Overview of the LLRF Developments for FLASH

M.Grecki for LLRF Collaboration

3rd EuCARD Annual Review, WUT, 25-27.04.2012

FLASH

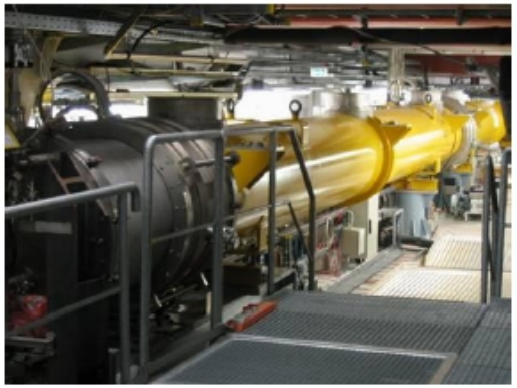
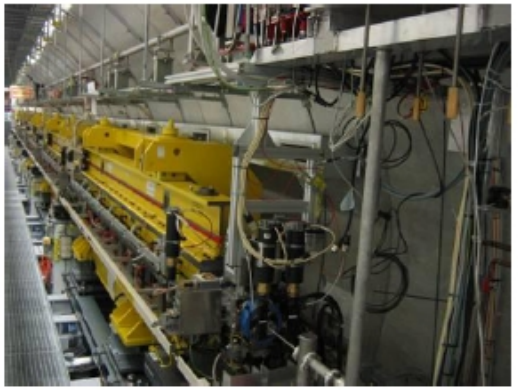
Free-electron LASer in Hamburg

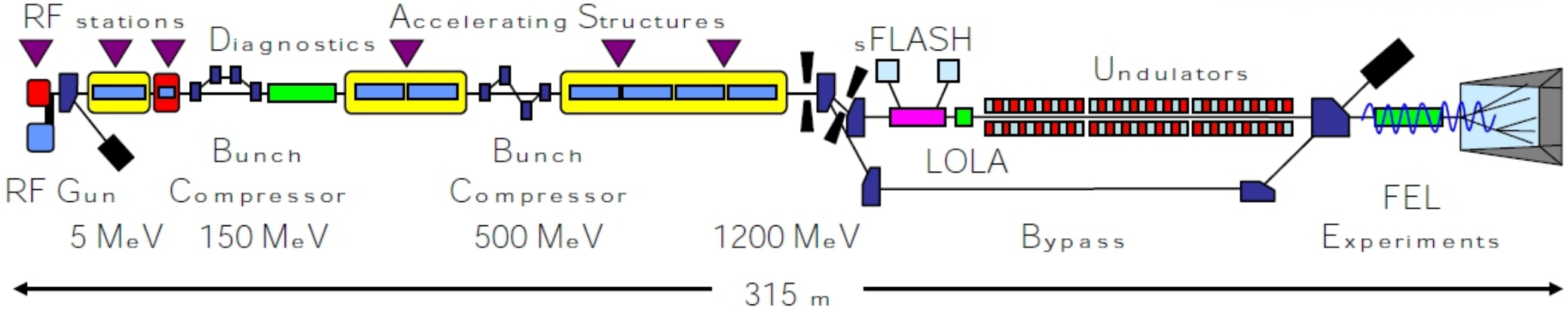
- Single-pass high-gain SASE FEL

  SASE = self-amplified spontaneous emission

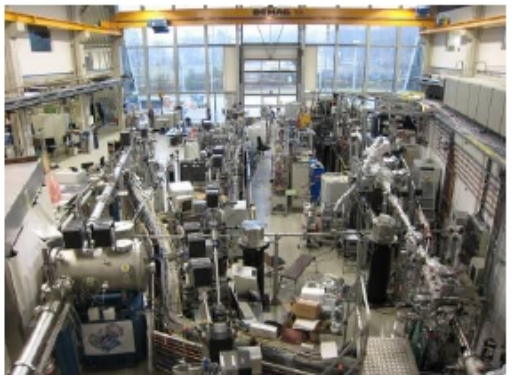
- Photon wavelength range from vacuum ultraviolet to soft x-rays
- Free-electron laser user facility since summer 2005
  - 1st period: Jun 2005 – Mar 2007
  - 2nd period: Nov 2007 – Aug 2009
  - 3rd period: Sep 2010 – Sep 2011
  - 4th period: Mar 2012 – Dec 2012 (with few short breaks)
- FLASH is also a test bench for the European XFEL and the International Linear Collider (ILC)
- FLASH II, a second undulator beam line is in preparation

FLASH layout



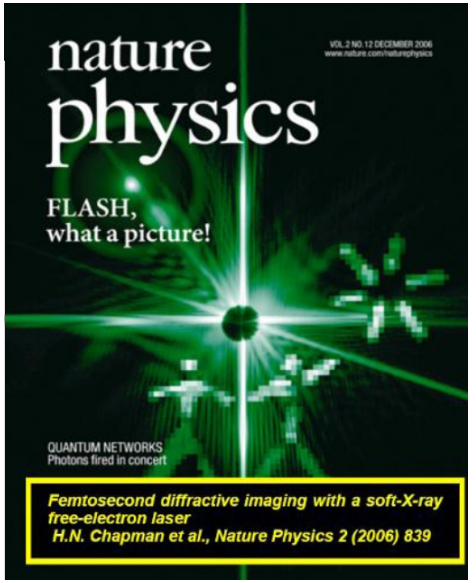



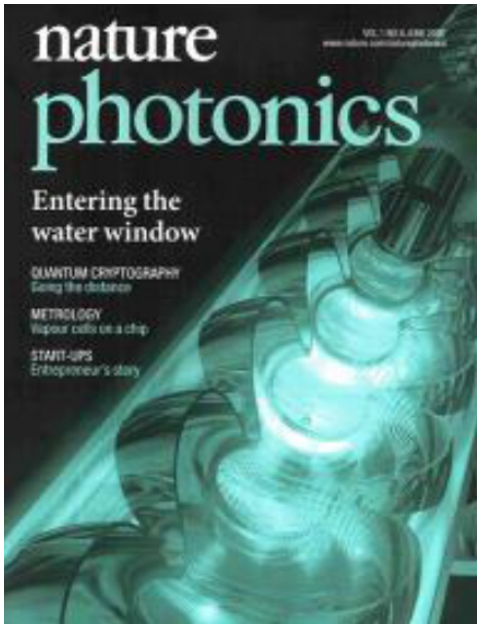
FLASH performance 2nd user period

(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} *

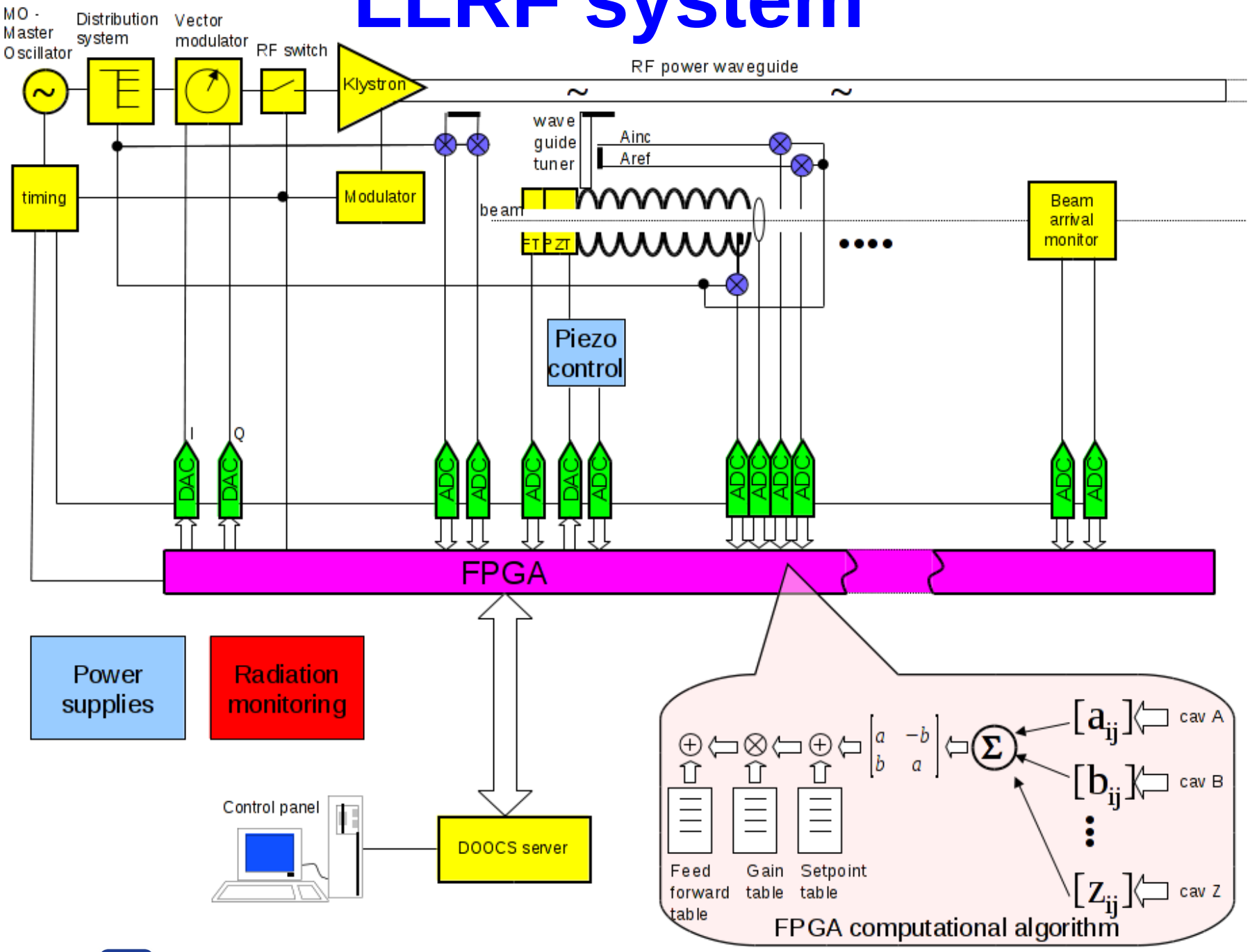
    * photons/s/mrad^2/mm^2/0.1%bw





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

LLRF system


MO - Master Oscillator
Distribution system
Vector modulator
RF switch
Klystron
RF power waveguide
timing
Modulator
wave guide tuner
Ainc
Aref
beam
FT
PZT
Beam arrival monitor
Piezo control
I
Q
DAC
DAC
ADC
FPGA
Power supplies
Radiation monitoring
Control panel
DOOCS server
Feed forward table
Gain table
Setpoint table
cav A
cav B
cav Z
FPGA computational algorithm

RF Control Requirements

- Maintain Phase and Amplitude of the accelerating field within given tolerances to accelerate a charged particle beam (e.g. injector: 0.01% for amplitude and 0.01 deg. for phase)
- Minimize Power needed for control
- RF system must be reproducible, reliable, operable, and well understood.
- Other performance goals
  - build-in diagnostics for calibration of gradient and phase, cavity detuning, etc.
    - provide exception handling capabilities
    - meet performance goals over wide range of
    - operating parameters

Old hardware platform

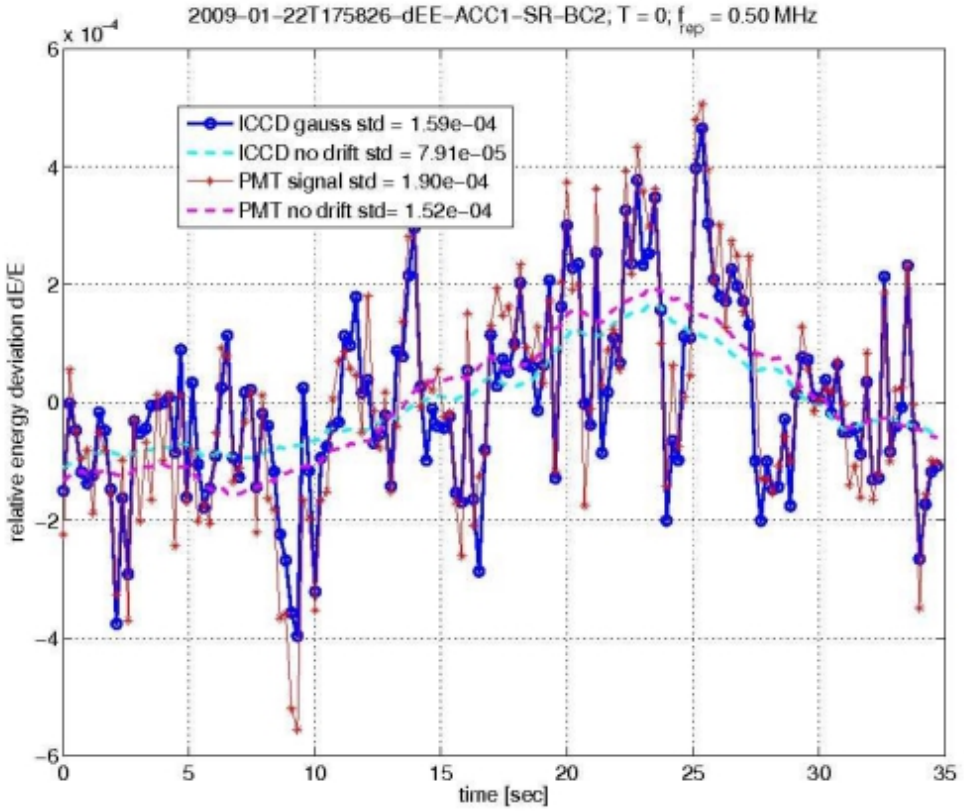
- DSP C67 (2002)
  - 1x C67 DSP for up to 32 cavities
  - 8x Gigalink Interface (4x8ADC, DAC)
  - 1 MHz sampling, 4 microsecond latency

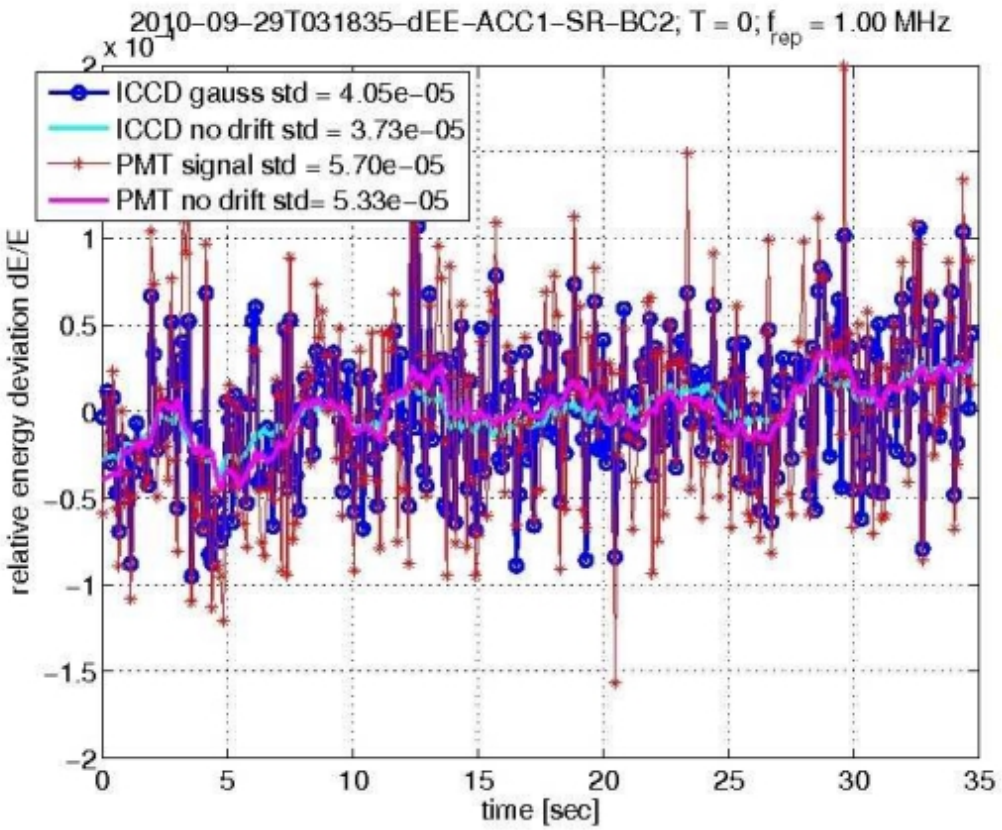
Outcome of CARE project

SimconDSP

- VME interface
- 10xADC, 8xDAC
- Xilinx Virtex II Pro (20/30/50), PowerPC
- DSP, Tiger Sharc
- 2 opto gigalinks
- Ethernet

Energy stability





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

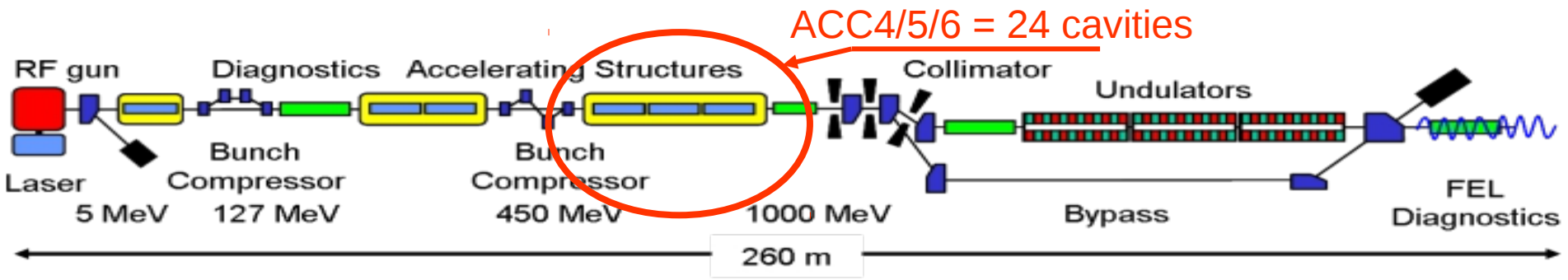
- FLASH elogbook 29.9.10 03.21h
- ACC1, ACC39 on-crest
- Best results: dE/E = 0.5e-4

Christopher Gerth, et al.

before

after

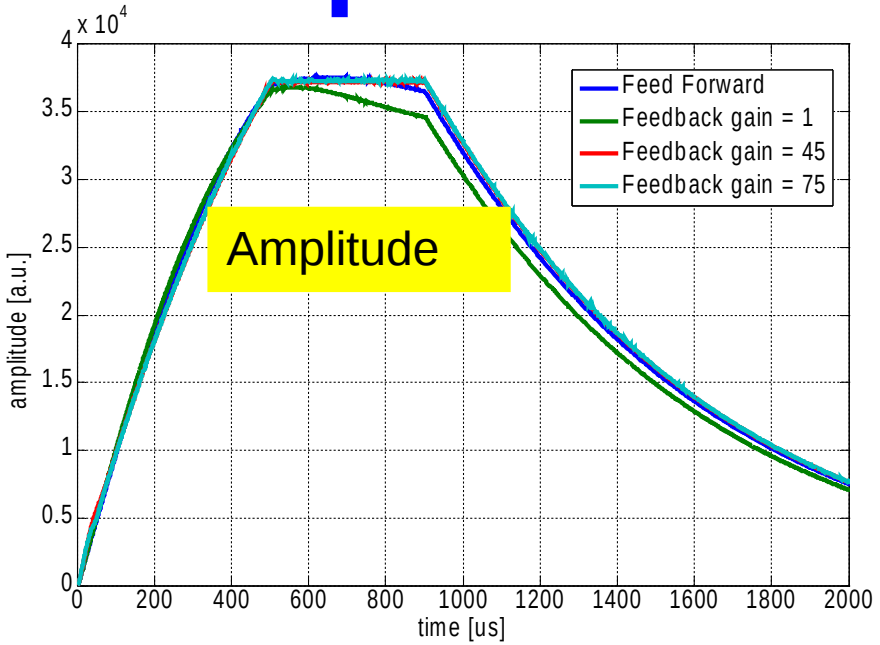
ATCA at FLASH ACC4/5/6

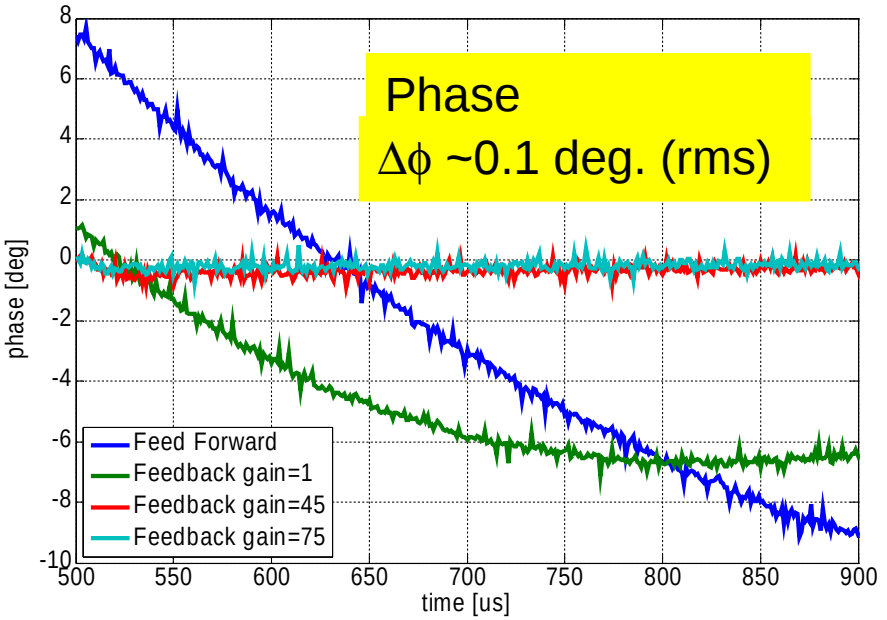


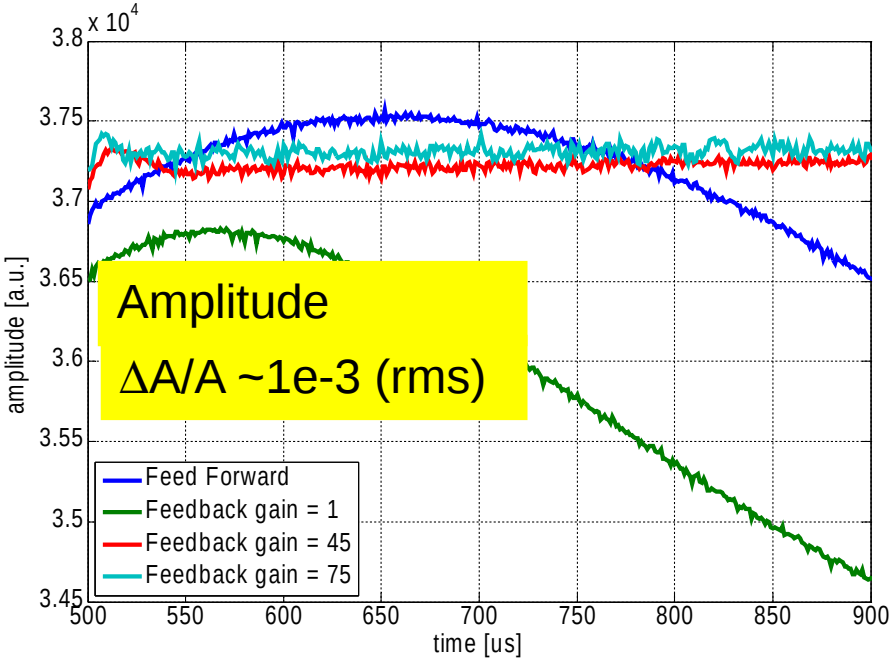
Front view

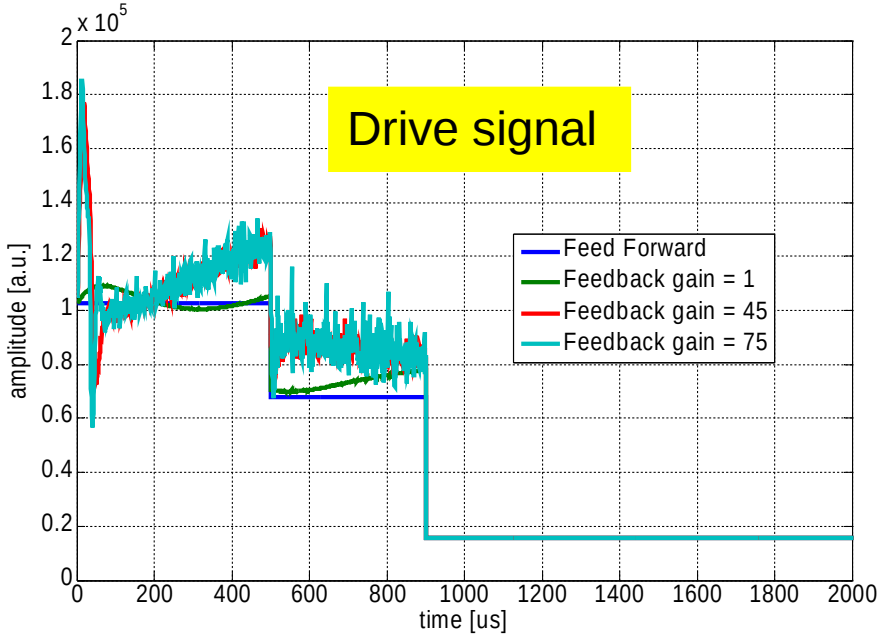
Rear view

Amplitude and Phase Control

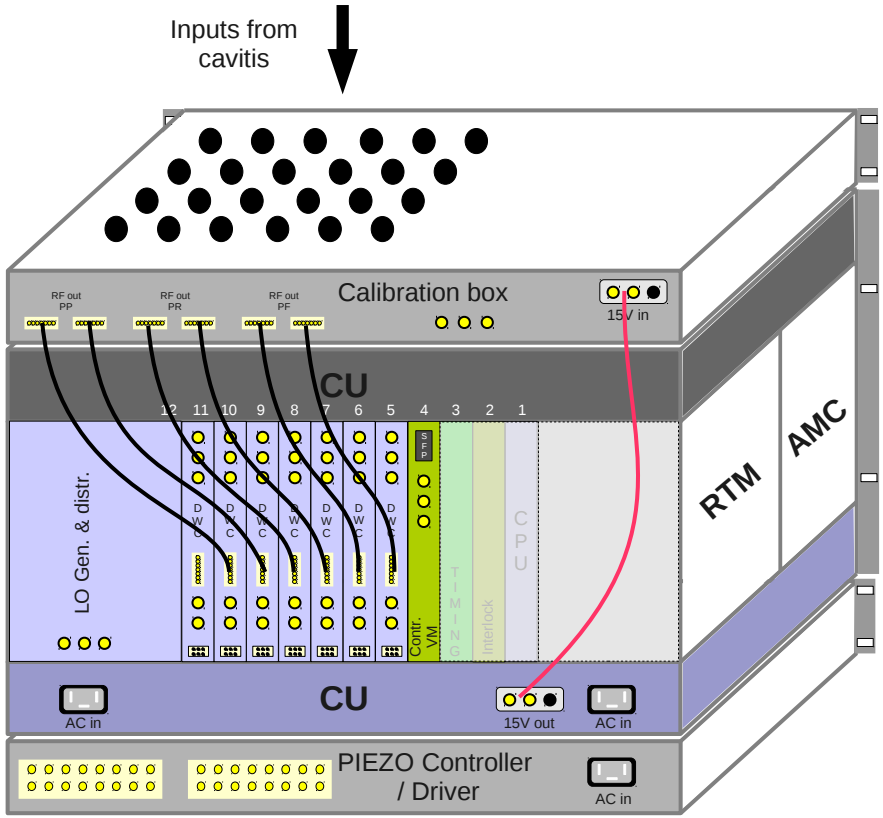


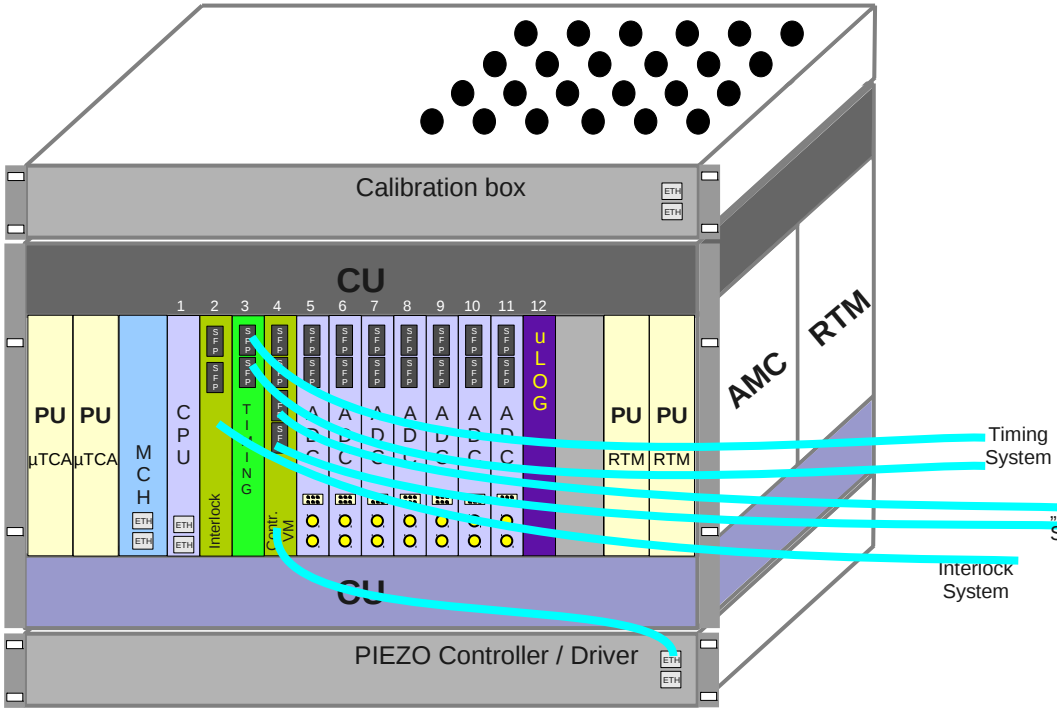




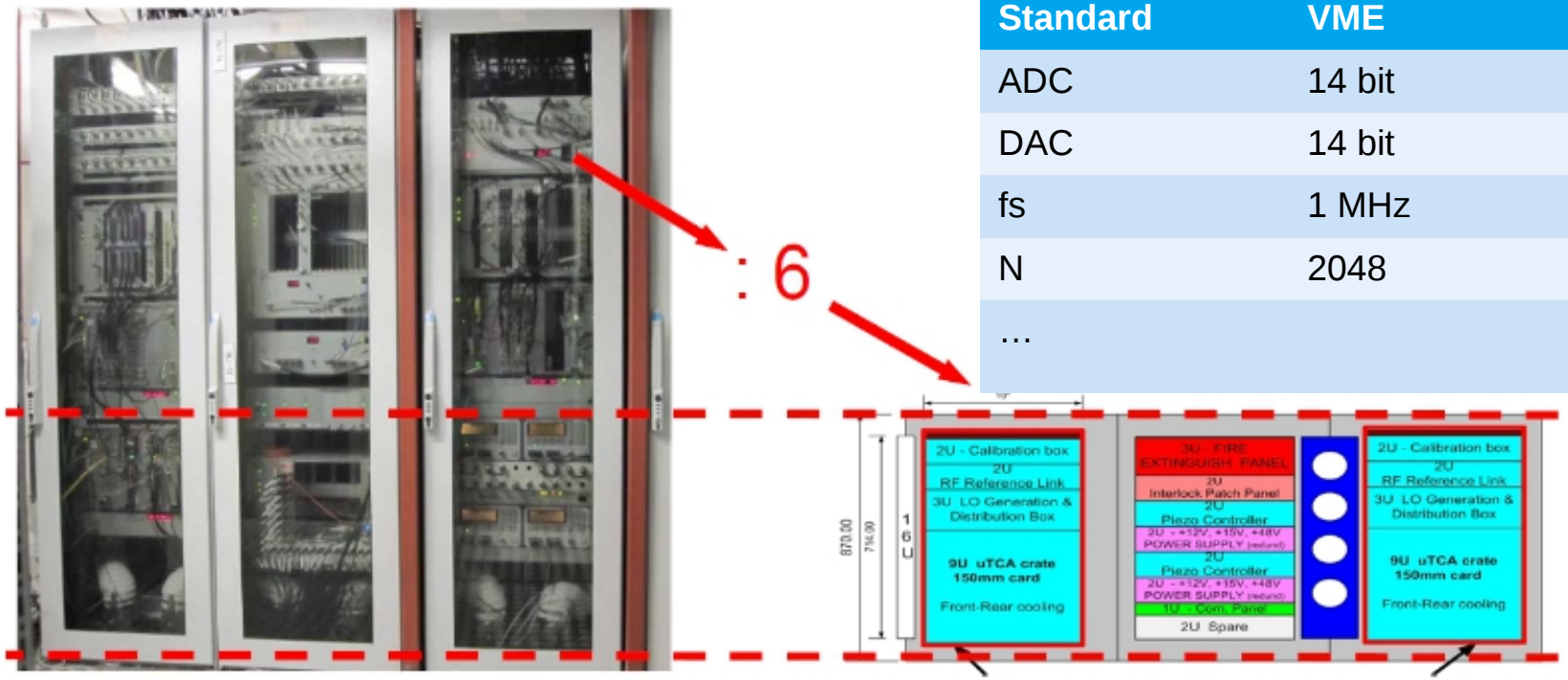


uTCA based LLRF system

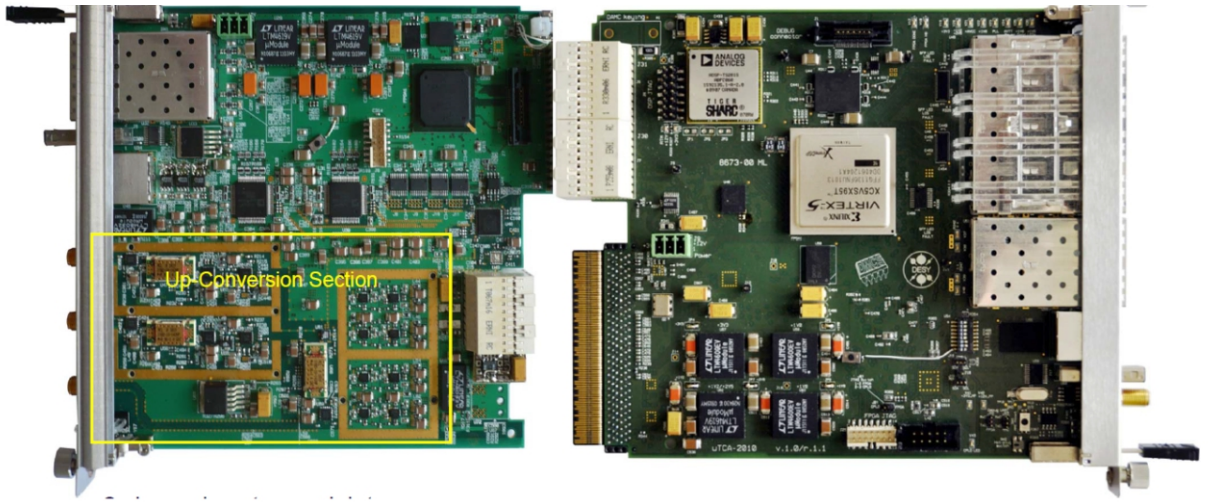




Upgrade to uTCA standard



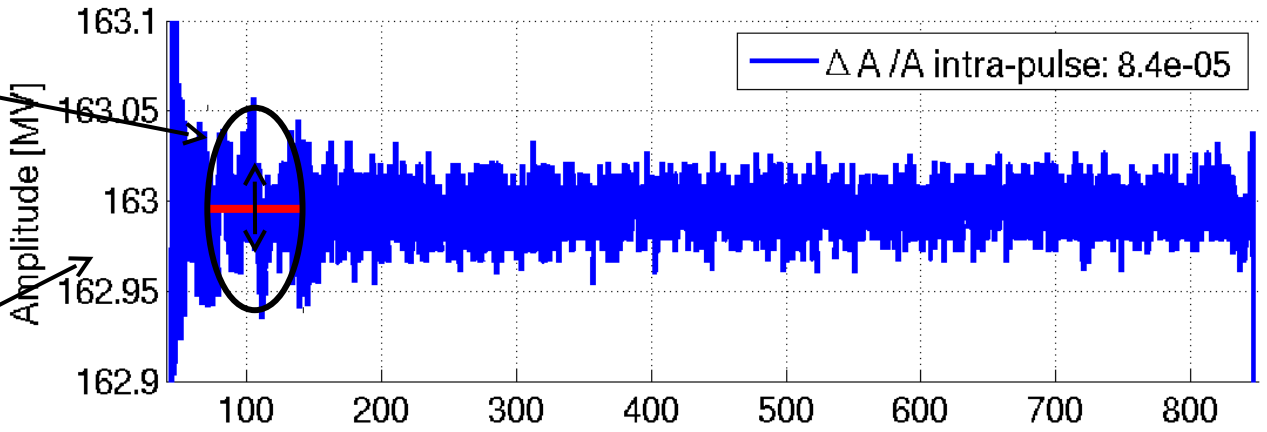
Standard	VME	uTCA
ADC	14 bit	16 bit
DAC	14 bit	16 bit
fs	1 MHz	9 MHz
N	2048	16384
…		



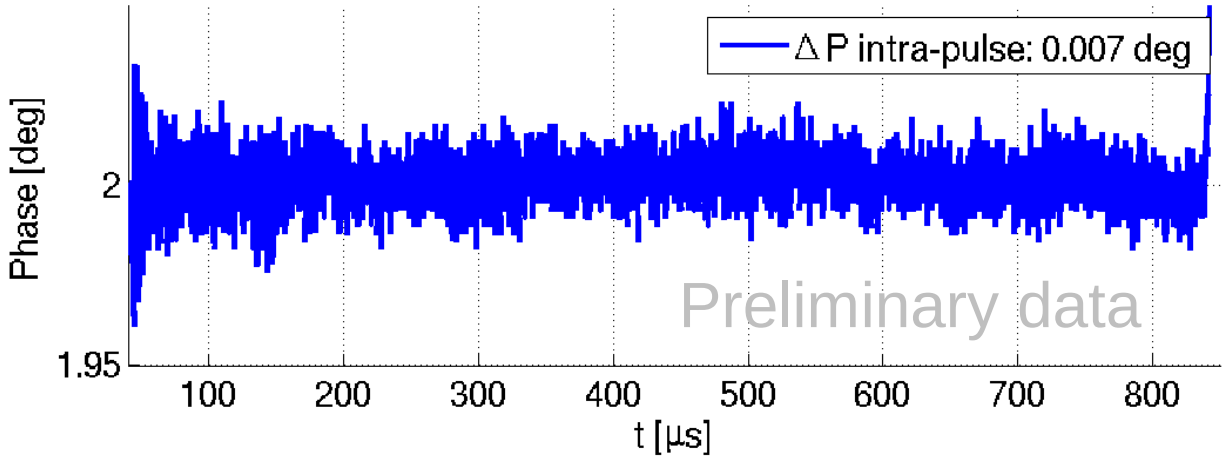
- Tunnel installation
- Drift compensation
- Scalability
- Non-IQ sampling
- …

Measured amplitude and phase stability

Pulse to pulse variation

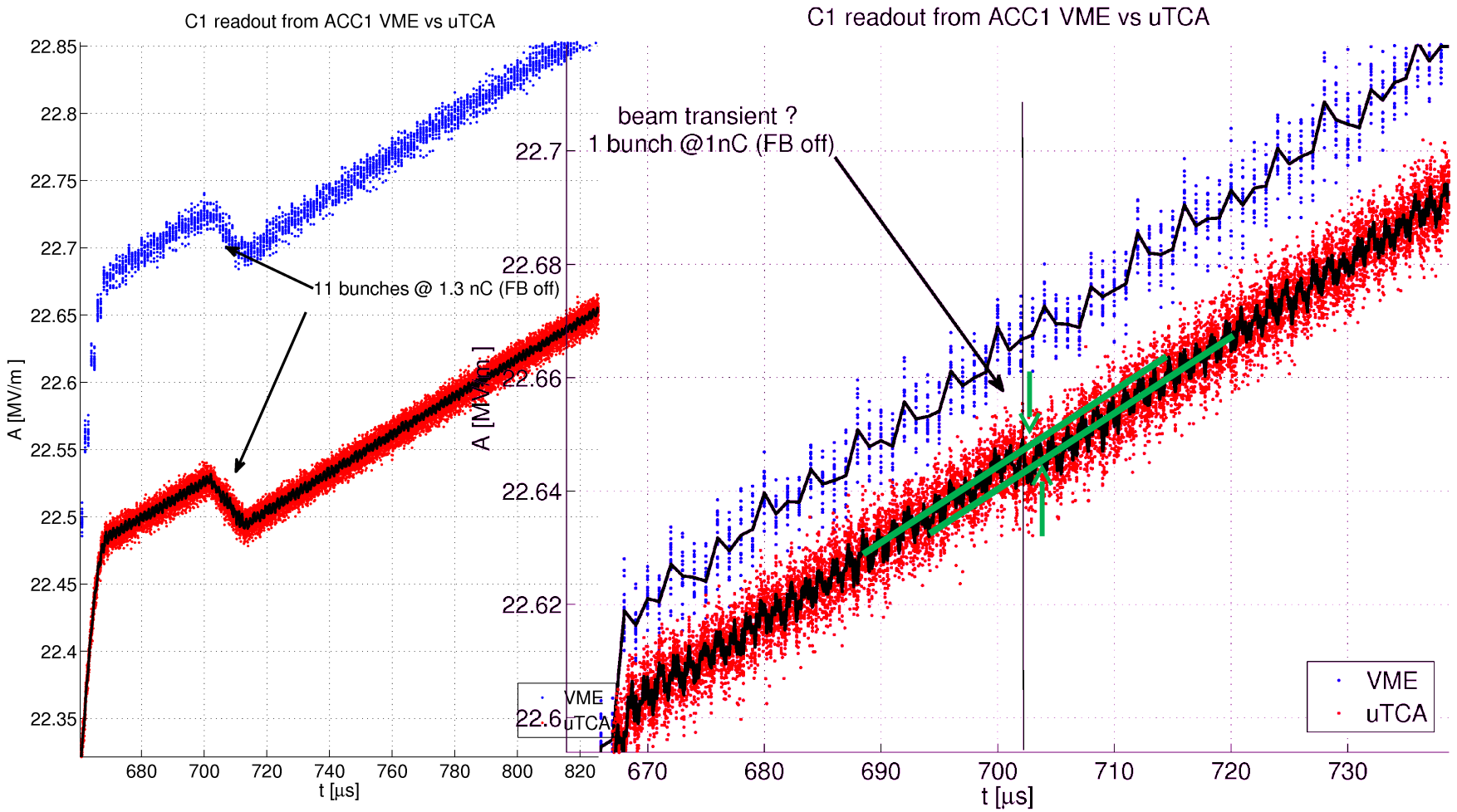


Oscillations after filling transition



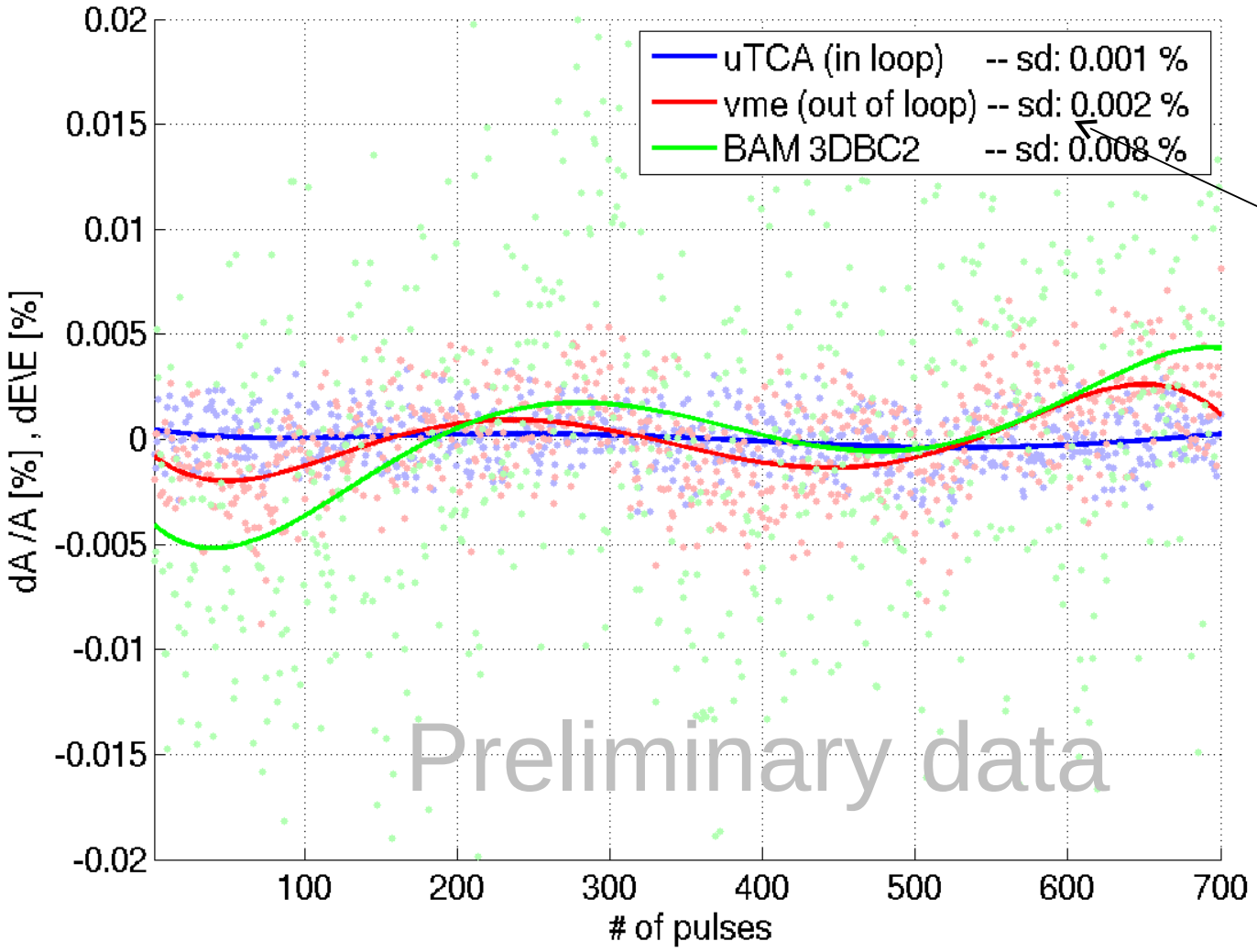
- uTCA System in control loop, with LFF and MIMO-Feedback
- Higher bandwidth compared to VME, In-loop measurements fulfill specifications

Single bunch detection



Possible advancement of vector sum calibration in terms of accuracy and machine setup requirements (currently 3nC with 30 bunches)

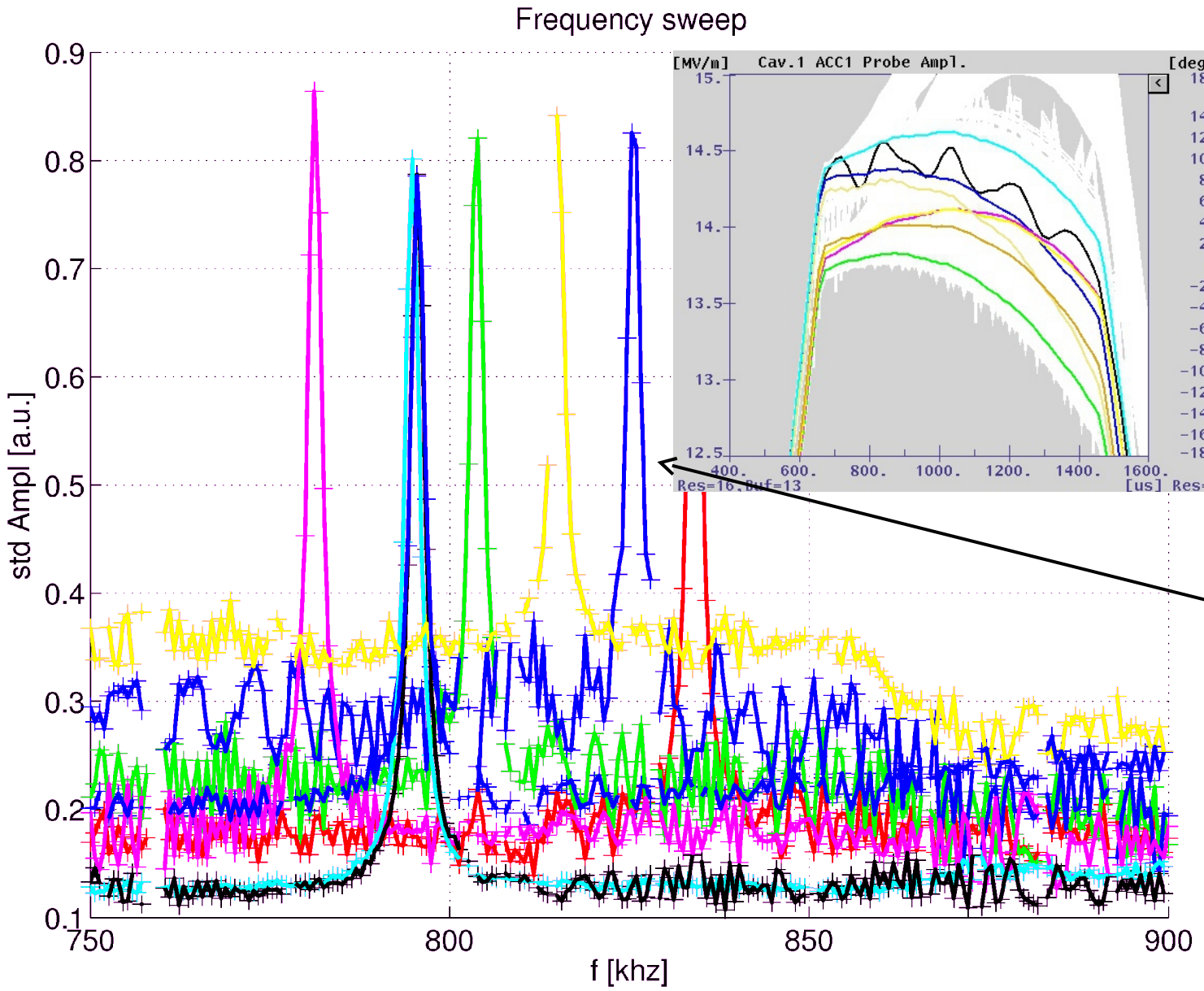
Amplitude pulse to pulse variation



Approx. 30 % improvement

- Difference between out of loop measurement and beam based data probably due to link to optical synchronization system

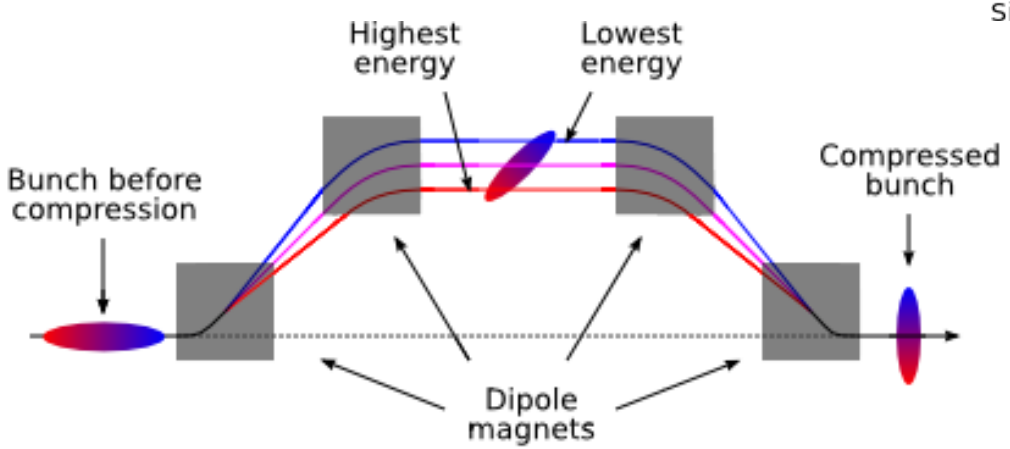
Excitation of the 8/9-Pi mode



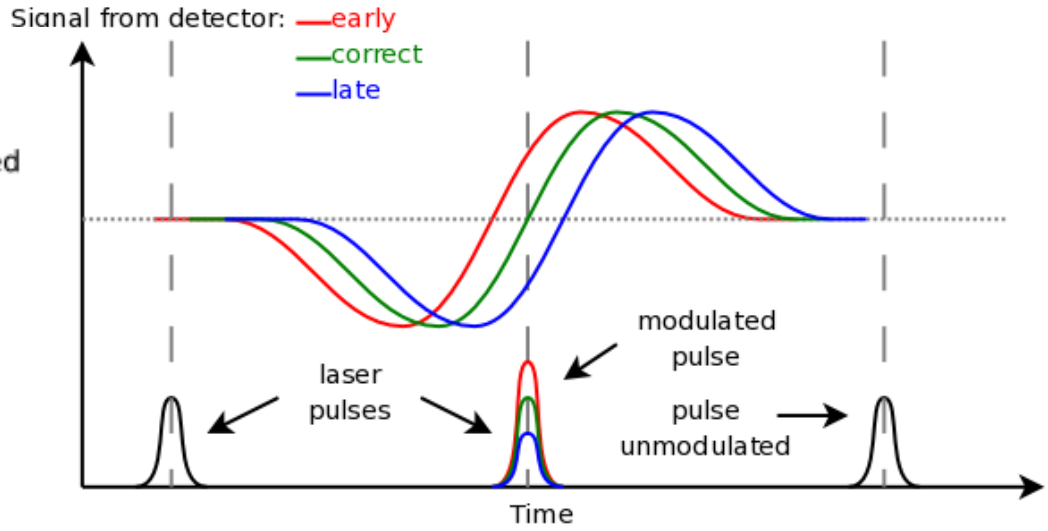
Individual cavity resonance frequencies

- Filtering with controller
- New modeling methods
- Spread of cavities

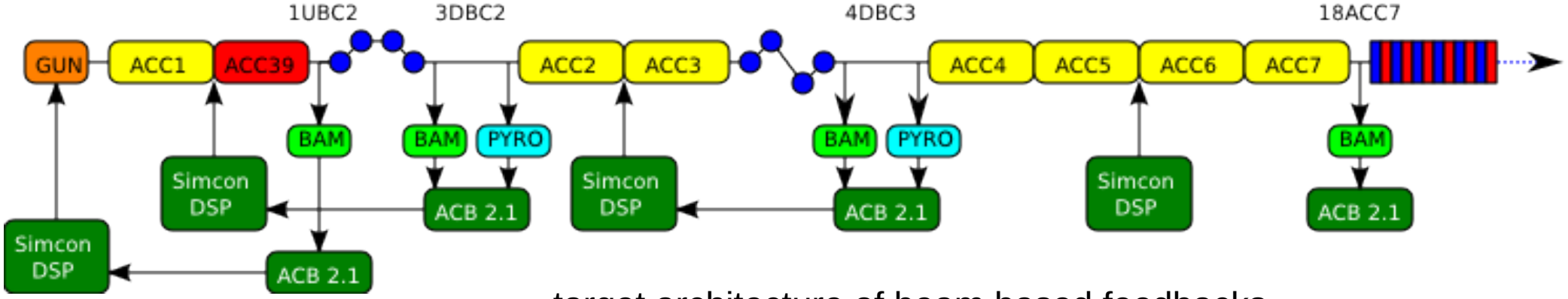
Beam-based feedbacks



idea of buch compression and energy measurements

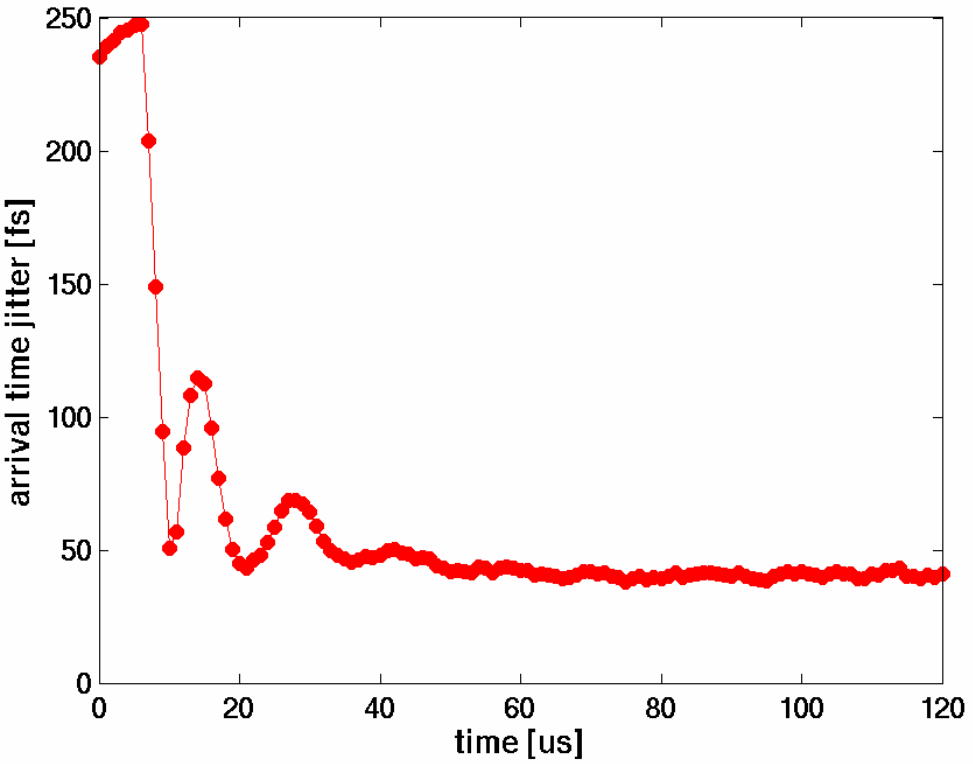


beam arrival time measurements

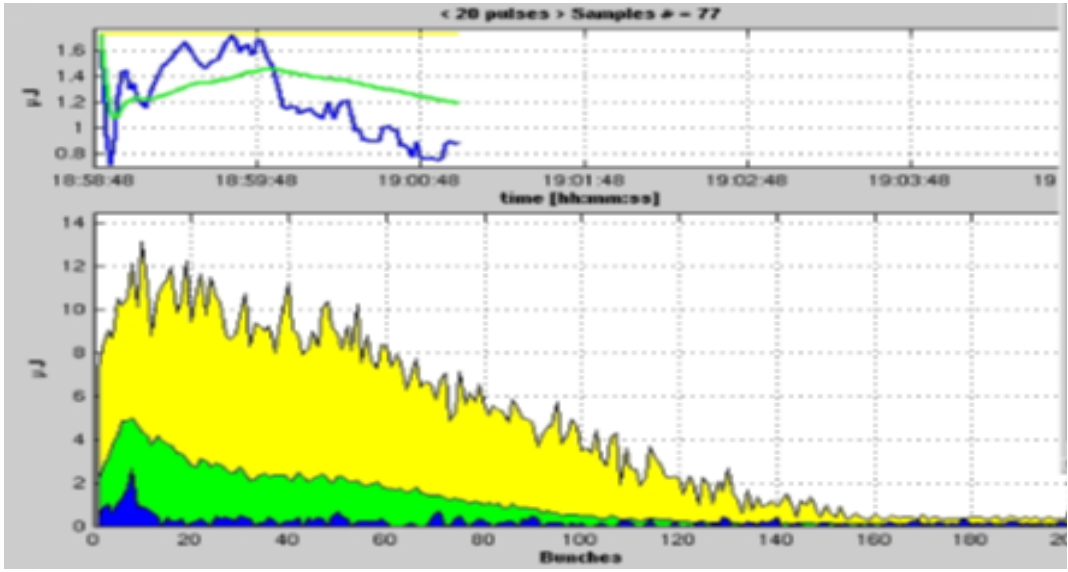


target architecture of beam based feedbacks

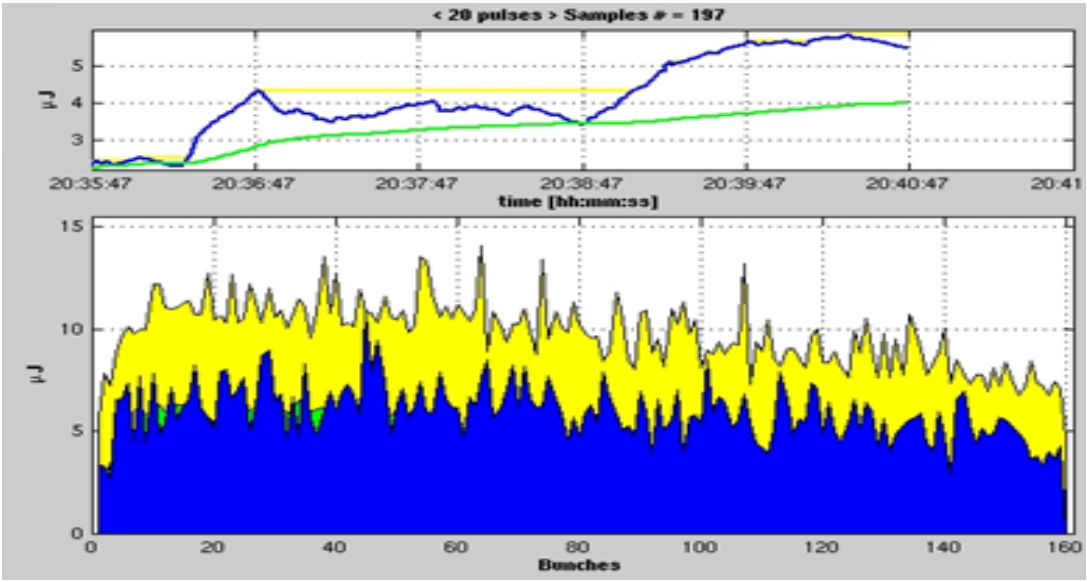
Beam-based feedbacks



BBF reduced the jitter in arrival time of subsequent bunches in the one bunch train which means that the energy spread within one bunch train was reduced



SASE without beam feedback



SASE with beam feedback

Summary

- thanks to EU support (CARE/EuCARD) the strong collaboration was organized
- xTCA extension for instrumentation has been proposed (hardware manufacturers has started components design and production)
- the new LLRF system has been developed using the xTCA architecture
- the prototype system has been initially tested at FLASH and CMTB with very good results (performance improvements)
- permanent FLASH installation is in progress

lack of EuCARD^2 support – danger for collaboration future