Power and Particle Control Lessons Learned on DIII-D

S.L. Allen and the DIII–D team

Burning Plasma Workshop

GENERAL ATOMICS UCSD ornl

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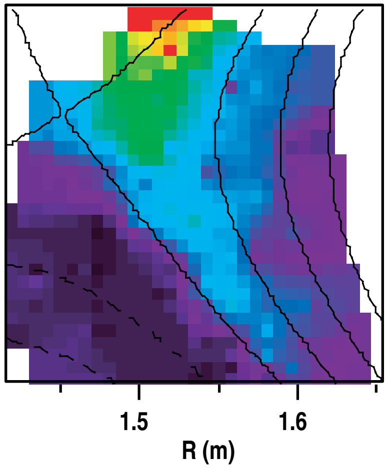
UNIVERSITY OF WISCONSIN MADISON Department of Engineering Physics

PPPL PRINCETON PLASMA PHYSICS LABORATORY

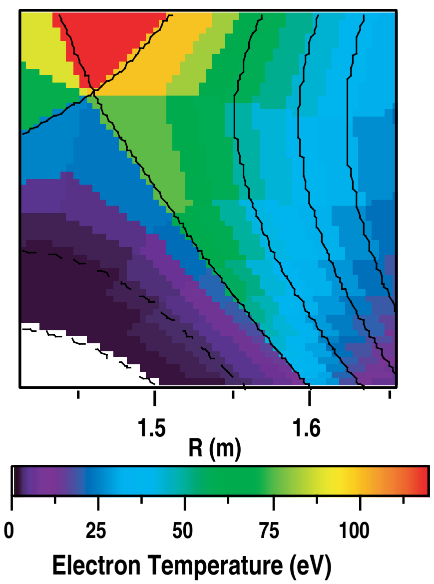
UCLA

Detached divertors for particle and power handling

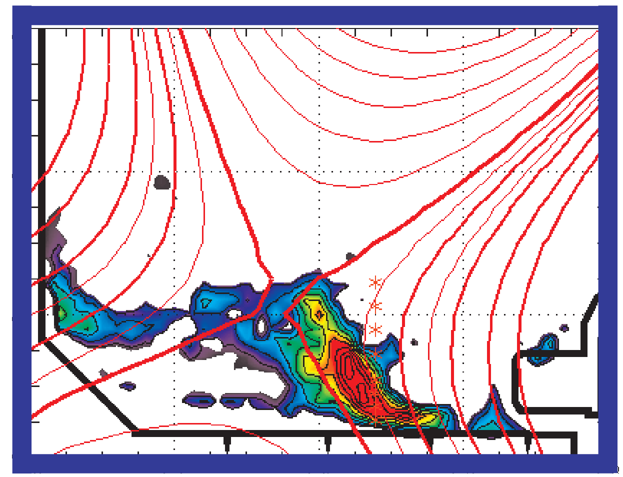
Data Shows Low T_e



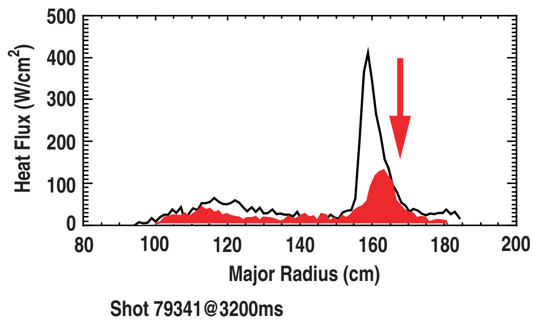
Model Shows Low T_e



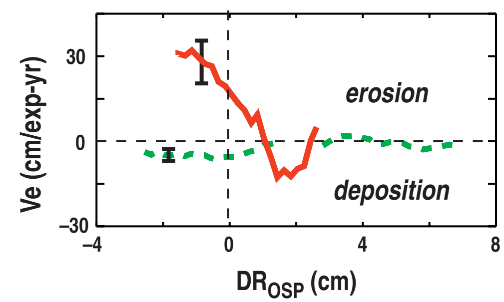
Recombining Plasma Near Plate (D_γ/D_α)



Divertor Heat Flux is Reduced



Erosion is Reduced



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We have a high density divertor solution

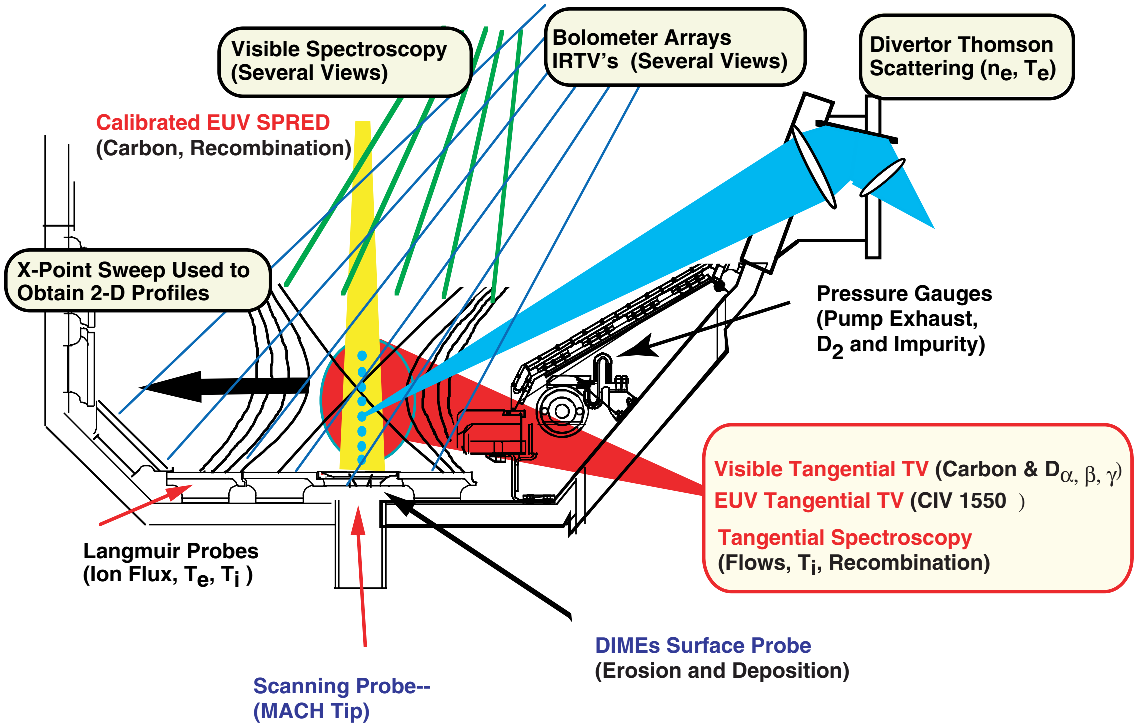
We have a reasonable scientific basis for a conventional long-pulse tokamak divertor solution at high density (collisional edge, detached)

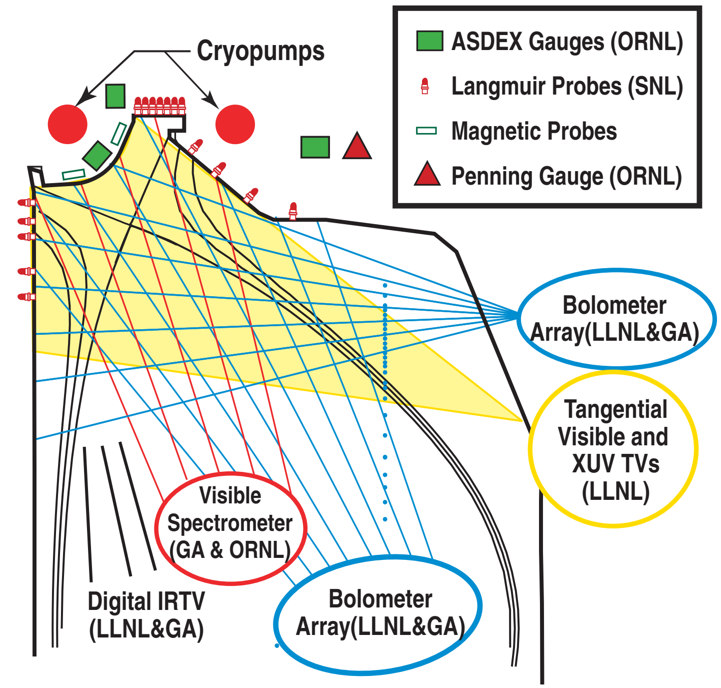
- Low Te recombining plasma leads to low heat and particle fluxes at wall
- Adequate ash control, compatible with ELMing H–mode confinement
- Appropriate for future tokamaks (e.g. to high density ITER-RC)
- Concerns about ***simultaneously*** handling disruptions/ELMs and tritium inventory which shorten divertor lifetime

The challenge is to find self consistent operating modes for other configurations ...

(U.S. Snowmass working group, July 2000)

DIII–D divertors can compare open (low-δ) and closed (high-δ) operation with flexible pumping





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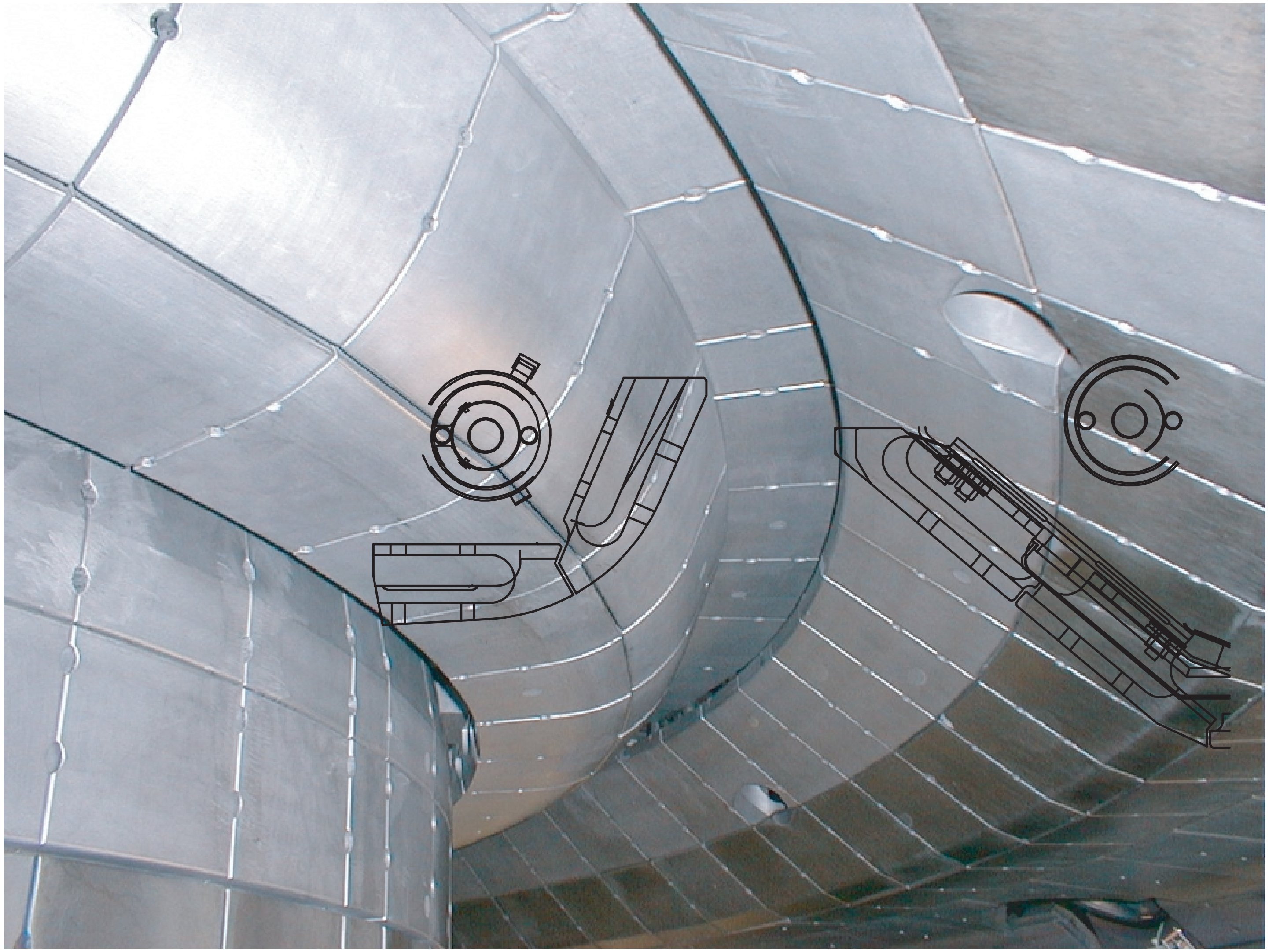
NEW CRYOPUMP AND BAFFLE STRUCTURE ADDED TO UPPER DIVERTOR REGION



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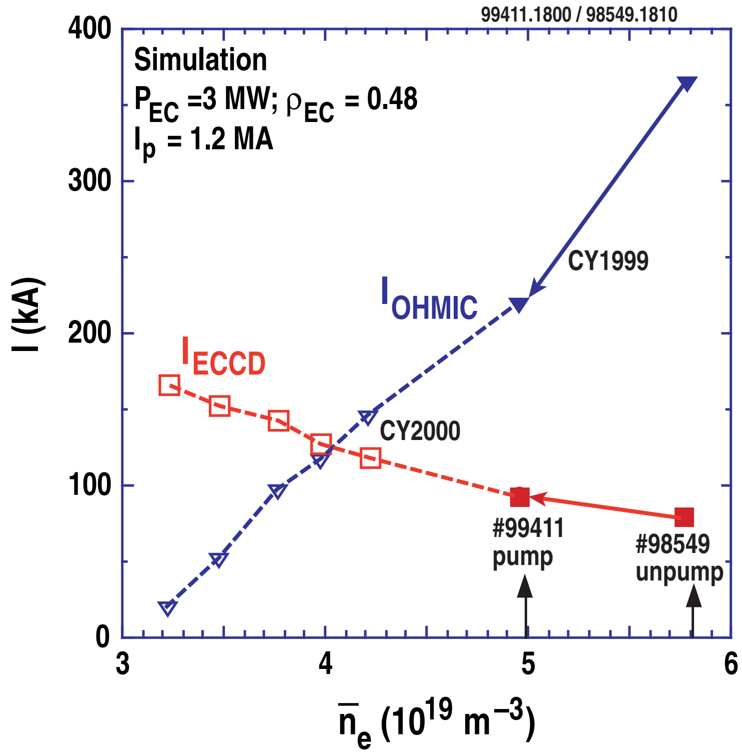
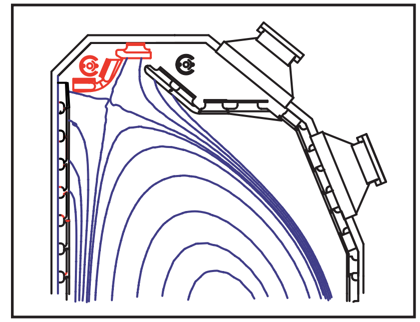
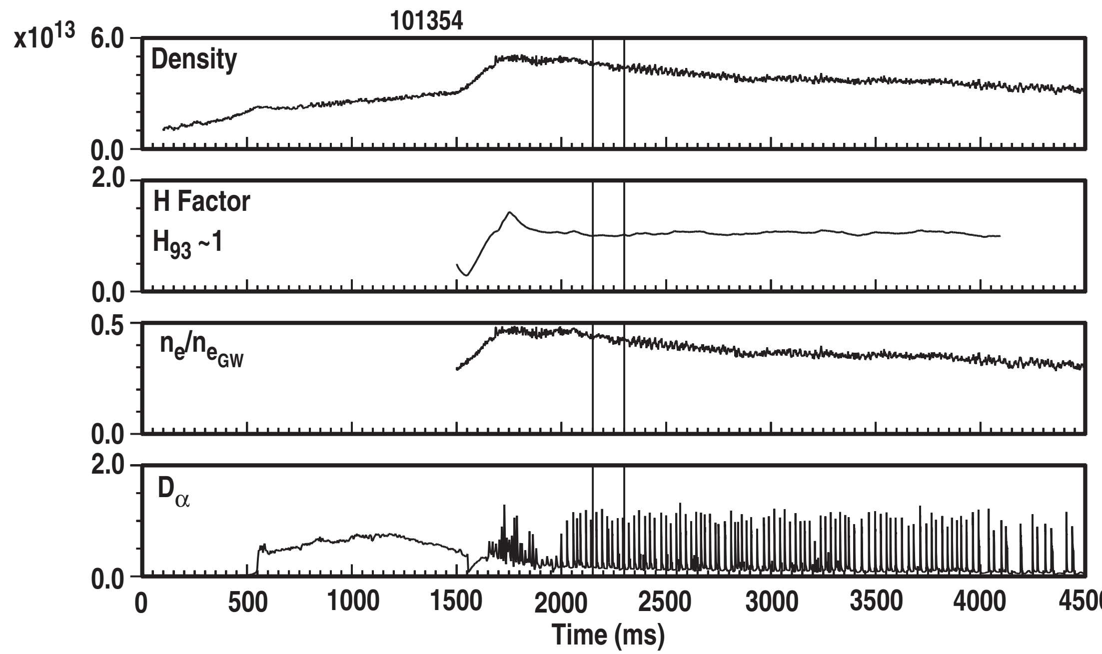
With available ECH power on DIII–D, density and impurity control are critical - these are provided by the divertor







- $I_{CD} \propto \frac{T_e}{n_e} \frac{1}{(Z_{eff} + 5)}$

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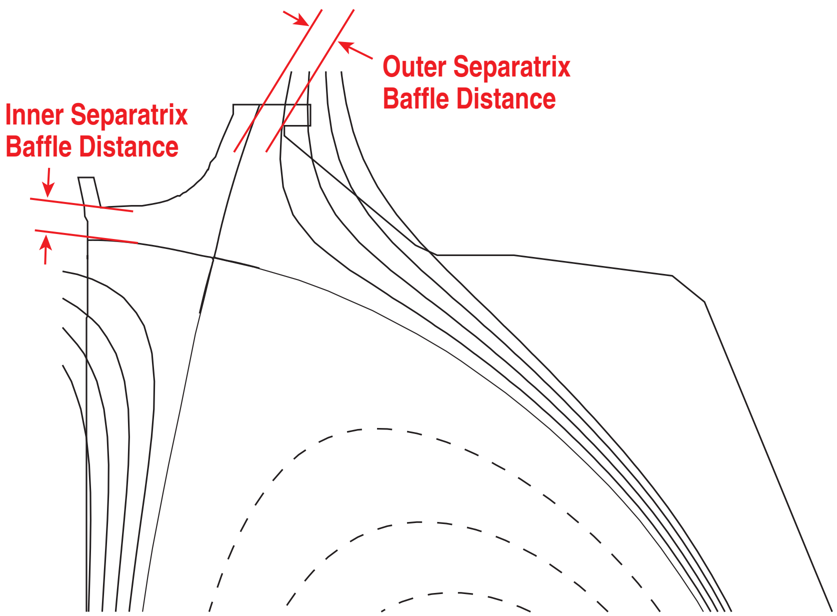
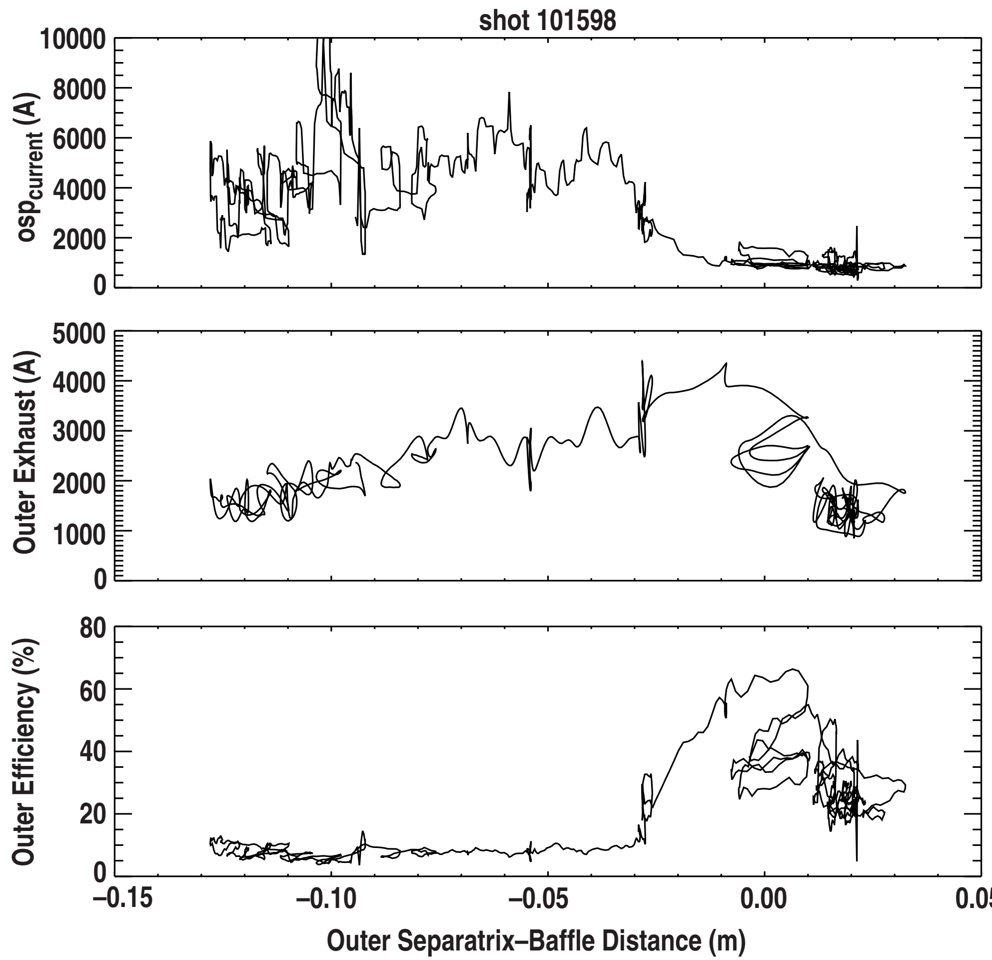
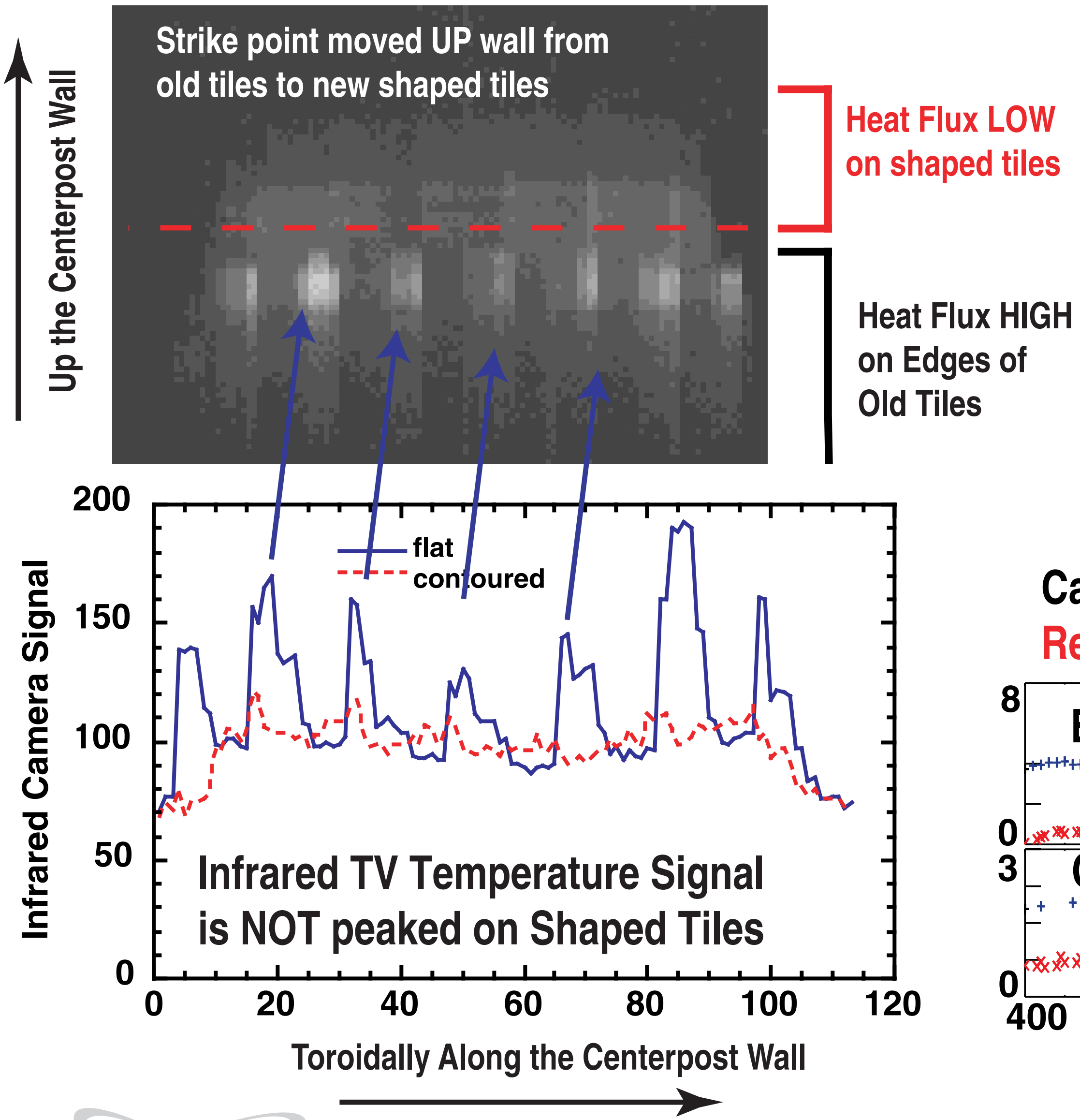
OUTER PUMP EXHAUST PEAKS WHEN STRIKE POINT IS AT THE PUMP APERTURE

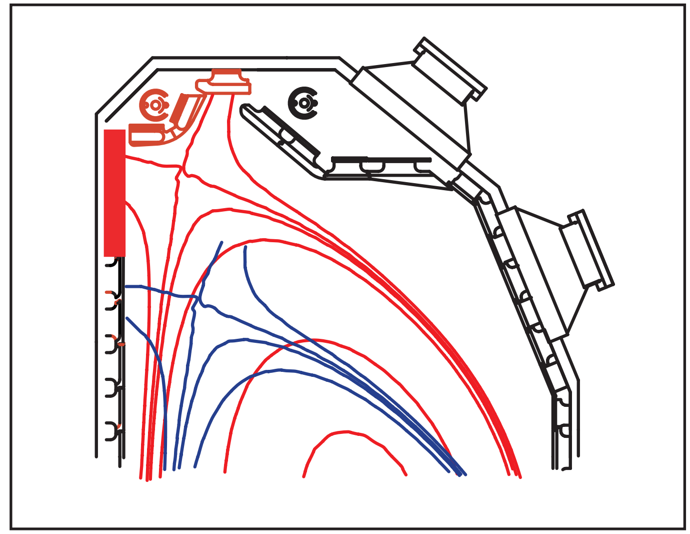




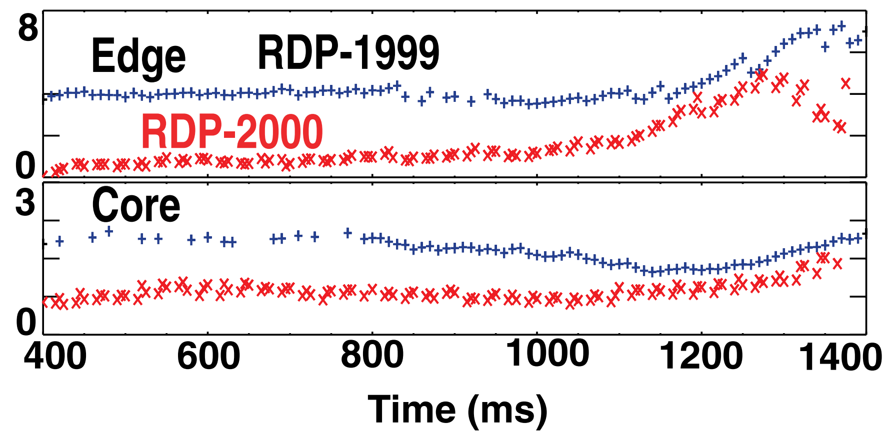
J. Watkins, SNL 112-00/jy

Impurity Control In AT Plasmas With Careful Tile Shaping





Carbon Concentration (%) is
Reduced Compared to Previous Operation



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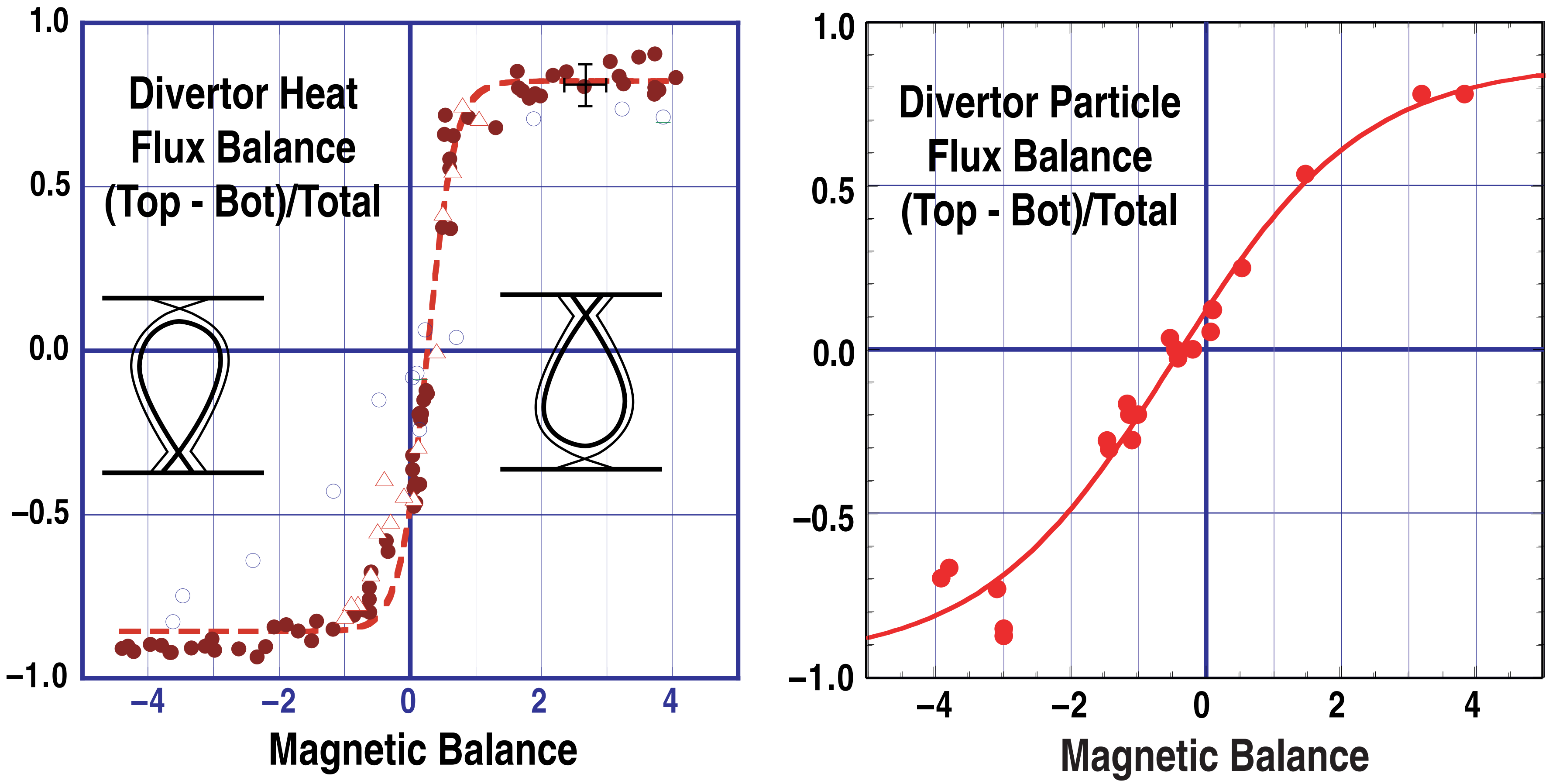
Magnetic balance can be used for power and particle control



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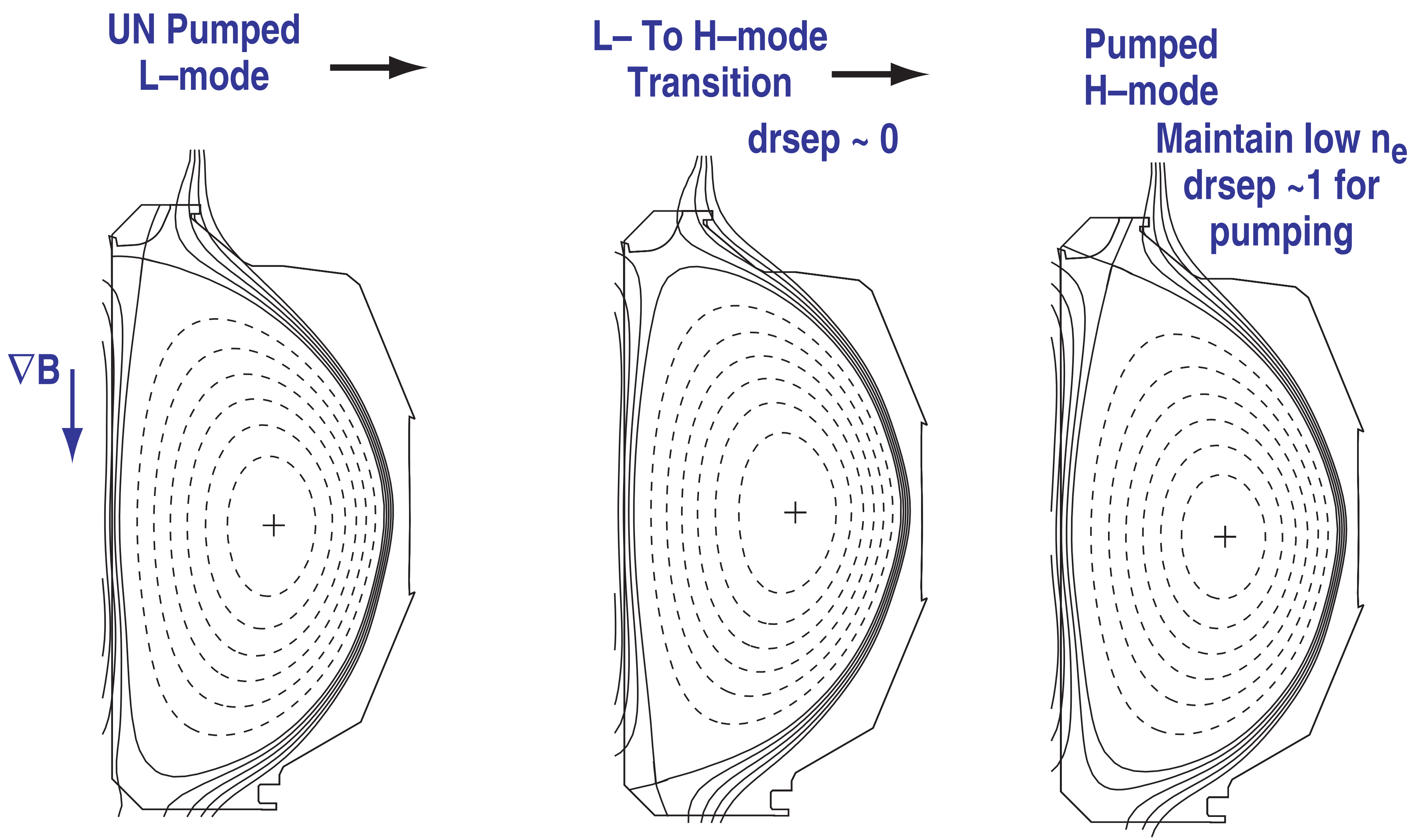
AT Scenario Uses Divertor Shapes For Real-time Control



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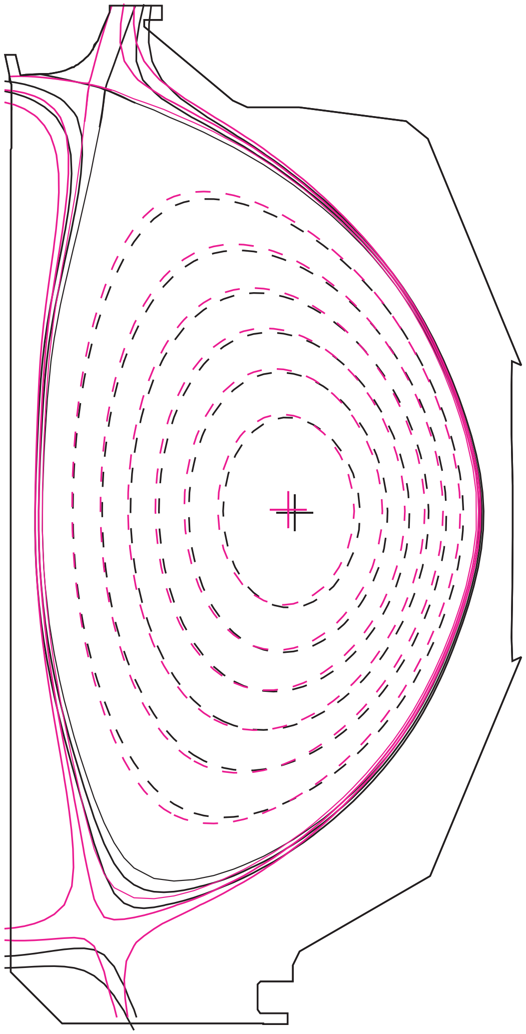
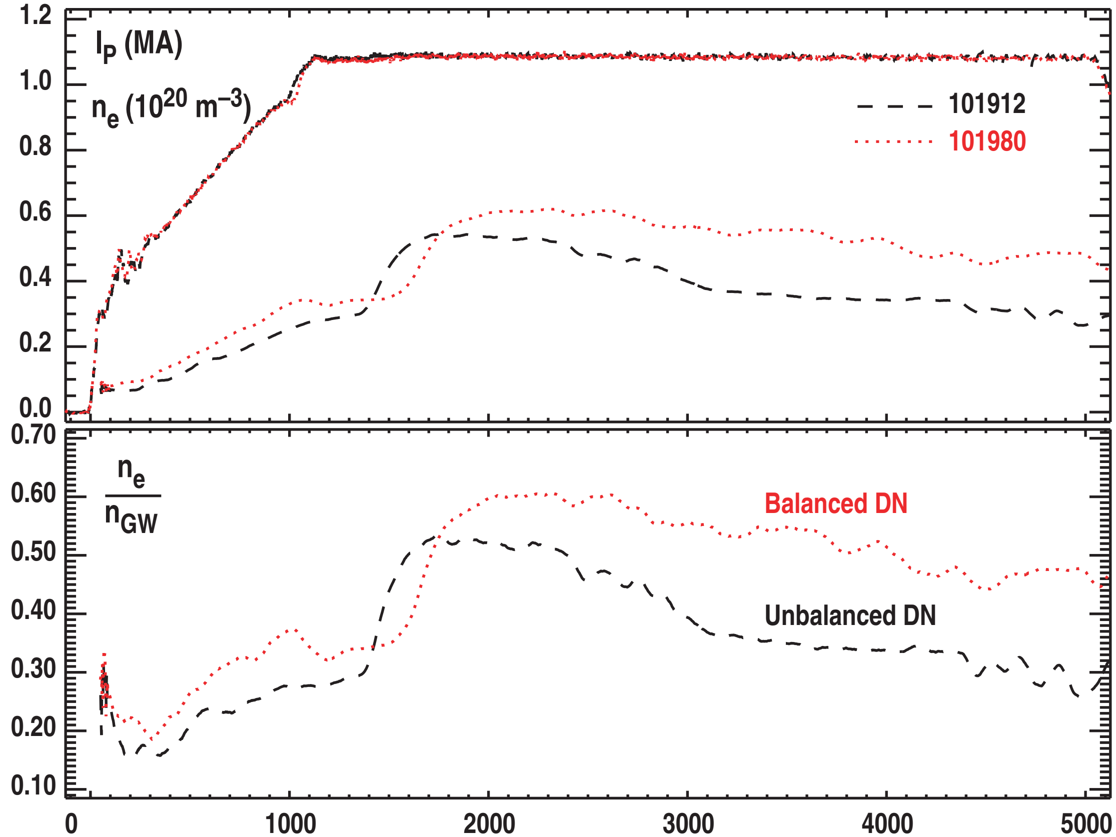
DESIRABLE DENSITY CONTROL IS ACHEIVED IN DOUBLE NULL SHAPES BY BIASING THE CONFIGURATION TOWARDS THE UPPER DIVERTOR





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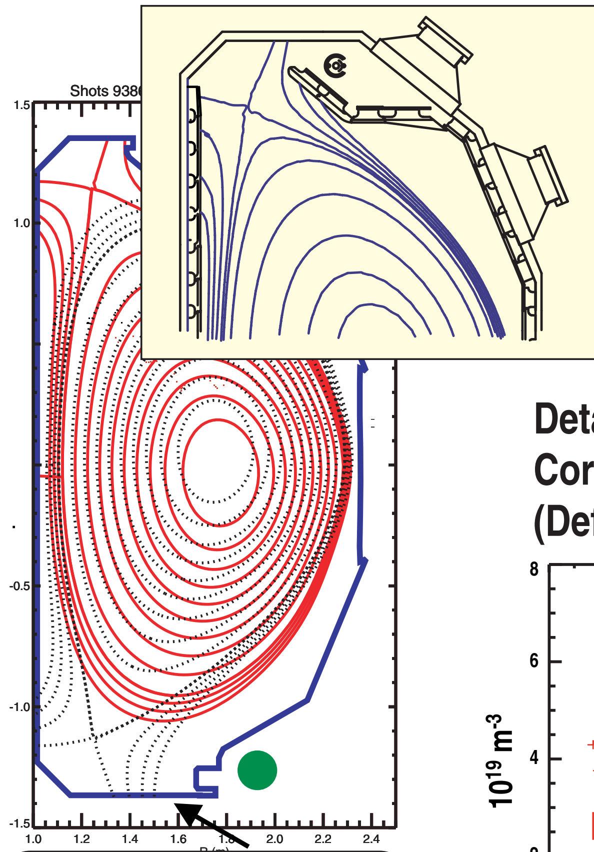
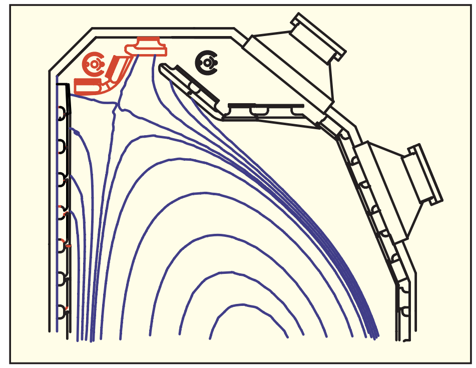
RDP 2000 is a closed divertor and reduces core ionization source (even without cryopumping)

RDP-1999
Data F = 2.5
UEDGE F = 3.5

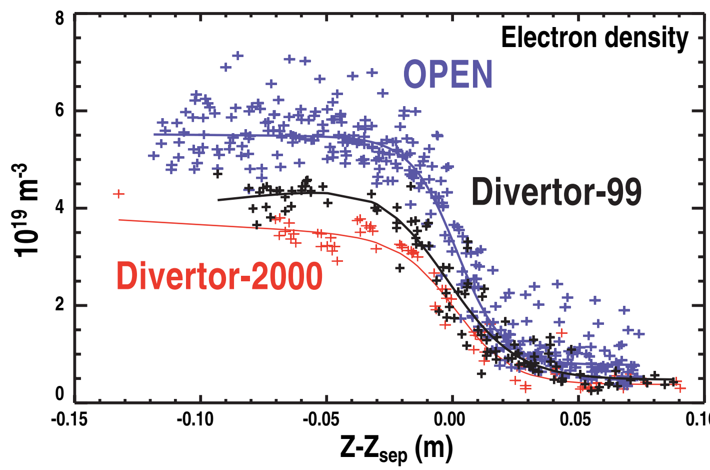
RDP-2000
Data (Prelim.) F ~ 5
UEDGE (Prelim.) ~ 6





Open Lower Divertor

Detailed n_e profile used to calculate Core Ionization Relative to Open Divertor (Defined to be F)



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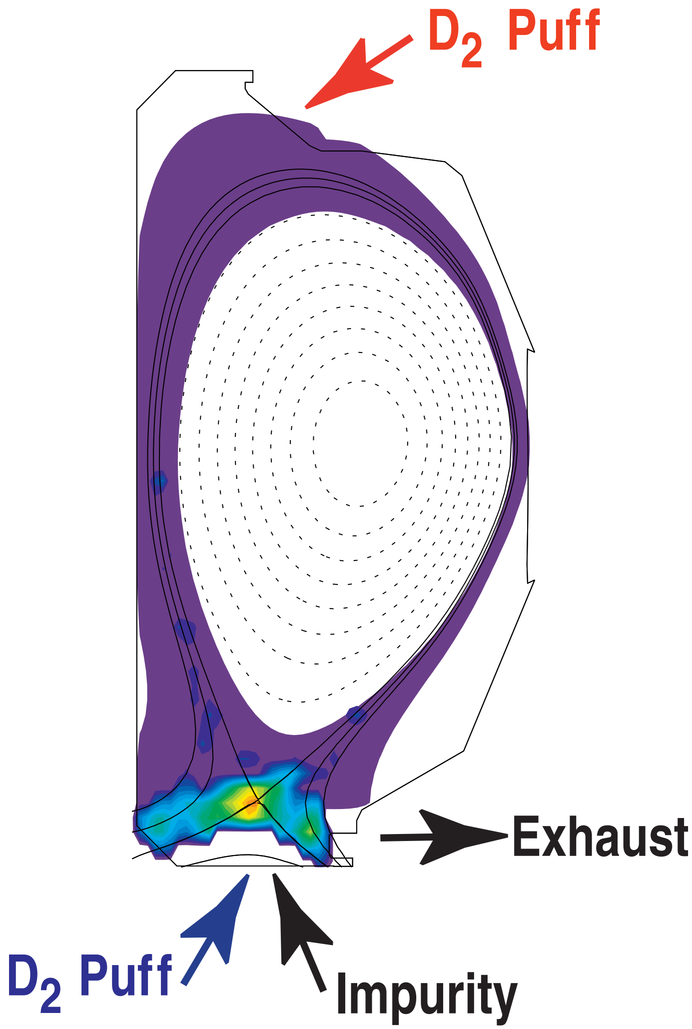
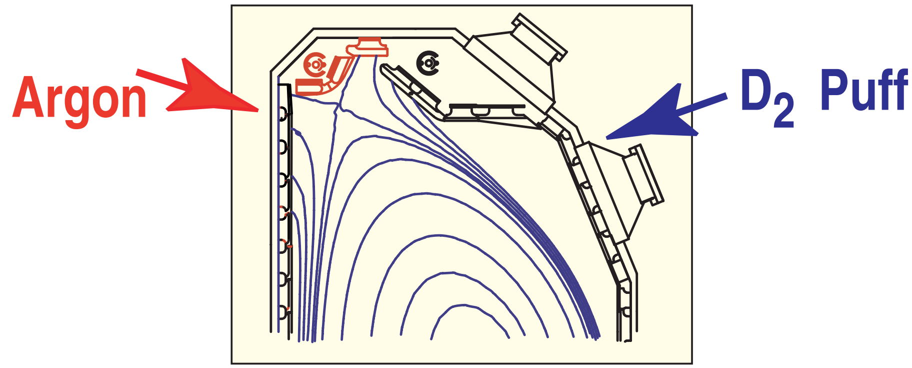
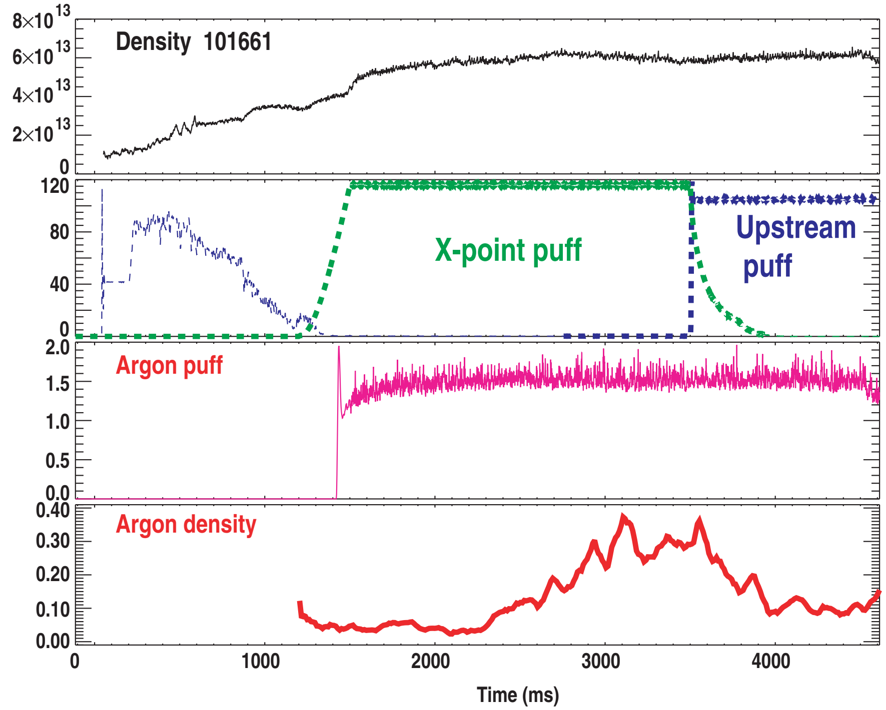
Puff And Pump In Both The Open And Closed Divertors







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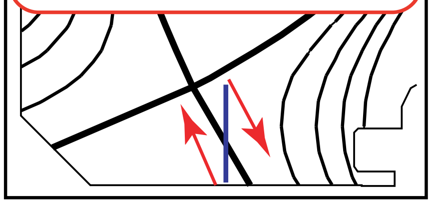
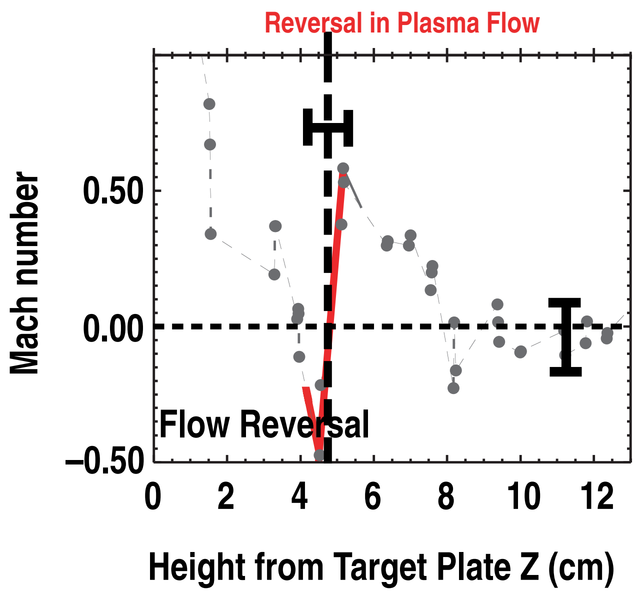
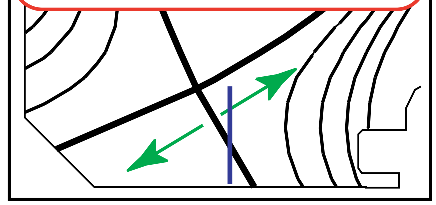
New physics in the x-point and private flux region

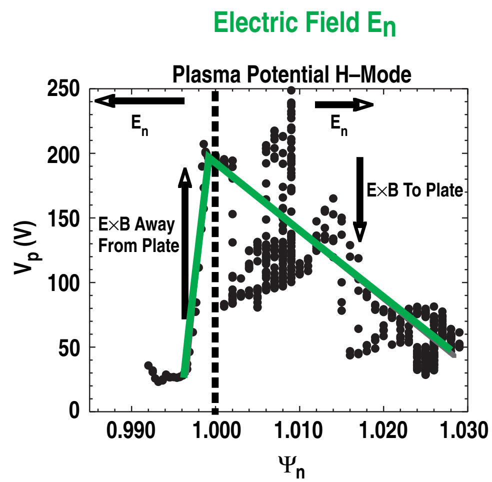
Flow Reversal



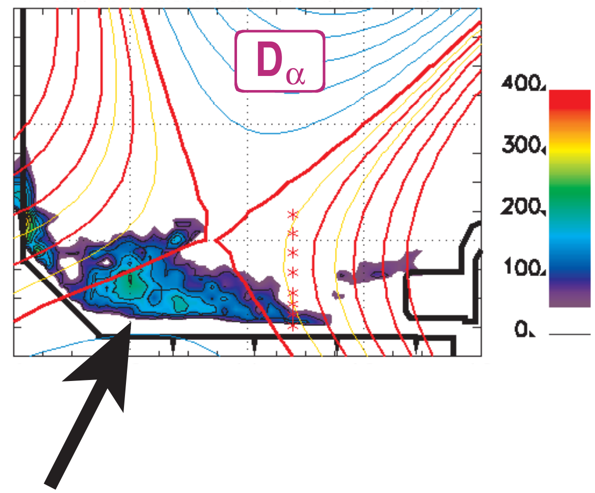


E x B Drifts





Recombination in "Private Flux"



Appreciable T_e, n_e In this Region

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“AT Divertors are not just for heat flux reduction”

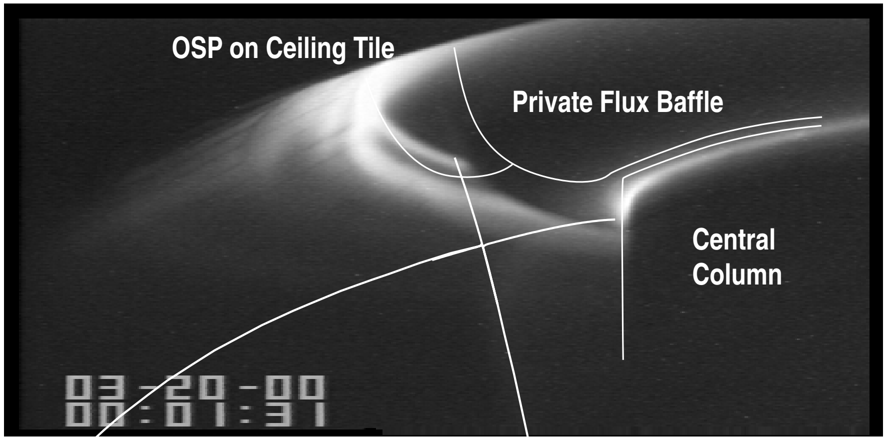
Advances in detached plasmas by this community have made possible a high density divertor solution (with some caveats, of course!) ...

- Now divertor particle control is vital for AT modes
- Shaped plasmas are "standard", needed for high performance
- Real Time Shape control enables H-mode power threshold control, particle control
- Current profile control (ECCD) is at the heart of the AT, *Impurities* are important!

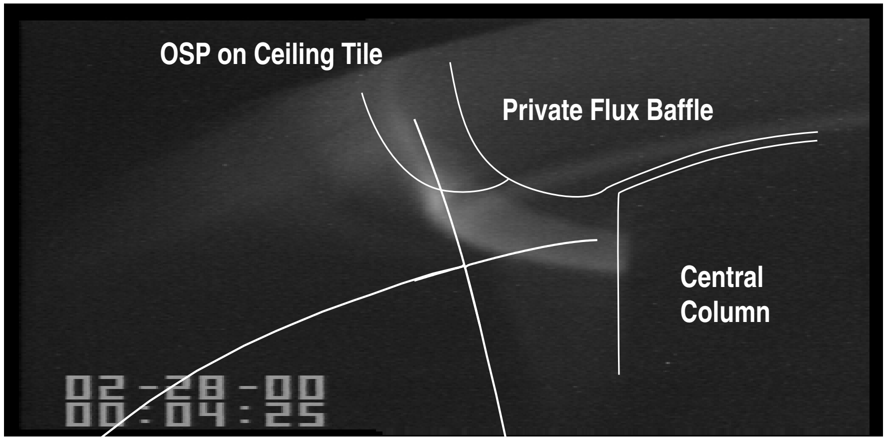
Heat flux control in AT plasmas is expected to require impurity flow control

- "Puff and Pump" or active flow control, need progress in understanding flows
- Lots of new, exciting physics in the pedestal and x-point region

Experience gained in lower divertor (with DTS) is applied to upper divertor (with simplified diagnostics)



Attached Plasma at Low Density



Detached Plasma at High Density

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