High Luminosity LHC

HL-LHC: Where are we ? Where do we go ?

V. Baglin on behalf of WP12
CERN-TE-VSC
4-12-2015

The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.

Outline

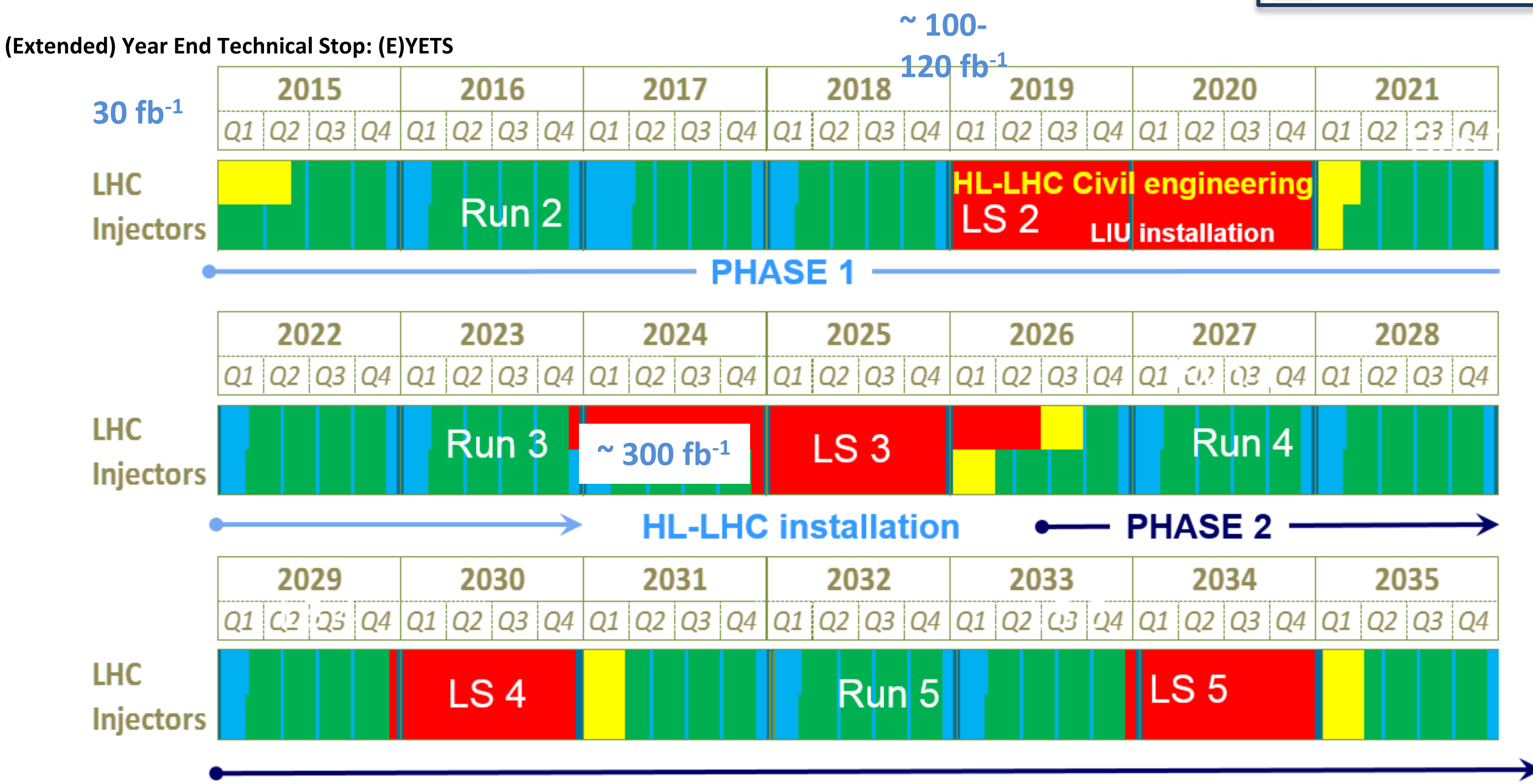
1. General Information
2. WP12: Vacuum
3. HL-LHC beam screens
4. Crab cavities
5. Collimation
6. Layout
7. LHCb request
8. Options
9. LS2 & LS3
10. Summary

1. General Information

New LHC roadmap: according to MTP 2016-2020

LS2	starting in 2019	=>	24 months + 3 months BC
LS3	LHC: starting in 2024	=>	30 months + 3 months BC
	Injectors: in 2025	=>	13 months + 3 months BC

- Physics
- Shutdown
- Beam commissioning
- Technical stop

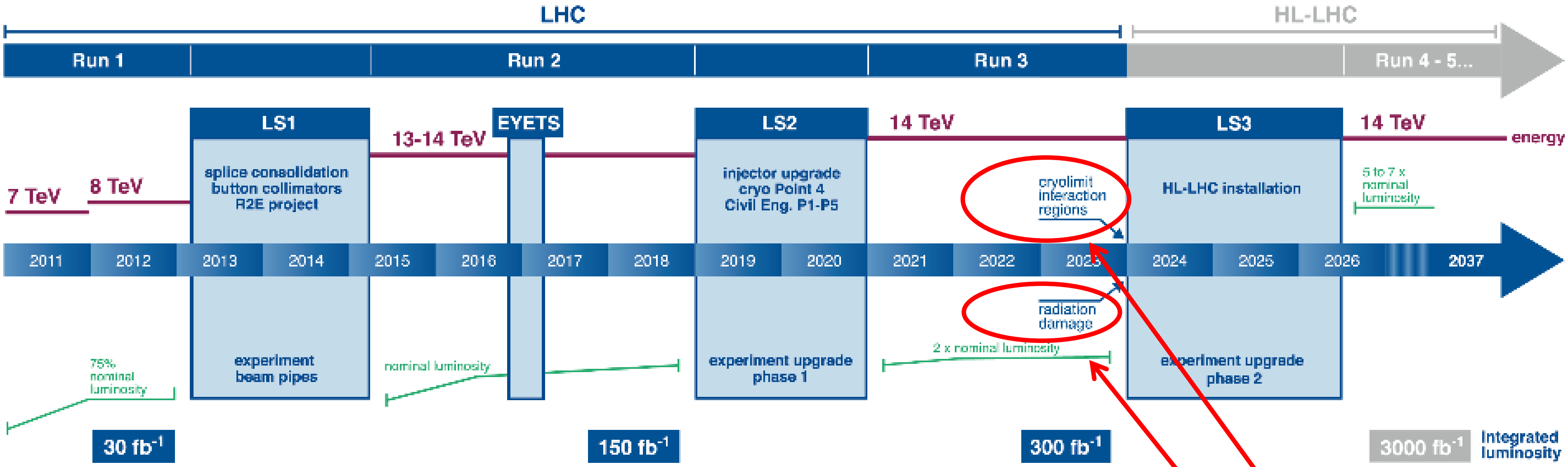


Goal of 3'000 fb^{-1} by mid 2030ies

F. Bordry

High Luminosity LHC

LHC / HL-LHC Plan



$0.75\ 10^{34}\ cm^{-2}s^{-1}$
50 ns bunch
high pile up ~40

$1.5\ 10^{34}\ cm^{-2}s^{-1}$
25 ns bunch
pile up ~40

$1.7\text{-}2.2\ 10^{34}\ cm^{-2}s^{-1}$
25 ns bunch
pile up ~60

Technical limits to lumi increase (Machine & Experiments)

50 $\Rightarrow$ 25 ns

L. Rossi

Goal of High Luminosity LHC (HL-LHC) as fixed in Nov. 2010

From FP7 HiLumi LHC Design Study application

The main objective of HiLumi LHC Design Study is to determine a hardware configuration and a set of beam parameters that will allow the LHC to reach the following targets:

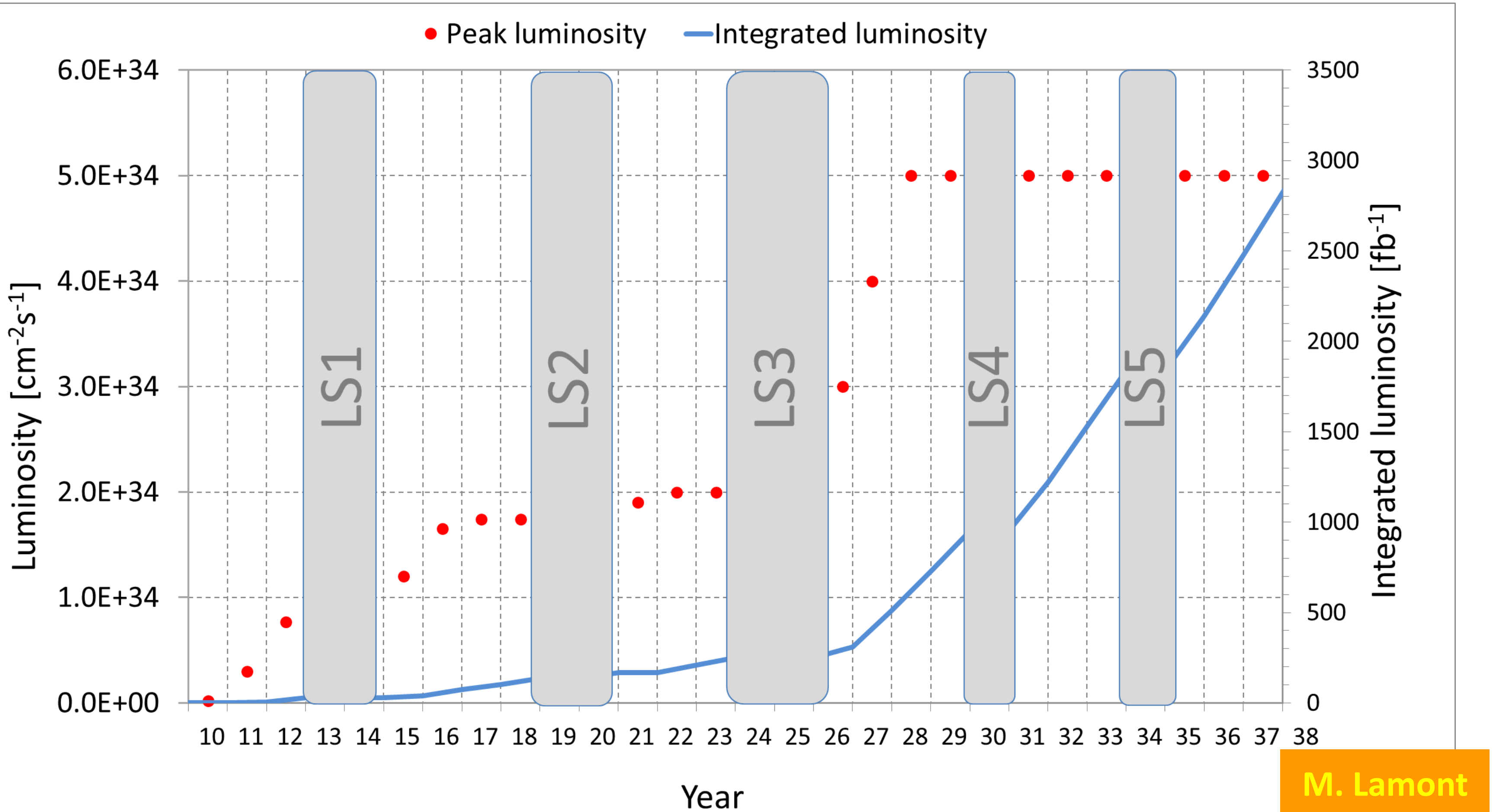
A peak luminosity of L_{peak} = **5×10^{34} cm^{-2}s^{-1} with levelling**, allowing:

An integrated luminosity of **250 fb^{-1} per year**, enabling the goal of **L_{int} = 3000 fb^{-1}** twelve years after the upgrade.
This luminosity is more than ten times the luminosity reach of the first 10 years of the LHC lifetime.

Concept of ultimate performance (use of existing magin) defined:
L_{ult} ≅ 7.5 10^{34} cm^{-2}s^{-1} and **Ultimate Integrated $L_{int\ ult}$ ~ 4000 fb^{-1}**
LHC should not be the limit, would Physics require more…

L. Rossi

3000 fb^{-1} would be reached in 2037



M. Lamont (Lumi plots are maintained by the Head of LHC operation)
Time for proton physics till 2030 is standard; then it increases (no ions and MDs and less Tech Stops.)

Quality management of LHC and its injector is **a must** to reach the required **efficiency** (R2E, R2P, spare, performance follow up …)

HL-LHC Baseline Parameters - WP2 charge

Back-up scenario

G. Arduini

Parameter	Nominal	25ns HL-LHC	8b+4e
Bunch population N_b [10^{11}]	1.15	2.2	2.3
Number of bunches	2808	2748/2604	1968
Beam current [A]	0.58	1.09/1.03	0.82
Crossing angle [μrad]	285	590	554
Beam separation [σ]	9.9	12.5	12.5
Minimum β^* [m]	0.55	0.15	0.15
Normalized emittance ε_n [μm]	3.75	2.5	2.2
ε_L [eVs]	2.5	2.5	2.5
r.m.s. bunch length [m]	0.075	0.081	0.081
Virtual Luminosity (w/o CC) [10^{34} cm^{-2}s^{-1}]	1.2 (1.2)	18.9 (6.73)	16.8 (6.0)
Max. Luminosity [10^{34} cm^{-2}s^{-1}]	1	5.30	3.6
Levelled Pile-up/Pile-up density [evt. / evt./mm]	27/0.2	140/1.2	140/1.2
Integrated luminosity [fb^{-1}/year]	45	260	190

LIU

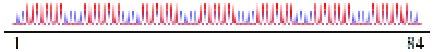
Impedance, efficiency etc.

New IT Quads & ATS

Crab Cavity with levelling

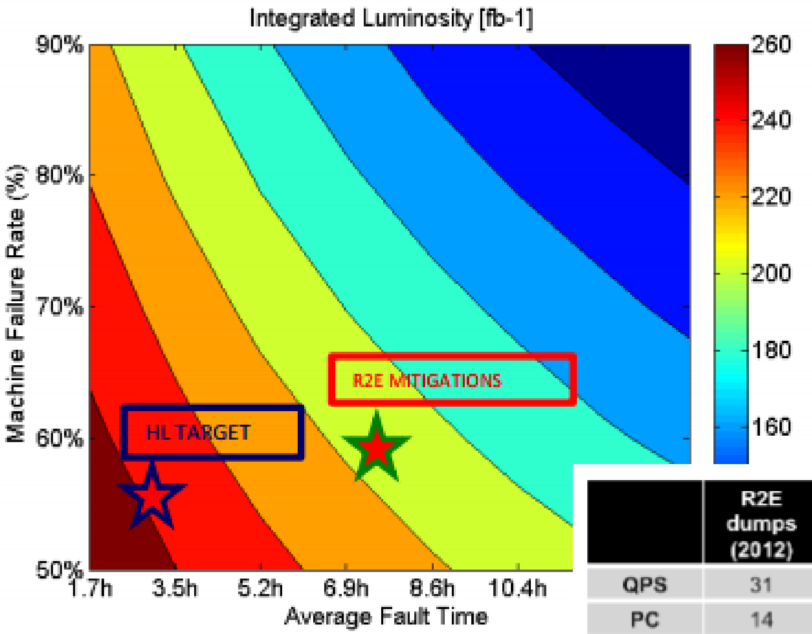
$$L = \gamma \frac{f_{rev}\, n_b\, N_b^2}{4\pi \varepsilon_n \beta^*} R$$

Efficiency requires long fill times (6-10 h)

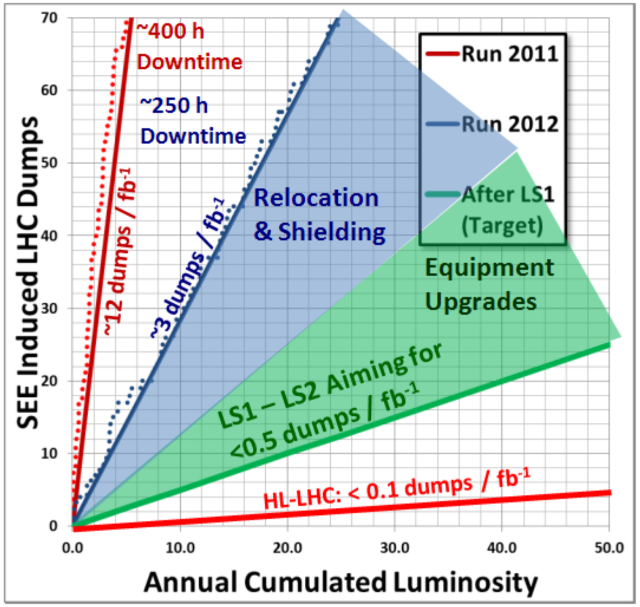


VSC to review performance compatibility with HL-LHC to **identify consolidation** and build **new systems compatible with HL-LHC**

Availability and Downtime



	R2E dumps (2012)	R2E downtime (2012)	Target yearly dumps (HL-LHC)	Target R2E downtime (HL-LHC)
QPS	31	~ 80 h	9	32 h
PC	14	~ 60 h	4	14 h
CRYO	4	~ 70 h	1	3.5 h
Vacuum	4	~ 20 h	1	3.5 h
Other	3	~ 30 h	1	3.5 h



D. Wolmann

M. Brugger

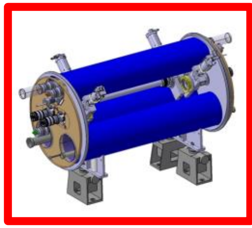
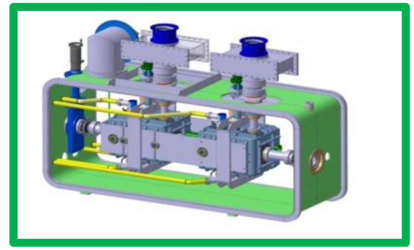
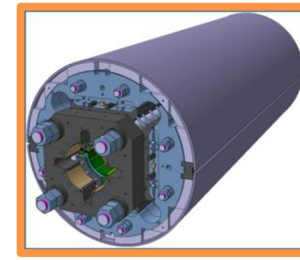
Upgrade of interlocking system (integration to avoid spurious dump)
Reduction of (generous) of interlock levels
R2E
Robust and reliable equipments
Identification of "fast" repair scenario
Etc.

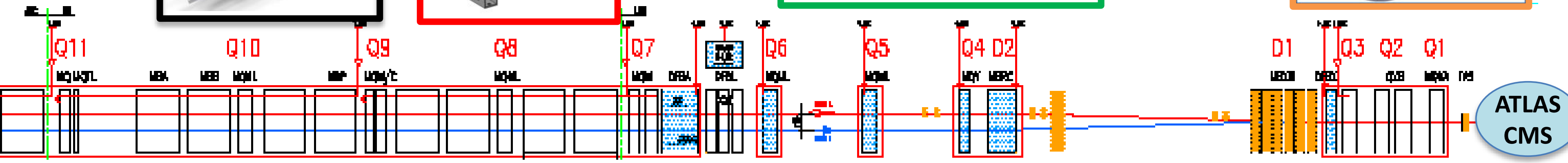
VSC performances:
on track for HL-LHC !

Year	Issue count	Average downtime	Beam dump
2015	6	2.5 h	1

High Luminosity LHC

HiLuMi: largest HEP accelerator in construction



Dispersion Suppressor (DS) | **Matching Section (MS)** | **Interaction Region (ITR)**

Modifications

1. In IP2: new DS collimation in C.Cry.
2. In IP7 new DS collimation with 11 T

+ Cryogenics, Protection, SC Links, Interface, Vacuum, Diagnostics, Inj/Extr, new infrastruct.

Complete change and new lay-out in IP1-IP5

1. TAN
2. D2
3. CC
4. Q4
5. All correctors
6. Q5 (Q6 @1.9 K?)
7. New MQ in P6
8. New collimators

Complete change and new lay-out in IP1-IP5

1. TAS
2. Q1-Q2-Q3
3. D1
4. All correctors
5. Heavy shielding (W)

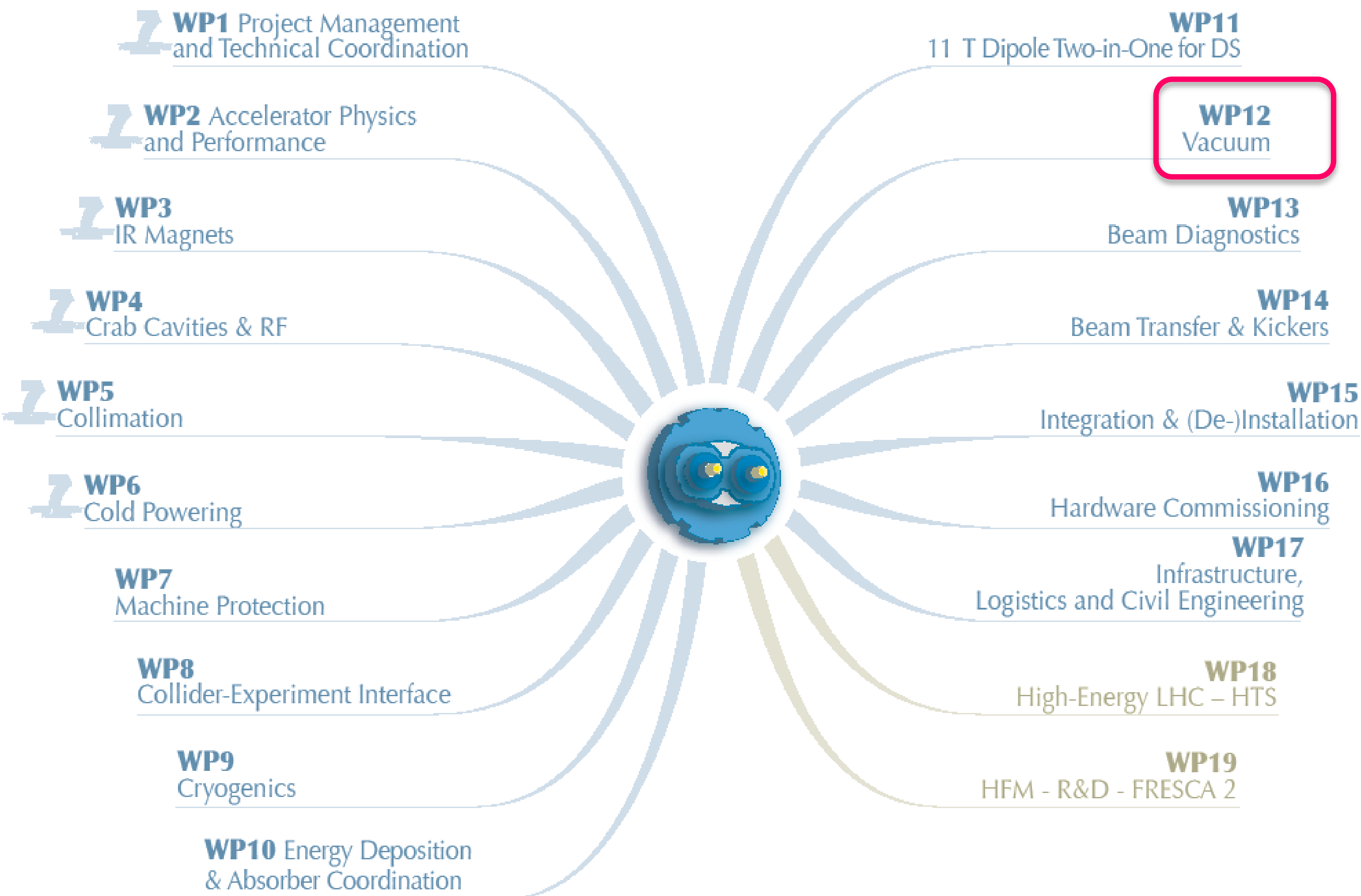
> 1.2 km of LHC !!

L. Rossi

10

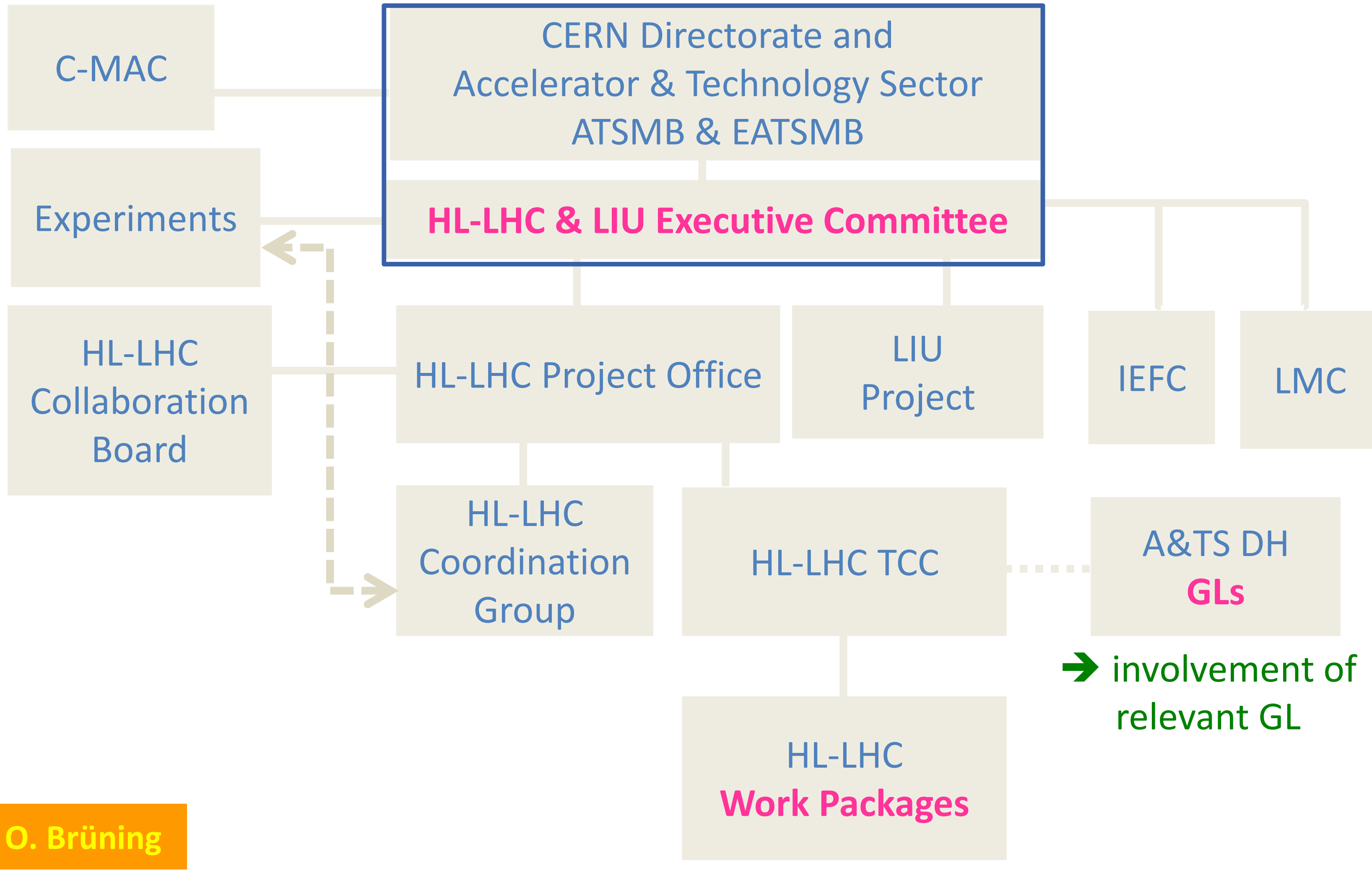
Organisation

https://espace.cern.ch/HiLumi/default.aspx



A single point of entry (VB and RK) for a TEAM work across VSC and partners

New Project Governance



O. Brüning

HL-LHC Project Office

Project Leader & Deputy
L. Rossi & O. Brüning
Project Definition & Strategy
Report to CERN Management and DHs
Report to Collaboration Board
Coordination technical WPs (2-14) & Collaborations

Safety officer

Budget Officer
Budget & its follow-up
Link to RC and to DAT

KT, Outreach and Communication

Project Office Manager
L. Tavian
Coordination among officers, secretariat, interface with host states, General Planning Coordination, Safety follow up

Technical Infrastructure Officer
L. Tavian

Civil Engineering
Impact & Environ. Studies
Electrical Distr. & CV
Access & Alarm
Logistics & link to Test Infra.
Consolidation & Operations

Configuration, Quality and Resource Officer
I. Bejar Alonso

TDR Edition & Tech. Baseline
(PBS, interfaces, Tech. Specs, Technical documentation & ECR)
Quality and Risk management
Resource & Purchase Plan

Integration and Installation Officer
P. Fessia

Integration study and layout
Lead (de-) installation
Survey

O. Brüning

Mandate of the HL-LHC Technical Coordination Committee

The HL-TCC is the main forum for defining, in collaboration with the work package (WP) leaders and the project management, the baseline* of the HL-LHC project and establishing and maintaining coherent sets of parameters and the associated hardware lay-out for the HL-LHC. These sets will be referred to as the HL-LHC Baseline and Options in the following. The HL-TCC will monitor and recommend changes in parameters or machine layout and the required resources and workplan based on the technical discussions at the HL-TCC meetings, interim reports from the WP leaders or any other relevant bodies of the project or of the CERN A&T sector such as group leaders and department heads. When applicable, it will also request dedicated studies to solve or mitigate any possible kind of inconsistencies and interface issue between different systems or equipment and prepare the decision making process. The HL-TCC may give also recommendation on hardware equipment, especially when the HL-LHC operation and functionality is involved, without prevailing on the responsibility of the WP leaders.

➔ The HL-TCC reports to the HL-LHC Project Leader.

➔ The HL-LHC Deputy Project Leader is the HL-TCC chair ex-officio and is assisted by a deputy chair(s) and a scientific secretary(s).

*A Baseline is a set of attributes at a point in time. It serves as a basis for defining change. HL –LHC maintains Scope, Schedule and Cost Baselines

L. Rossi

Main HL-LHC events in 2015

- Cost and Schedule Review, March 2015
- Joint HiLumi-LARP meeting & 24th LARP Collaboration Meeting, May 2015
  - https://indico.fnal.gov/conferenceDisplay.py?ovw=True&confId=9342
- Goes to Industry, June 2015
  - https://indico.cern.ch/event/387162/overview
- Joint LIU / HL-LHC meeting, October 2015
  - https://indico.cern.ch/event/437662/
- 5th Joint HiLumi LHC-LARP Annual meeting, October 2015
  - https://indico.cern.ch/event/400665/overview
- TDR-v0, Del-D1.10: http://hilumilhc.web.cern.ch/science/deliverables
- Regular meetings such as Parameter & Lay-out Committee, Technical Coordination

2. WP12: Vacuum

WP12 Scope

- *Deliver a vacuum system compatible with HL-LHC beam parameters*
- *Study, define, produce, install and commission the HL-LHC vacuum system*
- *Including specific vacuum components and machine components (produced and installed by other WP)*

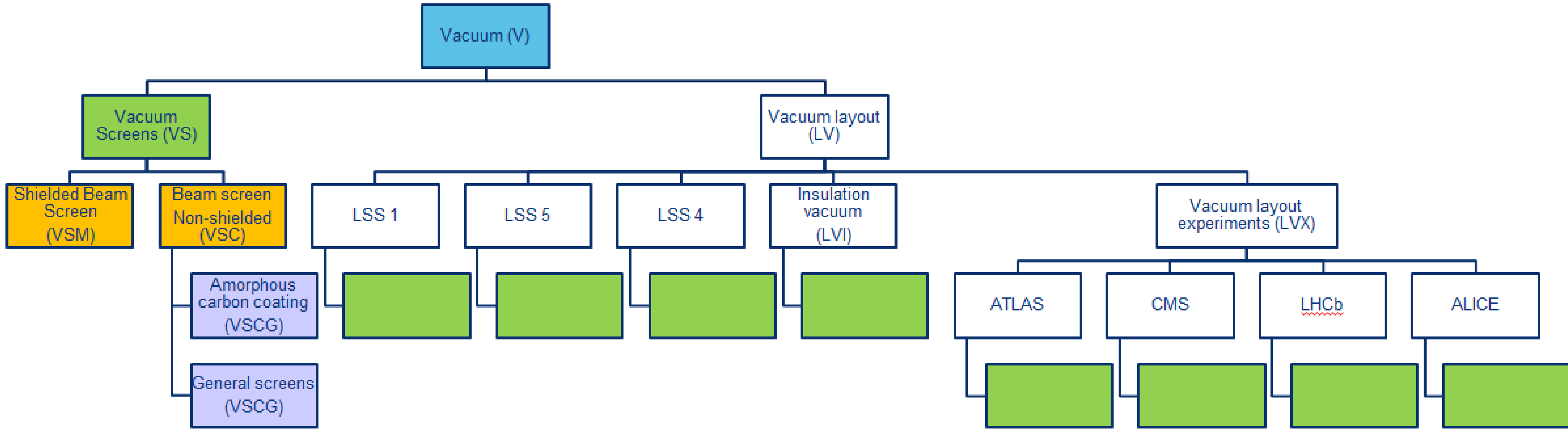
WP12 Detailed Scope

- *New beams screens:*
  - *Beam screens with shielding (Inner Triplets)*
  - *Beam screens without shielding (other magnets)*

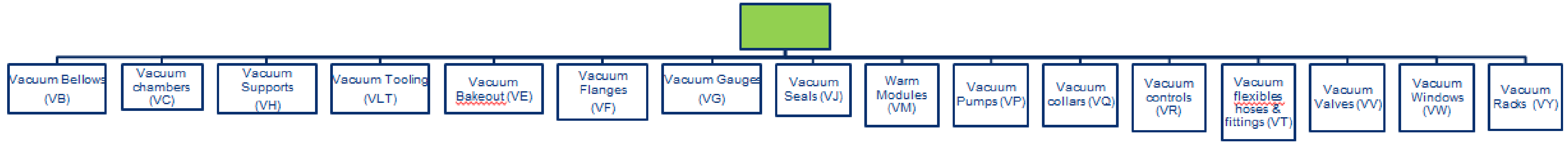
- *Implementation of new vacuum layouts in Long Straight Sections, LSS:*
  - *1 and 5*
  - *2, 3, 7 mainly for WP 5 (collimation)*
  - *6, 8 mainly for WP 14 (beam tranfert & kickers)*
  - *4 mainly for WP4 (crab cavities and RF) and for WP13 (beam diagnostics)*
  - *Insulation vacuum*

System Architecture (EDMS 14005228)

- *New components to produce :*
  - *beam screen with and without shielding*
  - *amorphous carbon coated beam screens*
  - *vacuum layouts to implement*

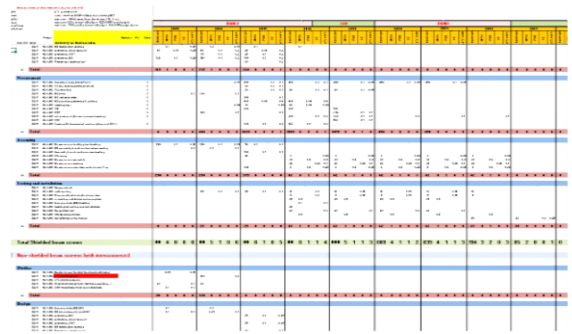


- *Where the empty green box represent a vacuum component (bellow, chamber, support etc) according to the LHC naming convention*

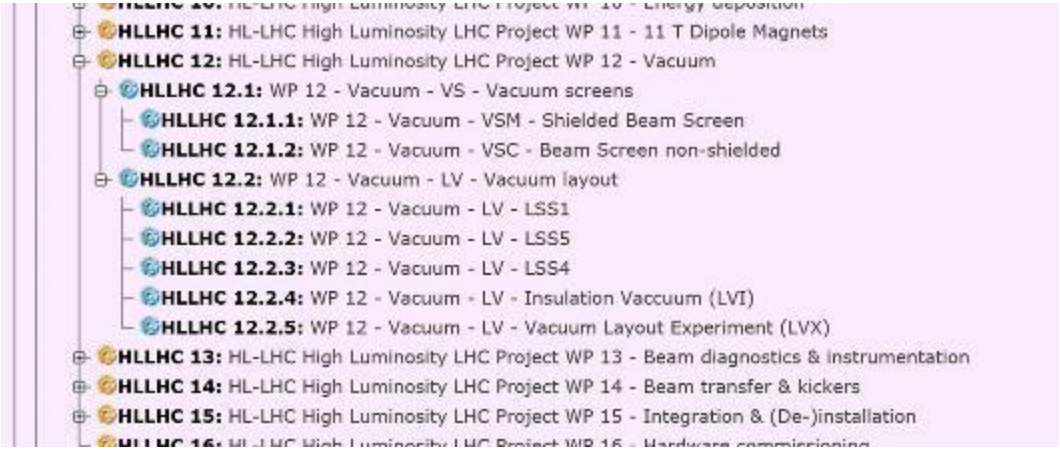


Cost and Schedule Review

- Identification of resources needs with a feed back bottom-up and up-down process
- Thanks to all sections for their precious inputs !
- Covers 2015 till 2026
- Includes studies, design, prototyping, procurement, assembly, testing and installation for:
  - Shielded beam screens
  - Non-shielded beam screens
  - In-situ treatment of IT2 & 8
  - Room temperature vacuum system in LSS1, 5
  - Room temp vacuum system in experimental areas 1 & 5 (without Exp. Beam pipes)
  - Insulation vacuum



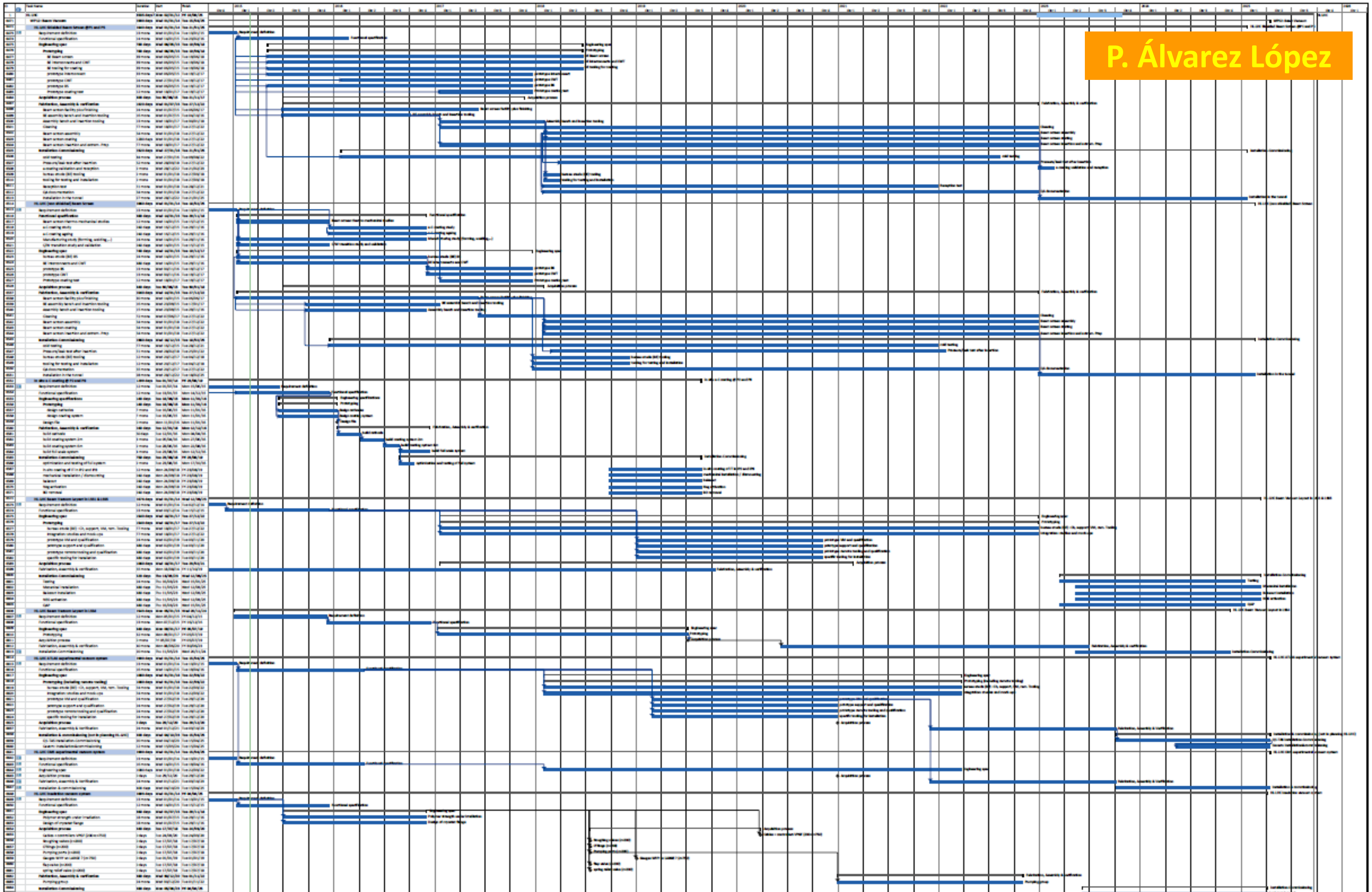
- The inputs are all integrated in APT



- Next C&S review: November 2016

Schedule

- Maintained by the project office



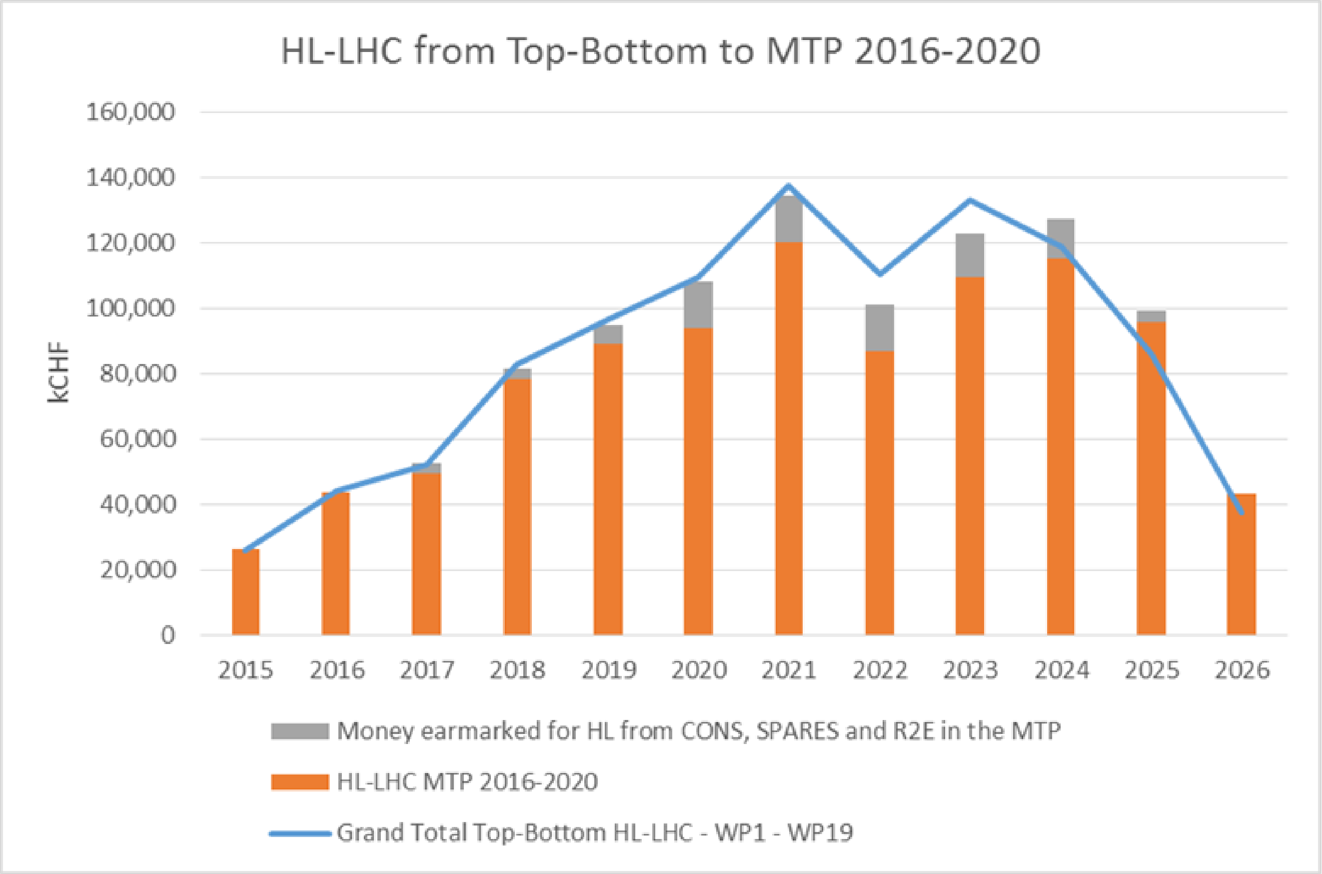
Simplified Schedule

LS2 (2019–2020) LS3 (2024–2026)

What	Activity / deliverable	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Key inputs
Beam screen with and without shielding	Procurement: beam screen, plug-in-modules													Beam screen dimension finalised in 2016
	Procurement: tungsten, cold bore,													Cold bore dimension finalised in 2016
	Procurement: interconnects, cold warm transition													Drawings available 2017
	Assembly													Facility design and procurement from 2015
RT LSS1 and 5	Design: layout, integration, prototype													Layout defined at 50 % for 2018, at 90 % for 2020 rest …
	Procurement: instrumentation, chambers, modules													All equipment procured before installation started !
	Component test & installation													~ 2.5 years installation

HL-LHC Cost to Completion

- Following the success of C&S R: CERN management inserted the HL-LHC CtC in the MTP2016-2020 with profile till 2026 (LTP):
  - ➔ MTP and strategy approved by Sept. 2015 Council.



B. Delille

∫ (grey) =82.8 MCHF

∫ (orange) =953.8 MCHF

∫ (blue line) =1036.6 MCHF

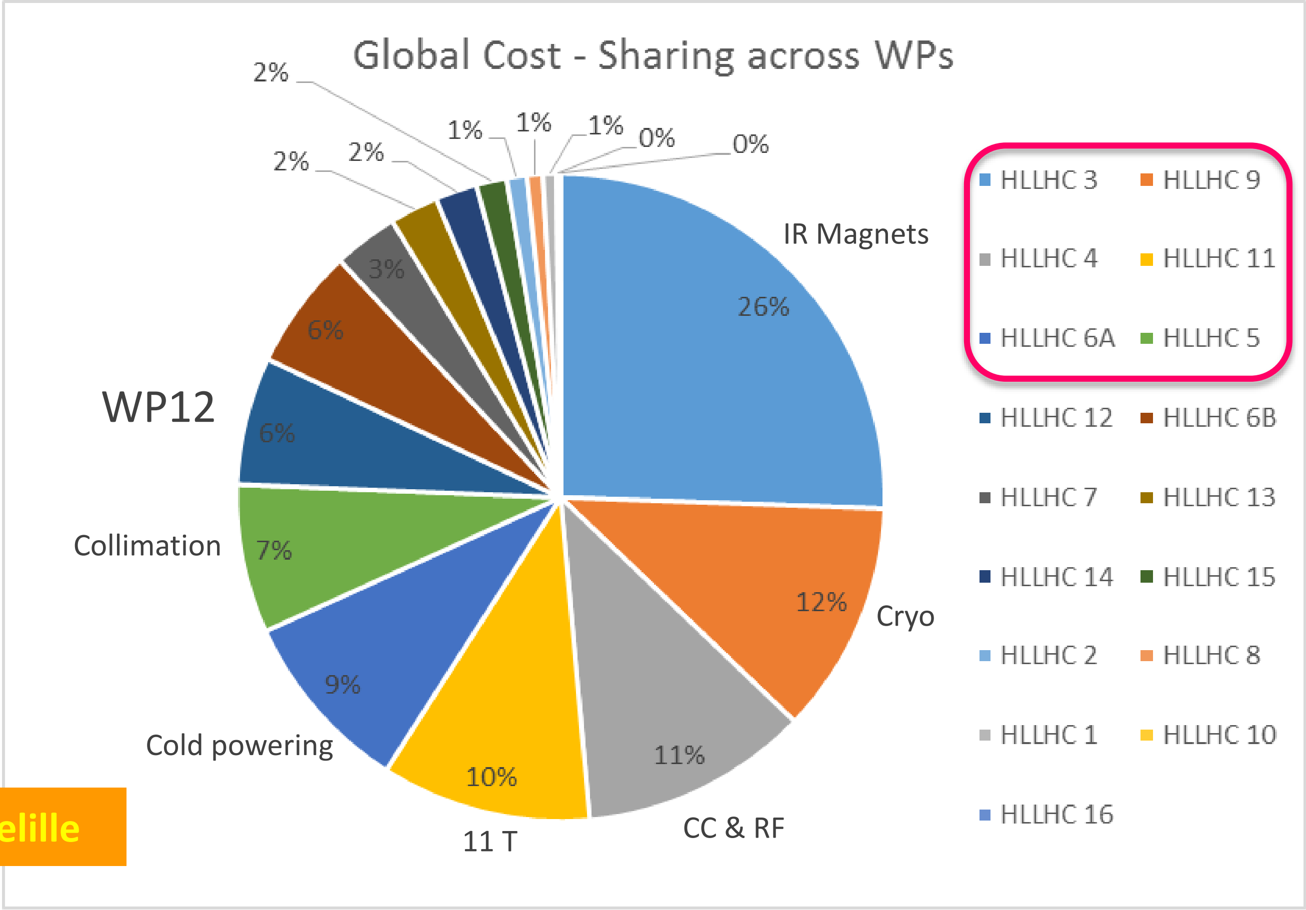
CERN personnel: 1600 FTE-y

No overheads, no contingency

L. Rossi: "We have all the money we asked for, therefore we have no other possibility than succeed"

HL-LHC Cost : Distribution across WPs

- WP12 : 6% ➔ ~ 54 MCHF with hardware, IS, FSU, MPA and CERN staff included
  - Cost of Goods ~ 31 MCHF

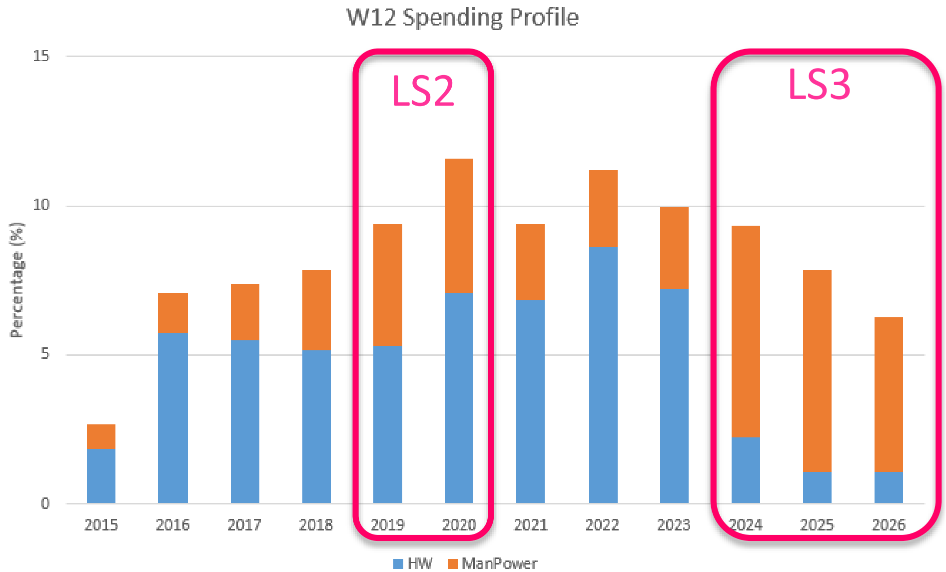


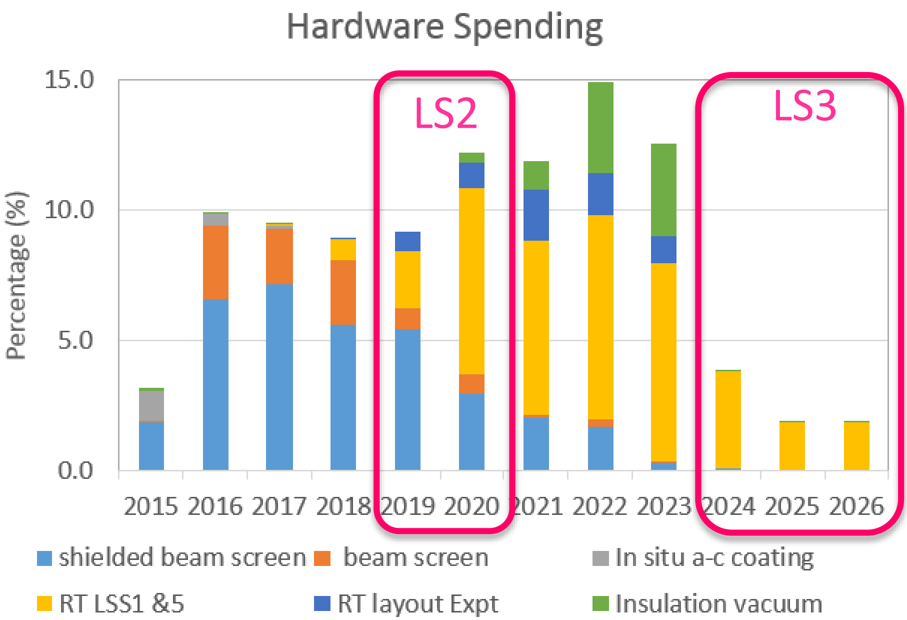
S = 75 %

B. Delille

HL-LHC Cost : WP12 profiles

- 2015-2023:
  - Mainly hardware with beam screens first then room temperature vacuum system
- 2024-2024:
  - Mainly manpower





Need to commit large quantity of money from 2016 onwards

HL-LHC Budget Codes

- Follows the PBS
- For WP12 scope only (yellow band):
  - HL-LHC money
  - CONS money
- For other WP scope (green band)

HL-LHC	91701 TE-VSC	HL-LHC WP12-Vacuum for LSS
HL-LHC	91702 TE-VSC	HL-LHC WP 12-Vacuum Layout Experiment
HL-LHC	91703 TE-VSC	HL-LHC WP14-Vacuum for absorbers
HL-LHC	91704 TE-VSC	HL-LHC WP12-Vacuum Screens
HL-LHC	91705 TE-VSC	HL-LHC WP14 Vacuum for kickers
HL-LHC	91707 TE-VSC	HL-LHC WP14 Vacuum for absorbers/kickers (Personnel)
HL-LHC	91710 TE-VSC	HL-LHC WP 12-Insulation Vacuum
HL-LHC	91711 TE-VSC	HL-LHC WP 12-Vacuum (Personnel)
Projet_CONS	97730 TE-VSC	VSC Prj: HL-LHC WP12-Vacuum Screens-Consolidation

Please use:

91701 VSC Prj: HL-LHC WP12-Vacuum for LSS for HL-LHC activities related to the room temperature beam vacuum system.
91702 VSC Prj: HL-LHC WP 12-Vacuum Layout Experiment for HL-LHC activities related to the LHC experiments (i.e. between Q1 and Q1), machine side.
91704 VSC Prj: HL-LHC WP12-Vacuum Screens for HL-LHC activities related to the cryogenic beam vacuum system.
91710 VSC Prj: HL-LHC WP 12-Insulation Vacuum for HL-LHC activities related to the insulation vacuum system.
91711 HL-LHC WP 12-Vacuum (Personnel) for HL-LHC personnel (P and M4P).

In case of doubts, please do not hesitate to contact me,

Please respect the appropriate use of BC !

Documentation

- Quality Assurance Management Plan (EDMS 1513591)
- A technical design report V0 (development stage) will be issued in the coming months
- WP12 as a Workspace in EDMS, please upload relevant documentations there !

EDMS NO.	REV.	VALIDITY
1513591	1.0	VALID

REFERENCE : EU Deliverable .1.9

PLAN

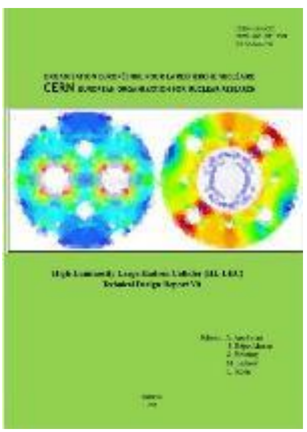
QUALITY ASSURANCE MANAGEMENT PLAN

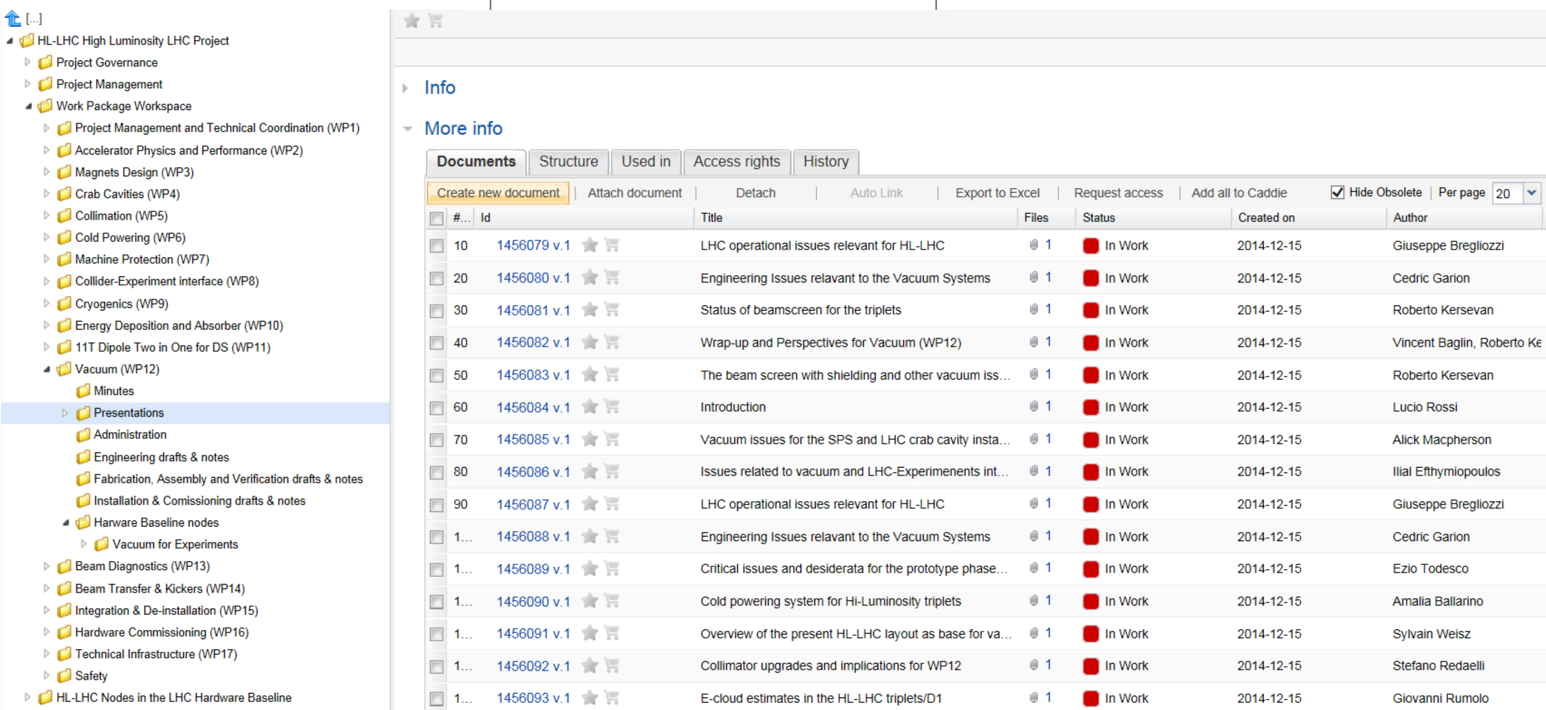
Abstract

The HL-LHC project is committed to be a project of excellence respecting the best practises in project and quality management. It is the policy of HL-LHC to develop and maintain a quality program complying with regulatory requirements and considering best industry practices.

This document defines the way in which the HL-LHC project will implement its Quality Management System (QMS) and provides an overview of the quality procedures and other quality related documentation that are part of the HL-LHC quality management system.

I. Bejar Alonso





#...	Id	Title	Files	Status	Created on	Author
10	1456079 v.1	LHC operational issues relevant for HL-LHC	1	In Work	2014-12-15	Giuseppe Bregliozzi
20	1456080 v.1	Engineering Issues relavant to the Vacuum Systems	1	In Work	2014-12-15	Cedric Garion
30	1456081 v.1	Status of beamscreen for the triplets	1	In Work	2014-12-15	Roberto Kersevan
40	1456082 v.1	Wrap-up and Perspectives for Vacuum (WP12)	1	In Work	2014-12-15	Vincent Baglin, Roberto Ke
50	1456083 v.1	The beam screen with shielding and other vacuum iss...	1	In Work	2014-12-15	Roberto Kersevan
60	1456084 v.1	Introduction	1	In Work	2014-12-15	Lucio Rossi
70	1456085 v.1	Vacuum issues for the SPS and LHC crab cavity insta...	1	In Work	2014-12-15	Alick Macpherson
80	1456086 v.1	Issues related to vacuum and LHC-Experiments int...	1	In Work	2014-12-15	Ilial Efthymiopoulos
90	1456087 v.1	LHC operational issues relevant for HL-LHC	1	In Work	2014-12-15	Giuseppe Bregliozzi
1...	1456088 v.1	Engineering Issues relavant to the Vacuum Systems	1	In Work	2014-12-15	Cedric Garion
1...	1456089 v.1	Critical issues and desiderata for the prototype phase...	1	In Work	2014-12-15	Ezio Todesco
1...	1456090 v.1	Cold powering system for Hi-Luminosity triplets	1	In Work	2014-12-15	Amalia Ballarino
1...	1456091 v.1	Overview of the present HL-LHC layout as base for va...	1	In Work	2014-12-15	Sylvain Weisz
1...	1456092 v.1	Collimator upgrades and implications for WP12	1	In Work	2014-12-15	Stefano Redaelli
1...	1456093 v.1	E-cloud estimates in the HL-LHC triplets/D1	1	In Work	2014-12-15	Giovanni Rumolo

Safety and Quality Documentation

- EDMS 1549066
- Assess hazards and later issue the Launch Safety Agreement (LSA)
- Manufacturing and Inspection Plan (MIP): contains fabrication steps and quality controls

  - Detailed Manufacturing Steps of production

  \+

  - Quality Controls to be performed during manufacturing

  MIP →

  - Follow-up the Production & Project Progress
  - Keep track of Inspections
  - Foresee the Critical Points
  - Record of Verifications and Manufacturing Data
  - Identification of Deviations (NCR)

H. Garcia Gavela

- Each point of the MIP will be classified by WP12 such as:
  - N (Notification Point)
  - H (Hold Point)
  - R (Review)
- Manufacturing and Traveller Folder (MTF) will be created from MIP for each asset and fed during production

Valid for components manufactured inside and outside CERN

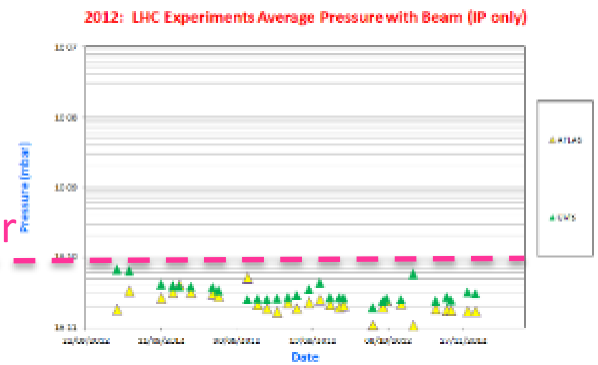
Reminder: LHC Baseline

- Reduce to an acceptable level the background to the experiments:
  - Room temperature vacuum system:
    - Bakeable system (collimators, MKI, TDI etc.)
    - Vacuum activated TiZrV getter coated system
  - Cryogenic temperature vacuum system:
    - Unbaked by design
    - Perforated beam screens to provide pumping
    - Anti-multipacting solenoids when needed

  → Rely on vacuum conditioning

A. Rossi, CERN LHC PR 783, 2004.

	H2_eq / m3	mbar
<$LSS_{1\ or\ 5}$>	~ 5 10^{12}	10^{-10}
<ATLAS>	~ 10^{11}	10^{-11}
<CMS>	~ 5 10^{12}	10^{-10}



10^{-10} mbar

- Reduce to an acceptable level the heat load on the cryogenic system:

  → Rely on beam conditioning: scrubbing

δ_{max}=1.2

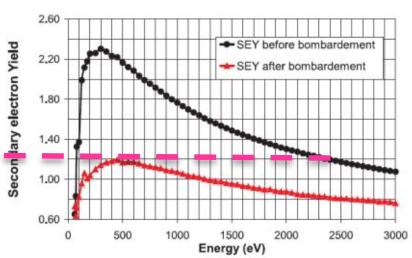
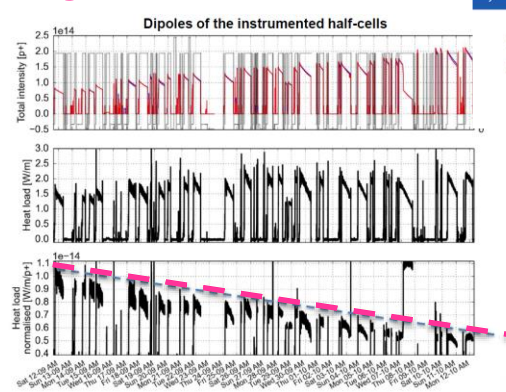


Figure 1: Variation of δ_{SEY} as a function of the primary electron energy, for a sample of copper colaminated on stainless steel, before and after bombardment with 500 eV electrons, corresponding to a dose of 5×10^{-3} C/mm^2.

N. Hilleret *et al.*. PAC 1999



Conclusions

- 6.5 TeV fundamentals look good
- Commissioning and scrubbing went well
  - Still have significant electron cloud – has slowed progress
  - The good news – we can do physics in the presence of E-cloud

P. Collier 26/10/15

HL-LHC Baseline

- Applicable to new and upgraded components: LSS1 , LSS5 and part of LSS2, 4, 8
  - ➔ arcs excluded !
- Room temperature vacuum system:
  - ➔ same as LHC base line
- Cryogenic temperature vacuum system:
  - ➔ a-C coated beam screens when needed to mitigate multipacting in order to reduce:
    1) Background to the experiments
    2) Heat load on the beam screens *e.g.* IT in all LSSS !
  - ➔ a-C performances must be validated at cryogenic temperature

10^{-10} mbar

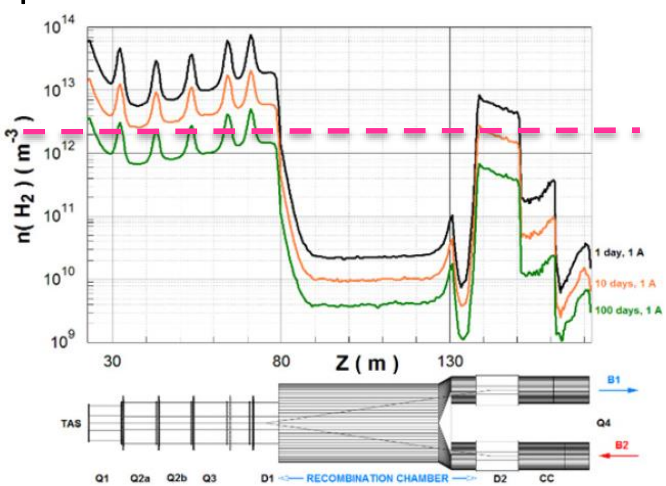
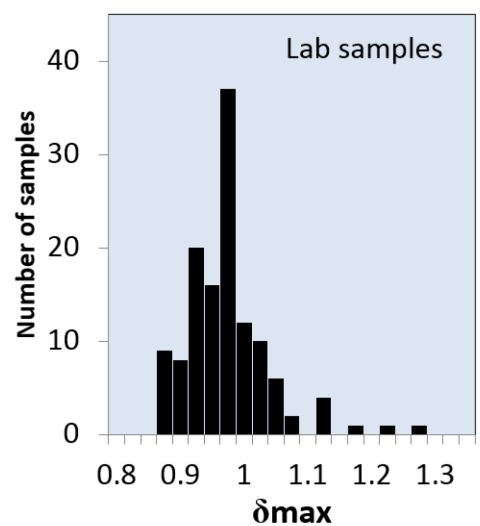


Figure 3: H_2 density profiles for 24, 240, and 2400 A·h.

R. Kersevan. IPAC 2015

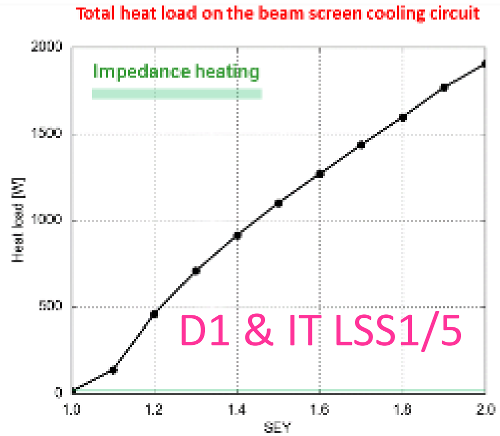


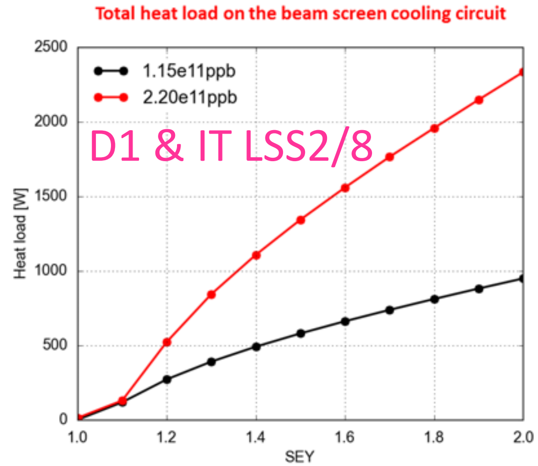
R. Kersevan

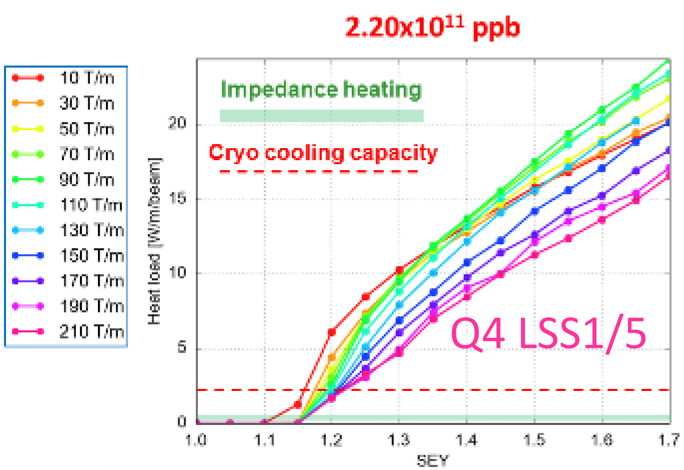
M. Taborelli

3. HL-LHC Beam Screens

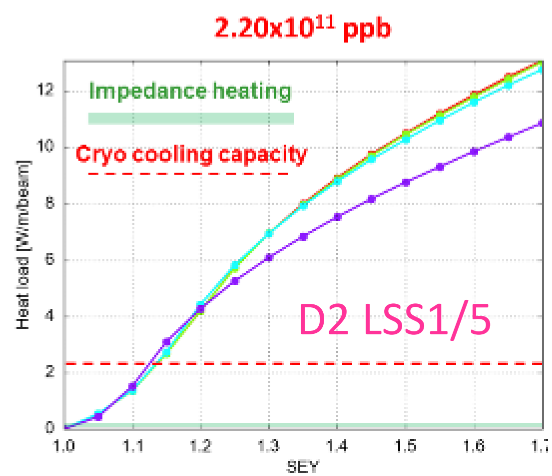
Electron Induced Heat Loads







G. Iadarola



- a-C coating to mitigate multipacting: $0.9 < \delta_{max} < 1.1$, thereby reducing heat load to acceptable values
- All components are new, except in LSS2 & 8 ➔ In-situ a-C coating

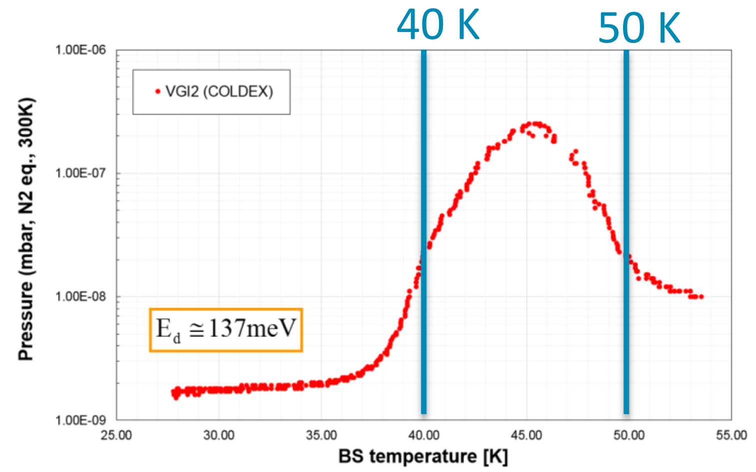
To be confirmed by the Heat Load Working Group during 2016

a-C coating at Cryogenic Temperature

- The COLDEX program

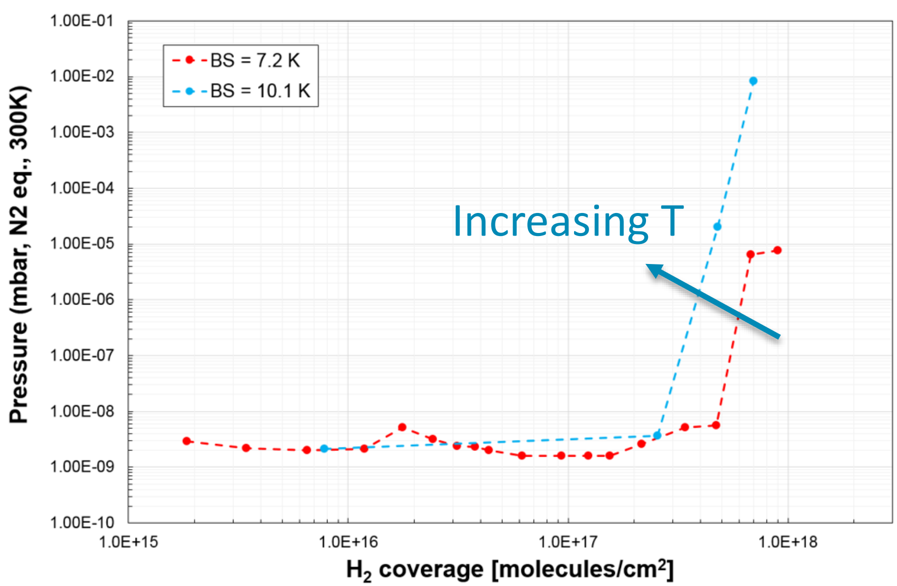
- Thermal desorption spectroscopy
- Physisorbed / condensed H_2 is released from 400 nm thick a-C coating in the 40-50 K temperature range !

➔ The temperature window 40-60 K is not appropriated
➔ TBC in the coming year(s) if 50–70 K is an alternative



- H_2 adsorption isotherm
- a-C coating is a cryosorber !
- At 10 K:
  - capacity ~ 100 Cu
  - but less than the LHC cryosorber

R. Salemme



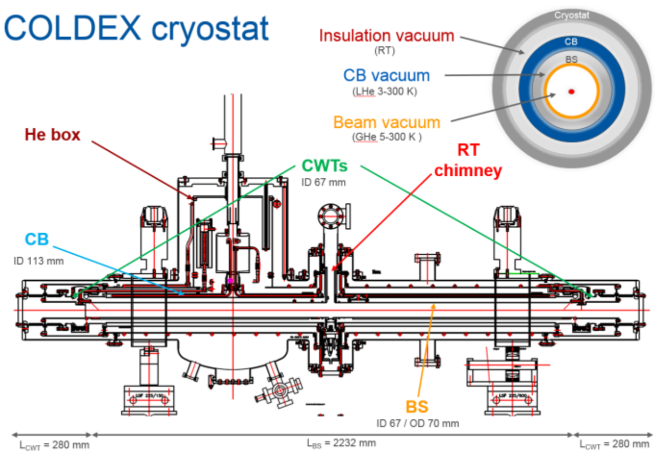
a-C coating at Cryogenic Temperature with P beams

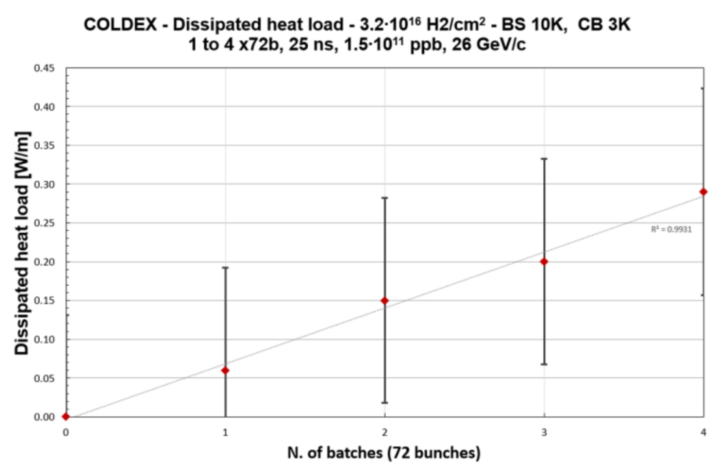
- COLDEX Studies with SPS beams:
  - A 2 m long LHC type cryogenic beam vacuum system
  - A beam screen temperature from 10 to 80 K and a cold bore temperature from 3 to 4.5 K

R. Salemme

- In the 10 – 80 K range:
  - Pressure rise < 10^{-9} mbar, dominated by H_2
  - Heat load < 0.4 W/m
  - Electron cloud activity < 2 10^{-9} A/cm^2

  } Inconsistency
- H_2 & CO condensation up to 2-3 10^{16} H_2/cm^2 do not strongly modify the behaviour



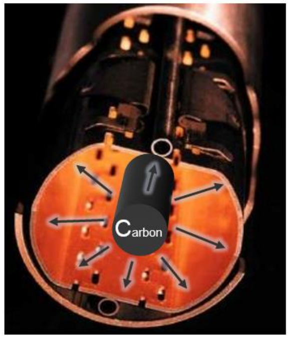


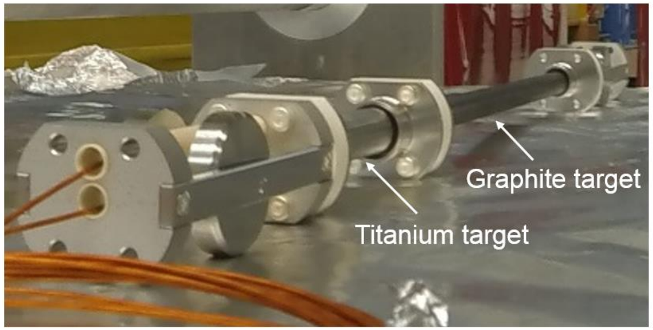
In-situ a-C coating

- During LS2: *in-situ* a-C coating of D1+ IT in LSS2 and 8
- By the end 2016, develop a "modular sputtering source" that can be inserted in a 150 mm slot and pulled by cables along D1 and the triplets

δ_{max} , unbaked	~ 1.2
δ_{max} , after baking at 100°C	~ 1.15

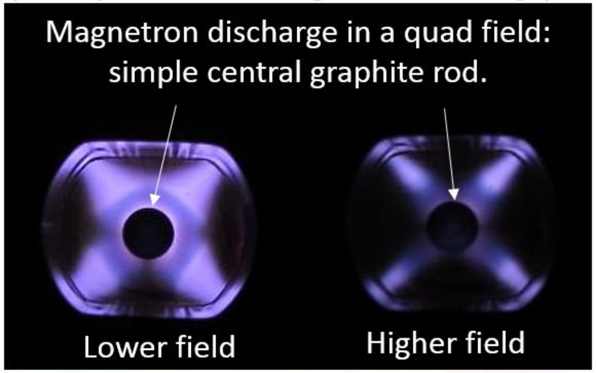
Results achieved in a 3 m long prototype using diode sputtering





- The current challenge is to decrease the SEY in the presence of outgassing and H_2 contamination from the cod bore and beam screen

- Increasing the sputtering rate with Hollow cathode with quadrupole field magnetron discharge to counteract the H_2 outgassing in a 10 m long prototype



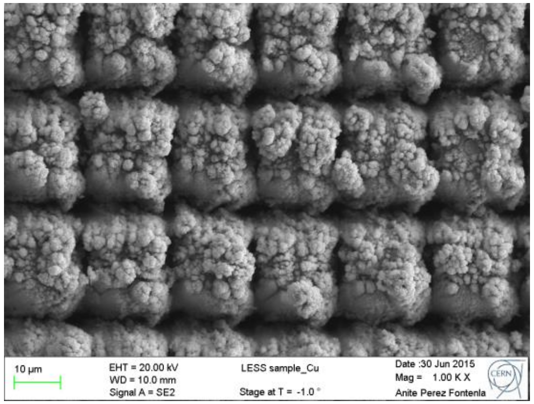
P. Costa Pinto

Laser Engineered Surface Structures: LESS

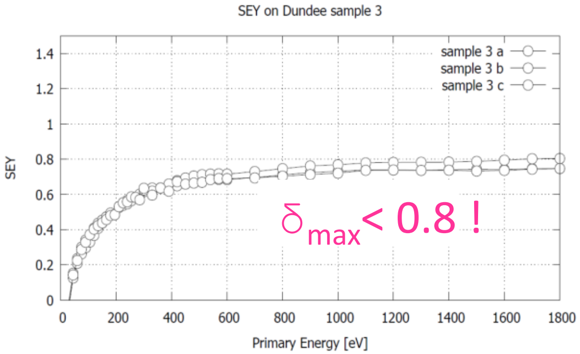
- A studied alternative to a-C coating. Principle: laser treatment of a tube at atmospheric pressure
- Collaboration with university of Dundee and ASTEC, patent deposition underway

- Challenges: validate vacuum performances by mid-2017:
  - Outgassing thermal and stimulated
  - Produce a tube and realise implementation on the field

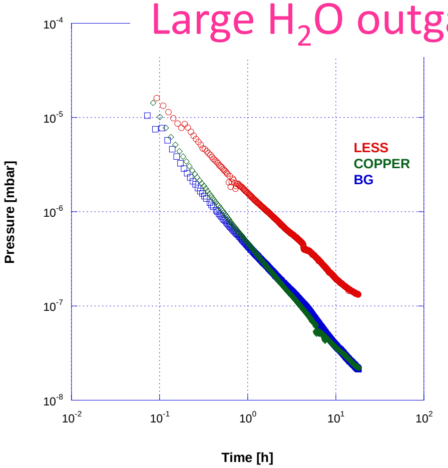
- Test liners to be installed in SPS BA5 and later in LHC VPS and COLDEX (EYETS 2016-17)



A. Abdolvand *et al.*,
Dundee University' s samples



CERN data

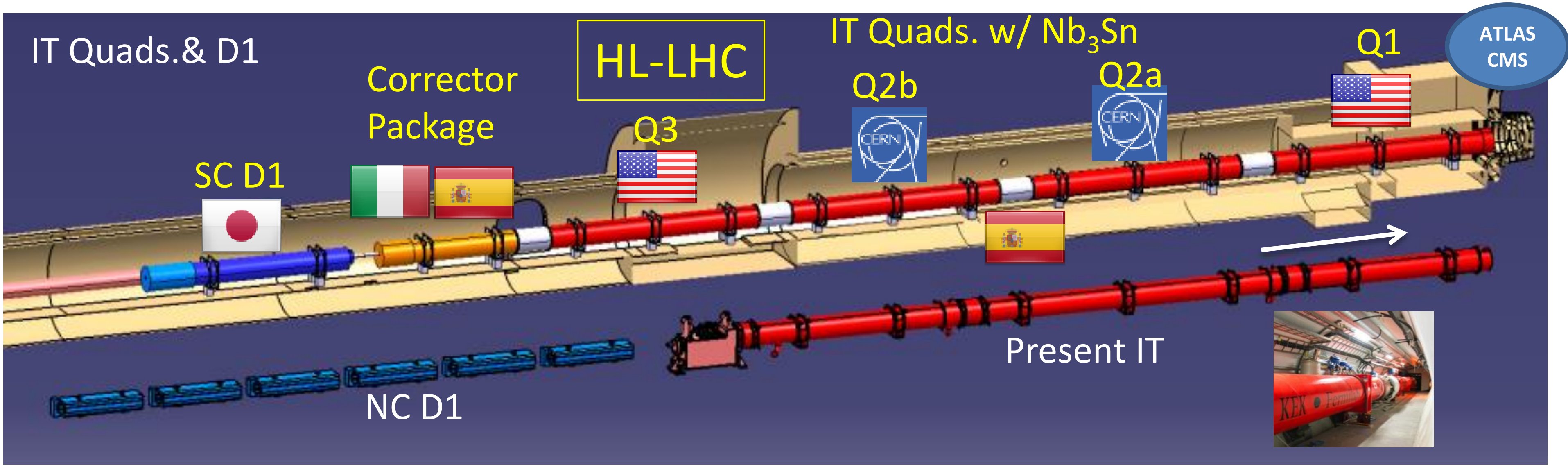


CERN data

S. Calatroni

Reminder: NEW focussing quadrupole and merging dipole

- Decrease beta (*i.e* beam size) at collision point (beta*) from 55 cm to 15 cm



- **New :** Q1, Q2, Q3, CP (corrector package), D1
  - All operating at 1.9 K
- Magnet aperture increase in IT quads : 70 mm to 150 mm, gradient = 132.6 T/m
- Superconducting D1 (aperture 150 mm, 5.6 T)

- Present IT+D1 **to be completely removed** (radiation to personnel !!)

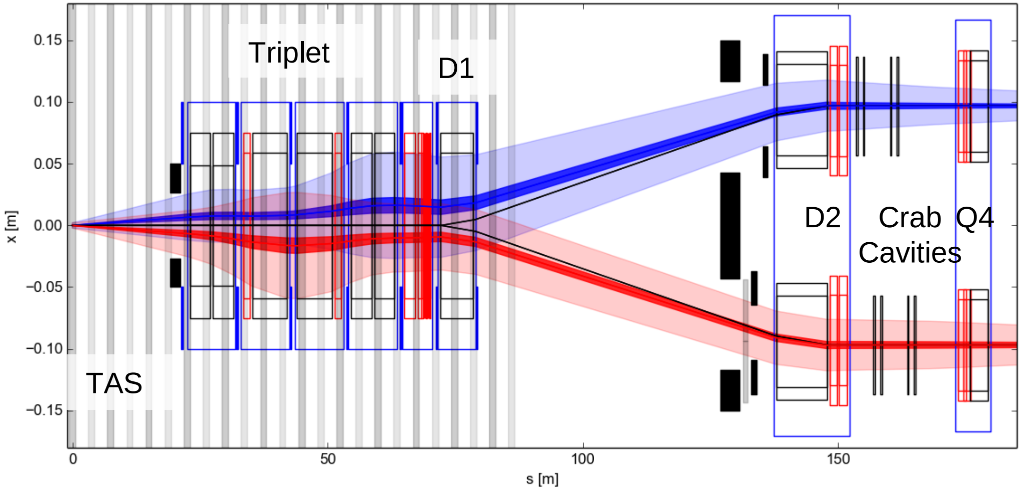
New beam screens, cold warm transition & interconnects to be designed and procured !

Reminder: NEW Optics HL-LHC

- New optic for HL-LHC : ATS (Achromatic Telescopic Squeezing), blow-up β in the arcs to reduce β*

S. Fartoukh

- New Matching section



Right side of IR1/IR5

Changes in IR1/5

- TAS aperture reduced .
- Triplet, BPM, corrector layout update.
- D1-D2 length reduction.
- TAN new aperture and separation.
- Displacement Q4 by 10m towards the arc
- 3 to 4 crab cavities per side per beam.
- New MCBRD – MCBYY length and strength
- for crab cavity beam based alignment.
- Additional masks and collimators
- Q5: MQYL to MQY at 200 T/m.

Changes in IR6

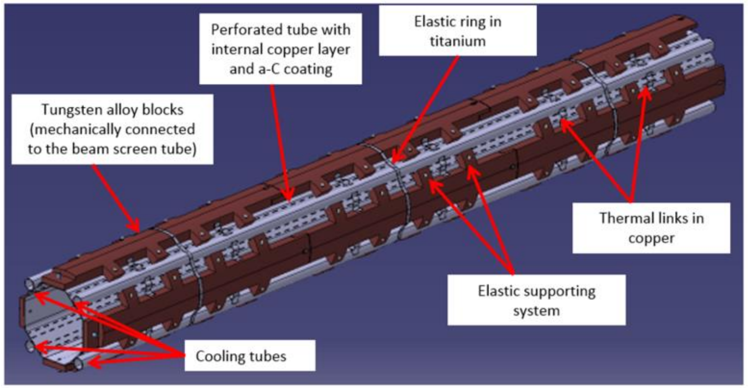
- Q5: MQYL to 2x MQY.

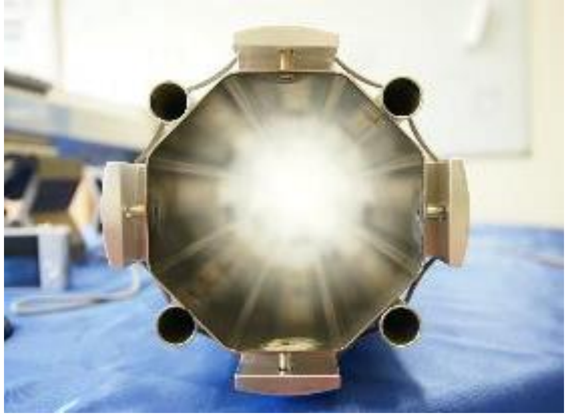
R. De Maria

Complete dismounting of LSS1 & 5
New layout

Shielded Beam Screen

- Tungsten alloy (Inermet) to intercept the debris
- 100-200 nm thick a-C coated onto 80 μm copper co-laminated beam screen
- Operating temperature : 40 – 60 K (base line under review) with the cold bore at 1.9 K
- Length ~ 10 m, weight ~ 500 kg , transparency for pumping ~ 2 % (cannot be lower !)
- Mechanical prototyping underway





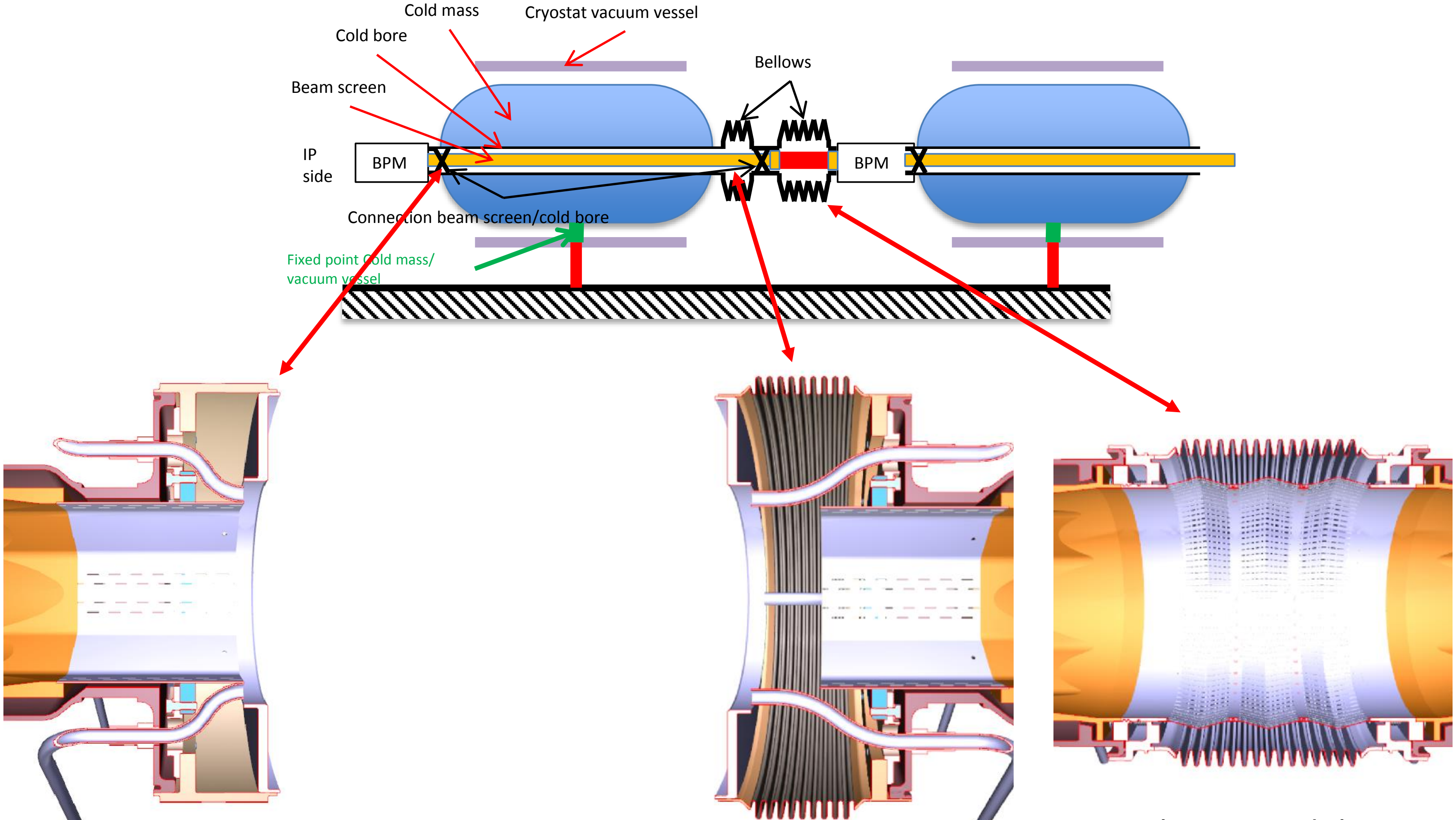
Element	Length [m]	CB ID [mm]	Shape	W thickness [mm]	BS aperture H(V); +/- 45° [mm]
Q1	10.1	136.7	Octagonal	16	99.7; 99.7
Q2-Q3-CP	35.7	136.7	Non regular octagonal	6	119.7;110.7
D1	7.3	1367.	Non regular octagonal	6	119.7;110.7
DFXJ	2.4	tbd	tbd	tbd	tbd

C. Garion

- Next steps: Validate thermal and quench models against experimental tests

Interconnection

- Optimisation of space and shielding



Fixed point

Sliding point

Plug-In module

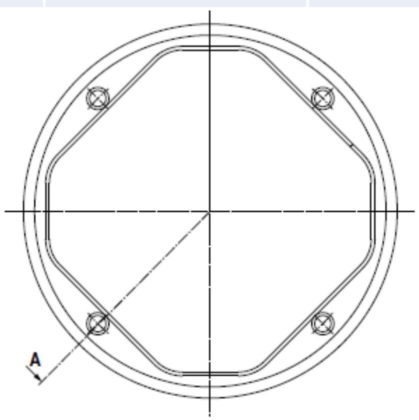
C. Garion

Non-shielded Beam Screens

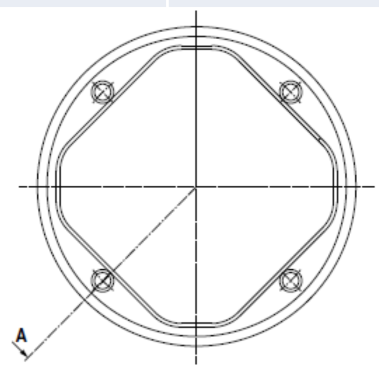
- Operating temperature : 5 – 20 K with the cold bore at 1.9 K
- a-C coated Cu co-laminated beam screen except Q5 & Q6
- Q5 is LHC Q4
- Q6 is LHC Q6

Element	Length [m]	Shape	BS aperture H(V); +/- 45° - Radial;Between flats [mm]
D2	13	Non regular octagonal	86;77
Q4	9	Non regular octagonal	72.8;62.8
Q5	8	racetrack	57.8;48
Q6	6.6	racetrack	45.1;35.3

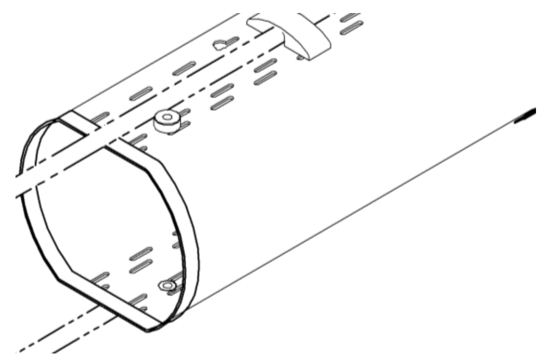
C. Garion



D2: octagonal shape,
CB ID: 94



Q4: octagonal shape,
CB ID: 79.8



Q5-6: racetrack shape,
CB ID: 63 -50

High Luminosity LHC

HL-LHC IT string

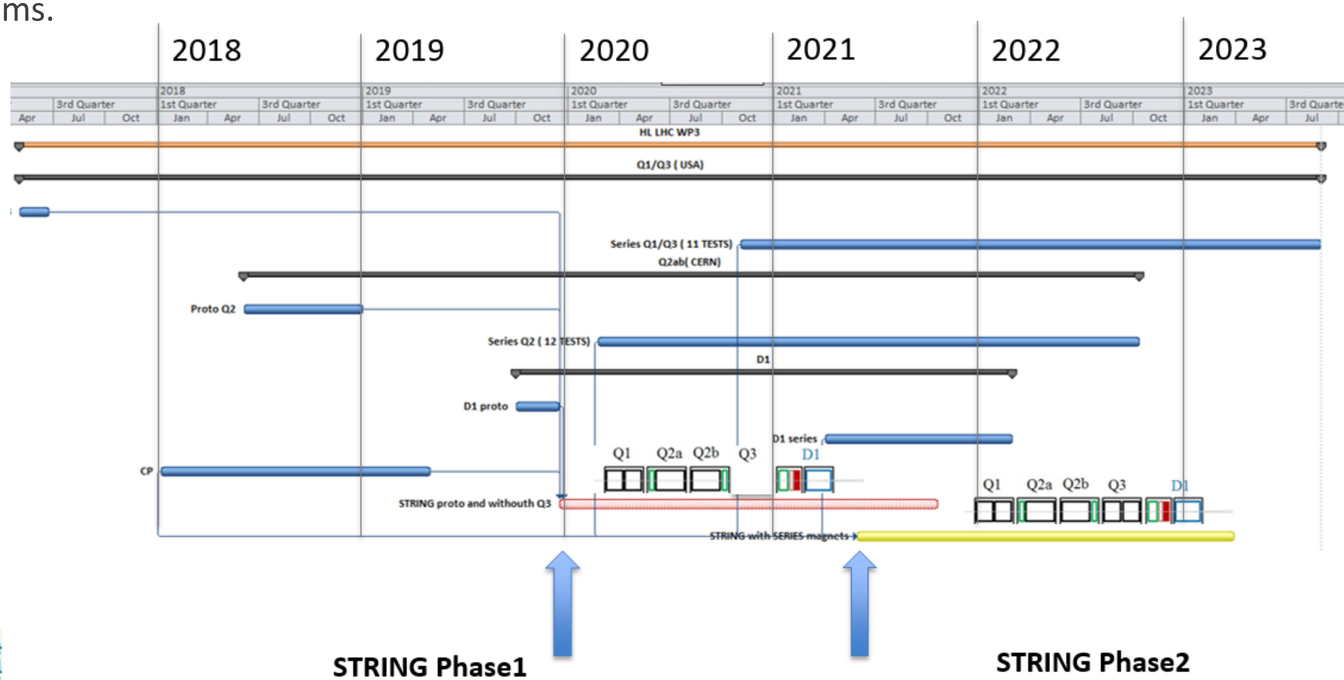
M. Bajko

MAIN GOAL

The HL LHC IT STRING will be a test stand to STUDY and VALIDATE the COLLECTIVE BEHAVIOUR of the different systems of the HL LHC: magnets, magnet protection, cryogenics for magnets and superconducting link, magnet powering, vacuum, and interconnections between magnets and superconducting link, alignment, interlocks.

TIMELINE: 2020-2021

The test is necessary to be performed BEFORE the series equipment will be INSTALLED in the future HL LHC machine. The HL LHC STRING test is planned for a total duration of max. 2 years while it will be operated in alternate with the HL LHC SC LINK test station using the same cryogenic installations and electrical powering systems.



VSC tests are drafted and communicated to the project

4. Crab cavities

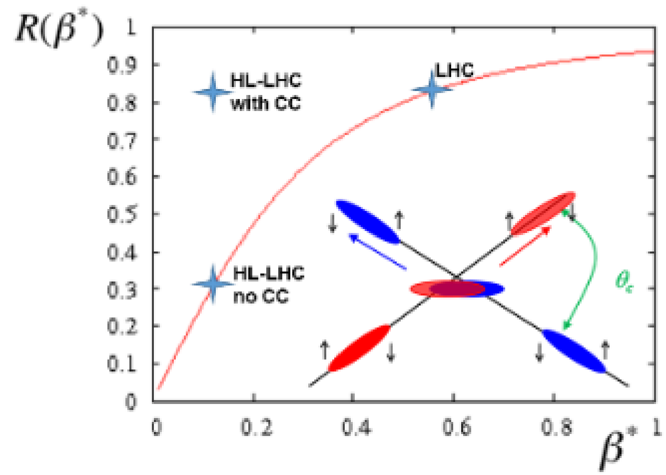
REMINDER: Crab cavities - luminosity

- Increase instantaneous luminosity by a factor 3 by "crabbing" the bunches
- Requires luminosity levelling to minimise number of event per crossing

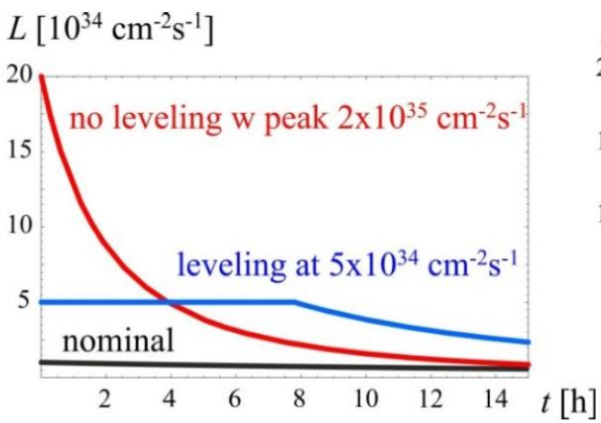
R. Calaga

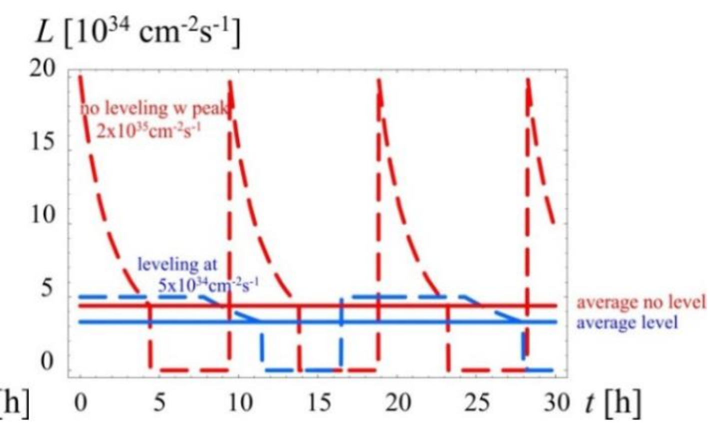
$$L = \gamma \frac{f_{rev}\, n_b\, {N_b}^2}{4\pi \varepsilon_n \beta^*} R$$

$$R = \frac{1}{\sqrt{1 + (\frac{\theta_c \sigma_s}{2\varepsilon_n \beta^*}\gamma)^2}}$$



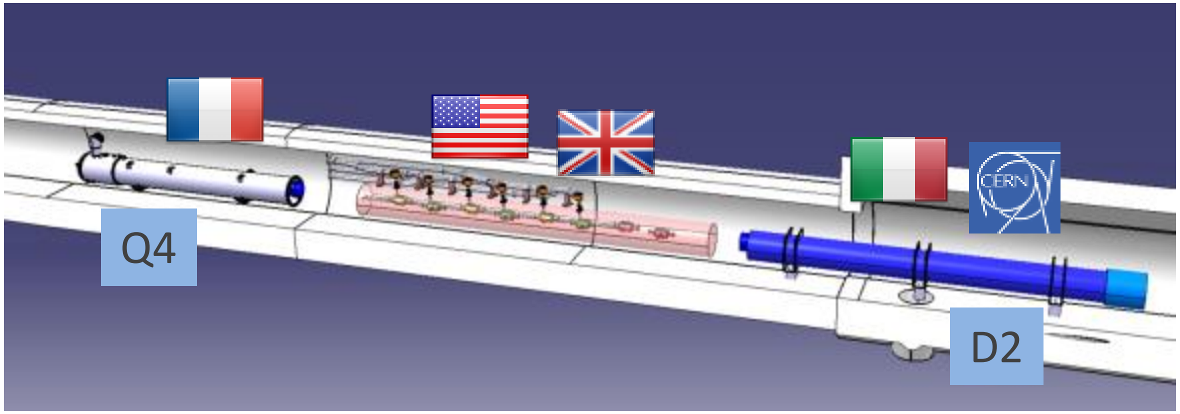
- Crab cavities maximise luminosity and can be used for luminosity levelling:
  - when luminosity is too high, CC are almost off and are slowly turned on to compensate proton burning ➔ allow to optimise integrated luminosity





Crab cavities

- Installed on left and right side of IP1 and IP5

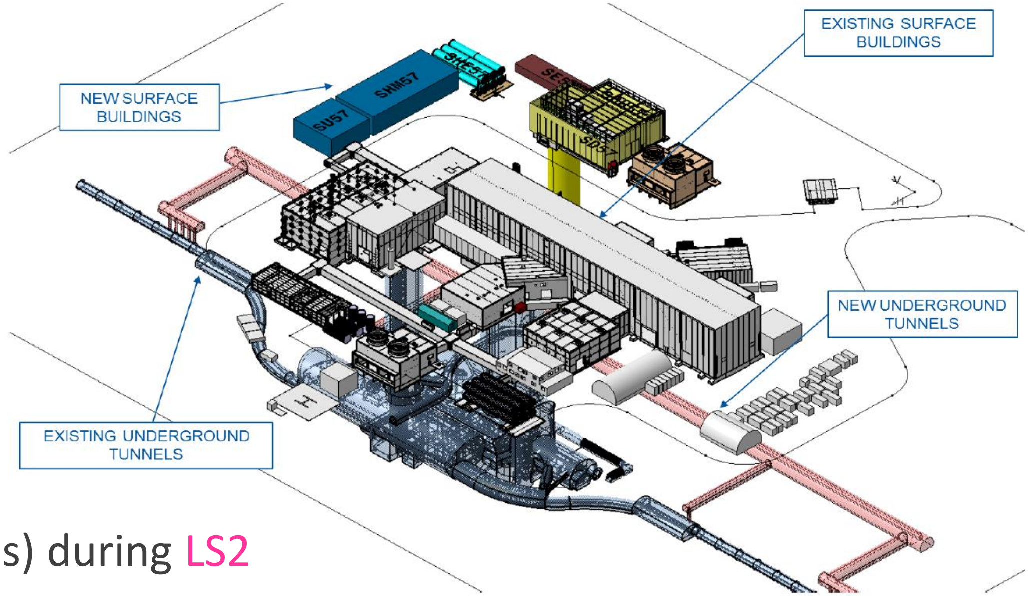


LARP-BNL

LARP-ODU-JLAB

- Installed between D2 and Q4
- 4 per side in IP1&5
- Two designs to evaluate
- Bulk Nb cavities

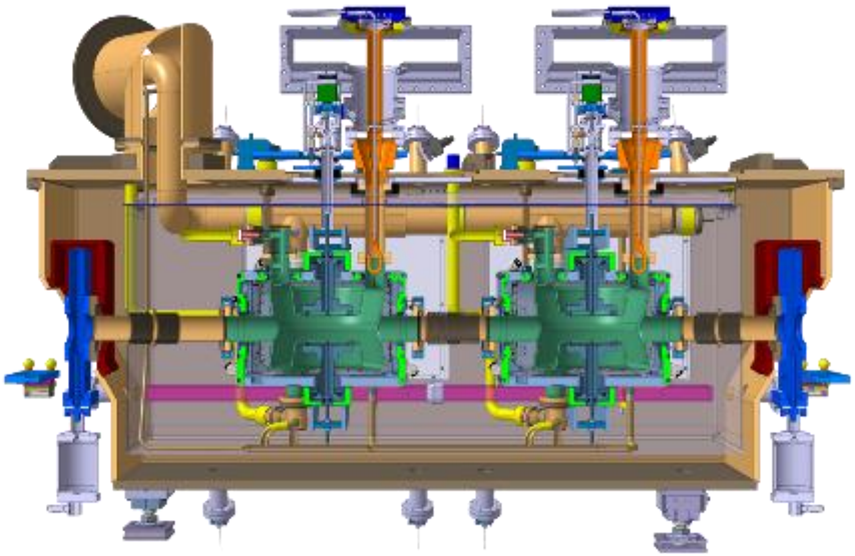
- Staged installation:
  - 2 per side in IP1&5 during LS3
  - the rest, after LS3



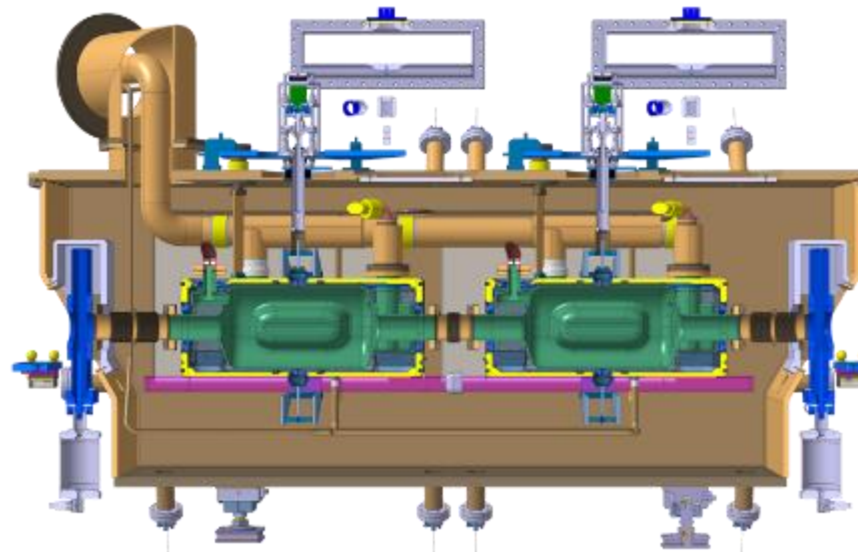
- Civil engineering (to host EPCs and DFHs) during LS2

Crab cavities cryomodules

- Operating pressure ~ 10^{-10} mbar with beams
- Bulk Nb cavity operating at 2 K



Double Quarter Wave,
Vertical Deflection (ATLAS)

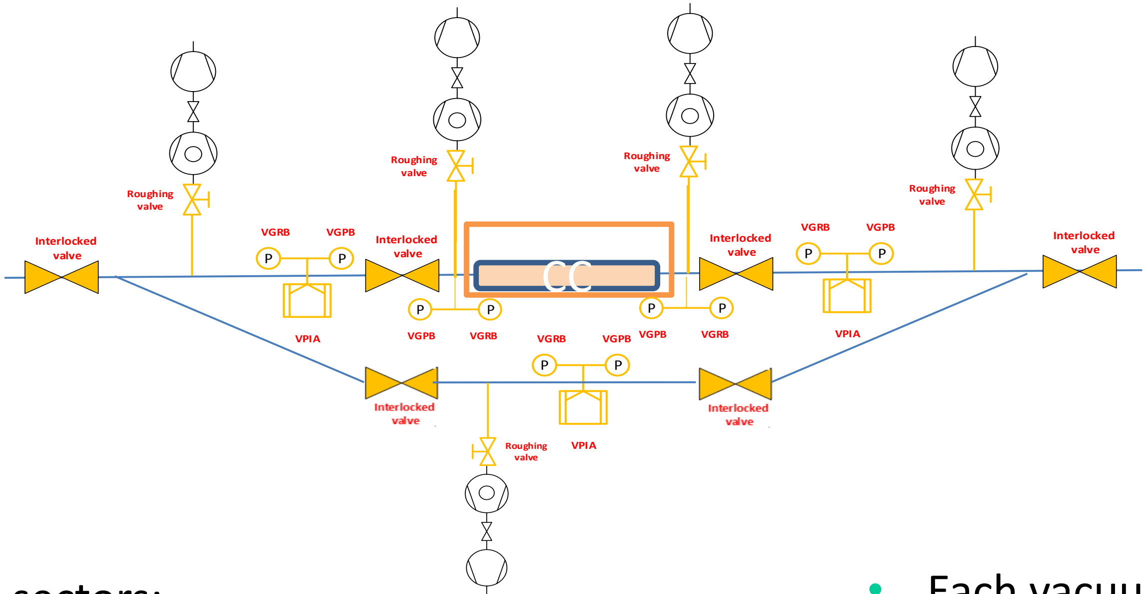


RF Dipole,
Horizontal Deflection (CMS)

R. Calaga, O. Capatina

Crab cavities test in SPS BA6

- Operating pressure ~ 10^{-10} mbar with beams
- New SPS sectorisation in BA6 by EYETS 2016-17
- Bypass design & installation by YETS 2017-18, Crab cavity module in the same time



- 4 vacuum sectors:
  - Upstream CC, NEG coated
  - CC
  - Downstream CC, NEG coated
  - Bypass, NEG coated

- Each vacuum sector has:
  - Penning / Pirani gauges
  - Roughing valve

- NEG coated sectors have:
  - Ion pumps

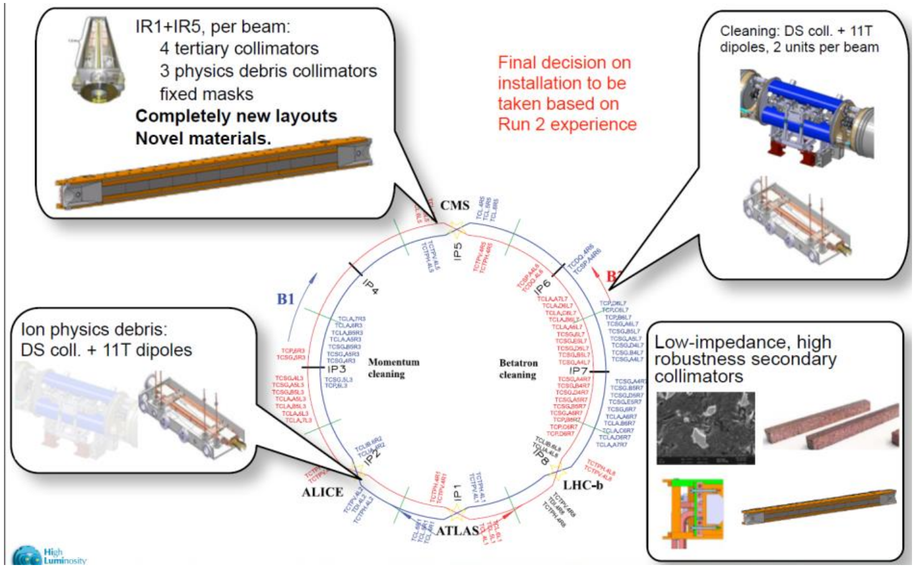
Layout under study

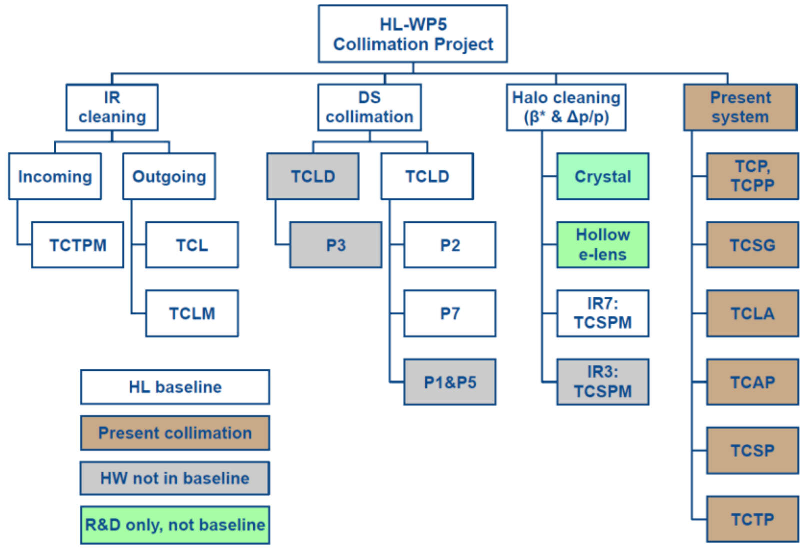
5. Collimation

Collimation baseline

- TCLD in point 2
  - 2+1 for LS2
- TCLD in point 7
  - 4 for LS3
- TCT in LSS1 & 5
  - 8 + 8 for LS3
- TCL in LSS1 & 5
  - 12 for LS3
- TCSPW in LSS7
  - 8-10 for LS2 if ready
  - 12-14 for LS3

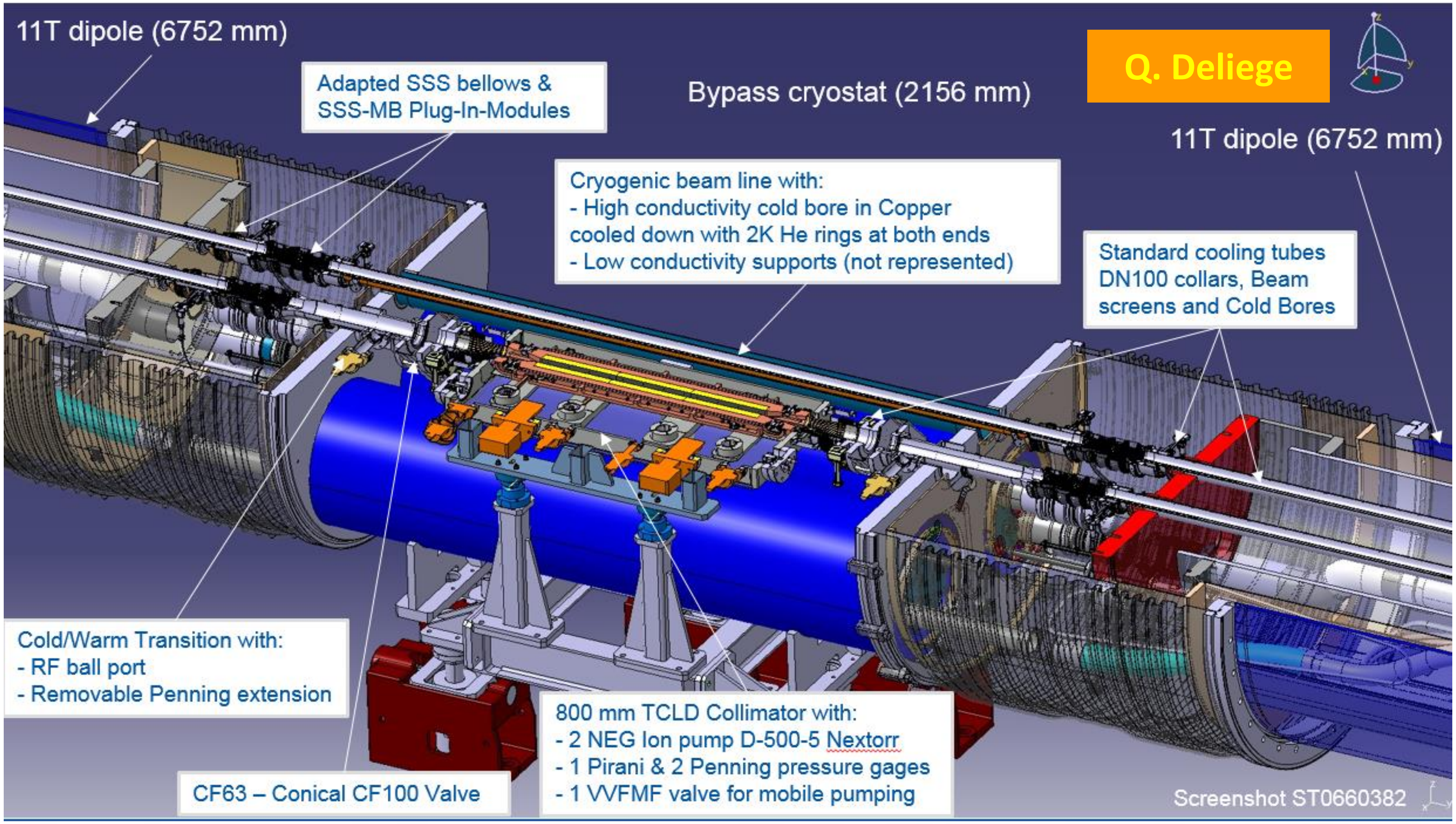
S. Redaelli





Collimation in DS

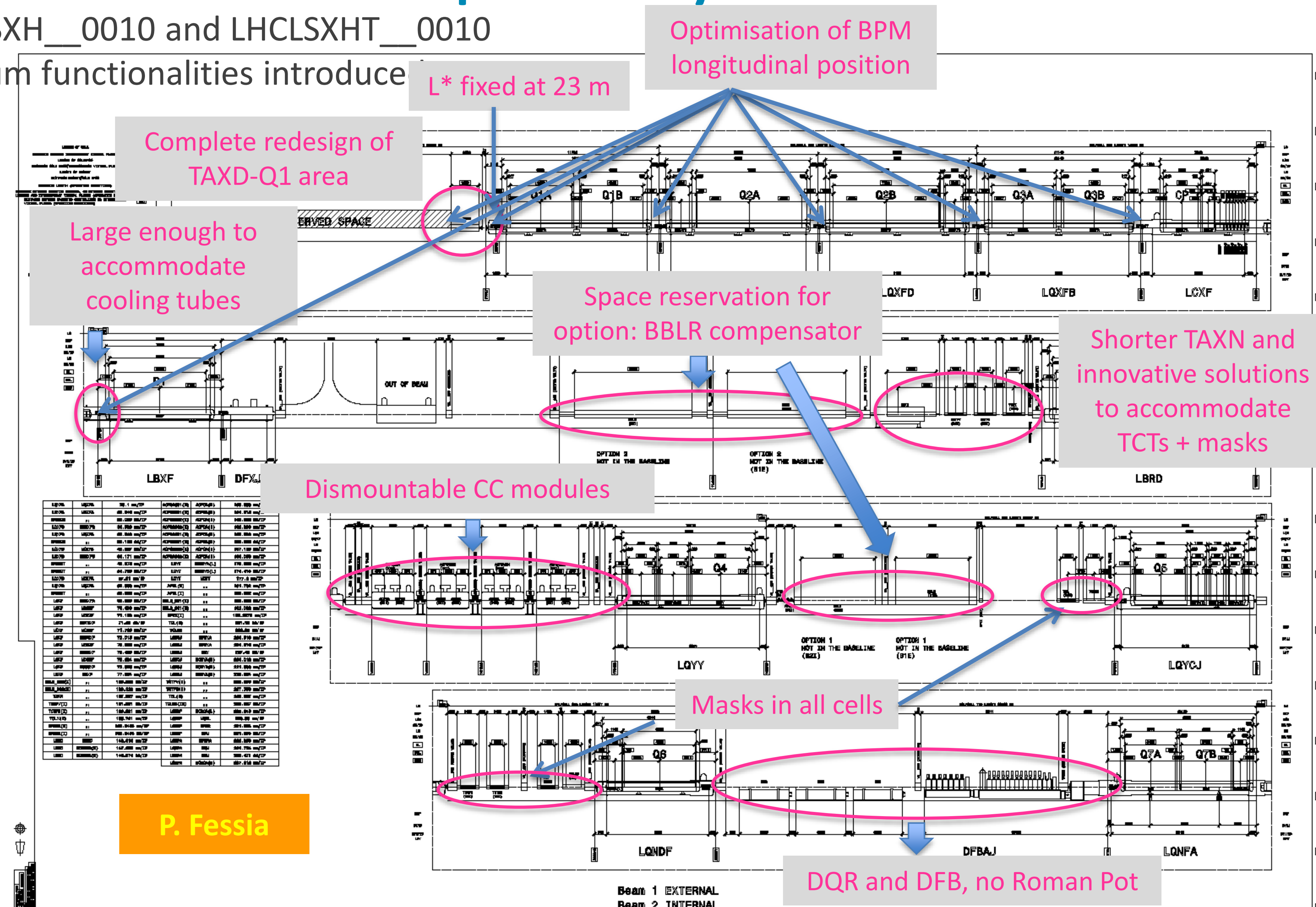
- Detailed definition of the vacuum system and bypass
  - Line 1: continuous arc beam line at cryogenic temperature
  - Line 2: cold to warm transition with a sectorised room temperature vacuum sector to allow the collimator to be *in-situ* baked.
- Prototyping for integration ongoing



6. Layout

Updated Layout

- LHCLSXH__0010 and LHCLSXHT__0010
- Vacuum functionalities introduced



P. Fessia

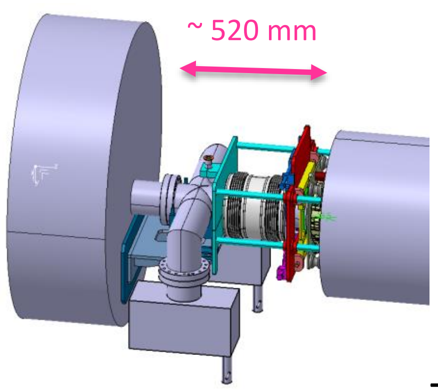
Optimisation of areas : TAXS-Q1, interconnects, TAXN-D2, crab cavities

New VAX area in IR1 and 5

- Move the instrumentation in front of Q1 to the experiment's cavern to reduce radiation to the personnel: robustness, remote handling and tooling are required
- Installation during LS3 during TAS exchange, the impact on the experimental vacuum chamber beam pipe still needs to be defined
- TAXS-Experiments & Q1-TAXS areas studies are coordinated by WP8
- Unbaked a-C coated TAXS

Pumping and bellow to decouple room temperature TAS from cryogenic temperature triplet

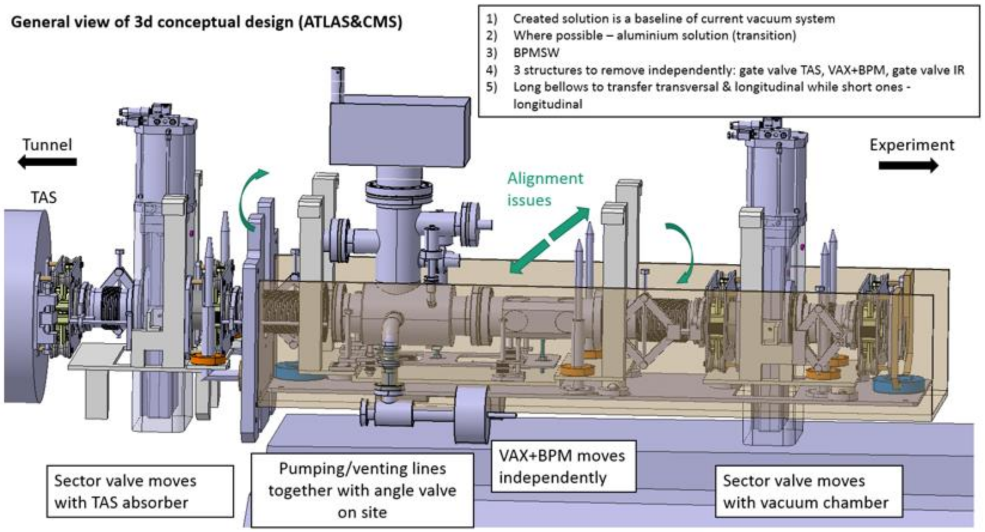
Sectorisation to decouple experiment's vacuum from machine vacuum



Q1

TAS

Courtesy L. Krzempek



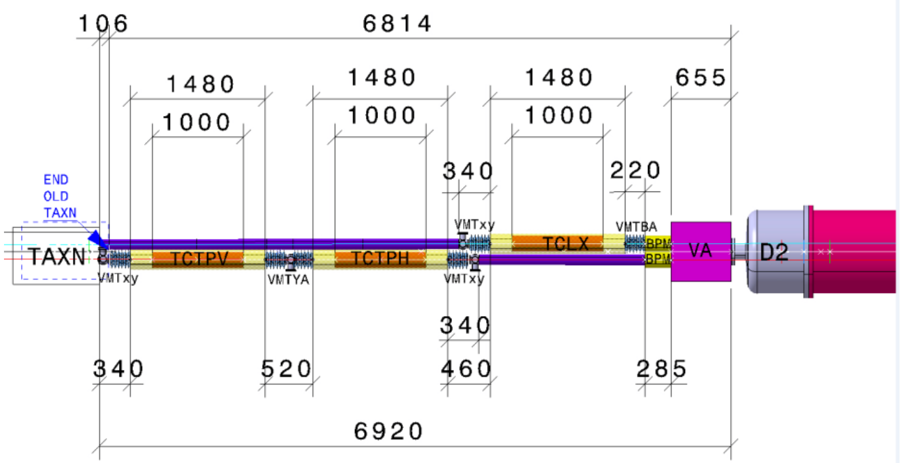
TAS

~ 16 m

J. Perez. Espinos

TAXN – D2 area

- Longitudinal layout defined including 5th axis for collimation
- Potential issue with transverse dimensions: learn from LHC YETS 2015



- Bakeout jacket of TCTPV removed to allow the installation of the beam pipe

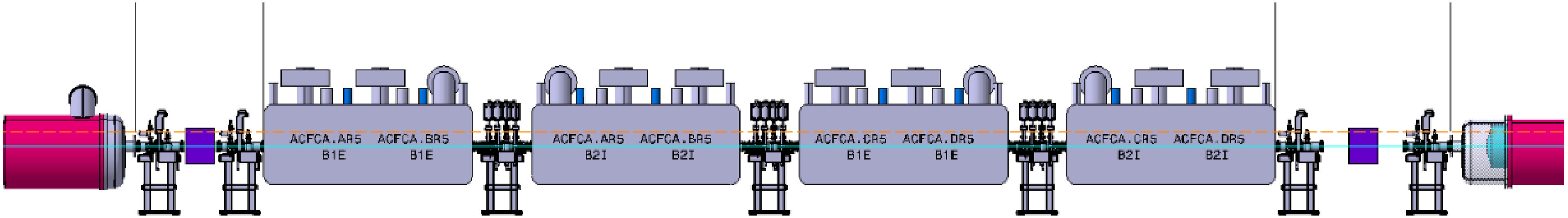
→ loss of vacuum performances

Layout D2-Q4

D2

LHCLSXH_0010 V0.3 under approval

Q4



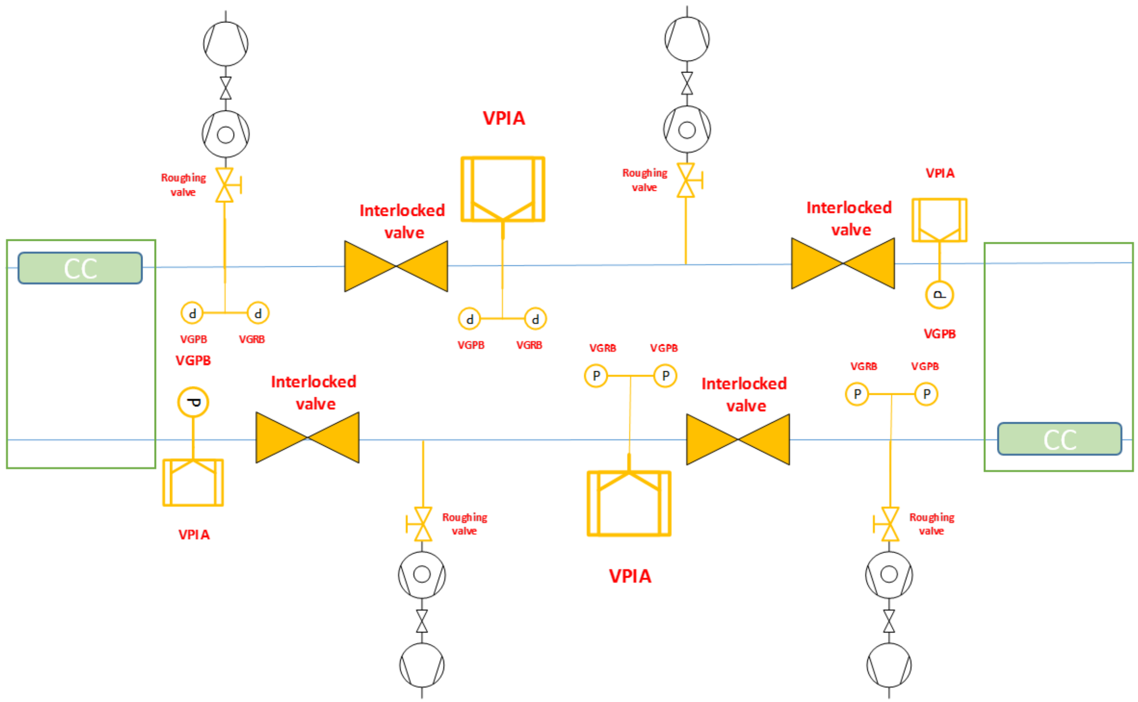
B. Vasquez de Prada

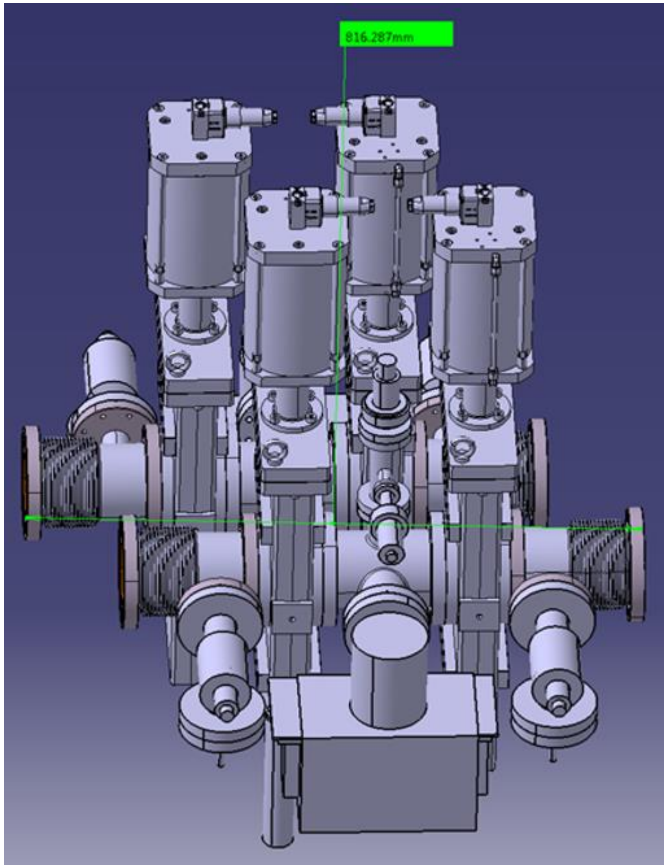
- 5 x 4 sector valves between D2 and Q4 !
- 9 x 2 vacuum sectors !
- Room temperature sectors (except CC modules): bakeable and NEG coated
- 4 sectorised CC modules: unbaked, operating at cryogenic temperature
- 3 types of sector valves assemblies (VAB)

Need to be reviewed following CC modification

Crab Cavities Modules Interconnection

- Progress in the definition of the inter-module: allocated length increased to 820 mm

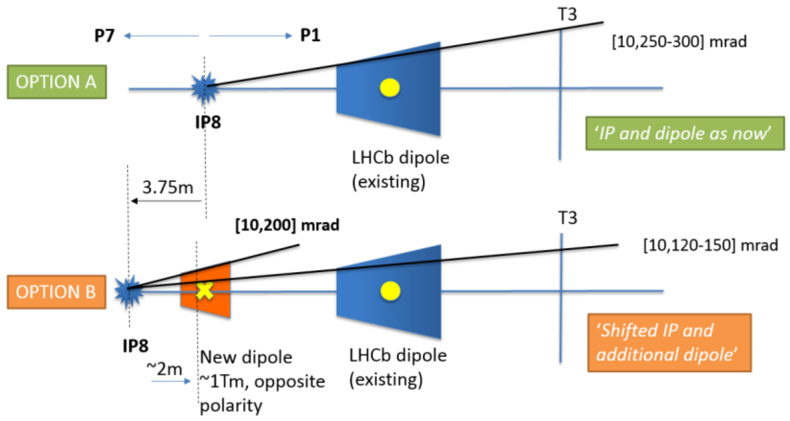


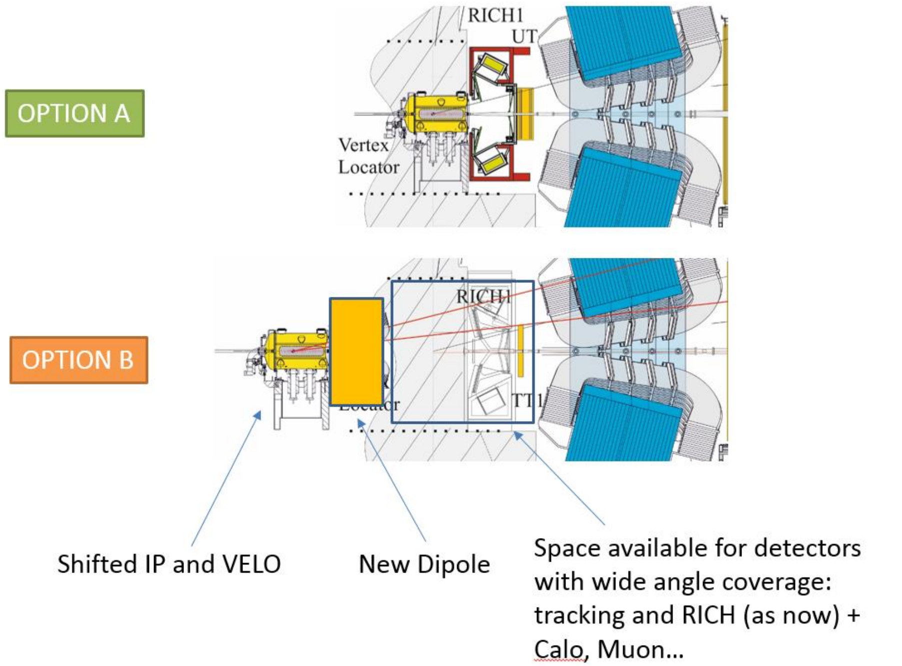


R. Fernandez Gomez

7. LHCb request

LHCb @ 10^{34} Hz/cm^2





- Option A:

Redesign detector to cope with higher rate

- Option B: This is the preferred solution !

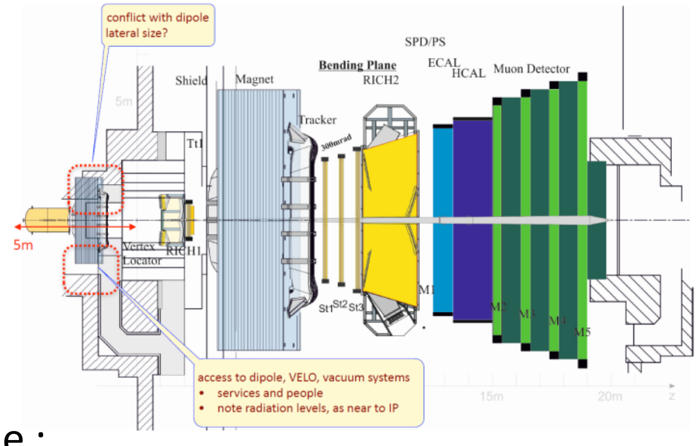
Displace VERTEX detector towards P7 by 3.75 m to reduce the rate and add a new dipole

E. Tomas

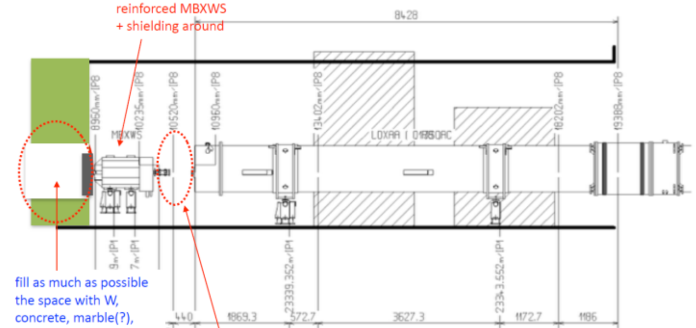
Impact of LHCb @ 10^{34} Hz/cm^2

- Shift of the experiment towards the left side by ~ 5 m:

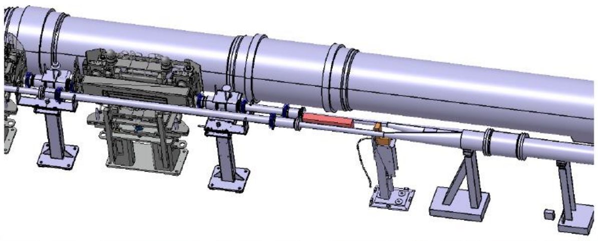
I. Efthymiopoulos



- "TAS" like object are needed on the left and right side :



- "TAN" like object are needed on the left and right side :



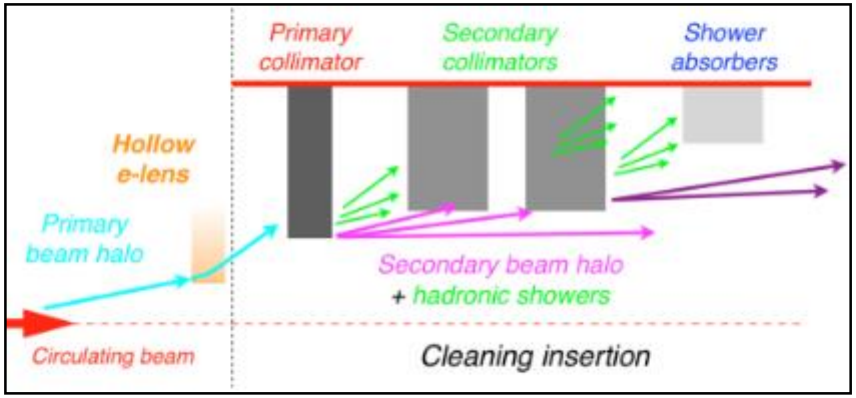
Under study !

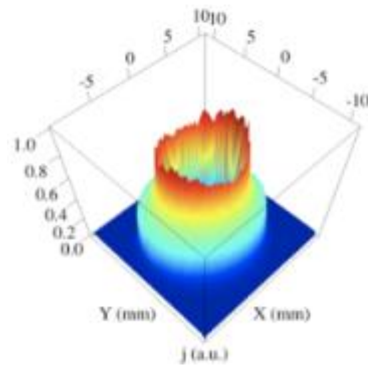
8. Options: not in base line but under study

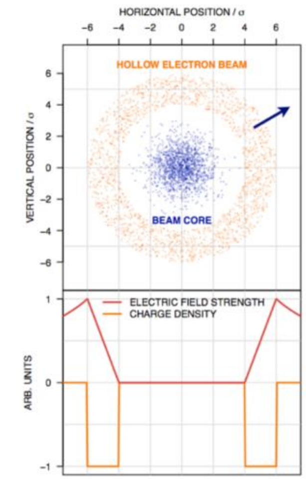
Option: hollow e-lens

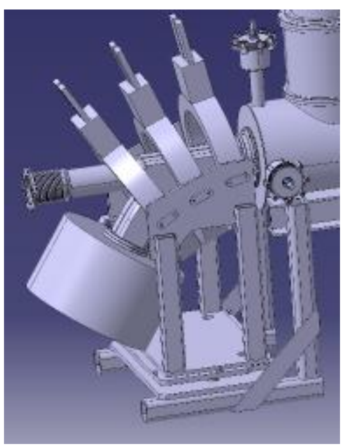
S. Redaelli

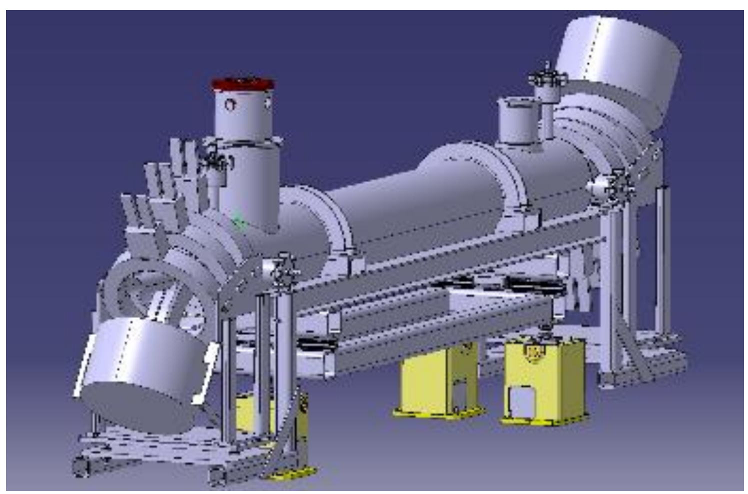
- Hollow electron beams running coaxially to the proton beam will provide an active control of beam halo population (fast failure of crab cavities) and beam loss rate. Installation LS2-LS3

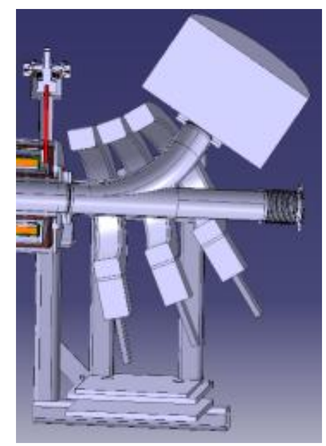










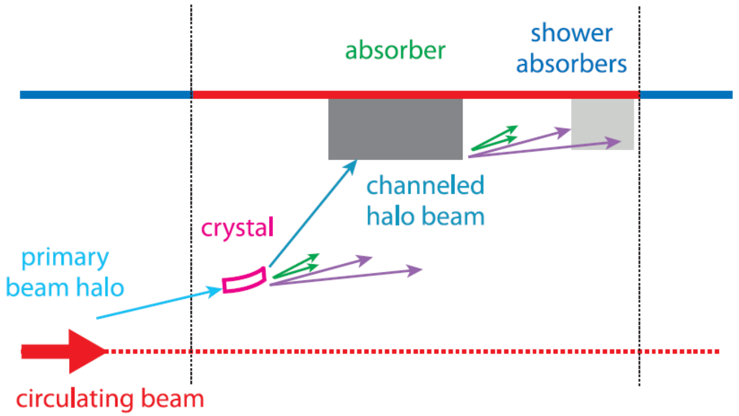


- 5T field
- 3 m long
- RT vacuum system, bakeable

D. Perini

Option: cristal collimation

- A possible mean to improve collimation cleaning while reducing impedance
- A test bed already (partially) installed in LSS7 !
- More news during run 2 ….



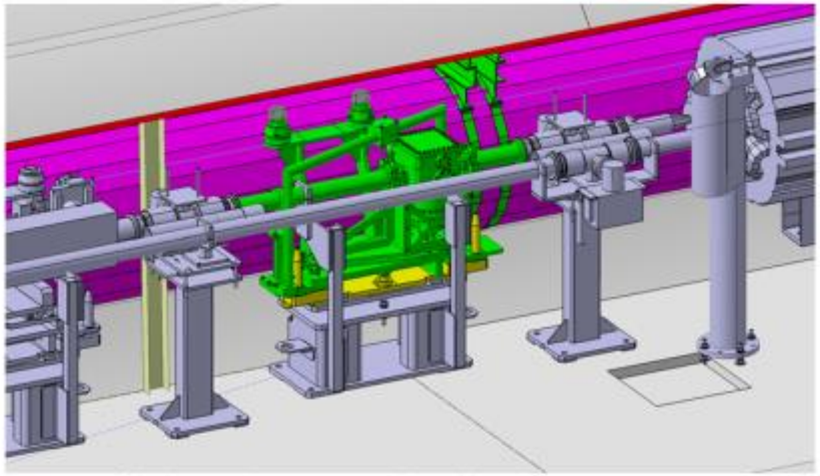


Figure 6: Integration of the horizontal goniometer, including additional beam pipe segments needed to fill the existing collimator slot.

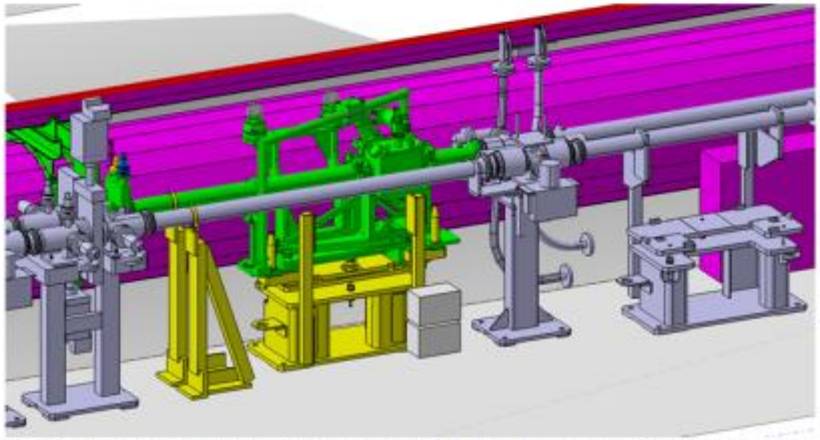


Figure 7: Integration of the vertical goniometer, including additional beam pipe segments needed to fill the existing beam pipe slot.

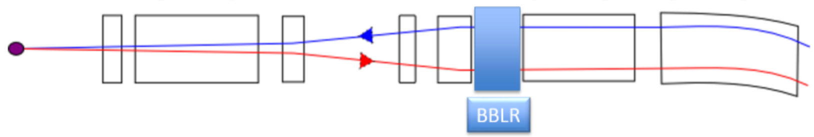
S. Redaelli

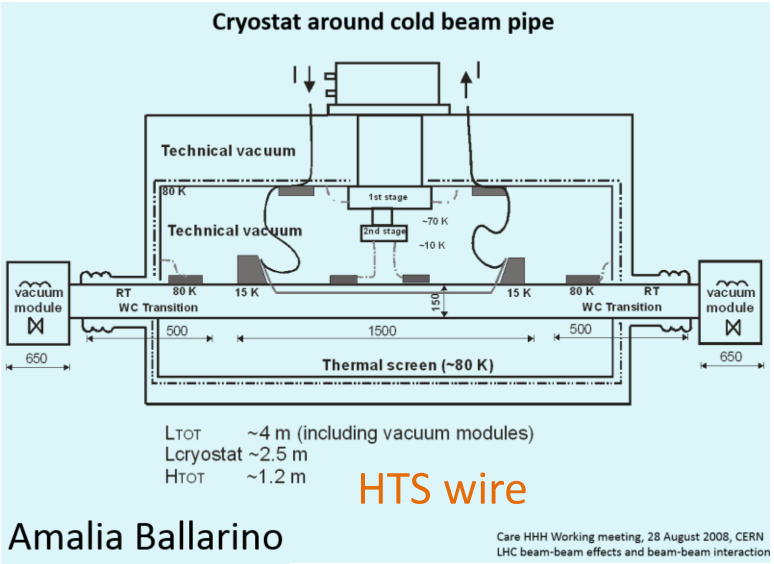
Option: BBLR

- Beam-beam long range compensation (BBLR) with a flat beam optic is a plan B for HL-LHC operation without crab cavities.

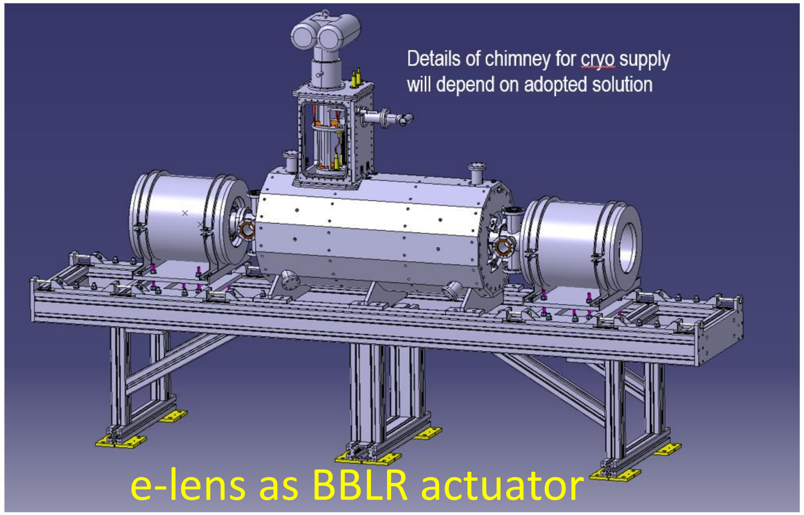
S. Farthouk

  - Distance from IR ~ 150 m
  - Distance to beam 9.3 s
  - Current ~ 125 A





1m long SC solenoid prototype (D. Perini *et al.*)

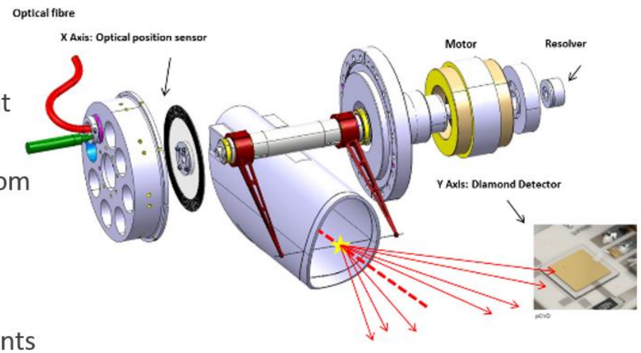


A prototype could be installed by LS2 !

H. Schmickler

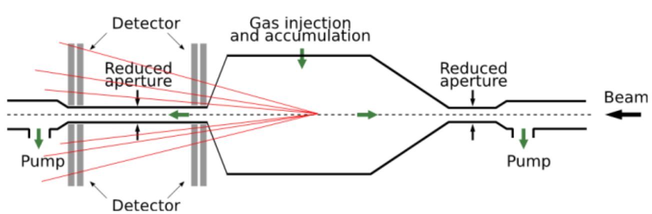
Option: BI

- Fast wire-scanners
  - All moving components in vacuum eliminating need for moving bellows
  - Coupled to diamond detector read-out system
  - Cost estimate based on predictions from SPS prototype development
  - Main risk identified
    - Achieving low impedance design
    - Mitigation through SPS measurements & optimisation by simulation

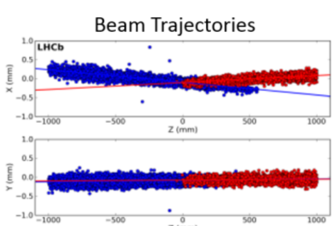


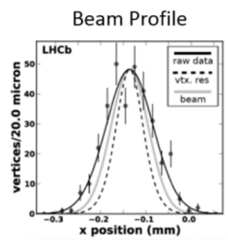
R. Jones

- Non invasive beam size measurement



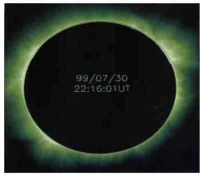
- Concept used by LHCb vertex detector (VELO)
  JINST 7 (2012) P01010, JINST 9 (2014) P12005
- Collaboration between CERN, EPFL (CH), RWTH (DE)

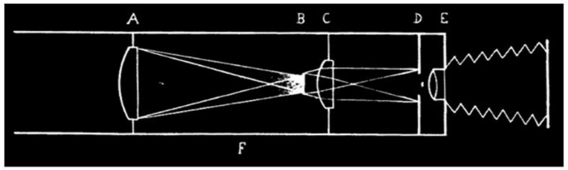




Beam Gas Vertex

- Halo diagnostic
  - No instrumentation currently installed in LHC to measure the beam halo
  - Important diagnostic for HL-LHC to measure Halo creation and mitigation techniques based on
    - Hollow electron beam collimation
    - Long range beam-beam compensators
  - Aiming at high dynamic range measurement (up to 10^{-5}) using non-Invasive technique
    - Optical techniques using synchrotron radiation in collaboration with KEK





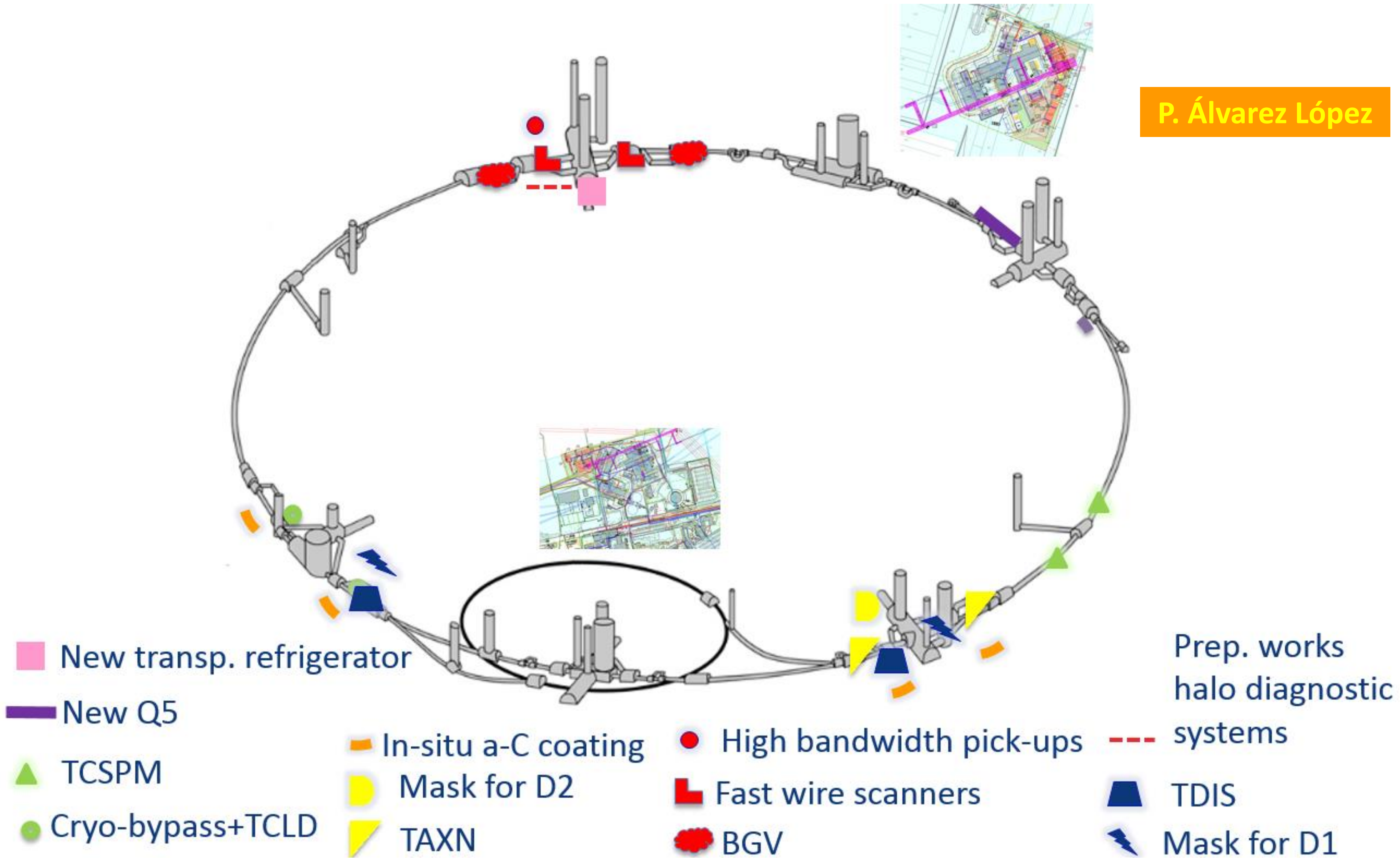
Lyot's Solar Coronagraph, 1936

Coronograph

9. LS2

Installation overview for LS2

P. Álvarez López



HL-LHC activities during LS2 & LS3

- Presented during LS2 days (P. Álvarez López, G. Bregliozzi)
  - In-situ a-C coating of IT in LSS2 and 8
  - Support to other WP

Equipment	Location
In-situ a-C coating	P2, P8
Works for other WPs[1]	P2, P4, P6, P7, P8

[1] EQUIPMENT REQUIRING VACUUM INTERVENTION

WP3	Q5	P6
WP5	By-pass collimator + TCLD	P2
WP5	Hollow e-lens	P4
WP5	TCSPM	P7
WP8	TAXN	P8
WP8	Mask for D2	
WP13	Fast wirescanners	P4
WP13	BGV	P4
WP14	TDIS	P2,P8
WP14	Mask for D1	P2, P8

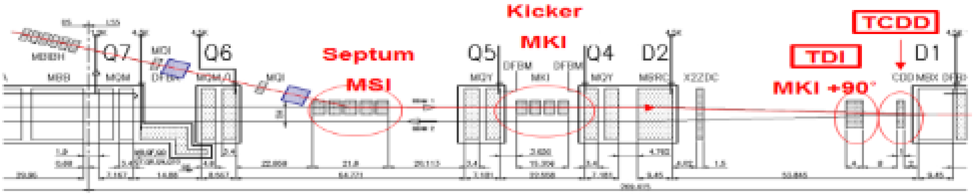
P. Álvarez López
LS2 days

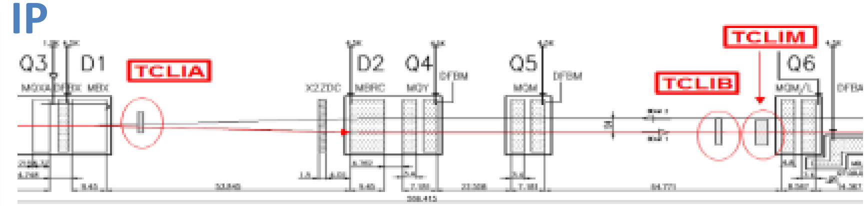
  - LS2 days: https://indico.cern.ch/event/436424/
- Detailed list of activities during LS2 and LS3 is drafted

	LHC	LS1	HL-LHC		
	Vacuum Sectors	Vacuum Sectors	Vacuum Sectors	LS2: Length (m)	LS3: Length (m)
Cryogenic temperature	92	92	56	57	700
Baked Room temperature	185	146	141	837	2555
Unbaked Room temperature	6	2	6	400	500

* HL-LHC options are excluded

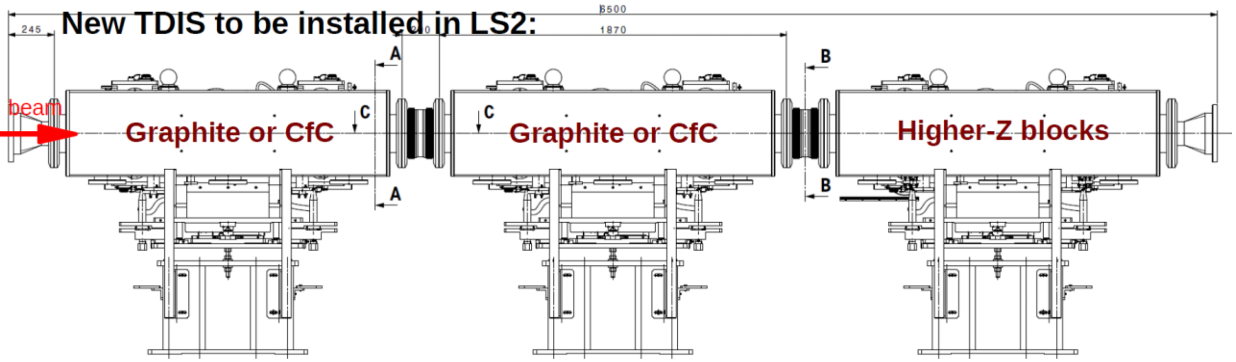
Beam transfer and kickers

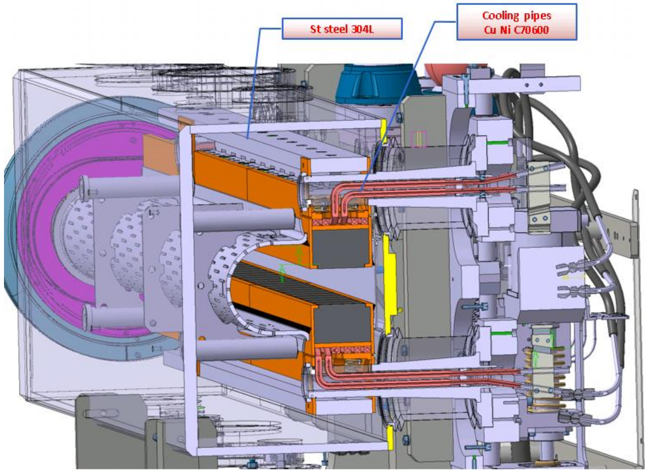




- Injection protection elements to be installed in **LS2**
  - Segmented TDIS
    - TDI interferometry on the way to be installed during run II
    - 3 x 1.5 m long modules : 2 x low Z material (graphite) + 1 x high Z material

J. Uythoven

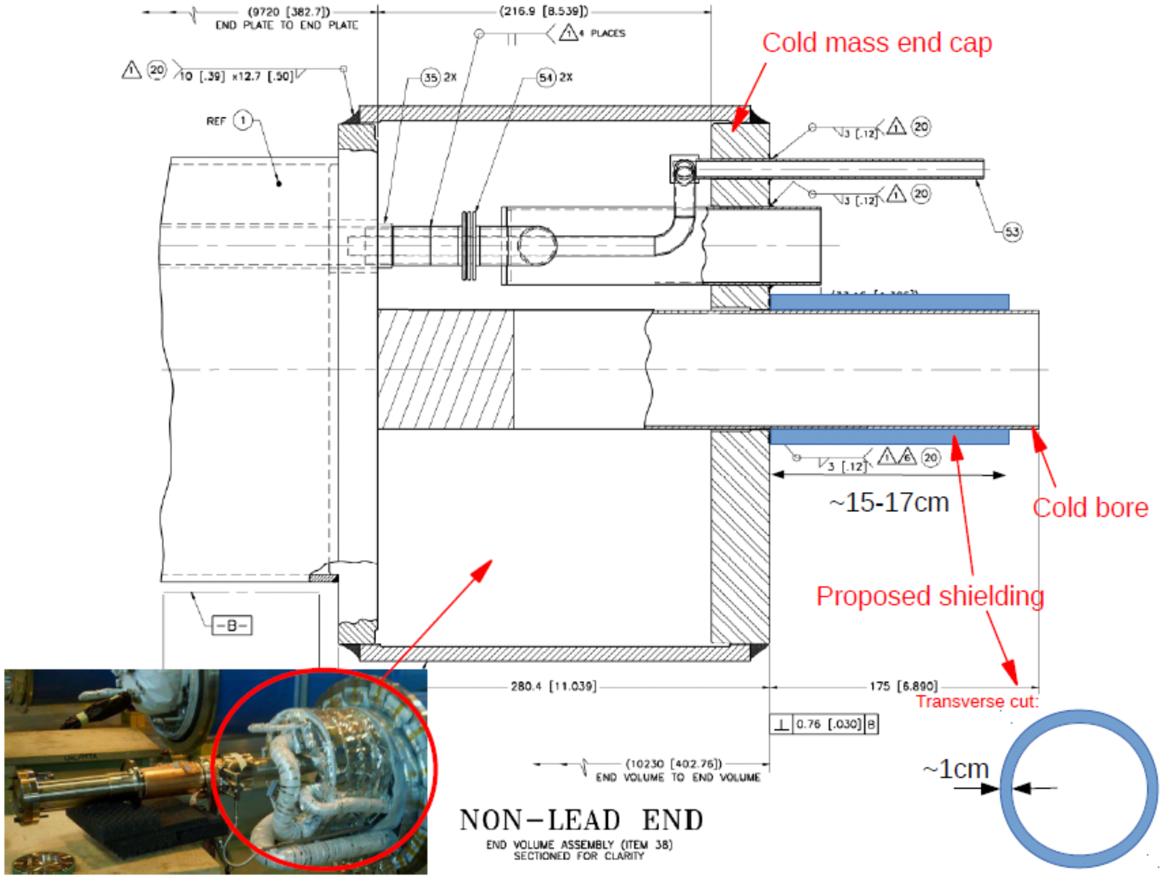




These upgrades must be **compatible with HL-LHC**

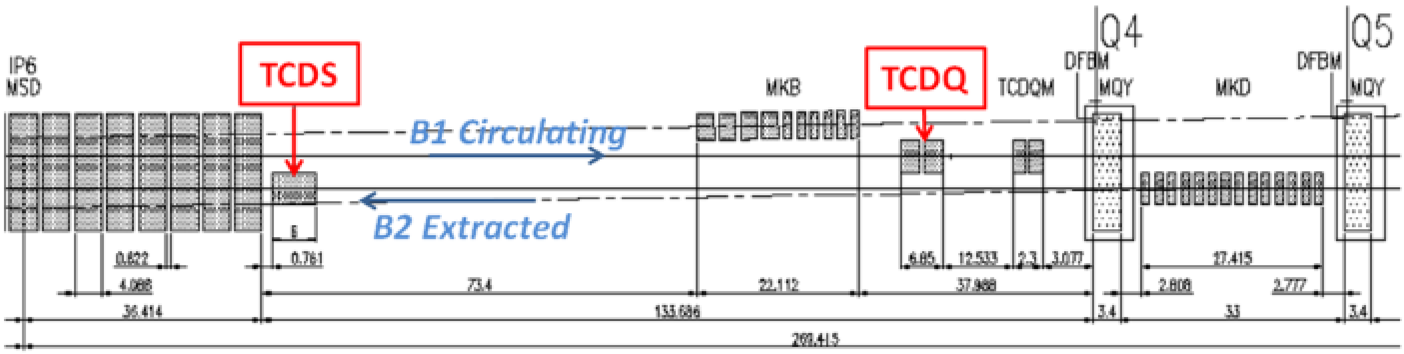
Beam transfer and kickers

- Injection protection elements to be installed in **LS2**
  - Absorber in front of D1
- TCLIA and TCLIB likely not replaced for protection reasons
  - However TCLIA IP2 larger opening because of ALICE ZDC?



J. Uythoven

Beam dumping system



- To be potentially upgrade in LS3 only

  - Verification of TCDS for HL-LHC beams: will likely need to be upgraded.
  - Check the already modified TCDQ : further upgrade not foreseen in the baseline.
  - Check TDE heating after multiple dumps – nitrogen venting.
  - Check TDE window – if this is an issue, might need to change dilution pattern. This is not part of the HL-LHC baseline.

J. Uythoven

LHC Experiments upgrades

G. Riddone
J. Sestak

- Work packages for LS2 (EDMS 1065775)

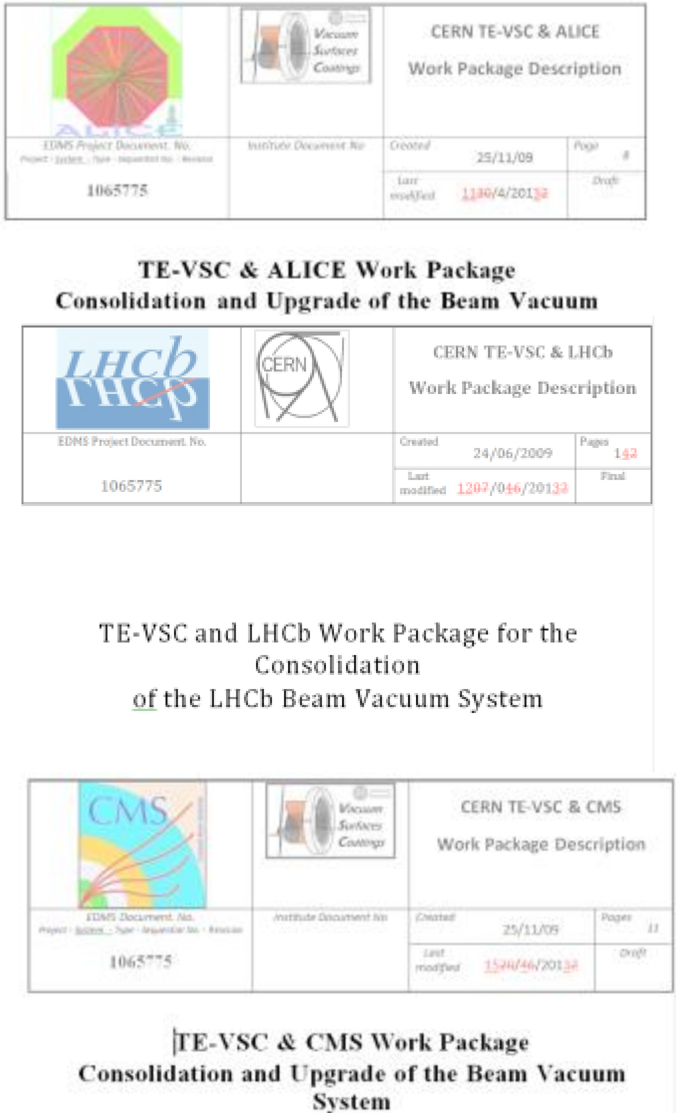
- Reduced ALICE Be beam pipe

- New VErtex LOcator for LHCb

- Replacement of stainless steel to Aluminum chambers for CMS

- ATLAS upgrade with a new small wheel

These upgrades must be **compatible with HL-LHC**
(EDMS 13601088-91) *e.g.* adaptation of ATLAS and CMS interface to new VAX area from LS3 onwards


CERN TE-VSC & ALICE
Work Package Description
EDMS Project Document No. 1065775
Created 25/11/09
Last modified 11/10/4/2013

TE-VSC & ALICE Work Package
Consolidation and Upgrade of the Beam Vacuum

CERN TE-VSC & LHCb
Work Package Description
EDMS Project Document No. 1065775
Created 24/06/2009
Pages 142
Last modified 1207/046/20133
Final

TE-VSC and LHCb Work Package for the Consolidation
of the LHCb Beam Vacuum System

CERN TE-VSC & CMS
Work Package Description
EDMS Document No. 1065775
Created 25/11/09
Last modified 1526/46/2013

TE-VSC & CMS Work Package
Consolidation and Upgrade of the Beam Vacuum System

10. Summary

Summary

- The design study phase is now finished (end of FP7)

- Many progress has been done in several areas of the project in the past years (studies of a-C coating, design of beam screens, interconnects, vacuum layout etc.)

- Beside the continuing studies and designs, next objectives are the TDR_V1 (Production stage: fabrication, assembly and verification) by end 2016 with a 2nd Cost & Schedule Review foreseen in Nov 2016

- There is a strong commitment of the group to the HL-LHC project which will become even stronger in the near future

Acknowledgments

- This presentation reflects the work of many people from the group. Particular credits should go to:

The group management for the support and stimulation: P. Chiggiato and P. Cruikshank
G. Riddone
BVO:
G. Bregliozzi, J.A. Ferreira Somoza, C. Pasquino, J. Sestak
DLM:
C. Garion, J. Perez Espinos, N. Kos, M. Sitko, A. Vidal, H. Rambeau, H. Kos, Q. Deliege, R. Fernandez Gomez, M. Morrone, L. Krzempek
ICM:
P. Gomes, G. Pigny
SCC:
M. Taborelli, P. Costa-Pinto and the team in charge of surface analysis

VSM:
V. Baglin, R. Kersevan, S. Calatroni, I. Wevers, A-L Lamure, R. Salemme

Thank you for your attention

The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.

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High
Luminosity
LHC

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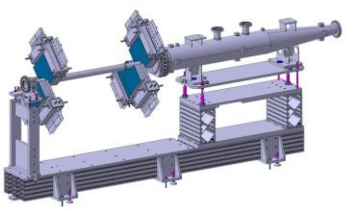
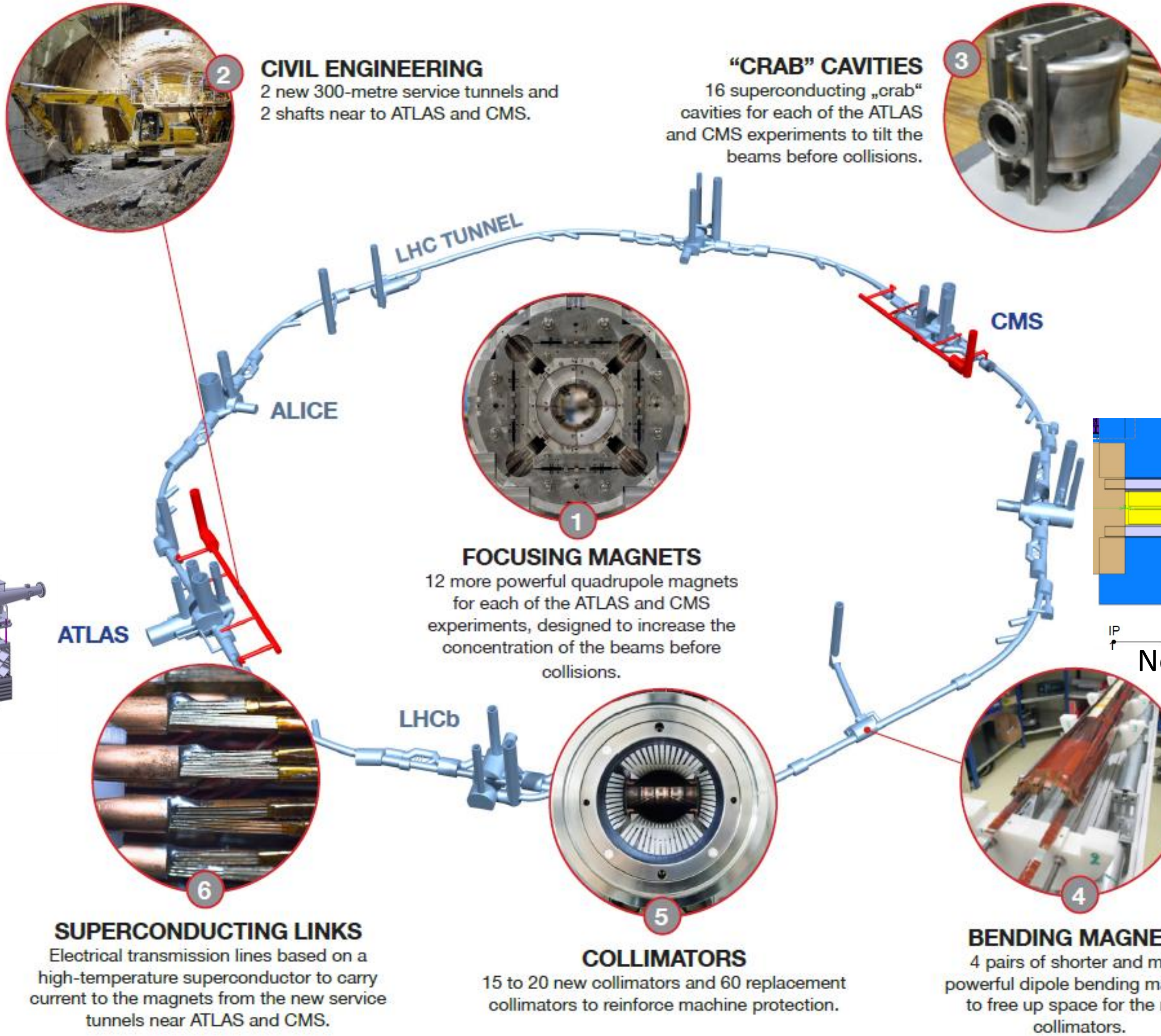
Back up slides

Works all around the ring… new C.E. and technical infrastructure

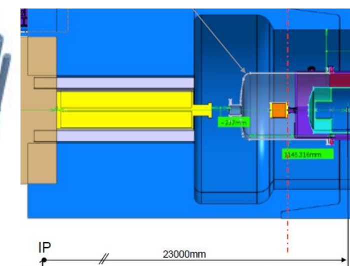
Cryo@P4



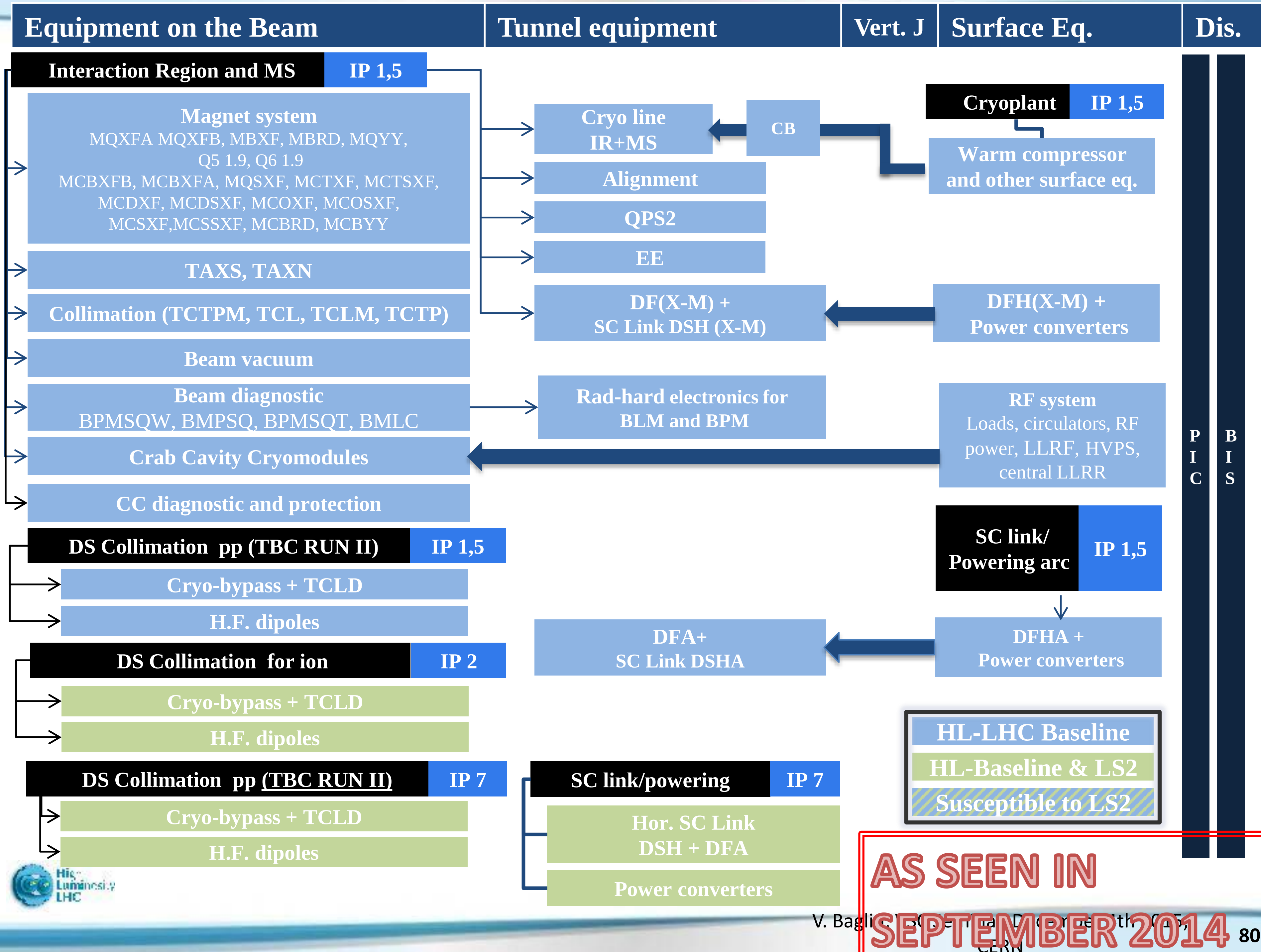
Beam diagnostics
BGV

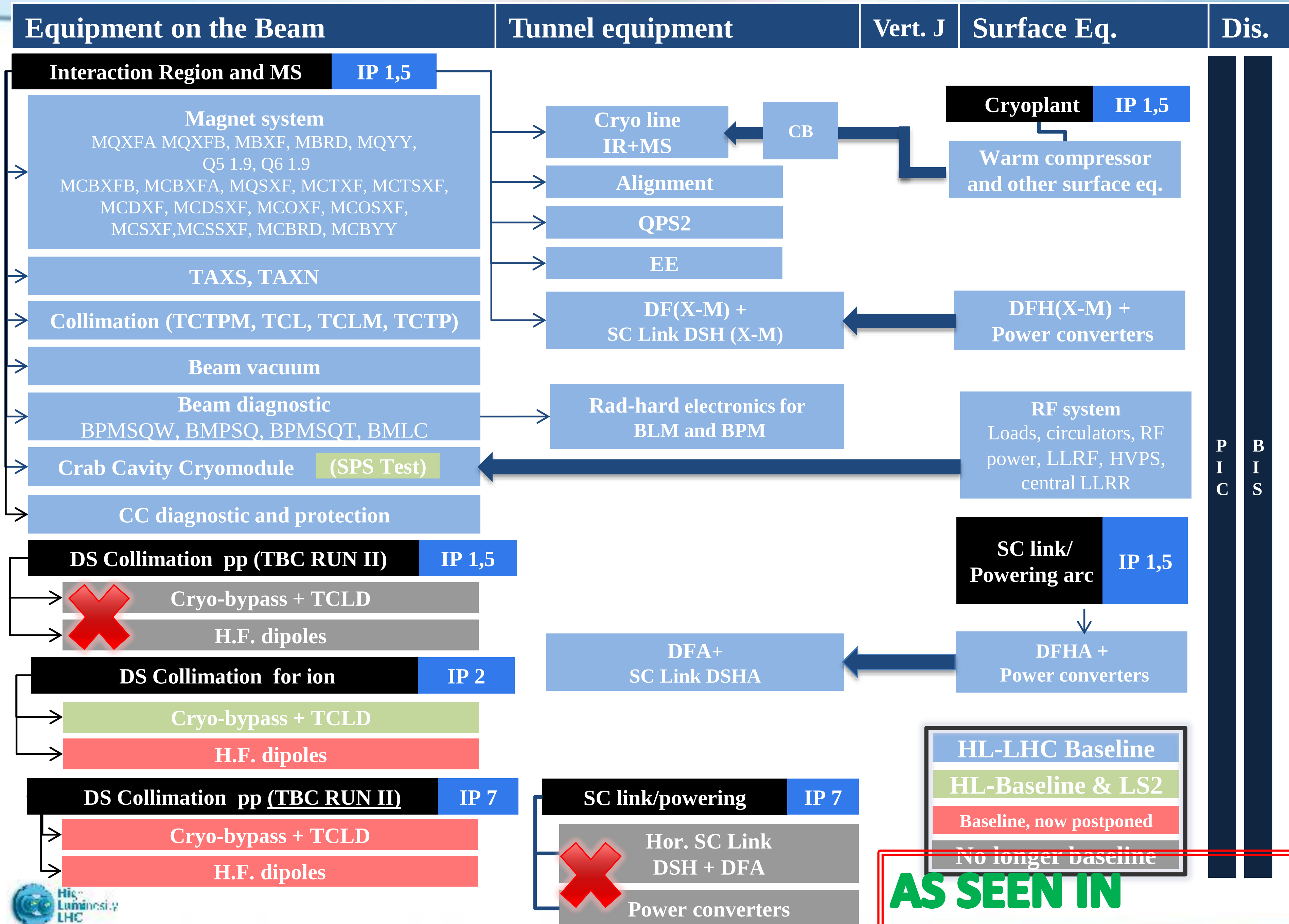


Cryo@P1-P5



New TAS and VCX


Equipment on the Beam
Tunnel equipment
Vert. J
Surface Eq.
Dis.
Interaction Region and MS
IP 1,5
Magnet system
MQXFA MQXFB, MBXF, MBRD, MQYY,
Q5 1.9, Q6 1.9
MCBXFB, MCBXFA, MQSXF, MCTXF, MCTSXF,
MCDXF, MCDSXF, MCOXF, MCOSXF,
MCSXF,MCSSXF, MCBRD, MCBYY
TAXS, TAXN
Collimation (TCTPM, TCL, TCLM, TCTP)
Beam vacuum
Beam diagnostic
BPMSQW, BMPSQ, BPMSQT, BMLC
Crab Cavity Cryomodules
CC diagnostic and protection
Cryo line
IR+MS
CB
Alignment
QPS2
EE
DF(X-M) +
SC Link DSH (X-M)
Rad-hard electronics for
BLM and BPM
Cryoplant
IP 1,5
Warm compressor
and other surface eq.
DFH(X-M) +
Power converters
RF system
Loads, circulators, RF
power, LLRF, HVPS,
central LLRR
PIC
BIS
DS Collimation pp (TBC RUN II)
IP 1,5
Cryo-bypass + TCLD
H.F. dipoles
DS Collimation for ion
IP 2
Cryo-bypass + TCLD
H.F. dipoles
DS Collimation pp (TBC RUN II)
IP 7
Cryo-bypass + TCLD
H.F. dipoles
SC link/
Powering arc
IP 1,5
DFHA +
Power converters
DFA+
SC Link DSHA
SC link/powering
IP 7
Hor. SC Link
DSH + DFA
Power converters
HL-LHC Baseline
HL-Baseline & LS2
Susceptible to LS2
AS SEEN IN
SEPTEMBER 2014



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Tunnel equipment
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H.F. dipoles
DS Collimation pp (TBC RUN II)
IP 7
Cryo-bypass + TCLD
H.F. dipoles
SC link/
Powering arc
IP 1,5
DFA+
SC Link DSHA
DFHA +
Power converters
SC link/powering
IP 7
Hor. SC Link
DSH + DFA
Power converters
HL-LHC Baseline
HL-Baseline & LS2
Baseline, now postponed
No longer baseline
AS SEEN IN
SEPTEMBER 2015

Equipment on the Beam	Tunnel equipment	Vert. J	Surface Eq.	Dis.

Collimation upgrade
- Secondary TCSPM — IP 3, 7
- Primary TCP TCPP — IP 3 ,7
- TCSG, TCLA, TCAP — IP 3, 7
- TCSP — IP 6

Injection protection — IP 2, 8
- TDIS
- TCLIA, TCLIB (TBC)
- TCDD TCDDM (TBC)
- TCLIM (TBC)
- MKI (TBC)

Beam diagnostic — IP 4
- Fast wire scanners BWSF
- New light extraction line BSRT
- Beam gas vertex detector BGV

Q5 at point 6 — IP 6

Dump (TBC) — IP 6
- TCDS (TBC)
- MKB, TDE (TBC)

High rad warm magnets (TBC) — IP 7

TAXN for LHCb — IP 8

AS SEEN IN SEPTEMBER 2014

Cryoplant — IP 4

Warm compressor and other surface eq. → CB → Cryoline for RF

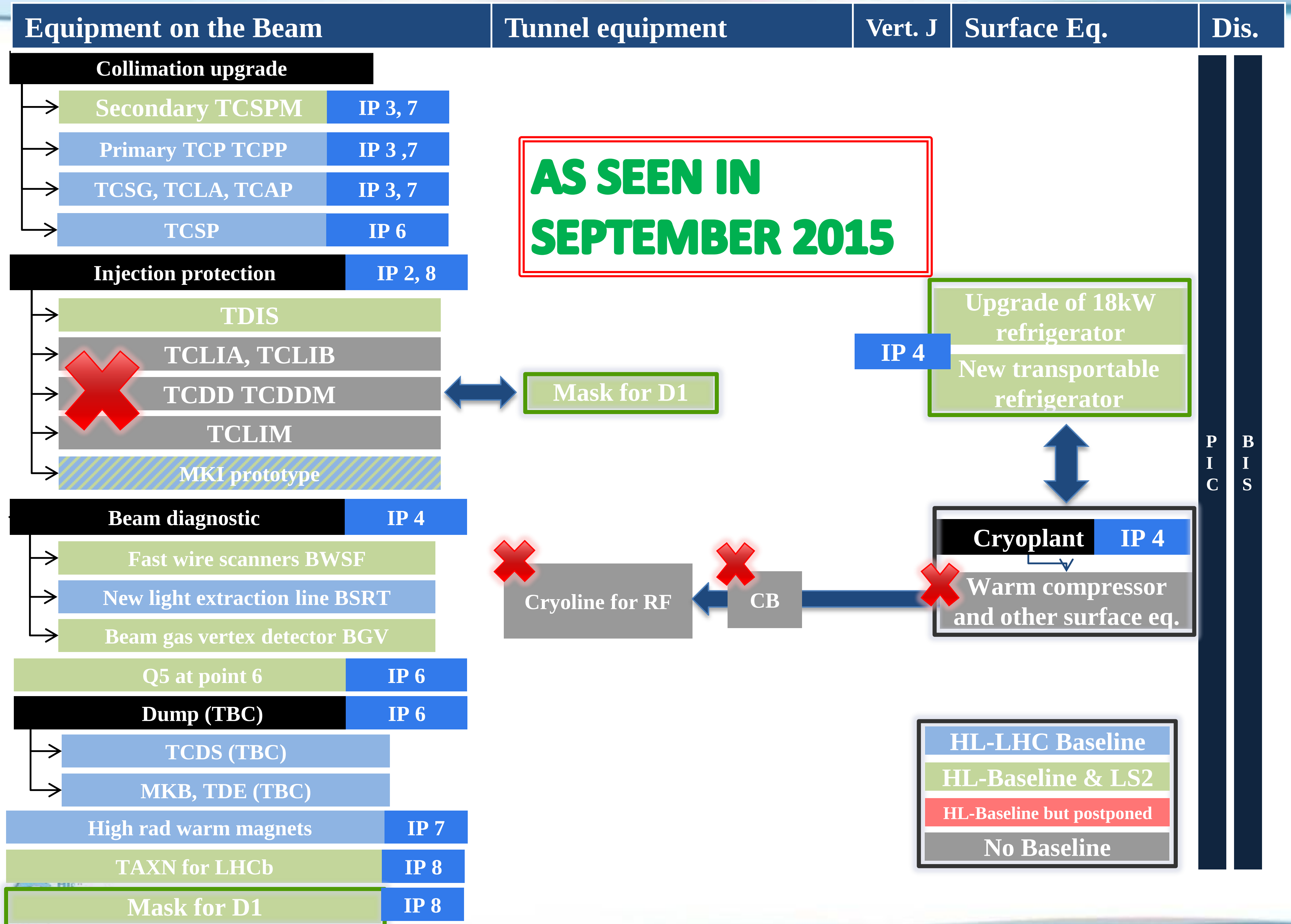
P I C

B I S

HL-LHC Baseline

HL-Baseline & LS2

Susceptible to LS2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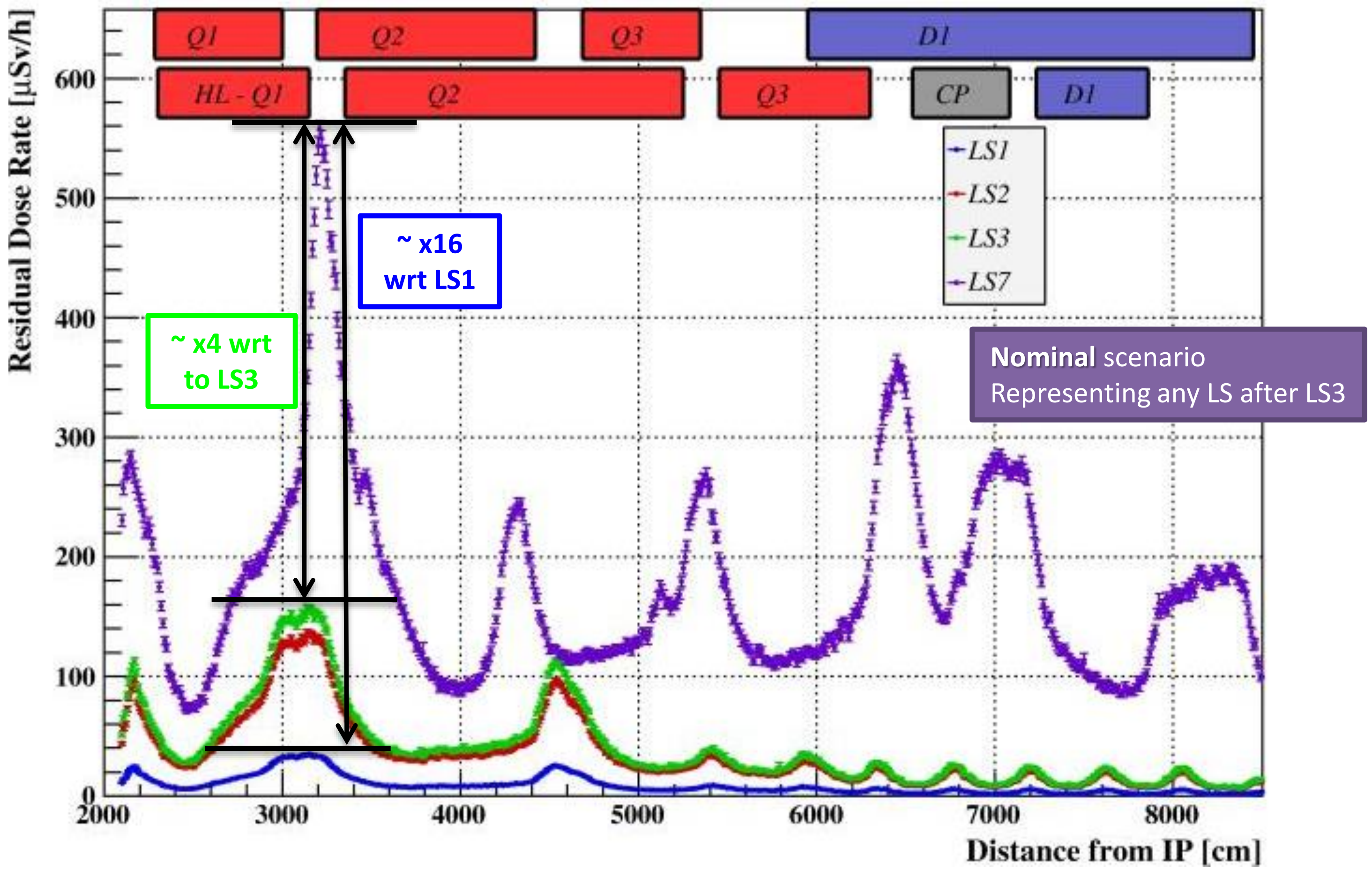
Tunnel equipment
Vert. J
Surface Eq.
Dis.
Collimation upgrade
Secondary TCSPM
IP 3, 7
Primary TCP TCPP
IP 3 ,7
TCSG, TCLA, TCAP
IP 3, 7
TCSP
IP 6
Injection protection
IP 2, 8
TDIS
TCLIA, TCLIB
TCDD TCDDM
TCLIM
MKI prototype
Beam diagnostic
IP 4
Fast wire scanners BWSF
New light extraction line BSRT
Beam gas vertex detector BGV
Q5 at point 6
IP 6
Dump (TBC)
IP 6
TCDS (TBC)
MKB, TDE (TBC)
High rad warm magnets
IP 7
TAXN for LHCb
IP 8
Mask for D1
IP 8
AS SEEN IN SEPTEMBER 2015
Mask for D1
IP 4
Upgrade of 18kW refrigerator
New transportable refrigerator
Cryoplant
IP 4
Warm compressor and other surface eq.
CB
Cryoline for RF
PIC
BIS
HL-LHC Baseline
HL-Baseline & LS2
HL-Baseline but postponed
No Baseline

Impact of radiation to personnel around IT

- 1 month cooling time, dose rates at 40 cm from the cryostat



C. Adorisio

Impact of radiation to personnel around IT (2)

- CERN Objective : 3 mSv/year maximum during LS (Rule for Cat B personnel : 6 mSv/y)

- Case study : When ? any LS after LS3, nominal

C. Adorisio

			Collective dose (man mSv)	
What	Where	How ?	1 month cooling time	4 months cooling time
Valve exchange	TAS-Q1	3 teams 5 workers	3	1
PIM exchange	Q1-Q2 IC	6 teams 8 workers	21	8

/2.5

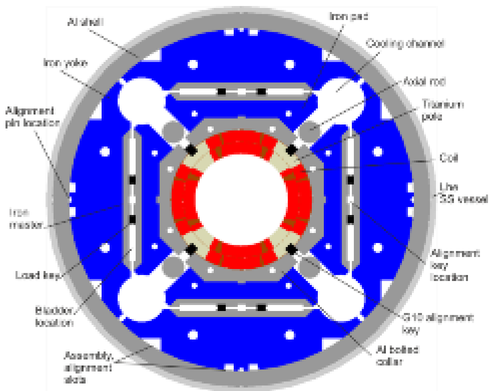
- Estimation of WDP (work dose plan) can also be done for LS3 and the removal of the present inner triplet magnets to optimize the work-methods

- Dose maps available from TAS to D1

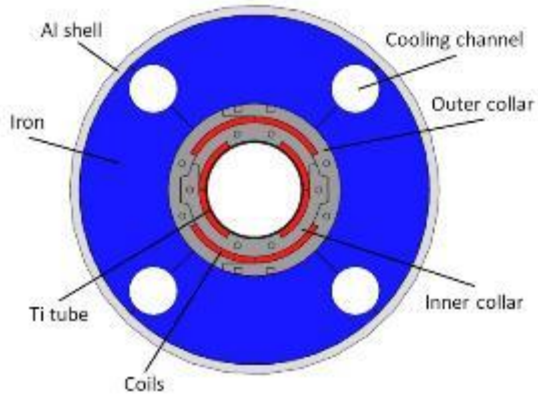
Optimisation of design, equipment robustness, intervention procedures (WDP) with use of remote tooling and training of people is **MANDATORY**

The magnet zoo in the IR

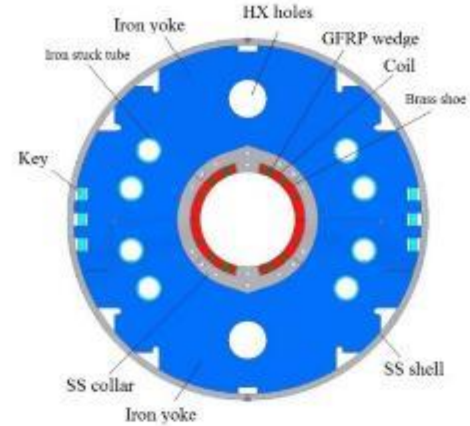
E. Todesco



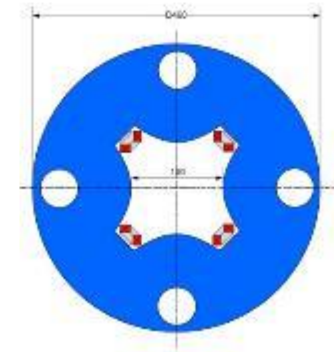
Triplet QXF (LARP and CERN)



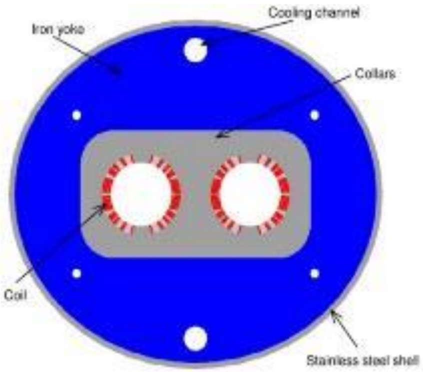
Orbit corrector (CIEMAT)



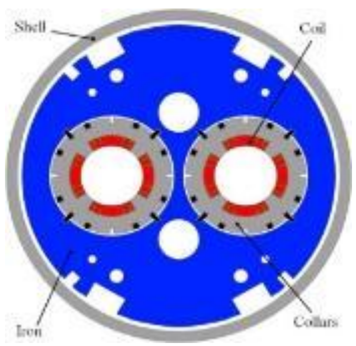
Separation dipole D1 (KEK)



Skew corrector (INFN)

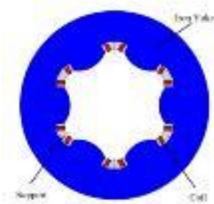


Recombination dipole D2
(INFN design)

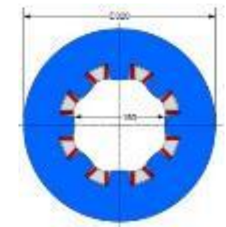


Q4 (CEA)

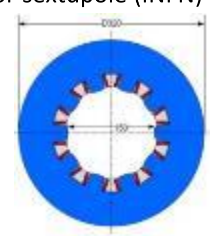
Cross-sections in scale



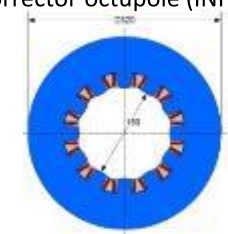
Corrector sextupole (INFN)



Corrector octupole (INFN)

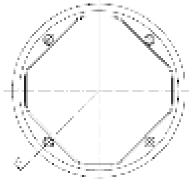


Corrector decapole (INFN)



Corrector dodecapole (INFN)

Many beam screens with interconnects and cold warm transitions to be designed, produced & installed



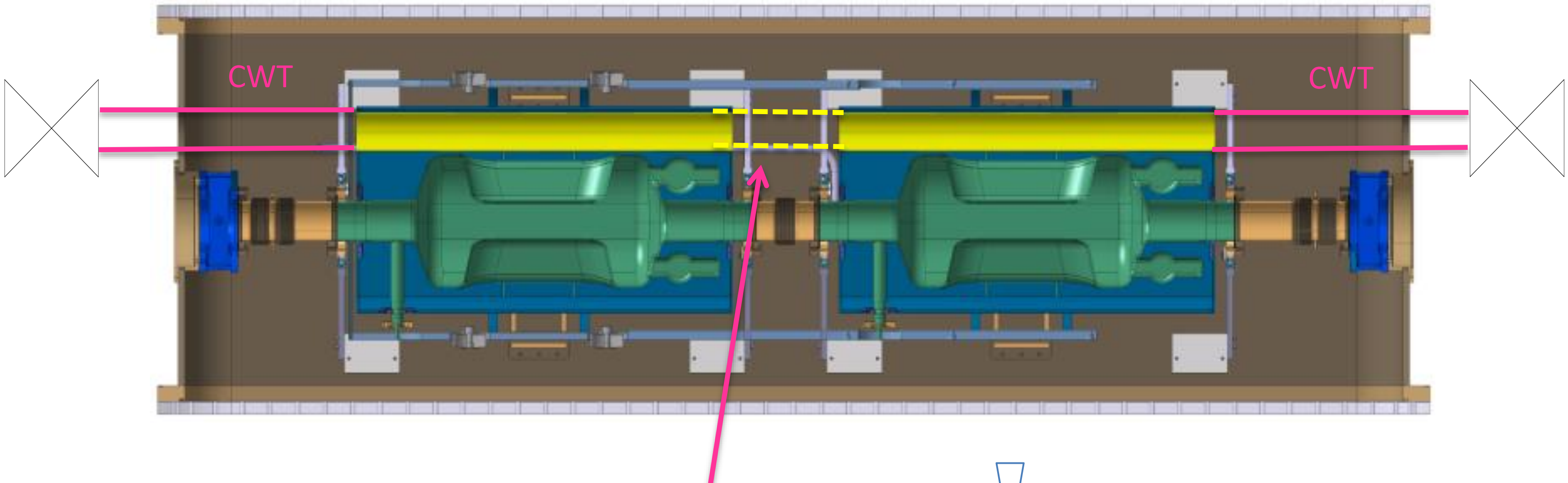
C. Garion

High Luminosity LHC

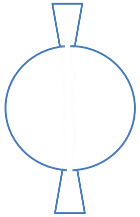
Layout –D2-Q4: 2nd beam pipe

- The 2nd beam pipe is held at 2 K and has cold warm transitions (CWT) !
- Current material is Ti, diameter limited by space

- In LHC, maximum length without beam screen is < 1 m (to be revised for HL-LHC)
- Detailed studies are needed to comply with vacuum stability and pressure level (electron cloud !)



A beam screen between 2 cryogenic pipes ?



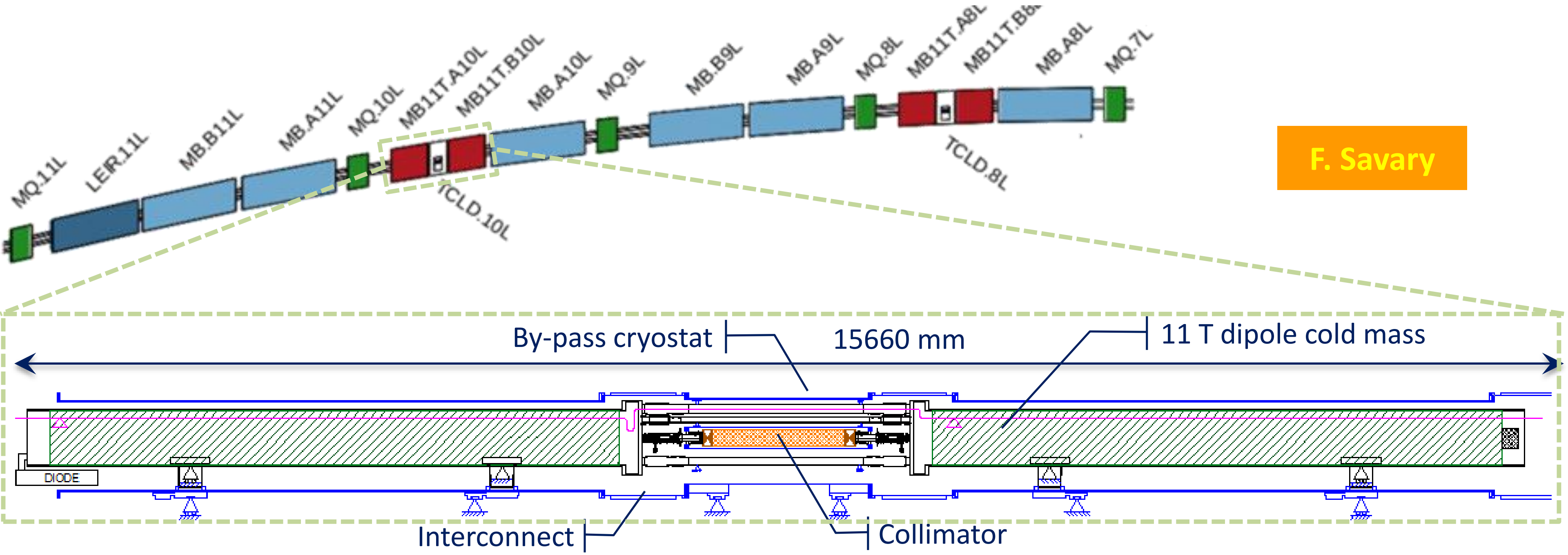
A beam pipe with Antechamber ?

11 T – DS collimator

- Arc Dispersion Suppressor areas (Q7 to Q11) serve as “energy spectrometer” : a collimator is needed to reduce background to ALICE with ion operation and to reduce beam loss on the cold masses with proton beams

- Using $NbSn_3$ technology, the dipole field can be increased up to 11 T

- A standard LHC dipole can be replaced by two 11 T magnets and one collimator (TCLD)



F. Savary

High Luminosity LHC

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