Variation of the midplane heat flux profiles with plasma current and heating power in the National Spherical Torus Experiment

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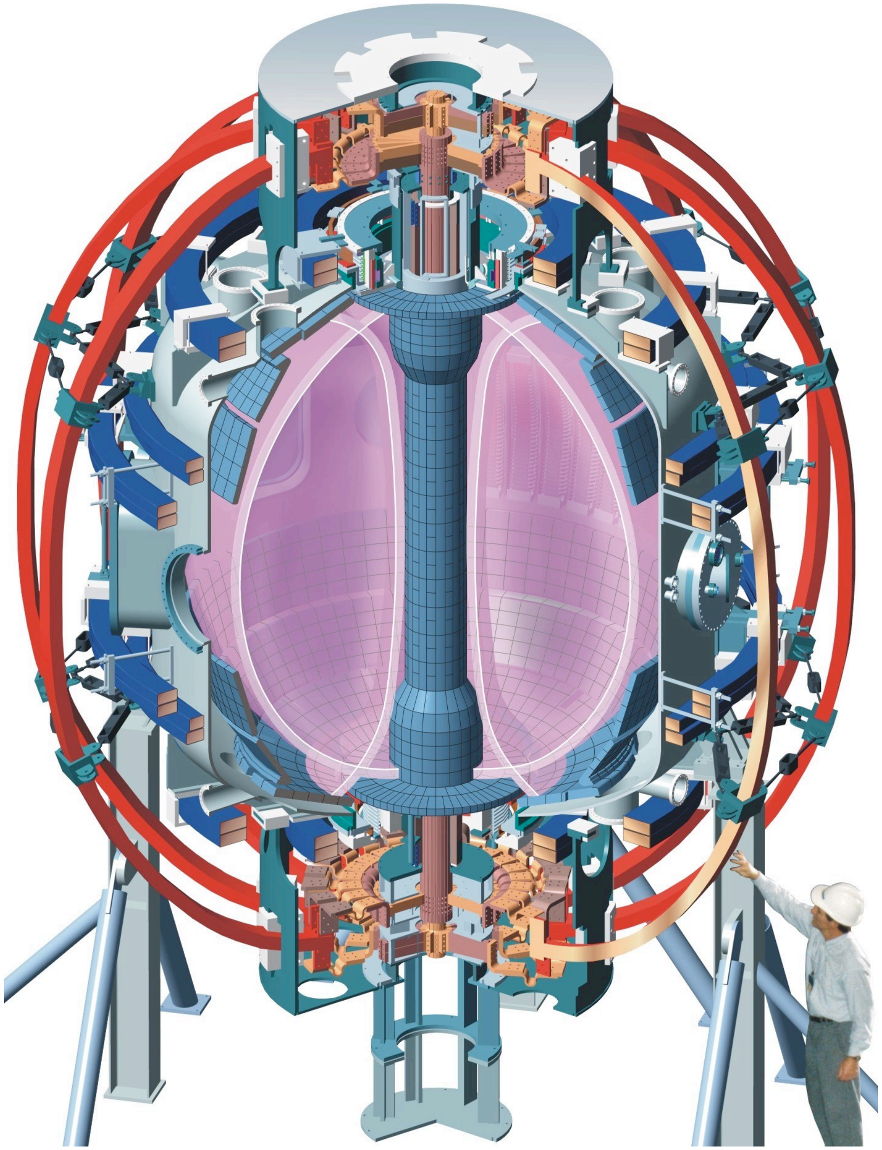


NSTX Facility Parameters

Major Radius 0.86 m

Minor Radius 0.67 m

Elongation ≤ 3

Triangularity ≤ 0.8

Plasma Current ≤ 1.5 MA

Toroidal Field ≤ 0.6 T

NBI Heating ≤ 7.5 MW

RF Heating ≤ 6 MW

Pulse Length ≤ 1.6 sec

Heat flux management an important issue for Spherical Tori (ST)

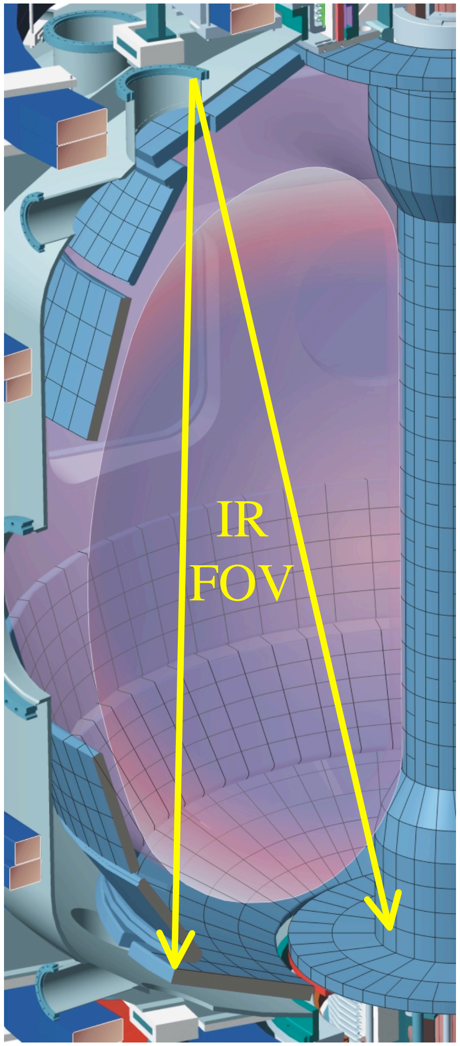
- Small major radius in ST implies small wall area, possibly high divertor power loading factor P/R
- High magnetic mirror ratio and large flux expansion in scrape-off layer may broaden power deposition to acceptable values
- In NSTX, plasma facing components are designed for a maximum transient temperature of 1200 ^{0}C
- Previous study indicates that a maximum pulse length of 2-3 sec can be tolerated at maximum observed peak heat flux of ~10 MW/m^2 before 1200 ^{0}C will be reached on PFCs
- $\underline{P_{NBI}}$ and $\underline{I_p}$ scaling of outer divertor peak heat flux midplane width shown here
- *Dissipative divertor research: Soukhanovskii P2.023*

Summary and Conclusions

- Peak heat flux increases with P_{NBI}, with a break (stronger dependence) in the slope at $P_{NBI} \sim 3$ MW
  - Simulations with the 2-point Borass model suggest that at the lowest NBI power, the outer divertor may be on the verge of detaching
- The change in slope above at $P_{NBI} \sim 3$ MW could correlate with the onset of the high recycling regime
- Heat flux midplane profile width weakly dependent on P_{NBI} in high recycling regime
- Heat flux midplane profile width decreases rather strongly with I_p - much stronger than a simple connection length dependence
- Simple models predict narrower SOL widths than observed, but Bohm cross-field transport gives proper order of magnitude

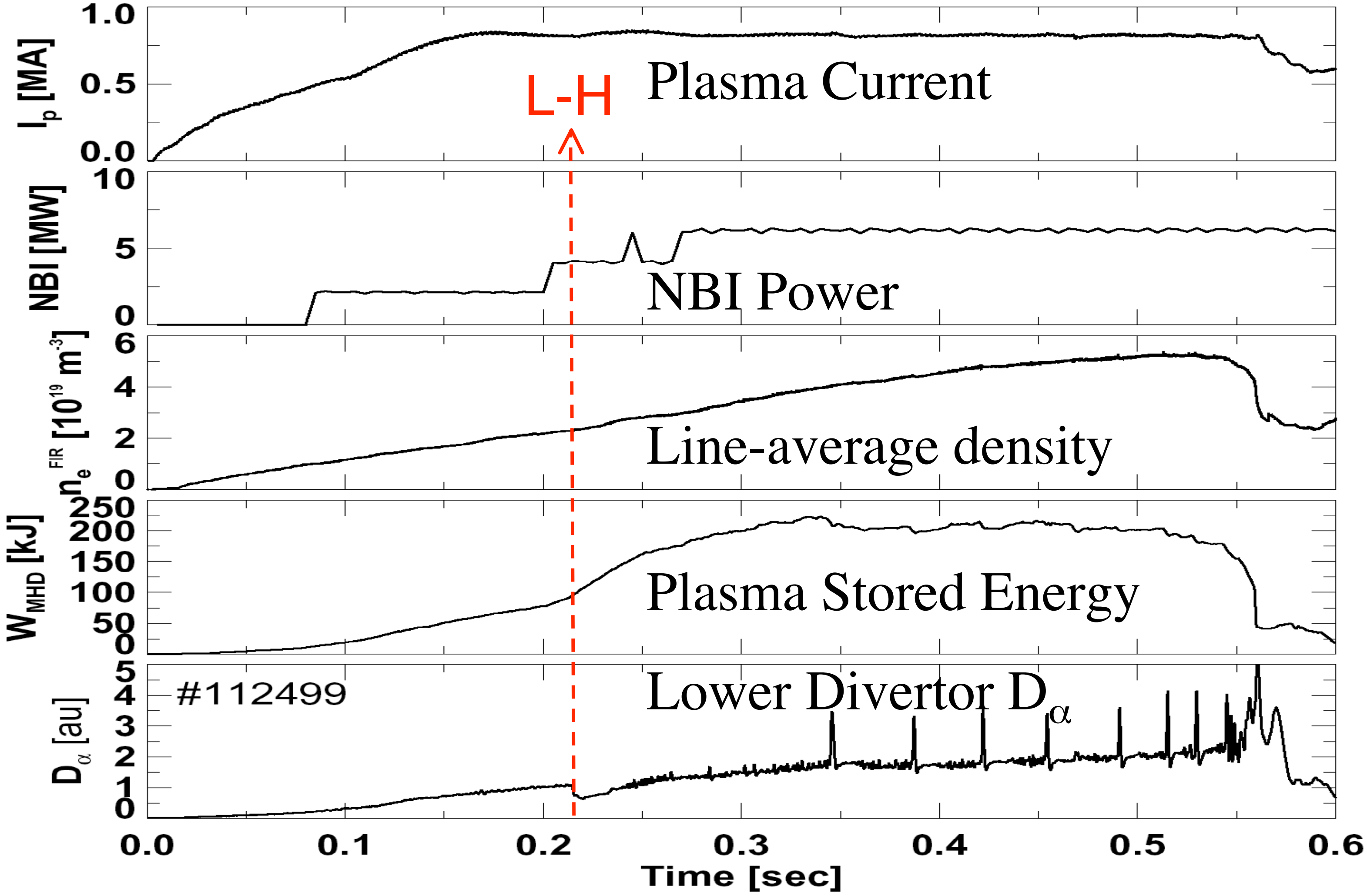
Lower divertor IR camera and 1-D conduction model used to compute heat flux

- Indigo ALPHA camera
  - I60 x 128 microbolometer array
  - 7-13 μm range
  - 30 Hz, 25ms thermal e-folding time
  - spatial resolution ~ 0.66 cm with present optics
  - 12-bit digital output, frame-grabbed on PC
  - Calibrated during in-situ bakes of the graphite tiles
- 1-D conduction model considers heat transport into tile bulk
  - temperature dependent ATJ graphite conductivity
  - neglects radial diffusion - ok for short pulses < few sec

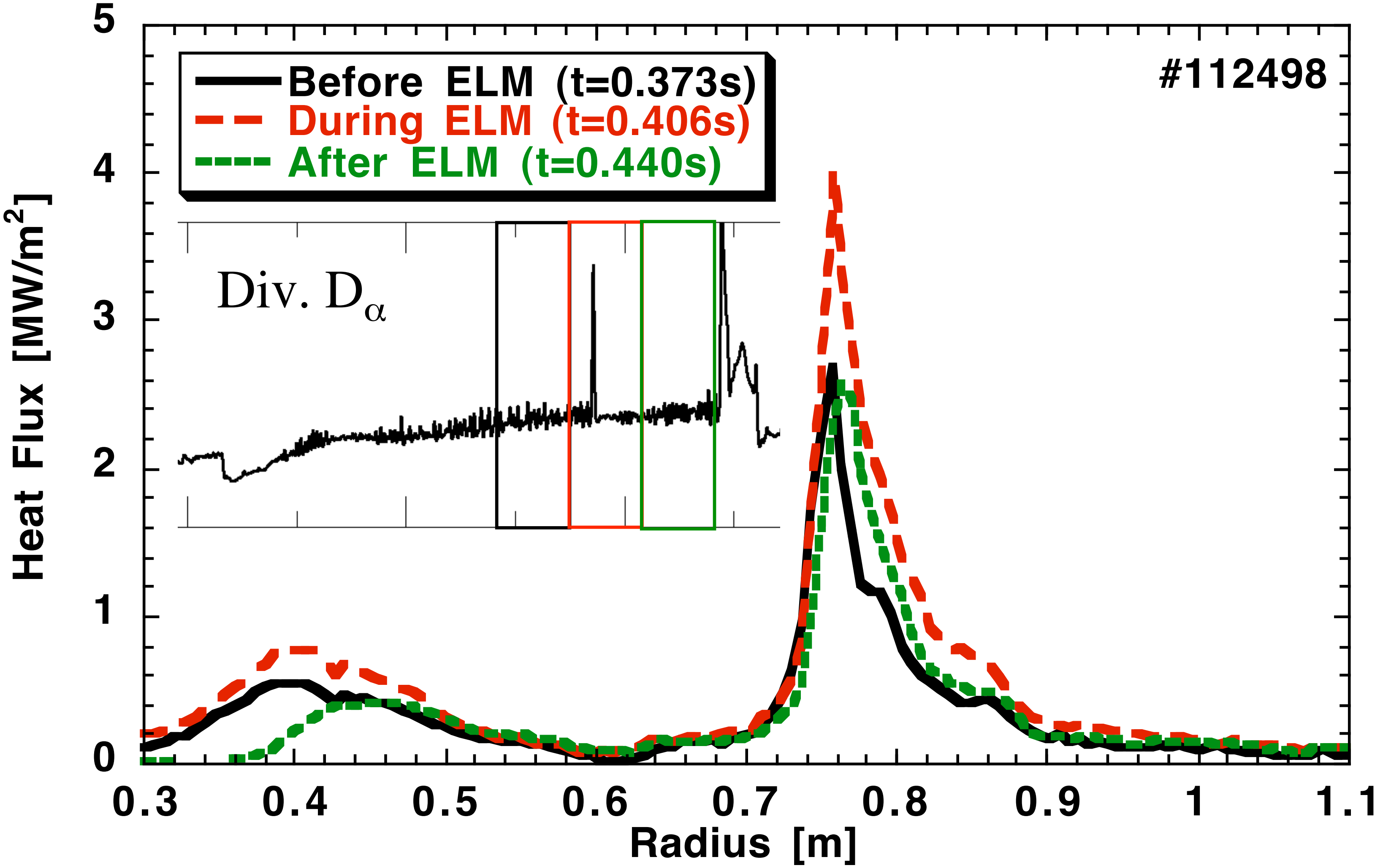


NBI-heated discharges used for heat flux scaling experiments (all with density ramping)

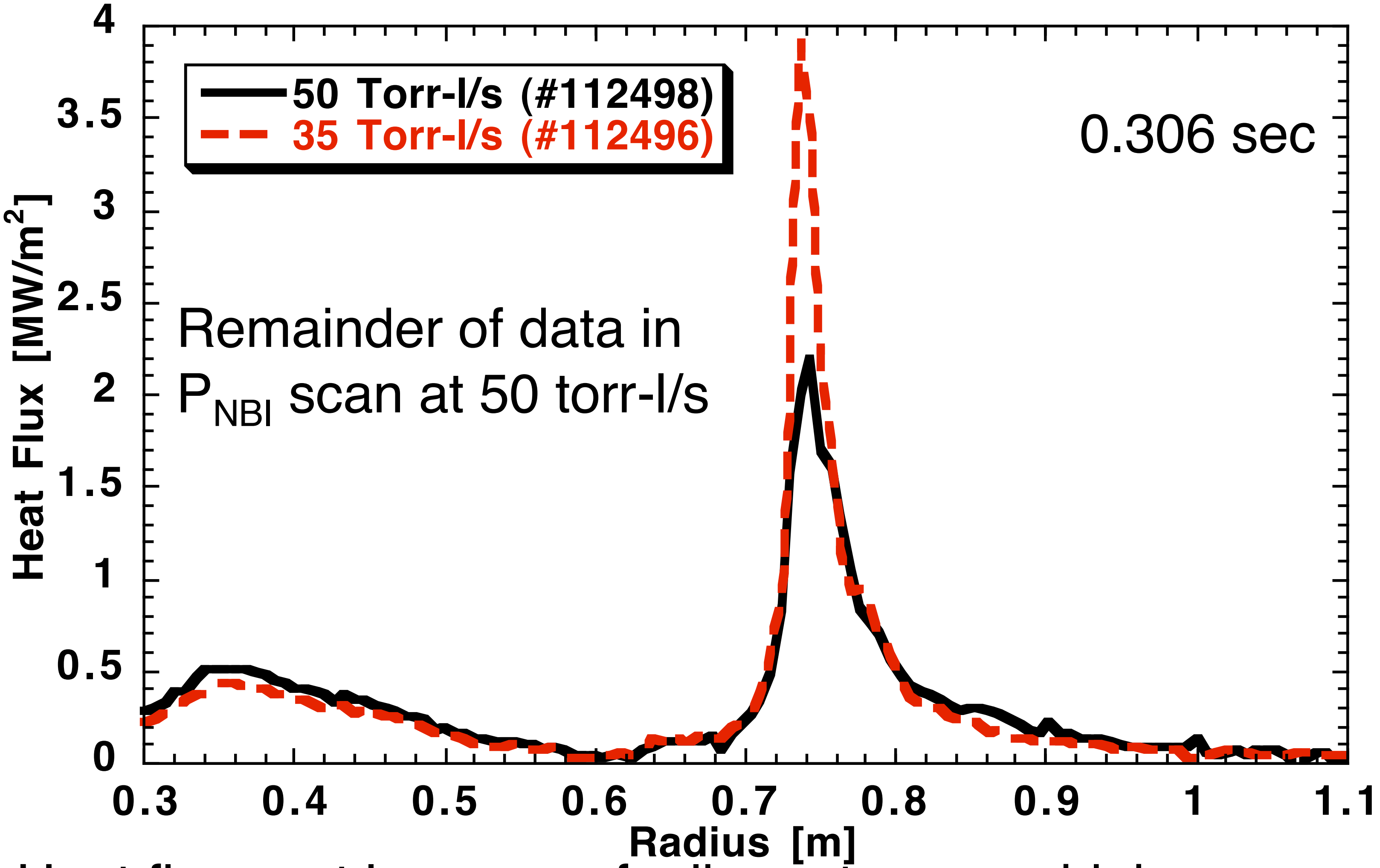
- Power accountability ~ 70% in these discharges (Paul, JNM 2005)



Heat flux profile changes moderately during Type I ELMs ($\Delta W/W<10\%$), due to long integration time



Peak Heat Flux Decreases with Center Stack Gas Fueling Rate (I_p=0.8 MA, P_{NBI}=4 MW, no big ELMs)



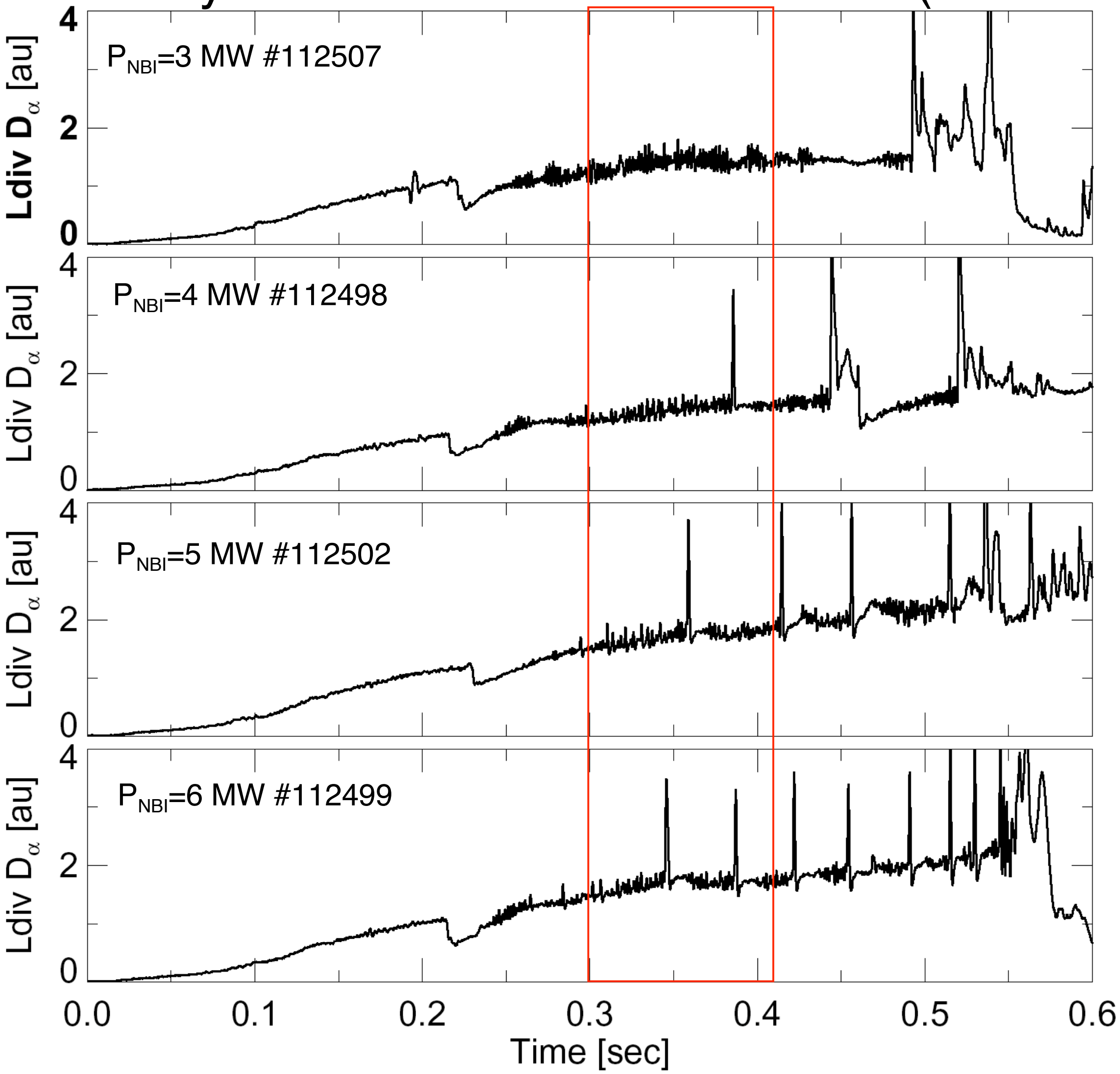
0.306 sec

Remainder of data in P_{NBI} scan at 50 torr-l/s

- Heat fluxes at lower gas fueling rates even higher

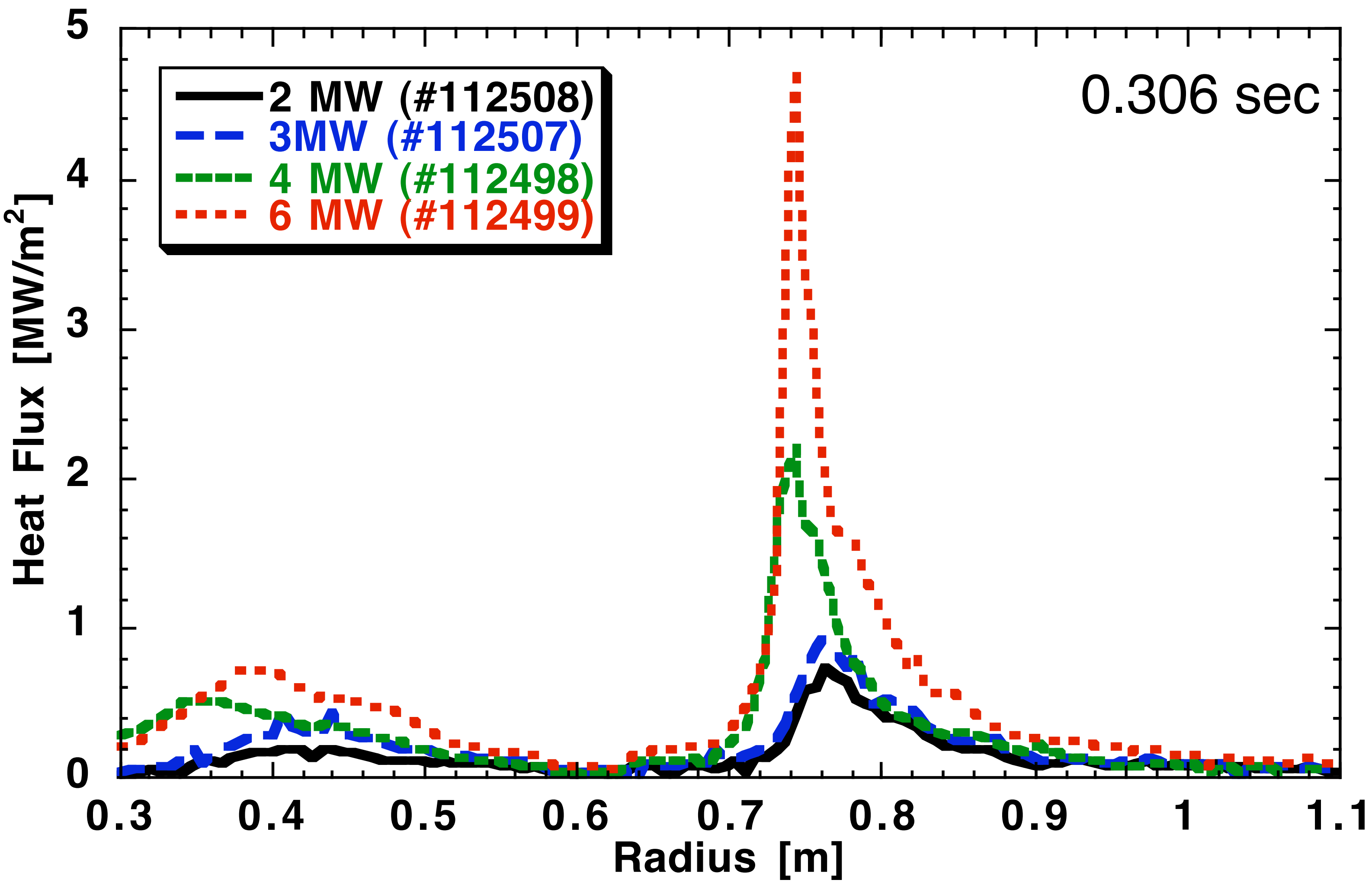
Discharges transition from small, Type V ELMs to mixed Type I V ELMs at P_{NBI} ~ 4 MW (I_P = 0.8 MA)

- Time of analysis between 0.3 and 0.41 sec (4 IR camera frames)



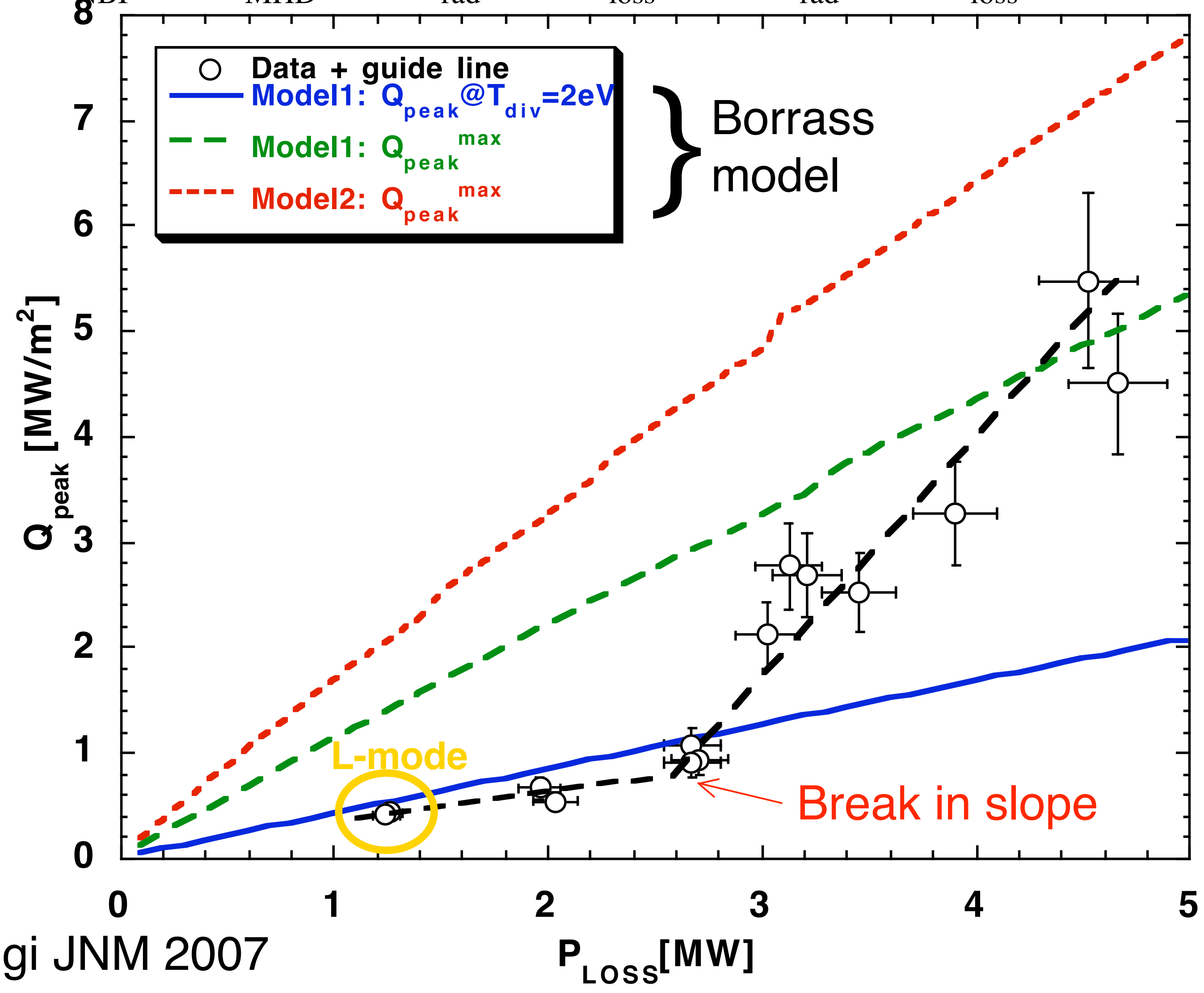
- Small, Type V ELMs
- Mixed small Type V + Type I ELMs
- Mixed small Type V + Type I ELMs
- Mixed small Type V + Type I ELMs

Heat flux profile becomes more peaked with increasing NBI power



Peak Heat Flux increased with NBI power, with a change in the slope for $2<P_{loss}<3$ MW

$$P_{LOSS} = P_{OH} + P_{NBI} - dW_{MHD}/dt - P_{rad}^{core} - P_{loss}^{fast\ ion};\ P_{rad}^{core} + P_{loss}^{fast\ ion} \sim 0.3(P_{OH} + P_{NBI})$$



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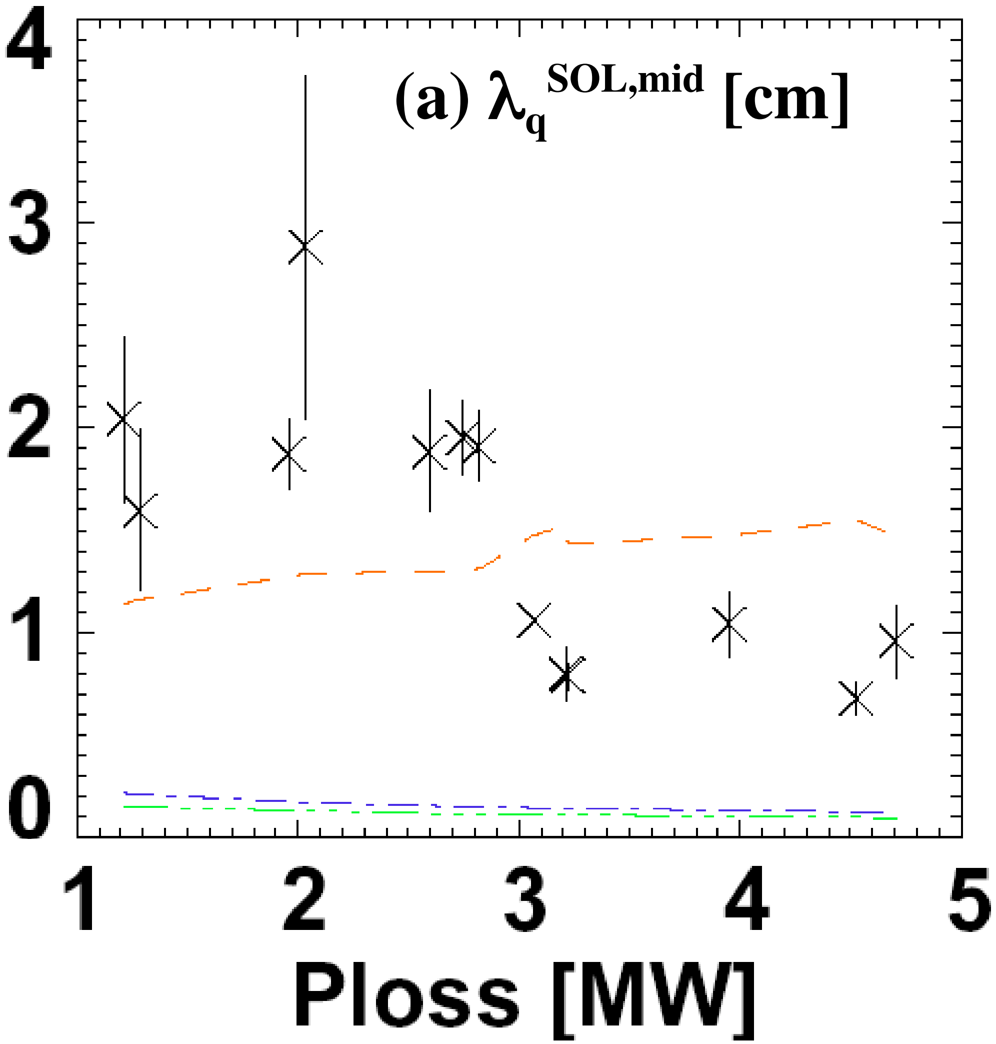
Midplane heat flux scale length depends weakly on P_{loss} in high recycling regime (P_{loss} > 3 MW)



Models (Counsell, JNM 1999)

- classical parallel transport
- different cross-field models

$\lambda_q^{B1}=0.3q_{95}^{0.73}R_m^{0.27}a_m^{0.18}P_{loss}^{0.18}B_t^{-0.57}n_{sep}^{-0.18}$

- Collisionless SOL
- Applies? NSTX SOL ν_e^* 5-100

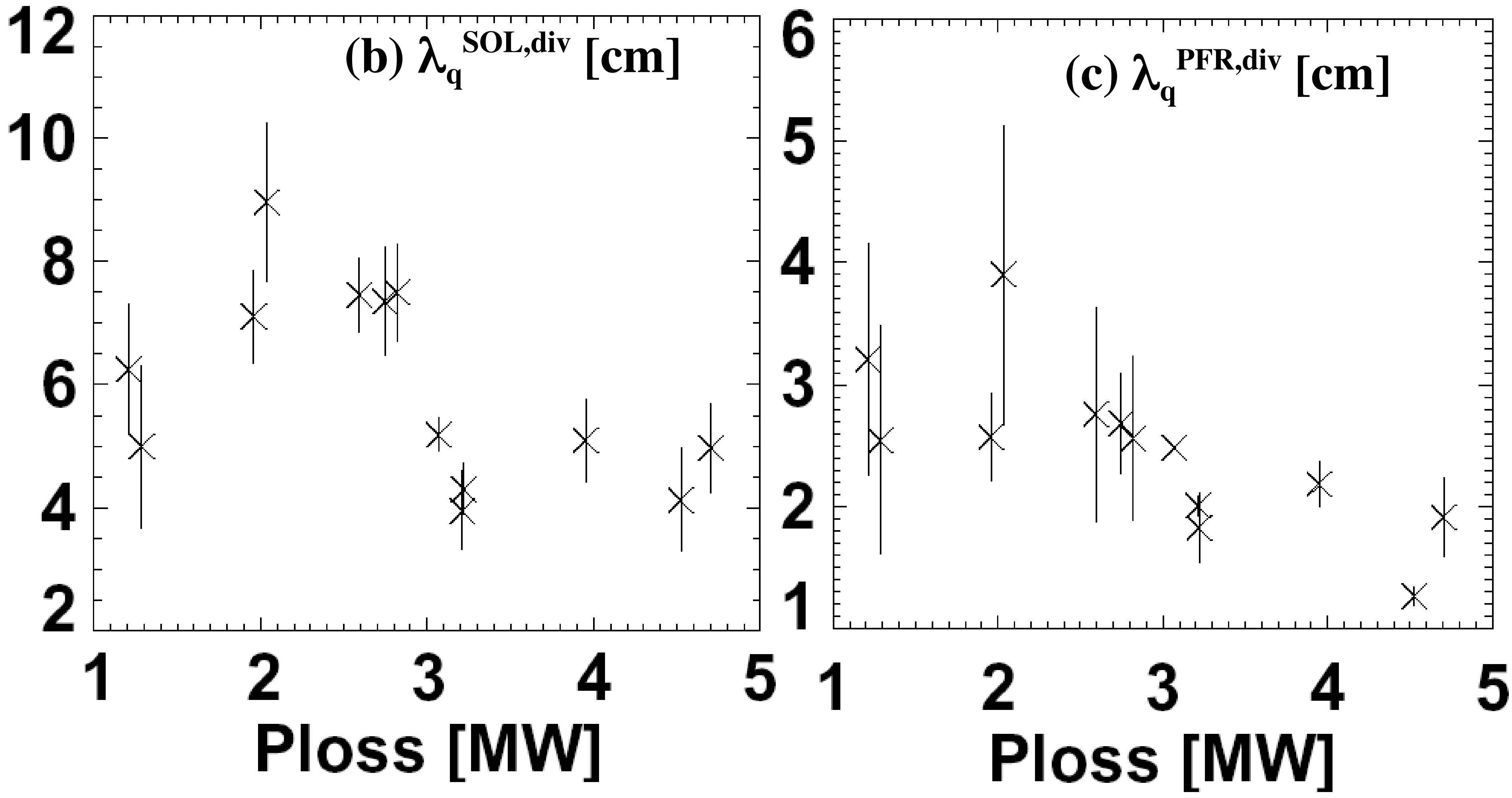
$\lambda_q^{D}=0.35q_{95}^{-0.1}R_m^{0.3}a_m^{0.4}P_{loss}^{-0.4}$

- collisional SOL
- cross-field from sheath resistivity

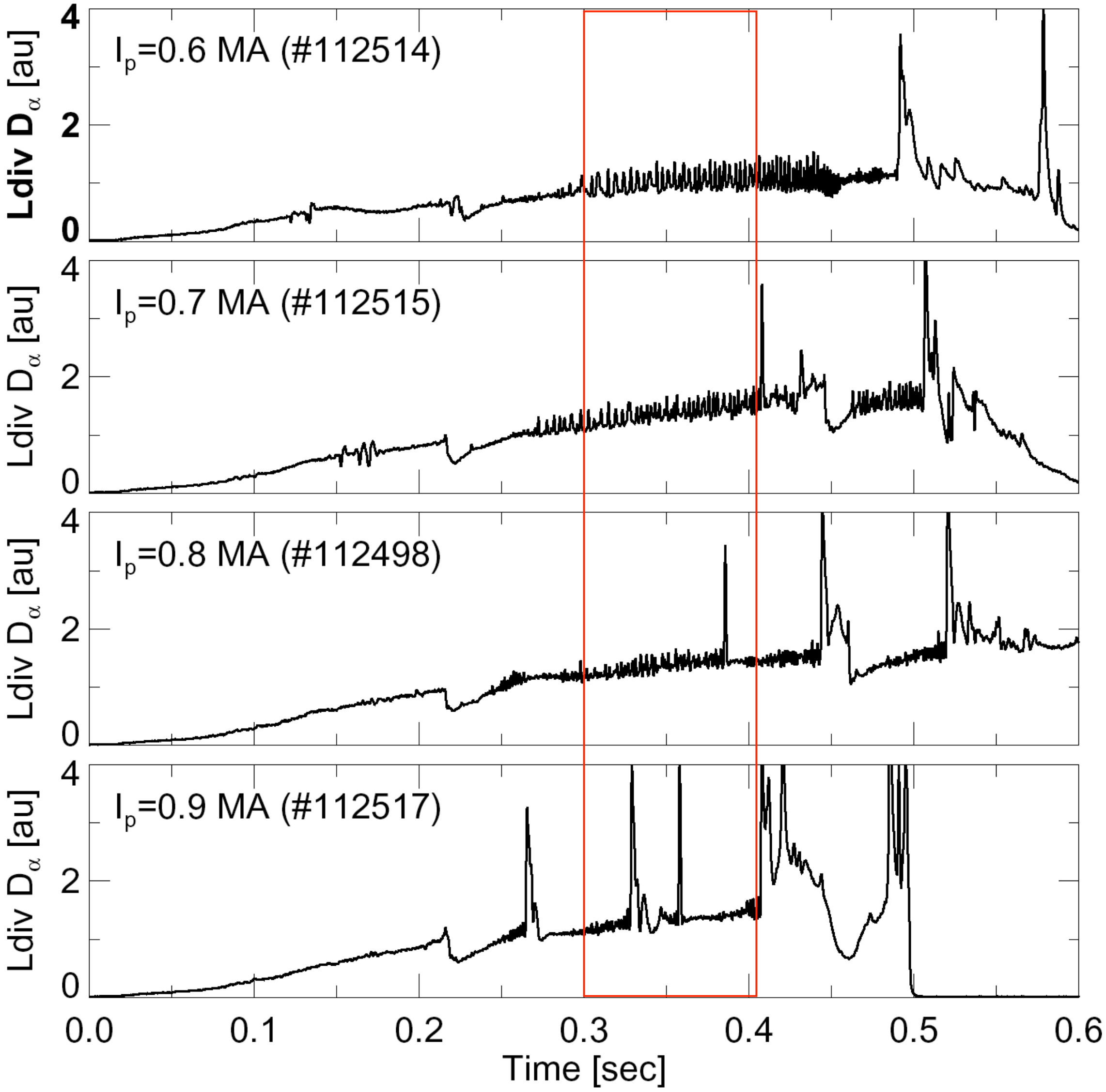
$\lambda_q^{M}=0.083q_{95}^{0.6}R_m^{1.0}a_m^{0.4}P_{loss}^{-0.4}$

- collisional SOL
- cross-field due to charge exchange

Ratio of divertor private-flux region scale length to scrape-off layer heat flux scale length ~ 2-3



Larger ELMs and other MHD observed more frequently as I_p increased (P_{NBI} = 4 MW)



- Small, Type V ELMs
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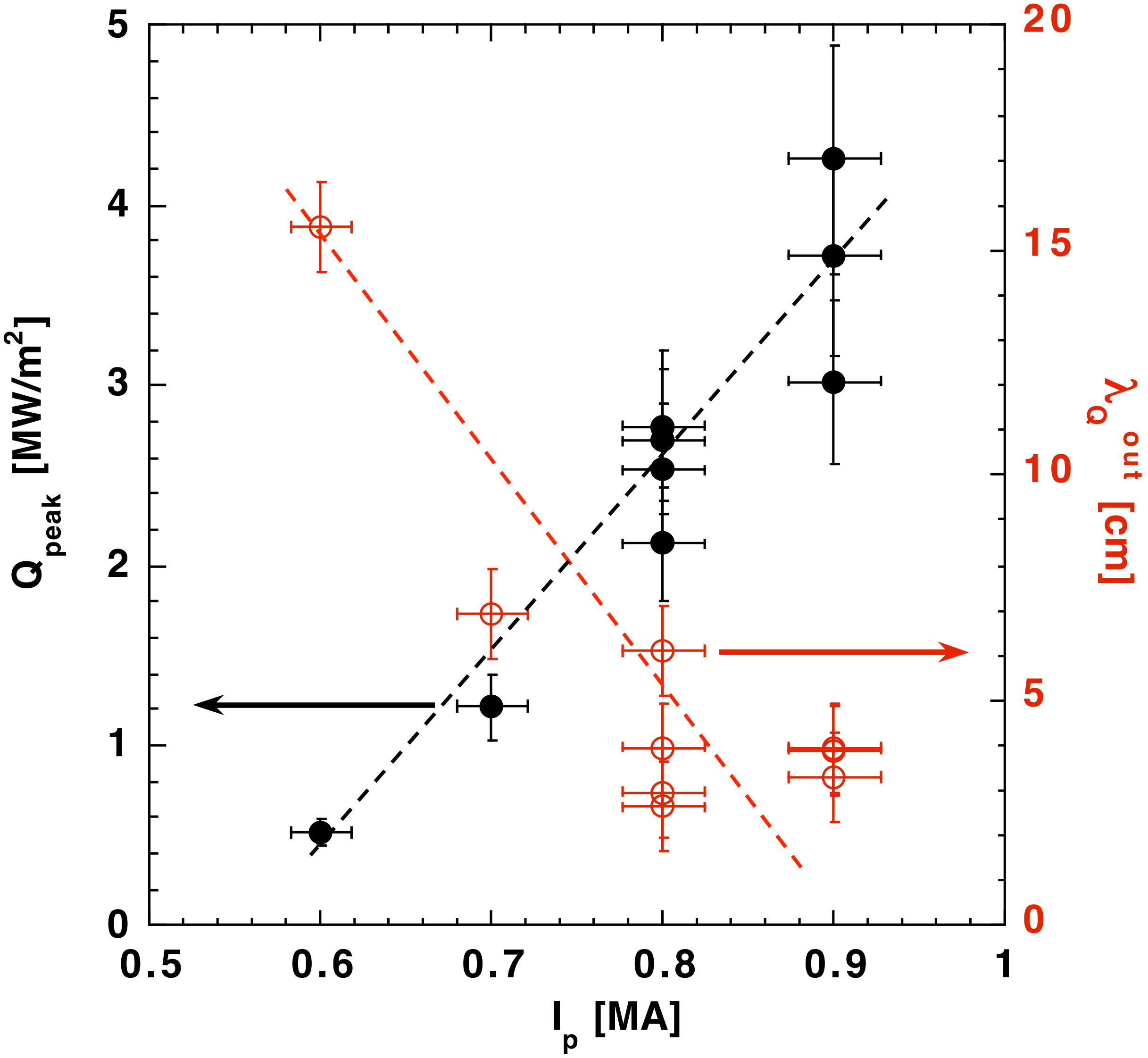
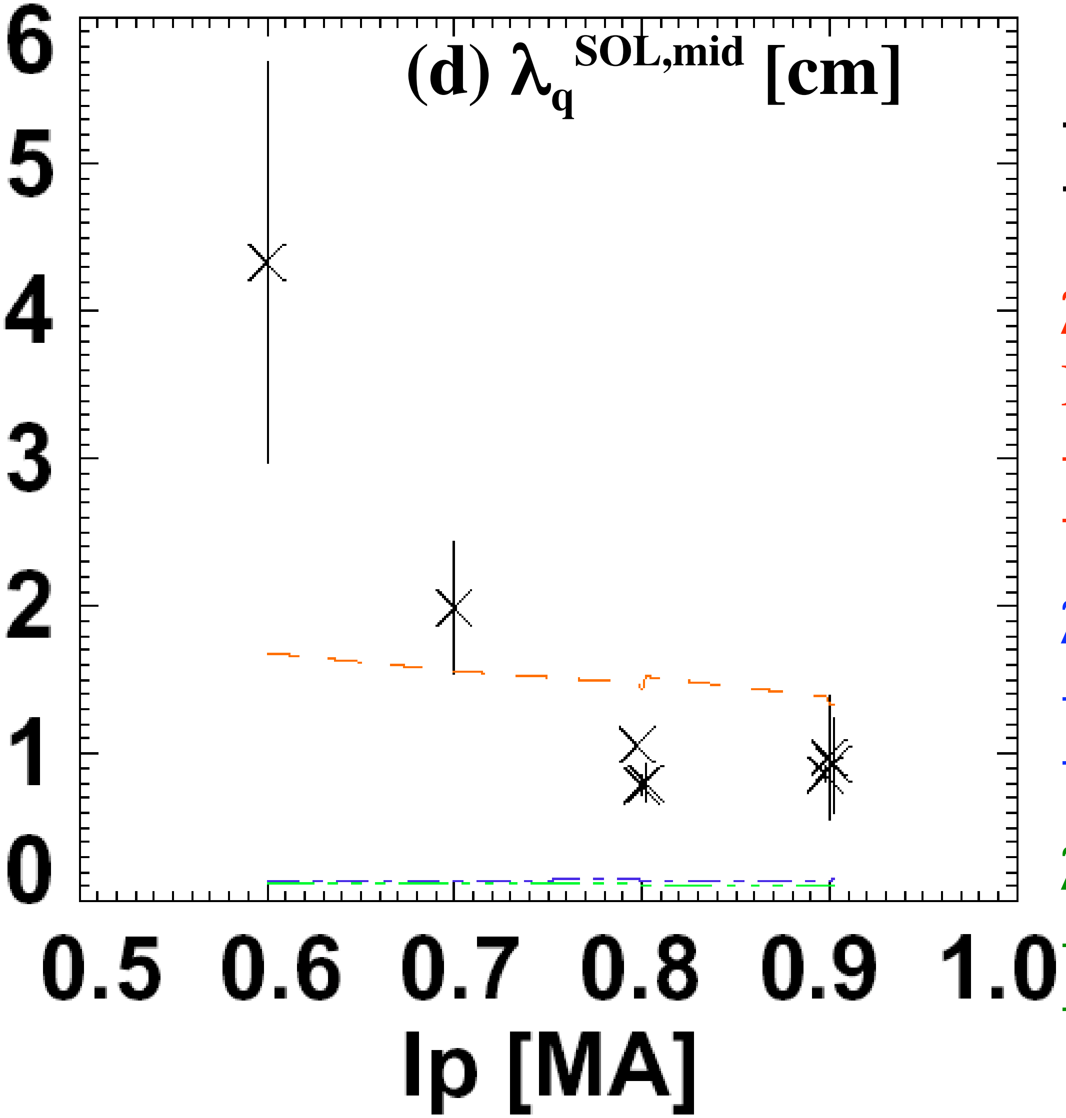
Divertor peak heat flux (profile FWHM) increases (decreases) with I_p



Midplane heat flux scale length depends strongly on I_p (P_{NBI} = 4 MW)



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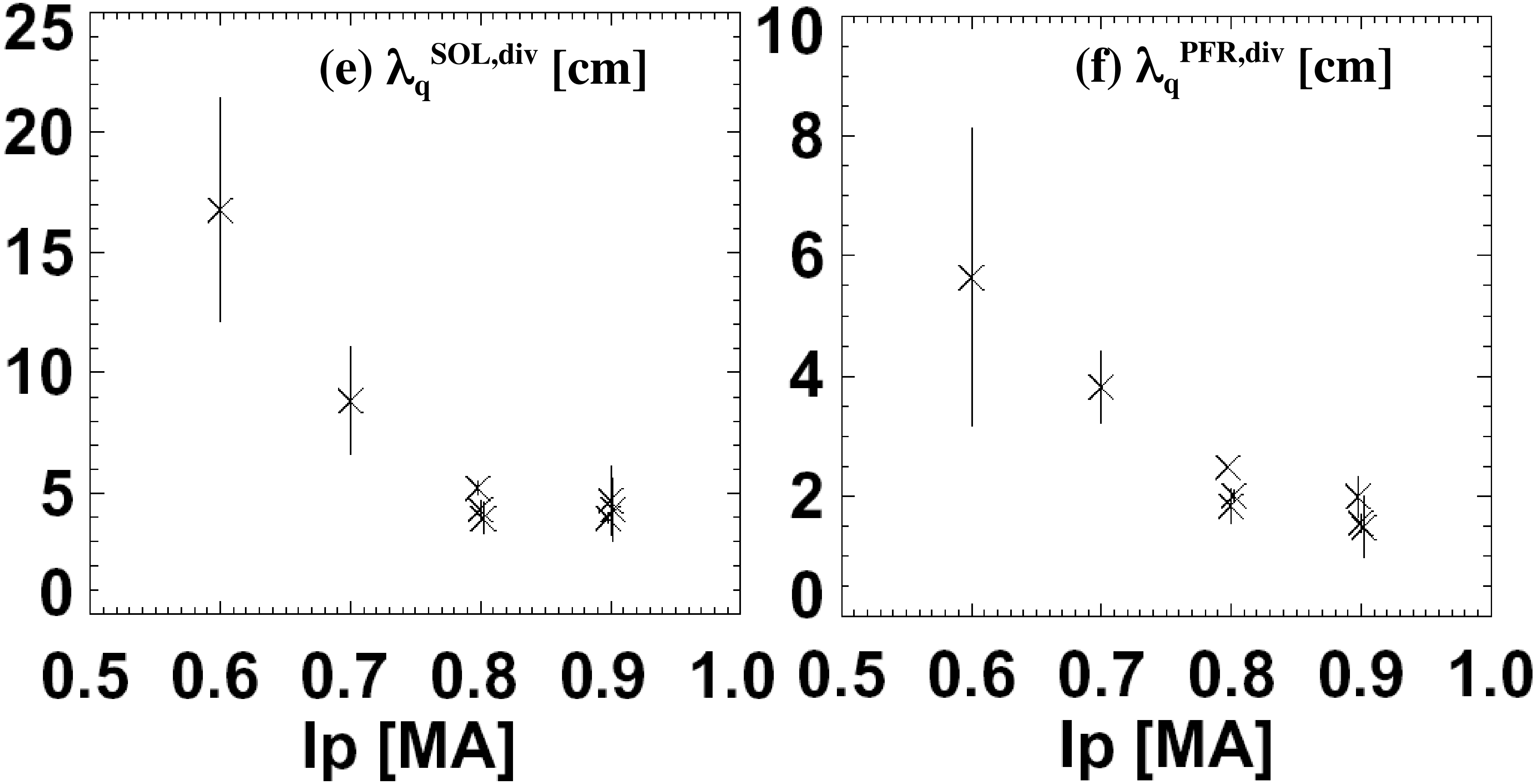
Ratio of divertor private-flux region scale length to scrape-off layer heat flux scale length ~ 2.5-3



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