ELM Suppression and Pedestal Structure in I-Mode Plasmas on Alcator C-Mod

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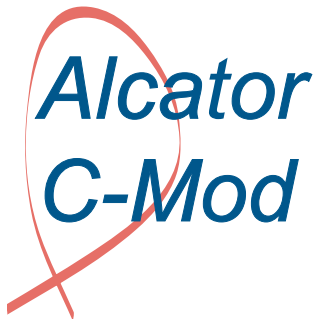


Thank you to...

- The thesis committee: JW Hughes, DG Whyte, AE White, JP Freidberg
- The I-mode crew: AE Hubbard, JL Terry, I Cziegler, A Dominguez, SG Baek, C Theiler, RM Churchill, ML Reinke, JE Rice...
- Physops: R Granetz, S Shiraiwa, S Wolfe, S Wukitch...
- C-Mod operations, engineering, researchers and techs
- PSFC grad students, past and present
- Family and friends
- the audience!

Outline

- **Context & Motivation**
  - High-performance regimes
  - Pedestal physics
  - Introduction to I-mode
- **Pedestal Modeling & Theory**:
  - Peeling-ballooning MHD stability
  - Kinetic-ballooning mode turbulence
- **ELMy H-mode physics**[1]
  - EPED Modeling on C-Mod

[1] JR Walk *et al.*, *Nuclear Fusion* **52** (2012)

Outline

- **I-Mode Pedestals & Global Performance**[1]
  - Pedestal response to fueling, heating power
  - Pedestal widths and gradients
  - Global performance and confinement scalings
- **I-Mode Pedestal Stability**
  - P-B MHD, KBM modeling
  - ELM characterization
- **Summary, Future Work, & Questions**

[1] JR Walk *et al.*, *Physics of Plasmas* **21** (2014)

The problem...

By default ("L-mode"), rapid transport of energy and particles from plasma driven by turbulence

- and energy transport gets *worse* with more heating power!
- need very strong magnetic field and/or large machine size to overcome poor plasma performance

L-mode likely not suitable for (economical) power plant development.

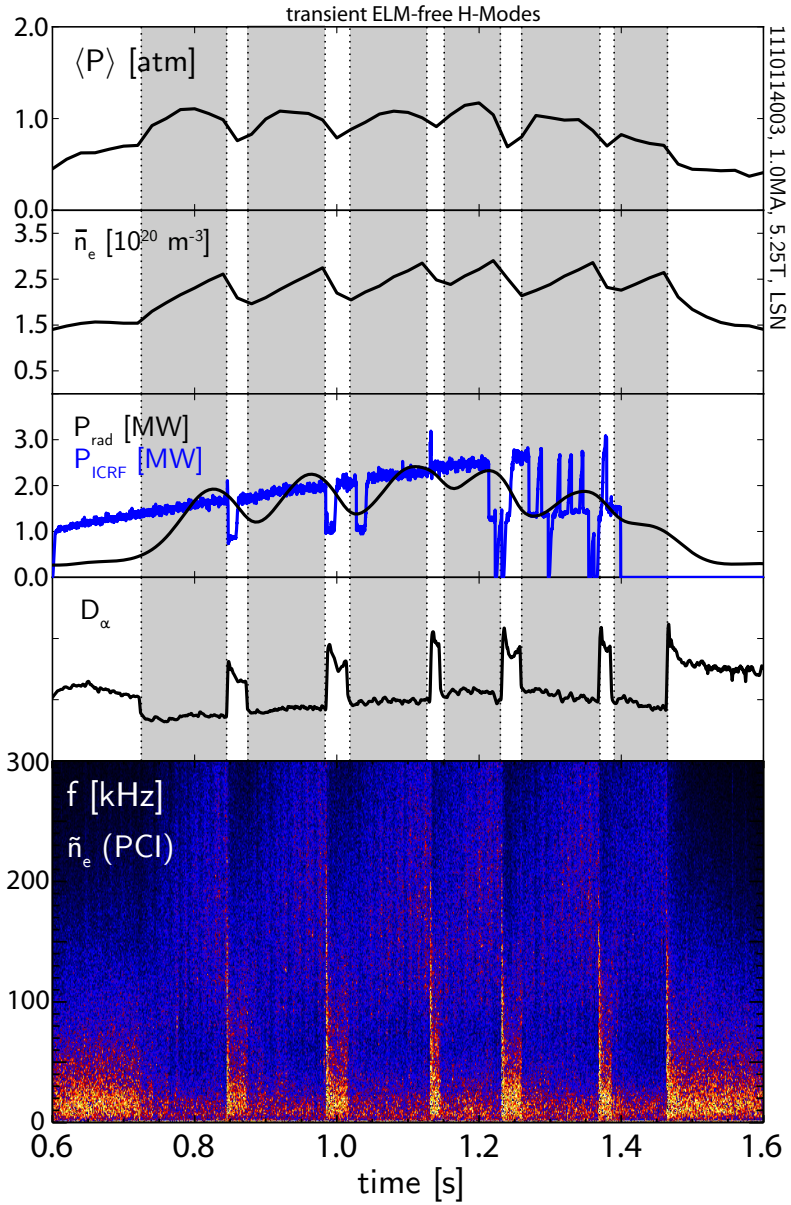
The solution?

Under right conditions, plasma forms "transport barrier" in edge, with steep gradients in density and temperature – the *pedestal*
$\rightarrow$ plasma transitions to "high-confinement" or H-mode

- immediate factor of ~ 2 increase in energy confinement
- pedestal supports higher core pressures $=$ fusion power density
- pedestal height sets strong constraint on global performance

...But this has problems of its own

- increased particle confinement = plasma retains impurities as well as fuel ions
- radiated power ($\sim Z^2$ for a given impurity species) increases, overcomes heating power $\rightarrow$ plasma drops back into L-mode
- inherently transient state

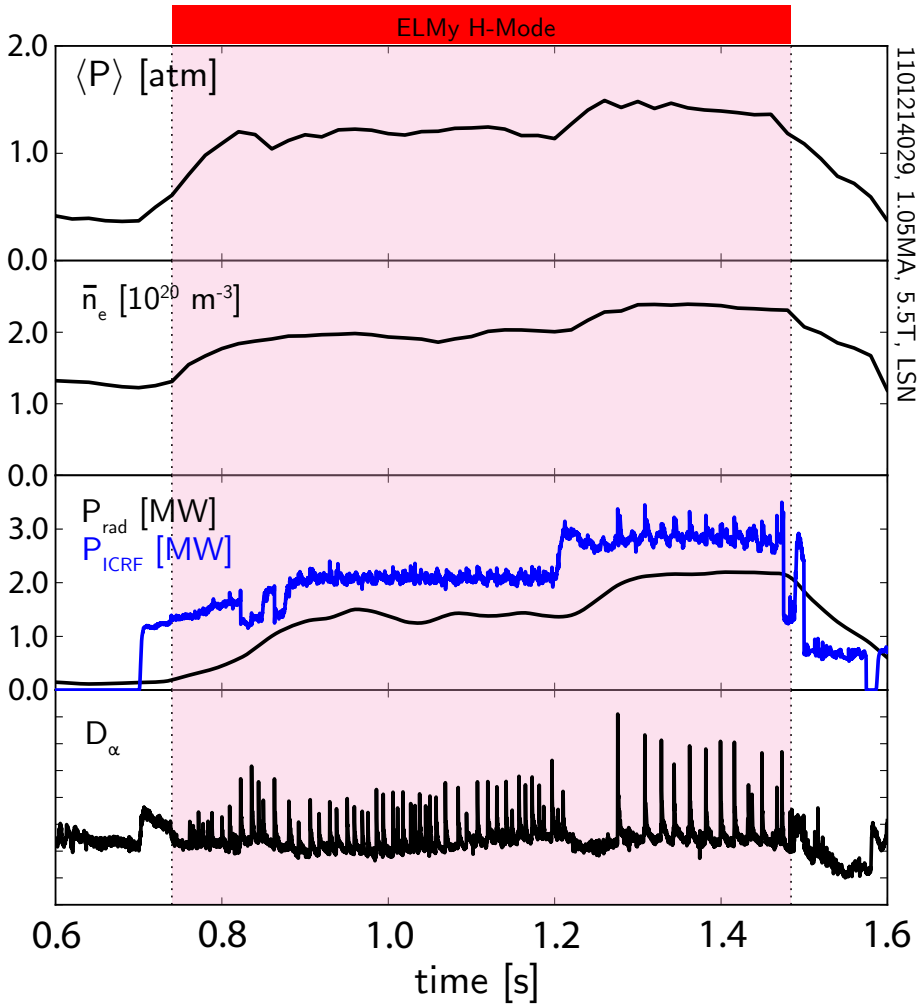


so, we need:

- high energy confinement
- low particle confinement (low enough, at least)
- ... and that's it, right?

The solution? (part II)

- Edge-Localized Modes (ELMs) – instabilities that relax the pedestal, drive bursts of energy, particle transport, enough to prevent impurity accumulation



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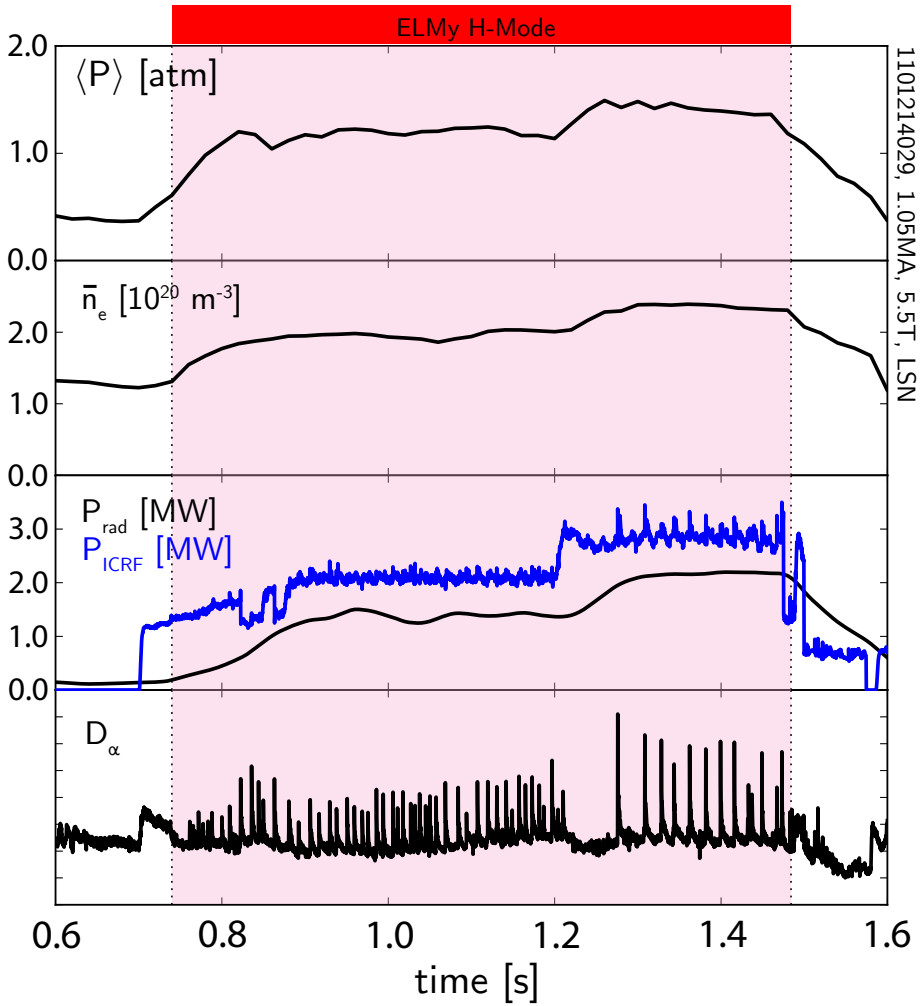
- large ELMs drive pulsed heat loads in excess of plasma-facing material tolerances



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Both engineering and physics solutions exist, including...