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Studies for a Muon Collider Optics with non-interleaved sextupole scheme

Contents:

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Motivation

The situation so far:

- Dipole First Optics (β^*=10 mm): local IR chromaticity correction (à la Montague) and 2 interleaved sextupole families in the FODO based arcs. Good energy acceptance, but small DA.

- Oide design (β^*=3 mm): non-interleaved chromaticity correction scheme. Good DA, large energy acceptance by playing with sextupoles (22 families), octupoles and decapoles. Strong sextupoles, very sensitive to misalignment errors (MCD Workshop, Dec 2007).

The “in loco” IR chromaticity correction has in general the advantage of a large energy acceptance range. This may be obtained in the non-local correction by optimising a *large number* of sextupole families, necessarily strong.

$\Rightarrow$ Try a more feasible optics for non-interleaved correction.

The non-interleaved scheme requires an optics "ad hoc": the transfer matrix between couple of sextupoles must be a pseudo[a] $-I$ in *both* planes so that the kicks on a particle going through the two sextupoles cancel each other.

An attempt of introducing a non-interleaved sextupole correction *only* in the arcs by using 90 degrees FODO cells gave only a marginal improvement of the DA (NFMCC, March 08)

Playing with the dipole *bending radius* of 90 degrees FODO cells to get large dispersion and small α_p, as alternative to the "2.5 π" Oide cells, did not lead to shorter arcs (LEMC 2008).

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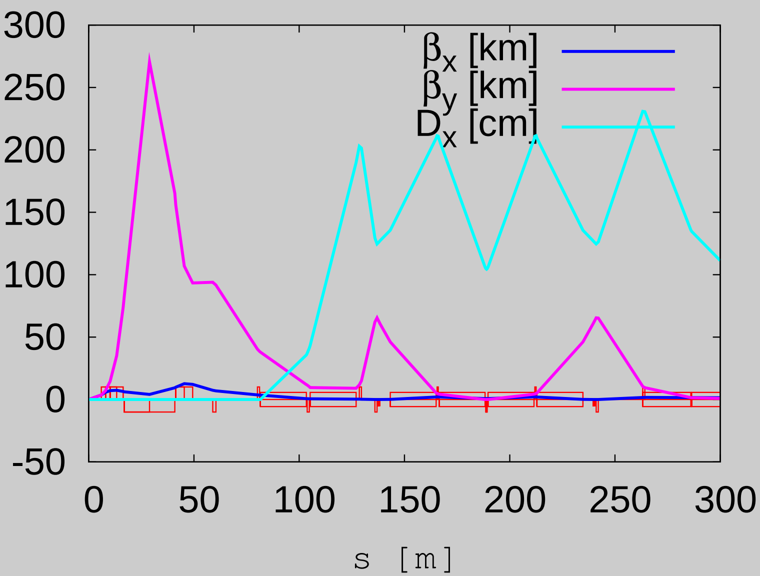
[a] $\alpha_1 \neq \alpha_0$

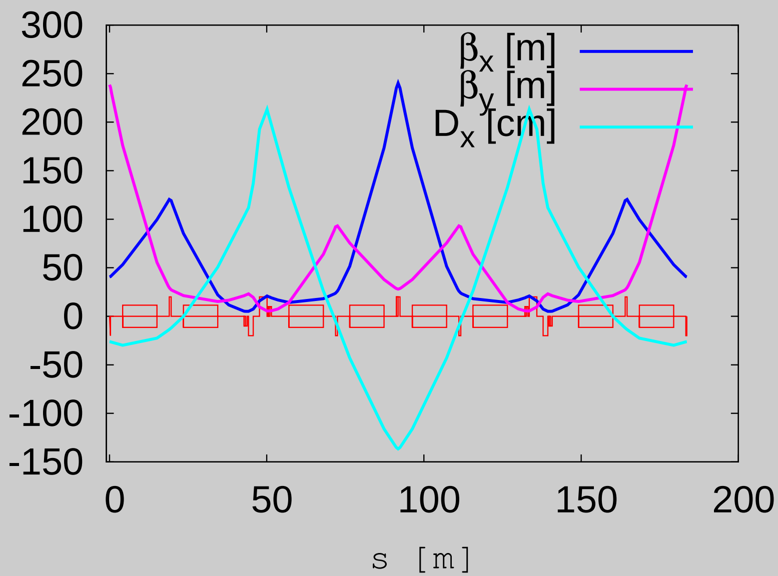
Linear Optics

- IR magnets *unchanged* wrt Oide design, but β^* increased to 10 mm
- use 2.5π cells, but reduce magnet length (Oide bends: L=22 m long, B=3.7 T)
- use 2 different bending angles to get an handle on dispersion
- add a dispersion free section for RF cavities and tuning quadrupoles

IR



2.5π Cell



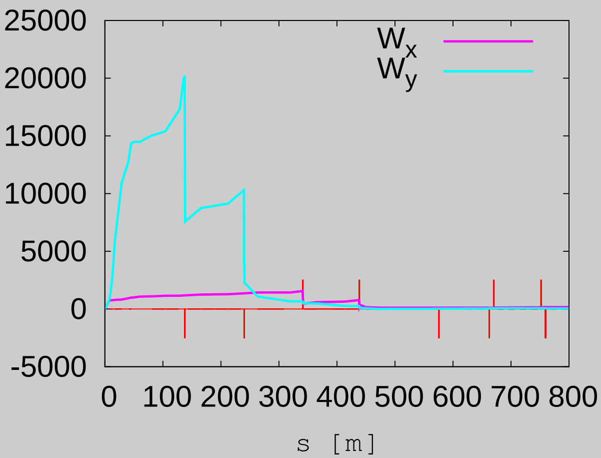
- $\boldsymbol{L}$=4855 m, one $\boldsymbol{IP}$, $\hat{\boldsymbol{\beta}}_{\boldsymbol{y}}$=275 Km (it was 900 Km)
- $\boldsymbol{Q_x}$=30.55, $\boldsymbol{Q_y}$=30.45
- $\boldsymbol{\alpha_p}$=1.8e-4

The tunes have been chosen to get maximum stability range under the assumption that the machine is stable near the half integer (KEKB does it!).

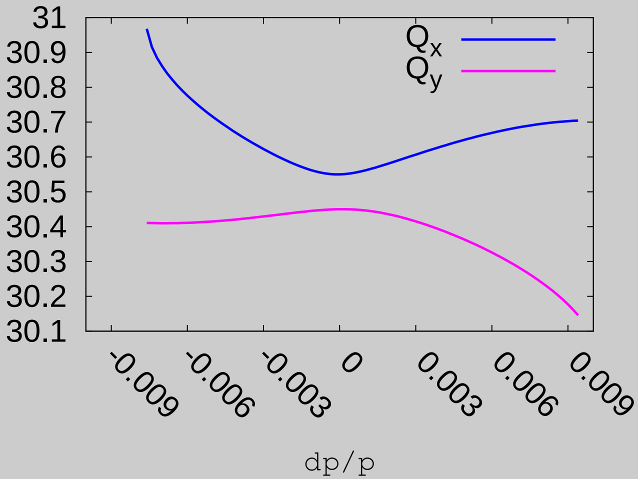
Chromaticity Correction

- IR chromaticity corrected with *one couple* of sextupoles per plane
- ring chromaticity corrected with *one family* per plane

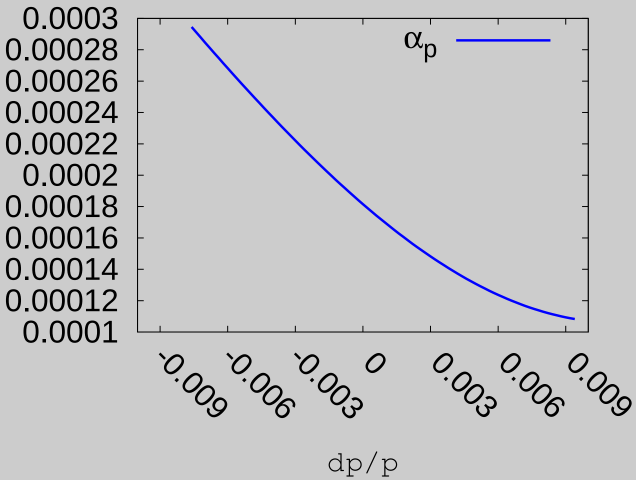
Montague functions



Tunes vs. dp/p



α_p vs. dp/p

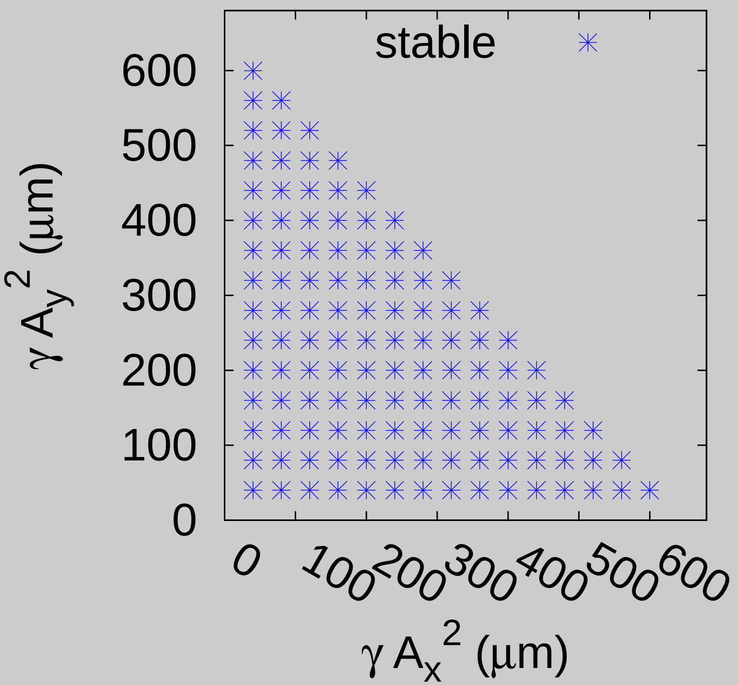


Dynamic Aperture

Tune Dependence on Amplitude (no octupoles) *(MAD8 STATIC)*	
dQ_1/dE_1	0.50×10^3
dQ_1/dE_2	0.30×10^4
dQ_2/dE_2	-0.16×10^7

Dynamic Aperture (on energy)

(MAD-X PTC)

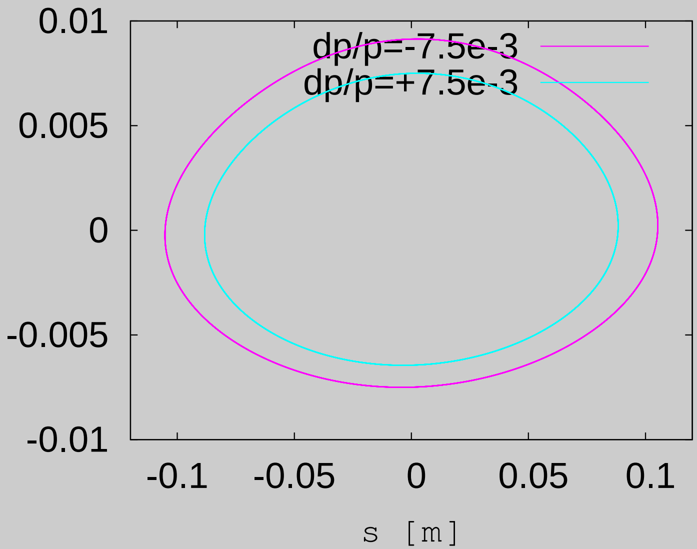


7 sigma's at least (ϵ_N=12.3 μm) !

The longitudinal phase space

The fact that $\boldsymbol{\alpha_p}$ is small makes higher order terms important:
trajectories in longitudinal phase space are *deformed* and the stable region is *asymmetric*!

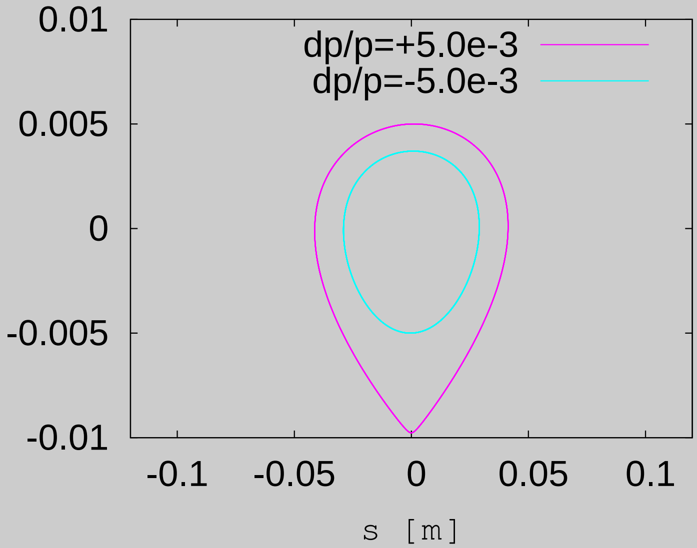
360 MV @ 600 MHz



a particle starting with (0,-7.5e-3) reaches $\boldsymbol{\Delta p/p}$=+9e-3 after half synchrotron period and is lost if the ring is not stable!

This effect *may reduce* further the energy range of the machine!

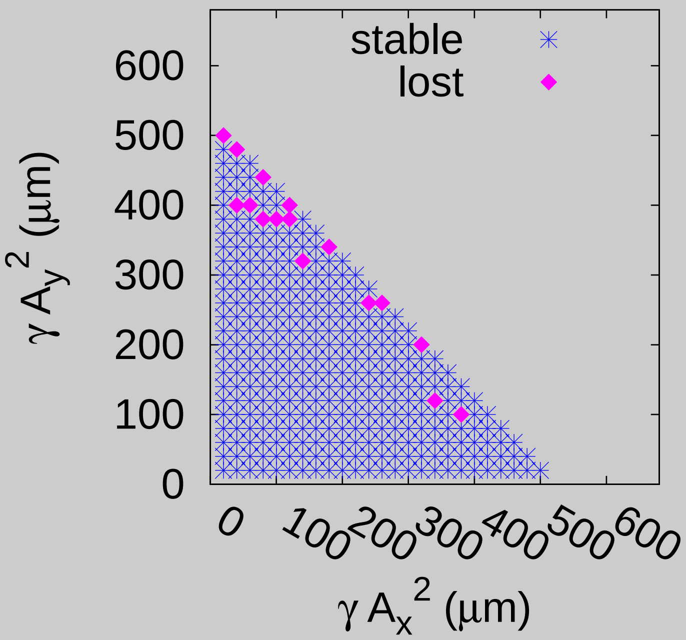
360 MV @ 600 MHz



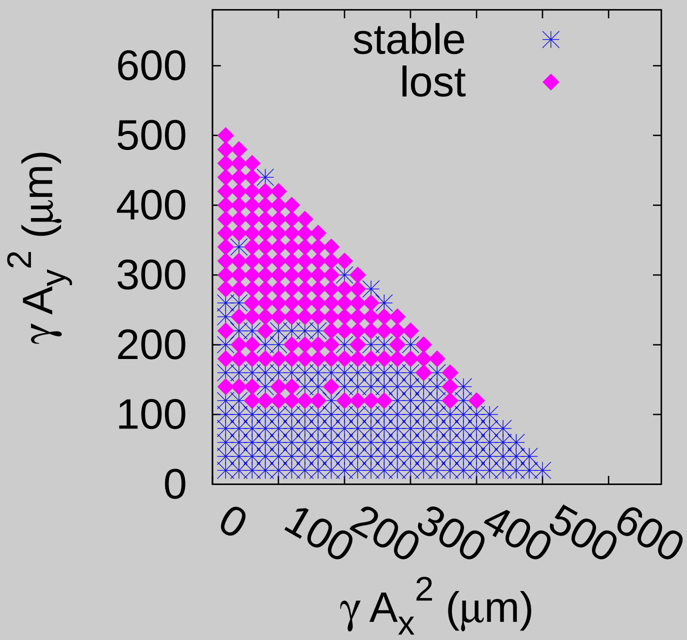
The effect is more evident for the "dipole first" optics, version with $\boldsymbol{\alpha_p}$= 9.7e-5. The $\boldsymbol{(dp/p)_{t=0}}$=+5e-3 trajectory is obtained in 2th order approximation.

Off energy DA with Synchrotron Motion (MAD8)

$\Delta p/p$=5e-3



$\Delta p/p$=7e-3



Summary and Outlooks

The optics here presented is still an *exercise*: the IR should be re-designed to get smaller β peaks and α_p is too large for 10 mm bunch length.

It seems difficult to me to get a sufficient DA with the "in loco" correction scheme. To be done next: combine the best of the two approaches!

- re-design IR to get smaller β peaks
- keep the Oide "asymmetry": allow the β in the plane which chromaticity is *first* corrected to grow larger than the other one
- use non-interleaved scheme for correcting chromaticity, but place first sextupole at $\Delta\mu$=0 from IR quads
- decrease α_p by re-fining the dispersion in the cells.

Do we need the non-interleaved scheme also for the arcs?

More in general: consider *crab waist* scheme, Mike Zisman suggestion to easy the constraint on α_p.

Acknowledgments

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