Update TAXN aperture

R. De Maria

Thanks P. Diaz, F. Cerutti, P. Bestmann, J. Hansen

WP2 Meeting 10/11/2020

Introduction

Present baseline: ID 85 mm

WP8 and WP12:

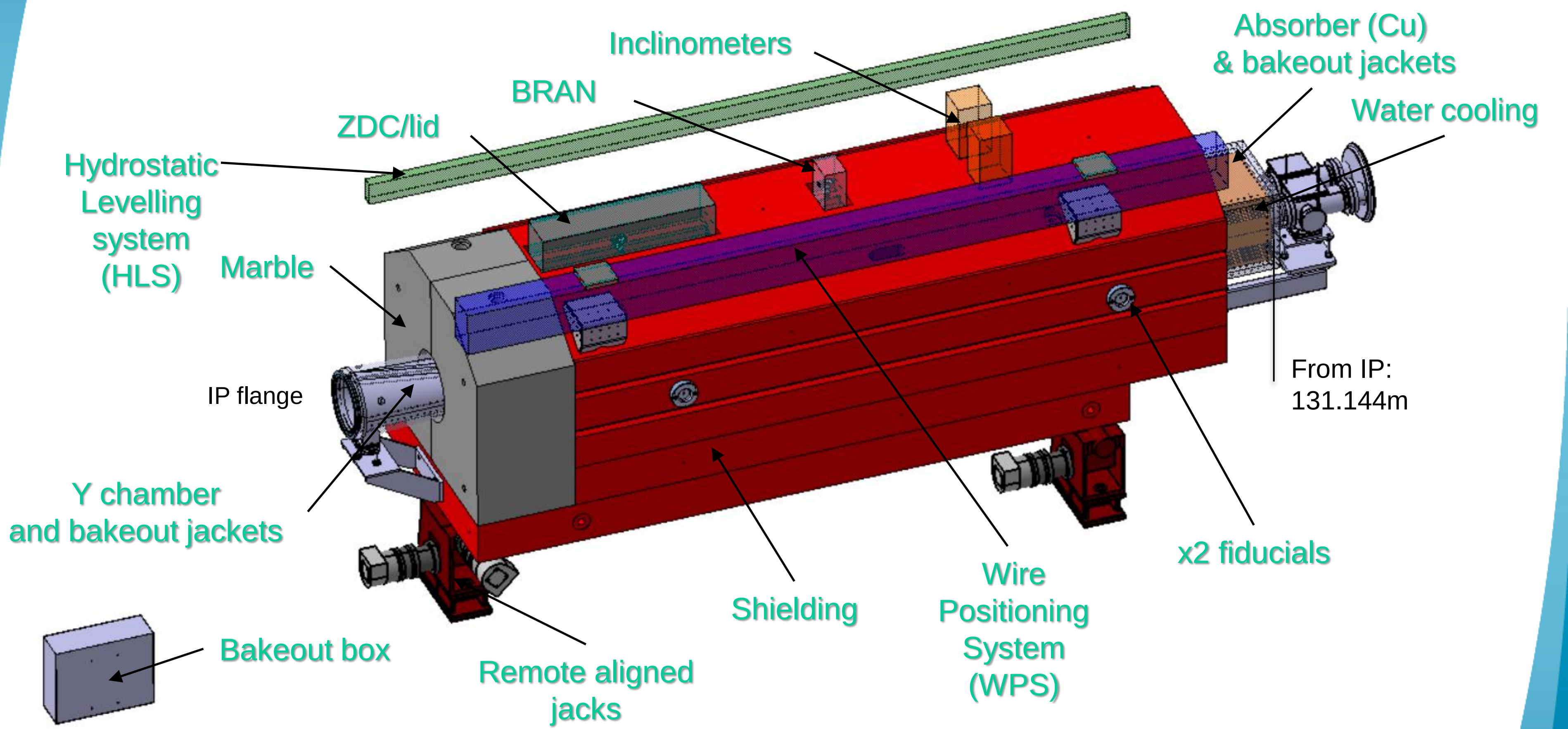
- Updated design of the absorber and Y chamber and proposed a new ID of 88 mm (86th WP8 meeting 28/1/2020 89th WP8 meeting 31/3/2020)
- Updated Mechanical Tolerances (30/9/2020 and presented at the WGA meeting 28/10/ 2020). Further update of tolerances on (9/11/2020) to be presented at the next WGA (11/11/2020)

Implications:

- Review impact of new tolerances on performance using the old and new ID (this talk).
- Review implications of new ID on energy deposition and radiation damage (work in progress F. Cerutti) to be presented at the next ColUSM (13/11/2020).

Overall TAXN design

- Overall design fixed while detailed absorber supports and cooling circuit in work.

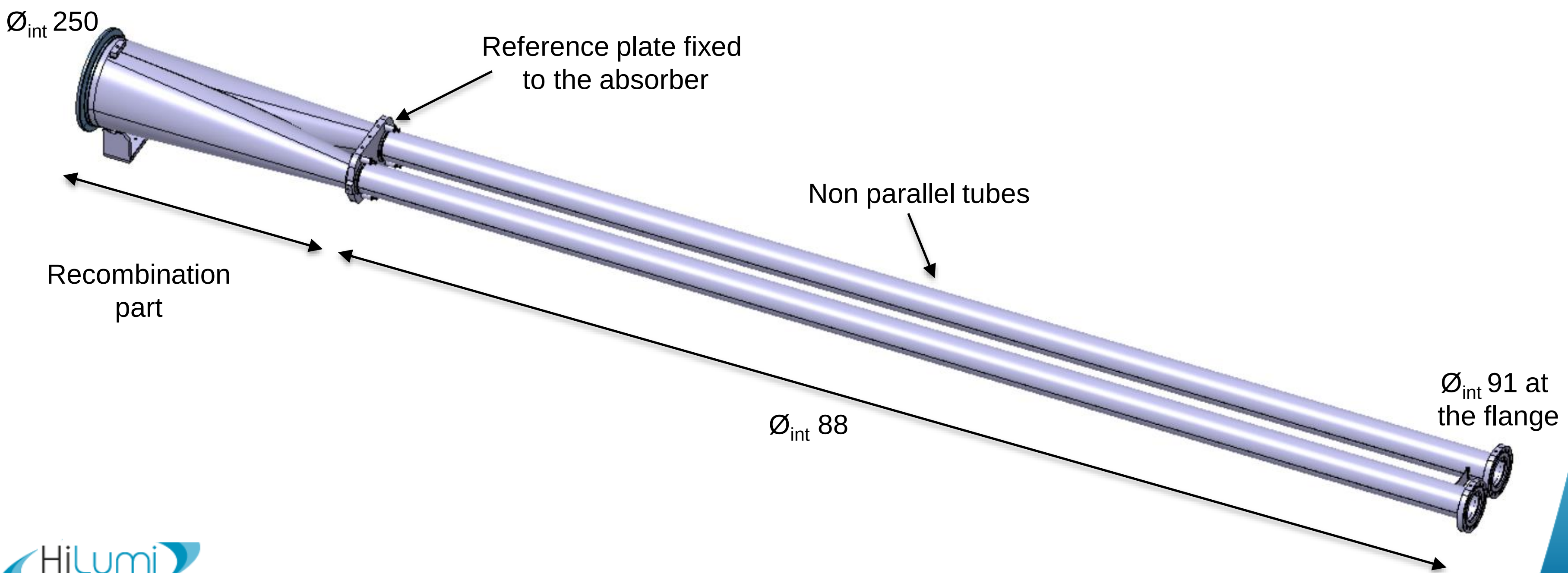


NOTES:

- The Hydraulic system is not used for the TAXN alignment, however, is to be taken into account for integration purposes.
- The geometry of the ZDC/lid and BRAN shown are space reservation.

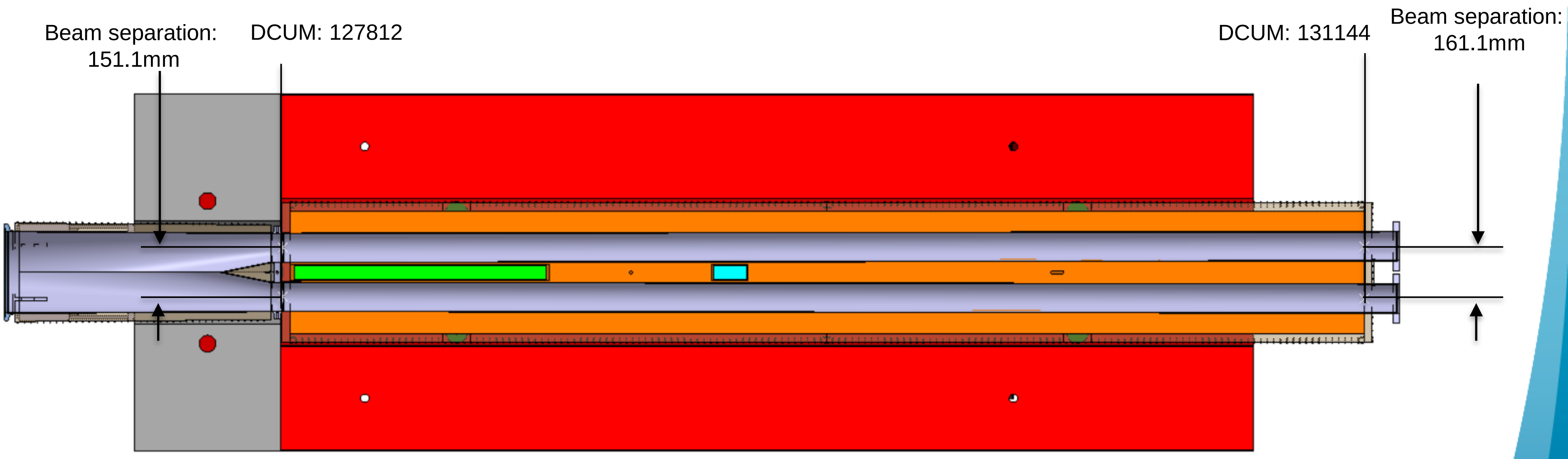
Recombination chamber

- Made of stainless steel and NEG coated.
- Mechanical tolerances defined.
- Integration of the bakeout jacket around the reference plate and alignment references completed.
- Drawing reference: LHCVCTYF0001.



Beam separation

- Absorber and Y-chamber geometry designed for the beam separation inputs provided by WP2 (confirmed on 06 of August of 2020).
- 0.172deg angle between double pipes.
- The total recombination chamber and absorber lengths are 4.3m and 3.31m, respectively.

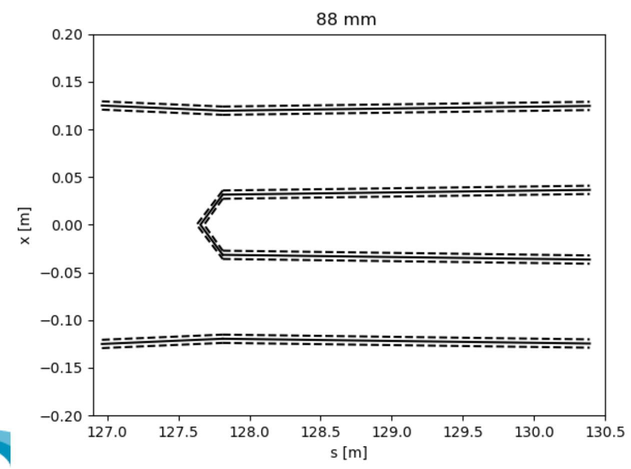


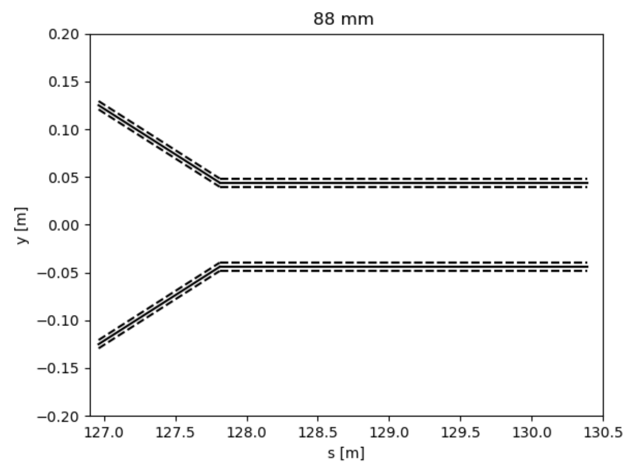
TAXN assumptions for aperture

	ID 85mm Old tol.	ID 85mm New tol.	ID 88mm New tol.
Y Chamber ID [mm]	85	85	88
Y Chamber OD [mm]	88	88	91
Copper groves ID [mm]	88.4	88.4	91.4
Mech. Tolerances ID [mm]	3	6.7 (4.9) [2]	6.7 (4.9) [2]
Align. Tolerances Pos[1] [H/V mm]	+/- 2.2/1.84	+/- 2.2/1.84	+/- 2.2/1.84

[1] Include fiducialization and ground motion, values based on LHC report 1008 (consistently applied for the other elements) and presently under review by WGA

[2] Presented at the WGA 28/10/2020 updated to 4.9 mm very recently 9/11/2020 (P. Diaz)





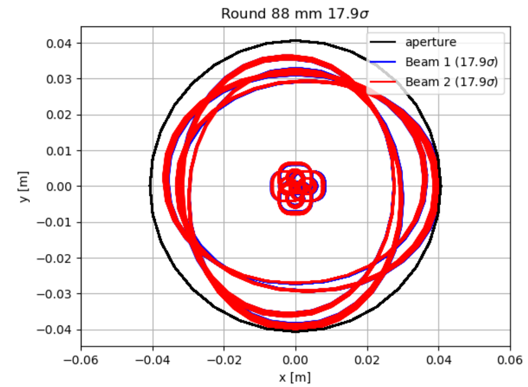
Aperture calculations

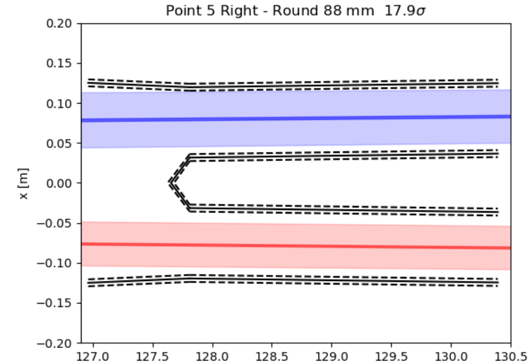
- Aperture calculation (min. transverse aperture in beam sigma):
- 3 different optics:
  - Round: baseline
  - Flat: back-up without crab cavities
  - FlatCC: optimization with crab cavities
- 5 different set of assumptions:
  - bare: nominal values
  - bstol: adding mechanical tolerances
  - align: adding alignment tolerances
  - beam: adding beam tolerances
  - offset: adding 2 mm IP offset with FRAS
- Aperture goals from most to least of important:
  1. Keep global beta* reach for the worst case scenario
  2. Sufficient margin with respect to the triplets (1-2 sigma)
  3. Similar margins with respect neighbouring elements

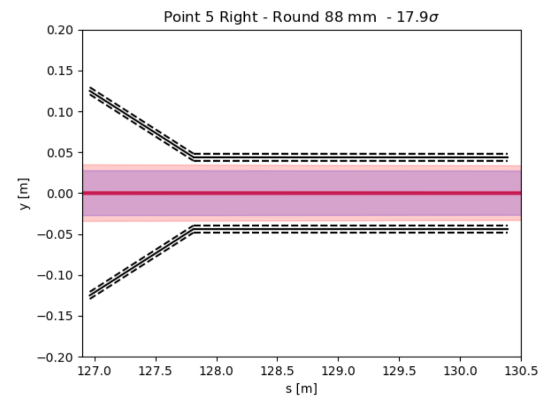
HiLumi HL-LHC PROJECT

Apertures: Round β*=15 cm, 500 µrad

	bare	bstol	align	beam	offset
TAXS	25.1	24.1	21.6	17.6	15.4
Q1	22.2	20.8	20.8	17.7	17.7
Q23	16.4	15.6	15.4	13.1	13.1
D1	17.4	16.5	16.3	13.9	13.9
D1 (ext)	17	16.1	15.9	13.5	13.5
TAXN (85mm, old)	23.6	22.7	21.3	18	18
TAXN (85mm, new)	23.6	20.5	20.2	17.1	17.1
TAXN (88mm, new)	24.5	22.4	21.1	17.8	17.9
TCTPV	22.1	22.1	22.1	18.8	18.8
TCTXH	22.7	22.7	22.7	19.3	19.3
TCLX	23.3	23.3	23.3	19.8	19.8
D2	24.9	24.9	23	19.3	19.3
D2 Corr.	25.7	25.7	24	20.1	20.1
CC (b.s)	27.8	27.8	25.9	21.8	21.8
Q4 Mask	25.9	25.9	23.6	19.3	19.3
Q4 Corr.	27.6	27.6	25.2	20.6	20.6
Q4	29	29	26.9	22.2	22.2
Q5 Mask	28.7	28.7	26.4	21.5	21.1
Q5 Corr.	31.4	29.8	27.4	22.3	22
Q5	31.8	30.2	27.9	22.7	22.4
Q6 Mask	36.5	36.5	34.1	27.9	26.7
Q6 Corr.	37.6	37.6	35.1	28.8	27.6
Q6	38	38	35.5	29.1	28.2



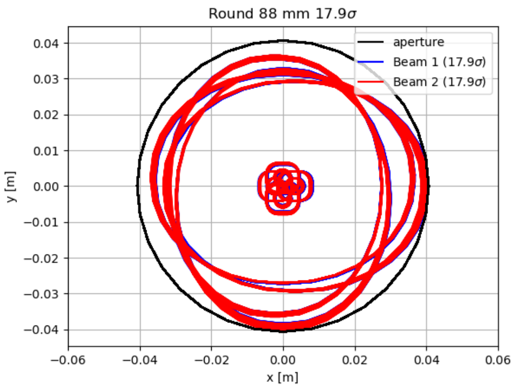


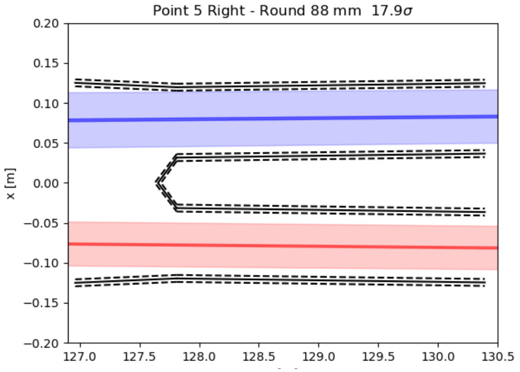


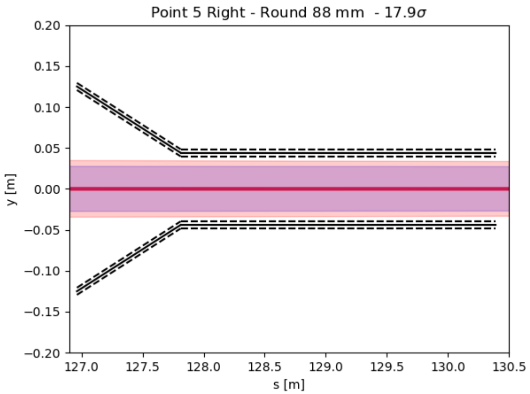
TAXN tol: 6.7 mm

Apertures: Round β*=15 cm, 500 μrad

	bare	bstol	align	beam	offset
TAXS	25.1	24.1	21.6	17.6	15.4
Q1	22.2	20.8	20.8	17.7	17.7
Q23	16.4	15.6	15.4	13.1	13.1
D1	17.4	16.5	16.3	13.9	13.9
D1 (ext)	17	16.1	15.9	13.5	13.5
TAXN (85mm, old)	23.6	22.7	21.3	18	18
TAXN (85mm, new)	23.6	21.1	20.8	17.6	17.6
TAXN (88mm, new)	24.5	23.0	21.7	18.4	18.4
TCTPV	22.1	22.1	22.1	18.8	18.8
TCTXH	22.7	22.7	22.7	19.3	19.3
TCLX	23.3	23.3	23.3	19.8	19.8
D2	24.9	24.9	23	19.3	19.3
D2 Corr.	25.7	25.7	24	20.1	20.1
CC (b.s)	27.8	27.8	25.9	21.8	21.8
Q4 Mask	25.9	25.9	23.6	19.3	19.3
Q4 Corr.	27.6	27.6	25.2	20.6	20.6
Q4	29	29	26.9	22.2	22.2
Q5 Mask	28.7	28.7	26.4	21.5	21.1
Q5 Corr.	31.4	29.8	27.4	22.3	22
Q5	31.8	30.2	27.9	22.7	22.4
Q6 Mask	36.5	36.5	34.1	27.9	26.7
Q6 Corr.	37.6	37.6	35.1	28.8	27.6
Q6	38	38	35.5	29.1	28.2





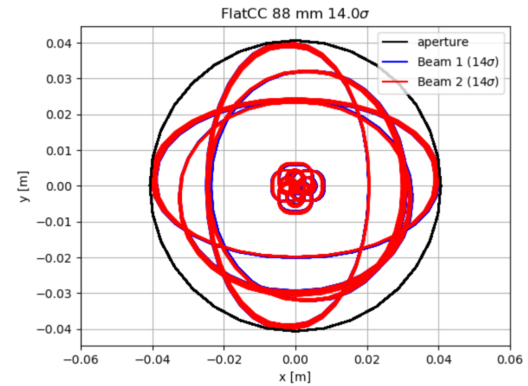


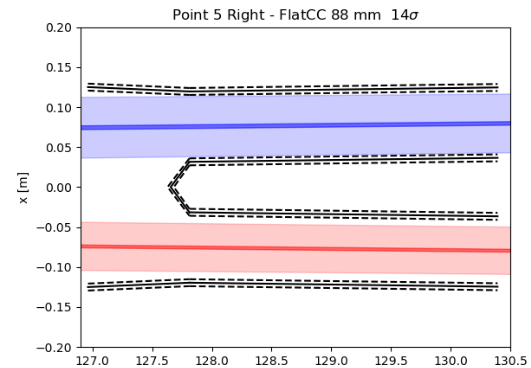
TAXN tol: 4.9 mm

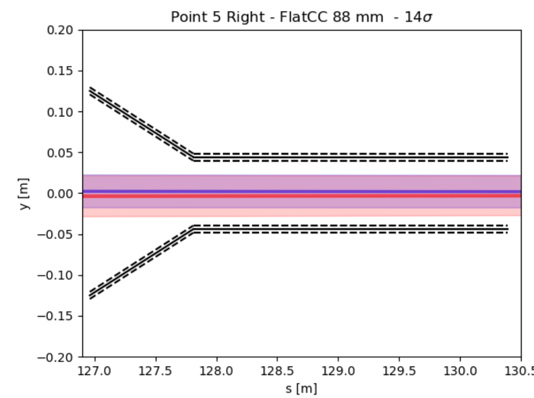
Aperture FlatCC: β*=7.5/18 cm, 480 µrad

	bare	bstol	align	beam	offset
TAXS	21	20.2	18.3	15.1	13.2
Q1	19.4	18.5	18.4	15.9	15.9
Q23	15.5	14.9	14.7	12.7	12.7
D1	15.8	15.1	14.9	12.9	12.9
D1 (ext)	15.5	14.8	14.6	12.6	12.6
TAXN (85mm, old)	18.2	17.6	16.6	14.1	14.1
TAXN (85mm, new)	18.2	16.0	15.8	13.4	13.4
TAXN (88mm, new)	18.9	17.5	16.5	14.0	14.0
TCTPV	17	17	17	14.4	14.4
TCTXH	17.2	17.2	17.2	14.7	14.7
TCLX	17.6	17.6	17.6	15	15
D2	18.9	18.2	17.1	14.5	14.5
D2 Corr.	21.3	20.5	19.3	16.4	16.4
CC (b.s)	20.6	19.7	18.3	15.4	15.4
Q4 Mask	19.2	18.3	16.7	13.6	13.6
Q4 Corr.	20.4	19.5	17.8	14.5	14.5
Q4	21.4	20.6	19.1	15.6	15.6
Q5 Mask	21.2	20.2	18.7	15.2	14.9
Q5 Corr.	22	20.9	19.4	15.8	15.6
Q5	22.3	21.1	19.5	15.8	15.6
Q6 Mask	25.8	25.8	24.1	19.7	18.9
Q6 Corr.	28.3	26.9	25.1	20.5	19.6
Q6	28.3	26.9	25.1	20.5	19.9

TAXN tol: 6.7 mm

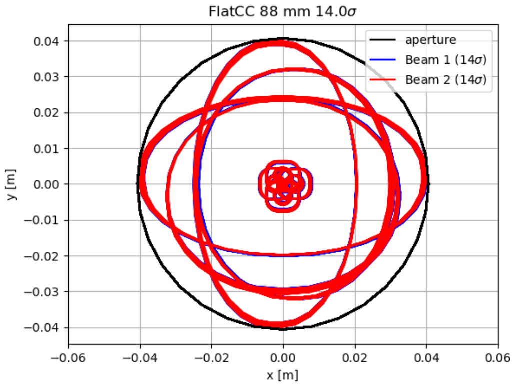


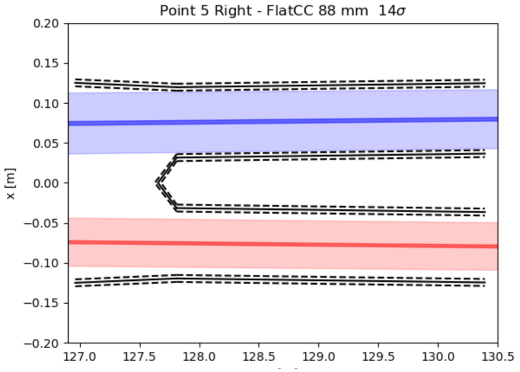


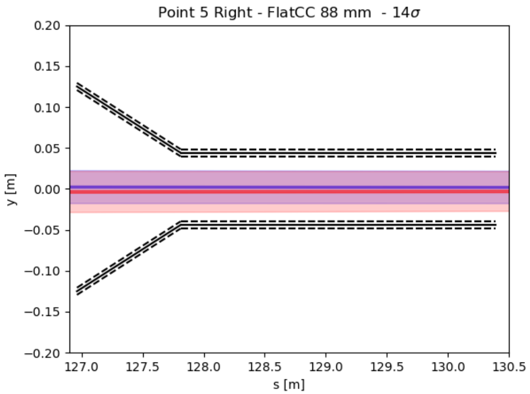


Aperture FlatCC: β*=7.5/18 cm, 480 µrad

	bare	bstol	align	beam	offset
TAXS	21	20.2	18.3	15.1	13.2
Q1	19.4	18.5	18.4	15.9	15.9
Q23	15.5	14.9	14.7	12.7	12.7
D1	15.8	15.1	14.9	12.9	12.9
D1 (ext)	15.5	14.8	14.6	12.6	12.6
TAXN (85mm, old)	18.2	17.6	16.6	14.1	14.1
TAXN (85mm, new)	18.2	16.4	16.2	13.8	13.8
TAXN (88mm, new)	18.9	17.8	16.9	14.3	14.3
TCTPV	17	17	17	14.4	14.4
TCTXH	17.2	17.2	17.2	14.7	14.7
TCLX	17.6	17.6	17.6	15	15
D2	18.9	18.2	17.1	14.5	14.5
D2 Corr.	21.3	20.5	19.3	16.4	16.4
CC (b.s)	20.6	19.7	18.3	15.4	15.4
Q4 Mask	19.2	18.3	16.7	13.6	13.6
Q4 Corr.	20.4	19.5	17.8	14.5	14.5
Q4	21.4	20.6	19.1	15.6	15.6
Q5 Mask	21.2	20.2	18.7	15.2	14.9
Q5 Corr.	22	20.9	19.4	15.8	15.6
Q5	22.3	21.1	19.5	15.8	15.6
Q6 Mask	25.8	25.8	24.1	19.7	18.9
Q6 Corr.	28.3	26.9	25.1	20.5	19.6
Q6	28.3	26.9	25.1	20.5	19.9







TAXN tol: 4.9 mm

Apertures: Flat β*=7.5/30 cm, 490 µrad

	bare	bstol	align	beam	offset
TAXS	21.1	20.4	18.5	15.2	13.5
Q1	19.4	18.5	18.5	15.9	15.9
Q23	15.5	14.9	14.7	12.7	12.7
D1	15.8	15.1	14.9	12.9	12.9
D1 (ext)	15.5	14.8	14.6	12.6	12.6
TAXN (85mm, old)	18.2	17.6	16.6	14.1	14.1
TAXN (85mm, new)	18.2	16.1	15.9	13.4	13.4
TAXN (88mm, new)	18.9	17.4	16.5	14.0	14.0
TCTPV	17	17	17	14.4	14.4
TCTXH	17.3	17.3	17.3	14.7	14.7
TCLX	17.6	17.6	17.6	15	15
D2	18.9	18.2	17.1	14.5	14.5
D2 Corr.	21.3	20.5	19.3	16.4	16.4
CC (b.s)	20.6	19.7	18.3	15.4	15.4
Q4 Mask	19.2	18.3	16.7	13.6	13.6
Q4 Corr.	20.5	19.5	17.8	14.5	14.5
Q4	21.5	20.6	19.1	15.6	15.6
Q5 Mask	21.3	20.2	18.7	15.2	14.9
Q5 Corr.	22	20.9	19.4	15.8	15.6
Q5	22.3	21.1	19.5	15.8	15.6
Q6 Mask	25.9	25.9	24.2	19.7	18.9
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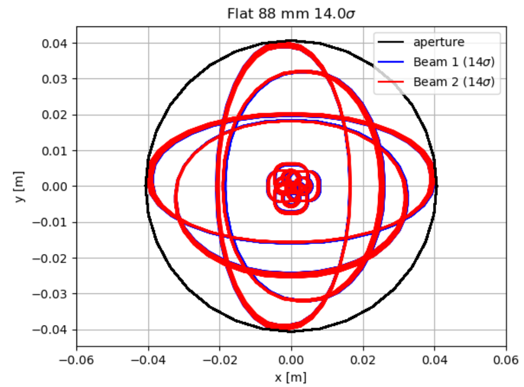
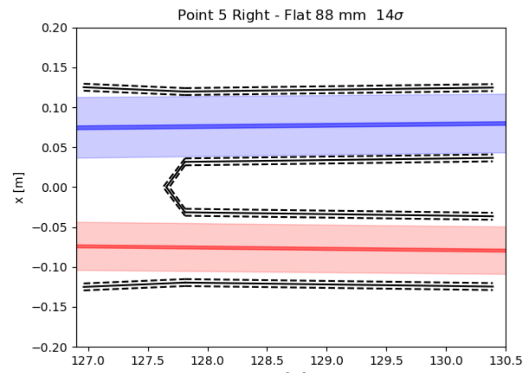
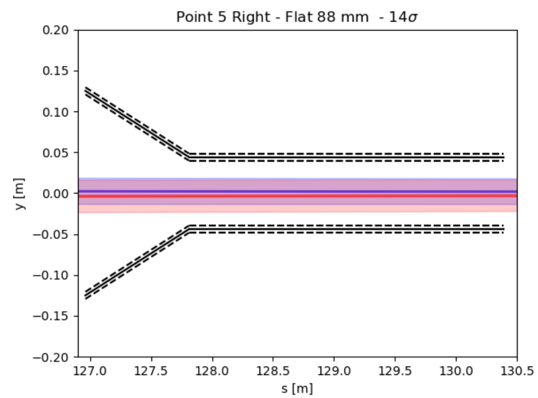
Q6	28.3	26.9	25.1	20.5	19.9







HiLumi HL-LHC PROJECT

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	bare	bstol	align	beam	offset
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Q23	15.5	14.9	14.7	12.7	12.7
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TCTPV	17	17	17	14.4	14.4
TCTXH	17.3	17.3	17.3	14.7	14.7
TCLX	17.6	17.6	17.6	15	15
D2	18.9	18.2	17.1	14.5	14.5
D2 Corr.	21.3	20.5	19.3	16.4	16.4
CC (b.s)	20.6	19.7	18.3	15.4	15.4
Q4 Mask	19.2	18.3	16.7	13.6	13.6
Q4 Corr.	20.5	19.5	17.8	14.5	14.5
Q4	21.5	20.6	19.1	15.6	15.6
Q5 Mask	21.3	20.2	18.7	15.2	14.9
Q5 Corr.	22	20.9	19.4	15.8	15.6
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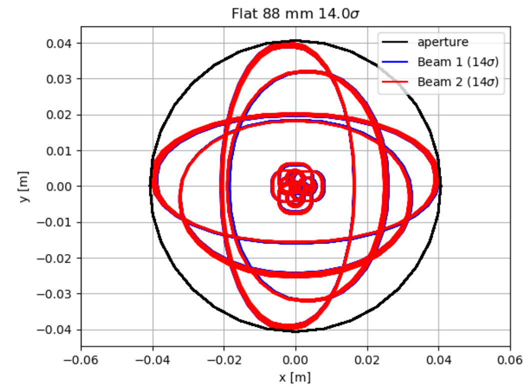

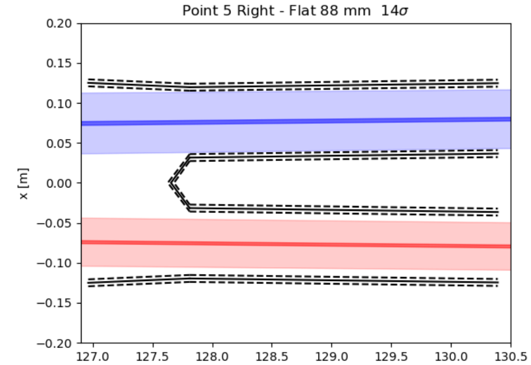

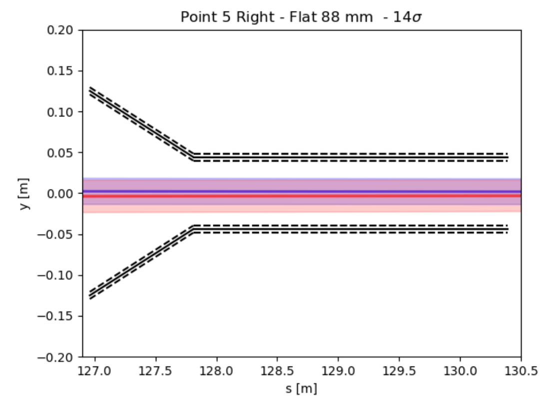

TAXN tol: 4.9 mm

Conclusion

- Aperture goals in order of importance:
  1. Keep global beta* reach for the worst case scenario
  2. Sufficient margin with respect to the triplets
  3. Similar margins with respect neighbouring elements

Criteria (Round /Flat Optics)	ID 85mm Old tol.	ID 85mm New tol.	ID 88mm New tol.
1. Aperture worst case [sigma]	18.0 / 14.1	17.1 /13.4	17.9 / 14.0
2. Triplet margin	4.9 / 1.5	4.0 / 0.8	4.8 / 1.4
3. Margin with respect to D2	-1.3 / -1.4	-2.2 / -1.1	-1.4 / -0.5

- TAXN is the local aperture bottleneck in the D2 region.
- New tolerances with 85 mm reduces margin with respect to the triplet, but still at an acceptable level.
- New aperture with new tolerance is equivalent or slightly improve old baseline in the aperture
- Energy deposition studies are needed to accept 88 mm.

Conclusion

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1. Aperture worst case [sigma]	18.0 / 14.1	17.6 /13.8	18.4 / 14.3
2. Triplet margin	4.9 / 1.5	4.5 / 1.2	5.3 / 1.7
3. Margin with respect to D2	-1.3 / -1.4	-1.7 / -0.7	-0.9 / -0.2

- TAXN is the local aperture bottleneck in the D2 region.
- New tolerances with 85 mm reduces margin with respect to the triplet, but still at an acceptable level.
- New aperture with new tolerance is equivalent or slightly improve old baseline in the aperture
- Energy deposition studies are needed to accept 88 mm.

Back-up

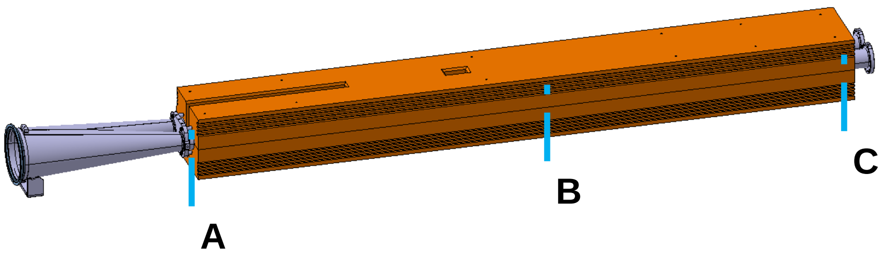
Tolerances summary

- The estimated worst tolerance case, if a sum of them is carried out, implies a mechanical aperture lost of 7.7mm in each pipe.

Tolerance type	Concept	Accuracy / Standard manufacturing [mm]
Alignment	Precision of the measurement from the measured reference axis to the fiducials	1
	Precision of the transfer measurement from the fiducials to the permanent monitoring system	
	The alignment precision with respect to the neighbouring element (via WPS and inclination sensors)	
Mechanical	Pipe thickness	0.2
	Pipe circularity	1
	Position of the pipes with respect to each other	2
	Reference plate holes	0.5
	Welding of the pipes to the reference plate	1.5
	Absorber groove cilindricity	1.8
	Bakeout cycle returning position (theoretical)	0.5
	Remaining movements of the absorber with respect to the shielding (theoretical)	0.5
	Maximum shimming adjustment offset	0.7
		7.7

Tolerances computation

P. Santos Diaz, P. Bestmann, J. Hansen & R. De Maria; 09.11.2020



Tolerance type	n	Concept	Accuracy / Standard manufacturing [mm]	A	B	C
Alignment	0.1	Precision of the measurement from the measured reference axis to the fiducials	1	1	1	1
	0.2	Precision of the transfer measurement from the fiducials to the permanent monitoring system				
	0.3	The alignment precision with respect to the neighbouring element (via WPS and inclination sensors)				
Mechanical	1	Pipe thickness	0.2	0.2	0.2	0.2
	2	Pipe circularity	1	1	1	1
	3	Position of the pipes with respect to each other	2	2	N/A	N/A
	3.1	Reference plate holes	0.5	0.5	N/A	N/A
	3.2	Welding of the pipes to the reference plate	1.5	1.5	N/A	N/A
	4	Absorber groove cilindricity	1.8	N/A	1.8	1.8
	5	Bakeout cycle returning position (theoretical)	0.5	0.5	0.5	0.5
	6	Remaining movements of the absorber with respect to the shielding (theoretical)	0.5	0.5	0.5	0.5
	7	Maximum shimming adjustment offset	0.7	0.7	0.7	0.7
			TOTAL	5.9	5.7	5.7

Protected Apertures

Parameters	7 TeV	0.45 TeV
Radial CO [mm]	2	
Mom offset	$2\ 10^{-4}$	$8.6\ 10^{-4}$
Dispersion	0.1	0.14
Beam size	1.1	1.05
Min Ap. no TCT [σ]	19.4	12.6
Min H. Ap. with TCT [σ]	table	12.6
Min V. Ap. with TCT [σ]	11.2	12.6

$\Delta\mu_x$ MKD-TCT [°]	H. Ap. W [σ@2.5μm]	H. Ap. CuCD [σ@2.5μm]
0-20	11.2	11.2
30	11.9	11.2
40	12.9	11.9
50	13.8	12.8
60	14.5	13.6
70	14.6	14
80-90	14.6	14.3

R. Bruce et al. CERN-ACC-2017-0051 and proposal of differentiating H/V collimators (R. Bruce).

- CuCD collimators give about ~1 σ additions H margin from 40° to 60° MKD-TCT phase advance.
- MKD-TCT phase advance constrains:
  - mostly IR6 optics for TCT5 for both beams and
  - mildly IR4 and arcs 23, 34, 67, 78 optics for TCT1

Impact of CuCD is relevant when Point 5 bottlenecks is in H plane.

Optics, aperture, crossing plane

	Round	Flat	FlatCC	FlatCCHV	FlatCCHV
β* Xing/Sep [cm]	15/15	30/7.5	18/7.5	18/9	18/7.5
Xing angle [μrad]	±250	±245	±240	±240	±240
Crossing plane IP5	V (or H)	H	H	V	V
Aperture Xing plane [σ]	13.1	15.6	14.2	14.2	14.2
Aperture Sep plane [σ]	16.5	12.7	12.7	13.9	12.7
H Aperture Point 1/5	13.1/16.5	12.7/15.6	12.7/14.2	14.2/13.9	14.2/12.7
MKD-TCT [°] IP1 [B1/B2]	5/19	23/10	4/6	13/22	8/22
MKD-TCT [°] IP5 [B1/B2]	30/31	14/22	27/25	40/45	51/54
H Ap. Protected IP1 W/Cu	11.2/11.2	11.4/11.2	11.2/11.2	11.3/11.2	11.3/11.2
H Ap. Protected IP5 W/Cu	11.9/11.2	11.3/11.2	11.7/11.2	13.3/12.3	14.1/13.1
Ap. Margin W [σ]	1.9 (or 1.2)	1.3	1.5	0.6	-1.4
Ap. Margin CuCD [σ]	1.9 (or 1.9)	1.5	1.5	1.6	-0.4

Assuming different settings for TCTH and TCTV, which is under study (R. Bruce):

- IR6 optics is constraining only for flat optics and V crossing in Point 5.
- CuCD collimators:
  - Improve β* reach for flat optics with crab cavities from about 8.7 cm to 7.8 cm (based on scaling).
  - Allow H crossing in Point 5 without performance losses (but CMS forward physics preferred V).
  - Allow ±10° additional potential flexibility in IP1 to IP5 for flat optics with crab cavities phase advance for lifetime optimization without compromising β* reach.

Detailed calculations

Round 15 cm	IP1 (H xing)	IP5 (V xing)
Aperture [σ] [H/V]	13.1/16.5	16.5/13.1
MKD-TCT [°] [B1/B2]	5/19	30/31
Ap. Protected W [σ] [H/V]	11.2/11.2	11.7/11.2
Ap. Protected CuCD [σ] [H/V]	11.2/11.2	11.2/11.2
Ap. Margin W [σ] [H/V]	1.9/5.3	4.8/1.9
Ap. Margin CuCD [σ] [H/V]	1.9/5.3	5.3/1.9

FlatCCHV 18/7.5 cm	IP1 (H Xing)	IP5 (V Xing)
Aperture [σ] [H/V]	14.2/12.7	12.7/14.2
MKD-TCT [°] [B1/B2]	13/22	39/54
Ap. Protected W [σ] [H/V]	11.3/11.2	14.1/11.2
Ap. Protected CuCD [σ] [H/V]	11.2/11.2	13.1/11.2
Ap. Margin W [σ] [H/V]	2.9/1.5	-1.4/3.0
Ap. Margin CuCD [σ] [H/V]	3.0/1.5	-0.4/3.0

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