Preliminary

Optics with finite chromaticities + several changes

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Finite chromaticities

- It has been pointed out finite chromaticities $\xi_{x,y} \sim (+5, +3)$ are required to suppress the coherent beam-beam instabilities, esp. for the recent reverse RF phase scheme (I. Karpov, e.g. https://indico.cern.ch/event/1456331/).

- Then beam optics for Z with such chromaticities are produced.

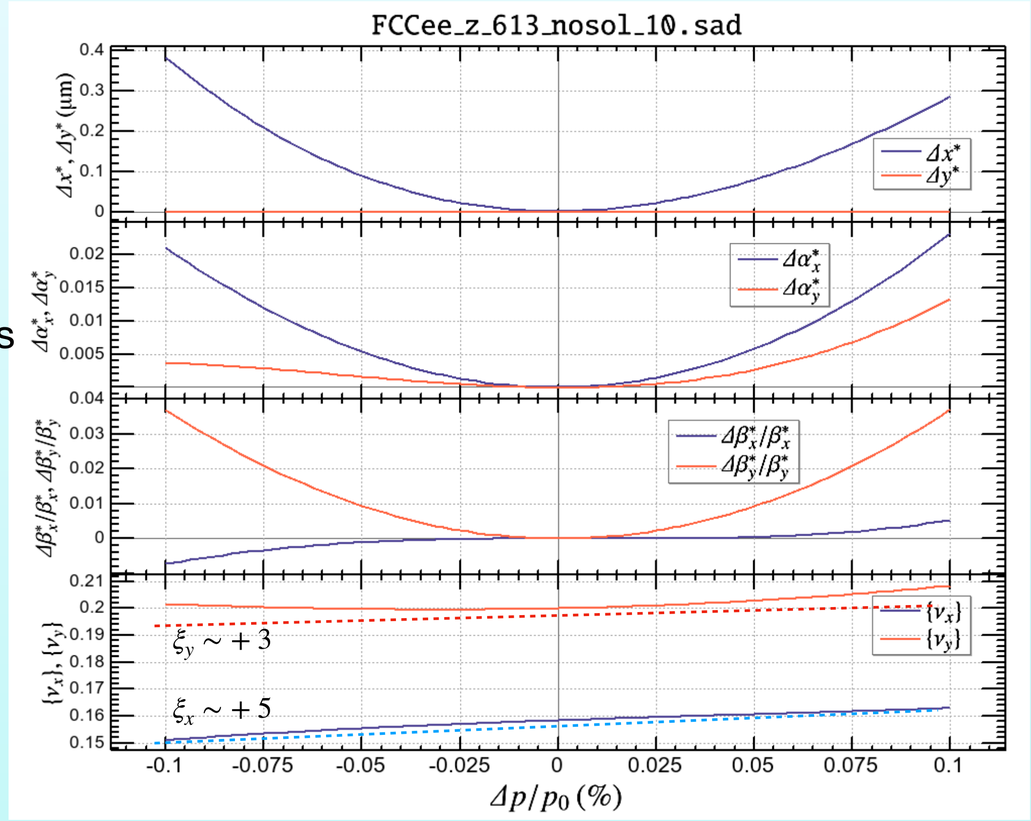
  - Such “chromatic constraints” have been included in the optics design since 2015.

  - The changes of $\beta^*_{x,y}, \alpha^*_{x,y}, \mu_{x,y}$ by a change of sextupole $\Delta k'$ are expressed as

$$\frac{\Delta\beta^*_{x,y}}{\beta^*_{x,y}} = \mp \frac{\cos(\mu_{x,y} - \psi_{x,y})}{2\sin\mu_{x,y}} \beta_{x,y} \Delta k' \eta_x \delta \ ,$$

$$\Delta\alpha^*_{x,y} = \mp \frac{\sin(\mu_{x,y} - \psi_{x,y})}{2\sin\mu_{x,y}} \beta_{x,y} \Delta k' \eta_x \delta \ ,$$

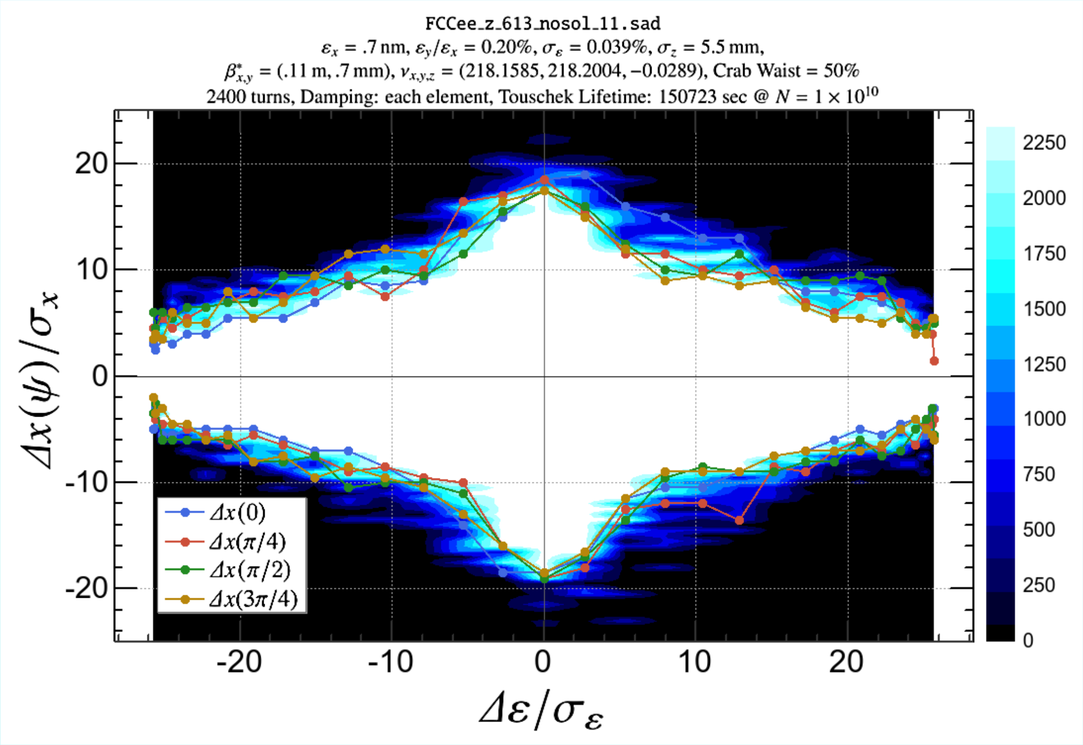
$$\Delta\mu_{x,y} = \pm \frac{1}{2} \beta_{x,y} \Delta k' \eta_x \delta \qquad ,$$

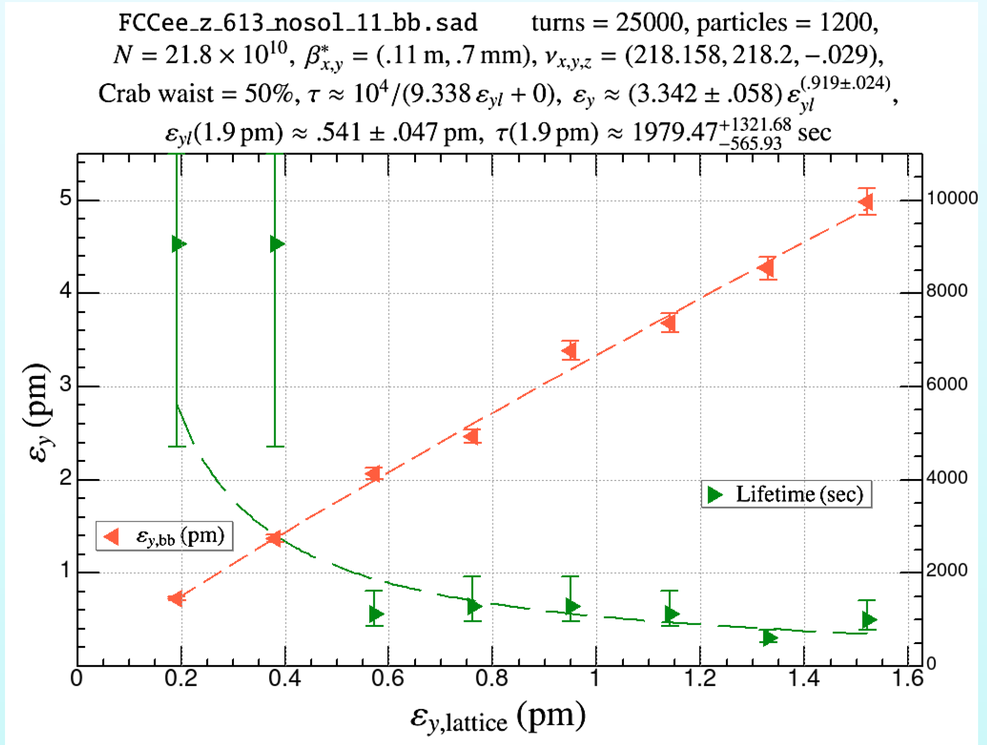


which construct (6 x *n*) response matrix M for *n* sextupoles. We have assumed $\alpha^*_{x,y} = 0$, and $\psi_{x,y}$ are the phase advance from the IP to the sextupole.

  - During the optimization of sextupoles, if we change $\Delta k'$ within the *null space* of the matrix M, these chromaticities of $\beta^*_{x,y}, \alpha^*_{x,y}, \mu_{x,y}$ are preserved.

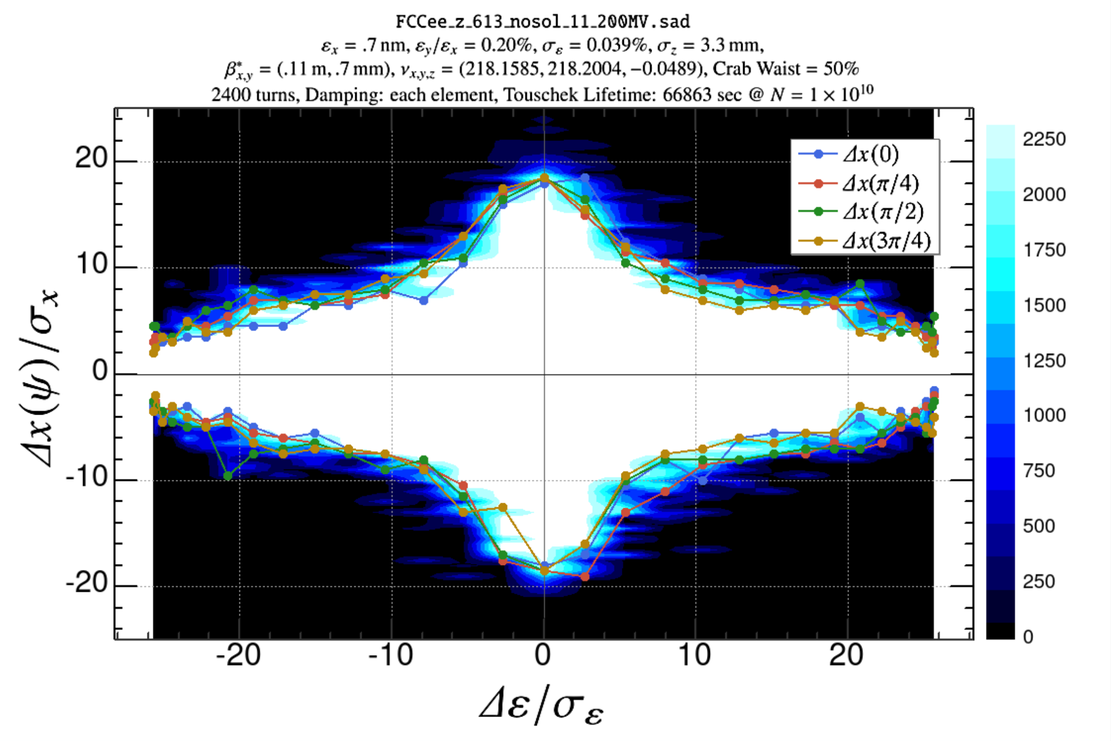
DA & beam-beam

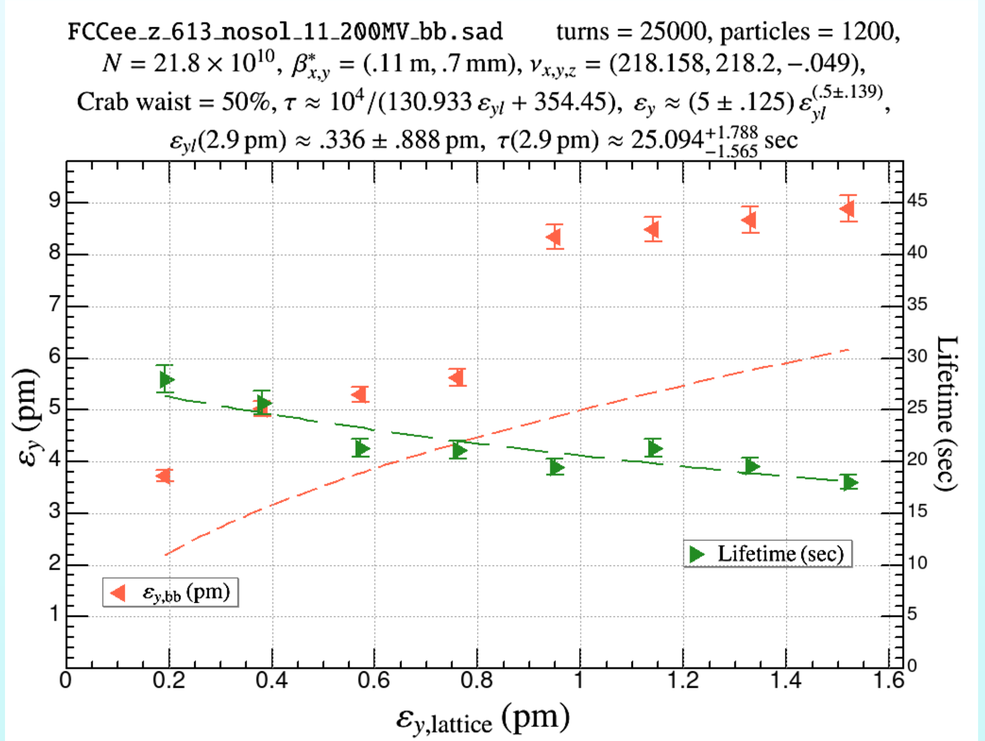




- The DA(MA) looks OK.
- However, the beam-beam performance is worse than before:
  - larger blowup (~3.3x vs ~2.2x) and shorter lifetime (2000 s vs 12000 s).
  - Due to chromaticity or other changes shown later? Needs further investigation.

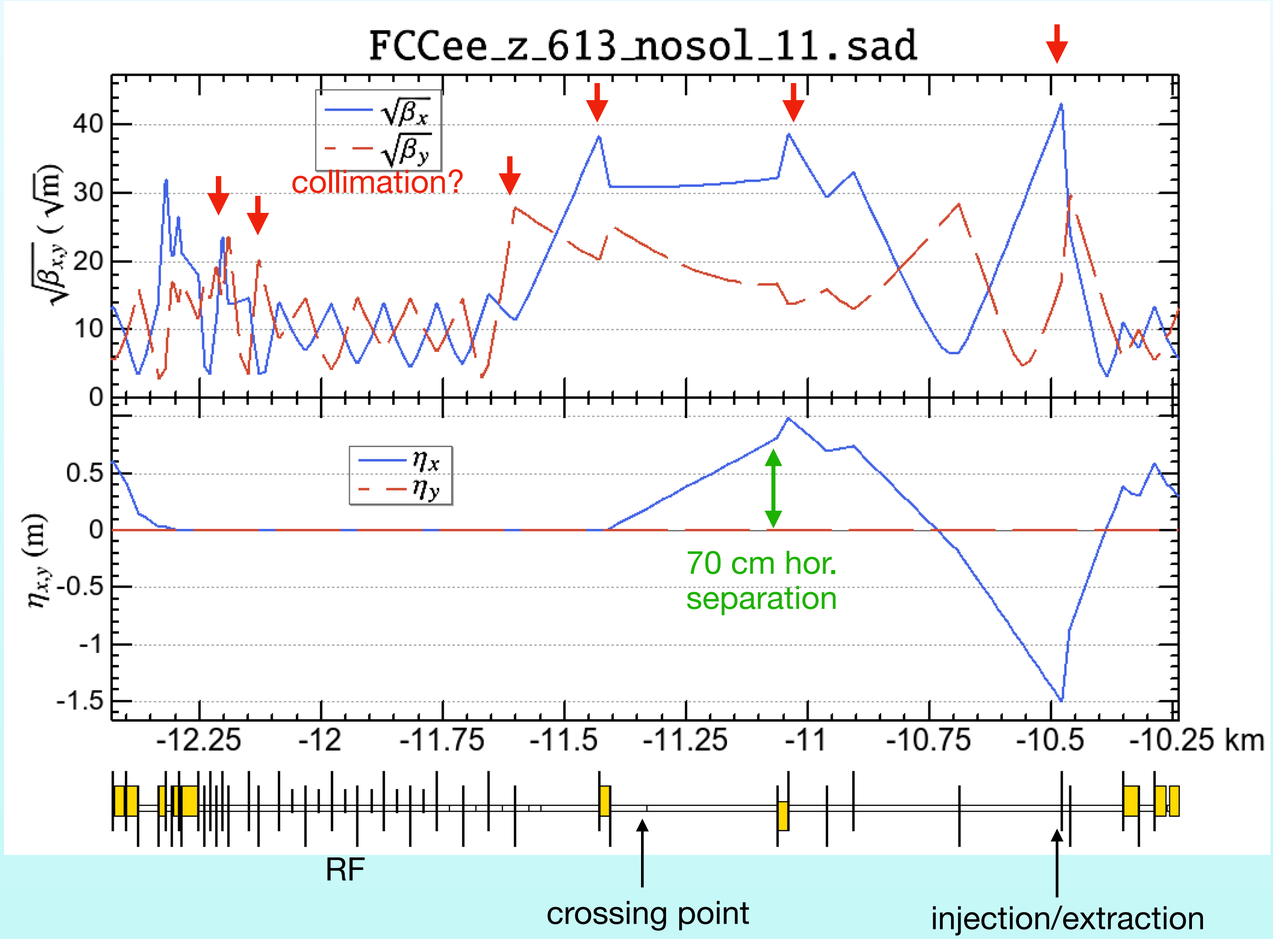
High voltage option (V_c = 200 MV)





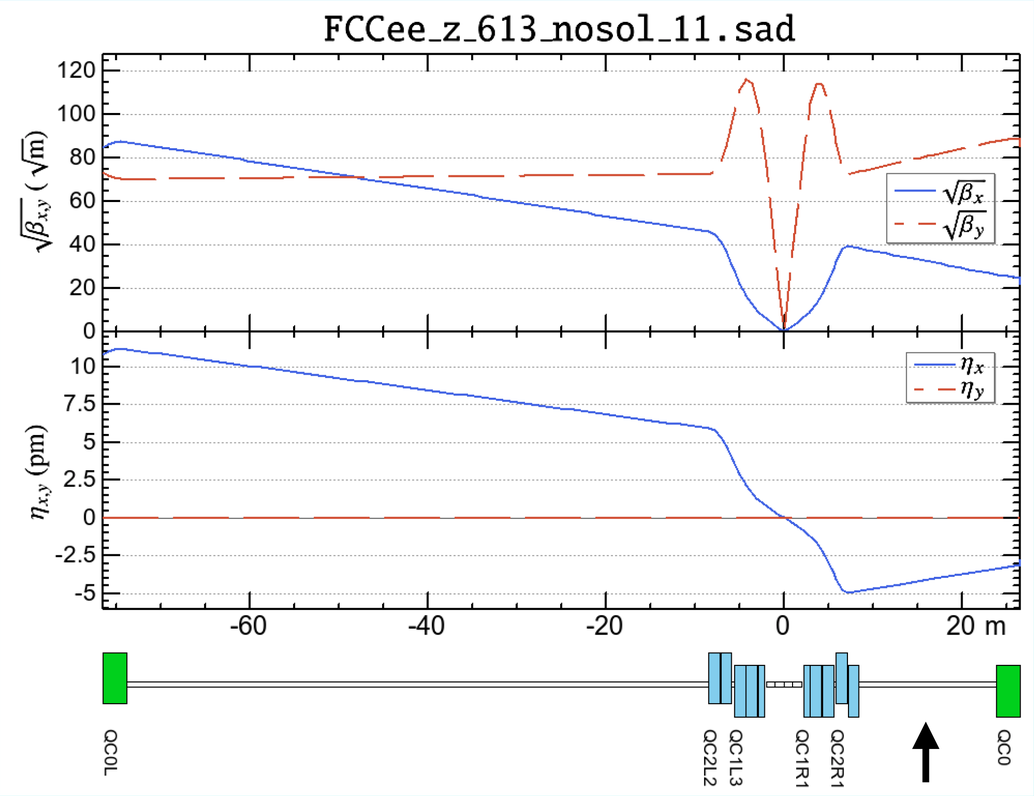
- As suggested by X. Buffat, a high voltage option has been tried.
- Here the beam-beam parameter is set nearly equal to the original (Vc = 79.4 MV), by assuming a higher vertical emittance at collision (2.9 pm vs. 1.9 pm).
- The DA(MA) looks similar to the original.
- Beam-beam performance is very poor, probably due to the large bunch energy spread (0.150% vs. 0.111%), as pointed out by M. Zobov.
- Fine choice of the tunes may improve the situation.
- Probably a shorter abort gap will be necessary for the reverse phase scheme.

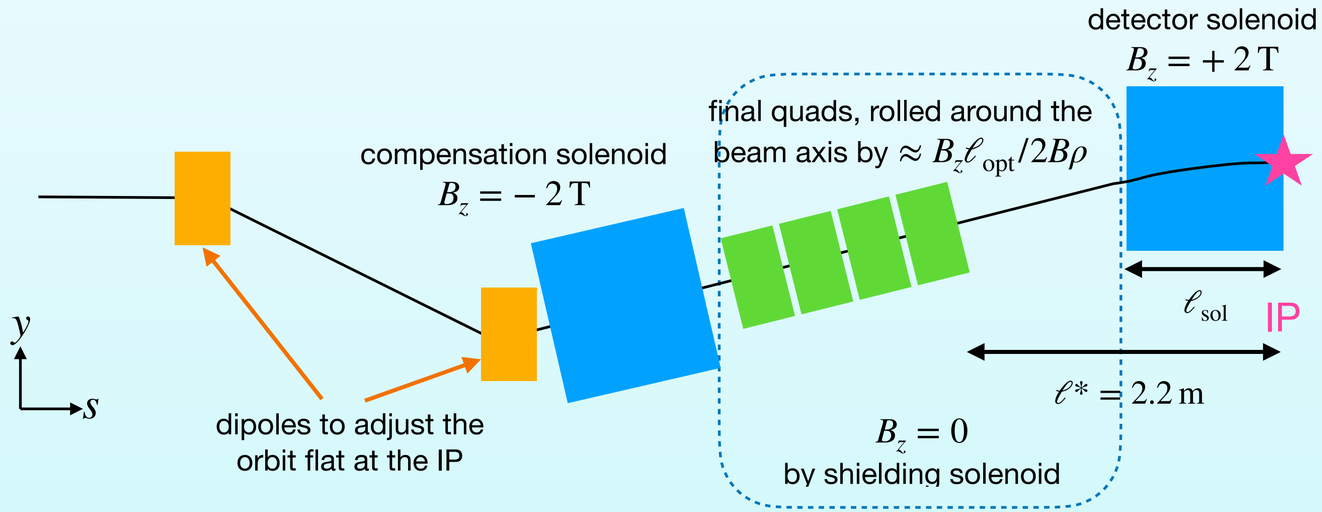
Other changes: Common LLSS (Z/W)



- A common LLSS optics for RF, injection/extraction, collimation?
  - The superperiodicity / sextupole setting are preserved.
  - $\beta_{x,\text{inj}} = 1800\,\text{m}, D_{x,\text{inj}} = -1.5\,\text{m}.$
- The horizontal separation of two beams are increased from 35 cm to 70 cm after the crossing.

Other changes: Spaces for non-local solenoid compensation, etc.





https://indico.cern.ch/event/1456331/contributions/6147515/attachments/2935557/5156234/Nonlocal_Oide_240926.pdf

- The downstream space after QC2R is extended to 15 m to accommodate the compensation solenoid and vertical dipoles for the non-local compensation scheme.
- Most quadrupoles except in the LLSS is shortened from 2.9 m to 2.7 m.

Summary

- Finite chromaticity optics are explained.
  - Using *null space* search for the response matrix from sextupoles to $\beta^*_{x,y}, \alpha^*_{x,y}, \mu_{x,y}$ during the optimization.
  - This time $(\xi_x, \xi_y) = (+5, +3)$ is tried at Z.
  - DA(MA) looks OK, but the beam-beam lifetime & blowup look worse.
    - The reason has not been identified; some of those changes below might be an issue; needs further investigation.
  - A high voltage option is tried for the reverse-phase RF scheme.
    - The beam-beam performance is poor, probably due to the large energy spread by stronger beamstrahlung.
- A few changes are made for the optics:
  - Common LLSS optics for RF, injection/extraction, collimation?
    - needs feedback from these experts.
  - Spaces for the non-local solenoid compensation.
  - Shorter quadrupoles except LLSS.