TLEP IR Chromatic Correction

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October 16, 2013

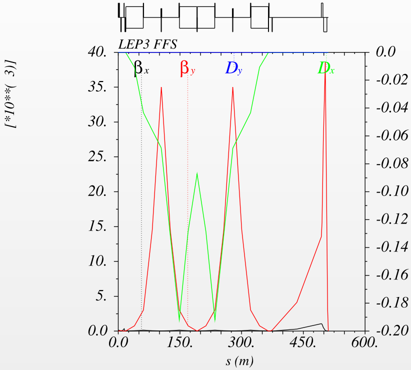
New parameters

Parameter	**[Units]**	TLEP t A	TLEP t B
Beam energy E_{beam}	[GeV]	175	175
Circumeference f_{rep}	[km]	100	100
Bunch population N_e	[10^{11}]	0.88	7.0
Number of bunches n_b		160	20
Bunch length σ_z	[mm]	0.77	1.95
IP beam size σ_x^*/σ_y^*	[μm]	45/0.045	126/0.126
Emittance (IP) ϵ_x/ϵ_y	[nm]	2.0/0.002	16.0/0.016
Beta functions (IP) β_x^*/β_y^*	[m]	1.0/0.001	1.0/0.001
Luminosity $\mathcal{L}_{\mathrm{T}}$	[$10^{34}\mathrm{cm}^{-2}s^{-1}$]	1.32	1.04

Final Focus Design

FFS facts

- Following linear colliders, we consider dedicated chromatic correction scheme.
- Since the horizontal beta function β_x^* is very large (1 m) we do not consider horizontal chromatic correction section (CCX).
- Vertical correction is performed using horizontal dispersion and normal sextupoles.



FFS parameters

- $L_{\text{FFS}} = 511\,\text{m}$
- $L^* = 3.5\,\text{m}$
- $L_{\text{QD0}} = 7.90\text{m}$
- $k_{\text{QD0}} = -0.034262\text{m}^{-2}$

Bending section

- Bending Angle, bending magnet length and dispersion comparable to the arc.
- $B_{\text{dip}} = 0.06\,\text{T}$, $D_x^{\text{max}} = 0.19\,\text{m}$

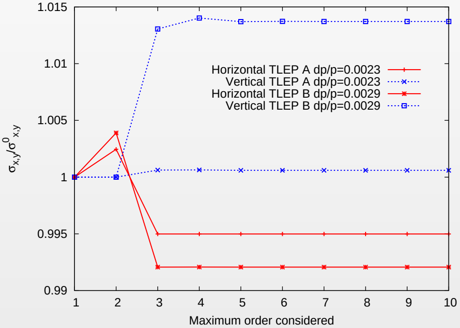
Nonlinear optimization

MAPCLASS Beam sizes

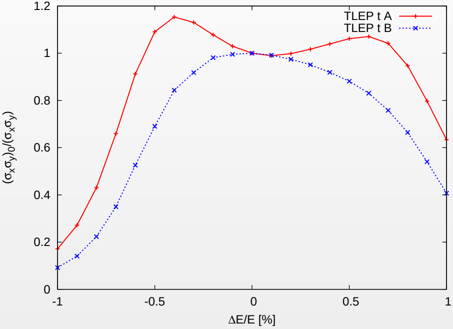
$$\sigma_x^*(A) = 44.50\,\mu\text{m},\ \sigma_y^*(A) = 44.78\text{nm}$$

$$\sigma_x^*(B) = 125.49\,\mu\text{m},\ \sigma_y^*(B) = 128.31\text{nm}$$

- Even without horizontal chromatic correction, the horizontal aberrations are negligible.
- Vertical chromatic correction is almost perfect for TLEP A and the aberration content is below 1.5% of the beam size for TLEP B.



Performance at the IP



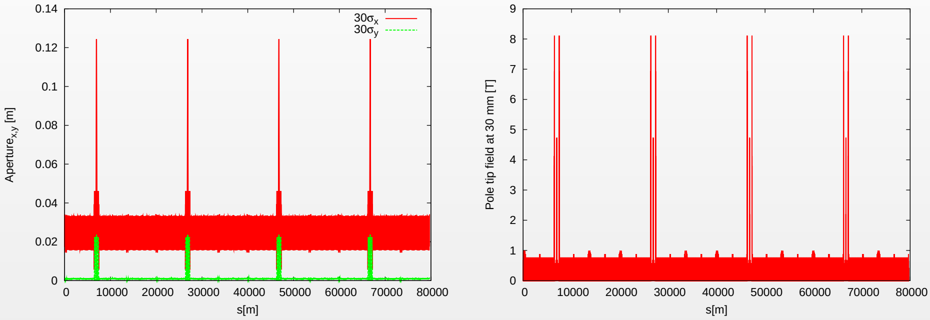
PLACET Beam sizes

$$\sigma_x^*(A) = 44.67\,\mu\text{m},\ \sigma_y^*(A) = 44.66\text{nm}$$

$$\sigma_x^*(B) = 123.74\,\mu\text{m},\ \sigma_y^*(B) = 131.7\text{nm}$$

The effect of synchrotron radiation is negligible since the strength of the bending magnets is comparable to the ones used in the arc.

Inserting the FFS in the ring lattice



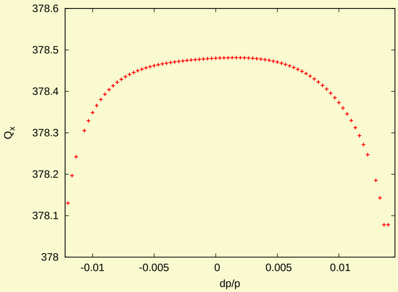
Open issues

- Pole tip field at QF1 is quite high. Field of 14 T at 12σ (collimation).
- Take into account β-variation due to beam-beam effects. This variation is around $10 - 20\%$ that represents the same variation in the aperture and pole tip field.

Stability: Tunes

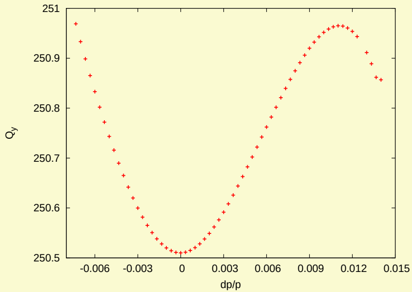
Final Focus System:

$Q_x = 378.48$



- Relatively small plateau for $dp/p = \pm 1\%$.

$Q_y = 250.51$

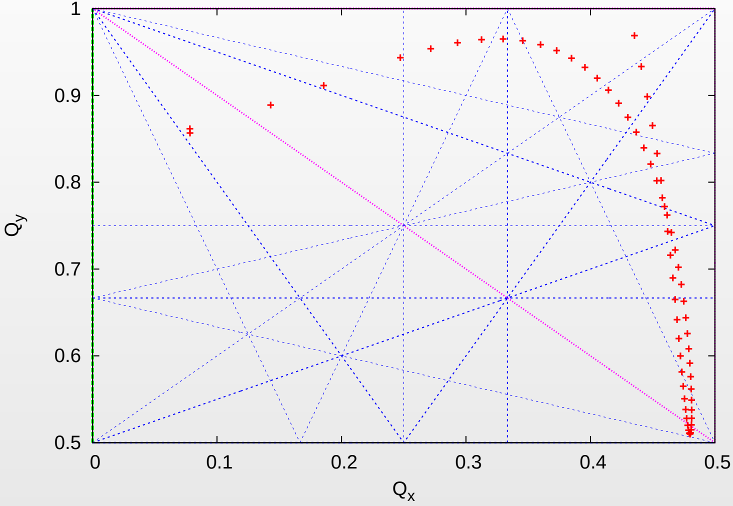


- Some third order contributions remain.
- Almost $dp/p = \pm 1\%$ stability.

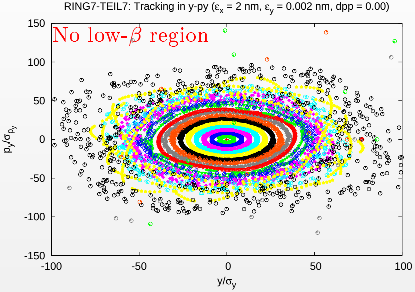
Without chromatic correction

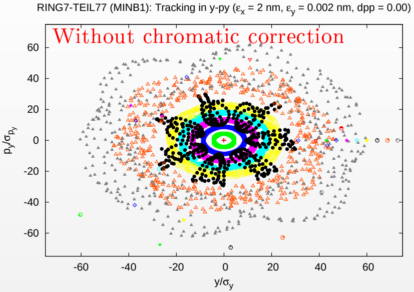
The stability for this scheme is below $dp/p = 0.03\%$. This means that a dedicated chromatic correction section is needed.

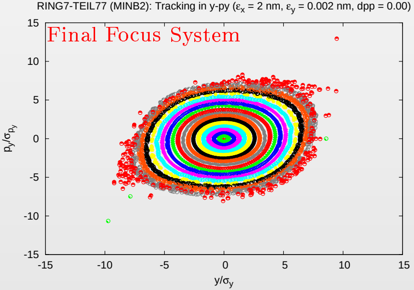
Stability: Tunes



Vertical phase space after 500 turns. On momentum. tlep A



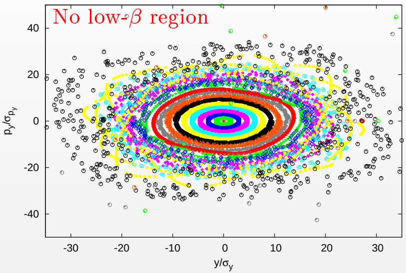




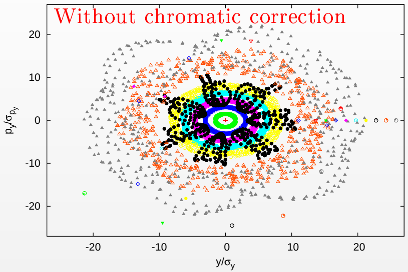
- For on momentum particles the phase space without low-β insertions is stable $> 25\sigma$.
- Without chromatic correction this is reduced to $\sim 20\sigma$.
- For the FFS the stability region is $\sim 6\sigma$.

Vertical phase space after 500 turns. On momentum. tlep B

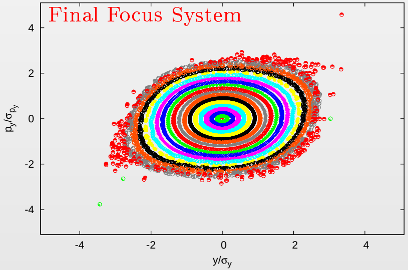
RING7-TEIL7: Tracking in y-py (ϵ_x = 16 nm, ϵ_y = 0.016 nm, dpp = 0.00)



RING7-TEIL77 (MINB1): Tracking in y-py (ϵ_x = 16 nm, ϵ_y = 0.016 nm, dpp = 0.00)

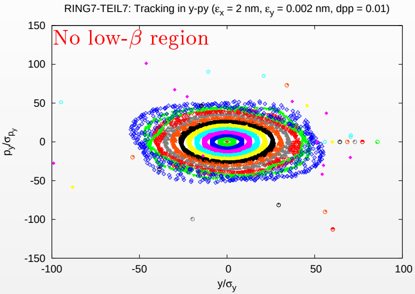


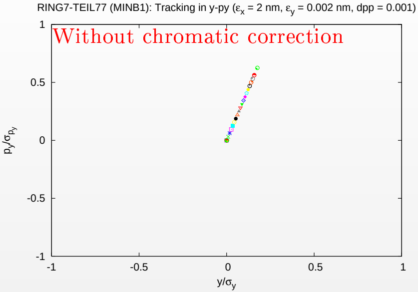
RING7-TEIL77 (MINB2): Tracking in y-py (ϵ_x = 16 nm, ϵ_y = 0.016 nm, dpp = 0.00)



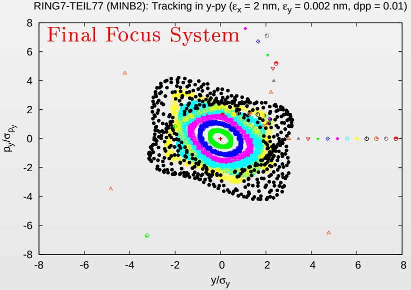
- For on momentum particles the phase space without low-β insertions is stable $> 10\sigma$.
- Without chromatic correction this is reduced to $\sim 7\sigma$.
- For the FFS the stability region is $\sim 2\sigma$.
- Far from the desired performance.

Vertical phase space after 500 turns. Off momentum $dp/p = 1\%$. tlep A

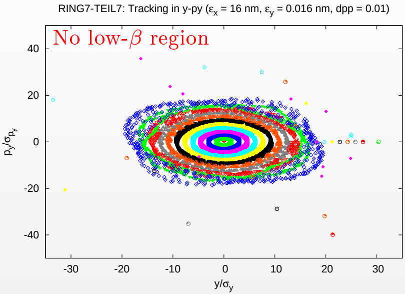


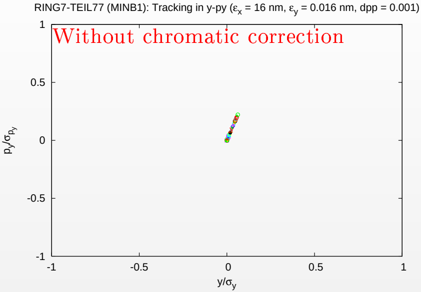


- DA for the Ring without low-β insertions is slightly reduced. But still $> 25\sigma$.
- Without chromatic correction all the particles are lost within the first turn even with momentum spread of $dp/p = 0.1\%$.
- For the ring with FFS, the DA is notably reduced. Particles are stable only for $< 2\sigma$.
- Clearly needs some improvement.



Vertical phase space after 500 turns. Off momentum $dp/p = 1\%$. tlep B





- DA for the Ring without low-β insertions is slightly reduced. But still $> 10\sigma$.
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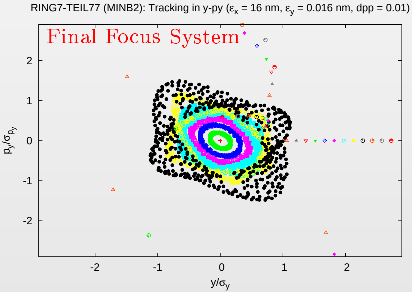
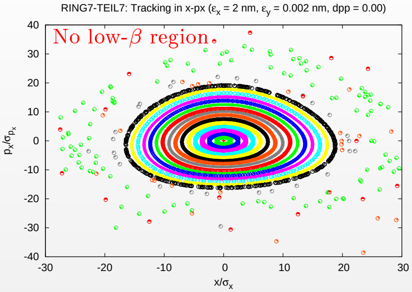
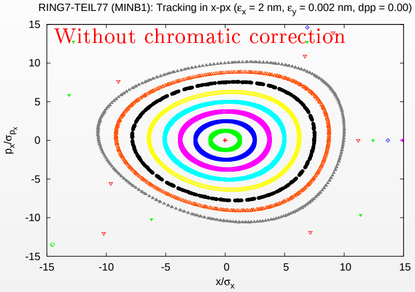
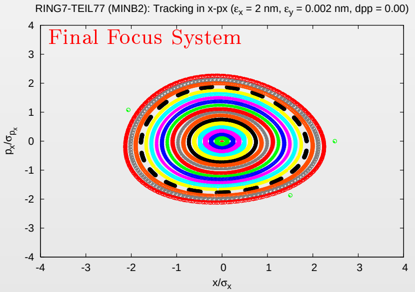


Horizontal phase space after 500 turns. On momentum. tlep A

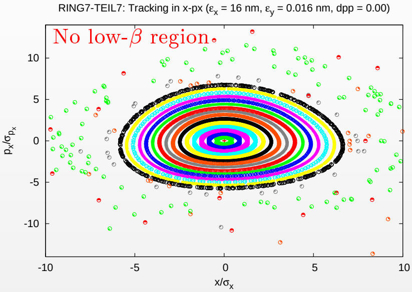


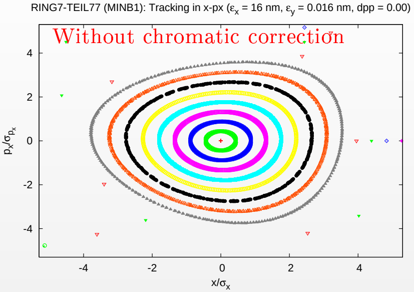


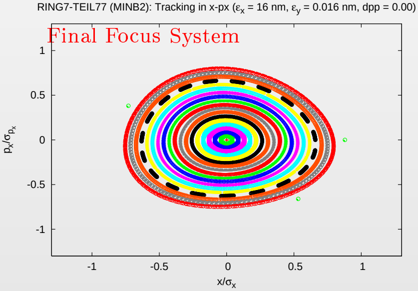


- For on momentum particles the phase space without low-β insertions is stable $\sim 15\sigma$.
- Without chromatic correction this is reduced to $\sim 10\sigma$.
- For the FFS the stability region is $\sim 2\sigma$.
- Far from the desired performance.

Horizontal phase space after 500 turns. On momentum. tlep B

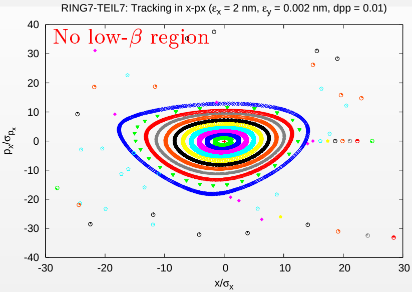


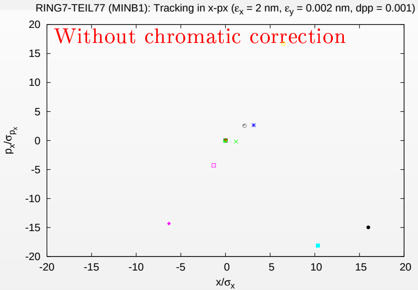




- For on momentum particles the phase space without low-β insertions is stable $> 5\sigma$.
- Without chromatic correction this is reduced to $\sim 3\sigma - 4\sigma$.
- For the FFS the stability region is $> 0.5\sigma$.
- Far from the desired performance.

Horizontal phase space after 500 turns. Off momentum $dp/p = 1\%$. tlep A





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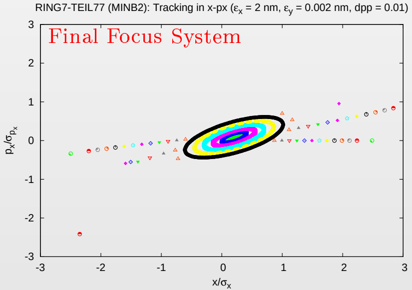
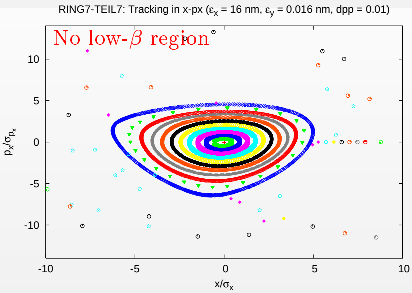
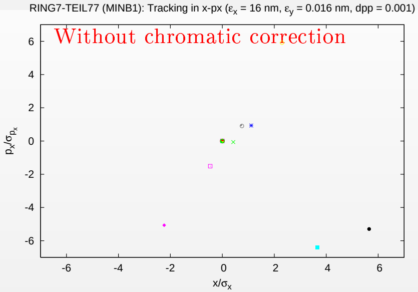


Horizontal phase space after 500 turns. Off momentum $dp/p = 1\%$. tlep B





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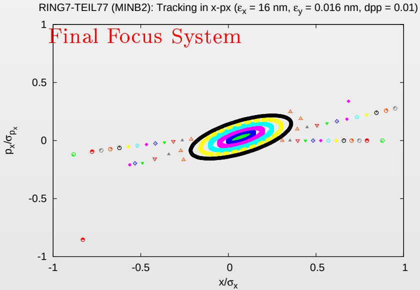
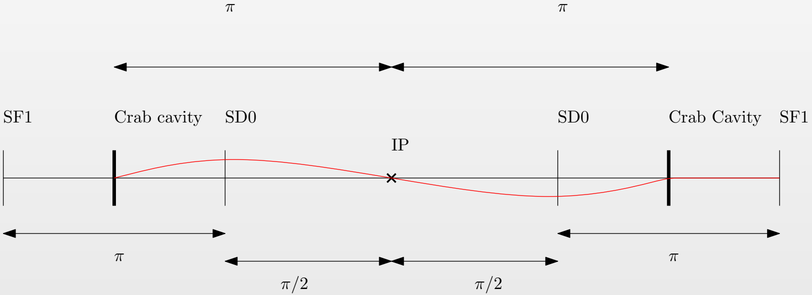


Traveling waist scheme

- We expect some luminosity gain when we consider a crab waist scheme.
- The structure of the FFS allows the introduction of a crab cavity between vertical sextupoles.
- Orbit bumps introduced by Crab cavities are compensated choosing the right phase advance between them.



Conclusions and future prospects

- It seems that local chromatic correction is needed to compensate aberrations and ensure stability.
- We have designed a proposal for the FFS based on linear colliders.
  - From the point of view of chromatic aberrations, horizontal correction section perhaps is not needed.
- Stability needs improvement.
- Horizontal plane stability possible solutions:
  - Add a horizontal chromatic correction section (CCX).
  - Octupoles.
  - Match arc FODO cell sextupoles phase advance.
  - Match phase advance between IP's.
- Vertical plane stability:
  - Add higher order multipoles to correct remaining aberrations.
  - Match phase advance between IP's.
- Magnet alignment and magnetic field quality tolerances need to be studied.
- Traveling waist scheme would fit into de FFS structure. Detailed studies are required.