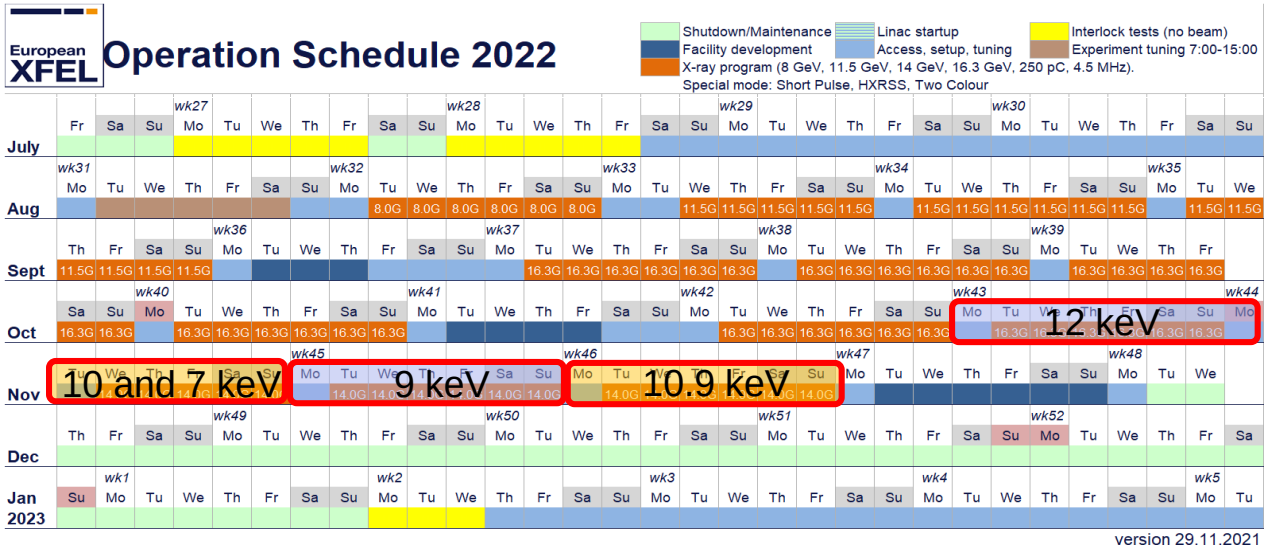
Hard X-ray Self-seeding operator training

Shan Liu,
DESY

Oct. 18, 2022

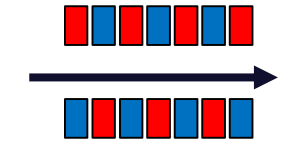
Outlines

- Why Hard X-ray Self-seeding?
- How it works?
- What is special at the European XFEL?
- How to set-up HXRSS? (single chicane case)
- How to tune HXRSS?
- What can happen during user run?
- How to switch back to SASE?

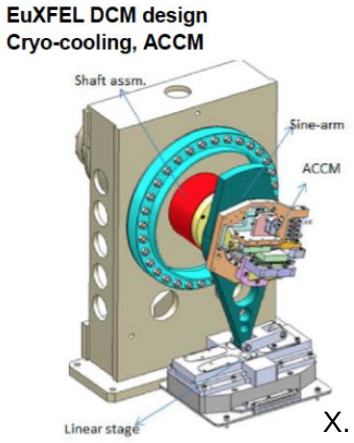


Important for upcoming 4 weeks of user delivery!

Why Hard X-ray self-seeding (HXRSS)?

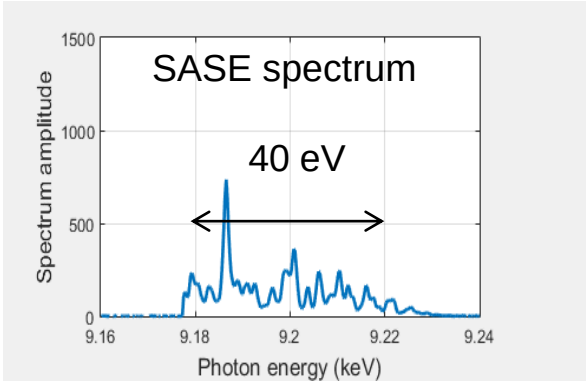


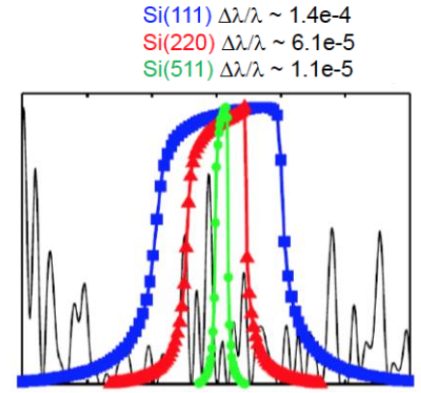
SASE undulator



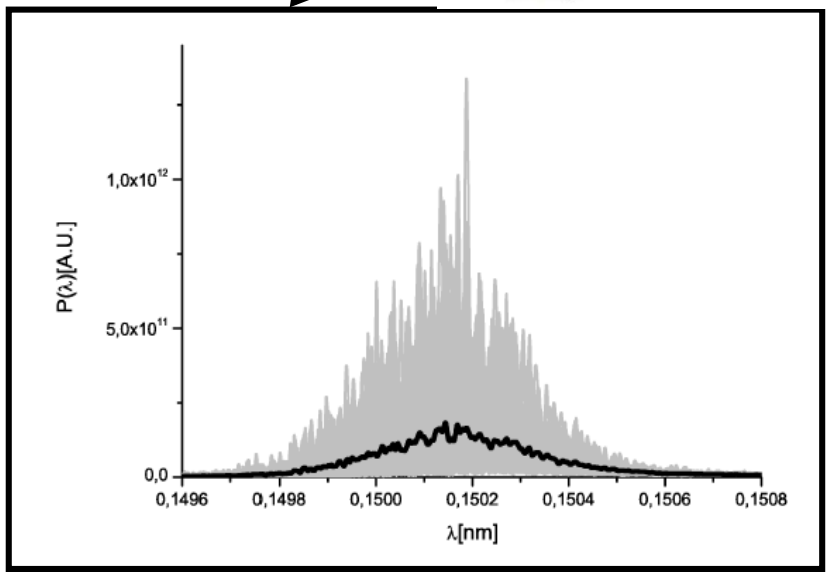
X. Dong *et al.*

Monochromator at MID



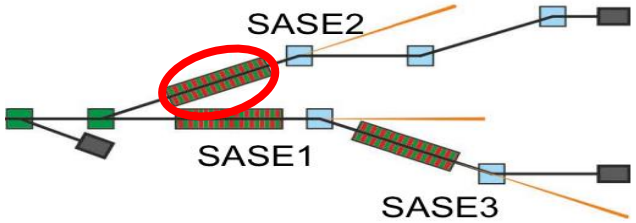


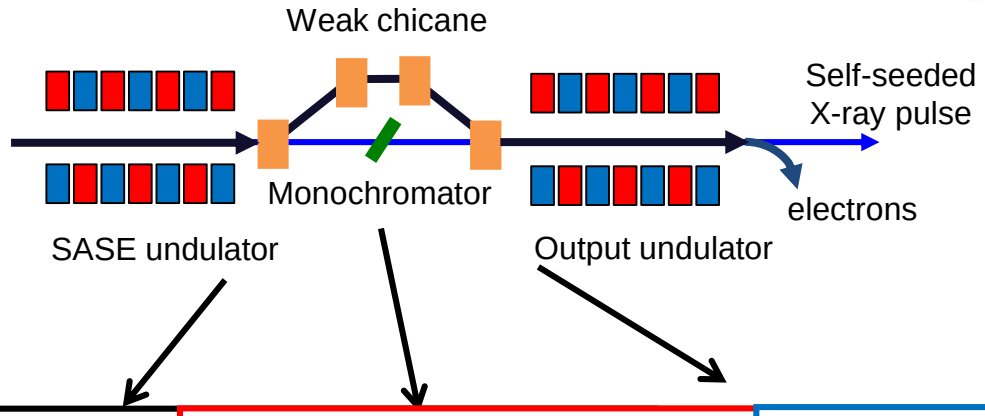
Courtesy of Anders Madsen

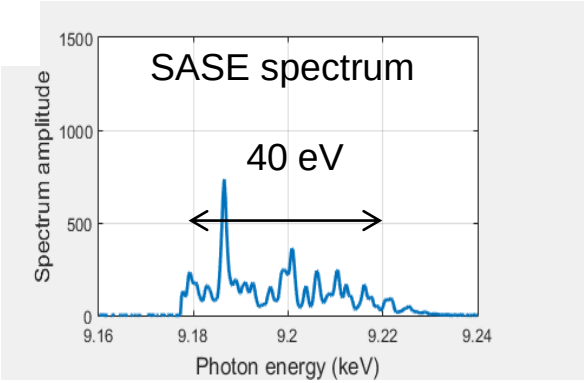


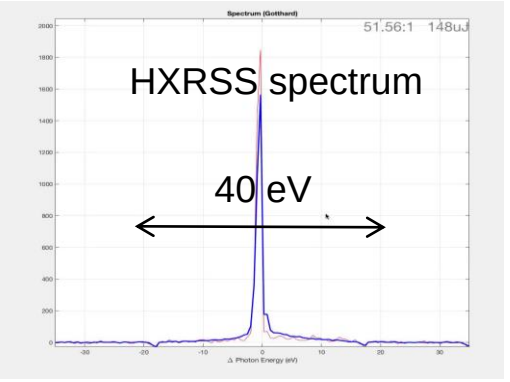
- **1e-4 –1e-5 BW is required** for many coherent scattering experiments
  - Monochromators **reduce intensity** and **increase intensity fluctuations**
  - **Temporal coherence** of reflected beam **varies from pulse to pulse**
  - Cryocooled Si monochromators cannot transmit more than ~ 50 mJ during MHz train (**adiabatic heating**)
- **Seed pulse** can **lock in phase** different regions of the e-beam
- **External seeding not available** yet in hard X-ray range -> self-seeding

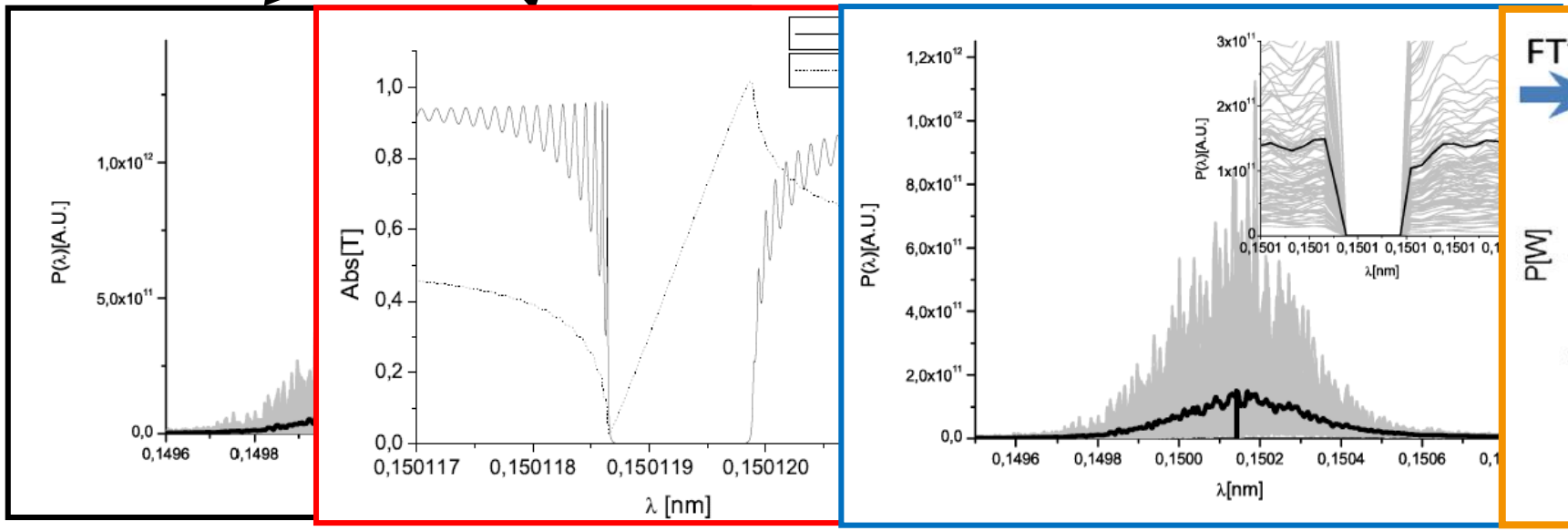
How HXRSS works?

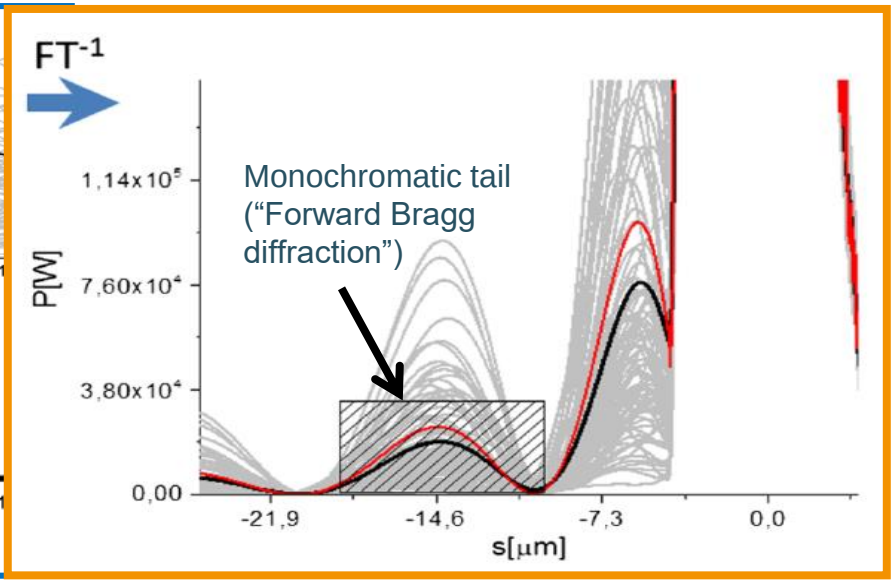






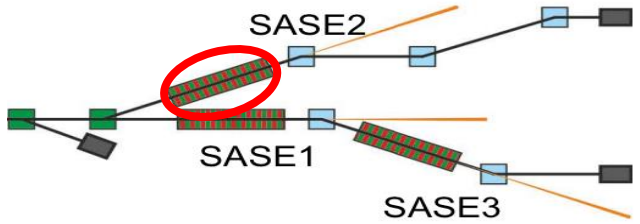


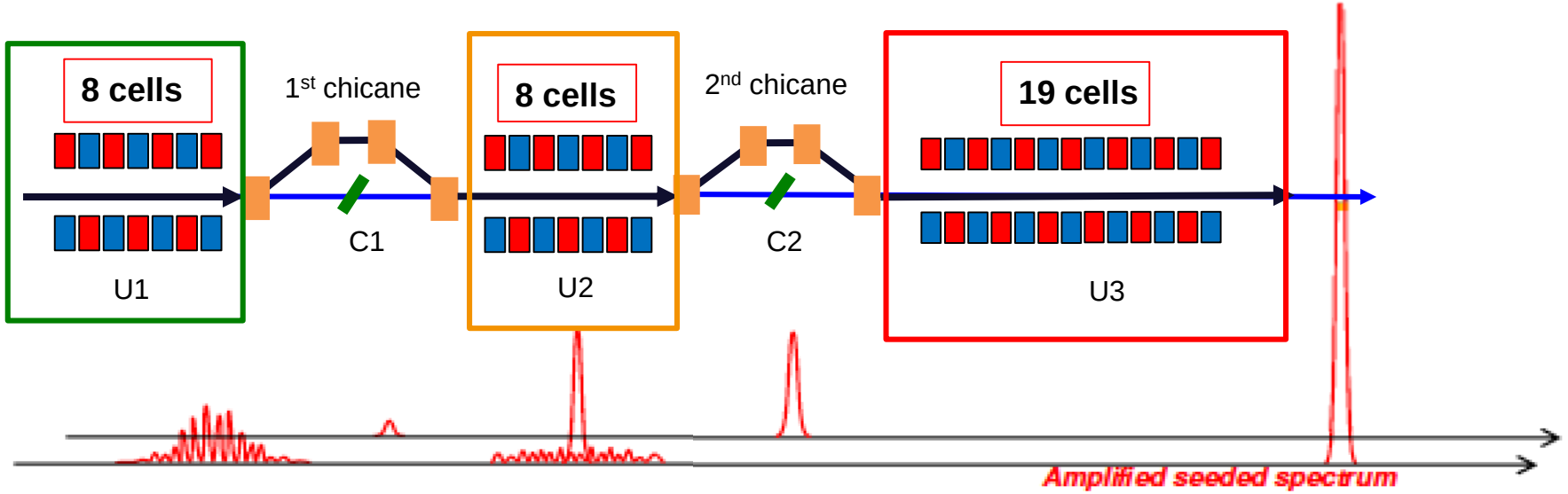




* G. Geloni, V. Kocharyan, E. Saldin (*DESY 10-133*)

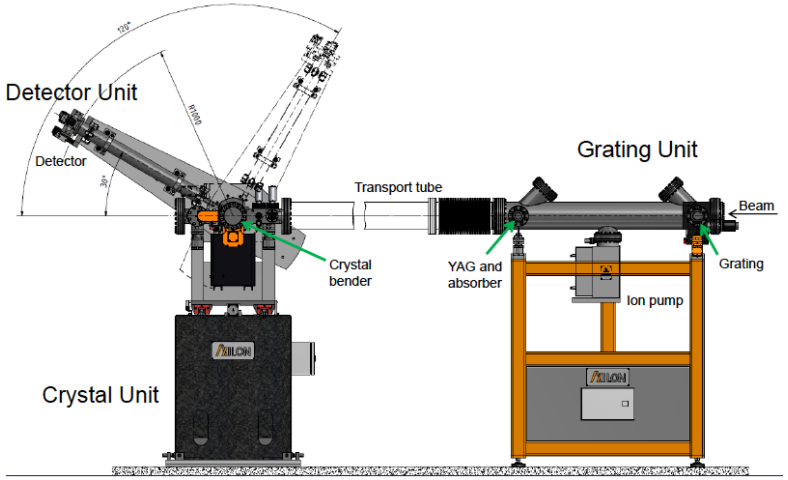
What is special at the European XFEL?





- Two stages
  - use both C1 and C2 with two chicanes
  - used for lower photon energies (< 8keV)
  - increases SNR and share the heat load on crystal
- Single stage
  - use only C2 with 2nd chicane
  - used for higher photon energies (> 8 keV)
  - no heat load issues

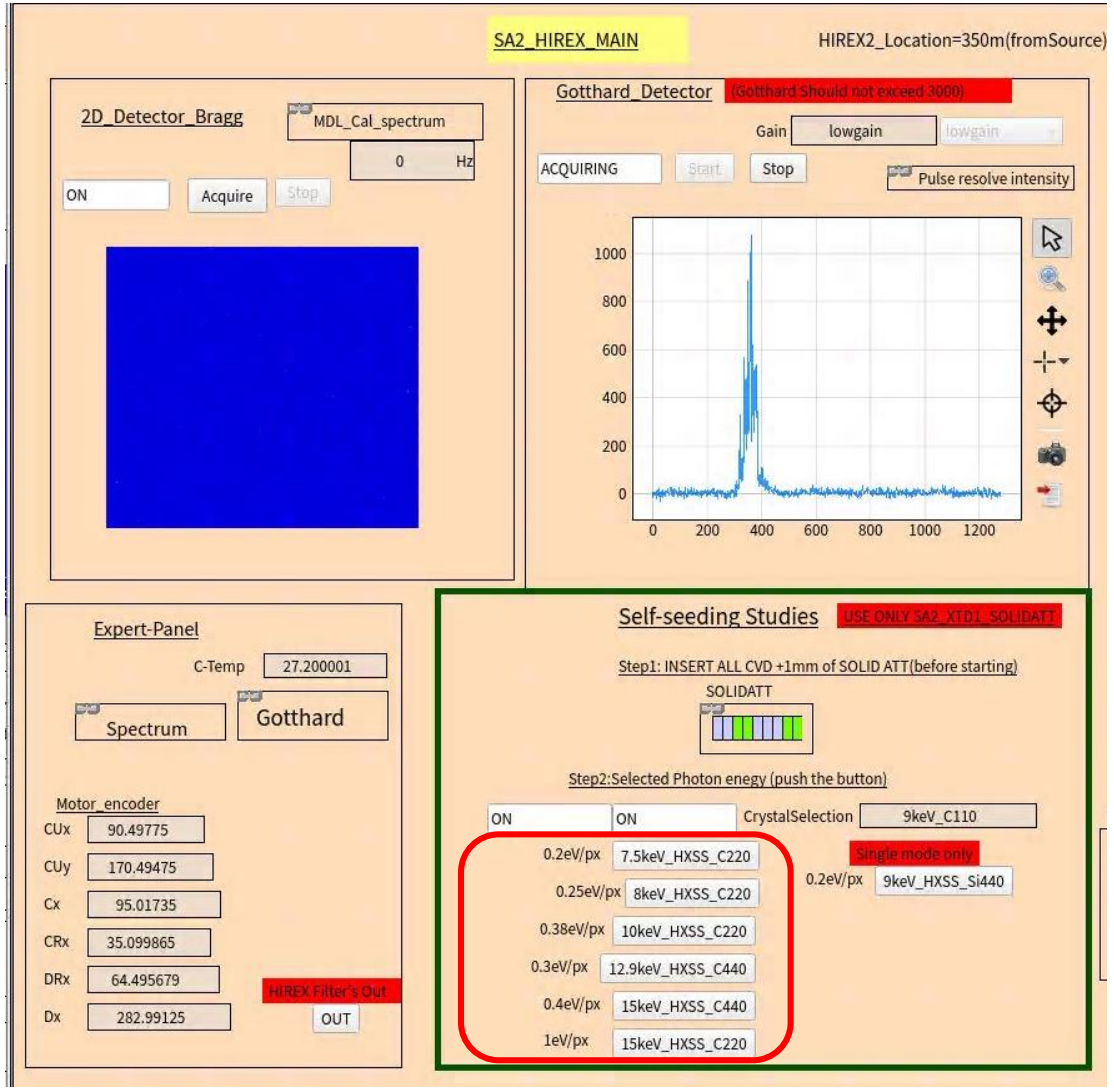
HIREX* diagnostic spectrometer



- **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)

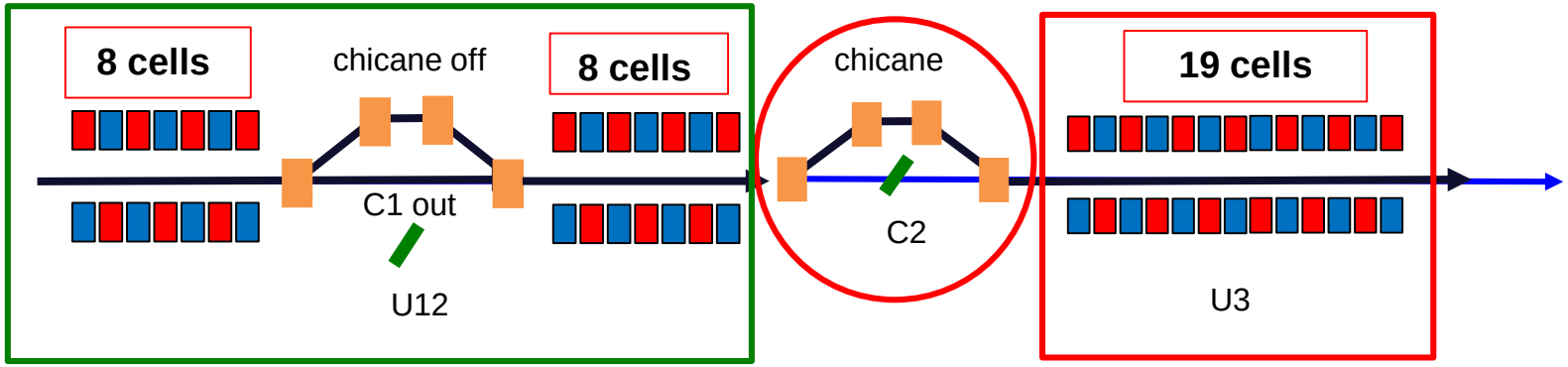
J. Grünert et al., JSR 26 (5), 1422 (2019)

* **HIREX** = **HI**gh **RE**solution hard **X**-ray

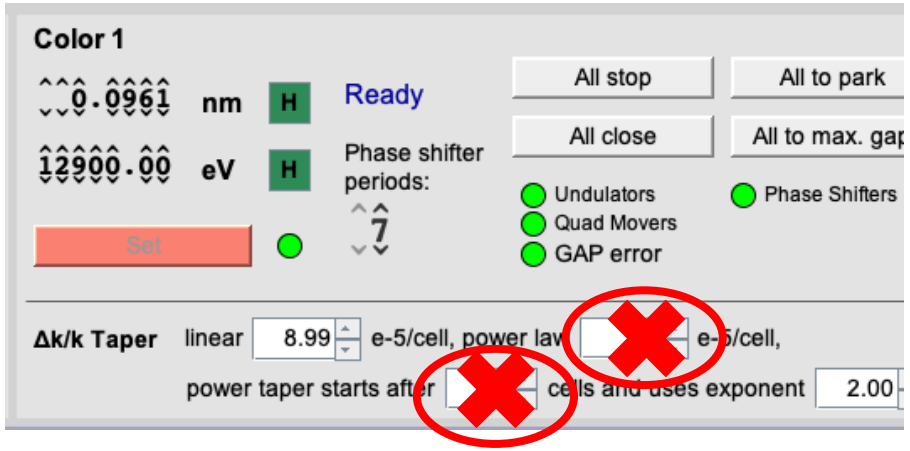


Developed by Naresh Kujala

How to set-up HXRSS? -- single chicane case

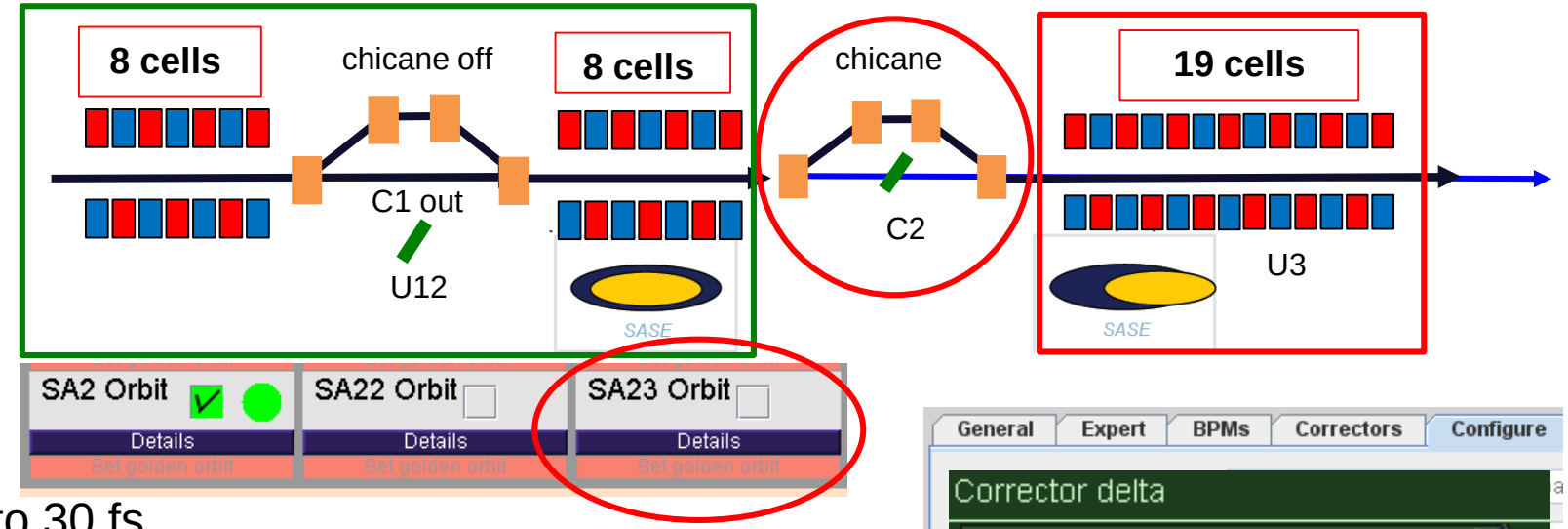


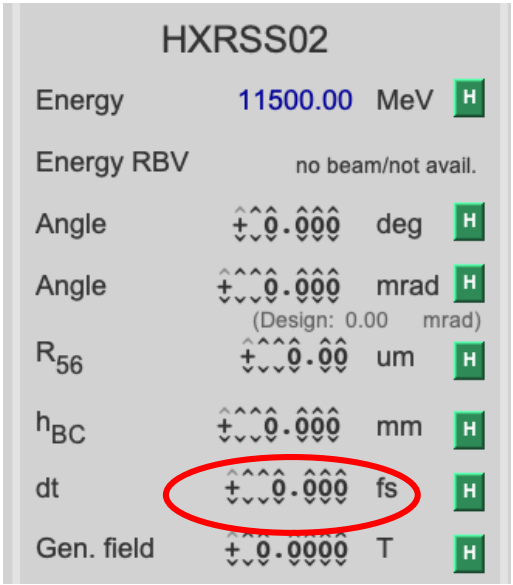
- SASE requirements
  - SASE from U12 should be >10 uJ (ideally around 40-50 uJ)
  - >10 cells in U3 should contribute (at least cell 19-28) -> good orbit downstream is required
- SASE tuning
  - similar to standard SASE tuning but **without quadratic taper**
  - open U3 to check U12 SASE level, optimize if needed
  - add U3 cell by cell (or two cells at one time)
    - ► optimize orbit with air coils for this cell
    - ► if you have > 100 uJ with linear taper, open first cells in U12
    - ► save a golden orbit and a file after optimization is done

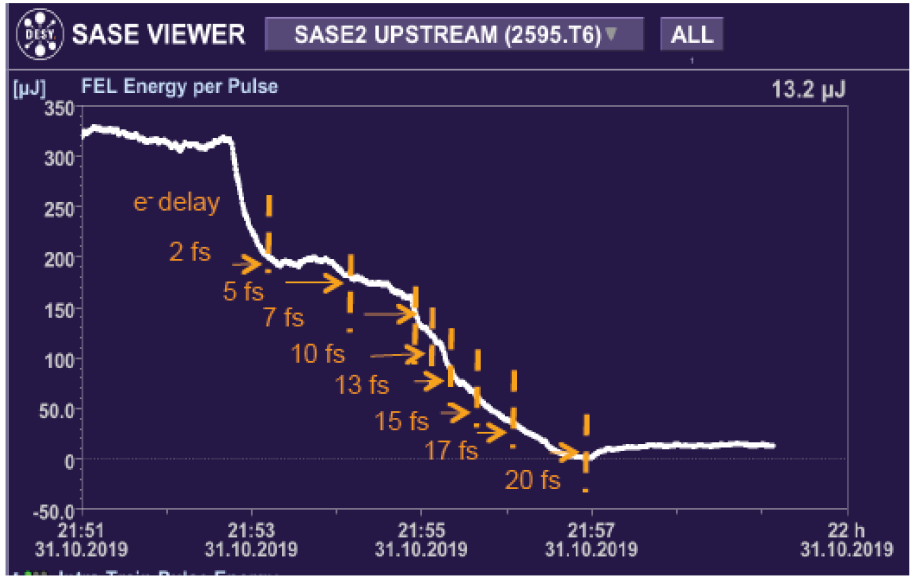


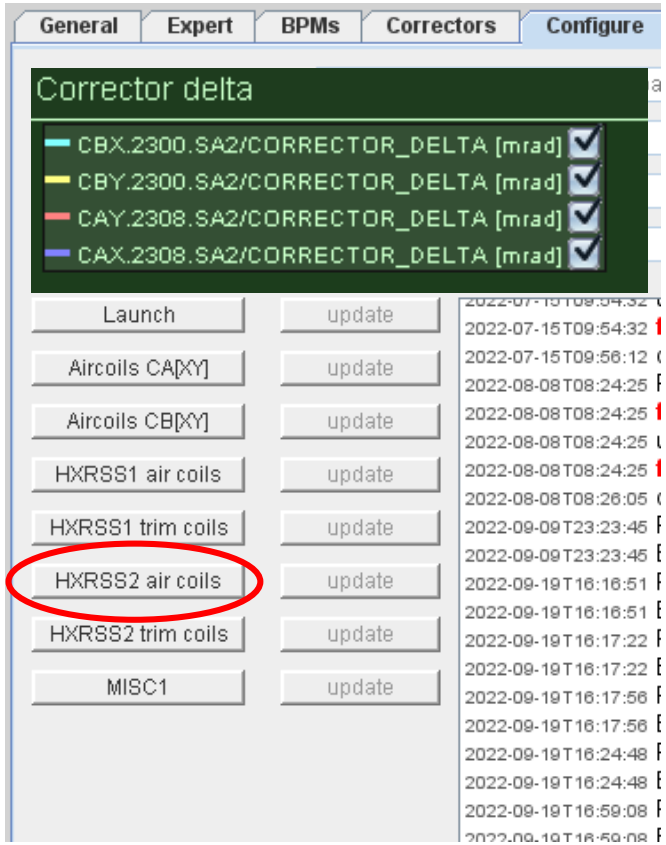
How to set-up HXRSS? -- single chicane case

- Seed with SASE
  - switch on **SA23 feedback**
  - switch on **chicane HXRSS2**
  - increase delay step by step up to 30 fs

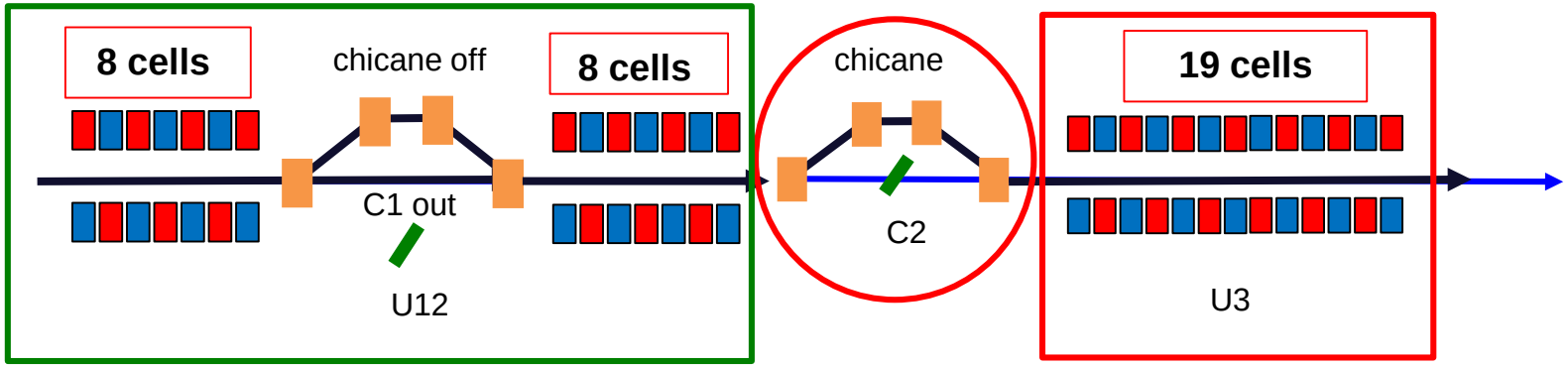




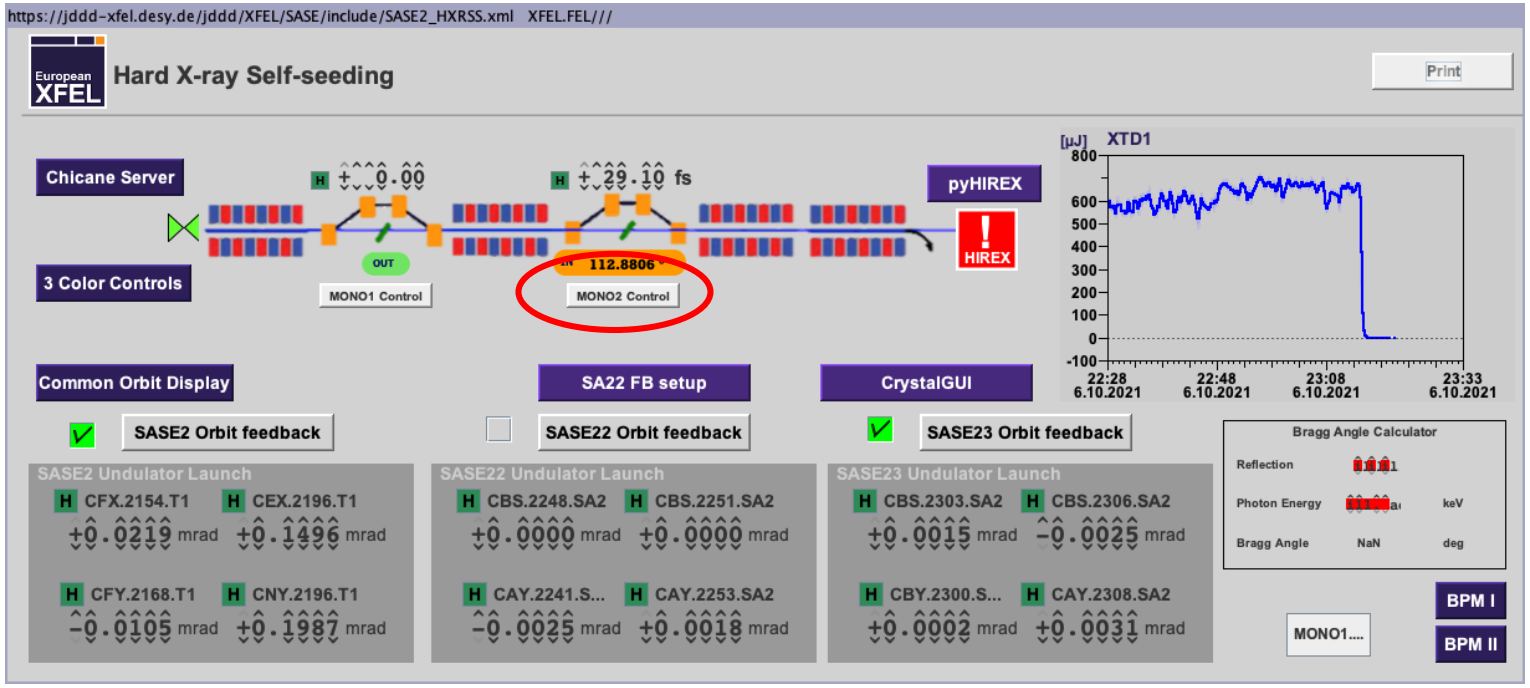


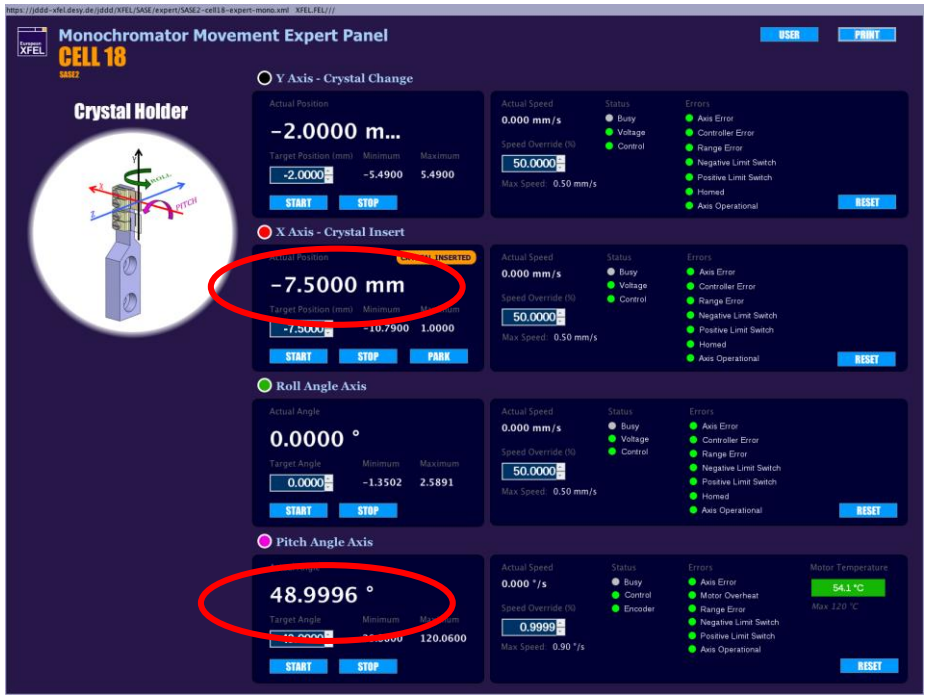


How to set-up HXRSS? -- single chicane case

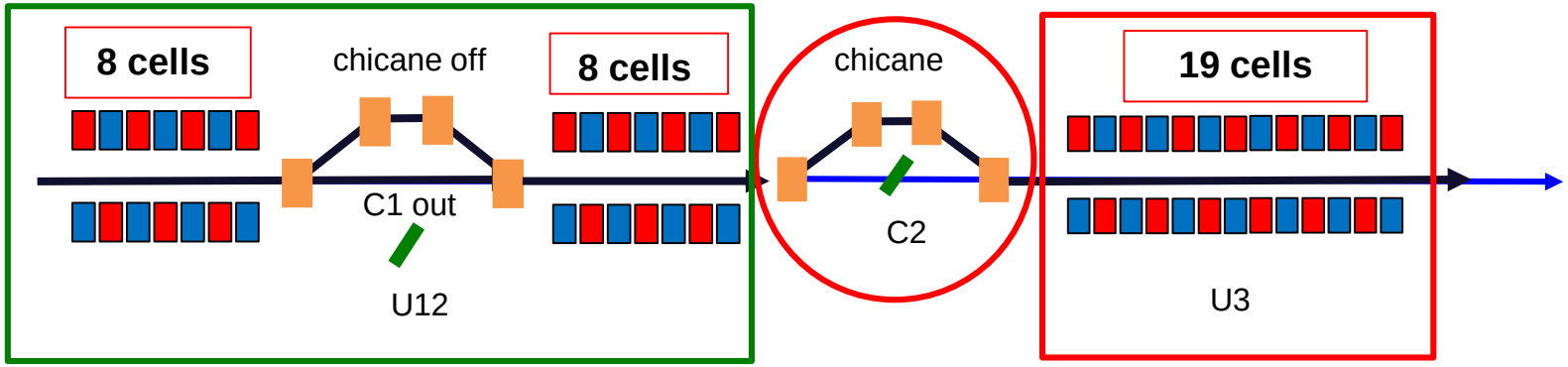


- **Insert crystal**
  - XFEL main task panel -> Photons -> Expert Panels-> SASE2-> HXRSS



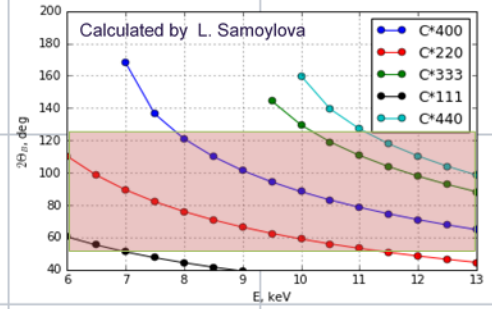


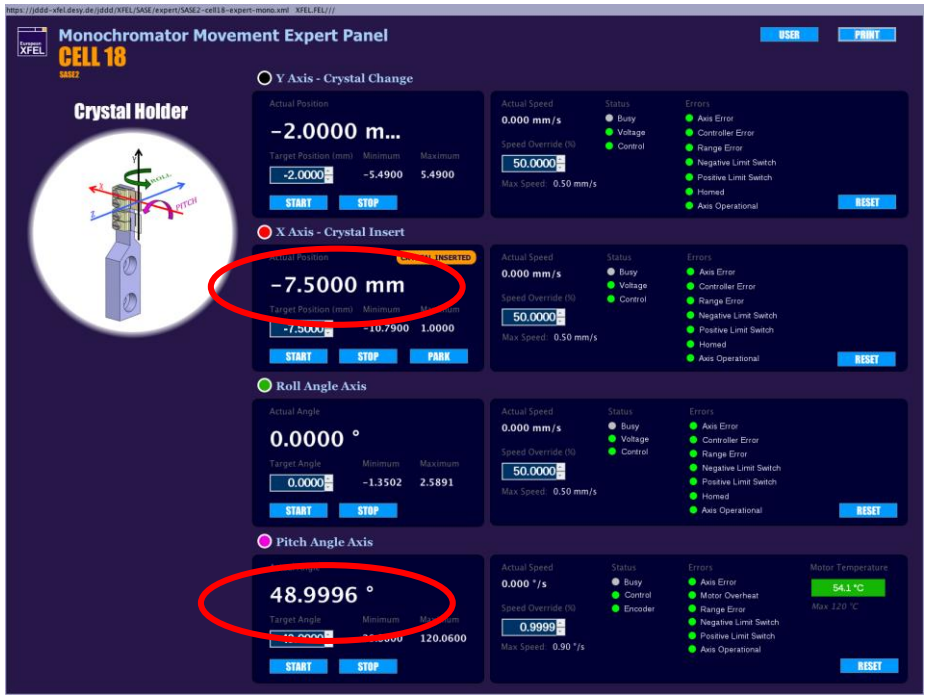
How to set-up HXRSS? -- single chicane case



- **Insert crystal**
  - Crystal angle information on confluence page

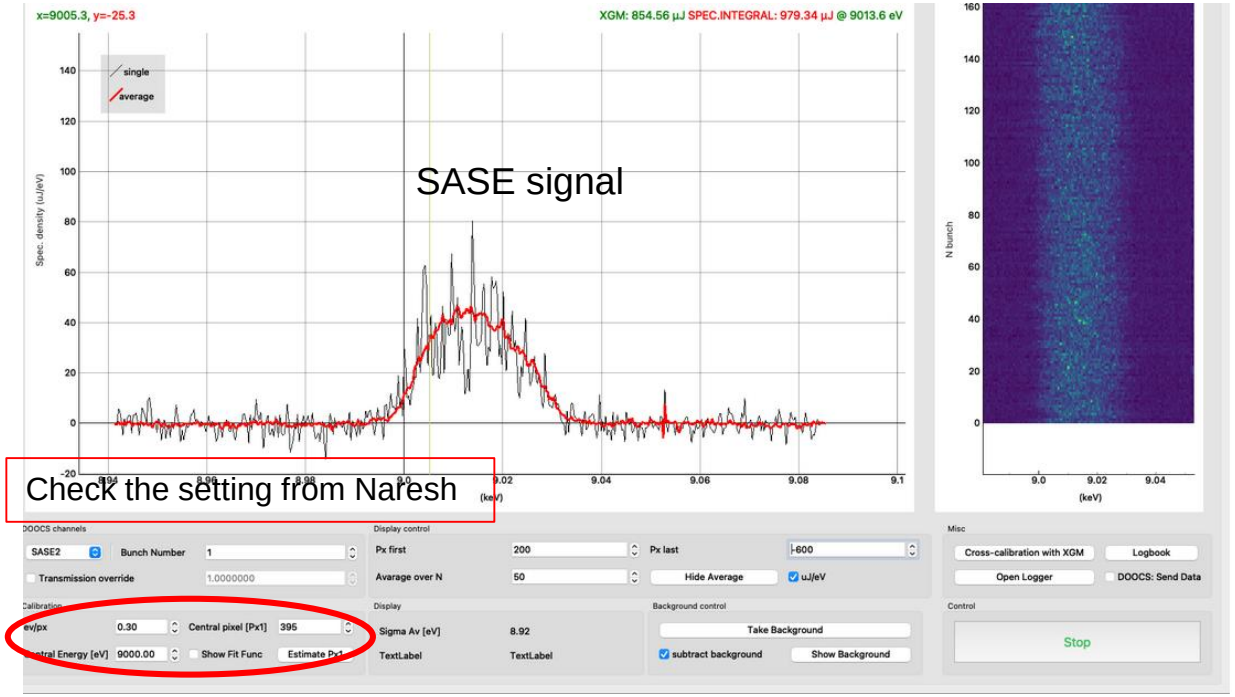
				7.5 keV	8 keV	9 keV	10 keV	13 keV
	Mono2	Crystal I	C004			49.09-49.49 https://ttfinfo.desy.de/XFELelog/show.jsp?dir=/2020/40/02.10_n&pos=2020-10-03T01:40:06	60.49 https://ttfinfo.desy.de/XFELelog/show.jsp?dir=/2021/11/17.03_a&pos=2021-03-17T19:50:16	
			C220	49.02 https://ttfinfo.desy.de/XFELelog/show.jsp?dir=/2021/09/07.03_n&pos=2021-03-08T00:58:30				Five lines crossing https://ttfinfo.desy.de/XFELelog/show.jsp?dir=/2020/47/19.11_n&pos=2020-11-20T03:46:20
			C111	101.39 https://ttfinfo.desy.de/XFELelog/show.jsp?dir=/2021/09/07.03_n&pos=2021-03-08T00:18:00	101.39			
			C(-1,3,1)					111.56
			C(1,1,-1)					112.1



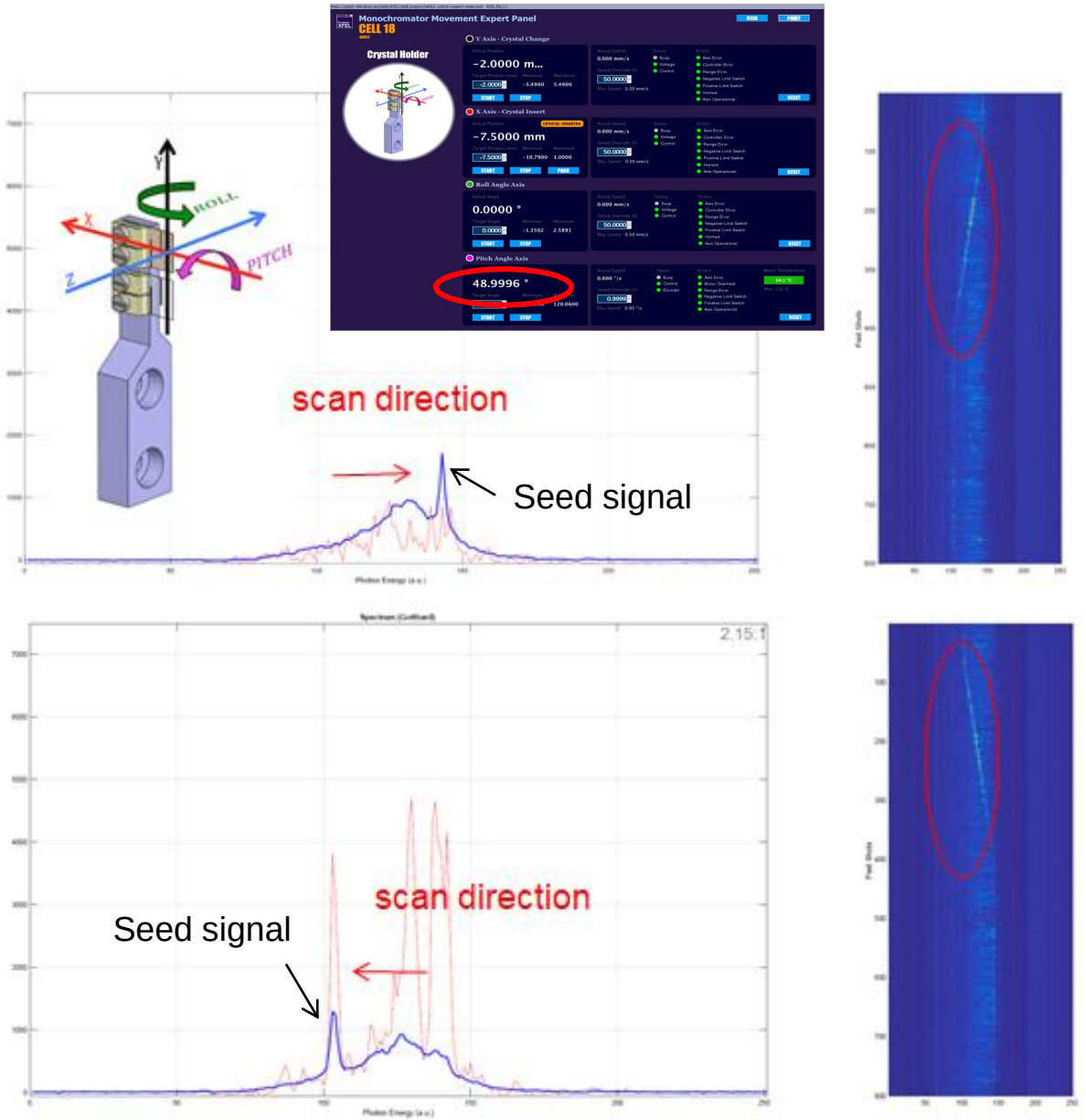


How to set-up HXRSS? -- single chicane case

- **Find seeded signal**
  - XFEL main task panel -> Photons -> Spectrum-> pySpec SA2

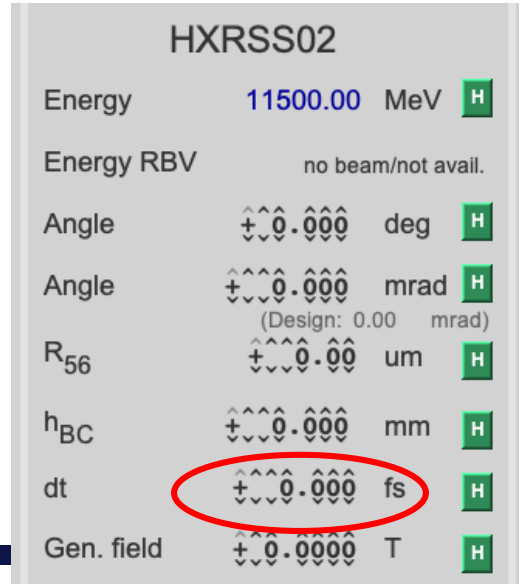


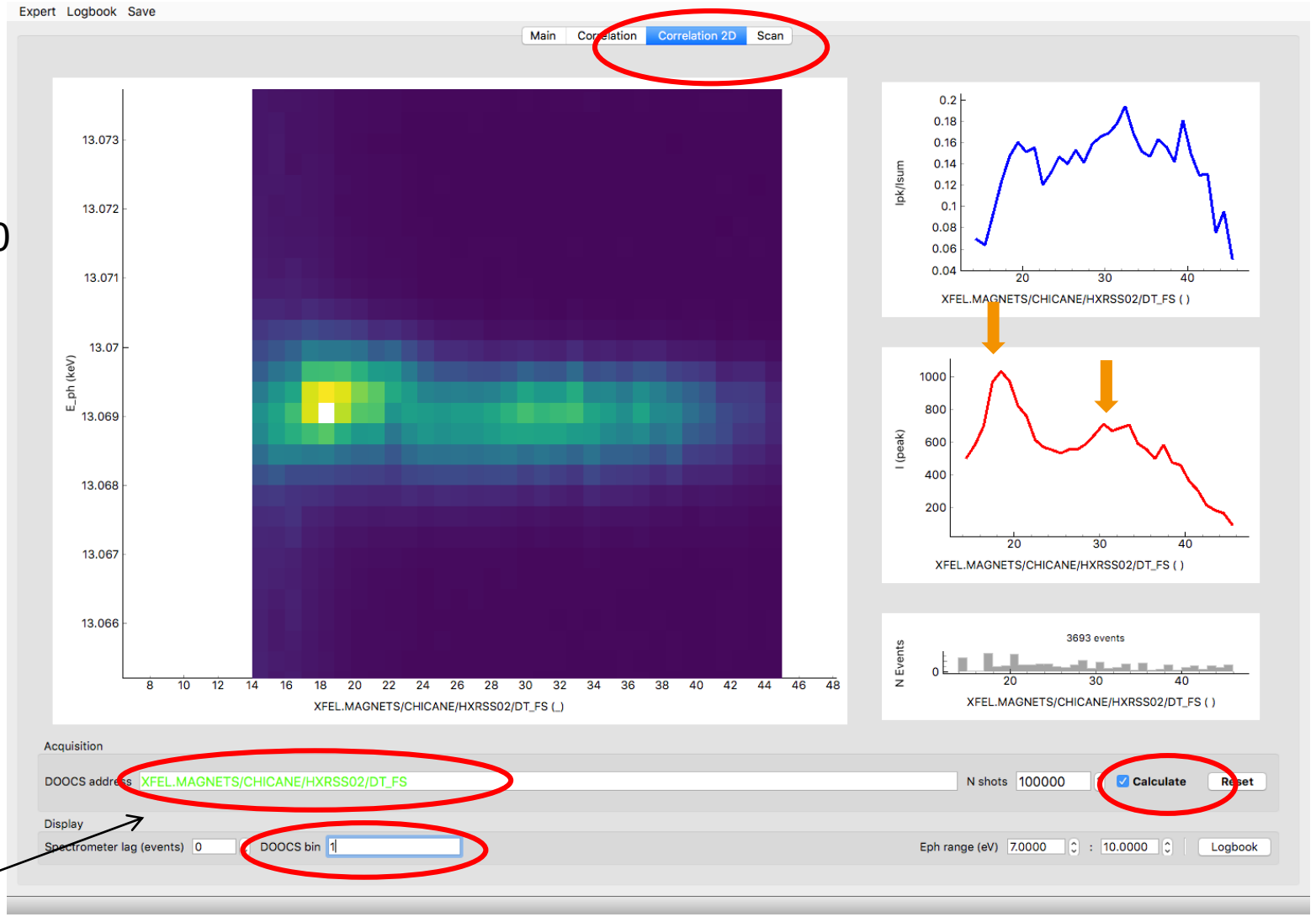
Check the setting from Naresh



How to tune HXRSS?

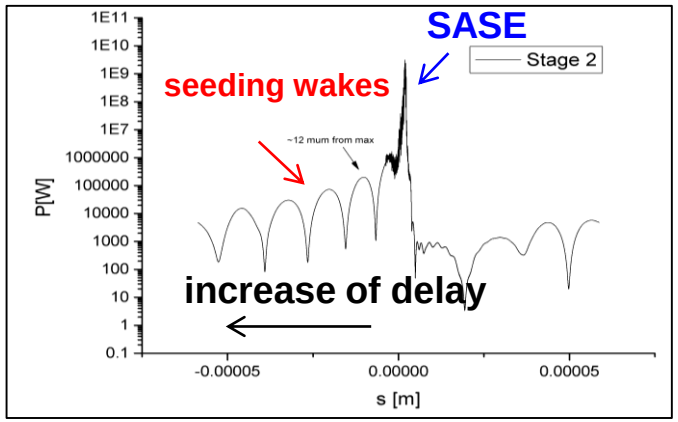
- **Fine tune the delay** again (using Correlation2D function from PyHirex
- Manually change dt in the range of 18-40 fs while looking at the peak signal in PyHirex
- Find the delay for maximum peak signal

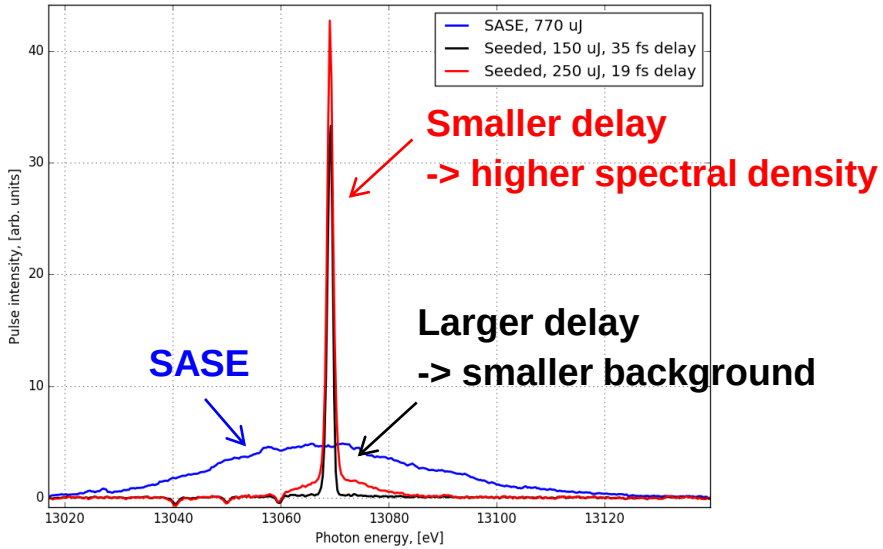


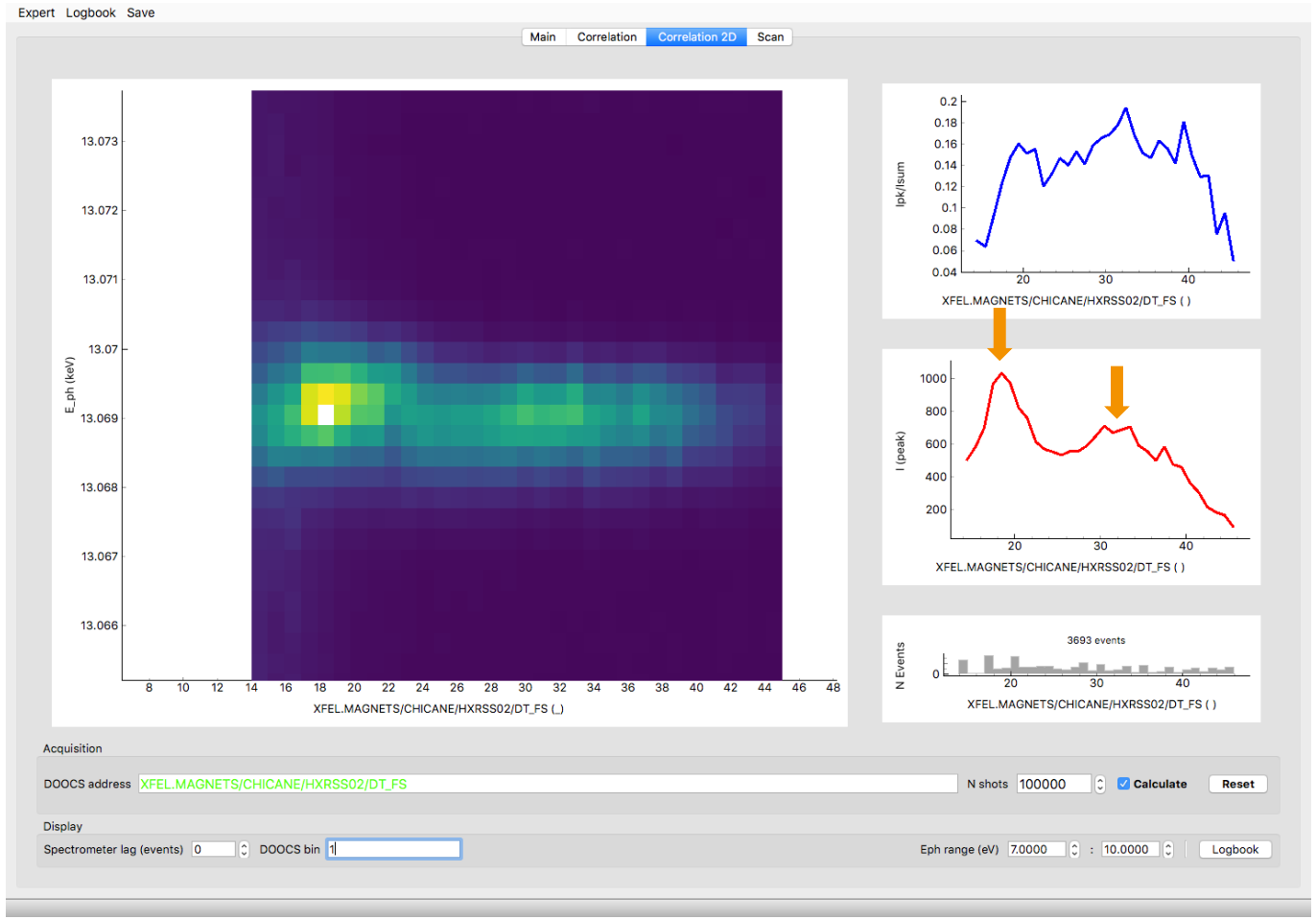


How to tune HXRSS?

- Larger delay can reduce the background, but seeding input is also lower







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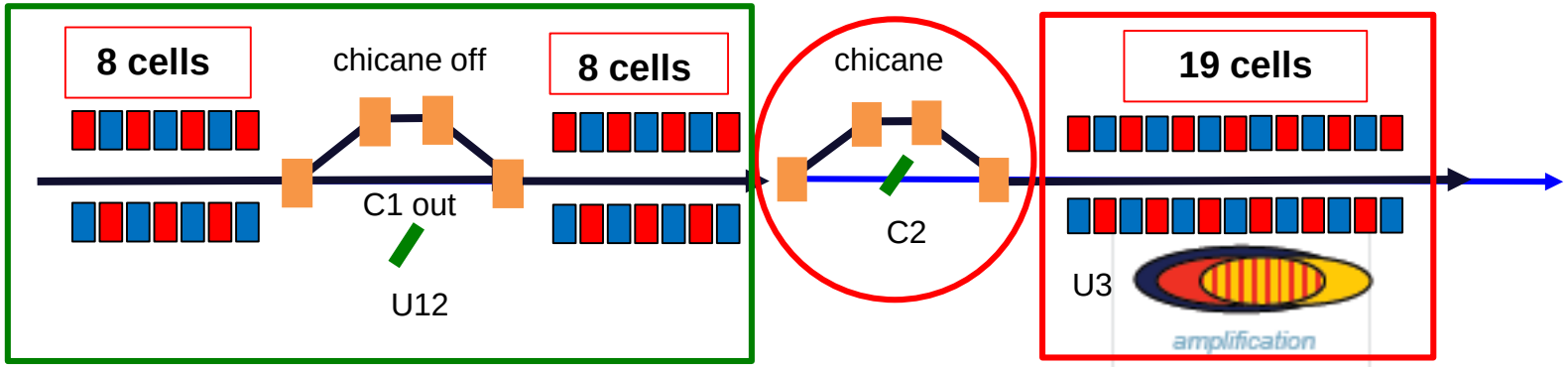
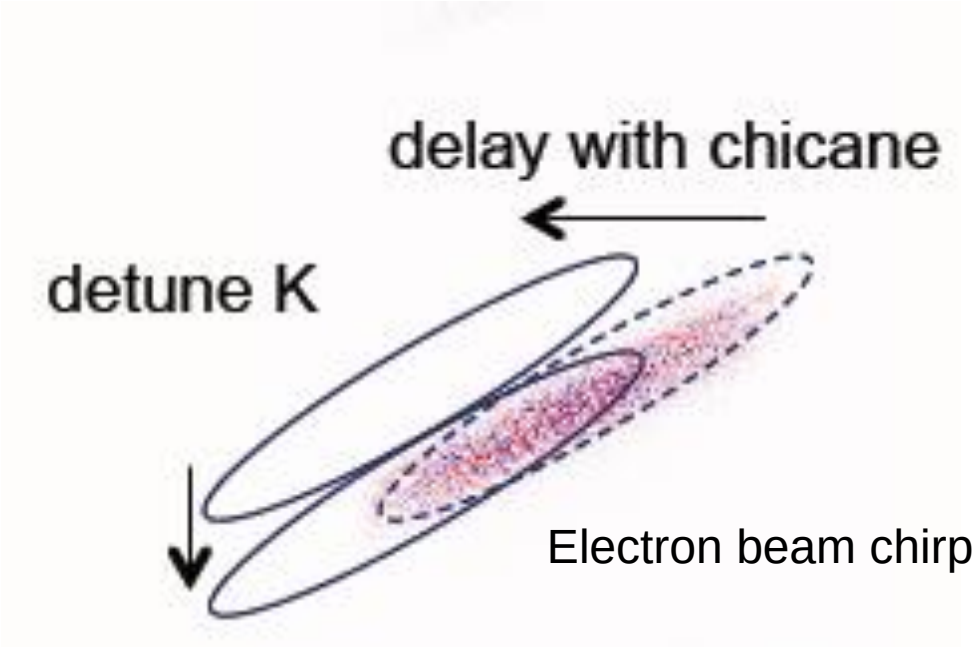
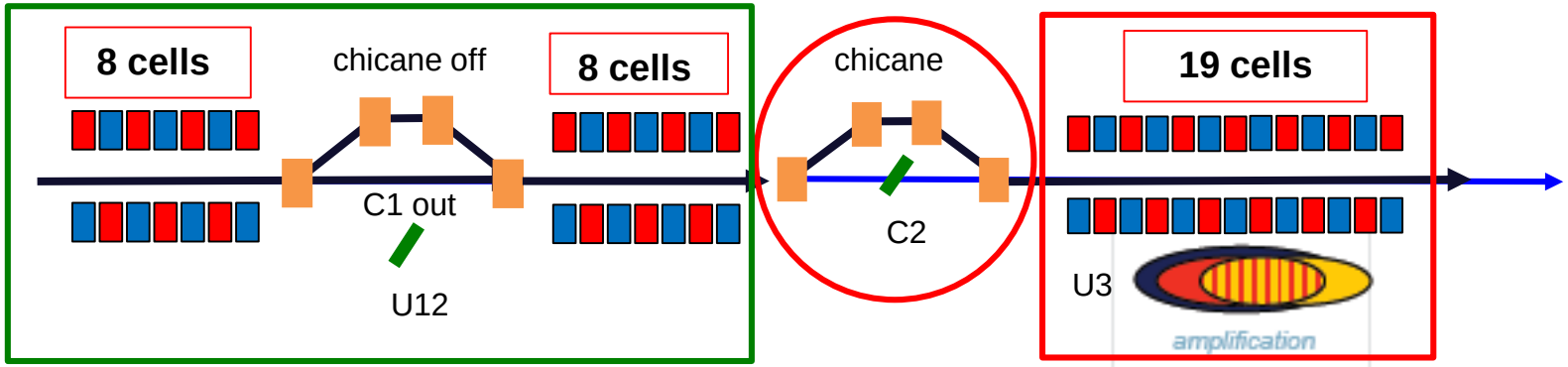
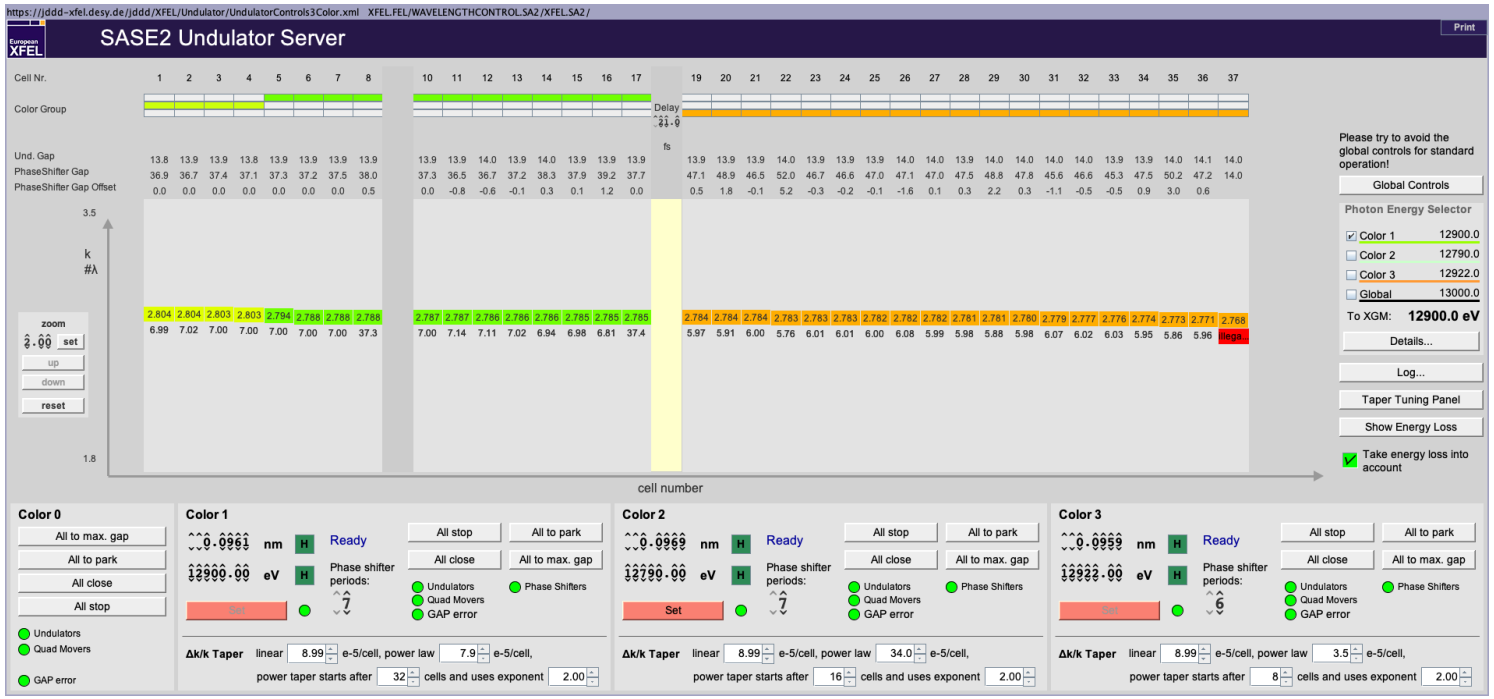


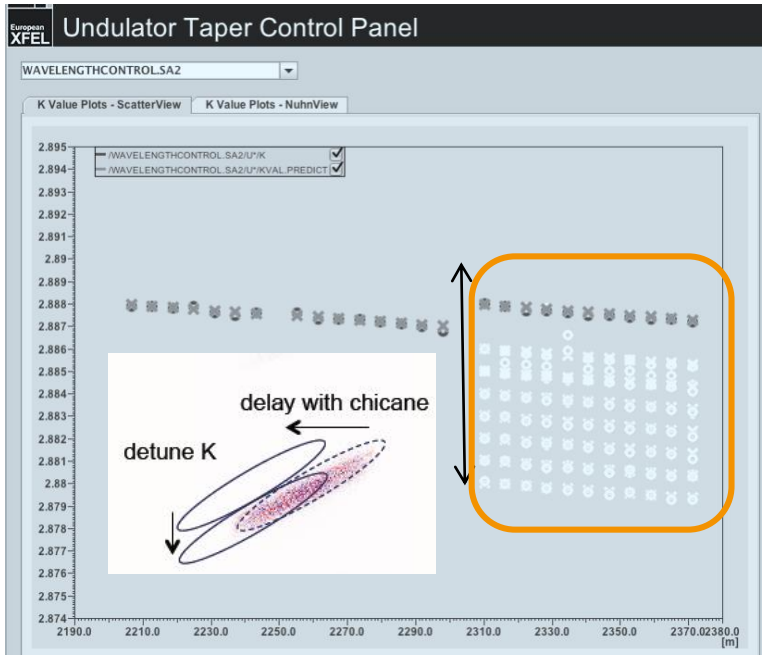


How to tune HXRSS?

- **Set-up color 2/3 and adapt detune for U3**
  - **scan in several eV step**







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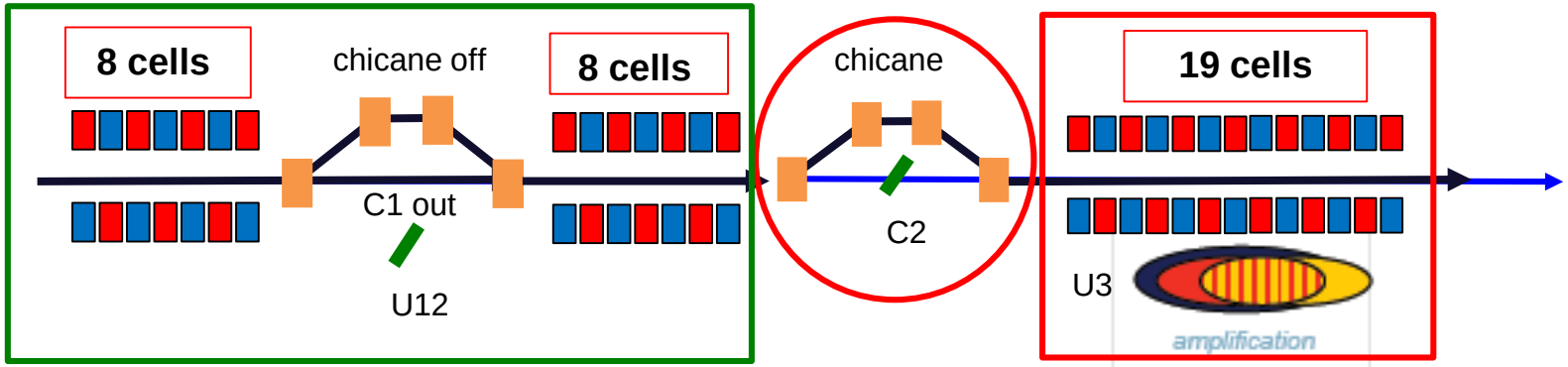
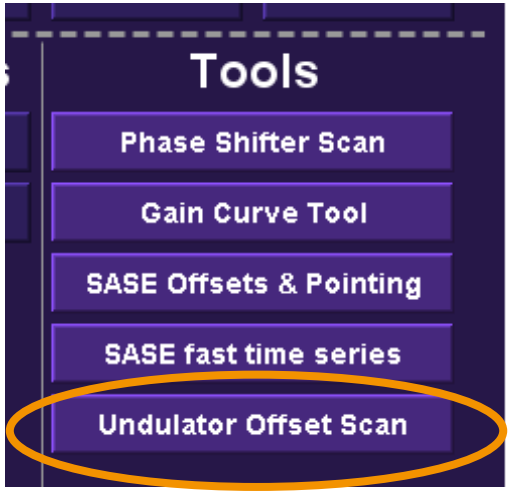
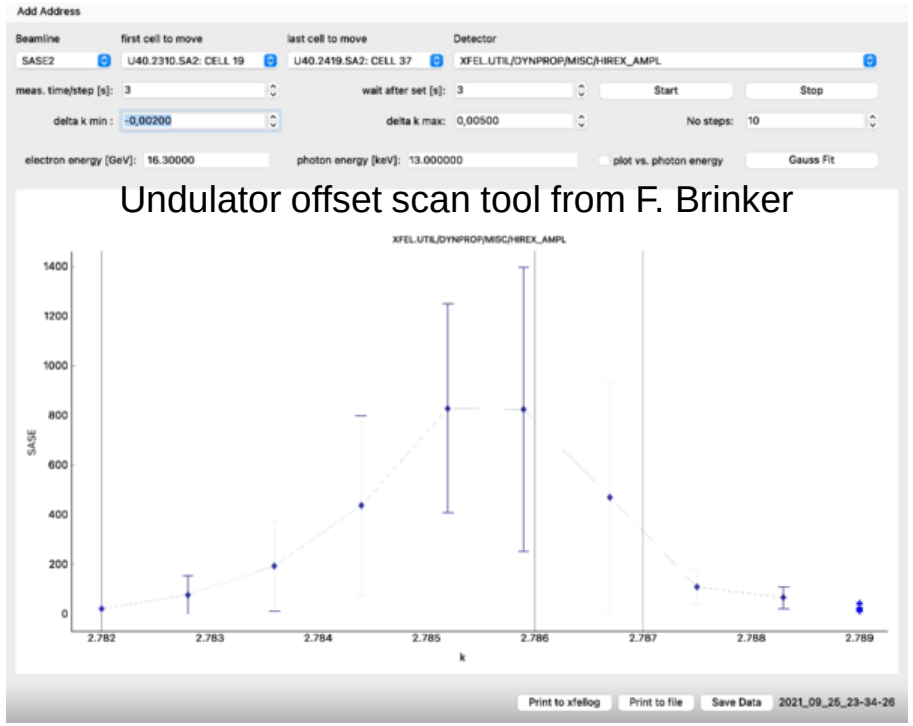
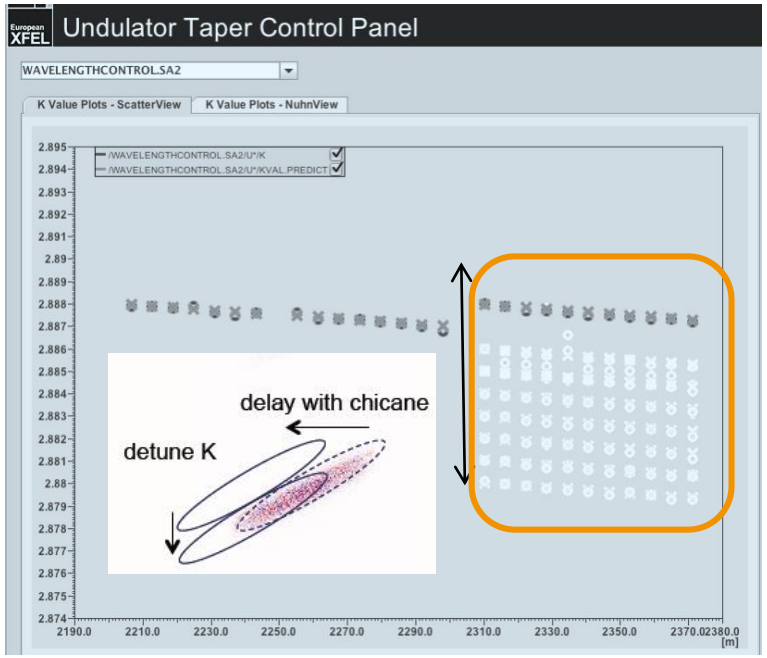




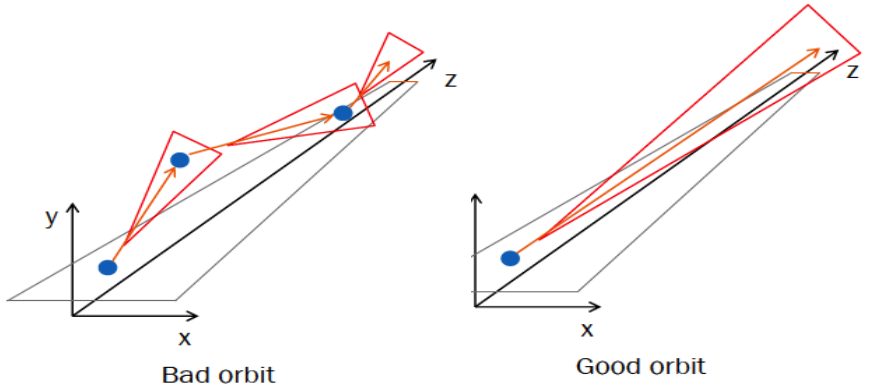


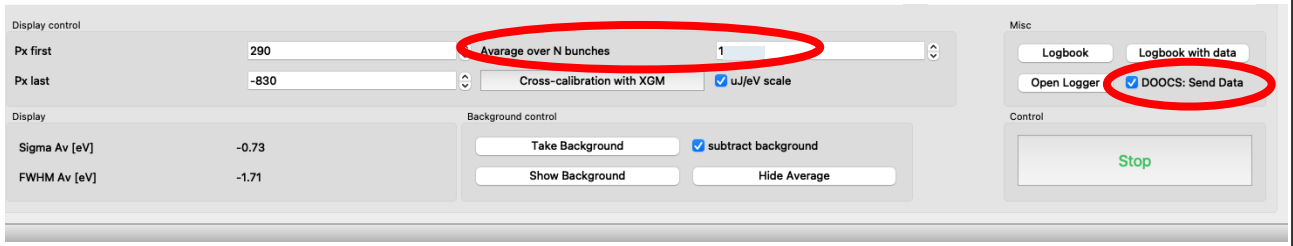
Undulator offset scan tool from F. Brinker

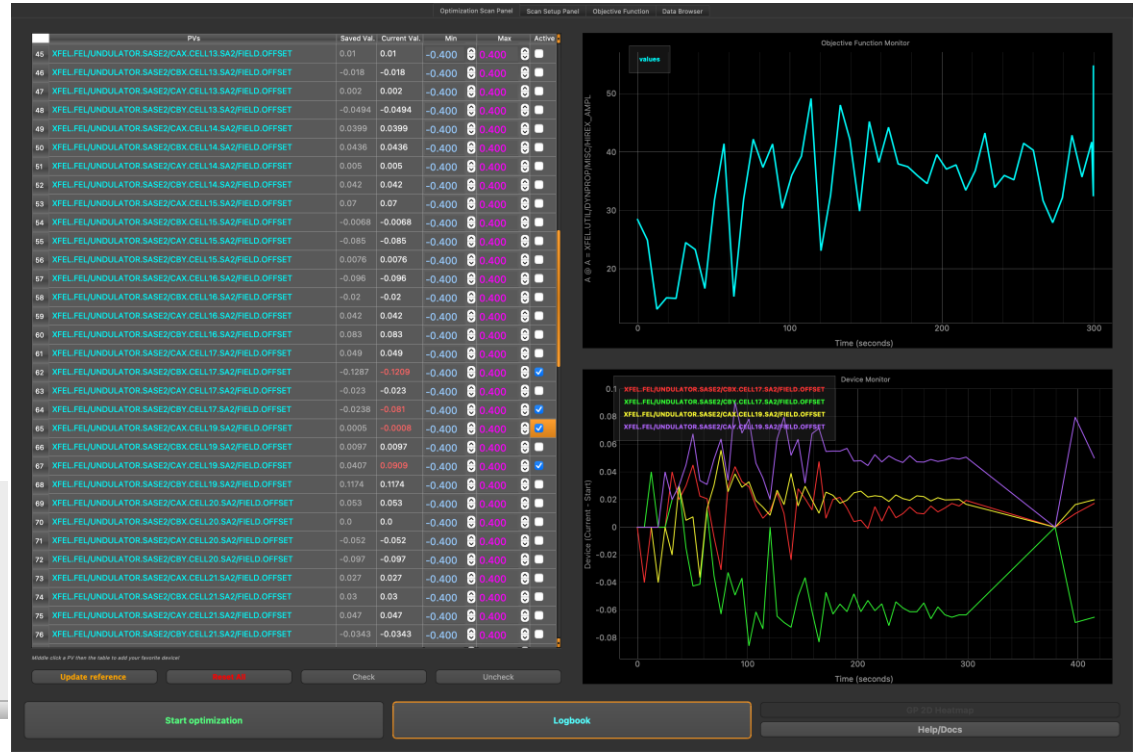


How to tune HXRSS?

- **Air coil optimization** after the chicane, start with launching correctors for **SA22** or **SA23**
- Send only 1 shot (Average over N bunches=1) to DOOCS (with DOOCS: Send Data checked)
- Using seeded peak signal from HIREX in Ocelot: XFEL.UTIL/DYNPROP/MISC/HIREX_AMPL

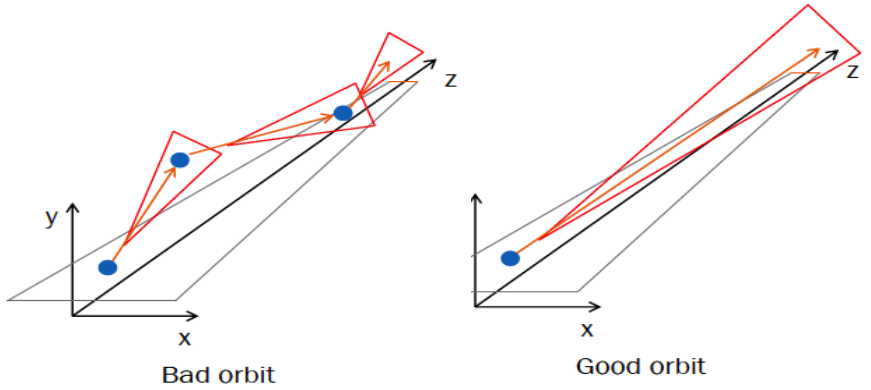






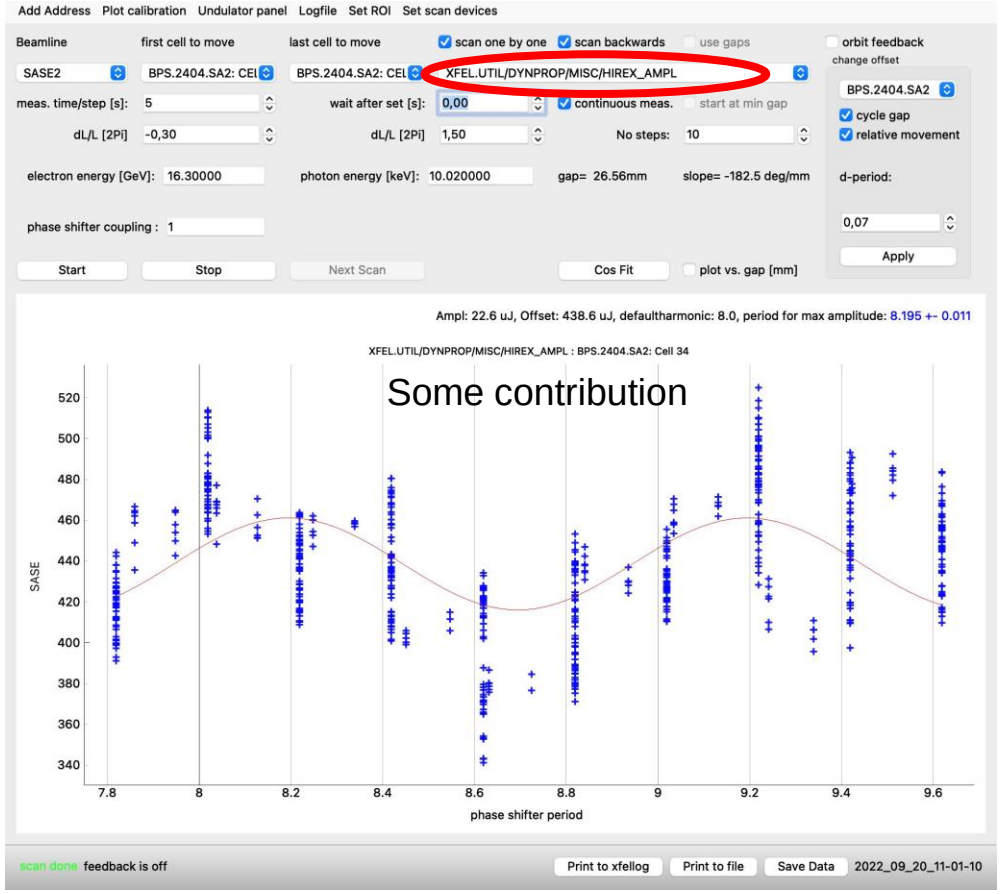
How to tune HXRSS?

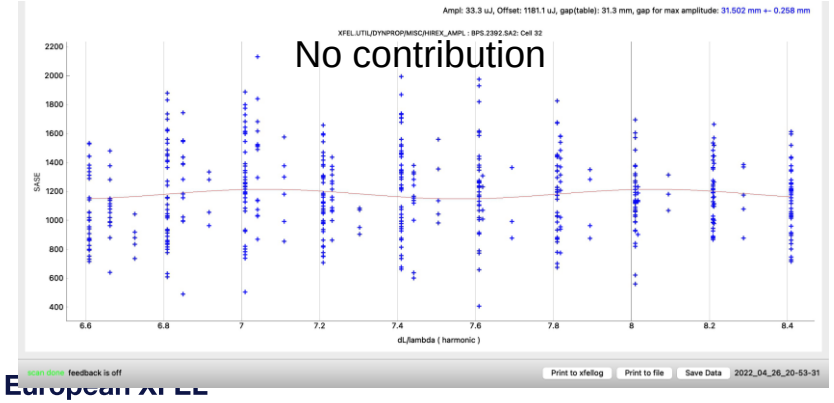
- **Air coil optimization** after the chicane, start with launching correctors for **SA22** or **SA23**
- Switch off the SA23 feedback before optimizations, keep SA2 feedback running
- Save golden orbit in SA23 feedback after optimizations



How to tune HXRSS?

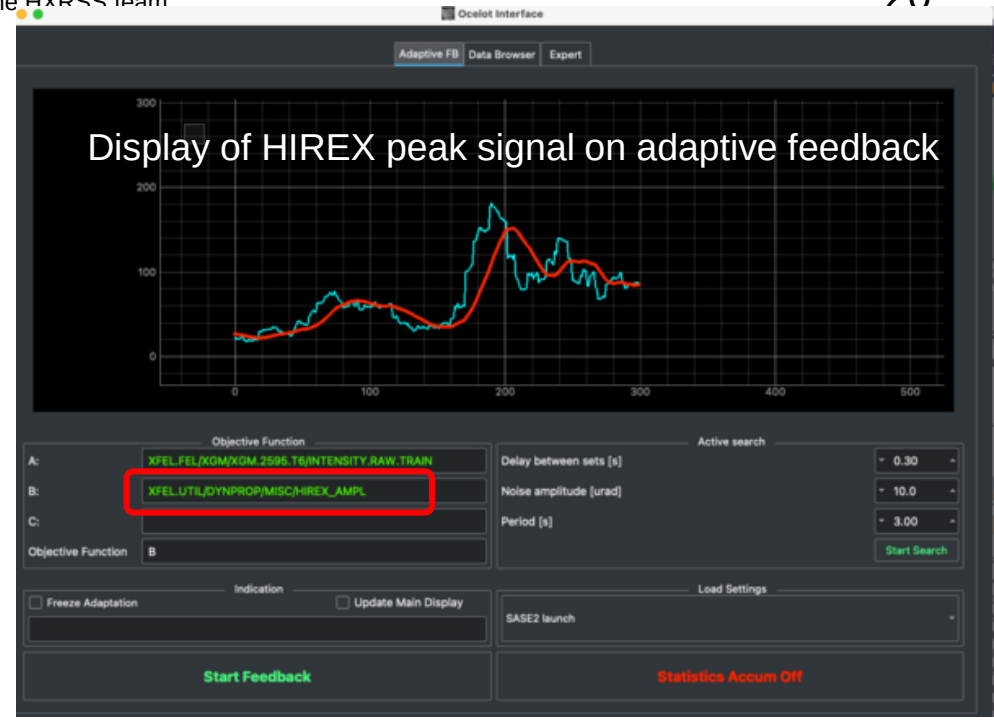
- **Phase shifter scans**
  - using seeded signal: XFEL.UTIL/DYNPROP/MISC/HIREX_AMPL
  - first for undulators downstream of chicane, then also for the upstream undulators
  - if there's no contribution from one cell, optimize the orbit upstream of that cell again until it contributes



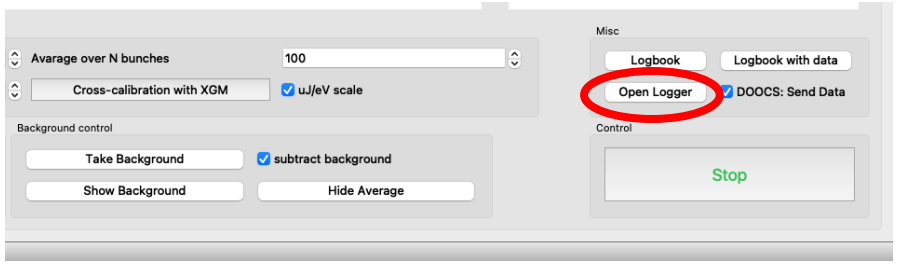


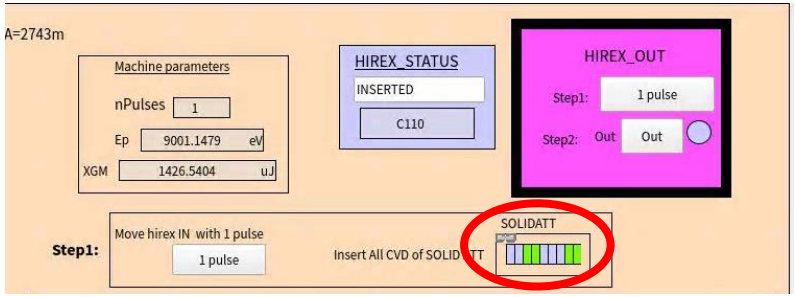
How to tune HXRSS?

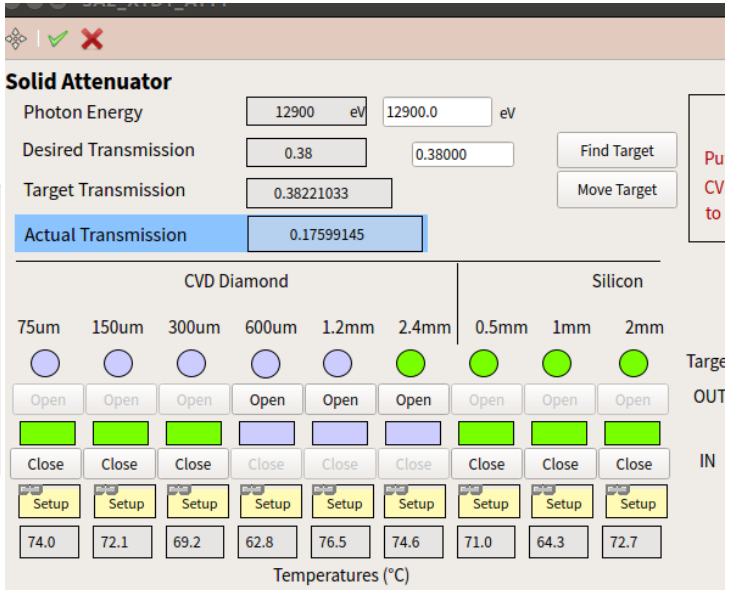
- **Matching quads** using ocelot
- **Taper** optimization -> increase of SNR (larger linear taper, earlier start of power taper)
- **Laser heater**, **compression**
- Always **keep an eye on HIREX peak signal:** XFEL.UTIL/DYNPROP/MISC/HIREX_AMPL
- **Close more attenuators if peak signal > 3000**



Display of HIREX peak signal from pySpec

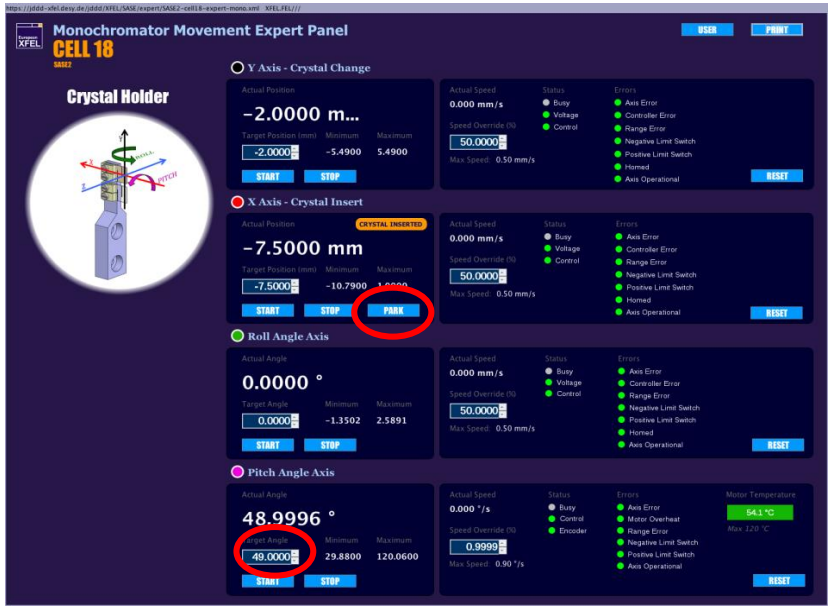


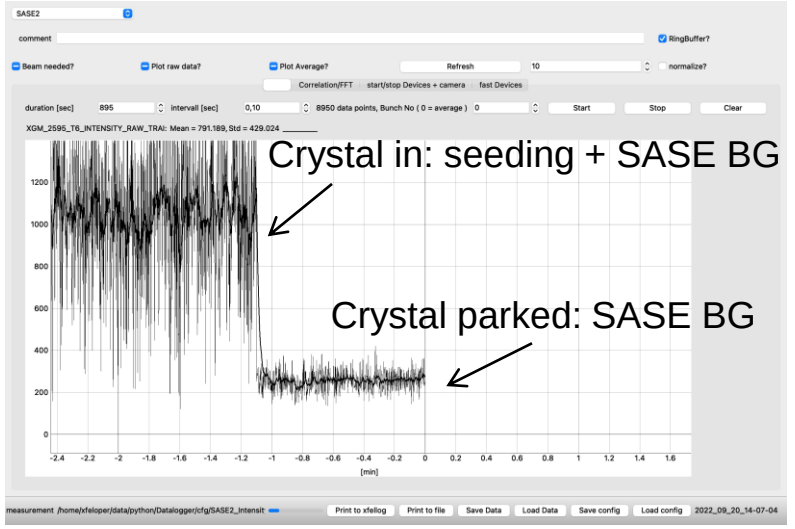




What can happen during user run?

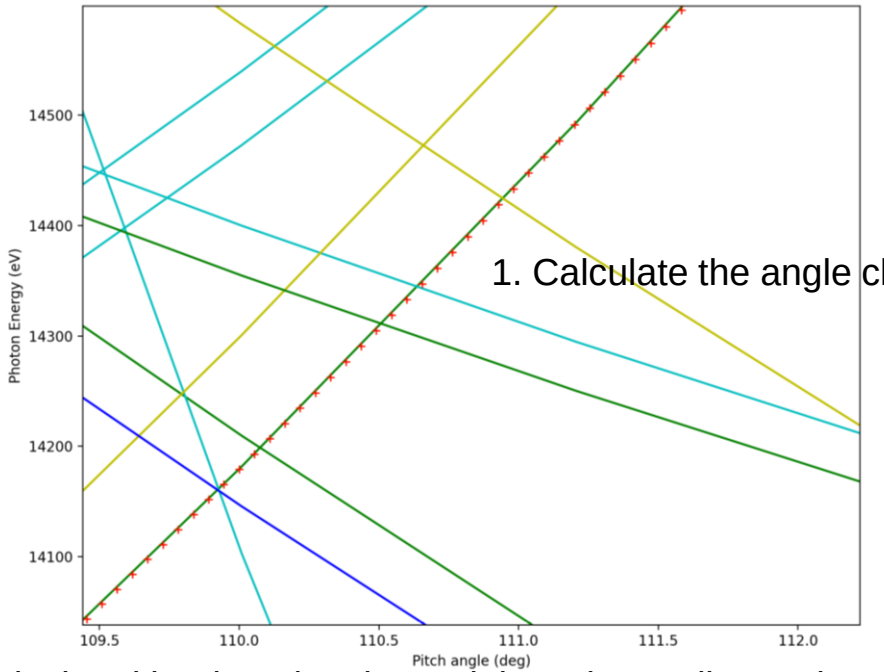
- Signal to noise ratio check
  - park crystal or detune the pitch angle
  - can also be used to check if seeding is still there when HIREX is off
- Intensity drop during delivery
  - fine tune compression
  - optimize launch SA2 using adaptive feedback
  - optimize launch SA23 using ocelot





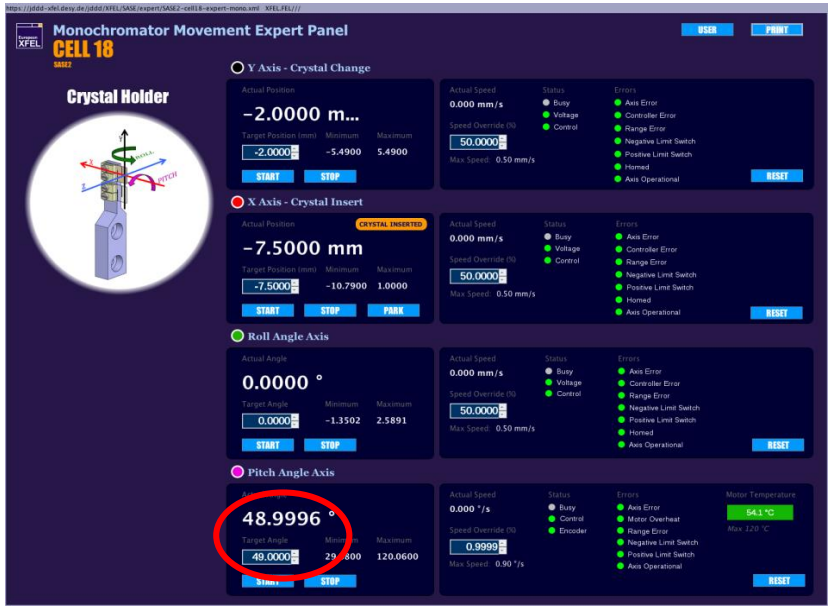
What can happen during user run?

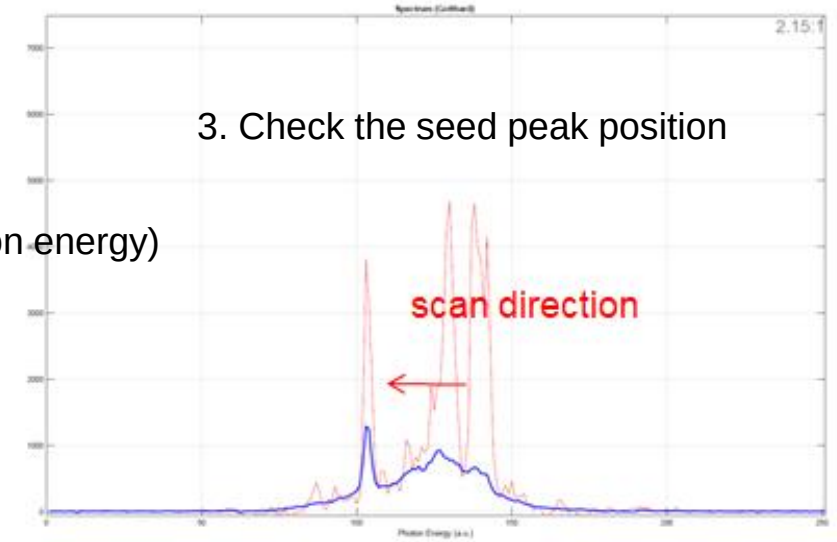
- Energy scan



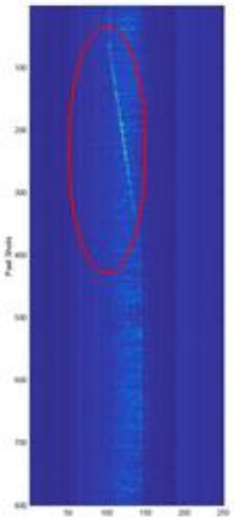
1. Calculate the angle change

2. Change the angle

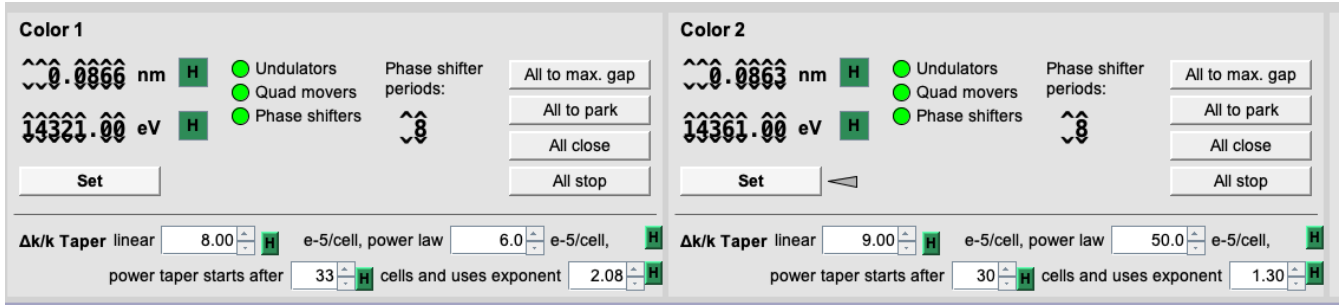




3. Check the seed peak position

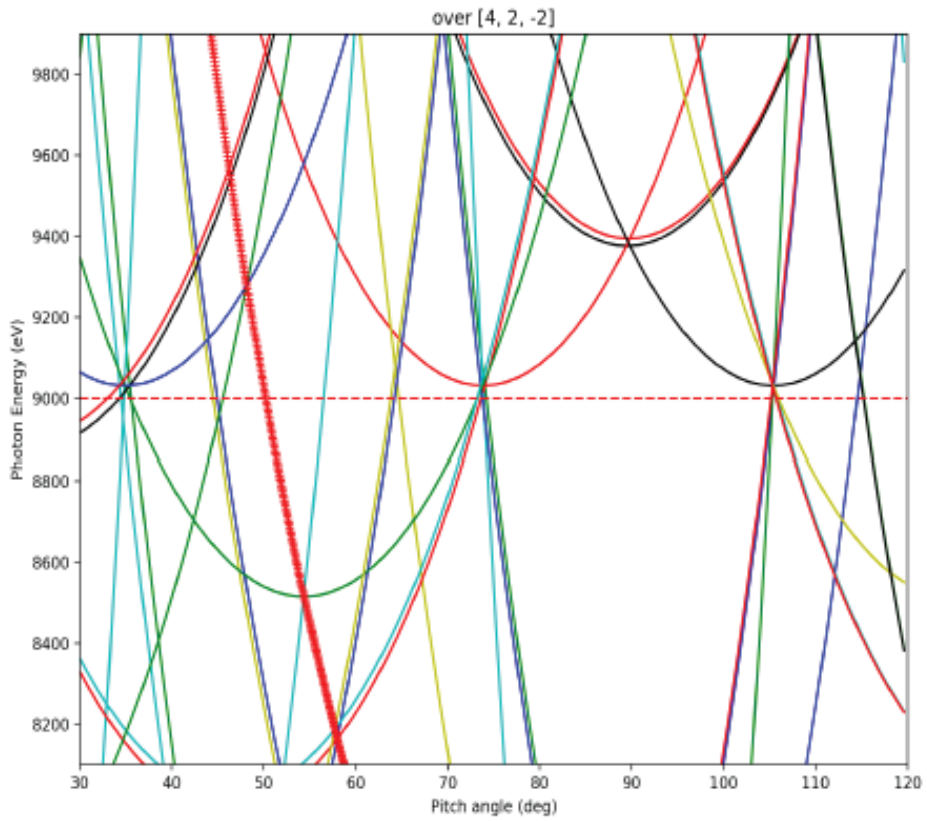


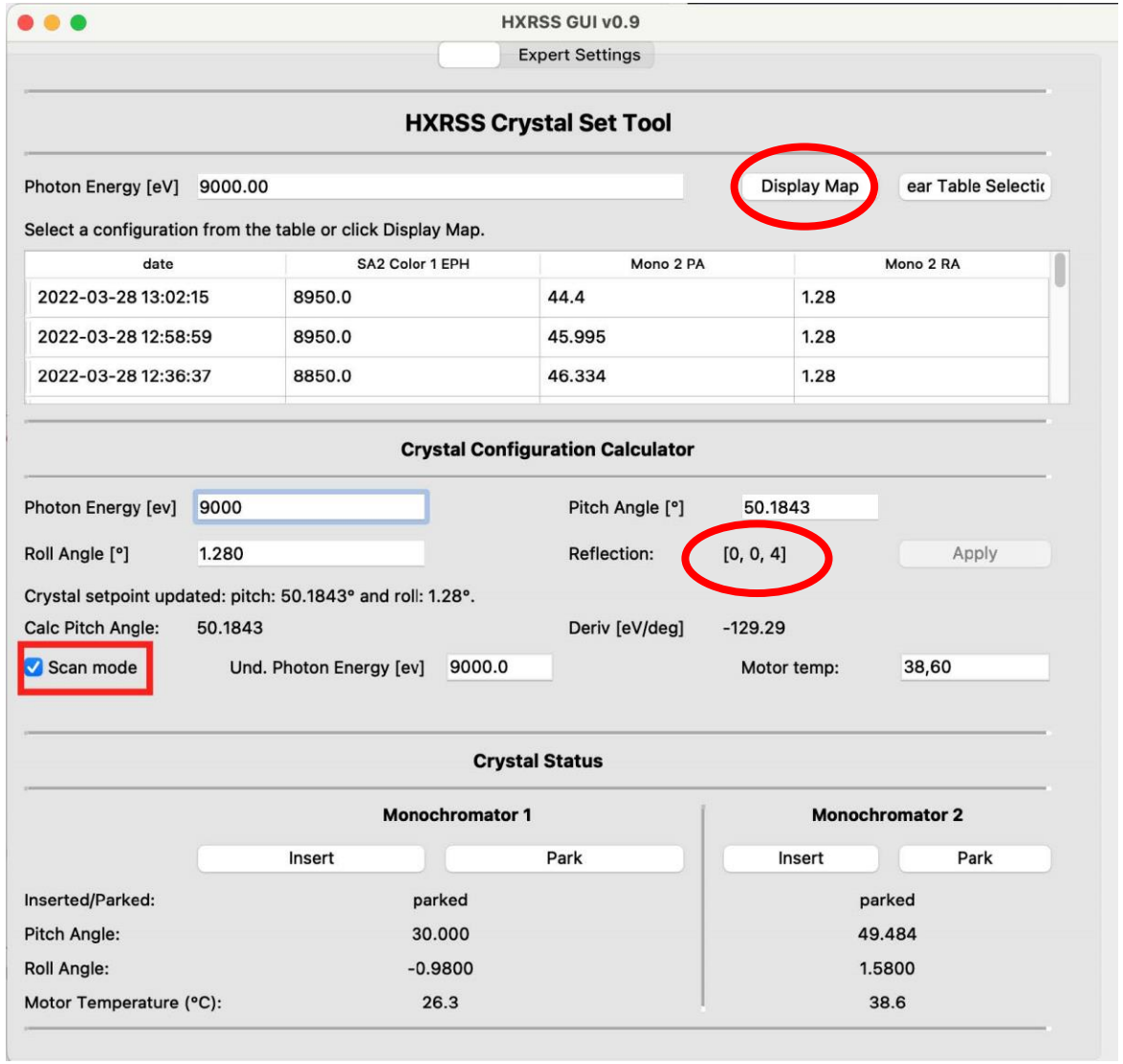
4. Optimize peak signal by detuning the undulator (according to the change of photon energy)



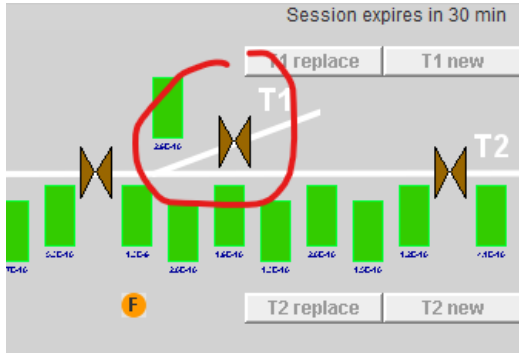
What can happen during user run?

- Energy scan tool
  - XFEL main task panel -> Photons -> Expert Panels-> SASE2-> Crystal set tool





How to switch back to SASE?



- **Retract the crystals** (all of them) by set the X position to park
- **HIREX out** (close all the attenuators, and close Gotthard shutter)
- Set chicane delay to 0 and **degauss the chicanes** (to allow parallel operation in other beamlines, please insert the first vacuum valve in T1)
- Switch off the SA22 and SA23 feedback
- Use the photon energy switch tool to **prepare a photon energy file** from the file saved before HXRSS set-up and use **seq. to change photon energy** to apply the file settings
- **Launch optimization** using adaptive feedback if needed
- If SASE level is still not back to the file value
  - scan phase shifters near the two chicanes
  - use ocelot optimizer to optimize orbit near the two chicanes (using air coils)

Summary

SASE tuning

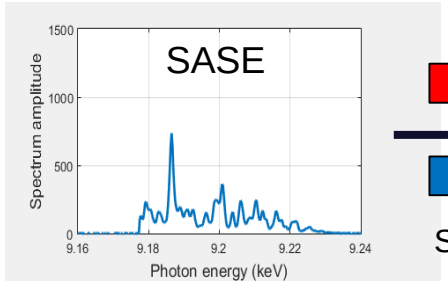
Orbit feedback on

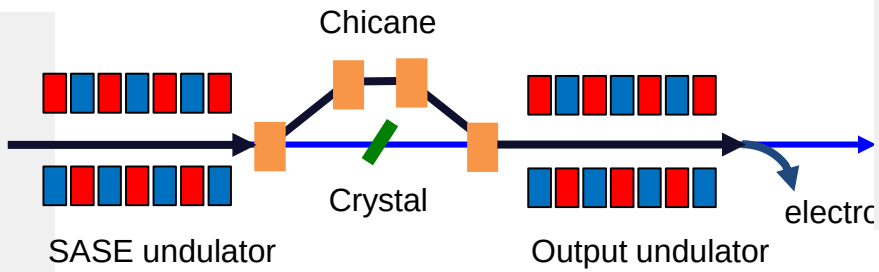
Chicane on

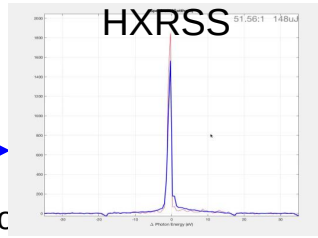
Crystal in

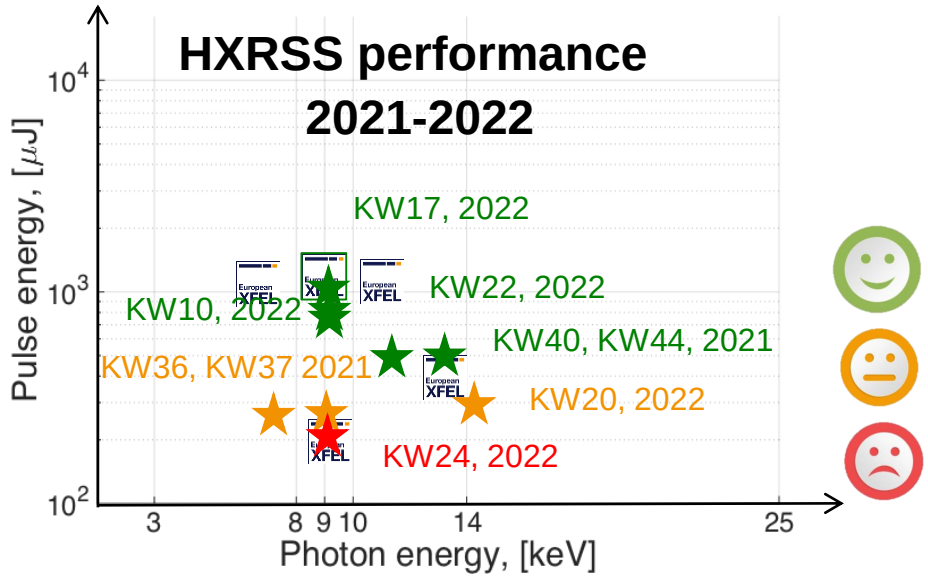
Find seed signal

Optimize seeded signal









Thank you for your attention !

Happy users, happy delivery!

HXRSS confluence pages

https://confluence.desy.de/display/XFELOp/HXRSS+set-up+procedure

https://confluence.desy.de/display/HTUD/HXRSS+user+delivery+history