Baseline optics

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Content

For the HL-LHC new layouts 4 triplet scenarios have been identified:

technology	aperture [mm]	gradient T/m
NbTi	140	100
NbTi	120	118
Nb_3Sn	140	150
Nb_3Sn	120	170

In the following the optics will be labeled by the gradient only, since the aperture is relevant only for the obtainable β^*.

Triplet options

The triplet layout are optimized to allow the smallest β^* compatible with the left/right pre-squeeze phase condition.

aperture m	gradient T/m	l_{Q1} m	l_{Q2} m	d_{Q12} m	d_{Q22} m	β^* m	Δ_{Q5} m
0.14	100	10.629	8.695	1.915	3.56	0.5	14
0.12	118	9.465	7.97	1.64	3.05	0.43	14
0.14	150	7.685	6.577	1.915	3.56	0.4	11
0.12	170	7.204	6.184	1.64	3.05	0.37	11

From 140T/m one can squeeze more than the possibility to locally correct the chromatic effect with the neighbouring arc sextupoles. The minimum β^* with the ATS depends only on the aperture available and the size of the beam.

β max comparisons

A detailed layout of the available aperture is still under development $\rightarrow$ realistic β^* limit cannot be estimated.
However, triplet options can be compared in terms of β_{max} at a fixed $\beta^* = 0.6$ m, or of a β^* range by applying a simplistic scaling [1]

aperture m	gradient m	$\beta^{\rm max}$ T/m	$\beta^*_{\rm range}$ m	$\beta_x^{\rm Q4}$ m	$\beta_y^{\rm Q4}$ m
0.14	100	6295	0.18 to 0.31	828	956
0.12	118	5447	0.24 to 0.42	652	888
0.14	150	4852	0.14 to 0.24	563	836
0.12	170	4451	0.20 to 0.34	508	757

[1] assuming the aperture bottleneck in crossing plane at the β_{max} location $\beta^* = \left(\frac{n_{\rm bb}+2n_{\rm coll}}{a-a_{\rm shield}}\right)^2 \epsilon \beta^{\rm max}_{\rm ref} \beta^*_{\rm ref}$ with $\epsilon = 3.5\mu rad$, $n_{\rm bb}$=10 to 14, $n_{\rm coll}$=11 to 14, $a_{\rm shield}$=4cm. Not official specs, used for illustration only.

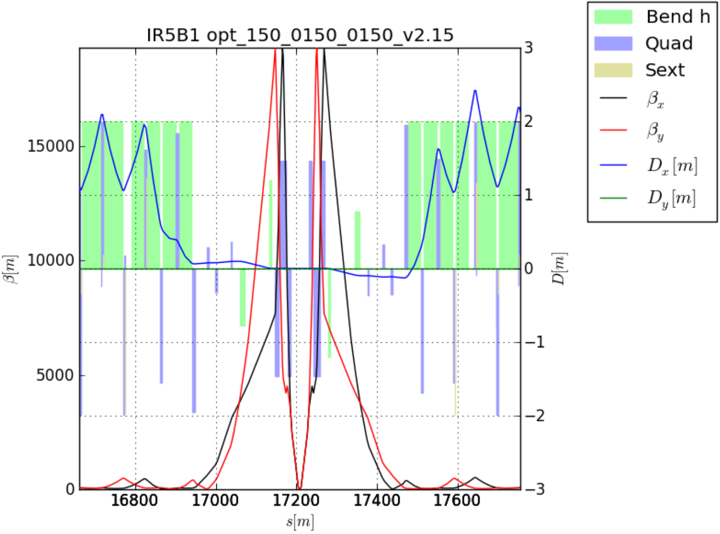
Available optics

Developed before and after the HL-LHC project

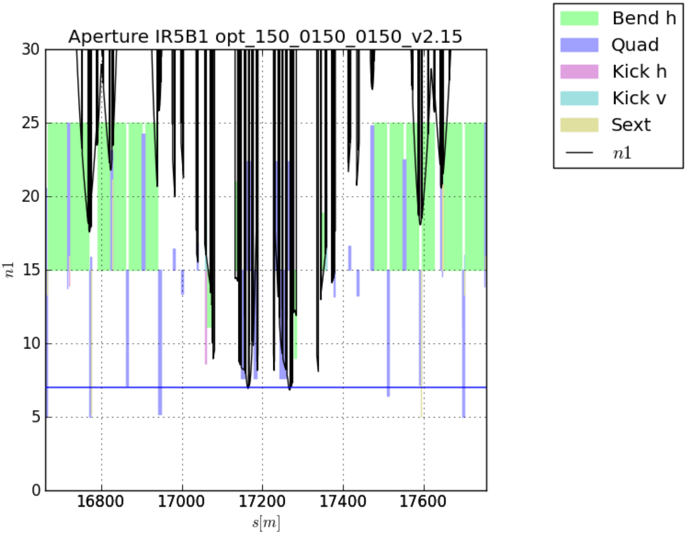
gradient T/m	pre-squeeze β^* cm	round β^* cm	flat β^* cm	inj β^* m	note
100	50	19, 15			SLHCV3.1a
118	50				
123	60	15	7.5/30	11	SLHC3.01
150	40, 200	15, 10	7.5/30, 5/20	5.5, 11	SLHCV3.1b
170	38, 40	20, 15			
220	200 to 40	10		11	ATS_V6.503

Flat optics are straight forward to generate once they are available for one layout. Minimum β^* for injection optics needs time to develop.

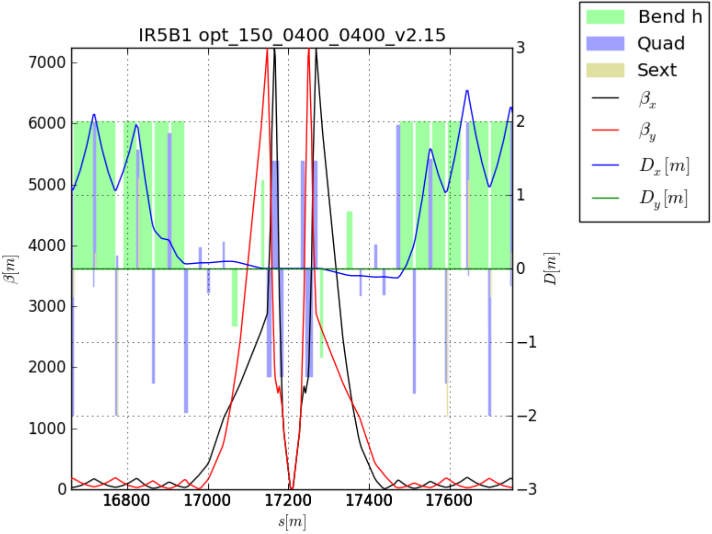
Squeeze IR1/5: optics



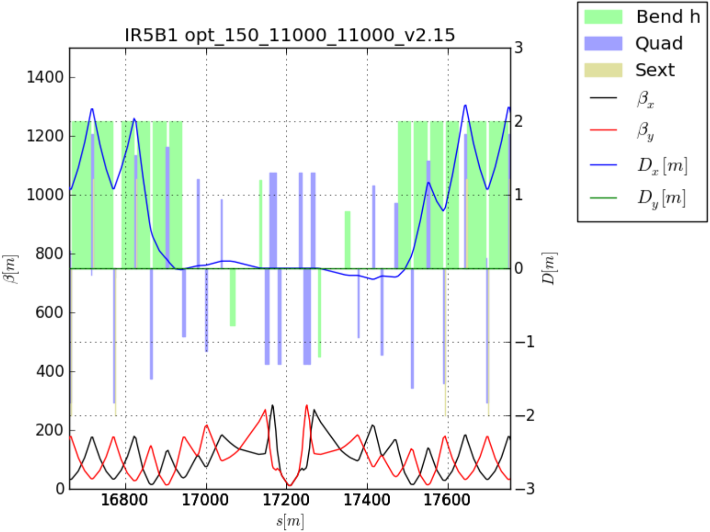
Squeeze IR1/5: apertures



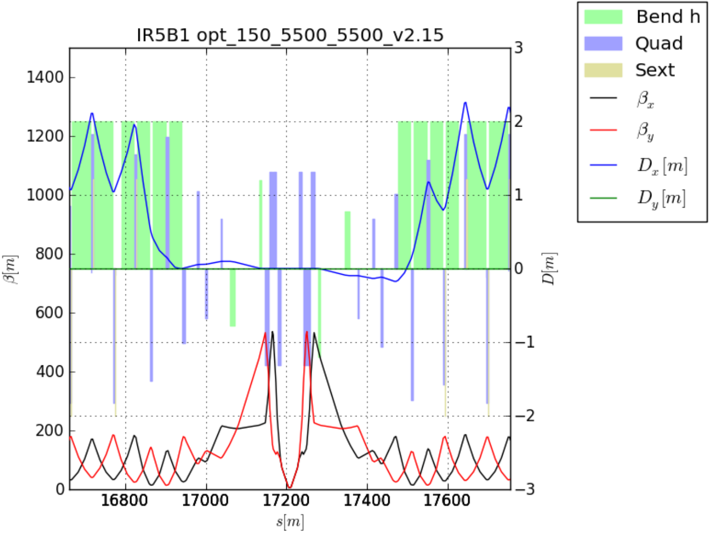
Pre-squeeze IR1/5: optics



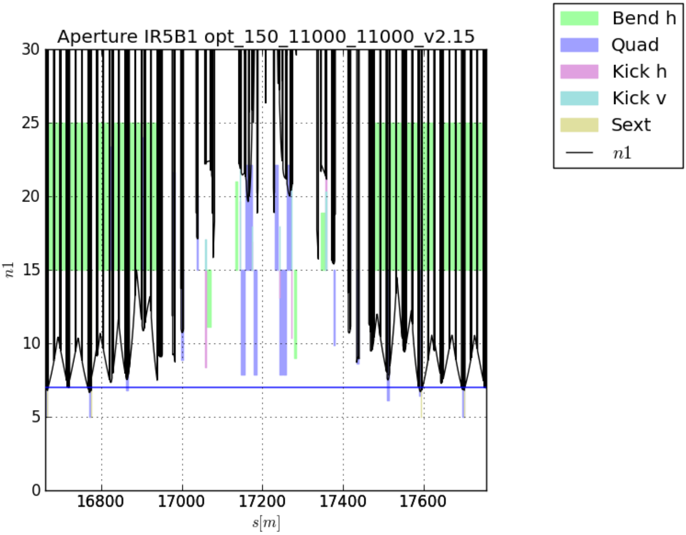
Injection IR1/5: optics β^{*}= 11 m



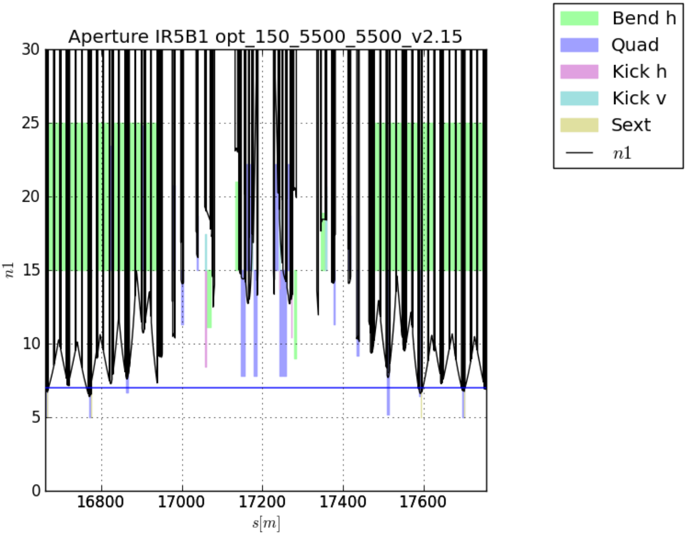
Injection IR1/5: optics β^{*}=5.5 m



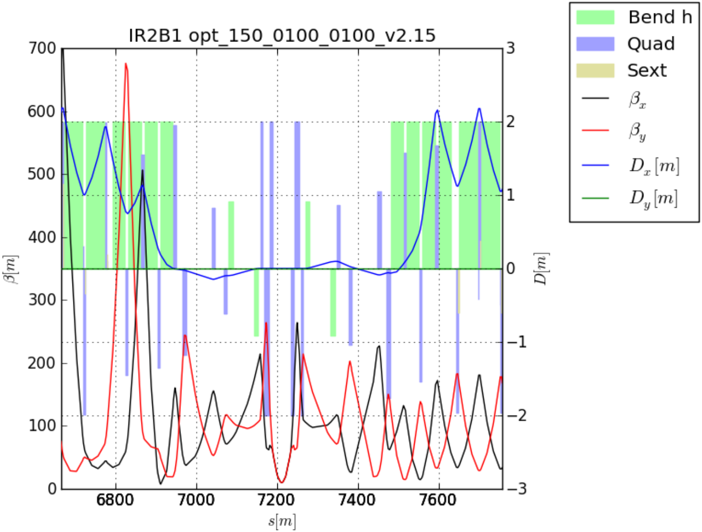
Injection IR1/5: apertures β^{*}= 11 m



Injection IR1/5: apertures β^{*}= 5.5 m

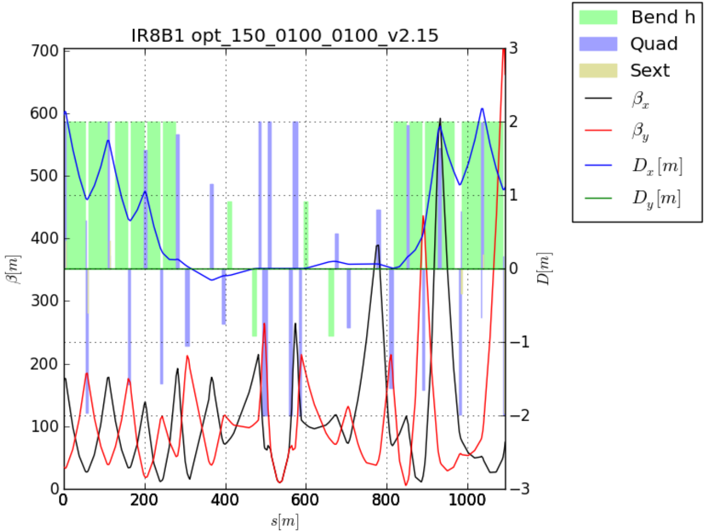


Squeeze IR2



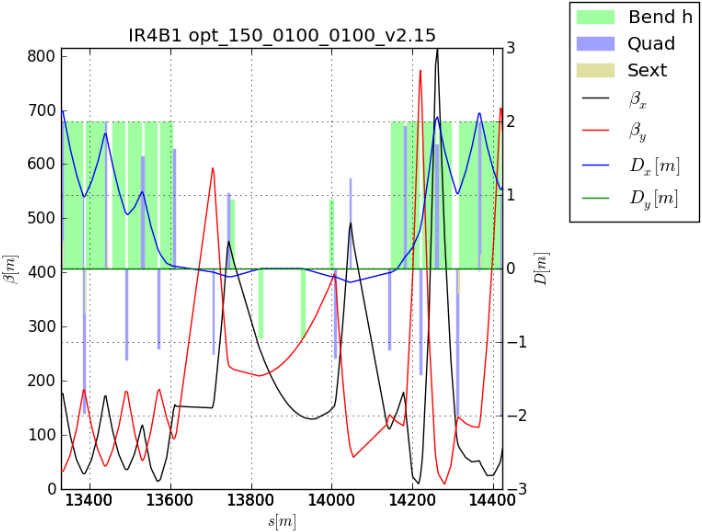
IR2B1 opt_150_0100_0100_v2.15
700
600
500
400
300
200
100
0
3
2
1
0
−1
−2
−3
6800
7000
7200
7400
7600
$\beta[m]$
$D[m]$
$s[m]$
Bend h
Quad
Sext
β_x
β_y
$D_x\,[m]$
$D_y\,[m]$

Squeeze IR8



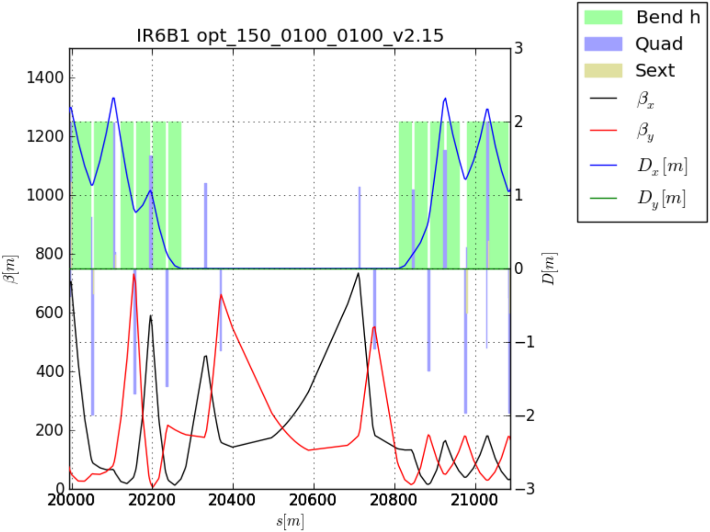
IR8B1 opt_150_0100_0100_v2.15
β[m]
s[m]
D[m]
0
100
200
300
400
500
600
700
0
200
400
600
800
1000
−3
−2
−1
0
1
2
3
Bend h
Quad
Sext
β_x
β_y
$D_x\,[m]$
$D_y\,[m]$

Squeeze IR4



IR4B1 opt_150_0100_0100_v2.15
800
700
600
500
400
300
200
100
0
3
2
1
0
−1
−2
−3
13400
13600
13800
14000
14200
14400
$\beta[m]$
$D[m]$
$s[m]$
Bend h
Quad
Sext
β_x
β_y
$D_x\,[m]$
$D_y\,[m]$

Squeeze IR6


IR6B1 opt_150_0100_0100_v2.15
Bend h
Quad
Sext
β_x
β_y
$D_x\,[m]$
$D_y\,[m]$
$\beta[m]$
$D[m]$
$s[m]$
1400
1200
1000
800
600
400
200
0
20000
20200
20400
20600
20800
21000
3
2
1
0
−1
−2
−3

Conclusion

- The ATS scheme can be applied to all the triplet options making an efficient use of the available aperture
- At 100T/m the optics flexibility is at the limit
- Large apertures and high gradients are the preferred options.

To be addressed:

- minimum β^* at injection for low gradient triplets
- robustness to linear imperfections (see C. Milardi's talk)
- impact of fringe field (see R. Appleby's talk)
- demonstrate transitions (see M. Korostelev's talk)

On going:

- new layout for 150mm 140T/m (with new optimized phase advances of IR2 and IR8, see A. Bogomyagkov's talk)
- investigation for new matching section layout for crab cavity efficiency (see B. Dalena talk)
- compare pro and cons of alternative scenarios to the ATS (see R.Appleby, J. Payet, A. Faus-Golfe talks)