Characterization of the divertor heat flux width and the mid-plane SOL widths

J-W. Ahn, J. A. Boedo
University of California – San Diego

R. Maingi
Oak Ridge National Laboratory

V. Soukhanovskii
Lawrence Livermore National Laboratory

R. Maqueda
Nova Photonics

S. Zweben
Princeton Plasma Physics Laboratory

Motivation and goals of the experiment

Near SOL

Parallel e-conduction dominates heat transport, the relation between T_e and q_{target} SOL widths close to the classical prediction

Far SOL

Cross field transport becomes more important, resulting in the long tail of the profile.

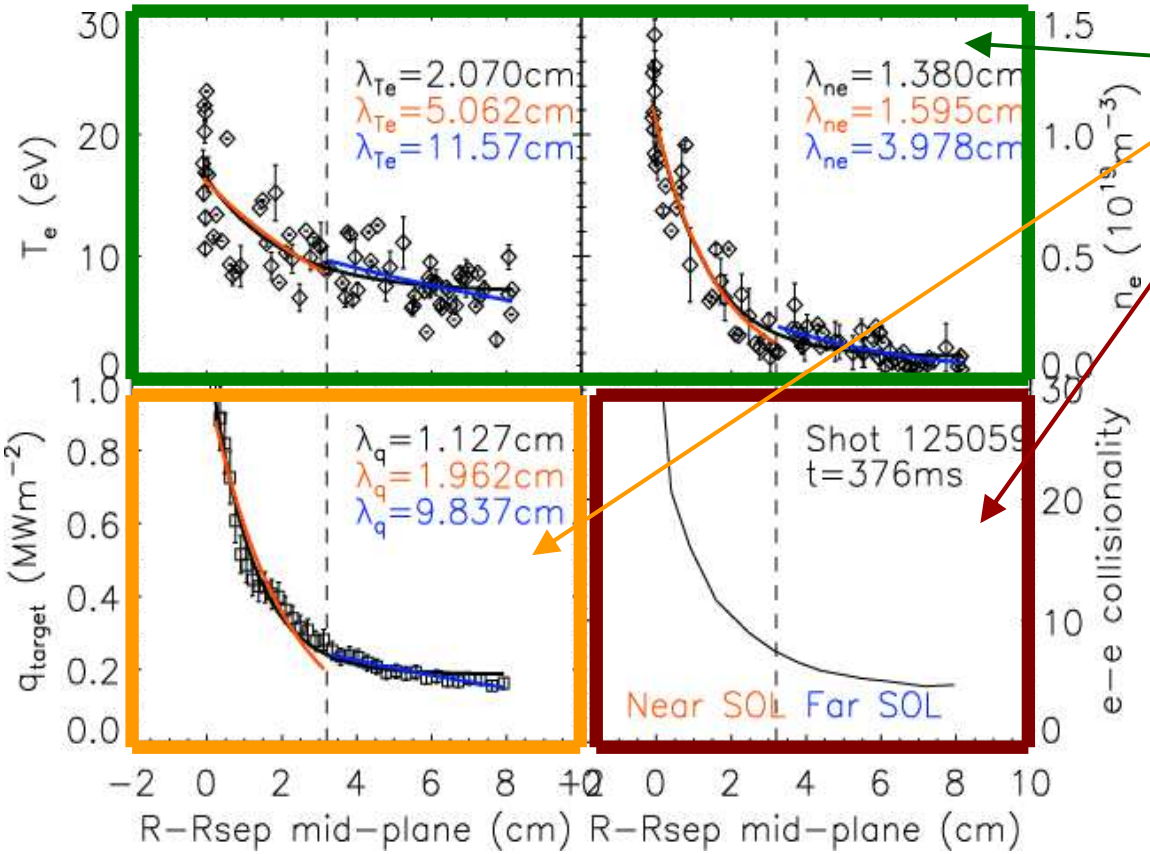
Topics of investigation in FY08 (all in H-mode)

(1) To find the relation between the target heat flux width and the upstream SOL widths

(2) To develop SOL width scalings

(3) To find the relation between SOL widths and the edge turbulence characteristics (eg, blob/filament)

NSTX SOL profile has two zones – Near and Far SOLs



- probe measurement
- IR measurement
- Calculation from measured Te and ne
- All profiles mapped to the mid-plane

Near SOL: steep exponential decay length
Far SOL: non-exponential tail

—— Offset exponential fitting to the whole profile
—— Simple exponential fitting to the near SOL profile
—— Simple exponential fitting to the far SOL profile

Relation between λ_q and λ_{Te} in Near SOL (conduction-limited regime)

|| electron conduction with $\nabla_{||} T_e$

$$T_e \sim \left(\frac{7}{2} \frac{q_{||} L_c}{\kappa_0} \right)^{2/7}$$

(1) Assume simple exponential profiles

$$T_e = T_{e0} \exp\left(-\frac{R - R_{sep}}{\lambda_{Te}} \right)$$

$$q_{target} = q_0 \exp\left(-\frac{R - R_{sep}}{\lambda_q} \right)$$

$$\lambda_{Te} = \frac{7}{2} \lambda_q$$

Conventional relation

(2) Assume offset exponential profiles

$$T_e = T_{e1} + T_{e0} \exp\left(-\frac{R - R_{sep}}{\lambda_{Te}} \right)$$

$$q_{target} = q_1 + q_0 \exp\left(-\frac{R - R_{sep}}{\lambda_q} \right)$$

$$\lambda_{Te} = \frac{7}{2} \lambda_q \left(\frac{T_e - T_{e1}}{T_e - C q_1 T_e^{-5/2}} \right) \qquad C = \frac{7}{2} \frac{L_c}{\kappa_0}$$

Additional factor introduced

Conventional SOL width relation in Far SOL (Sheath-limited regime)

NSTX

Electron energy balance equation

$$L_c \frac{d}{dr}\left[n\chi_\perp \frac{d(kT_e)}{dr} + \frac{5}{2} kT_e D_\perp \frac{dn}{dr} \right] = \frac{1}{2} n c_s \gamma_s^e kT_e$$

Power flow into the SOL

Power reaching target through the sheath

Assume simple exponential profiles

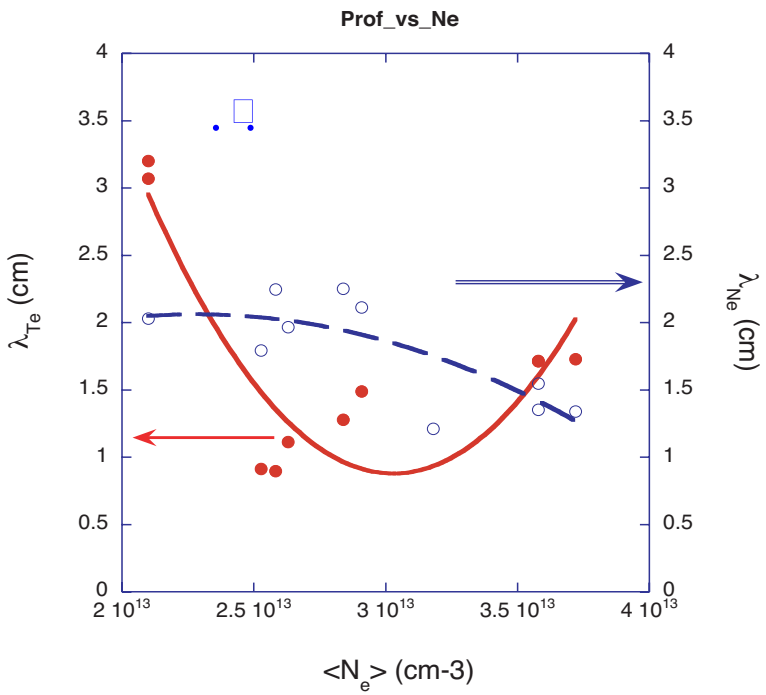
$$T_e = T_{e0} \exp\left(-\frac{R - R_{sep}}{\lambda_{Te}} \right) \qquad q_{target} = q_0 \exp\left(-\frac{R - R_{sep}}{\lambda_q} \right)$$

$$\frac{1}{\lambda_q} = \frac{1}{\lambda_n} + \frac{3}{2\lambda_{Te}}$$

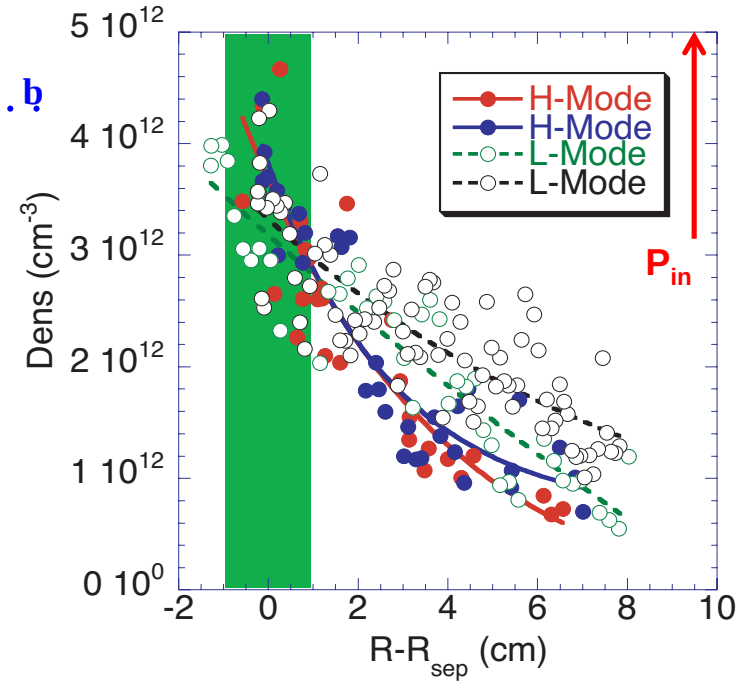
Summary of SOL Widths Relations – Meausrement and Prediction

	Measurement by fitting to profile		*Prediction from two-point model using,*	
	Simple exponential	**Offset exponential**	**Simple exponential**	**Offset exponential**
λ_{Te} / λ_q in near SOL	2.6	1.84	3.5	2.2
λ_q in far SOL	9.8cm	–	2.6–4cm	–

SOL scaling (Near SOL)



λ_{Te} and λ_{ne} on nebar (L-mode)

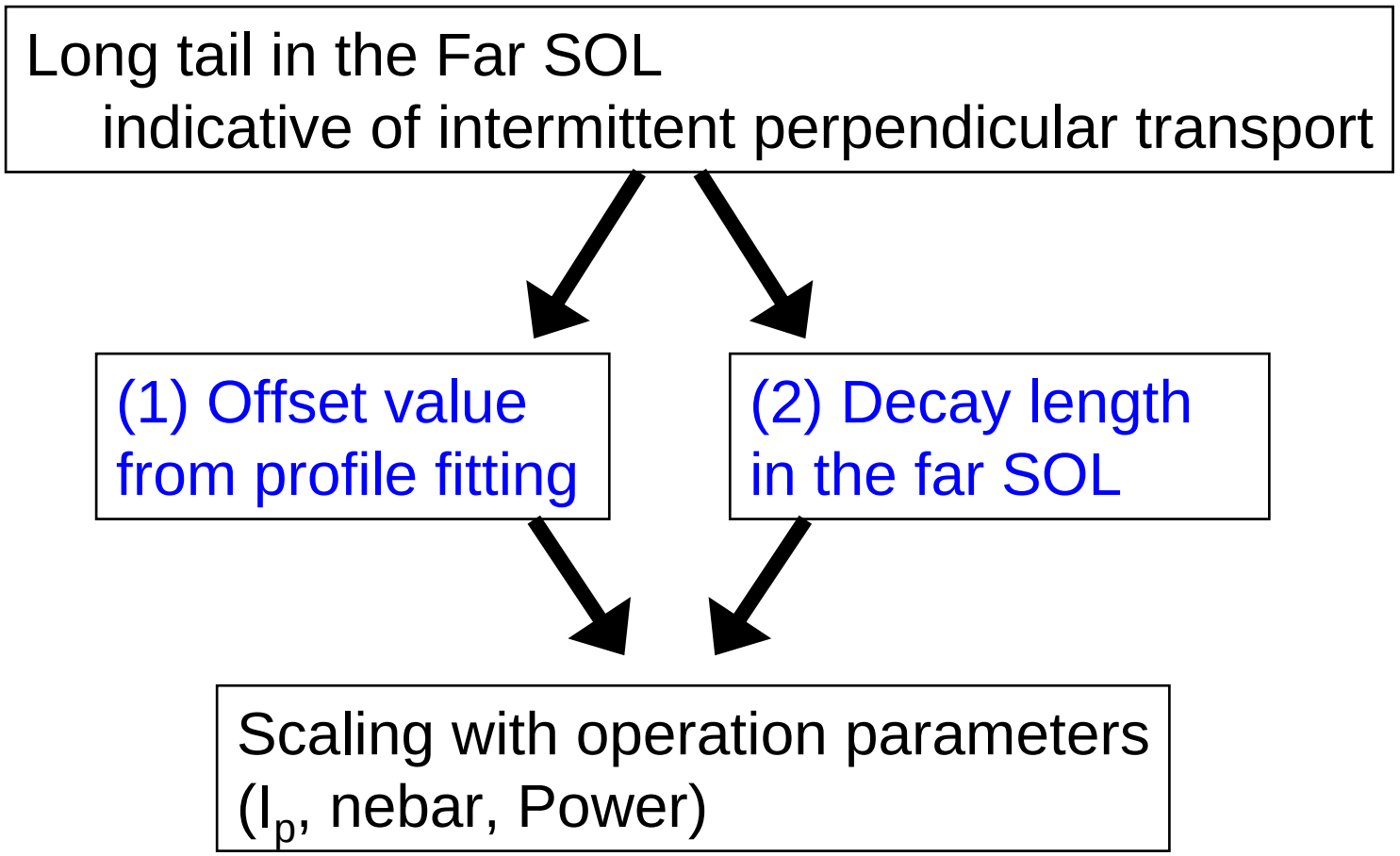


n_e profiles during a power scan

J.Boedo, NSTX RF2006

- Data from FY07: λ_{Te}, λ_{ne}, λ_q decreased with increasing I_p
- A bigger SOL width dataset (H-mode) will allow scalings with operation parameters (I_p, nebar, Power)
  - ⟷ Comparison with analytic models

SOL scaling (Far SOL)



SOL widths comparison with edge turbulence characteristics

§ How would the edge turbulence characteristics affect the SOL widths? Particularly with Blob characteristics.

Edge turbulence characteristics measurement

§ The number of filaments
§ The size of filaments/blobs
§ Blob speed and direction

} GPI diagnostic, FIReTIP, Divertor fast visible camera, etc

§ Broadband turbulence — Fast probe Isat fluctuation

Simultaneous measurement of SOL widths and edge turbulence characteristics find the relationship

Operational details

- Derate NBI src. C to 1MW
- Reproduce #125065 (1MA, 0.55T).

  NBI order: 2MW, 80-300ms (A); 2MW, 140-250 (B); 1MW, 300-500ms (C)
- Plunge probe at 350ms
- Plasma configuration: LSN, Drsep~3cm, κ=2.0, δ=0.45
- Timing for other diagnostics: GPI, IR, FIReTIP, etc

  to be aligned with probe plunge time, ie 300-500ms as planned
- Density scan: plunge probe at 2 different times

  roughly at 300ms (3.0e19) and 400ms (5.0e19)

Shot plan for 1 run day

- Establish baseline shot: 1.0MA, 0.55T, 1MW NBI (4 shots)
  start from shot #125065
- Ip scan at approximately fixed q95
  0.7MA, 0.385T, 1MW (4)
  0.8MA, 0.45T, 1MW (2)
  0.9MA, 0.495T, 1MW (2)
- Density scan
  0.8MA, 0.45T, 1MW, 3.0e19 (4)
  0.8MA, 0.45T, 1MW, 5.0e19 (4)

- If time permits,
  Power scan
  0.8MA, 0.45T, 0MW NBI (4)
  Bt scan at fixed Ip
  0.8 MA, 0.55 T (4) ; 0.8 MA, 0.35 T (4)