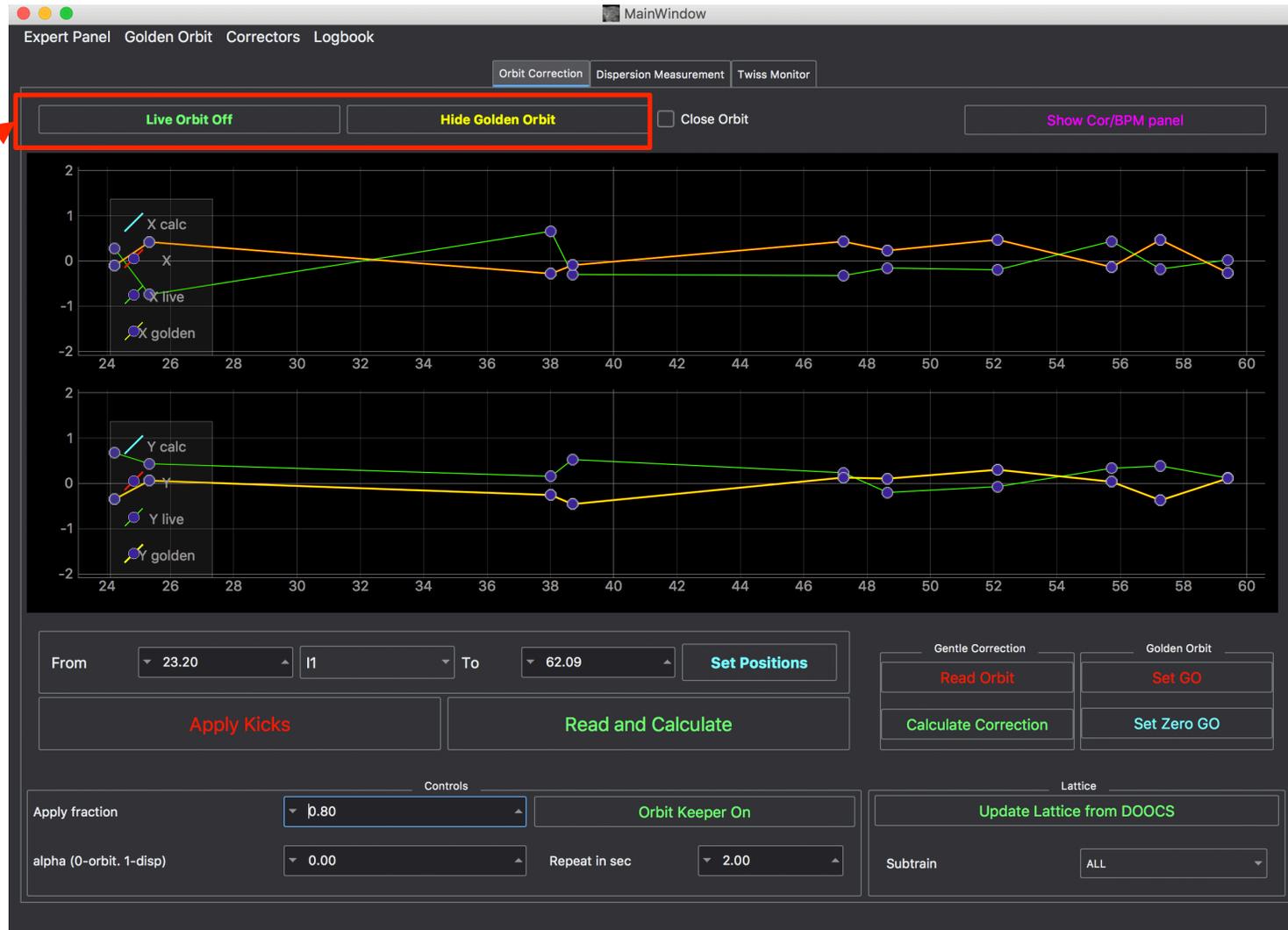
Switch on/off:

1. "Live orbit" – orbit wrt the golden orbit
2. „Show GO“ – show GO if one was store



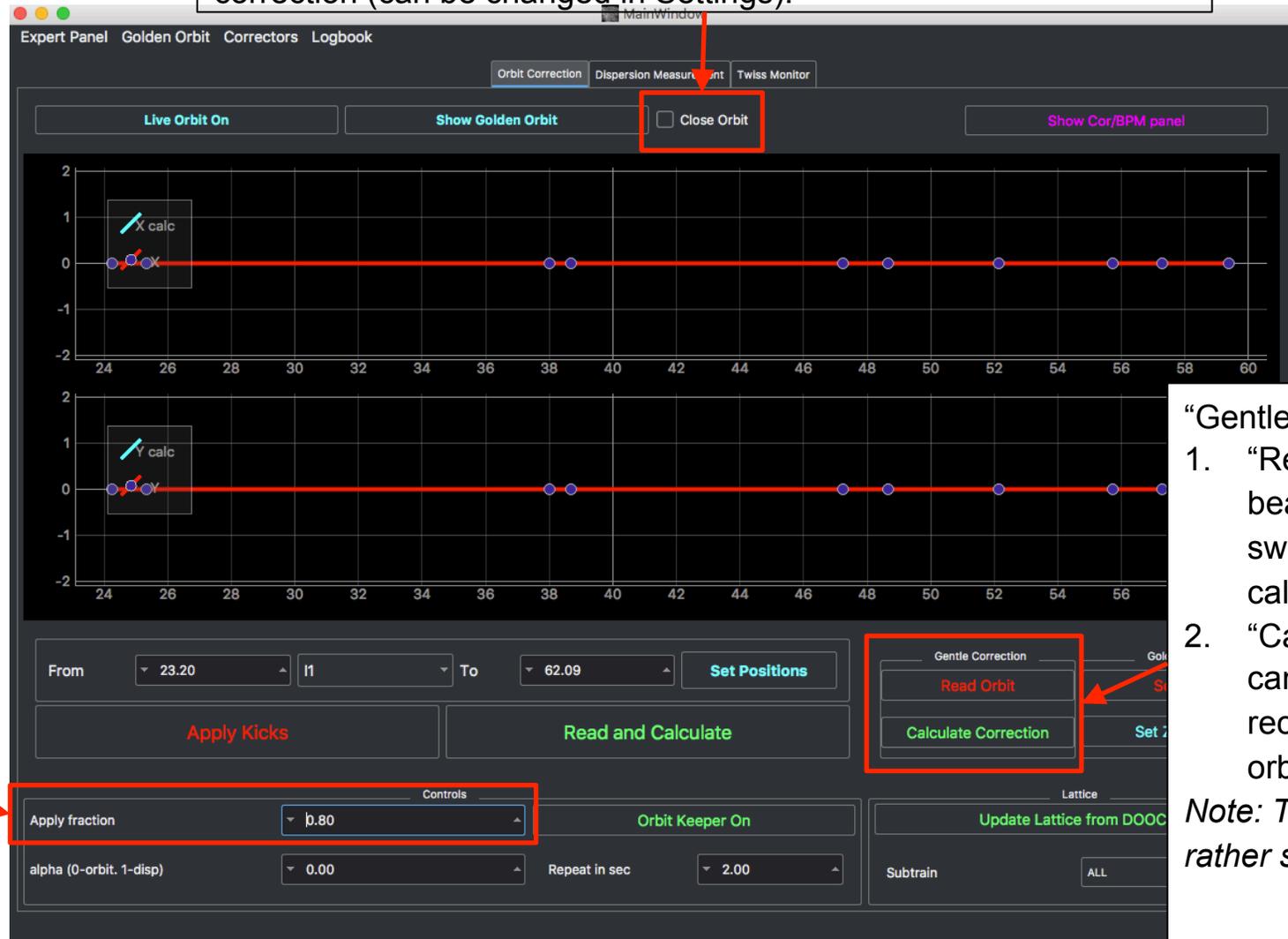
# Orbit Correction Tool

- Switch on/off:
1. "Live orbit" – orbit wrt the golden orbit
  2. „Show GO“ – show GO if one was store



# Orbit Correction Tool

Close Orbit – calculates the kicks in such a way to prevent distribute oscillation from correction to downstream sections. By default, only for 5 last BPMs takes into account to calculate closed correction (can be changed in Settings).



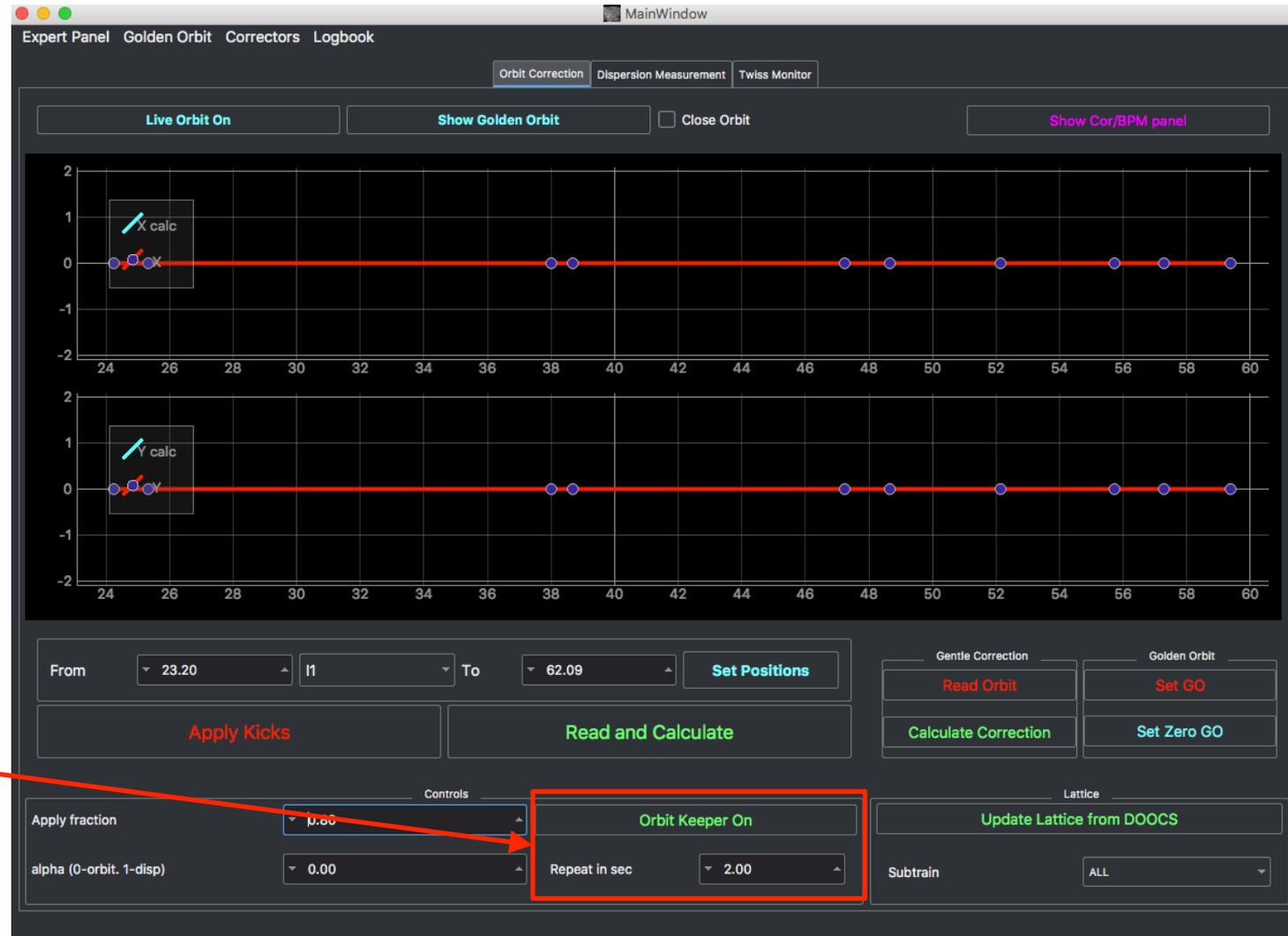
“Apply Fraction“: The fraction of the kicks to be applied – by default 0.8

“Gentle Correction“:

1. “Read Orbit“: switch beam on, read orbit, switch beam off, and calculate correction.
2. “Calculate Correction“ can be used to recalculate kicks w/o orbit reading

*Note: The first reading is rather slow.*

# Orbit Correction Tool



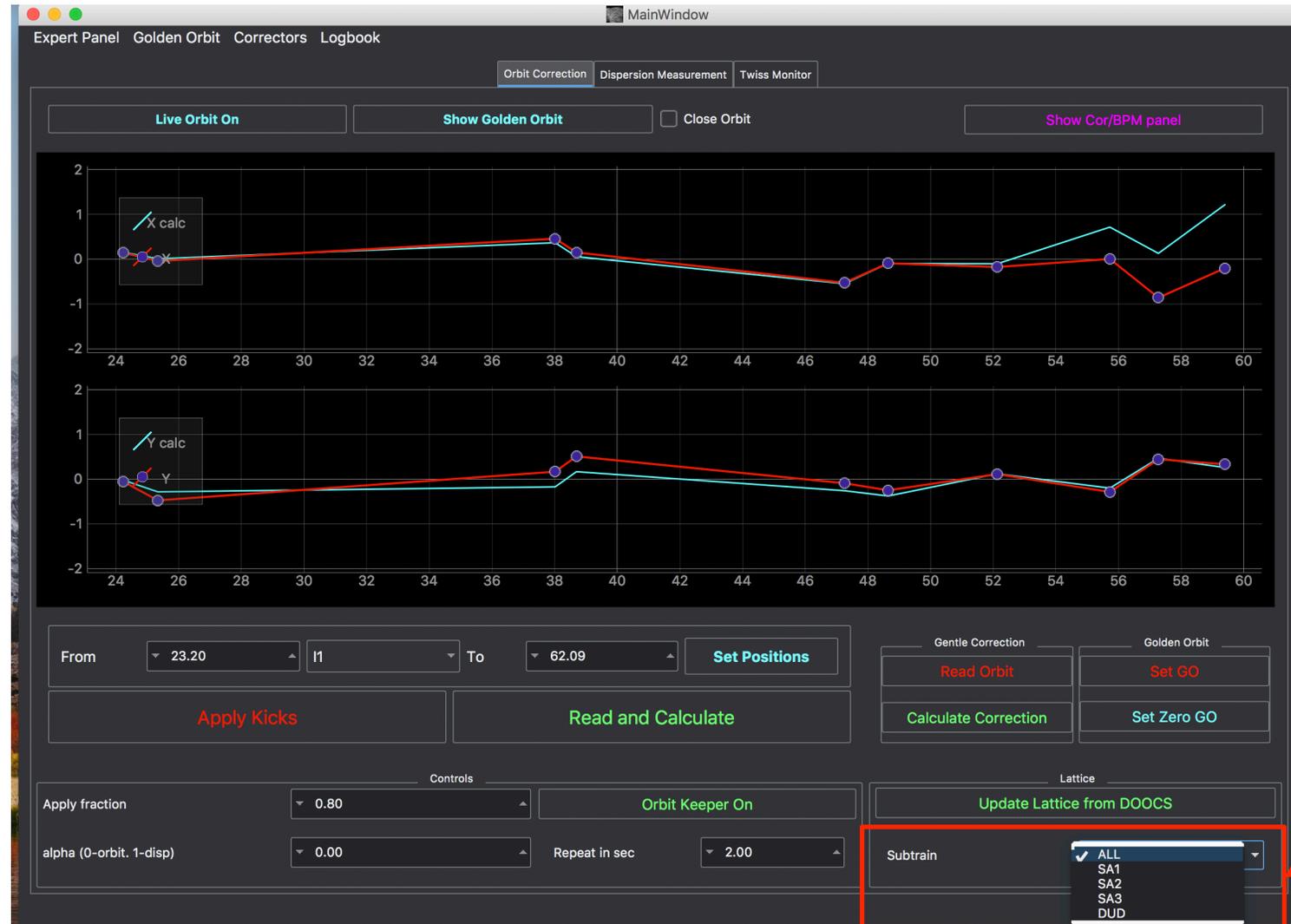
Sometimes you need to repeat correction for the same section many times. This option can save you from routine.

# Orbit Correction Tool

The screenshot displays the Orbit Correction Tool interface. At the top, there are tabs for 'Expert Panel', 'Golden Orbit', 'Correctors', and 'Logbook'. Below these are sub-tabs for 'Orbit Correction', 'Dispersion Measurement', and 'Twiss Monitor'. The main area features two graphs: the top one for 'X' and the bottom one for 'Y', both showing 'X calc' (red line) and 'X' (blue dots) data points. A dialog box titled 'Recalculate Orbit Response Matrix?' with a question mark icon and 'No'/'Yes' buttons is centered over the graphs. Below the graphs are control panels for 'From' (23.20) and 'To' (62.09) positions, 'Apply Kicks', 'Read and Calculate', 'Gentle Correction' (Read Orbit, Calculate Correction), and 'Golden Orbit' (Set Zero GO). A 'Lattice' section at the bottom right contains a button 'Update Lattice from DOOCS' which is highlighted with a red box. Other controls include 'Apply fraction' (0.80), 'Orbit Keeper On', 'alpha (0-orbit, 1-disp)' (0.00), 'Repeat in sec' (2.00), and a 'Subtrain' dropdown set to 'ALL'.

If you change the quad settings a lot or the energy profile in linacs without touching quads you might need to update the lattice and recalculate RM  
*Note: You also can see result of the lattice updating in „Twiss Monitor“ tab*

# Orbit Correction Tool



Subtrain choice



# Orbit Correction Tool

This option is to save correctors current kicks to file, which means you can restore kicks even you close the tool. For restoring press „Load“ and than „Apply Kicks“.

The screenshot shows the Orbit Correction Tool interface. A menu is open over the 'Correctors' tab, highlighting 'Save', 'Load', and 'Uncheck Red' options. The main window displays two plots for X and Y orbit positions, a table of corrector values, and various control buttons.

Corrector	Init. Val.	Cur. Val.	Active
1 CKX.23.11	-0.1889	-0.169	<input checked="" type="checkbox"/>
2 CKY.23.11	-0.2116	-0.134	<input checked="" type="checkbox"/>
3 CKX.24.11	-0.2519	-0.235	<input checked="" type="checkbox"/>
4 CKY.24.11	-0.2137	-0.151	<input checked="" type="checkbox"/>
5 CKX.25.11	-0.0032	-0.001	<input checked="" type="checkbox"/>
6 CKY.25.11	-0.4456	-0.440	<input checked="" type="checkbox"/>
7 CX.37.11	-0.3288	-0.326	<input checked="" type="checkbox"/>
8 CY.37.11	0.1707	0.1958	<input checked="" type="checkbox"/>
9 CX.39.11	0.4059	0.420	<input checked="" type="checkbox"/>
10 CY.39.11	0.2405	0.267	<input checked="" type="checkbox"/>

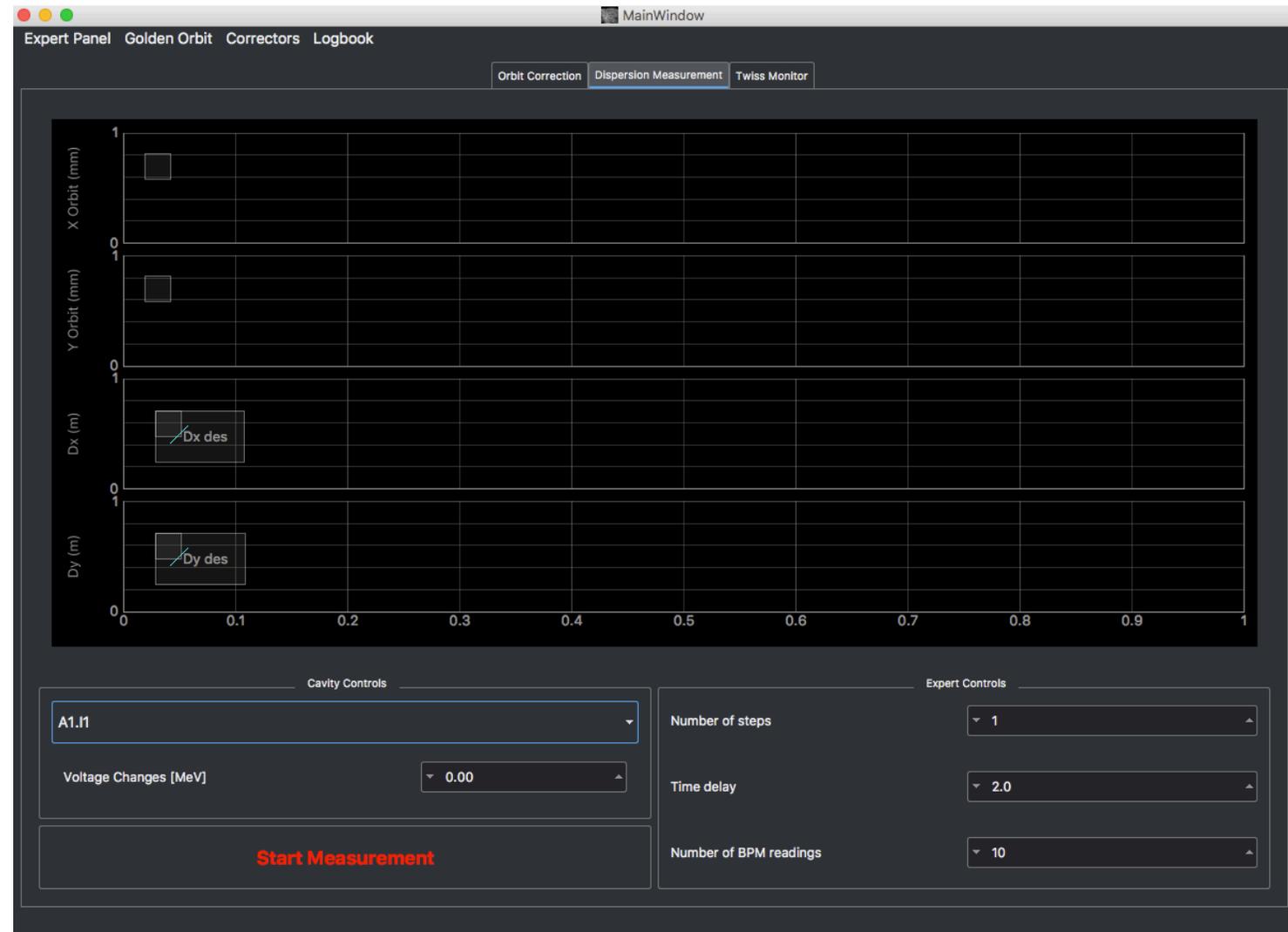
Every time, when you press „Apply Kicks“ button the kicks saved in a temporal variable (will be lost in case of the tool closing). To make undo -> press „Undo“ as many times as you need (it sends kicks to „Cur. Val“ column) and then you have to press „Apply Kicks“.

## Orbit Correction Tool. Dispersion measurement

### How it works

- Choose RF station
- Set up Voltage changes:  
e.g. - 2MV
- Press “Start Measurement”

The Longitudinal FB should be switched off



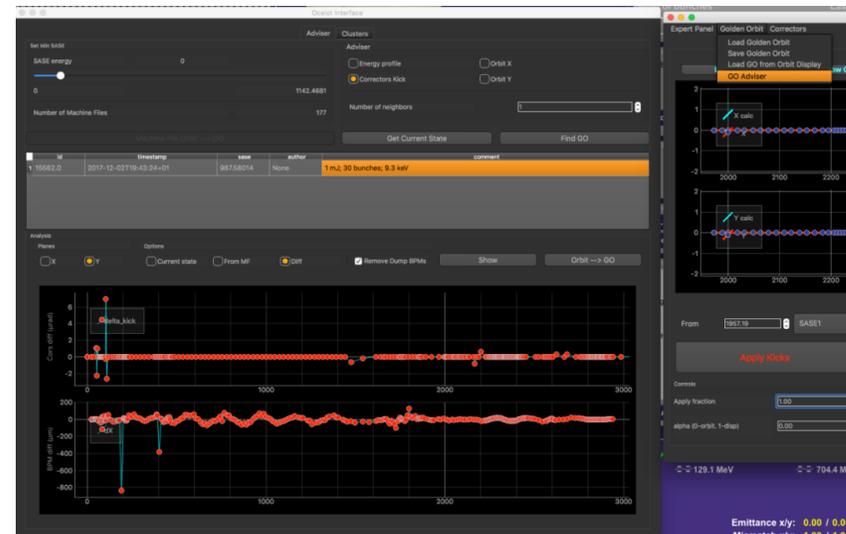
# Orbit Correction Tool. Twiss Monitor

■ To check design settings with current setup.



## Golden Orbit Adviser

- Recently we introduced to the Ocelot orbit correction tool a "Golden orbit adviser" (in test mode).
- The idea is to find the machine file in the database that is as close as possible to the current machine setup.
- For instance, you can select as a reference vector the corrector kicks (or beam orbit in X/Y plane) and ML method (Nearest Neighbors) will find the machine file with the corrector kicks (or orbit) closest to the current conditions.



# Adaptive Feedback

The screenshot displays the OCELOT software interface with the following components:

- Expert Panel:** A dropdown menu with options: Settings, Calculate ORM, Calculate ORM and DRM, Read BPMs and Corrs, and Adaptive Feedback (highlighted).
- MainWindow:** Contains tabs for Orbit Correction, Dispersion Measurement, and Twiss Monitor.
- Graphs:** Two plots showing X and Y coordinates over time. The top plot is labeled 'X calc' and the bottom plot is labeled 'Y calc'. Both plots show a red line for 'X' and a cyan line for 'Y', with data points connected by lines.
- Correctors Table:** A table listing 10 correctors with their initial and current values and active status.
 

Corrector	Init. Val.	Cur. Val.	Active
1 CKX.23.I1	-0.1889	-0.169	<input checked="" type="checkbox"/>
2 CKY.23.I1	-0.2116	-0.134	<input checked="" type="checkbox"/>
3 CKX.24.I1	-0.2519	-0.235	<input checked="" type="checkbox"/>
4 CKY.24.I1	-0.2137	-0.151	<input checked="" type="checkbox"/>
5 CKX.25.I1	-0.0032	-0.001	<input checked="" type="checkbox"/>
6 CKY.25.I1	-0.4456	-0.440	<input checked="" type="checkbox"/>
7 CX.37.I1	-0.3288	-0.326	<input checked="" type="checkbox"/>
8 CY.37.I1	0.1707	0.1958	<input checked="" type="checkbox"/>
9 CX.39.I1	0.4059	0.4205	<input checked="" type="checkbox"/>
10 CY.39.I1	0.2405	0.2675	<input checked="" type="checkbox"/>
- Buttons:** 'Undo (3)', 'Check', and 'Uncheck' buttons are located below the correctors table.
- Positioning:** 'From' (23.20), 'To' (62.09), and 'Set Positions' button.
- Actions:** 'Apply Kicks' and 'Read and Calculate' buttons.
- Controls:** 'Apply fraction' (0.80), 'alpha (0-orbit. 1-disp)' (0.00), 'Repeat in sec' (2.00), and 'Orbit Keeper On' button.
- Lattice:** 'Update Lattice from DOOS' button and 'Subtrain' dropdown (set to ALL).
- Correction Modes:** 'Gentle Correction' (Read Orbit, Calculate Correction) and 'Golden Orbit' (Set GO, Set Zero GO) buttons.

# Adaptive Feedback

The screenshot displays the Ocelot Interface software. On the left, a vertical 'Expert Panel' is visible with a menu containing 'Settings', 'Calculate ORM', 'Calculate ORM and DRM', 'Read BPMs and Corrs', and 'Adaptive Feedback'. The main interface features several plots: two plots on the left showing 'X calc' and 'Y calc' with data points and trend lines; a top-left plot showing 'X' and 'Y' with 'X calc' and 'Y calc' lines; and a top-right plot showing a single data point. Below the plots are control panels: 'Objective Function' with input fields for A, B, C, and the function name; 'Statistics Data Control' with dropdowns for Array Length (100), Reading Delay (0.10), Averaging Over (10.00), and Recalculate GO (1.00); 'Correction control' with dropdowns for Ref Orbit averaging over last (readings) (1) and Apply Fraction (0.70); 'Indication' with a checked 'Update Main Display' checkbox and a red arrow pointing to the 'Load Settings' panel; and 'Load Settings' with a dropdown for 'SASE1 launch' and 'Load'/'Save' buttons. At the bottom, there are buttons for 'Apply Feedback Every s' (3.00), 'Start Feedback', and 'Statistics Accum On'. A bottom panel includes 'Apply fraction' (alpha (0-orbit, 1-disp) 0.00), 'Repeat in sec' (2.00), and 'Subtrain' (ALL).

# Adaptive Feedback

The screenshot displays the Ocelot Interface, a software tool for orbit correction and optimization. The interface is divided into several sections:

- Expert Panel (Golden Orbit C):** Contains a menu with options: Settings, Calculate ORM, Calculate ORM and DRM, Read BPMs and Corrs, and Adaptive Feedback (highlighted). Below the menu are three small plots showing X and Y coordinates over time, with 'X calc' and 'Y calc' lines and data points.
- Main Display:** Features two larger plots at the top. The left plot shows X and Y coordinates with 'X calc' and 'Y calc' lines. The right plot shows a single data point at approximately (0.1, 0.8).
- Objective Function:** A section with input fields for A, B, and C, and a text area for the Objective Function.
  - A: `'FEL..FEL/XGM.PREPROCESSING/XGM.2643.T9.CH0/RESULT.TD`
  - B: `XFEL.FEL/XGM/XGM.2643.T9/INTENSITY.TD`
  - C: (empty)
  - Objective Function: `np.mean(np.array(A)[:1])`
- Statistics Data Control:** A section with dropdown menus for:
  - Array Length: 300
  - Reading Delay (s): 0.10
  - Averaging Over (%): 10.00
  - Recalculate GO (s): 2.00
- Correction control:** A section with dropdown menus for:
  - Ref Orbit averaging over last (readings): 5
  - Apply Fraction: 0.60
- Indication:** A section with a checkbox for 'Update Main Display' (checked).
- Load Settings:** A section with a dropdown for 'SASE1 launch' and 'Load' and 'Save' buttons.
- Buttons and Controls:**
  - 'Apply' button (red text)
  - 'Apply Feedback Every s' dropdown: 2.00
  - 'Start Feedback' button (green text)
  - 'Statistics Accum On' button (green text)
  - 'Apply fraction' section with 'alpha (0-orbit, 1-disp)' dropdown: 0.00 and 'Repeat in sec' dropdown: 2.00
  - 'Subtrain' dropdown: ALL

# Adaptive Feedback

The screenshot displays the Ocelot Interface software. On the left, an 'Expert Panel' is visible with a menu containing 'Settings', 'Calculate ORM', 'Calculate ORM and DRM', 'Read BPMs and Corrs', and 'Adaptive Feedback'. The main interface features several plots: two for 'X calc' and 'Y calc' showing calculated orbits and current positions, and a 'Statistics Data Control' plot. Below the plots are control panels for 'Objective Function', 'Statistics Data Control', 'Correction control', 'Indication', and 'Load Settings'. The 'Objective Function' section includes fields for A, B, and C, and a function definition: `np.mean(np.array(A)[:1])`. The 'Statistics Data Control' section has dropdowns for Array Length (300), Reading Delay (0.10), Averaging Over (10.00), and Recalculate GO (2.00). The 'Correction control' section has dropdowns for Ref Orbit averaging over last (readings) (5) and Apply Fraction (0.60). The 'Indication' section has a checkbox for 'Update Main Display'. The 'Load Settings' section has a dropdown for 'SASE1 launch' and 'Load' and 'Save' buttons. At the bottom, there are buttons for 'Start Feedback' and 'Statistics Accum On', with red arrows pointing to them from the 'Apply Fraction' and 'Update Main Display' fields respectively. Other controls include 'Apply Feedback Every s' (2.00), 'Apply fraction' (0.00), 'Repeat in sec' (2.00), and 'Subtrain' (ALL).

# Adaptive Feedback

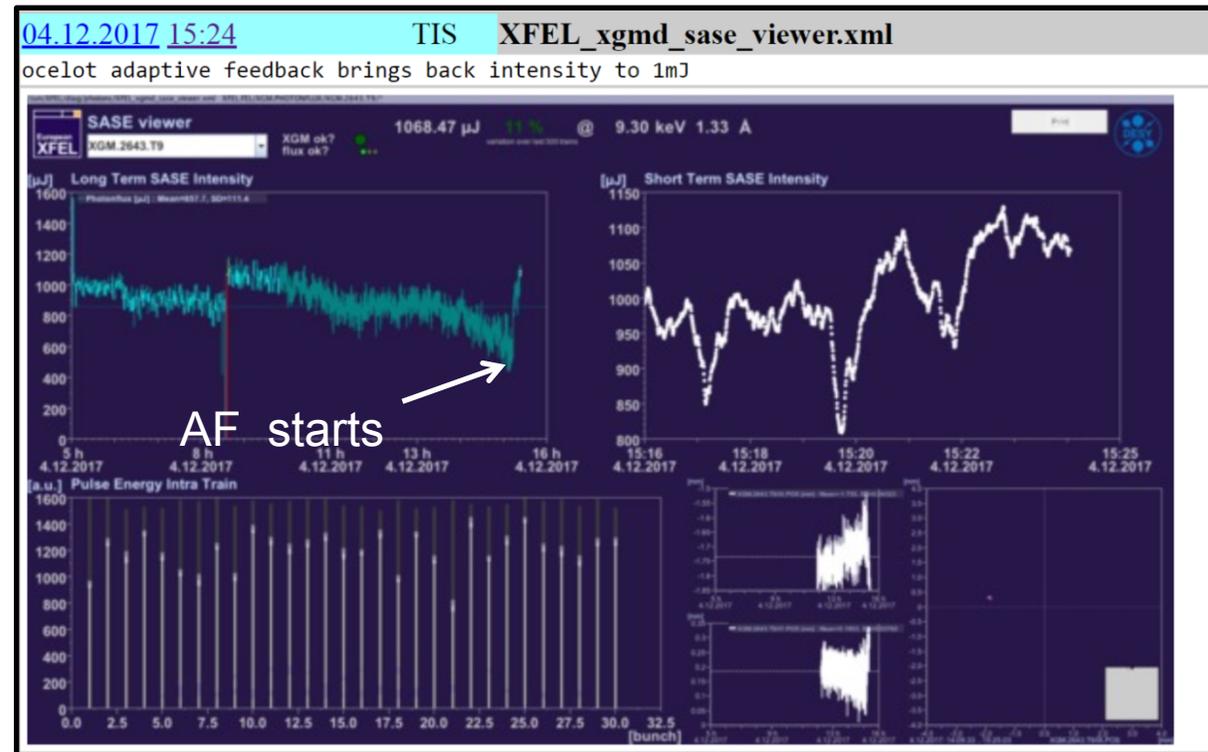
Adaptive FB also checks if the standard FB is running. And if you switch the standard FB on the Adaptive FB will be stopped

The screenshot displays the Ocelot Interface with several key components:

- Graphs:** Three plots showing orbit parameters. The top-left plot shows 'X calc' with a blue dot and a red line. The bottom-left plot shows 'Y calc' with a blue dot and a red line. The right plot shows a single data point at approximately (0.1, 0.8).
- Objective Function Panel:**
  - A: `'FEL..FEL/XGM.PREPROCESSING/XGM.2643.T9.CH0/RESULT.TD'`
  - B: `XFEL.FEL/XGM/XGM.2643.T9/INTENSITY.TD`
  - C: (empty)
  - Objective Function: `np.mean(np.array(A)[:1])`
- Statistics Data Control Panel:**
  - Array Length: 300
  - Reading Delay (s): 0.10
  - Averaging Over (%): 10.00
  - Recalculate GO (s): 2.00
- Correction control Panel:**
  - Ref Orbit averaging over last (readings): 5
  - Apply Fraction: 0.60
  - Apply Feedback Every s: 2.00
- Indication Panel:**
  - Update Main Display
  - Start Feedback** (button)
  - Statistics Accum On** (button)
- Load Settings Panel:**
  - SASE1 launch (dropdown)
  - Load (button)
  - Save (button)
- Bottom Panel:**
  - alpha (0-orbit, 1-disp): 0.00
  - Repeat in sec: 2.00
  - Subtrain: ALL

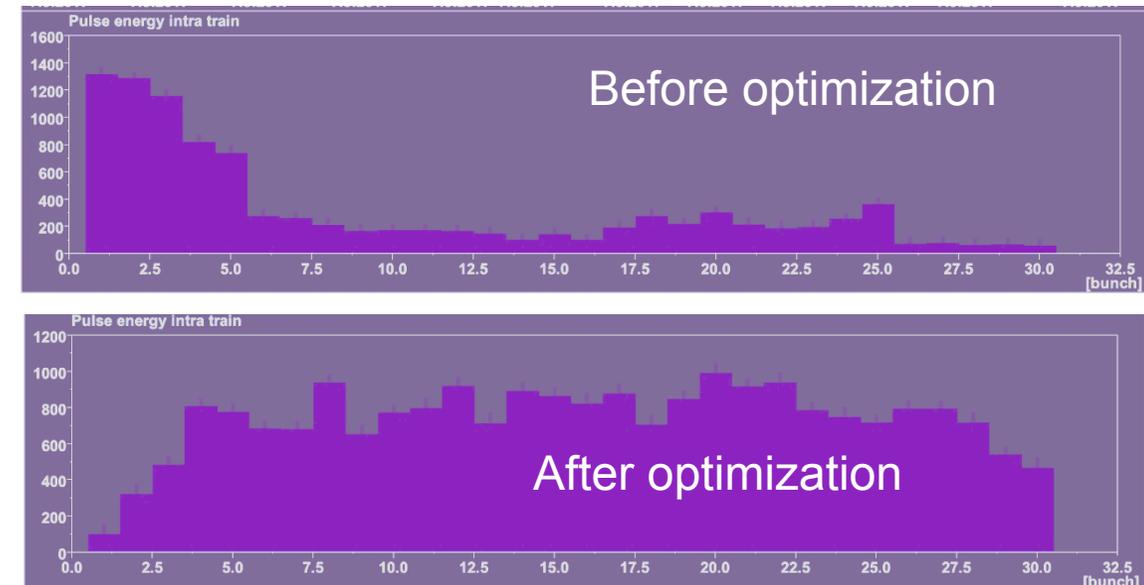
## Adaptive feedback (SASE1)

- Algorithm of Adaptive Feedback\*
  - Shot-to-shot collection of orbits (~ 300 - 700) and the corresponding SASE pulse energy.
  - Sorting orbits according to SASE energy.
  - Taking 10-20% of the orbit with highest SASE and calculating new golden orbit for the feedback.



## Adaptive feedback (SASE1)

- Optimization of the orbit upstream the undulator. Only first three bunches were lasing before optimization. The IBFB was not commissioned at that time. Thus not all bunches were on the same orbit.
- The adaptive feedback optimizes by default the averaged SASE signal over all bunches in one bunch train. However, it is also possible to optimize for dedicated bunches if required.
- The lasing of the first bunches was suppressed but all following bunches contributed to the SASE level after the optimization with the adaptive feedback.



# OCELOT Optimizer

# OCELOT Optimizer

The screenshot shows the OCELOT interface with three main components highlighted:

- Fields for device limits:** A table with columns for PVs, Setpoint, Current, Min, and Max. A yellow box highlights the Min and Max columns.
- Objective Function monitor:** A line graph showing the value of the objective function over time (seconds). A red box highlights the graph area.
- Device Monitor:** A line graph showing the status of various devices over time (seconds). A green box highlights the graph area.

The screenshot shows the 'Objective and Alarm Function Setup' panel with several sections:

- Objective Function def.:** A section for defining the objective function, including fields for PV: A, B, C, D, E, and the Objective Function definition: `np.mean(np.array(A)[:,-1])`. A red box highlights this section.
- Machine Status:** A section for setting up alarms, including Alarm 1, Limits (Min, Max), and Wait time. A green box highlights this section.
- Scanner Parameters:** A section for selecting the optimization algorithm (Simplex Norm), number of iterations (50), and relative step in % (5.00). A blue box highlights this section.

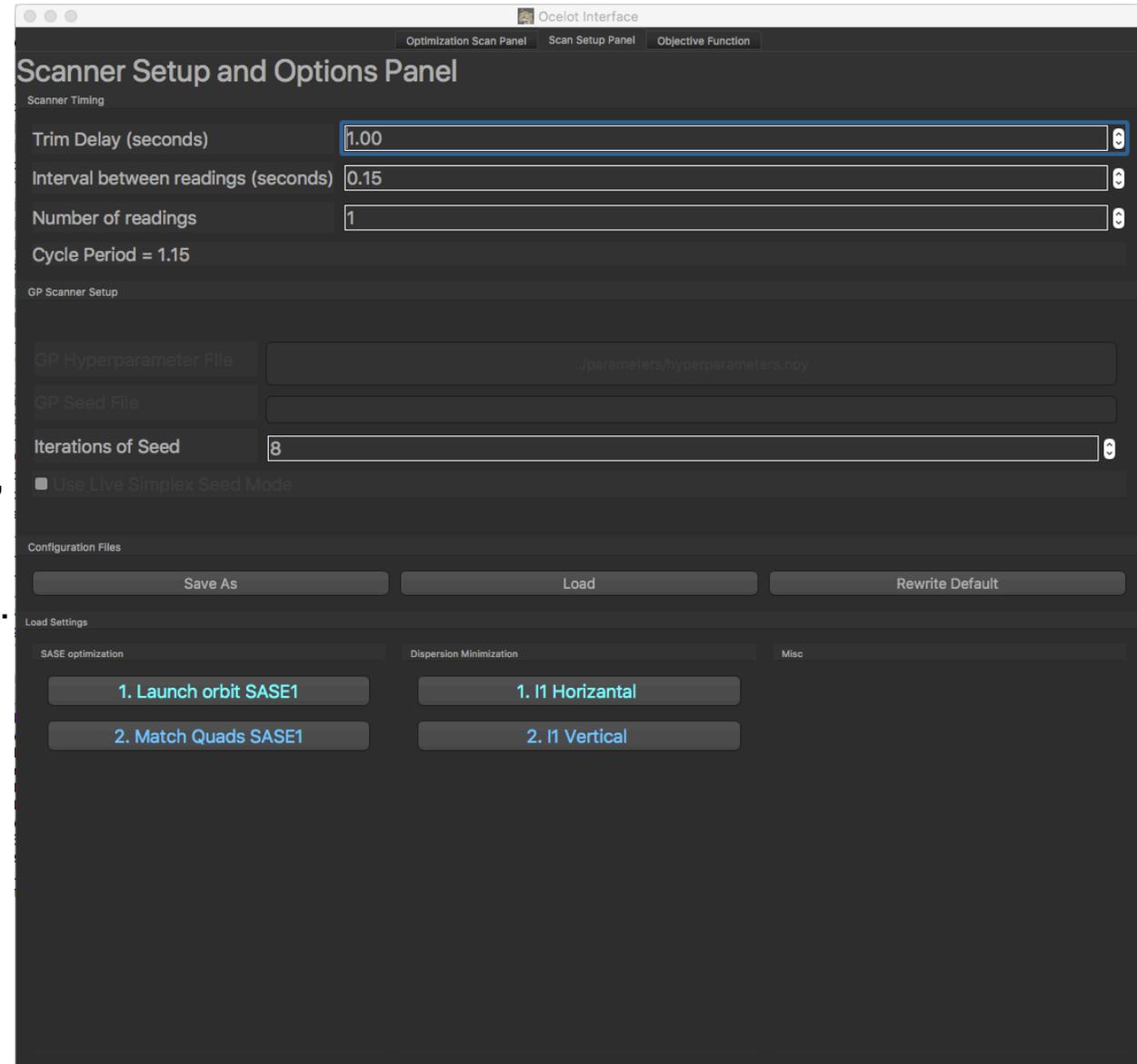
# OCELOT Optimizer

- Several different customized variants of the optimizer were used only a few times for different tasks.
- Examples for earlier customized setups:
  - Minimization of beam losses while keeping a reasonable orbit in the main dump beamline.
  - Orbit distortion compensation with air coils in an undulator section.
  - Minimization of HOM (higher order mode) signal in an accelerator module (FLASH).
  - SASE maximization (FLASH).
  - Dispersion correction (FLASH)



# OCELOT Optimizer

- Trim delay: delay between setting new values to the devices and start reading the Target function.
- Some noisy signals like SASE might need averaging. For that, you can use “Number of readings” and Interval between readings”
- Any configuration can be saved and loaded.
- There are 4 standard configs: 2 for SASE1 optimization and 2 for dispersion minimization
- During dispersion minimization the Longitudinal FB should be switched off



# Objective Function

**Objective and Alarm Function Setup**

Objective Function

PV: A: XFEL.DIAG/ORBIT/BPMC.38I.I1/X.SA1

PV: B: XFEL.DIAG/ORBIT/BPMR.38I.I1/X.SA1

PV: C:

PV: D:

PV: E:

Objective Function: -A

Max Penalty: 100

Use Predefined Objective Function  Maximize  Minimize

Edit Objective Function

Machine Status

Alarm 1: Value: -0.29

Limits: Min: -1.70 Max: 100.00

Wait: 3.00 sec after recovering

Scanner Parameters

Select Optimiser Algorithm: Gaussian Process sklearn

Number Iterations: 50

Set Best Solution After Optimization

Simplex With Normalization

Relative Step in %: 5.00

Use Initial Simplex/Step [step = (Max - Min) \* RelStep[%]]

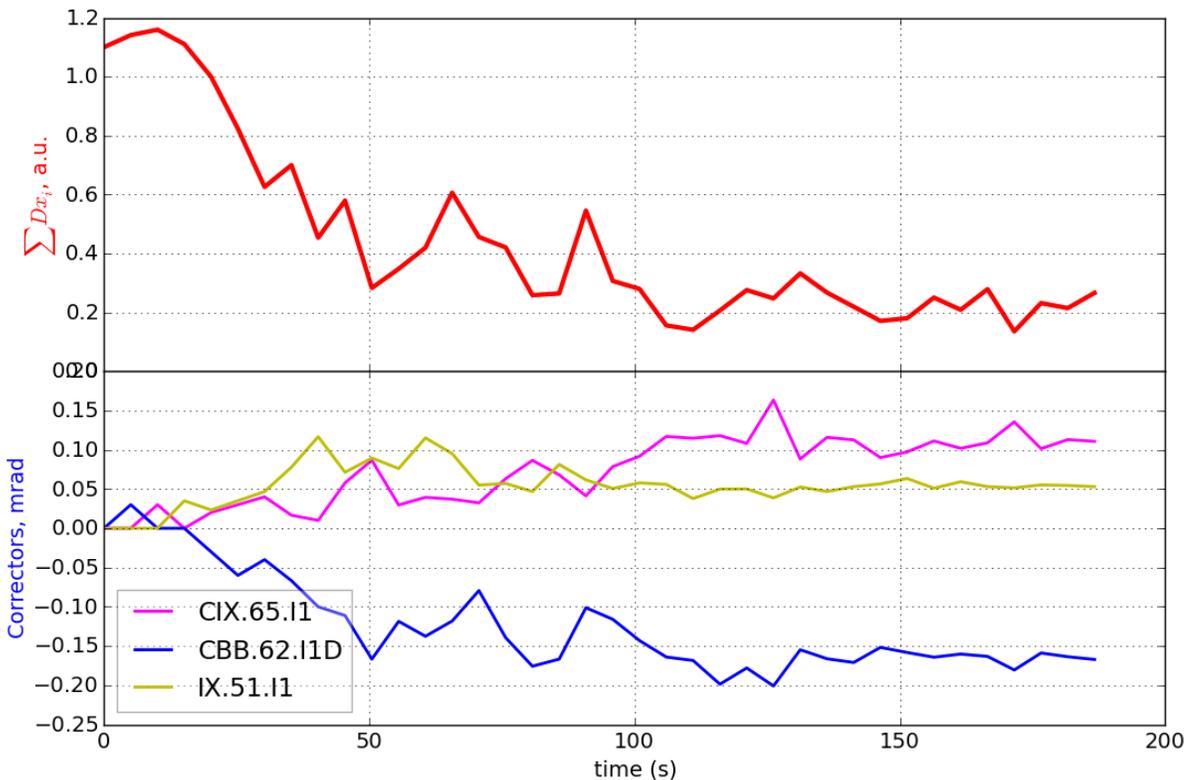
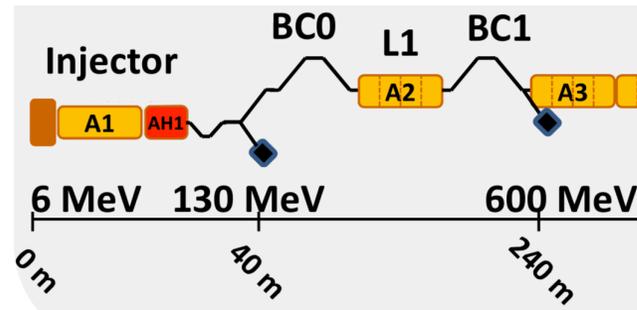
```

5 """
6 from __future__ import absolute_import, print_function
7
8 from mint.opt_objects import Target
9 import numpy as np
10 import time
11
12
13 class XFELTarget(Target):
14 """
15 Objective function
16
17 :param mi: Machine interface
18 :param pen_max: 100, maximum penalty
19 :param niter: 0, calls number get_penalty()
20 :param penalties: [], appending penalty
21 :param times: [], appending the time evolution of get_penalty()
22 :param nreadings: 1, number of objective function readings
23 :param interval: 0 (seconds), interval between readings
24 """
25 def __init__(self, mi=None, eid="x57**2 + y57**2 + x59**2 + y59"):
26     super(XFELTarget, self).__init__(eid=eid)
27
28     self.mi = mi
29     self.debug = False
30     self.kill = False
31     self.pen_max = 100
32     self.clean()
33     self.nreadings = 1
34     self.interval = 0.0
35
36 def get_alarm(self):
37 """
38 Method to get alarm level (e.g. BLM value).
39
40 alarm level must be normalized: 0 is min, 1 is max
41
42 :return: alarm level
43 """
44 return 0
45
46 def get_value(self):
47 """
48 Method to get signal of target function (e.g. SASE signal).
49
50 :return: value
51 """
52 x57 = self.mi.get_value("XFEL.DIAG/ORBIT/BPMA.57.I1/X.SA1")
53 y57 = self.mi.get_value("XFEL.DIAG/ORBIT/BPMA.57.I1/Y.SA1")
54 x59 = self.mi.get_value("XFEL.DIAG/ORBIT/BPMA.59.I1/X.SA1")
55 y59 = self.mi.get_value("XFEL.DIAG/ORBIT/BPMA.59.I1/Y.SA1")
56 return -np.sqrt(x57 ** 2 + y57 ** 2 + x59 ** 2 + y59 ** 2)
57
58 # values = np.array([dev.get_value() for dev in self.devices])
59 # return 2*np.sum(np.exp(-np.power((values - np.ones_like(values)), 2) / 5.))
60 # value = self.mi.get_value(self.eid)
61
62
63 def get_penalty(self):

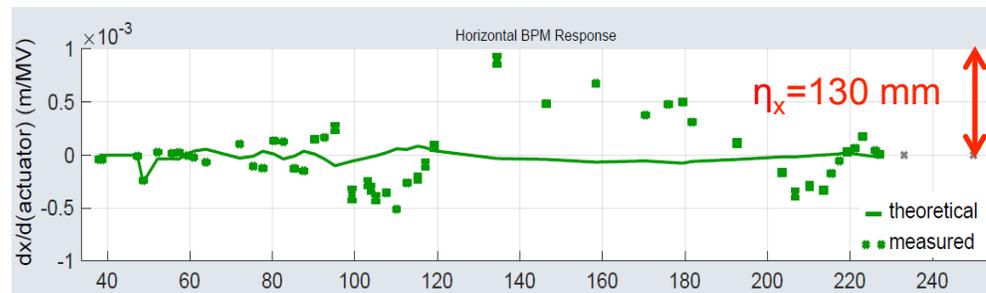
```

# OCELOT Optimizer: local dispersion correction

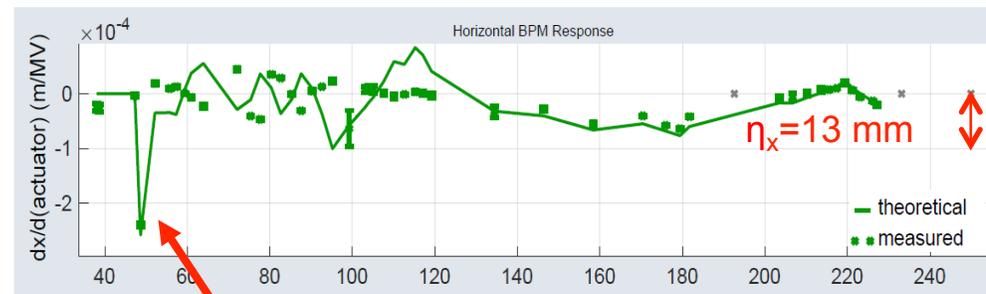
Horizontal spurious dispersion correction with 3 corrector magnets.



Before correction



After correction



Laser Heater chicane

## OCELOT Optimizer: SASE optimization

- Air coils between the undulator cells were used to optimize the SASE signal
- Up to 6 air coils are typically used at the same time.

