Crab Cavities for the HL-LHC
Project Definition and Design Study

E. Ciapala, E. Jensen, J. Tuckmantel (CERN)
R. Calaga (BNL)

US-LARP CM15, November 2010, SLAC.

Crab Cavities for the HL-LHC

- CM14 conclusions
- HL-LHC and Crab Cavities
- FP7 HL-LHC Design Study
- WP-4 Planning, Tasks, Deliverables and Milestones
- Conclusions

CM14 Conclusions - Fermilab April 2010

- IR upgrade Phases 1 & 2 may now become a single upgrade
- Crab cavities offer significant luminosity improvement, without intensity increase, important issue for LHC and the whole injector chain.
- "Highly speculative" but needs to be pursued vigorously

- **CC Work an integral & essential part of the upgrade study** (Task Force)

- **Baseline is compact cavities** with **elliptical as back up** for proof of principle with studies in SPS at an early stage

- Several challenges identified in key areas:
  Beam issues, machine protection, SC technology…..

- **A dedicated meeting on CCs followed the CM14 meeting**
  (Technical Issues, project structuring & defintion)

MOTIVATION:

- LHC has now reached nearly **2.0×10^{32} cm^{-2}s^{-1}**, (400 bunches on 400) exceeding the goal of **10^{32} cm^{-2}s^{-1} by end 2010**, and anticipating a total integrated luminosity of > **1 fb^{-1} by end of 2011** (**50 pb^{-1}** achieved to date)
- Push towards 7 TeV after 2012 shutdown and consolidation
- After reaching nominal parameters the challenge is to aggressively pursue the experimental goal of **3000 fb^{-1}**.
- This can only be achieved with an LHC upgrade **HL-LHC** that can reach beyond the ultimate intensities, with β^* well below the nominal and having a means to do luminosity leveling through the coast.
- The IR upgrade will use Nb_3Sn magnets at 13-15 Tesla, β^* down towards 22 cm.

- => Compensation of beam crossing angle and luminosity leveling **essential**.
- **Crab Cavities are the preferred choice…**

LHC Luminosity Upgrade – HL-LHC

- HL-LHC *is one of CERN's major projects for the future, along with:*
- LHC and Injector consolidation,
- Injector intensity upgrade (LIU) and
- Future linear collider.

- HL-LHC Project leader Lucio Rossi / Oliver Bruning
- Overall HL-LHC project planning/costing in progress – FP7 HL-LHC Proposal
- **CERN BE-RF** takes responsibility **for CC activities**, a **major project** in itself. (E. Ciapala/E. Jensen)
- A very large part of the CC effort - study, design and technical, already comes and needs to continue come from **outside partners**.

$\Rightarrow$ Strong participation already from **US-LARP**, Cockroft Institute, and others..

Crab Cavities for the HL-LHC

- **Overall CC project document** outlining the strategy, the planning, milestones, breakdown of activities and the costing is in preparation.

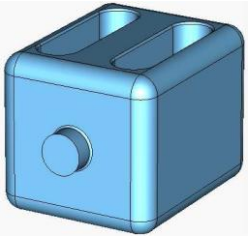
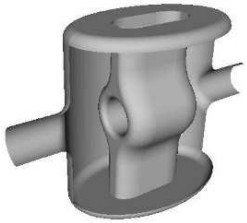
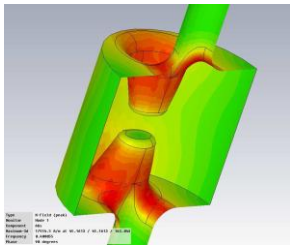
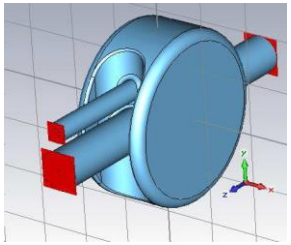
- Mission Statements on **HL-LHC** and on **Crab Cavities** have been sent to US DoE

- An FP7 HL-LHC Design Study Proposal (Mid 2011 to Mid 2015) has been sent to Brussels – This an initial draft proposal.

- Crab Cavity is Work Package 4 in the overall project

- Discussions with partners ongoing

Strategy & Planning for Crab Cavities

Main Goal : Compact Crab Cavities for LHC Local Scheme
(Following CC09 workshop recommendation)

Four Stages:

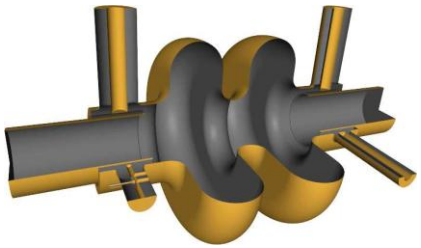
- Complete conceptual designs of the main candidates
- Down-select to at least two designs, with full spec. and mechanical drawings of the cavities. Conceptual designs for tuner and He tank, the SOM,HOM and LOM coupler and the cryostat.
- Hardware prototyping and test on above, tooling, construction of prototype bare cavities prototypes, surface treatments and tests to confirm gradient and performance
- Do full technical design of the complete CC cryomodule

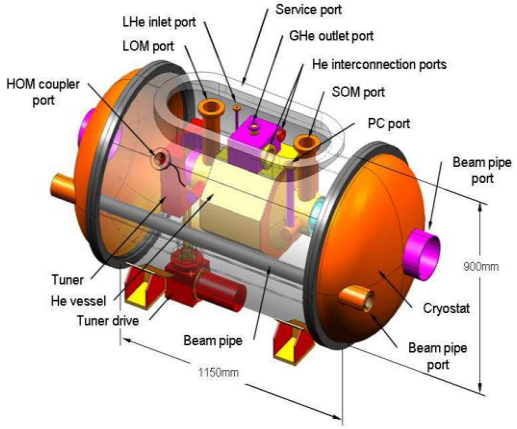
Back-up strategy for Crab Cavities

Retain a conventional cavity option in the unlikely event of major unforeseen 'show stopper' with all compacts…

- Would entail significant civil engineering costs and use of dogleg sections in the IRs, but this would still be acceptable, in view of the importance gaining back luminosity from the crossing angle.

- A straightforward conventional cavity installation in IR 4 as a global scheme would serve as an alternate option in the worst case. To this end, for the TDR, a full mechanical design of the elliptical cavity, its accessories and the elliptical cavity cryostat is also envisaged.



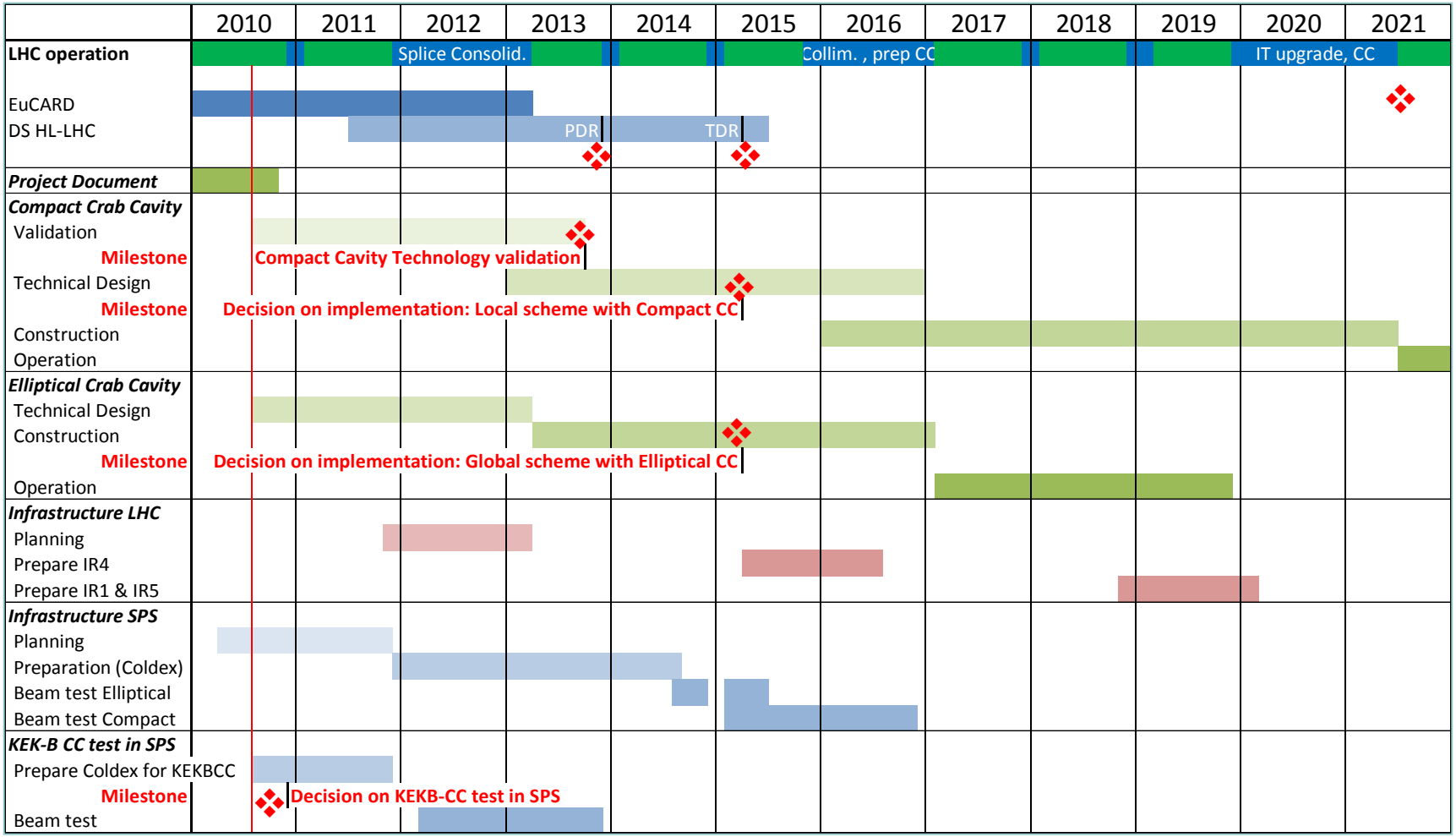


LHC and Luminosity Upgrade

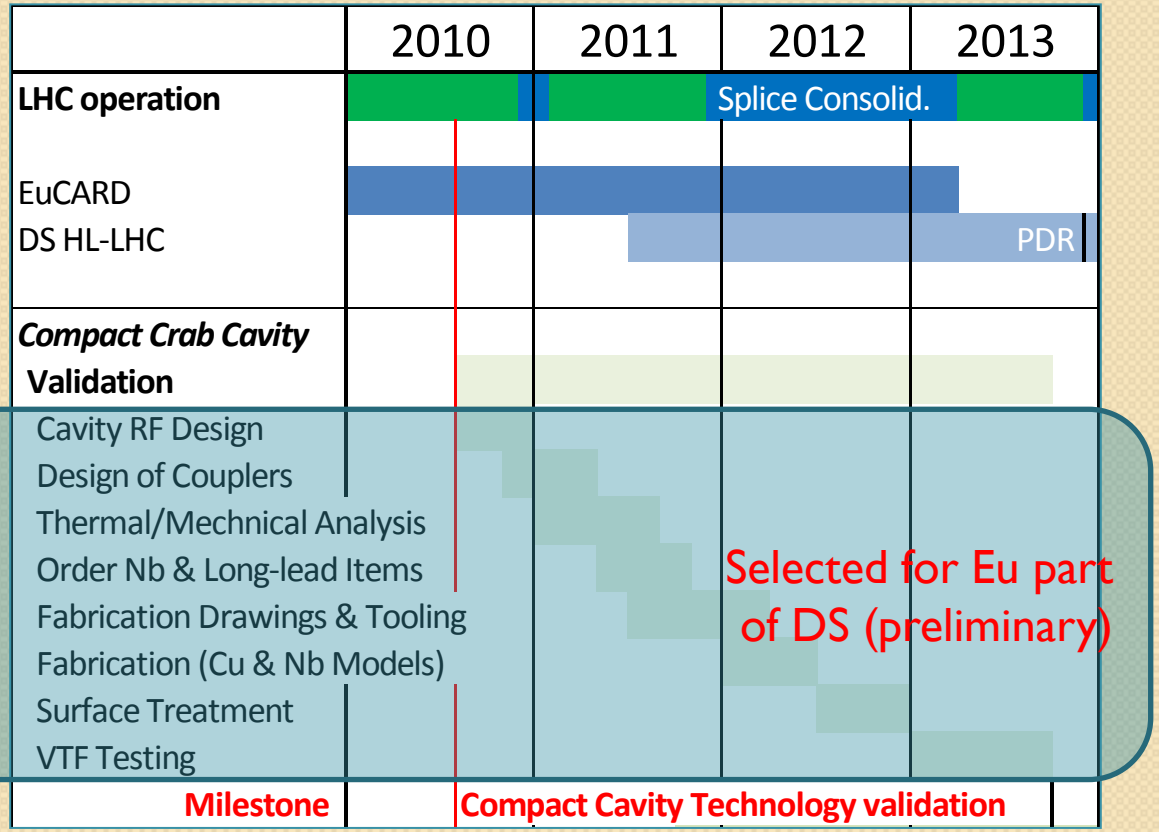
- Major shutdowns 2016 and 2020/21 (preparation & actual installation)

Crab Cavities for HL-LHC – Planning

Overall schedule of the crab cavity project synchronized with the expected LHC operation schedule and the HL-LHC project proposal.

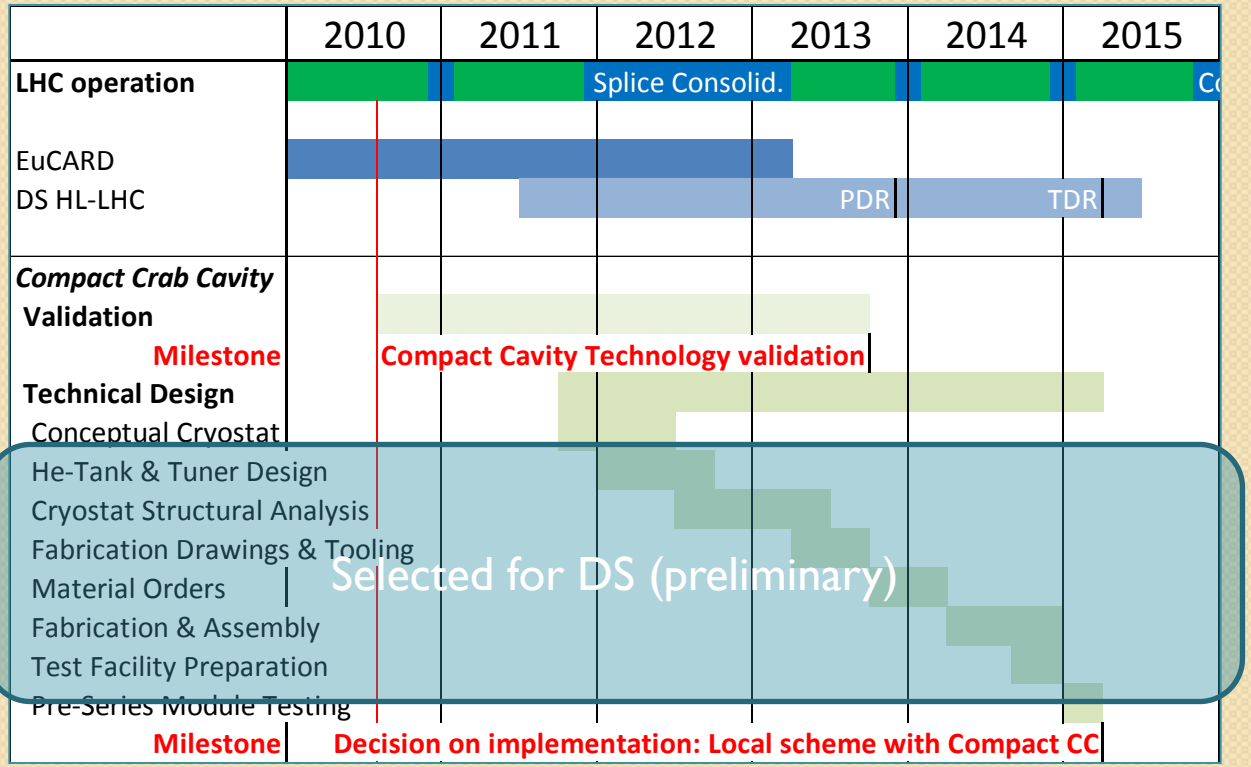


Compact CC Validation



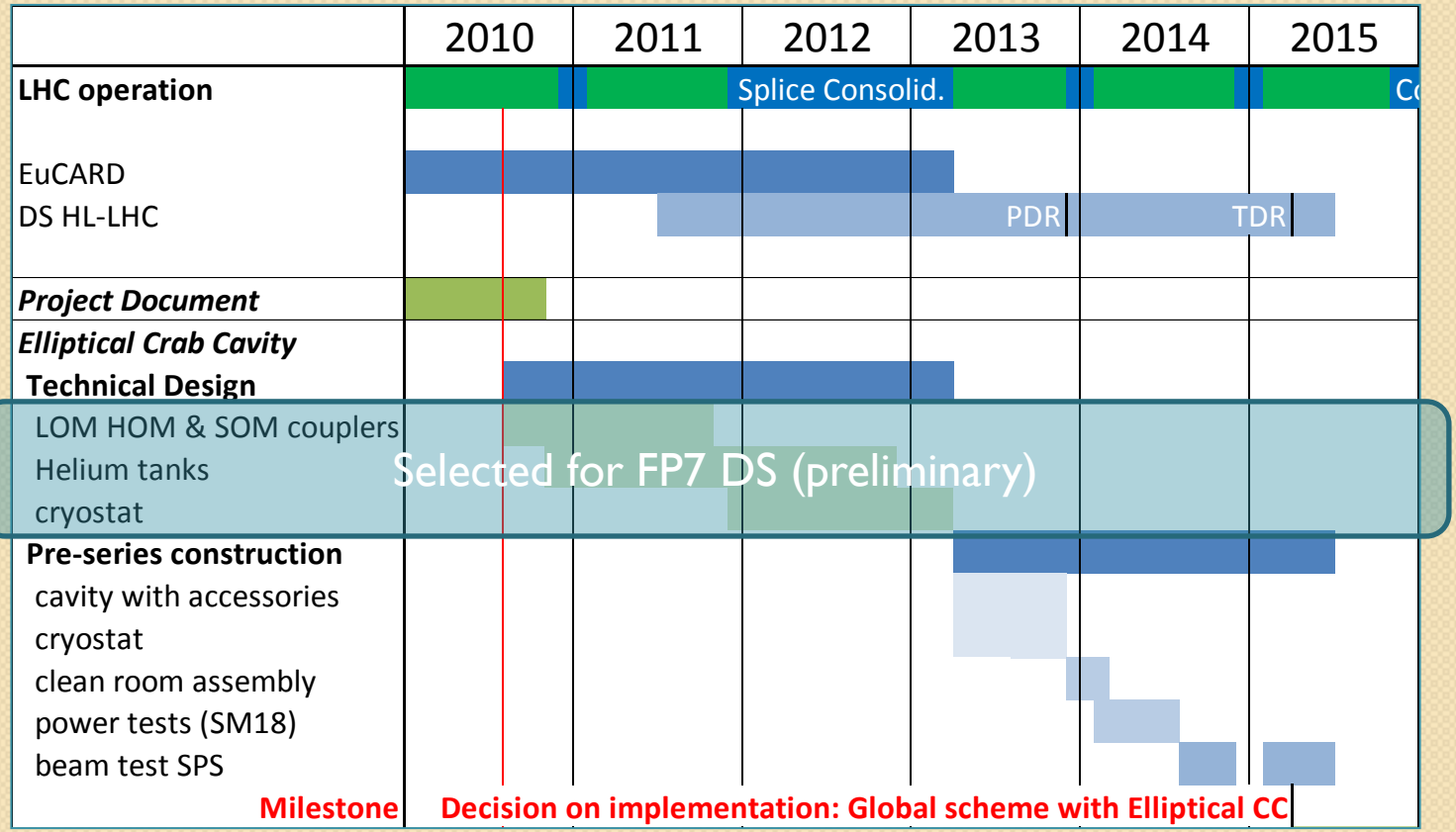
❖ **For PDR 2013**

Compact CC Technical Design



❖ **For TDR 2015**

Elliptical CC Technical Design



❖

For TDR 2015

WP4: Prelim. Tasks List (2nd draft)

Task 4.1: Coordination and Communication • Coordination and scheduling of the WP tasks • Monitoring the work, informing the project management and participants within the JRA • WP budget follow-up	CERN, LARP, ULANC
Task 4.2: Support studies • Tunnel preparation SPS and LHC • Local IR layout and spatial integration • Effect of phase noise , LLRF system conceptual design • RF power system specification • Operational aspects (how to commission/make invisible) • Interlocks and fast Feedback	CERN, KEK, LARP
Task 4.3: Compact Crab Cavity design • Complete cavity and cryomodule specifications • Design optimisation for novel schemes • Conceptual design of SOM, HOM and LOM couplers • Conceptual design of helium tank and cryostat • Multipacting simulations on cavity & couplers • FEM simulations: mechanical & thermal aspects • Initial down-selection of the CC options • Completion of a full technical design on the initial down-selected options, with mechanical drawings and specification. • Design of tooling, dies and cavity fabrication equipment	ULANC, LARP, CERN, JLAB

WP4: Prelim Tasks List (2nd draft)

Task 4.4: Elliptical Crab Cavity Technical design • Coupler development and testing • Tuner design and mock up on copper models • Study of mechanical effects: resonances, microphonics. • Cavity performance with couplers and horizontal cryostat • Performance difference between 2 K & 4 K • Cryostat and He Tank Design • Complete the full technical design	CERN, CEA, CNRS, KEK
Task 4.5: Compact Crab Cavity Prototyping and Test • Procurement /fabrication of tooling, dies and equipment. • Construction of models to refine manufacturing techniques and tooling. • Fabrication of prototype niobium cavity • Cleaning and electro-polishing on the bare niobium cavity. (i.e. no couplers, antennas or other accessories), including cavity surface inspection. • Development and procurement of all test equipment and instrumentation. • Low power tests and measurements on the bare cavity in a test cryostat to test for compliance with design gradient and cavity performance specs. • Make the final CC design down-selection	CERN, CEA, CNRS, ULANC, STFC, LARP

Deliverables and Milestones

Deliverables of tasks	Description/title	Nature	Delivery month
1	Valid proposal on handling machine protection issues		6
2	Valid proposal on ensuring an acceptable minimum of perturbation to normal LHC operation		18
3	Specification documents on conceptual design of High Power and Low Level RF systems.		24
4	Integration drawings for SPS and LHC CC installations		
5	Conceptual design of SOM, HOM and LOM couplers		24
6	Conceptual design of He tank and cryostat for CCs		24
7	**Preliminary Design Report (PDR)**		28
8	Technical design of a complete elliptical cavity in its cryostat with ancillaries		40
9	**Technical Design Report (TDR)**	TDR	48

Milestone	Description/title	Nature	Delivery mo (appr.)	Comment
1	**Machine protection concerns satisfied**		6	
2	**Operating scenario during LHC ramping specified**		12	
3	**CC Technology validation**		24	For PDR (W28 - Nov 2013)
4	**Completion of technical design of elliptical cavity in its cryostat**		40	For TDR (W48 - Mid 2015)
5	**Decision – Local or Global**		40	For TDR (W48 - Mid 2015)

For Eu proposal deliverables will have to be revised! (# activities, cost, outside scope..)

First estimate on man-power:

... will have to be revised!

Work package number	WP4		**Start date or starting event:**			M1	
Work Package title	Crab Cavity Design						
Activity type	RTD						
Participant id	**CERN**	**ULANC**	CEA	CNRS	STFC	BNL	FNAL	JLAB
Person-months per beneficiary:	153	91.8	25.2	60	28.8	30.6	43.8	76.2
Participant id	LBNL	SLAC	KEK					
Person-months per beneficiary:	10.8	78.6	82.2					

Show Excel: "Crab Cavities for LHC spending profile DS_Oct20.xlsx".

Potential Partners

Participant no. *	Participant organisation name	Short name	Country
1 (Coord-inator)	European Organization for Nuclear Research	CERN	IEIO
2	Commissariat à l'Énergie Atomique et aux énergies alternatives	CEA	France
3	Centre National de la Recherche Scientifique	CNRS	France
4	Stiftung Deutsches Elektronen-Synchrotron	DESY	Germany
5	Istituto Nazionale di Fisica Nucleare	INFN	Italy
6	Budker Institute of Nuclear Physics	BINP	Russia
7	Consejo Superior de Investigaciones Cientificas	CSIC	Spain
8	École Polytechnique Fédérale de Lausanne	EPFL	Switzerland
9	Royal Holloway, University of London	RHUL	UK
10	University of Southampton	SOTON	UK
11	Science & Technology Facilities Council	STFC	UK
12	University of Lancaster	ULANC	UK
13	University of Liverpool	UNILIV	UK
14	University of Manchester	UNIMAN	UK
15	High Energy Accelerator Research Organization	KEK	Japan
16	Brookhaven National Laboratory	BNL	USA
17	Fermi National Accelerator Laboratory (Fermilab)	FNAL	USA
18	Lawrence Berkeley National Laboratory	LBNL	USA
19	Old Dominion University	ODU	USA
20	SLAC National Accelerator Laboratory	SLAC	USA
21	University of Florida	UFL	USA

US LARP Collaboration

Looking Beyond - Production of CCs

⇒ **A substantial program involving:**

- Completion of specifications for cavity production, couplers, cryostats and other components,
- Launching series production of cavities, couplers and other cavity components,
- Launching series production of cryostats,
- Launching series production of RF and power equipment,
- Successful low power testing of series bare cavities,
- Completion of clean room assembly of series cavities and their ancillaries in their cryostats,
- Successful power testing of the completed series cryomodules in the dedicated test stand,
- Test in SPS of a completed CC cryomodule.

Other systems:

- RF SYSTEM – RF POWER, LLRF
- CRYOGENICS
- CONTROLS

Conclusions & Outlook – LHC crab cavities

- Main objective for LHC is full local scheme with compact cavities
- 'Conventional' SC Cavity 800 MHz is retained as an option.
- Crab Cavity work firmly implanted in the HL-LHC project
- Project breakdown, planning and costing in preparation
- CCs are in the EuCARD HL-LHC Design Proposal as WP 4
- DS Scope to include prototyping of novel CCs
- Resources to be allocated by CERN, EU and partners, hopefully including LARP
- Request for DoE support initiated
- Resources now to be negotiated in US context

- **Feedback from US partners needed in defining specific contributions and support for the different tasks, within LARP.**

- **Working together to get DoE support for US colleagues in hardware prototyping and beyond the design stage proper**.

Thanks for your attention

CC presentations at CM15

Crab Status & Plans - Rama Calaga
HWSR Cavity Development - Z enghai Li
Crab SPS Studies – Hyung Jin KIM

NOTE: LHC Crab Cavity workshop CC10
CERN, December 2010