NSTX Heat Flux Scaling Experiments

R. Maingi, H. Kugel, C.Lasnier, D. Mastrovito, T. Tan, T. Gray, L. Roquemore, V. Soukhanovskii, S. Paul, and the NSTX Team

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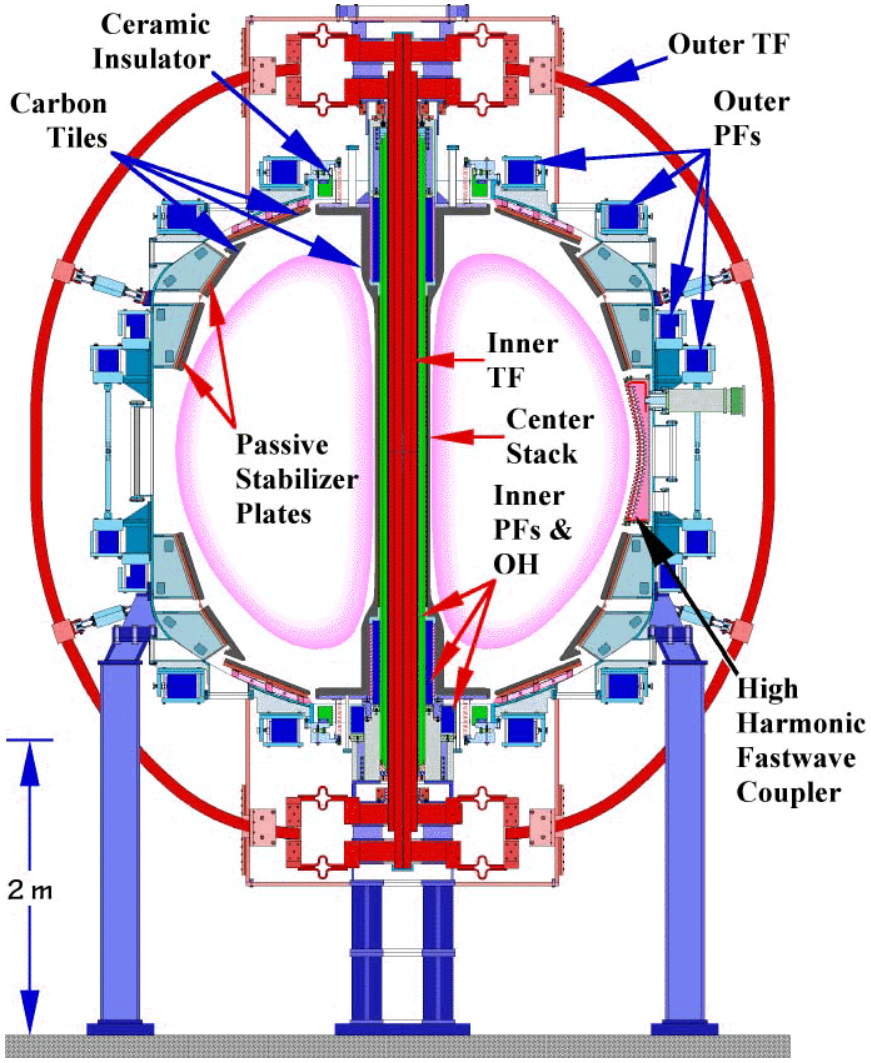
Workshop Agenda

NSTX Explores Low Aspect Ratio (A=R/a) physics regime



Parameters	Design	Achieved
Major Radius	0.85m	
Minor Radius	0.67m	
Plasma Current	1MA	1.5MA
Toroidal Field	0.6T	0.6T
Heating and Current Drive		
NBI (100keV)	5MW	7 MW
RF (30MHz)	6MW	6 MW

Wall Conditioning:

350 deg. bakeout of graphite tiles

Regular boronization (~3 weeks)

Helium Glow between discharges

Center stack gas injection

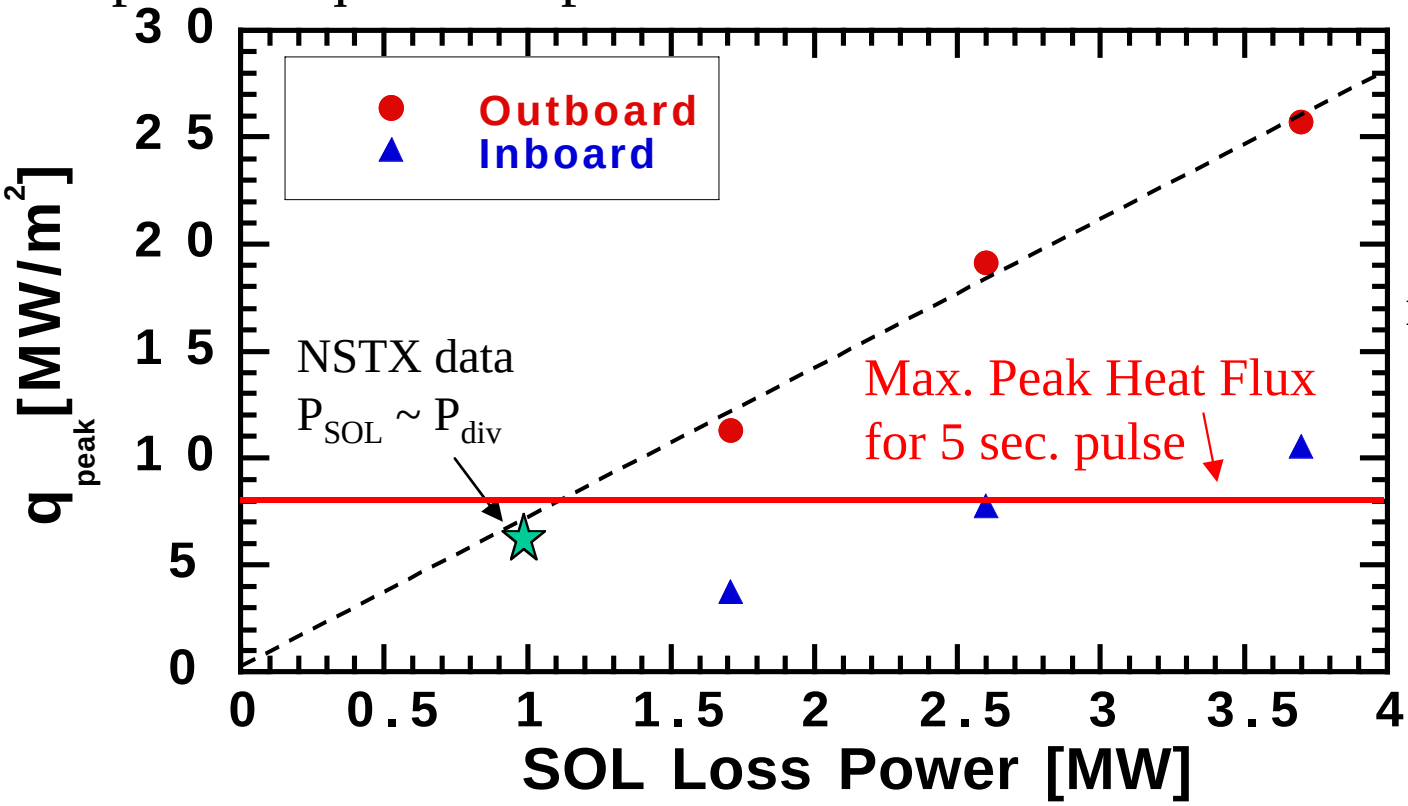
ST's Can Have High Heat Flux Because of High P_{heat}/R

- **NSTX Power Handling Goal**
  - NSTX: $P_{NBI} \sim 7$ MW, $P_{RF} \sim 9$ MW, $P_{heat}/R \sim 18.8$
- **Highest q_{peak} in NSTX ~ 10 MW/m^2**
  - $\Delta T_{div} \sim 300\ ^0$C in LSN
  - extrapolates to ~ 3 sec. pulse length limit ($\Delta T_{div} \sim 1200\ ^0$C)

    Acceptable for projected current diffusion times < 0.5 sec
- **Goal: assess power balance and survey heat flux in many scenarios (vs. shape, input parameters, etc.)**
- **Staged plan**
  - quasi-steady power balance in near term; transient events in future
  - evaluate PFCs heating; upgrade if needed
  - develop innovative liquid lithium solution to heat flux problem

Prior to NSTX First Plasma, 2-D Model Predicted Peak Heat Fluxes Could Impose Pulse Length Limitation

- NSTX data from 2001 lay near the scaling if we assume the loss power equals the power observed at the divertor



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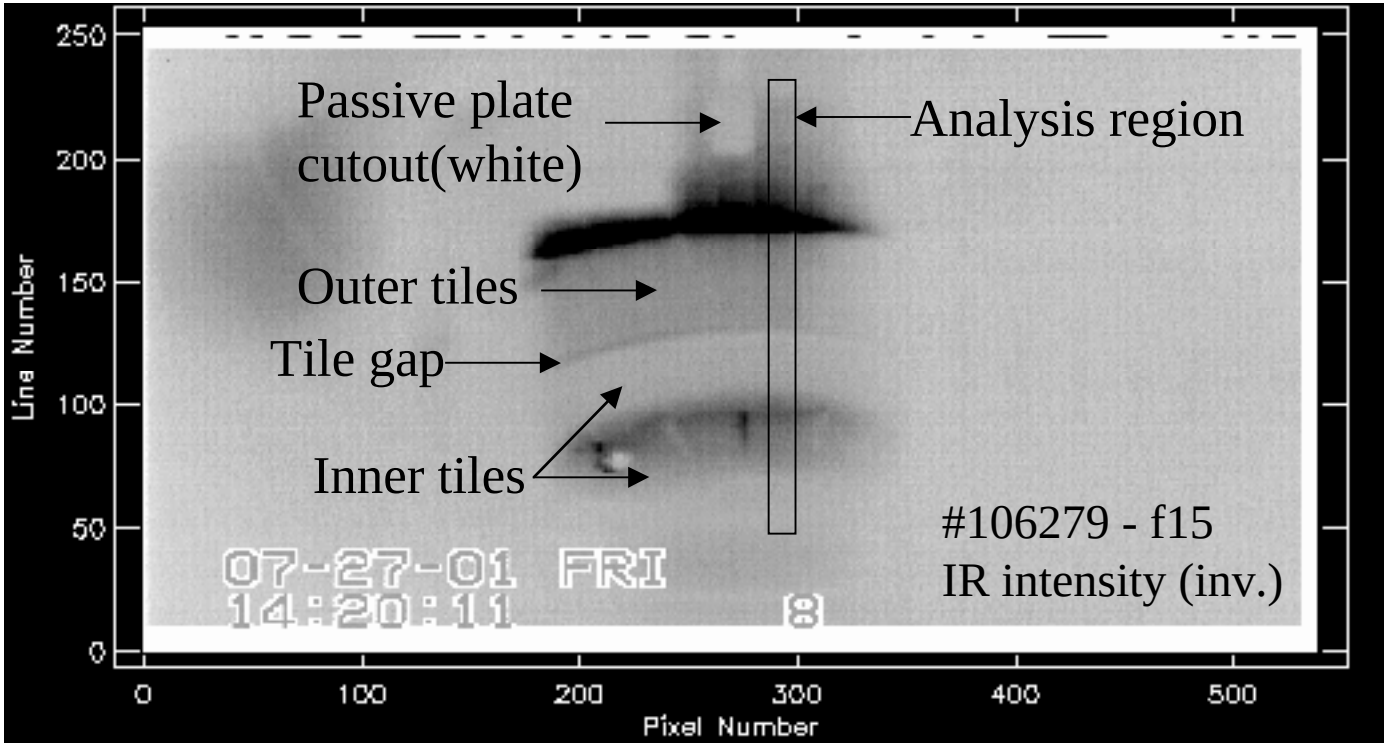
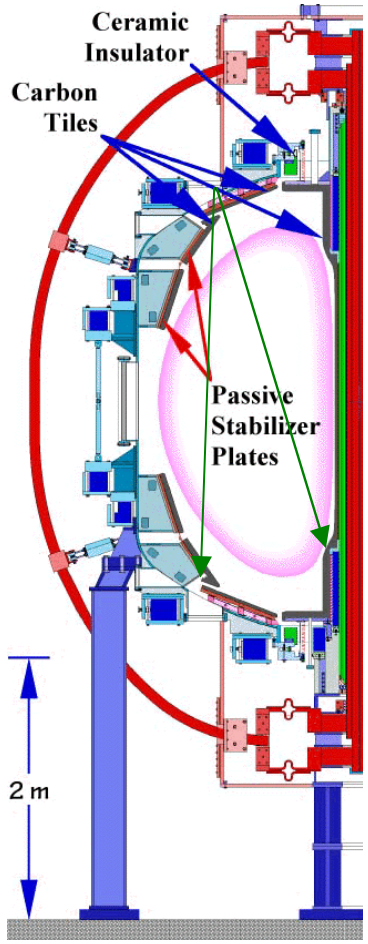
(b2.5 code, 4 m^2/sec cross-field transport, deuterium radiation)

IR camera view allows radial profile measurements

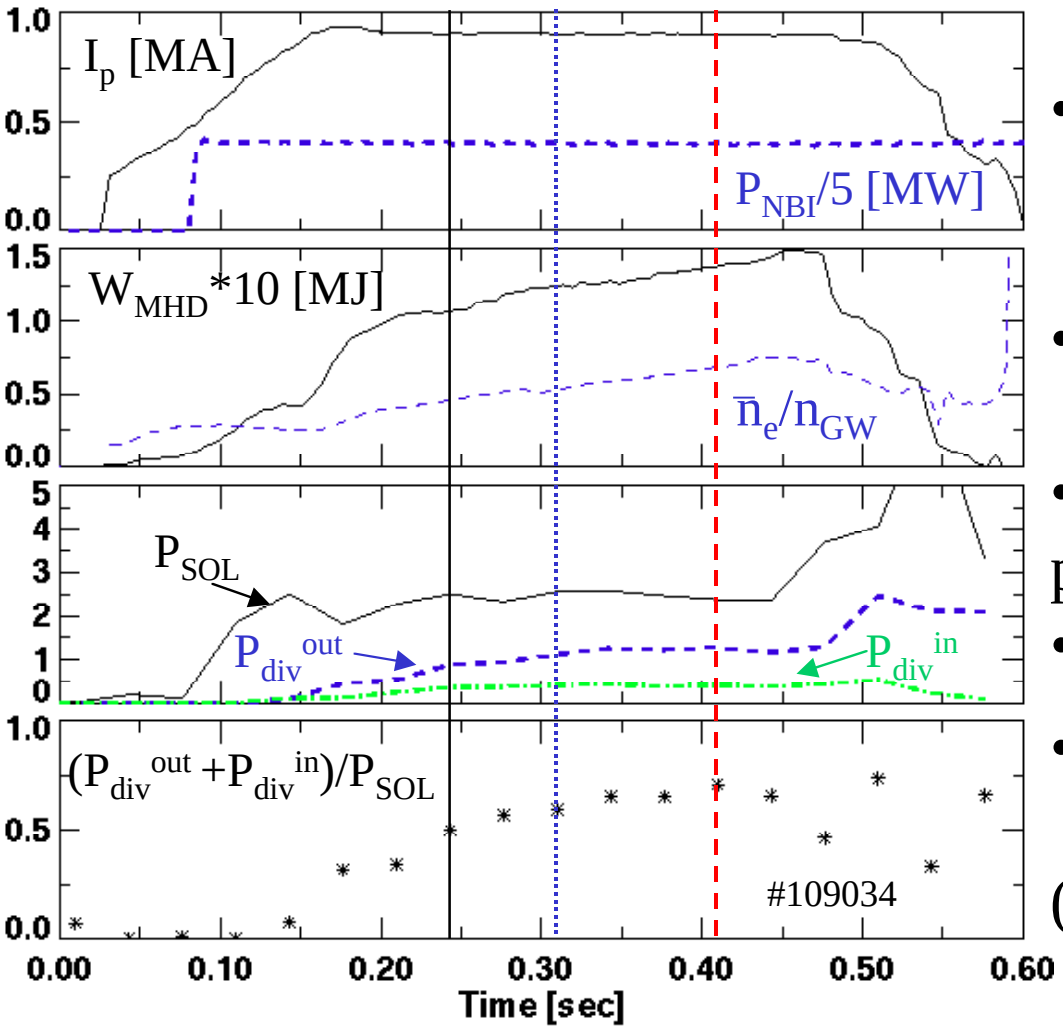




IR camera Used to Measure Lower Divertor Fluxes. 1-D Conduction Model Used to Compute Heat Flux.

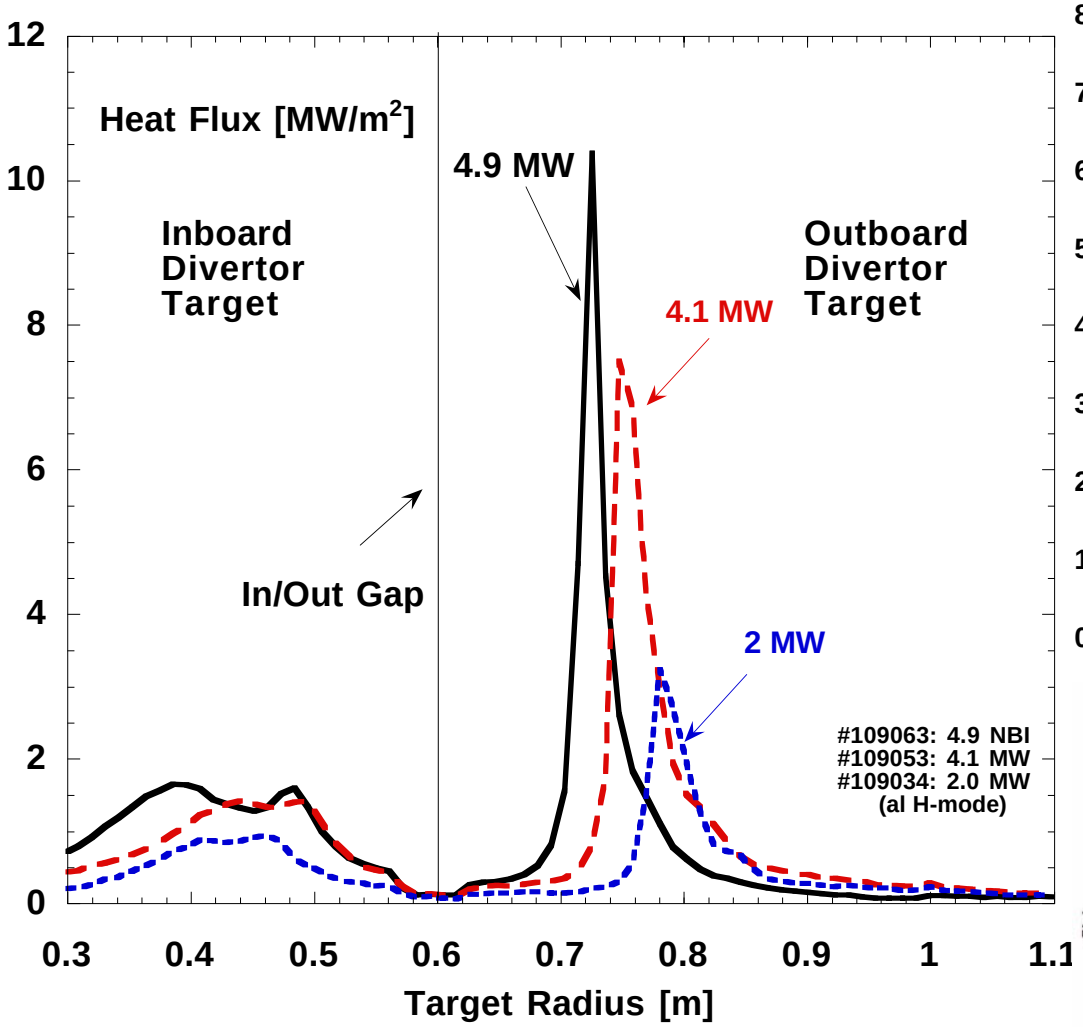
- Indigo ALPHA camera
  - 160 x 128 microbolometer array
  - 7-13 μm range,
  - 30 Hz, 20ms thermal e-folding time,
  - spatial resolution ~ 1 cm with present optics
  - 8-bit video output, frame-grabbed on MAC
  - spatially calibrated and outboard side intensity calibrated
- 1-D conduction model considers heat transport into tile bulk
  - temperature dependent ATJ graphite conductivity
  - neglects radial diffusion - ok for short pulses

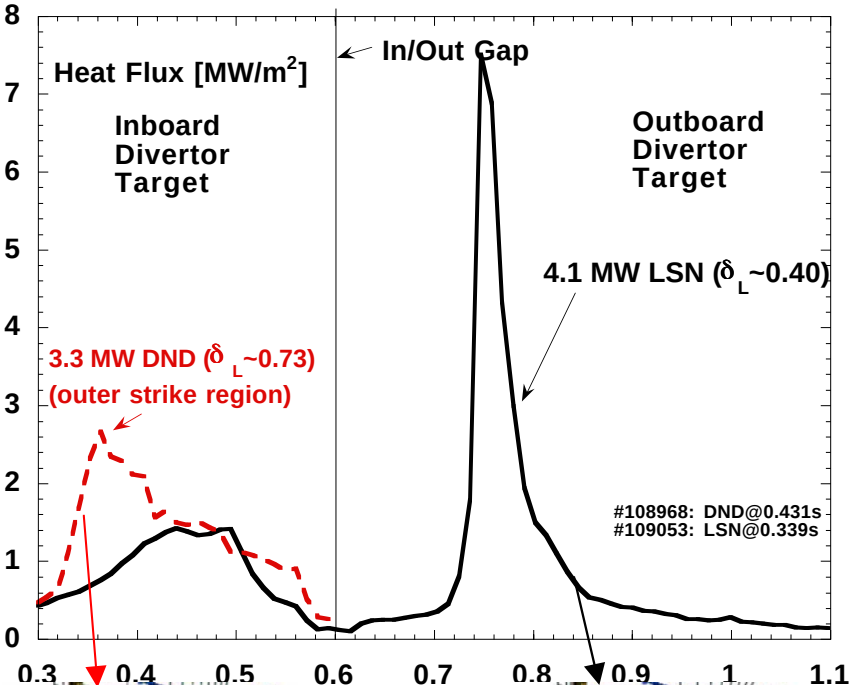
High Fraction of SOL Power Observed in Divertor During Quiescent H-modes

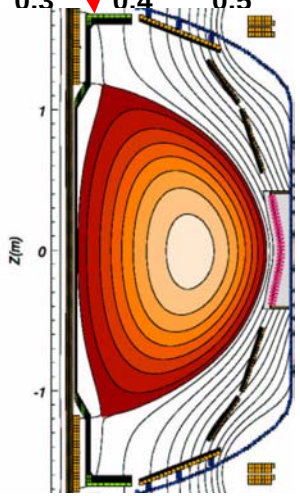


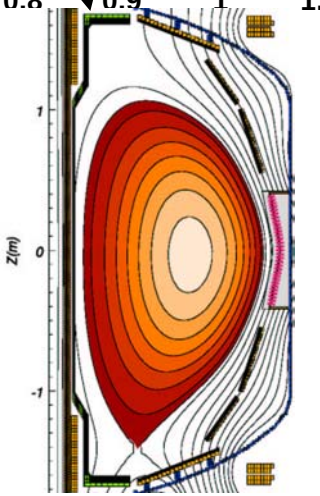
- Constant NBI power
- Rising n_e and stored energy
- Both inner and outer side profiles come to equilibrium
- P_{out} ~ 3-4x P_{in}
- 70% of max. SOL power appears in divertor ($P_{SOL}^{max}=P_{OH}+P_{NBI}$-dW/dt)

Peak Heat Flux Increased With NBI Power in LSN and Was Reduced in DND Relative to LSN









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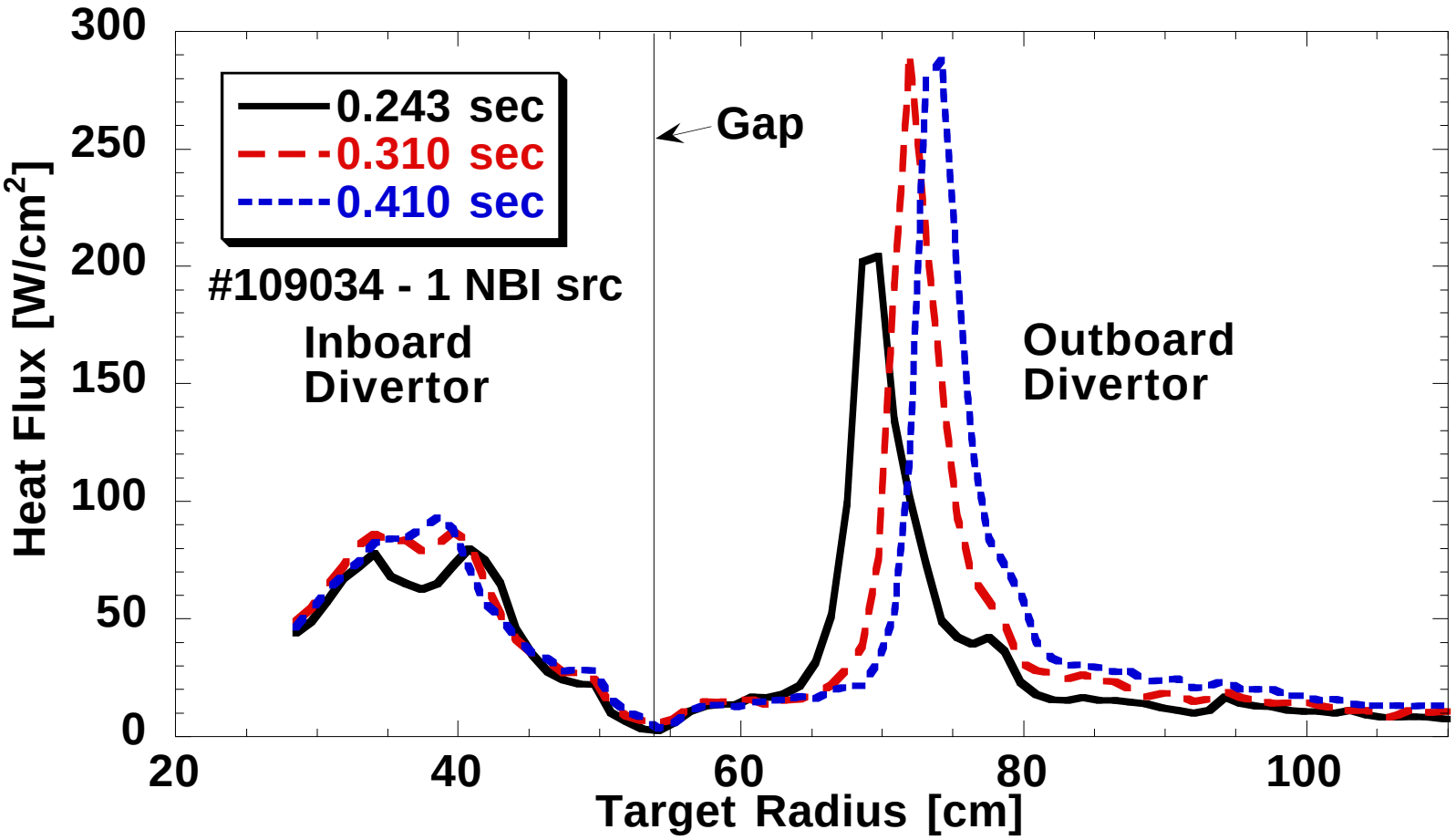
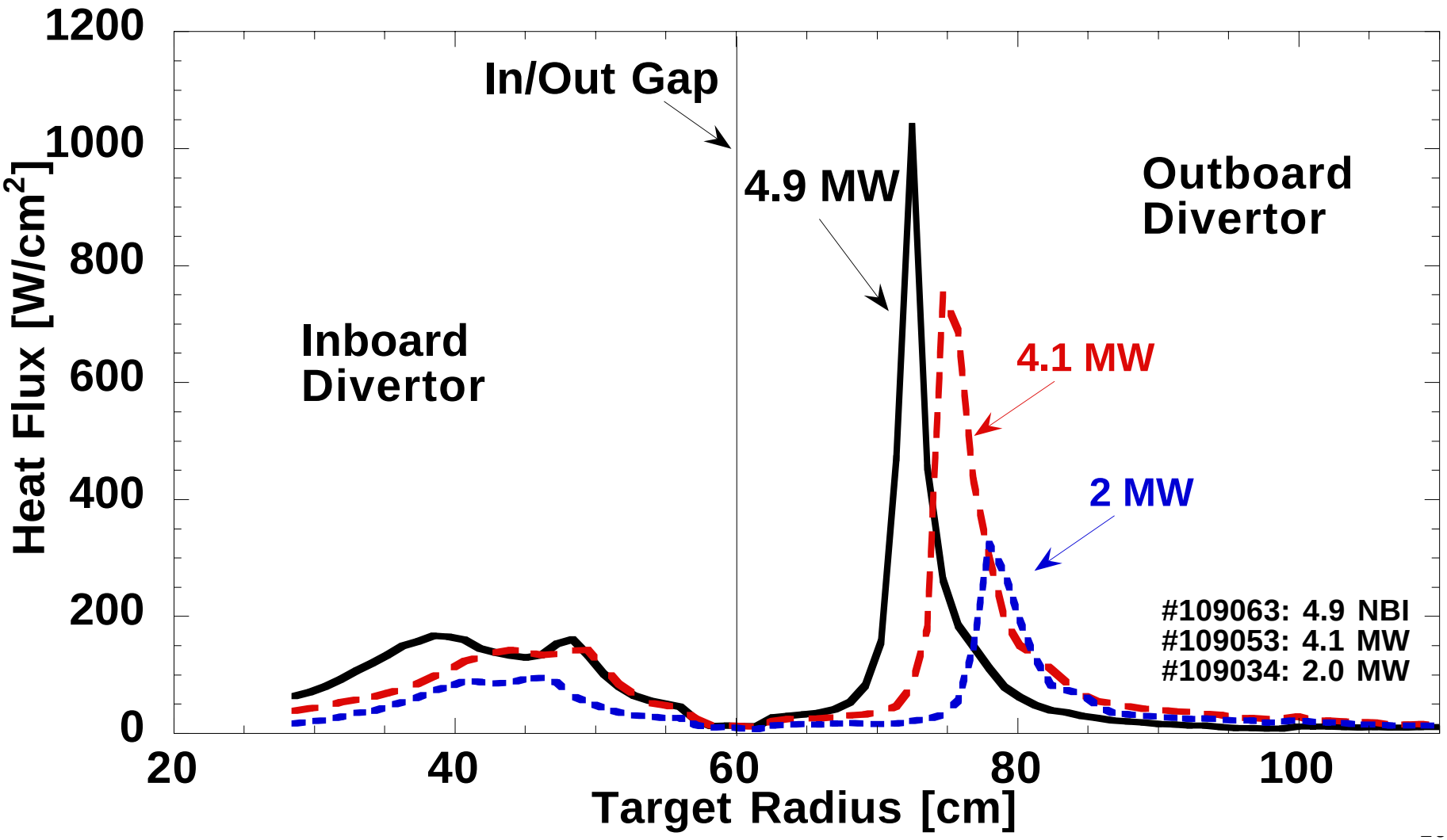
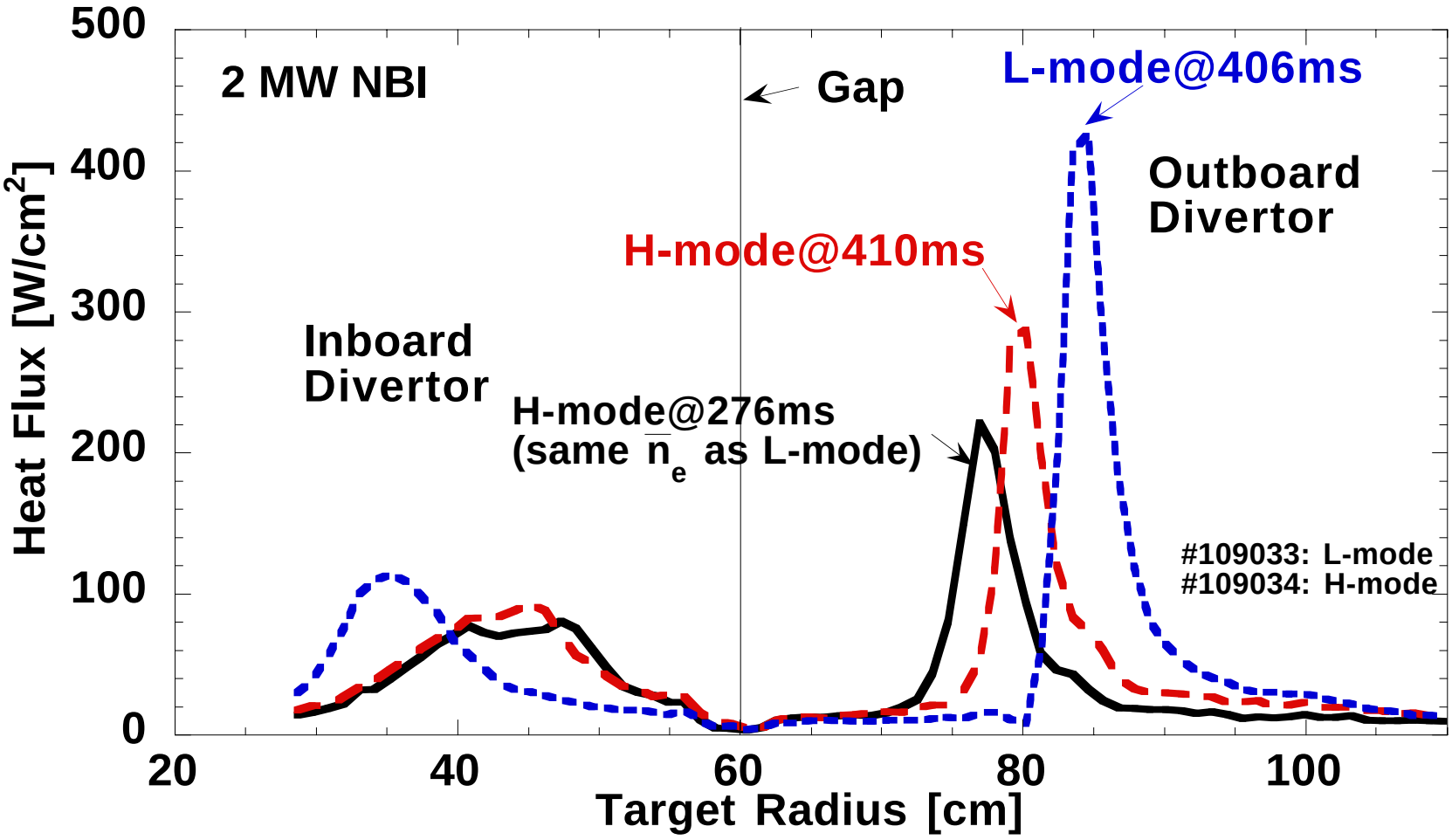
Heat Flux Profile with 1 NB Source Reaches Equilibrium



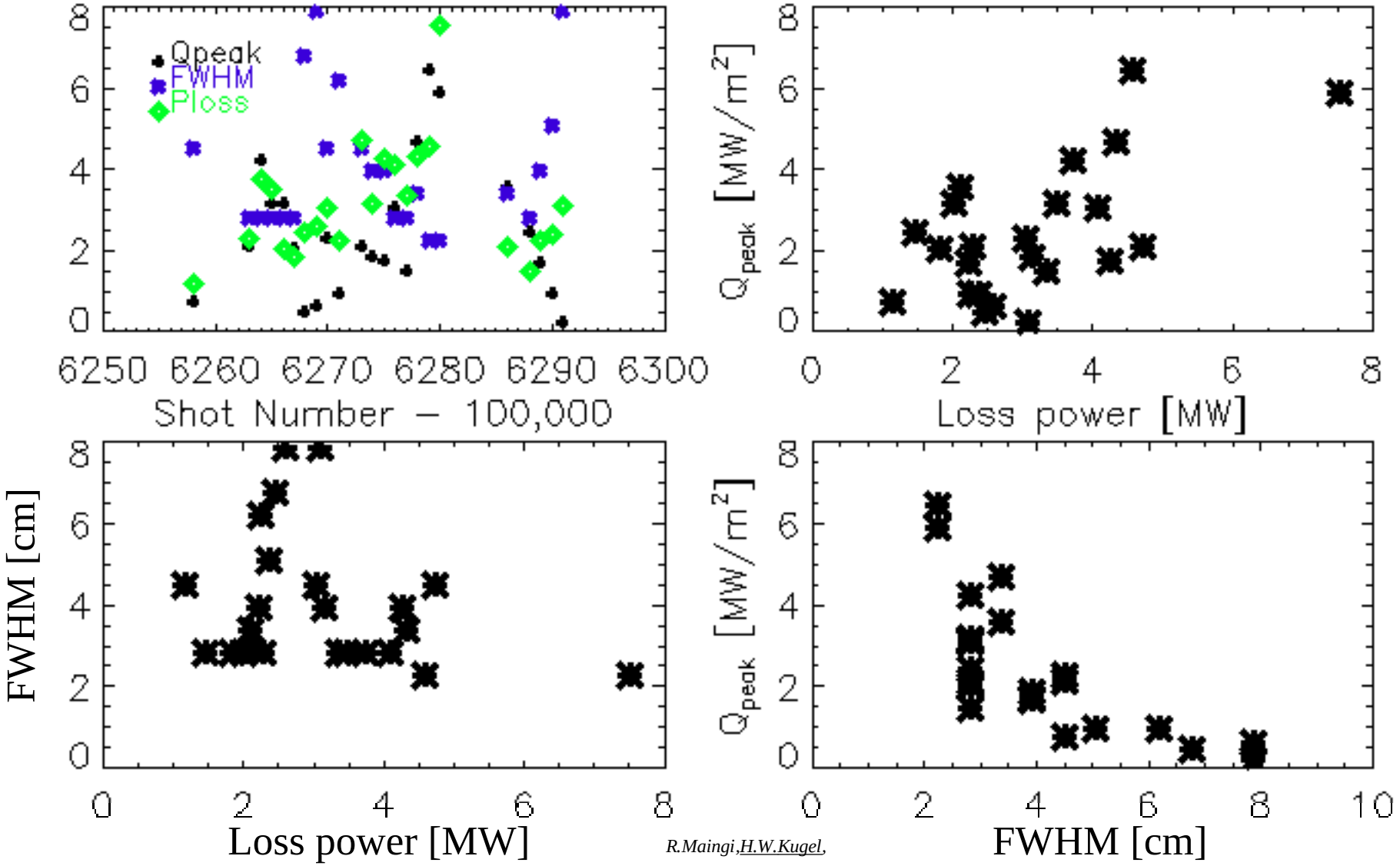
Peak Heat Flux Increases Non-Linearly with Heating Power



Higher Outer Divertor Heat Flux in L-mode vs. H-mode



Peak Heat Flux Increases With Heating Power
Profile Width Decreases With Increasing Power



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Power handling and mitigation plan

- Experimental plan
  - Power balance studies (FY02+)
    - divertor heat flux vs core and divertor radiation
    - parallel vs perpendicular transport
  - Detailed comparison between single-nulls and double-nulls (FY04+)
  - Heat flux reduction studies (FY04+) [PFC upgrade end FY05]
  - Impact of fast events, e.g. ELMs, IREs, and disruptions (FY05+)
  - Liquid lithium solution to heat flux issues (FY06 -, FY09)

- New Diagnostics
  - Cross-calibrate core bolometry with platinum-foils (FY04)
  - Add and optimize divertor bolometer channels (FY04-05)
  - Add one slow and one fast infrared cameras (FY04, FY05)
  - Lithium surface module diagnostics (FY08)

Summary and Conclusions

- Outer peak heat flux 3-4x higher than inner, but inner profile has much larger width (partially detached?)
- Peak heat flux increased non-linearly with NBI power in H-mode
- Peak heat flux higher in L-mode than H-mode at same NBI
  - ✓ L has higher P_{oh}, lower dW/dt
- Surprisingly good power accountability: 70% max. SOL power observed in divertor
- Profiles require ~ 100ms for equilibration
- Detailed simulation with UEDGE is starting

Workshop Agenda