EuCARD2 proposal

LLRF Optimization at FLASH

M.Grecki for the LLRF team

FLASH

Free-electron LASer in Hamburg

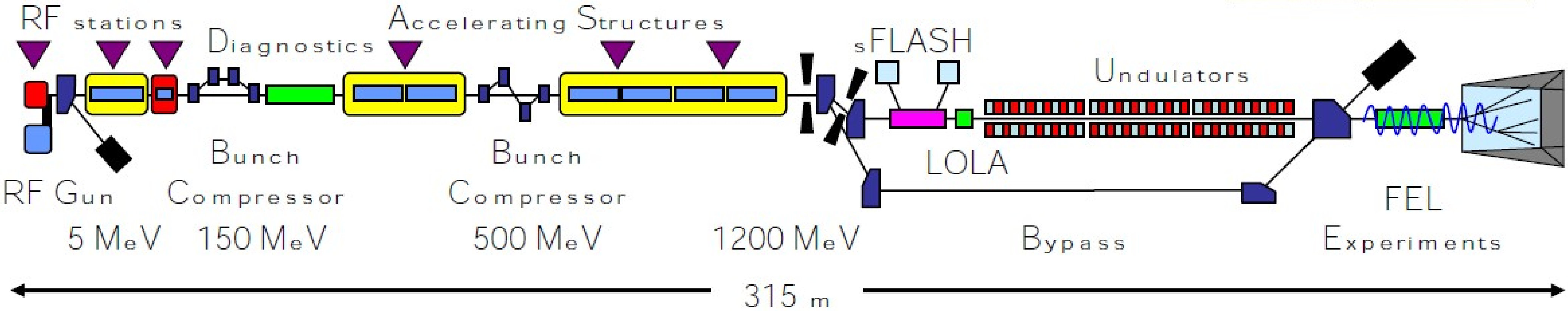
- Single-pass high-gain SASE FEL

  SASE = self-amplified spontaneous emission

- Photon wavelength range from vacuum ultraviolet to soft x-rays
- Free-electron laser user facility since summer 2005
  - 1st period: Jun 2005 –Mar 2007
  - 2nd period: Nov 2007 –Aug 2009
  - 3rd period: Sep 2010 –Sep 2011
- FLASH is also a test bench for the European XFEL and the International Linear Collider (ILC)
- FLASH II, a second undulator beam line is in preparation

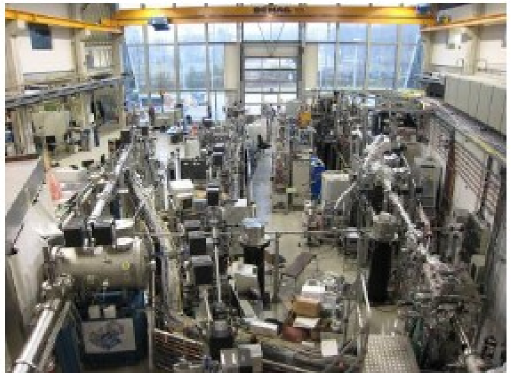
FLASH



RF stations
Diagnostics
Accelerating Structures
sFLASH
Undulators
RF Gun
Bunch Compressor
Bunch Compressor
LOLA
FEL
5 MeV
150 MeV
500 MeV
1200 MeV
Bypass
Experiments
315 m



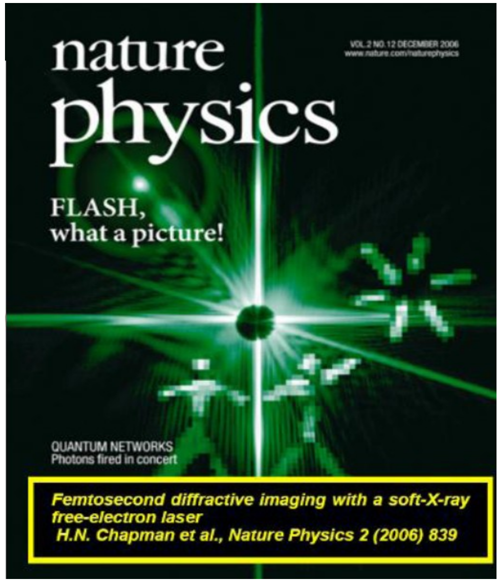
FEL performance 2nd user period

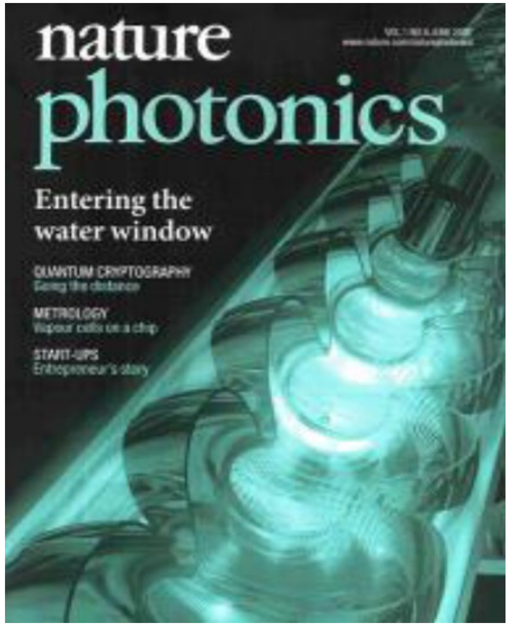
(Nov-2007 –Aug-2009)

- Typical user operation parameters 2nd user period
  - Wavelength range (fundamental) 6.8 –40.5 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} *

* photons/s/mrad^2/mm^2/0.1%bw

more than 100 publications on photon science at FLASH in high impact journals
http://hasylab.desy.de/facilities/flash/publications/selected_publications





LLRF upgrade 2009/10 - hardware

- Master Oscillator
  - Redundant MO with distribution
  - Local distribution in Cryoannex
- Field control
  - Uniform SimconDSP based LLRF system at FLASH
  - New cabling in GUN, ACC1
  - Installation of ACC39 control
- Piezo control
  - Permanent installation at ACC1, ACC3, ACC5, ACC6, ACC7

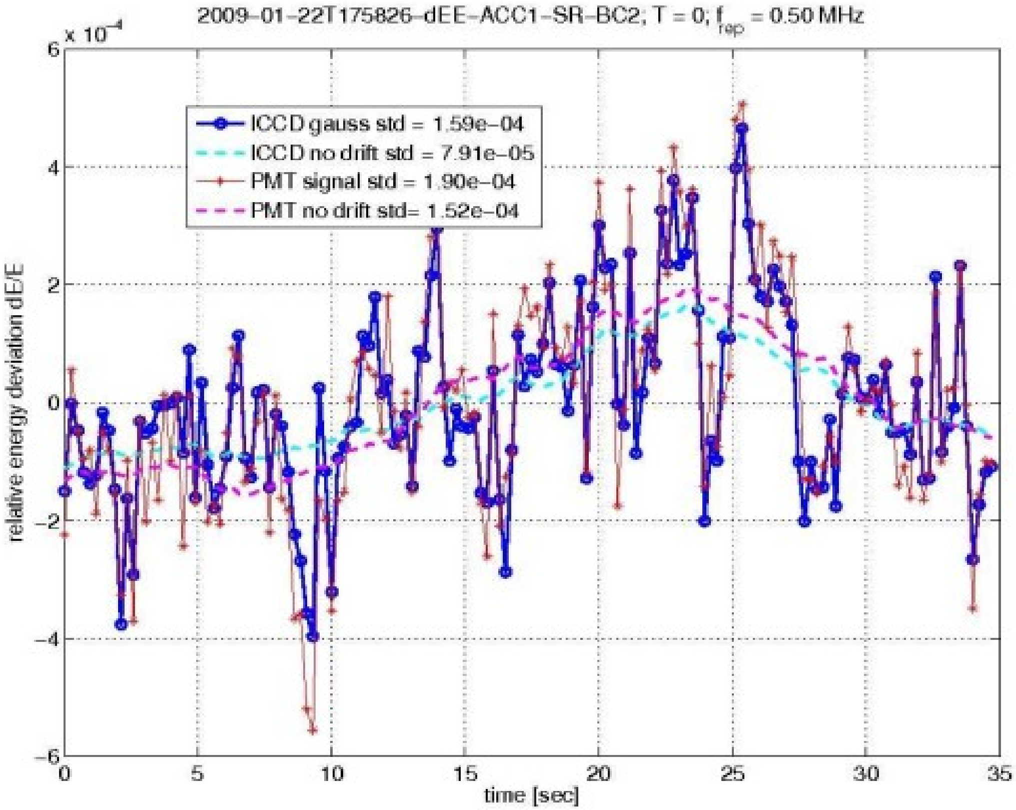
LLRF at FLASH in EuCARD

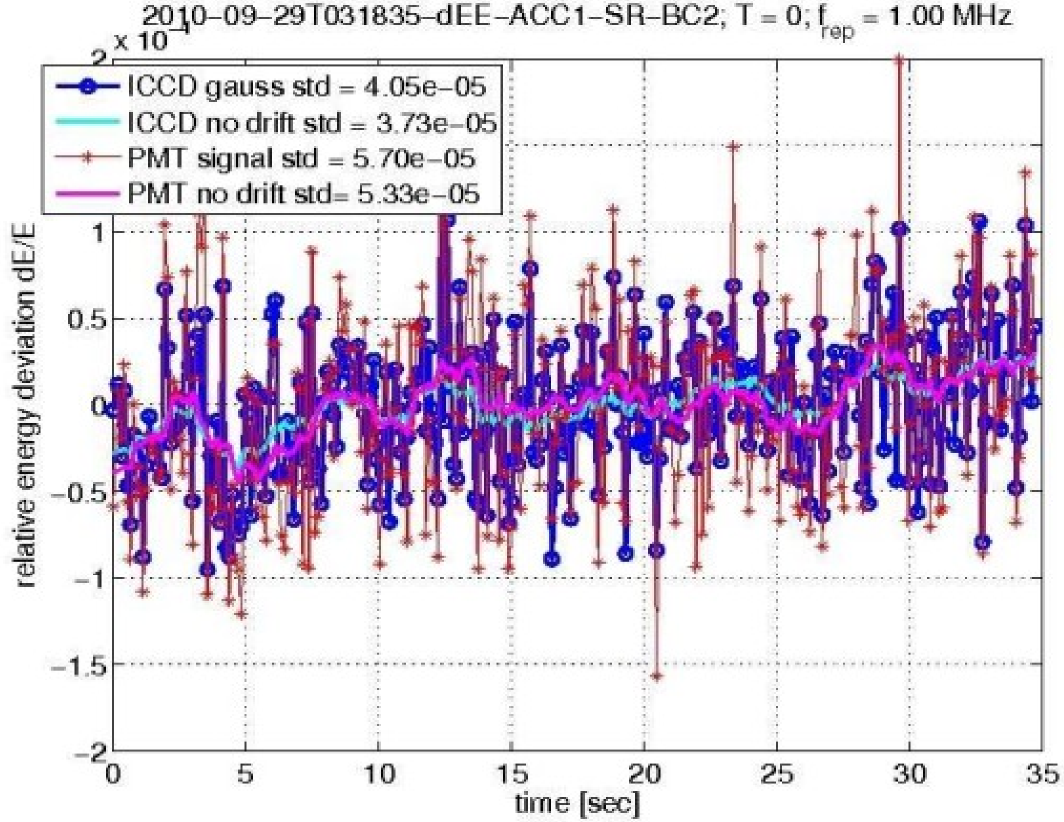
The goal of the project is to advance RF Control Technology and to test developed solutions in FLASH accelerator:

- develop LLRF implementation as HA xTCA System with required fast and ultra fast analogue and digital IO
- develop new frequency conversion and multi-channel downconverter
- develop radiation monitoring (based on customized ASIC and standard components)
- develop other necessary control systems (piezo, waveguide) and integrate them with xTCA based LLRF system
- improve technical performance
- optimize reliability availability
- reduce cost

Project is in progress but the performance and reliability boost is already visible.

Energy stability





- FLASH elogbook 22.1.09 18.08h
- ACC1 off-crest
- Typical values of dE/E = 1.5e-4

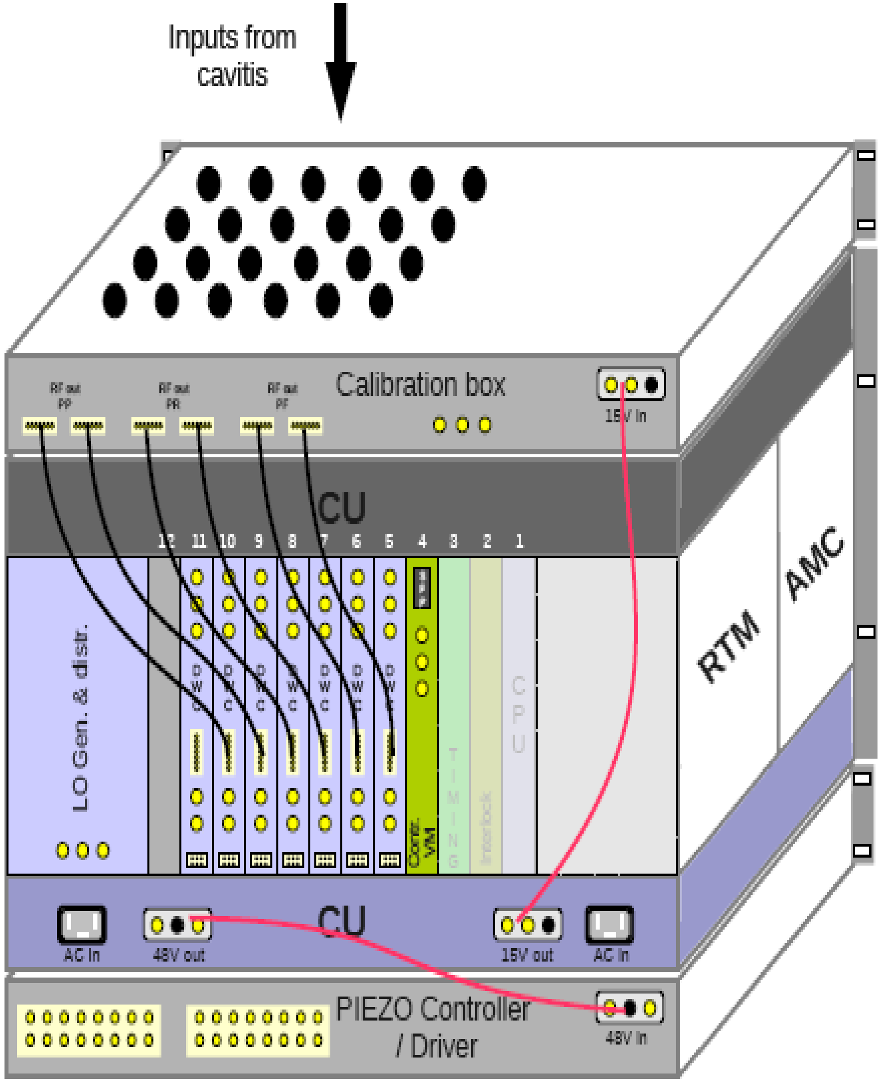
- FLASH elogbook 29.9.10 03.21h
- ACC1, ACC39 on-crest
- Best results: dE/E = 0.5e-4

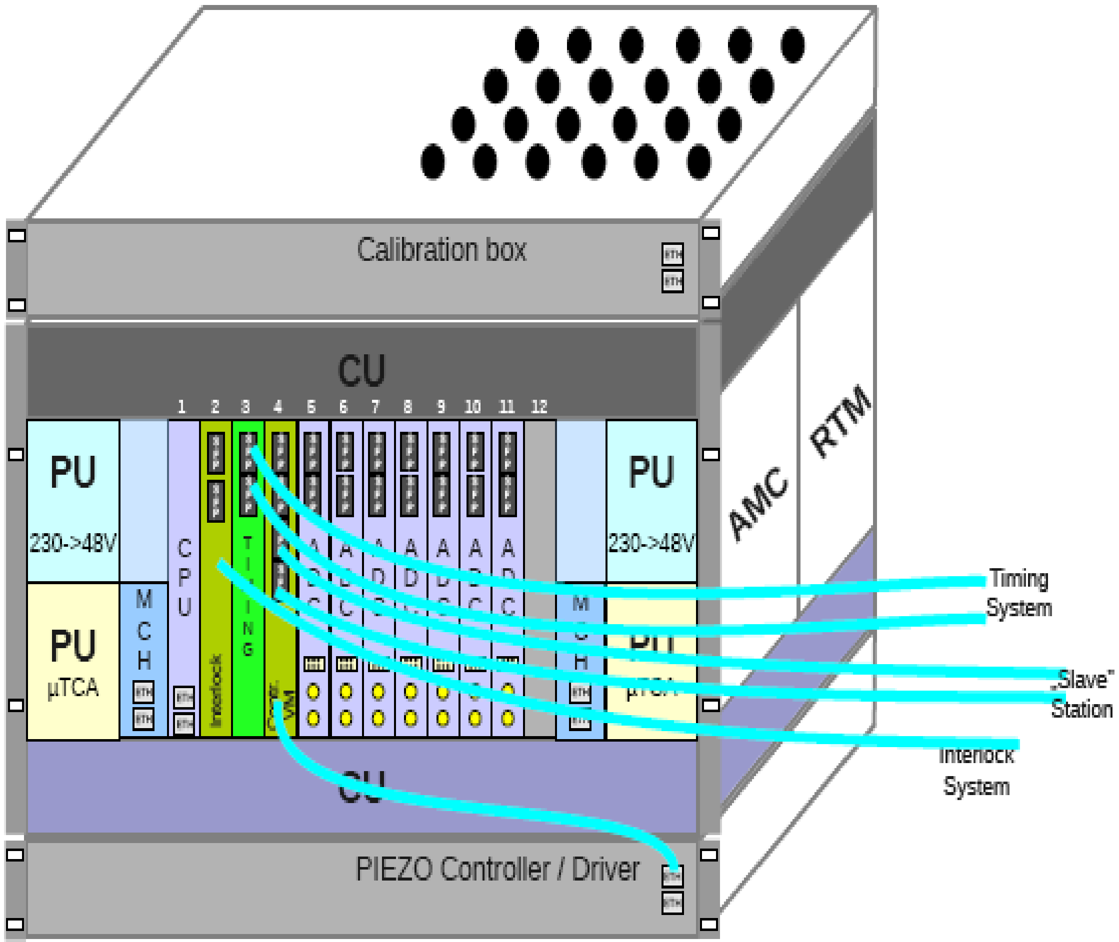
Christopher Gerth, et al.

before

after

Target LLRF system at FLASH





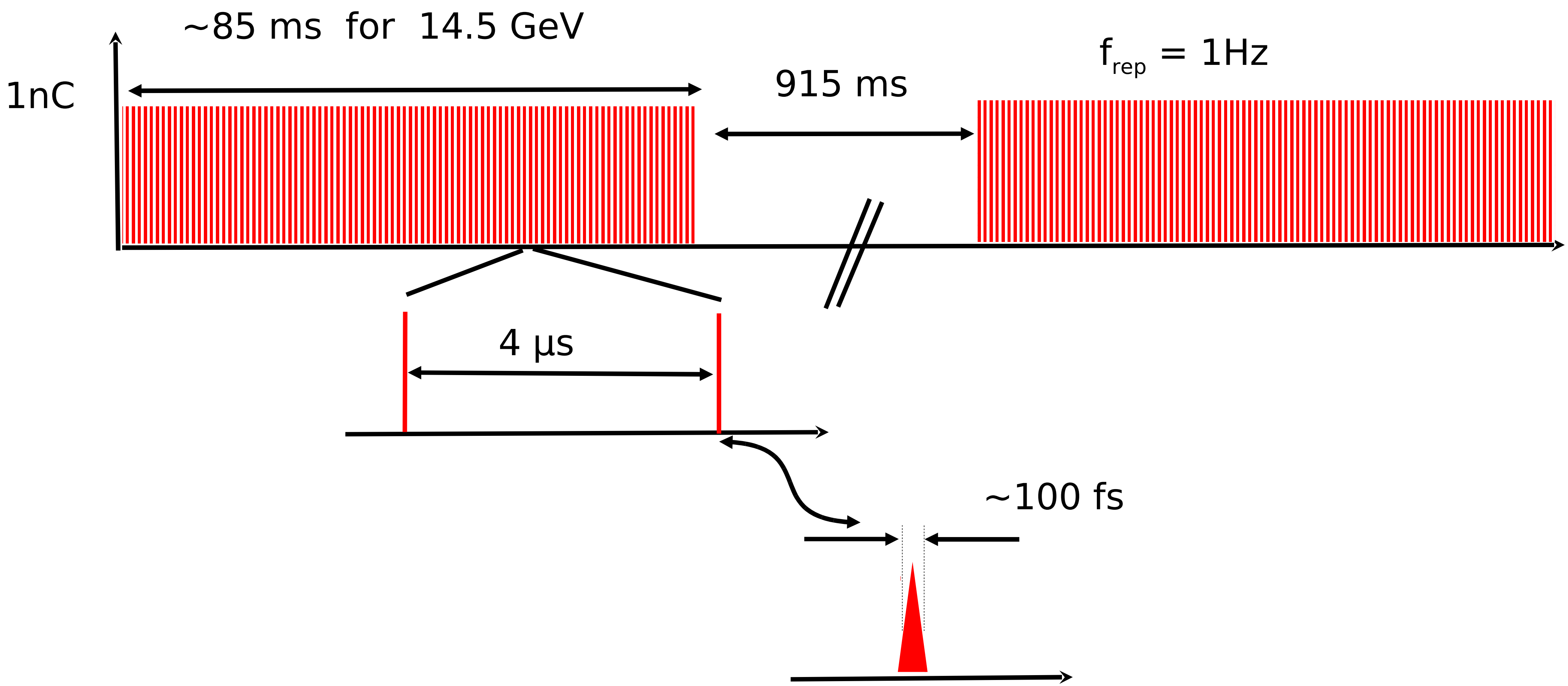
LLRF optimization at FLASH

- Development of software for automation, diagnostic, exception handling
- Beam based feedbacks
- High precision synchronization system

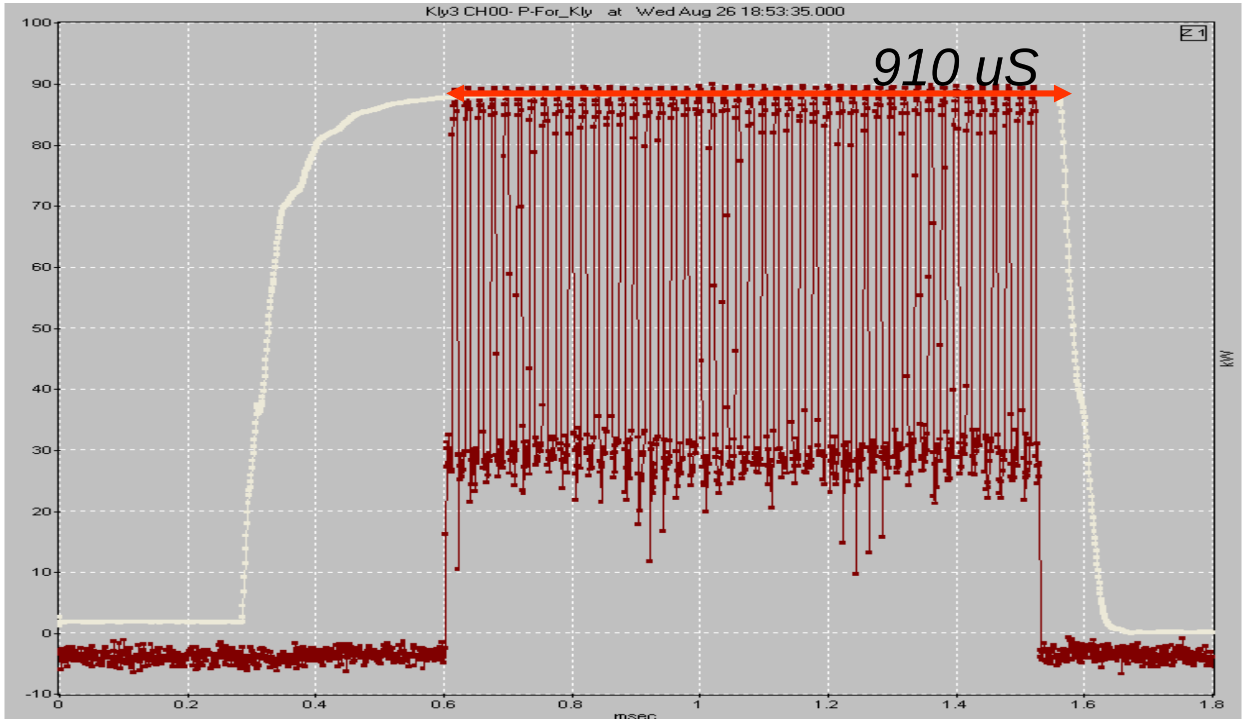
Development of software for automation, diagnostic and exception handling

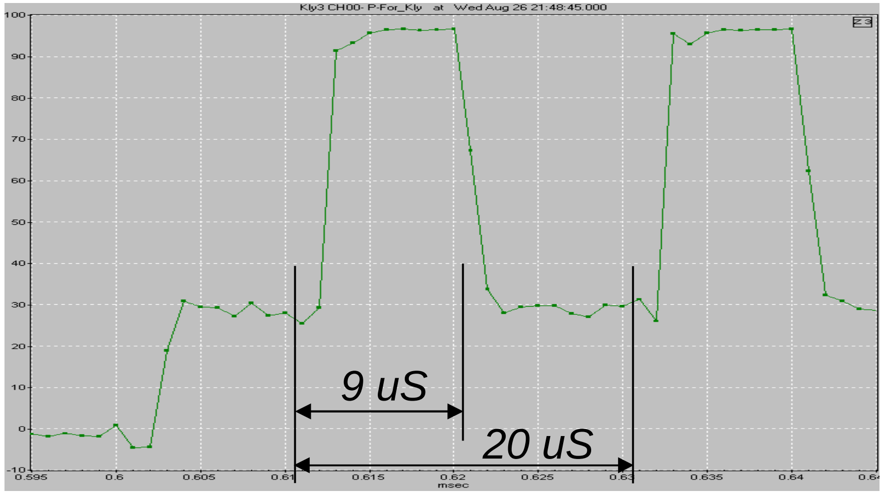
- Software optimization due to accuracy, timing constrains and resources consumption (algorithms distribution), modules reusability, algorithms' numerical precision and stability
- Availability maximization by means of standard operation procedures automation (e.g. online VS calibration, on-crest phase measurement, cavity tuning to resonance, etc.)
- Optimization of operational power level and margins (energy overhead, regulation precision, LFD compensation, operation near to saturation, etc.)
- Extend the operation range by special modes of operation, like extension of pulse lenghts towards CW operation, RF Gun Operation with Alternating RF Pulse Structure,
- Microphonics compensation

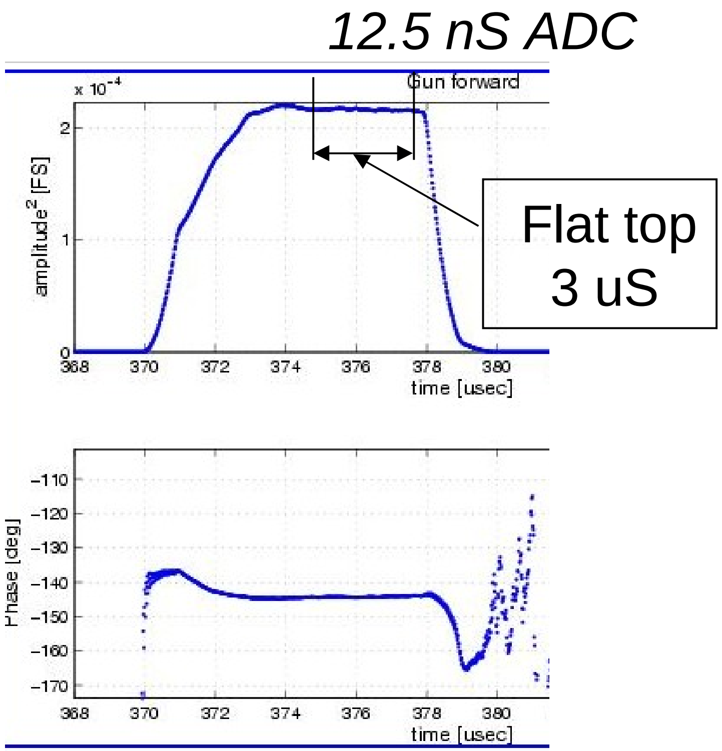
Towards CW operation



PiP mode: preliminary studies



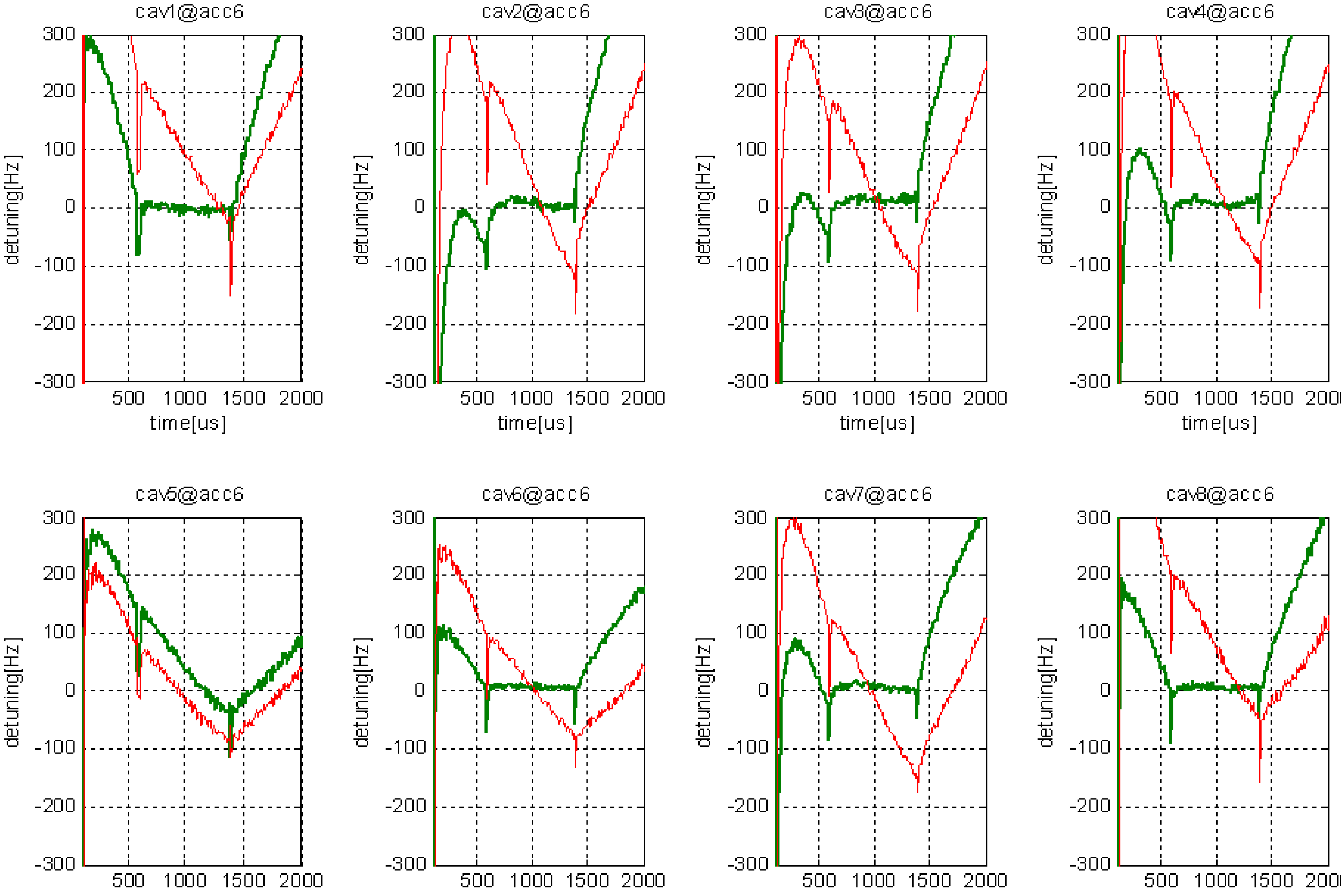




46 bunches,(50kHz), P forward = 4.0MW

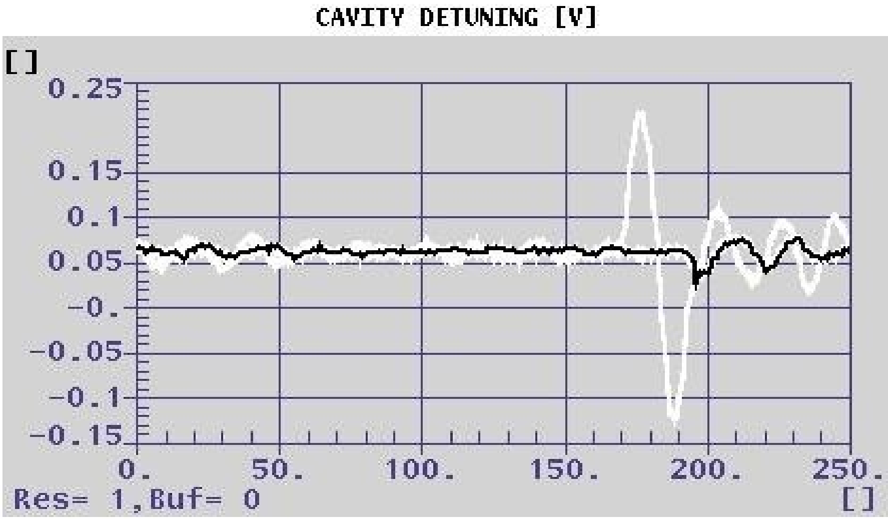
about 1 hour of operation without any interlock!

LFD compensation by piezos

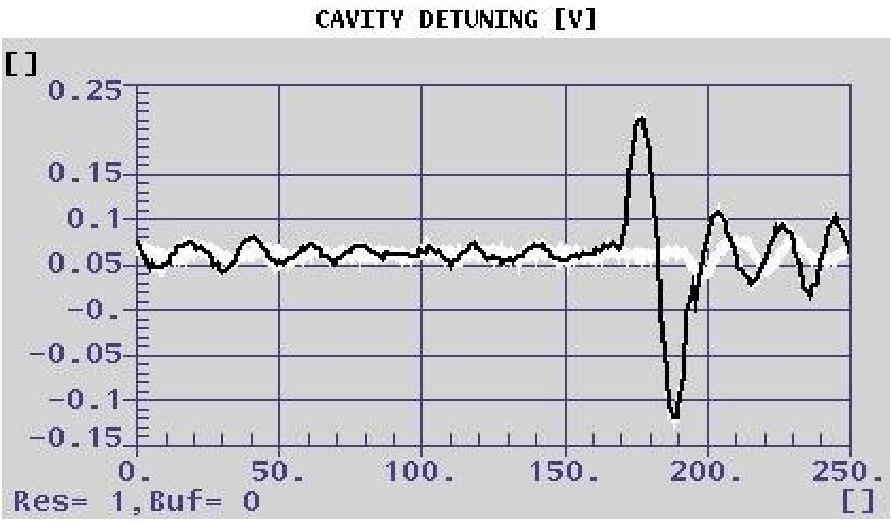


ACC6 (SP = 20 MV/m, rep = 5 Hz)

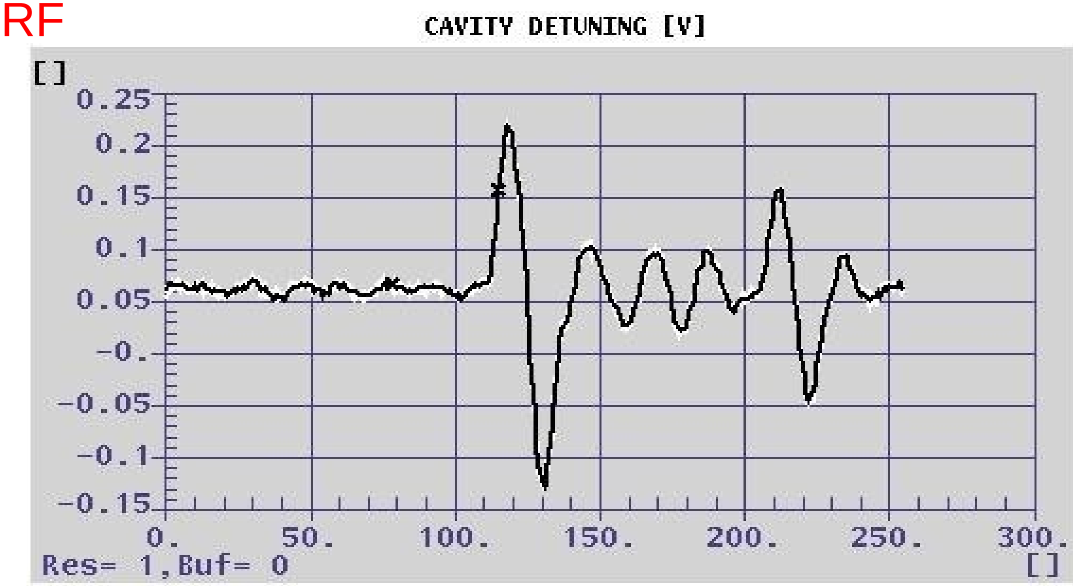
Cavity vibrations due to LFD compensation by piezos



Piezo sensor - only RF



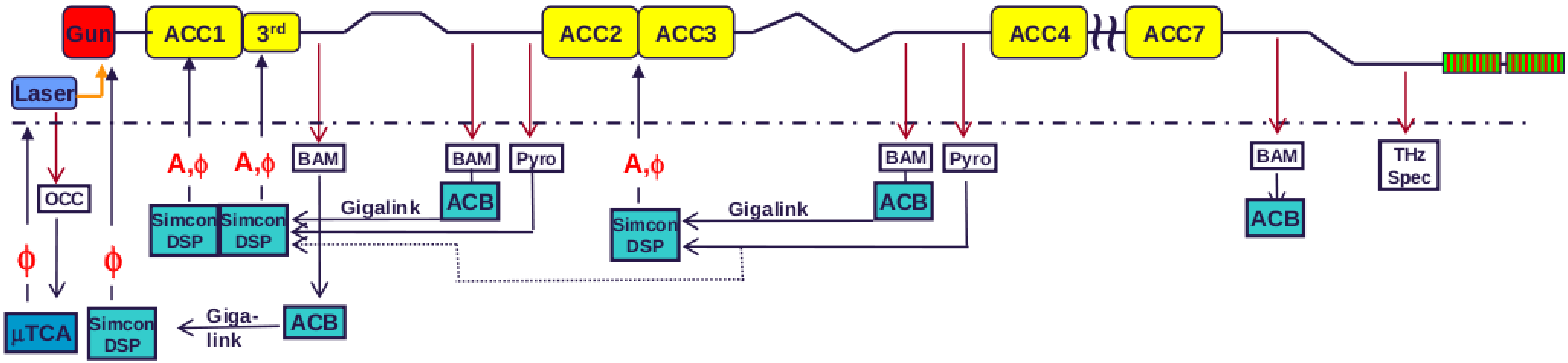
RF plus LFD compensation by piezo



RF plus LFD compensation by piezo plus active attenuation

Beam based feedbacks

- Intra-bunch-train digital feedback for femtosecond arrival-time control of FEL pulses
- Autocalibration

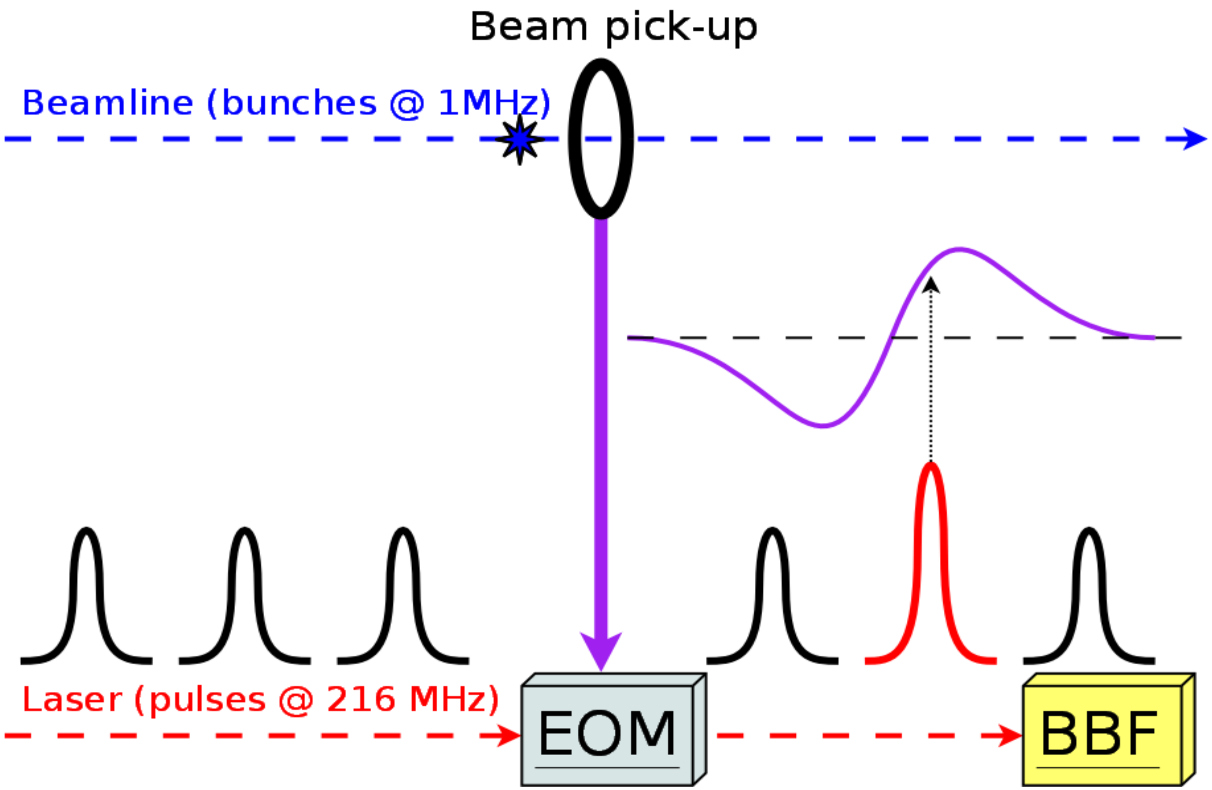


Beam Based Feedback

The proposed BBF compensating system is based on a single RF station and it is composed of:

- Normal temperature, single cell, large bandwidth, low power cavity (25 kW),
- High-speed low-latency digital control system with a data concentrator, vector modulator and timing module,
- High-power preamplifier.
- The interfaces to the LLRF control system

The beam energy feedback



- The energy of the bunch is estimated by the arrival time
- To measure the arrival time, laser pulses' height is modulated in the electro-optical modulator (EOM) by signal from the bunch arrival time monitor (BAM)
- Every 216-th laser pulse is modulated by the traveling bunch
- The role of the Beam Feedback system is to select modulated pulsed, and calculate the correction of the amplitude for the LLRF system

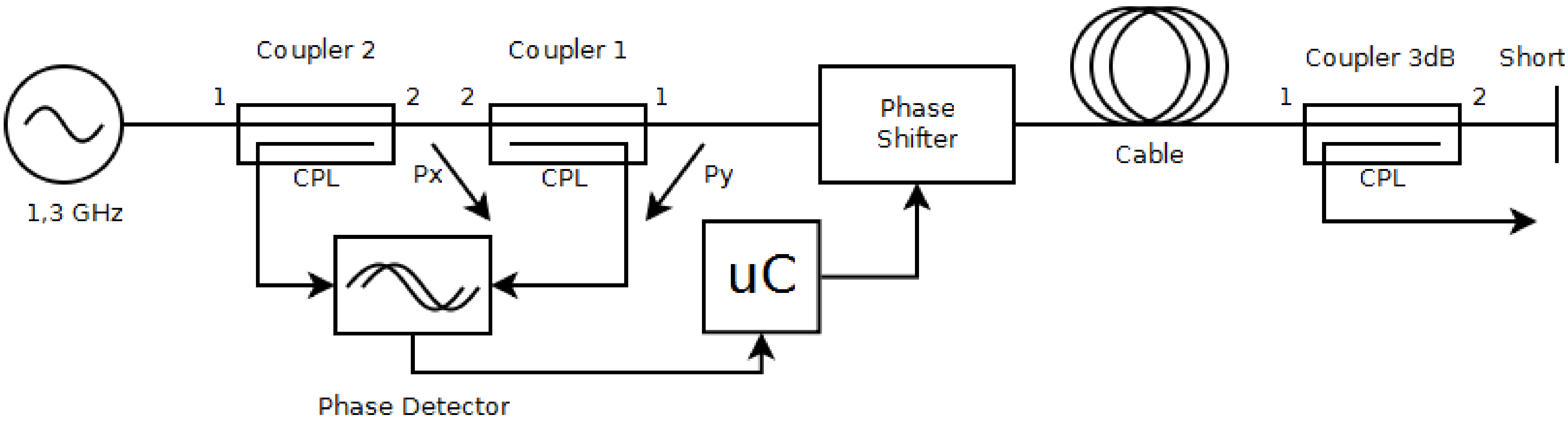
High precision synchronization system

- Master Oscillator development (new scheme for frequency generation with GPS stabilization)
- Interferometer stabilization system
- Investigation of cables drift and development of temperature stabilization system

Master Oscillator

- New MO starting from 10 MHz - 100 MHz - 1,3 GHz GPS stabilized as a pre-test of the XFEL-MO, very low phase noise 10 MHz OCXO and 100 MHz OCXO are already in house
- Derivation of all other frequencies from 1.3 GHz on, must be modified including new timing system based on 1.3 GHz as for XFEL
- side remark: GPS receiver is already installed, but can only be synchronized with a extra box (to be built) from 1.3 GHz /130 divider and then compare it to 10 MHz GPS receiver box reference

Interferometer stabilization system



Investigation of cables drift and development of temperature stabilization system

- Extended climate characterization of coax cables and design of single and multi cable temperature stabilization of accelerator LLRF signal cables to achieve fs range phase stability. That includes measurements of temperature, humidity and atmospheric pressure influence on RF signal phase shift in different coax cables and design of active RF signal cables temperature stabilization using electronic thermostats with sectioned heaters or cheap and simple self-regulating heating elements.

Institutions

DESY Deutsches Elektronen-Synchrotron, Hamburg, Germany

DMCS Department of Microelectronics and Computer Science, Technical University of Lodz, Poland

ISE Institute of Electronic Systems, Warsaw University of Technology, Poland

INP Niewodniczanski Institute of Nuclear Physics, Krakow, Poland

INP The Andrzej Soltan Institute for Nuclear Studies

Project budget (very provisional)

Task	Manpower FTE/[k€]	Hardware and Consumables [k€]	Total [k€]
Development of software for automation, diagnostic, exception handling	12/840	100	940
Beam based feedbacks	7/490	400	890
High precision synchronization system	5/350	300	650
Total	20/1680	800	2480