Argonne
NATIONAL
LABORATORY

… for a brighter future

U.S. Department
of Energy

THE UNIVERSITY OF
CHICAGO

A U.S. Department of Energy laboratory
managed by The University of Chicago

Lattice Work at ANL

Louis Emery presenting Aimin Xiao's results,
March 5th 2007

Lattice Design

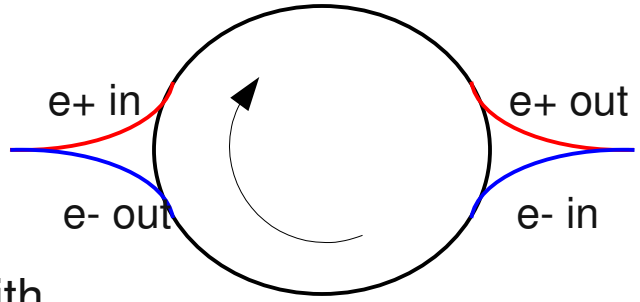
- Review of lattice versions and calculations
- Thoughts (?) on creating lattices of different momentum compaction
- First look at circumference-adjusting chicane
- Injection straight section change

Lattice History

- OCS (Summer 2005): 12 superperiods, 6.1 km, α_c=1.6x10^{-4}, 192 dipoles
  - Good DA: high symmetry and phase advance of straight sections adjusted for maximal dynamic aperture
- OCS6 (Jan 2006): Follow baseline recommendation, 10 (or 8?) arcs, two long straight sections, combined injection/extraction straight section, 6.6 km, higher α_c=4.2x10^{-4}, 120 dipoles
- OCS6: change to 6 arcs (machine function plots to follow), DA calculations

Lattice Future

- Separated injection/extraction
- Need to include chicane to lattice file
- Explore possibility of 2 wiggler sections
- Demonstrate momentum compaction variation with phase advance per cell



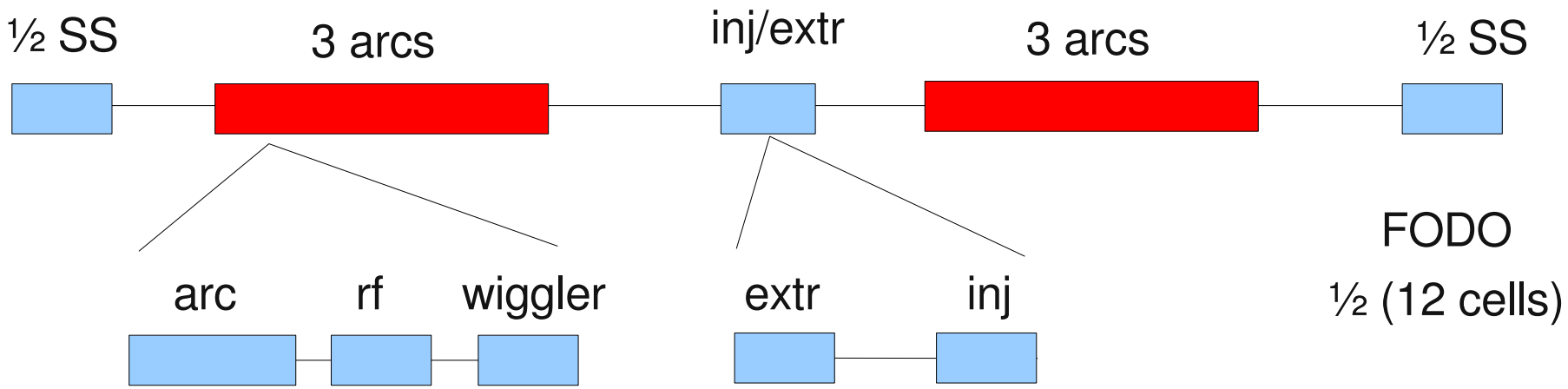
[I learned later that
the beams in the different rings
should actually be counter rotating]

Of course:

Dynamic aperture with various errors!!!

Present OCS6 Layout

Unwrapped from middle of long straight section



TME
18 cells

FODO
2 cells

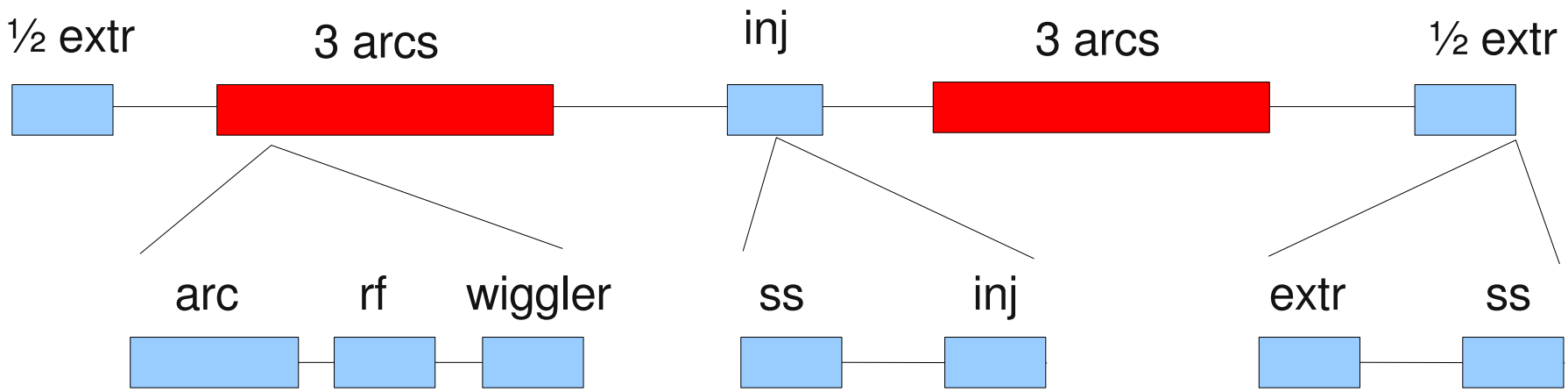
FODO
10 cells

pi-FODO
6 cells

(rf cavities not
necessarily present)

OCS6 Future Layout

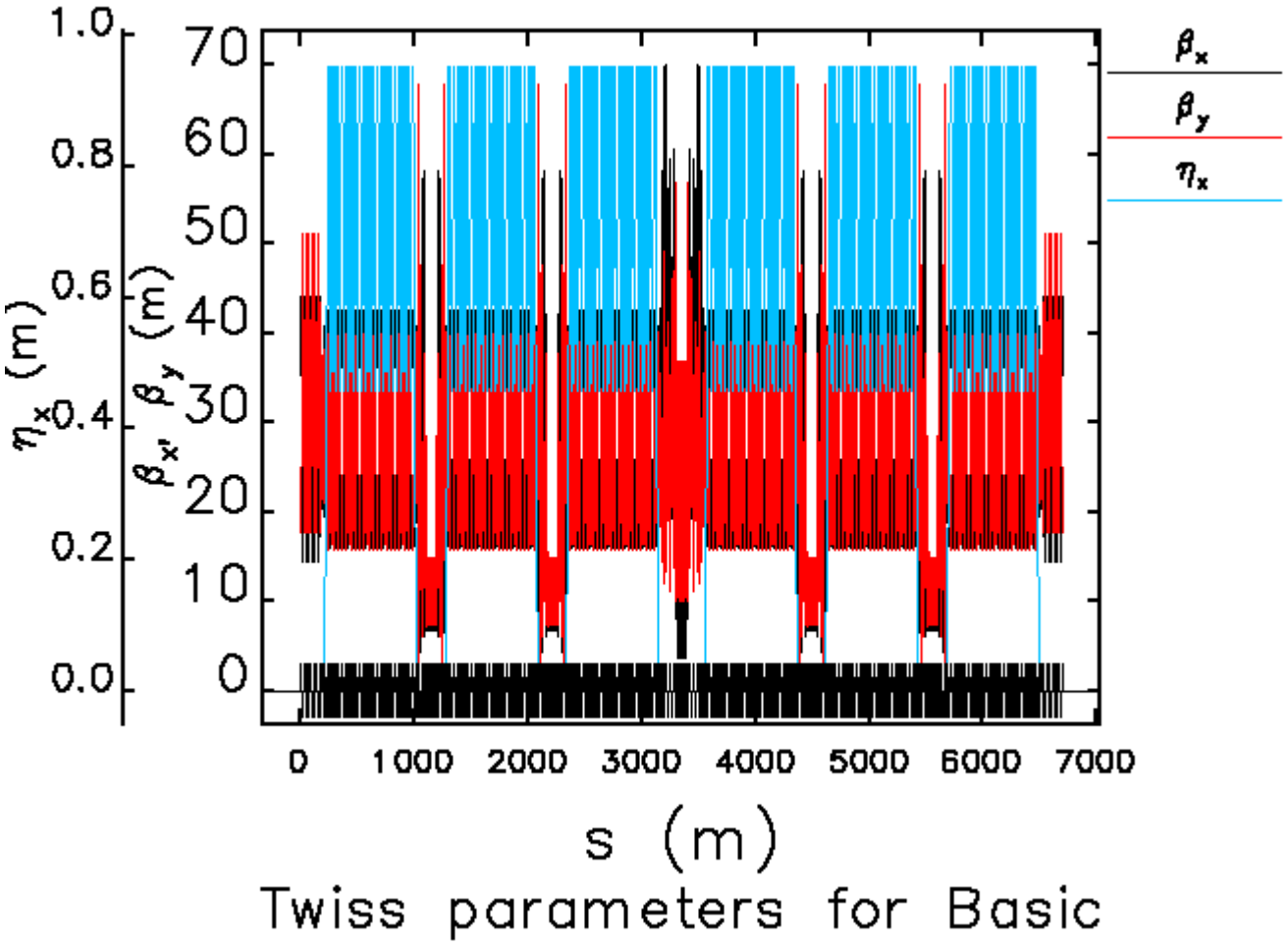
Unwrapped from middle of long straight section



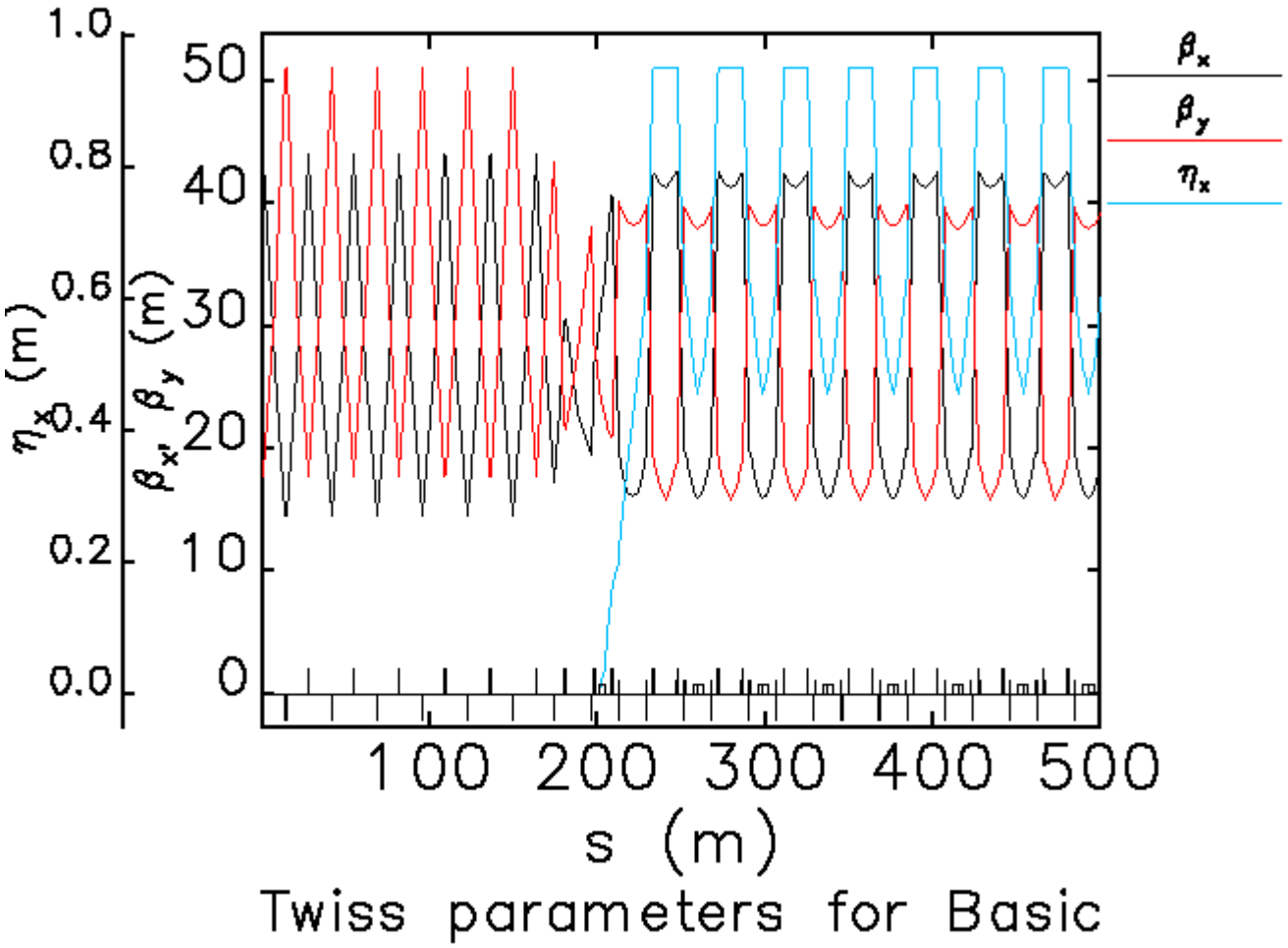
TME	FODO	FODO	FODO	FODO
18 cells	2 cells	10 cells	5 cells	5 cells

(rf cavities not necessarily present)

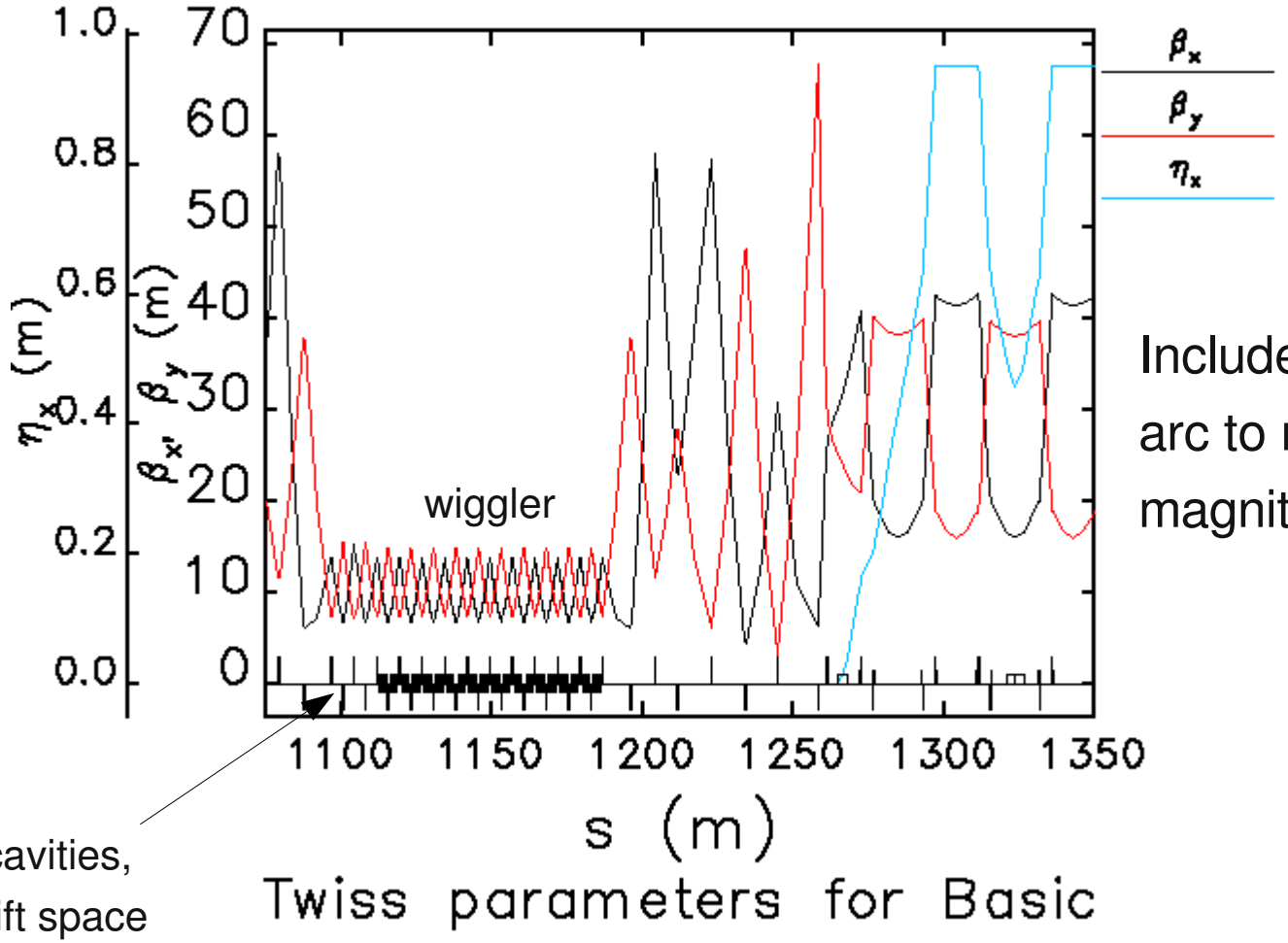
Present OCS6, Six Arcs



Zoom-in of TME cell with FODO long straight section



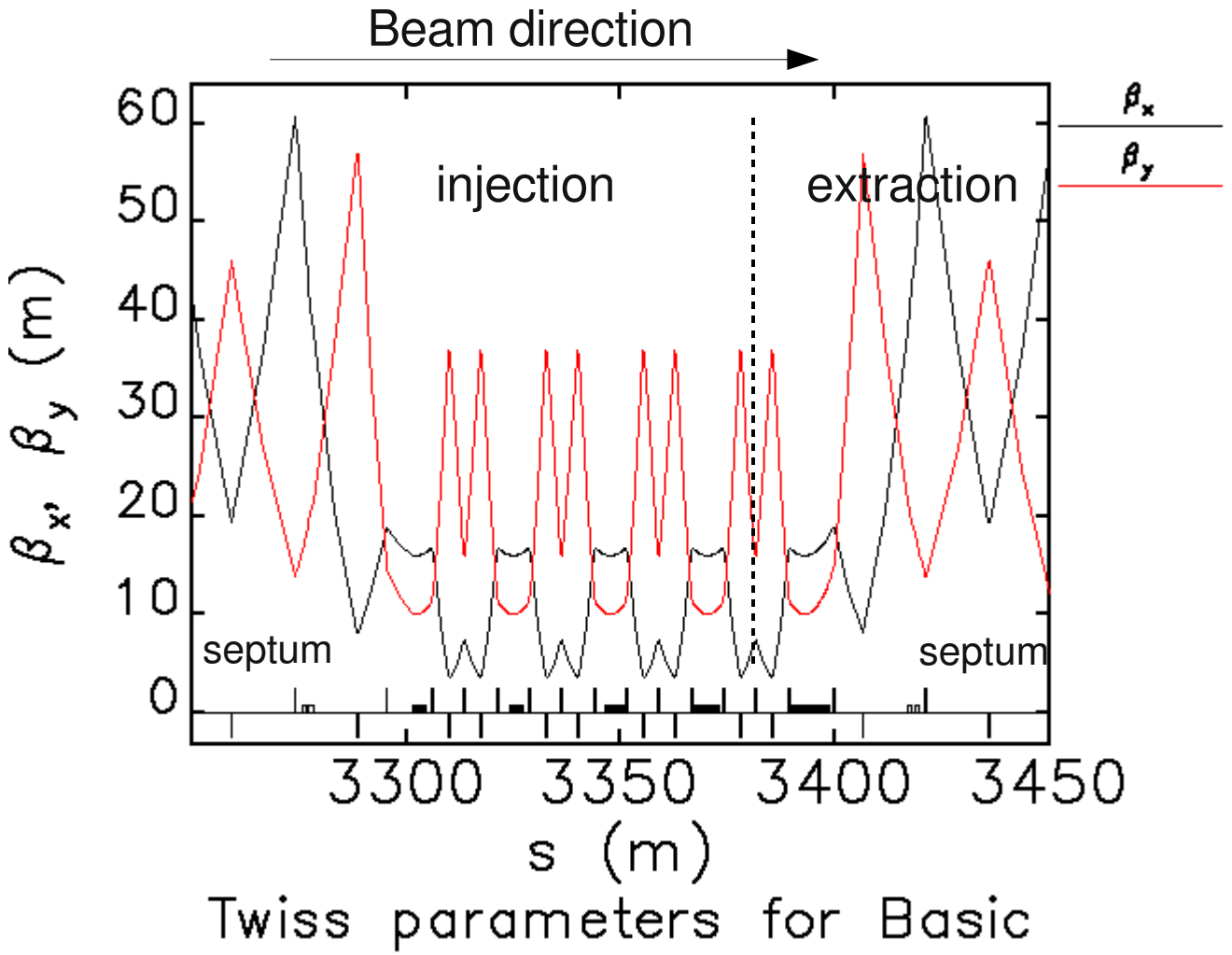
RF/Wiggler straight section



Eight RF cavities, two per drift space

Included some arc to note varying magnitude of β

OCS6, injection long straight section

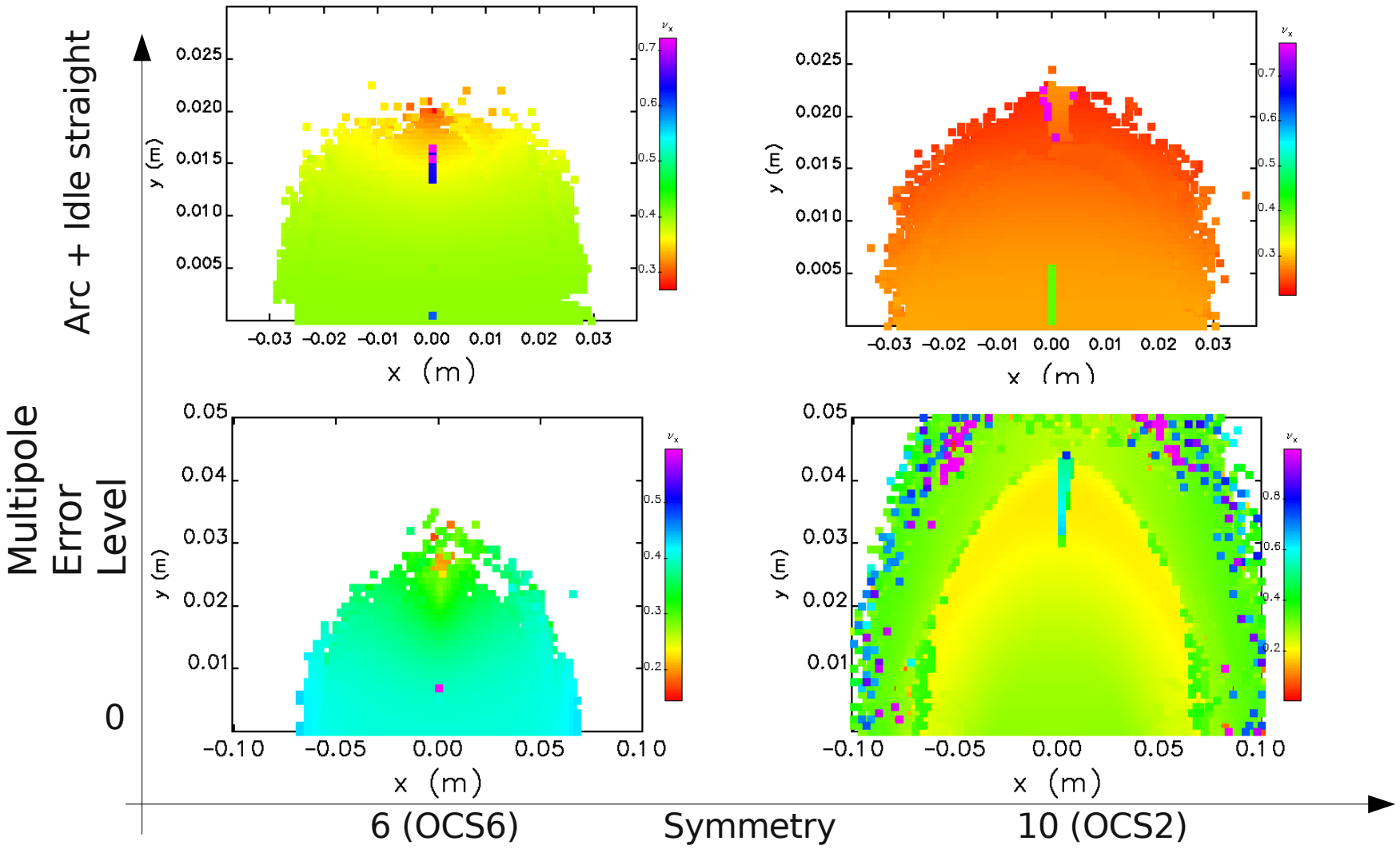


DA with Errors and Comparison

- With multipole errors, dynamic apertures of various lattices are quite similar
- When neglecting multipole errors different lattices may have very different dynamic aperture, which could lead to mistaken initial preferences in general

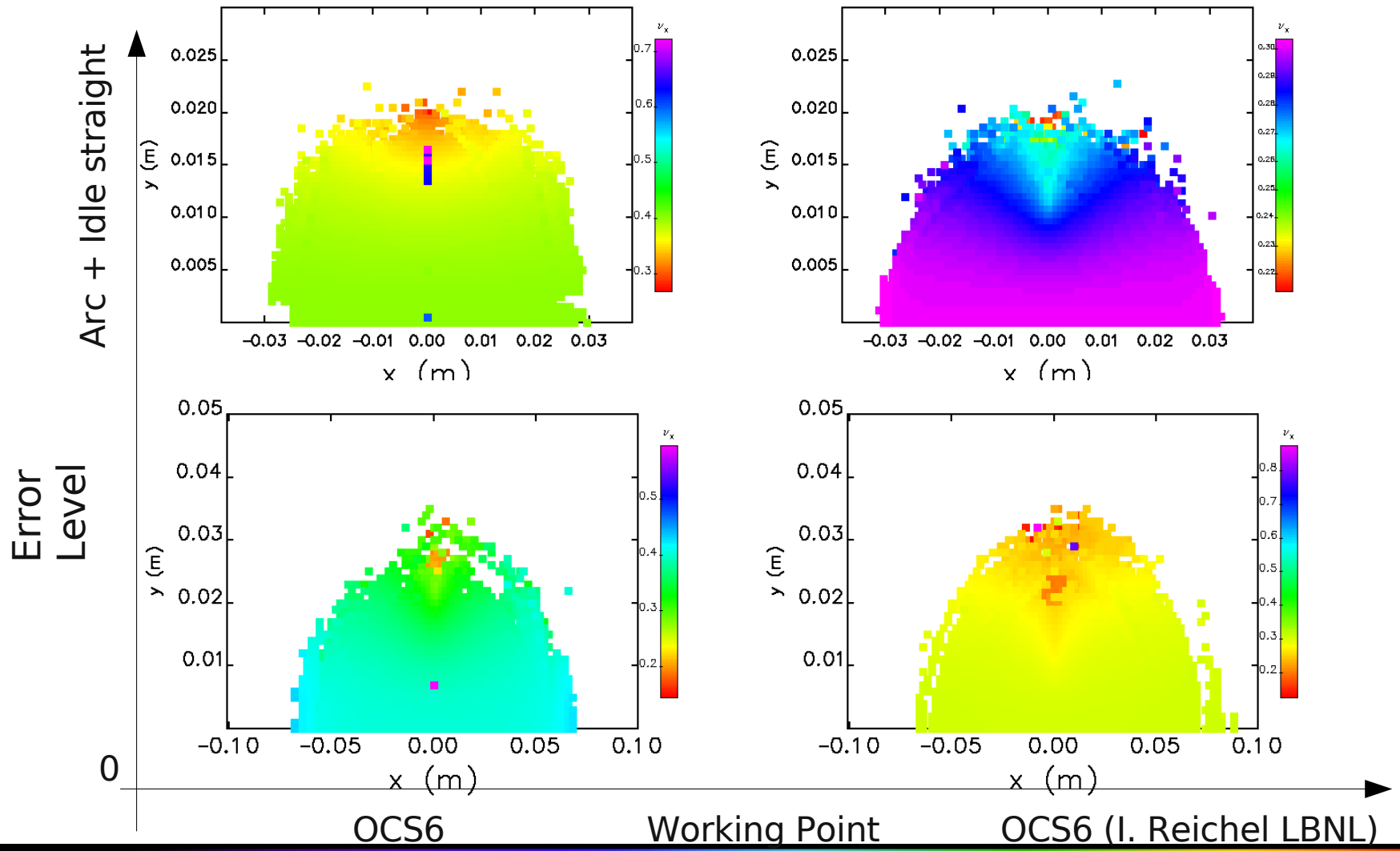
Comparing Dynamic Apertures w/ and w/o Errors

Dynamic Apertures with errors are very similar. Need x=20 mm, y=12 mm



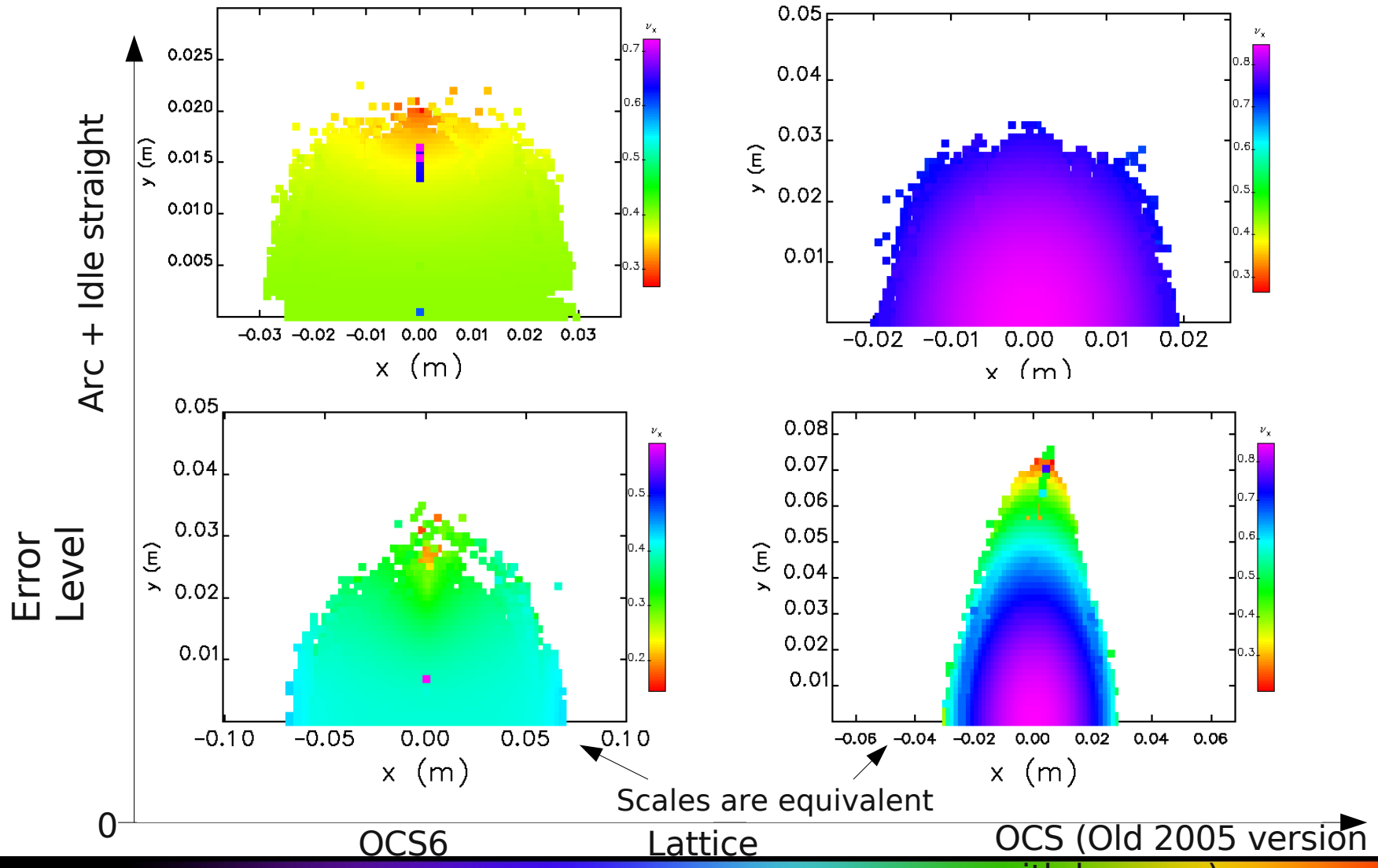
Dynamic Apertures for Different Tunes

Dynamic Aperture Improvement – small. Need x=20 mm, y=12 mm



Comparison of DA with old lattice version

Need x=20 mm, y=12 mm for OCS6

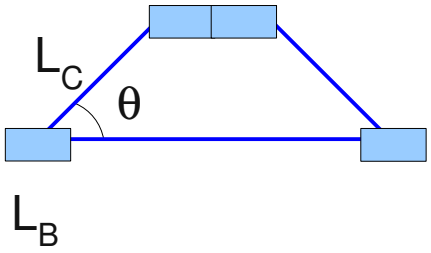


Chicane (1)

- Normal chicane path length change ds

$$ds = 2L_C\left(\frac{1-\cos\theta}{\cos\theta}\right) + 4\rho(\theta - \sin\theta)$$

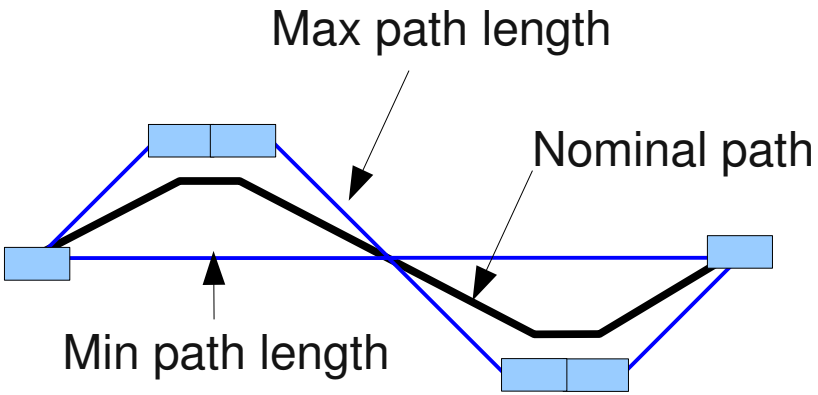
$$ds \approx \theta^2\left(L_C + \frac{2}{3}L_B\right)$$ for small bending angle



- Zigzag chicane

$$ds = 4L_C\left(\frac{1-\cos\theta}{\cos\theta}\right) + 6\rho(\theta - \sin\theta)$$

$$ds \approx 2\theta^2\left(L_C + \frac{1}{2}L_B\right)$$



- For low β_x fit into a TME cell without dipole

Can put magnets and VC on movers to preserve aperture and impedance, e.g. APS bunch compressor

Ref.: Emma and Raubenheimer
www-project.slac.stanford.edu/lc/ilc/TechNotes/lccnotes/PDF/LCCNote_0008.pdf

Chicane (2)

- Emittance dilution

$$\epsilon_x = C_q \gamma^2 \frac{I_5}{I_2 - I_4}$$

  - I2 is determined by damping time and doesn't change much with chicane. So,

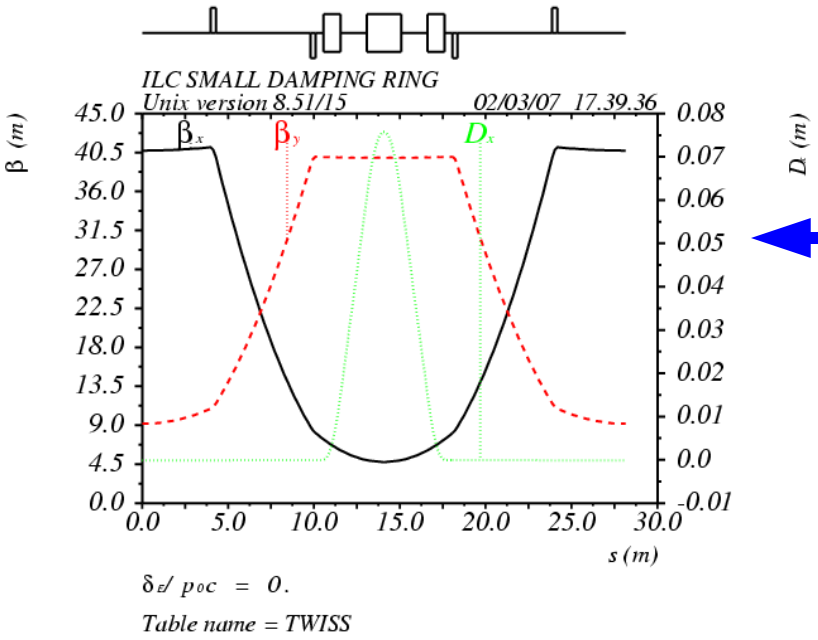
$$\frac{d\epsilon_x}{\epsilon_x} = \frac{\Delta I_5}{I_5}$$

- Energy spread

$$\sigma_e^2 = C_q \gamma^2 \frac{I_3}{2I_2 + I_4}$$

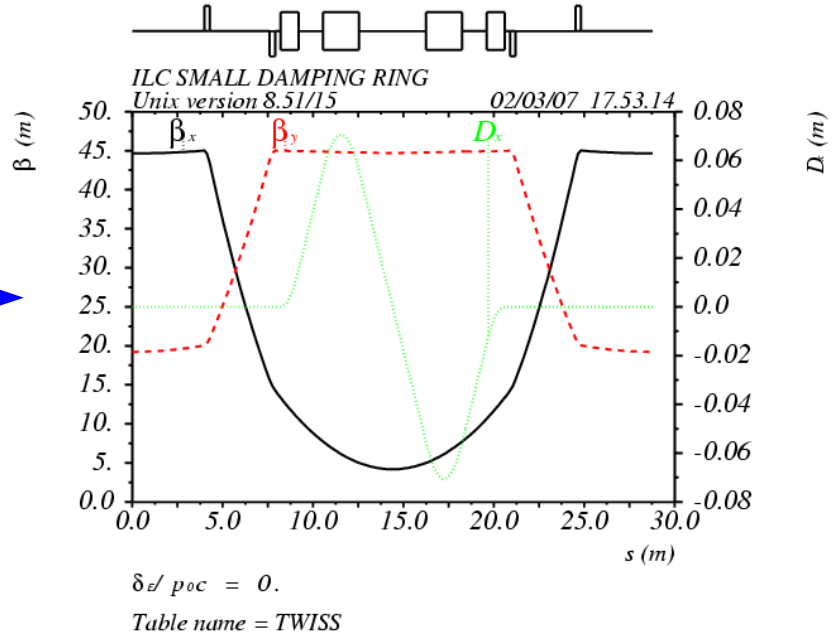
  - strong wigglers controls I_3 so chicane will have small effect

Chicane (3)



May have smaller emittance growth

More cells needed for getting the ds range we need



More compact than two of the type above

May have larger emittance growth

Chicane (4)

- Assuming relative circumference error 10^{-6}
  - Required adjustment range ± 7mm
  - Couldn't be achieved by single chicane while keeping emittance growth reasonable
  - Using normal chicane, we need 8 units, emittance growth is about 15% for ± 7 mm adjustment
  - Using zigzag chicane, we need 4 units, emittance growth is about 16%
- Note: APS ring and booster had circumference error of 10^{-5}
- During DR commissioning, girders may be realigned uniformly radially to get within 2 mm of ideal (0.3 mm settability limit)
  - Need fewer chicane
  - Need input from alignment people on this.
- Because both rings are in the same tunnel, circumference will be within 2 mm, i.e. 0.3 mm relative misalignment.

Injection Region Reworking (1)

- Original injection was designed based on technical specification from BCD document
- The weak kicker strength from strip-line requires very long injection section and oscillating injection beam orbit (to preserve aperture)
  - many people didn't like it...

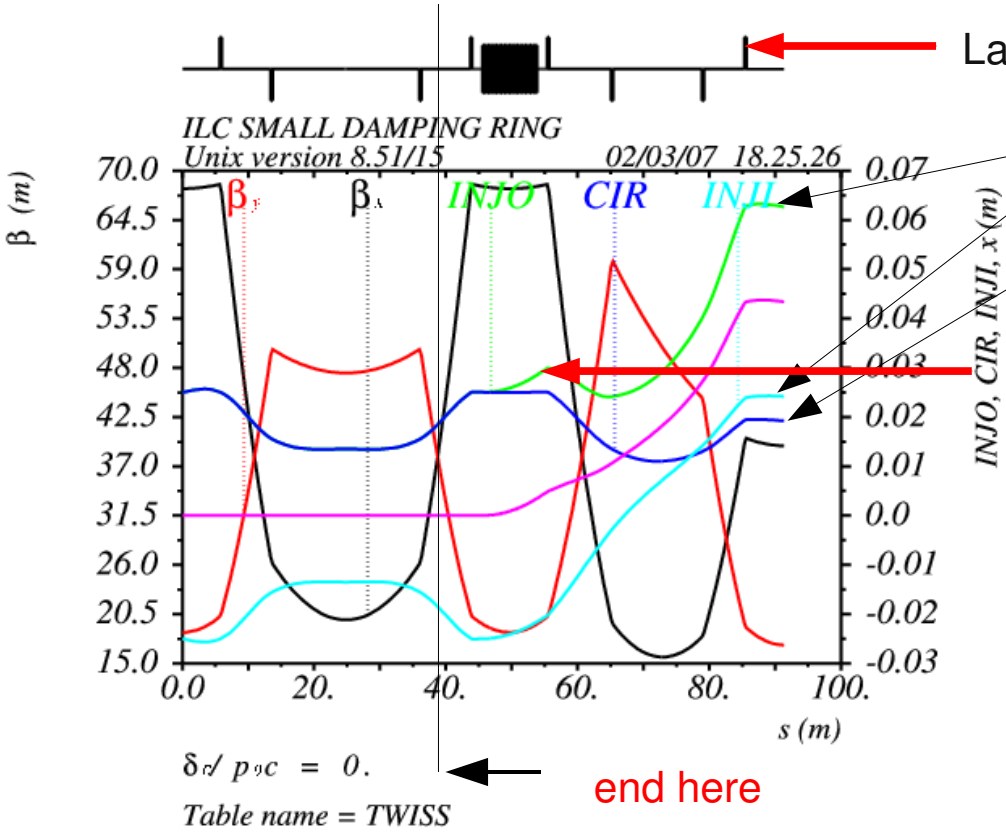
Correction in assumption:

- Have two 10 kV pulsers per stripline kickers (which doubles its strength)
  - Keep kick angle at 0.04 mrad, but double aperture from ±15 mm to ±30 mm, and quadruple β_x from 15 m to 70 m

We got a solution with all strip-lines consecutive!!!

  - 21 kickers of 0.04 mrad
  - Small angle make injection trajectory smaller in kickers

Injection region Reworking (2)



Large aperture quad required: r=70mm

Injection beam envelop

Circulation beam envelop

Beam envelope in strip-line<30mm

end here

Beam direction

Conclusion

- New lattice features: chicane and new injection
- Need to assemble ring and adjust phases for maximum dynamic aperture
- Check DA with errors