NSTX

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Status of follow-on work from FY10 JRT

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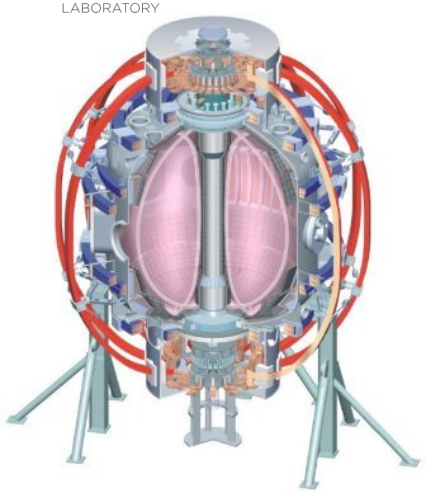
R. Maingi

OAK RIDGE National Laboratory

For the FY10 JRT research team

ECC meeting 2012
Annapolis, MD
April 13, 2012

PPPL PRINCETON PLASMA PHYSICS LABORATORY



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Outline

- Main experimental and modeling results from FY10 JRT, including LaBombard APS2010 Invited talk
- Follow on work: Goldston drift model (NF 2012)
- Follow on work: Eich evaluation of AUG and JET (PRL 2011)
- Follow on work: Makowksi APS 2011 invited talk on analysis of US database from FY2010 JRT, + upstream/downstream comparisons
- Follow on work: Gray FY10 JRT results from NSTX + Gan evaluation of effect of ELMs on heat flux profiles
- Follow on work: modeling with SOLT code (Lodestar)
- Follow on work in progress: various PSI2012 papers, including 2 invited talks (Maingi needs help for this!)

Summary of FY2010 JRT main experimental results

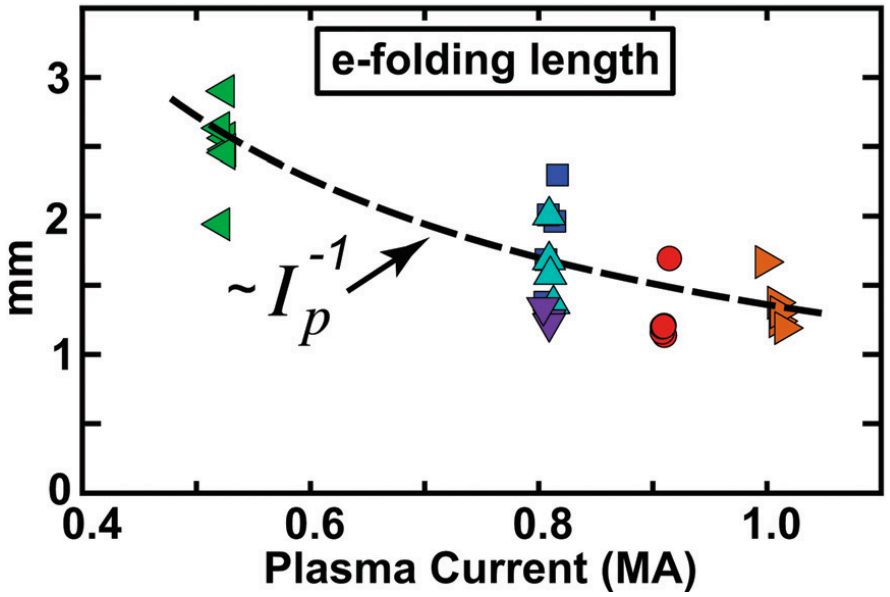
- Alcator C-Mod: EDA H-mode, L-mode, Ohmic
  - In FY2010 report: found a $1/I_p$ scaling of heat flux width near the separatrix in L-mode; H-mode scaling weaker because of far SOL
  - Just after JRT (APS 2010), reported $1/I_p$ in near SOL H-mode
  - Installed large number of new diagnostics
- DIII-D: ELMy H-mode with NBI or ECH
  - In FY2010 report: found a $1/I_p$ scaling of heat flux width near the separatrix in H-mode
  - Global stability limits (β_N ~ 5.5-6) encountered before edge (ELM) stability limits
- NSTX: ELMy H-mode and ELM-free H-mode
  - In FY2010 report: found a $1/I_p^{\alpha}$ scaling of heat flux width near the separatrix in H-mode, α ~ 1.6
  - No appreciable B_t or P_{heat} dependence

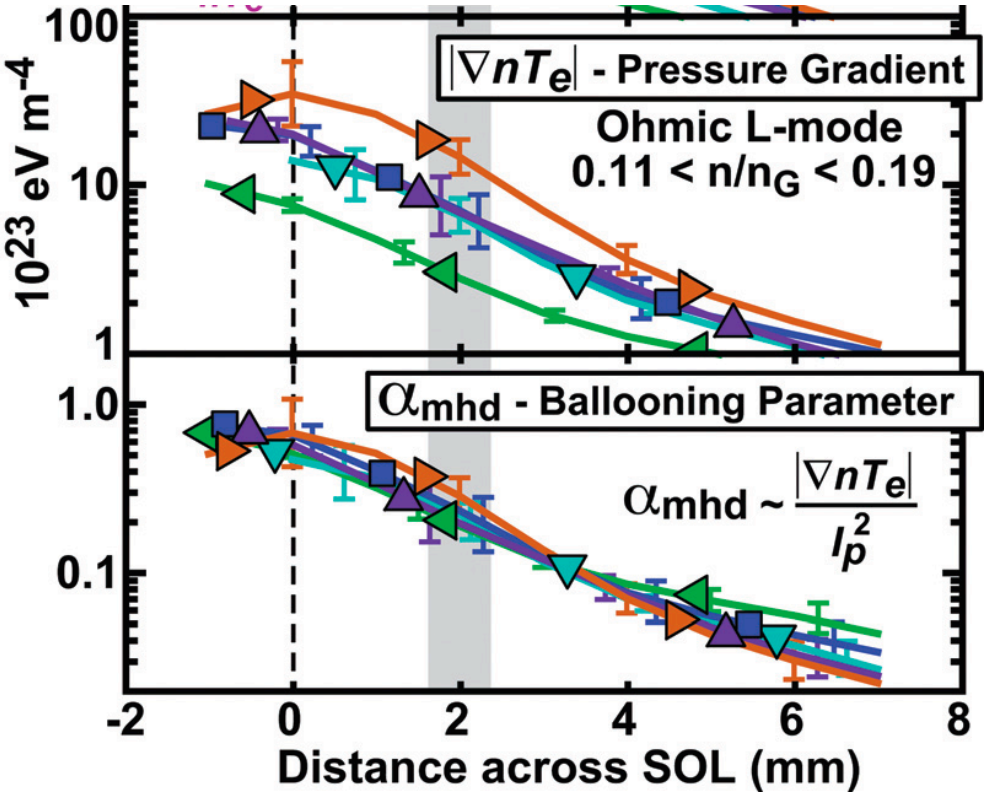
Summary of FY2010 JRT main modeling results

- Modeling of Alcator C-Mod and DIII-D with UEDGE
  - Modeled similarity expt. discharges
  - C-Mod profiles matched with transport coefficients that increased wih radius
  - Drift effects important in both devices
- Modeling of Alcator C-Mod and NSTX with SOLT
  - In C-Mod, computed SOL width was ~ 1mm, less than data; single mode found unstable that may correspond to QC mode
  - In NSTX, trend of heat flux width decreasing with I_p reproduced, but not as strong as data: importance of X-point spreading identified
  - Transition from diffusive to convective radial transport identified
- Modeling of DIII-D and NSTX with XGC0
  - $1/I_p$ scaling of heat flux width with neoclassical transport alone
  - Heat flux widths 50% smaller than measured ones

Follow-on work in FY2011 and FY2012 - LaBombard

- Alcator C-Mod
  - APS 2010 invited by B. LaBombard (PoP 18 (2011) 056104): documented main results from C-mod part of FY2010 report
  - Highlighted the unifying effect of $\alpha_{MHD} \sim |grad(nT_e)|/I_p^2$ ballooning parameter: α_{MHD} clamped ~ 0.5 near separatrix, decreasing into SOL





Follow-on work in FY2011 and FY2012 to date: Goldston

- Heuristic drift-based model derived (NF 52 2012 013009)

$$\lambda = 5671 \cdot P_{\mathrm{SOL}}^{1/8} \frac{(1+\kappa^2)^{5/8} a^{17/8} B^{1/4}}{I_{\mathrm{p}}^{9/8} R} \left(\frac{2\bar{A}}{(1+\bar{Z})} \right)^{7/16} \times \left(\frac{Z_{\mathrm{eff}}+4}{5} \right)^{1/8} \quad \text{all units SI}$$

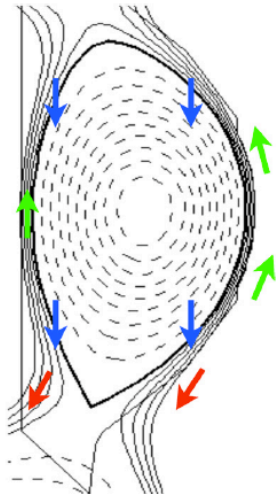


Table 1. Comparison with recent experimental data in deuteriu

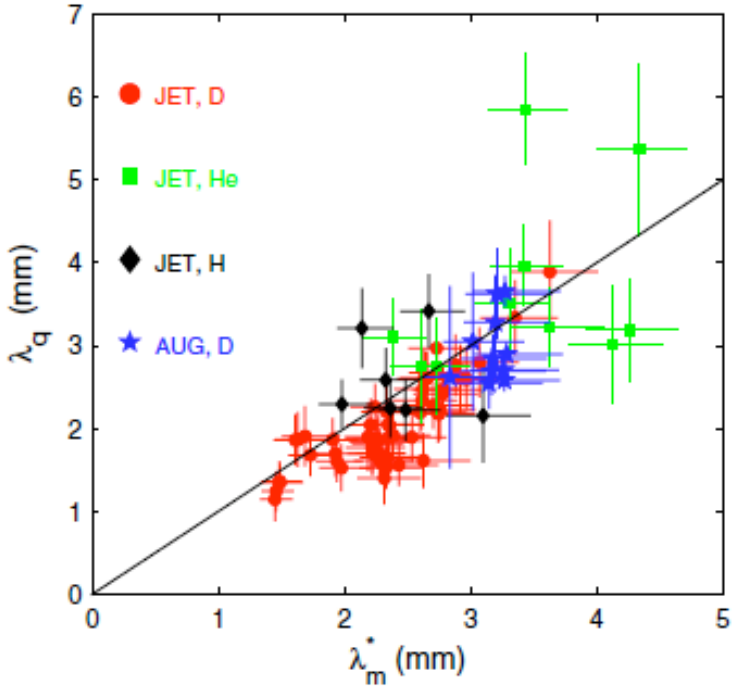
	JET low λ	JET high λ	NSTX, 1 MA	DIII-D, 1 MA	C-Mod, 1 MA
P_{SOL} (W)	1.05E + 07	1.05E + 07	5.50E + 06	4.30E + 06	2.00E + 06
B_{t} (T)	3.00E + 00	2.00E + 00	4.40E − 01	2.00E + 00	5.40E + 00
κ	1.68E + 00	1.68E + 00	2.25E + 00	1.75E + 00	1.65E + 00
a (m)	9.50E − 01	9.50E − 01	5.90E − 01	5.95E − 01	2.20E − 01
I_{p} (A)	3.00E + 06	1.20E + 06	1.00E + 06	1.00E + 06	1.00E + 06
R (m)	2.95E + 00	2.95E + 00	8.70E − 01	1.76E + 00	6.80E − 01
Z_{eff}	2.00E + 00	2.00E + 00	2.00E + 00	2.00E + 00	2.00E + 00
λ (exp't)	4.00E − 03	6.10E − 03	8.00E − 03	6.30E − 03	3.50E − 03
λ (model)	2.83E − 03	7.18E − 03	9.15E − 03	5.08E − 03	1.75E − 03

Follow-on work in FY2011 and FY2012 to date: Eich

- ASDEX-Upgrade and JET:
  - Eich (PRL 107 (2011) 215001) described new formula and $1/I_p$ scaling

$$q(\bar{s}) = \frac{q_0}{2}\exp\left[\left(\frac{S}{2\lambda_q f_x}\right)^2 - \frac{\bar{s}}{\lambda_q f_x}\right]\mathrm{erfc}\left(\frac{S}{2\lambda_q f_x} - \frac{\bar{s}}{S}\right) + q_{BG}$$

  - good agreement with Goldston drift-based model (NF 52 2012 013009)



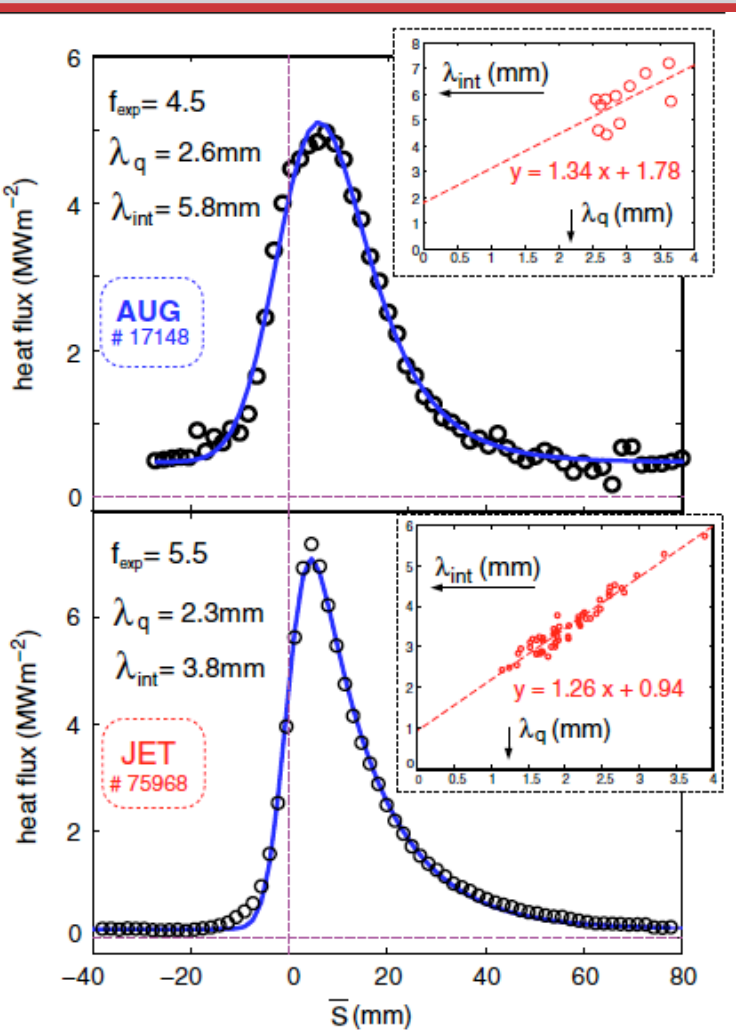
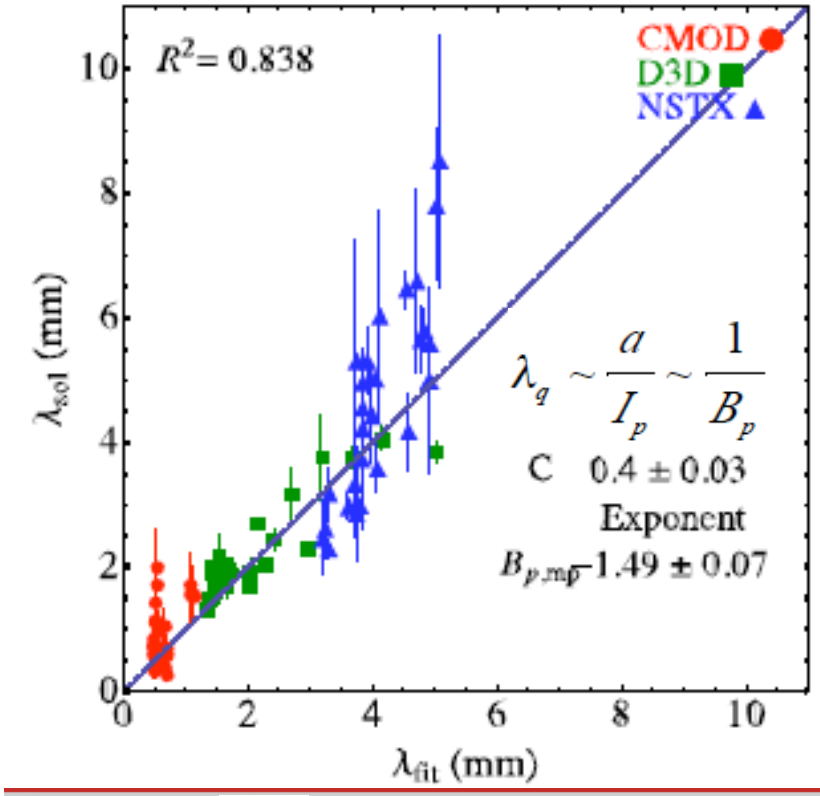
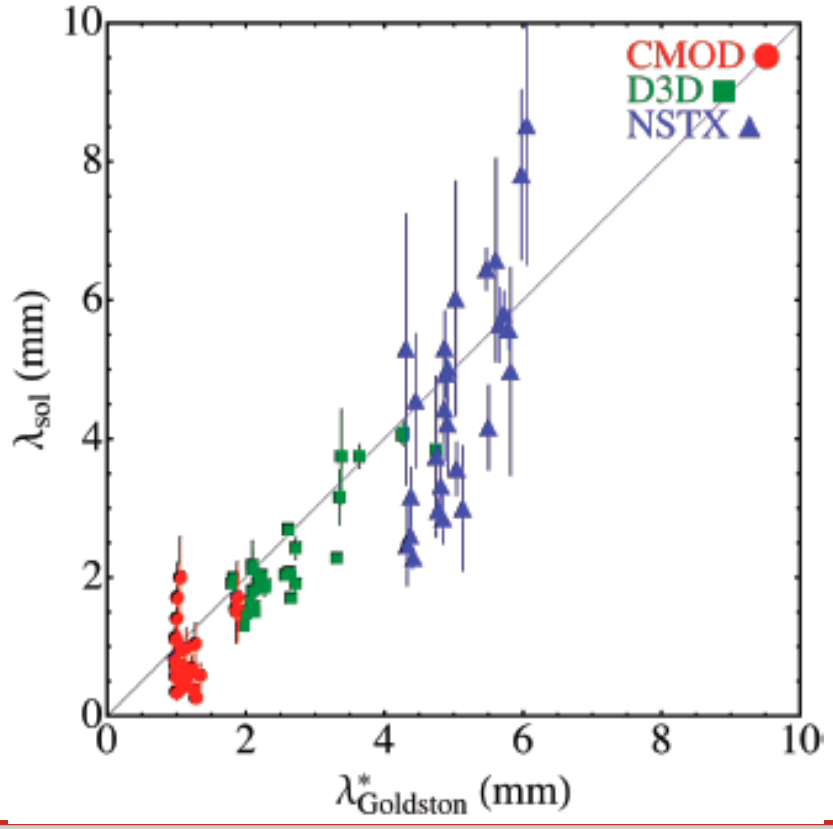


FIG. 2 (color online). Heat flux profiles measured on the outer divertor target and fits using Eq. (2). The inserts show the relation between λ_q and λ_{int} which are well expressed by a linear fit.

Follow-on work in FY2011 and FY2012 - Makowksi

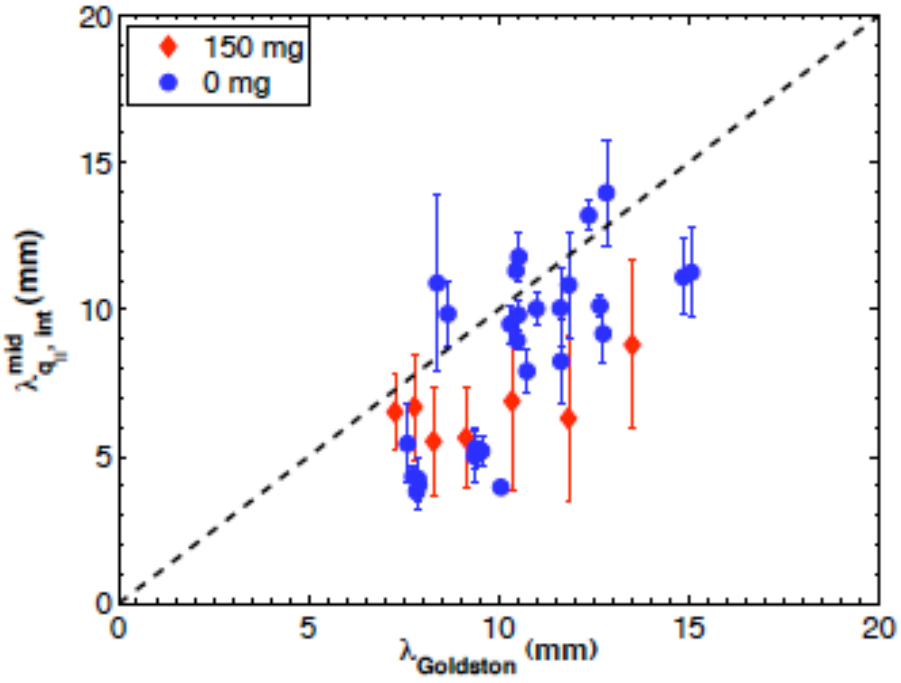
- DIII-D
  - APS 2011 invited by M. Makowski, that included data from all three devices with emphasis on DIII-D upstream measurements
  - Multi-machine database with all three devices showed integral definition of heat flux width (Loarte or Eich versions) ~ $I_p^{-0.9}$, with basically a B_{pol} dependence



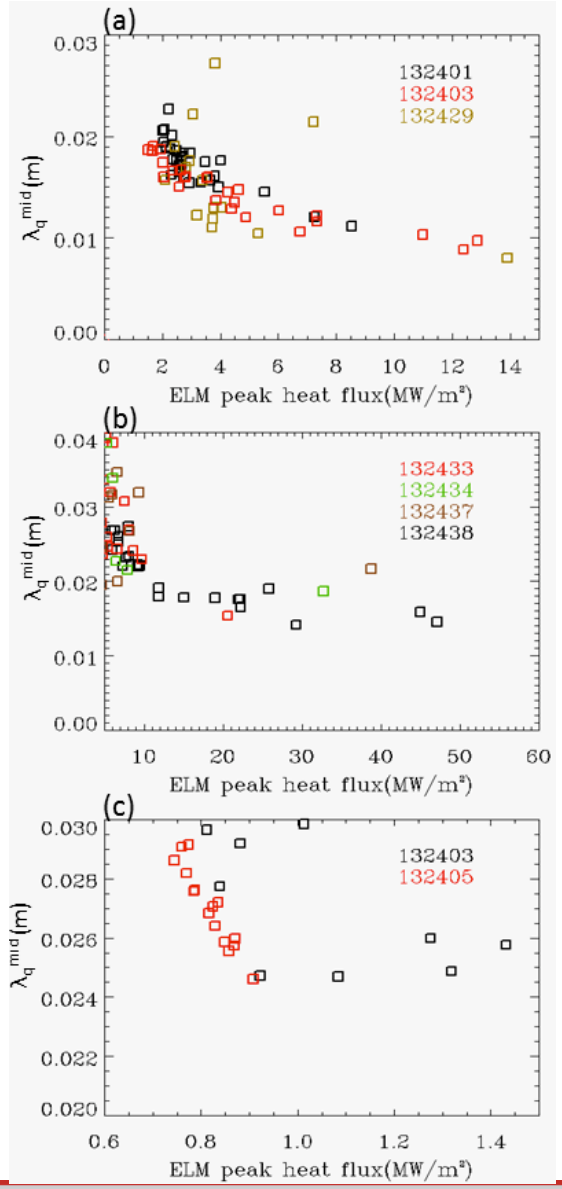


Follow-on work in FY2011 and FY2012 - Gray, Gan

- NSTX
  - Effect of lithium on heat flux widths and peaks, c/w Goldston (draft NF)



  - Analysis of profile evolution as a function of ELM type (draft PPCF)



Follow-on work in FY2011 and FY2012 - Lodestar

- Diffusive/convective transition boundary found in SOLT work being published (Myra, PPCF 2012)
- Studies of QC-mode discussed at TTF 2012 meeting
- Blobs, flows, and separatrix-crossing transport presented by Myra at TTF 2012 meeting

Follow-on work in FY2011 and FY2012 - PSI2012

- Eich (invited): combining European + US databases
- Maingi (invited): results from FY10 JRT, FY11 JRT, and possible relation between pedestal ballooning physics and SOL heat flux footprints
  - Need help from ECC to evaluate role of ballooning mode physics on profiles just inside and outside separatrix!
- Alcator C-Mod
  - Terry: heat flux footprints in I-mode
  - Whyte: ballooning physics and ITER SOL widths
  - Brunner: 'death ray' overpressure explained as Langmuir probe measurement phenomenon
- DIII-D
  - Makowski: further analysis + SOL KBM model
- NSTX
  - Gray: continuing analysis on NSTX data w/lithium