Cold BPM Options

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OPTIONS

- Strip line
- Button
- Pill box RF cavity
- Re-entrant RF cavity
- Accelerating RF cavity

PROPERTIES @ 10-15 K

i. Positionning accuracy w.r.t. SC Quadrupole

ii. Resolution :
  - Single bunch
  - Bunch train: average
  - Bunch train: bunch to bunch

iii. Beam centering accuracy

Strip line

- Naturally broad band $\Delta\tau \sim cL \Rightarrow$ single bunch / bunch to bunch BPM (directional)

- Submicron resolution achieved in SLC Final Focus and FFTB
  - Resolution $\propto$ beam pipe diameter or electrode separation

- Not advised in cold modules because of mechanical deformation during cool-down (*discussion with M. Wendt for the IR fast feedback BPM in SC doublet cryostat*): resolution > 10 μm

Button BPM

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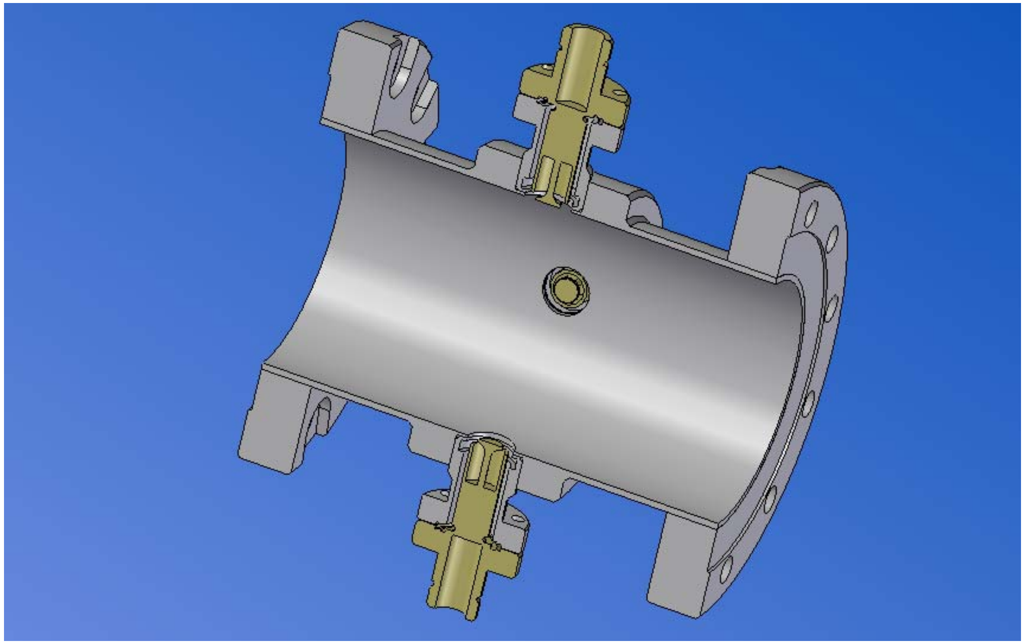
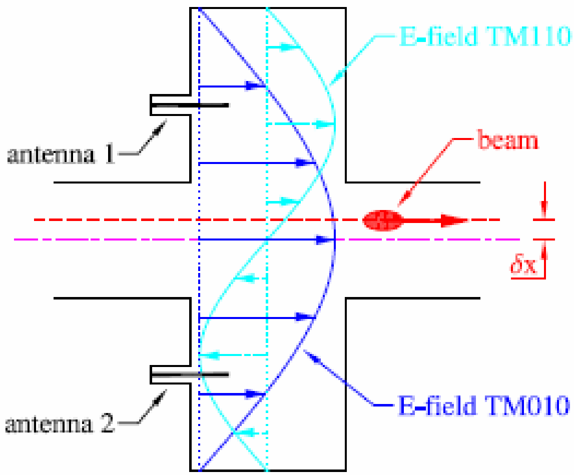
- Naturally broad band $\Rightarrow$ single bunch / bunch to bunch BPM
- Resolution $\propto$ beam pipe diameter or electrode separation
  - 1 µm resolution for single bunch questionable
- Robust in the cold: one option for the XFEL



Pill box RF BPM

- Resonant cavity naturally narrow band ⇒ not a bunch to bunch BPM
- Resolution proportional to beam pipe diameter:
  resolution << sub-micron (cf Shintake, Balakin, KEK-ATF program).
- Robust in the cold
- Symmetrical and easy machining

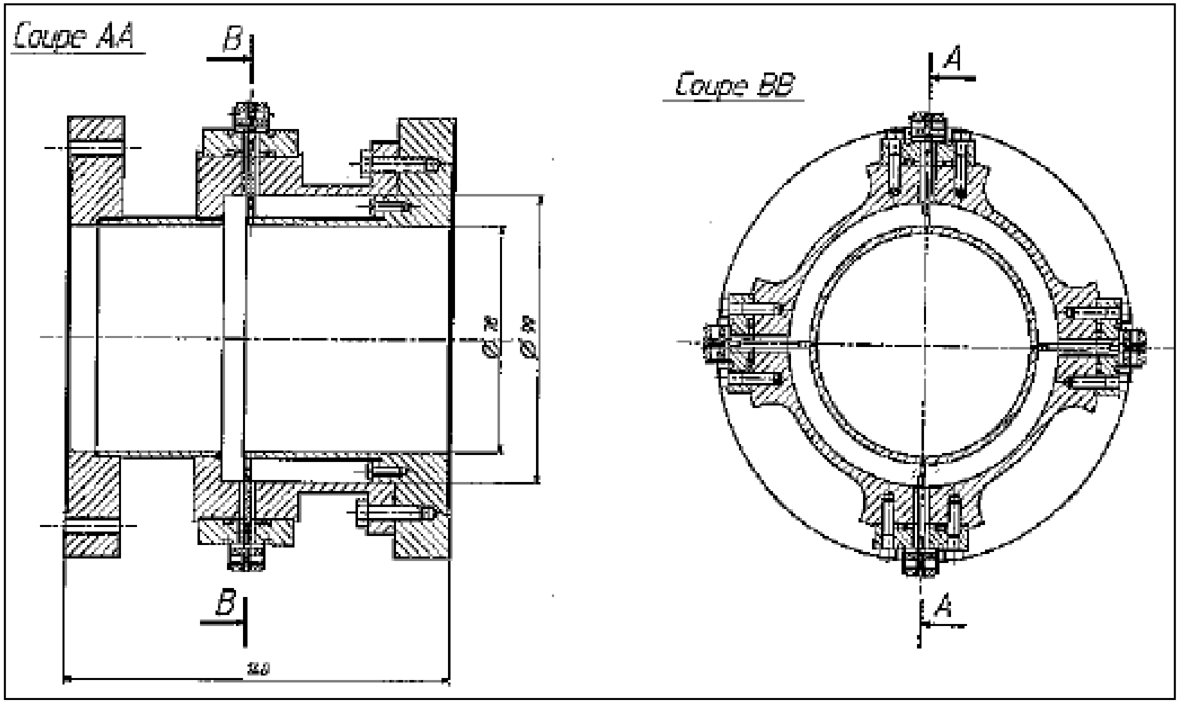


- Q_L << 1000 needed for bunch to bunch
  - TTF module BPM in Stainless Steel to reduce Q_0
  - Intercept @ 15K about 1 W from high frequency HOMs before the dedicated lossy ferrites (compared to 2 W for SC cavity @ 35 MV/m-5 10^9 and 10-50 mW from BPM cavity itself)
- Copper coated BPM with low Q_{ext} provided by different coupling antennas (*V. Sargsyan, TU Berlin*) ⇒ $\Delta\tau$ ~200 ns, not really bunch to bunch.

Re-entrant RF BPM

- Broad band cavity $Q_L = 50$, $\Delta\tau \sim 10$ ns
  ⇒ single bunch and bunch to bunch BPM
- Resolution proportional to beam pipe diameter:
  it can be ~1 µm (cf. M. Luong and C. Simon).
- Robust in the cold
- Symmetrical and easy machining

TTF-ACC1
prototype



Re-entrant RF BPM: Old Design

Resonant modes for the BPM in ACC1 (Simulation with HFSS)

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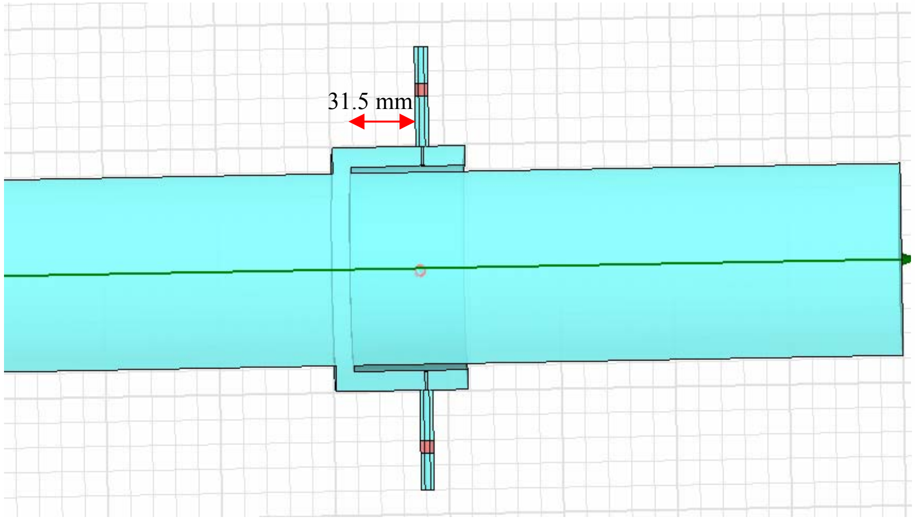
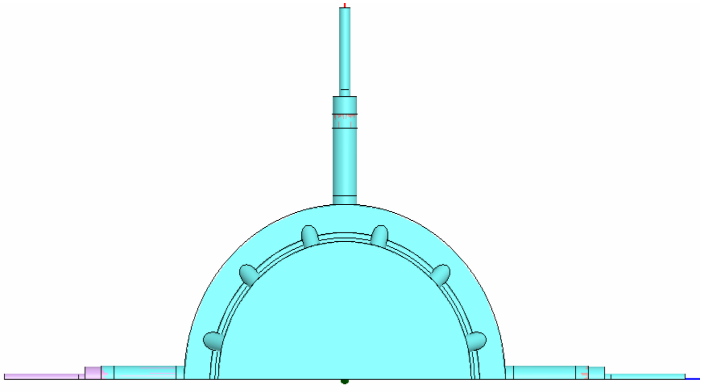
	BPM in ACC1			
	F (Ghz)	**Q**	**R/Q at 5mm of the center of cavity**	**R/Q at 10mm of the center of cavity**
Mode1 : Monopolar mode	1.58	2.15	20.2	20.4
Mode 2: Dipolar mode	2.01	4.11	0.53	2.2
Mode3: Quadrupolar mode	2.25	0.97	0.01	0.015
Mode 4: Dipolar mode	2.30	1	0.3	1
Mode 5: Monopolar mode	2.34	1.02	3.7	4.1

When the feedthrough is simulated without cavity, in driven mode, a resonant frequency, around 1.4Ghz, exists. That's why there are 2 monopolar modes and 2 dipolar modes in eigen mode when the cavity is simulated with feedthroughs.

New mechanics design

- New design of the cavity BPM (For the cleaning, 12 holes of diameter 5mm have to be added)





- Resonant modes with the new design (simulated with HFSS)

	New BPM			
	F (Ghz)	Q	R/Q at 5mm of the center of cavity	R/Q at 10mm of the center of cavity
Mode monopolaire	1.25	24	13	13
Mode dipolaire	1.72	51.4	0.25	1.11

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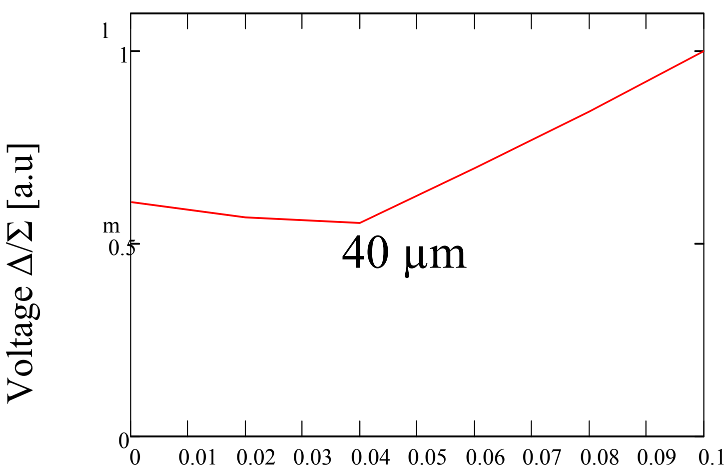
Linearity and **Centering Accuracy**

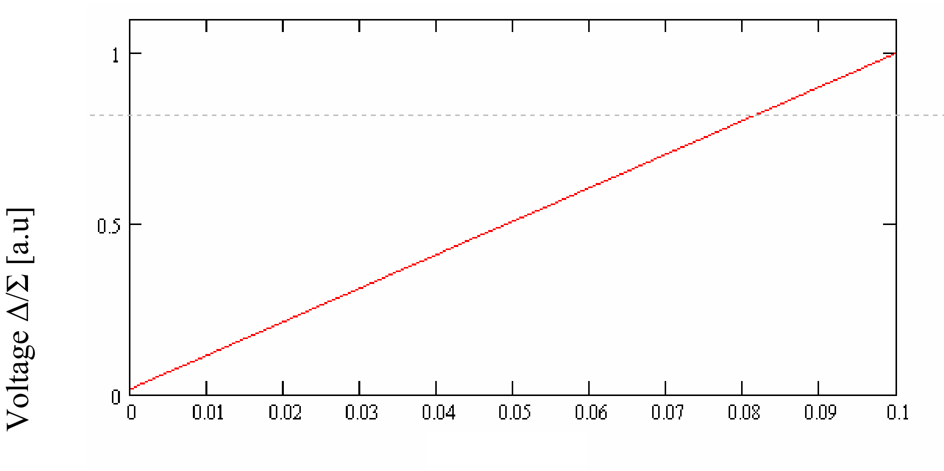
Old design

New design

Voltage Δ/Σ

[a.u]





Position of the beam (mm)

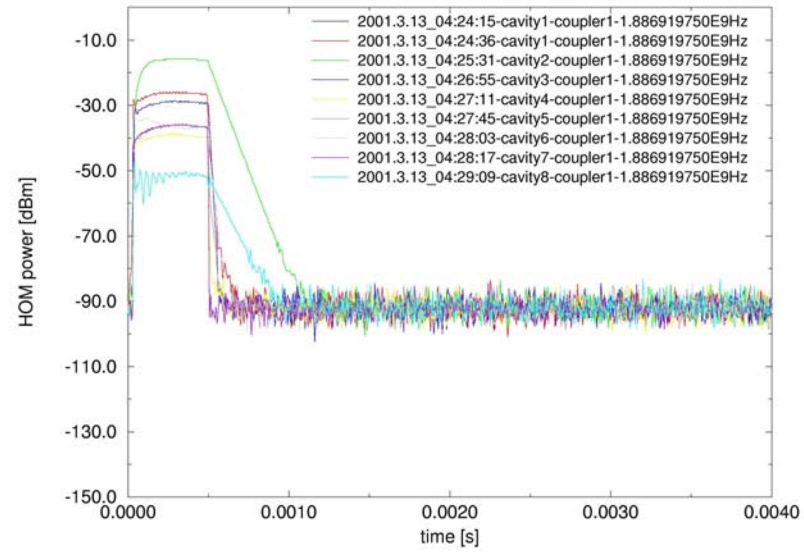
Position of the beam (mm)

Accelerating RF Cavity

- Naturally narrow band cavity : $Q_L \approx 10^4$, $\Delta\tau \sim 1$ μs

$\Rightarrow$ single bunch,

but not bunch to bunch BPM



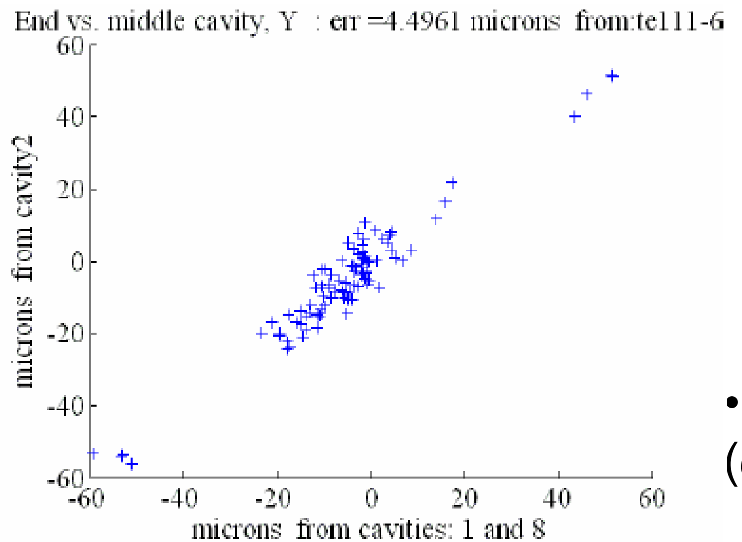
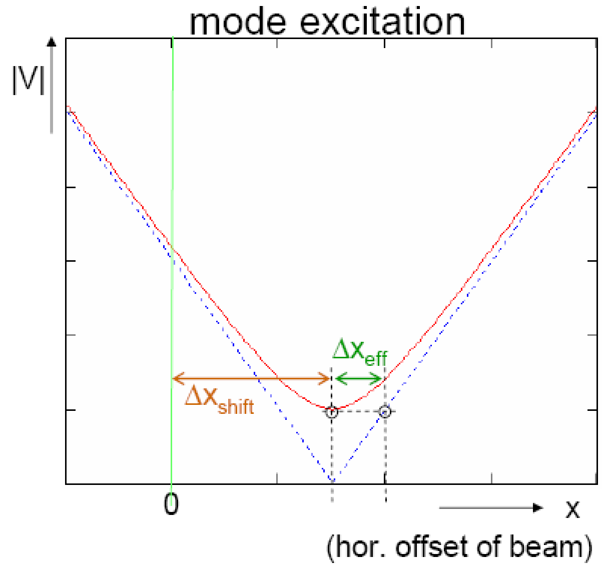


Figure 5: x predicted from the TE111-6 mode signals of cavity 2 vs that predicted from cavities 1 and 8 (at either end of the cryomodule). The width of the residual is approximately 4.5 microns, giving an estimate of the error associated with the measurement of a single cavity of about 3 microns.

- Relative position resolution ~ 4 μm (*cf. M. Ross and J. Frisch*).

Accelerating RF Cavity

- Absolute position resolution ~100 μm (cf. M. Dohlus)



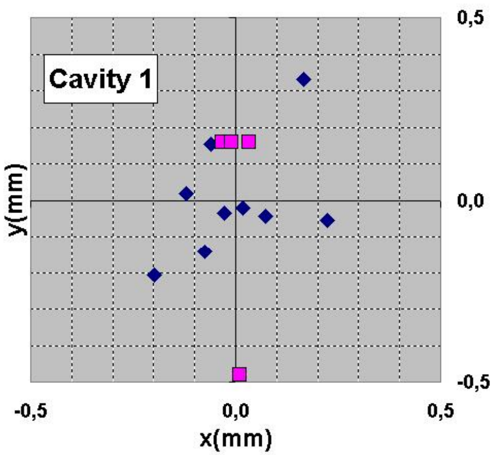
shifted offset: Δx_{shift}

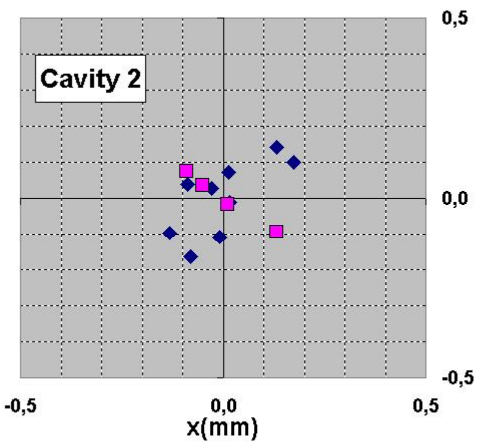
effective offset: Δx_{eff}
(residual coupling)

mode	f	k	Δx_{shift}	Δx_{eff}
	GHz	V/Cm^2	μm	μm
6	1.707	272	4	110
7	1.735	428	85	-35
13	1.866	191	55	100
14	1.875	254	75	-40

last 2 columns reversed !!

- Absolute position resolution ~100 μm (TTF measurements, 2004)





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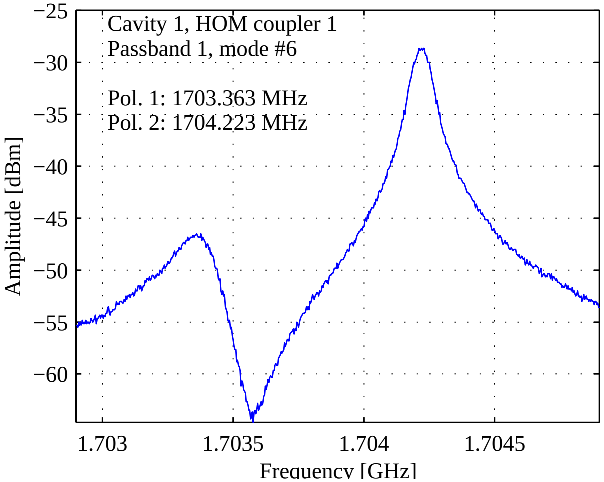
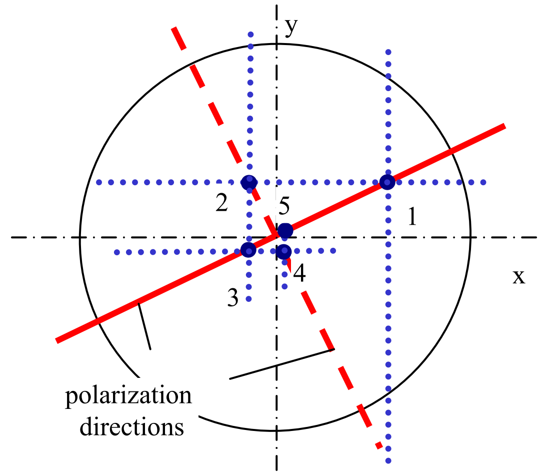
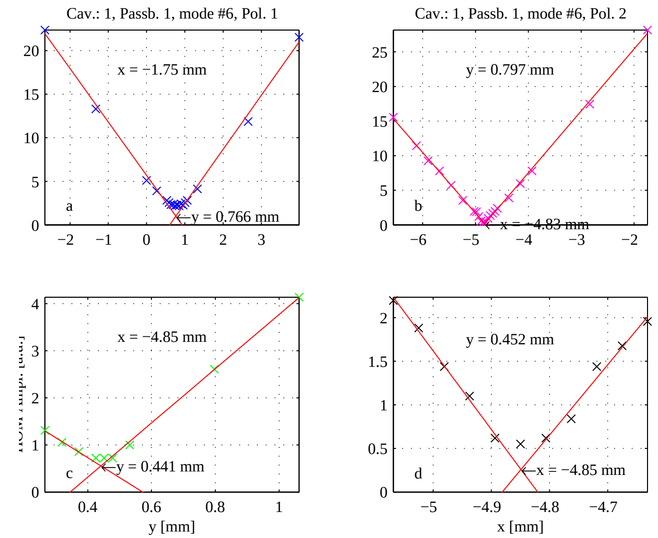
Accelerating RF Cavity

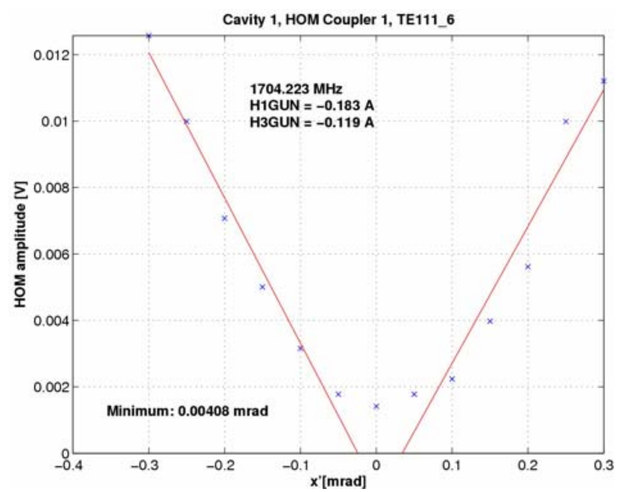
- Centering accuracy < 40 μm, using a single mode (2 polarisations)







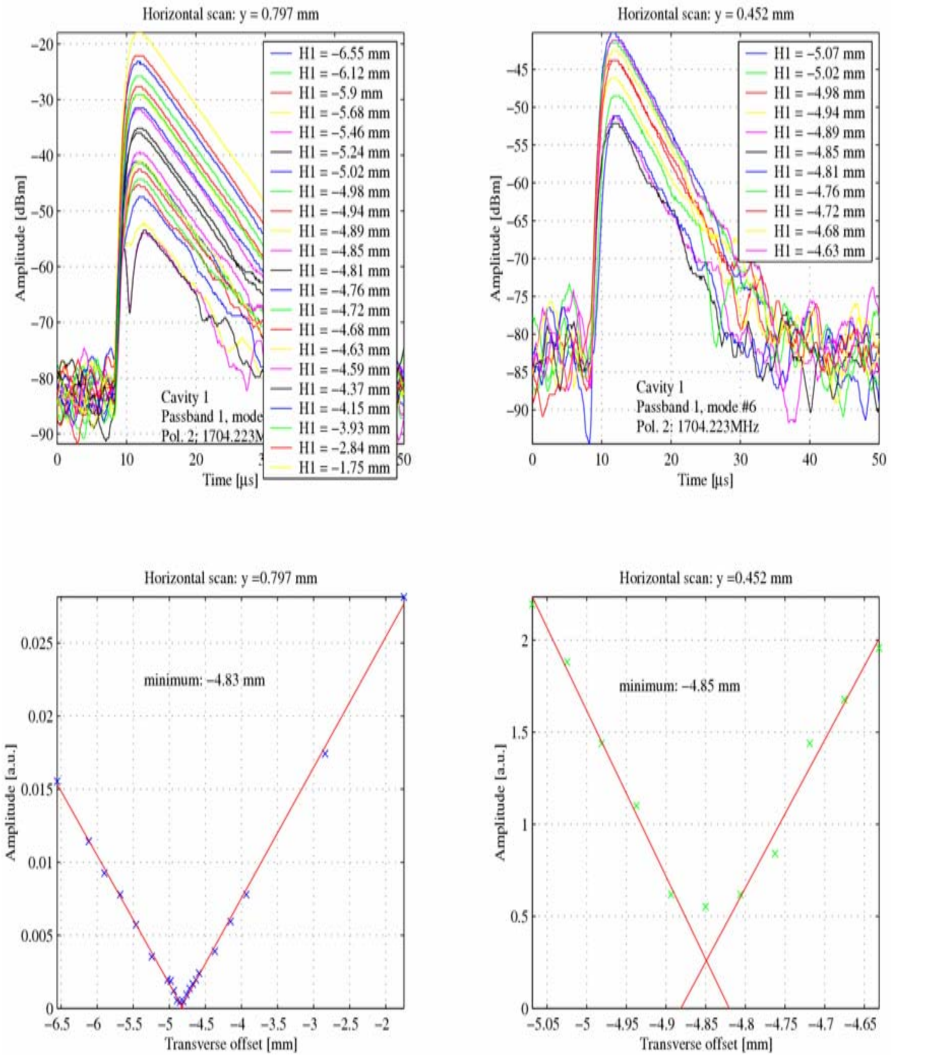
Angular scan resolution and accuracy < 50 μrad



Accelerating RF Cavity

Many measurements :
10000 x 4 dipole modes

Cavity 1, TE111_6



- BUT : neither rigid nor rigidly attached to the cold SC quadripole

Cavity 1, TE111_6

1 3 2 4