Cavity
BPM for CALIFES

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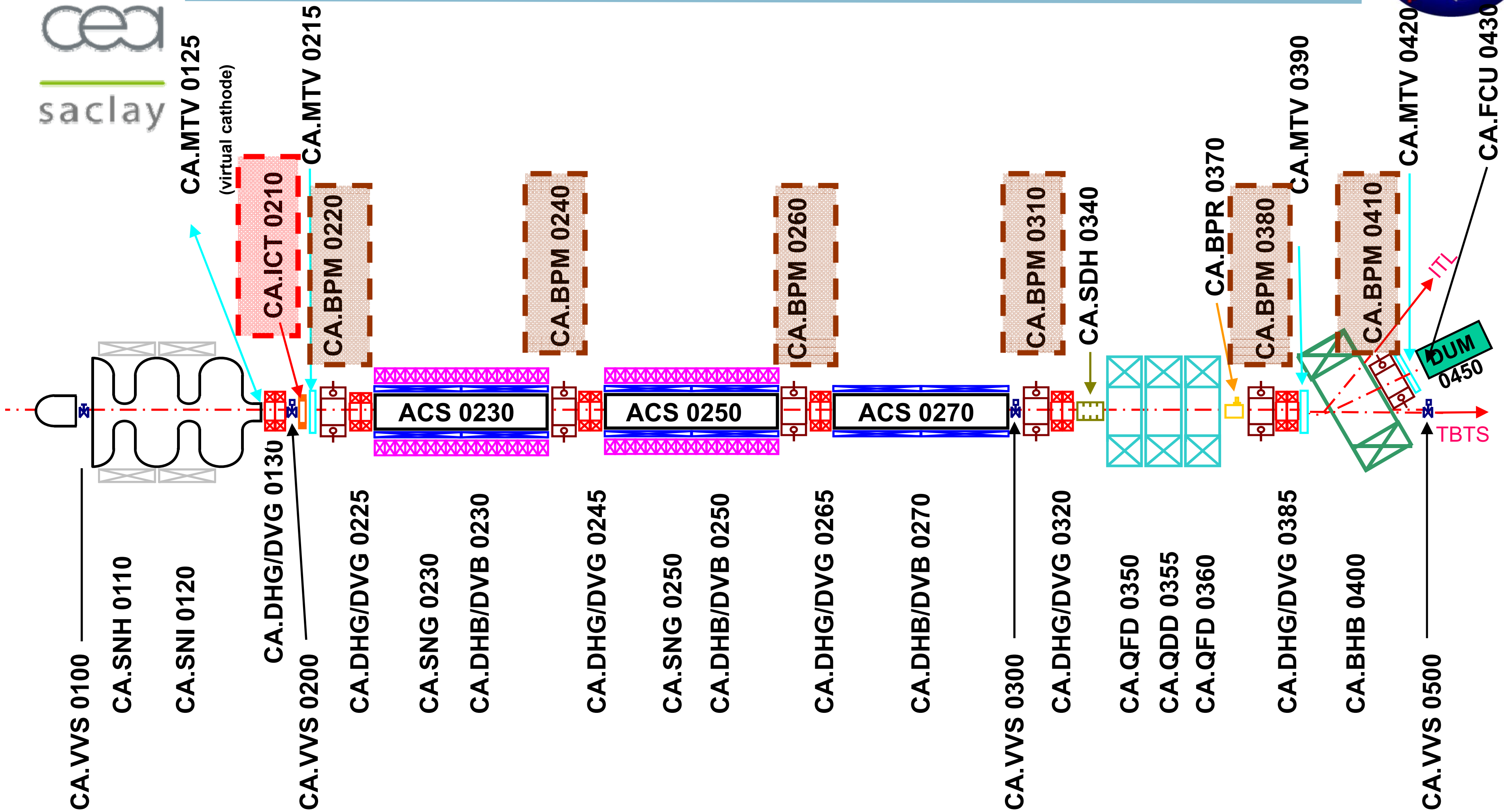
CALIFES linac

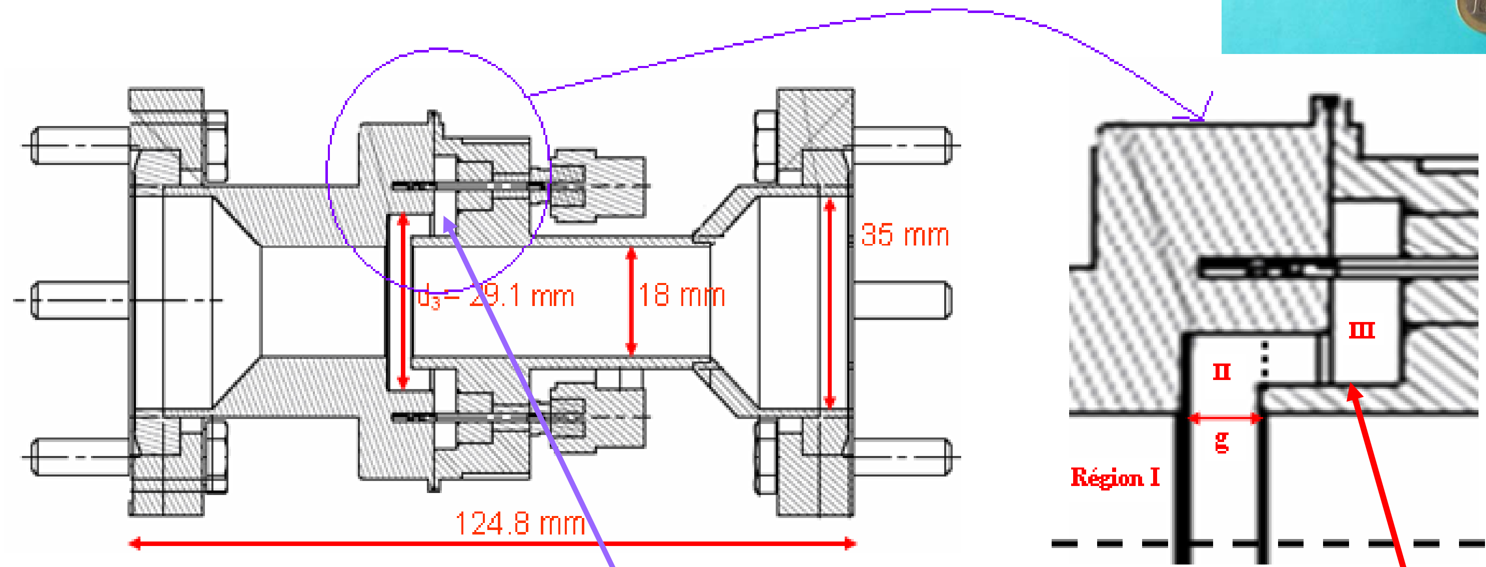


6 BPMs are installed on the CALIFES linac

Reentrant Cavity BPM for CALIFES

- It is operated in single and multi-bunches modes
- 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

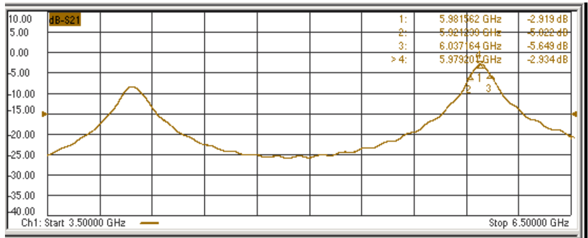
- a low loop exposure to the electric fields

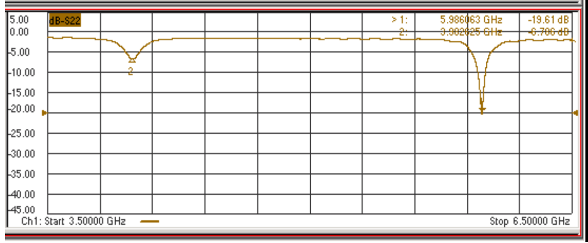
RF characteristics

- RF characteristics of the cavity: frequency, coupling and R/Q

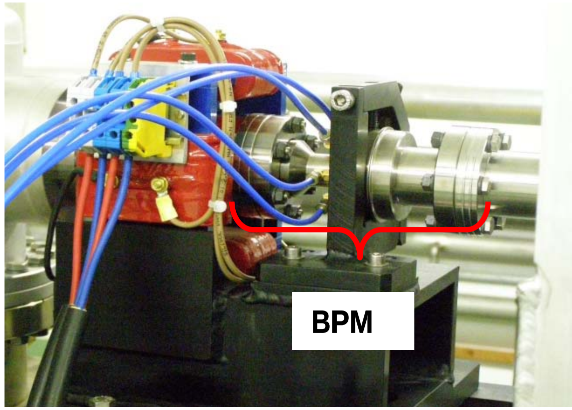
Eigen modes	F (MHz)		Q_l		(R/Q) (Ω)	(R/Q) (Ω)
	Calculated with HFSS in eigen mode	Measured in the CLEX	Calculated with HFSS in eigen mode	Measured in the CLEX	Calculated Offset 5 mm	Calculated Offset 10 mm
Monopole mode	3991	3988	24	26.76	22.3	22.2
Dipole mode	5985	5983	43	50.21	1.1	7

Monopole and dipole transmission measured by the network analyzer





Monopole and dipole reflection measured by the network analyzer



- Similar results from one BPM to another, and in-situ results are comparable to Saclay in-lab measurements

Due to tolerances in machining, welding and mounting, some small distortions of the cavity symmetry are generated.

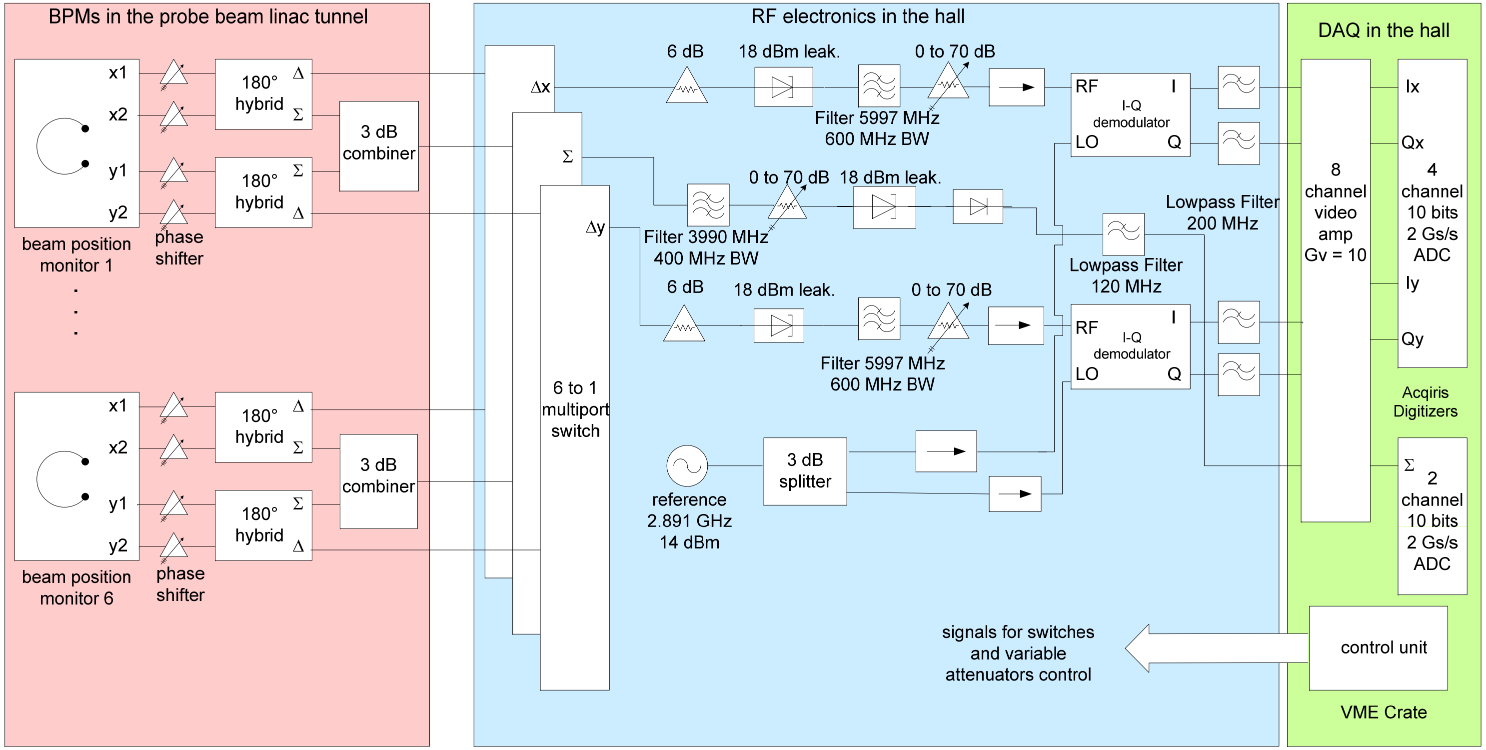
This asymmetry is called cross talk and the isolation is evaluated > 26 dB.

Signal Processing

- 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.

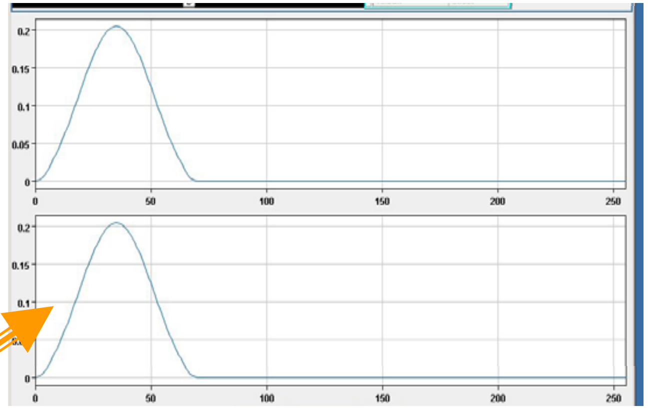


Control Command of BPMs

1/Sampling with acqiris boards and readout signals on OASIS

6 BPMs implemented

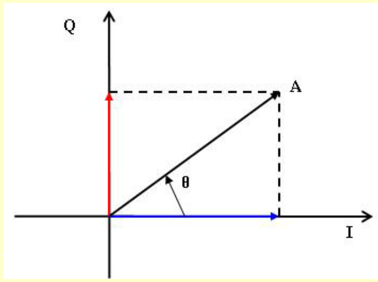
3/Results sent on graphic windows under JAVA and in a file to be used with Matlab



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

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

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

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

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

Simulations (1)

❖ **Signal voltage determined by the beam's energy loss to the dipole mode.**

Dipole mode signal depends on frequency fi and external coupling Qi of this mode

$$S_i = \Phi(t)\left[V_i \exp\left(-\frac{\omega_i . t}{2 Q_i}\right)\left(\cos\left(\omega_i . t - \frac{\omega_i . \sin(a_i . t)}{2 Q_i . a_i}\right)\right)\right]$$

single bunch

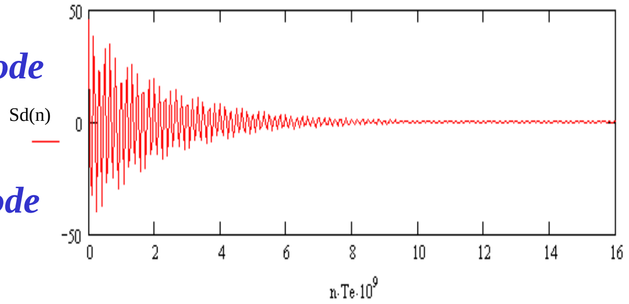
$$a_i = \omega_i \sqrt{1 - \frac{1}{4 Q_i^2}} \qquad V_i = \sqrt{\frac{\omega_i^2 . (R/Q)_i . q^2 . R_o}{\zeta_i . Q_i}}$$

$\Phi(t)$ = heaviside function, q = bunch charge, R0 = 50 Ω, (R/Q)i = coupling to the beam and ζi = 2 (dipole mode)

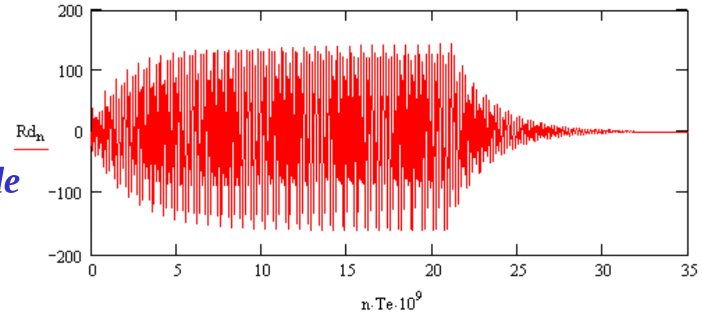
$$Rd_n := \sum_{I=0}^{32} \mathrm{Phi}(n \cdot Te) \cdot \left[Vod \cdot e^{-2 \cdot \pi \cdot Fd1 \cdot \frac{n \cdot Te}{2 \cdot Qd1}} \cdot \left(\cos(ad1 \cdot n \cdot Te) - 2 \cdot \pi \cdot Fd1 \cdot \frac{\sin(ad1 \cdot n \cdot Te)}{2 \cdot Qd1 \cdot ad1} \right) \right]$$

32 bunches

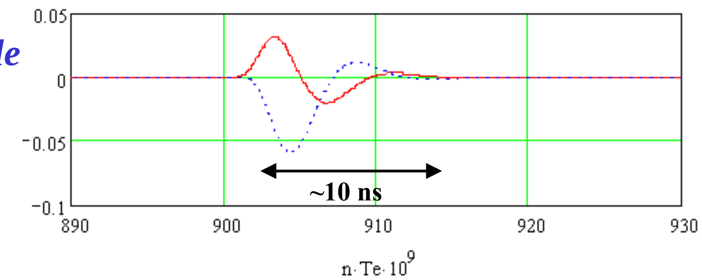
Dipole mode signal in single bunch mode



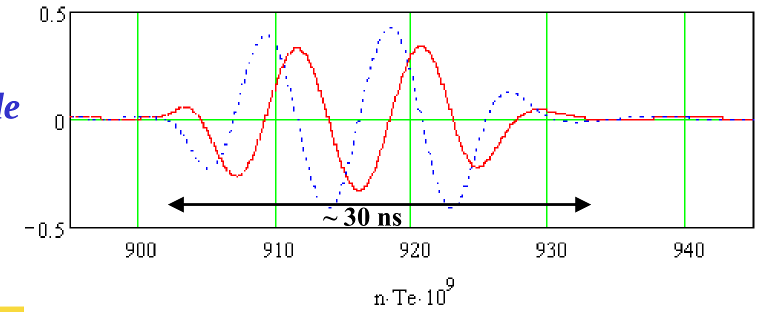
Dipole mode signal in 32 bunches mode



Signal in single bunch mode behind RF electronics



Signal in 32 bunches mode behind RF electronics



Simulations (2)

❖ **Noise** is determined by :

Thermal Noise : $P_{th} = k_b * T * BW$

kb = Boltzmann constant, BW (Hz) = Bandwidth, T (K) = Room Temperature.

Noise from signal processing channel : $P_n = NF * G * P_{th}$.

with $$NF = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 * G_2} + \ldots$$

Pth = Thermal noise, NF=Total noise figure of the signal processing, Fi and Gi respectively the noise factor and the gain of component i.

Re-entrant Cavity at CALIFES

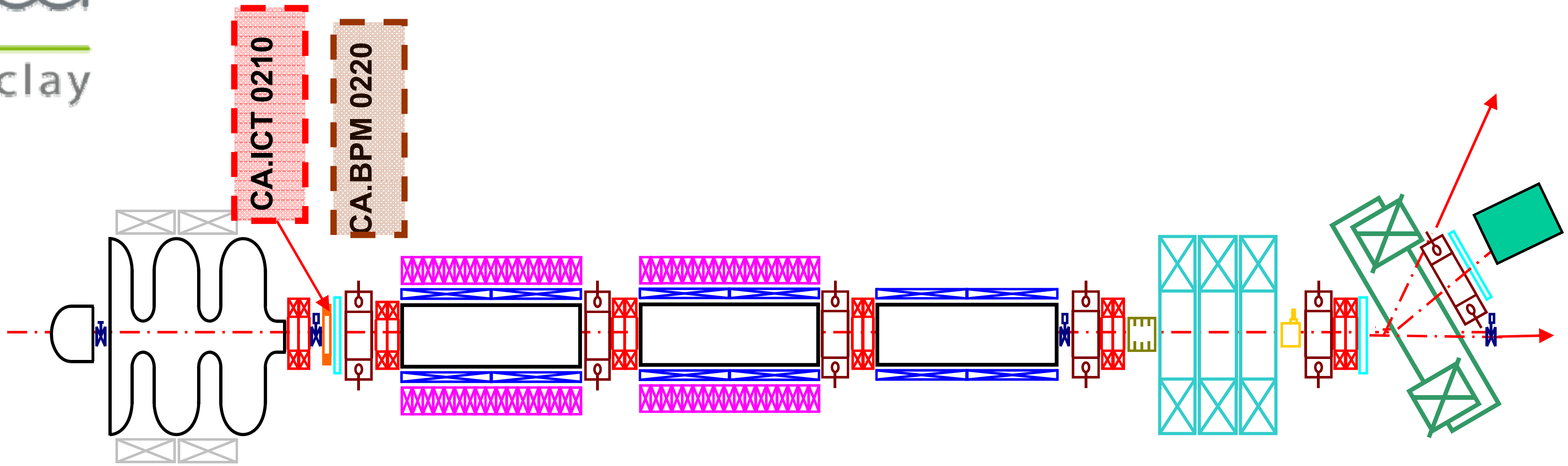
Environment Noise RMS: **66 µV** (measured at FLASH)

Δ signal (gain adjusted to get an RF signal ~ 0 dBm, simulated in single bunch)

with 5 mm offset : **590 mV** (simulated), **Noise:** **0.5 mV** (calculated) ➡ **Resolution :** **3.2 µm** (simulated)

with 0.1 mm offset : **555 mV** (simulated), **Noise:** **0.1 mV** (calculated) ➡ **Resolution :** **100 nm** (simulated)

BPM calibration (1)

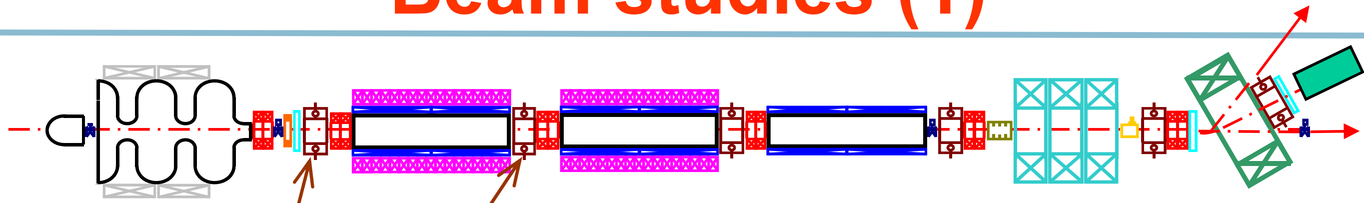


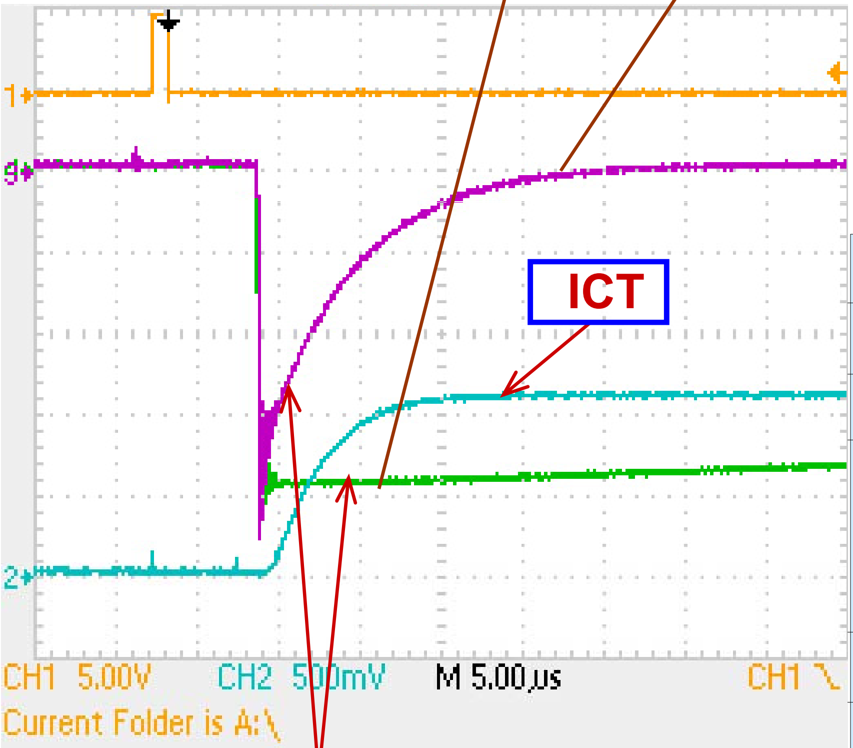
❖ All BPMs have same electronics and same losses

→ coefficients should be the same

❖ Charge calibrated with charge calculated by ICT

Beam studies (1)

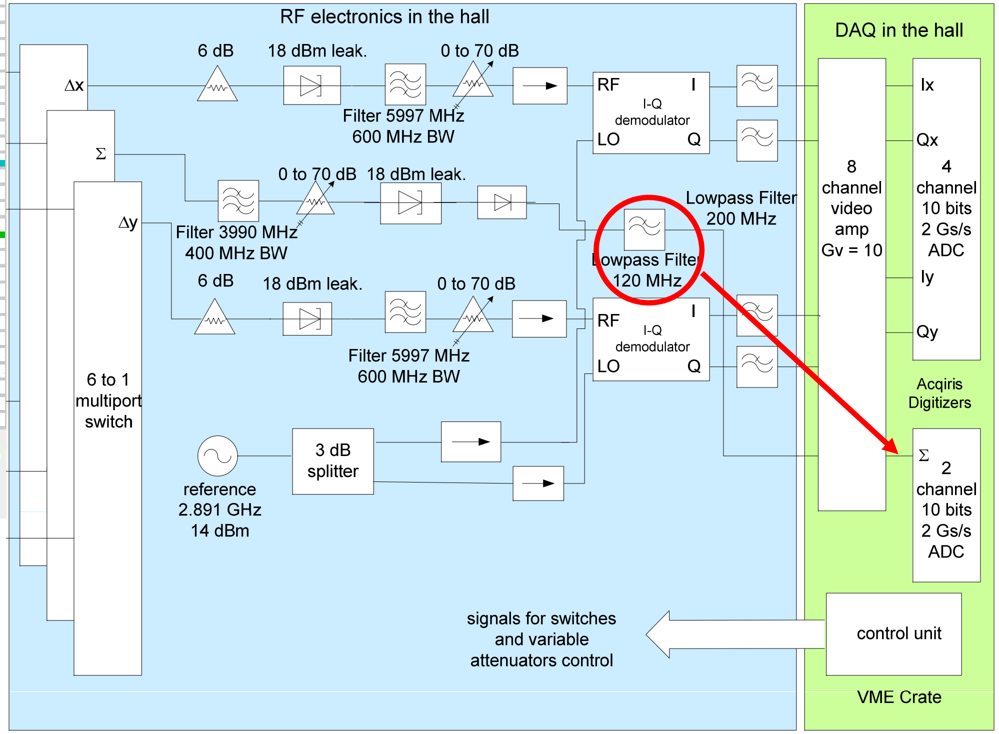




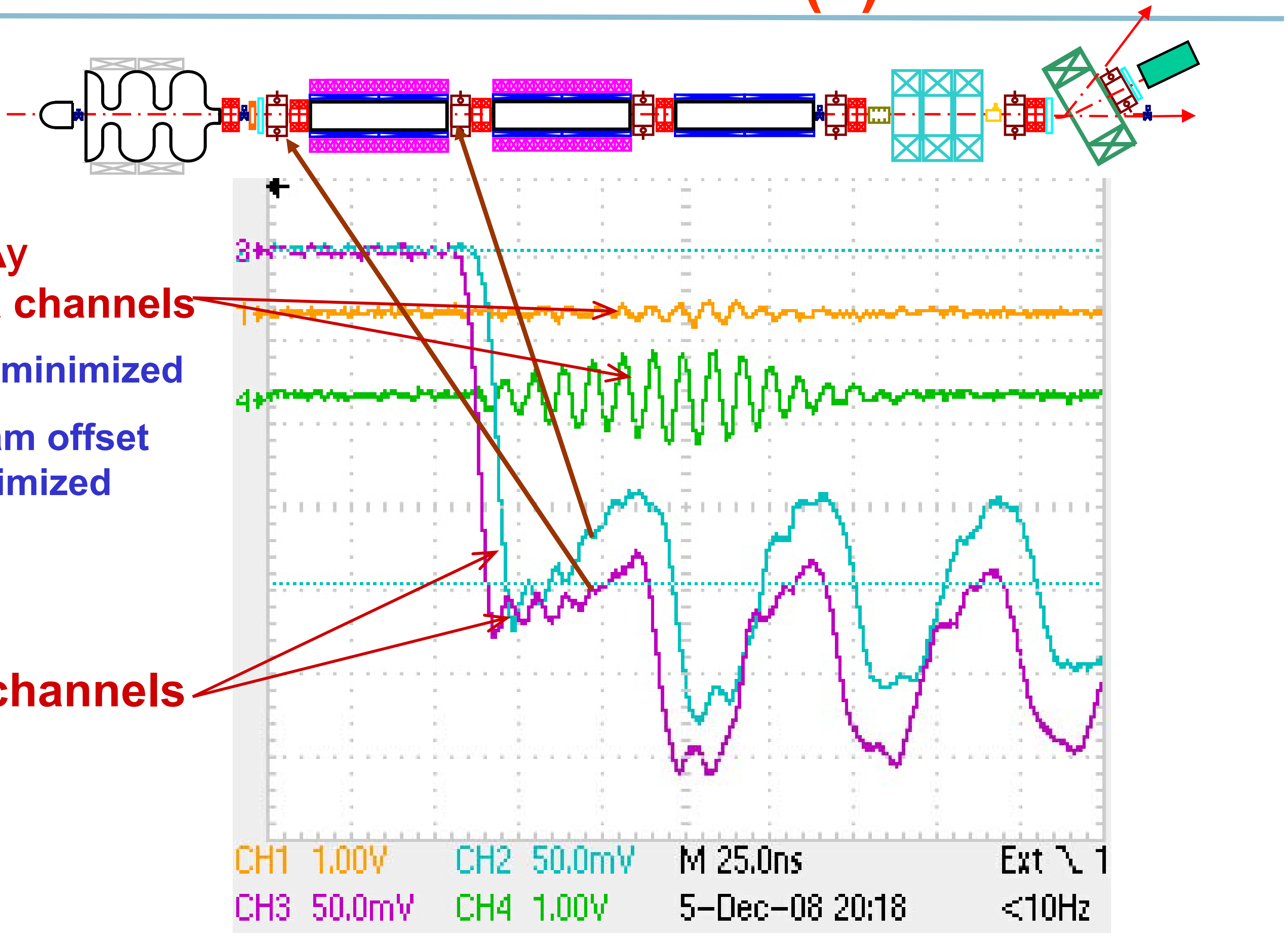
Σ channels

Amplitude of signals corresponds to 6 nC with 150 bunches determined thanks to ICT

- **τ too long on Σ channel (green) → problem with diode**
- **Impedance problem? -> Move lowpass filter**



Beam studies (2)



Δy
I and Q channels

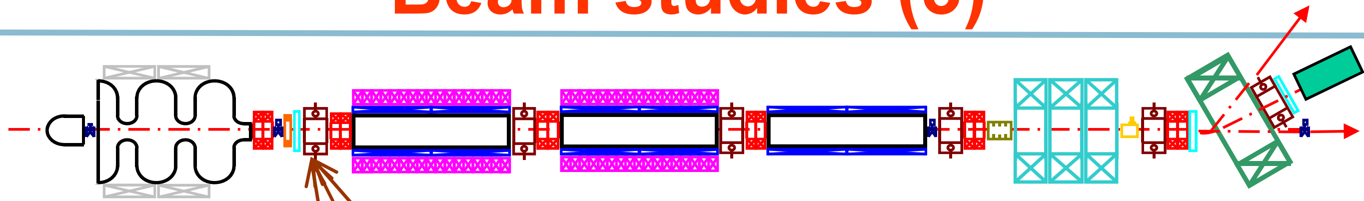
Signals minimized

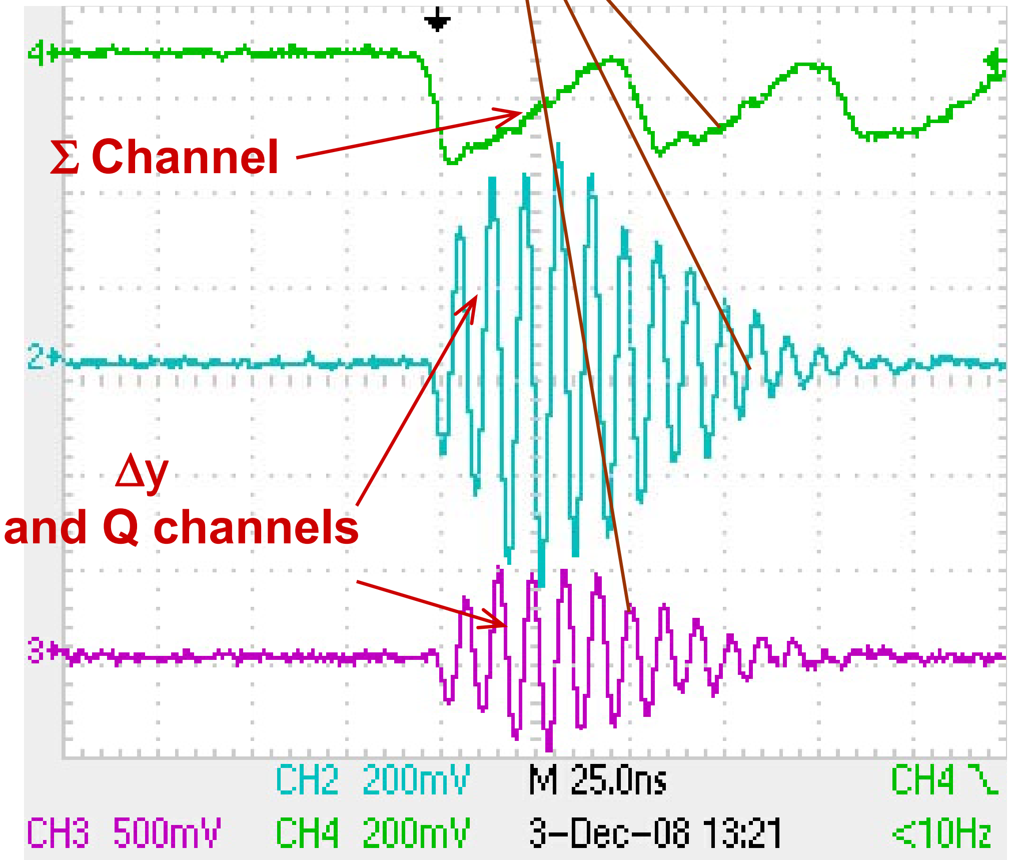
→ beam offset minimized

Σ channels

Charge ~ 6 nC read by the first and second BPM.
~ 100 % transmission behind 1st section

Beam studies (3)



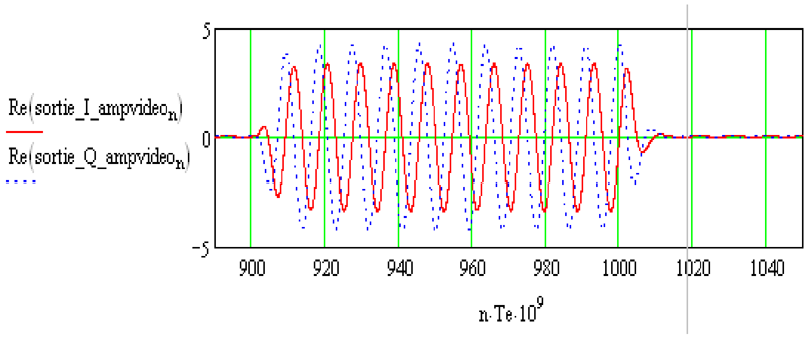


- **Signal frequency: 100 MHz**
- **Shape of Δy shows in the pulse train :**

  - charge not constant

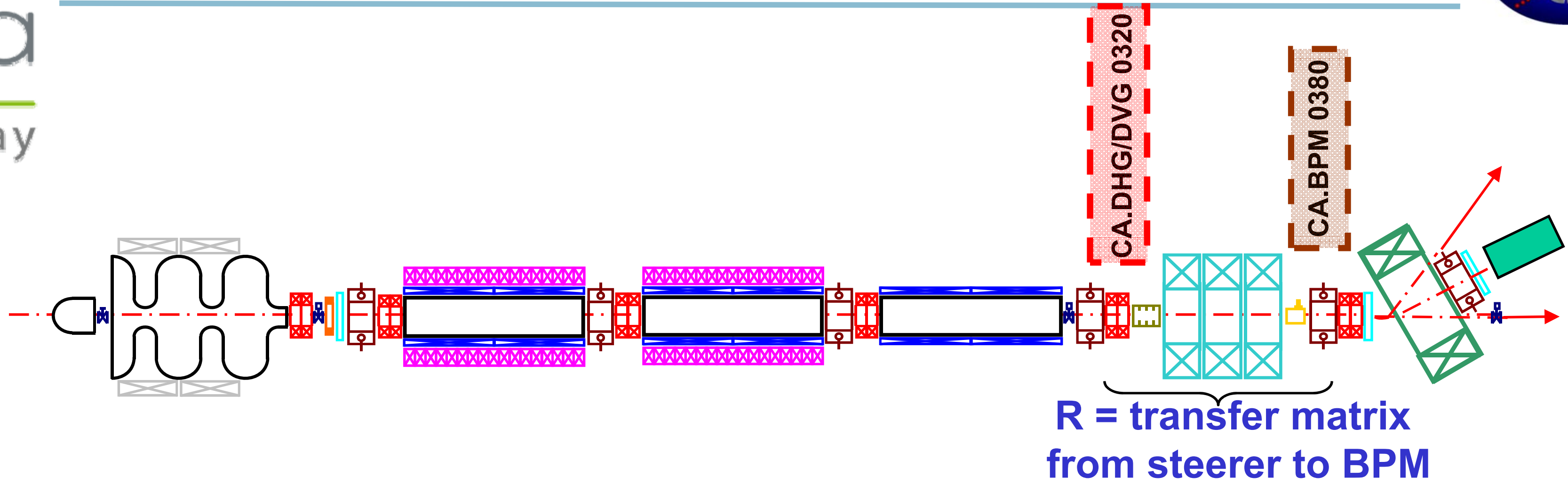
  or

  -beam position not constant



Simulation of I and Q signals

BPM calibration (2)



❖ **Magnets switched off between steerers and studied BPM to reduce errors and simplify calculation.**

❖ **Move beam with one steerer in horizontal and vertical frame.**

❖ **Average of 500 points for each steerer setting.**

❖ **Calculate for each steerer setting, the relative beam position in using a transfer matrix between steerer and BPM :**

Dx = R12*Dx'(angle at steerer)

Summary

❖ **Reentrant cavity BPM features for CALIFES:**

- **Operated in single and multi-bunches**
- **Single bunch resolution potential < 1 µm**
- **Charge of beam measured**

❖ **Software under development.**

❖ **First beam seen by BPMs → Dec. 2008**

❖ **New beam tests → end of March 2009**

Acknowledgements

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Thank you for your attention