Dynamic Aperture Optimization

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Outline

- Problem definition
- DA optimization methods overview
- Best sextupole pair method
- Tune point optimization
- Examples

Problem definition

- A short term DA is considered
- DA is restricted by chromatic sextupoles
- Natural chromaticity has to be corrected with large (maximum?) DA
- Only quadrupole and sextupole magnets can be used to get a large DA

Problem definition (crab waist colliders)

- Extremely large perturbation of the FF region
- (Very) low emittance lattice (light sources, damping rings) $\rightarrow$ large chromaticity and strong sextupoles
- Low symmetry lattice $\rightarrow$ dense net of structural resonances

DA optimization methods

- Earlier efforts added harmonic sextupoles reducing effects of leading orders systematic resonances
- Typical modern approach is based on the 1-turn Lie transformation study and minimization of some “figures-of-merit”:

In particular, the expansion used here, requires minimization of 52 terms:

- 27 geometric resonance modes,
- 12 amplitude dependent tune shift terms, and
- 13 chromatic terms

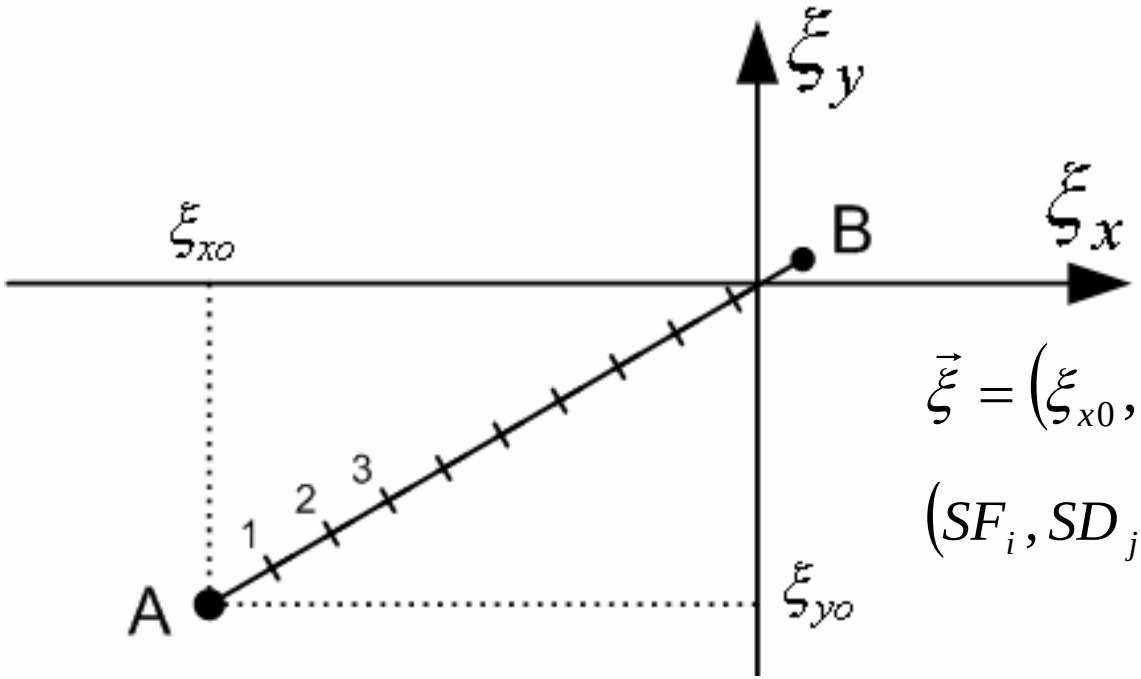
Proceedings of 2005 Particle Accelerator Conference, Knoxville, Tennessee

DYNAMIC APERTURE OPTIMIZATION FOR LOW EMITTANCE LIGHT SOURCES*

S.L. Kramer# and J. Bengtsson
BNL/NSLS, Upton, NY 11973, U.S.A.

All these parameters do not relate directly to the DA size!

Best sextupole pair algorithm

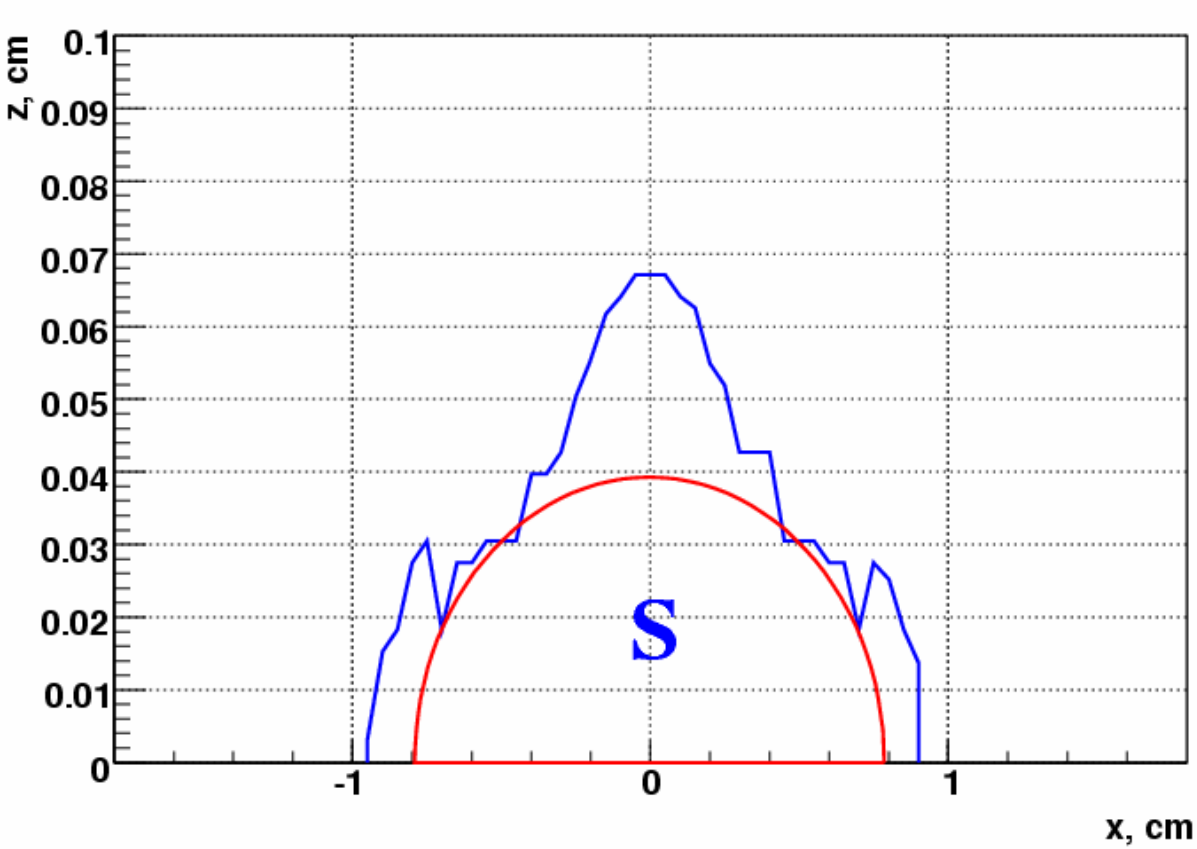


$\vec{\xi} = \left(\xi_{x0}, \xi_{y0}\right)$ - chromaticity vector

$\left(SF_i, SD_j\right)$ - sextupole pair

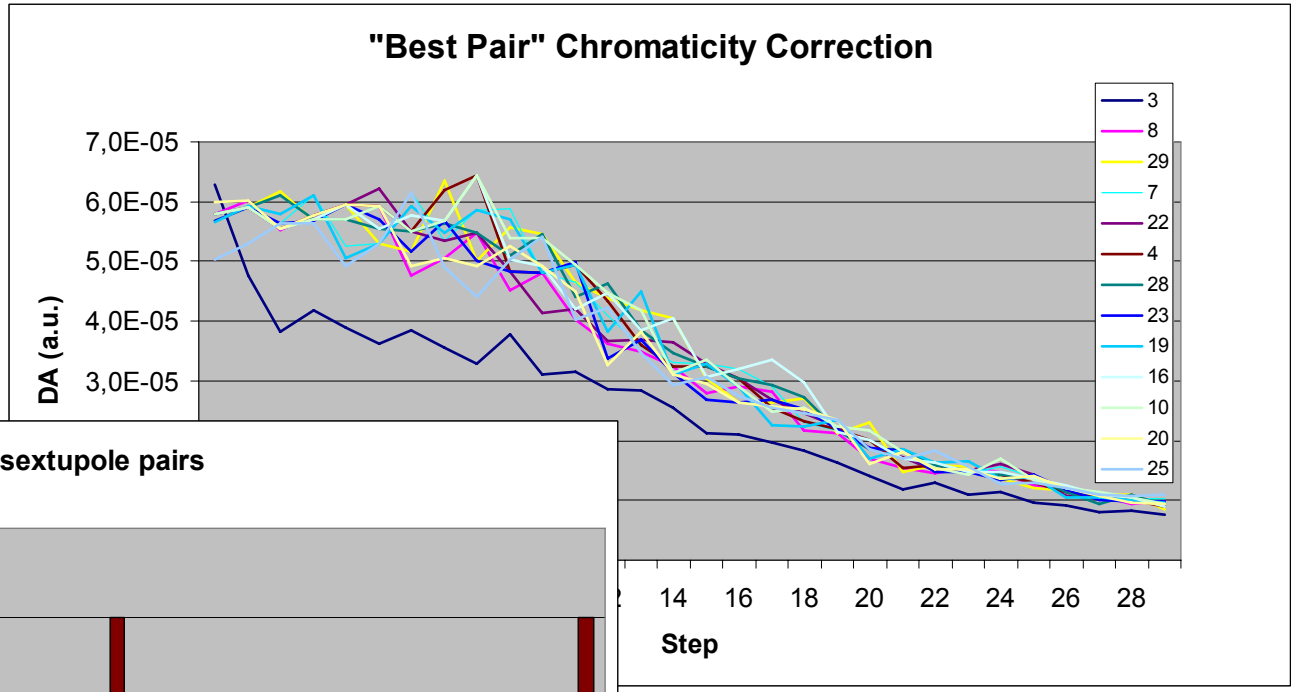
- Chromaticity correction by every sextupole pair along the chromaticity vector in N small steps
- The pair providing the largest DA at the step is fixed
- The procedure is repeated until the chromaticity is corrected
- Off-energy aperture optimization is available
- Achromatic sextupole (zero dispersion) is included by the gradient search

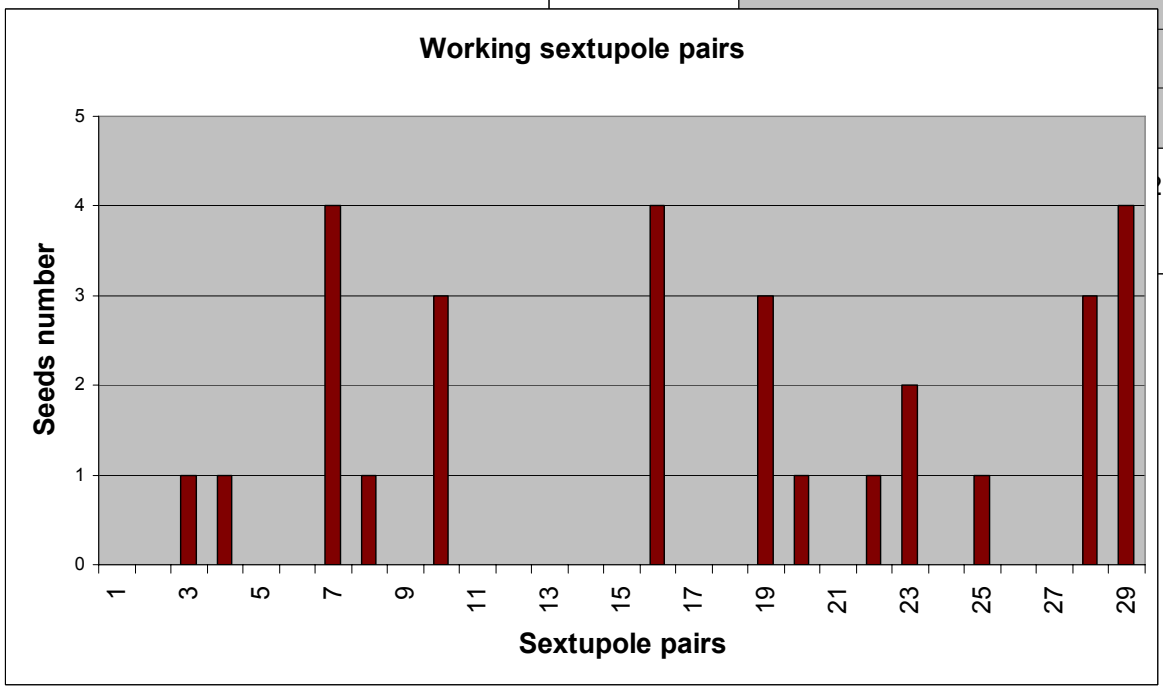
DA determination



The area of the ellipse inscribed in the complicated shape of the DA border is, as it was found empirically, the best optimization parameter.

Step-by-step chromaticity correction





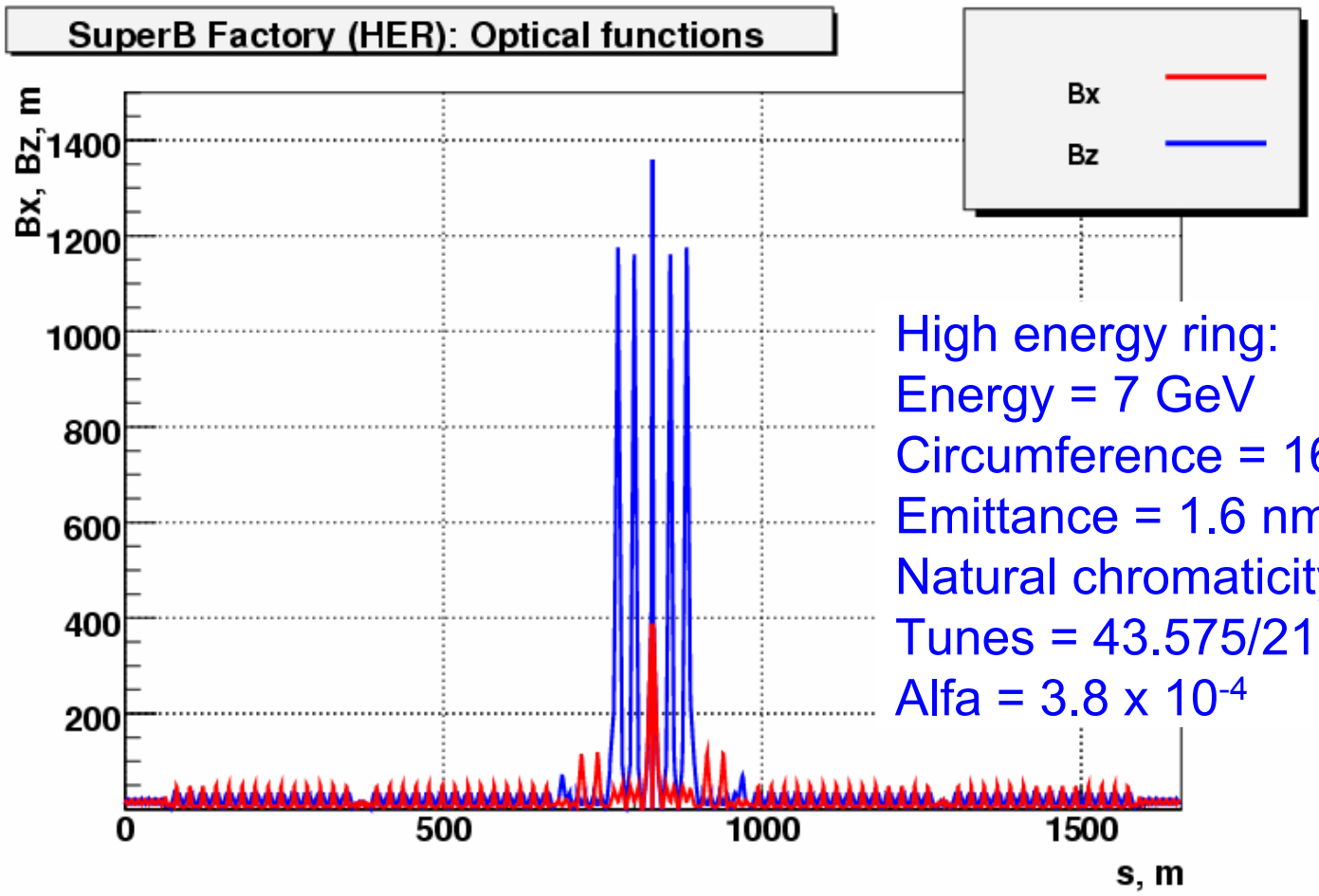
Only small number of pairs really works from all possible combinations

Optimization procedure

- Chromaticity correction by the “best sextupole pair” (BSP) method. Reasonable number of the sextupole families (degrees of freedom) is desired.
- DA tune scan and (tiny) matching of the tune point
- DA re-optimization by the gradient search (~10-20% of the DA increase usually)
- Study of the inner region of the DA and phase space portrait (to exclude of the high-order resonances)

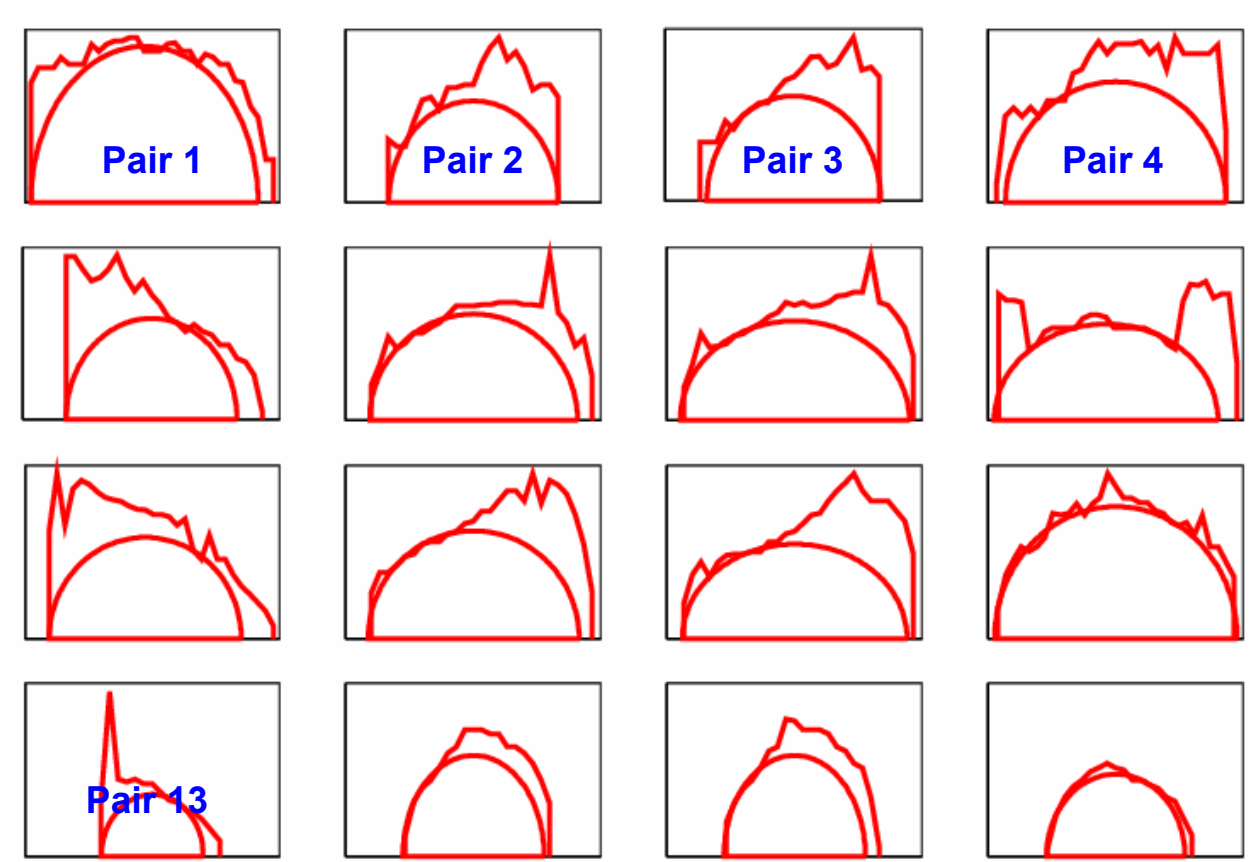
Examples for the SuperB lattice
from Marica Biagini
↓

Lattice and parameters



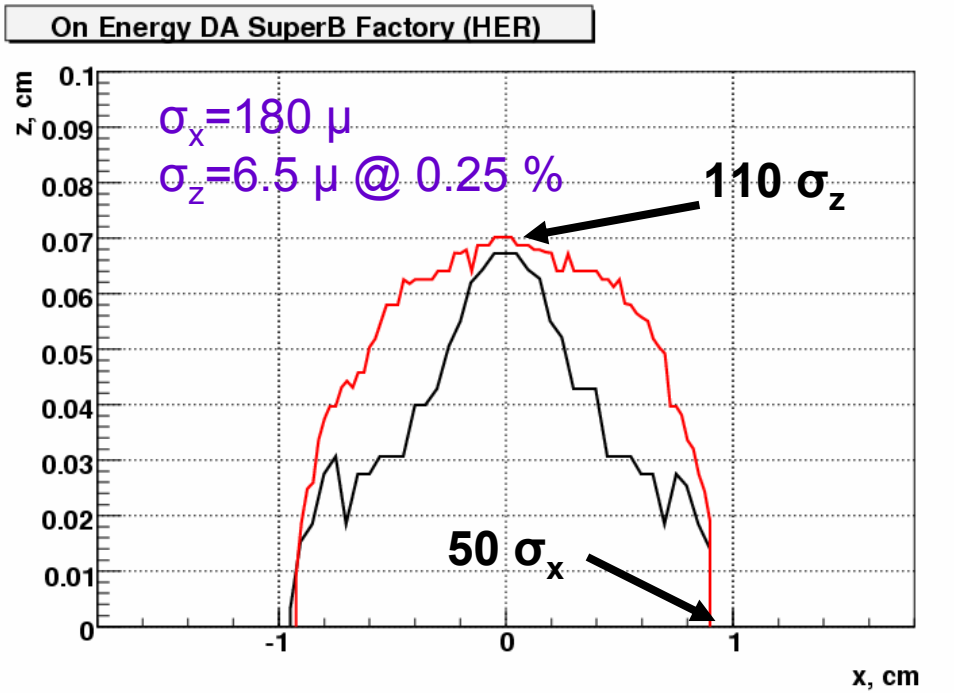
High energy ring:
Energy = 7 GeV
Circumference = 1657.5 m
Emittance = 1.6 nm
Natural chromaticity = -136/-587(!)
Tunes = 43.575/21.595
Alfa = 3.8×10^{-4}

Chromaticity correction by the BSP (1 step)



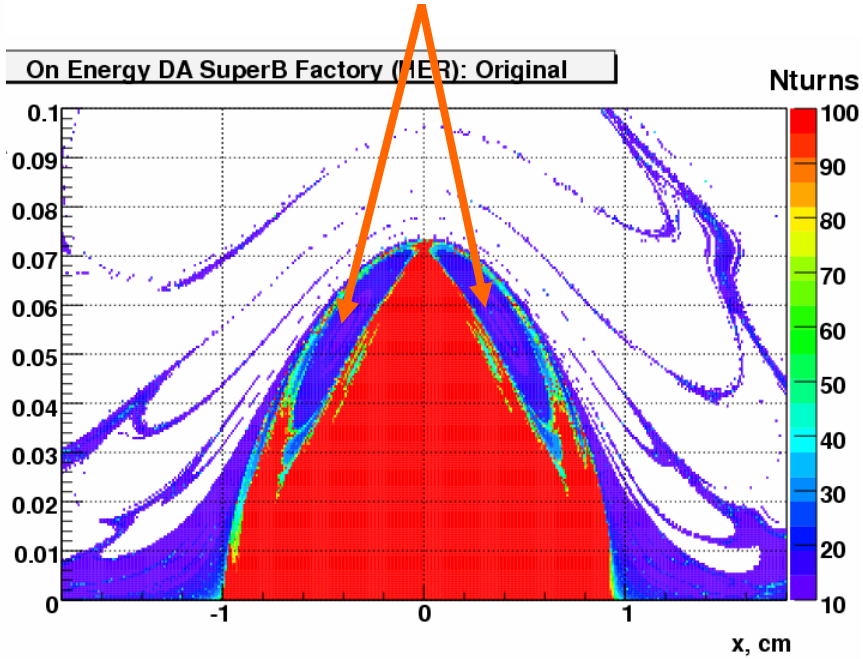
The pair 13 gives the worst DA while the pair 1 – the best one and is fixed at this step.

First optimization by BSP



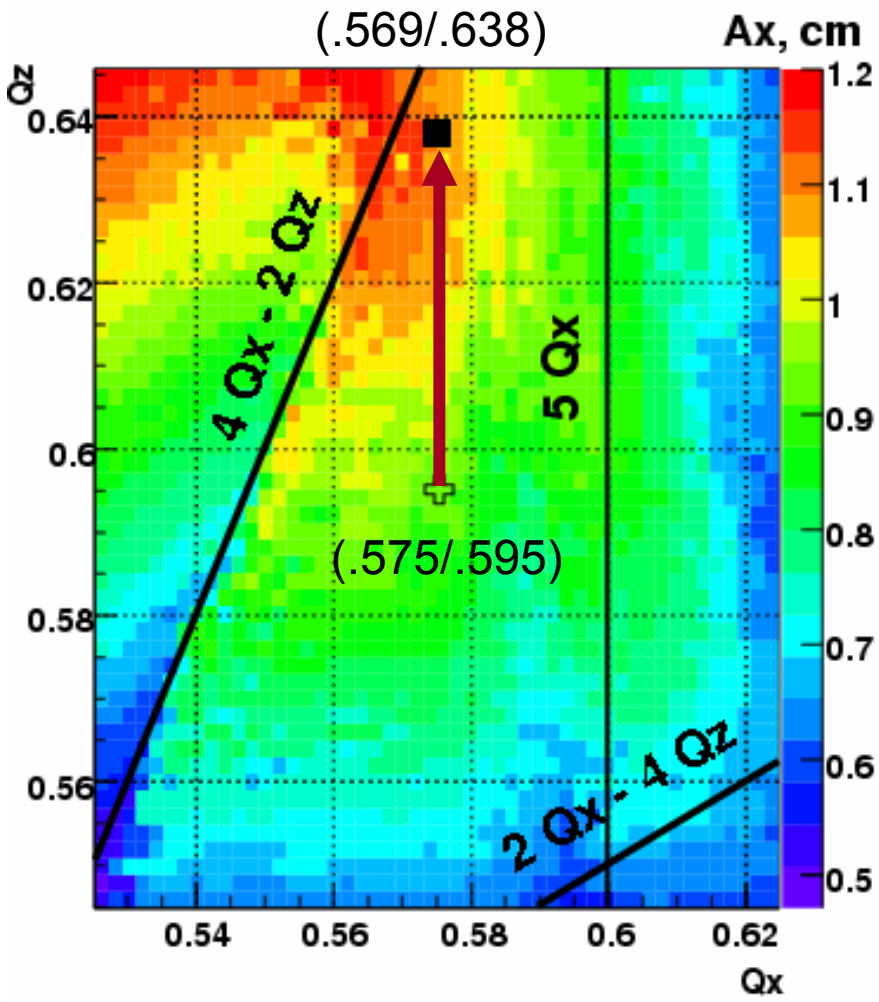
Black is the original DA (.575/.595)
Red is the optimized DA (.575/.595)

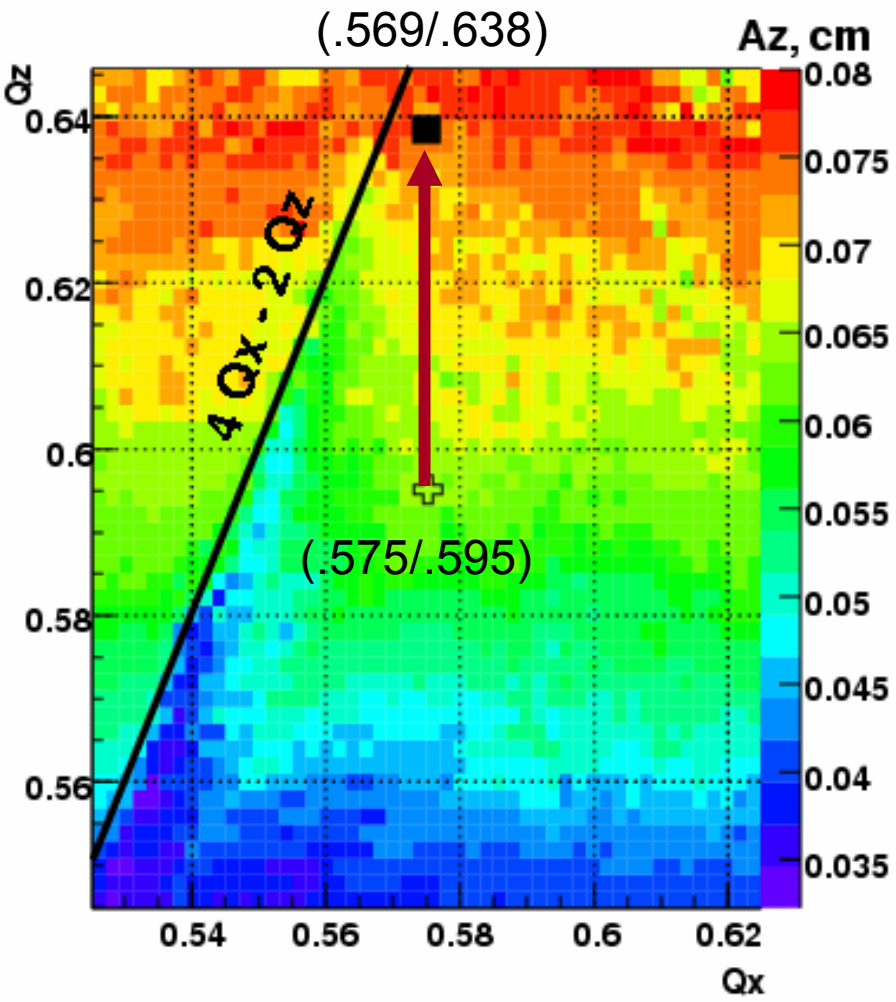
Resonance structures



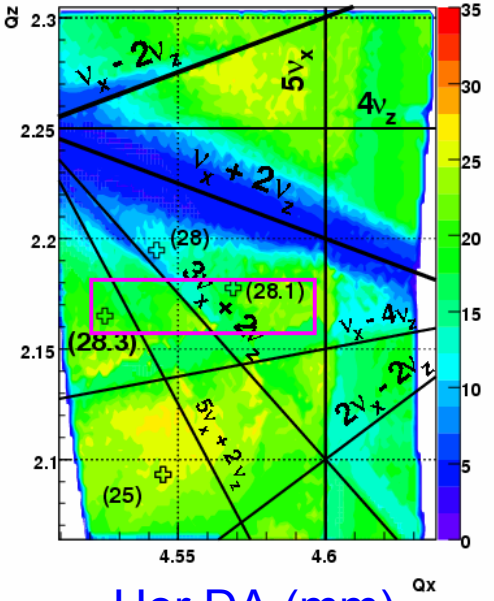
High resolution survival plot for the original DA

Super B DA tune scan

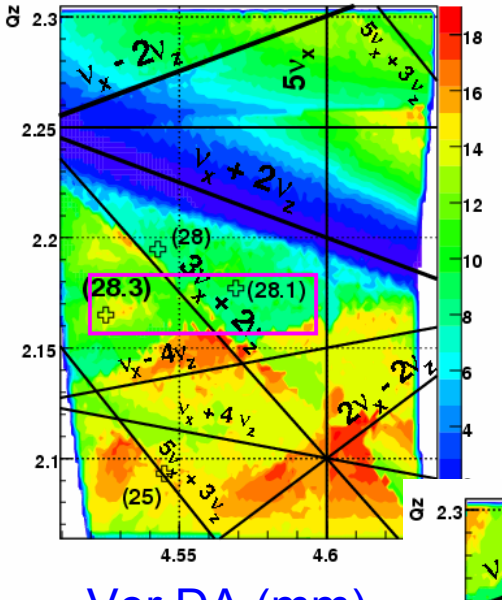




DA tune scan (not for SuperB)



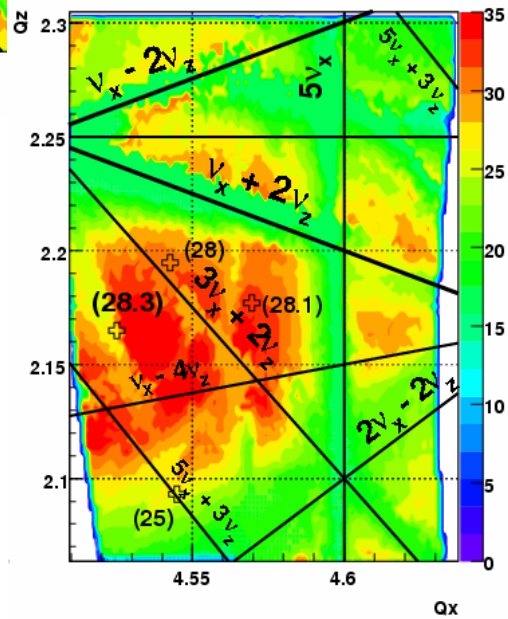
Hor DA (mm)



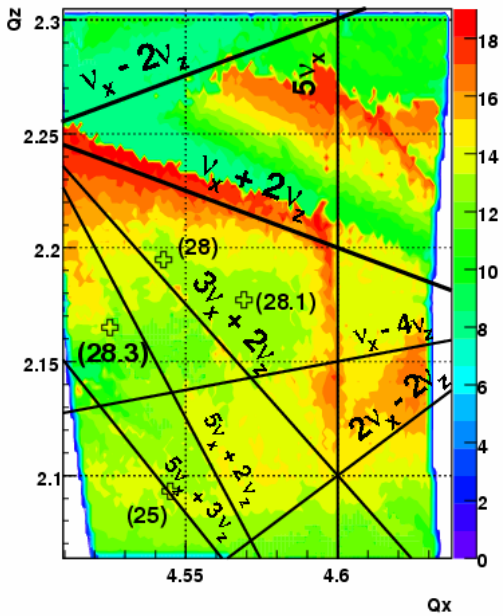
Ver DA (mm)

← DA tune scan
before optimization

DA tune scan →
after optimization

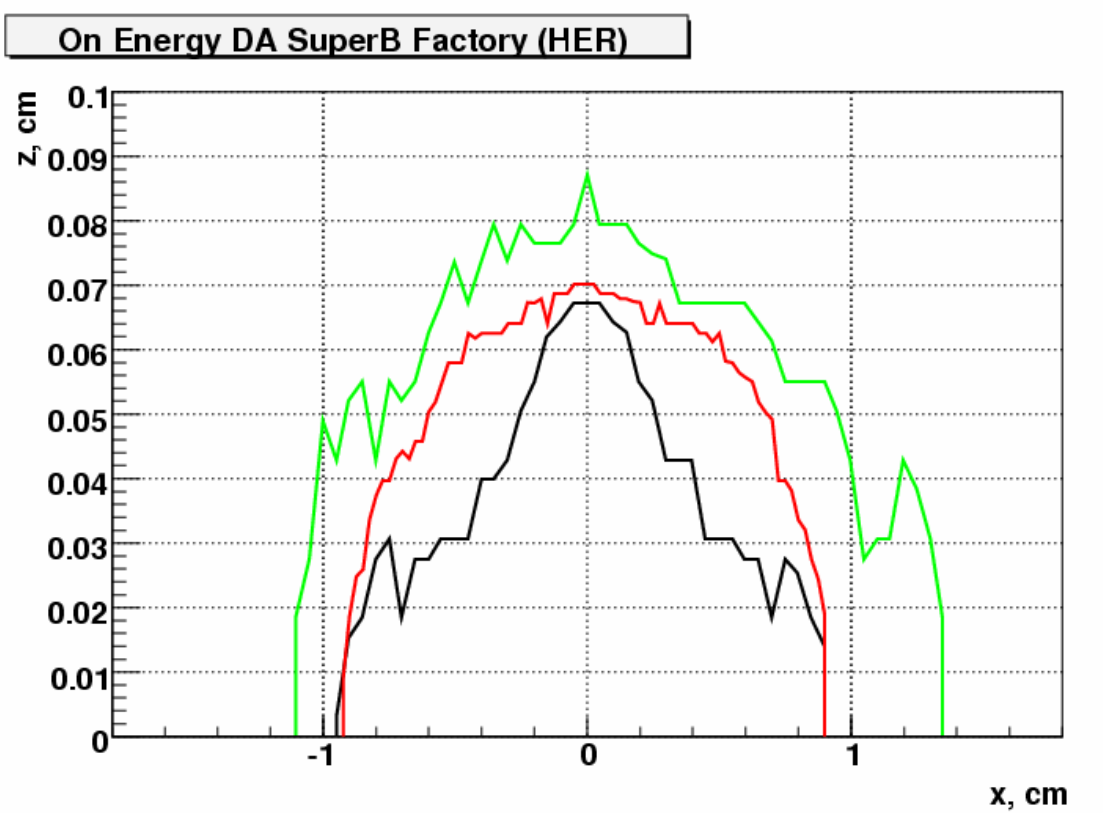


Hor DA (mm)



Ver DA (mm)

DA in the new point

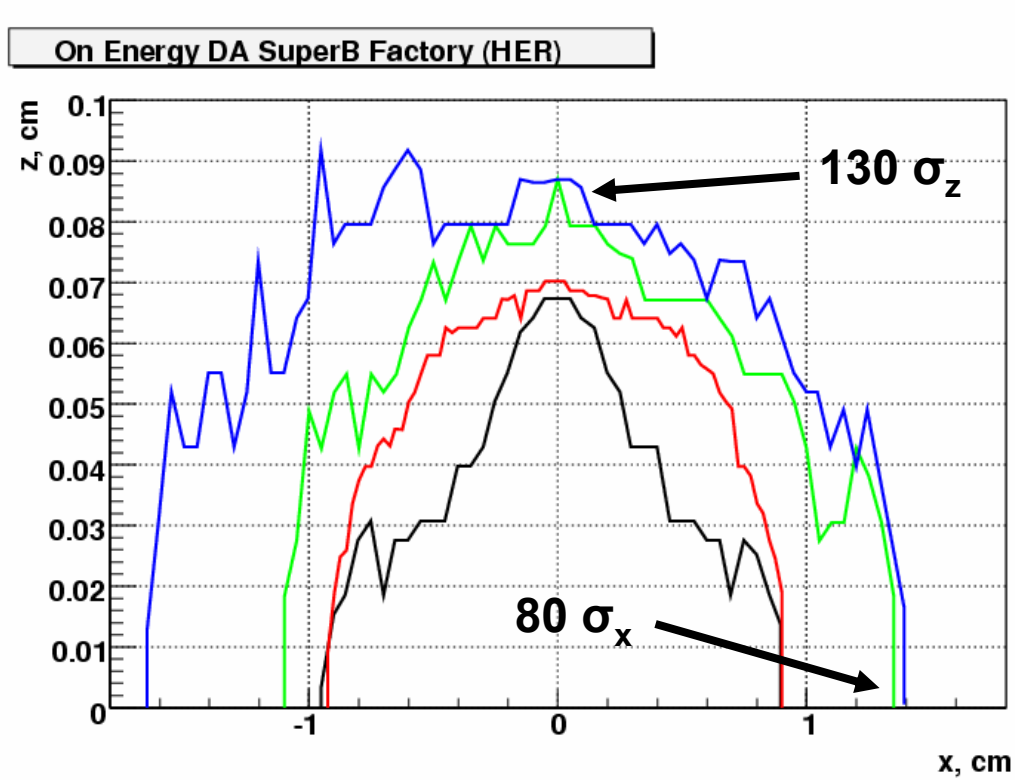


Black is the original DA (.575/.595)

Red is the optimized (.575/.595)

Green is the DA in the new tune point (.569/.638)

DA re-optimization in the new point



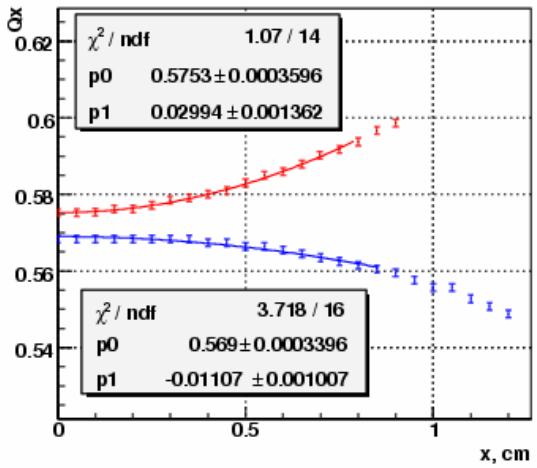
Black is the original DA (.575/.595)

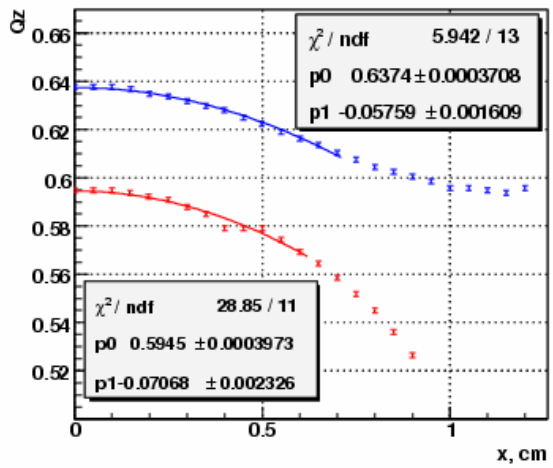
Red is the optimized (.575/.595)

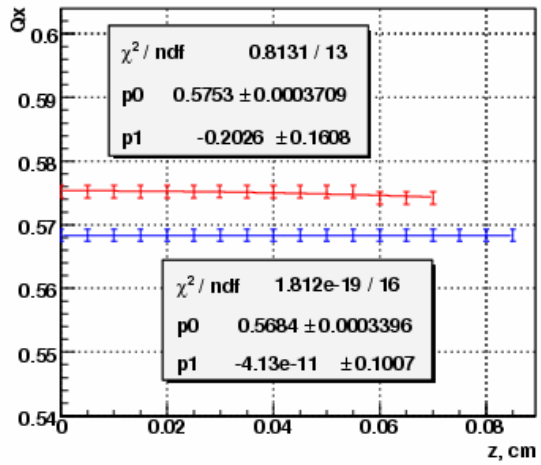
Green is the DA in the new tune point (.569/.638)

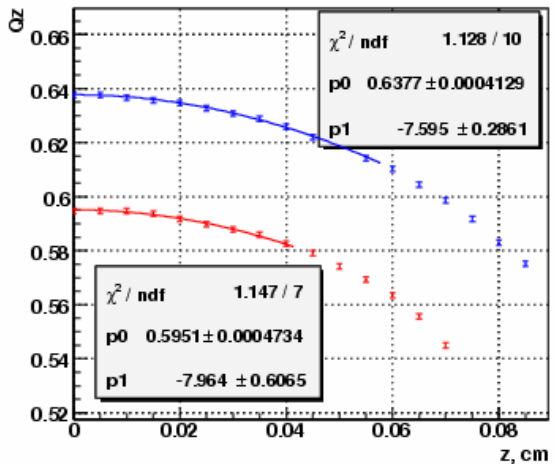
Blue is the DA re-optimized in the new tune point (.569/.638)

DA re-optimization in the new point









The horizontal and the vertical tune as a function of the horizontal and the vertical amplitude for the initial and final dynamic apertures

Summary

- The report describes and illustrates the algorithm for the DA optimization by selecting the best sextupole pairs as the natural chromaticity is corrected step-by-step.
- The algorithm is simple and straightforward and can be applied to any lattice; the results of the algorithm application seem promising.
- Off-energy dynamic aperture can be optimized as well.