



**High
Luminosity
LHC**

Report from Parameter and Layout Committee

M.Zerlauth, O.Bruning in the name of all HL-LHC PLC members & speakers

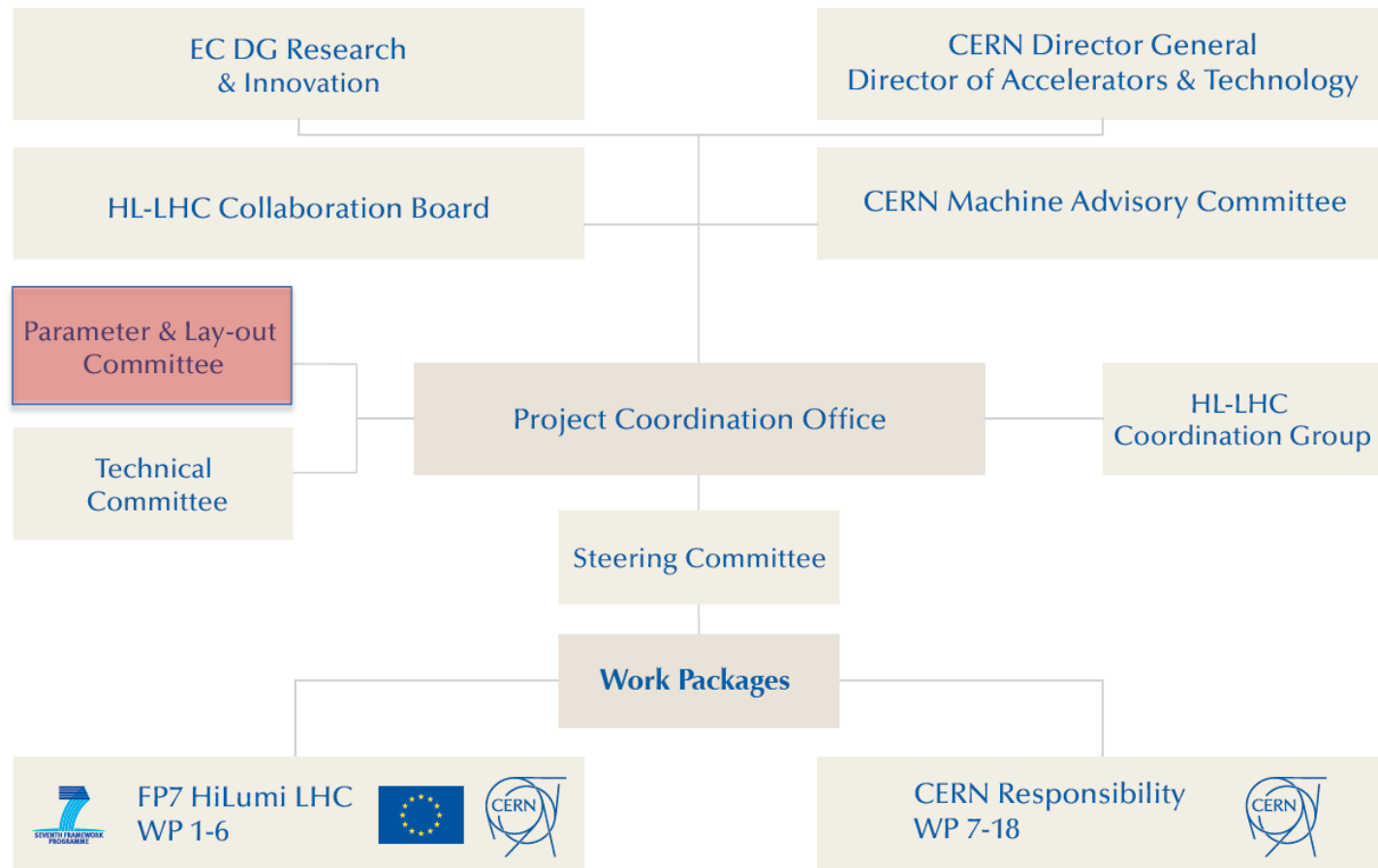
Acknowledgments: A.Ballarino, I.Bejar Alonso, R.Calaga, F.Cerutti,
S.Chemli, R.de Maria, P.Fessia, G. Iadarola, E.Jensen, R.Jones, R.Kersevan,
H.Prin, L.Rossi, G. Rumolo, E.Todesco, R.van Weelderren

Outline

- Parameter Layout Committee in the HL-LHC
Organigram and Mandate
- Main topics of first meetings – quick walkthrough
- Key decisions and ongoing work
- Future topics

HL-LHC PLC in the Organigram

High Luminosity LHC Project



PLC Mandate

- Establish and maintain a coherent and dynamic list of parameters and associated hardware layouts for the HL-LHC (beam parameters, new accelerator components including interfacing with the experimental detectors)
- The PLC will also maintain a list of processes or operational cycles for the HL-LHC run.
- The PLC will monitor and recommend changes in parameters or machine layout based on interim reports from the work package (WP) leaders or any other relevant bodies. When applicable, it will also request dedicated studies to solve or mitigate any possible kind of inconsistencies and prepare the decision making process at the Steering Committee (SC).

PLC Composition and Meeting Schedule

- Organization

Chairman: Oliver Brüning
Scientific secretary: Markus Zerlauth
Administrative support: Cecile Noels

- Composition

- Project coordination office, WP holders and main hardware groups
- 2 meetings in 2012 and 4+1 in 2013
- Approximately 1 meeting every 2 month
- PLC page under High Lumi Project Intranet
 - [HL-LHC PLC Website](#)
 - [Indico Site](#)

Parameter & Lay-out Committee meetings

December 2013

03 Dec 7th HL-LHC PLC meeting [View](#)

September 2013

03 Sep 6th HL-LHC PLC meeting

July 2013

02 Jul 5th HL-LHC PLC meeting

March 2013

26 Mar 4th HL-LHC PLC meeting

January 2013

18 Jan 3rd HL-LHC PLC Meeting

September 2012

25 Sep 2nd HL-LHC PLC Meeting

July 2012

03 Jul 1st PLC meeting

HL-LHC : work around the ring > 1.2 km

800MHz (additional)
200MHz (new main) RF systems,
BI equipment,
New cryo plant
hollow e-lens,...

Crab cavities, new triplets & matching quads +
powering/sc links, BBC, TAS/TAN....

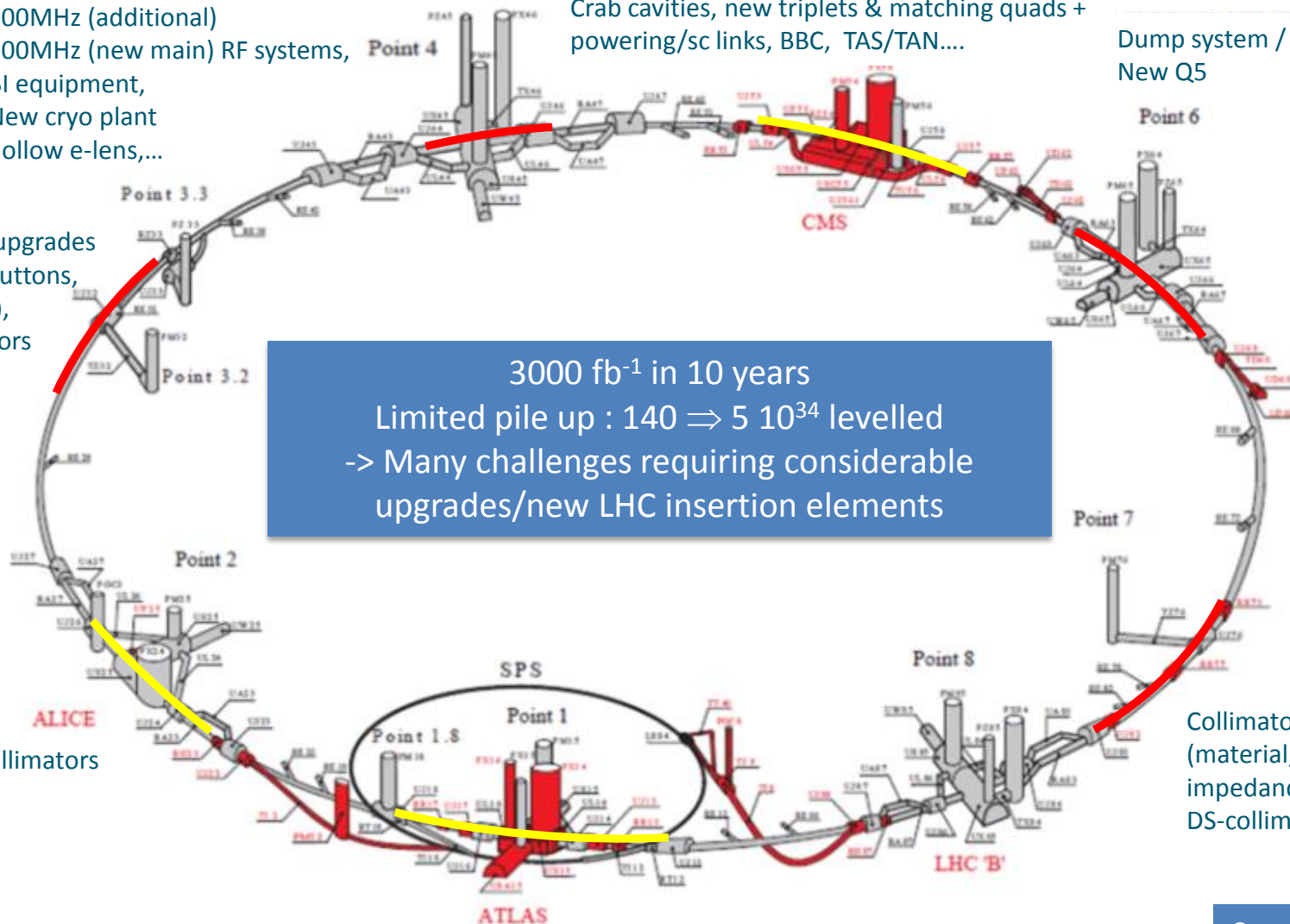
Dump system / protection
New Q5

Collimator upgrades
(material, buttons,
impedance),
DS-collimators

3000 fb⁻¹ in 10 years
Limited pile up : 140 ⇒ 5 · 10³⁴ levelled
-> Many challenges requiring considerable
upgrades/new LHC insertion elements

DS-collimators

Collimator upgrades
(material, buttons,
impedance),
DS-collimators



Crab cavities, new triplets & matching quads + powering/sc links, BBC, TAS/TAN....

Courtesy L.Rossi



Main topics for first meetings:

- Mandate and composition ✓
- Baseline parameters ✓
- Database and documentation ✓
- IR1 and IR5 baseline Layout and optics ✓
 - TAS & TAN space, space for additional components, Survey needs ✓
- Approval of triplet coil diameter of 150mm ✓
- Triplet beam screen and vacuum ✓
- Cryogenics (current limitations → IR and arcs) ✓
- Beam instrumentation (space reservations) ✓
- Crab cavity (layout and parameters) ✓
- Common Glossary with the experiments ✓

Main topics for first meetings:

- Required corrector circuits (e.g. triplet, additional octupoles...) ✓
- DS collimators ✓
- Places for new equipment in IR4: ✓
 - ➔ New Beam Instrumentation (e.g. 3d bunch profile monitor); new RF systems (e.g. 800 MHz Higher Harmonic RF, new 200 MHz capture system etc.)
- IR3 and IR7 warm magnet consolidation options ✓



O.Bruning: Report on outcome of RLIUP and ECFA workshop

HL-LHC Baseline Parameter Set ([Link](#))

HL-LHC Parameters V3.0 (Last updated 13-Mar-2013)

"Stretched" Baseline Parameters following 2nd HL-LHC/LIU:

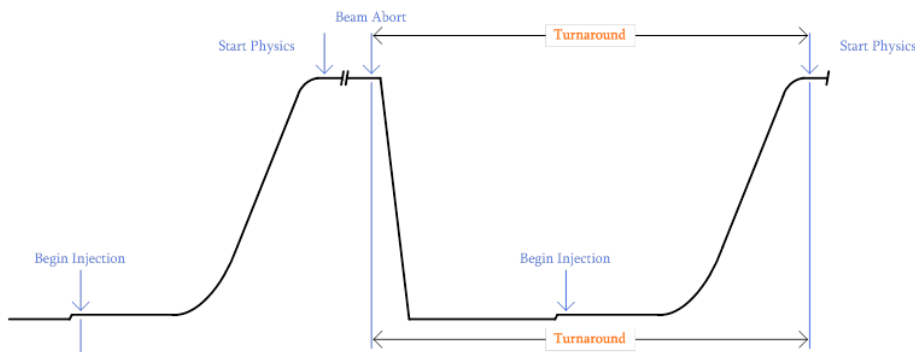
Parameter	nominal	Baseline	Backup	'Stretched' Baseline
		25ns	50ns	
N_b	1.15E+11	2.2E+11	3.5E+11	'Stretched' baseline taking into account limitations /possibilities due to injector , LHC + experiment upgrades, e- cloud, PU ...
n_b	2808	2808	1404	
N_{tot}	3.2E+14	6.2E+14	4.9E+14	
beam current [A]	0.58	1.11	0.89	
x-ing angle [μ rad]	300	590	590	
beam separation [σ]	9.9	12.5	11.4	
β^* [m]	0.55	0.15	0.15	
ϵ_n [μ m]	3.75	2.50	3	
ϵ_L [eVs]	2.51	2.51	2.51	
energy spread	1.20E-04	1.20E-04	1.20E-04	
bunch length [m]	7.50E-02	7.50E-02	7.50E-02	
IBS horizontal [h]	80 -> 106	18.5	17.2	
IBS longitudinal [h]	61 -> 60	20.4	16.1	
Piwinski parameter	0.68	3.12	2.85	
Reduction factor 'R1*H1' at full crossing angle (no crabbing)	0.828	0.306	0.333	
Reduction factor 'HO' at zero crossing angle (full crabbing)	0.991	0.905	0.905	
beam-beam / IP without Crab Cavity	3.1E-03	3.3E-03	4.7E-03	
beam-beam / IP with Crab cavity	3.8E-03	1.1E-02	1.4E-02	
Peak Luminosity without levelling [$\text{cm}^{-2} \text{s}^{-1}$]	1.0E+34	7.4E+34	8.5E+34	
Virtual Luminosity: $L_{peak} \cdot H_0 / R_1 / H_1$ [$\text{cm}^{-2} \text{s}^{-1}$]	1.2E+34	21.9E+34	23.1E+34	
Events / crossing without levelling	19 -> 28	210	475	
Levelled Luminosity [$\text{cm}^{-2} \text{s}^{-1}$]	-	5E+34	2.50E+34	
Events / crossing (with leveling for HL-LHC)	*19 -> 28	140	140	
Leveling time [h] (assuming no emittance growth)	-	9.0	18.3	

- Need to establish possible parameter envelope for baseline parameters (min ϵ_n , injected bunches...) for upgrade of e.g. protection elements ✓

Glossary and Definitions

Glossary and Definitions

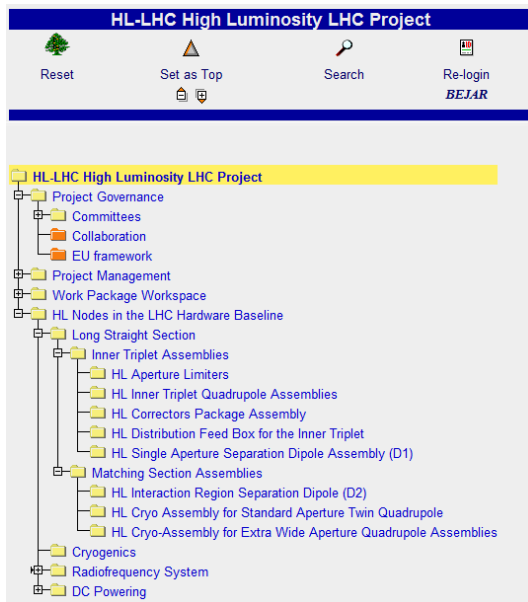
- β' : Optical β -function at the IP.
- η : Machine slip factor.
- η_D : Normalized dispersion: $\eta_D = D\sqrt{\beta}$, where D is the machine dispersion.
- γ : Optic gamma function: $\gamma(s) = (1 + \alpha^2(s))\beta(s)$ where $\beta(s)$ is the optical betatron function along the machine and $\alpha(s) = \frac{d\beta}{2 ds}$.
- γ_r : The relativistic gamma factor.
- abort gap:**
Area without any bunches in the bunch train that fits the time required for building up the nominal field of the LHC dump kicker.
- arc:**
The part of the ring occupied by regular half-cells. Each arc contains 46 half cells. The arc does not contain the dispersion suppressor.
- arc cell:**
It consists of two arc half-cells and presents the basic period of the optic functions.
- arc half-cell:**
Periodic part of the LHC arc lattice. Each half-cell consists of a string of three twin aperture main dipole magnets and one short straight section. The cryo magnets of all arc half-cells follow the same orientation with the dipole lead end pointing upstream of Beam 1 (downstream of Beam 2).



- HL-LHC [Glossary](#) & Definitions as dynamic collection of definitions and terms (based on LHC Design report)
- Progressing HL-LHC Design (and future operation) requires maintenance/extension of glossary and definitions to ensure coherence across activities + prepare future integration into existing Layout Database
- Definitions for operation's metrics (turnaround/ recovery / fault time, availability, machine/physics efficiency,..) being worked on
- To be linked to HL-LHC pages with regular releases

D.Wollmann: Machine protection and required availability for HL-LHC

Documentation, Naming and HW baseline



- First nodes for HL-LHC already defined in LHC Hardware Baseline + regrouped in dedicated structure (Q1, Q2, Q3, D1/D2, correctors...)

- No versioning (yet)

I.Bejar Alonso: WBS of HL-LHC

- Naming proposals exist for magnets and cold-masses of new inner triplet, cavities and beam-beam compensator (BBC)

- New refrigerators, sc links, DFBs, absorbers... tbd
- HL-LHC will require extension above 5 characters

- First IR 1 layout drawing built from baseline optics HLLHCV1.0

- Drawing codes LHCLSXH & LHCLSXGH and access rights sorted out

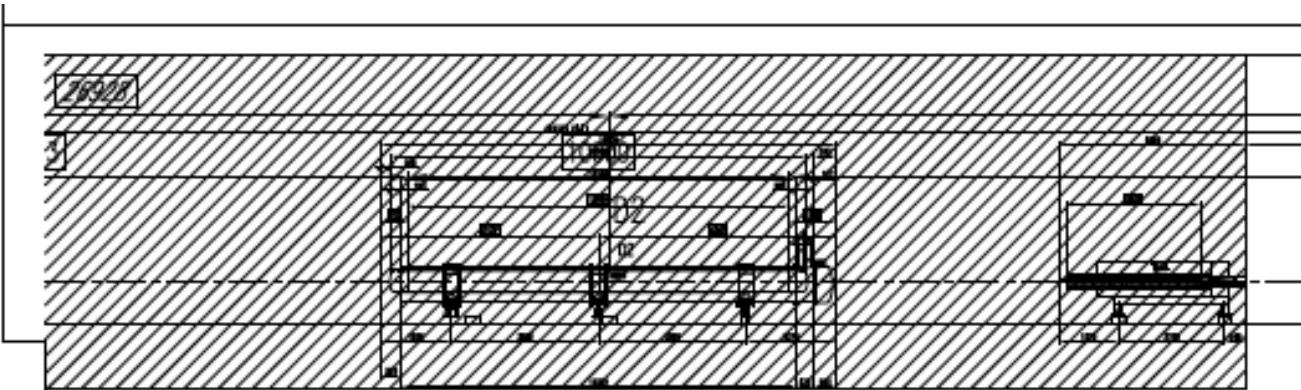
- Inclusion of crab-cavities, BBC tbd

- Layout to be turned into simplified 3D models

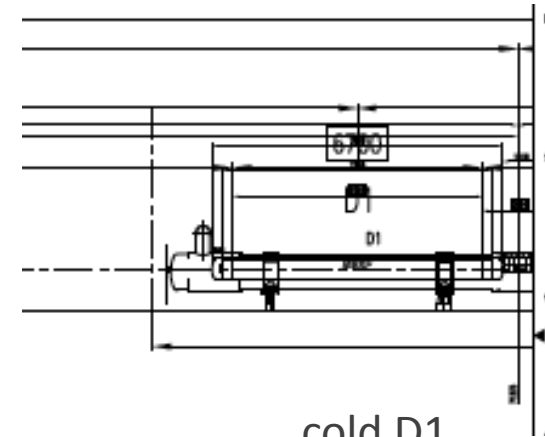
	Drawing	Cryo-magnet	Cold mass	Magnets
Q1		LQXFA	LMQXFA	MQXF
Q3		(LQXFB)	(LMQXFB)	
Q2a		LQXFC	LMQXFC	MQXFL + MCBXFA/B
Q2b		(LQXFD)	(LMQXFD)	
D1		LBXF	LMBXF	MBXF

R. De Maria: IR1 & IR5 Layout configuration

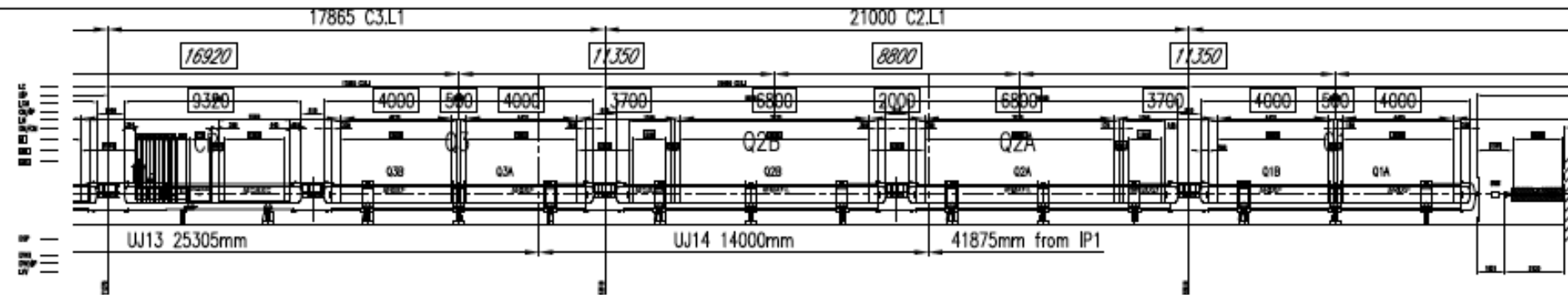
Preliminary Layout (Q1-D2)



D1-D2 Beam Separation area



cold D1

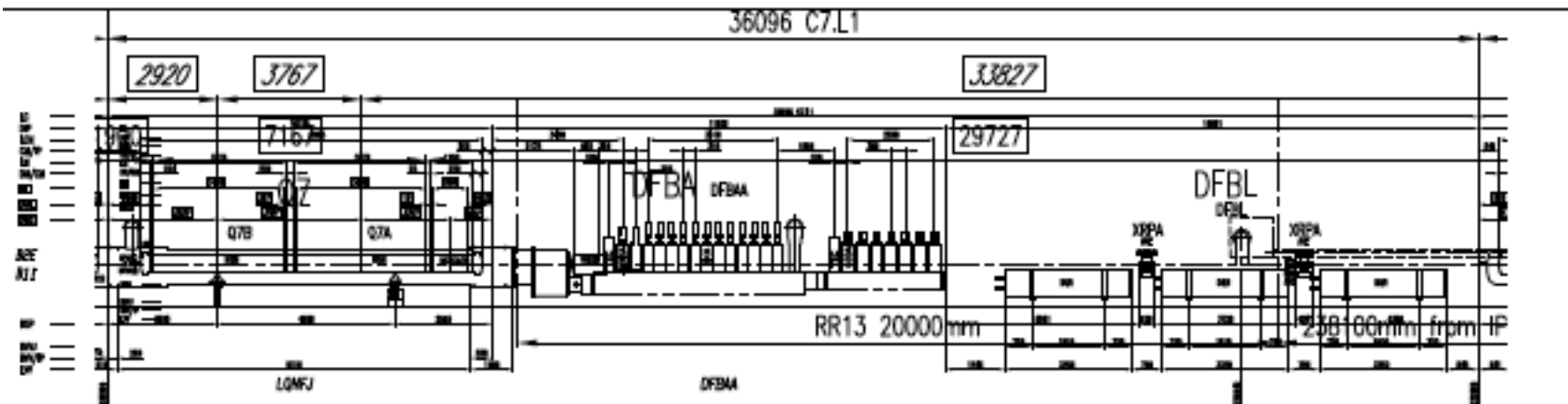


Q1-Q2-Q3 and Correctors Package area

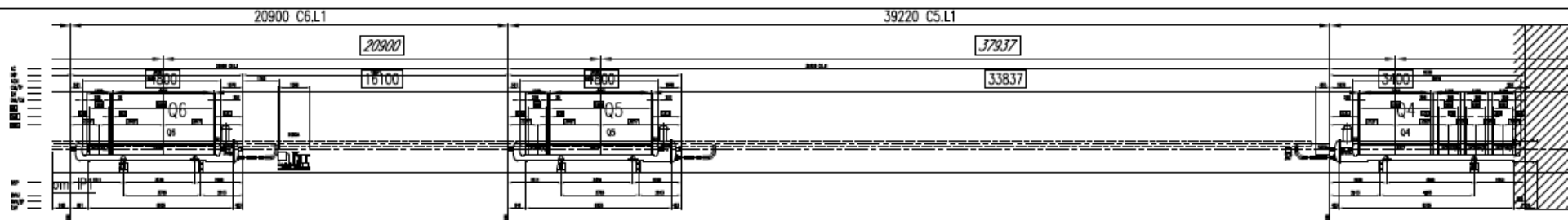
ATLAS ->

P.Fessia: Present baseline of HL-LHC integration

Preliminary Layout (Q4-Q7)

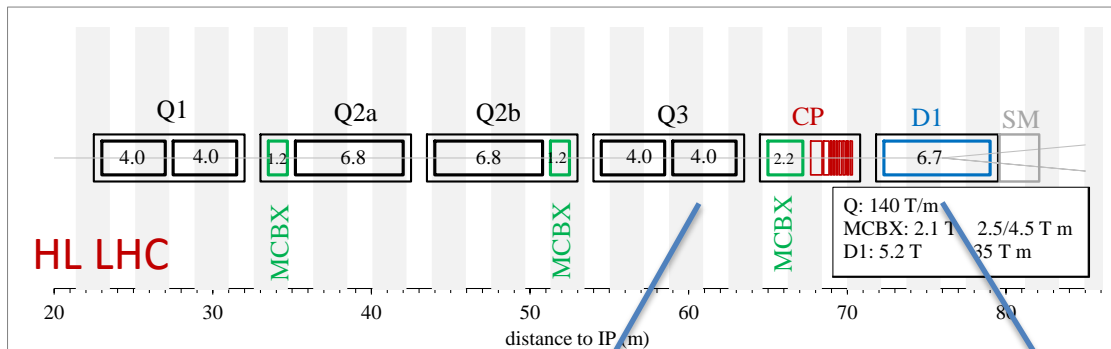
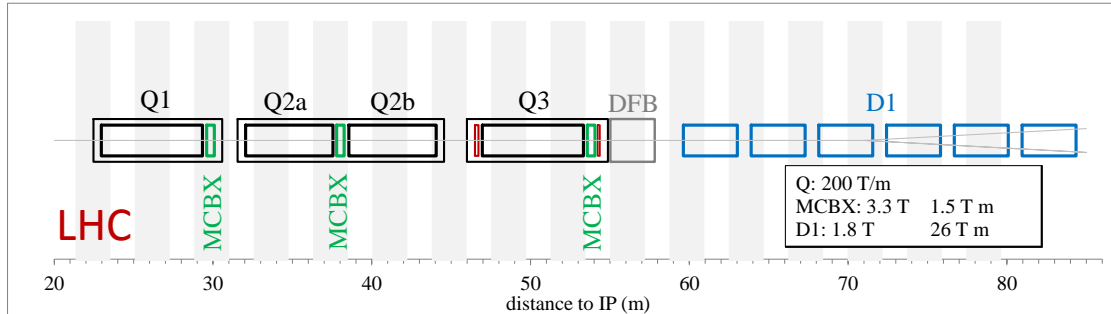


Q7-DFBA-DQR area

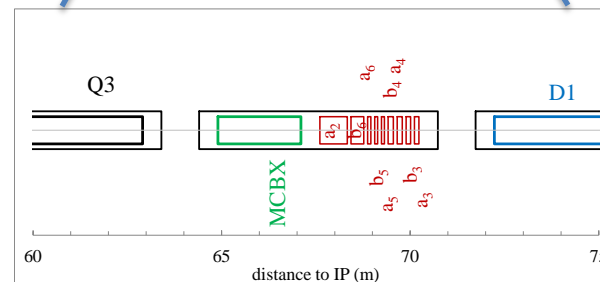


Q6-Q5-Q4 Matching section area

Triplet magnets and aperture



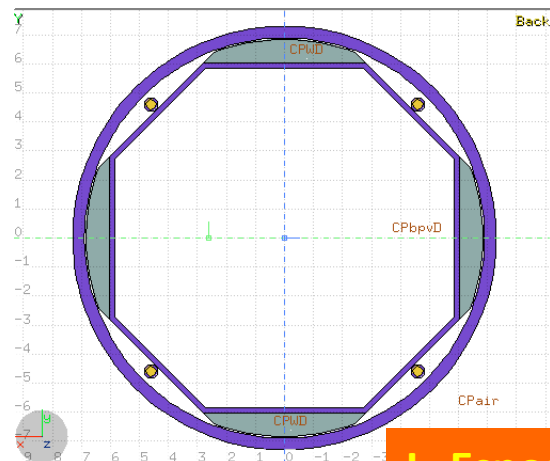
Name	Multipole	Coil length (m)	Force (T m)
MCQ5X3	a_2	0.728	1.0000
MCTX3	b_6	0.339	0.0860
MCTSX3	a_6	0.087	0.0168
MCDX3	b_5	0.079	0.0254
MCD5X3	a_5	0.079	0.0254
MCOX3	b_4	0.137	0.0458
MCOSX3	a_4	0.137	0.0458
MCSX3	b_3	0.121	0.0625
MCSSX3	a_3	0.121	0.0625



- Larger apertures considered for more performance (Initial baseline of 120mm)
- Adopted 150 mm aperture with Nb_3Sn as baseline (>strands, > strand diameter, increase cold mass size)
- Protection is a very important issue
- A large shielding is needed to avoid radiation damage, reducing available aperture for the beam to ~ 120 mm
- Heat load should become a manageable aspect

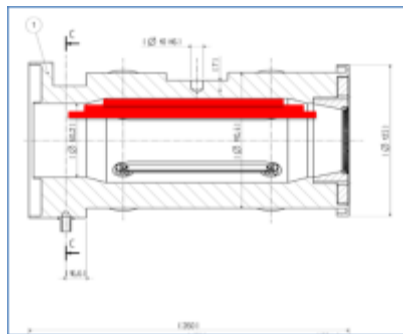
E.Todesco: Magnet status and open issues

Shielding and beam screen



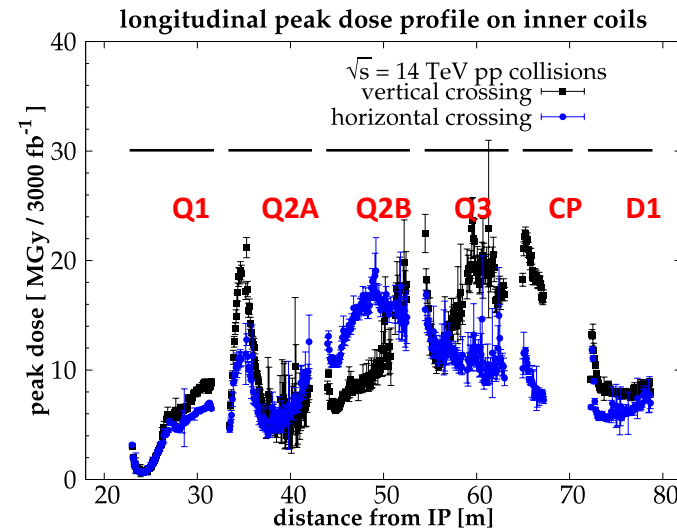
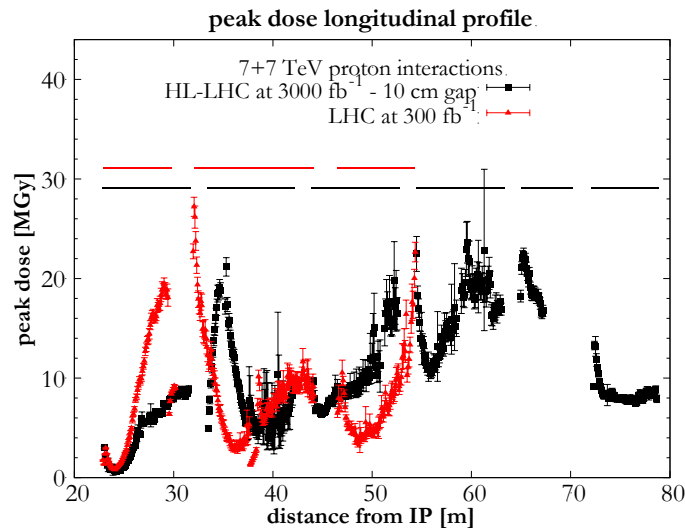
L. Esposito

- For Q1-Q2-Q3-CP-D1: Decision on continuous W shielding of Q1 (16mm) and up to D1 (6mm)
- Due to tolerances, mechanics, beam screen ... available aperture reduces to ~120mm
- Thinner BS would be preferable (→ +2 mm for aperture!)
- Requires studies of quench dynamics (forces), bonding techniques for W inserts, ...
- Beam screen needs to be matched to inner diameter of cold bore -> need to demonstrate possibility of machining with required tolerances
- W shielding integrated into the BPM design would help (careful design of cooling path and impedance contribution needed)



R.Kersevan: The beam screen with shielding and other vacuum issues

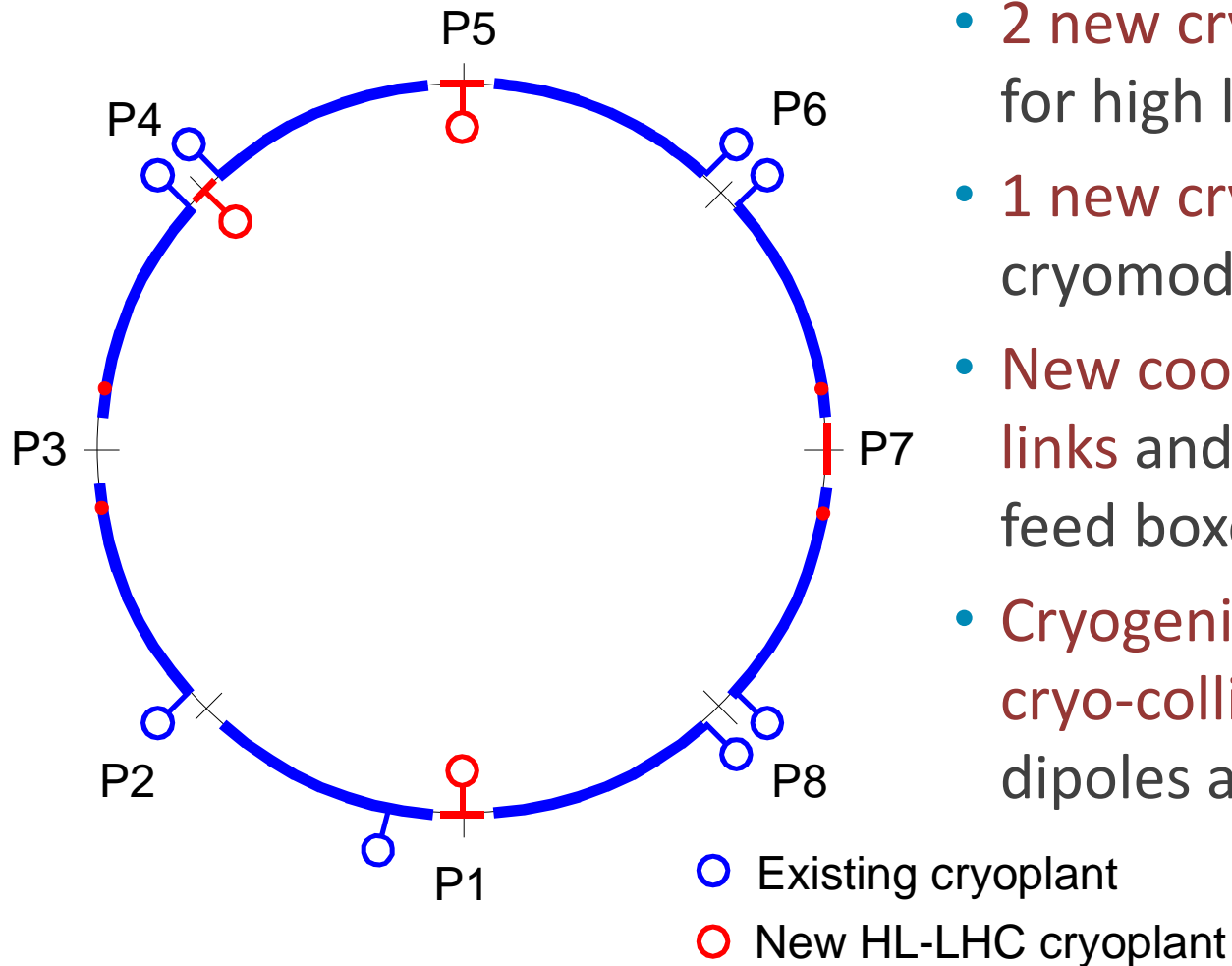
Peak dose HL-LHC vs LHC



- Continuous tungsten shielding allows not to exceed the peak dose value of the present triplet and to keep peak power density quite below the envisaged quench limits
- beam screen shielding interruption in the interconnects, along the BPMs, features an evident worsening on the front face of Q2B, Q3 and in the CP orbit corrector
- In Q1-D1 string, cold mass and beam screen are each subject to a load of more than 600W at 5L₀
- no significant effect is found for the D1 aperture shrinking to 150mm
- the HL-LHC crossing angle and (TAN) aperture are expected to expose the downstream elements (D2 in primis) much more than now, especially for horizontal crossing

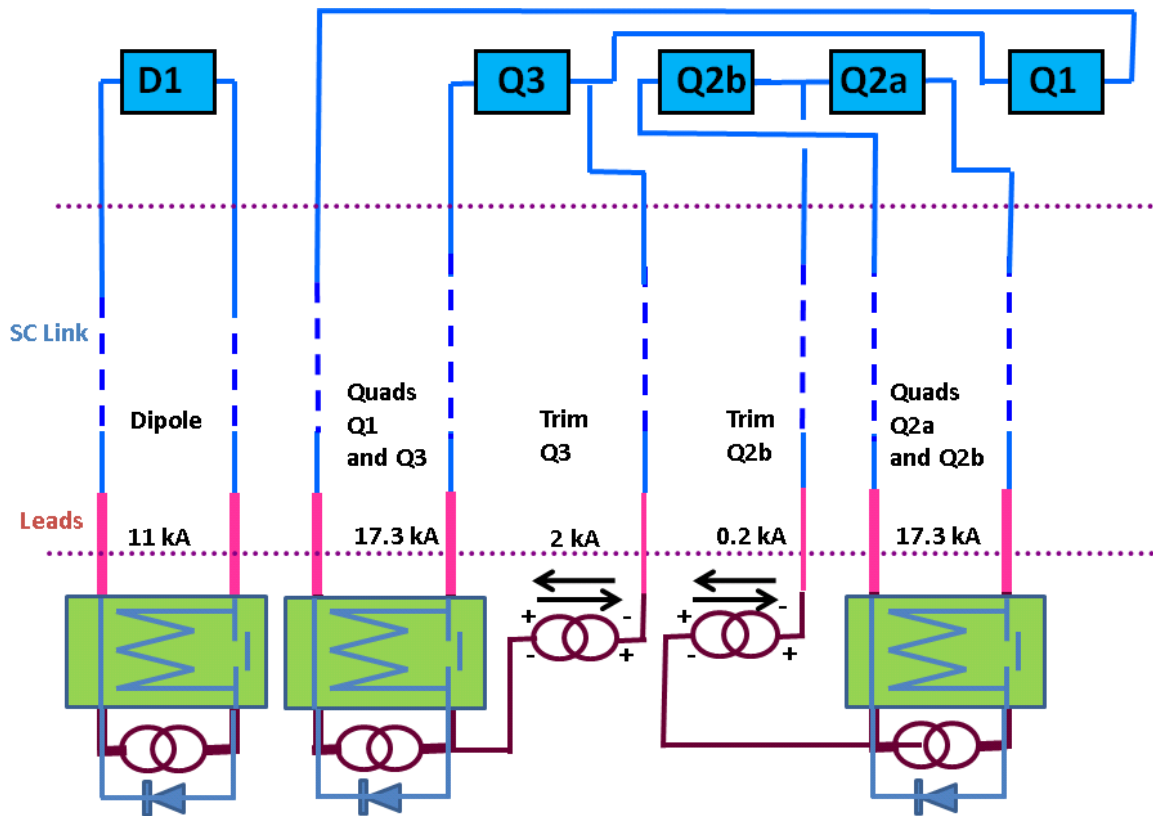
F.Cerutti: Heat deposition and MS layout implications of different optics

Cryogenics for HL-LHC



- 2 new cryoplants at P1 and P5 for high luminosity insertions
- 1 new cryoplant at P4 for SRF cryomodules
- New cooling circuits at P7 for sc links and deposed current feed boxes
- Cryogenic design support for cryo-collimators and 11 T dipoles at P3 and P7

Powering Layout – Inner Triplet



- Baseline of two pairs of quadrupoles in series with trims to assure
- Full flexibility for the optics
- Reduced constraints for magnet protection
- Reasonable compromise for cold powering system and sc links (+ 2×17.3 kA)
- Preferred solution for the power converters
- Final location of 2 kA trim - Q3 or Q1 – to be defined at later stage

A.Ballarino: Report from Task 6.1

Powering Layout – Inner Triplet



DFBX - $I_{tot} \sim 40$ kA

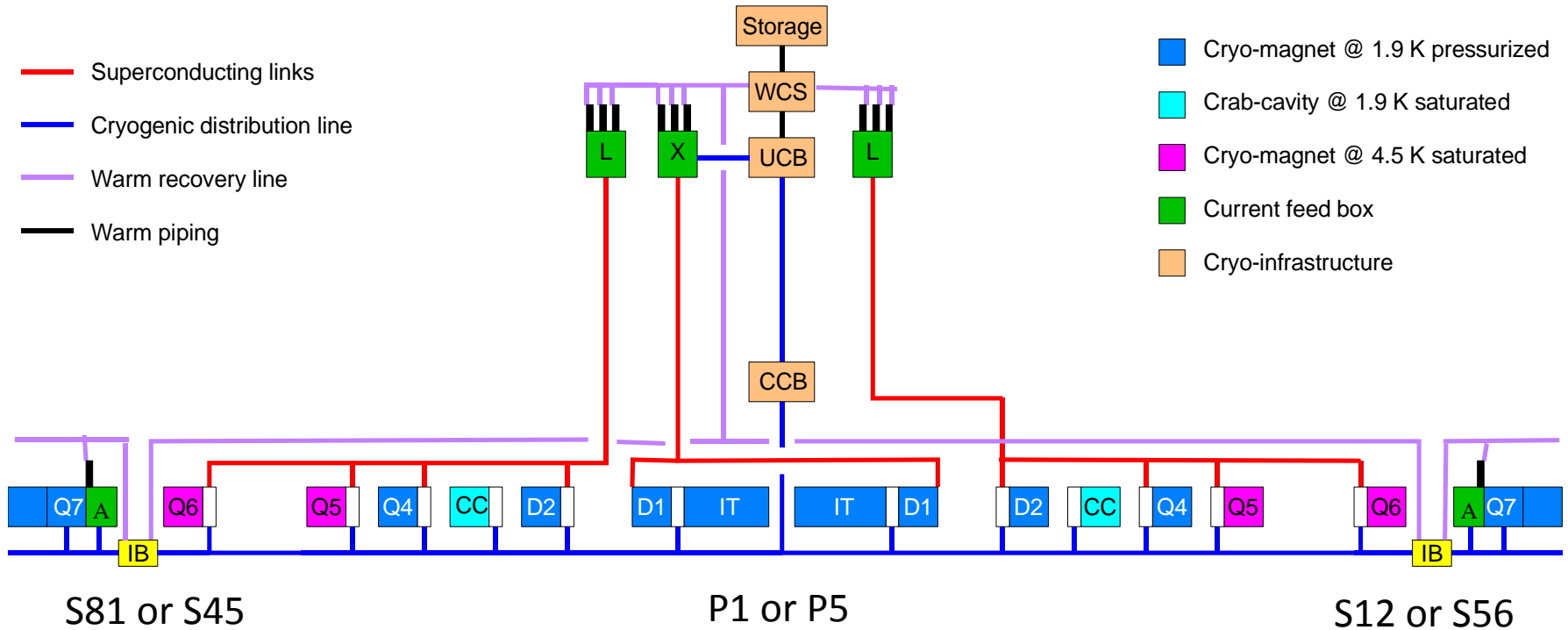
N. of leads	Rating (A)
10	120
14	600
4	7500

Hi-Lumi DFB and SC Link HTS cables $I_{tot} \sim 150$ kA (!)

N. of leads	Rating (A)
18	120
12	3000
2	2400
2	400
2	13000
4	20000

Teststand for sc links in SM18

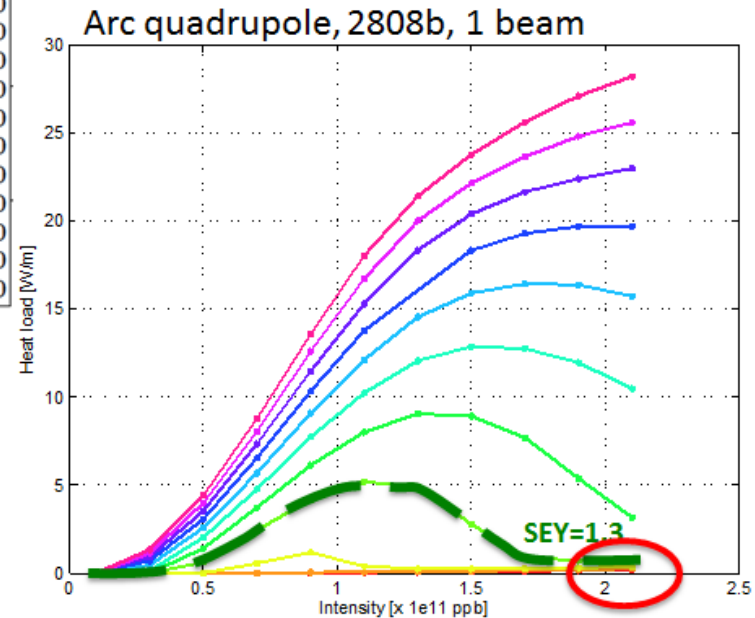
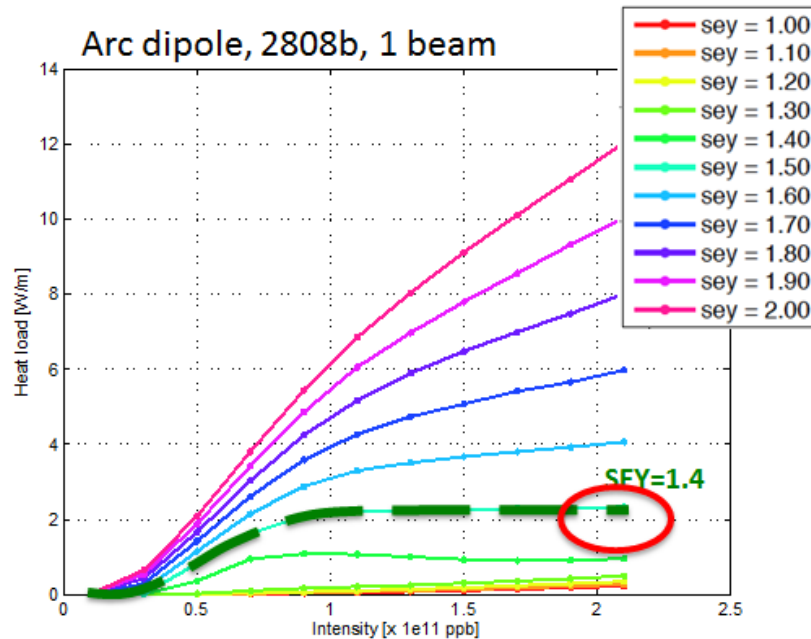
Baseline for P1 & P5 layout: Matching section cooled with inner triplet cryoplants



- Q5, Q6 at 4.5 K,
- DFBA remains in tunnel, # of superconducting links and surface DFB-boxes to be optimized,
- level of cryogenic redundancy (IB) to be detailed
- Space requirements for CCB and shaft-piping

R.Van Weelderen: Cooling configuration in IR1&5

E-cloud vs heatload

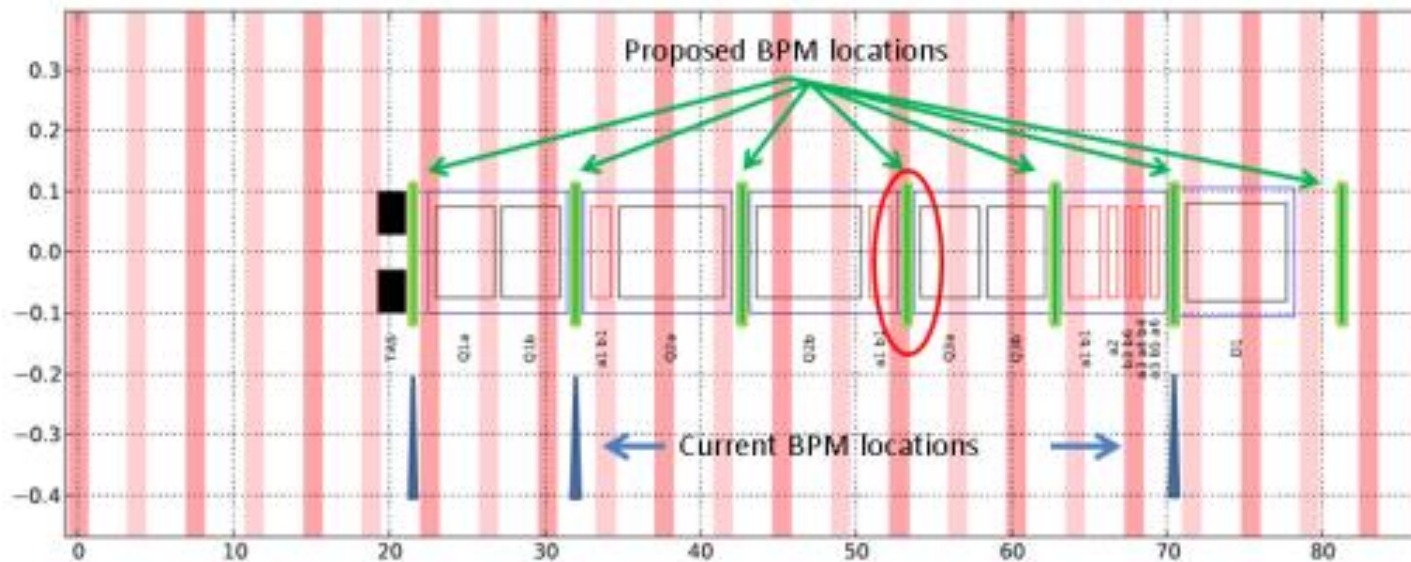


G. Rumolo, G. Iadarola (RLIUP Workshop)

E-cloud solution currently betting on:

- Scrubbing for dipoles for suppression of electron cloud
- Expected to be difficult to eliminate the electron cloud in the quadrupole
- For SEY as achieved in 2012, heat load for 2e11 ppb in standard arc half-cell almost 2x higher than available cooling power

Beam Instrumentation for HL-LHC



- BPMs
 - Maintain directional couplers in common beampipe regions, avoiding long range encounters
 - Redundancy for some locations studied to improve robustness of correction & feedback
 - If proven useful, maintain integrated BPMs in all collimators
- BLMs
 - Maintain BLMs external to cryostat, add cryogenic BLMs in all new Quadrupoles (6 per magnet)



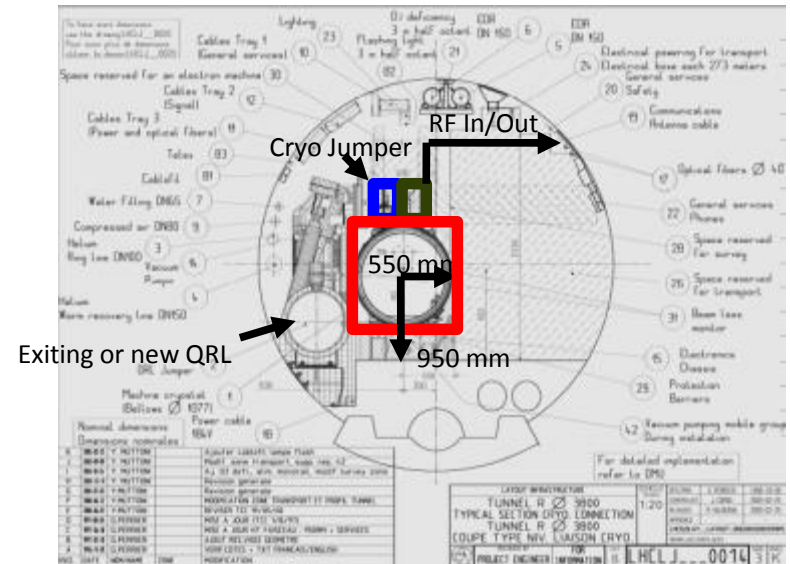
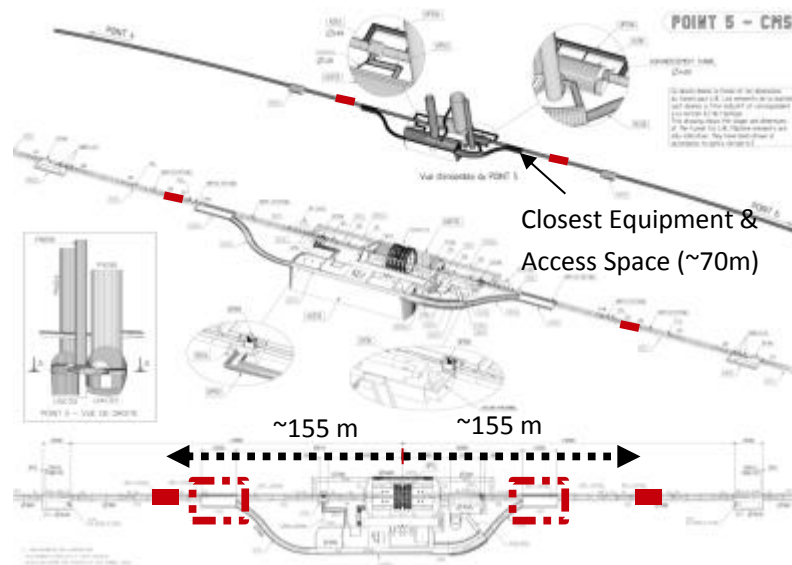
Beam Instrumentation for HL-LHC

R.Steinhagen: Status of the BBLR design

- Long Range Beam-Beam Compensators
 - Optimal location will depend on optics
 - Ideally require equal beta for H&V
 - Ideally require wire location at mean separation of long range collisions
 - Propose to maintain current idea of in-collimator design
 - Needs staggered B1 & B2 space reservation before D2
 - Total of 2m per beam per side of each IR – combined with collimator?
- Crab Cavity Diagnostics
 - Current proposal is for Head-Tail monitors
 - Either based on existing long striplines or higher bandwidth optical BPM currently being studied
 - Need to reserve 800mm space at suitable optics location (90 degree phase advance)
 - Do we want 2 measurement points (as close as possible to IR and after crab cavities?)

Crab cavities+ Survey

- Encouraging first test results from cold test @ CERN
- Beside technical + protection challenge, **crab cavities pose major integration issue**
- **Ideal position @155m from IP, >70m from UL and RR caverns** (RF power, drivers & controls have to be in a shielded area + close to the cavities)
- **New parallel cavern ideal but very costly! Additional solutions being studied**, assuming new baseline of 4 crab-cavity modules/beam/IP side with 3.5MV each
- Positioning and alignment during full energy cycle <1mm -> **survey system up to Q5**



E. Jensen: RF baseline and open issues

HL-PLC key decisions so far

- Approval of HL-LHC Baseline parameters
 - 25ns reference & 50ns backup
- New Triplet aperture
 - Approval of 150mm coil aperture for Inner Triplet and D1
 - Continuous Tungsten shielding of 16mm in Q1 and 6mm up to D1 (allows not to exceed the expected peak dose value for current triplet during HL-LHC).
- Baseline for Cryogenic and Powering sectorization of the insertions
 - Cryogenic separation of the Matching Section from the ARCs
 - Independent powering of 2 pairs of quadrupoles
- 4 Crab Cavities per beam on each side of IR1 and IR5

Topics that require technical follow-up

- Crab Cavity integration in IR1 and IR5:
 - ➔ Space limitations and radiation aspects in the RRs; need for new underground cavern? Wave guides and powering between cavities and klystrons.
- Long Range Beam-Beam Wire compensation:
 - ➔ Space reservation in IR1 and IR5; detailed mechanical design and integration with collimation system required prior to final implementation
- Places for higher harmonic RF systems and new BI in IR4
 - ➔ 800 MHz Higher Harmonic RF; new 200 MHz RF cavities

Future topics

- Review of beam parameters following the RLIUP workshop:
 - Revision of the 25ns bunch intensity and emittance; number of bunches with new **BCMS scheme**.
 - Adoption of **new 8b+4e 25ns bunch scheme** as replacement for 50ns backup scenario (e-cloud driven back-up).
- Review of Optics configurations and impact on MS:
 - Flat beam options and Neutron absorption by the TAN; protection of Crab Cavities; option of a **movable TAN?** and **TAS with removable inserts?**
- e-cloud activity in the common beam pipes:
 - **Coating options**; clearing electrodes inside **the triplet beam screens** etc.
- Ion beam parameters during HL-LHC
 - Option and required installations **for Stochastic Cooling in the LHC**.
- Review of Beam Current limitations
 - Cryogenic limitations; Impedance driven limitations.
- Options and operation scenarios for Pileup density leveling
 - Crab Kissing scheme; use of 200MHz or 800MHz RF systems etc.

Fin

Questions?



cern.ch

E-cloud vs heatload

	Available cooling * [W]	Max Meas 3429 [W]	Scaling factor ($N_{\text{bun}} = 2700$)	Scaling factor (E=7 TeV + nominal filling)	US1, US2 [W] (SEY like 2012)	US1, US2 [W] (dipoles fully scrubbed)
Arc half-cell	255	45	x3.4	0.81x3.5(0.0) + 0.19x0.15	438 (x 1.72)	4.4 (x 0.02)
SAM 1	16	12	x3.4	x0.15	6.12 (x 0.38)	6.12 (x 0.38)
SAM 2	24	17	x3.4	x0.15	8.67 (x 0.36)	8.67 (x 0.36)
D3IP4	24	4	x3.4	x3.5(0.0)	47.6 (x 1.98)	–
Semi-SAM	40	18	x3.4	0.3x3.5(0.0) + 0.7x0.15	70.69 (x 1.77)	6.43 (x 0.16)

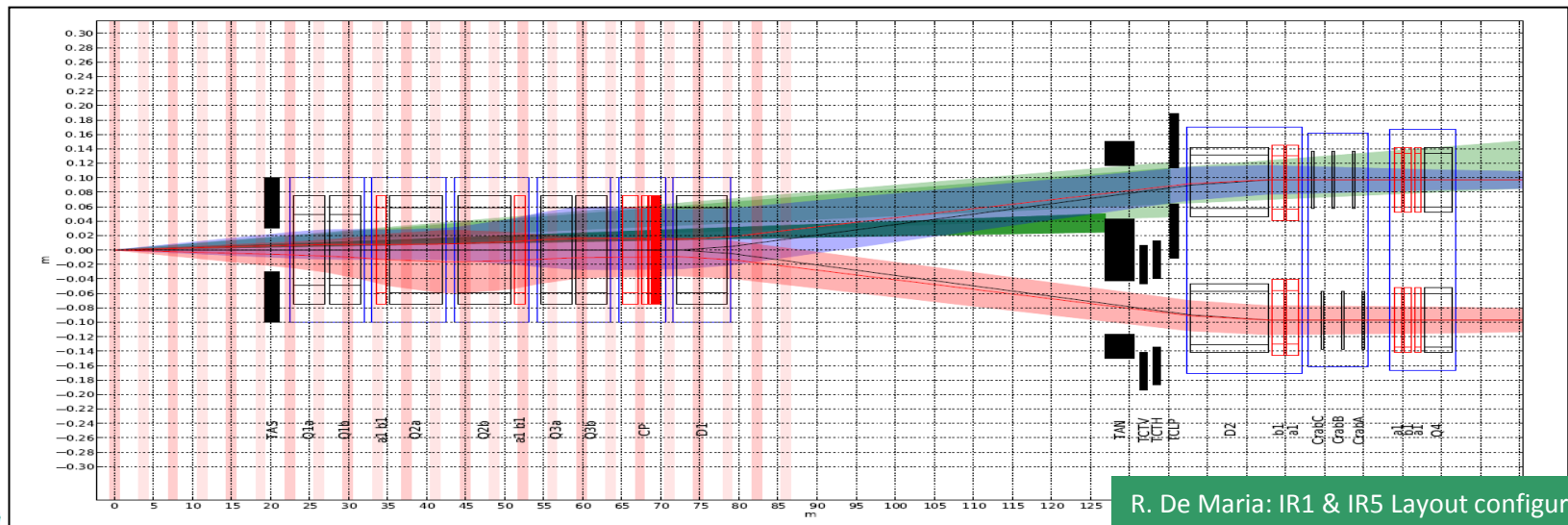
* From L. Taviani, Evian Workshop 2012

If dipoles not fully scrubbed (but maybe just enough to cope with heat load), the higher intensity bunches of US1 and US2 could still suffer more from the interaction with the electron cloud

G. Rumolo, G. Iadarola

Optics

- **Baseline optics HLLHCV1.0 established**, including triplet region and matching section quadrupoles (based on **decision of 150mm aperture in triplet and D1**) – squeeze optimizations still ongoing
- Further studies in **Q4-7 region ongoing** to improve optics flexibility and minimize **crab voltage requirements**
- Layout and optics still pending validation in several areas (TAN Q4 area, Q5 magnet types, orbit feedback with MCBX only)
- E.g. neutrals generated at IR: Corrector package and D1 affected by power deposition



R. De Maria: IR1 & IR5 Layout configuration