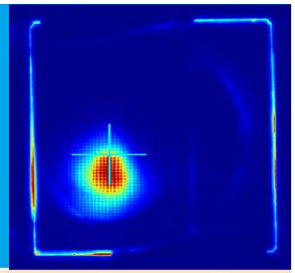
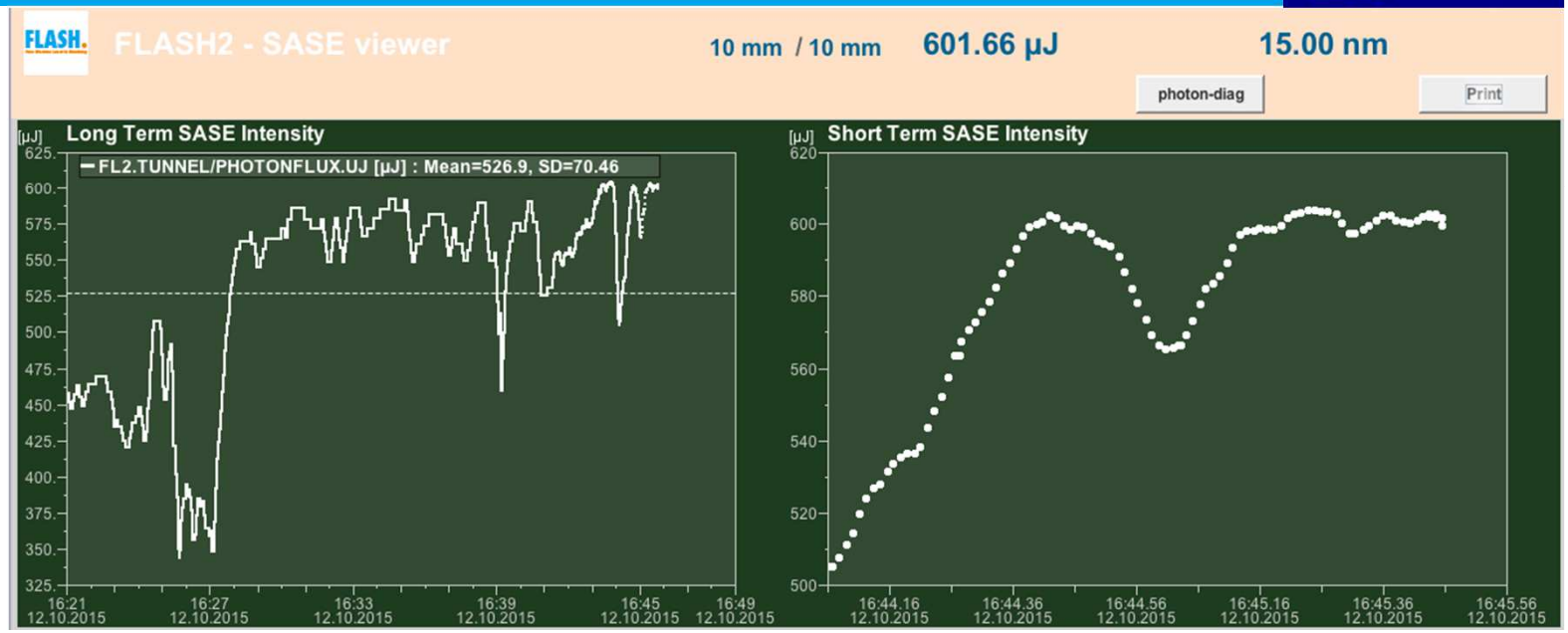
FLASH 2



FEL seminar



Charge: 0.5 nC

Juliane Rönsch-Schulenburg

Overview of FLASH 2

Hamburg, 2016-03-22

HELMHOLTZ ASSOCIATION

DESY

Overview

1. FLASH 2 Overview
    1. Layout parameters
2. Operation FLASH2.
    1. Lasing at wavelengths between 4 and 60 nm.
    2. Parallel operation FLASH1 and FLASH2 established.
    3. User Operation starts in 2016.

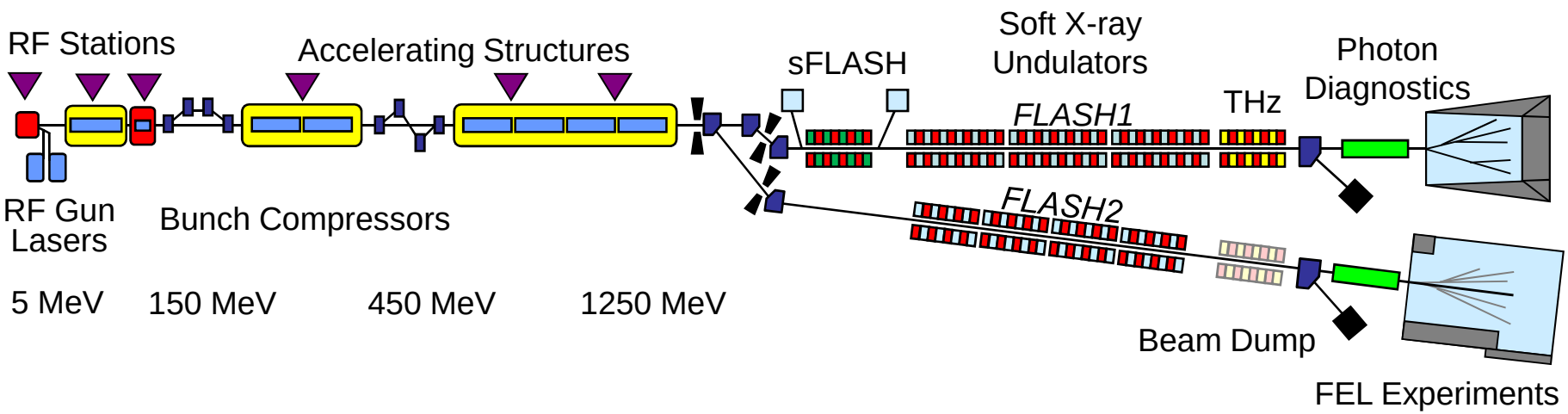
Parameters.

	FLASH1	FLASH2
Beam parameters		
Beam Energy	0.5 – 1.25 (1.6) GeV	0.5 – 1.25 (1.6) GeV
Normalized emittance (proj.)	1.4 – 3 mm mrad	1.4 – 3 mm mrad
Energy spread	0.2 MeV	0.5 MeV
Peak Current	2.5 kA	2.5 kA
Bunches per second*	<8000	<8000
Bunch Charge	0.07 – 1 nC	0.02 – 1 nC
Undulator parameters	Fixed gap	Variable gap
Period	27.3 mm	31.4 mm
Segments length	4.5 m	2.5 m
Number of segments	6	12
Focusing Structure	F0D0	F0D0

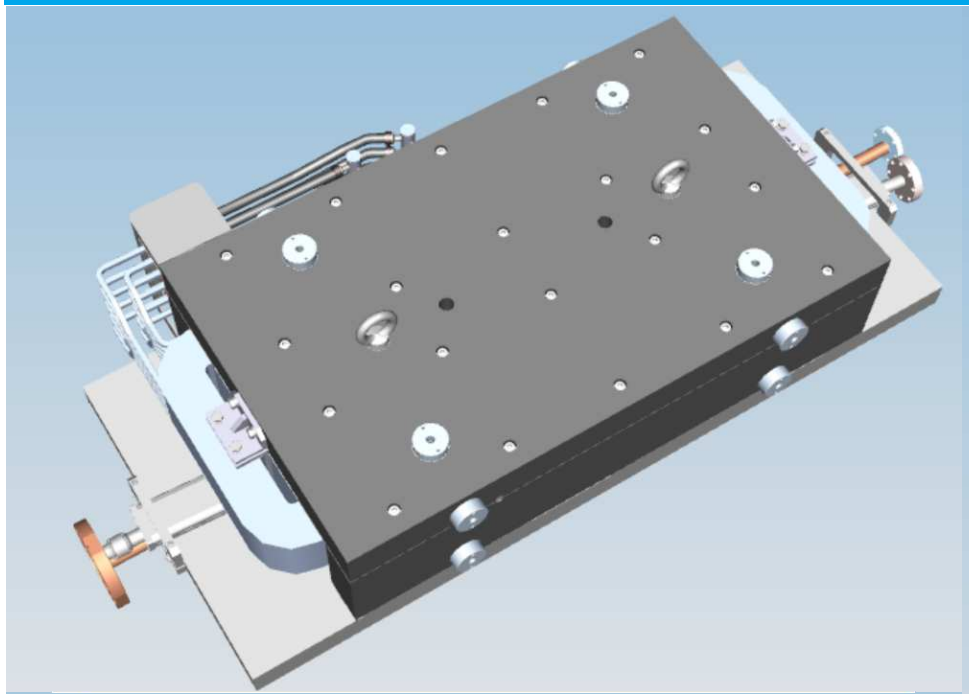
*Shared between FLASH1 and FLASH2

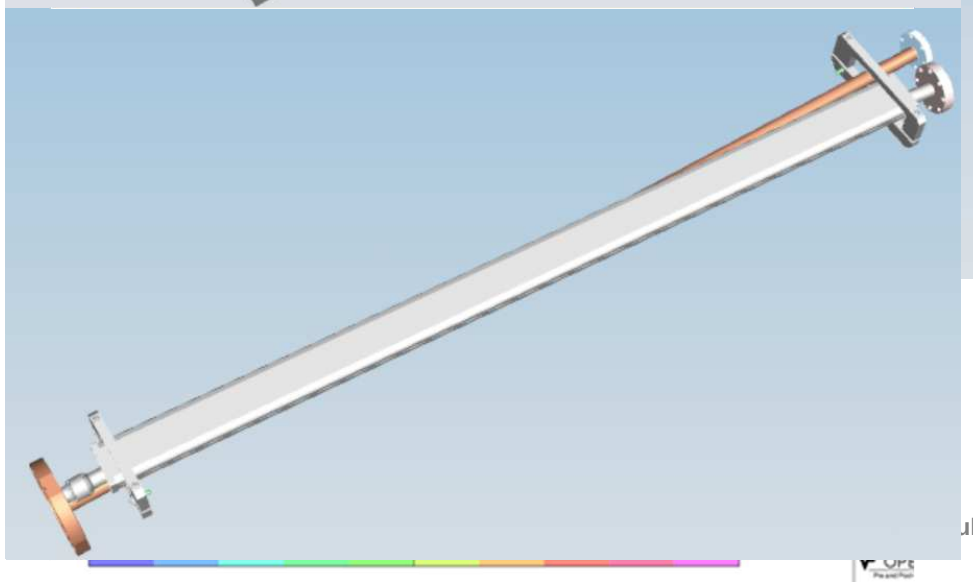
Layout.

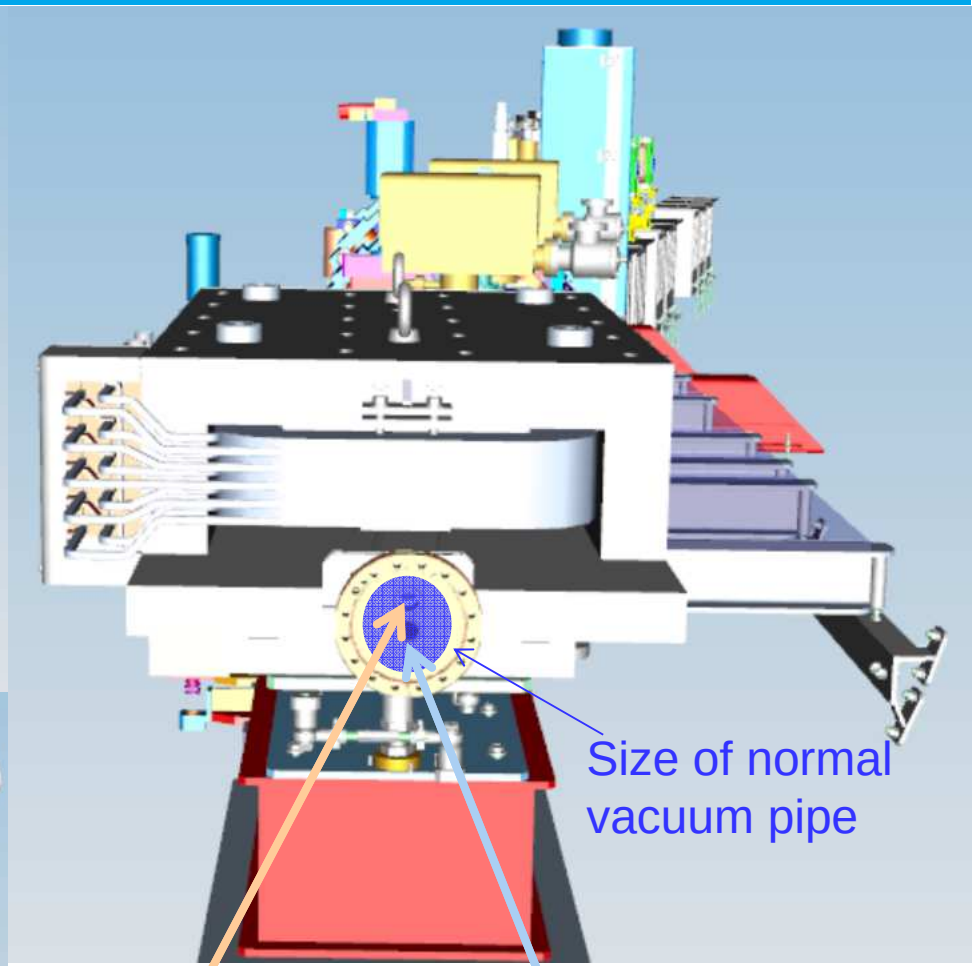
- Separation FLASH and FLASH2 behind last accelerator module
- Tunability of FLASH2 by undulator gap change
- Extend user capacity with SASE and seeding



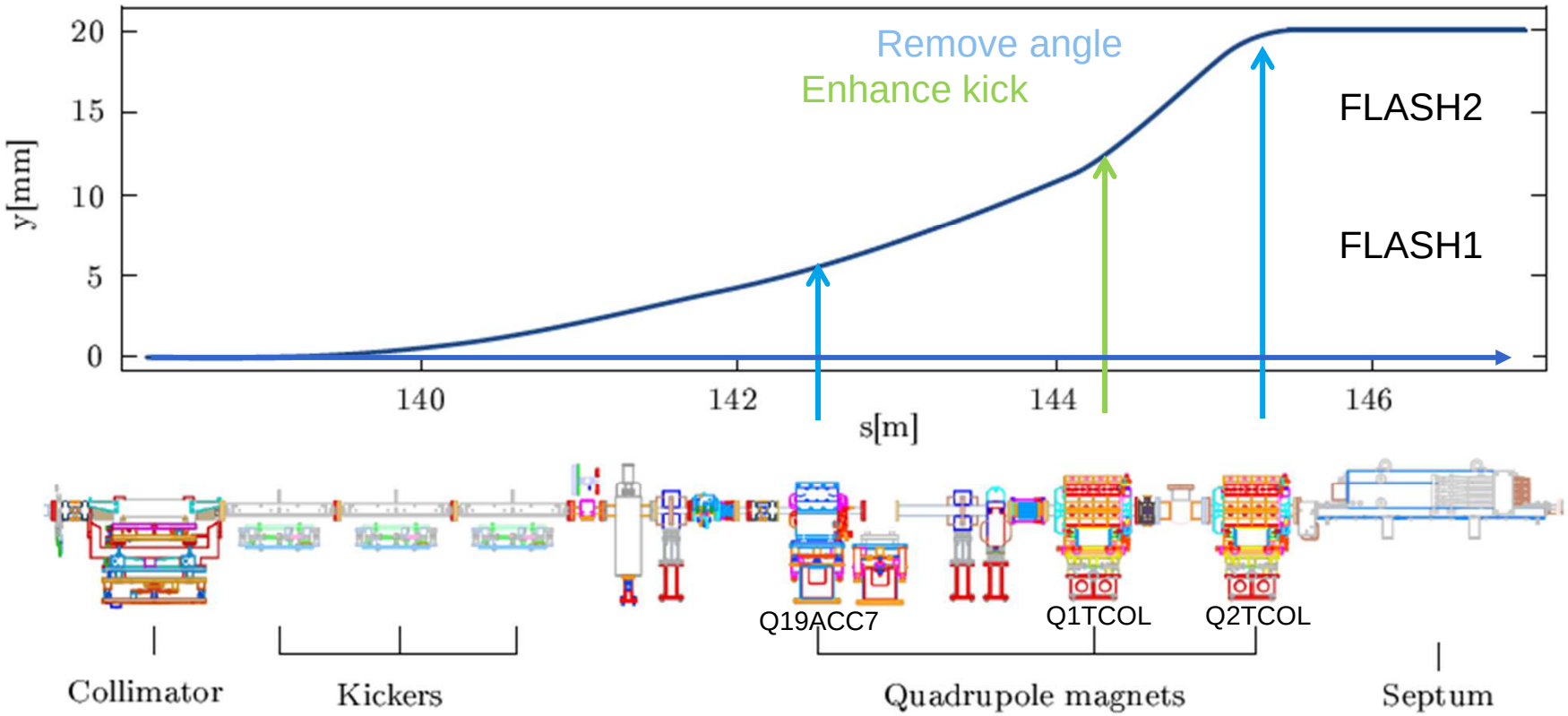
Separation FLASH1 and 2: the septum.







Small apertures to get FLASH1 and FLASH2 beam through.



Kicks of Quadrupoles Q19ACC7, Q1TCOL and Q2TCOL are needed to get beam into FLASH2

Different Quad settings → different kick = angle or offset.

With a FLASH1 vertical beam offset, FLASH2 will normally have the same offset with respect to Septum.

Courtesy M. Scholz

Undulators Control (status November 2015).

Set undulator gaps based on beam energy and desired wavelength. All undulators characterized individually

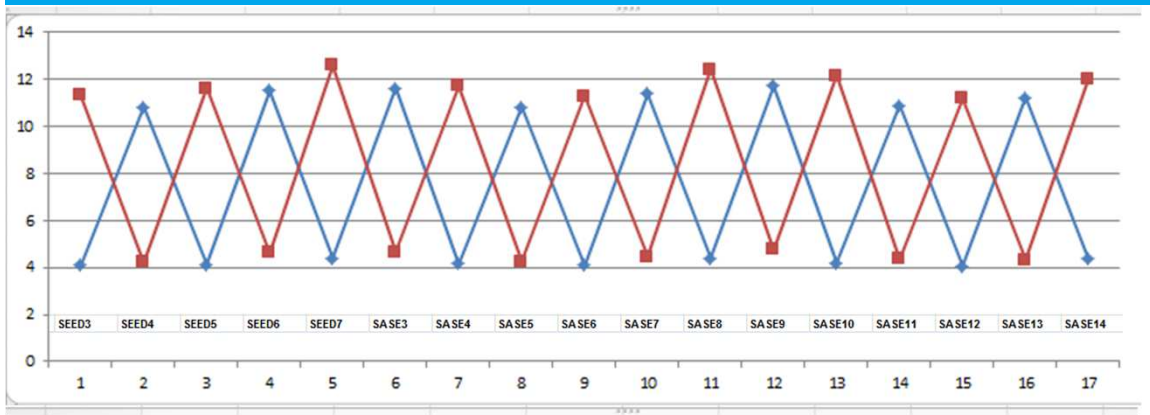
Allows tapering (in different groups) and global phase change.

Undulator focusing.

- Undulators focus the beam vertically
  - Focusing usually much smaller than quad focusing.
  - Energy dependence of quad and undulator focusing different.
- At low energy, this effect becomes comparable to quad focusing
  - Quadrupole currents need to be adjusted.
  - Optics depend on energy and on undulator gap (as compared to FLASH1, where the gap is fixed).
- Server should take care of the optics inside the undulator, depending on gap of each individual undulator.

The effect could be seen during the beamtime at 0.4 GeV (38 nm at FLASH1).

Optics at 0.4 GeV.



Hor.

Vert.

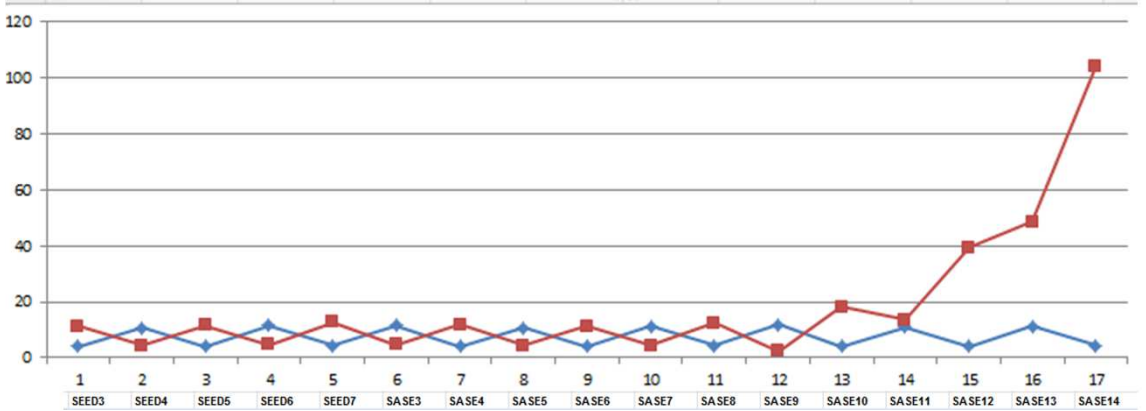
Beam size $\sigma^2 \sim \beta$

Undulator open

$4<\beta_y<12$ m

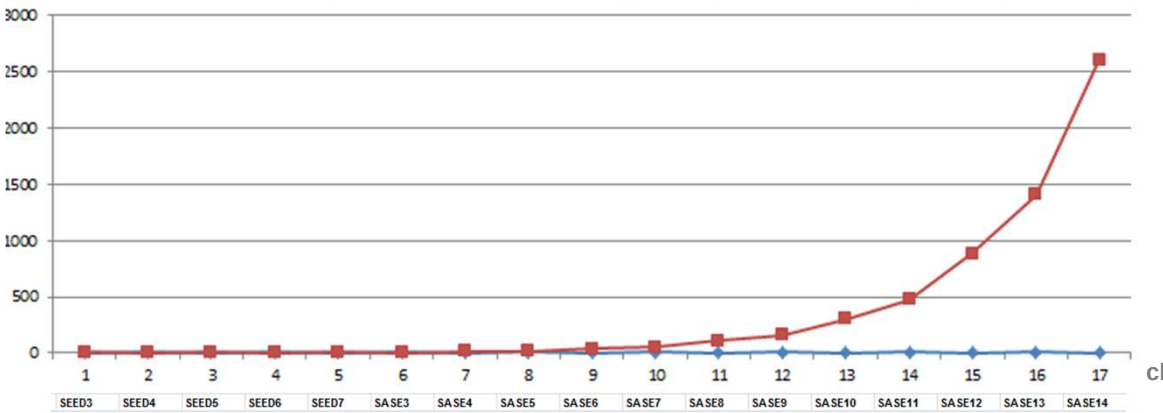
Last 6 undulator closed

$1<\beta_y<120$ m

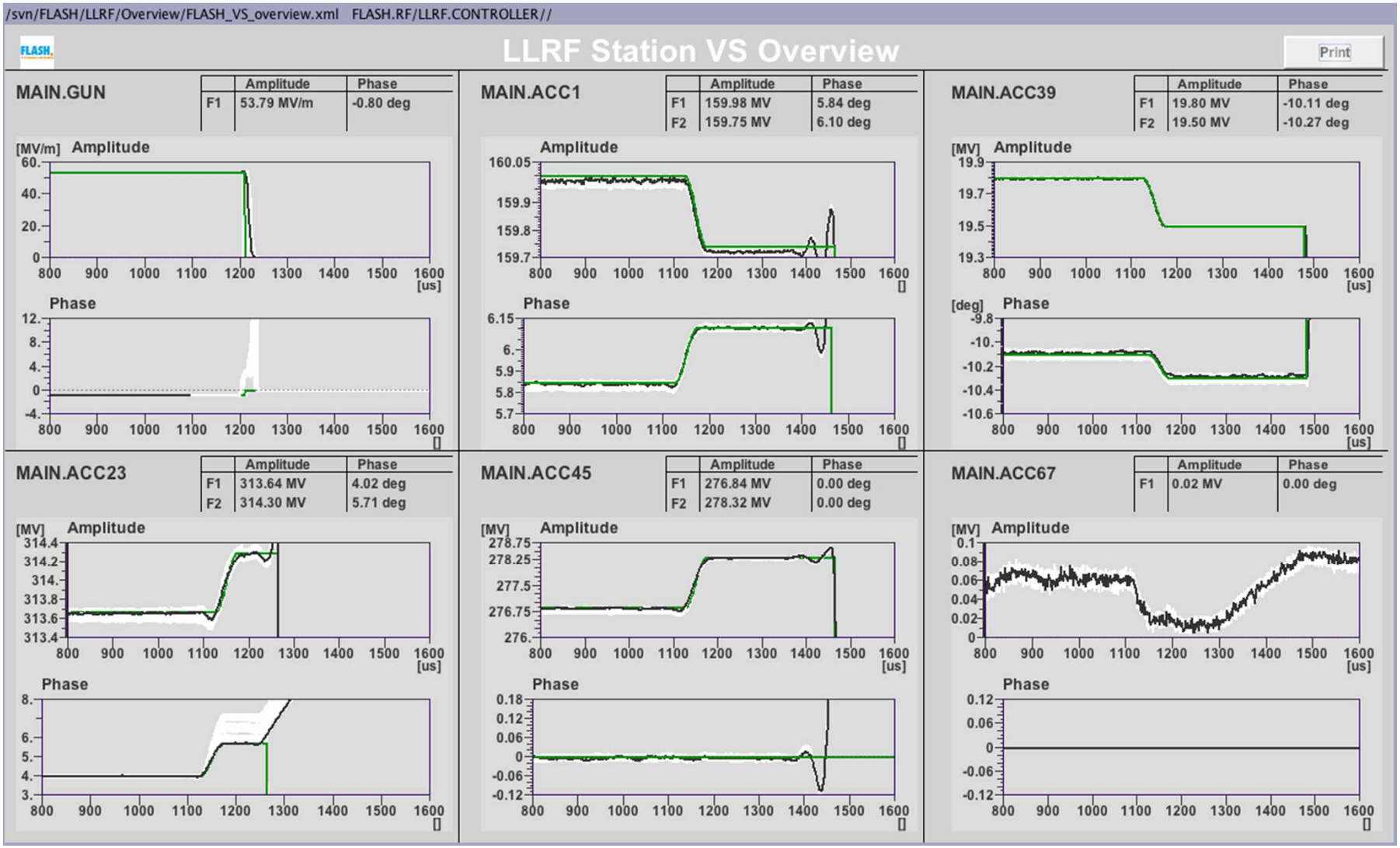


All 12 undulators closed

$0<\beta_y<3000$ m

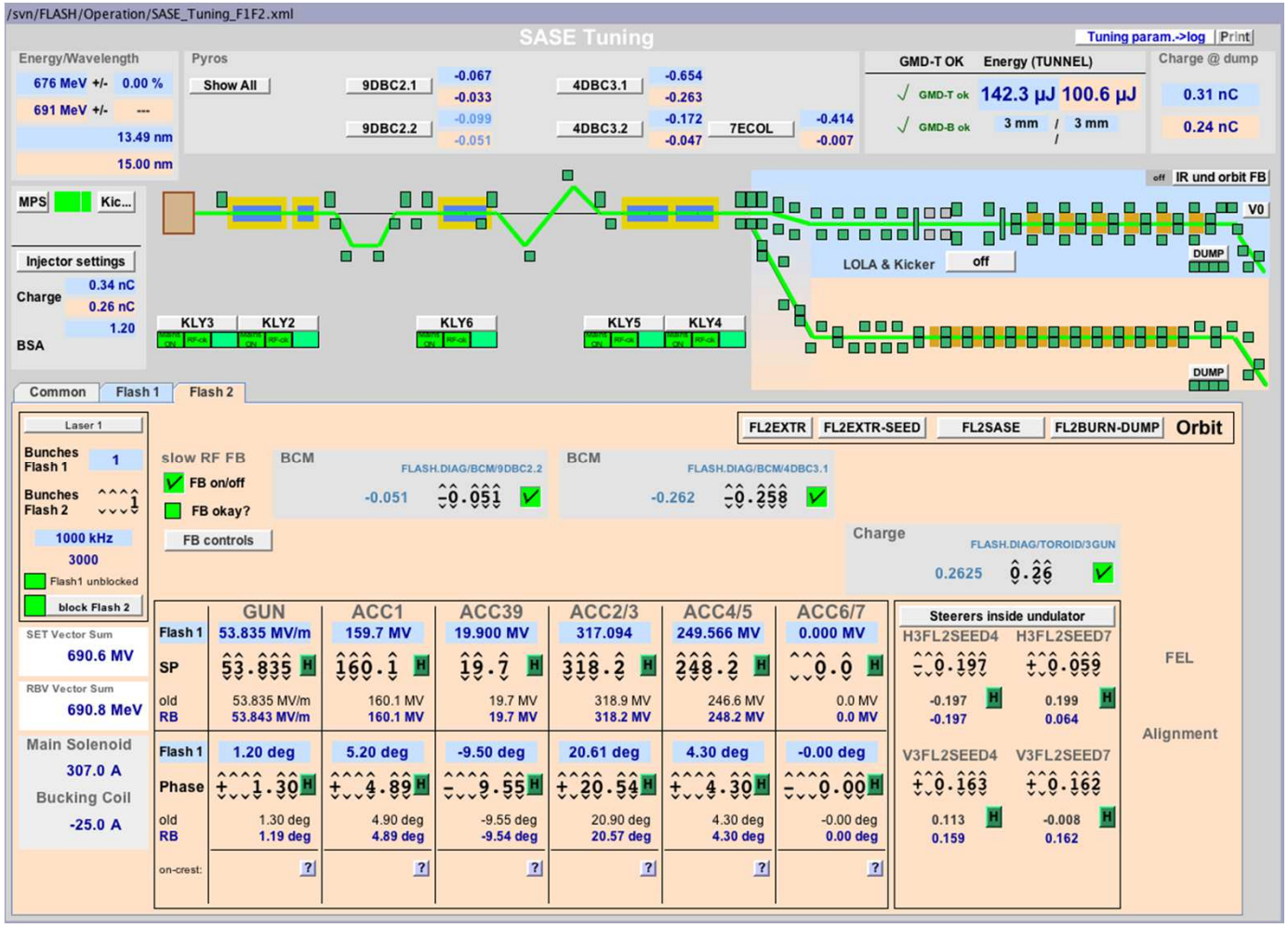


LLRF Steps



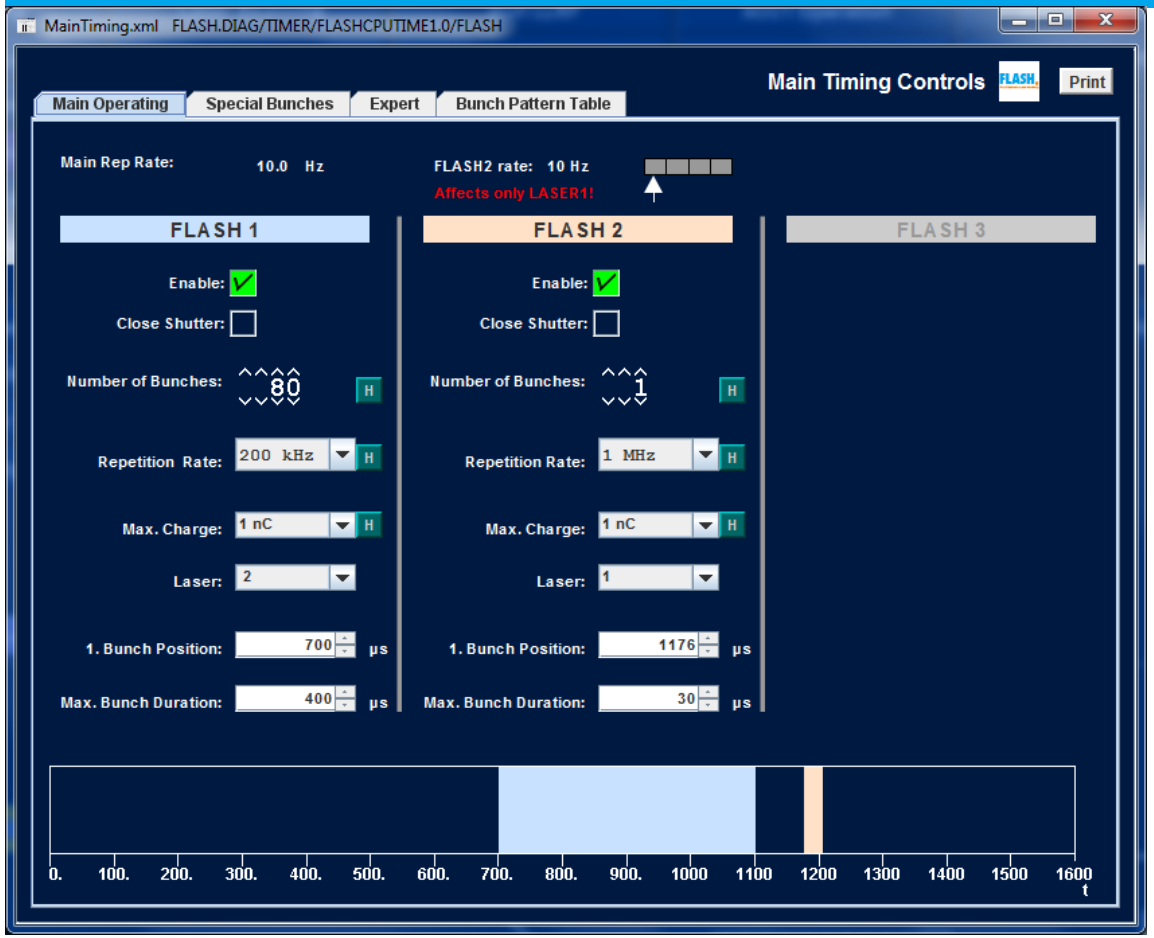
Max. step: 10MV, 5°
Gun olny without pulse width feedback

SASE tuning



Slow online Intensity Monitor
LLRF learning FF

Main timing of FLASH.



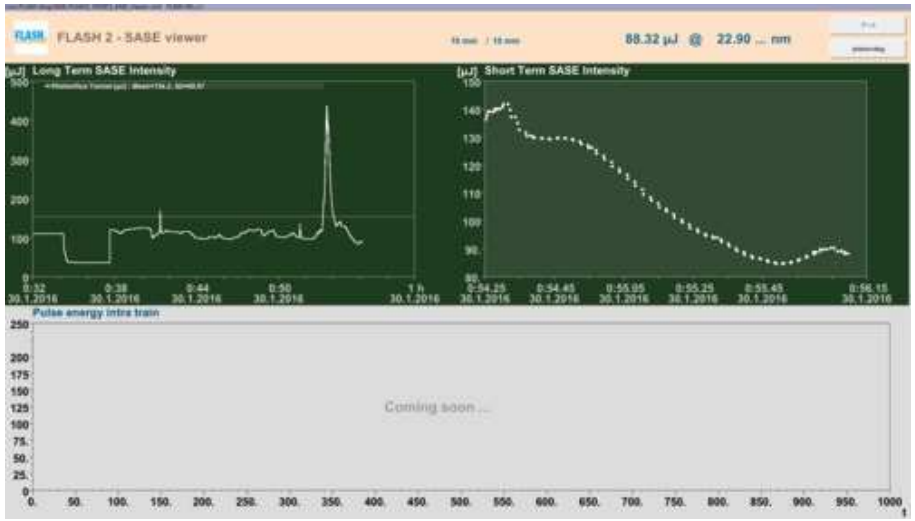
Settings for FLASH1 and 2 chosen independently.

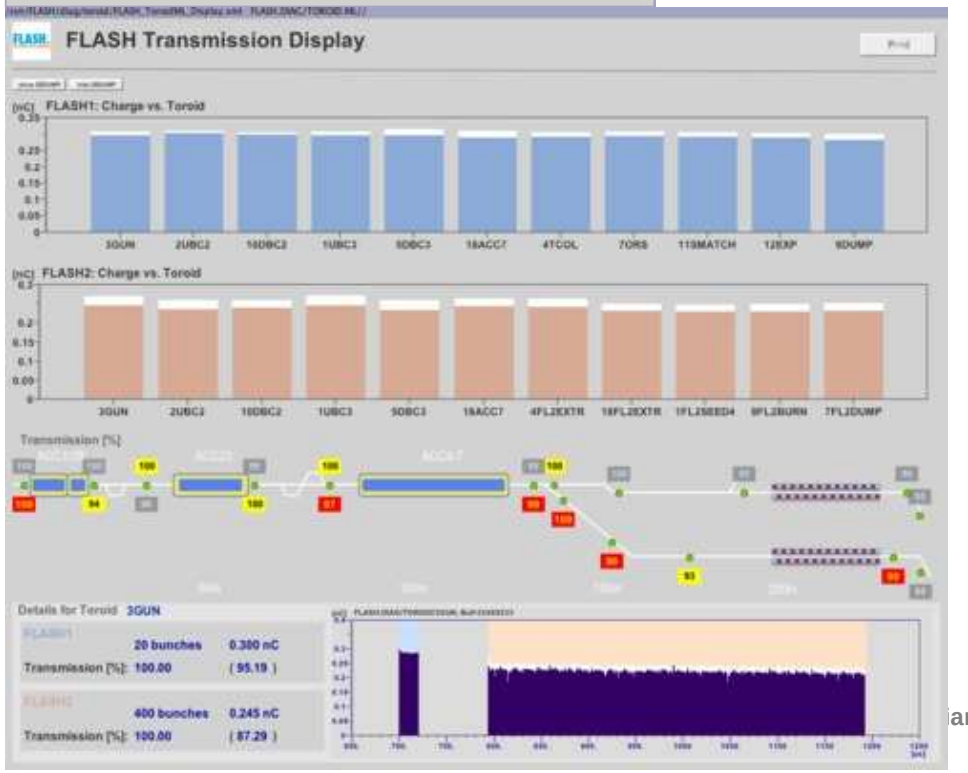
1 Hz operation at FLASH2 possible.

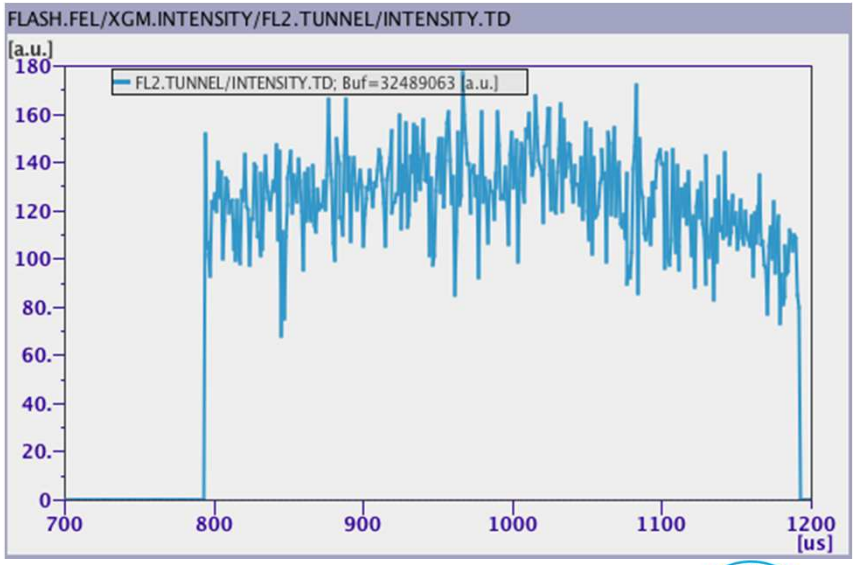
Start time for FLASH2 flexible: all diagnostics on electron and photon side, kicker and LLRF steps adjusted automatically.

Long pulse trains are also possible at FLASH2.

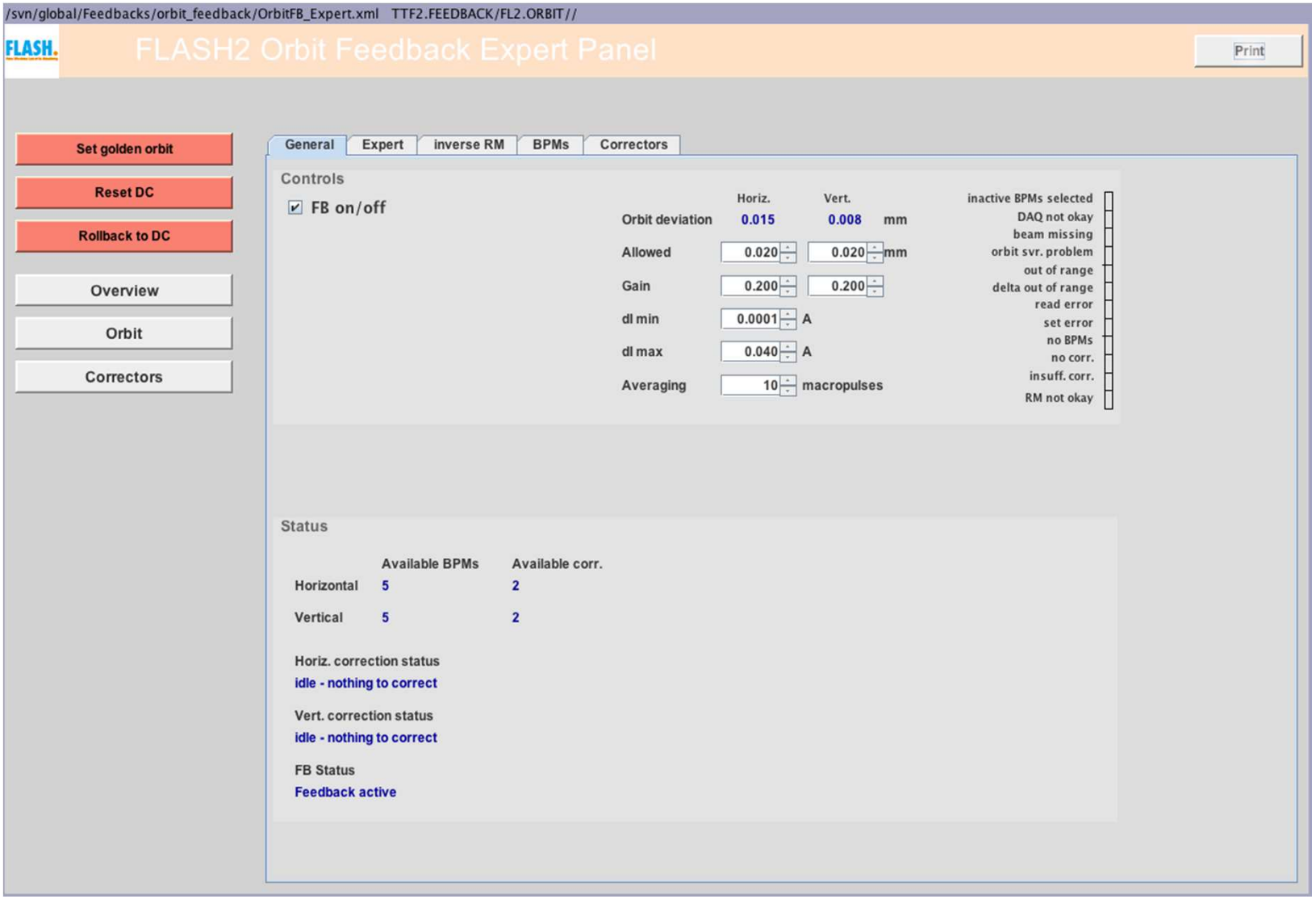
Long bunch trains at FLASH 2.



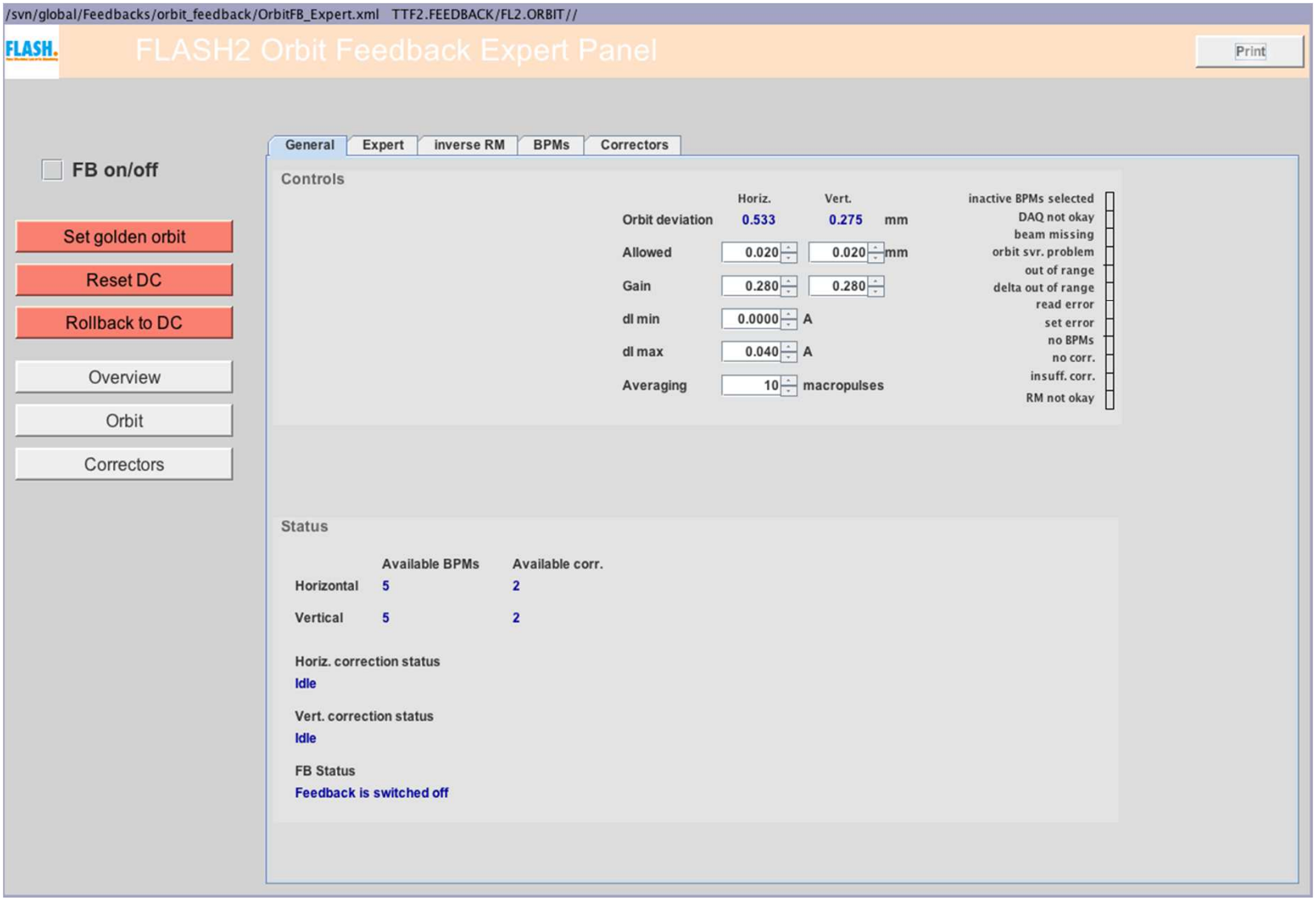




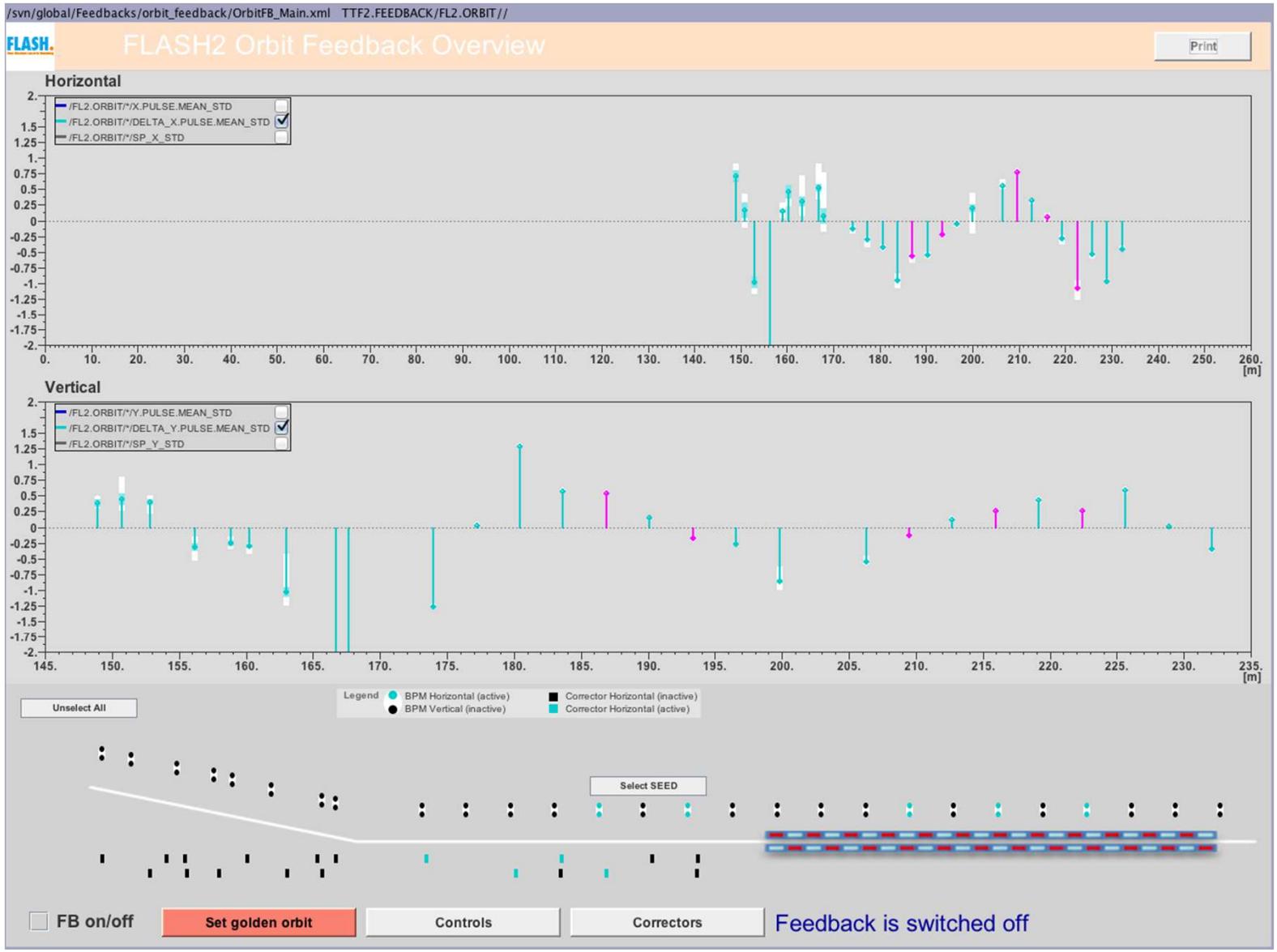
Orbit feedback.



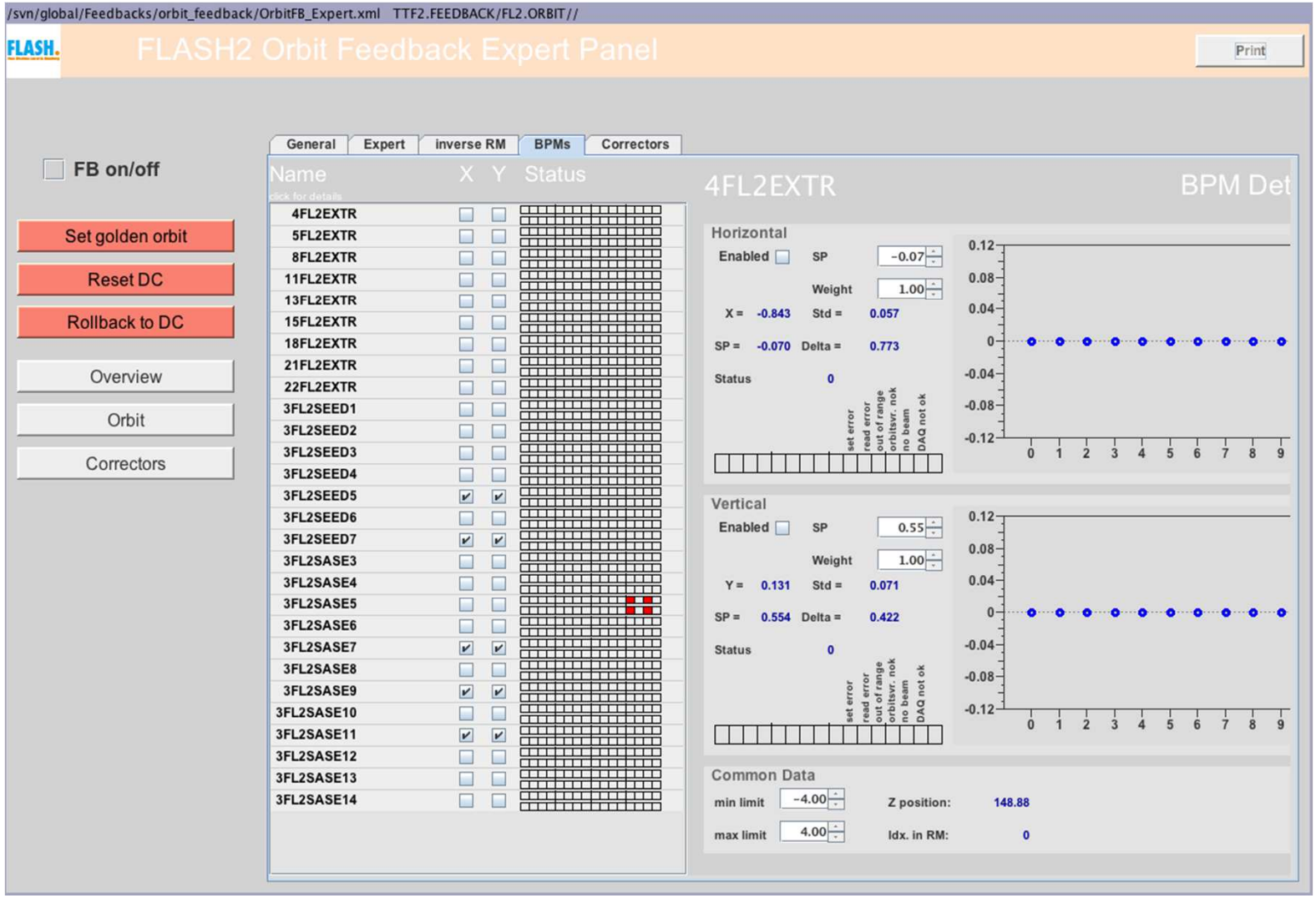
Orbit feedback.



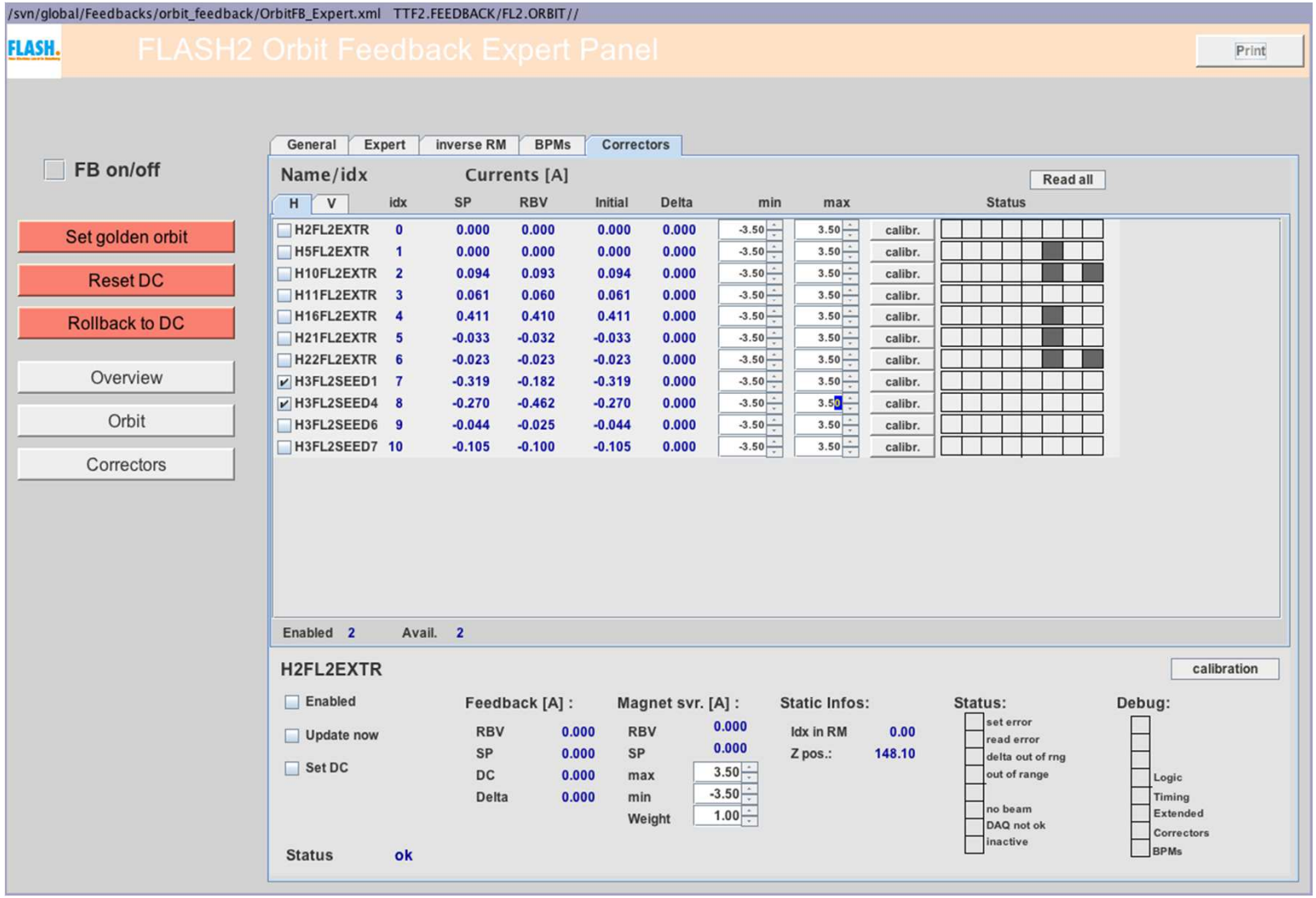
Orbit feedback.



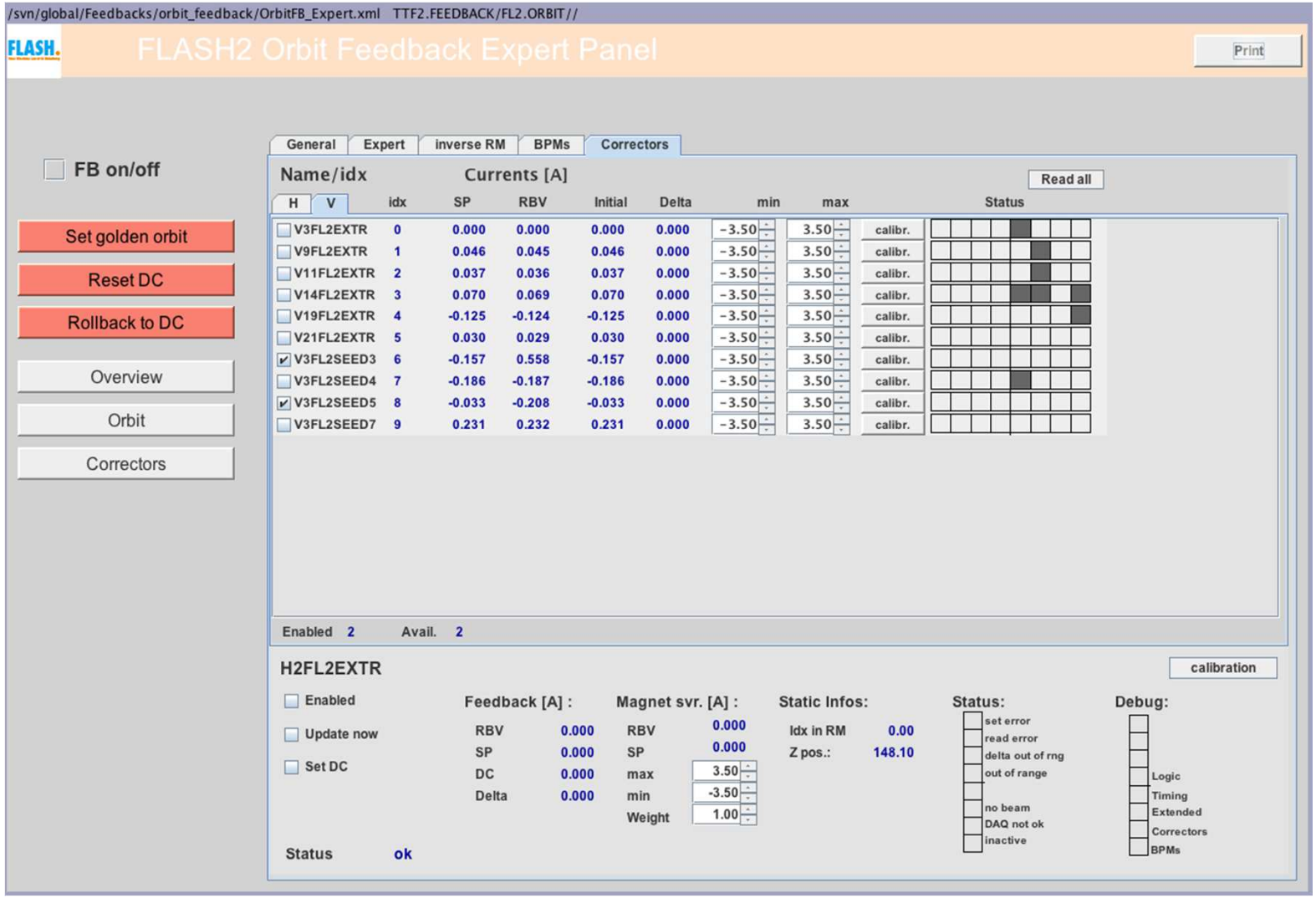
Orbit feedback.



Orbit feedback.



Orbit feedback.



Photon Diagnostics.

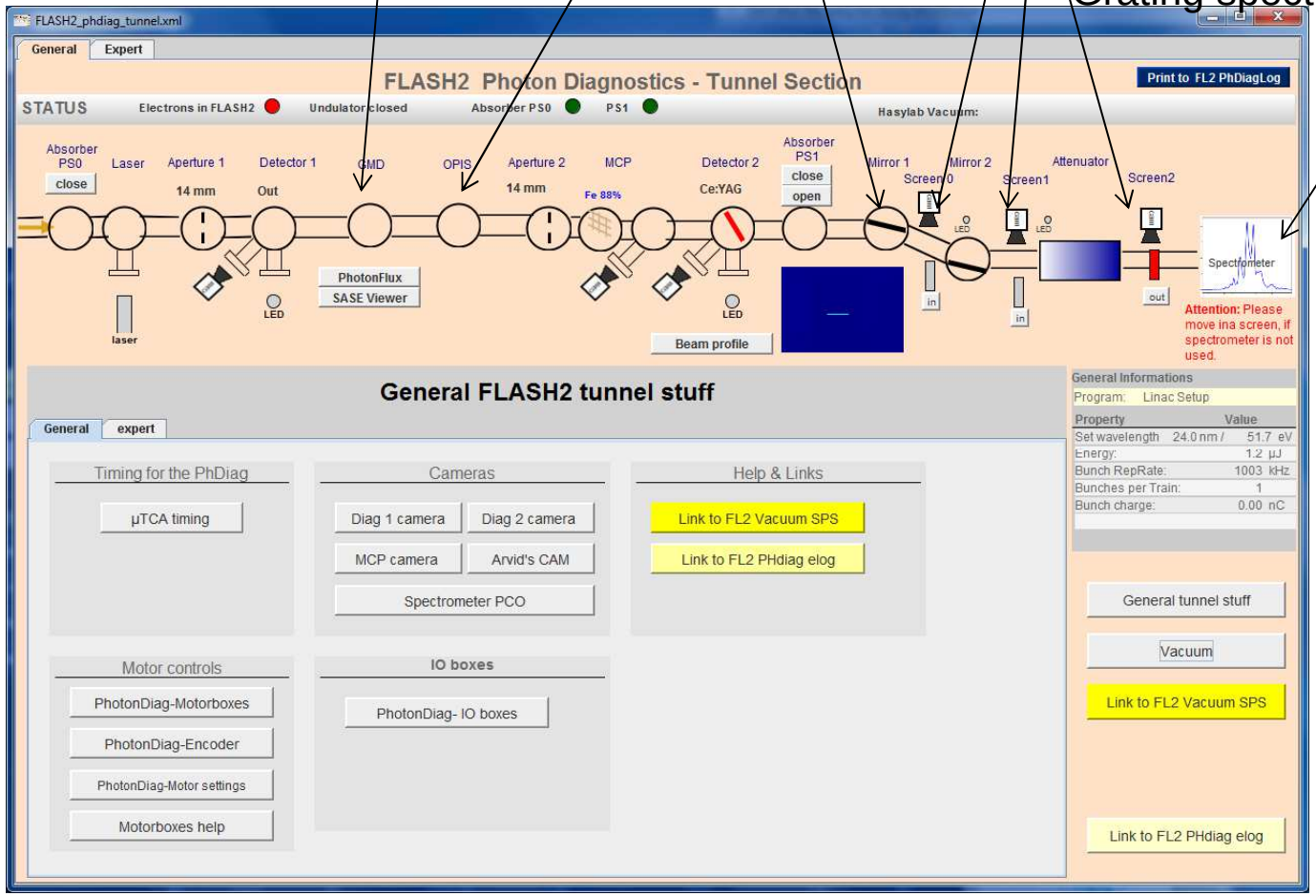
Gas monitor detector slow-signal in operation.

Online spectrometer being commissioned.

Mirrors in operation.

Photon screen(s) in operation.

Grating spectrometer (was) in operation.



Details on Photon Diagnostics in two weeks by M. Kuhlmann!

Commissioning/Setup.

FLASH.
Free-Electron Laser FLASH

FLASH1: Maintenance/ 5h, Machine Setup (use settings from Feldhaus/Dziarzhyts
FLASH2: Simultaneous Operation
News: FEL prize 2015

2015
45
03.11_M
02.11_n
02.11_a
02.11_M
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30

View Current
Show only FLASH1
Show only FLASH2
Logbook Search
Logbook Help

Op. Schedules
Beam Request
Access Requests

TTF / FLASH safety
Links
Remote Access
Printer: ttflog

DOOCS eLogBook

- 7h-15h
  - FLASH1: Maintenance/ 5h, Machine Setup (use settings from Feldhaus/Dziarzhytski experiment) / 3h
  - FLASH2: Simultaneous Operation
- 15h-23h
  - FLASH1: SASE tuning (~9.9 nm, use settings from Feldhaus/Dziarzhytski experiment)/ 4h, Statistical analysis and optimization of FEL performance ~9.9 nm (FL1 + FL2)/ 4h
  - FLASH2: Simultaneous Operation
- 23h-7h
  - FLASH1: Wavelength change (10.4 nm +/- 0.1 nm, 400 bunches 1 MHz, > 100 uJ)
  - FLASH2: Simultaneous Operation

Wednesday, November 4
- 7h-15h
  - FLASH1: SASE tuning (10.4 nm, 400 bunches 1 MHz, > 100 uJ)/ 4h, VUV Raman at FLASH (10.4 nm, 400 bunches 1 MHz)/ 4h
  - FLASH2: Tests Undulator server
- 15h-23h
  - FLASH1: VUV Raman at FLASH (10.4 nm, 400 bunches 1 MHz)
  - FLASH2: Tests Undulator server
- 23h-7h
  - FLASH1: Compensation of Steerer Crosstalk betwen FL1/FL2 in Septum Area
  - FLASH2: Compensation of Steerer Crosstalk betwen FL1/FL2 in Septum Area

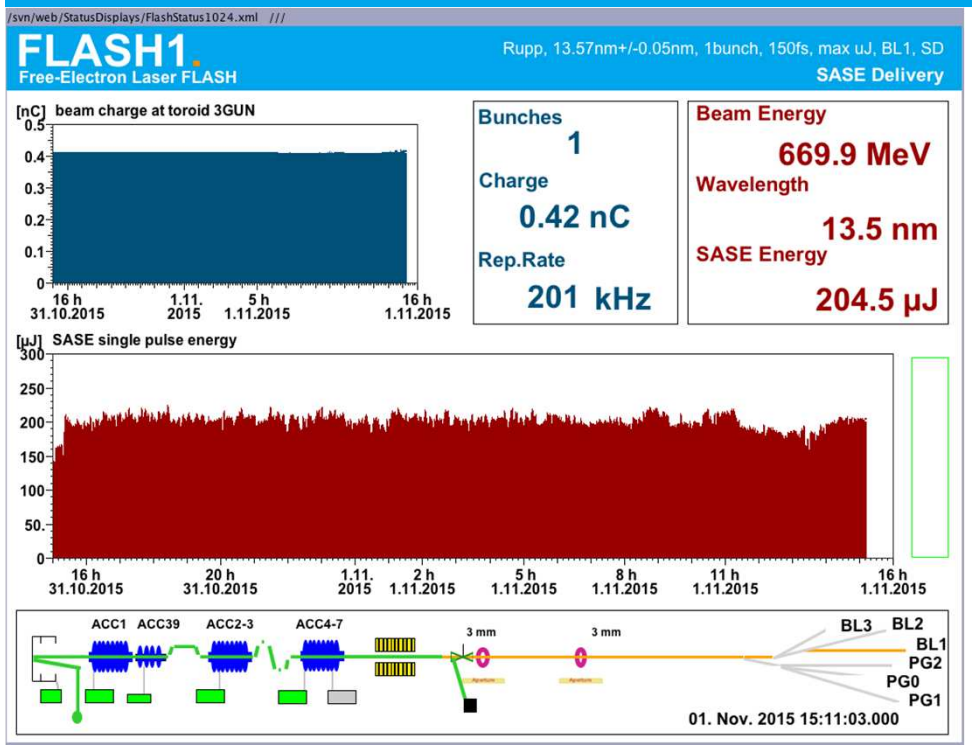
Thursday, November 5
- 7h-15h
  - FLASH1: Operator Training/ 4h, SASE tuning (10.4 nm)/ 4h
  - FLASH2: Long pulse trains
- 15h-23h
  - FLASH1: XUV pulseduration measurement with THz - streaking (10.4 nm, 1 bunch)
  - FLASH2: Simultaneous Operation
- 23h-7h
  - FLASH1: Commissioning of BL1 KB focusing system and new VMI spectrometer for the CAMP Endstation (10.4 nm, 1 bunch)
  - FLASH2: Simultaneous Operation

Friday, November 6
- 7h-15h
  - FLASH1: BL-Commissioning (10.4 nm)/ 4h, SASE tuning (10.4 nm, 400 bunches 1 MHz)/ 4h
  - FLASH2: Undulator Tapering
- 15h-23h
  - FLASH1: VUV Raman at FLASH (10.4 nm, 400 bunches 1 MHz)
  - FLASH2: Undulator Tapering
- 23h-7h
  - FLASH1: VUV Raman at FLASH (10.4 nm, 400 bunches 1 MHz)/ 4h, SASE tuning (10.4 nm, 30 bunches 200 kHz) / 4h
  - FLASH2: Simultaneous Operation

Saturday, November 7
- 7h-15h
  - FLASH1: THz-Commissioning (10.4 nm, 30 bunches 200 kHz)
  - FLASH2: Simultaneous Operation
- 15h-23h
  - FLASH1: THz-Commissioning (10.4 nm, 30 bunches 200 kHz)/ 4h, Wavelength Change (13 nm)/ 4h
  - FLASH2: Simultaneous Operation
- 23h-7h
  - FLASH1: SASE tuning (13 nm)
  - FLASH2: Simultaneous Operation

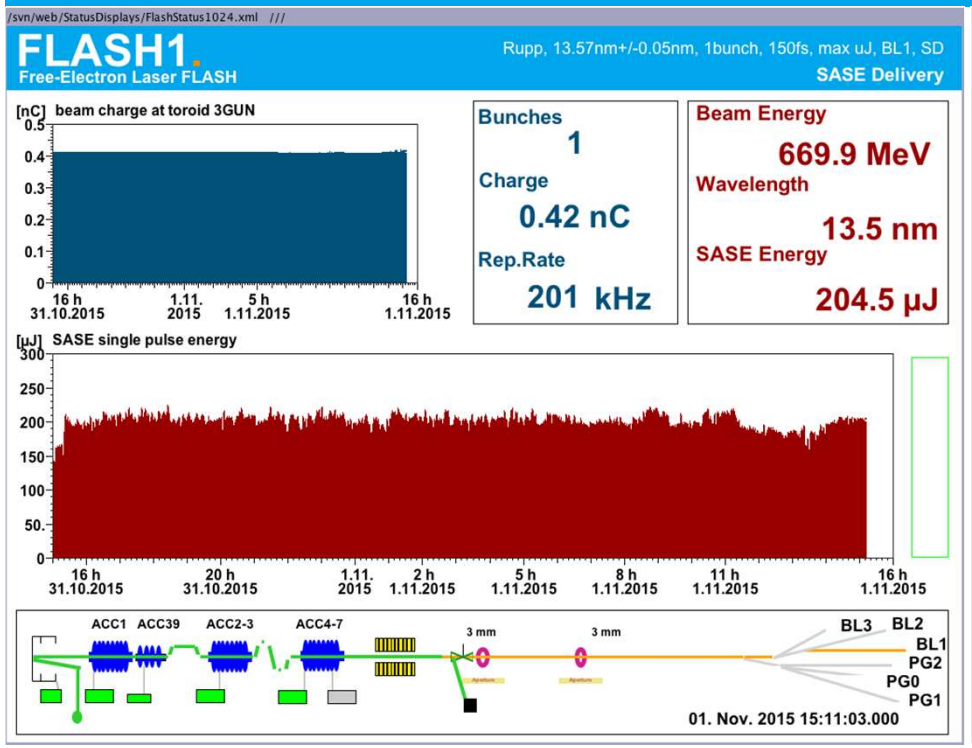
- Most setup FLASH2 (including lasing) done by FLASH operators.
- Only dedicated studies/tests done by experts.
- Programs of FLASH1 and FLASH2 now always in parallel (mostly during user runs FLASH1).

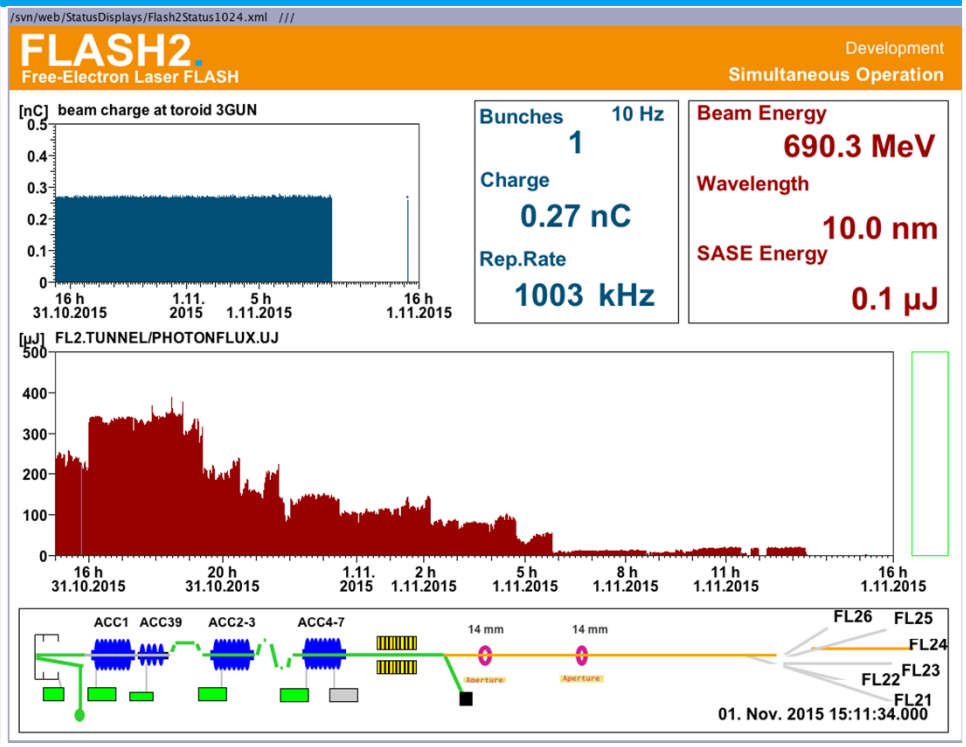
Tunability.



FLASH1: 13.57 nm for users

Tunability.

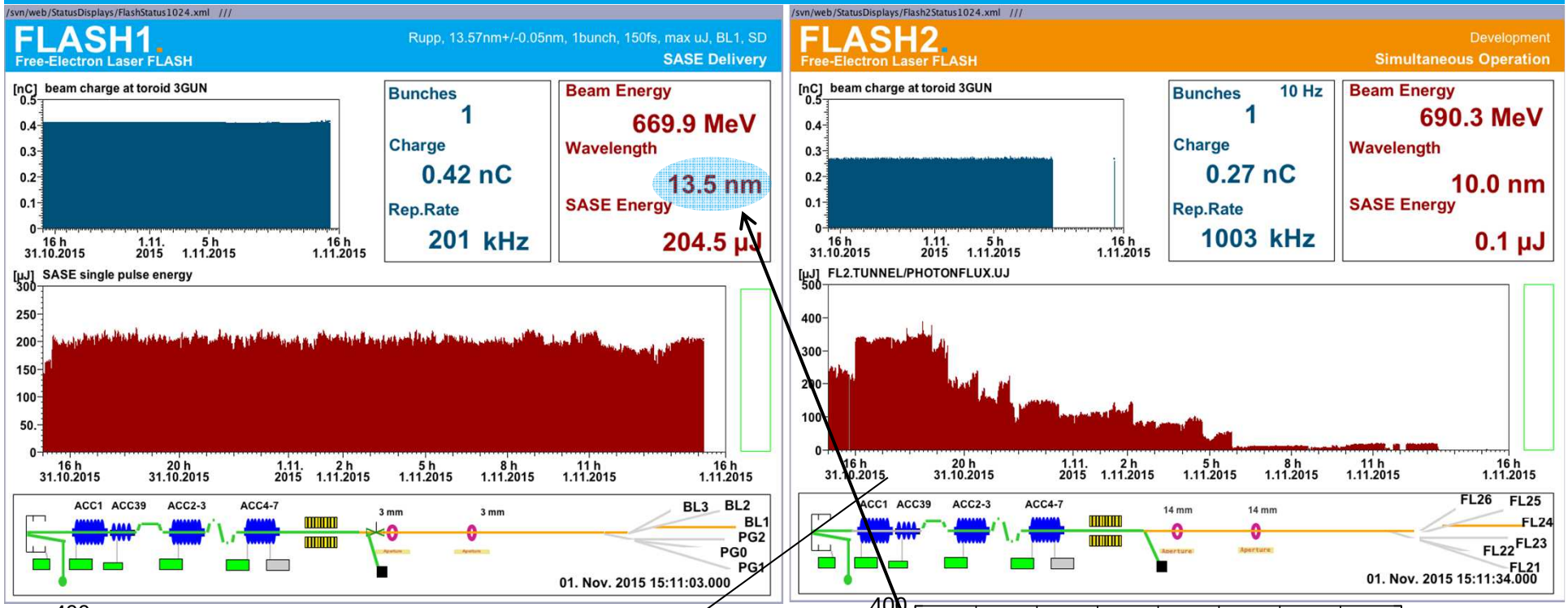


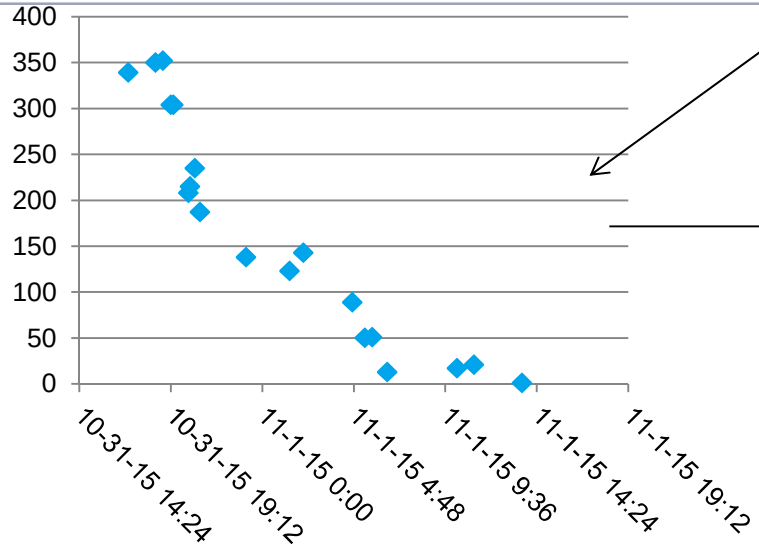


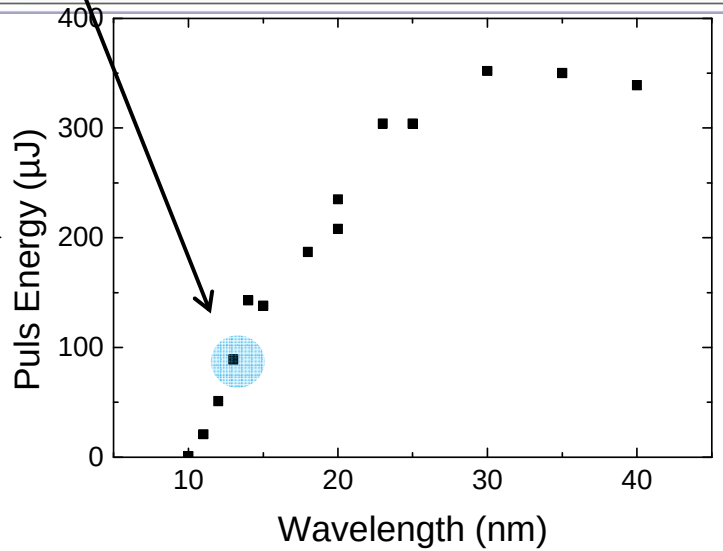
FLASH1: 13.57 nm for users
FLASH2: large variation in intensity from 350 to 1 µJ

Tunability.

FLASH1: 13.57 nm for users
FLASH2: Wavelength scan from 40 to 10 nm

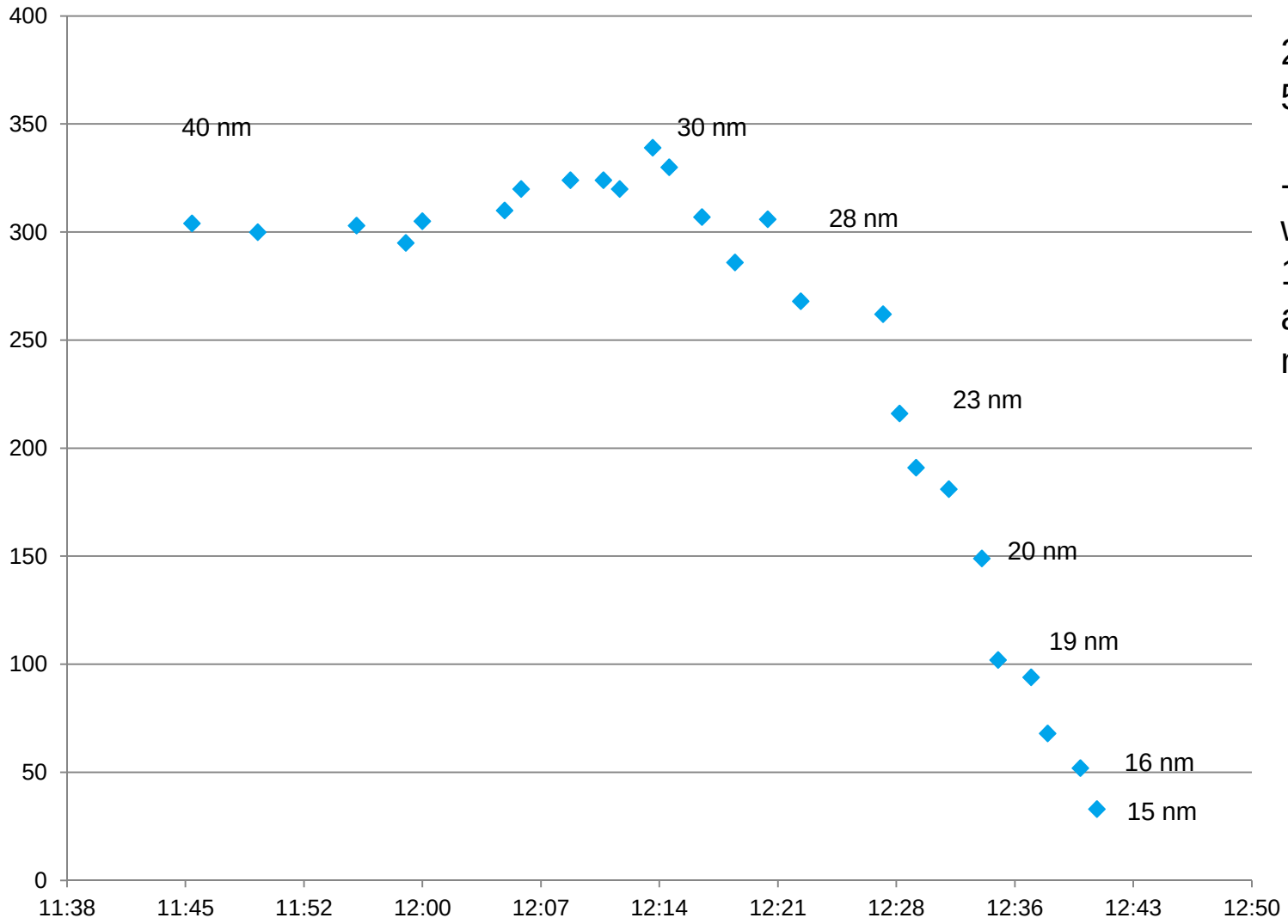






Fast Tunability.

FLASH1: 13.57 nm for users
FLASH2: Wavelength scan from 40 to 10 nm



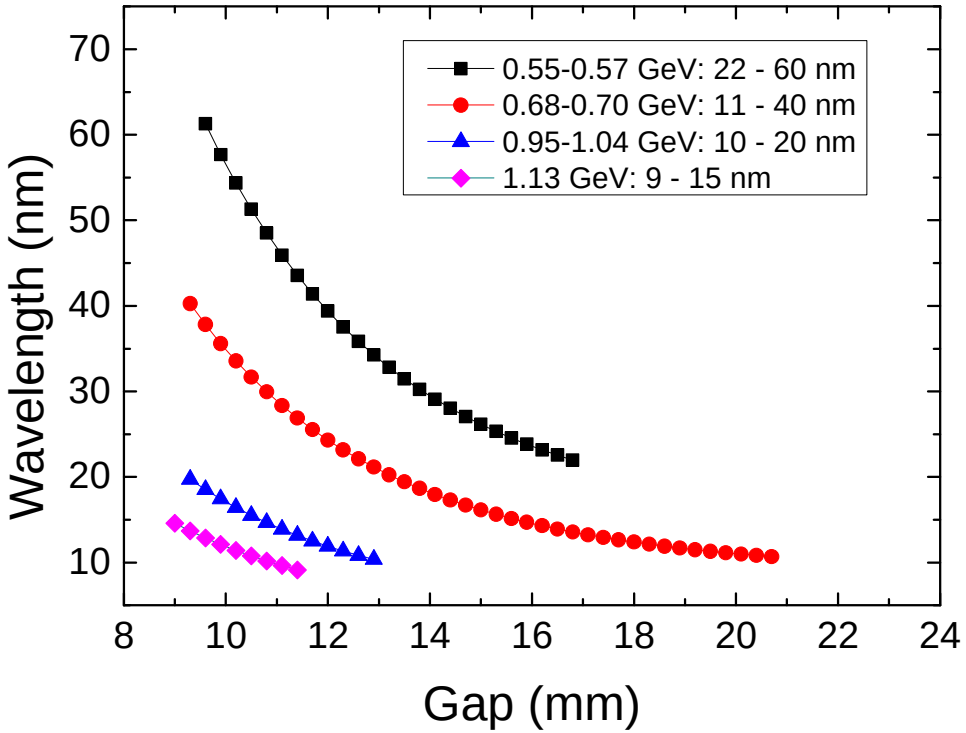
26 wavelength in 55 minutes

-> change wavelength in a 1nm step took in average 2 minutes

Wavelengths reached.

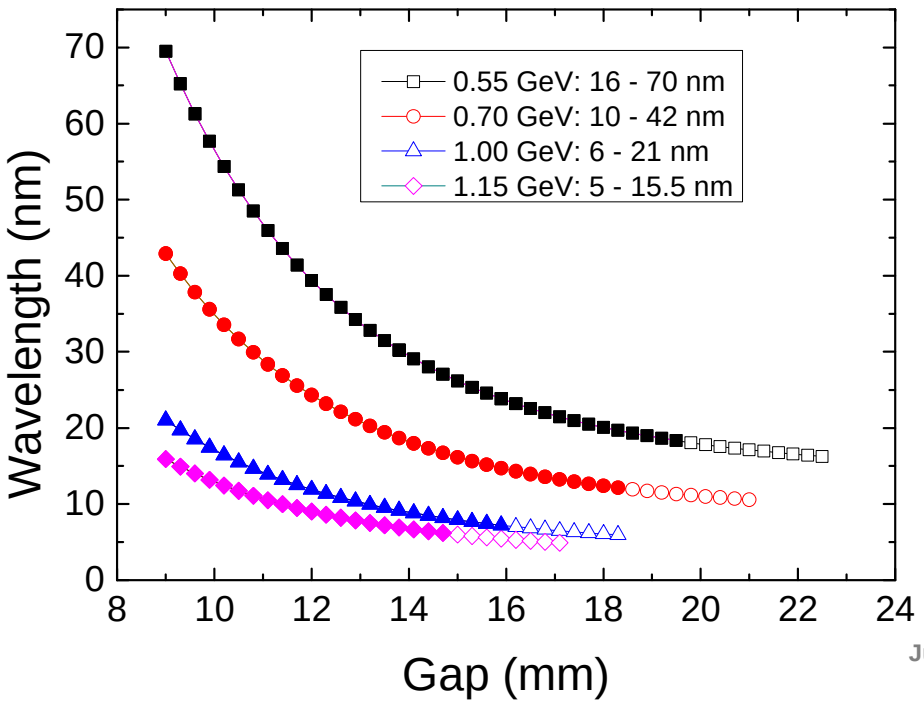
Complete wavelength ranges have been covered:

- Sometimes without GMD
- Sometimes with pulse energy below 50 µJ



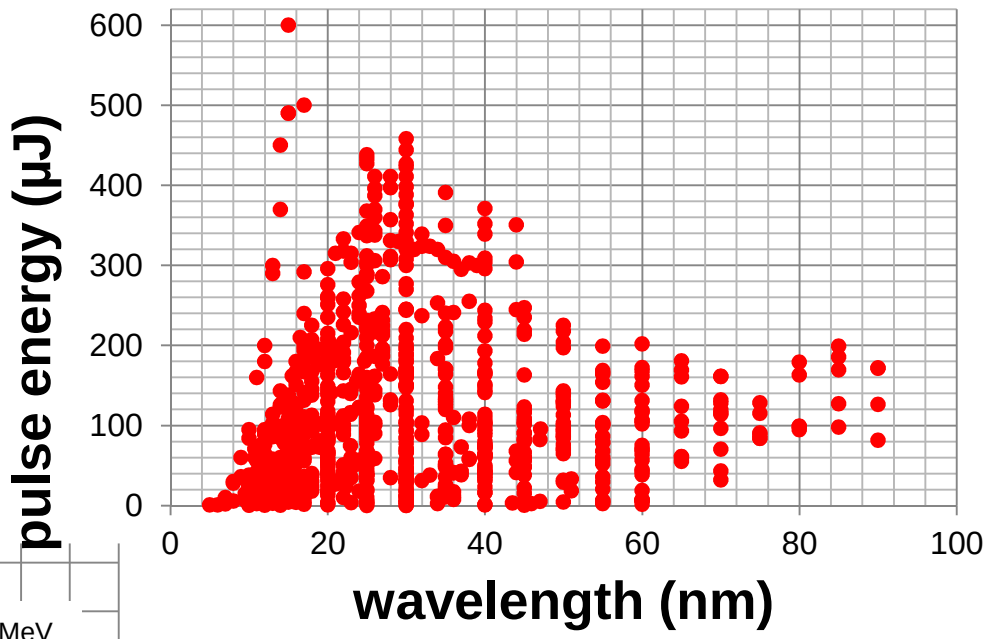
Wavelengths reached with >50 µJ

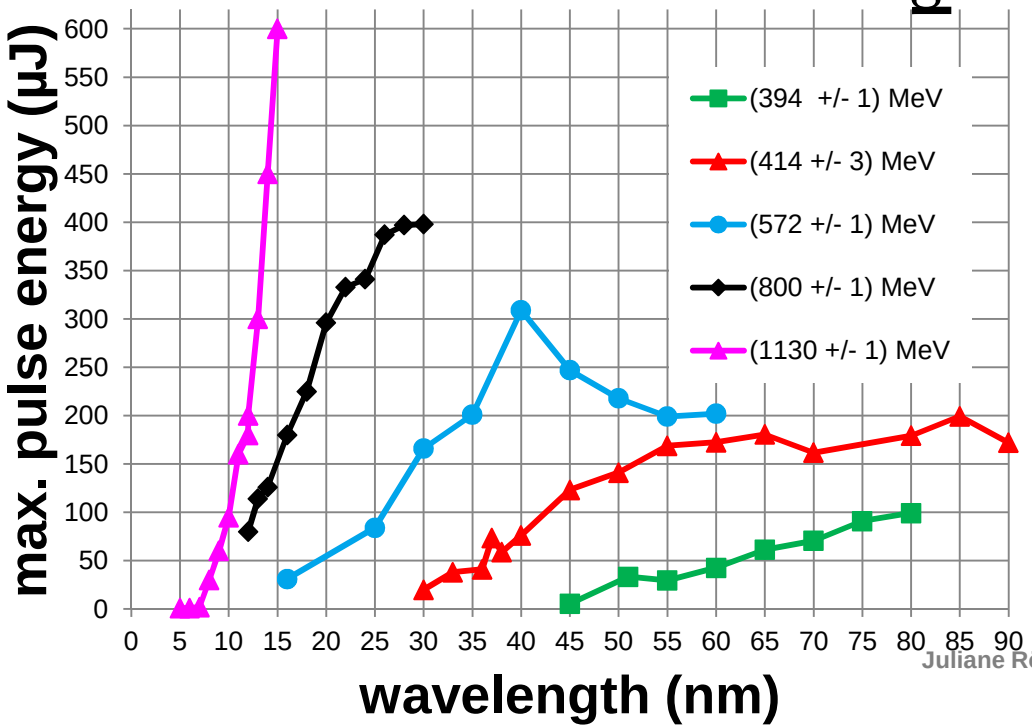
Open symbols for 2.5 kA
Filled symbols for 1.5 kA



Wavelength reached at FLASH 2

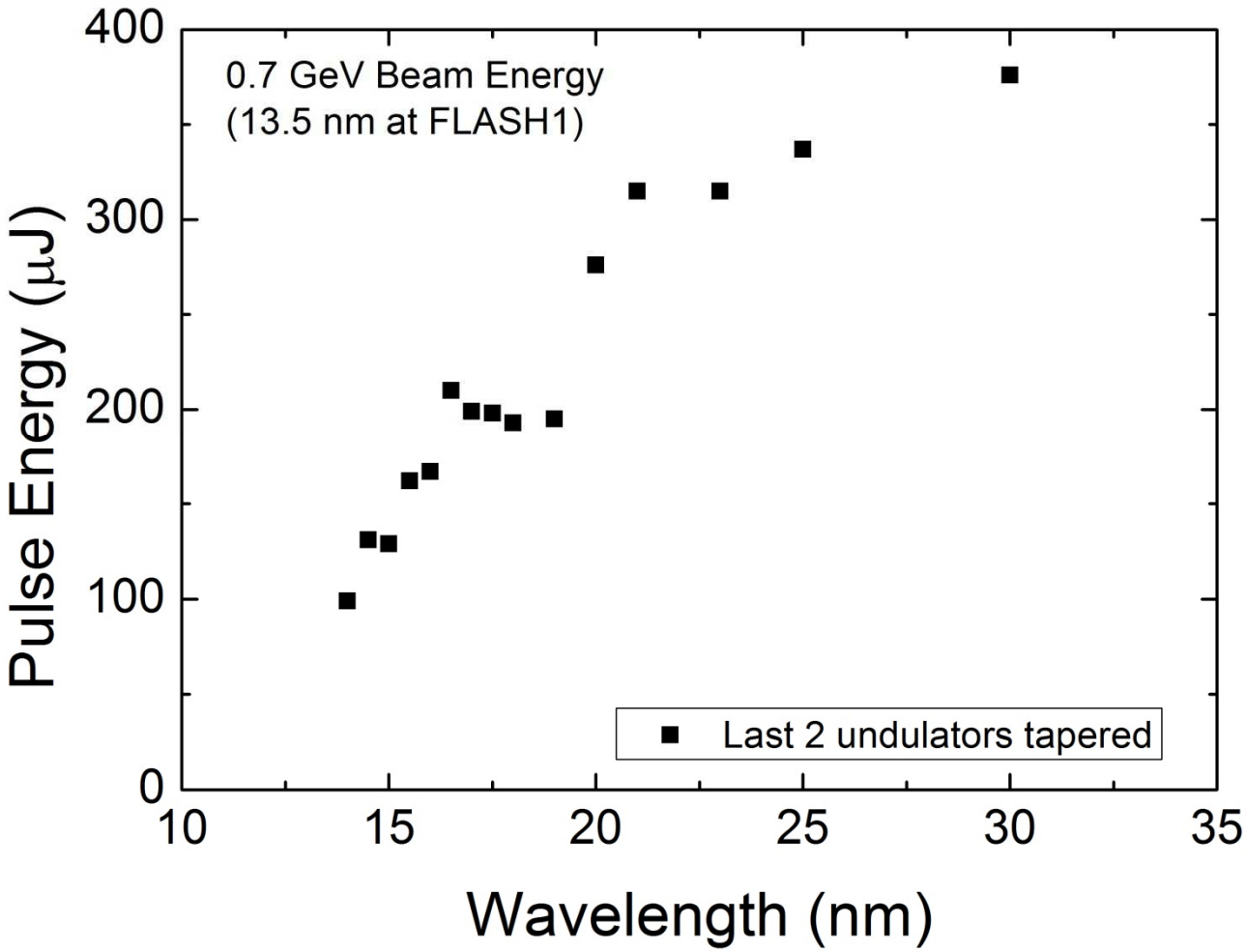
This includes measurements of experts as well as from the shift crew





Energy	FLASH1	FLASH2
394 MeV	41.5 nm	39.6 nm – 80 nm
414 MeV	37.6 nm	35.9 nm – 80 nm
572 MeV	19.7 nm	18.8 nm – 58.2 nm
800 MeV	10.1 nm	9.6 nm – 29.7 nm
1130 MeV	5.0 nm	4.8 nm – 14.9 nm

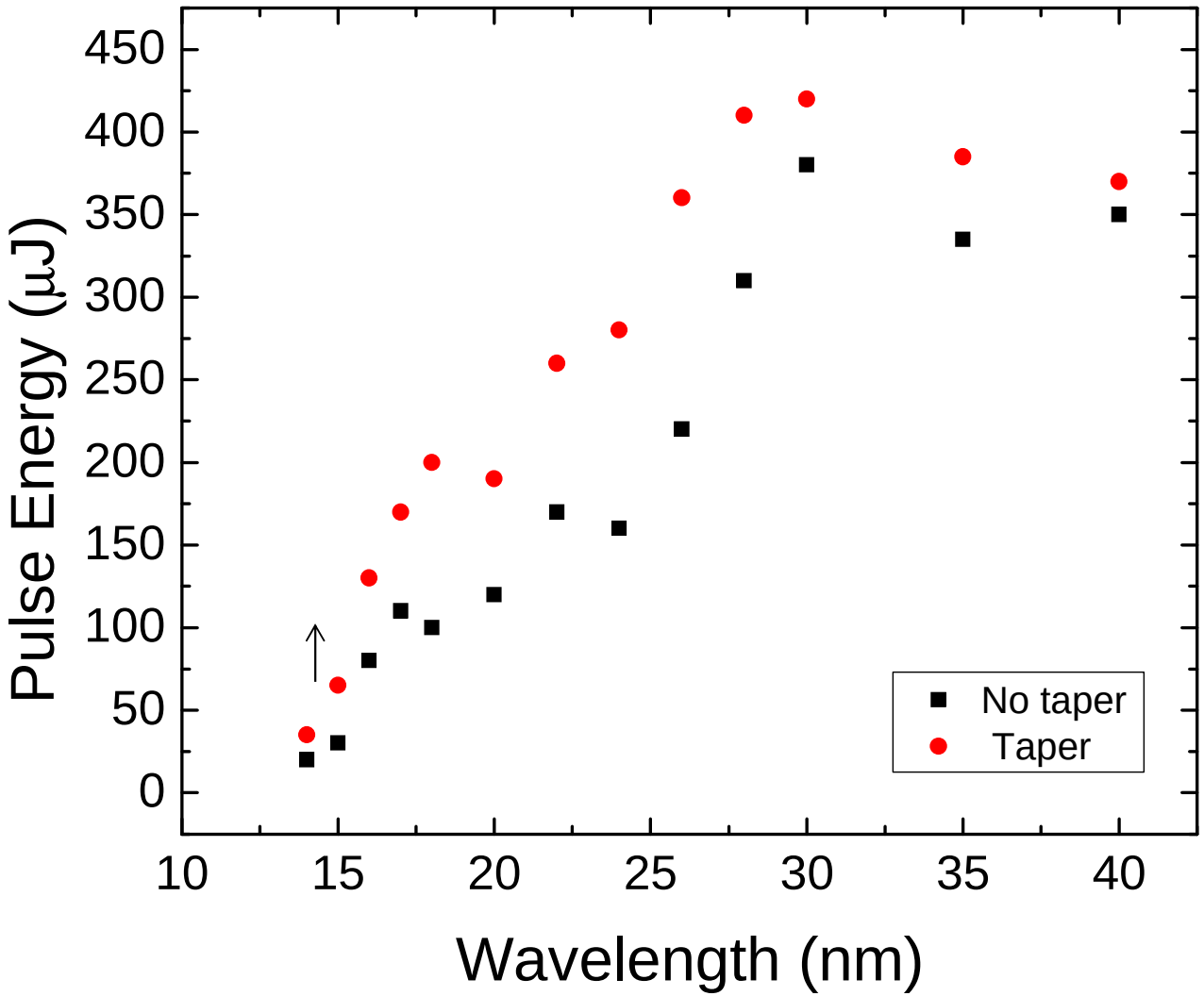
Tunability: study by expert(s).



For same shift we have:

- Pointing
- Divergence
- Spectra with OPIS and grating spectrometer

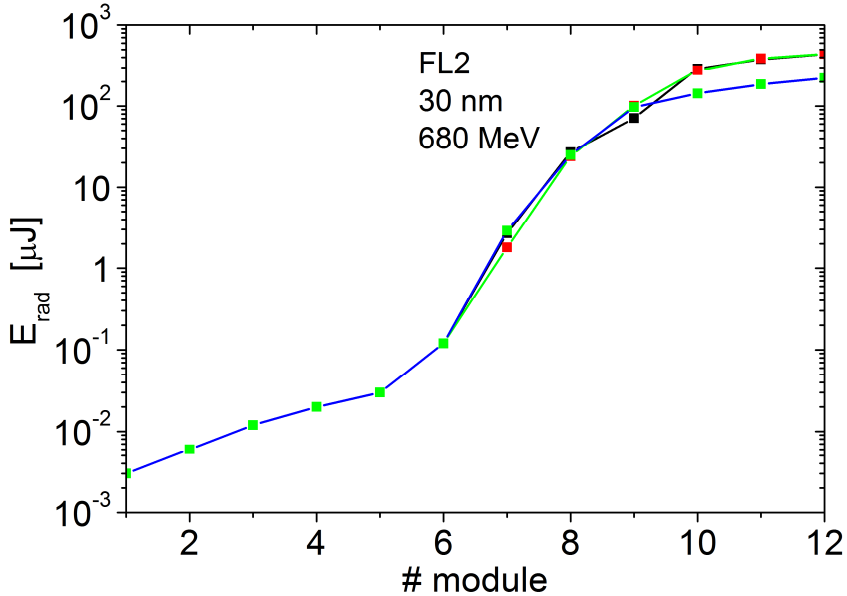
Tunability: setup by operators.

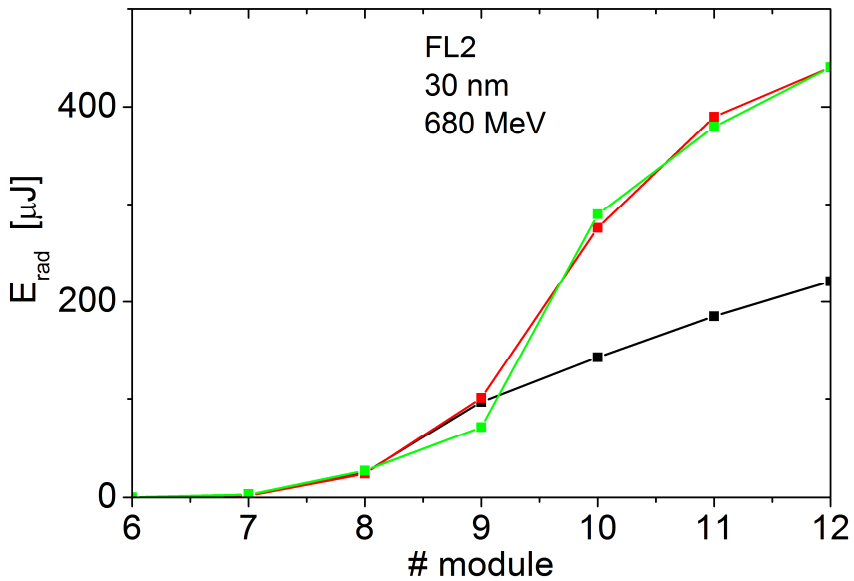


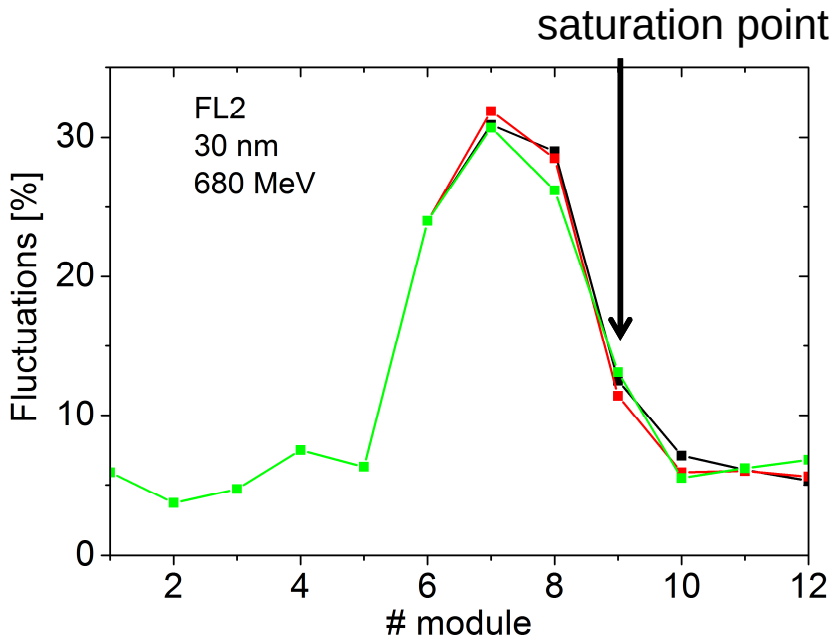
Comparison taper/no taper

At short wavelength, optimization is needed.

Tapering of undulators.







Untapered case:
220 uJ after 12 modules
100 uJ after 9 modules (saturation point)

Linear tapering: 440 uJ
Quadratic tapering: 440 uJ
Increase of output pulse energy over saturation is x4
Increase of output pulse energy at full undulator length is x2

Courtesy M. Yurkov & E. Schneidmiller

Outlook.

Continued commissioning

- Further education of operators.
- Commissioning of photon diagnostics (see M. Kuhlmanns talk).
- Commissioning of CRISP5 (right now theere is no bunch length measurements at FLASH2).
- Steps in the gun
- Wider ranges of charge differences between FLASH1 and FLASH2.
- Further optimize and automatize undulator server.
- Energy server, orbit feedback, …
- Beam Based Alignment, Optics studies
- Influence of varying conditions FLASH1 (bunch number) on pyro signal of FLASH2
- Lasing at short wavelength

User operation

- First users starting from April

Thanks

- To all the operators
- Special thanks to B. Faatz, he did most of the work presented here