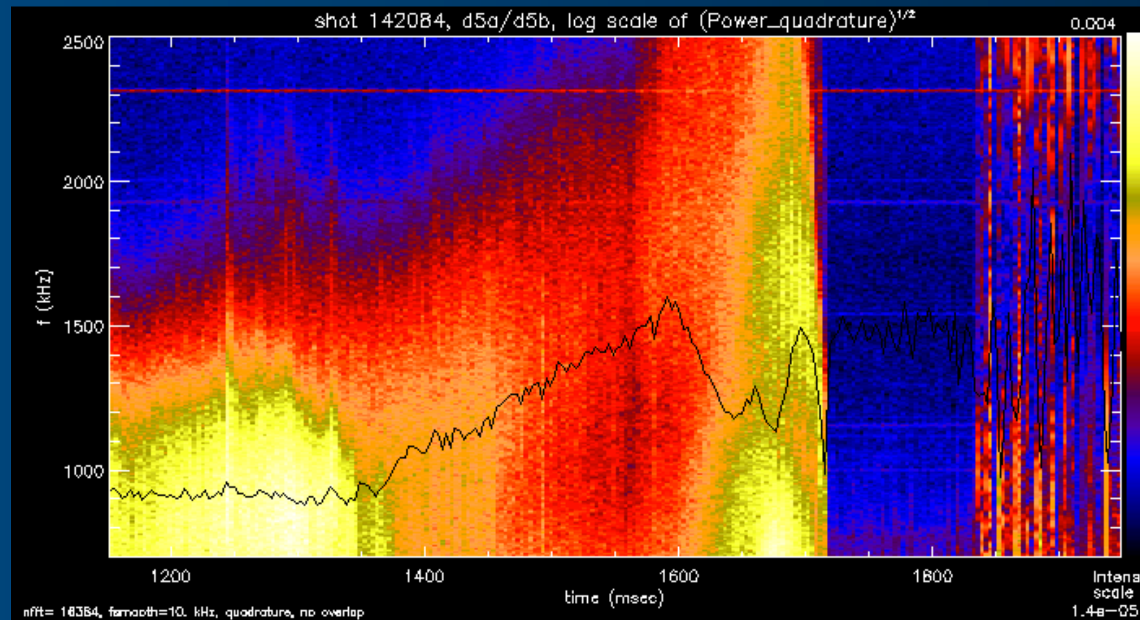
Development of Experimental Plan to Test Pedestal Physics Processes



R.J. Groebner, P.B. Snyder, T.H. Osborne, S.P. Smith, D.M. Thomas, R. Prater, T.L. Rhodes, L. Schmitz, Z. Yan, G.R. McKee, J.D. Callen, D. Eldon, R. Maingi, P. Diamond, J. Hughes, C.S. Chang, X. Xu

Presented at Joint US-EU Transport Taskforce Workshop TTF 2011
April 6, 2011

DIII-D NATIONAL FUSION FACILITY

GENERAL ATOMICS

Outline

DIII-D pedestal physics program for 2011 has been developed with a strong emphasis on testing and validating models of physics processes which potentially play important role in controlling pedestal structure

- **DIII-D research goals direct us to study theoretically-motivated pedestal physics processes**
- **Physics processes are identified from contemporary theory/modeling**
- **Existing observations/results help guide the planning process**
  - And, we either have or expect to soon have theory to make needed quantitative predictions
- **Four physics process have been selected for testing this year**
- **Tests for the various processes have been identified**

DIII-D Goals Point Us to Study Theoretically Motivated Pedestal Physics Processes

- **One year goal: Perform experiments to identify physics processes that are most likely to control pedestal structure**
  - In support of the "FY2011 DOE FES Joint Research Target on pedestal physics" and DIII-D FY2011 Milestone 176
  - JRT: "Improve the understanding of the physics mechanisms responsible for the structure of the pedestal and compare with the predictive models described in the companion theory milestone … "

- **Long term goal is a validated predictive model of pedestal structure**
  - Initial focus on pedestal pressure height (support ITER)
  - Predicting separate n, T, Ω profiles is also becoming an issue
    - Will recycling neutrals be able to fuel ITER's density profile?
    - Details of n and T profiles affect bootstrap current, ELM stability
    - Details of rotation are important for ITER, other machines
    - Validated models of n, T, Ω profiles needed for integrated modeling codes

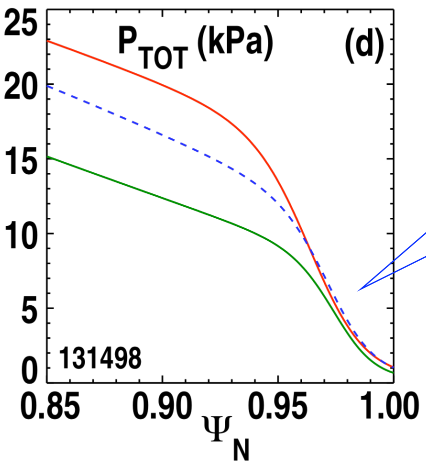
Current Theoretical and Modeling Work Suggest Several Physics Processes for Pedestal Structure - I

Models for Height	Physics processes
EPED	Kinetic ballooning; Peeling-ballooning
Callen model	Paleoclassical transport; ETG (at pedestal top)
Guzdar model	Double Beltrami states (ion skin depth); Infinite-n ballooning

Transport Codes/ Frameworks	Physics Processes
XGC0	Neoclassical ion transport (orbit loss); Neutral fueling
XGC1	ITG (pedestal top)
ASTRA	ETG; χ_e from paleoclassical
FACETS	Neutral fueling
TGYRO	ETG, KBM, neoclassical (NEO), other turbulence

Simulation Codes	Physics Processes
TGLF	Linear KBM, ETG, ITG/TEM,
GYRO, GS2, GENE, GEM	ETG, KBM, ITG/TEM, KH, μT ...

Current Theoretical and Modeling Work Suggest Several Physics Processes for Pedestal Structure - II

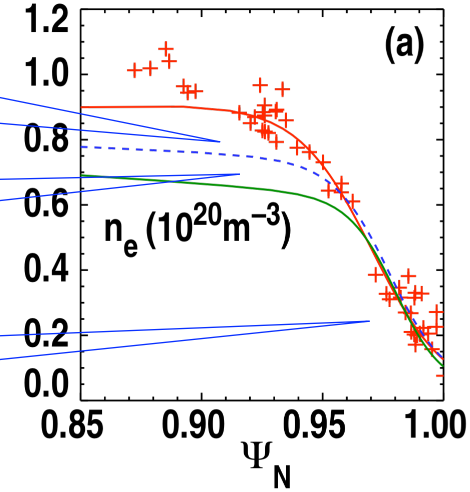


Kinetic Ballooning modes limit max pressure gradient?

Density pinch?

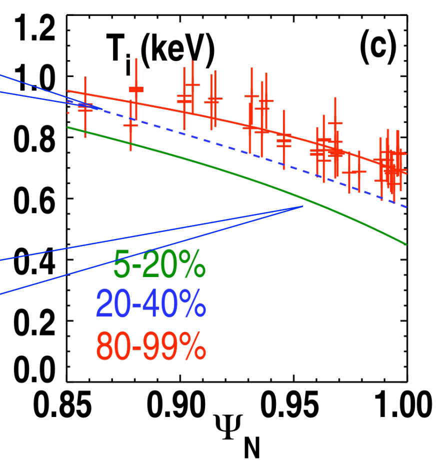
Core fueling?

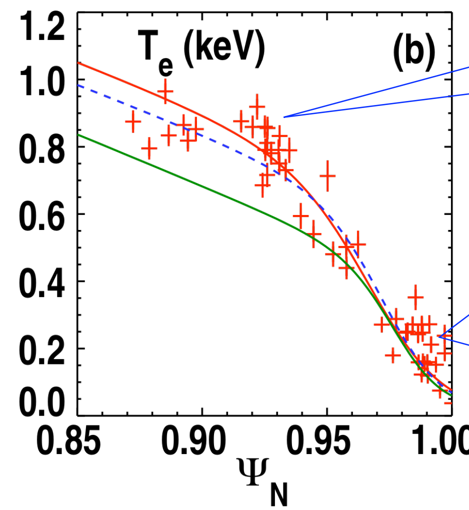
Neutral fueling shapes profile?



Remnant ITG/TEM affects T_i?

Neoclassical ion transport in pedestal?



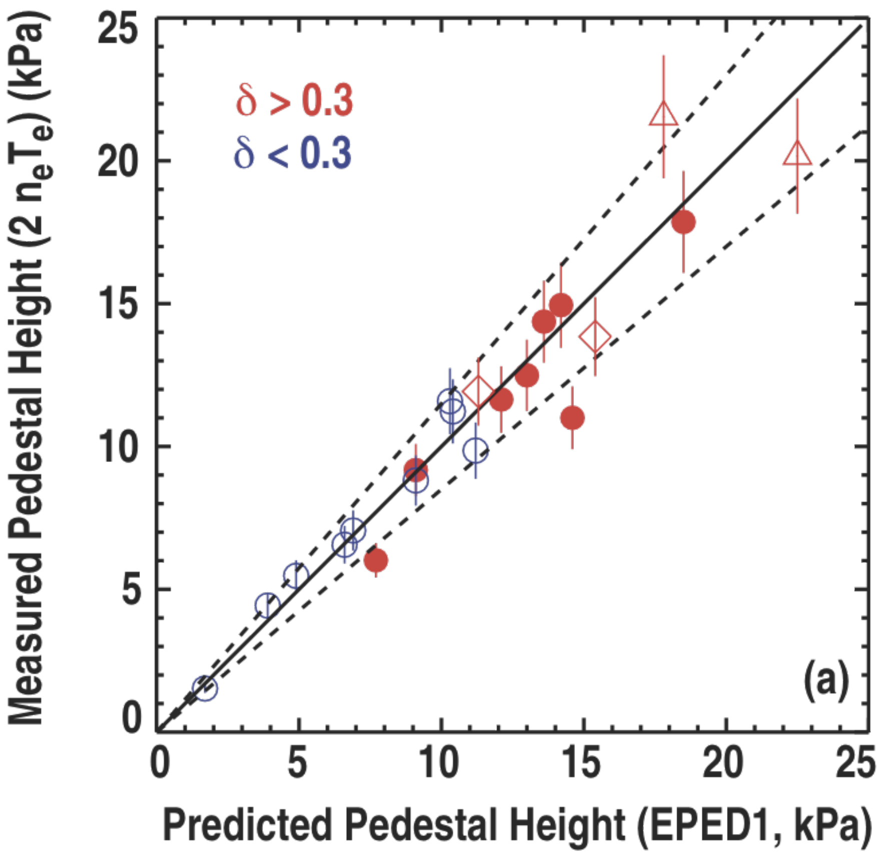


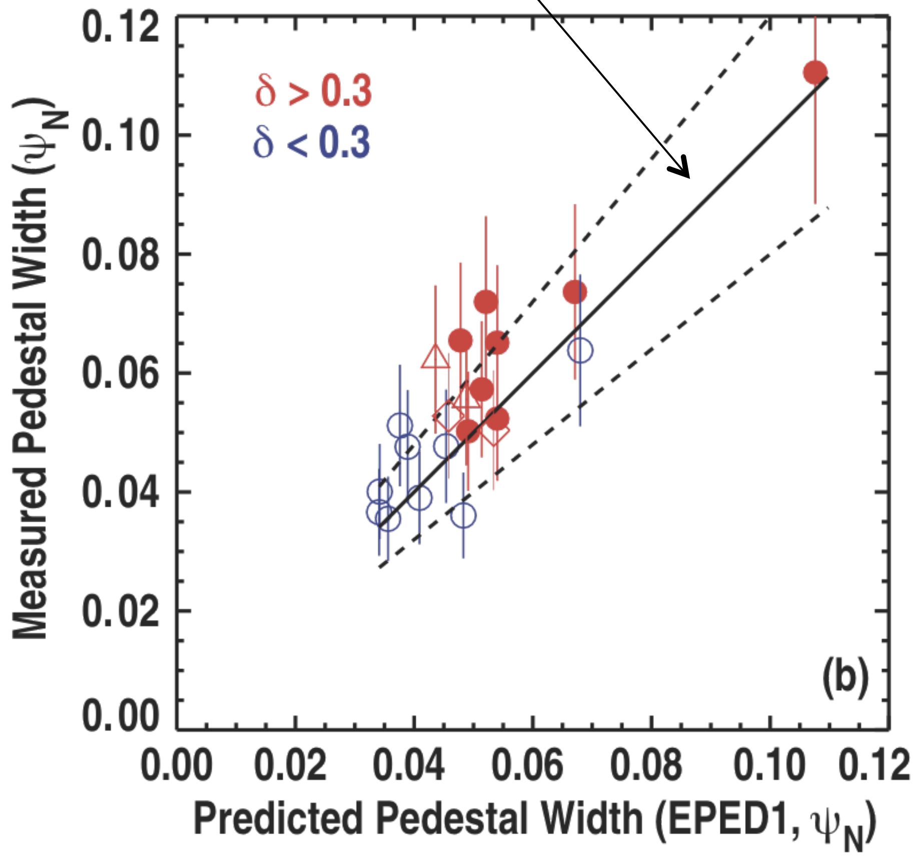
ETG limits T_e in pedestal?

Paleoclassical transport limits T_e in outer pedestal?

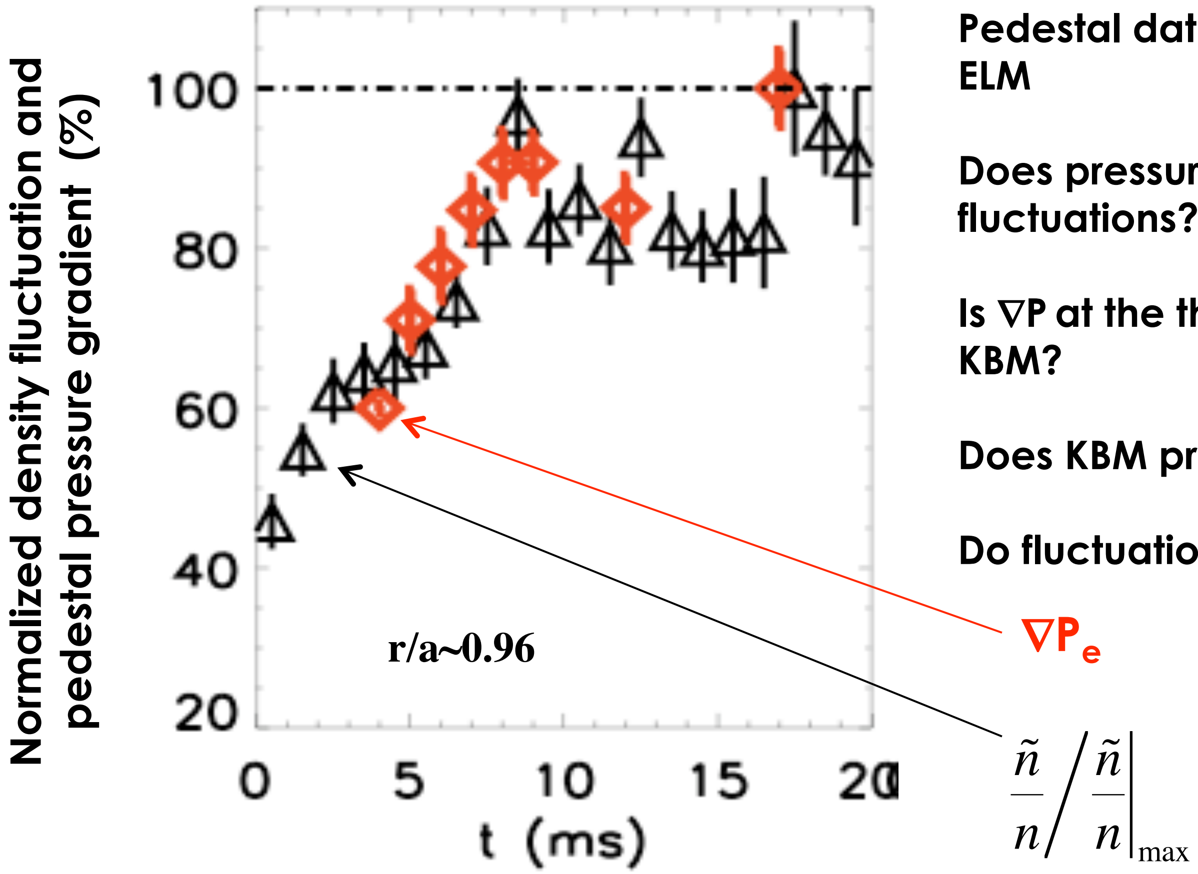
A KBM Width Model Agrees with Data within Error Bars

More data at high width (high beta-poloidal) are desirable





Are Low-k Fluctuations due to KBM and Do They Saturate Pedestal Pressure Gradient?



Pedestal data during recovery from an ELM

Does pressure gradient drive the fluctuations?

Is ∇P at the threshold for turning on KBM?

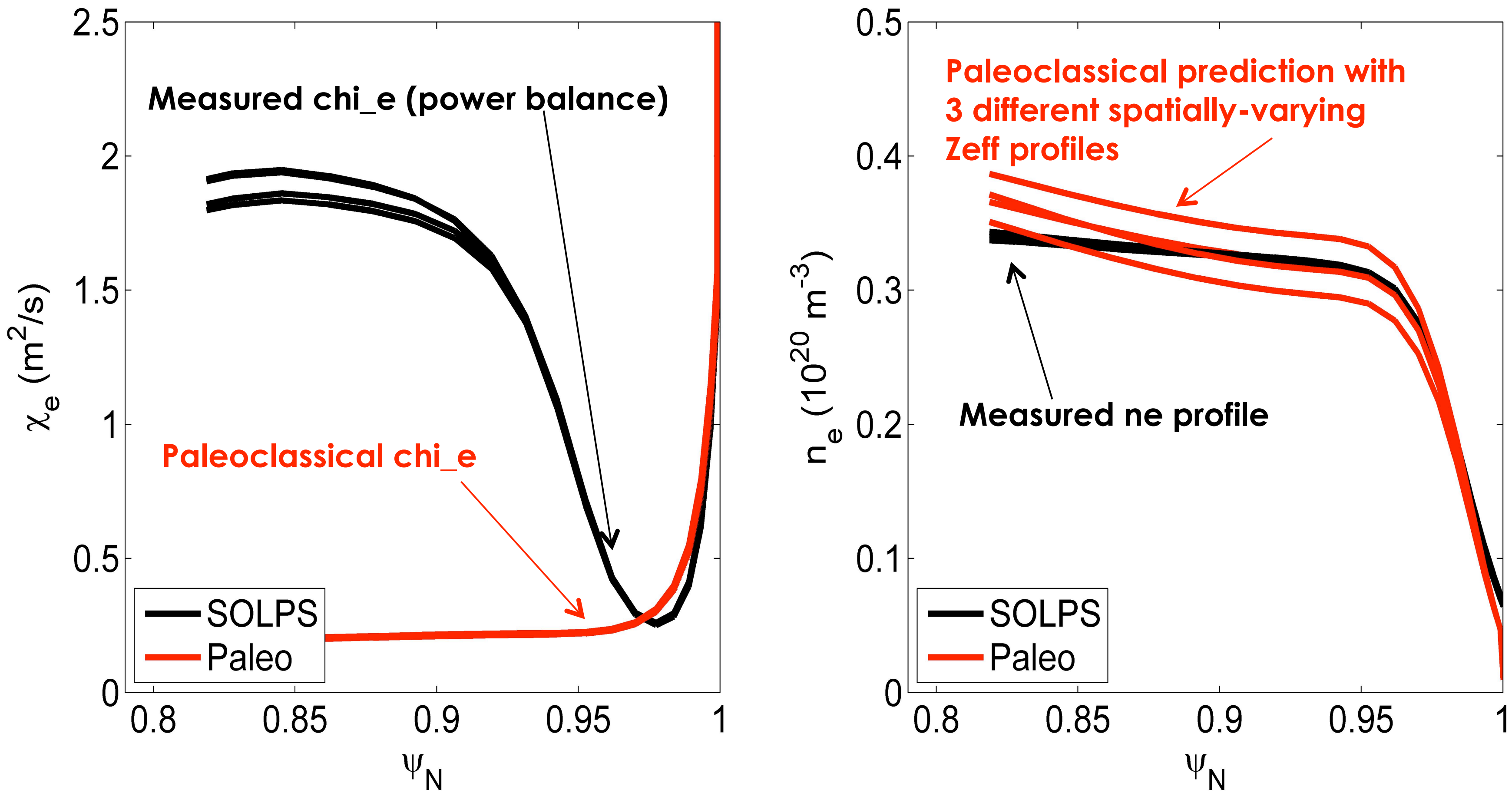
Does KBM produce the fluctuations?

Do fluctuations saturate the gradient?

(BES, Z. Yan et al APS/DPP2010, GA–A26970, submitted to PoP)

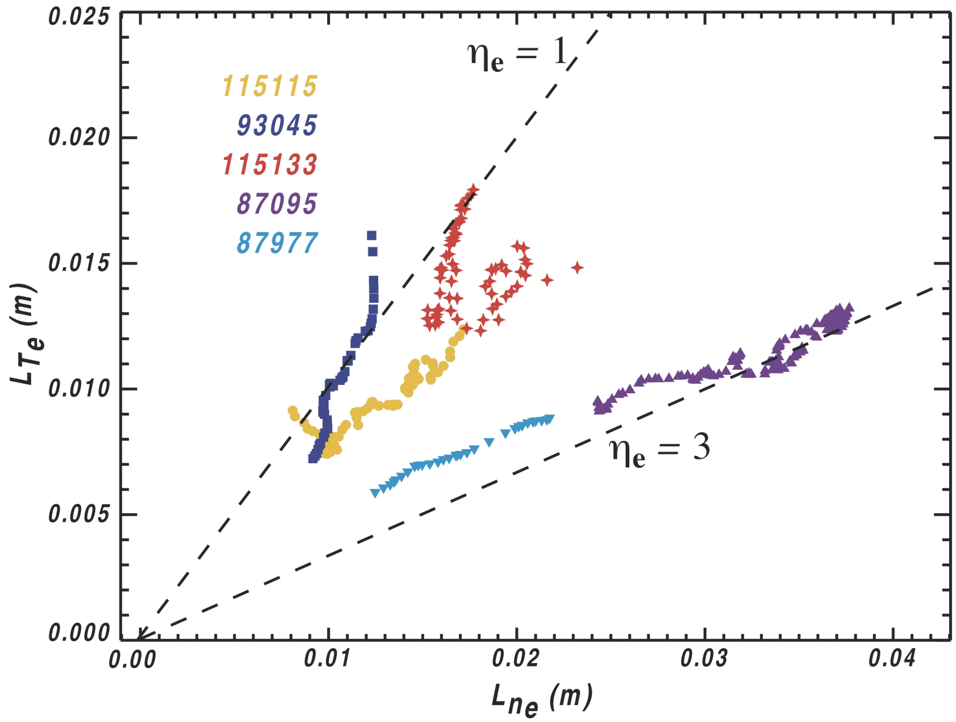
Does Paleoclassical Theory Predict Pedestal Electron Thermal Transport and Particle Transport?

Analysis of DIII-D discharge 98889 by J.Canik

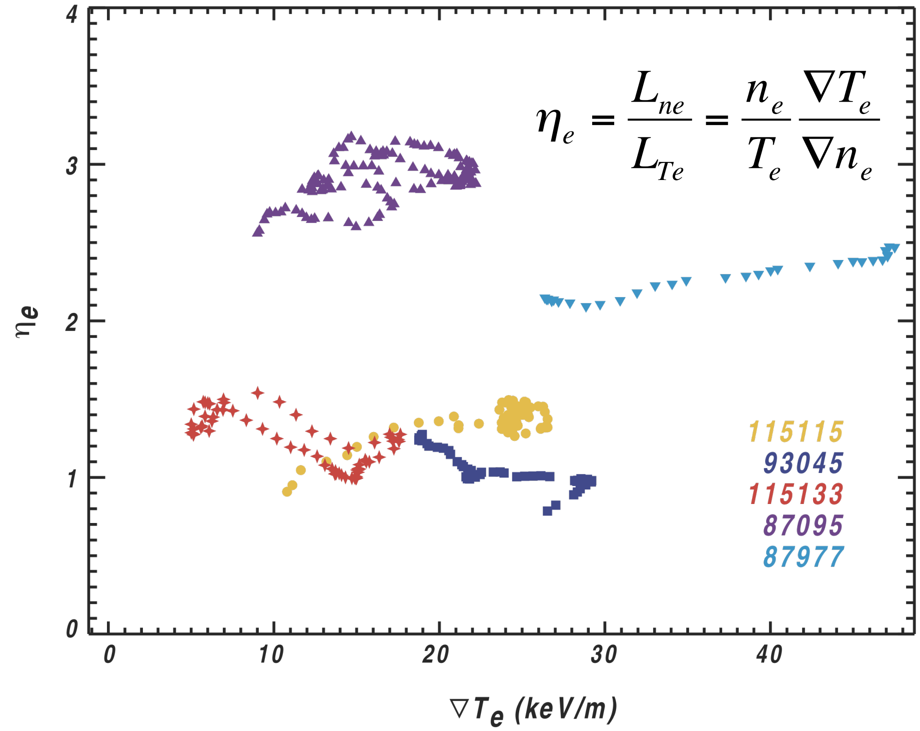


Does ETG Turbulence Cause Pedestal Electron Thermal Transport? And is η_e a Good Metric?

Trajectories of ∇T_e and ∇n_e in 5 shots: ∇T_e and ∇n_e both vary during shot

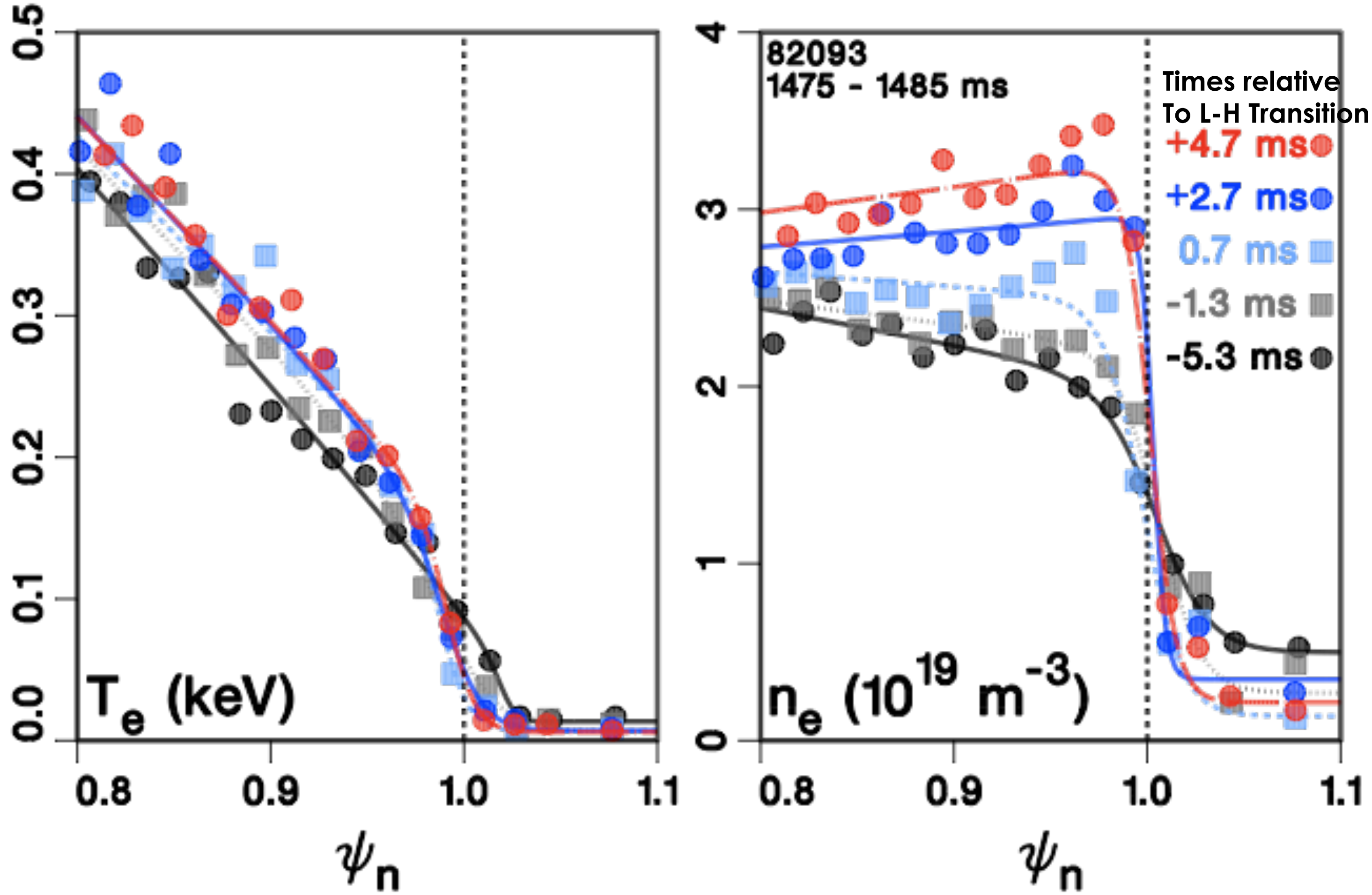


∇T_e and ∇n_e both vary such that η_e is approximately constant in time



Groebner et al., 31st EPS Conference on Plasma Phys. 2004 ECA Vol. 28G, P-2.173 (2004)

Is Neutral Fueling in Pedestal Strong Enough to Explain Rate of Rise of Density Buildup?

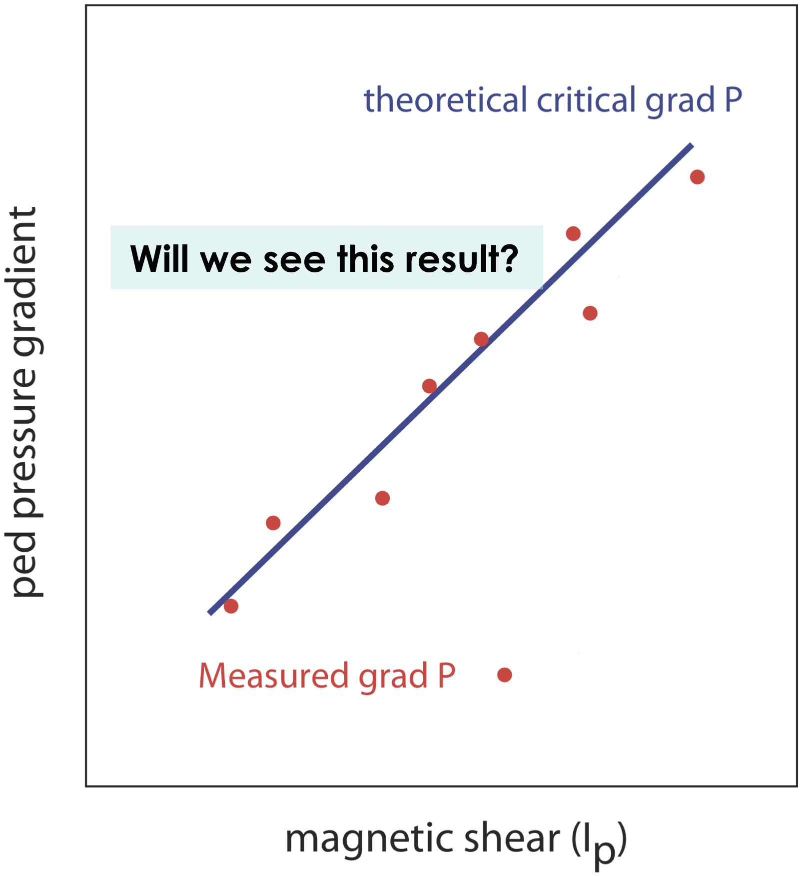


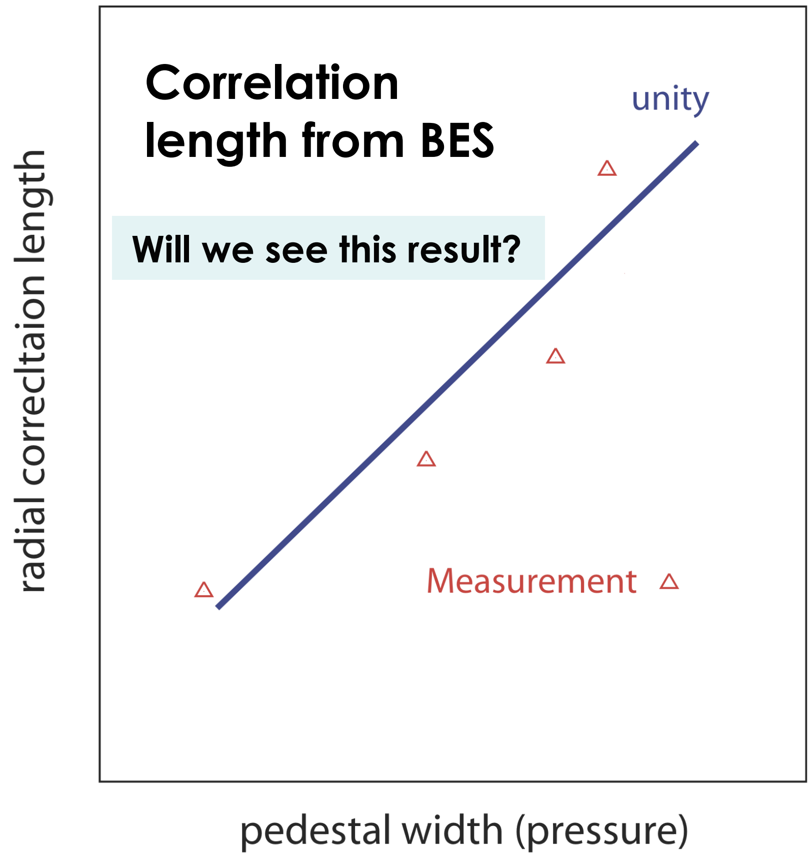
Can we infer particle source with enough accuracy from edge-2D analysis to answer this question?

Quantitative Models Exist or Will Soon Exist to Evaluate these Physics Processes

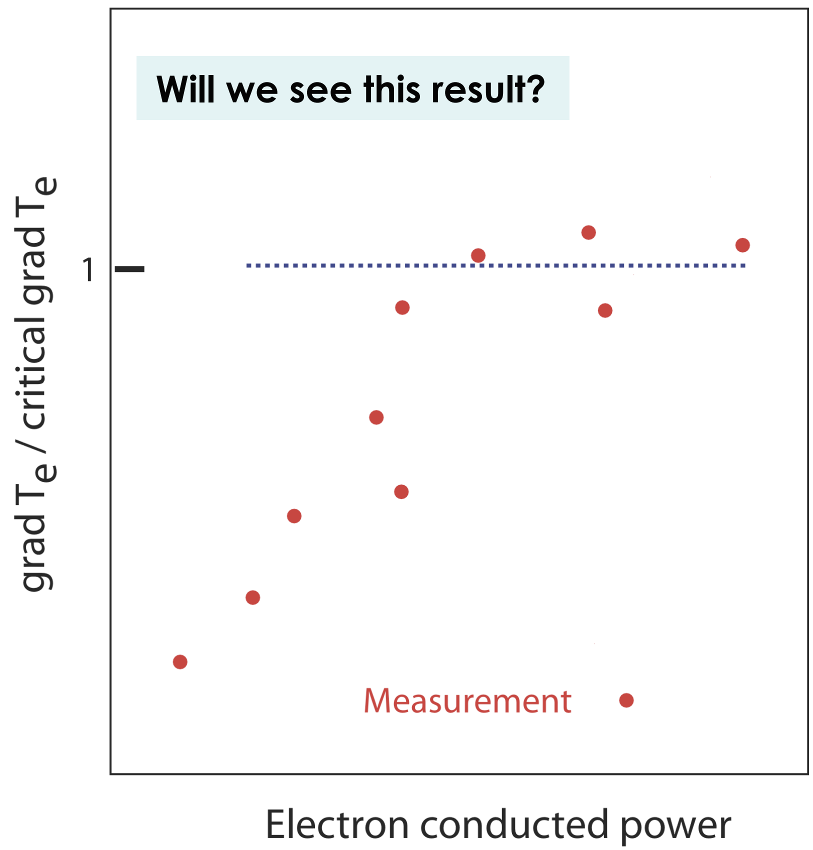
Physics Process	Control Parameters	Scans to Vary Control Parameters	Tests (Measurements plus Theory)
KBM	S (magnetic shear); α pressure gradient	-Magnetic shear (via pedestal β_{pol} and shape)	- ∇P clamped to predicted critical gradient? - Radial correlation length of low-k fluctuations scales with $\beta_{pol}{}^{1/2}$?
Paleo-classical	Magnetic diffusivity D_η; heating power	- D_η (via collisionality) - Separatrix density (via pumping)	- $\nabla T_e \sim P_e / D_\eta$ - $n_e(\rho)\ D_\eta(\rho)$ ~ constant in pedestal? At predicted value? - ∇Te ~ constant in pedestal? At predicted value?
ETG	η_e	- L_{Te} (Via electron heating) - L_{ne} (Via density)	- η_e clamped at critical value? - High-k fluctuations increase as L_{Te} is decreased (∇T_e increased)?
Particle fueling	Neutral depth	- SOL neutral opacity	- Particle pinch builds pedestal density profile? - Can D3D match ped profiles in a machine with very different fueling characteristics?

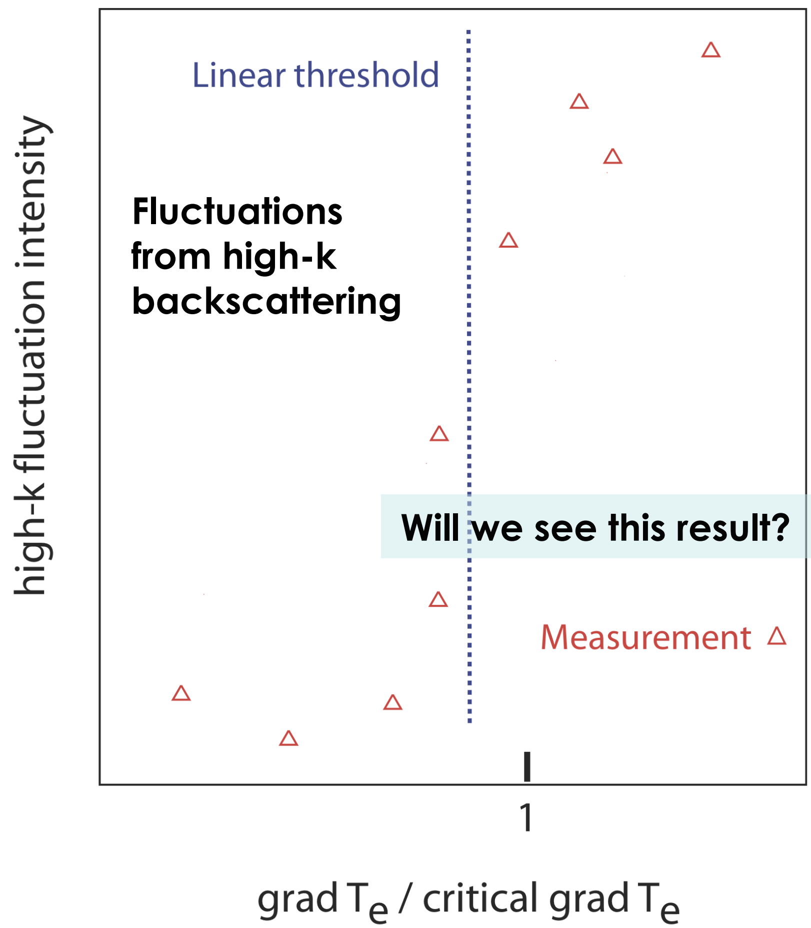
KBM: Test Pedestal Pressure Gradient; Test Low-k Fluctuation Radial Correlation Length



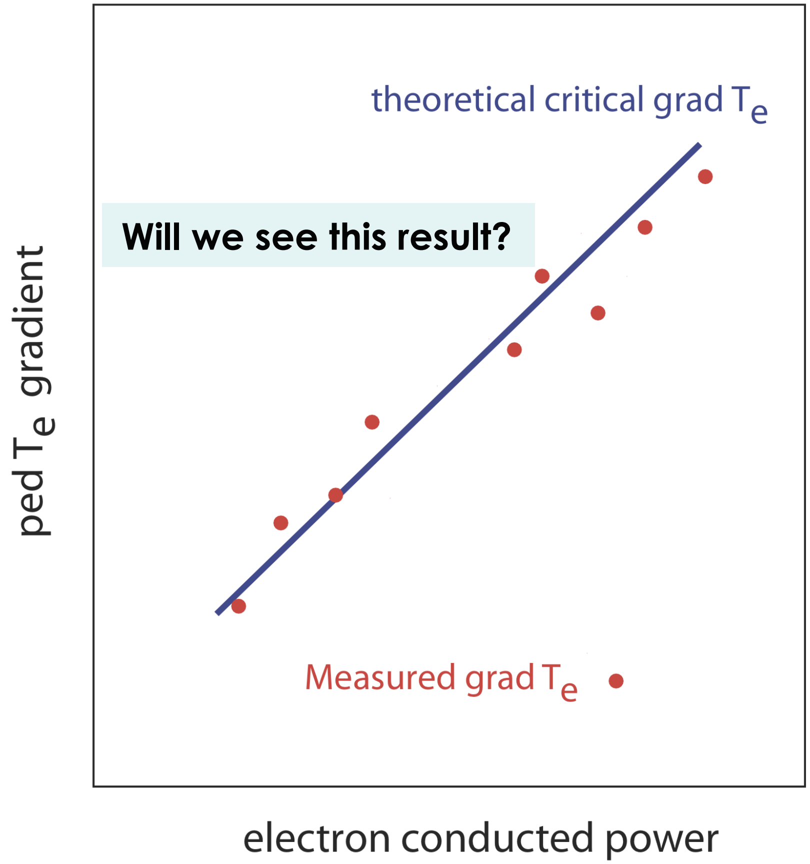


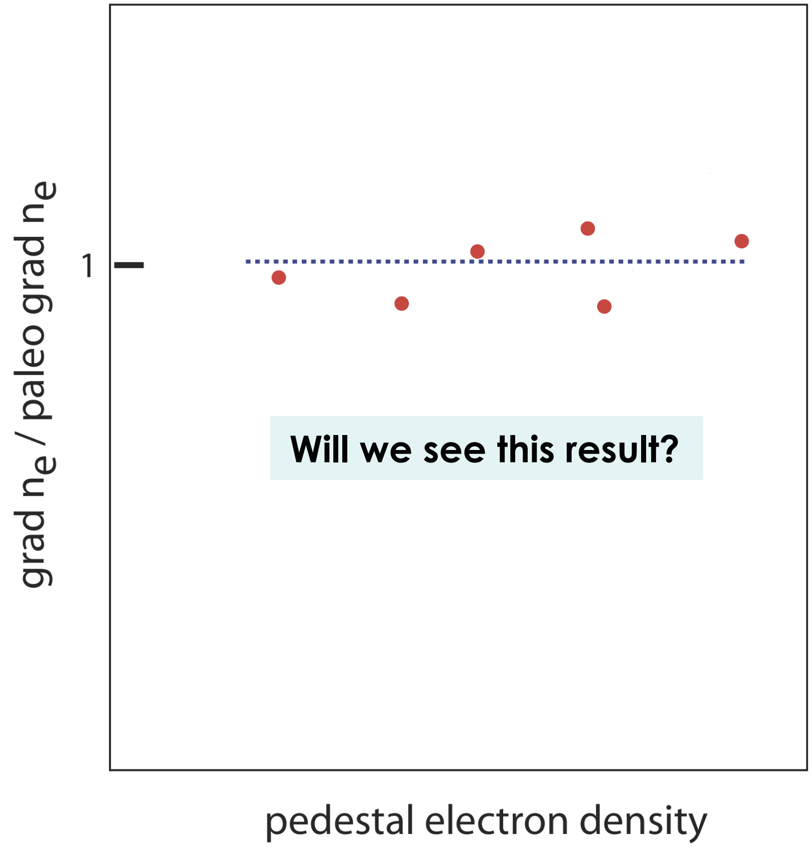
ETG: Test Pedestal T_e Gradient; Test High-k Fluctuation Intensity



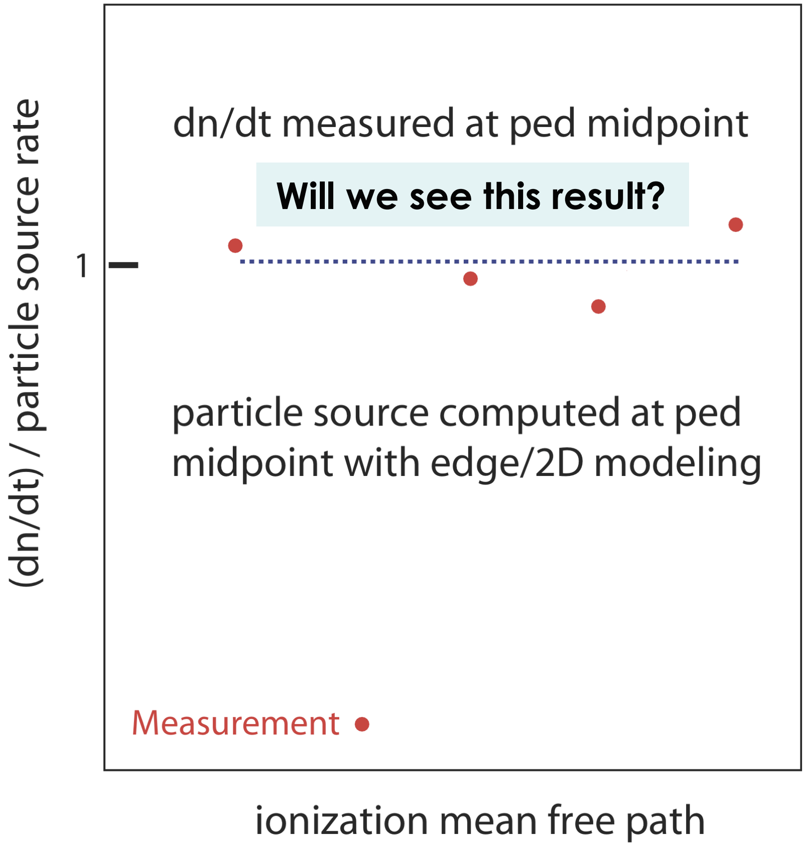


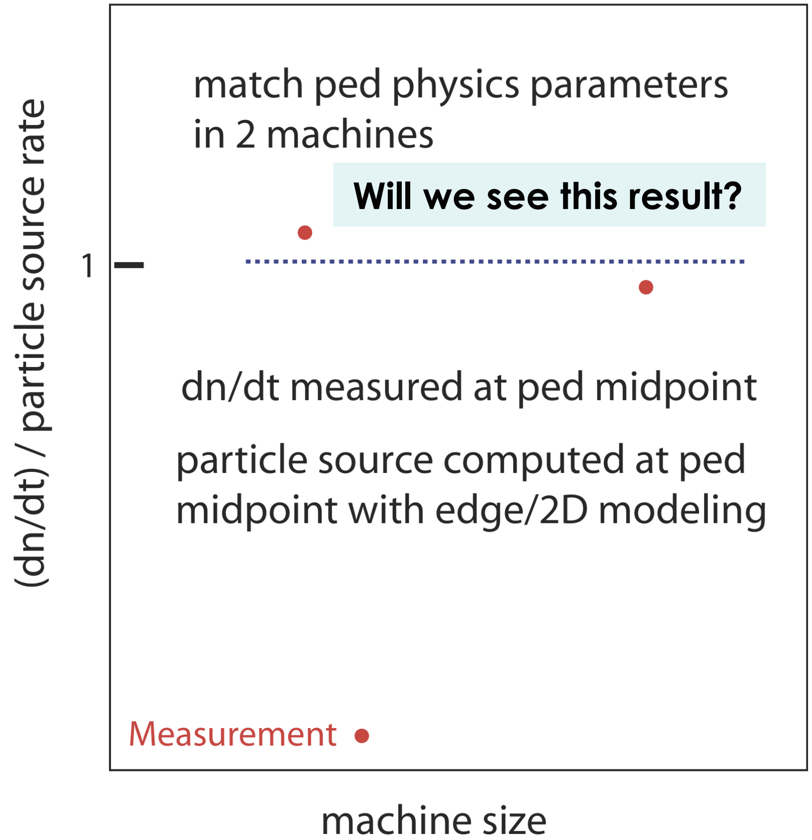
Paleoclassical: Test Predictions for Pedestal Grad T_e and Grad n_e





Neutral Fueling / Particle Pinch: Compare Rate of Density Rise to Neutral Fueling Rate





Summary

DIII-D pedestal physics program for 2011 has been developed with a strong emphasis on testing and validating models of physics processes which potentially play important role in controlling pedestal structure

- **Physics planning has identified four physics processes for study**
  - The processes are KBM, paleoclassical, ETG, neutral fueling
  - One or more contemporary pedestal modeling codes predicts that these process play an important role in shaping pedestal structure
  - Sufficient theory exists or is expected to exist with this fiscal year to allow good tests of these processes
- **Four run days have been allocated for 2011 to DIII-D basic pedestal physics**
  - Final development of the plan will be performed shortly after TTF meeting