

Meeting of Task 2.2 on HL-LHC Lattice & Optics

Status of Optics calculations

impact on magnet R & D
on crab cavity R & D

input for tracking calculations (magnet quality & multipole compensation)
for beam-beam simulations
for collimation task

etc etc

mid term goal: establish [HL-LHC V1.0](#) (Nov. 2012)

Meeting of Task 2.2 on HL-LHC lattice & optics

time	Wednesday 19-Sep	chair: <u>Bernhard</u>
09:00-09:40	Welcome and Overview	<u>Bernhard</u>
09:40-10:20	Layout Conditions & Scripts	<u>Riccardo</u>
10:20-10:40	Coffee	
10:40-11:20	Baseline Optics	Barbara
11:20-12:00	Optics Transitions	Maxim
	Lunch	
		chair: <u>Riccardo</u>
14:00-14:40	Robustness & Tolerances	<u>Catia</u>
14:40-15:20	Fringe Field Effects	Rob /Luke / Matthew
15:20-15:40	Coffee	
15:40-16:20	Optics in IR 2 & IR 8	Anton
16:20-17:00	Flat Beam Option	<u>Riccardo</u>

Basic Idea: $\approx 30 \dots 40$ min presentation, $0 \dots 10$ min discussion

time	Thursday 20-Sep	chair: Andy
09:00-09:40	Magnet Design	<u>Ezio</u>
09:40-10:20	Crab Cavity Conditions	<u>Rama</u>
10:20-10:40	Coffee	
10:40-11:20	Q4 Conditions (CRC's)	Barbara
11:20-12:00	Non-ATS Alternatives	Rob
12:00-12:40	Local Chromaticity Correction	Antoine & Jacques
12:40-13:00	Non-ATS Alternatives	Angeles
	summary discussion	Andy

Wednesday evening: 19:30 Pizzeria d'Oro

HL-LHC: Task Optics & Lattice Layout:

Plan Nov 2011

Overview about the possible topics

I.) Setting the Baseline for the ATS Optics in IR1 and IR5

This will set the groundwork for the ATS optics; the goal is to establish a feasible beam optics for smallest β^* in IP1 & 5, within the limits given by the magnet strengths (triplet and matching section) and the magnet apertures in the triplet area.

- 1.) MAD-x optics calculations to establish the 120mm aperture / 180 T/m gradient ATS-optics versions: [Barbara Dalena, CEA](#)
- 2.) Optics solutions for 140mm compatible gradients: [Riccardo CERN](#)
- 3a.) Study the robustness of the HL optics with respect to longitudinal alignment errors and gradient errors within the boundary condition of 10% beta beat limit and /or re-"matchability": [Catia Milardi](#)
- 3b.) Study the linear & non-linear fringe field effects:
[Anton Bogomyagkov, Novosibirsk](#)
- 4.) Optics transition Injection / ATS-Lumi of 1.) : [Maxim Korostelev, Cockcroft](#)

II.) Establish a Set of different Beam Optics in IR2 and IR8

As the matching section in the neighboring sectors to IR1&5 is used for the ATS squeeze, the beam optics in the IRs 2,8 and 4,6 has to be calculated respecting these boundary conditions. Namely the flexibility of different β functions in IR 2, IR8 - as desired by the experiments LHCb and ALICE - has to be studied.

5a.) Optimisation / Flexibility of IR4 / 6 for ATS optics squeeze:

5b.) Optimisation / Flexibility of IR2 / 8
Anton Bogomyagkov, Novosibirsk

III.) Flat Beam Option in IP1 & 5

6.) As fall back solution to the round beam option, where crab cavities will be needed to compensate the geometric luminosity loss factor, a beam optics has to be studied with unequal β s in the two transverse planes. Up to now this will follow the pre-squeeze optics and so is considered as an alternative part of the ATS scheme.

IV.) Alternative Scenarios for smallest β^* without ATS

In parallel to the ATS optics explained in I.) options are studied to gain the smallest possible β^* in IP1 & 5 without ATS. Re-design of parts of the matching section is considered as well as an attempt to investigate a completely new layout of the IRs.

7.) Re-design the matching section for optics flexibility and smallest possible β^*

* Shifting the position of the matching quadrupoles ... done ?

* Introducing additional quadrupoles & explore alternative phase advance
IP / arc-sextupoles / Rob Appleby, Cockcroft

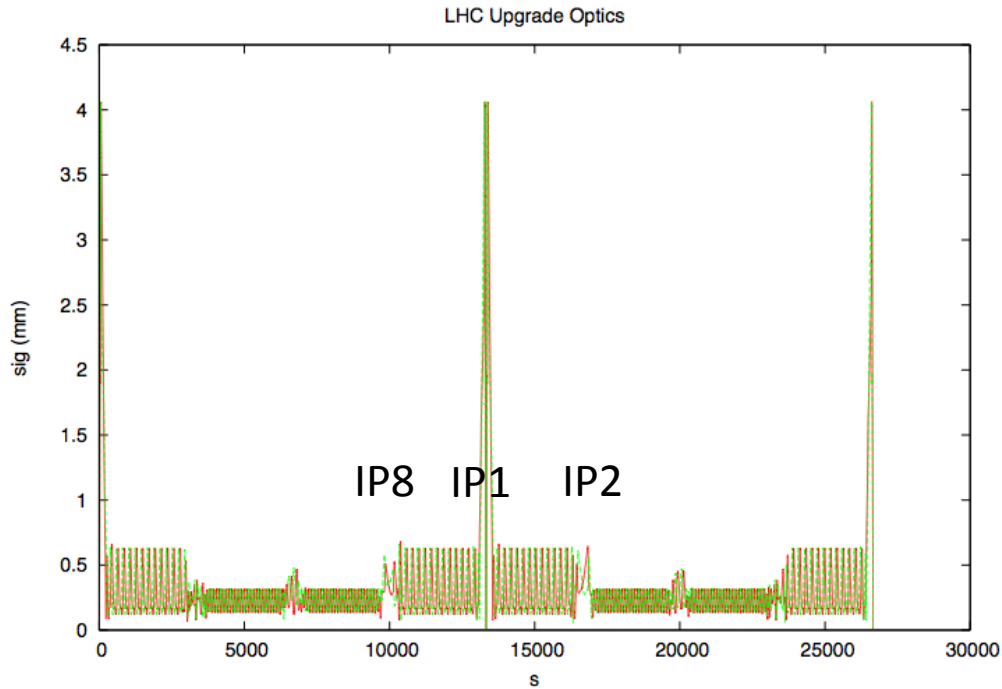
8.) Re-design of matching section for smallest reachable β^* (additional quads, doublets at Q4/Q5 for sign flip etc) Angeles Faus-Golfe Valencia

9.) Introducing local sextupole correction scheme (second triplet at Q4)
to improve chromaticity correction: Jaques Payet & Antoine Chance, CEA

LHC Upgrade Challenges



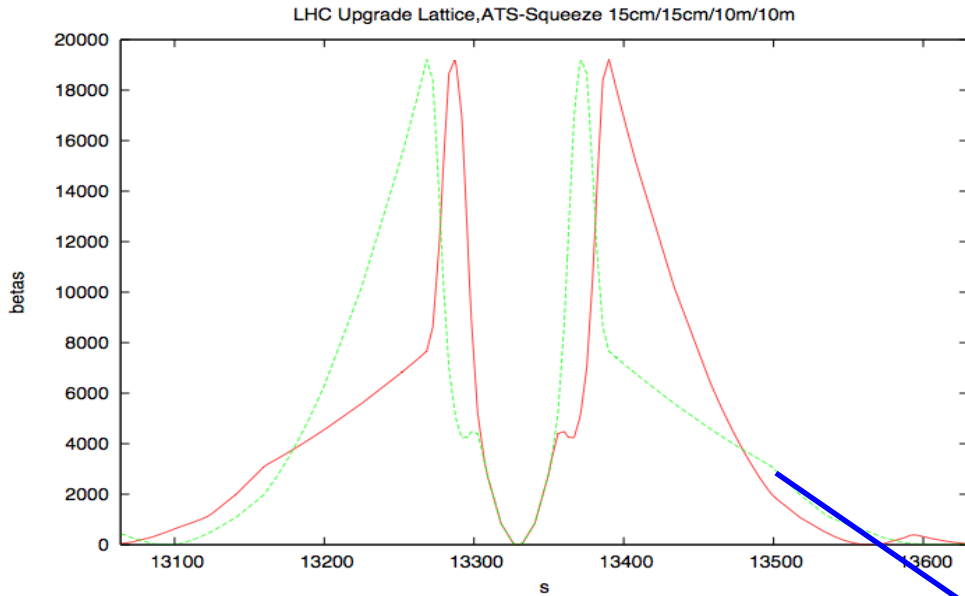
LHC Luminosity Upgrade in ATS



set up four baseline optics
based on assumptions on
aperture & magnet technique

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

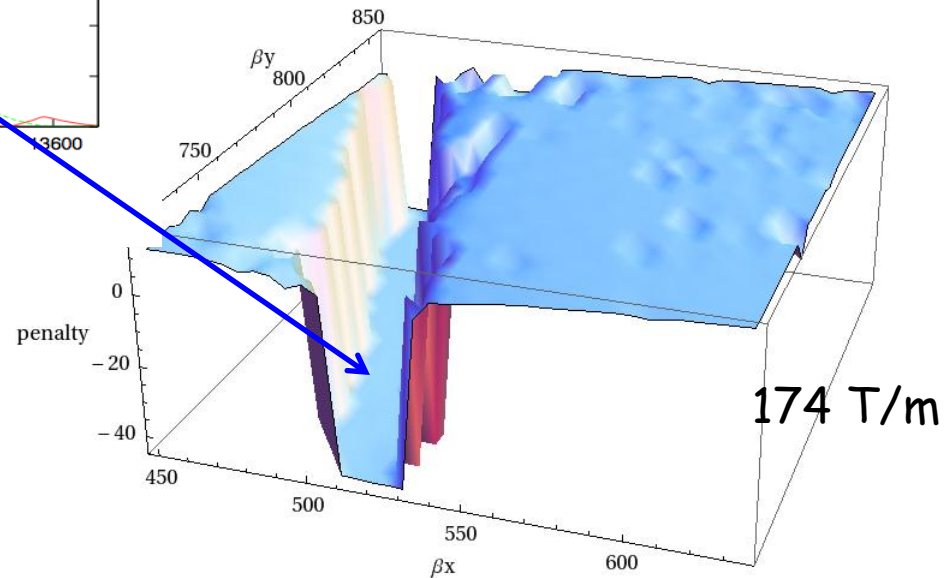
LHC Upgrade Optics in IP1 / IP5



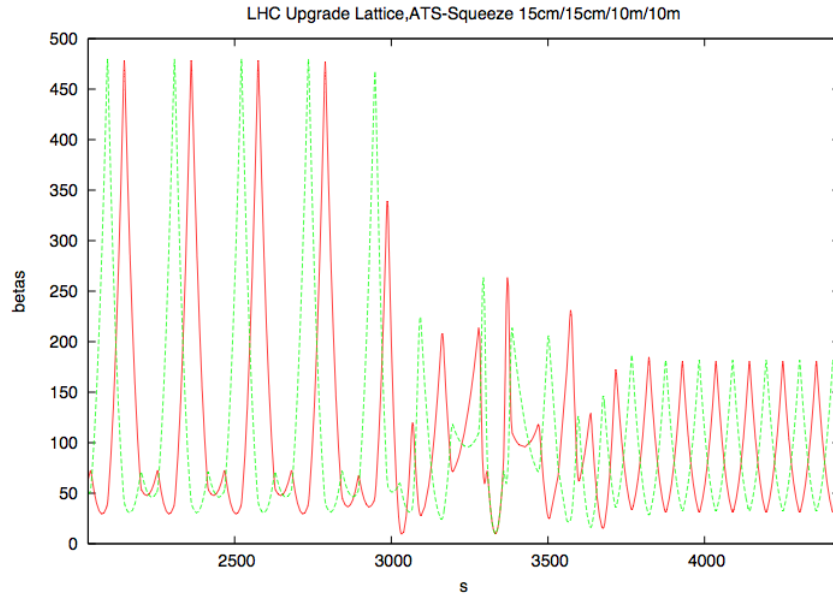
⇒ We need to generate the triplet with different boundary conditions according to the triplet gradient we want to reach

⇒ For which hardware limitations do we get an optics solution AT ALL ??

Don't forget: any solution must fit to the rest of the machine !!!



LHC Upgrade Optics in IR2



the “ATS Squeeze Optics
(15cm/15cm/10m/10m)

IP1, ATS Optics



IP2



IP3, Standard FoDo Optics

*Find an optics solution that is feasible for the Luminosity upgrade
and guarantees adequate conditions for the ALICS and LHCb experiment at the same time.*

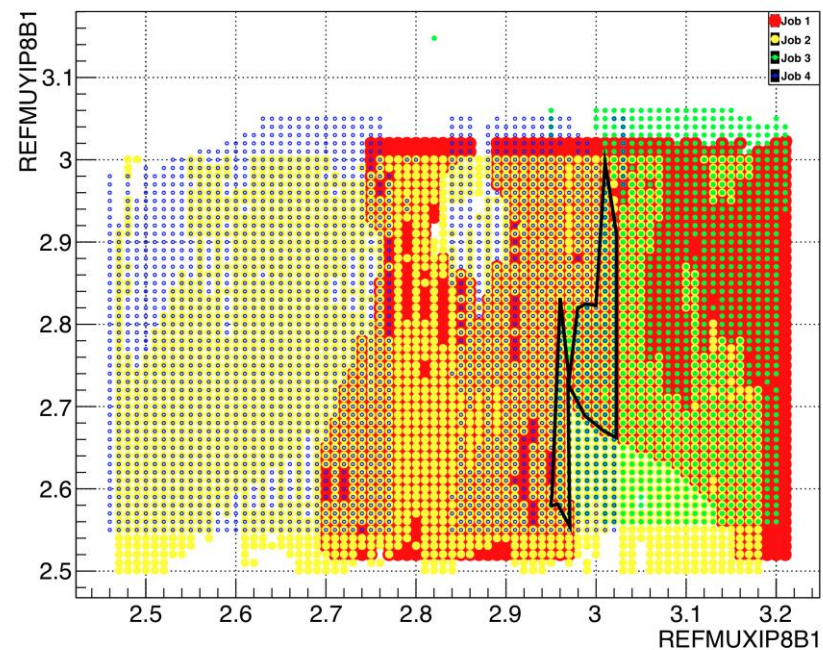
A large variety of beam optics studied & optimised

bog_150_0100_0100_3000_3000.madx
bog_150_0050_0200_3000_3000.madx
bog_150_0050_0200hv_3000_3000.madx
bog_150_5500_5500_10000_10000.madx
bog_150_0400_0400_0500_0500.madx

$\beta^*(IP8) = 3m$ standard ATS, round
 $\beta^*(IP8) = 3m$ standard ATS, flat_xy
 $\beta^*(IP8) = 3m$ standard ATS, flat_yx
 $\beta^*(IP8) = 10m$ ATS_injection
 $\beta^*(IP8) = 50cm$ ATS ions

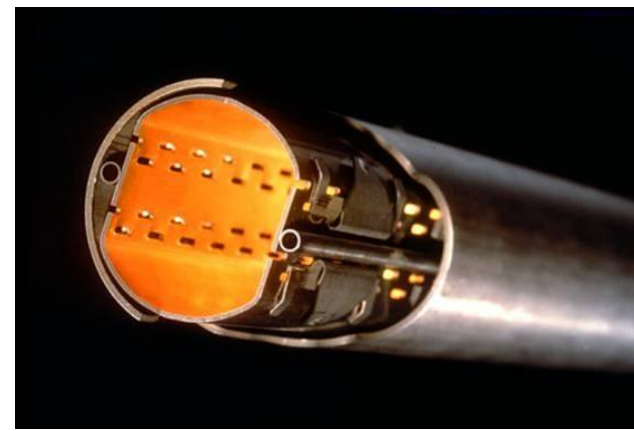
Each optics has to be „implemented“ into the overall LHC lattice & optics.

Main Issue: Search for ideal phase advance over IR8.

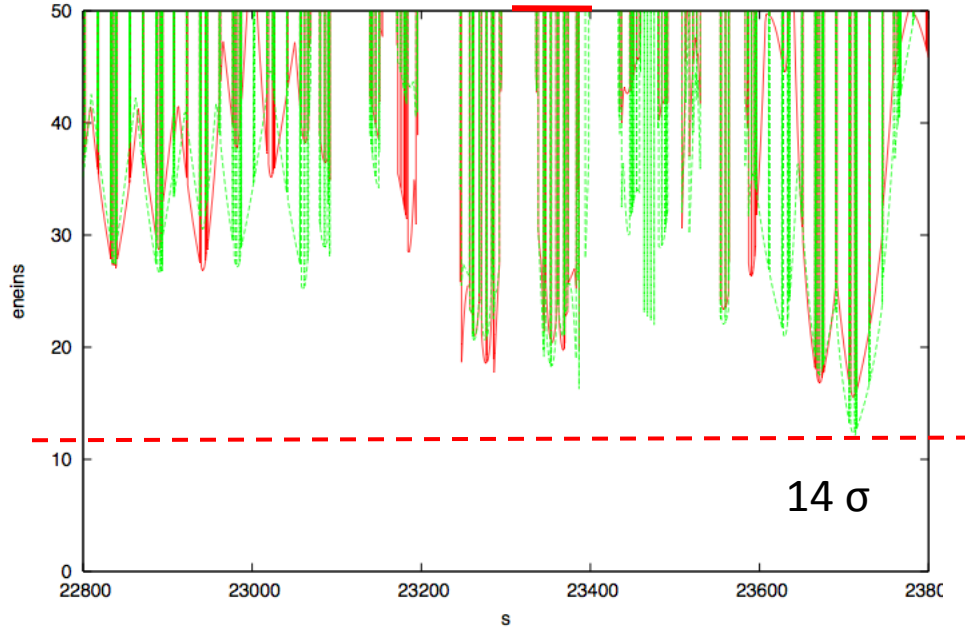


Aperture Calculations

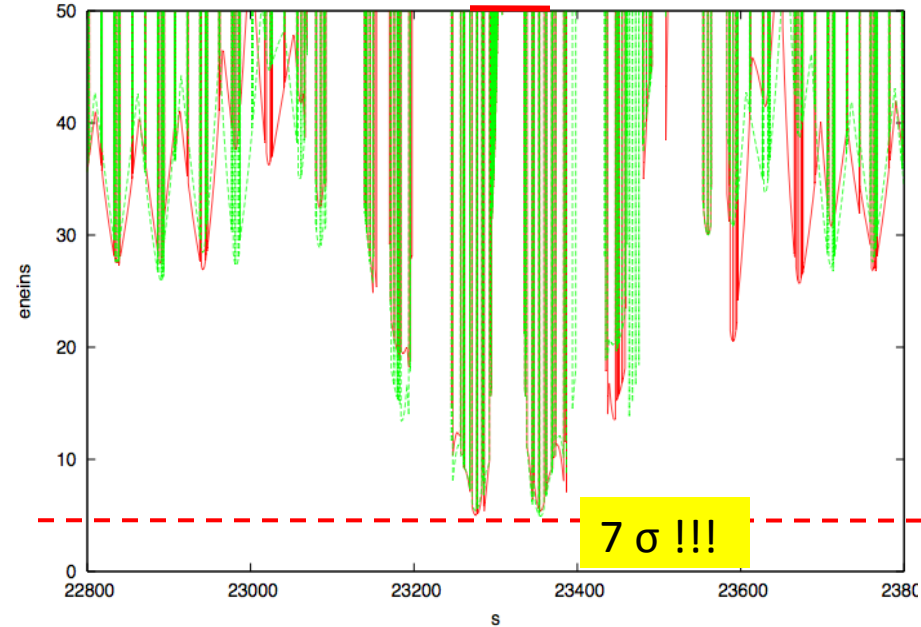
calculate the number of σ that – for a given bam optics –
fits into the vacuum chamber
magnet aperture
new experiment beam pipe



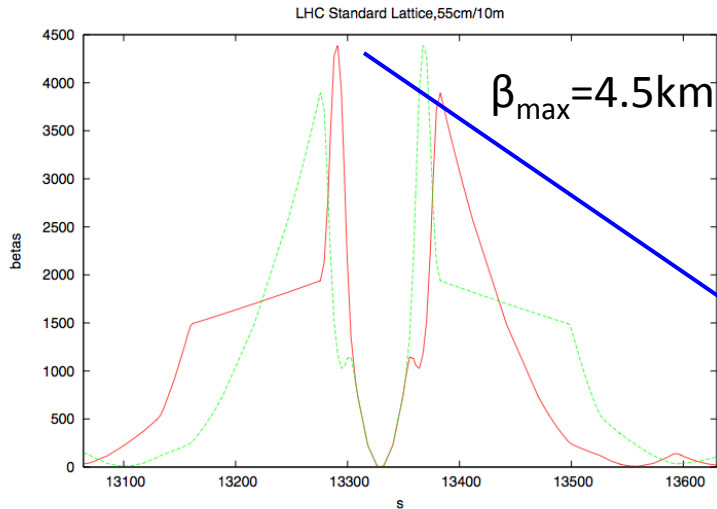
LHC Optics, IP8 10cm/3m, new pipe



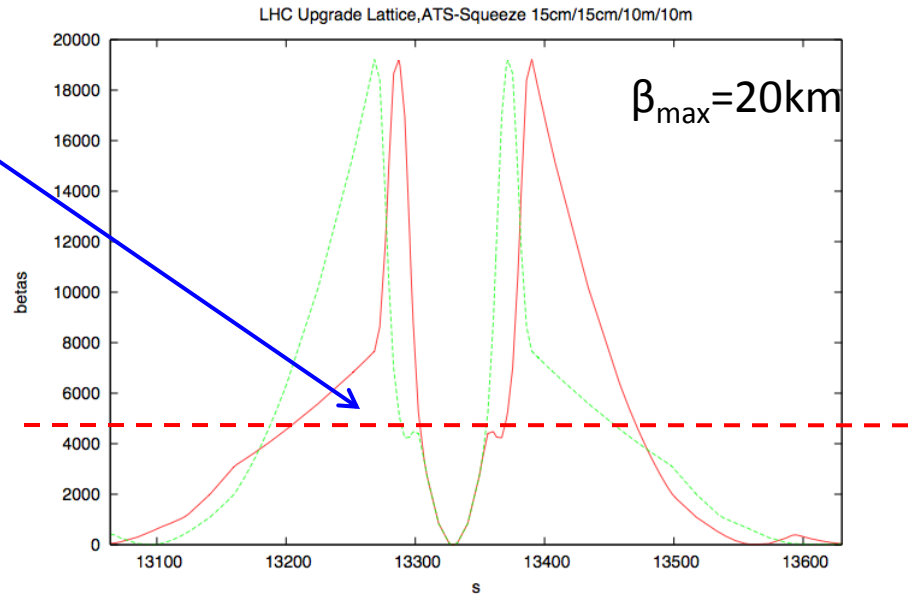
LHC Optics, IP8 40cm/50cm, new pipe



LHC Upgrade Optics Tolerances & Robustnes



LHC Standard: $\beta^* = 55\text{cm}$



LHC Upgrade: $\beta^* = 15\text{cm}$

*Impact on magnet strength,
apertures,
sensitivity of the beam (gradient errors & multipoles)
crab cavity voltage etc*

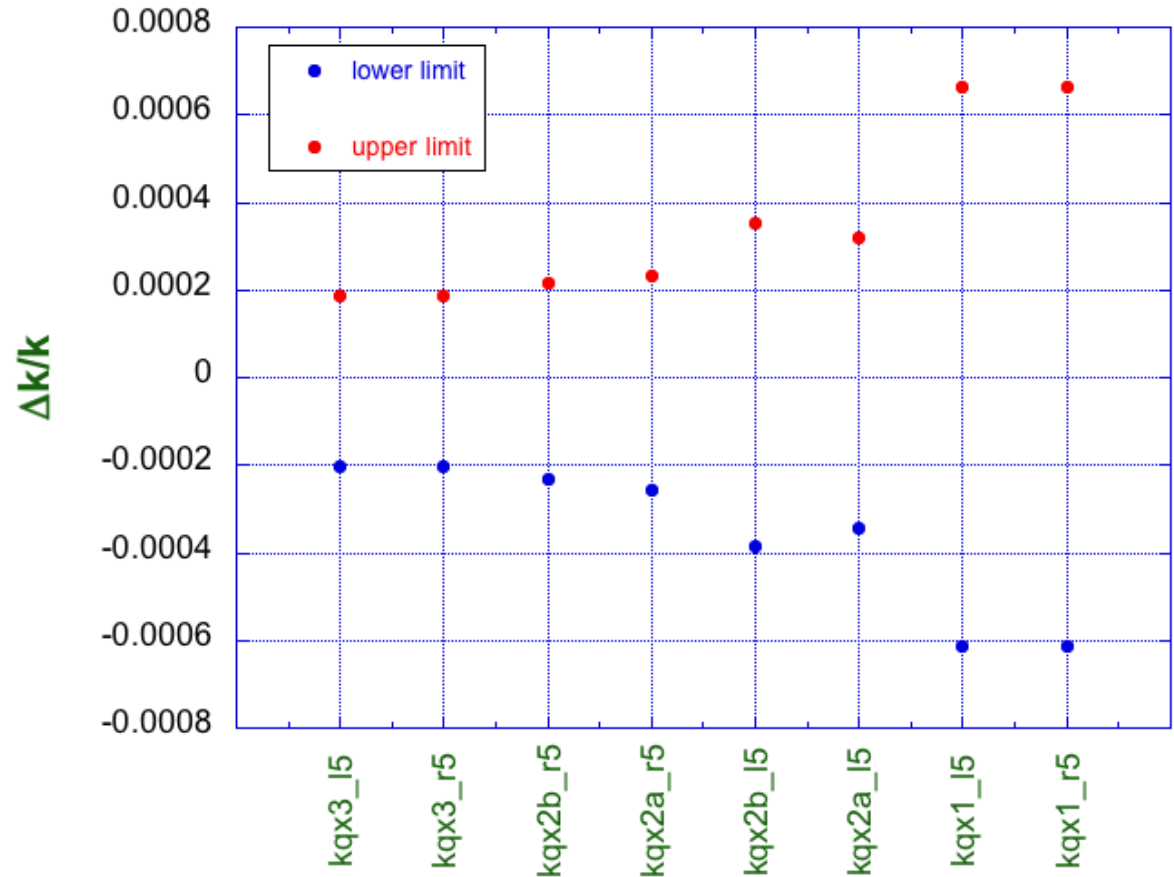
High Luminosity LHC

Study of the tolerances for the quadrupole strengths in the IR5

check the allowed tolerance window in magnet length, power converter stability, quadrupole gradient ...



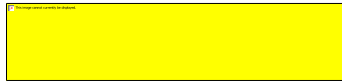
Tolerance criteria:



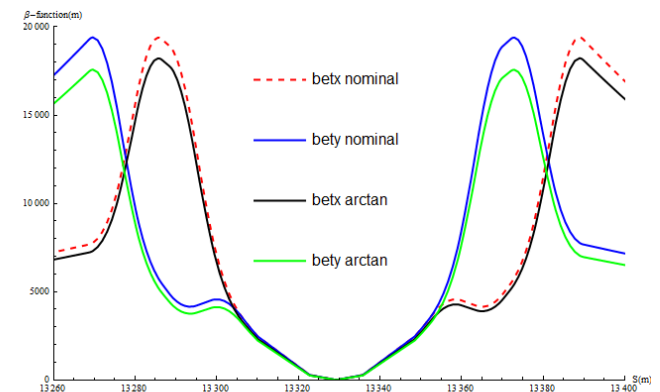
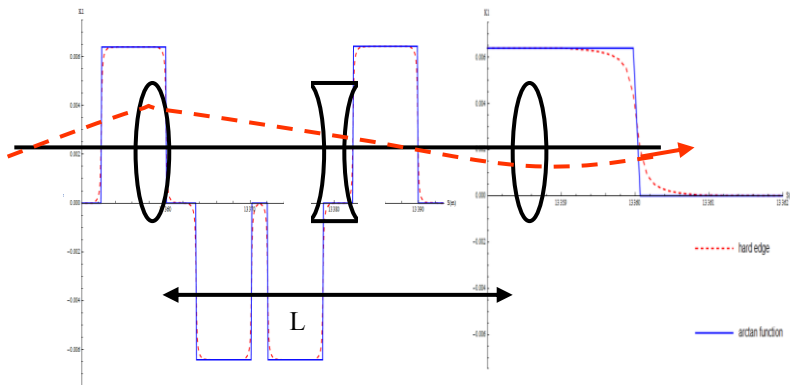
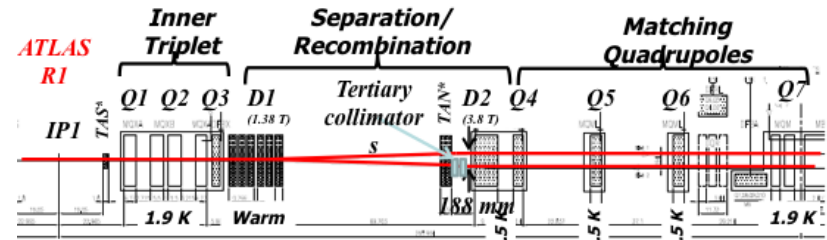
LHC Upgrade Optics Fringe Field Effects

improve the magnet box model, taking into account realistic fringe field effects

clearly we require:



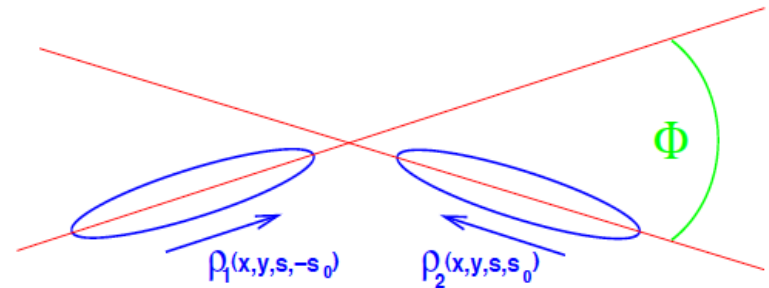
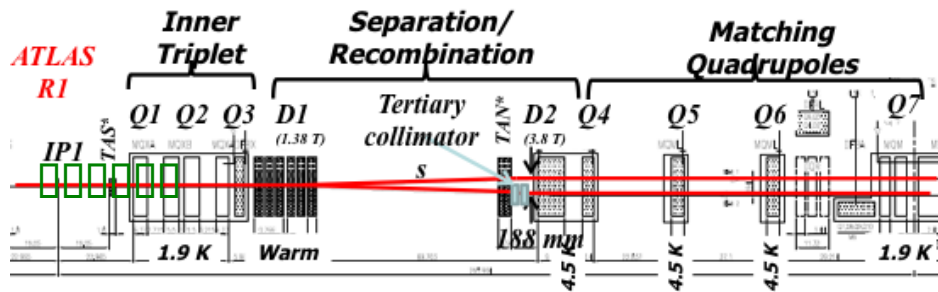
but the effect on the beam is determined also by the β -function



LHC Upgrade Optics x-angle, Crab Cavities, Flat Beam Option

$$\mathcal{L} = \frac{N_1 N_2 f n_b}{2\pi \sqrt{\sigma_{1x}^2 + \sigma_{2x}^2} \sqrt{\sigma_{1y}^2 + \sigma_{2y}^2}} * S$$

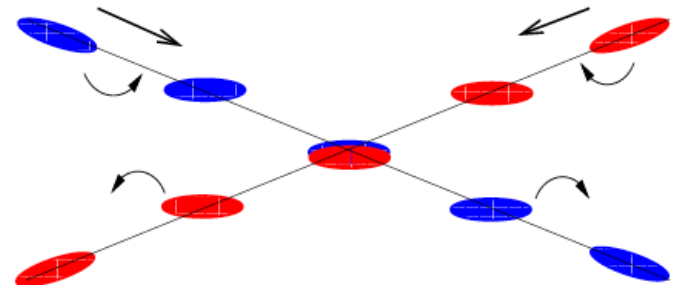
ideal luminosity formula



loss factor due to crossing with an angle
(pure geometric effect ... but large)

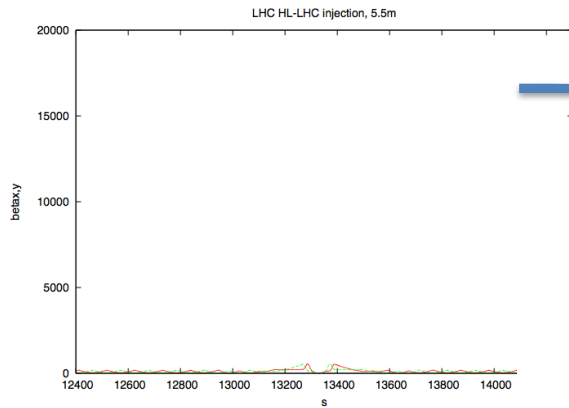
$$\Rightarrow S = \frac{1}{\sqrt{1 + \left(\frac{\sigma_s}{\sigma_x} \tan \frac{\phi}{2}\right)^2}} \approx \frac{1}{\sqrt{1 + \left(\frac{\sigma_s \phi}{\sigma_x 2}\right)^2}} \approx 0.37$$

”crab” crossing scheme

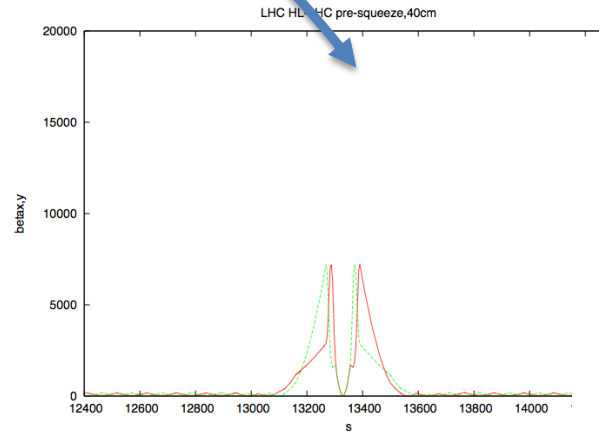


LHC Upgrade Optics Transition Injection - Presqueeze

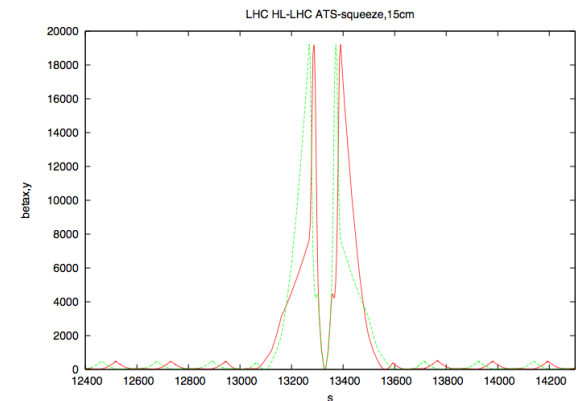
find a smooth transition without (too many) hysteresis problems



5.5m injection optics



40cm pre-squeeze optics



15cm ATS optics

LHC Upgrade: Non-ATS Solutions

Re-Design of the Matching Section for Optics Flexibility and for Plan “B”

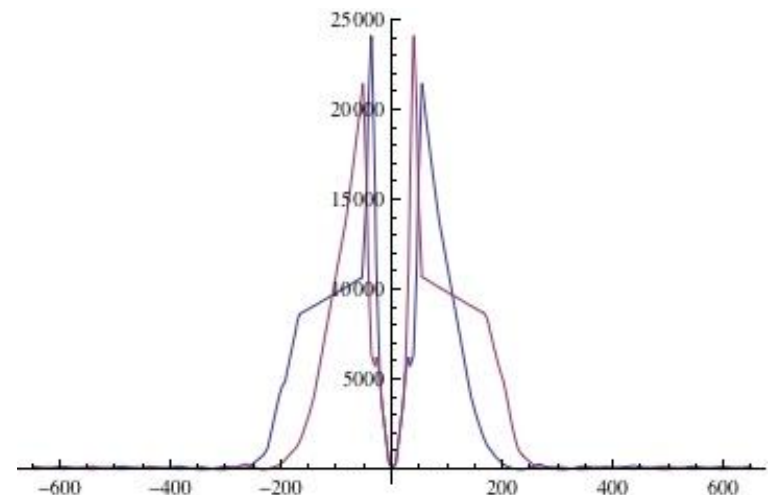
re-positioning of the matching quadrupoles, namely Q4...Q6

introducing an additional quadrupole lens between q3 and q7.

get the smallest β^* at the IP1 & 5, to establish an ambitious pre-squeeze optics or - even more to obtain β^* values that will allow us to get the required luminosity without ATS squeeze.

Re-Design of the Matching Section on Big Scale

Local Sextupole Correction Scheme



Than'x to all of you for the great effort and motivation

