HL-LHC Crab Cavity Review

Introduction and Overview

O. Brüning

CERN, 19 June 2019

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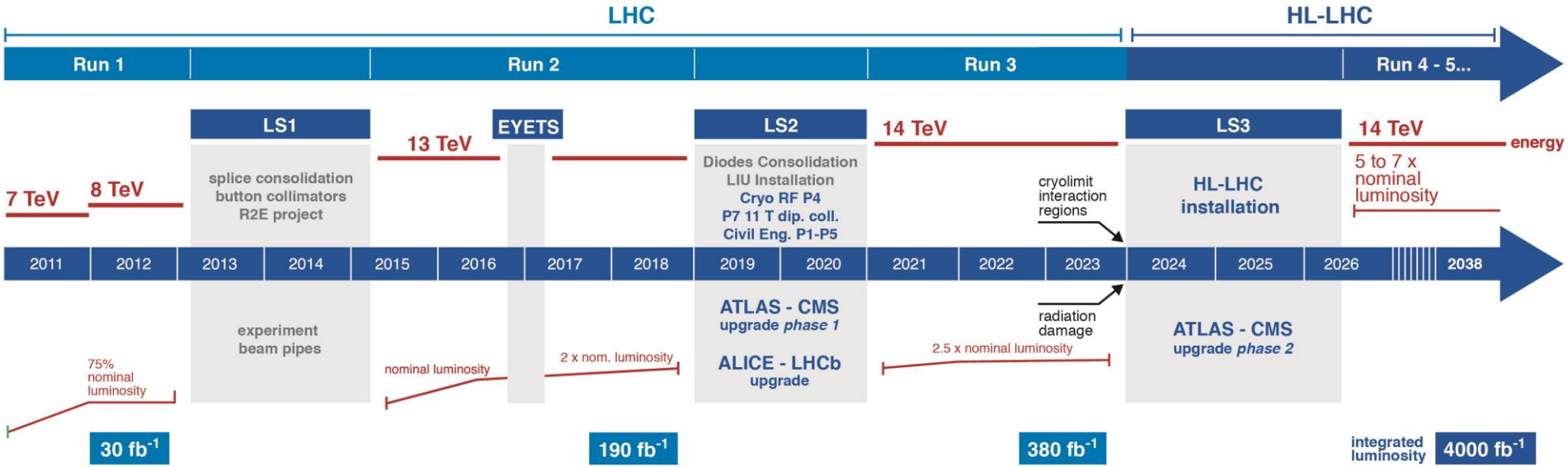
The project management calls this review to assess if the present design of the cavities with their cryomodules and all ancillaries is adequate to meet the required performance and if the production plan is well harmonized with due margin (considering the complex scheme with many in-kinds) in the HL-LHC schedule.

Review Panel members: Akira Yamamoto (Chair, CERN), Edward Daly (JLAB), Carlo Pagani (INFN), Sébastien Bousson (IN2P3) and Delio Duarte Ramos (CERN).

Review link persons: R. Calaga (CERN), T. Jones (UK-STFC), B. Laxdal (TRIUMF), L. Ristori (US-AUP)

LHC / HL-LHC Plan



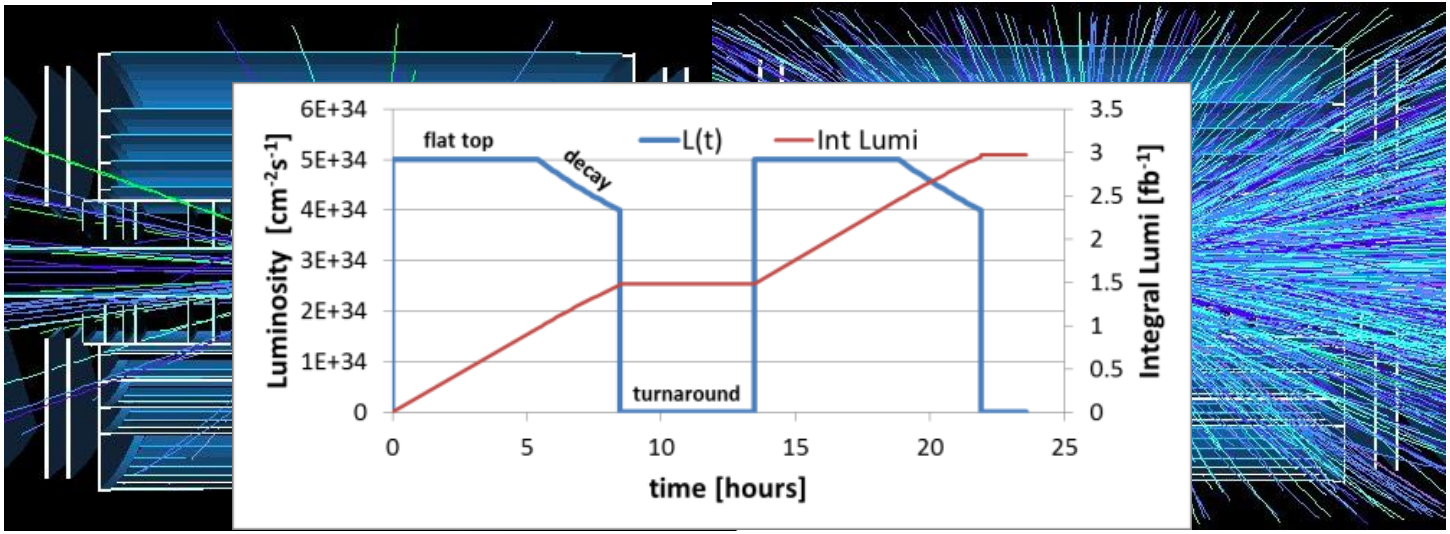
HL-LHC TECHNICAL EQUIPMENT:

DESIGN STUDY	PROTOTYPES	CONSTRUCTION	INSTALLATION & COMM.	PHYSICS

HL-LHC CIVIL ENGINEER:

DEFINITION	EXCAVATION / BUILDINGS

Goal of High Luminosity LHC (HL-LHC):



implying an integrated luminosity of **250 fb^{-1} per year**,

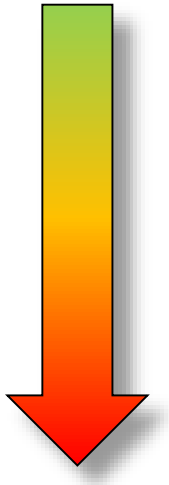
design oper. for μ δ **140** (➔ peak luminosity **5 10^{34} cm^{-2} s^{-1}**)

➔ Operation with levelled luminosity!

➔10x the luminosity reach of first 10 years of LHC operation!!

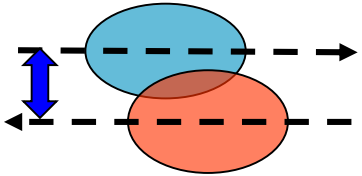
Luminosity Levelling

- In certain conditions and depending on the experiments request, it is desirable to adapt the luminosity dynamically with beams in collision – **levelling**
- Each levelling technique has its advantages and drawbacks

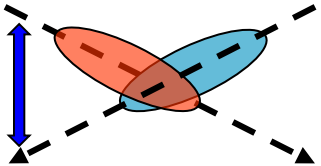


Complexity

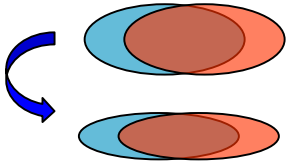
Levelling by beam offset / separation



Levelling by crossing angle



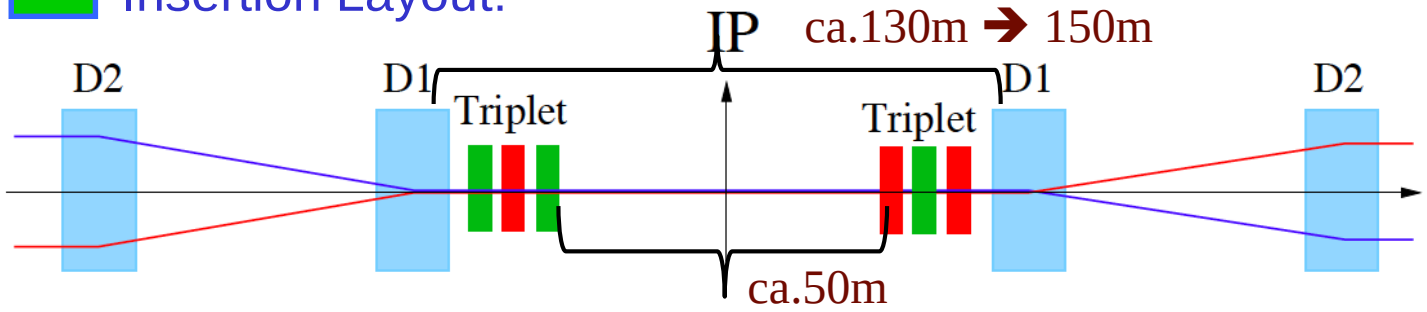
Levelling by β^* (= beam size at IP)



All levelling Options have been successfully demonstrated in LHC Run2!!!

Luminosity Optimization: Crossing Angle & Crab Cavities

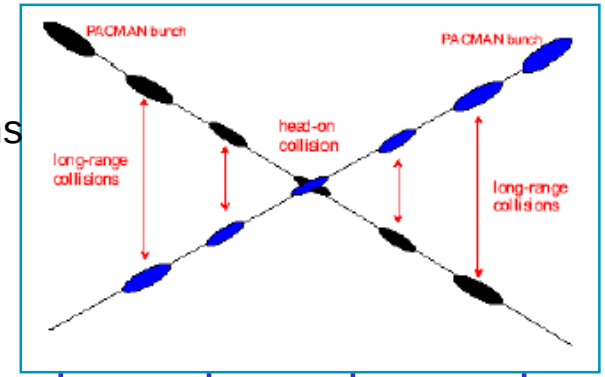
Insertion Layout:



Parasitic bunch encounters:

Operation with ca. 2800 bunches @ 25ns spacing ➔ approximately 30 unwanted collision per Interaction Region (IR).

➔ Operation requires crossing angle



non-linear fields from long-range beam-beam interaction:

efficient operation requires large beam separation at unwanted collision points ➔ Separation of 10 -12 σ ➔ luminosity reduction!!!

Luminosity Optimization: geometric reduction

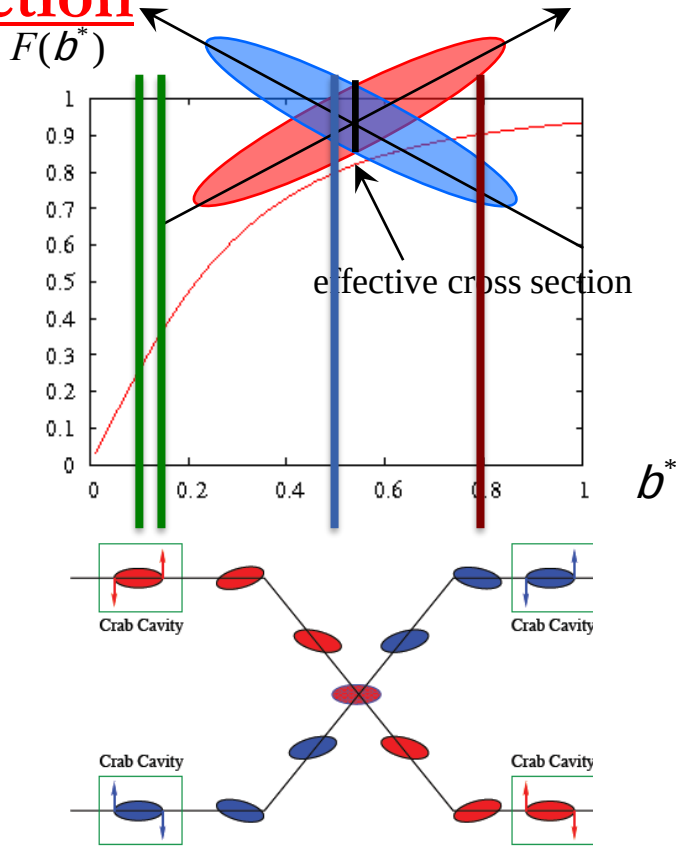
Crab Cavities: Geometric Luminosity Reduction Factor:

- Reduces the effect of geometrical reduction factor
- Independent for each IP

$$F = \frac{1}{\sqrt{1+Q^2}}; \quad Q = \frac{q_c s_z}{2 s_x}$$

- Challenging space constraints:

➔ requires novel compact cavity design



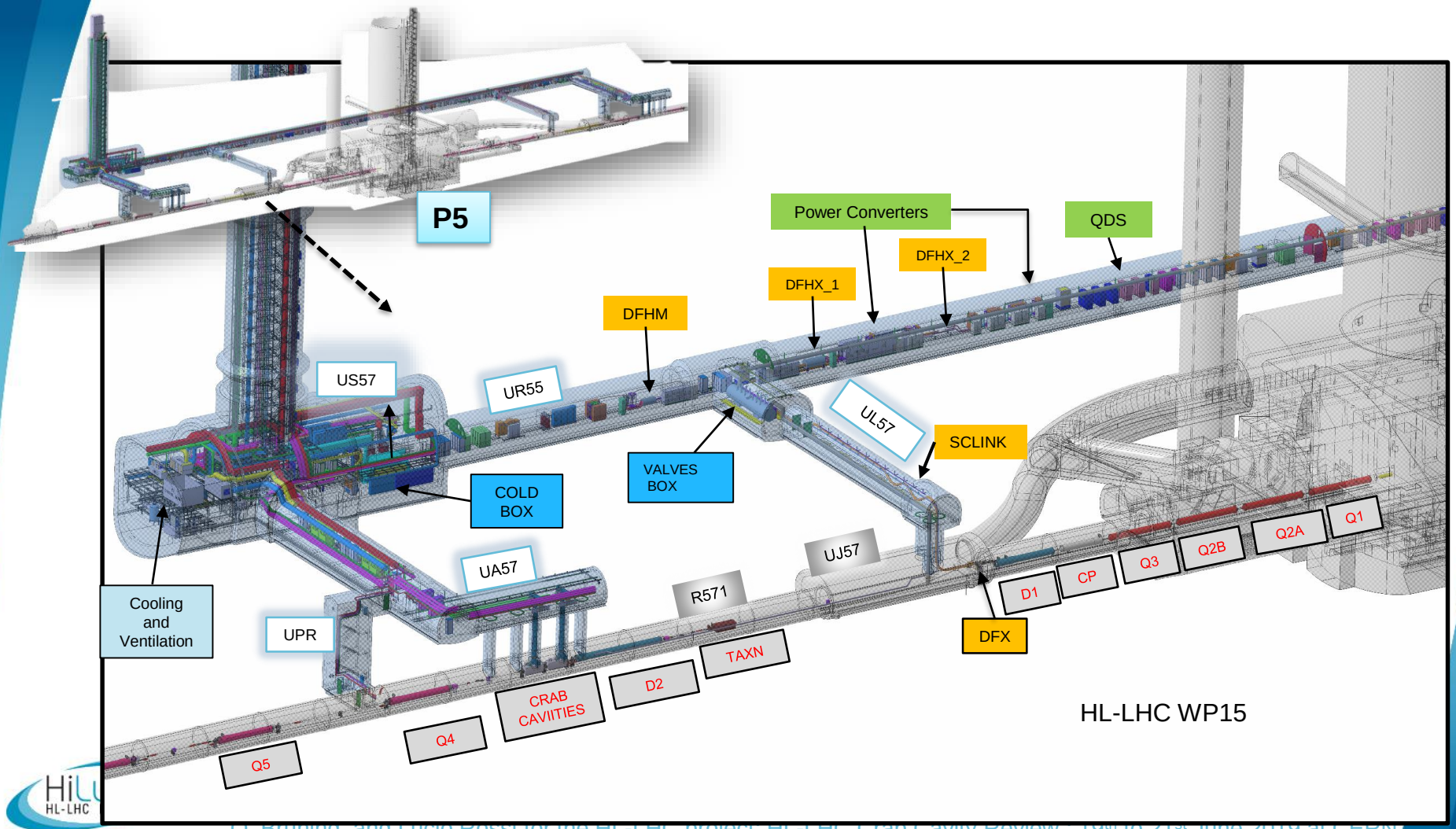
Crab Cavities Implementation for HL-LHC

HL-LHC baseline [after re-baselining in 2016]:

2 Crab Cavities in one cryostat on each side of the main Interaction Points per beam ➔ 8 Crab Cavities per IP
➔ 16 Crab Cavities in total

IP1: horizontal crossing angle and CC deflection
IP5: vertical crossing angle and CC deflection
➔ Two types of Crab Cavities [horizontal and vertical]

HL-LHC baseline: full overlap with CC and β^* levelling

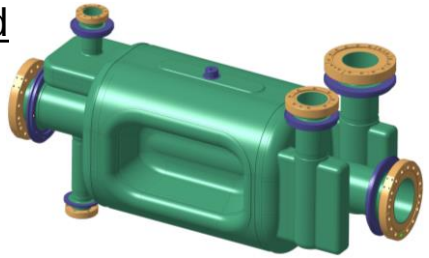

P5
Power Converters
QDS
DFHX_2
DFHX_1
DFHM
US57
UR55
UL57
SCLINK
VALVES BOX
COLD BOX
Cooling and Ventilation
UA57
UPR
R571
UJ57
DFX
D1
CP
Q3
Q2B
Q2A
Q1
TAXN
D2
CRAB CAVIITIES
Q4
Q5
HL-LHC WP15

HL-LHC cavity designs

Double Quarter Wave

2 Designs with
Different Coupler concepts and
Deflection planes

RF Dipole



$f_0 = 400$ MHz

$V_T = 3.4$ MV

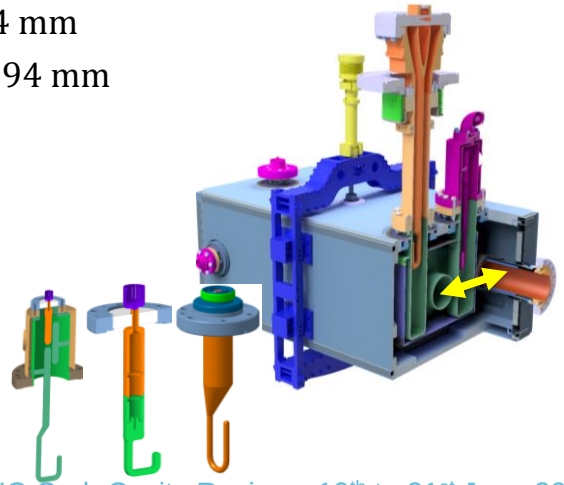
$(E_p, B_p < 40$ MV/m, 70 mT)

Beam aperture = 84 mm

Beam-to-beam dist = 194 mm

Common FPC

DQW crab-cavity
Cryomodule for
SPS tests



Crab cavity cryo-module for installation in the SPS

Magnetic shields from UK (UNILAN-CI)

String assembly completed Aug 18, 2017

Compact Crab Cavity: SPS Installation

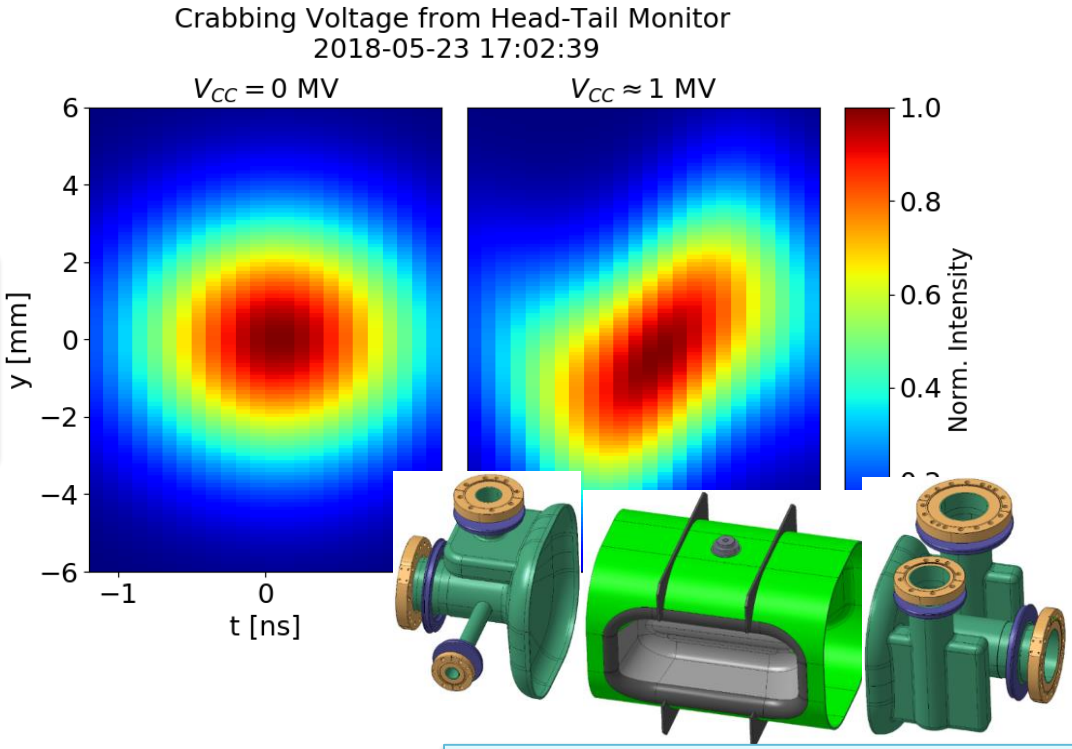
Commissioned in 2018 and now ready for operation with beam!!!

New SRF infrastructure in the SPS!!

First proton crabbing ever!

TEST in SPS ongoing since 2018

Study and R&D has been very useful to obtain this result



RFD proto: delayed design will not be installed in LS2

Multi-National Collaboration

- Cavity Design: US-LARP [SLAC, LBNL, BNL and FNAL], Lancaster, ODU, CERN
- Prototyping:

  DQW: Manchester, Liverpool, Lancaster, CERN &

  LARP-NIOWAVE [DOE-SBIR], [KEKB electro-polishing]

  RF-Dipole: LARP-NIOWAVE [DOE-SBIR], CERN, JLAB, ODU, FNAL-ANL
- Production:

  DQW: CERN, UK-STFC Lancaster & RI

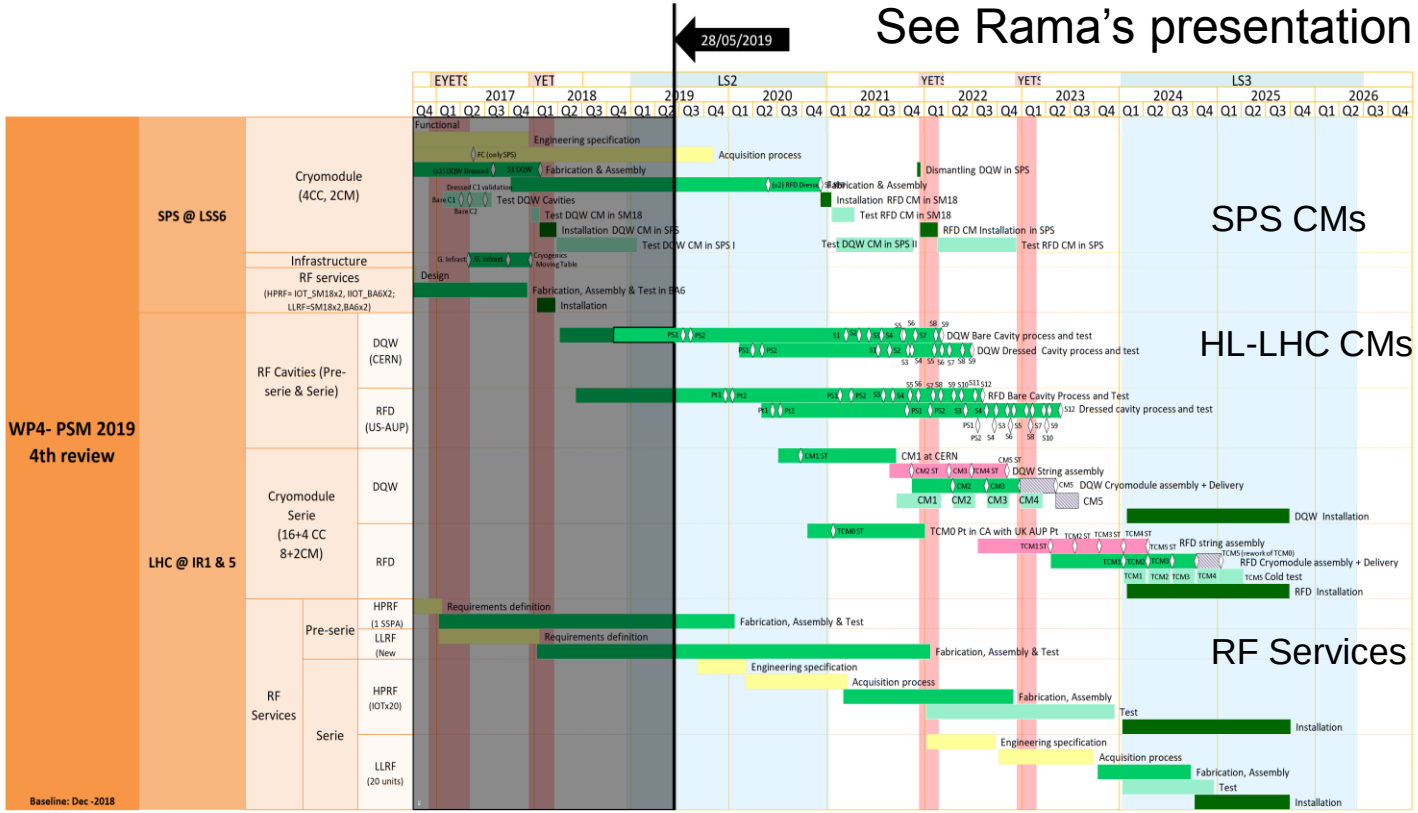
  RF-Dipole: CERN, AUP-FNAL, JLab, TRIUMF & Zanon
- Power: Solid State Power Sources: BINP Novosibirsk [Russia]

In-kind Contribution

- UK1 – RFD-Cryomodule prototype with CERN providing dressed cavities & partial components
- US-AUP – 10 RFD dressed cavities (He-tank, HOMs, Field Ant)
- UK2 – 4-DQW cryomodules with CERN providing dressed cavities & partial components [and CERN building 1 DQW CM]
- TRIUMF – 5-RFD cryomodules with US-AUP providing dressed cavities and CERN with partial components
- Novosibirsk – Proposal to provide SSPA amplifiers jointly with Russian industrial partner [special Russian contribution]

Masterplan

See Rama's presentation for details!



Review Goals

- Review of the CC System readiness for production

  -Pre-series will be launched in 2019 before we can finalize RF-Dipole tests in the SPS

  -Multi-National and Multi-Laboratory network for series production

  ➔ are all interfaces sufficiently defined and established?

- Future SPS test:

  -What is missing from the DQW SPS tests?

  -What should be the focus of the RF-Dipole tests in the SPS

- Reserve

Completion of the shaft excavation at Point 1

Shaft picture seen from the bottom

Reinforced concrete ring at the shaft end

Start of cavern excavation at Point 1

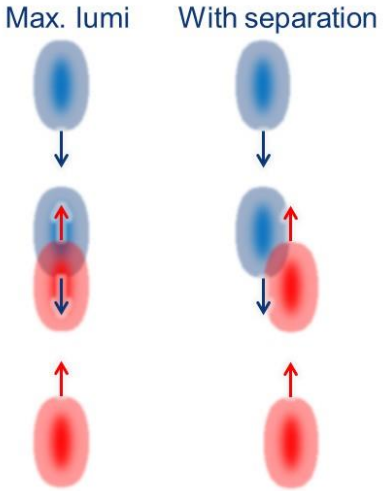
Hydrocarbon presence
(as expected)

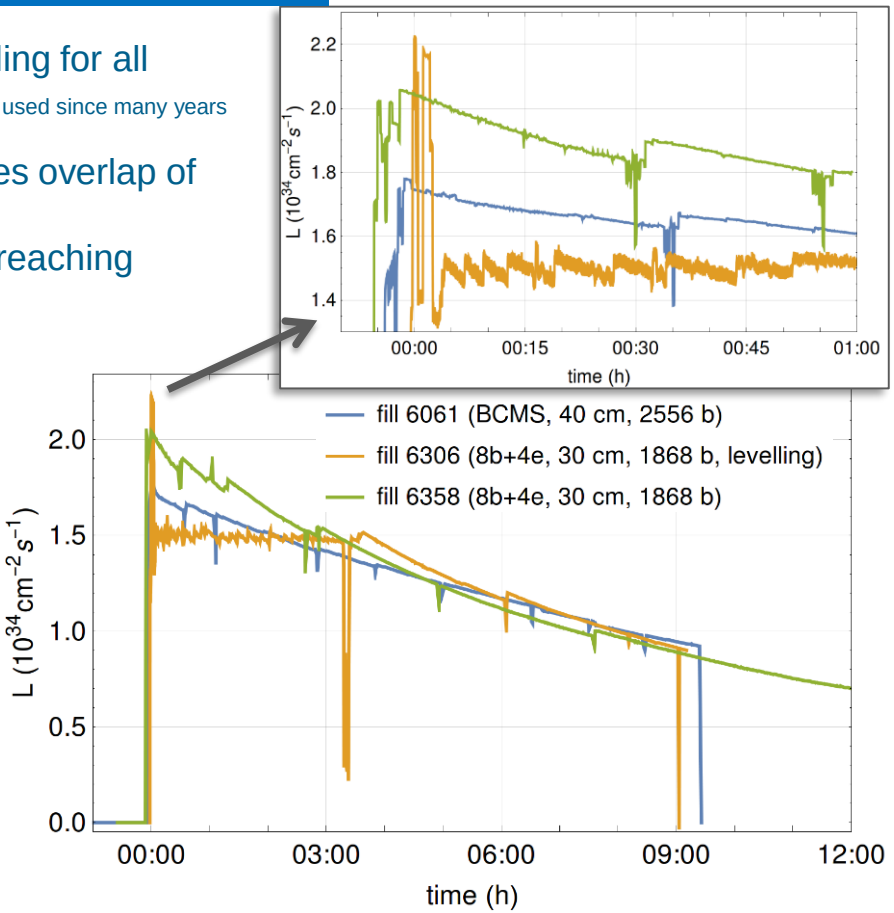
C.E. : so far so good with a few issues under control
Some necessary modification causes moderate extra-cost.

Panoramic view (08 Apr 19) - Contract T118 – CIB (P5)

LHC 2017 : separation levelling

- Introduced separation levelling for all experiments (Separation levelling is used since many years for ALICE and LHCb)
- Dynamic orbit bump changes overlap of colliding bunches
- Initial spike before leveling reaching $2.2\times10^{34}\,cm^{-2}s^{-1}$





International Review of the Crab Cavity system design and production plan for the HL-LHC

19-21 June 2019
CERN
Europe/Zurich timezone

Search...

Elodie Kurzen
elodie.kurzen@cern.ch
00.41.75.411.87.46

The CC system is a critical equipment in the HL-LHC project. Following the construction of the first HL-LHC CC cavities at CERN and in the US, and the crash program for the SPS DQW cavity cryomodule construction and installation in the new SPS facility, the first tests with proton beam in a CC were successfully achieved in the SPS during 2018. The final design of CC and the complete cryomodule is being finalized, both for DQW (double quarter wave) and RFD (RF Dipole) types, while the construction of a second complete cryomodule prototype (RFD type) is under construction by CERN and UK. The in-kind contribution from US-AUP (all dressed cavities of RFD type), UK-STFC and Lancaster U. (four DQW cryomodule assemblies) and Canada-Triumf (five RFD cryomodule assemblies) are agreed or in final negotiation stage. The construction of the DQW jacketed cavities by Industry for CERN is already under way.

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Date and Place: The review is scheduled from **19 June afternoon** to **21 June 2019** at CERN, room **774-R-013**.

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