F-Praktikum Review Day: **EXP21 “Femtosecond X-Ray Experiments”, now in “Atom-, Molekül-und Laserphysik”, and no longer in “Themenübergreifend”**

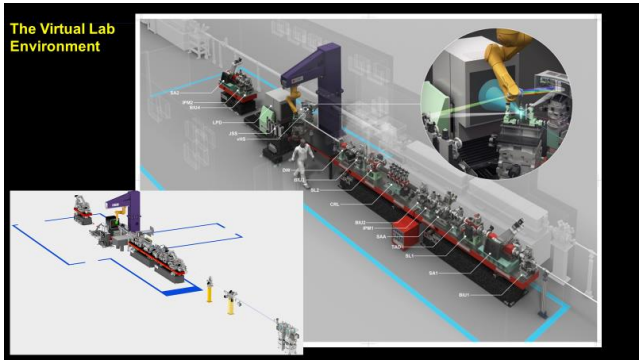
EXP21 represents a new teaching tool for experimental physics. We are also starting to blend it into a Masterstudent course (with partner university Aarhus):

EXP21 “Femtosecond X-Ray Experiments”

Scientific contest

- How is the experiment linked to the scientific bachelor program?
  Not so much for the Bachelor Course Lectures (yet… suggestions welcome)

- Added value to the experiment to the lectures
- Provides a first deep insight into a complex and modern experiment
- Provides a deep look into the basics of a typical SR beamline (FLASH, PETRA III, EuXFEL)
- Brings them super-close to contemporary experiments at EuXFEL



Specific points of reflection

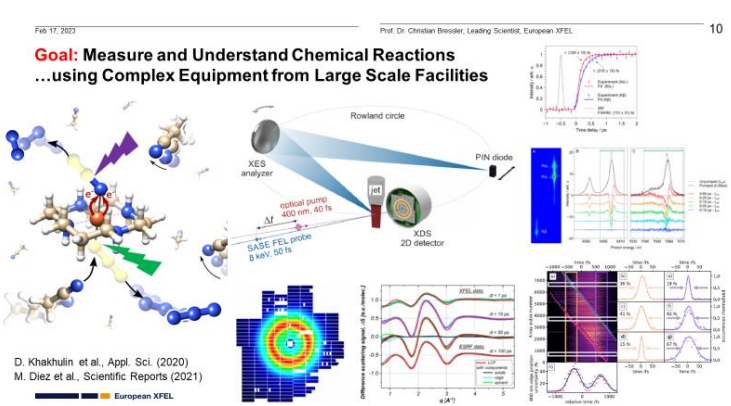
Aim of the experiment

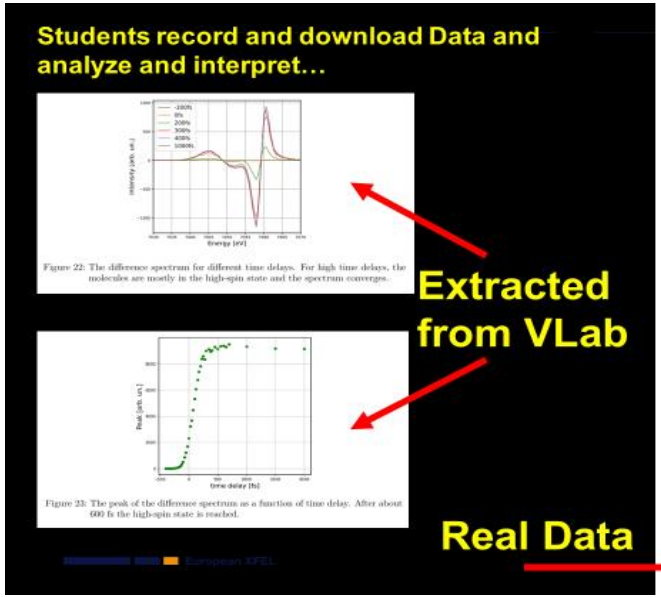
- What is the emphasis of the experiment? (data analysis, experimental method, systematic study, precision measurement, discovery…)
  in priority order: Experimental Method, systematic study, data analysis, discovery

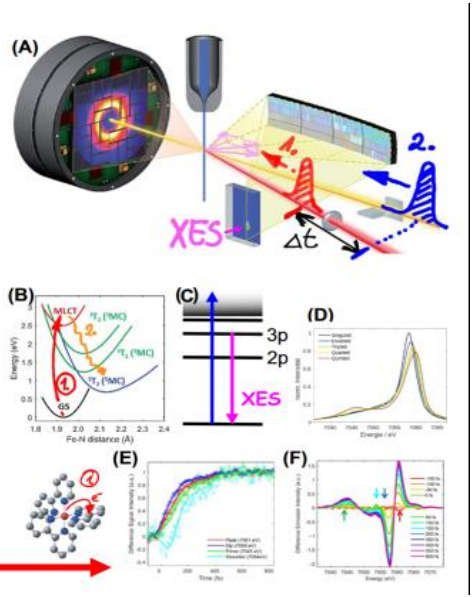
- Which aspects of the experimental method are particularly important?
  Basic aspects from large-scale light sources, from undulator source to experiment, Basic beamline Alignment, identifying basic beam properties (intensity, spectrum, spot sizes) for the experiment, light-matter interactions,…

- How does it compare to state of the art experiments in the research field?
  EXP21 is very close to a real EuXFEL beamline (digital twin), the (published) experimental data are actually fully extractable in VLab

Aim of the experiment







Specific points of reflection

Experimental setup (The black box)

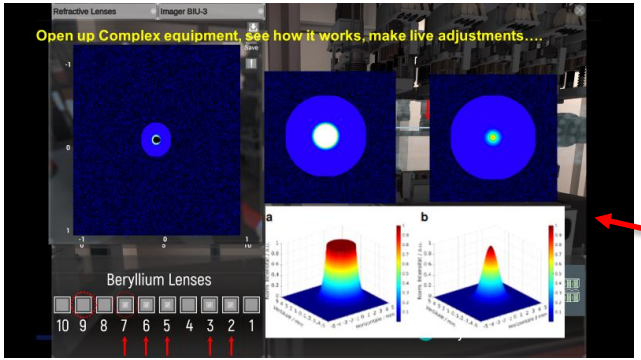
- Do students have the possibility to assemble the setup?
- Can they modify parameter? What is the largest systematic effect?
- Do they learn how is the measurable “signal” obtained?

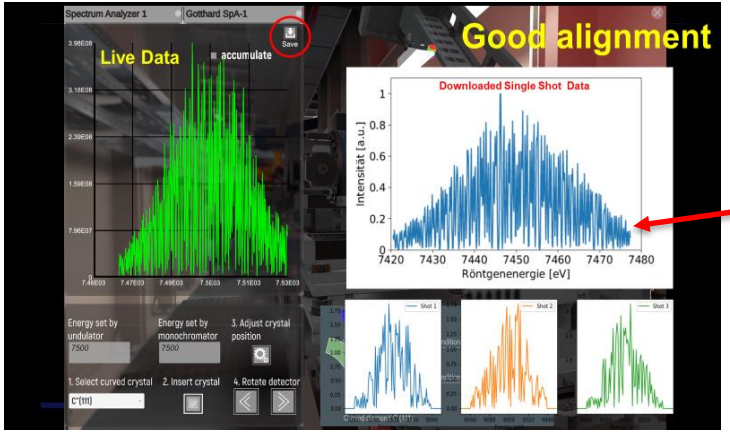
Note: also for experiments based on already available data it is essential that the students gain understanding of the setup that generated their data, difference between raw data and calibrated data, systematic effects

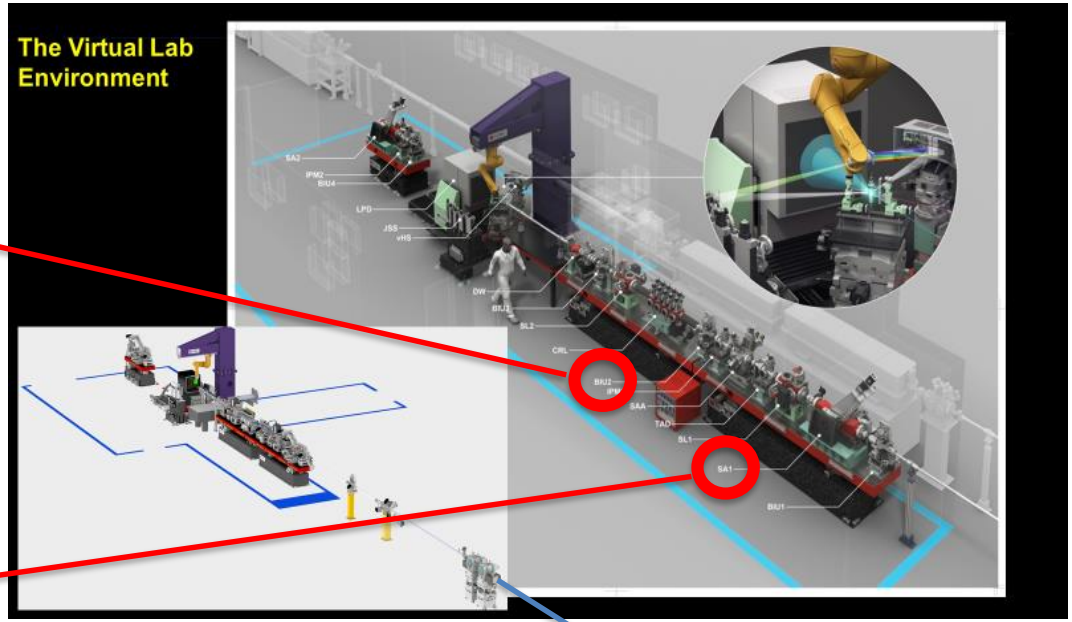
No self-assembly (yet…), ample control of most parameters, decides whether they observe anything, noisy data, or useful data. The script stepwise guides them to understand/document every bit of the setup.

They modify parameters to receive better or worse signals, they learn about the basic input (flux, spot size), but Vlab is currently underway to implement more detector-related characteristics.

Experimental setup (The black box)







1 km to x-ray source
(virtual undulator)

Specific points of reflection

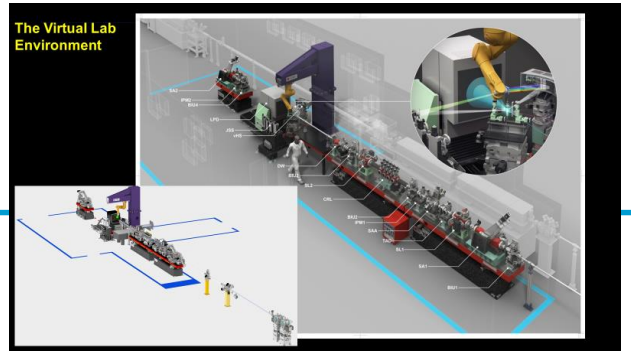
Data analysis method (The other black box)

- Is data analysis a key aspect of this experiment?
- What are the challenges?
- Ideally students should analyse the data with own written code
- If this is not the case, they still should gain understanding of what the provided code does.
- Particular attention to statistical treatment of data: error treatment, binning, fit quality, …

Basic plotting of usefully extracted data, 2D plots with false-color scales, currently part/part: some do the above themselves, others depend on delivered python codes

Statistics: currently further under development, few case examples implemented but more relevant ones underway in VLab

Specific points of reflection



Key scientific results

- What do students learn from this experiment?
- What is the precision achieved ? How does it compare to literature / state of the art?
- What is the emphasis of the experiment?
- Which skills do students learn?

- How to think all the way through a “real” SR beamline and design of an experiment. E.g. need to characterize the beam along the entire beampath (record data…)
- Results reflect (recent!) published results with that experimental precision
- Emphasis: experience an experiment without the usual boundaries in Fprak-experiments, learn how to reliably establish a functional experimental environment, understand that selected XES tools aim to reveal otherwise inaccessible information (e.g., fs laserlab experiments)
- Skills: all of the above

Specific points of reflection

Link to modern research in the physics department

(if applicable links to clusters of excellence)

- What is the modern application of this technologies / experimental methods
- In which group are these technologies / experimental methods applied
- What skills do the students gain which can be used in the research group?
- What is the difference between state of the art equipment and the F-praktikum setup?

- EXP21 is already a modern research experiment in the physics department
- Represents a digitial twin of an existing EuXFEL beamline, several UHH and CUI groups use these methods (and variants of): Huse, Martens, Rübhausen, Chapman, …
- pump-probe, XAS, XANES, XES, (powder diffraction, EXAFS…)
- Hardly any difference in methodology to contemporary experiments, details still scarce, but growing over time

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Grade your experiment

Each F-praktikum experiment accounts for 2.5 LP (= 2.5 Semester Wochen Stunden)

This should correspond to:

- 3 full days Lab in presence [à 8h] for data taking & fast analysis [24 h]
- Analysis and Protocol (<20 page) [14 h]
- 5 days of experimenting/pre-analysis/pre-protocol (according to experience)
- Ca 1-2 days of post-analysis and protocol

Grade the complexity of the various aspects of your experiment in a scale from 1-5 where 1 is high and 5 low

Theory / preparation	Setup / experimental	Data taking	Analysis	Protokol
3	1-2	2	2	3

Fortgeschrittene Praktikum

Leistungs Punkte (12 LP)

Statistik & Computer (2 LP)

- Lectures 5 days [3 h/ day]
- Exercise 5 days [3 h/ day]

KV (1.5 LP)

- 1 day Lab in presence: data taking & analysis [8 h]
- Short protocol (<10 pages) [6 h]

Seminarvortrag (1 LP)

- 15 min talk + rehearsal [12 h]

3x Versuche (2.5 LP)

Festkörper- Teilchen- und Laserphysik

- 3 days Lab in presence: data taking & fast analysis [24 h]
- Analysis and Long Protocol (<20 page) [14 h]

1 LP = 14 h work