Cornell University
Laboratory for Elementary-Particle Physics

Dynamic Aperture Studies at Cornell: 7 Lattices, 3 Wigglers

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Description of Simulations

- Performed using BMAD
  - Tracking using 3rd order Taylor Map
  - Radiation Damping and Excitation Capable
- Types of Results
  - Frequency Map Analysis
  - Dynamic Aperture
- Simulation Parameters
  - Match Tune with Matrix Transformation
  - Sextupoles Untouched in Lattices
  - Synchrotron Oscillations

Lattices were compared on:

- Wigglers
- Multipole Errors
- Energy Aperture

GOAL: Cross-checking of codes between different laboratories and generation of baseline results for seven viable damping ring lattice options.

Bmad Wiggler Models

- **Model A: Linear -**The linear wiggler model is composed of a series of dipole magnets (or, nearly equivalently, a 1st order Taylor map of the full nonlinear model). This model includes the vertical linear focusing and damping provided by the wigglers but none of the higher order beam dynamics of a real wiggler.
- **Model B: Ideal Nonlinear -** The ideal nonlinear wiggler model is a single element in Bmad which represents an infinitely wide wiggler magnet with a vertical magnetic field varying sinusoidally in the longitudinal direction. This model includes linear focusing, plus the vertical octupole term intrinsic in all wiggler magnets, which produces the dominant nonlinearity: the quadratic dependence of the vertical tune shift on vertical amplitude.
- **Model C: Full Nonlinear -** The full nonlinear wiggler model is an arbitrary order Taylor map in Bmad which comes from the symplectic integration of an analytic expression for the full wiggler field. This model includes the nonlinearities of the ideal nonlinear model plus all of the nonlinearities in the field coming from a realistic wiggler magnet with finite width poles, end poles, and fringe fields.

Wiggler Fitting Procedure

$$B_{fit} = \sum_{n=1}^{N} B_n(x, y, s; C_n, k_{xn}, k_{sn}, \phi_{sn}, f_n)$$

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

f_n=1:

$$B_x = -C\frac{k_x}{k_y}\sin(k_x x)\sinh(k_y y)\cos(k_s s + \phi_s)$$

$$B_y = C\cos(k_x x)\cosh(k_y y)\cos(k_s s + \phi_s)$$

$$B_s = -C\frac{k_s}{k_y}\cos(k_x x)\sinh(k_y y)\sin(k_s s + \phi_s)$$

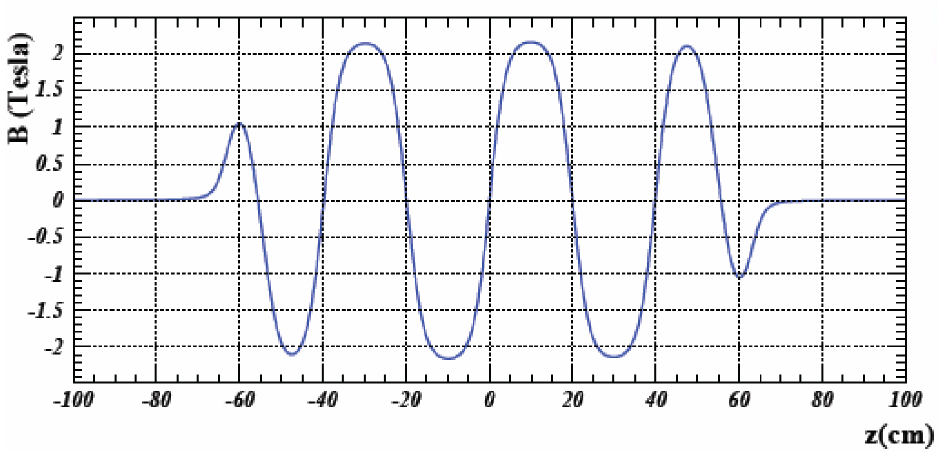
$$k_y^2 = k_x^2 + k_s^2$$

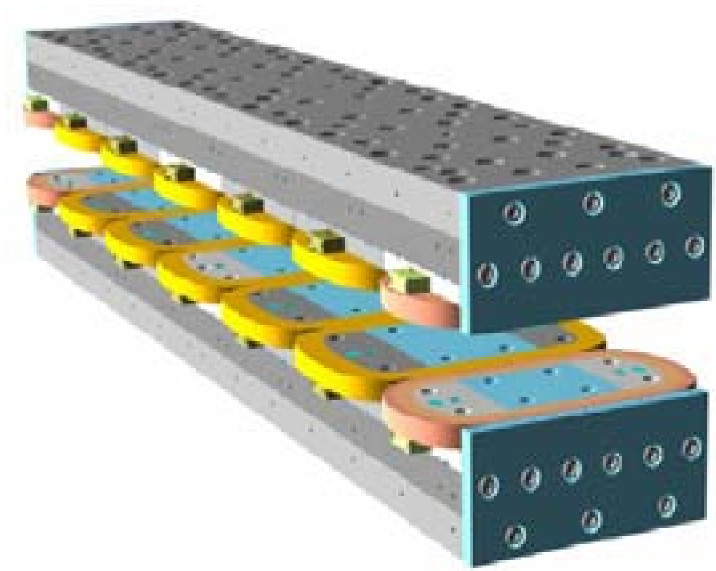
f_n=2 and f_n=3 select different combinations for fit

CESR-c Wiggler

- 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

A modified version of the CESR-c wiggler was developed to match the peak field and length of the TESLA TDR wiggler. Physical dimensions unchanged.



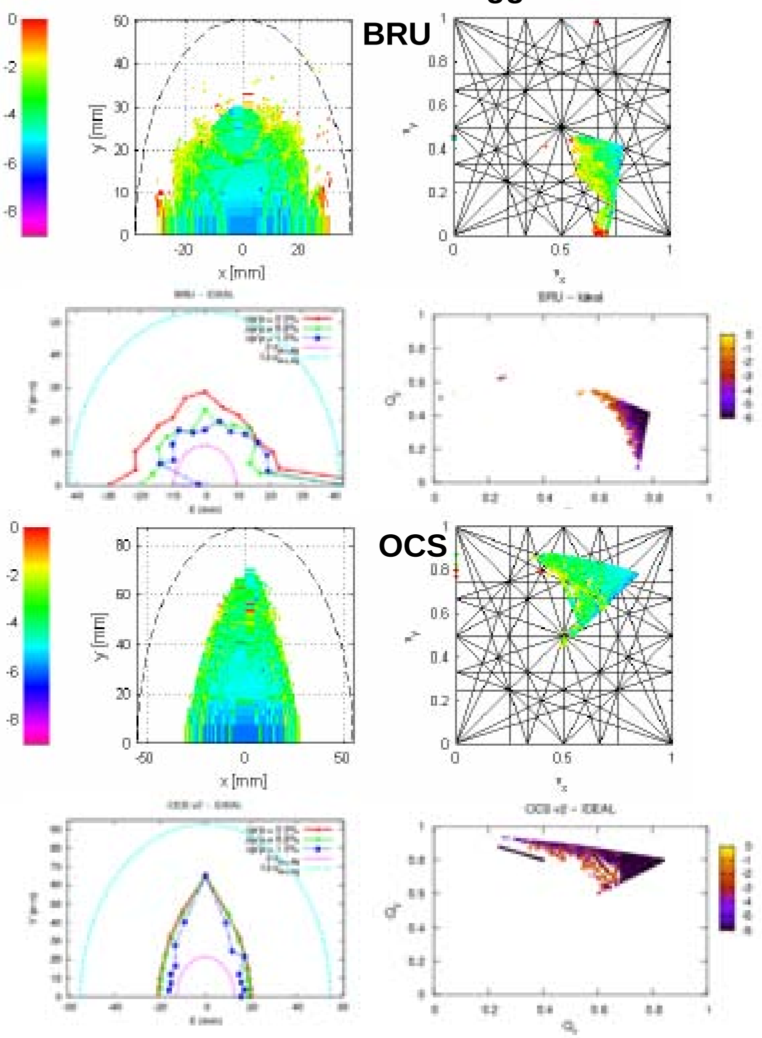


Non-Linear Wiggler Results

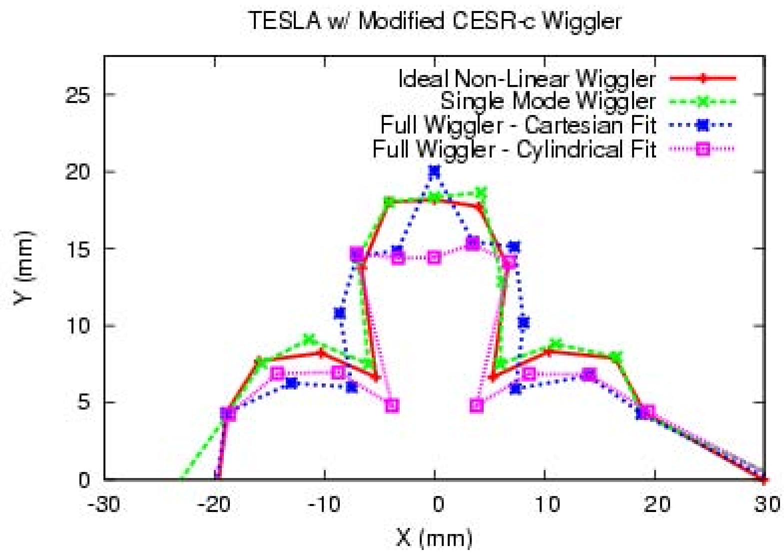
A. Wolski

J. Urban

Ideal Non-Linear Wiggler



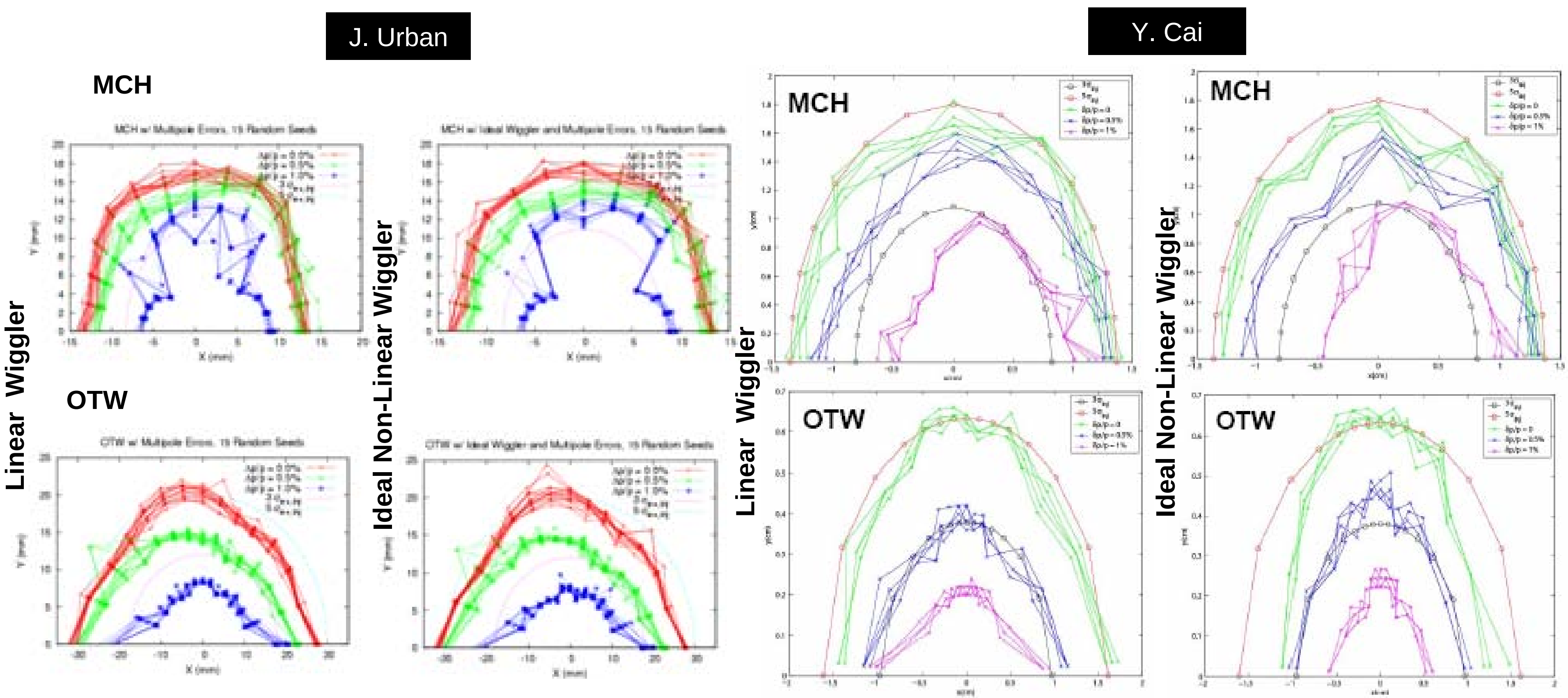
Results from PAC2005 showed the TESLA TDR wiggler was unsatisfactory. All wiggler studies performed with the CESR-c wiggler.



The CESR-c wiggler has a large aperture which produces fields well approximated by the Ideal Non-Linear Wiggler Model = Single Mode Wiggler Model.

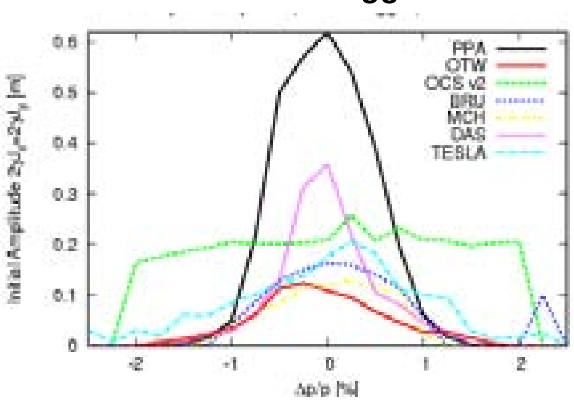
Multipole Error Results

Using systematic and random multipole errors on dipoles, quarupoles, and sextupoles, as determined from PEP-II & SPEAR3 magnets by Y. Cai.

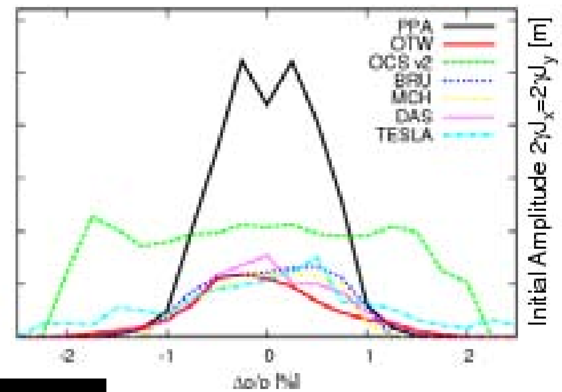


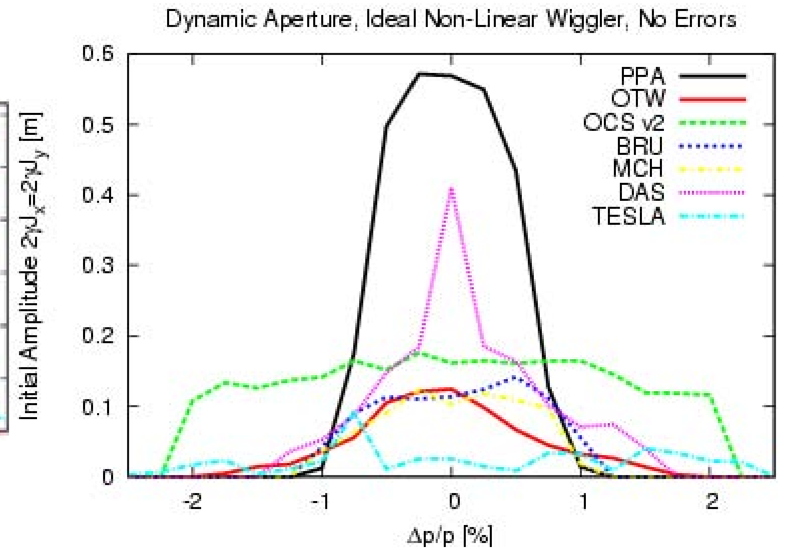
Energy Offset Results

Linear Wiggler

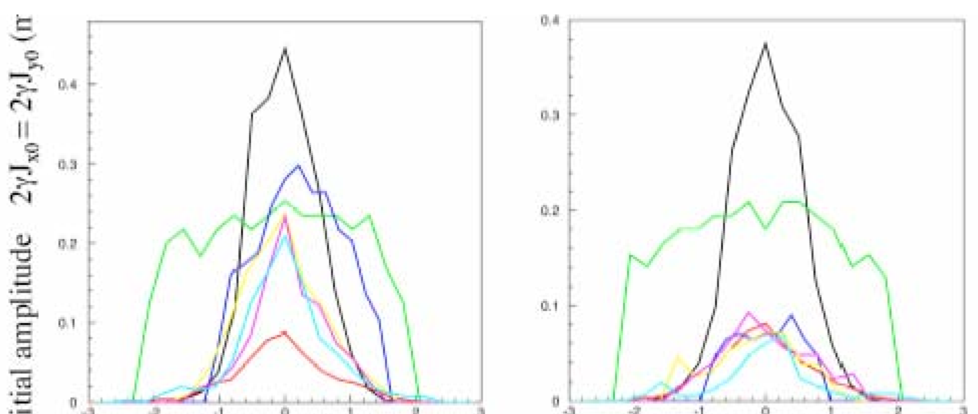


w/ Multipole Errors

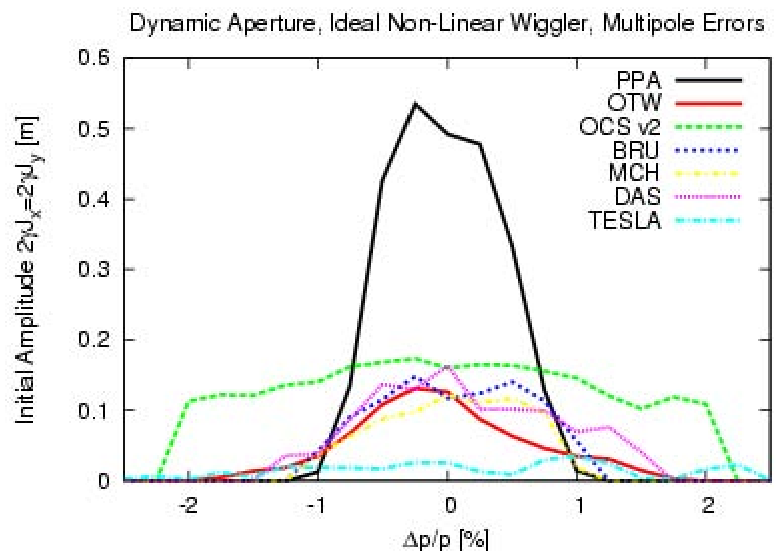




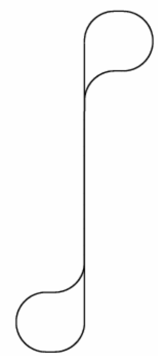
J. Urban



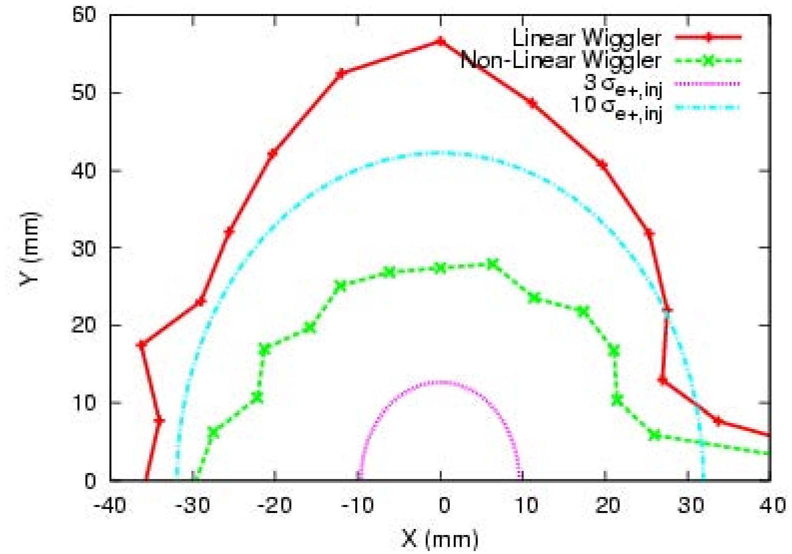
Y. Ohnishi



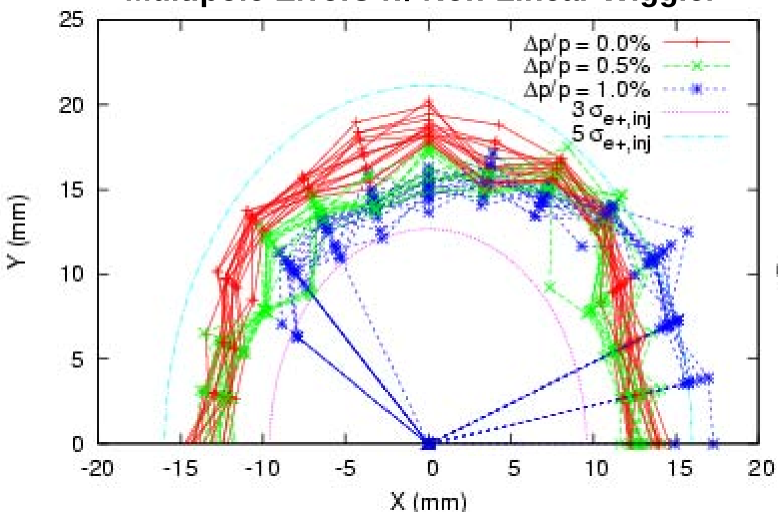
BRU



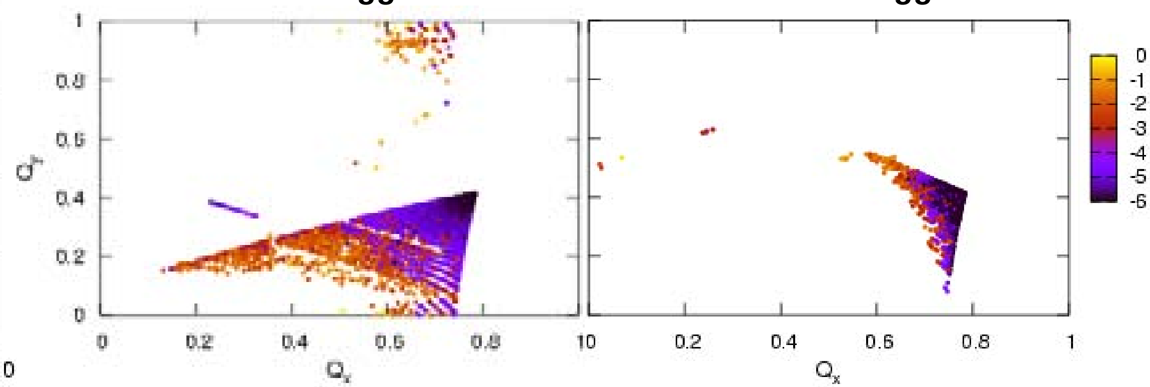
Length	6.333 km
Energy	3.740 GeV
Arc Cell	FODO
Q_x	65.78
Q_y	66.41
σ_z	9.22 mm
τ_x	1,208 Turns



Multipole Errors w/ Non-Linear Wiggler

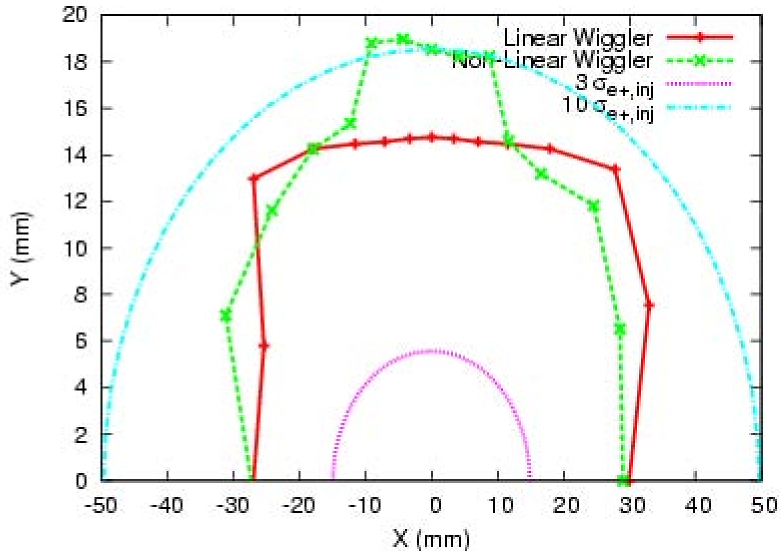


Linear Wiggler **Non-Linear Wiggler**

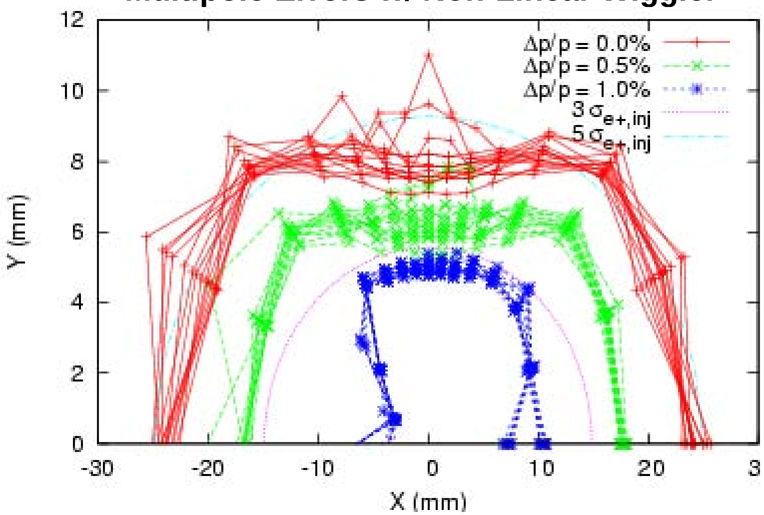


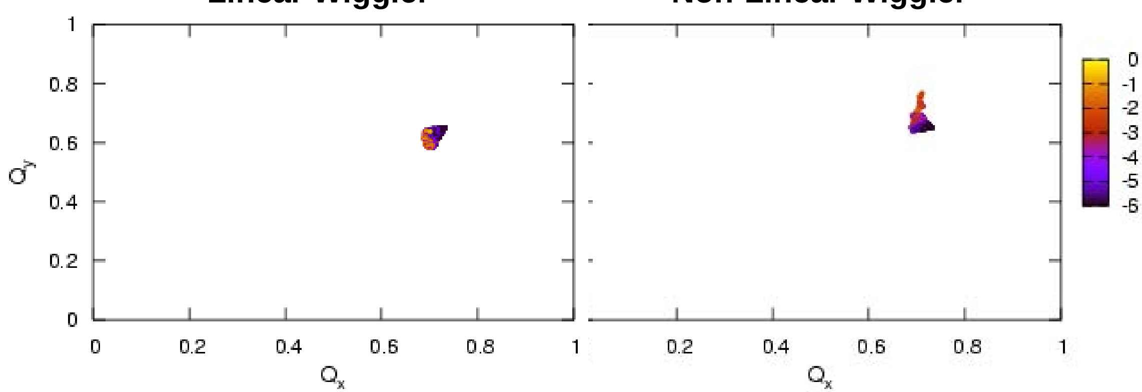
DAS

Length	17.014 km
Energy	5.000 GeV
Arc Cell	PI
Q_x	83.73
Q_y	83.65
σ_z	5.69 mm
τ_x	475 Turns

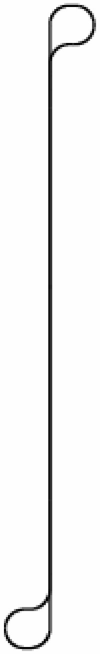


Multipole Errors w/ Non-Linear Wiggler

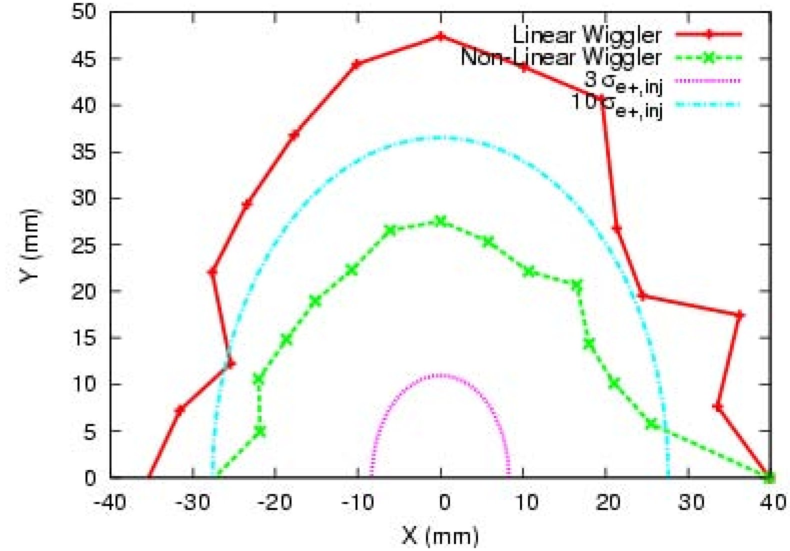




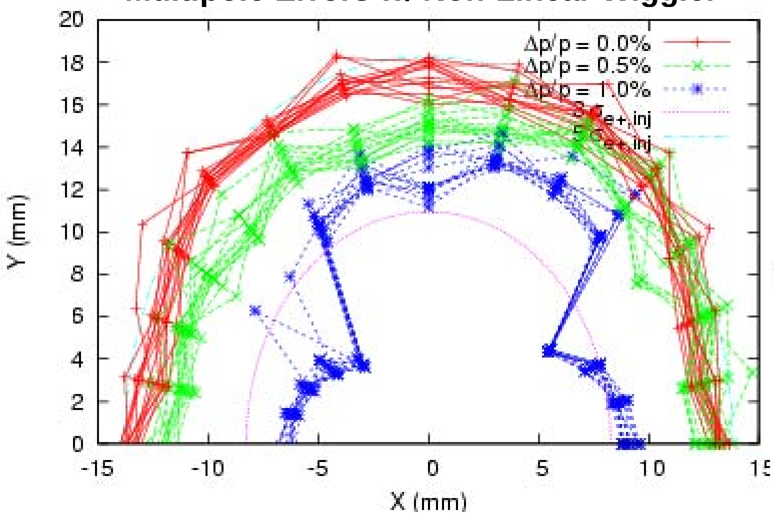
MCH



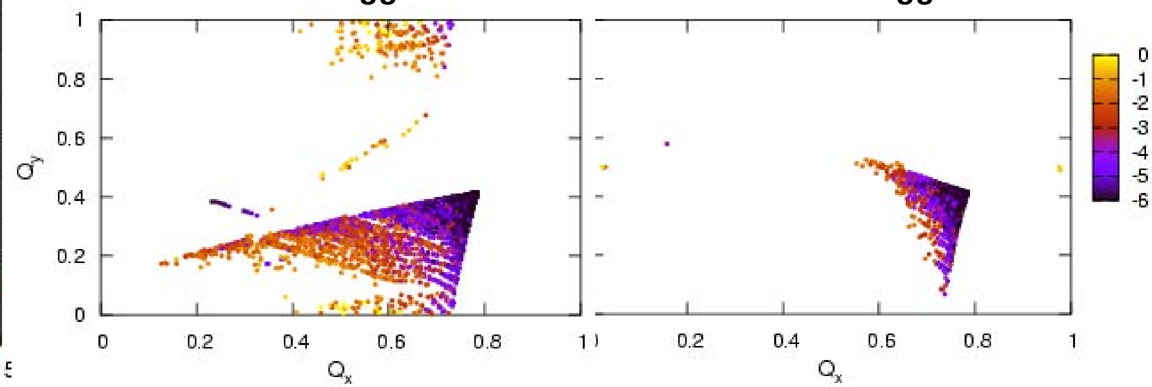
Length	15.935 km
Energy	5.000 GeV
Arc Cell	FODO
Q_x	75.78
Q_y	76.41
σ_z	9.35 mm
τ_x	505 Turns



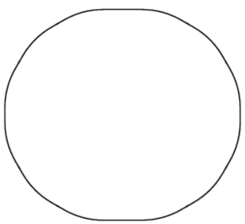
Multipole Errors w/ Non-Linear Wiggler



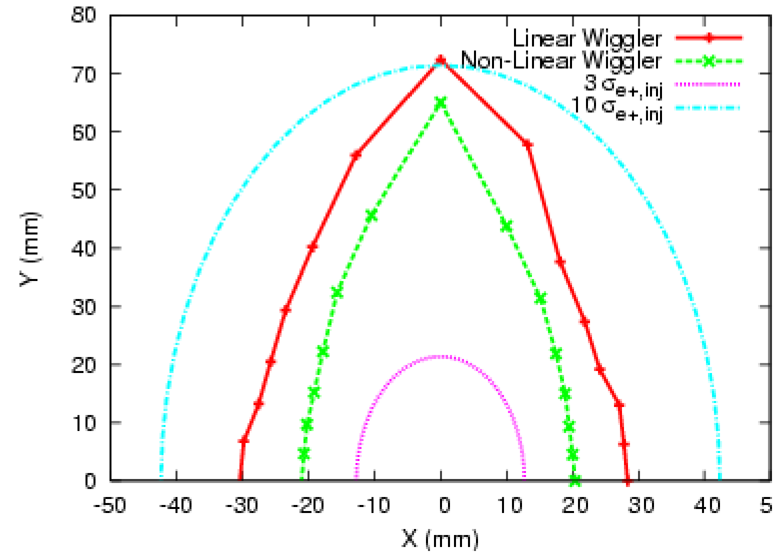
Linear Wiggler **Non-Linear Wiggler**

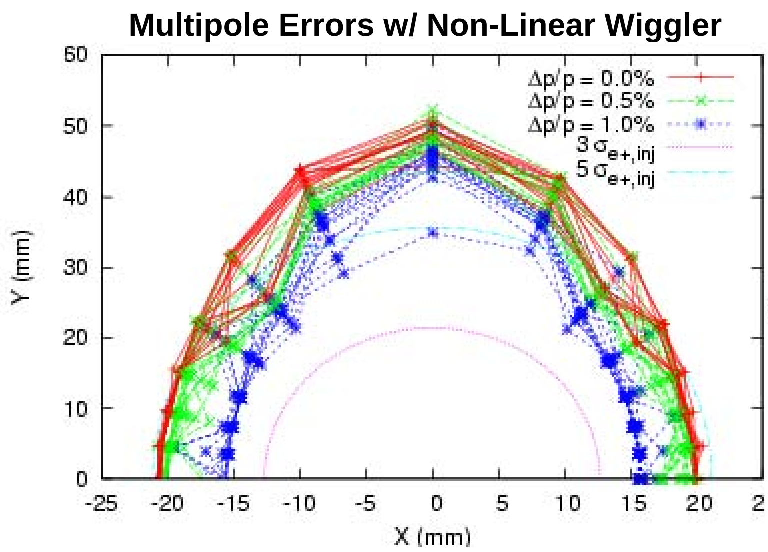


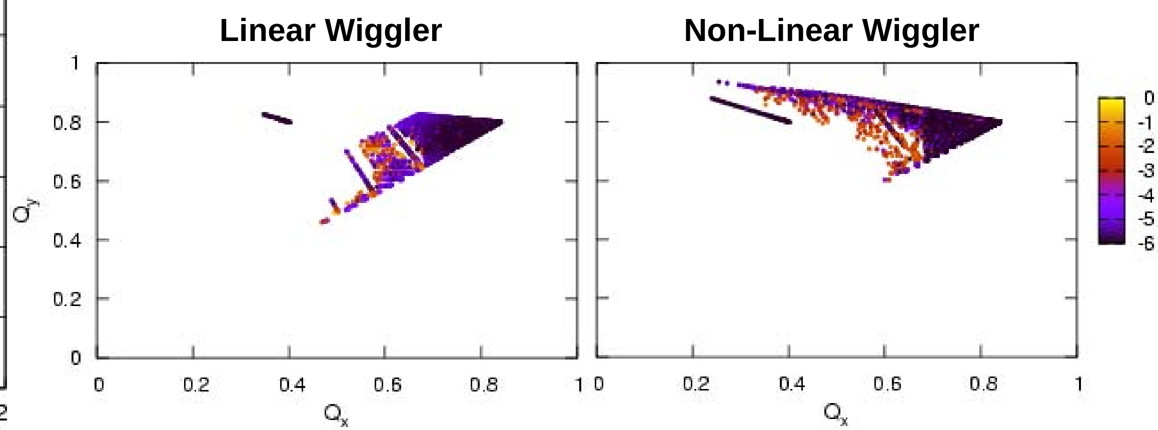
OCS



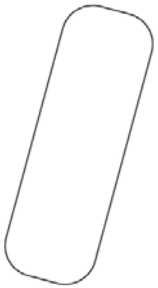
Length	6.114 km
Energy	5.066 GeV
Arc Cell	TME
Q_x	50.84
Q_y	40.80
σ_z	5.66 mm
τ_x	1,086 Turns



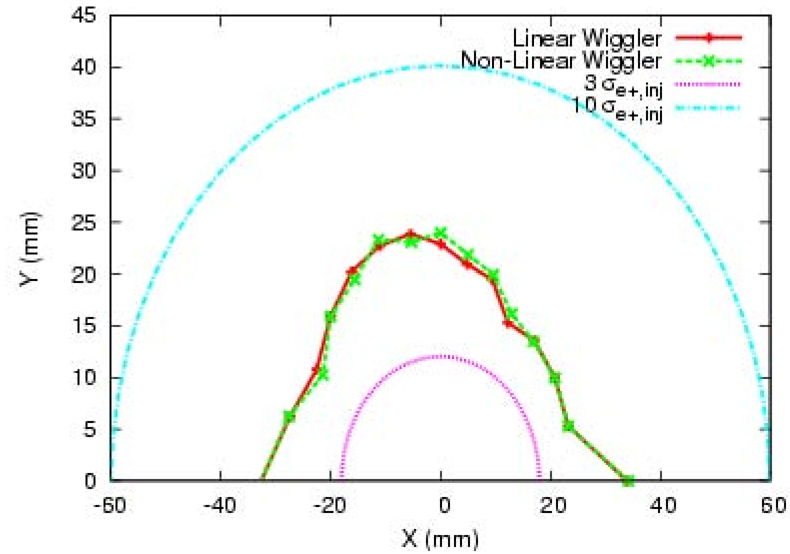




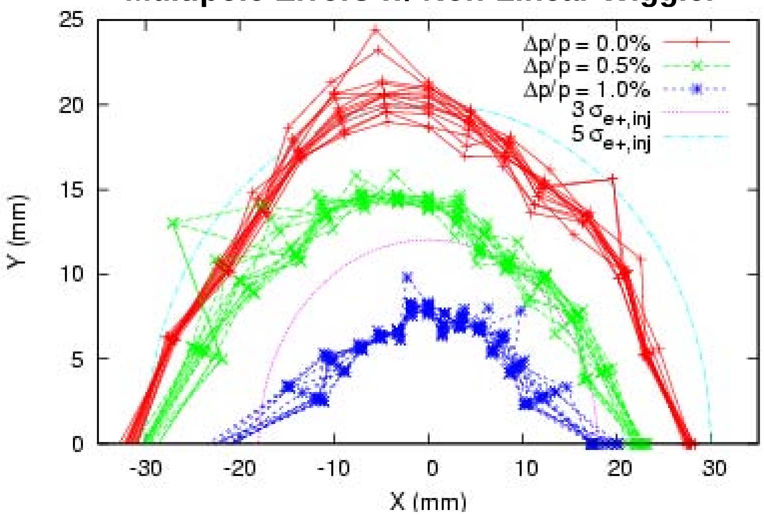
OTW

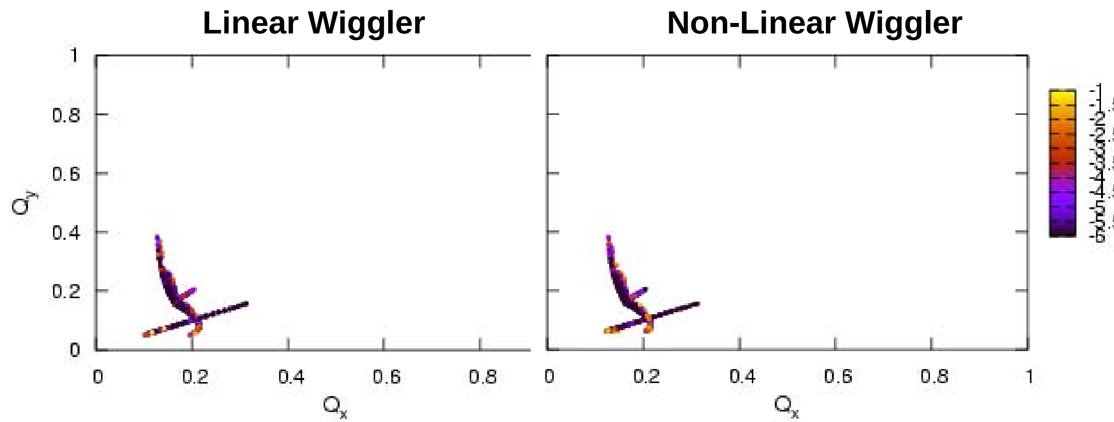


Length	3.224 km
Energy	5.000 GeV
Arc Cell	TME
Q_x	45.16
Q_y	24.16
σ_z	5.77 mm
τ_x	1,130 Turns

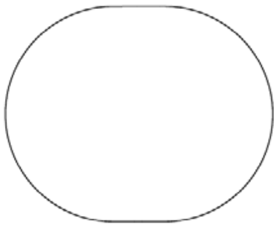


Multipole Errors w/ Non-Linear Wiggler

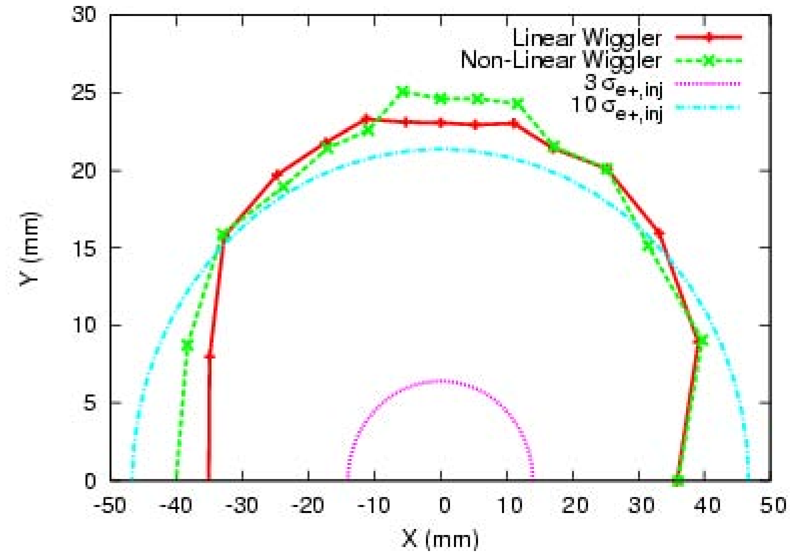




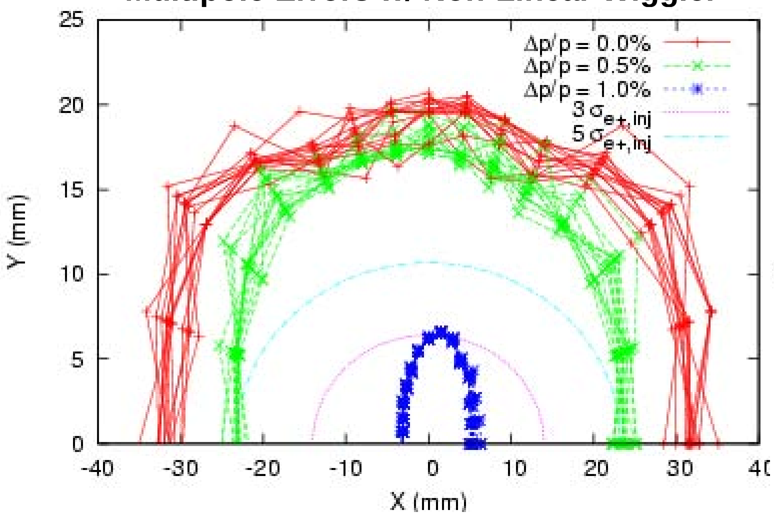
PPA



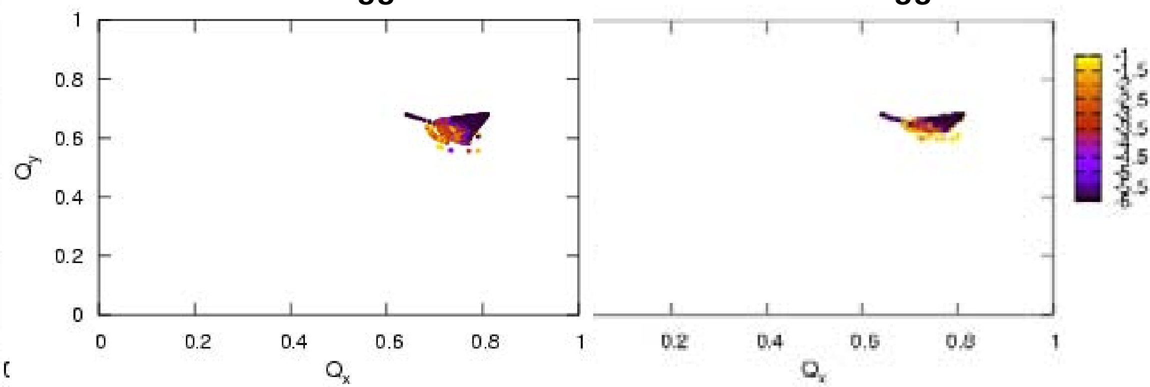
Length	2.824 km
Energy	5.000 GeV
Arc Cell	PI
Q_x	47.81
Q_y	47.68
σ_z	5.90 mm
τ_x	2,127 Turns



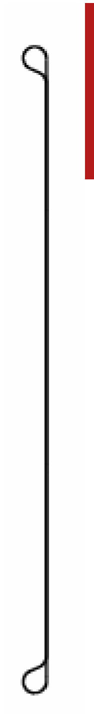
Multipole Errors w/ Non-Linear Wiggler



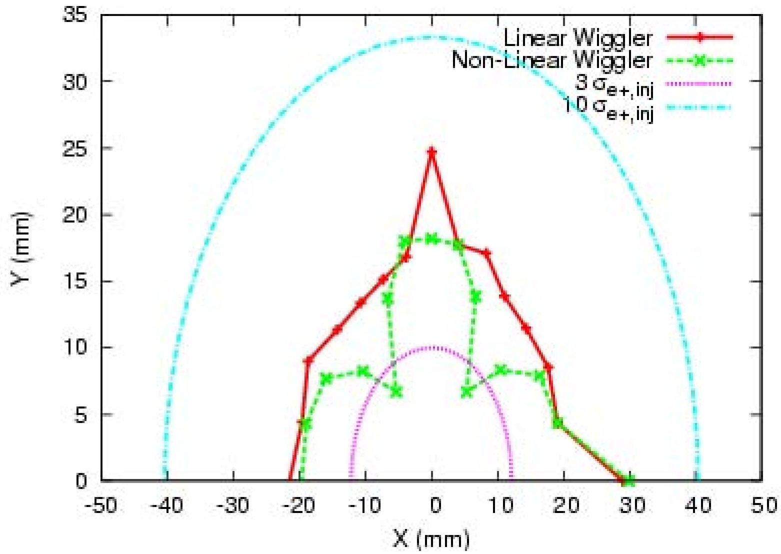
Linear Wiggler **Non-Linear Wiggler**



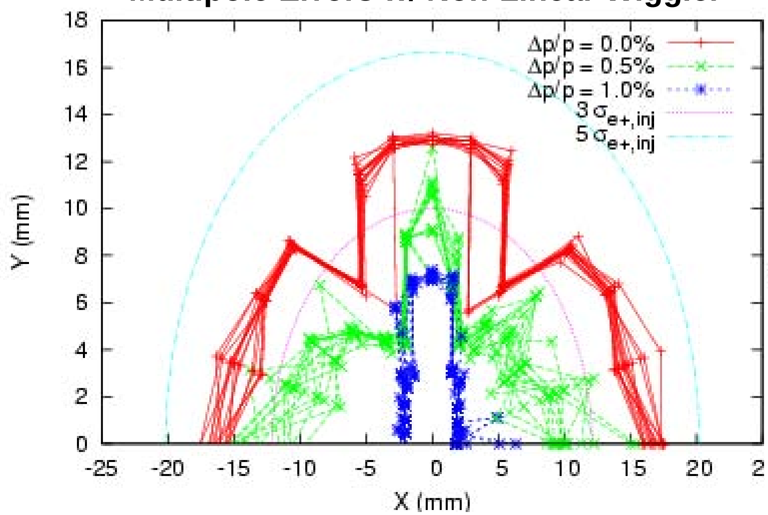
TESLA



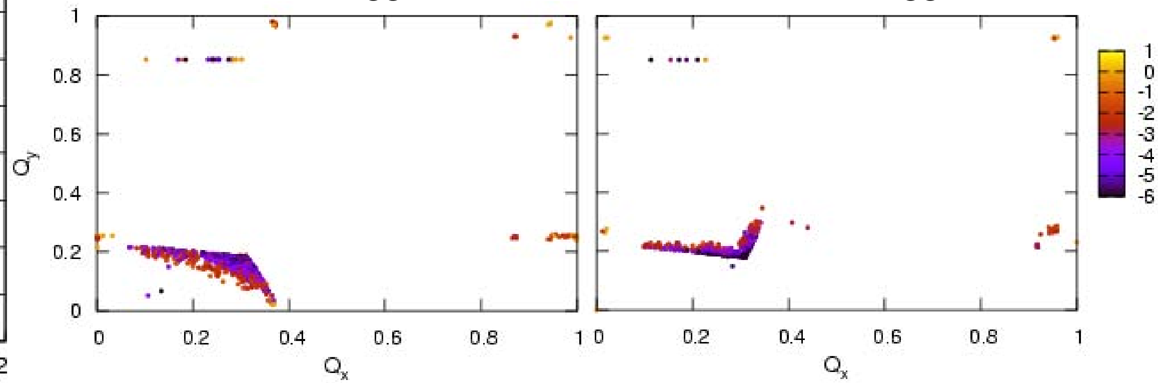
Length	17.001 km
Energy	5.000 GeV
Arc Cell	TME
Q_x	76.31
Q_y	41.18
σ_z	5.77 mm
τ_x	491 Turns



Multipole Errors w/ Non-Linear Wiggler



Linear Wiggler **Non-Linear Wiggler**



Conclusions

- See full results at: *www.lepp.cornell.edu/~jtu2/eval_dr/*
- CESR-c wiggler does not significantly degrade dynamic aperture for any lattice
- Multipole errors dominate dynamic aperture reduction over wiggler non-linearities
- Systematic approach for analyzing lattices developed with Bmad
- Benchmarking of simulation codes progressing well, agreement found across time-zones
- Lattice choice? PPA and OCS are potentials, see other talks, listen to other task-forces, and discuss at Snowmass