



# WP10.3 Crab Cavities Overview

## EUCARD SRF Annual Review

Peter McIntosh

(STFC, ASTeC, Daresbury Laboratory)

4 – 5 May 2011, Orsay

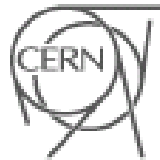


# Outline

- The Collaboration Team
- Description of the Scientific Work
- Project Planning
- Deliverables and Milestones
- Publications and Events
- WP10.3 Programme

# The Collaboration Team

- CERN (Switzerland)
  - Fellow (Luca Ficcadenti )
    - 18 m.m. from May 2010



- **CERN Total 18 m.m.**

- ULAN-CI (UK)
  - RA-Cavity (P Ambattu)
    - 18 m.m.
  - RA-LLRF (I Tahir) – **Left July 2010**
    - 10 m.m.
  - Academic-Cavity (G Burt)
    - 4 m.m.
  - Academic-LLRF (A Dexter)
    - 4 m.m.

- **ULAN-CI Total 36 m.m.**
- **RA-LLRF post not replaced**

- UMAN-CI (UK)
  - PDRA-Cavity (A D’Elia)
    - 16 m.m.
  - Academic-Cavity (R Jones)
    - 2 m.m.

- **UMAN-CI Total 18 m.m.**
- **All in post**

- STFC (UK)
  - WP Coordinator (P McIntosh)
    - 4 m.m.
  - RF Engineer (P Goudket)
    - 10 m.m.
  - Mech Designer (Undefined)
    - 4 m.m.

- **STFC Total 18 m.m.**
- **All in post**

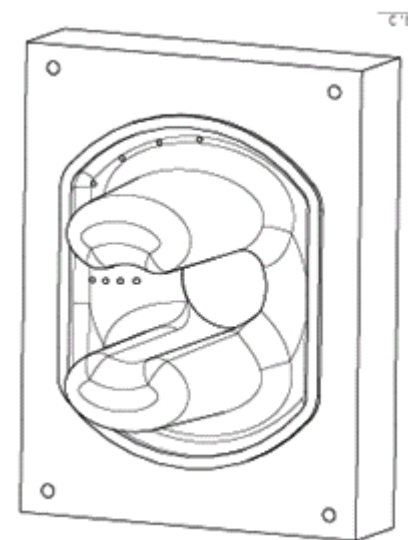
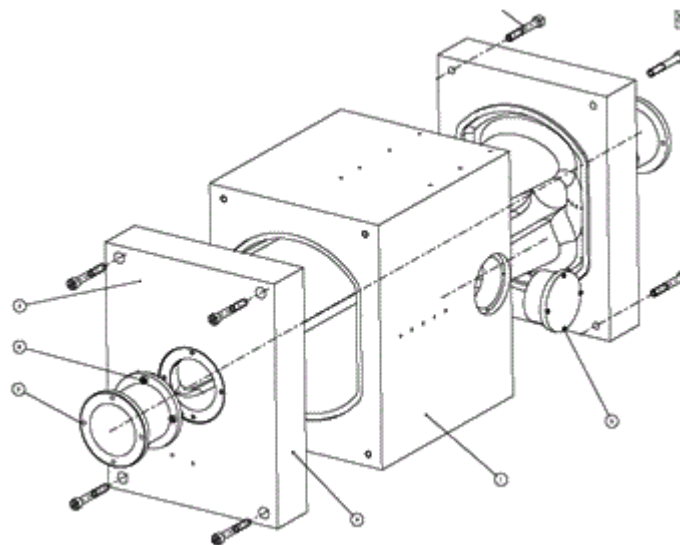
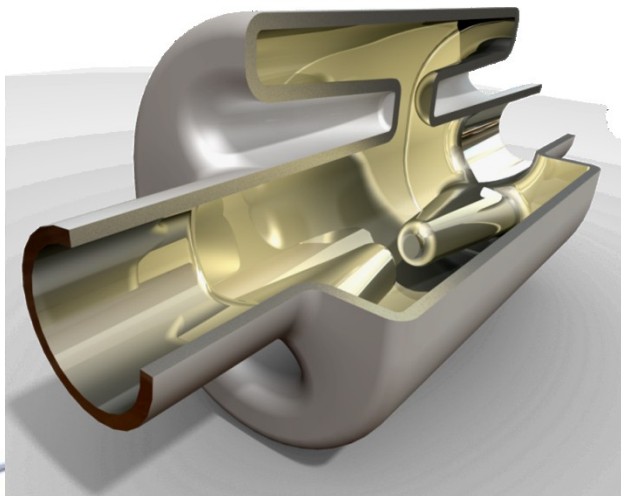


## WP10.3 Crab Cavities

- Design, build and test a single LHC and CLIC crab cavity structure, including input coupler, mode couplers and tuners.
- Design, build and test a LLRF and synchronization system that meets the crab cavity phase and amplitude control specifications for LHC and CLIC.
- If the beam time and the necessary hardware become available, validate and test the assembled crab system solutions (as part of wider collaboration teams) and LLRF control systems on LHC and CTF3 in 2011; otherwise make performance predictions based on the measured noise characteristics.

# LHC-CC Progress

- A study of the LHC-CC HOMs has been completed, this study will feed into further work on HOM couplers.
- Alterations to the cavity specifications made in light of work at CERN identifying that the field variation across the aperture should be minimised from 20% down to 3%.
- Electromagnetic design work has now been focussed on the LOM couplers for this cavity geometry.
- A contract has now been placed with a UK company for prototype cavity fabrication.

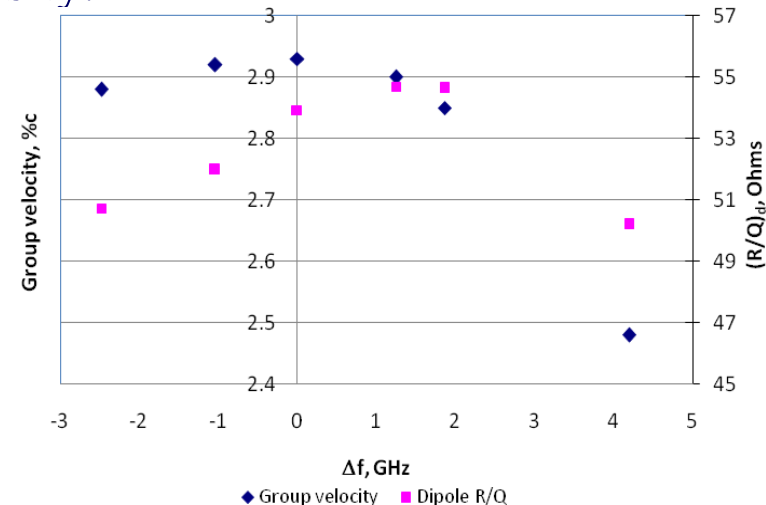
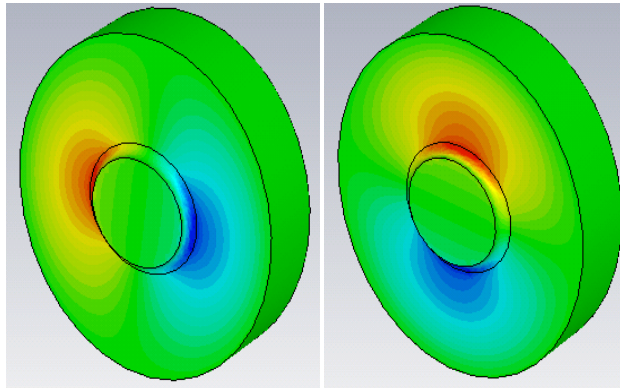
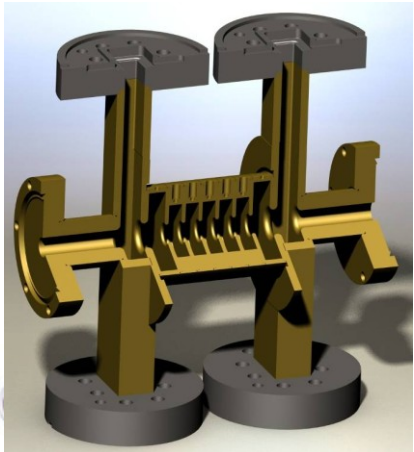


# LHC-CC10 CERN: 15-17 Dec 10

- Crabs are the \*baseline\* tool for geometric compensation and luminosity levelling for the HL-LHC:
  - The nominal scheme is for local crab crossing with 400 MHz superconducting cavities independent of each IP (IP1 and IP5).
  - Backup options pursued if technology limits or machine protection issues are identified.
- No cavity down selection will be made now:
  - Foreseen after the results from prototyping yield conclusive reasons to pick the best candidate for the LHC.
  - Expected by the end of 2013.
- Identical systems for both IPs are preferable but this is not an absolute requirement:
  - Should pursue the best candidate satisfying the appropriate crossing scheme.
- KEK-B crab cavities will not be installed in the SPS due to several reasons:
  - Cost, difficulty, extrapolation to LHC, risk etc.
- Machine protection with crab cavities needs detailed investigation with realistic RF failure signals in conjunction with the upgraded collimation system to give a clear conclusion.
- No show stoppers identified for the compact cavity designs presented:
  - 3 – 4 promising designs compatible with the LHC footprint exist.
  - Cavity engineering design and prototyping should follow.
  - A common platform for couplers, tuners and cryomodule equipment should be studied.
- Detailed specifications for the cavities should be given, addressing the requirements on:
  - transparency,
  - impedance,
  - field quality,
  - fundamental mode damping,
  - trip rate,
  - synchro-betatron resonances,
  - plane of crabbing, etc.

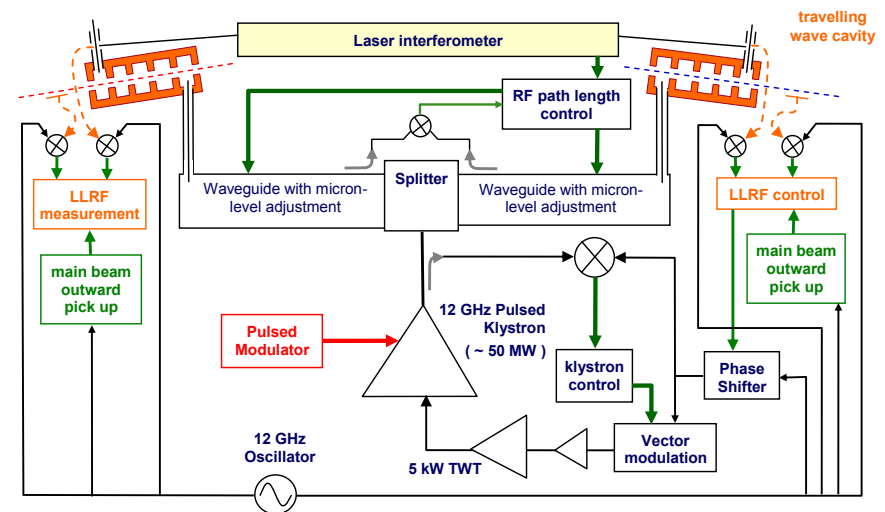
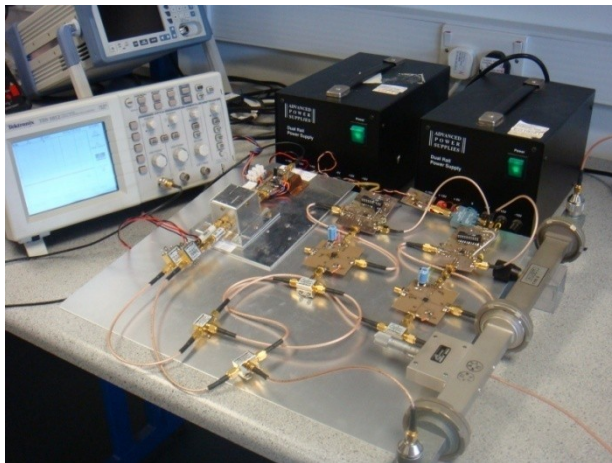
# CLIC-CC Developments

- A complete study of the long range wakefields in the CLIC crab cavity has been completed:
  - highlighted a need for a 1 GHz separation between the vertical and horizontal crabbing modes.
  - Studies are now looking at the optimum method of implementing this frequency shift without increasing surface fields.
- A study of various damping methods has concluded that waveguide damping is the optimum solution for the CLIC crab cavity, although exact dimensions need iterating with the polarised cavity design.
- PLACET and Guinea pig simulations have continued investigating the effect of the crab cavity on the CLIC luminosity.



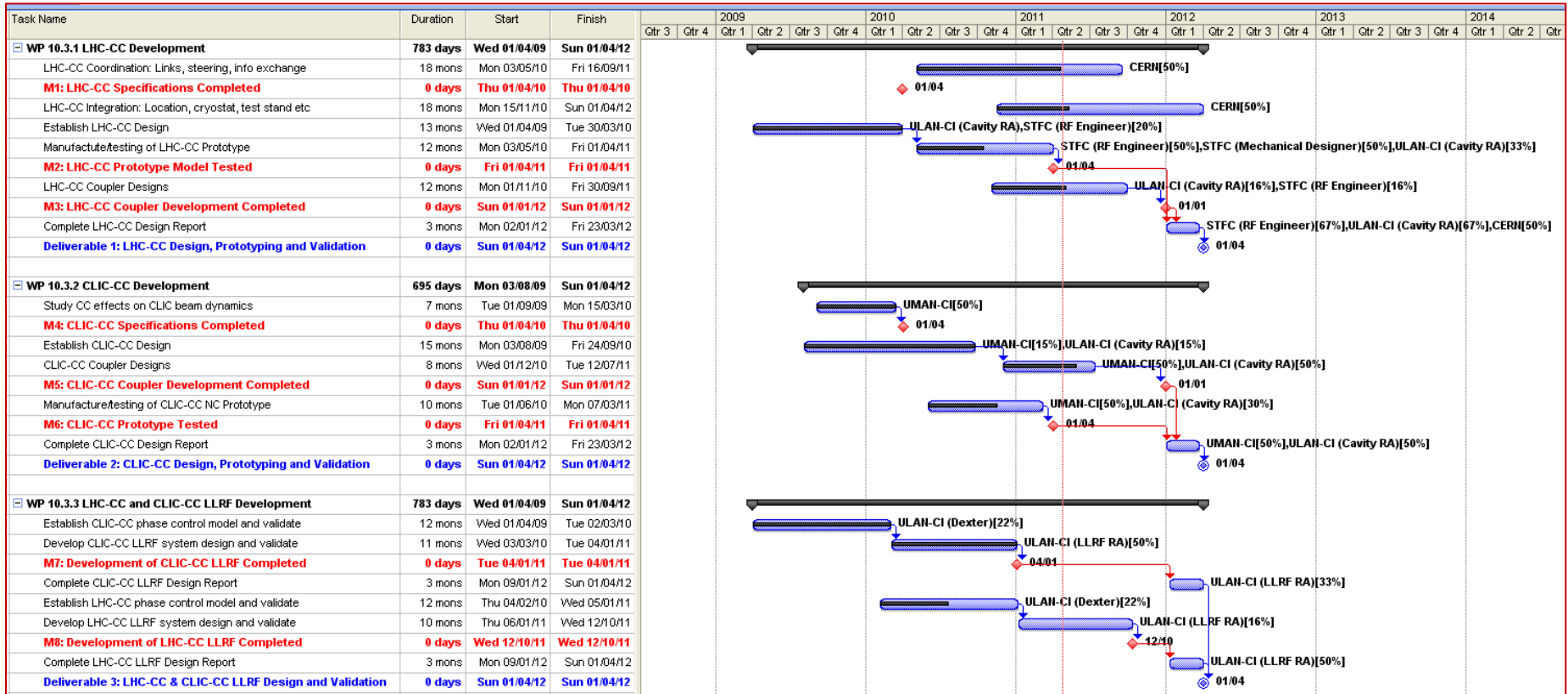
# Crab Cavity LLRF Solutions

- LHC-CC
  - Full digital system anticipated, based on ILC-CC R&D.
  - Interferometer synchronisation.
  - Stability tolerance expected:  $<0.04\%$  and  $0.003^\circ$  @ 8 mrad.
- CLIC-CC
  - Hybrid digital-analogue system anticipated.
  - Analogue adjustment during the bunch train.
  - Digital for train to train optimisation of control loop.
  - Timing tolerance expected: 6 fs.





# 10.3 Project Plan and Milestones



## WP10.3 Milestones

Number	Title	Output	Month
M10.3.1	LHC crab cavity specifications completed	R	M12
M10.3.2	LHC model crab cavity completed	P	M24 ⇒ M27
M10.3.3	LHC input and LOM mode coupler design development finished	P/R	M33
M10.3.4	CLIC crab cavity specifications completed	R	M12
M10.3.5	CLIC model crab cavity completed	P	M24 ⇒ M26
M10.3.6	CLIC input and mode coupler design development finished	P/R	M33
M10.3.7	Development of CLIC LLRF system	P/R	M21 ⇒ M24
M10.3.8	Development of LHC LLRF system	P	M30

## WP10.3 Milestone Status

- M10.3.2 LHC model crab cavity fabricated
  - Delayed due to specification changes implemented during LHC-CC09.
  - Prototype CC released for fabrication and expected in M27.
- M10.3.5 CLIC model crab cavity fabricated
  - Delayed due to precision tolerances not being met post-braze at manufacturer.
  - Prototype CC awaiting final brazing steps and expected in M26.
- M10.3.7 Development of CLIC LLRF System
  - Due in M21 and submitted in M24.
  - Delayed due to loss of LLRF-RA at Lancaster University.

## WP10.3 Deliverables

- WP1: LHC-CC Design (F Zimmerman, CERN)
- WP2: CLIC-CC Design (R Jones, UMAN-CI)
- WP3: LHC-CC and CLIC-CC LLRF (A Dexter, ULAN-CI)

Number	Title	Output	Month
10.3.1	LHC crab cavity final report	R	M36
10.3.2	CLIC crab cavity final report	R	M36
10.3.3	LHC and CLIC LLRF final reports	R	M36

# Publications & Events

## Publications

### Status of LHC Crab Cavity Simulations and Beam Studies, R Calaga et al

- Particle Accelerator Conference 2009, Vancouver, 2009.

### LHC Upgrade Scenarios, F Zimmermann et al

- Particle Accelerator Conference 2009, Vancouver, 2009.

### Wakefield Damping for the CLIC Crab Cavity, P Ambattu et al

- Particle Accelerator Conference 2009, Vancouver, 2009.

### Status of LHC Crab Cavity Cryostat, N Solyak et al

- Particle Accelerator Conference 2009, Vancouver, 2009.

### Novel Geometries for the LHC Crab Cavity, B Hall et al

- Particle Accelerator Conference 2009, Vancouver, 2009.

### Study with One Global Crab Cavity at IR4 for LHC, Y Sun et al

- Particle Accelerator Conference 2009, Vancouver, 2009.

### Tune Shift due to Crossing Collision and Crab Collision, Y Sun et al

- Particle Accelerator Conference 2009, Vancouver, 2009.

### New Cavity Shape Developments for Crabbing Applications, G Burt

- Superconducting RF Conference 2009, Berlin, 2009.

### Novel Geometries for the LHC Crab Cavity, B Hall et al

- International Particle Accelerator Conference 2010, Kyoto, 2010.

### Evolutionary Algorithms in the Design of Crab Cavities, C Lingwood et al

- International Particle Accelerator Conference 2010, Kyoto, 2010.

### Analysis and Control of Wakefields in X-Band Crab Cavities for Compact Linear Collider, P.K. Ambattu et al

- accepted by NIM-A subject to modifications (2011)

### CLIC Crab cavity Design optimisation for Maximum Luminosity, A Dexter et al

- accepted by NIM-A subject to modifications (2011)

## Events

EuCARD ACCNET workshop on LHC crab cavities, "LHC-CC10," at CERN, 15-17 Dec 2010

ICFA Mini-Workshop on X-Band Structures, Beam Dynamics and Sources, at Cockcroft Institute, 30 Nov - 3 Dec 2010

# WP10.3 Review Programme

- **WP10.3 Crab Cavities Overview & Status**
  - P McIntosh (STFC) 15 mins
- **CLIC-CC Development**
  - G Burt (ULAN-CI) 20 mins
- **CERN LHC Crab Requirements and LHC-CC10 Impact**
  - E Ciapala (CERN) 20 mins
- **LHC-CC Development**
  - B Hall (ULAN-CI) 20 mins
- **LLRF System Developments**
  - G Burt (ULAN-CI) 20 mins