HXRSS Towards User Delivery

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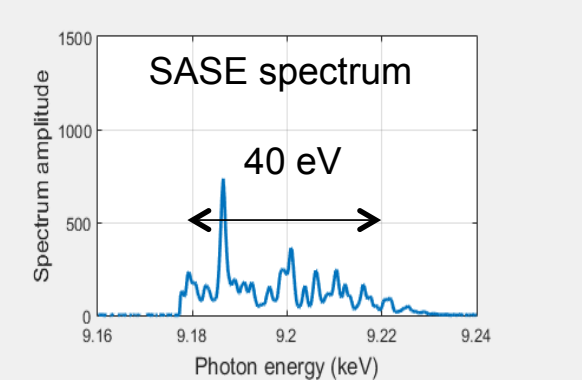
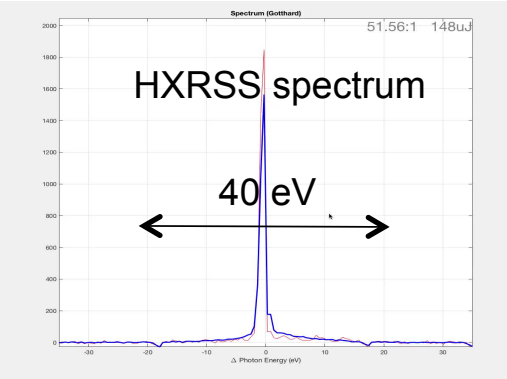
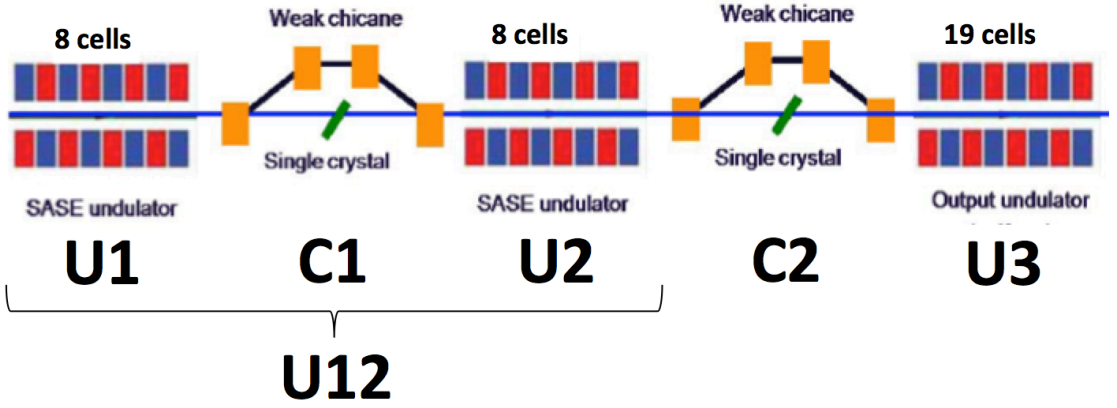
on behalf of the HXRSS commissioning team

Beam dynamics meeting
Hamburg, 08.12.20

Hard X-Ray Self-Seeding







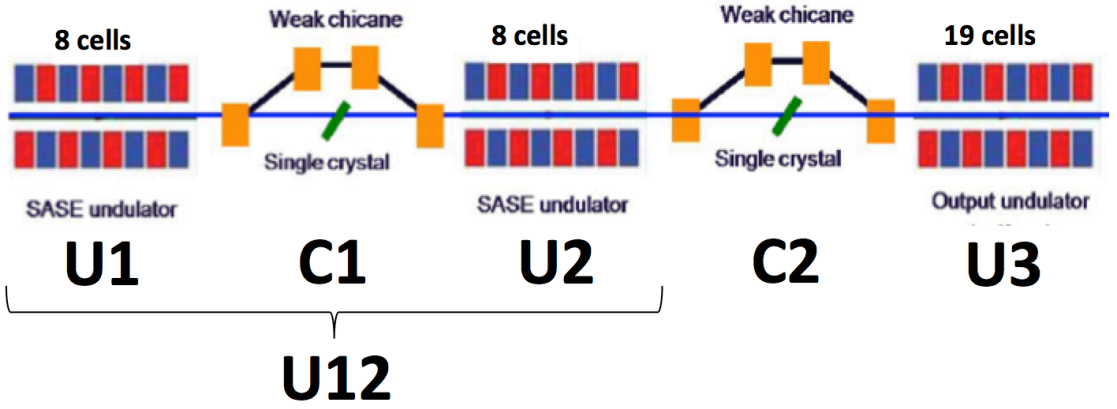
* First demonstrated at LCLS, now available also at PAL and SACLA

Unique at European XFEL:

- **Superconducting linac**: bunch trains with low bunch-to-bunch energy and trajectory jitter
- **High repetition rate** -> large heat load -> **two chicanes** to increase the SNR and share the heat load on the crystal
- **Large chicane delay**: up to 400 fs (with 11 GeV e^- beam) for 2-color applications
- **Long undulator** beam line (35 segments): HXRSS+ post saturation taper

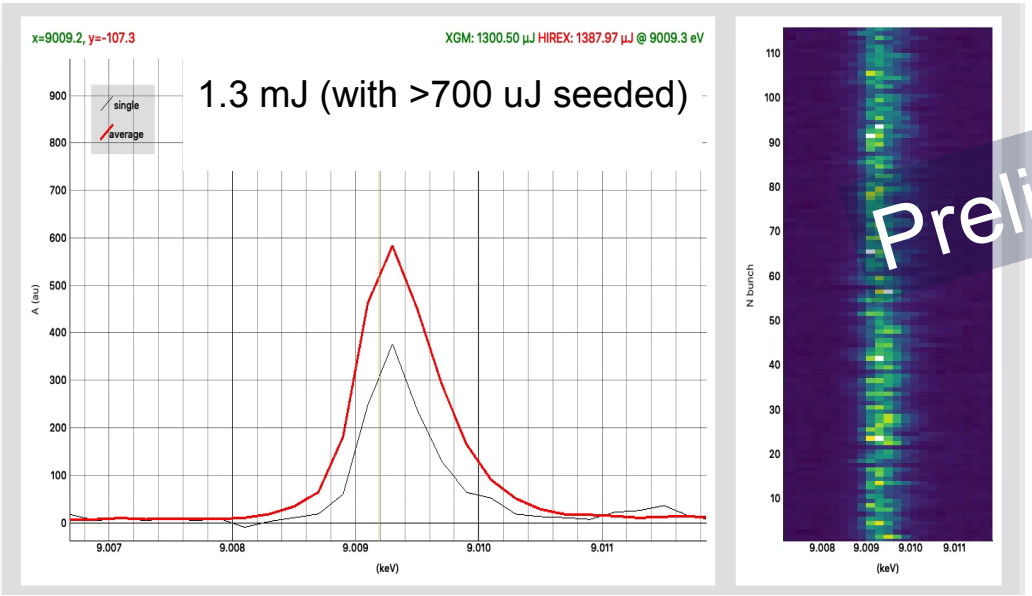
HXRSS commissioning results

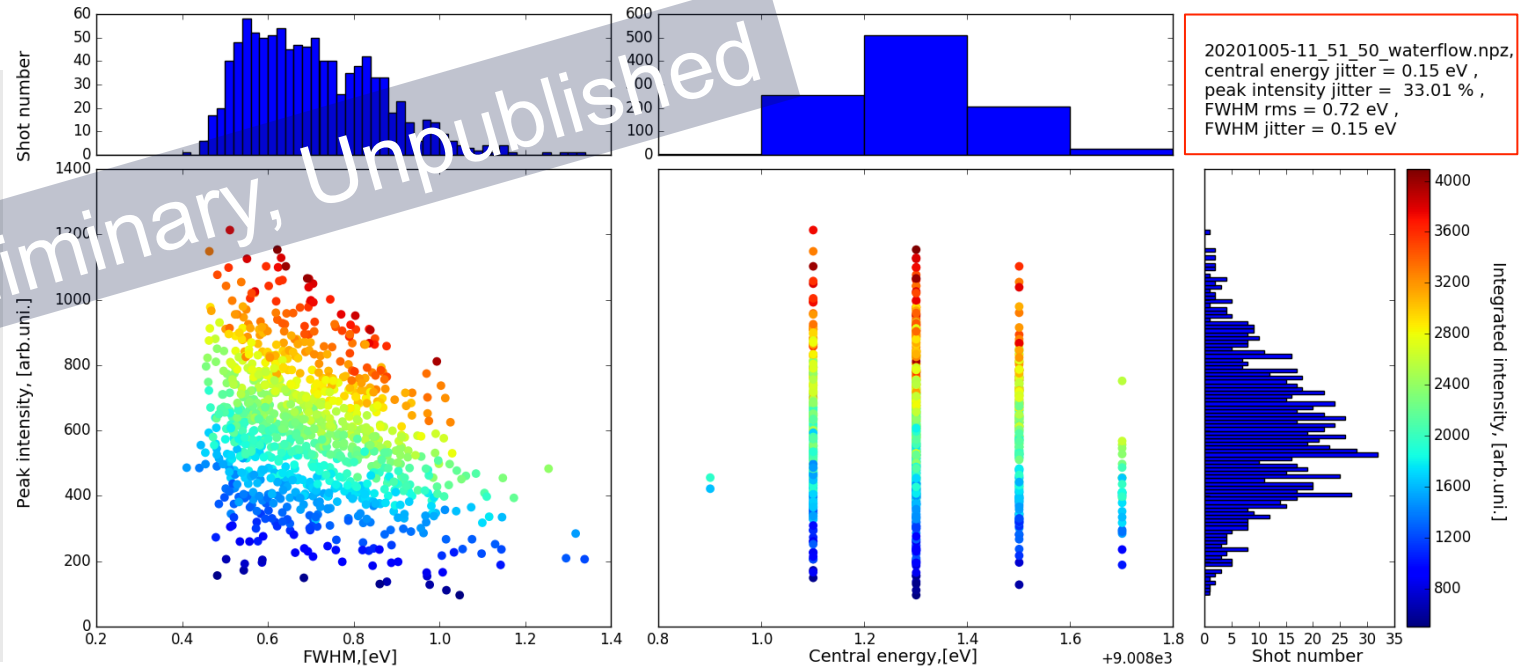
- Commissioning started in Sept. 2019 (but only 3 tries in 2019)
- Intensive shifts in Sept.-Nov. 2020
- Achieved 1.3 mJ in Oct. 2020



	9keV	9keV	12.9keV
e- beam energy	14 GeV	14 GeV	16.5 GeV
e- beam charge	250 pC	100 pC	250 pC
SASE performance	up to 2 mJ	550 uJ	up to 1.2 mJ
Best seeding with 1st chicane	900 uJ	-	-
Best seeding with 2nd chicane	1.3 mJ	190 uJ	300 uJ
Seeding with two chicanes	500-900 uJ	-	-
Seeding bandwidth (FWHM)	~0.7 eV	~0.6 eV	~1 eV

Best performance so far @ 9 keV



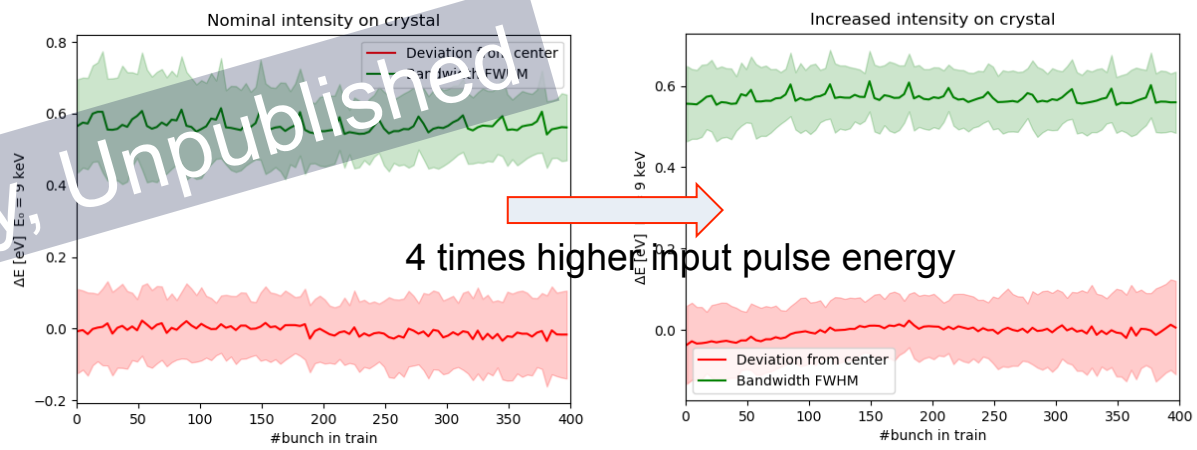


- Averaged pulse energy 1.3 mJ (max. 850 uJ @ PAL) -> BG estimated by extracting crystal (<600 uJ)
- Peak intensity jitter ~33% (min. 40% @ PAL)
- Central energy jitter (0.15 eV) and FWHM (0.72 ± 0.15 eV)
- Statistics calculations are limited by the HIREX detector resolution (0.2 eV/ pixel)

High repetition rate runs @ 9 keV

- 400 bunches at 2 MHz repetition rate
- Almost no difference in BW and central energy after adding more input pulse energy on crystal

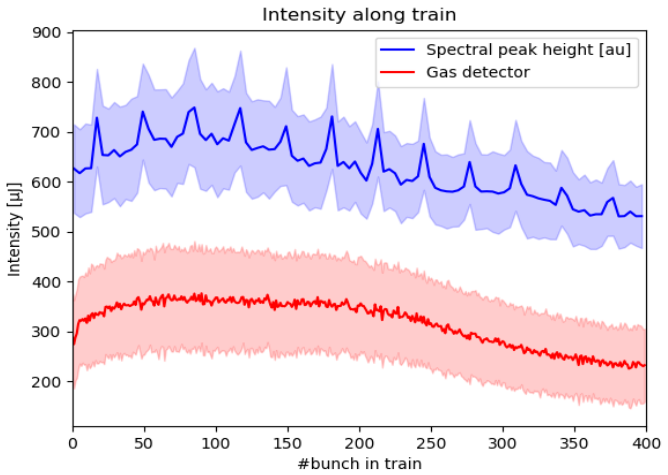
  -> no visible heat-loading effects at 9 keV

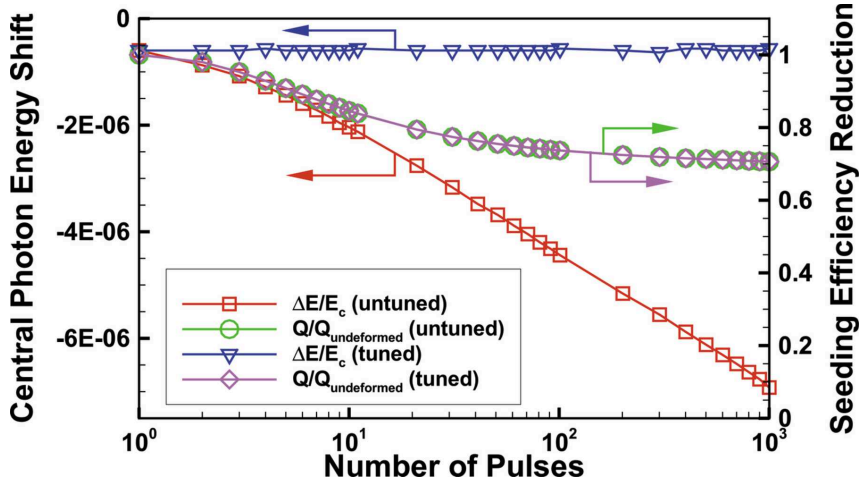


- Spectrum intensity changes along the pulse train

  -> to be further investigated

- Study to be continued at lower photon energies

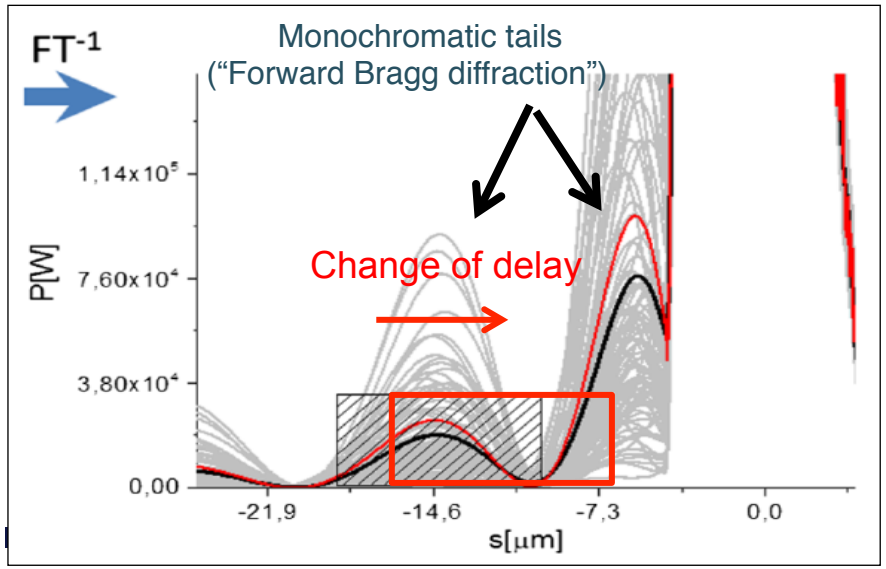




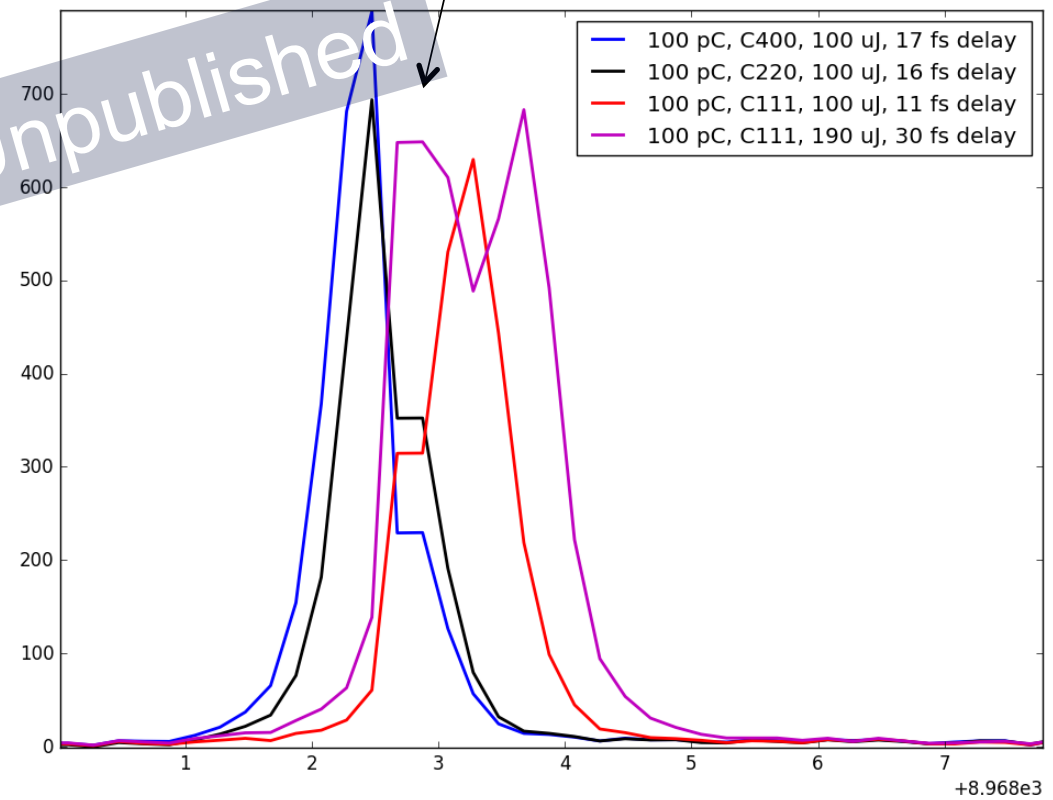
Qu, Zhengxian, et al. NIMA (2020): 163936.
Qu, Zhengxian, et al. *JSR* 27.6 (2020): 1725-1729.

100 pC run

- Shorter bunch -> shorter lasing window -> narrower BW
- Tried different reflections with different delays
- Double peaks observed when seeding on two bumps



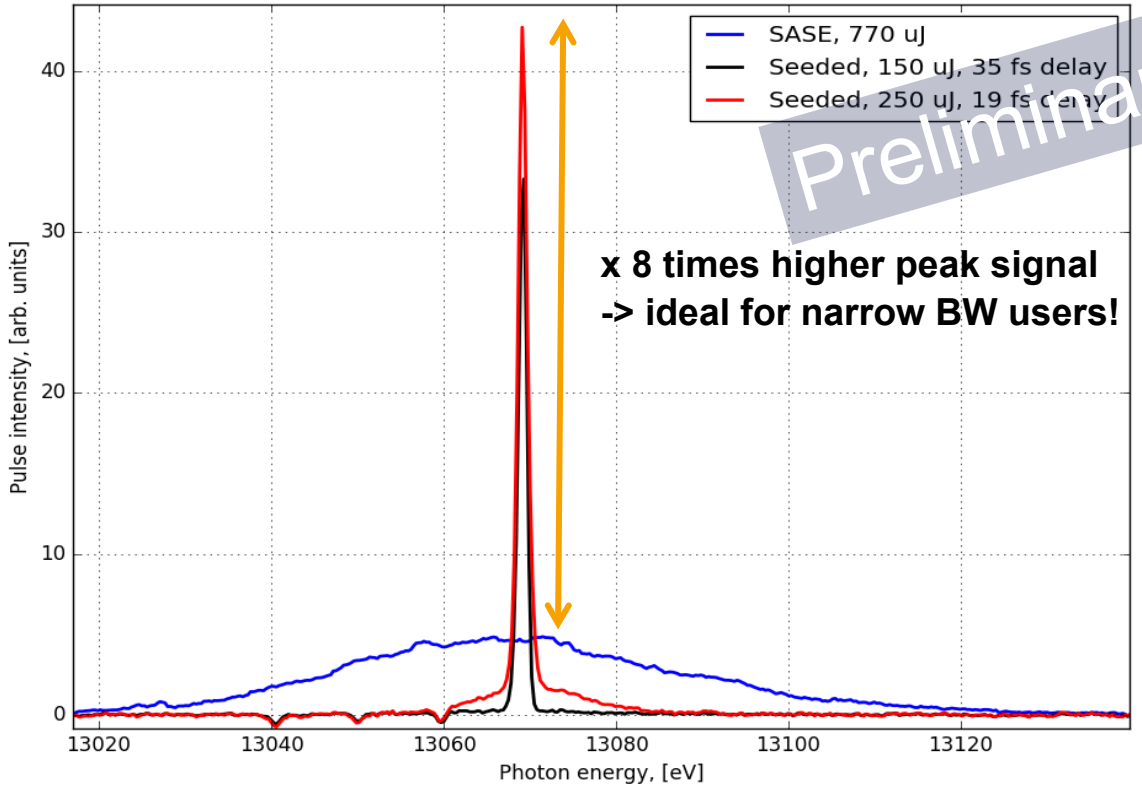
artificial effect?



Statistics for C400:

20201023-06_35_21_waterflow.npz,
central energy jitter = 0.11 eV ,
peak intensity jitter = 54.55 % ,
FWHM rms = 0.58 eV ,
FWHM jitter = 0.15 eV

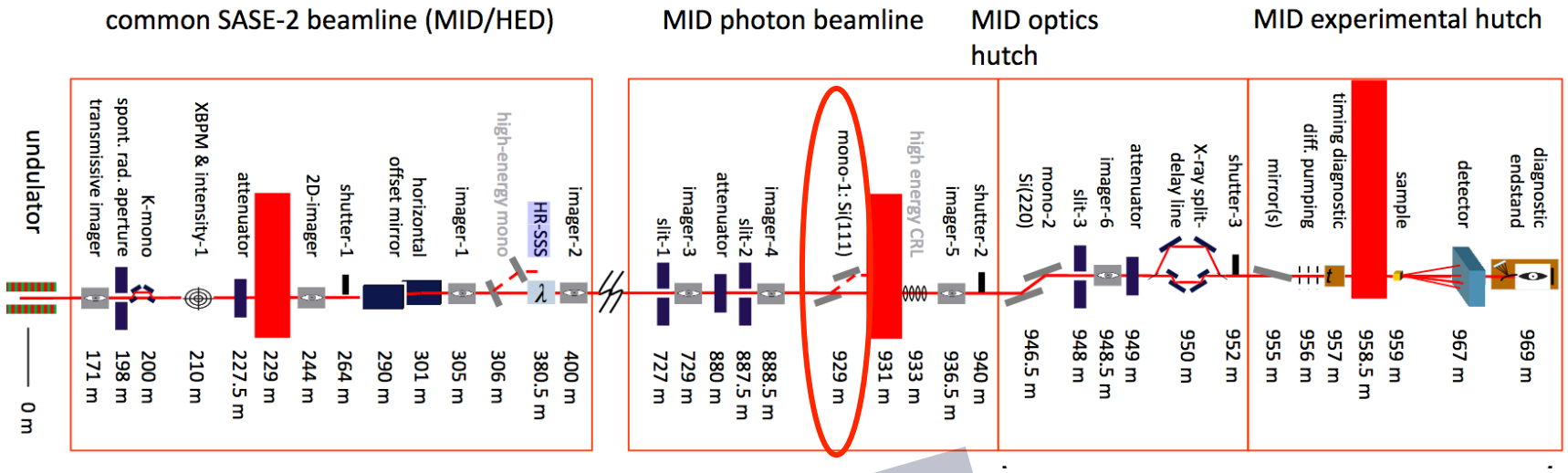
12.9 keV run – SASE vs HXRSS (averaged over 1000 shots)

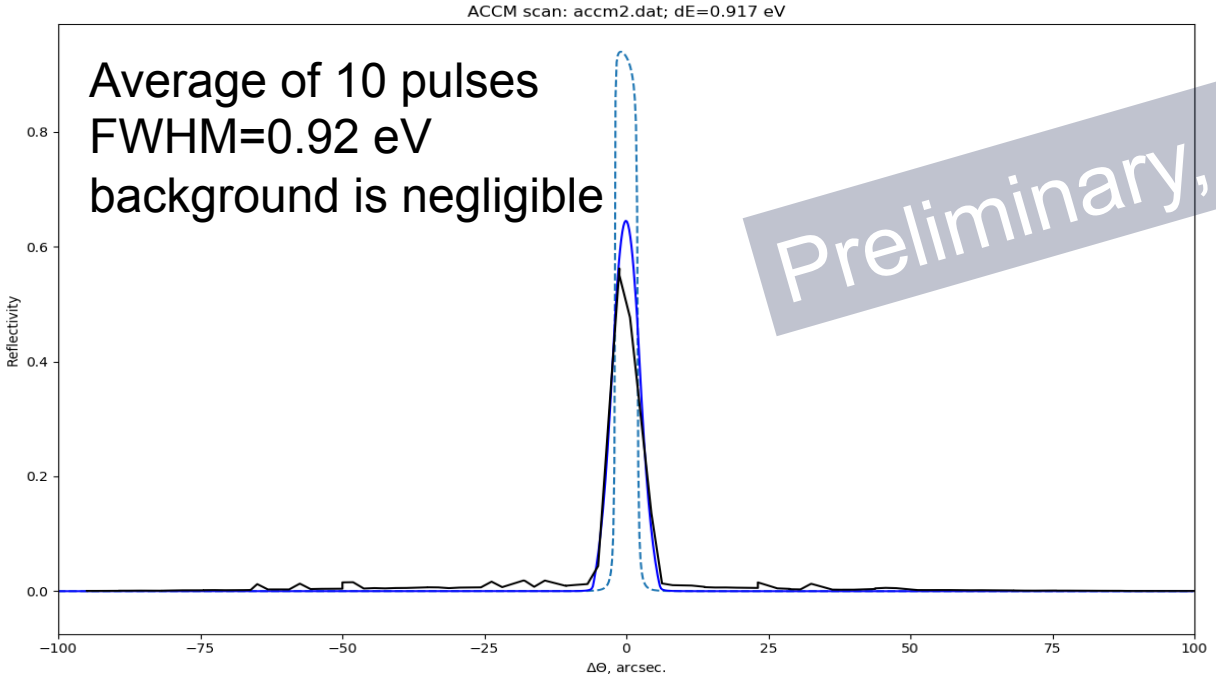


	SASE	HXRSS (19 fs delay)	HXRSS (35 fs delay)
Pulse energy	700 uJ	250 uJ	150 uJ
Central energy jitter	11.85 eV	0.30 eV	0.25 eV
Peak intensity jitter	51%	42%	59%
FWHM rms	-	1.21 eV	1.13 eV
FWHM jitter	-	0.25 eV	0.20 eV

Signal normalized by the ratio between integrated spectrum (central non-zero region) and XGM readout

Data taken by MID spectrometer



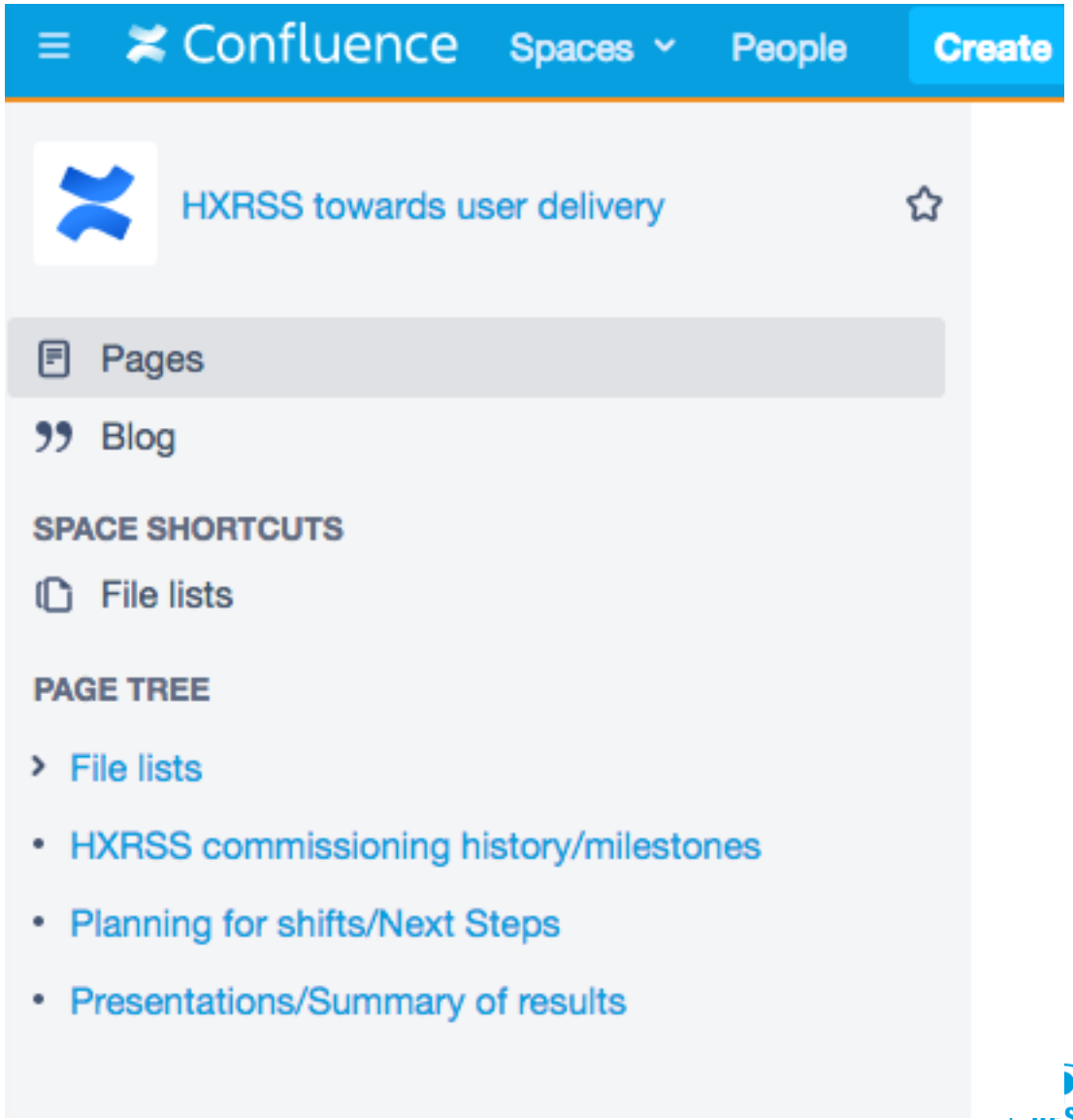


courtesy of Alexey Zozulya (MID)

Summary and future plans

- Commissioned HXRSS at 9 keV and 12.9 keV
- Up to 1.3 mJ achieved at 9 keV with 0.7 eV BW
- 6 user runs planned for HXRSS in 2020
- Seeding with two chicanes demonstrated

  -> large room for improvements
- Continue to investigate the HXRSS parameter space at different photon energies : 6keV, 7 keV, 11 keV and >=14.4 keV
- Advanced seeding schemes (multi-color, fresh slice self-seeding ect.) -> will be tested soon!



Thank you!

Special thanks to **Gianluca, Svitozar, Marc, Naresh, Sergey, Frank…**