SUGGESTED DIII-D RESEARCH FOCUS ON PEDESTAL/BOUNDARY PHYSICS

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OBJECTIVES

- Fundamental understanding of edge/boundary physics that will enable:

  1) the development of a predictive model for the edge pedestal pressure, temperature and density profiles in the absence of or between ELMs;

  2) the mitigation or avoidance of ELMs;

  3) the optimization of the edge pedestal; and

  4) the development of a predictive model for the SOL-DIV and its interaction with the pedestal.

OVERVIEW of Proposed Research

- Measure thermal diffusivities and toroidal angular momentum transport rates in edge pedestal and identify the transport mechanisms producing them.
- Understand the causes of the toroidal and poloidal rotation and the radial electric field in the edge pedestal and how to control them.
- Understand the coupling of edge pedestal physics and SOL-DIV physics (including PMI).

Predictive Edge Pedestal Profile Model in the absence of ELMs or between ELMs derived from first 4 moments of Boltzmann Eq.

- Force balance among the pressure gradient, VxB forces, Er and lesser forces determines the ion pressure gradients

$$L_{pi}^{-1} \equiv -\frac{1}{p_i}\frac{dp_i}{dr} = \frac{V_{ri} - V_{pri}\left(E_r, V_\theta, ..\right)}{D_i\left(\nu_{ik}, \nu_{cx}, \nu_{visc}, ..\right)}$$

- Heat conduction determines the ion and electron temperature gradients $L_{T_{i,e}}^{-1} = \dfrac{q_{i,e}}{n_{i,e} T_{i,e} \chi_{i,e}}$

- Ion density gradients then are determined from $L_{ni}^{-1} = L_{pi}^{-1} - L_{Ti}^{-1}$

Predictive Model (cont.)

- "Diffusion coefficient"

$$D_i \equiv \frac{m_i T_i \nu_{ik}}{\left(e_i B_\theta\right)^2}\left(1+\frac{\nu_{cxi}+\nu_{visci}+\nu_{anomi}}{\nu_{ik}}-\frac{e_i}{e_k}\right)$$

- "Pinch velocity"

$$V_{pri}=\frac{\left[-M_{\phi i}-n_i e_i E_\phi^A+n_i m_i\left(\nu_{ik}+\nu_{cxi}+\nu_{visci}+\nu_{anomi}\right)\left(B_\phi V_{\theta i}+E_{rad}\right)/B_\theta-n_i m_i \nu_{ik} V_{\phi k}\right]}{n_i e_i B_\theta}$$

- The conductive heat fluxes $q_{i,e}$ are determined by solving the ion and electron heat balance equations for the total heat fluxes, solving the ion continuity equation for the particle flux and subtracting the convective heat fluxes from the total heat fluxes, then subtracting ion orbit loss and X-loss heat fluxes.

CONCLUSIONS

- THE RADIAL ELECTRIC FIELD, THE ROTATION VELOCITIES AND THE ENERGY & MOMENTUM TRANSPORT COEFFICIENTS ARE IMPORTANT PHYSICS PARAMETERS IN THE EDGE PEDESTAL—WE SHOULD UNDERSTAND THEM.

- THERE SHOULD BE A STRONG RELATION BETWEEN THE EDGE PEDESTAL PARAMETERS AND THE SOL-DIV—WE SHOULD UNDERSTAND IT.

BACKGROUND

WORK TO DATE INDICATES PATH TO A PREDICTIVE EDGE PEDESTAL MODEL

- Peeling-ballooning mode[1] theory predicts the limiting edge pressure (for a given pressure width), or equivalently limiting pressure gradient, for ELM onset[2].
- Pedestal width can be correlated[3] with $\sqrt{\beta_\theta}$, consistent with KBM.
- Expt. and theoretical evidence[4] for a particle pinch that depends on E_{rad} & V_θ
- Theoretical model[5] for pressure, temperature and density profiles in edge pedestal developed from first 4 fluid moments. Needs thermal and angular momentum transport coefficients and models for E_{rad}, V_θ & V_ϕ in edge plasma as input.
- RMP suppresses ELMs in low-collisionality edges by reducing the density, which seems to be associated with a reduction in inward pinch caused by a reduction in E_{rad}.
- Most of the comparisons[6] of theory with experimental χ_i have not taken ion orbit loss into account in determining χ_i^{exp} and need to be redone.

1) PoP 9, 1277(2002). 2) NF 51, 103016(2011). 3) NF 50, 06400 (2010). 4) NF 51, 063024(2011). 5) NF submitted (2011). 6) PoP 15, 052503(2008).

Experiment Interpretation Indicates In the absence of ELMs or between ELMs

- The D pinch velocity V_{pDr} is predominantly determined by the radial electric field and the poloidal rotation velocity.
- The D pinch velocity is generally inward and much larger than the D radial particle velocity determined from the continuity equation taking into account recycling neutrals. Thus, the pressure gradient is primarily determined by Erad and Vpol.
- The D pinch velocity is different for L-mode vs. H-mode[7], for H-mode vs. RMP[8], for just before an ELM vs. just after an ELM[9]. This is due largely to differences in the radial electric field and the poloidal velocity.
- There are large, poloidally asymmetric D particle flows in the SOL (also found in model calculations[10]) which could affect flows in edge pedestal.

7) PoP 17, 112512 (2010). 8) NF 51, 013007 (2011). 9) NF 51, 063024 (2011). 10) PoP 16,042502 (2009).

Focus of the Pedestal/Boundary Experimental Program Could be Understanding & Controlling

1. The mechanisms that determine the radial electric field and poloidal velocities (e.g. ion orbit and X loss, velocity spin-up, coupling with SOL and divertor) and how to control them--- *control the pressure profile by controlling the force balance (pinch)*.

2. The mechanisms that determine the angular momentum transport frequencies (e.g. viscosity, anomalous transport) , which contribute to determining the pressure profile via the diffusion coefficient D.

3. The mechanisms that determine the thermal diffusivities, which determine the temperature gradients. (Note that this requires an accurate determination of conductive heat fluxes, taking into account particle pinches, ion orbit losses[11] and other non-conductive mechanisms that are usually neglected.)

11) PoP 18, 102504(2011)