Comparison of Experimental H-mode Pedestal Widths in DIII-D to a Neoclassical Pedestal Model

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Presented at the
21st US Transport Task Force Workshop

Boulder, CO

25-28 March, 2008

DIII-D NATIONAL FUSION FACILITY

GENERAL ATOMICS

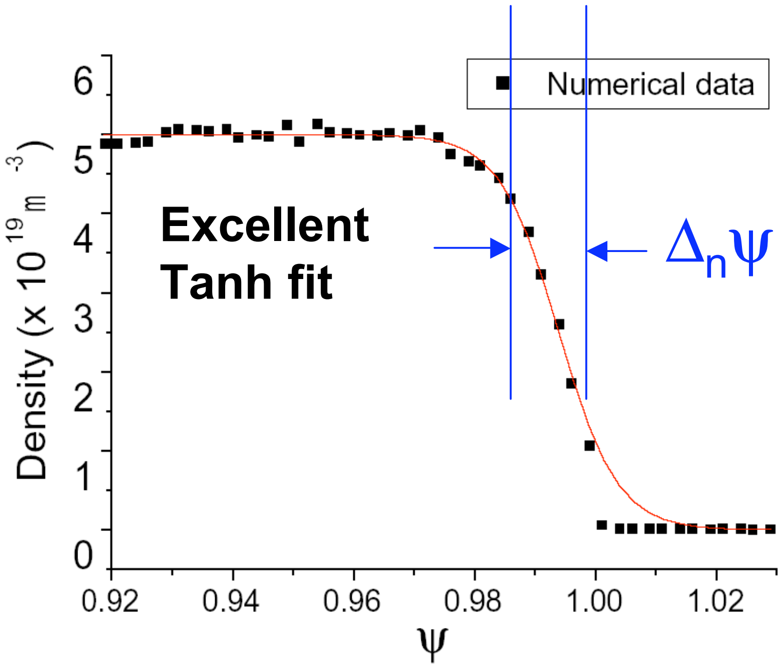
Overview and Motivation

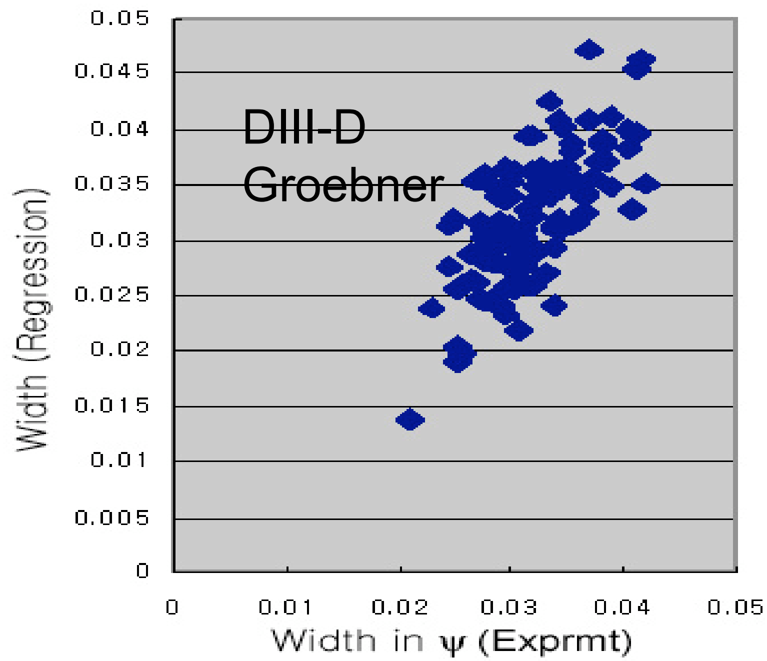
- **Understanding and predicting pedestal width remains an outstanding problem for confinement physics**
- **The XGC0 code has been used to develop a theoretical scaling for pedestal density width**
  - Chang, Ku, Weitzner PoP 11, 2649 (2004)
  - Chang, *et al.*, Bull. Am. Phys. Soc. 49, 314 (2004)
- **This scaling uses measurable quantities**
  - Therefore, it can be tested
- **Initial tests have been done of the scaling for purposes of "validation"**
  - That is, can we falsify the scaling?
  - Can model make useful predictions?

Experimentalist's Description of XGC0

- **Code solves ion thermal transport and ion particle transport equations**
  - Edge particle source is via a Monte Carlo neutrals model
  - Ion orbits are followed by a Monte Carlo guiding center model
  - Particle and heat losses are via ions leaving plasma due to orbits intersecting material surfaces
  - Realistic geometry used
  - When run to steady state, code predicts pedestal density and T_i profiles which look qualitatively like experiment
- **Many runs of code have been made to develop a scaling for width of pedestal density profile**
  - The result: $\Delta_n \propto M_i^{1/2} (T_i^{0.5}-0.23) / B_T$
  - Δ_n is ion density width in ψ_n, M_i is ion atomic mass, T_i is pedestal ion temp in keV and B_T is toroidal magnetic field in T

Density width is obtained from XGC0 output with same tanhfit, as used in experiment





XGC finds neoclassical density pedestal width scaling

$$\Delta_n\psi(\text{neo}) \propto \mathbf{M_i^{1/2}}\ \mathbf{(T_i^{0.5}\text{-}0.23)\ /B_T}$$

Regression fit on DIII-D data set gives

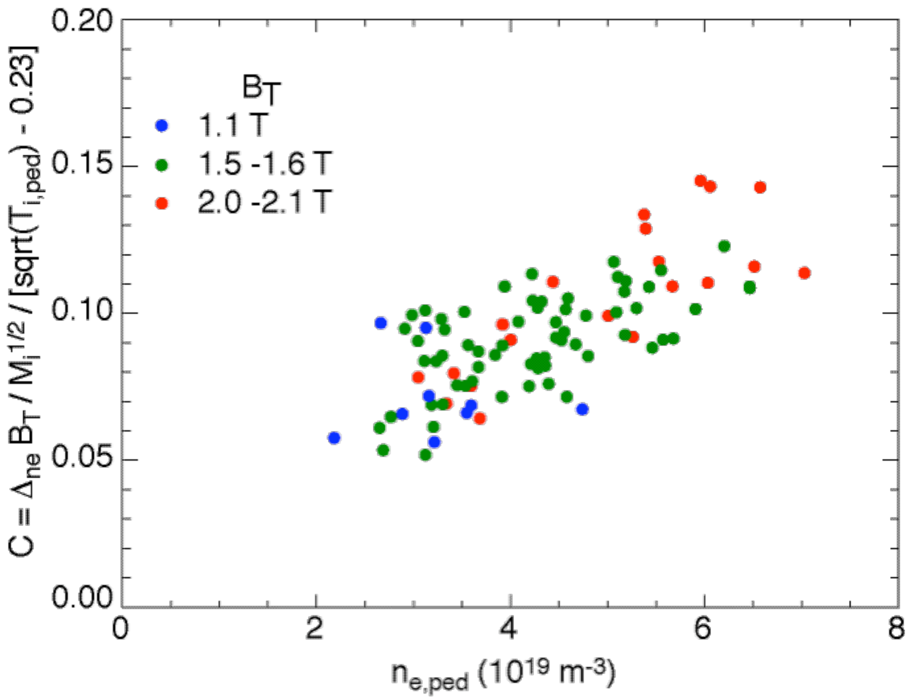
$$\Delta_n\psi(\text{exp}) = \mathbf{0.075\ (T_i^{0.5}\text{- }0.22)/B_T} + \mathbf{0.0092\ n/q95}$$

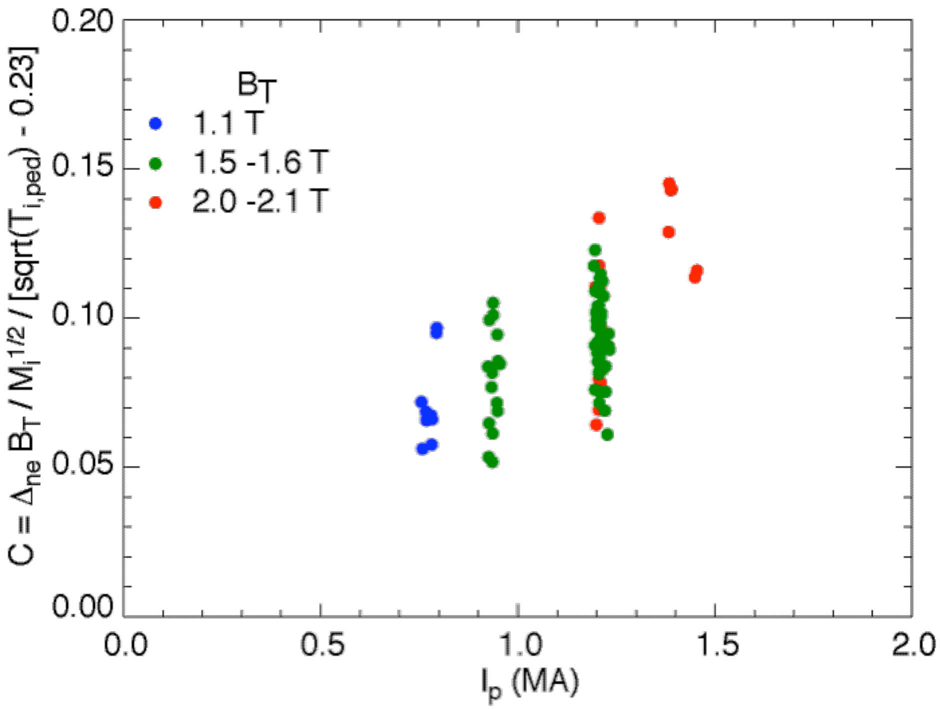
Viewgraph from
C.S. Chang

Experimental Procedure for Testing

- **Assemble data set for a range of $T_{i,ped}$, $n_{e,ped}$, I_p, B_T**
- **Use data from plasma shape very similar to shape used for model development**
  - It would seem that details of plasma geometry and even position within the tokamak could be important
- **Use data from ELM-free H-mode**
  - Model not designed to deal with ELMs
  - Moreover, ELM-free H-mode gives a wide range of pedestal parameters and highest temps that we see in an H-mode
- **Parameter evaluation**
  - Use electron density width as proxy for ion density width
  - Use measured $T_{i,ped}$

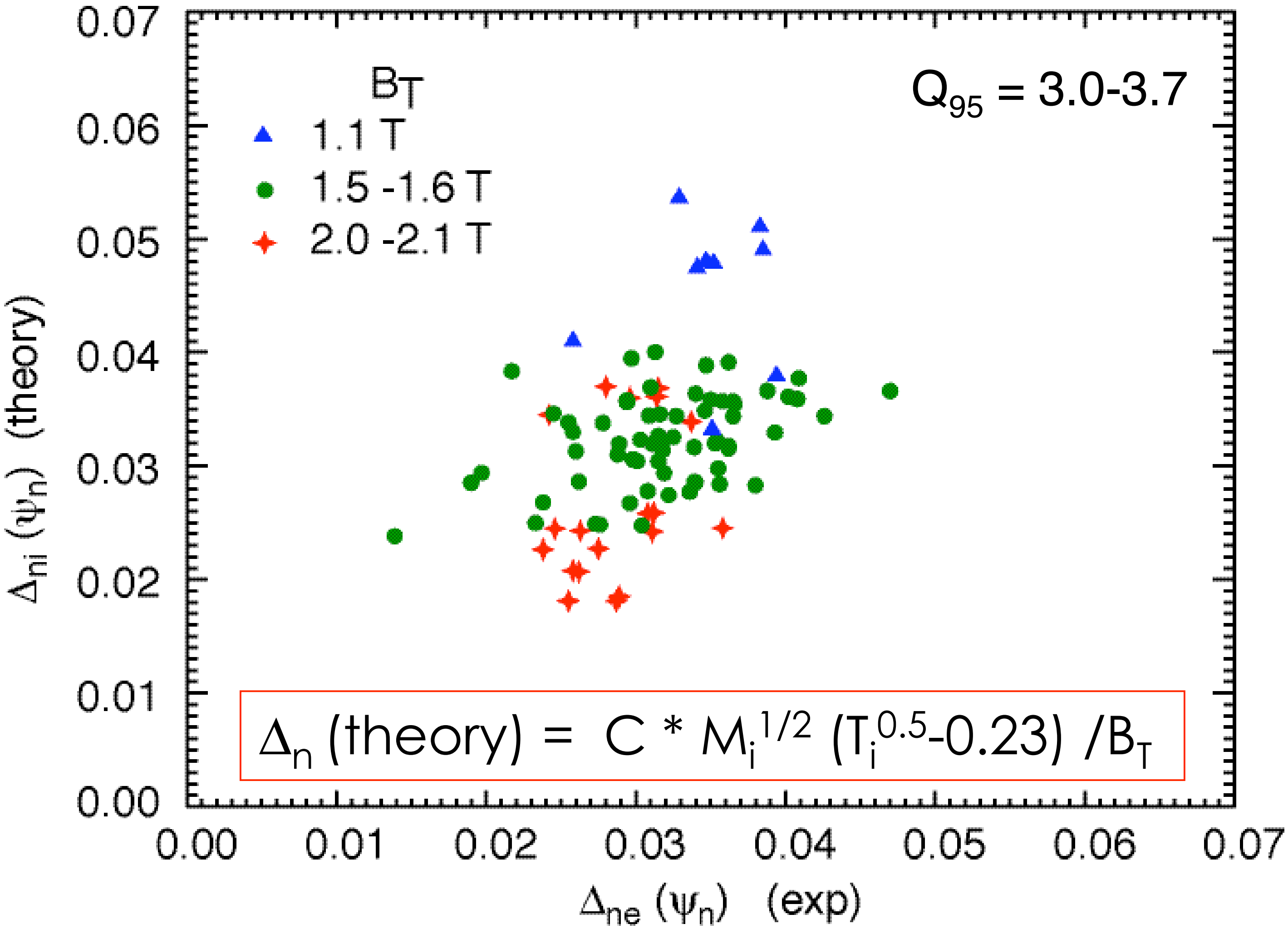
Estimate of C can be obtained from data. In dataset, C shows some variation with $n_{e,ped}$ and I_p



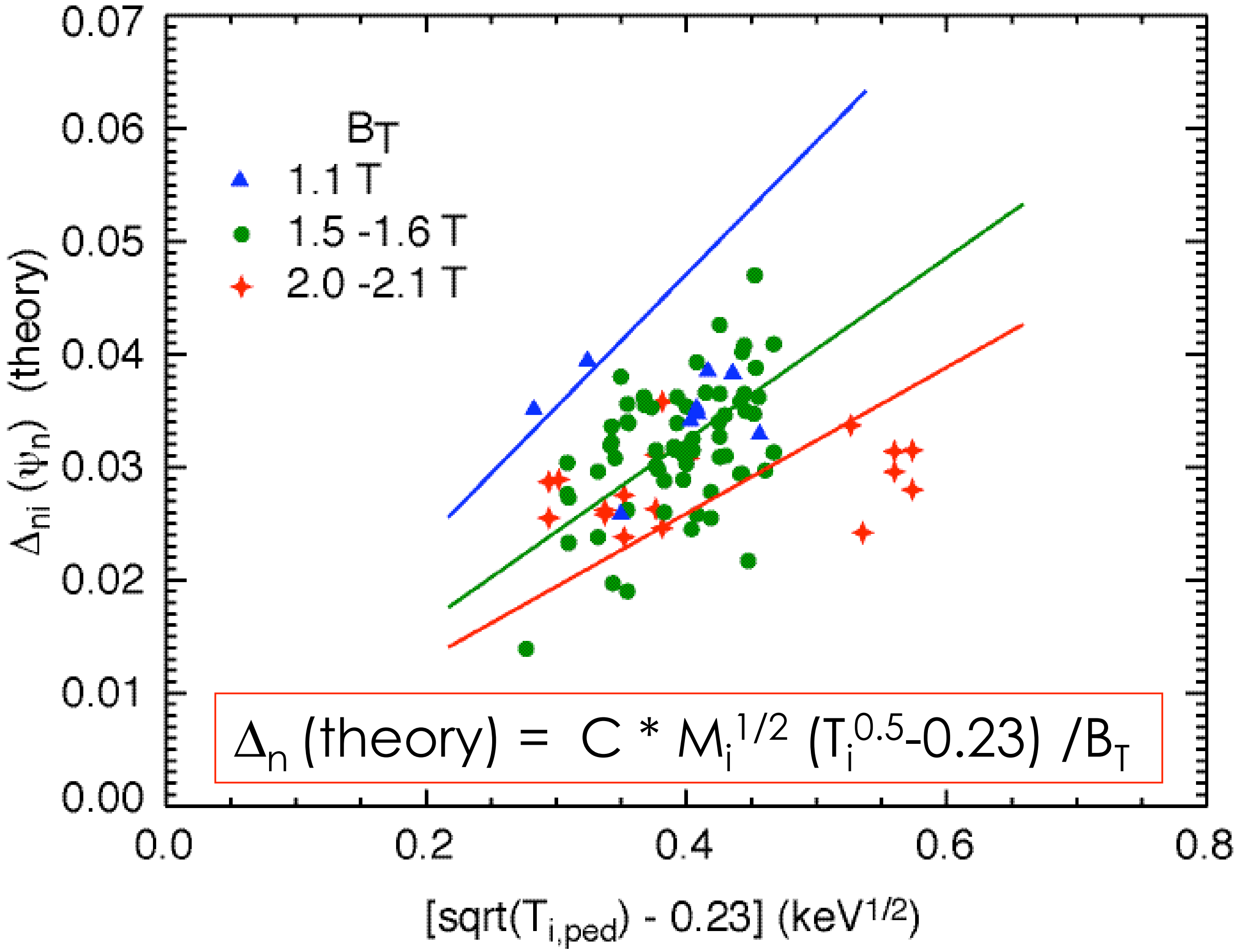


- C is determined for each experimental data point from $C = \Delta_{ne} * B_T / M_i^{1/2} / (T_i^{0.5} - 0.23)$
- For perfect agreement between data and model, would need C to be independent of $n_{e,ped}$ and I_p

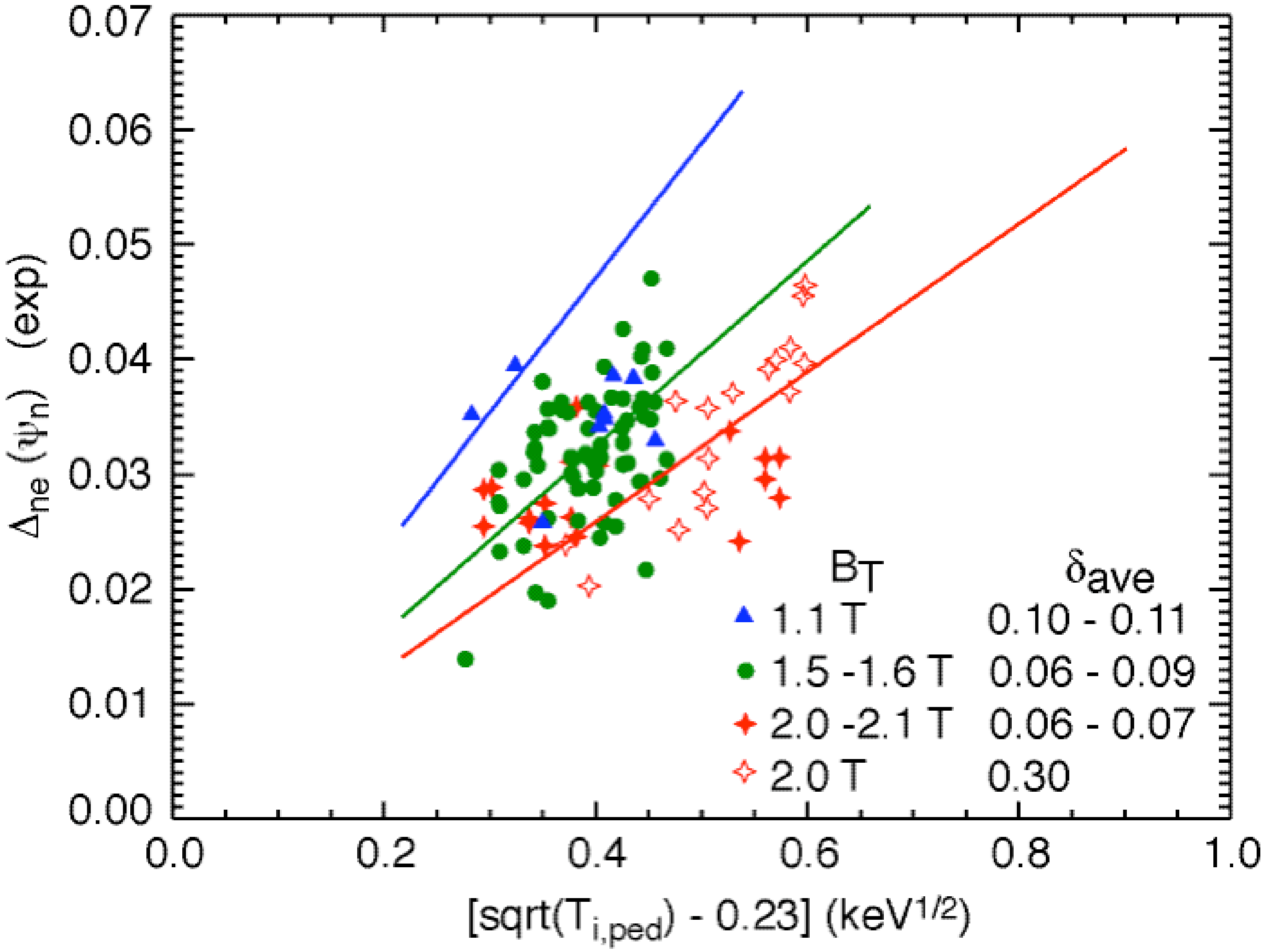
A single constant C for further study is taken as average of Δ_{ne} * B_T / $M_i^{1/2}$ / $(T_i^{0.5}-0.23)$ for all data.



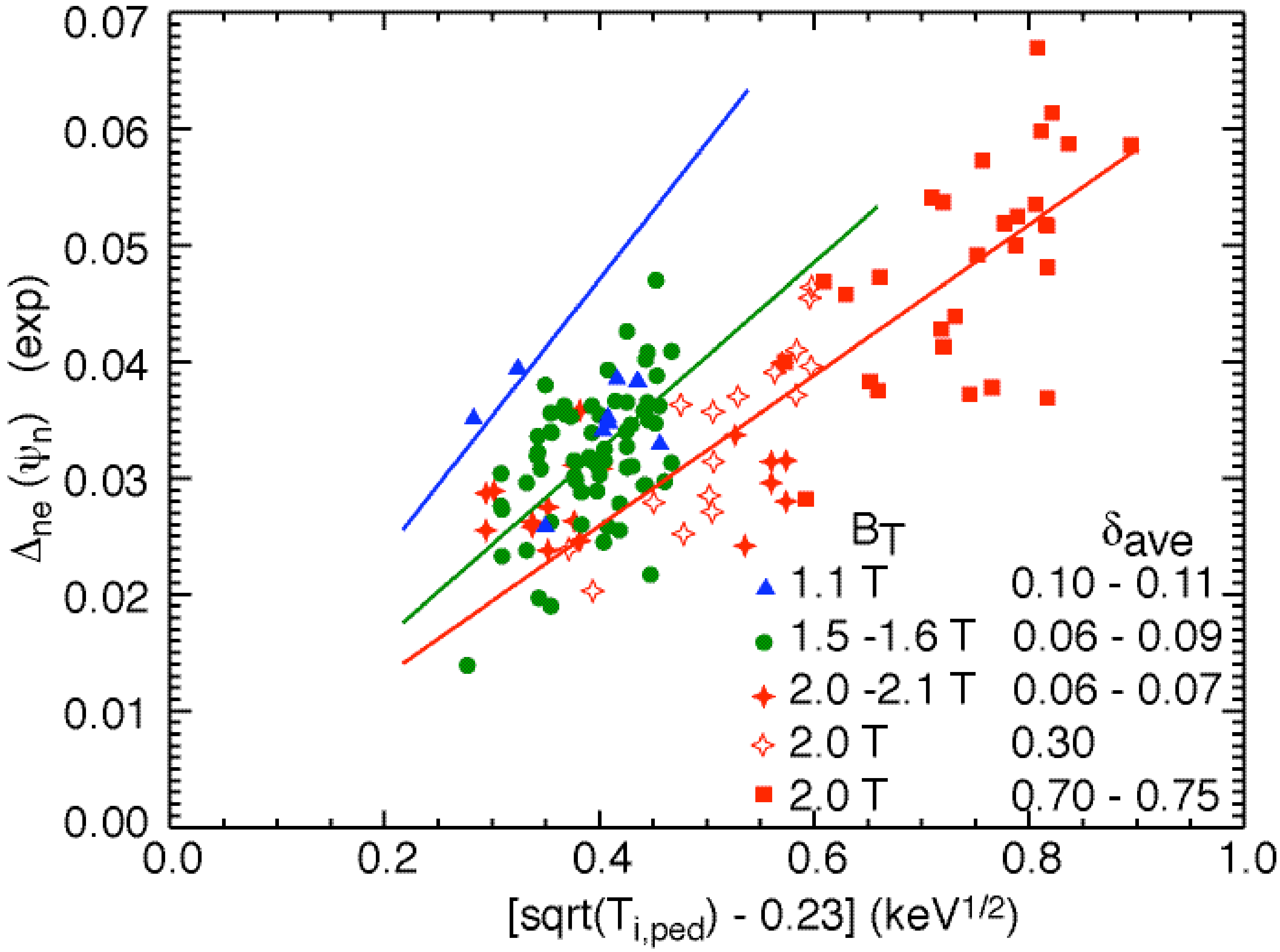
For a fixed B_T, model predicts $\Delta_{ne} \propto (T_i^{0.5}-0.23)$. Look for this dependence for different B_T.



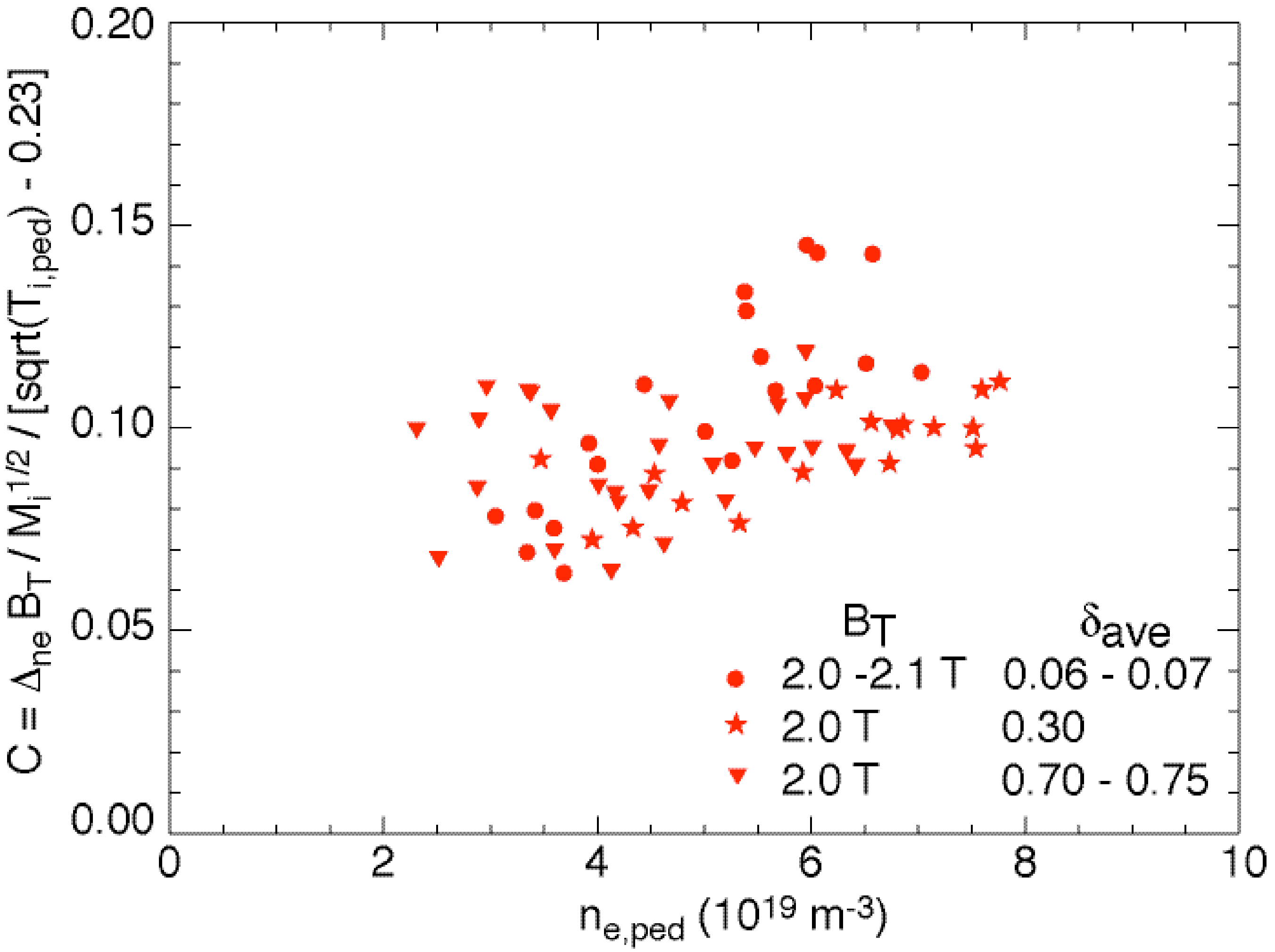
Data from higher triangularity plasmas extends $T_{i,ped}$ range. Widths at 2 T fall along predicted trend.

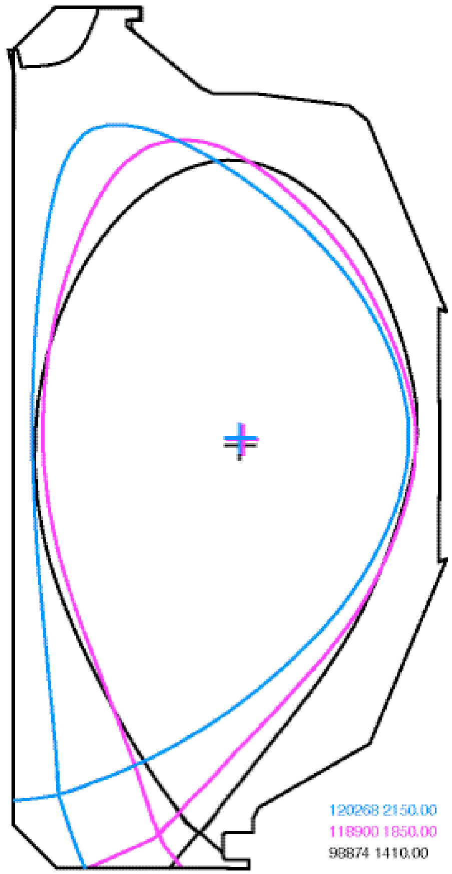


Data from VH-modes extend $T_{i,ped}$ range even further. These widths also fall along prediction for B_T = 2 T.

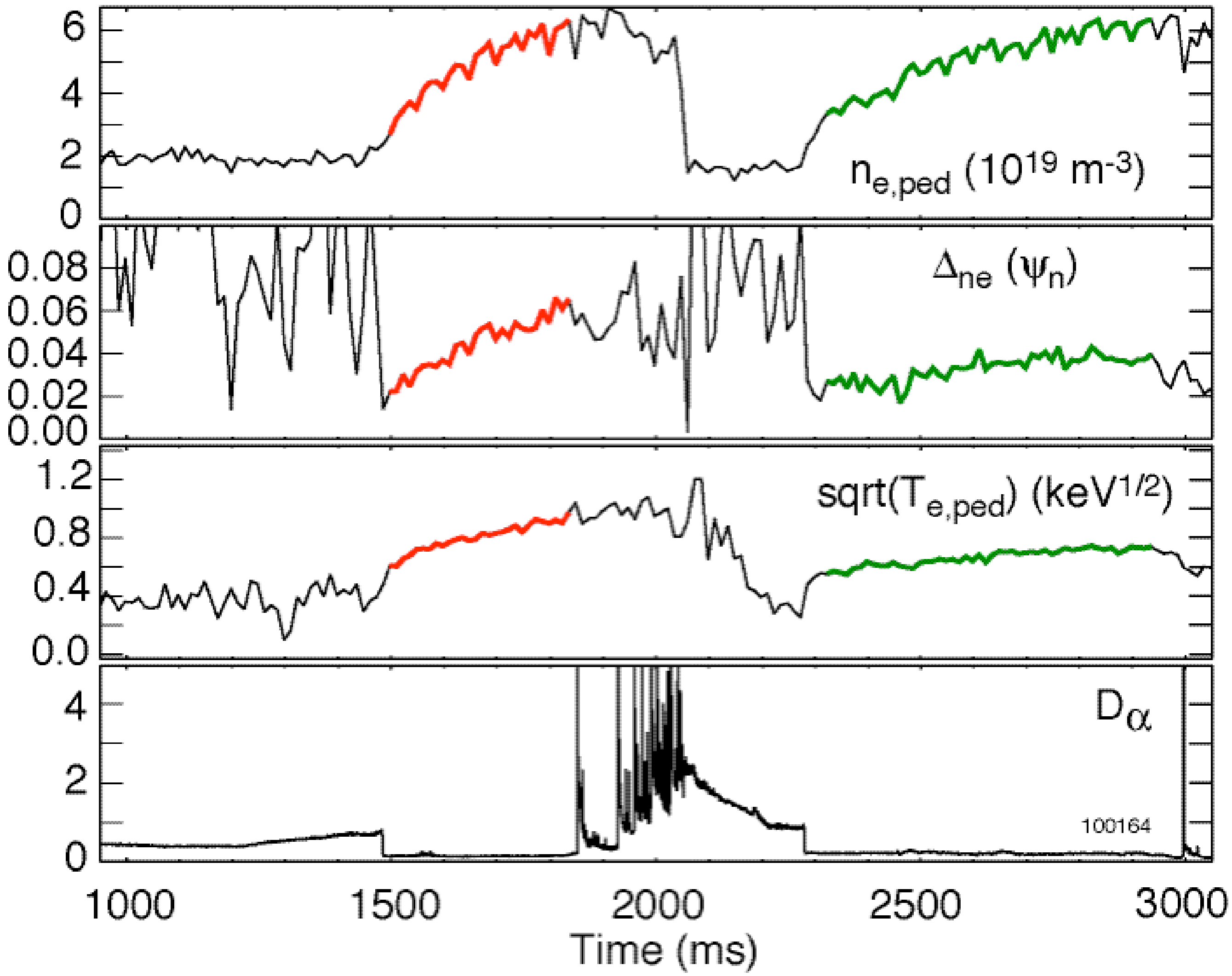


The constants obtained from full 2T data set show weak trend with $n_{e,ped}$. Is shape change an issue for theory?

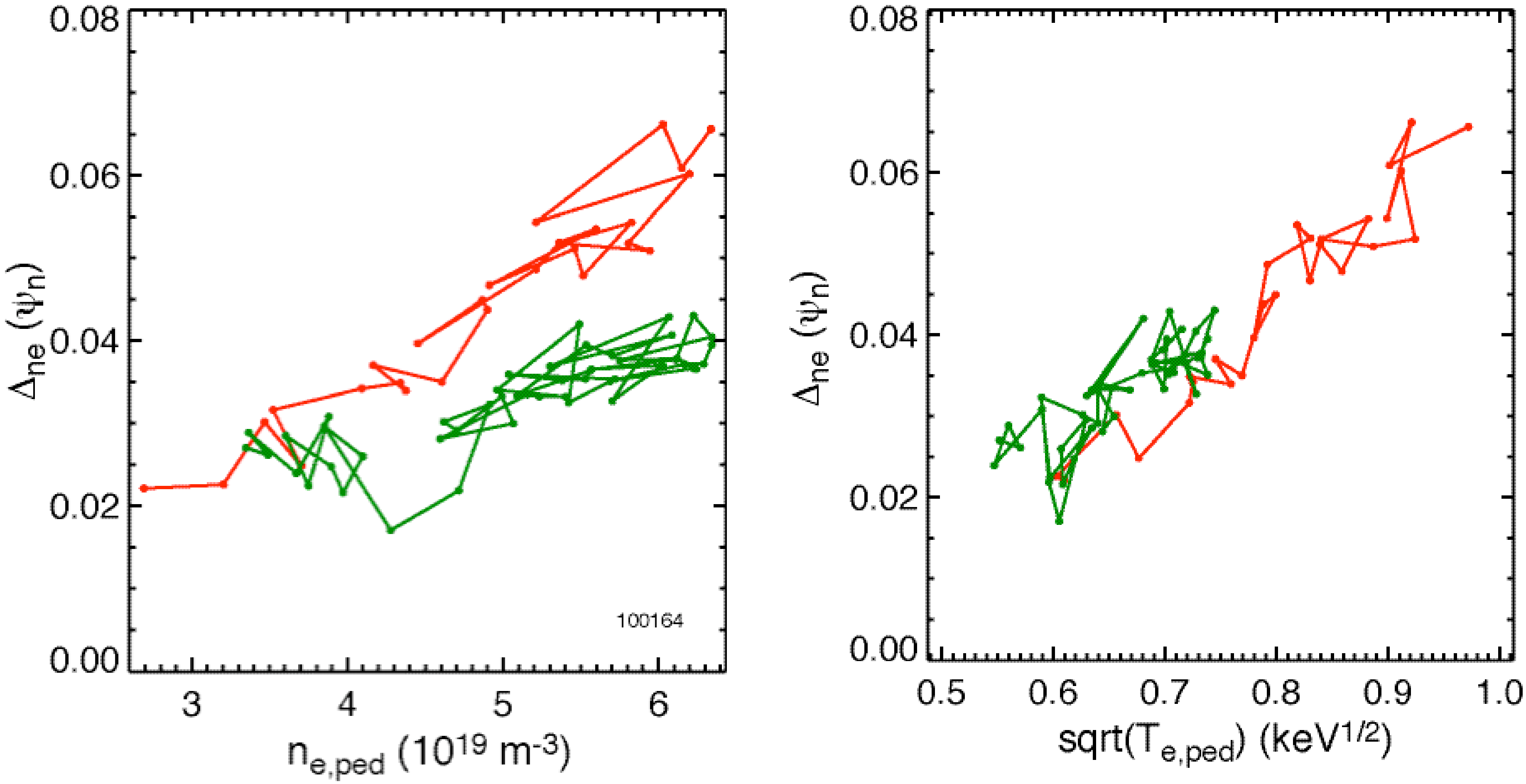




Δ_{ne} , $n_{e,ped}$ and $T_{e,ped}$ are correlated - all increase with time during ELM-free phases of H-mode



Δ_{ne} correlates better with sqrt ($T_{e,ped}$) than with $n_{e,ped}$



Data are from two phases of ELM-free H-mode in same discharge

Conclusions

- **Initial tests have not falsified the neoclassical pedestal model**
  - In fact, this study provides strong evidence that there is a correlation between Δ_{ne} and $T_{i,ped}$
  - Cannot rule out possibility for correlation with $n_{e,ped}$ or I_p
  - Insufficient B_T range to test B_T predictions
- **This model predicts that Δ_{ni} scales approximately as ion toroidal gyroradius ρ_i**
- **Similar predictions are made by very different models**
  - ExB shear suppression models of pedestal tend to predict dependence of pedestal width on power of ρ_i or $\rho_{I,\theta}$
  - E.g., Kotschenreuther et al., 1996 IAEA
- **Big caveat: Despite the results shown here, pedestal width at ELM-crash in DIII-D does not show ρ_i dependence**

Discussion - how do we move forward?

- **Experiment**
  - Data scatter can be improved via averaging techniques
  - Need to obtain data over a wider range of B_T
  - Need to make similar studies for wider range of I_p
  - Make measurements for different ion mass (hydrogen)
  - But, how do we distinguish between radically different models which make essentially the same prediction?
    - i.e., a model with no turbulence versus a model with turbulence and ExB shear suppression
- **Neoclassical model**
  - Would be good to know sensitivity of prediction to plasma shape
- **Turbulence models**
  - Need predictions which are more specific about which "width" to test and about model dependence on ρ_i or $\rho_{i,\theta}$