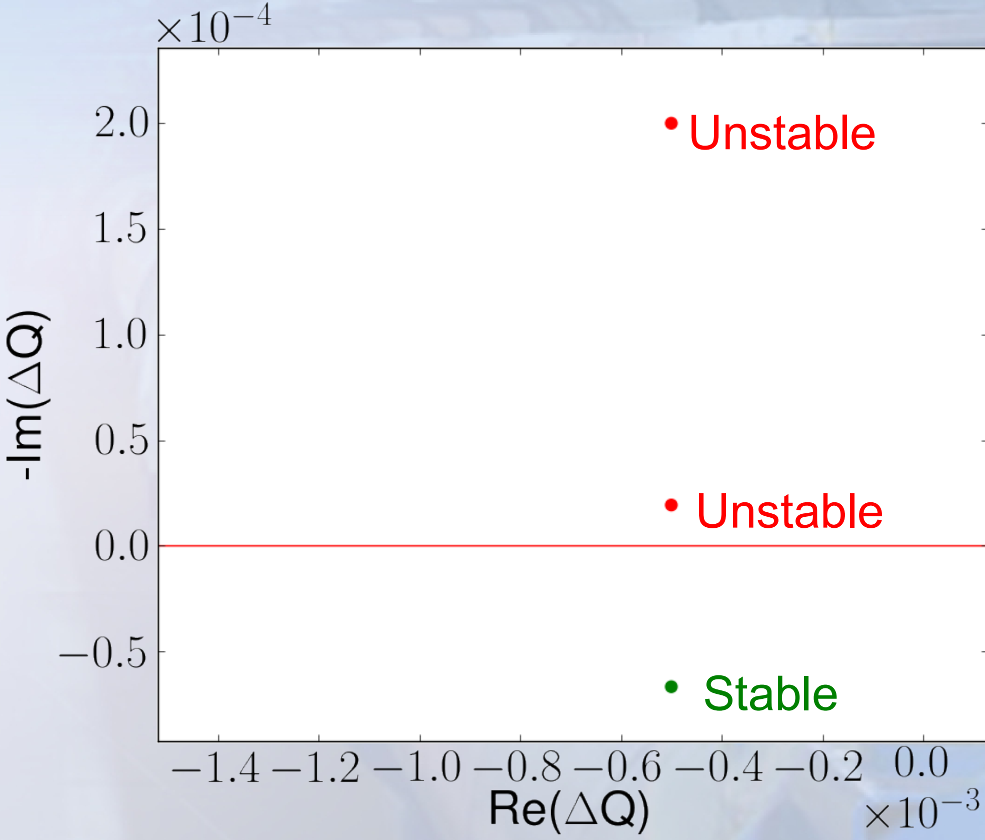
- **ICE action 8 (XB and AB)**: Clarify the situation with the stability diagram in the presence of both octupoles and LR beam-beam

Stability diagrams

- An oscillation mode is represented by its complex tune shift
- It depends mainly on :
  - The machine impedance
  - The beam intensity
  - The chromaticity
  - The nature of the mode

$$\vec{x}(t)=\vec{x}_0 e^{i\omega(Q+\Delta Q)t}$$

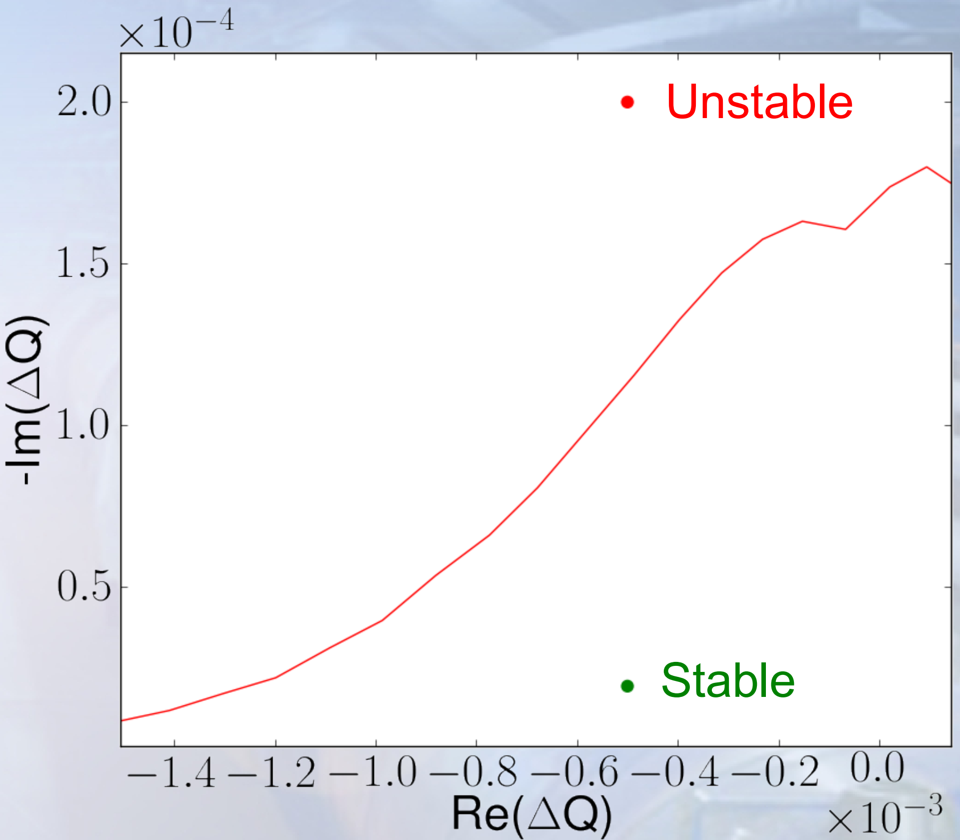


Stability diagrams

- Representation of the effect of Landau damping on impedance driven mode

  → The limit of stability is higher than Im(ΔQ) = 0

- Depends mainly on :
  - The amplitude detuning
  - The beam distribution (i.e. the beam emittance)



Models :

- Tracking with MAD-X
- Numerical evaluation of the dispersion integral
- (**Py**thon **S**olver for **S**tability **D**iagrams)
- Full LHC complexity included but :
  - *"Large"* computing time
  - Numerical noise

2D dispersion integral, without coupling

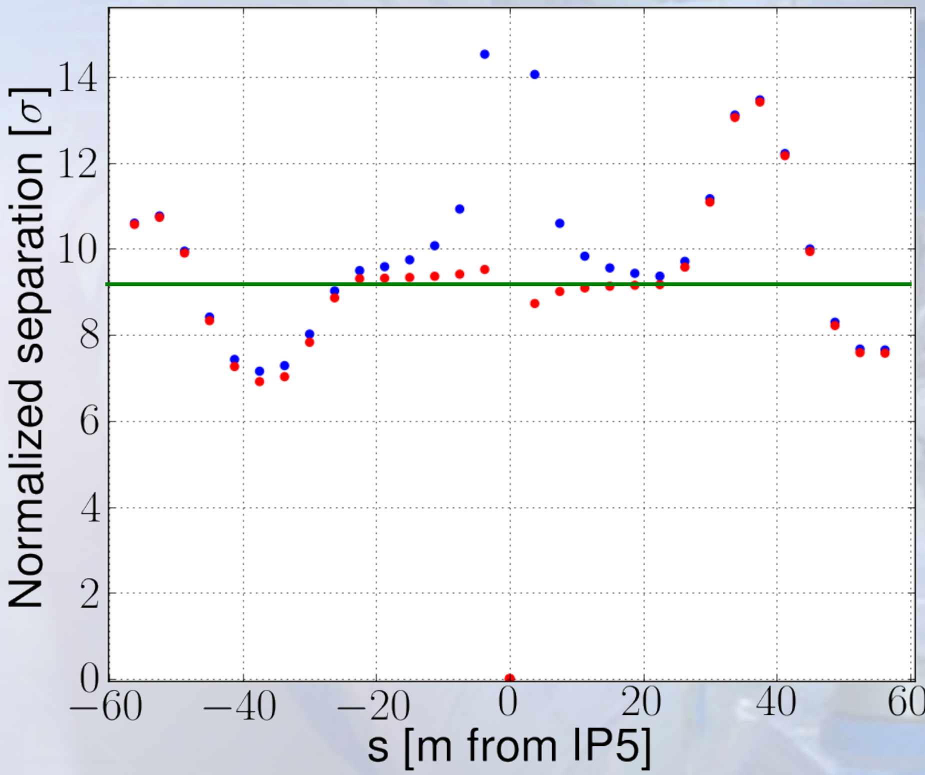
$$\frac{-1}{\Delta Q}=\iint \frac{J_x \frac{\partial \Psi}{\partial J_x} dJ_x dJ_y}{Q_0 - Q_x(J_x, J_y)}$$

Models : AB approx

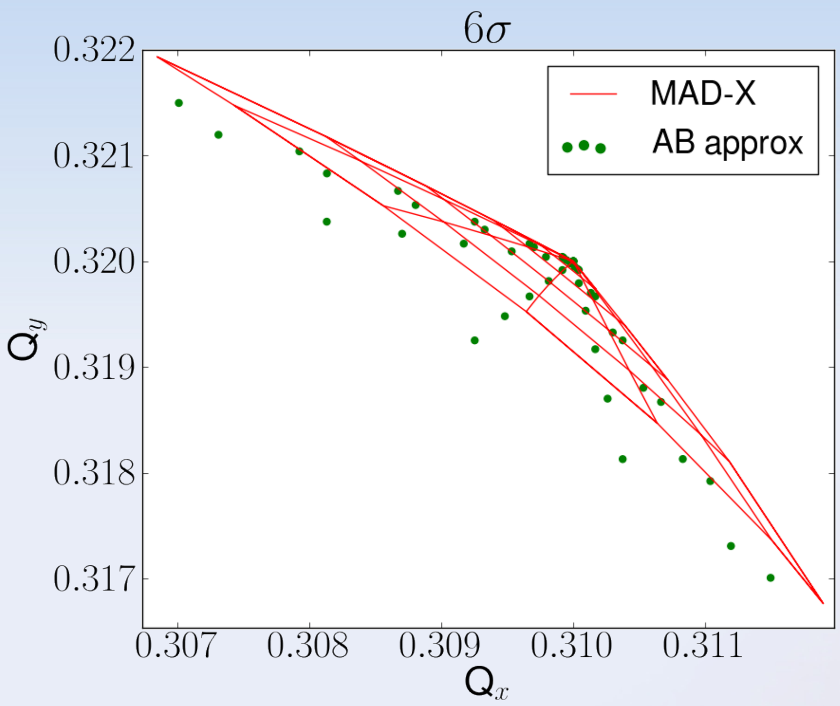
$$\Delta_{bb}Q_x^{(1)} = \frac{3\,|\Delta_{bb}Q_x^{(0)}|}{2r^2}\frac{J_x - 2J_y}{\varepsilon}$$

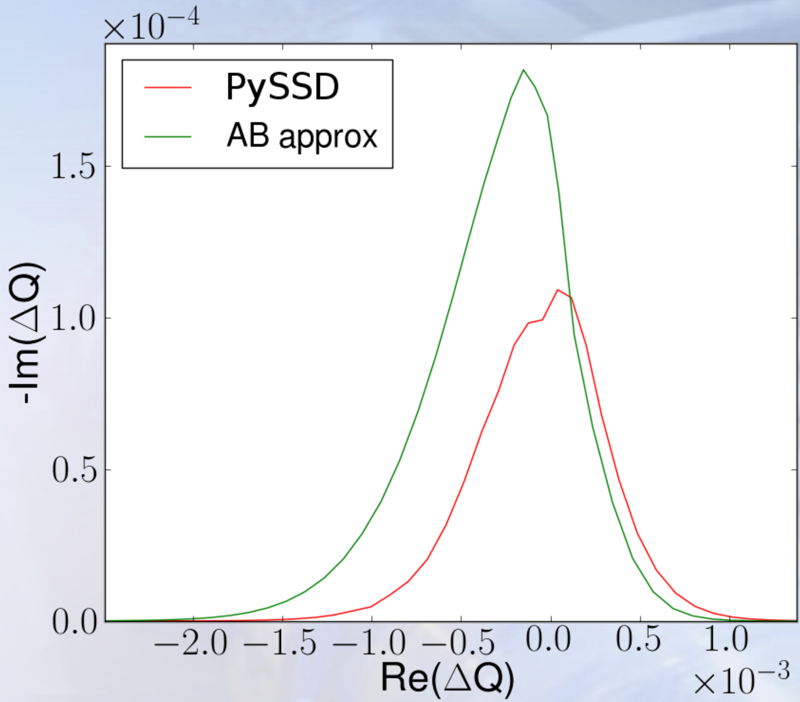
- $\Delta_{bb}Q_x^{(0)}$ is the tune shift for a single IP, AB uses 2.5E-3
- r is the normalized separation, AB uses 9.3
- Total detuning with IP1&5 is twice $\Delta_{bb}Q_x^{(1)}$
  - Linear detuning (r >> 1)
  - Constant separation
  - No // separation
  - IP1&5 only, with alternating Xing

MAD-X tracking without // separation
MAD-X tracking with // separation
AB approx



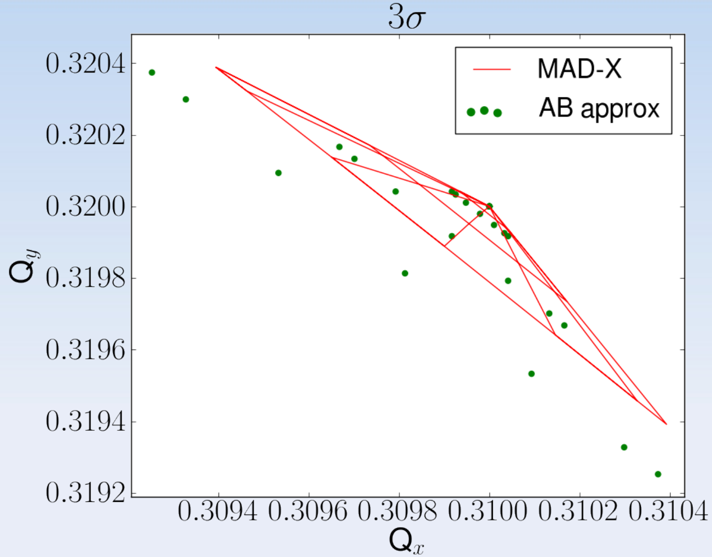
Comparison without // sep

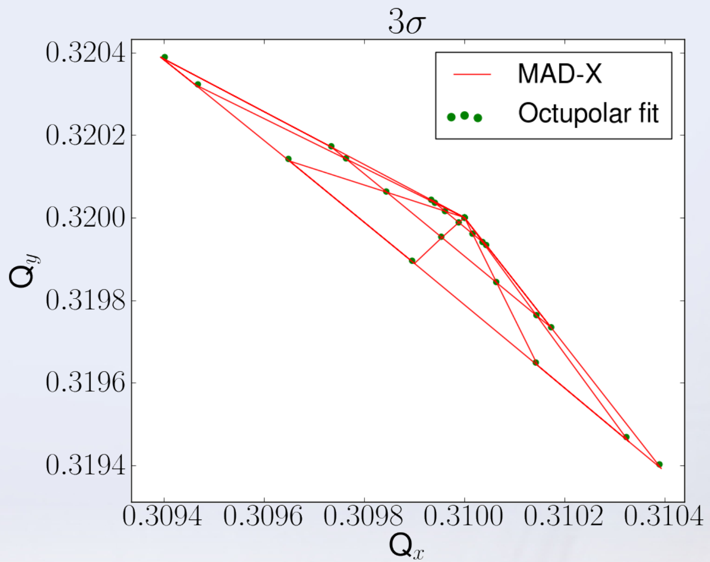


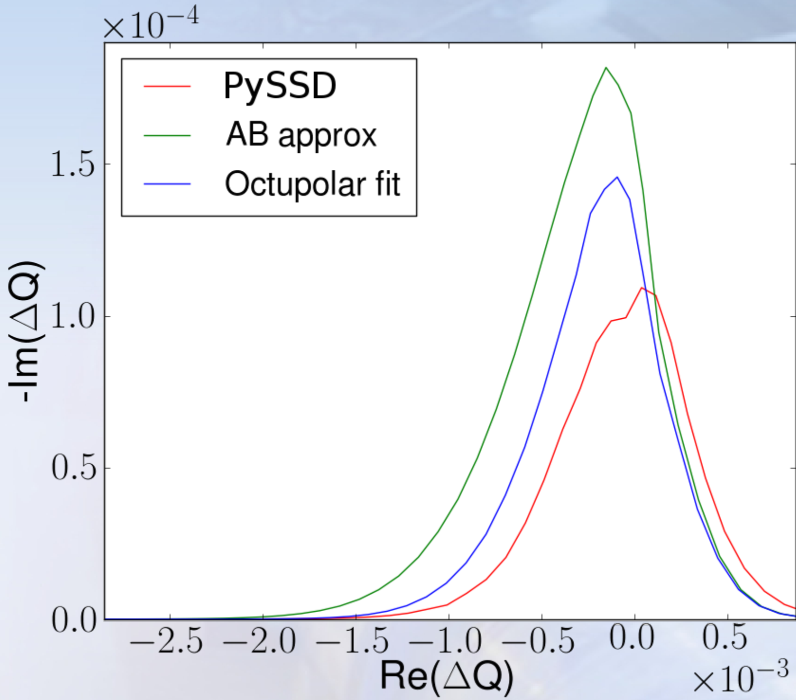


- Why such a large impact on the stability diagram ?

Comparison without // sep

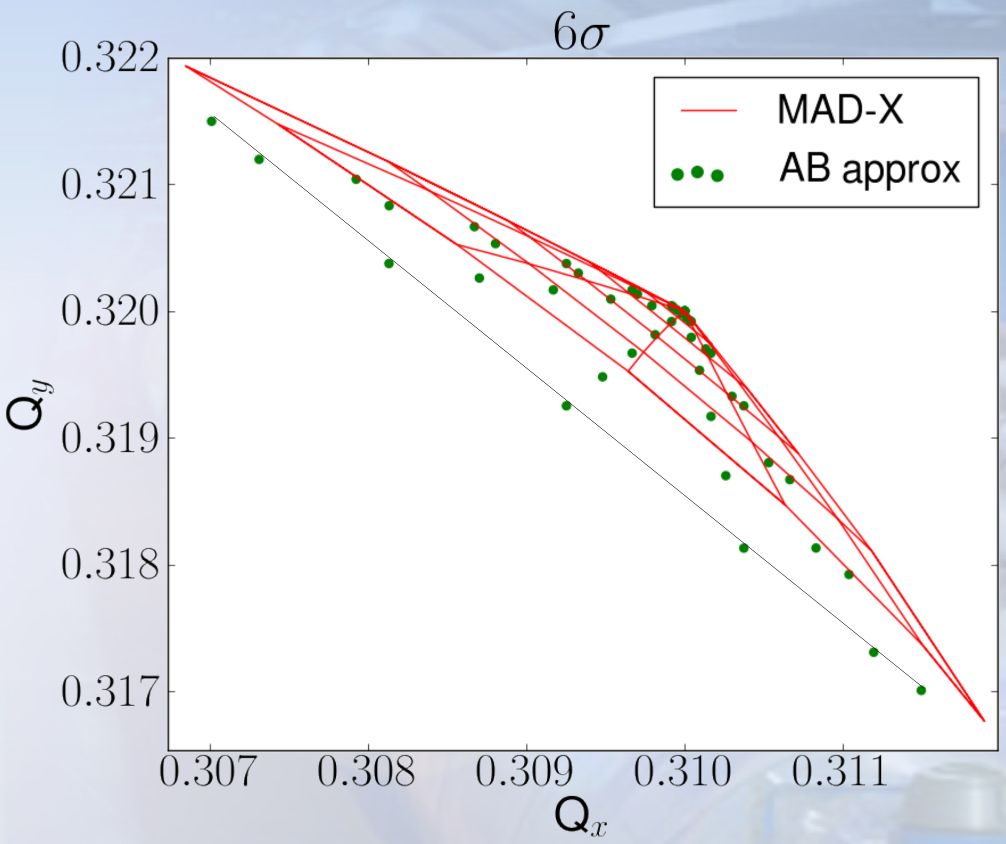






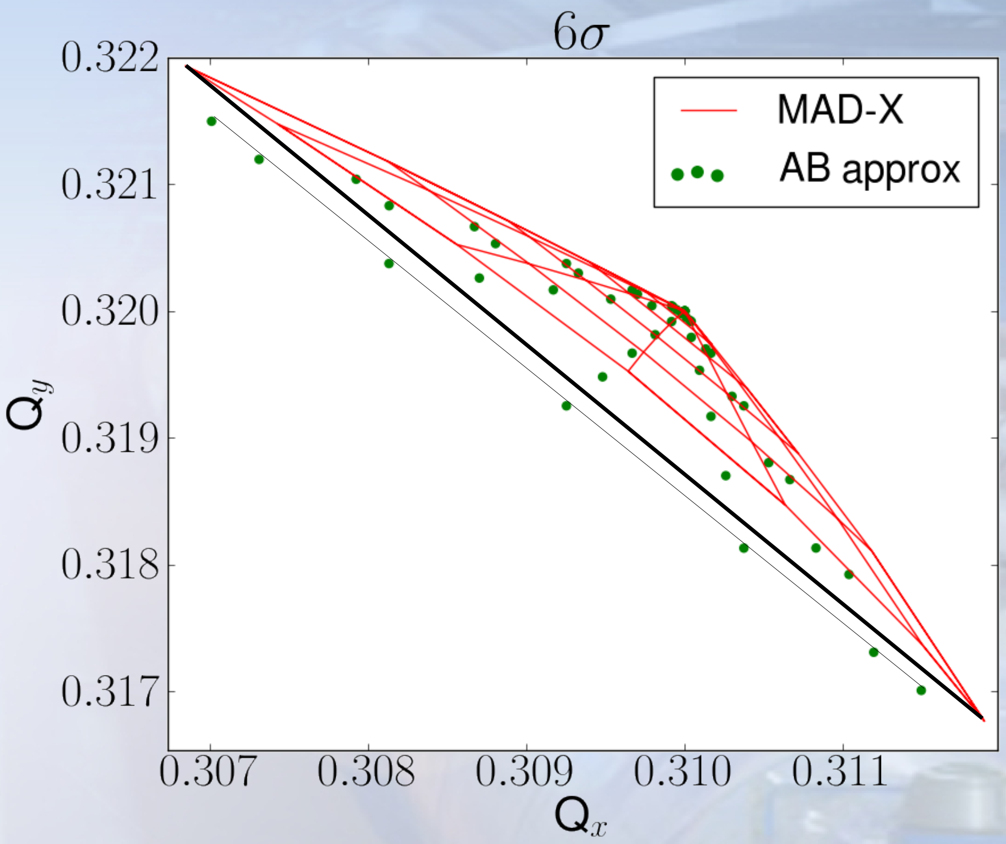
- Linear detuning is over-estimated

Long-range non-linearity

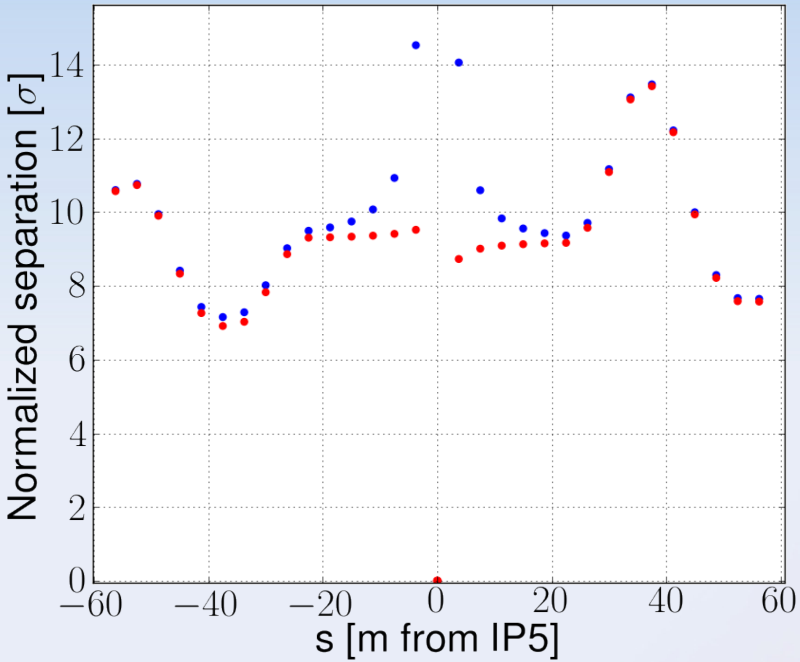


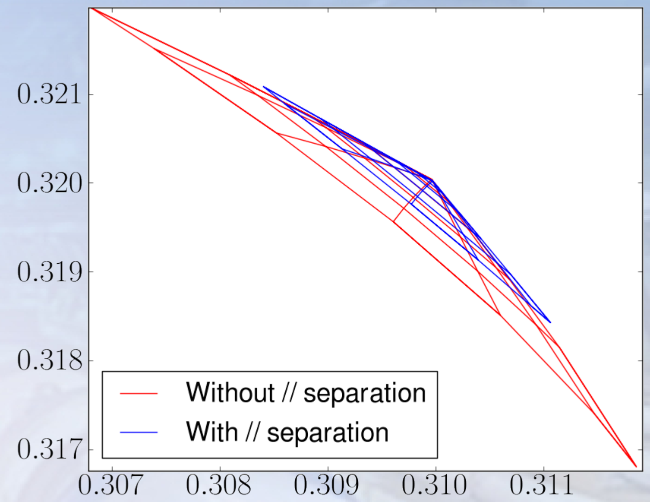
Long-range non-linearity

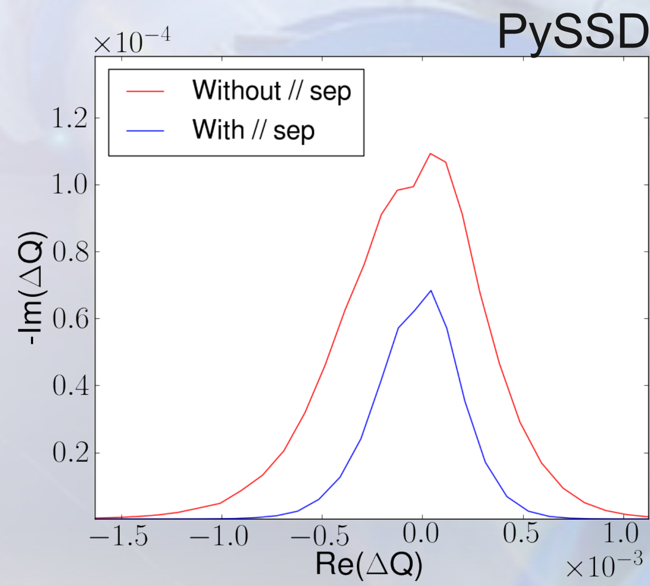
- Long range is not an octupole



Effect of the parallel separation



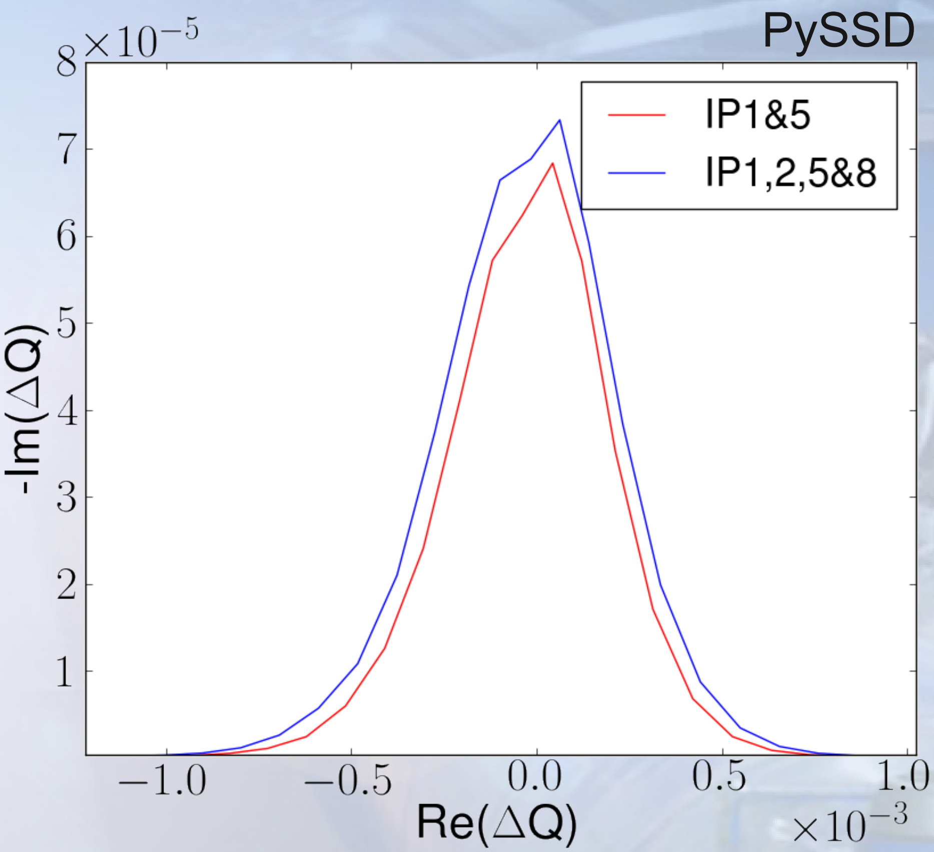




- Parallel separation does play an important role

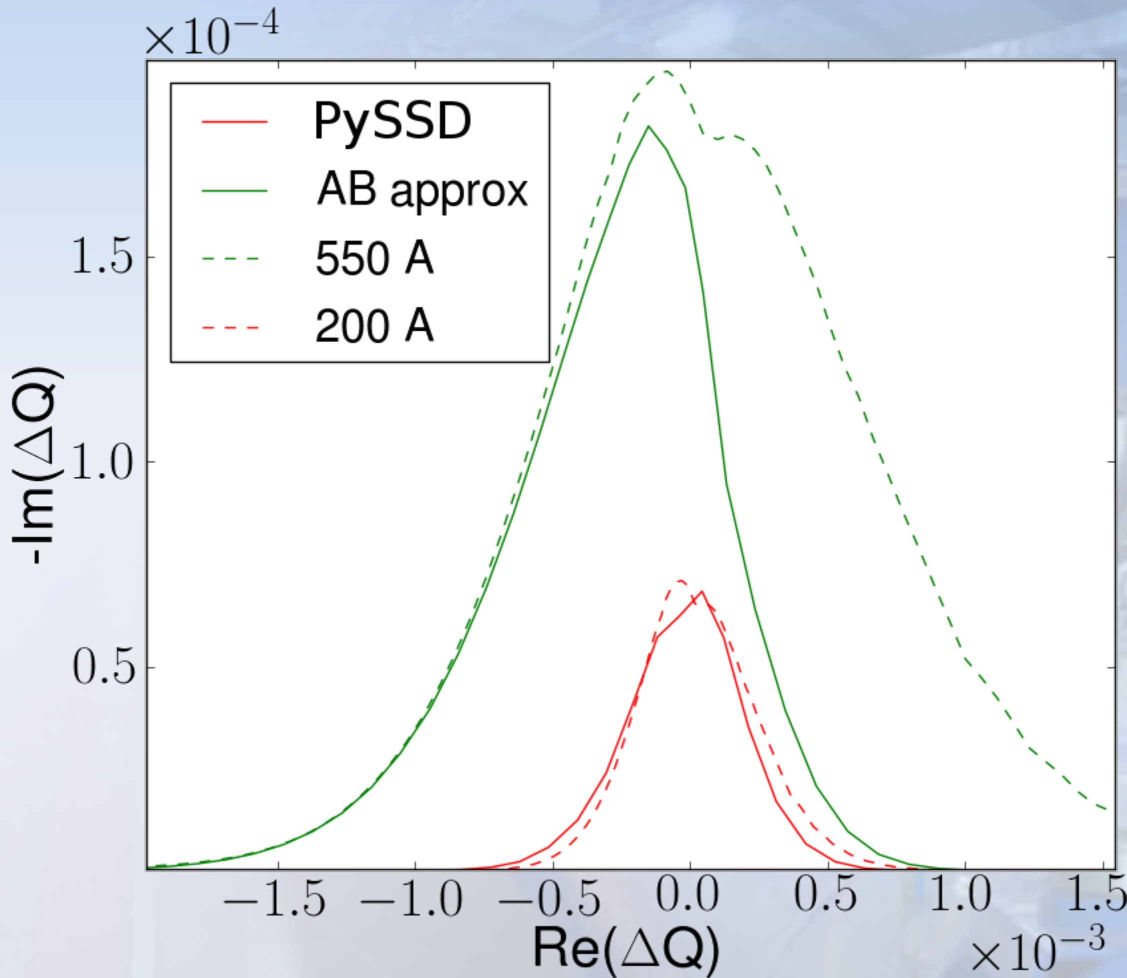
Effect of IP2&8 with // sep

- Effect of IP2&8 is indeed marginal in current configuration



Comment on Alexey's paper

- 175 % over estimation of LR component at the end of the squeeze
  (in term of ”octupole equivalent”)



Comment on Alexey's paper

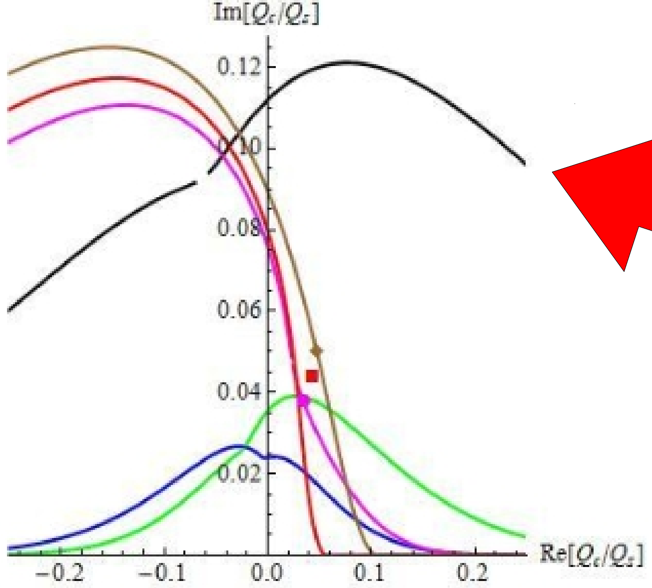
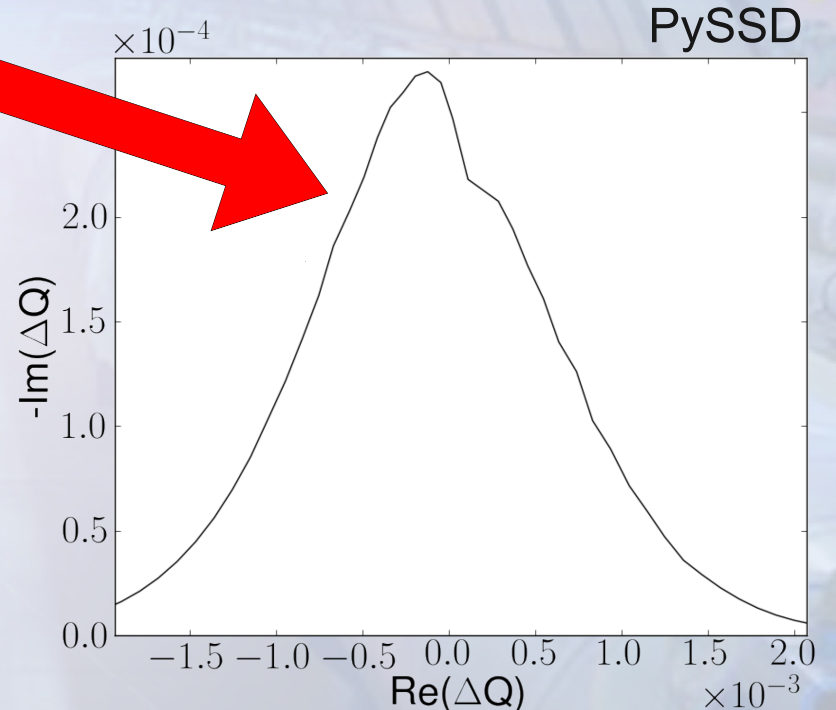


Fig. 3: LHC stability diagrams: a separated stable beam with +200A of the Landau octupoles (green); pacman beam-beam only (no octupoles) at the end of the squeeze (blue); this pacman beam-beam and +500A of the octupoles in addition (black); same as the black line plus e-cloud with total $N_e = (1.3, 1.5, 1.7) \cdot 10^{10}$ (magenta, red, brown). Markers of the corresponding colour show the most unstable modes.

Identical stability diagrams, but inverter sign of the real part



Conclusion

- The linear detuning is over-estimated by AB approx, compared to MAD-X, even without considering the parallel separation
- Long range beam-beam is not an octupole and higher order multipoles have an impact on the stability diagrams
- The parallel separation at the end of the squeeze is on, and it does have an impact on the stability diagram