

TRANSPORT IN EDA H-MODE AND ITS RELATION TO FLUCTUATIONS AND THE MICRO-STABILITY OF THE PEDESTAL



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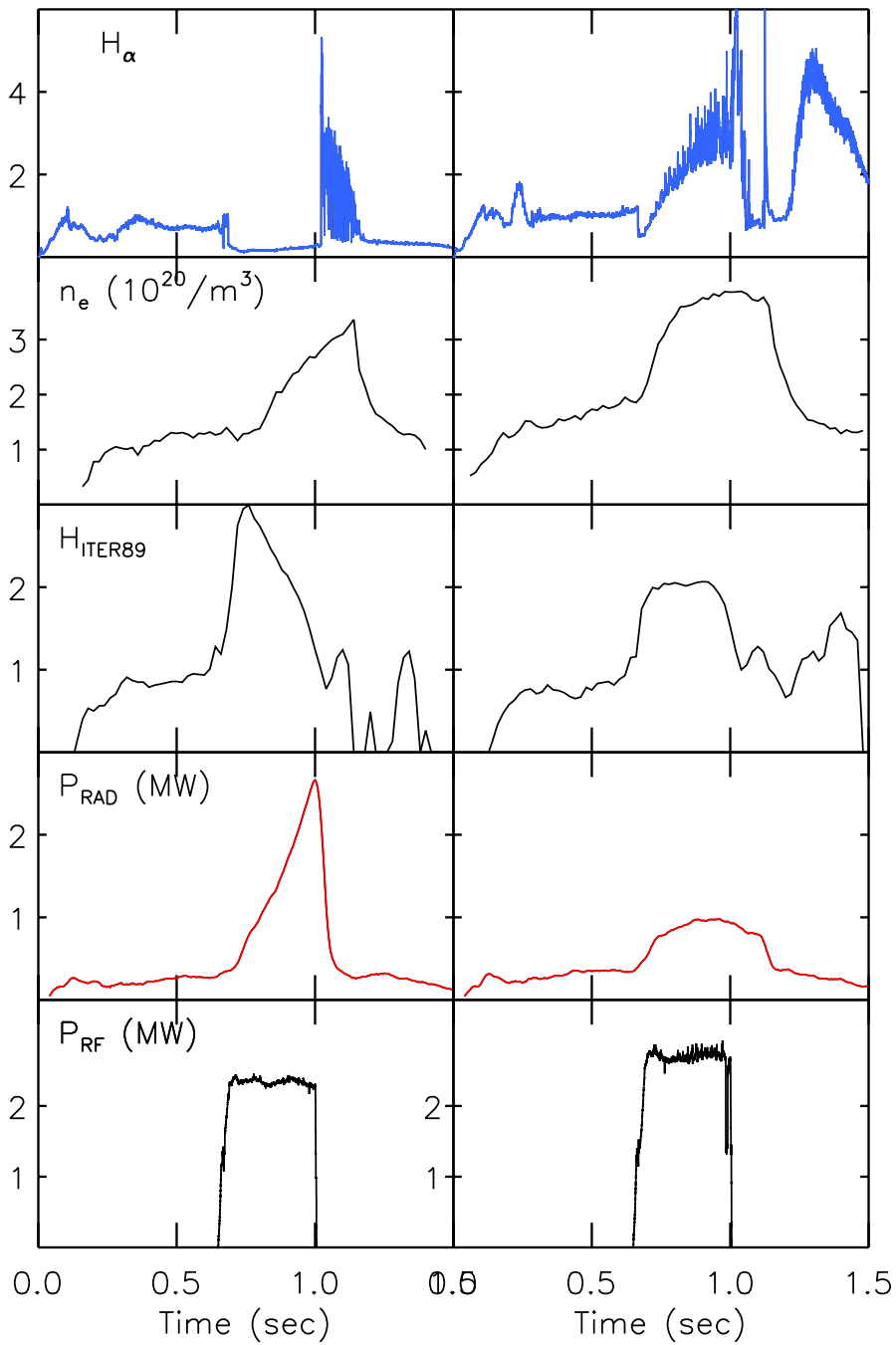
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EDA H-MODES HAVE GOOD ENERGY CONFINEMENT BUT DO NOT SHOW IMPURITY ACCUMULATION



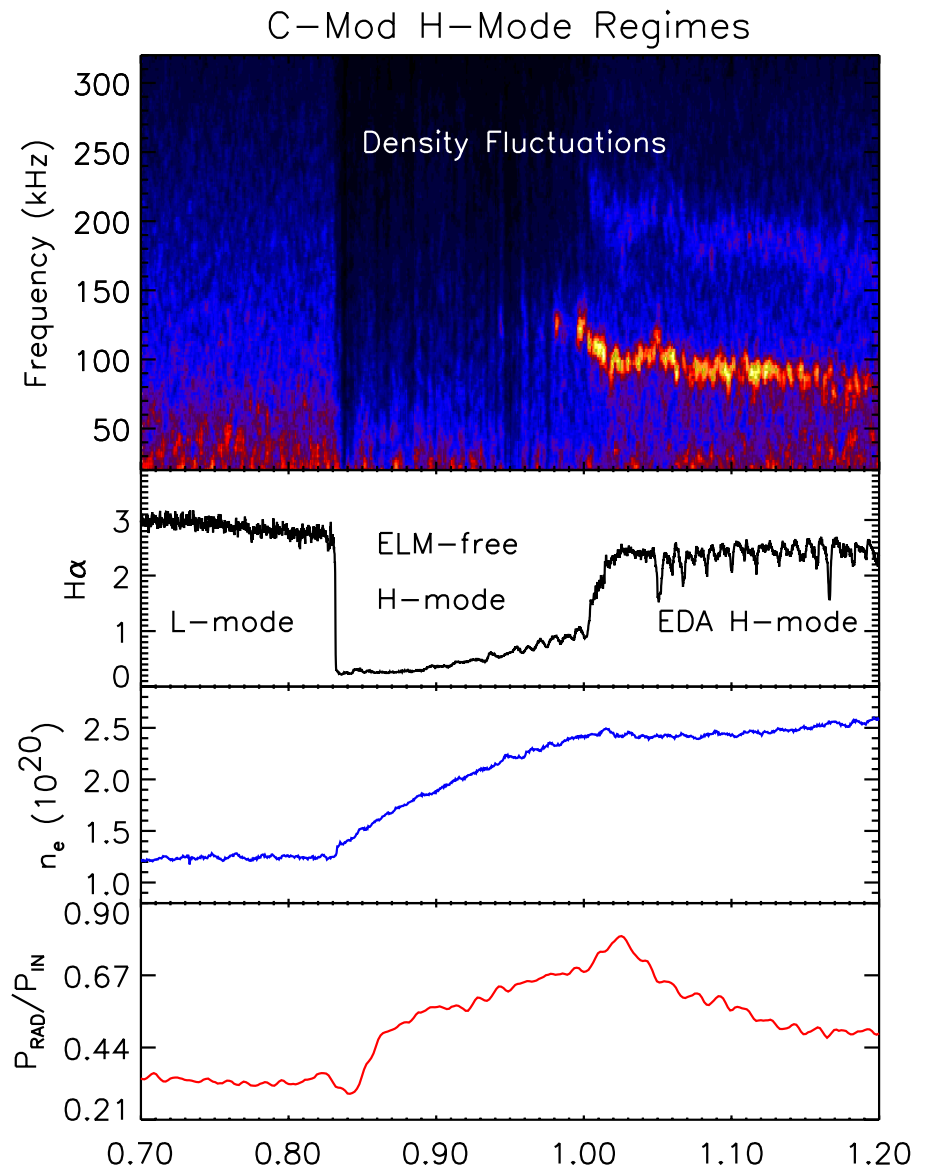
ELM-free

EDA

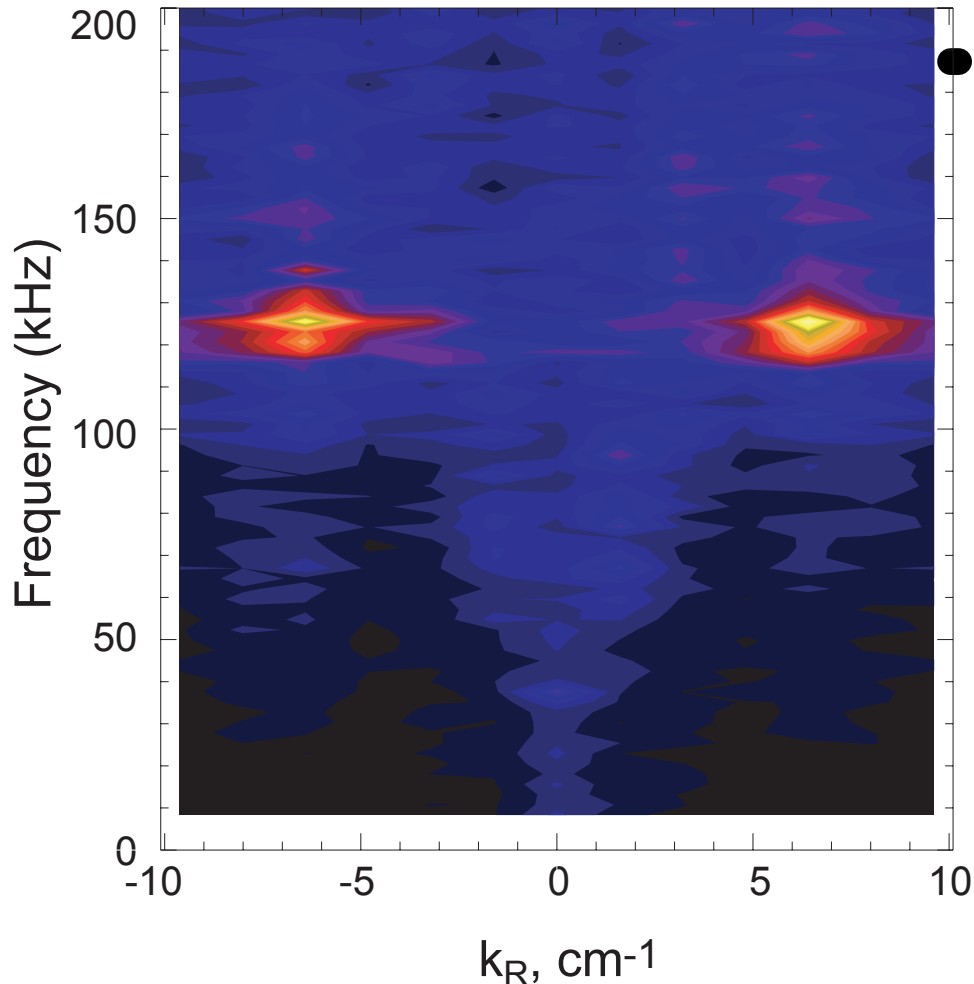
**TYPE I ELMy DISCHARGES ARE NOT SEEN IN C-MOD
INSTEAD, A REGIME THAT WE HAVE CALLED EDA
(ENHANCED D α) IS OBSERVED**



- **No large discrete ELMs**
- EDA regime shows **continuous** degradation of pedestal transport
- Quasi-coherent mode seen with PCI, probes, reflectometry
- Clearly correlated to change in particle transport
- Seen in RF and OH plasmas



PCI AND PROBES SHOW A WELL DEFINED ω AND k STRUCTURE



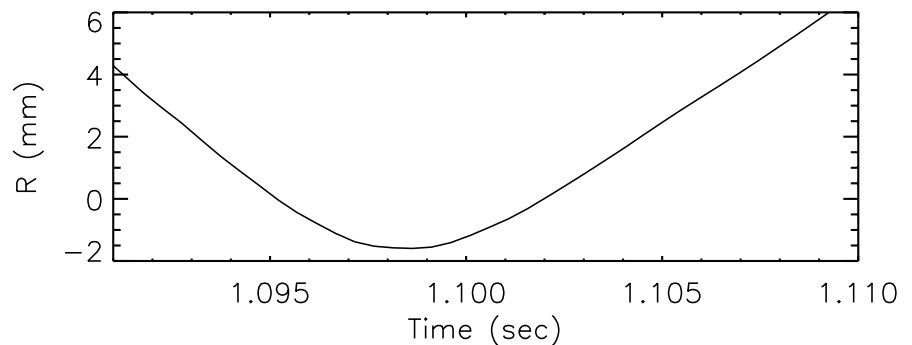
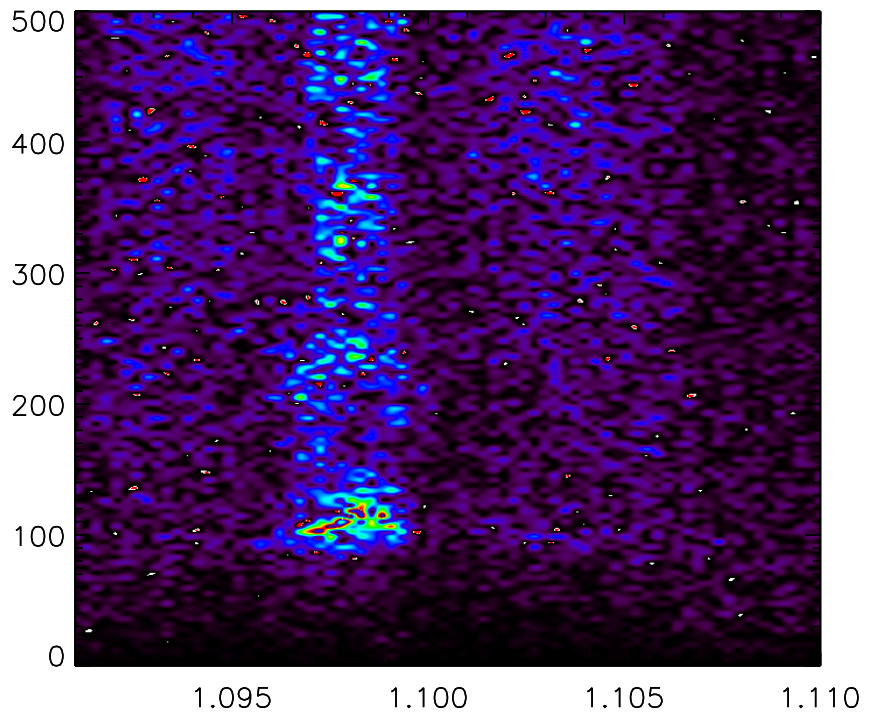
- \tilde{n} , $\tilde{\phi}$, \tilde{B} observed with reflectometry, PCI, probes with $f \sim 100\text{-}140$ kHz, $\frac{\delta f}{f} \approx 0.1$
- $k_\theta \sim 3\text{-}5$ cm⁻¹, propagates in the electron diamagnetic direction.
- Fluctuations are localized in the lower part of the density pedestal

A SET OF SCANNING LANGMUIR PROBES HELPS LOCALIZE THE MODE

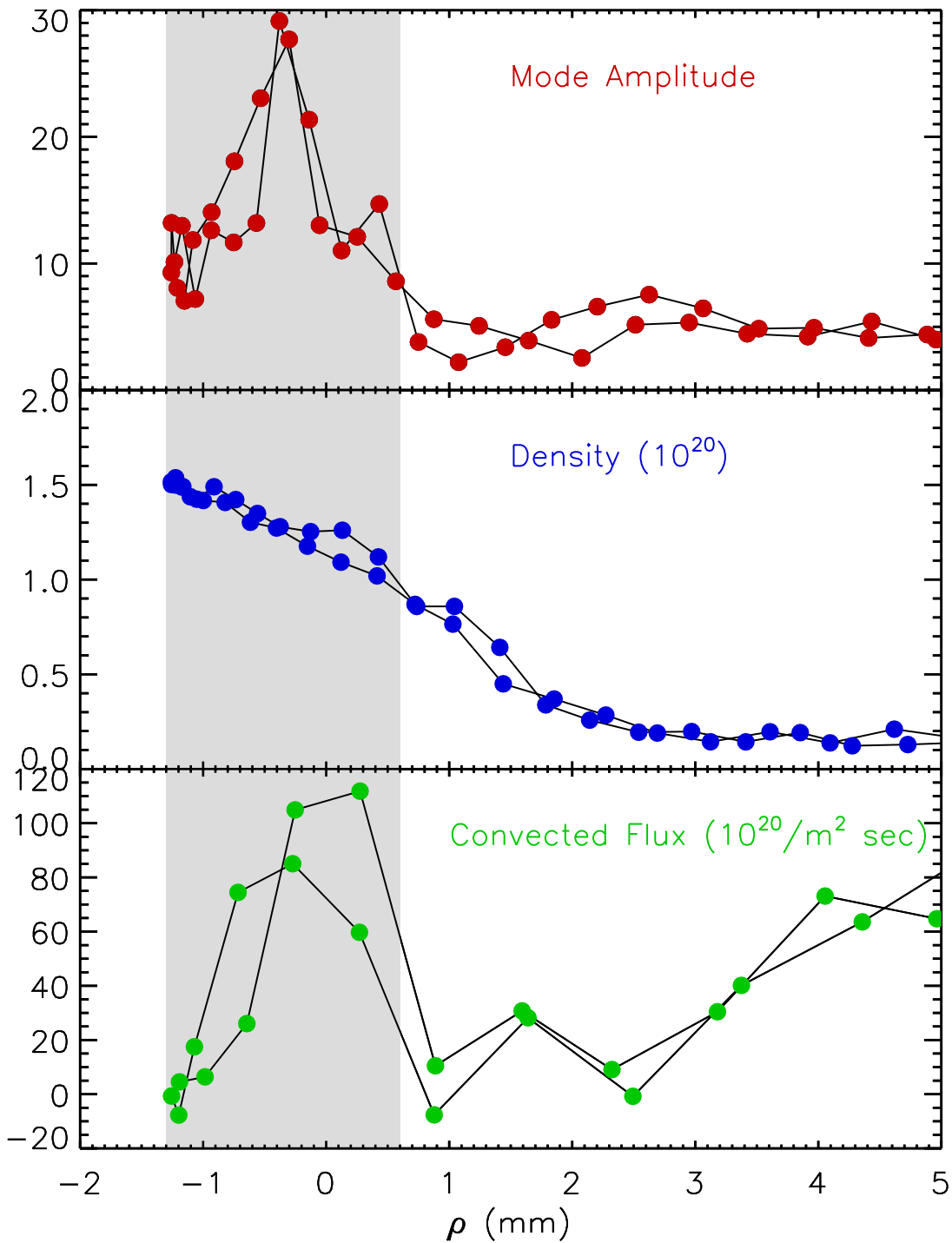


- Measure local temperature, density and floating potential.
- Q-C fluctuations in ion saturation current and floating potential and their relative phase are measured
- Fluctuations are seen only in EDA and only when the probe crosses or approaches the separatrix.

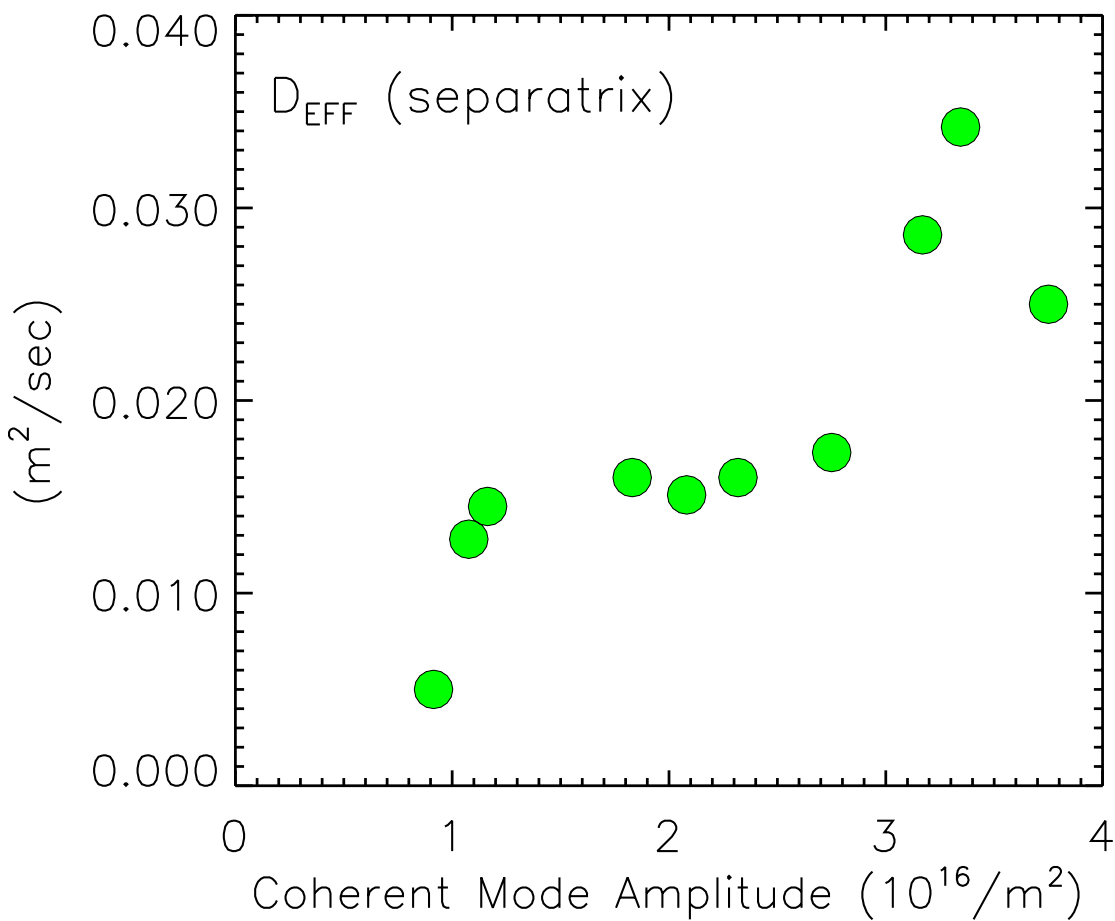
FSP_1—North Potential Fluctuations — 990831014



ANALYSIS OF $\langle \tilde{n}\tilde{E} \rangle$ SHOWS THAT THE OSCILLATIONS DRIVE SIGNIFICANT PARTICLE TRANSPORT

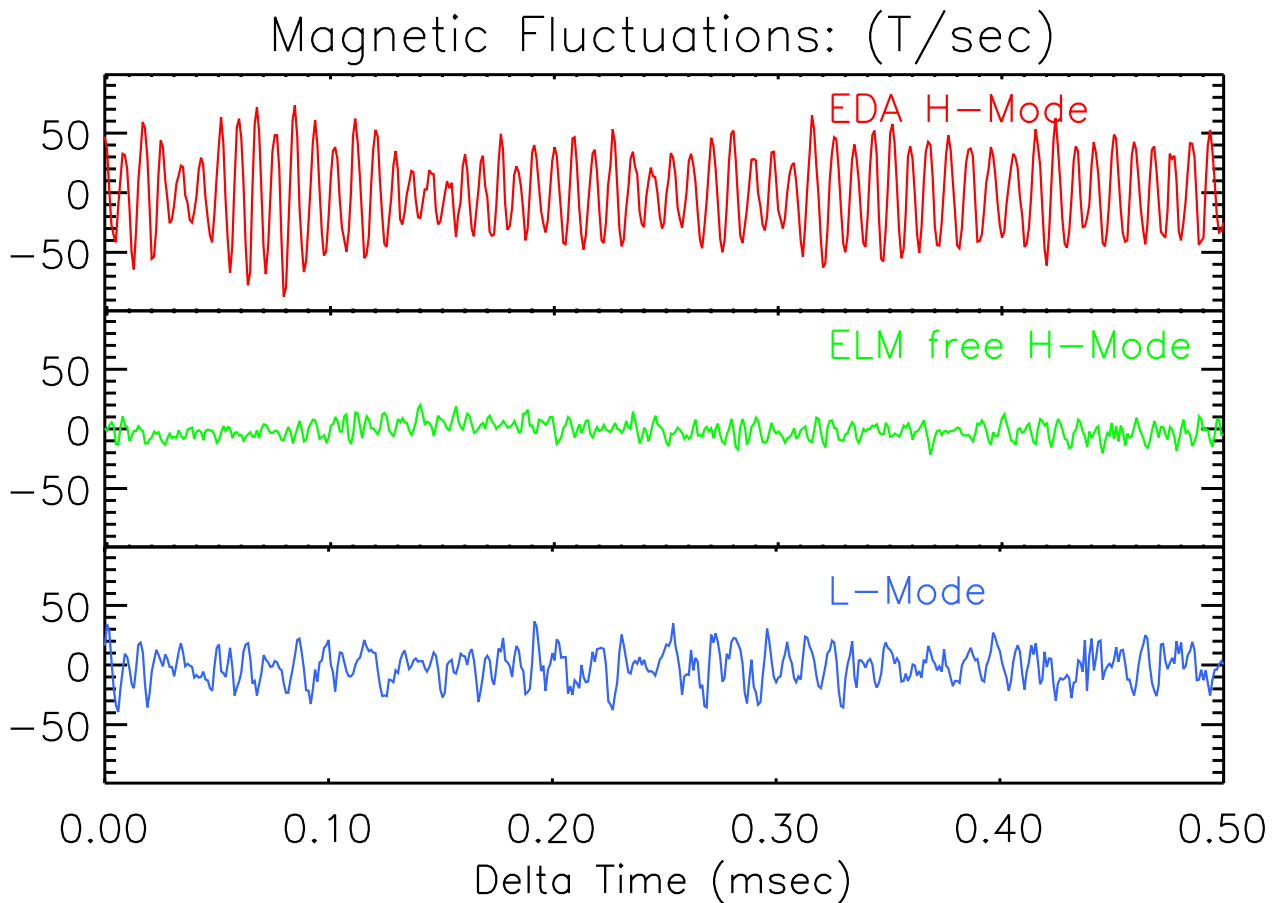


INCREASED PARTICLE TRANSPORT IS CORRELATED WITH THE STRENGTH OF THE QUASICOHERENT MODE AS MEASURED WITH PCI



- Particle source calculated with Lyman- α emission, $n_e(r)$, and $T_e(r)$
- $D_{\text{EFF}} = (\text{Integrated Source} - dN/dt) / \nabla n$

THE QUASI-COHERENT FLUCTUATION HAS AN IMPORTANT MAGNETIC COMPONENT



- Recently observed with a fast scanning magnetic probe (**Not** seen with standard set of fast magnetic pickups: m, k too large)
- $\tilde{j} \approx 20 A/cm^2$ with $j_{Ohmic+Bootstrap} \approx 100 A/cm^2$
- These are **not** ELM precursors (which are also seen, but at much lower m (10-20))

SO.... QUESTIONS ABOUT EDA BECOME QUESTIONS ABOUT THE QUASI-COHERENT MODE



- What is the origin of the QC mode?
 - What determines its poloidal wavelength, frequency?
 - What is determines the radial structure?
 - What determines its stability and growth rate?
- Why is it a single mode - no mixing or turbulence?
- Why does it cause more particle than energy transport?
- How does it survive the shear layer?
- Is it seen on other machines?
 - Why doesn't it dominate transport in these cases?

THEORETICAL WORK ON QC MODE AND RELATED THINGS

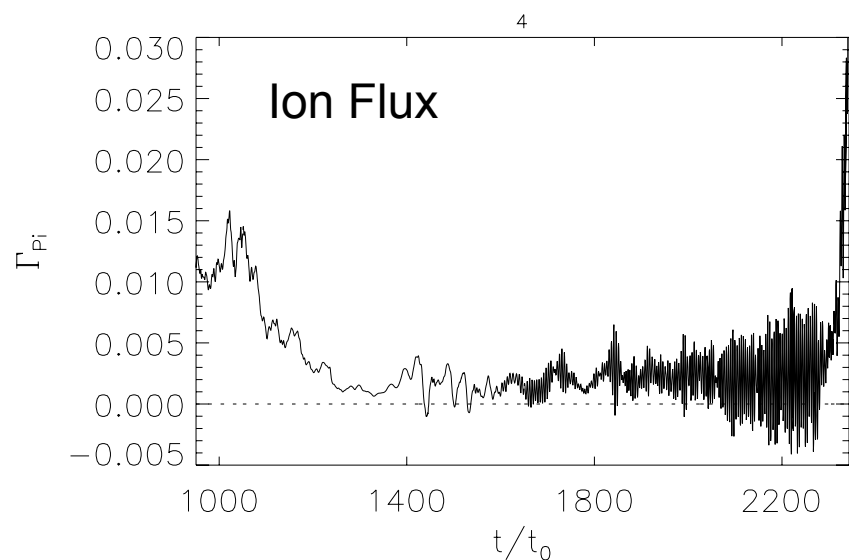
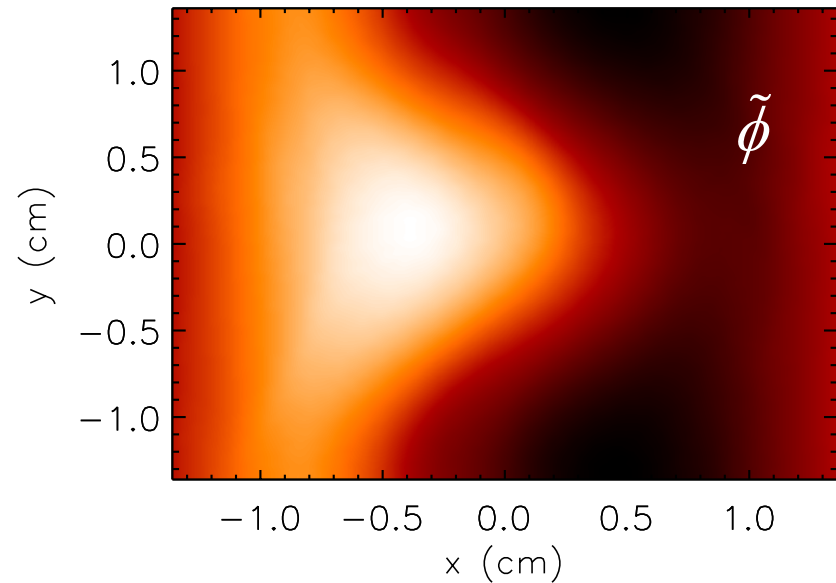


- **Drake and Rogers:** Drift-Alfven Simulations
 - Gyro-fluid, flux tube, electromagnetic, electron dynamics
 - Coherent mode found, Resistive Ballooning?
- **Dorland, Yuh, Greenwald** - GS2 Simulations
 - Gyro-kinetic, flux tube, electromagnetic, electron dynamics
 - Similar mode found, more evidence for resistive ballooning
- **Garcia, Carreras, Lynch** - Resistive Ballooning simulations
 - Nonlinear resistive MHD, global
 - Finds coherent mode near marginal stability
- **Hastie, Porcelli, Ramos** - Analytic calculations of resistive ballooning modes
 - Extends linear stability analysis, parametric dependences
- **Xu, Nevins** - BOUT code
 - Includes separatrix geometry
 - Resistive X-point mode

NONLINEAR SIMULATIONS OF DRIFT-BALLOONING TURBULENCE SHOW AN MHD-LIKE MODE ARISE AT HIGH EDGE PRESSURE GRADIENTS

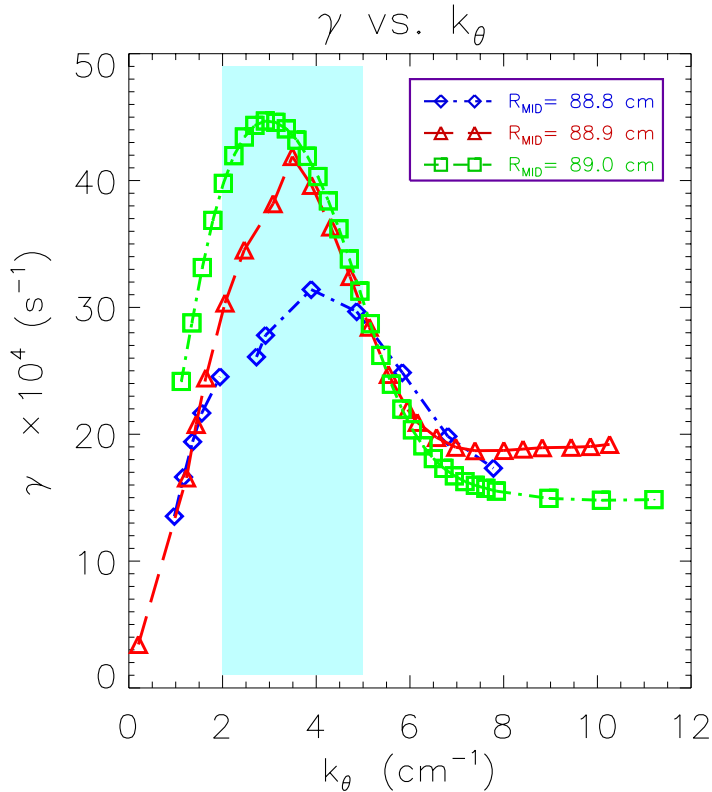


The calculated k (3-6 cm^{-1}) and frequency (50-200 kHz) of this mode¹ are in rough agreement with our measurements



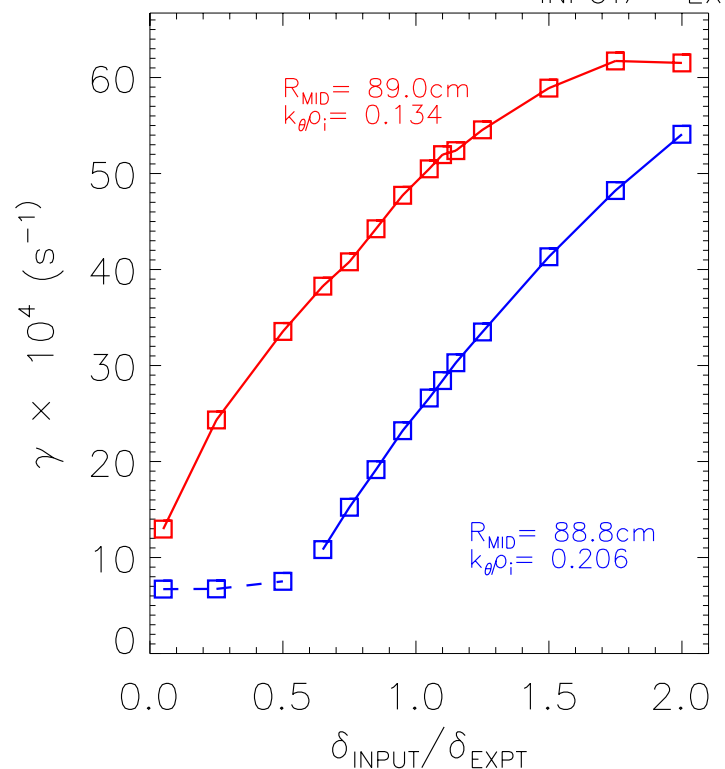
¹Rogers and Drake, *Phys. Plasmas*, **6**, 2797 (1999)

GROWTH RATES FOUND BY GS2 SHOW DEPENDENCIES CONSISTENT WITH EXPERIMENTS



- Most unstable modes have k and ω in the range found in the experiment
- $D \sim \gamma/k^2 \sim 1 \text{ m}^2/\text{sec}$ is significant
- Curvature, trapped particles unimportant

Growth Rate vs. $\delta_{INPUT}/\delta_{EXPT}$

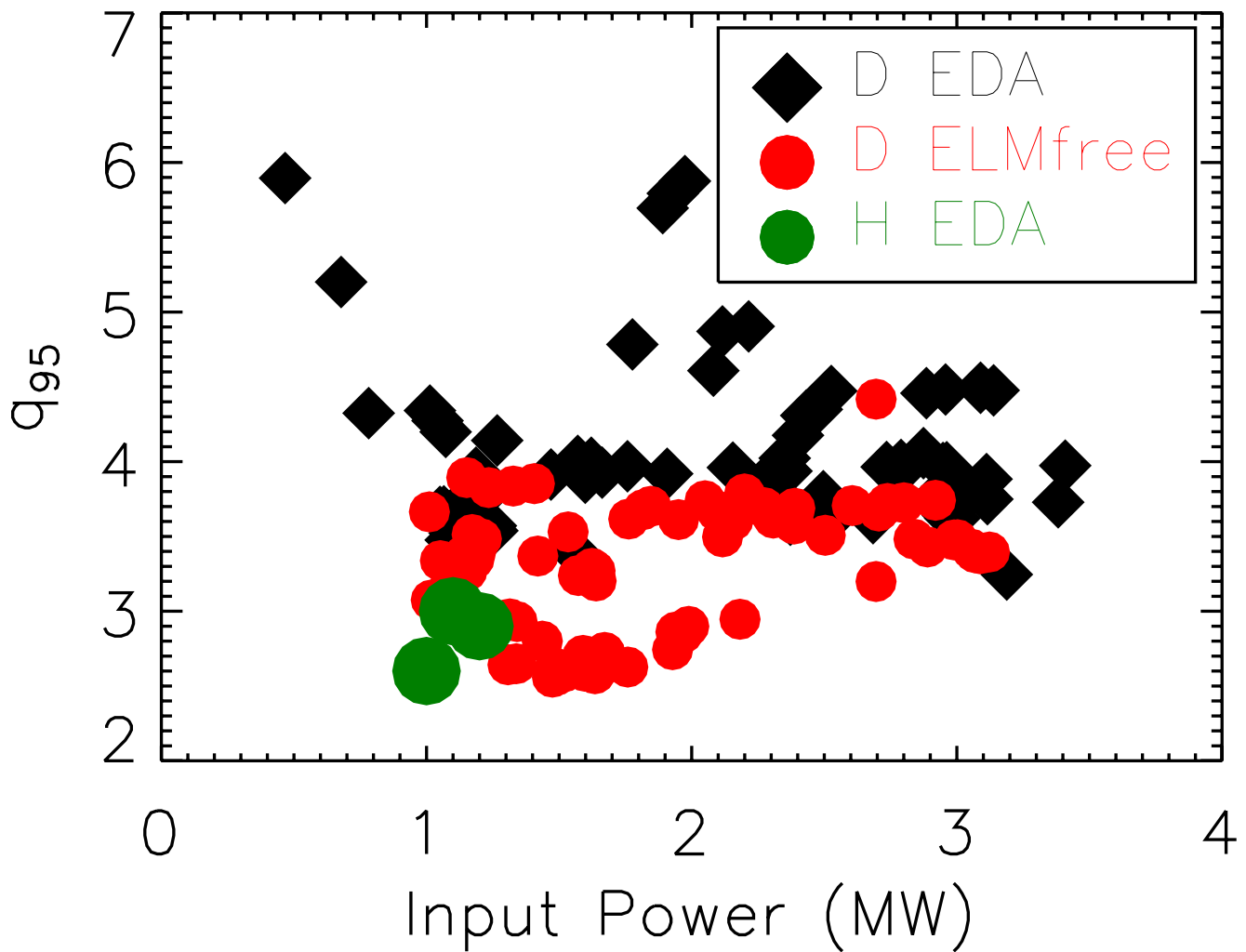


- Growth rate increases with shaping (δ)
- May correspond to threshold seen in experiment

SCALING OF EDA/ELMFREE BOUNDARY WITH q AND ION MASS IS CONSISTENT WITH LINEAR STABILITY OF RESISTIVE BALLOONING MODES

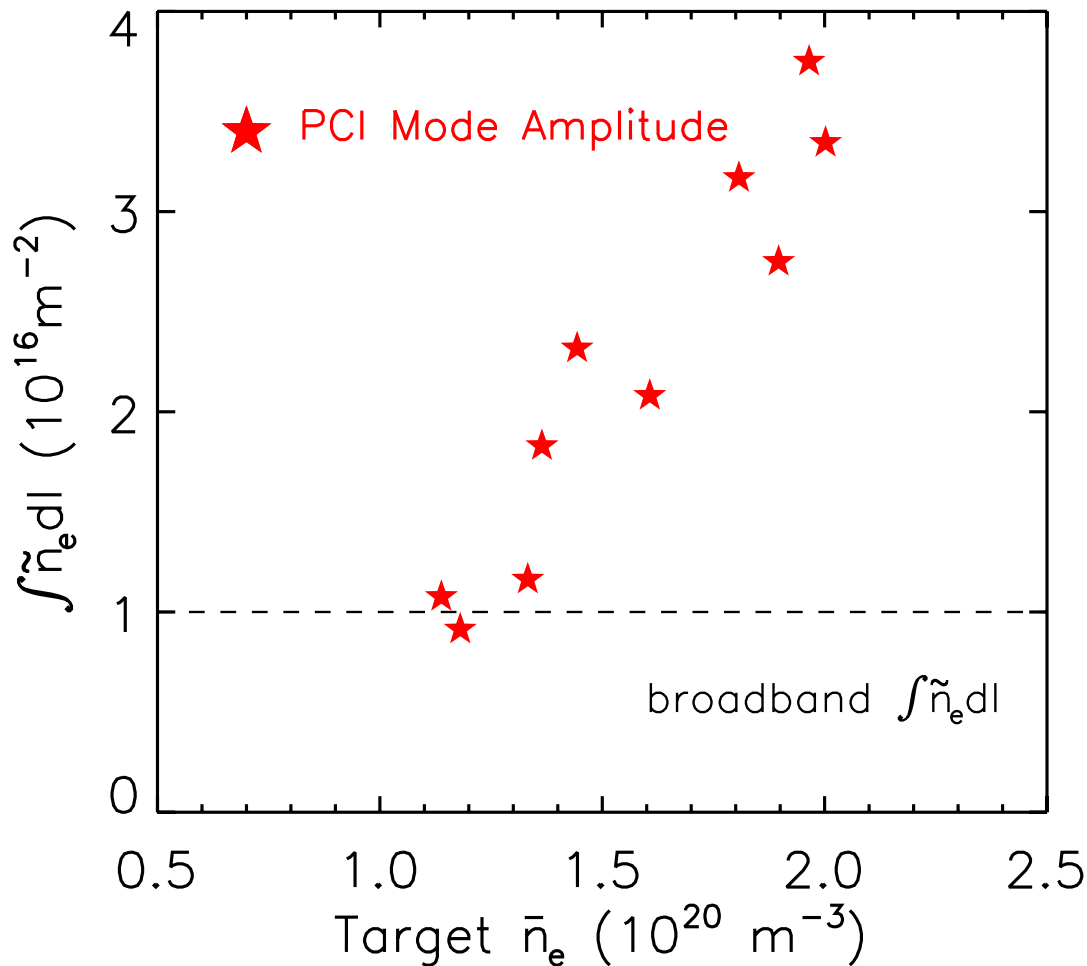


- Analytic work finds validity condition for Carreras-Diamond mode $4 \times 10^{-3} q^2 v^* / m_i > 1$



COLLISIONALITY DEPENDENCE MAY BE SEEN IN EXPERIMENTS

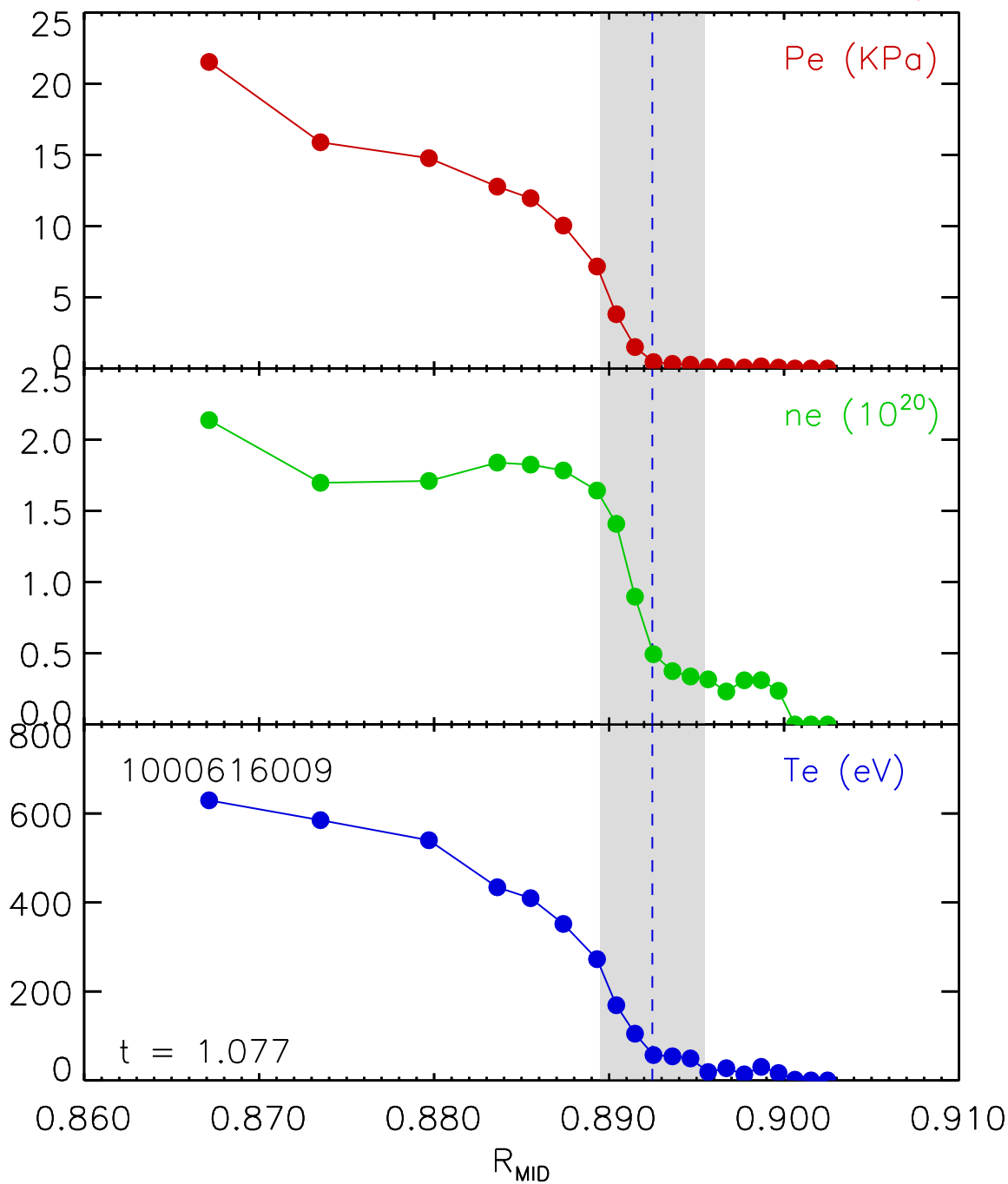
Alcator
C-Mod



- Consistent with resistive effects
- At very low density (for C-Mod), isolated ELMs are seen rather than EDA
- If ELMs are current driven, higher edge collisionality might stabilize current driven modes via reducing bootstrap.

PERHAPS THE DIFFERENCE IN PARTICLE AND ENERGY TRANSPORT DRIVEN BY THE MODE IS THE RESULT OF ITS LOCATION IN THE PEDESTAL?

Alcator
C-Mod



SUMMARY



- The **EDA** H-mode regime combines **good energy confinement, moderate particle confinement** and **no ELMS**
- The pedestal gradient is limited by a continuous rather than intermittent process, related to **electromagnetic fluctuations** which are observed. ($f \sim 100$ kHz, $k \sim 5$ cm⁻¹)
- A coherent mode with similar properties was **seen in non-linear simulations** - identified as **resistive ballooning?**
- **Linear stability analysis recovers some of the parametric dependencies.**
- We are also investigating the **role of collisionality** in suppressing edge current/ peeling modes.
- **Transport may be effected by the location of the mode** at the base of the density pedestal.
- **The mode is apparently seen on other devices** - PDX, PBX, CCT, DIII-D, TEXTOR?, ASDEX-upgrade?