Comparison of Analytic Model for Density Profile to UEDGE Simulations*

R.J. Groebner, N.S. Wolf, G.D. Porter,
M.A. Mahdavi, R.L. Boivin,
A.W. Leonard, T.H. Osborne

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Key Points

- Plasma density and neutral density must obey continuity equations
- These equations have been used to derive a simple analytic model for edge density profiles
- Simple model is consistent with several features of edge density profiles in DIII-D - widths and gradients
- Here, model is compared to the far more sophisticated neutrals model in the UEDGE code
- Agreement between the two models is reasonable
  - Widths agree within better than 30% - gradients within factor of two

An Analytic Model Is Formulated to Relate Pedestal Width to Pedestal Height

$$\partial n / \partial t + \nabla \bullet \Gamma = S$$

$$\Gamma_e = D dn_e / dx \qquad \Gamma_n = n_n V_n$$

$$n_e(x) = n_{e,ped} \tanh[C - x / \Delta_{ne}]$$

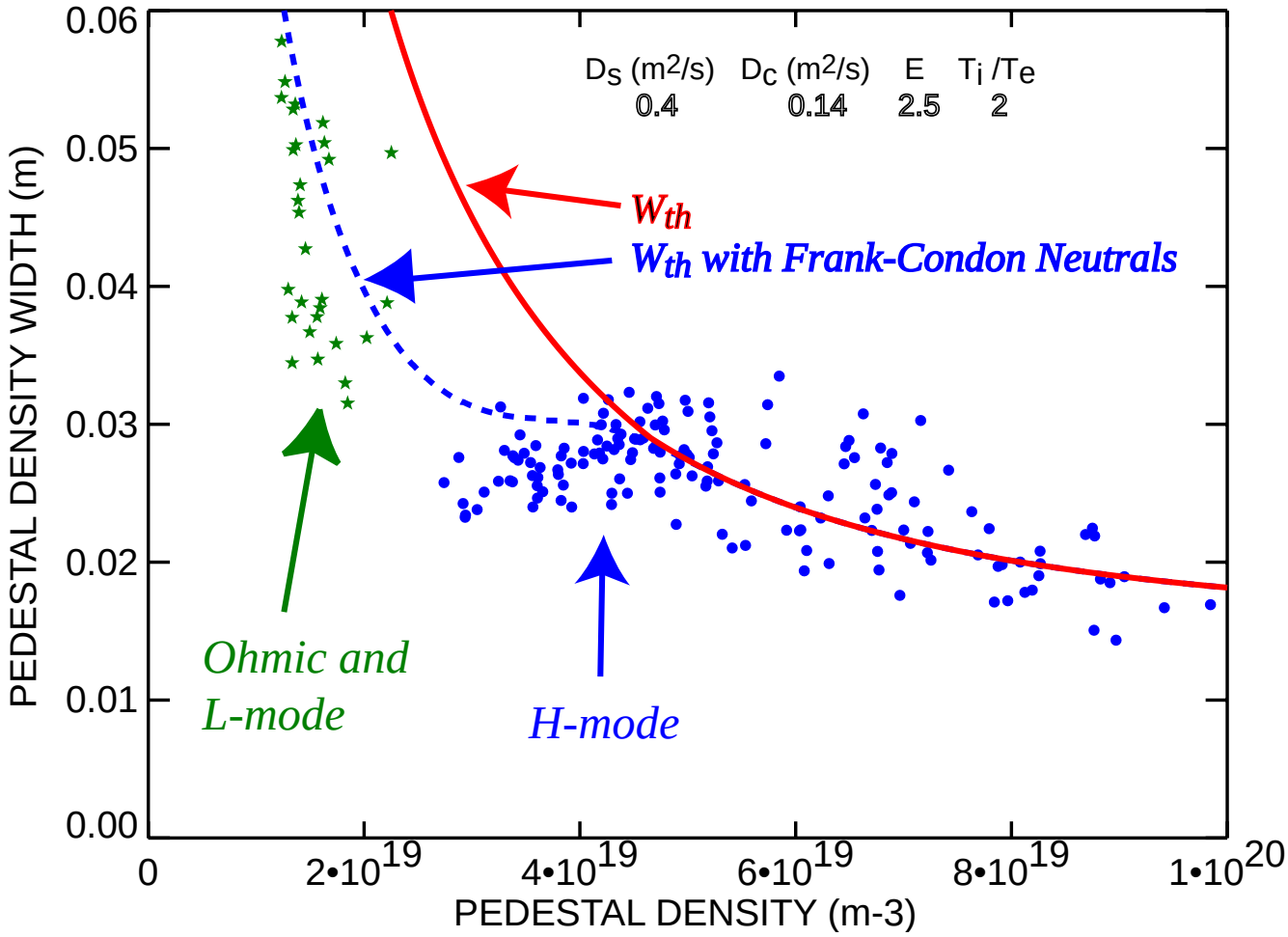
$$C = 0.5 \sinh^{-1}(U) \qquad U = \left[\sqrt{D_s \tau_{\|}}\, \sigma_i V_e / V_n\right] E n_{e,ped} D_c / D_s$$

$$\Delta_{ne} = 2 V_n / (\sigma V_e E n_{e,ped})$$

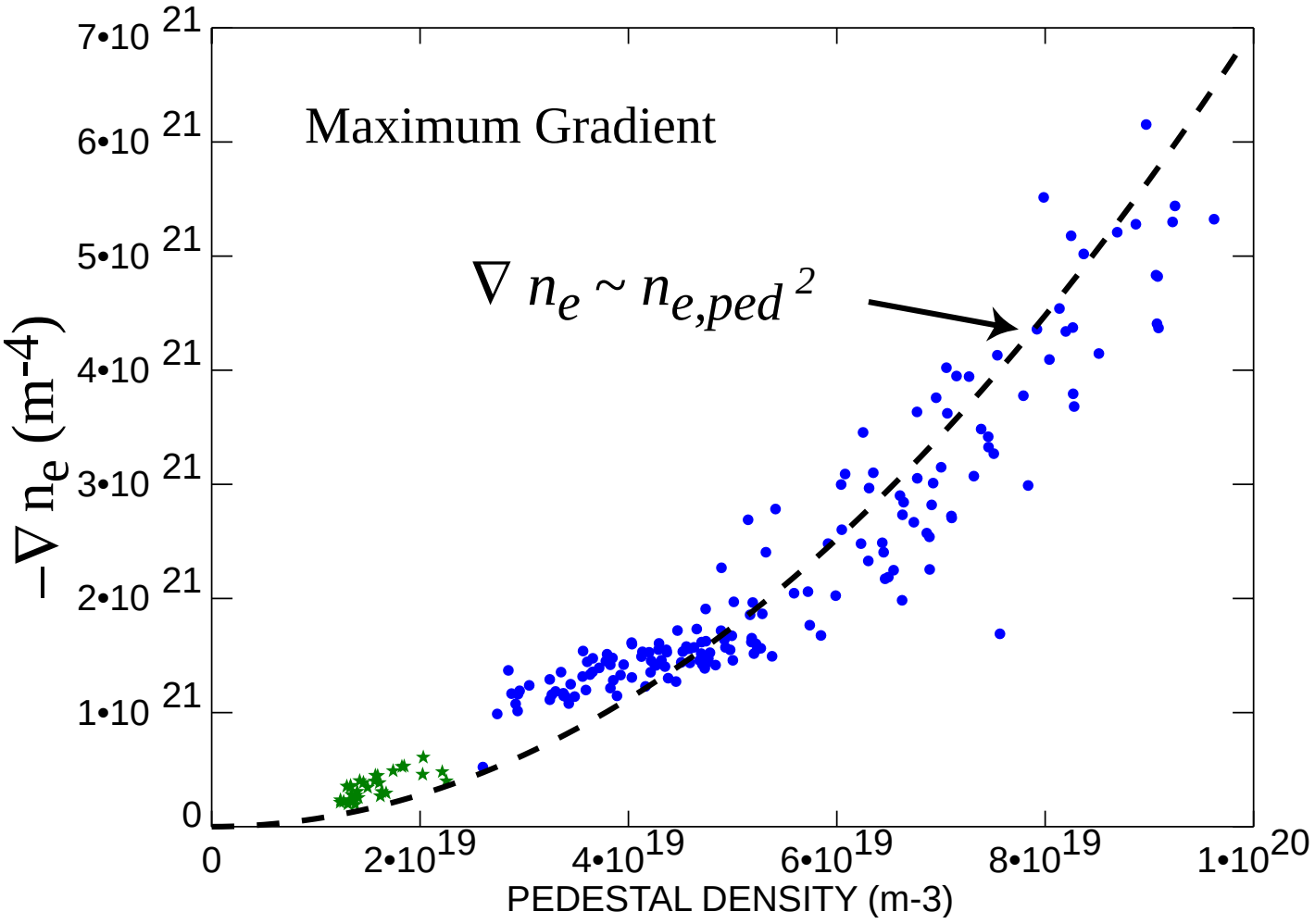
Steady-state, slab geometry, fuelling assumed to be localized poloidally, flux surface expansion accommodated, separate but fixed D in SOL and core, profile effects neglected, neutral collisions neglected, T_d taken as 0.5 T_i, impurities neglected, pinch neglected, neutrals assumed to be equilibrated with ions, dependence of ionization cross section on temp neglected, model valid for temp in range 0.02 - 0.3 keV

Model Predicts Qualitative and Quantitative Dependence of Experimental Width W_{ex} on $n_{e,ped}$

- Theoretical width W_{th} is defined to emulate W_{ex}
- W_{th} is distance from 12% to 88% of $n_{e,ped}$ in model function
- Parameters in model are typical values



Model Predicts The Qualitative Dependence: Maximum $\nabla n_e \sim n_{e,ped}^2$ *(limit of* $n_{sep} = 0$*)*



UEDGE is a Sophisticated 2-D Edge Modeling Code

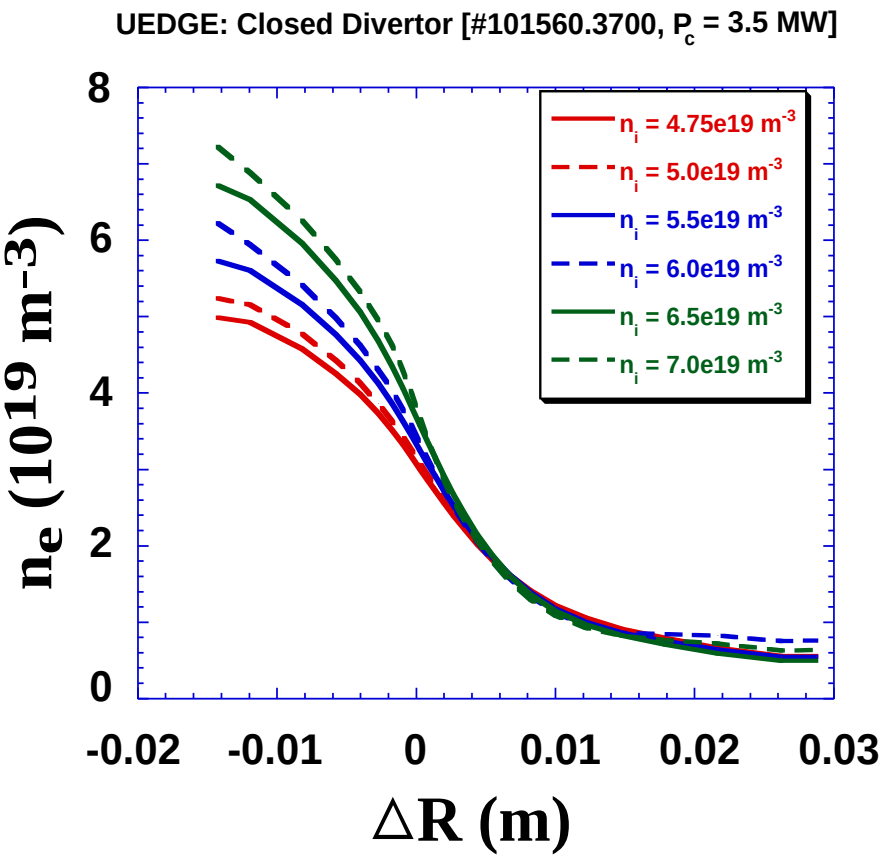
- **UEDGE solves fluid equations in 2-D**
  - **Models from typically ψ_n = 0.98 to divertor plate**
- **Obtains profiles of temperature, density and velocity for a multi-species plasma with neutrals**
  - **Anomalous perpendicular transport is specified**
  - **Classical transport parallel and perpendicular to B**
- **Neutral transport treated with a fluid model**
  - **Navier-Stokes model coupled to ion parallel flow via CX**
  - **Perp transport is diffusive, arising from CX and neutral-neutral collisions**
- **Neutral source from recycling, beams and impurities**

Technique for Comparing UEDGE and Analytic Model

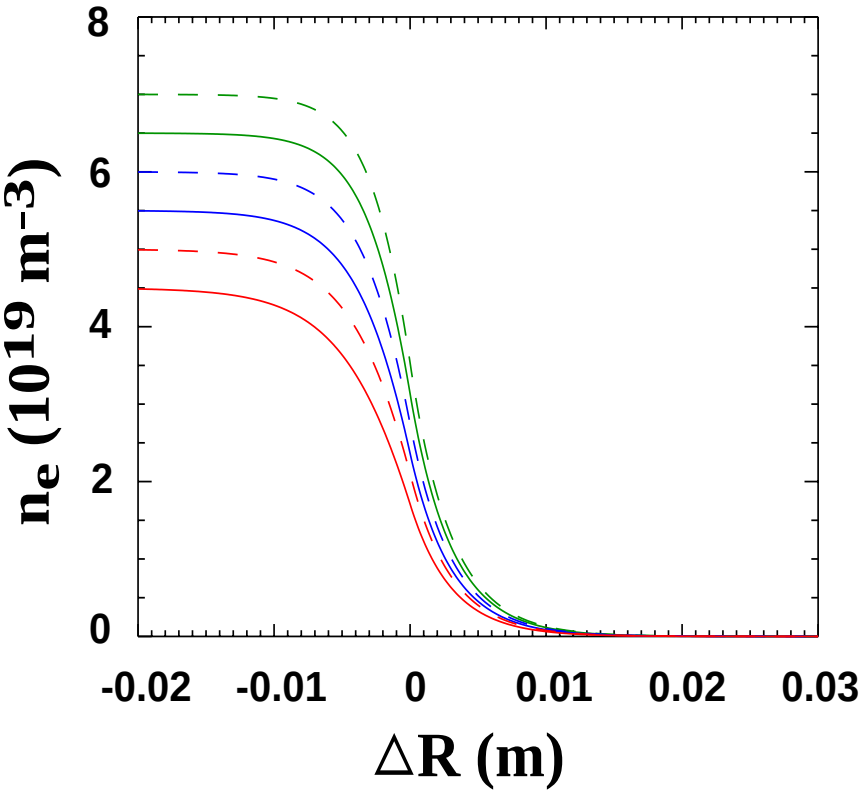
- **Scan of pedestal density was performed with UEDGE with other parameters constant**
  - **Fixed plasma shape, current and field**
  - **Fixed beam power, heat and particle diffusion coefficients**
- **Scan of pedestal density was performed with analytic model with input parameters taken from UEDGE**
  - ***D = 0.075 m^2/s (SOL and core)***
  - ***E = 7.2 (7.0 - 7.7 in UEDGE)***
  - ***T_i = 0.15 keV (0.11 - 0.18 in UEDGE)***
- **Compare density profiles, widths and gradients**

Comparison of Density Profiles from UEDGE and Analytic Model

UEDGE



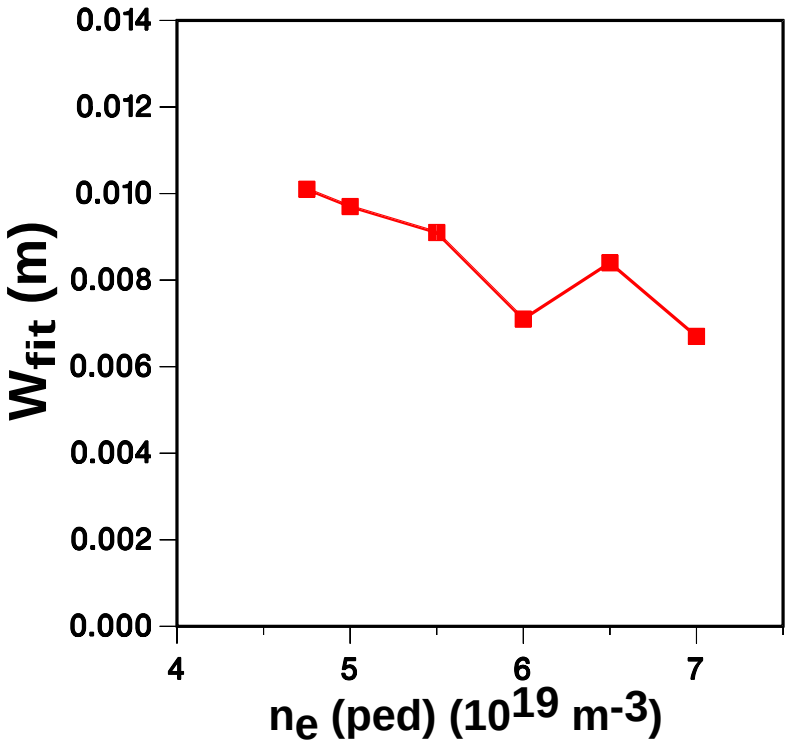
Analytic Model



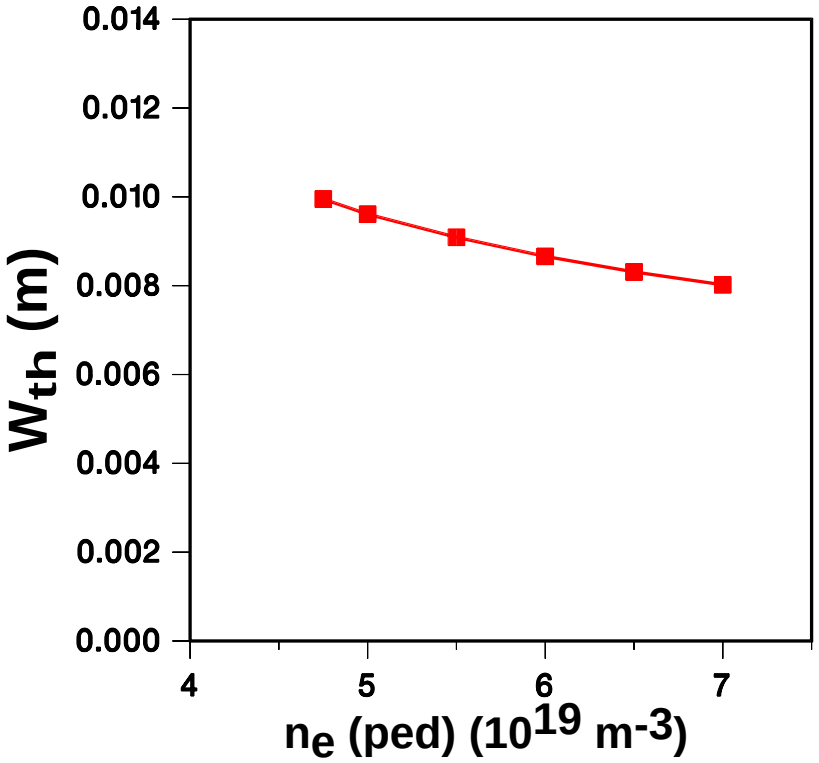
Comparison of Widths from UEDGE and Analytic Model

UEDGE

(TANHFIT to model profile)

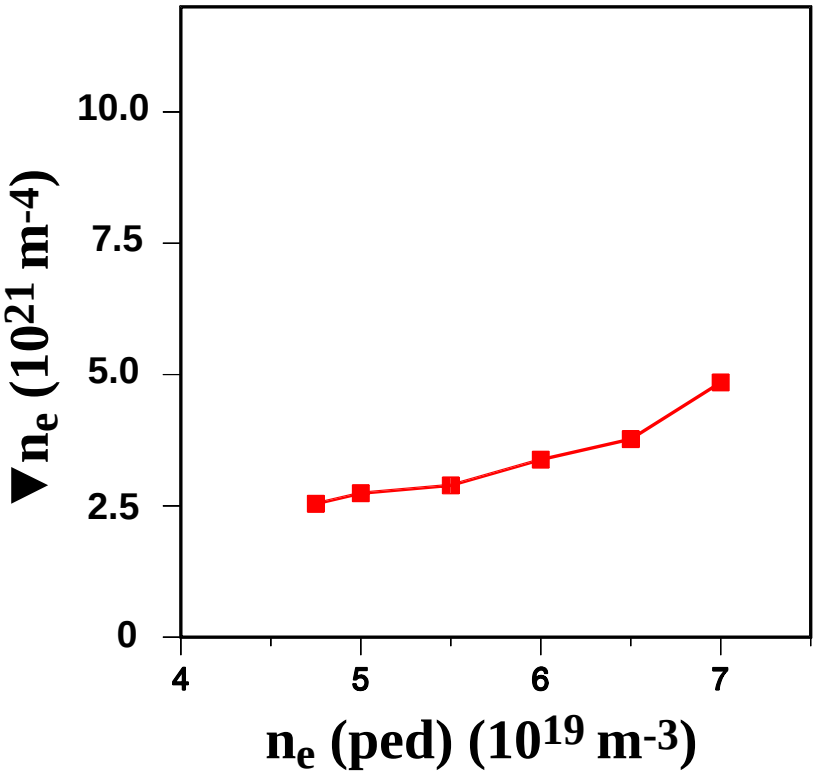


Analytic Model

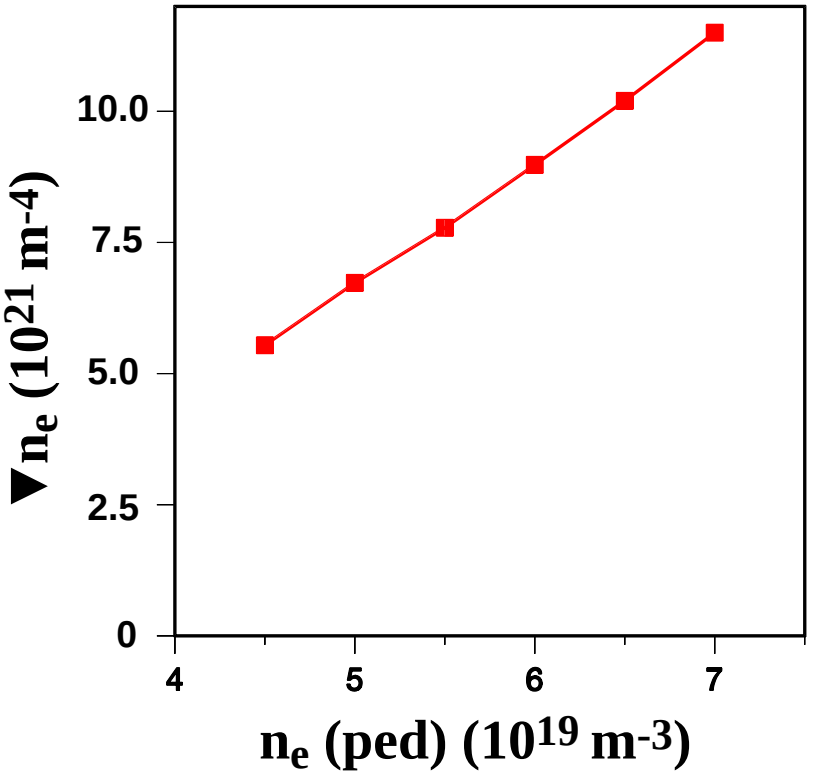


Comparison of Gradients from UEDGE and Analytic Model

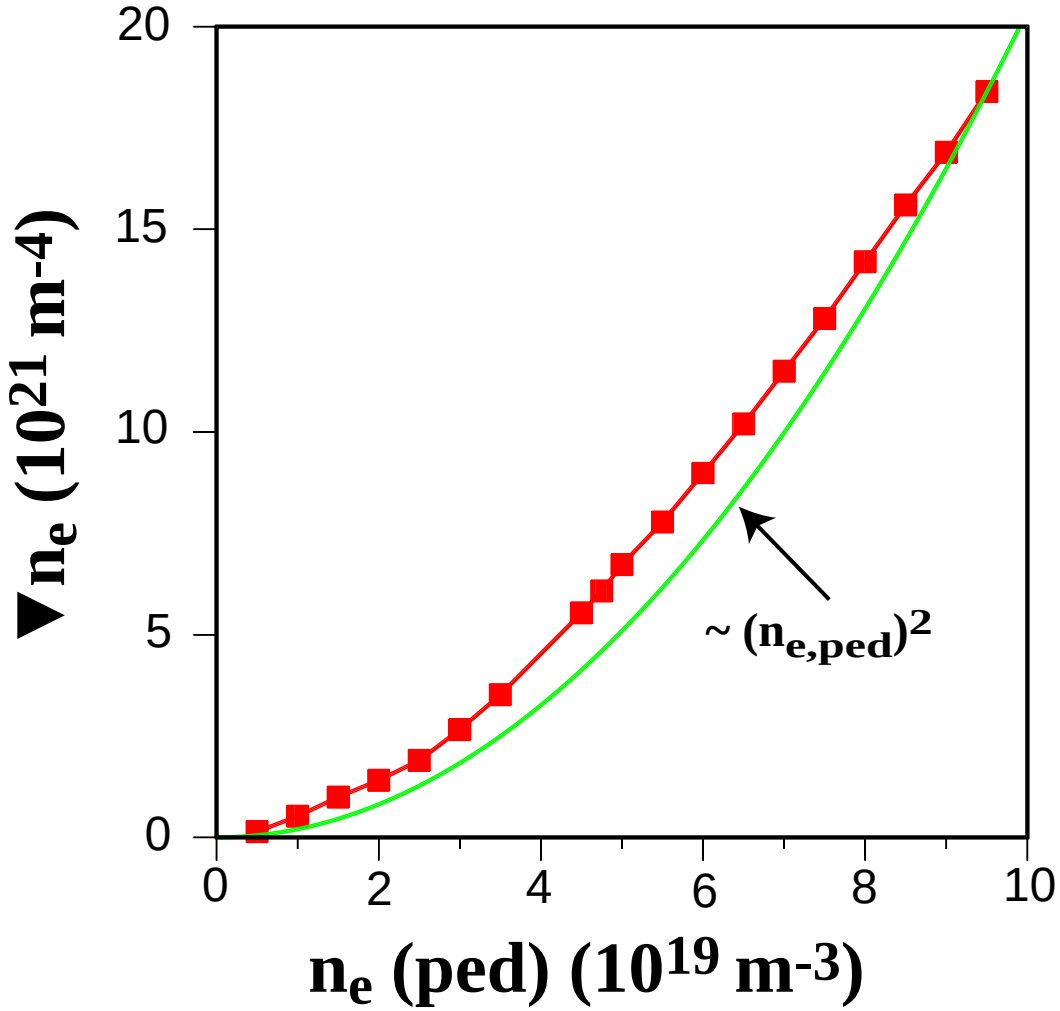
UEDGE



Analytic Model - *non-zero* n_{sep}



Gradients from Analytic Model with Non-Zero Density at Separatrix



Discussion

- **Both a simple analytic model and the sophisticated UEDGE model produce similar density profiles, for similar input parameters**
  - **Both models show a narrowing and steepening of n_e profile as $n_{e,ped}$ is increased**
  - **Widths are within ~ 30% or less, gradients within ~ factor of two**
  - **Results valid for low edge temperature (a few hundred eV or less)**
- **These results provide support for the use of the simple model to guide experiments and examine trends in the data**
- **The larger question remains: Does edge neutral source play a significant role in formation of H-mode n_e profile?**
- **Can we find ways in which the continuity equations are satisfied and the neutral source is not important?**