Overview of Longitudinal Beam Based Feedback at FLASH

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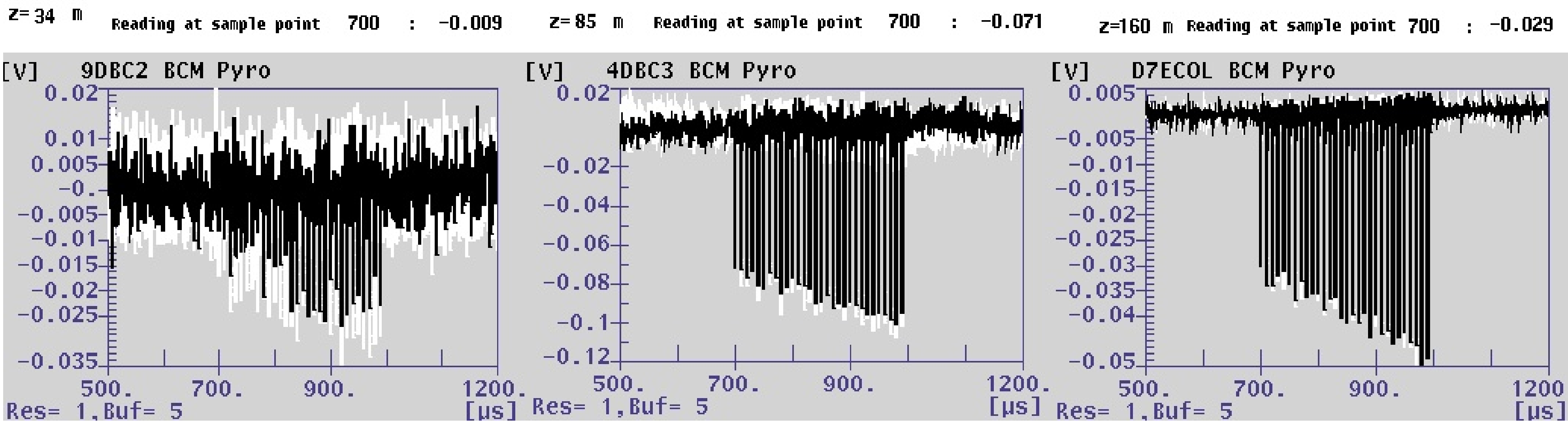
Agenda

- Introduction
- Beam based feedback principle
  - Energy feedback
  - Compression feedback
- Installation in FLASH
- Results
- Actual development – uTCA upgrade
- Plans for future upgrades

The problem

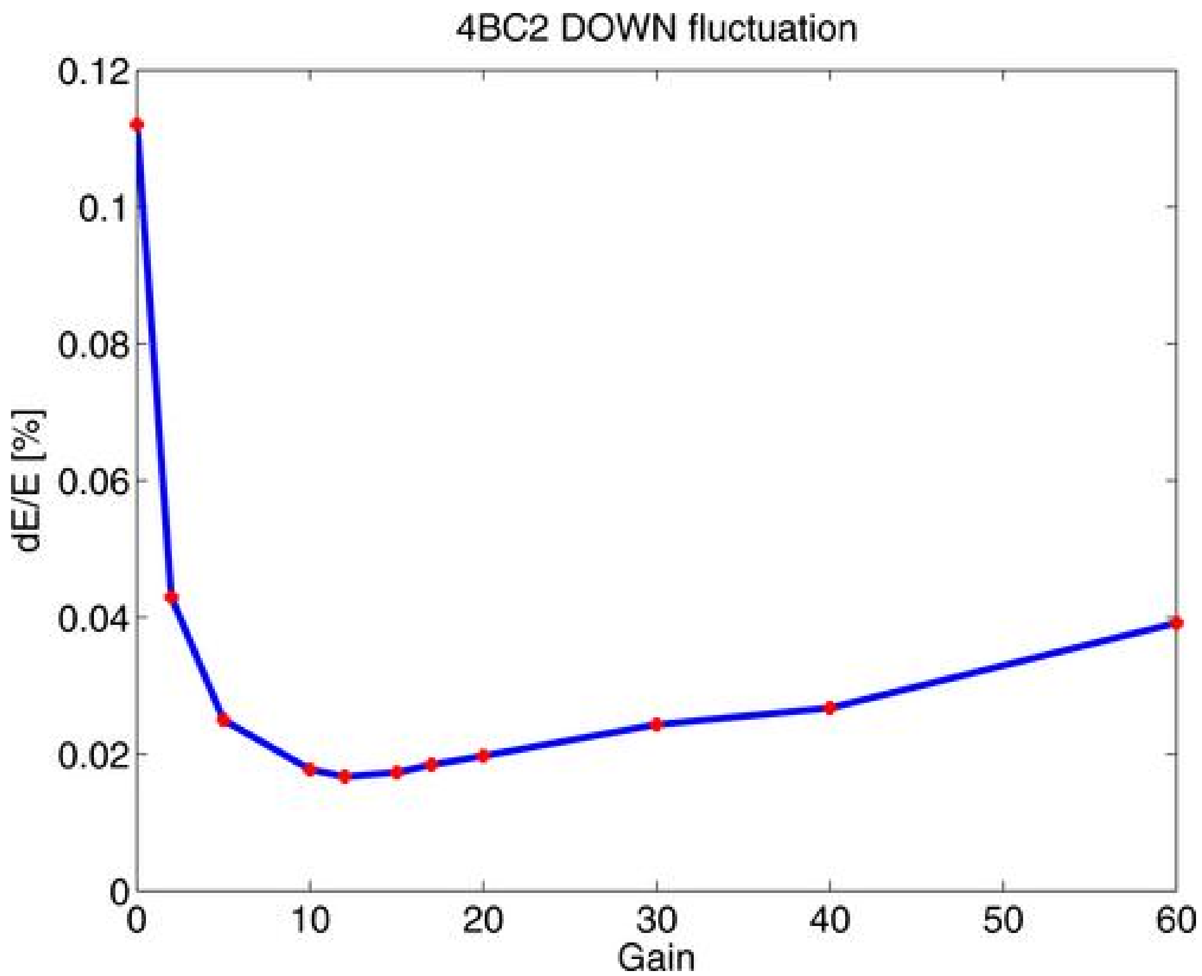
- In circular accelerators, bunch passes each station several times, and its parameters (energy, compression) can be tuned
- In the linear accelerators, each bunch travels through the machine only once, and we have no other chance to correct it
- We can not correct the bunch which was measured, we have to estimate corrections for the subsequent bunches

Beam parameters drifts



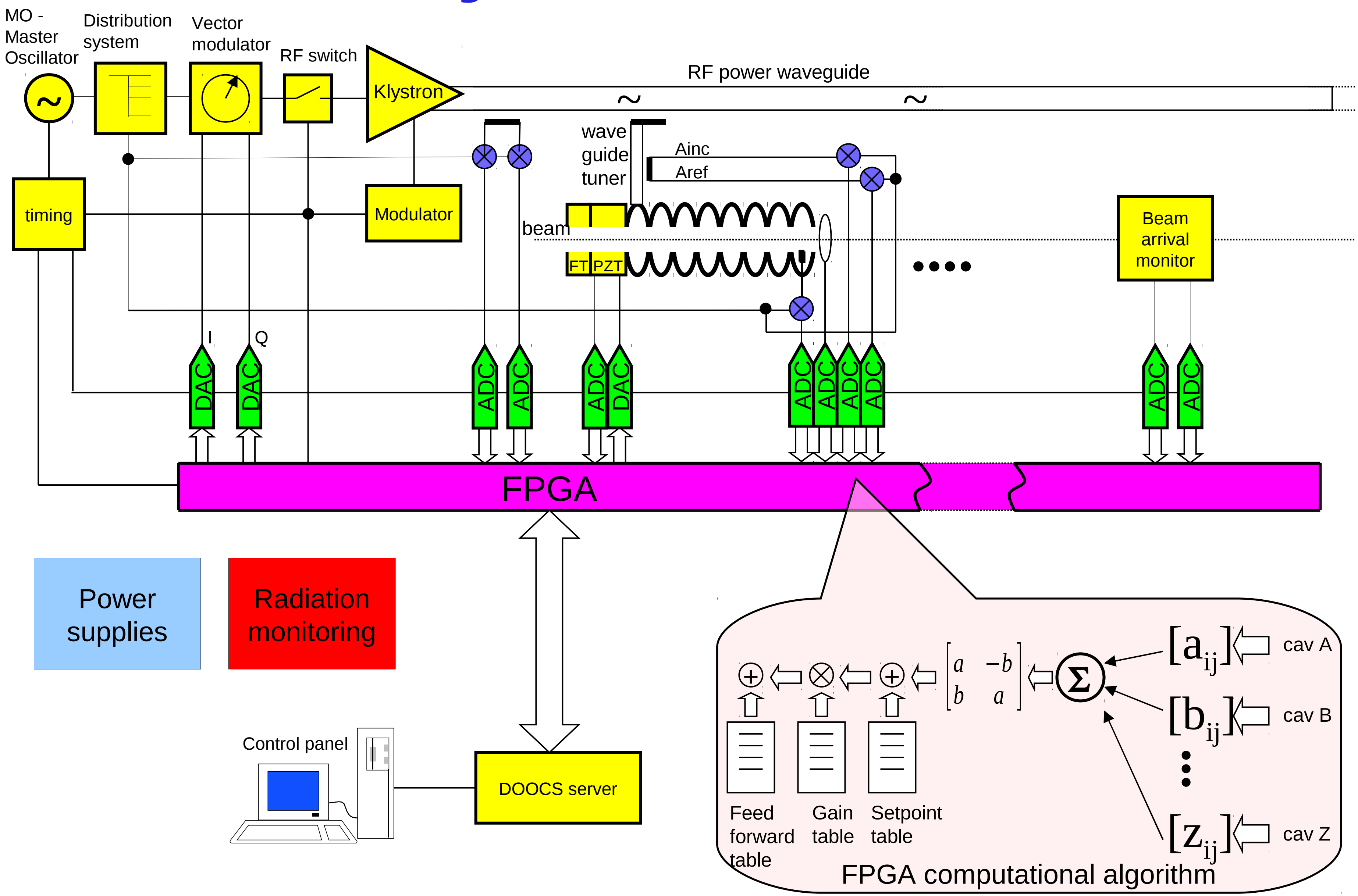
- Beam parameters changes are monotonic
- We can estimate the corrections for the next bunches

Beam stability

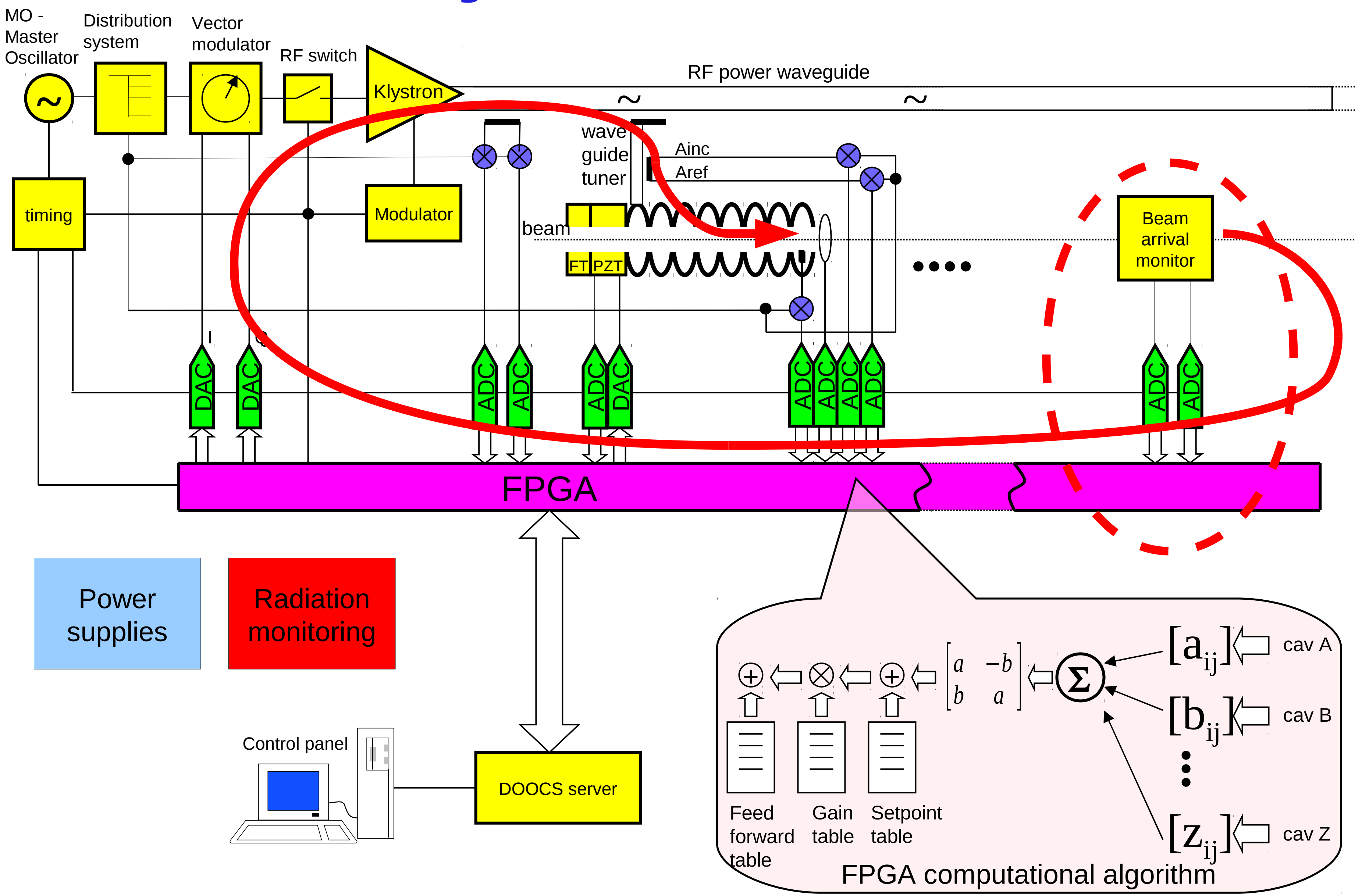


- Beam stability decreases with the higher LLRF feedback gains

LLRF system architecture



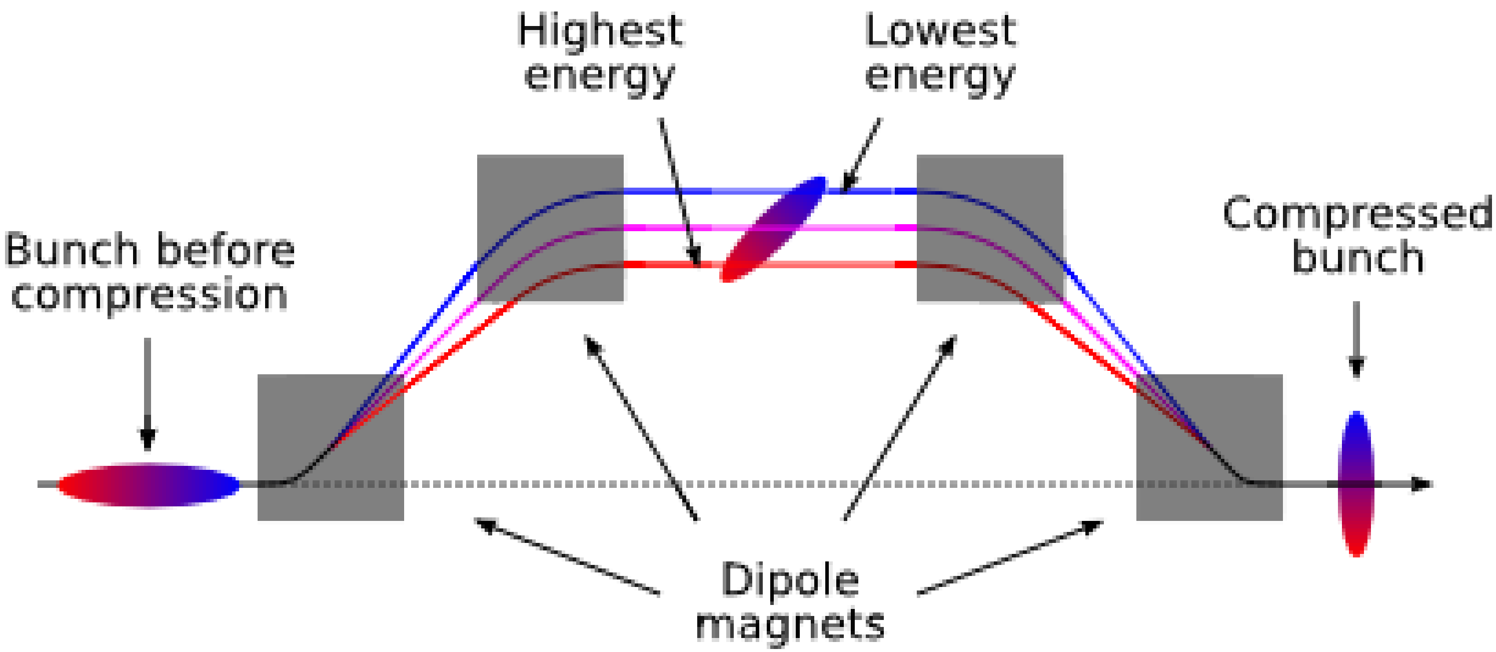
LLRF system architecture



Energy feedback

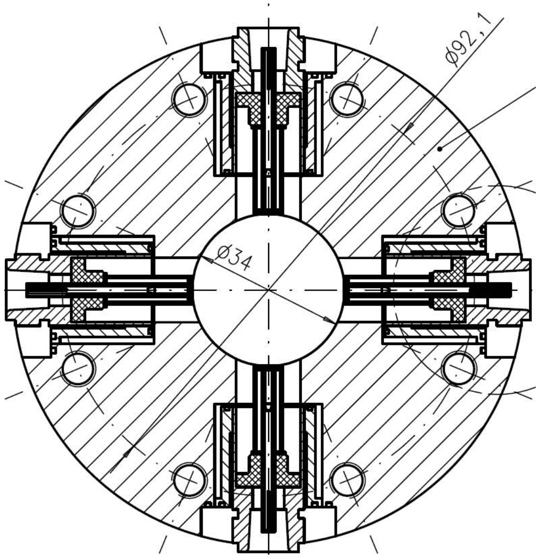
- Bunch energy depends on the amplitude of the RF field
- Bunch energy is measured by difference in arrival time of the bunch (w.r.t reference synchronization source)
- Energy fluctuations are converted to the arrival time changes in the bunch compressor
- Arrival time is measured by Bunch Arrival time Monitor (BAM)

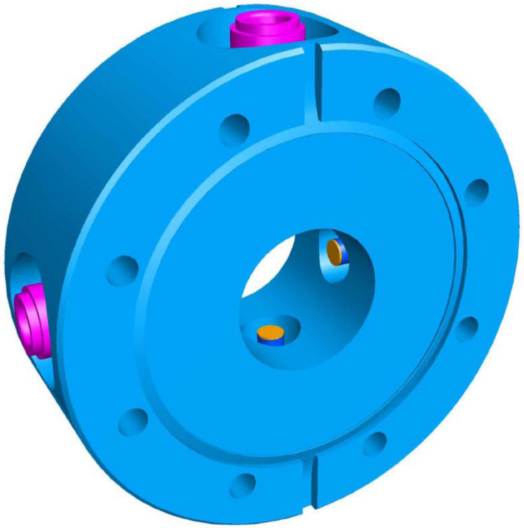
Bunch compression

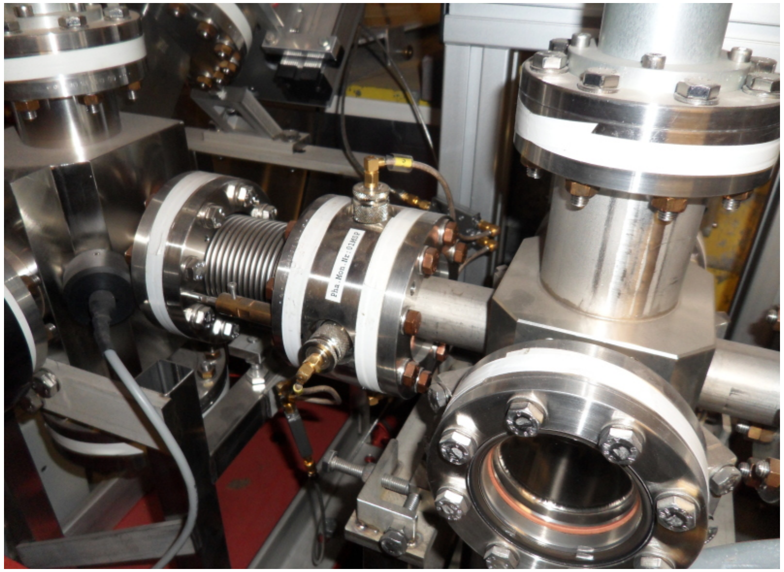


- Bunch compression makes the electrons of different energies travel over different ways.
- This converts energy changes to arrival time changes

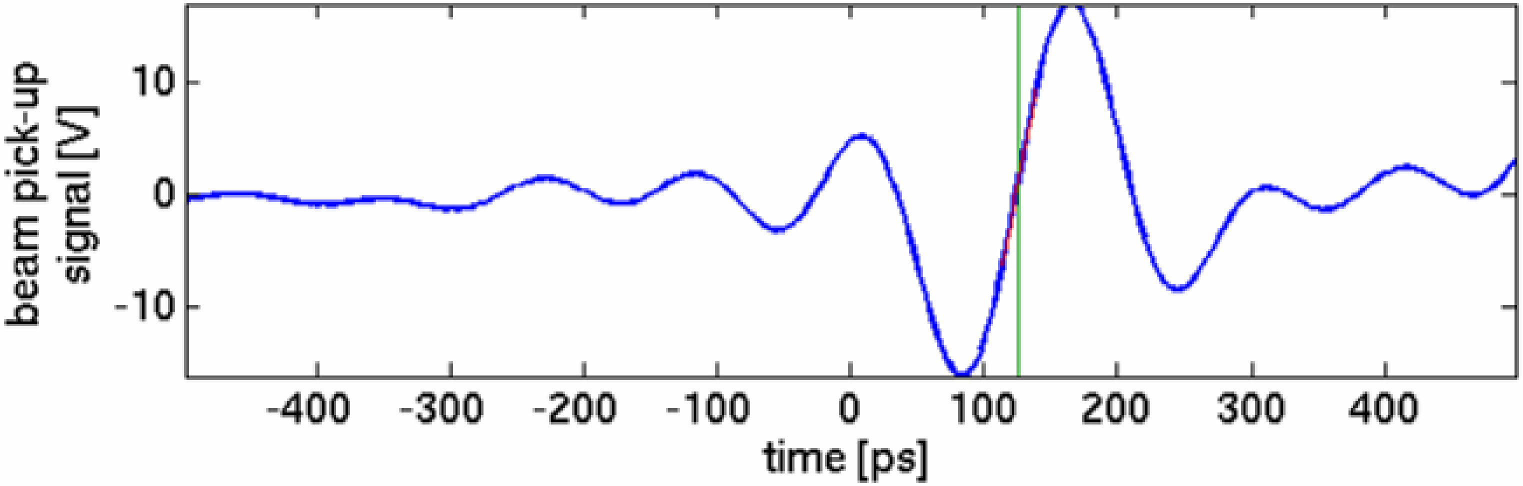
Bunch Arrival time Monitor (BAM)



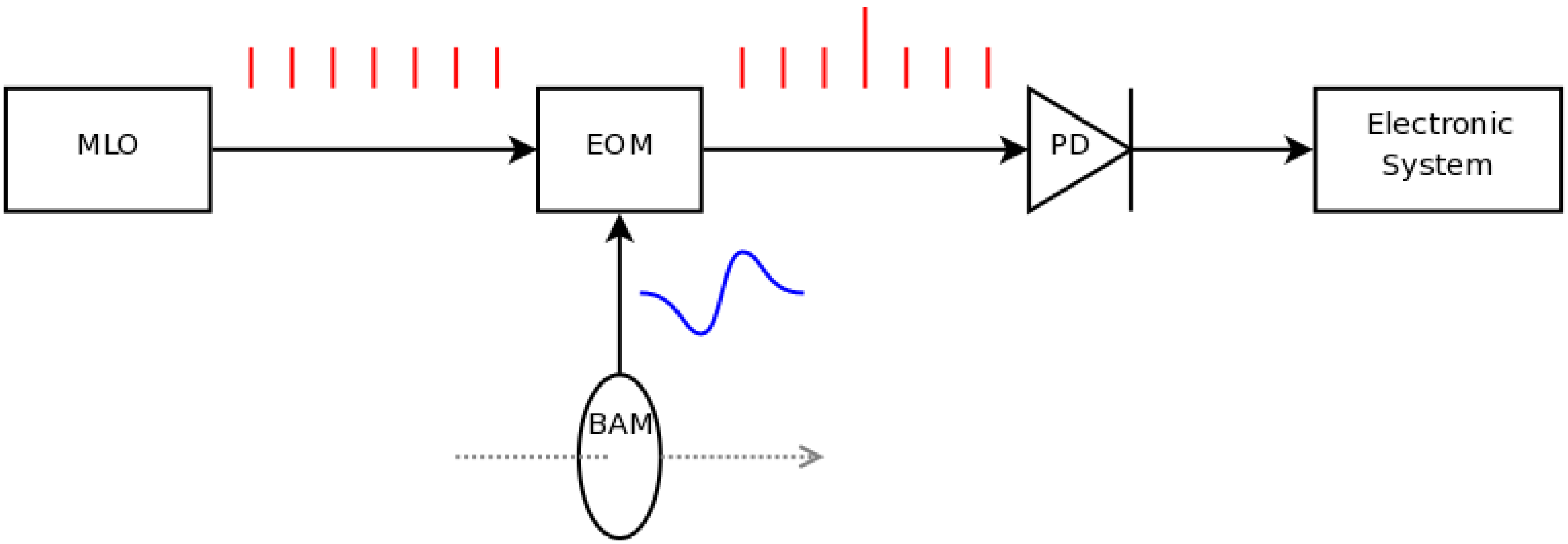




Response:

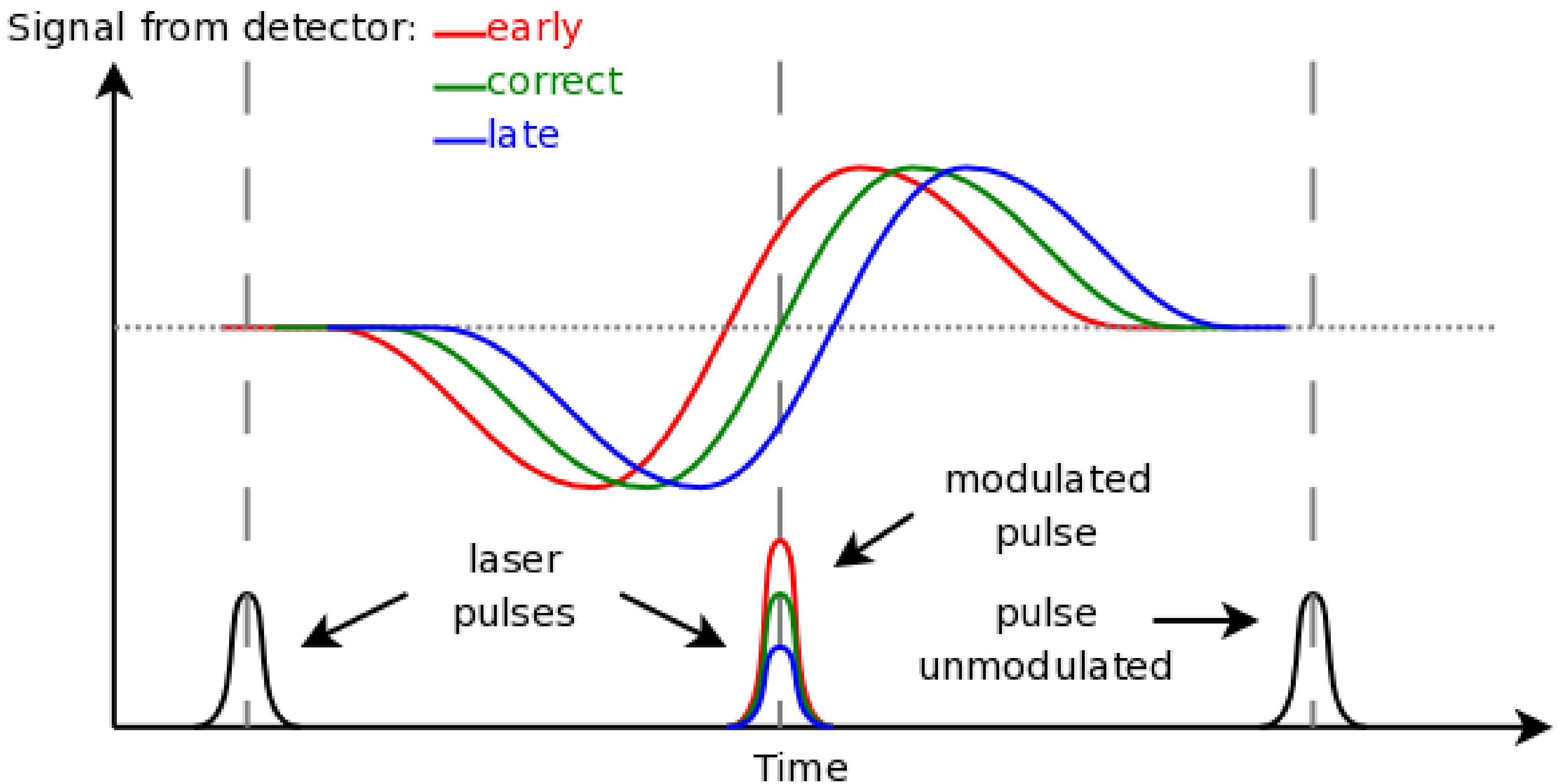


Laser pulses modulation



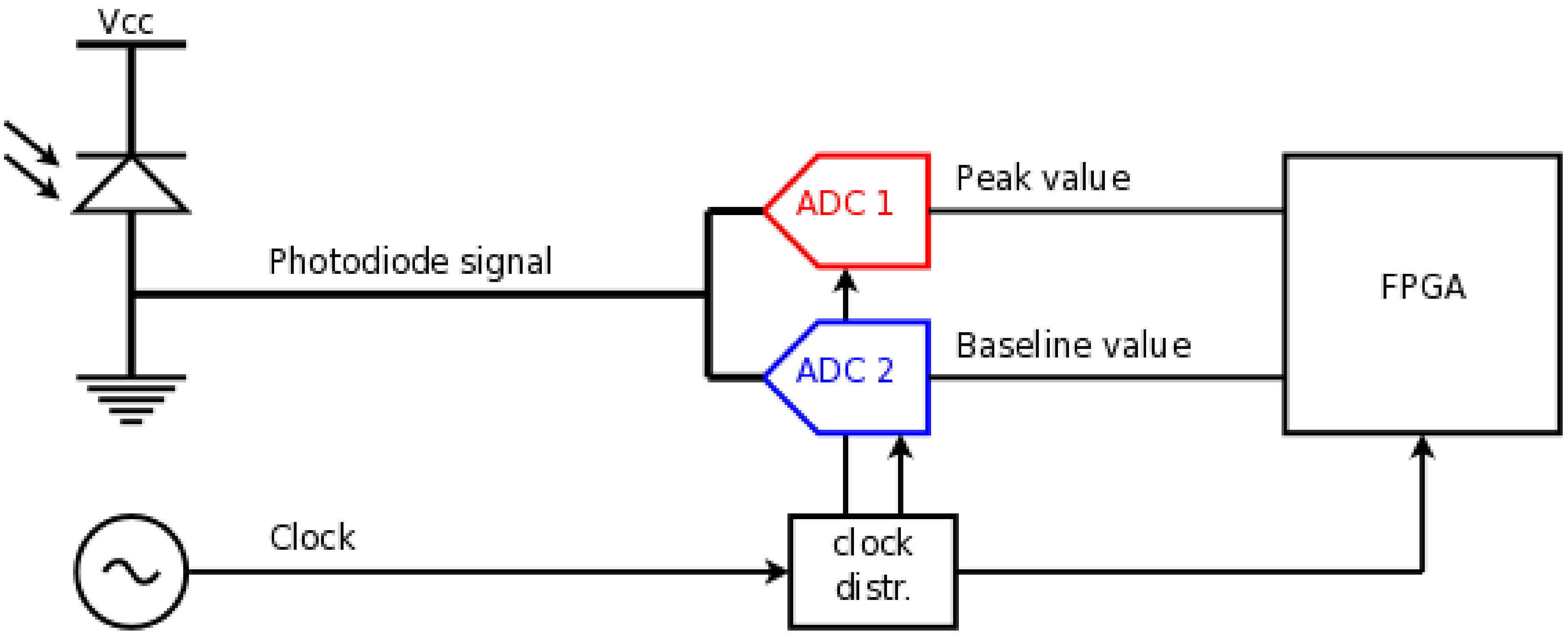
Amplitude of laser pulses generated by the reference synchronization system (MLO) is modulated by the arrival time of the traveling bunch

Laser pulses modulation



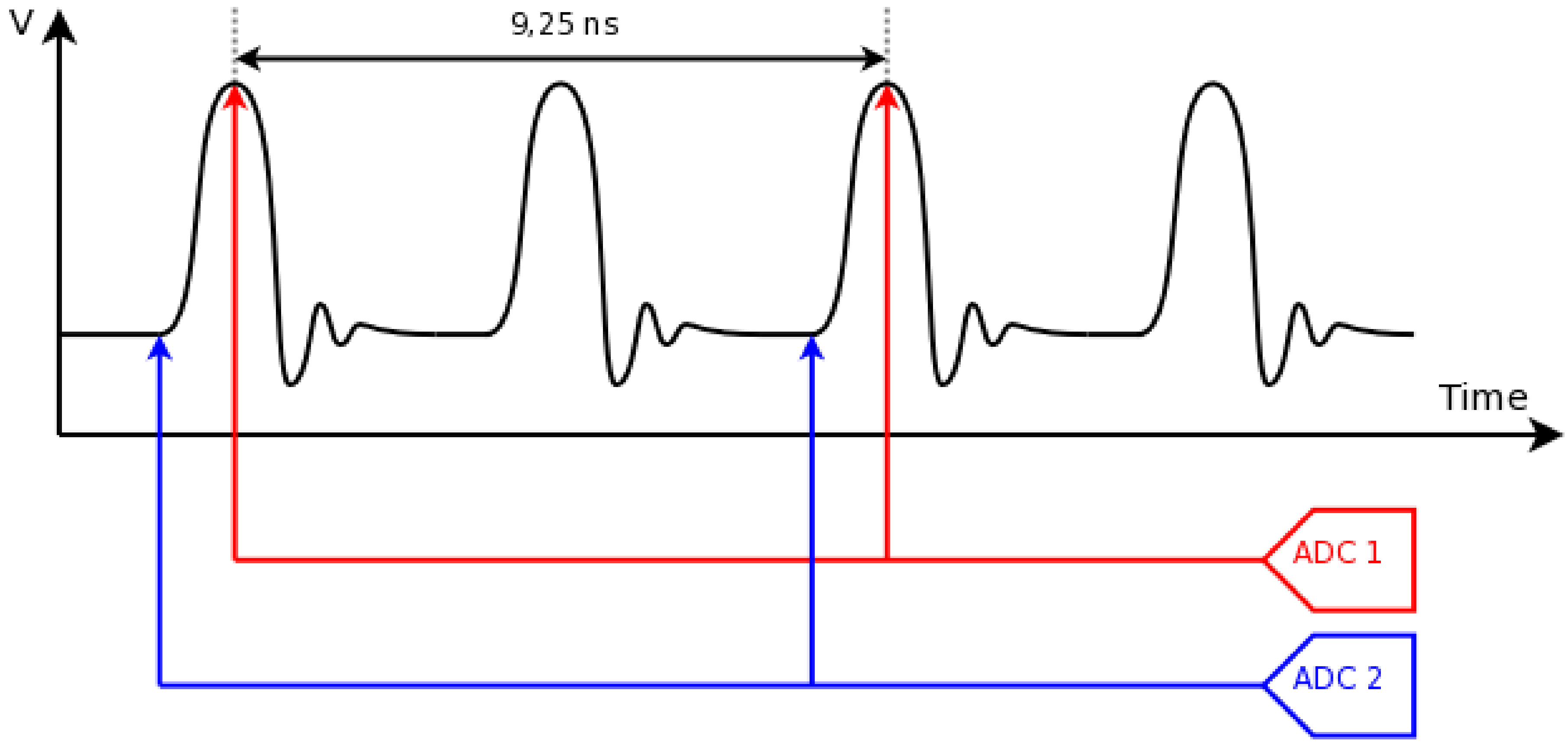
The amplitude of the correct in time bunch is same as the amplitude of the unmodulated pulses, due to zero-crossing

Laser pulse amplitude measurement



Signal from photo diode is sampled using two ADCs, with clock signal shifted in phase

Laser pulse amplitude measurement

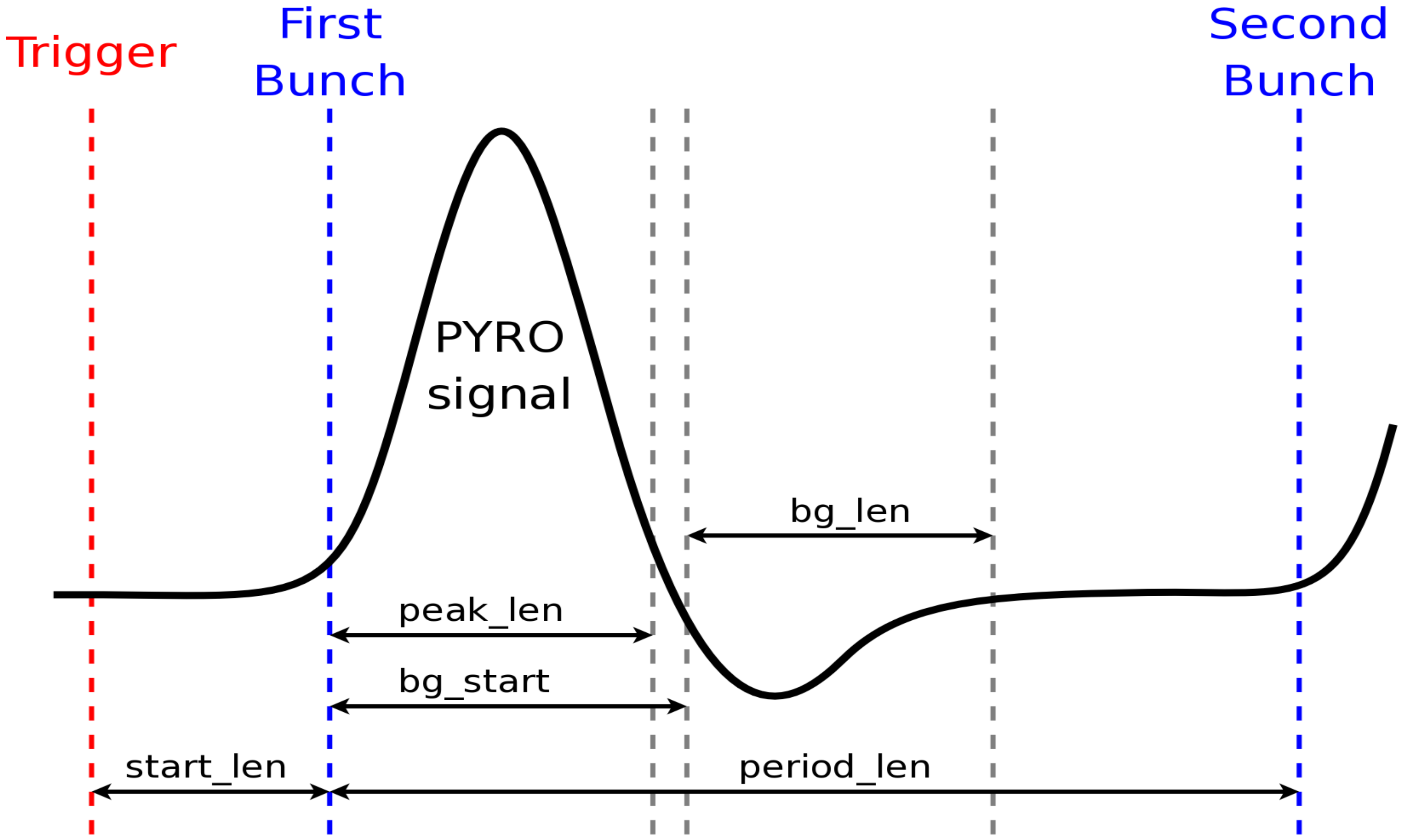


$$A_{corr} = \frac{Peak_{mod} - Base_{mod}}{Peak_{unmod} - Base_{unmod}}$$

Compression feedback

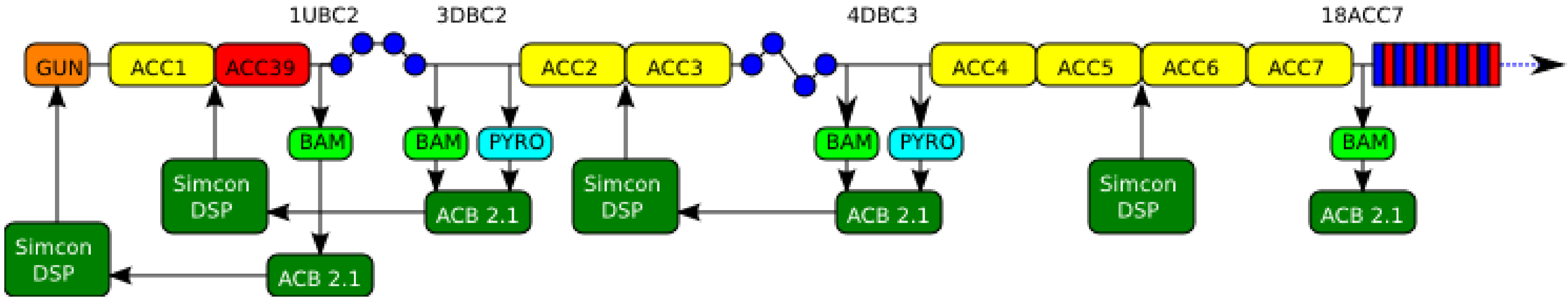
- Bunch compression depends the phase of the RF field
- Bunch compression is measured by the pyro-electric detector (PYRO)
- PYRO is located after the bunch compressor and it measures CSR radiation from it
- Amplitude of generated electric pulse is proportional to the compression of the bunch which generated radiation in the bunch compressor

Compression feedback



$$P_{corr} = \sum peak - \sum background$$

Installation at FLASH

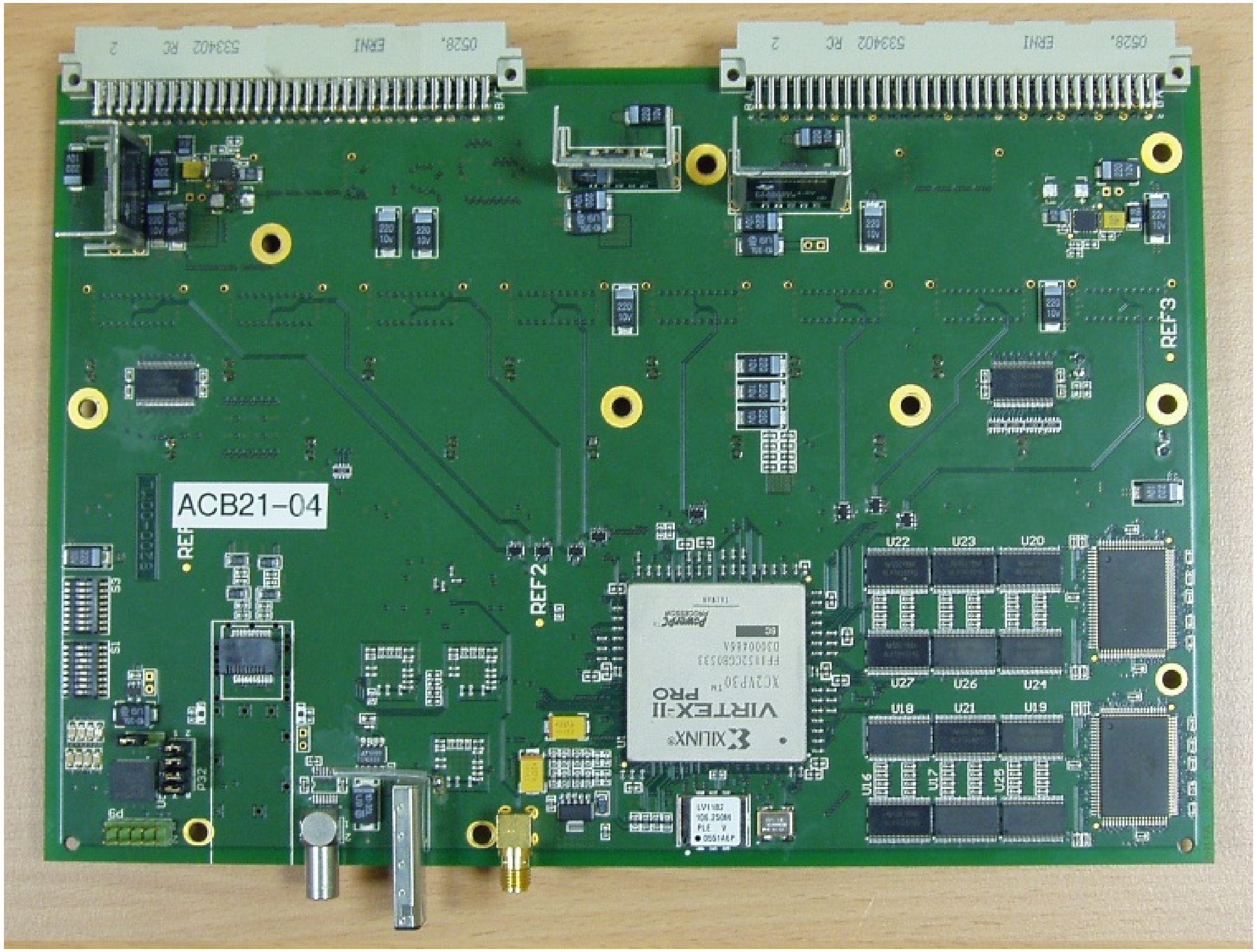


- BAMs:
  - 1UBC2
  - 3DBC2
  - 4DBC3
  - 18ACC7
- PYROs:
  - 3DBC2
  - 4DBC3
- Electronic devices:
  - ACB2.1 (for BBF)
  - SimconDSP (for LLRF)

ACB 2.1

- VME-based board for processing signals from beam detectors
  - 1x Virtex-II Pro FPGA
  - Up to 4 ADCs
    (LTC2206, 16-bit, 125 MSPS has been used)
  - 3x AD9510 clock distribution chip
  - 1x SFP interface
    (for transferring correction to LLRF system)

ACB 2.1


ACB21-04
REF2
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U22
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U26
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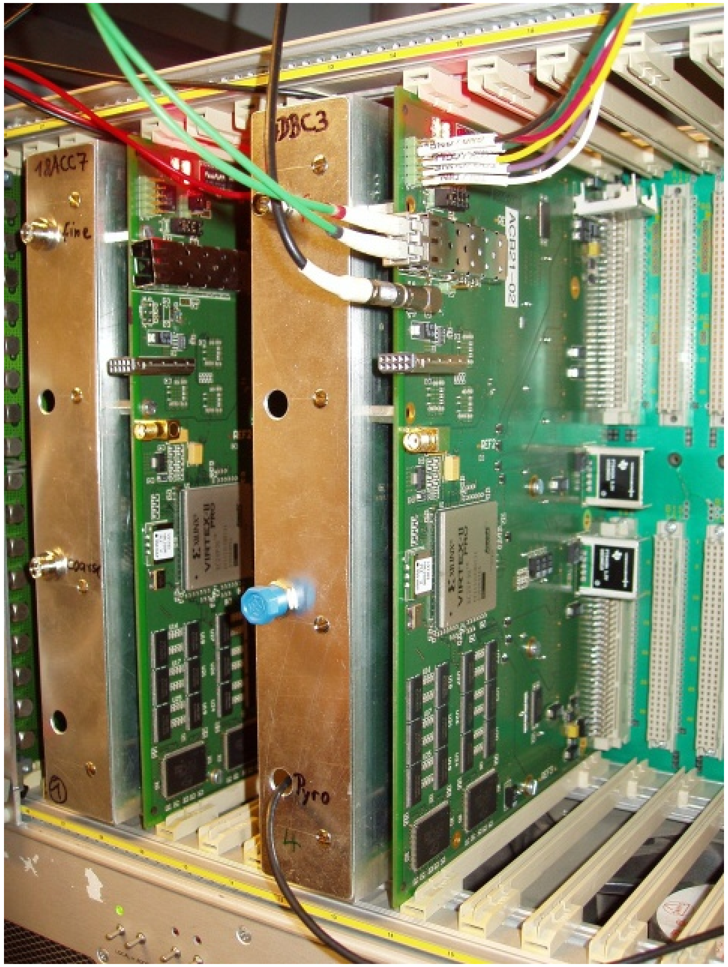
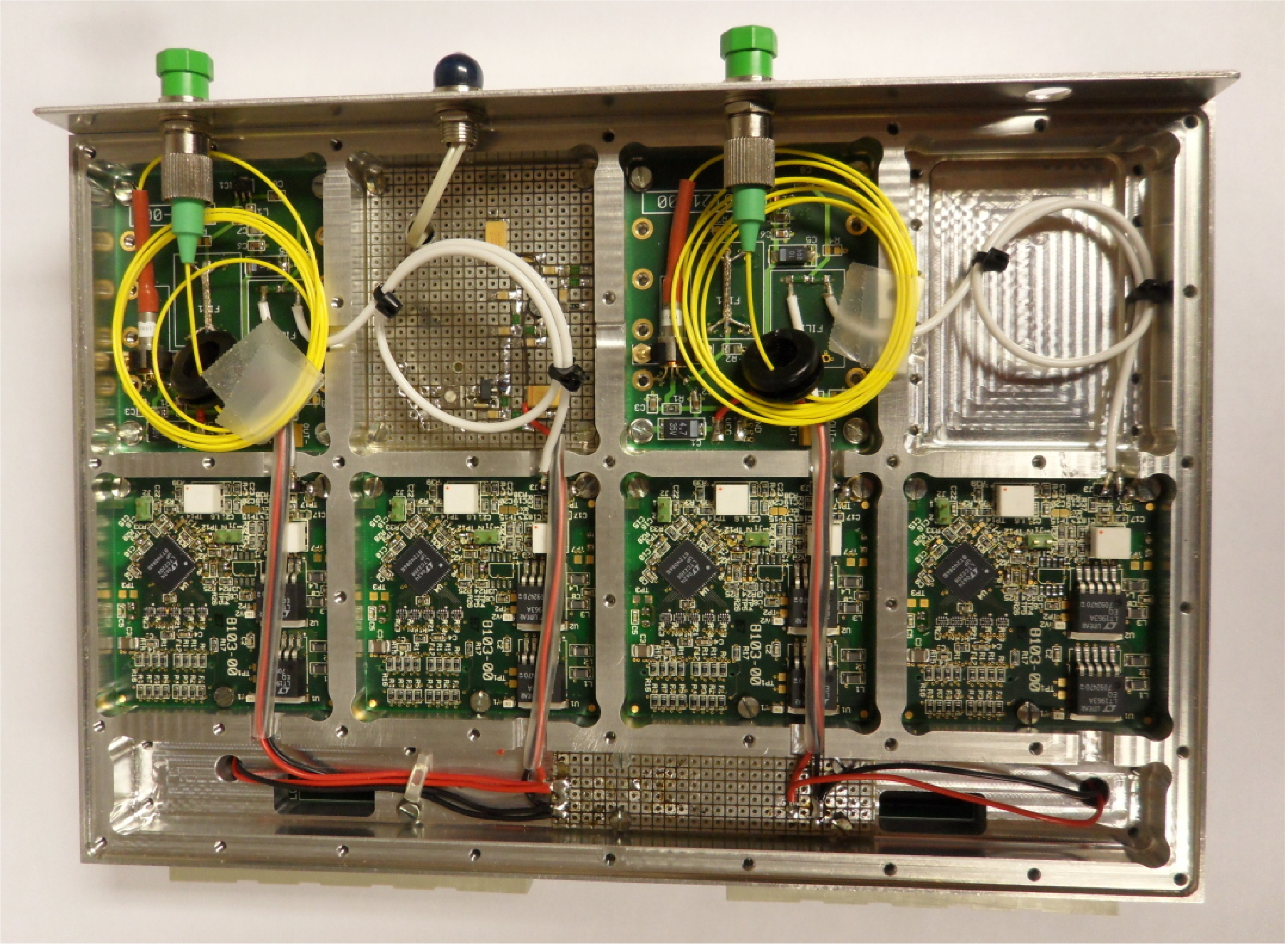
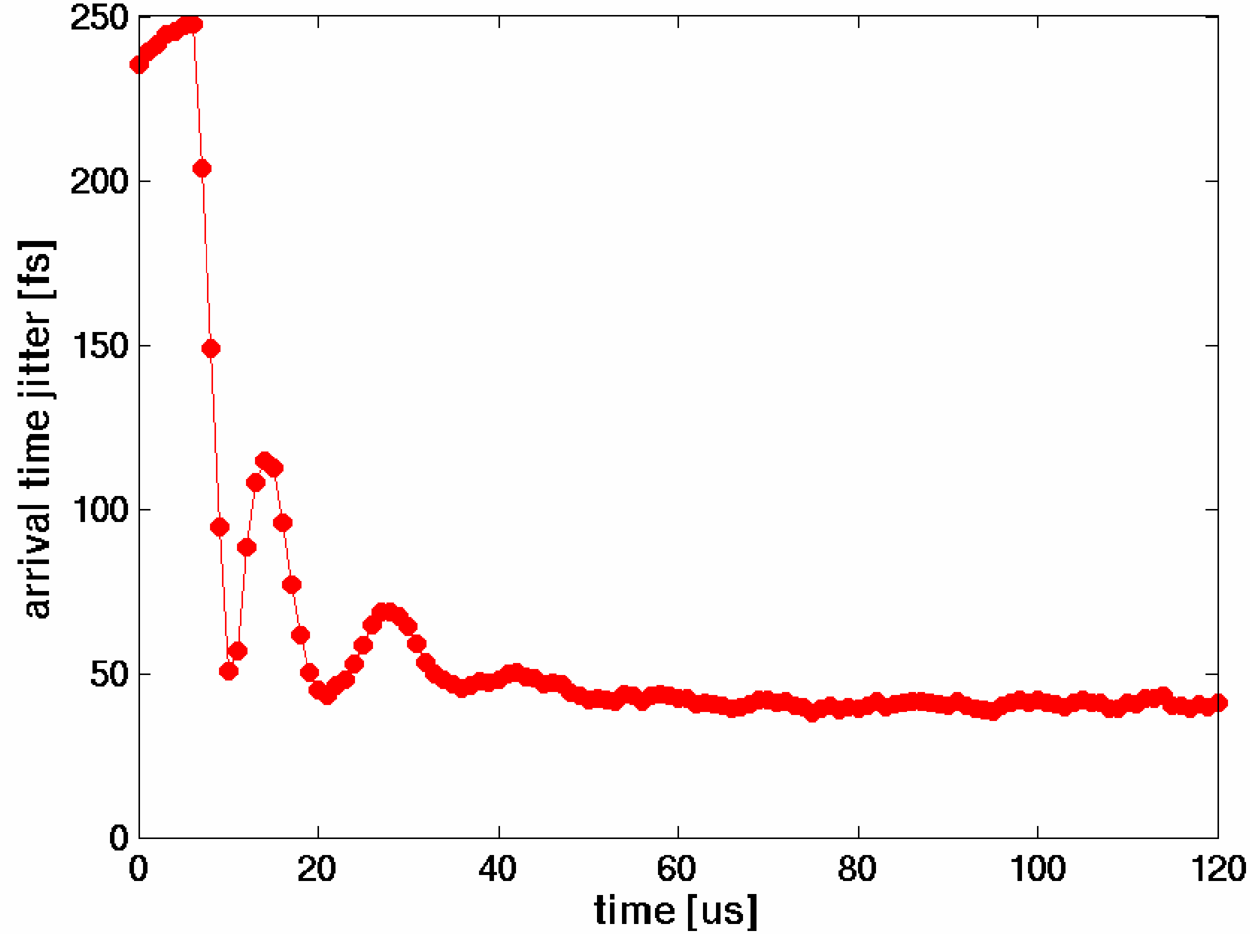
U18
U21
U19
XILINX
VIRTEX-II PRO


DBC3
Pyro

Analog Front-end

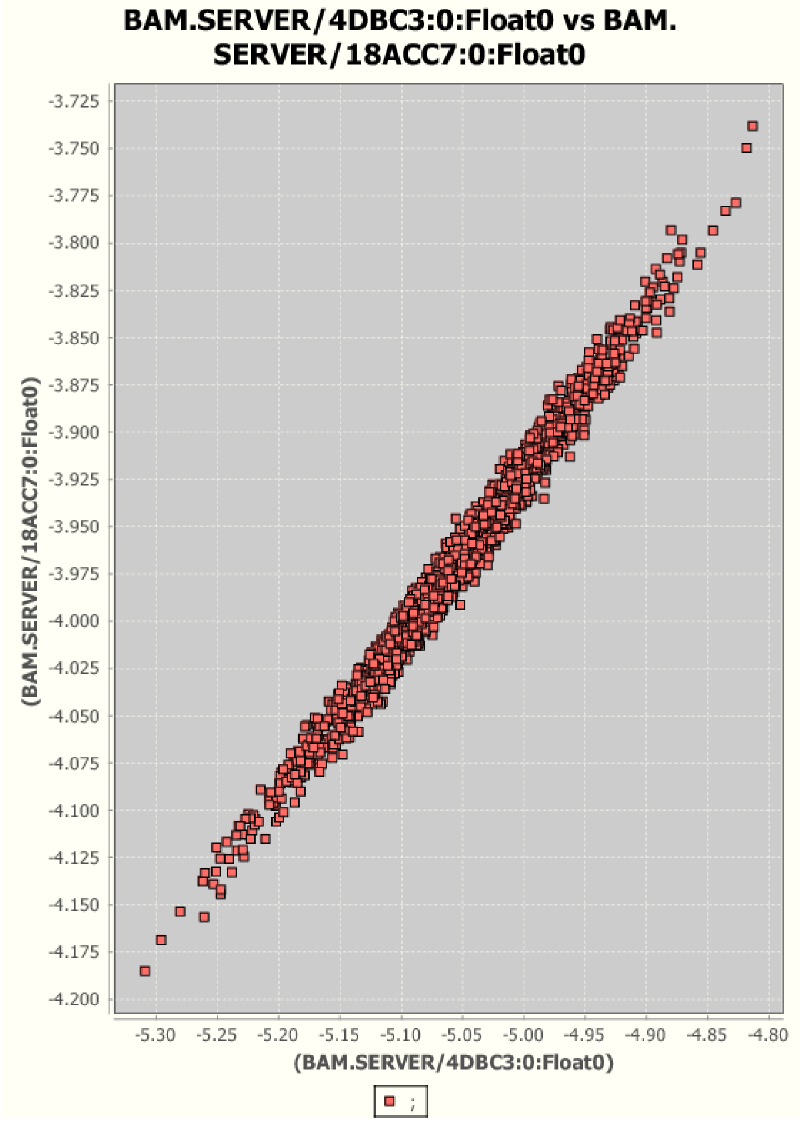


Results – Arrival time jitter

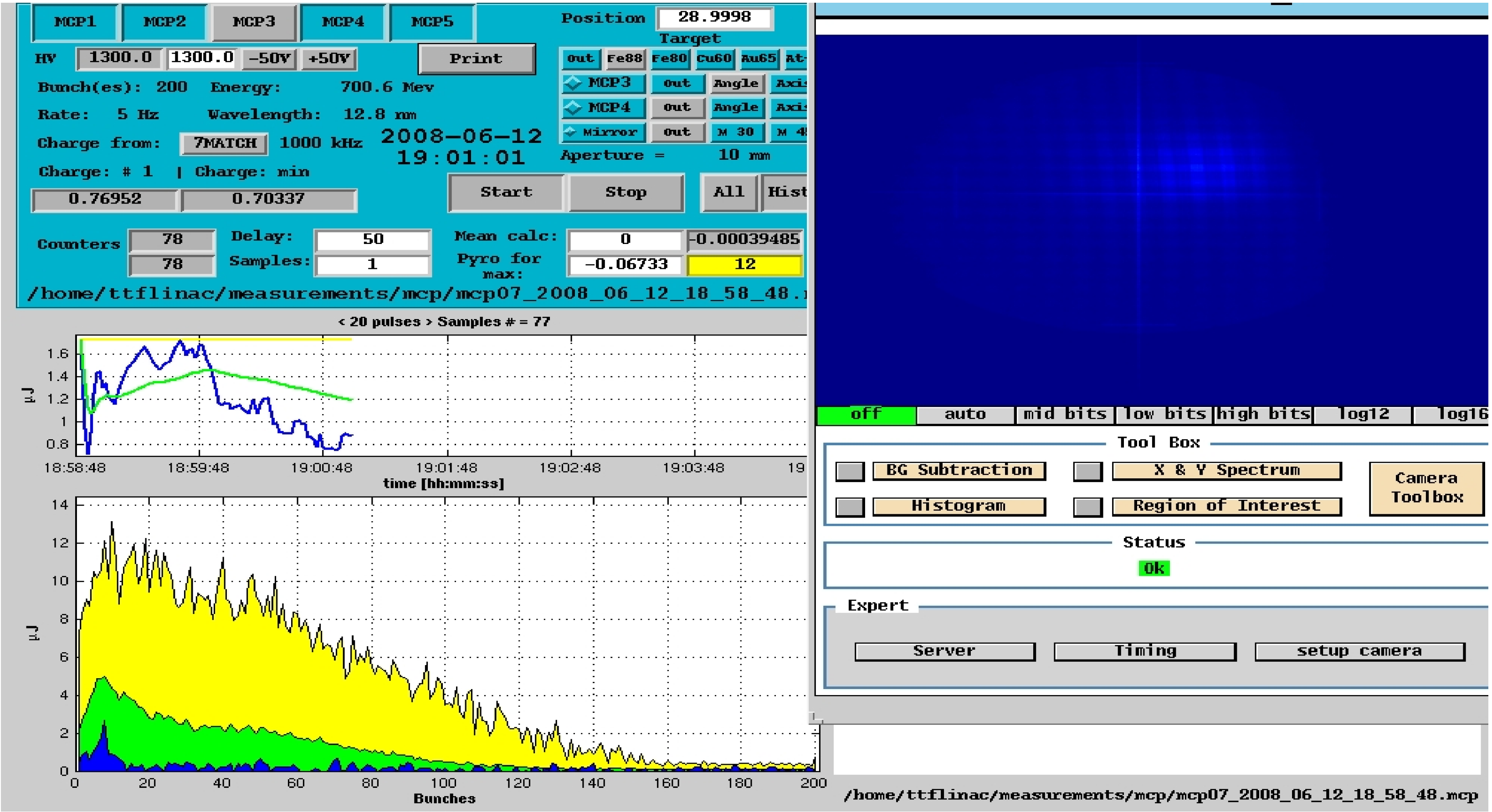


Arrival time jitter over the bunch train

Results – Correlation of 2 BAMs

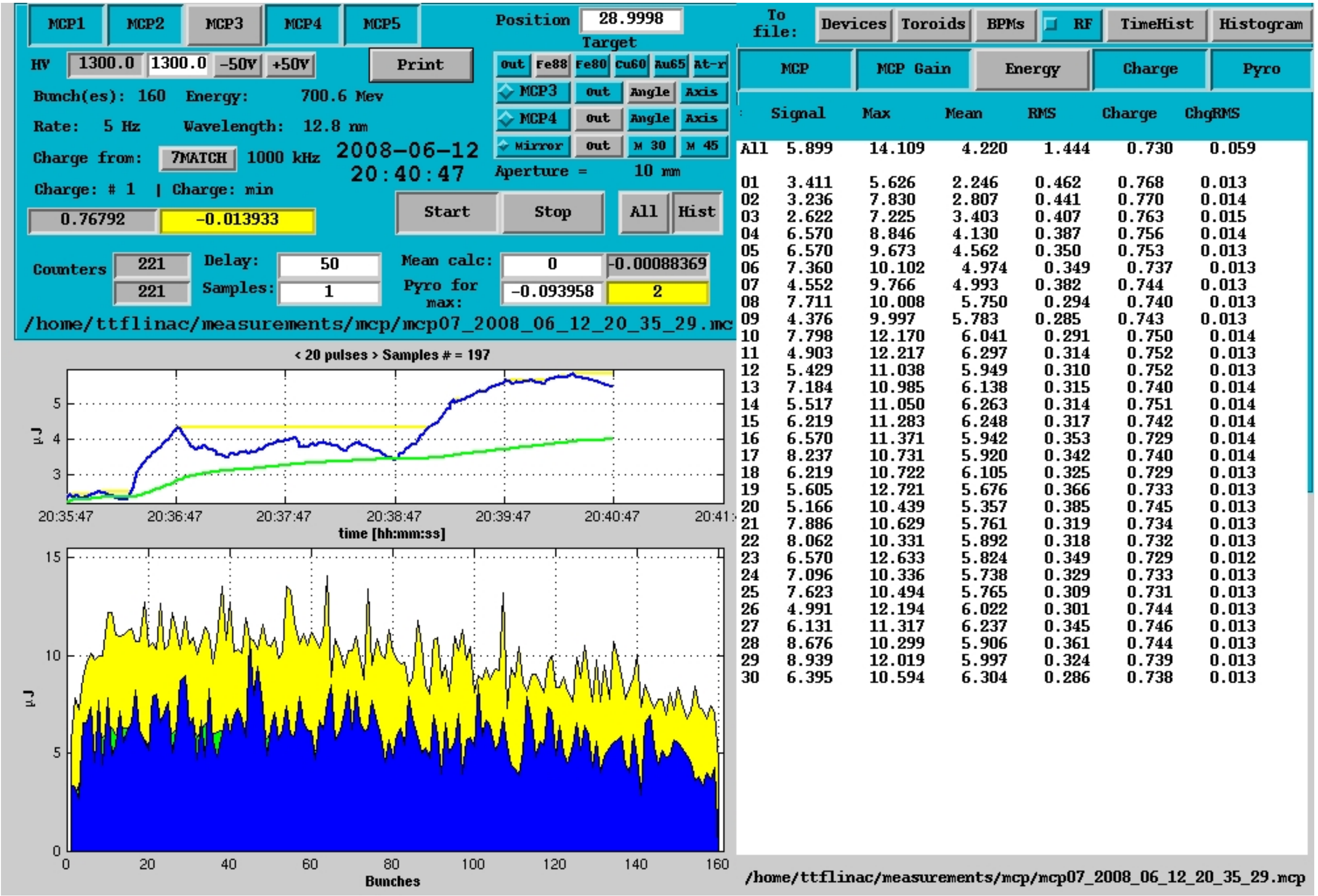


Results - SASE



SASE without beam feedback

Results - SASE



SASE with beam feedback

Next steps

- BBF system has been developed in the the VME technology
- It was tested with the VME LLRF system, but it can provide control corrections to the new uTCA LLRF System (using SFP fiber optic link)
- The next natural step for BBF is upgrade to uTCA, to have system compatible with the rest of FLASH electronics

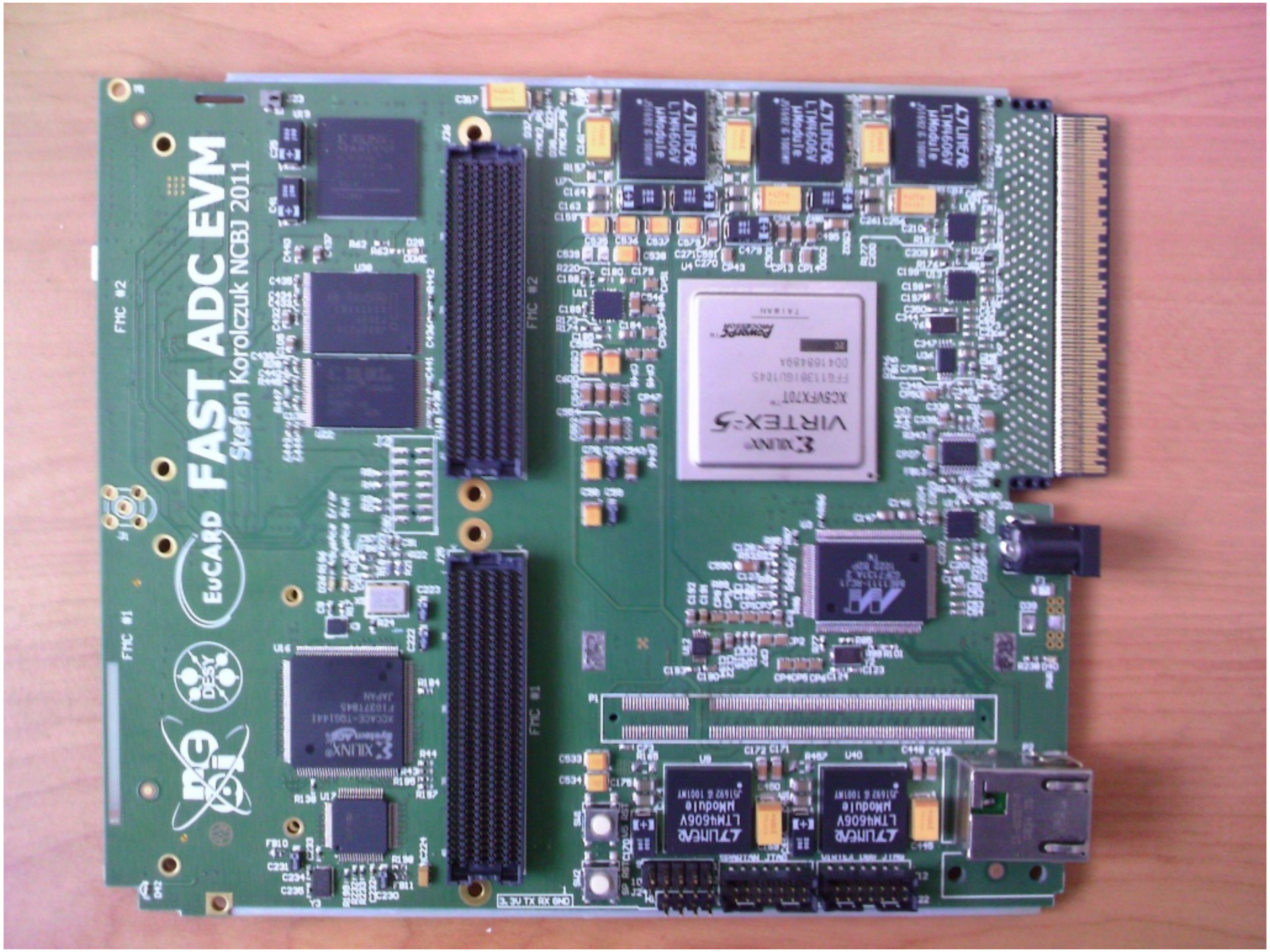
uTCA upgrade

- Laser pulses are generated with the frequency of 216 MHz
- ACB 2.1 was able to sample with frequency of 108 MHz (every second laser pulse)
- Bunches are generated in FLASH with frequency of 1 MHz – so every 108-th laser pusle was modulated
- In the new solution will sample every pulse with the rate of 216 MHz

uTCA BBF Upgrade

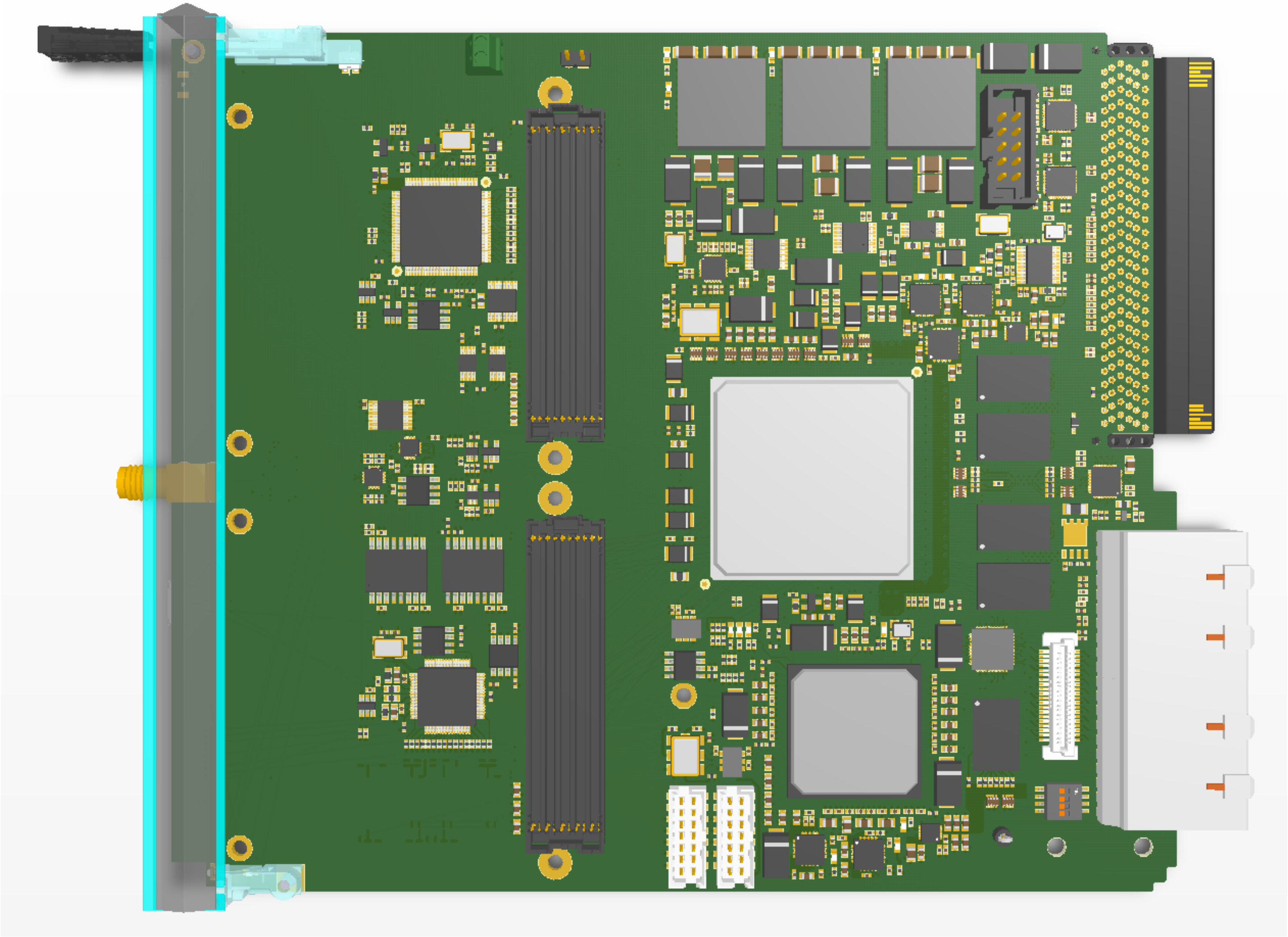
Improvements	ACB 2.1	uFMC25
Faster ADCs	125 MSPS	up to 1 GSPS
Newer FPGA	Virtex-II Pro	Virtex-5
Mezzanine cards	Custom	FMC (commercial std.)
Remote firmware update	No	Yes
Backplane Interconnect	VME (32 bit)	uTCA (PCIe, Eth)
Diagnostic interface	RS-232	USB
Ethernet	No	Yes

uFMC25v1 board



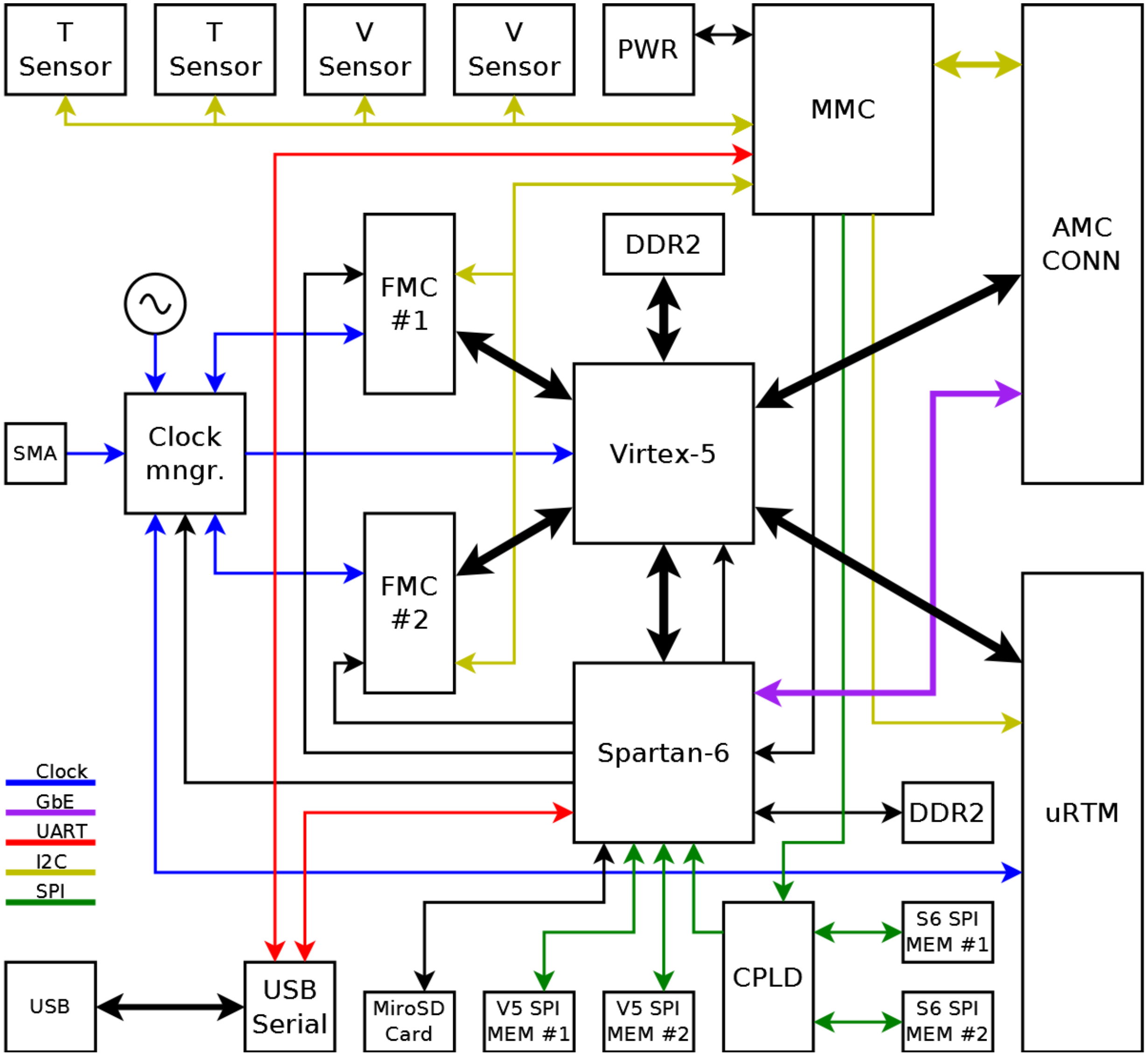
uFMC25 ver.1 is being tested now

uFMC25v2

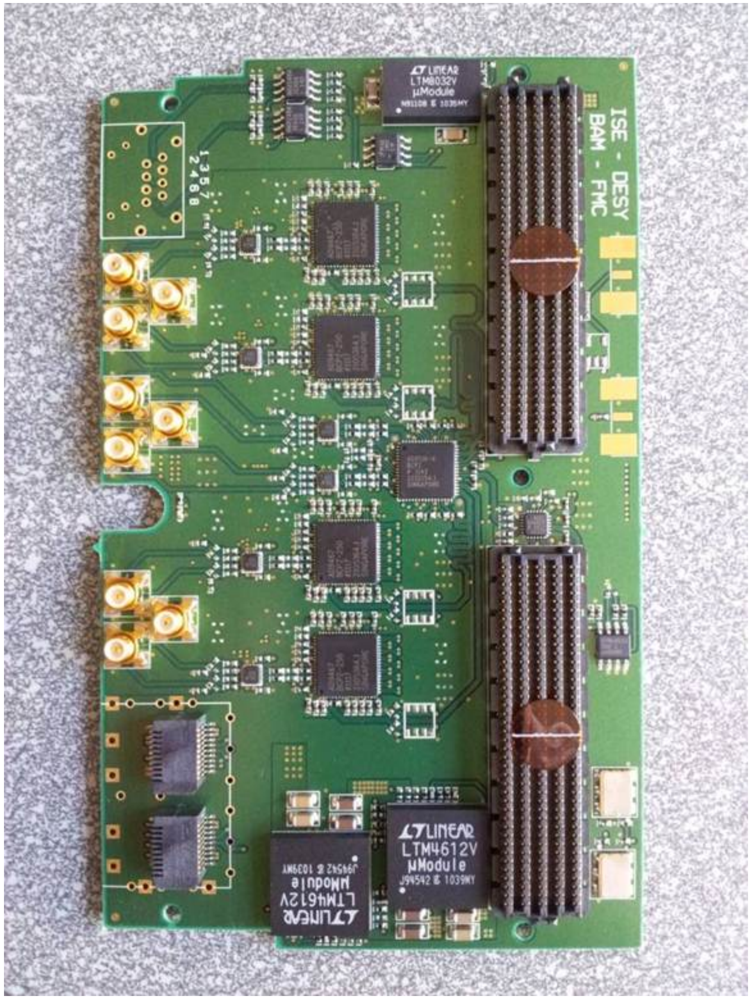


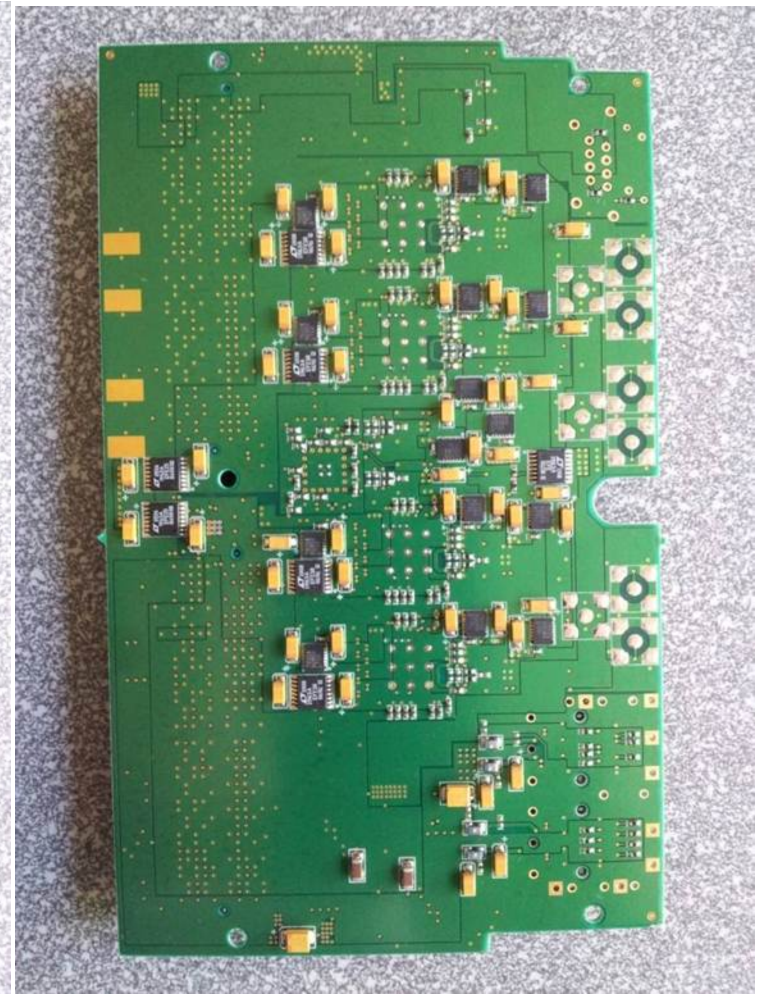
uFMC25 ver.2 is designed and prepared for production

uFMC25v2 block diagram



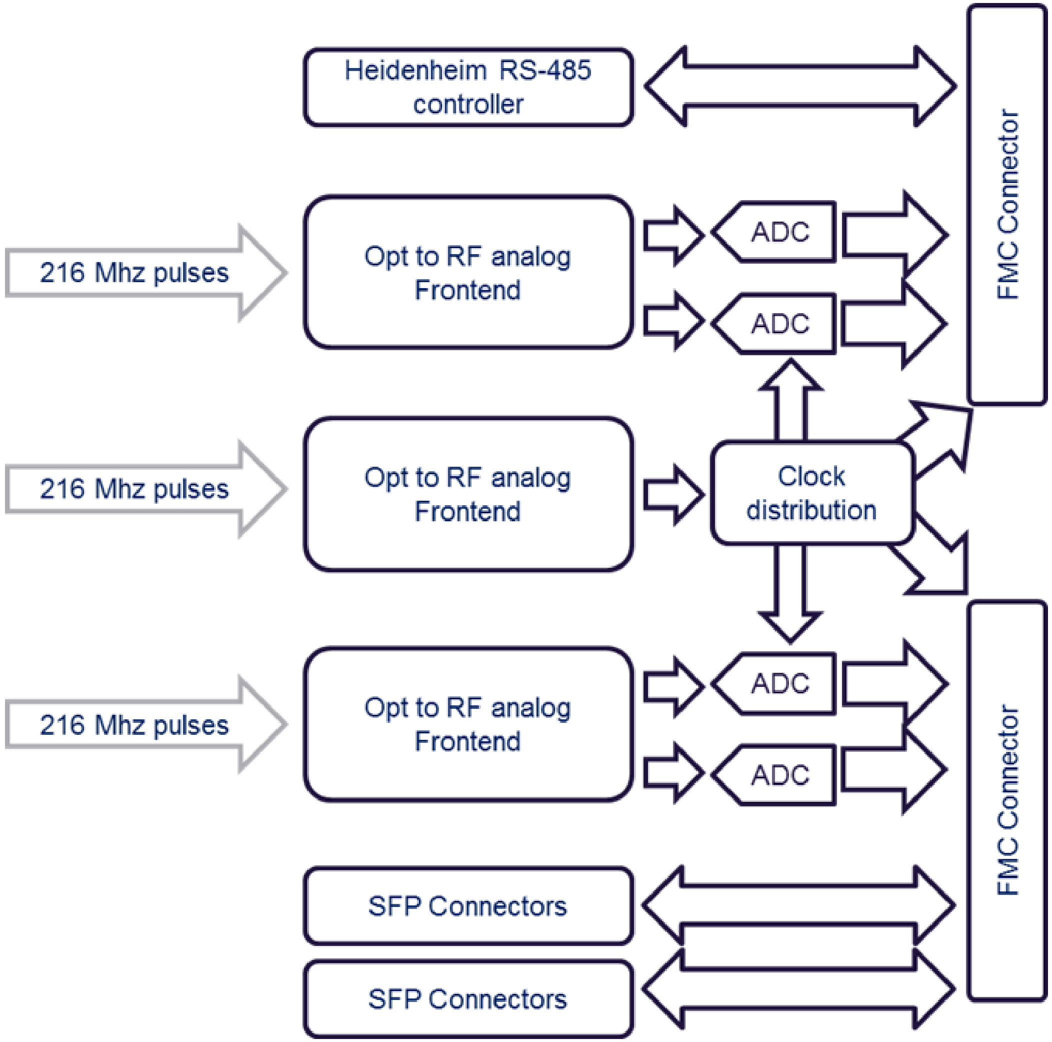
BAM FMC Mezzanine board





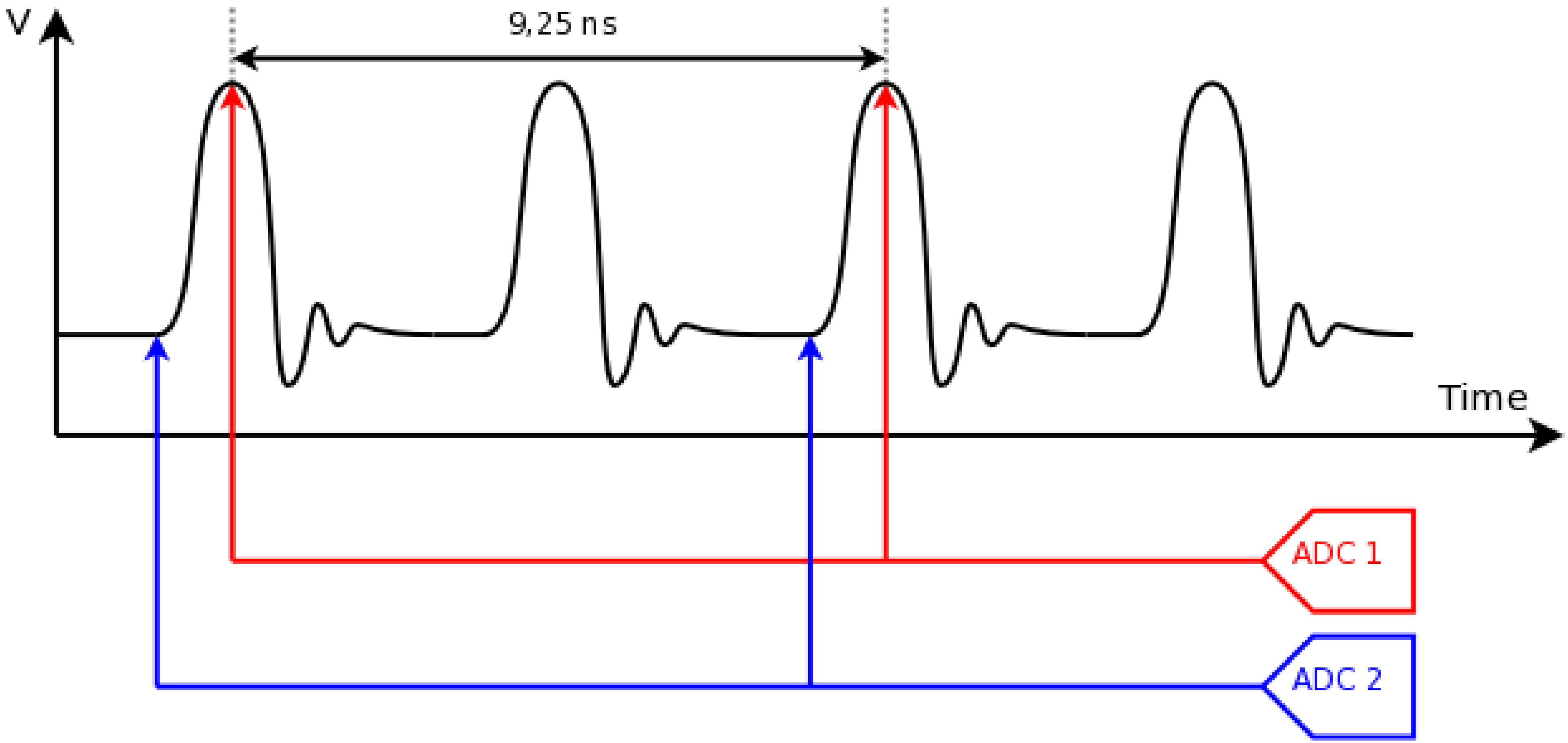
Courtesy: Samer Bou Habib

BAM FMC Block diagram



Courtesy: Samer Bou Habib

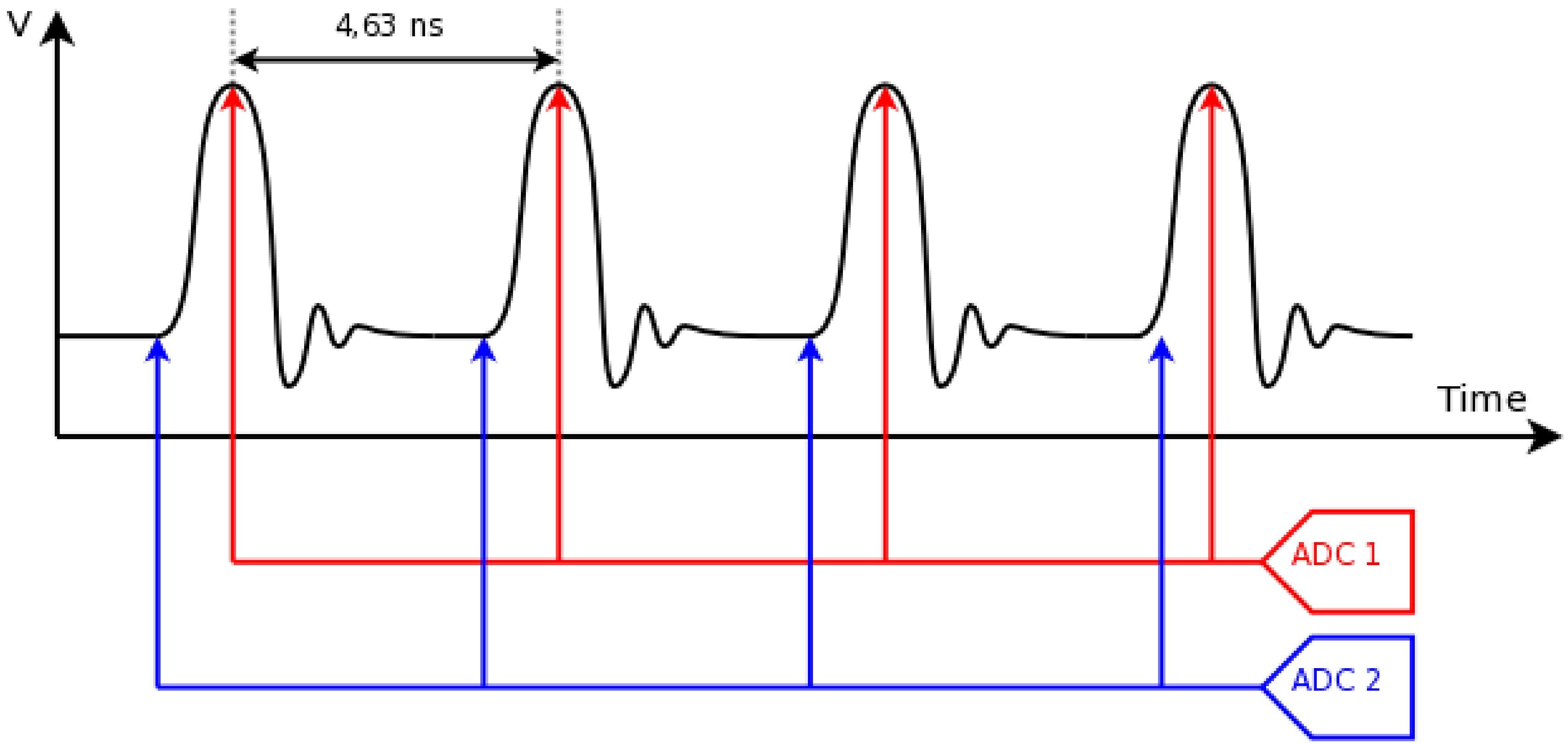
Actual sampling scheme



108 MHz sampling

Every second laser pulse is sampled

New sampling scheme

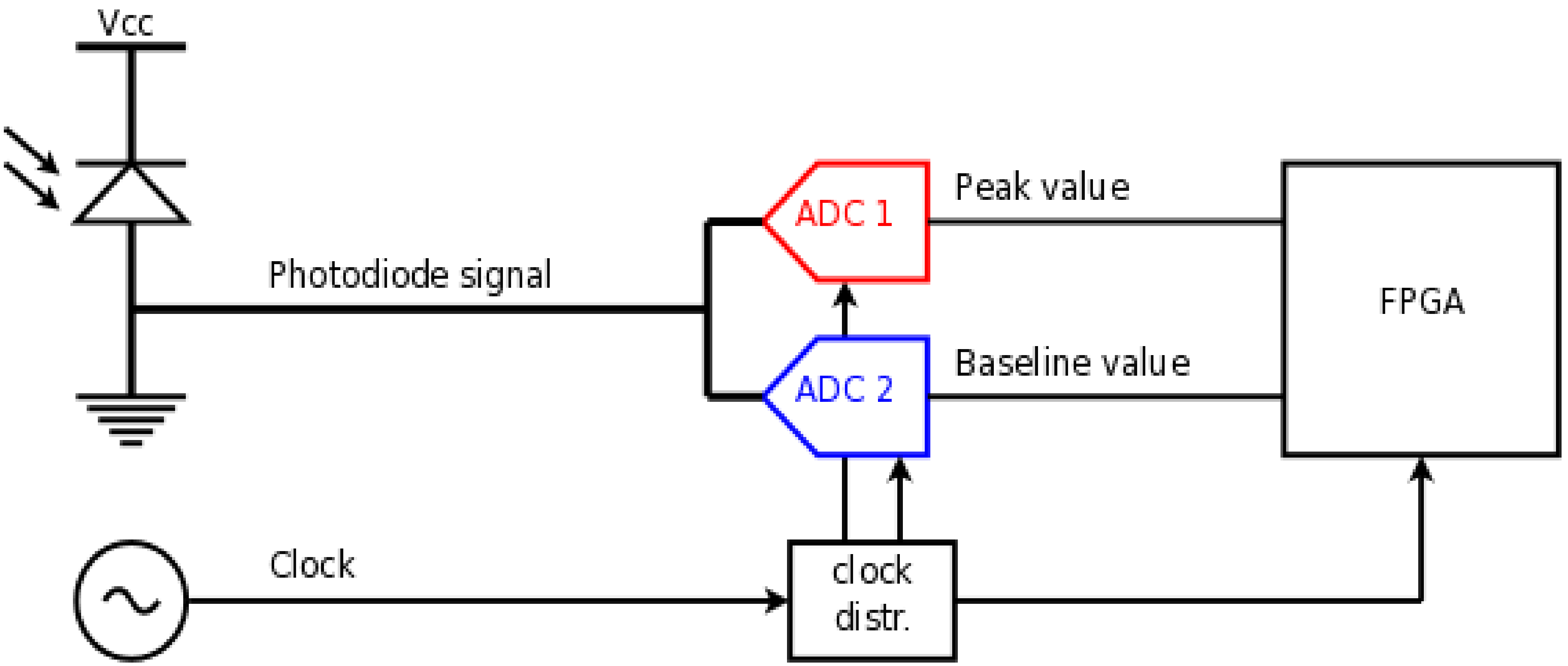


216 MHz sampling

We do not have to look for modulated pulse,

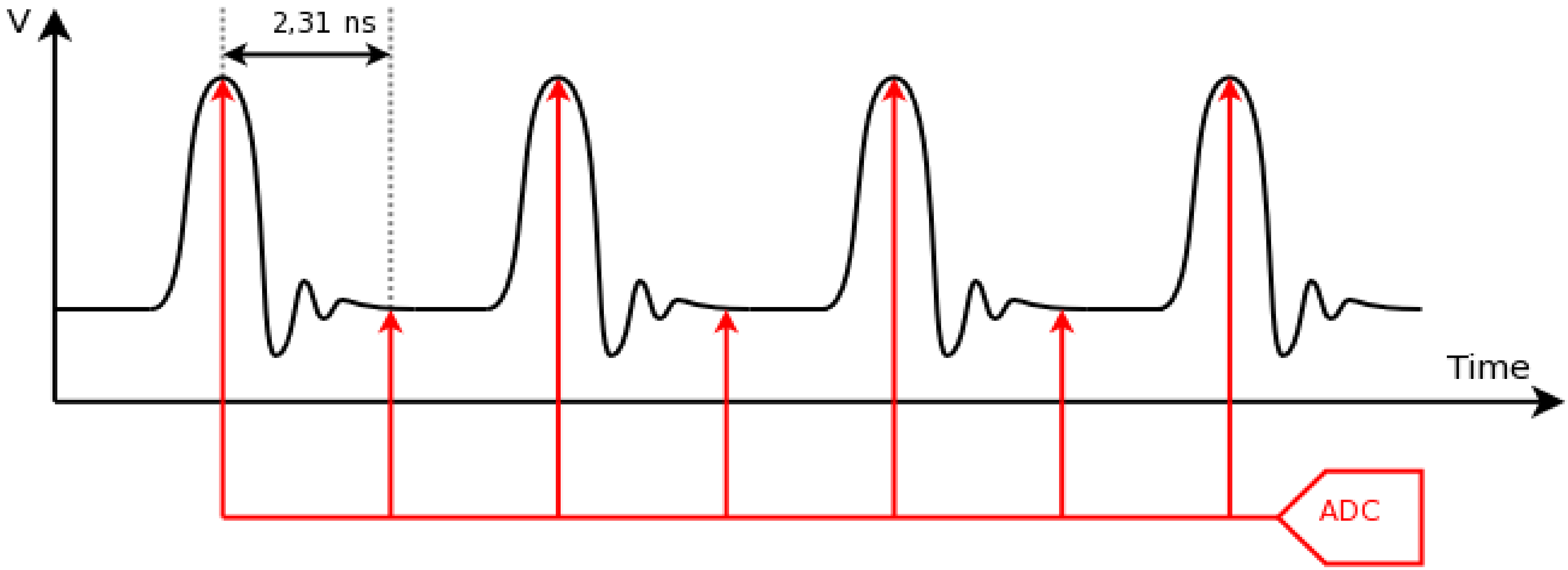
all pulses are sampled

Signal distribution



Signal distribution with 2 ADCs - “T” distribution is weak point

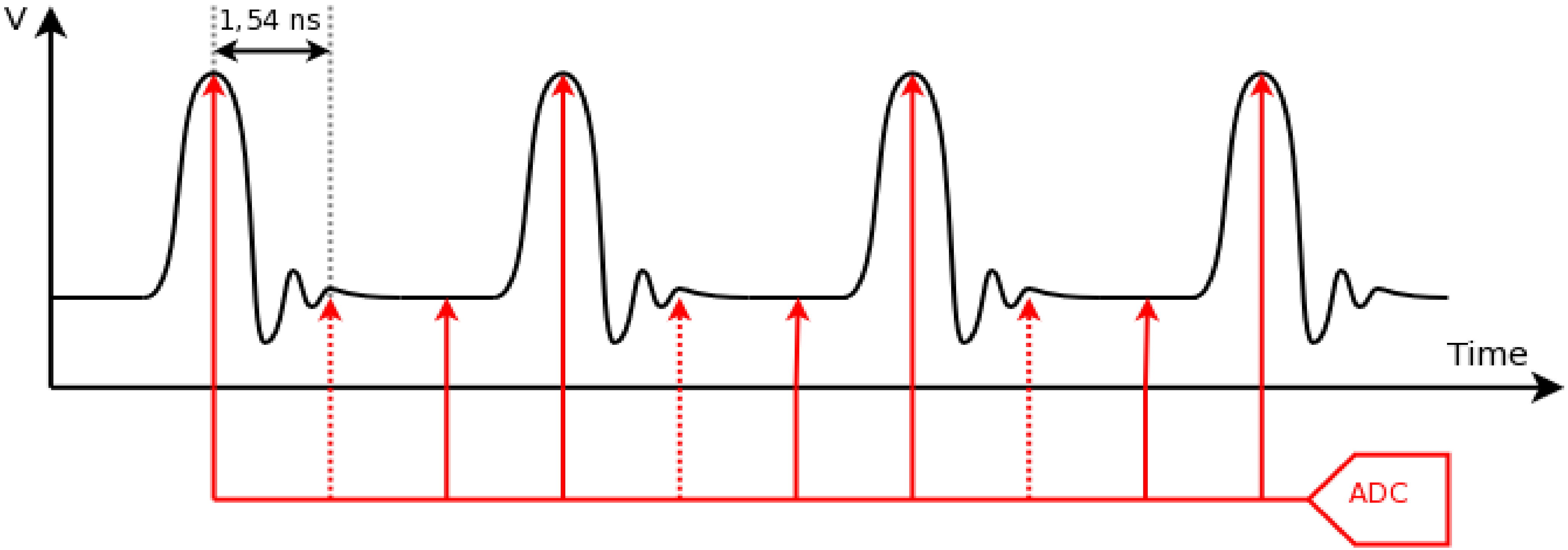
Solution - Faster ADC



432 MHz – only one ADC is needed,

but ringing may affect the baseline sample

Solution - Even faster ADC



632 MHz sampling – avoids sampling the baseline in the ringing area

The End

Thank You