



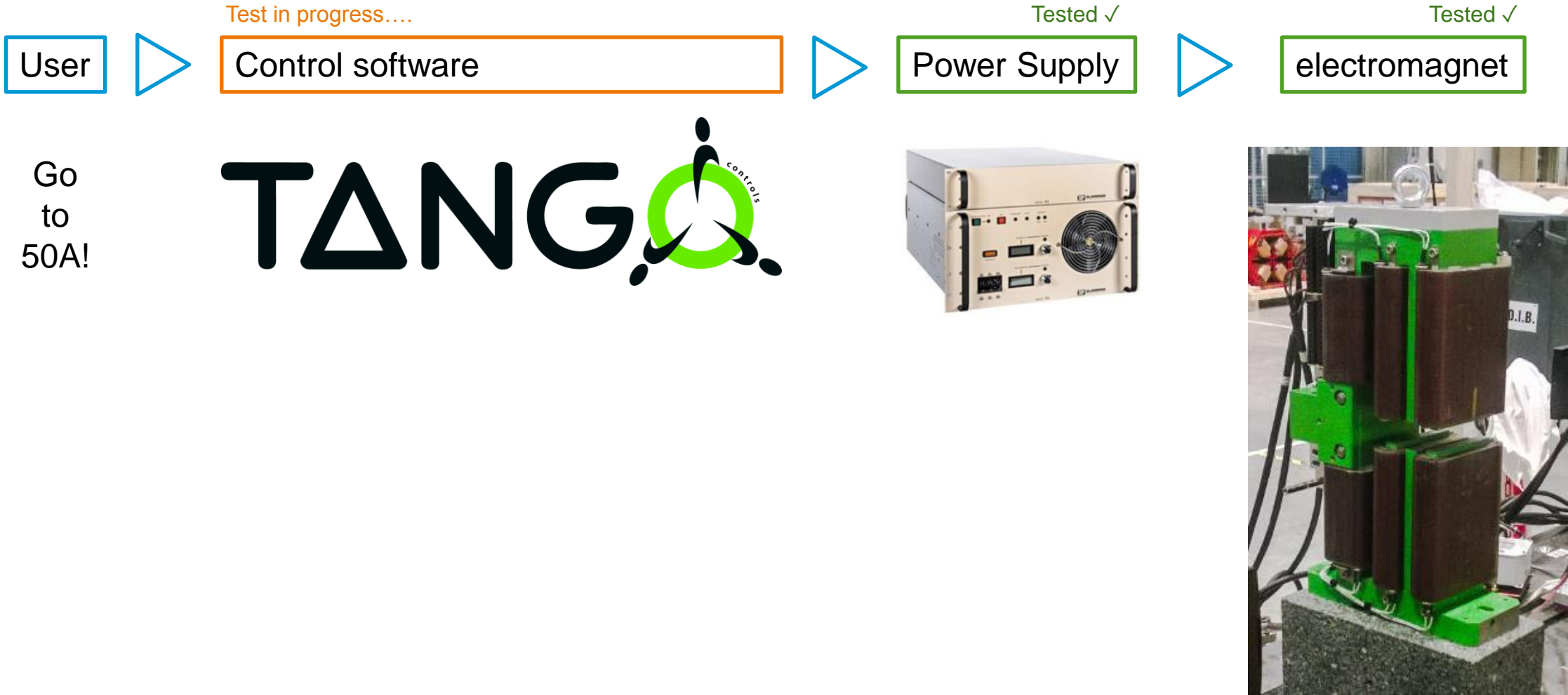
| The European Synchrotron

ESRF (SIMULATOR) activities update

Simone Liuzzo on behalf of the
EBS-Simulator Team Accelerator Control Unit + Beam Dynamics

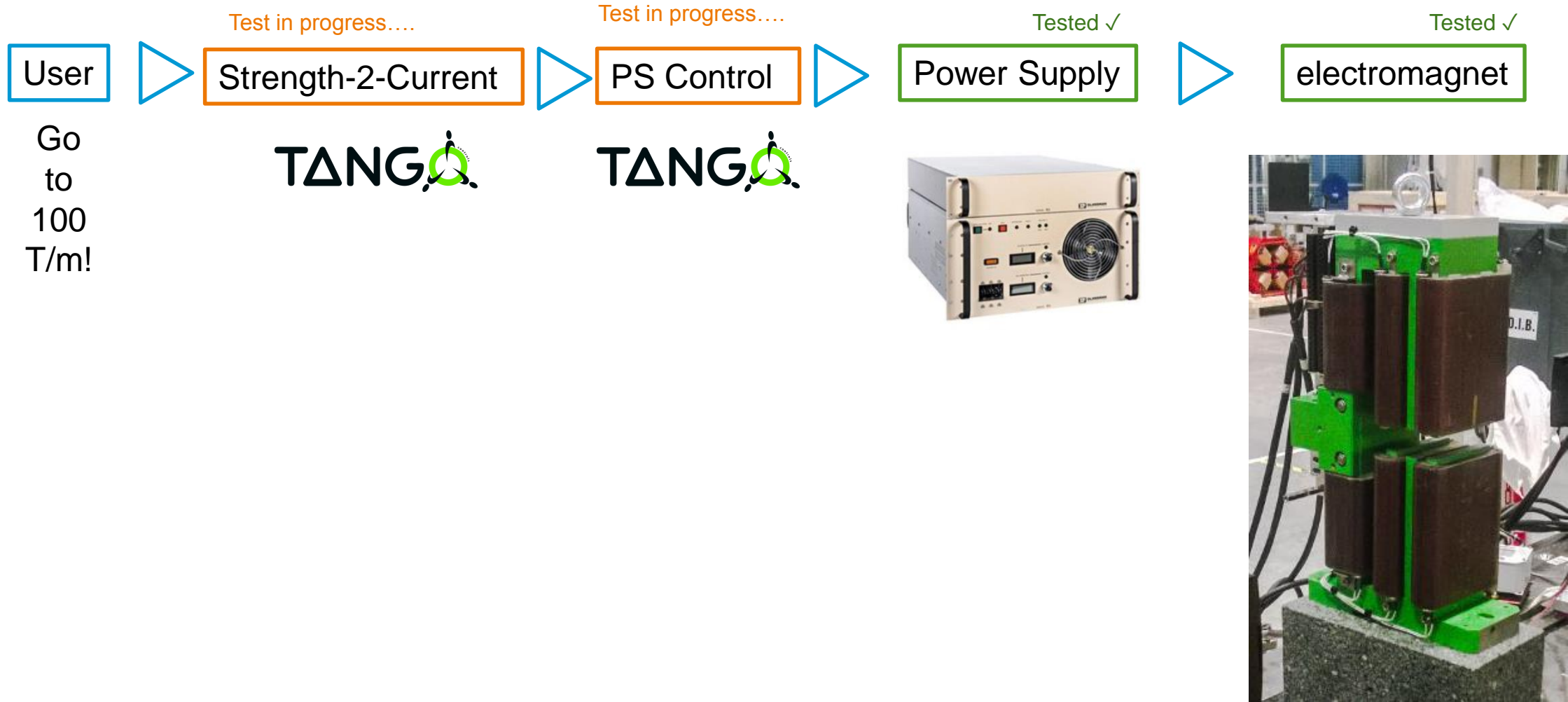
LEAPS workshop 11th May 2021

HOW TO TEST CONTROL SOFTWARE?



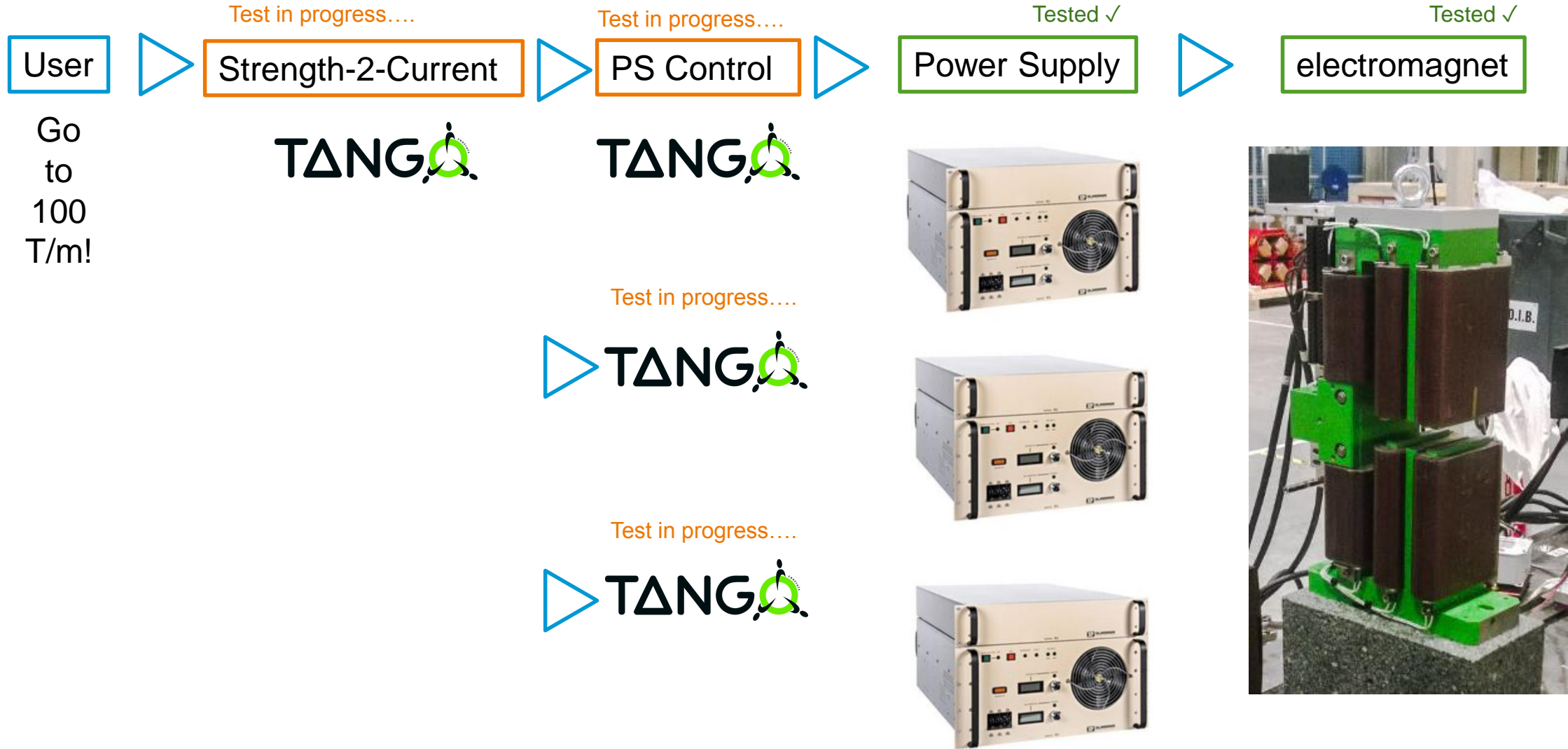
If the equipment we want to test can be **separated** from the rest it may be close to trivial.

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

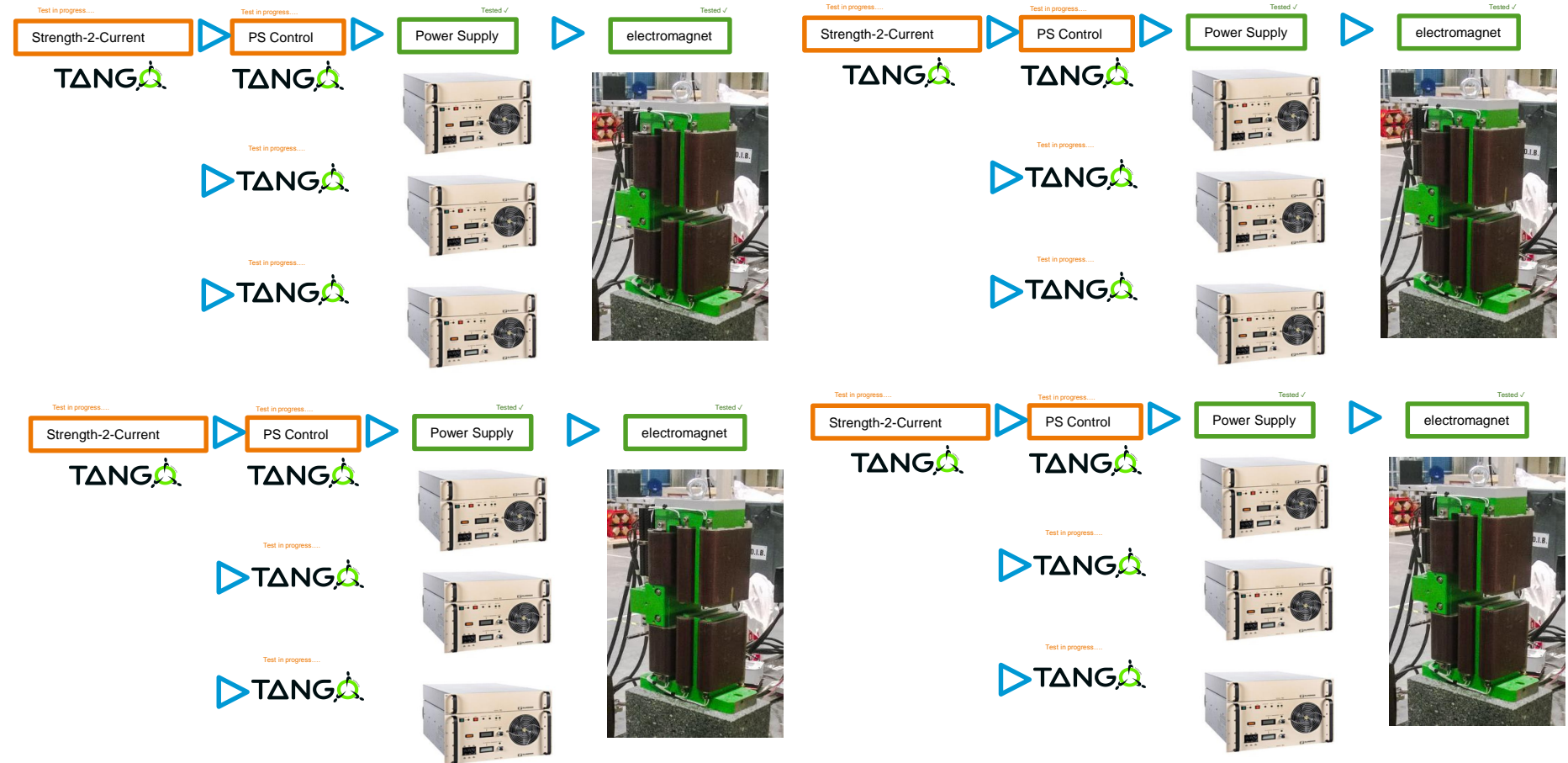
21T/m

-10T/m

61T/m

-120T/m

...

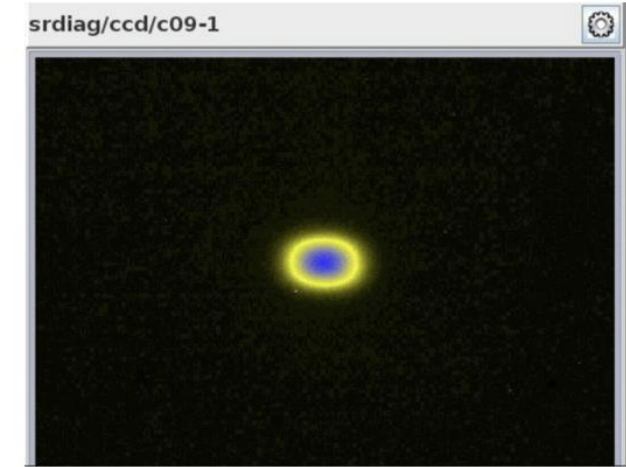


There may be several layers of layers of hardware and software

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

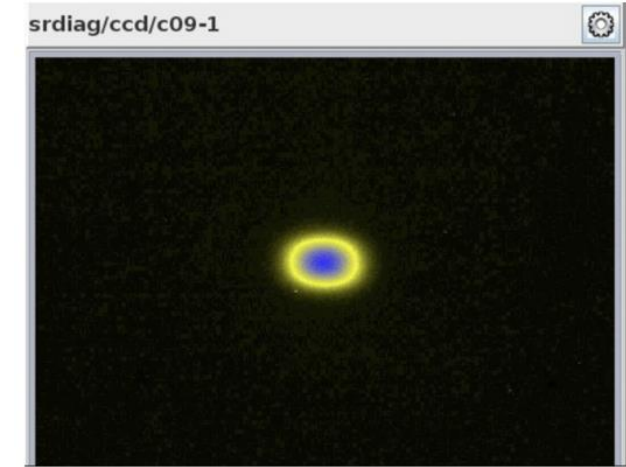
IN SOME CASES IT IS NOT POSSIBLE TO SEPARATE FROM THE WHOLE



Go to
133 pm!



What to do?



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

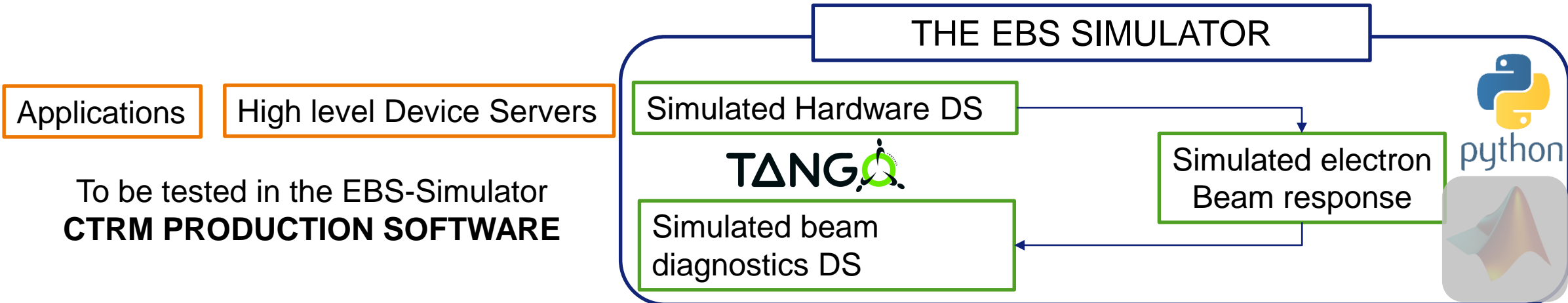
THE EBS SIMULATOR



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
- HSMMagnetQ0/of1
- HSMMagnetQ0/qd2
- HSMMagnetQ0/qd3
- HSMMagnetQ0/qd5
- HSMMagnetQ0/qf1
- HSMMagnetQ0/qf4ae
- HSMMagnetQ0/qf4bd
- HSMMagnetQ0/qf6
- HSMMagnetQ0/qf8

Level 5

- HSMMagnetQ0/qd3i
- HSMMagnetQ0/qf1i
- HSMMagnetQ0/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

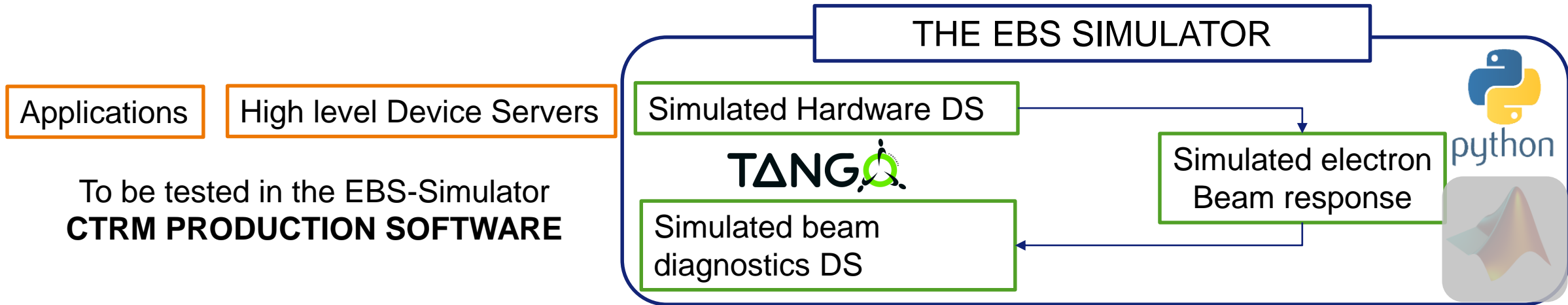
- CorrectorType/ebs
- DevicesMux/ebs
- Dummy/ebs
- MagnetType/ebs
- SettingsManager/ebs
- SimulatedEbsBpm/ebs
- SimulatedEbsEmit/ebs
- SimulatedEbsMS/ebs
- SimulatedEbsTm/ebs

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.



To be tested in the EBS-Simulator
CTRM PRODUCTION SOFTWARE

**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

Terminal - liuzzo@raki2: ~

```
File Edit View Terminal Tabs Help
liuzzo@raki2:$ export TANGO_HOST=ebs-simu:10000
liuzzo@raki2:$
liuzzo@raki2:$ █
```

◀ SIMPLY CHANGE TANGO_HOST!

[MATLAB R2020a - non-...] [Terminal - liuzzo@raki2...] Terminal - liuzzo@raki2: ~

2021-04-20 14:43

SAME APPLICATIONS AS IN CONTROL ROOM

The screenshot displays a desktop environment with a terminal window and the JEbsCo 7.1 application. The terminal window shows the user 'liuzzo@raki2' running the command 'jebco &' and receiving a response '[1] 28812'. A yellow callout box with a black border and a yellow arrow points to the terminal, containing the text 'CALL SAME APPLICATION as in CONTROL ROOM'. The JEbsCo 7.1 application window is titled 'JEbsCo 7.1' and has a menu bar with 'File', 'View', 'Correction', 'Reset', and 'Expert'. The interface includes several control panels and data displays:

- Control Panels:**
 - Autocor:
 - H Feedback:
 - V Feedback:
 - H Steerers:
 - V Steerers:
 - BPMS:
 - Orbit:
- Orbit Statistics:**
 - H Orbit:** Peak 12.03 μm , RMS 2.82 μm , Avg -0.01 μm
 - V Orbit:** Peak 0.24 μm , RMS 0.04 μm , Avg 0.00 μm
- Steerer Statistics:**
 - H Steerers:** Min $-7.317\text{e-}05$ rad, Max $4.325\text{e-}05$ rad, Std $4.846\text{e-}06$ rad, Mean $1.028\text{e-}11$ rad
 - V Steerers:** Min $-2.643\text{e-}07$ rad, Max $4.286\text{e-}07$ rad, Std $4.336\text{e-}08$ rad, Mean $5.664\text{e-}10$ rad
- SR Current:** 142.233 mA

The application also features two plots showing position (mm) versus cell number (4 to 32). The top plot, titled 'Horizontal', shows a blue line with high-frequency oscillations between approximately -0.0005 mm and 0.0005 mm. The bottom plot, titled 'Vertical', shows a green line with lower-frequency oscillations around 0 mm. The interface includes a 'Plot' section with a 'Freeze' checkbox, a 'Reference Orbit' section with a 'Show reference' checkbox, and an 'Orbit File' section with a dropdown menu set to 'Ignore' and buttons for 'Load Orbit' and 'Save Orbit'. A 'Zoom' section has radio buttons for 'Horizontal' (selected) and 'Vertical', and a 'First Cell' input field set to '4'. The system tray at the bottom shows the date '2021-04-20' and time '14:47', along with icons for the terminal and other applications.

CHANGE A MAGNET STRENGTH

The screenshot displays the SR Magnets 3.5-SNAP control interface. The main window, titled "Horizontal Steerers", 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. The cell at row SD1A, column C8 is highlighted with a red dashed box. A red dashed arrow points from this cell to the "Strength" control in the "AtkPanel 5.9 : srmag/hst-sd1/c08-a" window. This window shows the strength set to 0.000000 rad. Below the strength control, there are sections for "Main Magnets" (QF1, QD2, QF2ae, QD3, SD1ae, QF4ae, SF2, QF4bd), "Correctors" (H Steerers, V Steerers, Skew Quads), "Condition for Injection" (SR Magnets Strengths), and "All Magnets" (On ..., Off ..., Reset ..., Cycle ...). A "Reference" section at the bottom left shows a mean value of 1.471e-11 rad. A "Config File" section at the bottom left shows "Settings2021Feb10_133439".

	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28
SH1A	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
SD1A	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
SF2A	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
SD1B	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
DQ1B	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
SH2B	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
DQ2C	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
DQ1D	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
SD1D	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
SF2E	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
SD1E	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
SH3E	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

CHANGE A MAGNET STRENGTH

Changes 4
simulated Power
Supply Devices
CHECK
CALIBRATIONS!

The screenshot displays the SR Magnets 3.5-SNAP control interface. At the top, a grid of magnets is shown, with columns labeled C5 through C27. A red dashed box highlights a cell in the grid, with an arrow pointing to the 'Strength' control in the 'Main Magnets' panel. The 'Main Magnets' panel includes a 'Strength' control set to 0.000100 rad, a 'Click' button, and a 'Scalar' section. Below this, there are 'Correctors' (H Steerers, V Steerers, Skew Quads) and 'Condition for Injection' (SR Magnets Strengths) sections. A 'Settings File' section is also visible. In the bottom left, a plot shows a red line graph with a peak at x=1. A red dashed box highlights the plot area, with an arrow pointing to the 'Strength' control. A blue dashed box highlights the 'Strength' control, with an arrow pointing to the 'Strength' control in the 'Main Magnets' panel. A blue dashed box highlights the 'Strength' control, with an arrow pointing to the 'Strength' control in the 'Main Magnets' panel. A blue dashed box highlights the 'Strength' control, with an arrow pointing to the 'Strength' control in the 'Main Magnets' panel.

Change as in Control Room

Visible on plot

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

CHANGE A MAGNET STRENGTH

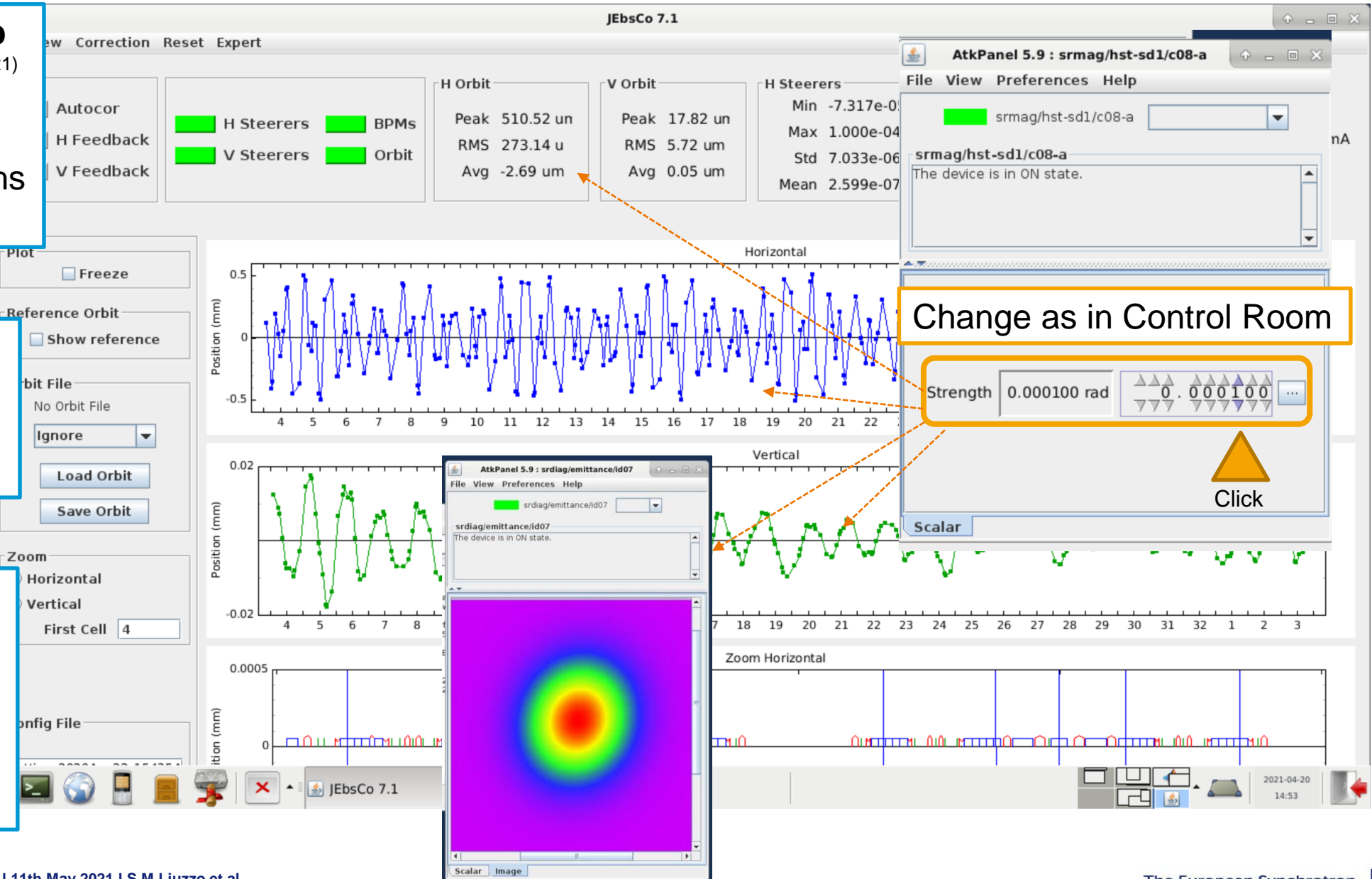
Simulator Loop

(matlab <2021 or python > 2021)

continuously monitors all magnets strengths (0.2-2.0Hz).

If change **COMPUTE** New beam parameters

Modified *simulated* diagnostics reading, control room operational observable.



Change as in Control Room

Strength 0.000100 rad 0.000100

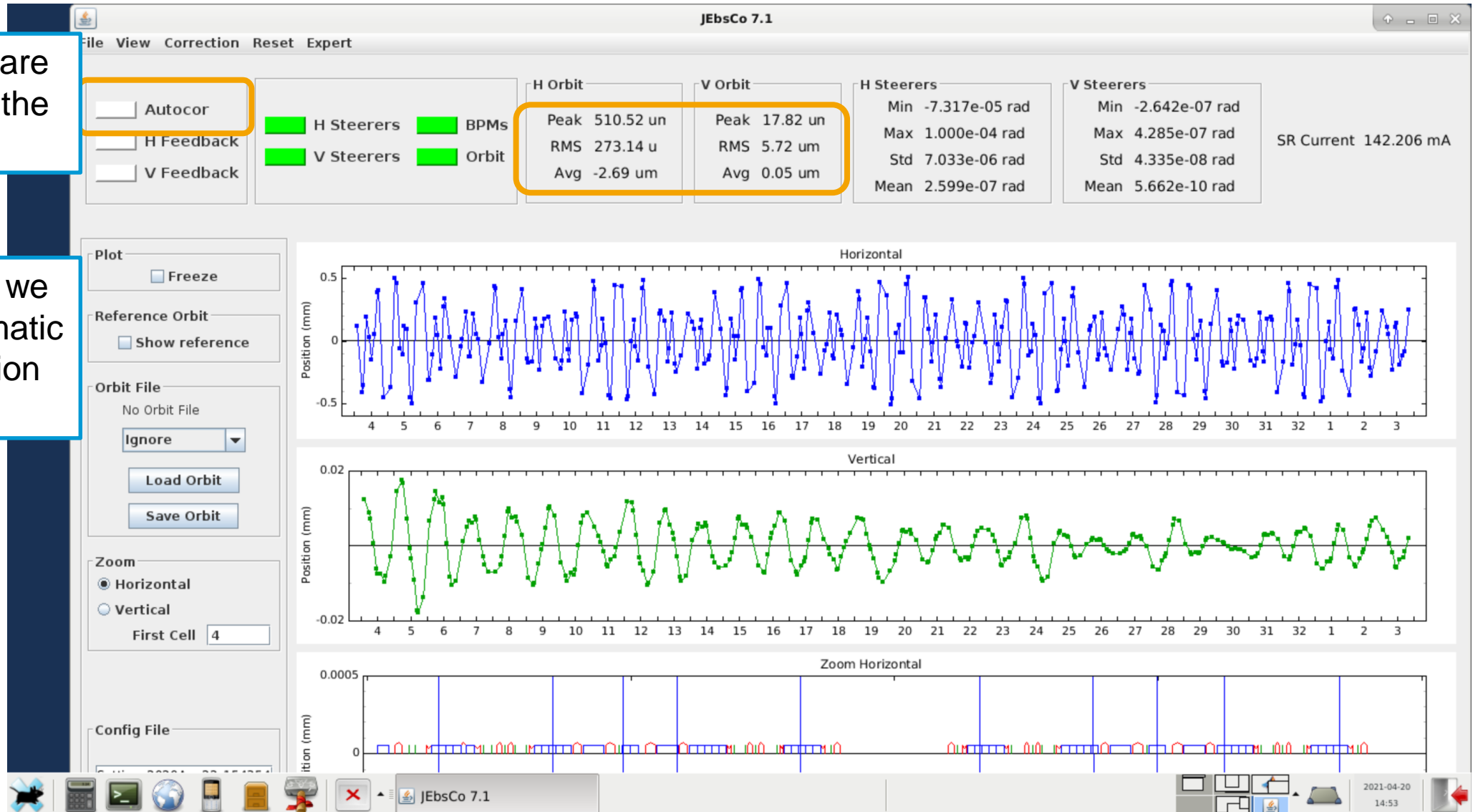


AUTOMATIC ORBIT CORRECTION TEST IN THE SIMULATOR

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 specific magnet in the grid, with a red arrow pointing to the 'Strength' field in the 'Main Magnets' panel. The 'Strength' field is set to 0.000006 rad. Below the grid, a graph shows the strength of the magnets as a function of position (rad), with the y-axis ranging from -4 to 4 and the x-axis from 4 to 14. The graph shows a blue line that fluctuates around zero. The 'Main Magnets' panel includes icons for QF1, QD2, QF2ae, QD3, SD1ae, QF4ae, SF2, and QF4bd. The 'Correctors' panel includes buttons for H Steerers, V Steerers, and Skew Quads. The 'Condition for Injection' panel includes a button for SR Magnets Strengths. The 'Settings File' panel includes a text field for Settings2021Feb10_133439 and a Status button.

Changed by Automatic correction

- 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 will replace Matlab for the simulator loop before June 2021
- 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)