ID: 637

Effects of turbulence in modifying helicon wave current drive propagation and efficiency

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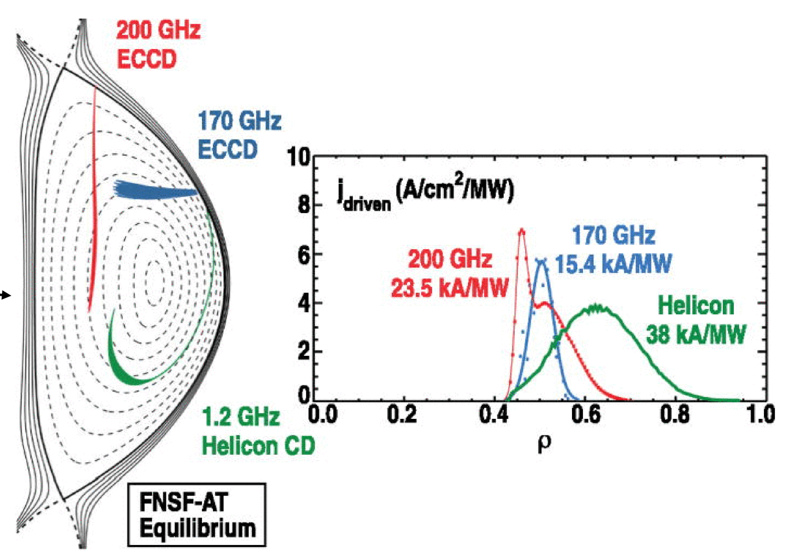
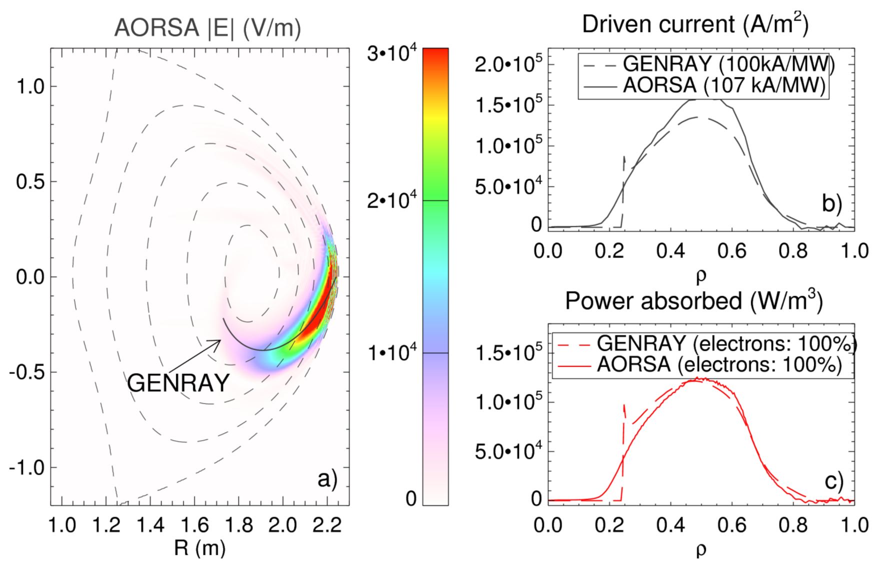
ABSTRACT

- Full-wave modeling without and with SOL turbulence has been developed and applied to helicon current drive on DIII-D tokamak
- Results are sensitive to turbulence parameters such as fluctuation amplitude and wavelengths, and may cause large helicon wave SOL losses
- Mode conversion to slow waves could be an important physical explanation in understanding large SOL losses

MOTIVATION

- Helicon current drive is expected to be an efficient mid-radius current drive actuator for tokamak experiments and reactors [1]
- High-powered experiments are expected for DIII-D [Van Compernolle, IAEA FEC2020], but no results to date
- Simulations can predict and understand helicon wave current drive efficiency and coupling Previous results using full-wave model without SOL shows expected large helicon wave mid-radius current drive efficiency for the DIII-D tokamak [2]



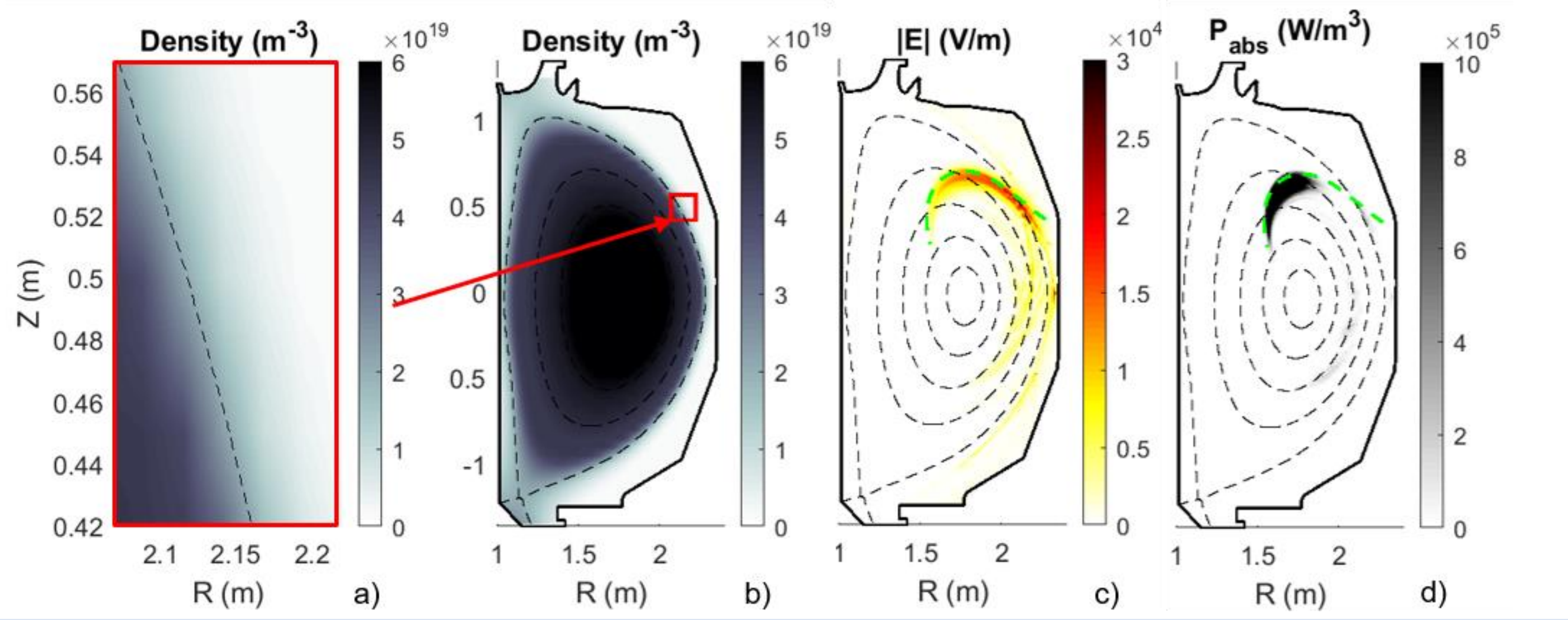


HELICON FULL-WAVE MODEL WITHOUT SOL TURBULENCE

- 2-D axisymmetric cold-plasma finite-element model is used to understand helicon wave propagation and absorption [3]

$$\nabla \times \left(\nabla \times \vec{E}_m(r,z)\right) - \frac{\omega^2}{c^2}\left(\vec{\varepsilon}(r,z) \cdot \vec{E}_m(r,z)\right) = 0$$

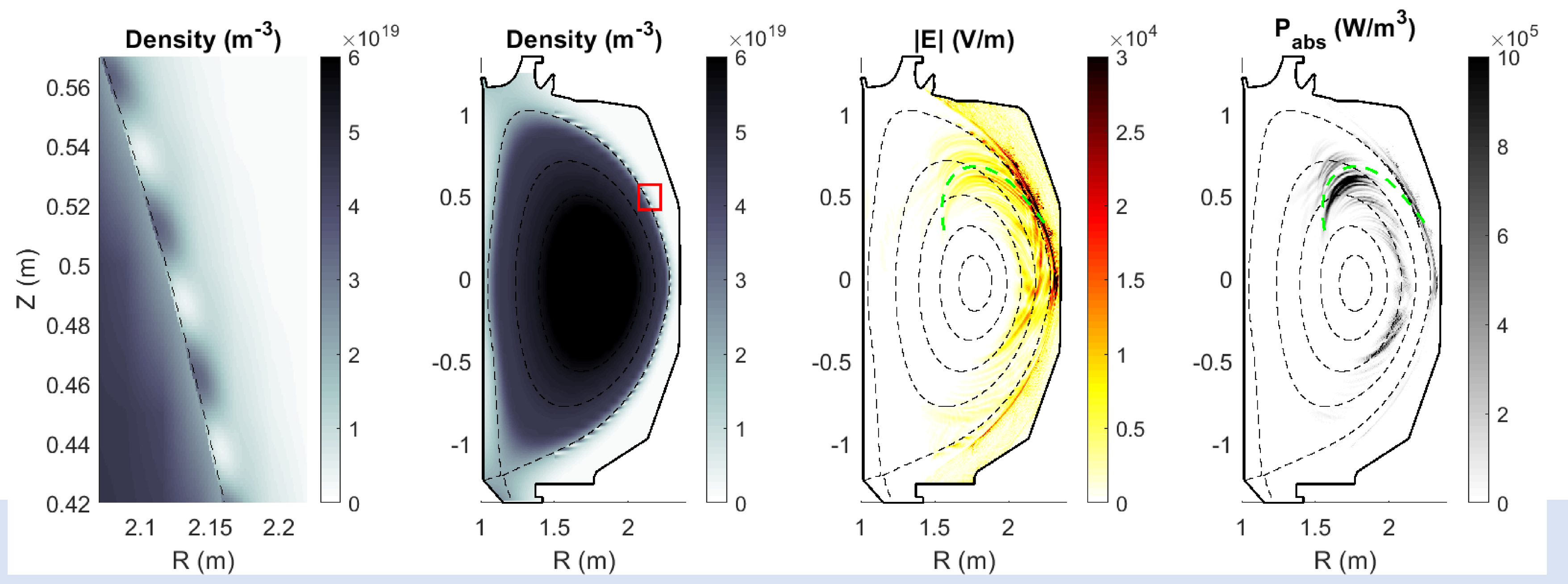
- Key input is density profile, which is an input into $\vec{\varepsilon}(r,z)$



HELICON FULL-WAVE MODEL WITH SOL TURBULENCE

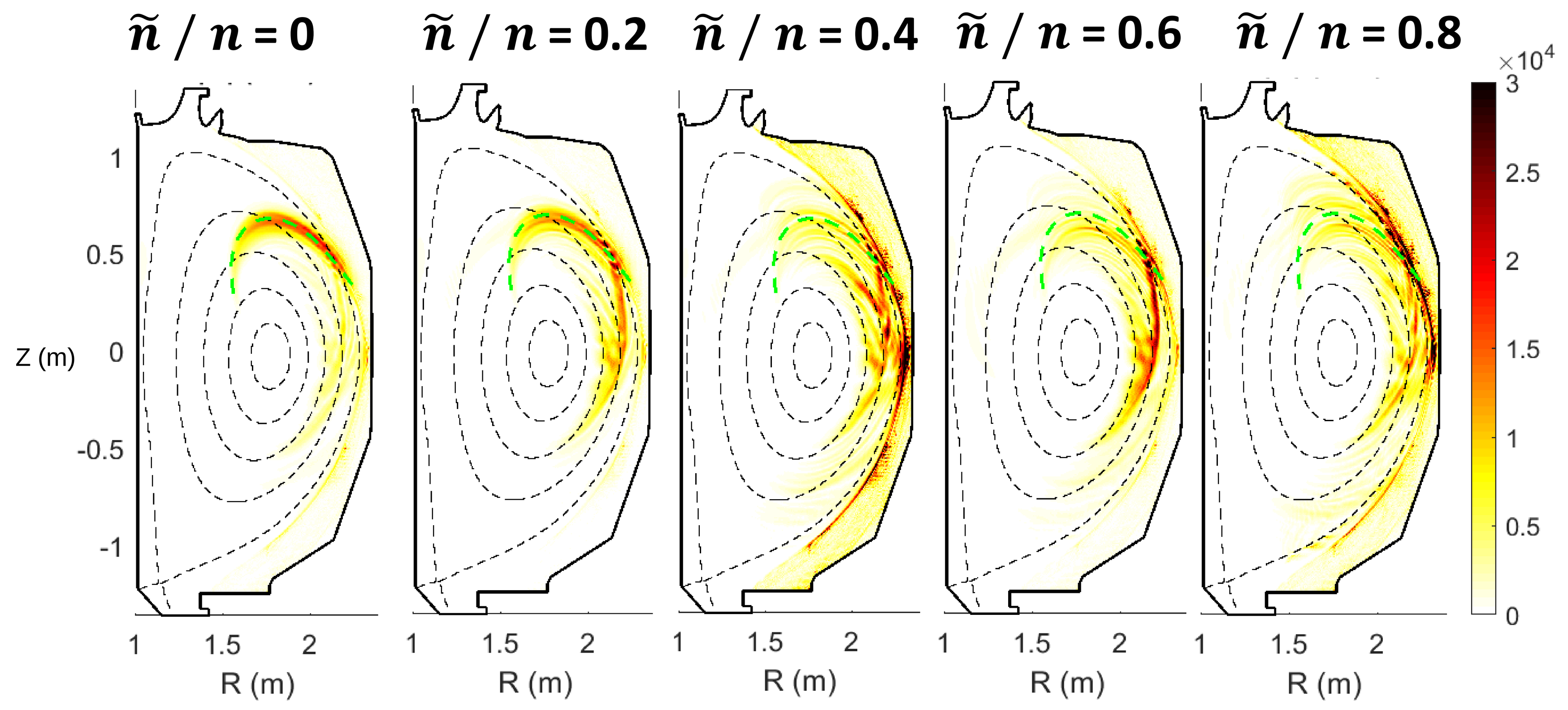
- Because helicon wave frequency >> turbulence frequency, turbulence is "frozen" and is an input to density profile in full-wave simulations
- Synthetic turbulence model is used here

$$n_{e,fluct} = n * \left[(1 + \frac{\tilde{n}}{n} * e^{-\frac{(p-p_c)^2}{\rho_w^2}} * \cos\left(\frac{\pi(z - z_c)}{\lambda_{fluct}}\right)\right]$$

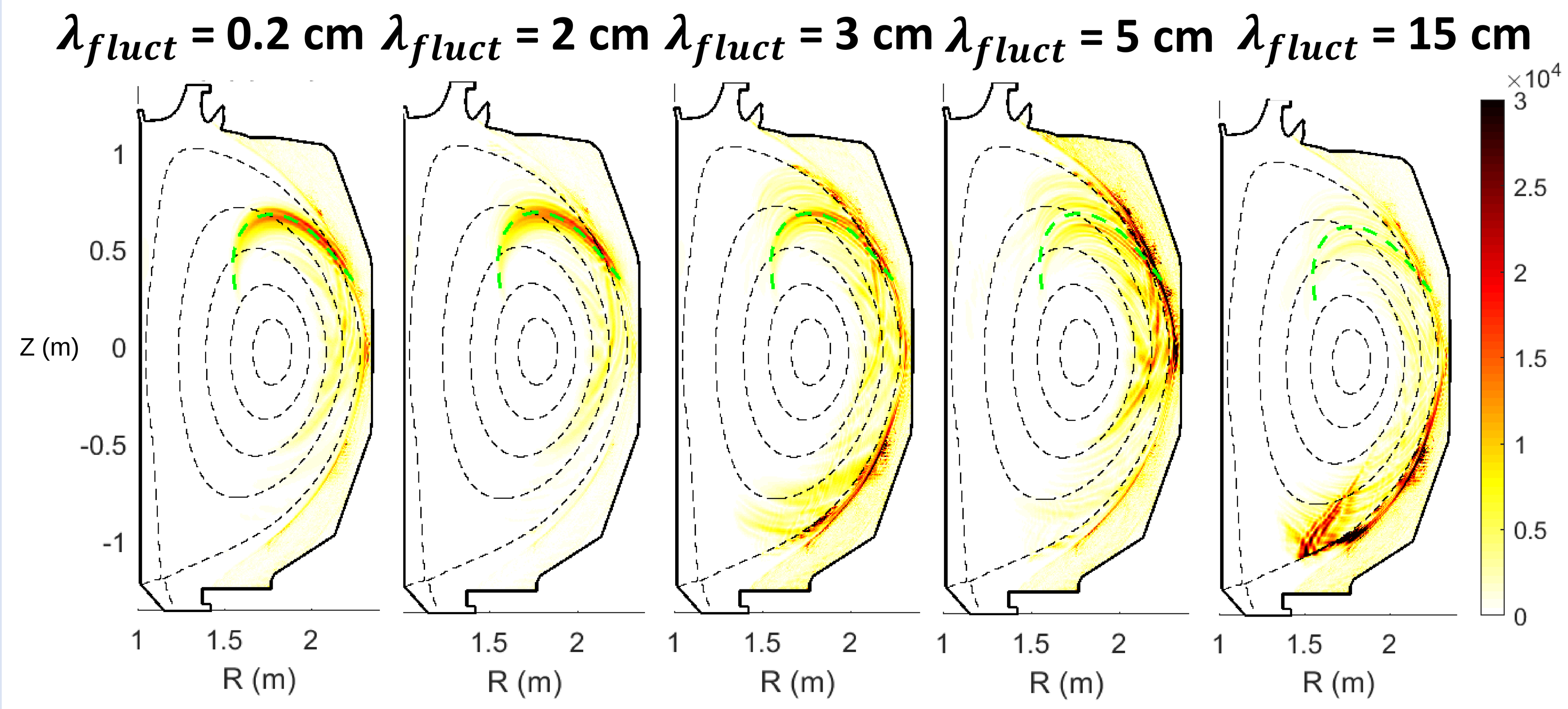


RESULTS

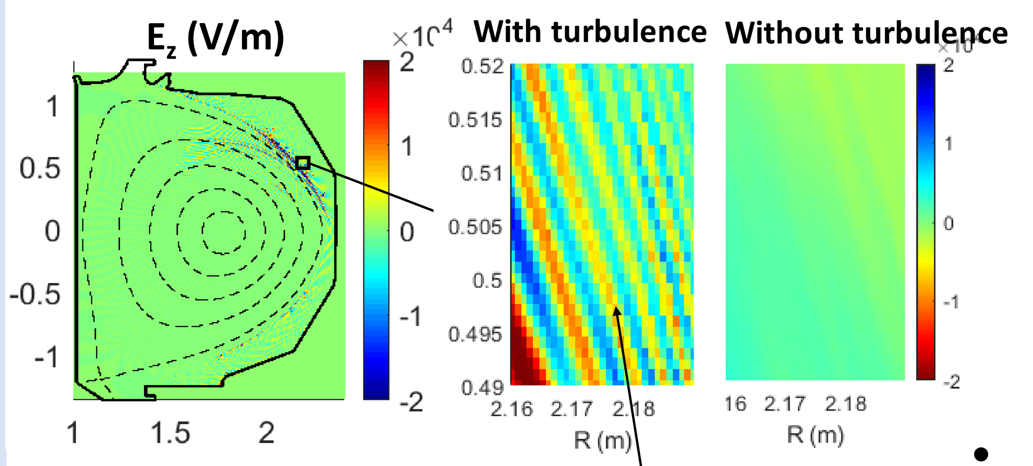
RESULTS WITH DIFFERENT DENSITY FLUCTUATION AMPLITUDES ($\frac{\tilde{n}}{n}$)

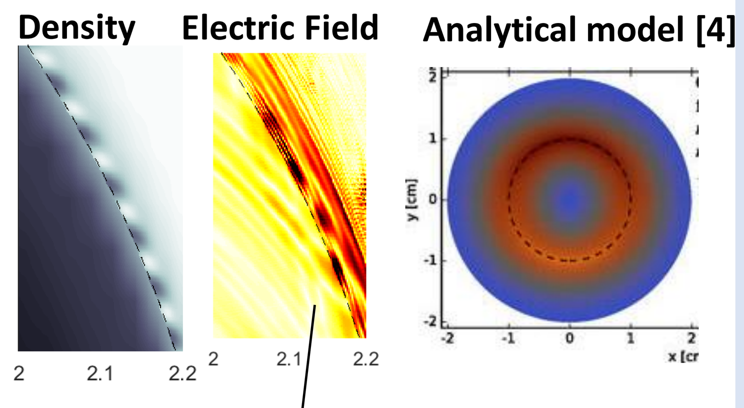


RESULTS WITH DIFFERENT DENSITY FLUCTUATION WAVELENGTHS (λ_{fluct})



OBSERVATION OF MODE CONVERSION





Mode conversion to slow wave dispersion relation is consistent

- at this location $\lambda_\perp = 6$ mm for slow wave, $\lambda_\perp = 50$ mm for fast wave
- $\lambda_\perp \sim 5$ mm from visual inspection

- Recent analytical model predicts filament modes that can cause localized losses within filaments due to mode conversion [4]
- Is that observed here?

CONCLUSION

- Helicon full-wave model with synthetic SOL turbulence shows that helicon wave propagation and absorption can be strongly affected by SOL turbulence properties such as density fluctuation amplitude and fluctuation wavelength
- Mode conversion to slow wave in the SOL is observed and may at least partially explain the large SOL electric fields observed
- Future work will involve comparisons of simulation to high-powered experiments expected later this year

ACKNOWLEDGEMENTS / REFERENCES

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