ELM and Pedestal Stability Physics

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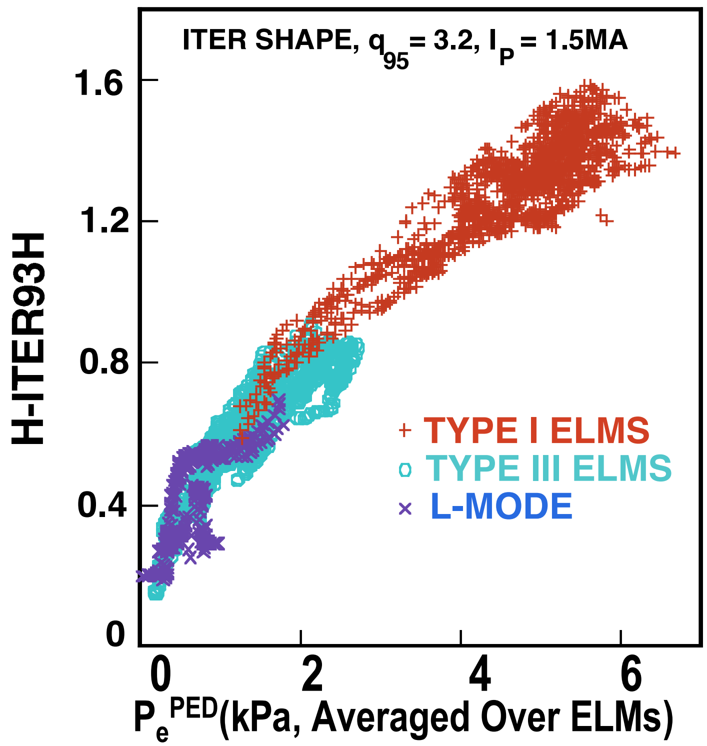
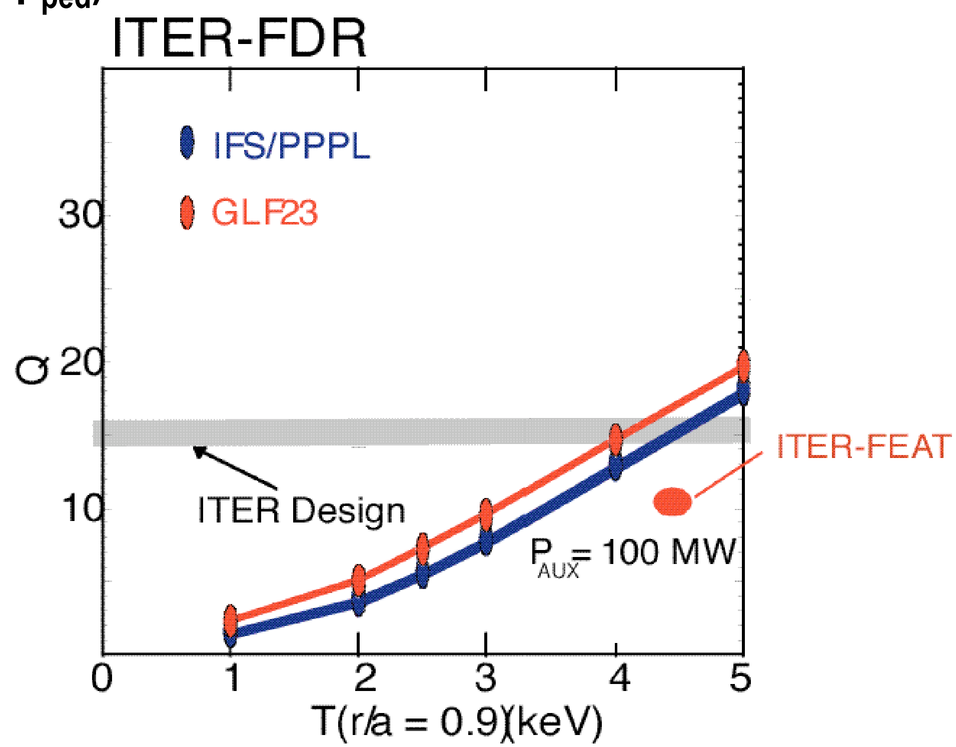
Pedestal & ELMs Key to Plasma Performance

- **Both experiment and theory predict a strong dependence of core confinement, and therefore Q on the pedestal height (T_{ped}, p_{ped})**

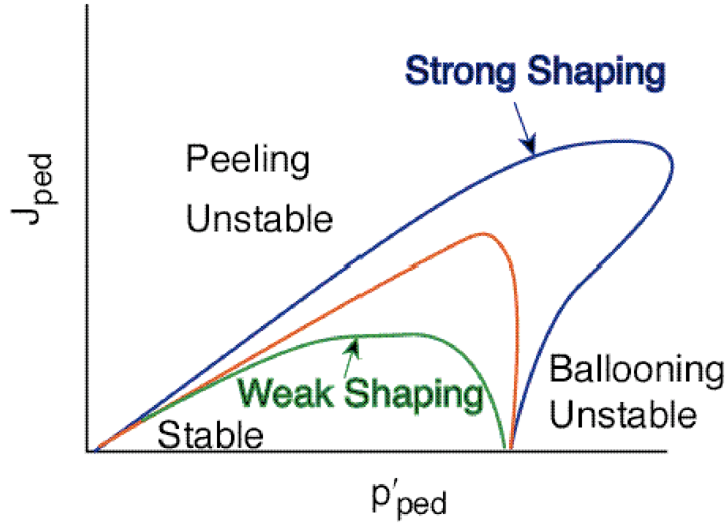


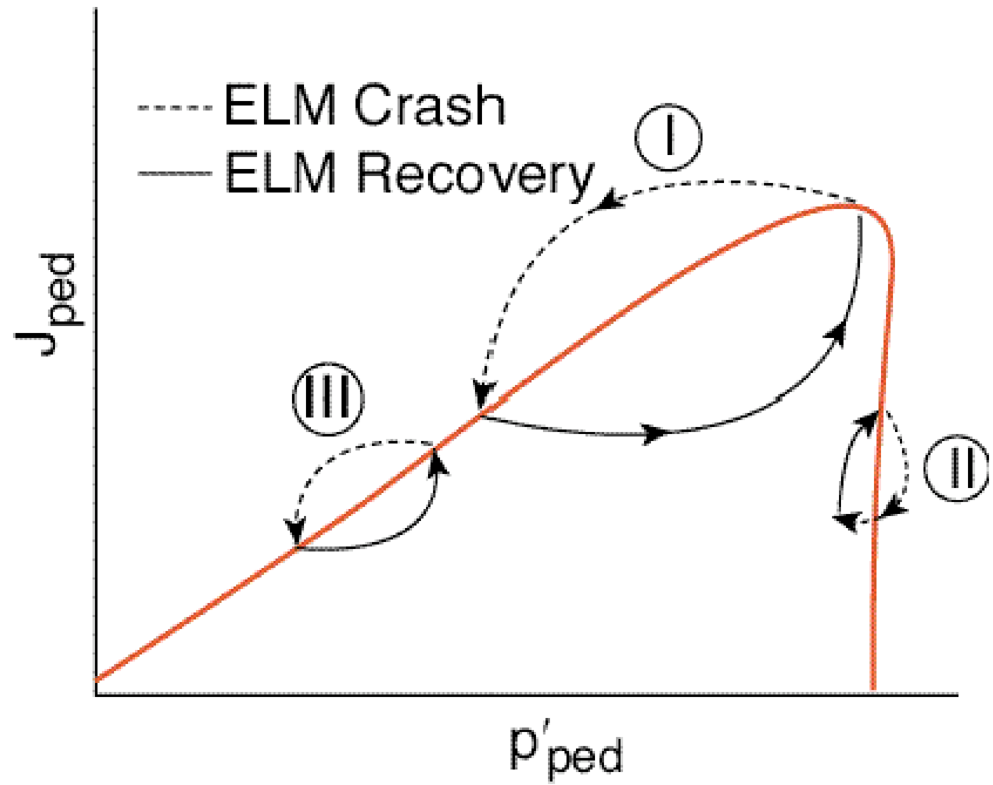


- **Pedestal stability constrains pedestal height, and ELM characteristics strongly impact divertor heat load constraints (large Type I ELMs may not be tolerable in Burning Plasma Candidates)**

➡ **Scaling of ELMs and Pedestal with aspect ratio key issue for low-A Fusion Devices**

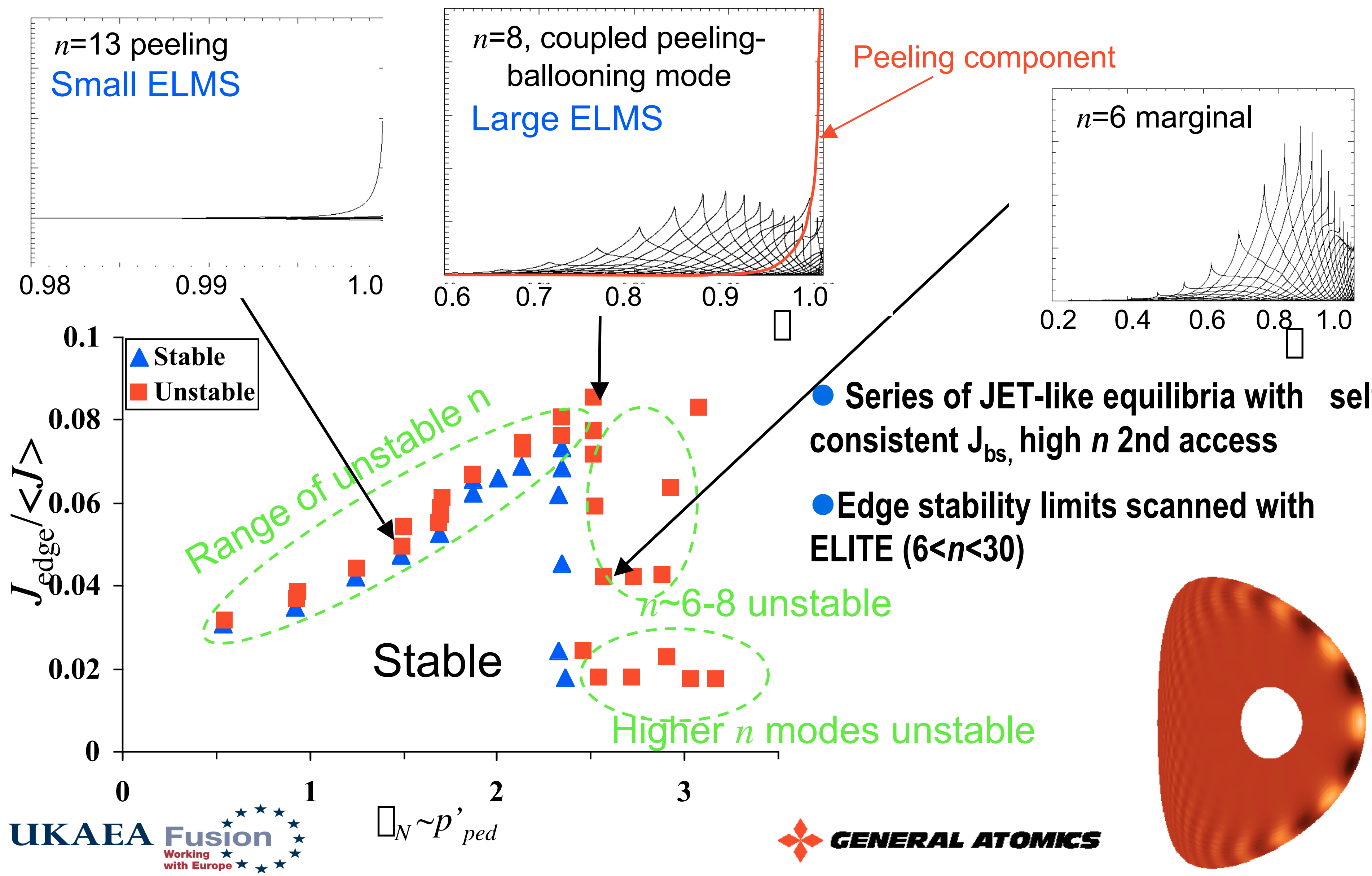
Model of ELMs and Pedestal Constraints





- ELMs triggered by intermediate-*n* peeling-ballooning modes, ELM size related to depth of most unstable mode and to location in parameter space
- Pressure rises up on transport time scale between ELMs, current rises to steady state value more slowly
- These figures are schematic! Detailed diagnostic info and careful equilibrium reconstructions needed for quantitative expt/theory comparisons. Finite-n modes feel non-local details, not just local gradients, bootstrap current introduces separate density and temperature dependencies: much more complicated than just a p’ (or alpha) constraint.

Pedestal Constraints and Mode Structures Can be Predicted



- Series of JET-like equilibria with self-consistent J_{bs}, high n 2nd access
- Edge stability limits scanned with ELITE ($6<n<30$)

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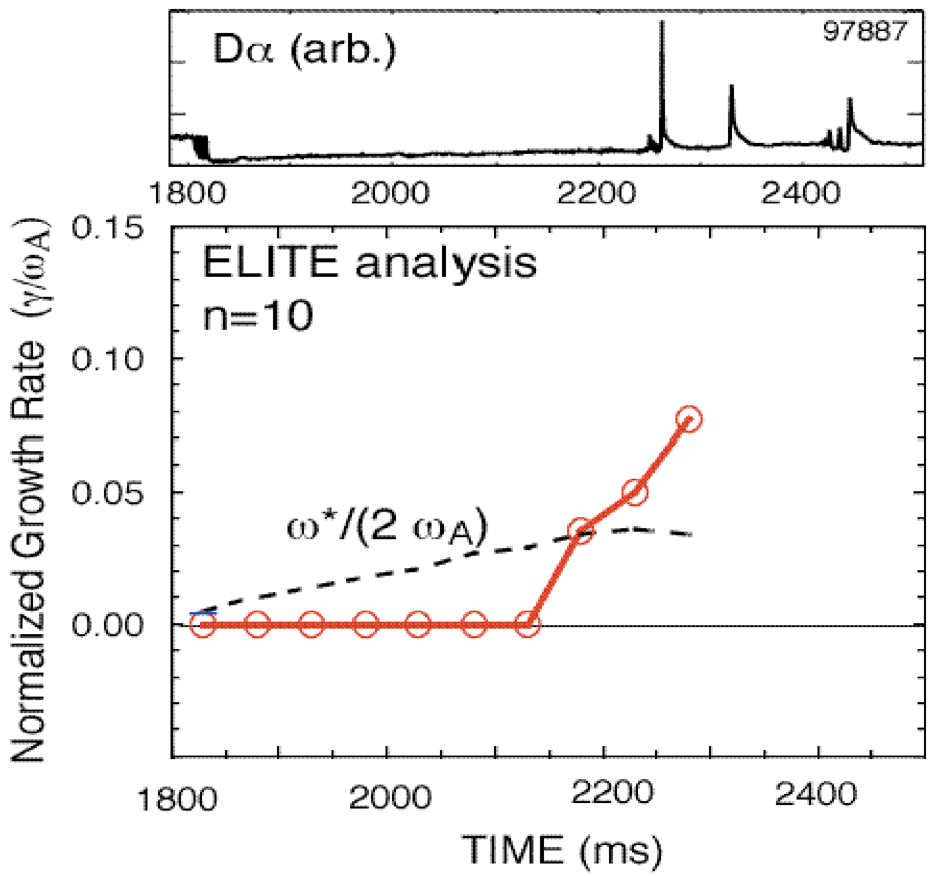
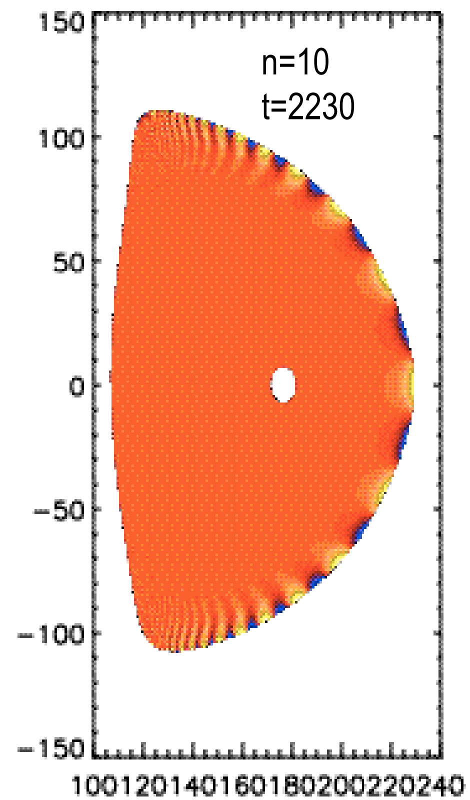
Case Studies Possible with high resolution diagnostics, detailed equilibrium reconstruction

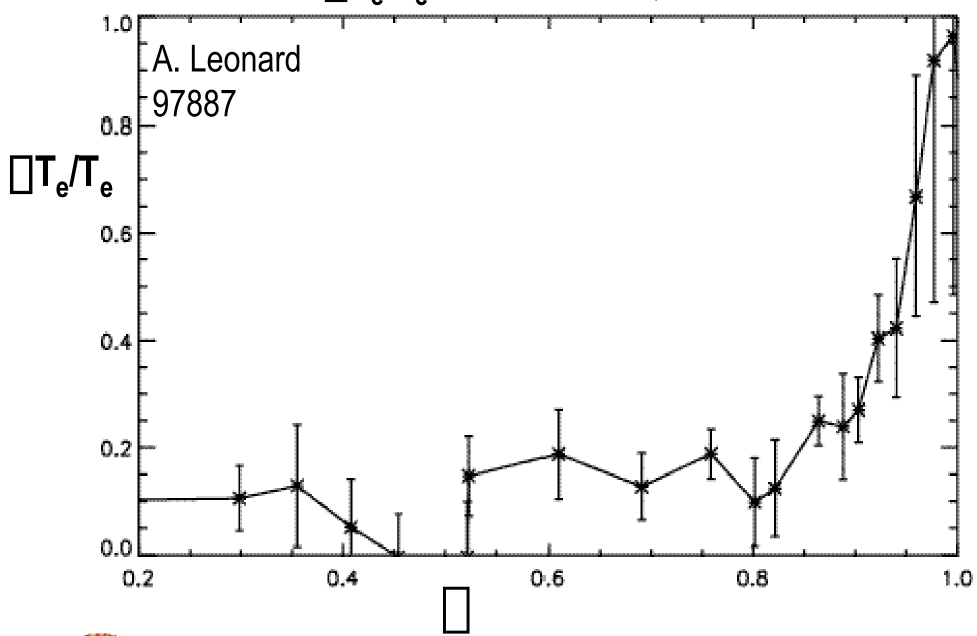




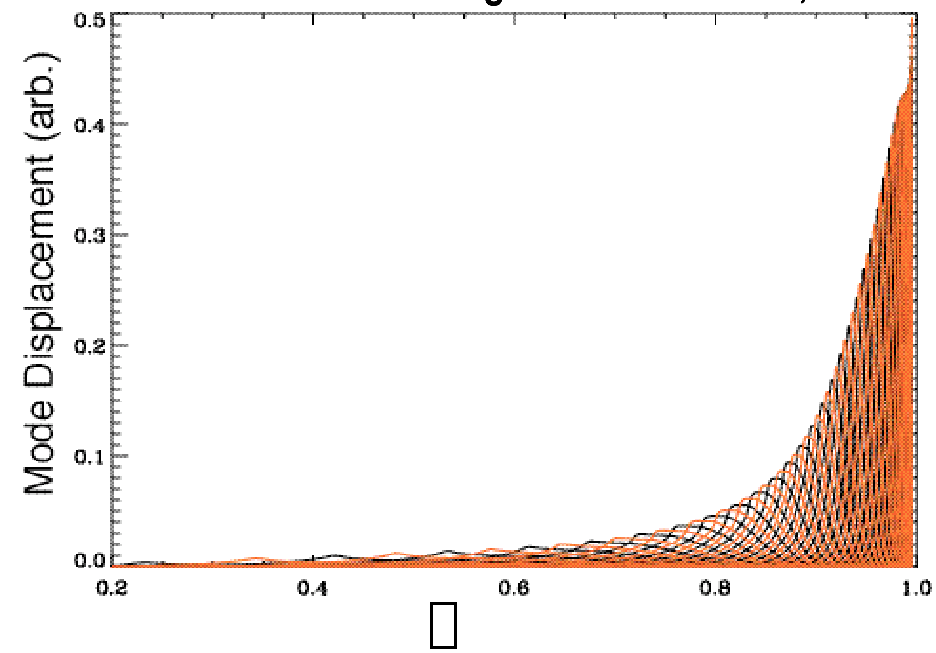
- DIII-D shot analyzed using experimental reconstruction of equilibria
- *n*=10 growth rate attains significant value just before ELM observed

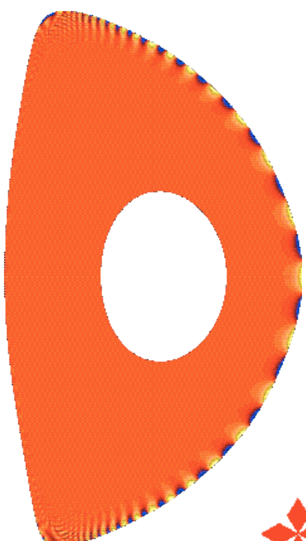
Mode Structure Comparisons Possible with sufficient diagnostic info

Observed $\Delta T_e/T_e$ across ELMs, t=2200-2400



Calculated n=10 radial eigenmode structure, t=2230





- Pedestal extends from ψ~.95–1, both observed depth and calculated mode extend well inside the pedestal
- More detailed comparisons with predicted mode structure possible divertor probes (double null), magnetic n measurements, SXR? GPI? Other?

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Possible Low-A Issues

-Impact on bootstrap current, peeling stability and ballooning 2nd stability

-Coupling of ELMs to core modes

-Impact of high q, local pitch of field lines

-Increased impact of non-ideal physics?

-Pedestal width scaling? Large orbit effects?

-Pedestal transport, power to reach stability thresholds, pervasiveness of ELMs

-Energy and density loss resulting from ELMs, SOL physics

Pedestal Stability and Dynamics Tools

ELITE is a 2D eigenvalue code, based on ideal MHD (amenable to extensions):

Efficient new linear code, calculates MHD growth rates and mode structures for 5<~n<~60

Benchmarked against GATO and MISHKA, employed in pedestal stability studies on DIII-D, C-Mod, JT-60U, JET, Asdex-U

Allows scans of 2D equilibria over wide pedestal parameter space

Study coupled peeling/ballooning modes and quantitative constraints on edge gradients and pedestal height

Plan to add sheared rotation and diamagnetic effects

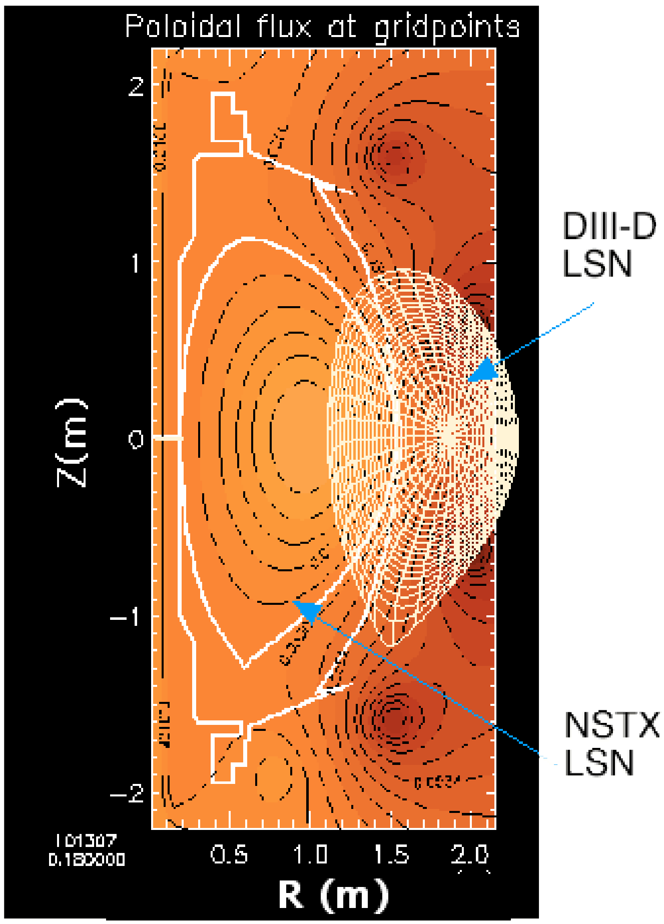
BOUT for nonlinear dynamics, non-ideal effects, X-point geometry

Kink term recently added

Future extensions to more collisionless regimes

GYRO (& other GK) for future gyrokinetic analysis, including non-local geometry

Diagnostics / Possible Experiments



Paoletti, Sabbagh (Columbia)

High resolution ne, Te, Ti, rotation measurements in pedestal

Measurement of edge current is the holy grail. Bootstrap models can be used.

Accurate, high resolution equilibrium reconstruction needed.

Very fast time resolution needed to look at mode structure. High spatial resolution as well for higher n's.

Comparison expts with other tokamaks could be useful for understanding low A effects.

Explore pedestal variation: shape, density, q

Control & optimize pedestal: theory & expt