INTRODUCTION

In order to achieve current profile control with electron cyclotron current drive for advanced tokamak operation in DIII-D and to maintain high triangularity, high performance plasmas, the core density must be controlled. While the particle sources for fueling are numerous (gas, beams, wall), the particle sinks are limited. To provide adequate particle sinks for density control, several in-vessel pumping systems have been installed. Most recently, an inner strike point pumping system was added to the upper divertor of DIII-D and is located in the private flux region. This cryo-pumping system is baffled and protected by graphite tiles. Previously, an outer pumping system was used for pumping high triangularity, upper single null plasmas. The new inboard system provides more pumping and the ability to control double null inner strike point conditions. The new pumping structure also affects the particle recycling and therefore the core plasma fueling sources.

GOALS OF THE DIII -D PARTICLE CONTROL PROGRAM

Control plasma density for both low and high triangularity plasma shapes

Lower plasma density to :

=> raise efficiency of electron cyclotron current drive (ECCD)

=> enable current profile control for advanced tokamak scenarios

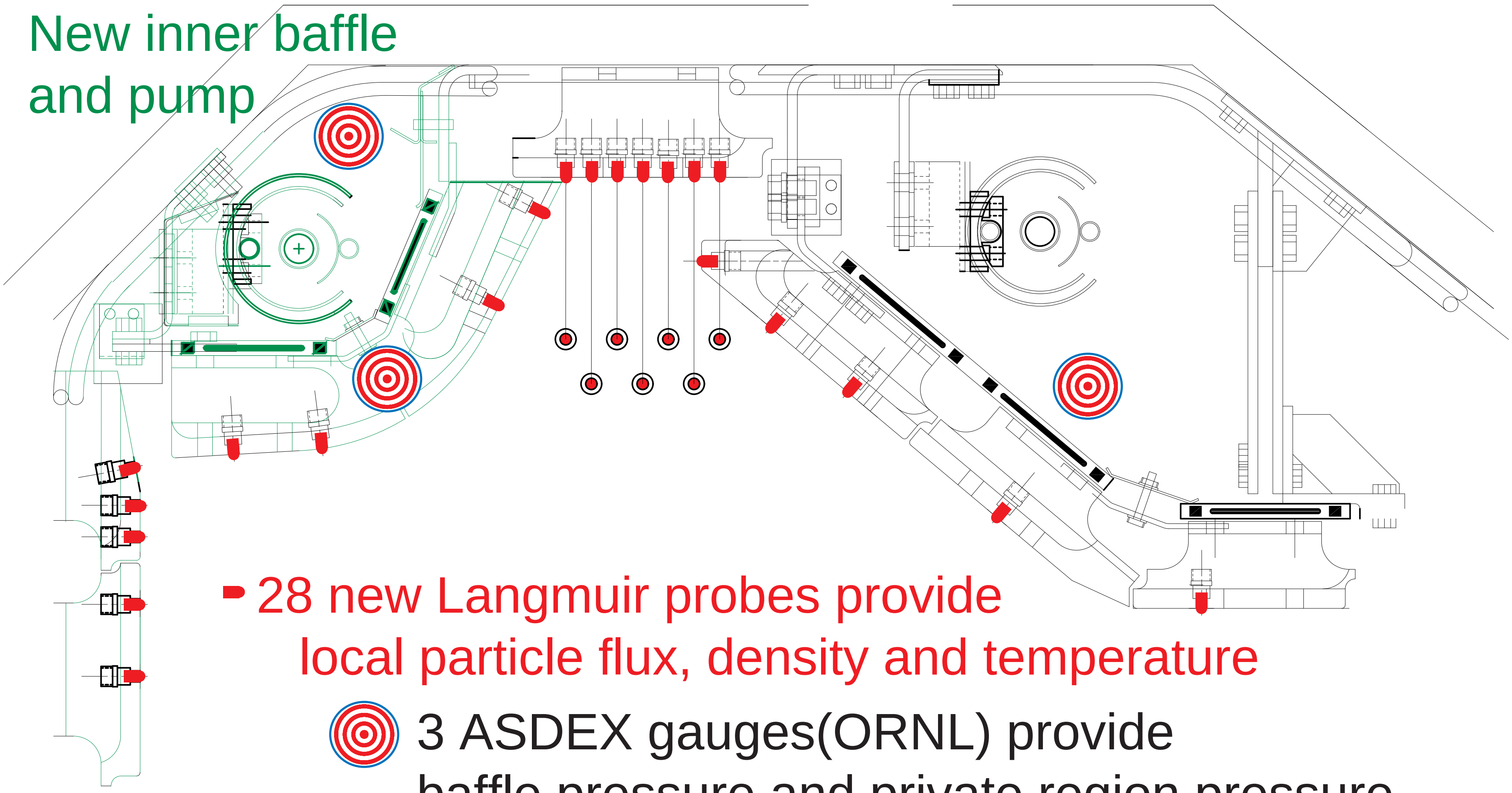
Maintain density control during long pulse, high performance plasmas

Exhaust particles in divertor to enable forced scrape-off layer flow for impurity control

Document plasma conditions to allow detailed modeling

Develop a physics understanding of divertor pump performance

Divertor 2000 with new Langmuir Probes and ASDEX gauges



New inner baffle and pump

▬ 28 new Langmuir probes provide local particle flux, density and temperature

◎ 3 ASDEX gauges(ORNL) provide baffle pressure and private region pressure

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SOURCES, SINKS, AND PARTICLE REMOVAL EFFICIENCY

Sources:

- Gas puffing
- neutral Beam injection
- recycling
- wall

Sinks:

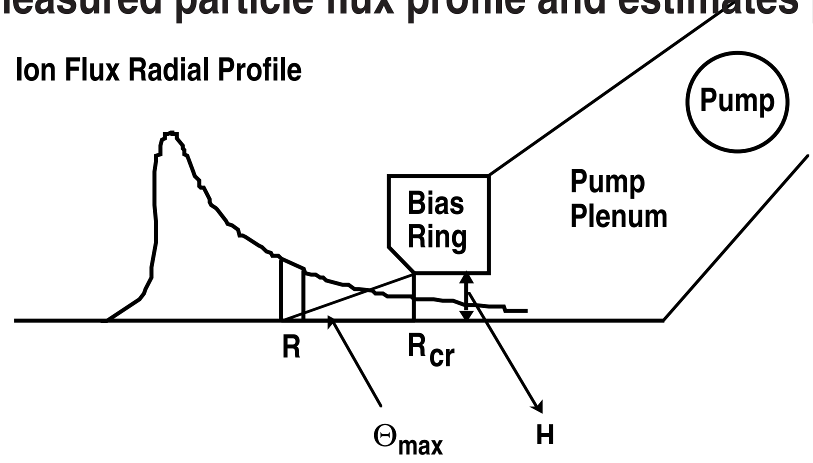
- inner pump (typical calibrated pumping speed = 18000 liters/sec)
- outer pump (typical calibrated pumping speed = 40000 liters/sec)
- wall

Particle removal efficiency, our particle removal figure of merit, provides a normalized method of determining the optimum geometry for exhaust of particles largely independent of changing plasma conditions. It is defined by the ratio of the particle exhaust to the total target plate particle flux, i.e.

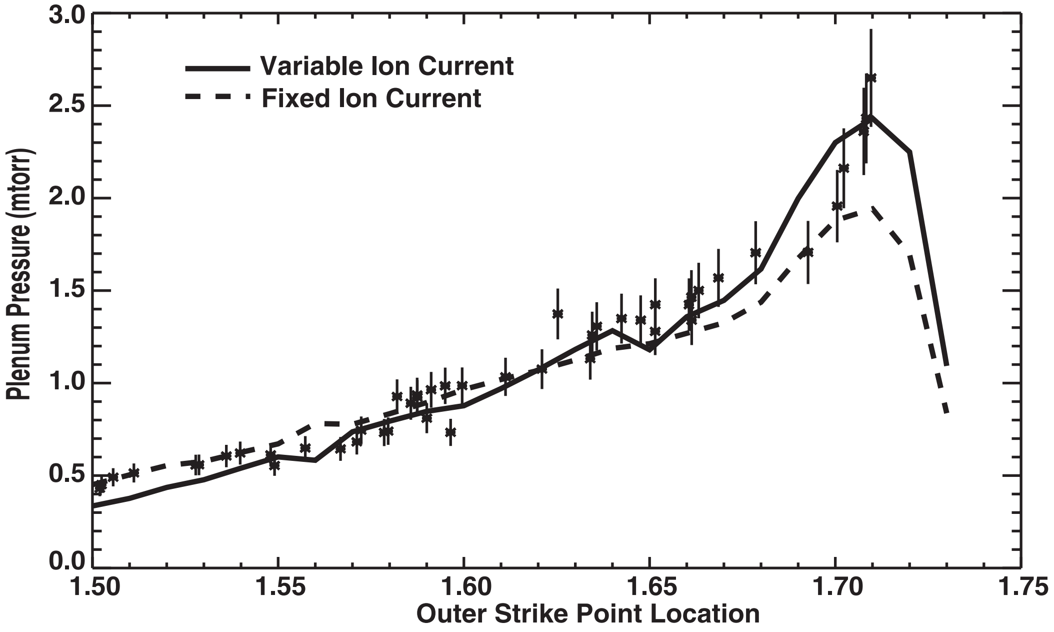
$$\text{Particle Removal Efficiency} = \frac{2 \text{ x } P_{\text{baffle}} \text{ x } S_{\text{pump}}}{\text{Jsat}(R)RdR}$$

Plenum Apertures were Chosen Based a First-Flight Neutrals Transport Model Which Had Been Benchmarked Against Previously Obtained Data

- First flight neutral transport model
  - Takes as input the measured particle flux profile and estimates plenum entrance as an aperture



- Model simulates plenum pressure measurement quite well



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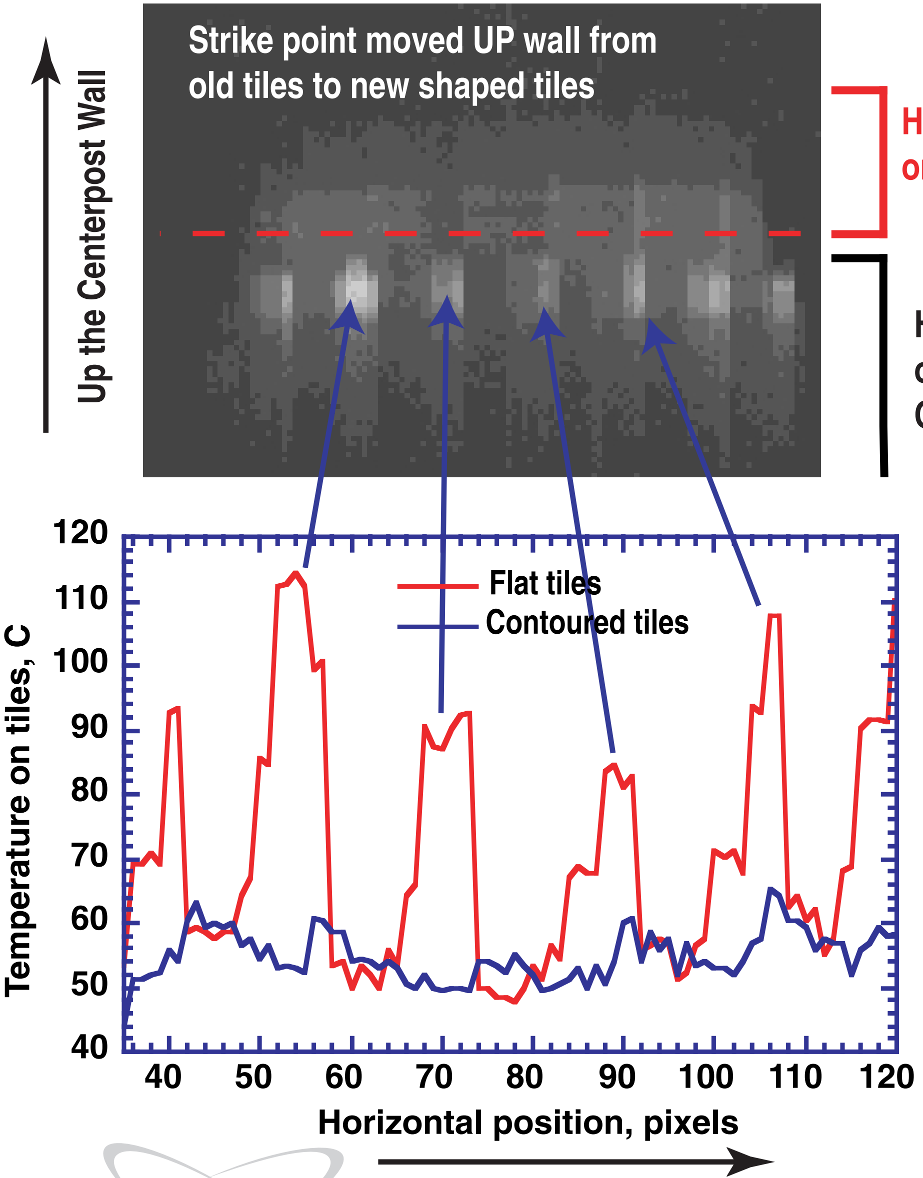
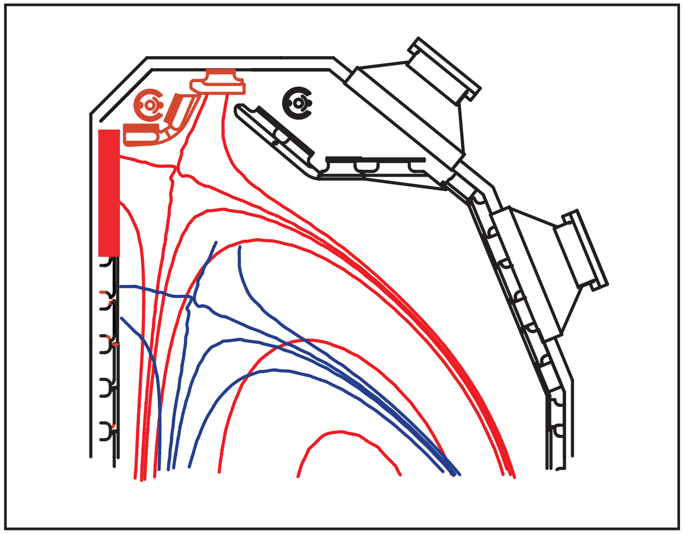
Impurity Control In AT Plasmas With Careful Tile Shaping



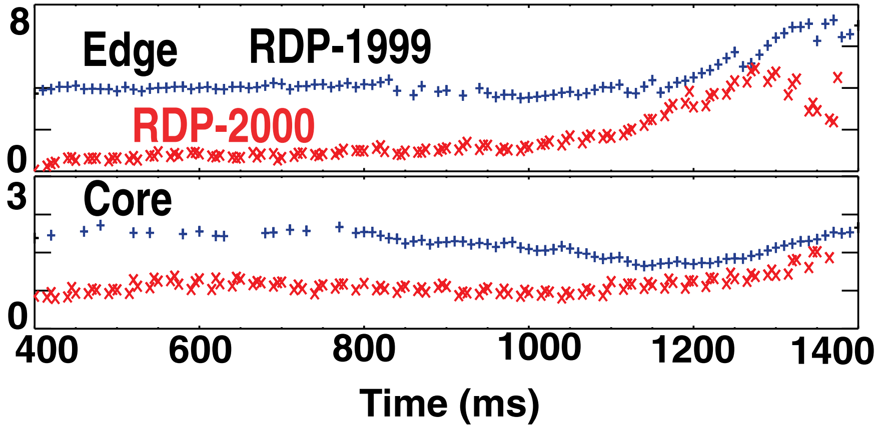
Strike point moved UP wall from old tiles to new shaped tiles

Heat Flux LOW on shaped tiles

Heat Flux HIGH on Edges of Old Tiles



Carbon Concentration (%) is Reduced Compared to Previous Operation



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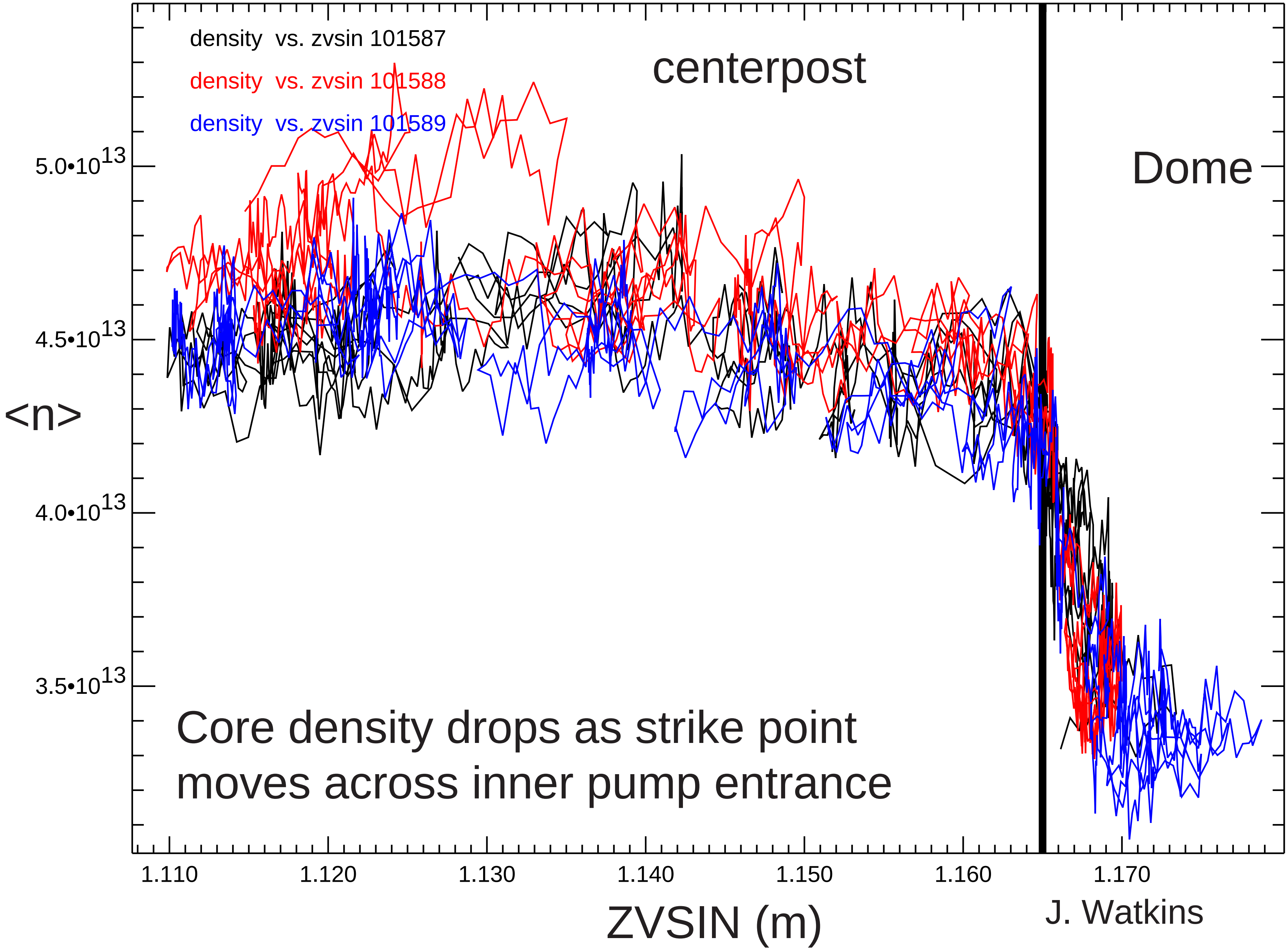
Inner Pump/dome Lowers density



Core density drops as strike point moves across inner pump entrance

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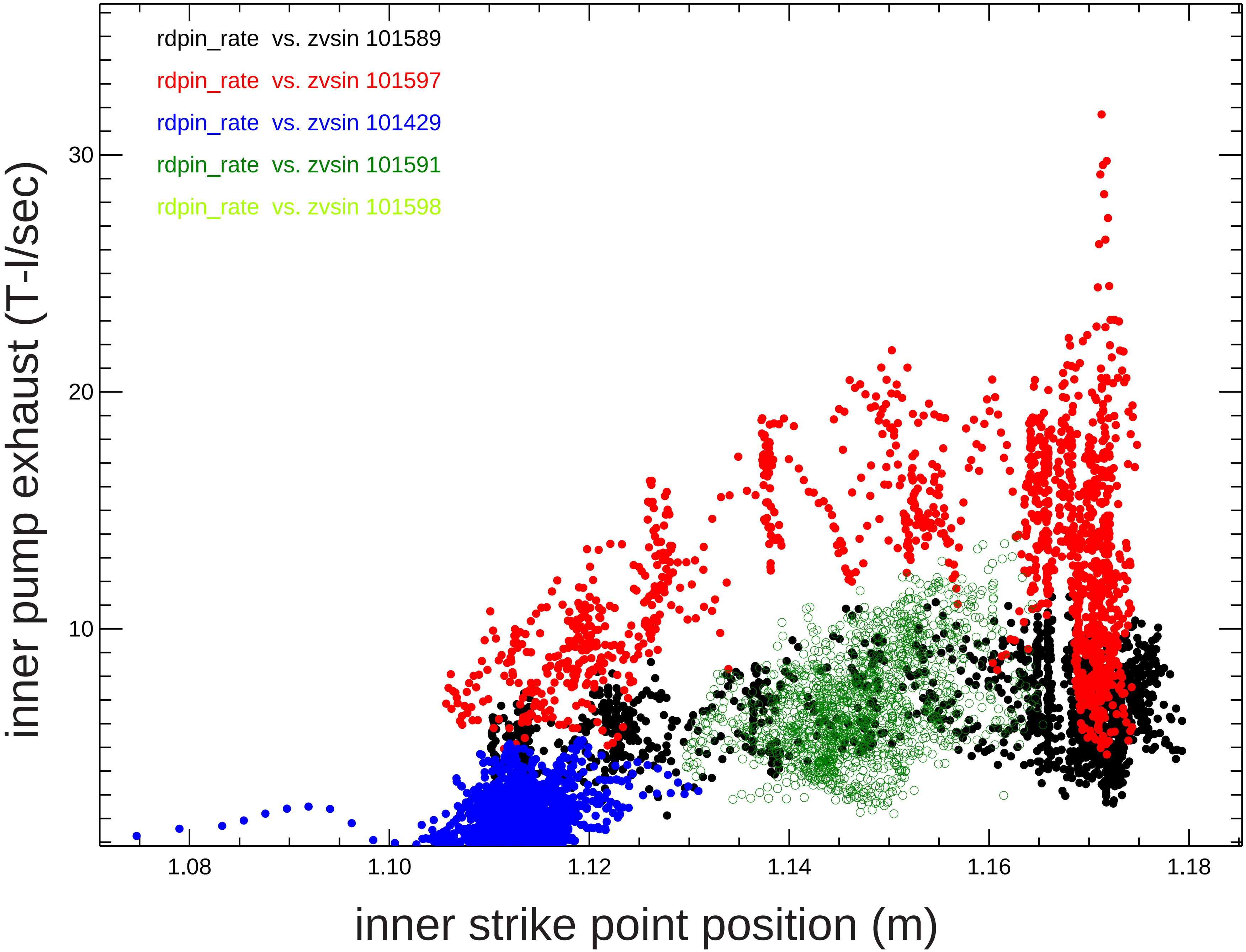
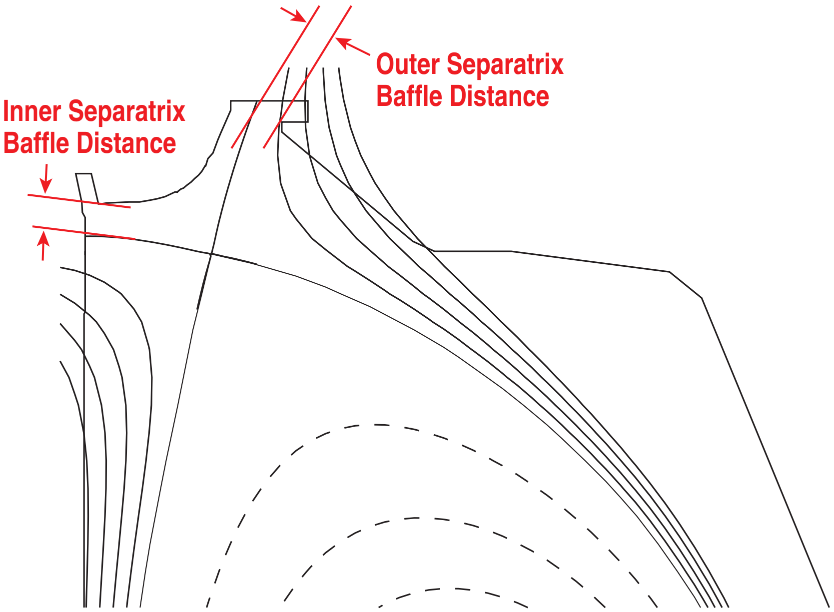
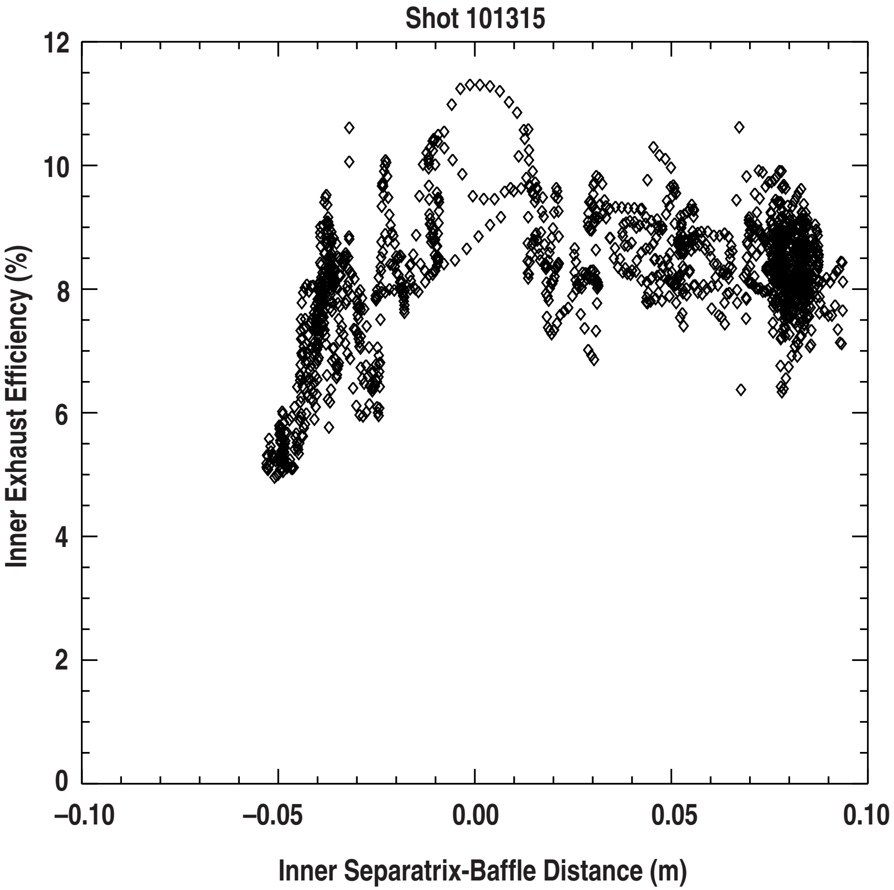

rdpin_rate vs. zvsin 101589
rdpin_rate vs. zvsin 101597
rdpin_rate vs. zvsin 101429
rdpin_rate vs. zvsin 101591
rdpin_rate vs. zvsin 101598
inner pump exhaust (T-l/sec)
30
20
10
1.08
1.10
1.12
1.14
1.16
1.18
inner strike point position (m)

INNER PUMP EXHAUST EFFICIENCY PEAKS WHEN STRIKE POINT IS AT THE PUMP APERTURE





- ∇B drift toward X–point

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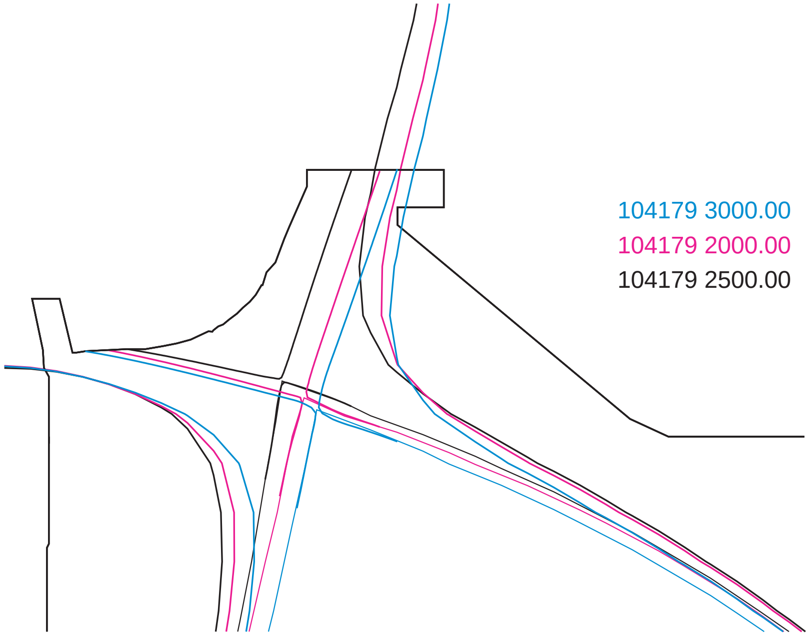
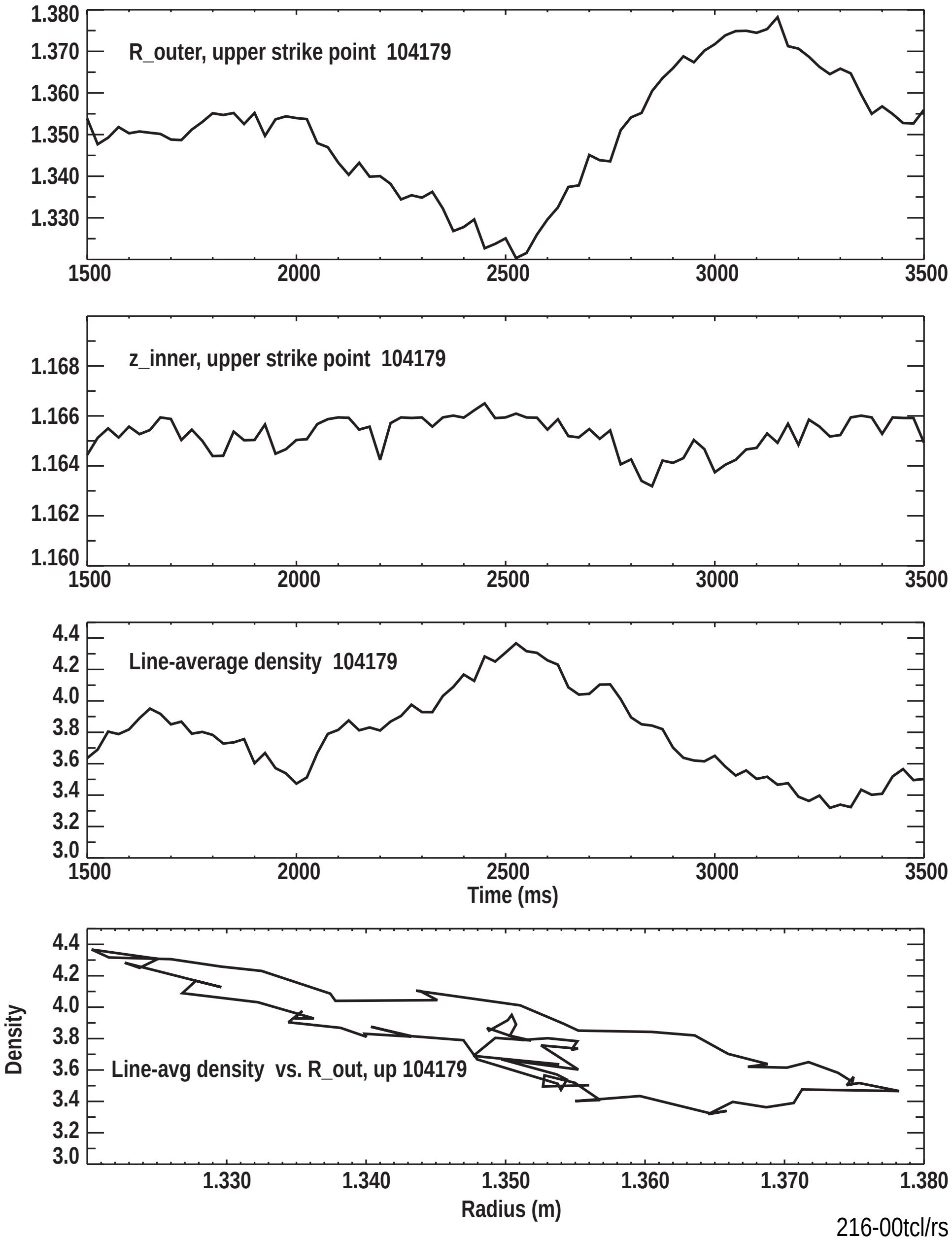
STRIKE POINT SWEEP SHOWS DIRECTLY THE EFFECTIVENESS OF THE PUMPING





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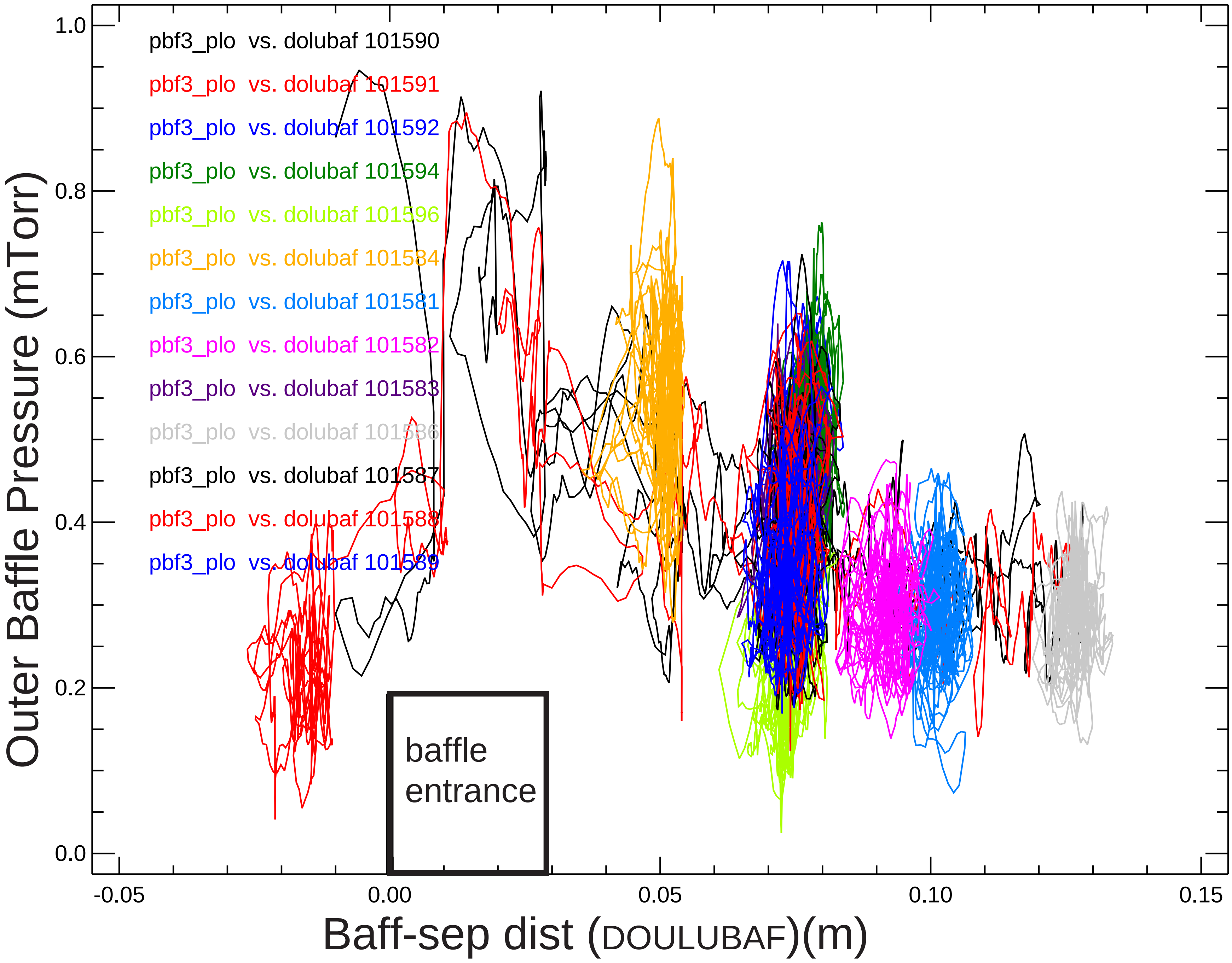
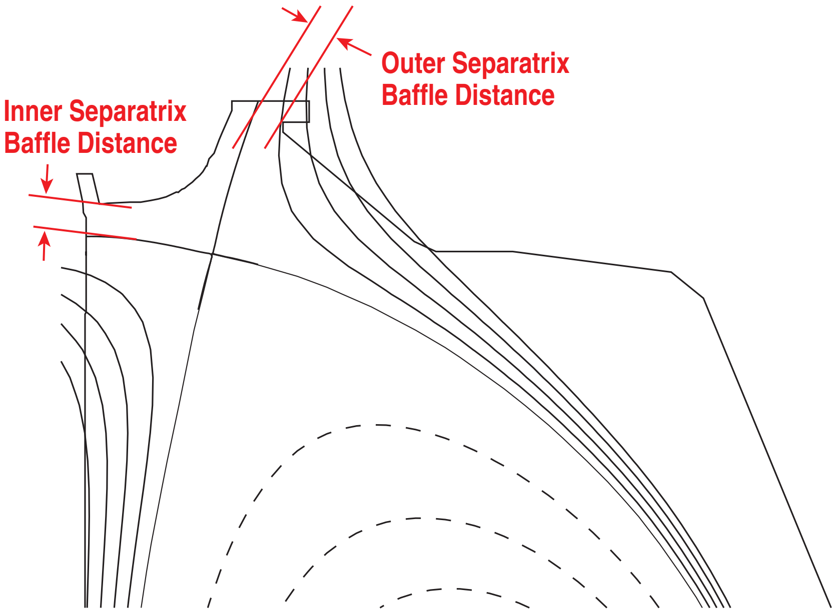
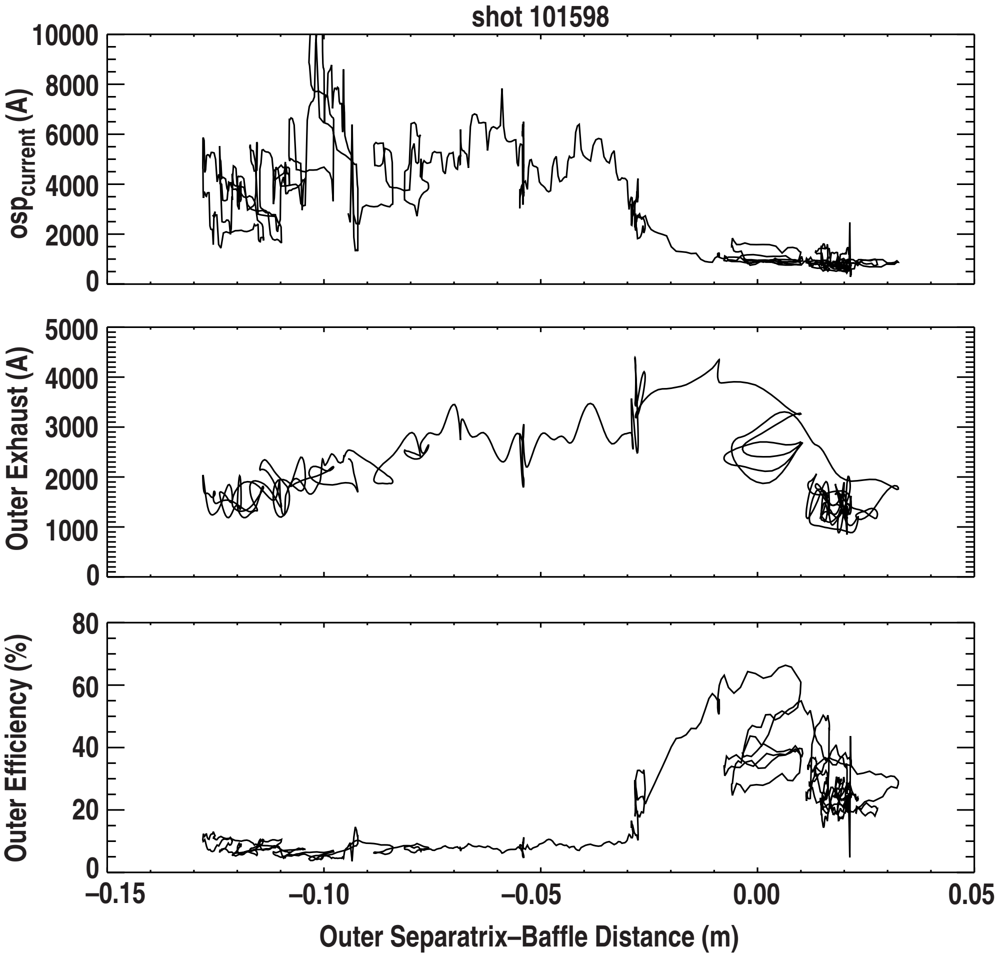
Outer baffle pressure depends on strike point position



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





- ∇B drift toward X–point

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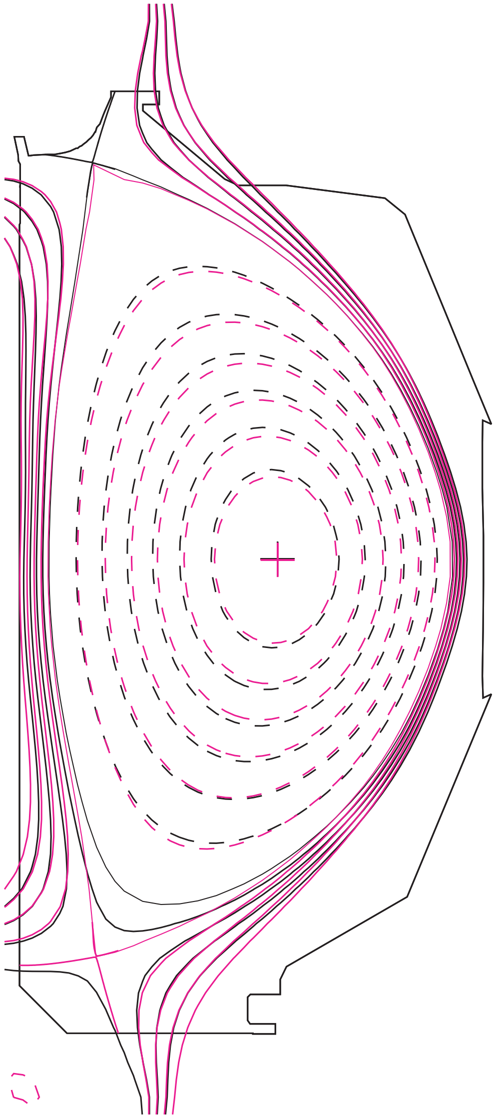
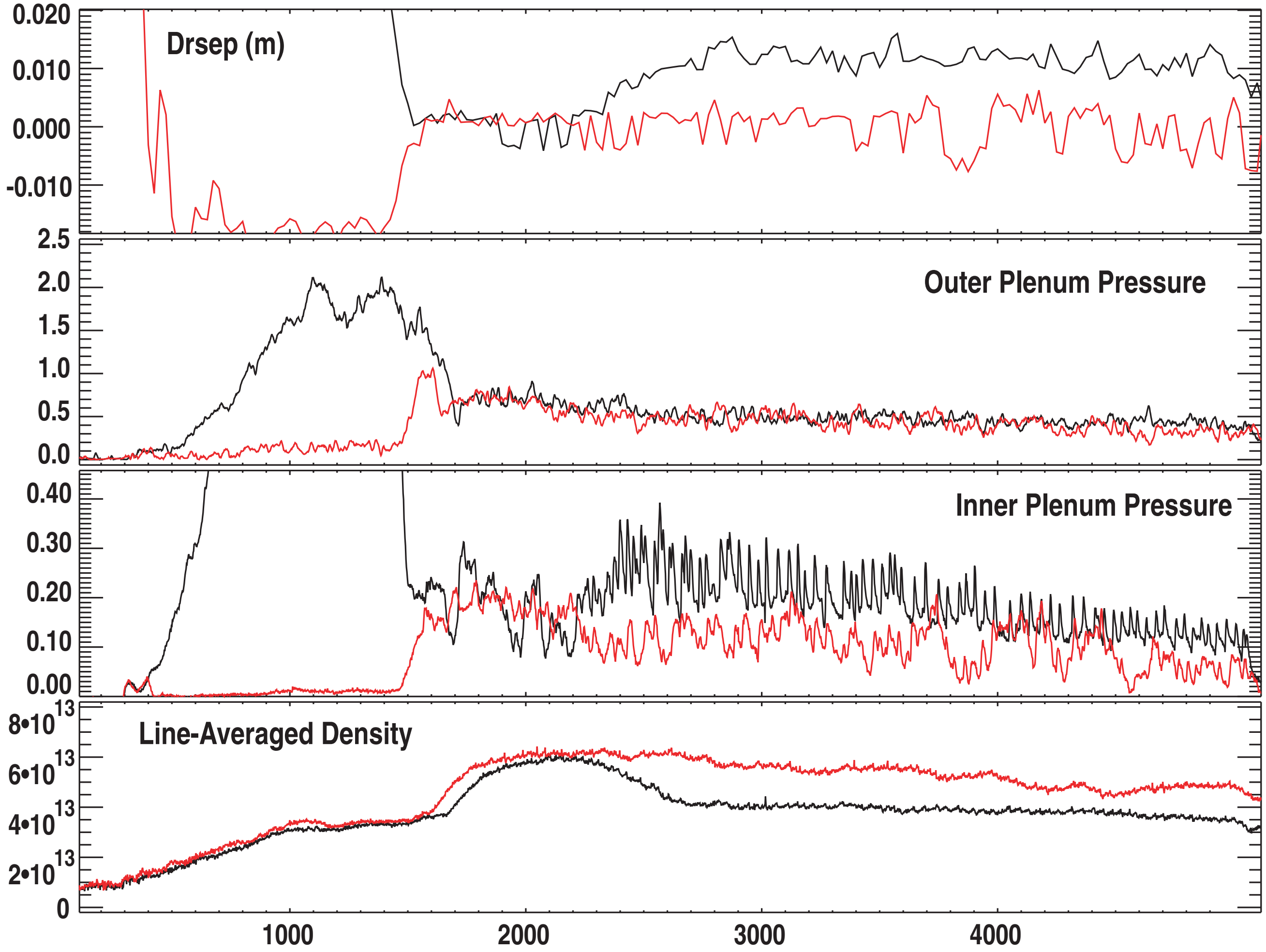
SLIGHTLY UNBALANCED USN (DRSEP ~1 cm) FOUND TO BE SUFFICIENT FOR ADEQUATE PUMPING





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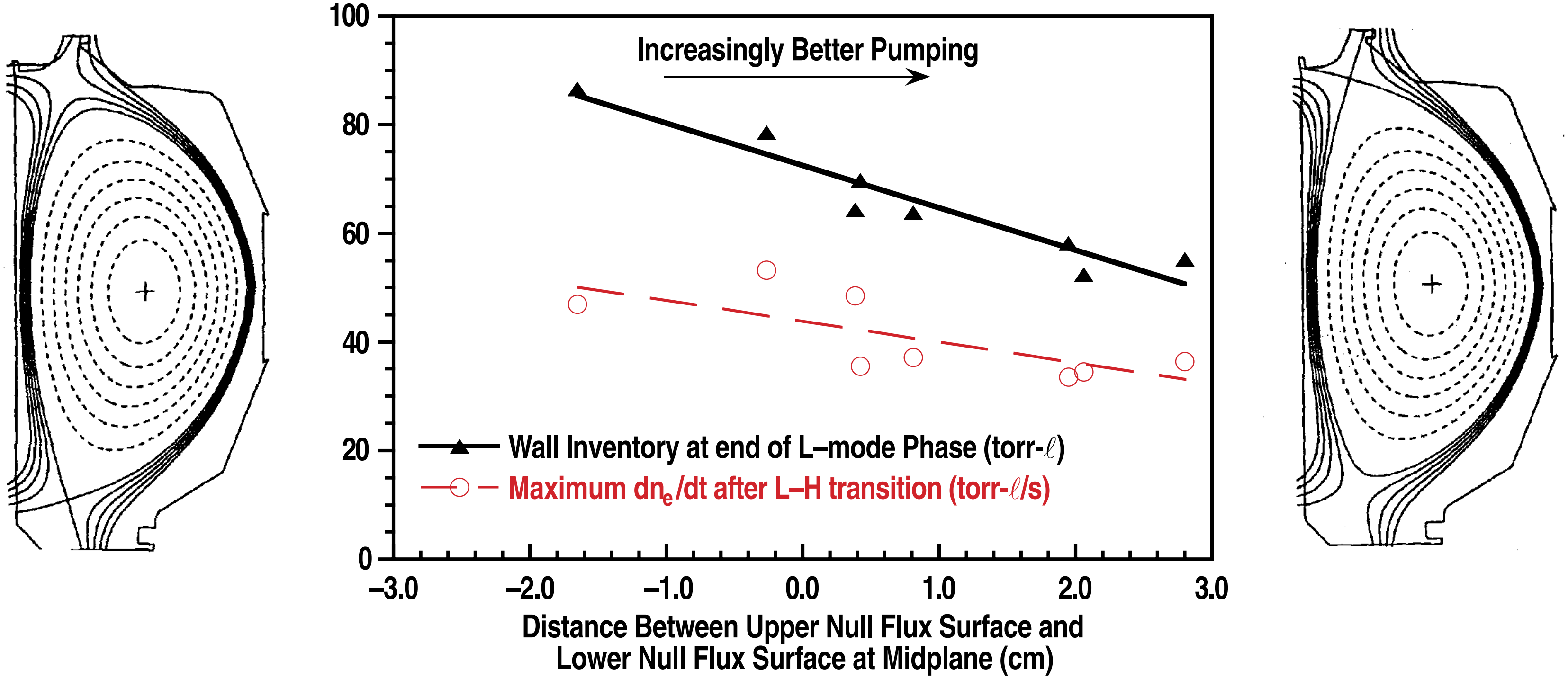
INCREASED PUMPING DURING THE CURRENT RAMP DECREASES WALL INVENTORY, RESULTING IN REDUCED DENSITY RISE DURING ELM-FREE PHASE

- Experiment
  - Vary degree of pumping during current ramp phase by varying the magnetic balance between the upper and lower nulls in a double nulls configuration
  - Line-averaged density the same in all cases through density feedback



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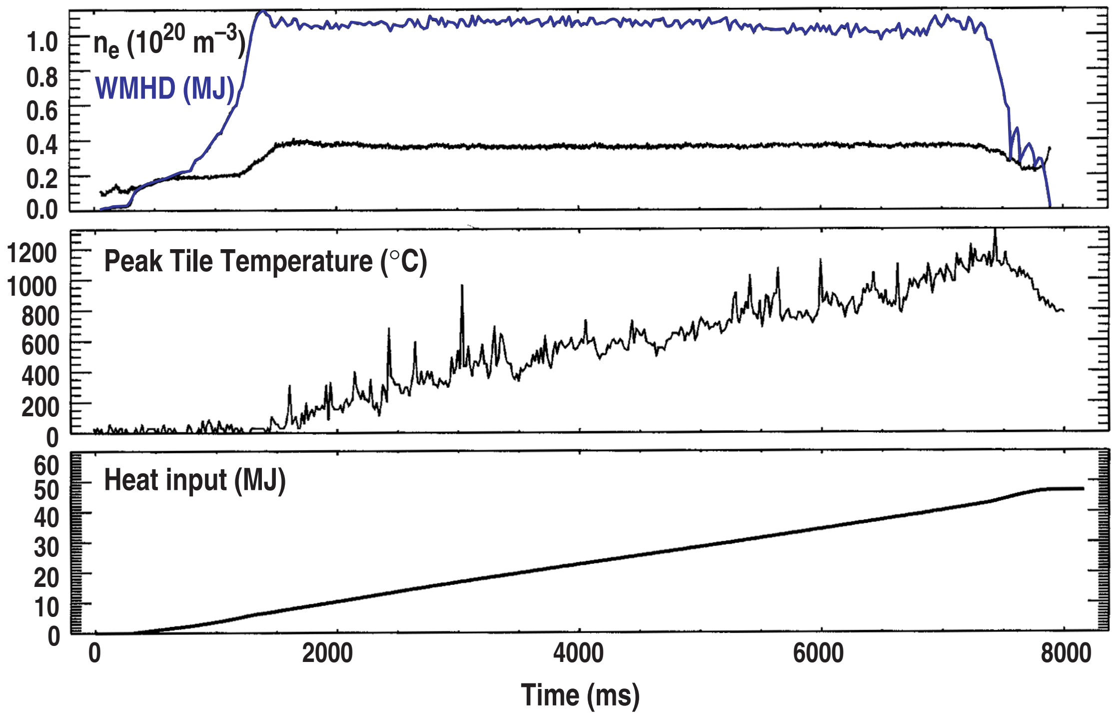
OUTSTANDING DENSITY CONTROL FOR AT PLASMA SCENARIOS. HANDLED 50 MJ ENERGY INPUT

- Density feedback regulated with divertor pumping
- Accurate tile alignment prevents hot spots
- Graphite surface temperature rises linearly with time
- Record 50 MJ deposited in plasma
- No increase in core carbon content observed



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Conclusions

Low density operation was achieved which enables AT operation.

Density control at high triangularity using the upper pumps allows long pulse, high performance operation.

The particle removal efficiency has been determined and is optimum with the strike points at the baffle entrance for both the inner and outer pumps.

Pump exhaust can be controlled with both:
1) strike point positioning,
2) up/down shifting (drsep control - "double null")

Using pumping early in the plasma discharge to deplete the wall, the density rise at H mode (dn/dt) can be reduced.