Effect of Three-Dimensional Quadrupole Magnet Model On Beam Dynamics

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HB Workshop

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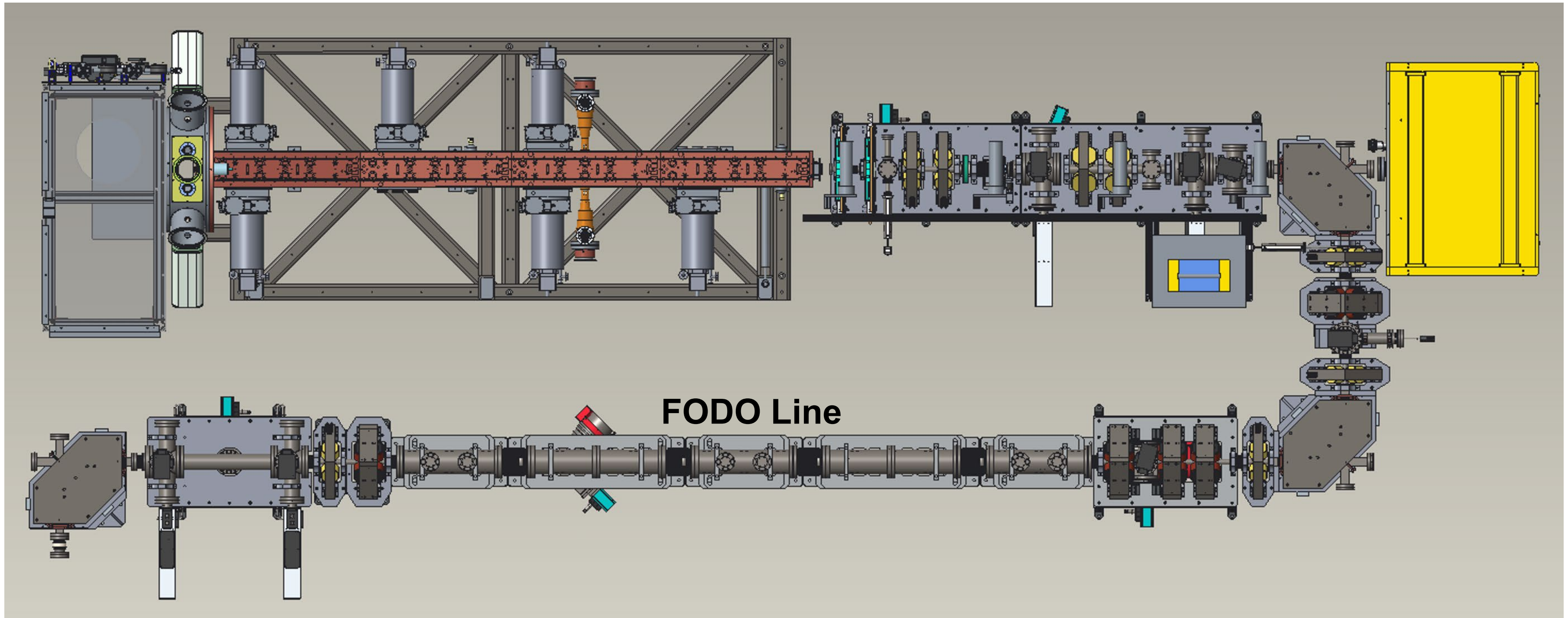
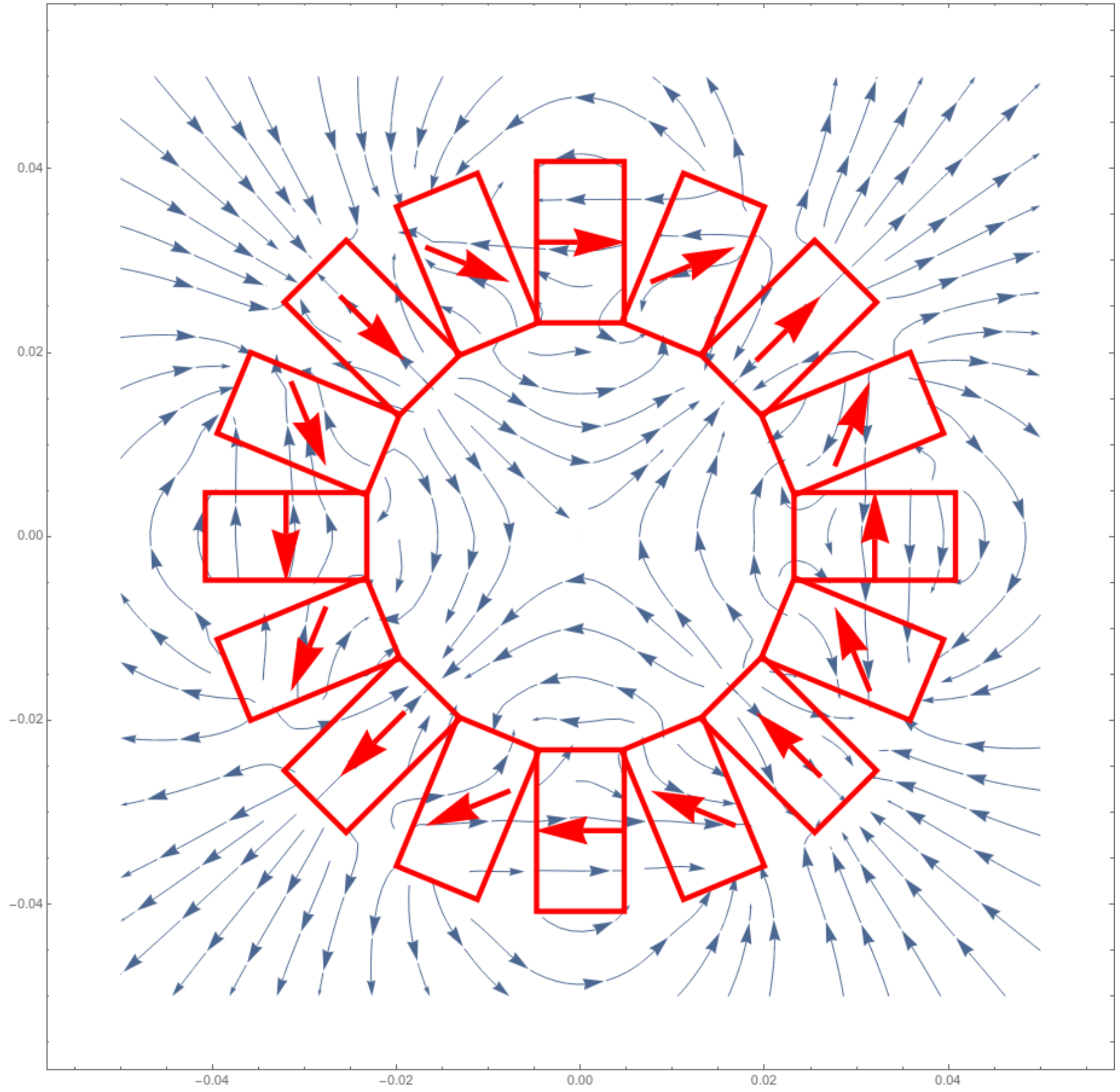
The SNS-BTF at ORNL

- Functional Duplicate of SNS Front End.
- Research into beam distribution, including full 6D measurements, and halo growth.



Permanent Magnet Configuration

- Halbach array quadrupoles in BTF FODO line.
- Allows full magnetic field model to be created.
- Current models use a perfect quadrupole.

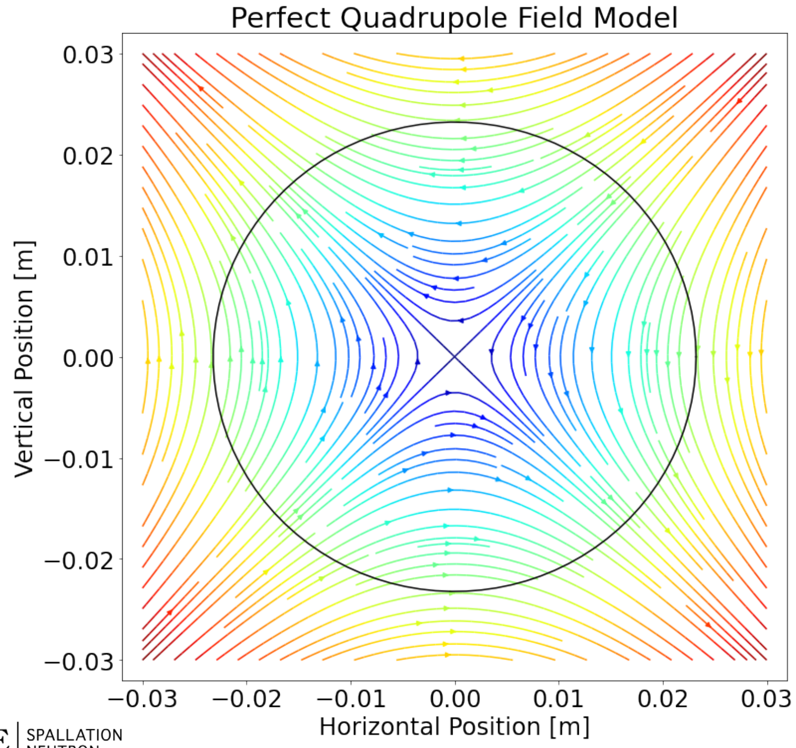


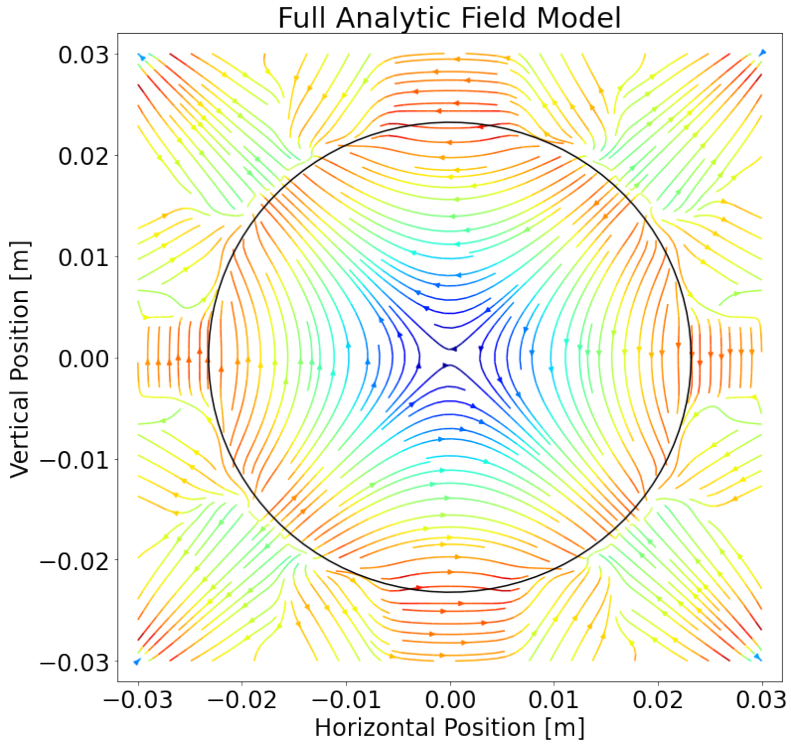
Purpose of Research into the Magnetic Models

- How accurate is the simplified model, specifically in the near aperture region?
- Is there a benefit to using the full model?

Magnet Model Field Diagram

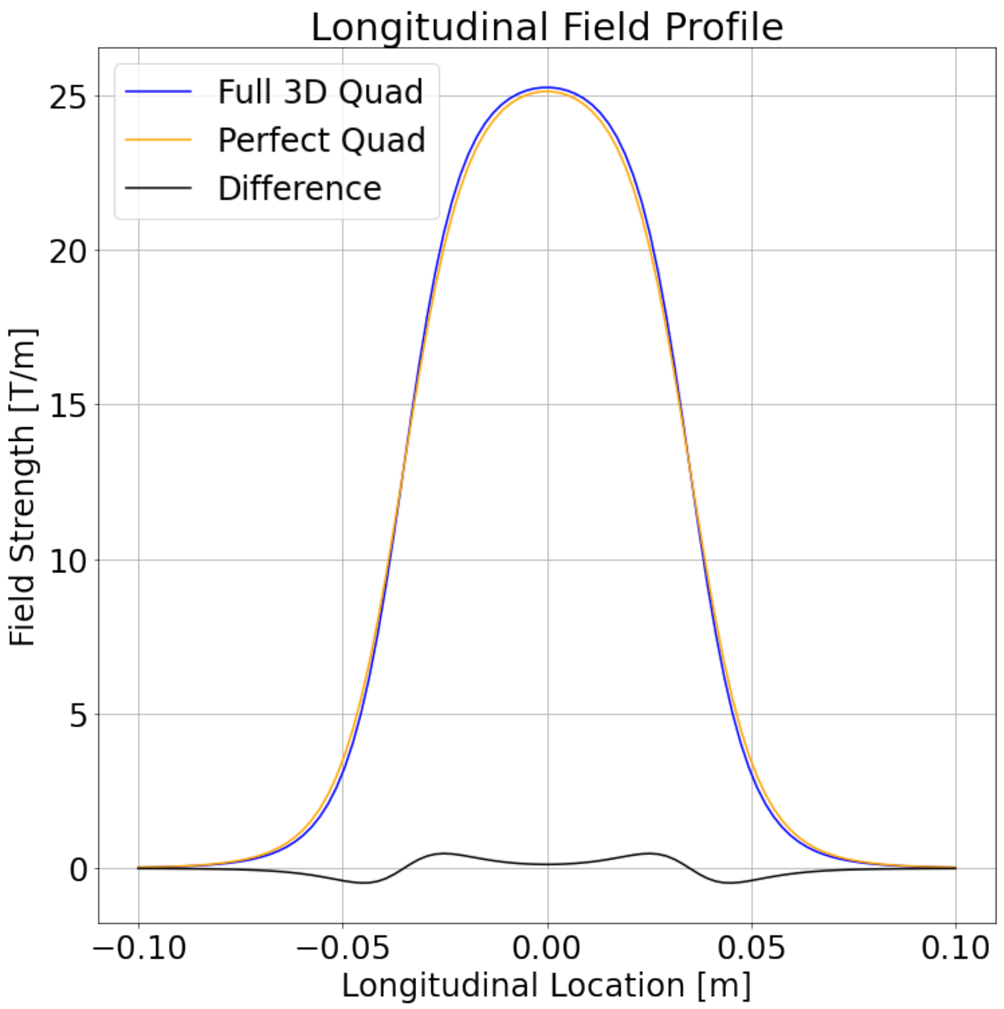
- Using the two magnet models the magnet field is determined at every position.
- The perfect quadrupole scales linearly in the transverse plain.





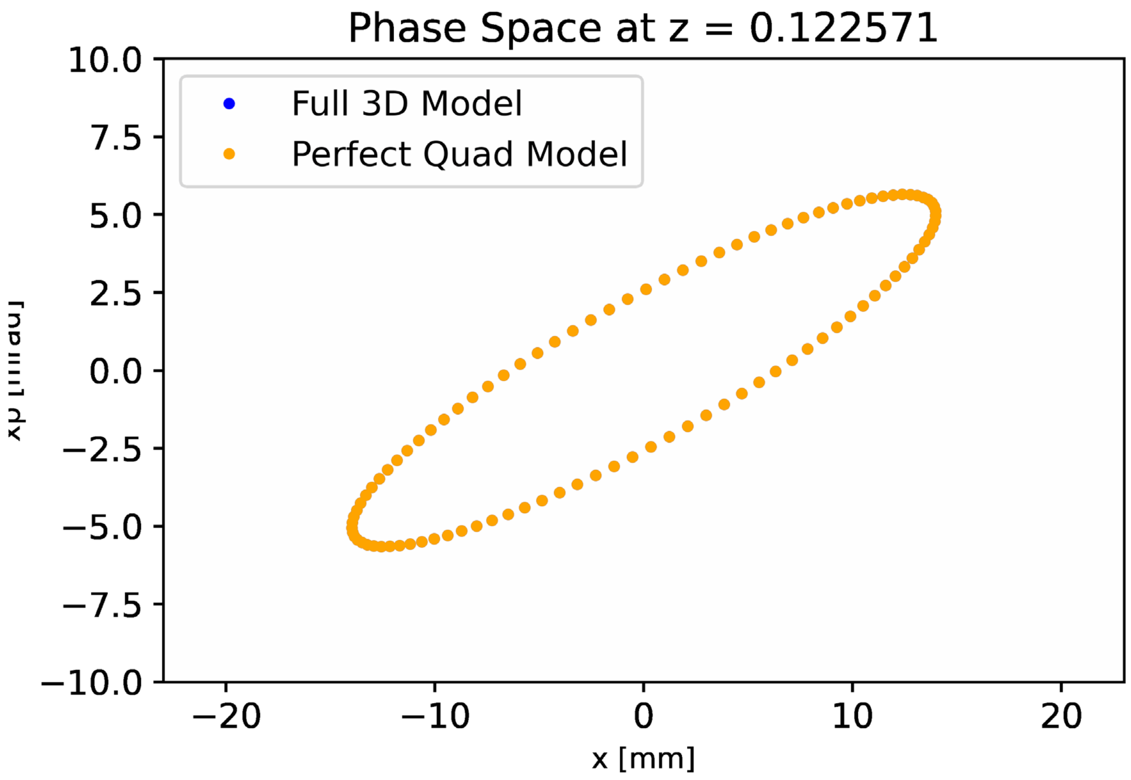
Integrated Field Strengths

- Scaling of Magnetic Field Strengths by scalar factor.
- Matched to BTF magnets integrated field value of 1.817 T.
- Virtual BTF FODO line created.



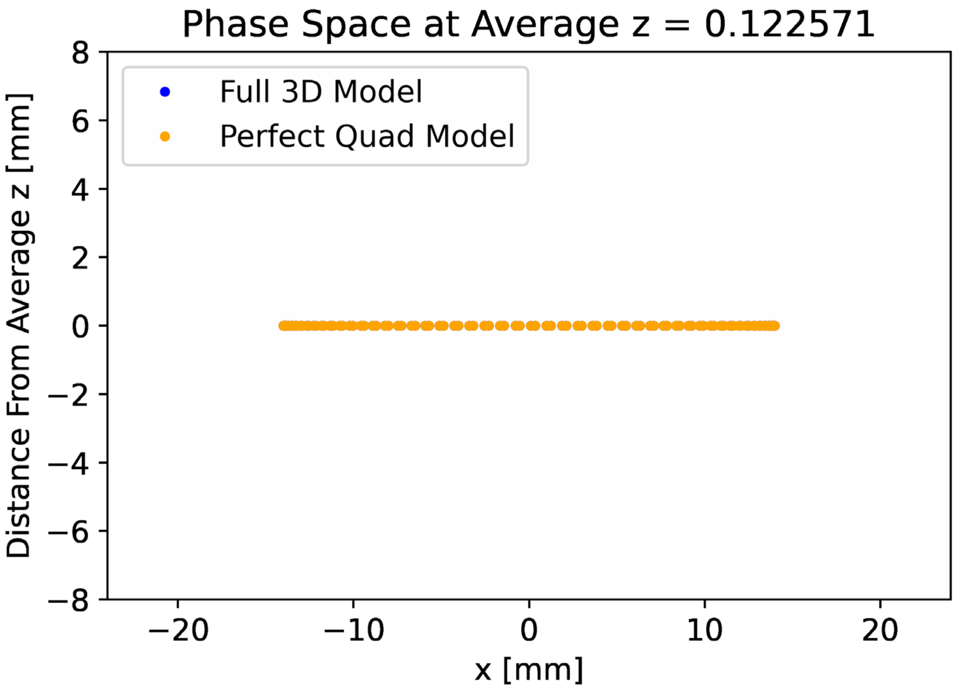
Initial Tracking of Particles

- Runge-Kutta r and p tracking of particles in x,x' phase space.
- Phase spaces from transforming normalized circle using matched condition twiss parameters.
- Models hold similar phase spaces, though distortions in phase spaces appear.



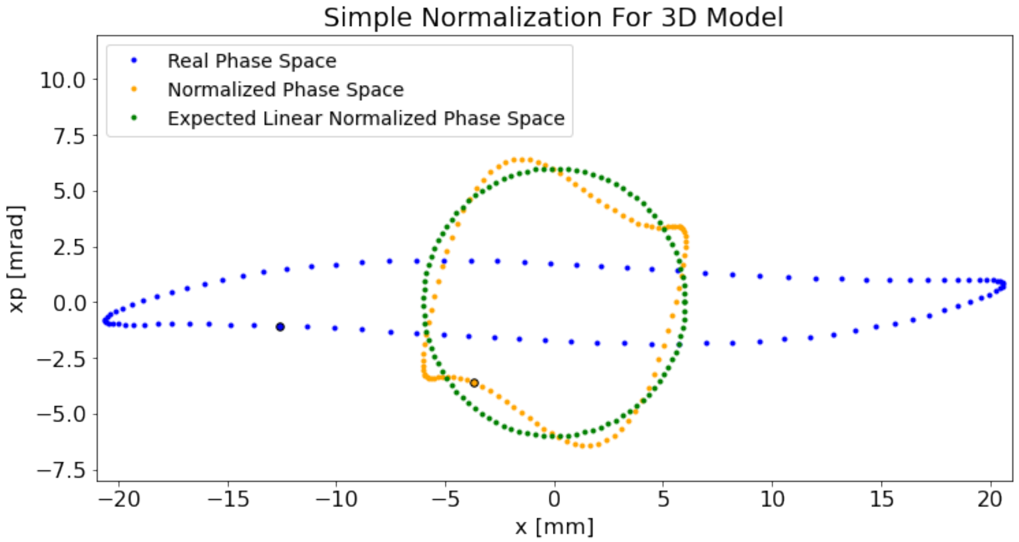
Why Are There Distortions in Phase Space?

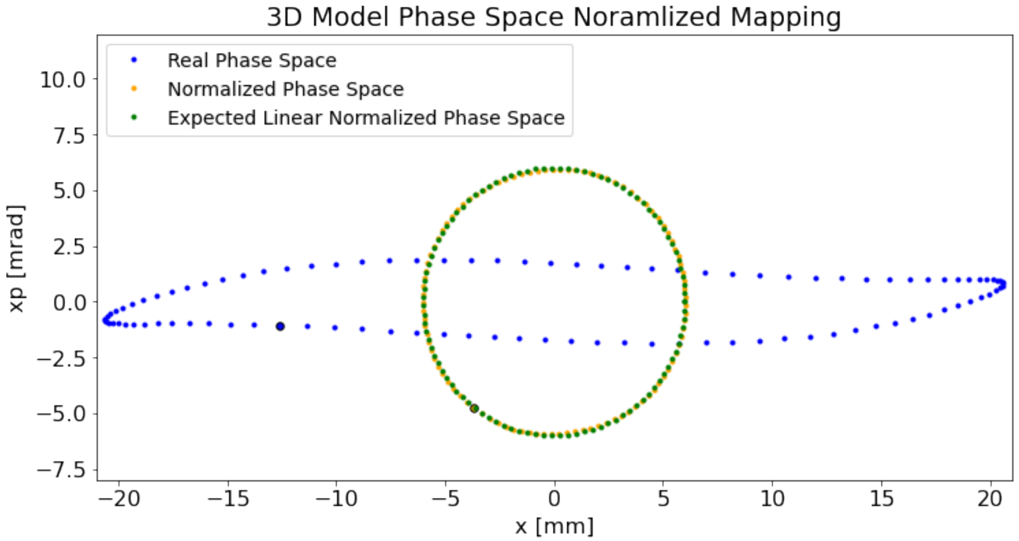
- All particles have same longitudinal velocity.
- Each particles starting position causes there to be different path lengths.
- With r and p tracking particles are at different z positions at one time.



Compensating for Z lag in Normalized Space

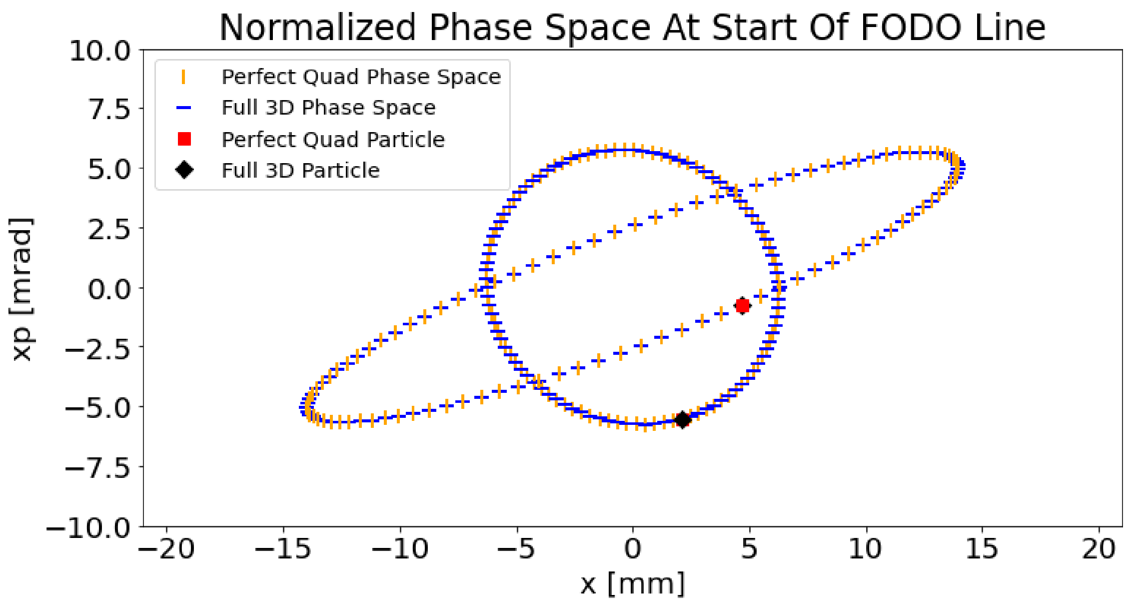
- Phase spaces can be normalized using twiss parameters.
- These twiss parameters depend on the z position of particles.
- Adjustment of twiss parameters for each particles allows correct normalization.

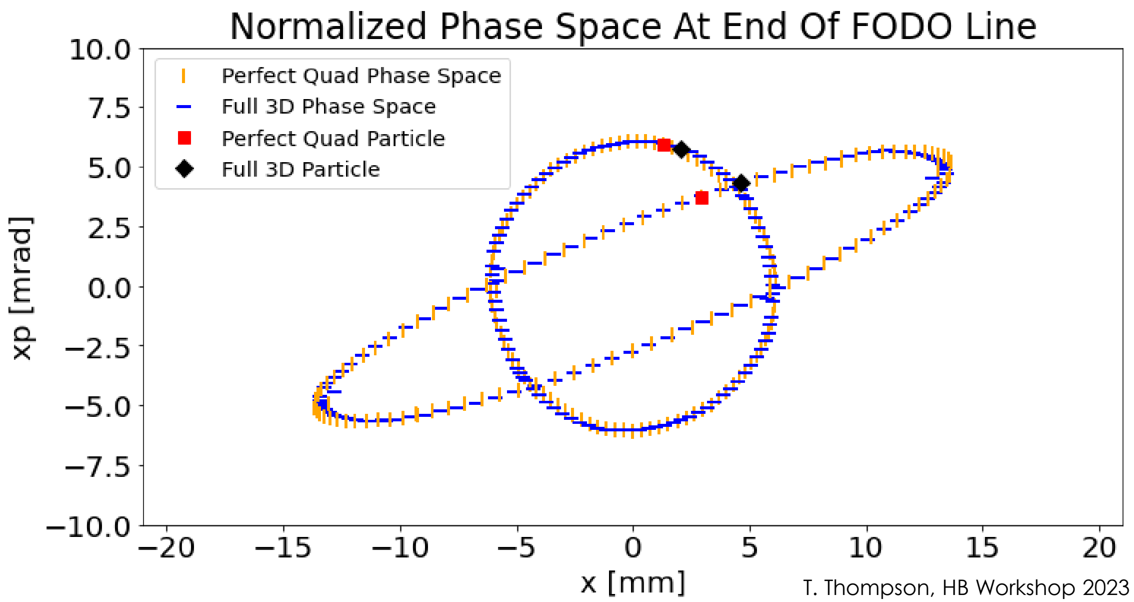




1D and 3D Models in Normalized Space

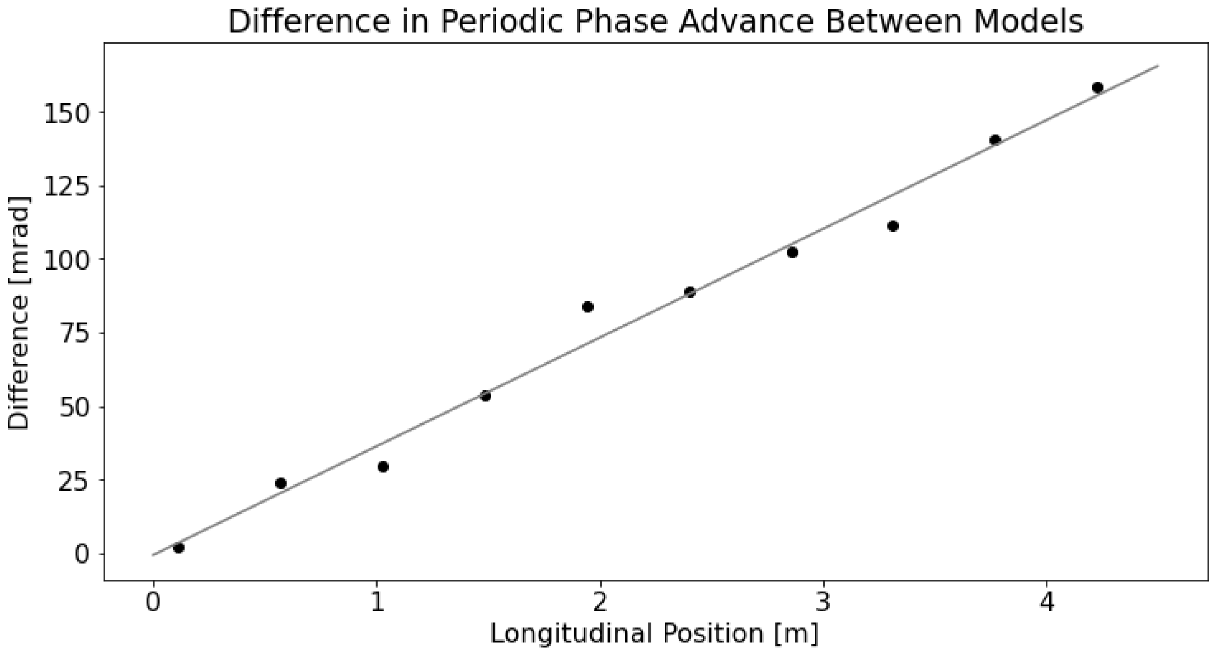
- They both normalize correctly along the length of the FODO line.
- Tracking a single particle reveals a phase advance difference.





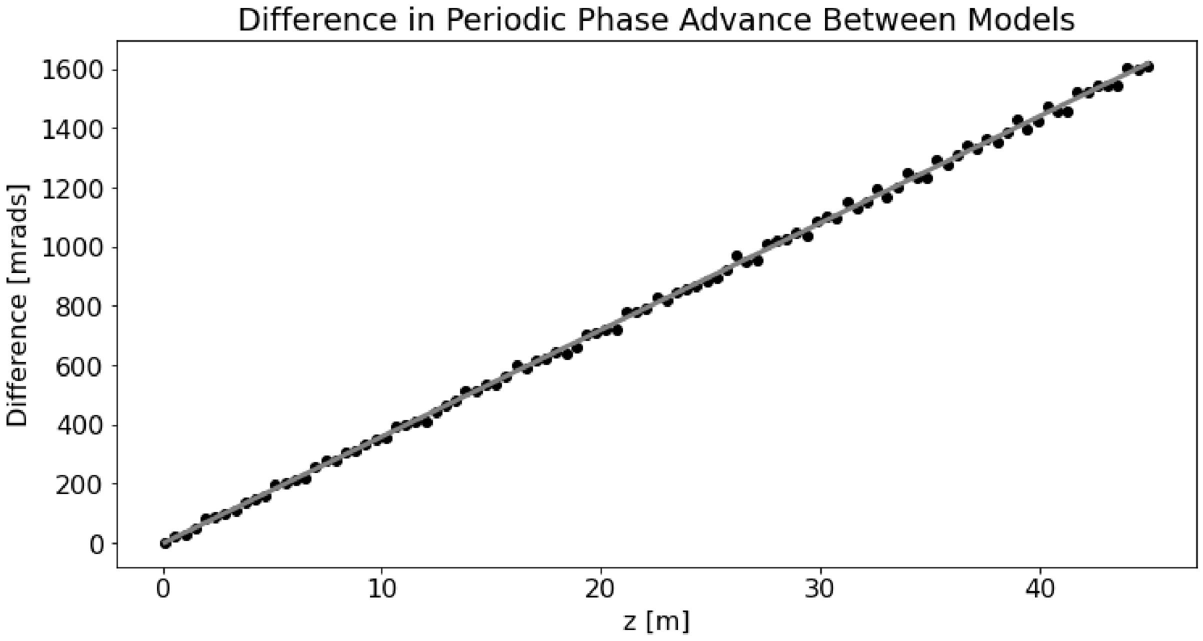
Quantizing The Phase Advance Difference

- Take the angle between a similar point in the normalized phase space.
- Repeat this along the FODO line to visualize the trend.
- Phase Advance Difference accrues by ~36 mrad/m (2.06 degrees/m)



Phase Advance Difference Extended

- Extending the FODO line to ~10x the length.
- Repeat the same analysis process.
- The Phase Advance Difference Trend is consistently ~36 mrad/m.



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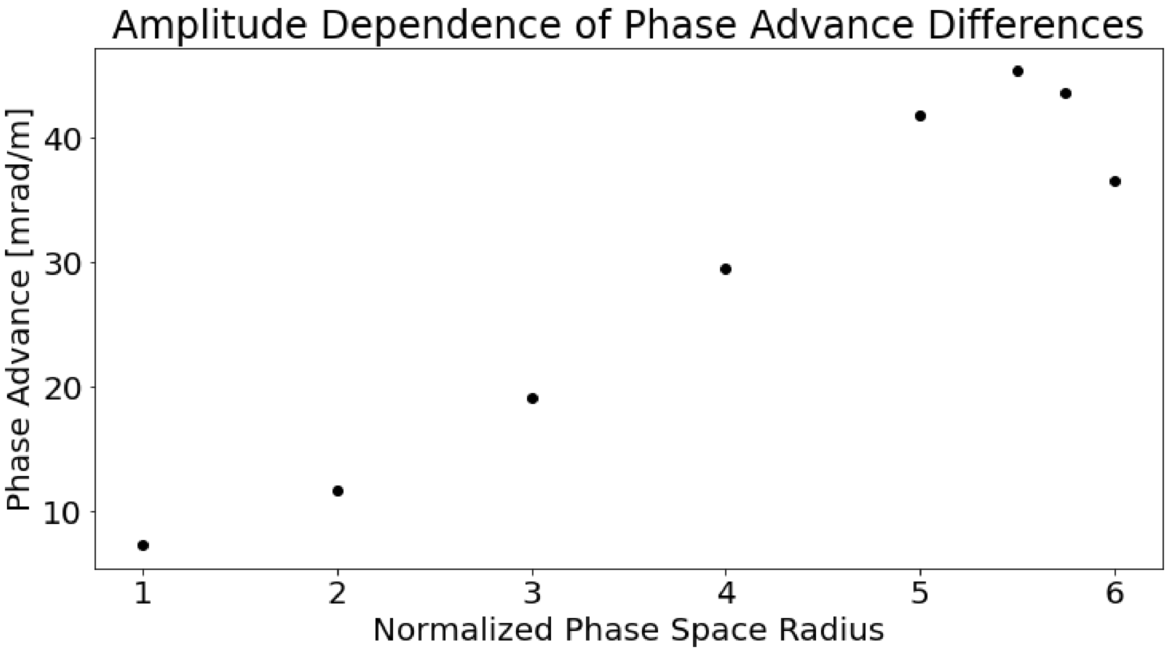
Phase Advance Difference at Amplitudes

- Phase advance difference of ~36 mrad/m at aperture.
- In general, this decreases as maximum particle amplitude decreases.



Conclusion

- The two models simulate near identical phase space ellipses.
- There is a difference in phase advance of ~36 mrad/m at aperture, that peaks at ~45 mrad/m slightly within aperture and decrease as particle amplitude decrease.