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: Bernhard
09:00-09:40	Welcome and Overview	Bernhard
09:40-10:20	Layout Conditions & Scripts	Riccardo
10:20-10:40	Coffee	
10:40-11:20	Baseline Optics	Barbara
11:20-12:00	Optics Transitions	Maxim
	Lunch	
		chair: Riccardo
14:00-14:40	Robustness & Tolerances	Catia
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	Riccardo

Basic Idea: ≈ 30 ... 40 min presentation, 0 ... 10 min discussion

time	Thursday 20-Sep	chair: Andy
09:00-09:40	Magnet Design	Ezio
09:40-10:20	Crab Cavity Conditions	Rama
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 βs 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

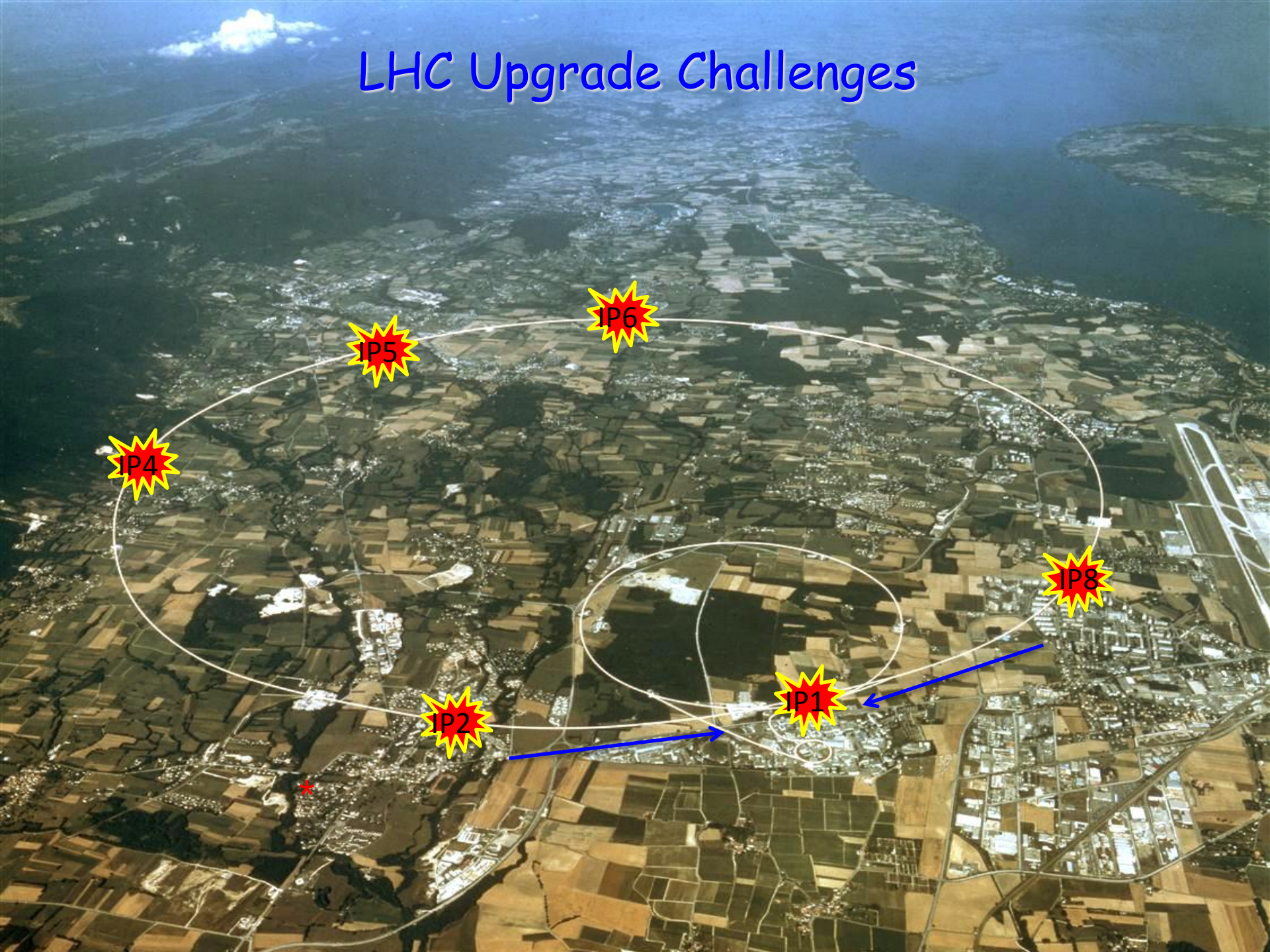
In parallel to the ATS optics explained in I.) options are studied to gain the smallest possible β* in IP1 & 5 without ATS. Re-design of parts of the matching section is considered as well as an attempt to investigate a completely new layout of the IRs.

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

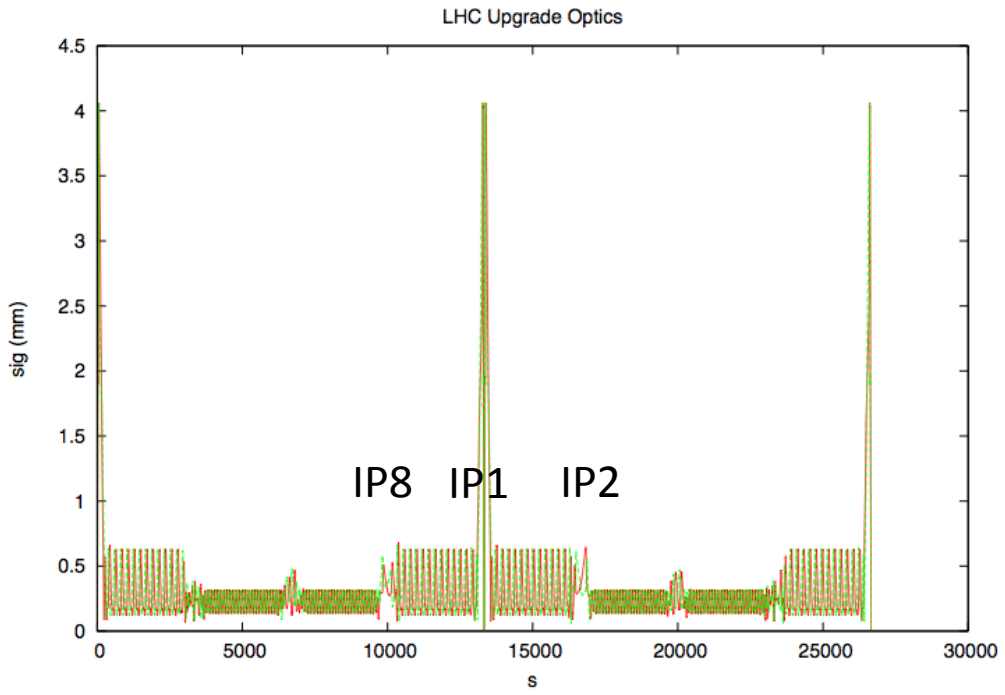
8.) Re-design of matching section for smallest reachable β* (additional quads, doublets at Q4/Q5 for sign flip etc) Angeles Faus-Golfe Valencia

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

LHC Upgrade Challenges



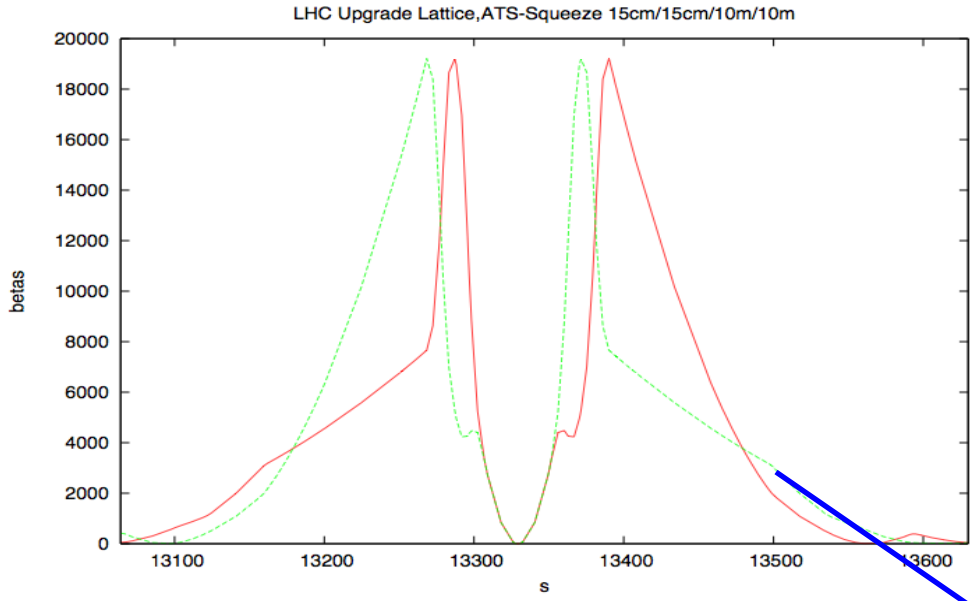
LHC Luminosity Upgrade in ATS

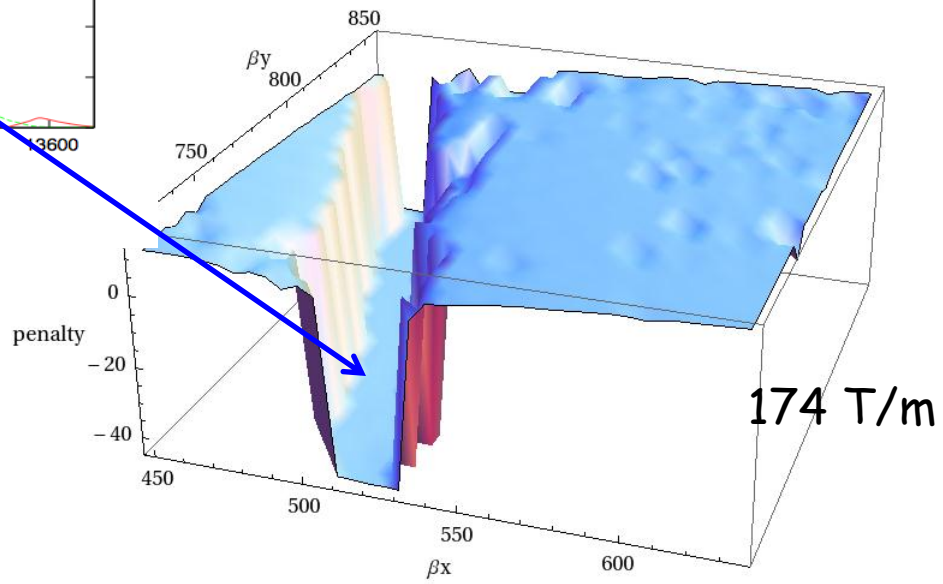


set up four baseline optics
based on assumptions on
aperture & magnet technique

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





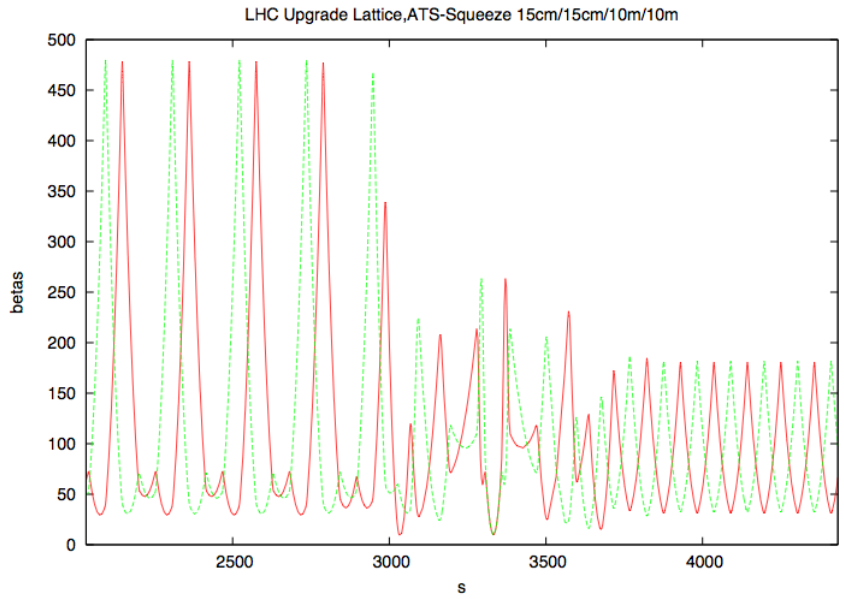
174 T/m

⇒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 Squeece Optics (15cm/15cm/10m/10m)

IP1, ATS Optics ⟵ IP2 ⟶ IP3, Standard FoDo Optics

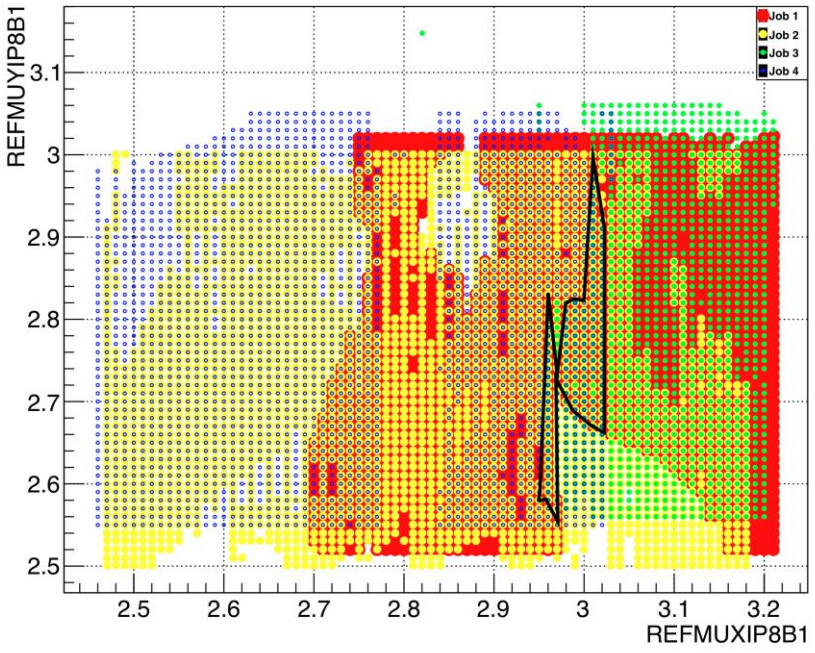
Find an otpics solution that is feasible for the Luminosity upgrade and guarantees adequate conditions for the ALICS and LHCb experiment at the same time.

A large variety of beam optics studied & optimised

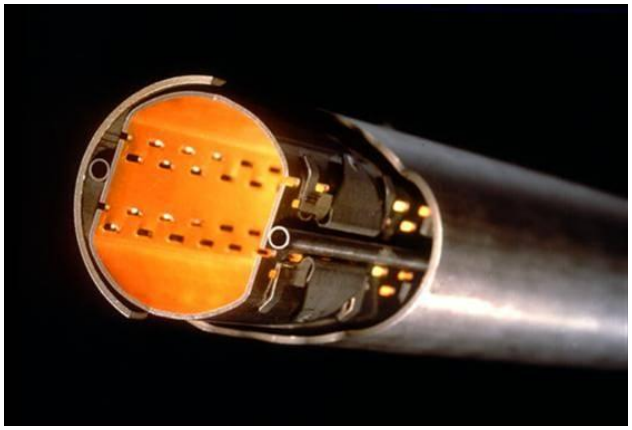
bog_150_0100_0100_3000_3000.madx	β*(IP8) = 3m	standard ATS, round
bog_150_0050_0200_3000_3000.madx	β*(IP8) = 3m	standard ATS, flat_xy
bog_150_0050_0200hv_3000_3000.madx	β*(IP8) = 3m	standard ATS, flat_yx
bog_150_5500_5500_10000_10000.madx	β*(IP8) = 10m	ATS_injection
bog_150_0400_0400_0500_0500.madx	β*(IP8)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

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

Main Issue: Search for ideal phase advance over IR8.



Aperture Calculations

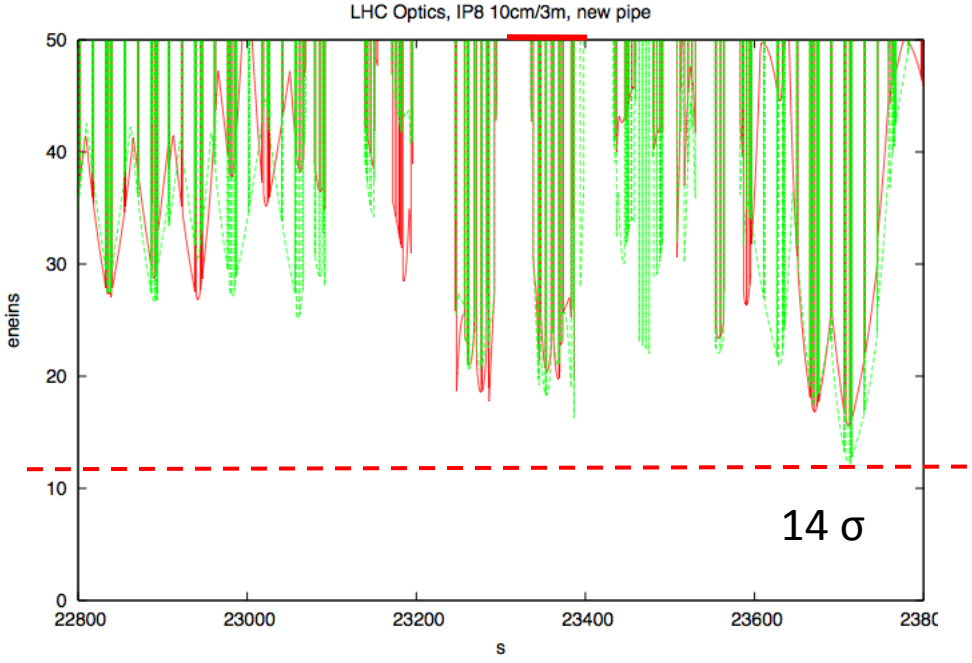


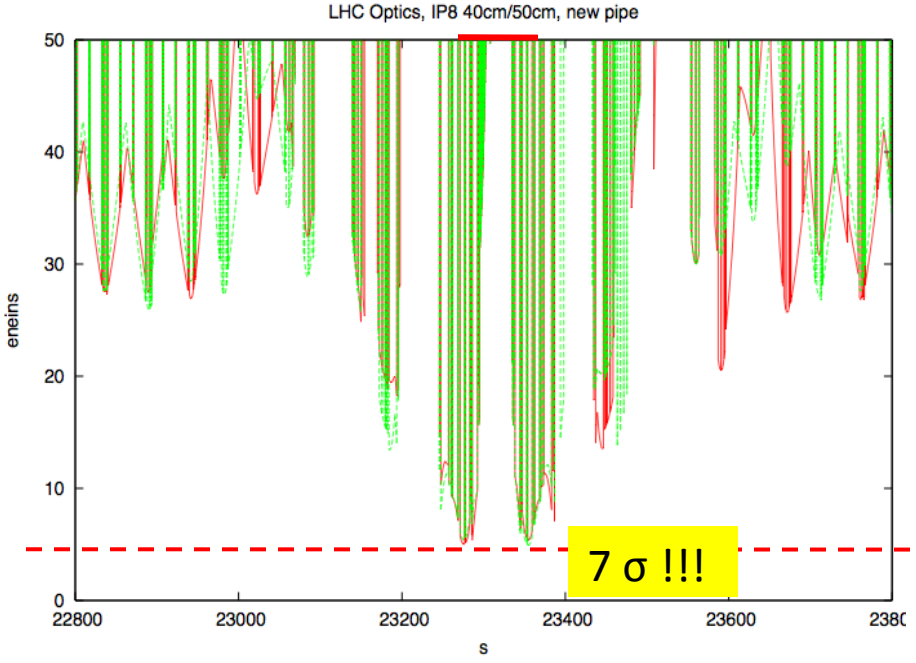
calculate the number of σ that – for a given bam optics –

fits into the vacuum chamber

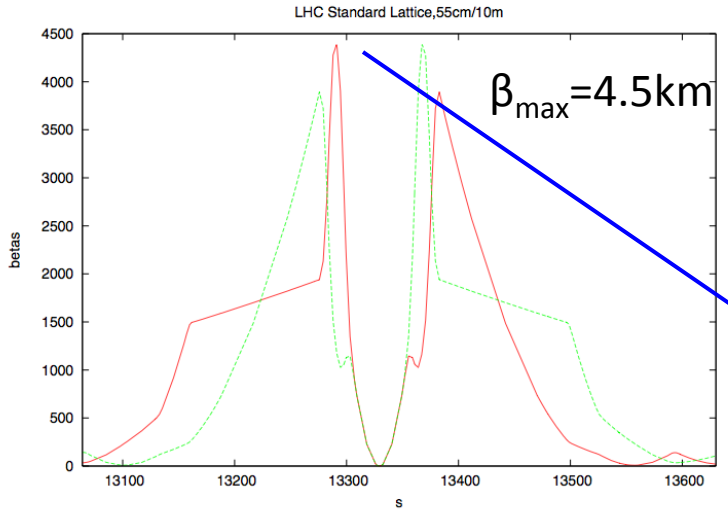
magnet aperture

new experiment beam pipe

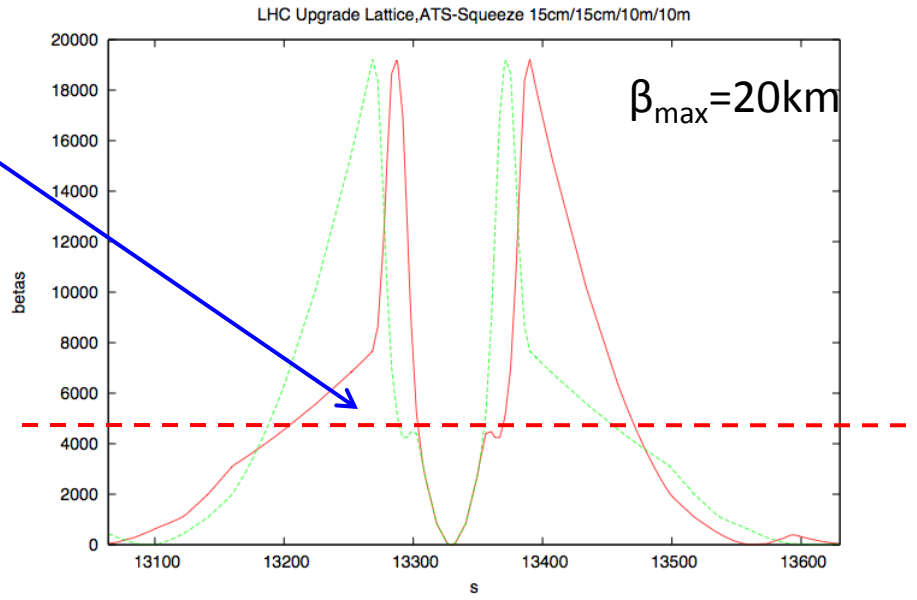




LHC Upgrade Optics Tolerances & Robustnes



LHC Standard: β*=55cm



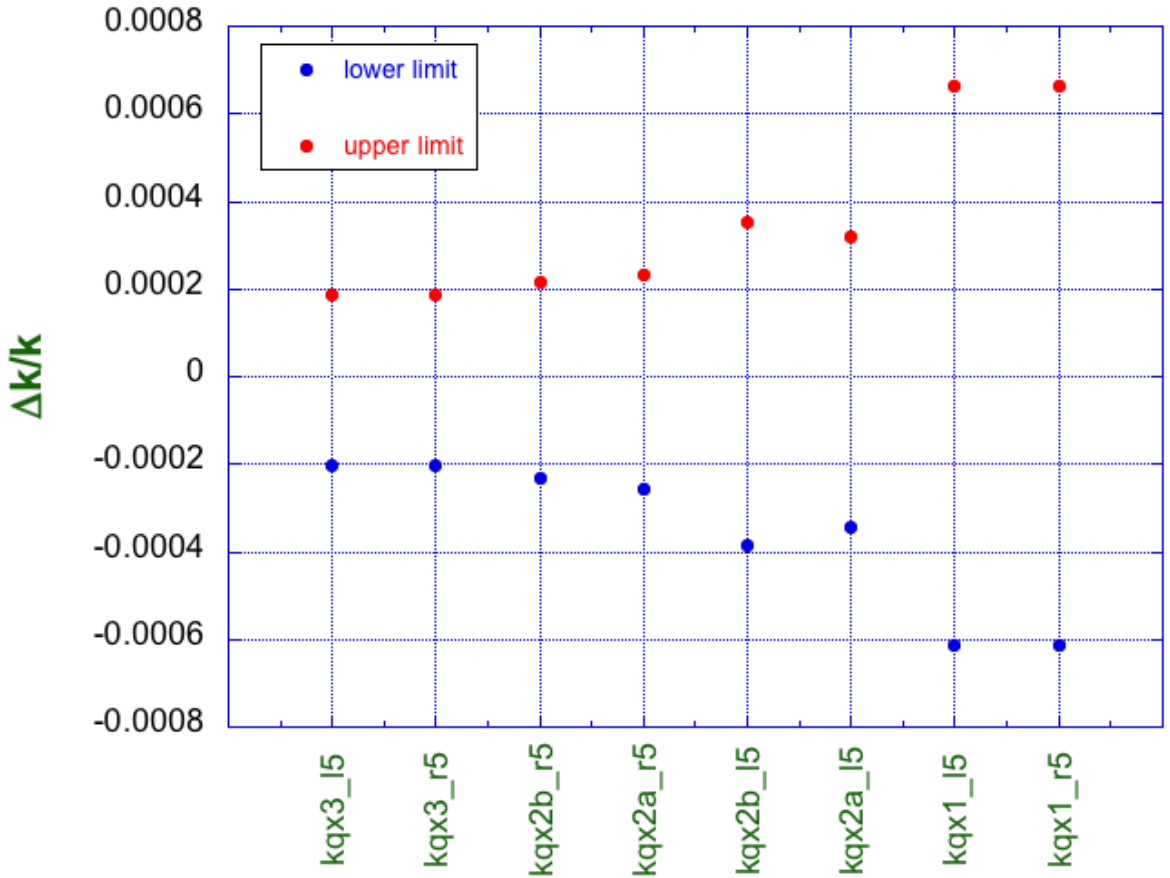
LHC Upgrade: β*=15cm

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:

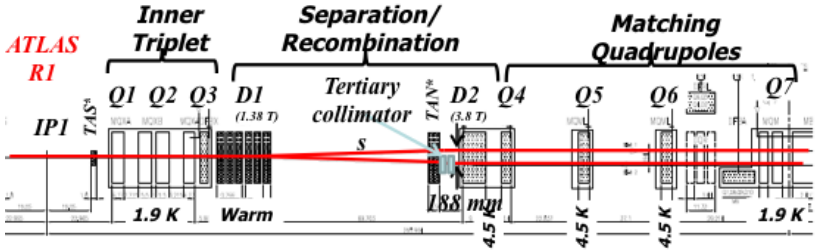


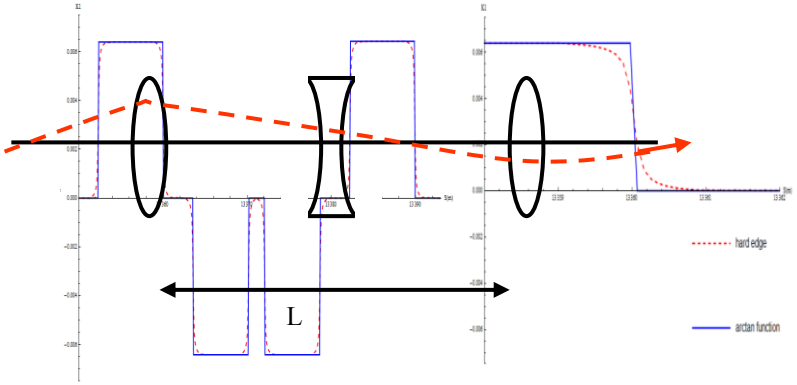
LHC Upgrade Optics Fringe Field Effects

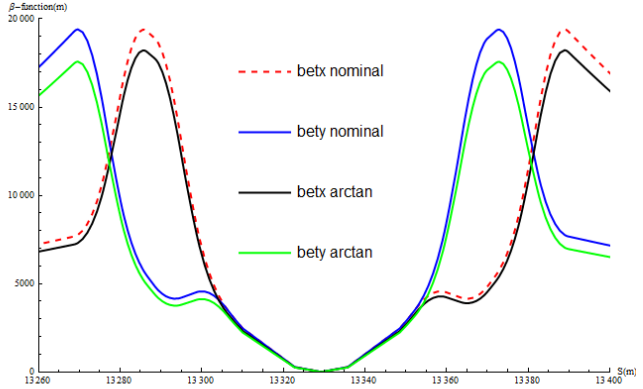
improve the magnet box model, taking into account realistic fringe field effects

clearly we require:

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



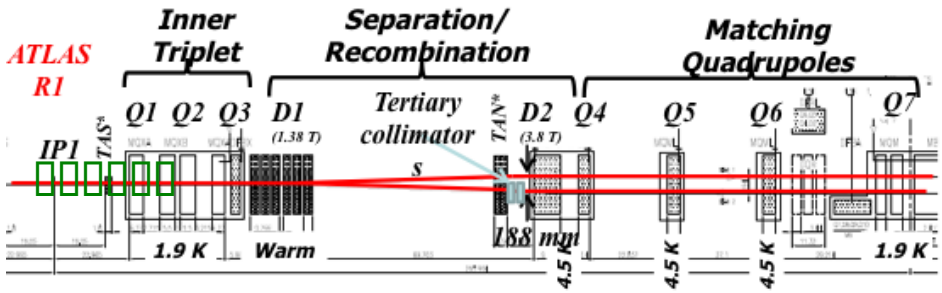


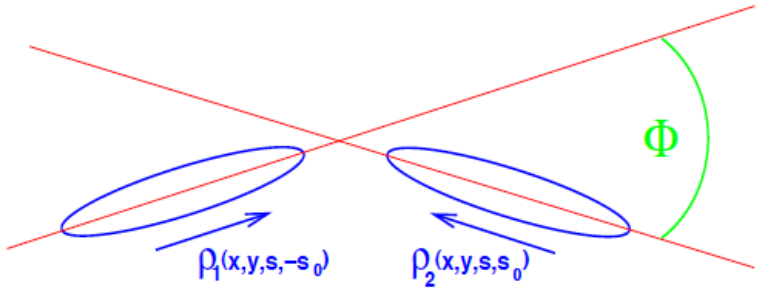


LHC Upgrade Optics x-angle, Crab Cavities, Flat Beam Option

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

ideal luminosity formula



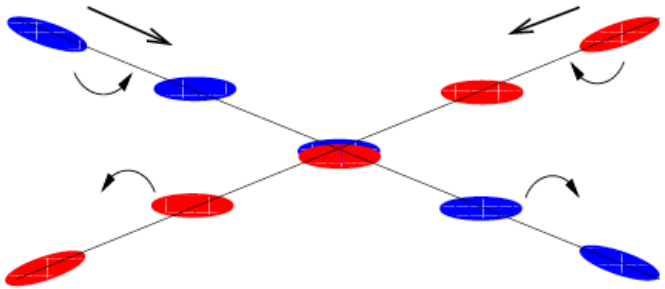


loss factor due to crossing with an angle
(pure geometric effect ... but large)

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

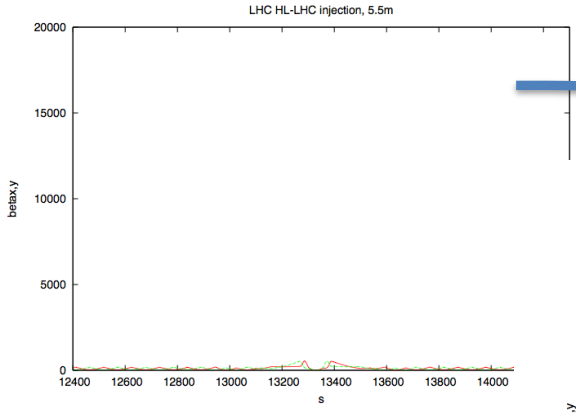
≈ 0.37

"crab" crossing scheme

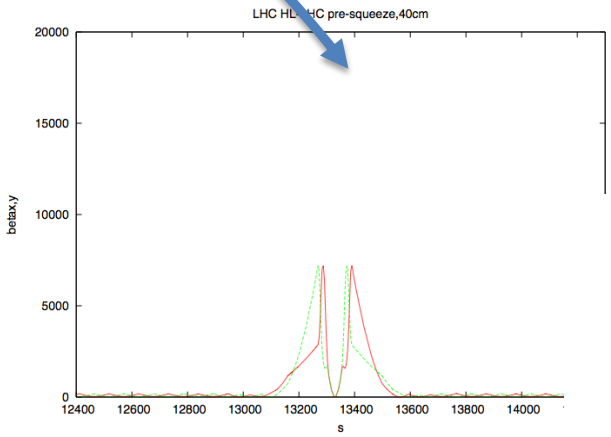


LHC Upgrade Optics Transition
Injection - Presqueeze

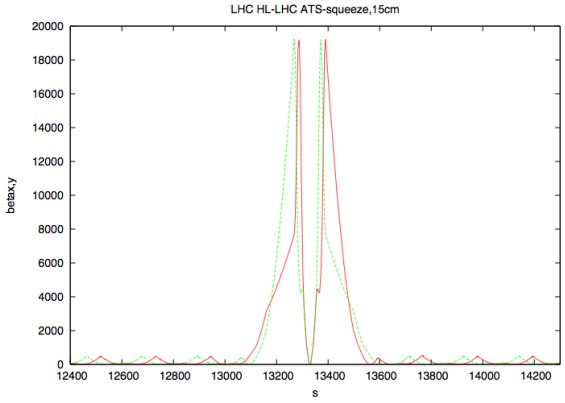
find a smoooooth transition without (too many) hysteresis problems



5.5m injection optics



40cmpre-squeeze optics



15cm ATS optics

LHC Upgrade: Non-ATS Solutions

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

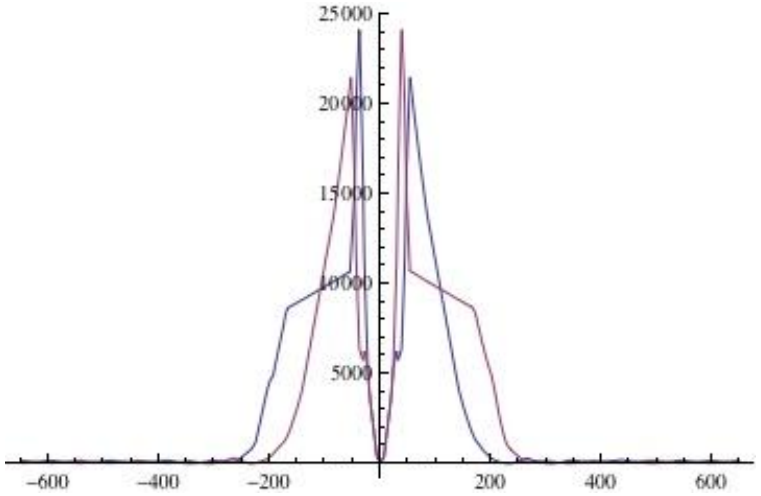
re-positioning of the matching quadrupoles, namely Q4...Q6

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 !