U.S. DEPARTMENT OF ENERGY | Office of Science

NSTX-U

Feasibility study of O-mode ECRH in NSTX-U startup plasma

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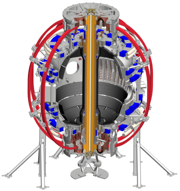
NSTX-U Results Review, September 21, 2016

PPPL

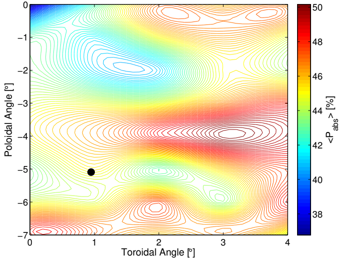


Motivation

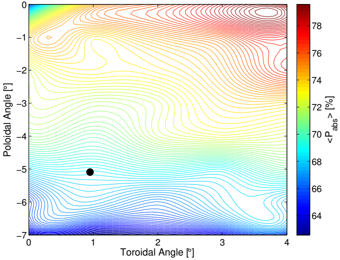
- 28 GHz ECRH system planned for installation on NSTX-U in 2018 [G. Taylor *et al* EPJ Web of Conferences **87** 02013 (2015)]
  - Simulations show HHFW coupling is improved via the preheating of electrons with ECRH [F.M. Poli *et al* Nucl. Fusion **55** 123011 (2015)]
- Previous ECRH optimization efforts utilized static plasma profiles and equilibrium
  - Unclear if the proposed injection angle will remain optimal throughout entire ECRH phase.
- Time-dependent simulations with TRANSP allow more complete optimization studies
  - Self-consistently evolve plasma parameters in response to injected EC power

Baseline angle $(1°, -5°)$ provides effective ECRH on fast density rampup, suboptimal on slow density rampup

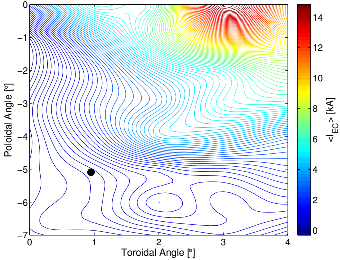
Fast Density $\langle P_{Abs} \rangle$



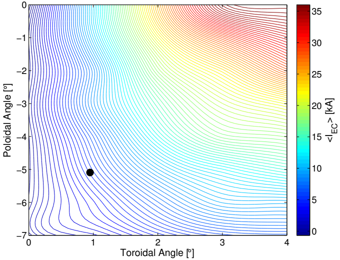
Slow Density $\langle P_{Abs} \rangle$



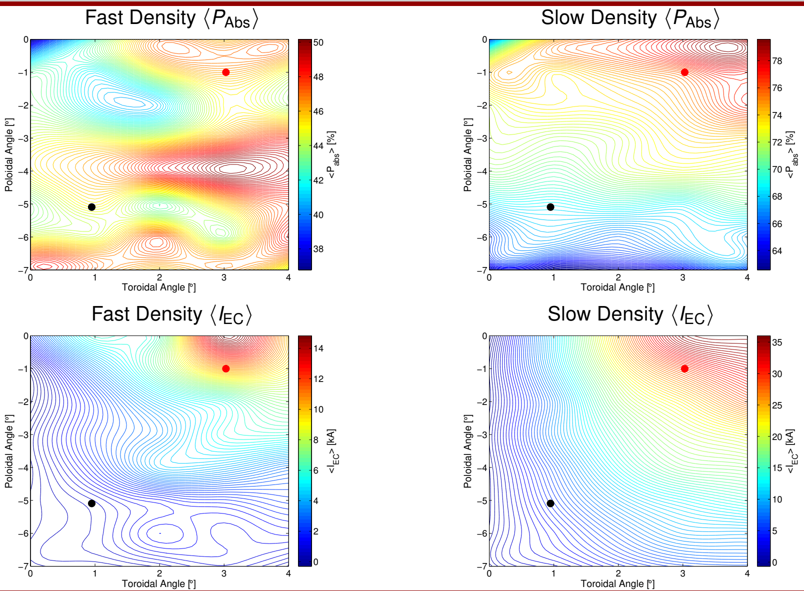
Fast Density $\langle I_{EC} \rangle$



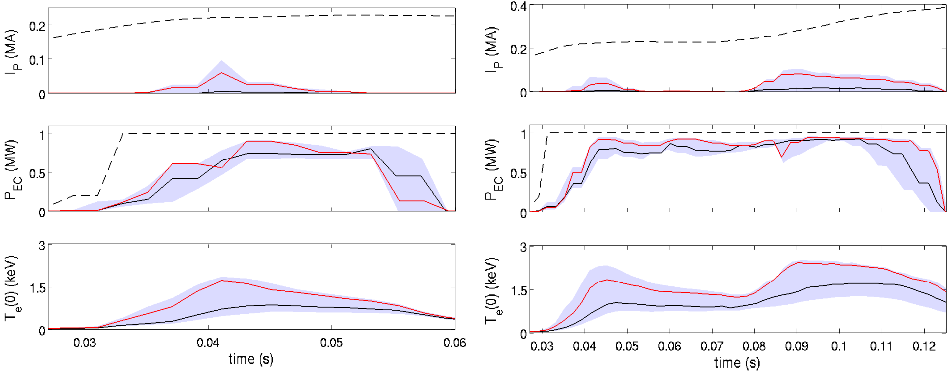
Slow Density $\langle I_{EC} \rangle$



$(3^\circ, -1^\circ)$ optimally balances $\langle P_{abs} \rangle$ and $\langle I_{EC} \rangle$ for both density rampups



Time-dependent performance of $(3^\circ, -1^\circ)$ (red) superior to that of $(1^\circ, -5^\circ)$ (black)



- $T_e(0)$ exceeding 1.6 keV, 2.4 keV and ECCD up to 59 kA, 81 kA attainable for fast, slow density rampups respectively

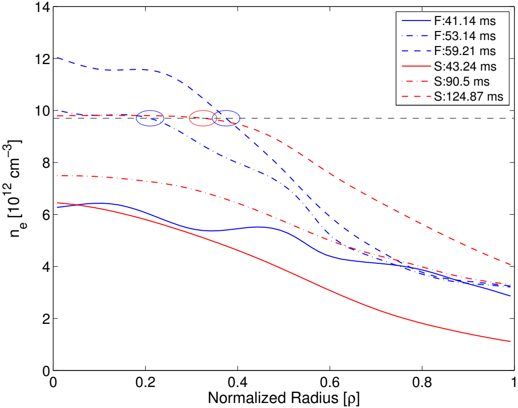
Future Work

- MHD stability analysis of peaked EC current profiles against ballooning modes
- Using GENRAY+CQL3D for quasilinear effects at low density
- Assess EBW startup feasibility

Backup Slides

Slow & fast density rampups

- Slow density rampup gets 'broadly' overdense at $\sim$ 125 ms
- Fast density rampup gets 'narrowly' overdense at $\sim$ 53 ms, broadens out at $\sim$ 60 ms



ECRH late-time poloidal dependence highly sensitive to n_e profile shape at critical density

Figure of Merit - Results

$$\text{FOM} = \frac{1}{6}\left(\langle \tilde{I}^{F}_{EC}\rangle + \langle \tilde{I}^{S}_{EC}\rangle + \langle \widetilde{P}^{F}_{Abs}\rangle + \langle \widetilde{P}^{S}_{Abs}\rangle + \frac{1}{2}\log(\hat{\Delta}^{F}_{40}) + \frac{1}{2}\log(\hat{\Delta}^{S}_{40})\right)$$

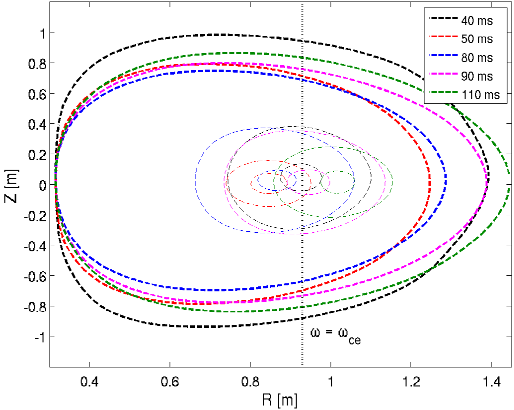
Top 5 angles:

1.	$(3^\circ, 0^\circ)$	—	0.689†
2.	$(3^\circ, -1^\circ)$	—	0.636
3.	$(4^\circ, 0^\circ)$	—	0.622
4.	$(4^\circ, -1^\circ)$	—	0.589
5.	$(3^\circ, -2^\circ)$	—	0.582

† Extra EC smoothing necessary in equilibrium calculations

Lateral motion during slow density rampup

- At 40 ms, magnetic axis starts moving from $R \approx 0.92$ m to minimum location $R \approx 0.82$ m
- After 80 ms, magnetic axis begins outward transit, approaching $R = 1.02$ m

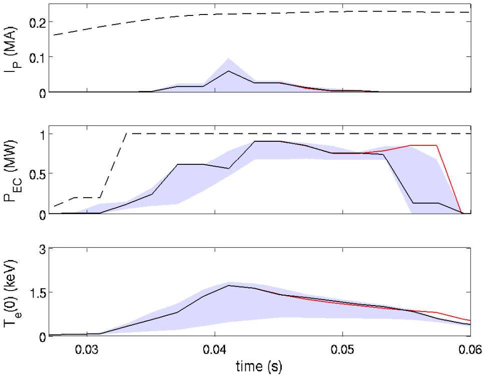


Lateral motion coincides with observed dips in I_{EC} and $T_e(0)$ traces

Dynamic Injection Angle

Angle trajectory: $p(t) = 2 \cdot \mathrm{rect}\left(\frac{t-47.5\text{ms}}{15\text{ms}}\right) \cdot \left[\frac{t-40\text{ms}}{5\text{ms}}\right] + 1 + 6 \cdot \Theta(t - 55\text{ms})$

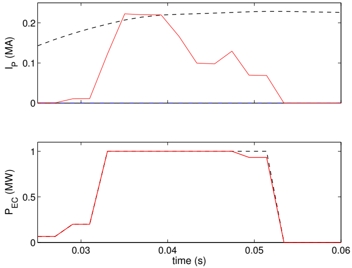
- Dynamically increasing poloidal injection angle reduces reflection-dominated deterioration on fast rampup
  - 20.20% increase in $\langle P_{Abs} \rangle$
  - 6.29% decrease in $\langle I_{EC} \rangle$
- Dynamic injection angles don't offer significant improvements to slow density rampup scenario



$(3^\circ, -p(t)^\circ)$ (**red**) compared to $(3^\circ, -1^\circ)$ (**black**)

EBW Startup - Work in Progress

Fast Density Rampup



Slow Density Rampup