HXRSS user delivery experiences

Shan Liu
on behalf of the HXRSS team

Beam dynamics meeting
Hamburg, 16.11.2021

HXRSS principle

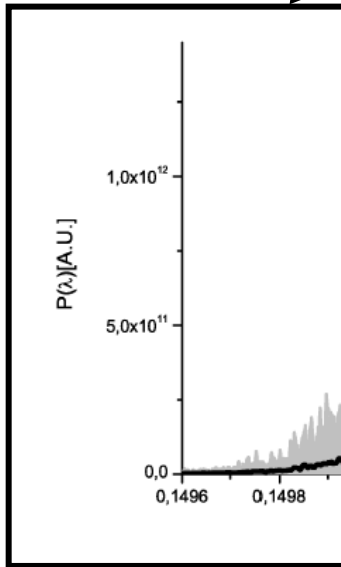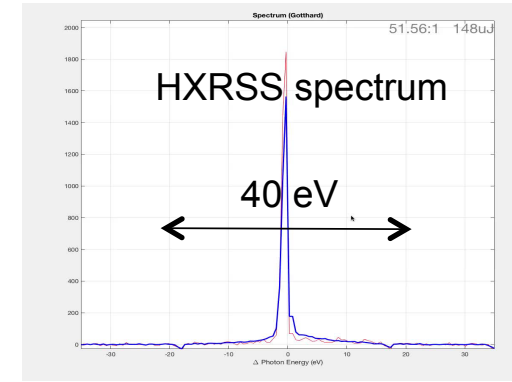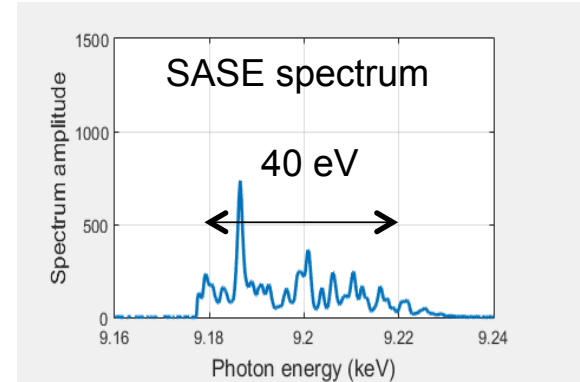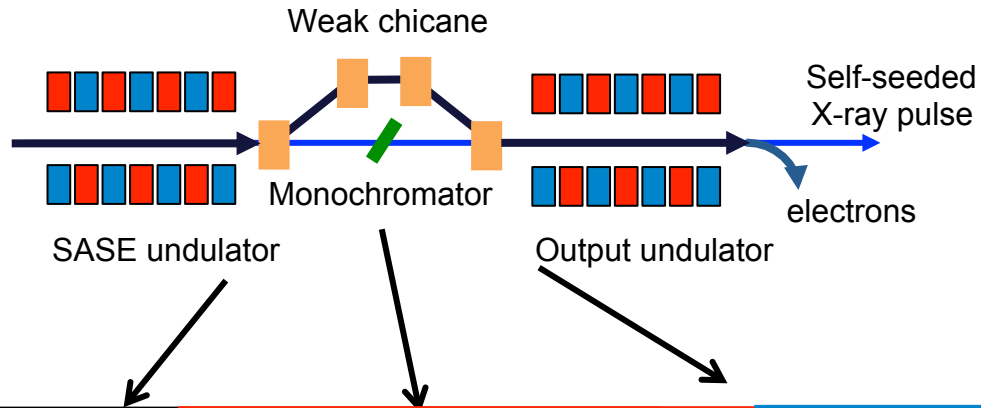SASE spectrum
40 eV

HXRSS spectrum
40 eV

Weak chicane

Self-seeded X-ray pulse

Monochromator

electrons

SASE undulator   Output undulator

Monochromatic tail ("Forward Bragg diffraction")

* G. Geloni, V. Kocharyan, E. Saldin (*DESY 10-133*)
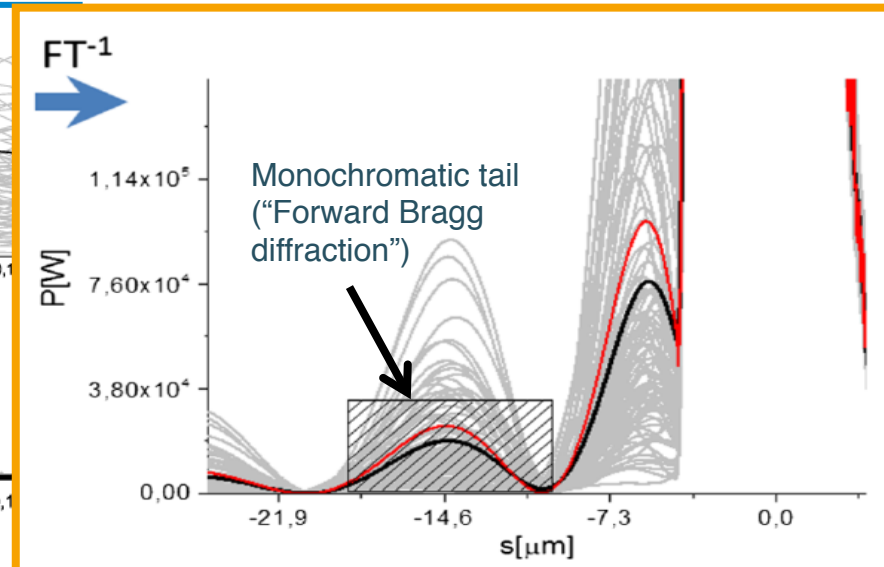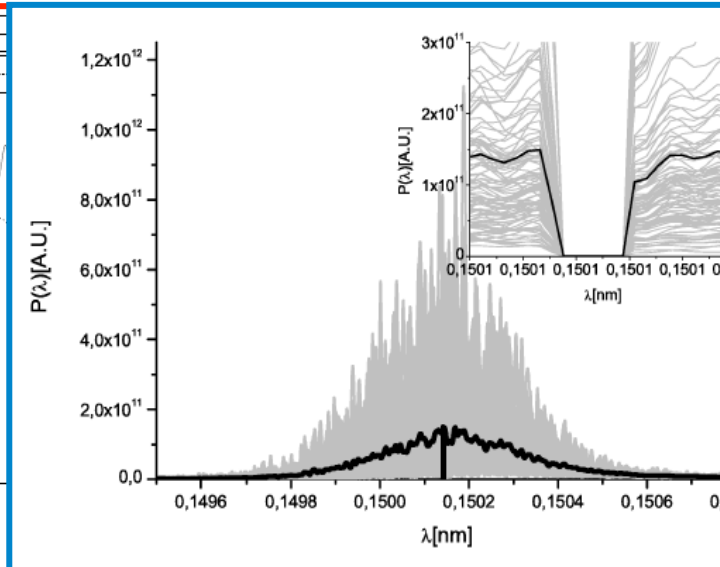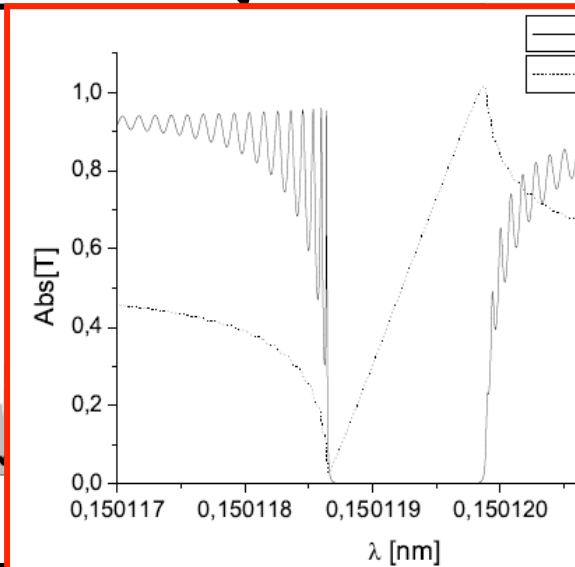
HXRSS and Monochromator panel

HIREX* diagnostic spectrometer

* **HIREX** = **HI**gh **RE**solution hard **X**-ray
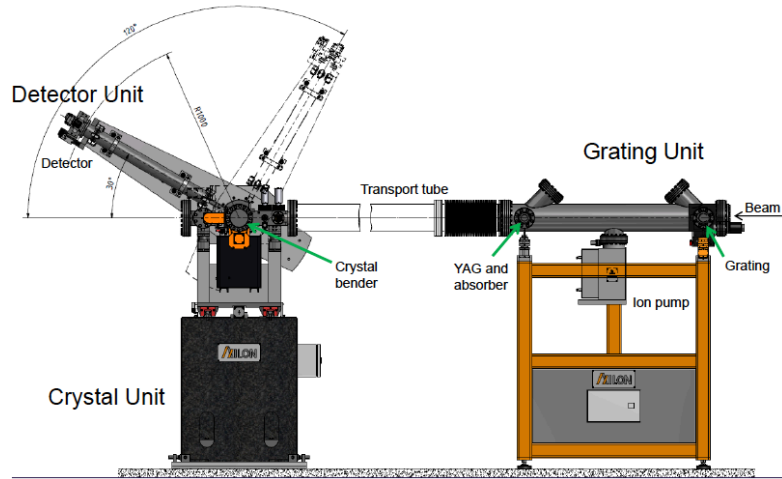
- **Shot-resolved spectra of pulsed X-ray beams at MHz rates**

- Covers hard x-ray range **5 - 20keV**

- **High resolving power** of up to 40,000 (resolution 0.2 eV at 8 keV)

- Energy calibration by changing crystal pitch

- Gotthard detector signal processing (especially for multi bunches) will be improved by upgrading to Gotthard-II)

J. Grünert et al., JSR 26 (5), 1422 (2019)

European XFEL

Developed by Naresh Kujala

Developed by S. Tomin, S. Serkez et al.

Crystal calibration

9keV

black C*[3-1-1], C*[1-31], Red C*[111], green C*[220], purple C*[33-1] with incident direction [00-1] at 13 keV

12.9 keV

- **Py-Hirex** development (correlator 1D and 2D)
- One application: easier crystal calibration
- Had only preliminary calibration
- Tool used for a number of purposes

European XFEL
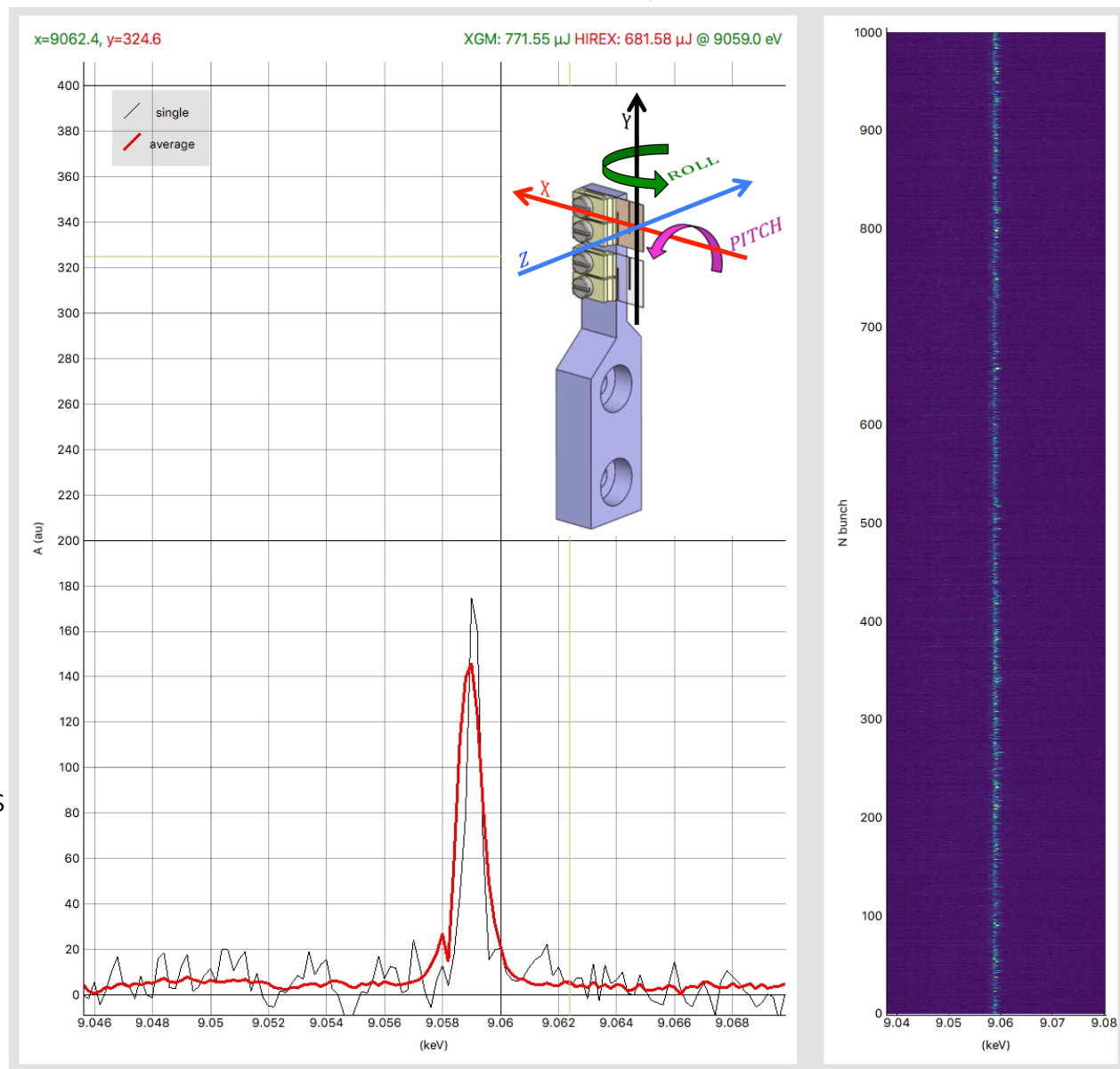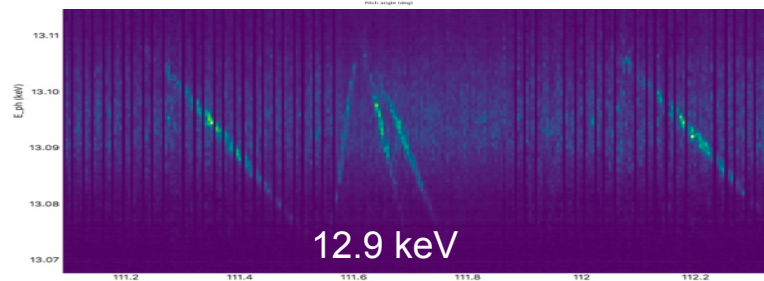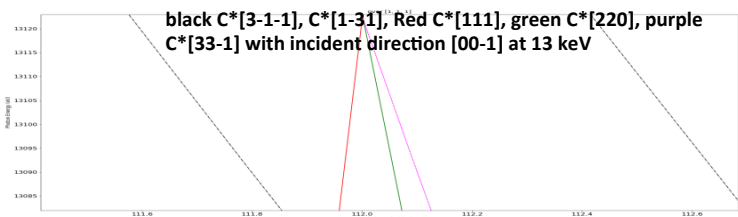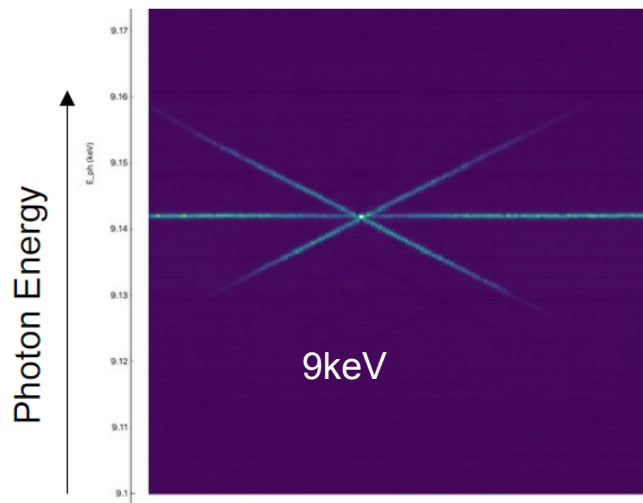
Energy Calibration Tool

Developed by Christian Grech

Calculator

| **Measurement** | **Model** |

2. Detected line in red

5. Display of the model in the scanned area

[3,3,1]
[3,3,5]
[4,0,4]
[4,2,2]
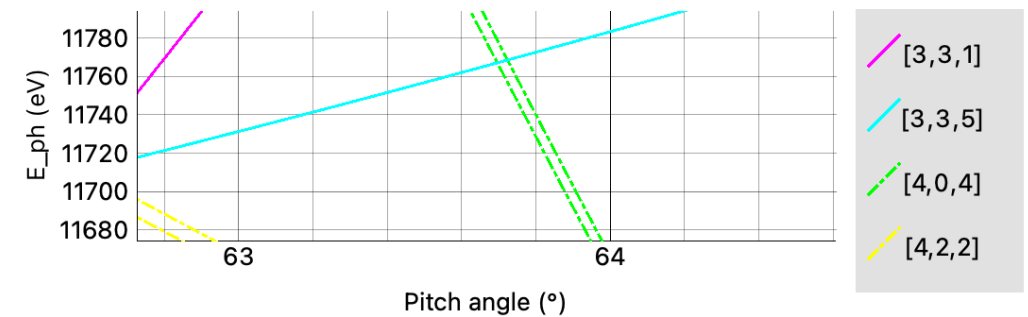
3. ML classifier predicts that this line is [3, 3, 5]

Calculate from file

| File name: | 20211102-12_54_53_cor2d.npz | Browse |
| Roll angle: | 1,2677 ° | |

1. Input image information

Monochromator 2 image found;
Machine status file found: roll angle=1.2677 deg

Reset

Logs

Image binarization complete
1 line(s) found
Id:[3,3,5] matched to line with
centroid: 63.2 deg

6. Save info in DOOCS/logbook

Logbook | Update DOOCS
| Load from DOOCS

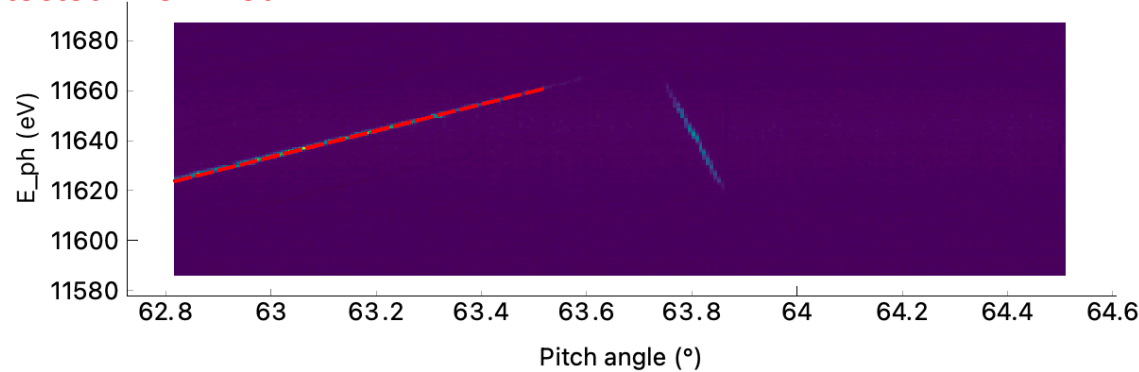|	Parameter	Current value	Proposed val
1	[3,3,5] Eoff	–	97.5 eV
2	[3,3,5]ev/px	0.597	0.57
3	Avg.ev/px	–	0.57
4	Avg.Eoff	–	97.5 eV
5	Eo	11647.0 eV	11744.0 eV
6			

4. Calculated offset (Avg.Eoff), pixel calibration (Avg.ev/px) and new Central Energy (Eo).

Software for HXRSS Crystal Control

Development in progress by Christoph Lechner
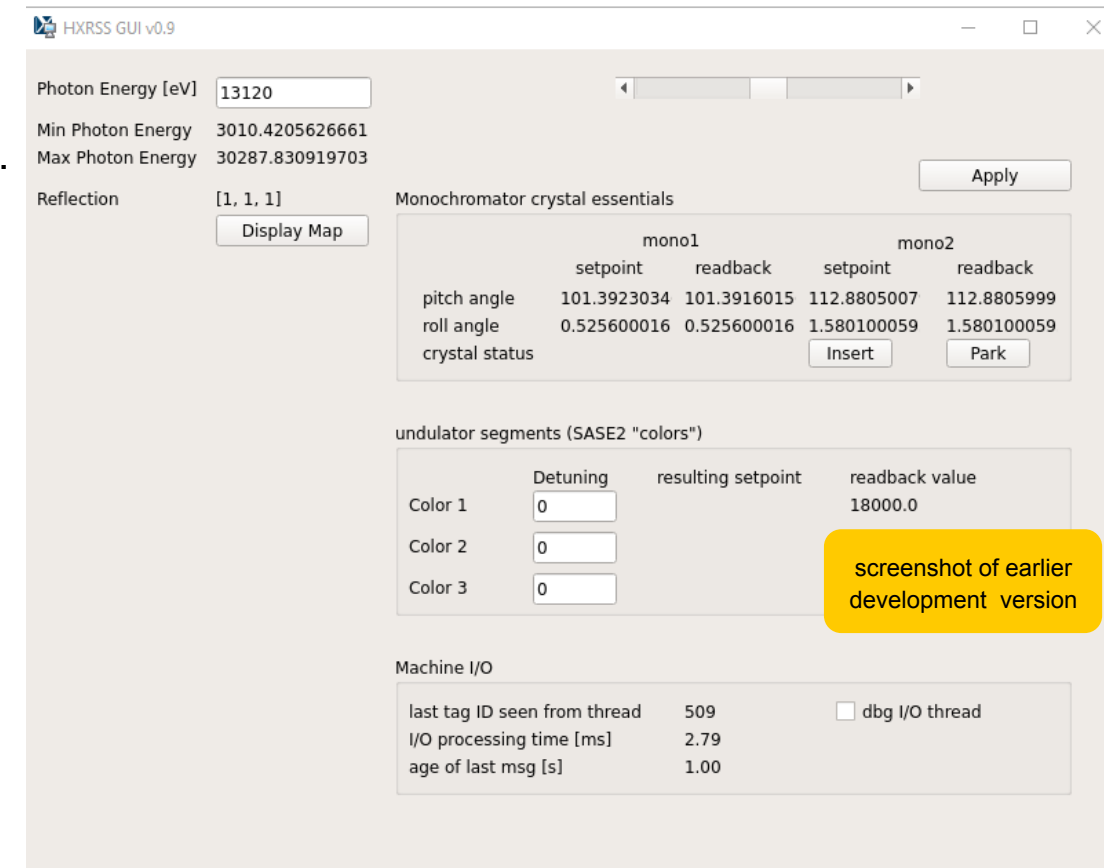
- **Challenges during HXRSS operation**
  - Significant wavelength shifts require simultaneous adjustments of multiple devices: crystal motors, undulators, ...
  - Take into account imperfections of the system, for instance: corrections of setpoints due to imperfect crystal mounting

- **Tool for HXRSS (crystal) operation is being developed**
  - Key task: Translate desired photon energy into crystal orientation, following curve of desired crystal reflection
  - Apply correction parameters as determined by Christian Grech's analysis tool

- **Ultimate goal: Produce tool for HXRSS routine operation**
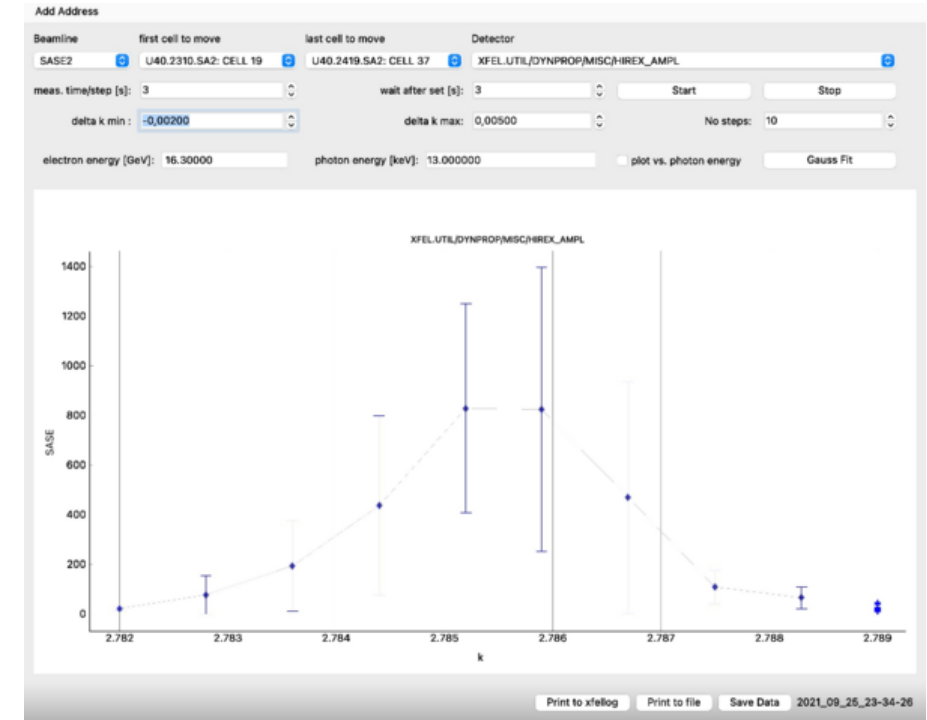 - Implement features such as undulator gap control

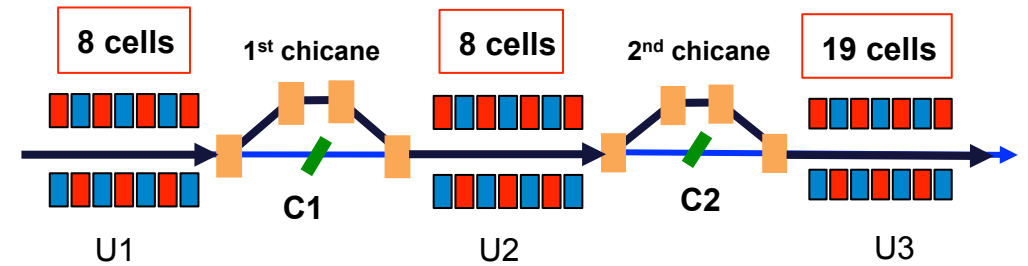**European XFEL**

Undulator panel and detune scan tool
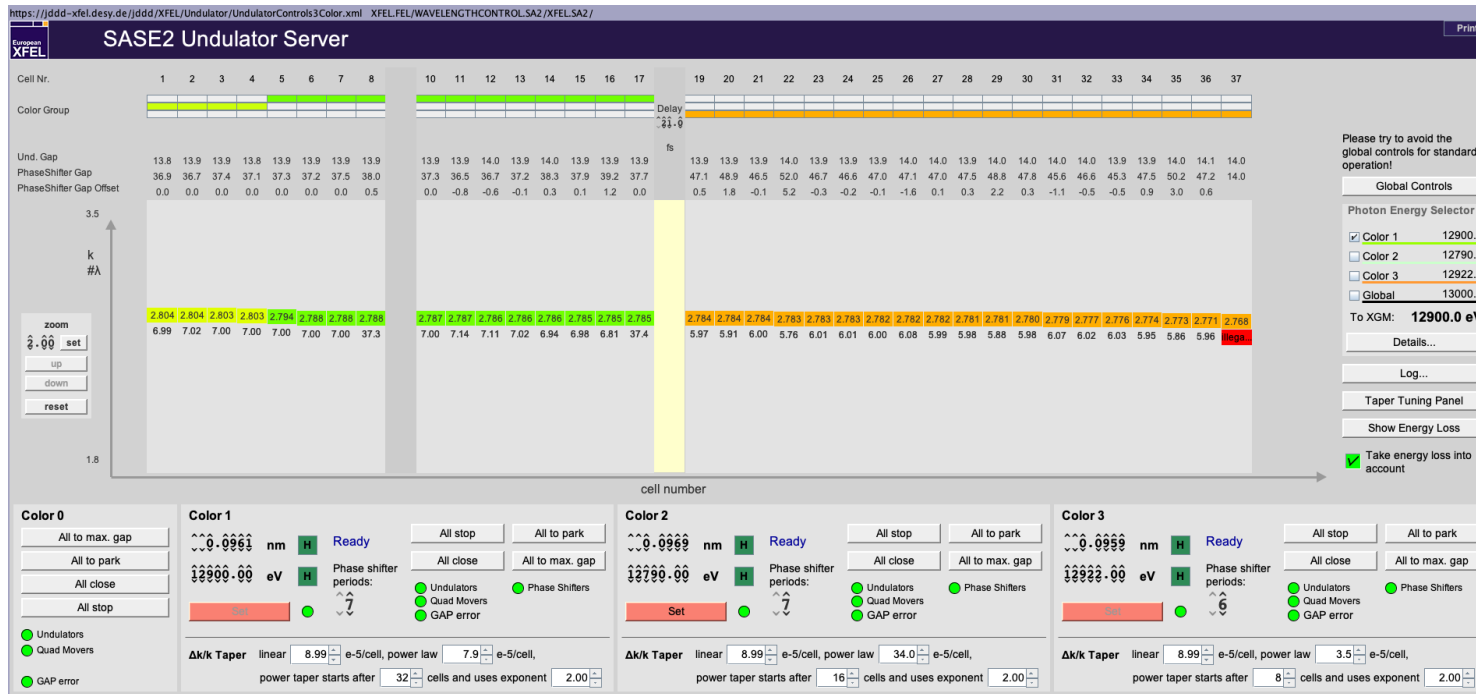
Developed by Olaf Hensler

Developed by Frank Brinker

European XFEL

HXRSS- User Runs in 2021

■ 4 user runs in Sept.-Nov. with different photon energies

■ Set-up time depends highly on the orbit

before BBA
(only 10 cells downstream 2nd chicane contribute)

after BBA
(18 cells downstream 2nd chicane contribute)

|	7.5 keV (KW37, HED)	9 keV (KW36, MID)	11.5 keV (KW44, MID)	12.9 keV (KW40, HED)	18 keV (KW45, tested not delivered)
e- beam energy	11.5 GeV	11.5 GeV	16.5 GeV	16.5 GeV	16.5 GeV
SASE performance	1.5 mJ (140 uJ/eV)	1 mJ (40 uJ/eV)	2 mJ (60 uJ/eV)	2 mJ (100 uJ/eV)	1 mJ (60 uJ/eV)
Seeding with 2nd chicane	-	250 uJ (160 uJ/eV)	700 uJ (300 uJ BG, up to 400 uJ/eV)	300-500 uJ (800 uJ/eV)	uJ level
Seeding with two chicanes	200 uJ (250 uJ/eV)	-	-	-	-
Seeding bandwidth (FWHM)	~0.6 eV	~0.8 eV	~0.7 eV	~0.6 eV	-

European XFEL

First user run at 9 keV

- 11.5 GeV, 250 pC e- beam @9 keV with 2.2 MHz

- Up to 1 mJ **SASE** with **40 uJ/eV** peak signal

- Up to 250 uJ **seeded** with up to **160 uJ/eV**
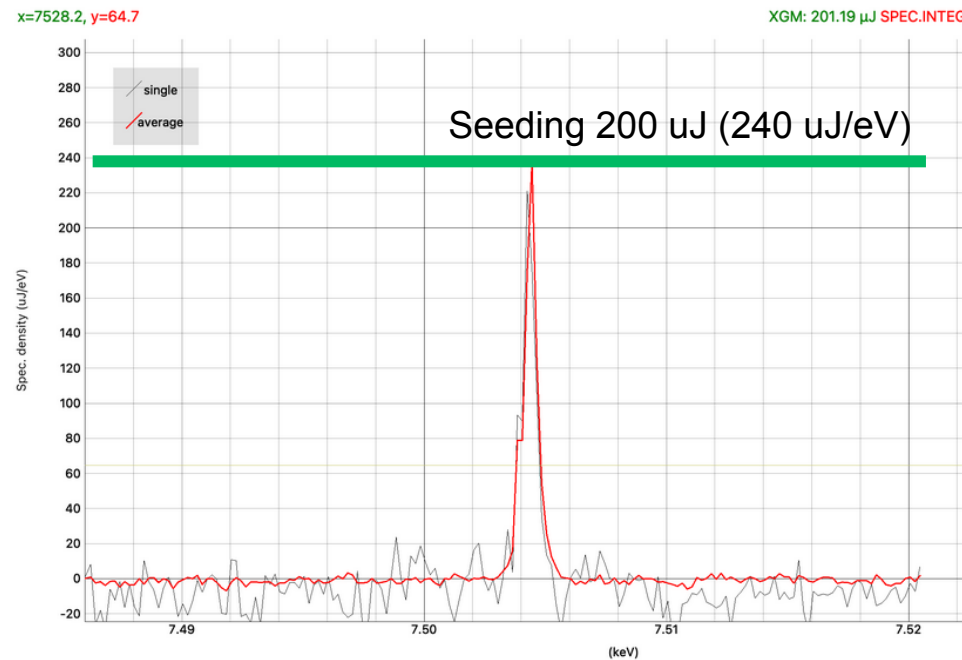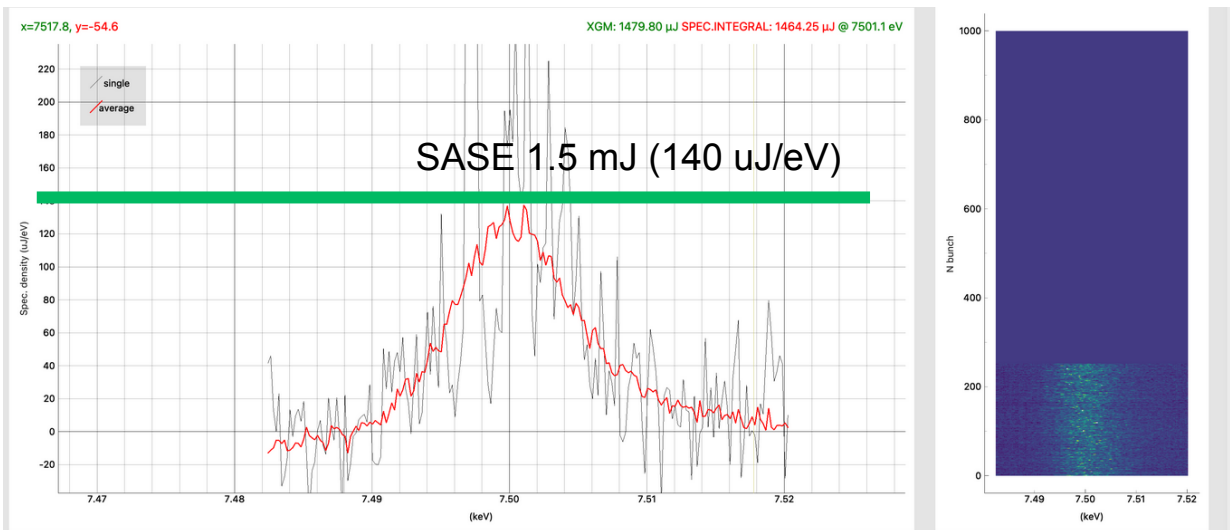
- Difficult to have cell 29+ lasing

40 uJ/eV
FWHM ~25 eV

160 uJ/eV
FWHM ~0.8 eV

European XFEL
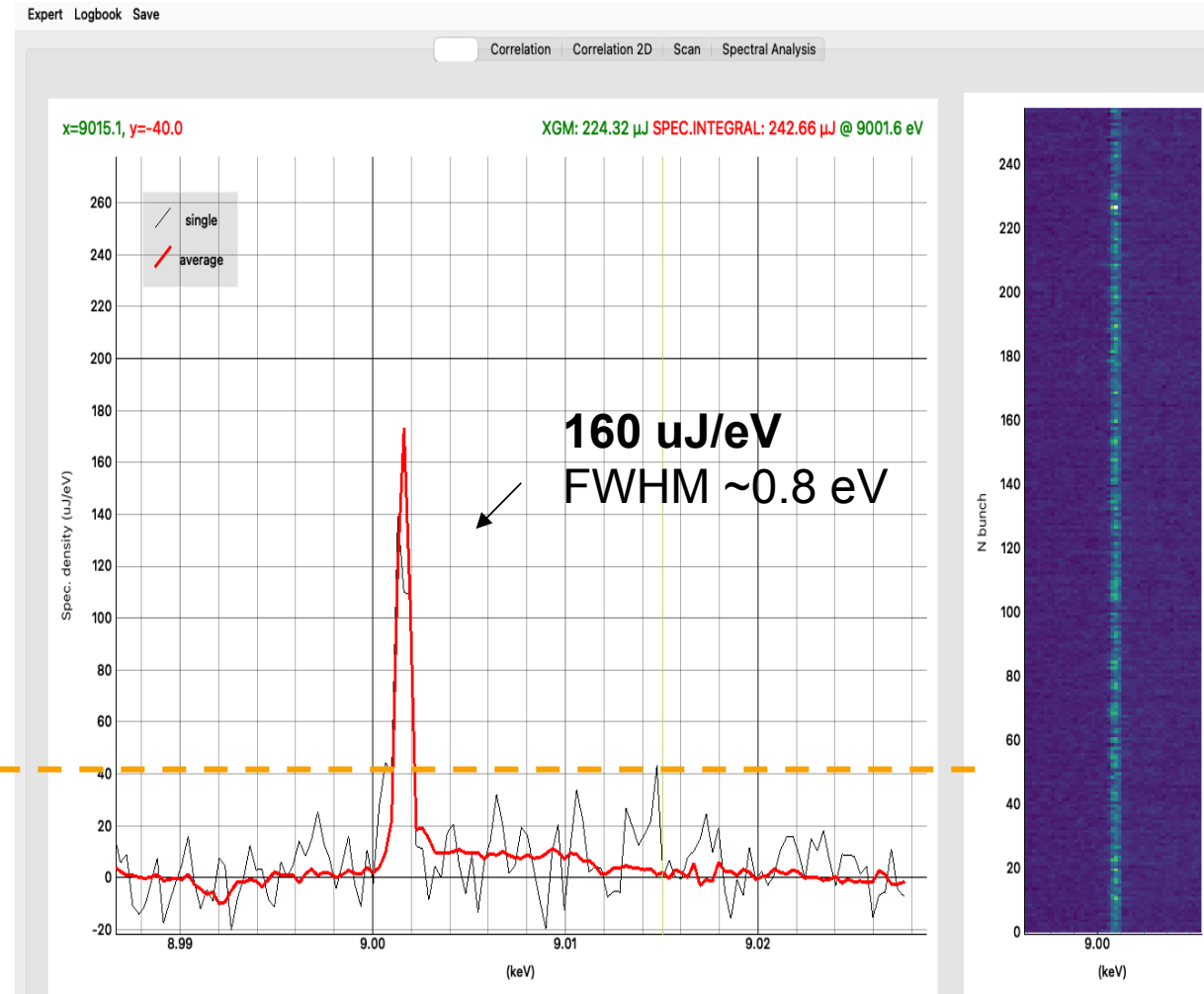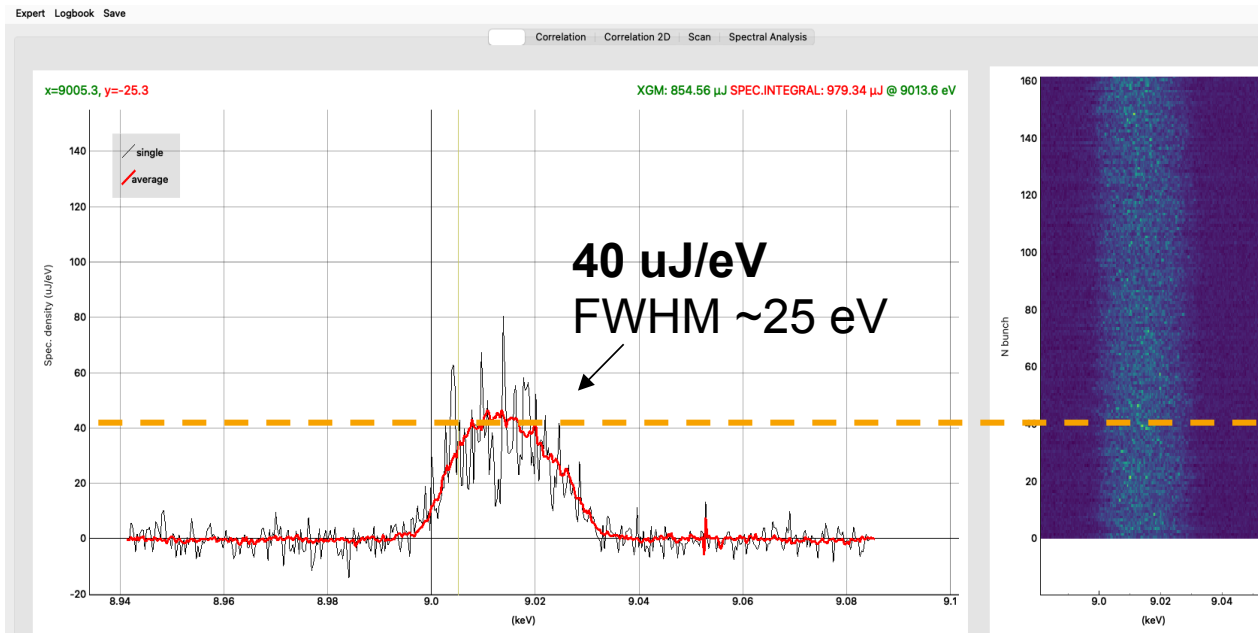
7.5 keV

■ Went down in steps from 9keV

■ Only up to cell 26-27 contributing with SASE

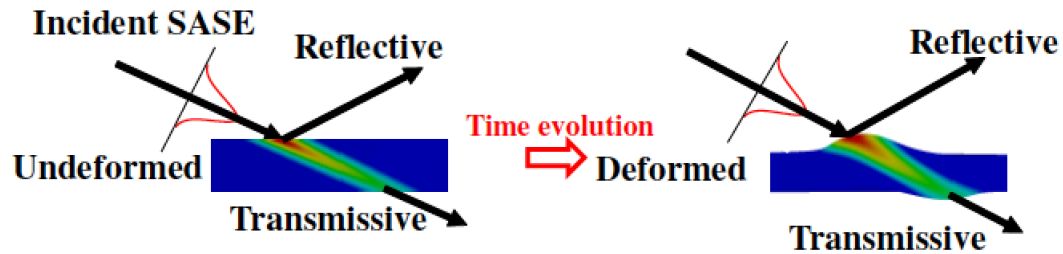■ Went to C1+C2 during the night (while seeding with C2 already) → much cleaner

SASE 1.5 mJ (140 uJ/eV)

European XFEL
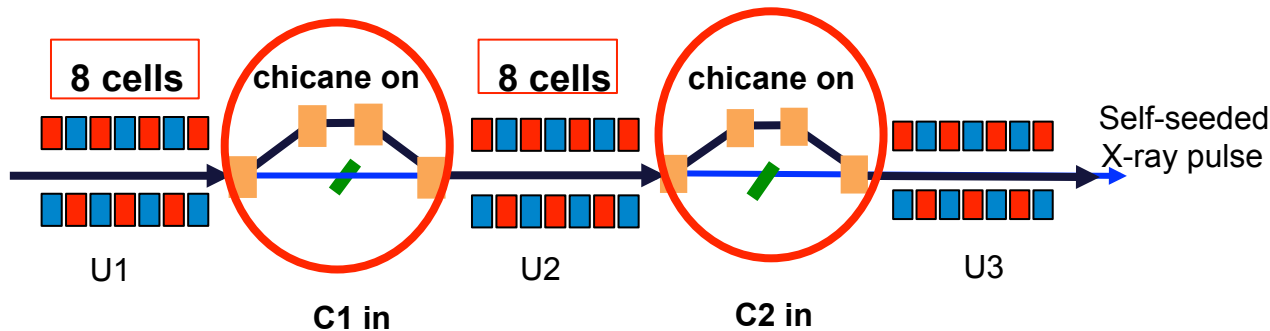
■ Cryo problem… back to seeding on Thu Sept 16th

Seeding 200 uJ (240 uJ/eV)

■ By Friday 17th early morning delivery to HED

Heat load study at 7.5 keV

2.2 MHz, 400 bunches

Qu, Zhengxian, et al., *NIMA* 969 (2020): 163936.

- Observed seeding wavelength shift (slope) along the bunch train for high impinging power (~40 uJ)

- Expect to have larger effect with lower photon energy

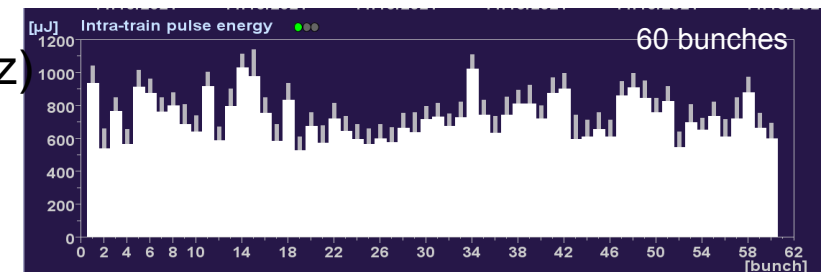- 2 chicanes can help to reduce heat load -> data to be analyzed

Seed dip

Pixel number on the detector, ~ Ephoton

Bunch number/4

**European XFEL**
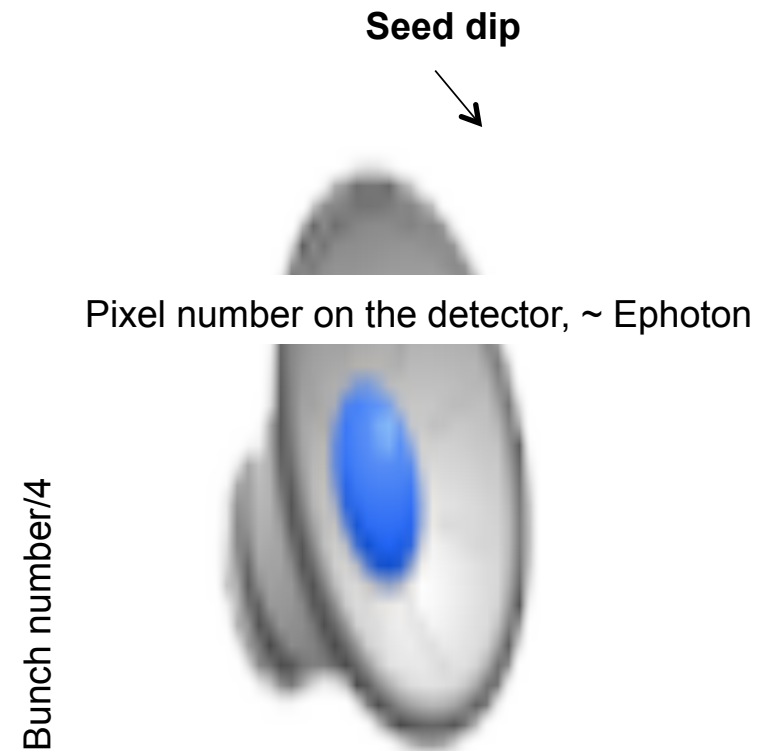
12.9 keV

🟧 After BBA (all cells contribute well)
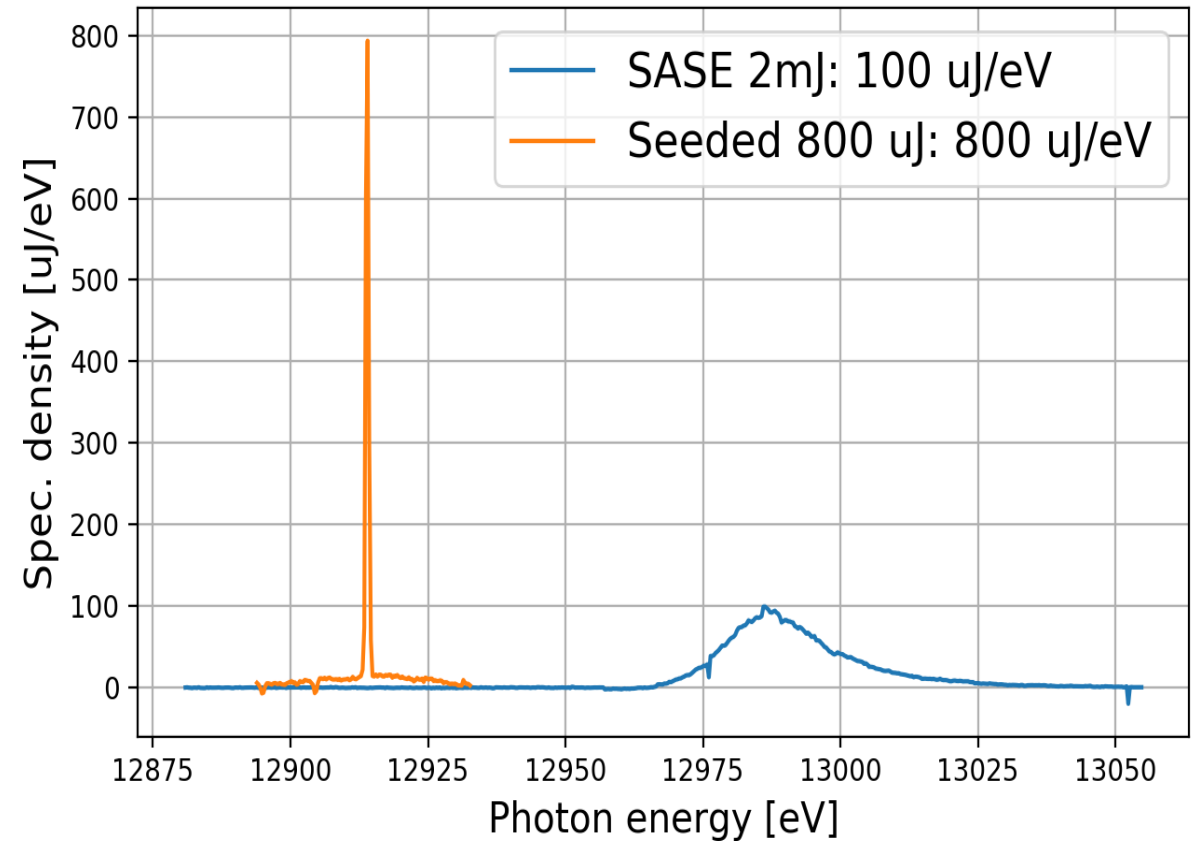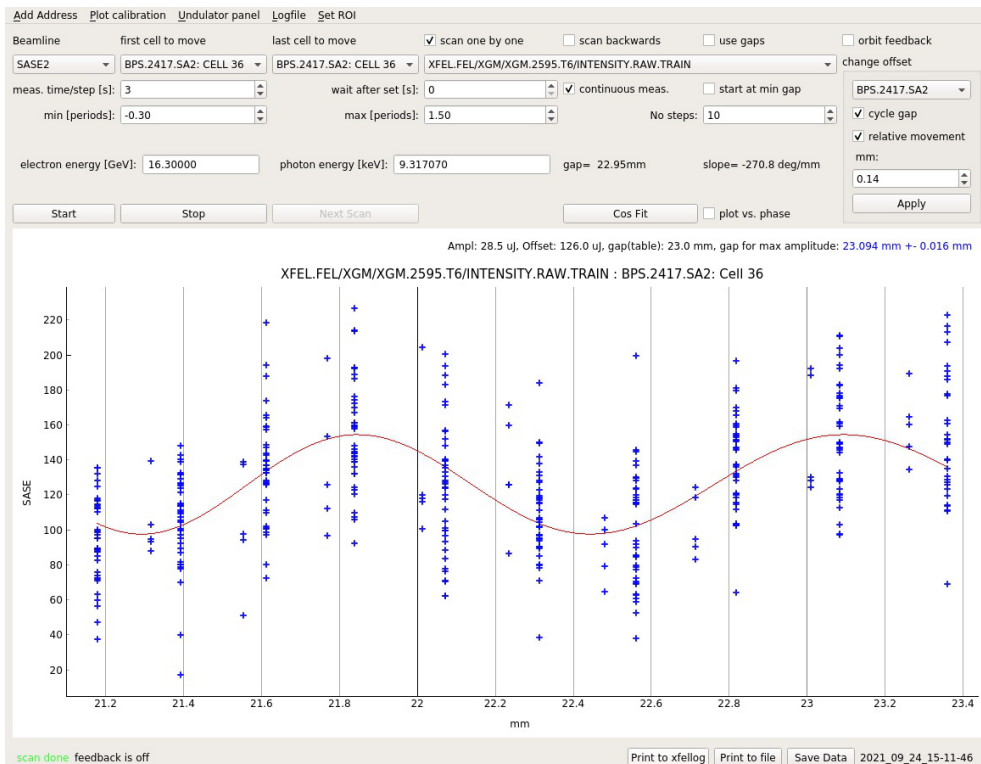
🟧 Delivery with high
repetition rate (2.2 MHz)
and multi-bunches

European XFEL

11.5 keV

- The piezo stage encoder "Crystal Change (Y-axis)" has got damaged. The main assumption is due to the radiation damage. Could find a solution to manually center the crystal to the beam.

- Seeding found quickly and optimized up to 400 uJ/eV comparing with 60 uJ/eV SASE (2mJ) in 2 shifts.

- User delivery with 200 bunches at 2.2 MHz, 640 uJ with 300 uJ background.

European XFEL
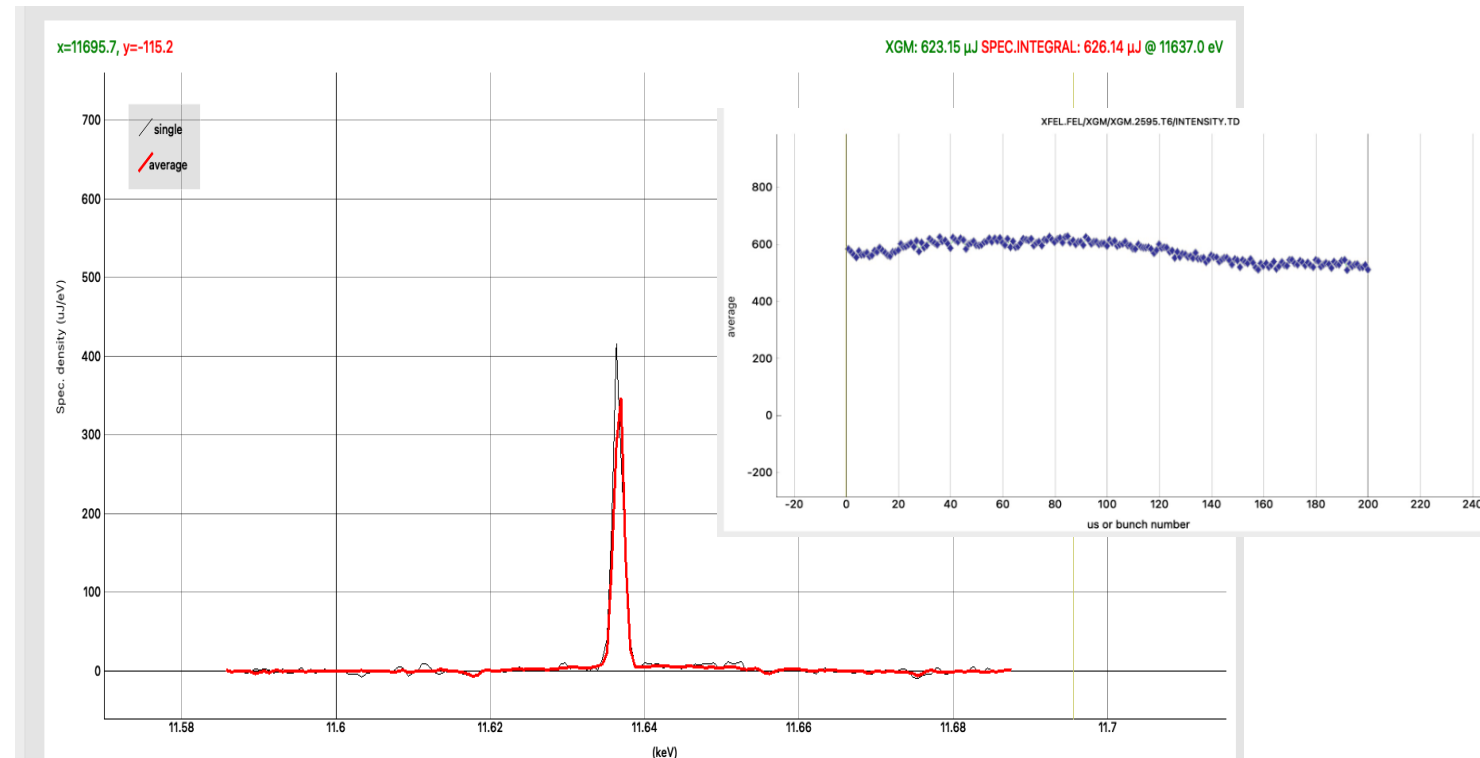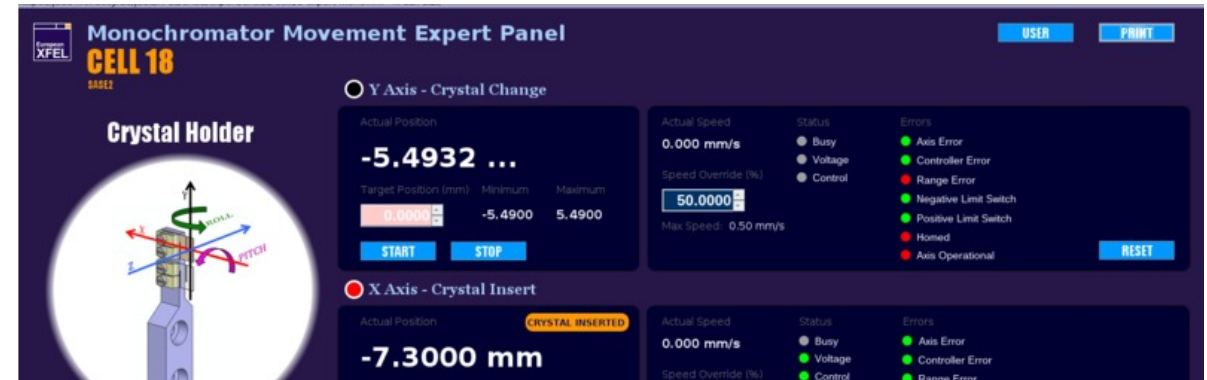
18 keV

■ Easily found seeded signal and could optimize to several uJ level with good contrast on HIREX
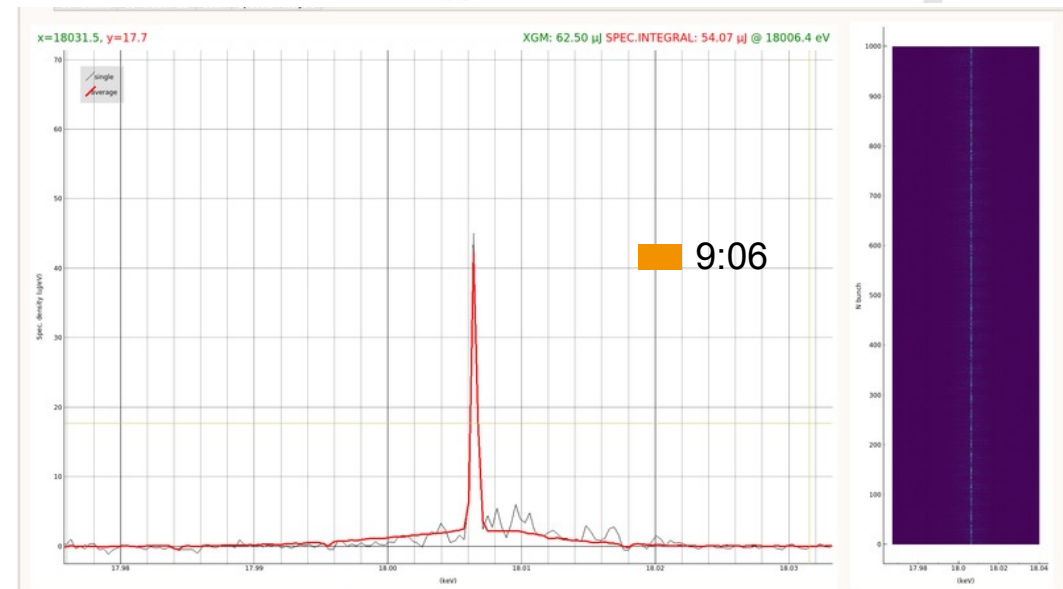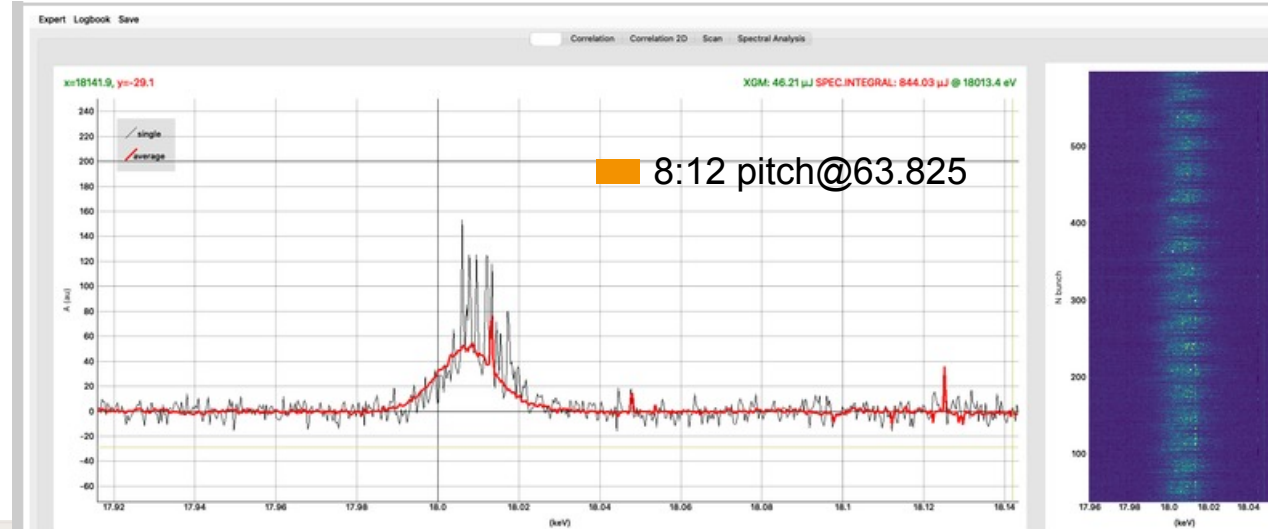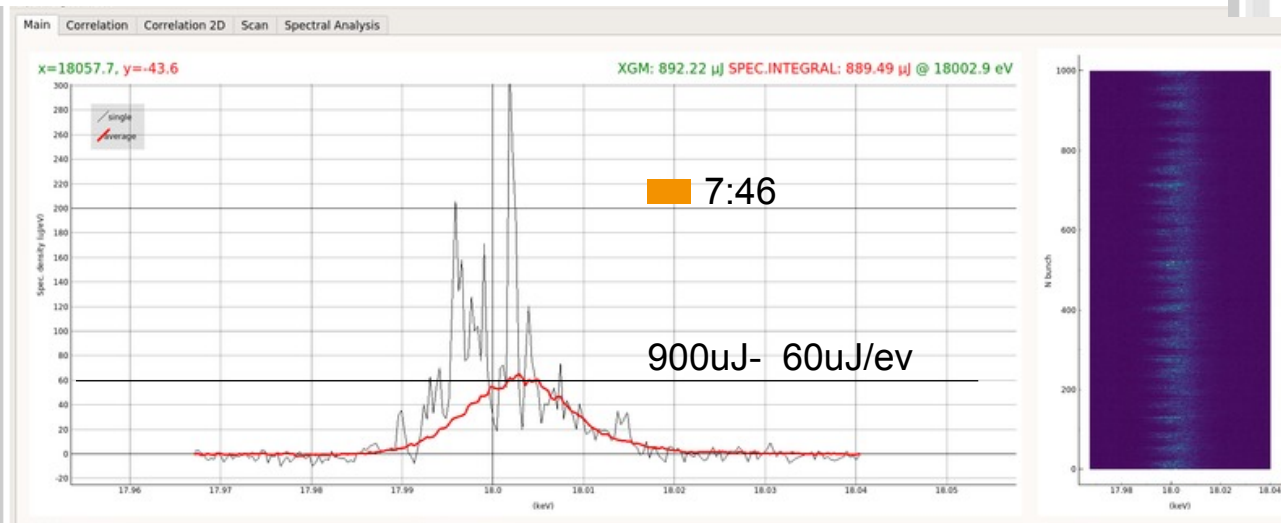
■ 8:12 pitch@63.825

■ 7:46

900uJ- 60uJ/ev

■ 9:06

European XFEL

Plan for next year

- Transfer set-up procedure to operators and minimize set-up time

- 4 user requests for the 1st half of year

- User interests also at lower photon energy (6.457 keV)

- Try 2nd harmonic at 7.5 and 9 keV

- Advanced operation schemes (two color, fresh slice seeding etc.)

Thank you!

Special thanks to the HXRSS set-up team!!!