Heat Transport in Off-axis EC-Heated Discharges in DIII-D

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with
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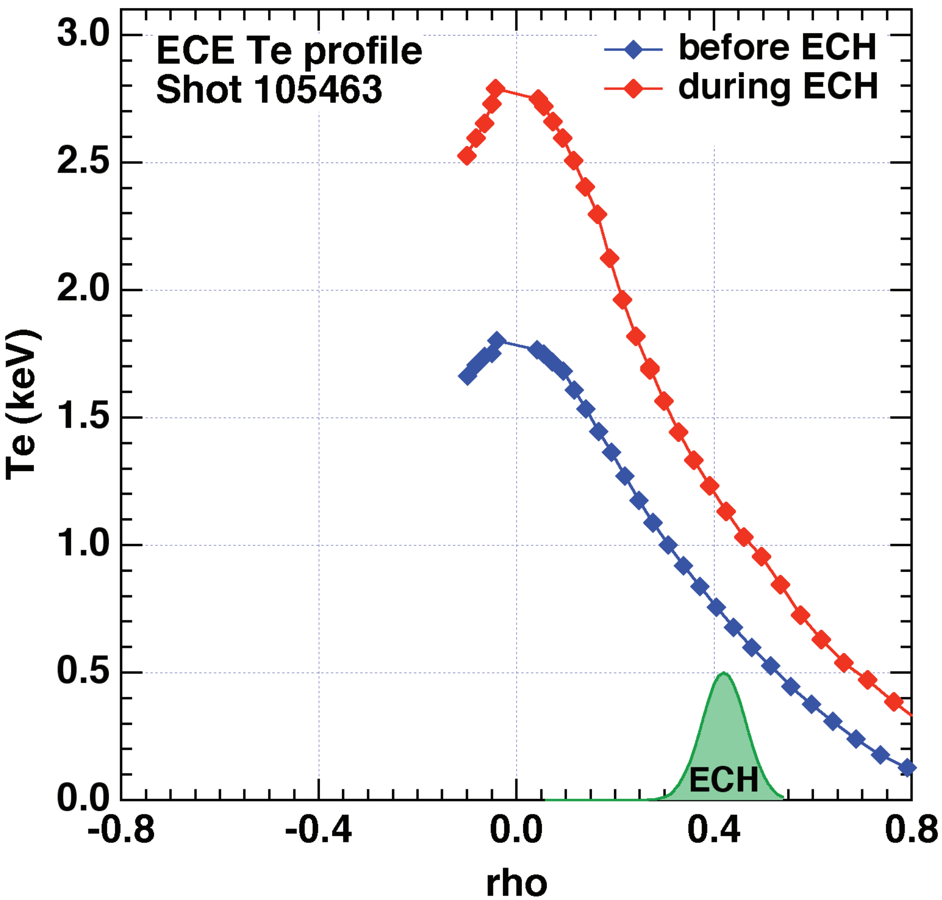
Motivation: Study Counter-Example to Heat Pinch Phenomenon

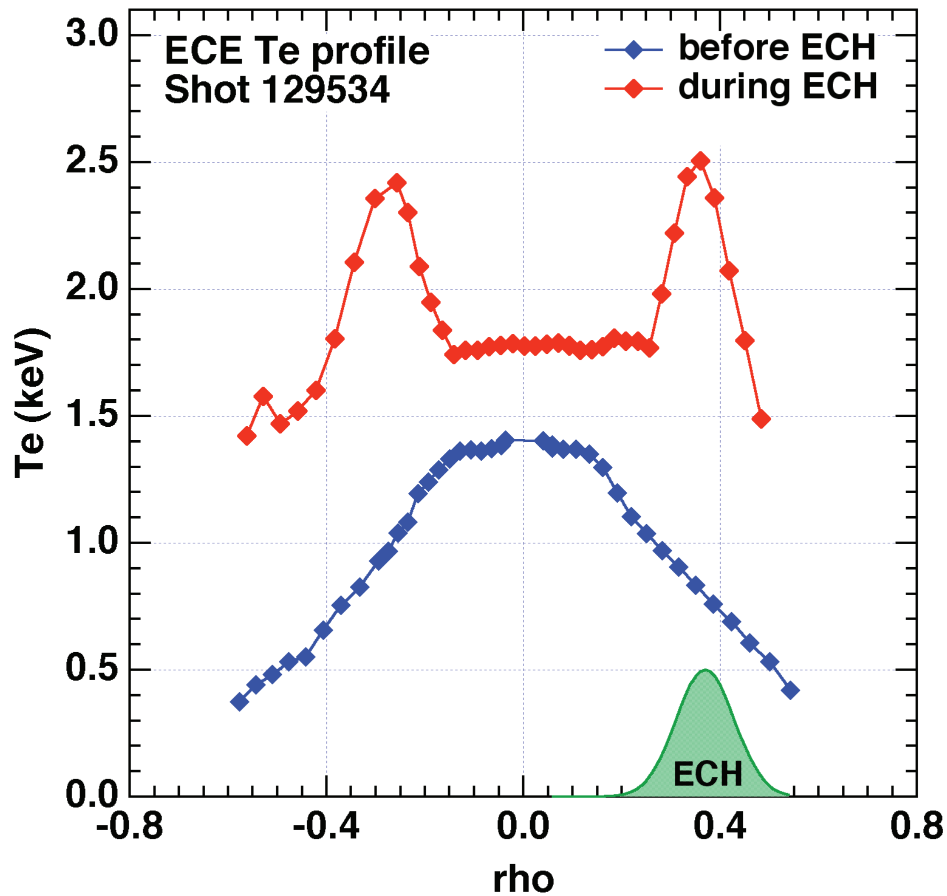
Heat pinch

Heat reaches core in a few ms



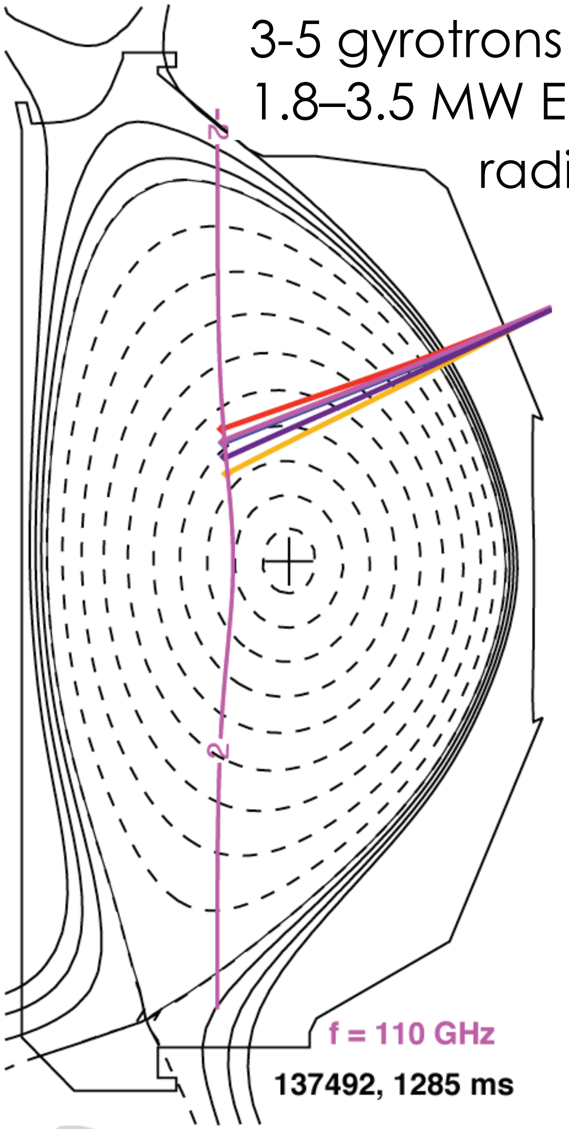
Bat-ears

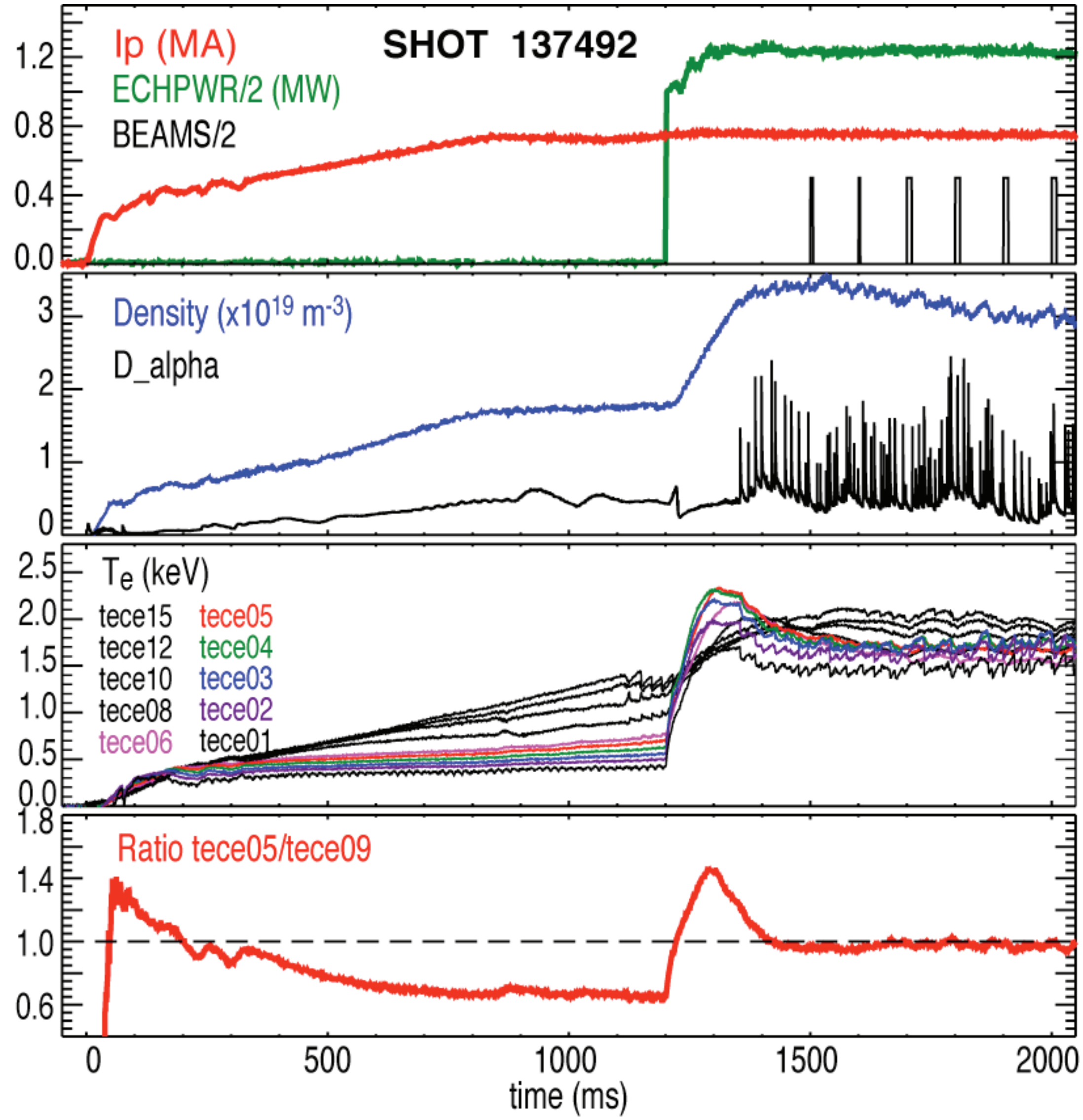
Heat diffuses to core in 100-200 ms



"Bat-eared" T_e Profiles Observed During Early Phase of ECH H-mode

3-5 gyrotrons
1.8–3.5 MW ECH
radial launch

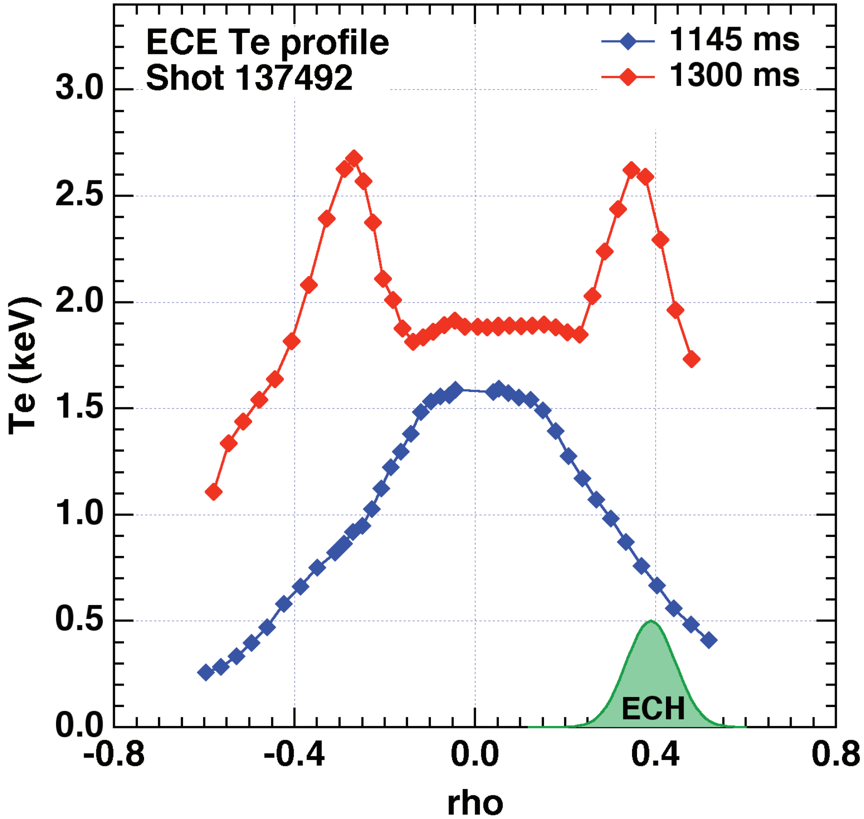


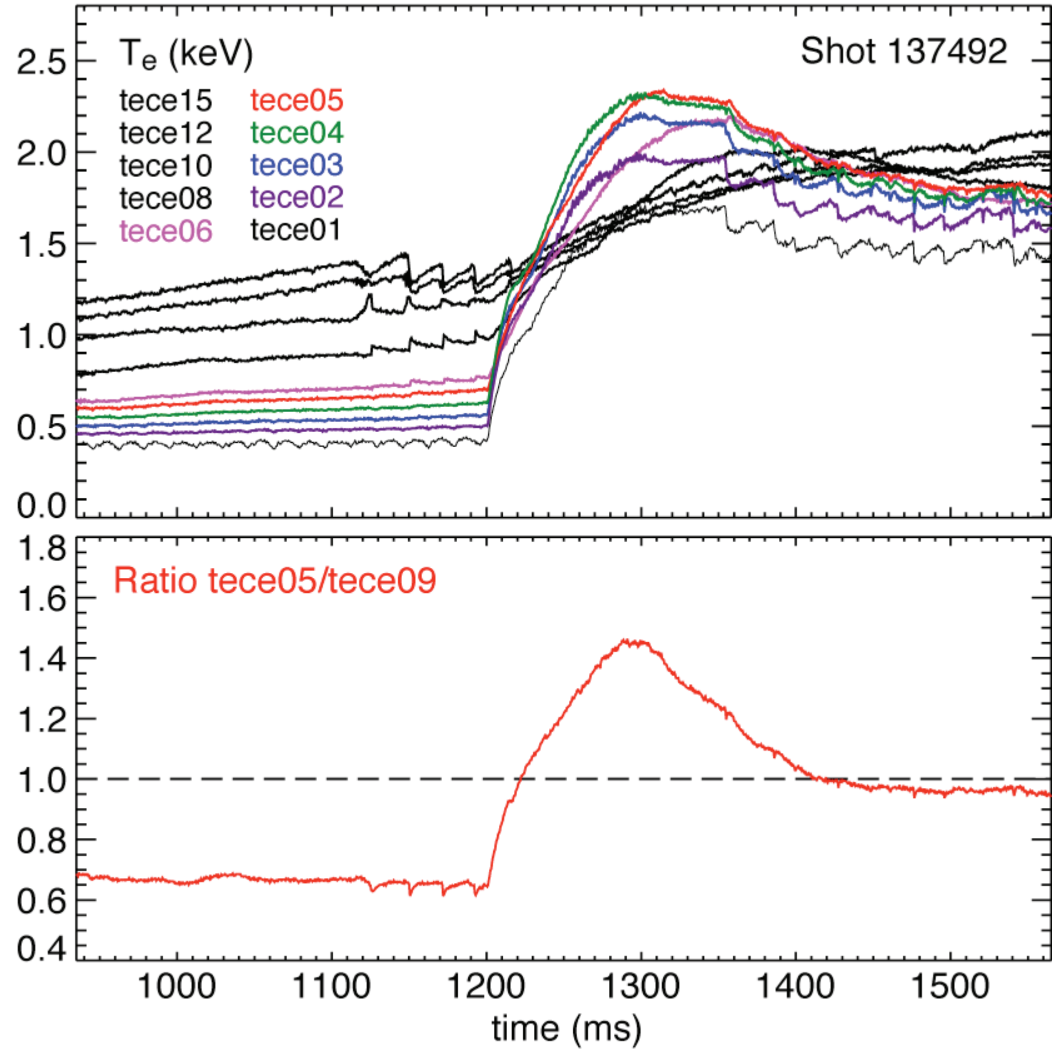


- ECH *radial* launch – minimal current drive

Bat-Eared T_e Profile Develops on a Transport Time Scale

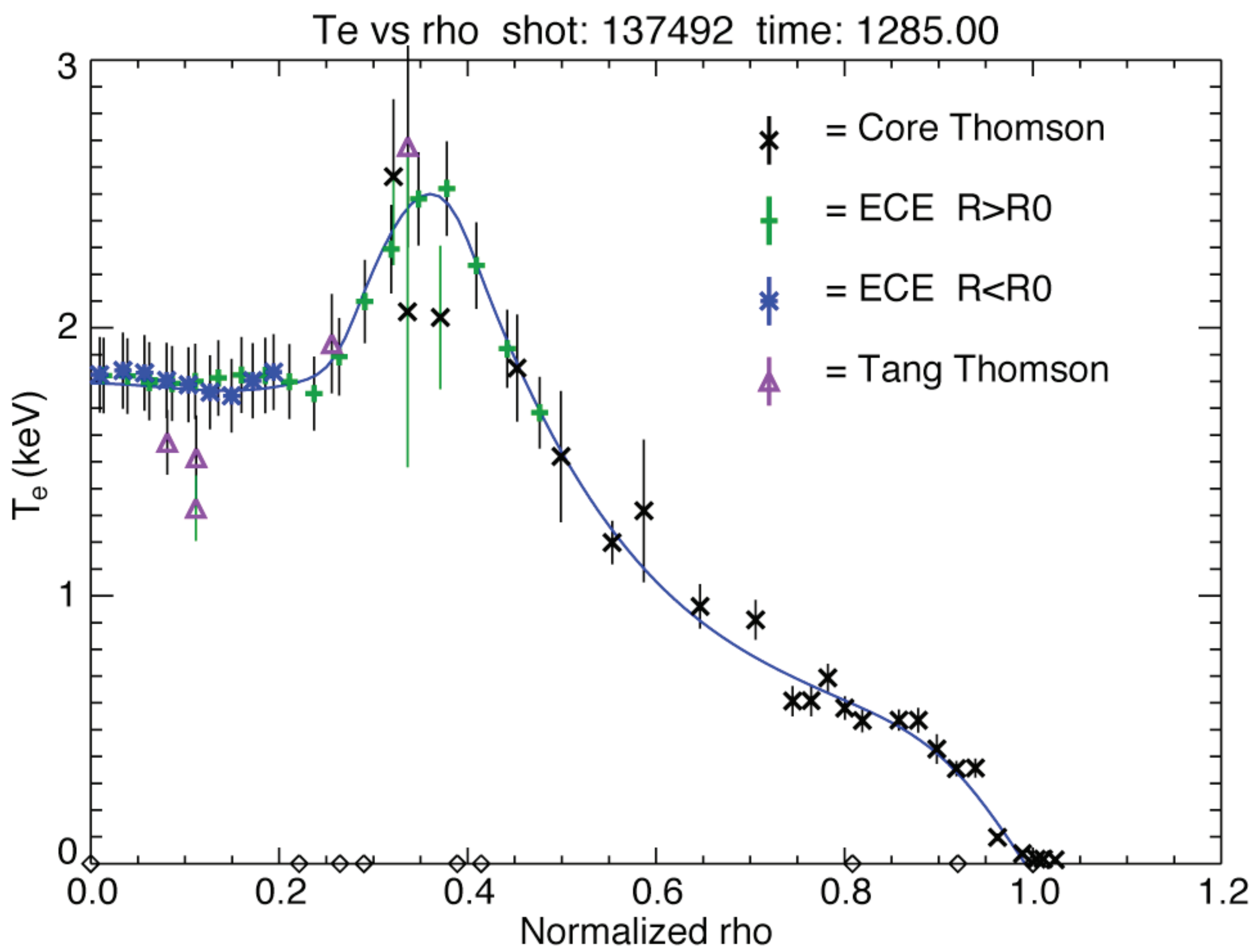
- Key is heating at $0.35 < \rho < 0.45$ with at least 3 gyrotrons
- Heat diffusion much slower than expected





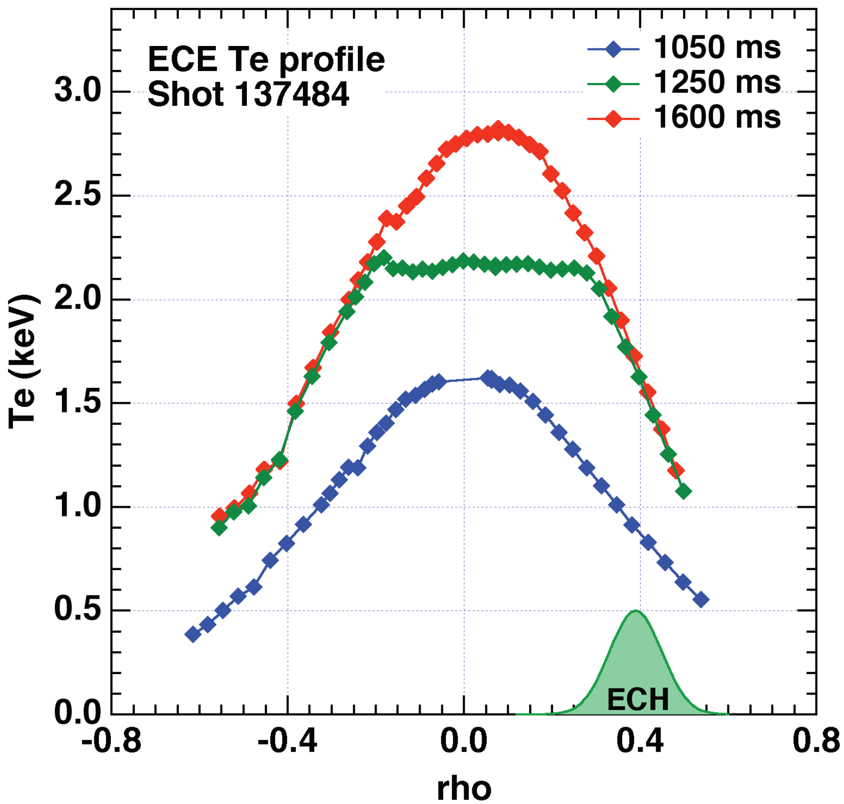
Bat-Eared Profiles Not Due to Nonthermal ECH Effects

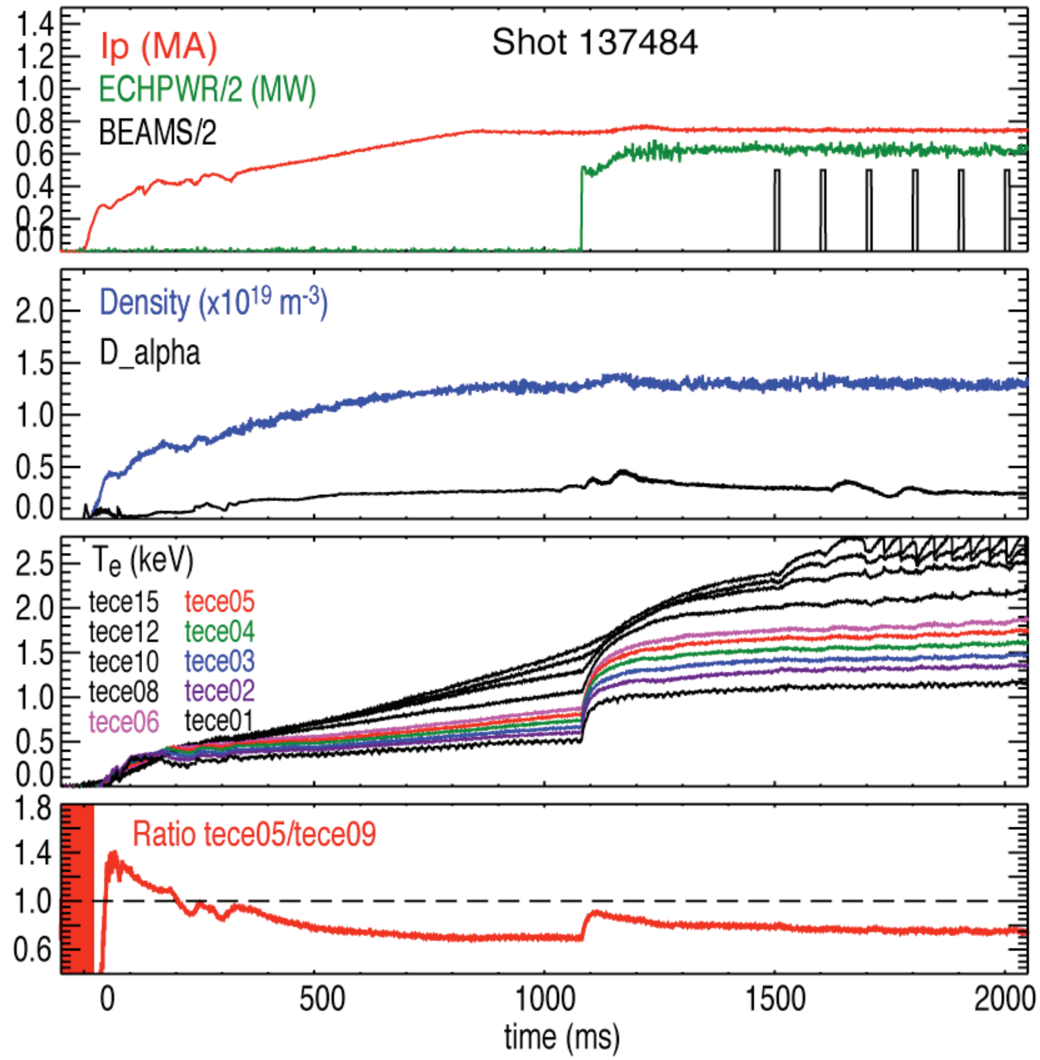
- **Thomson scattering & ECE agree during ECH**
- **Peaks in T_e-ECE are symmetric**



L-mode Discharges Exhibited No Off-axis Peaking

- Reduced density, plasma shape change –> higher H-mode power threshold

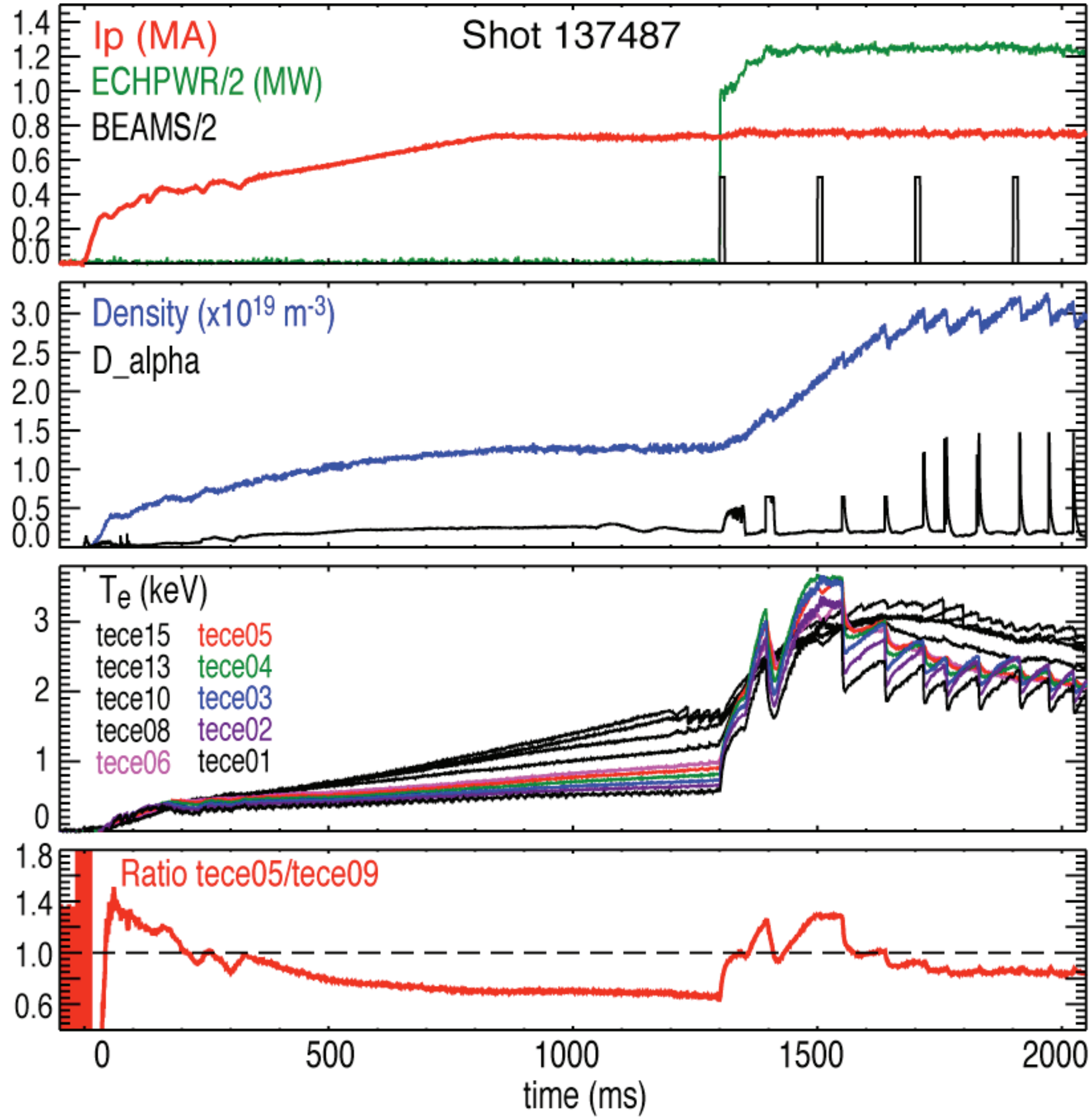




Dithering Discharges Confirm H-mode Requirement

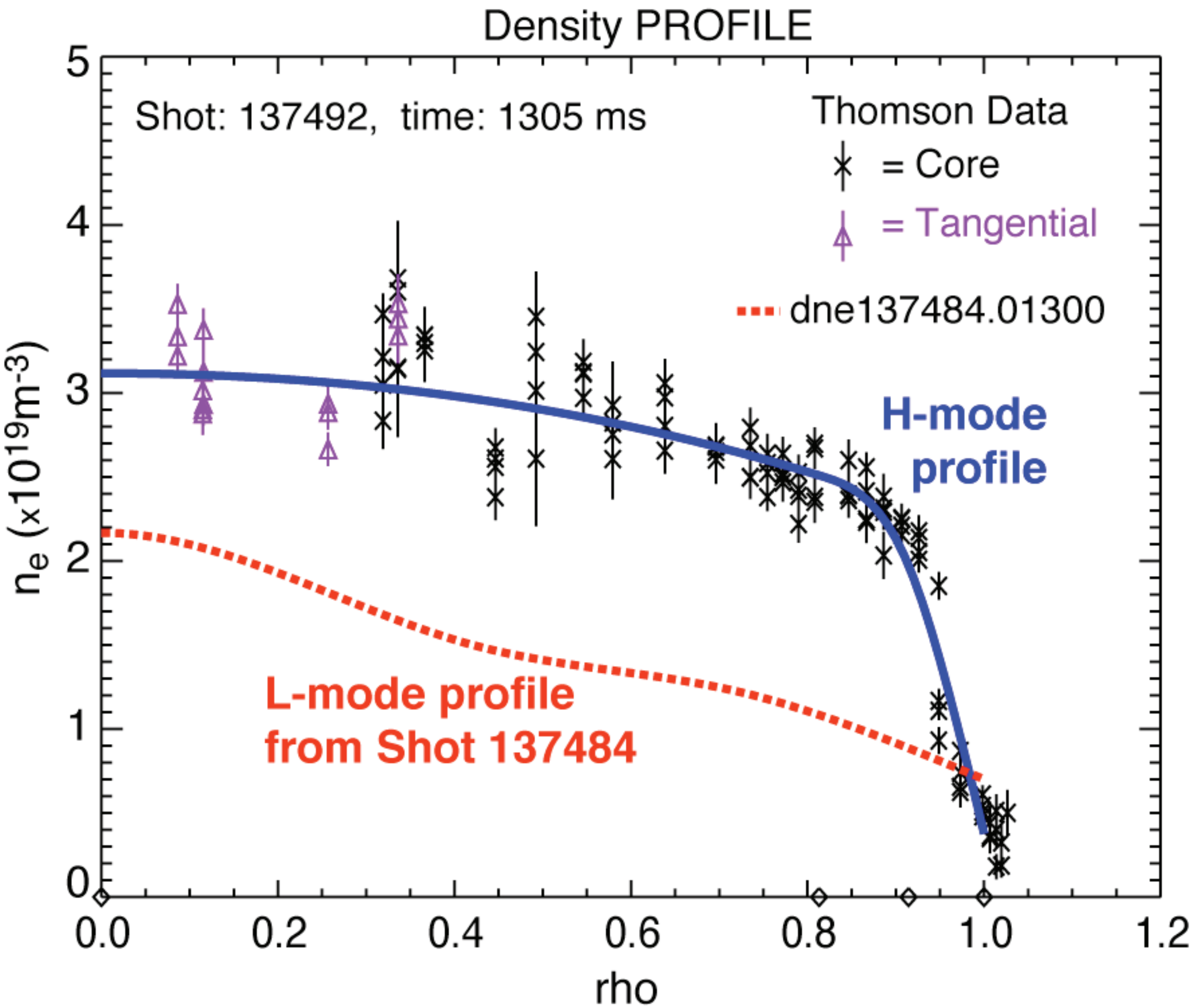
- **Several discharges had intermittent H-mode transitions**
- **Off-axis peaking only occurred in H-mode phase**
- **Conclusion:**

  H-mode necessary to obtain bat-eared T_e profile



Differences in T_e in off-axis heated L-mode vs H-mode may be due to density profiles

- **Criteria for bat-eared T_e:**
  - Heat deposition ρ ~ 0.4
  - H-mode
  - No NBI (no central heat)
- **Possible reason:**
  - L-mode –> peaked profile, H-mode –> flat profile
  - Transport dependence on off-diagonal terms
  - e.g. Weiland 1992 claimed peaked density leads to heat pinch
- **Another possibility: H-mode leads to local changes in current profile, *q* profile?**



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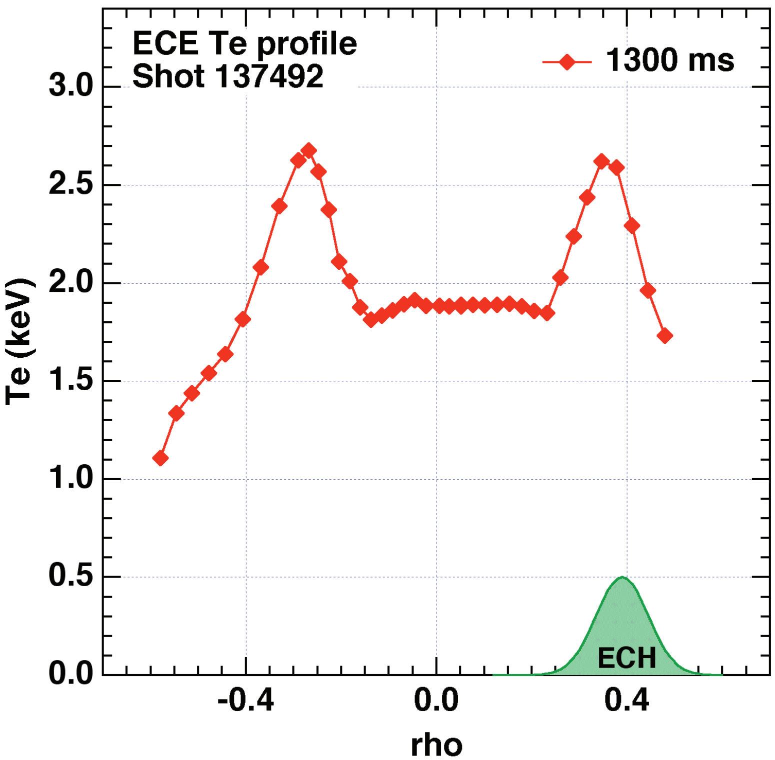
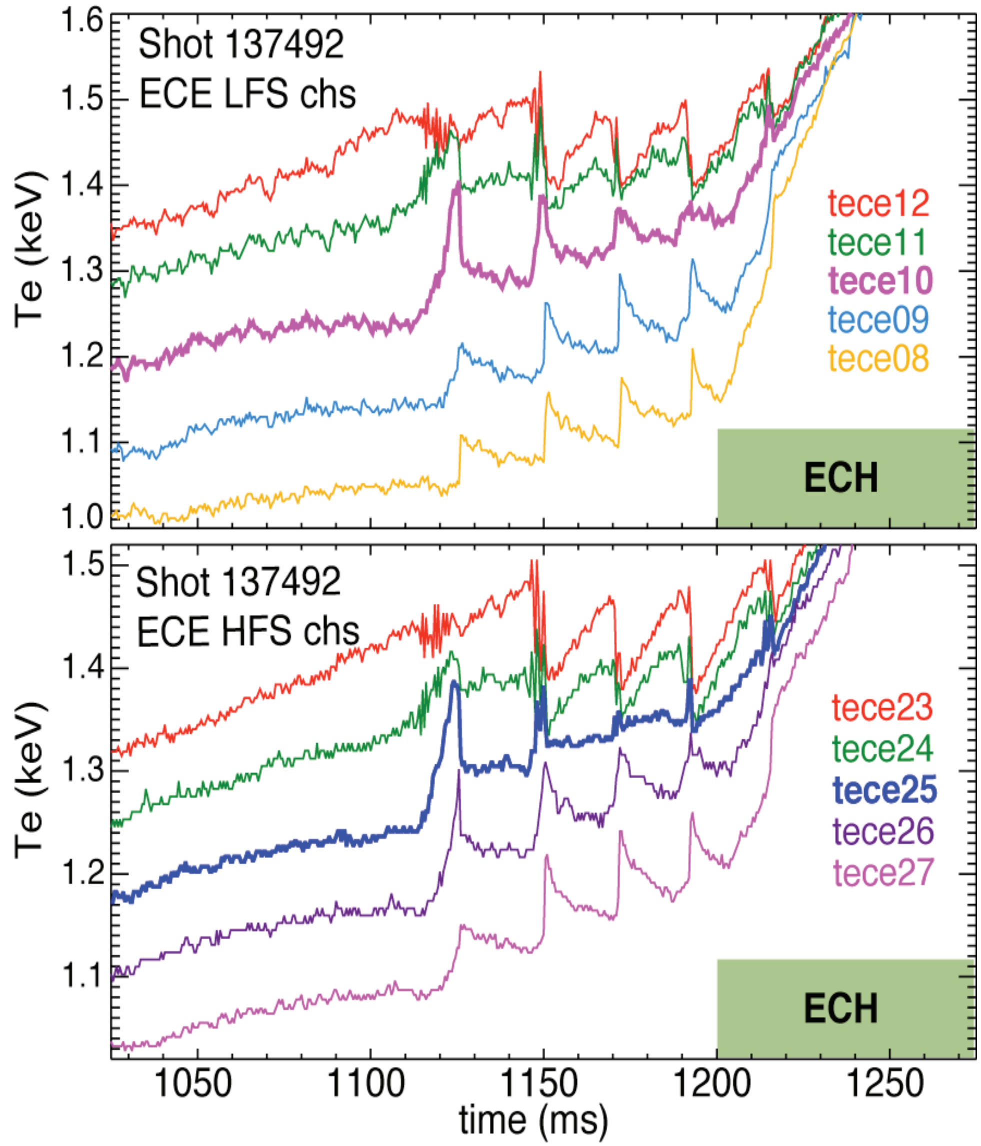
Transport Barrier at *q*=1?

- **Use sawtooth inv. radius in ECE to determine *q*=1**

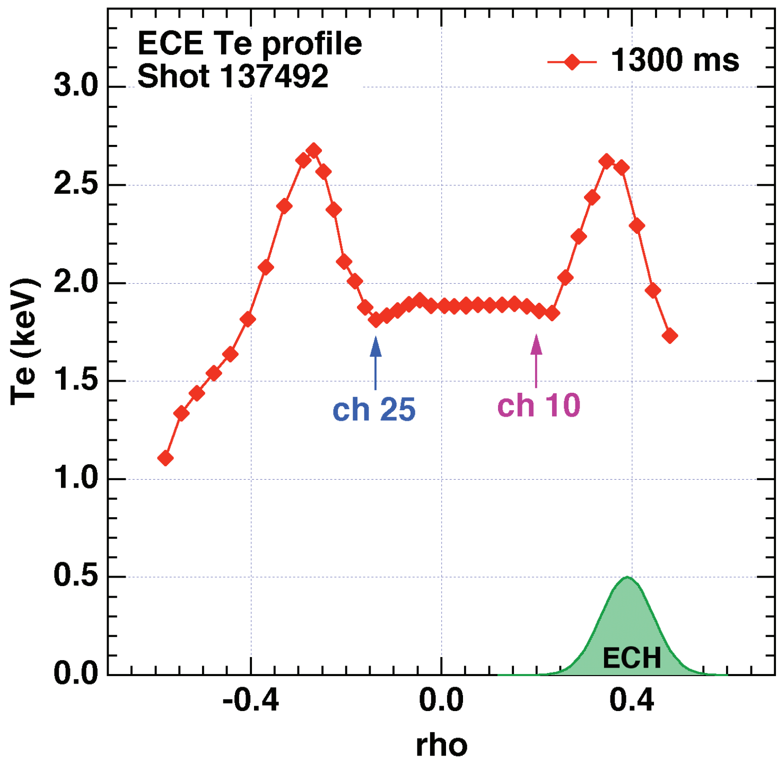


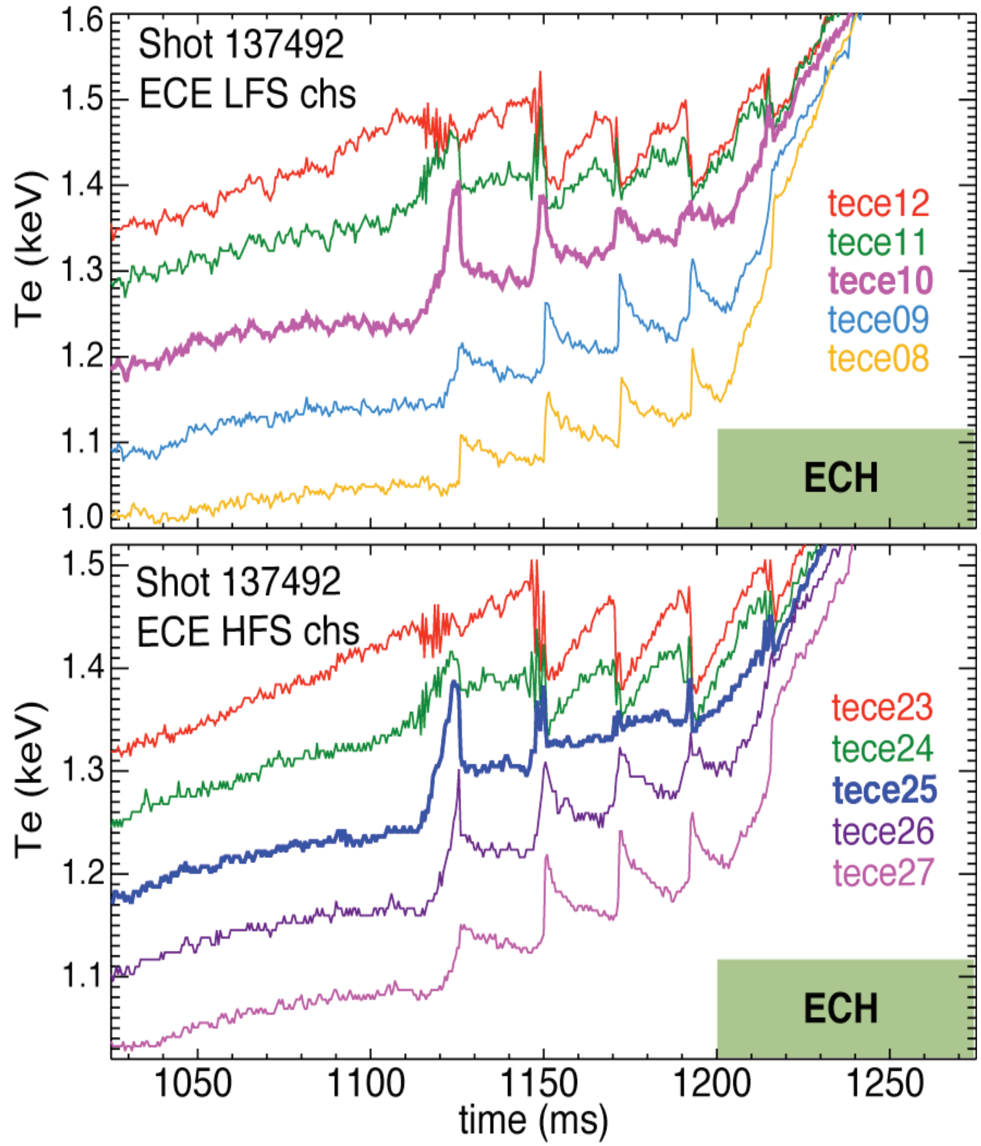


Transport Barrier at q=1?

- **Use sawtooth inv. radius in ECE to determine q=1**

–> matches apparent barrier





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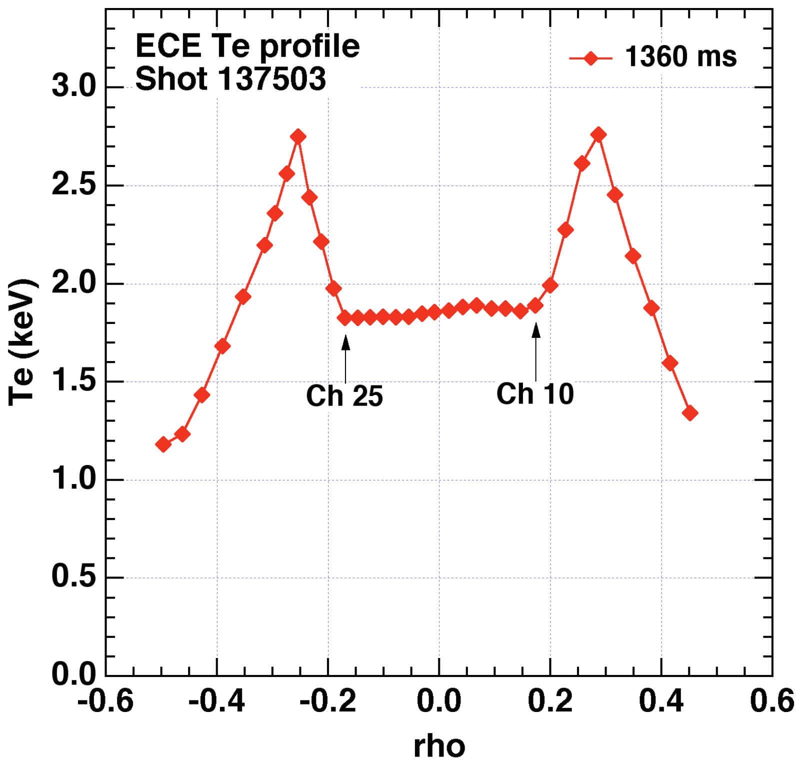
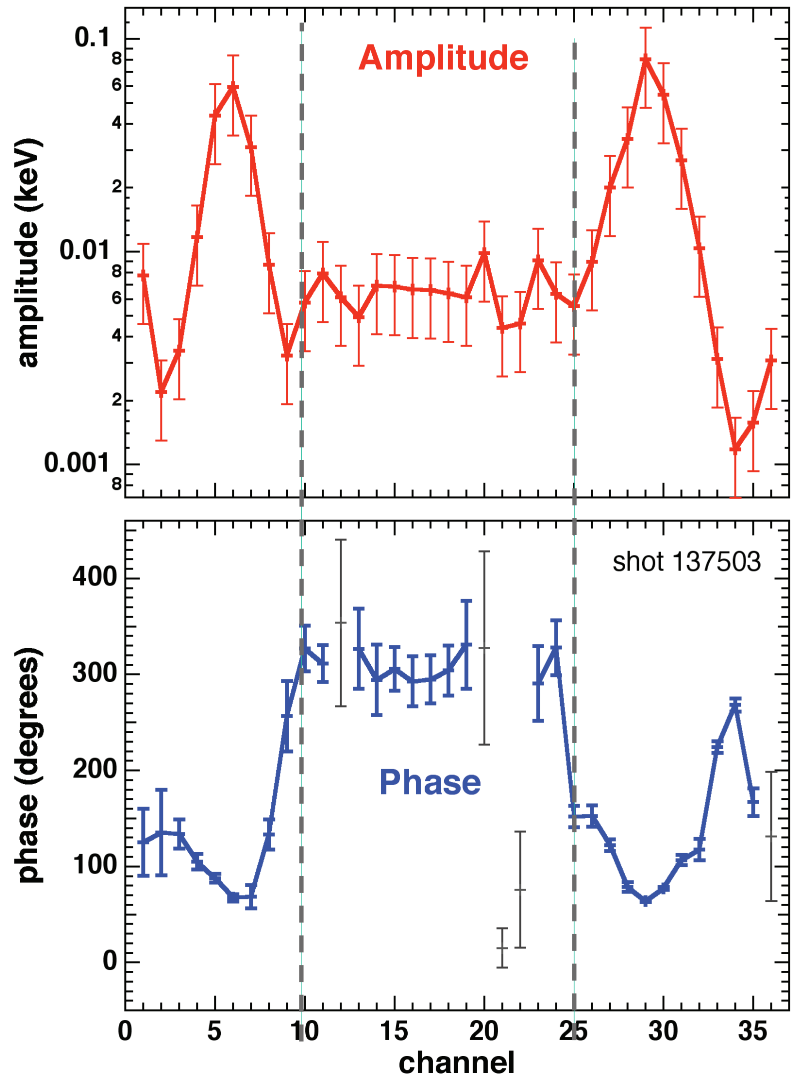
Internal Transport Barrier Inferred from Heat Pulse Analysis

- **Modulated ECH - 1 gyrotron at T_e peak**
- **Drop in amplitude, jump in phase indicate barrier**





- **Barriers at low-order rational *q* now conventional wisdom**
- **Key is transition mechanism**

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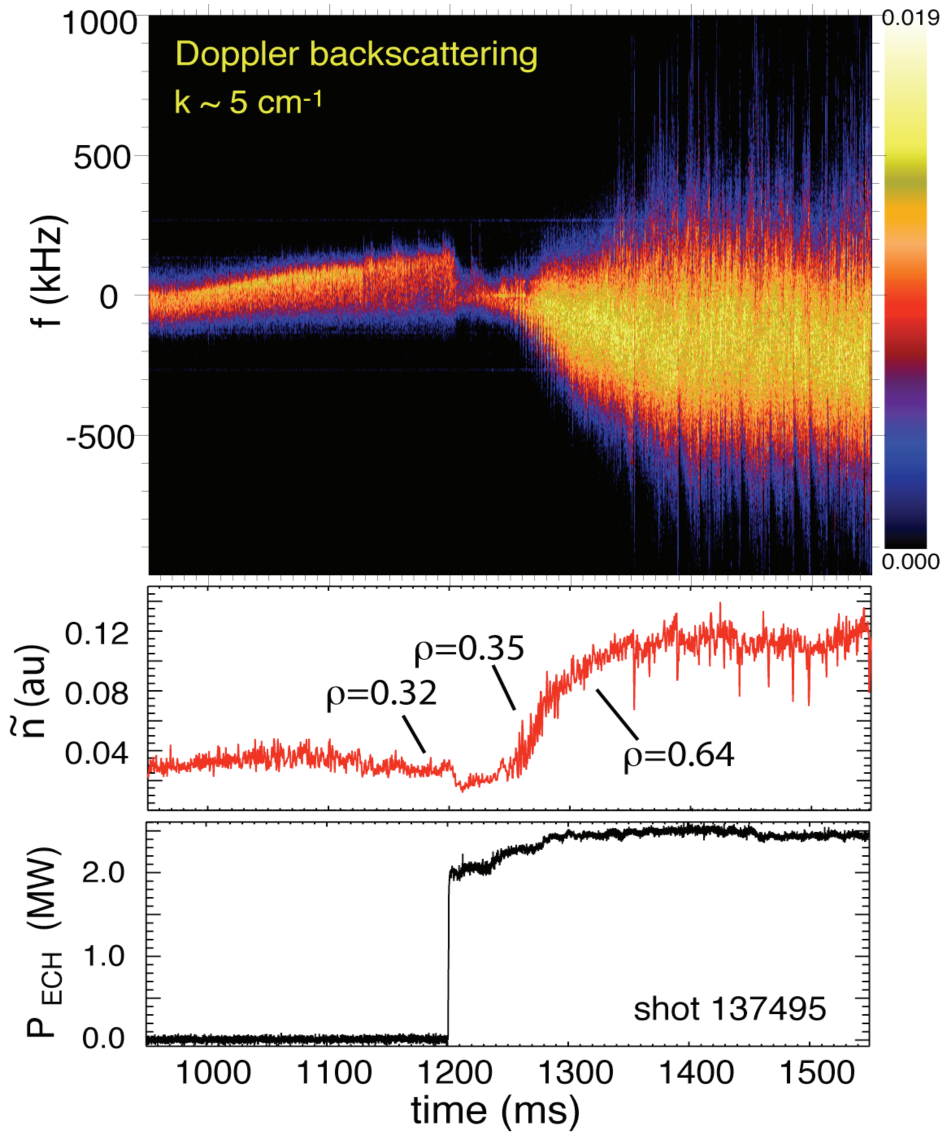
Fluctuation Measurements Show Signatures of Reduced Transport

- **Doppler back-scattering (DBS) sweeps out as n_e rises**
  - Core fluctuations drop (not typical in H-modes)
  - cross-over of turb. flow velocity

- **Obtained large set of fluctation data**
  - FIR scattering
  - CECE
  - Reflectometry



Summary

- **Investigated strong off-axis peaking of T_e in EC-heated H-modes in DIII-D**
- **H-mode is a necessary condition for bat-eared T_e profile**
- **Sawtooth inv. radius and heat pulse analysis indicate barrier at q=1 surface**
- **Fluctuation measurements show reductions in turbulence, changes in *ExB* flow in core**

- **Future:**
  - Analyze profiles for transport, measurement of q profile
  - Compare with empirical & fluid model predictions