Measurements of Heat Flux Profiles for the FY2010 Joint Research Milestone

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**R. Maingi, J-W. Ahn,
T.K. Gray, A.G. McLean, R.J.
Maqueda**

**NSTX Boundary Physics TSG meting
Princeton, NJ
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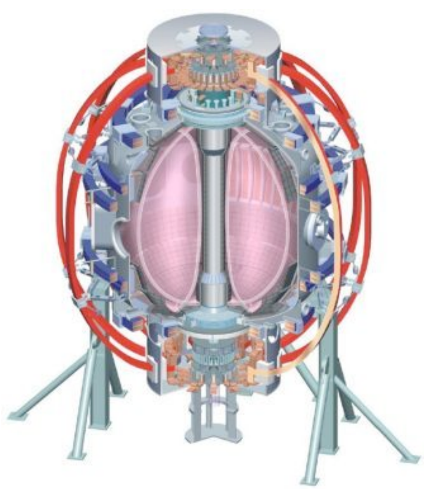

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Additional data needed to fulfill FY2010 Joint Research Milestone on SOL thermal transport

✓Obtained, analyzed, and published slow IR camera data from several pre-li data sets:

- wide P_{NBI} and moderate I_p scans at medium $\delta \sim 0.5$
- Nice I_p scan, flux expansion, and narrow P_{NBI} scans at high $\delta \sim 0.7$
- Main results: divertor heat flux width (mapped to midplane) independent of P_{SOL}, flux expansion, but narrows rapidly with increasing I_p

• Desired: comparable data set for post-li discharges, plus additional B_t scan, magnetic balance (δ_r^{sep}) scan, and data from scaled poloidal shape match to C-Mod

• Dedicated data with GPI to see if turbulence changes

Simplest 0-D heat flux projection based on power balance extrapolates from measured NSTX heat flux profiles

- IR thermography measures heat flux profile $q_{div}^{out}(r)$ for calculation of divertor power loading: $P_{div}^{out} = \int_{R_{\min}}^{R_{\max}} 2\pi R_{div}^{out} q_{div}^{out} dr$
- Define characteristic divertor heat flux scale length, $\lambda_{q,div}^{out}$:

$$\lambda_{q,div}^{out} = P_{div}^{out} \Big/ \left(2\pi R_{div,peak}^{out} q_{div,peak}^{out}\right)$$

- Assume $\lambda_{q,div}^{out}$ related* to characteristic midplane scale length through flux expansion f_{exp}: $\lambda_q^{mid} = \lambda_{q,div}^{out} / f_{\exp}$ with $f_{\exp} = \dfrac{R_{mid} B_\theta^{mid}}{R_{div} B_\theta^{div}}$

– Project NSTX-U q_{peak}^{div}: I_p=2 MA, P_{loss}=10 MW, B_t=1 T, f_{exp}=30
  - For P_{loss} extrapolation, use $P_{div}^{out} = f_{div} P_{loss}$ with $f_{div} = 0.5$

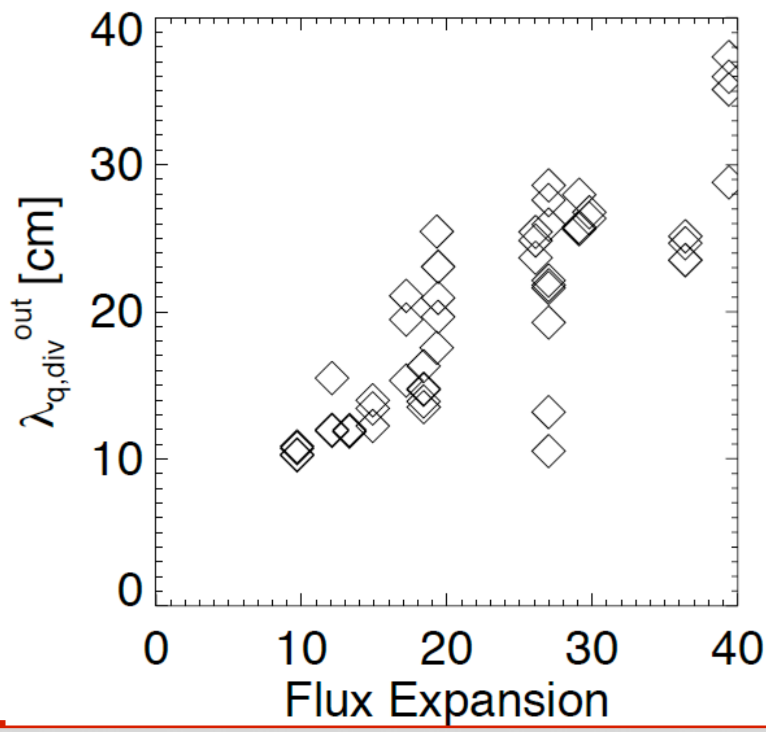
$$q_{div,peak}^{out} = f_{div} P_{loss} \Big/ \left(2\pi R_{div,peak}^{out} f_{\exp} \lambda_q^{mid}\right) \quad \text{with } \lambda_q^{mid} = f\left(I_p, P_{loss}, B_t, f_{\exp}\right)$$

➢ Determine dependence of λ_q^{mid} on external parameters (I_p, P_{loss}, B_t, flux expansion) from NSTX data (FY10 Joint Research Target)

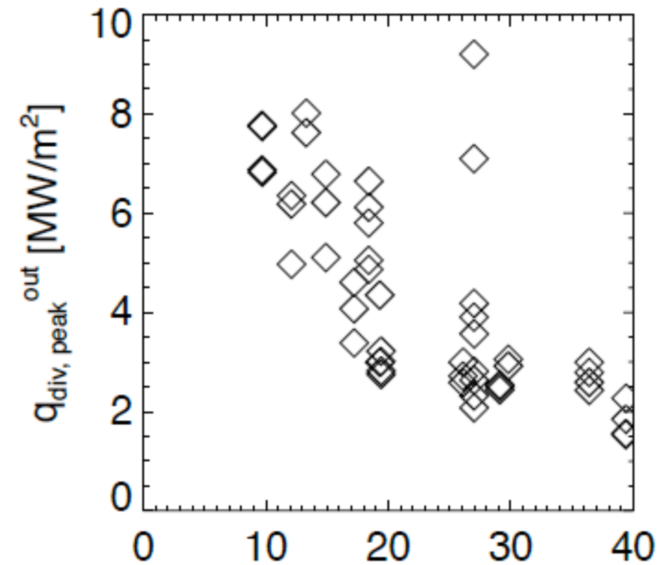
*Loarte, JNM 1999

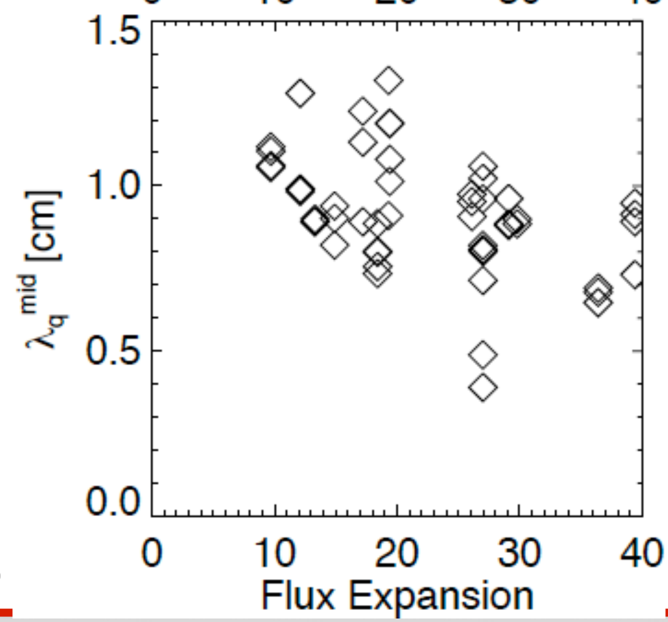
Peak heat flux decreases inversely with flux expansion with roughly constant λ_q^{mid} in NSTX

- λ_q^{div} increases with flux expansion
- λ_q^{mid} stays approximately constant during the scan

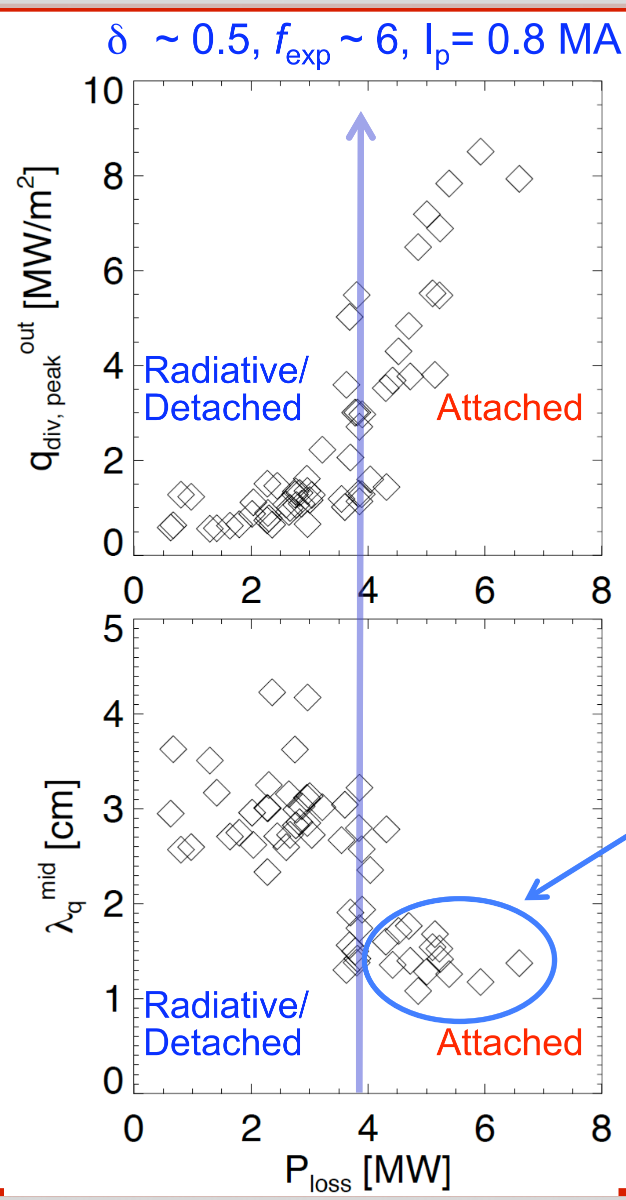


Gray, PSI10





Heat flux width λ_q^{mid} largely independent of P_{loss} in attached plasmas in NSTX



- Peak divertor heat flux increases with P_{loss}
- Apparent change in slope near P_{loss}=4 MW in these conditions, as divertor transitions from a radiative /detached divertor to an attached divertor
- λ_q^{mid} relatively independent of P_{loss} in high heat flux regime
- All data in this talk averaged over ELMs and before lithium coatings

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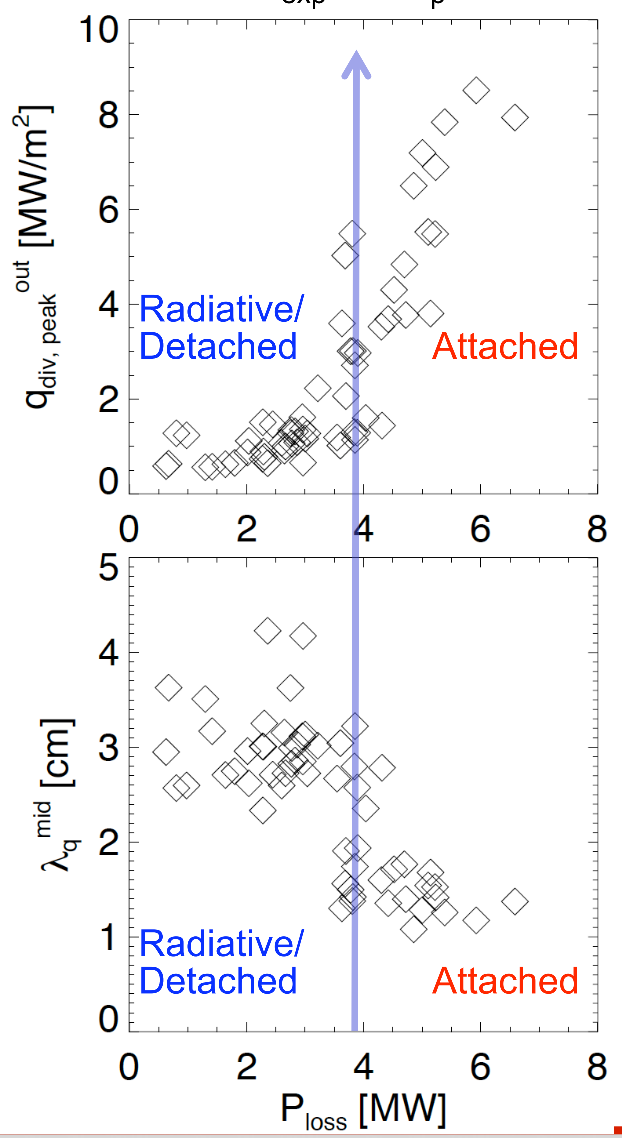
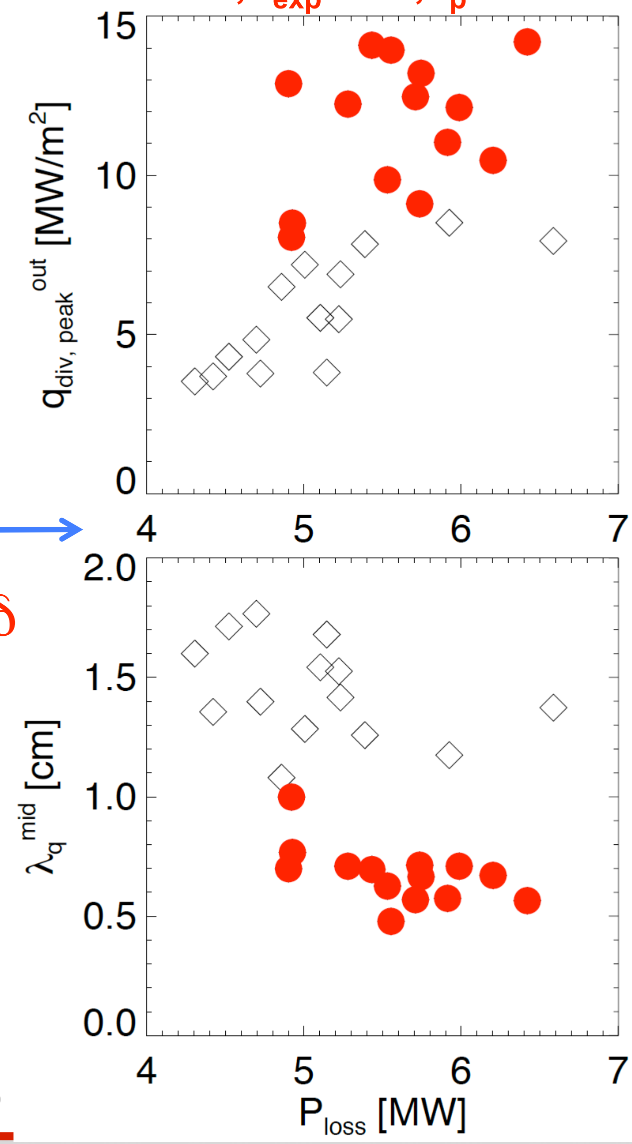
Heat flux width λ_q^{mid} largely independent of P_{loss} in attached plasmas in NSTX

δ ~ 0.5, f_{exp} ~ 6, I_p= 0.8 MA



- Narrow P_{loss} plot range
- Add in high δ data
- Apparent I_p or q_{95} effect

+ δ ~ 0.7, f_{exp} ~ 16, I_p= 1.2 MA



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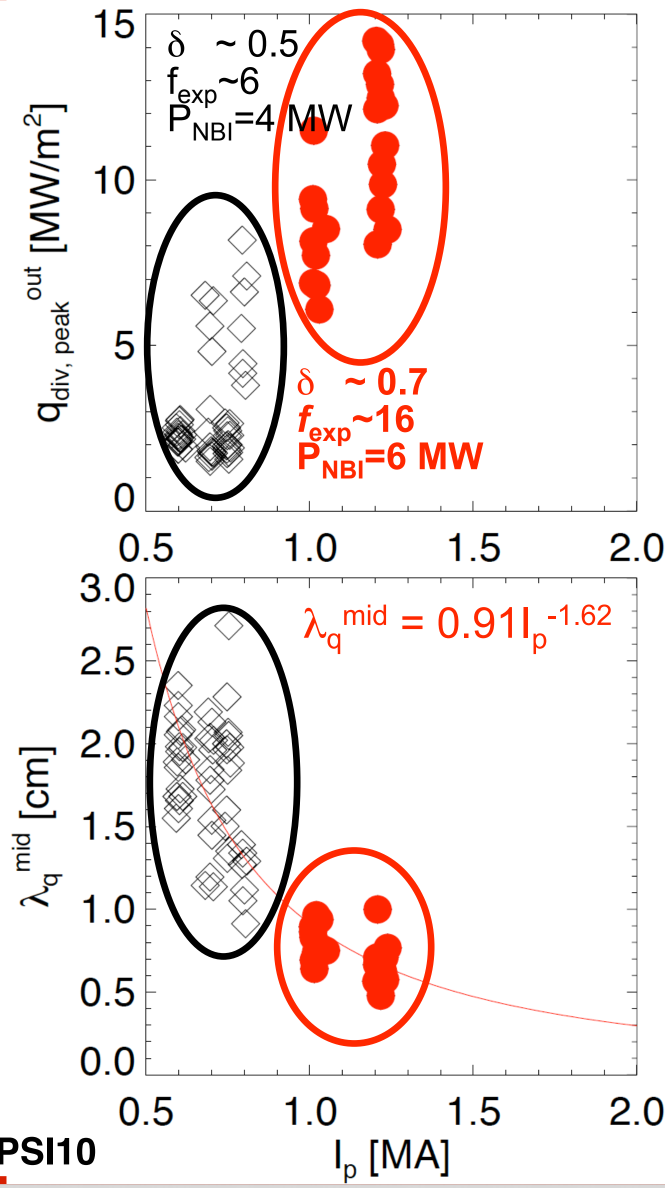
Heat flux width decreases with I_p in NSTX

- Combined data from dedicated I_p scans in low δ and high δ discharges
  - I_p dependence also in DIII-D, JET
  - Different P_{NBI} and f_{exp}, but previous slides shows no P_{loss} or f_{exp} effect on λ_q^{mid}
  - q_{95}, $\ell_{||}$ different
- Power law fit: $\lambda_q^{mid} \sim 3$ +/- 0.5 mm @ 2 MA
- Lodestar group making progress on simulations (Myra, PSI10)



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Proposed shot plan elements in priority order

- I_p scan from 0.7-1.3 MA (0.1 MA increments) at high δ
- B_t scan from 0.35-0.55 T (0.05 T increments) at high δ
- P_{NBI} scan from 2-max (1 MW incr.) MW in H-mode at high δ
  - Highest I_p provides new dataset in region of interest, and lower I_p satisfies GPI requirement
- Scaled poloidal shape match to C-Mod and DIII-D to match ν^*, κ, δ: (e.g. from XP721: $\delta \sim 0.5$, κ=1.8, large δ_r^{sep})
- δ_r^{sep} scan from 0 to (-2) cm, at high and medium δ

> Note: High δ => R=0.4m, Low δ => R=0.7m, with *strike point control* used for each

Proposed shot plan sequencing

- Develop baseline 1.2 MA, 0.45 T (based on pre-li 128797)
  - Vary fueling +/- 100 torr with 100-200 mg Li between shots to set up target (6)
  - P_{NBI} scan: 2-max MW (1 MW increments) (8)
  - Drop I_p=0.8 MA; P_{NBI} scan: 2-max MW (1 MW incr.) (10)

- I_p scan at 3 or 4 MW NBI: 0.8 MA, 1.3 MA, 0.7 MA, 1.0 MA, 1.1 MA, 0.9 MA (18)
- B_t scan from 0.35-0.55 T (0.05 T increments) - 0.8 MA, high δ (8)

- Scaled poloidal shape match to C-Mod and DIII-D to match ν^*, κ, δ: (e.g. from XP721: $\delta \sim 0.5$, κ=1.8, large δ_r^{sep}) (6)
- δ_r^{sep} scan: -6mm, -3mm, 0mm, -10mm, -20 mm, at high δ and repeated for medium δ (20)

Backup

FY2010 Joint Research Milestone: Thermal Transport in the Scrape-off Layer

- Conduct experiments on major fusion facilities to improve understanding of the heat transport in the tokamak scrape-off layer (SOL) plasma, strengthening the basis for projecting divertor conditions in ITER.

- Divertor heat flux profiles and plasma characteristics in the tokamak scrape-off layer will be measured in multiple devices to investigate the underlying thermal transport processes. The unique characteristics of C-Mod, DIII-D, and NSTX will enable collection of data over a broad range of SOL and divertor parameters (e.g., collisionality, beta, parallel heat flux, and divertor geometry). Coordinated experiments using common analysis methods will generate a data set that will be compared with theory and simulation.