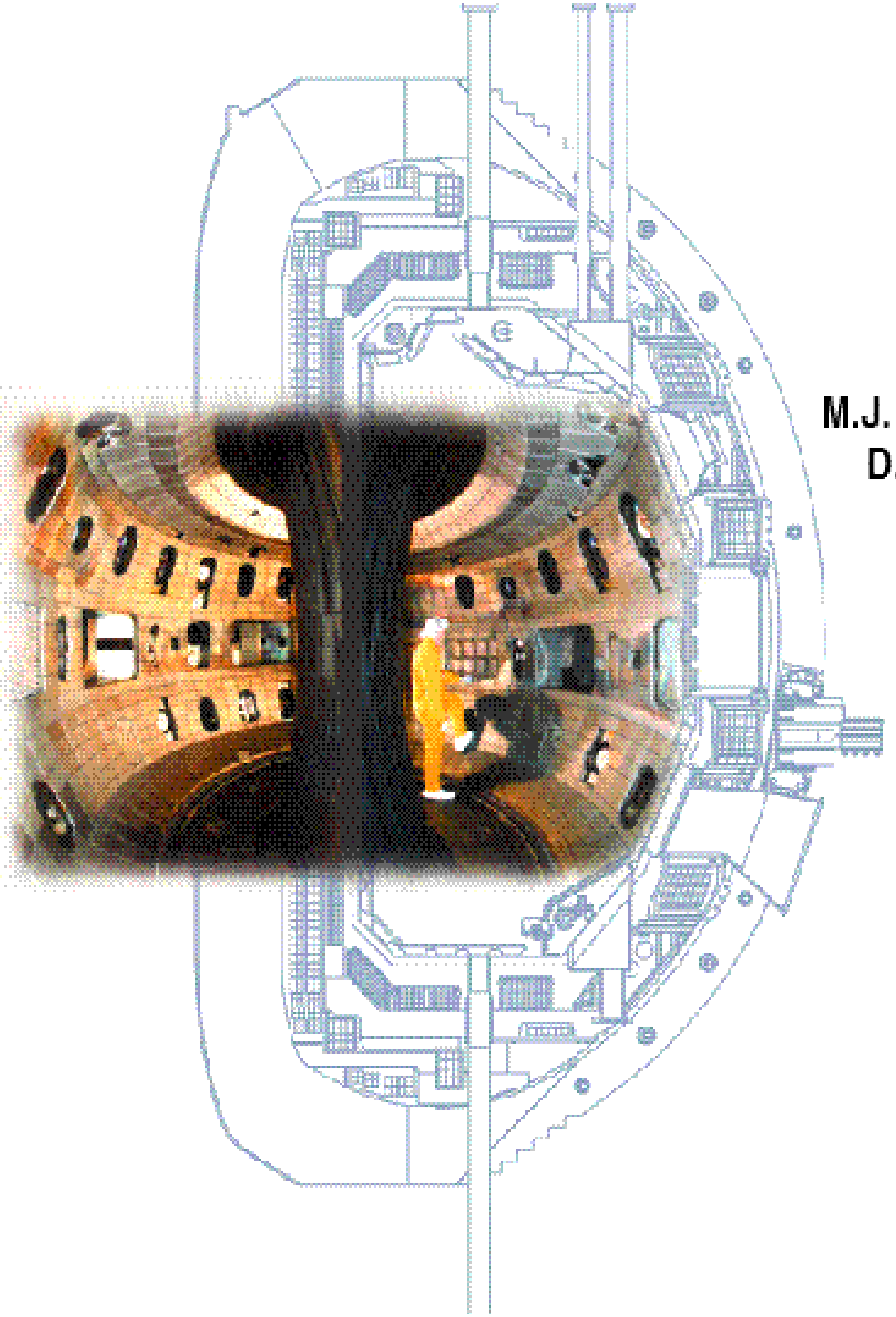

Plasma Flows in the DIII–D Divertor

by
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DIII–D
NATIONAL FUSION FACILITY

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Plasma Flows in the DIII-D Divertor[1] J.A. BOEDO, R.A. MOYER, M.J. SCHAFFER, N.H. BROOKS, M.A. MAHDAVI, R.C. ISLER, C.J. LASNIER, G.D. PORTER, J.G. WATKINS, The DIII-D National Team — Comprehensive measurements of parallel D^+, impurity flow, and poloidal $\mathbf{E} \times \mathbf{B}_\mathrm{T}$ drifts were made that show their importance in understanding divertor in-out asymmetries and other divertor phenomena. Poloidal $\mathbf{E} \times \mathbf{B}_\mathrm{T}$ flows on the private side of the separatrix that circulate $\sim 10^{22}$ ions/s, or about 30% of the total ion flux to the target are produced by the plasma potential gradients at the separatrix, driven by temperature gradients. In attached plasmas, the D^+ parallel flow on the outer divertor SOL is toward the divertor target. Flow reversal develops at the separatrix as the divertor plasma approaches detachment. In PDD cases, the deuterium flows approach Mach 1 over the whole outer divertor SOL volume and the convected heat flux transports 80% of the total heat flux to the target plates. Impurity ions feature both "forward" flows in the SOL and reversed flows near the separatrix in attached plasmas. The forward impurity flow velocities speed up whereas the reversed flows slow down during detachment.

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- [X] Prefer Oral Session
- [ ] Prefer Poster Session

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Special instructions: DIII-D Contributed Oral Session, immediately following TW Petrie

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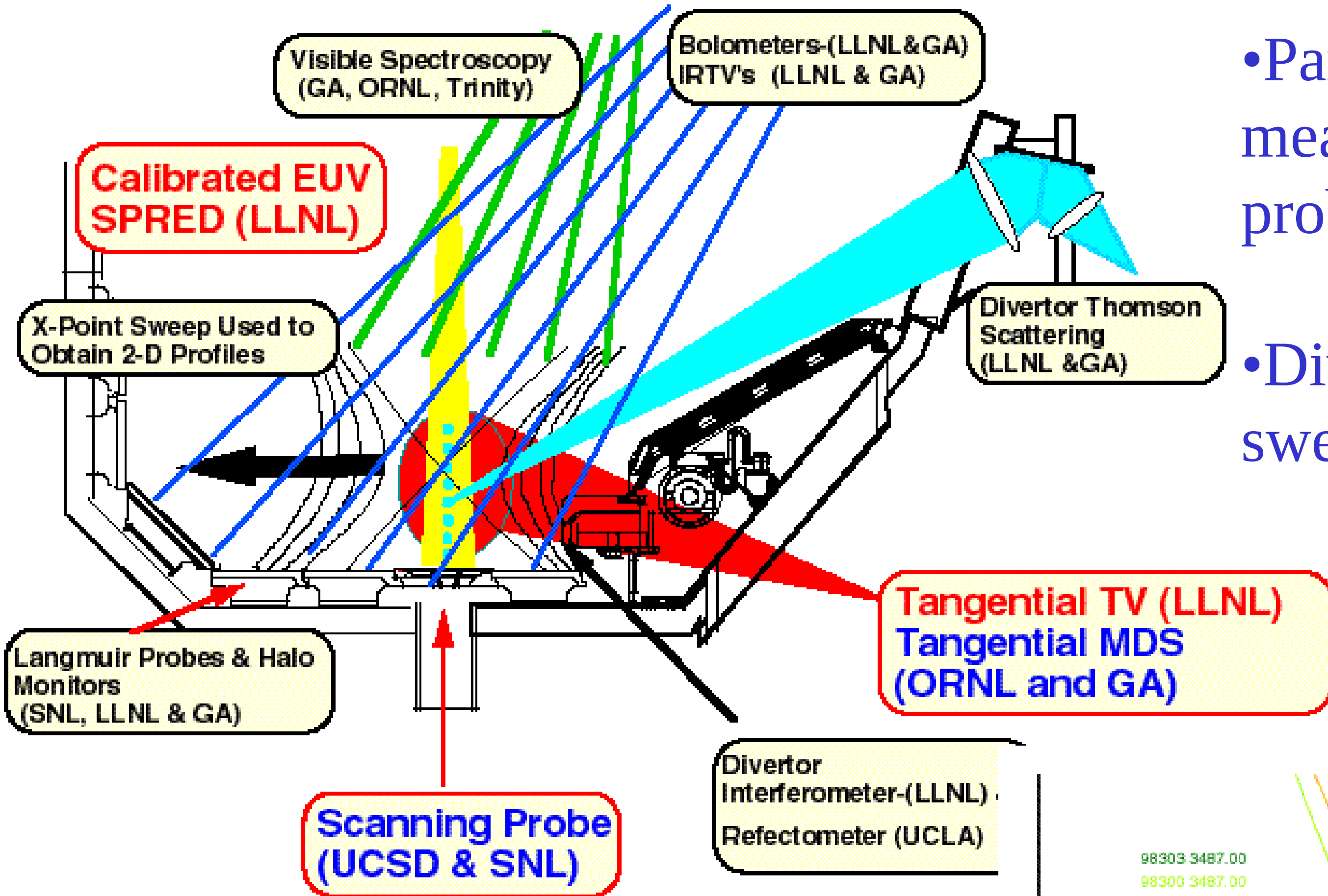
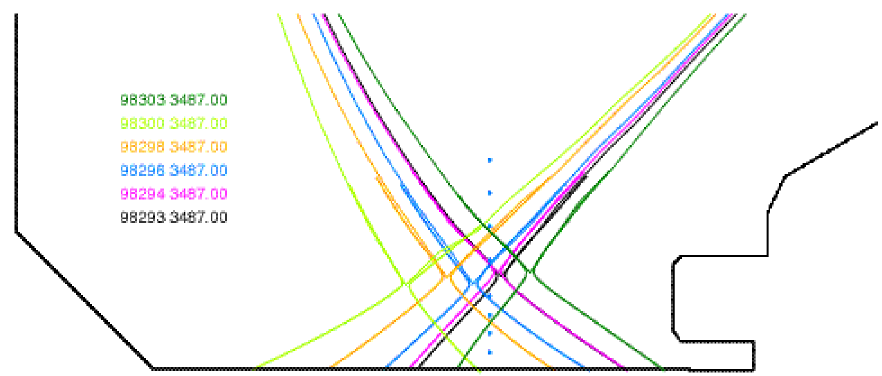
DIVERTOR DIAGNOSTICS & MACH PROBE



- •Parallel flows measured with a Mach probe
- •Divertor geometry is swept for 2-D coverage



OUTLINE

- Motivation
- Parallel Flows in divertor Plasmas.
  Attached and detached
- UEDGE Simulations
- Conclusions

- ExB Flows in the divertor
  Attached and detached.
- Overall Conclusions

Motivation

•Particle transport.

-Deuterium => Pumping, Density Control.

-Impurity => Core contamination, performance.

$$F_z = \underbrace{m_z \left(\frac{V_b - V_{\parallel,i}}{\tau_{si}} \right)}_{\text{Drag}} + \underbrace{\left[0.71\ Z_z^2 \frac{\partial T_e}{\partial s} + \beta_z \frac{\partial T_b}{\partial s} \right]}_{\text{Thermal}} + Z_z e E$$

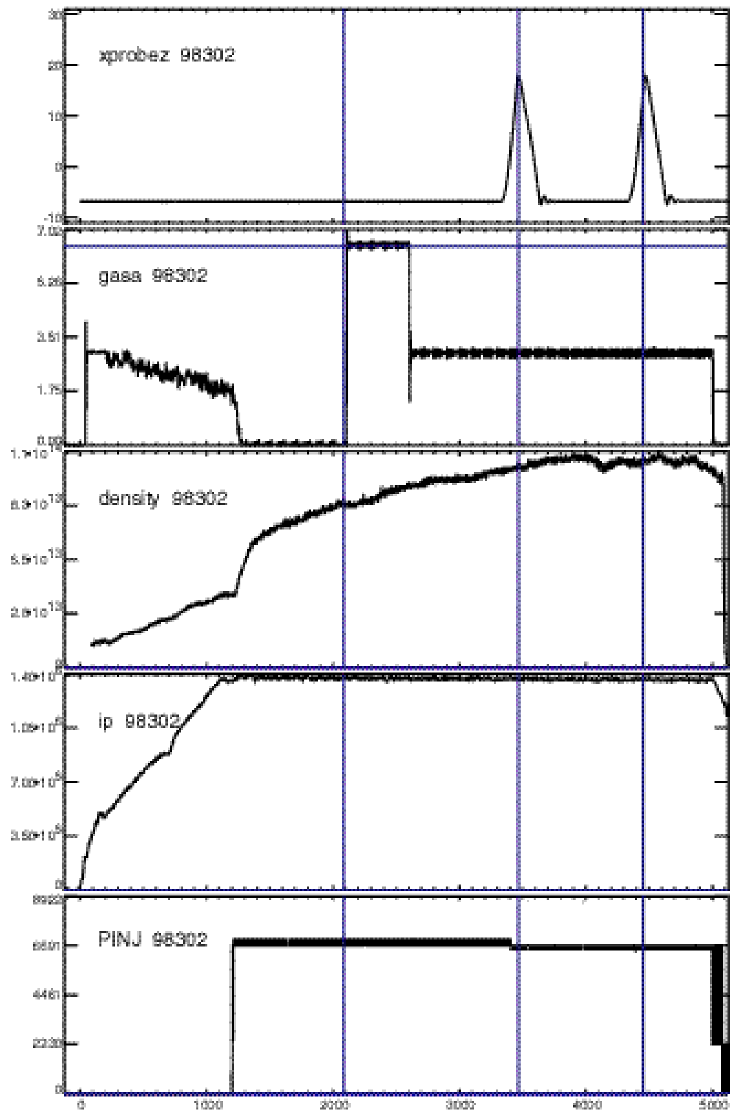
•Heat Transport.

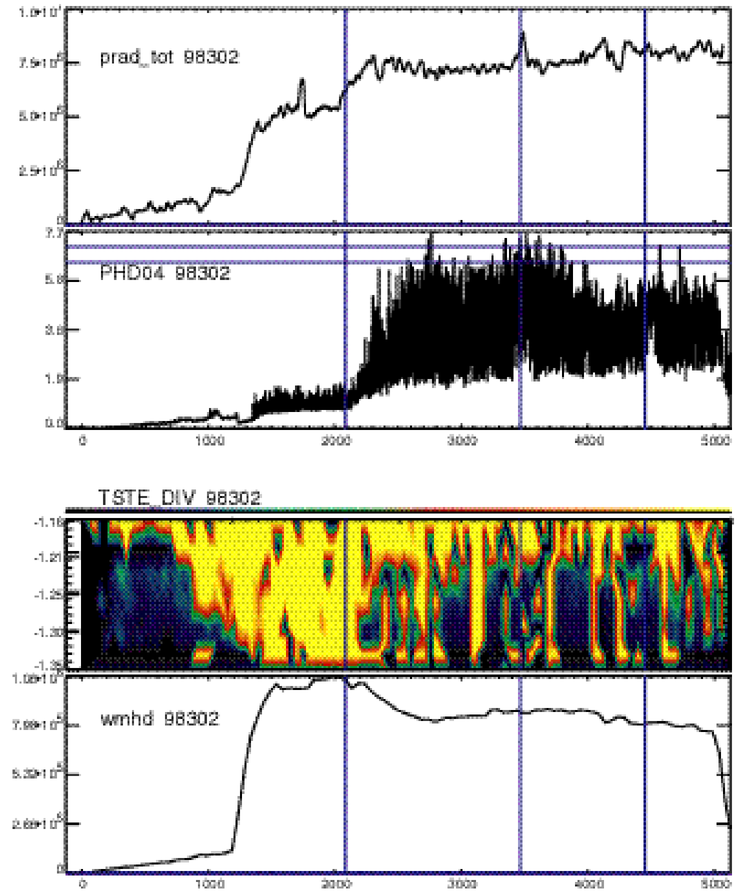
$$q_{\parallel} = \underbrace{\kappa T_e^{5/2} \frac{\partial T_e}{\partial s}}_{\text{Conduction}} + \underbrace{n V_{\parallel} \left[\tfrac{5}{2} (T_e + T_i) + \tfrac{1}{2} m V_{\parallel}^2 + I_o \right]}_{\text{Convection}}$$

Convection => 30% in attached, 80-90% in PDD.

Conduction => 70% in attached, 10-20% in PDD.

Gas Puff at t=2200. PDD Follows. Two Probe Plunges





Gas Puff 2100 ms

Probe **Probe**

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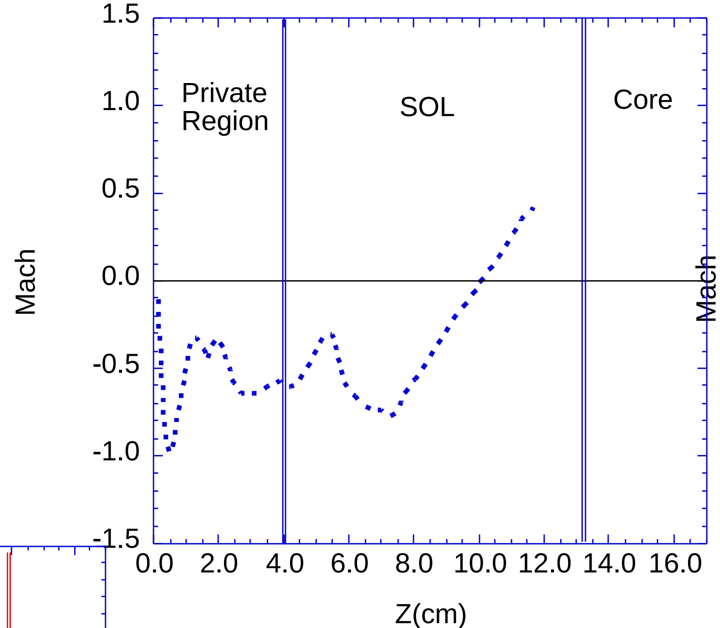
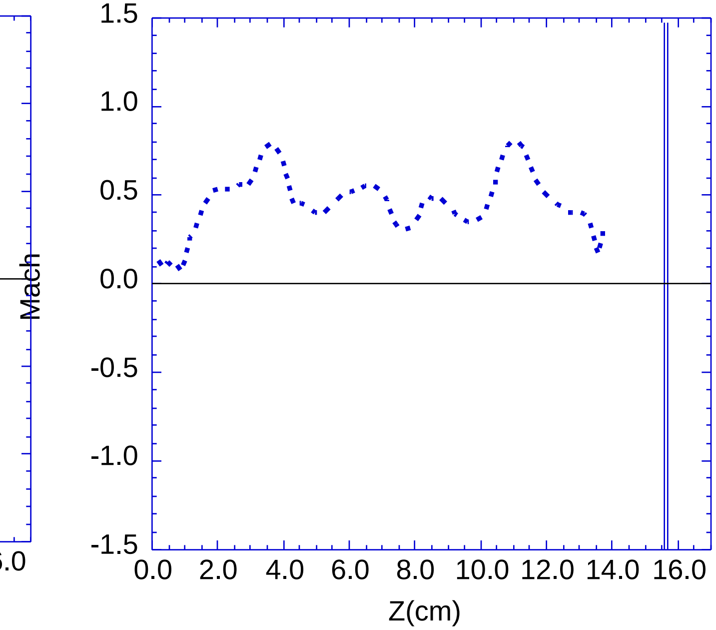
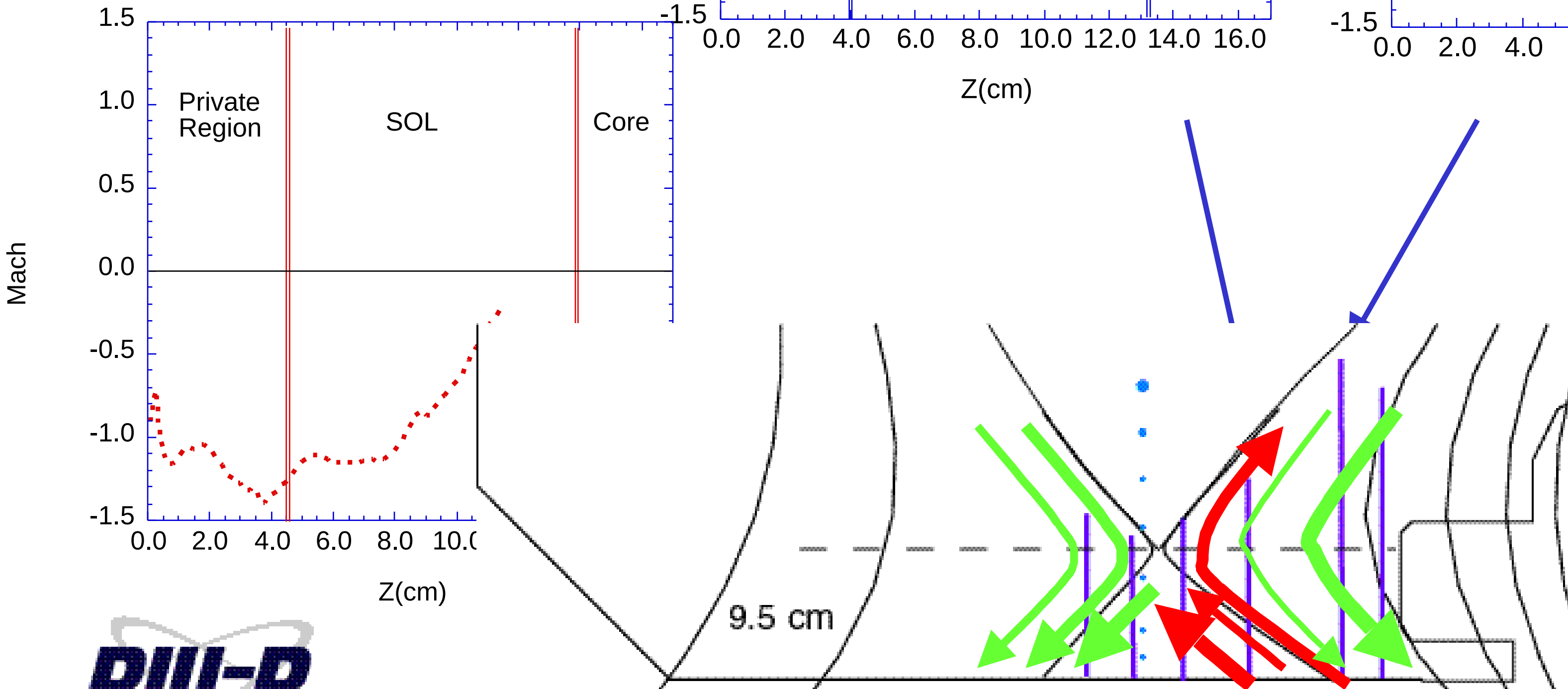
Parallel Flow: Reversal Region exists at Separatrix at 3500 ms







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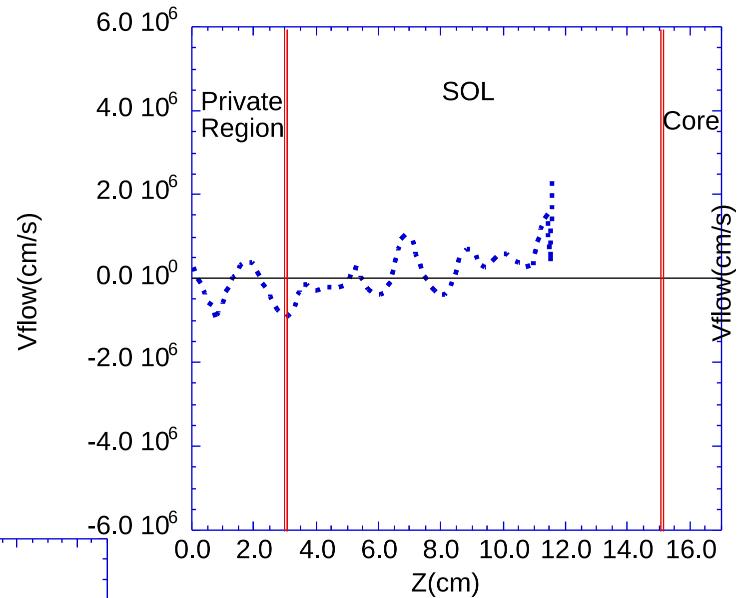
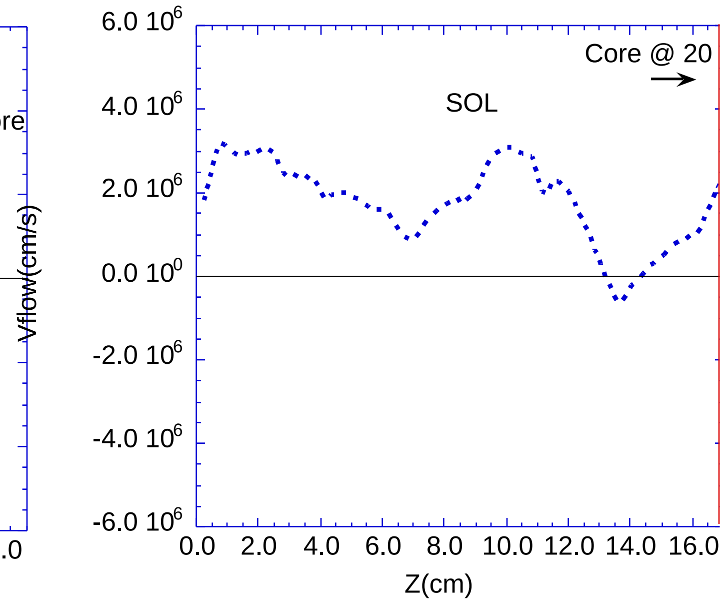
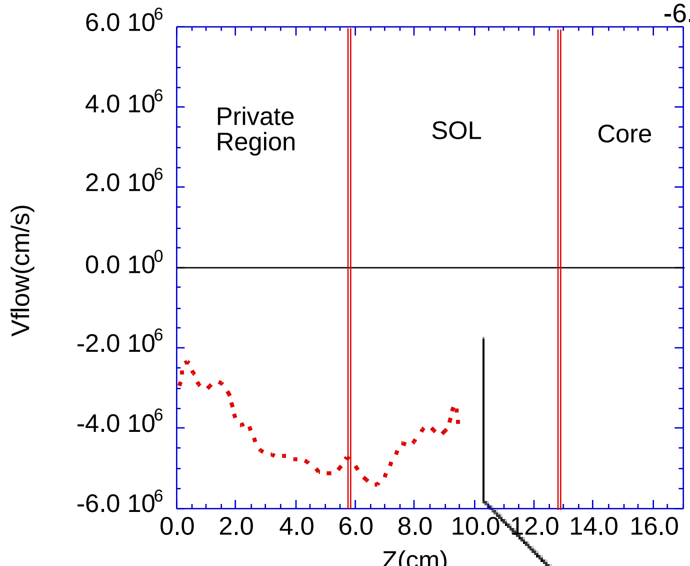
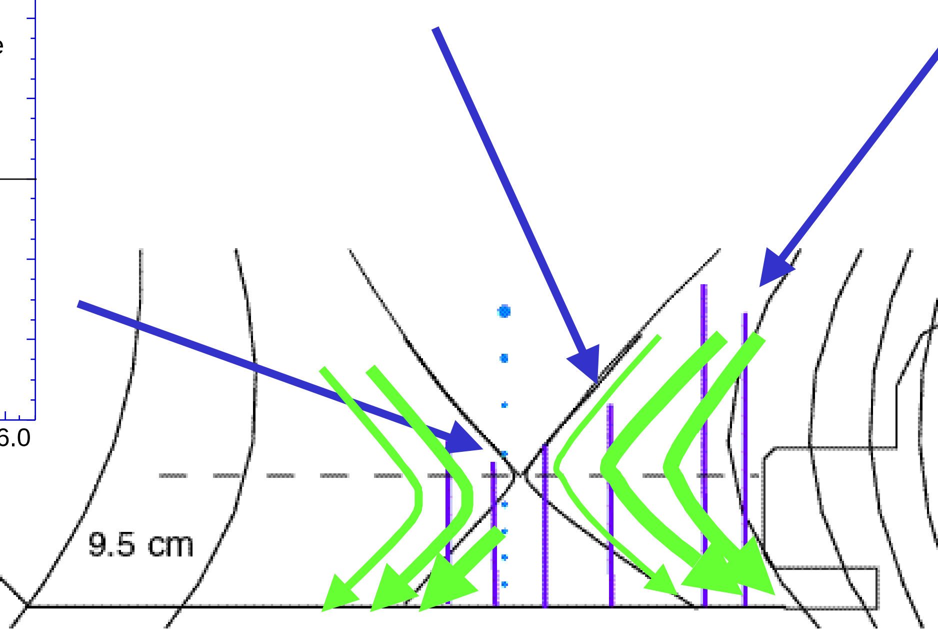
Parallel Flow. NO Flow Reversal at 4500 ms









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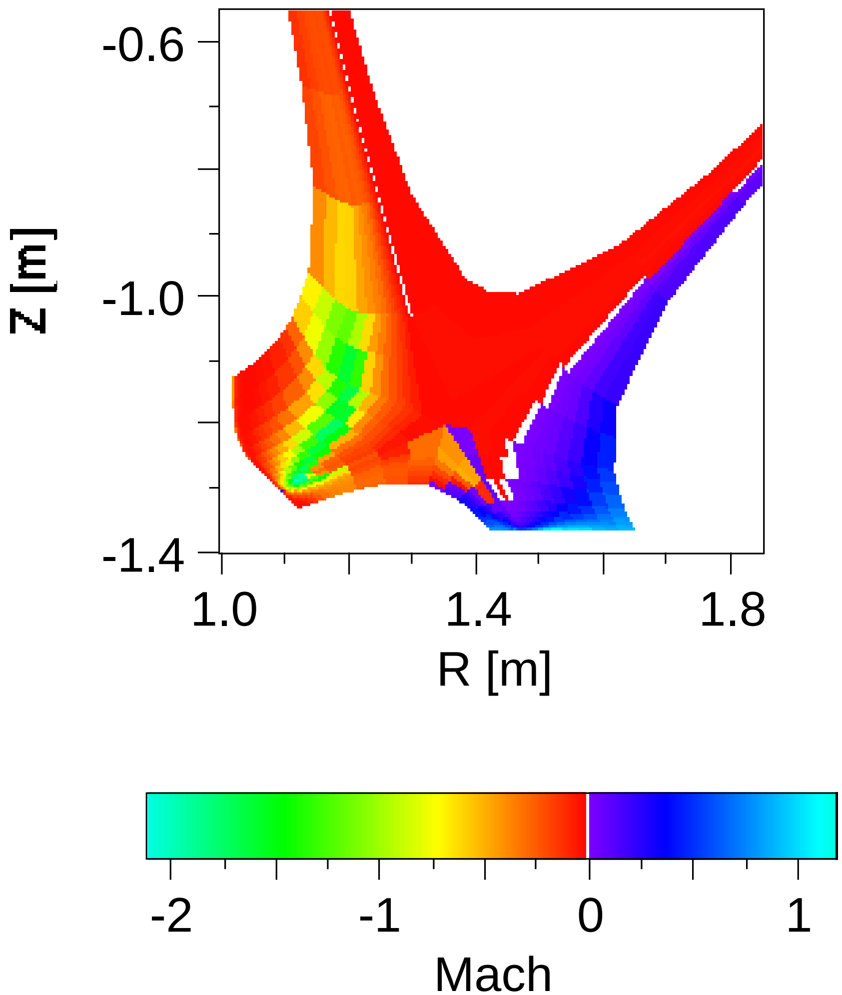
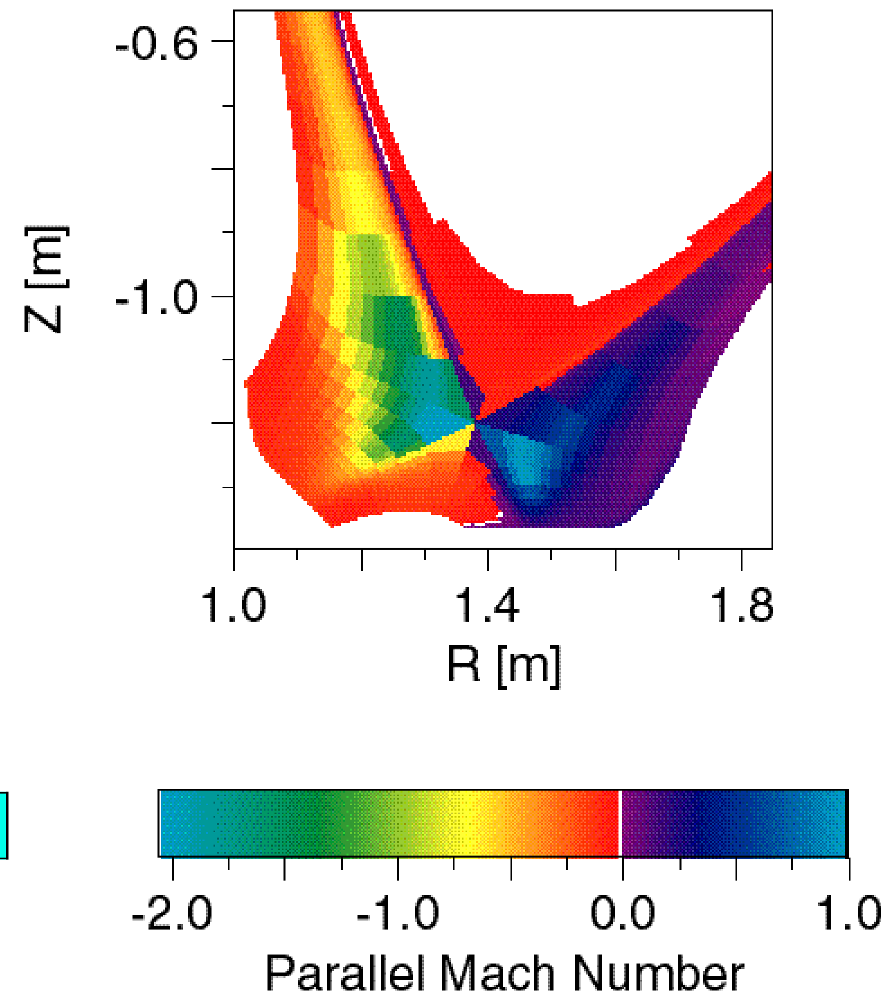
UEDGE: Flow Reversal Region Disappears Upon Detachment

Attached Outer Leg



Detached Plasma



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CONCLUSIONS: Parallel Flow

•Microscopic divertor plasma evolution is slow (~ sec)

•Initial high recycling results in a reversed flow zone at the separatrix

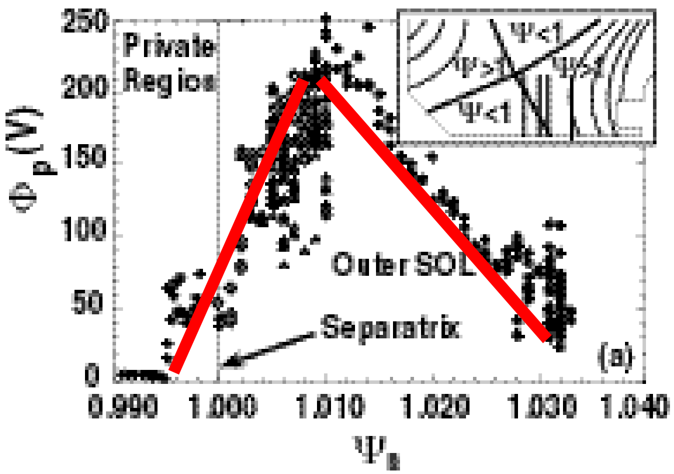
•The reversed flow zone disappears later and divertor plasma has high Mach # flow towards the plate.

•Speed is similar in both regimes (except reversal zone).

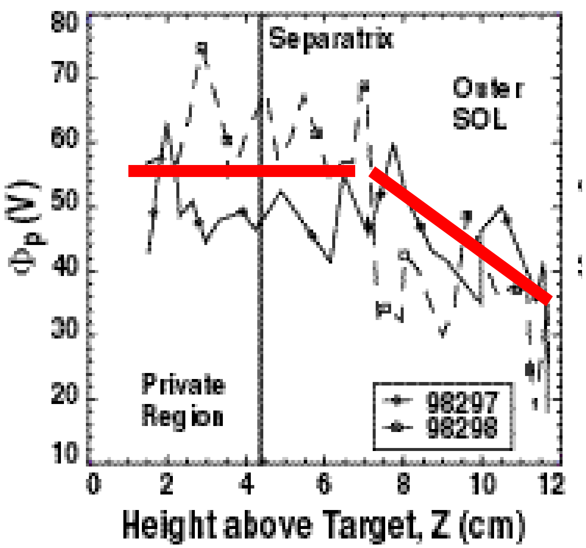
•Carbon behaves similarly > Poster by R. Isler

•UEDGE is able to reproduce these features.

ExB Flows are Important at the Separatrix!



Attached



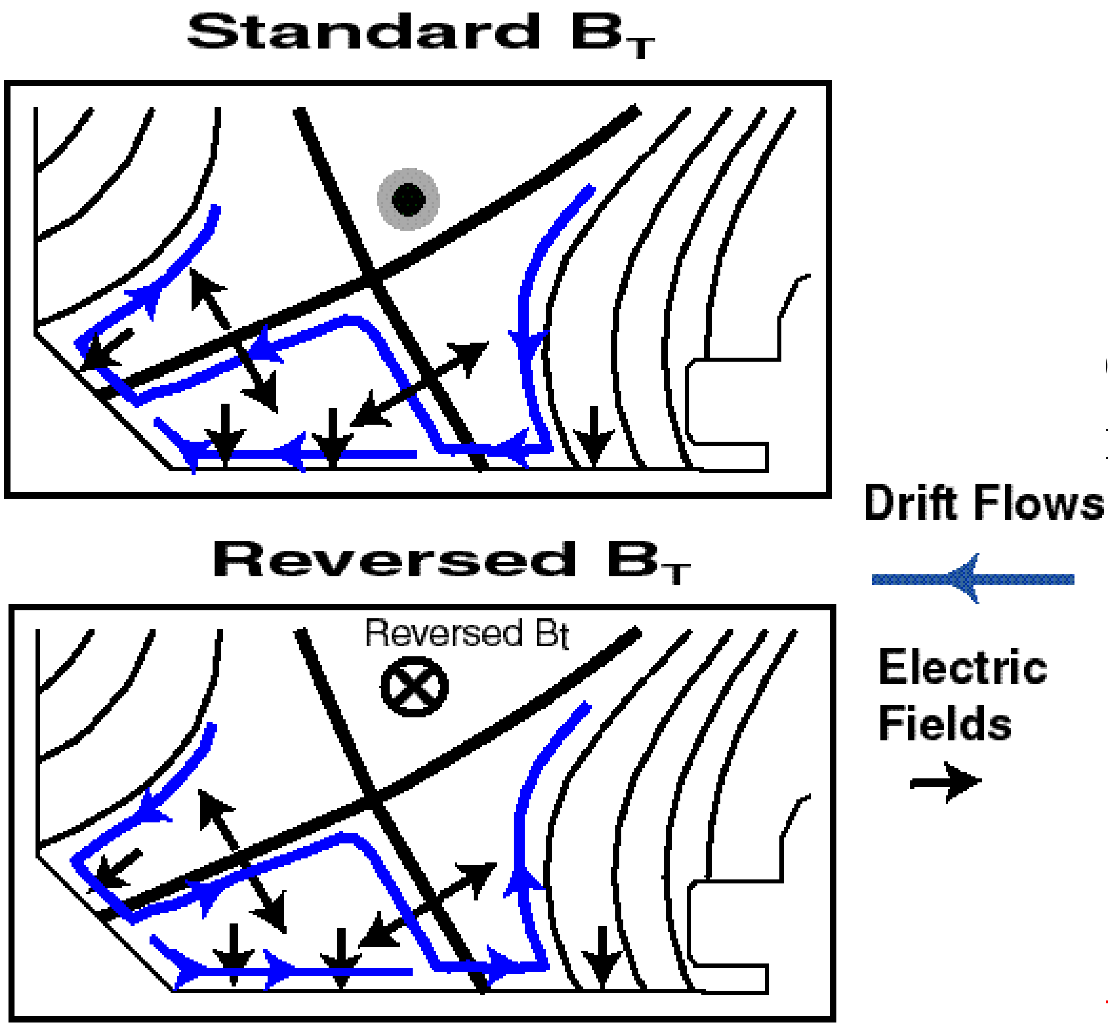
Detached

•Field across separatrix is 4-5 kV/m

•Field in SOL is ~1kV/m

•ExB Flows disappear upon Detachment

ExB FLOWS AFFECT PARTICLE AND POWER BALANCE



Particles

0^{22} ions or 30% of the total

Power

tal to Divertor => 1.43 MW

nvected by ExB => 0.2 MW

Peak heat flux

ISP 0.4 MW/m^2

OSP 1.0 MW/m^2

ExB convected heat flux

0.48 MW/m^2

LOCALLY IMPORTANT

CONCLUSIONS

Parallel Flows:

- We Have Observed Complex Flow Patterns in the Divertor

-Slow divertor plasma evolution

-Flow Reversal at the Separatrix Plasmas => Carbon transport!!!

-Large Region Flow in the Outer Divertor for Detached Plasmas =>Power and Particle Transport!!

- The Patterns Depend on Operating Regime

-Sources and Sinks, Power available to ionize

-Flow Reversal channel widens with recycling

ExB Flows:

- **Large Normal electric Field at the Separatrix => ExB/B^2**

-Poloidal Flow Along the Separatrix => Inner-Outer SOL Coupling.

-Poloidal Flow direction is Bt is dependent => Divertor asymmetries.

-Flow is reduced during PDD >> Need confirmation!

-Initial understanding of the main features has been achieved in UEDGE.