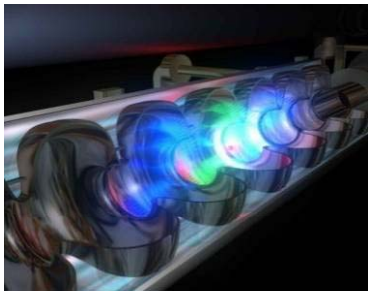
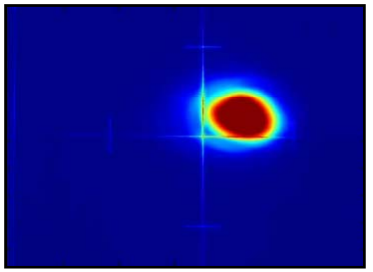
FLASH: Status and upgrade

FLASH
Free-Electron Laser in Hamburg

FLASH – The Free-Electron Laser User Facility

- Layout
- Performance and operational issues
- Upgrade





Bart Faatz for the FLASH team
DESY

FEL 2009
Liverpool, UK
August 23-28, 2009

HELMHOLTZ GEMEINSCHAFT

DESY

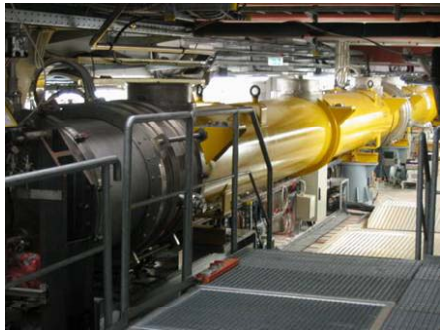
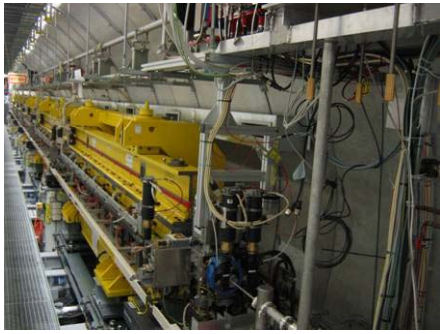
FLASH at DESY in Hamburg

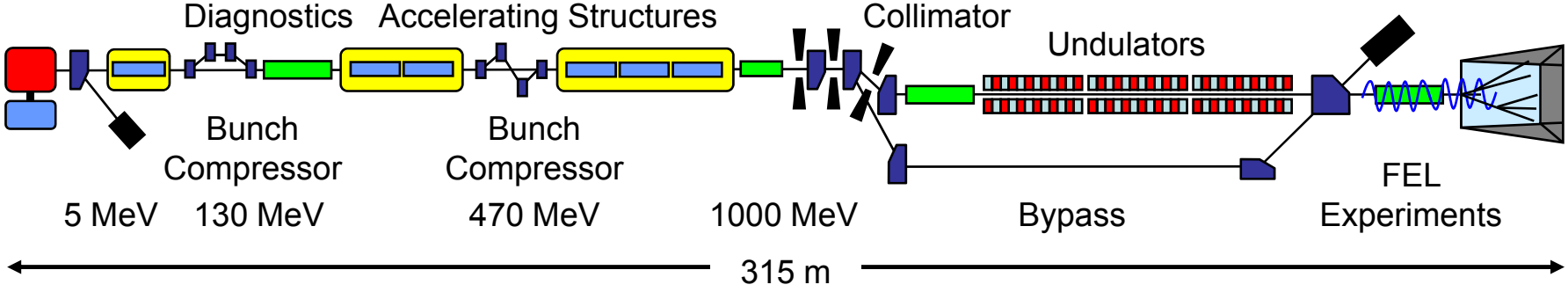
FLASH
Free-Electron Laser in Hamburg

- FEL user facility since summer 2005
- Photon wavelength range from vacuum ultraviolet to soft x-rays: 6.8-47 nm, 10-100 μJ, 10-70 fs FWHM pulse length
- Single-pass high-gain SASE FEL
  - SASE = self-amplified spontaneous emission
- Some first lasing events:
  - Jan 2005 – 32 nm
  - Apr 2006 – 13 nm
  - Oct 2007 – 6.5 nm
- User experiments
  - 1st period: Jun 2005 – Mar 2007
  - 2nd period: Nov 2007 – Aug 2009
  - 3rd period: starting summer 2010
- FLASH is also a test bench for the European XFEL and the ILC

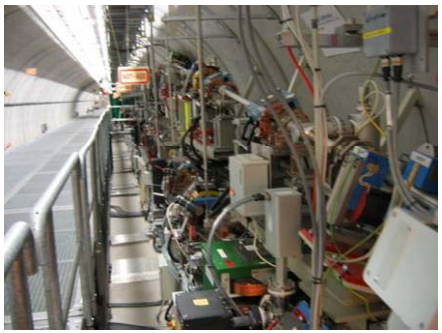
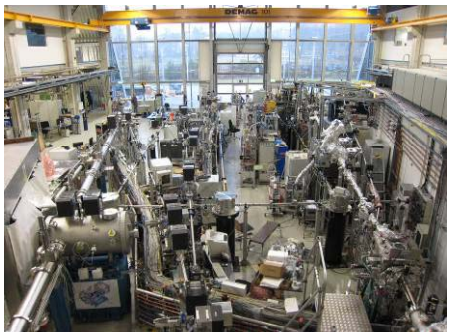
FLASH overview

FLASH
Free-Electron Laser in Hamburg



No 3rd harmonic cavity to linearize phase space → short spike, long tail

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SASE performance

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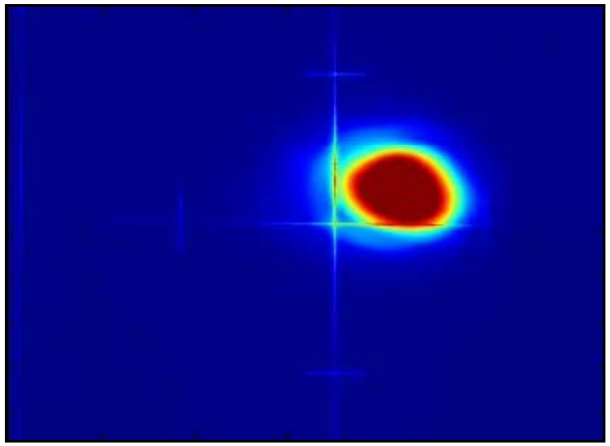
Free-Electron Laser in Hamburg

Typical user operation parameters:

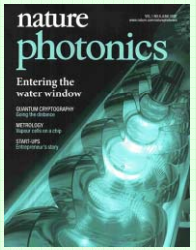
Wavelength range (fundamental)	6.8 – 47 nm
Average single pulse energy	10 – 100 µJ
Pulse duration (FWHM)	10 – 70 fs
Peak power (from av.)	1 – 5 GW
Average power (example for 500 pulses/sec)	~ 15 mW
Spectral width (FWHM)	~ 1 %
Peak Brilliance	10^{29} - 10^{30} B

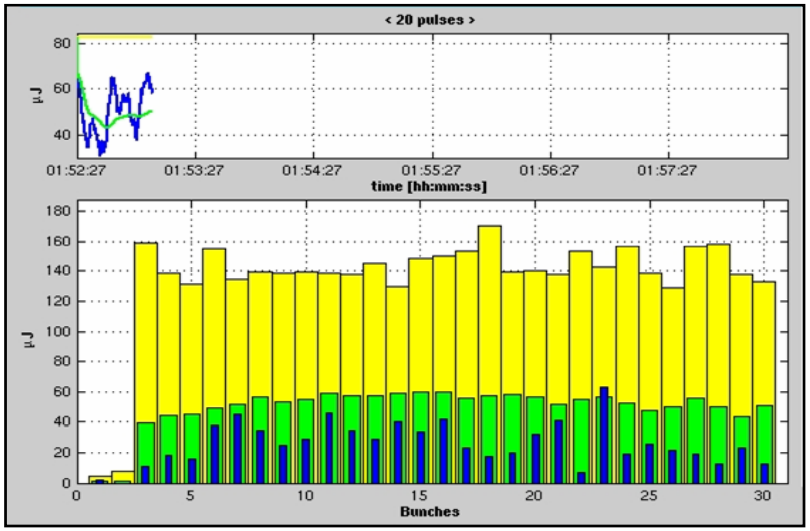


B = photons/s/mrad^2/mm^2/0.1%bw

Top performance at 13.7 nm:

Average energy 70 µJ
Peak energy 170 µJ
Pulse duration 10 fs
Peak power >10 GW
Peak brilliance (6 ± 3) 10^{29} B





Multibunch SASE signal (µJ) recorded with MCP detector

max
single
average

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Experiments

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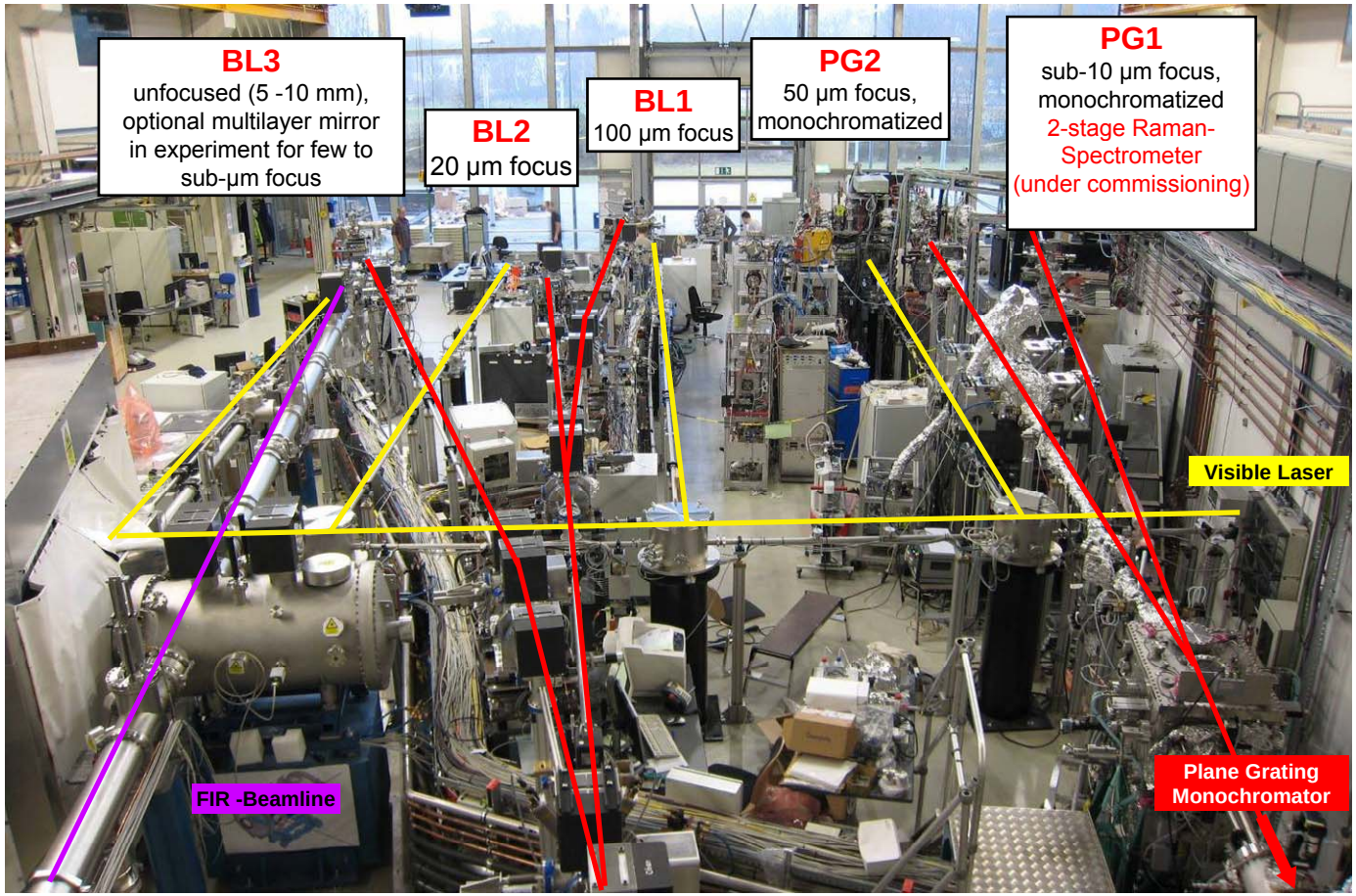
> ~60 publications (plus ~10 submitted) on photon science at FLASH:
1 Nature, 1 Nature Physics, 4 Nature Photonics, 12 PRL, 5 PRA/E, 5 APL, 3 Optics Express, 1 Opt. Lett., 2 JPB …



MOPC55 for THz

http://hasylab.desy.de/facilities/flash/publications/selected_publications/

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2nd user run

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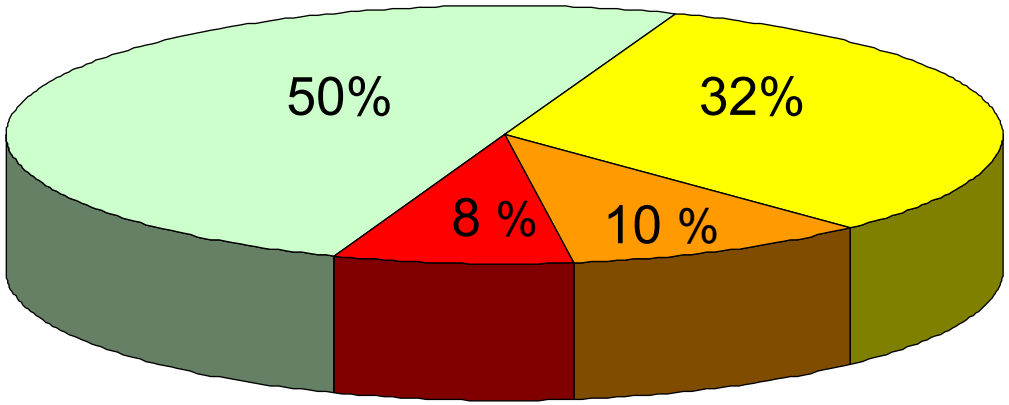
Free-Electron Laser in Hamburg

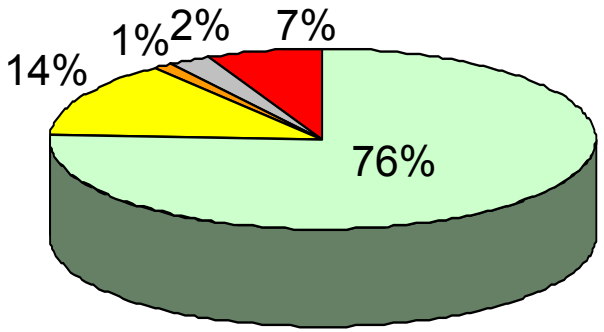
Period: November 26, 2007 to August 16, 2009

Total number of hours: 15216

Users	7608
FEL R&D	5352
XFEL & ILC R&D	1320
Scheduled Off*	936

SASE delivery	5712
SASE tuning	1080
Linac set-up	96
Maintenance	204
Down	504**





*Not including weekly maintenance

**20% (~40% in 2009) caused by RF stations.2+3, which will be exchanged

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Tuning during user runs

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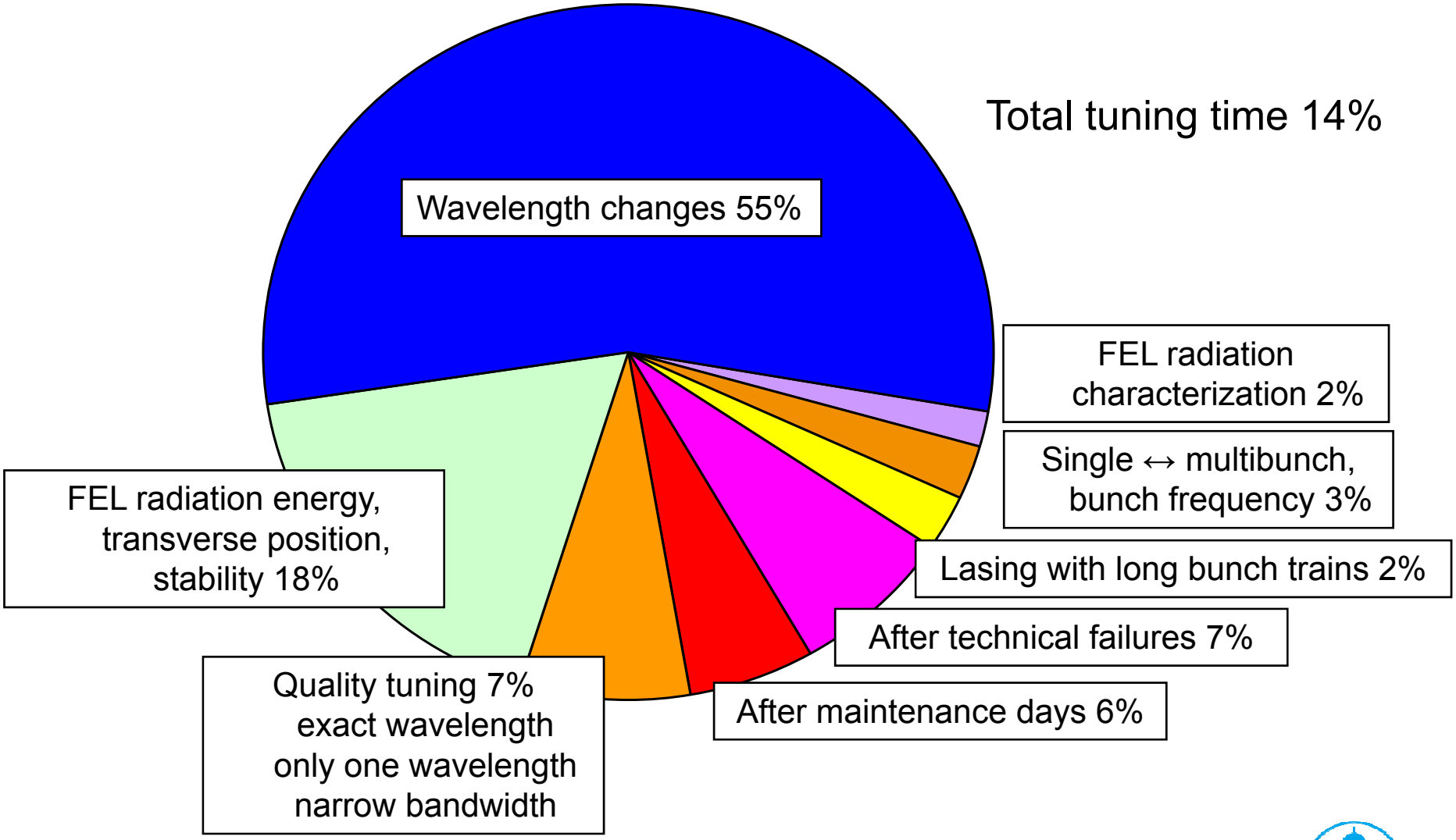

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Most demand on shortest wavelength or 13.5 nm

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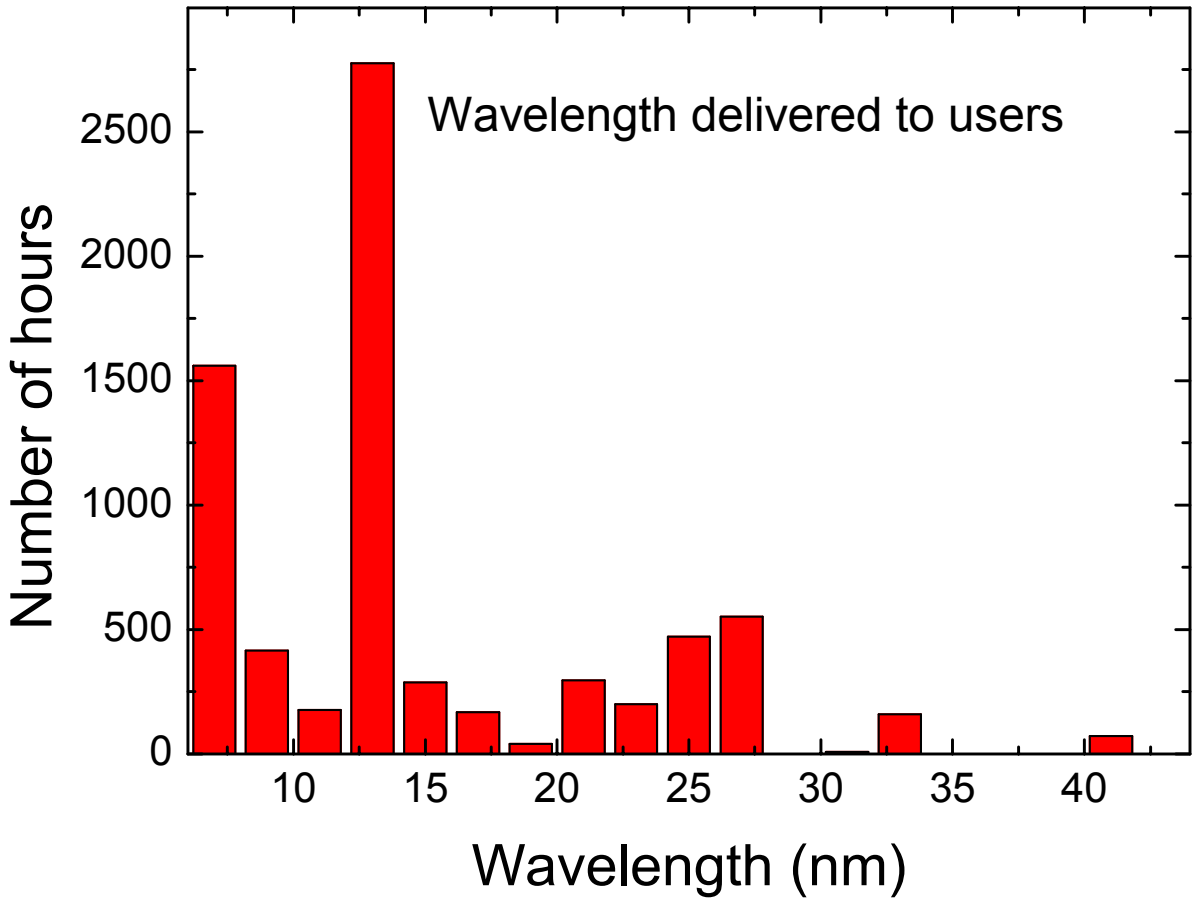

7 nm or 3rd harmonic

8 nm or 5th harmonic

40.5 nm + 3rd harmonic

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Wavelength change

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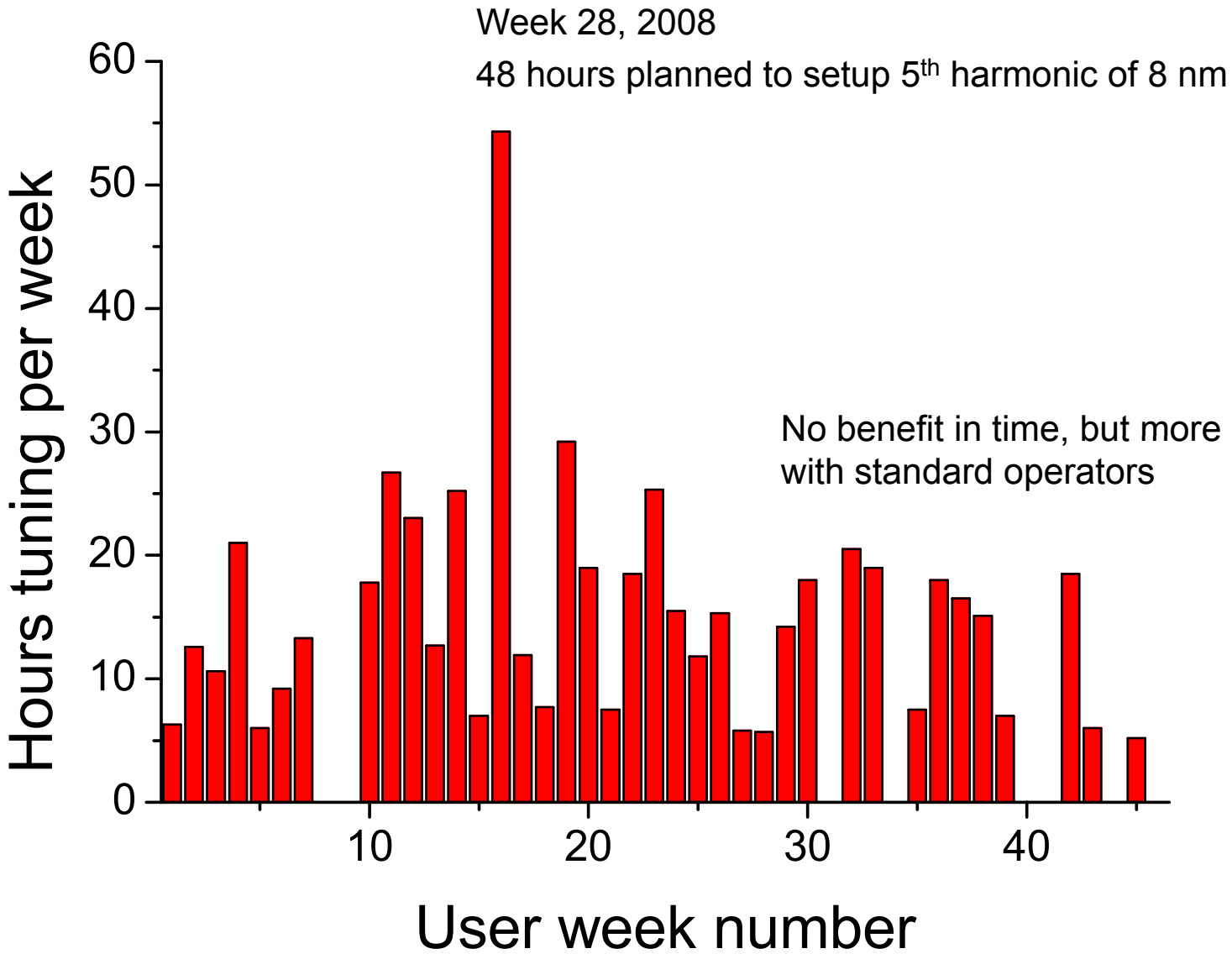
Free-Electron Laser in Hamburg



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FEL performance per user block

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	Week	SASE level (μJ)	Fraction long pulse trains	Collimation <= 1mm
2007	48-51	17.5		2%
	7-11	27.6	22	
	14-17	22.2	20*	5%
2008	26-29	13.4		6%
	33-36	10.8		16%
	43-45	22.2	Dump Vacuum	
	48-51	33.8		2%
2009	7-10	27.3		
	14-17	23		
	20-23	25.9		3%
	26-28	25.9		10%
	31-33	26.8		14%

No discrimination of wavelength made

* At some point reduced to 30 bunches due to energy/charge chirp

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Week 26-29, 2008 (June-July)

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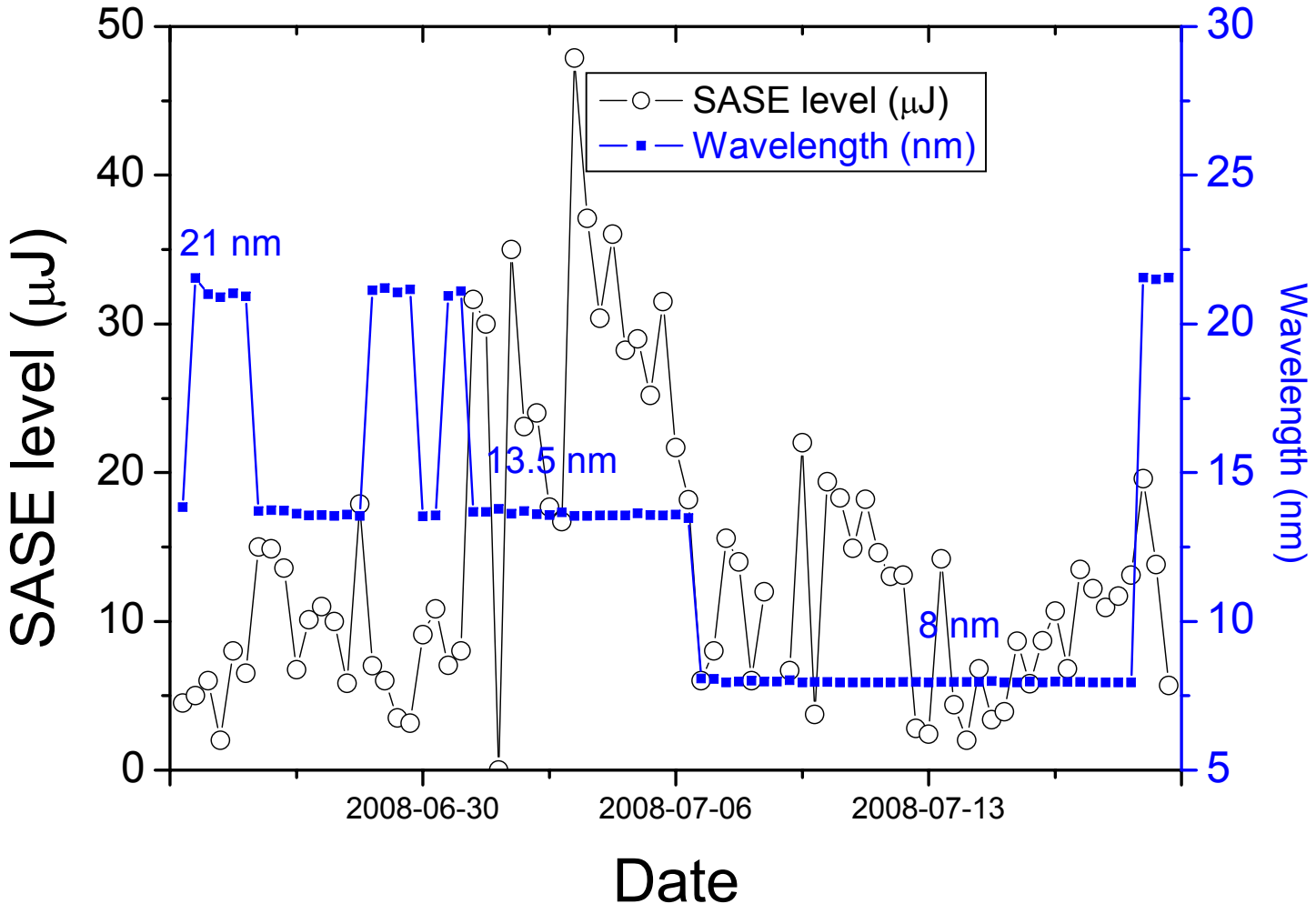

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Week 28, 2008 (July 7 to 13)

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Temperature at different positions along the undulator

On July 7, 48 hours reserved for wavelength change from 13.5 to 8 nm

DESY

Week 28, 2008 (July 7 to 13)

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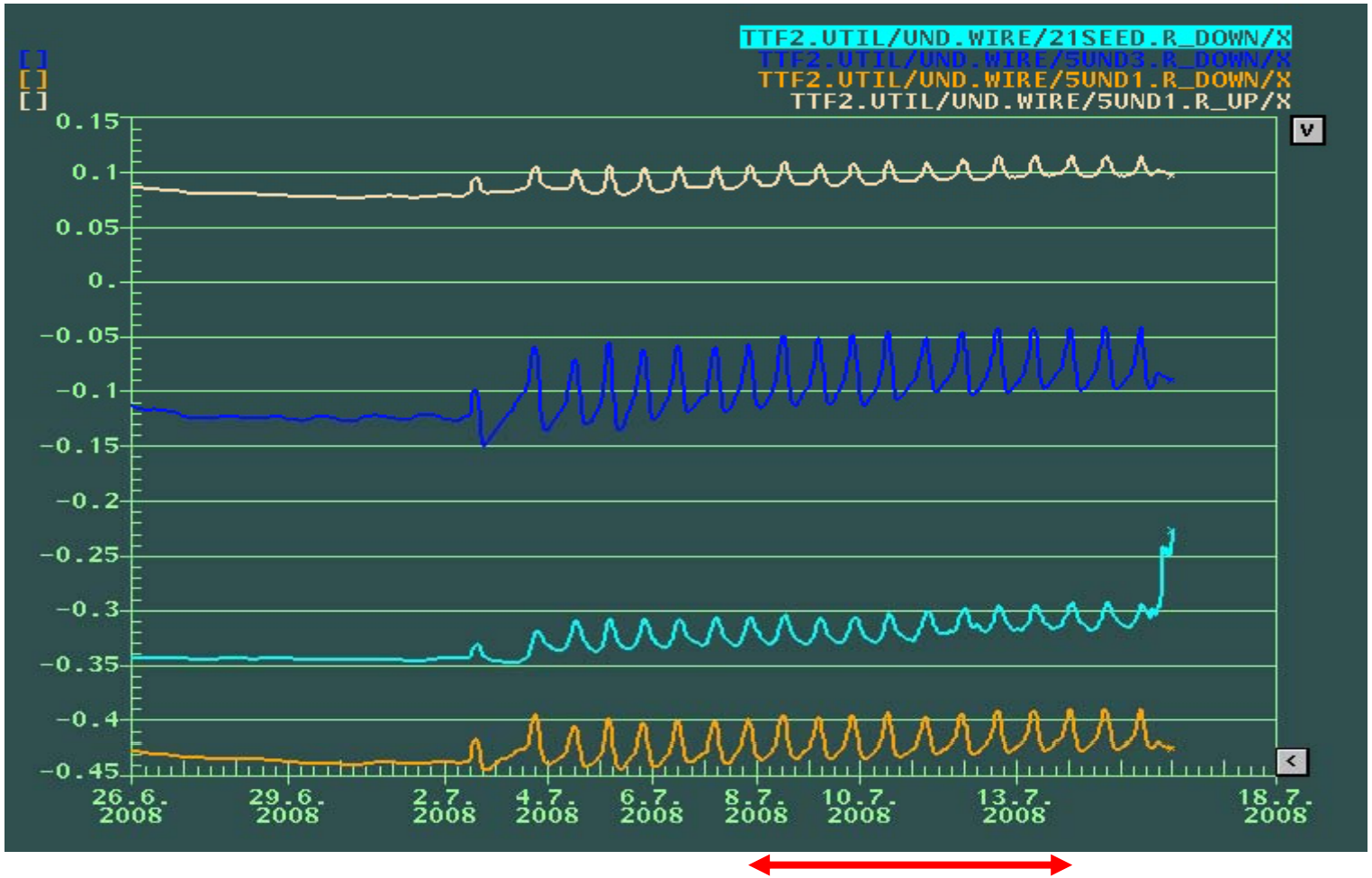
Movement of undulator quadrupoles : up to 100 μm



On July 7, 48 hours reserved for wavelength change from 13.5 to 8 nm

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Week 33-34, 2008 (August)

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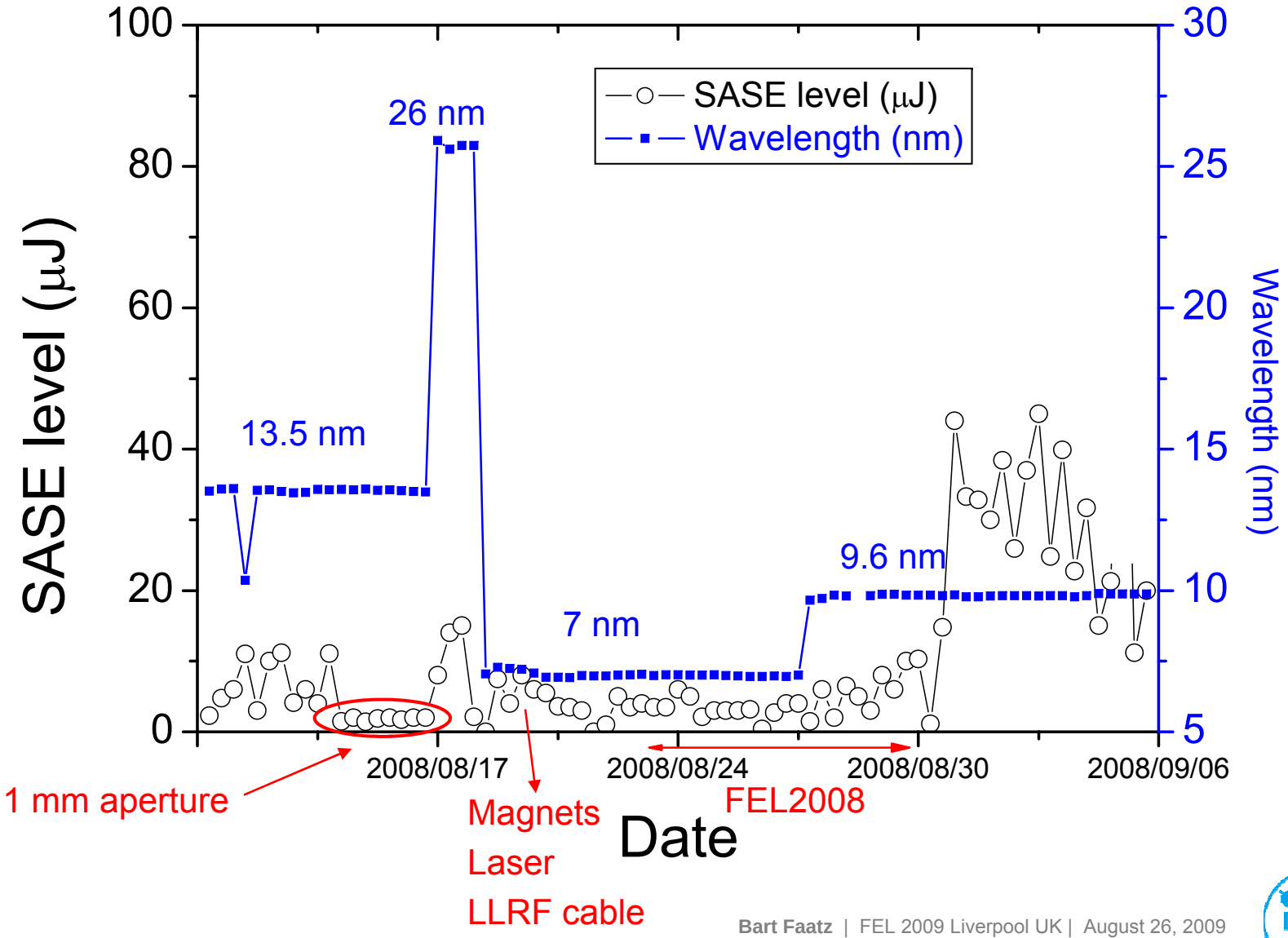

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Lasing distribution: August 20, 2008

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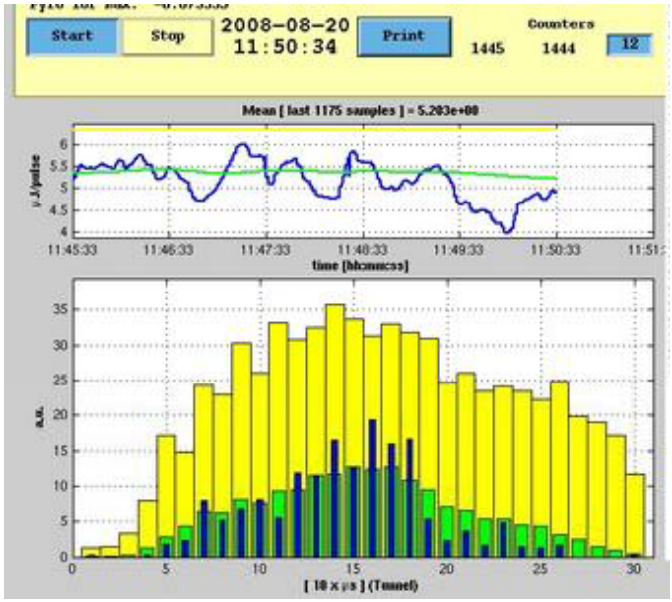
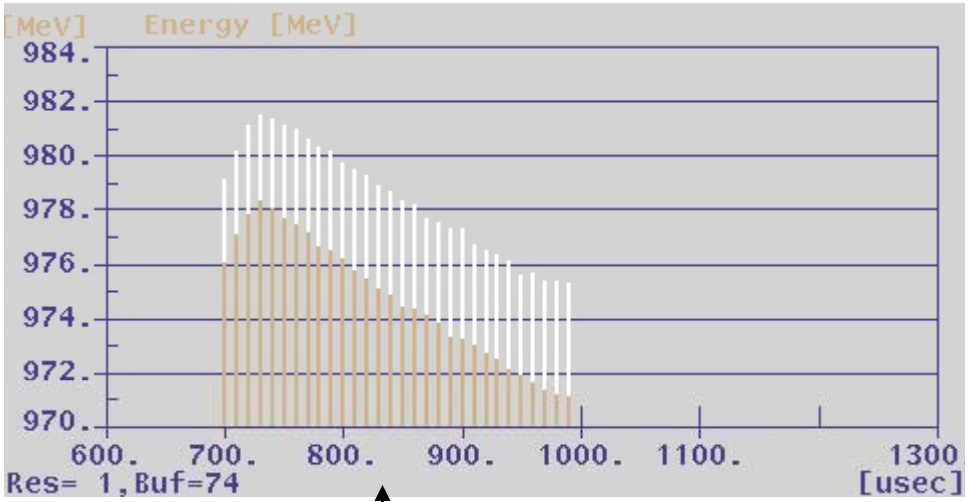
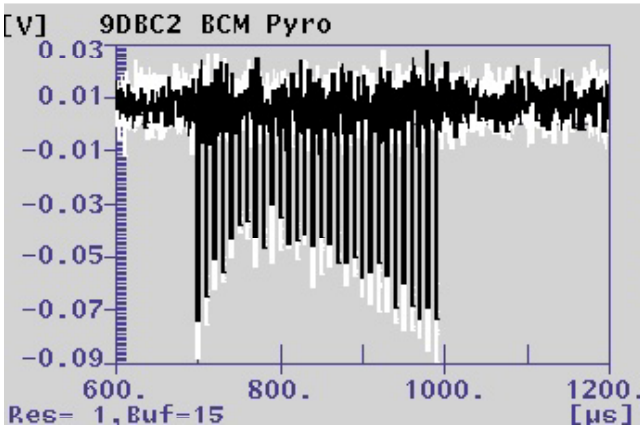
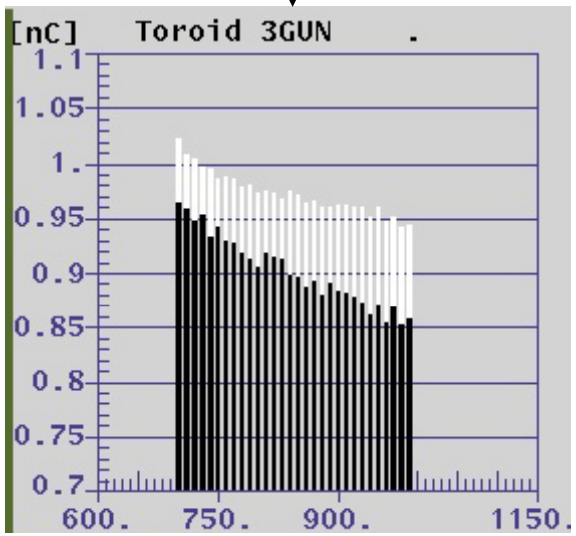




Distribution over energy, charge (not at the same time)





This performance was an exception

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Lasing distribution over a pulse train

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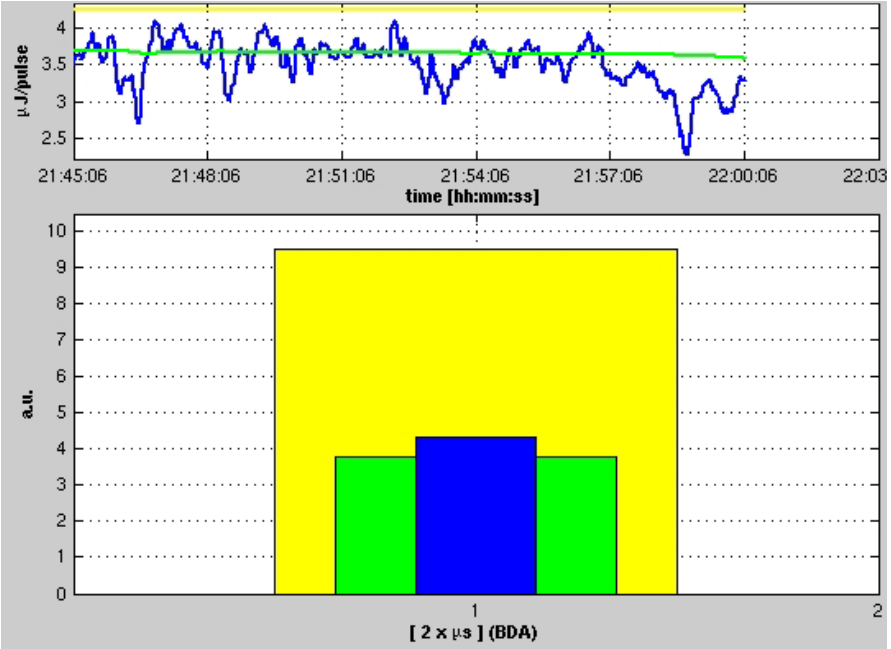
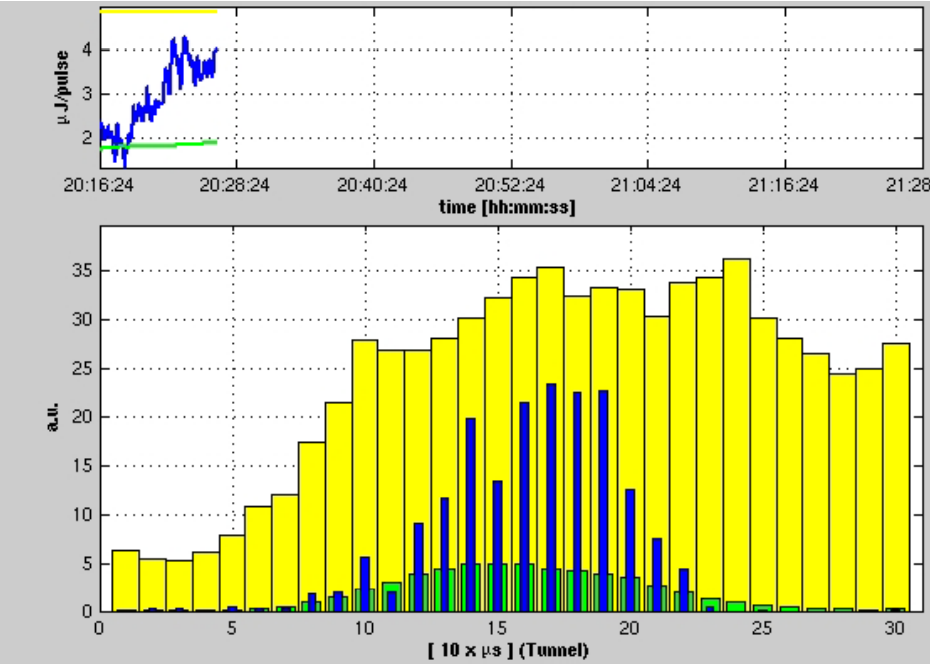
Up to 4 μJ for 1&1 mm apertures = 50%



Especially suffering were experiments with pulse trains



Re-optimization needed when switching between single bunch and trains

Up to 4 μJ for 10&10 mm apertures =15%

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Improvement of the machine performance

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Main Improvements

- Education of operators
- Improvements of tools/panels
- Cathode Laser stability (changed optics + exchanged BBO)
- LLRF, especially gun (oscillation gun power → tuning difficult)

Ongoing improvements

- Feedback for pulse train stability (RF and beam based)
- Beam based alignment/dispersion & orbit correction
- BPMs, especially undulator
- Online spectrometer/photon BPMs

RF Gun stability

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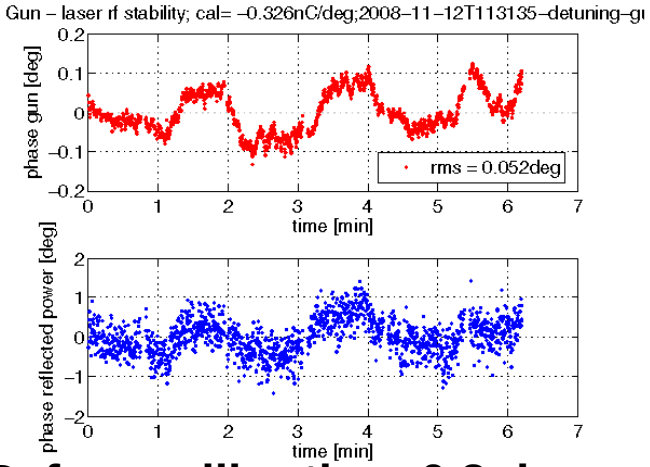
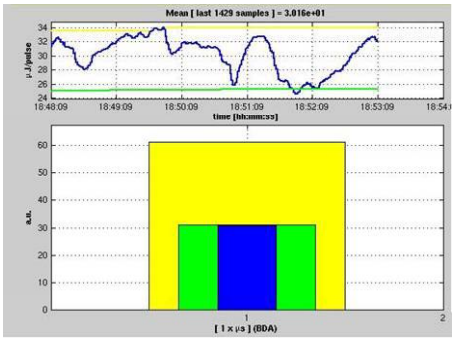
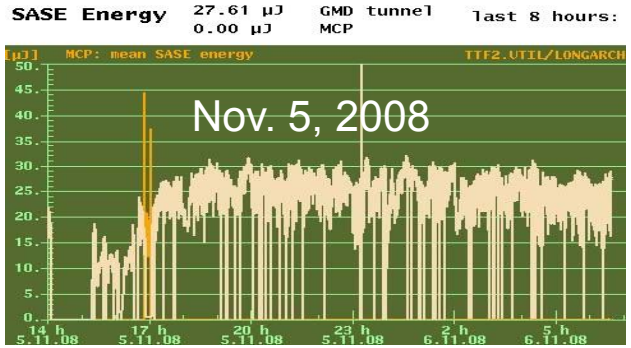
Free-Electron Laser in Hamburg



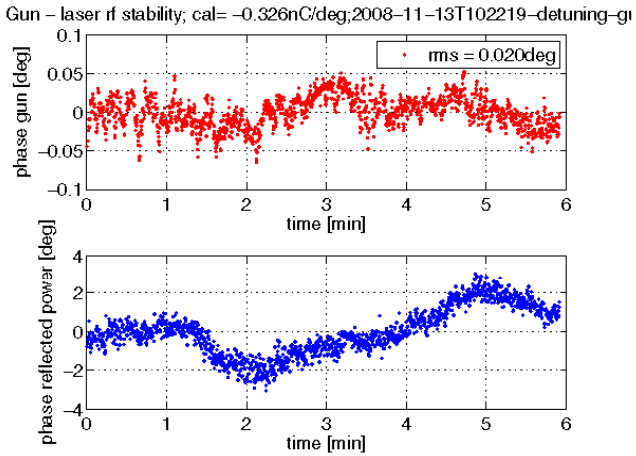
Before calibration: 0.2 degr.





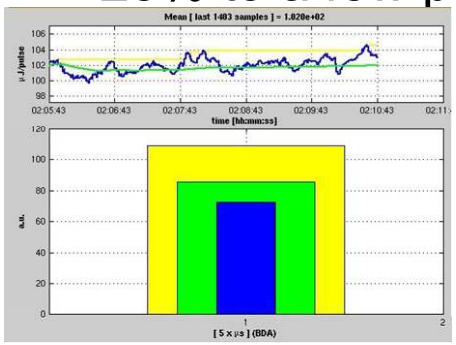
RF Gun field measurement calibration

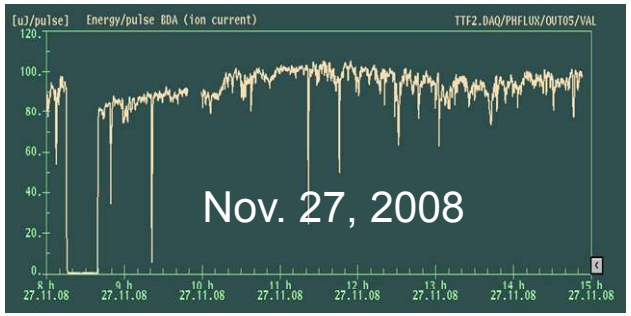
$$U_{trans} = U_{for} + U_{ref}$$



After calibration: 0.1 degr.

SASE intensity fluctuations down from 25% to a few percent





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Implementation status of optical synchronization system

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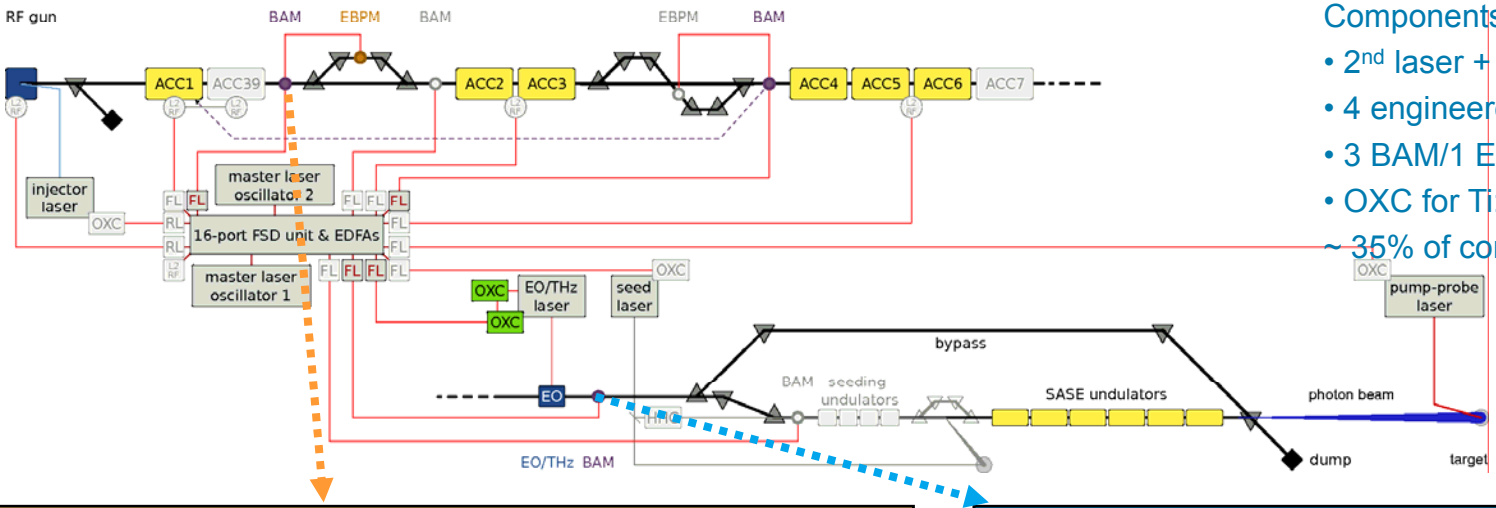


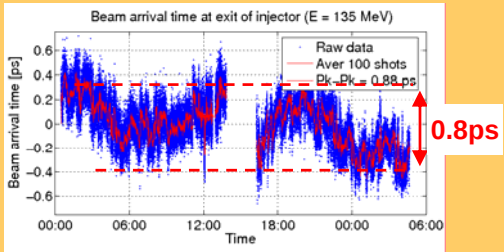
Components installed:
- 2nd laser + opt. distr.
- 4 engineered links
- 3 BAM/1 EBPM
- OXC for Ti:Sa

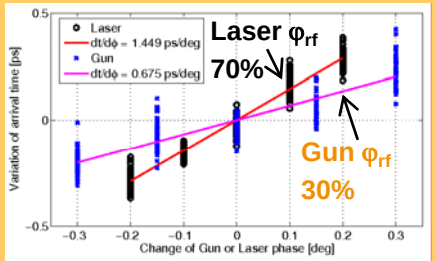
~ 35% of complete system

Posters
→ **WEPC66**
→ **WEPC69**
→ **WEPC70**
→ **WEPC72**

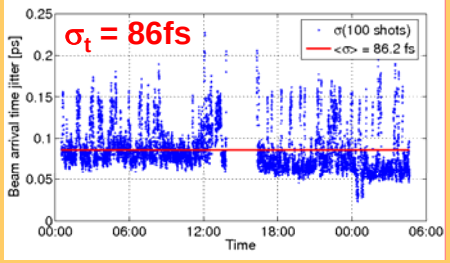
Talk:
→ **FROA05**

Arrival time drift & jitter from photo-injector

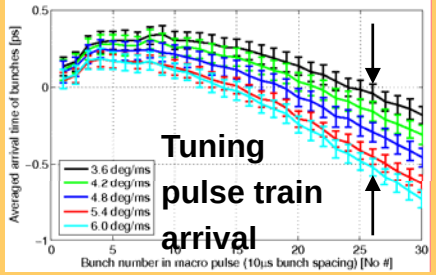




Without FB!

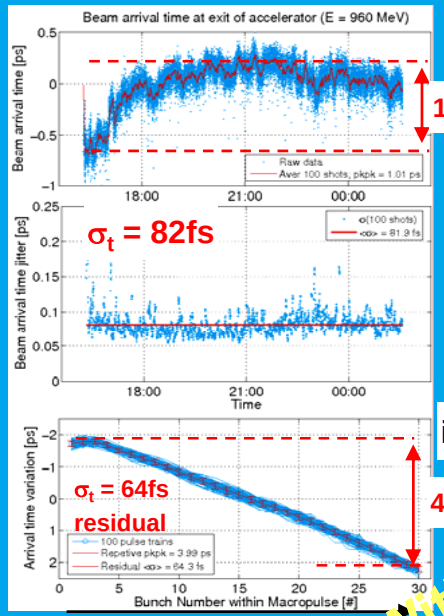


Without AFF!



For FB missing: robust exception handling

& exit of linac



Faatz

Improvement of the machine performance

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Comparison of 7 nm run during August 2008 and July /August 2009

7 nm most critical wavelength with minimal tolerance

Period of large temperature variations → high demand on stability

Same/similar user groups → similar demands on machine performance

Not representative of entire machine performance

August 2008 was an example of low SASE, high instability

Lasing distribution: July/August, 2009

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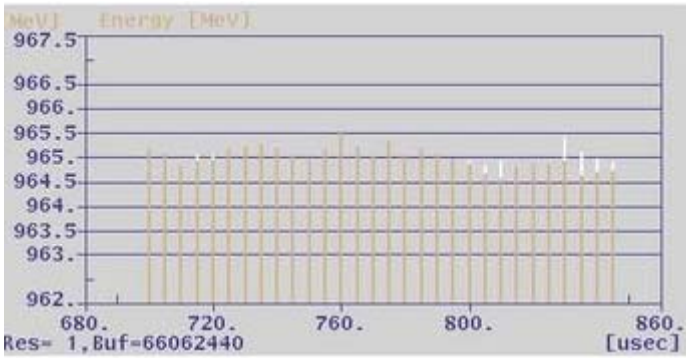
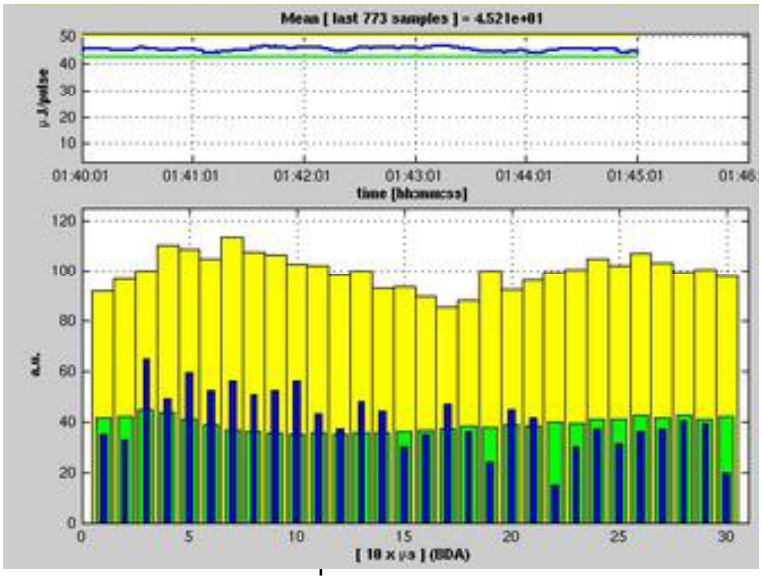
Free-Electron Laser in Hamburg

0.02% rms flatness over pulse train

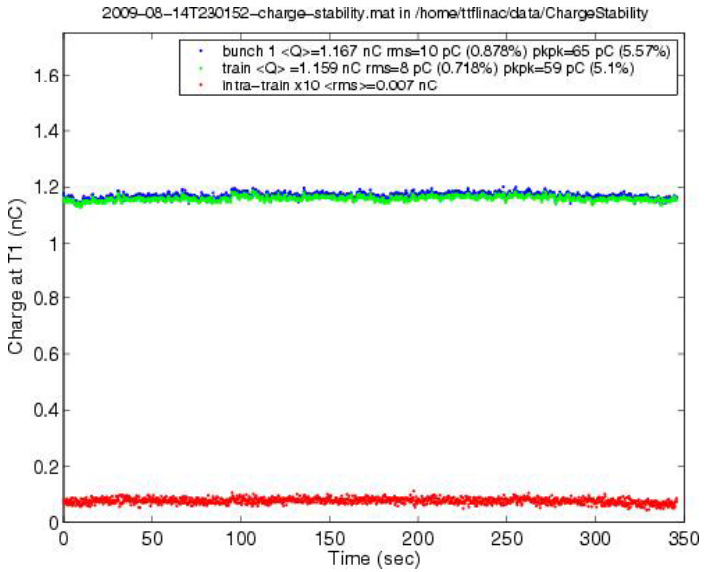


45 μJ for10x10 mm apertures, 100 kHz at 7.02 nm

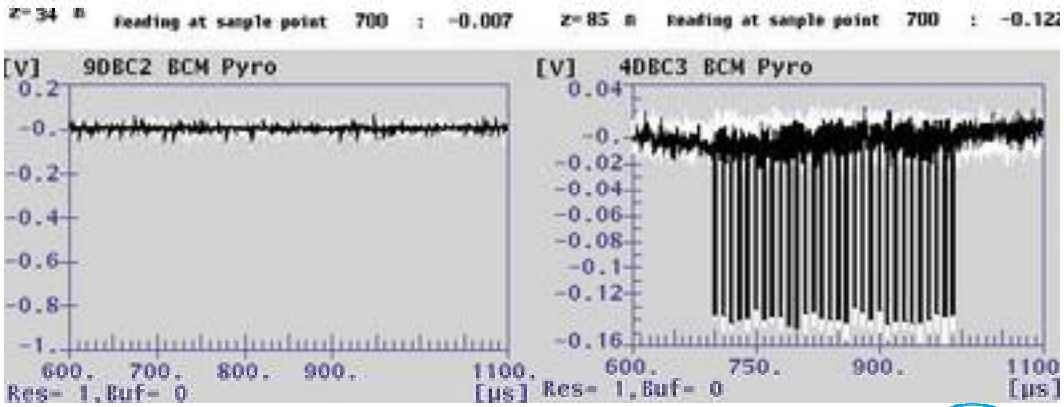


0.9% rms charge fluctuation

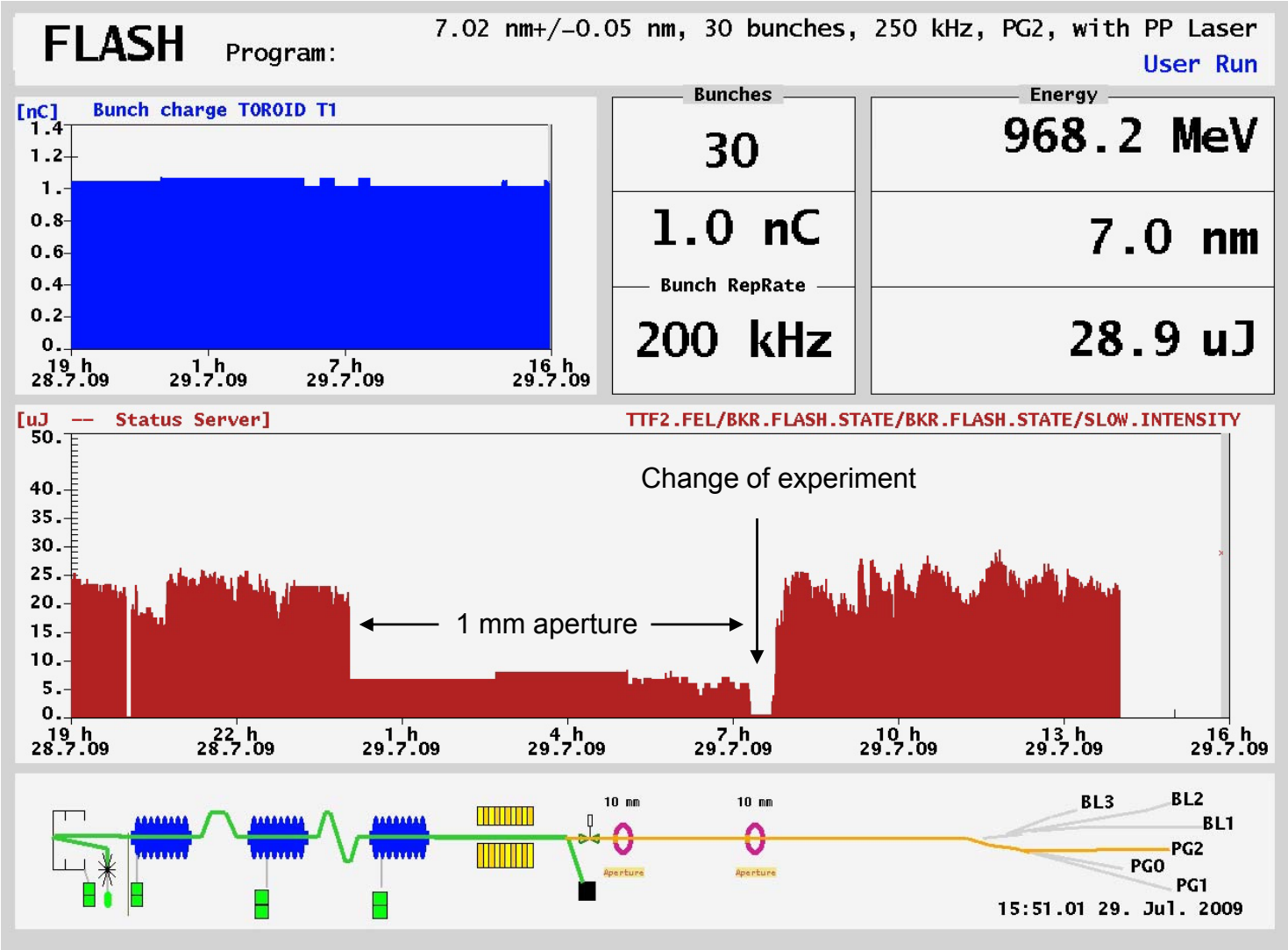
7 pC intra train flatness



Flatness of compression signal for feedback



DESY


FLASH
Program:
7.02 nm+/-0.05 nm, 30 bunches, 250 kHz, PG2, with PP Laser
User Run
[nC] Bunch charge TOROID T1
1.4
1.2
1.
0.8
0.6
0.4
0.2
0.
19 h 28.7.09
1 h 29.7.09
7 h 29.7.09
16 h 29.7.09
Bunches
30
1.0 nC
Bunch RepRate
200 kHz
Energy
968.2 MeV
7.0 nm
28.9 uJ
[uJ -- Status Server]
TTF2.FEL/BKR.FLASH.STATE/BKR.FLASH.STATE/SLOW.INTENSITY
50.
40.
35.
30.
25.
20.
15.
10.
5.
0.
Change of experiment
1 mm aperture
19 h 28.7.09
22 h 28.7.09
1 h 29.7.09
4 h 29.7.09
7 h 29.7.09
10 h 29.7.09
13 h 29.7.09
16 h 29.7.09
10 mm
10 mm
Aperture
Aperture
BL3
BL2
BL1
PG2
PG0
PG1
15:51.01 29. Jul. 2009

Upgrade Plans

FLASH
Free-Electron Laser in Hamburg

- Rebuild dump beamline (finished) + ILC 9mA test in September
- Upgrade in 2009/2010: major modifications
  - installation the 3rd harmonic (3.9 GHz) accelerating module
  - installation of the 7th accelerating module → energy up to ~ 1.2 GeV ↔ <5 nm
  - installation of an experiment for seeded VUV radiation “sFLASH”

  → replacement of complete electron beam line between collimators and SASE undulators (~ 40 meters)
  - exchange of the RF gun
  - upgrades of RF stations and waveguide distribution
- Commissioning spring 2010
- The 3rd FEL user period is foreseen to start summer 2010
- Beyond this upgrade: proposal for a 2nd undulator beamline (FLASH II) together with Helmholtz Zentrum Berlin (HZB)

Upgrade: Linac layout

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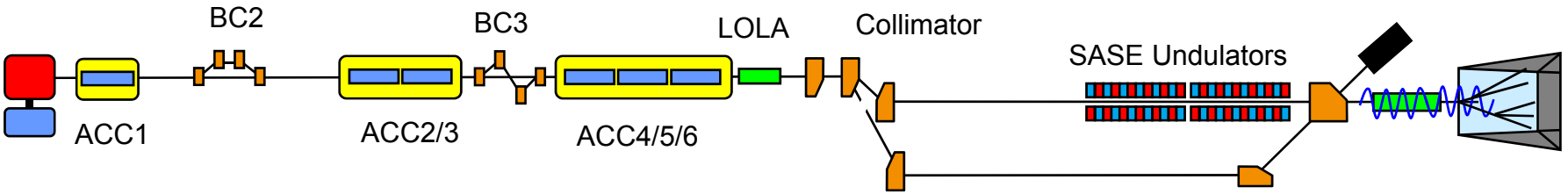
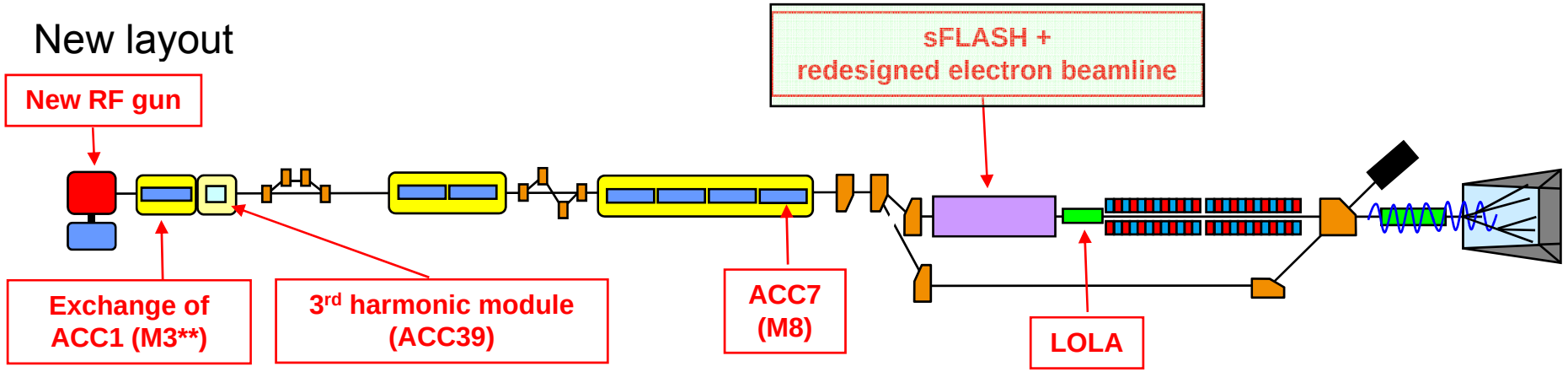
Free-Electron Laser in Hamburg

Present layout



New layout



DESY

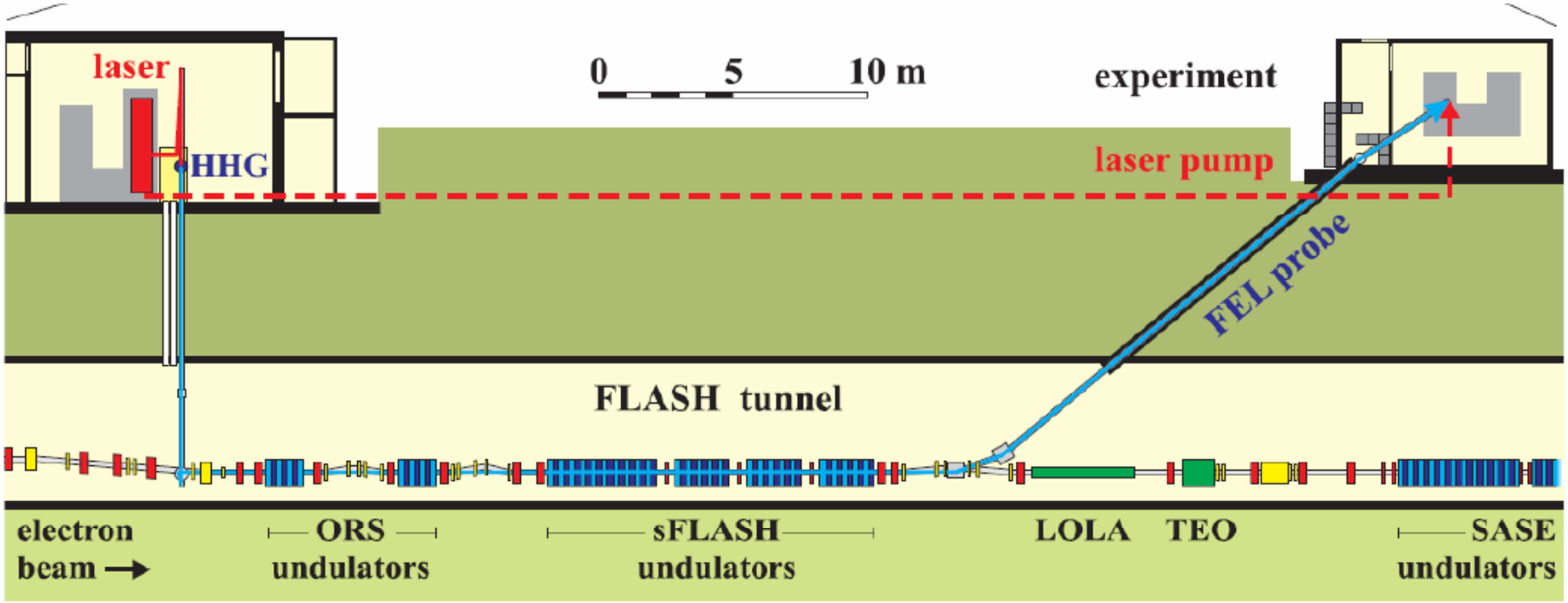
sFLASH

WEPC04, WEPC05, WEPC73, THOB05

FLASH
Free-Electron Laser in Hamburg

> High Harmonic Laser Seeding at 30nm

> To be installed between the linac and the FLASH undulators



top view

DESY

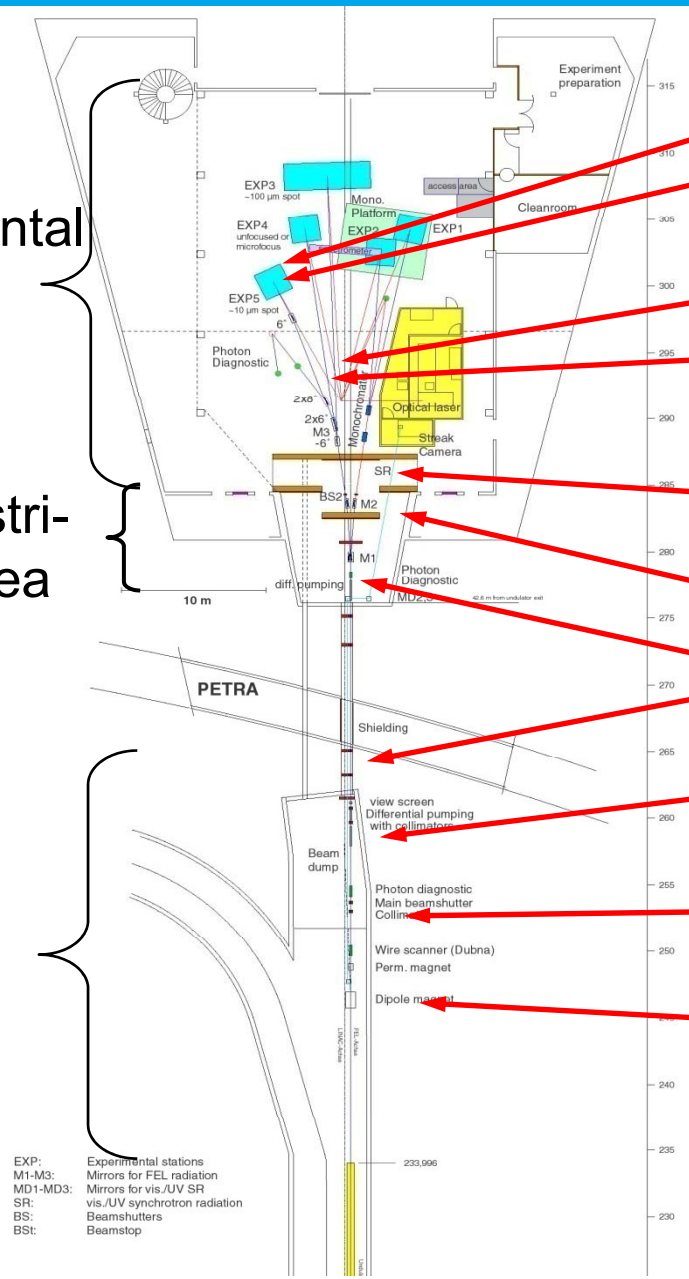
Upgrade: Hall layout

FLASH
Free-Electron Laser in Hamburg

Experimental hall

Beam distri-bution area

Tunnel



-Install a focusing mirror at BL3

-Modify differential pumping units of the BL2 and BL3 end stations

-Install a fast switching mirror unit

-Include the autocorrelator as a permanent device in the direct beamlines

-Install new filter units and new fast shutters

-Repair VLS spectrometer

-Modify differential pumping units

-Install additional BPMs with MCP/fluorescence screen monitor

-Install new online spectrometer based on atomic photoionisation (like GMD)

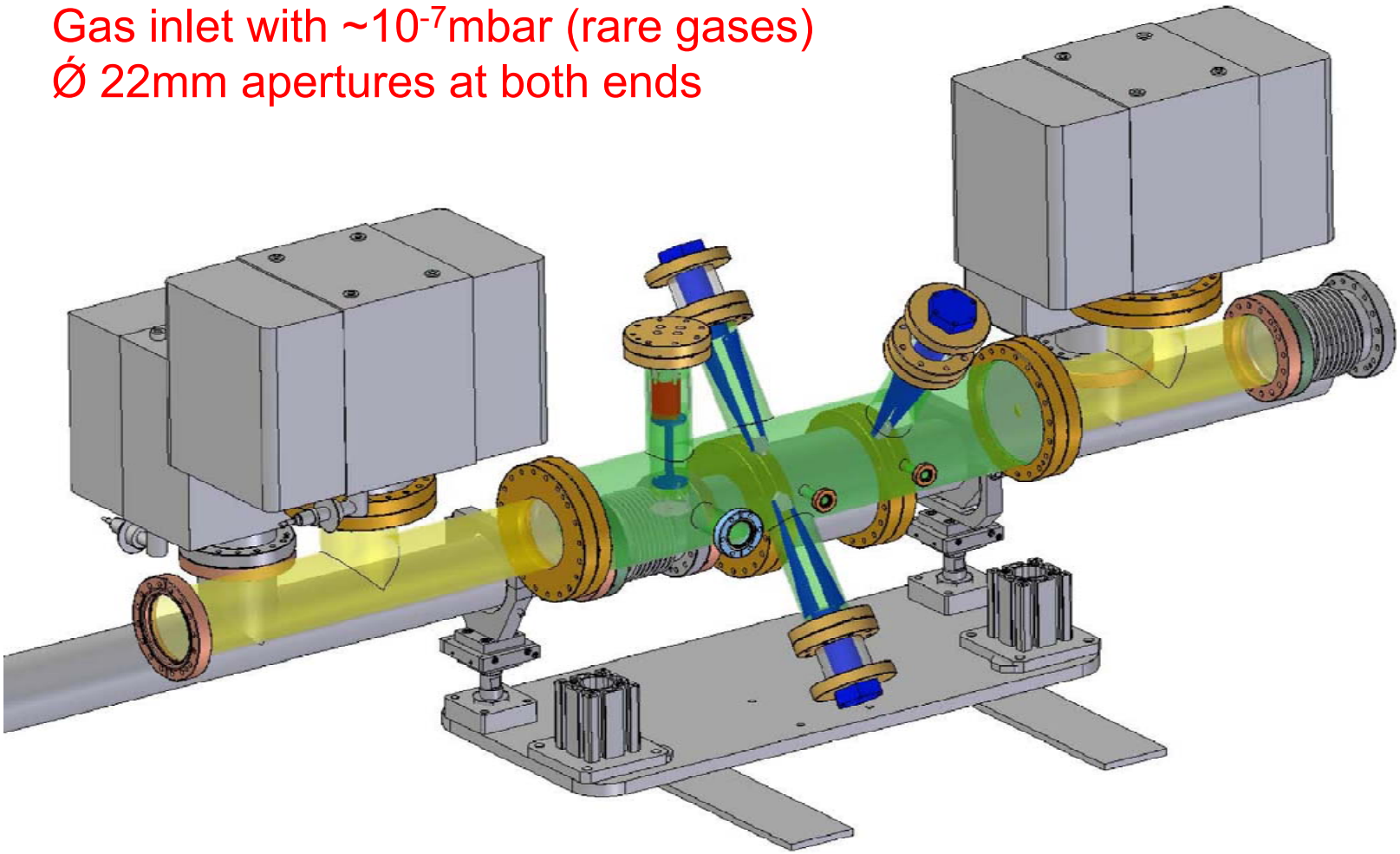
-Install a MCP/fluorescence screen monitor in the MCP tool

DESY

Online determination of the spectral distribution using i- and e- TOF spectrometer

FLASH
Free-Electron Laser in Hamburg

Gas inlet with ~10^{-7}mbar (rare gases)
Ø 22mm apertures at both ends



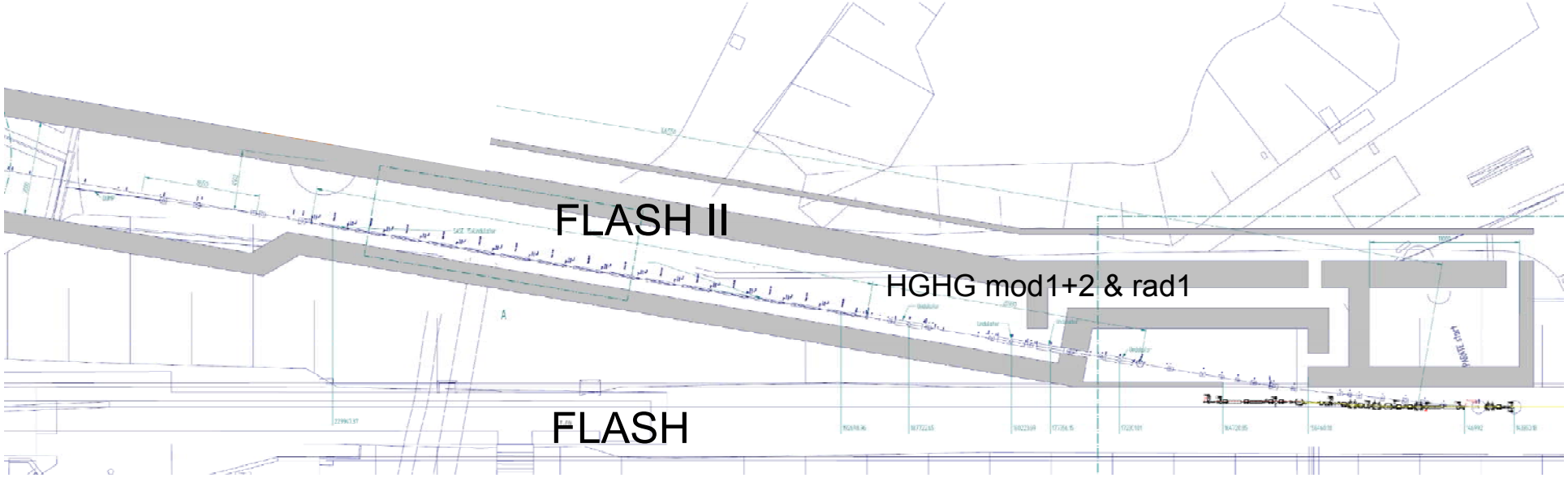
WEPC01 for details

DESY

HELMHOLTZ ZENTRUM BERLIN
für Materialien und Energie

Combined DESY/HZB proposal for a 2nd undulator line (FLASH II)

DESY



Extend user capacity with HHG/HGHG seeding

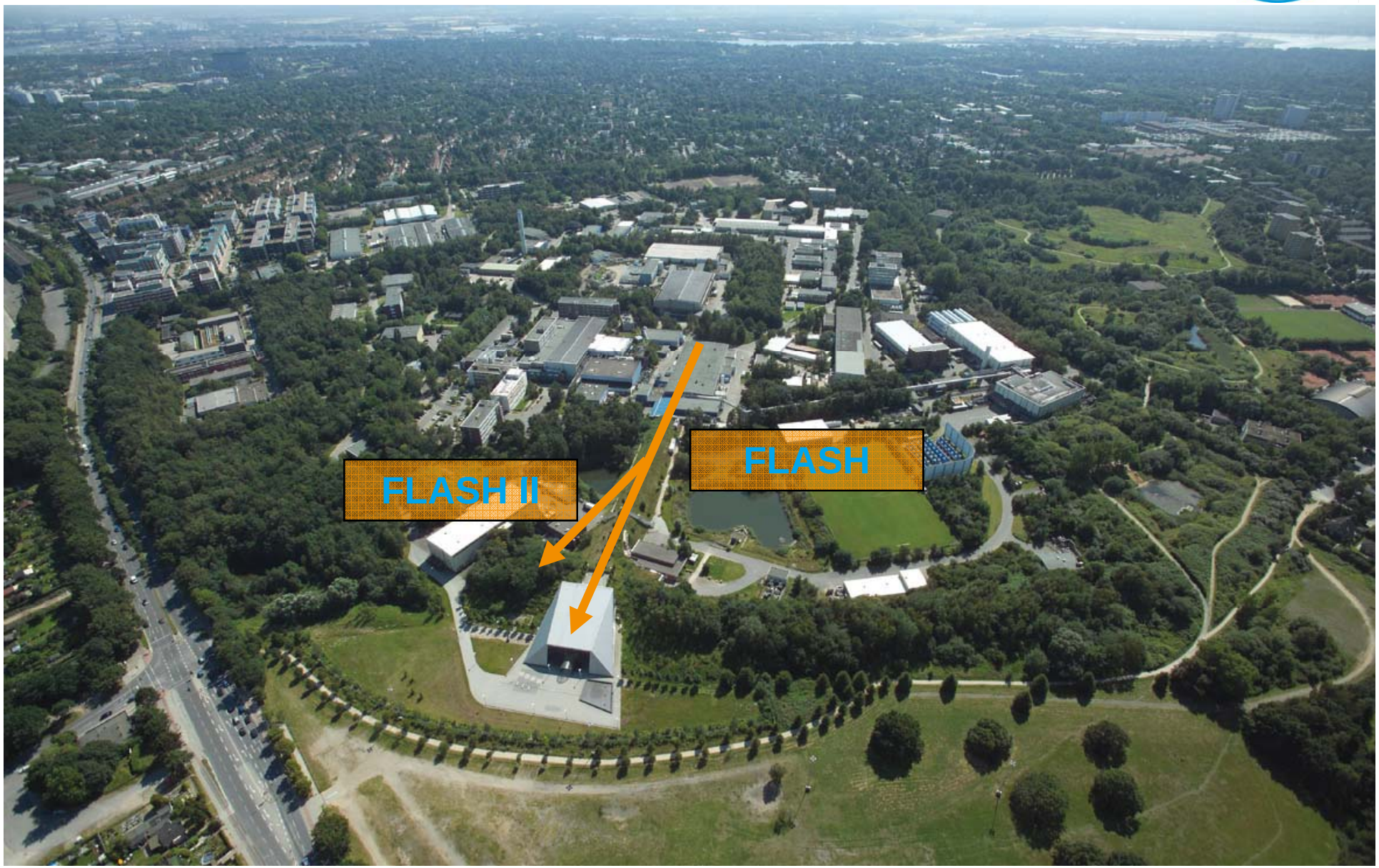
Use of existing infrastructure up to last accelerating module

New undulator tunnel, new experimental Hall

Decision on Funding end of 2009

HELMHOLTZ
ZENTRUM BERLIN
für Materialien und Energie

DESY



Summary

FLASH
Free-Electron Laser in Hamburg

- FLASH is a world-wide unique light source
  - in the wavelength range of 47 nm to 6.8 nm
  - ultra-short FEL pulses (10 to 50 fs)
  - unprecedented brilliance
- Since summer 2005, user FEL experiments in different fields have been performed successfully
- Upgrade shutdown 21-Sep-2009 to 1-March 2010
  - increase beam energy to 1.2 GeV (<5 nm)
  - 3rd harmonic cavity
  - seeding experiment sFLASH
- 3rd user period will start summer 2010
- Proposal pending for a 2nd beamline (FLASH II) together with HZB
- FLASH is also a world-wide unique test facility for SCRF technology

DESY