Structure and Scalings of the H-Mode Pedestal on Alcator C-Mod

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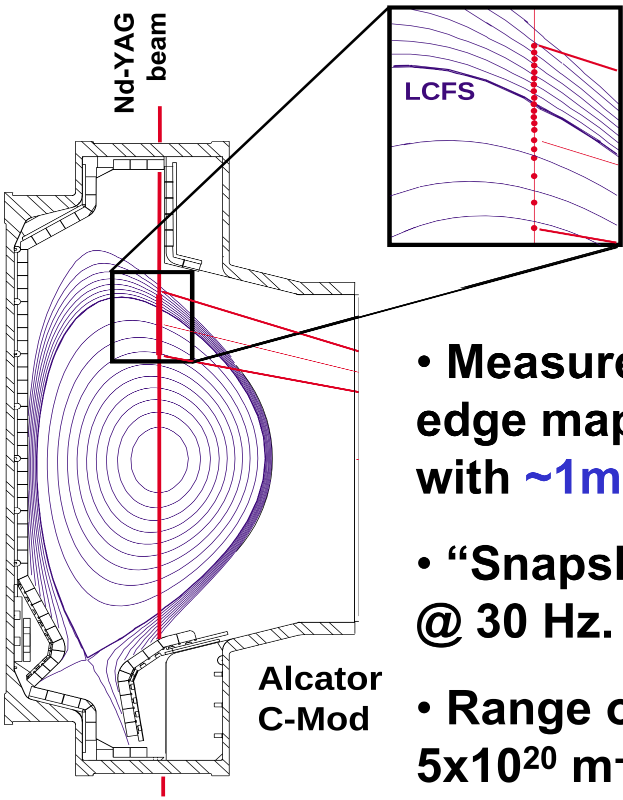
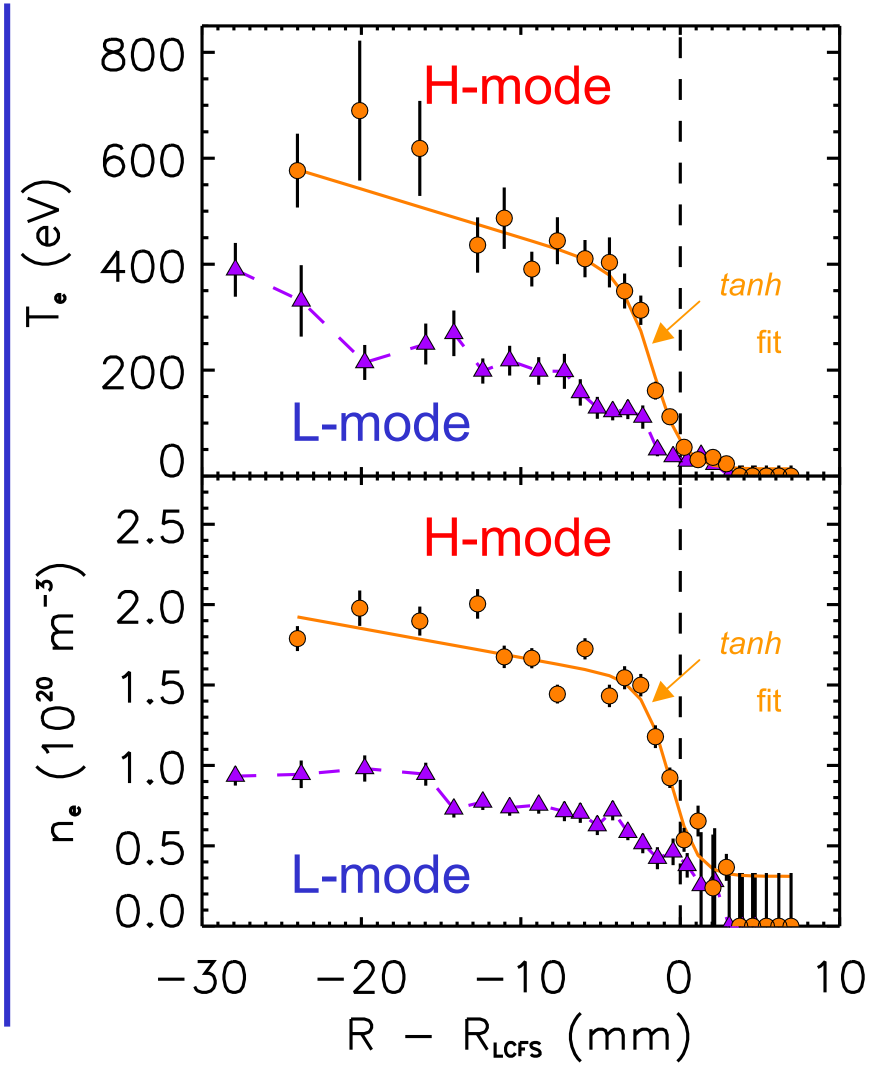
Introduction

- **Edge transport barriers in H-mode associated with improved particle, energy confinement in tokamaks**
- **Examine phenomenology of n_e, T_e pedestals**
- **Can correlate character of edge fluctuations with pedestal parameters**
  - **D. Mossessian, CO1.006 (following)**
  - **M. Greenwald, KP1.018 (Wed. AM)**
- **Scaling studies performed to establish correlations of pedestal parameters with plasma parameters.**

Edge Thomson scattering (ETS) resolves electron temperature and density pedestals



- **Measurements at upper edge mapped to midplane with ~1mm resolution**
- **"Snapshots" of profiles @ 30 Hz.**
- **Range of n_e: 3×10^{19}—5×10^{20} m^{-3}; T_e: 15—800 eV**



•Fully evolved H-mode edge:

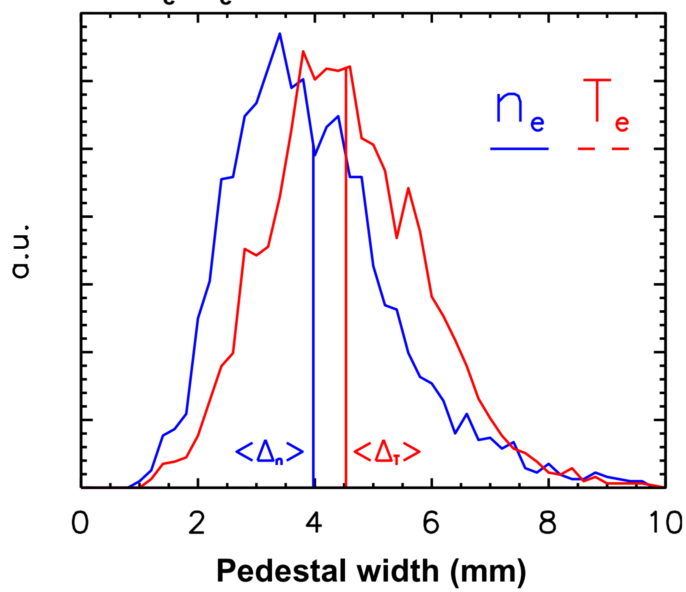
∇T_e: 50—100 keV/m; ∇n_e: 10^{22}—10^{23} m^{-3}/m

•Pedestals fit to standardized *tanh* function:

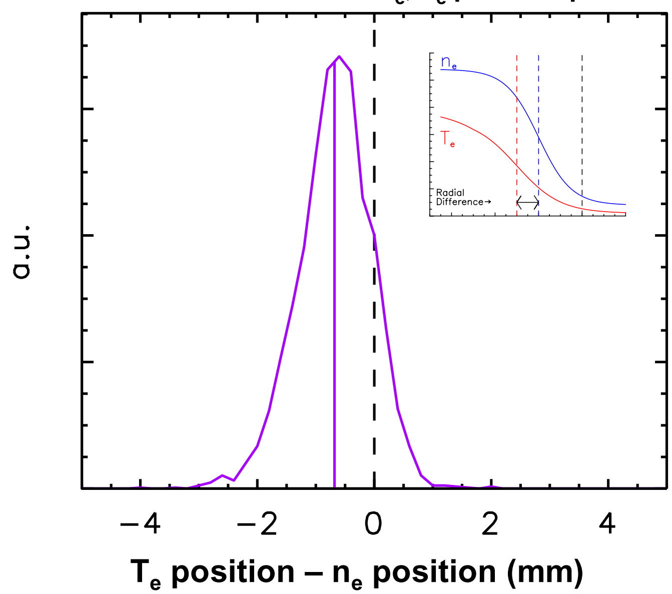
$$f = b + \frac{h}{2}\left[\tanh\left(\frac{R_0 - R}{\delta}\right) + 1\right] - m\left(R - R_0 + \delta\right)H\left(-R + R_0 - \delta\right)$$

Characteristic width and position of T_e, n_e pedestals

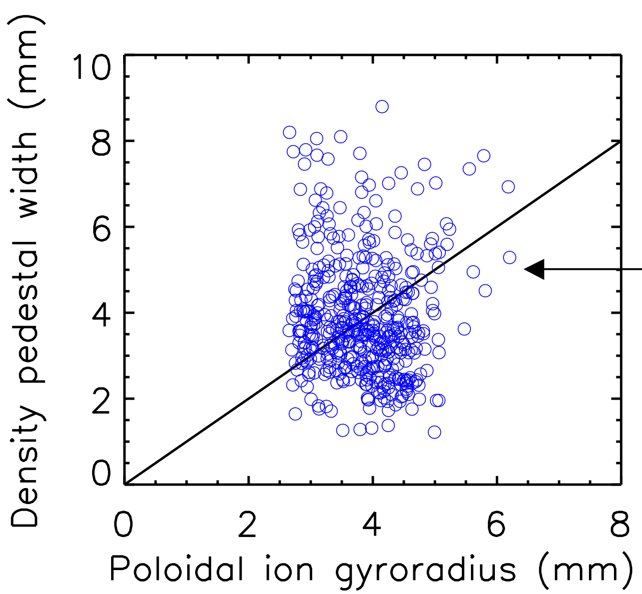
T_e, n_e width distributions:



Distribution of *difference* in T_e, n_e pedestal positions:



- **Pedestal "feet" lie near LCFS**
- **Typical pedestals are in the range of 2—6 mm in width (far left)**
- ***On average* the T_e pedestal is <u>wider</u> (far left) and is located slightly <u>inside</u> (left) the n_e pedestal**



Widths are on the order of, but don't explicitly scale with, $\rho_{i,p}$

Pedestal conditions in ELM-free and Enhanced D_α (EDA) H-modes

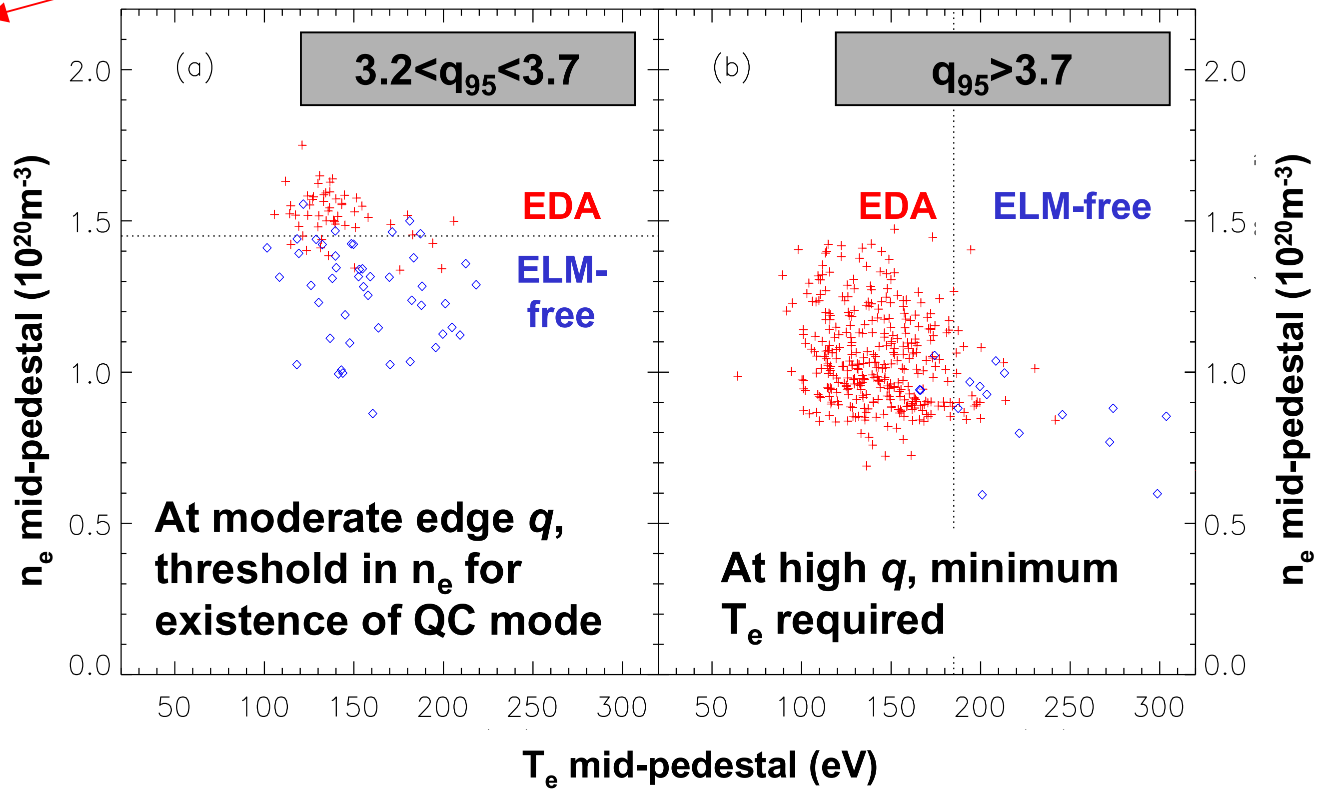
- **ELM-free H-modes**
  - Lack edge relaxation mechanism
  - Characterized by core density, impurity build-up, radiative collapse
- **EDA H-modes**
  - Enhanced particle, impurity transport, with good energy confinement
  - Always accompanied by edge quasi-coherent (QC) mode

–QC mode results in higher levels of particle transport

–Localized by scanning probes, reflectometry to the n_e pedestal

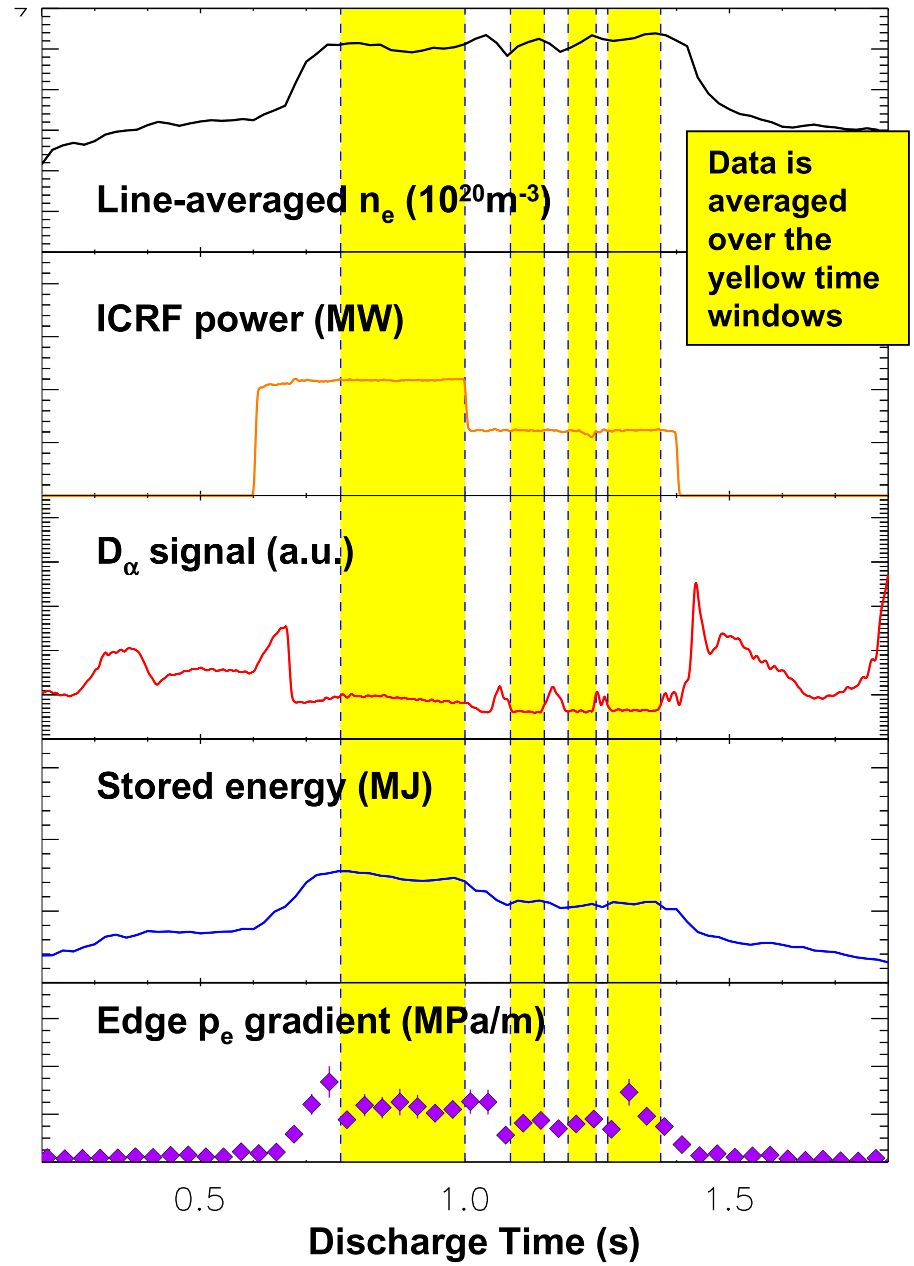
(CO1.006,007 this session)

–Presence depends on edge/pedestal conditions

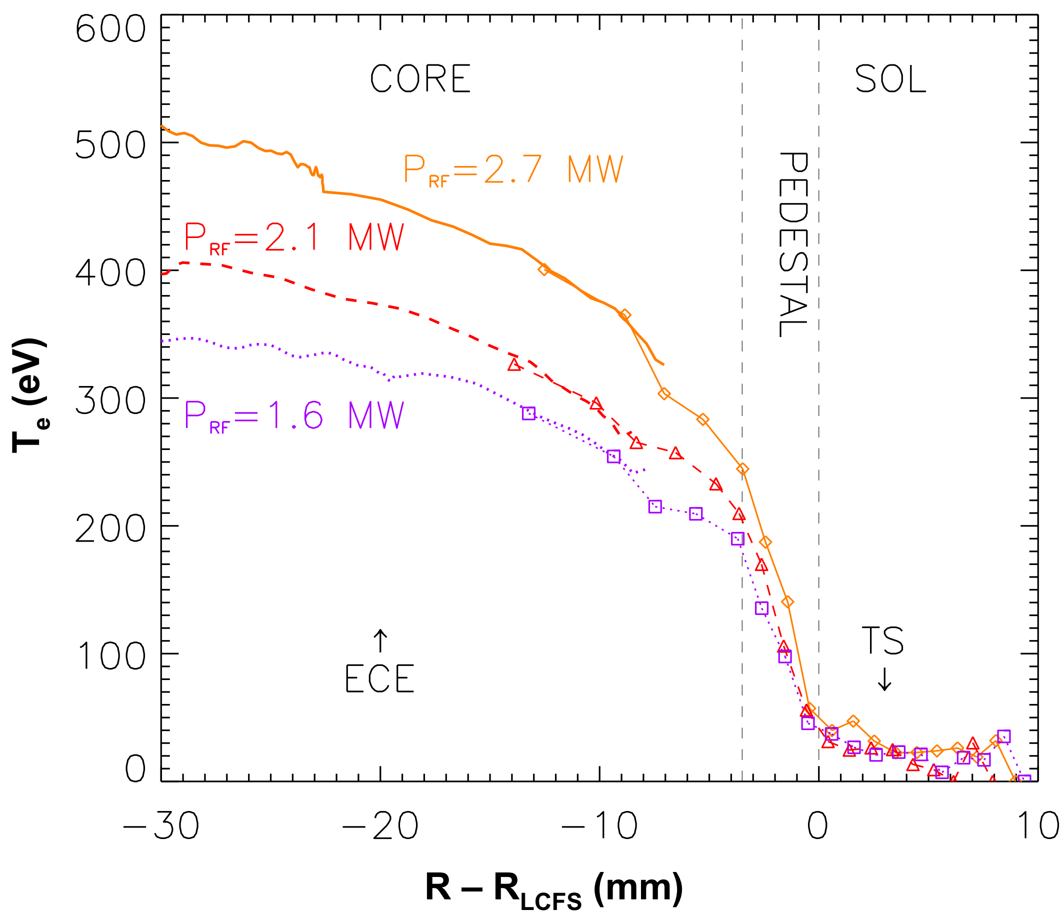


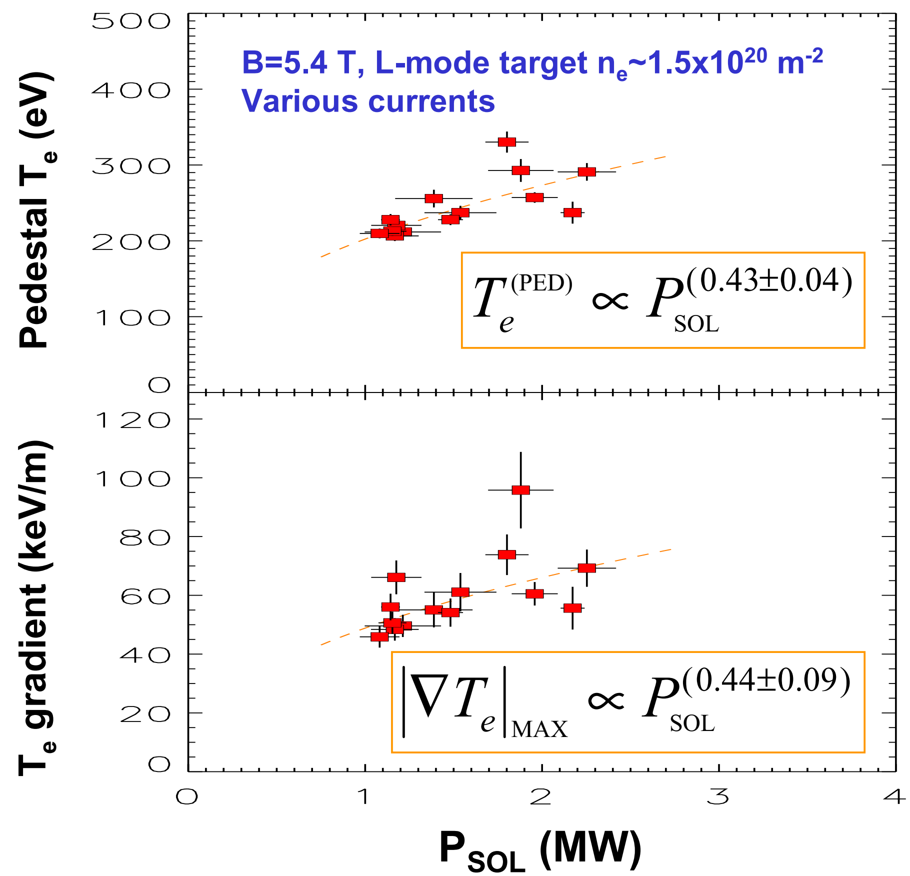
Scaling studies use *time-averaged* parameters in steady discharges

- **Study *scalings of pedestal parameters with global parameters*:**
  - I_P: 0.6—1.2 MA
  - Pedestal n_e: $1—3\times10^{20}$ m^{-3}
  - B_T: 4.5—6.0 T
- **Examine H-modes during steady ICRF heating, having *nearly constant* stored energy, W_P, and D_α emission.**
- **Select plasmas with low H/D ratio: (2—8%)**



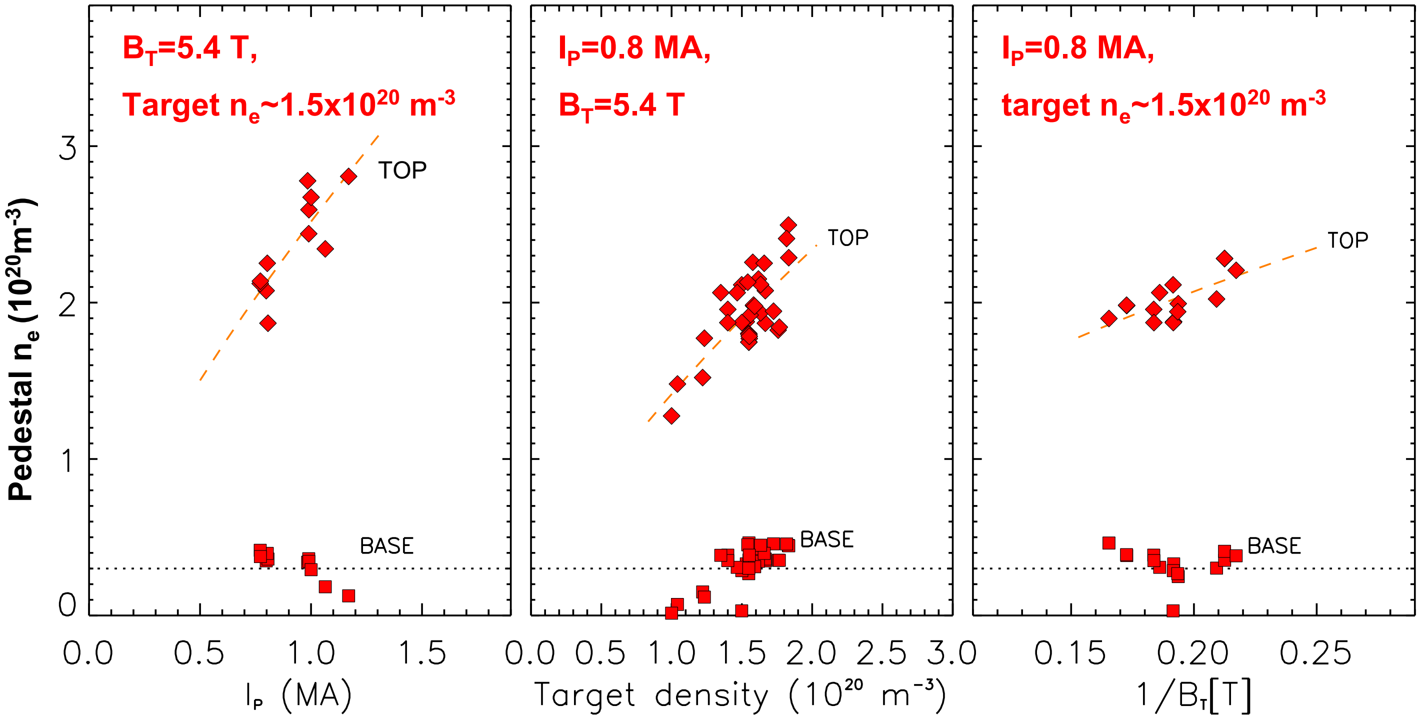
Effect of varying input power on T_e pedestals

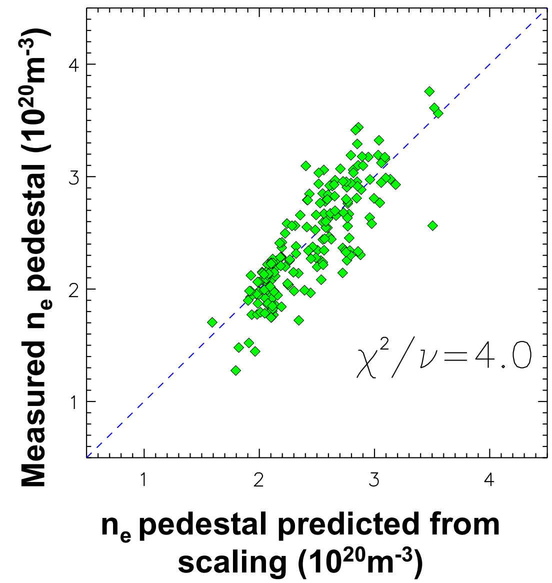




- Pedestal T_e, T_e gradient both increase with P_{SOL}
- Change in pedestal width is not significant
- No T_e dependence on plasma current
- No effect on n_e profiles

Density pedestal scalings





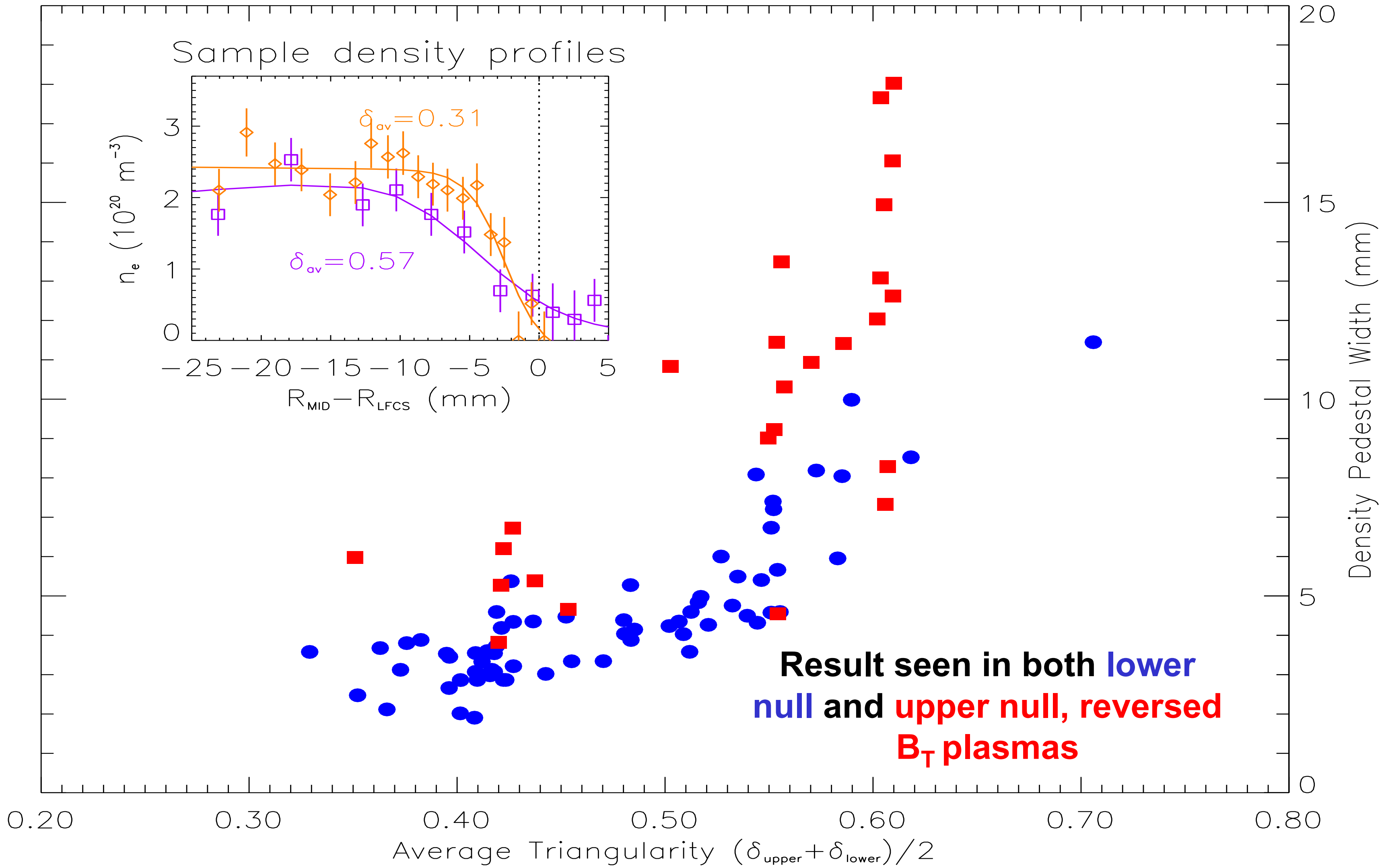
- Pedestal n_e proportional to plasma current
- Is sensitive to the initial L-mode target density, $\overline{n}_{eL}$
- Falls as B_T is raised
- Density pedestal somewhat wider on average at higher n_e

Predictive scaling for pedestal n_e:

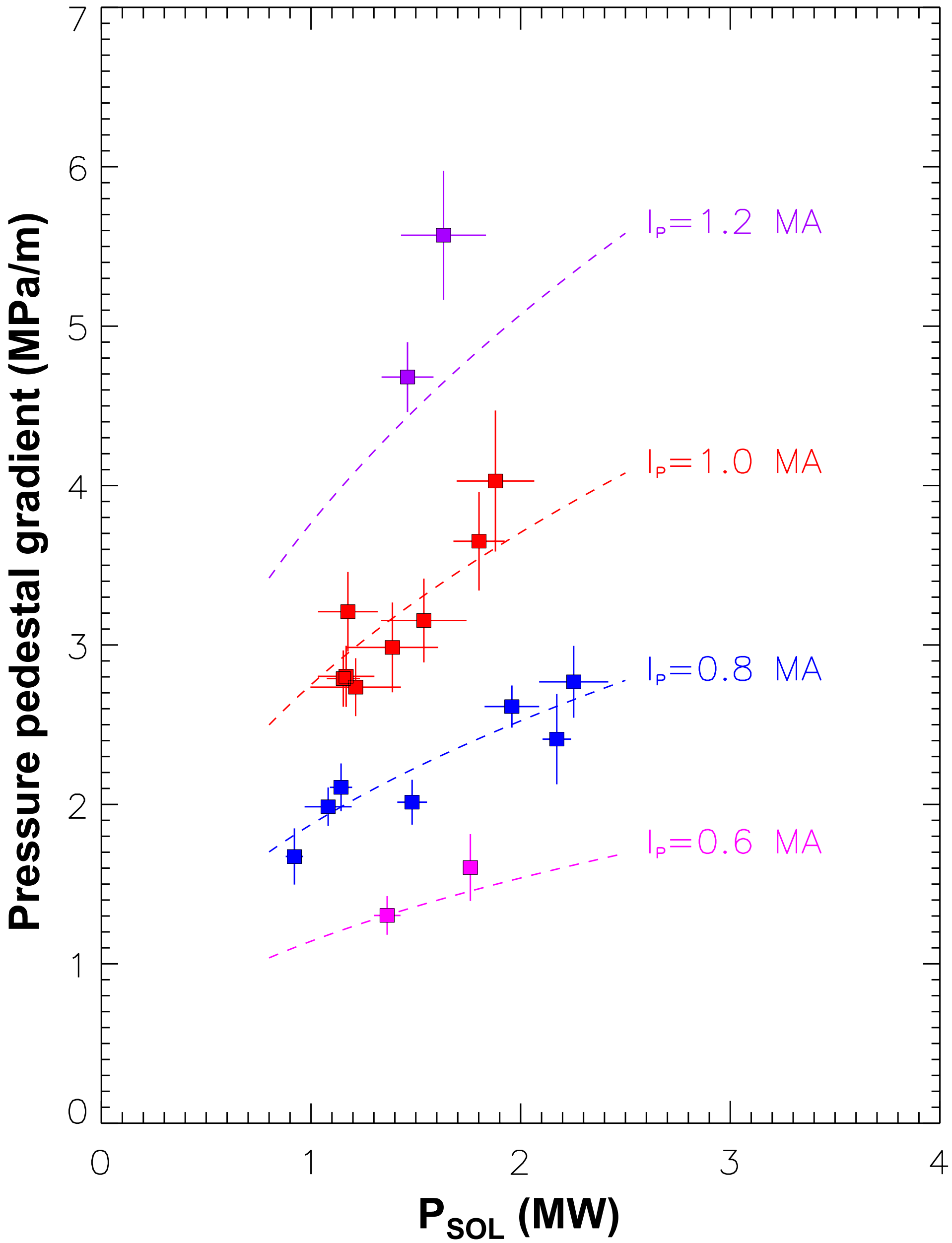
$$n_e^{(PED)} \propto I_P^{(0.89\pm0.03)} \overline{n}_{eL}^{(0.36\pm0.03)} B_T^{(-0.48\pm0.07)}$$

Effect of plasma shaping on density pedestal *width*

Dynamic scans of triangularity, δ, show an effect on Δ_n, with no appreciable effect on T_e width



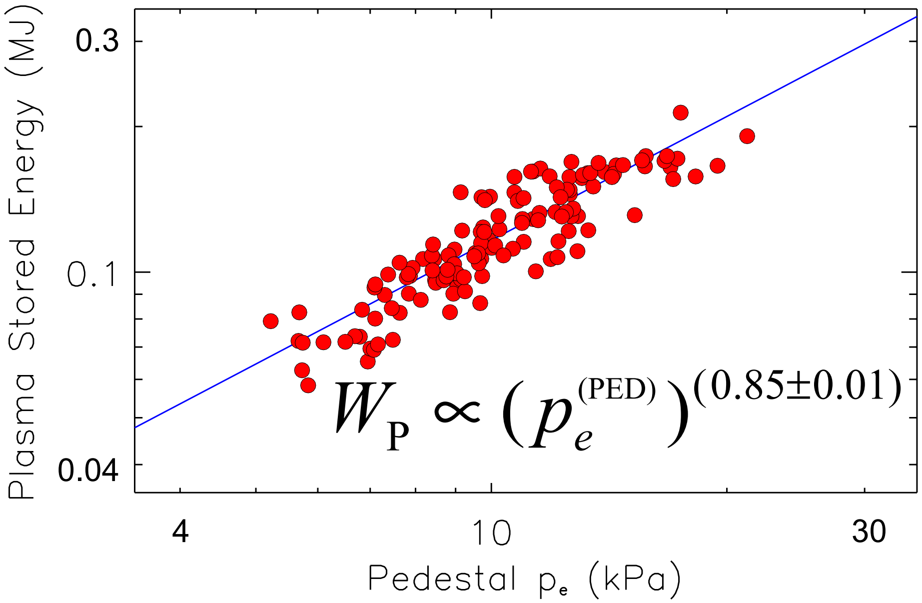
Pressure gradient scalings

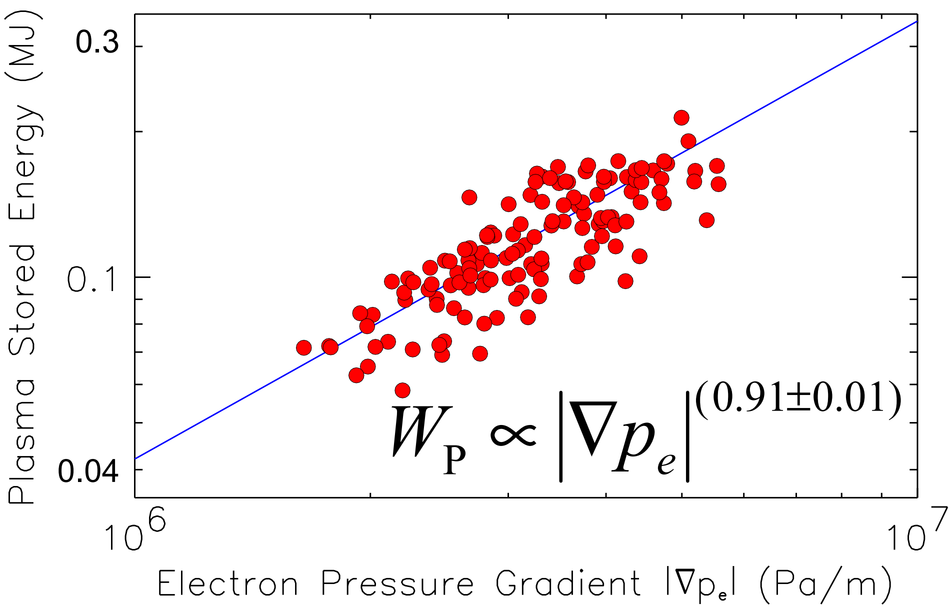


- **Results from dedicated I_P scan at 5.4 T, target density of 1.5—1.7x10^{20} m^{-3}**
- **Pressure gradient scales with power, as does $|\nabla T_e|$**
- **Scales more strongly with current than pedestal n_e**
- **Best fit scaling:**

$$|\nabla p_e|_{MAX} \propto I_P^{(1.72\pm0.20)} P_{SOL}^{(0.43\pm0.08)}$$

Strong coupling of global confinement with pressure pedestal





- **Over a broad range of plasma parameters and conditions, stored energy scales with pedestal p_e in a nearly linear fashion.**
- **Because Δp_e varies little, W_P scales similarly in terms of both p_e height *and* gradient.**

Summary

- H-mode edge transport barrier on C-Mod studied with millimeter resolution Thomson scattering
- Clearly resolved T_e, n_e pedestals: Δ~2—6 mm
- Pedestal T_e, n_e seem to influence stability of EDA-associated QC mode
- Scaling studies at fixed plasma geometry show

$$T_e^{(\mathrm{PED})}, \left|\nabla T_e\right|_{\mathrm{MAX}} \propto P_{\mathrm{SOL}}^{0.4}$$

$$n_e^{(\mathrm{PED})} \propto \overline{n}_{e\mathrm{L}}^{\,0.4} I_P^{0.9} B_T^{-0.5}$$

$$\left|\nabla p_e\right|_{\mathrm{MAX}} \propto I_P^{1.7} P_{\mathrm{SOL}}^{0.4}$$

- n_e pedestal width increases strongly with δ
- No clear scalings of pedestal widths on B_T, I_P
  - Correlations could be masked by scatter in the data set
  - Should rescan current and field at higher triangularity