ORBIT Status:
Beam Dynamics Calculations for High Intensity Rings

J. Holmes (ORNL)

S. Cousineau , V. Danilov, A. Shishlo (ORNL)
Y. Sato (Indiana University)
J. Abrams (Knox College)
S. Bunch (University of Tennessee)

ORBIT: General Description and Approach

- ORBIT is a particle (herd)-tracking code in 6D phase space.

- ORBIT is designed to simulate real machines: it has detailed (node) models for
  - Transport through various types of lattice elements
  - Magnet Errors, Closed Orbit Calculation, Orbit Correction
  - Injection foil and painting
  - RF and acceleration
  - 2.5D space charge with or without conducting wall beam pipe
  - Longitudinal impedance and 1D longitudinal space charge
  - Transverse impedance
  - 3D space charge
  - Feedback for Stabilization
  - Apertures and collimation
  - Electron Cloud Model

- ORBIT has an excellent suite of routines for beam diagnostics.

ORBIT: Transport Through Lattice - 6 Months Ago

- **ORBIT lattices can be constructed by reading MAD or DIMAD output files. There are also special facilities to specify lattices directly or to create uniform focusing channels.**

- **Linear transport through drifts, bends, or quadrupoles is carried out through symplectic matrix multiplication.**

- **Nonlinear elements, such as higher order multipoles, are evaluated in the thin lens approximation. Sextupoles can also be treated using MAD.**

- **Higher order single particle transport terms, such as chromaticity, are evaluated using second order transport matrices.**

- **There is no specific facility for the treatment of errors or fringe fields. Errors can be considered if they can be calculated in MAD and included in the MAD output.**

ORBIT: Transport Through Lattice - Now

- **In addition to the previous tracking methods, ORBIT lattices can now be built by parsing MAD lattice files and constructing nonlinear symplectic integration nodes, using a TeaPot type approach.**

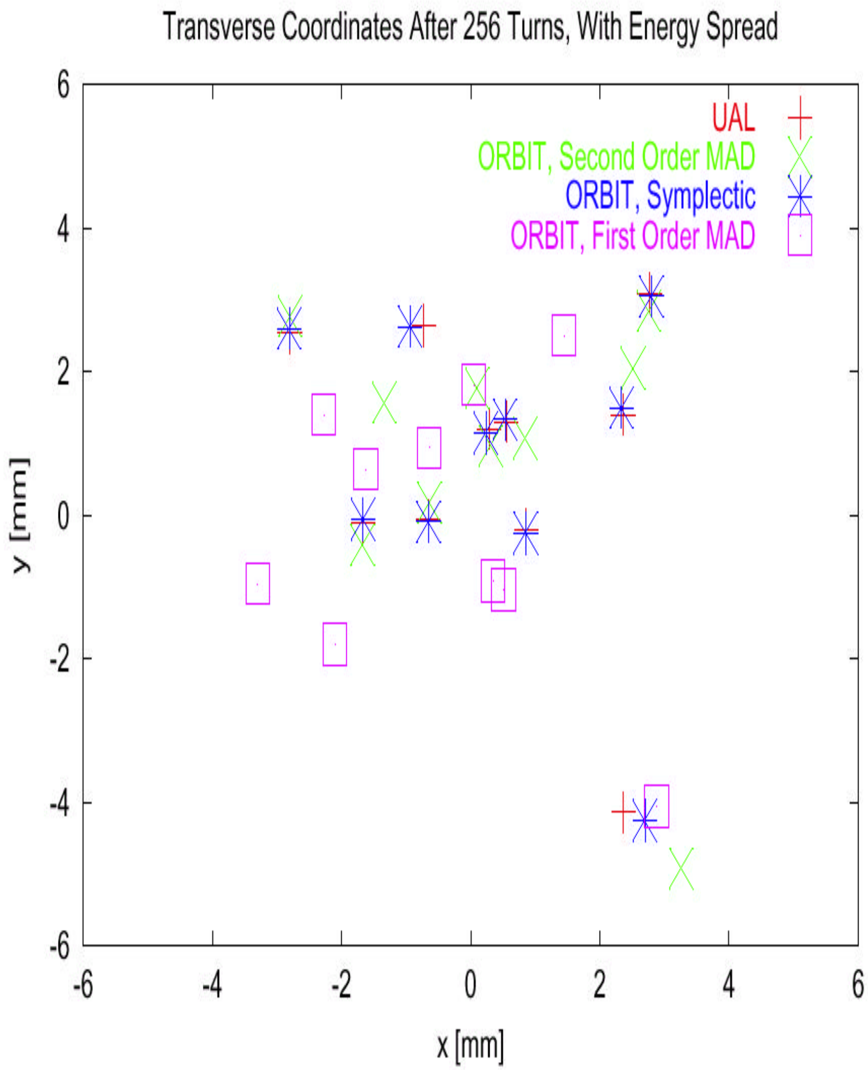
- **At present, symplectic nodes exist for drifts, bends, quadrupoles, higher order multipoles, and solenoids.**

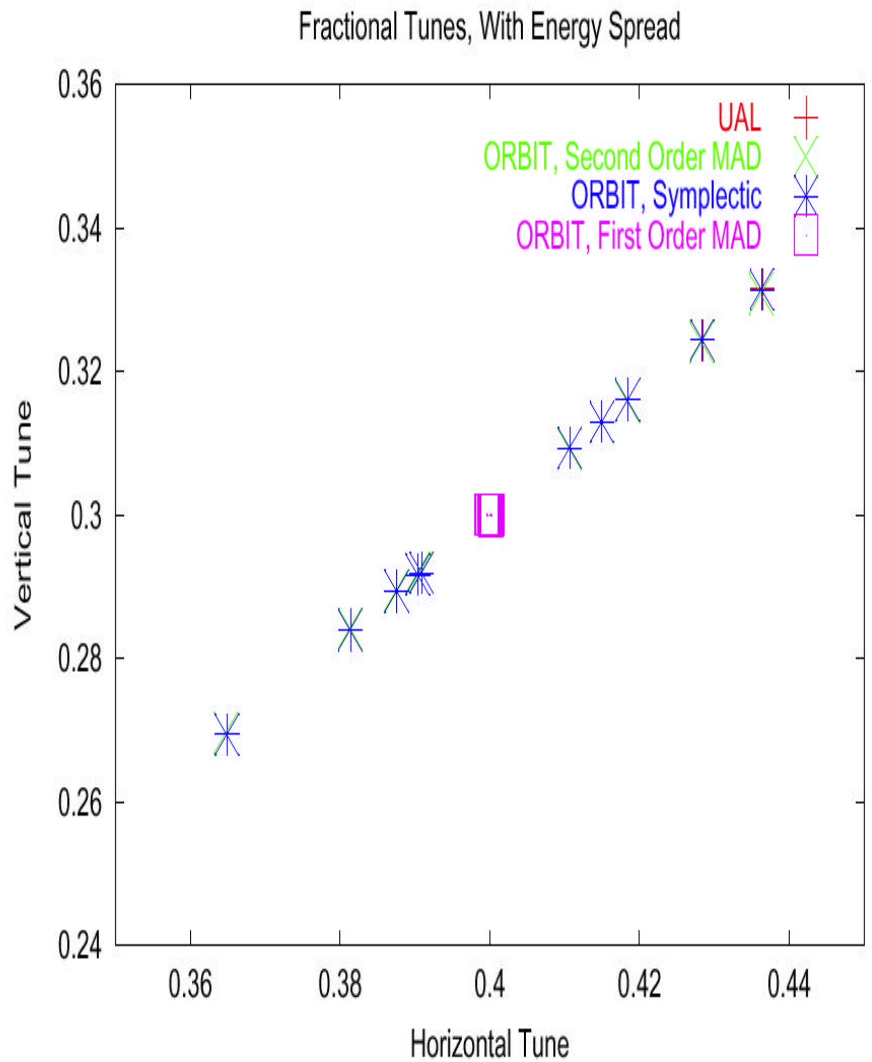
- **Hard edge fringe field models have been developed for bends, quadrupoles, and multipoles.**

- **These models have been benchmarked with independent MathCad calculations, with second order MAD transport and, more importantly, are now being compared with the UAL TeaPot tracking models.**

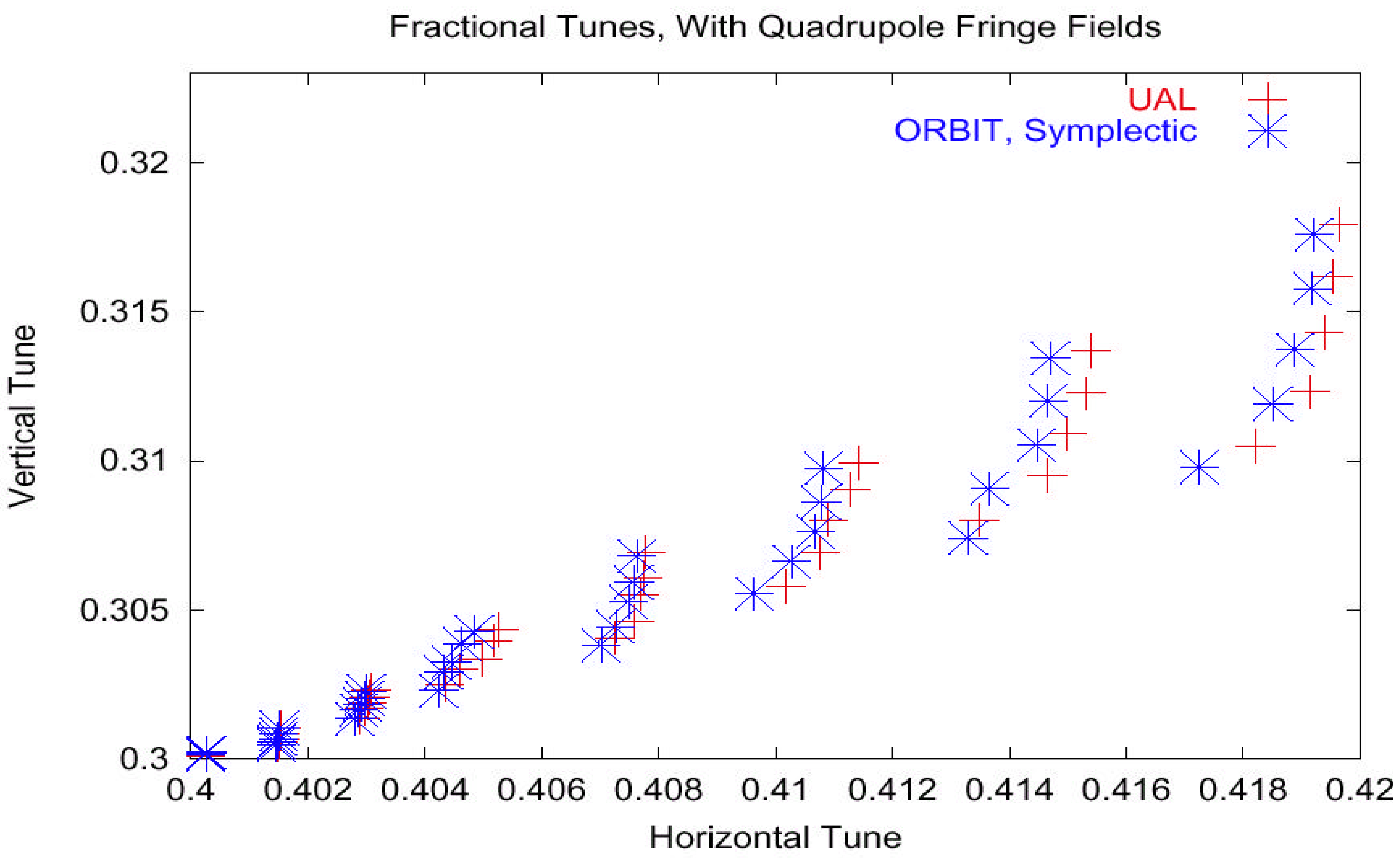
- **Benchmark results so far show good agreement, with fractional tunes between ORBIT and UAL agreeing to within 0.001. Difference is most likely due to kinetic nonlinearity treatment.**

ORBIT Benchmarking: Chromatic Effects in SNS





ORBIT Benchmarking: Quadrupole Fringe Fields



ORBIT: Transport Through Lattice - Magnet Errors, Closed Orbit, and Correction

- 6 Months Ago: "There is no specific facility for the treatment of errors or fringe fields. Errors can be considered if they can be calculated in MAD and included in the MAD output."

- We now have a full set of models for magnet alignment (displacement and rotation) and field strength errors.
- The models have been benchmarked against independent MatLab calculations.
- A closed orbit calculator has been constructed and tested. The calculation is performed using a shooting method.
- Two new types of nodes, BPM nodes and Dipole Corrector Nodes, have been developed and, together, they can be used for orbit correction studies.
- To carry out orbit correction, an optimizer adjusts Dipole Corrector Node strengths to minimize signals from the BPM nodes. Benchmark tests indicate good success, but the effect on losses depends on the placement of the nodes.

ORBIT: Injection and Foil

- 6 Months Ago: "ORBIT contains an injection foil model taken from ACCSIM. The model keeps track of foil hits and applies transverse kicks based on multiple Coulomb scattering. Particles that miss the foil at injection are removed from the beam."

- We are now incorporating an alternate foil model based on the physics of the collimation routine:
  - Multiple Coulomb scattering
  - Rutherford scattering
  - Ionization energy loss
  - Nuclear elastic and inelastic scattering and related losses

ORBIT: RF and Acceleration

- ORBIT contains an RF cavity model which provides longitudinal kicks based on a time-dependent waveform with multiple user-specified harmonics.
- For nonaccelerating cases, the synchronous phase is assumed to be zero, and the harmonics and time-dependent voltages are all that need to be specified.
- For accelerating cases, the harmonics, time-dependent voltages, and time-dependent dipole fields must be specified.
  - The synchronous phase and the resulting kicks are then solved by the model.
  - Transverse phase space is adjusted to conserve normalized emittance.

ORBIT: Feedback Nodes

- **A dynamic feedback node has been developed. The node model uses the longitudinal distribution of transverse beam centroid values over specified turns to determine an applied transverse kick to the particles to stabilize beam instabilities. It has been successfully applied to SNS with the old extraction kicker impedance.**

ORBIT: New Diagnostics

- **New diagnostics include:**
  - **Longitudinally localized calculations of transverse moments and emittances**
  - **BPM Nodes**
  - **Particle tune calculation by post-processing particle motion**

ORBIT Plan:
Electron Cloud Node.

- **We are just starting to develop the electron cloud node. The plan is to model both the ambient electrons and the beam using particles and to incorporate the effects of wall interactions and multipacting, magnetic fields, and the space charge forces on the motion of all particles.**