Beam-beam issues for 'phase 1' and 'phase 2'

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CARE-HHH-APD IR'07

Outline

GENERAL

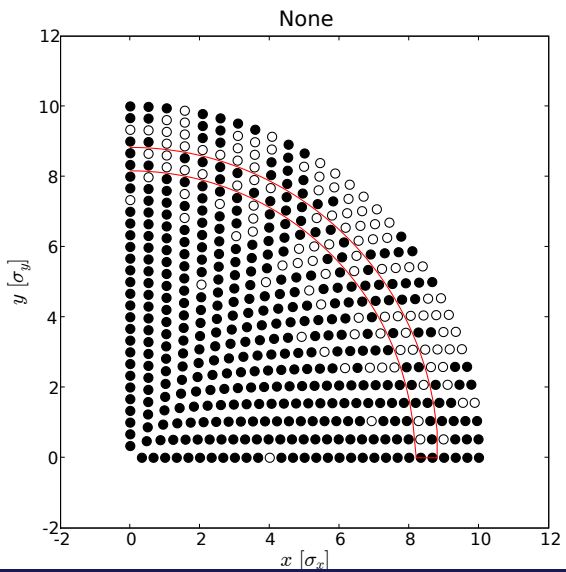
Linear transfer matrices between nonlinear elements

IP1 & IP5 only

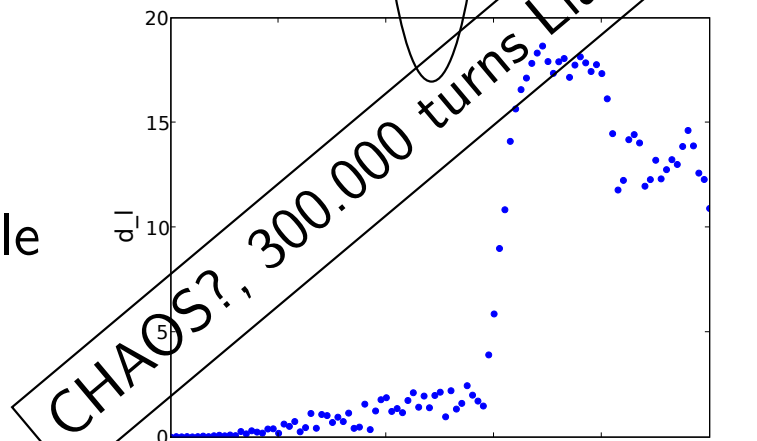
BBTrack

RHIC & SPS BBLR!

BBTrack: weak-strong 6D tracking code



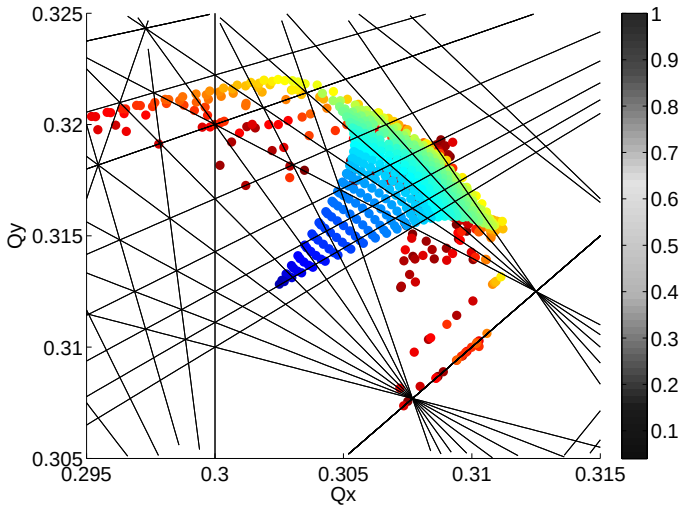
DA? 20 %unstable



CHAOS?, 300.000 turns Liapunov

NOMINAL LHC

- Reminder: 15 LR at each side of the IP with $\theta \approx 300 \mu rad$ ($\bar{d} \approx 9.5\sigma$) at 1.15 p/bunch seem just ok according to simulations and SPS BBLR experiment.
- For comparison: nominal LHC: no wire: $DA = 5.4\sigma$, compensated: $DA = 7.2\sigma$

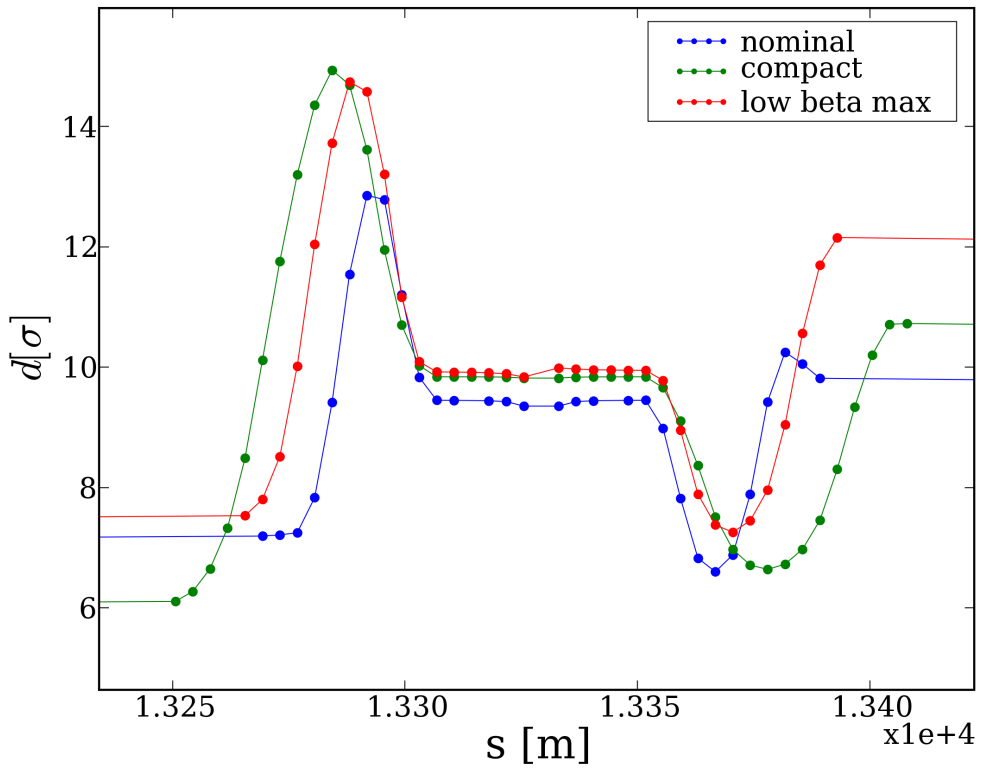


There is no margin!

OUTLINE

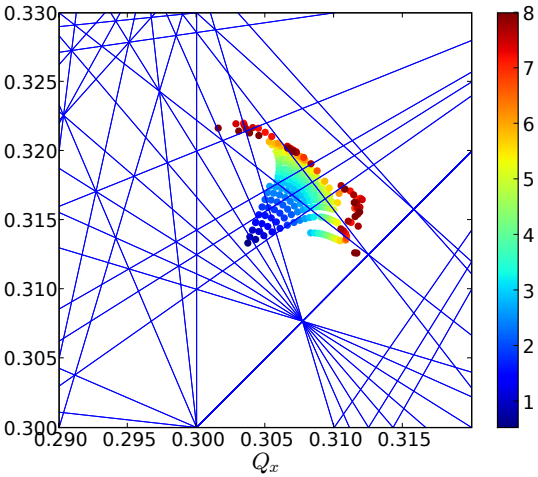
UPGRADE PHASE 1, latest optics version

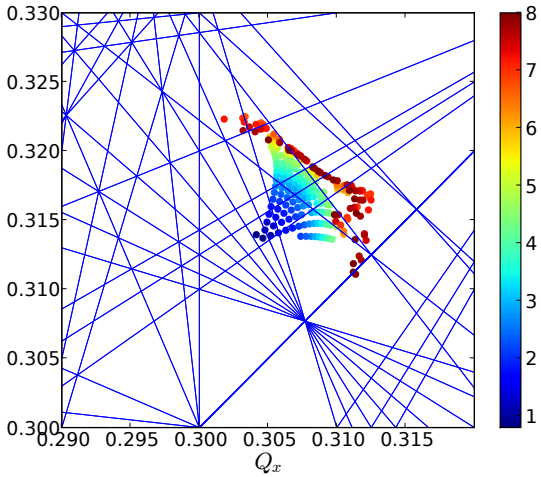
- R. de Maria et al [1] proposed 3 different LHC $\beta^* = 25cm$ optics.
- An increased crossing angle keeps the average beam-beam separation equivalent to nominal LHC $d \approx 9.5\sigma$
- But they differ greatly in length = # of LR encounters and d-spread (for wire compensation)

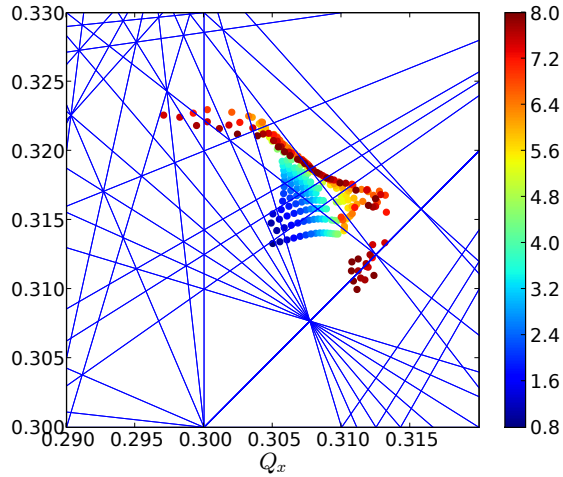


FOOTPRINTS - 8σ @ 1.15E11p/bunch

Where is the footprint folding?



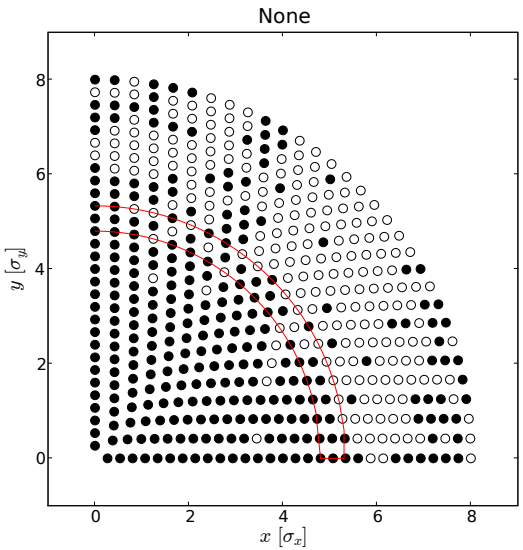




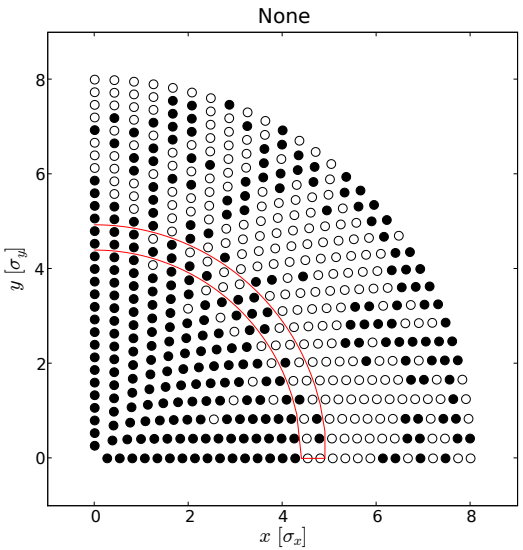
Low β max Compact Modular

The color encodes the initial amplitude

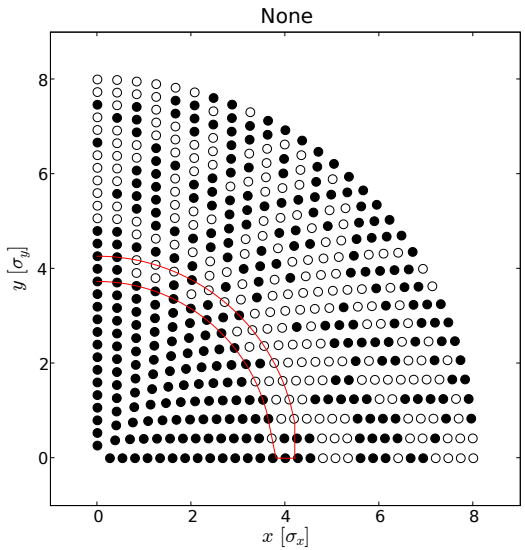
STABILITY



Low β max

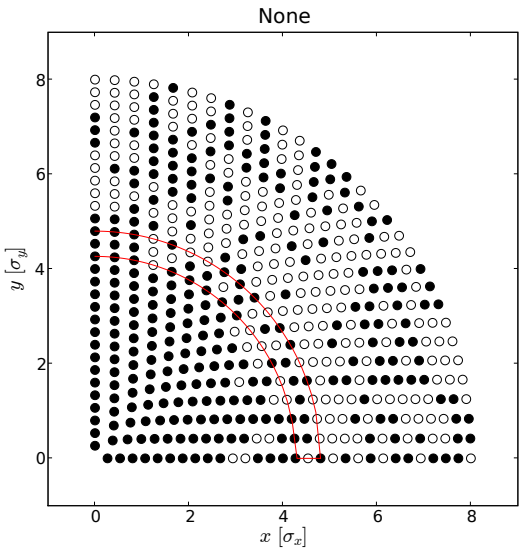


Compact

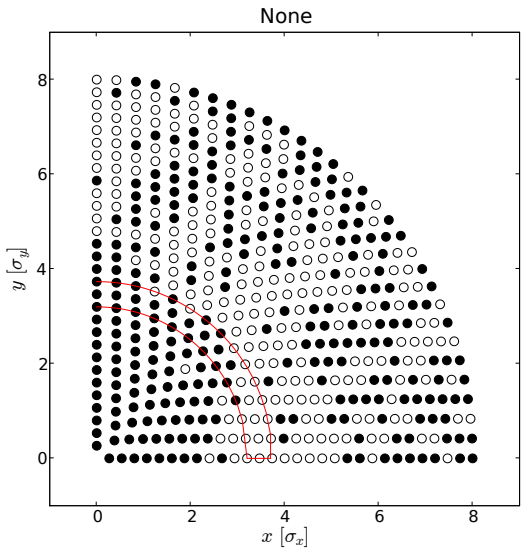


Modular

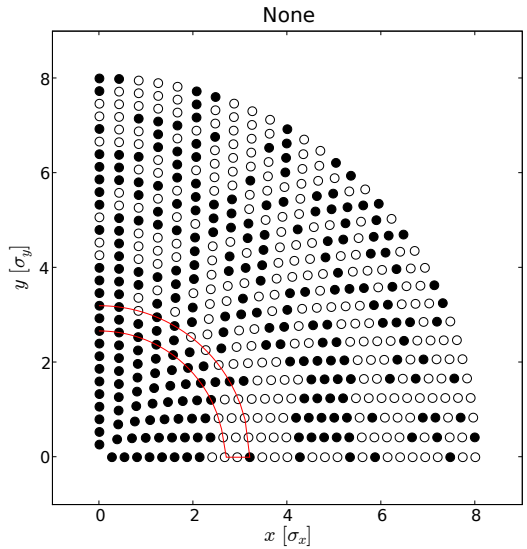
STABILITY - 1.7E11p/bunch



Low β max



Compact



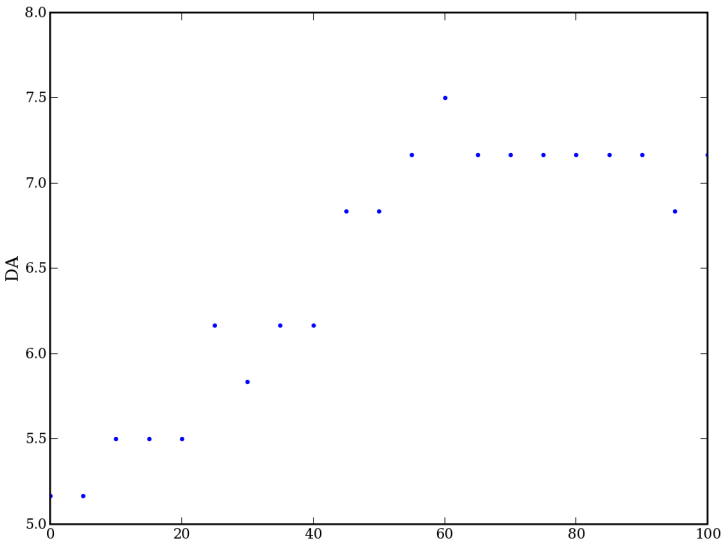
Modular

WIRE COMPENSATION

Feasibility:

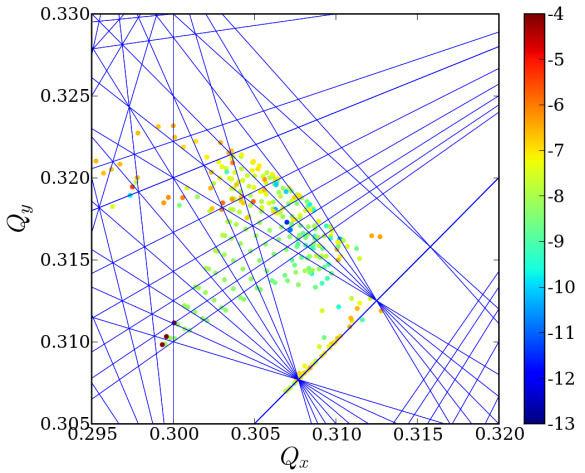
- equal β functions: ok
- β huge: ok
- $d_{bw} > d_{collimator}$: ok
- Separated beam pipes: ok
- $\Delta\Phi$: ok
- $d - spread$: ok

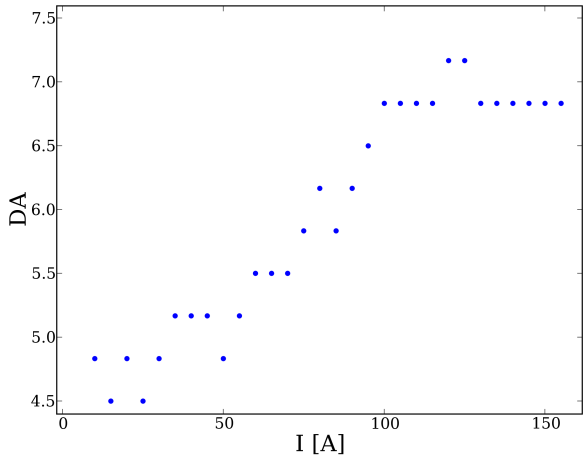
Let's wire compensate the Low β max optics!



1.15E11 p/bunch

1.7E11 p/bunch





PHASE 1 - CONCLUSIONS

- Upgrade Phase 1 seems feasible and should not differ a lot from nominal.
- Mind the triplet length!
- Wire compensation can be tested.
- Low β max optics is the best one.
- Symmetric is equivalent to low β max optics.

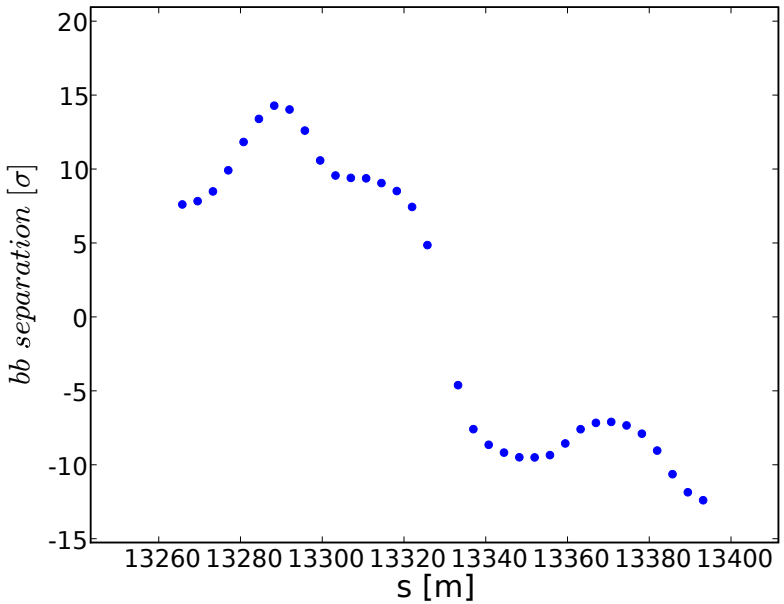
OUTLINE

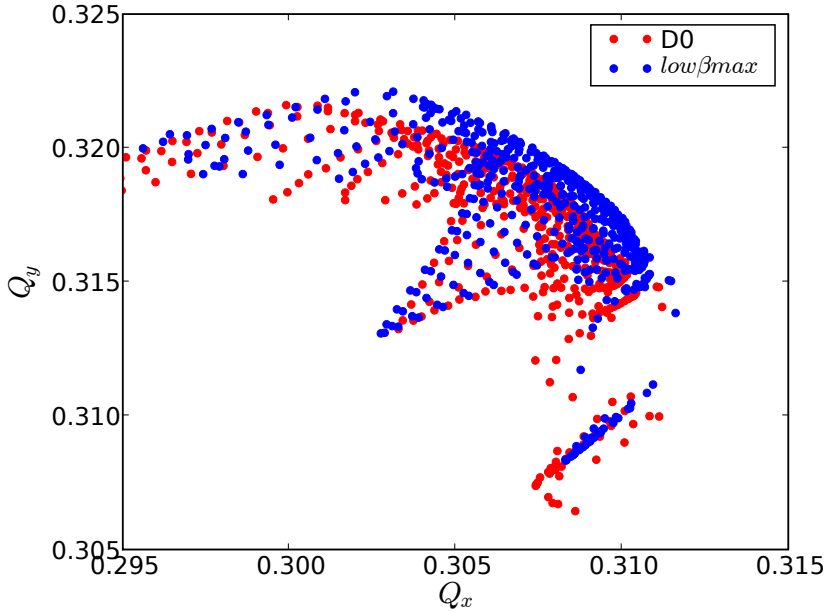
D0- general

- Can we stand two close LR interactions?
- $\beta^* = 0.08m - \sigma \Downarrow \Delta_x \Uparrow$ crab noise
- Is it really "only" 2 close LR encounter? $\beta^* \Downarrow \Rightarrow \sigma_{LR} \Uparrow +$ huge bb separation = large aperture $\rightarrow$ "weaker" magnets $\rightarrow$ longer triplet longer $\rightarrow$ more LR.
- Crab cavity: good luck, Rama!

D0 in low βmax

I got a D0 option implemented in the low β max optics..

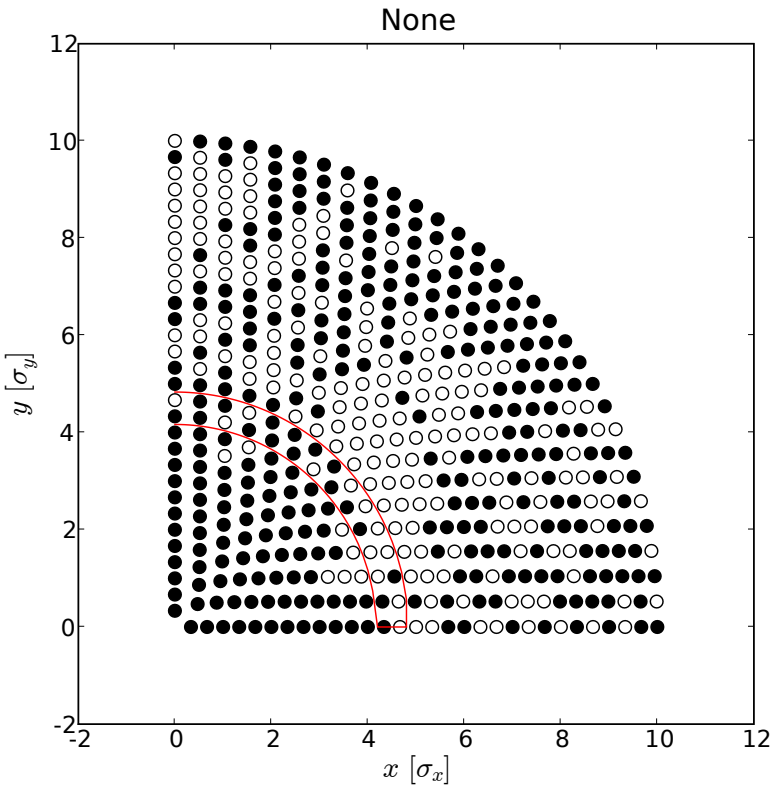




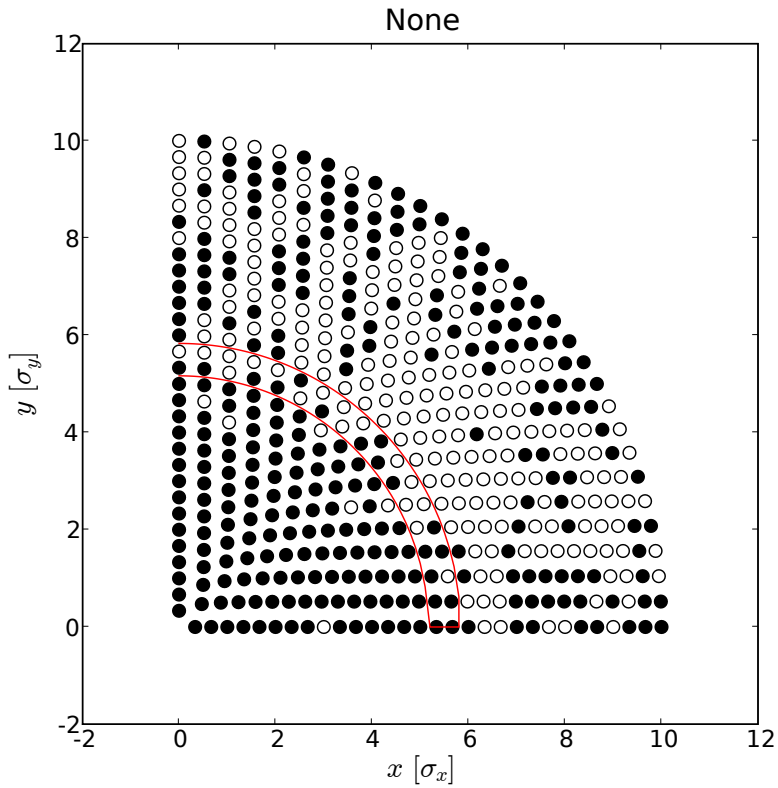
The footprint might look even smaller, but its the folding that occurs at lower amplitudes!

DA with nominal p/bunch

1.15E11 beamcurrent:



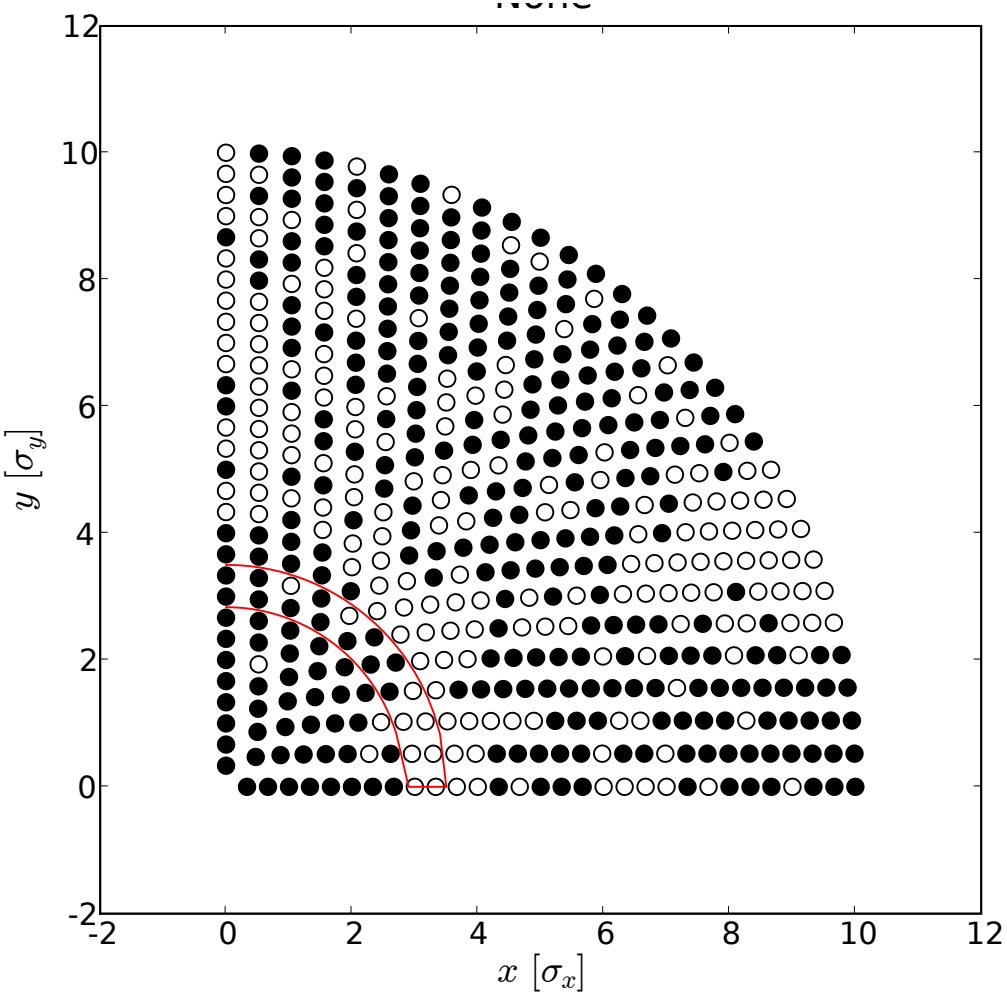
(a) stability for the D0 option



(b) for comparison the stability in the base line low β max optic

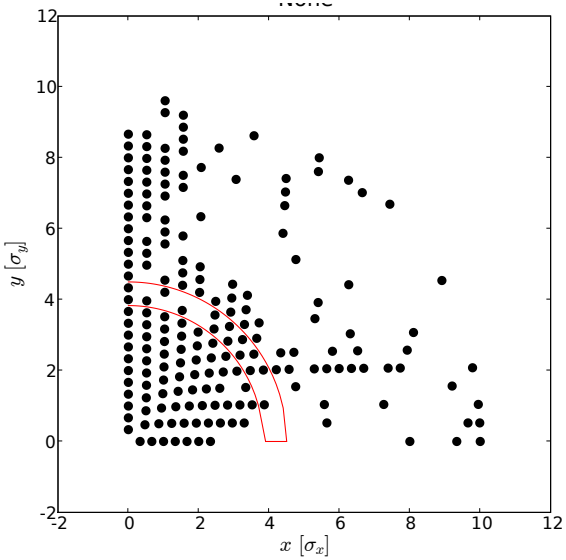
What about the planned beam current

1.7E11p/bunch

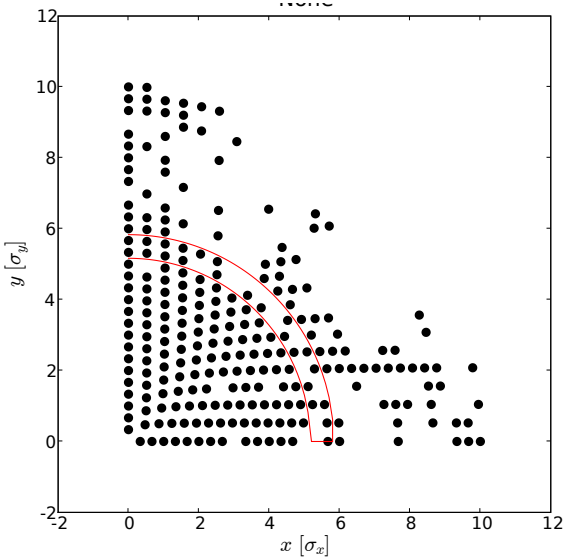


Needs a electron lens for compensation!

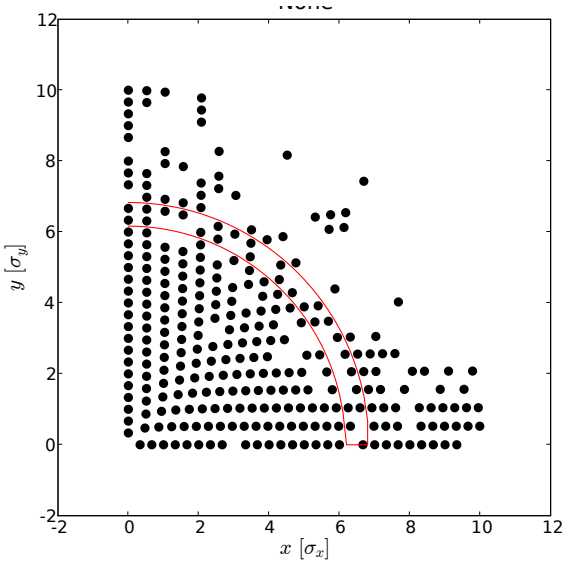
only 2 LR encounter per side per IP at 1.7E11p/bunch?



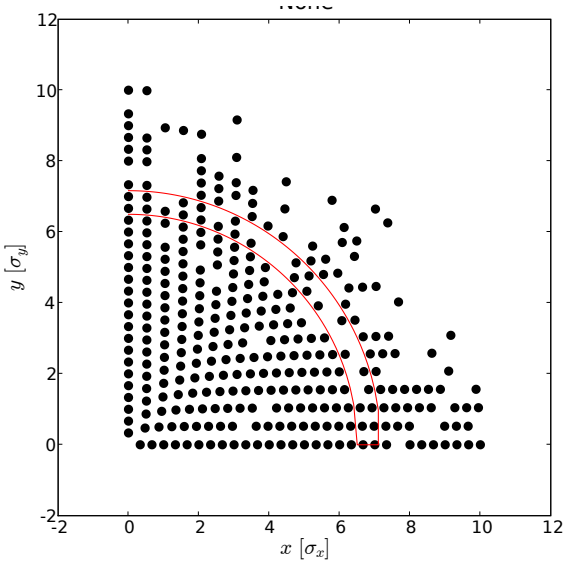
5σ



6σ



7σ



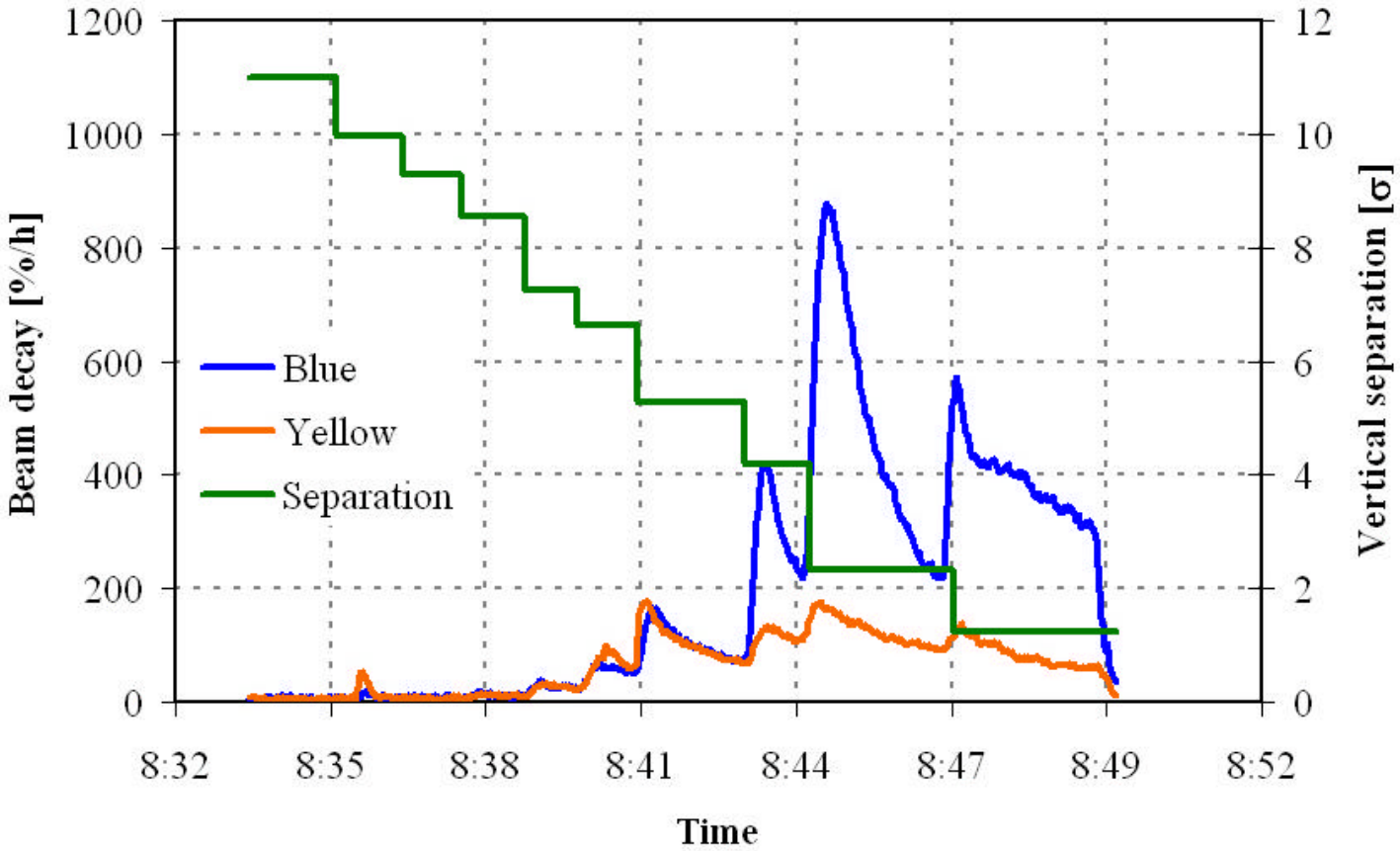
8σ

RHIC

- Big issue is the emittance measurement e.g: last MD values from 18 to 42 for different bunches - changes a lot including: beam-beam/ beam-wire distance and the slope of loss rate.
- RHIC wire results agree reasonable with the simulations (inj & top).
- There is more data than always cited.
- Great job by the RHIC BBLR team.

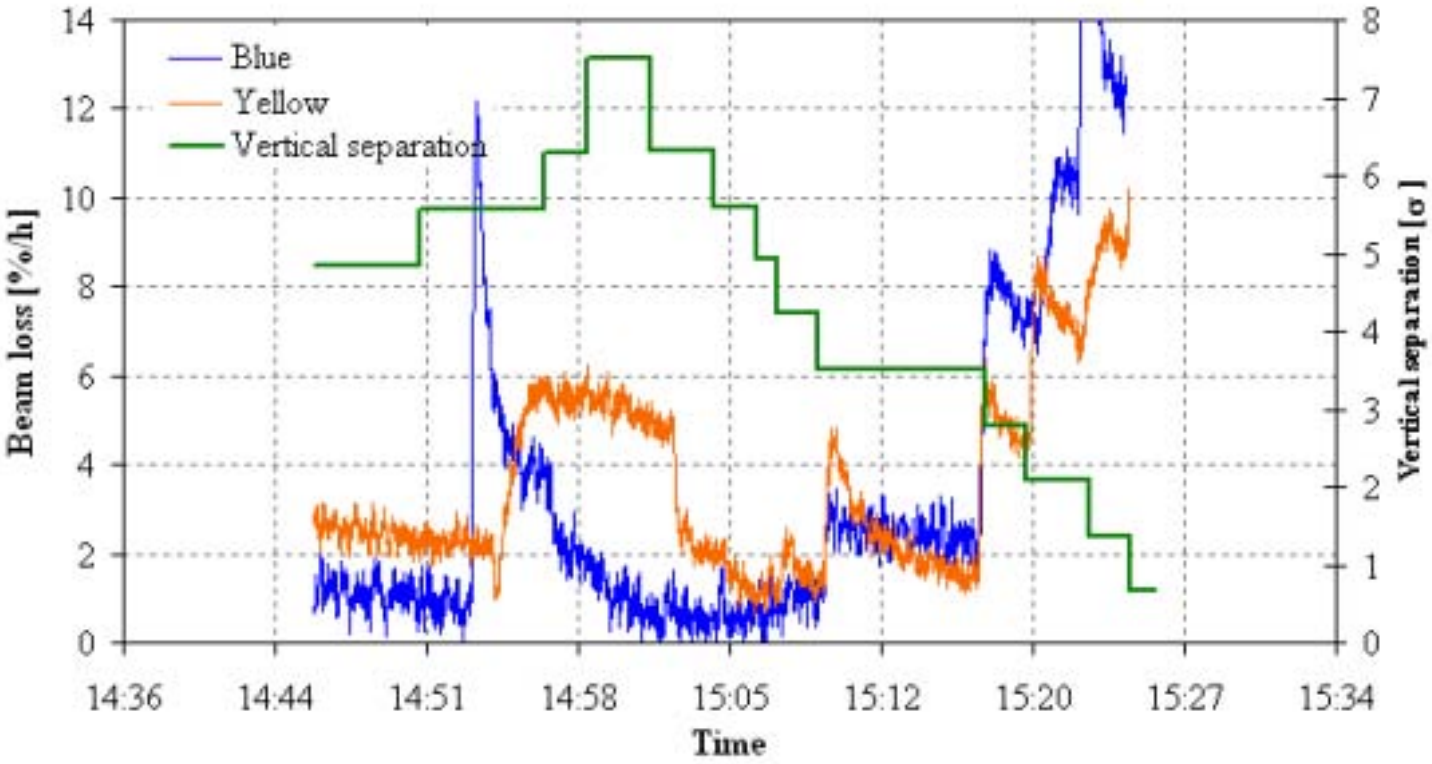
RHIC EXPERIMENTS - Beam-beam @ injection

Collision at s = 0 m, Blue beam moved vertically
Tunes B (0.733,0.722) Y (0.727,0.723)



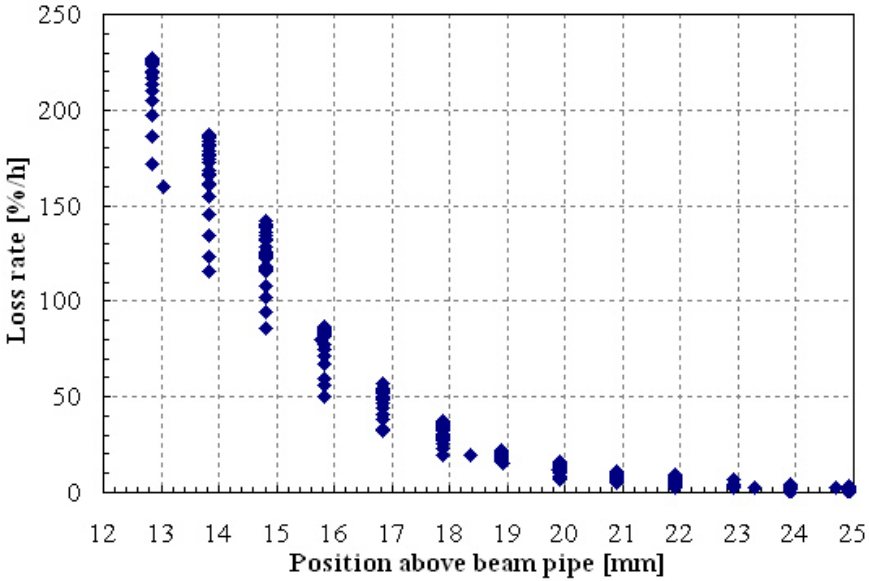
All 4 data set show the same results: loss at 8σ. Note decay shape.

RHIC EXPERIMENTS - Beam-Beam @ top

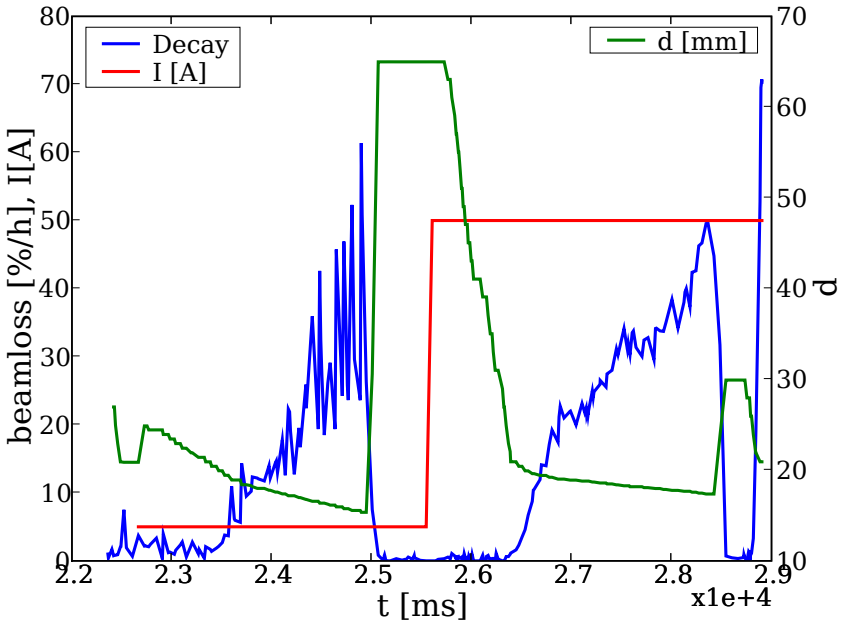


This top LRBB experiment is source of many discussions, but fits to simulations

BBLR at injection and Top (100GeV Ions)



$\sigma = 1.1mm$, injections



$\sigma = 4mm$, top

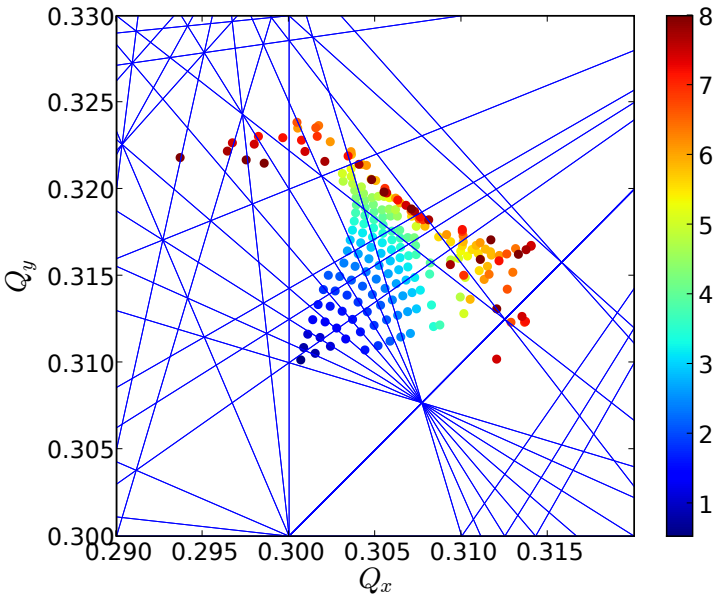
D0 - CONCLUSION

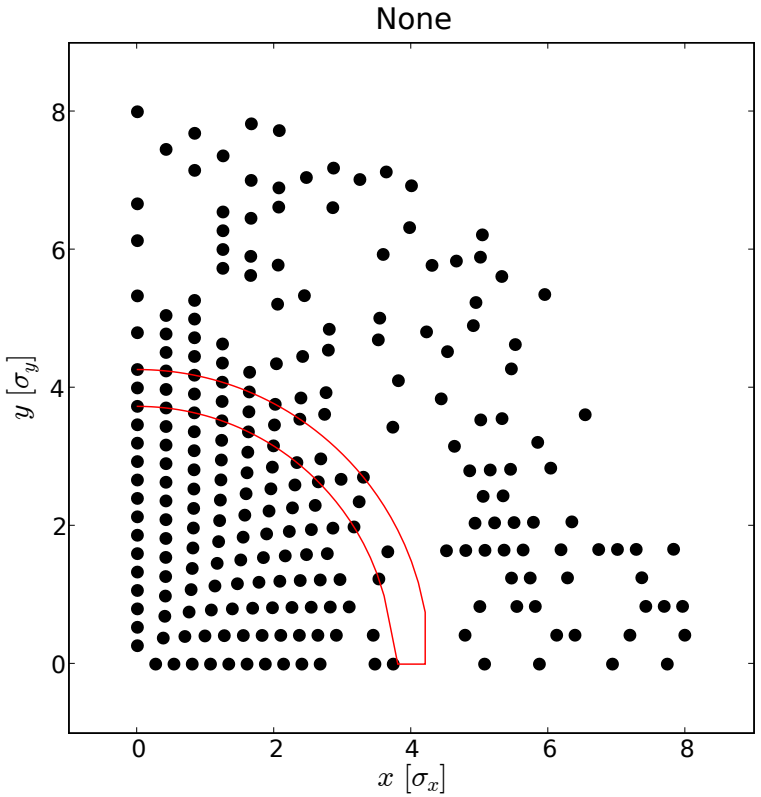
- We need a realistic optic asap.
- For me the SPS and RHIC experiments are benchmarking. RHIC experiments: 1LR per side per IP means trouble.
- Missing HO is a serious issue: e.g: low β max: With HO at 1.7E11: DA=4.5, NO HO at 2.5E11 $\rightarrow 5\sigma$!! (This might be the reason why my simulations for the last RHIC Md failed)
- RHIC MDs.
- Tevatron (only LR + HO hadrion collider): Removing one close LR incresed performance significally.
- Nobody said, it's going to be easy.

LPA

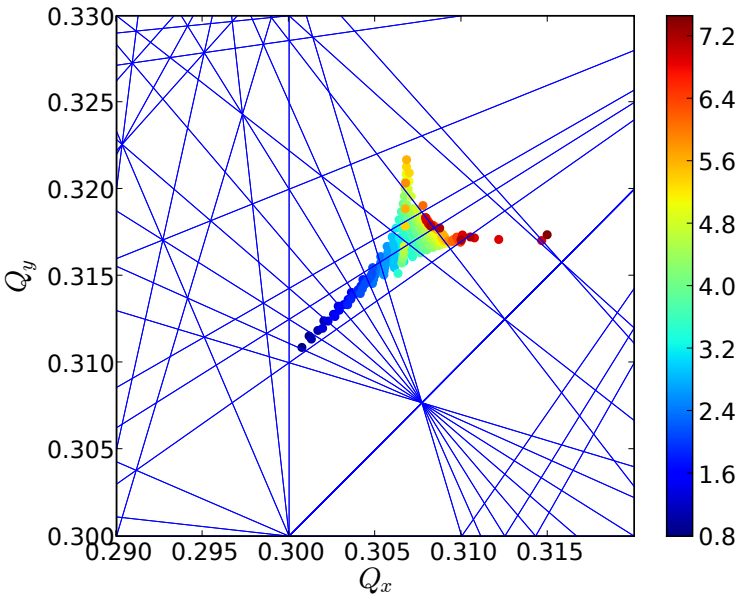
- $4.9E11$ p/bunch at 50ns spacing $\rightarrow$ LR $\times$ 2.5 compared to nominal.
- σ_z 11.8 cm - Chromaticity = tunemodulation (see RHIC and SPS)
- $\theta_{full} = 381\mu rad$ with flat beam: synchro betatron resonances for many particles
- How to handle long flat beams in HO? Need more experience (Using Hirata formalism, δp for DA?),

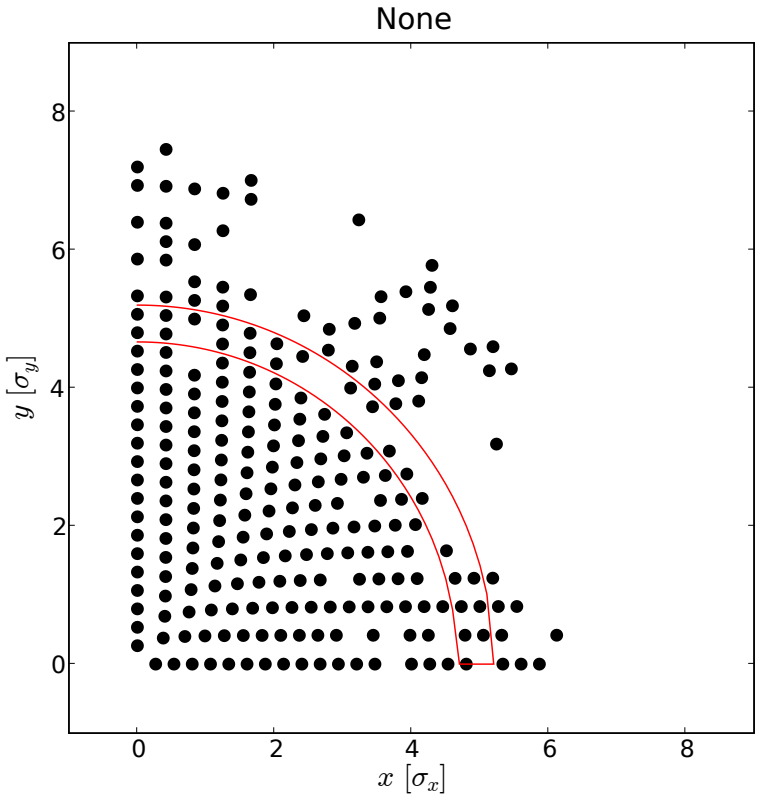
no compensation





wire compensated





LPA - conclusions

- Wire compesation must be built in upgrade phase 1 at least to experimentally prove it.
- Phase 1 will give good hints and allow good benchmarking if the same/similar optics is used.
- Room for improvement by crab cavities,....
- Is this DA enough?
- Requires more detailed studying of the tilted HO?

OUTLINE

Conclusions & Thanks

- Upgrade 1: Low β max is best and can operate up to 1.7E11p/bunch with wirecompensation
- Upgrade 2: In case of the LPA: Nominal and Upgrade Phase 1 are a test bench for BB and wire.
- Will there be a possibility to test a D0 like setup in nominal LHC
- D0 needs a full optic asap
- Noise issues are similar from crab cavity to pulsed BBLR (both resonant structures)
- Clarify remaining MD incosistenies at RHIC. (can we force a footprint folding?)

Thanks to:
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R. Calaga, R. Tomas, J.P Koutchouk, G Sterbini
The RHIC BBLR team