Cold BPM Options

OPTIONS

- Strip line
- Button
- Pill box RF cavity
- Re-entrant RF cavity
- Accelerating RF cavity (HOM)

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

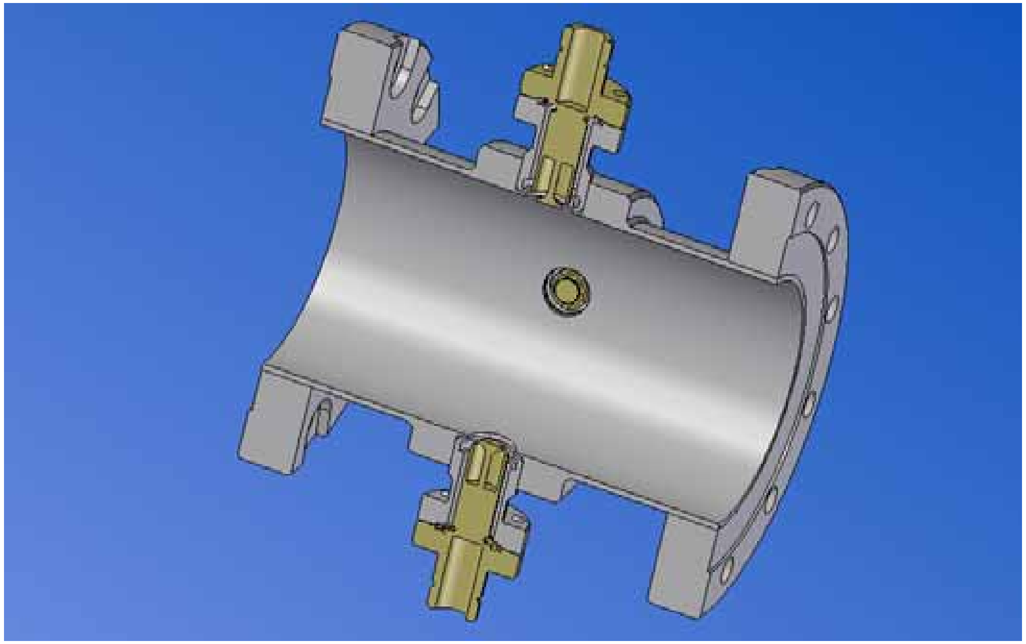
- Naturally broad band $\Delta\tau \sim cL \Rightarrow$ single bunch / bunch to bunch BPM (directional)

- 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

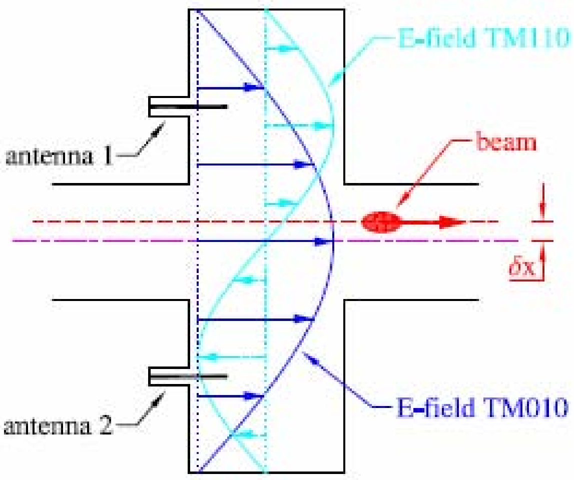
Button BPM

- Naturally broad band $\Rightarrow$ single bunch / bunch to bunch BPM
- Resolution $\propto$ beam pipe diameter or electrode separation
  - Single bunch resolution > 10 µm
- Robust in the cold: one option for the XFEL with 100 µm resolution *(maybe not anymore)*



Pill box RF BPM

- Resonant cavity naturally narrow band $\Rightarrow$ not a bunch to bunch BPM
- Resolution proportional to beam pipe diameter:
  resolution << sub-micron (*cf Shintake, Balakin, KEK-ATF program*).
- Mechanics:
  - Robust in the cold
  - Symmetrical
  - 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*) $\Rightarrow$ $\Delta\tau$ ~200 ns, not really bunch to bunch.

Re-entrant RF BPM

- Broad band cavity $Q_L = 50$, $\Delta\tau \sim 10$ ns
  $\Rightarrow$ single bunch and bunch to bunch BPM

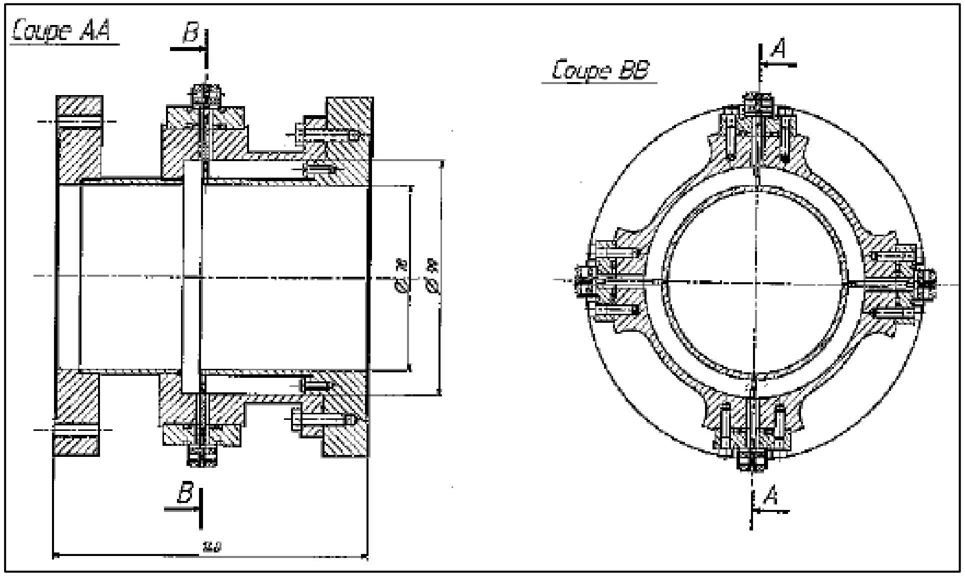
- Resolution proportional to beam pipe diameter:
  it can be ~1 µm (cf. C. Simon presentation).

- Bunch Charge and Dark Current measurements are possible via TM010 mode at the Σ output

- Mechanics:

  + Robust in the cold
  + Symmetrical
  + Easy machining
  – Cleaning issues

TTF-ACC1 prototype



Re-entrant RF BPM: Old Design

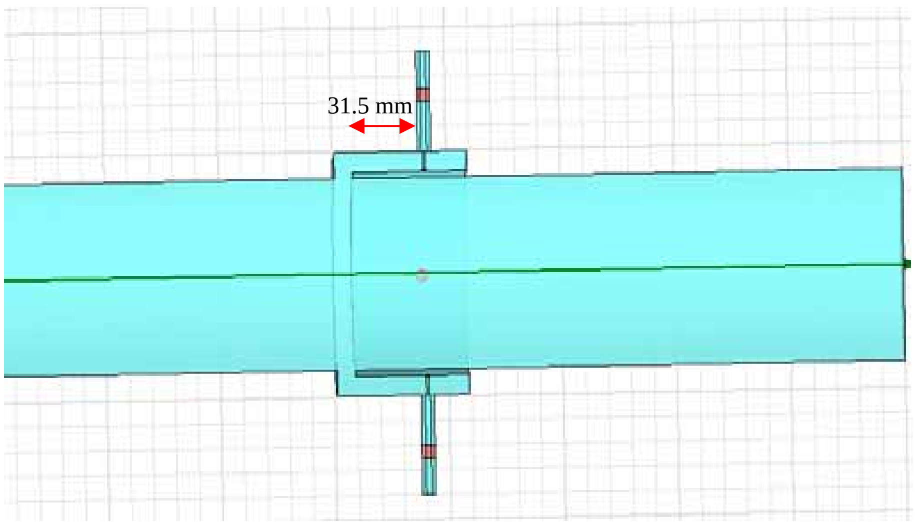
Resonant modes for the BPM in ACC1 (Simulation with HFSS)

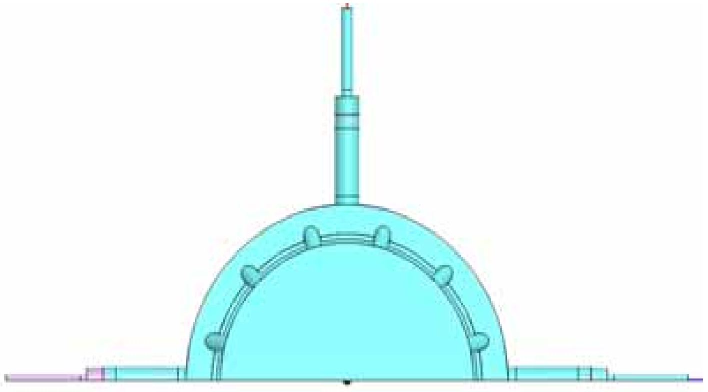
	BPM in ACC1			
	F (Ghz)	**Q**	**R/Q at 5mm of the center of cavity**	**R/Q at 10mm of the center of cavity**
Mode1 : Monopolar mode	1.58	2.15	20.2	20.4
Mode 2: Dipolar mode	2.01	4.11	0.53	2.2
Mode3: Quadrupolar mode	2.25	0.97	0.01	0.015
Mode 4: Dipolar mode	2.30	1	0.3	1
Mode 5: Monopolar mode	2.34	1.02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

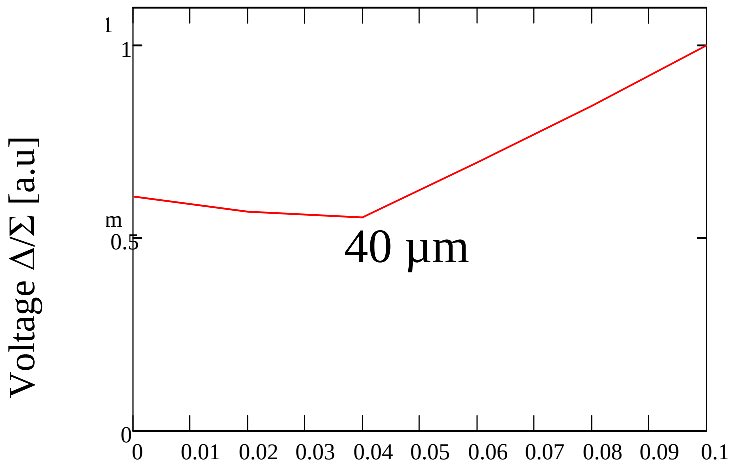
Cold Re-entrant BPM

Linearity and **Centering Accuracy**

Voltage Δ/Σ

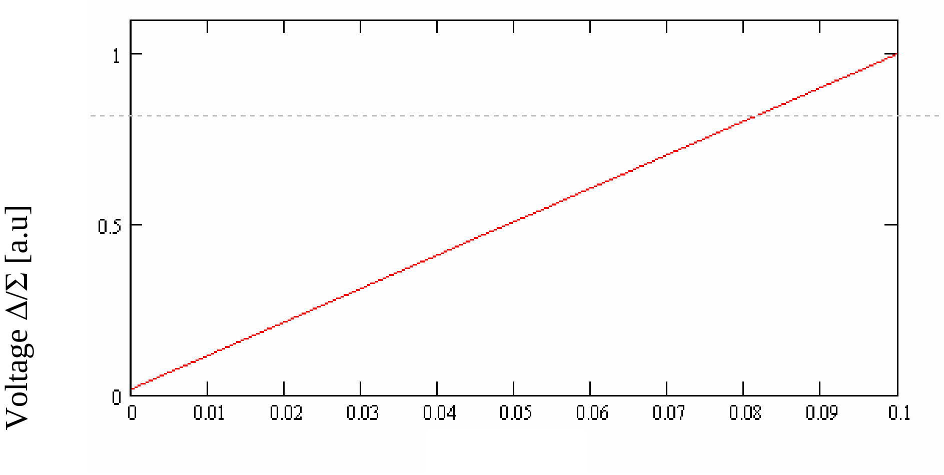
[a.u]

Old design



Position of the beam (mm)

New design



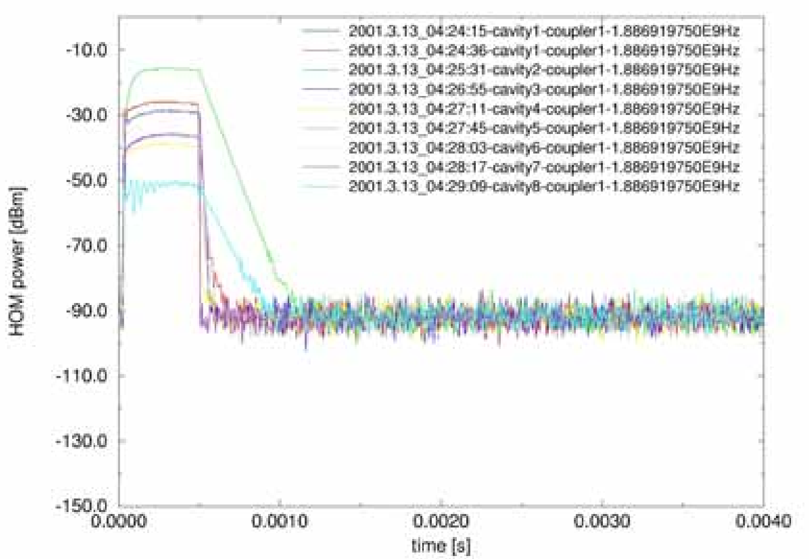
Position of the beam (mm)

Accelerating RF Cavity HOM

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

$\Rightarrow$ single bunch,

but not bunch to bunch BPM



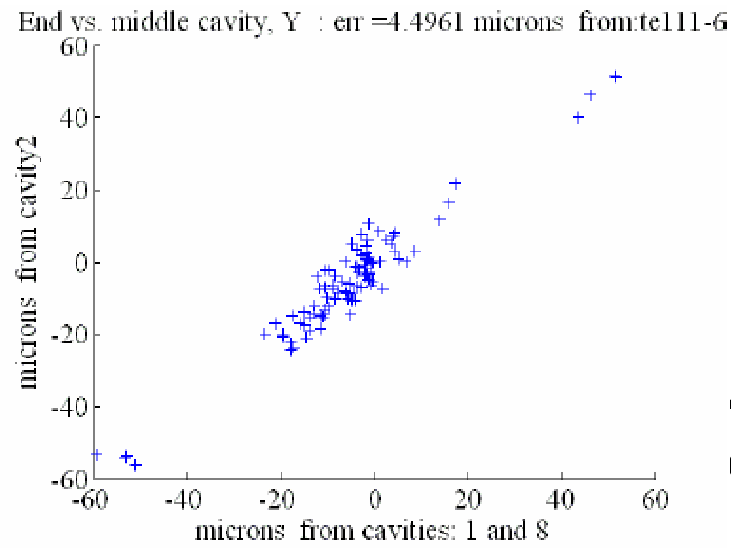
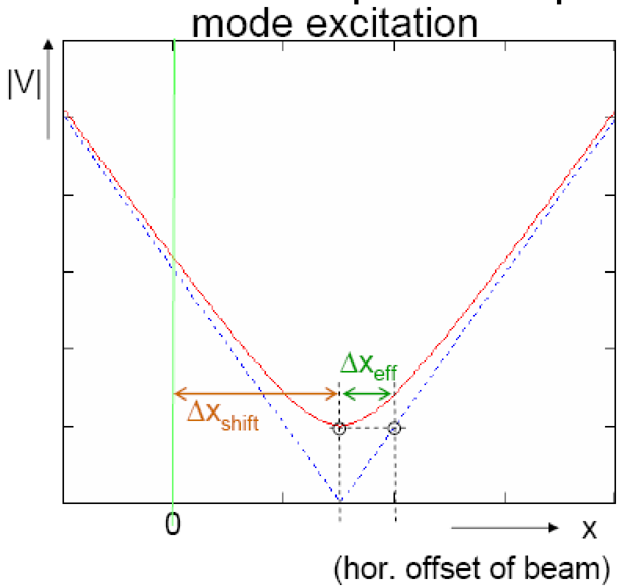


Figure 5: x predicted from the TE111-6 mode signals of cavity 2 vs that predicted from cavities 1 and 8 (at either end of the cryomodule). The width of the residual is approximately 4.5 microns, giving an estimate of the error associated with the measurement of a single cavity of about 3 microns.

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

Accelerating RF Cavity HOM

- Systematic center position spread ~100 µm (cf. M. Dohlus)



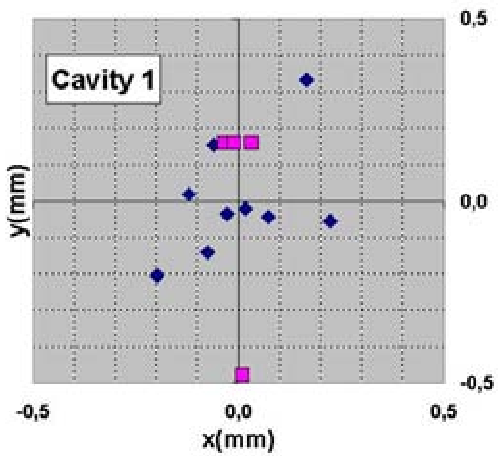
shifted offset: Δx_{shift}

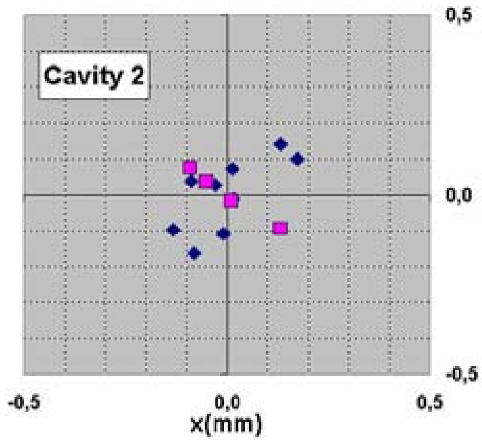
effective offset: Δx_{eff}
(residual coupling)

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 !!

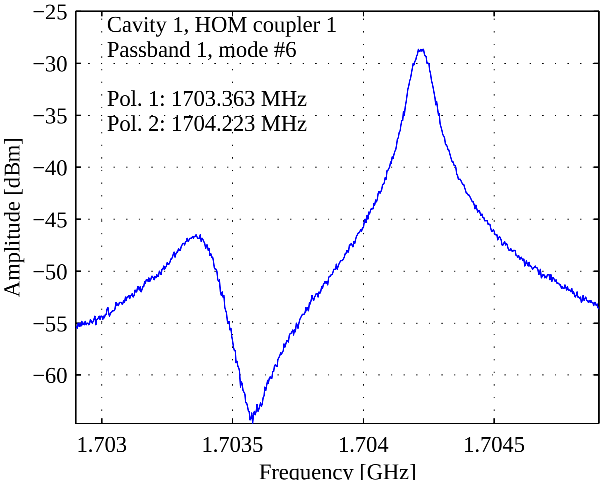
- Absolute position resolution ~100 µm (TTF measurements, 2004)

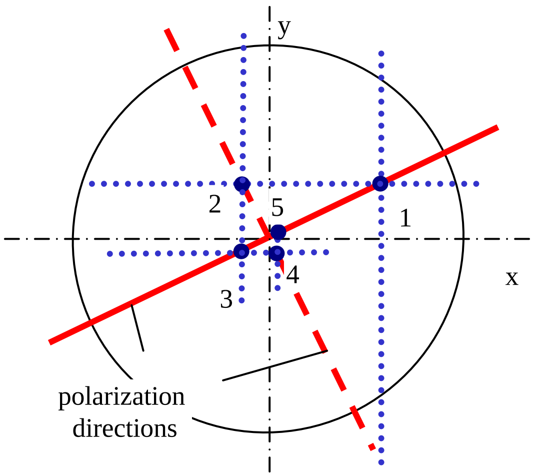


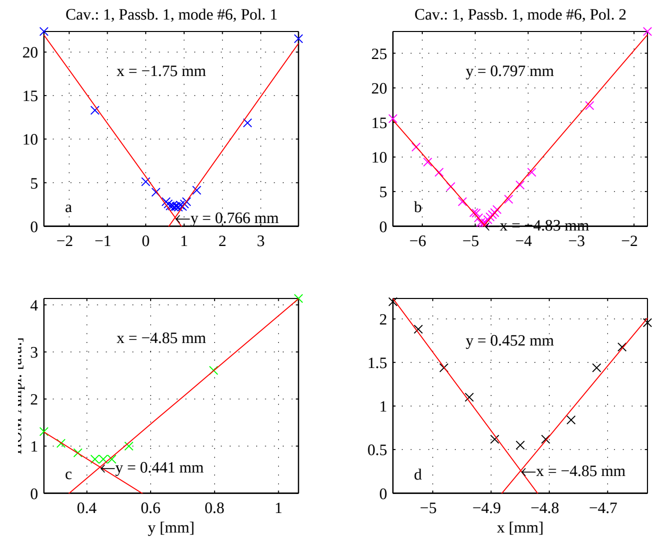


Accelerating RF Cavity

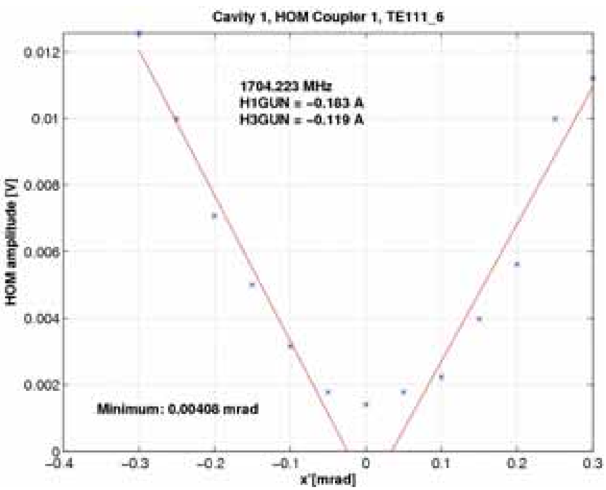
- Centering accuracy < 40 µm, using a single mode (2 polarisations)







Angular scan resolution and accuracy < 50 µrad

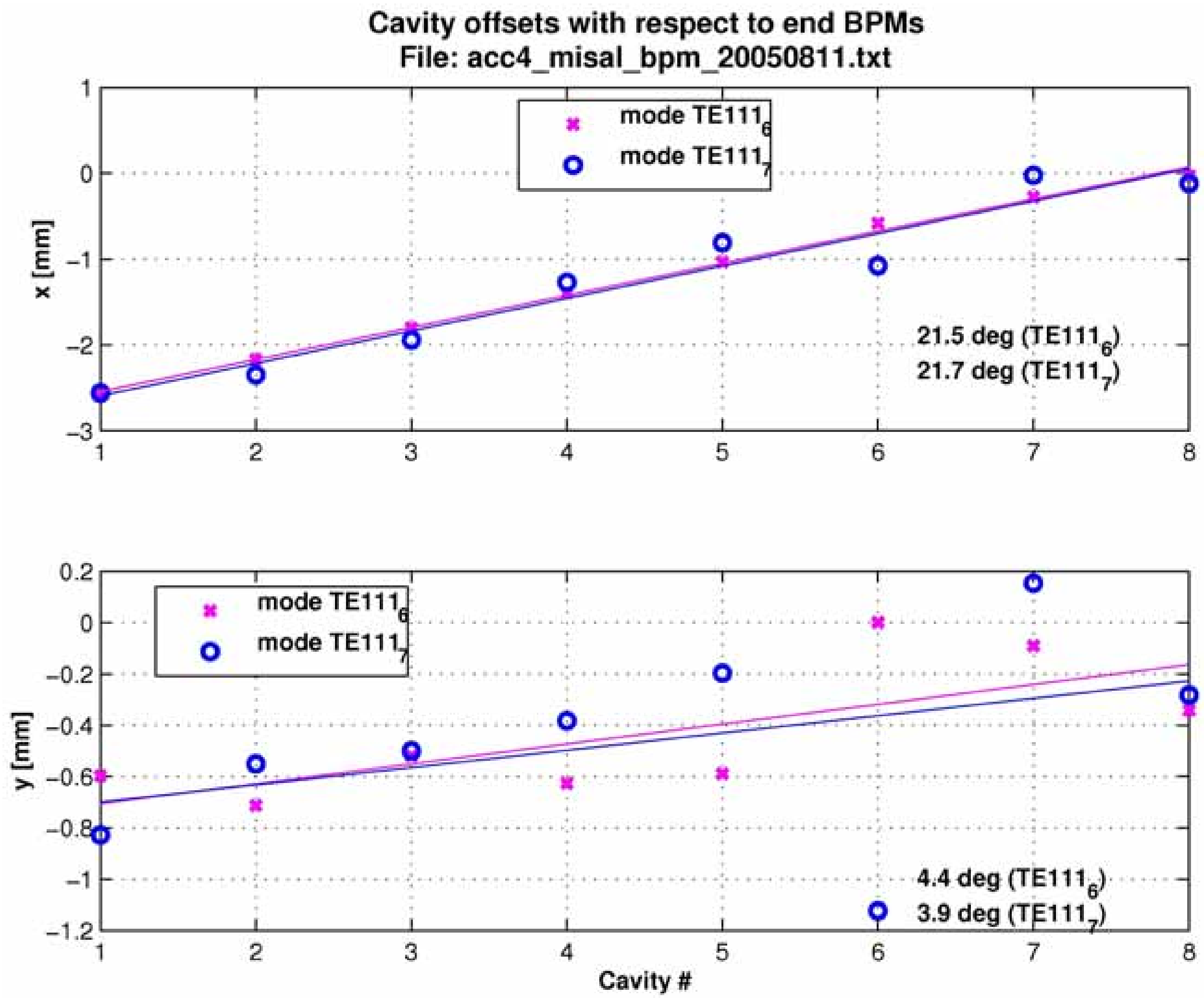


Accelerating RF Cavity

- Measuring the Cavity misalignment in Cryomodule
  - Experiment performed last week at TTF module 4 (ACC4) *(N. Baboi, J. Frisch, L. Hendrikson, R. Paparella, et al.)*
  - Accelerating gradients set to zero in all 8 cavities
  - Reference straight trajectory across the module set by 2 BPMs on both sides of the module
  - Modes used : $TE111_6$, $TE111_7$, $TM110_5$, $TM110_6$
  - PRELIMINARY RESULTS (problems of reproducibilty of HOM center reconstruction w.r.t. steering ranges !!)

Accelerating RF Cavity HOM

PRELIMINARY RESULTS (problems of reproducibilty of HOM center reconstruction w.r.t. steering ranges !!)



Cavity 1, TE111_6

1 3 2 4