The FERMI@Elettra Cavity BPM System: Description and Commissioning Results

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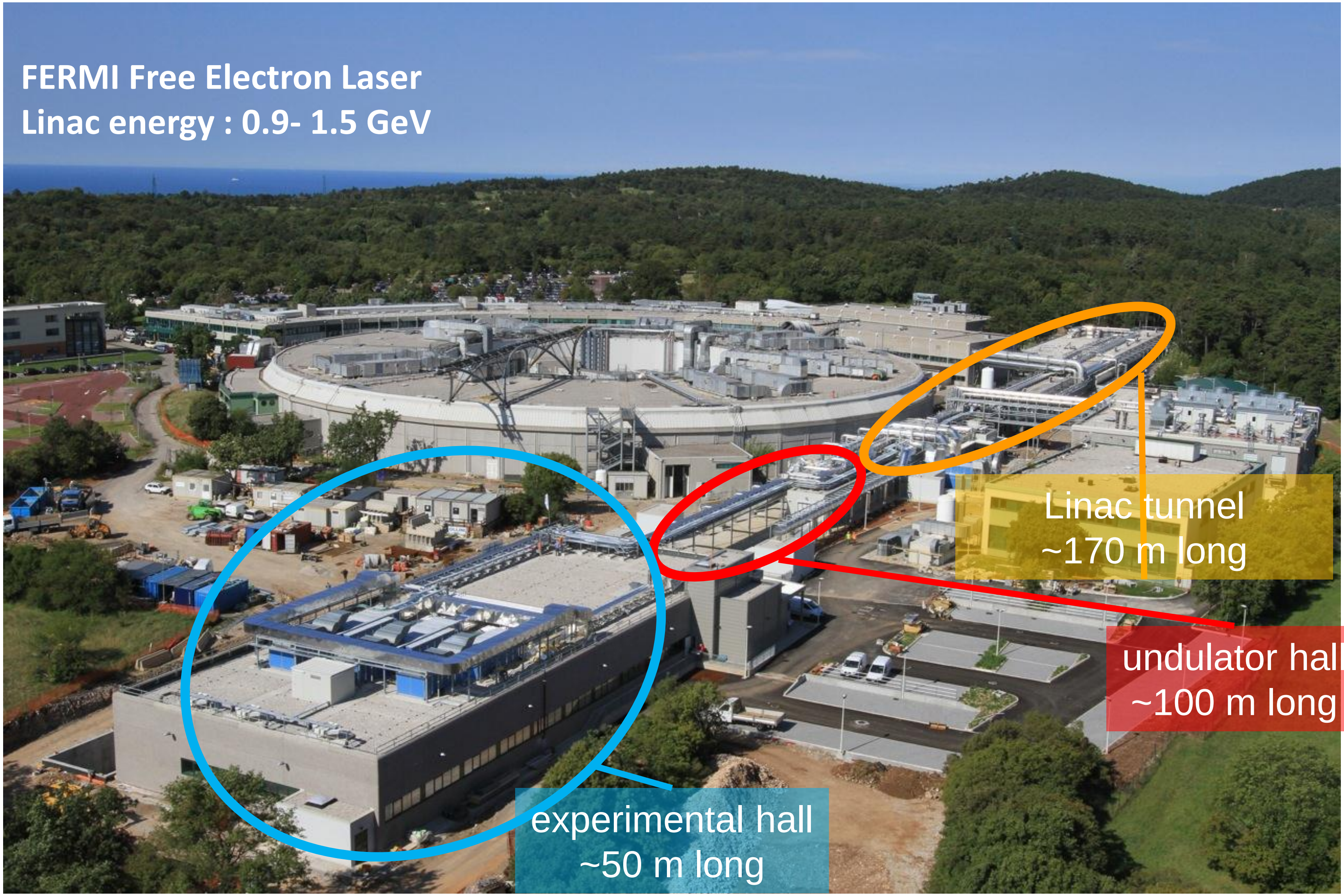
on behalf of the
FERMI@Elettra Cavity BPM System Team

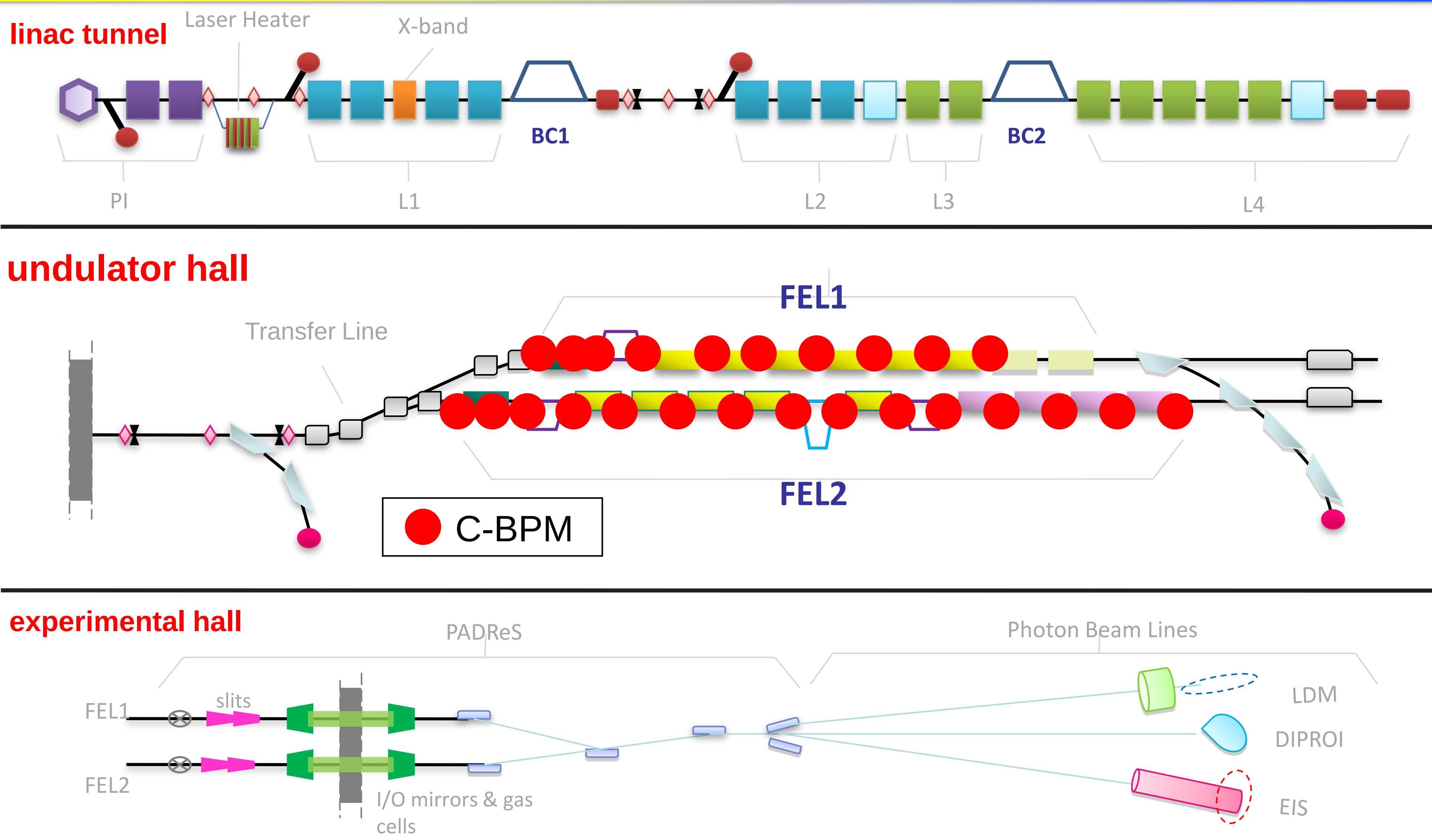
Outline

- FERMI FEL project
  - Simple Layout Description
  - Trajectory detection devices (BPMs)
- Overall Cavity BPM (C-BPM) system
  - Description
  - Installation Status
- **C-BPM functional blocks description, and detection working principles**
- **C-BPM system results and future improvements**

FERMI@Elettra Laboratory



FERMI Layout



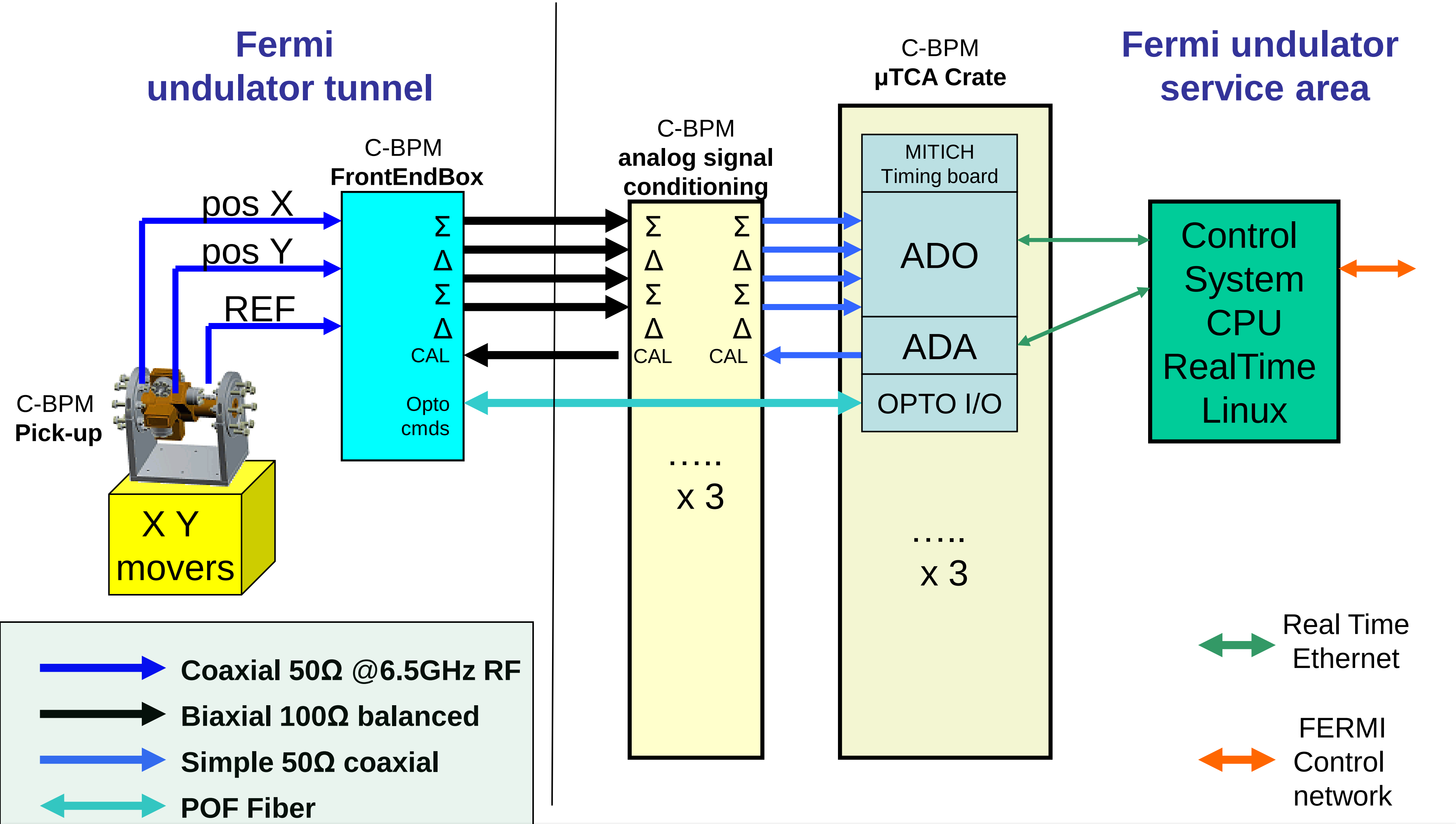
Trajectory detection devices (BPMs)

- **FERMI@Elettra FEL is equipped with:**

- 55 Stripline BPM with Libera SinglePass electronics from I-Tech in whole machine
- 10 Cavity BPM with all in-house designed and built electronics in FEL1 line
- 15 Cavity BPM with all in-house designed and built electronics in FEL2 line (to be mounted by August 2011)

System actual status/layout

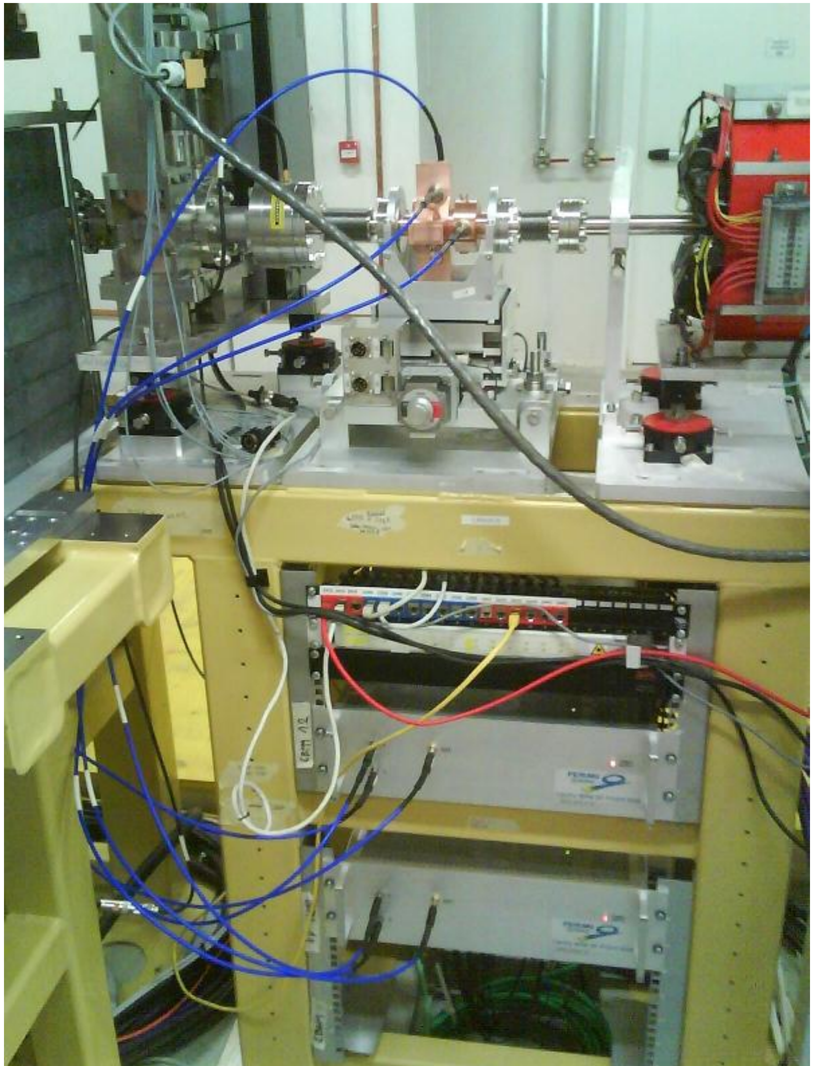
10 C-BPM Installed, tuned and running on FEL1 line

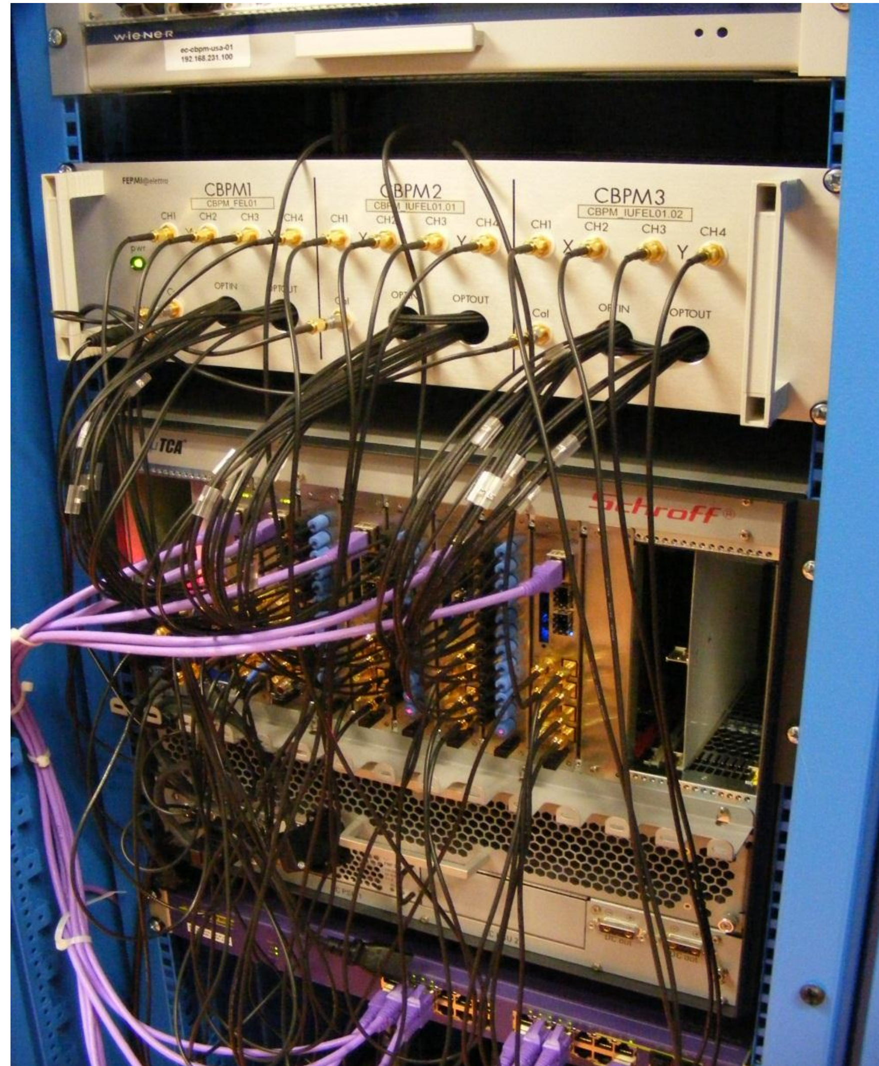


Installed hardware

Fermi tunnel

Fermi service area

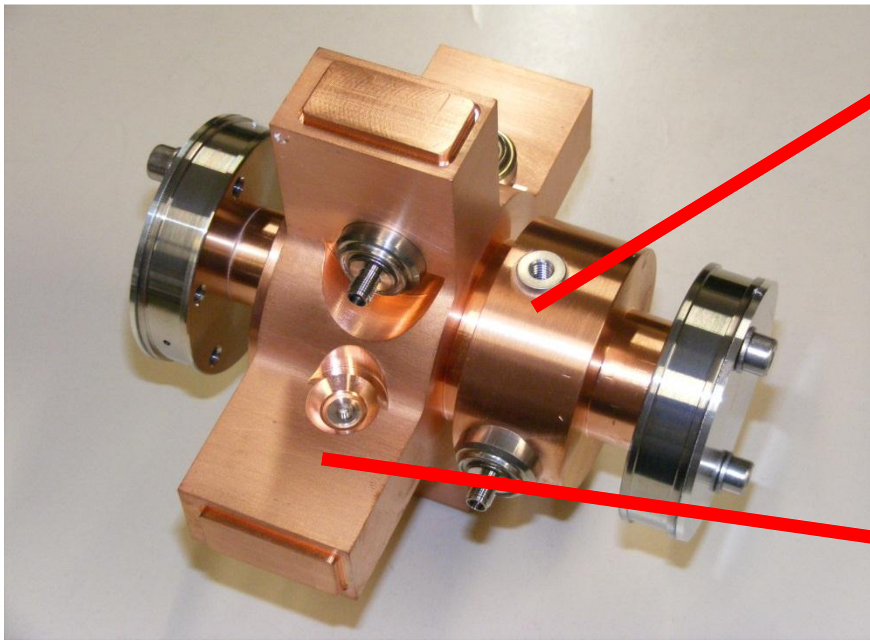




The pick-up Cavities

Fref ≈ Fpos ≈ 6.5 GHz damped Waveform

Duration (T): approx 500ns



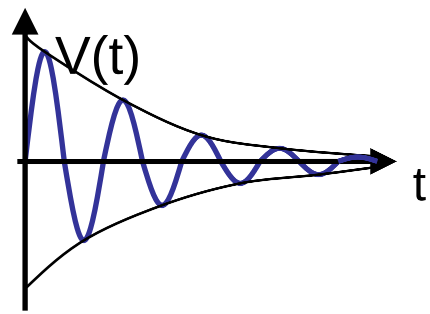
With Tuners <u>is possible</u> to keep the difference between the two frequencies less than 100KHz

TUPD14 P. Craievich, et al.: *commissioning of the Cavity BPM for the FERMI@Elettra FEL project*, Dipac 2011

Monopole Cavity (called REFERENCE)

627 mV Peak-to-Peak with 270pC of bunch charge

T ≈ 500ns

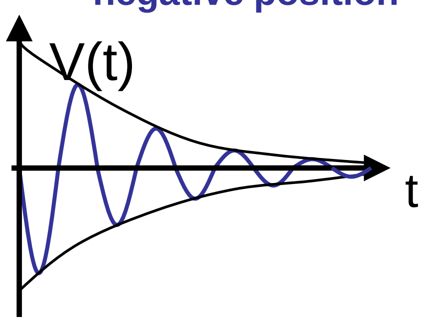


Dipole Cavity (called POSITION)

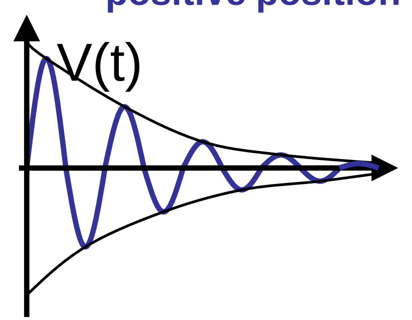
145 mV(Pk-Pk)/**mm** with 270pC of bunch charge

T ≈ 500ns

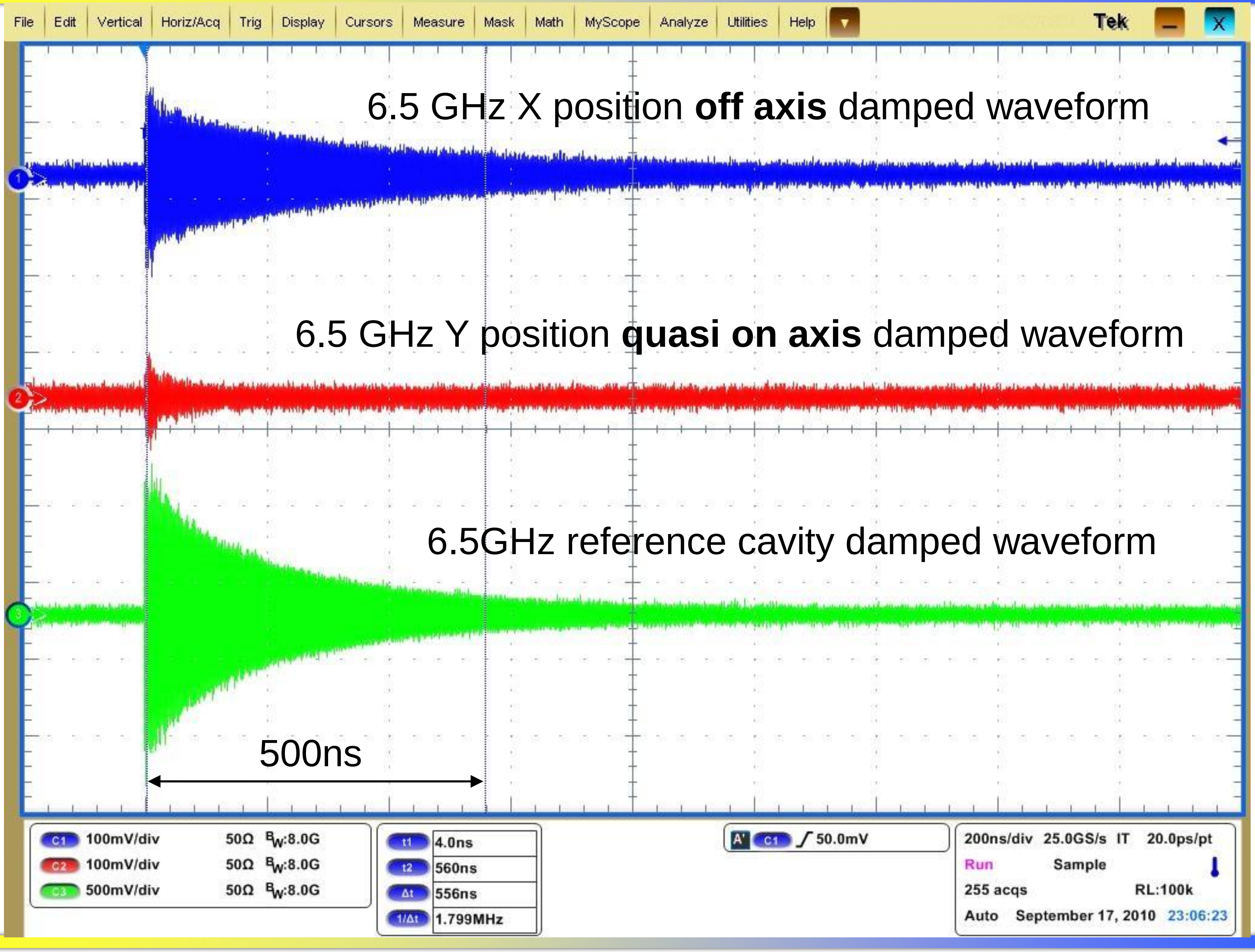
OFF AXIS
negative position



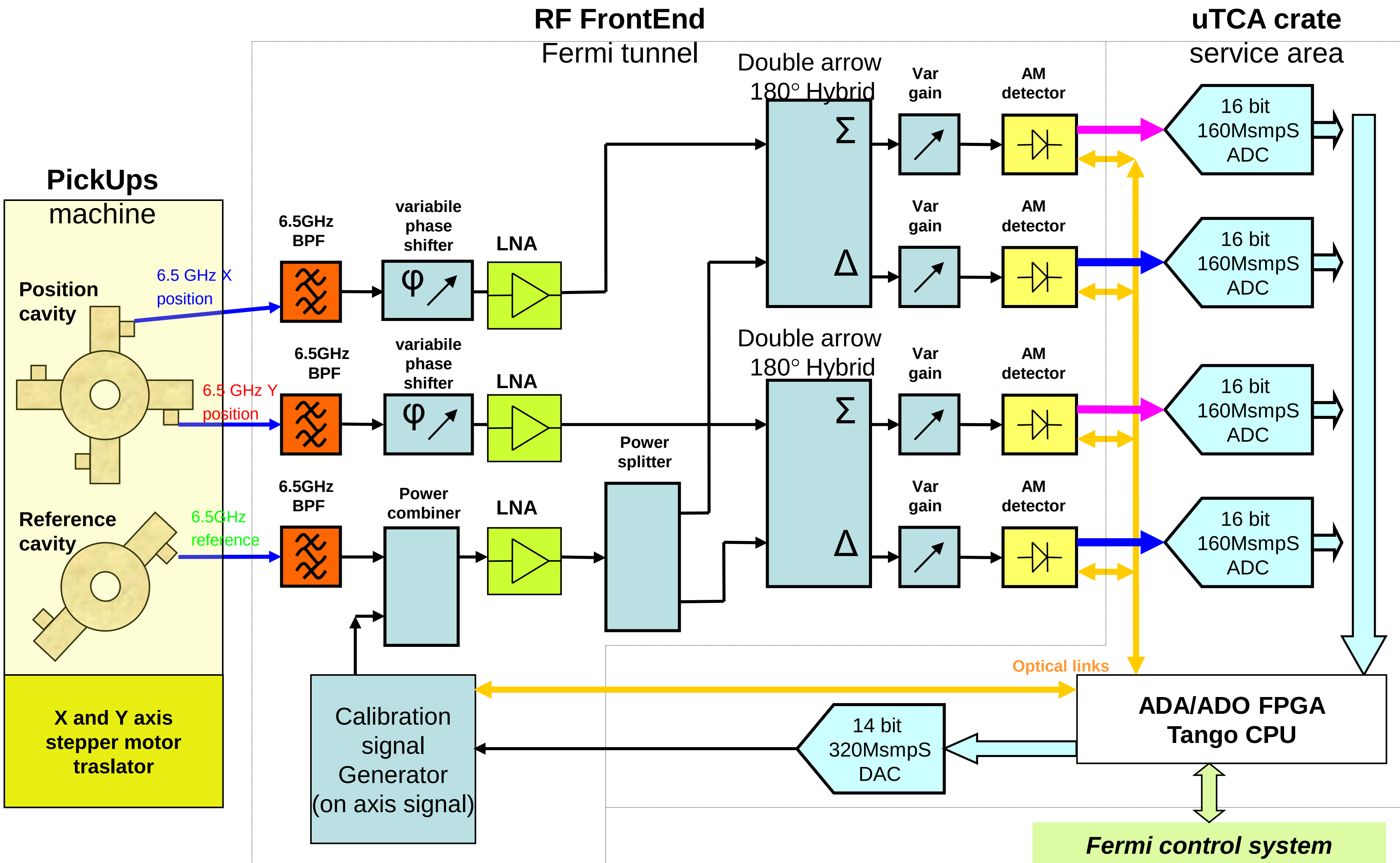
OFF AXIS
positive position



Real signals from pick-up Cavities



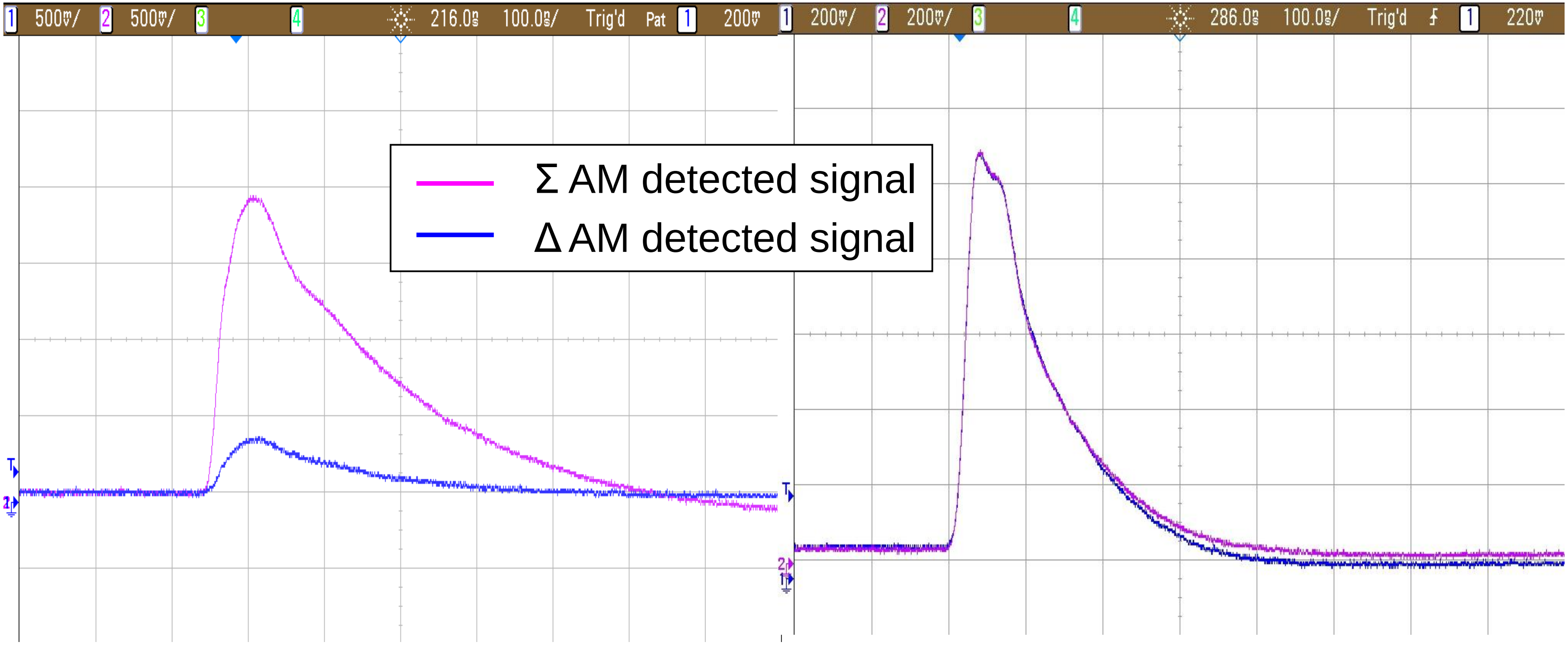
Acquisition block diagram



Envelope signals

OFF axis position envelope signals acquired with scope

ON axis position envelope signals acquired with scope



Area = the integral of the positive part of the waveform

Gain = *weight* assigned to the beam area signal, calculated from a well known signal from calibration signal generator

Position algorithms

$Gain_{\Sigma} = Area_{cal\Delta} \; / \; ((Area_{cal\Sigma} + Area_{cal\Delta}) / 2)$

$Gain_{\Delta} = Area_{cal\Sigma} \; / \; ((Area_{cal\Sigma} + Area_{cal\Delta}) / 2)$

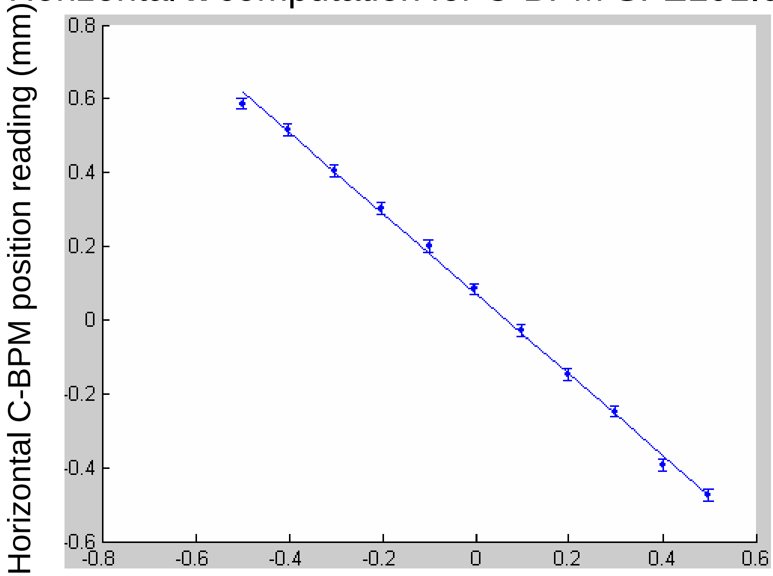
$A_{\Sigma} = Area_{beam\Sigma} * Gain_{\Sigma}$

$A_{\Delta} = Area_{beam\Delta} * Gain_{\Delta}$

$$Pos[mm] = k \frac{(A\Sigma - A\Delta)}{(A\Sigma + A\Delta)}$$

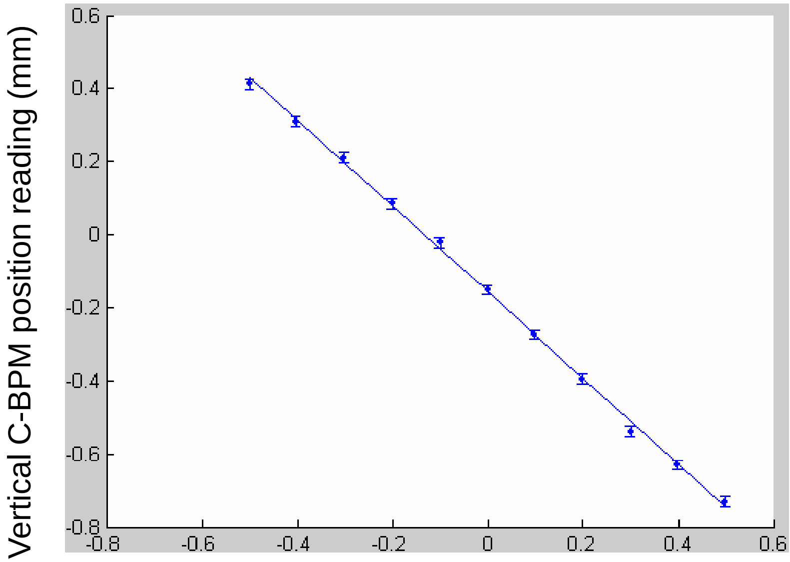
Where **k** is a constant conversion factor from arbitrary units (areas) to mm, and comes from known movement.

Horizontal **k** computation for C-BPM SFEL01.01



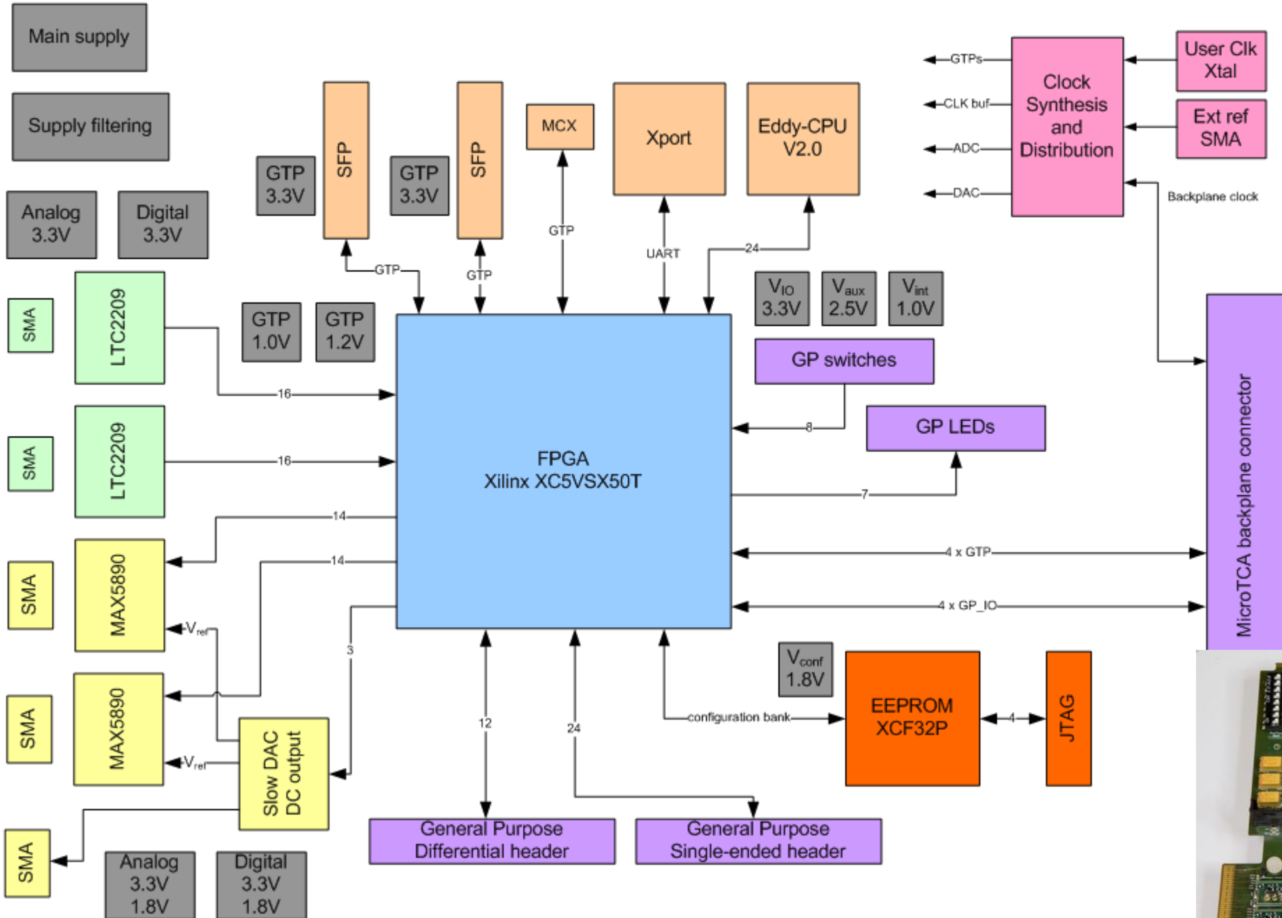
Horizontal Mover position set (mm)

Vertical **k** computation for C-BPM SFEL01.01

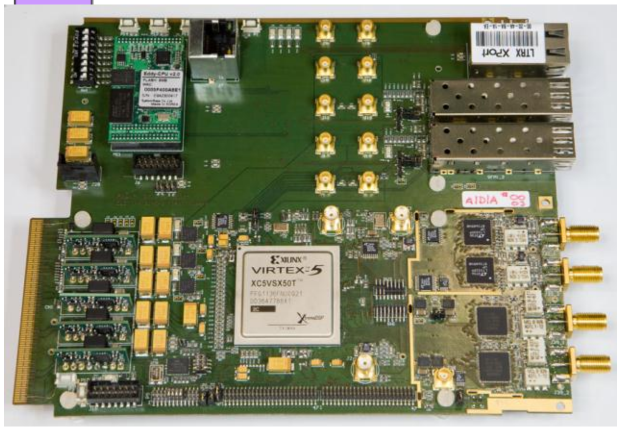


Vertical Mover position set (mm)

ADA - Analog Digital Analog Converter board



- **FPGA**
  Xilinx Virtex-5 SX50T
- **2 x ADC**
  Linear Technology LTC2208
- **2 x DAC**
  Maxim MAX5890
- **Ethernet interface**
  - Lantronix (day zero)
  - 2 x SFPs (handy)
  - Backplane communication to MCH (future)

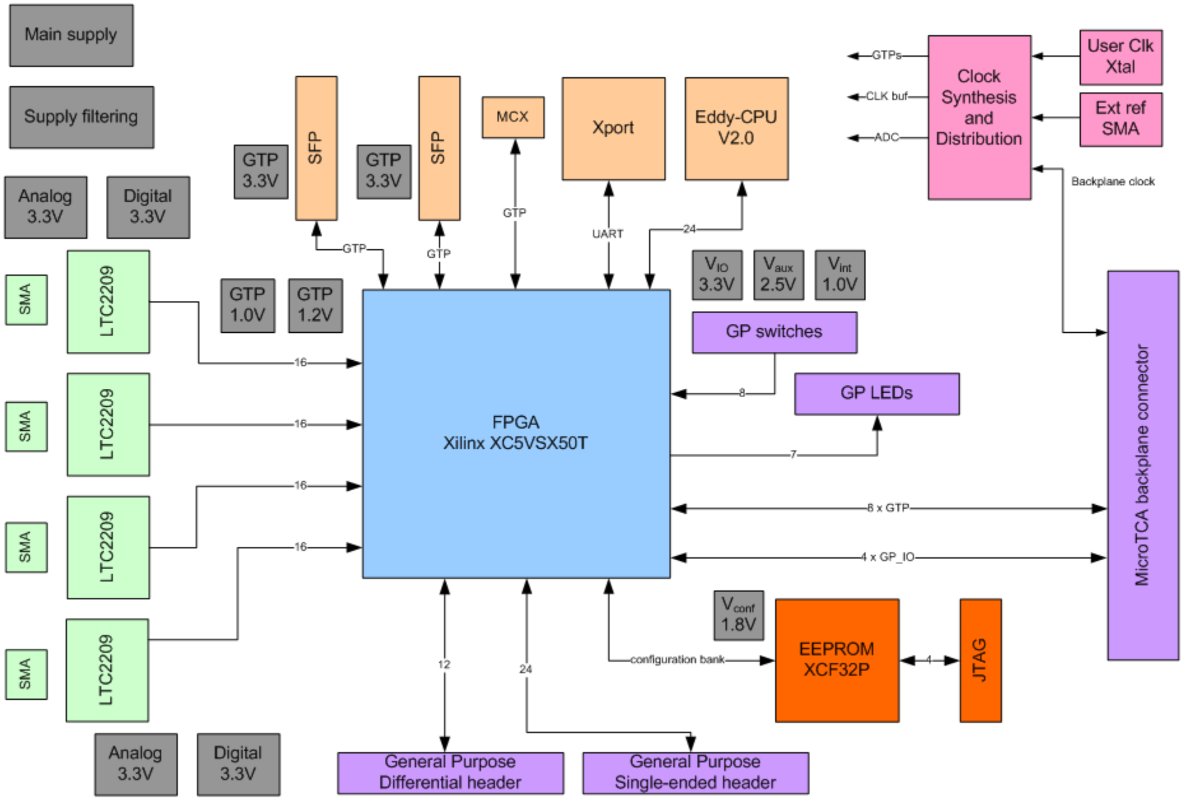


USE for C-BPM: fast data synthesis (Cal signal)

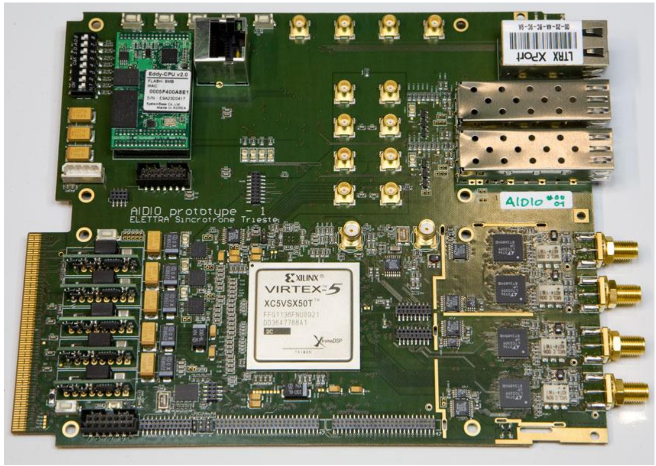
Courtesy of A. Borga

A. Borga et al.: “The diagnostics’ back-end system based on the in-house developed A|D|A and A|D|O boards”, BIW 2010

ADO - Analog Digital Only converter board



- **FPGA**
  Xilinx Virtex-5 SX50T
- **4 x ADC**
  Linear Technology LTC2208
- **Ethernet interface**
  - Lantronix (day zero)
  - 2 x SFPs (handy)
  - Backplane communication to MCH (future)

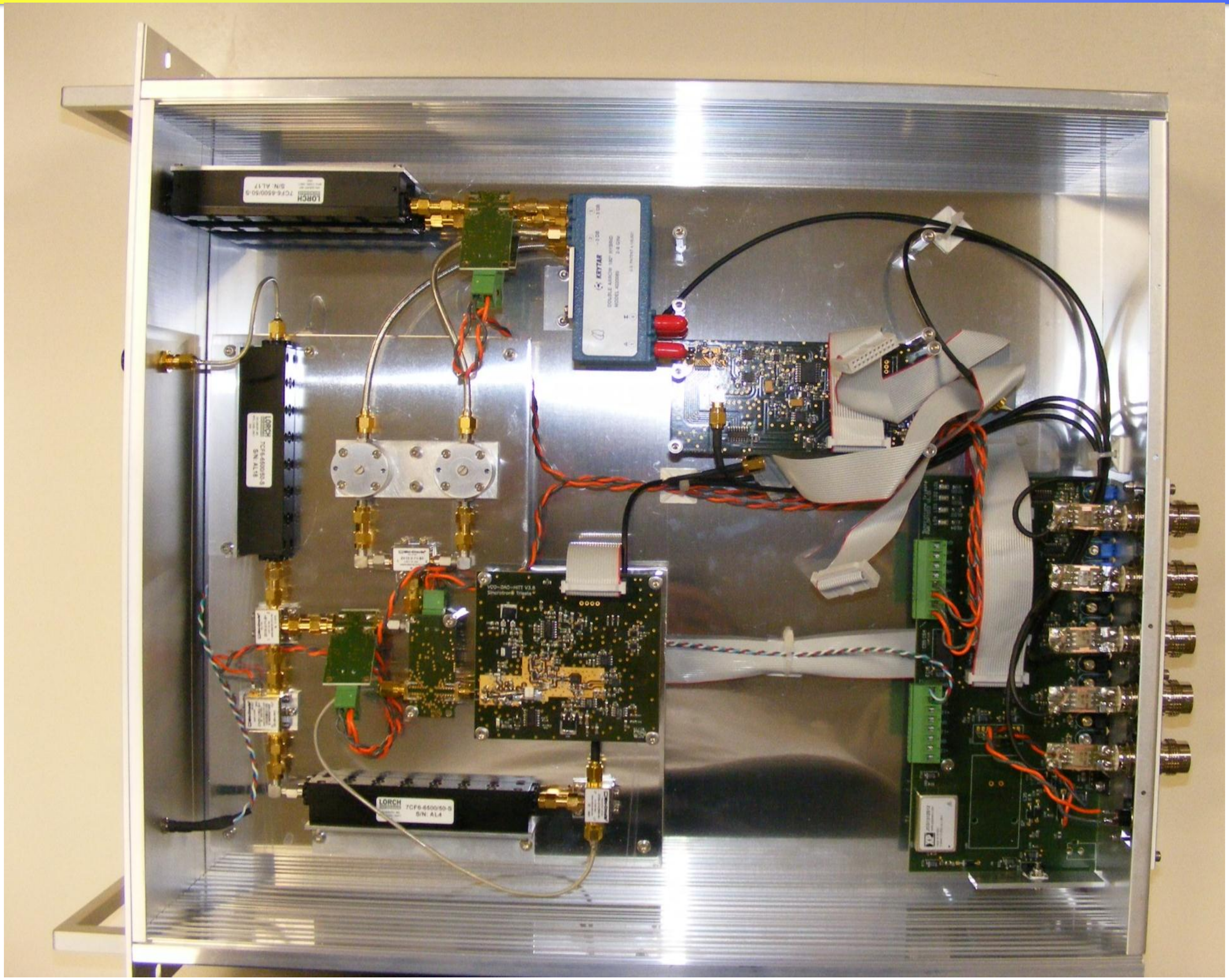


USE for C-BPM : fast signal data acquisition

Courtesy of A. Borga

A. Borga et al.: “The diagnostics’ back-end system based on the in-house developed A|D|A and A|D|O boards”, BIW 2010

C-BPM Front End electronics



RESULTS

- The C-BPM system for FEL1 is fully operational with 10 of 10 C-BPM.
- Acquisition data and position computation with 10Hz repetition rate is done in realtime and is fully integrated in Fermi Control System.
- Only one hardware fault from September 2010 (due to a tantalum capacitor short circuit).
- The measured resolution from 50 up to 350 pC is 4µm rms.
- During first steering through the undulator section the beam charge has been lowered to 50pC without loosing resolution which made FERMI@Elettra FEL commissioning possible.
- C-BPM system performs best resolution with on axis beam.
- No position drifts has been noticed during the operations
- The calibrations factors (k) calculated with the mechanical movers are constant in different times/conditions

Path to submicron resolution

- Fine tune phase delays using a remote stepper motor: this will increase the sensitivity
- Update μTCA power supplies with low noise's one
- Change the ADO RF input transformer to increase the positive signal area. This because the lower bandwidth is too high (see envelope signals: the duration is approx 250 ns instead of 500 ns)
- Reduce the amplifier gain of the reference signal to increase the "weight" of the position signal at higher charges

Acknowledgements

The Cavity BPM System team

- R. De Monte: acquisition system layout and RF Front End
- P. Craievich: Mechanical Physics devel/test
- M. Dal Forno: support in mechanical Physics devel/simulation/test
- A. Borga: Digital Acq./Gen.(ADA/ADO/MiTiCH) and FPGA programming
- M. Predonzani: FPGA programming
- G. Gaio: Tango server/Real Time
- F. Asnicar: Fermi CR panel
- M. Ferianis: head of Fermi's diagnostics !
- CINEL Strumenti Scientifici s.r.l. Vigonza (Padova) – Italy: pick-ups mechanical manufacturer

Many thanks to prof. **M. Vidmar** of Ljubljana University for his precious suggestions

Thank you for your attention

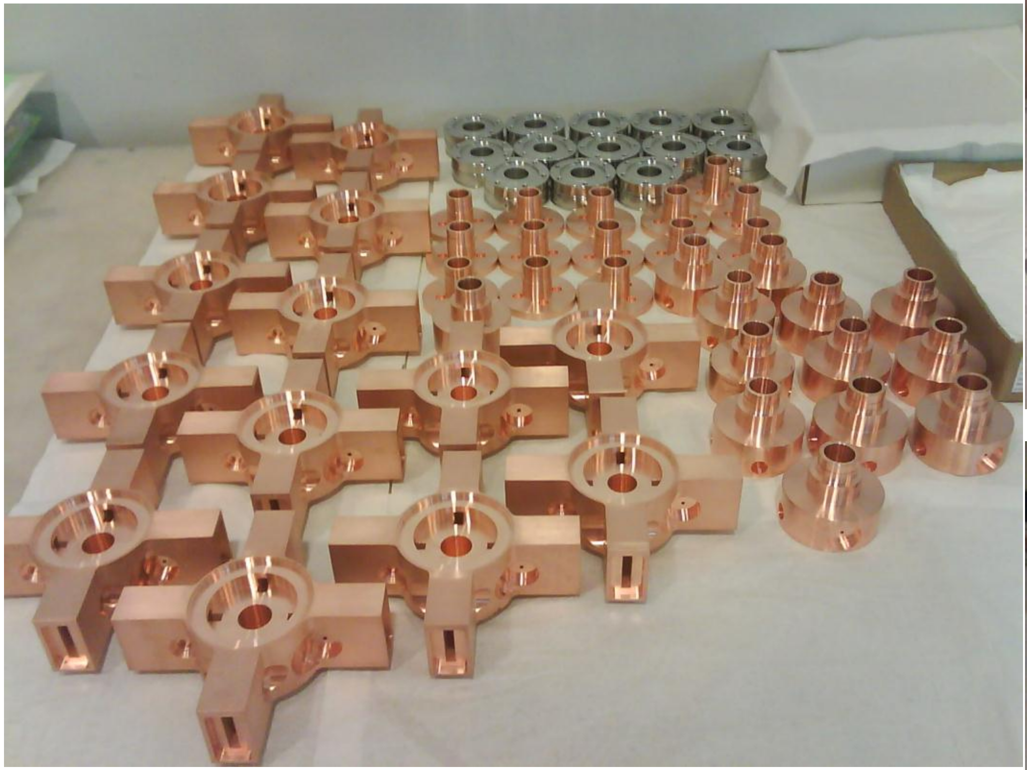
BACK SLIDES

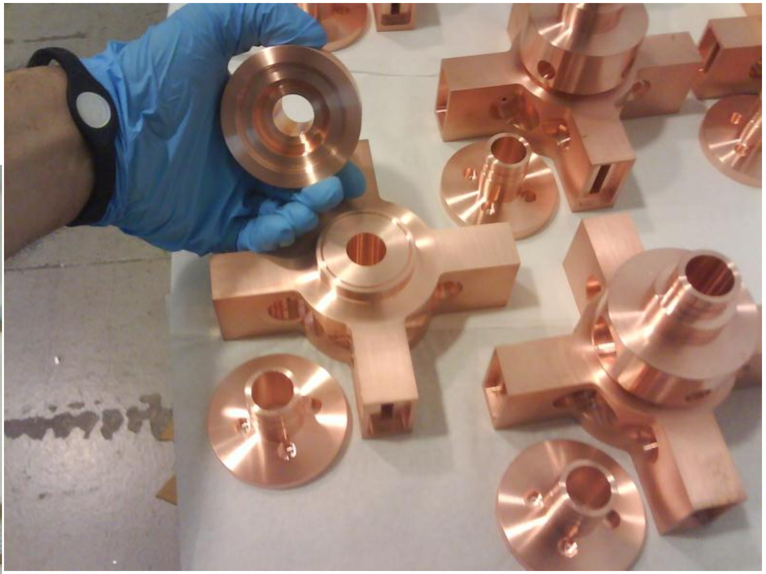
The measuring system's fulcrum

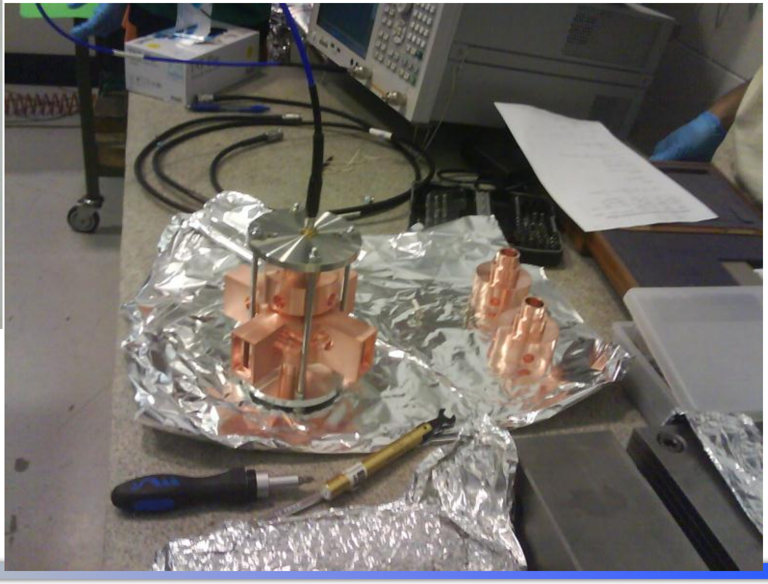
The output of port 1 is proportional to the **sum** of the two inputs. Port 1 of a 180° Hybrid Coupler is thus often referred to as the **sum** (Σ) port.

Port 4 is proportional to the **difference** between the two inputs. Port 4 a 180° Hybrid Coupler is thus often referred to as the **delta** (Δ) port.

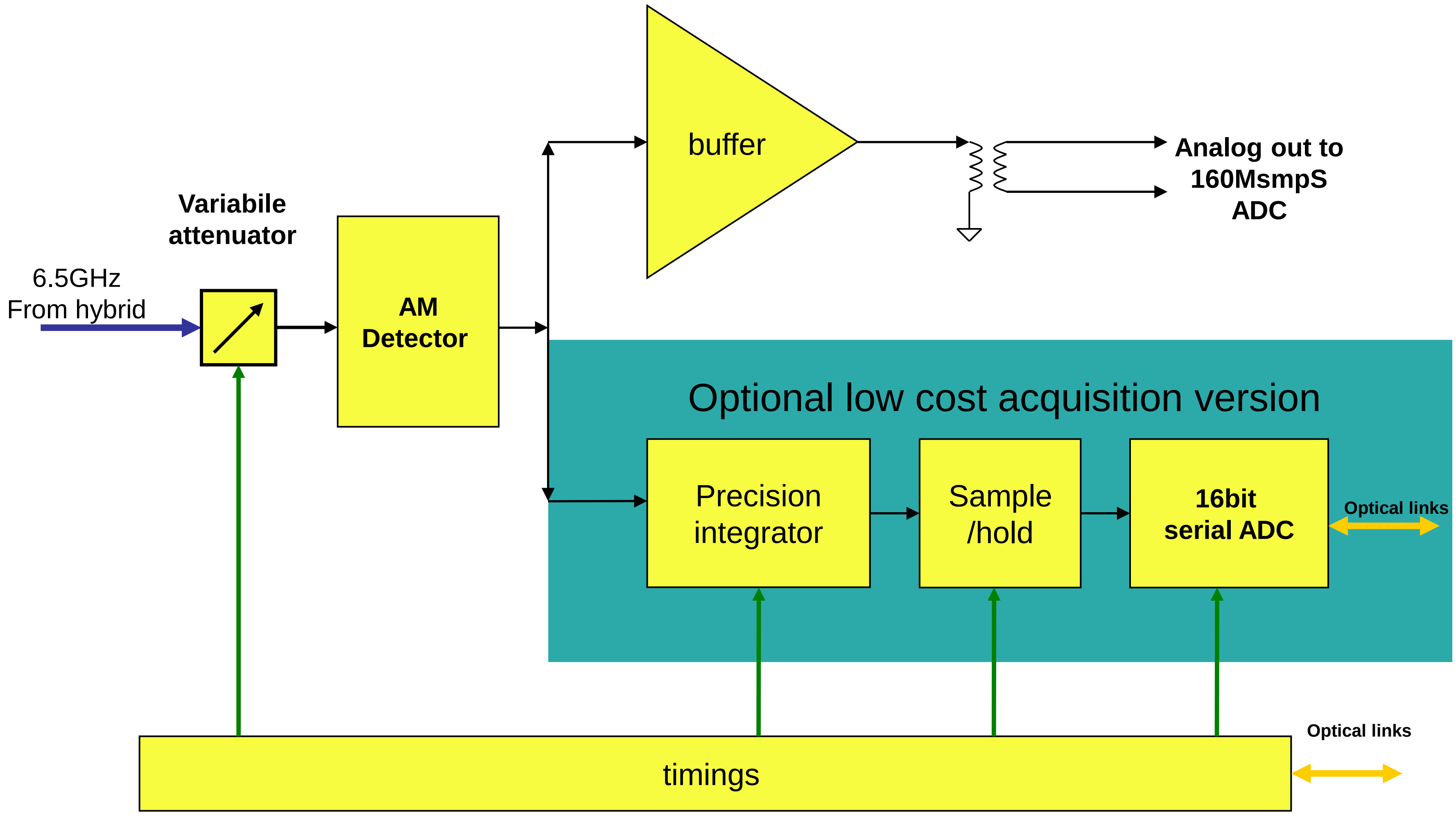
Cavity Fabrication and pre-brezing frequency tests







AM detector



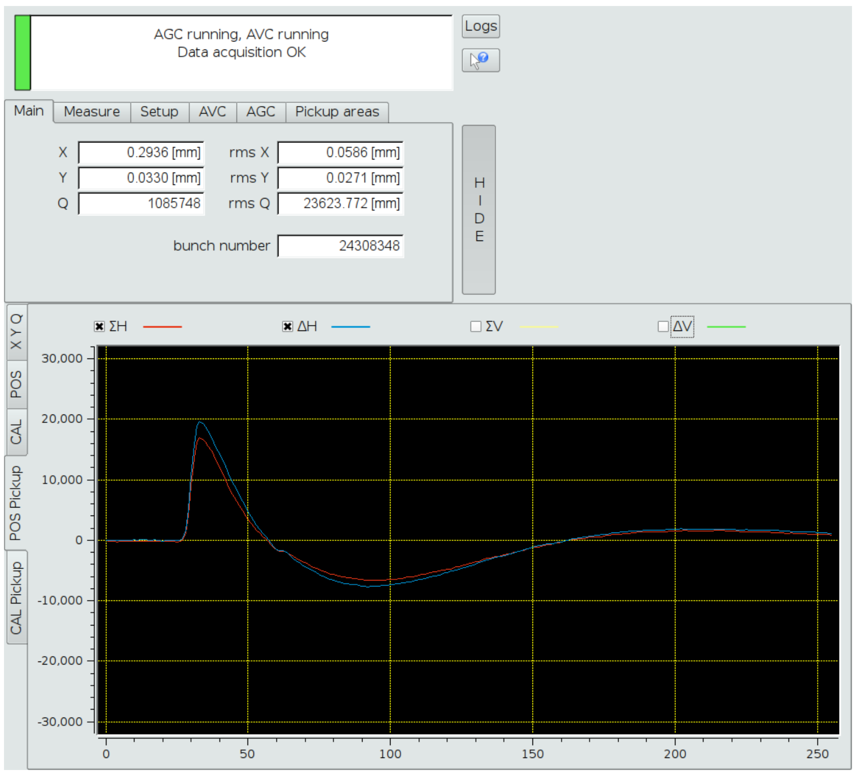
buffer
Analog out to
160MsmpS
ADC
Variabile
attenuator
6.5GHz
From hybrid
AM
Detector
Optional low cost acquisition version
Precision
integrator
Sample
/hold
16bit
serial ADC
Optical links
Optical links
timings

Control Room Tango Panels

Position Waveforms

The panels show also the AVC (automatic Volume Control for Cal) and AGC (Automatic Gain Control) performed by Tango server

X position waveforms real time plot



ALL position waveforms real time plot