HOM-based Beam Position Monitoring

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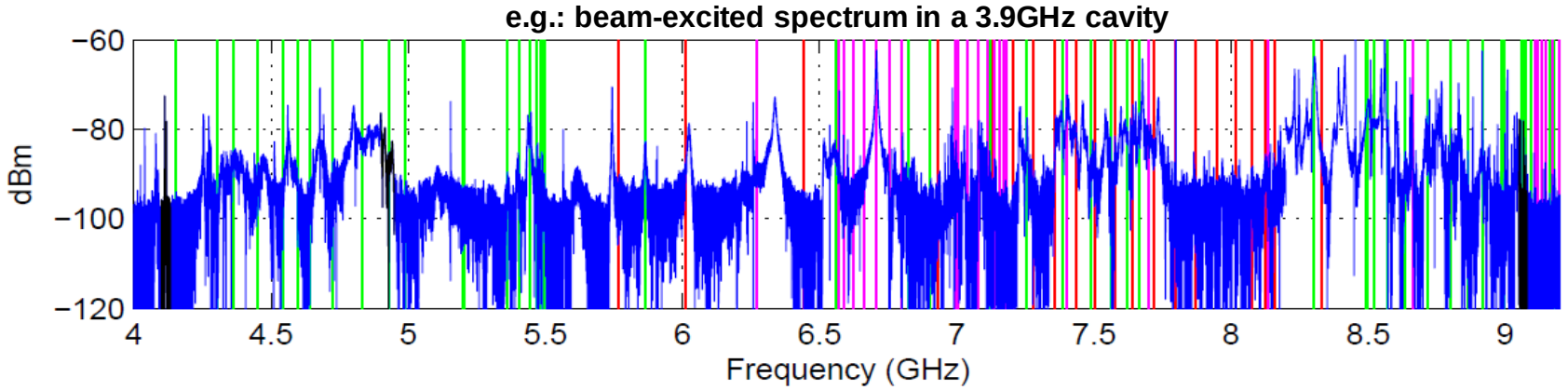
HOM issues in the ESS SC linac

Higher Order Modes (HOM)

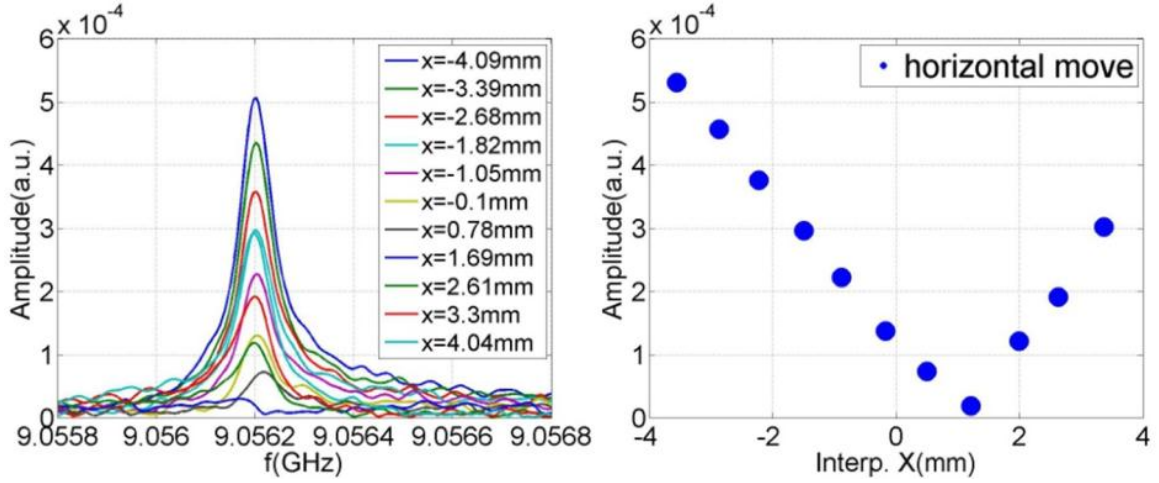
- HOMs = fields excited by the beam in accelerating cavities
  - Bad effect on beam, but also
  - Can be used for beam (and cavity) diagnostics
    - Properties depend on accelerating cavity and beam properties



  - Spectrum includes monopole, dipole, quadrupole etc. modes

Principle of HOM-BPMs

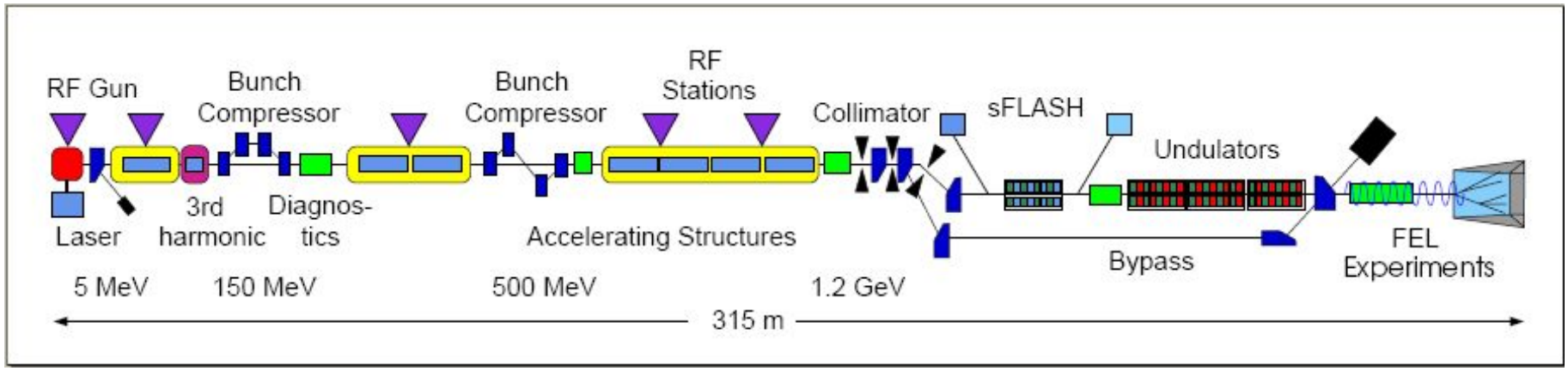
- Dipole modes have linear dependence on beam offset and charge



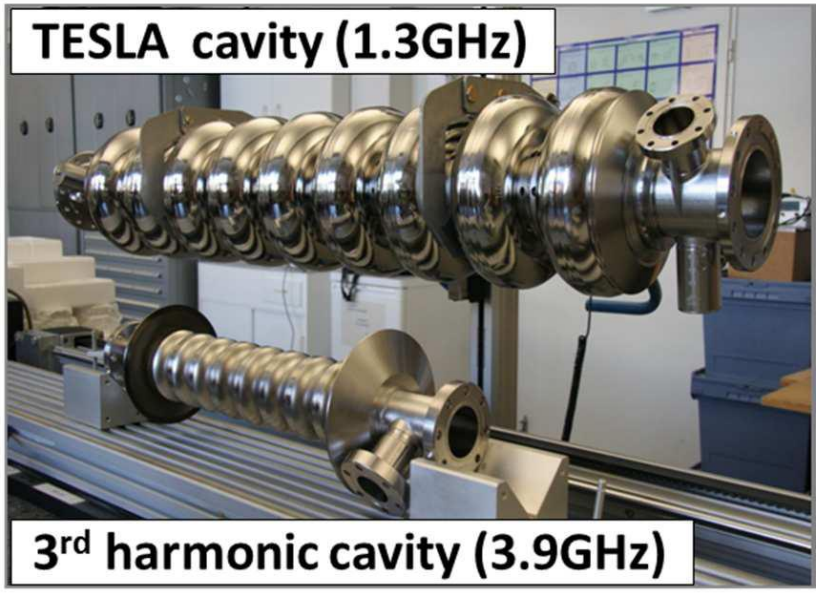
⇒ Idea: Use HOMs for beam position diagnostics (HOM-BPMs)

- Center beam (reduce wakes)
- Measure cavity misalignment

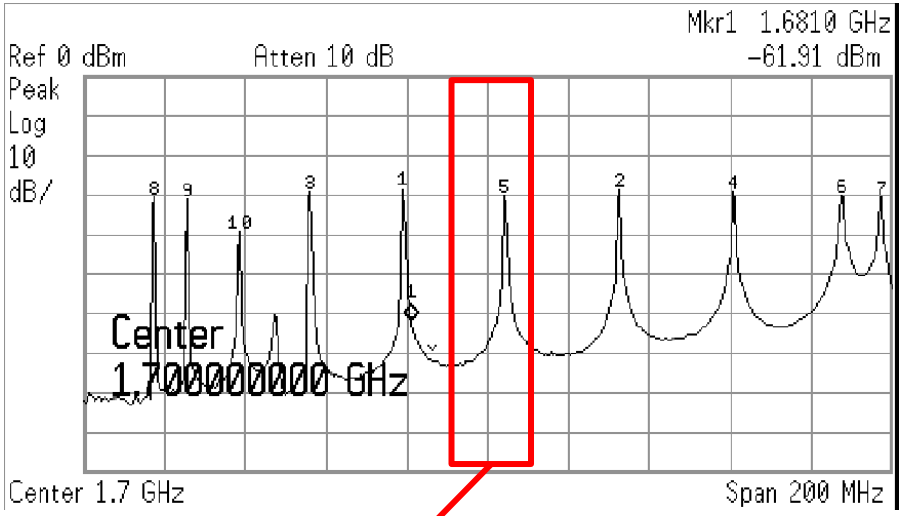
FLASH



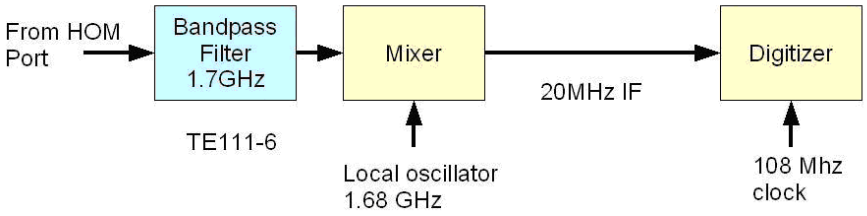
- **TESLA cavities**
  - **1.3 GHz**
  - **8 cavities / module**
  - **2 HOM couplers**
- **3rd harmonics cavities**
  - **3.9 GHz**
  - **Flattens RF field**
  - **4 cavities / module**
  - **Built at Fermilab**

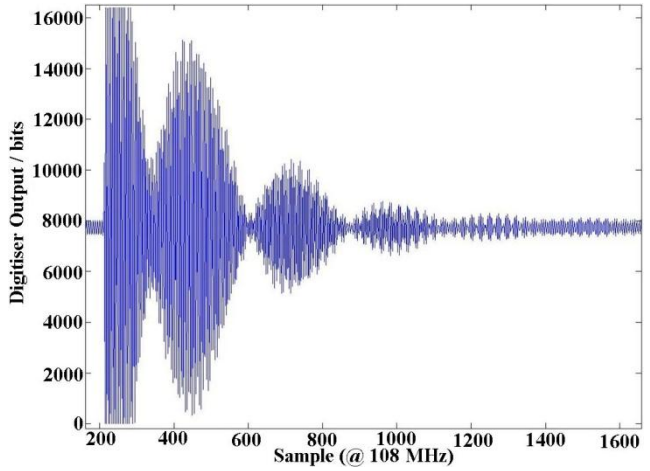


Previous work: HOM-BPMs at TESLA cavities



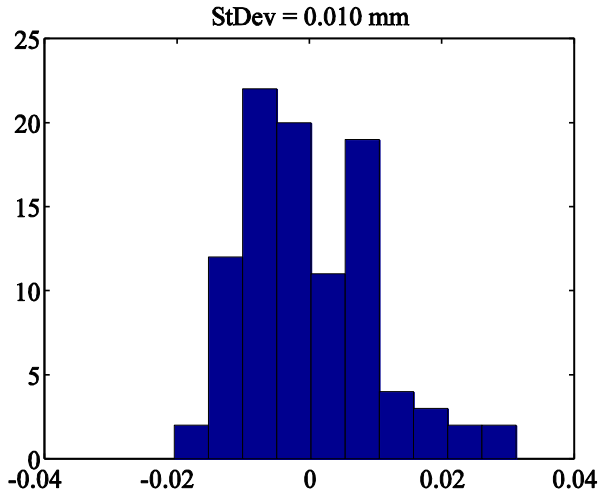
- **Electronics built by SLAC**





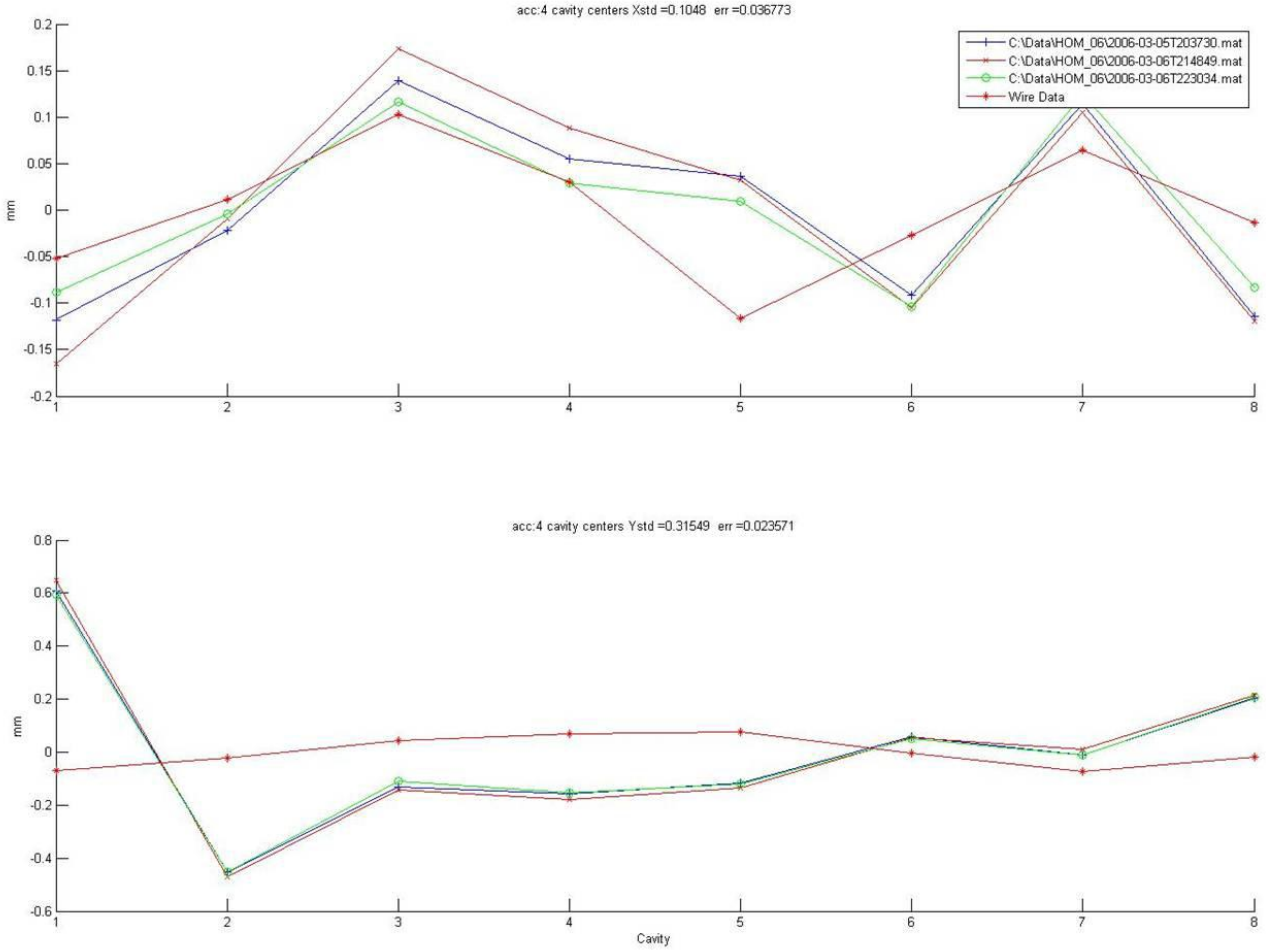
Previous work: HOM-BPMs at TESLA cavities (cont.)

- Use SVD to process data
- Evaluate resolution by comparing to adjacent cavities
  - 5-10 μm rms
  - Problem with calibration stability
- Raw signals
  - Used during commissioning periods to center the beam

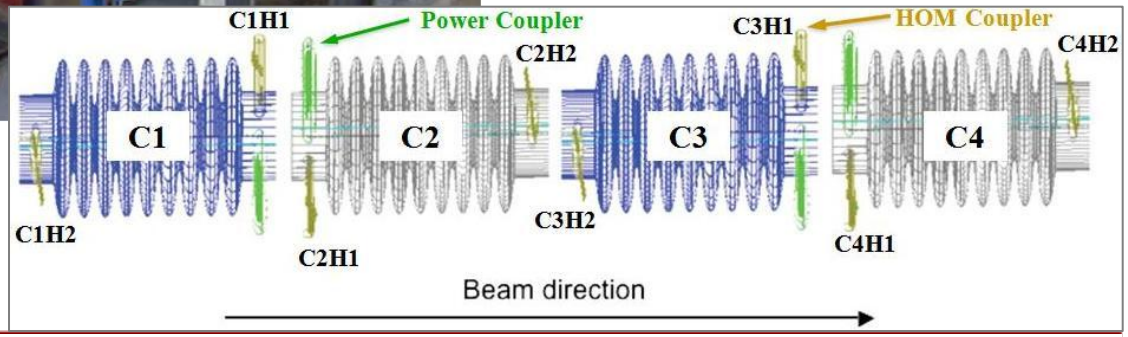


S. Molloy et al., PRST-AB 9, 112802 (2006)
J. Frisch et al., EPAC 2006, TUYPA02, Edinburgh, Scottland

Previous Work: Cavity Alignment



HOM-BPMs for 3rd Harmonic Cavities



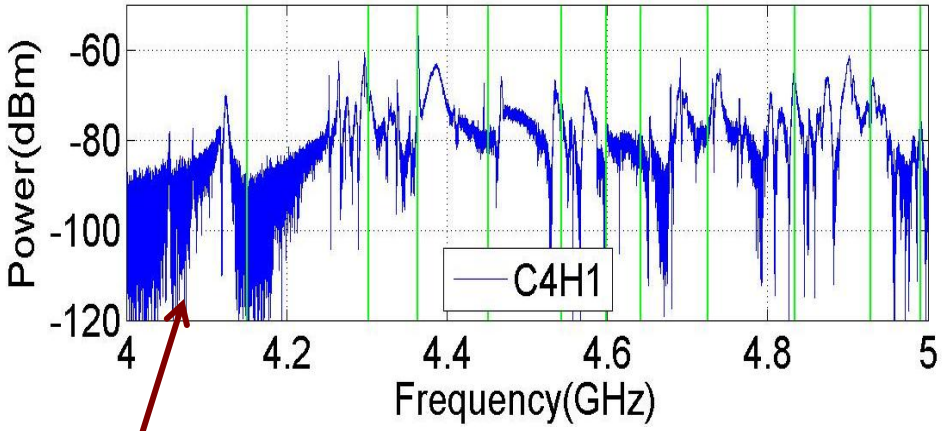
EuCARD WP 10 "Supercodnucting RF," Task 5 "HOM Distributions"

- Partially supporting our work
- Sub-tasks
  - 1: HOMBPMs
  - 2: HOMCD (HOM Cavity Diagnostics)
  - 3: HOMGD (HOM Distributions and Geometrical Dependencies)

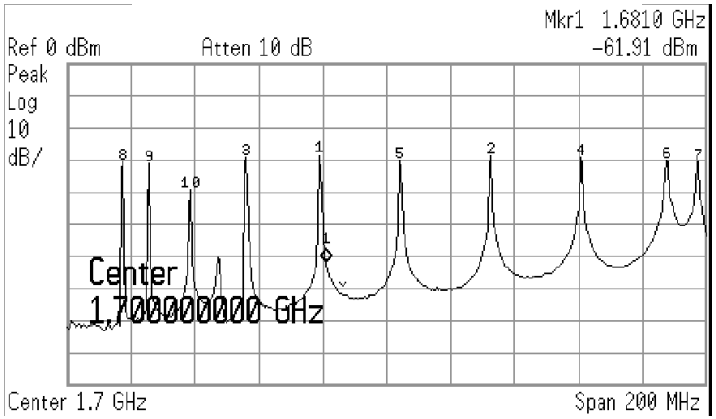
1st Dipole Band in one 3rd Harmonic Cavity

- Practically all cavity modes above cut-off
  - Crowded spectrum
  - Modes: not possible to identify
  - Idea: cut one portion of spectrum (several modes)
- Alternatives:
  - Beam-pipe dipole modes
  - Trapped modes in 5th dipole passband

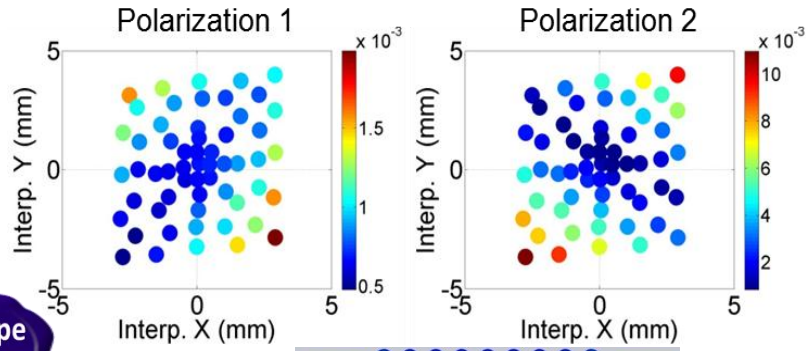
1st dipole band

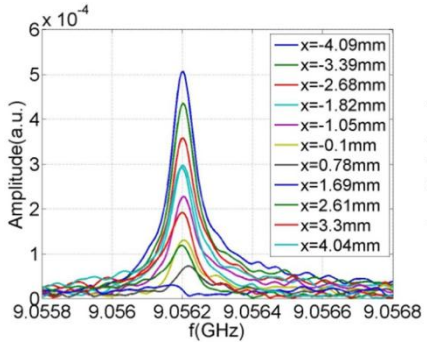


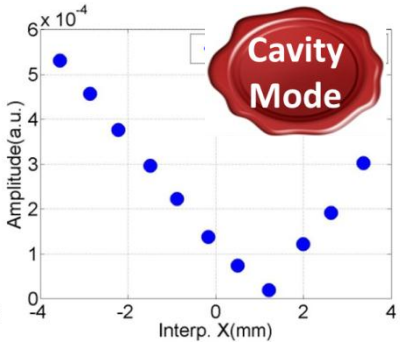
Compare to TESLA cavity:



3 Options for Modes to be used as BPM

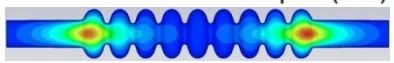


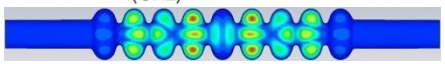


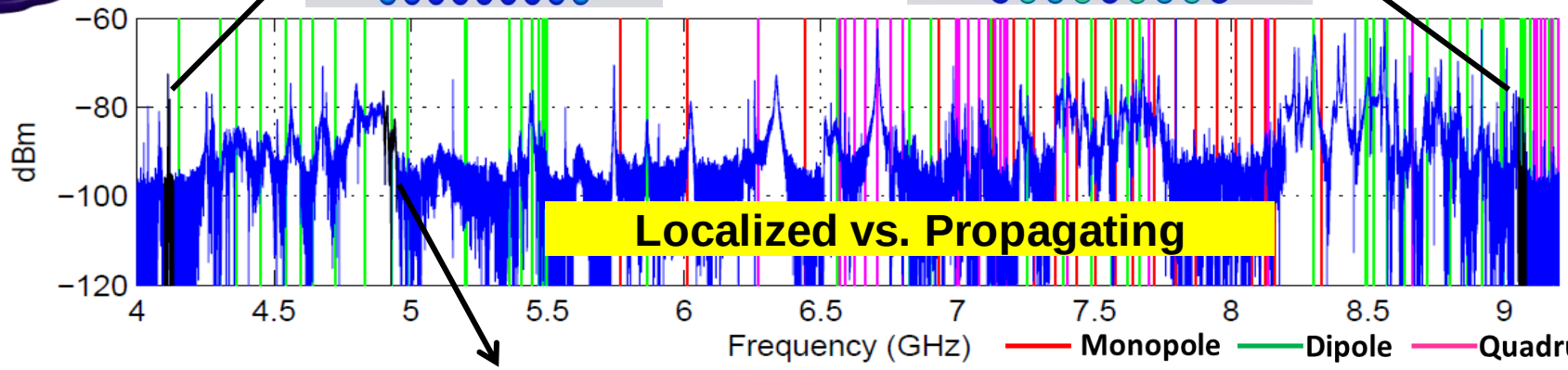


Cavity Mode

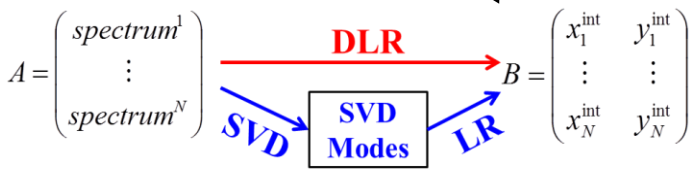
Beampipe Mode



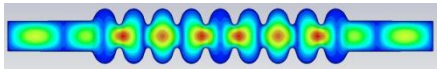


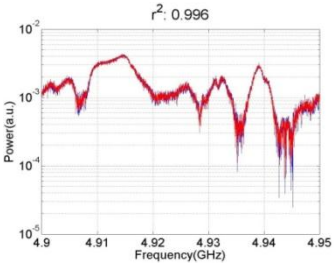


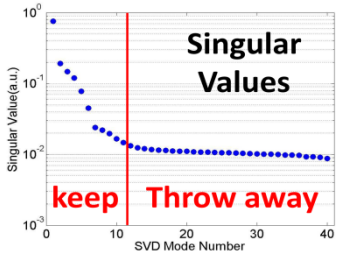
Localized vs. Propagating

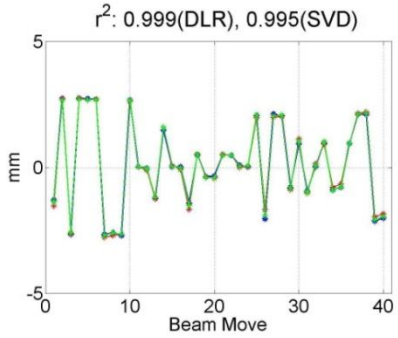


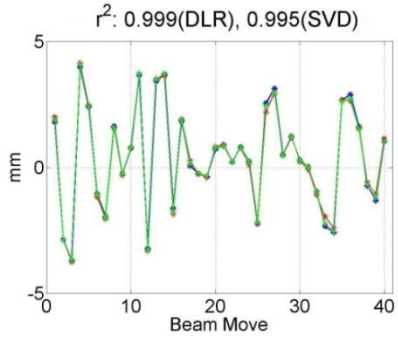
Coupling Mode











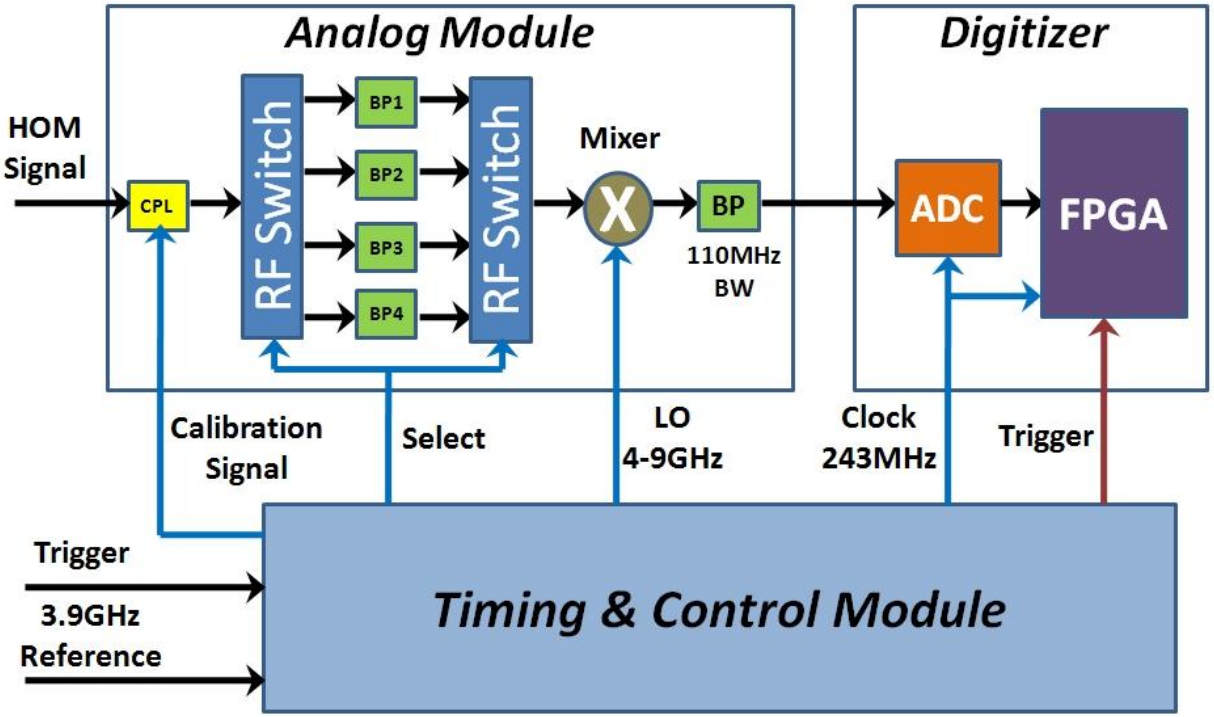
3 Options (cont.)

Dipole passband	Frequency [GHz] (theor.)	R/Q [W/cm^2]	Pros/Cons
Beam pipe	4.1486	0.24	Localized
	4.1487	1.31	Low R/Q ⇒ low BPM resolution Not in cavity
Cavity 1st band	4.723	10.37	
	4.831	50.20	High R/Q ⇒ high BPM resolution
	4.926	30.38	
Cavity 2nd band	5.444	20.88	Propagate in whole module
	5.470	16.07	
Cavity 5th band	9.057	0.05	Localized
	9.059	0.07	Cavity-based
	9.062	2.17	Low R/Q
	9.070	4.04	⇒ low BPM resolution

Electronics

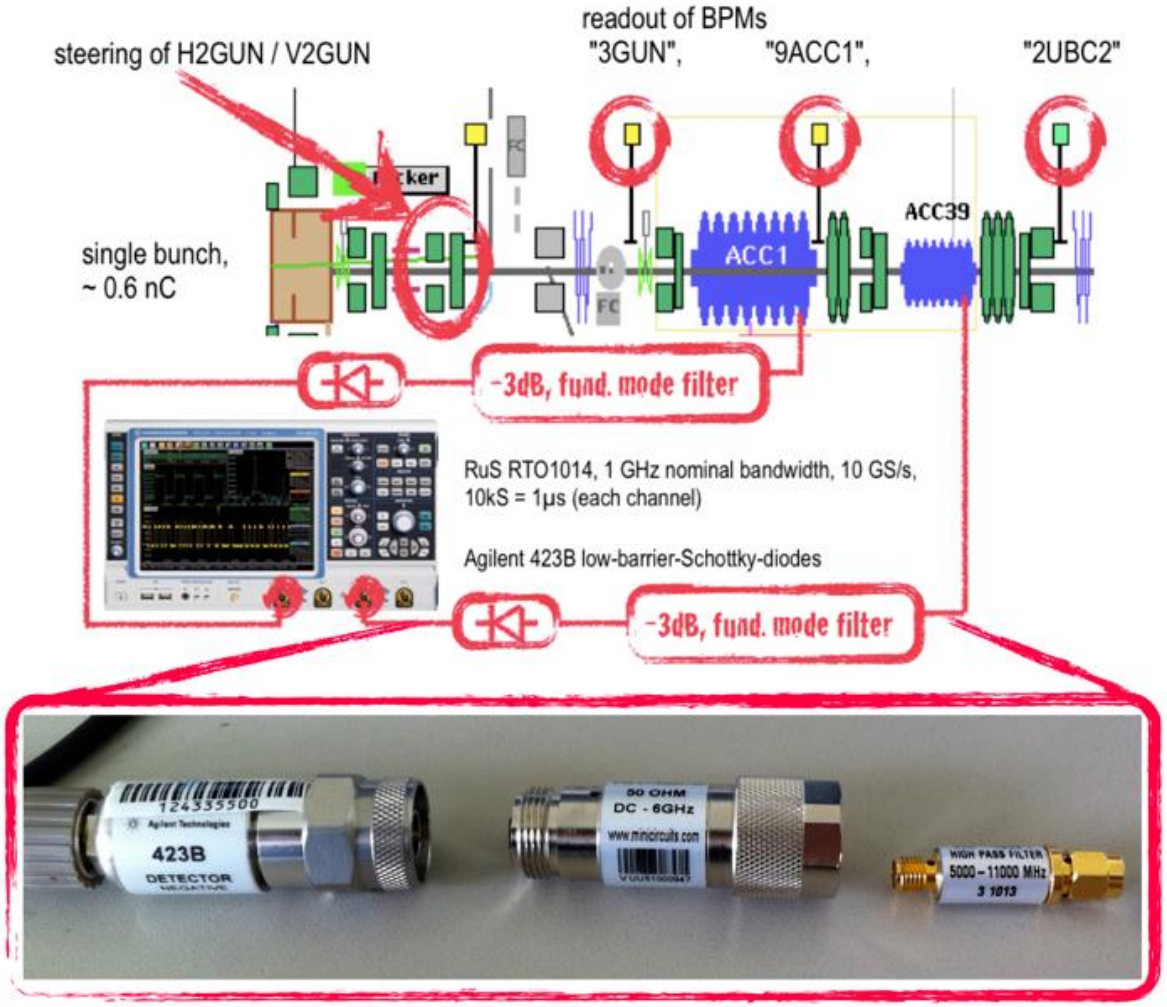
- Built by Fermilab
- “Play”-electronics will be tested early next year

preliminary



N. Baboi et al., SRF 2011, MOPO060, Chicago, IL, U.S.A.

Diode Based Signal Capturing



- Alternative electronics
  - Already tested
- Simple setup:

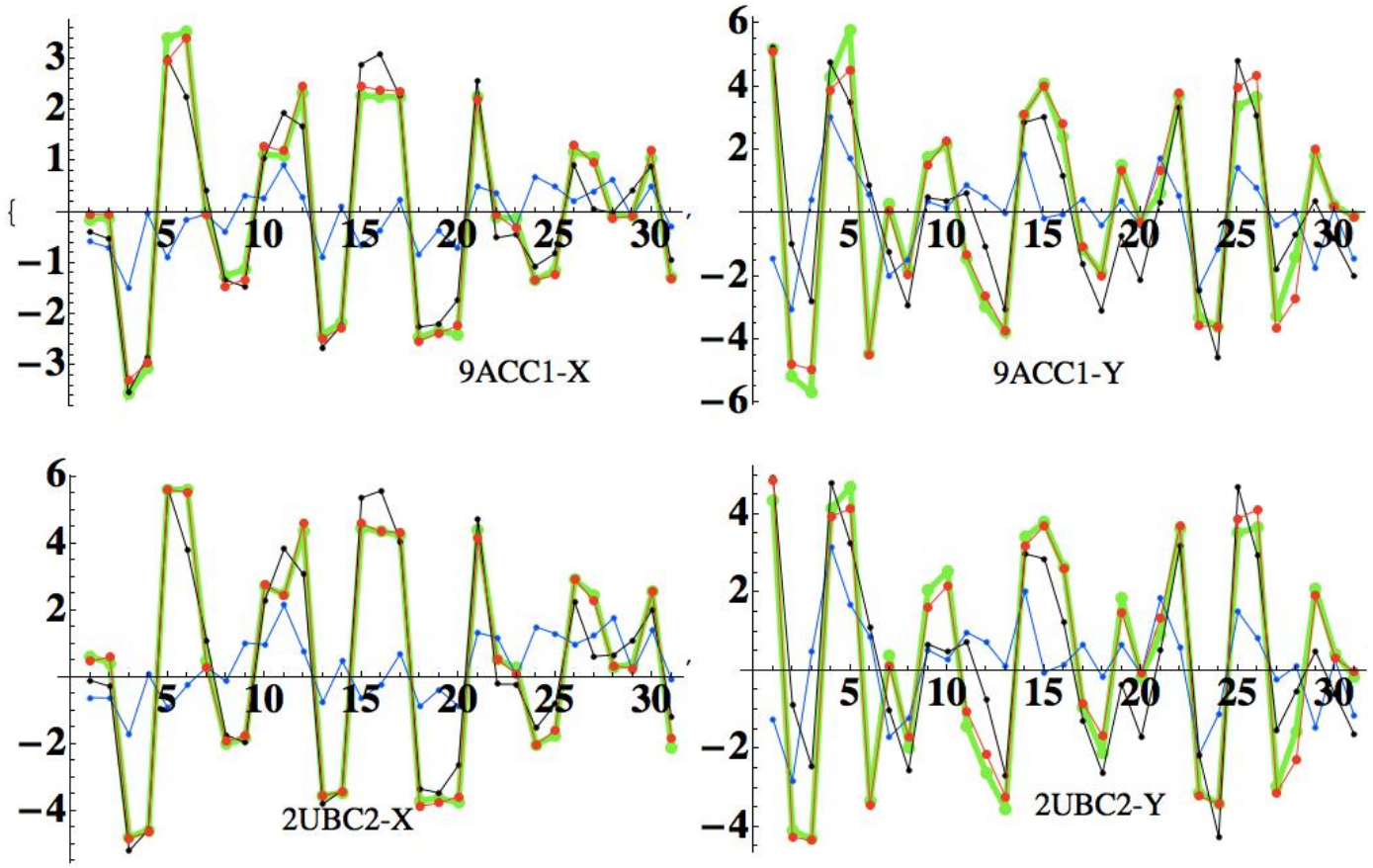
  Broad-band filter
  - to suppress strong 3.9GHz

  +RF detector diode
- Signal-output ~ total HOM power

H.W. Glock, DIPAC2011, MOPD25

Diode Based Signal Capturing (cont.)

- Complicated analysis, SVD based
  - But it works



Comments and Outlook

- Did not mention simulations
  - Important for understanding the HOM behavior
  - Not discussed here (see talk by R.M. Jones)
  - Cockcroft Inst. / Univ. Manchester and the Univ. Rostock
- Will test options (localized, propagating) with electronics at the beginning of 2012
  - Then decide which modes to use for final electronics
- HOMBPMs for the European XFEL
- Replace/fix current HOMBPMs for the TESLA cavities at FLASH