NSTX-U

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The role of lithium conditioning in achieving high performance, long pulse H-mode discharges in the NSTX and EAST devices

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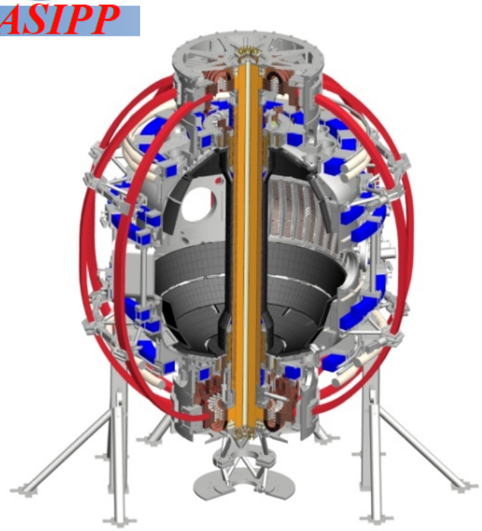
ASIPP

PPPL
PRINCETON PLASMA PHYSICS LABORATORY



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Power and particle exhaust a key challenge for future devices

- Lithium is being studied at ASIPP and PPPL both as a mechanism to coat high-Z substrates, and as liquid PFCs to supplement or replace other PFC materials
  - Lithium enables reduced recycling from PFCs

- NSTX used lithium wall conditioning between discharges
- EAST uses morning evaporation and Li during discharges

- In both EAST and NSTX, use of Li eliminates ELMs, albeit *via different physics mechanisms*

- Use of Li improved long pulse performance in both devices

Summary: Li improved long pulse discharges in both NSTX and EAST

- ELM elimination reduced volt-second consumption and contributed to long pulses
- Recycling reduction and profiles changes central to ELM elimination in NSTX
- De-stabilization of Edge Coherent Mode central to ELM elimination in EAST
  - Recycling reduced as in NSTX, but not clear that's important in ELM elimination and long pulses
  - Some aspects of results qualitatively similar to DIII-D with real time Li injection (see Jackson, PD paper, this conference)

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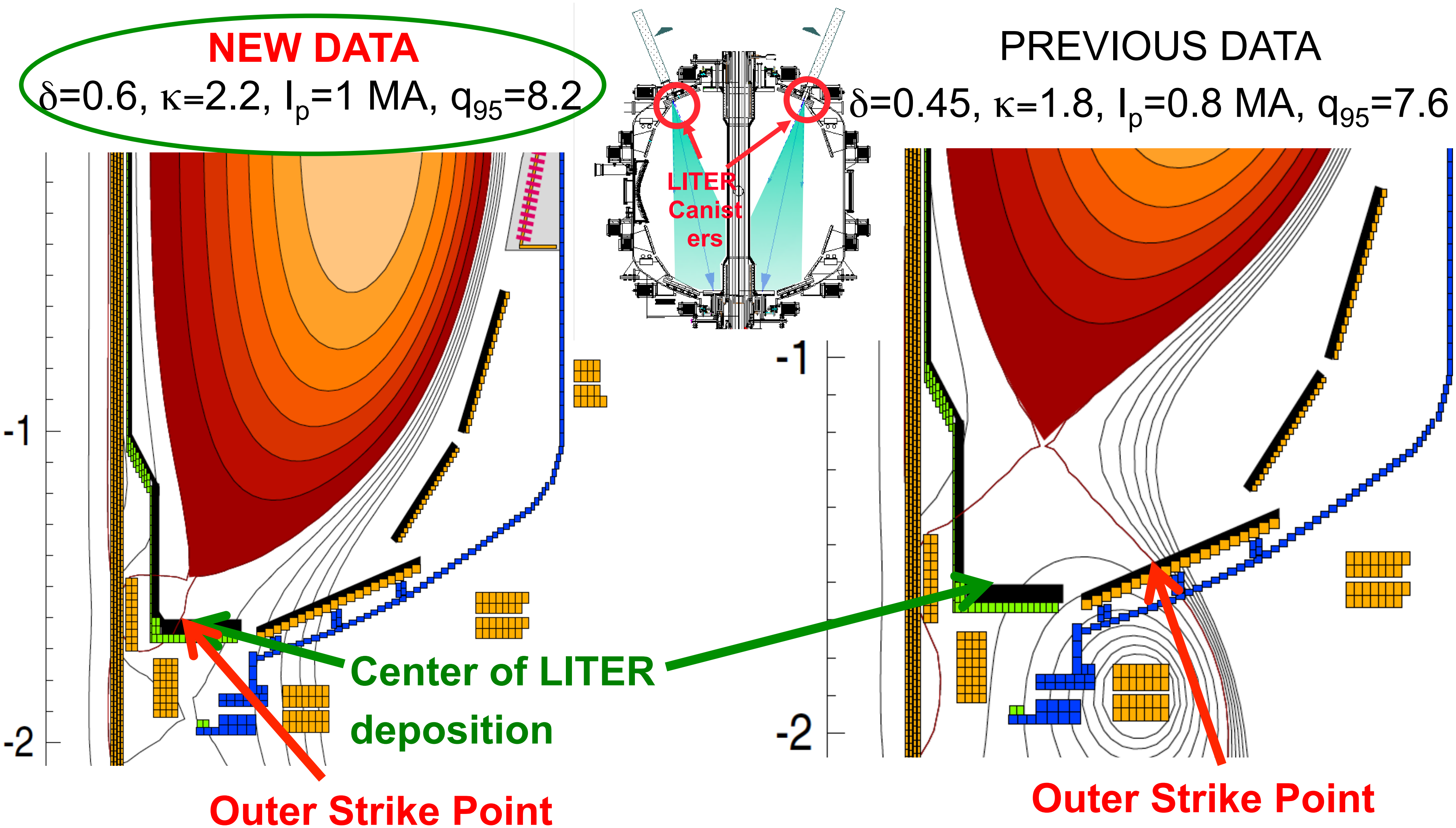
Plasma characteristics and stability improved with increasing lithium evaporation in strongly shaped NSTX discharges

- Lithium evaporated before each discharge
  - Amount scanned, as in weakly shaped discharge studies
  - (No liquid lithium divertor results in this talk)

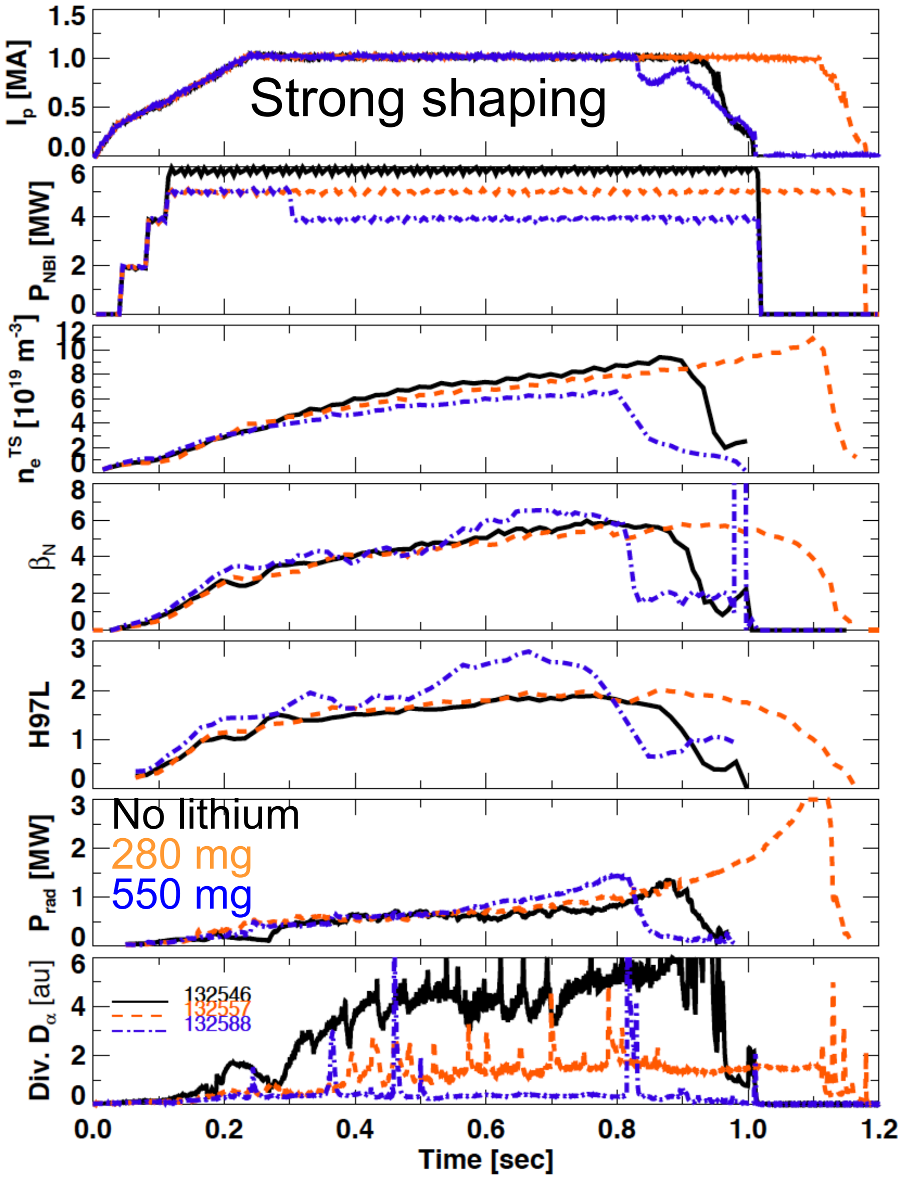
- Global characteristics changed
  - Recycling: D_α declined in all measured views
  - Energy confinement (τ_E, H-factor) improved
  - When discharges were ELM-free, radiated power increased with time *(several corrective techniques were developed - not discussed here)*

- Edge n_e, T_e, pressure profiles changed
  - Reduction in edge n_e gradient changed edge P', improving stability in weakly shaped discharges
  - Likely to be same physics in strongly shaped ones

New dataset from highly shaped plasmas in NSTX has center of Li deposition close to Outer Strike Point

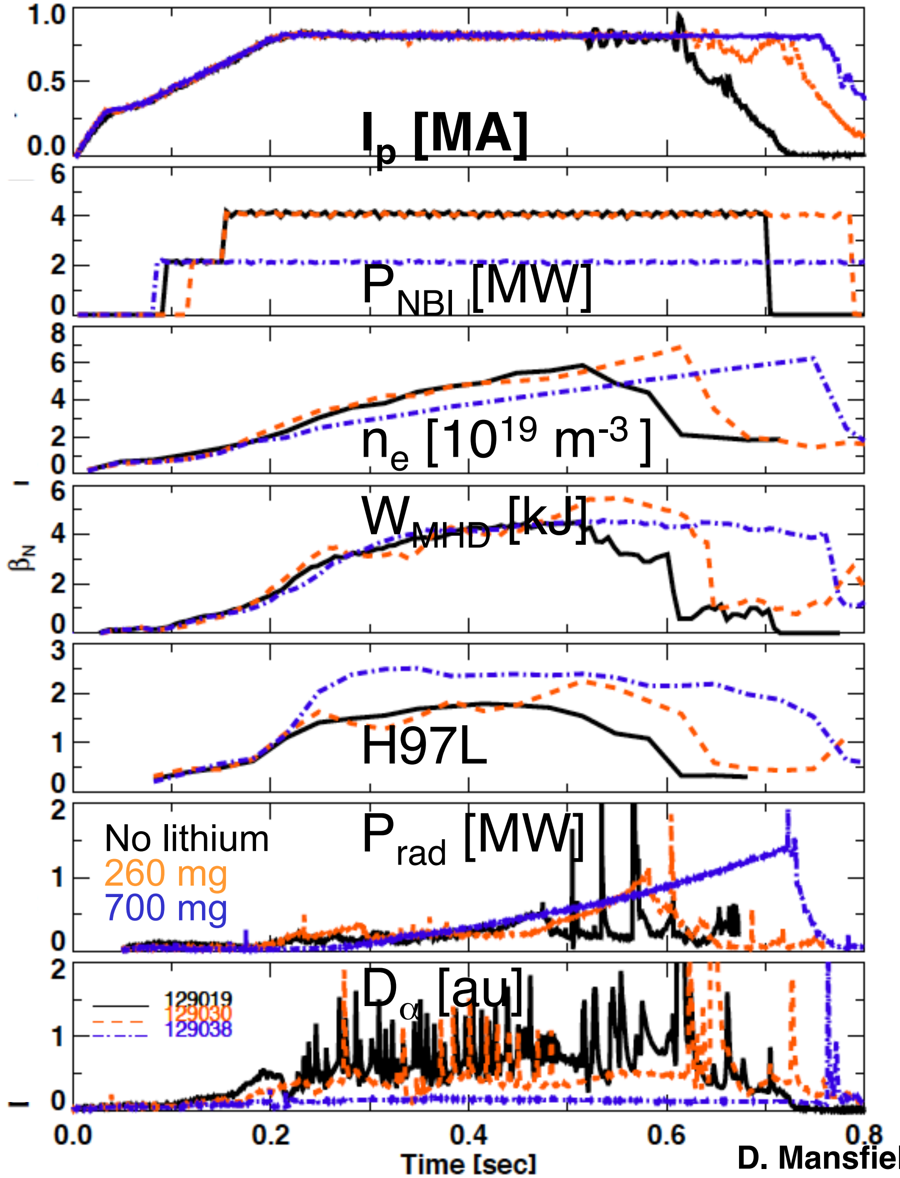


Performance of strongly shaped discharges improved with increasing Li, similar to weakly shaped ones in NSTX



- I_p duration not quite optimized with higher lithium
- Reduced P_{NBI}
- Reduced dN/dt
- Comparable stored energy
- Higher confinement
- Increasing P_{rad}
- Reduced recycling, long ELM-free phases

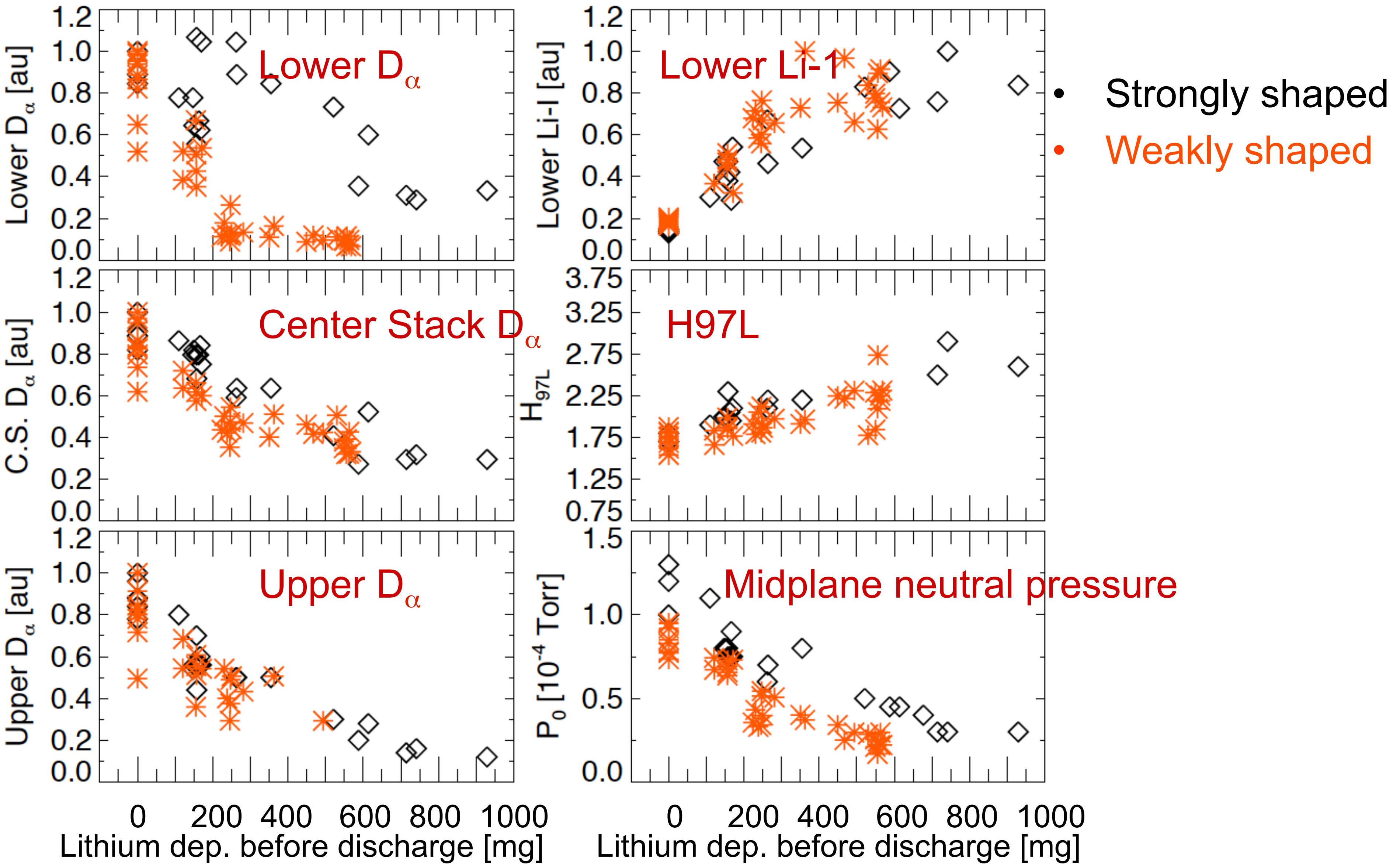
ELM-free H-mode induced by Li wall conditioning in <u>weakly shaped discharges</u> in NSTX



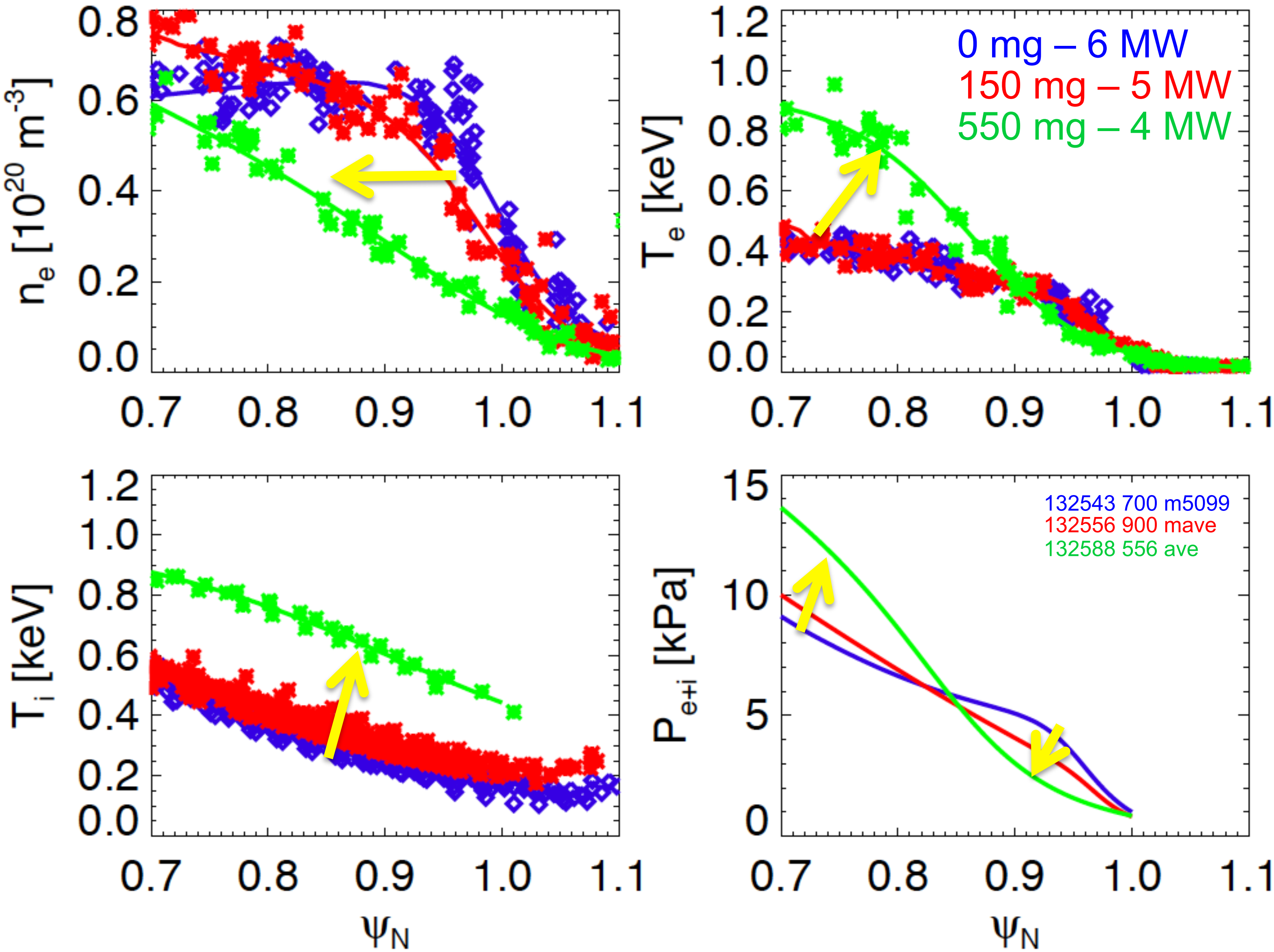
- Pre-Li, With-Li (260 mg), with-Li (700 mg)
- Lower NBI to avoid β limit
- Lower n_e
- Similar stored energy
- H-factor 40%↑
- Higher P_{rad} /P_{heat}
- Reduced divertor recycling, ELM-free in higher dose

D. Mansfield, JNM 2009; R. Maingi, PRL 2009

D_α and neutral pressure decreased, and H97L increased with increasing Li evaporation in both NSTX datasets



Edge profiles change markedly with increasing Li in strongly shaped discharges (as in weakly shaped ones) in NSTX



Flow chart of how Li causes ELM elimination similar for highly and weakly shaped discharges in NSTX

ψ_N from 0.95-1 (recycling region)

Li coatings reduce recycling and core fueling (SOLPS)

→

n_e and ∇n_e **reduced**
∇T_e fixed

χ_e increased
ETG? (GS2)

→

n_e, P_e gradient reduced

P_i gradient unchanged

→

J_{bs}, $J_{||}$ reduced - stabilizing (ELITE)

ψ_N from 0.8-0.94

D_{eff} reduced, most in ELM-free (SOLPS)

→

n_e and ∇n_e
T_e and ∇T_e
increased

χ_e reduced strongly – μT stable? (GS2)

→

Edge P_e follows n_e and T_e; peak P' shifts farther from separatrix

→

J_{bs}, $J_{||}$ increased but far from separatrix; improves stability to kink/peeling modes (ELITE)

Real-time conditioning with Li injector eliminated ELMs in 24 sec long H-mode discharges in EAST

- Large quantities (20-40g) of Li typically evaporated in morning before start of experiments
  - As Li wears off, real-time conditioning with Li dropper used
- Global characteristics changed with real-time Li conditioning
  - Recycling: D_{α} declined by 10-30% in all measured views
  - ELMs eliminated, but with steady P_{rad}, density
  - Edge Coherent Mode appeared
  - Energy confinement (τ_E, H-factor) steady at H98=0.75-0.8
- Hypothesis: Edge Coherent Mode provides particle transport that changes the edge gradients and eliminates ELMs
  - New profile measurements and stability analysis forthcoming

Li evaporators used for morning conditioning in EAST; Li injector used for real-time conditioning

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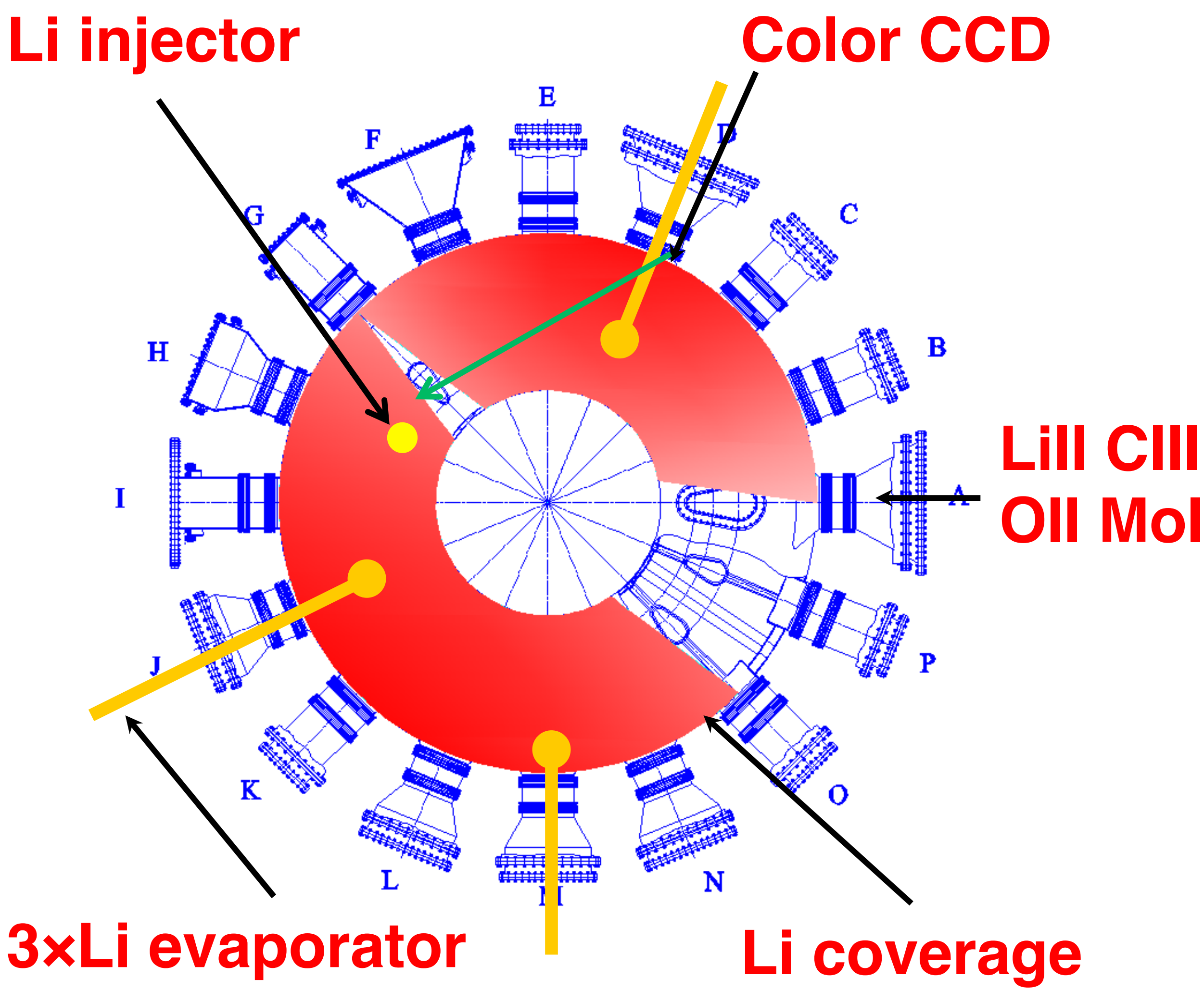
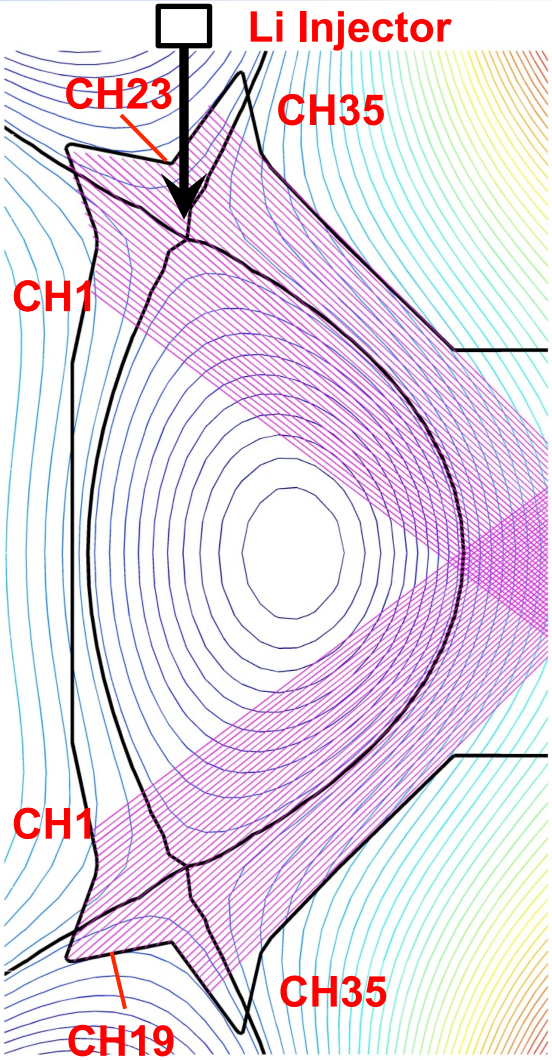
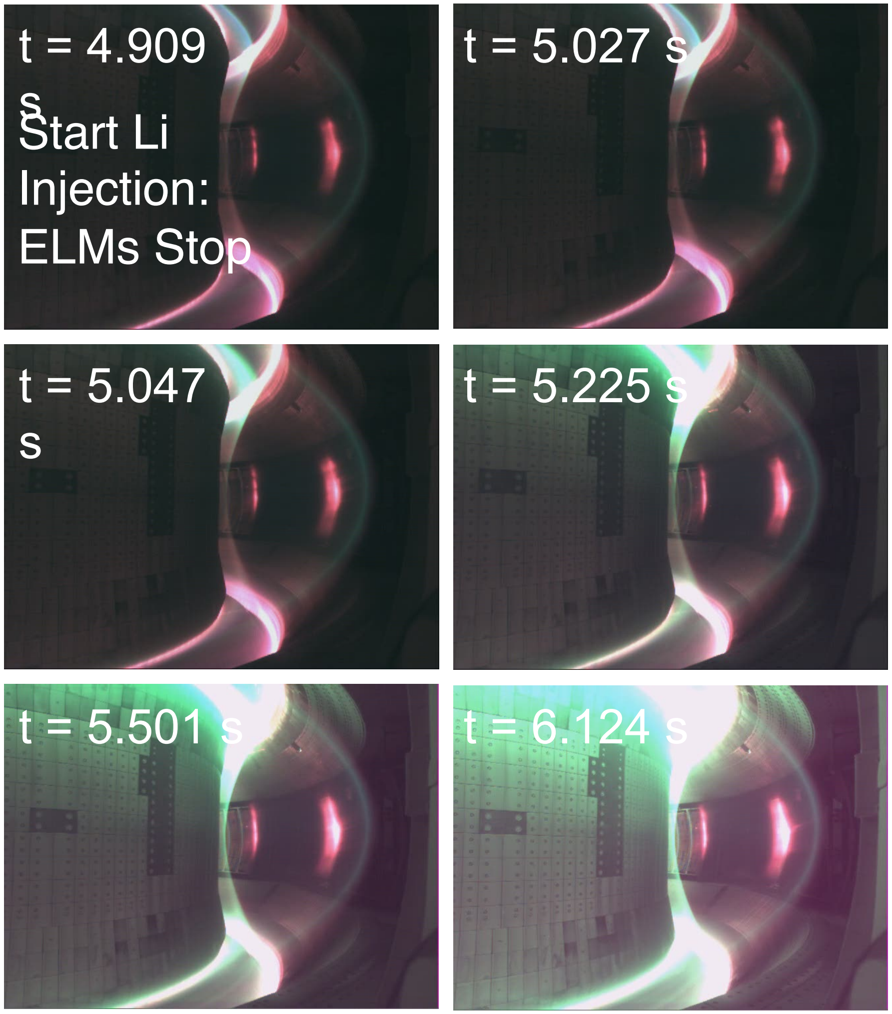
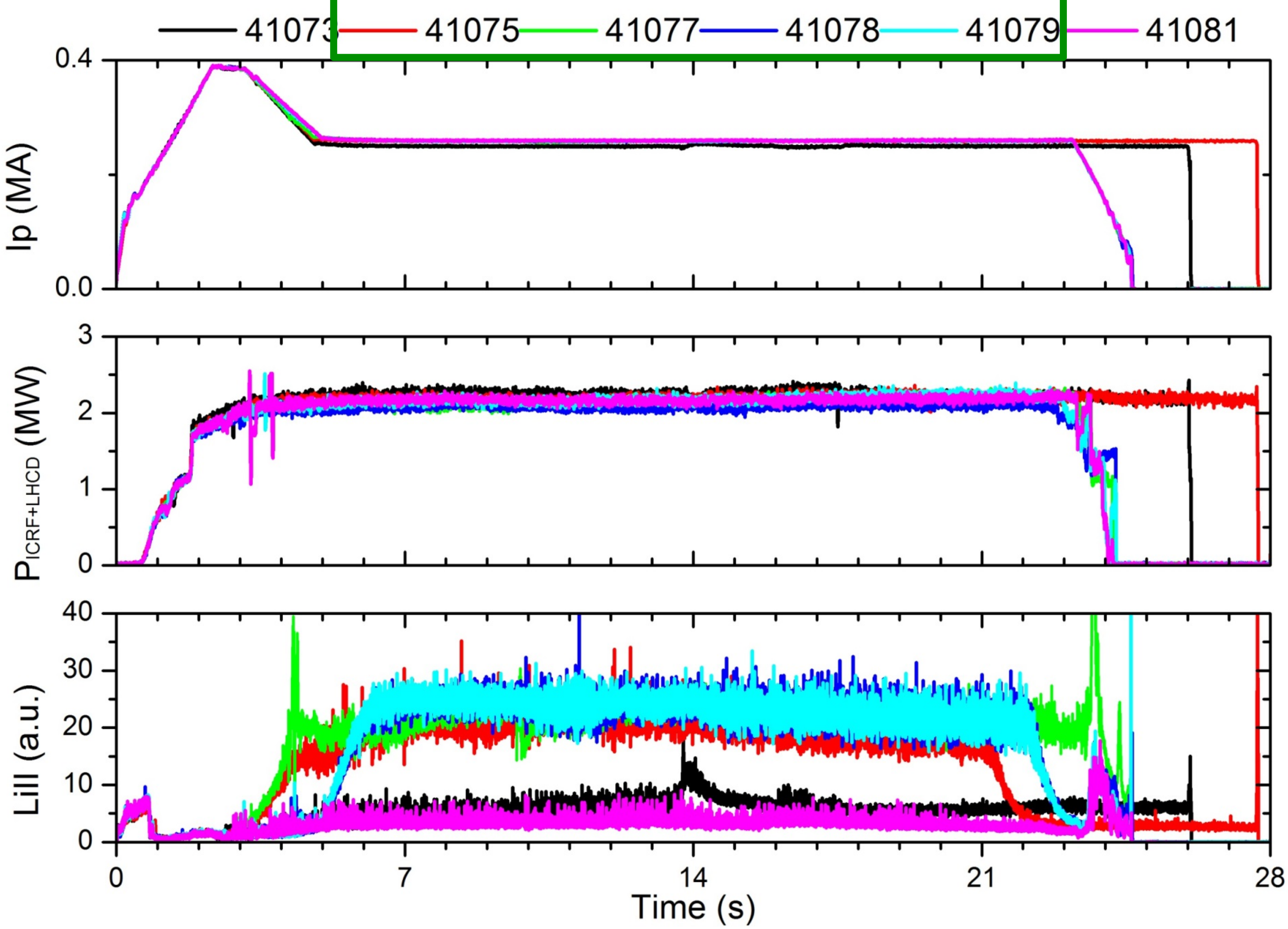


Li injector used for real time conditioning in near double-null discharges in EAST

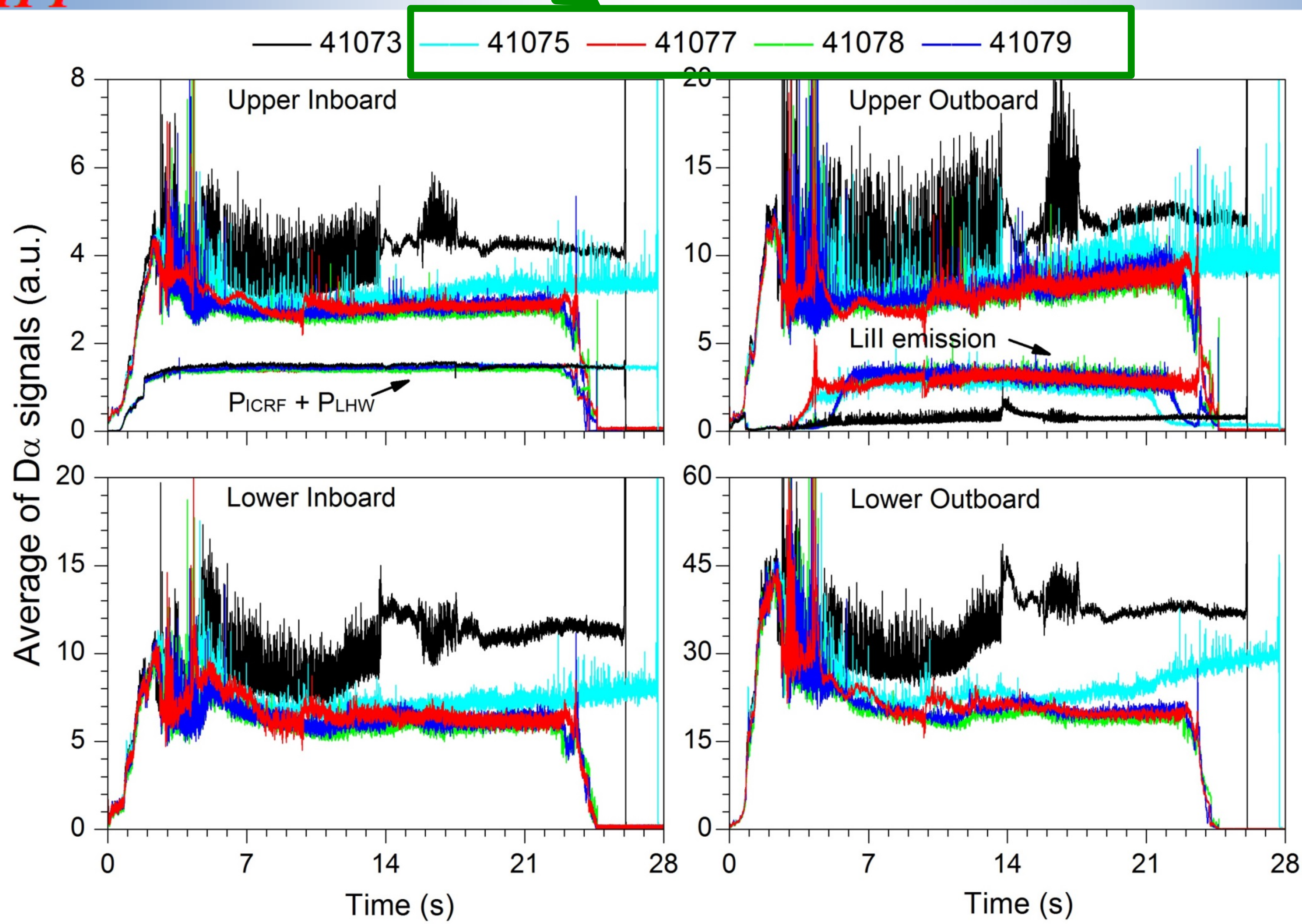




Li injector used for four contemporaneous discharges (41075-41079) in EAST



Recycling dropped in nearly all divertor legs with real time Li injection in EAST (41075-41079)



ELM frequency drop correlated with Li injection (first Li shot in sequence) in EAST; elimination required several sec

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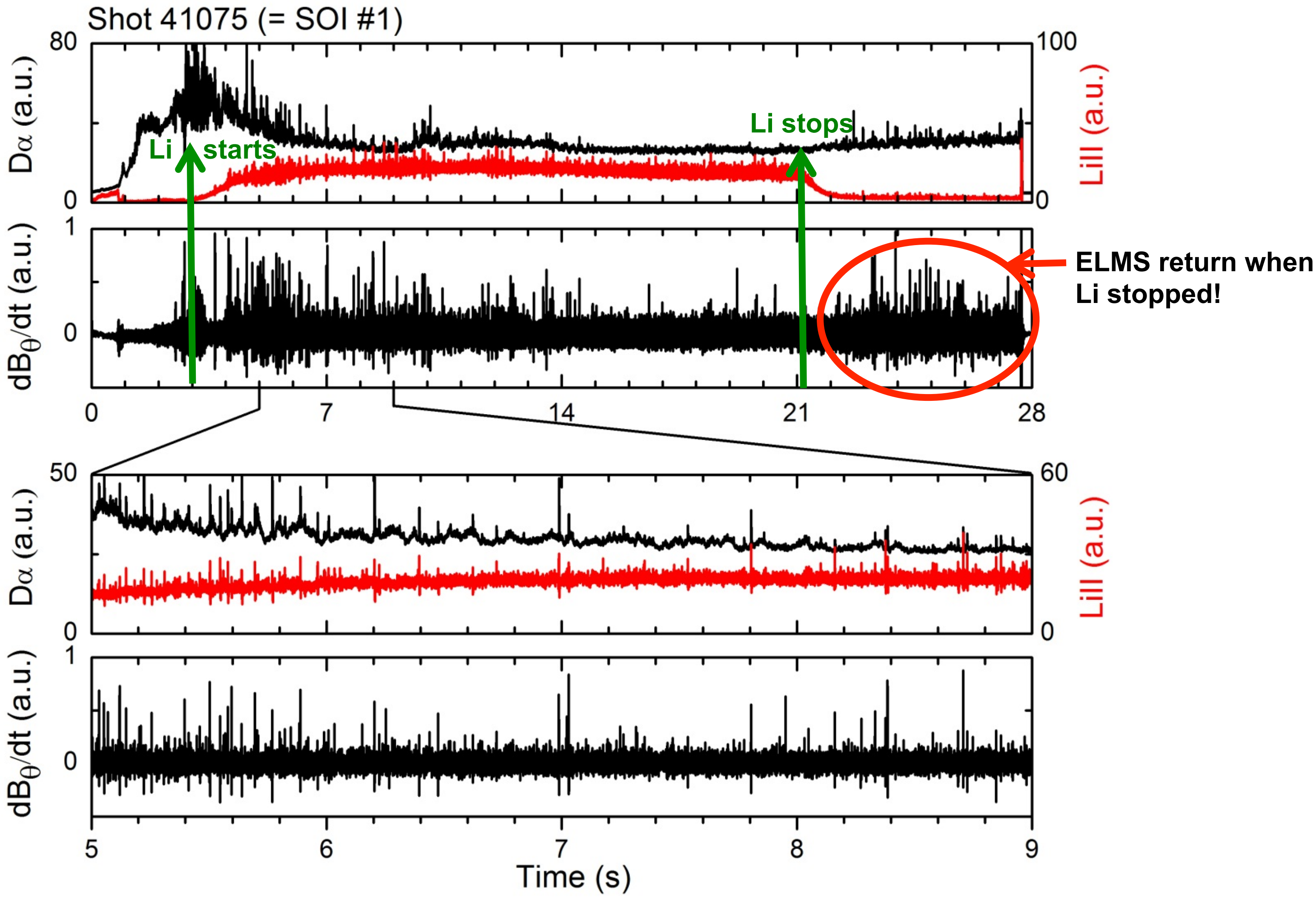

Radiated power and density remained steady during H-mode with eliminated ELMs in EAST

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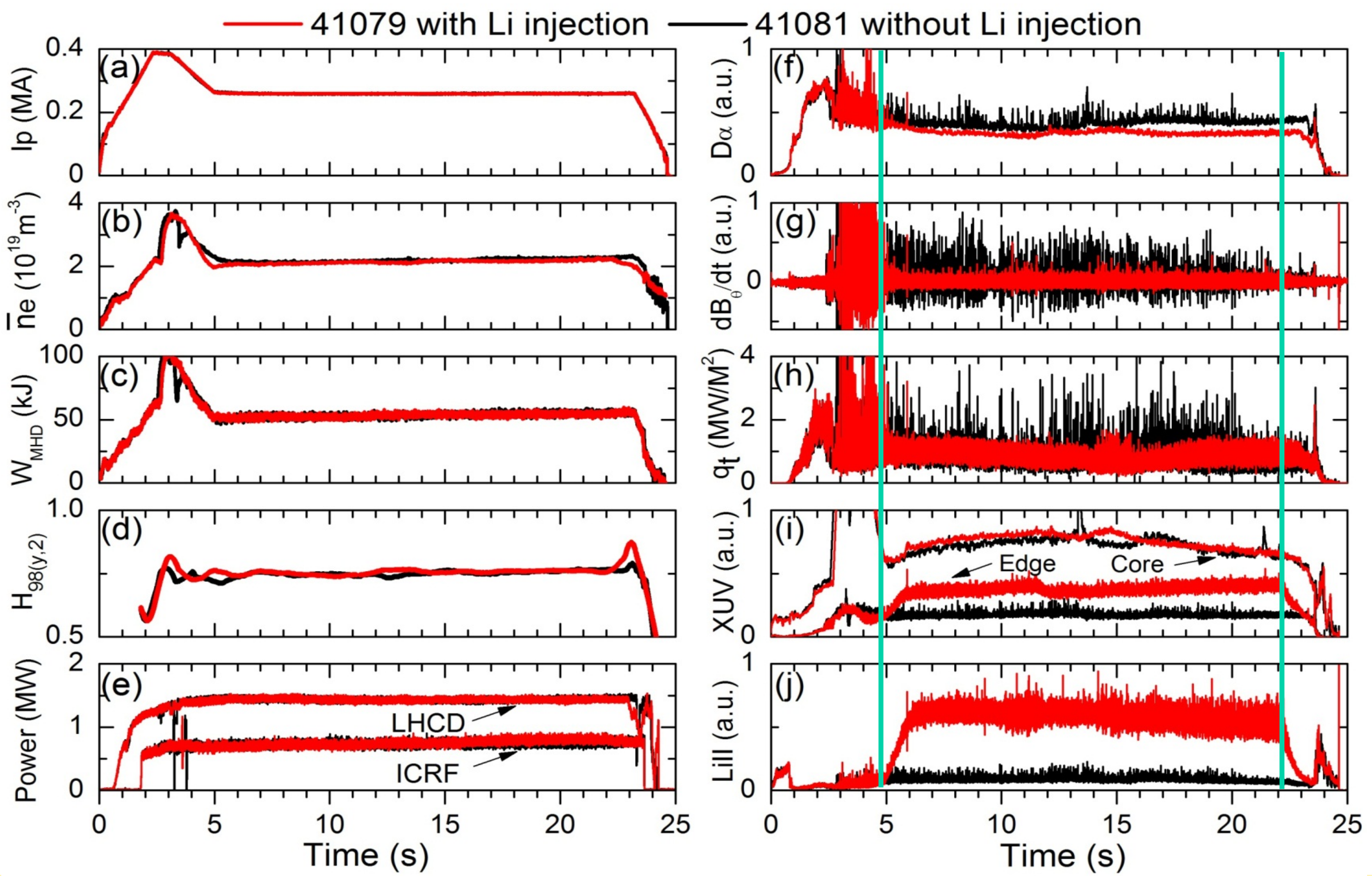
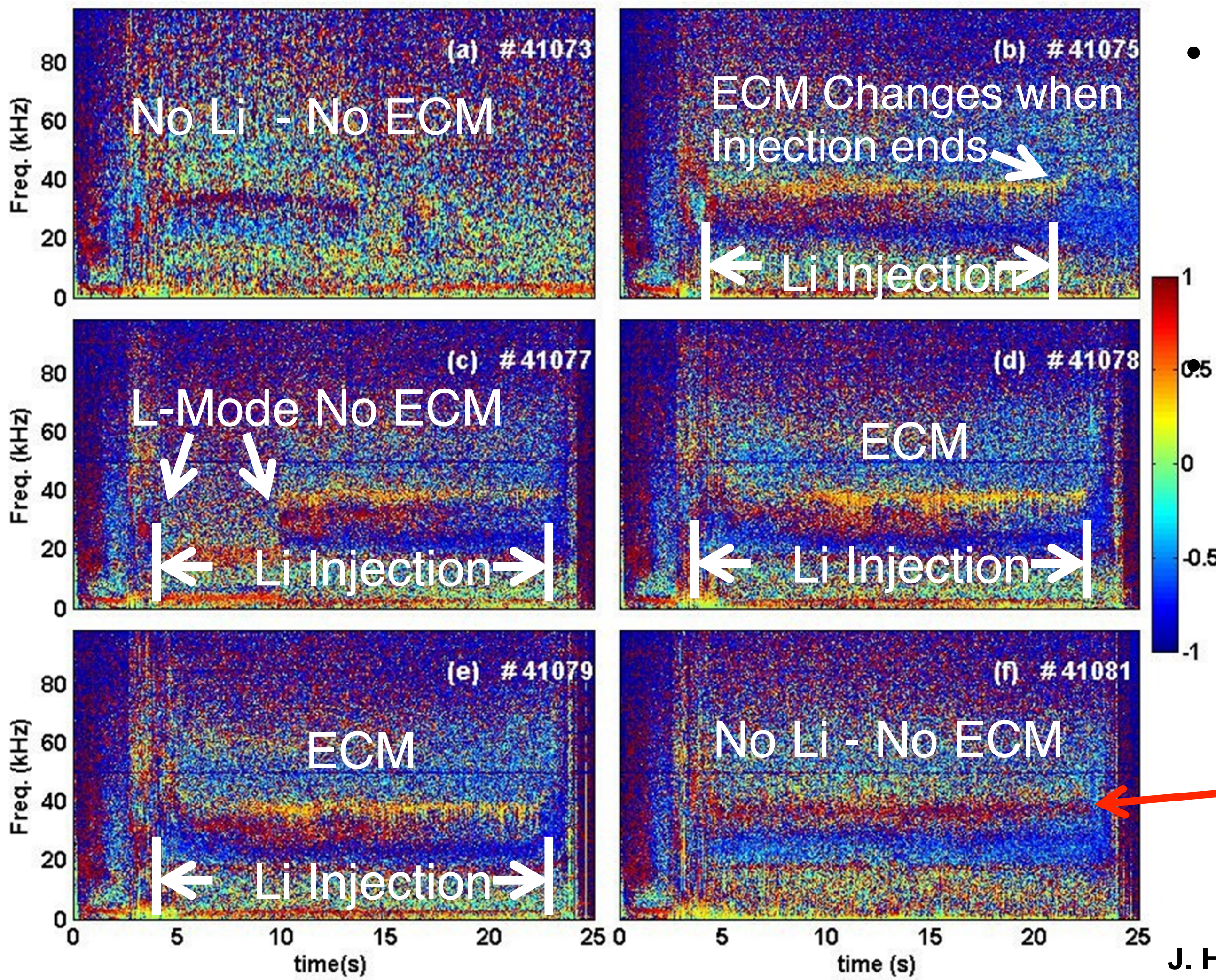


Edge coherent mode (ECM) turned on with Lithium injection (and correlated ELM elimination) in EAST



- **ECM thought to augment particle transport, which prevents impurity accumulation**

(Data from Mirnov coils)

Mode in red color at same frequency as ECM but different poloidal structure

J. Hu, PSI 2014, submitted to PRL