Divertor regimes in NSTX

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NSTX FY’04 Results Review

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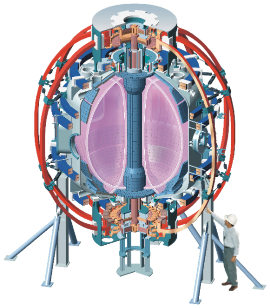

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- R. Raman (University of Washington)
- J. Boedo (UCSD)
- S. Sabbagh (Columbia University)

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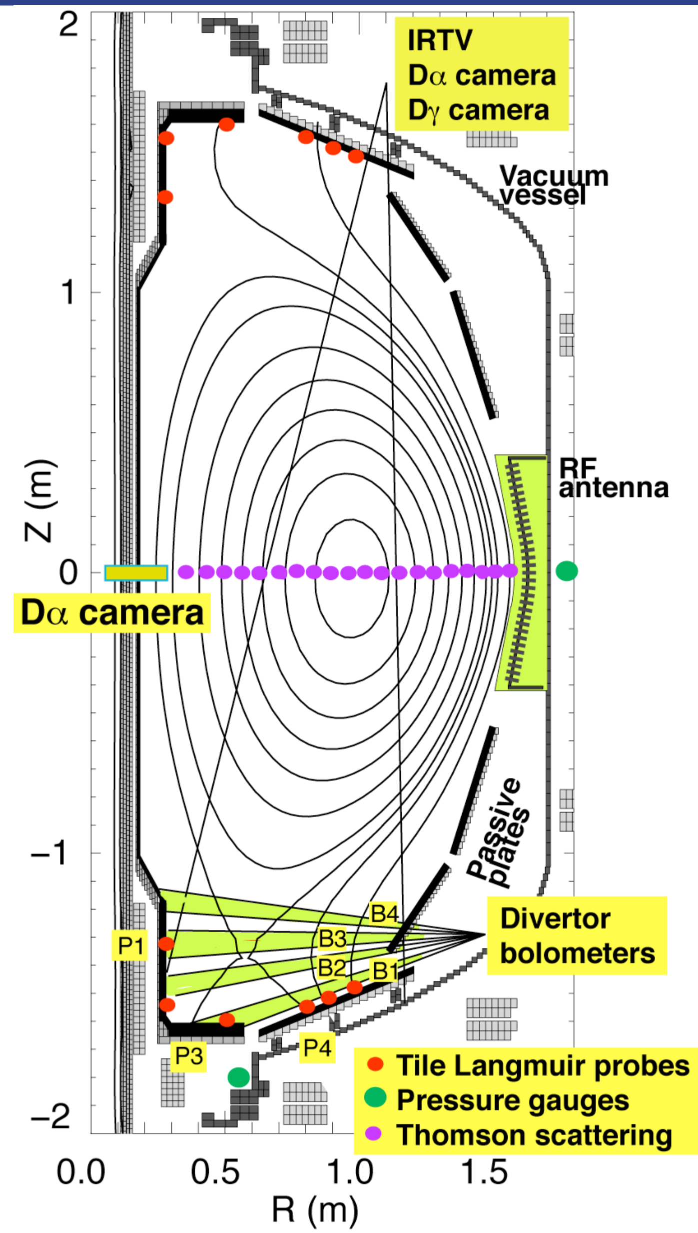
Motivation and status of SOL / divertor diagnostics

- Identify divertor regimes, determine boundaries in operational space, determine rel. role of SOL parallel heat transport channels (e-i, conduction, convection)
- Develop radiative divertor regime compatible with high performance H-mode plasmas
- SOL / divertor diagnostics greatly improved in **FY'04** : IRTV, D_α, C III filtered cameras, neutral pressure gauges, **D_γ filtered camera**, **high-resolution Balmer line spectroscopy (VIPS 2)**, **bolometry**, **Langmuir probes**



Status of XP 438 "Divertor regimes and divertor detachment"

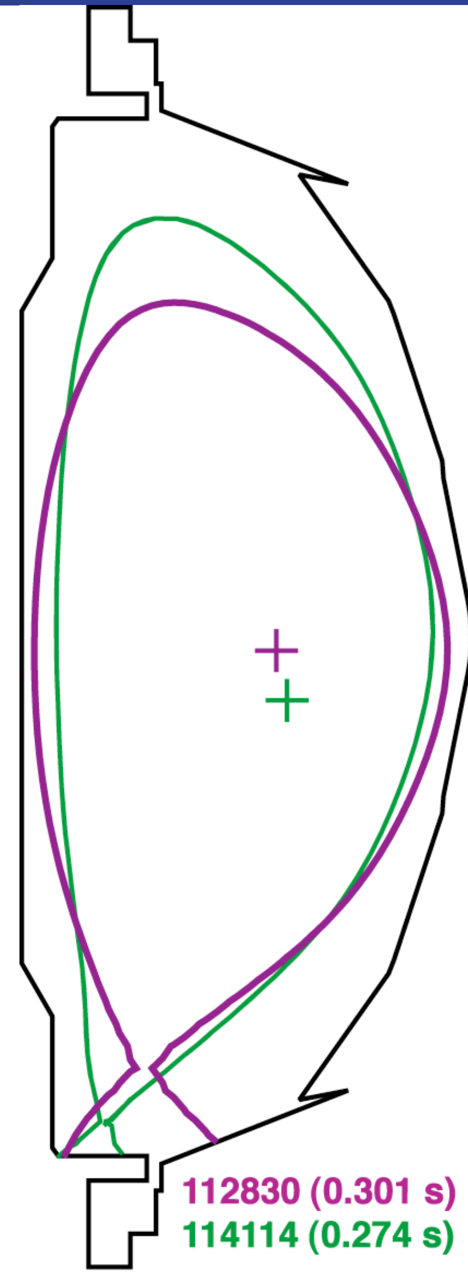
- XP was delayed for months due to D_γ filter availability issues
- Obtained only 3.5 hours due to lack of machine run time
- Out of 9 pulses, 2 pulses had machine problems
- Plan for XP originally included D_2 and *Ne* injection scans in L-mode to obtain edge n_e (i.e. ν^*_{SOL}) scan and edge P_{rad} scan. Had to settle for a crude D_2 injection scan.
- Obtained a 2 NBI source L-mode: possible if LFS gas is $\Gamma >$ 50 Torr l / s and $P_{NBI} = 2 - 3$ MW
- LDGIS proved to be too fast and disruptive for a systematic scan

- Inner divertor detachment threshold in $\langle n_e \rangle$, P_{in} is low
- Have not been able to detach outer divertor with D_2 $\Gamma_{LFS} <$ 120 T l / s
- Need to run a systematic experiment

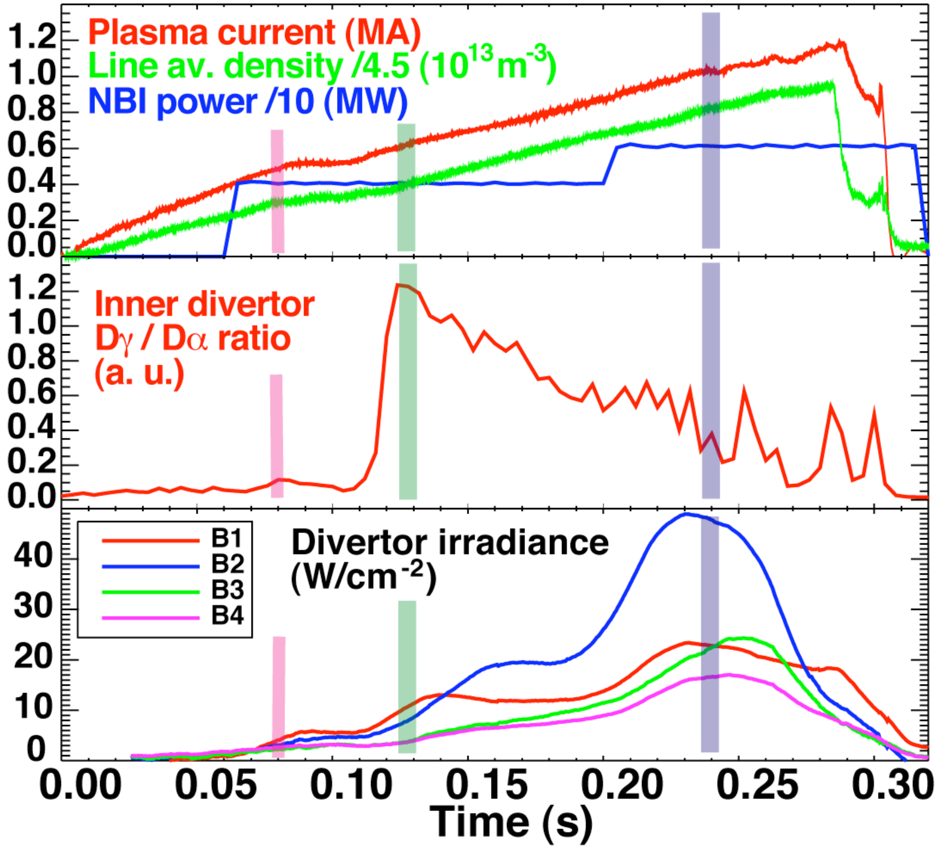
Wide parameter range LSN plasma available in 2004

	112830 (PF2L)	114114 (PF1B)
κ	1.85	2.40
δ	0.47	0.74
drsep	-1.8	-1.0*
q_{edge}	13	9.5

- Only LSN divertor can be studied at present, DN divertor in FY'05 - FY'06
- **PF1B coil LSN shape** (comp. to **PF2L**):
  - has **~ 1.5** connection length - beneficial for detachment
  - OSP magnetic flux expansion is ~ 10 (cf. 4)
  - inner divertor detaches at lower density
  - outer always attached



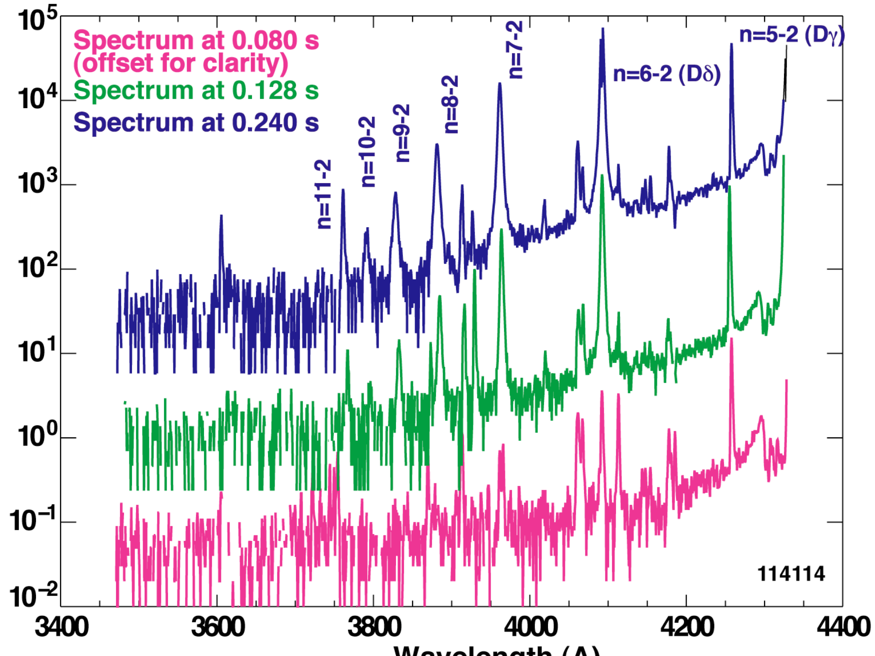
Inner divertor is cold / detached



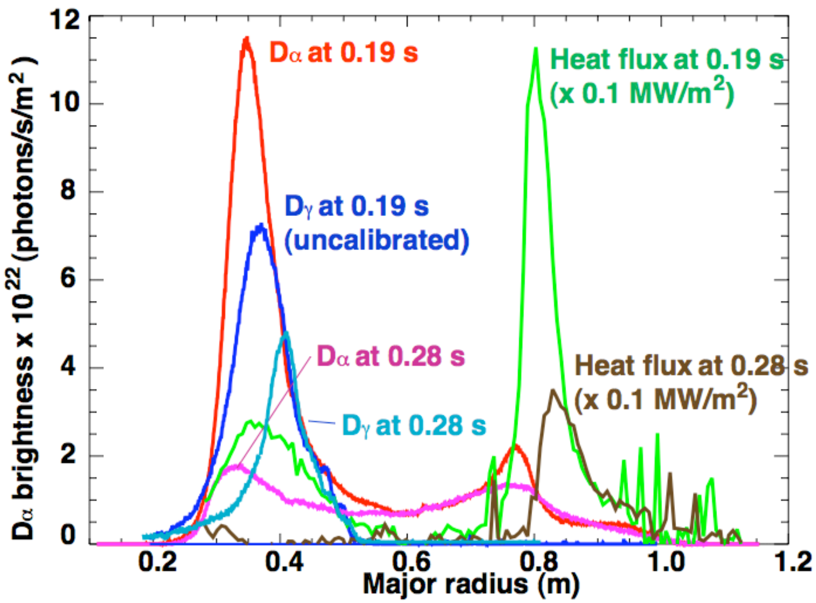
- Similar divertor behavior in L- and H-mode plasmas with $P_{NBI} < 6$ MW.
- Inner divertor is cold, often detached
- Heat flux $q < 1$ MW/m^2
- Sign of detachment: observed volume recombination (D_γ/D_α ratio increases), P_{rad} increase

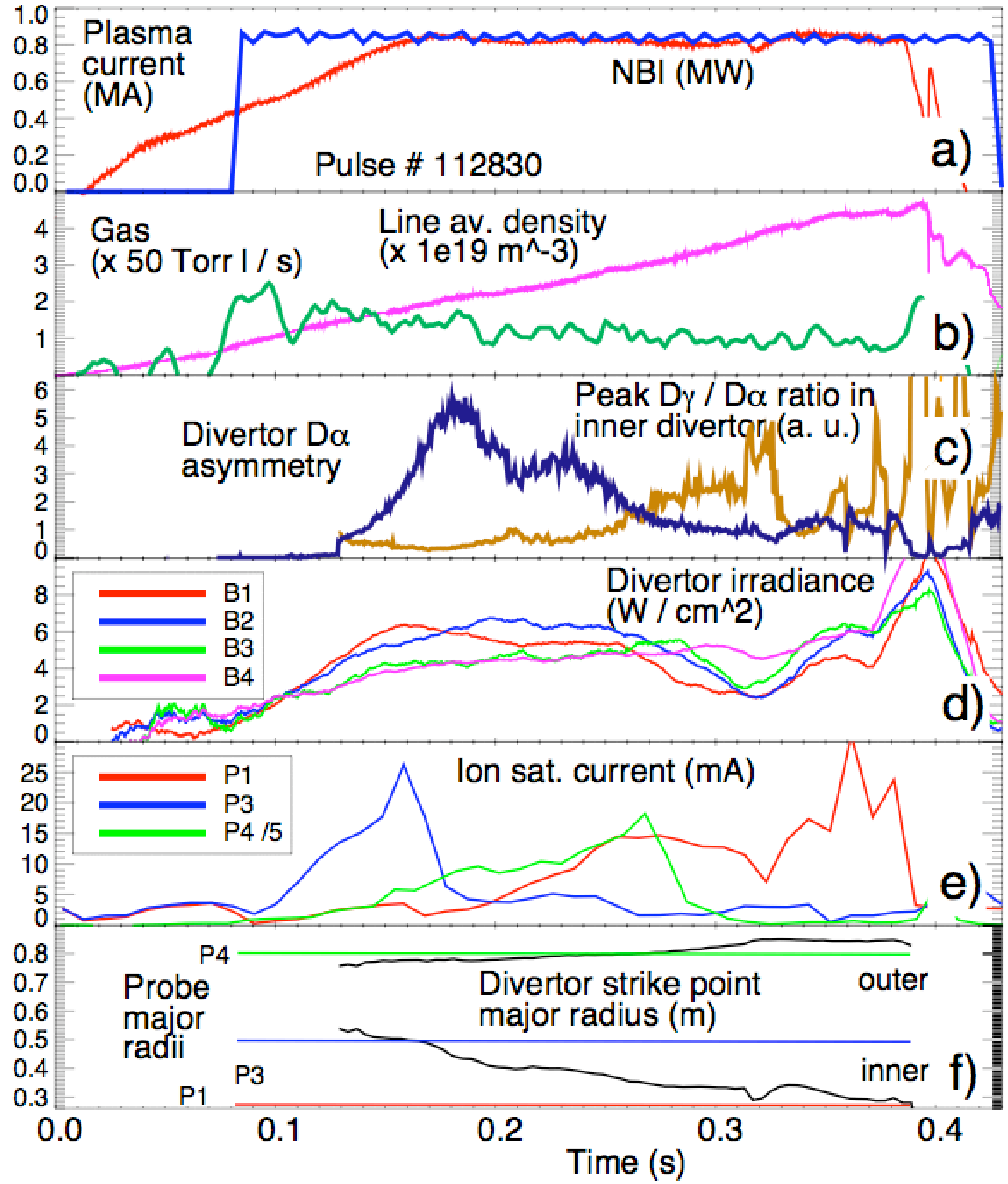
Appearance of Stark broadened high n Balmer series lines indicate:

- Volume recombination
- Apparently high n_e, n_0, low T_e
- Possibly optically thick

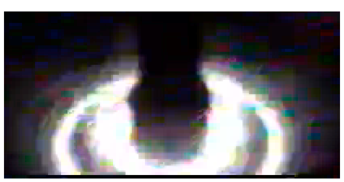


Inner divertor cold / detached in LSN plasmas





- 1 NBI src L-mode
- Inner divertor detached at $\langle n_e \rangle = 2.5\text{-}3 \times 10^{19}\ m^{-3}$

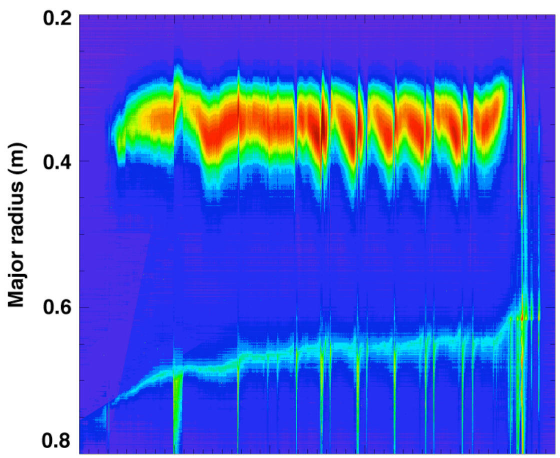


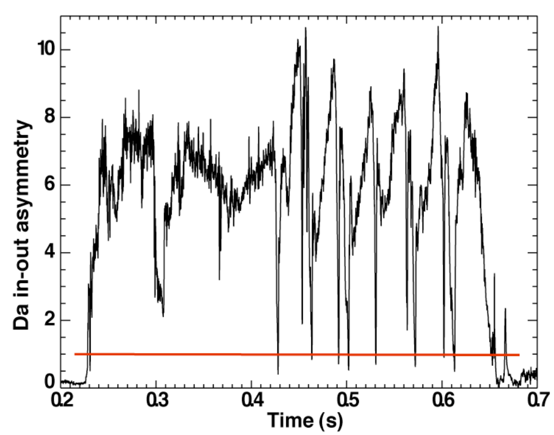
Outer SOL

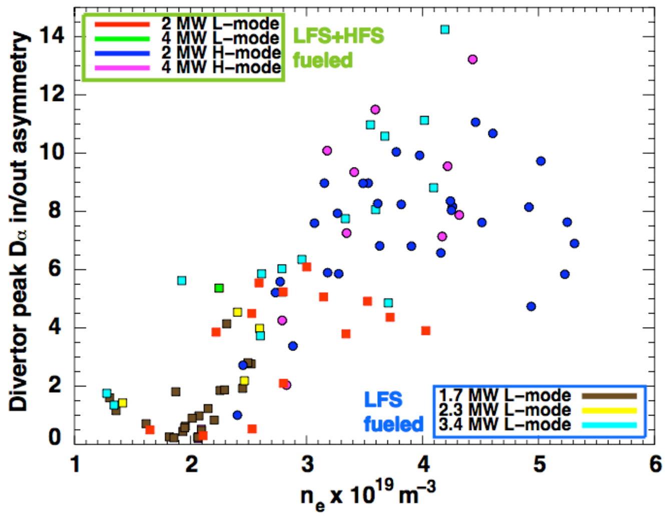
- Outer divertor is always attached, heat flux $q < 10$ MW/m^2
- Langmuir probe data analysis is in progress
- Outer divertor is in sheath-limited and high-recycle regime
- Uncertainty in LCFS position undermines analysis:
  - MPTS midplane $T_e = 5 - 40$ eV (5 - 15 eV or 20 - 40 eV?)
  - SOL collisionality $\nu^* = 0.5 - 100$ (mostly 10 - 60)
  - If midplane $T_e = 5 - 15$ eV then very weak $dT_e/dx_{||}$ rises questions about heat flux measurements, e-i partition and the heat transport mechanism
  - Carbon radiation zone is 10 eV
- Difficult experimental issue

Divertor asymmetries

- Heat flux asymmetry always q_{out}/q_{in} > , consistent with
  - SOL area factor: $A_{out} > A_{in}$
  - Magnetic flux expansion factor (mid/div): $f_{in} > f_{out}$
- Particle flux / recycling asymmetry (from D_α intensity)
  - Density and power dependent
  - Complex interplay of cold dense detached plasma and diagnostic geometry effects?
  - Analysis in progress to address radiation opacity effects (A. Pigarov, UCSD)



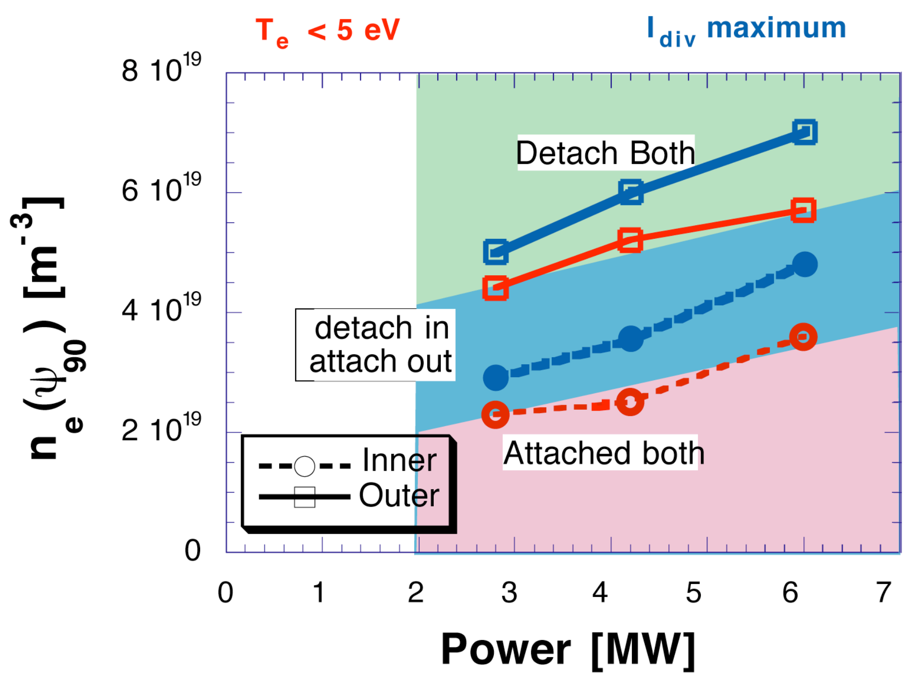


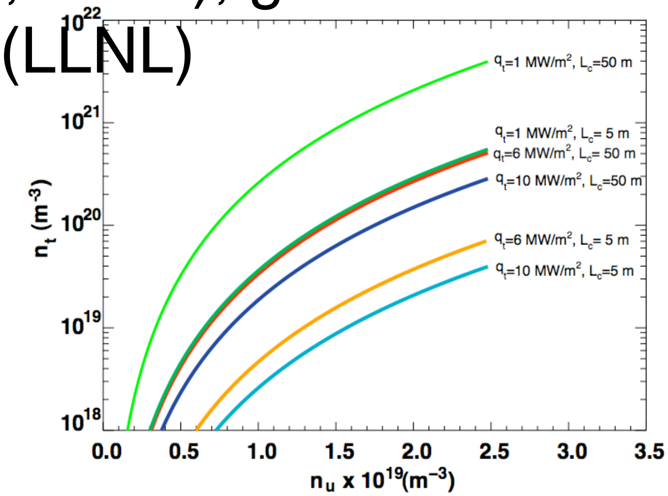


R. Maingi - IRTV

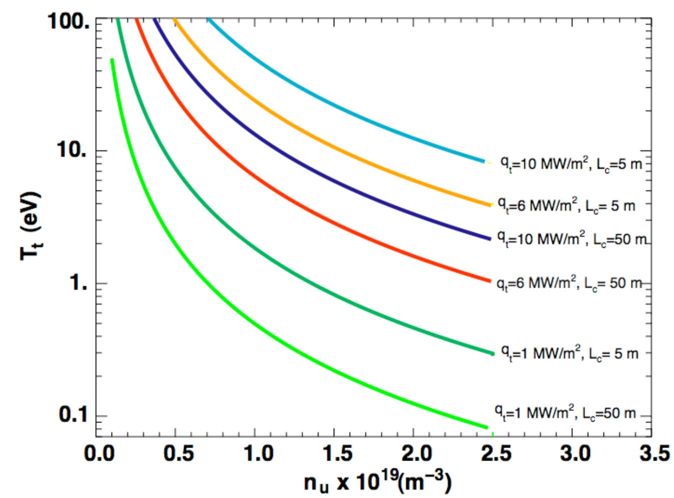
Analysis in progress

- Two point model
- 2D multifluid code UEDGE (UCSD, LLNL), generalized CRM and line shape code CRETIN (LLNL)





- UEDGE guidance of exp. divertor detachment space (diffusive transport model - G. Porter (LLNL))



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Summary

- Present analysis of heat and recycling fluxes in L- and H-mode plasmas suggests that the inner divertor operates in a detached state in $n_e > 2 - 3 \times 10^{19}$ m^{-3} ($0.2 < n_e/n_G < 0.9$), $P_{in} = 2 - 6$ MW LSN and DN plasmas, whereas the outer divertor is always attached

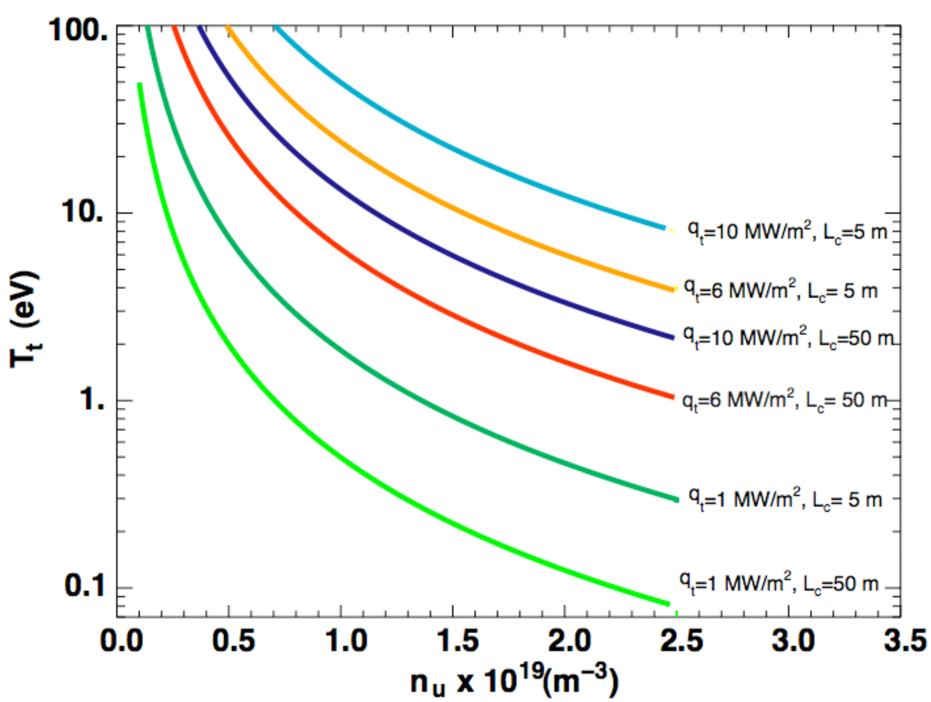
- The outer divertor is in the sheath-limited and flux-limited regime

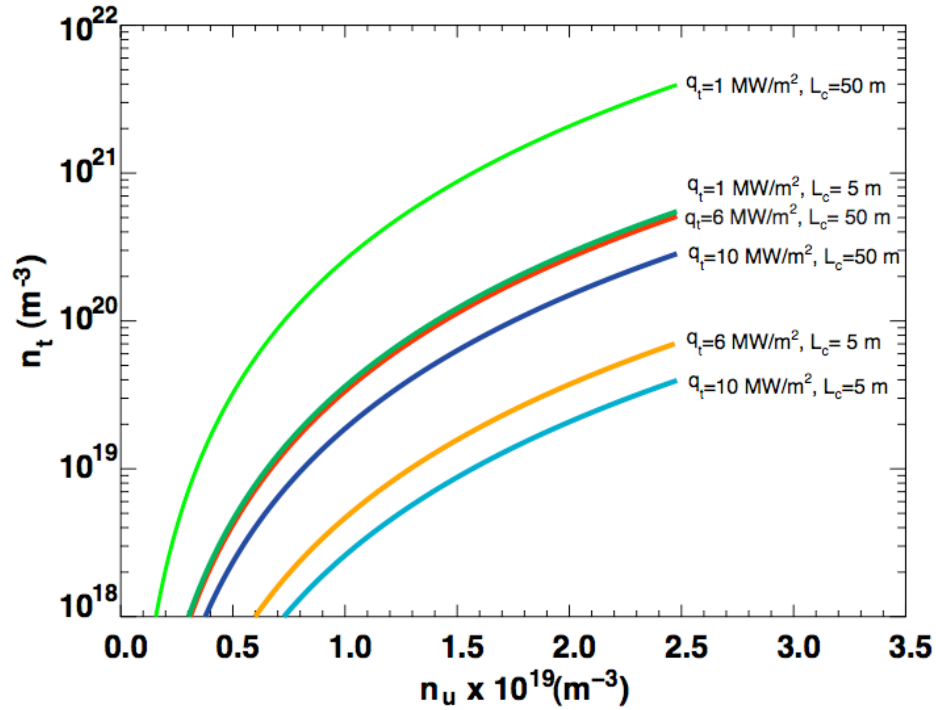
- This state is resilient to Type I and Type III ELMs

- Anxiously awaiting Langmuir probe data analysis (J. Boedo (UCSD), C. Bush (ORNL))

- Need to perform a systematic documentation experiment of divertor regimes - XP will be re-submitted to the BP ET group at the FY'05 Research Forum

2PM suggests detachment of inner divertor





$$2\, n_t\, T_t = n_u\, T_u$$

$$T_u^{7/2} = T_t^{7/2} + \frac{7}{2}\,\frac{q_{||}\, L_c}{\kappa_0}$$

$$q_{||} = \gamma\, n_t\, T_t\, c_{St}$$

P. C. Stangeby, *The plasma boundary of Magnetic Fusion Devices*, IoP Publishing, Bristol & Philadelphia, 2000

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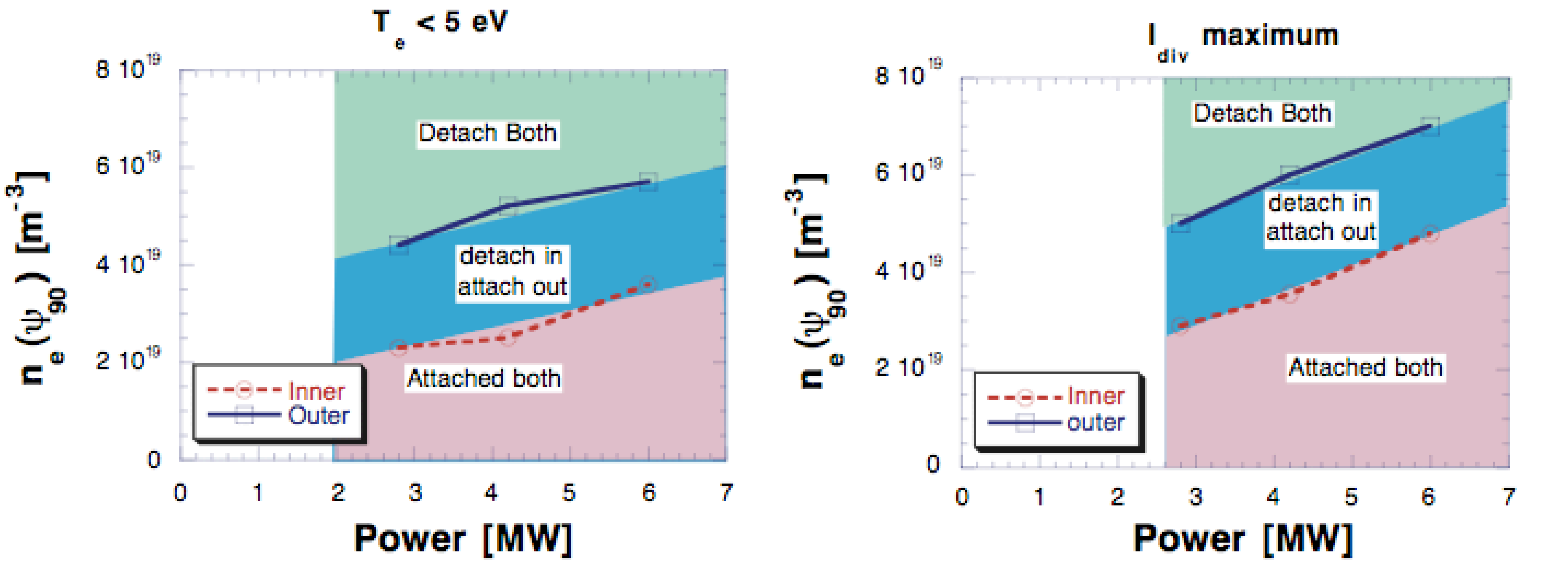
UEDGE modeling of detachment space



- H-mode LSN equilibrium used
- UEDGE diffusive transport model
- Impurities included
- Outer n_e, T_e profiles matched, Dα and IRTV not matched
- For guiding purposes only

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