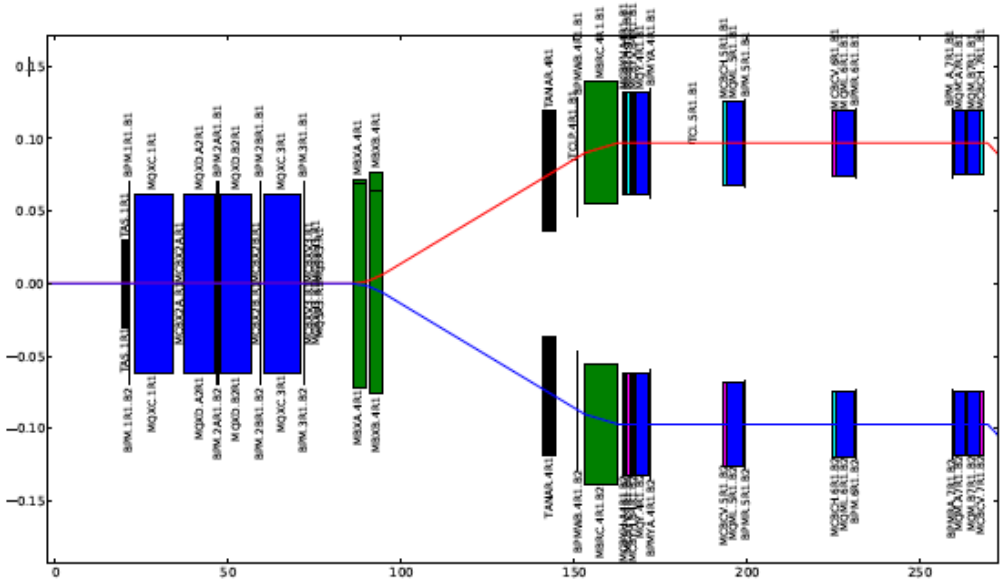
Status of the HL-LHC Lattice & Optics

1.) History Line: Baseline Optics

ap. [9] [mm]	grad [10] [T/m]	lengths [11] [m]	β^* [cm]	N1 [12] [ppb]	N2 [13] [ppb]	t [14] [h]
150	144(83%Sn)	8.2 , 7.0	13.0	1.99E11	1.21E11	6.06
150	96(83%Ti)	10.8 , 9.0	17.0	2.03E11	1.36E11	5.24
140	150(80%Sn)	8.00, 6.8	15.0	2.01E11	1.29E11	5.64
140	100(80%Ti)	10.5, 8.8	19.0	2.05E11	1.42E11	4.89
120	180(83%Sn)	7.1 , 6.1	18.6	2.05E11	1.42E11	4.96
120	120(83%Ti)	9.3, 7.8	24.0	2.11E11	1.58E11	4.14
85	160(78%Ti)	7.7, 6.6	44.0	2.41E11	2.11E11	2.33
80	257(80%Sn)	4.8, 5.5	39.0	2.33E11	1.99E11	2.65

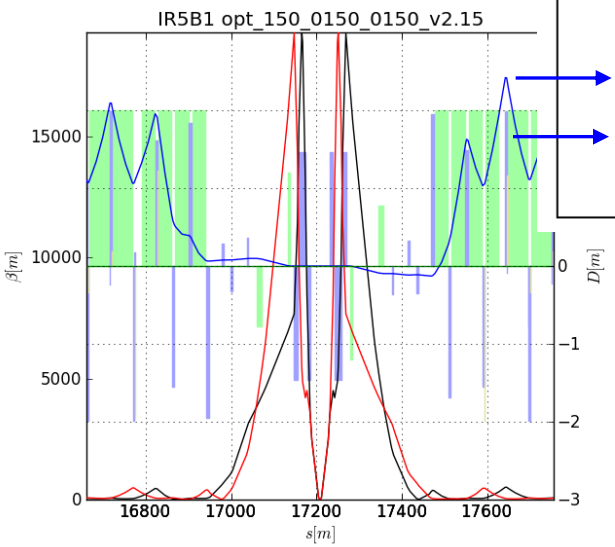


"Historic Baseline" Optics

after optimisation (RdM)

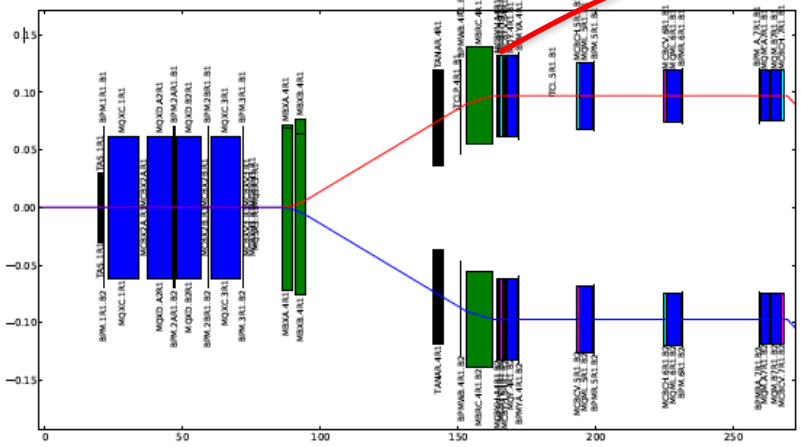
	aperture m	gradient T/m	l_{Q1} m	l_{Q2} m	d_{22} m	d_{12} m	β^* m	Δ_{Q5} m
NbTi	0.14	100	10.629	8.695	1.915	3.56	0.5	14
NbTi	0.12	118	9.465	7.97	1.64	3.05	0.43	14
Nb3Sn	0.14	150	7.685	6.577	1.915	3.56	0.4	11
Nb3Sn	0.12	170	7.204	6.184	1.64	3.05	0.37	11

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



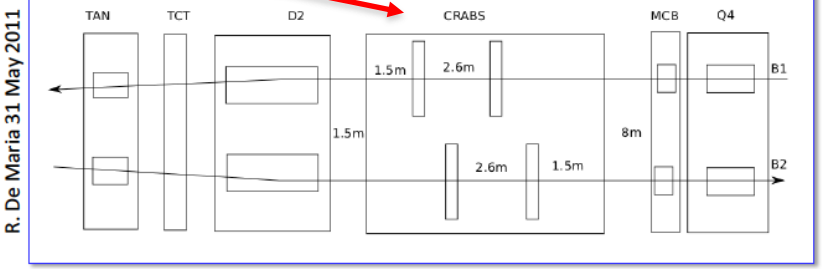
Q4 Conditions: Crab Cavities

(Barbara Dalena)

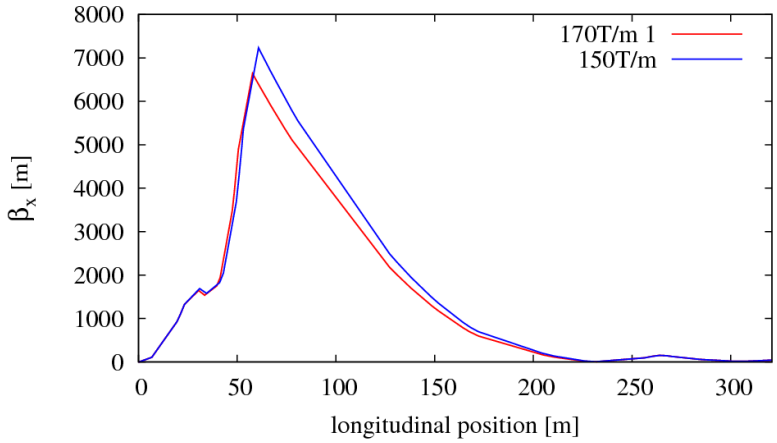


Baseline $V = 10\,\mathrm{MV}$, $\theta_c = 580\,\mu\mathrm{rad}$, $\omega = 2\pi \cdot 400\,\mathrm{MHz}$

$$V = \frac{cp}{e\omega}\frac{\theta_c}{2}\frac{1}{\sqrt{\beta^* \beta_{\mathrm{crab}}}}$$



Different Triplet Parameters lead to different Optics Conditions at Q4

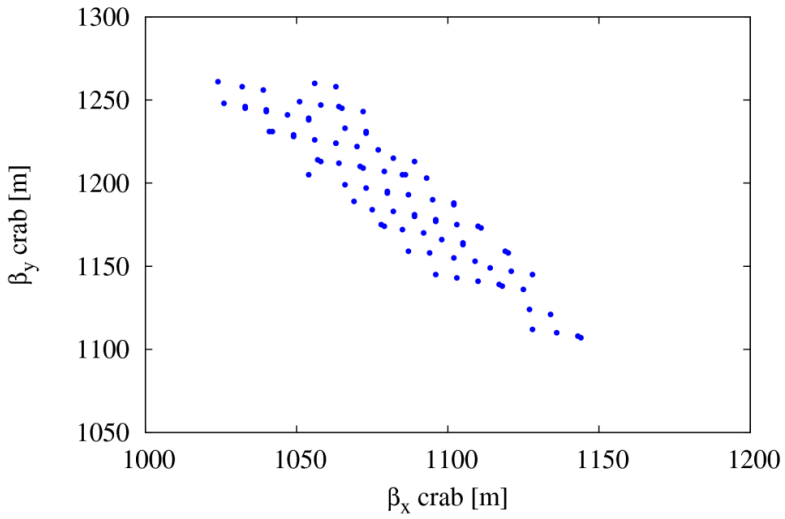


Q4 Conditions: Optimised Solutions

Situation for the "Standard" Pre-Squeeze Optics: 40cm

- ***distance between Q1 and Q2 (Q2 – Q3) = 3.05 m***
- ***distance between Q2A and Q2B = 1.64 m***
- ***aperture 120 mm***
- ***maximum triplet gradient 170 T/m***

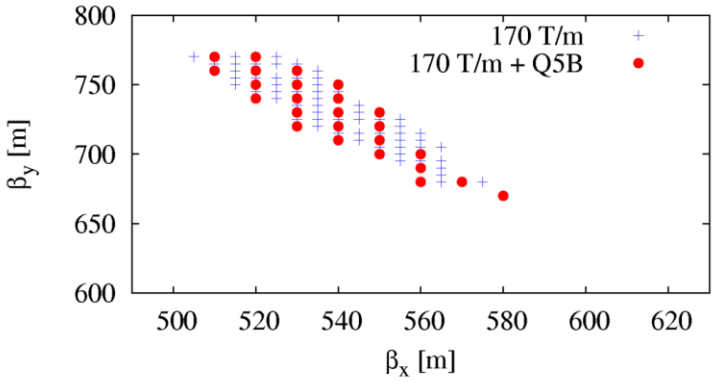
β*=40cm



Q4 Conditions, Theme and Variations:

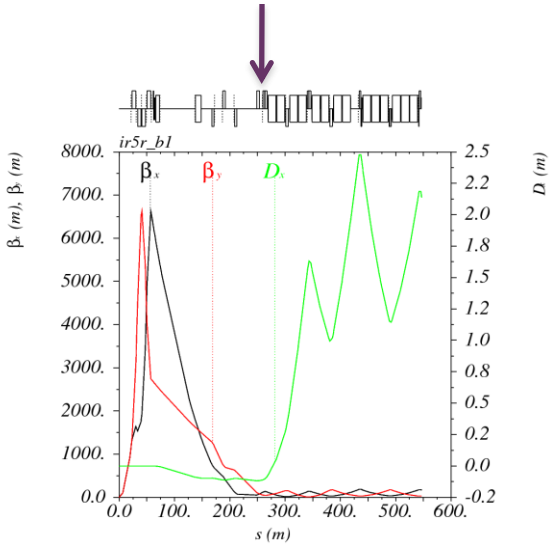
additional quadrupoles at Q5 / Q6 / Q7 ...

add. Quad at Q5
no big change
(*60cm optics !!*)

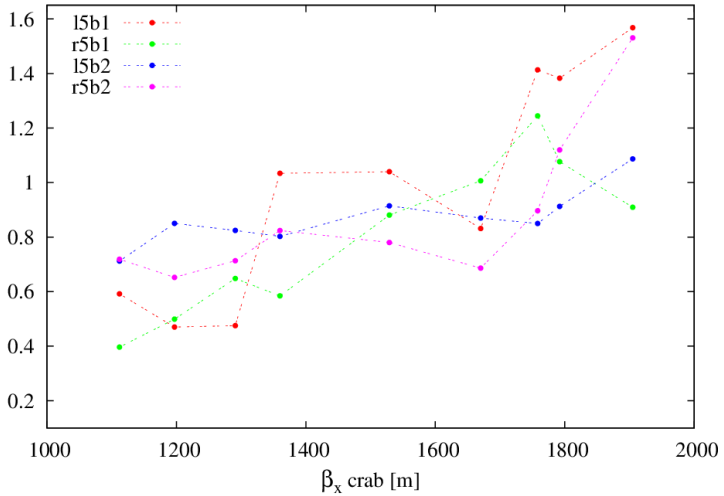


Q4 / Q5 / Q6 in triplet configuration & add. Q7

... allows for much larger βs at the Crab Cavities



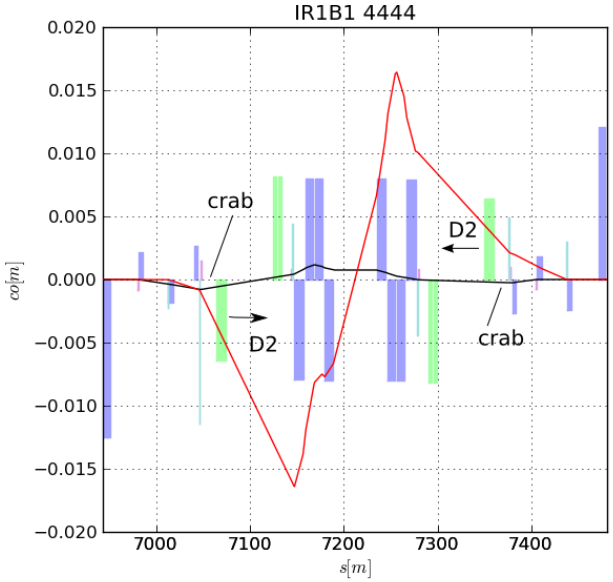
additional k-strength needed at Q7

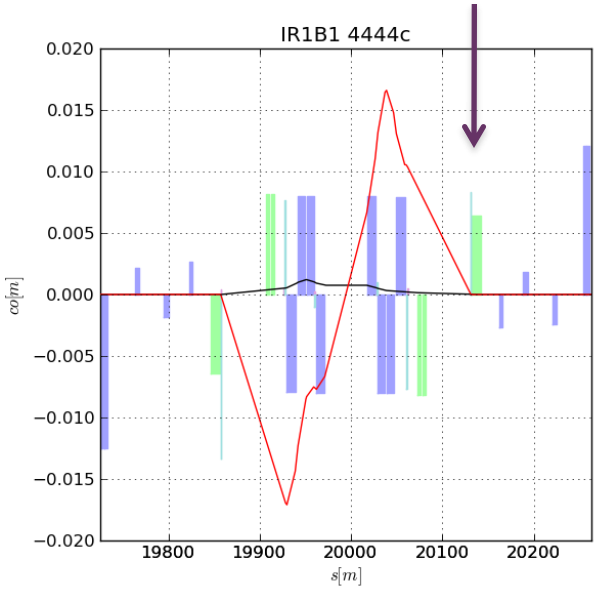


Q4 Conditions, Consequences:

additional strong orbit corrector coils

to avoid beam offset at crab cavities (RdM)





new crossing scheme cannot take full advantage of phase advance → strong orbit coils needed

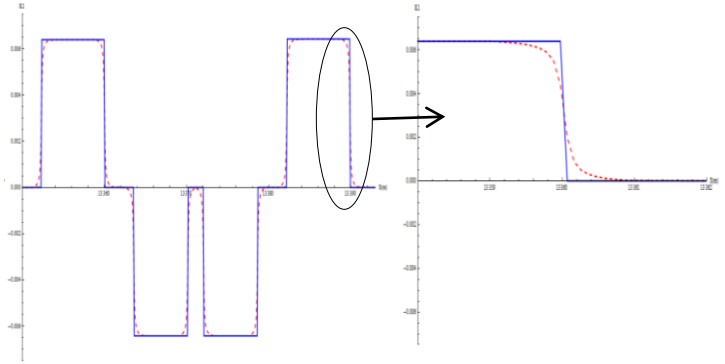
$l_B = 2.0m$

Miscellaneous:

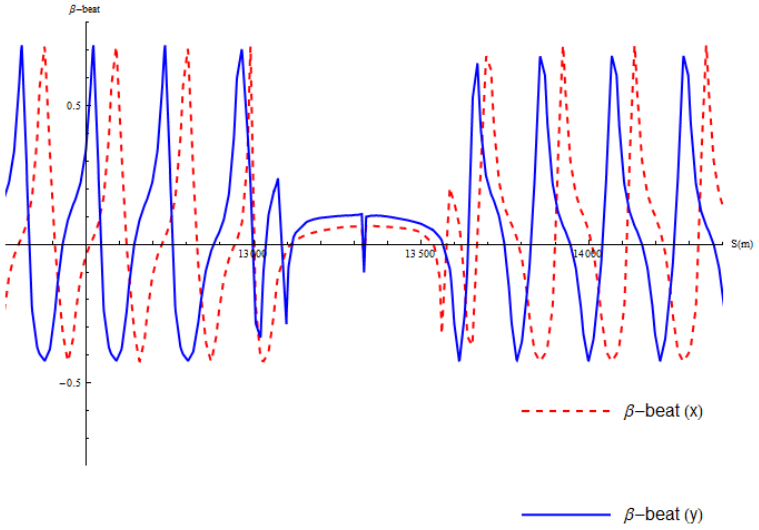
fringe field effects of large aperture triplet quadrupoles

(Matthew Thomas)

to be included in MADX HL-LHC (re-) matching



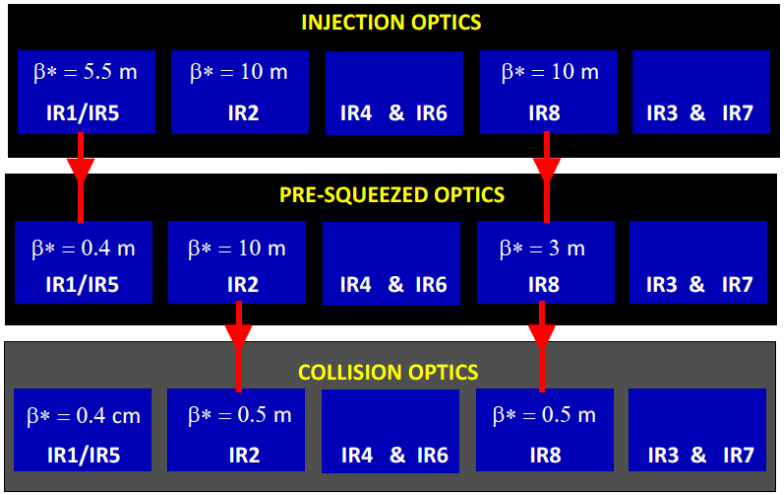
50%



Miscellaneous:

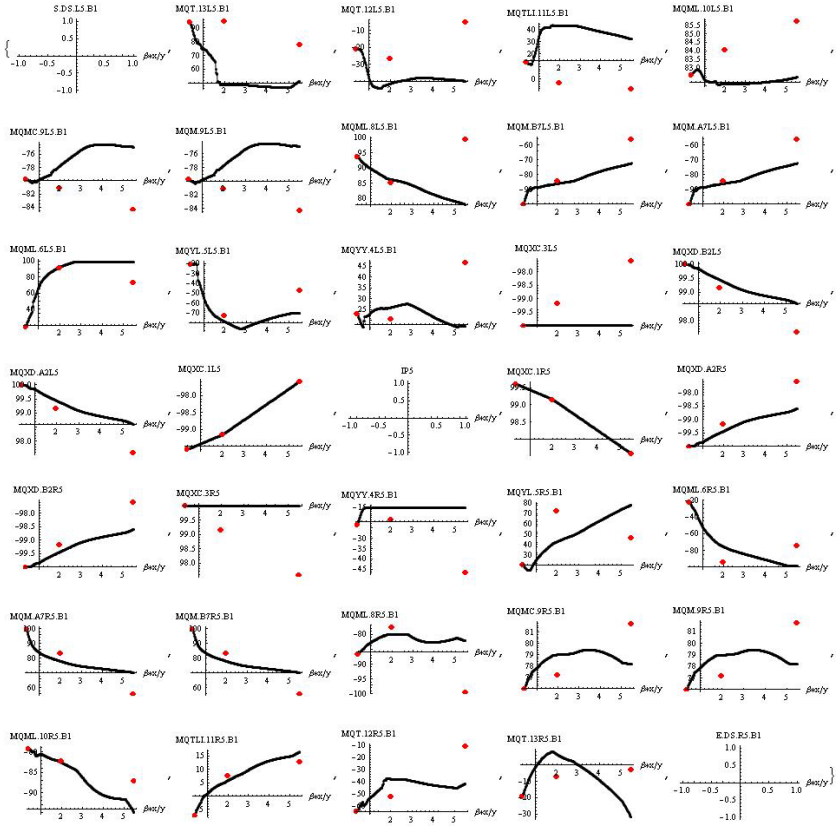
Optics Transitions *(Maxim Korostelev)*

Injection → pre-Squeeze

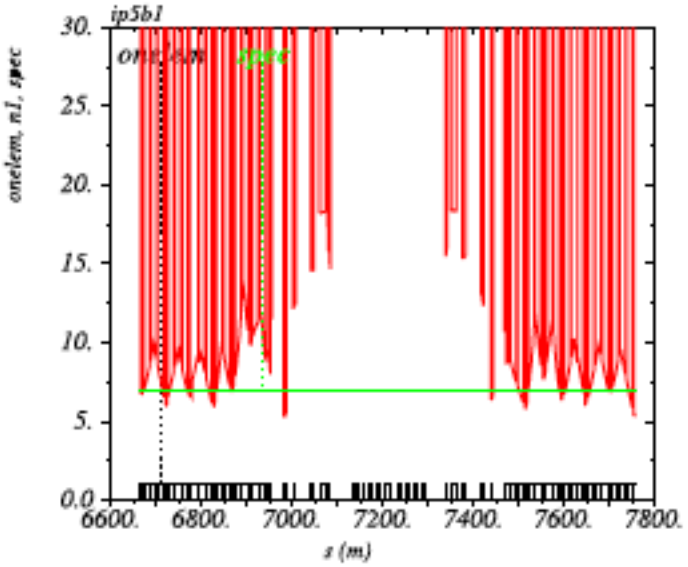


several options studied,
most beautiful (i.e. monotonic) one:

Quadruple Gradients



Aperture still to be optimised

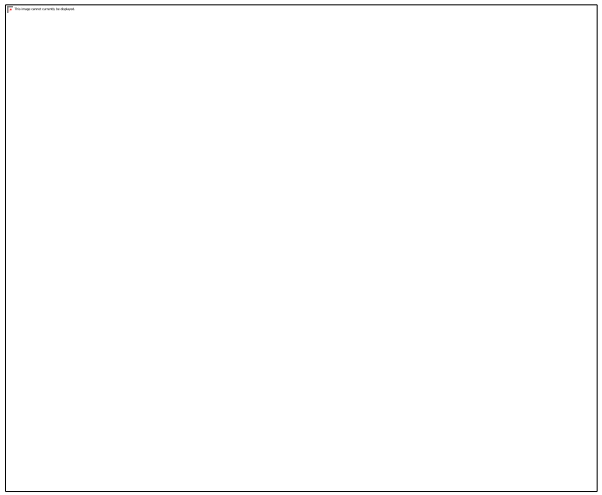


Miscellaneous:

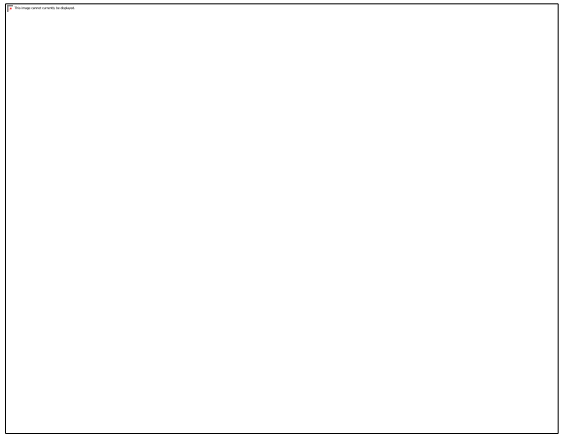
Optics Tolerance *(Catia Milardi)*

15 cm Optics

Tolerance criteria:



Triplet



Matching section

Miscellaneous:

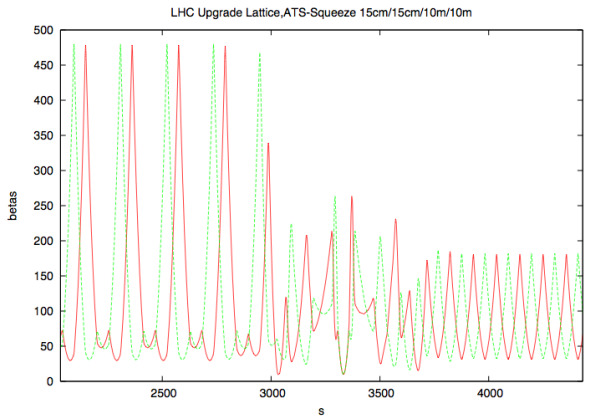
IR2 & IR8 Optics *(Anton Bogomyagkov)*

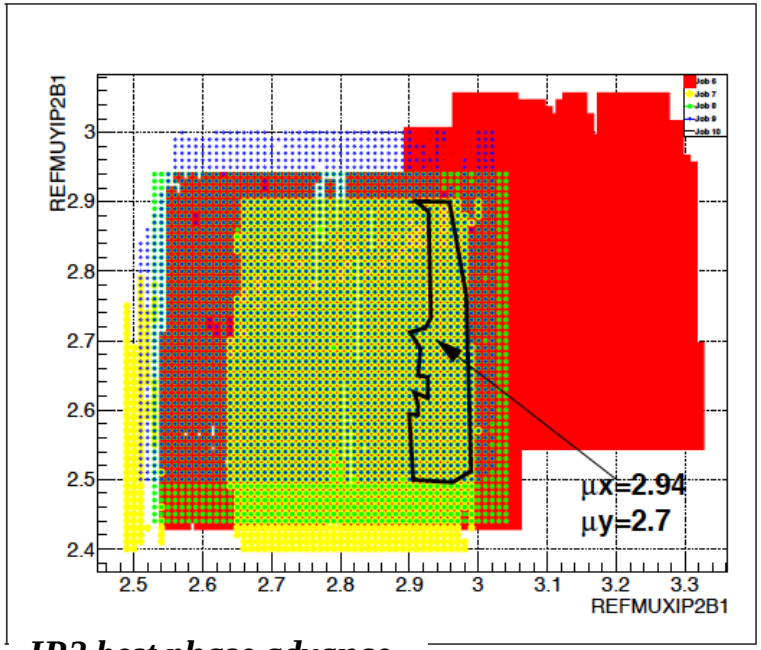
a large variety of beam optics studied & optimised

bog_150_0100_0100_3000_3000.madx	*β*(IP8) = 3m*	*standard ATS, round*
bog_150_0050_0200_3000_3000.madx	*β*(IP8) = 3m*	*standard ATS, flat_xy*
bog_150_0050_0200hv_3000_3000.madx	*β*(IP8) = 3m*	*standard ATS, flat_yx*
bog_150_5500_5500_10000_10000.madx	*β*(IP8) = 10m*	*ATS_injection*
bog_150_0400_0400_0500_0500.madx	*β*(IP8) = 50cm*	*ATS ions*

each optics has to be „implemented“ into the overall LHC lattice & optics.

Main Issue: Search for ideal phase advance over IR2 / IR8

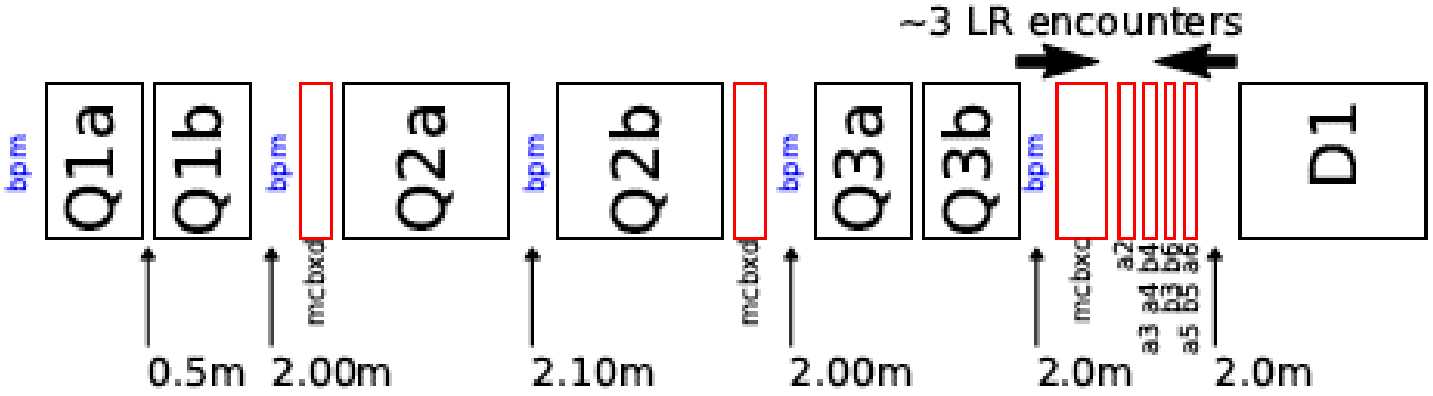




IR2 best phase advance

"New Working Hypothesis: 150mm Triplet"

first considerations (RdM)



Q1/3 a/b: 3.97m, 140 T/m, 150mm
Q2 a/b: 6.76m, 140 T/m, 150mm
D1: 7.7m, 40 Tm, 150 <-> 160mm
Q3-D1 distance (presently ~9m) is already critical

MCBXD: 1.3m, 1.8Tm, h/v nested orbit corrector
MCBXC: 2.00m, 4.5Tm in xing plane(for crab) and
1.8Tm in the other plane
MQSX3: 0.67m, skew quadrupole corrector
MCSTX3: 0.50m, (b3,b6) nested correctors
MCOSSX3: 0.50m, (a3,a4,b4) nested correctors
MCDTSX3: 0.50m, (a5,b5,a6) nested correctors

"New Working Hypothesis: 150mm Triplet"

Next Steps:

Finish the New Triplet Layout for IR1 & IR5

Combine with Lattice Optimisation for Crab Cavities (Q4/5/6 & additional Q7 ??)

Include in overall Lattice / Optics with new phase advance in IR2 & IR8
... tune adjust & rematch

Include Fringe Field Re-Match

Include new Triplet Layout in Optics Transition Match