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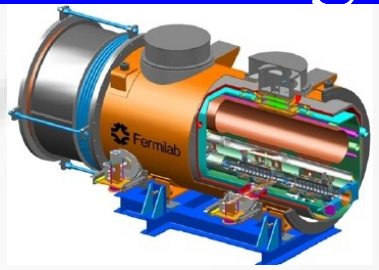
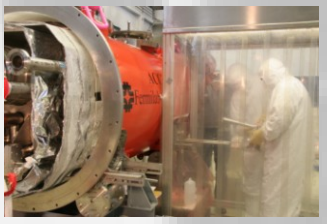
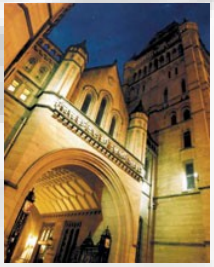
of Accelerator Science and Technology

Task 10.5 HOM Distribution:
THIRD HARMONIC SC Cavity Alignment/Diagnostics/BPM with HOM Measurements

-Roger M. Jones







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http://indico.cern.ch/conferenceOtherViews.py?view=cdsagenda&confId=118190

Task 10.5 Aspects of HOMs in SC Accelerator Cavities –EuCARD FP7

TASK 10.5	HOM Distribution	R.M. Jones
Sub-Task	Name	Coordinating Institute/Univ.
10.5.1	HOMBPM	DESY
10.5.2	HOMCD	Cockcroft/Univ. Manchester
10.5.3	HOMGD	Univ. Rostock

- I.R.R. Shinton, PDRA (assigned for a further year, until Nov. 2011)

Task 10.5 HOM Diagnostics in SC Accelerator Cavities -Staff

- **Sub-task leaders: Nicoleta Baboi (DESY), Ursula van Rienen (Univ. Rostock), Roger M. Jones (CI/Univ. Manchester).**
- **PDRAs: Hans-Walter Glock (Univ. Rostock), Ian Shinton (CI/Univ. of Manchester)**
- **Ph.Ds: Nawin Juntong (CI/Univ. Manchester), Pei Zhang (DESY/Univ. Manchester/CI), Thomas Flisgen (Univ. Rostock)**

WP 10.5.2

WP 10.5.3

WP 10.5.1

I. Shinton, CI/Univ. of Manchester PDRA

N. Juntong, CI/Univ. of Manchester PhD student (PT on FP7)

C. Glasman, CI/Univ. of Manchester PhD student (PT on FP7)

H-W Glock, Univ. of Rostock, PDRA

U. Van Rienen, Univ. of Rostock

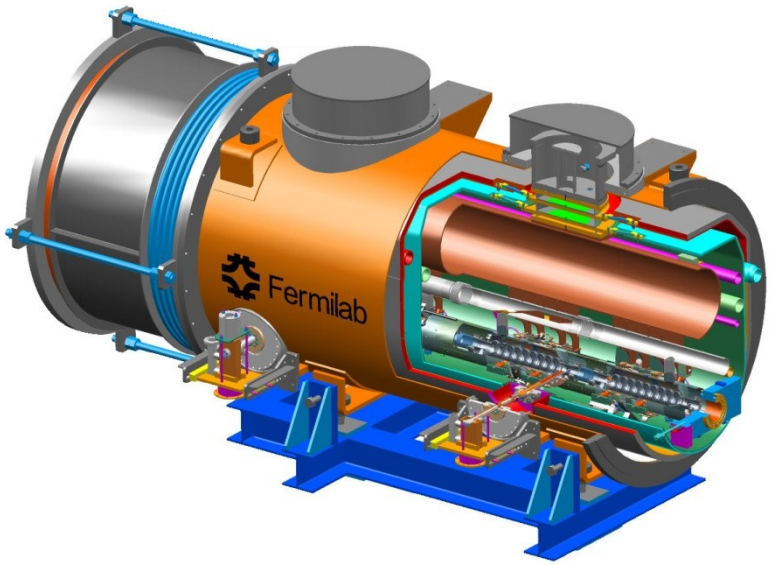
N. Baboi, DESY

T. Flisgen ,Univ. of Rostock

P. Zhang, DESY/Univ. Of Manchester

Task 10.5 Overview of the Function of Third Harmonic Cavities

- Fermilab has constructed a third harmonic accelerating (3.9GHz) superconducting module and cryostat for a new generation high brightness photo-injector.
- This system compensates the nonlinear distortion of the longitudinal phase space due to the RF curvature of the 1.3 GHz TESLA cavities prior to bunch compression.



- The cryomodule, consisting of four 3.9GHz cavities, has been installed in the FLASH photoinjector downstream, of the first 1.3 GHz cryomodule (consisting of 8 cavities).
- Four 3.9 GHz cavities provide the energy modulation, ~20 MV, needed for compensation.

Task 10.5: 3.9 GHz Parameters

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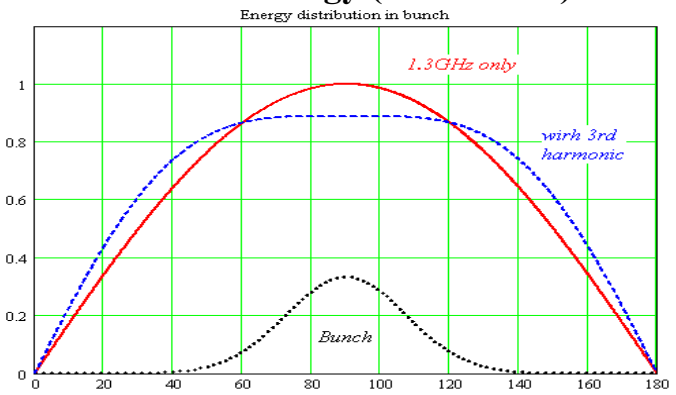
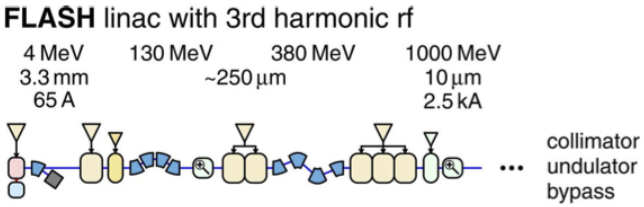
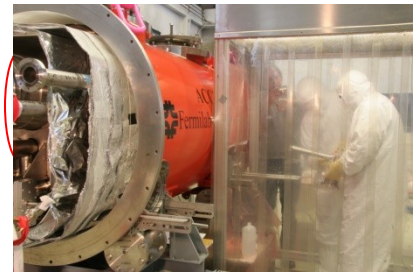
Number of Cavities	4
Active Length	0.346 meter
Gradient	14 MV/m
Phase	-179°
R/Q [=$U^2/(wW)$]	750 Ω
E_{peak}/E_{acc}	2.26
B_{peak} (E_{acc} = 14 MV/m)	68 mT
Q_{ext}	1.3 X 10^6
BBU Limit for HOM, Q	<1 X 10^5
Total Energy	20 MeV
Beam Current	9 mA
Forward Power, per cavity	9 kW
Coupler Power, per coupler	45 kW

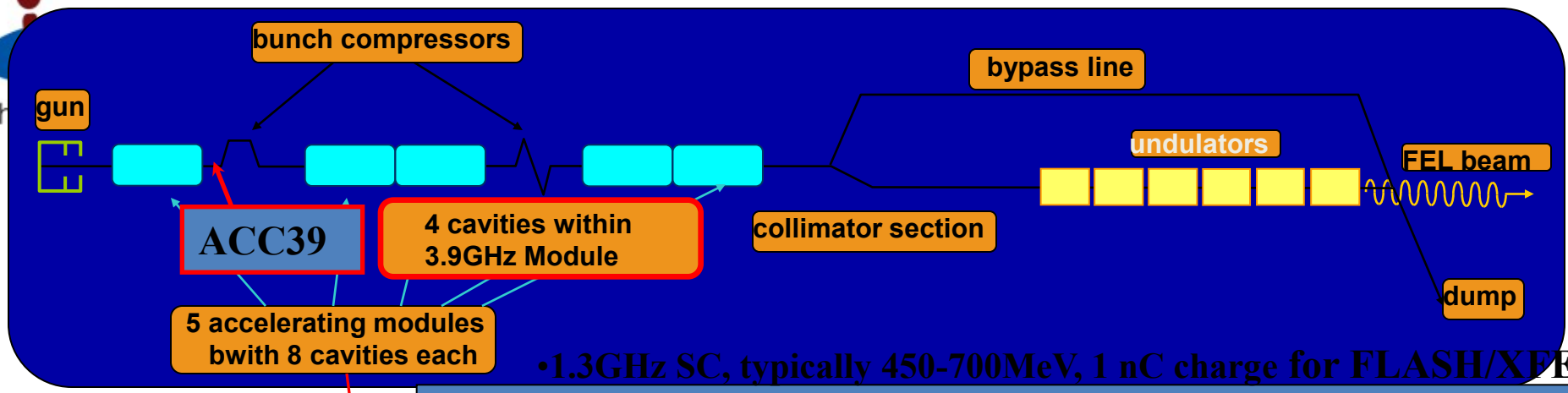
- Adding harmonic ensures the 2nd derivative at the max is zero for total field (could use any of the harmonics in the expansion, but using the lowest freq. ensures the transverse wakefields ~ ω^3 are minimised).
- The third harmonic system (3.9GHz) will compensate the nonlinear distortion of the longitudinal phase space due to cosine-like voltage curvature of 1.3 GHz cavities.
- It will linearise the energy distribution upstream of the bunch compressor thus facilitating a small normalized emittance ~1.10^{-6} m*rad.

Illustrative energy (not to scale)

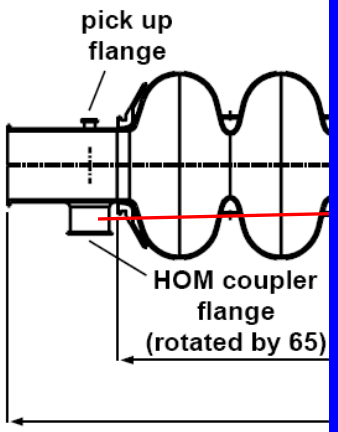






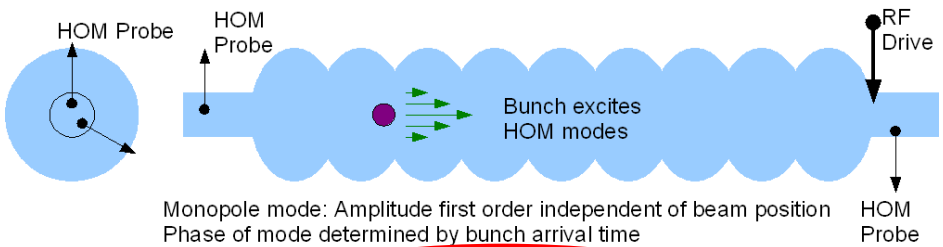


- 1.3GHz SC, typically 450-700MeV, 1 nC charge for FLASH/XFEL
- HOMs generated in accelerating cavities must be damped.
- Monitored HOMs facilitate beam/cavity info
- Forty cavities exist at FLASH.
  - -Couplers/cables already exist.
  - -Electronics enable monitoring of HOMs (wideband and narrowband response).

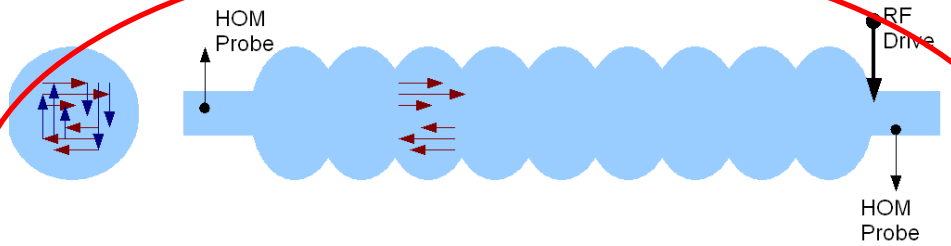


Based on 1.3 GHz (SLAC/FNAL/DESY) Diagnostics –redesigned for ACC39 as part of EuCARD

Task 10.5 Response of HOM modes to beam



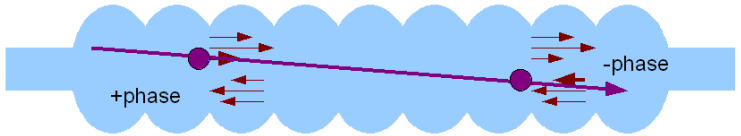
Monopole mode: Amplitude first order independent of beam position
Phase of mode determined by bunch arrival time



Dipole Modes: Each mode has 2 polarizations
Frequencies degenerate for ideal cavities
Frequency degeneracy broken by power coupler and fabrication errors

If frequency splitting is < line width, Need both couplers to separate polarizations

Dipole mode: Amplitude proportional to bunch transverse position
Phase determined by bunch arrival time for position offset



Beam at an angle will excite dipole mode with 90 degree phase shift relative to signal from position offset
Amplitude proportional to angle X effective mode length (~ 1 Meter)

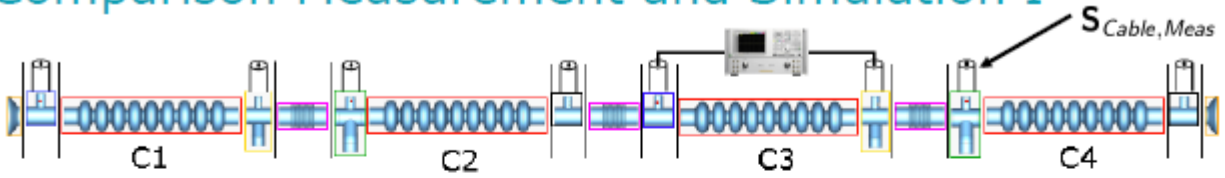
Tilted bunch will also excite signal at 90 degrees, amplitude proportional to bunch length and tilt: Not significant for short TTF bunches

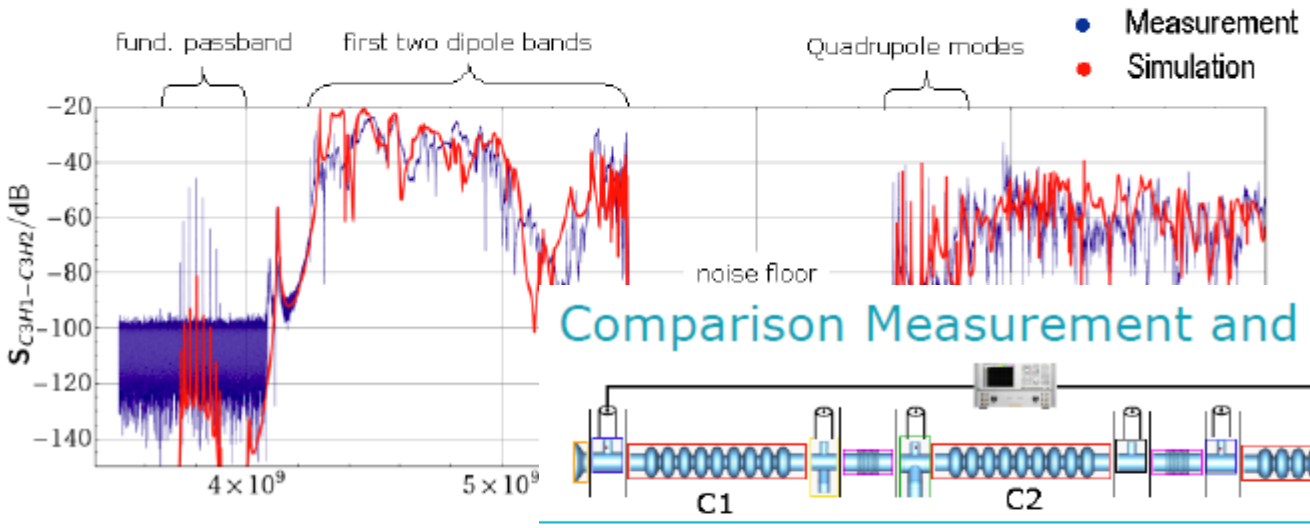
Selected Highlights

- **S-matrix measurements and comparison with simulations.**
  - **Transmission measurements.**
  - **Multi-cavity modes.**
- **Beam-based mode characterisation.**
  - **HOM pickup vs beam offset for trapped/isolated modes**

Task 10.5: S_{21} Exp vs Simulations

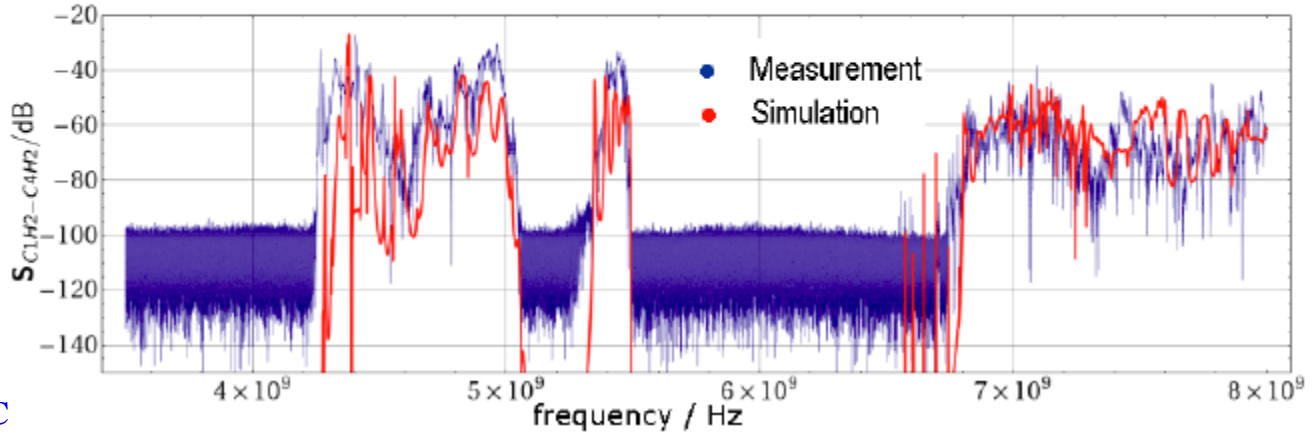
Comparison Measurement and Simulation I





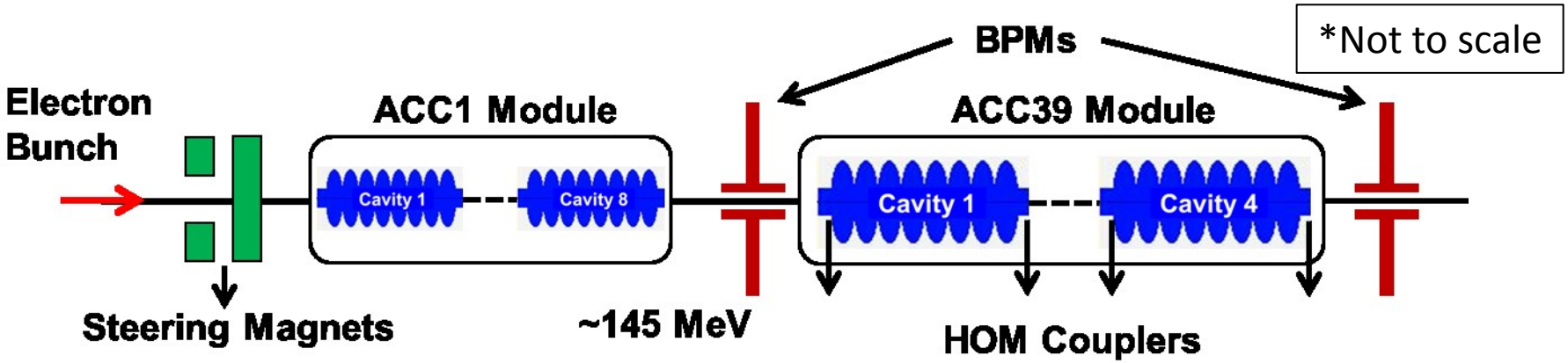
- **Transmission through single cavity in chain.**

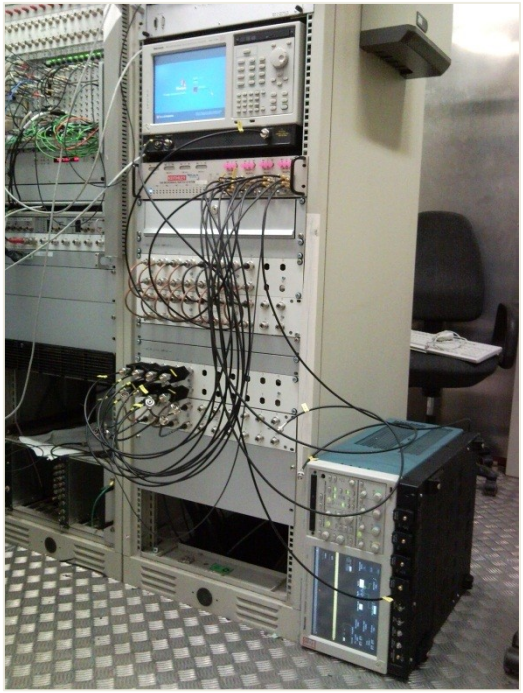
Comparison Measurement and Simulation II

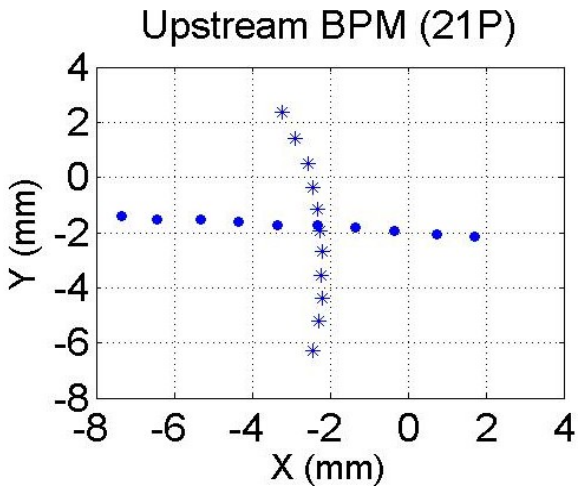


- **Transmission through complete chain.**

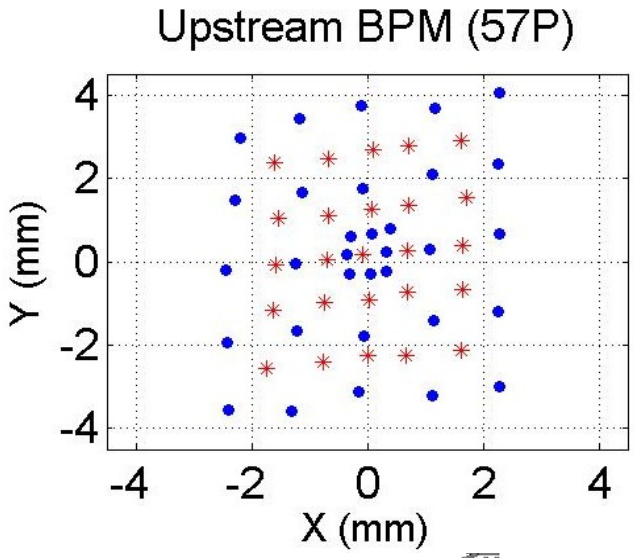
Task 10.5: Beam-Based HOM Measurements



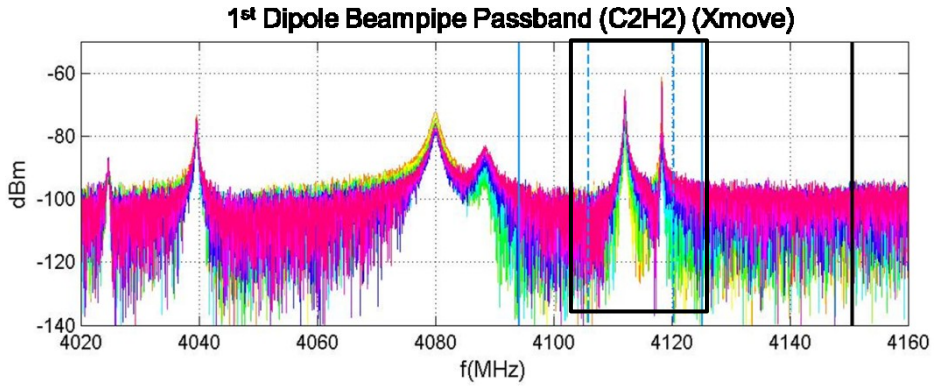


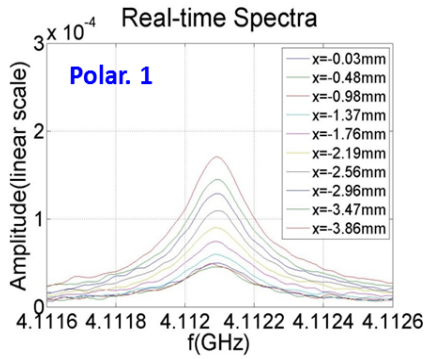


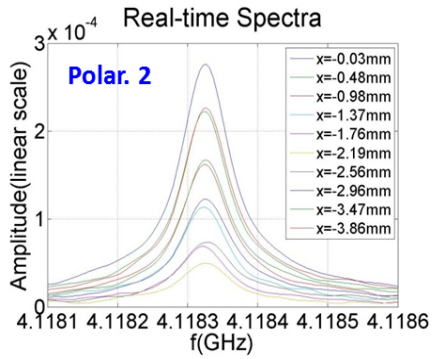
Steer the beam in various ways



Task 10.5: 1st Dipole Beampipe Modes

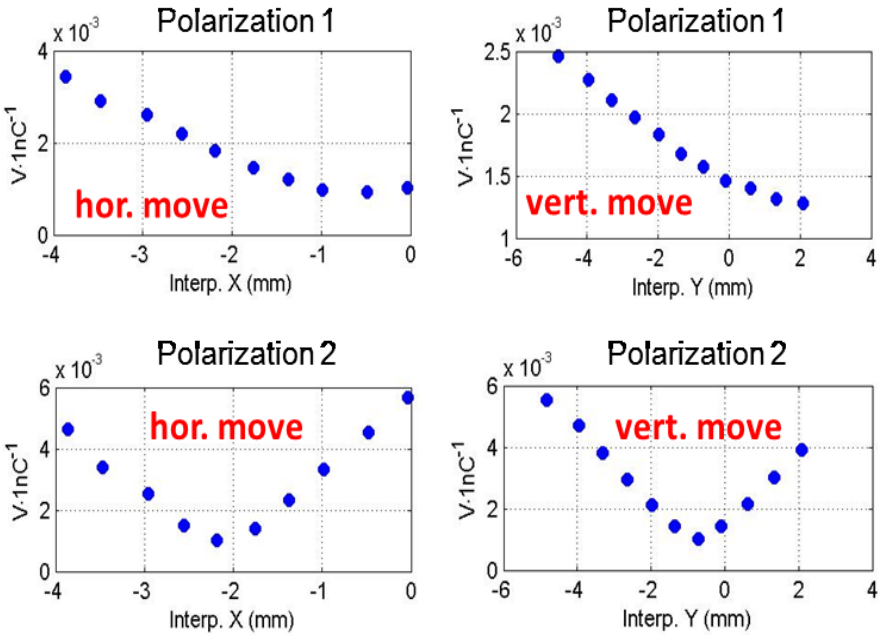


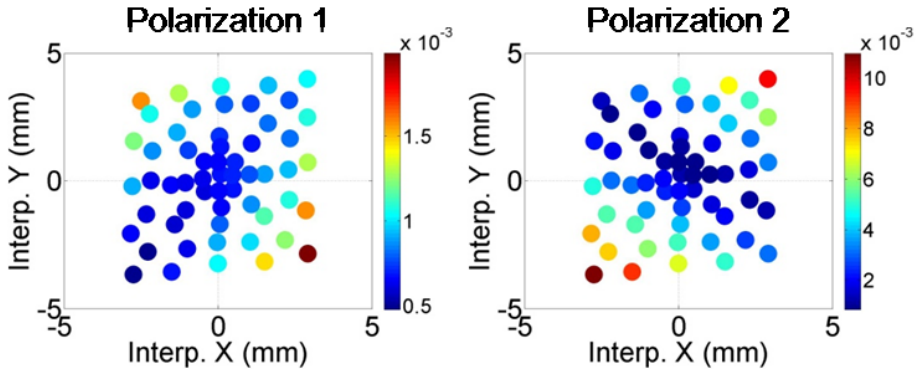


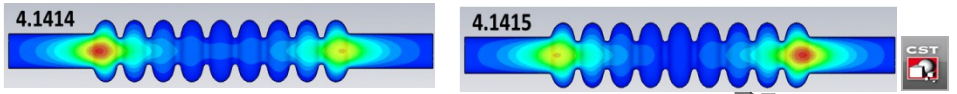


- Lorentzian fit to get mode amplitude

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







Task 10.5: 5th Dipole Cavity Band

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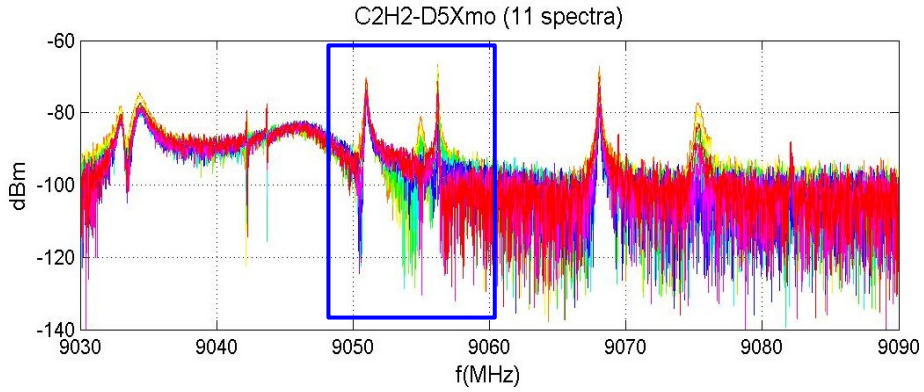
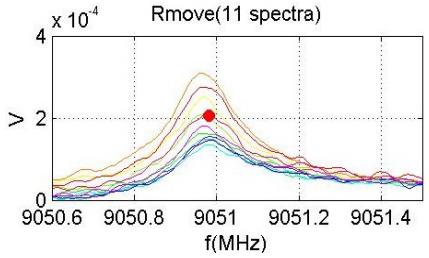
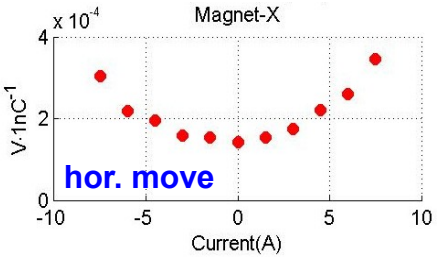
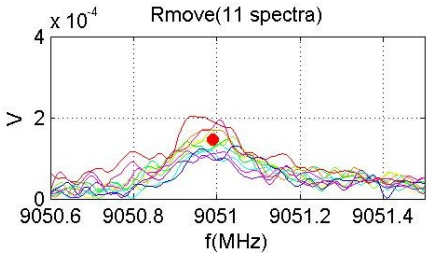


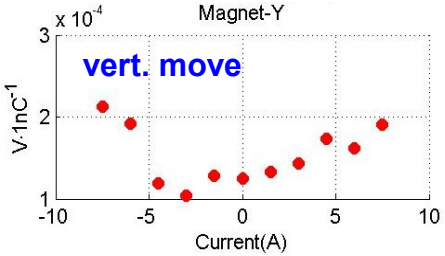
5th Dipole Band†	f (GHz)	R/Q
	9.0560	0.00
	9.0568	0.05
	9.0585	0.07
	9.0620	2.17
	9.0703	4.04
	9.0933	0.55

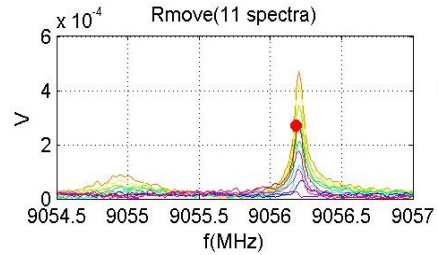
localized!

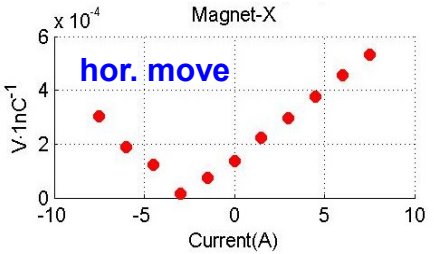


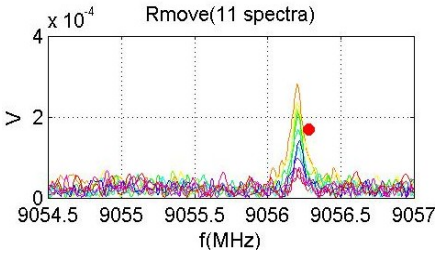


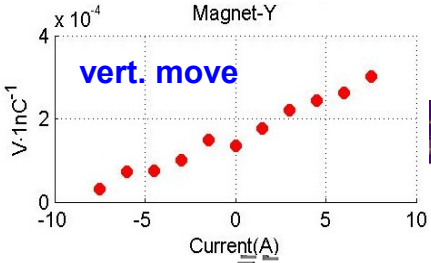












† I.R.R. Shinton, et al., "Mode Distribution …", CI Internal Note

Task 10.5: Milestones and Deliverables

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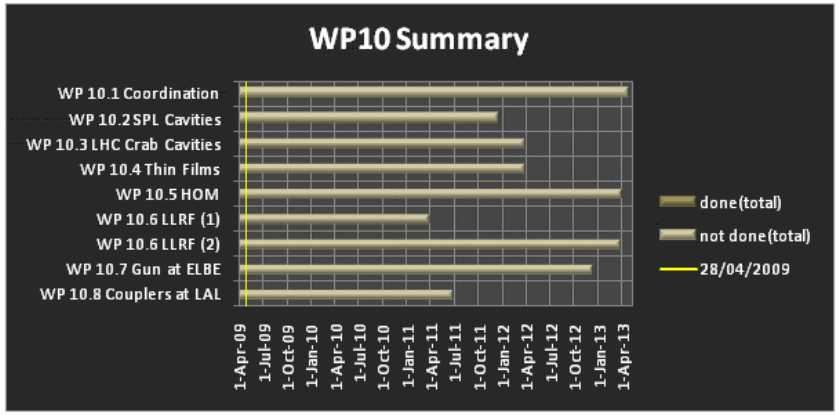
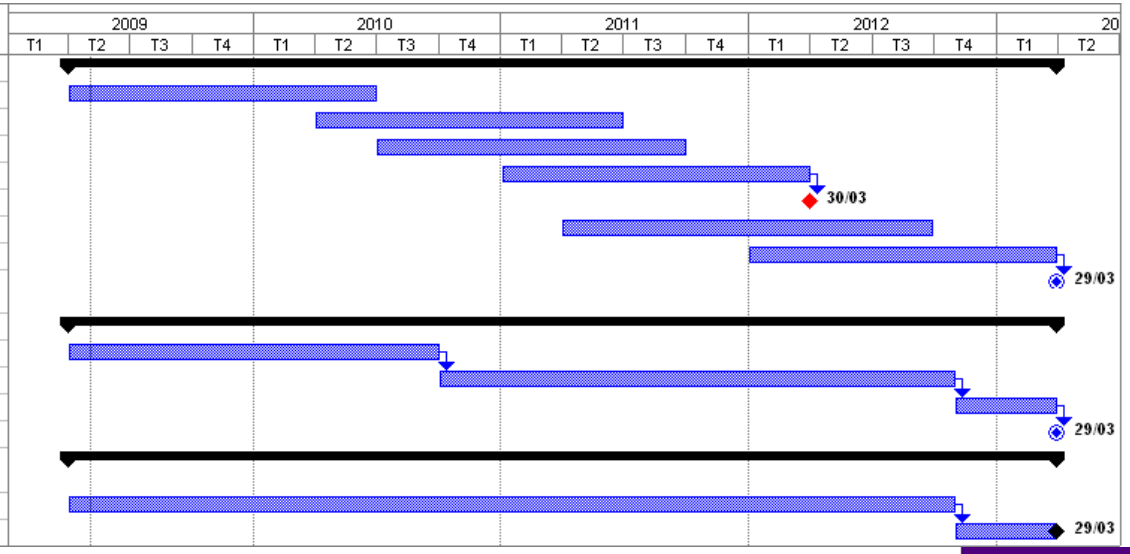


- **Start Date** 01/04/2009
- **Due Date** 31/03/2013

N°	Task Name
1	**Subtask 5.1: Development of HOM based beam position monitors (HOMBPM)**
2	Define requirements for HOMBPMs for 3.9 GHz
3	Study HOMs in the 3.9 GHz cavities at FLASH
4	Design and build electronics and LO
5	Test electronics
6	**Milestone 10.5.1: HOM alignment for 3.9 GHz cavity electronics verification**
7	Measure cavity alignment in 3.9 GHz cryomodule
8	HOMBPM calibration
9	**DELIVERABLE 10.5.1: HOM electronics and code to probe beam centering on 3.9 GHz cavities**
10	**Subtask 5.2: Development of HOM Cavity Diagnostics and ERLP (HOMCD)**
11	Develop HOM sub-structure alignment algorithm
12	Perform detailed sub-structure and cavity alignment via HOMs
13	Report on HOM experimental method and code
14	**DELIVERABLE 10.5.2: Report on HOM experimental method and code**
15	**Subtask 5.3: Measurement of HOM Distributions and Geometrical Dependences (HOMDG)**
16	Analyse mode distorsion and fabrication imperfections CSC
17	Report on influence of cavity fabrication tolerances on modes



✓**One Milestone on the horizon – 10.5.1 (Nicoleta) HOM Alignment Cavity Electronics Verification, 30th March 2012.**
✓**Two deliverables**
❑**10.5.1 (Nicoleta) HOM electronics and code to probe beam centering of 3.9 GHz cavities, 29th March 2013**
❑**10.5.2 (Roger) Report on HOM experimental method and code, 29th March 2013**

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Task 10.5: Summary

✓On track for milestones and deliverables

✓Five conf. pubs (10.5.1 -10.5.3)
-SCRF, PAC + two Linac (complete!) and an ongoing EuCARD/DESY internal report (written largely by Ian and reviewed by Hans-Walter, in process). PRST-AB Pub (spearheaded by Hans-Walter, in progress). Need to be proactive (upload to EuCARD)

✓Measurements continuing at FLASH –more analysis + exps needed to understand cavity coupling. Good progress –Pei first systematic comparison of SVD vs DLR.

✓Trapped 5th band (~ 9GHz) modes verified experimentally and linear dependence with offset observed! Mode candidate for diagnostics? Can the electronics be implemented at this frequency (Nicoleta in discussion with FNAL)?

✓Casscading (CST and recent HFSS results available).

✓Hans-Walter, Thomas and Roger presented at Cornell HOM workshop, 2010.
To be presented: Pei at Dipac, Nicoleta at SRF, Pei and Ian at IPAC (all 2011).

Task 10.5 Talks

- **Overview of HOM Distribution task, R.M. Jones (*University of Manchester/Cockcroft Inst.*)**

- **HOMBPM Beam Position Monitors - planned and extant experiments, P. Zhang (*DESY/University of Manchester*)**

- **HOMCD Cavity Diagnostics, I.R.R. Shinton (*University of Manchester*)**

- **HOMGD Geometric Dependencies, T. Flisgen (*University of Rostock*)**