FLASH
Free-Electron Laser
in Hamburg
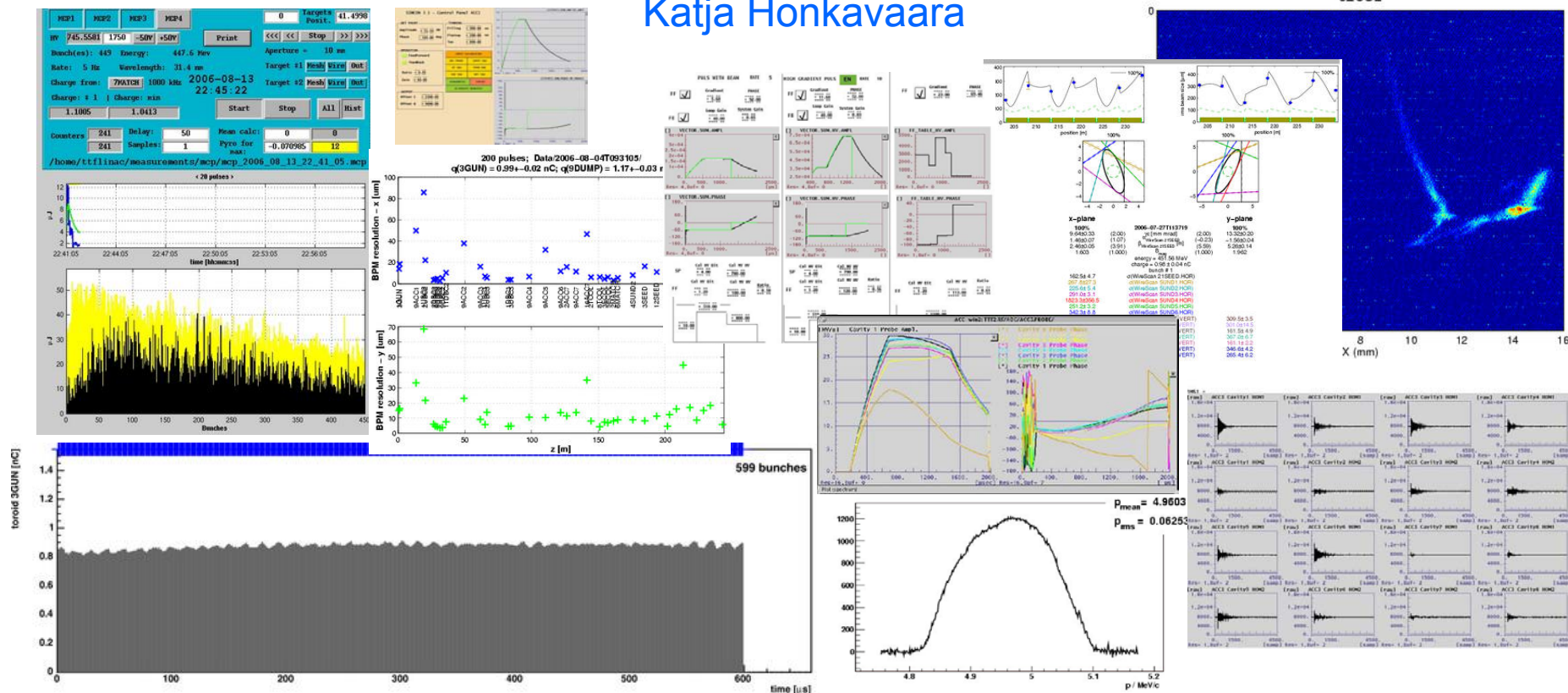
Accelerator studies at FLASH
24.7-14.8.2006

Katja Honkavaara

- Requests collected well in advance, beam-time has been allocated according to available beam time and possibilities, supervised by the BAC

- Requests for ~ 120 shifts (63 shifts available)

- Some of studies possible parallel, but still almost by factor of 2 more requests as available beam time

- Some studies shifted to FEL study periods

- Collaborators from different laboratories

Study subjects

Study	FLASH	XFEL	ILC
High gradient / cryo	(x)	(x)	x
HOM	x	x	x
Long bunch trains	x	x	
LLRF	x	x	x
Projected emittance	x	x	(x)
Slice parameters	x	x	
CSR effects		x	
Collimator studies	x		
Electron beam diagnostics (BPM, Phase monitors, THz, EO, SR)	x	x	(x)
RF-gun / QE / Laser	x	(x)	

General statistics

	Done	Planned
Accelerator developments	80%	89%
Tuning	10%	2%
Down	6%	5% (contingency)
Off (Maintenance)	4%	4%

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Distribution of beam time

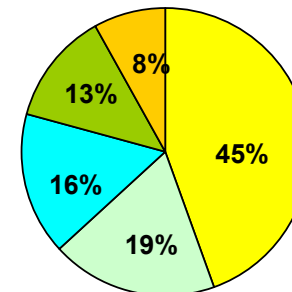| Beam time (including contingency)	Done	Planned	Comments
LLRF developments	18%	17%	Including parallel: 26% (24%)
Long bunch trains	13%	20%	Including tuning: 17%
High gradient + Cryo	11%	13%	
HOM	10%	10%	
Slice measurements	7%	7%	
Projected emittance	5%	6%	
Collimator studies	3%	5%	
BPM	3%	5%	
RF-gun / Laser / QE	2%	0%	Including parallel: 6% (6%)
CSR	3%	5%	
THz + EO	2%	3%	Including tuning: 3%
Phase (beam arrival time) monitor	1%	2%	
Phase monitor	1%	1%	
SR monitor	1%	1%	
Miscellaneous	2%	0%	

Distribution of beam time
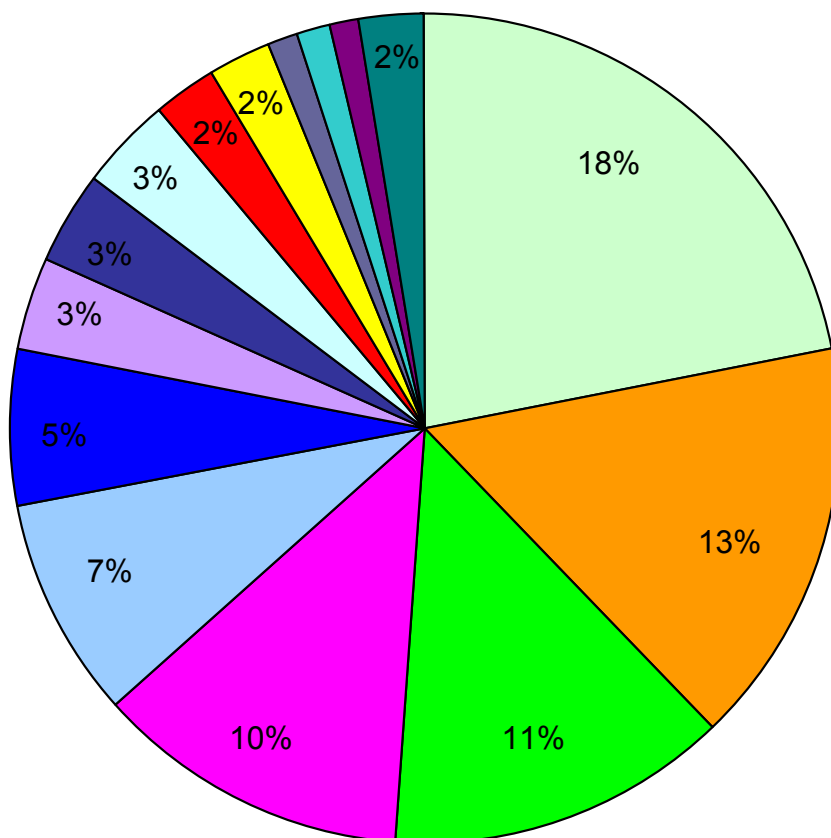
Legend:
- LLRF
- Long bunch trains
- High gradient + cryo
- HOM
- Slice measurements
- Projected emittance
- Collimator
- BPM
- CSR
- RF-gun
- THz+EO
- Phase monitor 1
- Phase monitor 2
- SR monitor
- Miscelleaneous

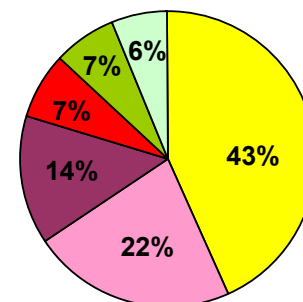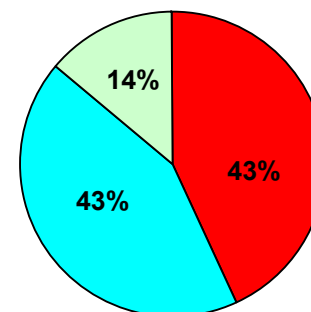Katja Honkavaara, FLASH seminar, 5.9.2006

Downtime

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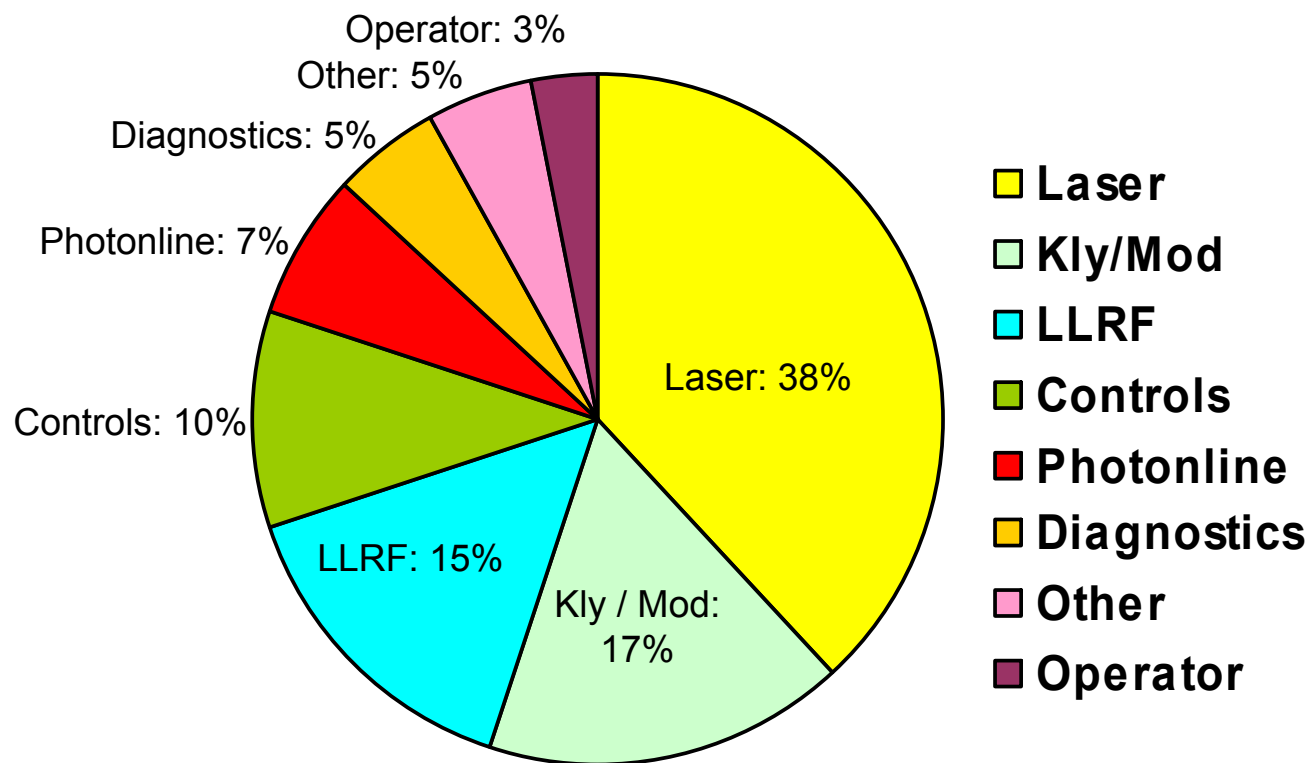
LLRF developments

- Installation of SIMCON 3.1 board to ACC1
  - → ACC1 controlled by FPGA instead of DSP
- Alternating gradient ACC4/5
  - Successful test to run ACC4/5 at 10 Hz with
    - Low gradient pulse (5 Hz) for beam (SASE)
    - High gradient pulse (5 Hz) for max performance of the module or with step gradient
  - SASE not disturbed
  - → can be used as permanent running mode
- Miscellaneous studies
  - Developments of LLRF controls based on SIMCON (FPGA)
  - Beam load compensation of ACC1 with SIMCON
  - Transient measurements
  - Characterization of klystron non-linearities
  - RF and klystron FSM
  - Detuning estimation
  - RF-gun studies (e.g. long RF pulse)
- Collaborators from Poland and TU-Harburg

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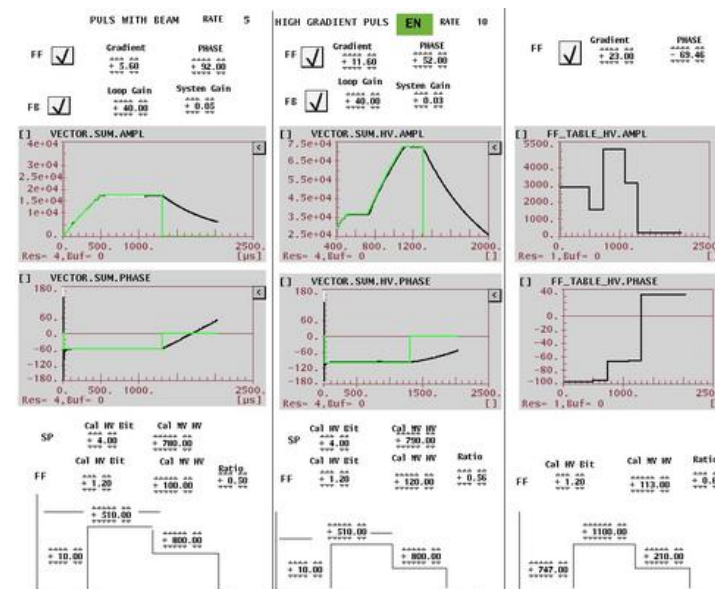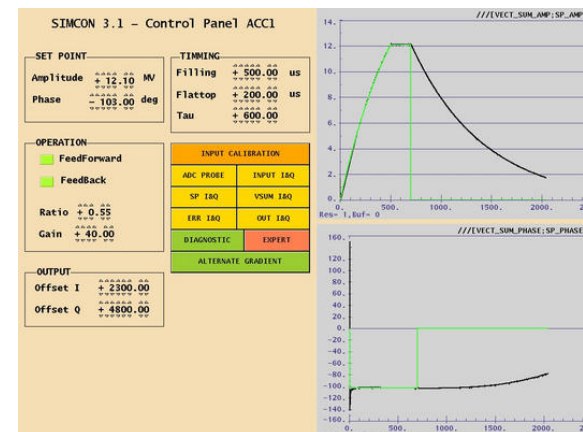
Lasing with long bunch trains

- Up to 600 bunches (1 MHz) through the undulator
  - 500 kHz, 100 kHz, and 50 kHz tested as well
- Lasing with at least 450 bunches (detector limit)
  - Level: tens of uJ
- Problems:
  - Toroid protection system not yet in operation
  - Improvements required for photon diagnostics
  - Beam loading compensation and other LLRF adjustments for 800 us flat top
  - Activation of beam line components due to darkcurrent (mostly from RF gun)

1 MHz
599 bunches

50 kHz

100 kHz

500 kHz

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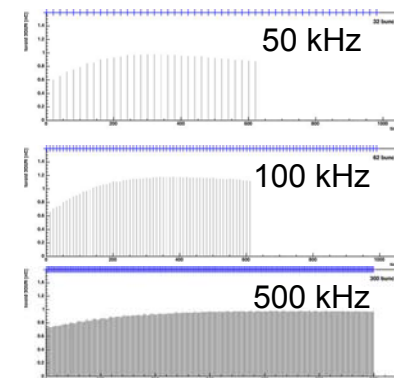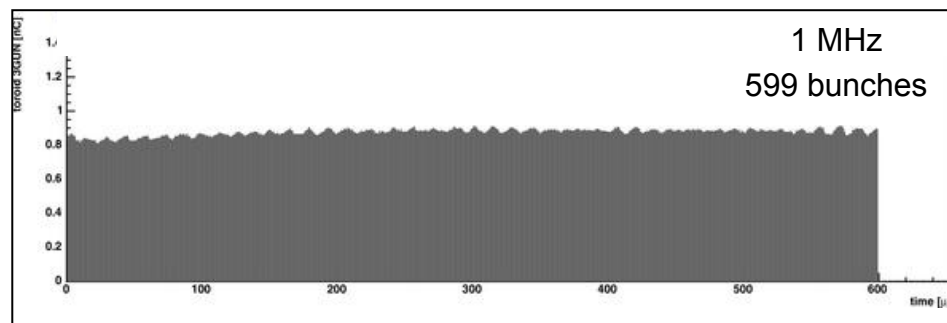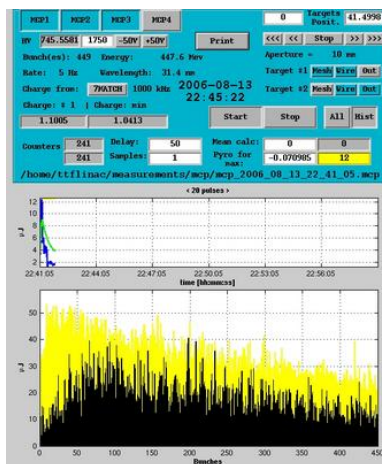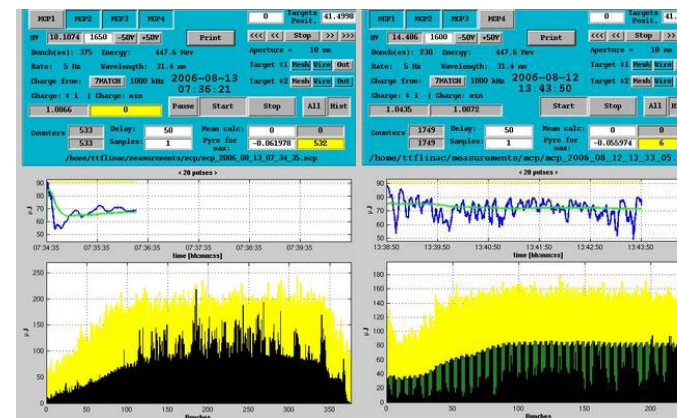
High gradient + cryo measurements

- ACC4/5 running with 10 Hz

- ACC4 ~ 20 MV/m and ACC5 ~ 22.5 MV/m
  - Run ~ 17 h
  - Cryo and radiation measurements (gammas and neutrons)

- Max gradient of ACC5, ACC4 gradient reduced
  - Run ~ 26 h
  - ACC5: ~ 28 MV/m (cavities 8 and 6 slightly detuned to get more power to other cavities)
  - ACC4: ~ 12 MV/m
  - Maximum cryogenic load to test the cryo system
  - Radiation measurements (gammas and neutrons)

ACC4

ACC5

ACC5

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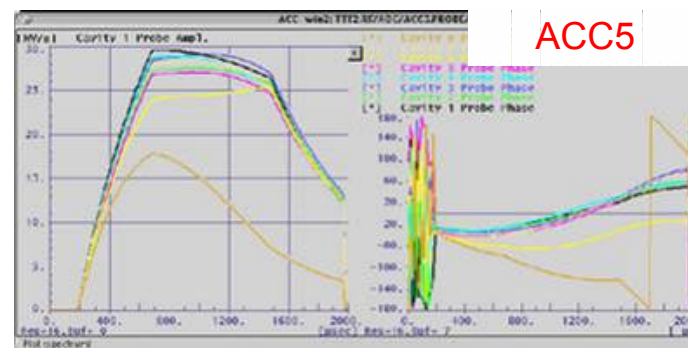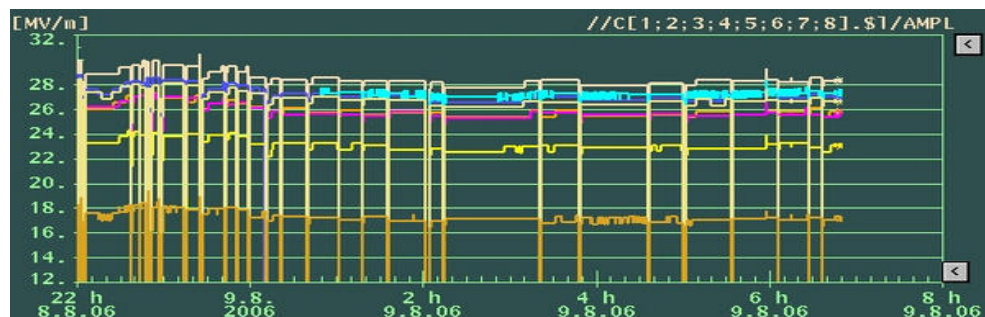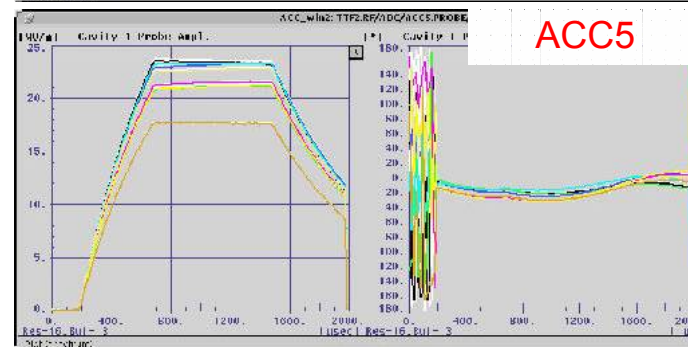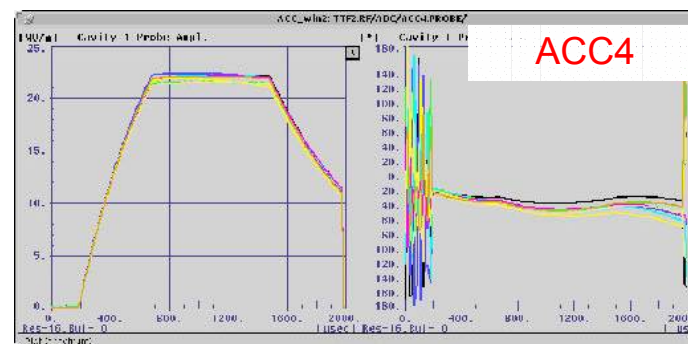
High order mode (HOM) measurements

- Development of on-line BPM like display of HOM based beam positions
- Dependence of HOM signal on the module phase
- Several scans done for each module
- Parallel: gather experience of DOOCS based control system
- Collaborators from SLAC, Fermilab, KEK

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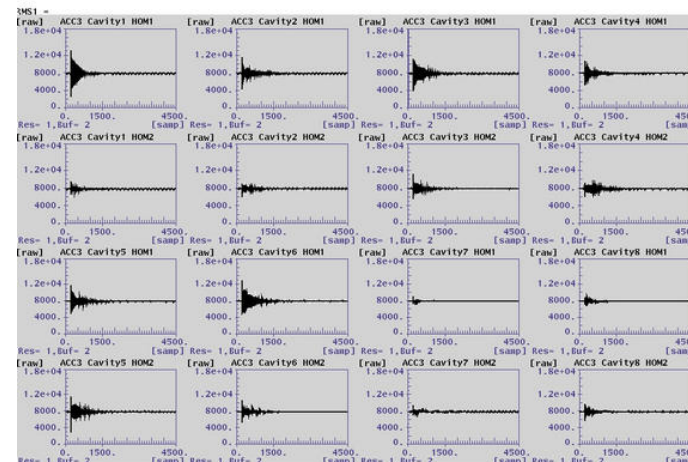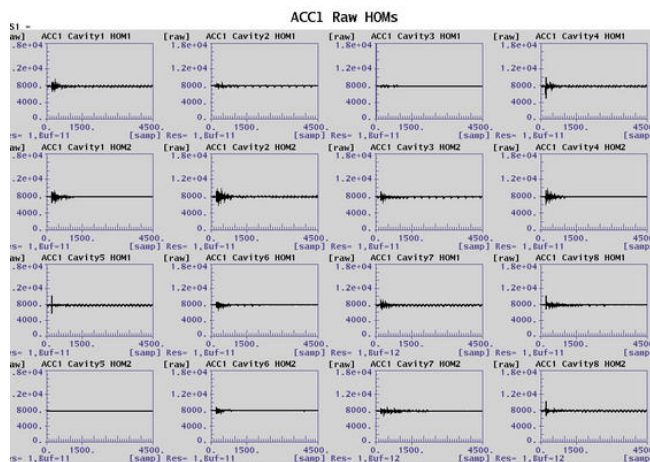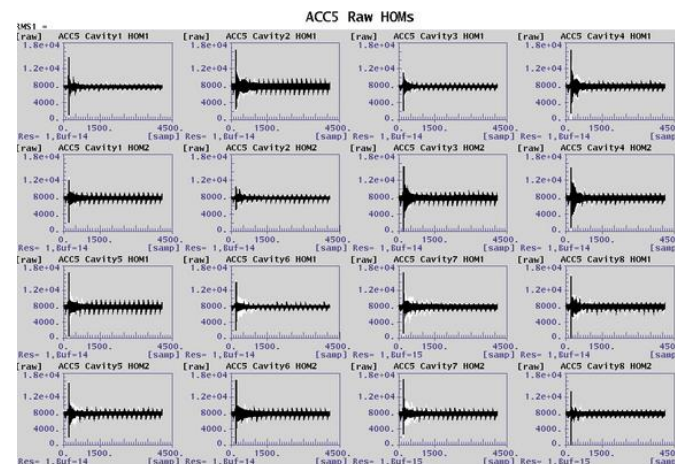
Measurements of slice parameters

- Measurements of energy-time correlation
- Data taken for slice emittance and spatial tomography under SASE conditions
- Study of the longitudinal tilts of the bunch

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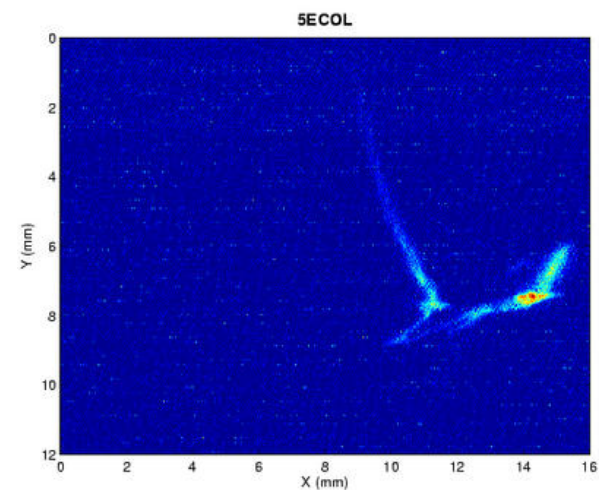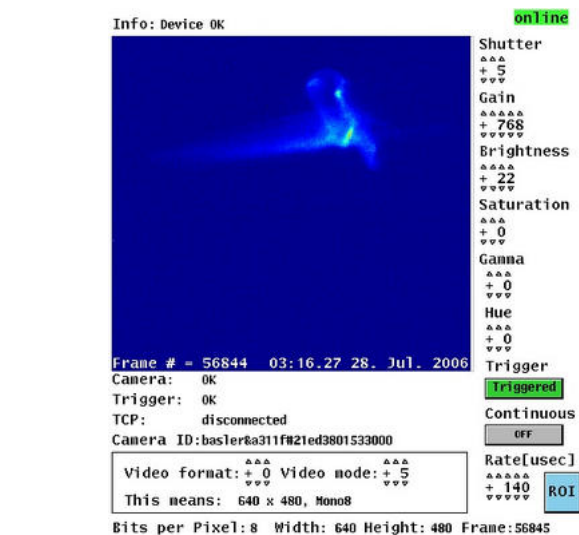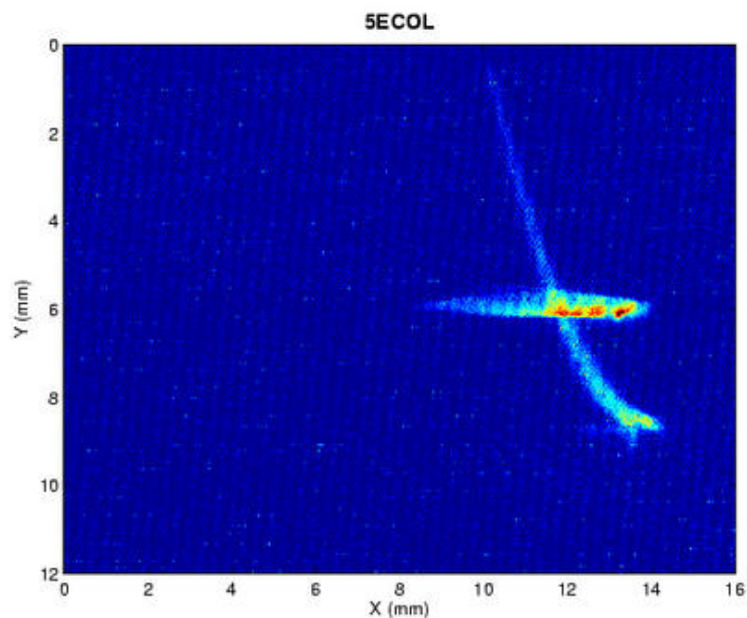
Projected emittance

- Emittance measurement program integrated with optical tool box by V.Baldin and N.Golubeva

- Measurements of projected emittance at DBC2 and undulator (on-crest and off-crest) + dispersion corrections

- Comparison with predictions from linear optics

- Discrepancies

  – Emittance growth by factor of ~ 2

  – Disagreements with linear optics

  → More studies required

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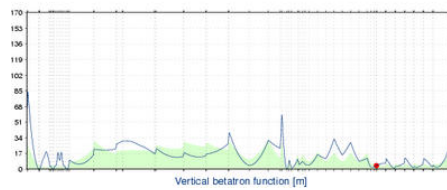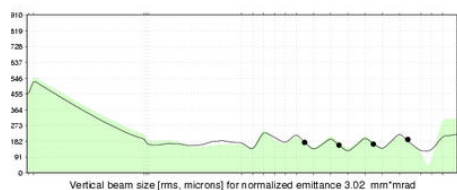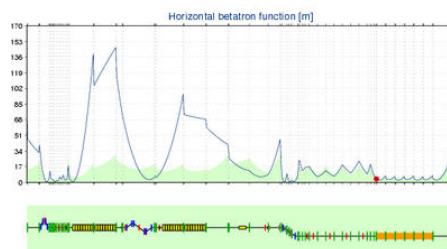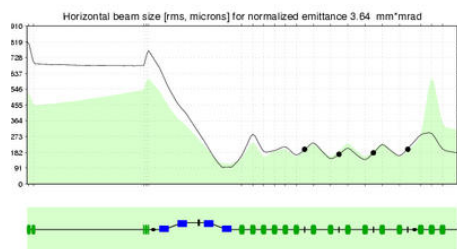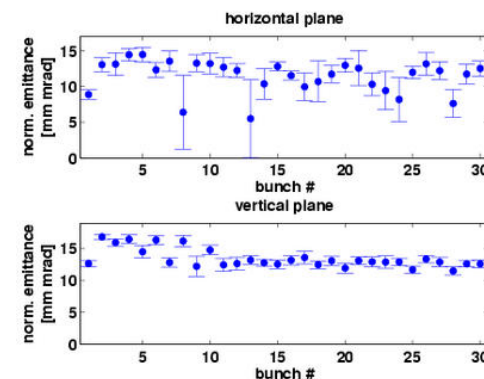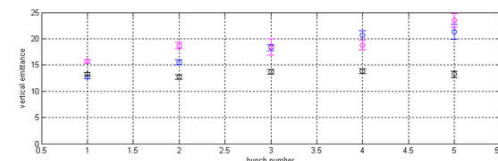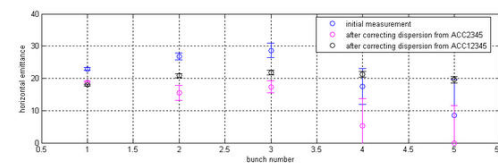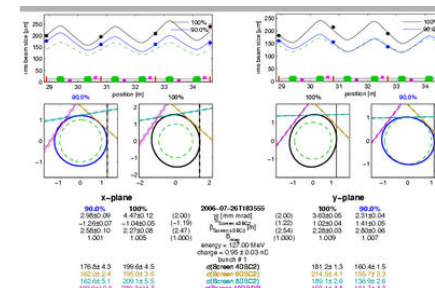
- QE measured as a function of gun power
- Software from PITZ to measure gun momentum distribution integrated to FLASH
- Gun momentum and momentum spread measured as function of gun phase

$p_{mean} = 4.9603$
$p_{rms} = 0.06253$

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BPM
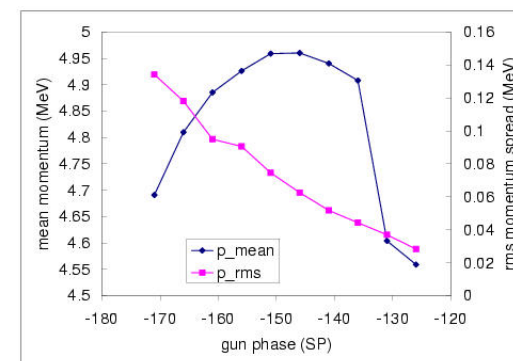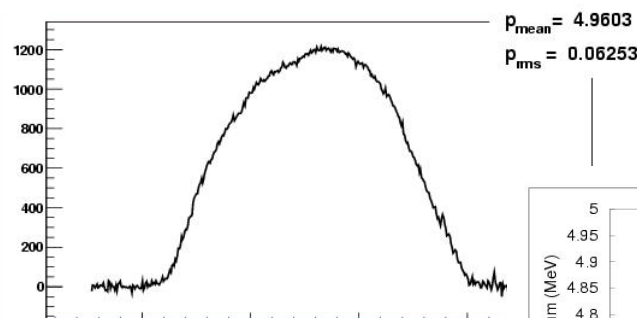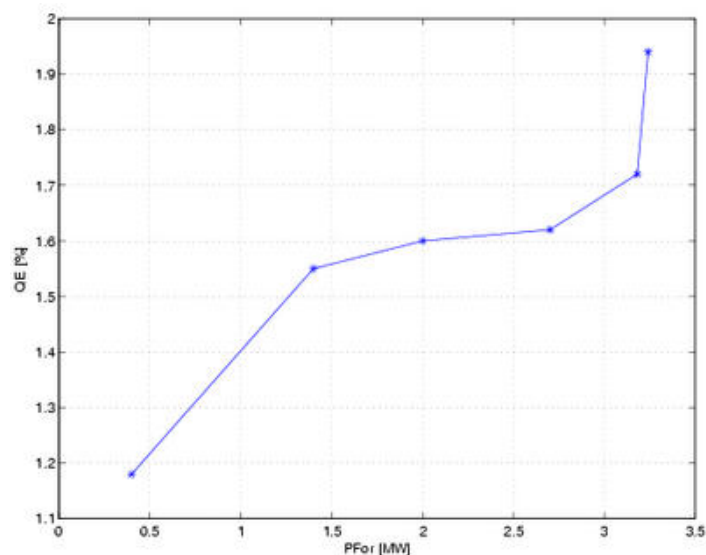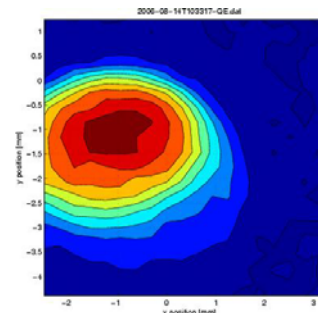
- Cold reentrant BPM prototype (Saclay)
  - Adjustments, noise studies, calibration
- Study on the dependency of BPM resolution on the charge (0.05 - 1.2 nC)
- Study on non-linearity of stripline BPM-electronics
- Timing and calibration checks

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Miscellaneous studies
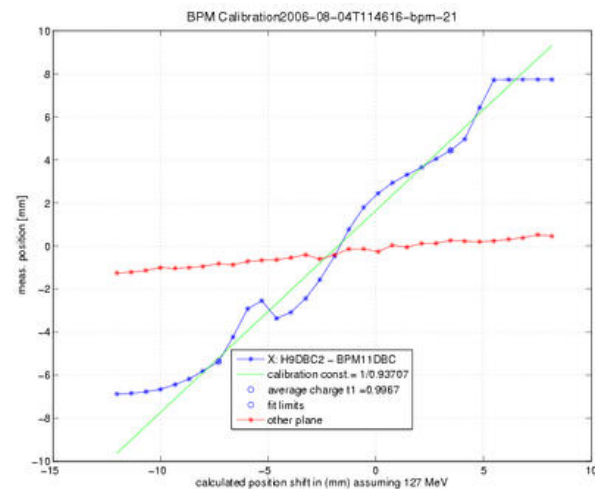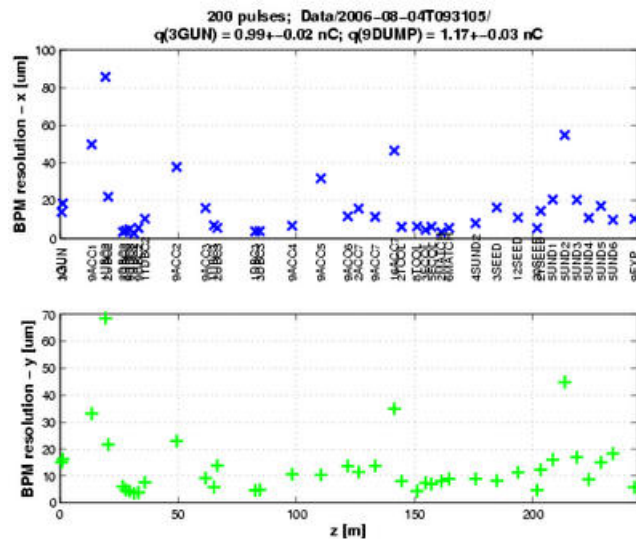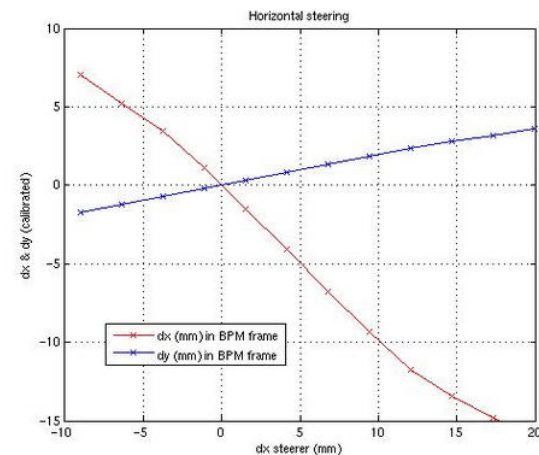
- Coherent synchrotron radiation (CSR)
  - CSR induced centroid shifts measured by LOLA for two different optics in BC2
  - Problems: bunch tilt, matching to DBC2
- Synchrotron radiation monitor BC2
  - Calibration of energy axis, SR images taken for several ACC1 phases
- Collimator studies
  - Acceptance of collimator 2TCOL measured in FEL mode and in BYPASS mode
- THz + EO measurements
  - THz: Spectra with old and new pyrodetectors. Shortest ever wavelengths (1.3 to 2.3 um) of coherent transition radiation measured.
  - EO: EO signal dependence on beam position. Calibrations for EO laser polarisation. EO timing measured in parallel with phase monitor timing.
- Phase (beam arrival time) monitor (ACC7)
  - Studies on orbit dependence
- Phase monitor
  - Test of phase monitor 4DBC3

Summary

- Important goals achieved:
  - Lasing with long bunch trains
  - ACC1 controlled by SIMCON 3.1 (FPGA)
  - Successful test to run ACC4/5 with 10 Hz with alternating gradient
  - High gradient + cryo test ACC4/5
  - HOM measurements (involved a large collaboration)
  - Studies on slice parameters and projected emittance (linear optics)
  - Several studies and developments on LLRF, electron beam diagnostics, RF-gun, CSR, …
- Results will be presented in FLASH seminars during autumn 2006
- Accelerator study blocks before shutdown in spring 2007
  - KW 50-51: 11.-22.12.2006
  - KW 2-3: 8.-21.1.2007
    - Partly used for start-up and machine set-up for SASE
  - Requests of beam time for both blocks will asked soon