Modeling and Simulation for CESR-c & ILC Wigglers

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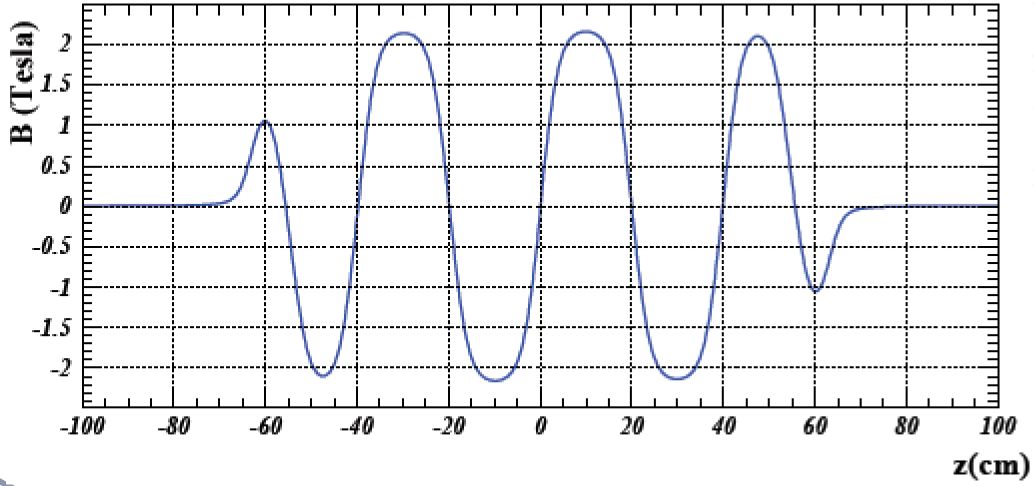
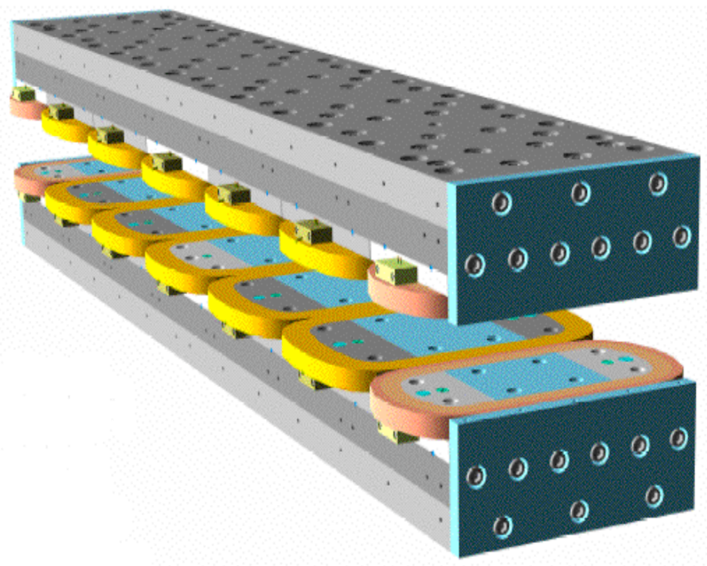
CESR-c Wiggler Design

- Energy = 1.88 GeV
- Superferric
- 8-Pole Wiggler
- Length = 1.3 m
- Peak Field = 2.1 T
- Horizontal Uniformity = 90 mm
- Period = 400 mm
- Gap Height = 76 mm
- Pole Width = 238 mm
- Realistic End Poles





CESR-c Wiggler Modeling

- OPERA 3-D _ Discrete
- Fit _ Analytic [1]
- Analytic _ Hamiltonian

[1] D. Sagan, J. A. Crittenden, D. Rubin, E. Forest,
A Field Model for Wigglers and Undulators, PAC 2003

CESR-c Wiggler Modeling

Note: k_{xn} & k_{sn} are free parameters in the fit, not = 2n□/□

f_n=1:

f_n=2 and f_n=3 select different combinations for fit

BMAD Tracking Methods

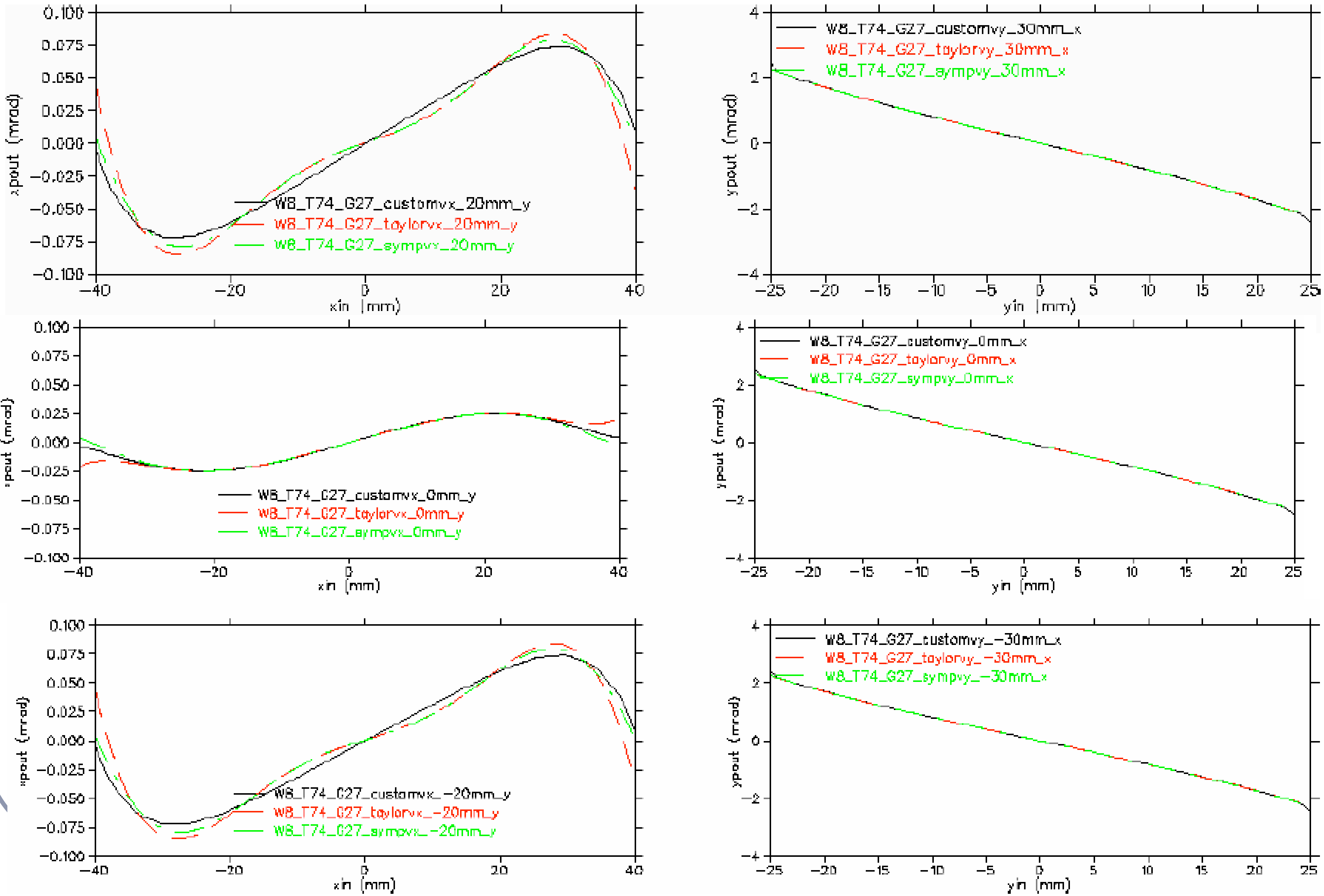
- Hamiltonian in Paraxial Approximation:

[illegible]

- Symplectic Inetgration[2]
  - To Track (250 steps)
  - To Generate Taylor Map (3rd order)
- Runge-Kutta through Field Table

[2] Y. Wu, E. Forest, D. S. Robin, H. Nishimura, A. Wolski, V. N. Litvinenko, *Symplectic Models for General Insetion Devices*, PAC 2001

CESR-c Transfer Functions

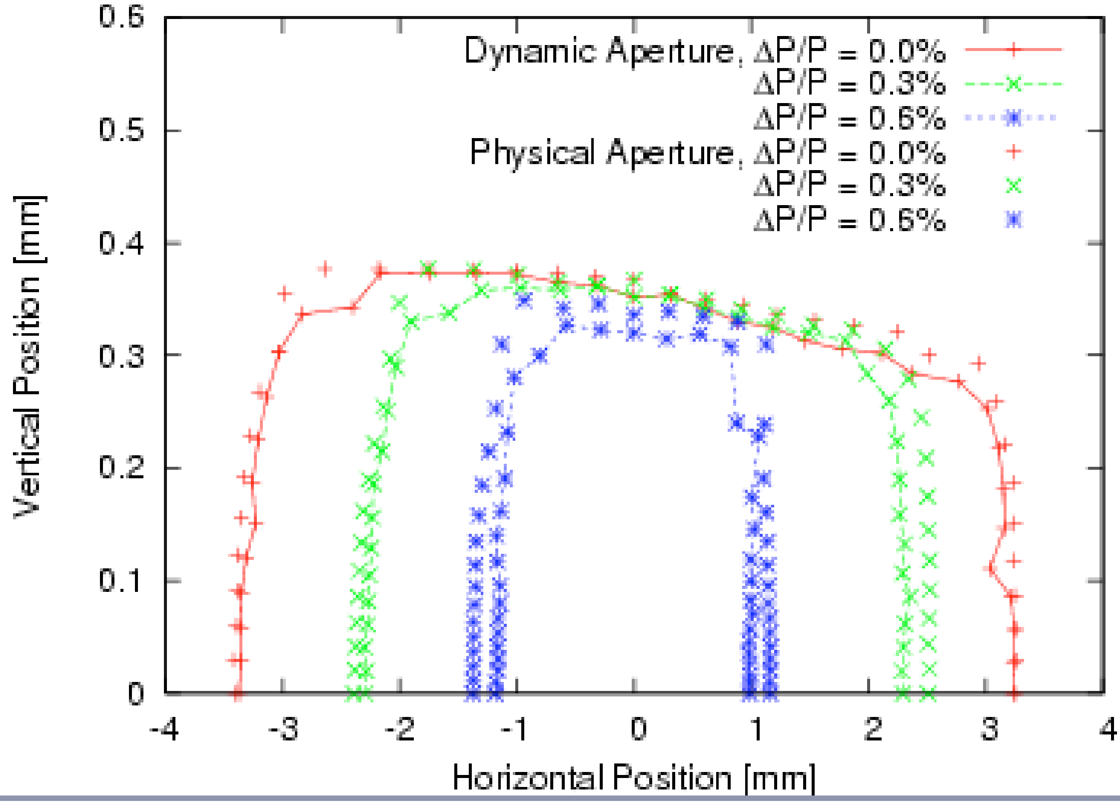


Simulation of CESR

Dynamic Aperture in CESR-c

Δp/p = 0%, 0.3%, 0.6%

$Q_x = 0.518$, $Q_y = 0.584$, $Q_z = -0.089$

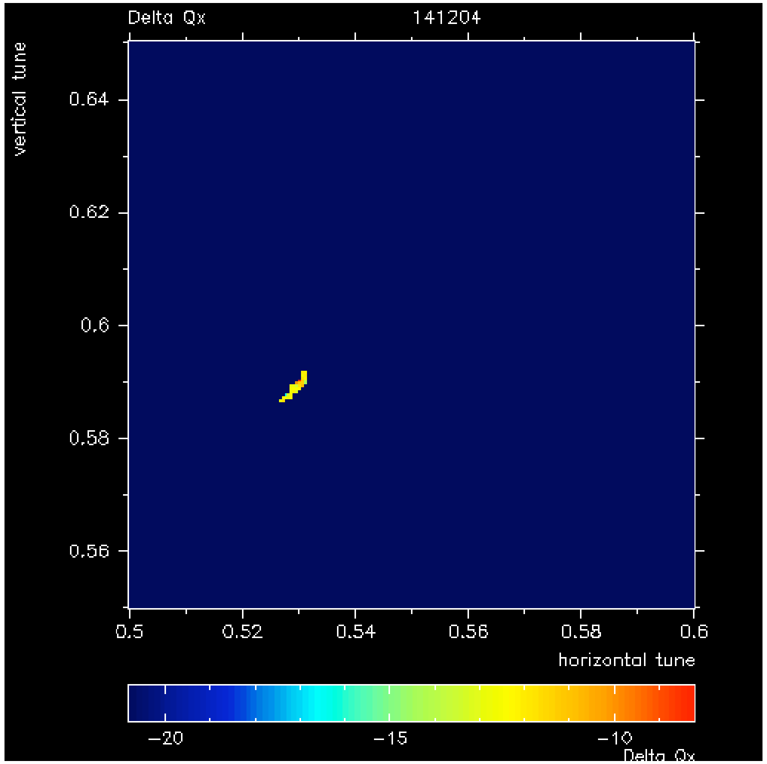


Simulation of CESR

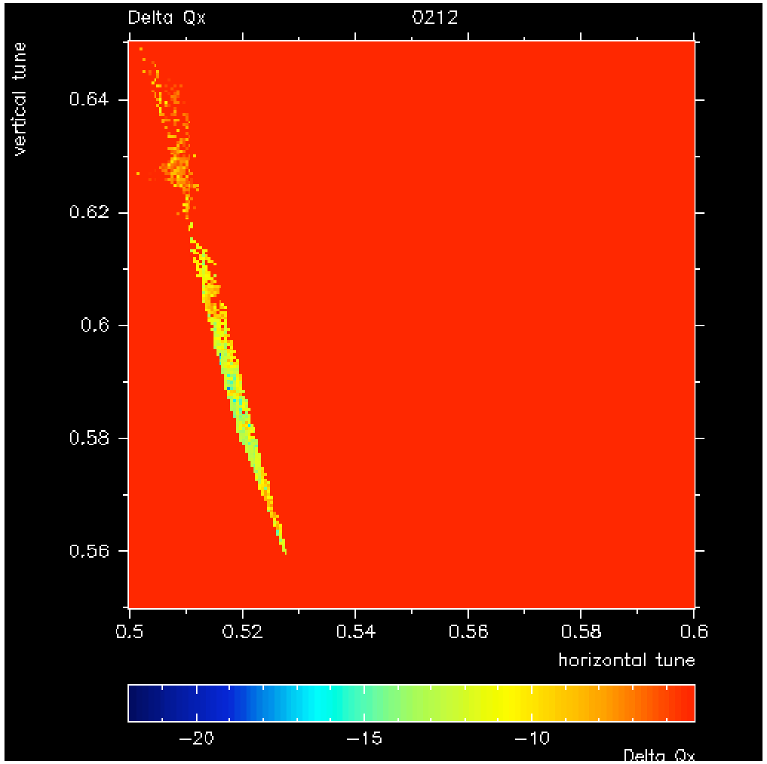
Horizontal Tune Shift vs. Tune in CESR-c

$Q_x = 0.53,\ Q_y = 0.59,\ Q_z = -0.089$

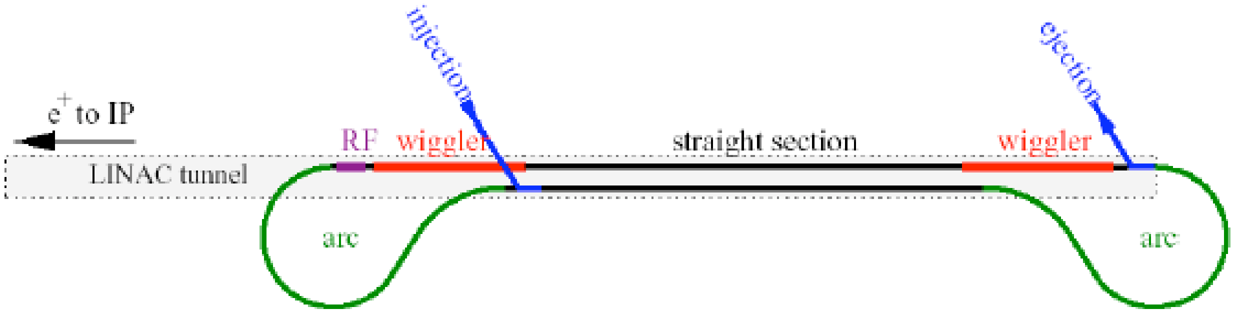
Linear Wiggler Model



Non-Linear Wiggler Model



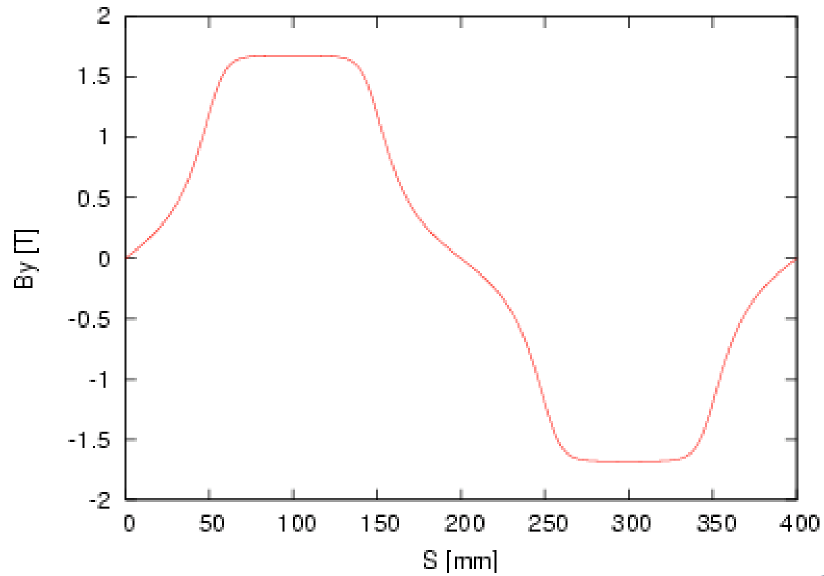
ILC Wiggler Design



Schematic of Dogbone Damping Ring from TESLA TDR

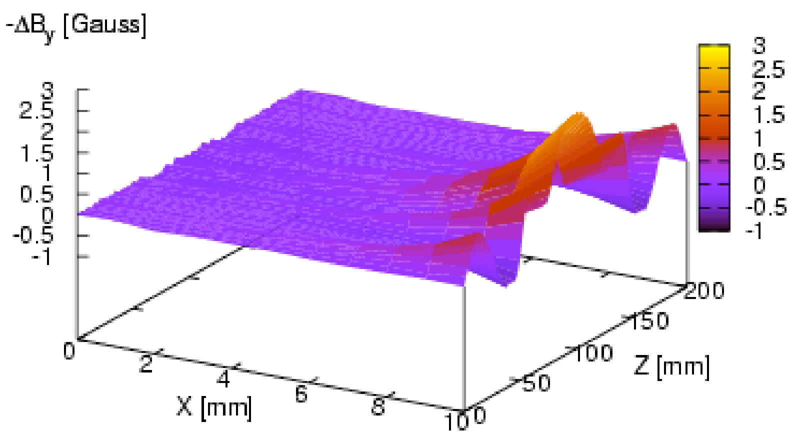
- Energy = 5 GeV
- Permanent Magnet
- Wiggler Length = 430 m
- Peak Field = 1.67 T
- Period = 400 mm
- Pole Width = 60 mm
- Gap Height = 25 mm
- Aperture = 2.8*$_{\text{—}y,e^+,\text{inj.}}$

Magnetic Field Profile

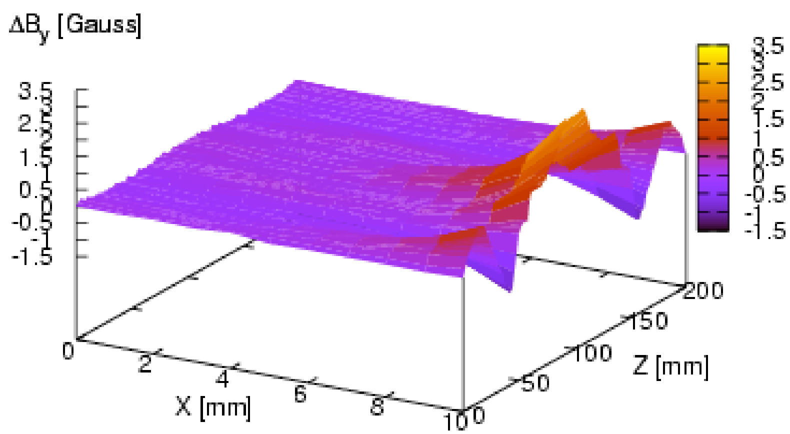


ILC Modeling

- Using 132 terms, differences with field table are less than 1 G on-axis and a few G at large amplitudes.

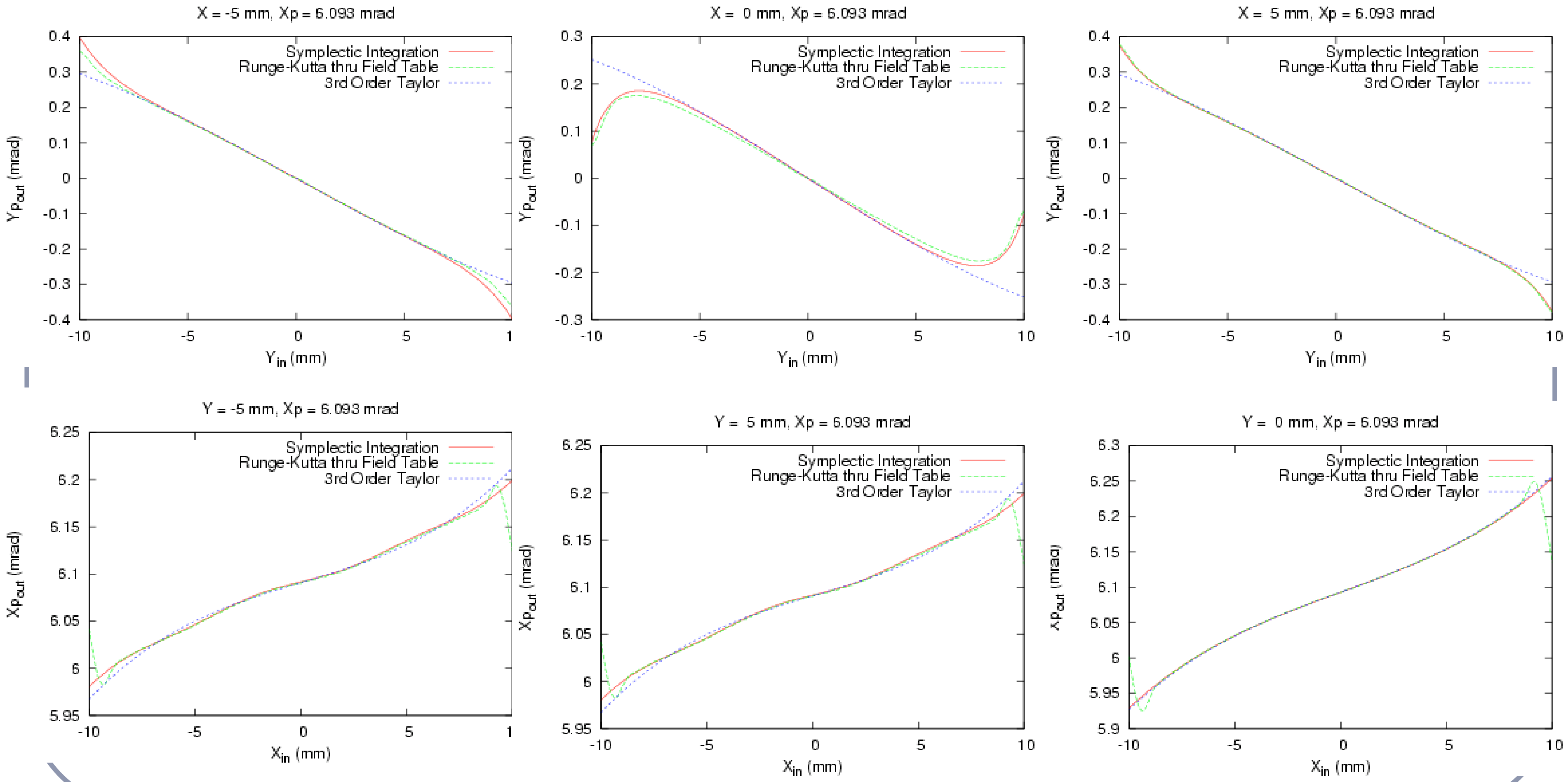


Residuals at Y = 0 mm



Residuals at Y = 6 mm

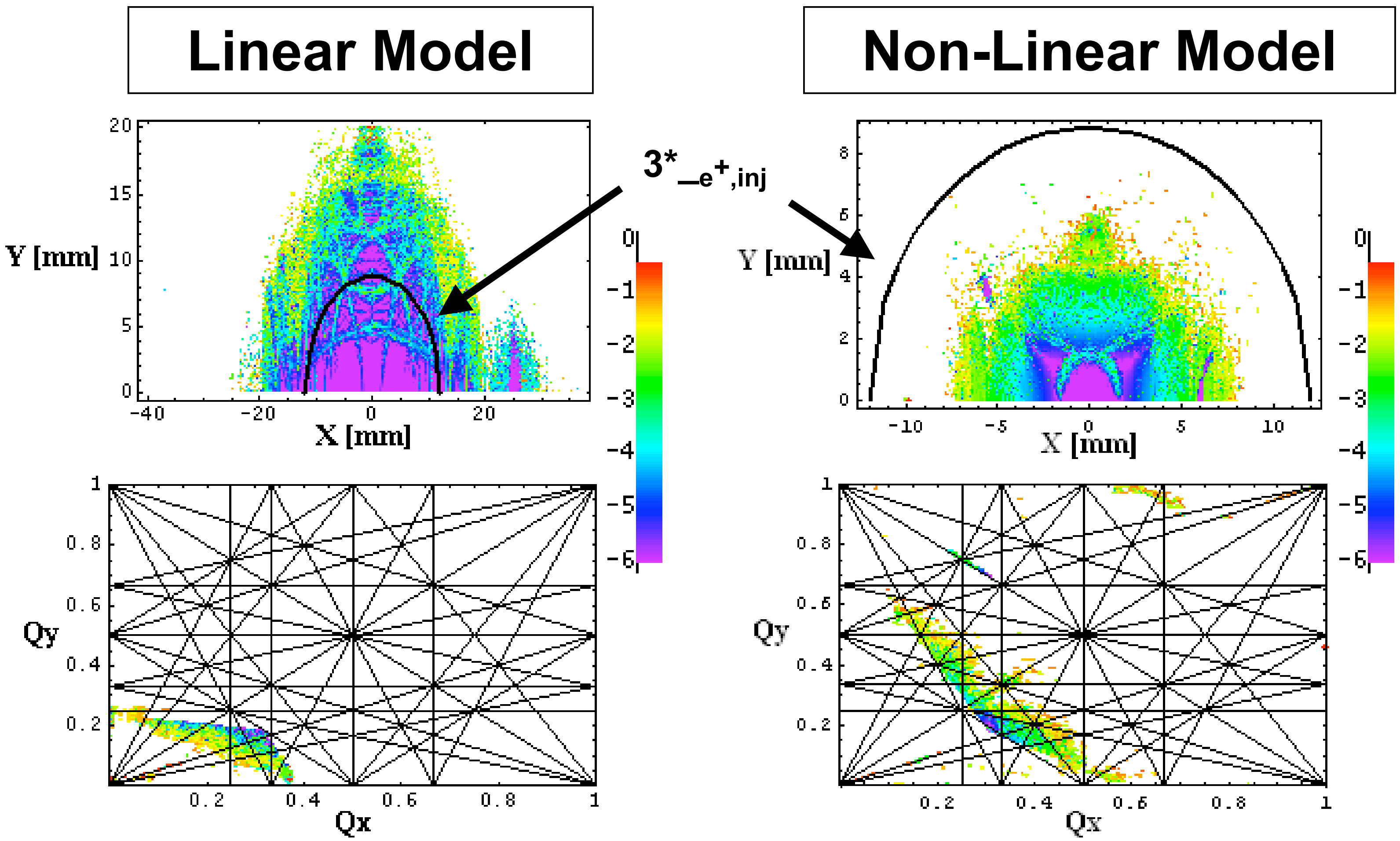
ILC Transfer Functions



In the Dogbone Damping Ring

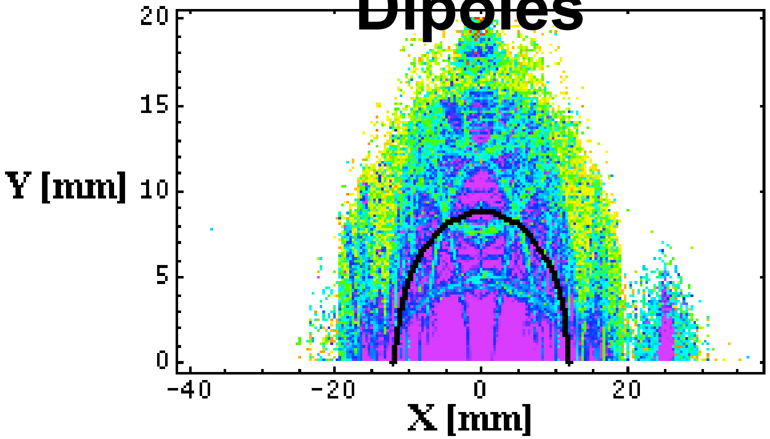
- Frequency Map Analysis
  - Intensity = Log (_Q_x)
- Dynamic Aperture
  - Reference Curve = 3*Injected Positron Beam Size
- Tune Scan
  - Intensity = Area Enclosed By Dynamic Aperture
- On-Momentum
- Working Point: $Q_x = 0.31$, $Q_y = 0.18$
- Match Tune with Matrix Transformation
- Sextupoles Untouched in Dogbone Lattice
- Tracking using 3rd order Taylor Map

Impact of Non-Linear Wiggler

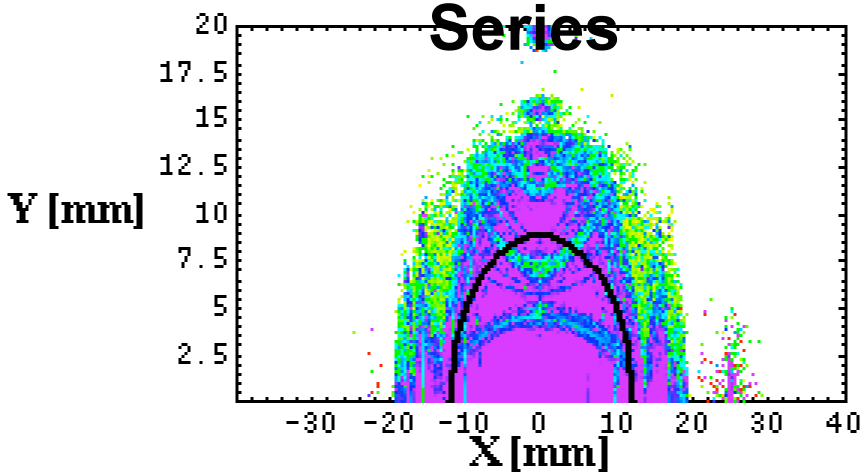


Which non-linearities restrict the DA?

"Linear" Model: Alternating Dipoles



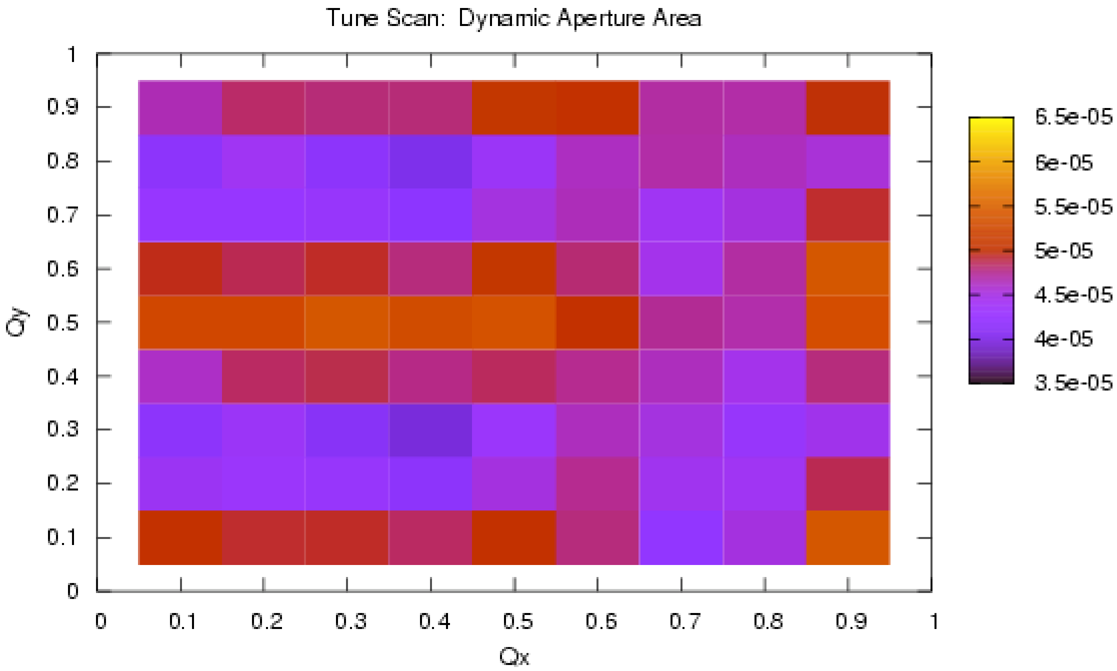
Linear Model: 1st Order Taylor Series



- The Perfect Wiggler:
  - pole width = ∞; $B_y \sim \sin(z)$
  - dominant non-linearity is the vertical octupole term
  - In Progress…

Tune Scan

- Working Point:
  $Q_x = 0.31$, $Q_y = 0.18$

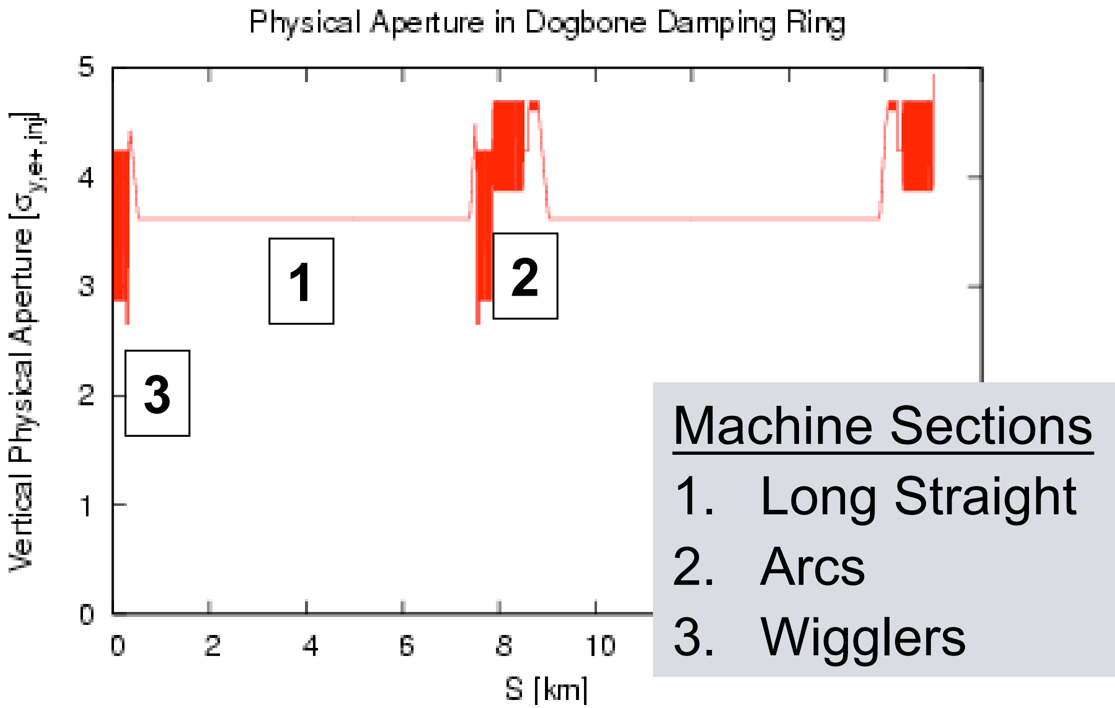


- The tune footprint is large but maybe better operating points exist.

- Analytic Vertical Tune Spread:

Physical vs. Dynamic Aperture

- Wiggler Gap Height = 25 mm
- Straight, Quad Bore Radius = 52 mm



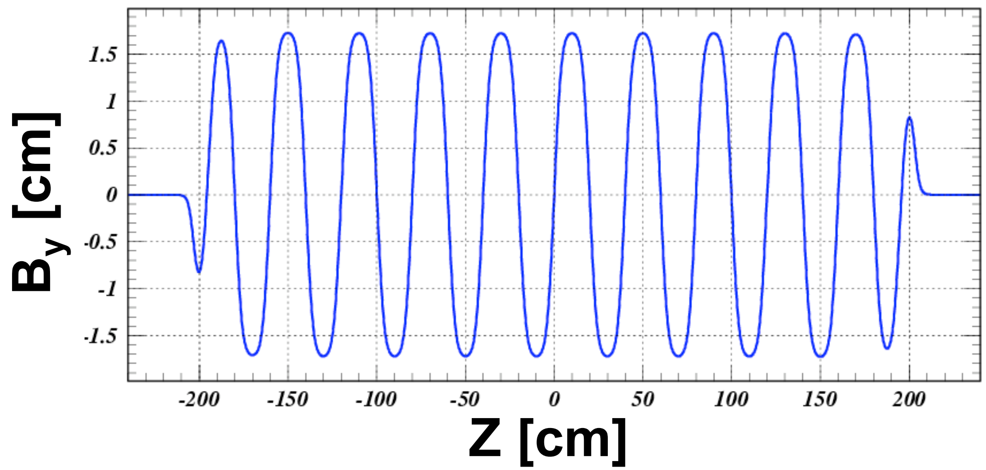
- How big do we need? How much will real effects in magnets reduce the dynamic aperture?
- In Progress: random distribution of multipole errors on every quadrupole, e.g.

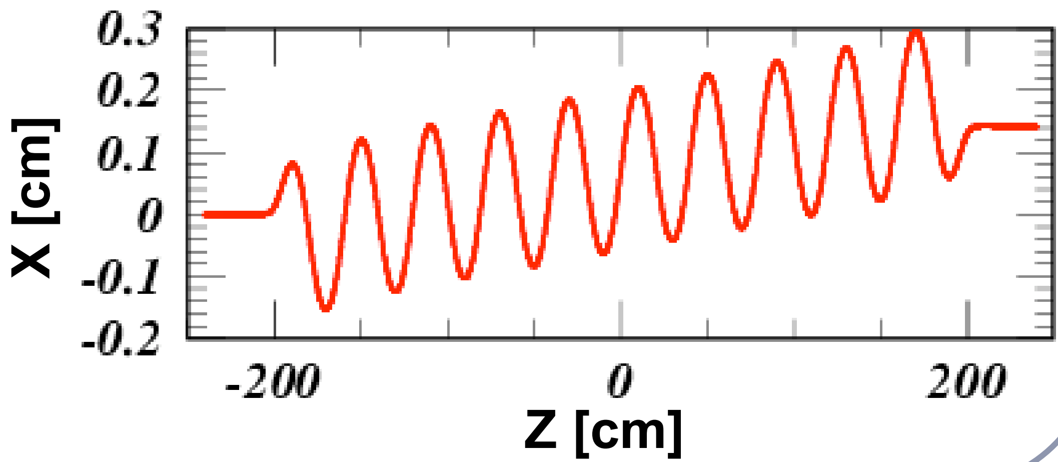
Modified CESR-c Wiggler

- Possible Benefits:
  - Larger Gap Height
  - Larger Pole Width
  - It's a real magnet!

- Modifications:
  - Lowered Peak Field
  - Lengthened Magnet

- In Progress…





Future Plans

- Identify non-linearities of ILC wiggler design which restrict the dynamic aperture
- Investigate ILC wiggler options to maximize dynamic and physical aperture
  - Vary Pole Width
  - Vary Gap Height
  - Superconducting

  } Modified CESR-c Wiggler Design
- Move to experimental investigation with CESR-c