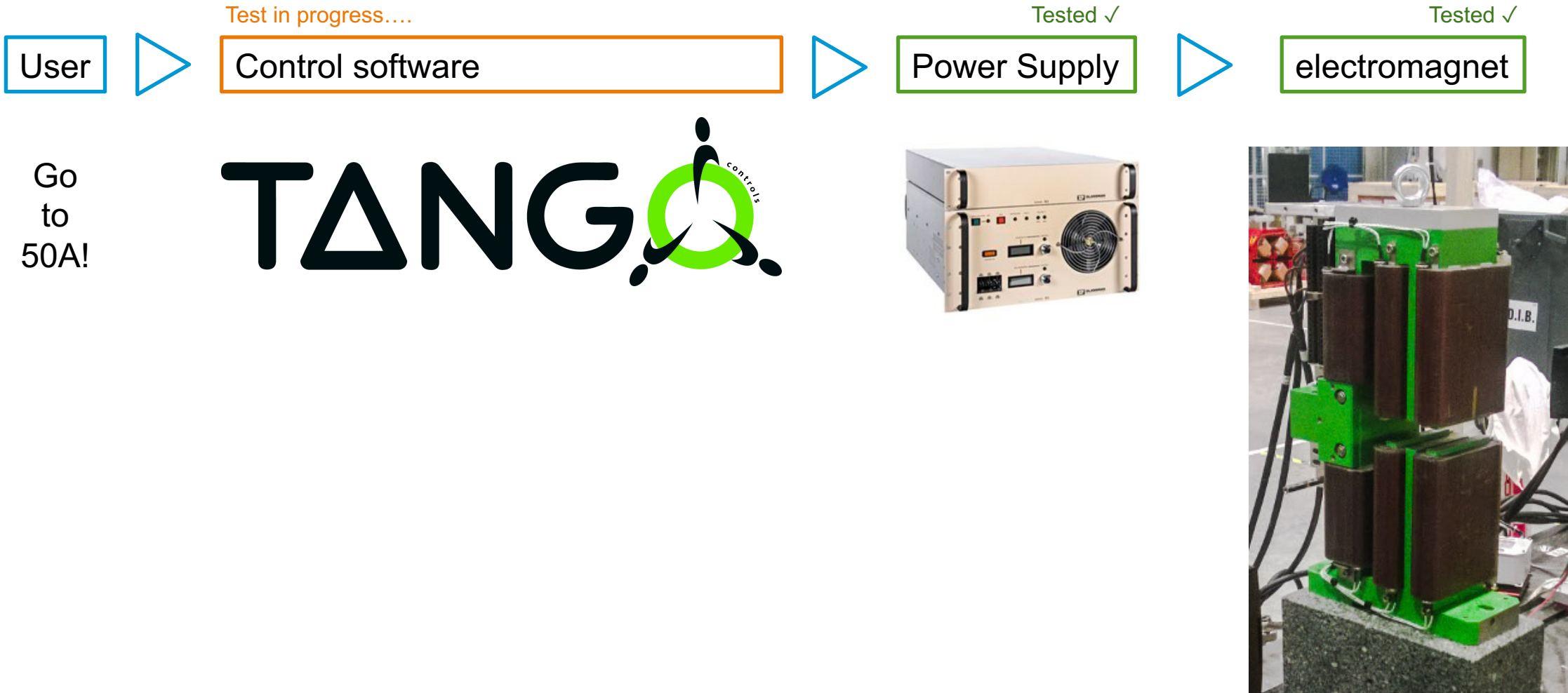




The ESRF-EBS Simulator: a Commissioning Booster

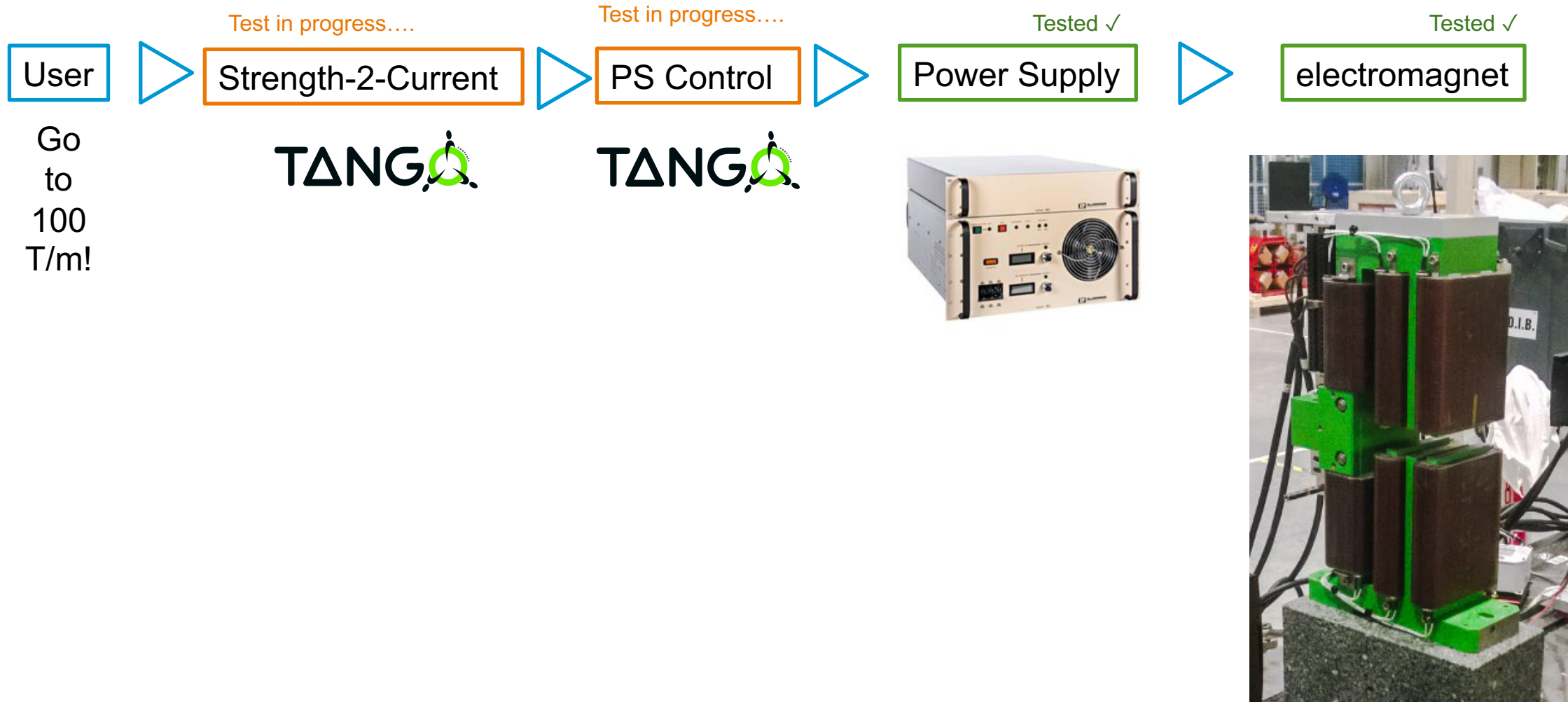
Simone Liuzzo, L.Carver, J.M.Chaize, L.Farvacque, A.Gotz, D.Lacoste, N.Leclercq, F.Poncet, E.Taurel, S.White

HOW TO TEST CONTROL SOFTWARE?



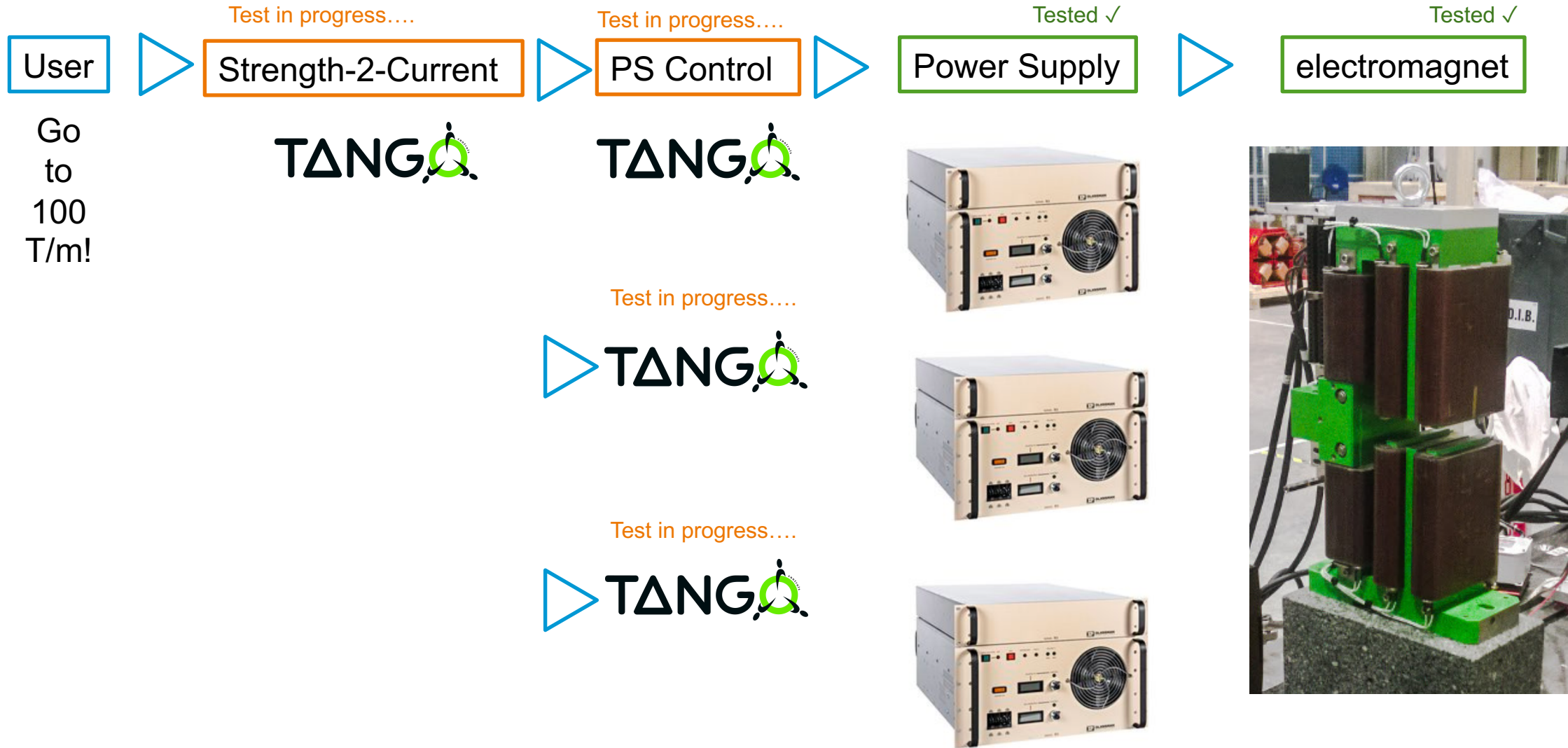
If the equipment we want to test can be **separated** from the rest it may be close to trivial.

THERE MAY BE MORE LAYERS OF SOFTWARE



There may be several layers of software

THERE MAY BE MORE LAYERS OF HARDWARE AND SOFTWARE



There may be several layers of hardware and software

THERE MAY BE MORE LAYERS OF LAYERS OF HARDWARE AND SOFTWARE

User 

Go to :

100T/m

30T/m

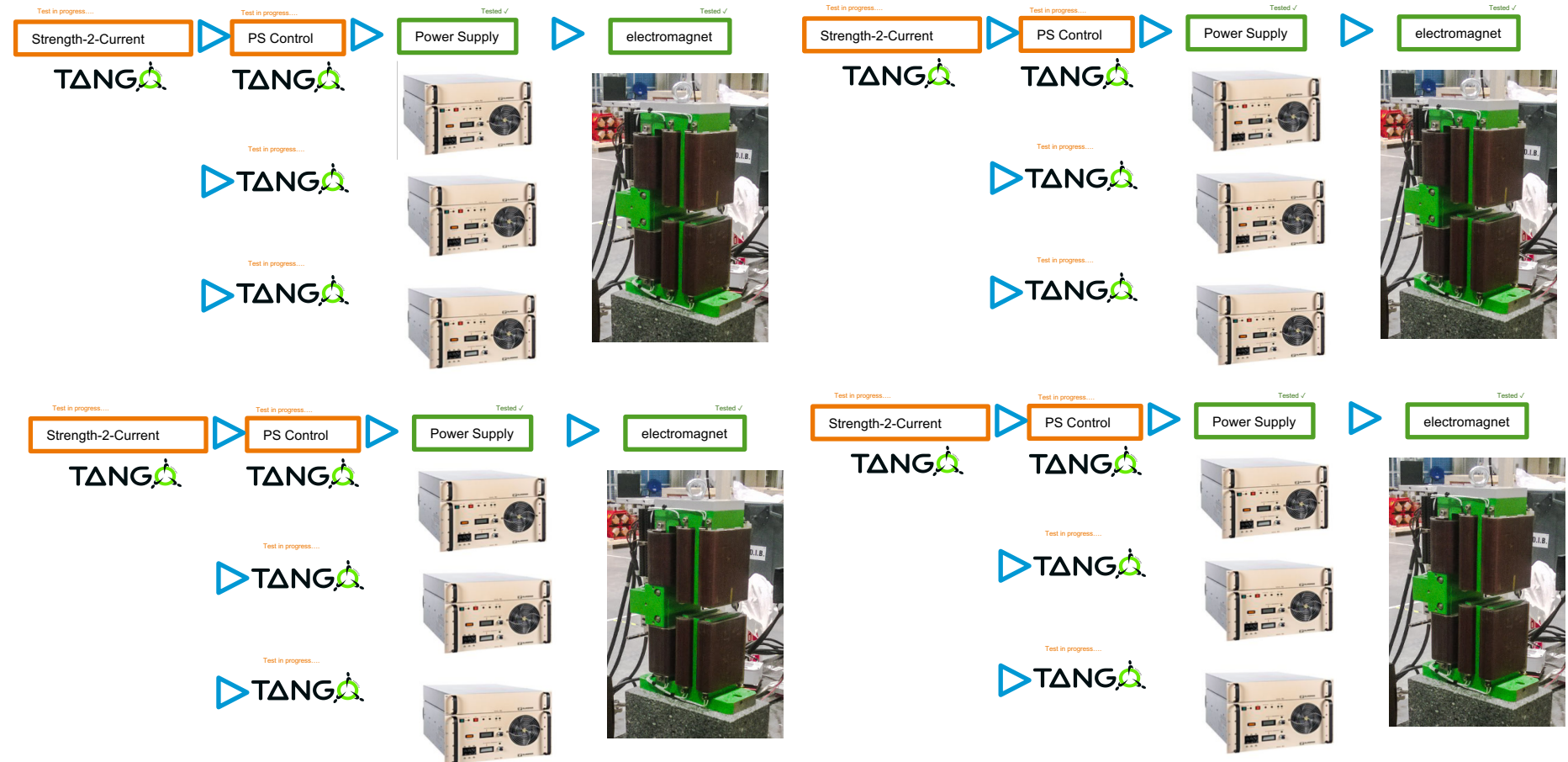
21T/m

-10T/m

61T/m

-120T/m

...

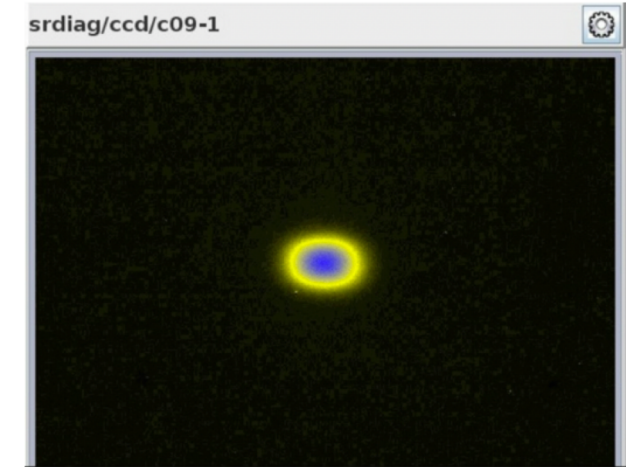


There may be several layers of layers of hardware and software

IN SOME CASES IT IS NOT POSSIBLE TO SEPARATE FROM THE WHOLE



Go to
133 pm!



In some cases it is **not** possible to separate from the whole

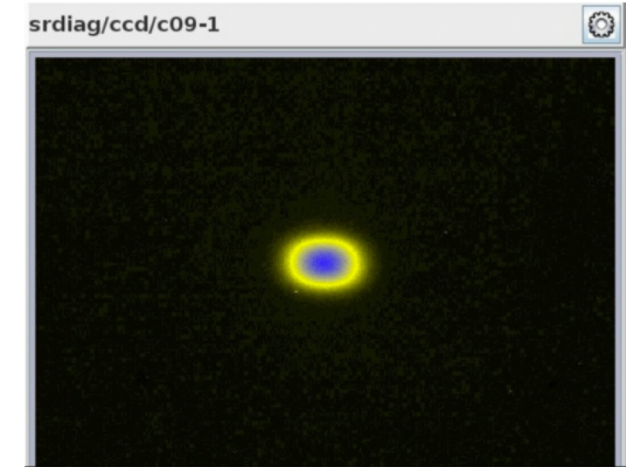
IN SOME CASES IT IS NOT POSSIBLE TO SEPARATE FROM THE WHOLE



Go to
133 pm!



What to do?



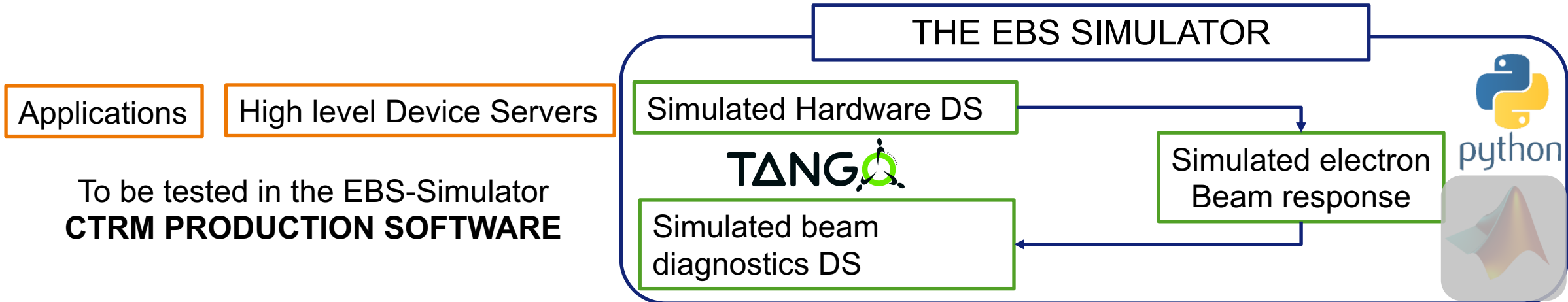
In some cases it is **not** possible to separate from the whole



Go to
133 pm!



Replace the electron beam by software!



To be tested in the EBS-Simulator
CTRM PRODUCTION SOFTWARE

Same DeviceNames/Attributes/Commands as CTRM

ebssimul (ring simulator) Control

Display All

86 Controlled Servers on ebssimul

Level 1

- GenericSimulator/simuCT
- MagnetStrengthCurrent/ebs
- MagnetStrengthCurrent/ebs_dq
- MagnetStrengthCurrent/ebs_hst
- MagnetStrengthCurrent/ebs_sqp
- MagnetStrengthCurrent/ebs_vst
- RingSimulator/ebs
- SrOrbit/ebs

Level 2

- DQModel/dq1
- DQModel/dq2
- MagnetFamily/ebs
- MagnetFamily/ebs_qd
- MagnetFamily/ebs_qf
- SextuCorrModel/sd1ae
- SextuCorrModel/sd1bd
- SextuCorrModel/sf2
- SrctSimu/ebs-simu

Level 3

- EbsCorrectorPS/inj-sh
- EbsCorrectorPS/sd1a
- EbsCorrectorPS/sd1b
- EbsCorrectorPS/sf2
- EbsCorrectorPS/sh1
- EbsCorrectorPS/sh2
- EbsCorrectorPS/sh3
- SimulatedBiltCh/dq1
- SimulatedBiltCh/dq2

Level 4

- HSMMagnetDQS/dq1
- HSMMagnetDQS/dq2
- HSMMagnetDQS/sd1ae
- HSMMagnetDQS/sd1bd
- HSMMagnetDQS/sf2
- HSMMagnetQO/of1
- HSMMagnetQO/qd2
- HSMMagnetQO/qd3
- HSMMagnetQO/qd5
- HSMMagnetQO/qf1
- HSMMagnetQO/qf4ae
- HSMMagnetQO/qf4bd
- HSMMagnetQO/qf6
- HSMMagnetQO/qf8

Level 5

- HSMMagnetQO/qd3i
- HSMMagnetQO/qf1i
- HSMMagnetQO/qf2i

Level 6

- EbsCorr/dq1-h
- EbsCorr/dq2-h
- EbsCorr/sd1a-h
- EbsCorr/sd1a-v
- EbsCorr/sd1b-h
- EbsCorr/sd1b-v
- EbsCorr/sf2-h
- EbsCorr/sf2-v
- EbsCorrector/sh1a-h
- EbsCorrector/sh1a-v
- EbsCorrector/sh1a-x
- EbsCorrector/sh2b-h
- EbsCorrector/sh2b-v
- EbsCorrector/sh3e-h
- EbsCorrector/sh3e-v
- EbsCorrector/sh3e-x
- EbsSqCorr/sd1a-s
- EbsSqCorr/sd1b-s
- EbsSqCorr/sf2-s
- EbsSqCorrector/sh1a-s
- EbsSqCorrector/sh2b-s
- EbsSqCorrector/sh3e-s

Level 7

- CorrectorType/ebs
- DevicesMux/ebs
- Dummy/ebs
- MagnetType/ebs
- SettingsManager/ebs
- SimulatedEbsBpm/ebs
- SimulatedEbsEmit/ebs
- SimulatedEbsMS/ebs
- SimulatedEbsTm/ebs

Level 8

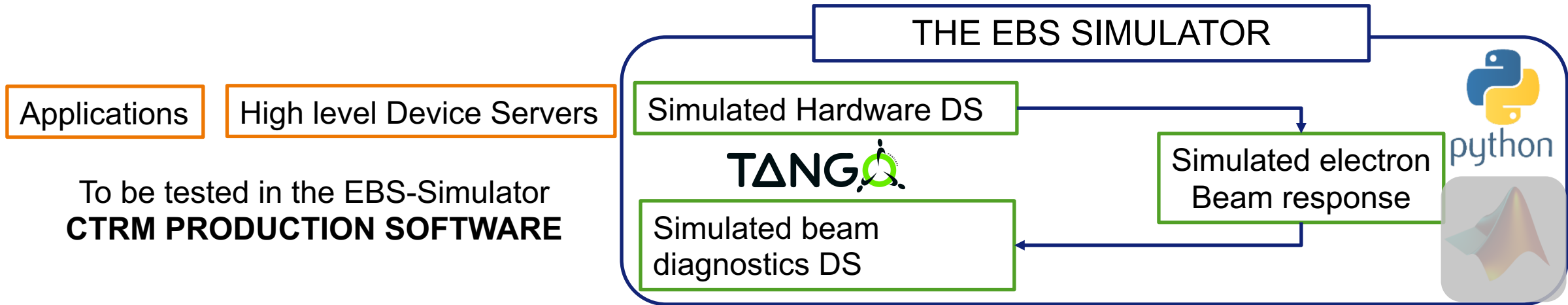
- AllQuadsWrapper/ebs
- Autocor/ebs
- Bump/ebs
- ChromaAdjust/ebs
- ChromaMeasurement/ChromaScan
- ChromaSource/measured
- JDoorWrapper/ebs_ps
- MacroServer/ebs_ps
- ResCor/quad
- ResCor/sext
- ResCor/skew
- TuneAdjust/ebs

servers (86) .
 devices (~4000)

514+96+288+64+384+288+288 + 4*288 +96 + 50(vectorized) + diagnostics 320 + 2 + strength-2-current 192 + bumps (more than 1000) + Autocor

To have multiple simulators on the same host computer, **simulators run within docker images**: 4 simulators running.

WITH THE EBS SIMULATOR WE CAN TEST APPLICATIONS ON BEAM NOW.



**Instead of explaining, I will show, what happens in the simulator.
All that you will see is real, a real EBS Control system simulator.**

The simulator served already for:
EBS **commissioning** applications and control system **specification, design, test**
EBS commissioning **debugging** and trouble shooting, etc...
EBS **operation** applications and control system specification, design, test
EBS operation debugging and trouble shooting
Development of new EBS applications

**It is so
useful that
we actually
have 4!**

SWITCH TO THE CONTROL-SYSTEM SIMULATOR

The image shows a terminal window titled "Terminal - liuzzo@raki2: ~". The terminal output is as follows:

```
liuzzo@raki2:$ export TANGO_HOST=ebs-simu:10000
liuzzo@raki2:$
liuzzo@raki2:$
```

A yellow callout box with a black border contains the text "SIMPLY CHANGE TANGO_HOST!". A yellow arrow points from the callout box to the command in the terminal.

The terminal window is part of a desktop environment. The taskbar at the bottom shows several open applications: a terminal window, a MATLAB R2020a window, and another terminal window. The system tray on the right shows the date "2021-04-20" and the time "14:43".

SAME APPLICATIONS AS IN CONTROL ROOM

Terminal - liuzzo@raki2: ~

```
liuzzo@raki2:~$ jebSCO &
[1] 28812
```

CALL SAME APPLICATION as in CONTROL ROOM

JEbsCo 7.1

File View Correction Reset Expert

Autocor
 H Feedback
 V Feedback

H Steerers
 V Steerers

BPMs
 Orbit

H Orbit		V Orbit		H Steerers			V Steerers		
Peak	12.03 μm	Peak	0.24 μm	Min	-7.317e-05 rad	Min	-2.643e-07 rad		
RMS	2.82 μm	RMS	0.04 μm	Max	4.325e-05 rad	Max	4.286e-07 rad		
Avg	-0.01 μm	Avg	0.00 μm	Std	4.846e-06 rad	Std	4.336e-08 rad		
				Mean	1.028e-11 rad	Mean	5.664e-10 rad		

SR Current 142.233 mA

Plot Freeze

Reference Orbit Show reference

Orbit File
No Orbit File

Zoom
 Horizontal
 Vertical
First Cell 4

Horizontal

Vertical

Zoom Horizontal

Taskbar: [MATLAB R2020a - non...], [Terminal - liuzzo@rak...], Terminal - liuzzo@raki... | 2021-04-20 14:47

CHANGE A MAGNET STRENGTH

The screenshot displays the SR Magnets 3.5-SNAP control interface. The main window is titled "Horizontal Steerers" and contains a grid of magnets. The grid has columns labeled C4 through C27 and rows labeled SH1A, SD1A, SF2A, SD1B, DQ1B, SH2B, DQ2C, DQ1D, SD1D, SF2E, SD1E, and SH3E. A red dashed box highlights the cell at row SD1A, column C8. A red dashed arrow points from this cell to the "Strength" control panel in the "AtkPanel 5.9" window. The "AtkPanel 5.9" window shows the device name "srmag/hst-sd1/c08-a" and a status message "The device is in ON state." The "Strength" control panel shows a value of "0.000000 rad" with a numeric keypad and a "Scalar" button. Below the "Strength" control panel is a "Condition for Injection" section with a button labeled "SR Magnets Strengths". The "SR Magnets 3.5-SNAP" window has a menu bar with "File", "View", "Expert", "Commands", and "Reset". It features a "Main Magnets" section with icons for QF1, QD2, QF2ae, QD3, SD1ae, QF4ae, SF2, and QF4bd. Below this is a "Correctors" section with buttons for "H Steerers", "V Steerers", and "Skew Quads". At the bottom, there is an "All Magnets" section with buttons for "On ...", "Off ...", "Reset ...", and "Cycle ...". A graph in the bottom left shows "Strength (rad)" on the y-axis (ranging from -1.00e-4 to 1.00e-4) and time on the x-axis (ranging from 4 to 14). The graph shows a blue line that starts at 0, drops to -1.00e-4, and then returns to 0. A "Reference" section at the bottom left has buttons for "Save", "Reset", and "ignore", and a "Mean" value of "1.471e-11 rad". A "Config File" section at the bottom left has a text box and a "Status" button.

CHANGE A MAGNET STRENGTH

Changes 4
simulated Power
Supply Devices
CHECK
CALIBRATIONS!

The screenshot displays the 'Horizontal Steerers' control panel. At the top, a grid of magnets is shown, with columns labeled C5 through C27. A red dashed box highlights a specific magnet in the grid. Below the grid, a plot shows a signal with a peak at approximately x=7.5, labeled 'Visible on plot'. To the right, the 'SR Magnets 3.5-SNAP' control panel is visible, featuring a 'Main Magnets' section with icons for QF1, QD2, QF2ae, QD3, SD1ae, QF4ae, SF2, and QF4bd. A 'Strength' control is set to 0.000100 rad. Below this, there are buttons for 'H Steerers', 'V Steerers', and 'Skew Quads'. At the bottom, there are buttons for 'All Magnets' (On, Off, Reset, Cycle) and a 'Settings File' section with a 'Status' button. A yellow triangle with the word 'Click' is positioned below the strength control.

Change as in Control Room

Visible on plot

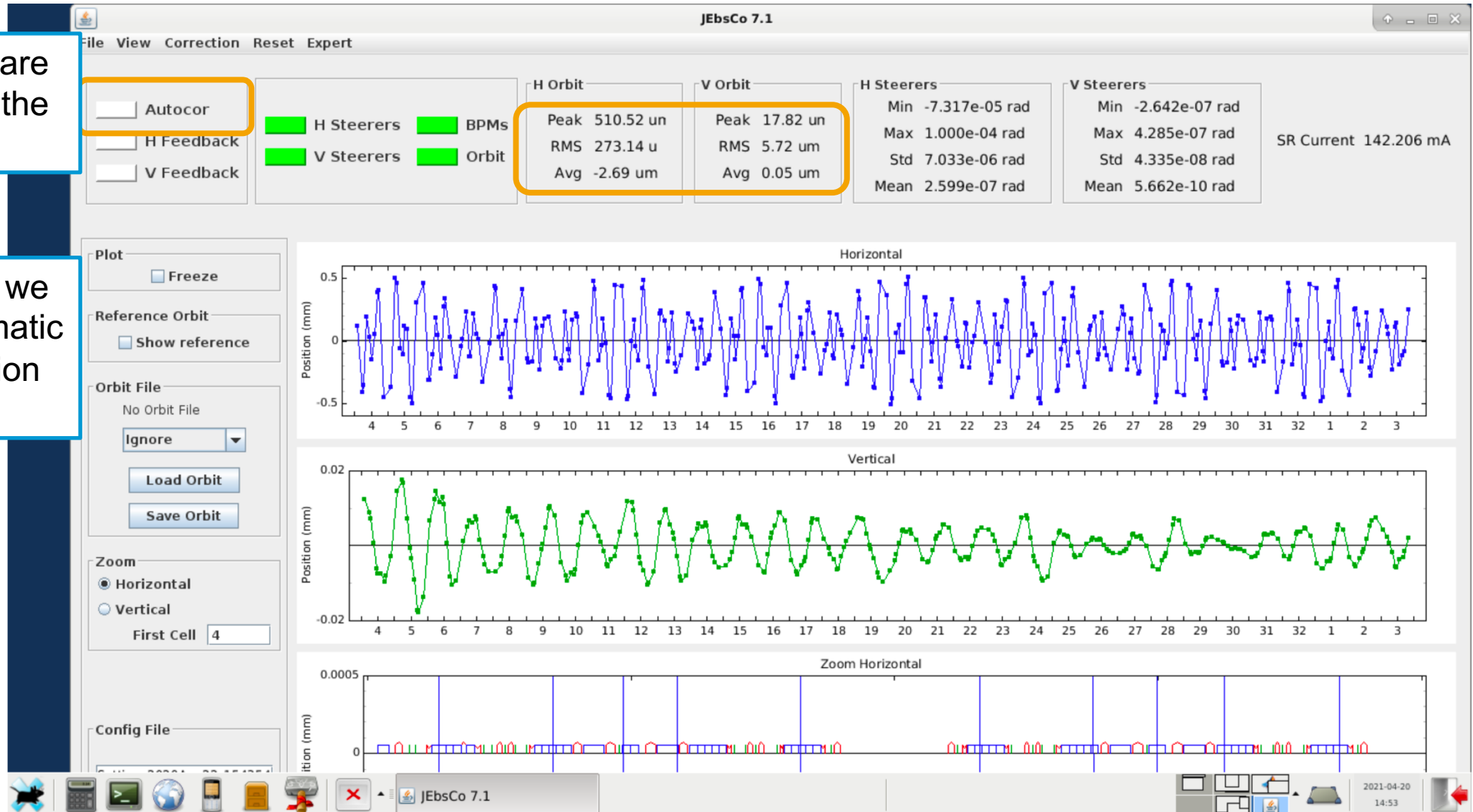
Values sent to Current Power Supply in real life. Stop here in Simulator

AUTOMATIC ORBIT CORRECTION TEST IN THE SIMULATOR

Applications are the same as the real ones.



For example we can run automatic orbit correction (Autocor)



EFFECT OF AUTOMATIC CORRECTION

Applications are the same as the real ones.

For example we can run automatic orbit correction (Autocor)



EFFECT OF AUTOMATIC CORRECTION

Applications are the same as the real ones.



For example we can run automatic orbit correction (Autocor)



Strengths are changed and orbit follows as expected.



EFFECT OF AUTOMATIC CORRECTION

Applications are the same as the real ones.

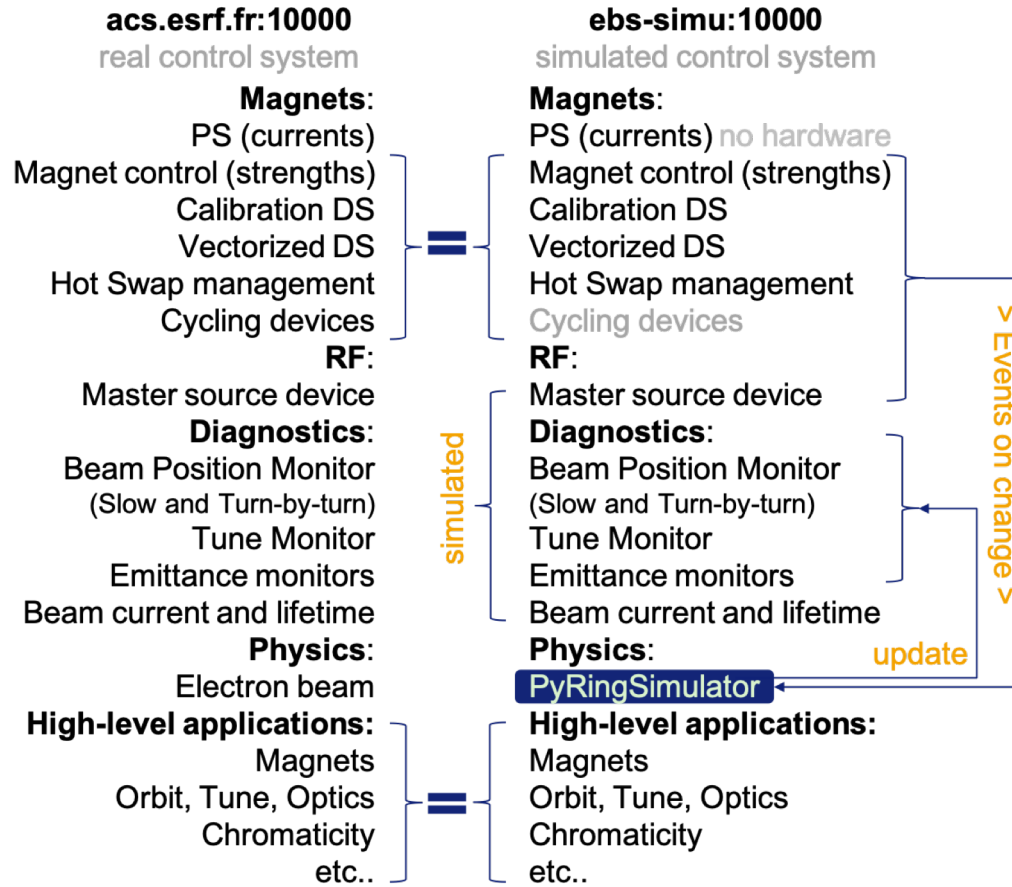
For example we can run automatic orbit correction (Autocor)

Strengths are changed and orbit follows as expected.

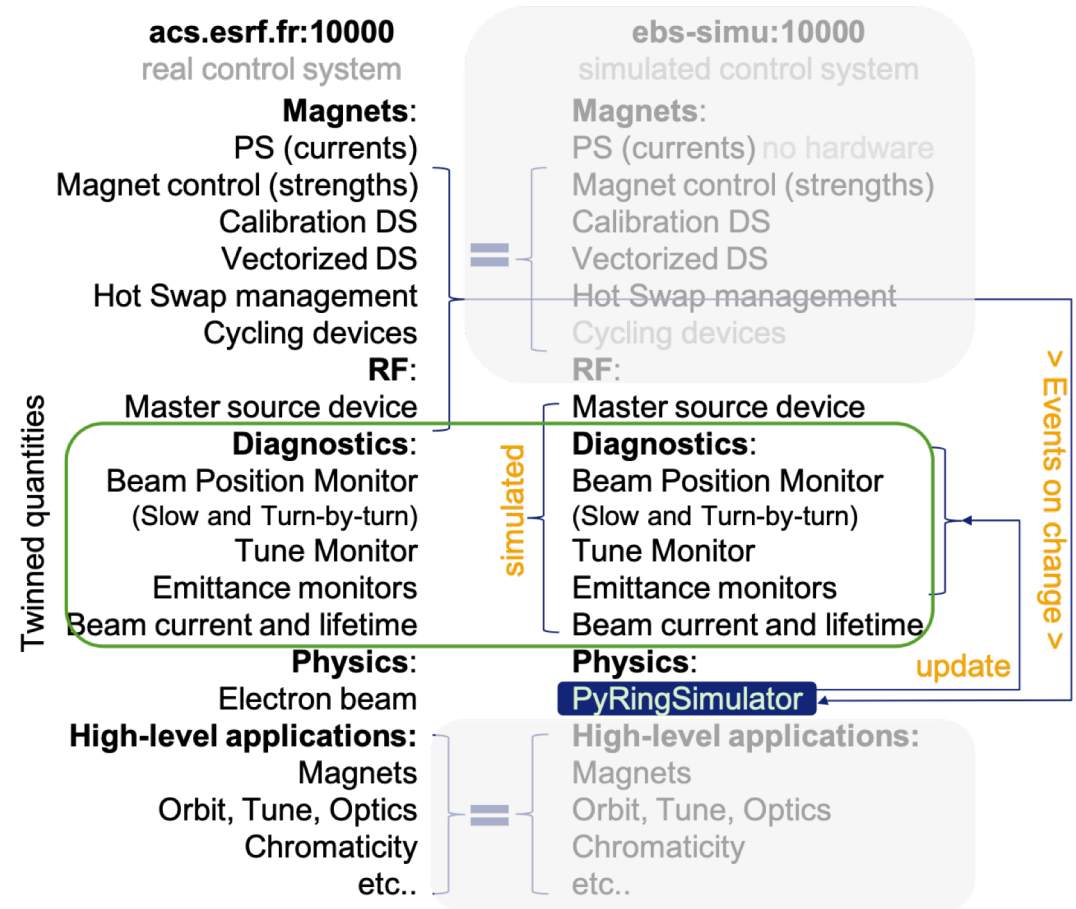
The strength that we set is now replaced by many correctors to cancel the "measured" orbit.

The screenshot displays the SR Magnets 3.5 software interface. At the top, a grid of magnets is shown, with columns labeled C4 through C27 and rows labeled DQ1B, SH2B, and DQ2C. A red dashed box highlights a cell in the grid, with a red dashed arrow pointing to the right. Below the grid is a graph showing the orbit length in radians over a distance of 14 meters. The graph shows a blue line fluctuating around a mean value of 0.00e0. To the right of the graph is a control panel for 'Main Magnets' with icons for QF1, QD2, QF2ae, QD3, SD1ae, QF4ae, SF2, and QF4bd. Below this are 'Correctors' buttons for 'H Steerers', 'V Steerers', and 'Skew Quads'. At the bottom, there are 'All Magnets' buttons for 'On ...', 'Off ...', 'Reset ...', and 'Cycle ...'. On the right side, there is an 'AtkPanel 5.9 : srmag/hst-sd1/c08-a' window showing a dropdown menu with 'srmag/hst-sd1/c08-a' selected and a status message 'The device is in ON state.'. Below this is a 'Scalar' window with a 'Strength' field set to '0.000006 rad' and a numeric keypad showing '0.000006'. A yellow box highlights this strength value with the text 'Changed by Automatic correction'. At the bottom right, there is a 'Settings File' section with a dropdown menu showing 'Settings2021Feb10_133439' and a 'Status' button.

Simulator configuration



Future development: Digital twin configuration



- Able to show **all single particle electron beam dynamic effects**: orbit, tunes, emittances, beam size, chromaticity, Turn by Turn beam trajectory etc. in presence of realistic errors (not visible to the user)
- Follows the **variation of any magnet and of the RF parameters**.
- Pilots **simulated PS devices** → used in real life to detect calibration issues!
- Control room applications work also in the simulator: **test applications without real beam**, spare precious machine dedicated time, help debugging, finding issues before production.
Examples of applications/scripts prepared in the simulator: magnets control, cycling, correction of optics and orbit, beam based alignment, chromaticity, bumps, first turns trajectory steering, etc. (many more)
- Python (pyAT <https://github.com/atcollab/at>) replaced Matlab for the simulator loop
- Simulator model updated on demand. Reinitialization of the simulator takes <1min.
- 1 core/simulator dedicated to simulation loop, at the speed of CPU available (3GHz).
- All other cores are used by the 86 Device Servers : 1 simulator 25-30% of a 16-core CPU-host

We are few steps from digital-twinning:

Linking the CTRM PS/RF setting to a simulator running the measured optics model. (much less trivial than it sounds)