Towards HL-LHCV1.4

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WP2 meeting 12/6/2018

Changes HLLHC1.3 → 1.4

Layout:

- 2+2 crab cavities → 2 crab cavities only
- Q4: 4xMCBY+MQY 1.9K → 3xMCBY+MQY 4.5 K
- Q5: 3xMCBY+MQY 1.9K → 1xMCBC+MQML 4.5
- Remote alignment system (i.e. machine can be realigned during beam commissioning)
- Extended D1 beam-screen
- New specification for TCTPV-TCTPH-TCLX stroke and apertures
- Increased distance D2-CRAB
- Changes in the triplet corrector package

Optics:

- Crossing bumps re-optimized thanks to remote alignment system
- Decision on crossing plane for Point 1/5
- New aperture estimates thanks to remote alignment system
- IR4 optimized for instrumentation and e-lens
- IR6 reviewed and re-optimized for TCDQ gaps, Q5 strengths
- Dedicated optics for 7TeV (using 7.5TeV equivalent currents where needed)

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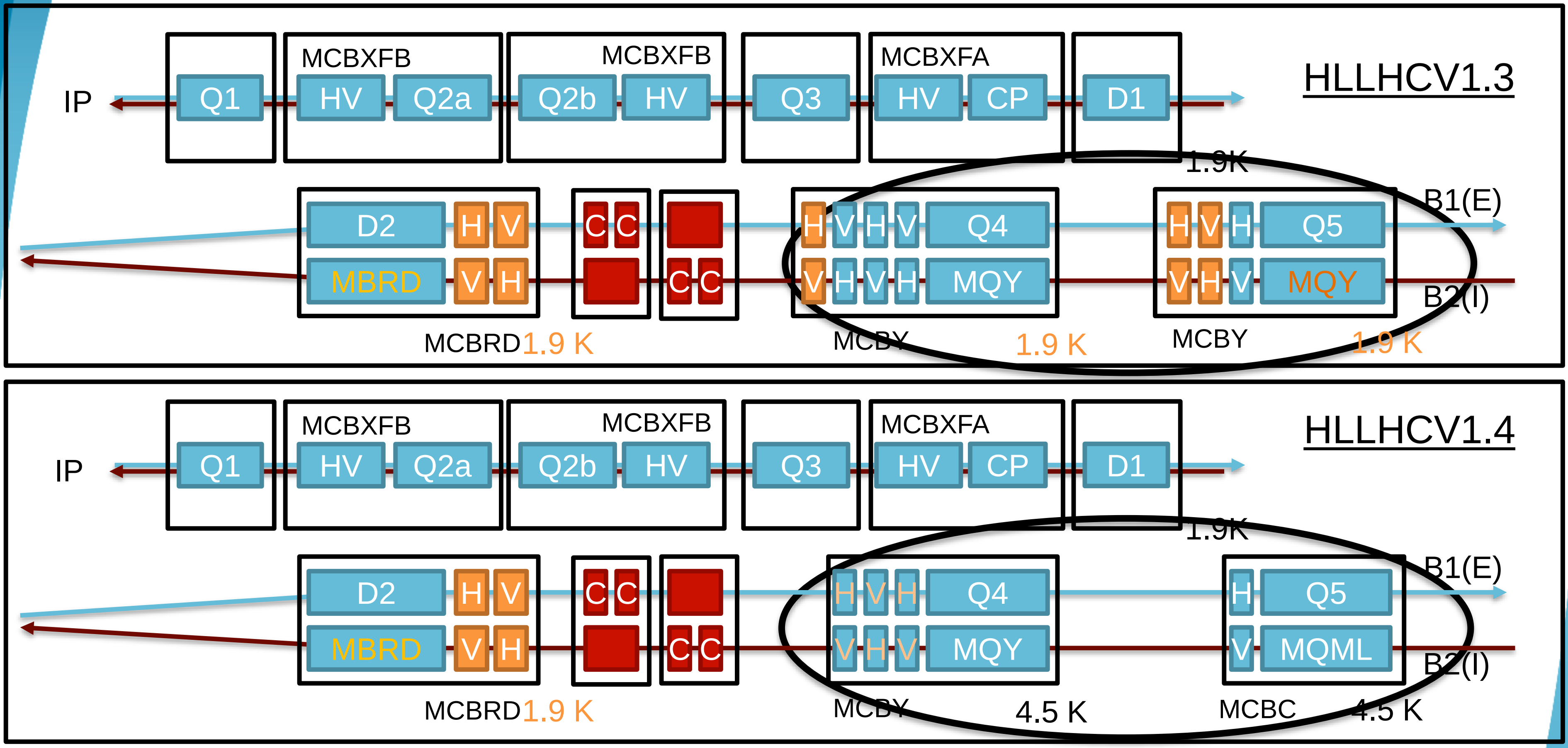
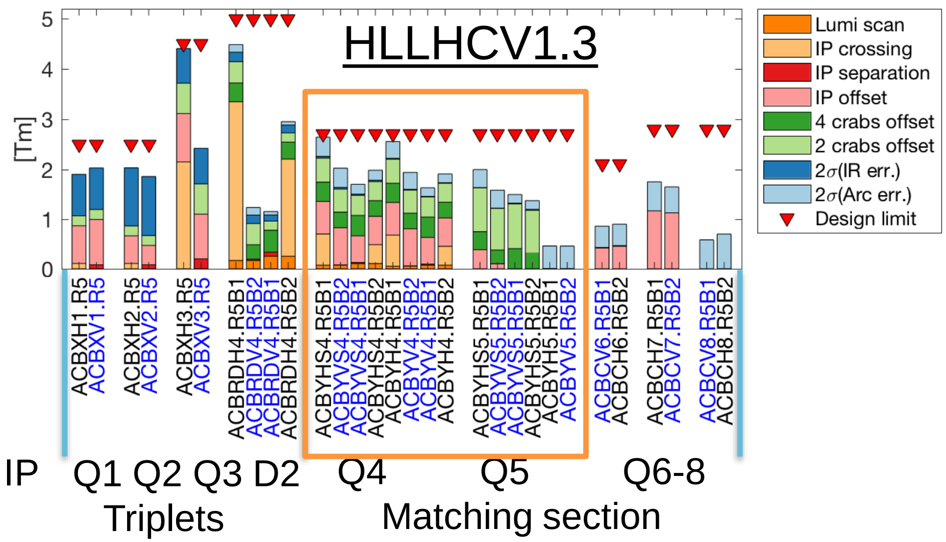
Layout changes



Changes with respect to the baseline:

- Q4: reusing existing cold mass (3 correctors instead of 4), no need of 1.9 K.
- Q5: reusing existing Q5 cold mass (1 corrector instead of 3), no need of 1.9 K.
- <u>Full deployment of remote alignment system to be used with safe beam</u>.

Orbit corrector strength budget



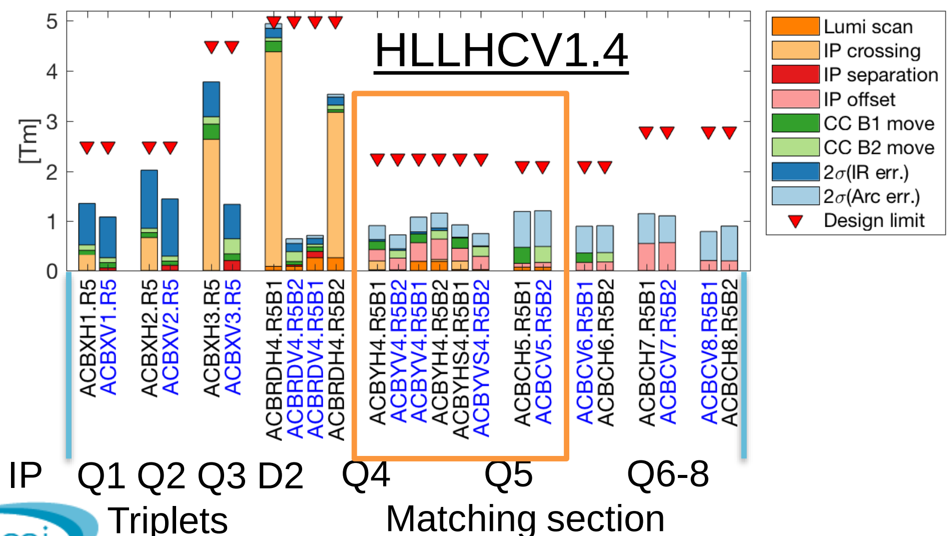
Right Point 5, H crossing.

The following symmetries apply:

- Left B1 -> Right B2,
- Left B2 -> Right B1
- H Point 5 -> V Point 1

HLLHCV1.4:

- orbit bumps reduced at the crab cavities
- IP offset performed by remote alignment
- Limited crab beam adjustment still possible

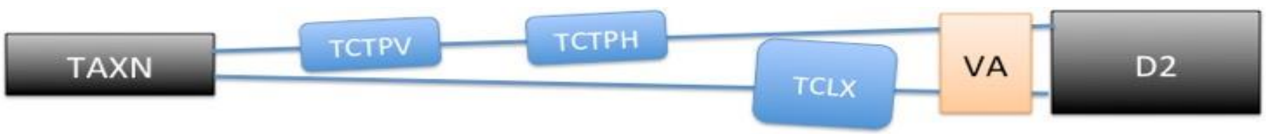


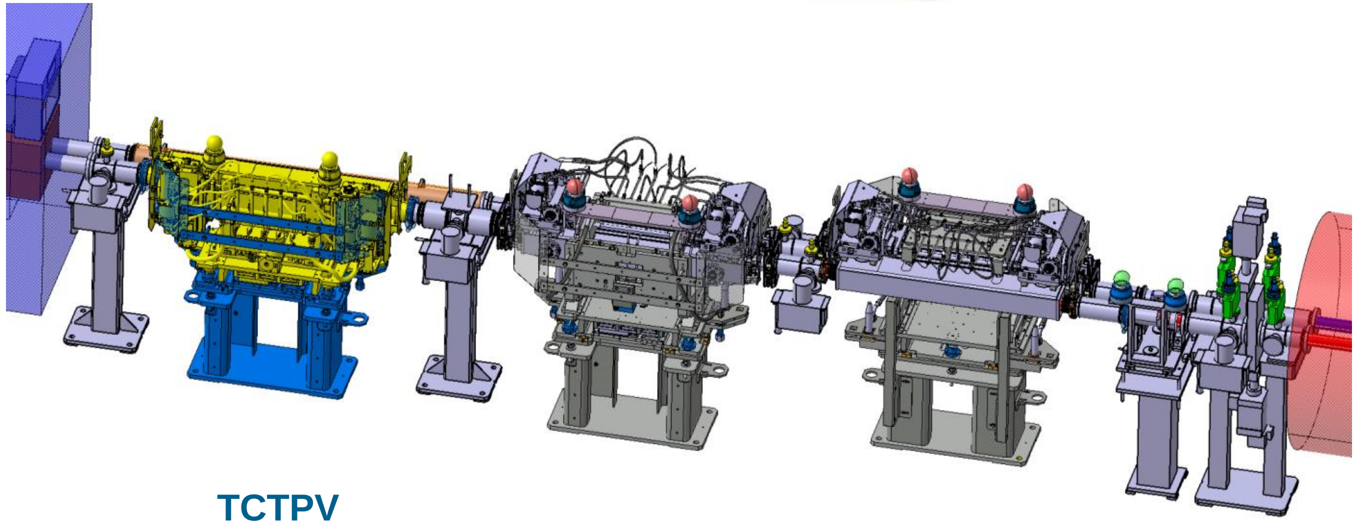
Crossing: ±295 μrad
Separation: ±0.75 mm
IP Offset: ±2.0 mm with re-alignment
Luminosity scan: ±100 μm
Crab knobs: ± 0.5 mm (baseline only)
Imperfection (2σ): from uniform distribution of mainly ±0.5 mm quad. alignment and 0.5 mrad / 20 units dipole errors.

TCLX – TCPH issues in HLLHC

- Beam size in between TAXN – D2 is much larger than LHC due to lower β* and D2 closer to the triplet, beam separation smaller than LHC because D1 – D2 distance is shorter.
- TCLX needs thicker internal jaw to provide dose protection to D2

-> Larger stroke in less space.





TCLX – TCPH issues in HLLHC

TCLX and TCPH required maximum gap >80 mm:
https://edms.cern.ch/file/1561432/1.0/CERN-ACC-2015-0129.pdf

ColUSM #67, 5/2/2016 https://indico.cern.ch/event/493012/

	TCTPV	TCTPH	TCLX
Orientation	Vertical	Horizontal	Horizontal
Absorber Cross-section	34 x 20 mm^2	34 x 20 mm^2	70 x 40 mm^2
Jaw Stroke	40 (+5) mm	**30** (+5) mm	**30** (+5) mm
Half Beam Separation	80.4-81.9 mm	83.4-84.9 mm	86-87.5 mm
Interference* with present layout	**11.3 mm**	**43 mm**	**58.1 mm**

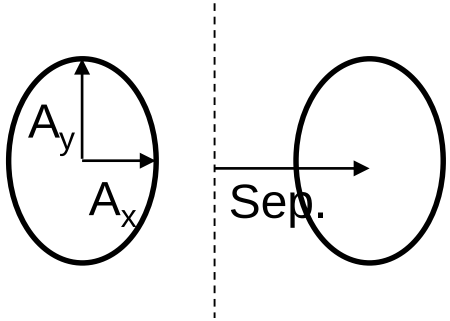
* Interference calculated assuming a **standard collimator tank** and including baking equipment thicknesses (tank jacket thickness 25 mm and/or vacuum chamber wrapping 5 mm) and a **new ID/OD 91/95 mm vacuum chamber.**

Further discussed at ColUSM #93 (22/9/2017) and integration meeting 12/1/2017: Interference solved but still with stroke limited to 30 mm.

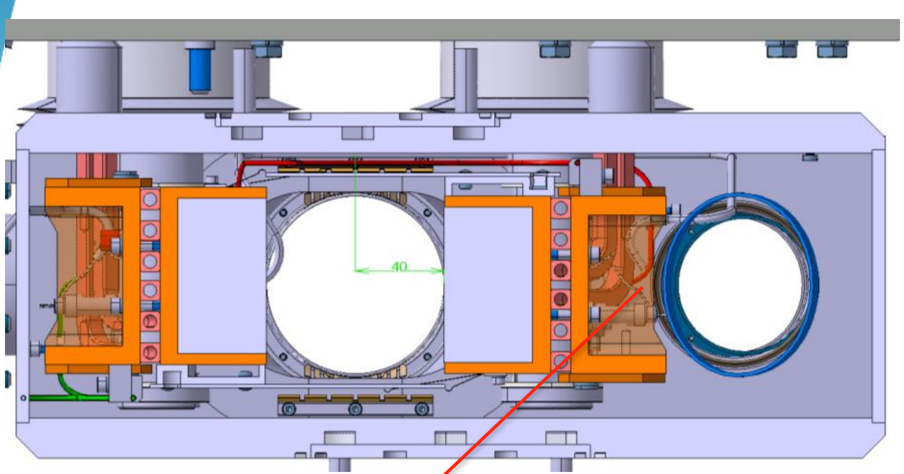
HiLumi HL-LHC PROJECT

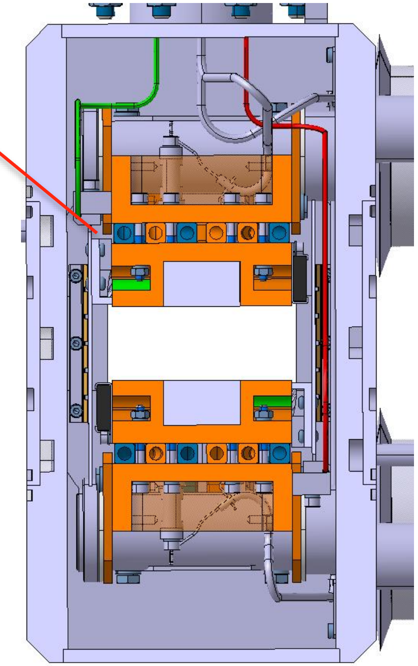
TCL-TCT Aperture specifications

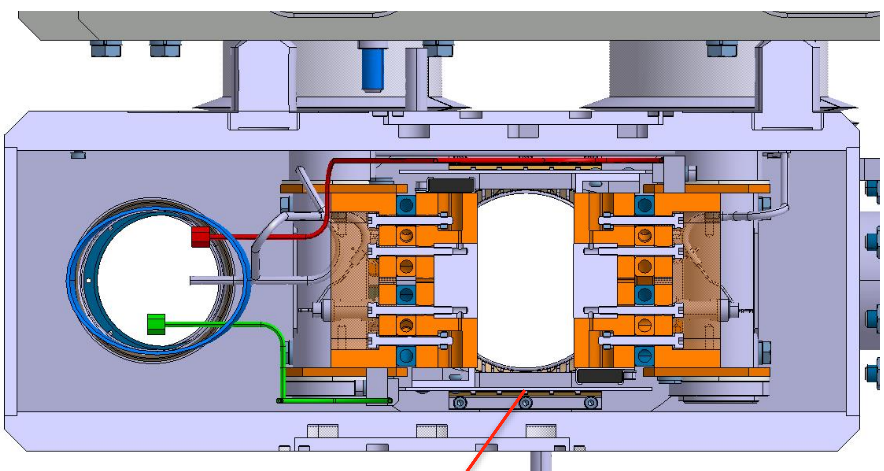
Offset (X,Y)	Baseline		Remote alignment		
Ground Motion + Fiduc.	~2 mm		~0.5 mm		
Orbit Error + crab adj.	2.5 mm		2.5 mm		
Collimator stroke	15 σ + 10 % (β-beat)		15 σ + 10 % (β-beat)		
Protected aperture	12 σ + 10 % (β-beat)		12 σ + 10 % (β-beat)		
2 mm IP shift	With orbit correctors		With re-alignment		
Round 15 cm	**A_x [mm]**	**A_y [mm]**	**A_x [mm]**	**A_y [mm]**	**Sep. [mm]**
TCLX	36.4	27.9	31.9	26.1	86.0-87.5
VTCLX	28.0	36.4	26.1	31.9	86.0-87.5
TCTPH	28.5	37.1	26.5	32.7	83.4-84.9
VTCTPH	37.0	28.1	32.5	26.4	83.4-84.9
TCTPV	28.9	38.0	26.9	33.7	80.4-81.9
VTCTPV	38.1	28.7	33.7	26.9	80.4-81.9
Flat 7.5/18 cm	**A_x [mm]**	**A_y [mm]**	**A_x [mm]**	**A_y [mm]**	**Sep. [mm]**
TCLX	42.8	33.8	38.3	32.0	86.0-87.5
VTCLX	33.9	42.9	32.1	38.4	86.0-87.5
TCTPH	34.2	43.5	32.3	39.1	83.4-84.9
VTCPTH	43.3	34.0	38.8	32.2	83.4-84.9
TCTPV	34.5	44.3	32.6	39.9	80.4-81.9
VTCTPV	44.2	34.5	39.8	32.5	80.4-81.9



New design proposal







	Stroke	Chamber
TCLX	40 mm	65/80 mm
TCTPH	32.5 mm	80/65 mm
TCTPV	40 mm	n/a

Remote alignment meeting, L. Gentini, 31/5/2018

Aperture update

Intermediate results: HLLHCV1.3 Optics without IP shift.

HL1.3	15 cm 500 µrad	7.5/18 480 µrad
TAXS	18.5	15.9
Triplet best case	16.5	15.5
Triplet with tolerances[1]	13.2	12.7
TAXN	17.5	14.0
D2	19.0	15.0
Q4	18.8	13.4
Q5	28.3	20.0
Q6	29.9	19.9

Round optics

- Triplets aperture bottleneck for all scenarios

Flat optics

- Q4, TAXN, D2 may become aperture bottleneck, but not limiting.

Possible improvements:

- Shorter crossing angle bump will improve TAXN, D2 apertures (and slightly Q4).
- Remote alignment expected to reduce ground motion and fiducialization tolerances (2 mm -> 0.5 mm).
- Detailed orbit error model from D. Gamba (expected 2 mm -> 1 mm).

[1] R. Bruce et al. CERN-ACC-2017-0051 + J. Jeanneret, LHC rep 1007

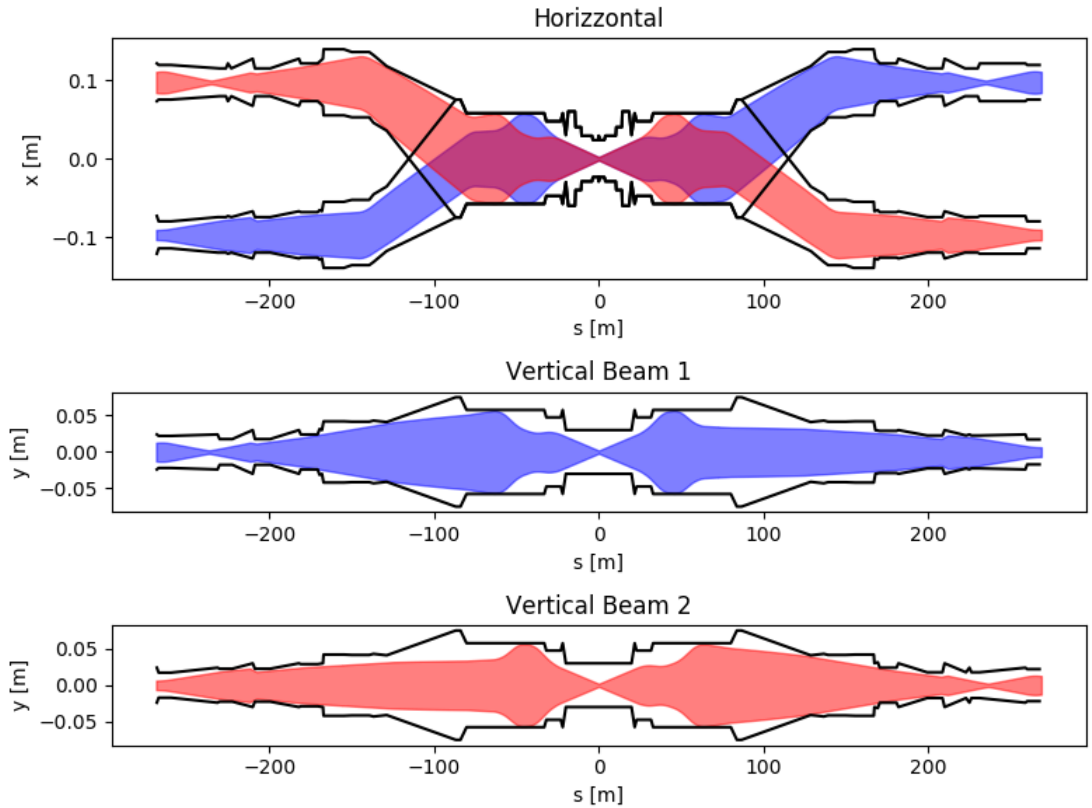
Aperture for vacuum layout

WP12 asked beam envelope without mechanical, alignment and fiducialization tolerances to specify vacuum apertures.
The request inverts the typical work flow because mechanical, alignment and fiducialization are not finalized.

Recipe given:

Beam stay clear =
$1.1\, n_\sigma\, \sigma_{nominal} + 2$ mm
where:
$n_\sigma = 13.25$ up to D1
$n_\sigma = 15$ TAXN-Q5
$n_\sigma = 20$ sigma Q6 to Q7.

In addition, new vacuum aperture should always have larger margins than those found in the triplet.
Table available here.



Consistent with present hardware and avoid additional aperture bottleneck.

Next steps

To release version 1.4:

1. Decision or study new position for Q4/Q5 for cryogenic integration.
2. Decision on how to gain 30 cm in between D2/crab cavities.
3. Consistency check between drawings and optics model.
4. Optimization crossing schemes and other orbit bumps.
5. Finalization IR6 optics and IR4 optics.
6. Freeze mechanical, ground motion, fiduc. tolerences.
7. Computation aperture margins and phase advance tunability.
8. Evaluation/choice of crossing planes.

Studies in parallel:

- Study optics at 7 TeV with ultimate currents in Q7 (more urgent if we want to ask for an hardware test at the end of the run).
- Update MS10 branch and follow-up of the DA studies.
- Optics optimization for forward physics.