HL_LHC, WP9-Cryo

Update of Cryo Baseline P4-RF, IR1/5 and SPS-BA6

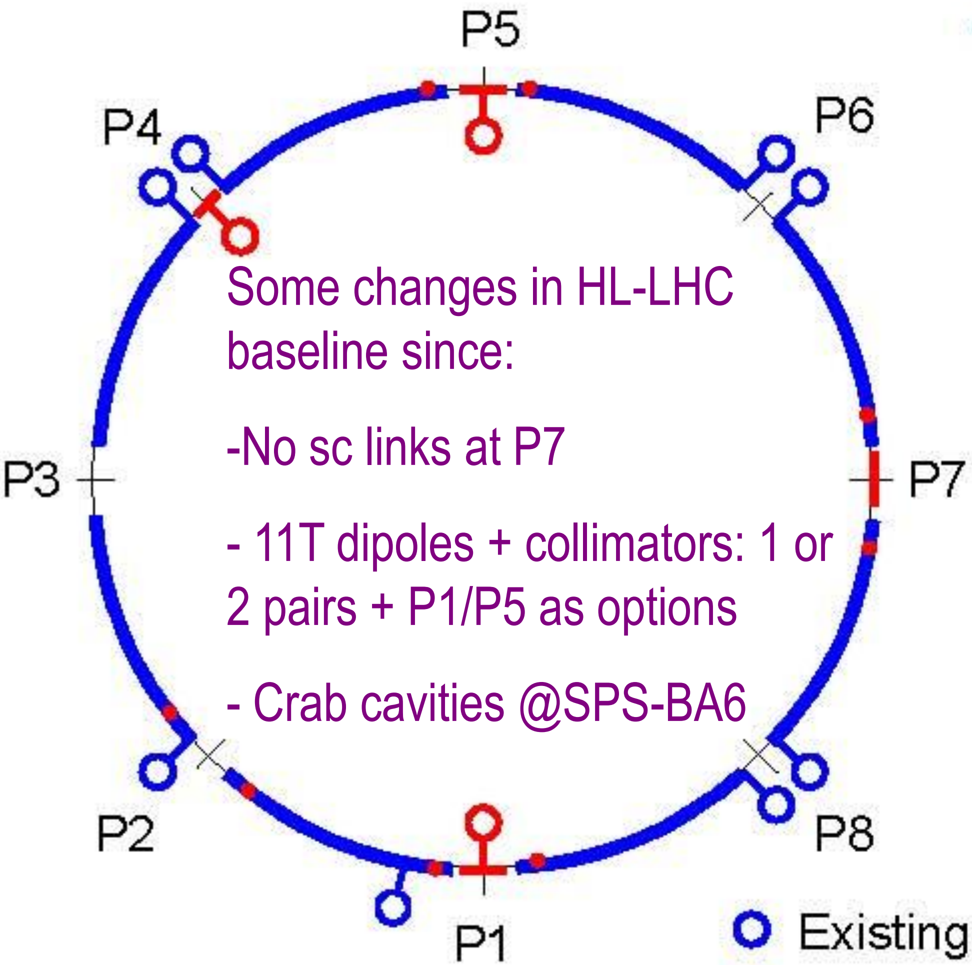
- *Baseline Sept'2014 and evolution since*
- *IR 1/5, evolution and perspectives*
- *P4-RF, evolution and perspectives*
- *SPS-BA6, new baseline*
- *Complementary items*
- *Summary*

S. Claudet, 24 Sept'15

On behalf of Cryo team involved in HL_LHC activities

Baseline, Nov'14

Overall HL-LHC cryogenic layout



Some changes in HL-LHC baseline since:

-No sc links at P7

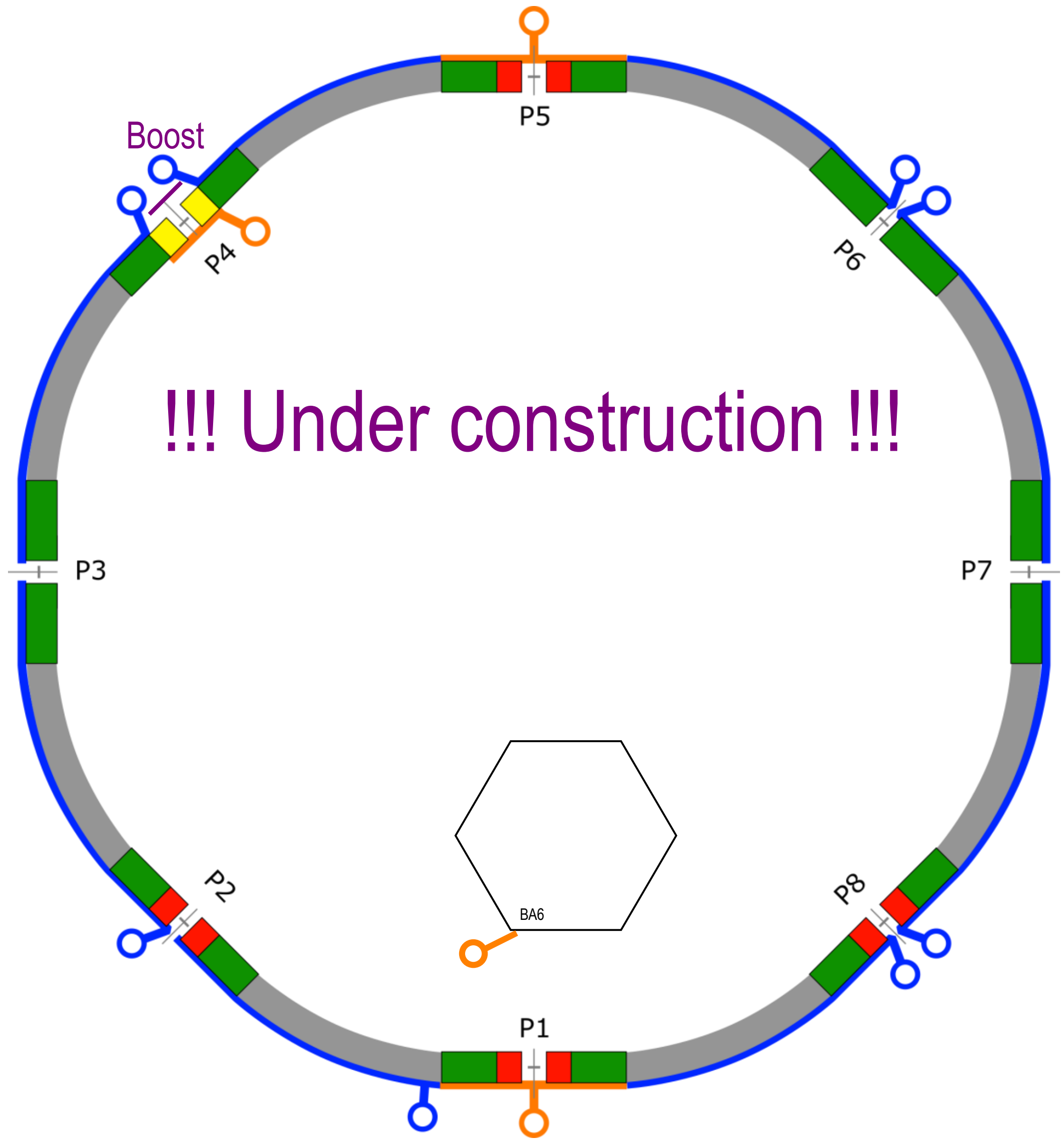
- 11T dipoles + collimators: 1 or 2 pairs + P1/P5 as options

- Crab cavities @SPS-BA6

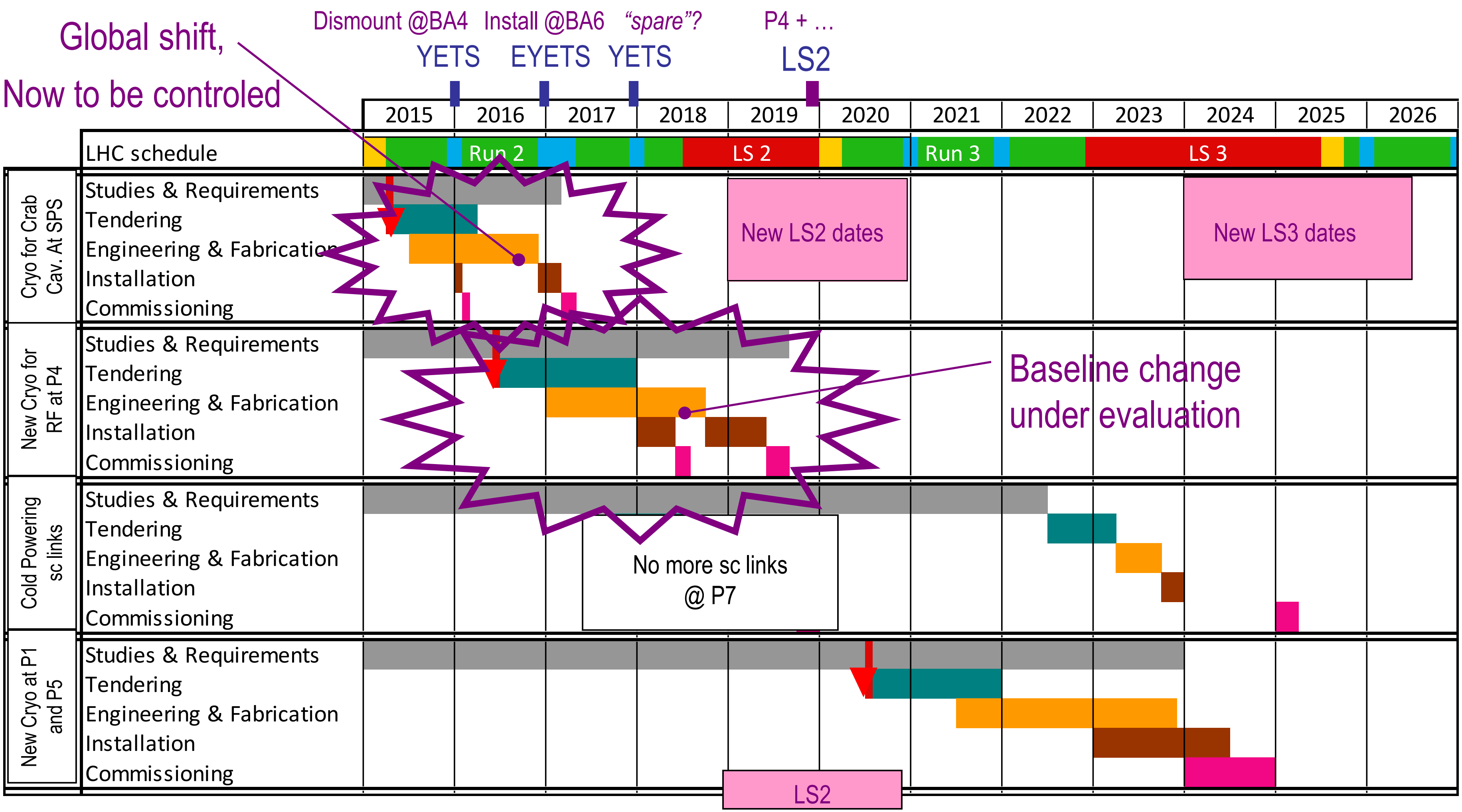
- HL-LHC cryo-upgrade:
  - 2 new cryoplants at P1 and P5 for high luminosity insertions
  - 1 new cryoplant at P4 for SRF cryomodules *Alternative?*
  - New cooling circuits at P7 for SC links and deported current feed boxes
  - Cryogenic design support for cryo-collimators and 11 T dipoles at P1, P3, P5 and P7

Existing cryoplant
New HL-LHC cryoplant
Cryo-collimator

Towards an update of Cryo baseline



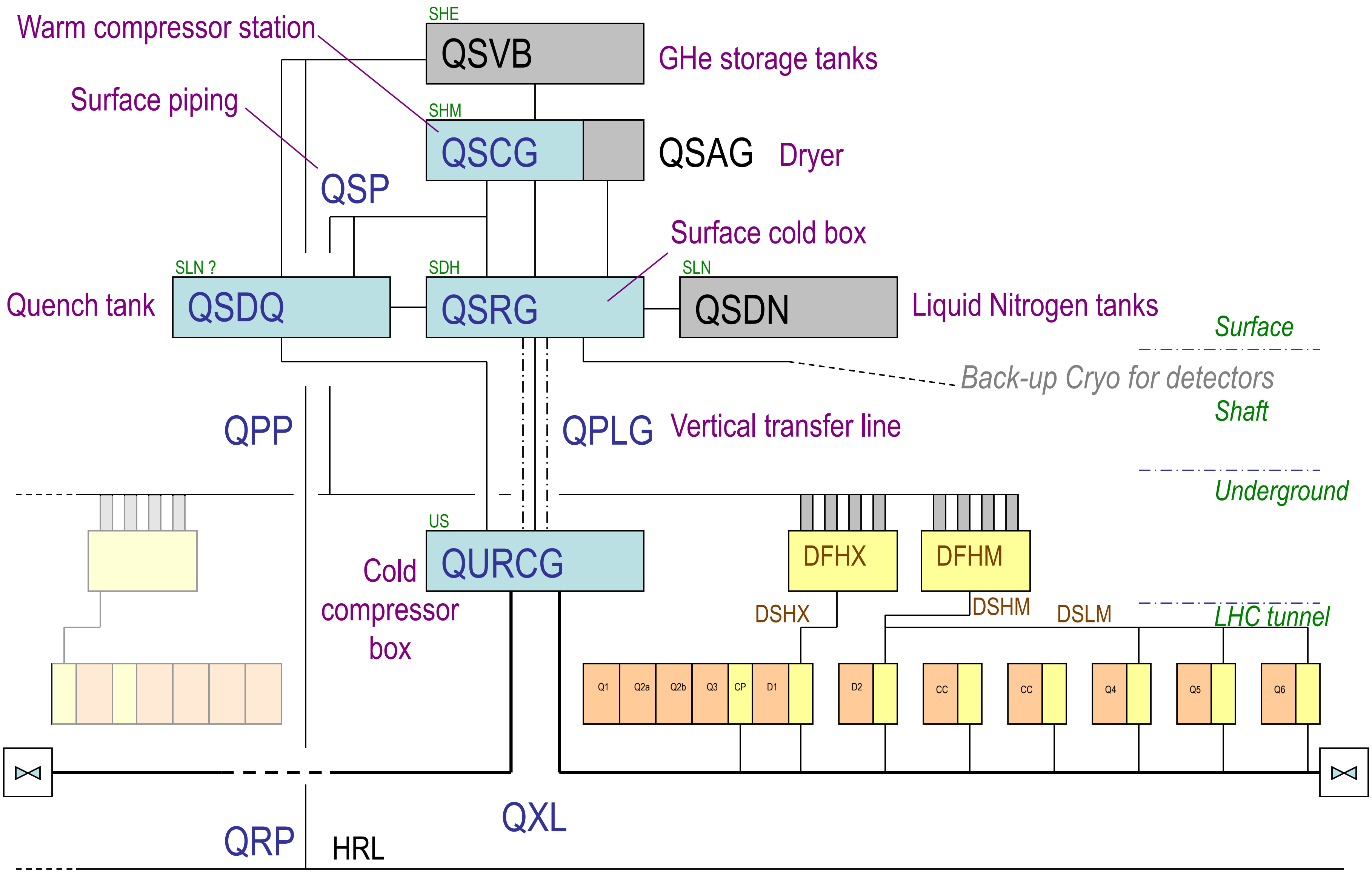
HL-LHC, Cryo general schedule



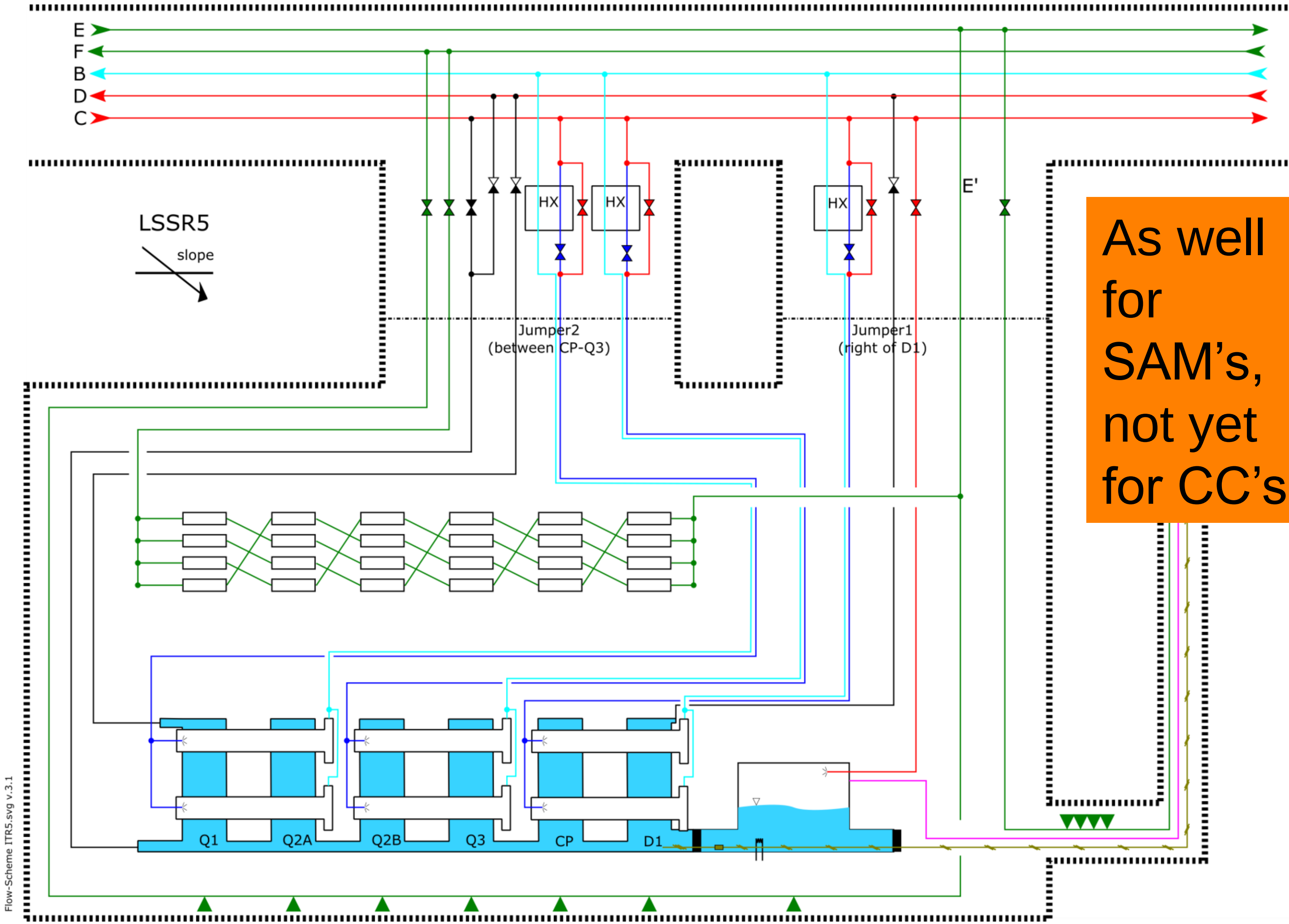
▼ *: decision/freeze of heat-loads to specify refrigerator and distribution*

+ 11T dipoles @ P2 ?
+ possible work on some Q5@P6
+ LSS2-LSS8 beam-screens ?

P1/P5 Cryogenic architecture

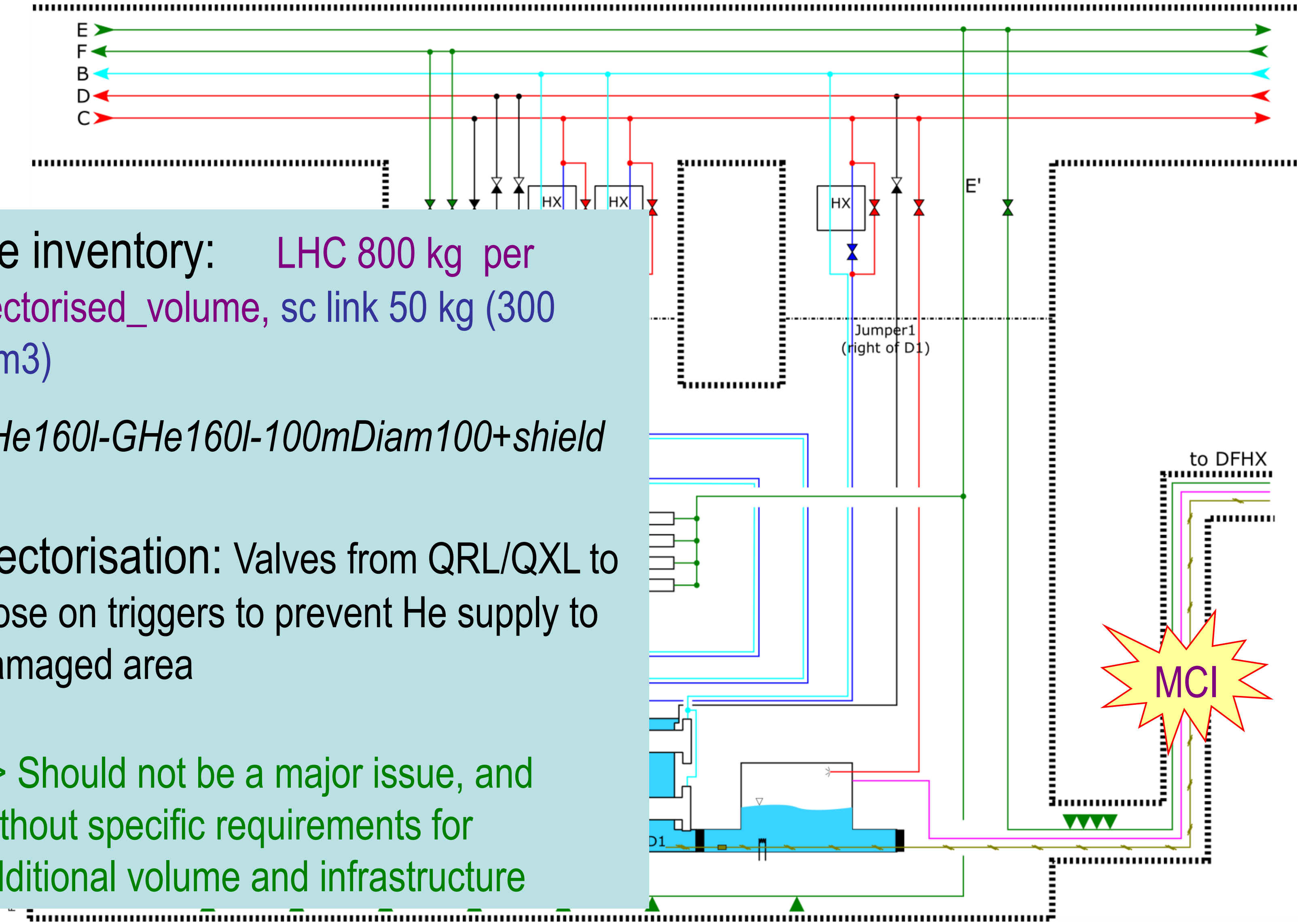


Flow diagram IT-R5



As well for SAM's, not yet for CC's

Few hints for sc links safety aspects



He inventory: LHC 800 kg per sectorised_volume, sc link 50 kg (300 Nm3)

LHe160l-GHe160l-100mDiam100+shield

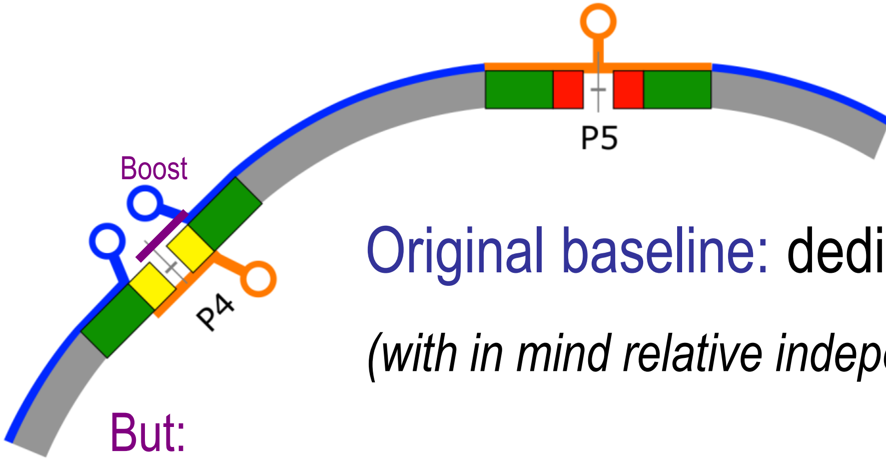
Sectorisation: Valves from QRL/QXL to close on triggers to prevent He supply to damaged area

=> Should not be a major issue, and without specific requirements for additional volume and infrastructure

P1/P5 Main evolutions of the baseline

- General lay-out and integration:
  - Current leads (DFH) in underground area
  - Efforts towards integration and definition for Civil Eng. Works
  - Flow diagrams now prepared for LSS
- Others:
  - Safety/risk analysis for sc links (MCI) initiated, to be continued
  - Availability studies, always 8 sectors but with 2x2 new LSS and 10/11 w.r.t 8 refrigerators
  - Preliminary studies for routing back-up lines for detectors cryogenic
- Next:
  - From known heat loads, definition of P, T, m' for each circuit, and then sizing of process pipe and major components
  - Complete distribution scheme with overall Process & Flow diagram
  - Iterate on heat loads, integration, process optimisation

P4 - RF Status and perspectives



Original baseline: dedicated 4.5K Refrigerator for RF

(with in mind relative independence from magnets operation/constraints)

But:

+ It does not work so bad for time being (RF never really late for beam commissioning)

- Availability for HL beam operation would be reduced with increased number of cryoplants to be operated simultaneously

• ideas summer 2014 to propose an upgradable refrigerator to match the RF needs (400MHz, then 800MHz as harmonic, switch to 200MHz with 400MHz as harmonic)

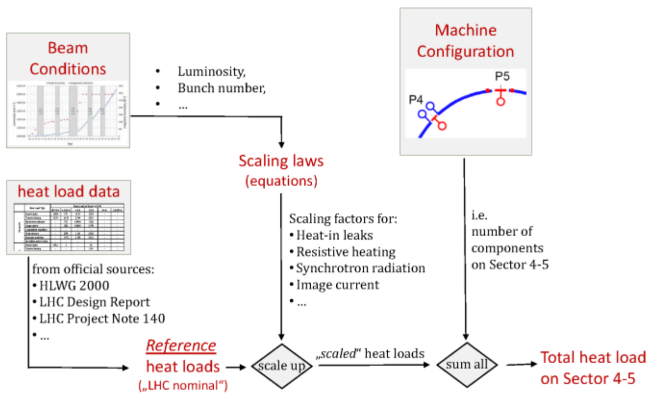
• Clear understanding at 4th_LARP_KEK_Nov'14 meeting that real gain for RF would be to test a module anytime during a LS, while Cryo would do maintenance

=> Proposal of alternative: Upgrade + corresponding distribution + mobile Ref

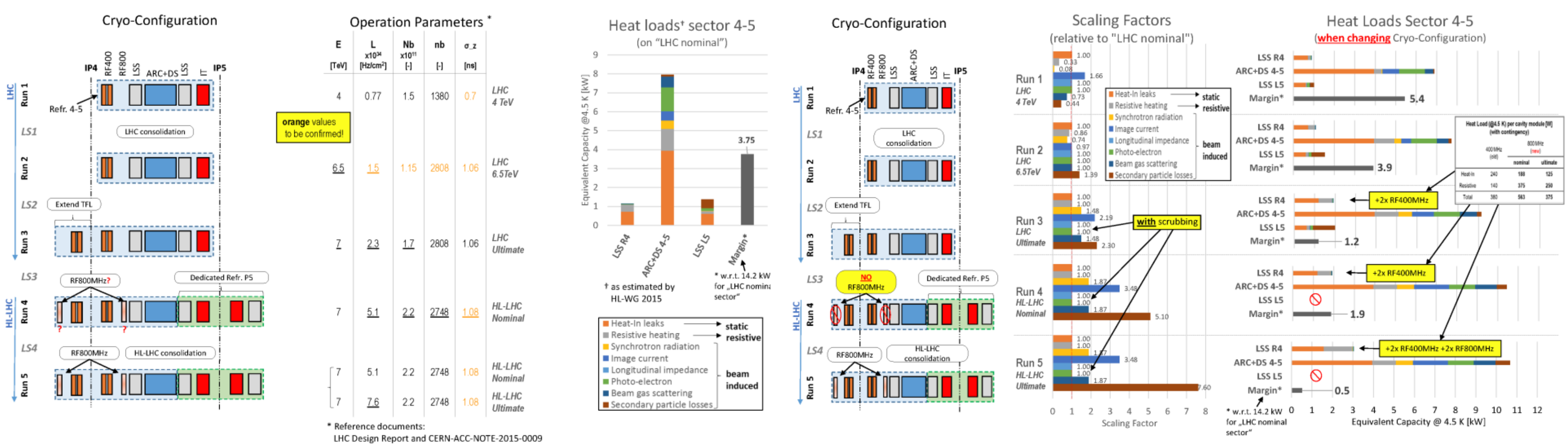
How much ? Anyway ! Concept !

Extra cooling capacity needed

Estimation of HL-LHC heat loads

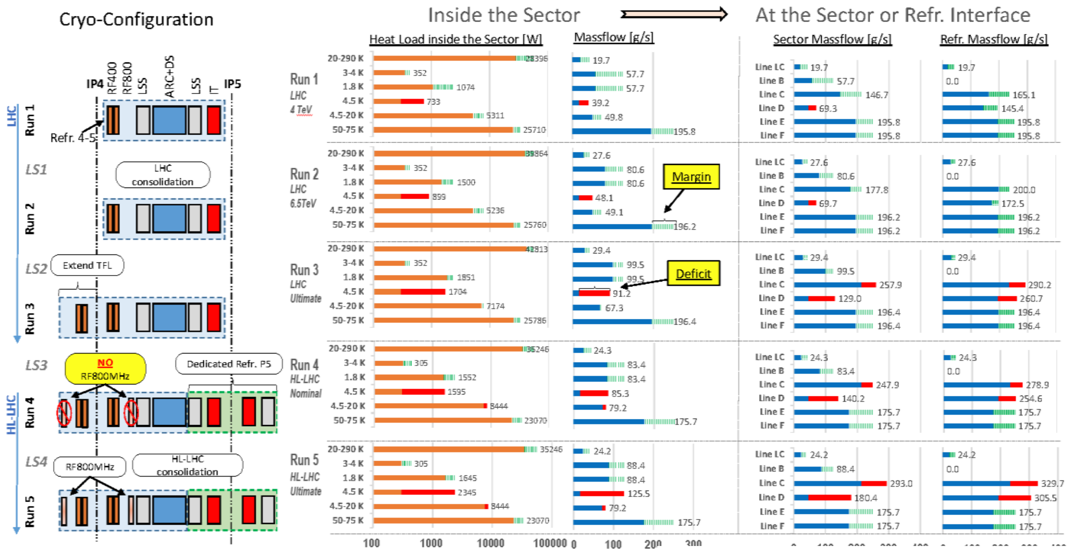


For completeness, brief description of the model/methodology



Global equivalence would tell that there is sufficient margin

Evaluation of capacity per level of temperature



Convertion for static and dynamic heat loads into cooling capacity requirements based on an "LHC like" approach for capacity margins at nominal and ultimate

Conclusions

- The design capacity of *LHC Refr. S4-5* presents a cooling deficit of **≈2.5 kW @4.5 K** w.r.t the required specifiction for HL-LHC (Run5). This is equivalent to a massflow deficit of **≈118 g/s** on Line C.

Studies to be done:

- Clarify the technological & economical impact of an upgrade of *LHC Refr. S4-5* to cover the refrigeration demands for RUN5. The study of 3 different scenarios are suggested:
  upgrade of 2.5 kW +/- 500 W @4.5 K
- The cryo-refrigeration margin at the other LHC Refrigerators (specially S3-4) has to be analysed as well, in order to ensure that all HL-LHC sectors have a similar margin.

Refr. Specification for RUN5 HL-LHC

In Sector Refrigeration

Heat Load [W]	50-75 K	4.5-20 K	4.5 K	1.8 K	3-4 K	20-290 K
LHC design	33000	7700	300	2400	430	55416
HL-LHC (Run5)	23070	8444	2721	1645	305	35246
Margin	9930	-744	-2421	755	125	20169

Refrigerator Interface

Massflow $\dot{m}$ [g/s]	Line F	Line E	Line D	Line C	Line B	Line LC
LHC design	251.3	251.3	194.4	235.1	-	41.0
HL-LHC (Run5)	175.7	175.7	328.2	352.3	-	24.1
Margin	75.6	75.6	-133.8	-117.2	-	16.9

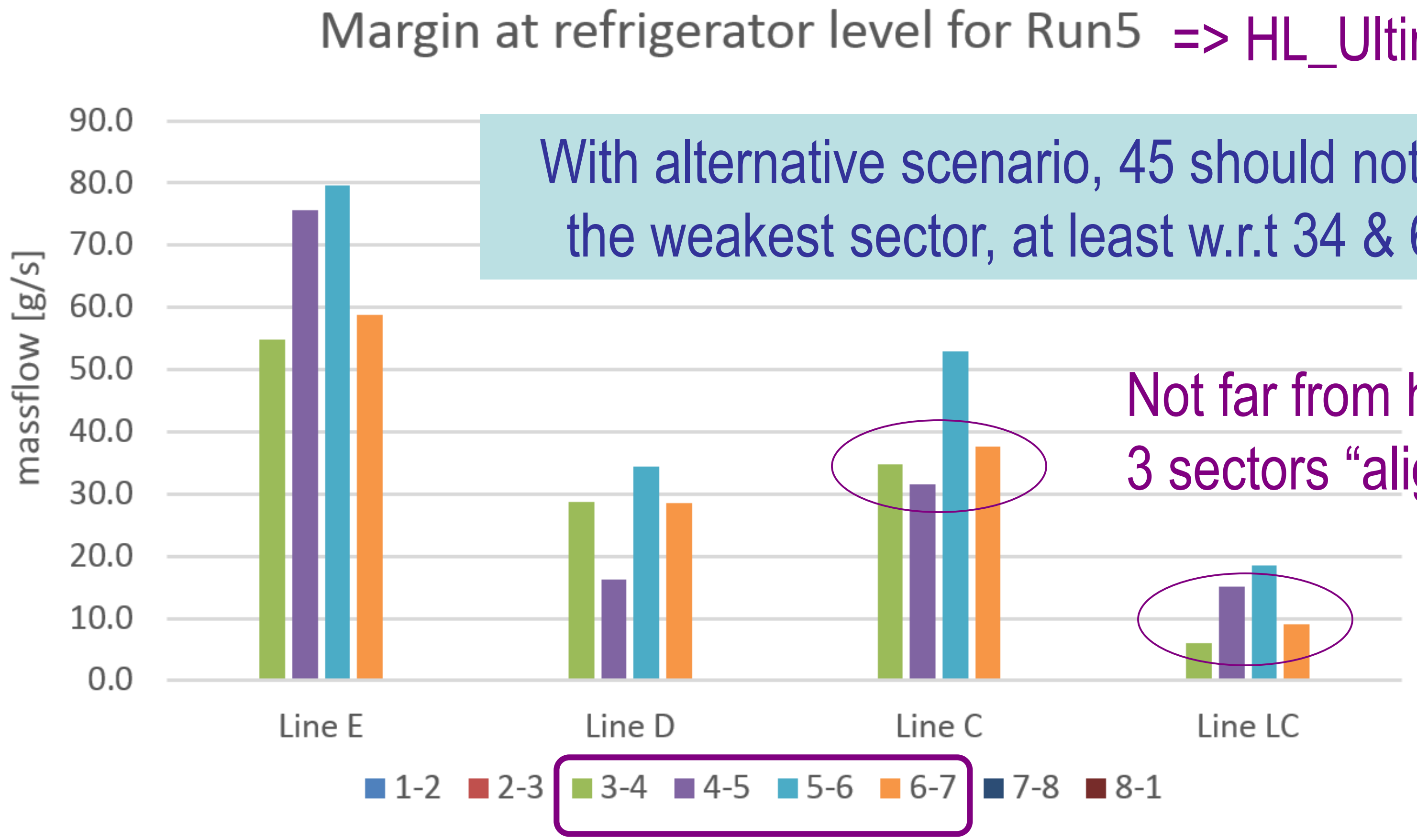
Presently under feasibility evaluation

(internal CRG, possibly with industry)

Upgrade of
2.5 kW +/- 500 W @4.5 K
for *LHC Refr. S4-5* required!

(+14% on 18kW)

Sector 45 w.r.t other sectors



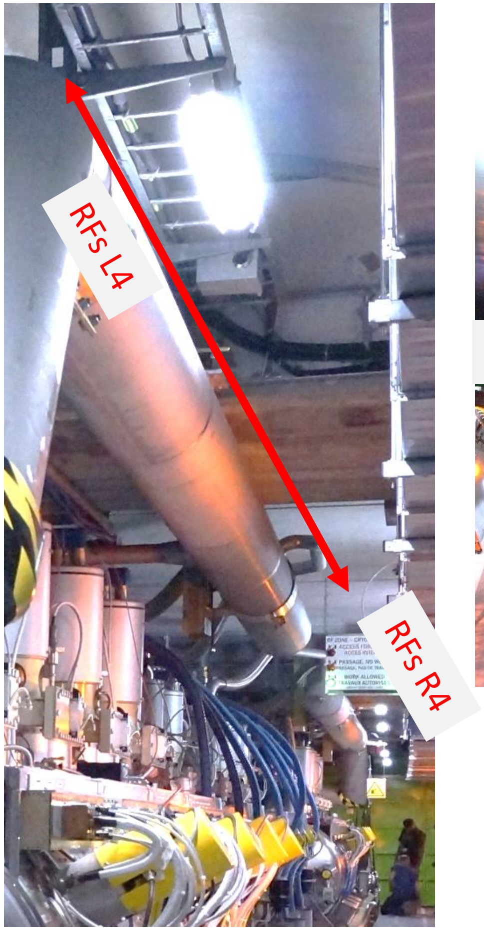
=> HL_Ultimate

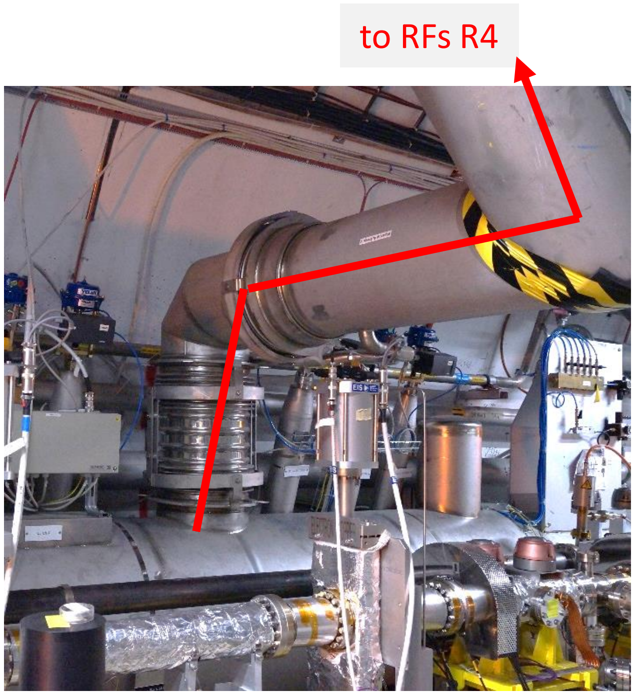
With alternative scenario, 45 should not be the weakest sector, at least w.r.t 34 & 67

Not far from having 3 sectors "aligned"

Sectors analysed so far (without triplets)

P4-RF distribution line

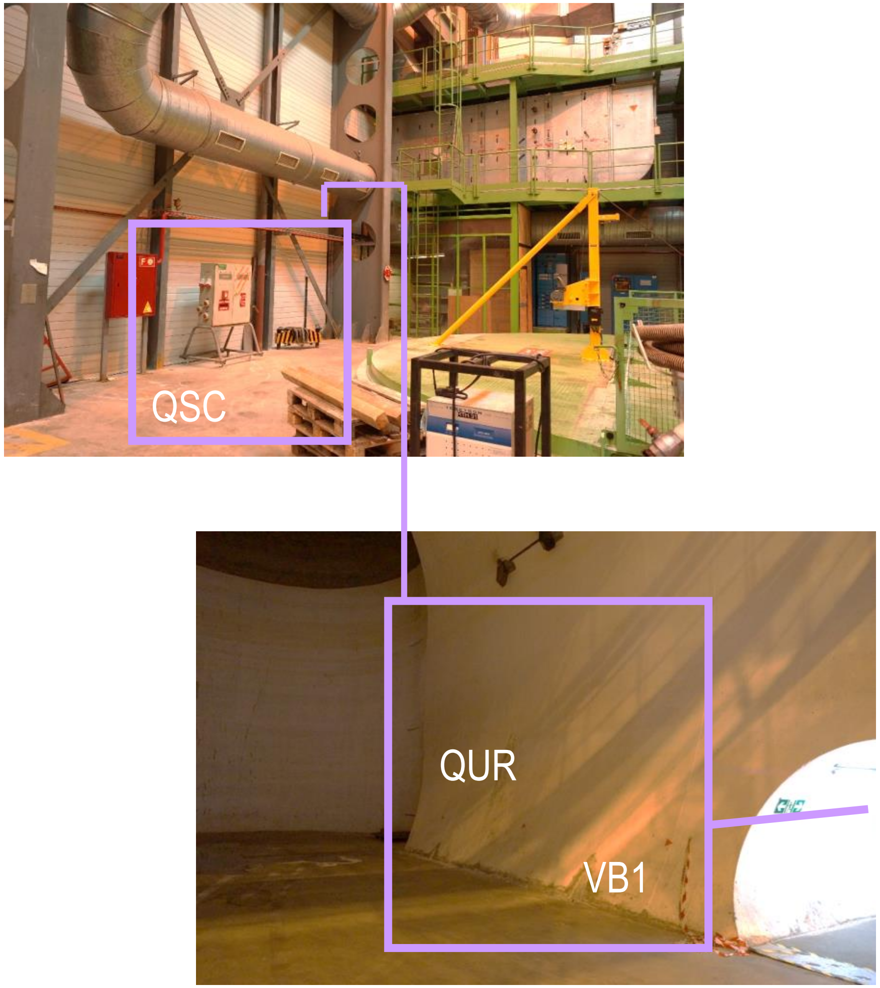




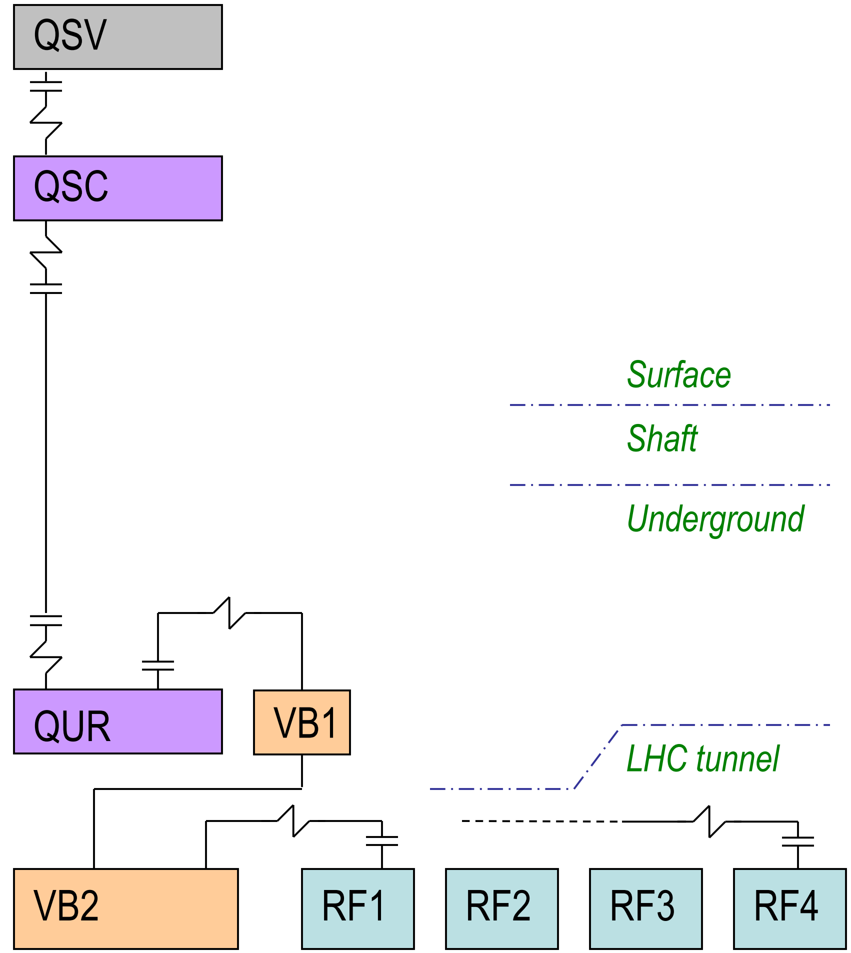
Connection to QRL and distribution along the existing and “future” RF zone (+e-lens!) to be looked at for present baseline and alternative scenario

RF tests refrigeration concept

Simplified infrastructure w.r.t baseline



LHC-P4 during Long Shutdowns

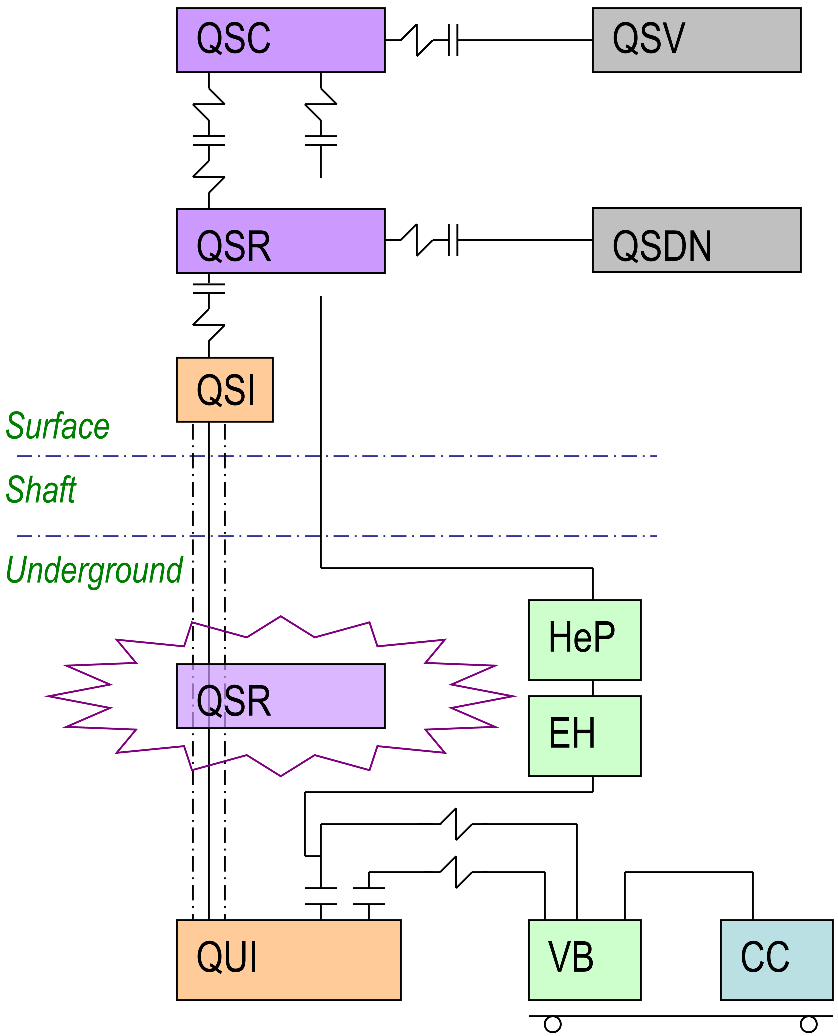


Cryo infrastructure for Crab Cavities

- Change of Baseline SPS-BA4 to SPS-BA6 June'15, with completely new cryogenic infrastructure required (considered during decision process)
- Studies started for new refrigerator, distribution line, gas storage, valve boxes, …
- But before that, technology validation is required at SM18, with specific interface required towards cryo distribution line in bunker M7 (1st on schedule!)
- Basic (re-)scheduling to be made considering installtion/connection windows (shut-downs at SM18 and E-YETS at SPS

RF tests refrigeration concept

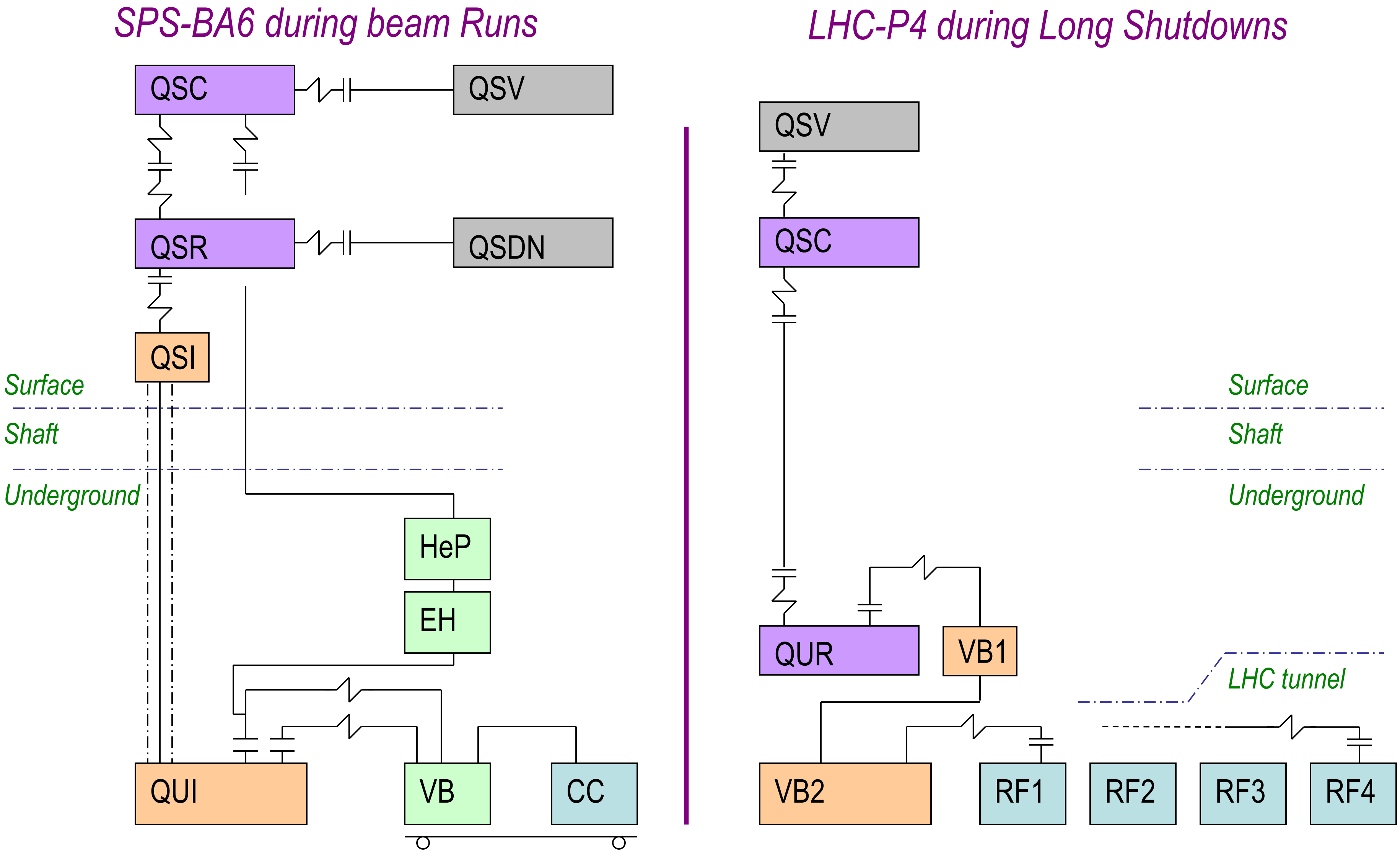
SPS-BA6 during beam Runs



Specific meetings/studies/reviews on the subject

Locating the cold box underground would really simplify cryo-distribution

RF tests refrigeration concept



“mobile” concept validated by industry

Summary

- Studies for P1/P5 are progressing for:
  - Heat transfer in the cold masses (coils, beam-screens, quench heaters)
  - First overall integration scenario completed (double-decker), incl. infrastructure
  - Flow diagrams, global process schemes and 1st sizing of components started
- P4-RF alternative scenario defined:
  - Required upgrade quantified, under feasibility evaluation before baseline change
  - Distribution scheme to be re-evaluated accordingly
- Crab cavities test areas: should be looked at with more priority/resources
  - Cryo infrastructure for technology tests at SM18 (from definition to procurement)
  - Completely new Cryo infrastructure for SPS-BA6 to be provided, with long lead items like refrigerator now to be specified (2015-Q4) and orderered (2016_Q1)
- Various alternative or long-term studies initiated (safety, availability, modifications of existing equipment BS_LSS, Q5s, back-up detectors)

=> 2015: integration, heat load model - 2016: increased resources required