D1 aperture optimization

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Motivation

- Beta* reach was one of the guiding design criteria for HL-LHC
- LHC and HL-LHC apertures have been designed to make sure that the triplets will be the aperture bottleneck by giving extra margins is D1, TAN, D2, Q4-Q5, because:
  - Triplet aperture is expensive and should not be waisted by not using it
  - In between Q1-Q5 It is possible to optimize one single aperture bottleneck per side
- This optimization is carried out for round and flat optics
- D1 aperture was not a bottleneck until it was decided to extend the service module and the b.s. with it. At the time of the decision, an aperture warning was issued with the agreement increasing the aperture if necessary.

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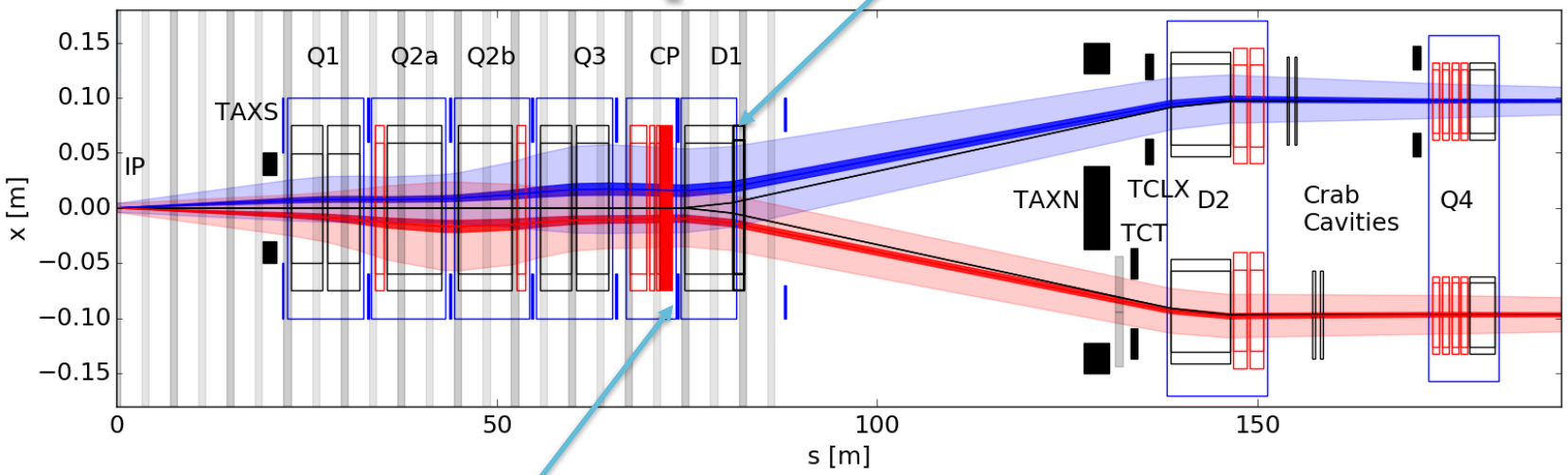
“RM expressed that after D1 we may require a larger aperture. DDR replied that the design is not yet done and thence it could be taken into account. It could be implemented by changing the diameter through the interconnect. “

Aperture general features

Aperture at edge of D1 cold mass already at the limit.

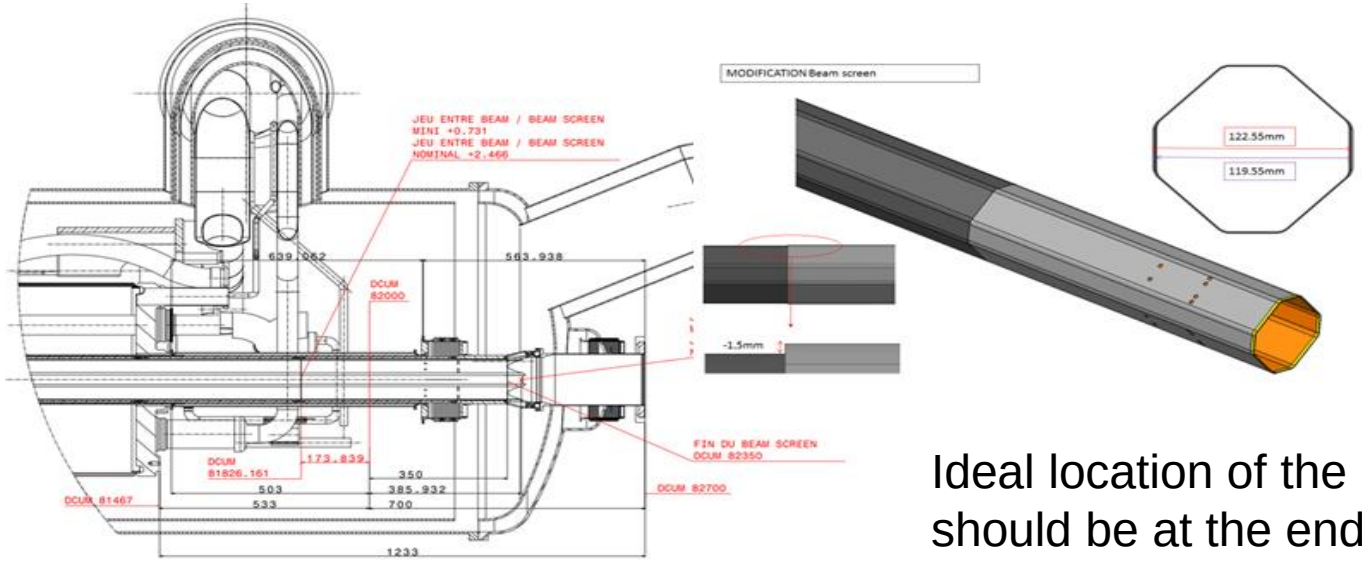
B.S. extension (not to scale)



Envelope not symmetric, misalign D1 towards the outside of the machine helps

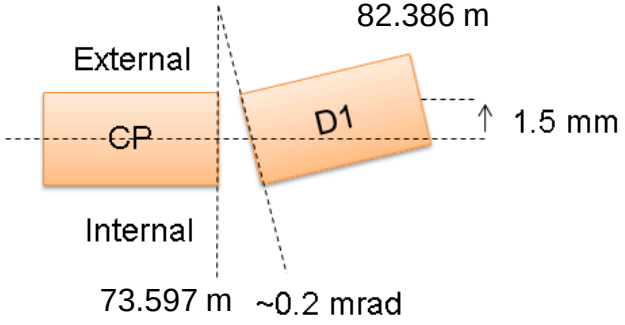
Mitigation Options

- New beam screen:



Ideal location of the b.s. transition should be at the end of the cold mass.

- Rotate D1



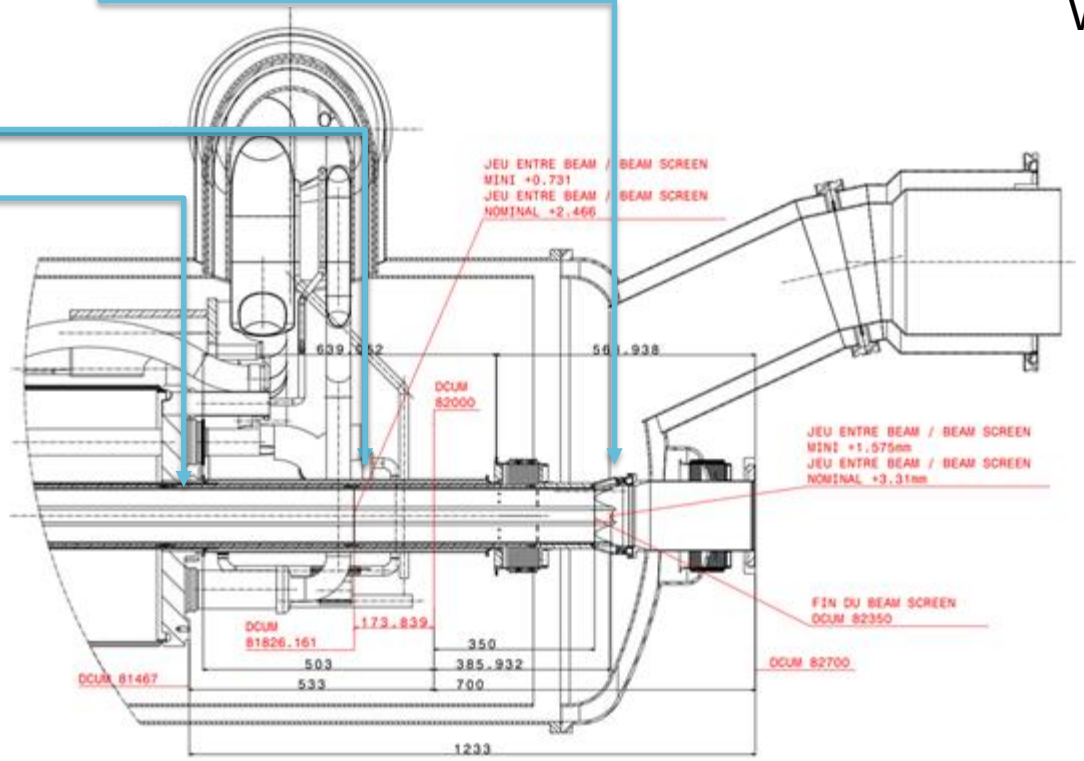
Rotation amplitude are quoted as displacement at 82.386 m.

Both options are can be adopted.

Detailed aperture

	S [m]	Base [σ]	New b.s. [σ]	Rot. [σ]	Rot. + b.s. [σ]
D1 Body	80.917	13.82	13.85	14.28	14.28
D1 old	81.826	13.36	13.36	13.88	13.88
D1 new	81.836	13.35	13.92	13.88	14.44
D1 new	82.386	13.17	13.70	13.70	14.27

Round optics
Worst case aperture



Summary aperture

	Best case [σ]		Worst case [σ]	
	Round	Flat	Round	Flat
Q2-Q3	16.4	15.4	13.1	12.7
D1 (old b.s. ,no rot)	16.6	15.2	13.1	12.4
D1 (new b.s., no rot)	16.9	15.4	13.3	12.8
D1 (old b.s., rot 1.5 mm)	17.3	15.7	13.7	12.8
D1 (new b.s, rot 1.5 mm)	17.5	15.8	13.8	12.9
D1 (old b.s., rot 2.0 mm)	17.5	15.8	13.9	12.9
D1 (old b.s., rot 2.5 mm)	17.7	15.9	14.1	12.8

- Adding new b.s. and rotation allows 1 sigma margin between triplet and D1.
- A rotation up to 2.5 mm further improves aperture for round optics also without changing the beam screen.
- The value of 2.0 mm (0.225 mrad from the virtual interconnect plane) gives a trade-off between round and flat.