EuCARD

EUCARD Collaboration
Crab Cavity Research

Peter McIntosh

(STFC, Daresbury Laboratory)

ICFA Beam Dynamics Mini-Workshop on
Deflecting/Crabbing Cavity Applications for Accelerators

The University of Manchester
MANCHESTER 1824
LANCASTER UNIVERSITY
Science & Technology Facilities Council
CERN

Outline

- The Collaboration Team
- Description of the Scientific Work
- Project Planning/Status
- Deliverables/Milestones
- Publications/Events
- Conclusions

EUCARD SRF-WP10 can be found at: https://espace.cern.ch/SRF/default.aspx

The Collaboration Team

- CERN (Switzerland)
  - Liasons (F Zimmermann and Ed Ciapala)
  - Fellow (Luca Ficcadenti)
    - 18 m.m. from May 2010
- CERN Total 18 m.m.

- ULAN-CI (UK)
  - RA-Cavity (P Ambattu)
    - 18 m.m.
  - PDRA-LLRF (I Tahir)
    - 10 m.m.
  - Academic-Cavity (G Burt)
    - 4 m.m.
  - Academic-LLRF (A Dexter)
    - 4 m.m.
- ULAN-CI Total 36 m.m.

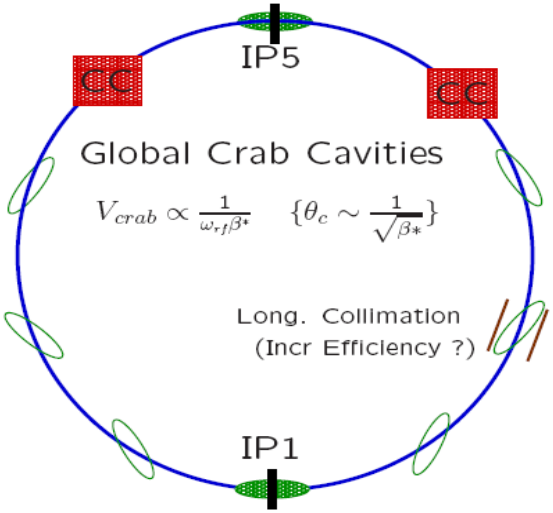
- UMAN-CI (UK)
  - PDRA-Cavity (I Shinton)
    - 16 m.m.
  - Academic-Cavity (R Jones)
    - 2 m.m.
- UMAN-CI Total 18 m.m.

- 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.

WP10.3 Crab Cavities

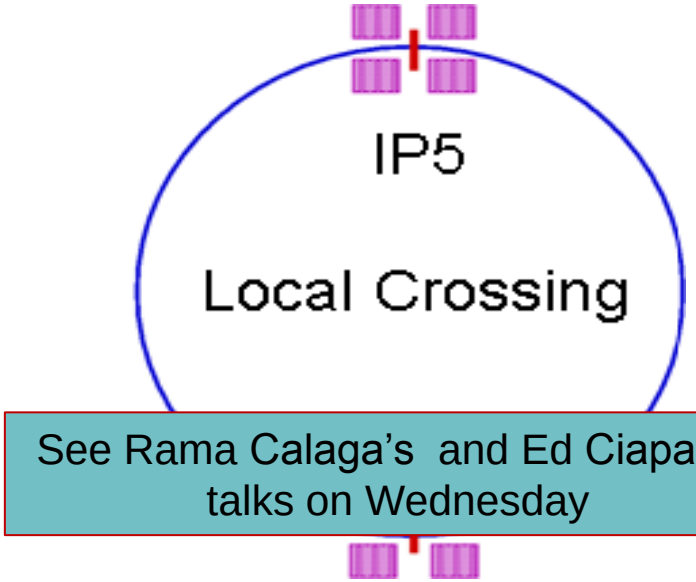
- Design, build and test a single LHC and CLIC crab cavity structure, including input coupler, mode couplers and tuners.
- Design, build and test a LLRF and synchronization system that meets the crab cavity phase and amplitude control specifications for LHC and CLIC.
- If the beam time and the necessary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

LHC-CC Local vs Global



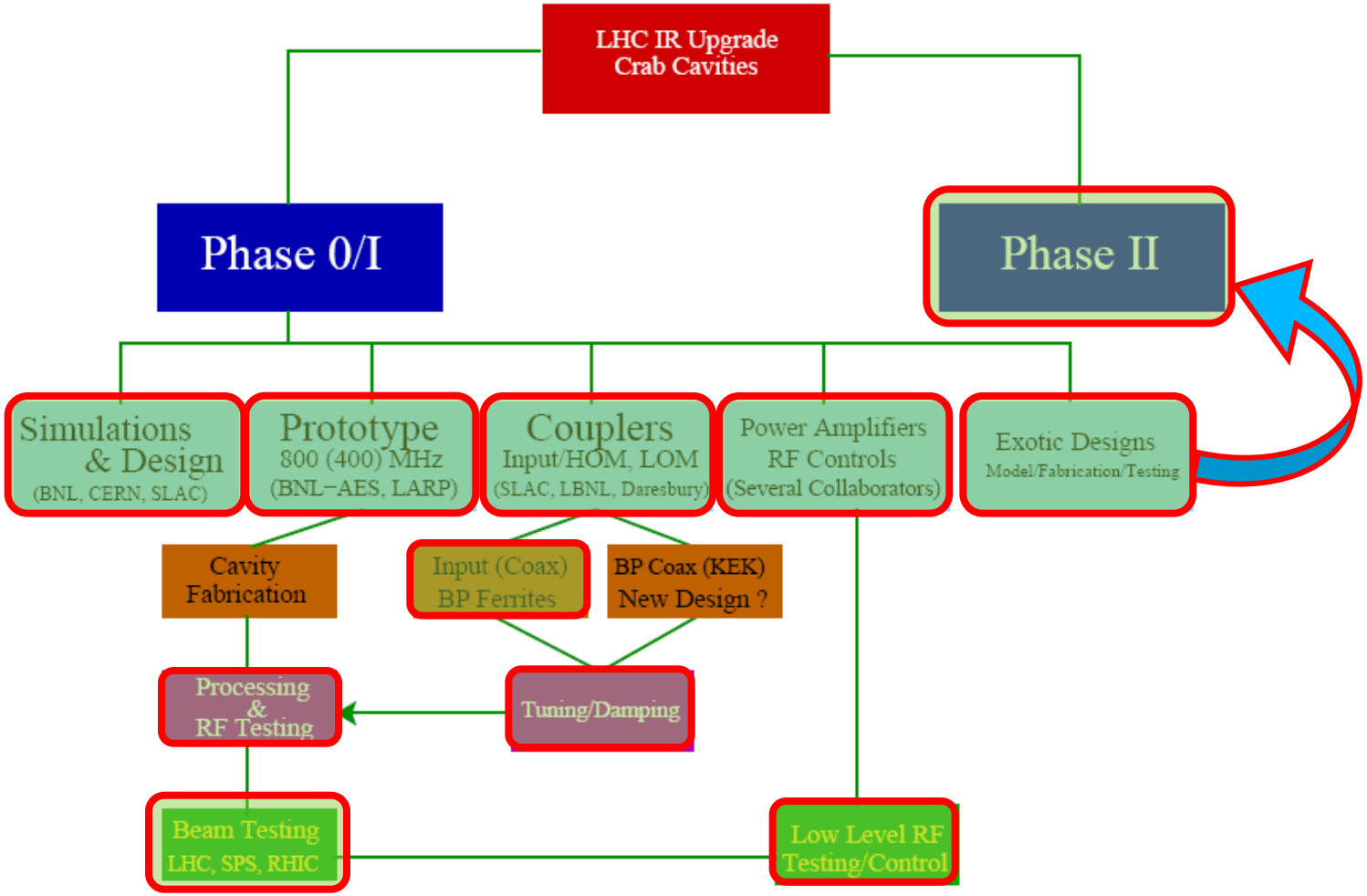
- Small crossing angle (~0.5 mrad):
- Global crab scheme is ideal choice for prototype **Phase-I**:
  - Test feasibility of crab crossing in hadron colliders,
  - Address all RF and beam dynamic issues,
  - Small orbit excursion and tune shifts,
  - Compatible with nominal and upgrade options to recover the geometric luminosity loss,
  - Collimation optimisation!
  - These cavities are feasible using available technology and the gradient requirements are within reach of current technology.

- Local crab crossing preferable (**Phase-II**):
  - Independent control at IPs,
  - Avoid collimation/impedance issues.
- Need compact cavities to fit in the IR region of the ring.
- Lower frequency hopefully!



See Rama Calaga's and Ed Ciapala's talks on Wednesday

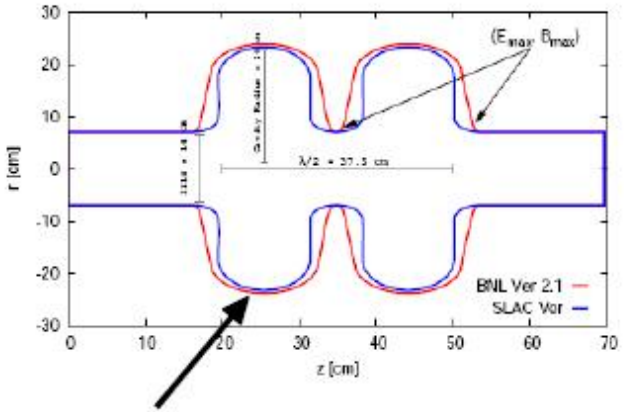
LHC-CC R&D Plan



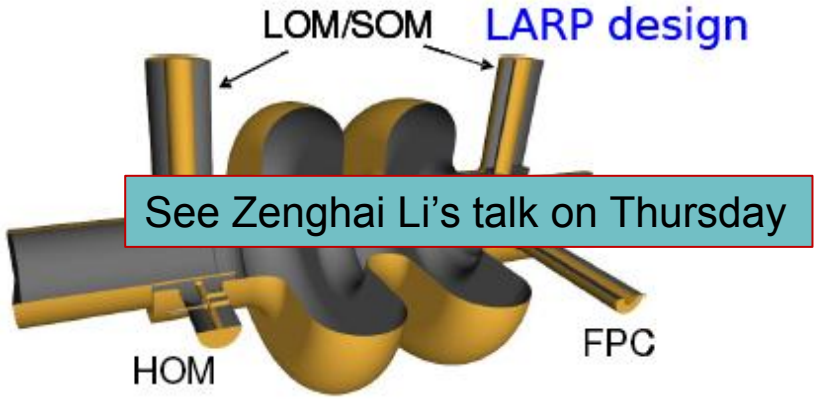
From LHC-CC08 BNL, 25-26 Feb 2008

LHC US-LARP Integration (Phase-I)

Prototype Cavity/Couplers

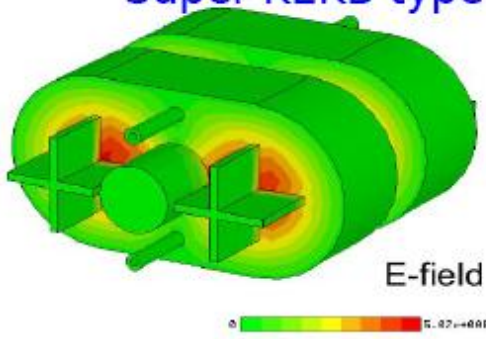


Note the cavity radius ~ 23 cm

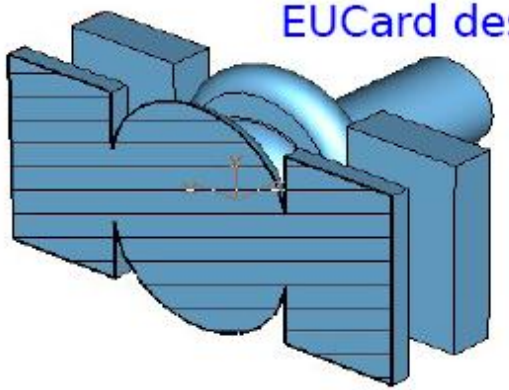


See Zenghai Li's talk on Thursday

Super-KEKB type design



EUCard design

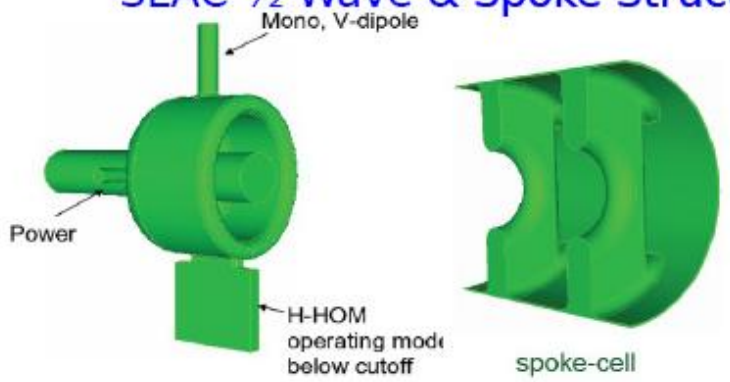


** Down-Selection within 1yr

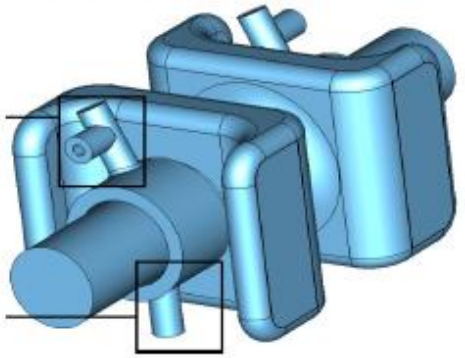
LHC US-LARP Integration (Phase-II)

Compact Structure, Phase II

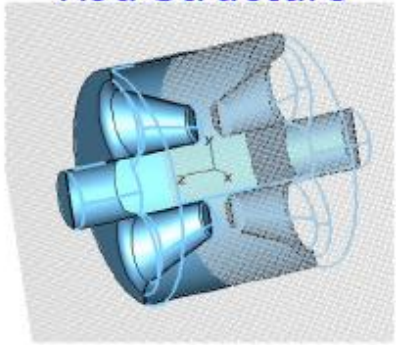
SLAC ½ Wave & Spoke Structures



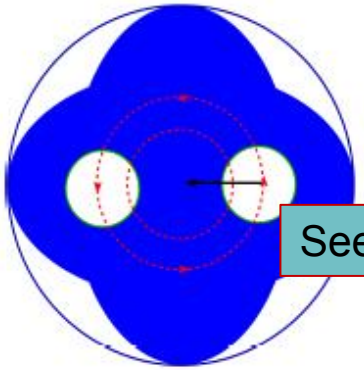
FNAL Mushroom Cavity



EUCard,UK-JLAb Rod Structure



BNL TM010, BP Offset



KEK Kota Cavity

See Graeme Burt's talk on Thursday

LHC-CC09 CERN: 16-18 Sept 09

- After the success of KEKB, **CERN must pursue crab cavities for the LHC**; the potential luminosity increase is significant.
- **Machine protection is potential show stopper**. Effect of fast cavity changes to be looked at with high priority. Impedance is concern as LHC (and SPS) revolution frequency changing during acceleration, and detuning of the cavity may be more difficult than for KEKB, strong damping of the dipole mode might need to be examined.
- **Demonstration experiments** with beam should focus on the **differences between electrons and protons** (e.g. effect of crab-cavity noise with beam-beam, impedance, beam loading) and on reliability & machine protection which are critical for the LHC;
  - beam test with a (KEKB?) crab cavity in another proton machine (SPS?) may be useful and sufficient.
- Both "global" and "local" crab schemes retained as options. **Future R&D focus should be on compact cavities**, which can be installed in the IR regions of IP1 and 5 as local cavities for the LHC upgrade phase II.
- Modifications of IR4 during the 2013/14 shutdown should be looked at; the **IR4 region could be used for the installation and test of compact crab-cavity prototypes** and for accommodating a possible global crab-cavity scheme.
- The crab cavity infrastructure should be kept in mind for all other LHC upgrades.

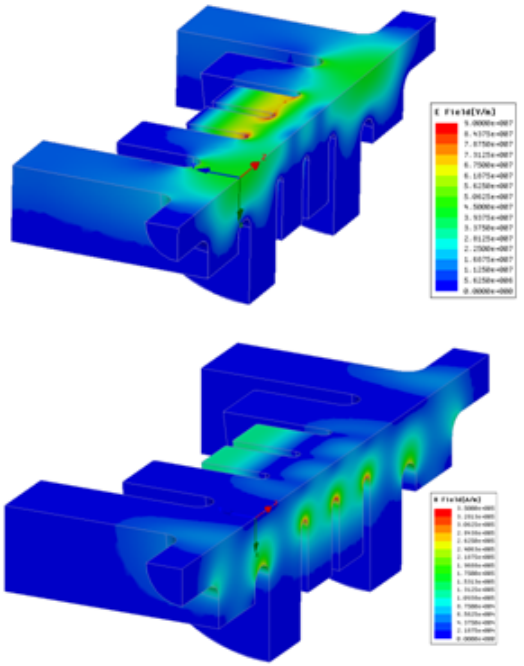
Steve Myers (CERN Director of Accelerators)

CLIC-CC Design Philosophy

- Design 12 GHz TW dipole copper cavity with high group velocity and thick irises:
  - 12 GHz is compact and has synergy with linac.
  - 12 GHz makes phase control tolerance larger than for sub harmonic frequency choices.
  - TW allows energy flow to mitigate beam-loading.
  - Thick irises reduces effects of pulse heating and phase drift.
  - Adjacent mode for SW cavities affect phase control performance.
- Investigate various damping options.

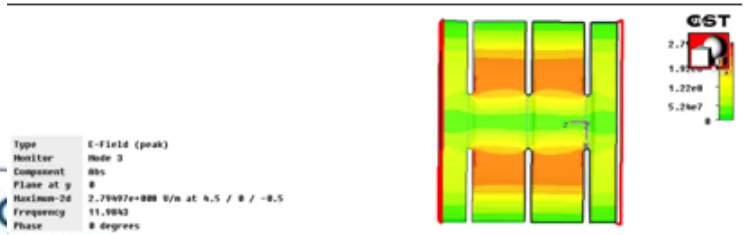
CLIC-CC Developments

- CLIC X-band Crab Cavity:
  - Dipole mode operating @ 12 GHz.
  - All unwanted modes heavily detuned and damped.
- Key technical challenges:
  - Complex geometries which are difficult to fabricate.
  - Extremely tight tolerances for all mode couplers.
  - Limited availability of high power RF sources.

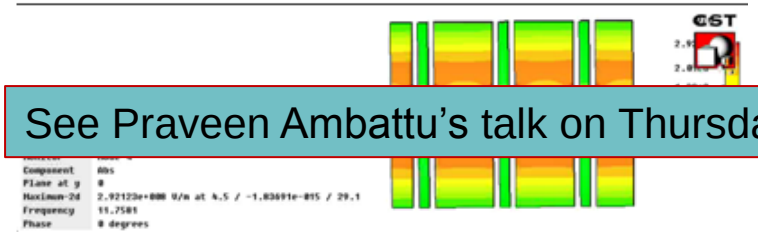


- Initial investigation of a possible X-band solution:

Travelling Wave

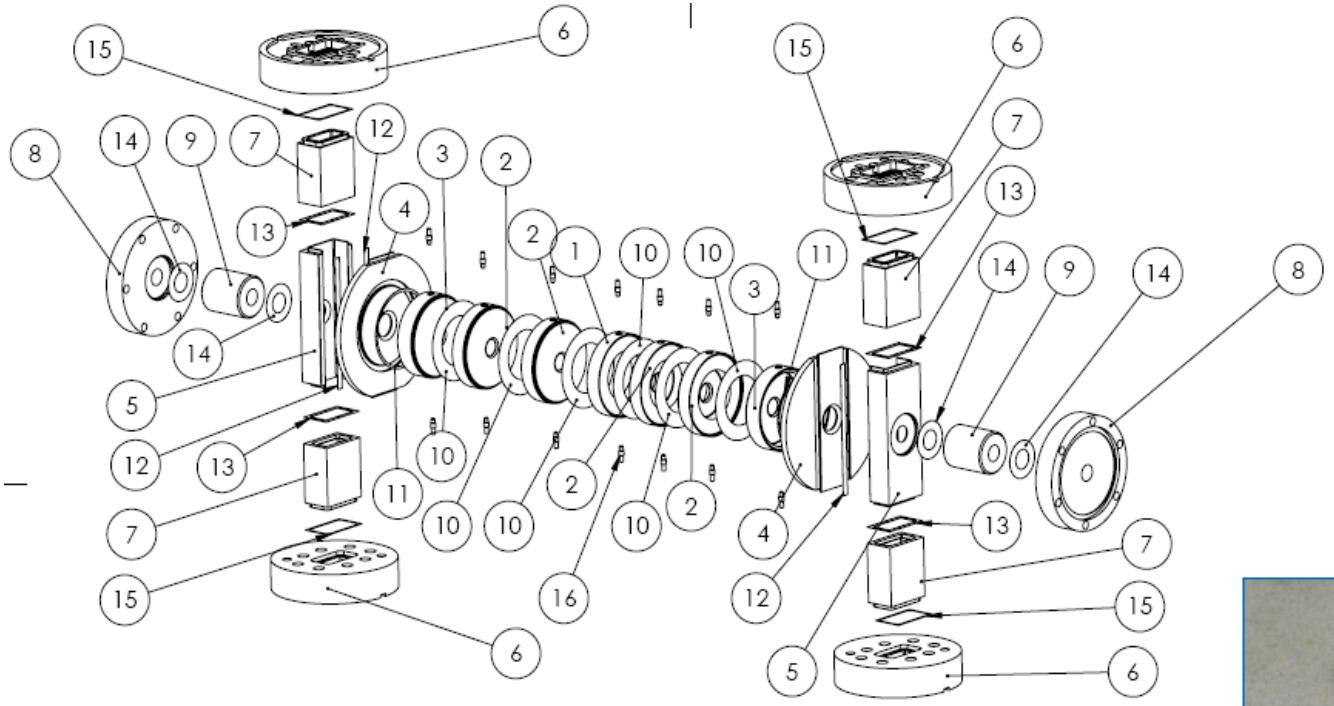


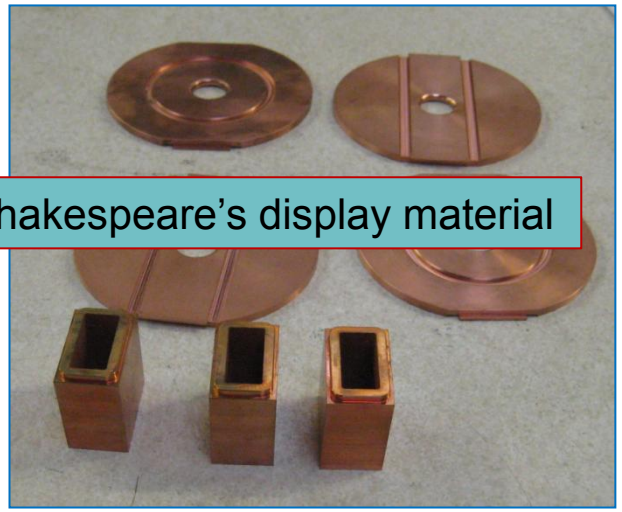
Bi-periodic



See Praveen Ambattu's talk on Thursday

CLIC-CC Fabrication





See Shakespeare's display material

Shakespeare ENGINEERING

EuCARD

Crab Cavity LLRF Solutions

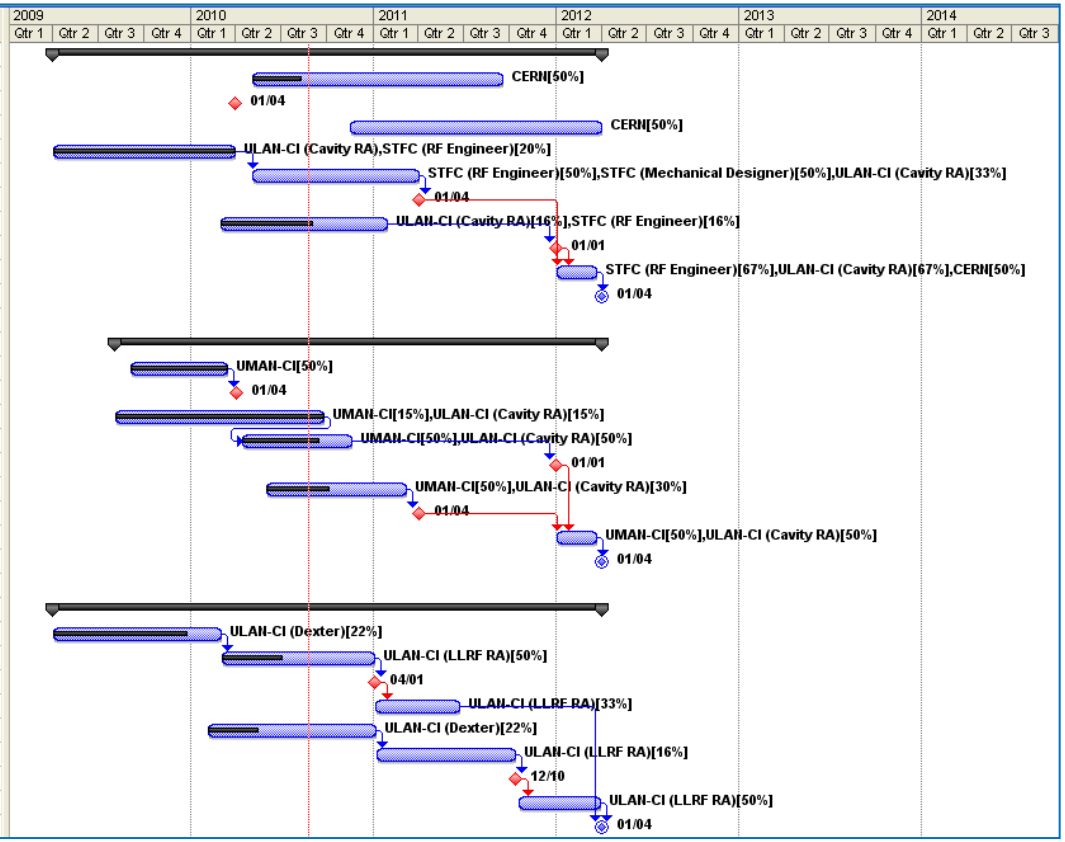
- LHC-CC
  - Anticipate a local crab crossing scheme < 0.522 mrad
  - Anticipate 400 MHz SRF cavities
  - Meeting single pass synchronisation requirement is straightforward
  - Meeting beam-beam instability synchronisation requirement is tough
  - Preventing phase noise causing beam blow up is a serious concern

- CLIC-CC
  - For CLIC anticipate both cavities driven with same Klystron
  - Need to assess added phase noise on separate distribution paths
  - Need a LLRF system to drive test cavity at CTF3
  - Need accurate relative cavity phase measurements for 200 ns pulses
  - Need a laser interferometer (not funded in EUCARD)

See Amos Dexter's talk on Thursday

10.3 Project Plan and Milestones

Task Name	Duration	Start	Finish
WP 10.3.1 LHC-CC Development	**783 days**	**Wed 01/04/09**	**Sun 01/04/12**
LHC-CC Coordination: Links, steering, info exchange	18 mons	Mon 03/05/10	Fri 16/09/11
M1: LHC-CC Specifications Completed	**0 days**	**Thu 01/04/10**	**Thu 01/04/10**
LHC-CC Integration: Location, cryostat, test stand etc	18 mons	Mon 15/11/10	Sun 01/04/12
Establish LHC-CC Design	13 mons	Wed 01/04/09	Tue 30/03/10
Manufactute/testing of LHC-CC Prototype	12 mons	Mon 03/05/10	Fri 01/04/11
M2: LHC-CC Prototype Model Tested	**0 days**	**Fri 01/04/11**	**Fri 01/04/11**
LHC-CC Coupler Designs	12 mons	Mon 01/03/10	Fri 28/01/11
M3: LHC-CC Coupler Development Completed	**0 days**	**Sun 01/01/12**	**Sun 01/01/12**
Complete LHC-CC Design Report	3 mons	Mon 02/01/12	Fri 23/03/12
Deliverable 1: LHC-CC Design, Prototyping and Validation	**0 days**	**Sun 01/04/12**	**Sun 01/04/12**
WP 10.3.2 CLIC-CC Development	**695 days**	**Mon 03/08/09**	**Sun 01/04/12**
Study CC effects on CLIC beam dynamics	7 mons	Tue 01/09/09	Mon 15/03/10
M4: CLIC-CC Specifications Completed	**0 days**	**Thu 01/04/10**	**Thu 01/04/10**
Establish CLIC-CC Design	15 mons	Mon 03/08/09	Fri 24/09/10
CLIC-CC Coupler Designs	8 mons	Mon 12/04/10	Fri 19/11/10
M5: CLIC-CC Coupler Development Completed	**0 days**	**Sun 01/01/12**	**Sun 01/01/12**
Manufacture/testing of CLIC-CC NC Prototype	10 mons	Tue 01/06/10	Mon 07/03/11
M6: CLIC-CC Prototype Tested	**0 days**	**Fri 01/04/11**	**Fri 01/04/11**
Complete CLIC-CC Design Report	3 mons	Mon 02/01/12	Fri 23/03/12
Deliverable 2: CLIC-CC Design, Prototyping and Validation	**0 days**	**Sun 01/04/12**	**Sun 01/04/12**
WP 10.3.3 LHC-CC and CLIC-CC LLRF Development	**783 days**	**Wed 01/04/09**	**Sun 01/04/12**
Establish CLIC-CC phase control model and validate	12 mons	Wed 01/04/09	Tue 02/03/10
Develop CLIC-CC LLRF system design and validate	11 mons	Wed 03/03/10	Tue 04/01/11
M7: Development of CLIC-CC LLRF Completed	**0 days**	**Tue 04/01/11**	**Tue 04/01/11**
Complete CLIC-CC LLRF Design Report	6 mons	Wed 05/01/11	Tue 21/06/11
Establish LHC-CC phase control model and validate	12 mons	Thu 04/02/10	Wed 05/01/11
Develop LHC-CC LLRF system design and validate	10 mons	Thu 06/01/11	Wed 12/10/11
M8: Development of LHC-CC LLRF Completed	**0 days**	**Wed 12/10/11**	**Wed 12/10/11**
Complete LHC-CC LLRF Design Report	6 mons	Mon 17/10/11	Fri 30/03/12
Deliverable 3: LHC-CC & CLIC-CC LLRF Design and Validation	**0 days**	**Sun 01/04/12**	**Sun 01/04/12**



WP10.3 Milestones and Deliverables

Output[1]	Description	Nature[2]	Delivery month[3]
M1	**LHC crab cavity specifications completed**	**R**	**M12**
M2	LHC model crab cavity completed	P	M24
M3	LHC coupler development finished	P/R	M33
M4	**CLIC crab cavity specifications completed**	**R**	**M12**
M5	CLIC model crab cavity completed	P	M24
M6	CLIC coupler development finished	P/R	M33
M7	Development of LHC LLRF system	P	M21
M8	Development of CLIC LLRF system	P	M30
D1	LHC crab cavity final report	R	M36
D2	CLIC crab cavity final report	R	M36
D3	LHC and CLIC LLRF final reports	R	M36

[1] M = Milestone, D = Deliverable
[2] Nature: R=Report, P=Prototype, D=Demonstrator, O=Other
[3] Counted from the starting date

http://cdsweb.cern.ch/collection/EuCARD

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.

Development of Crab Cavity Systems at the Cockcroft Institute, G Burt et al
- 51st ICFA Beam Dynamics Newsletter, April, 2010.

Novel Geometry for the LHC Crab Cavity, B Hall et al
- International Particle Accelerator Conference 2010, Kyoto, 2010.

Evolutionary Algorithms in the Design of RF Cavities, C Lingwood, et al
- International Particle Accelerator Conference 2010, Kyoto, 2010.

http://cdsweb.cern.ch/collection/EuCARD

Events

- EuCARD ACCNET workshop on LHC crab cavities, “LHC-CC09” at CERN, 16 – 18 Sept 2009.
- EuCARD SRF Annual Review 2010, at Cockcroft Institute, 7 – 9 April 2009.
- **ICFA Beam Dynamics Mini-Workshop on Deflecting/Crabbing Cavity Applications in Accelerators, at Cockcroft Institute, 1 – 3 September 2010.**
- ICFA Beam Dynamics Mini-Workshop on X-Band RF Structures, Beam Dynamics and Sources, at Cockcroft Institute, 30 Nov – 3 Dec 2010.
- EuCARD ACCNET workshop on LHC Crab Cavities, “LHC-CC10” at CERN, 15 – 17 Dec 2010.

Conclusions

- EUCARD collaboration team working well.
- LHC-CC priority at CERN raised considerably.
- Both LHC-CC (phase-I and phase-II) and CLIC-CC solutions identified and prototypes under development.
- Synchronisation and RF control requirements for each CC system are extremely challenging:
  - Solutions being proposed and investigated.
- Various talks identified will provide more details.