Beam-beam and octupoles stability diagrams in the betatron squeeze for HL-LHC optics

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Beam-beam meeting 21-08-2014

Outline

Set up of simulations tool:

- from LHC to HL-LHC
- mask file to produce Footprints
- PySSd for stability analysis

Footprints:

- Optics impact: LHC versus ATS
- Optics impact + LR: HL-LHC scenario

Stability Diagrams:

- Optics impact
- Beam beam LR impact

Summary and Outlook

Hi-Lumi mask file Madx

Version for beam-beam studies for Hi-Lumi

- Three input file for beam-beam setting:

1. `beamDefinition`
2. `collisionConfiguration`
3. `collisionPath`

- Octupole strength
- Beam-beam macro from Werner Herr

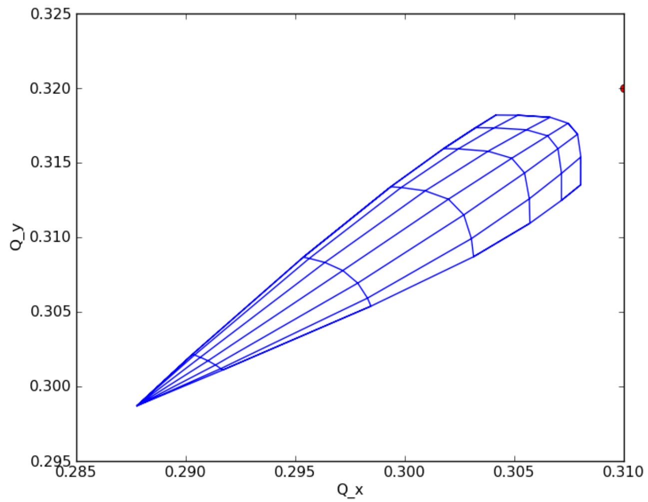
Hi-Lumi mask file Madx: 0 crossing angle problem

Collision in IP1 and IP5

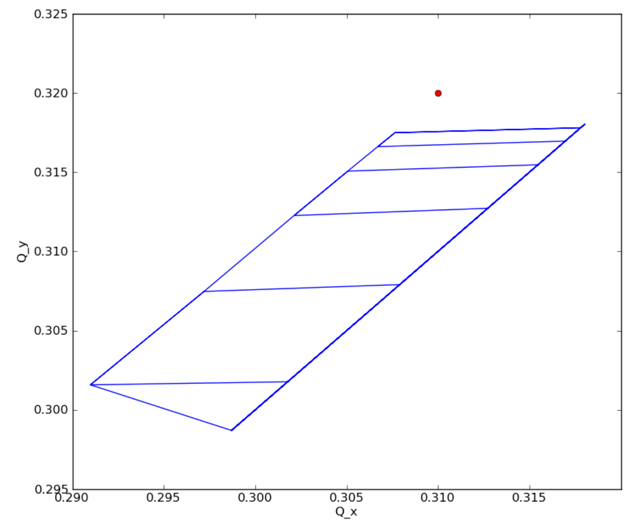
```
seqedit,sequence=lhcb1;
flatten;
cycle,start=IP3;
endedit;

use,sequence=lhcb1;
option,trace;
small=0.05;
big=sqrt(1.-small^2);
track;
xs=small; ys=small;
value,xs,ys;
start,fx=xs,fy=ys;  // zero amplitude
nsigmax=6;
n=1; // sigma multiplier
m=0; // angle multiplier
while (n <= nsigmax)
{
  angle = 15*m*pi/180;
  if (m == 0) {xs=n*big; ys=n*small;}
  elseif (m == 6) {xs=n*small; ys=n*big;}
```

IP2



IP3



Hi-Lumi mask file Madx: 0 crossing angle problem

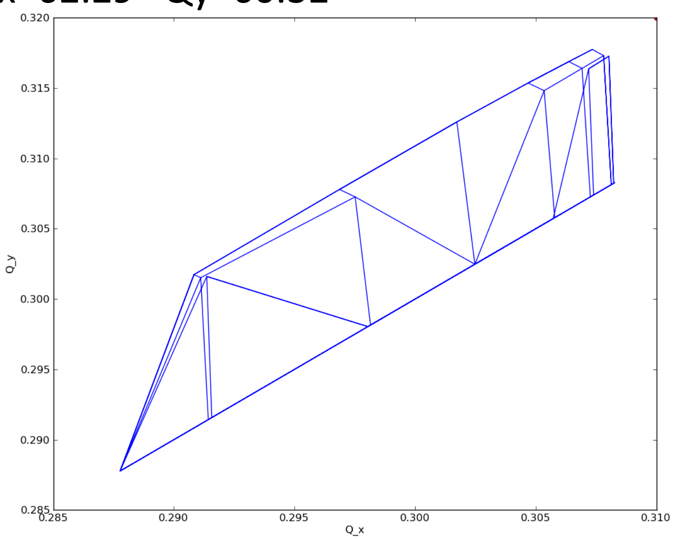
@ TIME %08s "15.08.06"

X	Y	TUNX	TUNY
%le	%le	%le	%le
2.106088112e-06	1.759995917e-05	0.2987018084	0.2987020003
0.0001502385133	0.0001564703148	0.2909825022	0.3015793587
0.0001213056337	0.0001946047525	0.3017726175	0.3017722602
7.821005157e-05	0.0002295754756	0.3019536515	0.3019536479
2.978458372e-05	0.0002489010095	0.3020474462	0.3020474559
-2.06706543e-05	0.000251264351	0.3020447097	0.302044571
-6.971722138e-05	0.0002365044421	0.3019452927	0.3019450507
-0.0001060633481	0.0002126885535	0.3017996958	0.301799918
0.0003004770267	0.0003129406295	0.2971987165	0.307472238
0.0002426112673	0.0003892095049	0.3079064253	0.3079063524
0.0001564201031	0.0004591509513	0.3082278519	0.3082279028

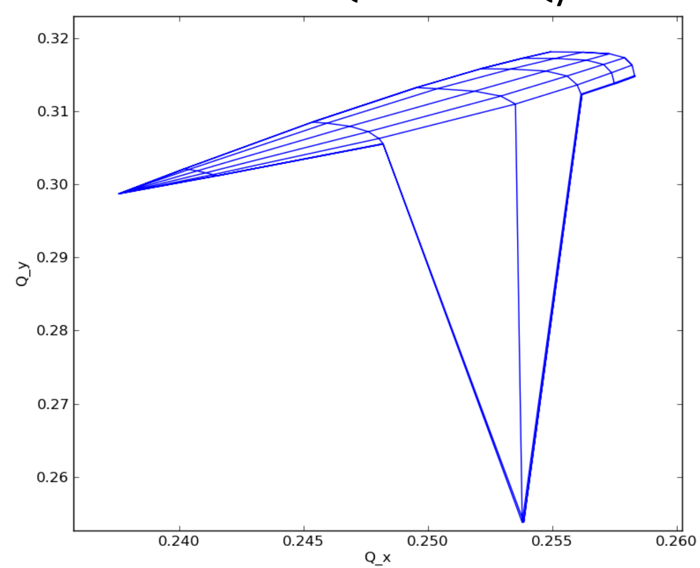
Sort of coupling?

Trying to change the tune:

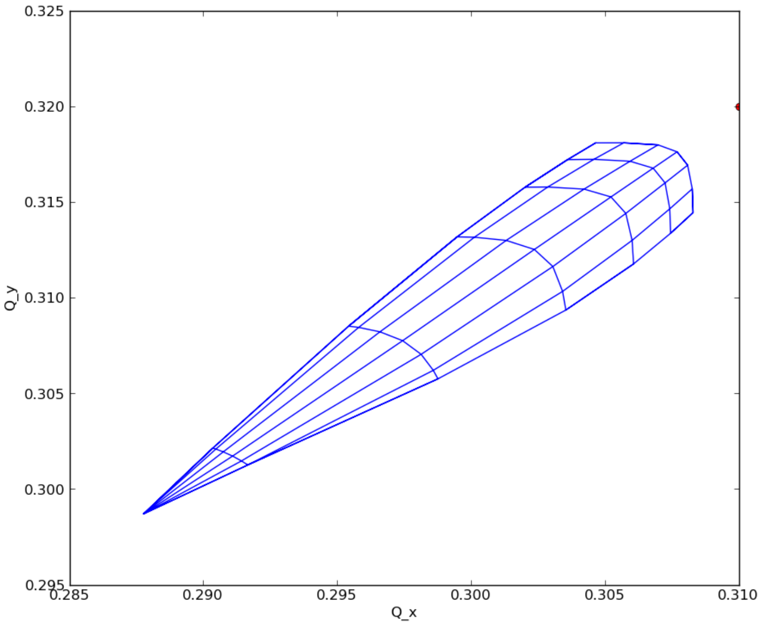
Qx=62.29 Qy=60.32



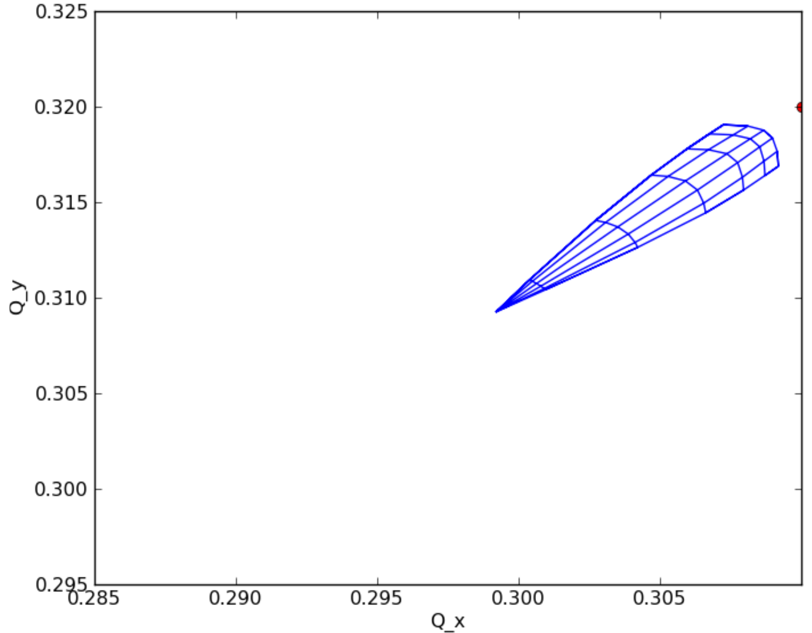
Qx=62.26 Qy=60.32



Crossing angle of 5 μrad
HO IP5, IP1

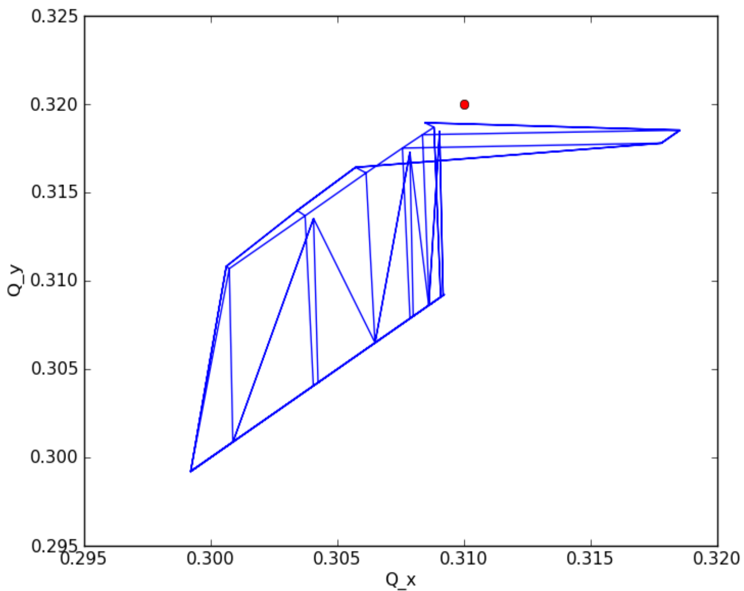


HO in IP5 with 0 crossing angle
crossing angle in IP1

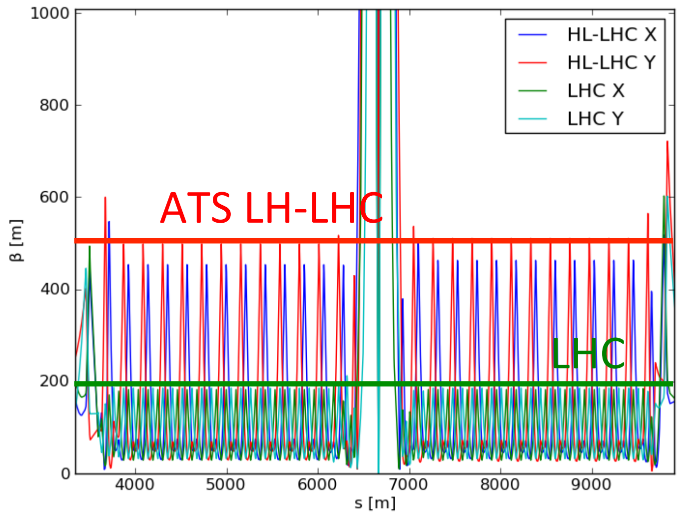


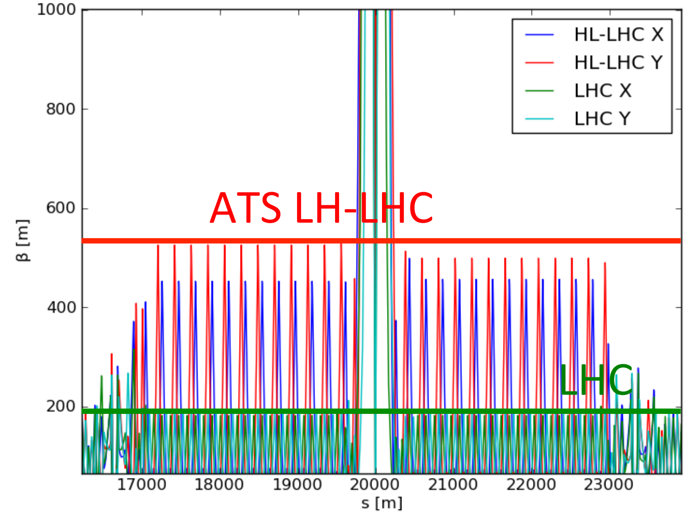
HO in IP5 with 0 crossing angle
0 crossing angle in IP1:

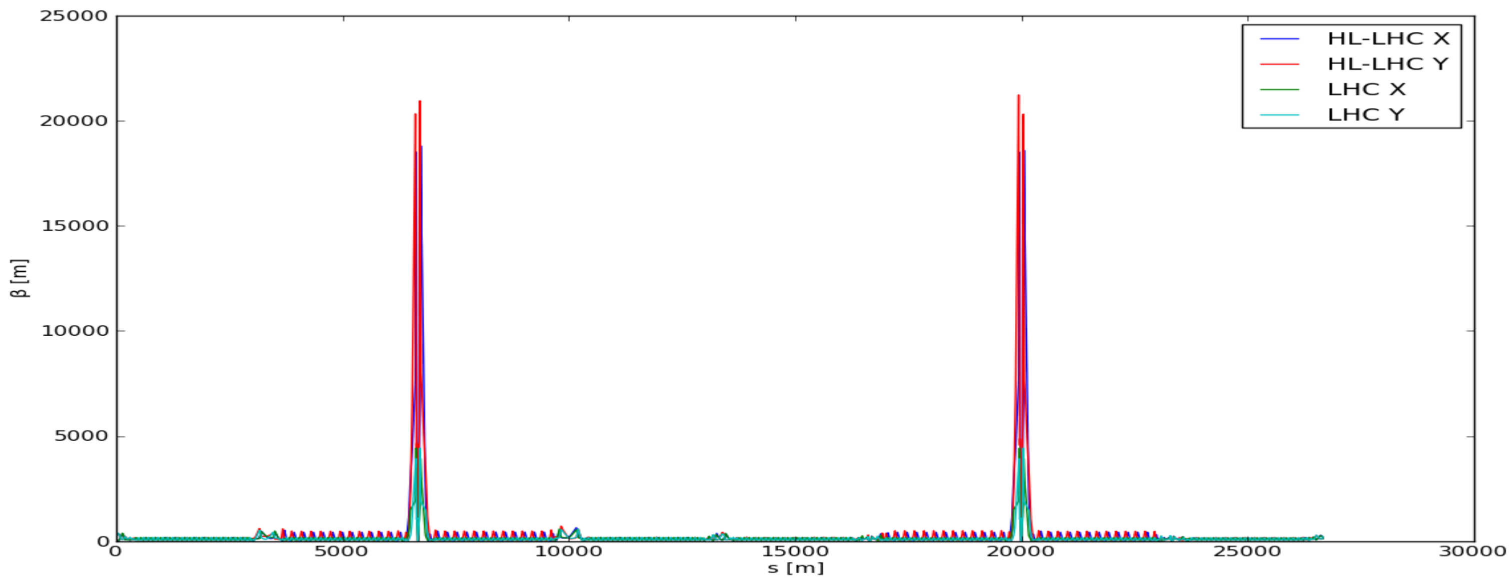
Still under investigation!



ATS optics


1000
800
600
400
200
0
4000
5000
6000
7000
8000
9000
s [m]
β [m]
HL-LHC X
HL-LHC Y
LHC X
LHC Y
ATS LH-LHC
LHC

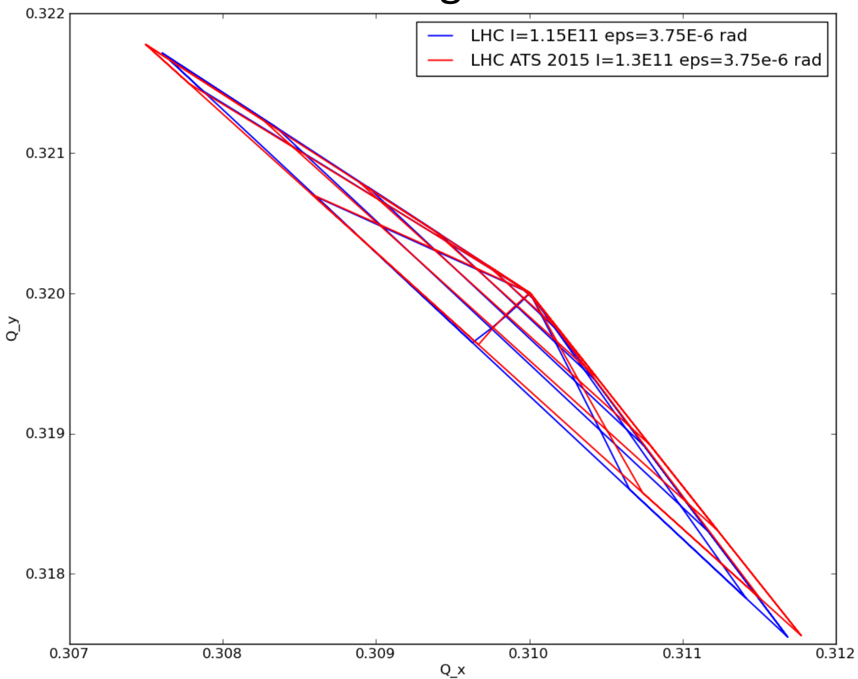

1000
800
600
400
200
17000
18000
19000
20000
21000
22000
23000
s [m]
β [m]
HL-LHC X
HL-LHC Y
LHC X
LHC Y
ATS LH-LHC
LHC


25000
20000
15000
10000
5000
0
0
5000
10000
15000
20000
25000
30000
s [m]
β [m]
HL-LHC X
HL-LHC Y
LHC X
LHC Y

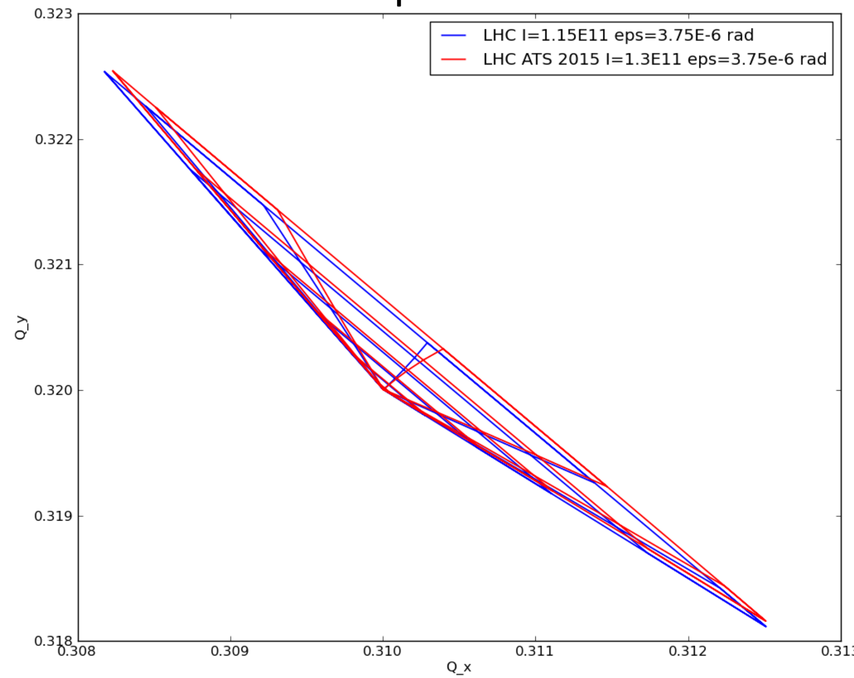
ATS: optics impact

Footprint comparisons: LHC and LHC ATS 2015 case

LOF negative



LOF positive

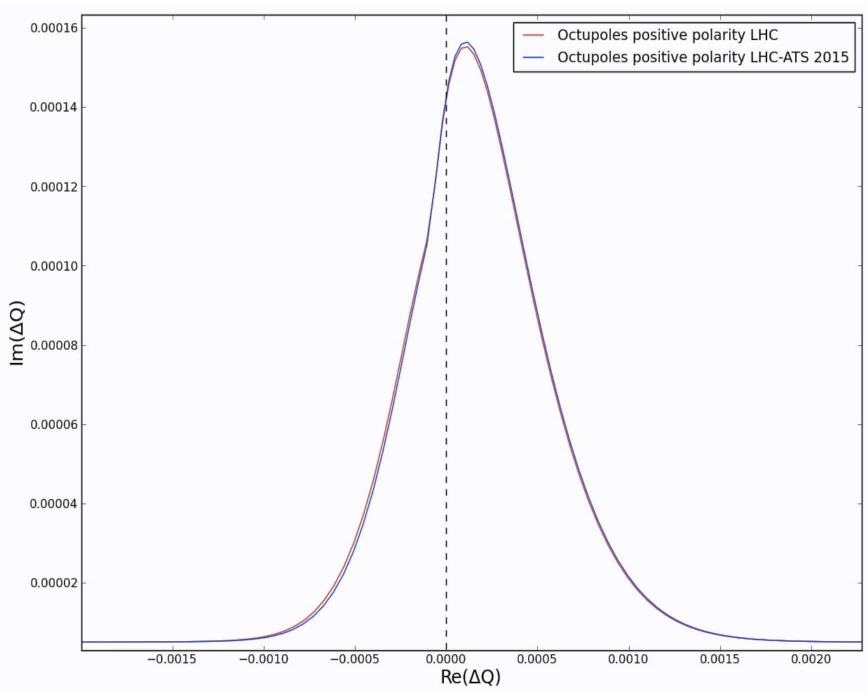


No much gain on the footprint for LHC ATS 2015

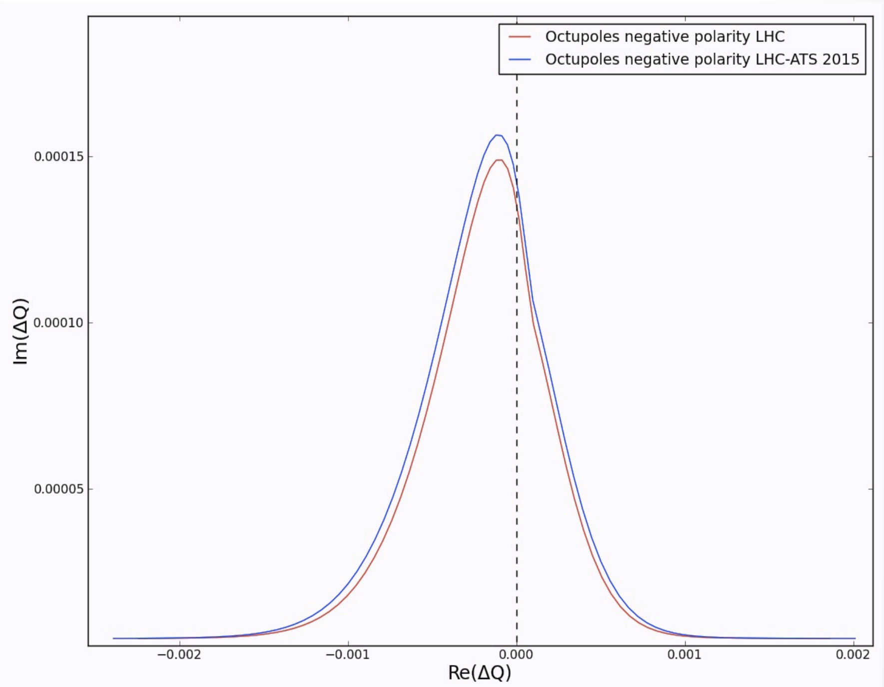
ATS optics: Stability Diagrams

LHC (nominal) vs LHC ATS 2015 (I=1.3E11, ε=3.75 μrad)

LOF positive



LOF negative



Landau Damping, Dynamic Aperture and Octupoles in LHC

J. Gareyte, J.P. Koutchouk and F. Ruggiero

$$\Delta Q_x = \left[\frac{3}{8\pi}\int \beta_x^2 \frac{O_3}{B\rho}\,ds\right] J_x - \left[\frac{3}{8\pi}\int 2\beta_x\beta_y \frac{O_3}{B\rho}\,ds\right] J_y,$$

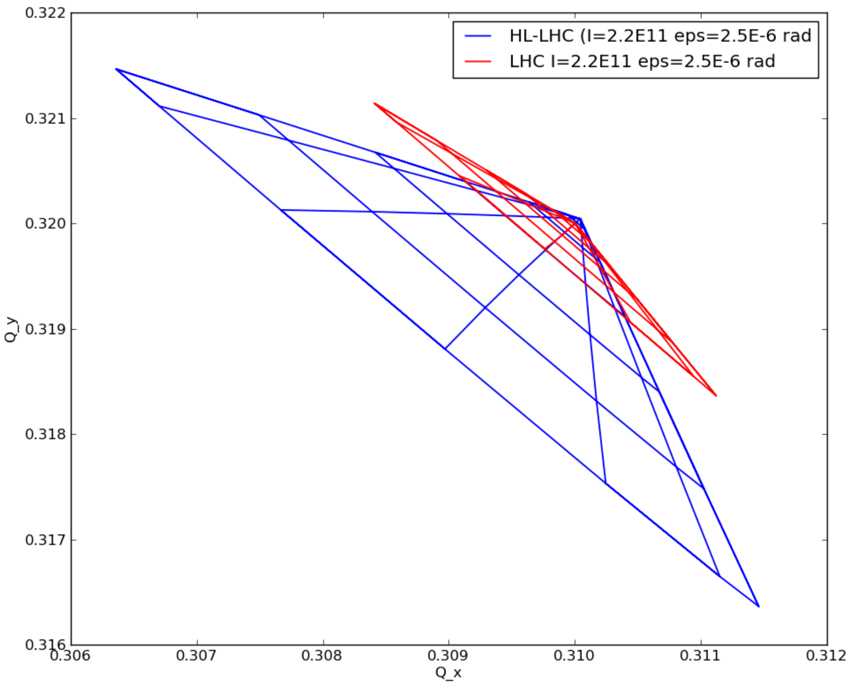
$\Delta Q_{oct} \propto \beta(s)^2$ $\quad \beta(s)^2_{LHC\ ATS}/\beta(s)^2_{LHC} \approx 1.05$

⚠ qualitative estimation...

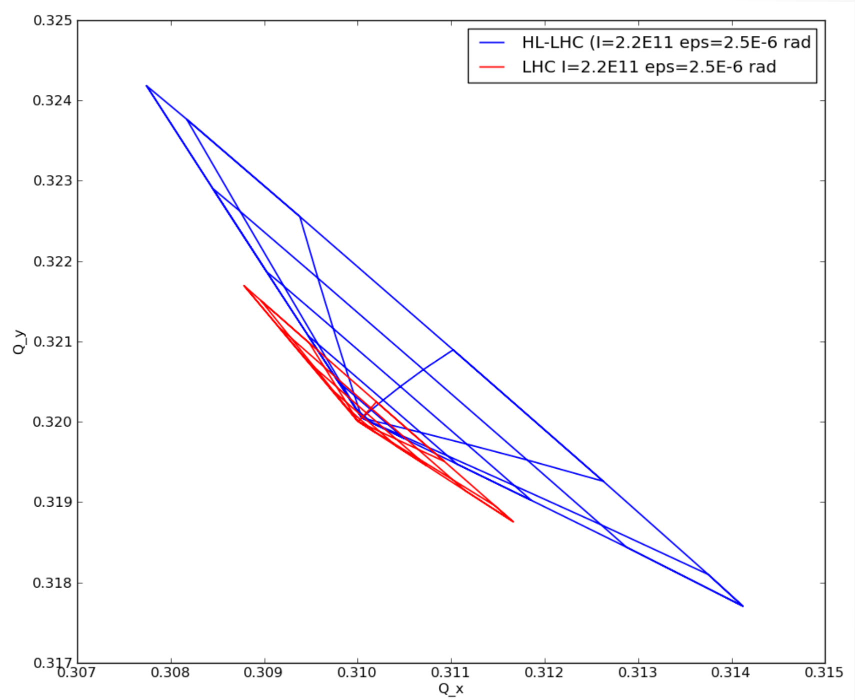
ATS: optics impact

Footprint comparisons: LHC and LH-LHC case

LOF negative



LOF positive

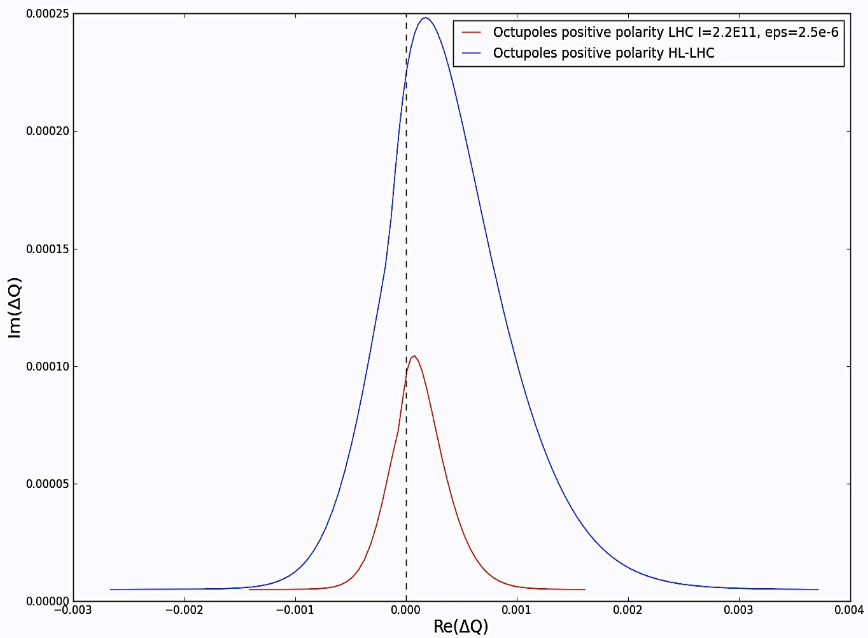


Strong impact for HL-LHC case with respect to LHC with same intensity and emittance

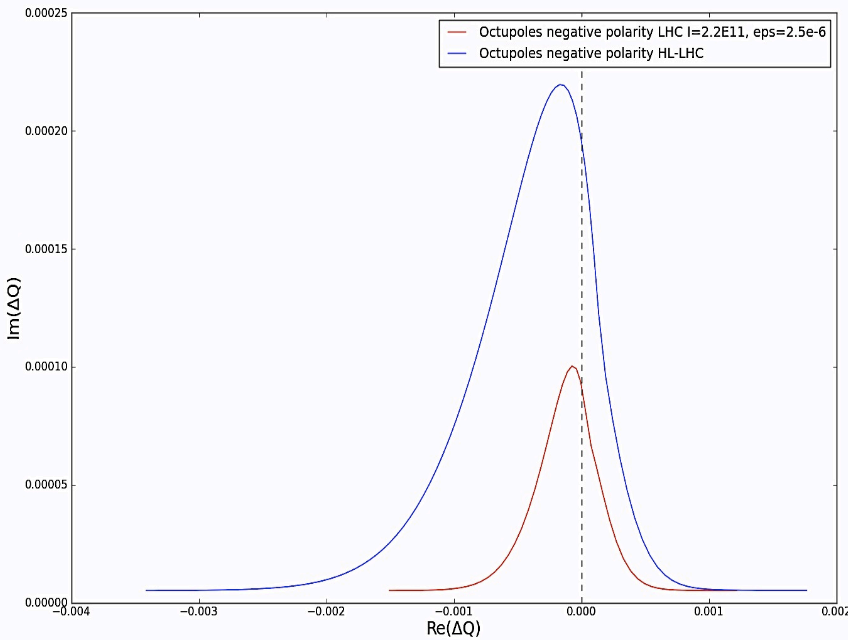
ATS optics: Stability Diagrams

HL-HLC vs LHC (I=2.2E11, ε=2.5 μrad)

LOF positive



LOF negative

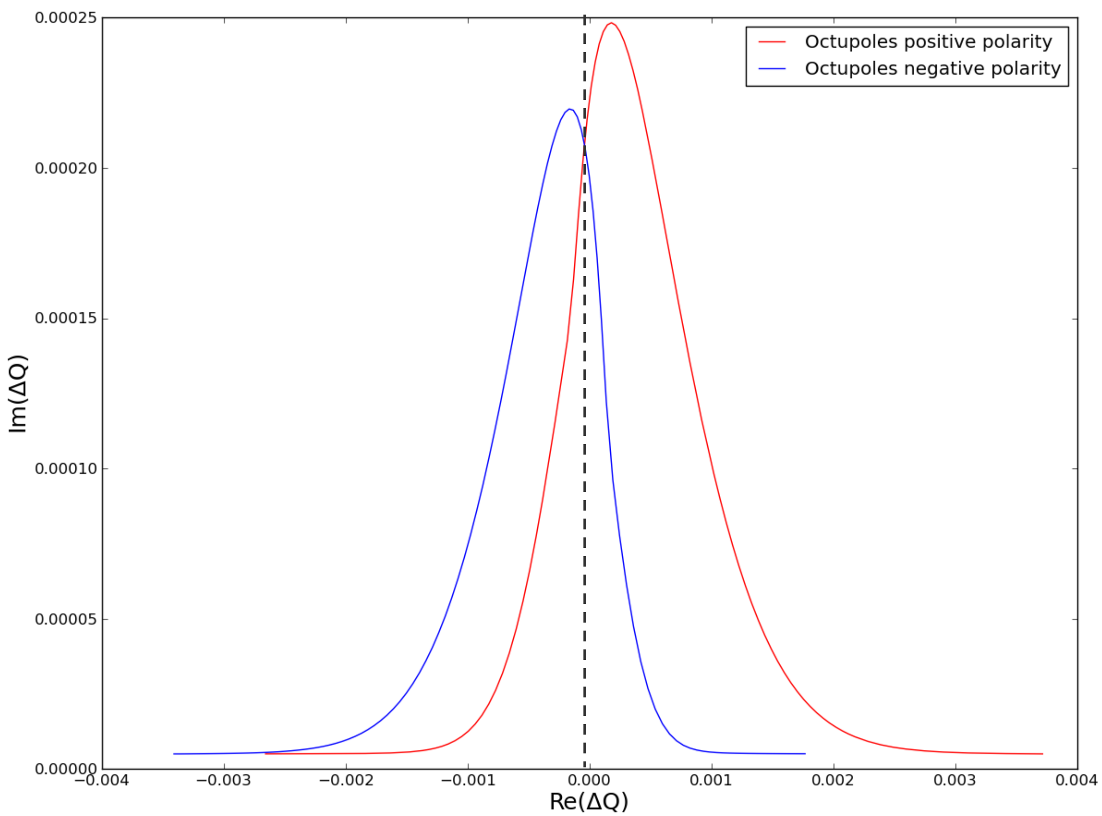


$\Delta Q_{oct} \propto \beta(s)^2$ $\quad \beta(s)^2_{HL-LHC}/\beta(s)^2_{LHC} \approx 2.5$ larger than the LHC case

⚠ qualitative estimation...

ATS optics: Stability Diagrams

HL-HLC case (only octupoles)

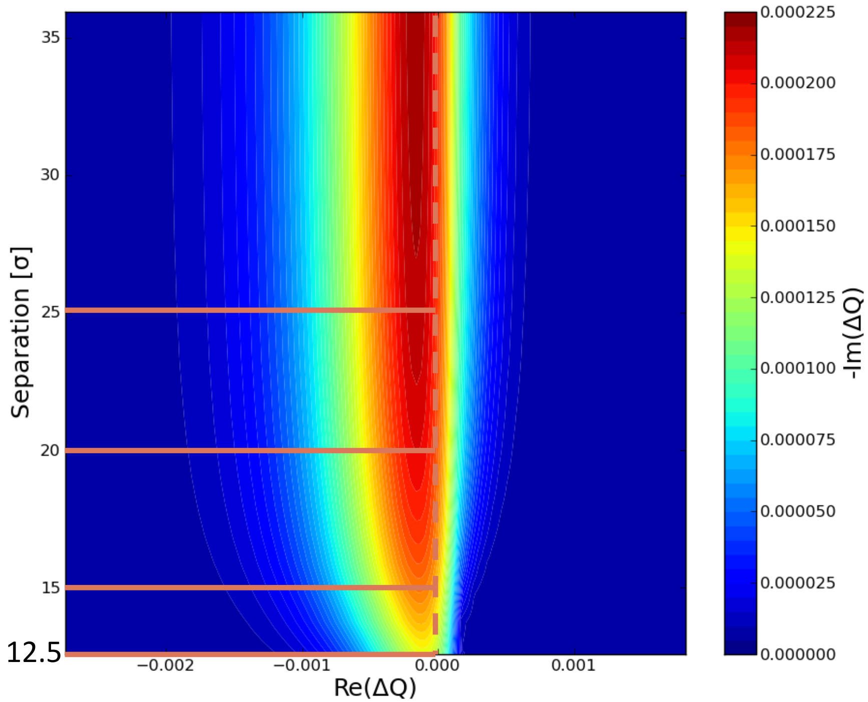


For single beam, larger stability diagrams for negative polarity

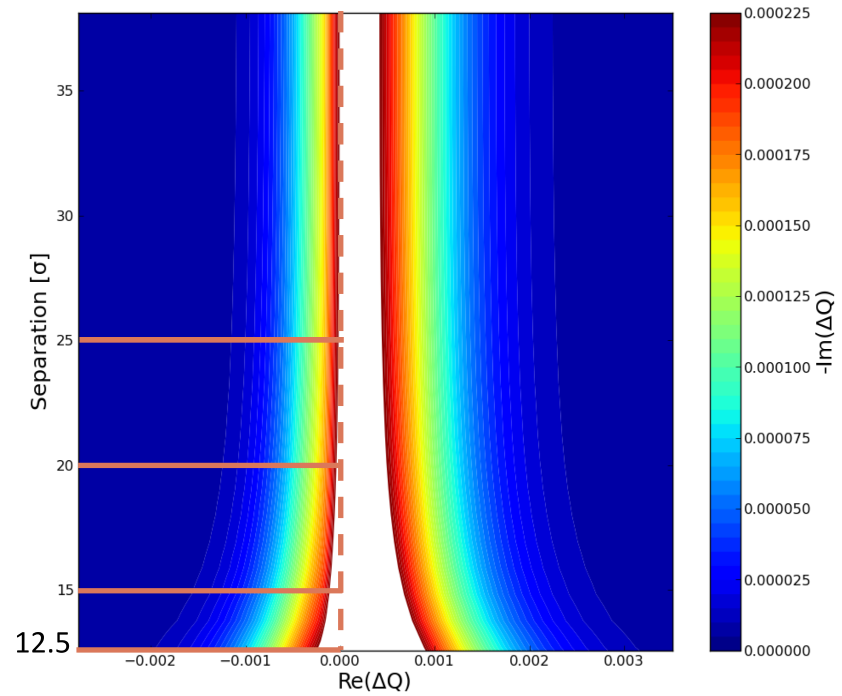
Betatron squeeze for HL-LHC optics

Evolution of the betatron squeeze with LR beam beam

Negative LOF



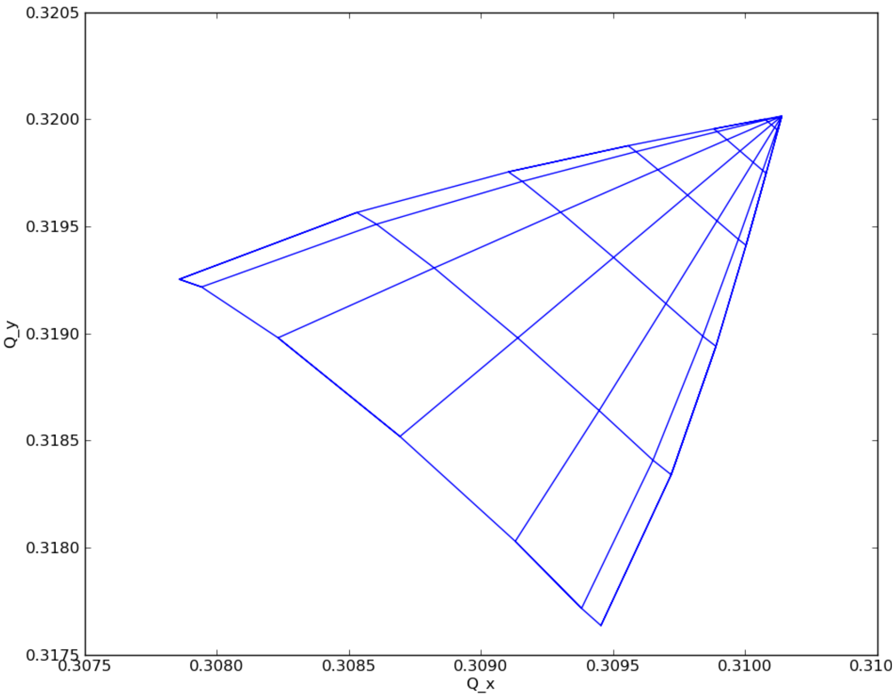
Positive LOF



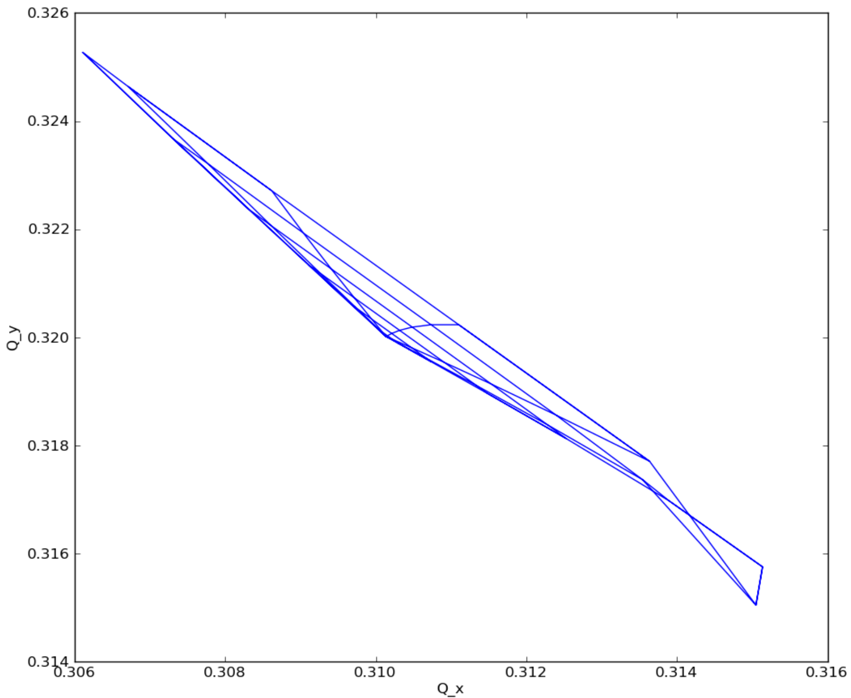
Due to the lack of intermediate optics, the betatron squeeze has been simulated by increasing the crossing angle: starting point 590μrad (d=12.5σ and β*=0.15m)

Betatron squeeze: footprint at 12.5σ

LR + negative LOF

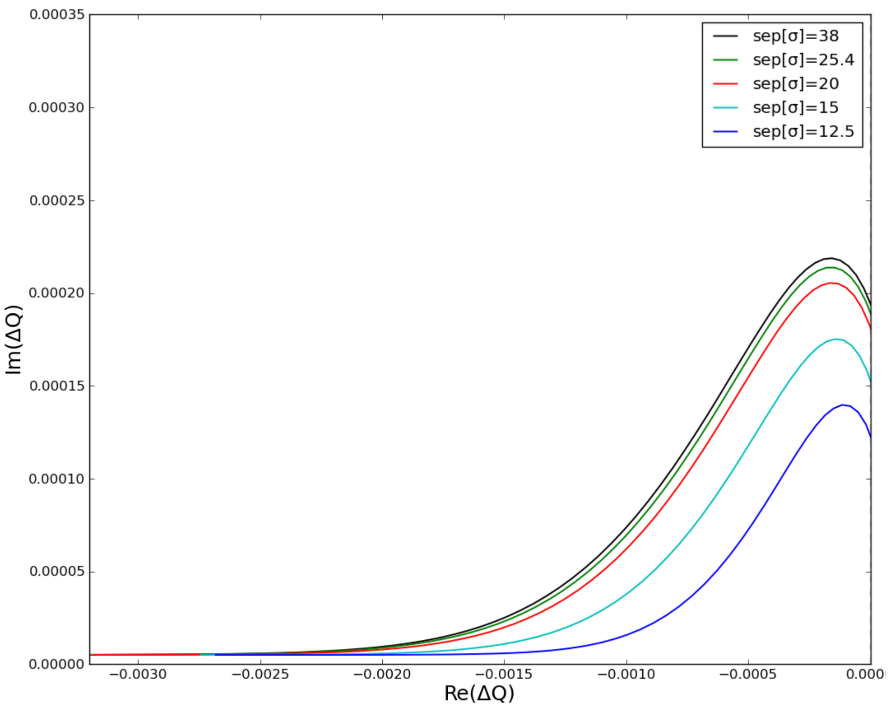


LR + positive LOF

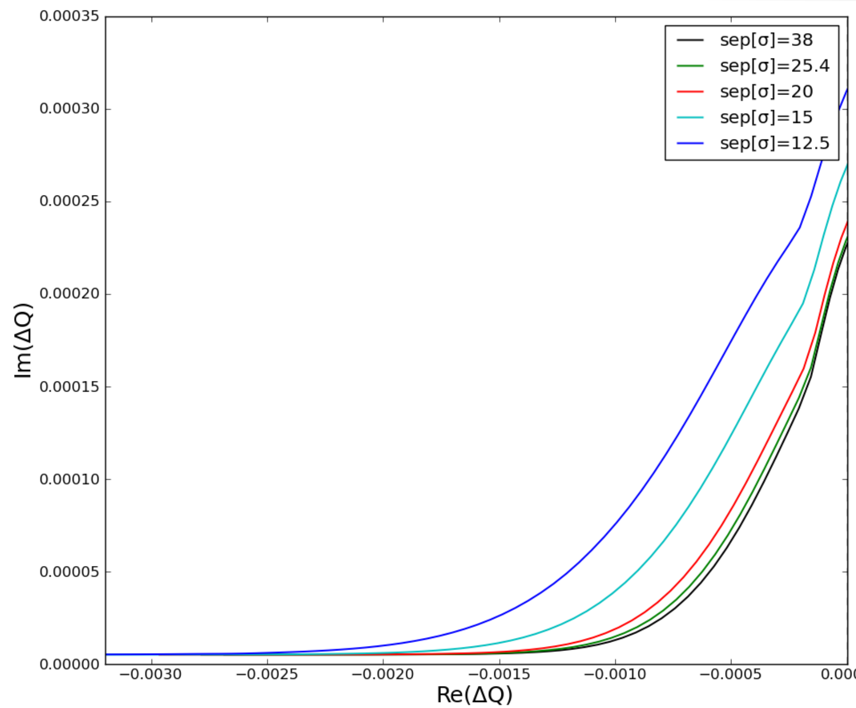


Betatron squeeze for HL-LHC optics

Negative LOF

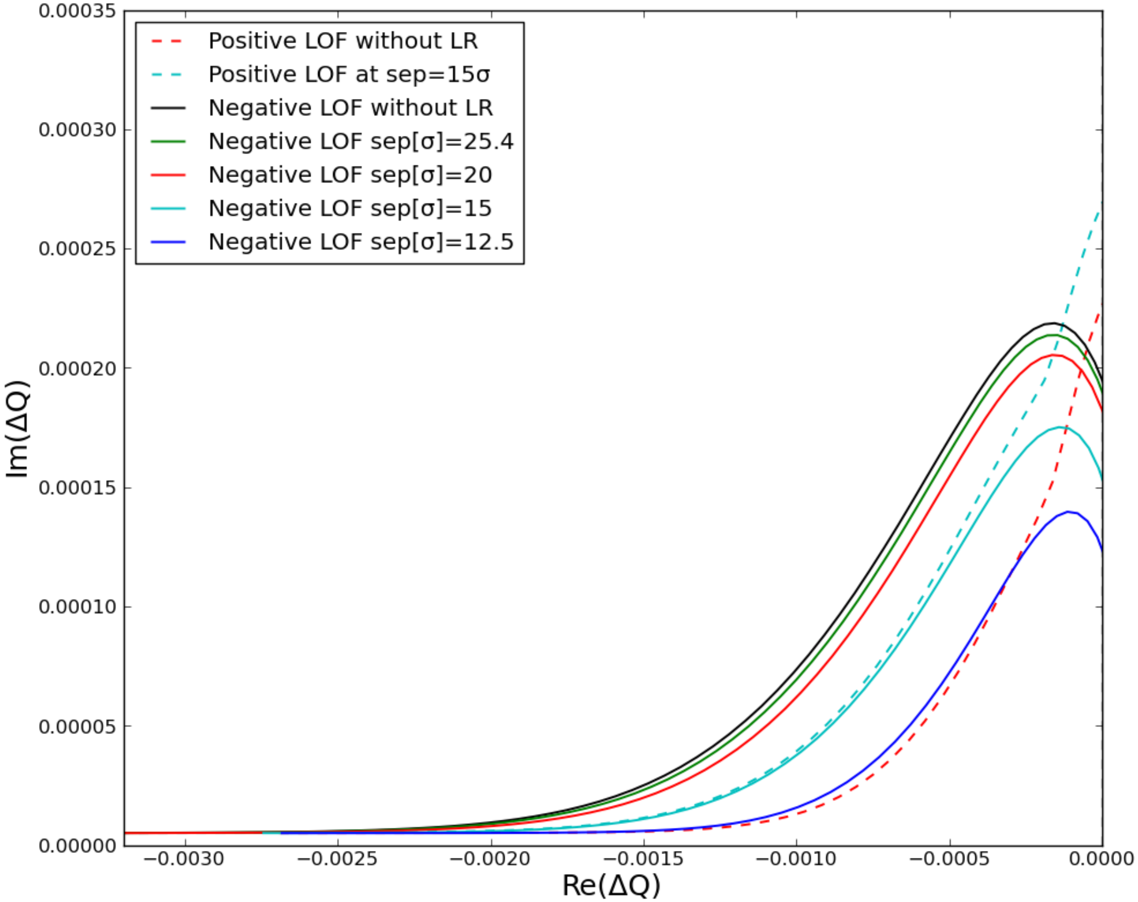


Positive LOF



Until ≈ 20σ separation the negative polarity is preferred
At ≈15σ separation, positive polarity starts to give a greater stability diagrams

Betatron squeeze for HL-LHC optics

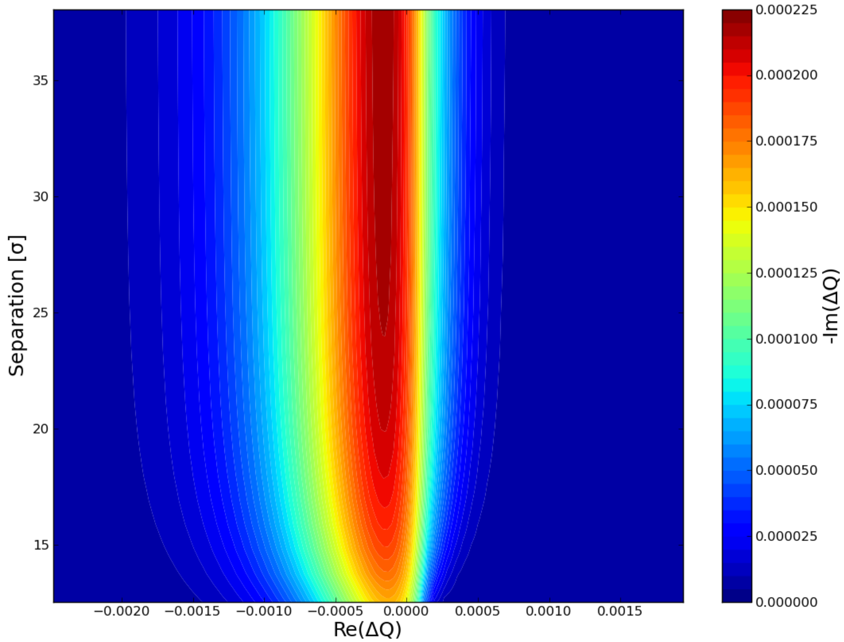


At ≈15σ separation, positive polarity starts to give a greater stability diagrams thanks to LR contribution

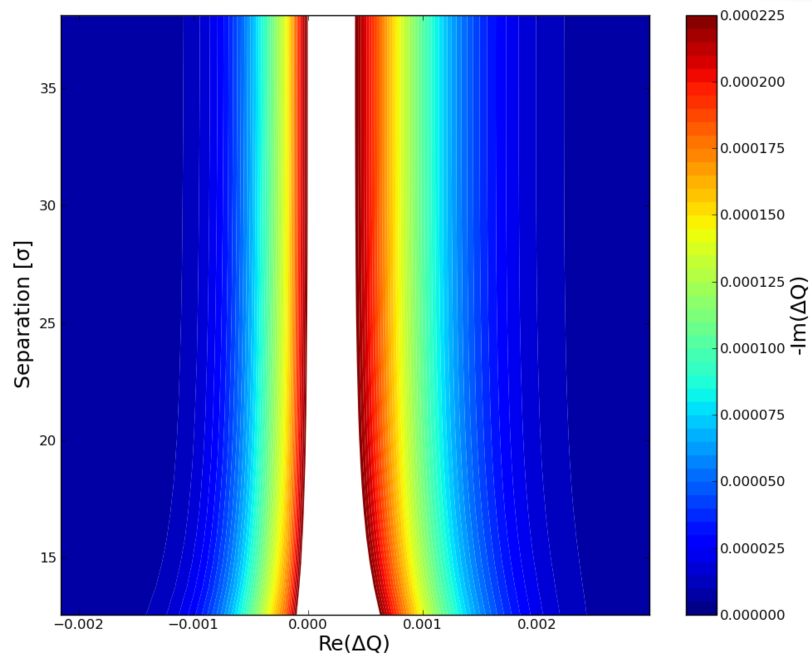
Betatron squeeze for HL-LHC optics PACMAN bunch

Evolution of the betatron squeeze with LR beam beam for PACMAN bunches

Negative Polarity

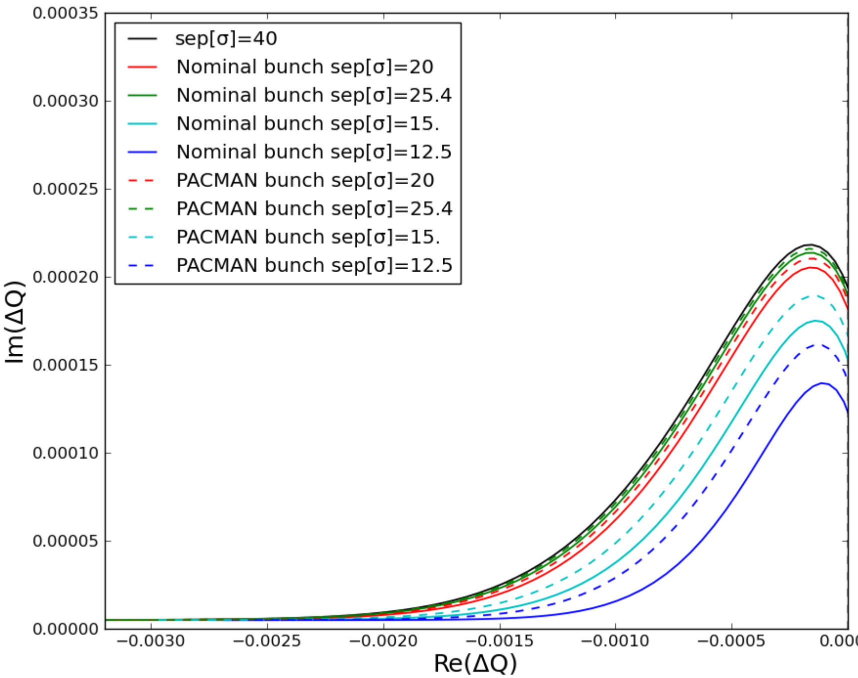


Positive Polarity

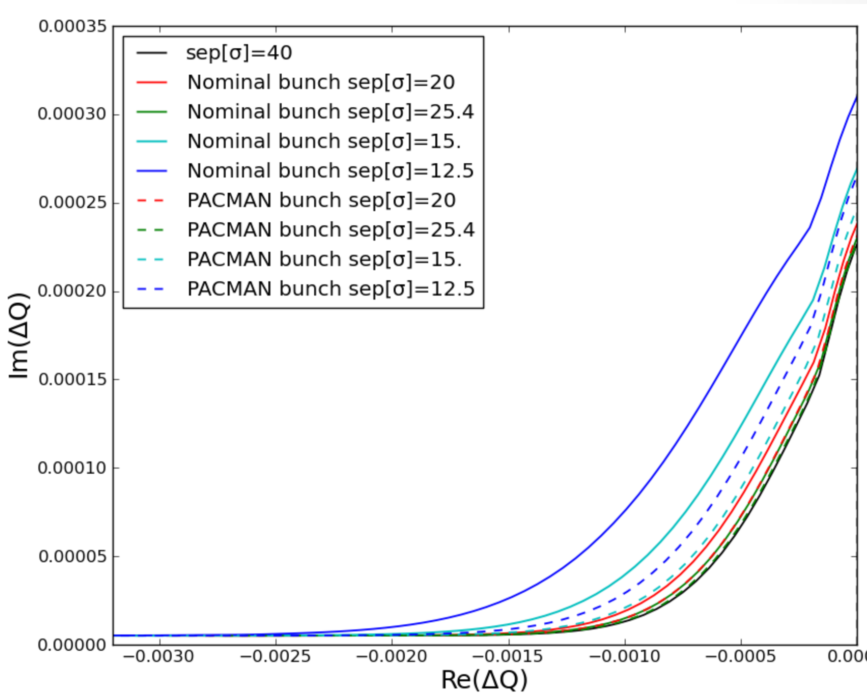


Betatron squeeze for HL-LHC optics PACMAN bunch

Negative Polarity



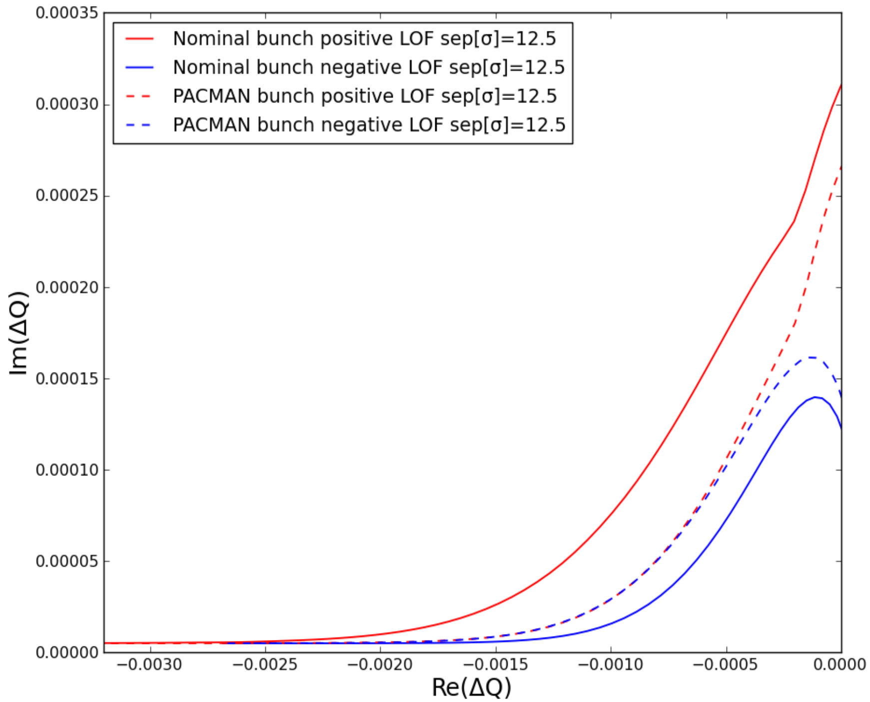
Positive Polarity



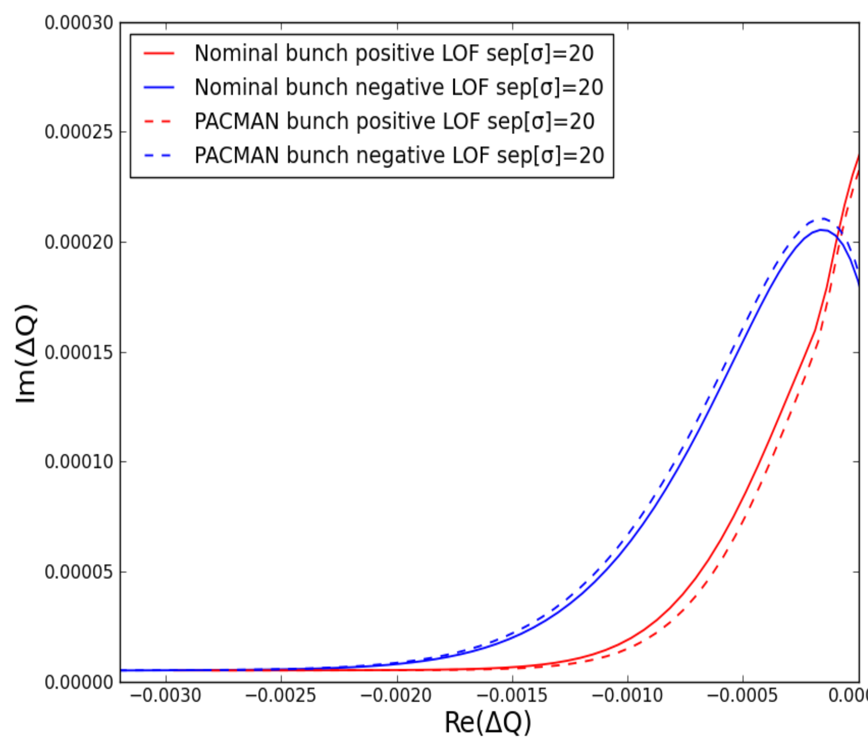
PACMAN bunches: greater SD in case of negative polarity

Betatron squeeze for HL-LHC optics PACMAN bunch

Larger SD for positive polarity at 12.5σ sep (β*=0.15m) for nominal bunch



Larger SD for negative polarity at 20σ sep for both PACMAN and nominal



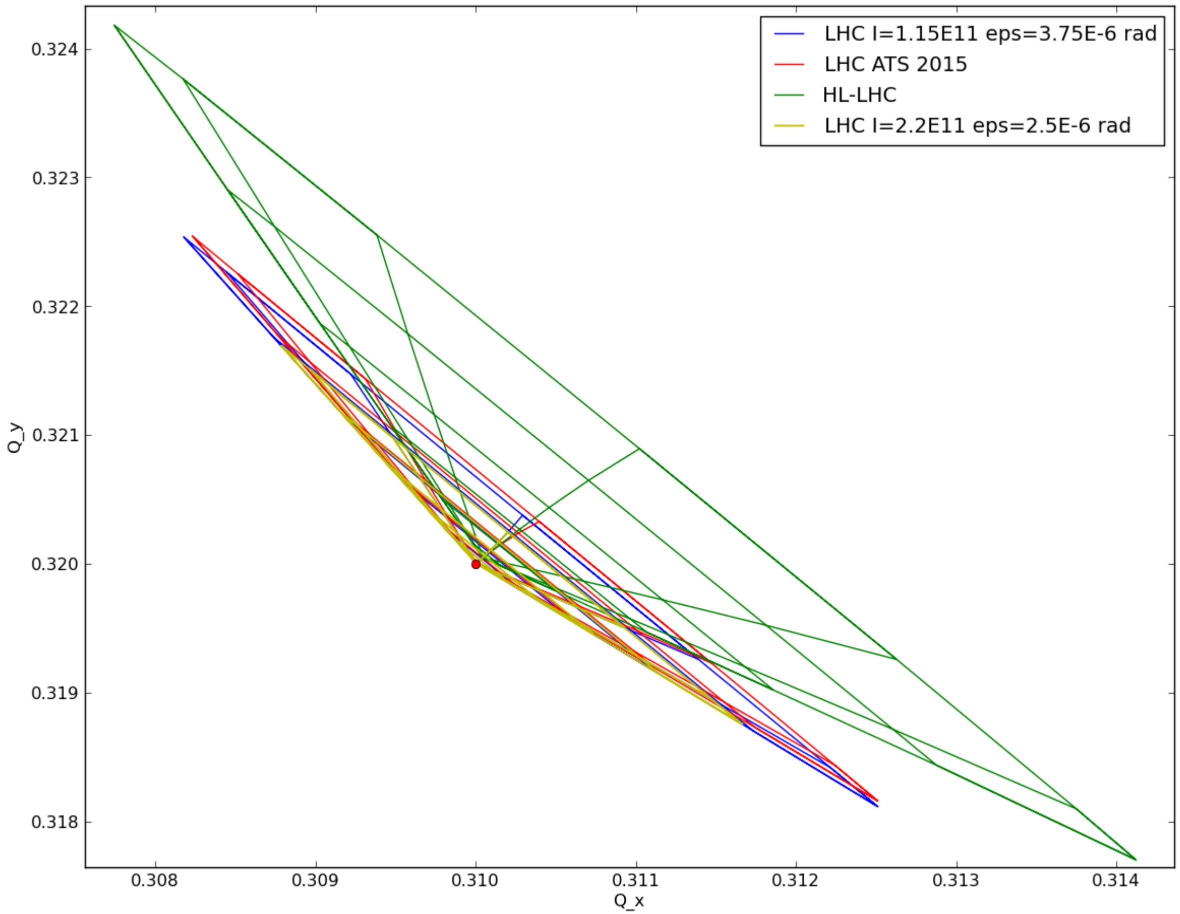
PACMAN bunch: same SD for negative and positive LOF at 12.5σ

Outline

- Simulation tools: set to perform HL-HLC studies
- Footprints and Stability Diagrams have been calculated with octupoles and during the betatron squeeze
- For single beam negative LOF more beneficial on SD, 2.5 larger than the LHC case (thanks to the high β(s) in the arcs)
- For HL-LHC scenario with β* leveling until H-O collision (≈20σ) negligible LR → Negative LOF is preferred
- At 12.5 σsep (β* =15cm) → Positive LOF is preferred
- Simulation tools will be set to to perform HO collision studies (crab cavities, bunch slices)

Backup slides

ATS optics: footprint



ATS optics: footprint