Empirical Study of η_e in H-mode Pedestal in DIII-D

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Empirical Motivation

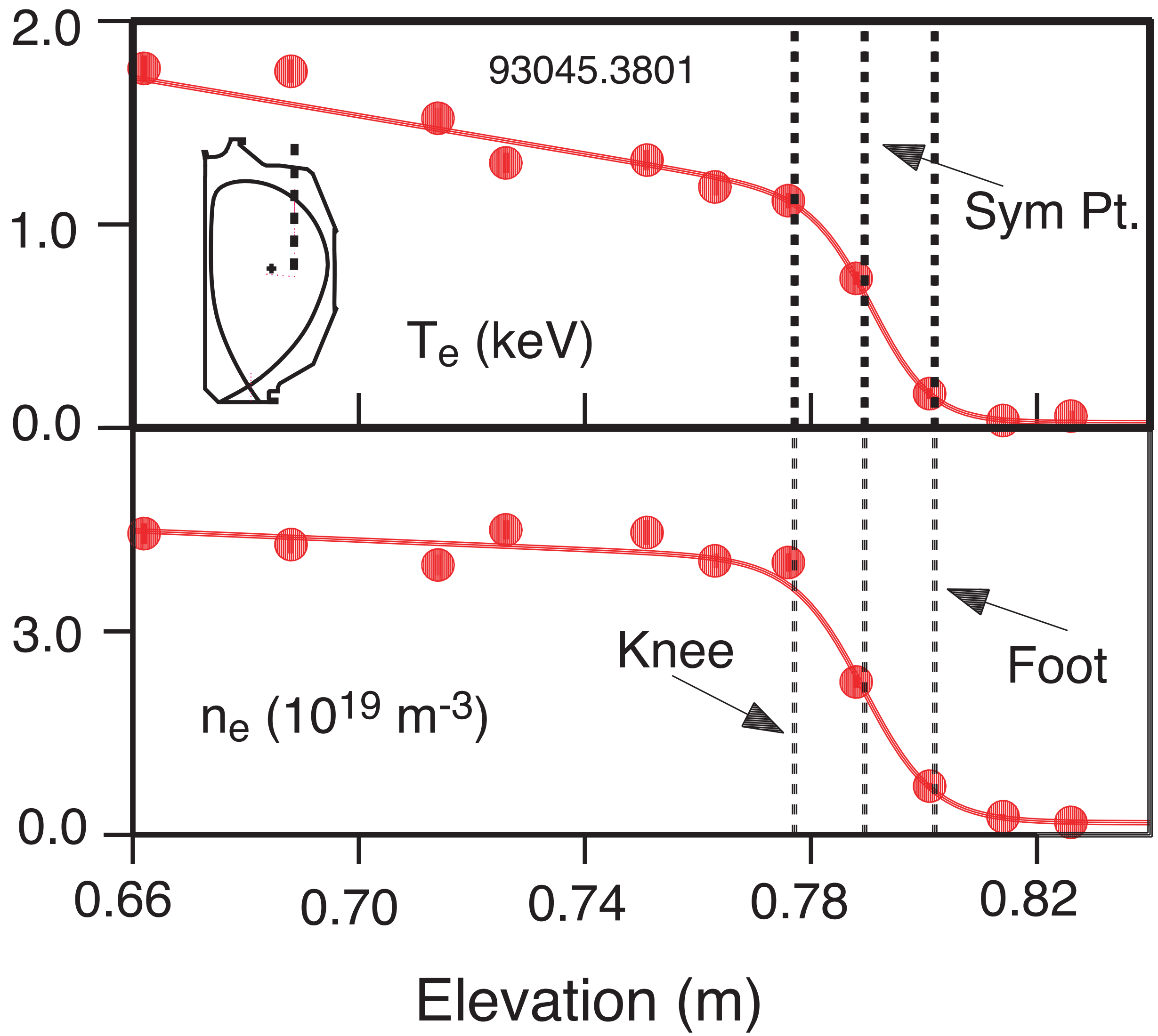
Empirical Evidence Exists for a Dependence of Pedestal T_e Profile on n_e Profile

- **Barriers in T_e and n_e are often found to overlap very well**
- **Width of n_e barrier forms an approximate lower limit for width of T_e barrier**
- **ASDEX-U has reported η_e is about two in the pedestal**
  - J. Neuhauser, *et al.*, Plasma Phys. Control. Fusion **44**, 855 (2002)

- **Purpose of this paper is to do a survey of L_{T_e}, L_{n_e} and η_e in DIII-D tokamak**
  - $L_{T_e} = T_e / \nabla T_e, \quad L_{n_e} = n_e / \nabla n_e$
  - $\eta_e = L_{n_e} / L_{T_e}$

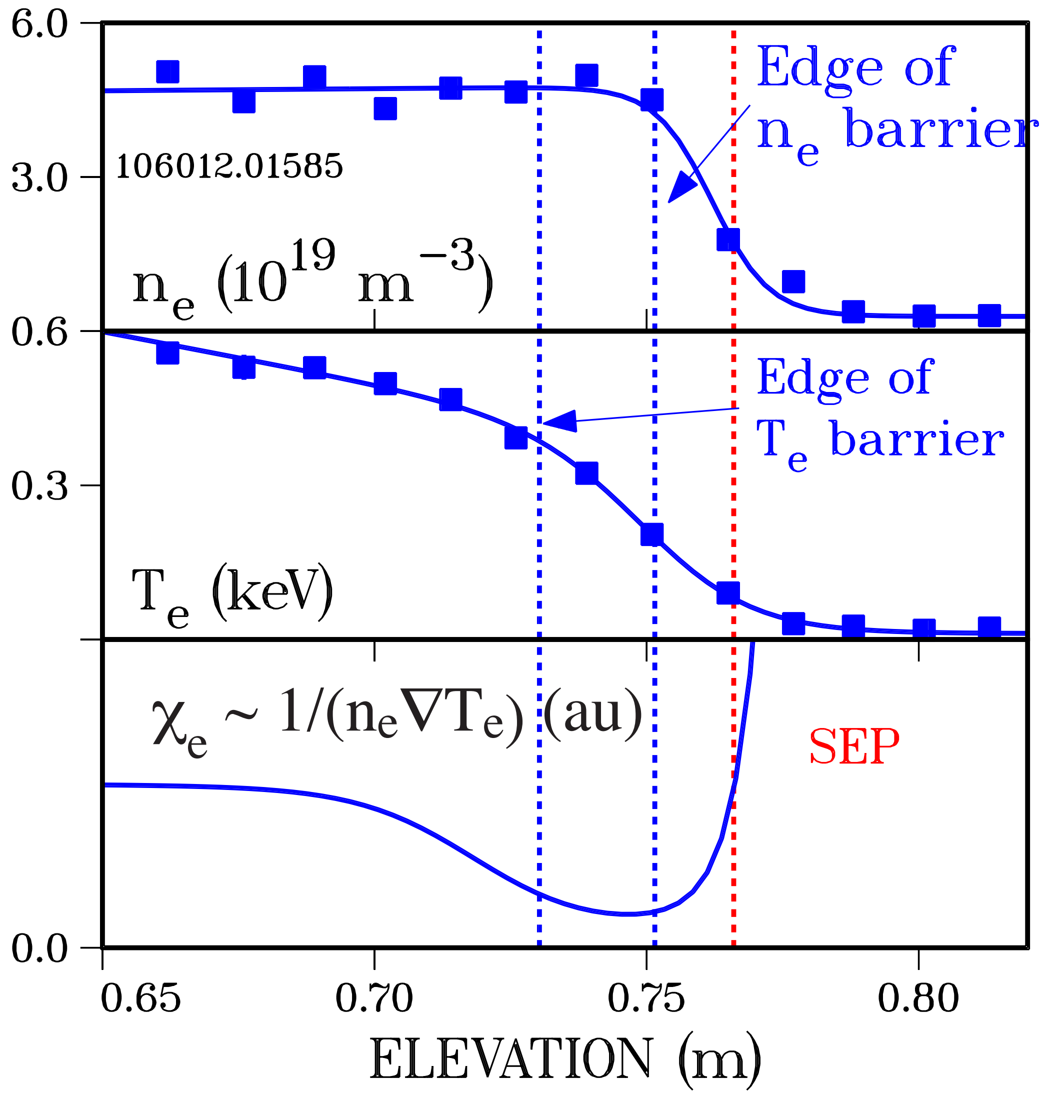
Profiles where T_e and n_e look similar

- Measurements are along Thomson laser chord, shown in inset



Profile where T_e barrier extends further into core than n_e barrier

- Inner edge of barriers is taken as the "knee" of each profile



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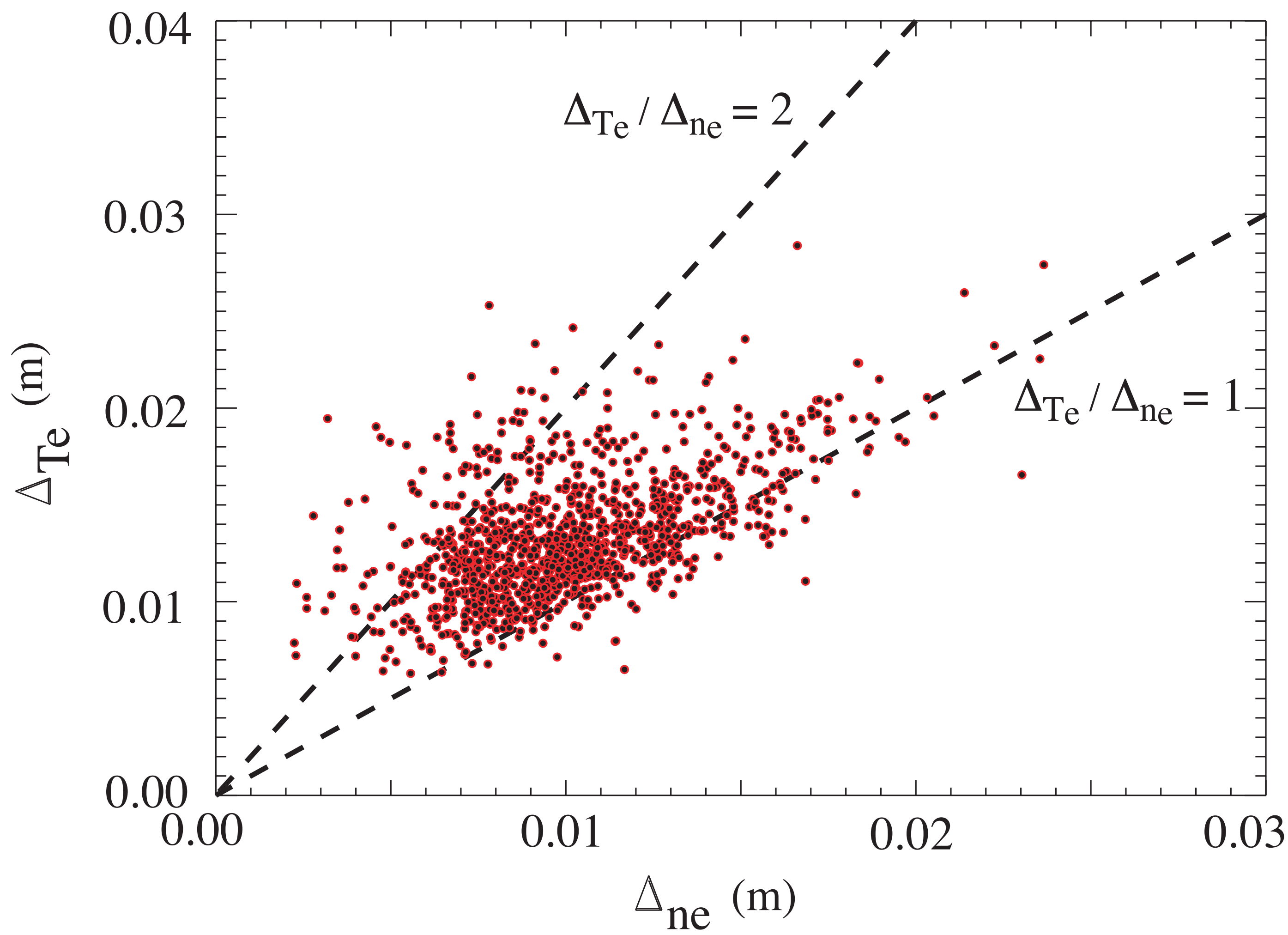
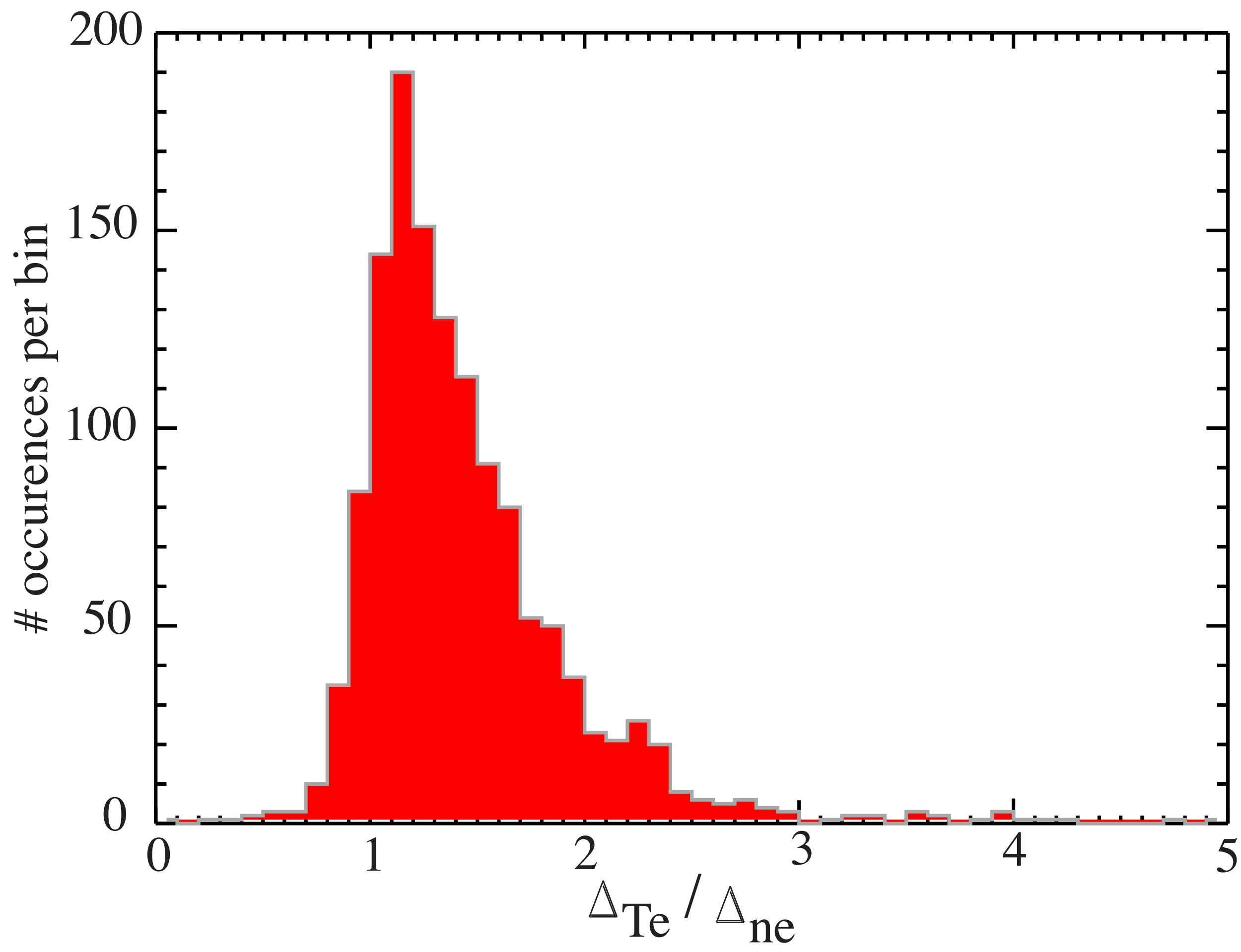
Width of T_e barrier is ~1-2 x width of n_e barrier

- **Inner edge of barrier is "knee" of the each profile**
- **Outer edge of each barrier is "foot" of T_e profile**



Most probable T_e width is ~1.1-1.2 x n_e width

- Data set covers a wide range of densities
- ELMs are removed
- Figure is a PDF of number of occurrences of various ratios of T_e to n_e width
- Widths are defined as in previous figure



Theoretical Motivation

Theoretical Motivation for Studying η_e

- **Gyrokinetic simulations have been used to develop an analytic formula for critical T_e gradient at linear threshold for Electron Temperature Gradient (ETG) turbulence**
  - F. Jenko, *et al*., Phys. Plasmas **8,** 4096 (2001).

$$\left(R/L_{T_e}\right)_{crit} = \max \left[0.8R/L_n, F(\tau, \hat{s}, q, \varepsilon, d\kappa/d\varepsilon)\right]$$

- **In the core, prediction is that L_{T_e} will not deviate far from the linear threshold**
  - **For sufficiently steep n_e profile, prediction is $L_{T_e} \approx L_{n_e}$**
  - **Or, $\eta_e = L_{n_e} / L_{T_e} \approx 1$**
- **However, in steep gradient region of edge, theory says that the T_e gradient might deviate from value at linear threshold**
- **Thus, we might expect $\eta_e \geq 1$ at edge**

Theory Motivates 3 Questions for Experiment

- **In the region of steep density gradient, is there a linear relation between L_{T_e} and L_{n_e}?**

- **If so, what is the η_e , the ratio of L_{n_e} to L_{T_e}?**

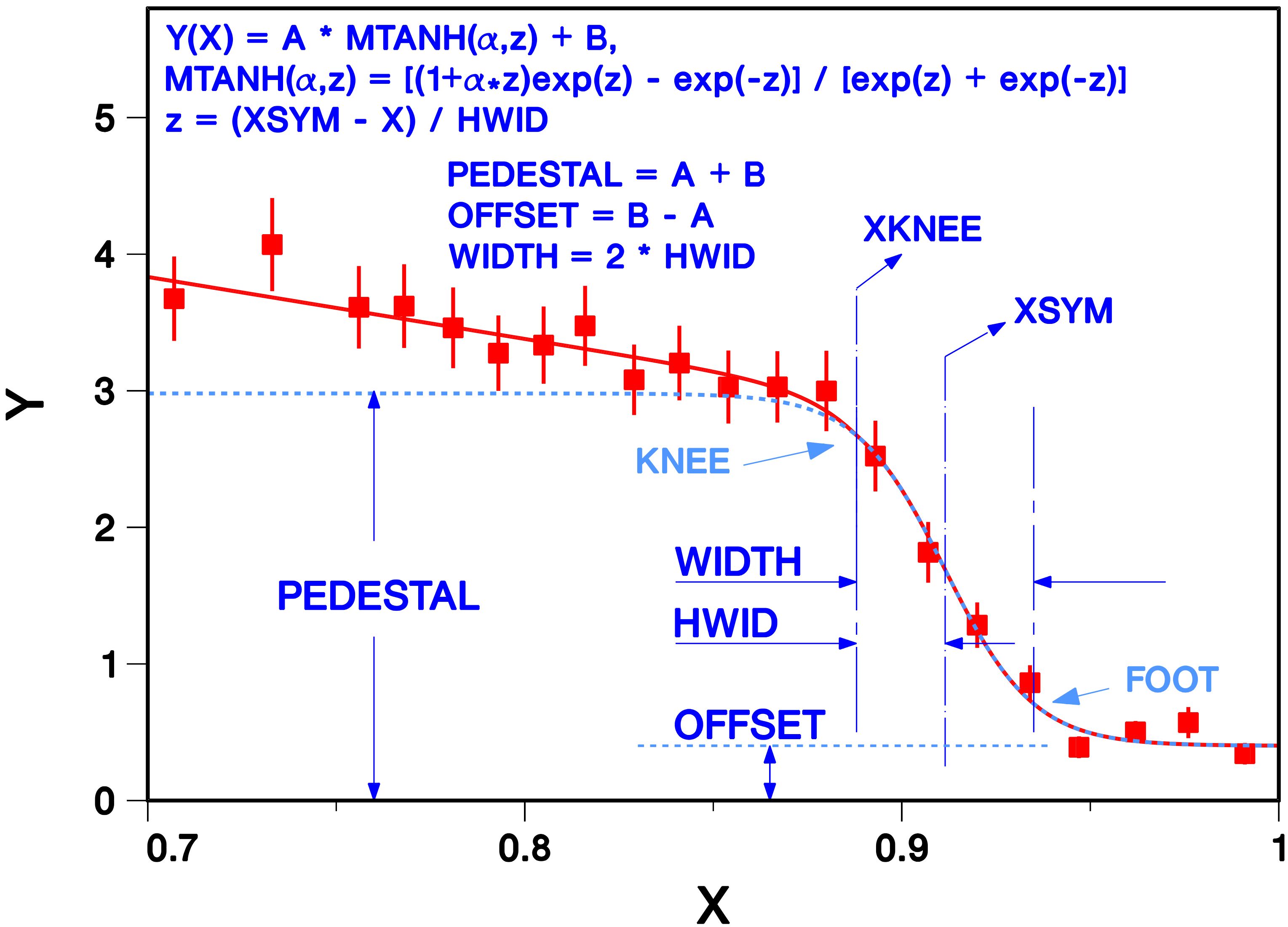
- **What is η_e throughout the region of steep density gradient?**

Analysis Procedure

Analysis Technique

- **Obtain modified hyperbolic tangent fits to edge T_e and n_e profiles**
  - **- Use these to evaluate L_{n_e}, L_{T_e} and η_e**
- **For a general survey, evaluate these quantities at the point of steepest density gradient**
  - **We might expect the effects of ETG turbulence to show up first at that location**
- **Evaluate data during ELM-free phases of several discharges**
  - **- Avoid potential complications due to ELMs**
- **Nota Bene: All measurements are in elevation along Thomson laser chord; no projections to midplane**

DEFINITION of MODIFIED TANHFIT



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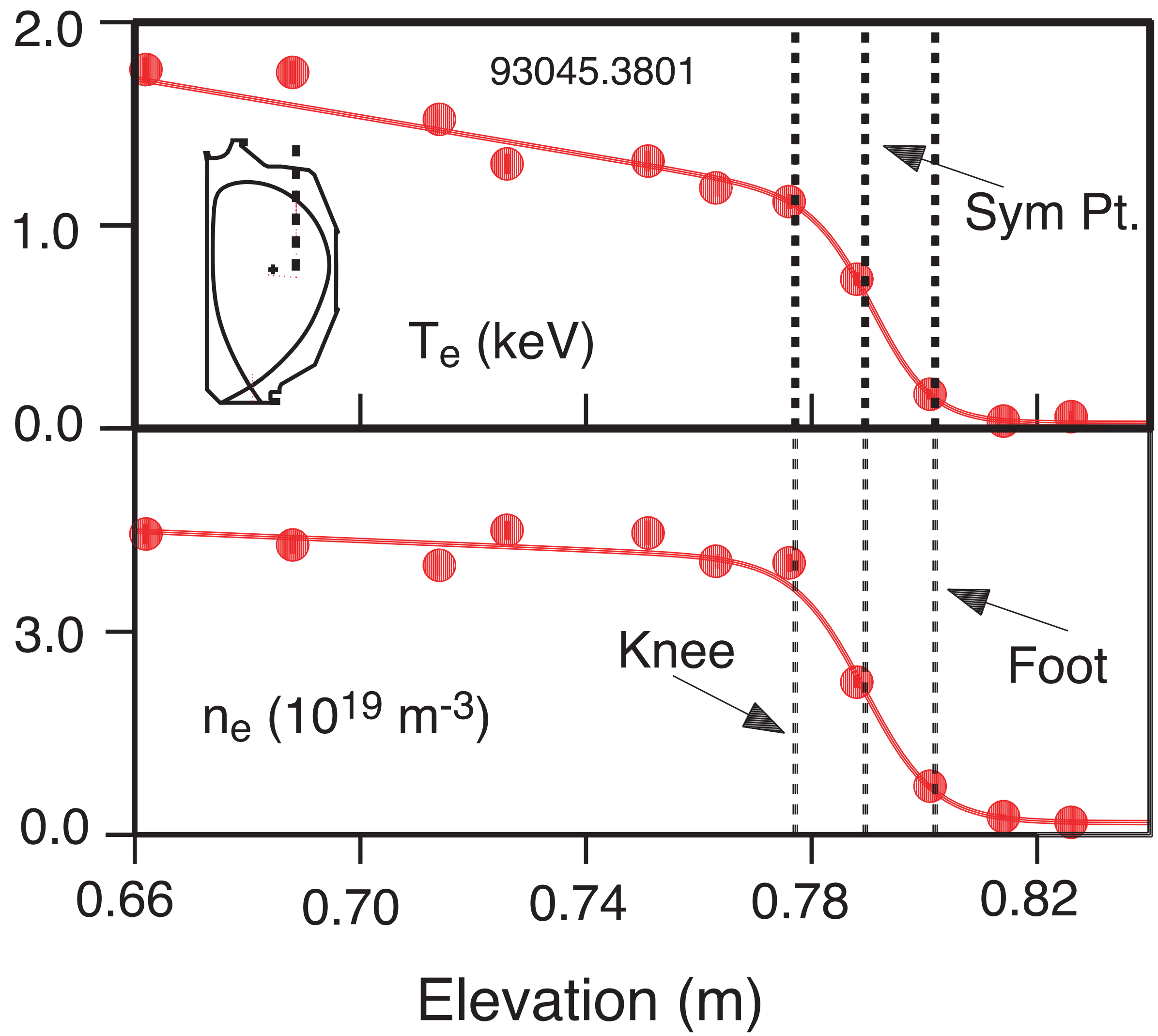
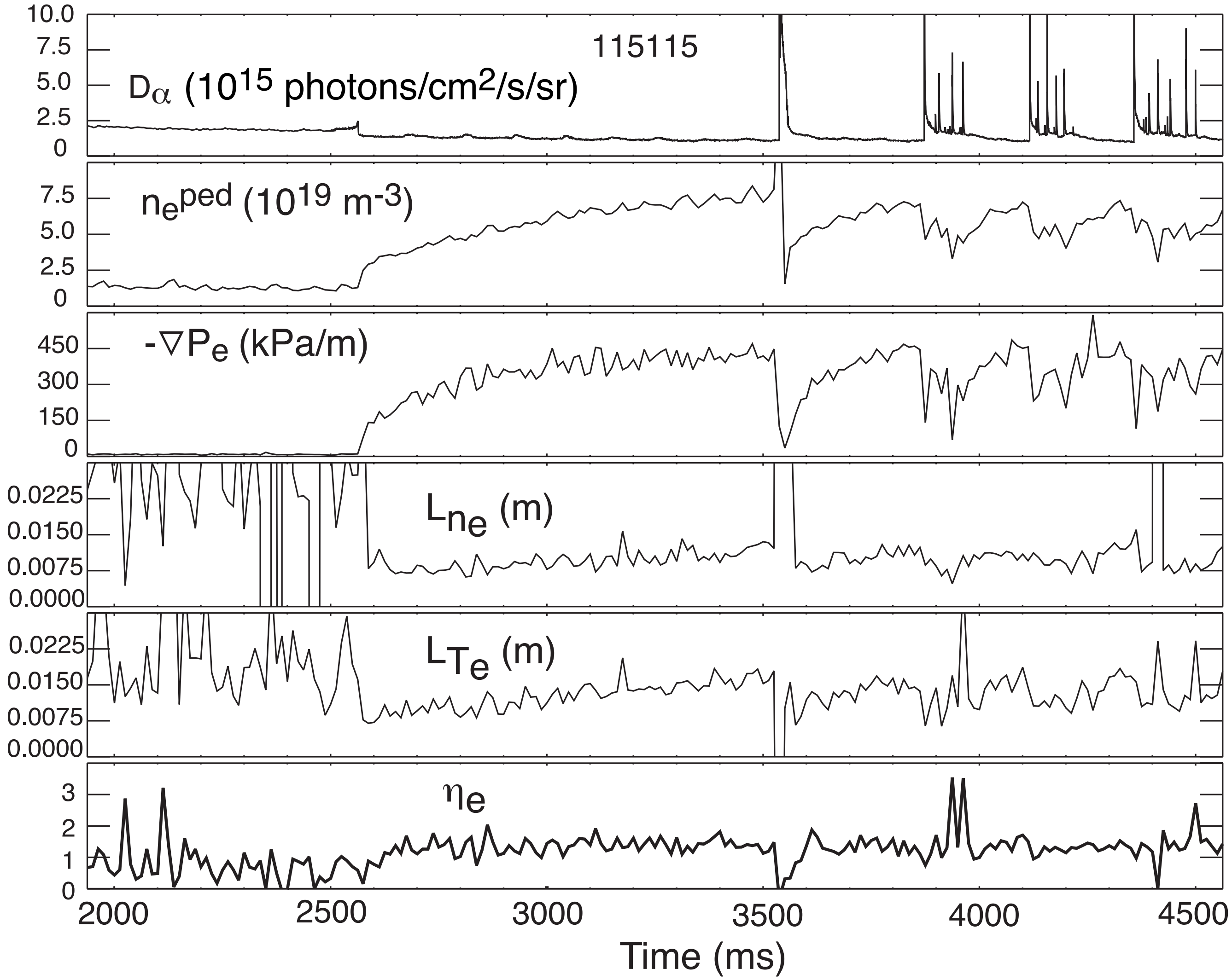
Picture of analysis technique

- Circles are data; solid lines are fits to data
- Region of steep density gradient is between knee and foot of the profile
- Steepest gradient is at symmetry point
- Coordinates are along Thomson chord



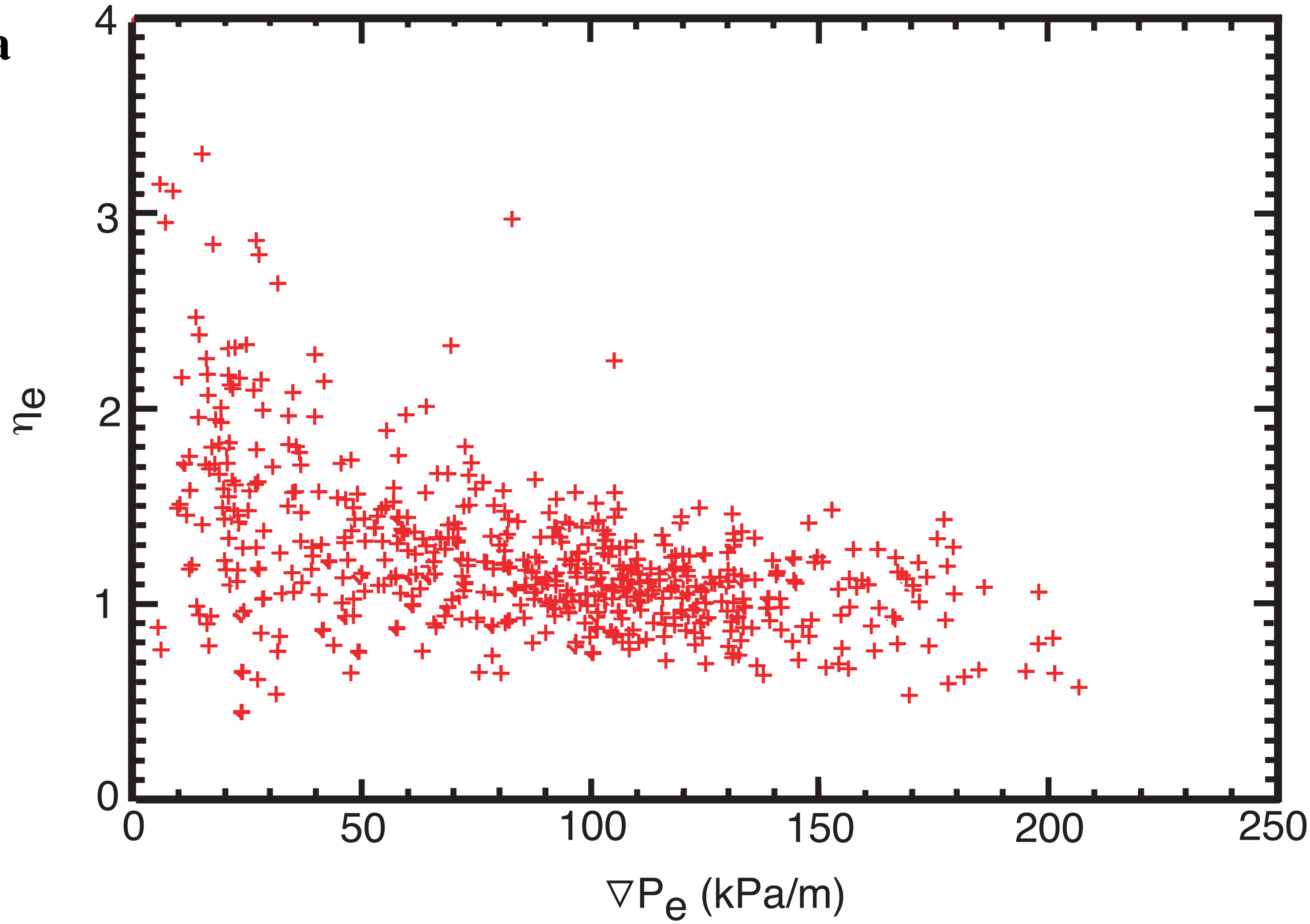
Results

Typical Waveform Showing Temporal Evolution of L_{n_e}, L_{T_e} and η_e



η_e Asymptotes to ~ 1 at Large ∇P

- Data are for a fixed discharge shape
- Cover a wide range of density, current and field
- Include two directions of ion ∇B drift



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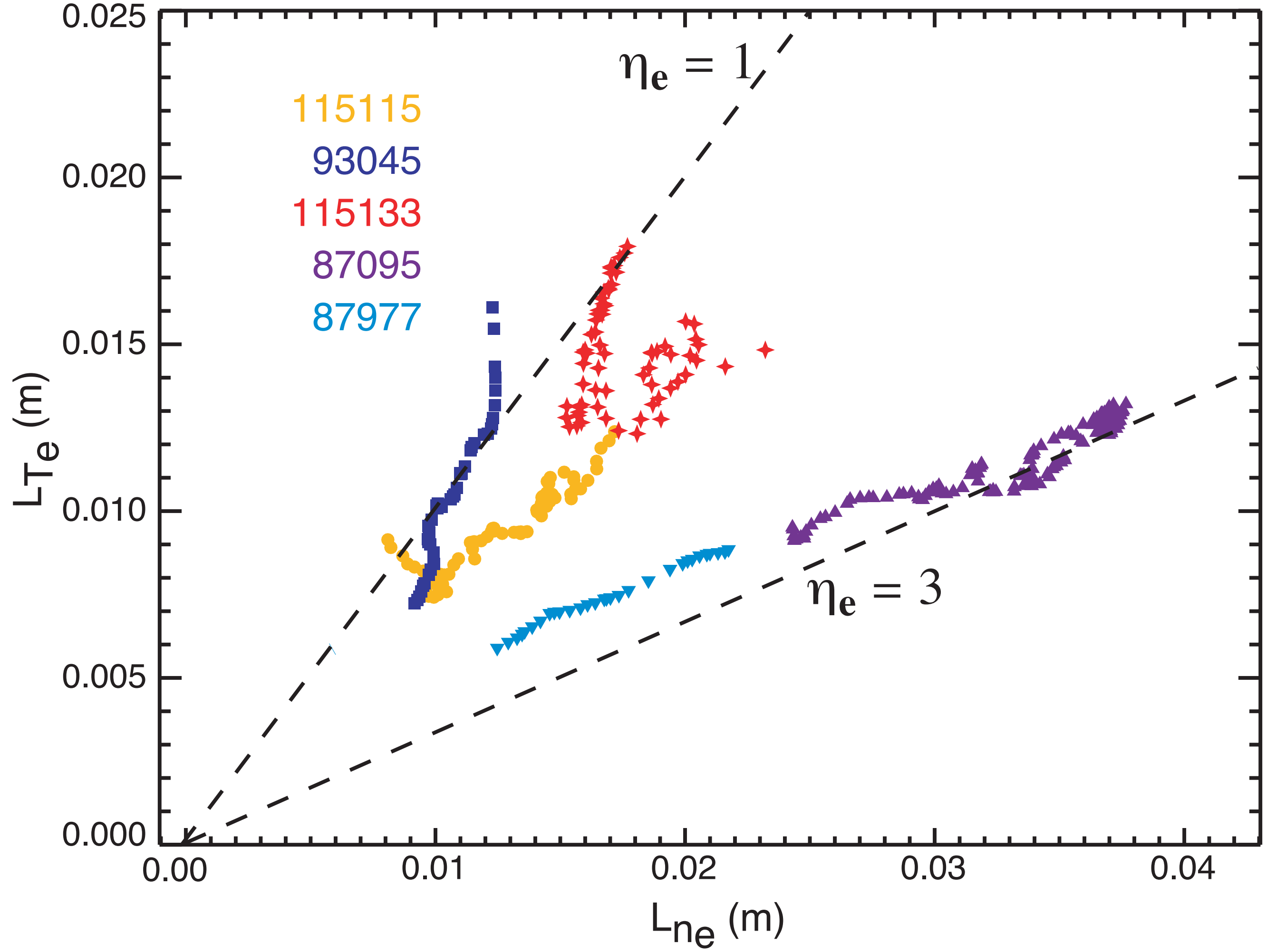
L_{T_e} is Roughly linearly related to L_{n_e}

- Data from ELM-free phases of discharges with a range of shapes
- 50 ms moving boxcar average has been applied to data



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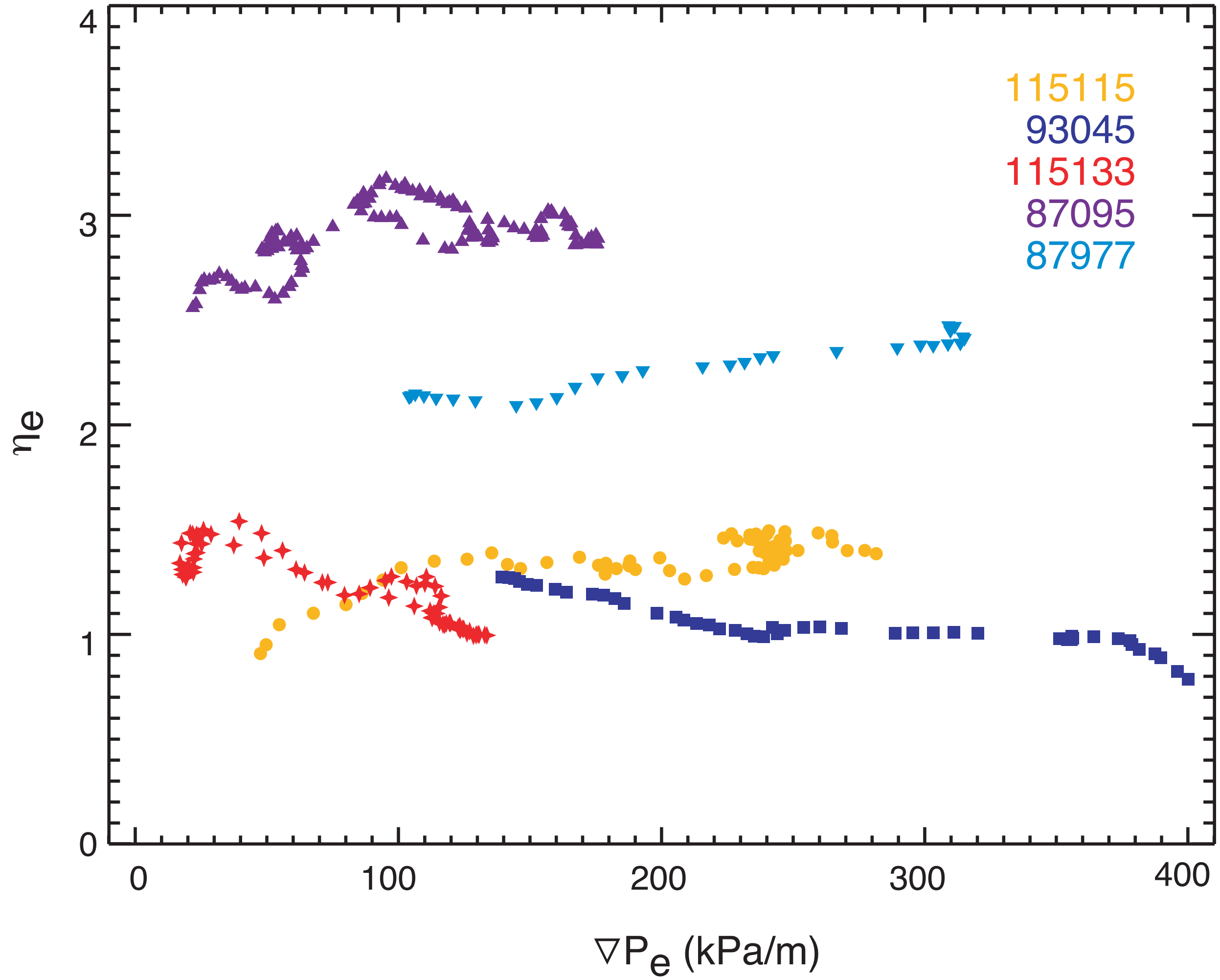
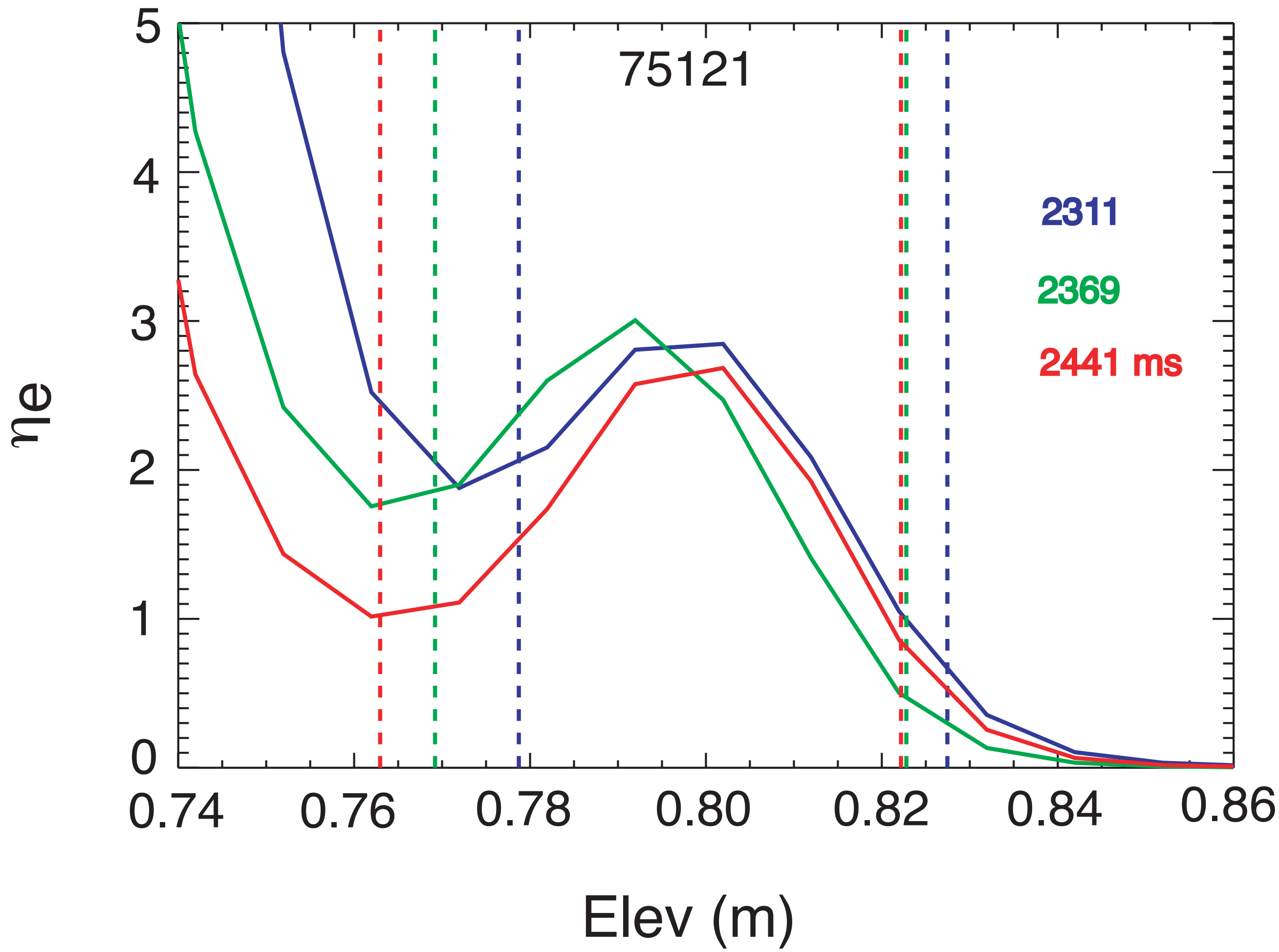
η_e is in range of ~ 1-3

- **Data are from survey shown in previous figure**
- **For a given discharge, η_e is approximately constant as ∇P_e varies**
- **Two discharges with highest η_e were high performance discharges in high δ, double null shape**



η_e Is In Range of 1-3 Throughout Pedestal

- A VH-mode discharge
- Dashed vertical lines show knee and foot of density profile at different times
- η_e is computed locally across the profiles from hyperbolic tangent fit



Summary/Conclusions

Summary

- Several empirical observations suggest that shapes of T_e and n_e profiles are related in H-mode barrier
- ETG theory has been used to design a survey of DIII-D data
- The results show evidence of:
  - Linear relationship between L_{T_e} and L_{n_e} at steepest part of density gradient
  - η_e is in range of ~1-3 at that location
  - η_e is in range of ~1-3 throughout density pedestal

Conclusions

- These data could be evidence that density profile has a strong effect on electron thermal transport
- ETG turbulence is a candidate for a mechanism that would have this feature
- Further studies await a model for ETG transport which is valid for pedestal conditions
  - Must explain the observed range of η_e