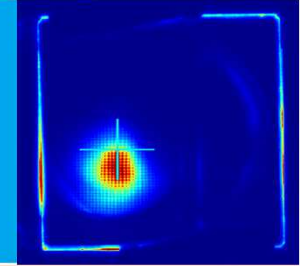


FLASH 2



FEL seminar

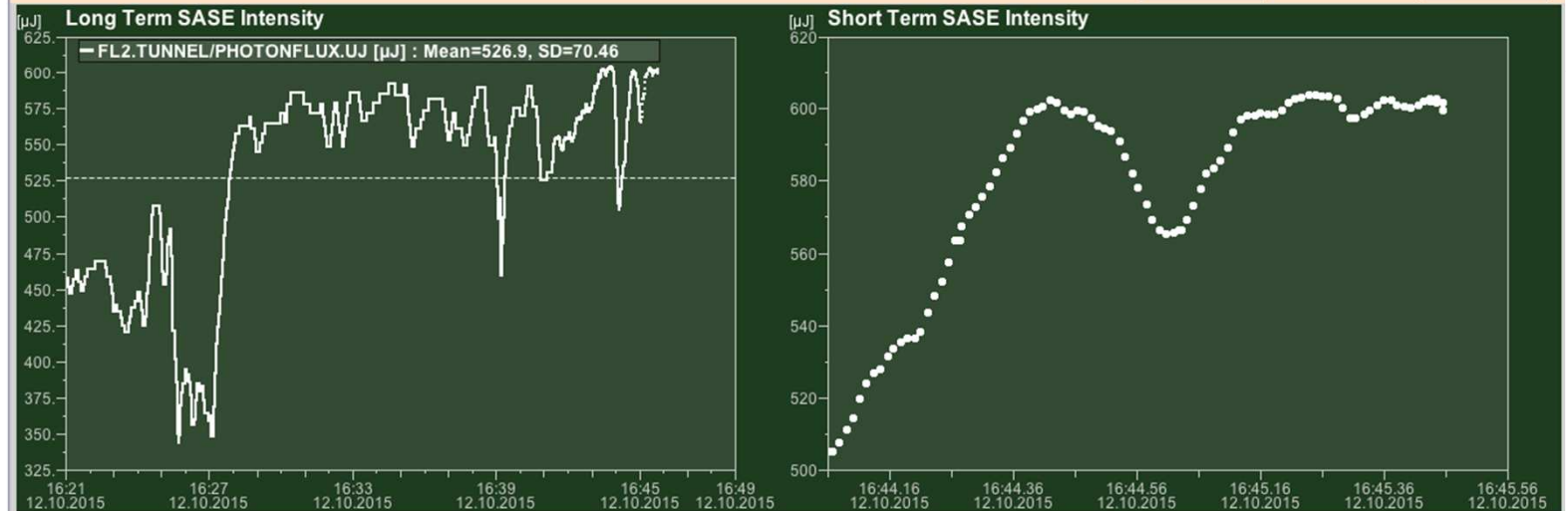
FLASH. FLASH2 - SASE viewer

10 mm / 10 mm 601.66 μJ

15.00 nm

photon-diag

Print



Charge: 0.5 nC

Juliane Rönsch-Schulenburg

Overview of FLASH 2

Hamburg, 2016-03-22

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.

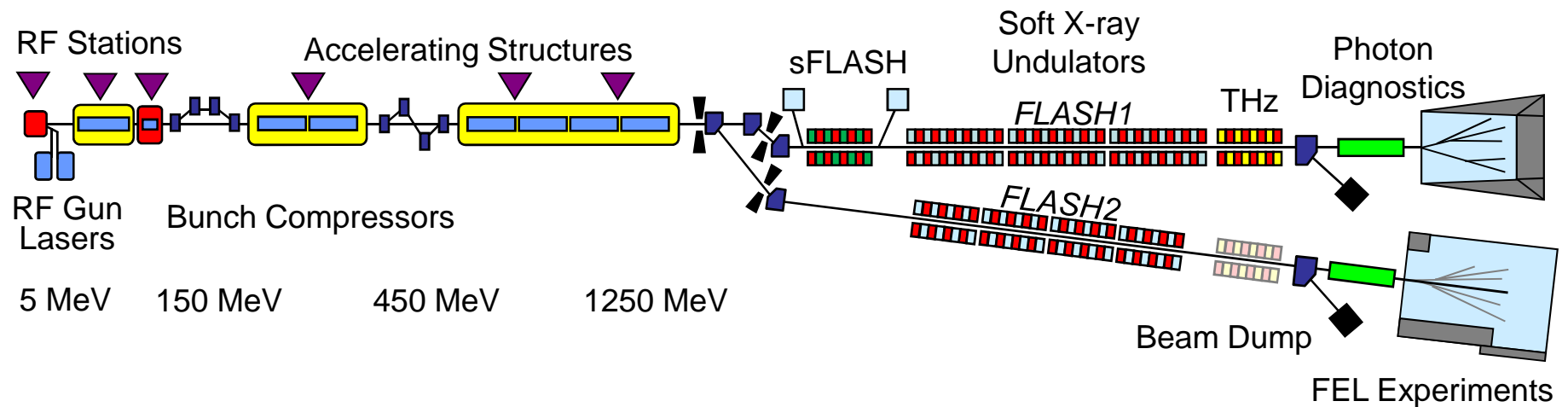
	FLASH1	FLASH2
Beam parameters		
Beam Energy	0.5 – 1.25 (1.6) GeV	0.5 – 1.25 (1.6) GeV
Normalized emittance (proj.)	1.4 – 3 mm mrad	1.4 – 3 mm mrad
Energy spread	0.2 MeV	0.5 MeV
Peak Current	2.5 kA	2.5 kA
Bunches per second*	<8000	<8000
Bunch Charge	0.07 – 1 nC	0.02 – 1 nC
Undulator parameters	Fixed gap	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

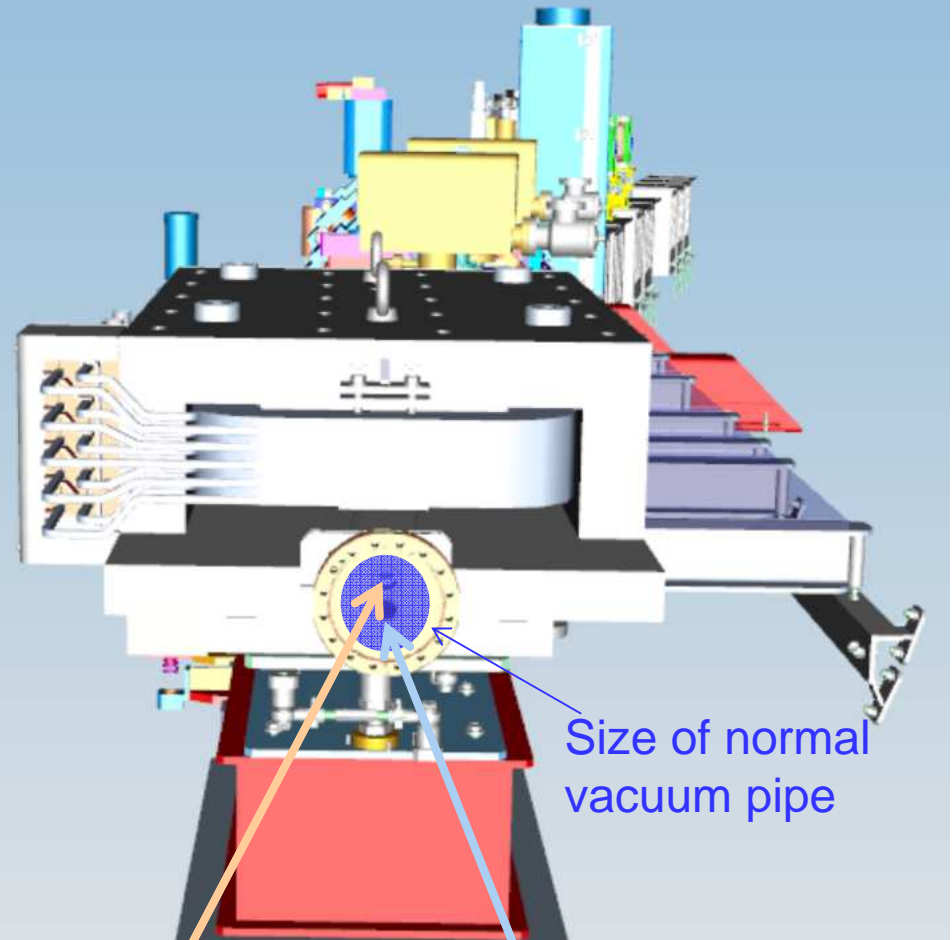
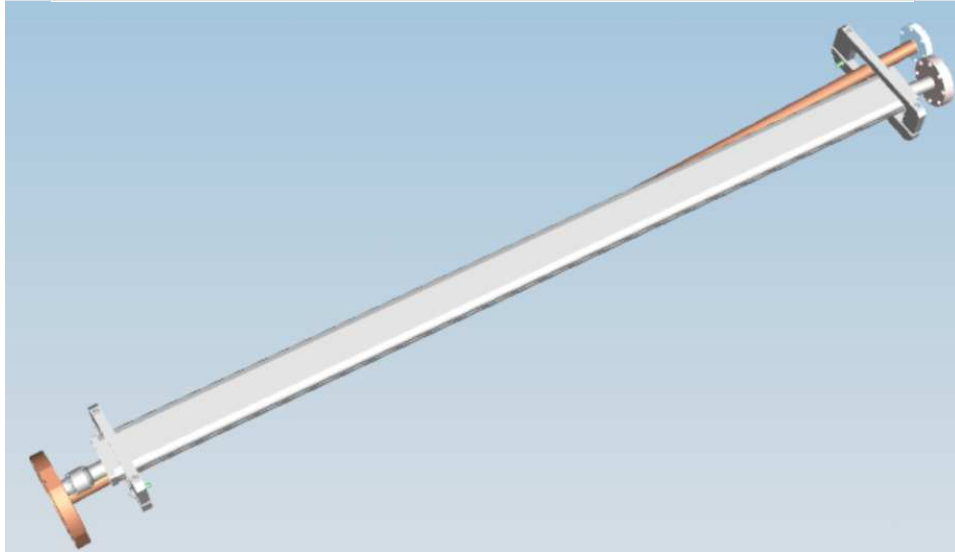
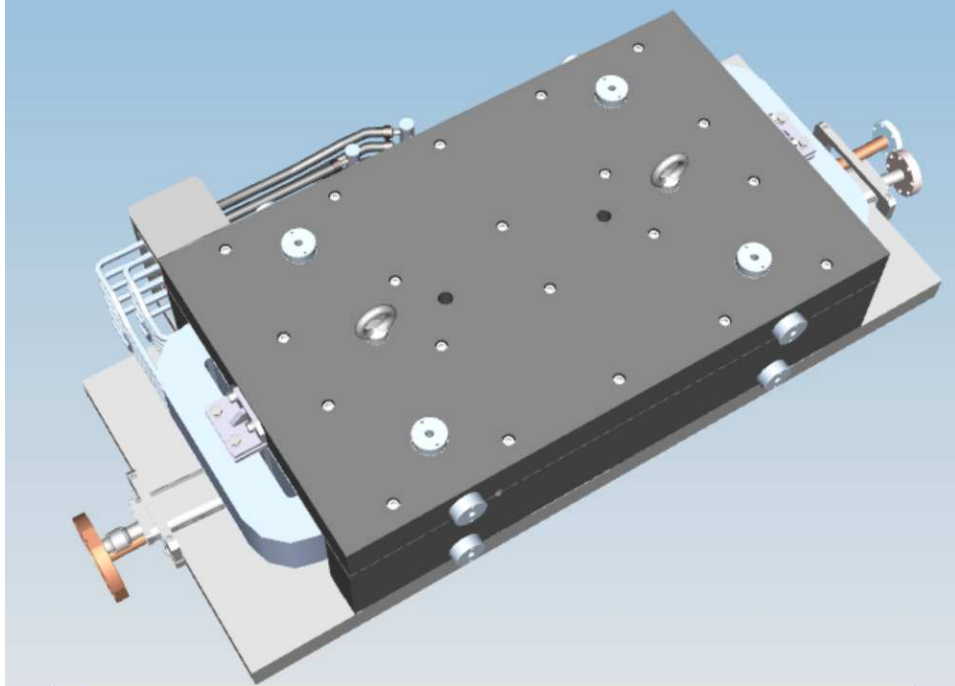


Layout.

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

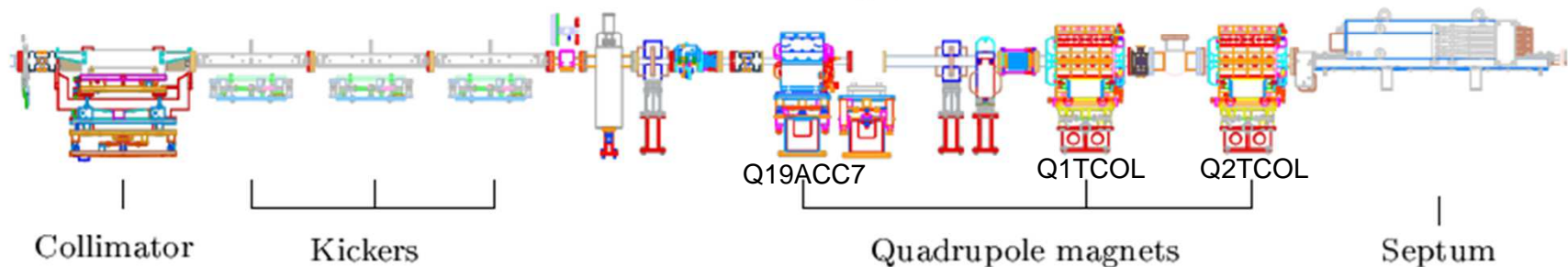
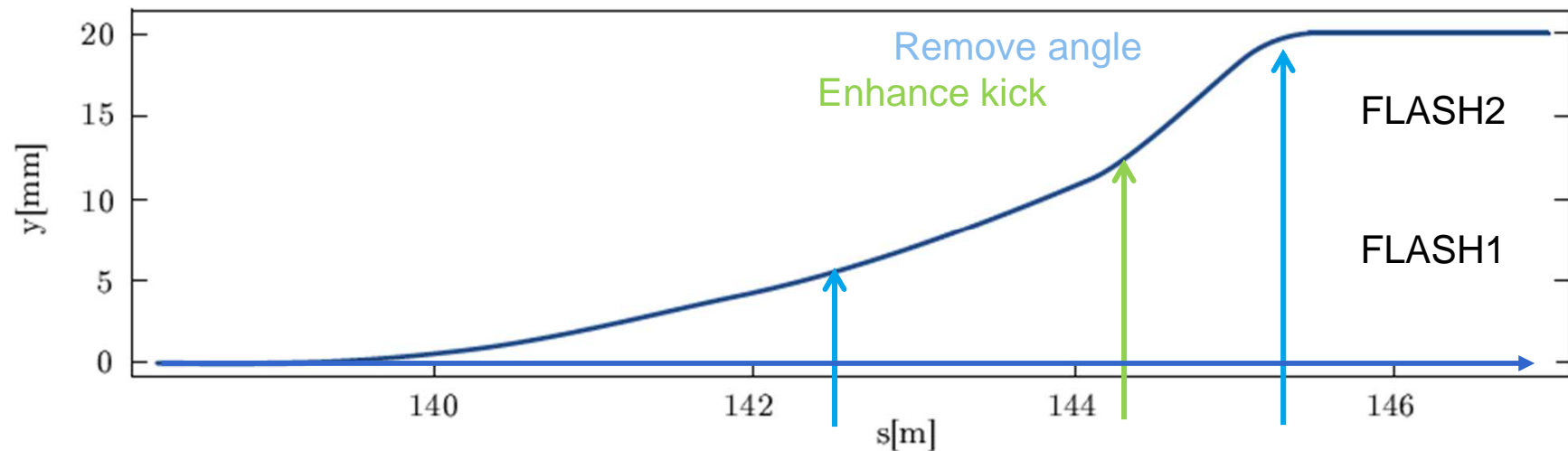


Separation FLASH1 and 2: the septum.



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.

Undulators Control (status November 2015).

FLASH2 Undulator Controls

Controls
Wavelength: 40.00 nm
Delta Phi: 31.0 eV
Status: Ready Energy: 698.21 MeV

Group actions
All Stop
All Open
All Close

Taper Controls
Group no: 1
Group no: 2
Group no: 3

Legend
Open
Closed
Moving

Undulator	Active	Phase Shifter	Δφ	Taper Group	ΔGap
FL2SASE3	<input type="checkbox"/>	<input type="checkbox"/>	90.000	1	0.00
FL2SASE4	<input type="checkbox"/>	<input type="checkbox"/>	90.000	1	0.00
FL2SASE5	<input type="checkbox"/>	<input type="checkbox"/>	90.000	1	0.00
FL2SASE6	<input type="checkbox"/>	<input type="checkbox"/>	90.000	1	-0.00
FL2SASE7	<input type="checkbox"/>	<input type="checkbox"/>	90.000	1	-0.00
FL2SASE8	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	90.000	2	-0.00
FL2SASE9	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	90.000	2	0.00
FL2SASE10	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	90.000	2	0.00
FL2SASE11	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	90.000	2	0.00
FL2SASE12	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	87.000	3	0.06
FL2SASE13	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	90.000	3	0.11
FL2SASE14	<input checked="" type="checkbox"/>	---	---	3	0.12

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

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



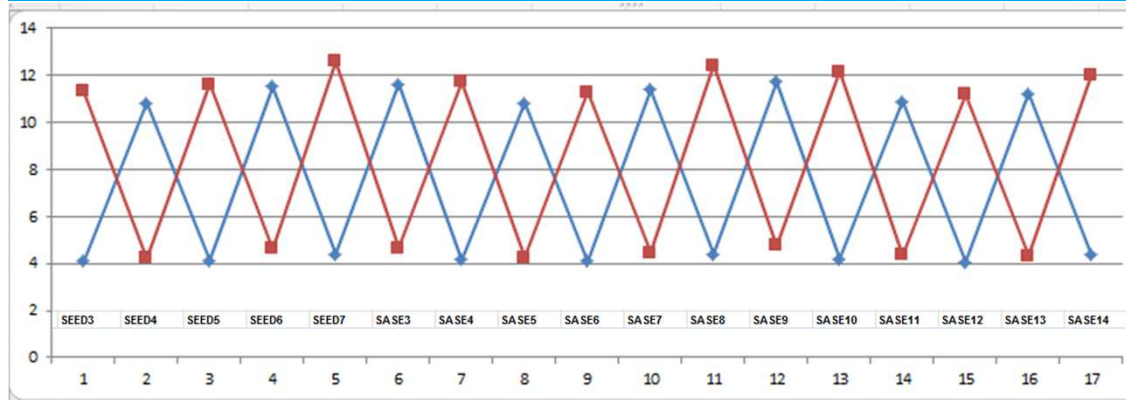
Undulator focusing.

- > 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.

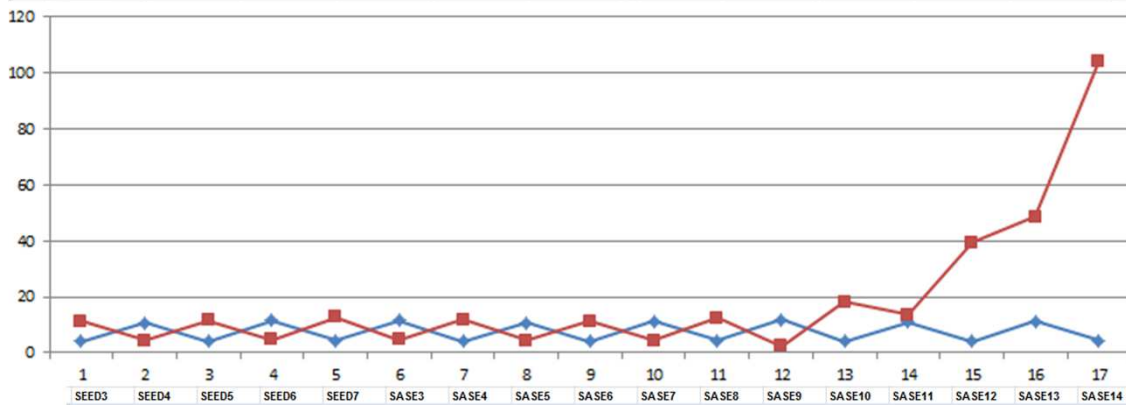
Beam size $\sigma^2 \sim \beta$

Undulator open

$4 < \beta_y < 12 \text{ m}$

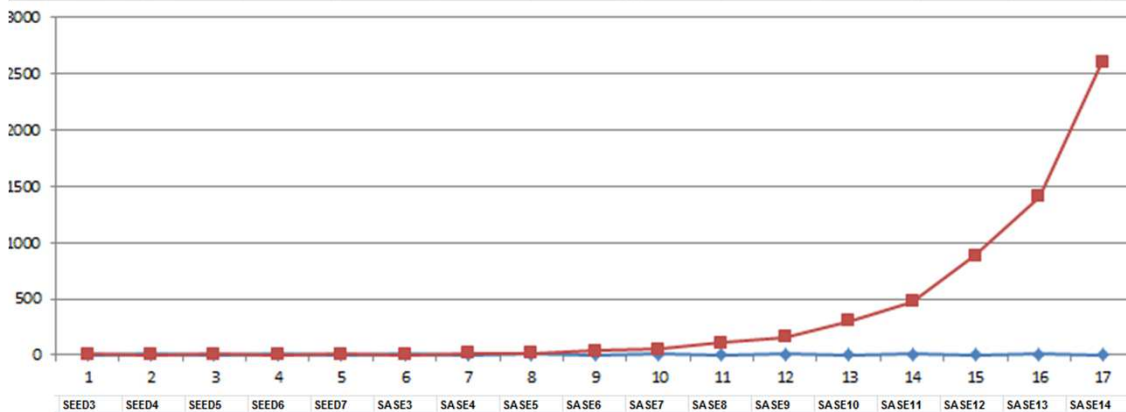
Last 6 undulator closed

$1 < \beta_y < 120 \text{ m}$

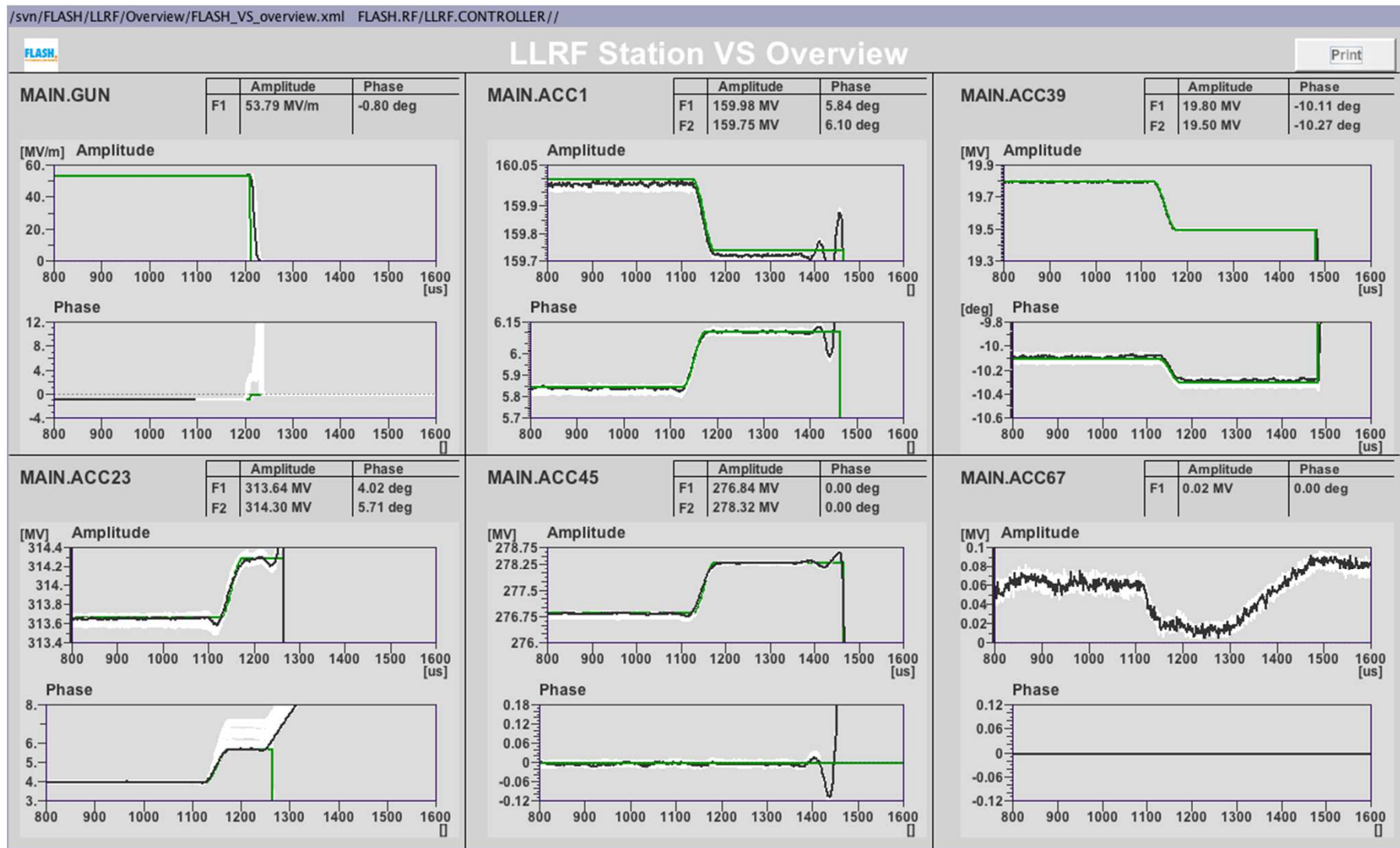


All 12 undulators closed

$0 < \beta_y < 3000 \text{ m}$



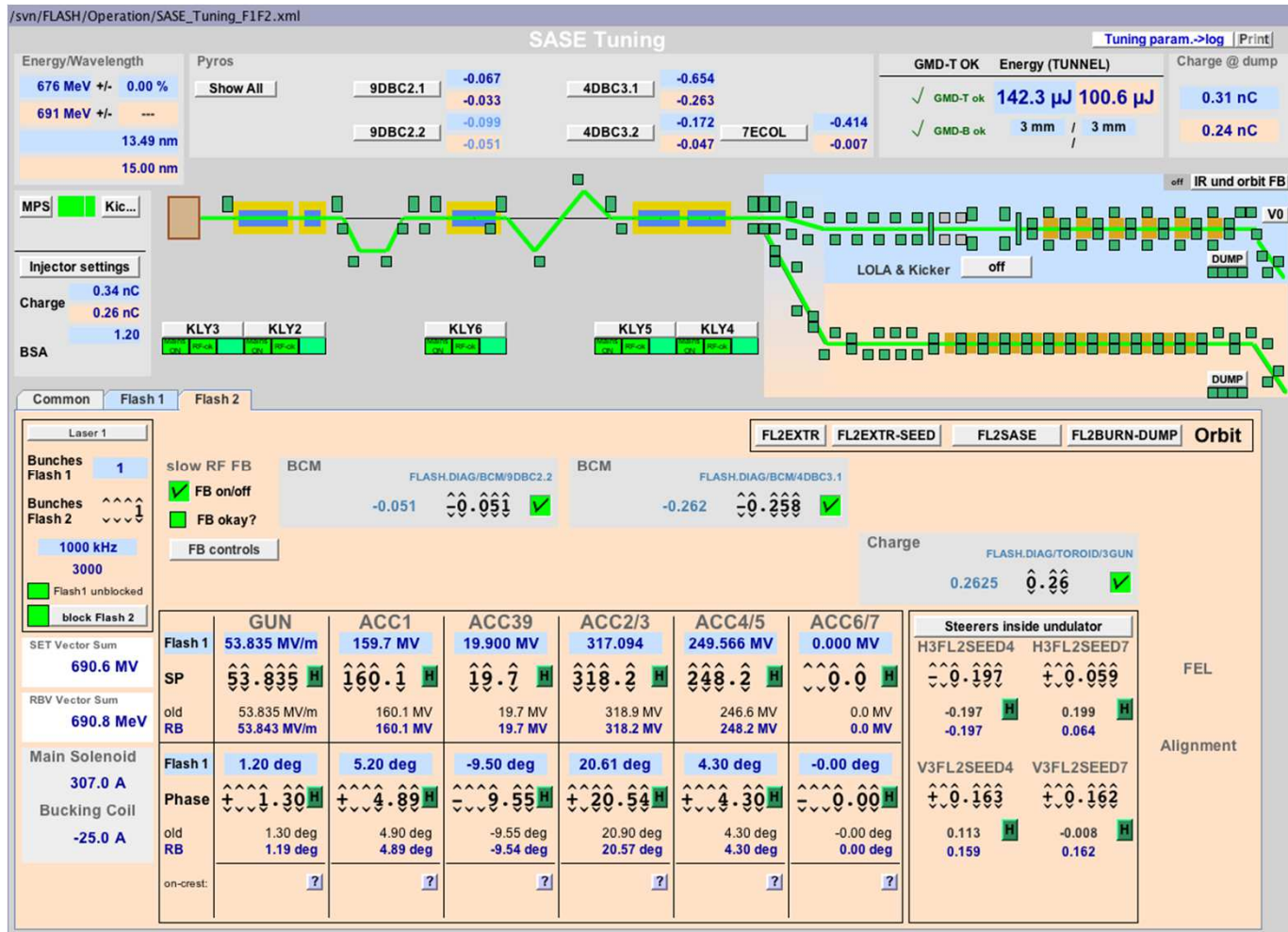
LLRF Steps



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



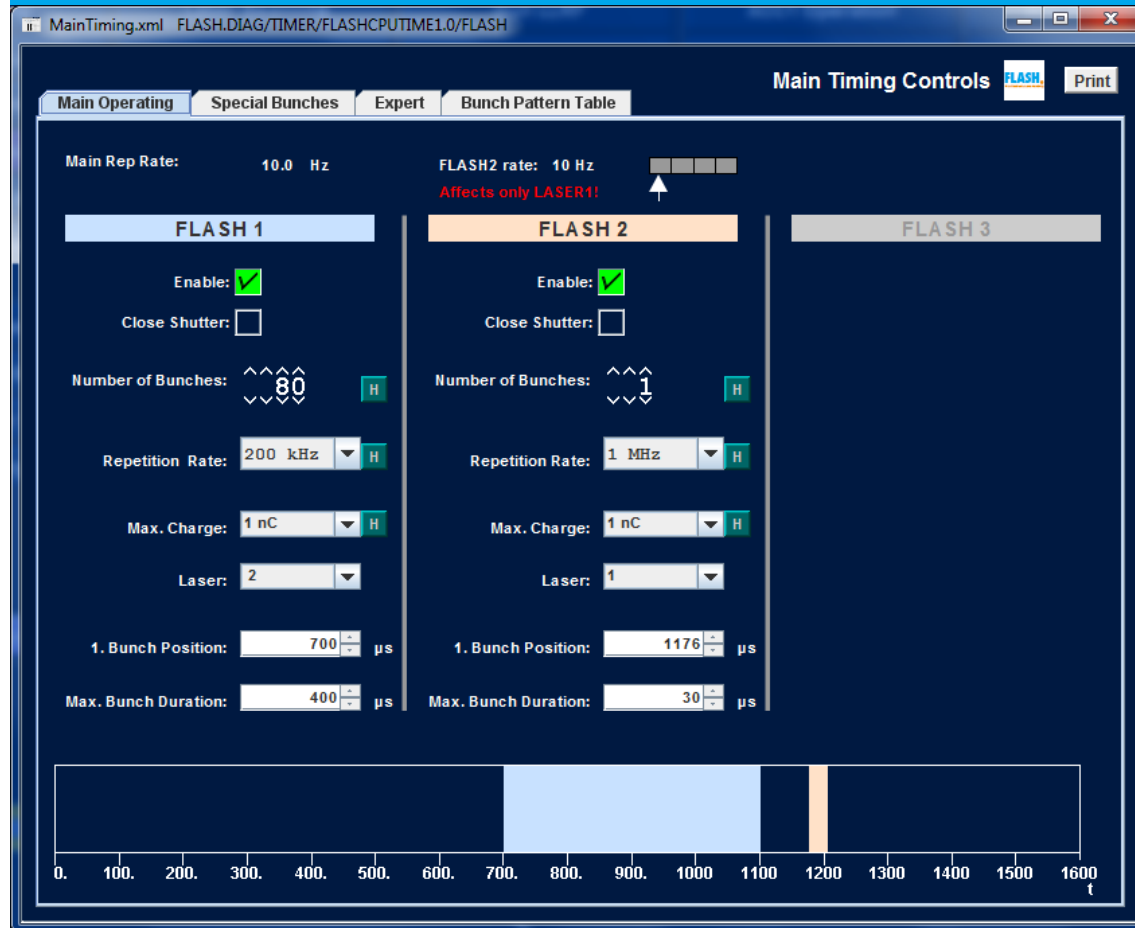
SASE tuning



Slow online Intensity Monitor
LLRF learning FF



Main timing of FLASH.



Settings for FLASH1 and 2 chosen independently.

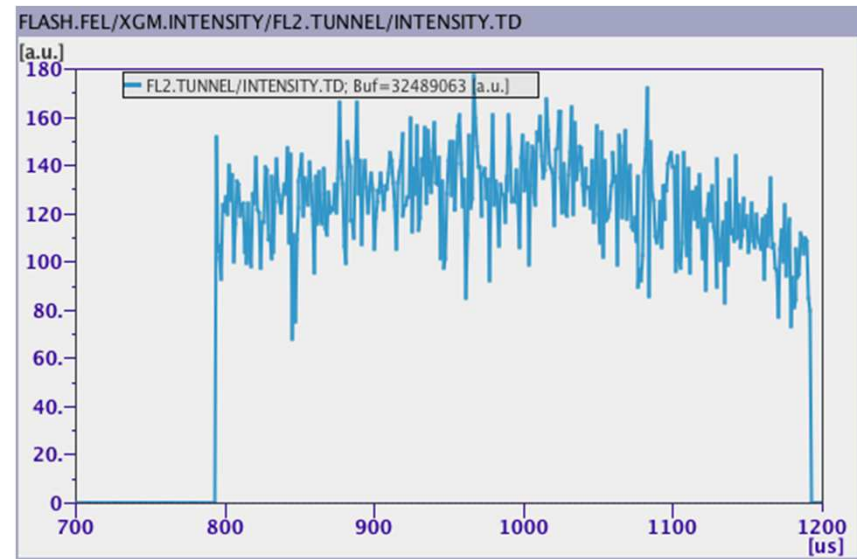
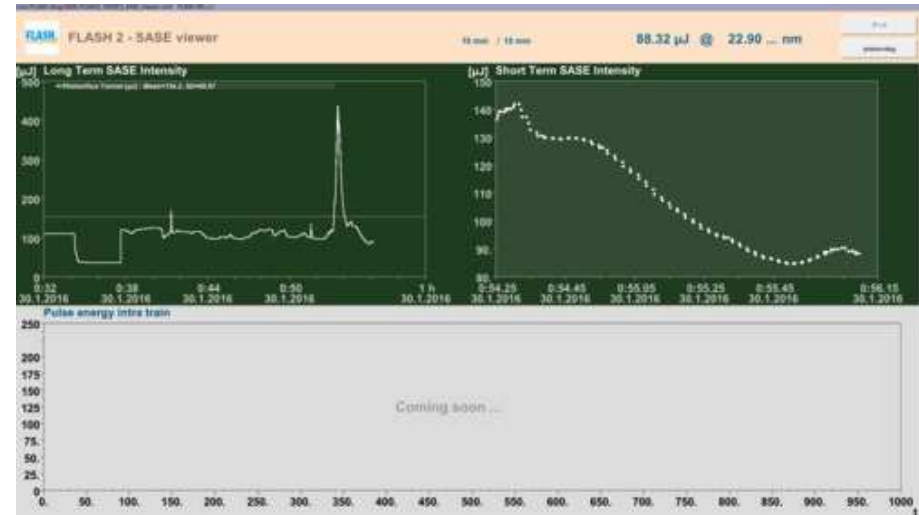
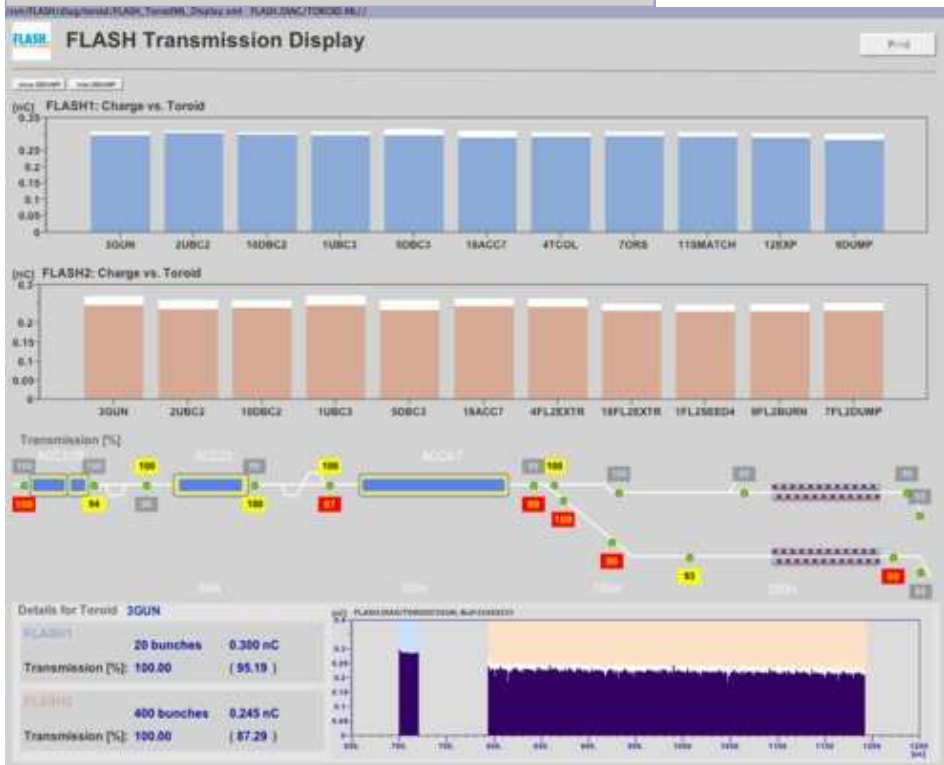
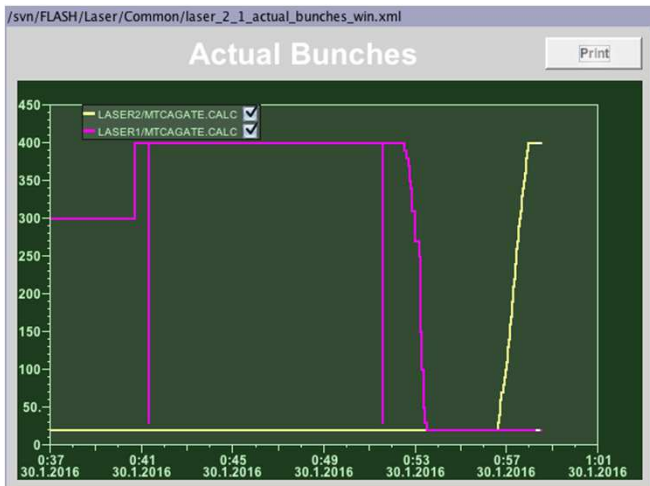
1 Hz operation at FLASH2 possible.

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.

/svn/global/Feedbacks/orbit_feedback/OrbitFB_Expert.xml TTF2.FEEDBACK/FL2.ORBIT//

FLASH. FLASH2 Orbit Feedback Expert Panel Print

Set golden orbit
Reset DC
Rollback to DC
Overview
Orbit
Correctors

General Expert inverse RM BPMs Correctors

Controls

FB on/off

Orbit deviation	Horiz. 0.015	Vert. 0.008	mm
Allowed	0.020	0.020	mm
Gain	0.200	0.200	
dl min	0.0001	A	
dl max	0.040	A	
Averaging	10	macropulses	

inactive BPMs selected

- DAQ not okay
- beam missing
- orbit svr. problem
- out of range
- delta out of range
- read error
- set error
- no BPMs
- no corr.
- insuff. corr.
- RM not okay

Status

	Available BPMs	Available corr.
Horizontal	5	2
Vertical	5	2

Horiz. correction status
idle - nothing to correct

Vert. correction status
idle - nothing to correct

FB Status
Feedback active



Orbit feedback.

/svn/global/Feedbacks/orbit_feedback/OrbitFB_Expert.xml TTF2.FEEDBACK/FL2.ORBIT//

FLASH. FLASH2 Orbit Feedback Expert Panel Print

FB on/off

Set golden orbit

Reset DC

Rollback to DC

Overview

Orbit

Correctors

General Expert inverse RM BPMs Correctors

Controls

Orbit deviation	Horiz. 0.533	Vert. 0.275	mm	inactive BPMs selected DAQ not okay beam missing orbit svr. problem out of range delta out of range read error set error no BPMs no corr. insuff. corr. RM not okay
Allowed	0.020	0.020	mm	
Gain	0.280	0.280		
dl min	0.0000	A		
dl max	0.040	A		
Averaging	10	macropulses		

Status

	Available BPMs	Available corr.
Horizontal	5	2
Vertical	5	2

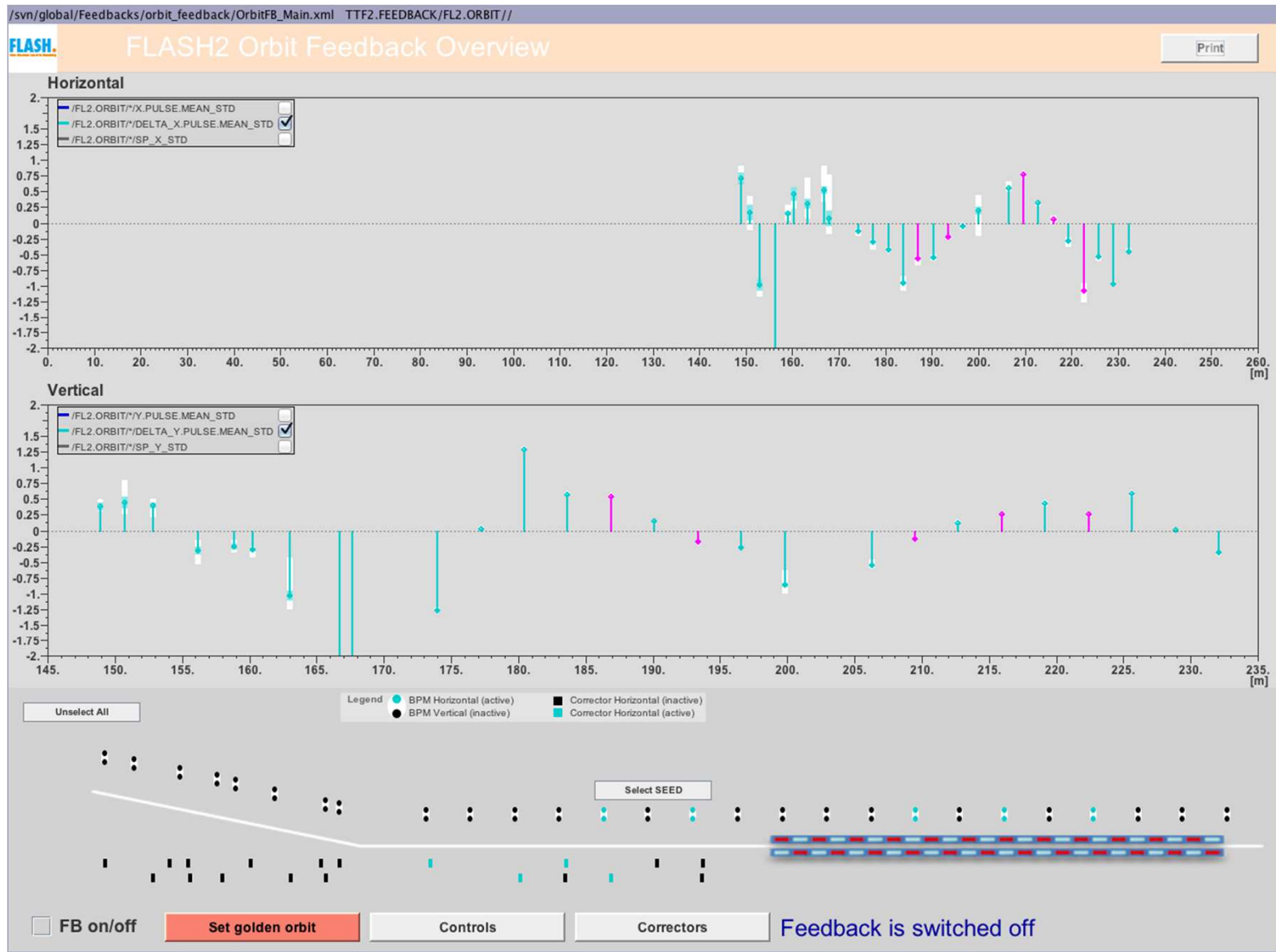
Horiz. correction status
Idle

Vert. correction status
Idle

FB Status
Feedback is switched off



Orbit feedback.



Orbit feedback.

/svn/global/Feedbacks/orbit_feedback/OrbitFB_Expert.xml TTF2.FEEDBACK/FL2.ORBIT//

FLASH. FLASH2 Orbit Feedback Expert Panel Print

FB on/off

Name	X	Y	Status
4FL2EXTR	<input type="checkbox"/>	<input type="checkbox"/>	
5FL2EXTR	<input type="checkbox"/>	<input type="checkbox"/>	
8FL2EXTR	<input type="checkbox"/>	<input type="checkbox"/>	
11FL2EXTR	<input type="checkbox"/>	<input type="checkbox"/>	
13FL2EXTR	<input type="checkbox"/>	<input type="checkbox"/>	
15FL2EXTR	<input type="checkbox"/>	<input type="checkbox"/>	
18FL2EXTR	<input type="checkbox"/>	<input type="checkbox"/>	
21FL2EXTR	<input type="checkbox"/>	<input type="checkbox"/>	
22FL2EXTR	<input type="checkbox"/>	<input type="checkbox"/>	
3FL2SEED1	<input type="checkbox"/>	<input type="checkbox"/>	
3FL2SEED2	<input type="checkbox"/>	<input type="checkbox"/>	
3FL2SEED3	<input type="checkbox"/>	<input type="checkbox"/>	
3FL2SEED4	<input type="checkbox"/>	<input type="checkbox"/>	
3FL2SEED5	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
3FL2SEED6	<input type="checkbox"/>	<input type="checkbox"/>	
3FL2SEED7	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
3FL2SASE3	<input type="checkbox"/>	<input type="checkbox"/>	
3FL2SASE4	<input type="checkbox"/>	<input type="checkbox"/>	
3FL2SASE5	<input type="checkbox"/>	<input type="checkbox"/>	
3FL2SASE6	<input type="checkbox"/>	<input type="checkbox"/>	
3FL2SASE7	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
3FL2SASE8	<input type="checkbox"/>	<input type="checkbox"/>	
3FL2SASE9	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
3FL2SASE10	<input type="checkbox"/>	<input type="checkbox"/>	
3FL2SASE11	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
3FL2SASE12	<input type="checkbox"/>	<input type="checkbox"/>	
3FL2SASE13	<input type="checkbox"/>	<input type="checkbox"/>	
3FL2SASE14	<input type="checkbox"/>	<input type="checkbox"/>	

4FL2EXTR

Horizontal

Enabled SP

Weight

X = -0.843 Std = 0.057

SP = -0.070 Delta = 0.773

Status 0

set error
 read error
 out of range
 orbisvr. nok
 no beam
 DAQ not ok

Vertical

Enabled SP

Weight

Y = 0.131 Std = 0.071

SP = 0.554 Delta = 0.422

Status 0

set error
 read error
 out of range
 orbisvr. nok
 no beam
 DAQ not ok

Common Data

min limit Z position: 148.88

max limit Idx. in RM: 0



Orbit feedback.

/svn/global/Feedbacks/orbit_feedback/OrbitFB_Expert.xml TTF2.FEEDBACK/FL2.ORBIT//

FLASH. FLASH2 Orbit Feedback Expert Panel Print

FB on/off

Set golden orbit

Reset DC

Rollback to DC

Overview

Orbit

Correctors

General Expert inverse RM BPMs **Correctors**

Name/idx		Currents [A]				min		max		Status
H	V	idx	SP	RBV	Initial	Delta				
<input type="checkbox"/>		H2FL2EXTR 0	0.000	0.000	0.000	0.000	-3.50	3.50	calibr.	
<input type="checkbox"/>		H5FL2EXTR 1	0.000	0.000	0.000	0.000	-3.50	3.50	calibr.	
<input type="checkbox"/>		H10FL2EXTR 2	0.094	0.093	0.094	0.000	-3.50	3.50	calibr.	
<input type="checkbox"/>		H11FL2EXTR 3	0.061	0.060	0.061	0.000	-3.50	3.50	calibr.	
<input type="checkbox"/>		H16FL2EXTR 4	0.411	0.410	0.411	0.000	-3.50	3.50	calibr.	
<input type="checkbox"/>		H21FL2EXTR 5	-0.033	-0.032	-0.033	0.000	-3.50	3.50	calibr.	
<input type="checkbox"/>		H22FL2EXTR 6	-0.023	-0.023	-0.023	0.000	-3.50	3.50	calibr.	
<input checked="" type="checkbox"/>		H3FL2SEED1 7	-0.319	-0.182	-0.319	0.000	-3.50	3.50	calibr.	
<input checked="" type="checkbox"/>		H3FL2SEED4 8	-0.270	-0.462	-0.270	0.000	-3.50	3.50	calibr.	
<input type="checkbox"/>		H3FL2SEED6 9	-0.044	-0.025	-0.044	0.000	-3.50	3.50	calibr.	
<input type="checkbox"/>		H3FL2SEED7 10	-0.105	-0.100	-0.105	0.000	-3.50	3.50	calibr.	

Read all

Enabled 2 Avail. 2

H2FL2EXTR calibration

Enabled

Update now

Set DC

Status **ok**

Feedback [A]: RBV 0.000 SP 0.000 DC 0.000 Delta 0.000

Magnet svr. [A]: RBV 0.000 SP 0.000 max 3.50 min -3.50 Weight 1.00

Static Infos: idx in RM 0.00 Z pos.: 148.10

Status: set error read error delta out of rng out of range no beam DAQ not ok inactive

Debug: Logic Timing Extended Correctors BPMs



Orbit feedback.

/svn/global/Feedbacks/orbit_feedback/OrbitFB_Expert.xml TTF2.FEEDBACK/FL2.ORBIT//

FLASH. FLASH2 Orbit Feedback Expert Panel Print

FB on/off

General Expert inverse RM BPMs **Correctors**

Name/idx		Currents [A]				min		max		Status
H	V	idx	SP	RBV	Initial	Delta				
<input type="checkbox"/>		V3FL2EXTR 0	0.000	0.000	0.000	0.000	-3.50	3.50	calibr.	<input type="checkbox"/>
<input type="checkbox"/>		V9FL2EXTR 1	0.046	0.045	0.046	0.000	-3.50	3.50	calibr.	<input type="checkbox"/>
<input type="checkbox"/>		V11FL2EXTR 2	0.037	0.036	0.037	0.000	-3.50	3.50	calibr.	<input type="checkbox"/>
<input type="checkbox"/>		V14FL2EXTR 3	0.070	0.069	0.070	0.000	-3.50	3.50	calibr.	<input type="checkbox"/>
<input type="checkbox"/>		V19FL2EXTR 4	-0.125	-0.124	-0.125	0.000	-3.50	3.50	calibr.	<input type="checkbox"/>
<input type="checkbox"/>		V21FL2EXTR 5	0.030	0.029	0.030	0.000	-3.50	3.50	calibr.	<input type="checkbox"/>
<input checked="" type="checkbox"/>		V3FL2SEED3 6	-0.157	0.558	-0.157	0.000	-3.50	3.50	calibr.	<input type="checkbox"/>
<input type="checkbox"/>		V3FL2SEED4 7	-0.186	-0.187	-0.186	0.000	-3.50	3.50	calibr.	<input type="checkbox"/>
<input checked="" type="checkbox"/>		V3FL2SEED5 8	-0.033	-0.208	-0.033	0.000	-3.50	3.50	calibr.	<input type="checkbox"/>
<input type="checkbox"/>		V3FL2SEED7 9	0.231	0.232	0.231	0.000	-3.50	3.50	calibr.	<input type="checkbox"/>

Enabled 2 Avail. 2 Read all

H2FL2EXTR calibration

Enabled
 Update now
 Set DC

Feedback [A] :	RBV 0.000	SP 0.000	DC 0.000	Delta 0.000
Magnet svr. [A] :	RBV 0.000	SP 0.000	max 3.50	min -3.50
	Weight 1.00			

Static Infos: Idx in RM 0.00, Z pos.: 148.10

Status:
 set error
 read error
 delta out of rng
 out of range
 no beam
 DAQ not ok
 inactive

Debug:
 Logic
 Timing
 Extended
 Correctors
 BPMs

Status **ok**



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.

Property	Value
Set wavelength	24.0 nm / 51.7 eV
Energy	1.2 μJ
Bunch RepRate	1003 kHz
Bunches per Train	1
Bunch charge	0.00 nC

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

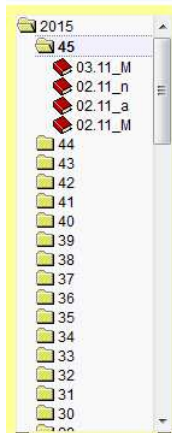


Commissioning/Setup.

FLASH.

Free-Electron Laser FLASH

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



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: ttflag

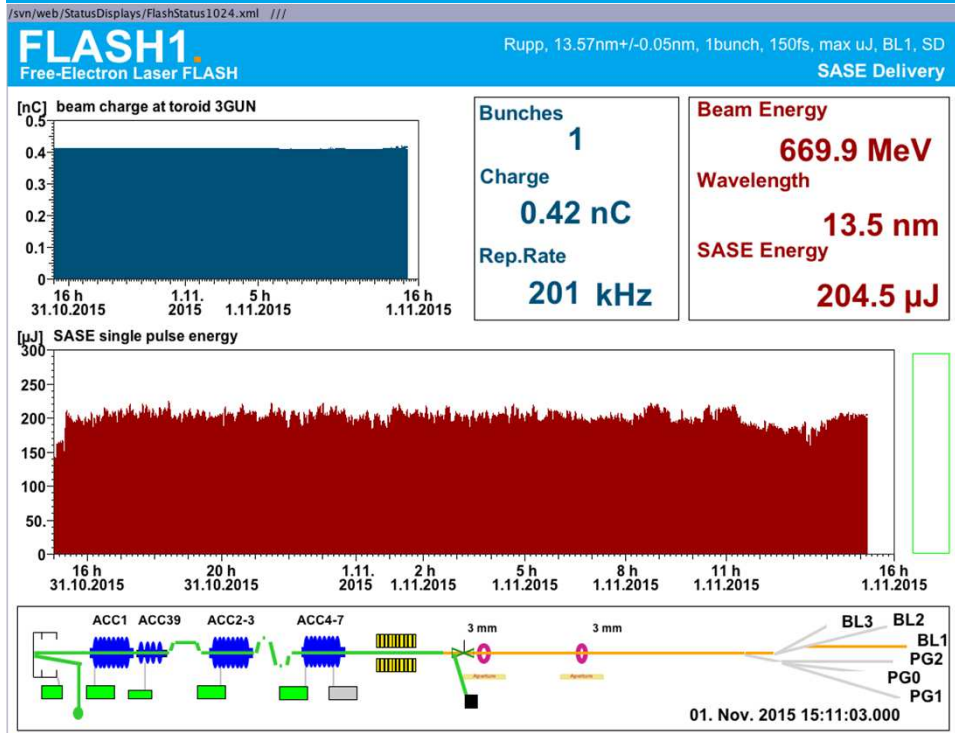


- 7h-15h
 - FLASH1: Maintenance/ 5h, Machine Setup (use settings from Feldhaus/Dziarzhytski experiment) / 3h
 - FLASH2: Simultaneous Operation
 - 15h-23h
 - FLASH1: SASE tuning (~9.9 nm, use settings from Feldhaus/Dziarzhytski experiment)/ 4h, Statistical analysis and optimization of FEL performance ~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 between FL1/FL2 in Septum Area
 - FLASH2: Compensation of Steerer Crosstalk between 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).



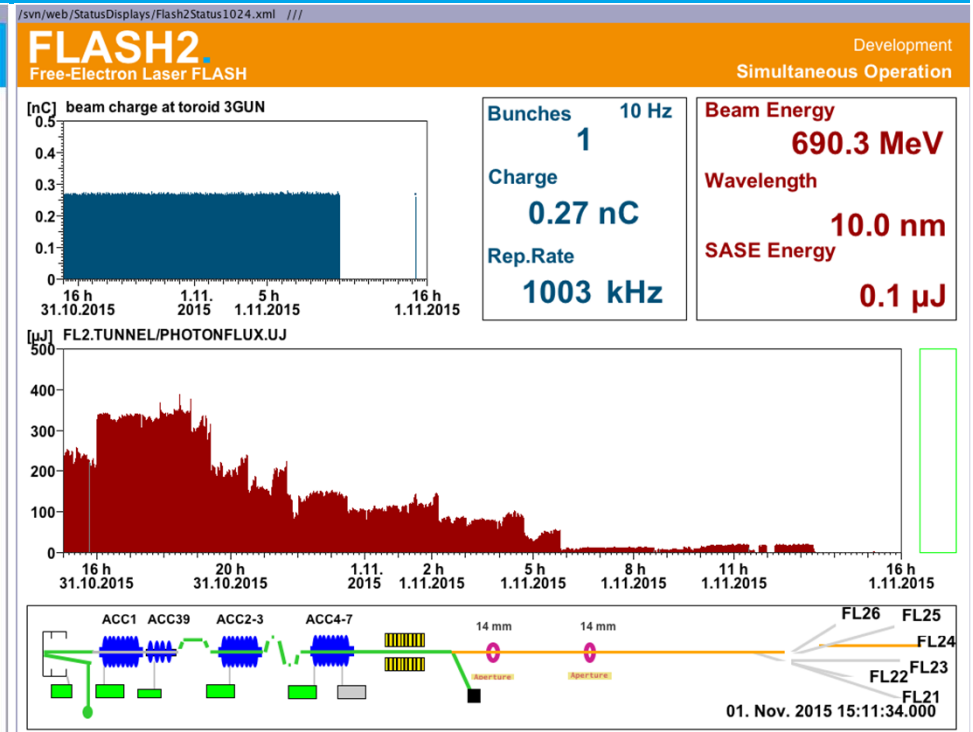
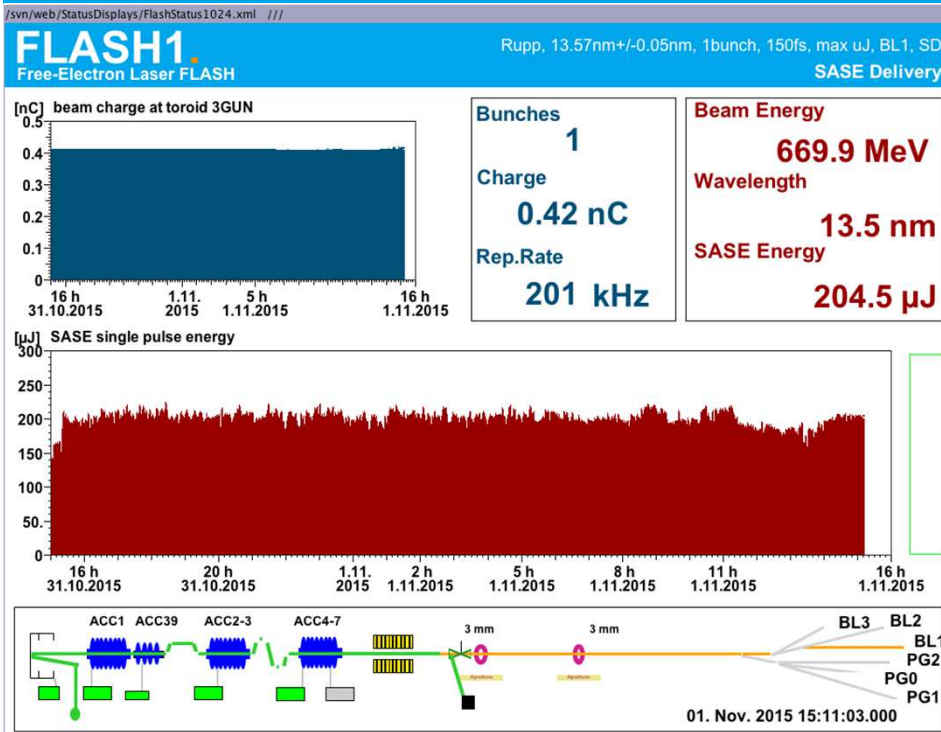
Tunability.



FLASH1: 13.57 nm for users



Tunability.



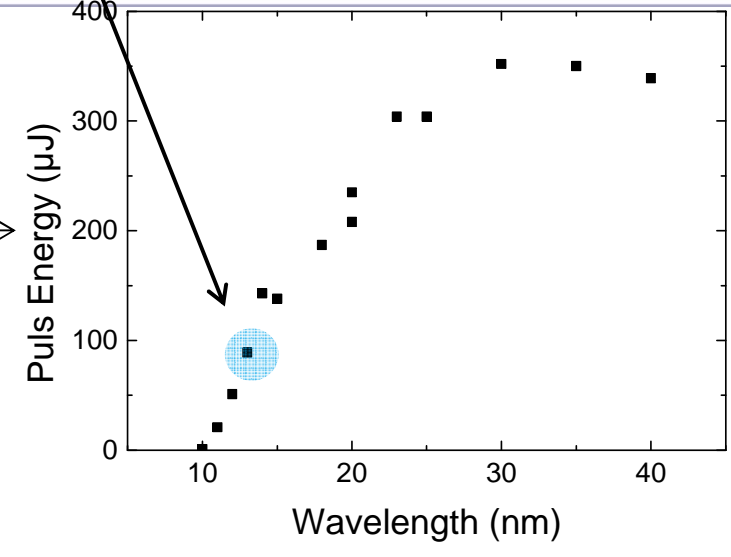
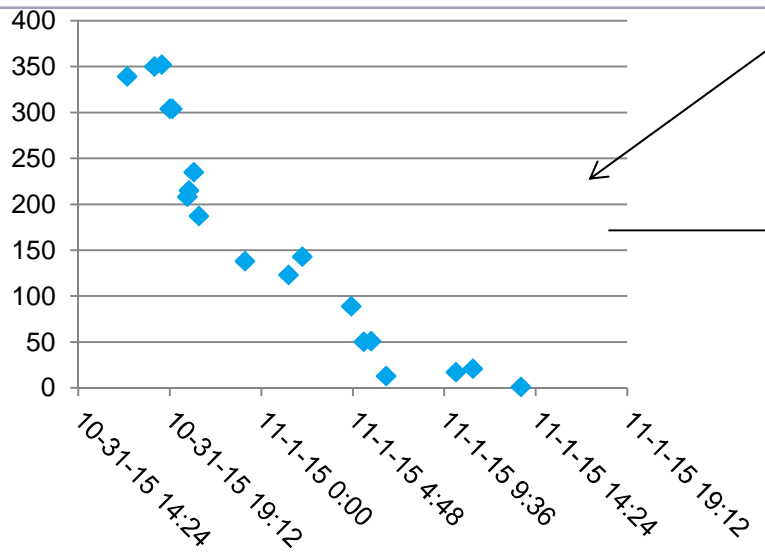
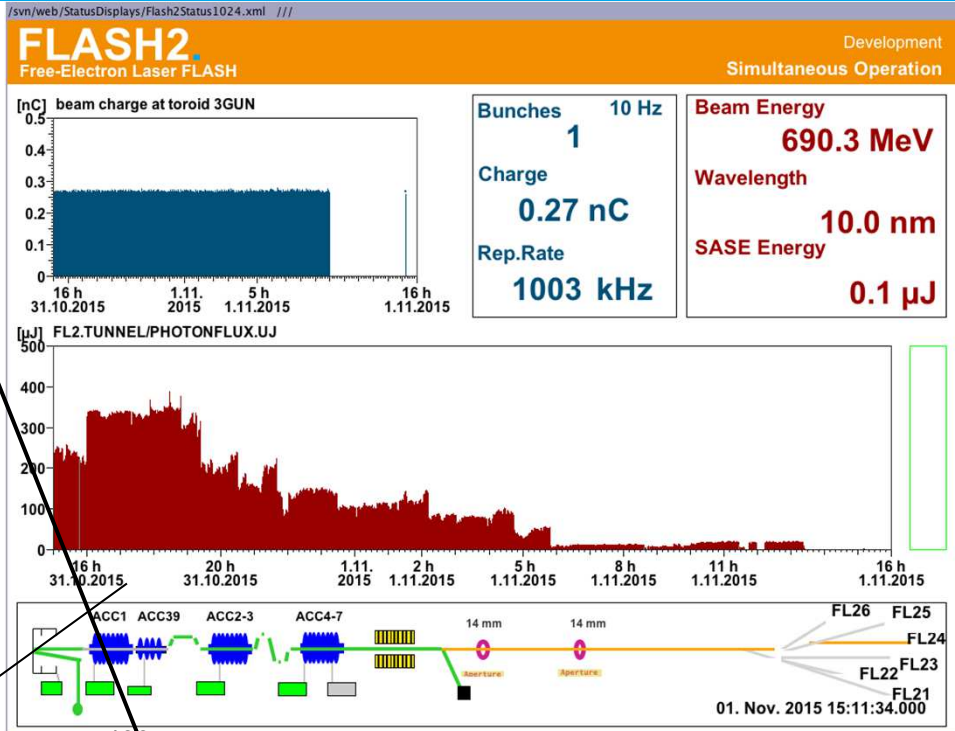
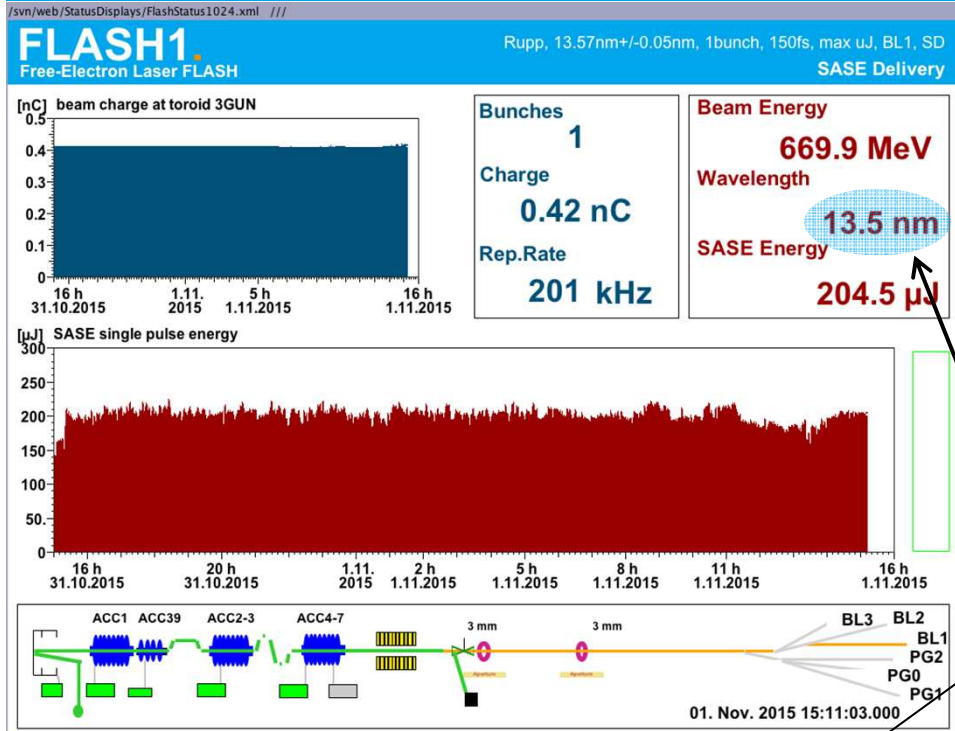
FLASH1: 13.57 nm for users

FLASH2: large variation in intensity from 350 to 1 μJ



Tunability.

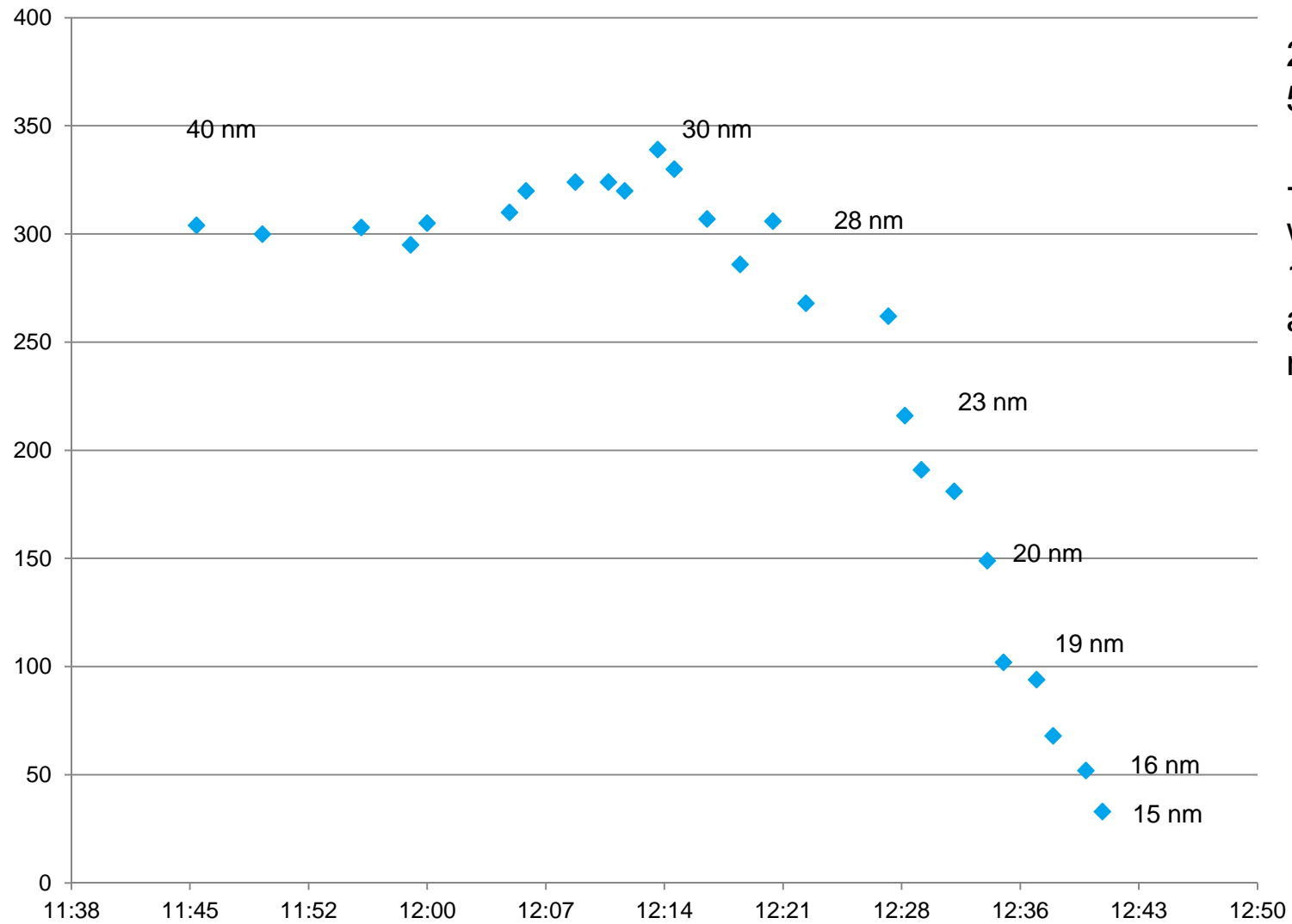
FLASH1: 13.57 nm for users
 FLASH2: Wavelength scan from 40 to 10 nm



Fast Tunability.

FLASH1: 13.57 nm for users

FLASH2: Wavelength scan from 40 to 10 nm



26 wavelength in
55 minutes

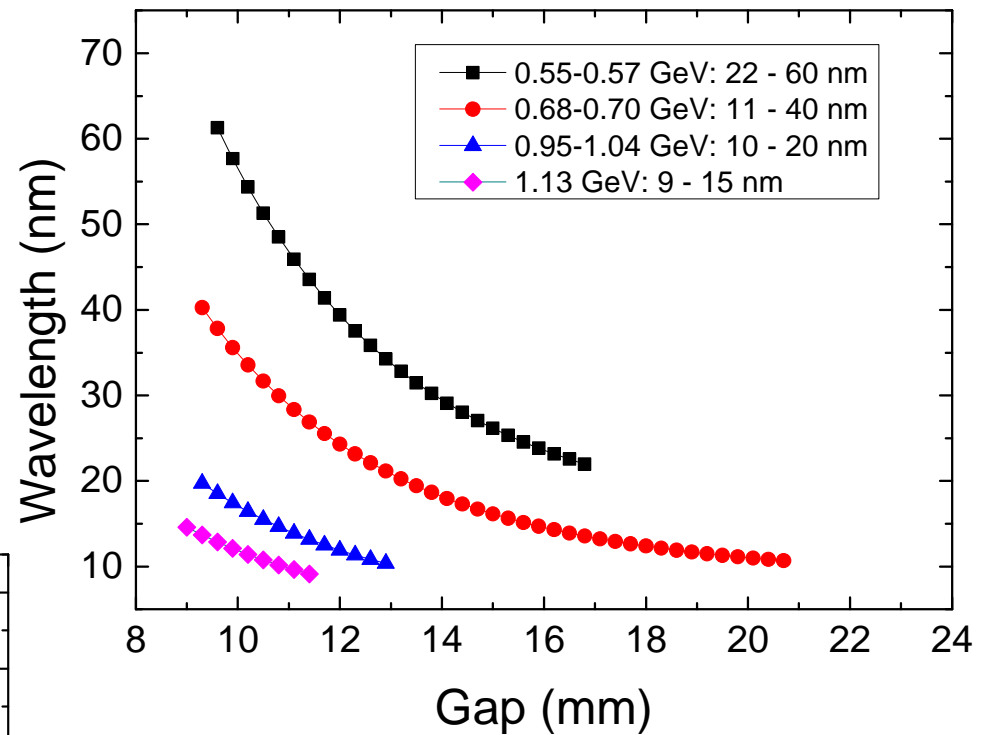
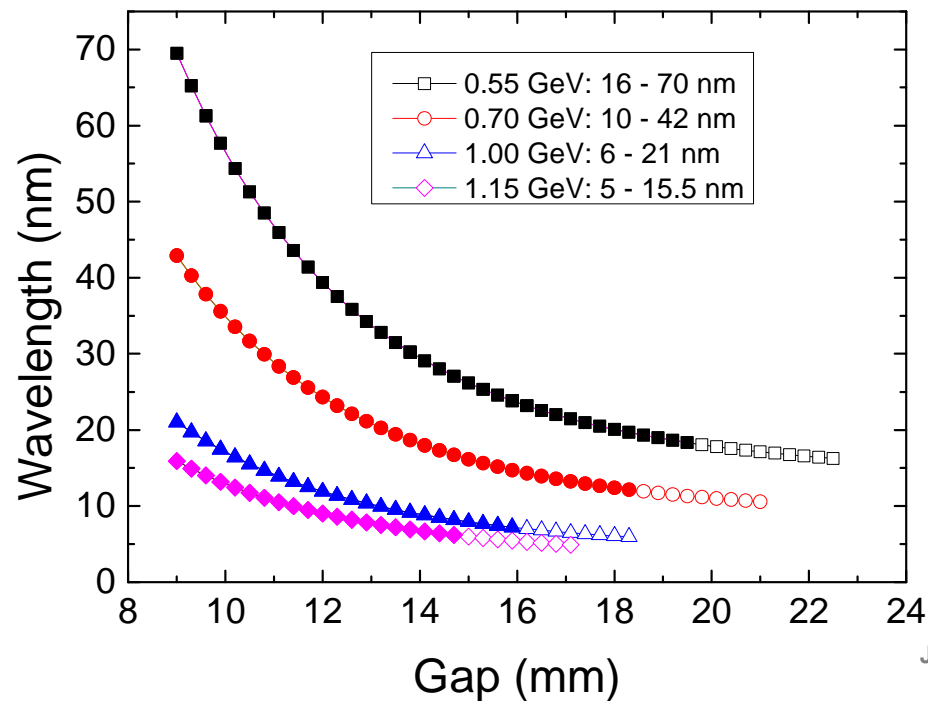
-> change
wavelength in a
1nm step took in
average 2
minutes

Wavelengths reached.

Complete wavelength ranges have been covered:

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

Open symbols for 2.5 kA
Filled symbols for 1.5 kA

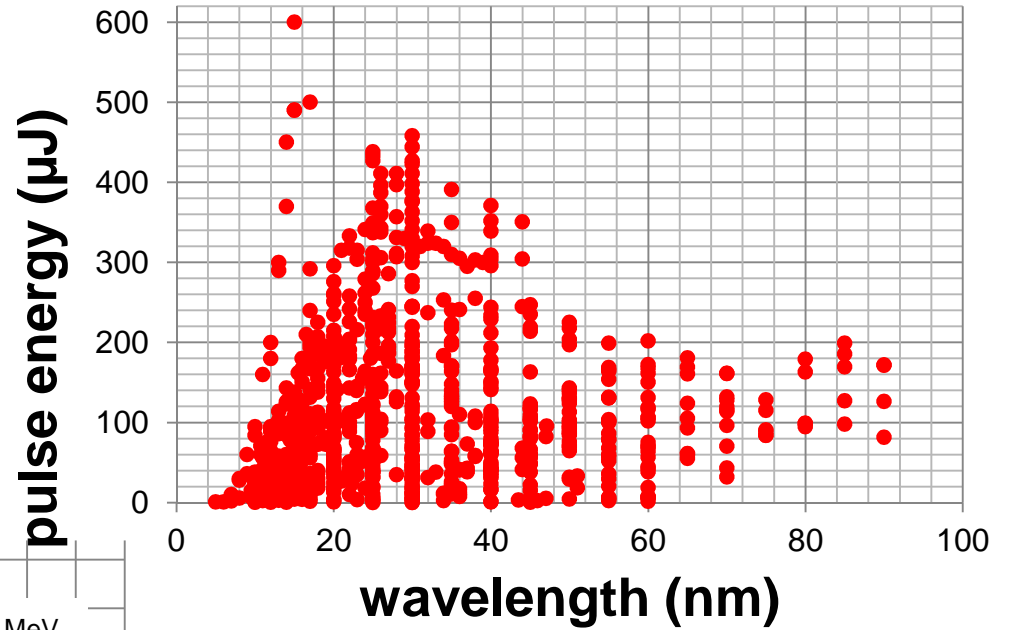
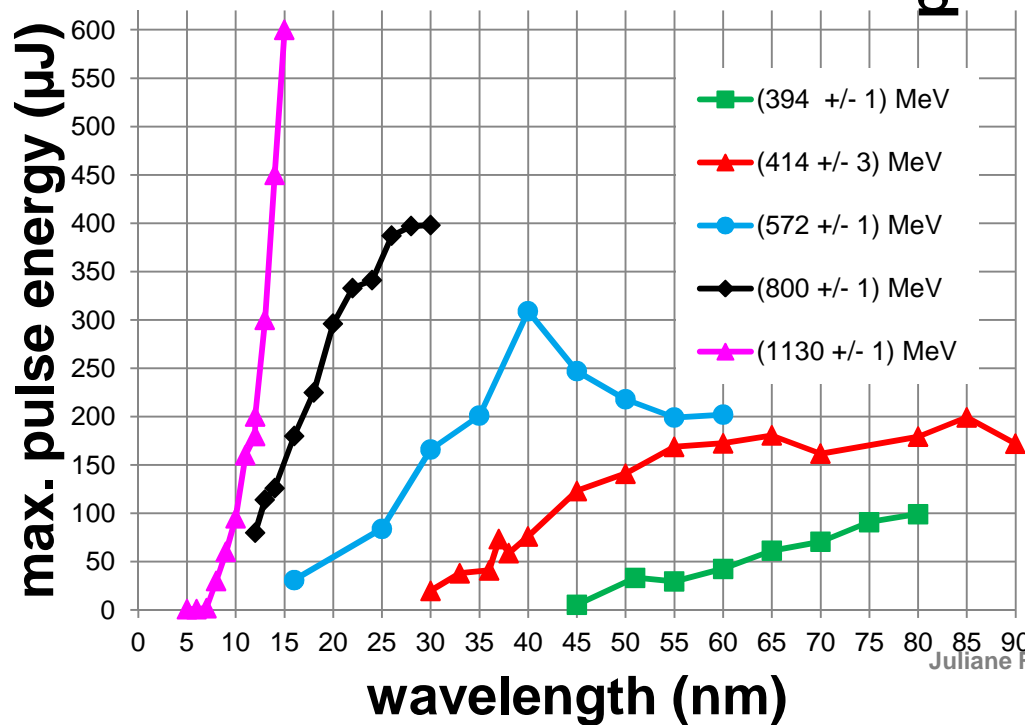


Wavelengths reached with $>50 \mu\text{J}$



Wavelength reached at FLASH 2

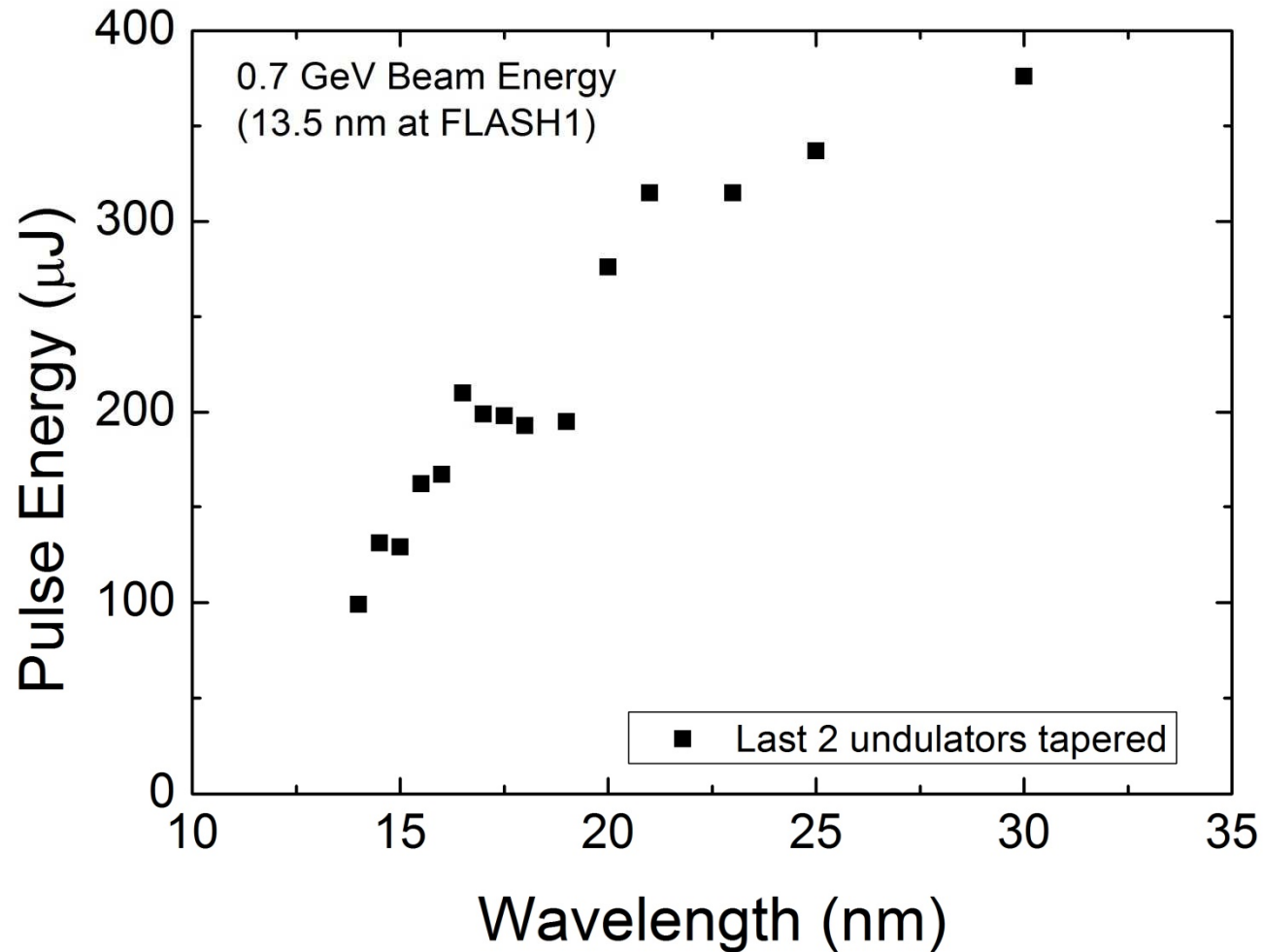
This includes measurements of experts as well as from the shift crew



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



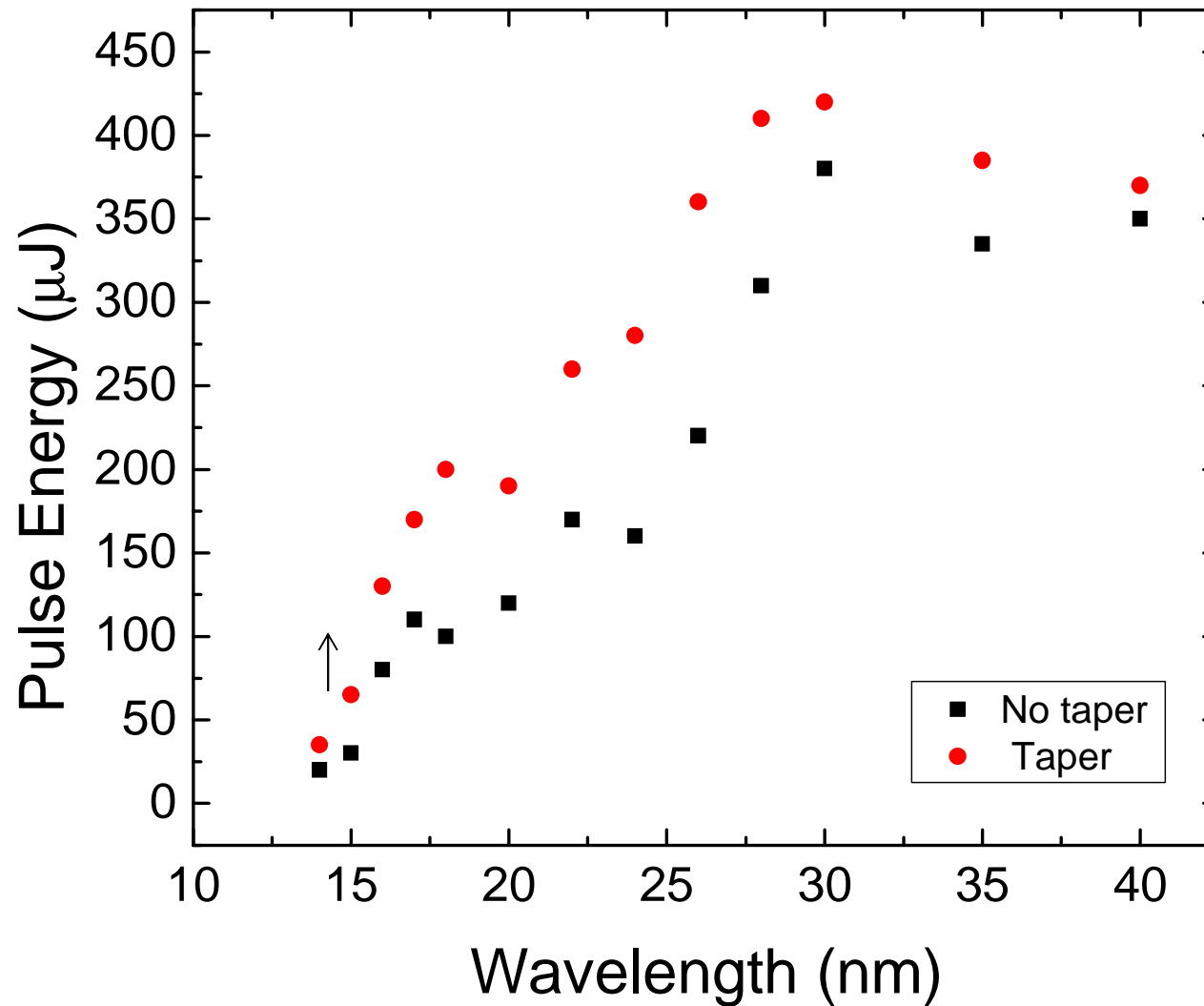
Tunability: study by expert(s).



For same shift we have:

- Pointing
- Divergence
- Spectra with OPIS and grating spectrometer

Tunability: setup by operators.

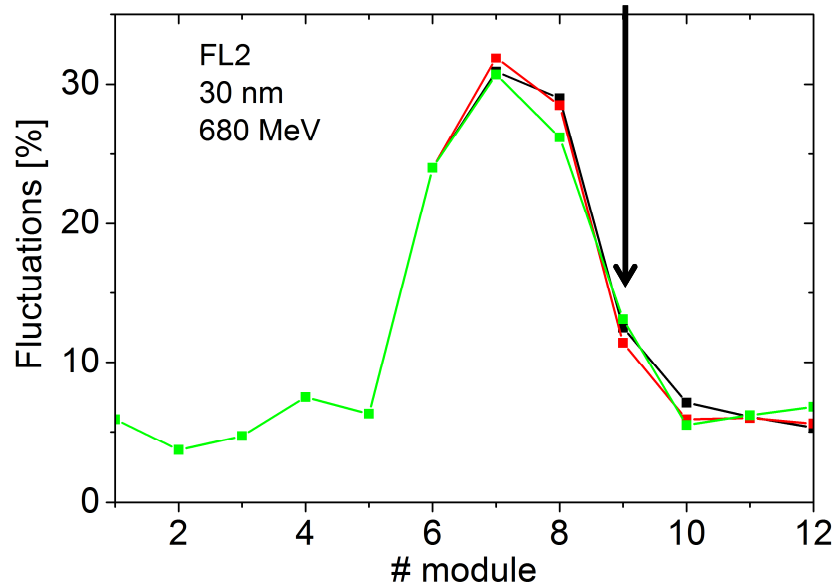
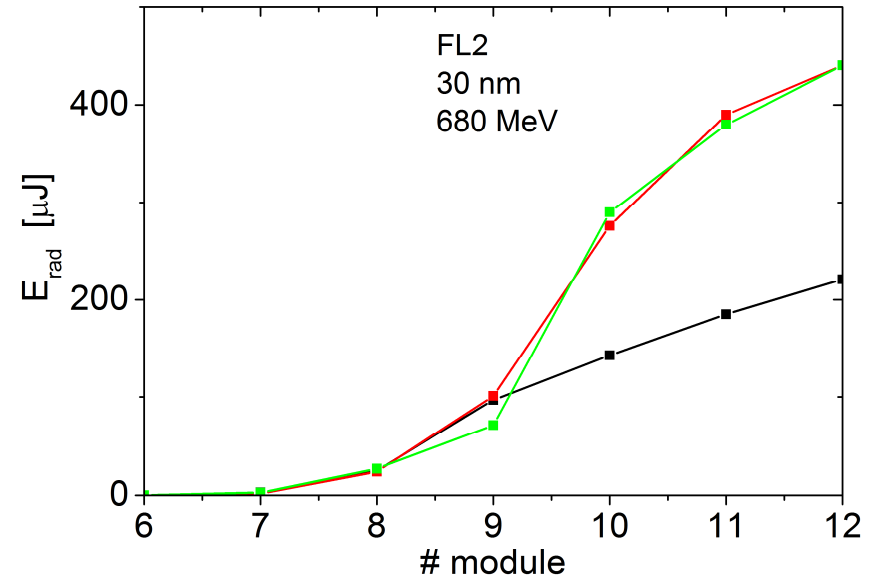
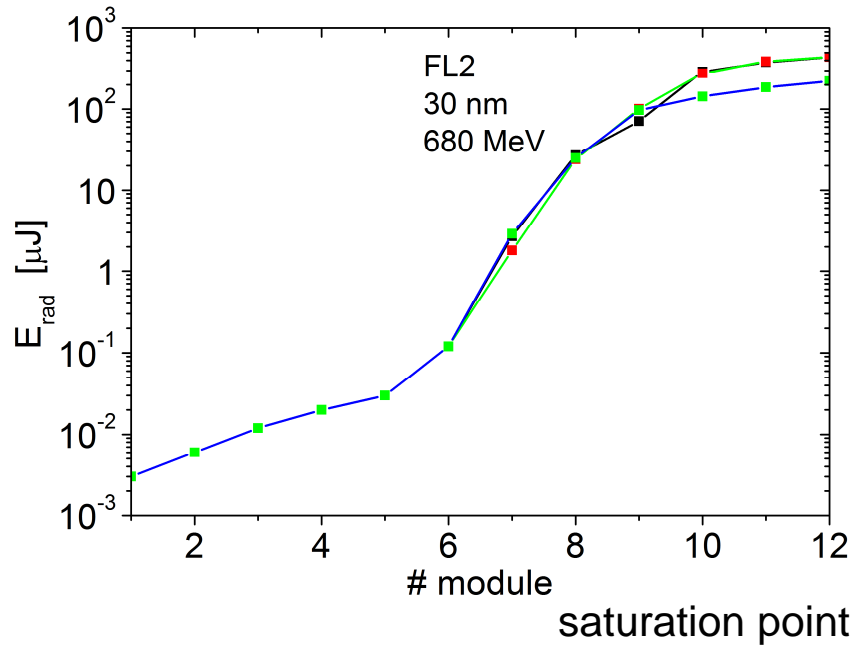


Comparison taper/no taper

At short wavelength,
optimization is needed.



Tapering of undulators.



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

Linear tapering: 440 μJ

Quadratic tapering: 440 μJ

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



Continued commissioning

- Further education of operators.
- Commissioning of photon diagnostics (see M. Kuhlmanns talk).
- Commissioning of CRISP5 (right now there 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

