Influence of plasma profiles on particle deposition in Wendelstein 7-X like simulation

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Abstract

An investigation of Beam Emission Spectroscopy (BES) signals subject to different plasma profiles is simulated for a Wendelstein 7-X (W7X) like configuration with the BEAMS3D code. BEAMS3D is a guiding center particle code that follows user defined particles and models neutral beam injection. A study is performed of the influence of plasma profiles on the particle deposition model. A goal of this study is to assess whether BES data can be used to constrain plasma density profiles. Simulation with different numbers of injected particles is being explored to assess incorporation of the BES forward model into STELLOPT for equilibrium reconstruction. As BEAMS3D is a Monte-Carlo code, the number of particles can play an important role in interpretation of results. Should a smaller number of starting particles produce comparable results, we can greatly reduce the runtimes and space needed when running the simulations.

BEAMS3D

- guiding center particle code following user defined particles and models neutral beam injection with Monte-Carlo approach
- follows particle trajectories from NBI while they traverse plasma and all the way to the wall [1]
- fully 3D neutral beam injection model coupling 3D equilibria to a guiding center code
- particle deposition calculated from neutral particle trajectories including the physical effects of charge-exchange and recombination, pitch angle scattering, and viscous slowing down [2]

Beam Attenuation

In experiments beam attenuation measured via spectroscopy
- Beam Emission Spectroscopy (BES)
- plasma diagnostic tool, collect light from different points along beam line and analyze the doppler shifted spectrum
- infers local fluctuations in density from fluctuations in light emitted by injected neutral beam [3]

Sensitivity of beam attenuation is explored in this work

Parameters

- Number of injected particles
- Electron density scale
- Electron temperature scale
- Ion temperature scale
- Plasma profile shape

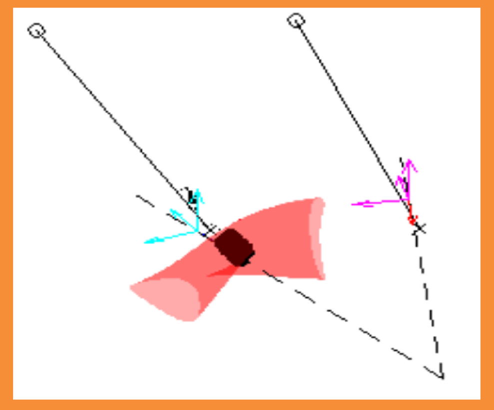

FIG 1: W7-X neutral beam geometry

Number of Particles

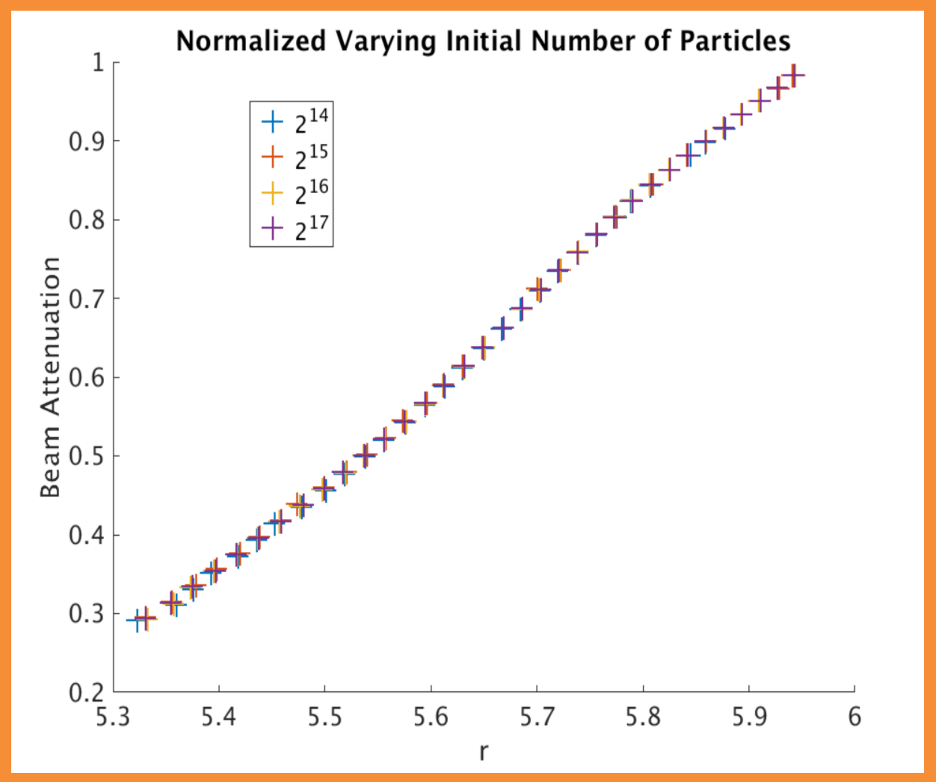

FIG 2: Normalized plot of four magnitudes of injected particles

Profiles

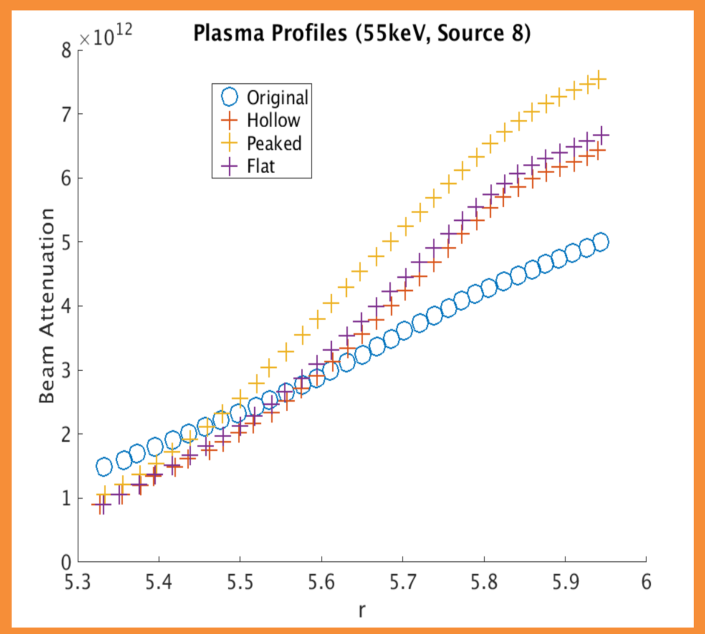

FIG 7: Attenuation for three different plasma profiles and the original

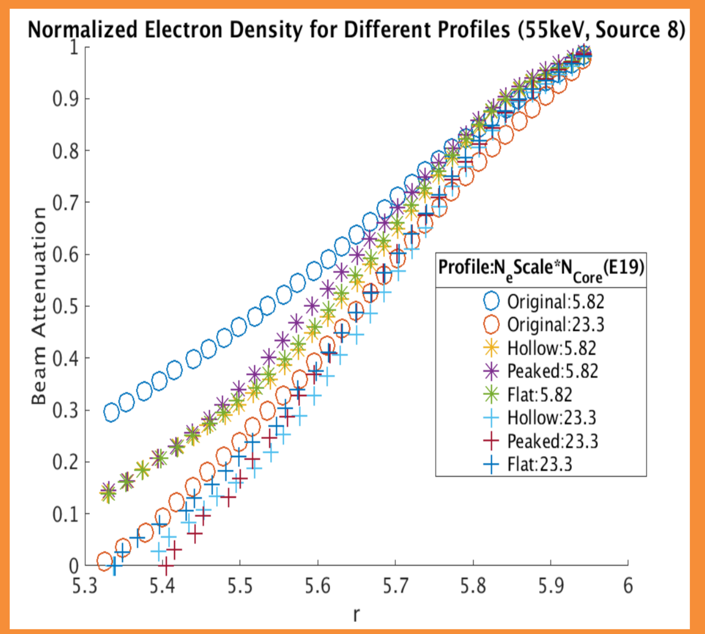

FIG 8: Normalized attenuation for all profiles at two electron density scales

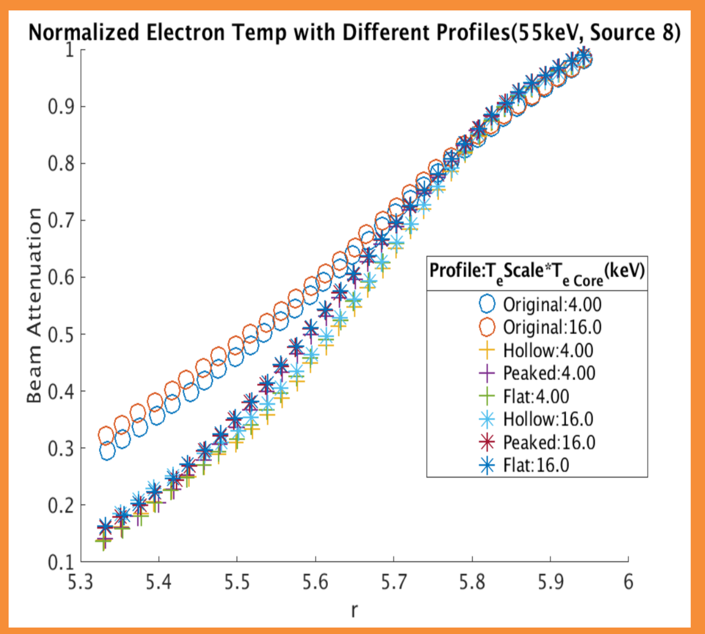

FIG 9: Normalized attenuation for all profiles at two electron temperature scales

Electron Density

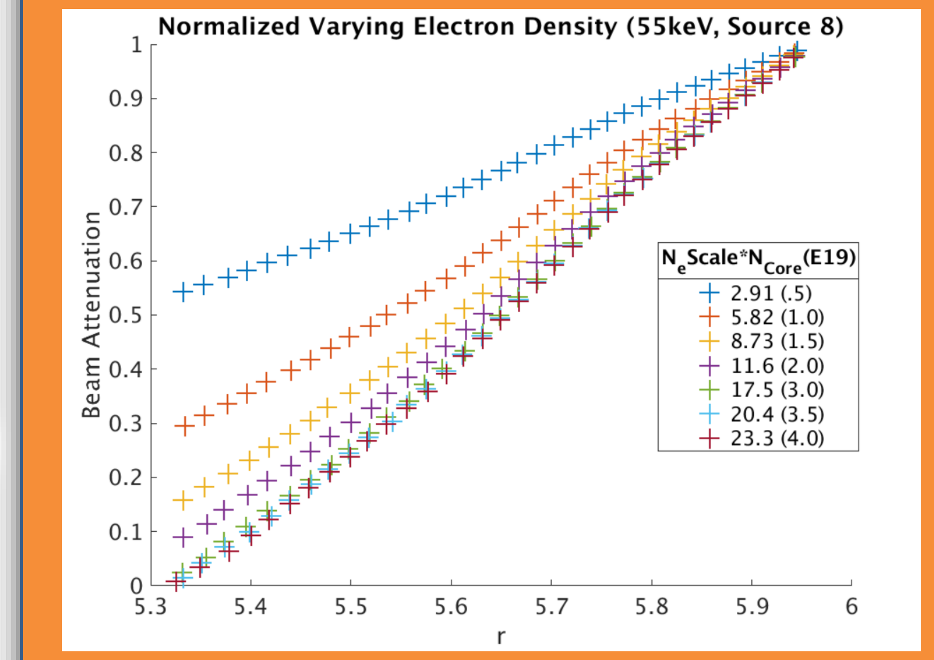

FIG 3: Normalized attenuation for electron density scales

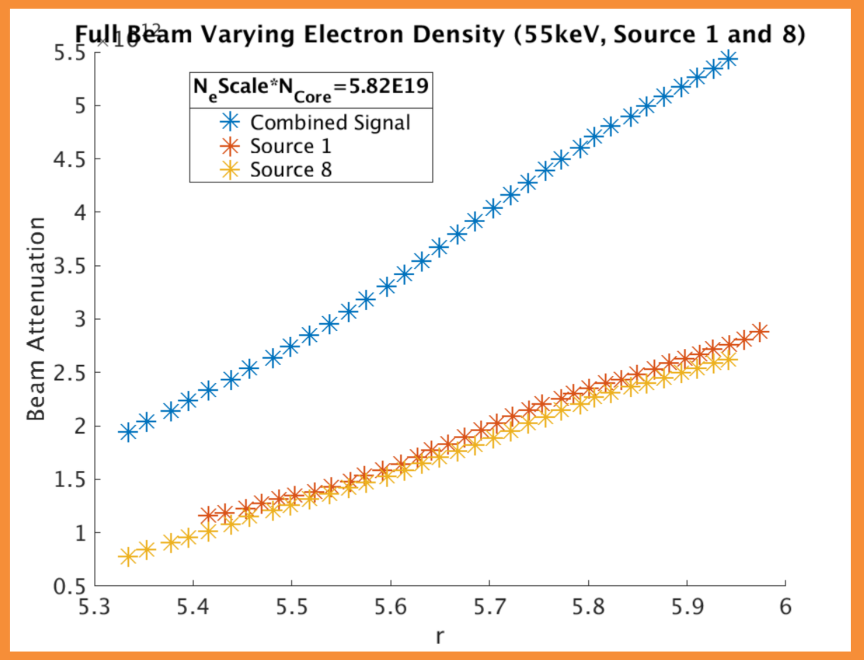

FIG 4: Attenuation for individual and combined NBI

Electron/Ion Temperature

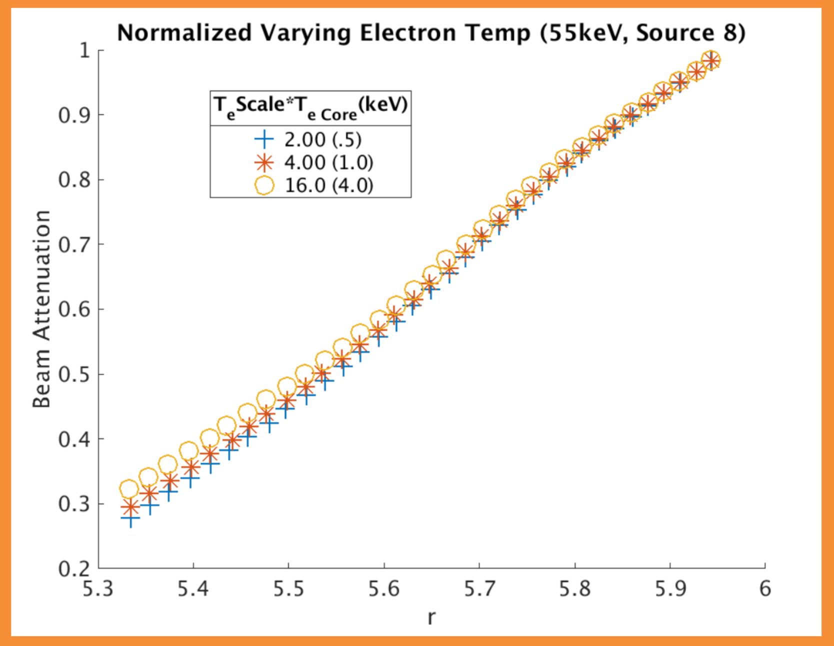

FIG 5: Normalized attenuation for electron temperature scales

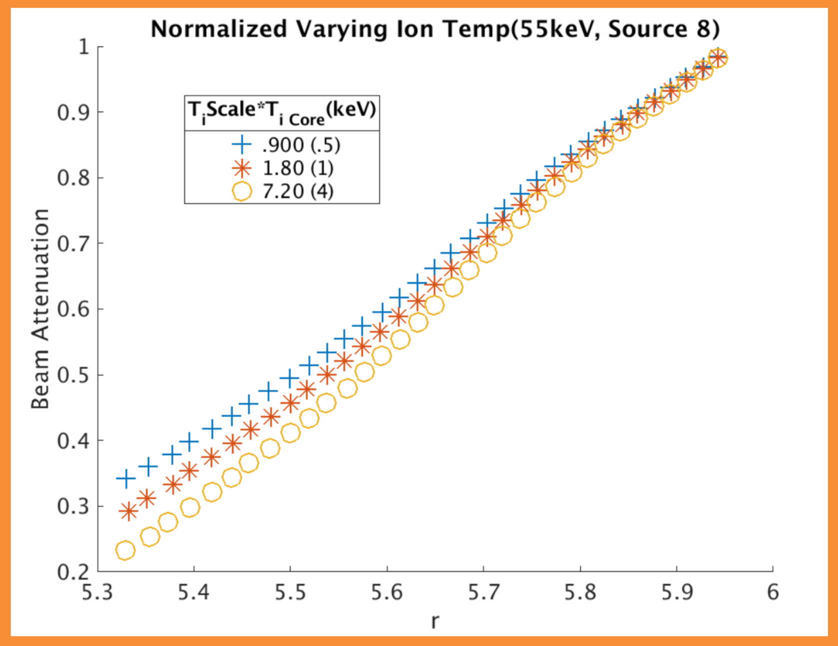

FIG 6: Normalized attenuation for ion temperature scales

Discussion

In this work BEAMS3D code has been used to simulate the deposition of a W7-X like neutral beam system to investigate the sensitivity of beam attenuation to certain plasma parameters. The number of particles injected into the plasma did not appear to significantly influence beam attenuation, which means that the model can be run with a smaller magnitude of particles while maintaining comparable results. This correction can help reduce resource use and runtime of the simulation. Electron density, both originally and included with different profiles appeared to have a significant effect on attenuation. Knowing this, beam attenuation data could be collected from similar experiments in W7-X and compared to the attenuation produced in these simulations. The electron density in the stellarator is then obtained by finding the matching signal, a process that is much simpler than the alternative route of trying to calculate that value. Because the attenuation is also sensitive to changes in plasma profile shape, the same process and conclusions apply here as well. Even at extreme temperatures, the beam attenuation remained relatively insensitive to electron and ion temperature. This is important to note, but not very helpful in mapping experimental data to simulations to find the true temperatures inside the stellarator

References

[1] McMillan M and Lazerson S. Plasma Physics and Controlled Fusion 56, 095019 (2014)
[2] Lazerson S and Dravlak M and Bolgert P and Gates D and McMillan M and W7-X Team EUROFUSION. WPS1-PR 16, 15275 (2016)
[3] Mandl W and C Wolf R and Von Hellermann Manfred and P Summers H. Plasma Physics and Controlled Fusion 35, 1373 (1999)

Acknowledgement

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