BPM development @CEA/Irfu

C. Simon *on behalf of the Saclay's group*

CLIC Instrumentation workshop

2nd - 3rd June 2009

Introduction

CEA/Irfu is developing two types of BPMs based on a radiofrequency reentrant cavity:

- The first monitor is developed for the CLIC Test Facility (CTF3) probe beam CALIFES at CERN:
  - is operated in single bunch and multi-bunches modes.
  - single bunch resolution potential < 1 µm

- The other BPM developed for the XFEL (Thirsty of those monitors will be installed in XFEL cryomodules) :
  - has an aperture of 78 mm
  - is designed to work at cryogenic temperature in a clean environment
  - can get a high resolution and the possibility to perform bunch to bunch measurements.

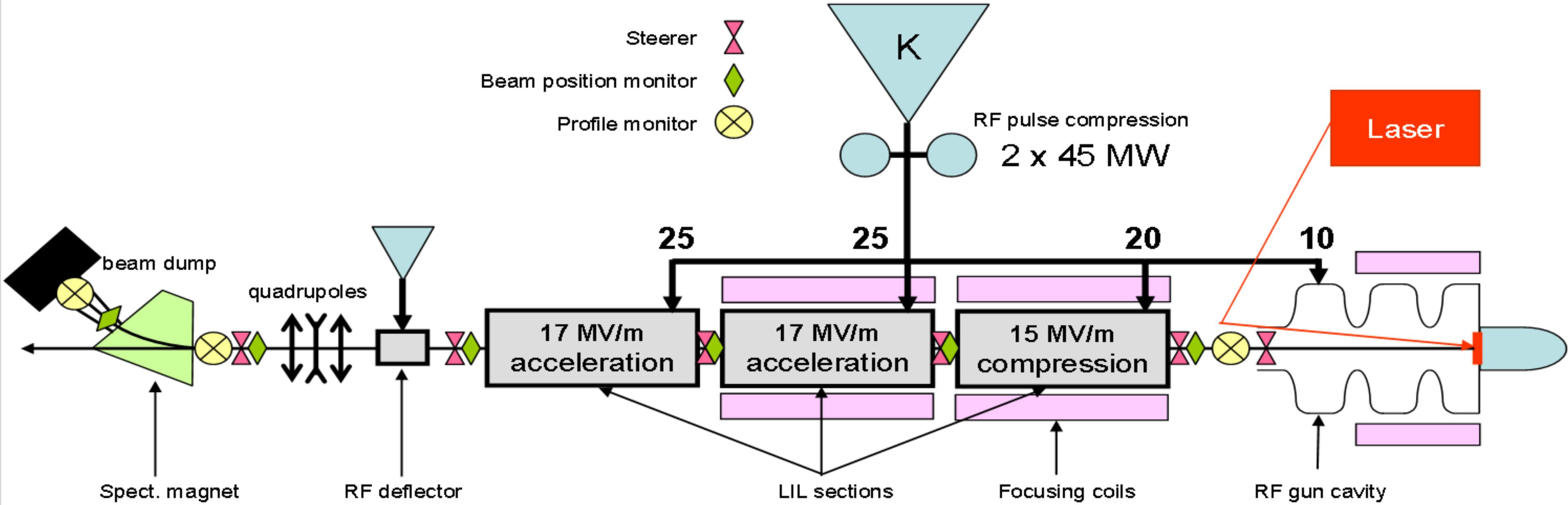
  One prototype is installed in a warm part in the Free electron LASer in Hamburg (FLASH), at DESY.

CALIFES linac

Specifications

Energy ~ 170 MeV
Emittance < 20 π.mm.mrad
Charge per bunch : 0.6 nC
Energy spread: <2%
Number of bunches : 1- 32 – 226

Bunch charge (single/multi bunch): 0.6 nC/ 6 nC/Nb
Bunch length (rms) : 0.75ps
Initial /final bunch spacing :5.3/1.8 ps, 1.6/0.5 mm
Train length: 21 - 150 ns
Train spacing (rep. rate): 5 Hz



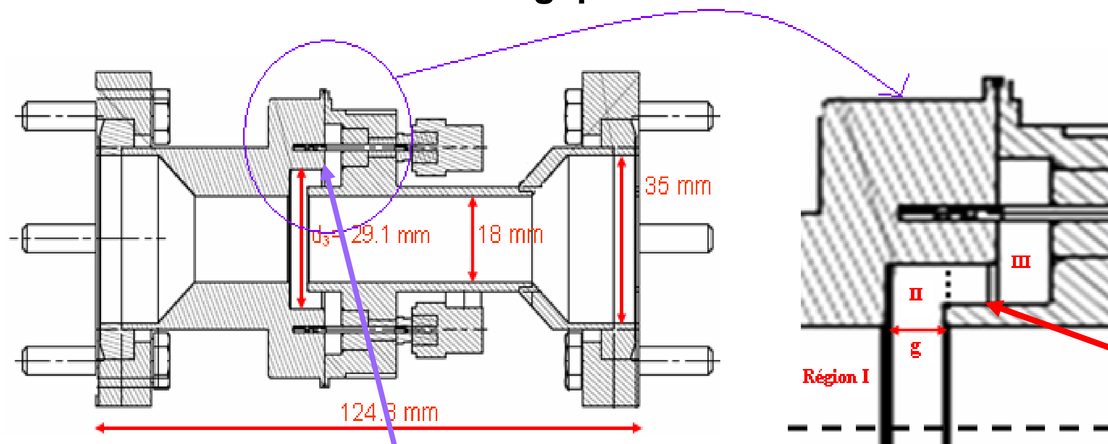
6 BPMs are installed on the CALIFES linac

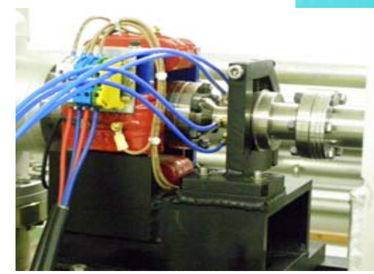
Reentrant Cavity BPM for CALIFES

• The cavity is fabricated with titanium and is as compact as possible :

~125 mm length and 18 mm aperture

4 mm gap





Reentrant Part

Bent coaxial cylinder designed to have:

-a large frequency separation between monopole and dipole modes

- a low loop exposure to the electric fields

Eigen modes	F (MHz)	Q_l	$(R/Q)_l$ (Ω) at 5 mm	$(R/Q)_l$ (Ω) at 10 mm
	Measured	Measured	Calculated	Calculated
Monopole mode	3988	29.76	22.3	22.3
Dipole mode	5983	50.21	1.1	7

Due to mechanical tolerances, dipole mode frequencies are different for each BPMs, 100 MHz IF frequency is, therefore, used so that monitors operate in single and multi-bunch modes.

Signal Processing for CALIFES BPM

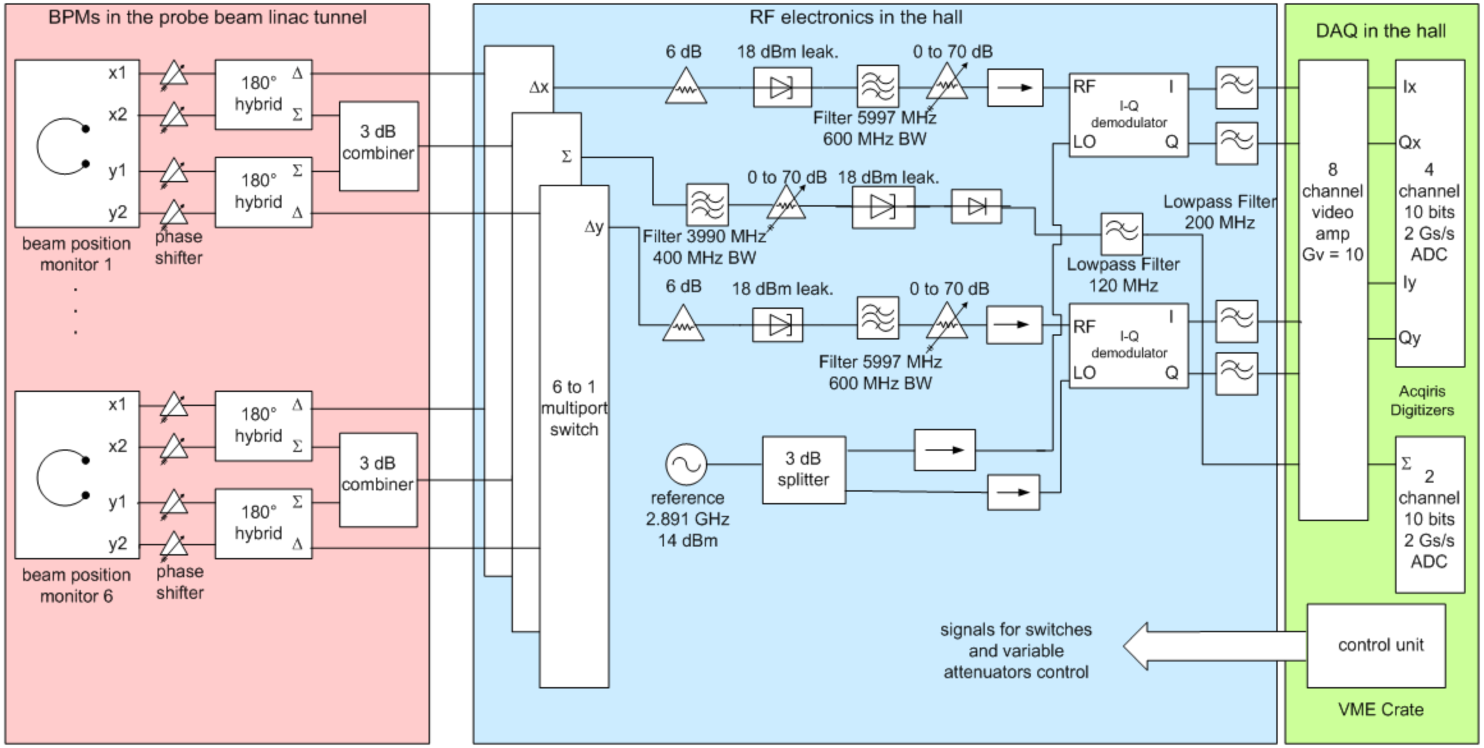
- Hybrids installed close to BPMs in the CLEX

- Multiport switches used to have one signal processing electronics to control six BPMs.

- Analog electronics with several steps to reject the monopole mode

Hybrid couplers

- RF electronics used synchronous detection with an I/Q demodulator.

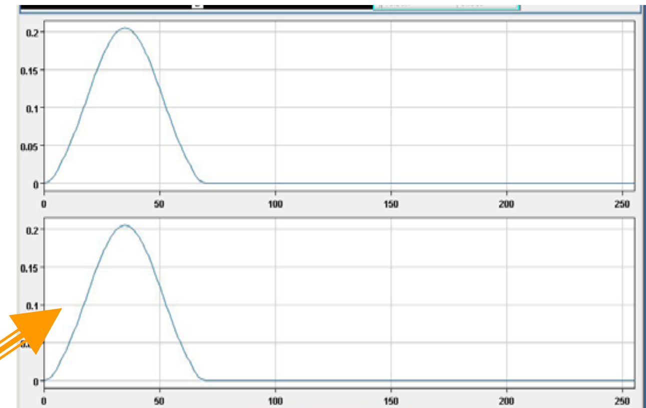


Control Command of BPMs

1/Sampling with acqiris boards and readout signals on OASIS

6 BPMs implemented

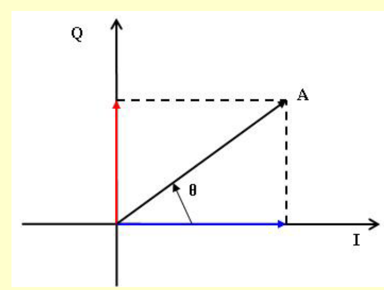
3/Results sent on graphic windows under JAVA and in a file to be used with Matlab



2/Signal processing:

Digital Down Conversion

- raw waveform multiplied by a local oscillator of the same frequency to yield a zero intermediate frequency
- real and imaginary parts of each IF are then multiplied by a 60 coefficient, symmetric, finite impulse response (FIR), low pass filter with 40MHz 3dB bandwidth



Beam position

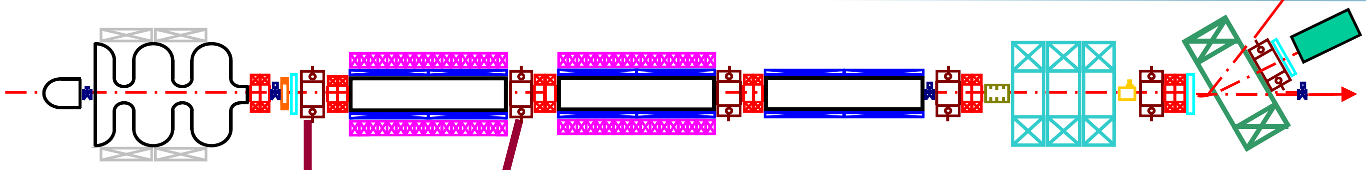
$$A = \sqrt{I^2 + Q^2}$$

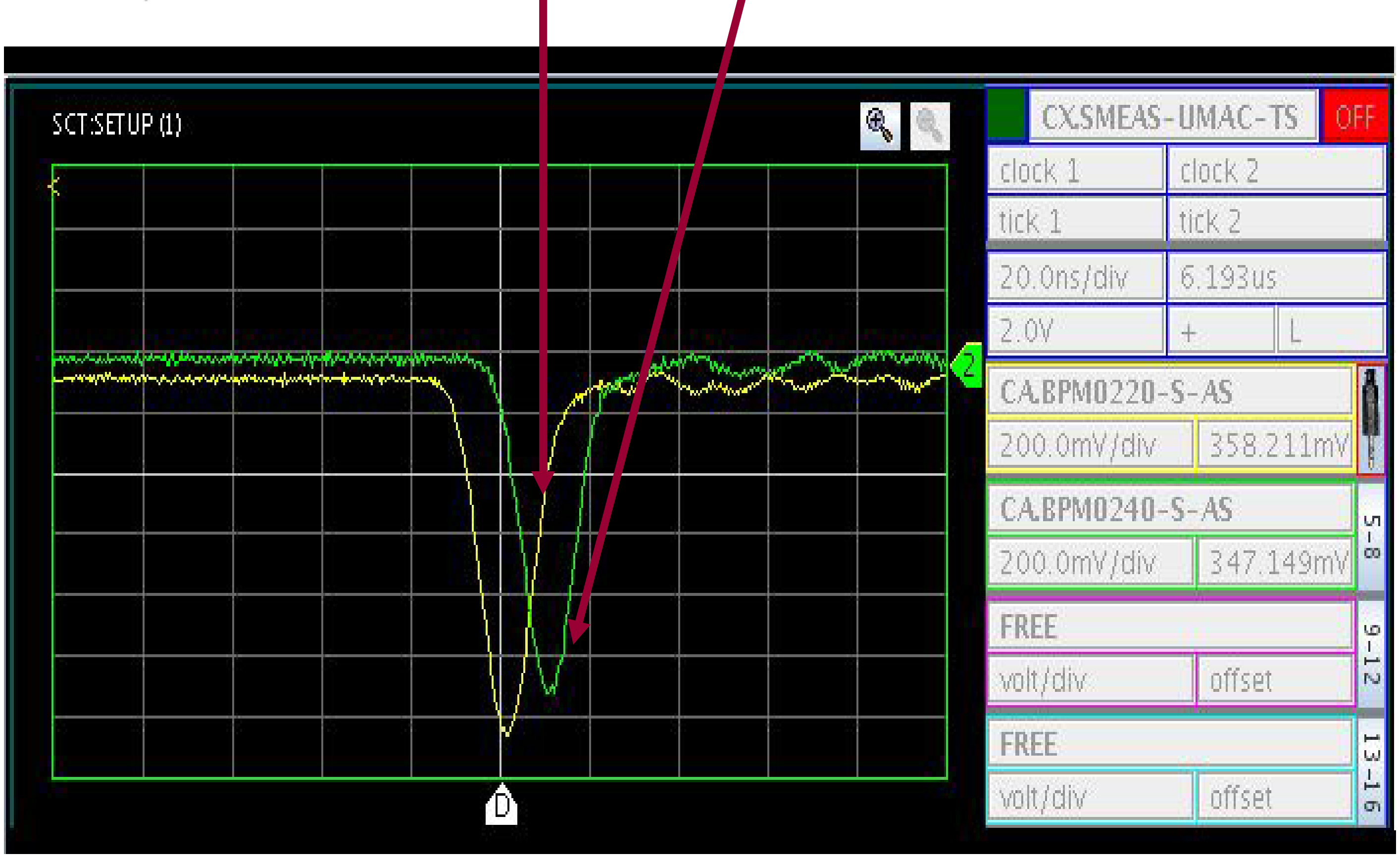
$$\cos\theta = \frac{I}{A} \qquad \sin\theta = \frac{Q}{A}$$

$$\Delta = I\cos\theta + Q\sin\theta$$

$$P = \frac{\Delta}{\Sigma}$$

Signals read with Oasis viewer (1)

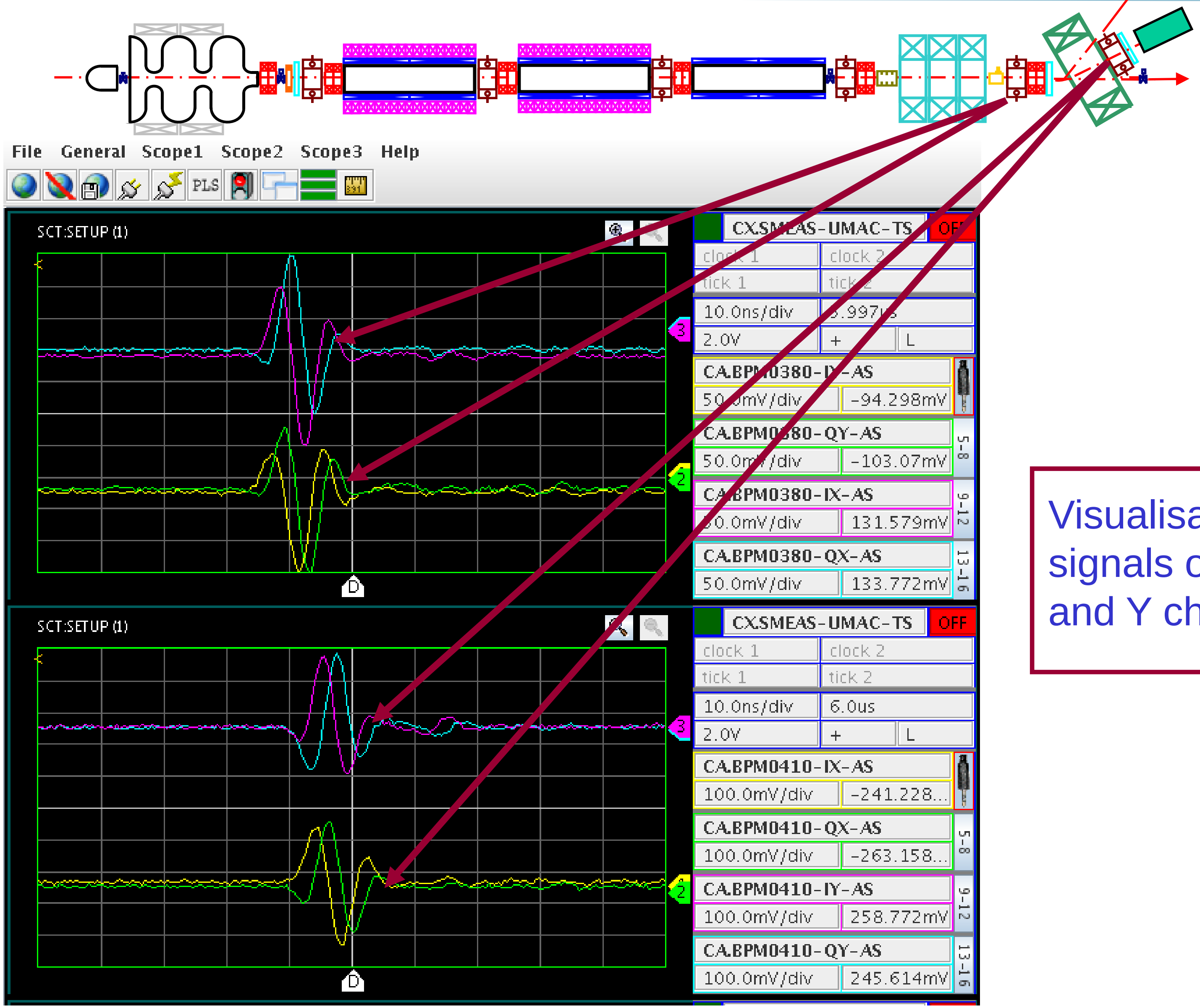




Σ channels

Good transmission behind the first section

Signals read with Oasis viewer (2)



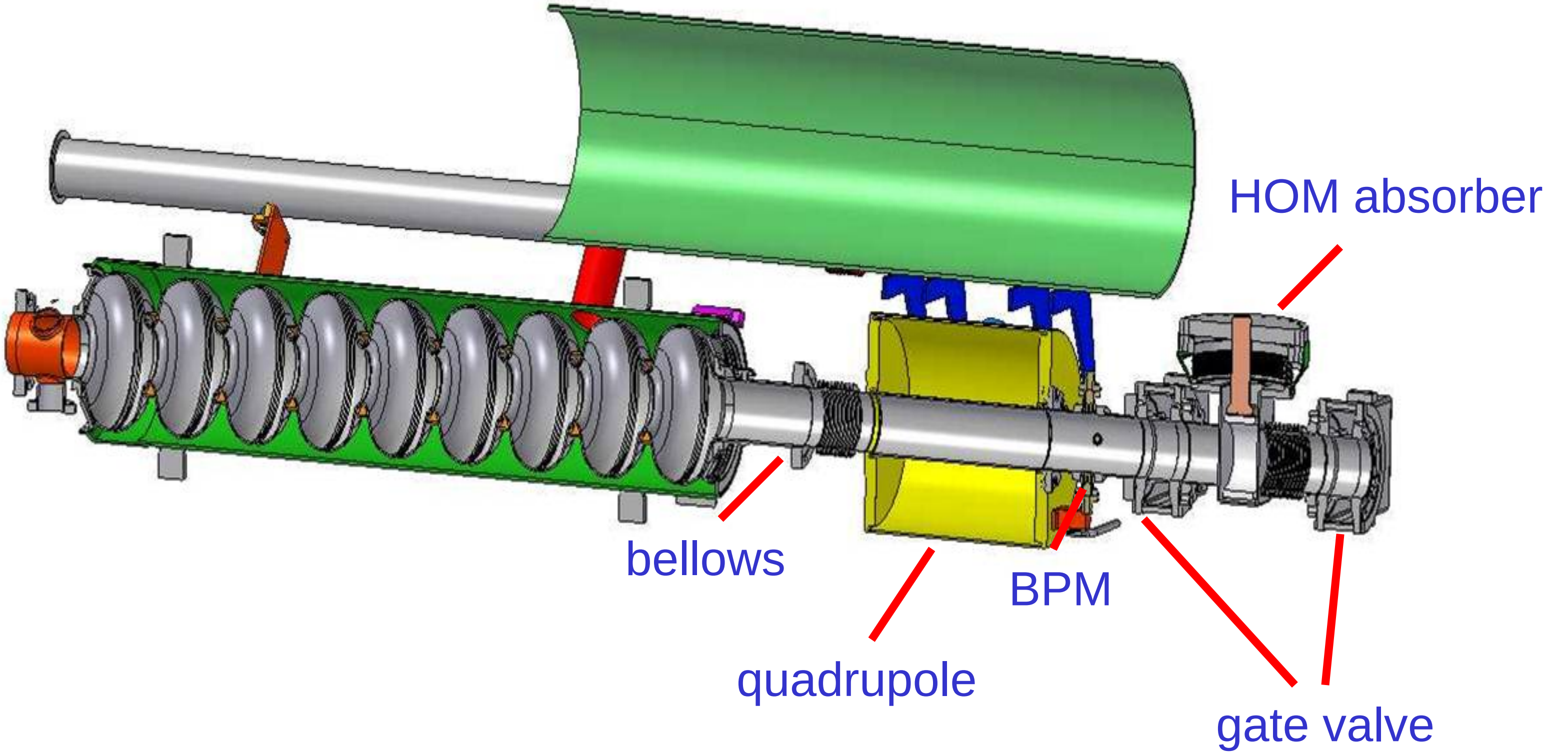
Visualisation of I/Q signals on the X and Y channels

Cold Reentrant BPM for the XFEL

Specifications

Single bunch resolution (RMS): 50 µm
Drift over 1 hour: 5 µm
Max. resolution range: +/- 3 mm
Reasonable signal range : +/- 10 mm
Linearity: 10%

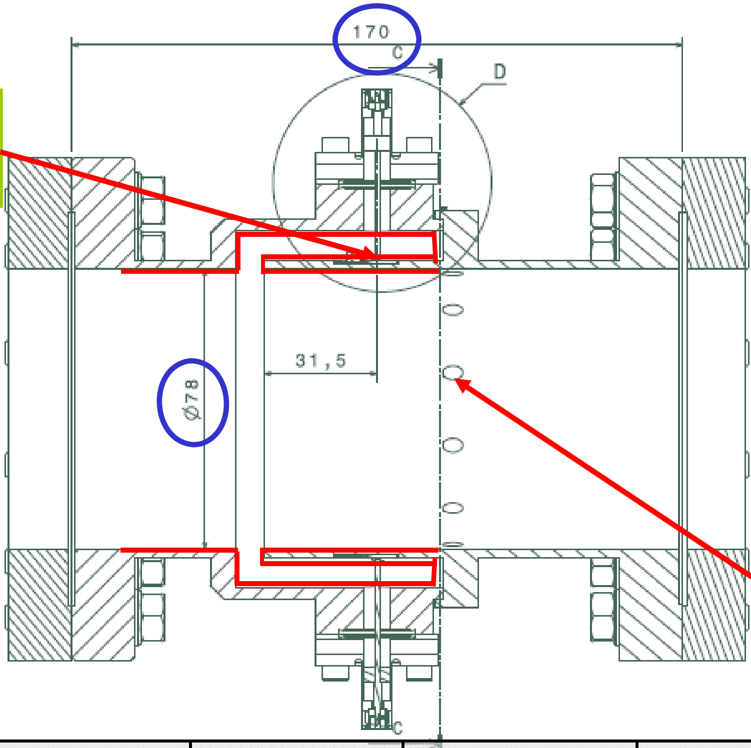
Transverse alignment tol. (RMS): 300 µm
Charge dependence : 50 µm



Cold Reentrant Cavity BPM for the XFEL (1)

- **30 reentrant cavity BPMs will be installed in XFEL cryomodules**

CuBe fingers to put in contact feedthrough and cavity



Twelve holes of 5 mm diameter drilled at the end of the re-entrant part for a more effective cleaning.

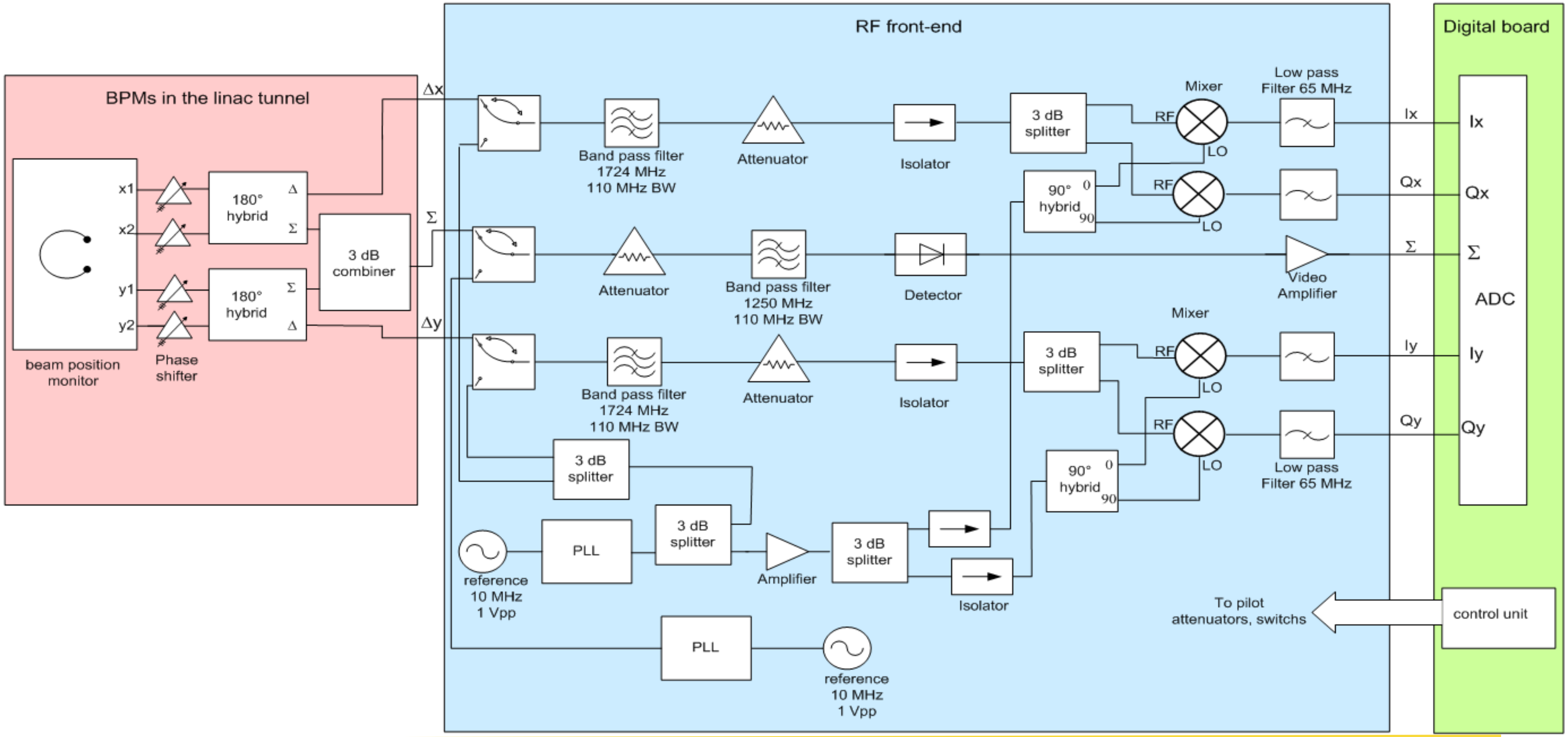
Eigen modes	F (MHz)	Q_l	$(R/Q)_l$ (Ω) at 5 mm	$(R/Q)_l$ (Ω) at 10 mm
	Measured	Measured	Calculated	Calculated
Monopole mode	1255	23.8	12.9	12.9
Dipole mode	1724	59	0.27	1.15

Cold Reentrant Cavity BPM for the XFEL (2)

- February 2009, a first prototype was sent to DESY to be installed in a cyomodule test
- Few problems are appeared but were resolved:
    - One of flange was re-manufactured
    - One of antennae was not in contact with the BPM
      → CuBe contact was therefore moved
- Finally, the prototype was assembled to the quadrupole
- The "cold reentrant BPM" passed leak test and high pressure rinsing

Signal processing for the cold reentrant BPM

- **Hybrids will be installed in the tunnel**
- **Signal processing electronics uses a single stage down conversion**
- **RF front-end electronics based on an PCB with surface mount components**
- **Digital electronics designed by PSI**



Beam Studies

- Beam tests carried out with the room temperature reentrant BPM on the FLASH linac

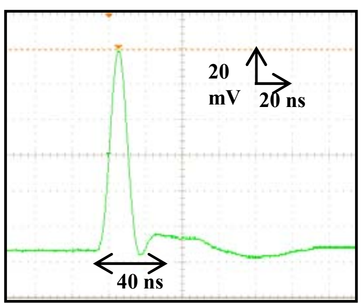
➡ **Good linearity in a range ± 12 mm**

➡ **RMS resolution: ~4 µm on the Y channel**
~8 µm on the X channel
} **with 1 nC and dynamic range +/- 5 mm**

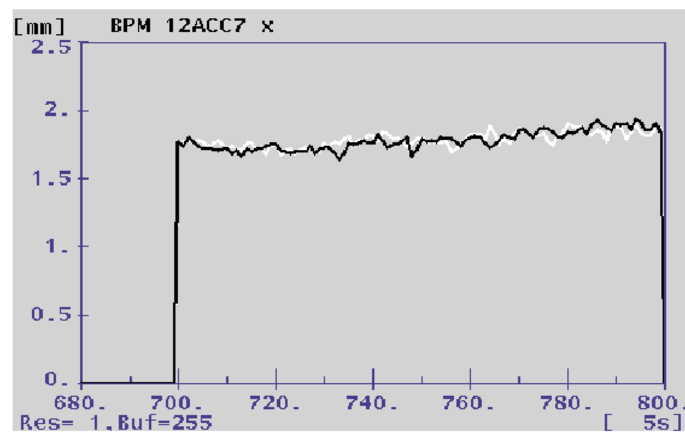
- **Simulated resolution with 1 mm beam offset: < 1 um**

Damping time (Cavity): 9.4 ns

Time resolution (Cavity + electronics): ~40 ns



IF signal behind Lowpass Filter on channel Δ



100 bunches read by the reentrant BPM

Possibility bunch to bunch measurements

Summary

❖ **Reentrant cavity BPM at CALIFES:**

- **Operated in single and multi-bunches**
- **Final signal post-processing and interface Java applications are under development and should be tested during the next beam time**
- **Need beam time to calibrate BPMs and determine resolution**

❖ **Reentrant cavity BPM for the XFEL:**

- **First prototype was assembled to the quadrupole for a XFEL cryomodule test**
- **PCB of the RF front-end Electronics designed to reduce the electronics cost**
- **Circuit is in the making and we need to test it soon…**

Thank you for your attention