



# The Dialogue Between the Science of Turbulence and Transport and a Burning Plasma Experiment

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# There is great value in discussing the scientific needs of and contributions from a burning plasma experiment

- n Heartfelt, strong sentiments from every vantage point
  - At issue is the quality of the scientific exchange
  - What are the issues and concerns a BP must address to be viewed as an attractive scientific test bed?

## Give & take:

- n What does a burning plasma experiment *need from* the science of turbulence and transport?
  - Assume that predicting the performance is of value
- n What would a burning plasma experiment *give to* the science of turbulence and transport (T&T)?
  - What the integration goal means to T&T
  - Flexibility

# The transport & turbulence community speaks consistently of a couple of major thrusts

I. A ***strong desire*** , what inspires the transport community scientifically, and what it feels is required to advance the field, is to develop predictive models *based on an understanding of turbulence and turbulence dynamics*.

*From Snowmass:*

- n “Goal 1: Comprehensive transport models
  - Goal 1a: Pursue the challenging, yet realistic *goal of developing comprehensive predictive transport models*, based on physically reasonable assumptions and well-tested against experiments.
  - Goal 1b: Detailed Experiment/Theory Comparisons” at the level of the turbulence

The second primary goal: develop tools for turbulence manipulation to control the plasma pressure

Again, from Snowmass:

- n "Goal 2. *Develop tools and understanding for control of transport and transport barriers...*"
  - *This is what the BP language of “integration” speaks to*
  - *Even a doubter of the value of transport barriers can benefit from control tools (managing a self-heated environment)*
  - *Many in the community ask: Is a BP the place to develop the understanding and the tools?*

Will a BP be able to find a self-consistent operating point?

What a BP needs from T&T: issues have been identified for predictive transport modelling during the next 10 years

Highlight items from the Snowmass report are:

- n Need convergence of models for reliable extrapolation
- n Reliable models for plasma boundary needed
- n Need accurate models for transport barrier dynamics (edge and core)

## There has been progress in developing transport models that capture experimental trends, but all models have flaws

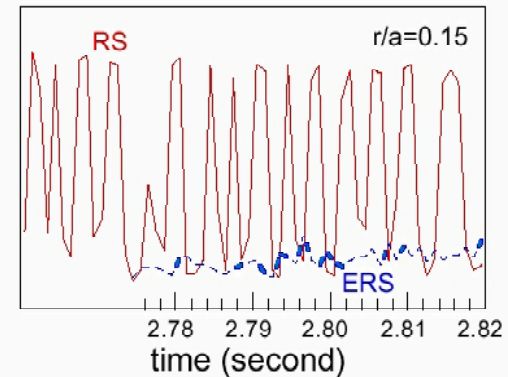
"Are you better off now than you were 8 years ago?"

- n For temperature profile predictions: several models are now reasonably successful, but no single model is generally preferred. All have some serious failures.
- n The underlying differences between reasonably successful models are large enough that we can't say that their characteristics point to the importance of particular processes
- n More complete physics is being included (electron dynamics, ExB shear, for example)

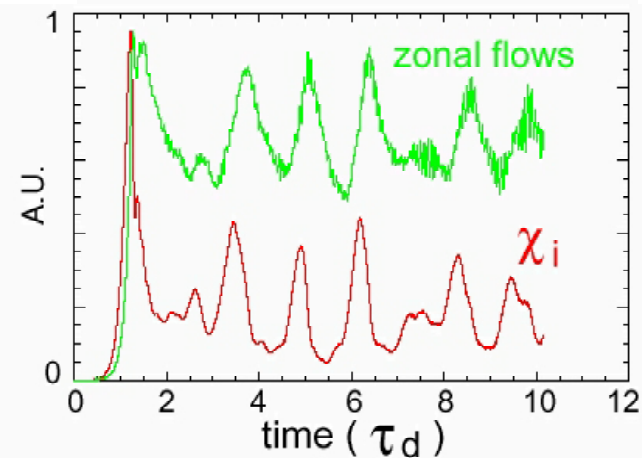
# Turbulence dynamics understanding is key to developing predictive capability and is a premier challenge

## Example 1: Zonal flow dynamics

- n Several facets have been appreciated only in the last several years:
- their existence (***not verified***)
  - interaction between zonal flows and microinstabilities - saturation levels
  - Some consistency in measured features (e.g. bursting), but there are other explanations



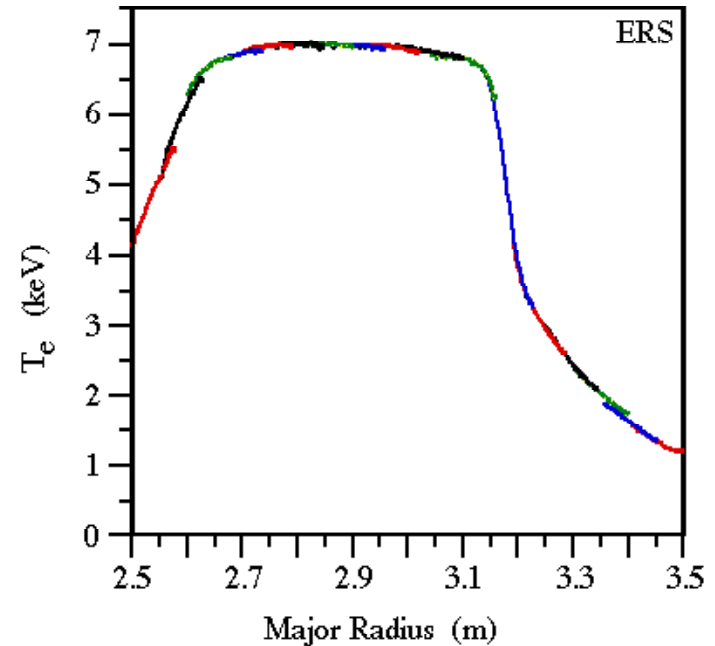
[Mazzucato, et al., PRL, 1996]



[Lin, et al., PRL, 1999]

# Knowledge of electron thermal transport is key to predicting BP performance

- n Some promising links between theory and experiment
- n Nevertheless, we are a long way from demonstrating that theory explains a lot of experimental data.
- n Critically important in prediction of  $\alpha$  heating effectiveness and need for ash removal strategies
- n Issue is forcing progress in codes: high k modes, streamers
- n Need for similar experimental assault



Zarnstorff, APS '98

Streamers Jenko et al., PoP 7, 2000



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# Predicting BP performance requires significant improvement in knowledge of pedestal height and width

Many caveats, contradictory theories, contradictory experiments predictive capability not in hand

n Over a range of theories, many have  $\Delta \sim \rho^{2/3-1}$ .

- JT-60U, JET support “standard” model of  $\Delta \sim \rho$  and gradient near the ideal MHD limit

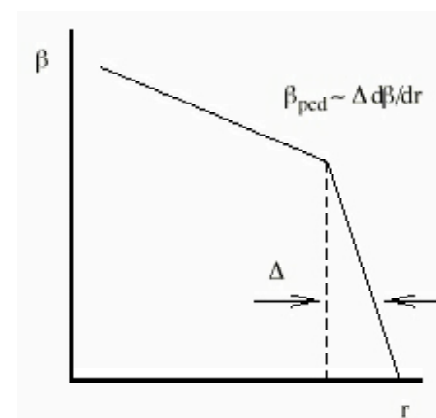
n Others (DIII-D) support  $\Delta$  independent of  $\rho$  and/or in second stability

n Progress: useful cross-machine database being developed

- ITER H-mode Edge Pedestal Expert Group, March 2000).

n Edge turbulence simulations becoming more realistic

- Xu and Cohen (LLNL), Rogers and Drake (U. Md.), Scott, Jenko, Zeiler et al. (Garching)



# Dynamical models capture many features of present experiments, but cannot yet predict

- n Required to assess robustness of operating point of a BP and to develop a control strategy
- n Self-consistent evolution of turbulence, fluxes, shear, and profiles beginning
- n Character of some dynamics seen in codes, but *robust predictions* are not in hand

