Session VI: Cryomodule Construction Summary

Peter McIntosh (STFC)

LHC-CC09 CERN, 16th – 18th Sept, 2009

Session: Thurs. 17th Sept, 10:35–12:15

10:35 Cavity Fabrication & Testing (20')

- Ilan Ben-Zvi (*Brookhaven National Laboratory*) ,
  Michael Cole (*Advanced Energy Systems*) Cavity SBIR and time line, engineering design, tooling, procurement, fabrication, e-beam welding, tuning, coupler ports, interfaces, Helium vessel, cavity treatment and testing options, impact based on down selection

10:55 Cavity-Coupler Treatment & Testing (20')

- Kota Nakanishi (*KEK*) Buffer chemical polishing and electro-polishing options, baking and high pressure rinsing, clean rooms, vertical test facility for 800 MHz crab cavities, high power RF, instrumentation and high gradient performance

11:15 Cryomodule Assembly & Test Stand (20')

- Pierre Maesen (*CERN*) Cryomodule assembly options at CERN, test stand for low power and high power testing, high power RF availability, cryogenics, gradient performance in horizontal cryostat, mechanical and transport issues

11:35 Discussion, CM Preparation & Cavity Down selection (40')

Prototype Cavity Fabrication and Test – I Ben-Zvi (BNL)

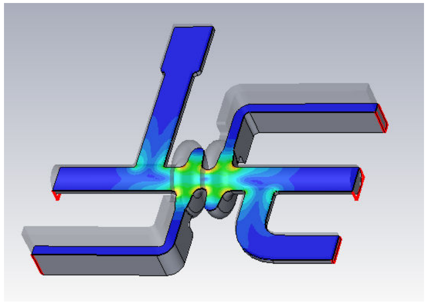
- SBIR Collaborators are AES, BNL, LBL, and SLAC
- Phase 1 - **APPROVED**
  - Preliminary Design of Cavity (3 man months supported by SBIR)
    - Coordinate transfer of Physics Design
    - Develop initial mechanical solid model
    - Perform Initial Thermal and Structural Analysis
    - Preliminary Mechanical Design and Fabrication Feasibility Study
    - 8-9 months (13 man weeks), funding imminent!
- Phase 2 (based on successful ph1, award late 2010)
  - Complete mechanical design with supporting thermal/structural analysis.
  - Generate complete fabrication drawing package for the Crab Cavity.
  - Fabricate Prototype Crab Cavity
  - Perform BCP and HPR on Prototype Crab Cavity at AES if our facilities can accommodate it.
    - We anticipate that we will be able accommodate an 800 MHz elliptical crab cavity.
  - Support Crab Cavity VTF testing at BNL
  - 2-year programme, $750k max

Cavity Engineering Development

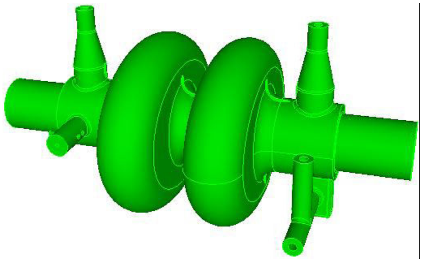
- Starting from the RF geometry developed from the physics and RF engineering efforts:
  - Driven by LHC-CC Down-selection process.
- AES will develop the cavity structure and RF volume solid models in Pro/Engineer.
- Design engineering will then develop approaches to cavity manufacturing and assembly:
  - Will involve the determination of the detailed parts that will be fabricated and the techniques used.
- Three dimensional finite element code ANSYS will be used for thermal analysis at 2 or 4K.
- A structural analysis will then be done to determine stress and displacement distributions.
  - Ensure the structure is within its material yield limit,
  - To determine structural frequencies.
- Displacement distribution then used to determine how the resonant frequency will vary from the temperature distribution.
- AES will fabricate the developed LHC-CC design (excluding couplers, cryostat, tuner etc)

Down-selection Impact

- Most critical issue is to make timely decision (now).
- A design which is complex but incorporates elements all of which have been done before may be superior (for fabrication) to a design which appears simpler but includes lots of "first of a kind" elements.
  - The UK design does look quite elegant as long as we can successfully get the irises in the cavity cells.



  - The LARP design does have more bits and pieces, but taken separately we have done them all before.



- At this point the LHC-CC strategy at CERN should drive the downselect.

AES Capabilities (for SBIR Phase 2)

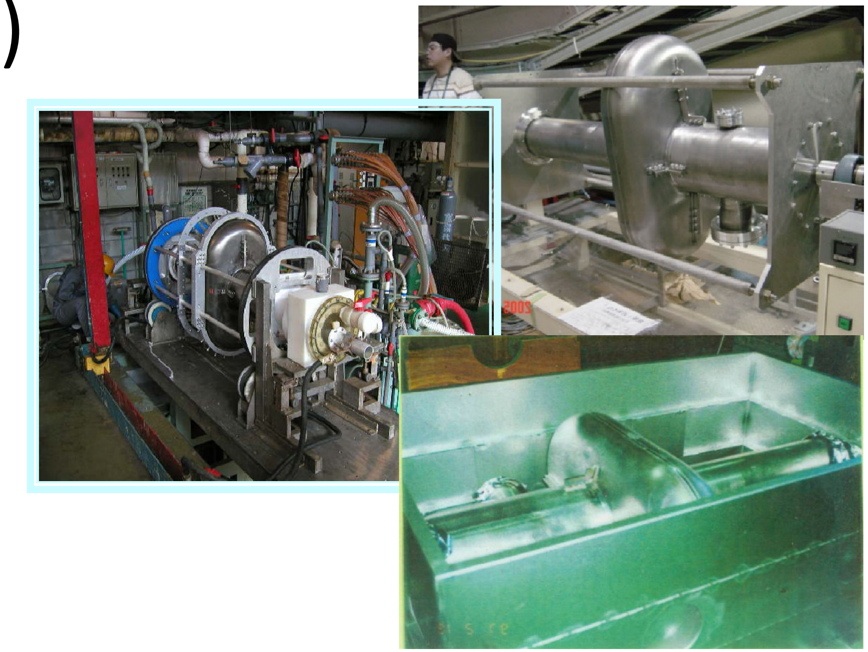
- AES fabricate complex cavity shapes with complex interfaces with waveguides and coaxial couplers.
- AES and BNL are currently installing a full cleaning facility at AES.
- Clean rooms, Extensive HPR, and BCP facilities are installed and being commissioned.
- Providing the cavity is compatible (likely) we will do the cavity processing at AES.

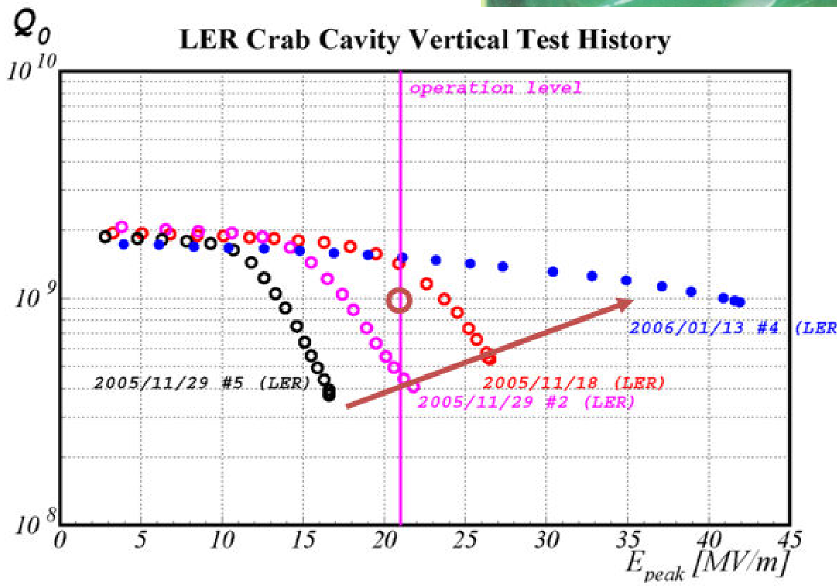
Fabrication

Infrastructure

Cavity-Coupler Treatment & Test – K Nakanishi (KEK)

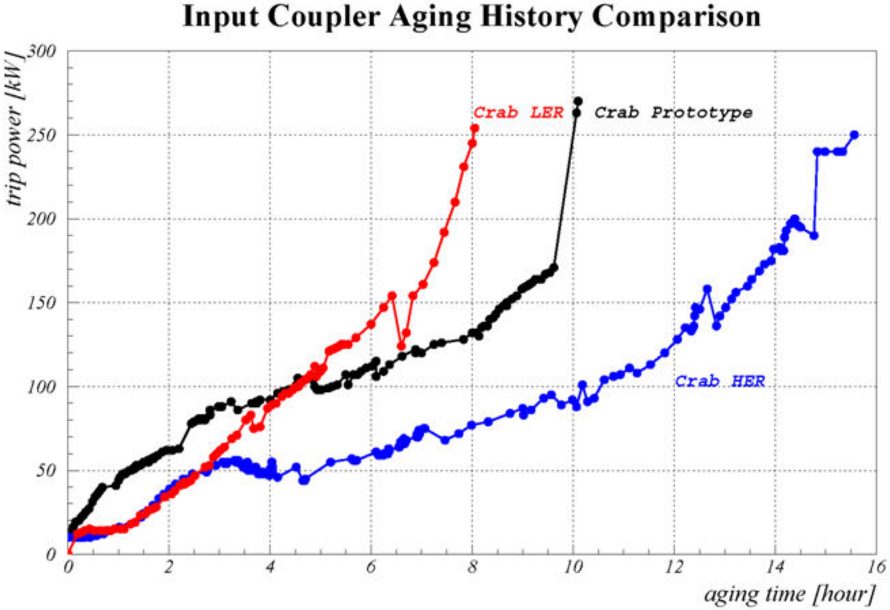
- Fabrication process described for the KEK-B crab cavity:
  - Barrel polishing
  - EP (100 μm and 5 μm)
  - Annealing
  - HPR
- Conditioned up to 250 kW TW and 200 kW SW (manually).
- 8 – 16 hours typically taken per coupler.





KEK-B Coupler Preparation

- KEKB-CC coupler developed from the accelerating cavity coupler.
- T-stub configuration incorporated
- Preparation:
  - Pure H_20 rinsing (0_3 water also)
  - N2 drying
  - Assembly
  - Baking (80C, indium seals)



Horizontal Tests

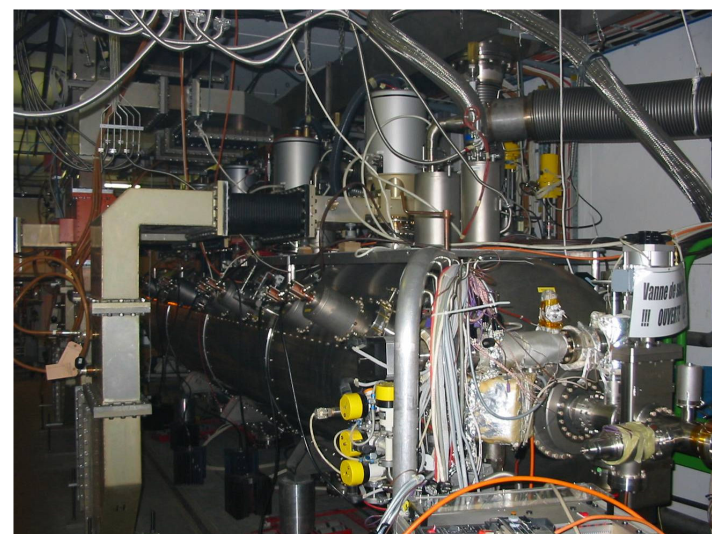
			Q_L		
	Input power	Observation	HER(Jun/2006)	HER(Nov/2006)	LER(Dec/2006)
RF power (1)	10kW	Band width	$1.59x10^5$	$1.66x10^5$	$1.86x10^5$
RF power (2)	20kW	Decay time	$1.66x10^5$	$1.34x10^5$	$2.07x10^5$
Simulation	(HFSS v9.2)			$1.66x10^5$	

	Achieved V_{kick}	Applied RF Power
HER	1.8MV	120 kW
LER	1.93MV	55kW

Q_0 and reachable V_{kick} were not deteriorated after assembling into the cryostat.

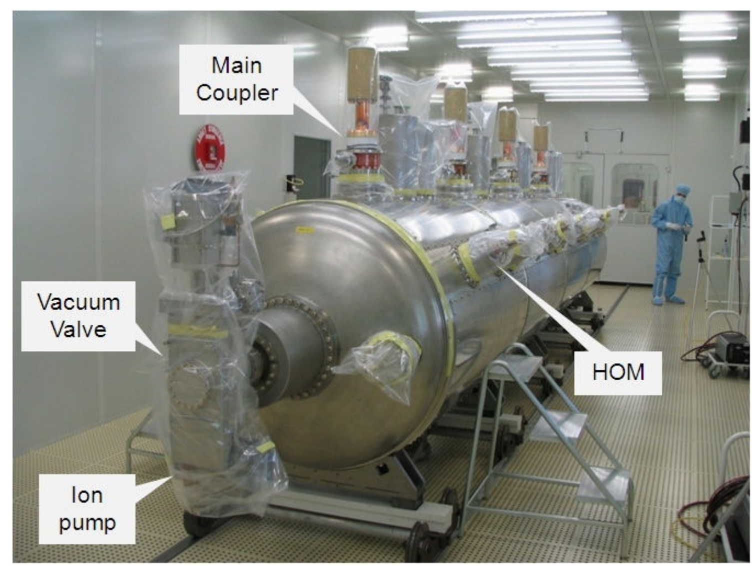
Possible Assembly and Test of LHC-CC in SM18 – P. Maesen (CERN)

- SM18 Configuration at present:
  - 2 x 15 meters grey-white room with rail
  - 1 canopy for pieces conditioning
  - 2 horizontal radiation-safe bunkers
    - First one fed by 352 MHz 300kW cw klystron
    - Second one fed by 400 MHz 300kW cw klystron
  - But :
    - Demin water capacity a bit short for parallel operation
    - Not equipped for 2 Kelvin
    - Limited Cryogens availability



Cavity and CM Transport

- Critical issue:
  - Transport from pumping after last cavity rinsing under vacuum.
  - Need to develop a bogie system for the LHC-CC cryomodule assembly in clean room.
- Based upon LHC RF CM experience.
- Transfer from SM18 to PT4 at low speed with G shock logging system.



Cryogens Availability

- Cryo operation became difficult with ageing ABB control interface and ageing instrumentation…
- As:
  - Share the He distribution with the LHC magnet test stand (2000 elements in machine)!
  - Since spring 2007 the SM18 cryo-plant capacity went down to 22 g/sec
  - Old RF transfer line consumes already 8 g/sec…
- There is a limited cryogens availability for SC serial tests!
- Cryoplant requires upgrade if 2K operation required for LHC-CC tests.

Other Constraints

- Need to buy and install an 800 MHz 60 kW cw RF amplifier beside the 400 MHz klystron.
- The 352 MHz bunker will be modified into pulse mode to be used for Linac4 and SPL study at 704 MHz:
  - Upgraded cryogenics included!
- The 400 MHz test stand must be kept in good shape for the LHC life time!
- LHC-CC cryomodule tests would have to share the LHC horizontal test stand -> for discussion!

Down-selection Discussion I

- What are the design specifications for the LHC-CC?
  - Beam dynamics, impedance .. etc
  - Space availability
- What are the fundamental goals for the Phase-I CC test?
  - Should not perturb LHC operation (demonstrate transparency)
  - Feasibility of crab-crossing in LHC.
  - With KEK-B now demonstrating Lumi increase:
    - Impedance, noise, collimation and Lumi levelling are more important demonstrations.
- Do we have to demonstrate ~10% Lumi increase in Phase-I test?
  - Could use KEK-B CC in SPS for Phase-I test.
  - Could then focus design effort on Phase-II (compact) CC design.
- EUCARD, US-LARP, SBIR (Ben-Zvi) and STTR (Delayen) funding available now:
  - Must focus effort/funding on a common strategy, driven by the down-selection process.
  - Can't afford to wait!
- Need CERN clarification for:
  - Capture cavity utilisation $\Rightarrow$ impact on Phase-I tests

Down-selection Discussion II

- Can compact CC go into LHC without a phase-I beam test on LHC?
  - If not then ph-I test in 2014 is a priority …. Looks extremely difficult!
- What verification tests can be performed elsewhere (SPS, Tevatron, KEK-B)?
  - Limited opportunity on KEK-B
  - Tevatron closing in 2011
- Compact designs are not at the stage for down-selection:
  - Need a definite spec for this design (apertures, beamline spacing)
  - Multipactor studies have not yet started.
  - Must not forget beam dynamics issues.
  - Timescales for possible tests of compact CC on LHC cannot match 2014 IR upgrade
- **Consensus**:
  1. Phase II Lumi upgrade using CC's is priority.
  2. Test of final CC in LHC is fundamental requirement.
  3. The best R&D approach would be 2-yr design study for compact CC and 3-yr engineering/fabrication/RF test phase, ready for LHC beam test.
  4. Focus CC design on compact structure.
  5. Elliptical CC development put on hold.
  6. Determine dedicated location for CC installation for both **test** and final location.
  7. Preparation for such a test in LHC should be made during LHC IR ph-I upgrade.
  8. Explore opportunity for CC tests at SPS, Tevatron (costs etc)
     - Determine benefits, Assess risks
     - NC prototype in SPS?!?