

# Sub-task 10.5.1 HOM-BPM

## HOM Based Beam Position Monitors

### Results on Mode Spectra and Alignment

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# Outline

**What we want?**

**Where we are?**

**What's next?**

# FLASH and ACC39

## Free-electron LASer in Hamburg (FLASH)

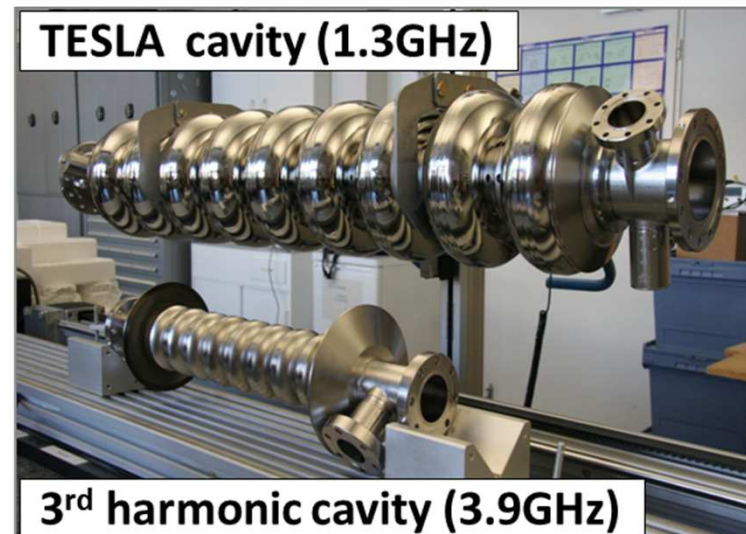
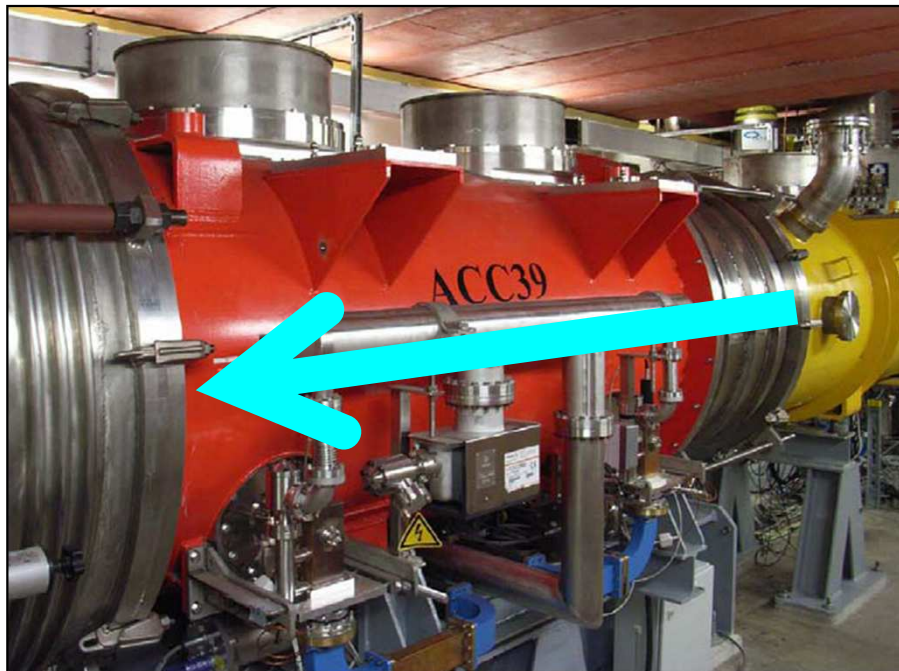
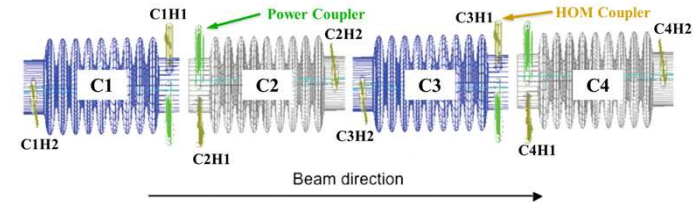
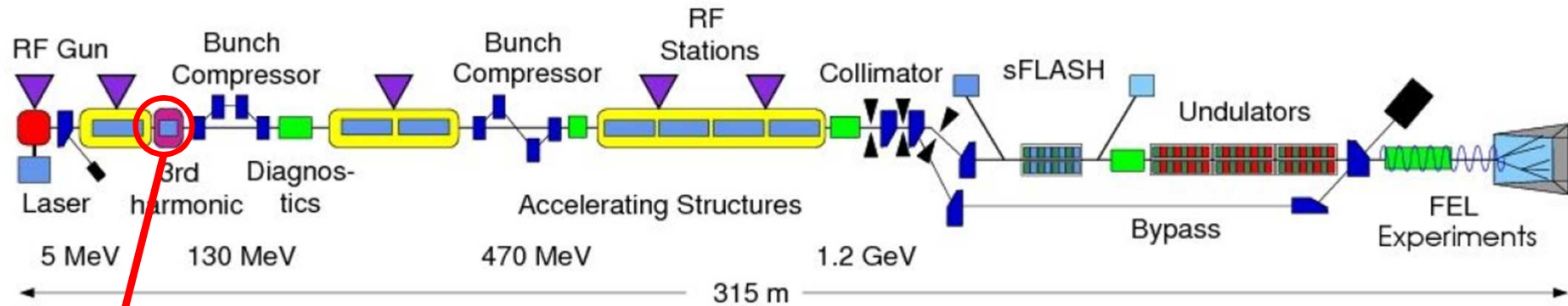


Photo courtesy E. Vogel & DESY

# Motivation

- **Higher order modes (HOMs) are excited by charge particles in cavity**
  - influence the beam both longitudinally and transversely
  - non-monopole modes excited by **off-axis particle**
- **Dipole modes dominate transverse wake potentials**

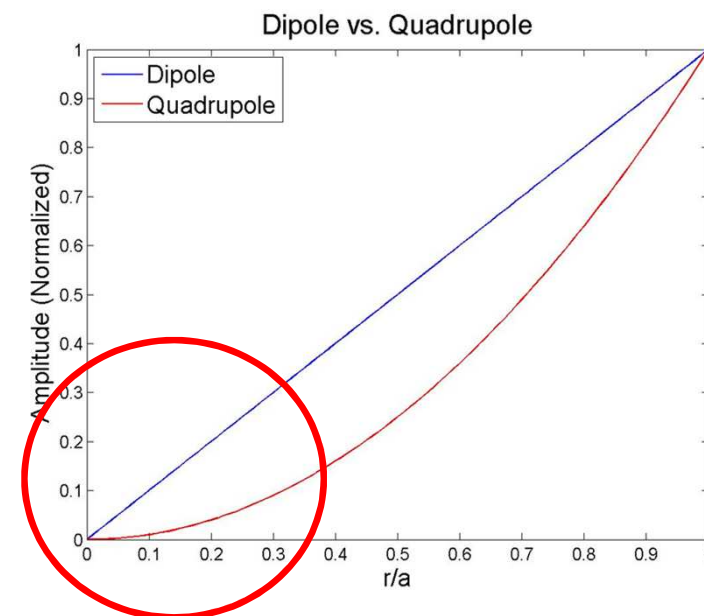
$$(Amplitude)_m \sim W_{\perp}^m \sim \left(\frac{r}{a}\right)^m \quad \begin{array}{l} r: \text{beam offset} \\ a: \text{iris radius} \end{array}$$

$m=1$ , dipole;  $m=2$ , quadrupole

- **Use HOMs (non-monopole modes) to**
  - align the beam to the **electric center**
  - monitor beam position (HOM-BPM)

Principle proved in 1.3GHz Tesla cavity

- [1] G. Devanz et al., EPAC2002, WEAGB003
- [2] N. Baboi et al., LINAC2004, MOP36
- [3] S. Molloy et al., Phys. Rev. ST-AB 9, 112802 (2006)



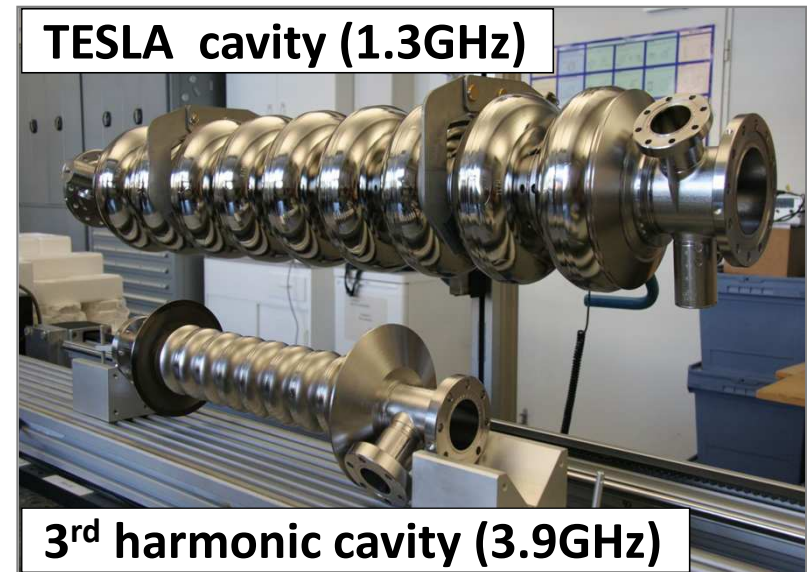
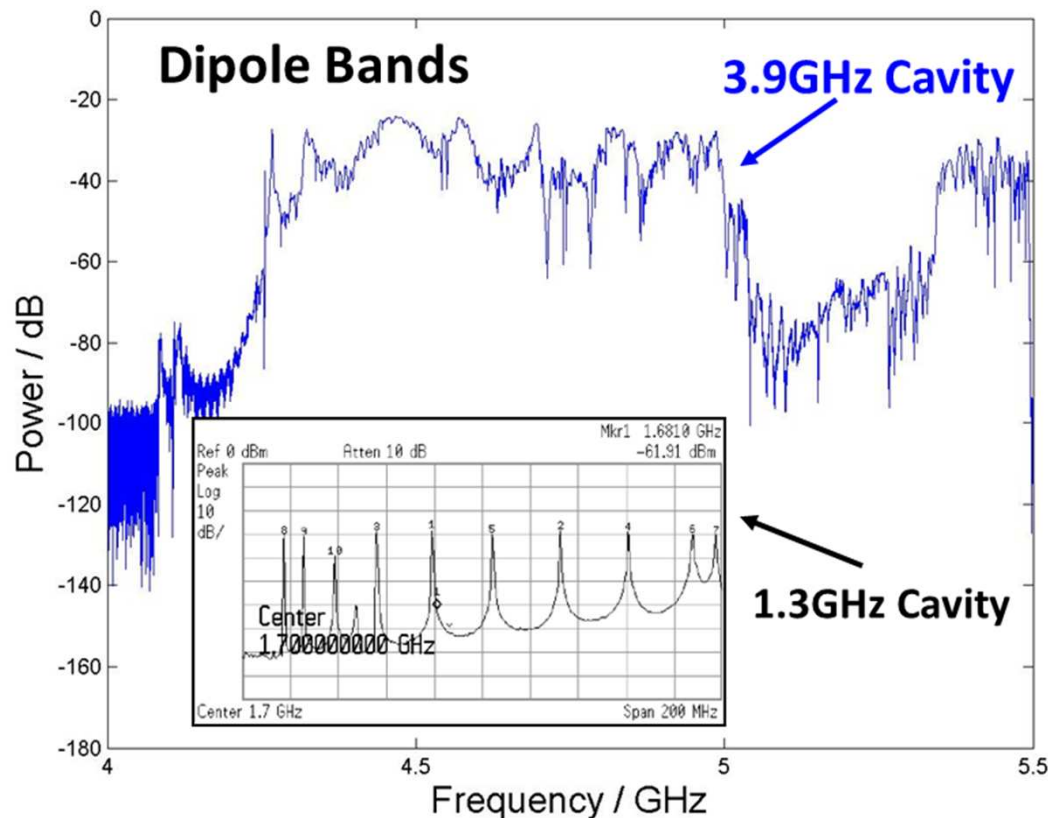
Normally in this region

# Motivation (Cont'd)

- Considerably larger wakefields (compare to 1.3GHz cavity)

$$w_{//} \sim \lambda^{-2}, \quad w_{\perp} \sim \lambda^{-3} \quad (\lambda \text{ is structure scaling factor})$$

- HOMs propagate through attached beam pipes
- HOMs shift frequencies in ACC39 module w.r.t. single cavity and hard to identify

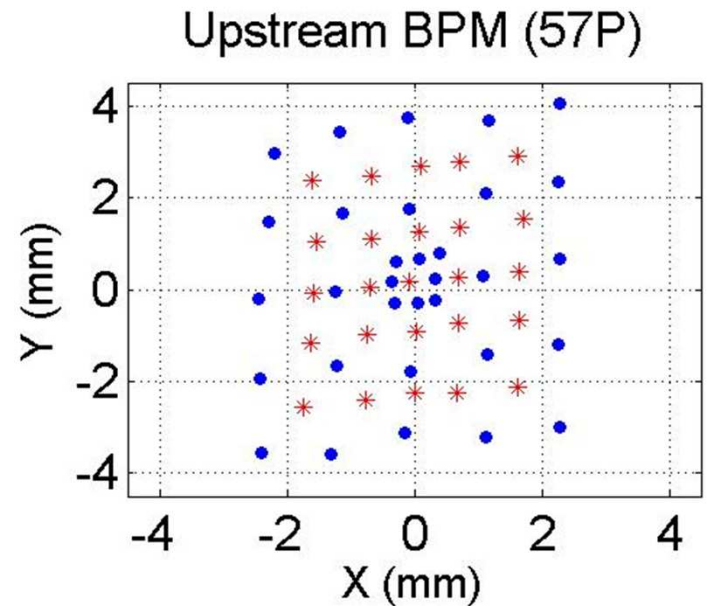
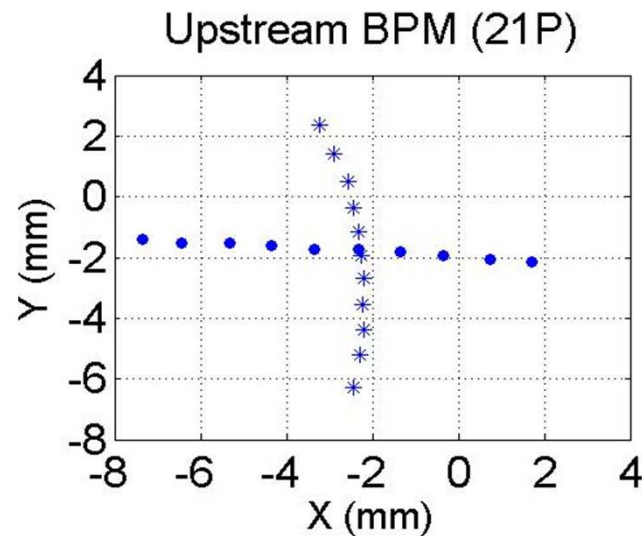
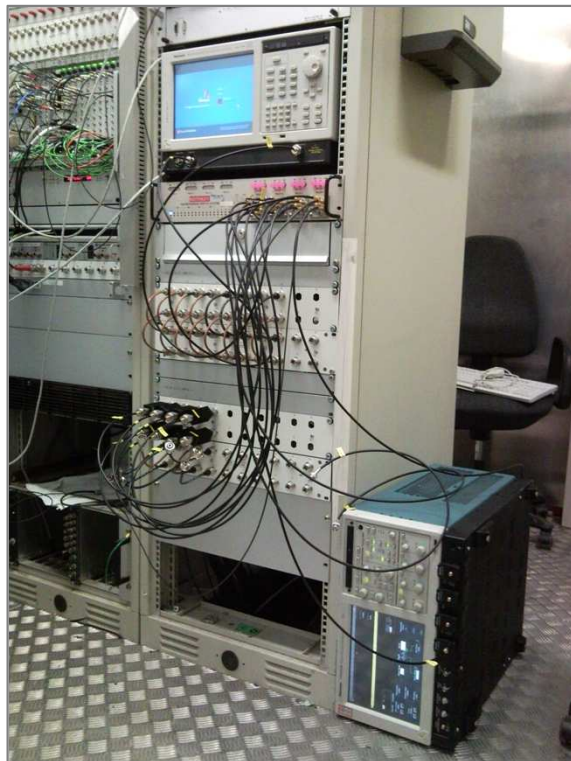
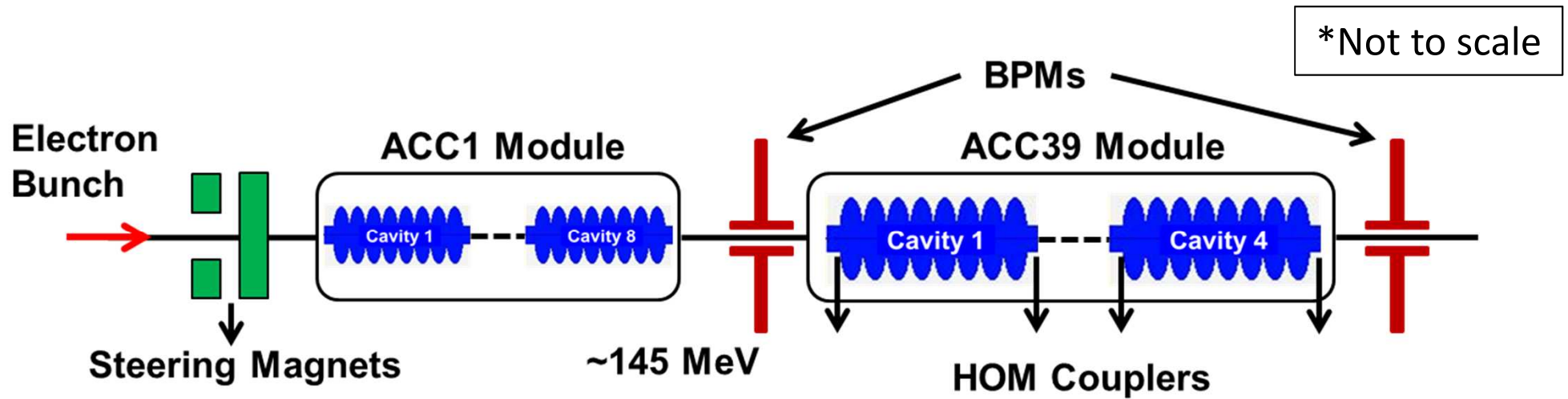


- 1.3GHz cavity  
multi-cell, single cavity modes
- 3.9GHz cavity  
multi-cavity modes

# Since last SRF meeting...

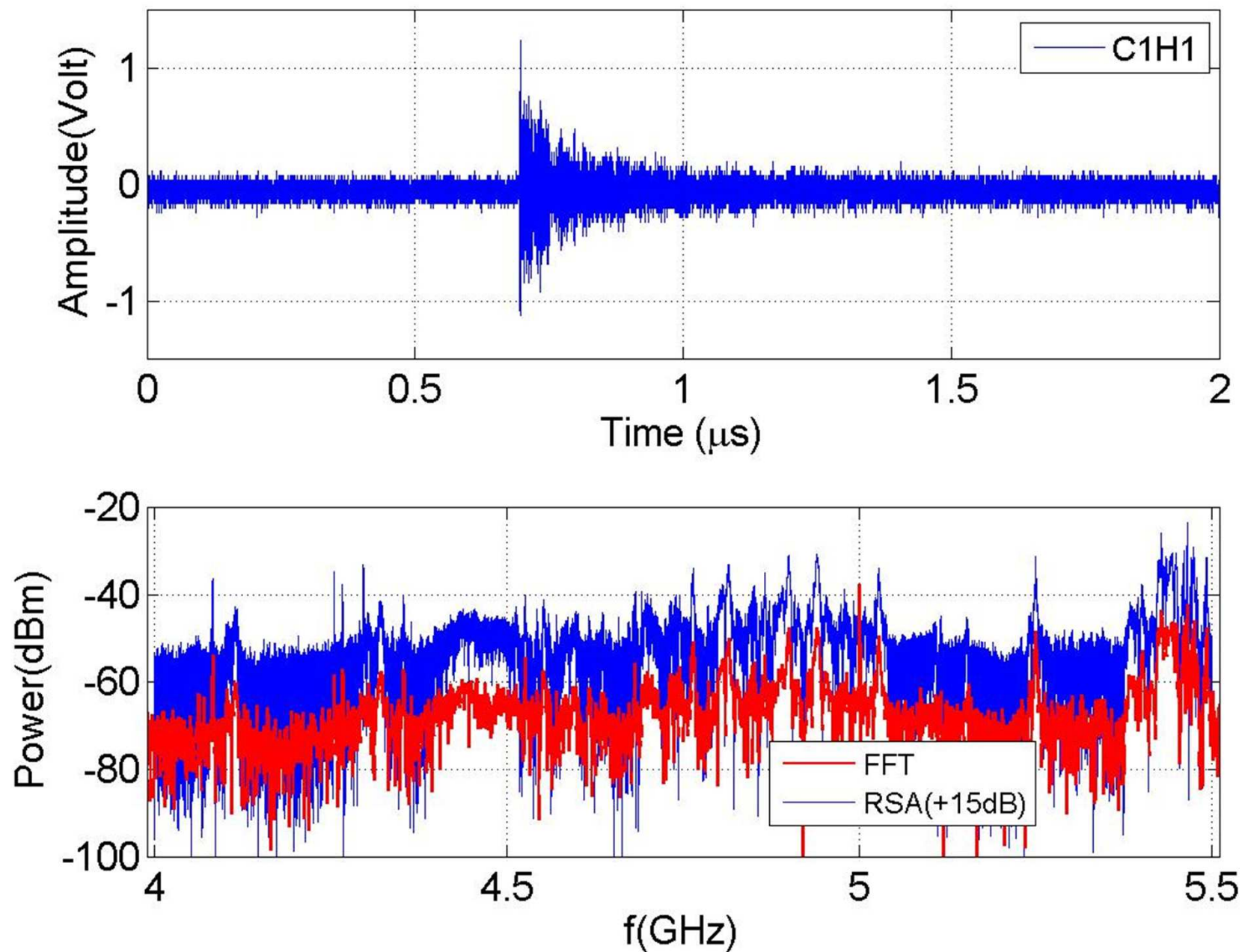
Data	Measurement info	Beam info
Apr. 2010	Transmission measurement	w/o beam
Jul. 2010	1 <sup>st</sup> parasitic measurement	w/ beam
Nov. 2010	2 <sup>nd</sup> parasitic measurement	w/ beam
Jan. 2011	1 <sup>st</sup> dedicated measurement	w/ beam
Feb. 2011	Multi-bunch measurement	w/ beam
Mar. 2011	2 <sup>nd</sup> dedicated measurement	w/ beam
Apr. 2011	Transmission measurement	w/o beam
May 2011	Mini measurement	w/ beam

# Generic Setup of HOM Measurement w/ Beam



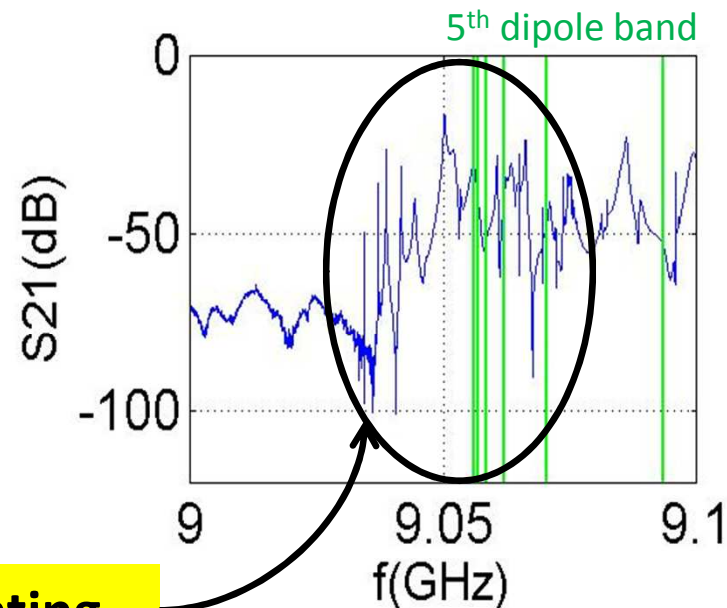
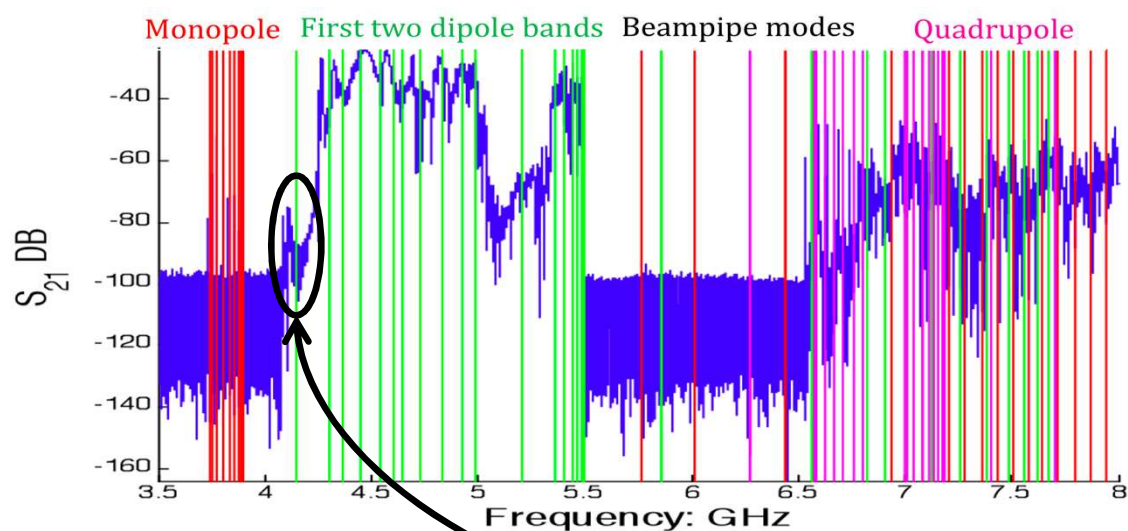
Steer the beam in various ways

# HOM Signal (1<sup>st</sup> and 2<sup>nd</sup> Dipole Bands)



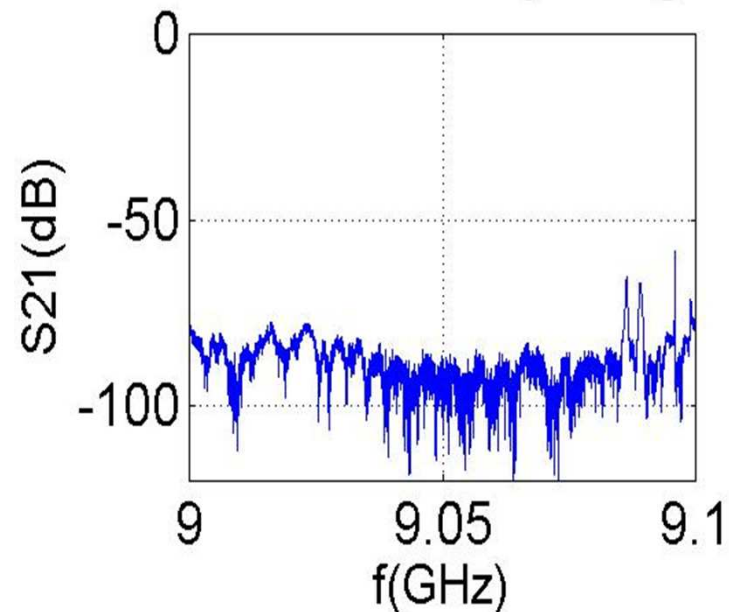
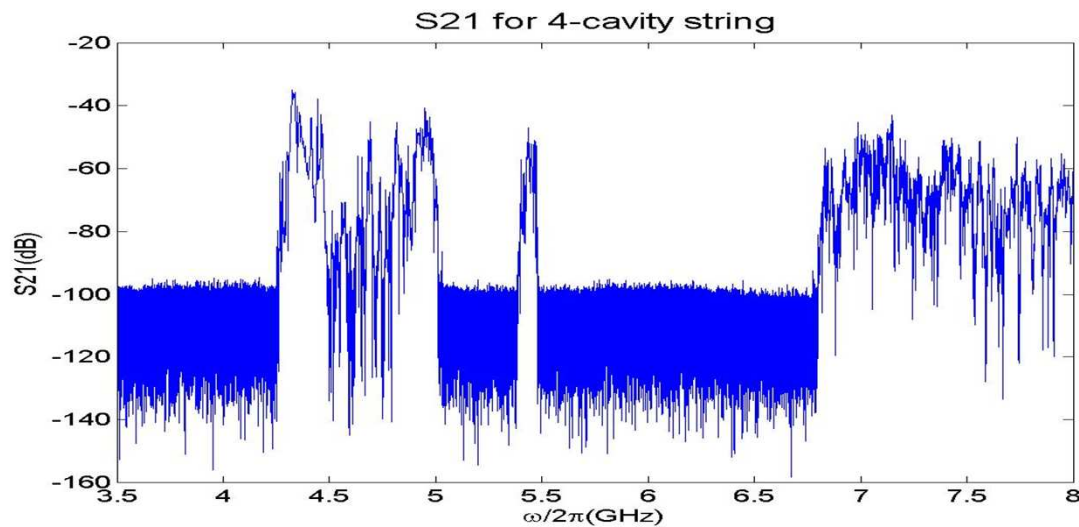


# Big Picture



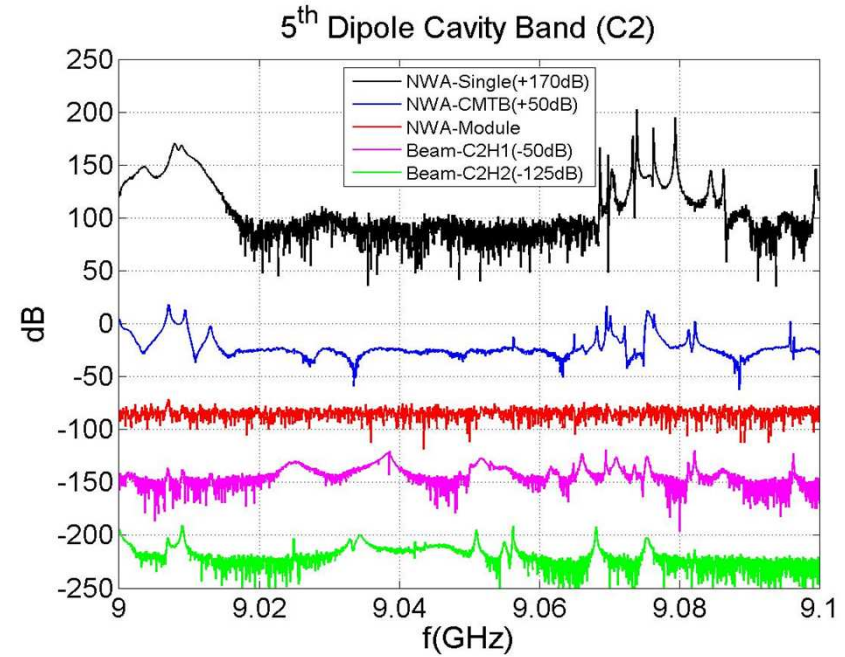
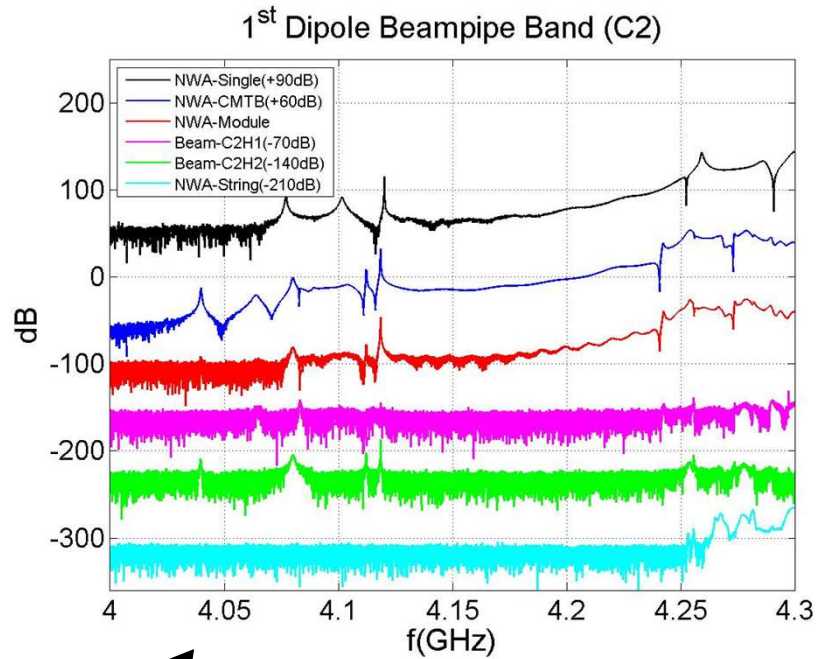
**Candidate hunting**

$S_{21}$  for 4-cavity string



From transmission measurement done in CMTB

# Hot Prospects

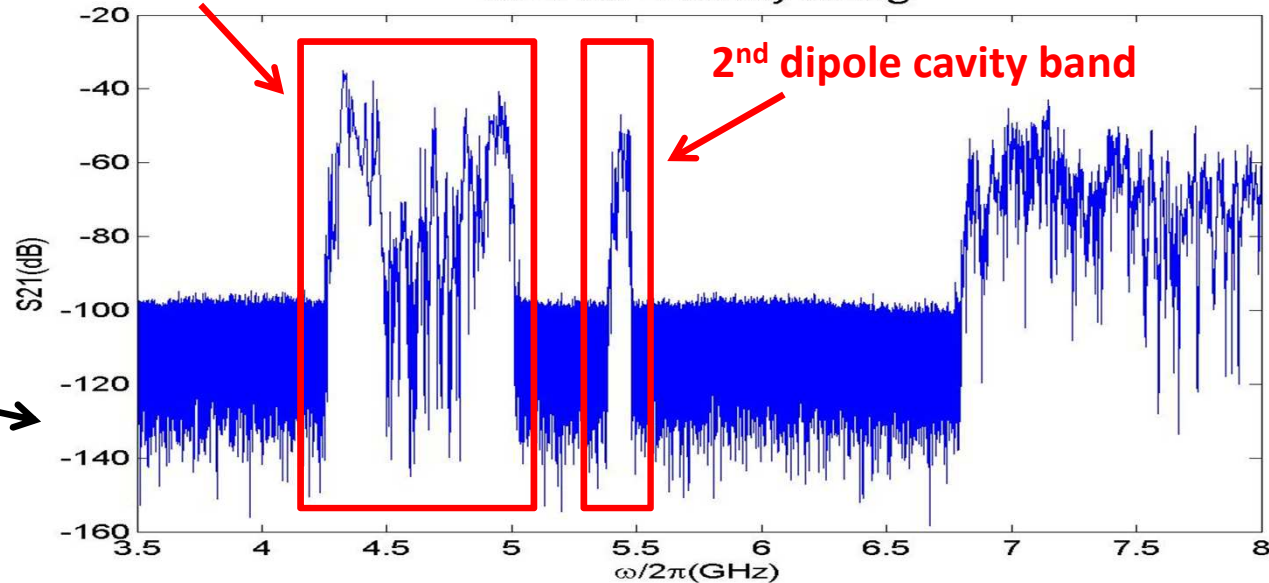


Beampipe  
(Cavity) based

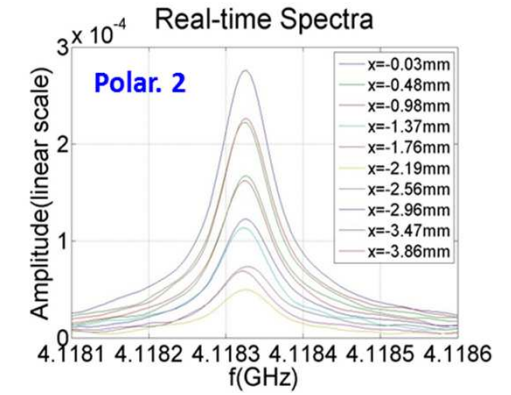
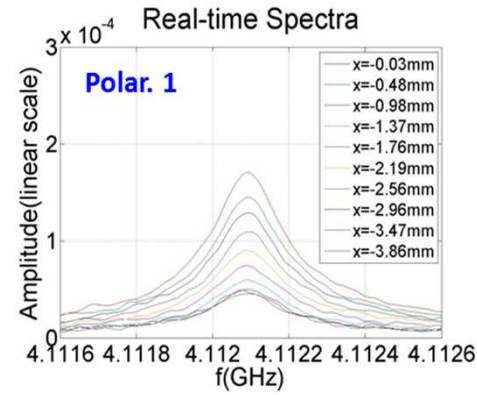
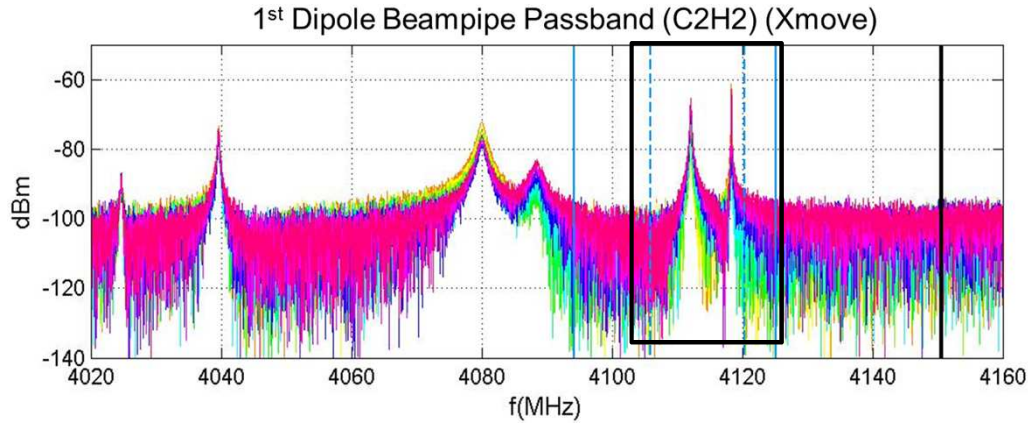
Module based

1<sup>st</sup> dipole cavity band

S21 for 4-cavity string

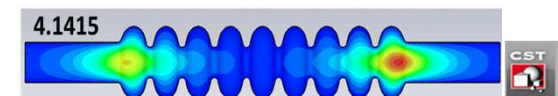
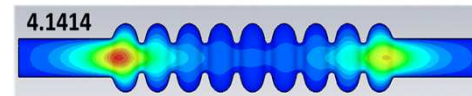
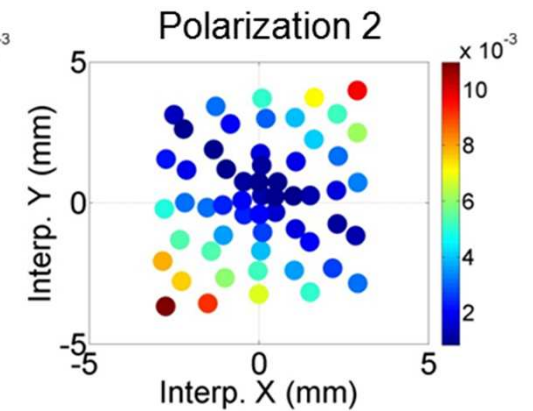
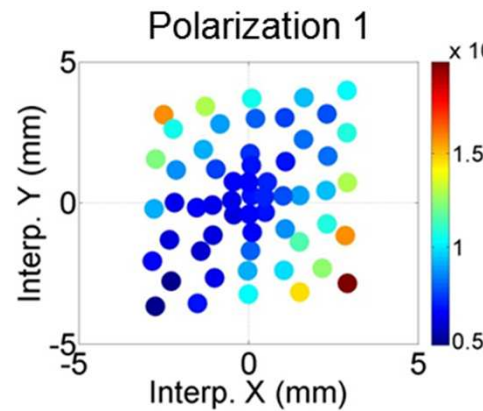
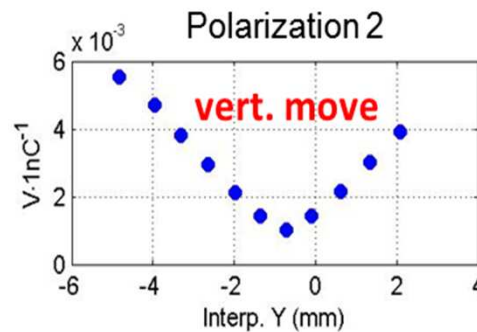
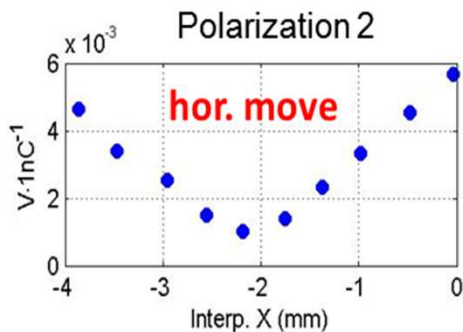
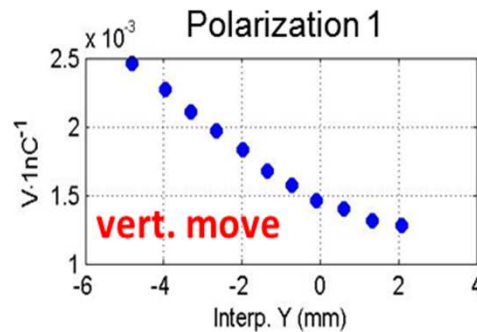
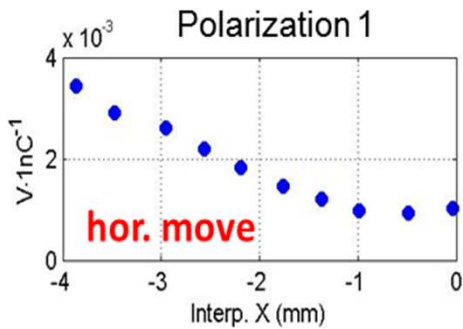


# 1<sup>st</sup> Beampipe Dipole Band

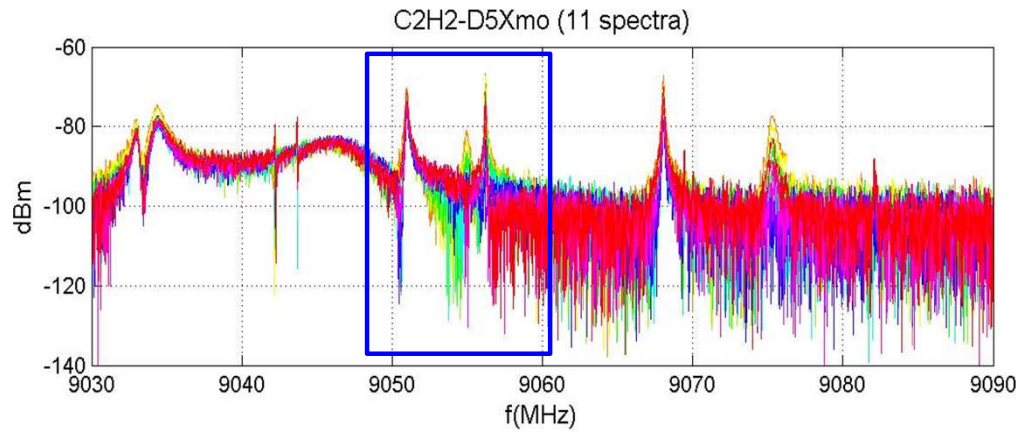


- Lorentzian fit to get mode amplitude

$$y = y_0 + A \cdot \frac{w^2}{(x - x_0)^2 + w^2}$$

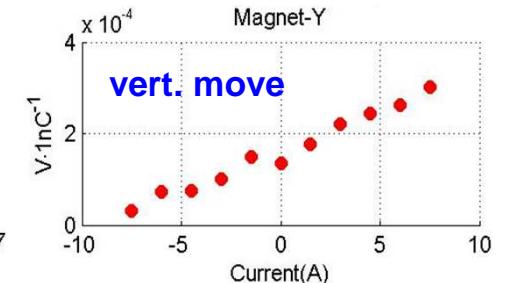
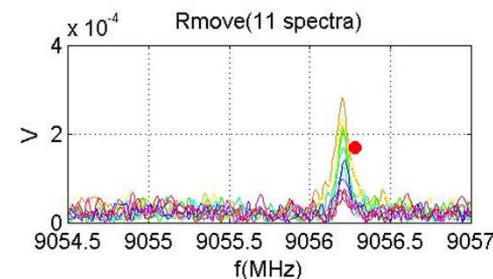
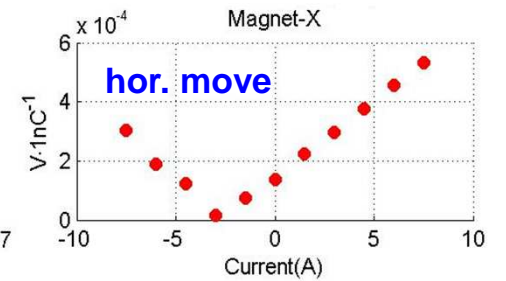
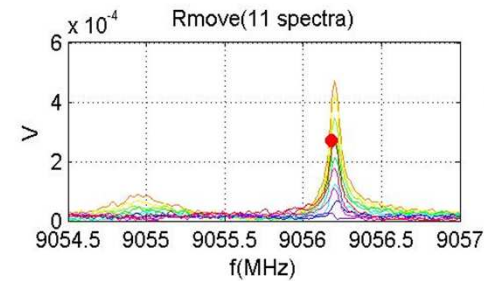
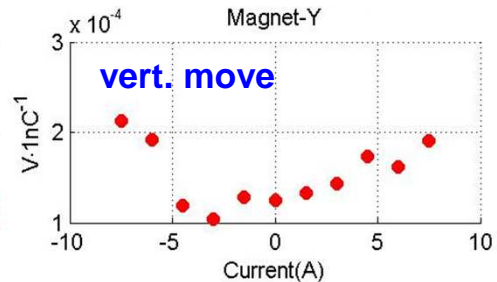
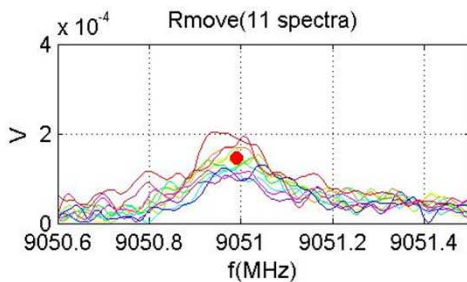
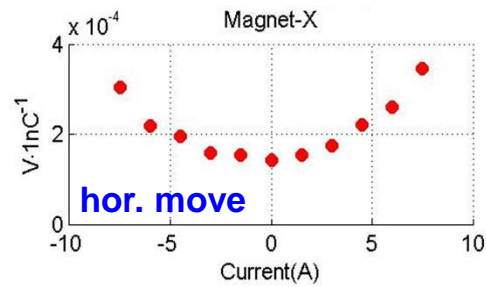
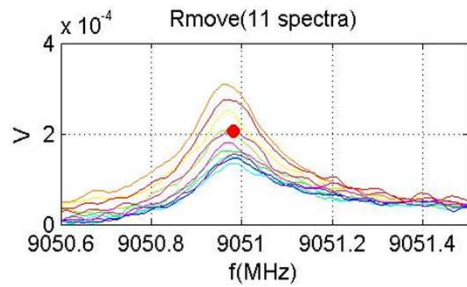


# 5<sup>th</sup> Dipole Cavity Band



5 <sup>th</sup> Dipole Band <sup>†</sup>	f (GHz)	R/Q
	9.0560	0.00
	9.0568	0.05
	9.0585	0.07
	9.0620	2.17
	9.0703	4.04
	9.0933	0.55

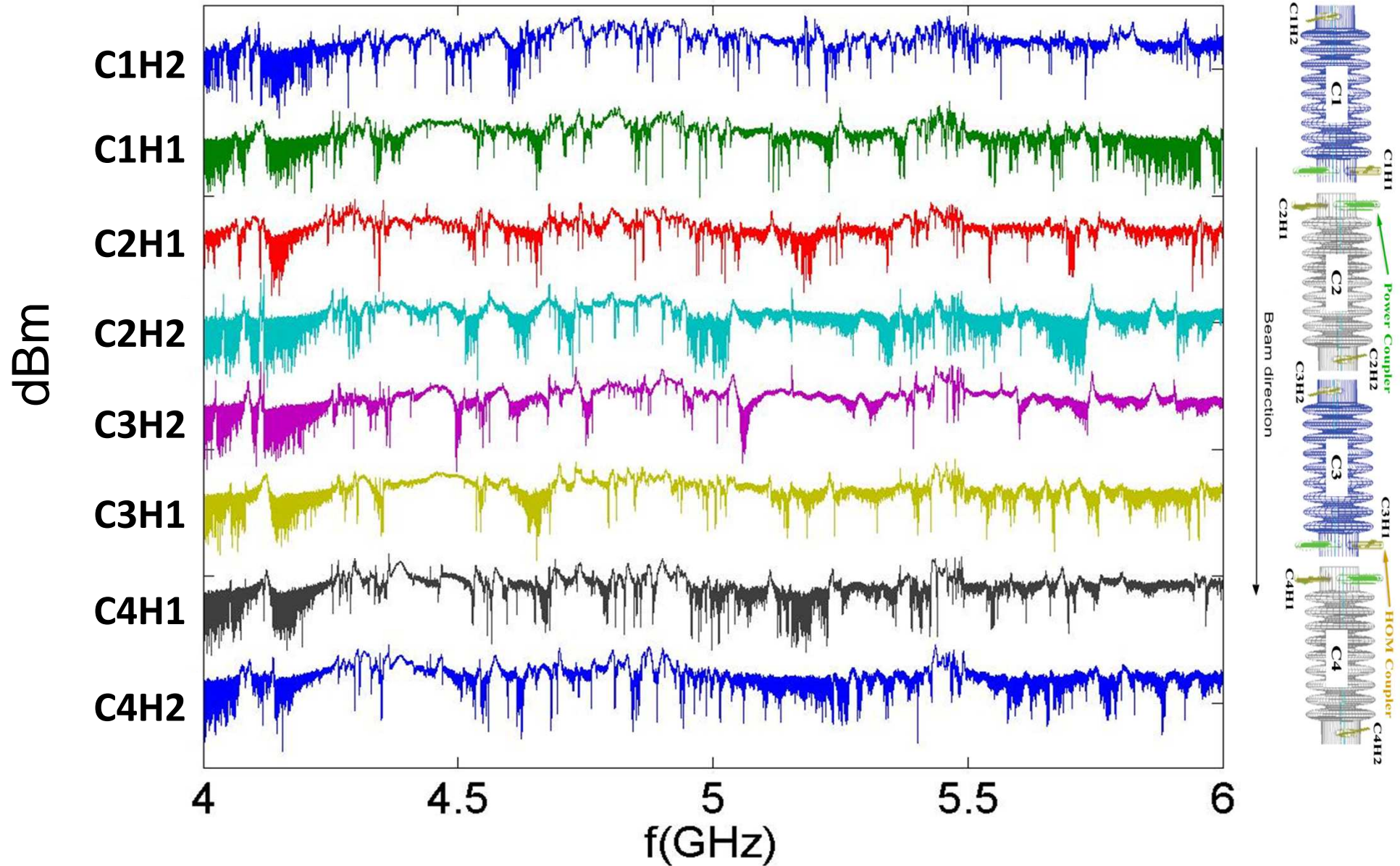
Look like localized!



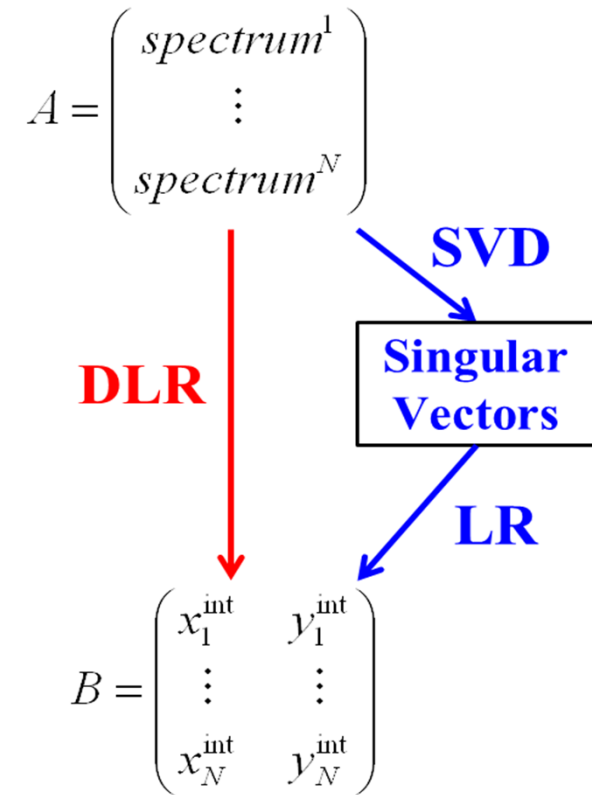
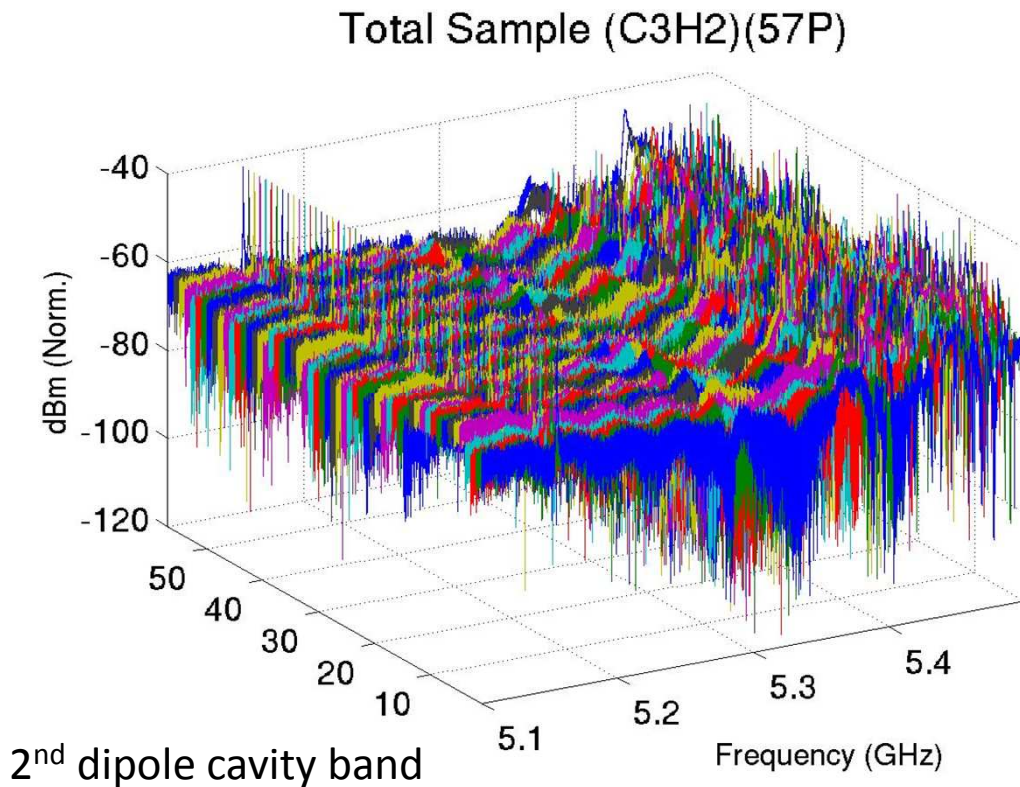
<sup>†</sup> I.R.R. Shinton, et al., "Mode Distribution ...", CI Internal Note

# Think Differently

## All 8 HOM Couplers



# Think Differently



- Direct Linear Regression (DLR)

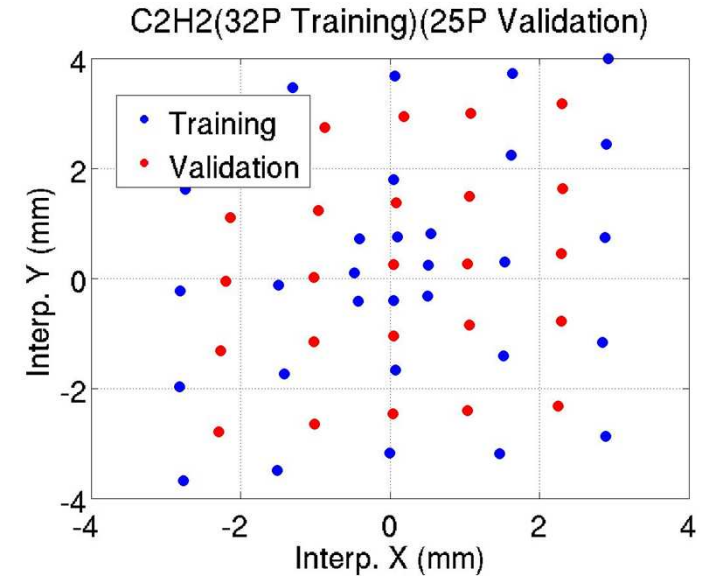
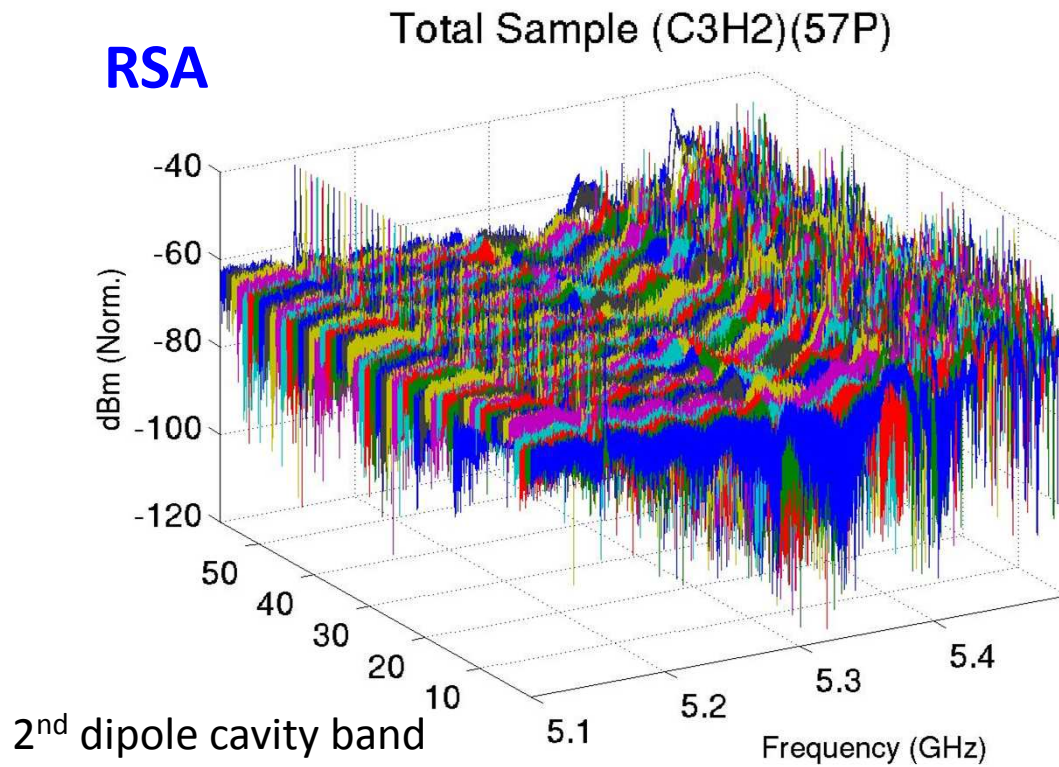
$$A \cdot M + B_0 = B$$

- Singular Value Decomposition (SVD)

$$A = U \cdot S \cdot V^T \longrightarrow A_S$$

$$A_S \cdot M_S + B_{0S} = B$$

# Direct Linear Regression

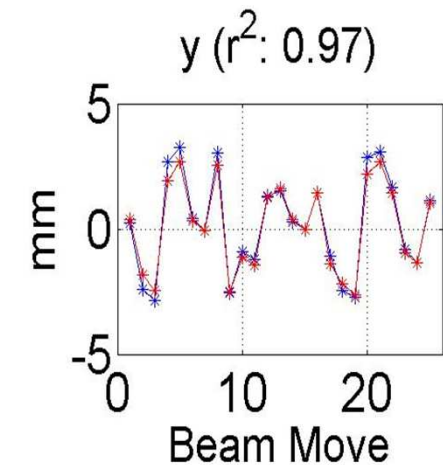
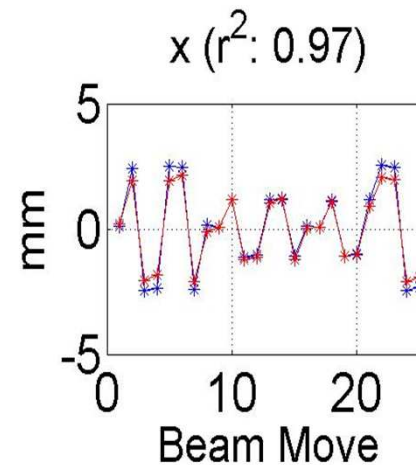


- **Direct Linear Regression (DLR)**

$$A \cdot M + B_0 = B$$

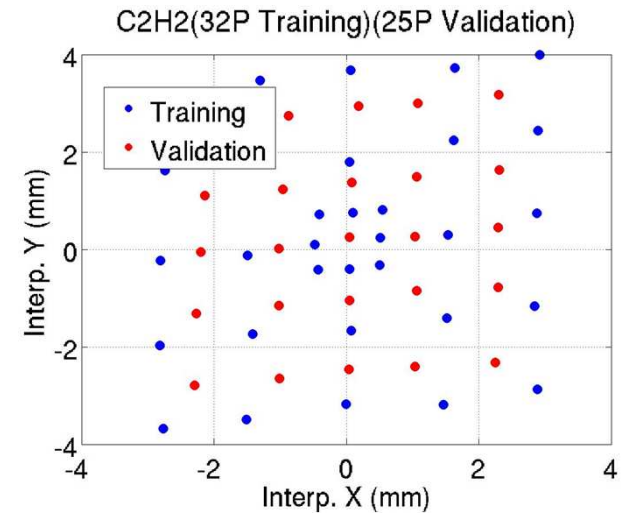
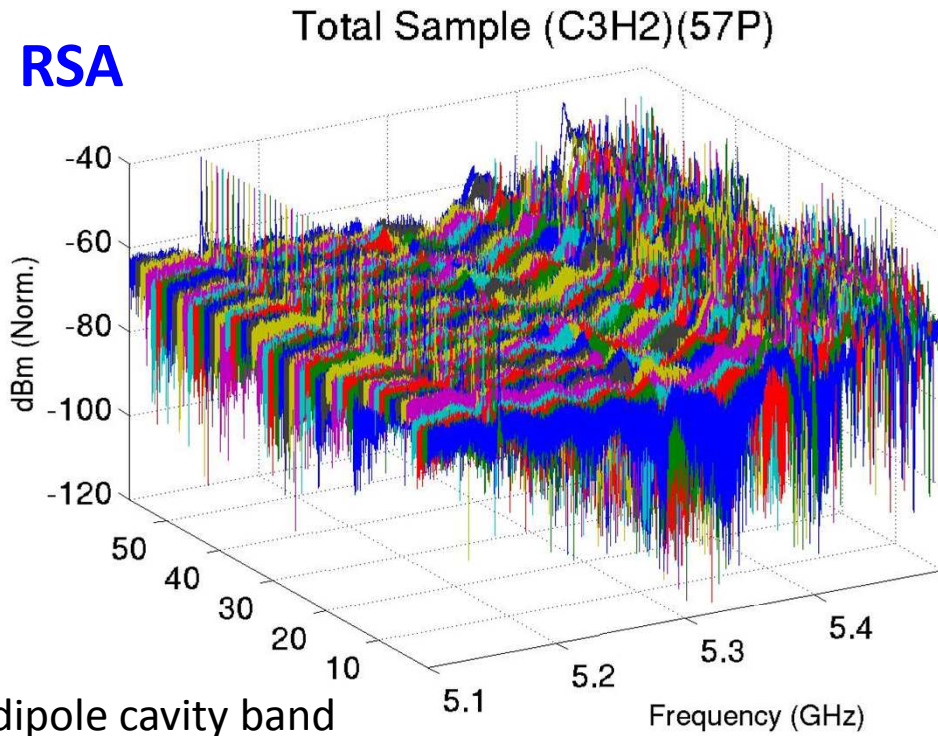
**A**: spectra matrix

**B**: beam position matrix



— Measurement  
— Prediction

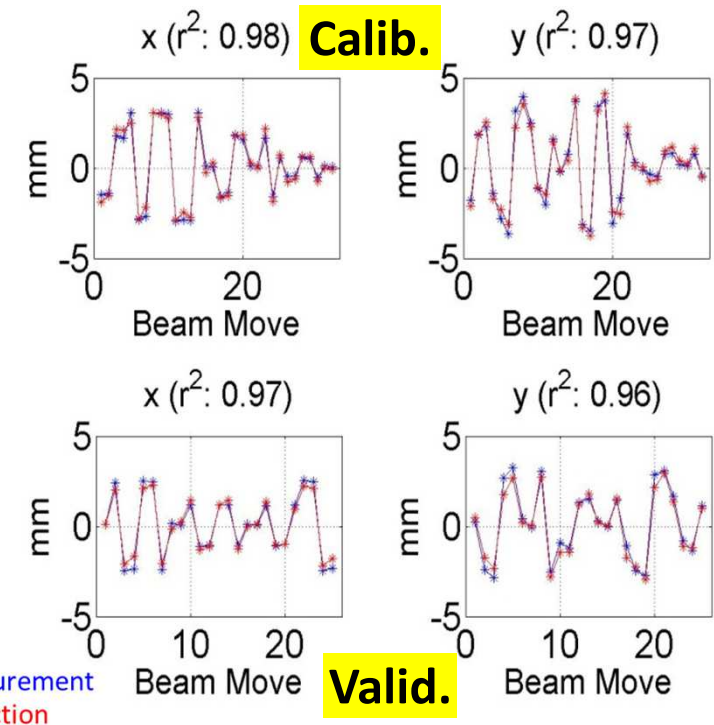
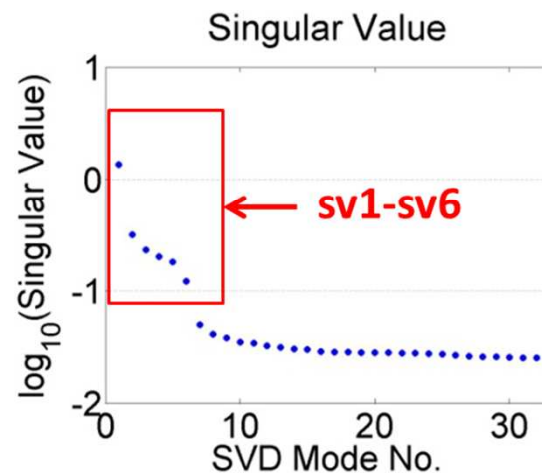
# Singular Value Decomposition



- **Two steps**

$$A = U \cdot S \cdot V^T \longrightarrow A_S$$

$$A_S \cdot M_S + B_{0S} = B$$





# Summary

- **First time:** HOM dependence on beam movement seen at the third harmonic cavity module
- **Candidate modes** evaluated

Dipole Candidates	$f$ range	Based-on
1 <sup>st</sup> beampipe	~ 4 GHz	beampipe
5 <sup>th</sup> cavity	~ 9 GHz	cavity
1 <sup>st</sup> or 2 <sup>nd</sup> cavity	~ 4-6 GHz	module

## What's next?

- Investigation of suitable modes for diagnostics electronics
- Design electronics for HOM-BPM for FLASH