Quiescent H-Mode Experiments in DIII–D With Counter Plus Co- Neutral Injection

by
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with
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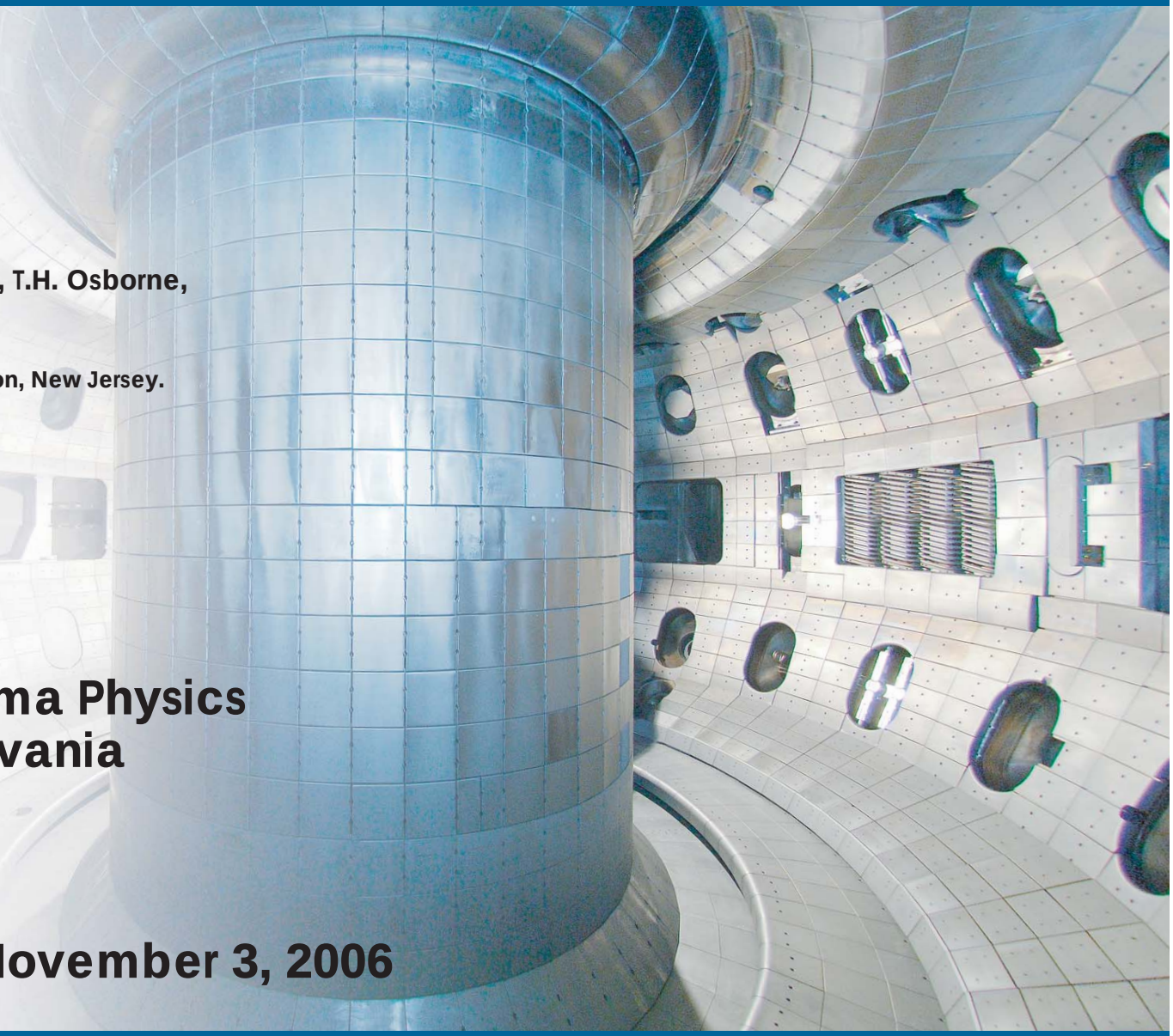

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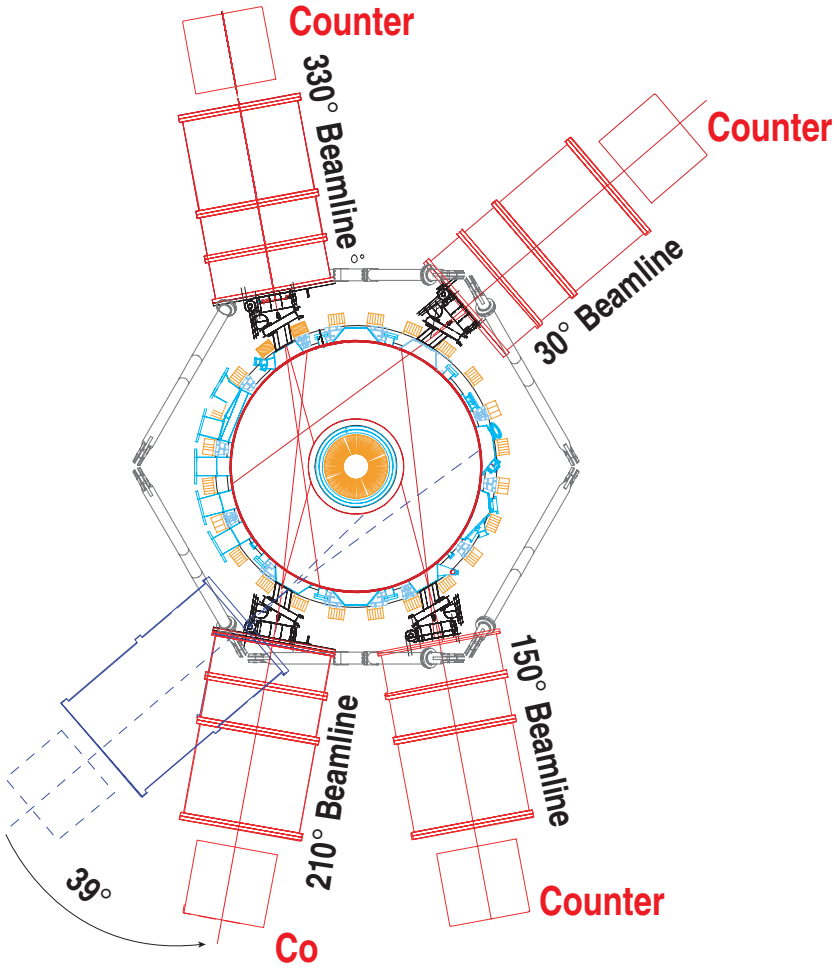
DIII-D NATIONAL FUSION FACILITY

GENERAL ATOMICS

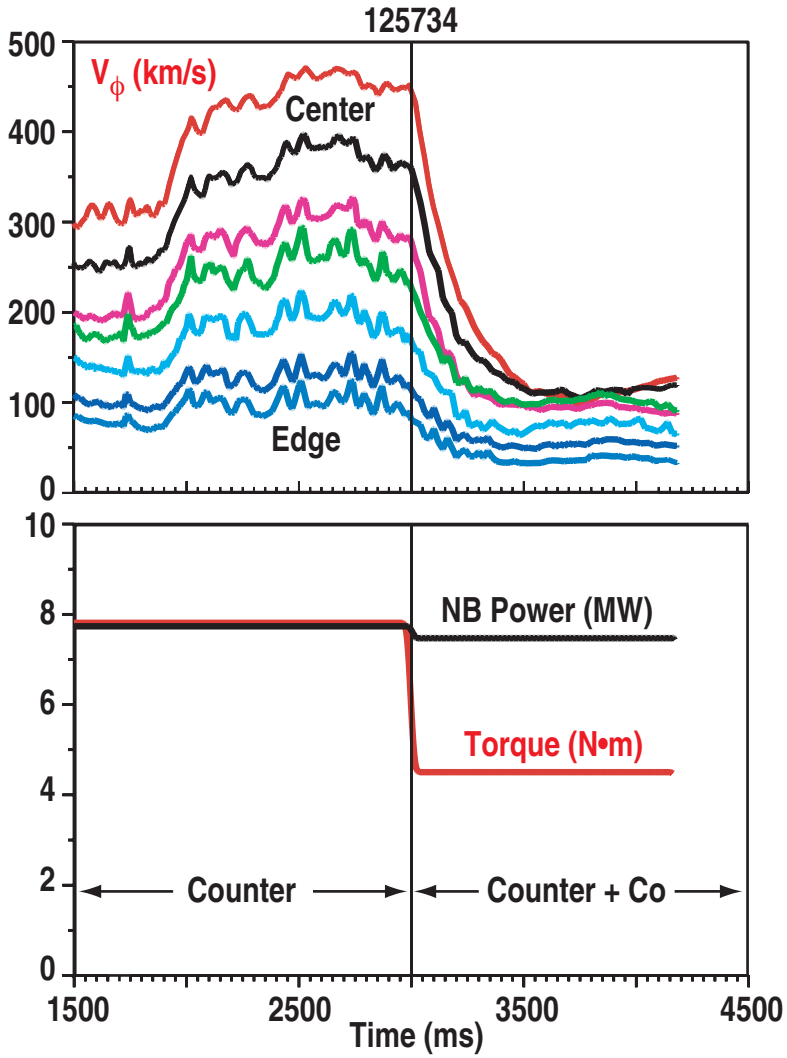
Major Equipment Changes Allow Novel Quiescent H-Mode Experiments

- **Quiescent H-mode (QH-mode) is in many ways the ideal H-mode**
  - Exhibits H-mode confinement level
  - Has ELM-free operation with stationary density and radiated power
- **Major equipment changes on DIII-D for the 2006 campaign allow novel QH-mode experiments**
  - Simultaneous co plus counter neutral beam injection gives control of plasma rotation
  - Divertor modification allows cryopumping of high triangularity, double null plasmas
- **We discovered that pedestal density can be altered by changing co-counter beam balance**
  - Since the edge harmonic oscillation (EHO) increases edge particle transport, we speculate that this EHO-related transport is sensitive to edge rotation
- **Using theoretically predicted increase in edge stability at high triangularity, we achieved record pedestal densities of up to $n_e^{PED}/n_{GW} = 0.5$**
  - Employed co plus counter beam injection for density control
- **We found ELM and EHO stability is sensitive to distance of plasma from the outer wall**

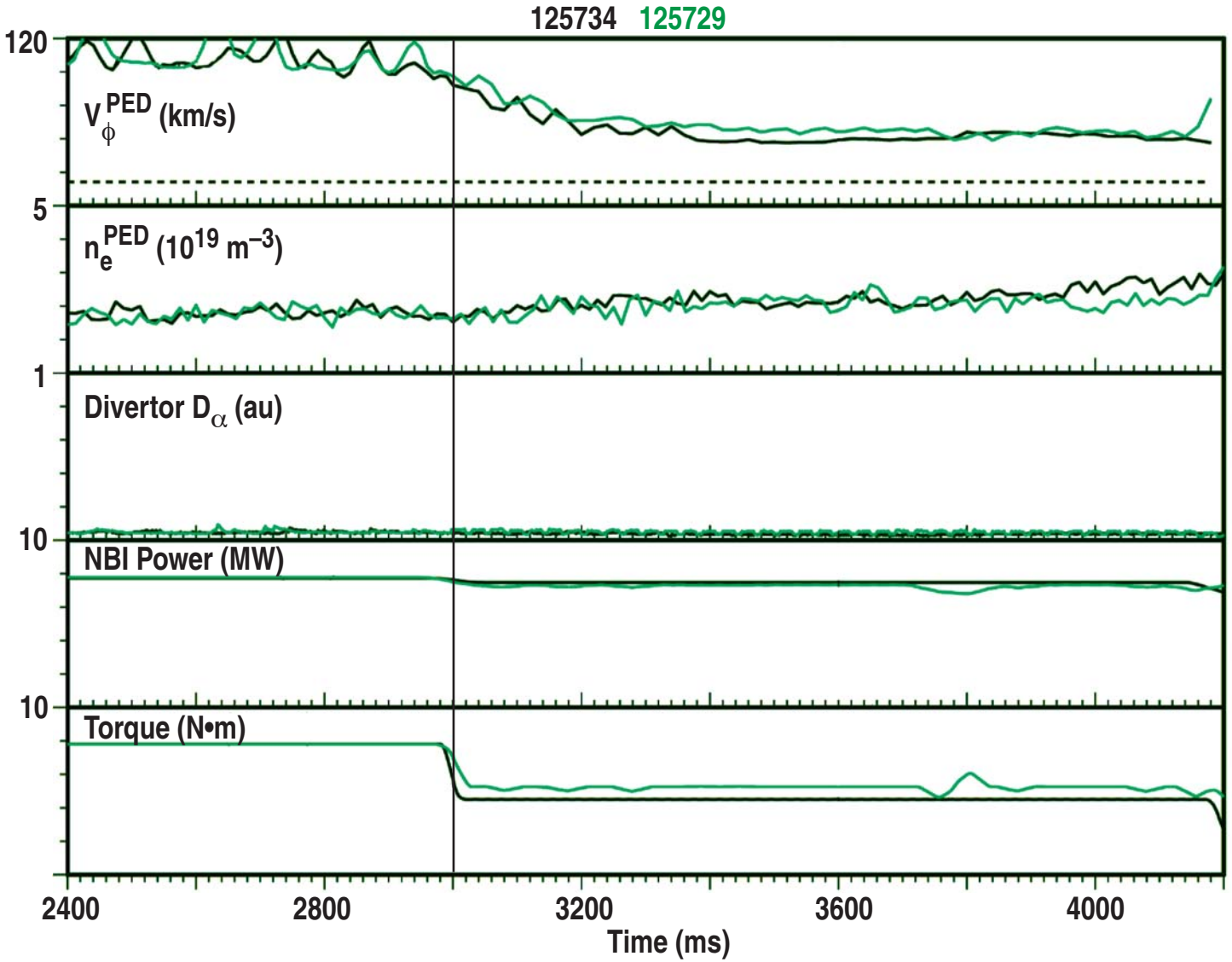
Counter Plus Co- NBI Allows Toroidal Rotation Control



⇒ **Rotation control**



H-Mode Pedestal Density Increases As Net Torque is Reduced



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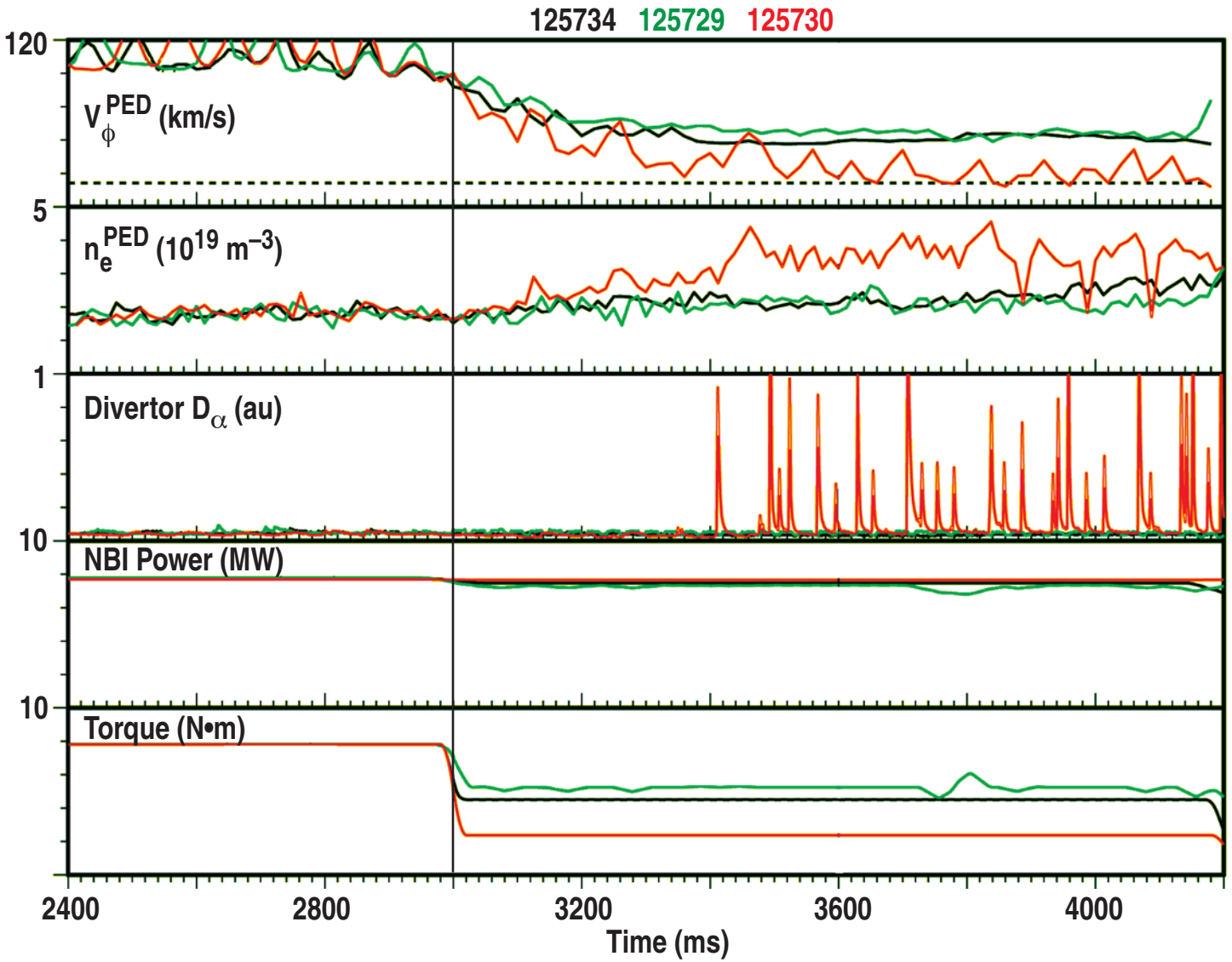
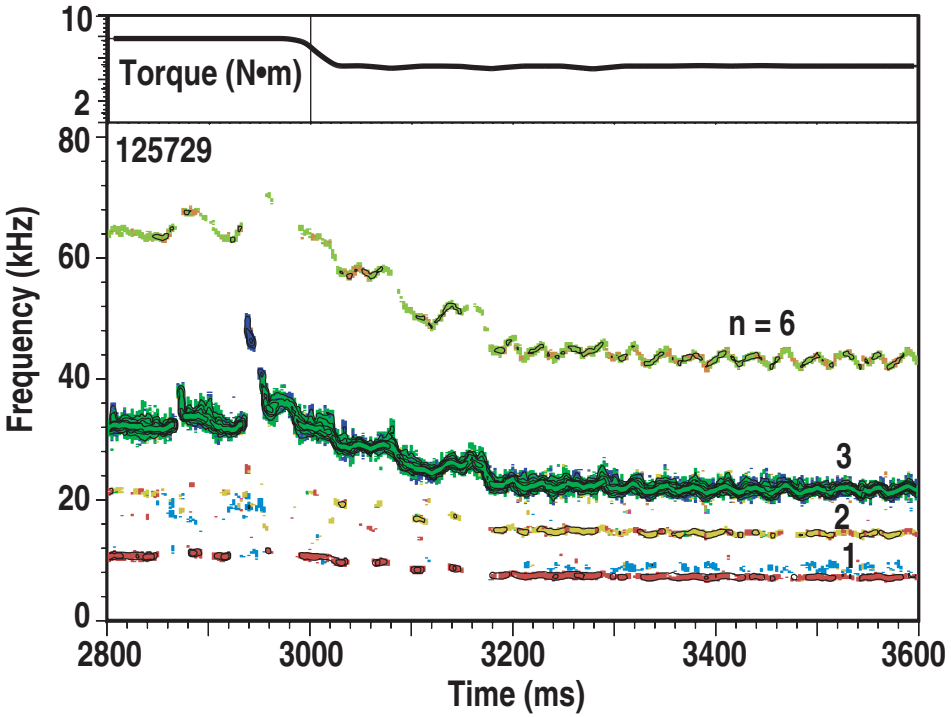
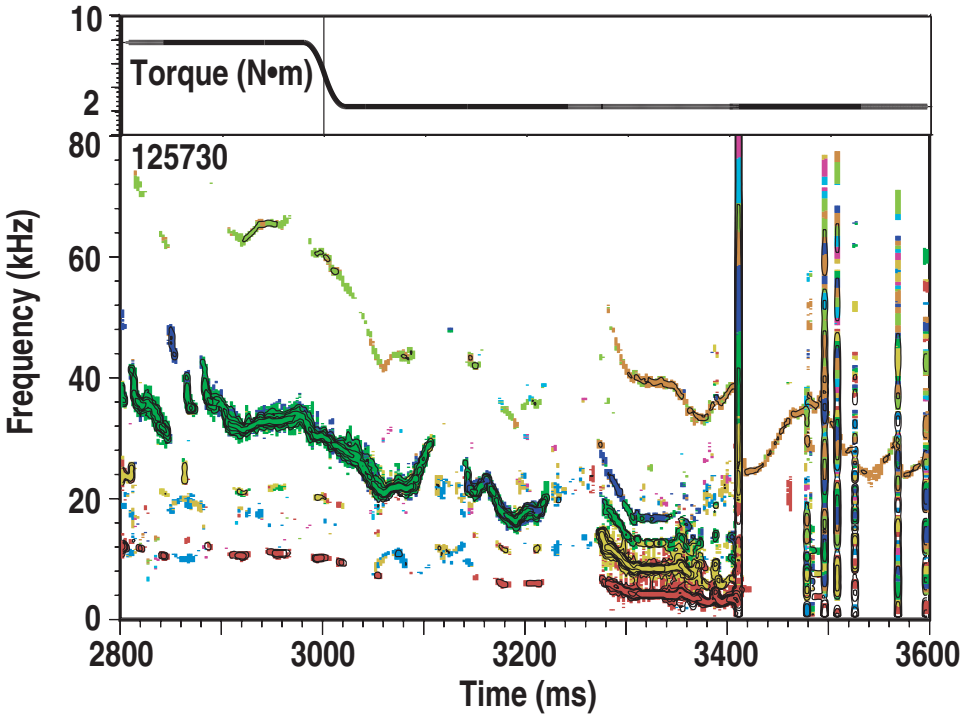


Decreased Torque Alters EHO Frequency and Toroidal Mode Spectrum

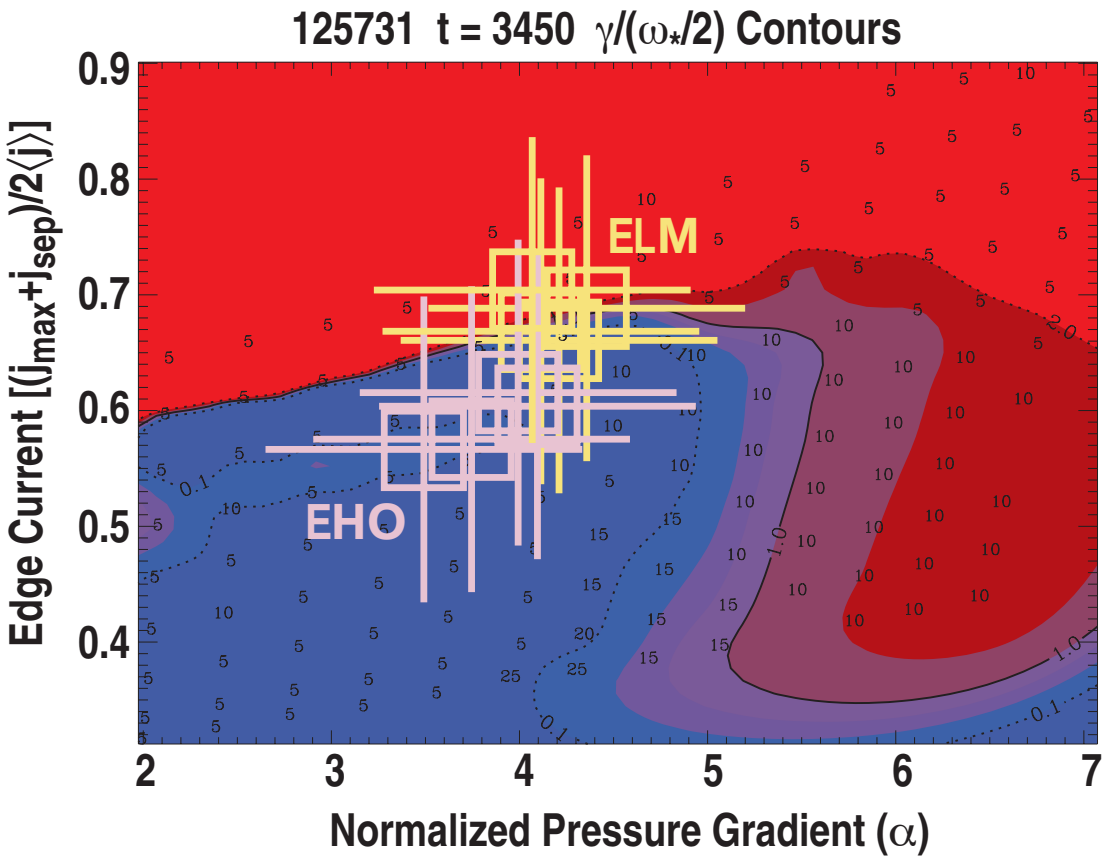
- EHO is a nonsinusoidal oscillation with multiple toroidal harmonics n
- Previous measurements have shown the EHO enhances edge particle transport
- Based on our observation of reduced particle transport with reduced torque and rotation, we speculate that EHO-induced particle transport decreases as edge rotation decreases





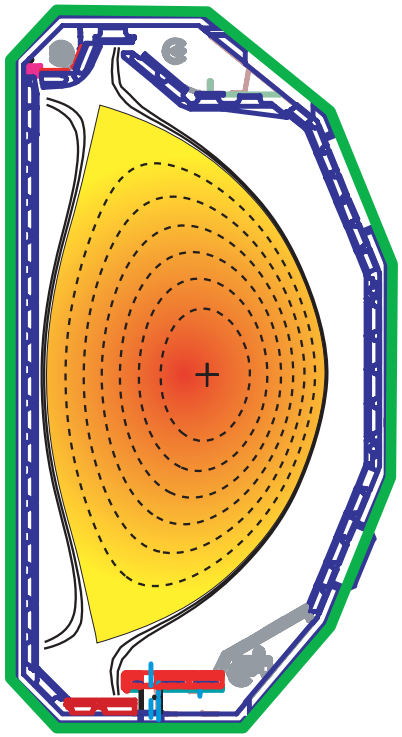
Operating Points of Shots at Various Torques Are Consistent with Edge Peeling-Ballooning Stability Theory

- Stability calculations performed with ELITE code
- QH-mode plasma with EHO operates near but below peeling stability boundary
- ELMing shots are closer to peeling boundary

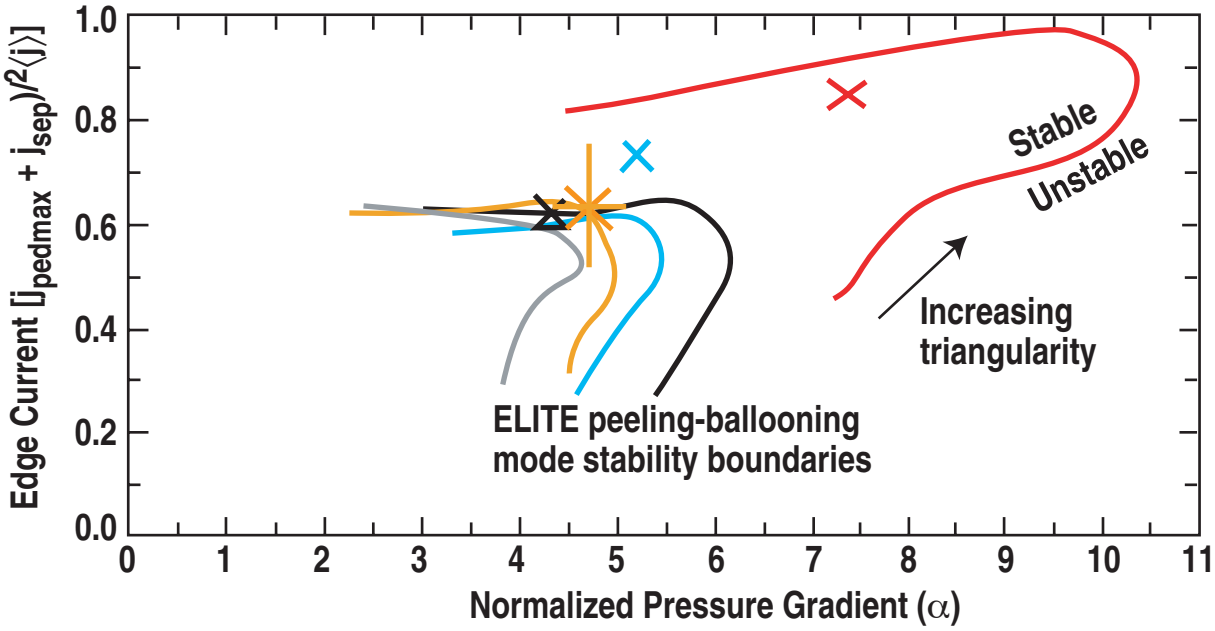


Increased Edge Stability Motivates Work At High Triangularity

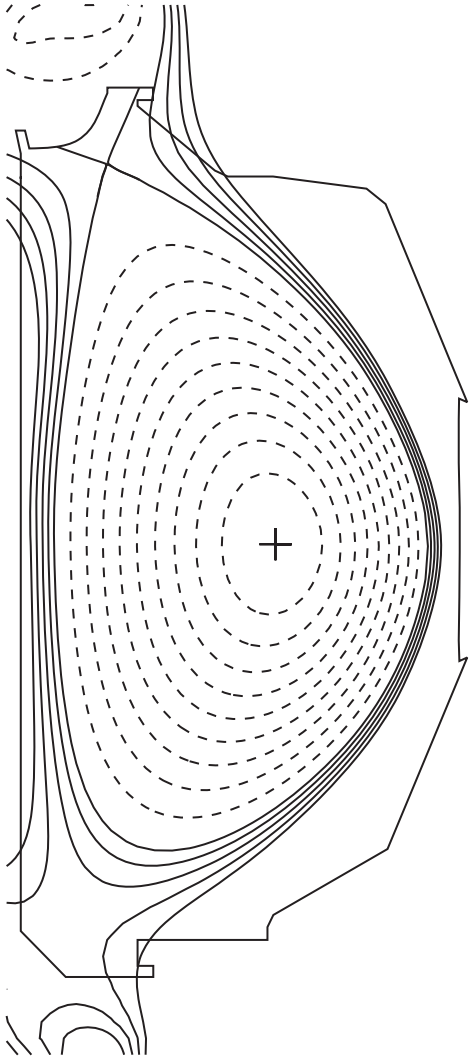
- New divertor configuration allows stronger pumping of high triangularity plasma

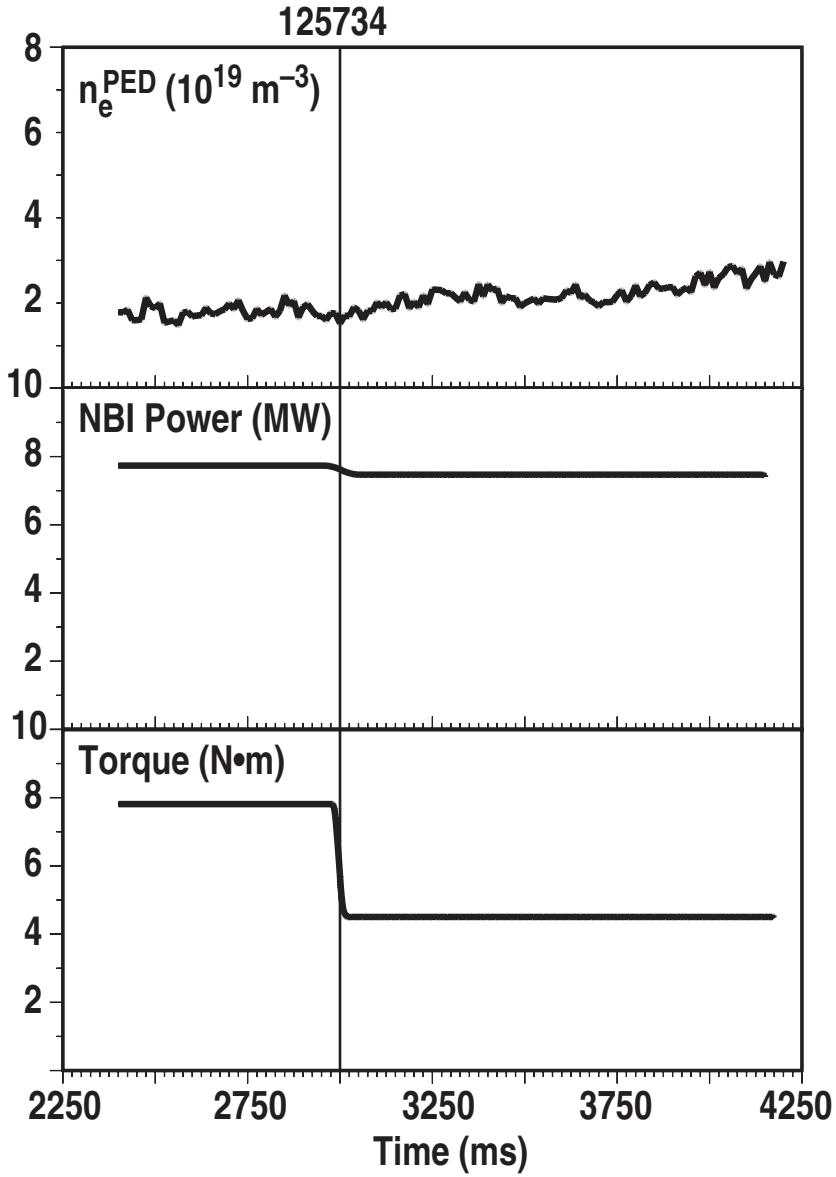


- ELITE calculations for previous experimental results show high triangularity plasma allows ELM-free operation at higher edge pressure



Higher Triangularity Allows QH–Mode Operation At Significantly Higher Pedestal Density





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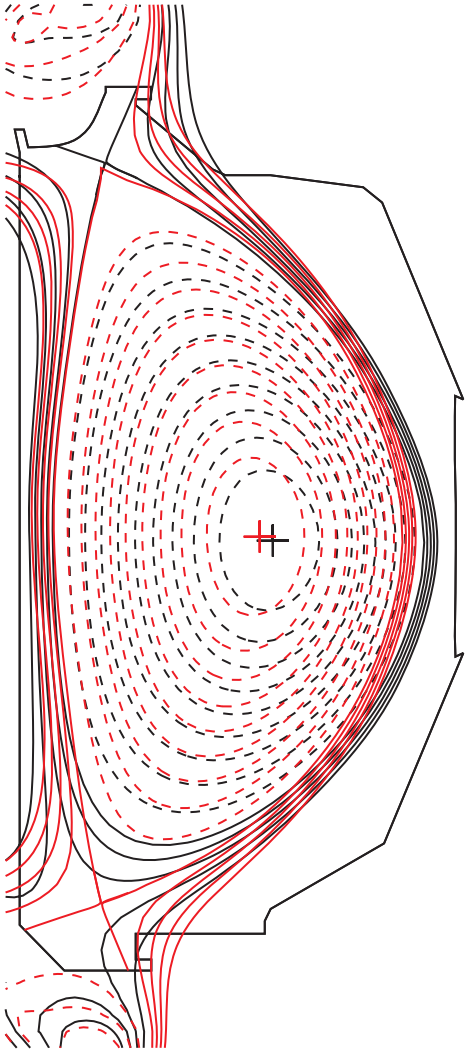
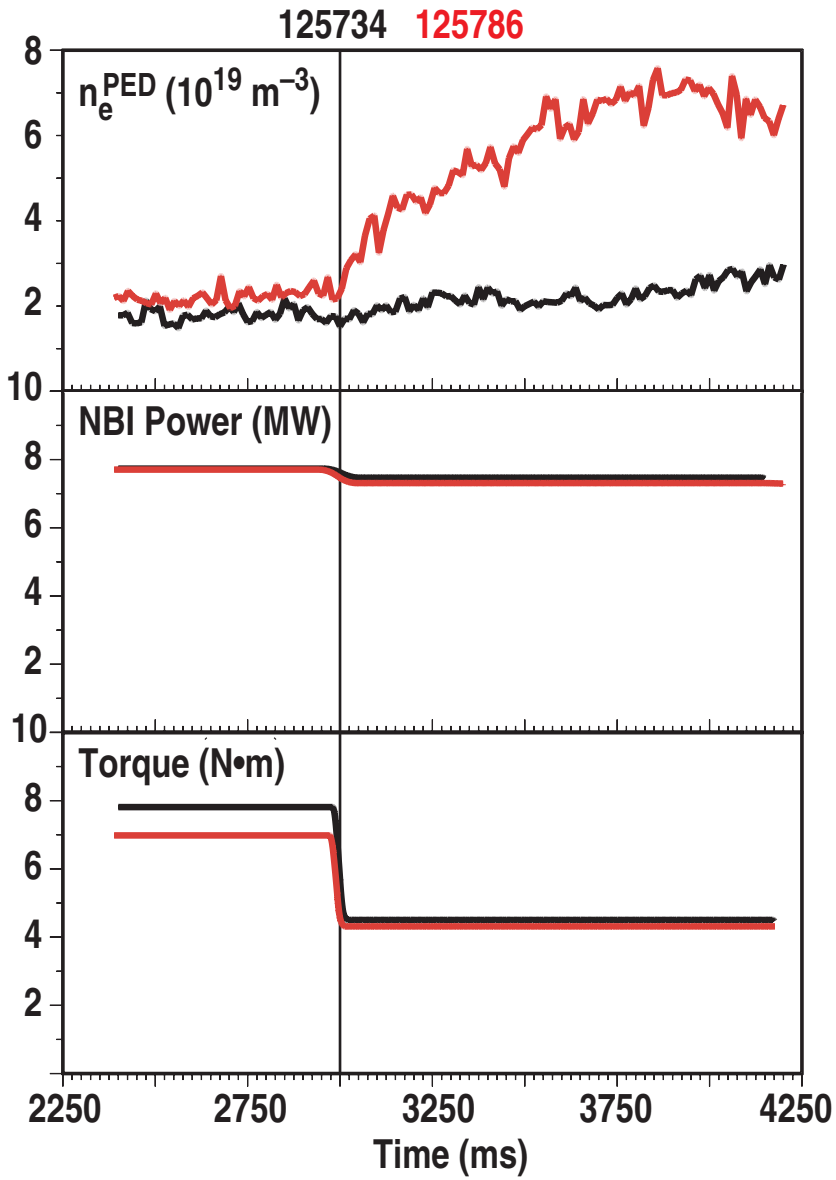
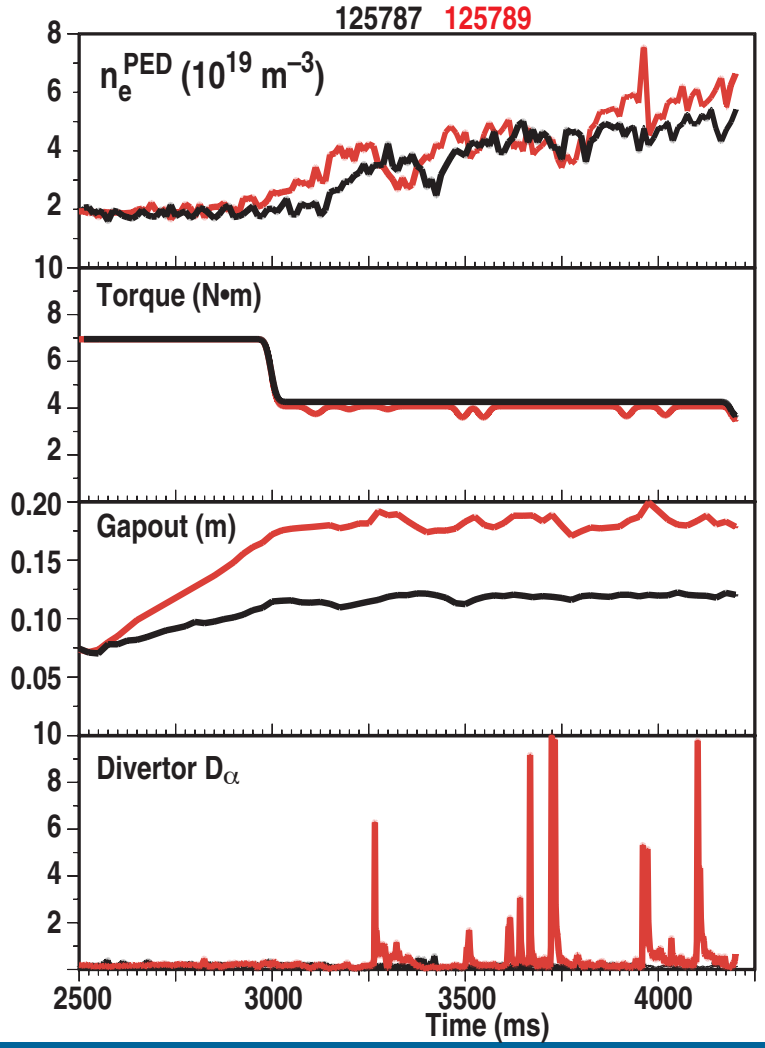


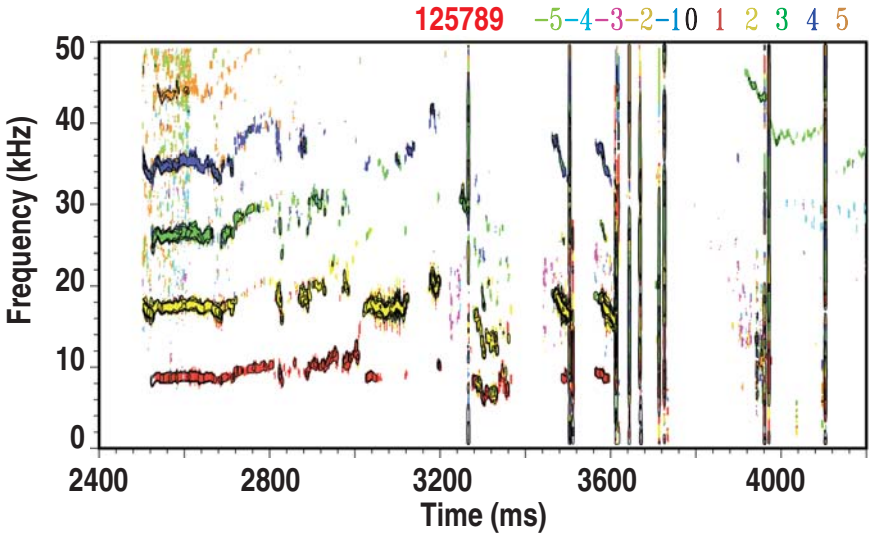


- n_e^{PED} up to 0.5 n_{GW}

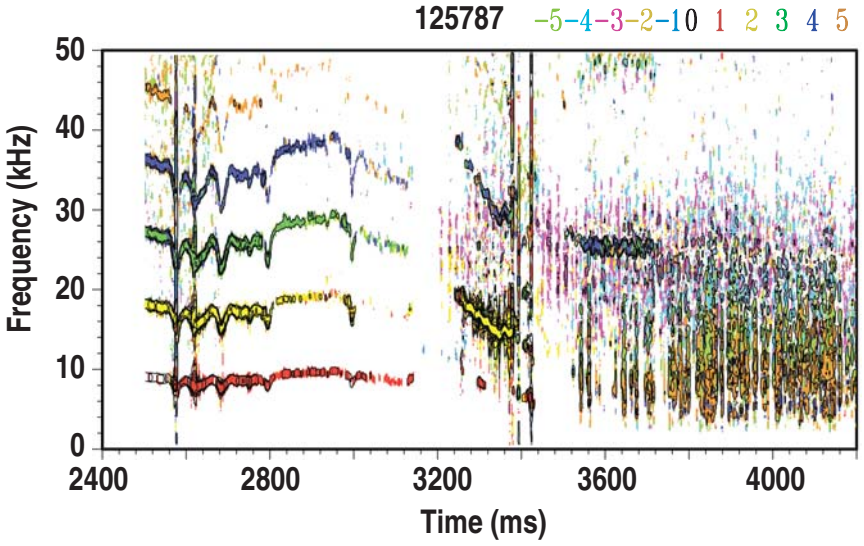
Outer Gap Change Alters EHO and ELM Behavior at Same Pedestal Density and Input Torque

- **Edge MHD stability is sensitive to distance from plasma edge to vessel wall at outboard midplane**





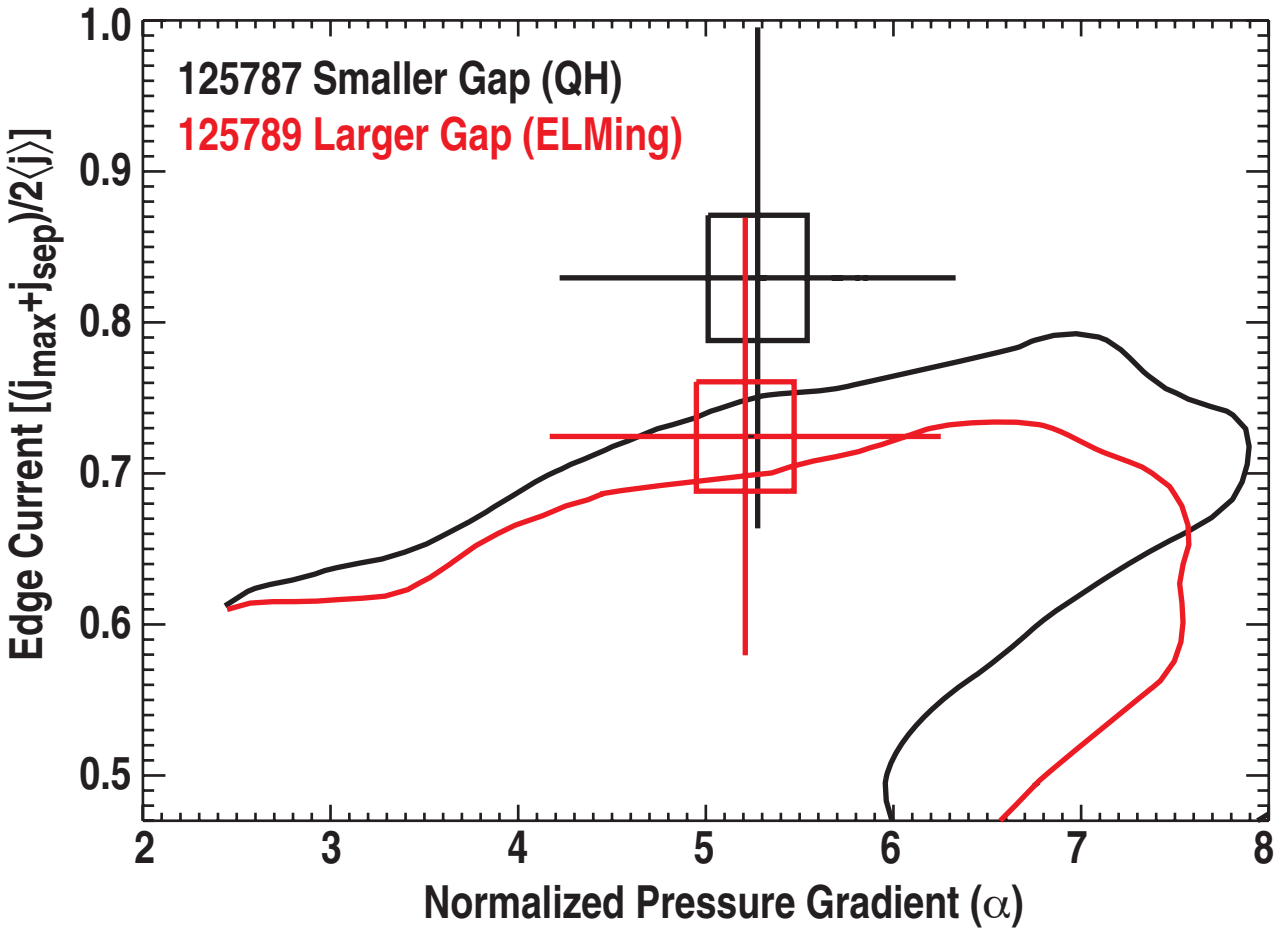
Large Gap ELMing



Small Gap QH-Mode

ELITE Calculation of Edge Stability Shows Very Similar Operating Points for Different Outer Gaps

- Errors in edge profile and current reconstruction are too large for stability calculation to distinguish experimentally unstable (ELMing) and experimentally stable (QH) cases



T.H. Osborne
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Conclusions

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