HELMHOLTZ ZENTRUM BERLIN für Materialien und Energie

FLASH II Tests

DESY

1. **Layout/Parameters.**
2. **Status.**
3. **Main Goals.**
4. **Tests needed.**
5. **First Results.**

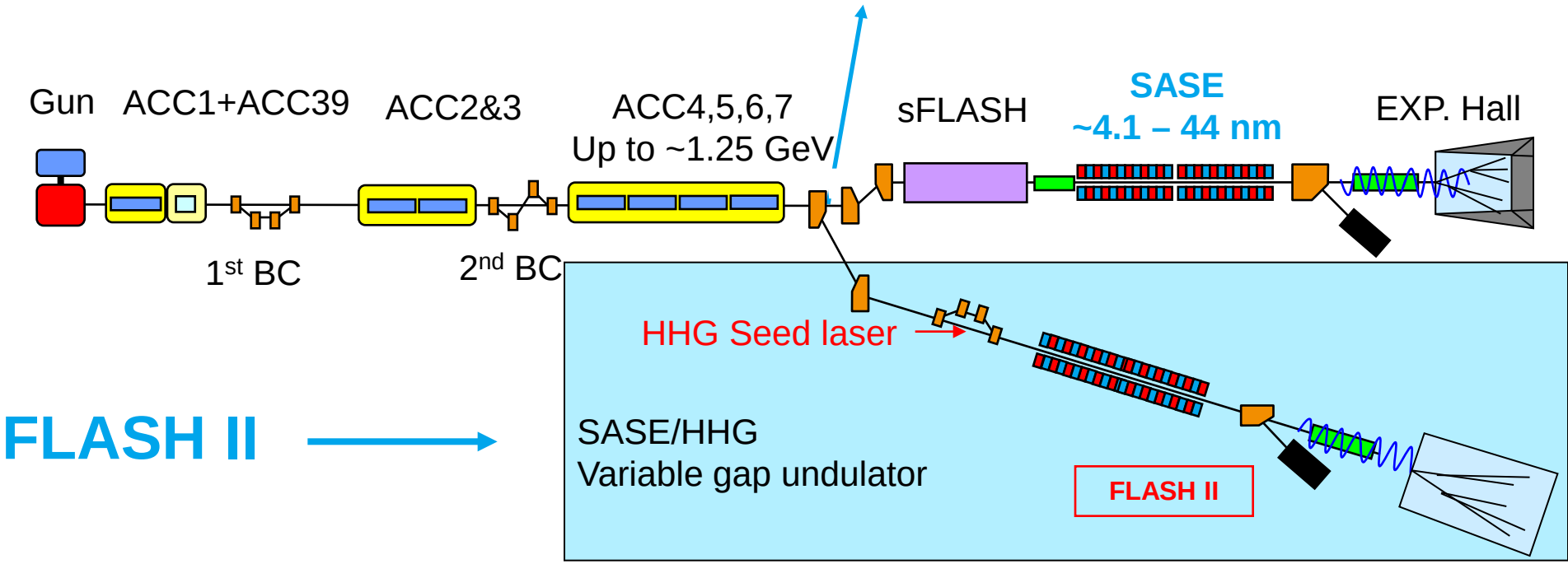
Tests performed by: S. Ackermann, V. Ayvazyan, W. Decking, C. Gruen, K. Klose, F. Obier, S. Pfeiffer , M. Scholz, M. Vogt, J. Wortmann and many others from MSK, MCS4, MPY, MIN, ….

HELMHOLTZ | ASSOCIATION

Bart Faatz
FLASH II
Hamburg, April 17, 2012

Upgrade: layout after upgrade FLASH II.

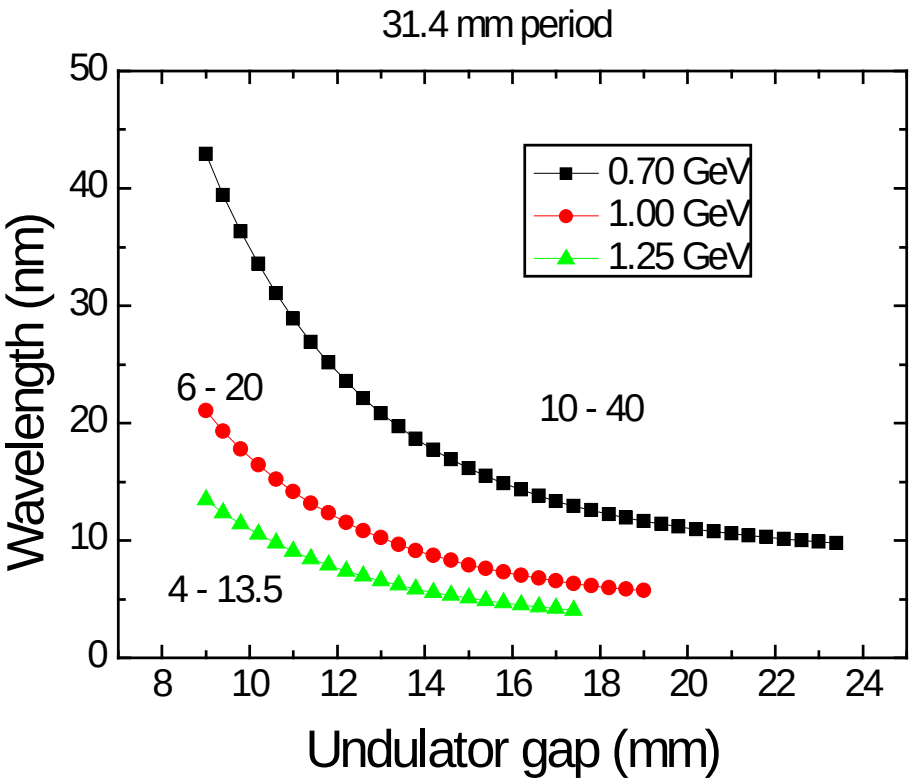
- Separation FLASH and FLASH II behind last accelerator module
- Tunability of FLASH II by undulator gap change
- Extend user capacity with SASE and HHG seeding
- Use of existing infrastructure up to last accelerating module



FLASH II: Electron beam parameters.

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

Wavelength range for main energies by varyang the undulator gap

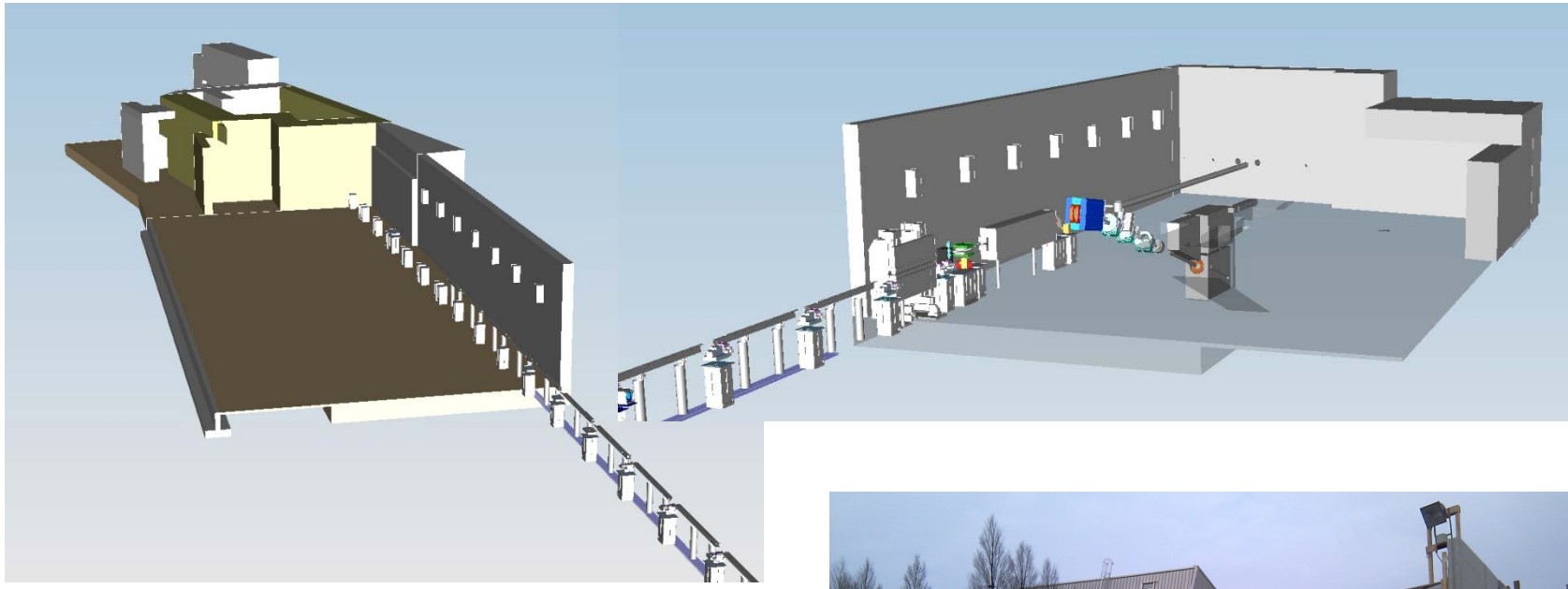


Energy (GeV)	31.4 mm
0.7	10 – 40
1.0	6 – 20
1.25	4 – 13.5

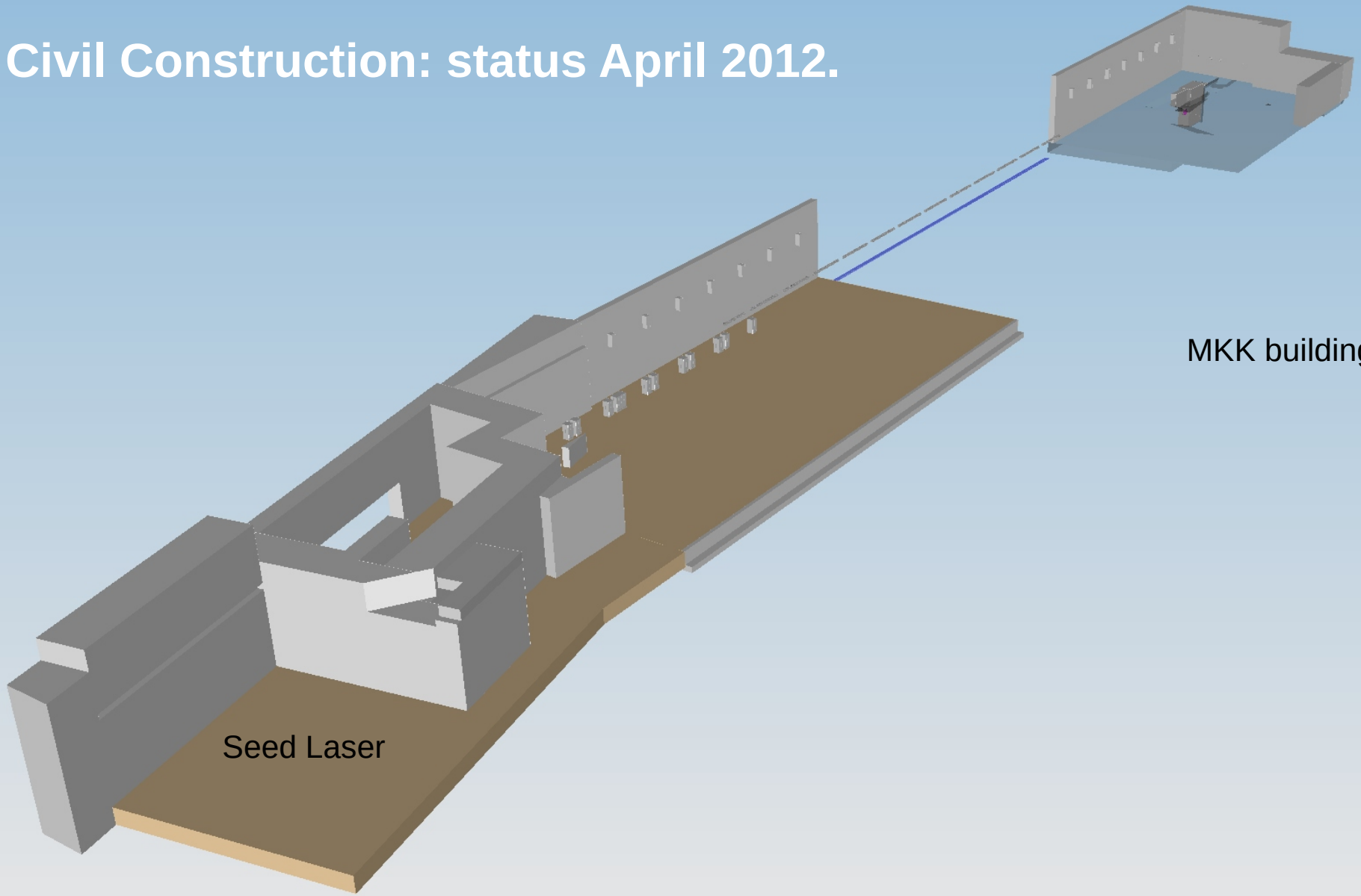
NOTE: proposal for FLASH I upgrade is 23 mm period!!!!!

10-40 nm at 0.7 GeV with HHG seeding
>40 nm with energies below 0.7 GeV

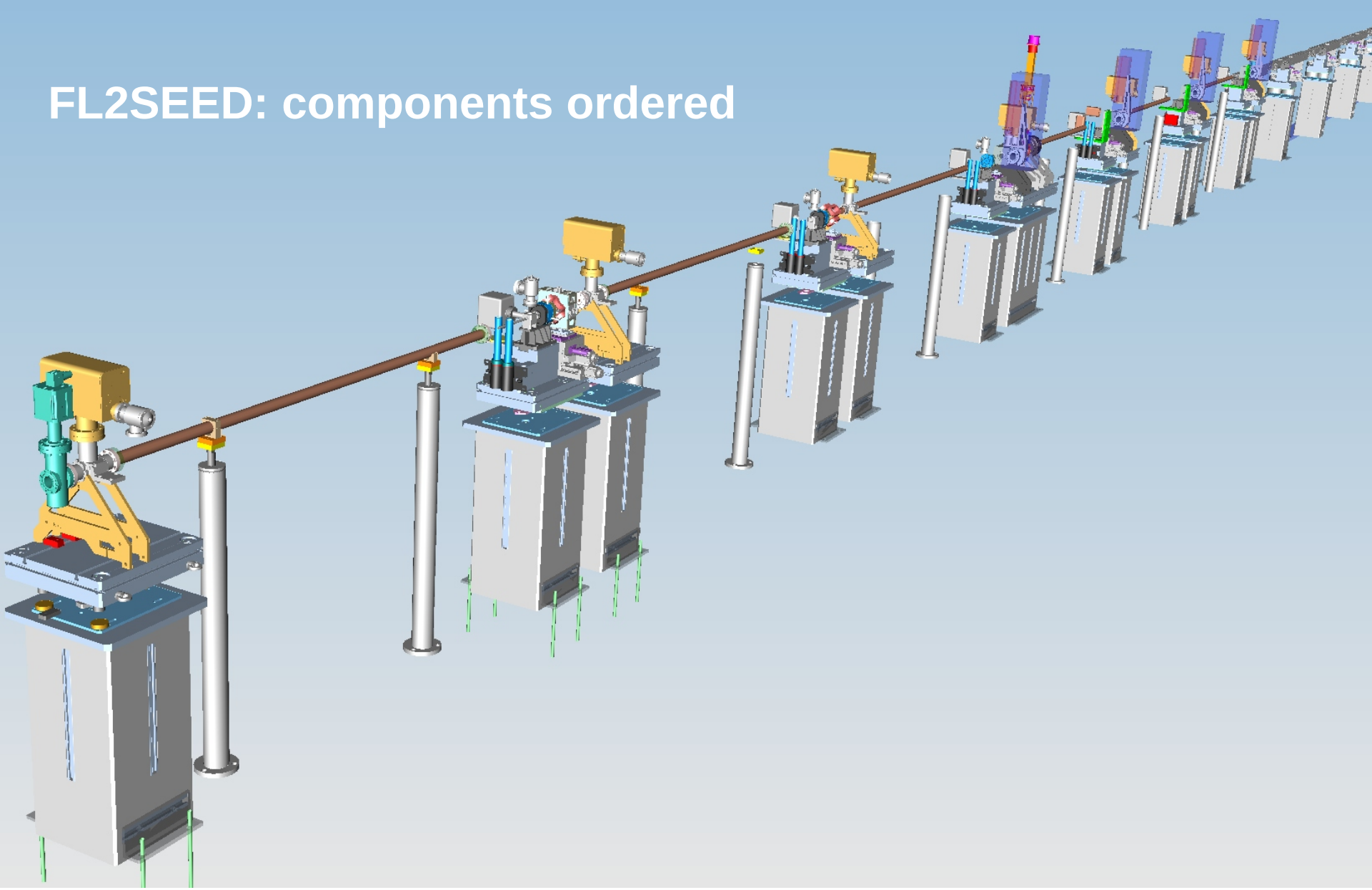
Civil Construction.



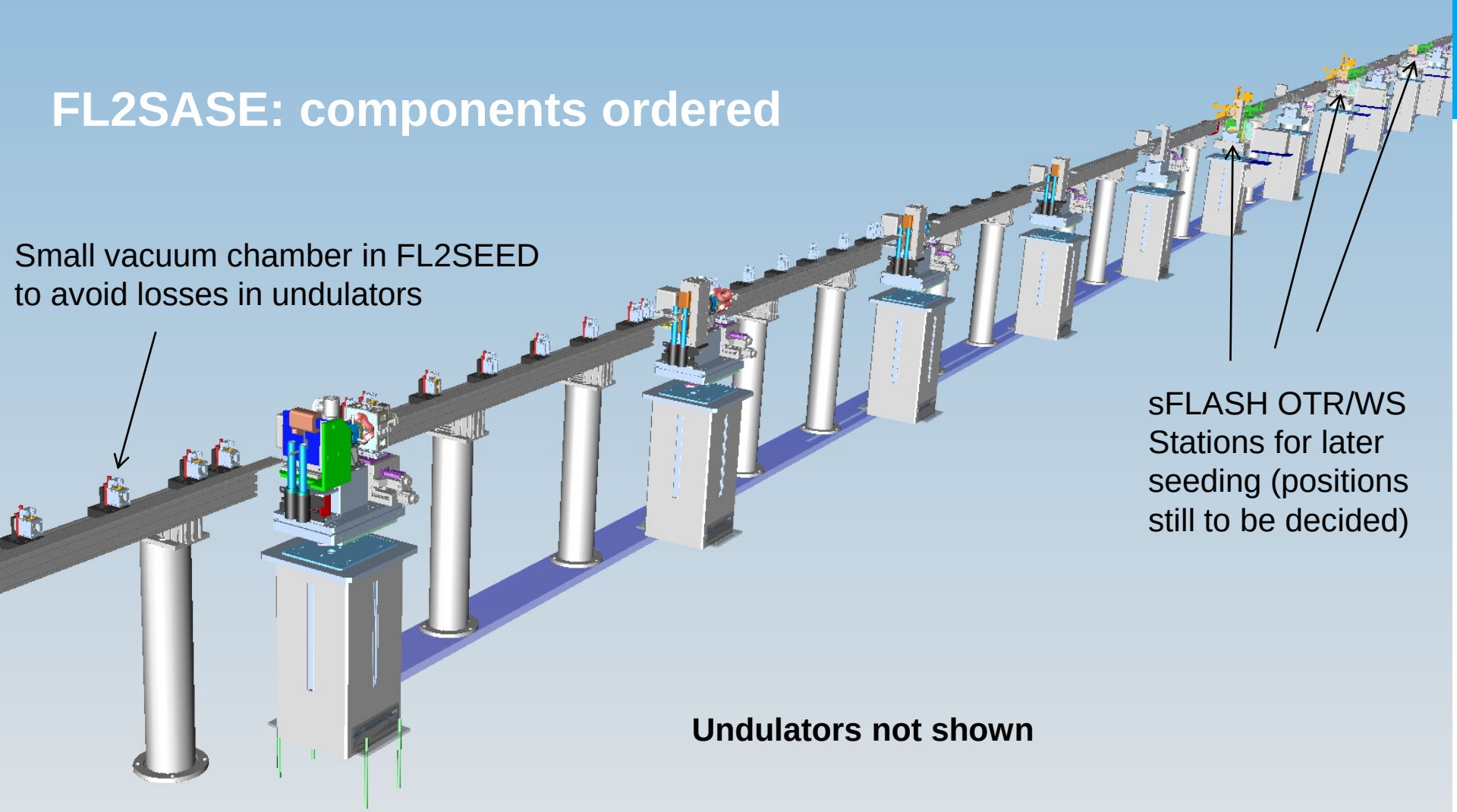
Civil Construction: status April 2012.



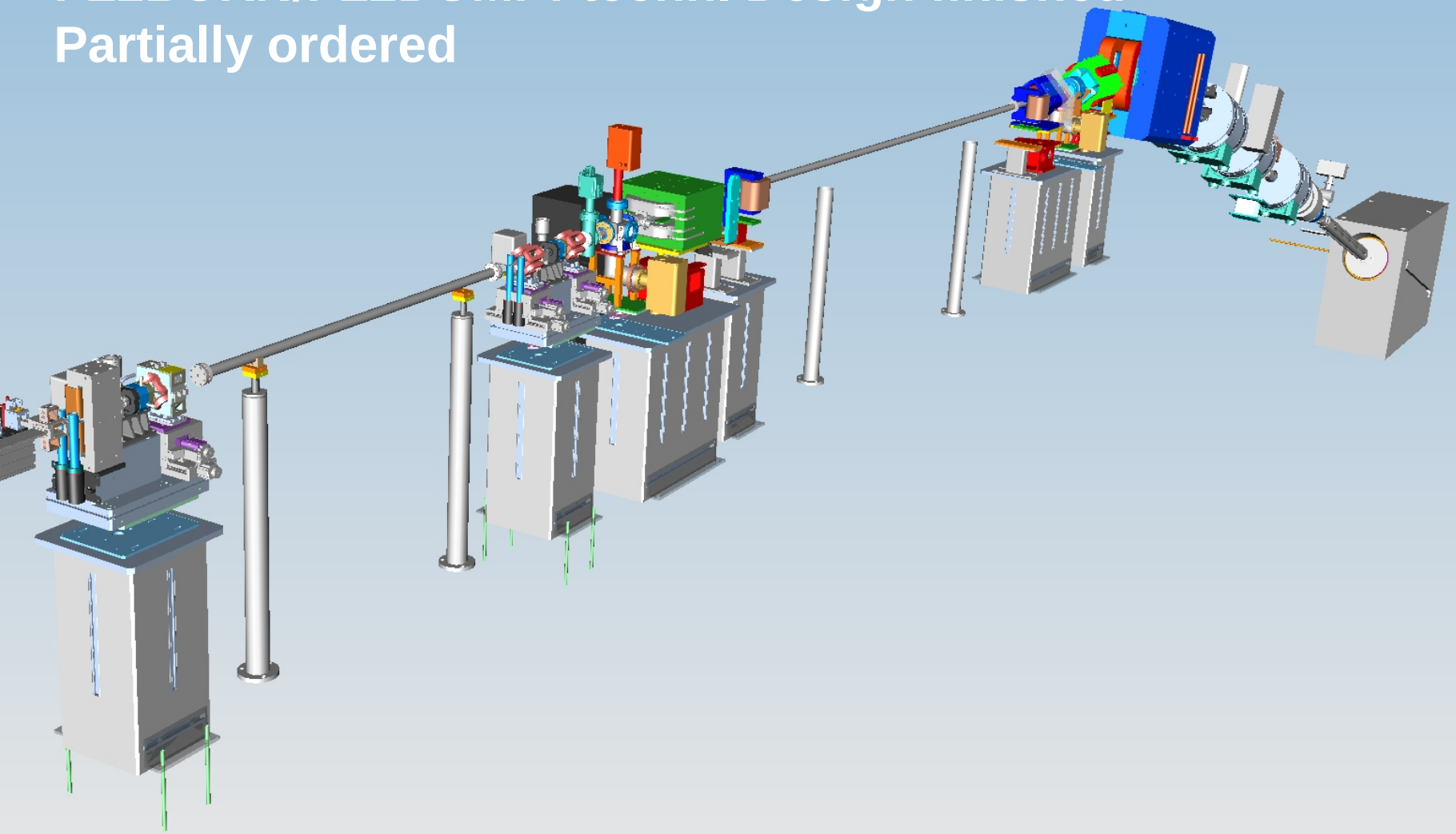
FL2SEED: components ordered



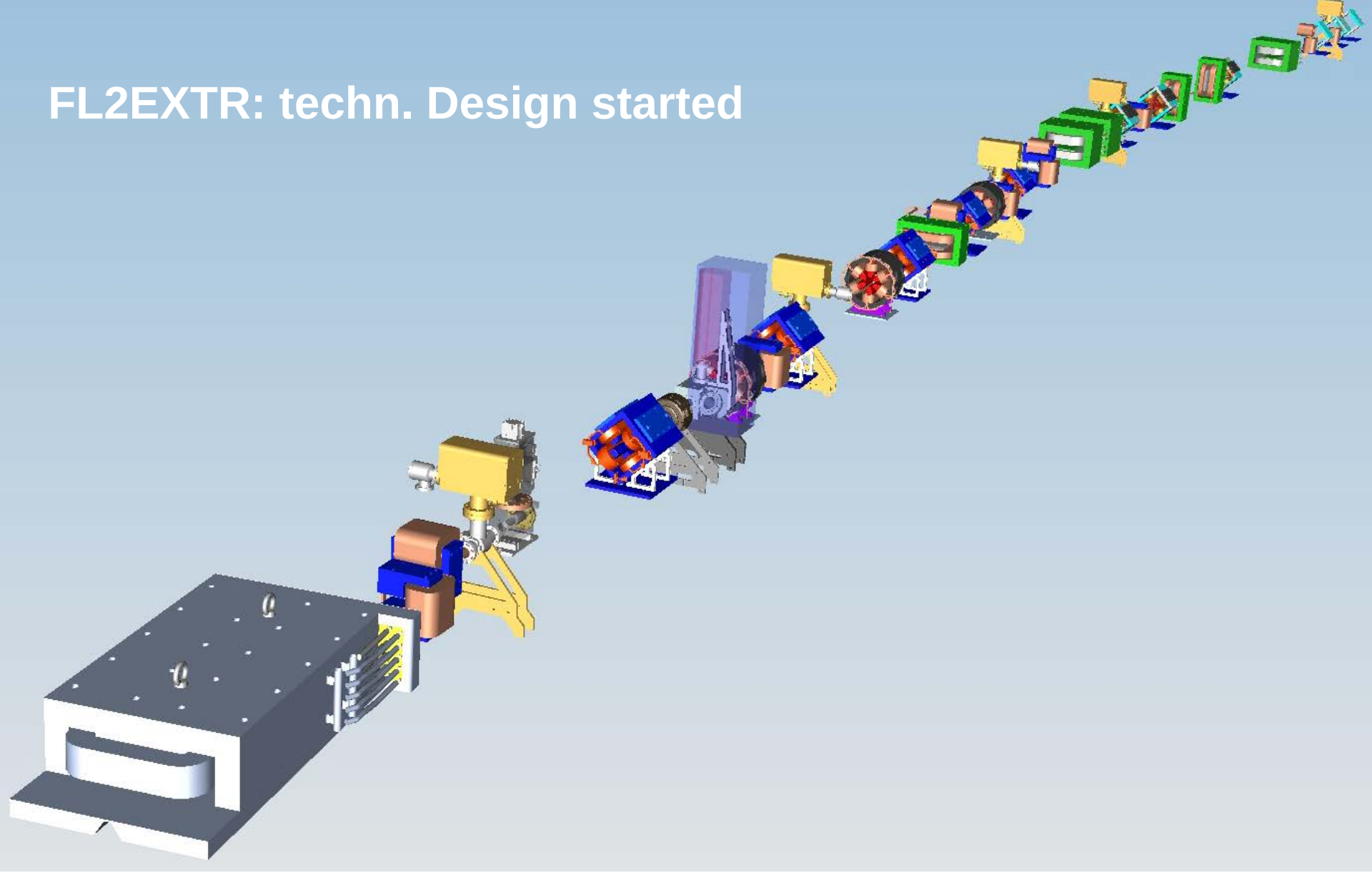
FL2SASE: components ordered



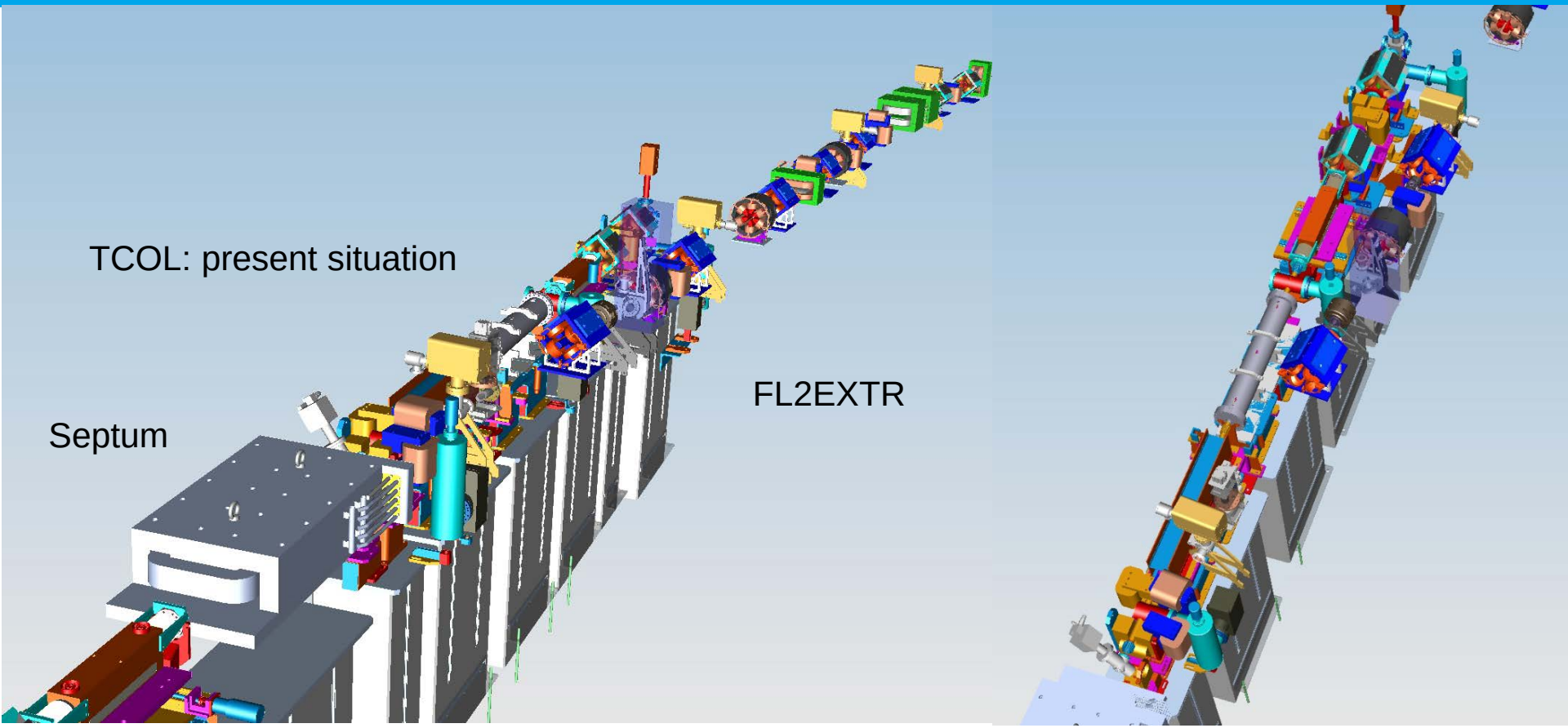
FL2BURN/FL2DUMP: techn. Design finished
Partially ordered



FL2EXTR: techn. Design started



FL2EXTR with TCOL



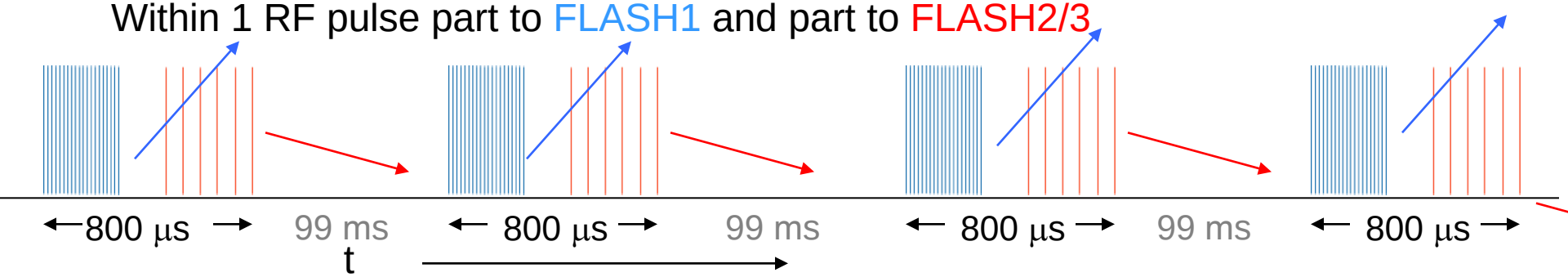
New design ACC7 and TCOL needed
At least one of the kickers in TCOL needs to be removed

Lasing of FLASH1 and FLASH2/3 Simultaneously

- No reduction in beamtime → no reduction from 10 to 5 Hz
  - Fast switching needed
- Possibility of Long pulse trains for both
  - Long flat top kicker
  - Change kicker start/end time and duration
- Different bunch length → different charges
  - Two lasers needed
  - Small changes in RF settings for compression
  - Different laser iris/BSA?
- Small wavelength scan for FLASH1 (fixed gap) → energy change
  - Small changes in RF settings (how far can we go)

Beamline switching (FLASH1 and 2/3).

Within 1 RF pulse part to FLASH1 and part to FLASH2/3



Requirements:

- Pulser/Kicker
  - Stability to avoid orbit jitter.
  - Flatness for long pulse trains.
  - Rise or Fall time of <50 μs.
  - Switch length and starting point variable.
  - 1st part or 2nd to FLASH2 depends on need of BAM FB without interference of “background” bunches
- Laser(s)
  - Different repetition rates and charges.
  - Switching to gun in <50 μs at different start time (related to kicker).
- LLRF
  - Different beam loading FLASH1 and 2/3.
  - Tunability of gradient or ACC45 and ACC67 for wavelength scans FLASH1.
  - Tunability in phases of Gun, ACC1, ACC39 and ACC23 for variation in compression FLASH1, 2 and 3.

Simultaneous Operation

2011: Tests with ONLY FLASH1, single laser
2012: Tests with only FLASH1, two lasers (starting in summer)
2013: Full tests starting in June (?)

2011/2012

- Check stability of kicker.
- Check flatness of kicker.
- Check steepness of leading and trailing edge (BAM FB with kicked bunches).
- Check charge range for lasing with short/long bunches.
- Check possibility of small RF phase/amplitude changes within RF pulse.
- Check possibility of small RF phase/amplitude changes from RF pulse to RF pulse.
- Check Energy range for lasing without touching “common” optics.

2012 with 2 lasers

- Check simultaneous lasing with different charges and rep.rates.

NOT Tested

Exception handling BIS switching off Beam FLASH1 or FLASH2.
Limits of short/long pulse trains.
…..

Delivering SASE at 10 Hz to FLASH1 and FLASH2

Offering BAM FB without disturbing un-stabilized bunches

→ Either 1st or 2nd part of bunch train to FLASH1, depending on which user needs stabilized conditions

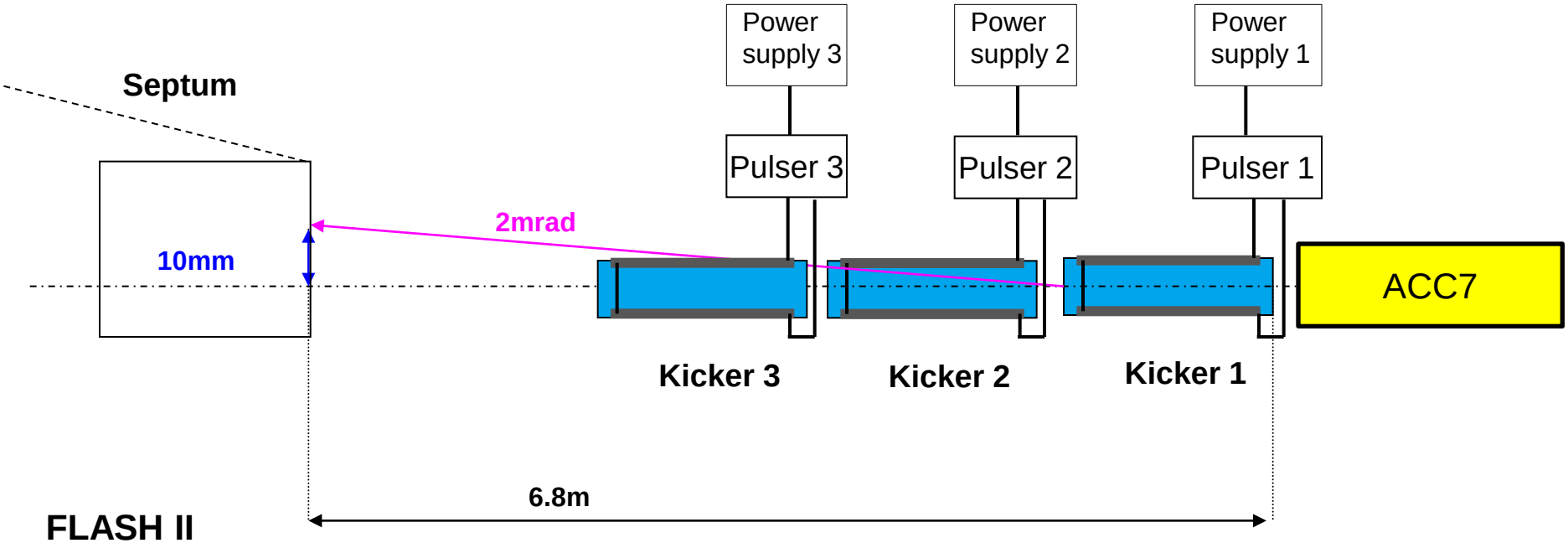
→ Both leading and trailing edge of kicker pulse need to be short

Kicker tests: Specification

	FLASH II
Pulse frequency	10 Hz
Pulse length	1ms
Pulse form	rectangle
Rise time	40µs
Fall time	20µs
Max. pulse voltages	0-250 V
Max. pulse current	0-400 A
Amplitude stability	< $3*10^{-4}$ or 0.6µrad
Energy	1.2 GeV
Kick angle	2 mrad
Kicker active length	600 mm
Number of Kicker	3

From F. Obier, 9 mA meeting

Kicker tests: Principle layout of beam distribution

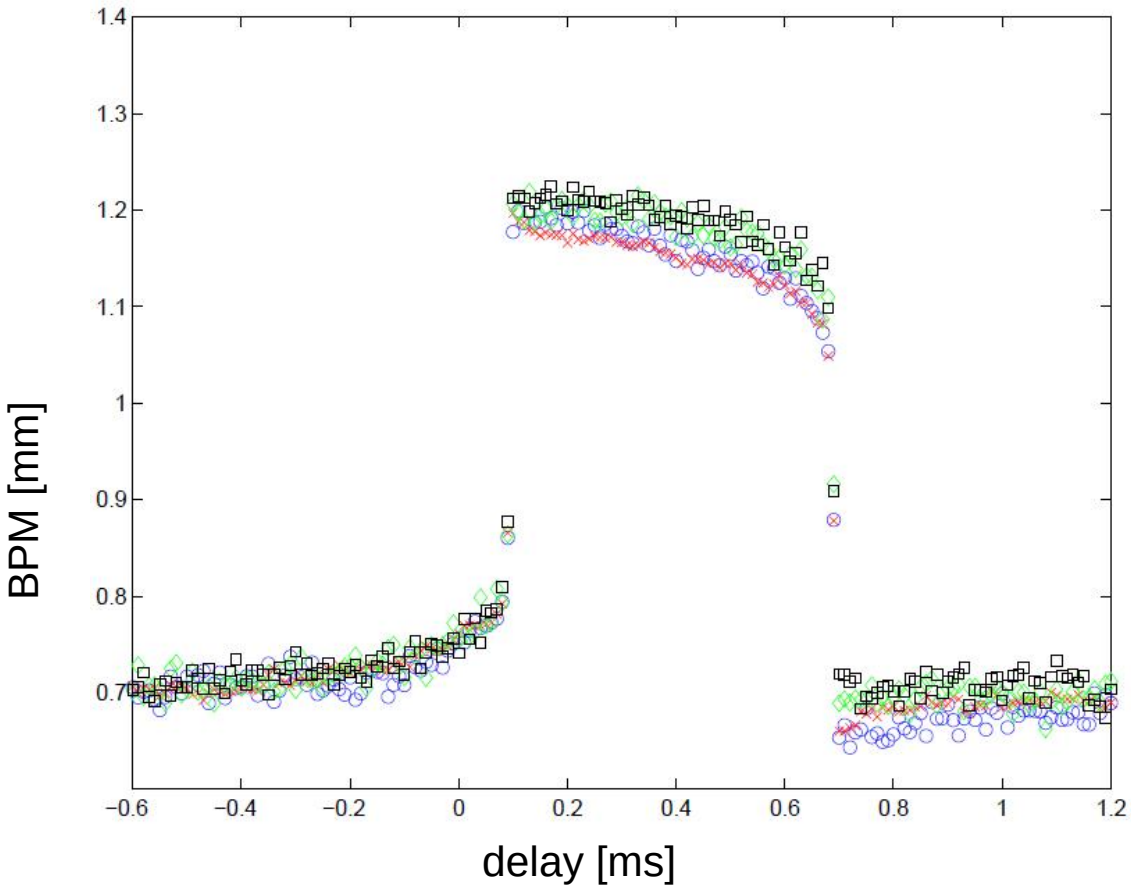


FLASH II

E_{max} = 450MeV - 1,6GeV
f = 10Hz
$t_{lücke}$ = 10-50µs
t_{puls} = 0-1000µs
$L_{Ceramic}$ = 0.7m (flange to flange)
$D_{Ceramic}$ = 38mm (inside) 46mm (outside)
L_{Kicker} = 0,6m
Stability = $3*10^{-4}$ or 0.6µrad

From F. Obier, 9 mA meeting

Kicker tests: Result of scan at FLASH



Puls current: 8.5A
Puls length: 600 µs

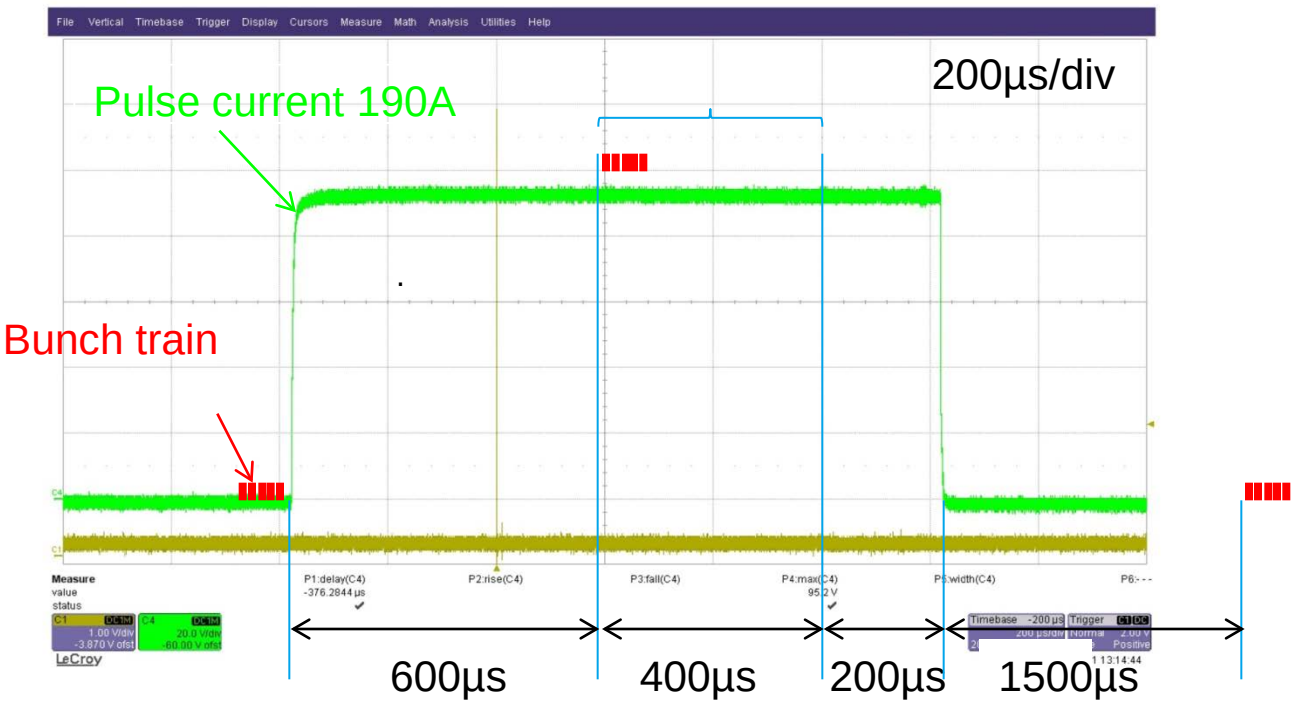
Adjustment at Flash:

- Energy Feedback off
- Scan-change in direction
- Read –out all BPMs

- Measurement with 4 BPM's
- All BPM show the same characteristics
- Deviation from pulse flatness
- Very slow fall time
- Why?

From F. Obier, 9 mA meeting

Kicker tests: Flatness measurements at FLASH

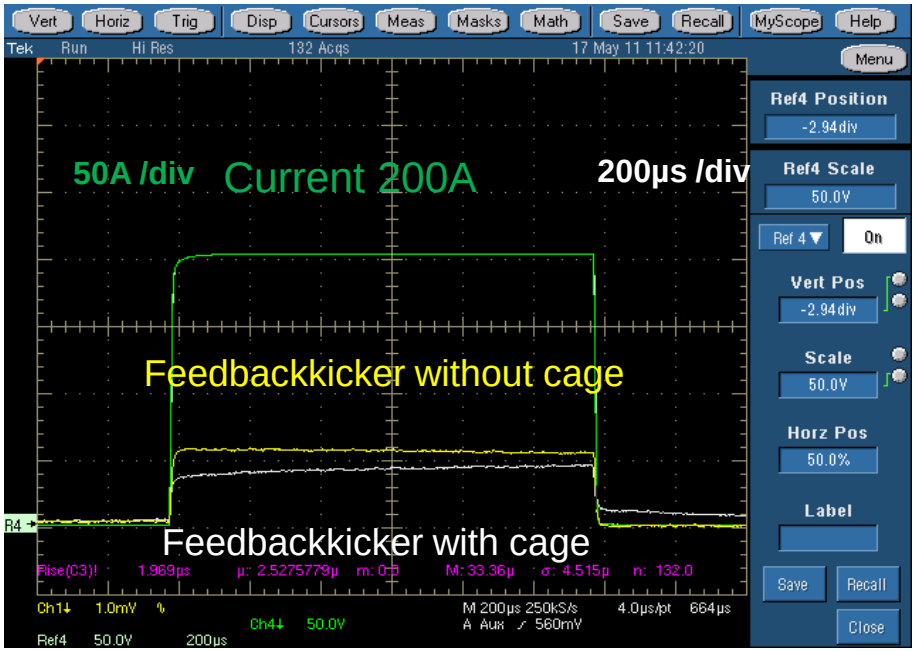


- Bunch train with 30 Bunches
- Bunch spacing of 4µs (250kHz)
- to shift the bunch train with a delay of 100µs and to look the variation of the SASE-level
- switch on kicker and adjust the beam position with a steerer
- On the top we have a area of 400µs with no variation of the SASE-level
- After the trading edge we have up to 1.5ms a variation of the SASE-level

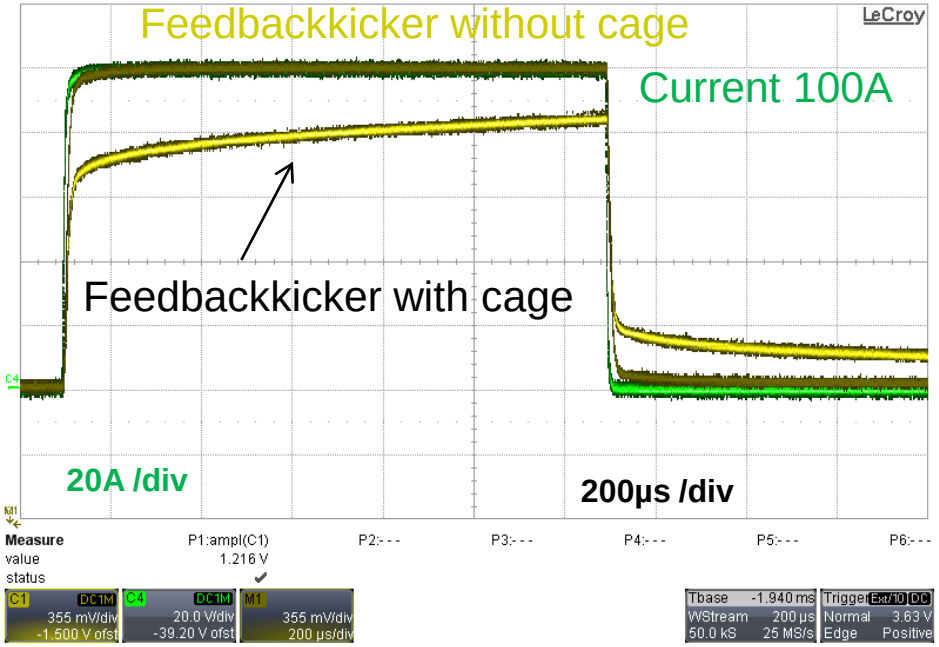
From F. Obier, 9 mA meeting

Kicker tests: Result of the magnetic field measurement

Air-core coil (1 winding) with integrator



CMR Sensor



green curve: pulse current of 200A

white curve: field measurement with a Feedbackkicker without cage (with a droop and a very slow fall time of 1ms)

Yellow curve: field measurement with a Feedbackkicker with cage (no droop and a fast fall time)

green curve: pulse current of 100A

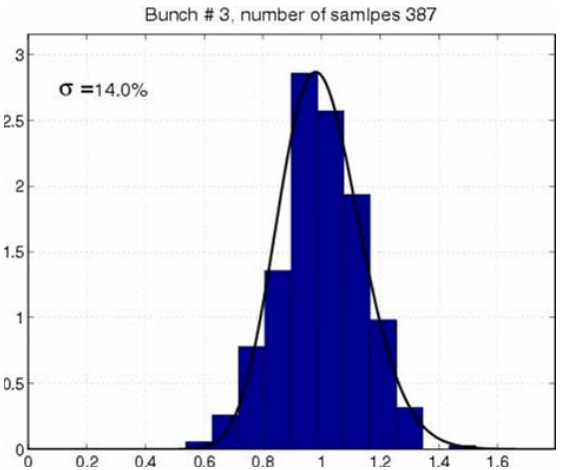
Yellow curve: field measurement with a Feedbackkicker with cage (with a droop and a very slow fall time of 1ms)

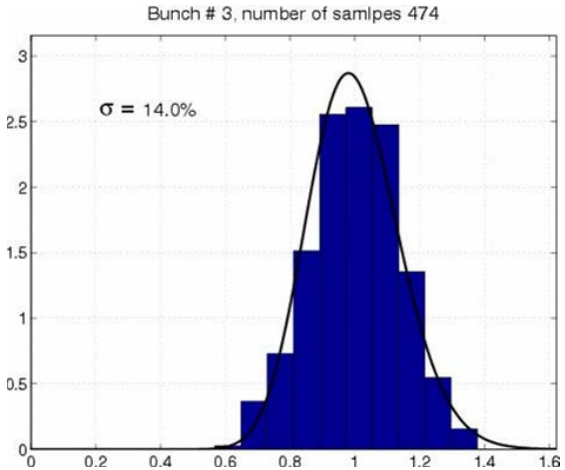
grey curve: field measurement with a Feedbachkicker without cage (no droop and a fast fall time)

Result: The eddy current on the kicker cage create the droop and a very slow fall time.

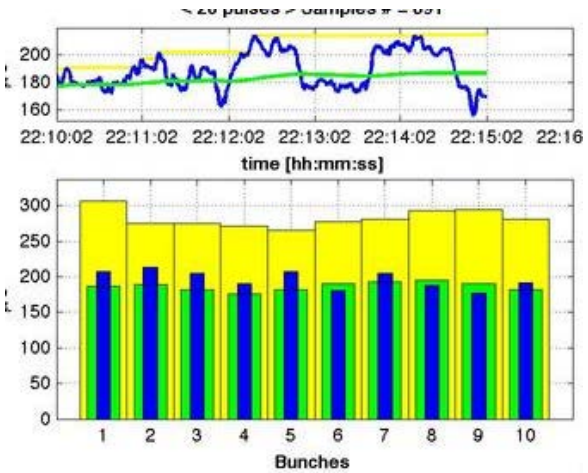
From F. Obier, 9 mA meeting

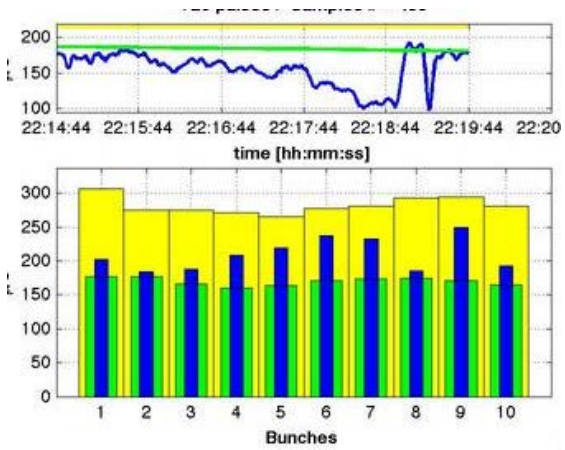
First Tests with SASE: stability OK, flattness not





Stability:
SASE intensity fluctuation without (left) and with (right) kicker and orbit correction. Depending on bunch number, fluctuation varies between 10 to 18%, both with and without kicker.





Pulse Flatness:
Variation of SASE intensity when moving the kicker flat top over the pulse train. Moving the kicker pulse back-and-forth by 100 ms shown SASE going up and down between 160 and 200 mJ. Moving the pulse over the entire range of 600 ms shows variation in average SASE intensity by a factor of 2.

Tests with kicker without cage showed also flatness OK.

Variation in RF amplitude and phase needed

For different charges different compression is needed
For wavelength scan of FLASH1 Energy changes needed

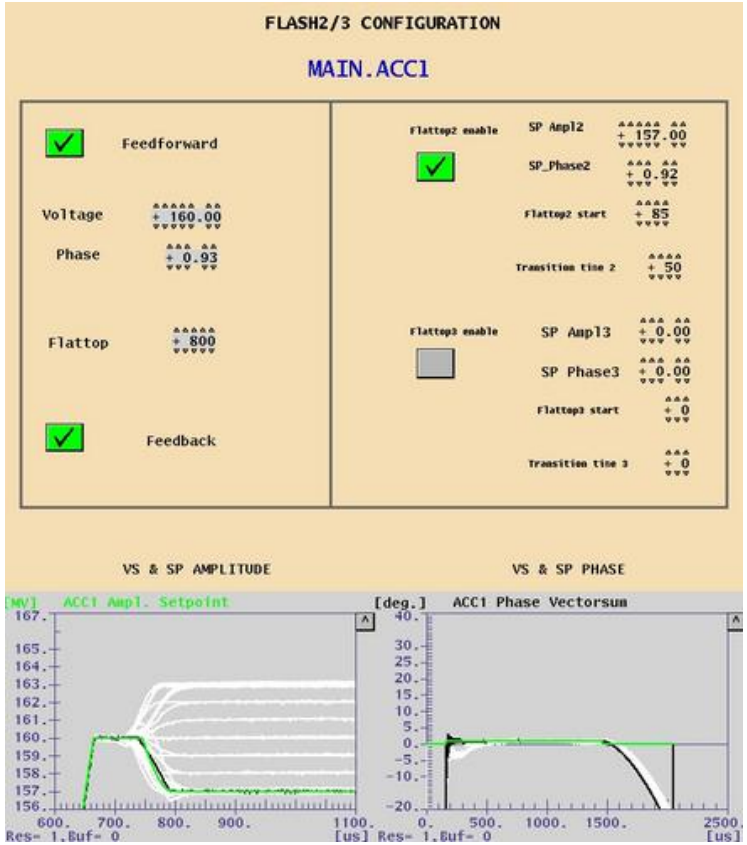
FLASH2: Requirements

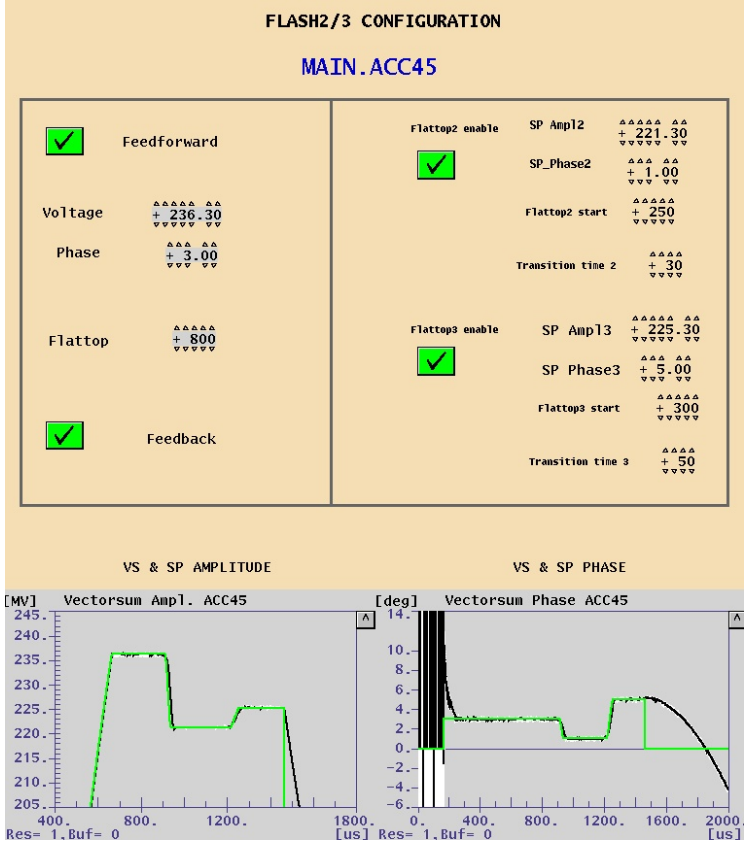
- RF amplitude and phase change within pulse
- RF amplitude and phase change from pulse to pulse
- Different beam loading for FLASH and FLASH2 (including arbitrary pulse patterns)
- Ability of gradient tuning of ACC45 and ACC67 (for wavelength scans FLASH)
- Ability of phase tuning of Gun, ACC1, ACC39 (for variation in compression FLASH and FLASH2)
- Ability of independent LLRF parameter adjustment for FLASH and FLASH2

From V. Ayvazyan, LLRF meeting

Tests Performed at March 2012

Gun, ACC1, ACC39, ACC23 & ACC45

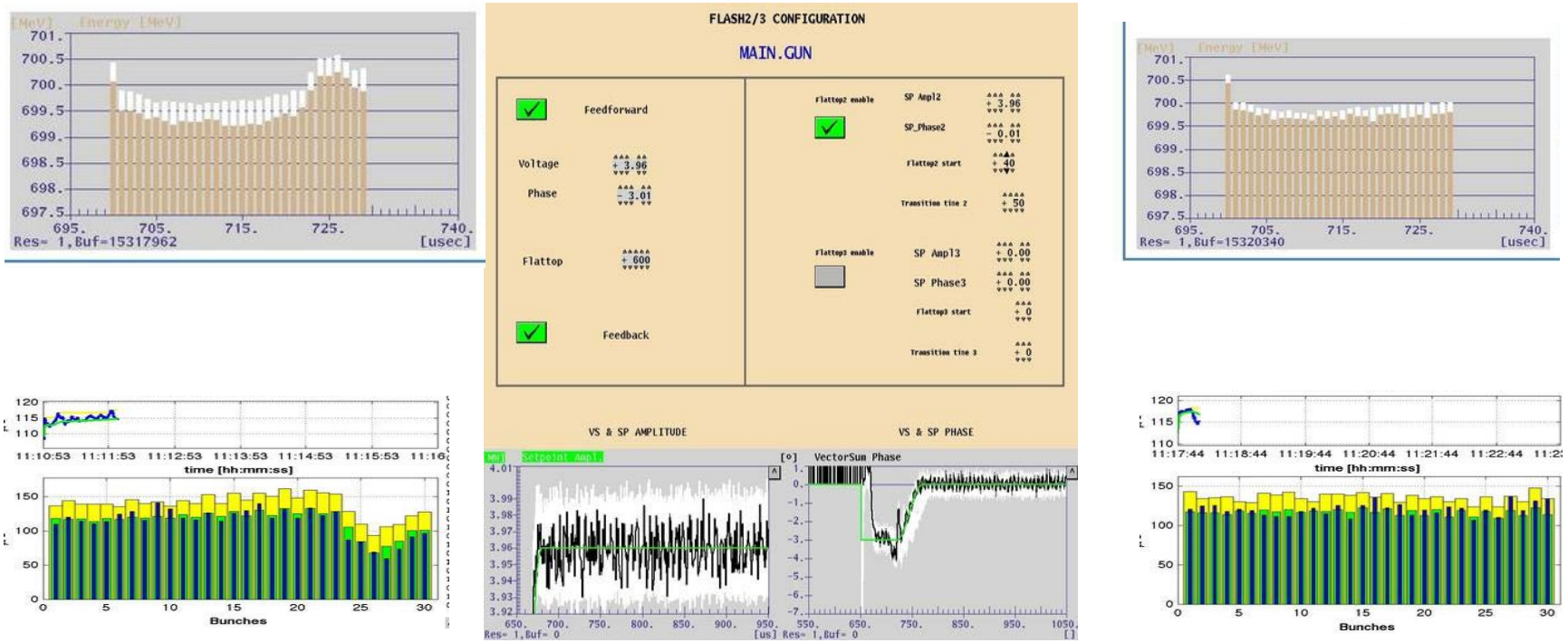




From V. Ayvazyan, LLRF meeting

Response of Gun Phase on Step

> Gun step position is at 40 µs (already 10 µs inside the pulse train) and 50 µs. Phase step of 3 deg.

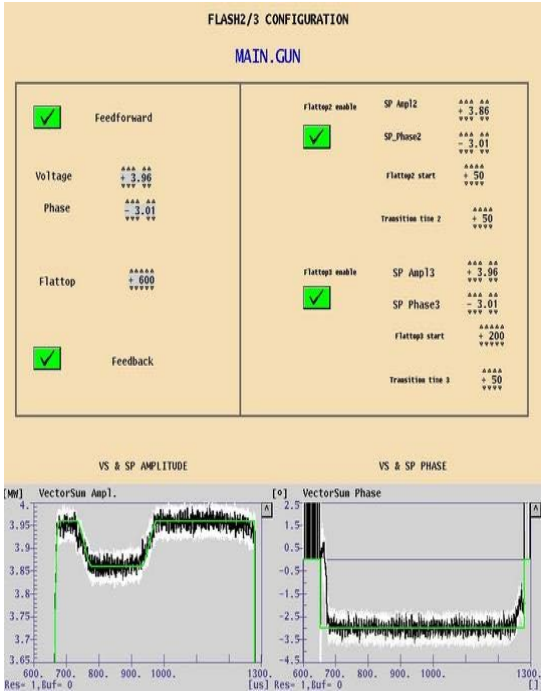


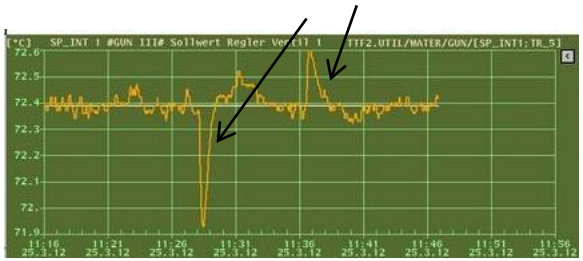
From V. Ayvazyan, LLRF meeting

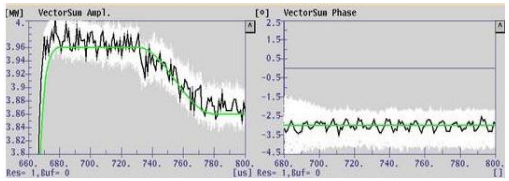
Response of Gun Gradient on Step

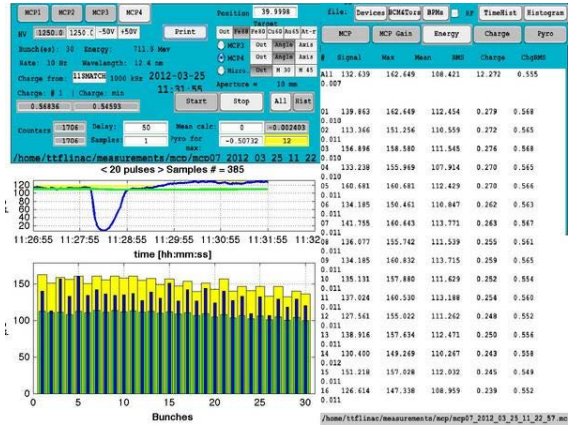
>SASE stable after gun gradient step for FLASH2 (down by 0.1) and FLASH3 (up by 0.1 to FLASH1 value and a FLASH2 duration of 200 -50 µs transition time)

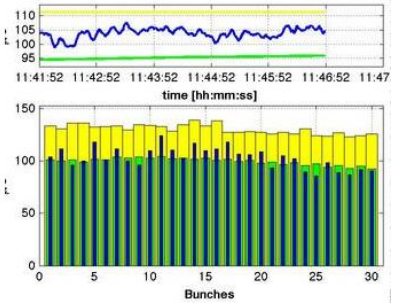
Gradient change GUN of 0.1 MW over full pulse length (left) and 200 us (right)







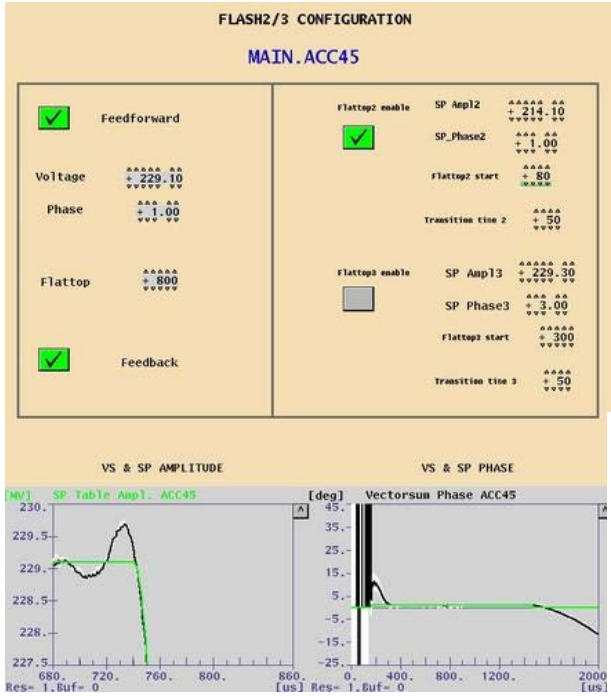


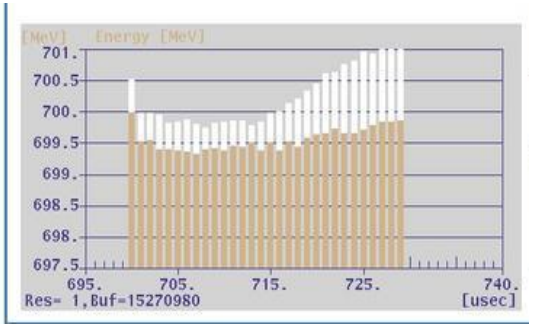


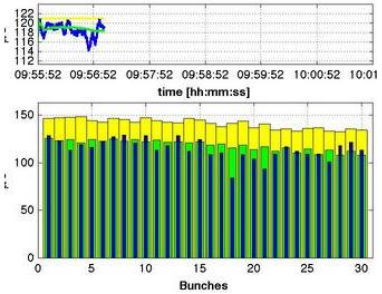
From V. Ayvazyan, LLRF meeting

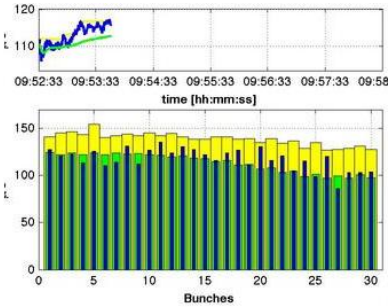
Response of ACC Gradient on Step

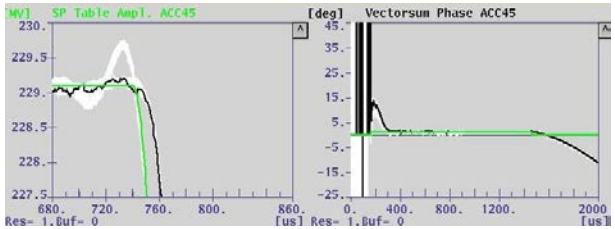
- ACC45 gradient response with and without LFF
- Transition time with sine wave [-pi/2 pi/2]







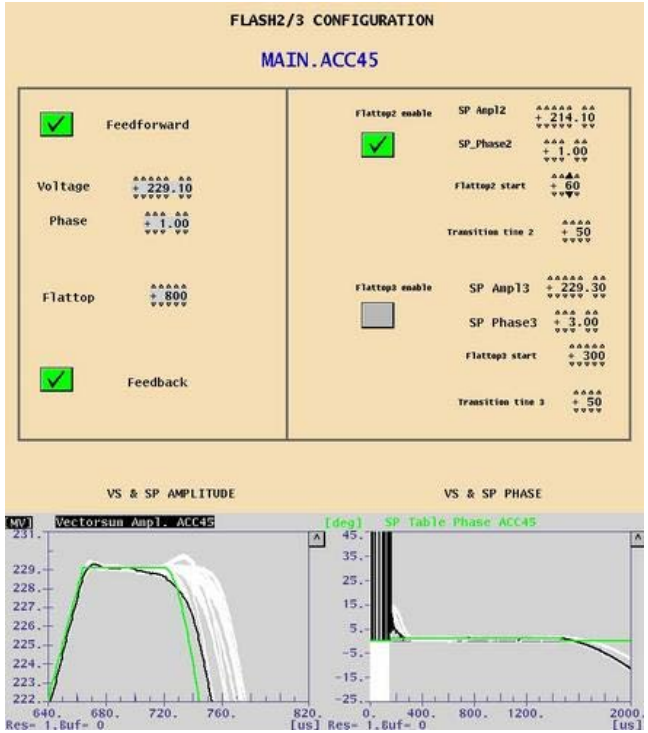


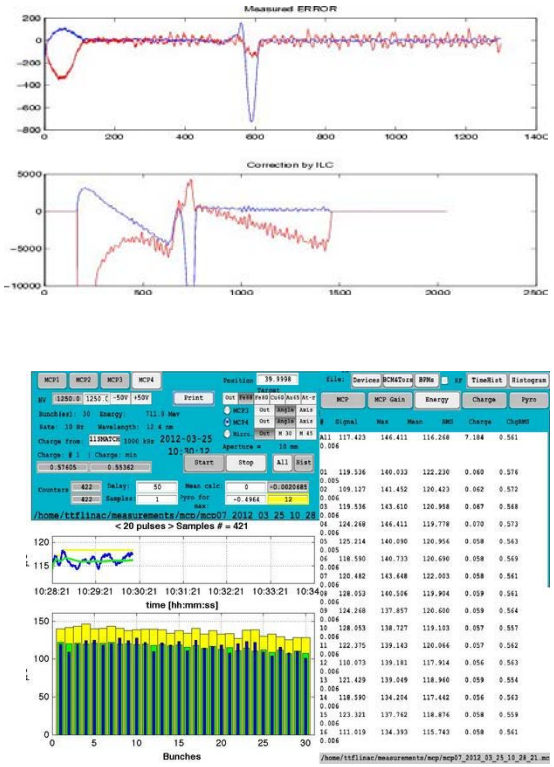


From V. Ayvazyan, LLRF meeting

Response of ACC Gradient on Step (2)

>Matlab script used with modified (includes new controller) adaptive learning feed-forward algorithm





From V. Ayvazyan, LLRF meeting

Summary: Switch Times Needed

- Checked expected ranges for phase and amplitude changes of Gun, ACC1, ACC39, ACC23 and ACC45
- The trailing edge stabilizes faster with the LFF on, but the leading edge stabilizes faster with the LFF switched off
- New LLF algorithm allows minimize time change by10-15 µs

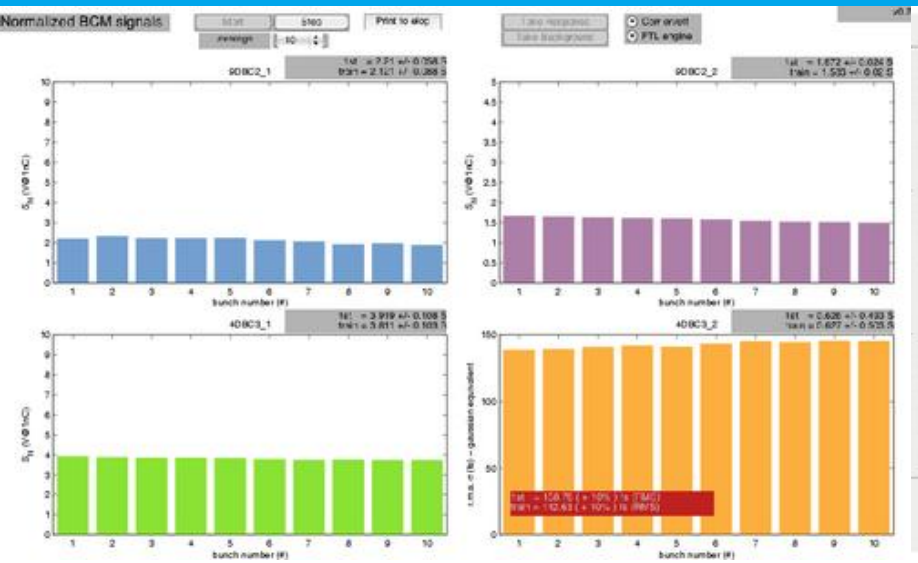
RF Station	Phase [deg.]	Amplitude [MV]	Transition time [µs]
GUN	+5	-0.1[MW]	50
ACC1	+/-2	+/-3	30
ACC39	+/-9	-3	60
ACC23	+/-3	-15	100
ACC45	+/-5	+/-15	100
ACC67			

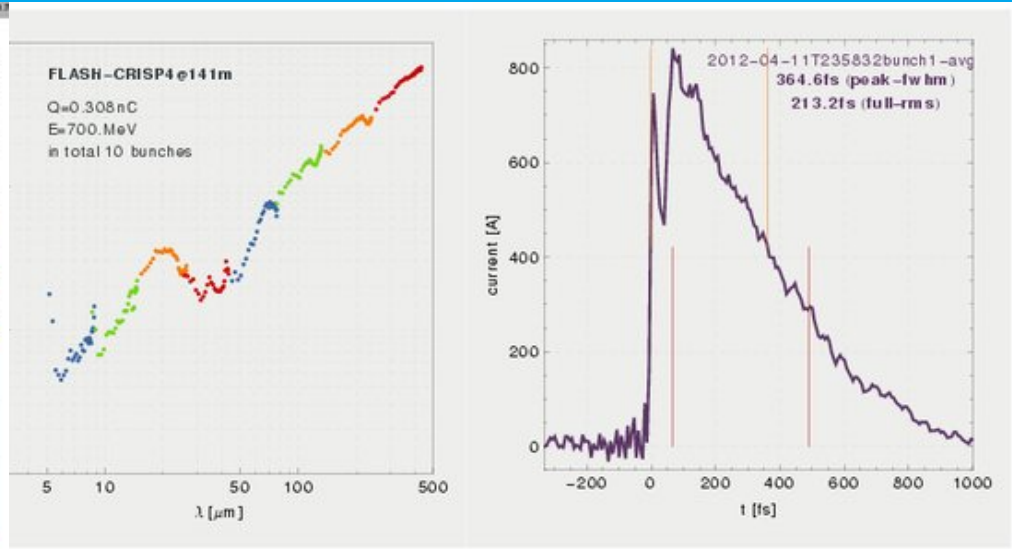
From V. Ayvazyan, LLRF meeting

Delivering different bunch length (pulse length) to FLASH1 and FLASH2
Charge variation and LLRF ranges needed to keep SASE

Problem: do I really start at the optimum?

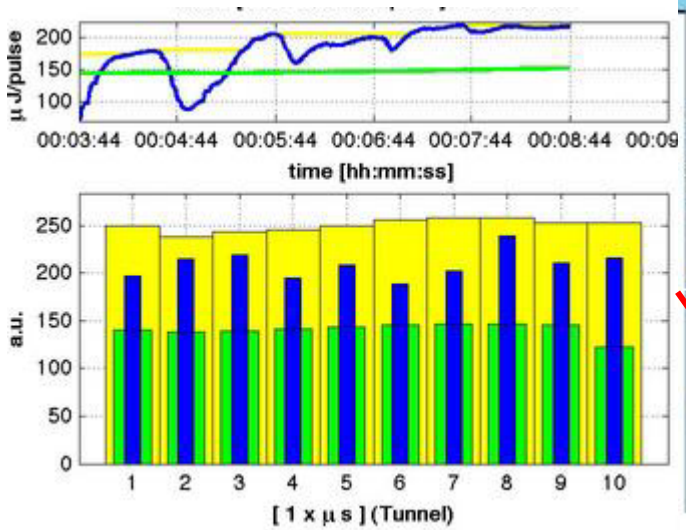
Charge dependence: 700 MeV, 0.3 nC

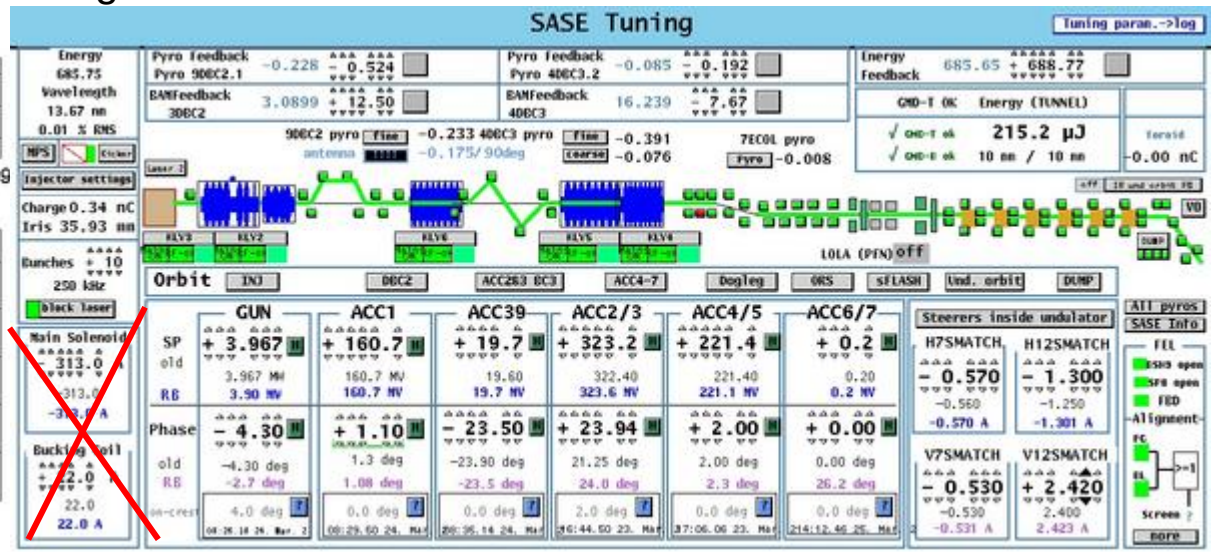




BCM as first indication on Pulse Length

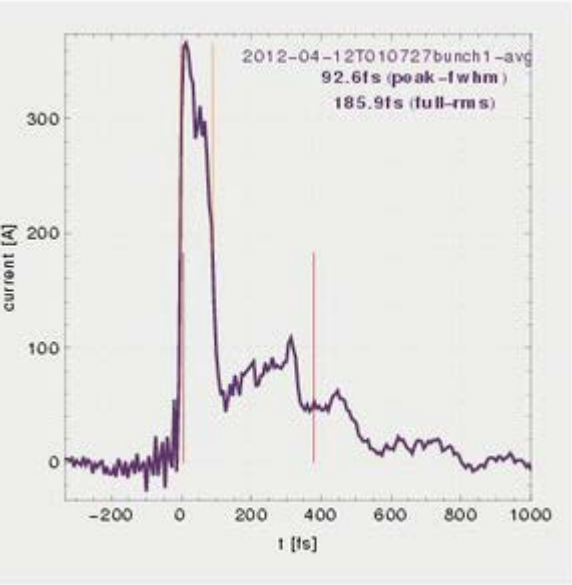
Check with CRISP4

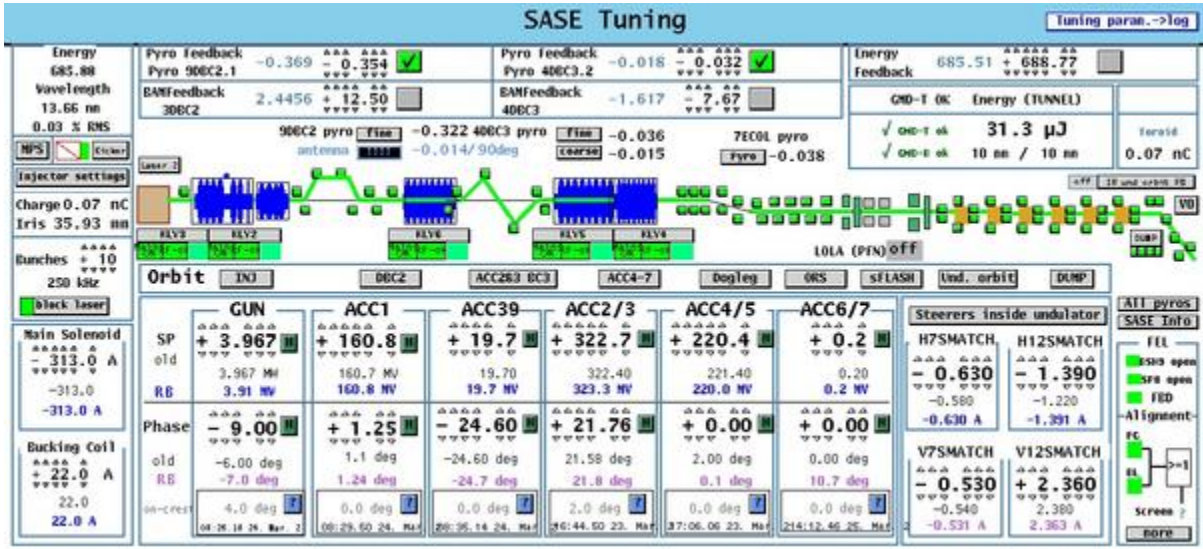


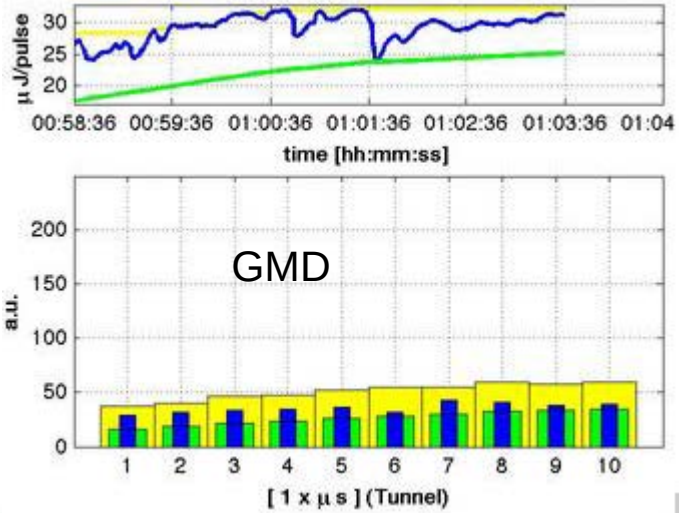


This is a NoNo

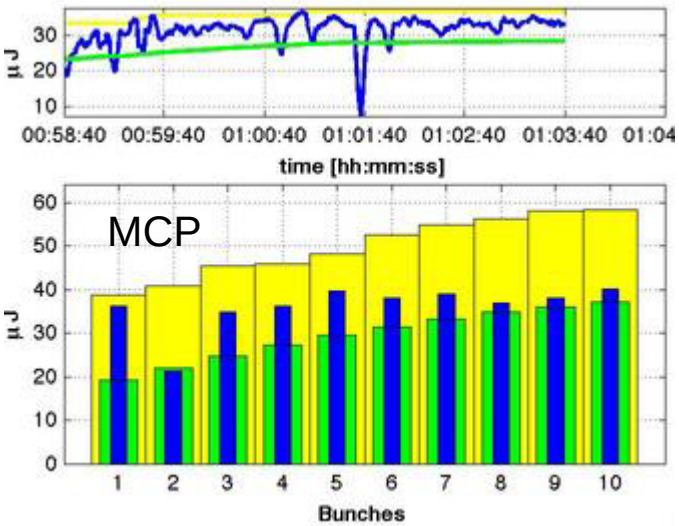
Charge dependence: 700 MeV, 0.07 nC



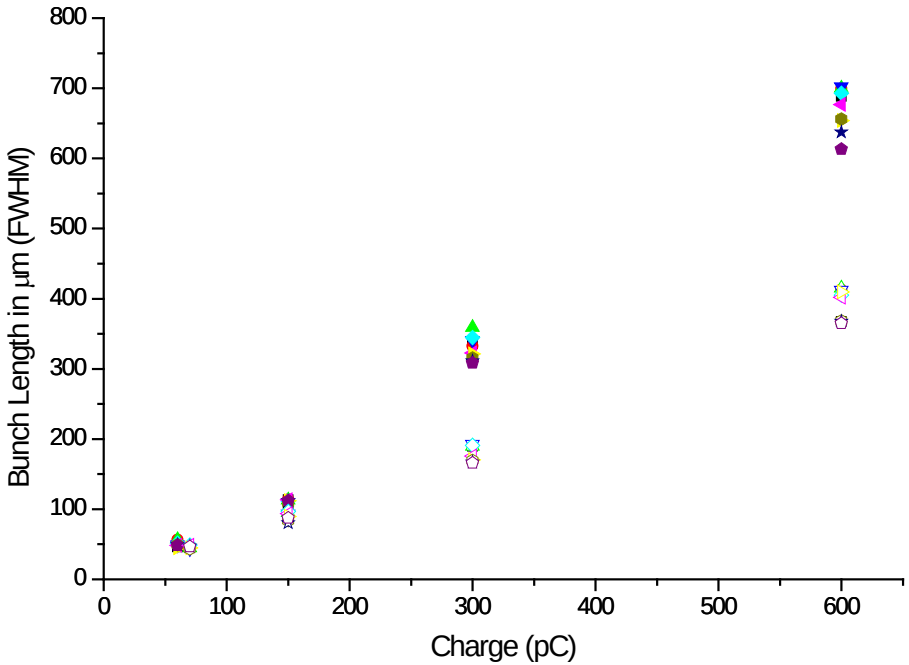




Cross-check with MCP at low Pulse Energy



Charge dependence: Measurements at 0.7 (solid) and 1.08 GeV (open symbols)



Charge (nC)	SASE (µJ) @0.7 GeV	SASE (µJ) @1.08 GeV
0.6	210	165/110
0.3	170	80/100
0.15	110	75
0.07	30/55	35

Measurement:

1. *Start with HIGH charge and go down, touching only RF parameters and orbit*
2. *Optimize at low charge*
3. *Start with LOW charge and go down, touching only RF parameters and orbit*

RF settings needed for different charges (tests KW1-11, 2012)

Charge (nC)	Gun phase	ACC1 phase	ACC39 phase	ACC23
0.7	-9.4	-0.82	-26.05	20.66
0.6	-9.5	-0.85	-25.95	19.98
0.5	-9.6	-0.92	-26.02	19.82
0.4	-9.6	-0.75	-25.69	19.6
0.3	-9.6	-0.77	-25.69	19.51
0.2	-9.6	-0.92	-25.69	20.39
0.1	-8.7	-1.07	-25.79	20.36

RF settings during the 2nd attempt at 0.7 GeV: on-crest phases are -3, 5, 13.6 and 0 degree.

Charge (nC)	SASE (uJ)	Bunch Length (um)
0.7	160	240
0.6	131	240
0.5	99	230
0.4	100	200
0.3	70	200
0.2	40	200
0.1	10	170

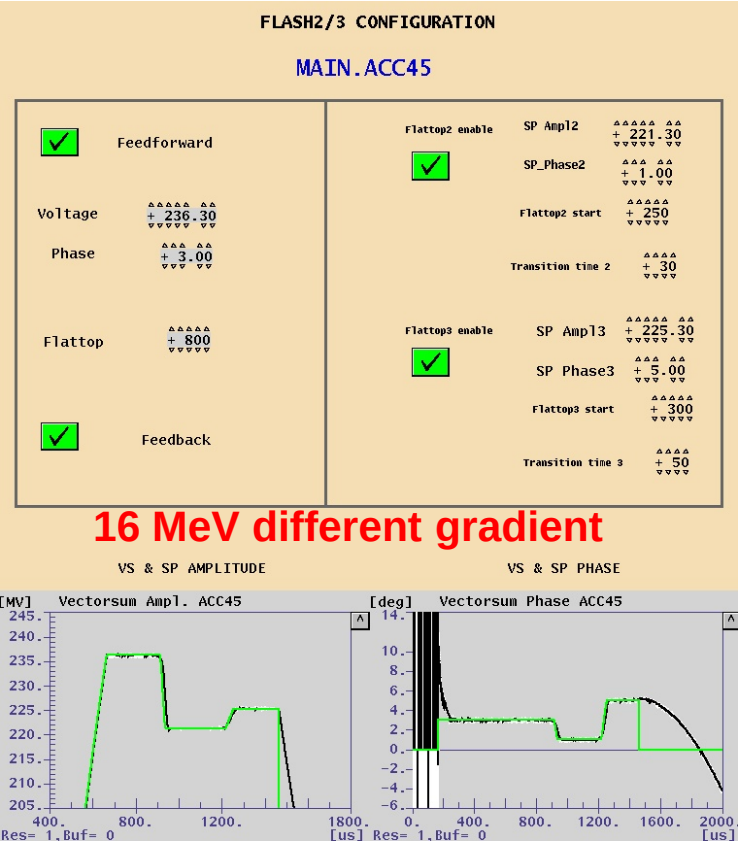
Test of charge variation during KW1-11, 2012.

Tests of last week show larger variations in phase, especially of the gun and ACC39, and also variation in the amplitude (incluring the gun)

Results of last week not yet evaluated in detail

Optics Mismatch
Changing wavelength for FLASH1 while delivering SASE for FLASH2

Change wavelength FLASH1 while keeping FLASH2 untouched



Optics can be correct only for one of the energies
What about losses of the mismatched beam in the collinator
What about lasing with a mismatched beam

NOTE: only needed for fixed gap undulator

Real situation:

- Energy of ACC45 or ACC67 changed (or both)
- Optics up to D1BYP (position of later Septum) unchanged
- Re-match optics behind septum
- adjust optics starting with ECOL corresponding to energy

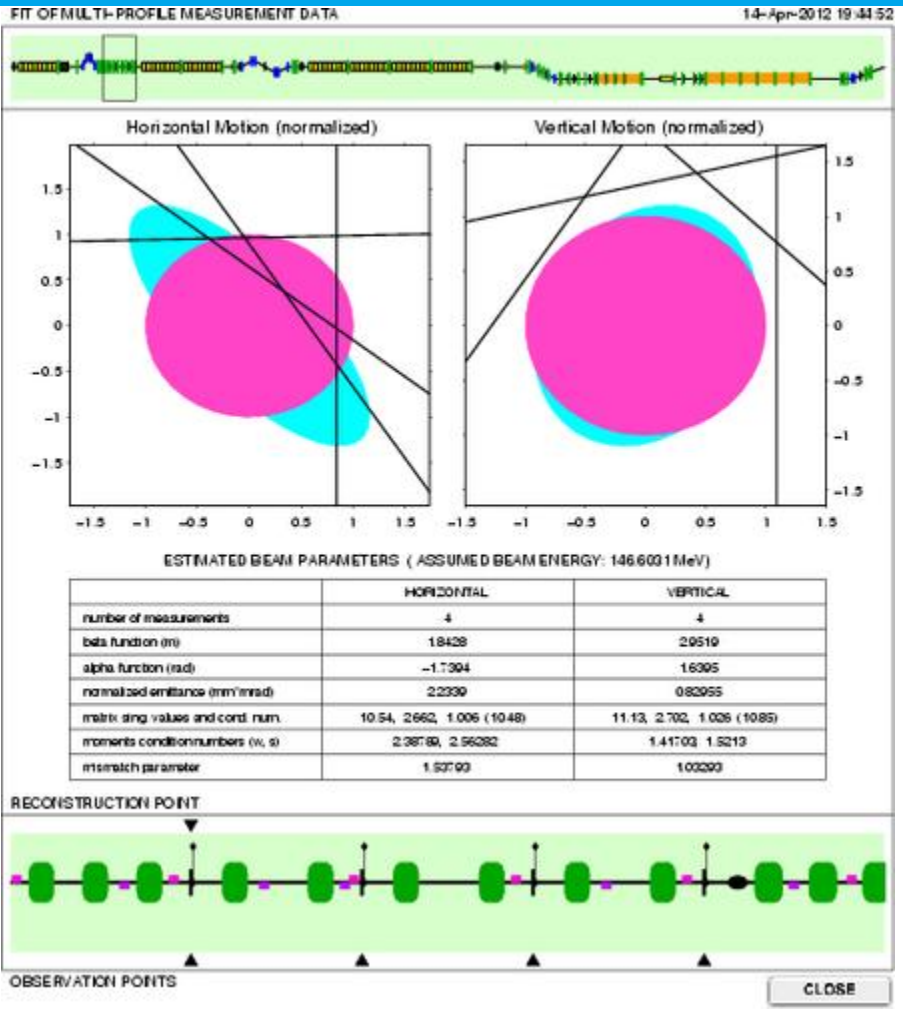
Problem:

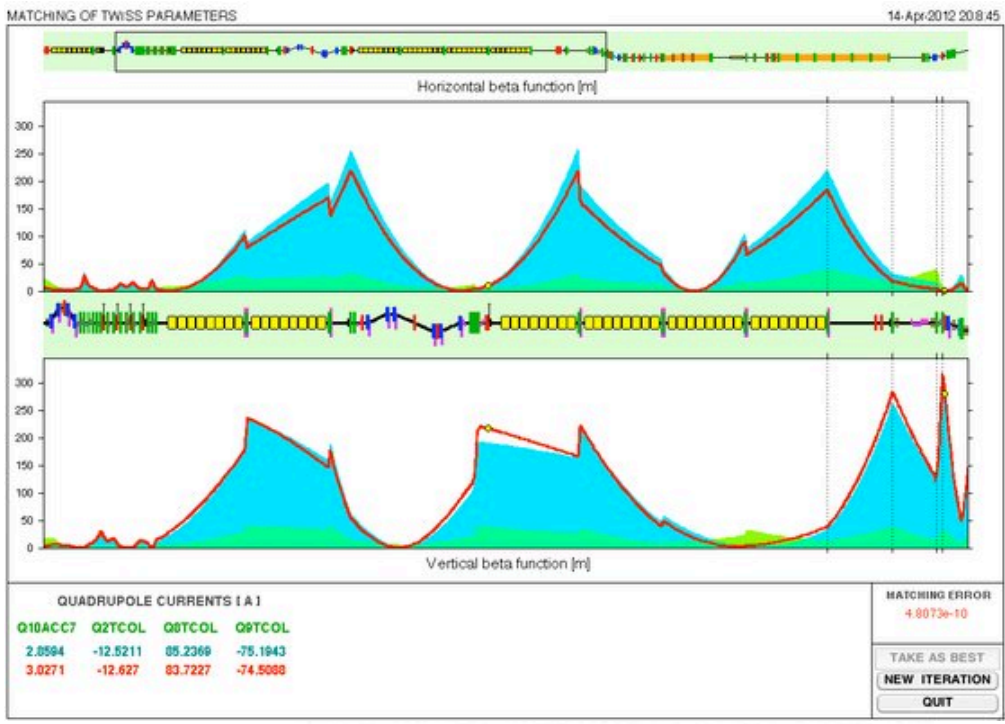
- Optics is different later (more restrictive)
- Number of quads is increased
- Collimator 2TCOL moved upstream behind module

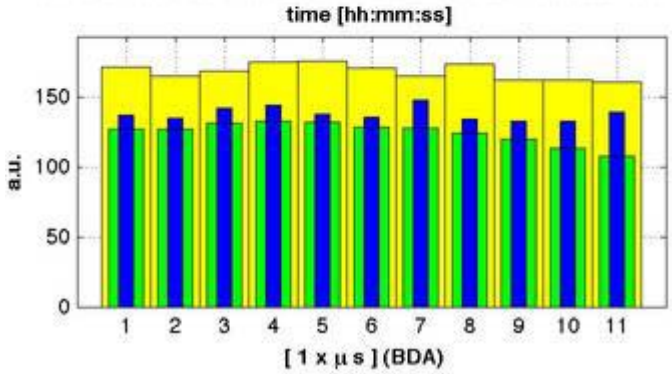
Used Procedure:

- Keep Energy constant
- Adjust ACC4567 and 2TCOL magnets to simulate mismatching
- Rematch using ????
- Keep magnets starting with ECOL unchanged

Change wavelength FLASH1 while keeping FLASH2 untouched

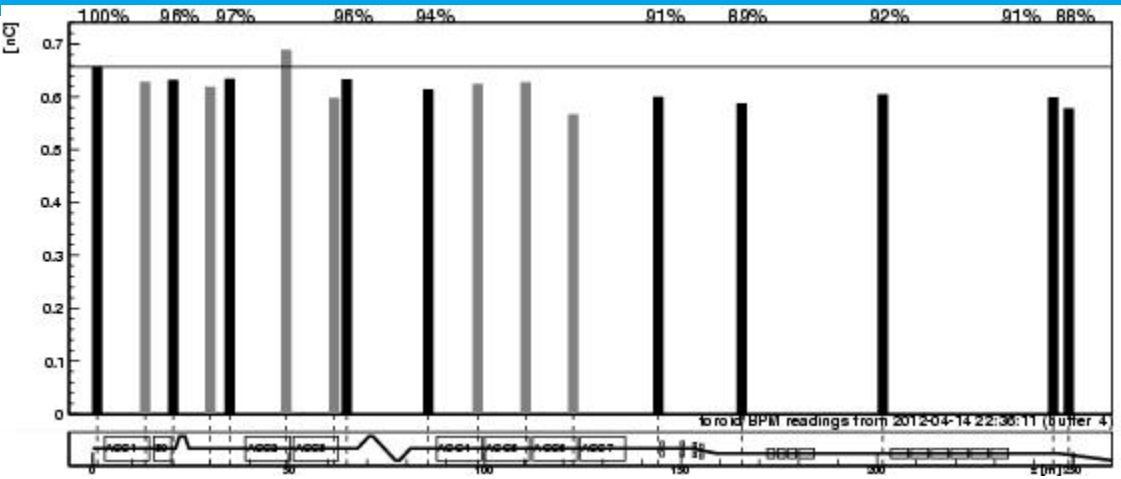


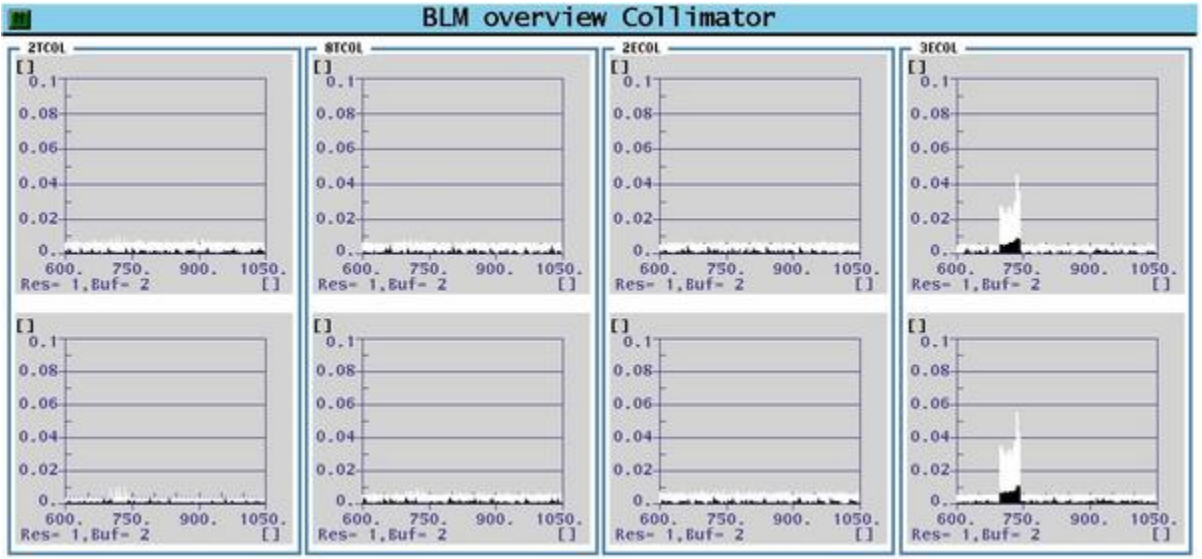


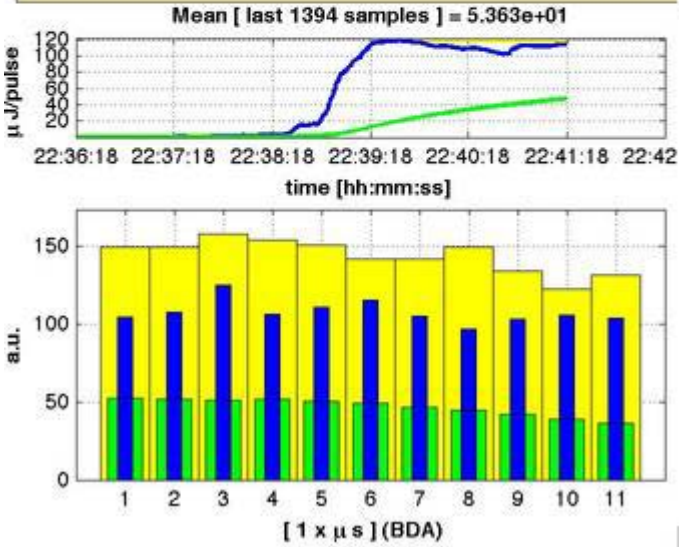


Checked optics in DBC2 but no re-matching
Recovered SASE to ~150 µJ at 5.5 nm

Change wavelength FLASH1 while keeping FLASH2 untouched

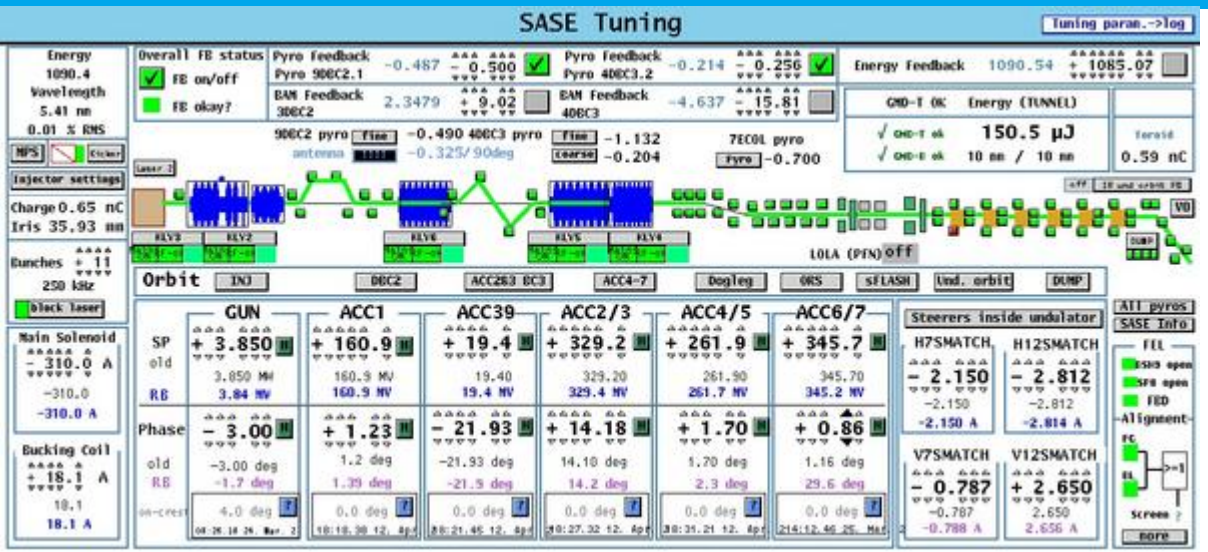


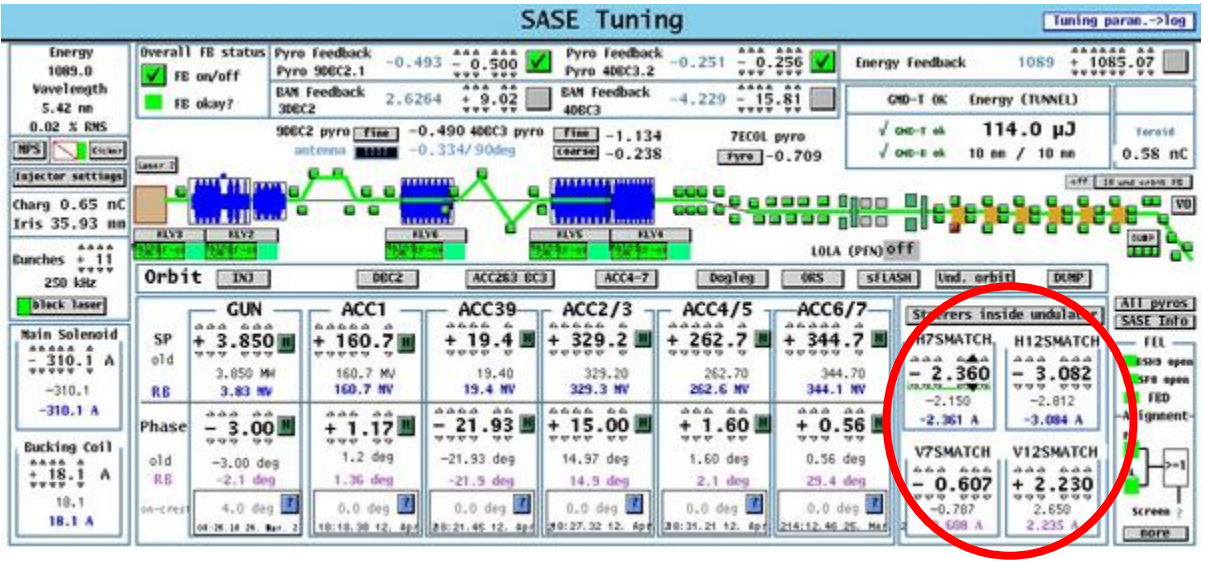




Result with 50 MeV mismatch: slightly increased losses in ECOL, slight decrease in SASE

Change wavelength FLASH1 while keeping FLASH2 untouched





Original: 150 µJ
Too far from Optimal ?

After 50 MeV mismatch: 115 µJ
Without re-matching
Mainly SASE steerers touched

Sensitivity to matching small, but also minimal increase in losses → need more thinking

Work to be done 2012 and 2013.

2012

- Continue **kicker** tests: flatness, stability and leading/trailing edge.
- **LLRF** gradient and phase stability test with beam.
- **Controls** to enable independent operation of FLASH2 and 3.
- Switching between **lasers** 1 and 2 with rep. rate/bunch number …
- Lasing with different charges
- ….

2013

- Continue tests of 2012
- Starting summer 2013 tests with beam in FLASH2/3
- SASE FLASH2 (non-parasitic, using steerers or kickers)
- …

Starting 2012 regular but short intervals for 1 to 2 hour tests?

Switching FLASH2 to FLASH3

VORTRAG von J. Biela (ETH Zürich) über die geplante Entwicklung vom "Pulse Power Supply" für die Strahlweiche FLASH2 und 3.

at 14:15 in this room!!!!!