Virtual Reality:
A New Way to Enter a Lab

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European XFEL

April 30, 2021

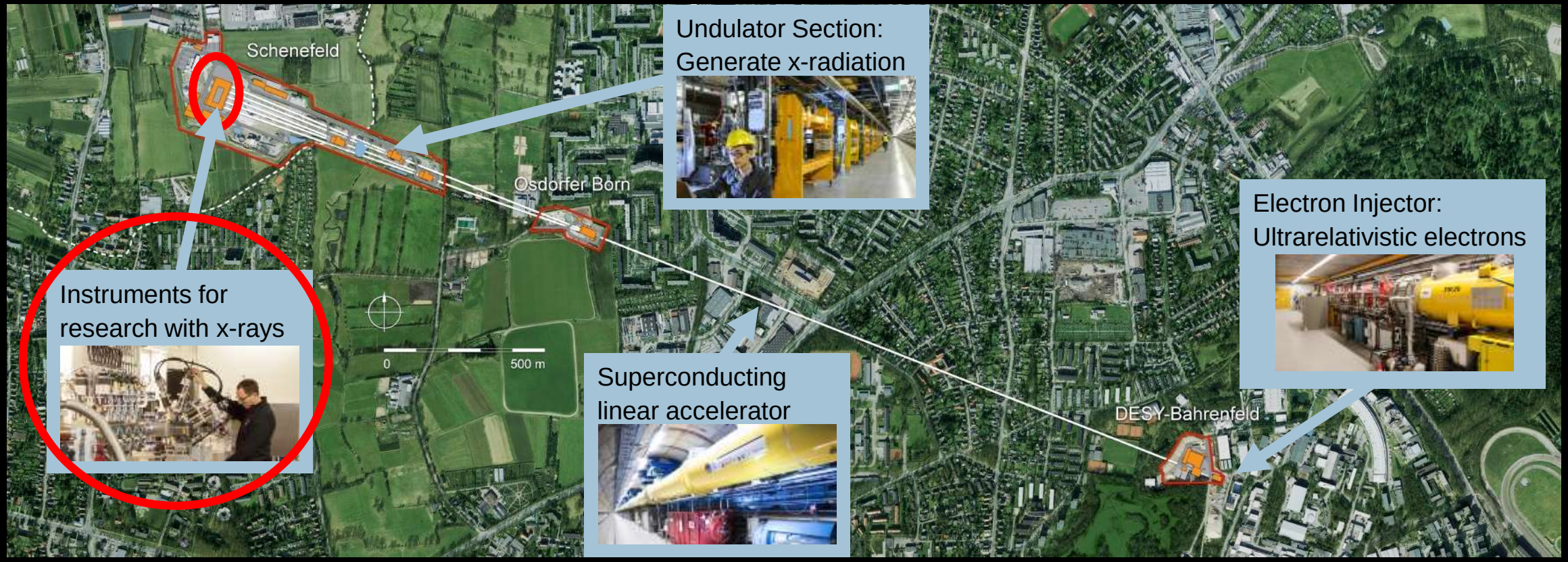
Agenda

- Brief Overview of a Large-Scale Facility Lab for femtosecond x-ray experiments

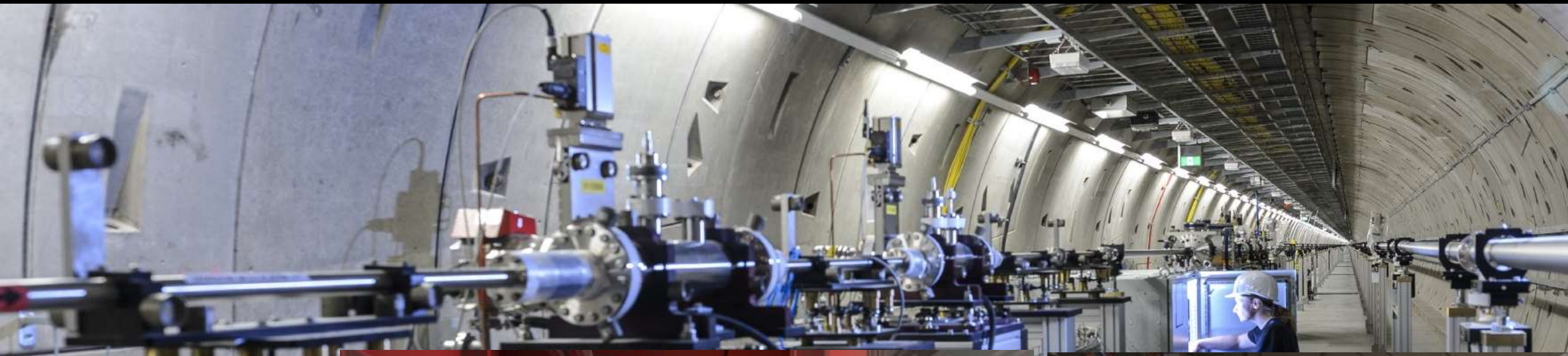
- Capabilities of the VR Software:
- **understanding complex instrumentation, different detector types**
- **Performing a complicated experiment**
- **Analyzing the virtual results, interpretation**

- Outlook: We can teach/lean **complicated experimental instrumentation remotely**!

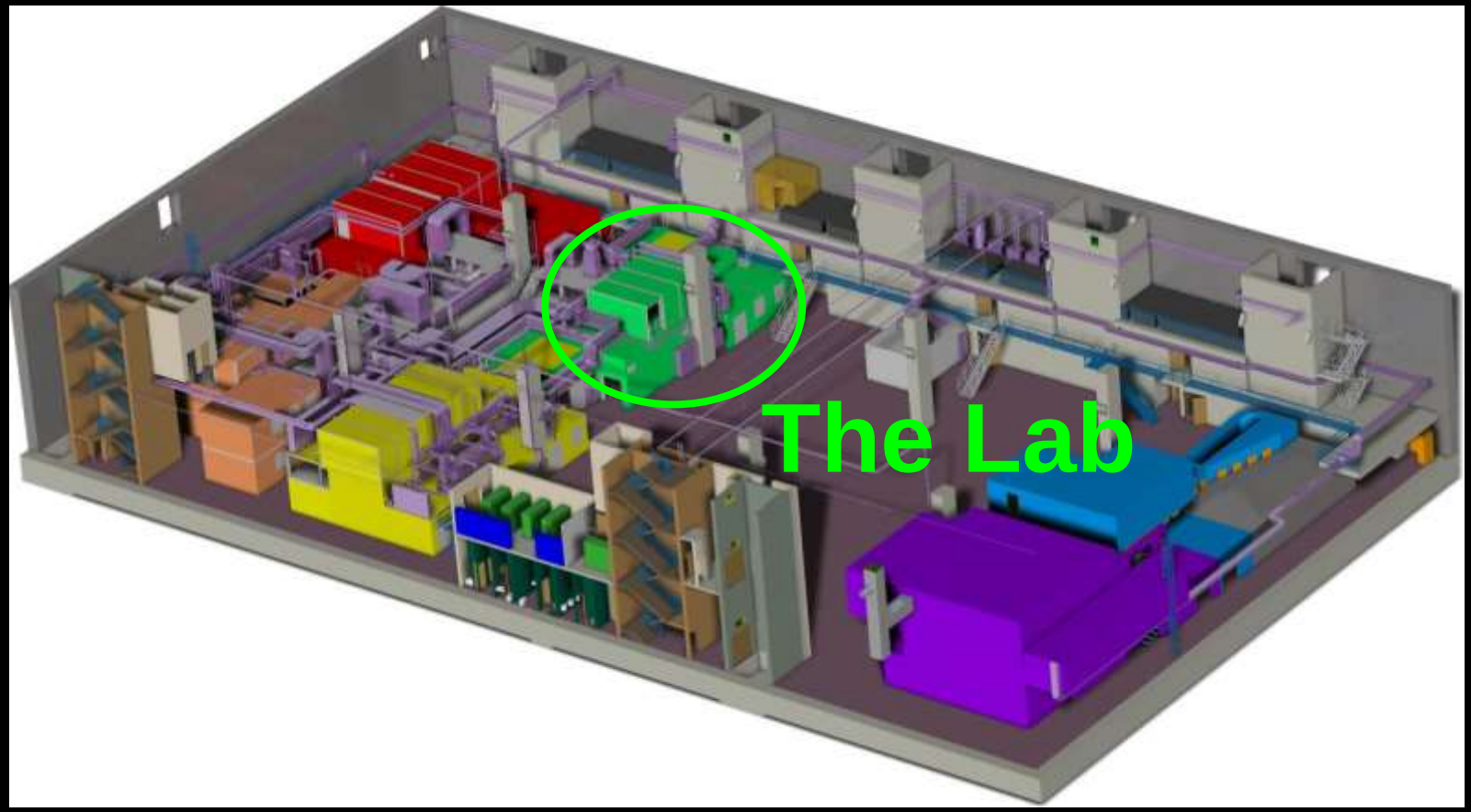
European XFEL : Intense Femtosecond X-Radiation



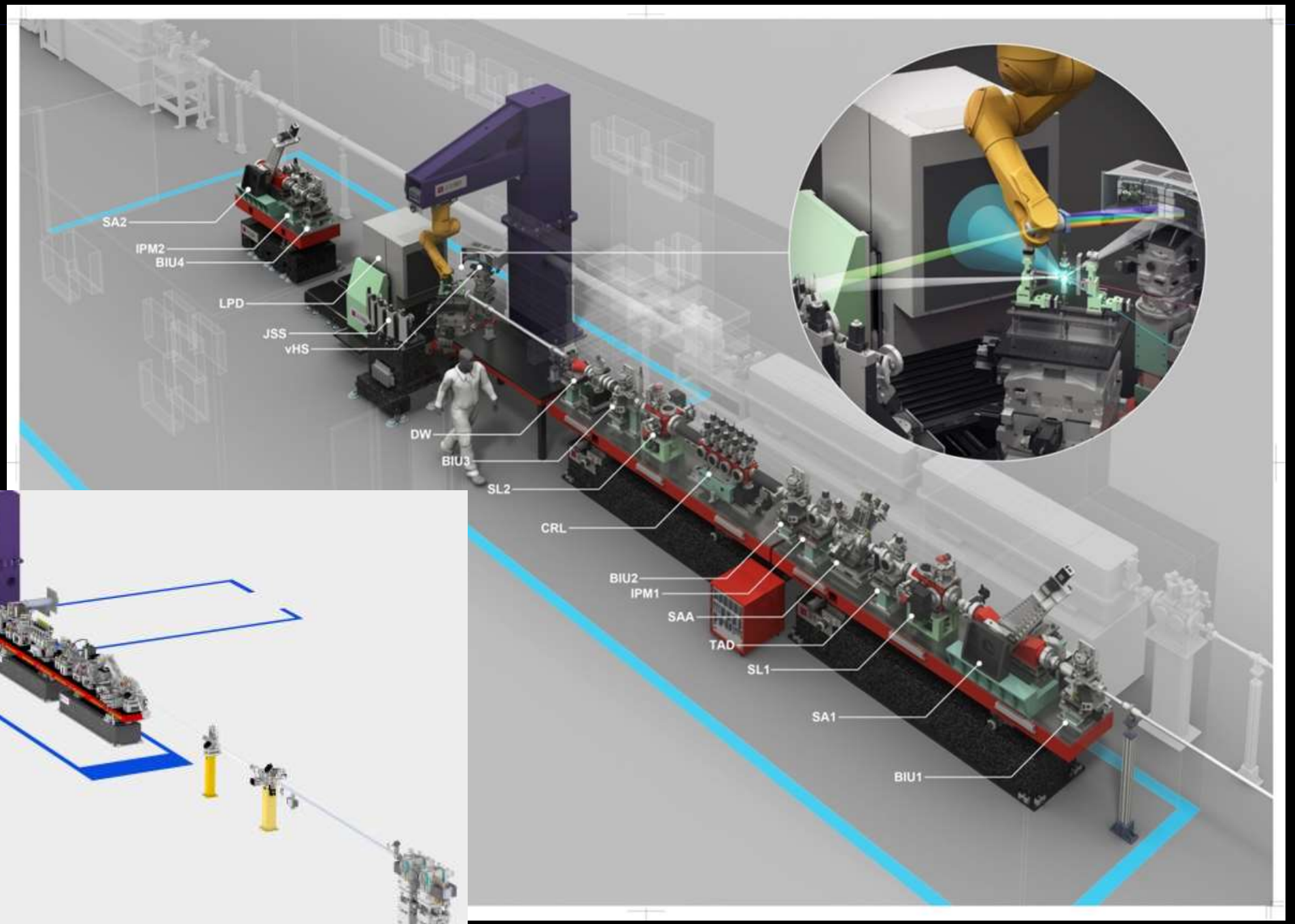
The Long Photon Beam Transport Tunnel

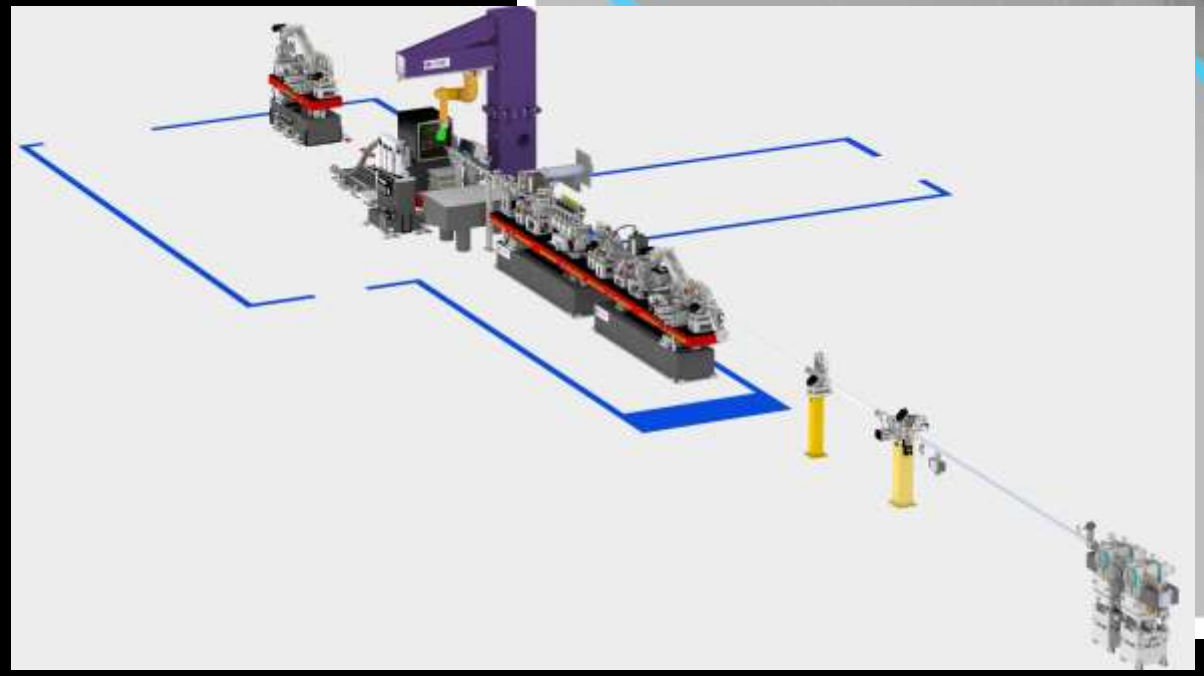


The experimental hall with loaded scientific instruments

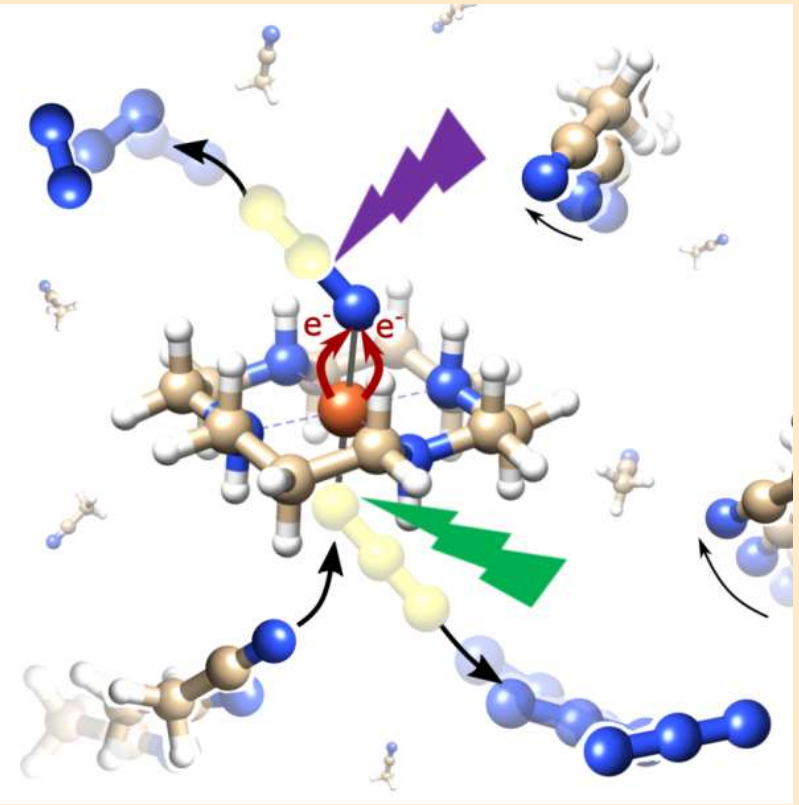


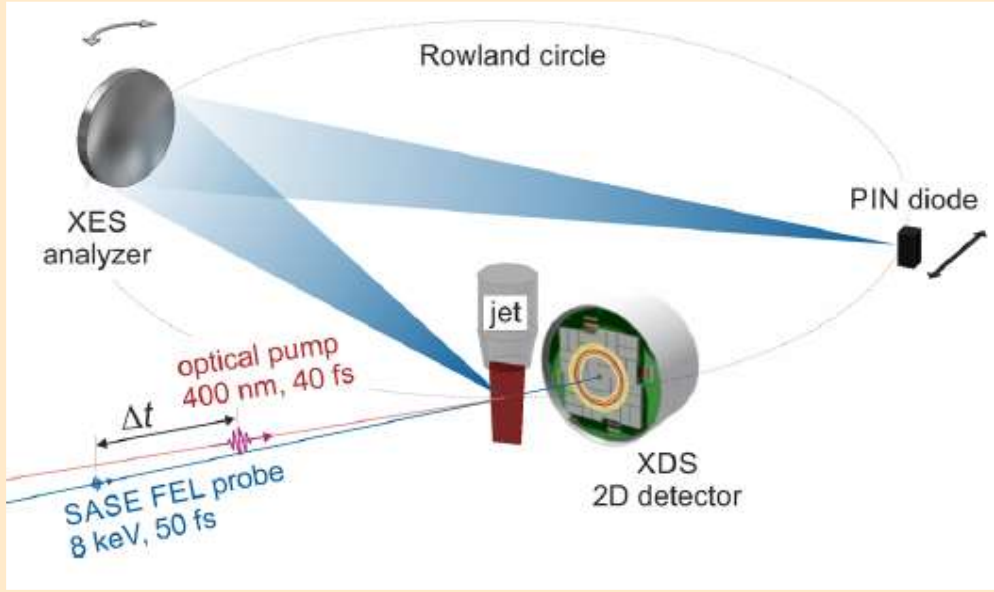
The VR Lab

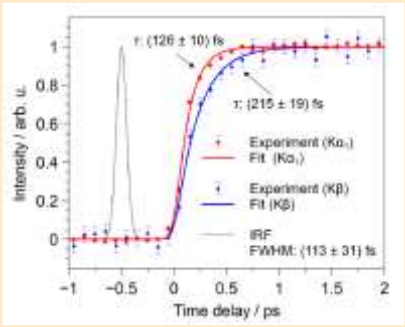

SA2
IPM2
BIU4
LPD
JSS
vHS
DW
BIU3
SL2
CRL
BIU2
IPM1
SAA
TAD
SL1
SA1
BIU1

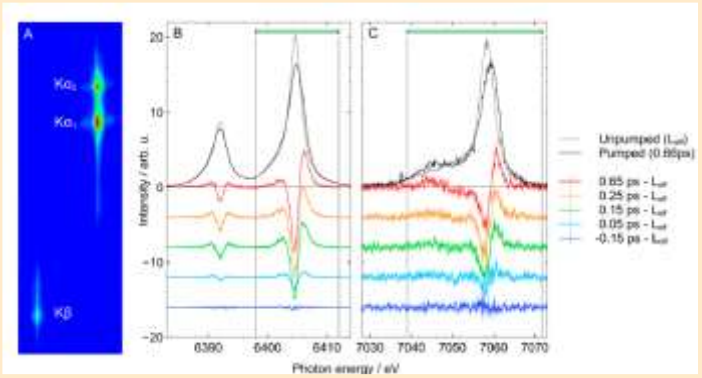


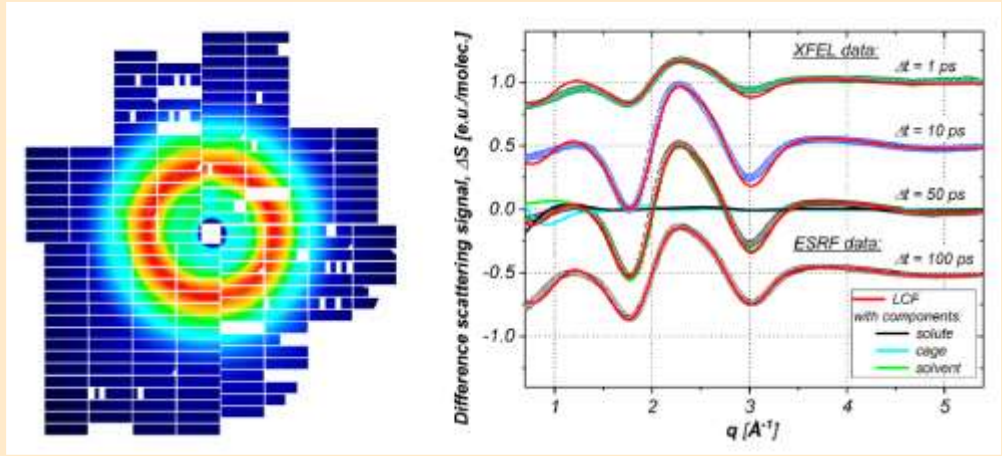
Goal: Measure and Understand Chemical Reactions …using Complex Equipment from Large Scale Facilities

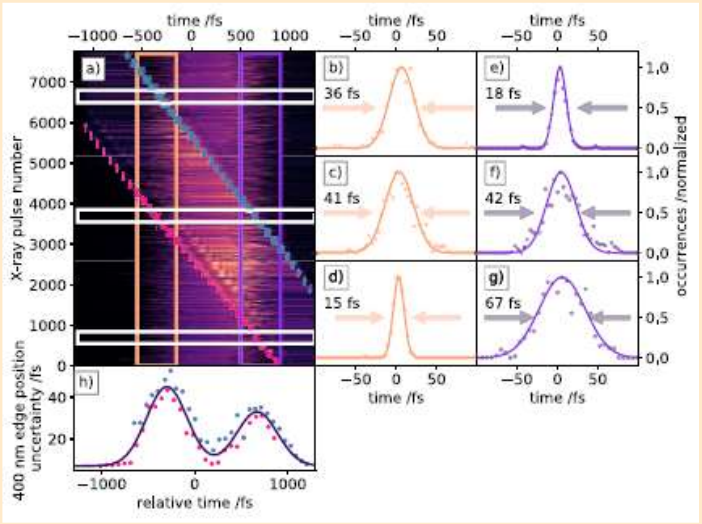








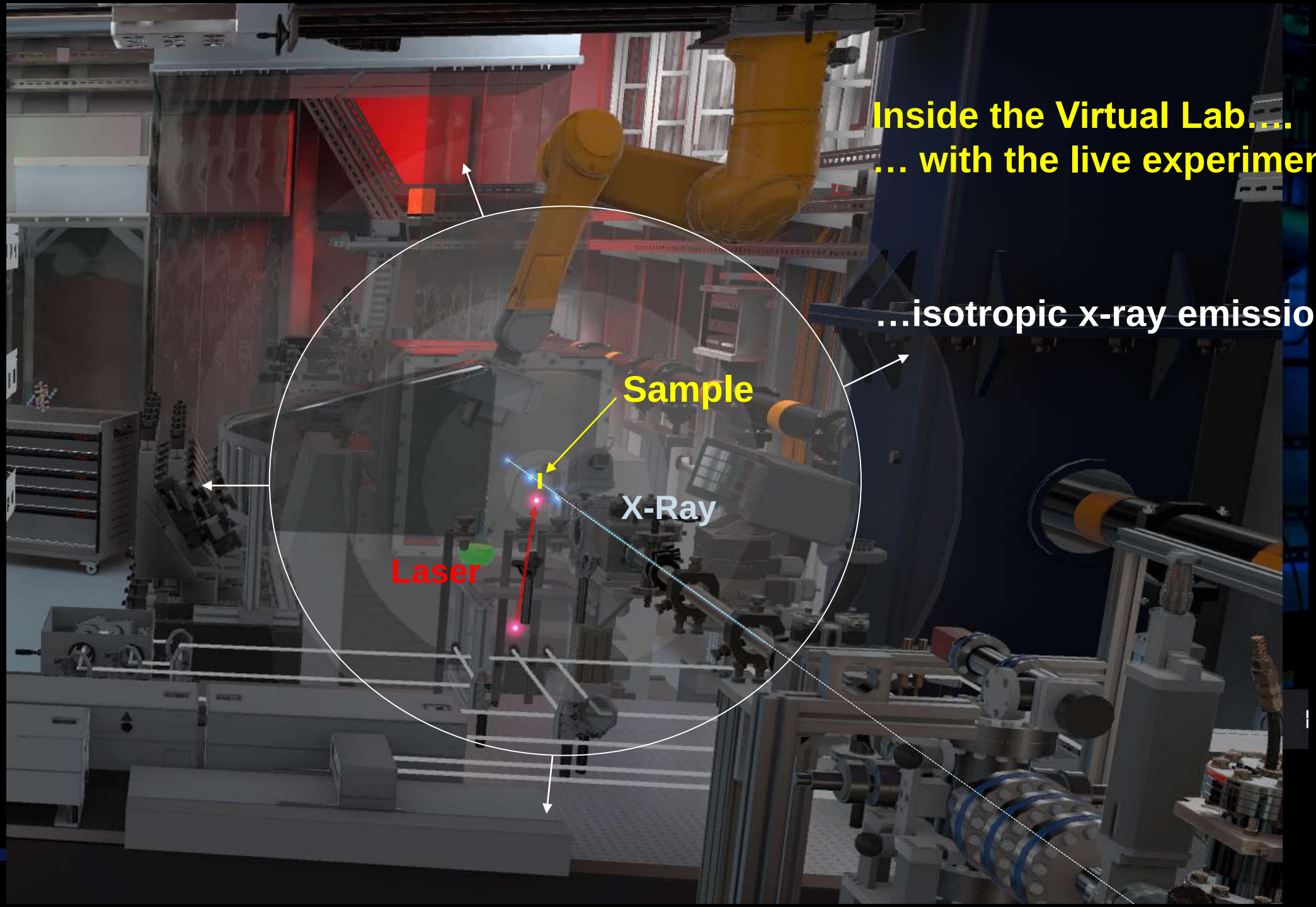


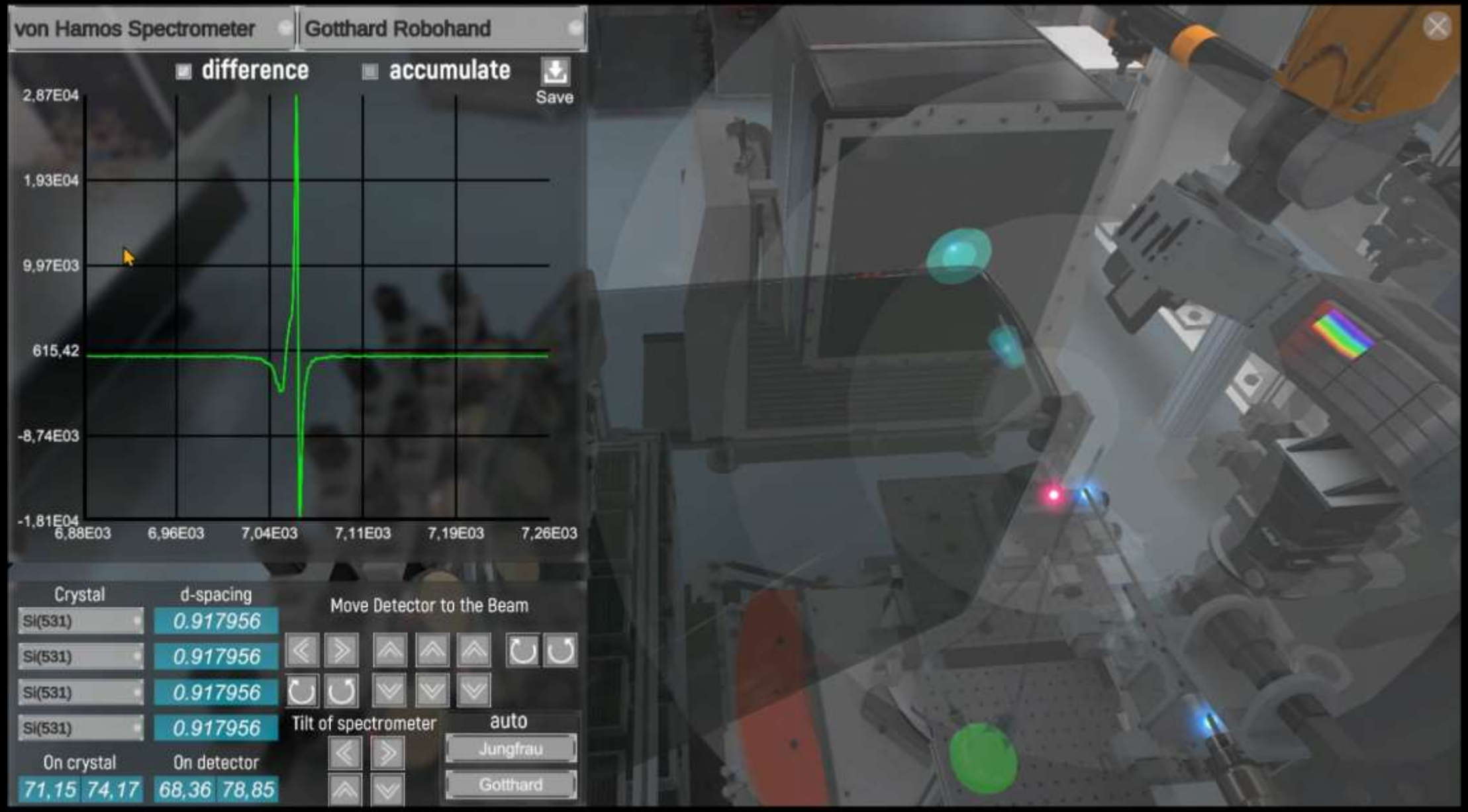


D. Khakhulin et al., Appl. Sci. (2020)
M. Diez et al., Scientific Reports (2021)

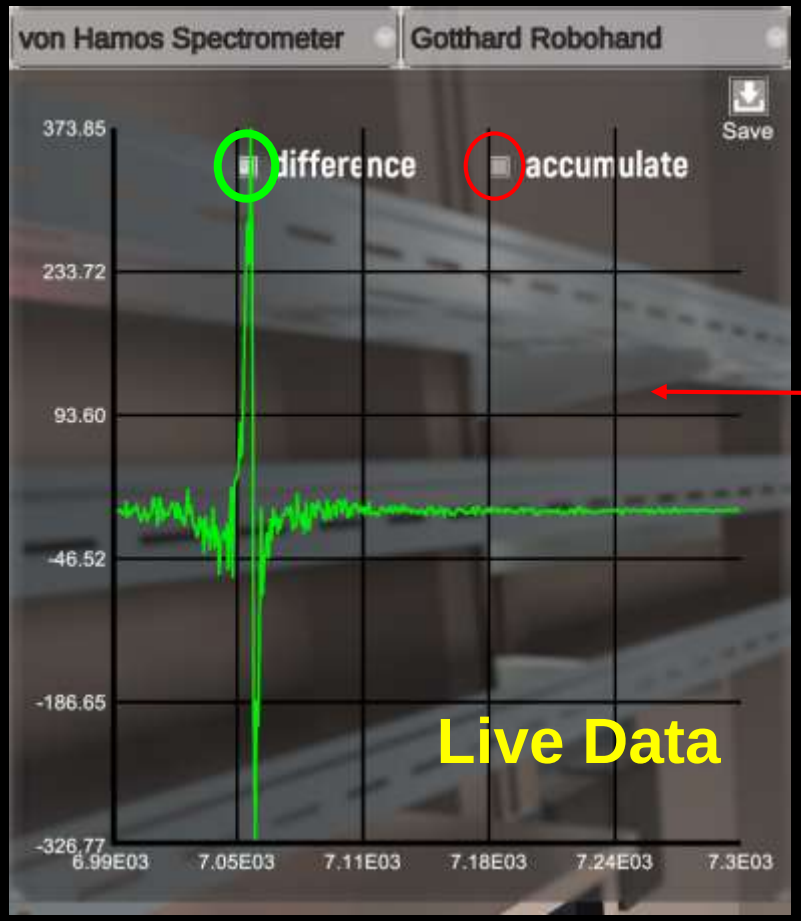
Inside the Real Lab….

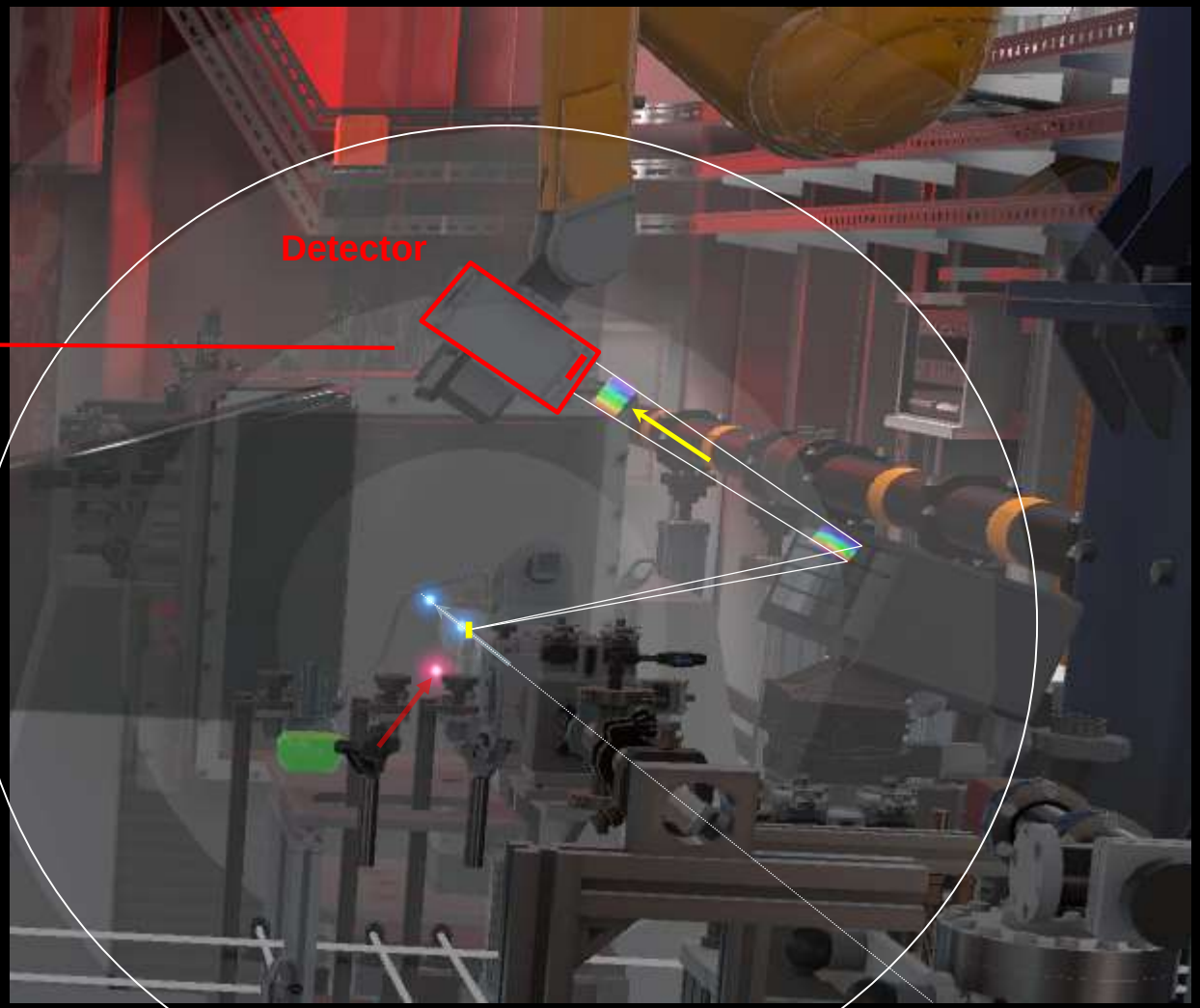

Inside the Virtual Lab….


Inside the Virtual Lab….
… with the live experiment
…isotropic x-ray emission
Sample
X-Ray
Laser


von Hamos Spectrometer
Gotthard Robohand
difference
accumulate
Save
2,87E04
1,93E04
9,97E03
615,42
-8,74E03
-1,81E04
6,88E03
6,96E03
7,04E03
7,11E03
7,19E03
7,26E03
Crystal
d-spacing
Si(531)
0.917956
Si(531)
0.917956
Si(531)
0.917956
Si(531)
0.917956
Move Detector to the Beam
Tilt of spectrometer
auto
Jungfrau
Gotthard
On crystal
On detector
71,15 74,17
68,36 78,85

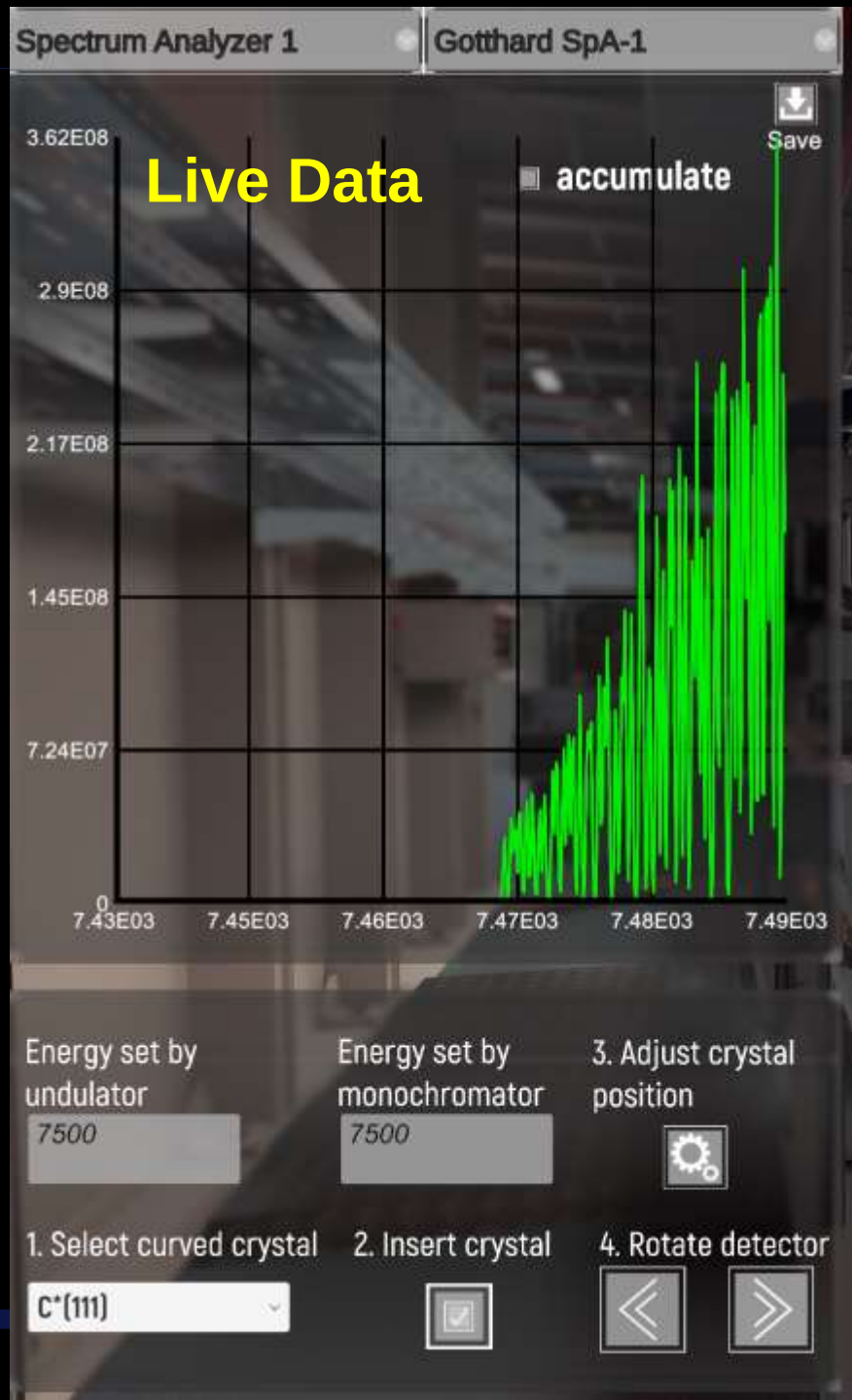
Experiment in Action

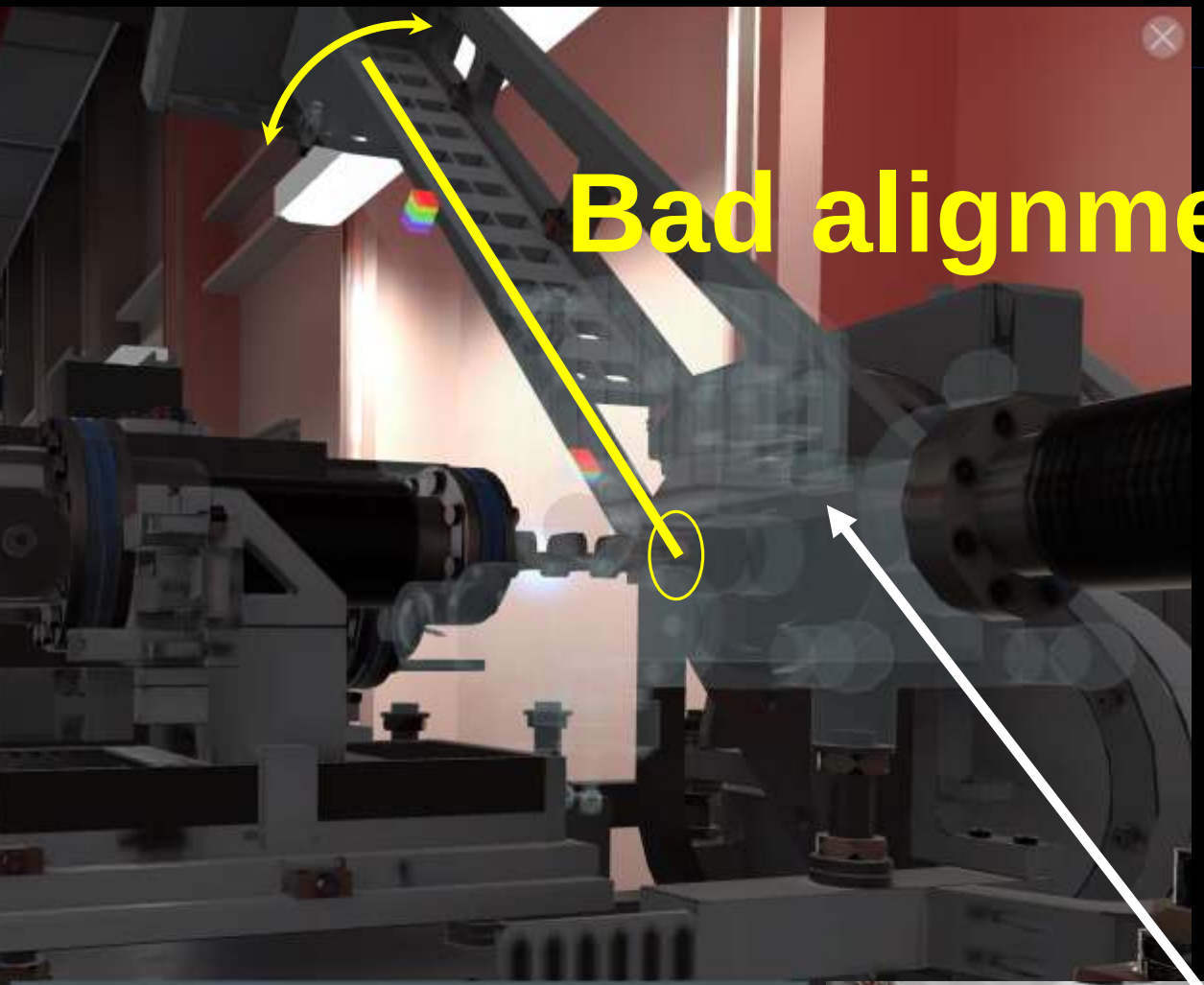




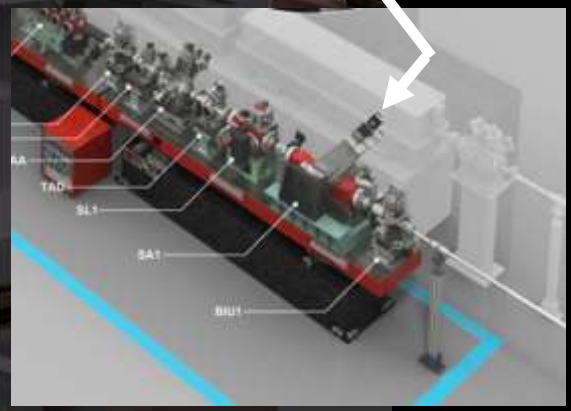

von Hamos Spectrometer
Gotthard Robohand
Save
406.72
342.71
278.71
214.70
150.70
86.69
difference
accumulate
7.69E03
7.83E03
7.97E03
8.1E03
8.24E03
8.37E03
Crystal
d-spacing
Si(531)
0.917956
Si(531)
0.917956
Si(531)
0.917956
Si(531)
0.917956
Move Detector to the Beam
Tilt of spectrometer
auto
Jungfrau
Gotthard
On crystal
On detector
70.38 73.44
53.75 61.35


von Hamos Spectrometer
Gotthard Robohand
Save
difference
accumulate
9.2E05
6.26E05
3.31E05
3.67E04
-2.58E05
-5.52E05
7E03
7.05E03
7.11E03
7.17E03
7.23E03
7.29E03
Crystal
d-spacing
Si(531)
0.917956
Si(531)
0.917956
Si(531)
0.917956
Si(531)
0.917956
Move Detector to the Beam
Tilt of spectrometer
auto
Jungfrau
Gotthard
On crystal
On detector
70.38 73.44
67.95 74.86

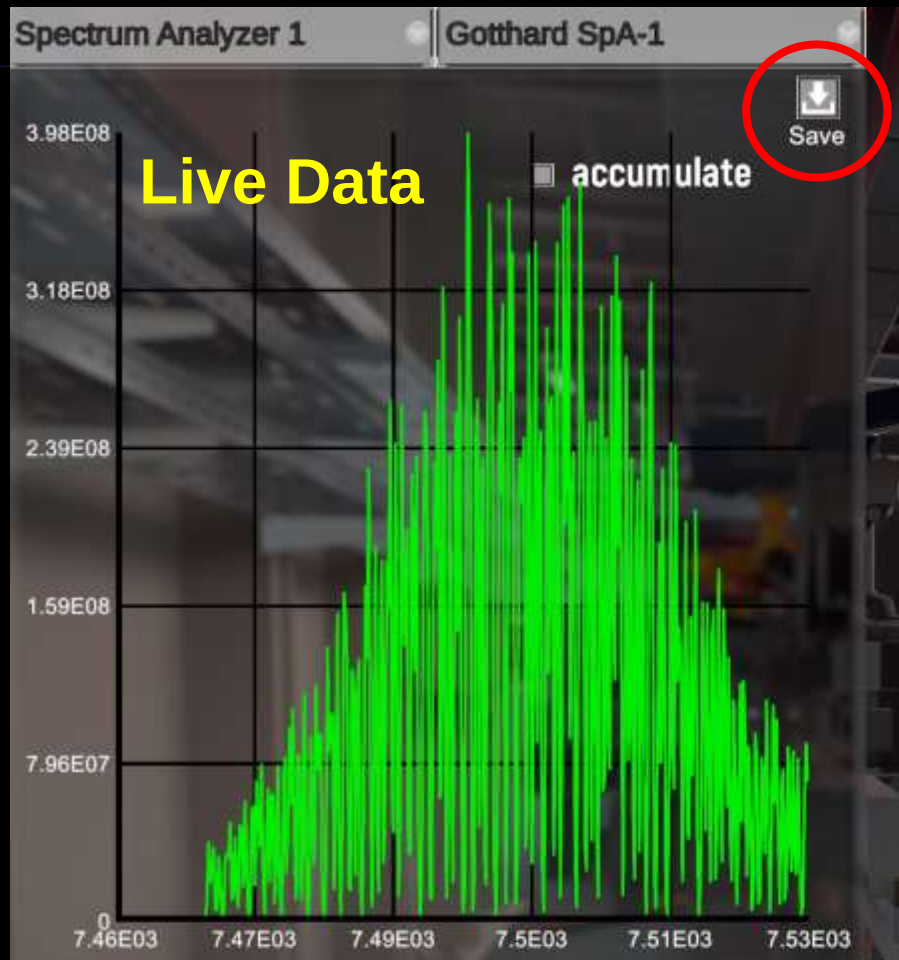

Spectrum Analyzer 1
Gotthard SpA-1
Save
Live Data
accumulate
3.62E08
2.9E08
2.17E08
1.45E08
7.24E07
0
7.43E03
7.45E03
7.46E03
7.47E03
7.48E03
7.49E03
Energy set by undulator
7500
Energy set by monochromator
7500
3. Adjust crystal position
1. Select curved crystal
C*(111)
2. Insert crystal
4. Rotate detector

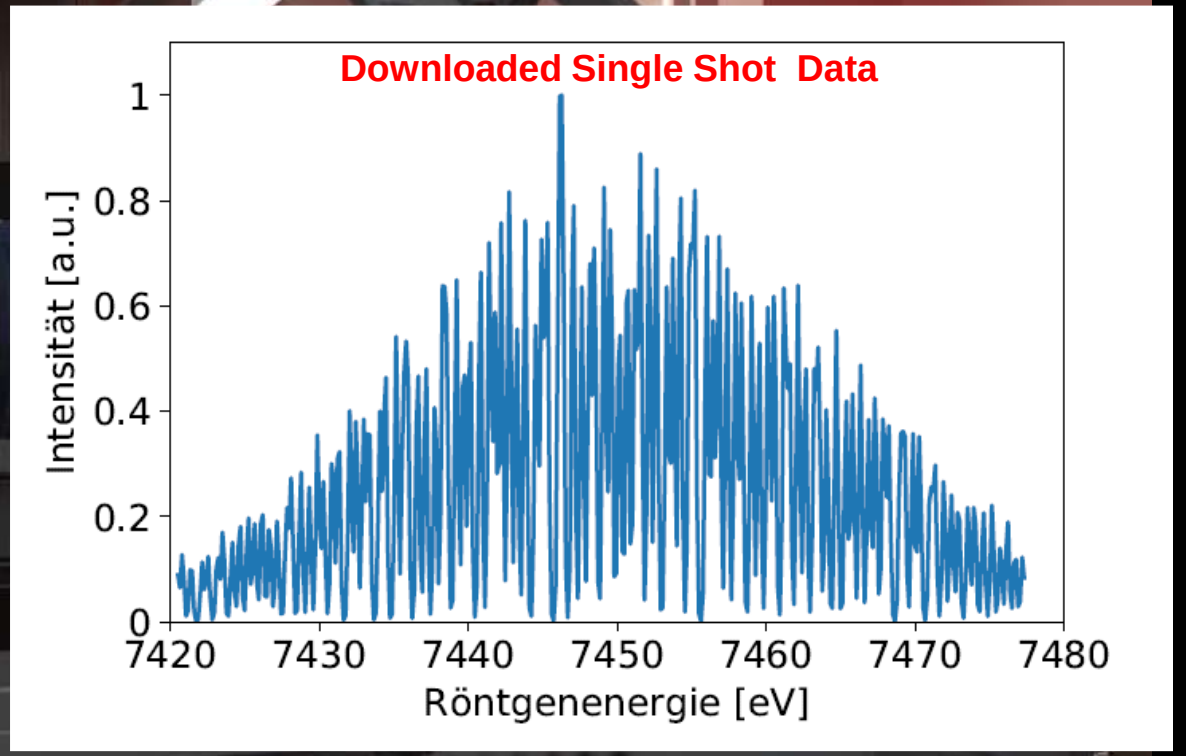

Bad alignment

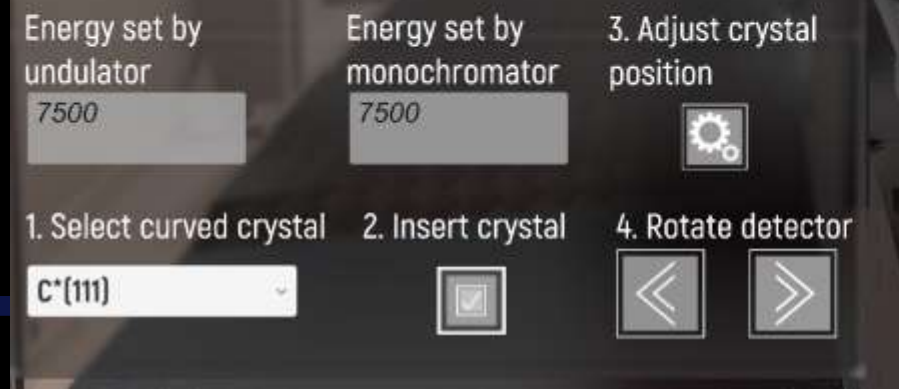

Bragg condition is satisfied
E=9300 eV
Bragg condition is not satisfied
E=9300 eV
θ2
θ1
Curved diamond C (111)



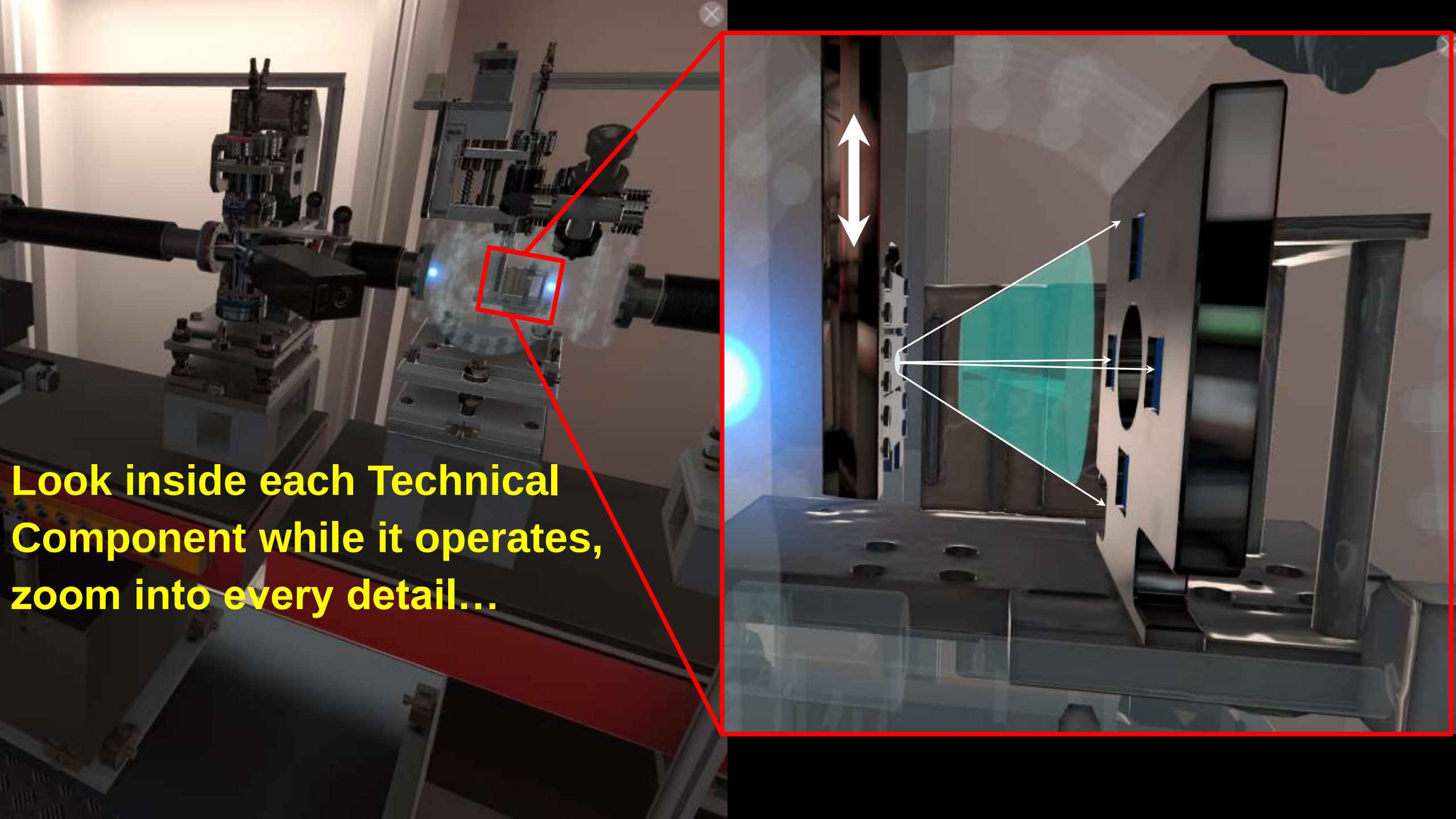
Good alignment



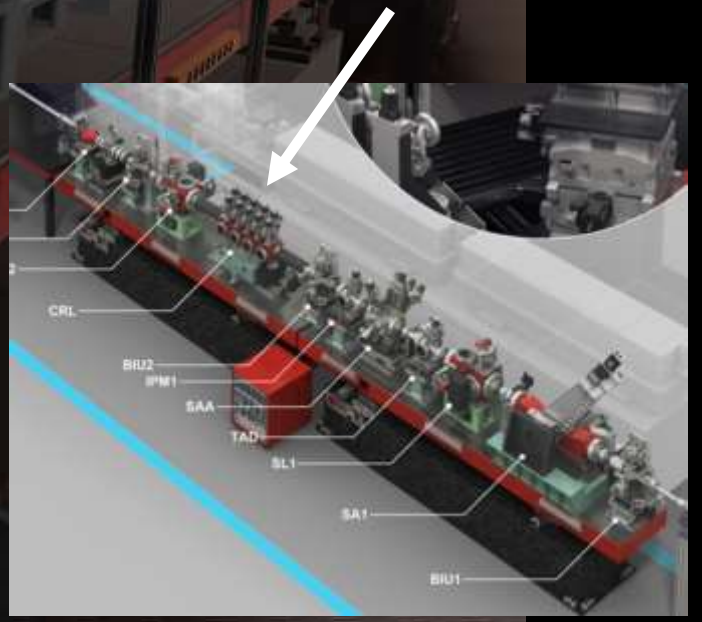


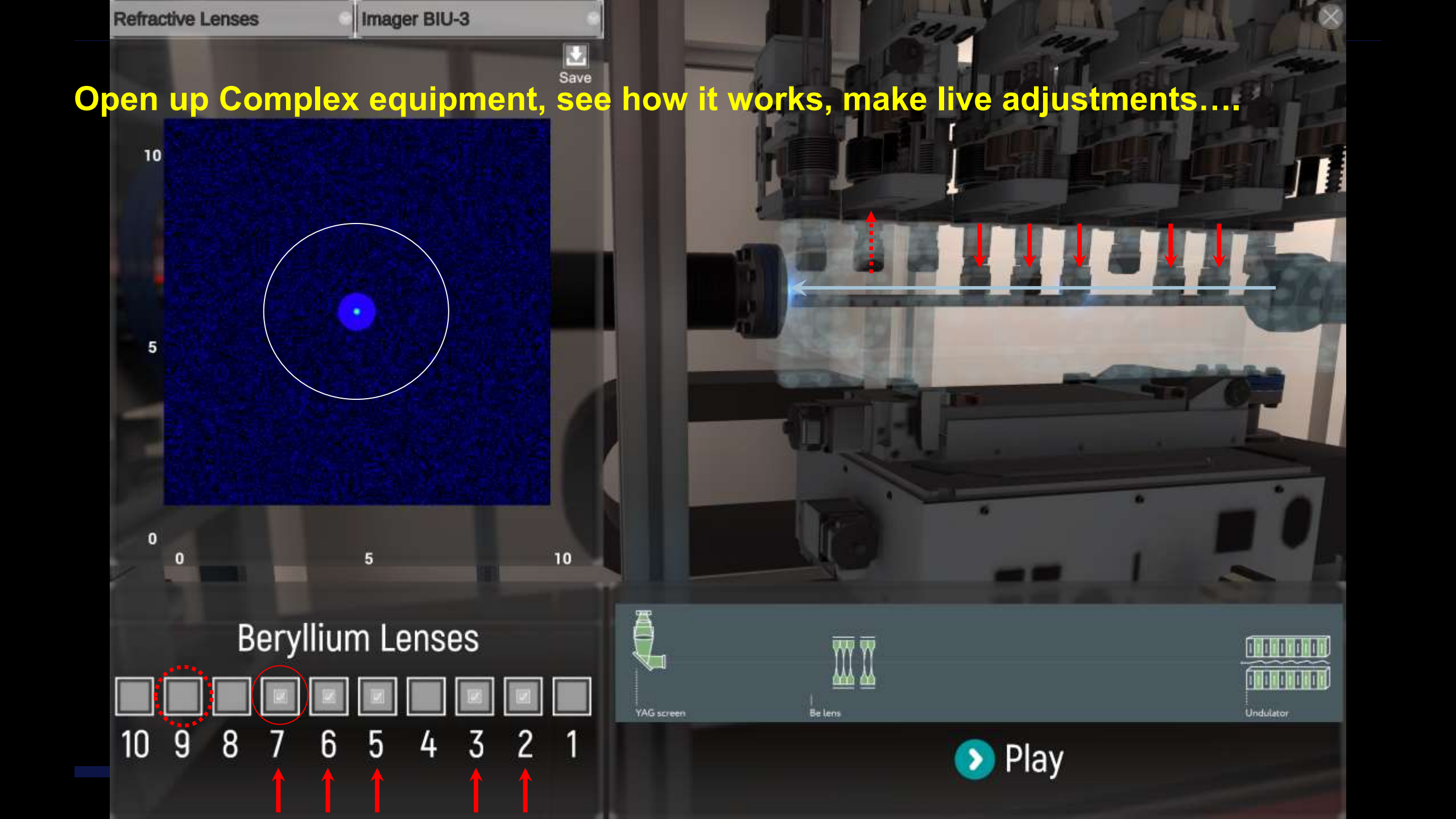



Spectrum Analyzer 1
Gotthard SpA-1
Save
accumulate
3.59E08
2.87E08
2.15E08
1.43E08
7.17E07
0
7.5E03
7.51E03
7.53E03
7.54E03
7.56E03
7.58E03
Energy set by undulator
7500
Energy set by monochromator
7480
3. Adjust crystal position
1. Select curved crystal
C*(111)
2. Insert crystal
4. Rotate detector
Bragg condition is satisfied
E=9300 eV
Bragg condition is not satisfied
E=9300 eV
Curved diamond C (111)

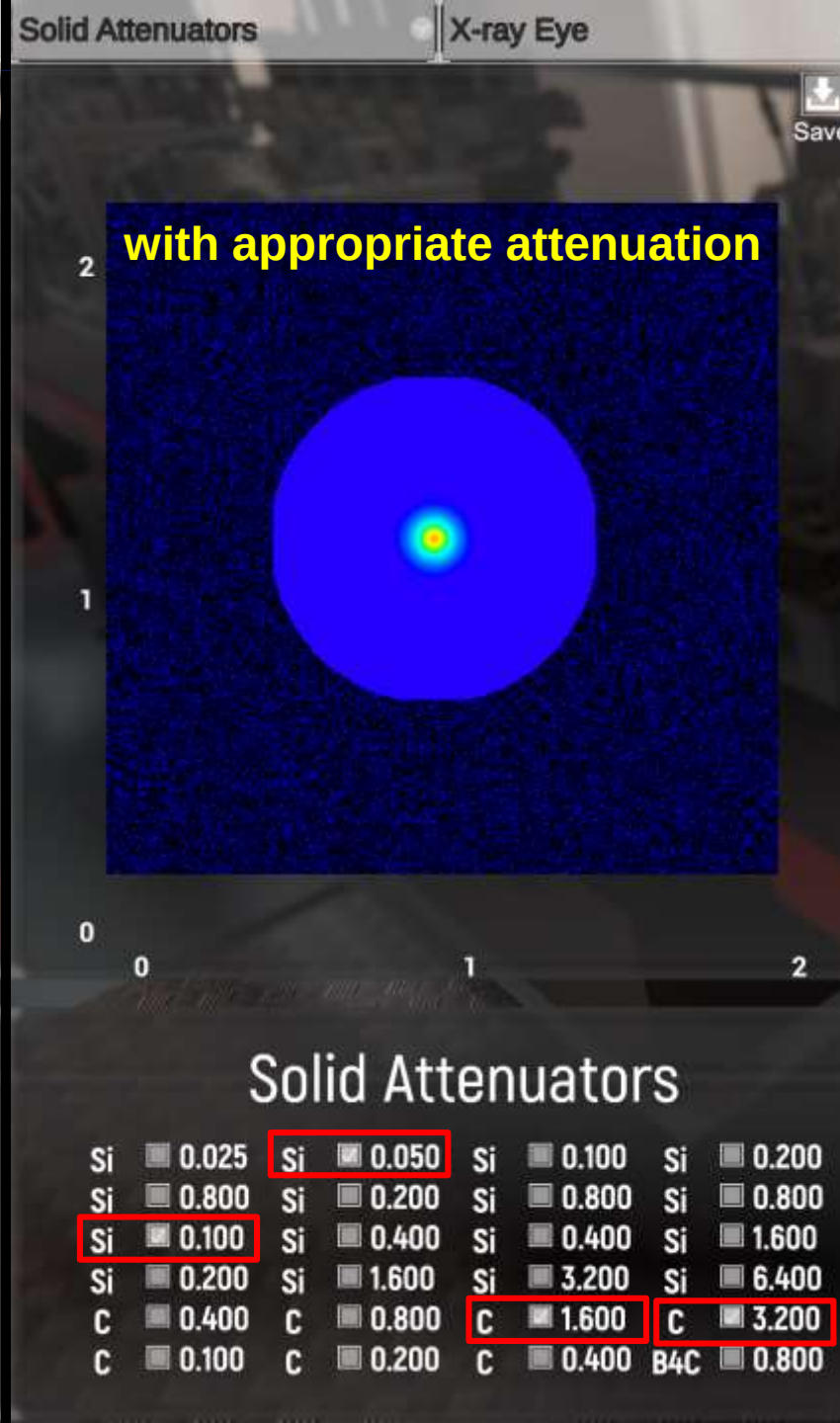

Look inside each Technical
Component while it operates,
zoom into every detail…

Open up Complex equipment, see how it works, make live adjustments….




Refractive Lenses
Imager BIU-3
Save
Open up Complex equipment, see how it works, make live adjustments….
10
5
0
0
5
10
Beryllium Lenses
10 9 8 7 6 5 4 3 2 1
YAG screen
Be lens
Undulator
Play

Screen images depend on incident intensity



Entering the VR Lab…
…the experiment control room

FORTGESCHRITTENPRAKTIKUM DER PHYSIK

Ultraschnelle Röntgen-Experimente

Virtuelle Experimente am Röntgenlaser European XFEL

Skript in Progress (Stand: 05. März 2021)

Universität Hamburg

CUI

- Implemented as **Advanced Lab-Practical Experiment** at the University of Hambuirg
- Test Run in March 2021 successful

- **Next Steps:**
  - short course (1 week) on Large-Scale Facility Experiments (**Bachelor/Master Level**)
  - include in Lecture on XFEL experiments
  - **PhD/postdoc** schools (HERCULES, etc.)
  - **Facility Users**
- **Other experimental environments**
  - SR Beamlines
  - other Labs possible
- **Include Undulators + Accelerators**
  → towards a fully virtual Large-Scale Facility
- **More ambitious Facilities**?? (CERN,…)

Virtual Reality:
A New Way to Enter a Lab

- Realistic scientific environment with physically meaningful parameters, signals and data
- Possibility to extend towards more complex experiments

"Flight Simulator for Physicists"

Acknowledgments:
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V. Myalkina, N. Namavir G. Okeshnikov

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DER FORSCHUNG | DER LEHRE | DER BILDUNG
CUI THE HAMBURG CENTRE FOR ULTRAFAST IMAGING

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European XFEL


Thank You for your attention