NSTX

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The continuous improvement of H-mode discharge and pedestal performance with progressively increasing lithium coatings in NSTX

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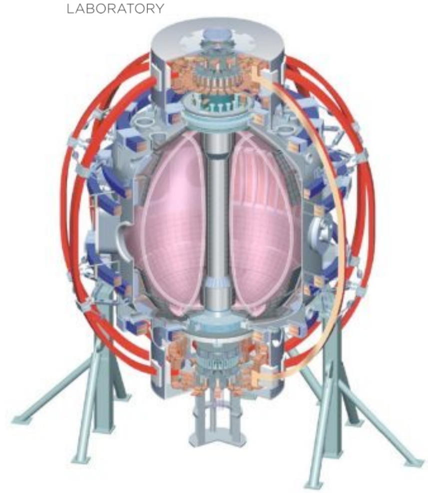

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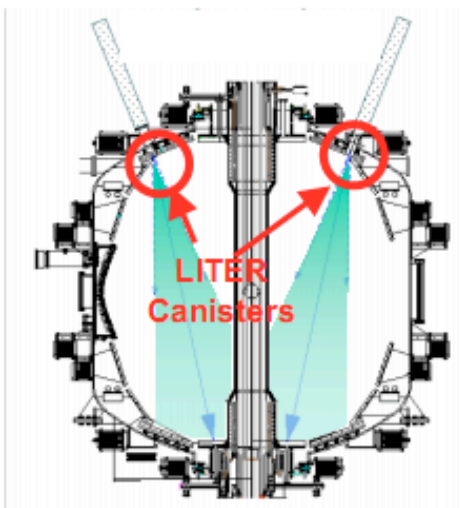
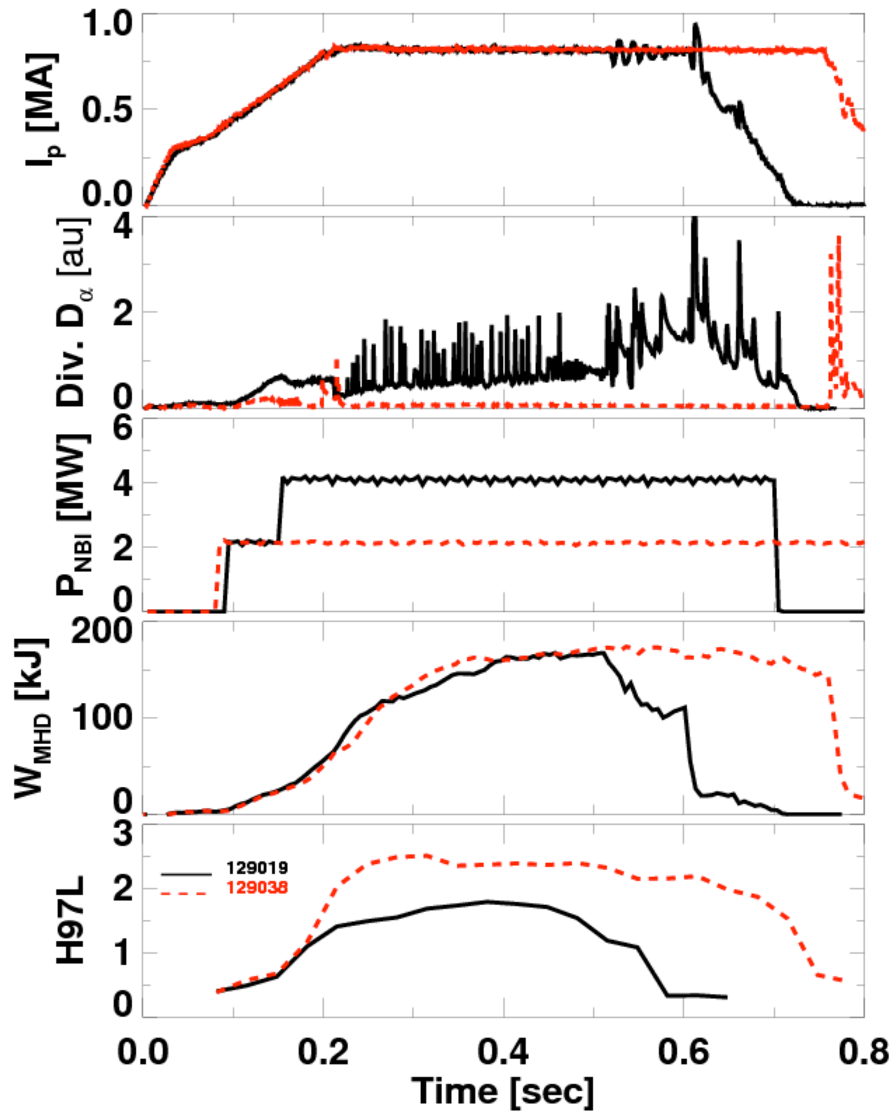
Type I ELMs eliminated, energy confinement improved with lithium wall coatings; (ELMs eliminated up to β_N limit)



~ 700mg Li
between 129037
and 129038



- Without Li, With Li *(pre-LLD)*
- ELM-free, reduced divertor recycling
- Lower NBI to avoid β limit
- Similar stored energy
- H-factor 40%↑

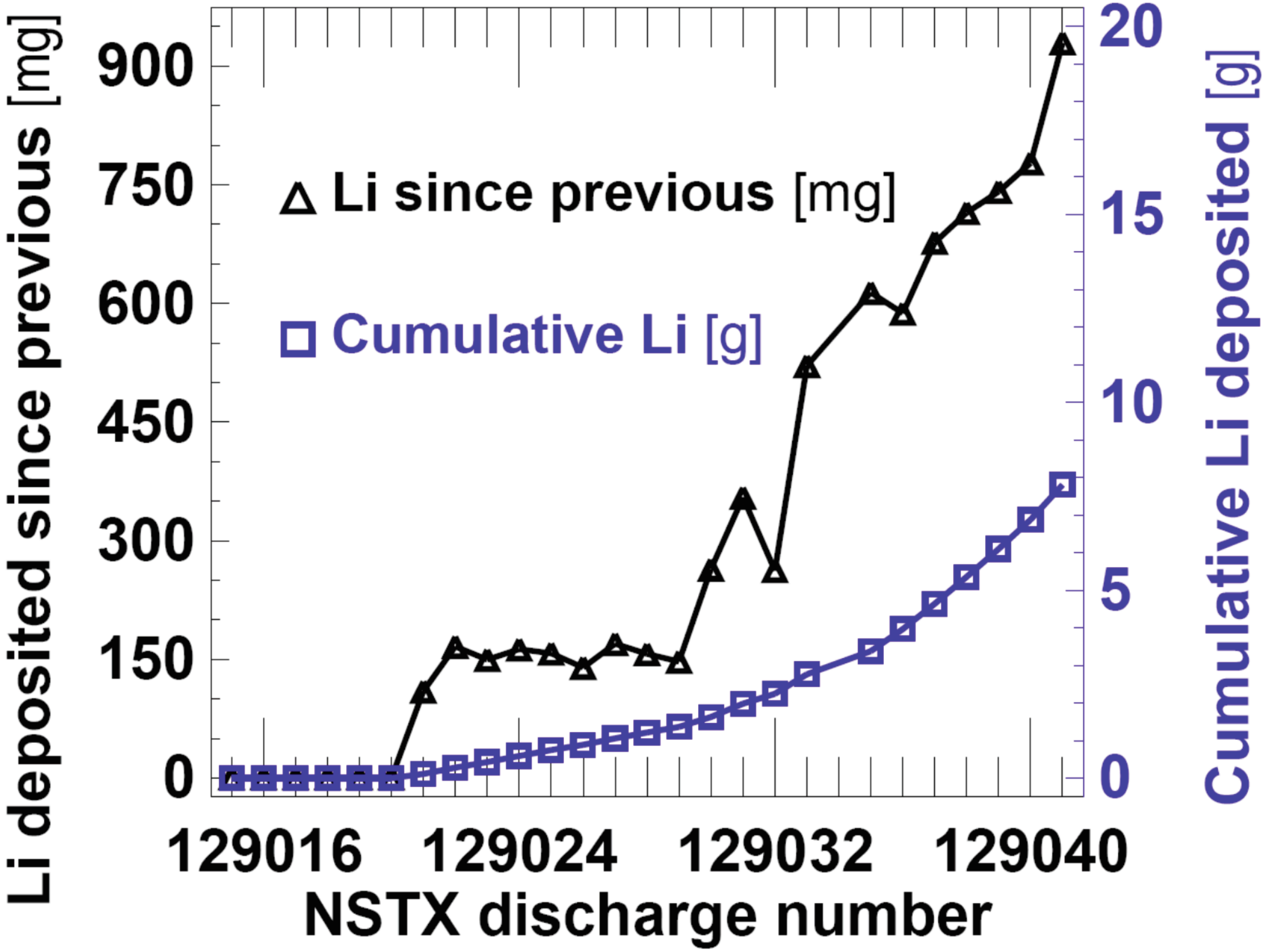
H. Kugel, PoP 2008
R. Kaita, IAEA 2008
M. Bell, PPCF 2009
D. Mansfield, JNM 2009
R. Maingi, PRL 2009

Plasma characteristics change (mostly improve) nearly continuously with increasing lithium evaporation

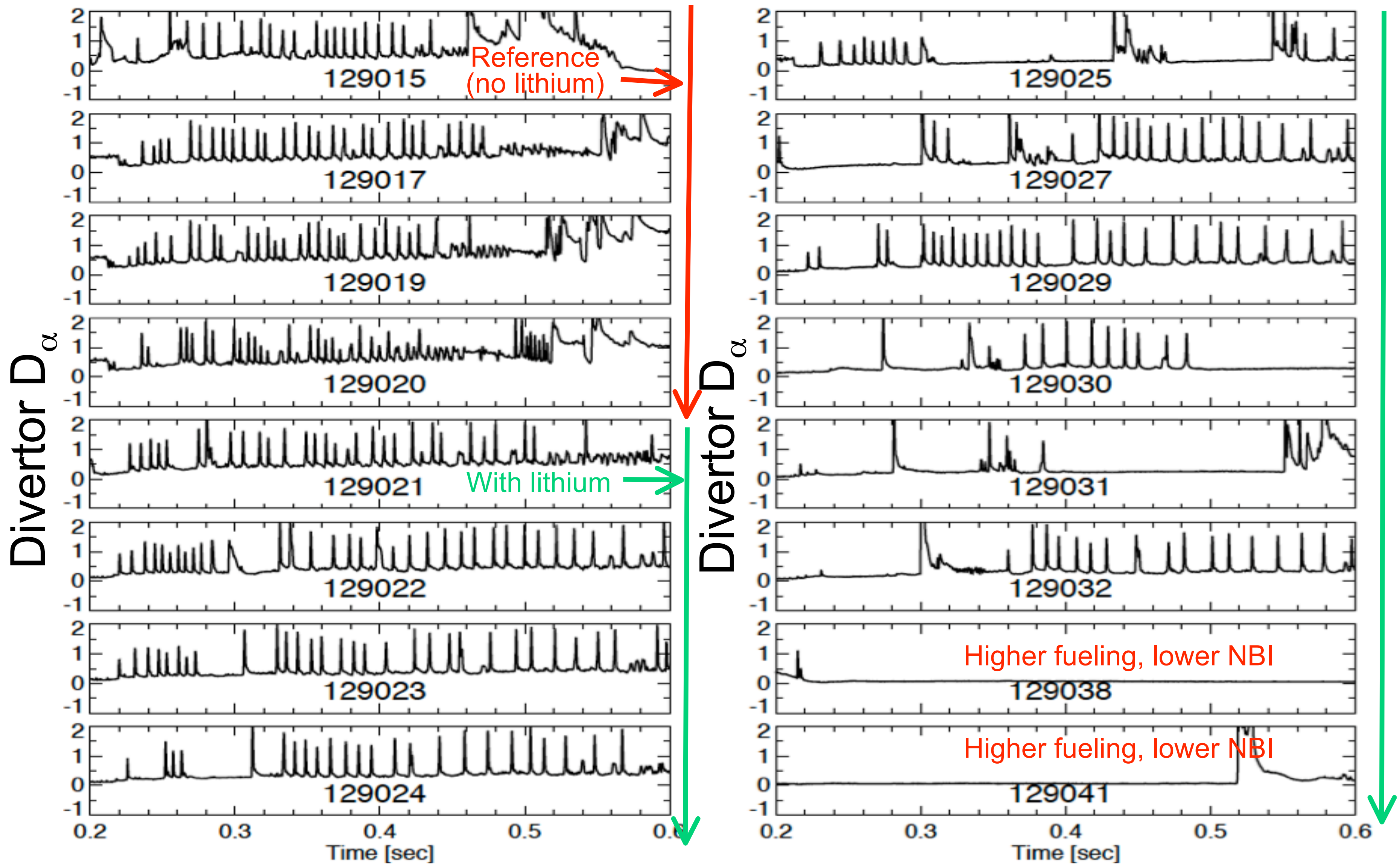
- ELM frequency first declines, and then goes to 0
  - n_e, P_e and P_{tot} profile widths increase with lithium — **D. Boyle, PPCF 2011**
  - Edge profile and stability analysis in *D. Boyle, B04.05*
- Global characteristics change — **R. Maingi, PRL 2011**
  - Recycling: D_α declines in lower divertor, center stack, upper div.
  - Li-I light from lower divertor increases
  - Edge neutral pressure decreases
  - Line average density at t=0.4 sec decreases
  - Confinement improves: Peak W_{MHD}, β_N increase at constant P_{NBI}
  - T_e and P_e profiles broaden; n_e profile peaks then broadens
- Edge transport declines — **J. Canik, PoP 2011**

* *Experiments conducted before LLD installation*

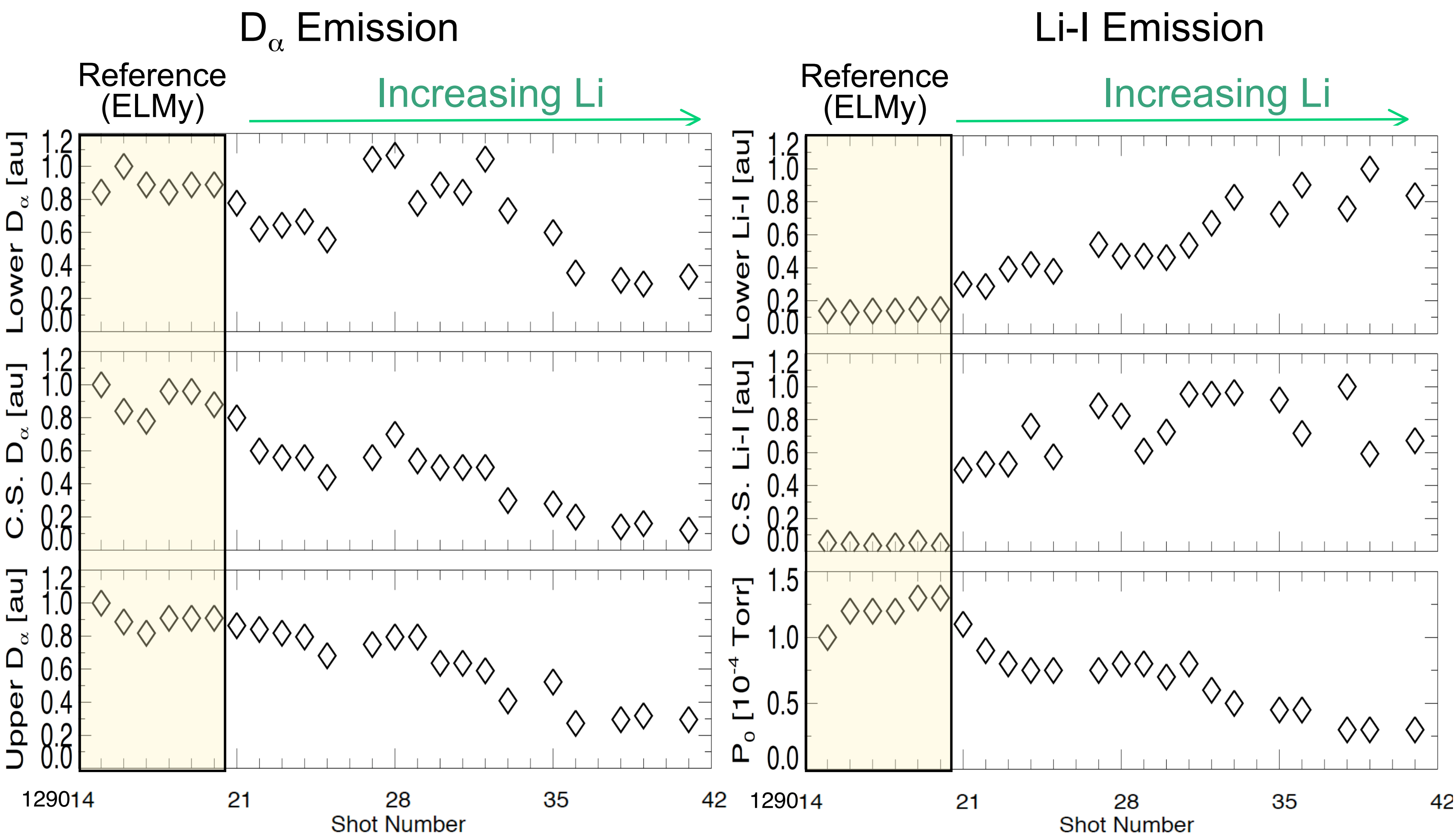
Lithium introduced methodically during experiment - first lithium in 2008 run campaign



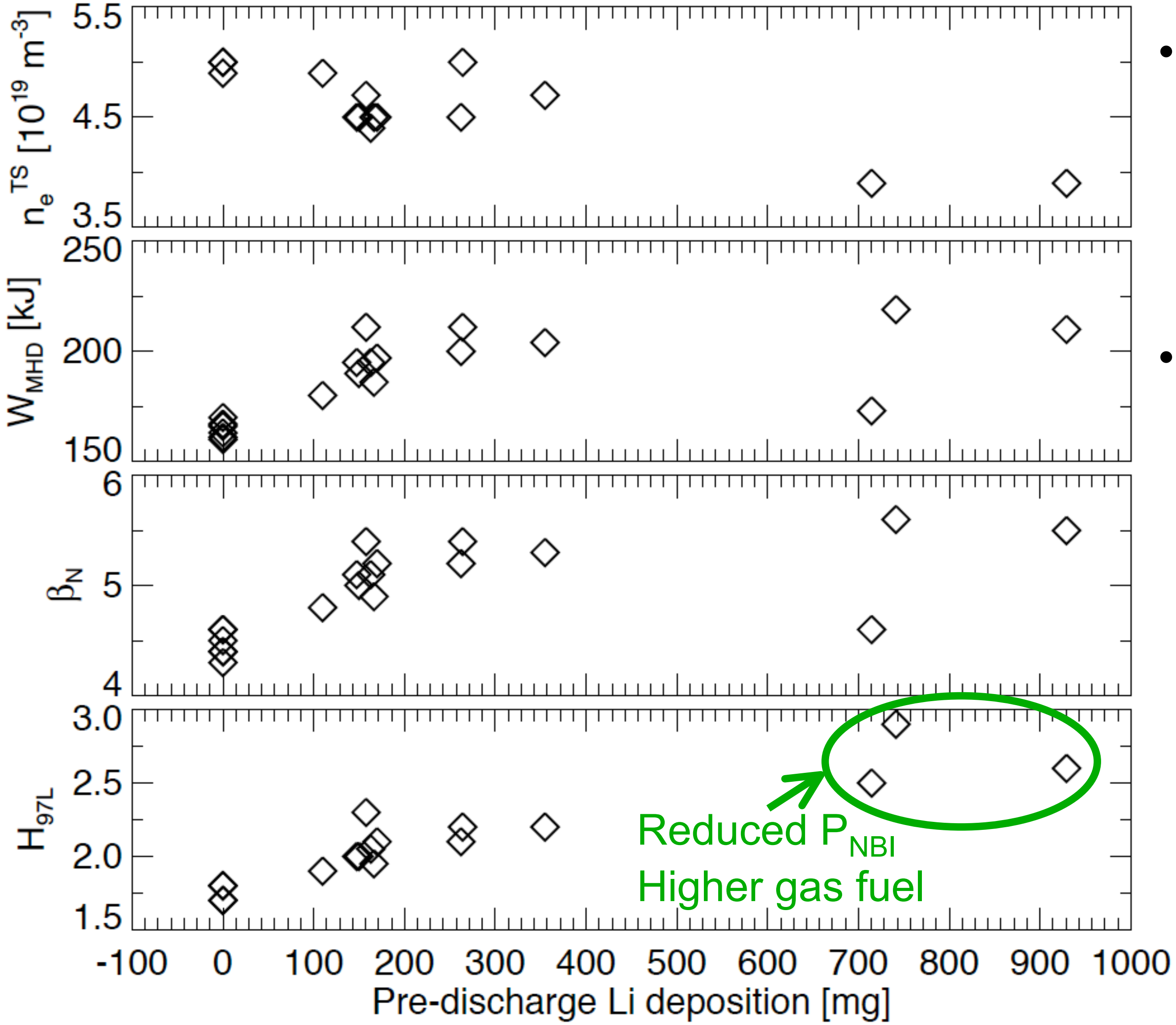
ELMs disappeared gradually during experiment



D_α decreases and lower divertor Li-I increases with increasing lithium evaporation

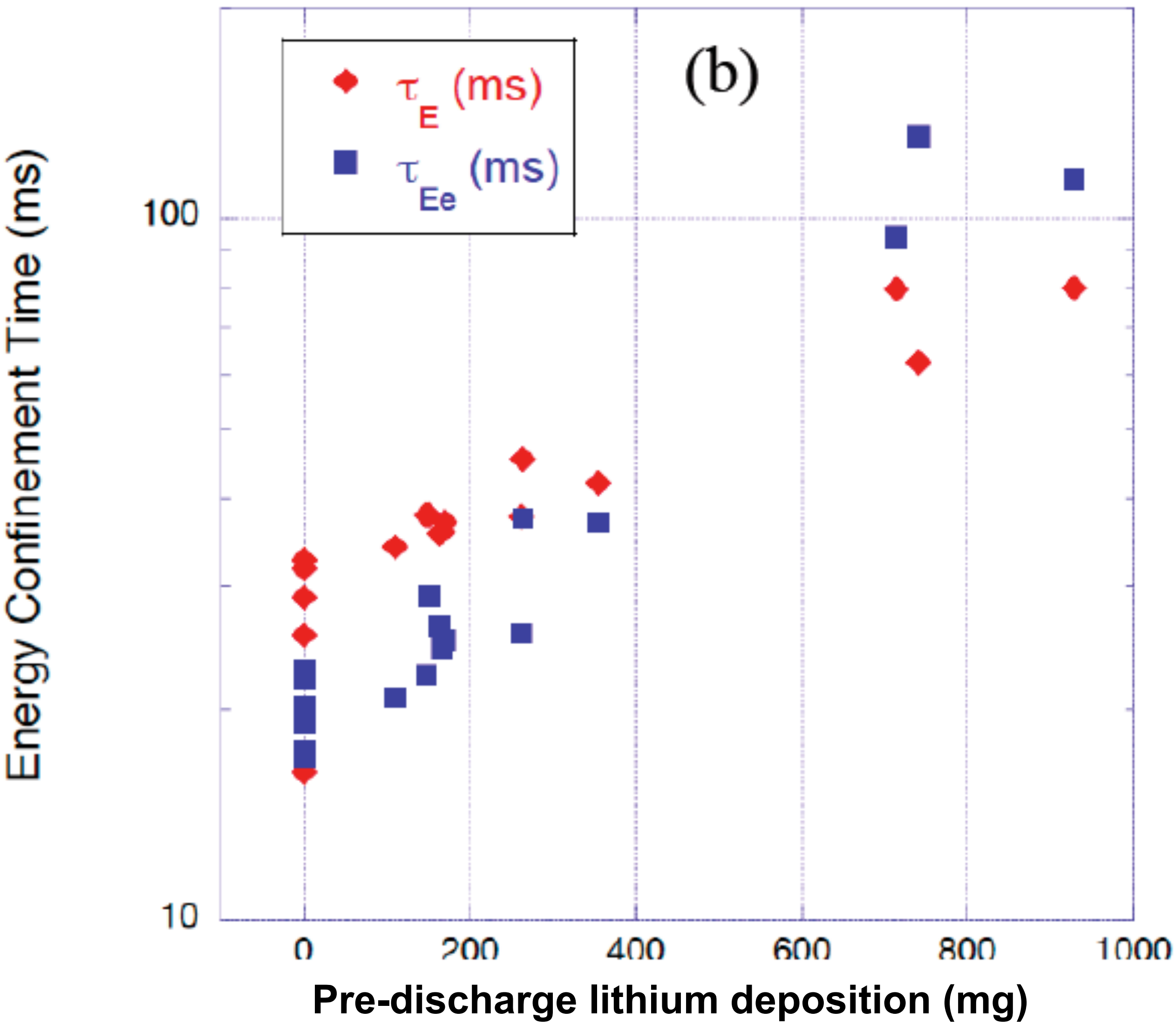


Global plasma performance improves nearly continuously with increasing lithium



- Line-average density from Thomson n_e^{TS} evaluated at t=0.4 sec (fixed time)
- W_{MHD} β_N, and H97L (global τ_E, not thermal) evaluated at time of peak W_{MHD}

Both global and electron confinement, τ_E and τ_{Ee}, increase with pre-discharge lithium evaporation

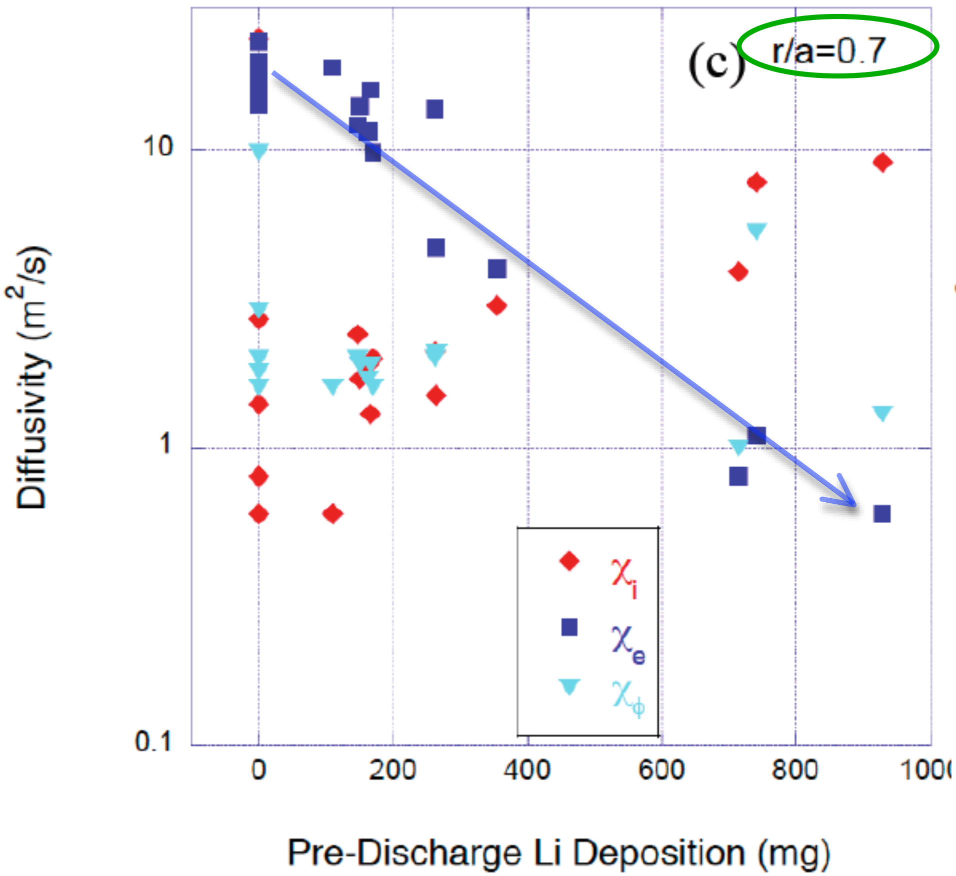


- Evaluated with TRANSP at time of peak stored energy, W_{MHD}
- *See S. Kaye, PP9.030, Wed. PM*

Edge χ_e decreases with increasing lithium

Edge

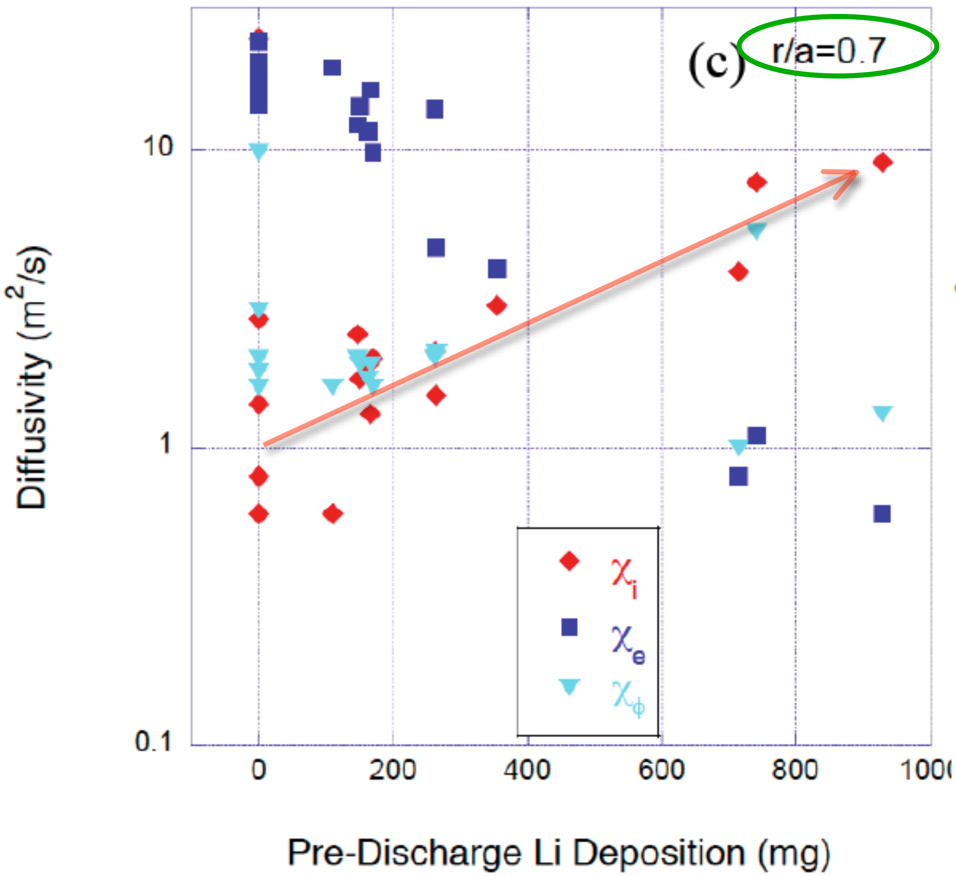
S. Kaye, PP9.030, Wed. PM



Edge χ_i increases with increasing lithium

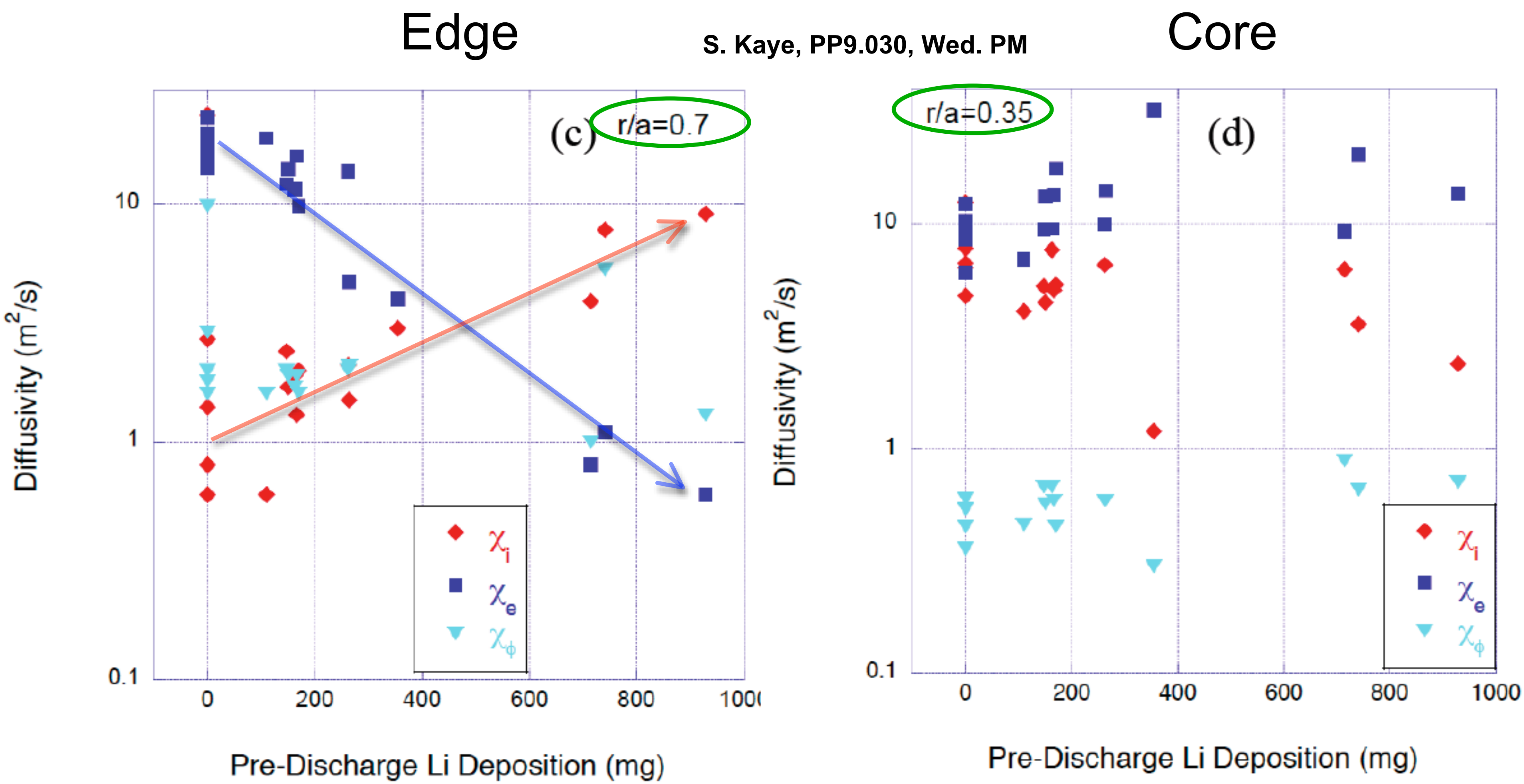
Edge

S. Kaye, PP9.030, Wed. PM



Edge χ_e goes down and χ_i goes up; core χ's unchanged

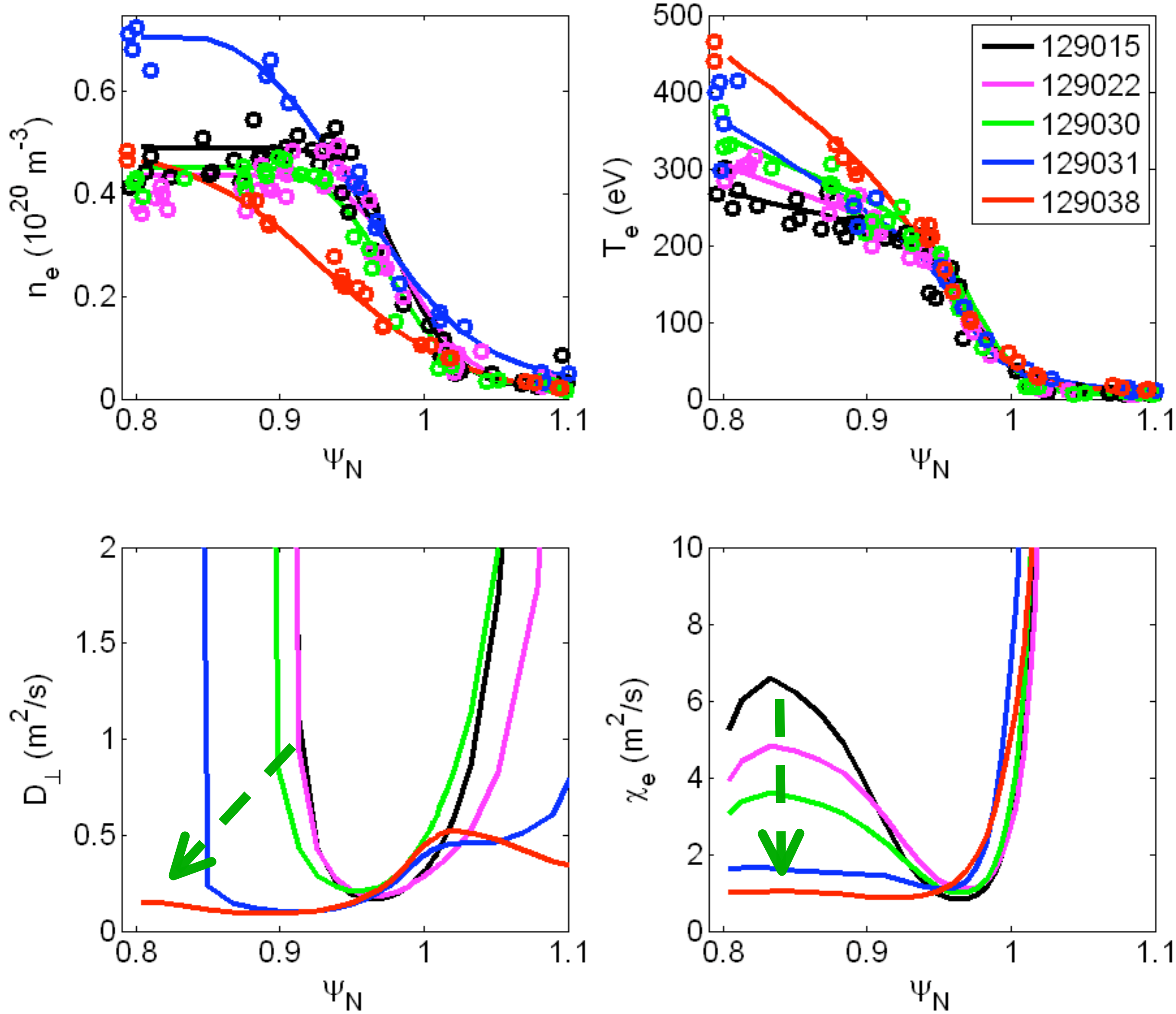
S. Kaye, PP9.030, Wed. PM



- Global increase in τ_E correlates with drop in edge χ_e
- Consistent with change in χ_e, D from SOLPS simulations

As lithium evaporation increases, transport barrier widens, pedestal-top χ_e reduced

- Several shots analyzed with increasing lithium thickness (direction of arrow)
- ELMy to reduced frequency to ELM-free
- T_e gradient clamped



J. Canik, PoP 2011

Summary and Discussion

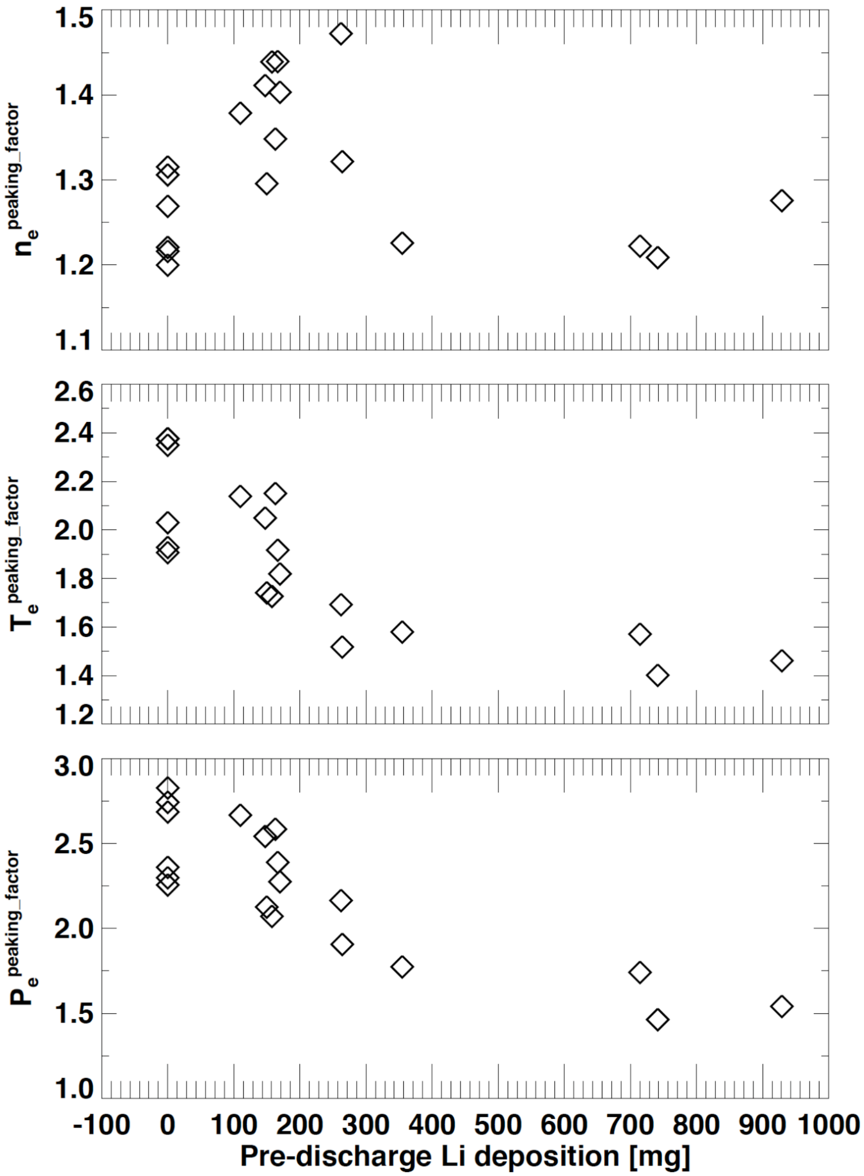
- Global characteristics change and edge electron transport declines with increasing deposition, *(ELMs suppressed)*

- Result surprising because of the nominal film thicknesses
  - Near strike point average lithium deposition in this experiment ranged from 60 nm - 500 nm
  - Simple calc. for NSTX divertor parameters shows ion implantation depth < 10 nm, i.e. << 60 nm – 500 nm

- Possible reasons for this dependence under investigation
  - Continual erosion of films near strike point
  - Slow evolution of films far from outer strike point (center stack)
  - Importance of oxygen in Li-C system for pumping D (*Allain, PI2.06*; *Taylor, B04.12*, *Nucl. Fusion submitted; Krstic, FED at press*)

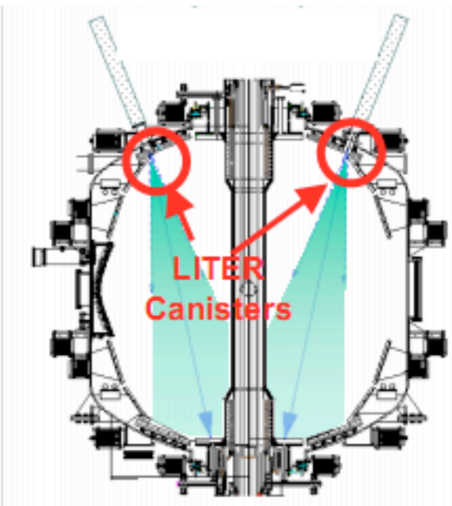
Backup

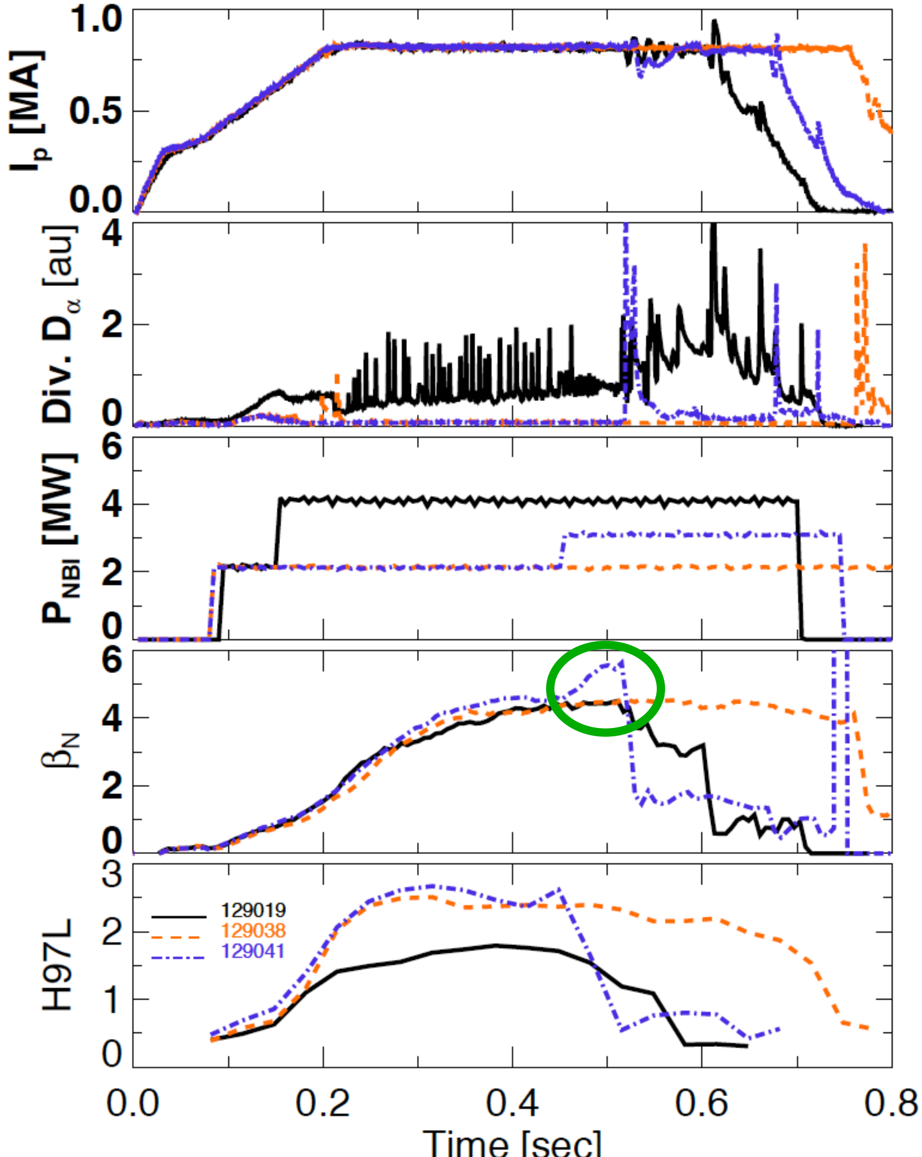
T_e and P_e profile peaking factors decrease with increasing lithium



- n_e profile peaking factor first increases as ELM ν goes down, and then decreases as ELMs disappear and profile becomes hollow
- T_e and P_e profile peaking factors decrease ~ continuously, good for MHD stability

Edge stability limits pushed beyond global stability limits with lithium coatings in NSTX





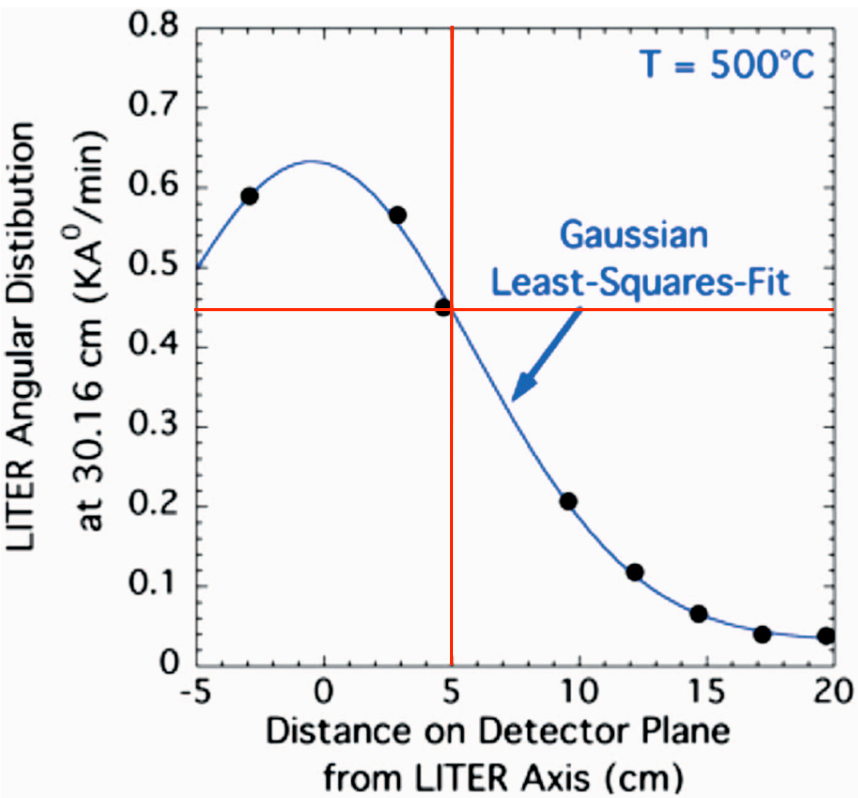
- Without Li, With Li, With Li
- ELM-free, reduced divertor recycling
- Power scan to identify β limit
- Core β limit observed, but no ELMs

D. Mansfield, JNM 09

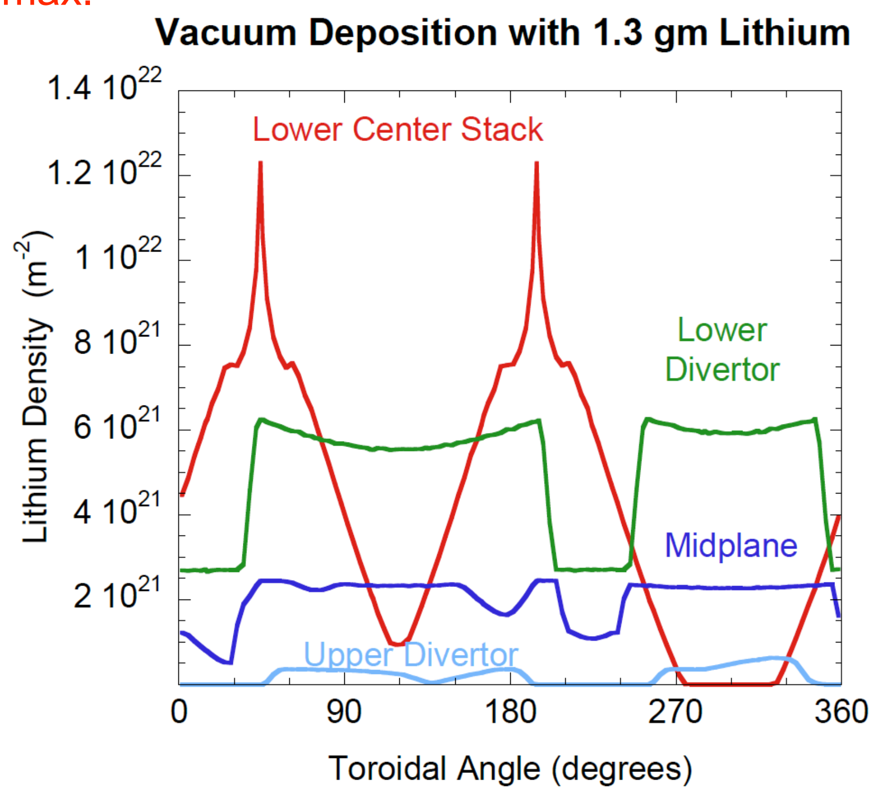
R. Maingi, PRL 09

LiTER deposition has toroidal and poloidal variation

- 30cm distance from LiTER to surface
- in NSTX, x-axis should be multiplied by 10x
- For R_{OSP}~0.8m, deposition 1/3 less than max.

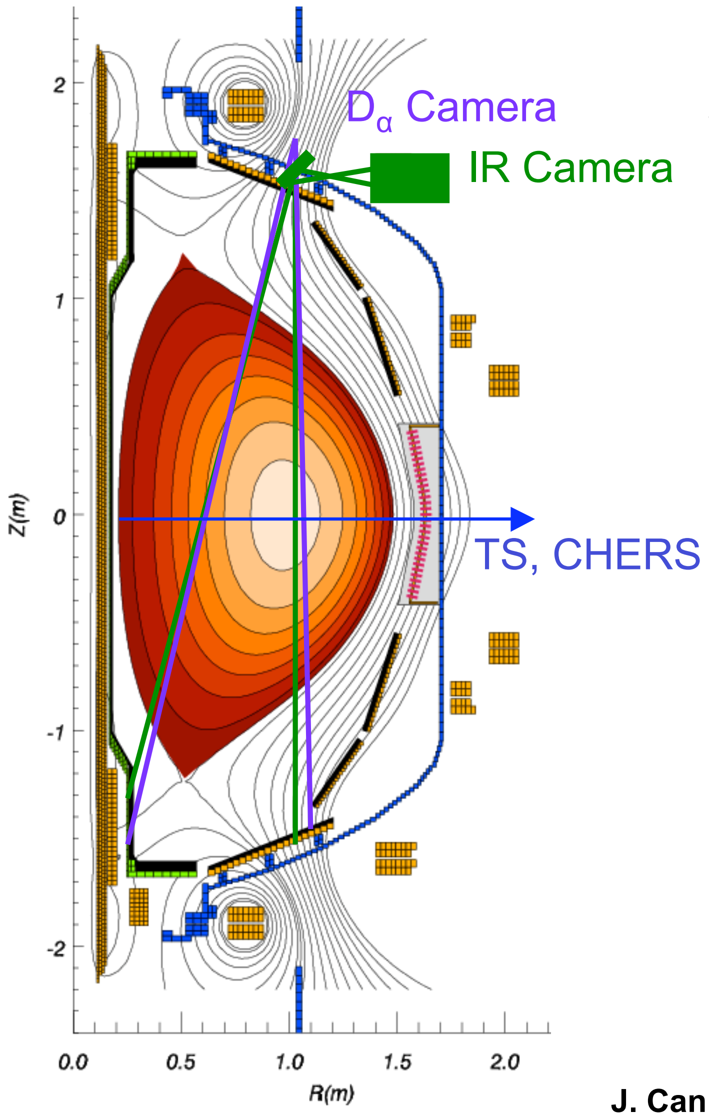


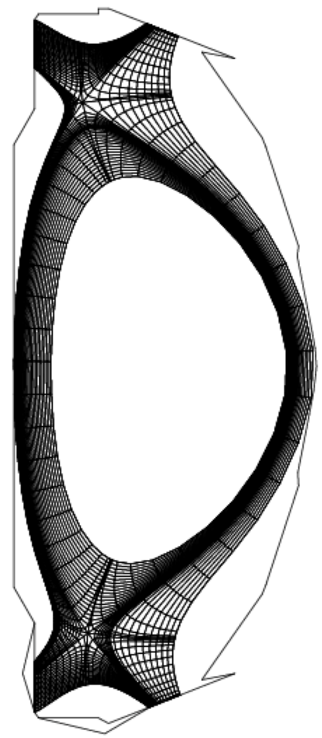
H. Kugel PoP 2008



* From H. Kugel, source?

Divertor recycling and far edge cross-field transport quantified with data-constrained SOLPS modeling





J. Canik PoP 2011

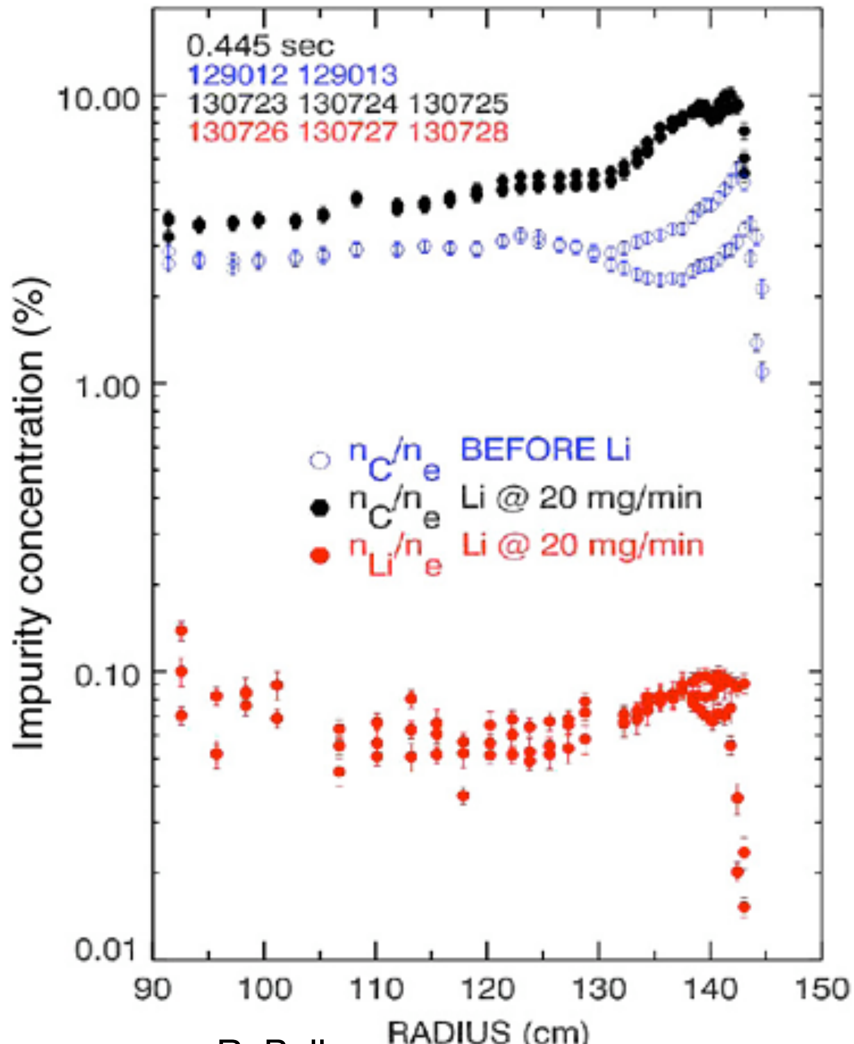
- SOLPS (B2-EIRENE: 2D fluid plasma + MC neutrals) used to model NSTX experimental data
  - Iterative Method
  - ✓ Neutrals, impurities contributions
  - ✓ Recycling changes due to lithium

Parameters adjusted to fit data	**Measurements used to constrain code**
Radial transport coefficients $D_\perp$, χ_e, χ_i	Midplane n_e, T_e, T_i profiles
Divertor recycling coefficient	Calibrated D_α camera
Separatrix position/T_e^{sep}	Peak divertor heat flux

Carbon is the dominant impurity species with lithium coatings

- Measured lithium concentration is much less than carbon
  - Carbon concentration ~100 times higher
  - Carbon increases when lithium coatings are applied
  - Neoclassical effect: higher Z accumulates, low Z screened out

- Increase in n_C may be due to lack of ELMs
  - Can be mitigated by triggering ELMs



R. Bell

M. Bell, PPCF **51** (2009) 124054