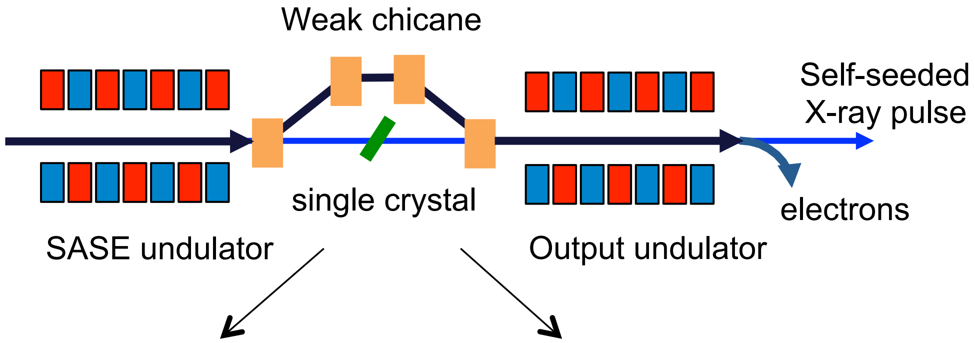
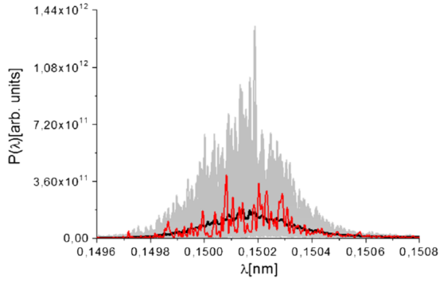
Hard X-Ray Self-seeding set-up experiences

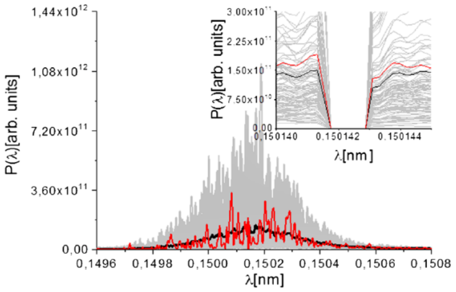
Shan Liu
on behalf of the HXRSS commissioning team

Beam dynamics meeting
Hamburg, 12.05.20

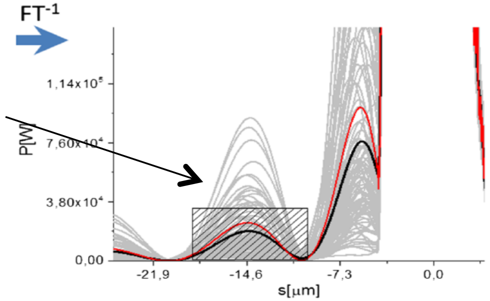
HXRSS principle and start of art





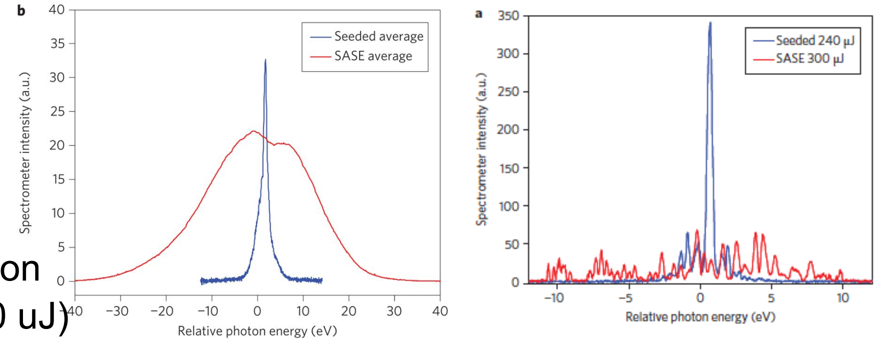


Monochromatic tail
(“Forward Bragg
diffraction”)

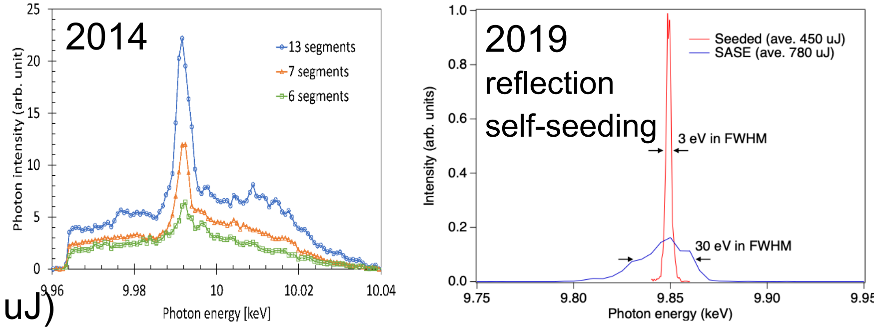


*** G. Geloni, V. Kocharyan, E. Saldin (*DESY 10-133*)**

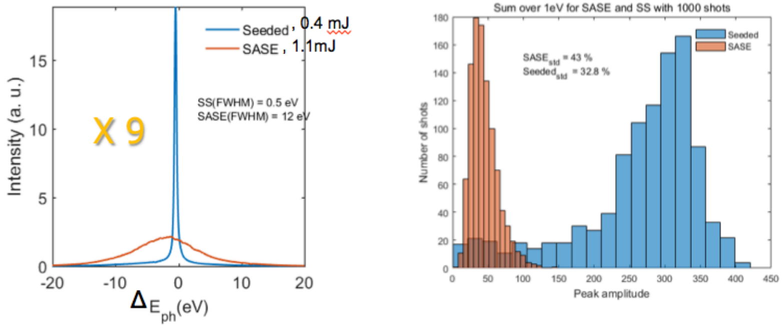
First demonstration
2012 (8.3 keV, 240 uJ)



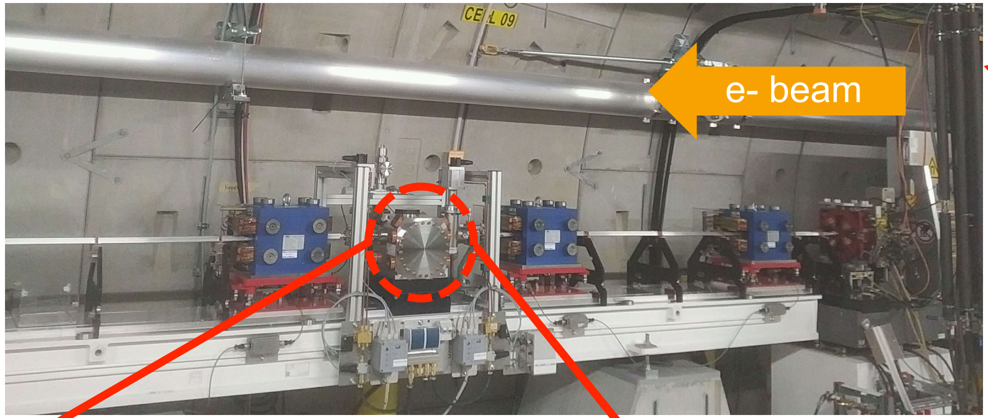
2019 (9.8 keV, 450 uJ)

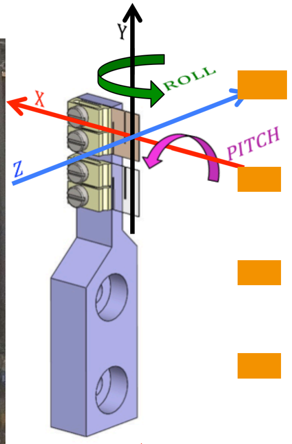


PAL performance
2019 (9.7 keV, 400 uJ)



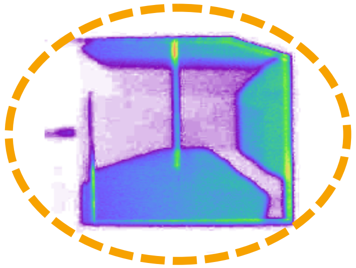
HXRSS Monochromator

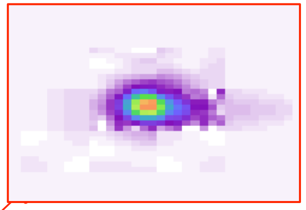


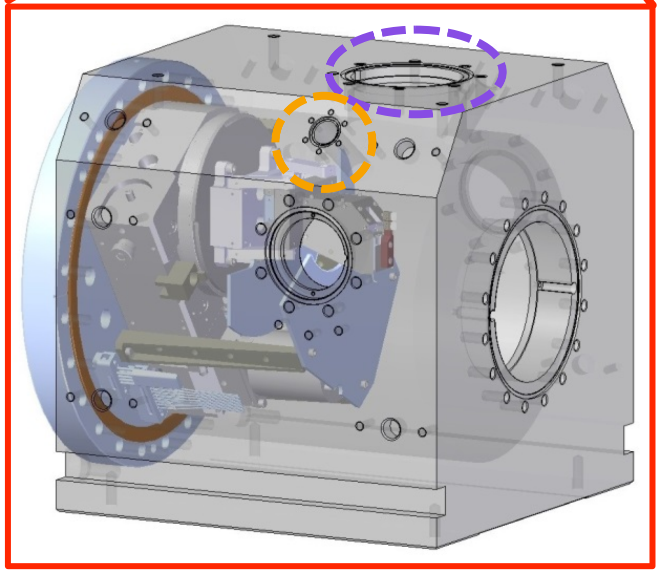


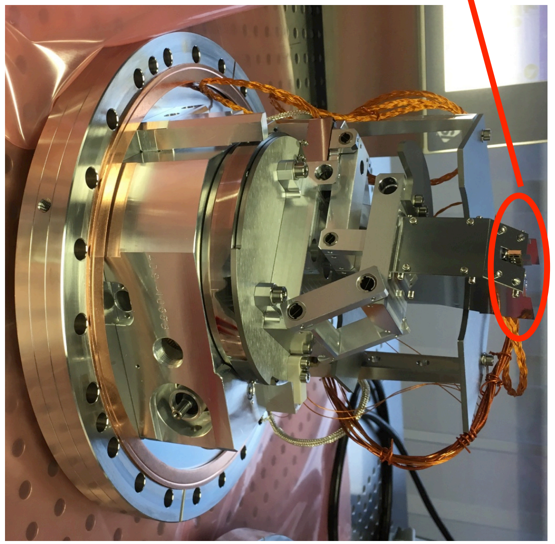
- Two crystals on one holder
- Mono. #1: 105µm <100> + 110µm <111>
- Mono. #2: 105µm <100> + 42µm <111>
- Spare one: 169µm <100> + 110µm <111>

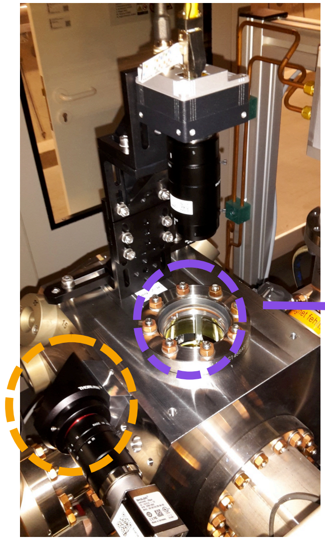
Diamond crystal



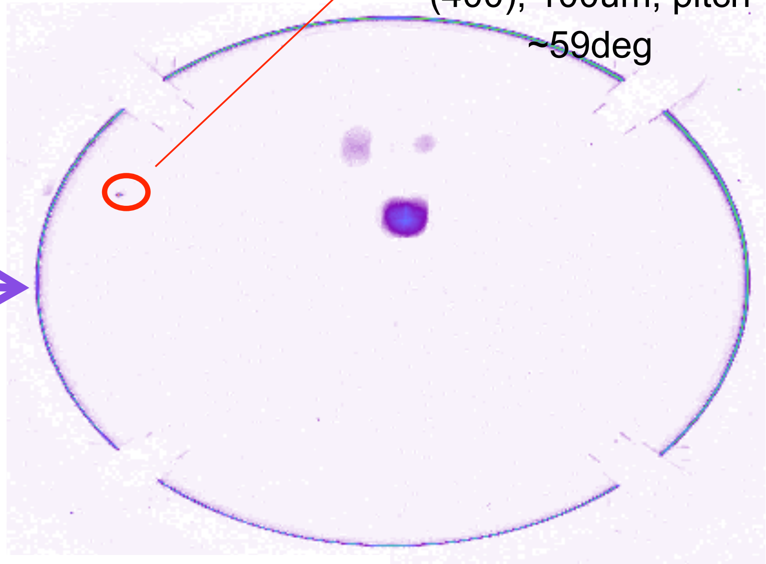






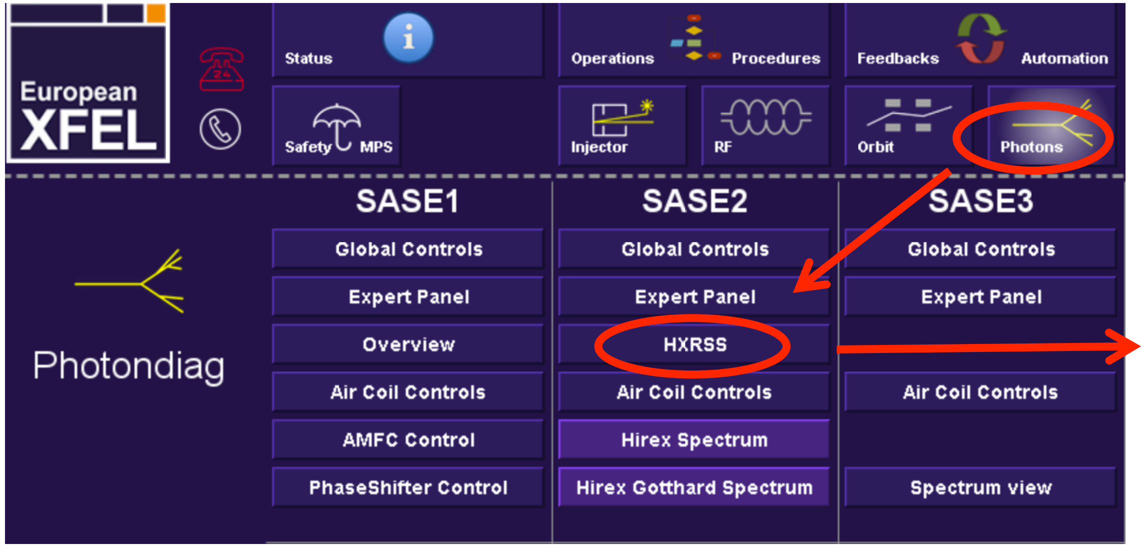


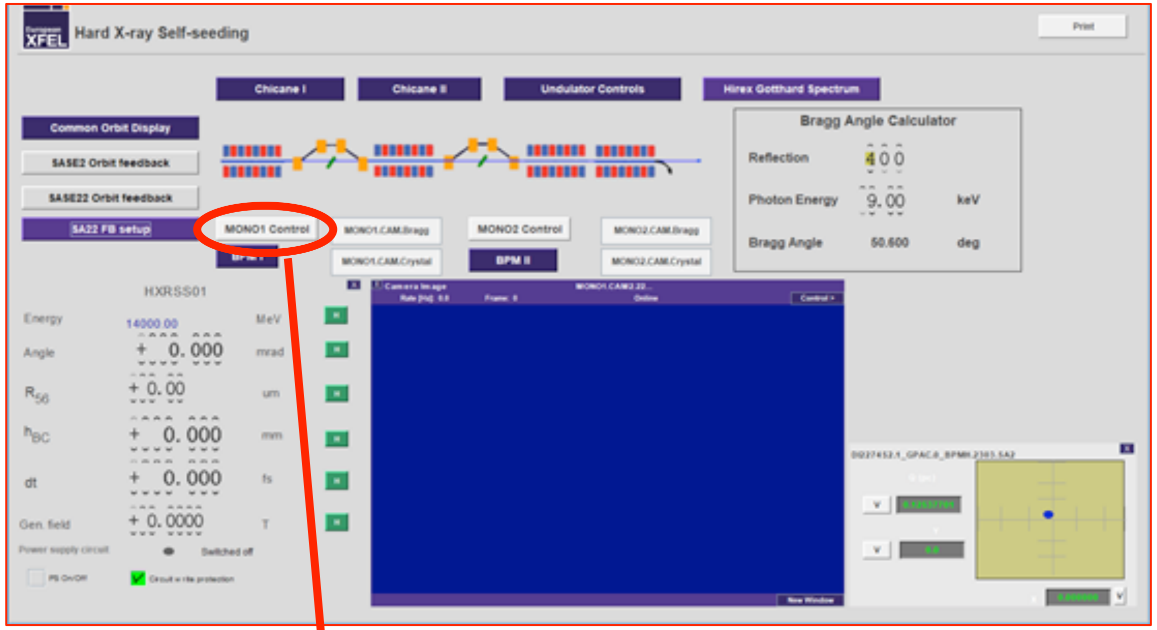
8 keV, bragg reflection (400), 100um, pitch ~59deg

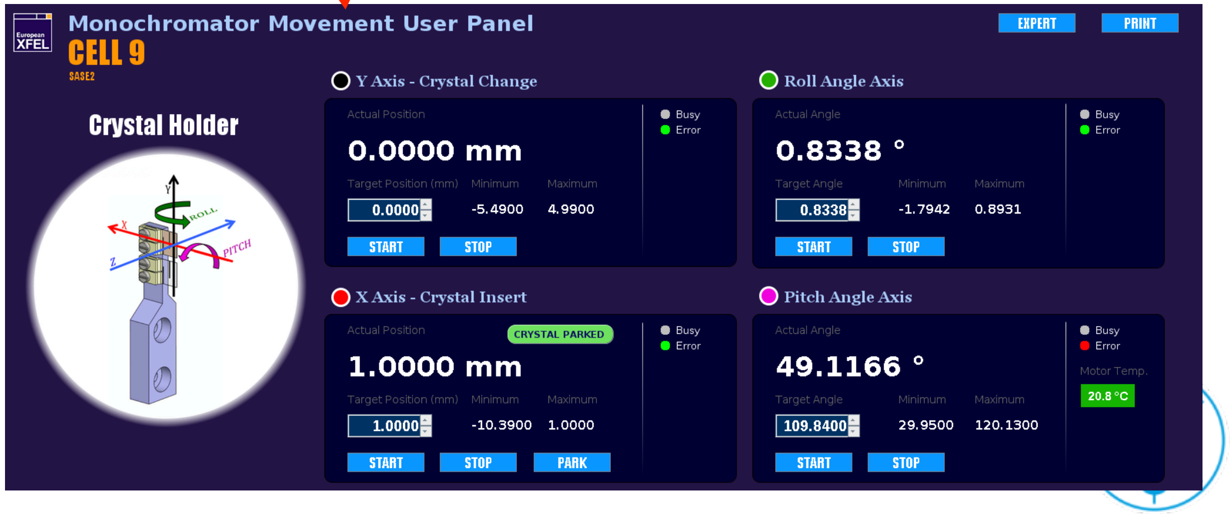


- Monochromators desinged by ANL (D. Shu) -> similar to LCLS and PAL design

HXRSS panel

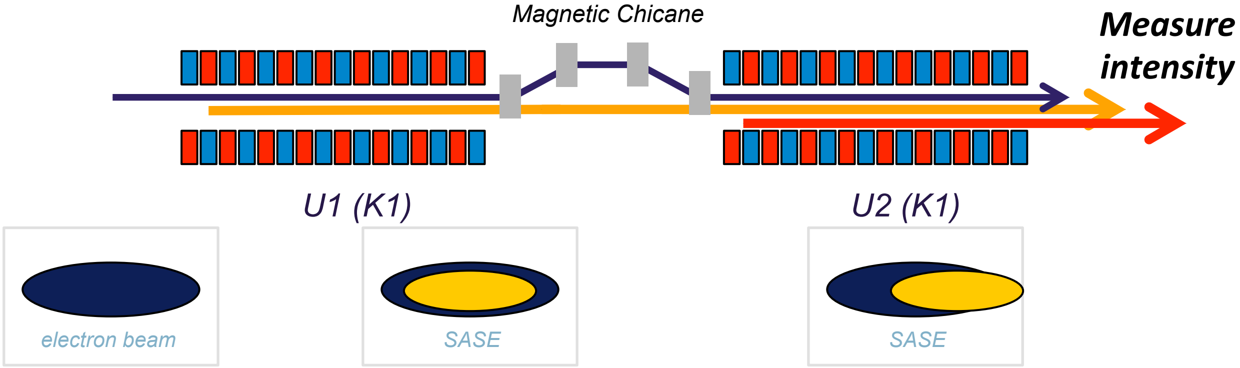


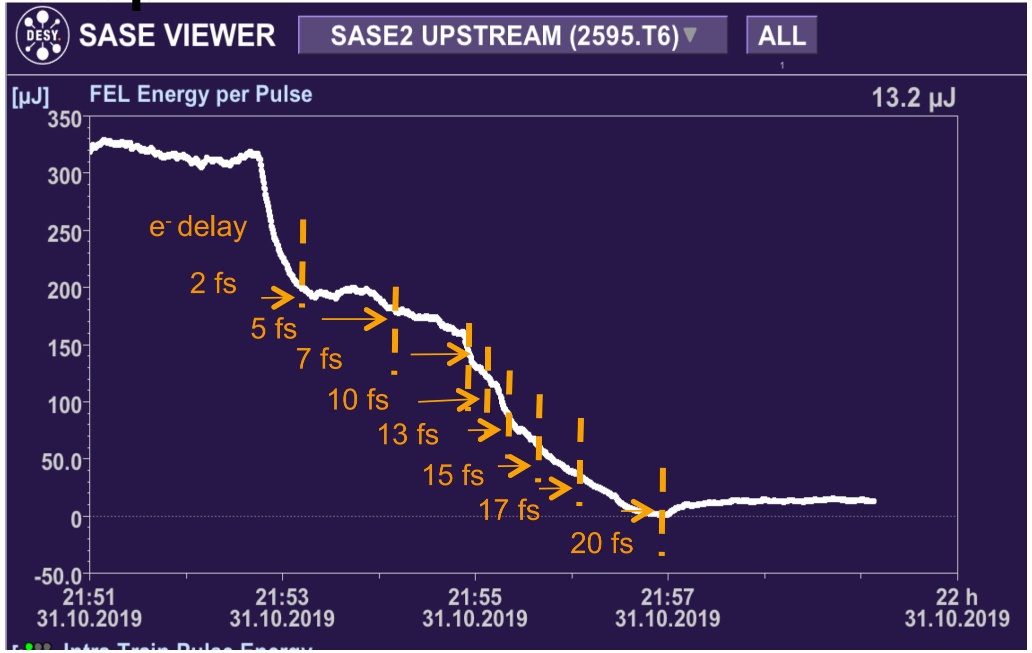




- Monochromators control now in DOOCS
- Orbit feedback, chicane control, undulator control etc.

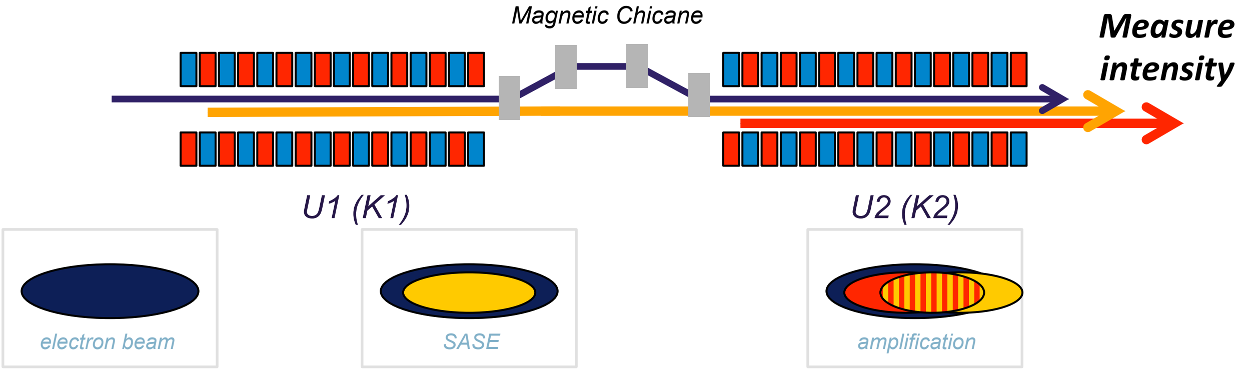
Diagnostics for longitudinal and transverse overlap



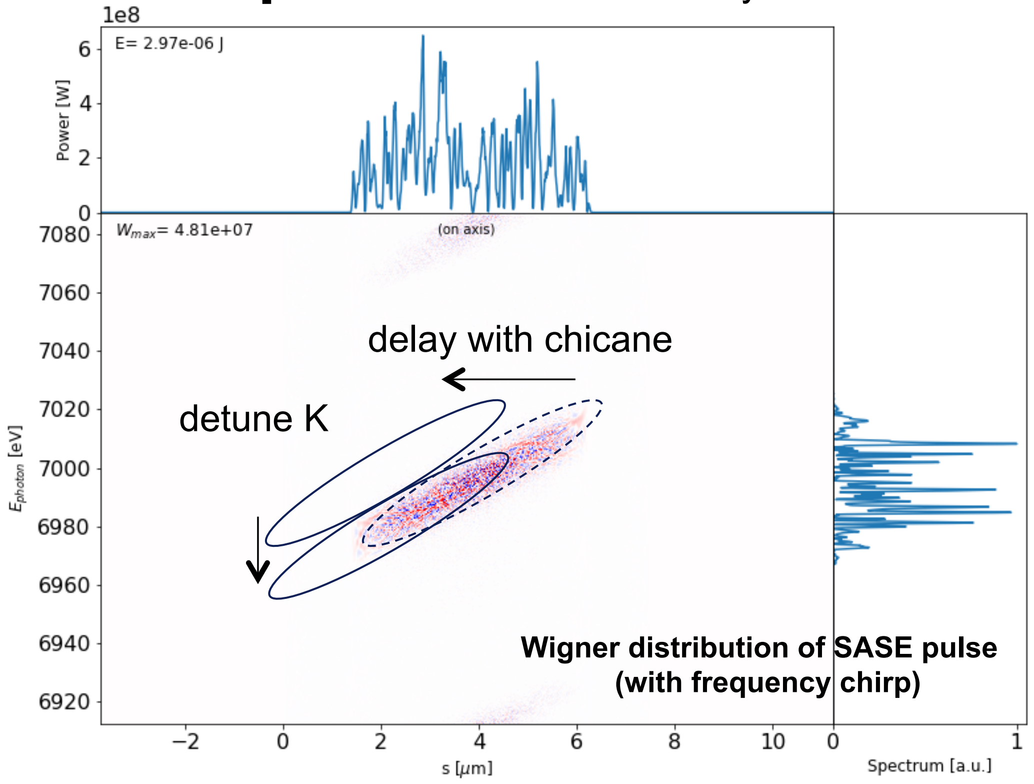


- Superposition between e^- beam and seed after chicane is crucial for self-seeding
- How to check the overlap? -> seeding with SASE
  - change e^- beam delay
  - measure output SASE intensity
  - optimize transverse overlap by orbit correction
  - longitudinal overlap (lasing window) depends on the chirp (long. phase space)

Diagnostics for longitudinal and transverse overlap

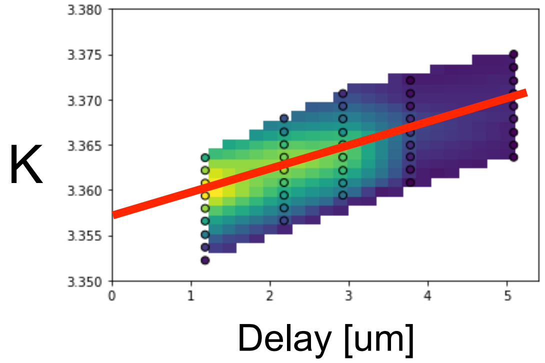


courtesy of S. Serkez

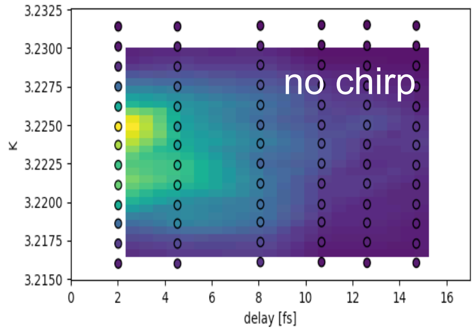


- Superposition between e⁻ beam and seed after chicane is crucial for self-seeding
- How to check the overlap? -> seeding with SASE
  - change e⁻ beam delay
  - measure output SASE intensity
  - optimize transverse overlap by orbit correction
  - longitudinal overlap (lasing window) depends on the chirp (long. phase space)
- Combine delay with K detuning (DD scan) one can reconstruct linear chirp

- Measurement 12.06.2019



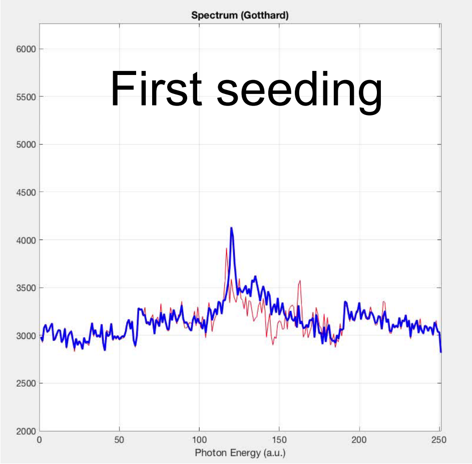
- Measurement 31.07.2019



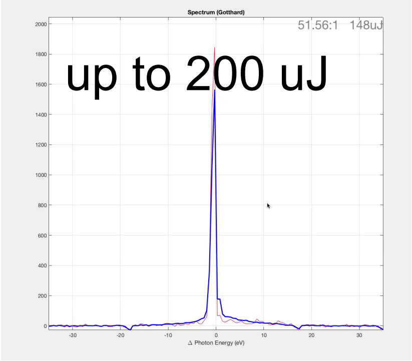
Commissioning history

2019 | Sep | Oct | Nov | Dec | 2020 | Feb | Mar | Apr | 2020

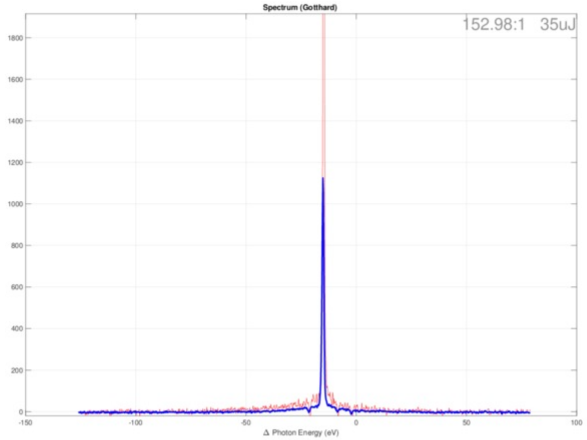
First seeding with 2nd chicane



Seeding @ 9 keV up to 200 uJ seeded signal achieved



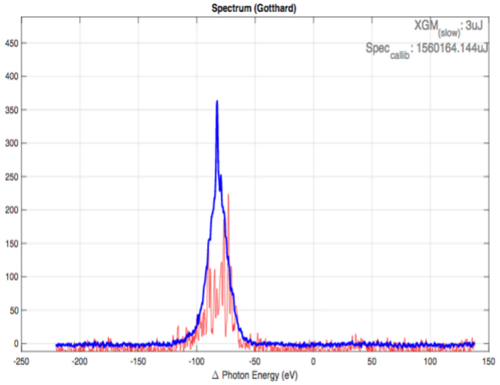
Seeding @ 9.3 keV



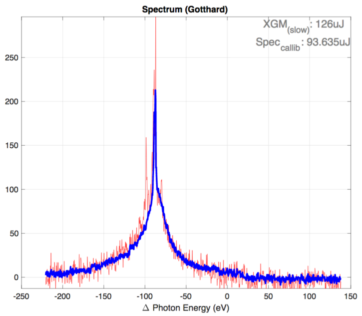
Winter shutdown

Seeding test
no seed signal found…

First seeding with 1st chicane

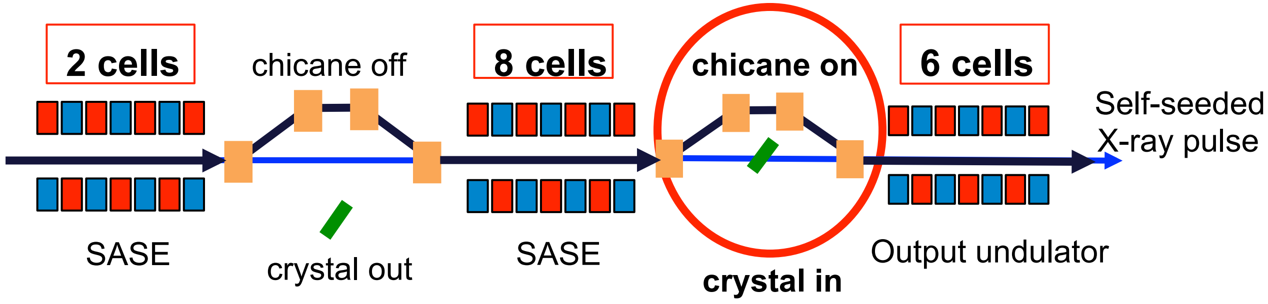


Seeding test after user run

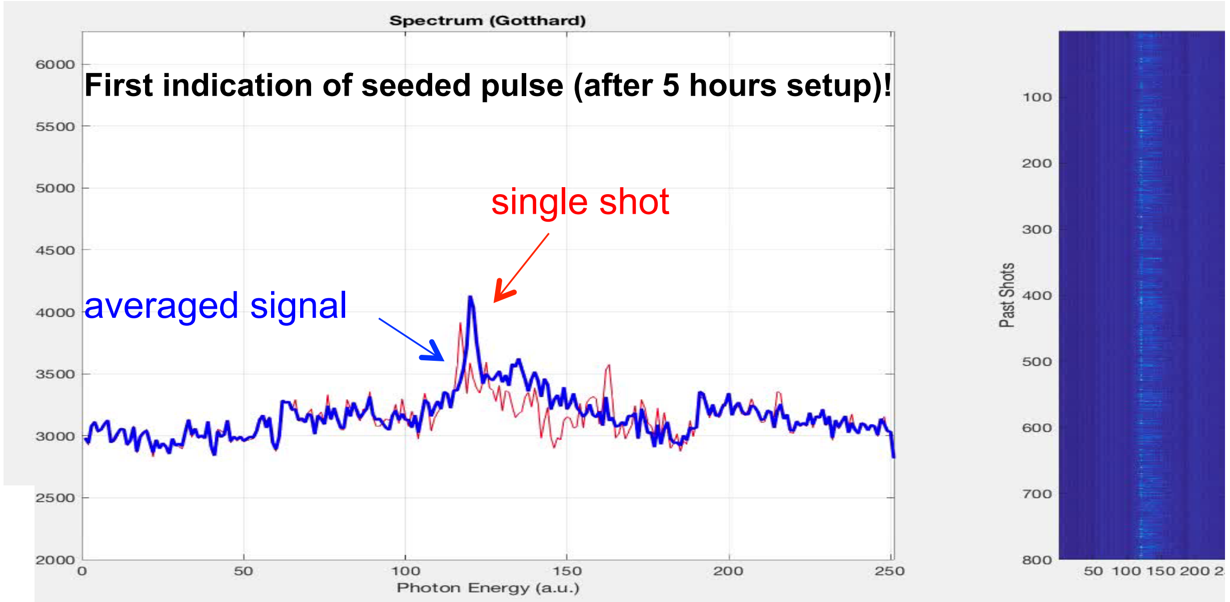


“Corona shutdown”

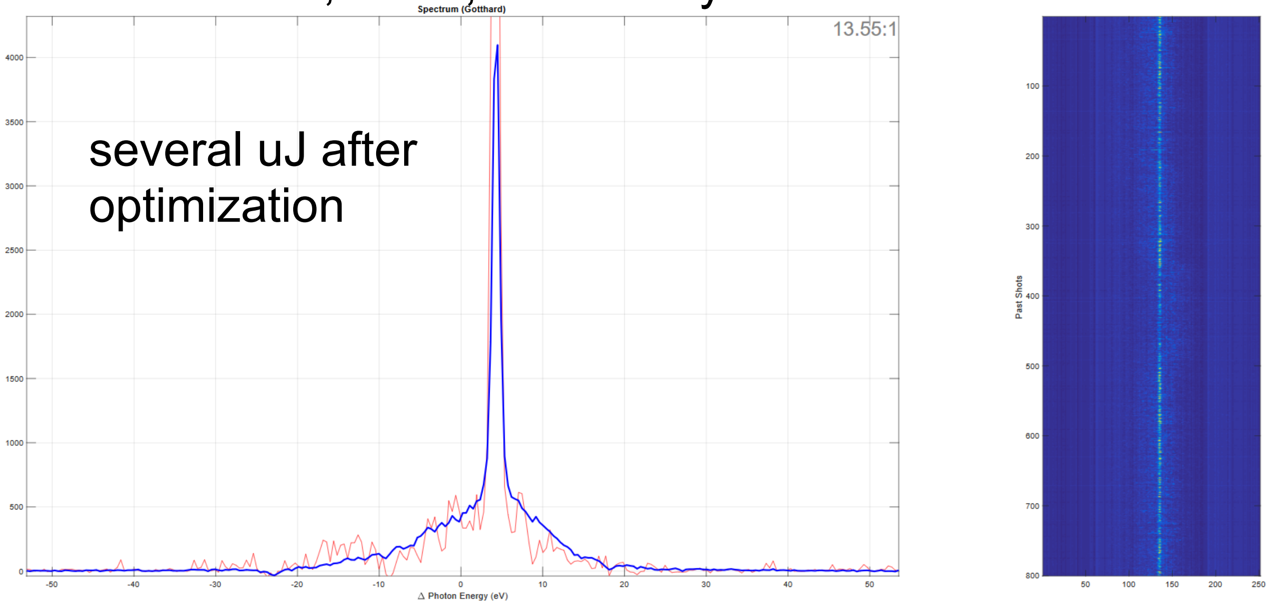
First seeding at 8 keV



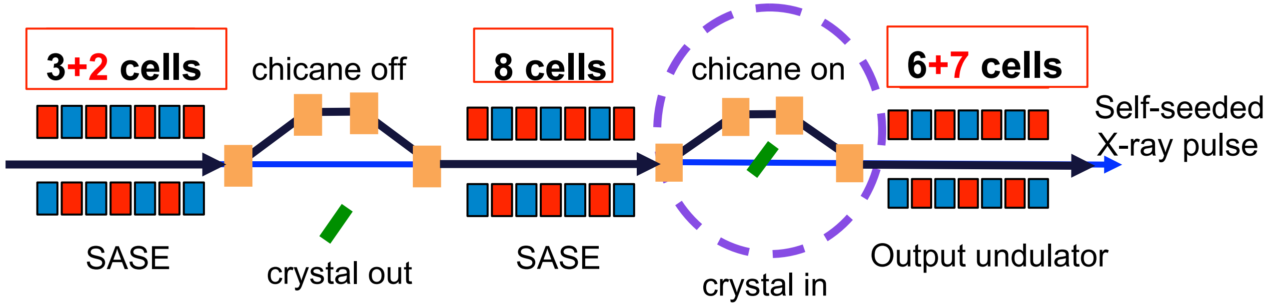
- SASE level before the 1st mono. was too low to see the reflections -> first try with 2nd chicane
  - Chicane on ->seeding with SASE and optimizing overlap
  - Crystal in -> find bragg reflection for C400
  - Scan delay -> find seeded signal
- First observation of self-seeding at SASE2 in the linear regime

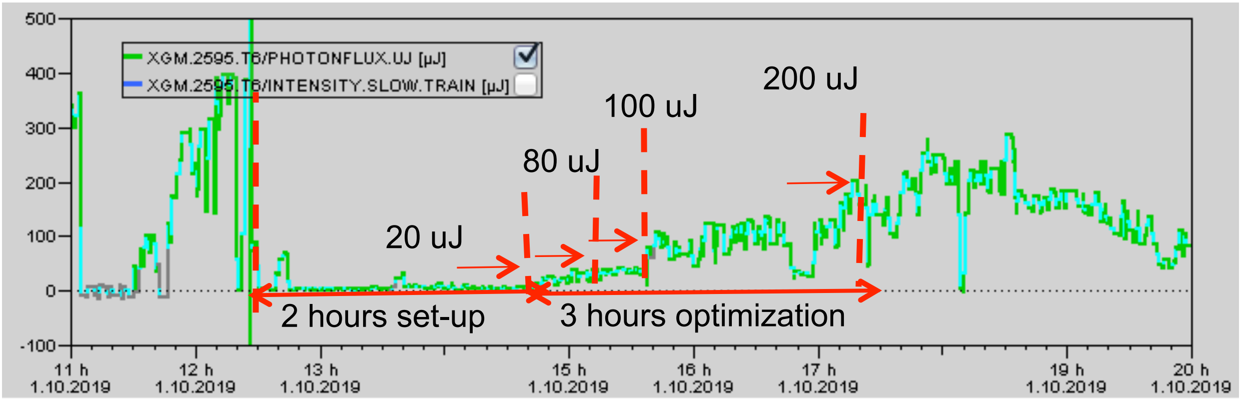


8keV, C400, 25 fs delay

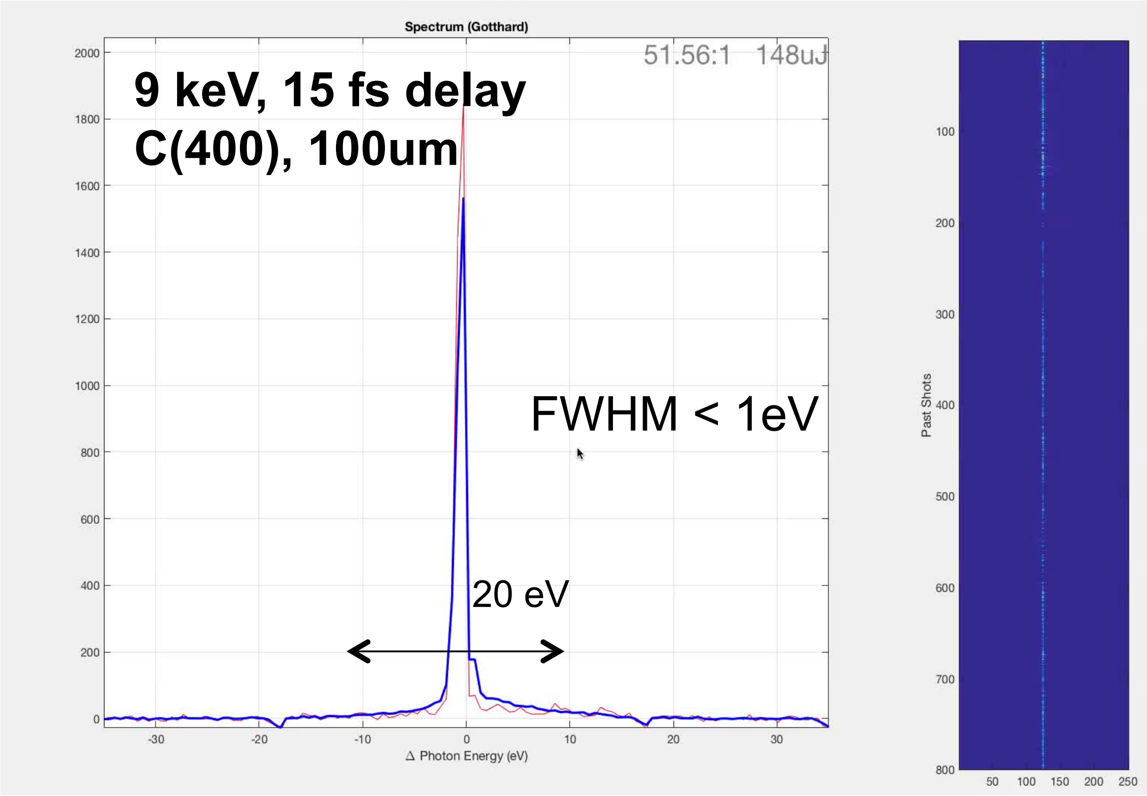


Seeding at 9 keV

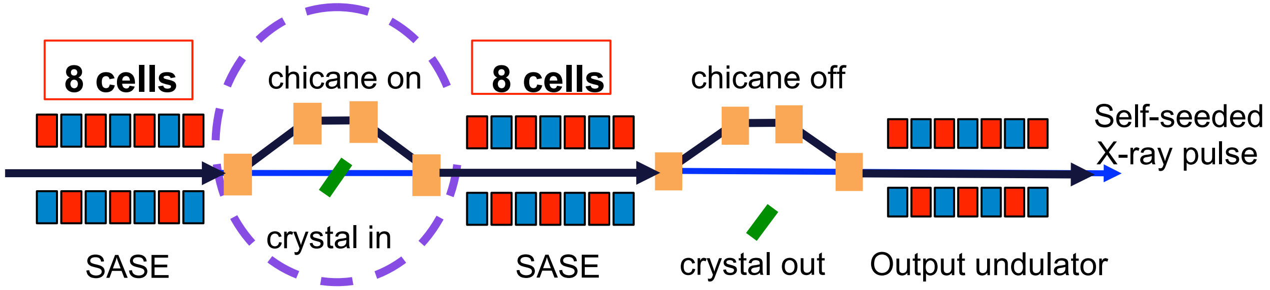


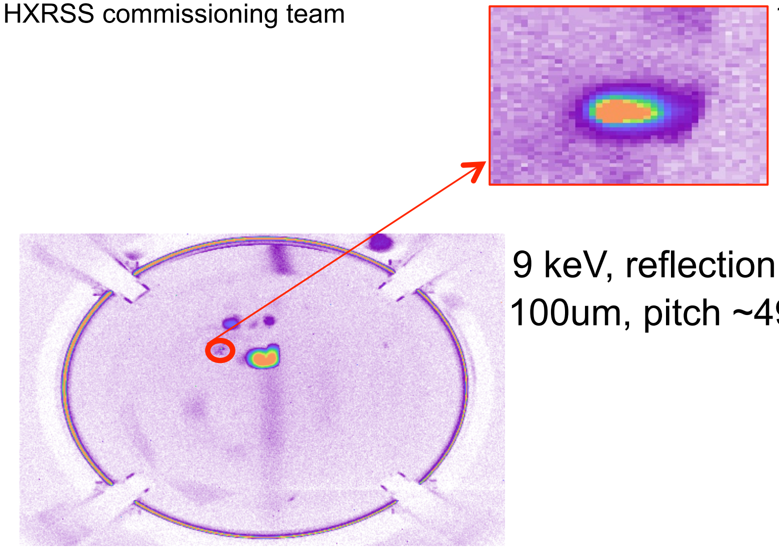


- Seeded signal found right after insetion of crystal
- Obtained 20 uJ after 2 hours setup
- Add 7 cells after chicane-> 80 uJ
- Add 2 cells before chicane, phase shifter scan with seeded signal-> 100 uJ achived
- Orbit tuning (transverse overlap) helped to increase pulse energy up to 200 uJ



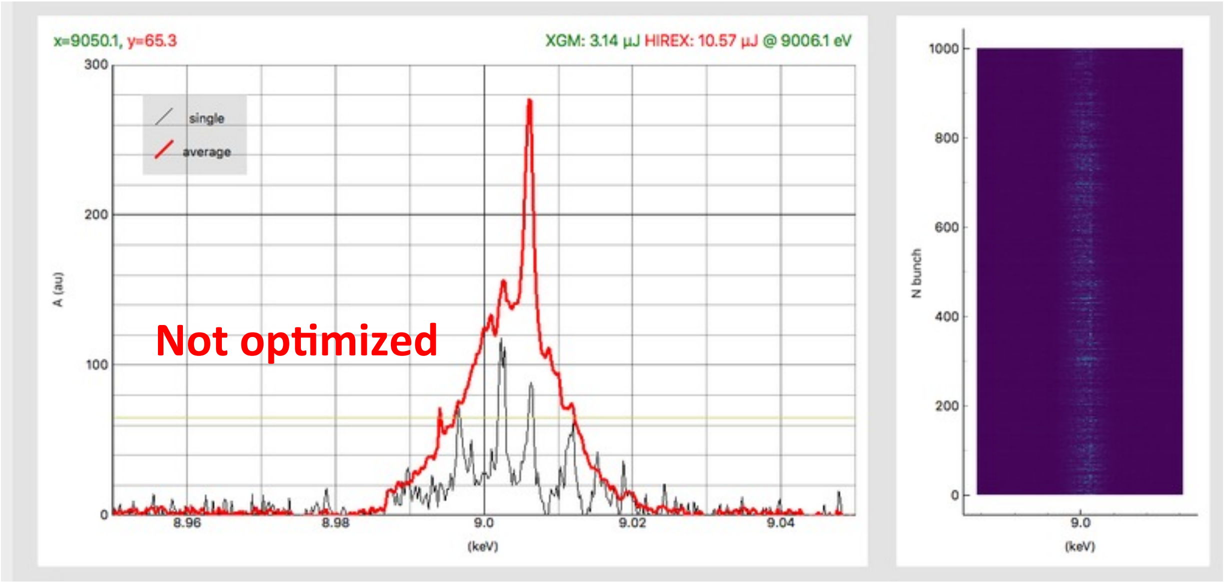
First seeding with 1st chicane





9 keV, reflection (400), 100um, pitch ~49.4deg

9 keV, C400, 100 um, 16 fs delay



- SASE level before 1st chicane could be improved (to several uJ) with better orbit alignment
- Seeded signal found right after setting to the observed bragg reflection angle
- SNR could not be optimized due to bad transverse overlap after 1st chicane (orbit feedback didn't work at that time)

Commissioning condition summary

	Sept. 2019	Oct. 2019	Nov. 2019	Feb. 2020	09.03.2020	16-17.03.2020
Initial SASE level	360 uJ @ 8 keV	1.1 mJ @ 9 keV	750 uJ @9.3 keV	700 uJ @ 9 keV	1 mJ @ 9 keV	1.6 mJ @ 9 keV
w/o quad. taper	360 uJ	400 uJ	250 uJ	300 uJ -> 410 uJ	240 uJ	300 uJ
Closed undulators	u7-u25	u7-u24	u1-u35	u1-u29	u3-u34	u3-u30
U1				8 uJ		<4 uJ
U12	few uJ	10 uJ	11 uJ	300 uJ	10 uJ	30 uJ
lasing with SASE (10 fs delay)	20 uJ -> 30 uJ	large signal drop	27 uJ	340 uJ	140 uJ	5 uJ (1st chicane)
Seeding on 1st chicane	Not tried	Not tried	Not tried	Problem with motor	Not tried	Yes
Seeding on 2nd chicane	Yes, several uJ	Yes, up to 200 uJ	Yes, 40 uJ @9.3 keV	No	Yes, not optimized	No

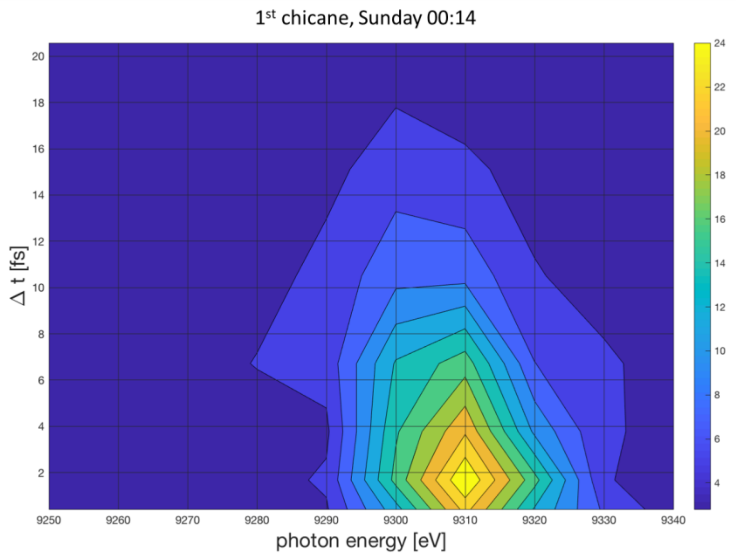
~ 300 uJ after removing quad. taper

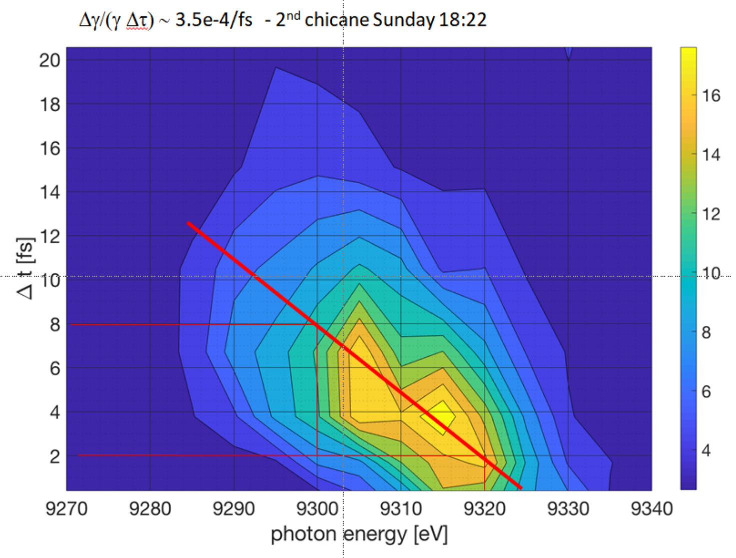
input power on crystal (5-10 uJ optimum?)

lasing window (~10 fs optimum?) SASE level drop by factor 10?

Troubleshooting failure (except for technical problems)

- Not enough **input pulse energy** (< uJ) on crystal -> main problem for 1st chicane
- Bad **transverse overlap** after chicane -> orbit could not be maintained straight
- (Feb. 2020) Did we have some open **dispersion**? If so, a **energy chirp** could have been fatal to us…

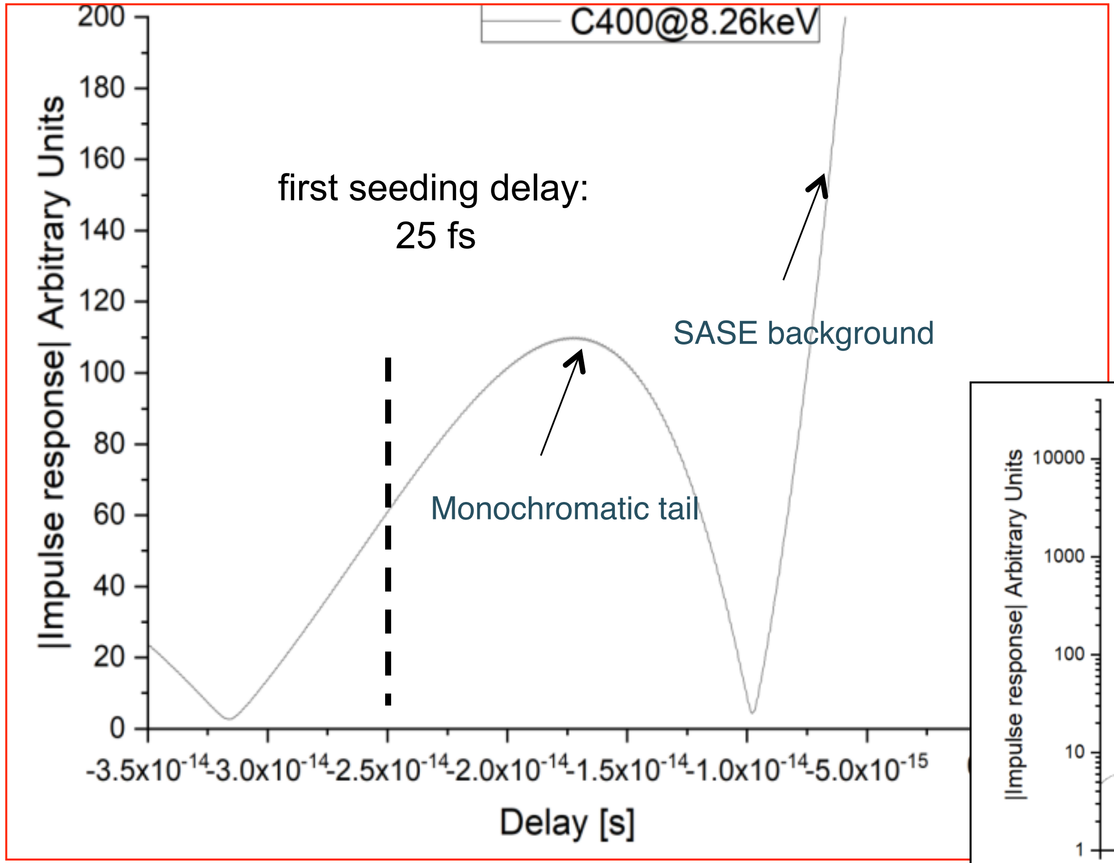


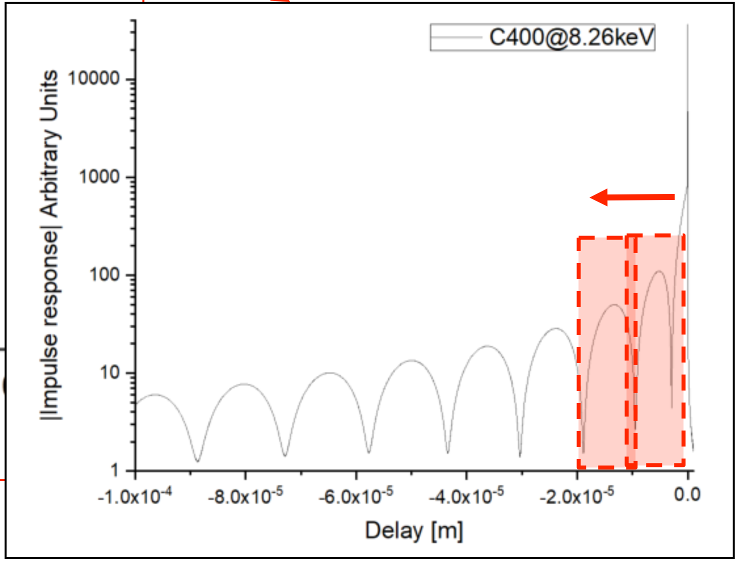


- (Mar. 2020) e- bunch (lasing window) too long? -> SASE background dominate the signal

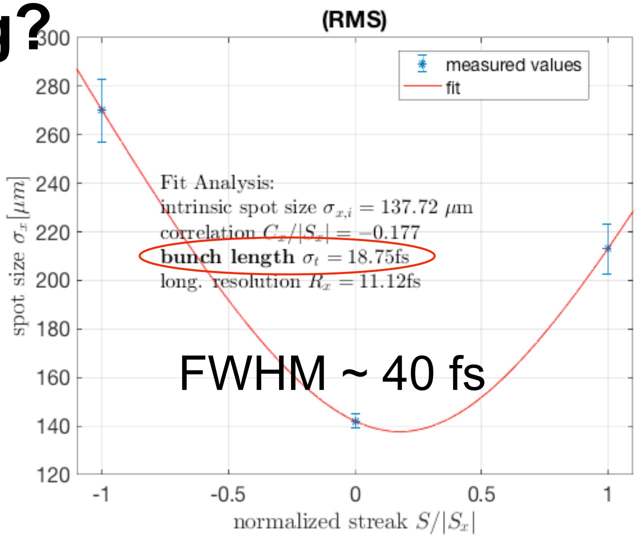
Troubleshooting failure: bunch too long?

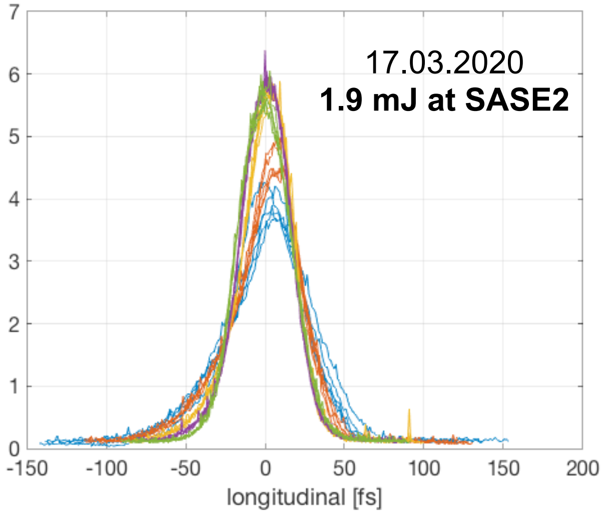
- Optimum bunch length: FWHM < delay?
- Longer bunch -> larger delay if input power is enough



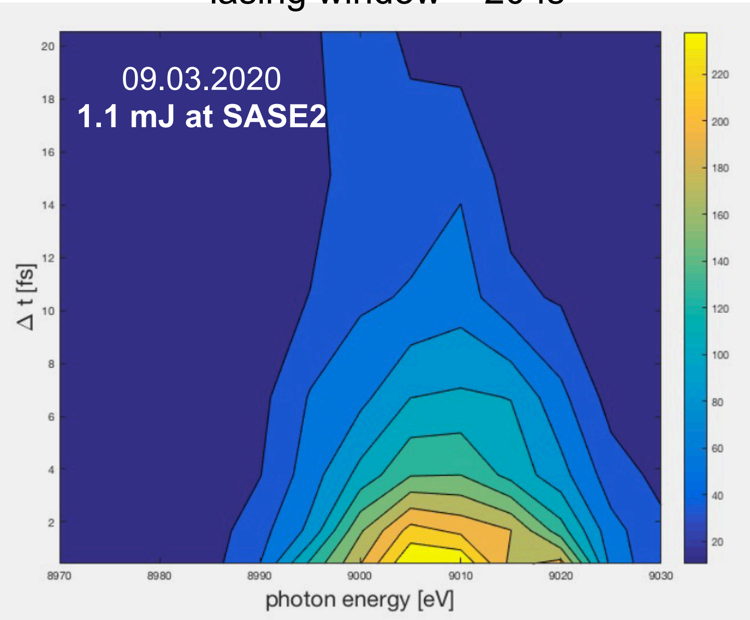


Current profile for 250 pC bunch measured using TDS in BC2





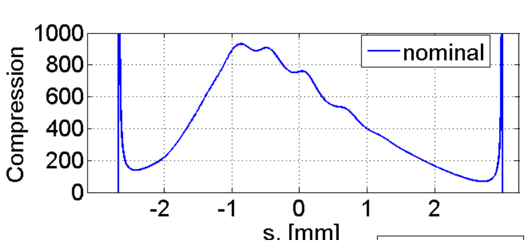
DD scan: no visible chirp with lasing window > 20 fs



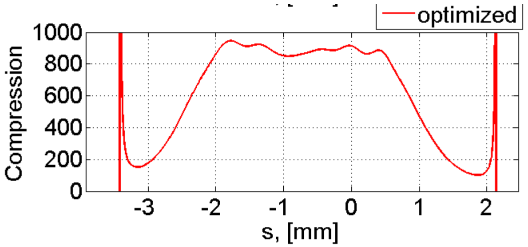
Longitudinal phase space optimization for HXRSS

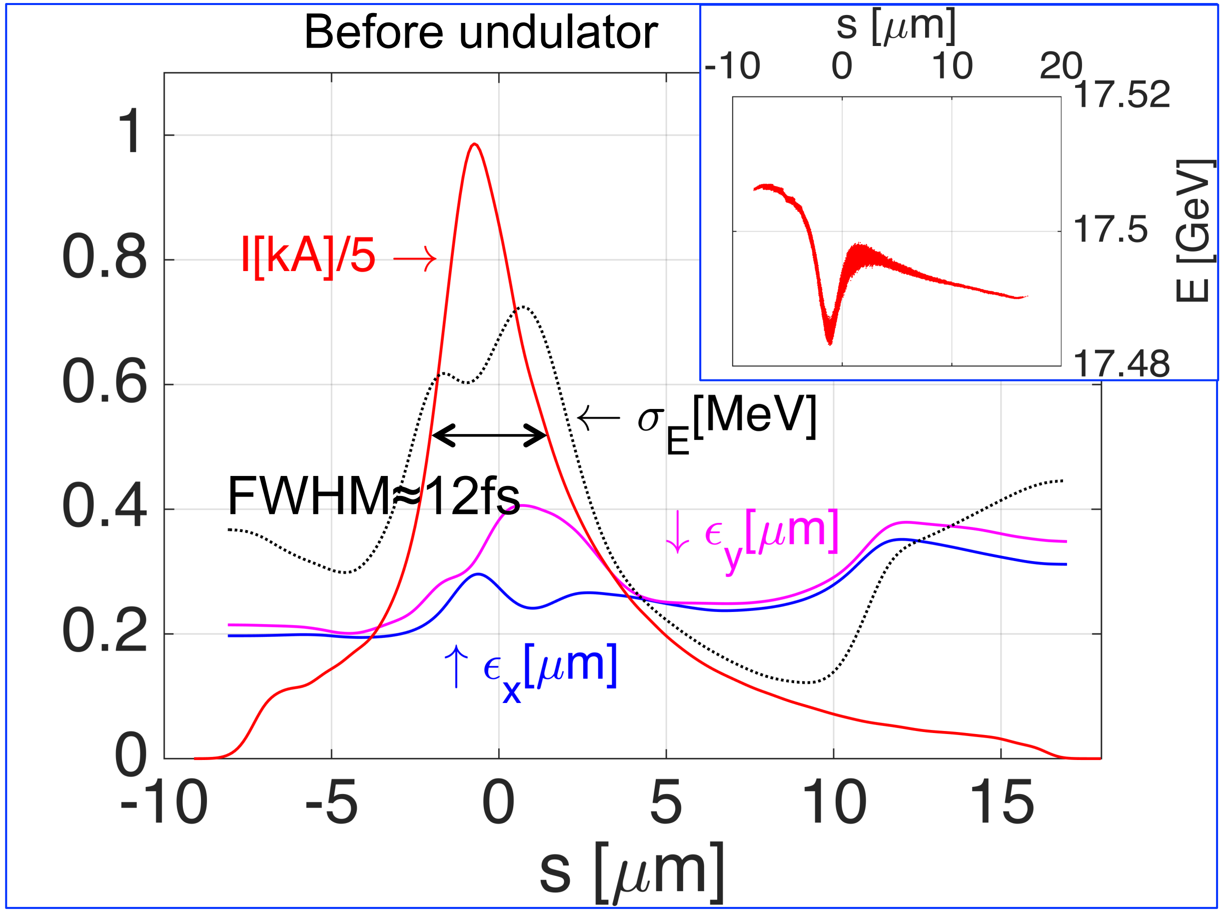
- S2E simulation for 100 pC beam -> for 250 pC case?
- Optimization done in 2017 -> need to be updated !

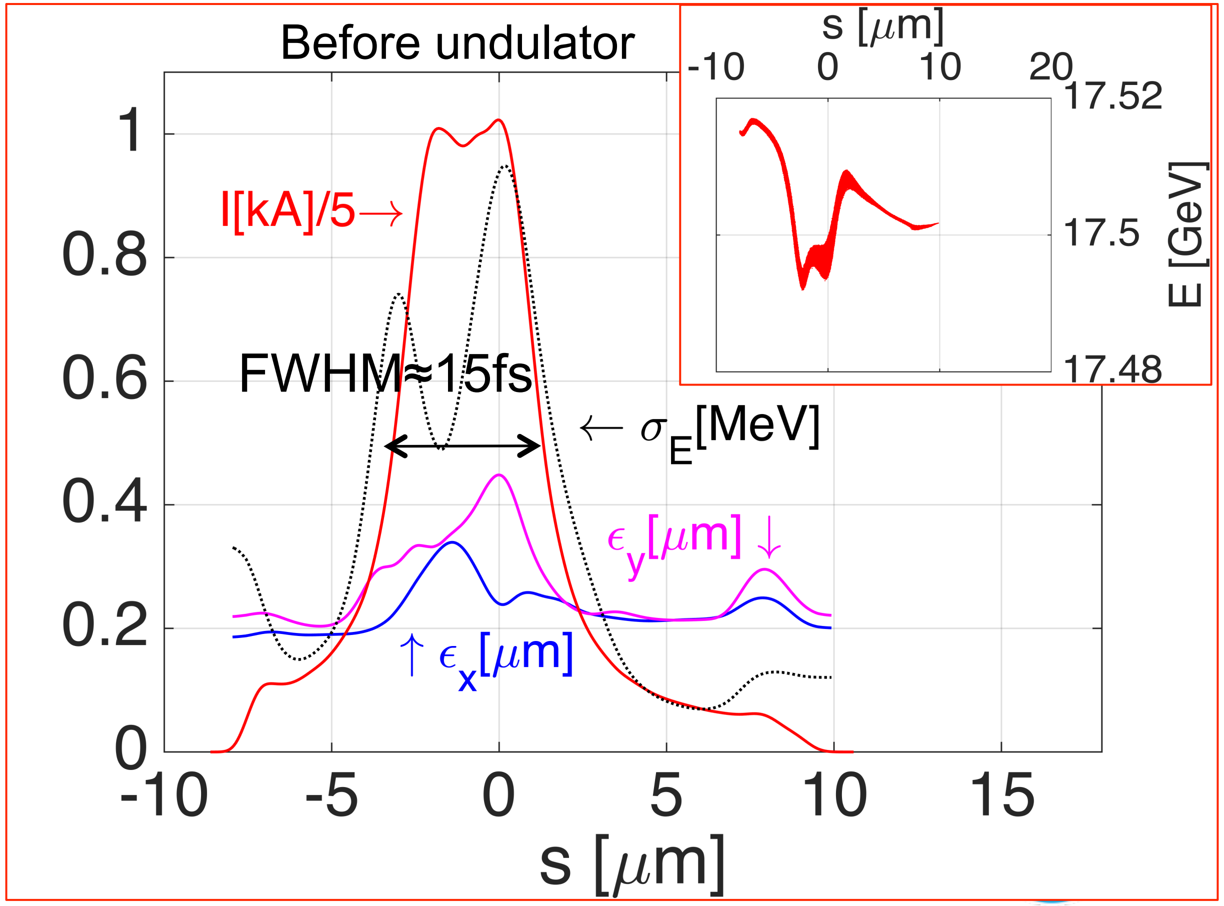
Before Optimization



After Optimization







Set-up procedure (to be discussed)

thanks to Gianluca for comments and suggestions!

SASE tuning for HXRSS

- Setup **HIREX**
- **BC2 TDS measurement**
- **SASE tuning** with linear taper
- Simplified **gain curve or XGM** readout to check
  - 12-16 segments across the chicane contribute equally
  - 1-10 uJ incident on crystal
- **Seeding with SASE**
  - stability of orbit (within 10 um?)
  - optimum lasing window ~10 fs
  - optimize the transverse overlap
- **Delay Detune scan** -> energy chirp

HXRSS set-up & optimization

- **Chicane** on
- Insert **crystal**, find bragg reflection
- Scan and fine tune **chicane delay** (10-20 fs) to and **crystal angle** to find seed signal
- **Air coil optimization** after the chicane
- **Undulator phase shifter** scans using seeded signal
- **Signal to Noise Ratio** optimization (open or close some cells before or after undulator)
- **Taper** optimization
- **Laser heater** optimization
- Check whether reached **saturation**, if yes: taper/increase U3 number (if available)

Set-up procedure (to be discussed)

- define some **numbers for the diagnostics** that we have, for example:

S2E simulation?

1) bunch length (measured by BC2 TDS) and lasing window (measured by DD scan)

2) pulse energy from XGM or a gain curve (for cells before 1st and 2nd chicane)

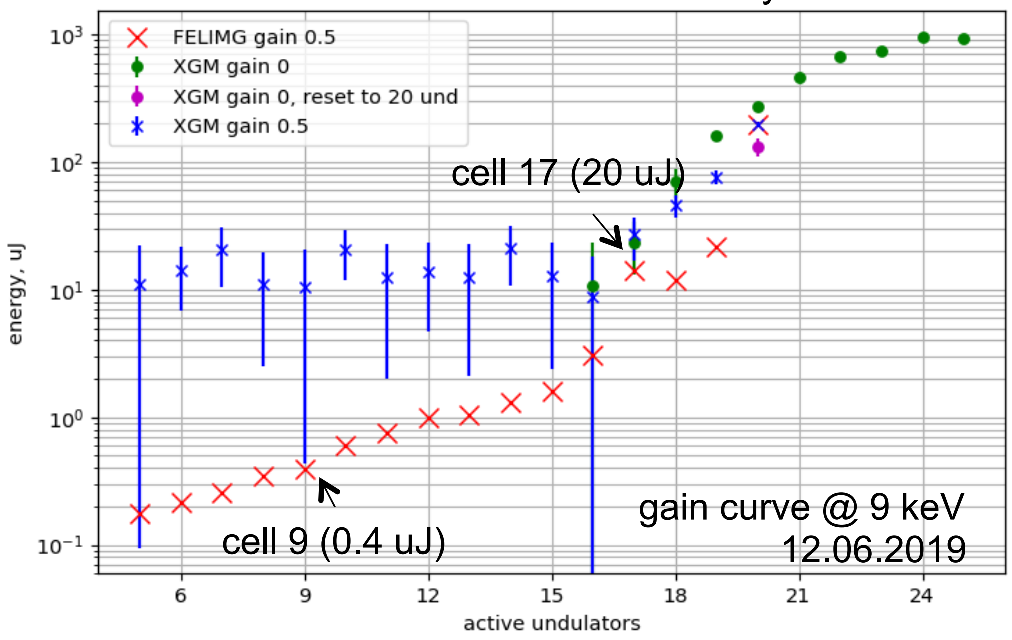
3) pulse energy from XGM when seeding with SASE (to define transverse overlap level after chicane)

- automation of some procedures?

Challenges and future plans

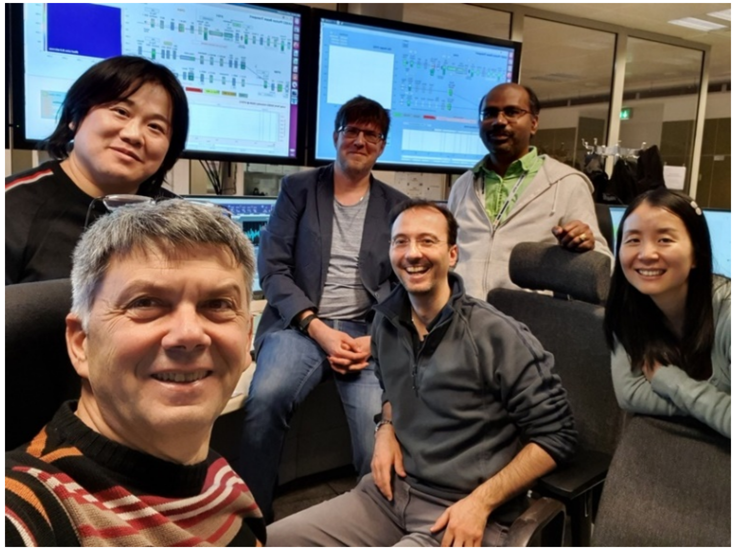
- Dedicated SASE tuning for HXRSS is needed in SASE2
  - Best achieved performance:
    - ▶ 8 uJ @ 9 keV before cell 9
    - ▶ 300 uJ @ 9 keV before cell 17
    - ▶ However, orbit could not be maintained straight downstream chicane to keep the transverse overlap
  - Longitudinal and transverse overlap after crystal need to be improved -> bring seeded signal to saturation!

courtesy of I. Petrov



- So far tested only with 250 pC beam (RMS bunch length ~20 fs -> SASE background can dominate the signal)
  - ▶ 100 pC or lower charge test will be planned

Thank you!



and many other colleagues…