Driftwave Based Modeling of Burning Plasmas

First Simulations of the H-mode Pedestal with GLF23

Gary Staebler

General Atomics

Jon Kinsey

Lehigh University

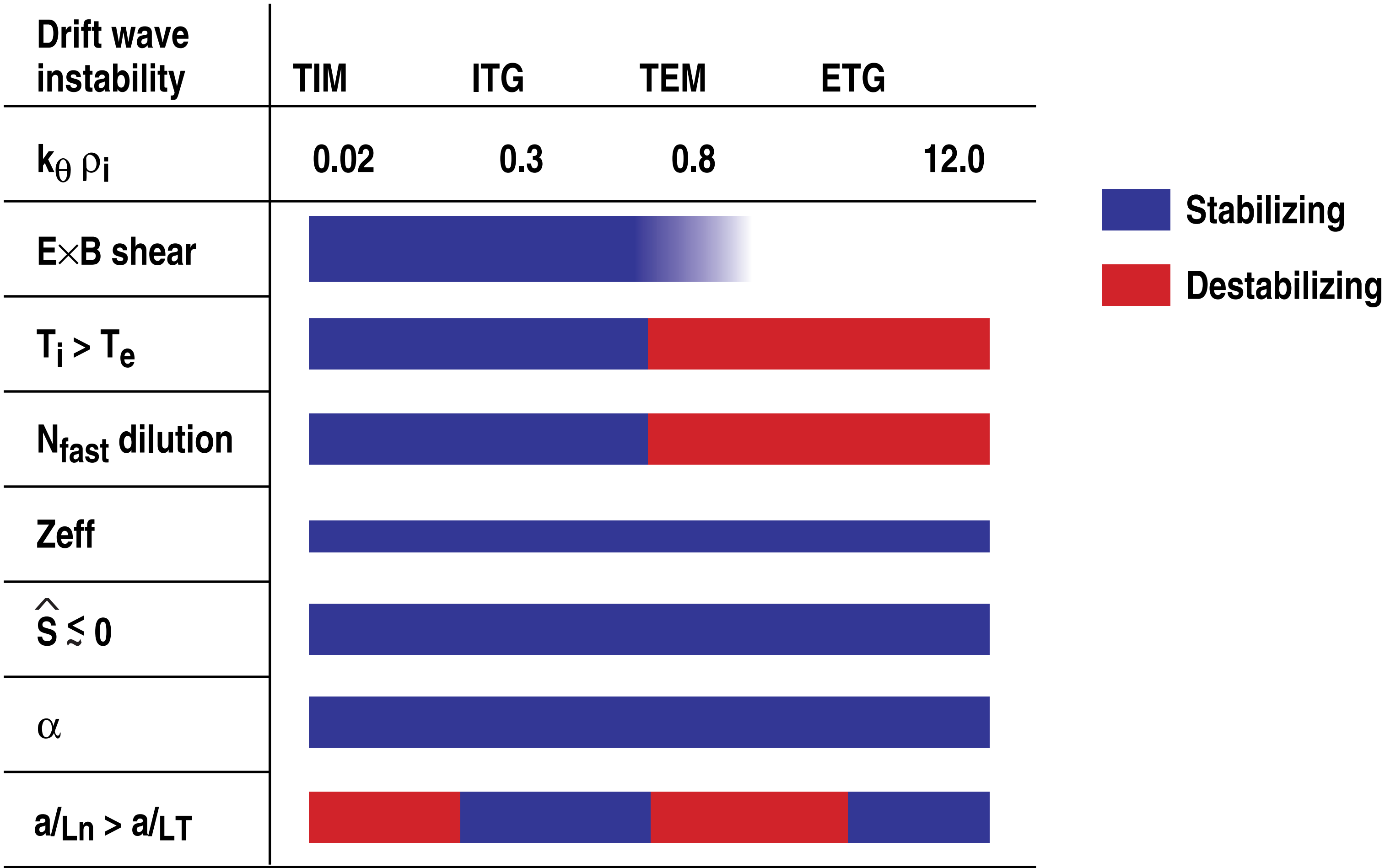
INTRODUCTION

- **Predicting the transport properties of tokamak plasmas is a key part of the design process for burning plasma experiments.**
- **Theory based models are, in principle, better at projecting to new regimes than empirical scaling.**
- **The strongly non-linear nature of transitions to enhanced confinement regimes renders power law scaling projections useless across such transitions.**
- **In present tokamak experiments, there are many distinct regimes of confinement, as is evident from the growing classification dictionary (SOC, L, SS, H, VH, RI, PEP, NCS/ERS/ITB, high beta-p, electron ITB, QDB).**
- **These macroscopic confinement states can be partially grouped by the properties of the fundamental driftwave instabilities.**
- **Driftwave-based transport models have been successful at simulating many of these confinement regimes.**

OUTLINE

- **The properties of the fundamental driftwaves and classification of tokamak confinement regimes**
- **The GLF23 driftwave-based transport model.**
- **Simulation of a DIII-D H-mode an example of a GLF23 prediction of the pedestal width and height.**
- **Summary.**

STABILITY PROPERTIES OF DRIFTWAVES



TRANSPORT CHANNELS ARE INFUENCED BY DIFFERENT DRIFT WAVES

Drift wave	TIM	ITG	TEM	ETG
Thermal	$\chi_i > \chi_e$	$\chi_i \sim \chi_e$	$\chi_i < \chi_e$	$\chi_i \ll \chi_e$
Particle	?	$D \sim \chi_i$	$D \sim \chi_i$	?
Ion momentum	?	$\chi_M \sim \chi_i$	?	?

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THE CONFINEMENT REGIMES OF TOKAMAKS REFLECT THE PROPERTIES OF THE DRIFT WAVE INSTABILITIES

● Strong influence ◐ Weaker influence

Confinement Regime	H–mode	VH–mode	NCS/ ERS	PEP	High β_p	RI	Hot ion H–mode	Supershot
E×B shear	●	●	●	◐	◐	◐	◐	◐
$T_i > T_e$		◐	●		●		●	●
N_{fast} dilution			●		●		●	●
Zeff		◐				●		●
$\hat{S} \lesssim 0$			●	◐	● ?			
α Shafranov shift	?		◐	◐	● ?			◐
$a/L_n > a/L_T$	?			●	◐	◐		●

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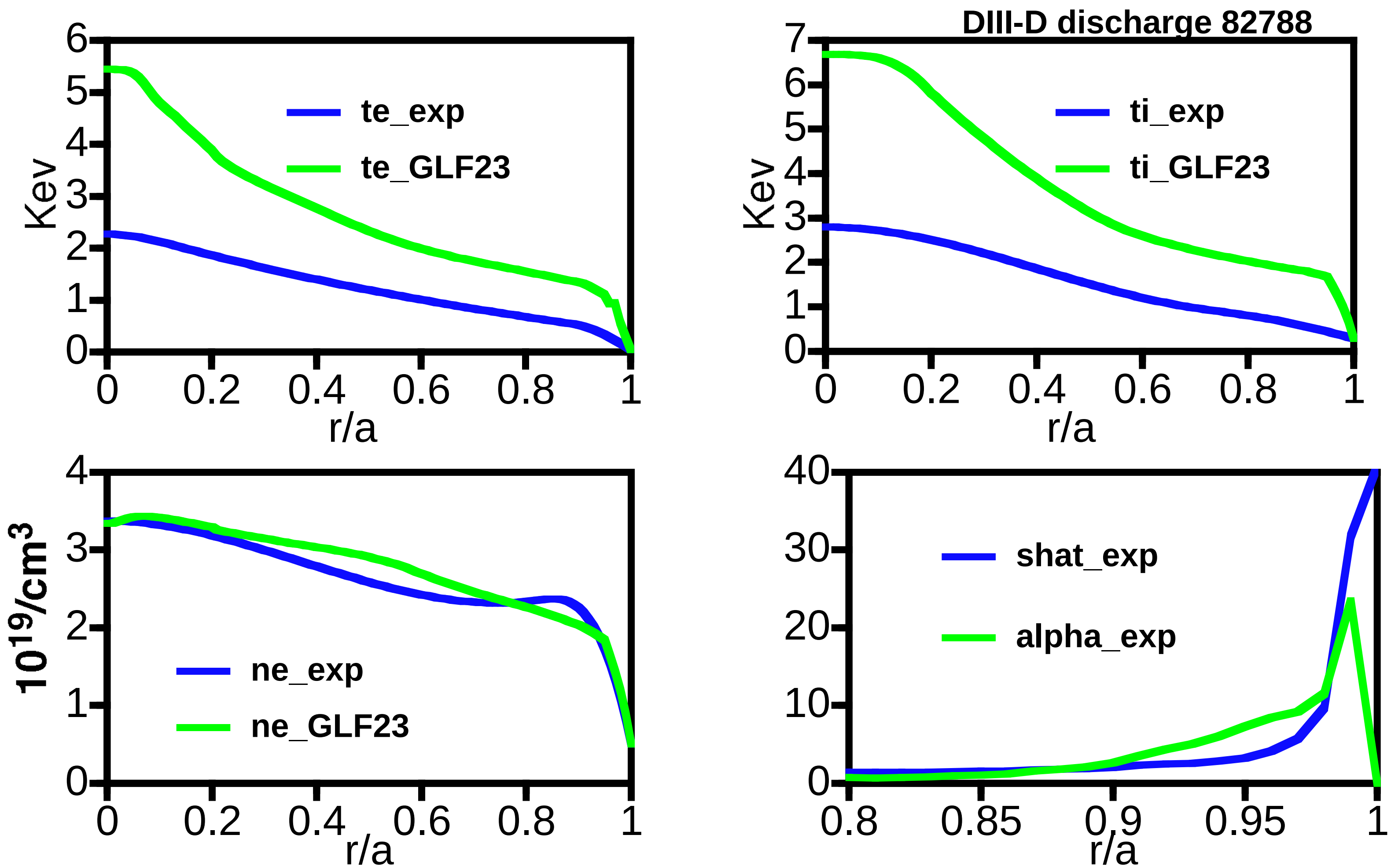
THE GLF23 TRANPORT MODEL

- The GLF23 transport model uses the linear instabilities of the gyro-Landau fluid equations which approximate the full gyro-kinetic theory.
- The transport fluxes are computed from quasilinear theory with a mixing length model for the saturated fluctuation level.
- The fitting parameters of the model are all fit to kinetic linear theory and to non-linear simulations of ITG-TEM turbulence. No fitting to experiment has been done.
- The theoretical basis for the transport due to ETG modes is not yet well established.
- The threshold level of ExB velocity shear needed to quench the ITG-TEM modes is taken from theory.
- The GLF23 model reproduces the L-mode and H-mode profiles from the ITER database to within about 20%. This primarily tests the ITG-TEM transport.

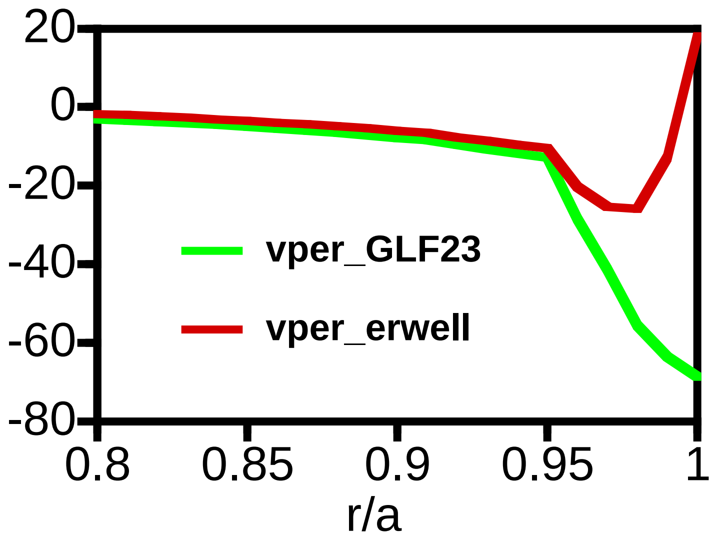
GLF23 PREDICTED PEDESTAL TEMPERATURES EXCEED THE OBSERVED VALUES

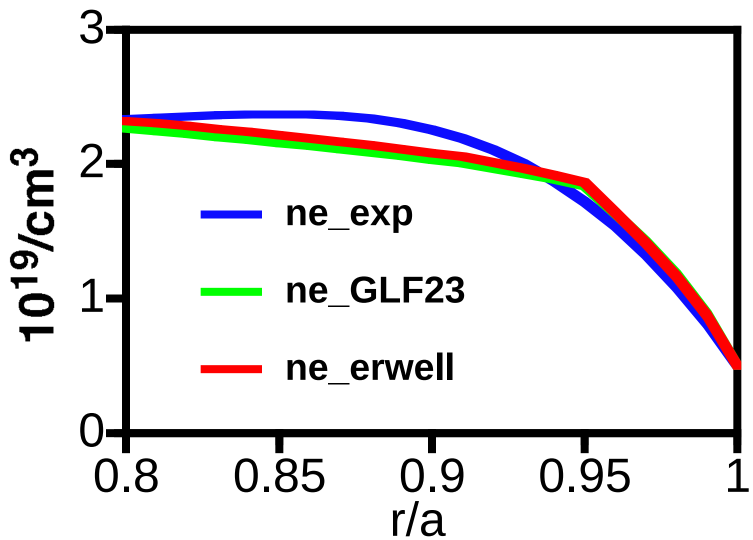


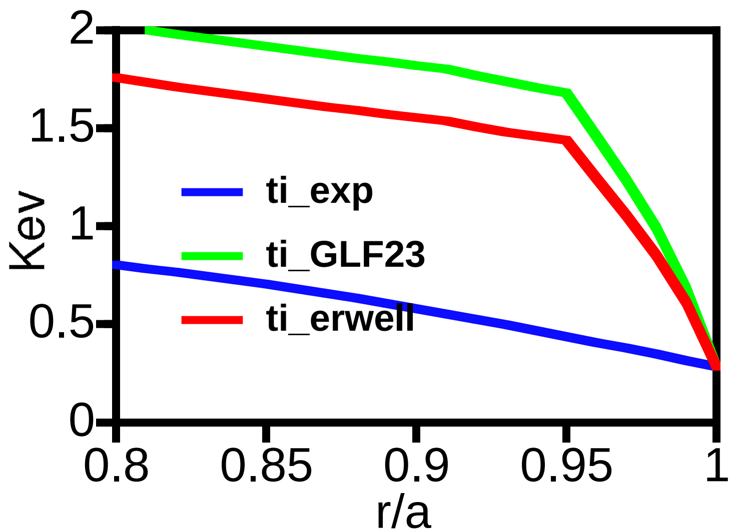
The magnetic shear and Shafranov shift for r/a>0.9 are far outside of the theoretical fit range for GLF23.

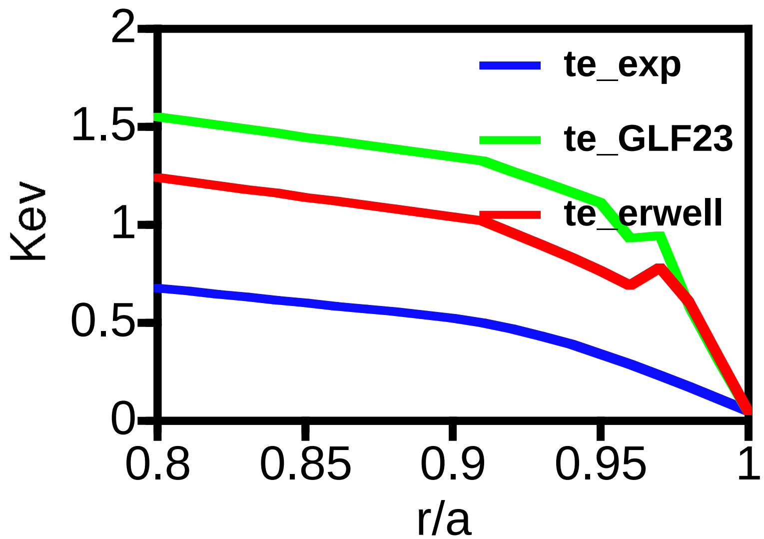
THE ELECTRIC FIELD WELL IS CONTROLED BY THE BOUNDARY

The steady state pedestal is not very sensitive to the boundary condition on the ExB velocity but the H-mode power threshold is!



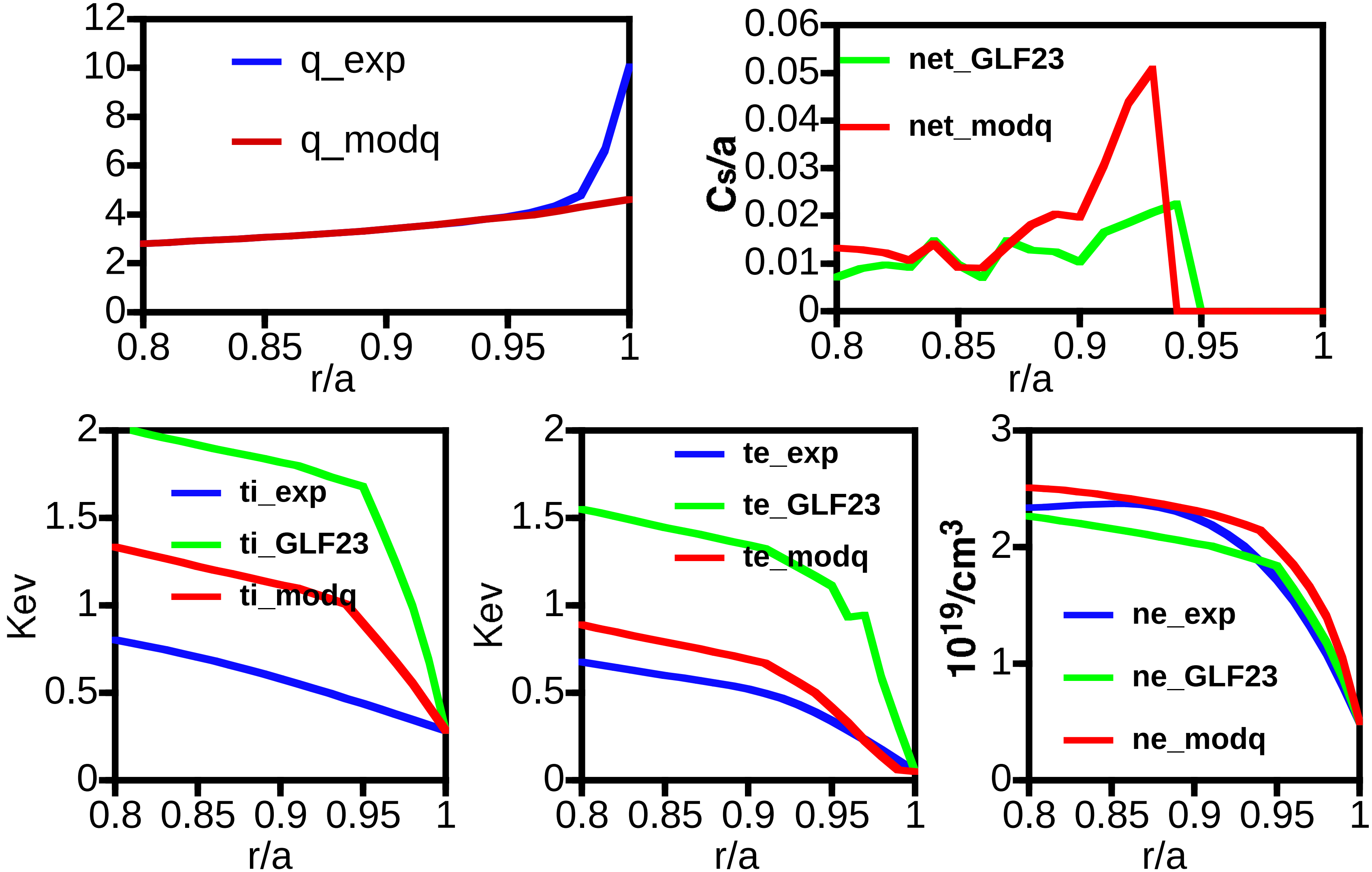






THE q-PROFILE NEAR THE SEPARATRIX CAN IMPACT THE PEDESTAL

ETG mode stability is important in the GLF23 pedestal prediction.



SUMMARY

- **The driftwave-based transport models like GLF23 are powerful tools for predicting transport in tokamaks.**

- **The qualitative properties of many confinement regimes can be reproduced with GLF23 due to its inclusion of the four fundamental driftwave instabilities.**

- **The first H-mode simulations with GLF23 have been performed including particle transport. The predicted pedestal temperatures are higher than the experimental values but the width is about right.**

- **In order to be able to predict the H-mode power threshold and pedestal accurately (theoretically) much work remains to be done.**
  - **Improve fit of GLF23 to linear modes near the edge.**
  - **Improve ideal ballooning mode stability threshold.**
  - **Develop SOL boundary condition model.**
  - **Include neutral transport/ionization self-consistently.**
  - **Develop peeling mode transport model for ELM's.**