The Li-wall Stellarator Experiment in TJ-II

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Outlook

- Introduction
- Why Lithium?
- Li coating technique in TJ-II
- 2008 Results
  - Particle recycling and confinement
  - Plasma and Radiation profiles
  - Electron energy confinement
  - ELMs and L-H Transition
- Conclusions

The Stellarator Reactor

Reactor issues:	Stellarator characteristics
Steady State operation	OK
Power loads	No disruptions, no Type I ELMs
High E confinement	H modes
High ne	No *Greenwald* density limit
Particle exhaust	Intrinsic divertor configurations
Low central Zeff(<1.6)	Impurity accumulation (?)

Stellarators are better suited for Fusion Reactor

but

low recycling (wall pumping), low Zeff still required

Lithium in Tokamaks

Why Li?

- Very low Z
- Strong H retention (LiH)
- Low melting point: Liquid PFC
- High impurity getter (O_2,N_2,CO, H_2O,CO_2…)

Very good results achieved in Tokamaks:

TFTR, CDX-U, FTU, T-10, T-11M….

Different ways of deposition; Liquid tray, pellets, LLL, CPS, evaporation……

But : problems in reproduce beneficial effect:Total coverage??

TJ-II: first stellarator operated under Li walls

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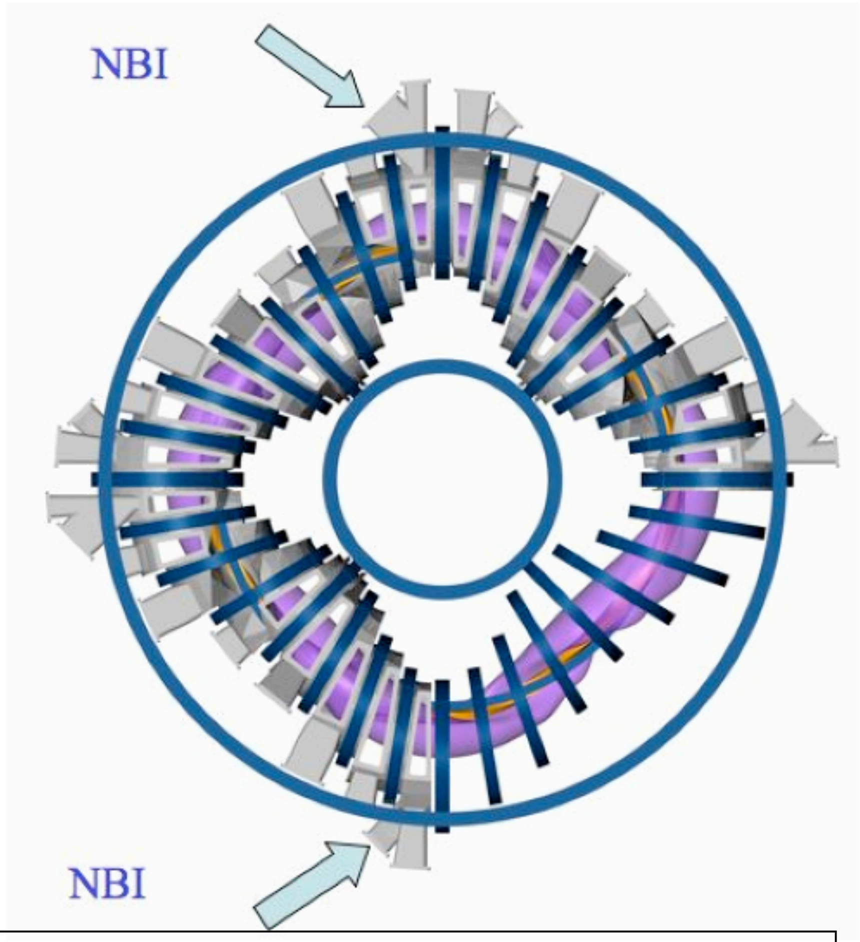
Plasmas in TJ-II

Heliac Stellarator 4 periods
R=1.5 m
<a>= 15-25 cm
B_T=1 T
ECH : 2x300kW,53.2 GHz
NBI:2x400 kW, >30 KeV

Vol Plasma ~ $1m^3$
$P_0=5.10^{-8}$ mbar

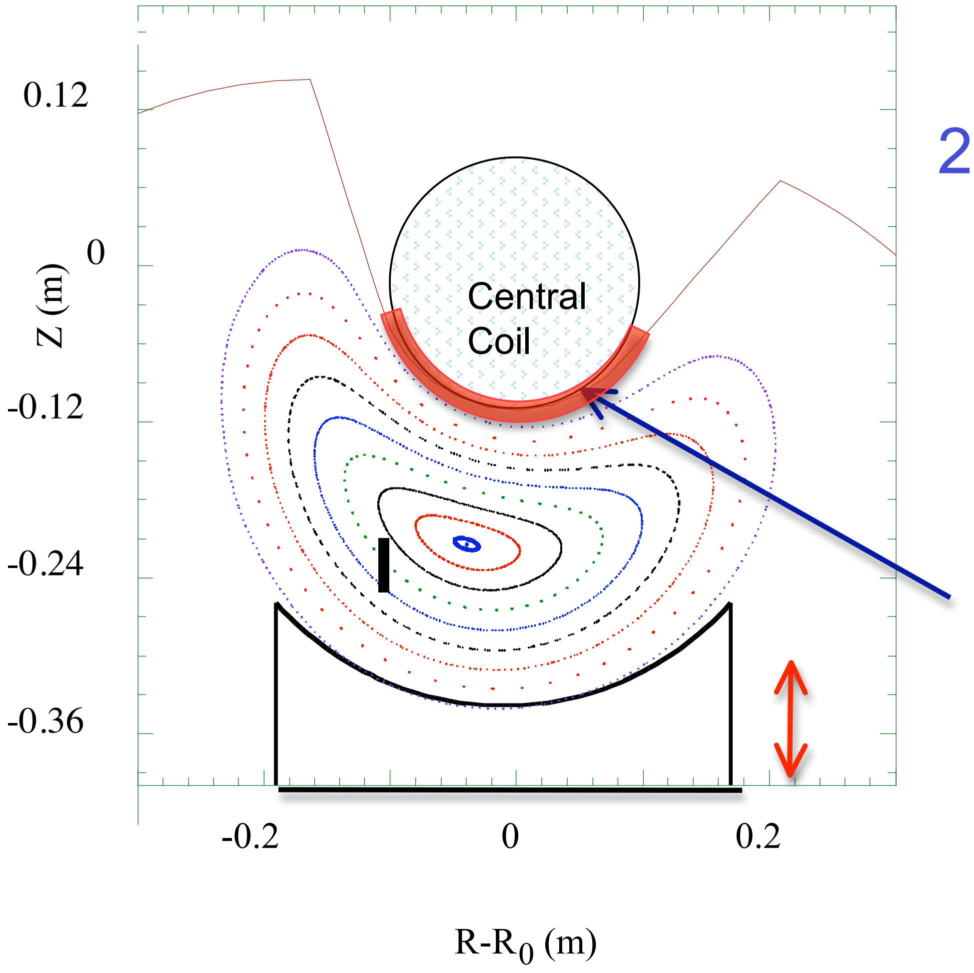
Low Z scenarios :
- 2 Graphite Limiters
- First Wall Boronization



Scientific goals: Scan in magnetic configuration,high β operation

→ Challenging for PWI control

P-W Interaction in TJ-II

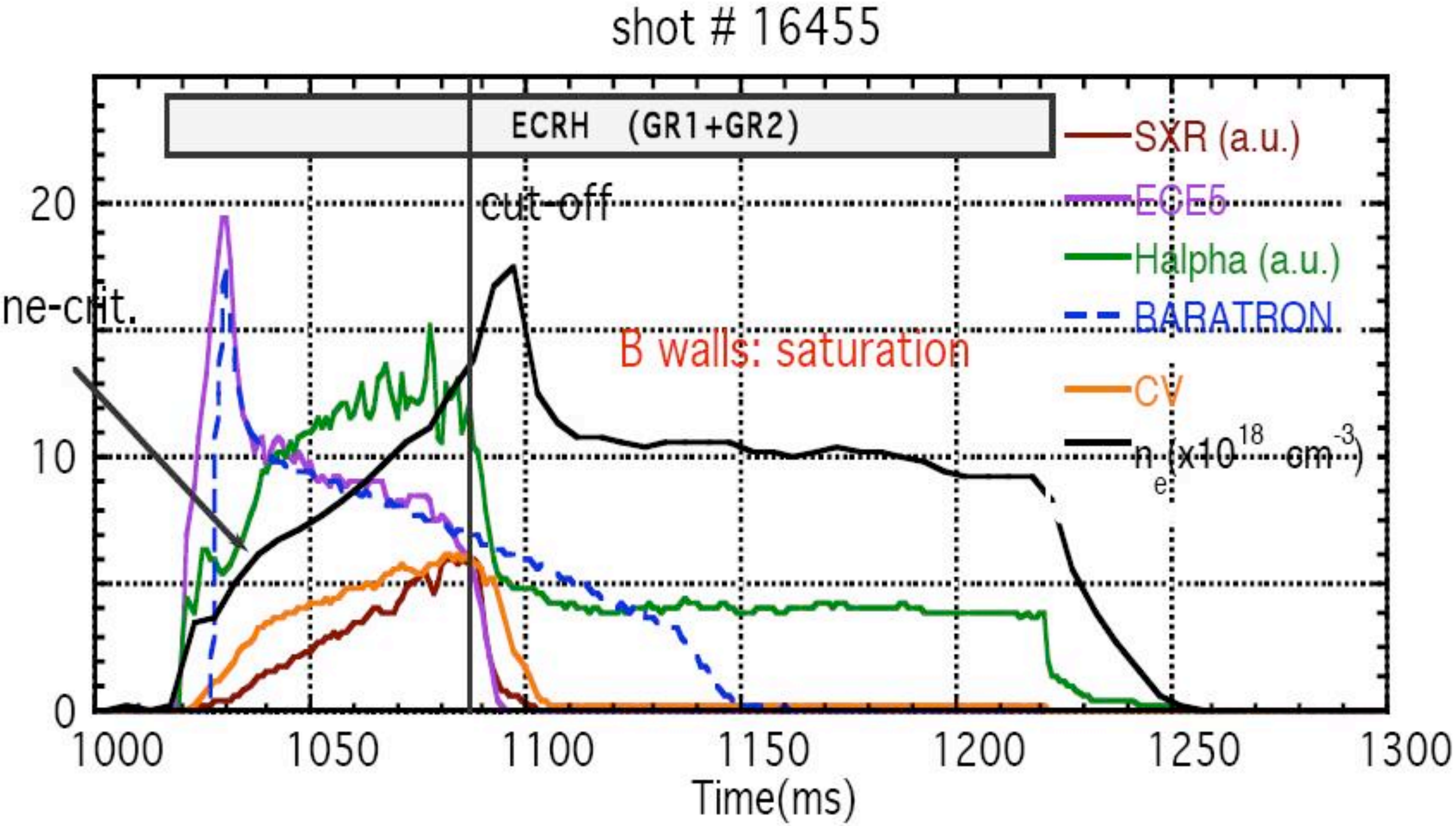


2 Mobile Limiters @180 º

But: *no limiter effect for <2.5 cm insertion in ECRH plasmas*

PWI mainly on Toroidal limiter (VV)

Density control under wall saturation (ECRH)



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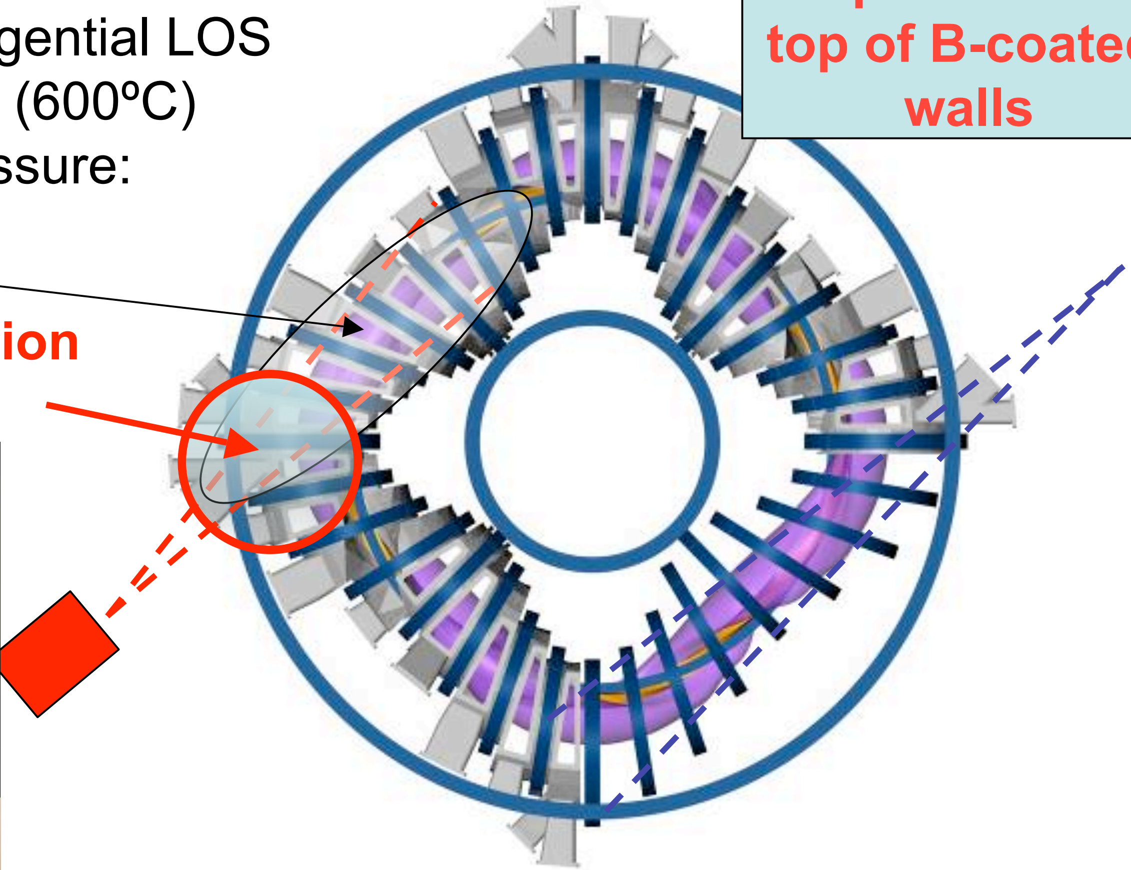
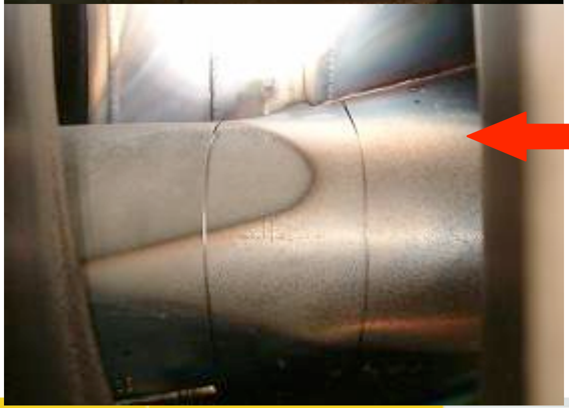
Lithium coating in TJ-II

- **4 ovens**, symmetric,tangential LOS
- 4 g deposited each time (600ºC)
- Role of background pressure:
  - **- HV: line of sight**
  - **- 10^{-3}-10^{-5}mbar: diffusion**



Deposition on top of B-coated walls

As deposited (HV)



Re-distribution by plasma: Improving with operation time!!

1 gr of Li per oven, heated to ~600 ºC during ~30 min (oven inventory > 8g)

Li-wall experimental campaigns

- May-June 2007: 4 g fully evaporated under vacuum. Li-wall plasmas: ECRH/NBI H plasmas: Presented at the ISHW, Toki Oct.07
  Nov-Dec 2007: B wall reference discharges ECRH/NBI H Plasmas + Improvement of NBI and ECRH heating systems
- Feb-June 2008: New Li-W Campaign: Refreshing of Li layer by repetitive evaporation: H/He/ECRH/NBI Plasmas

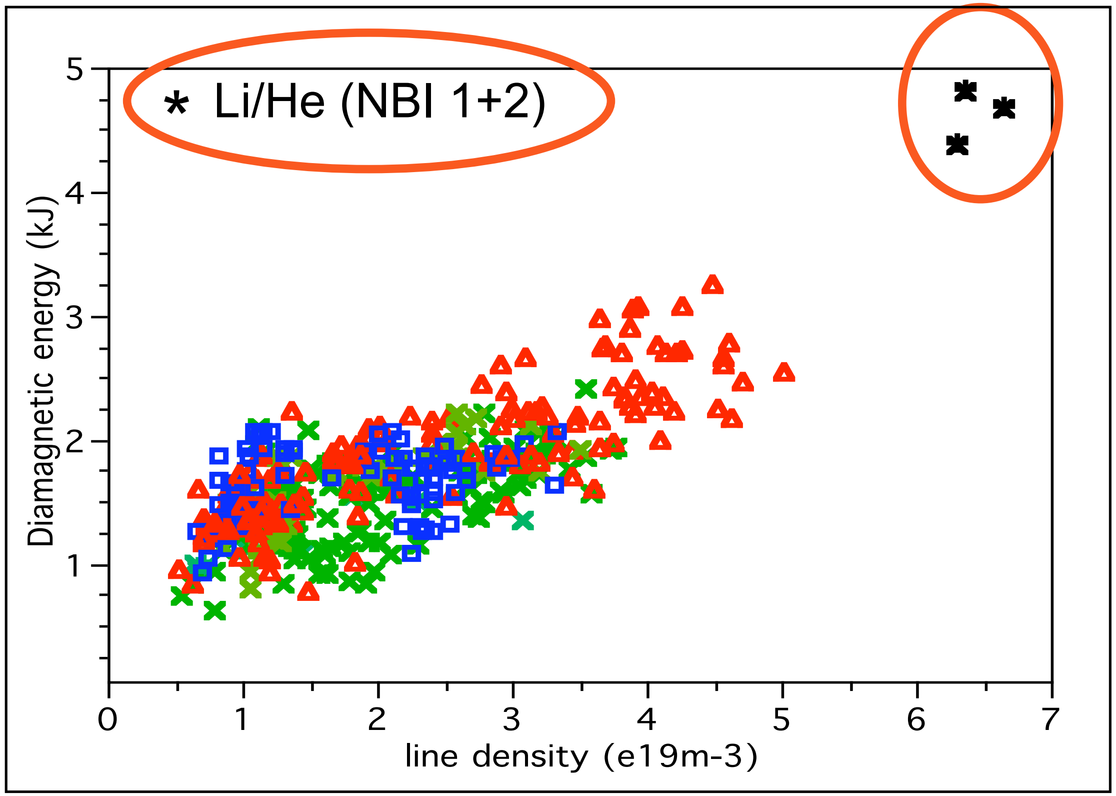
Operational Window: B vs Li

wall / plasma

x B / H

Δ Li / H

□ Li / He



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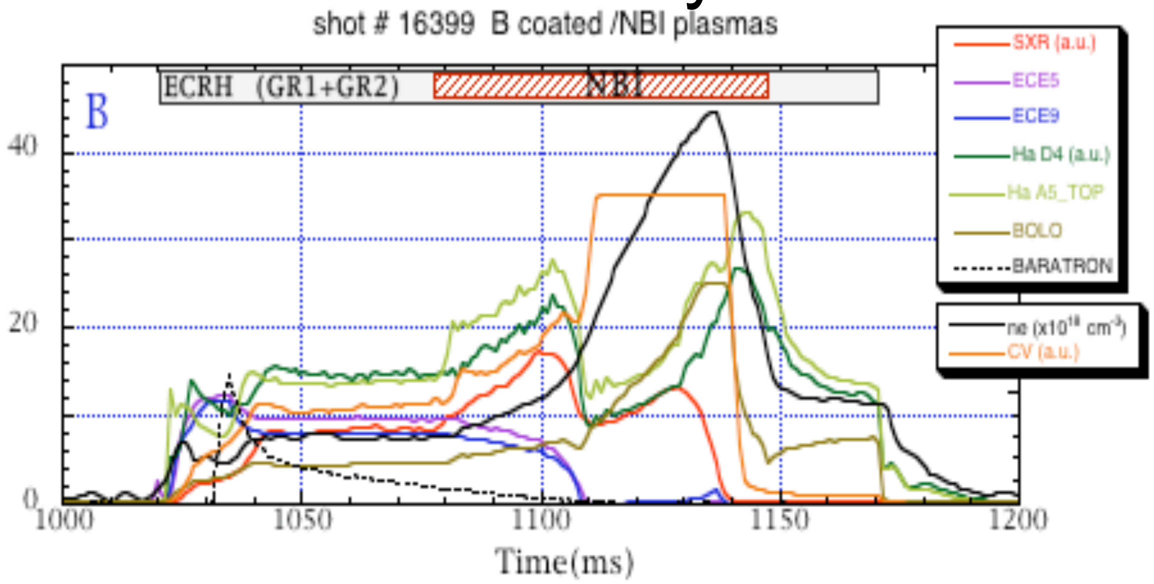
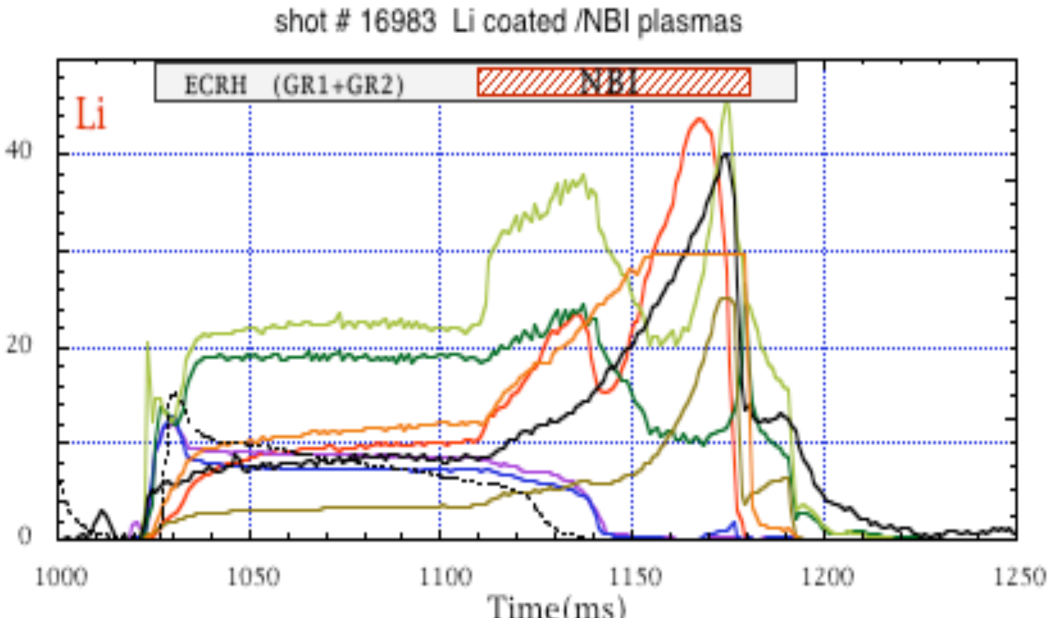
Density control evolution



B wall



Li wall 2007(full evap.)

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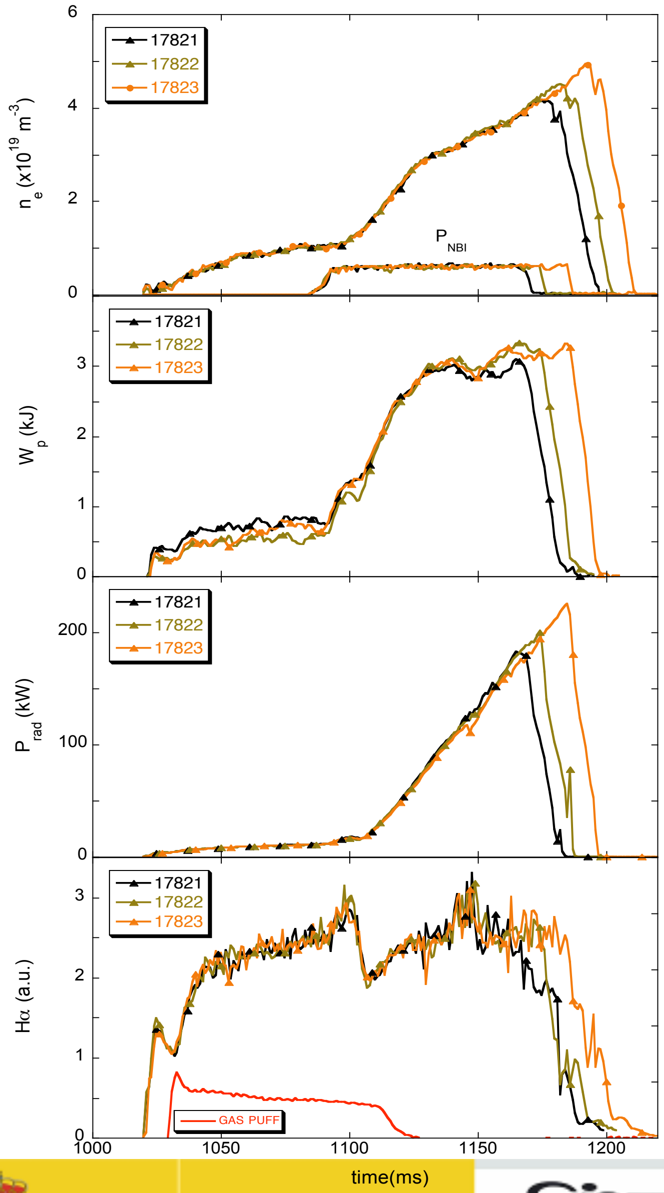
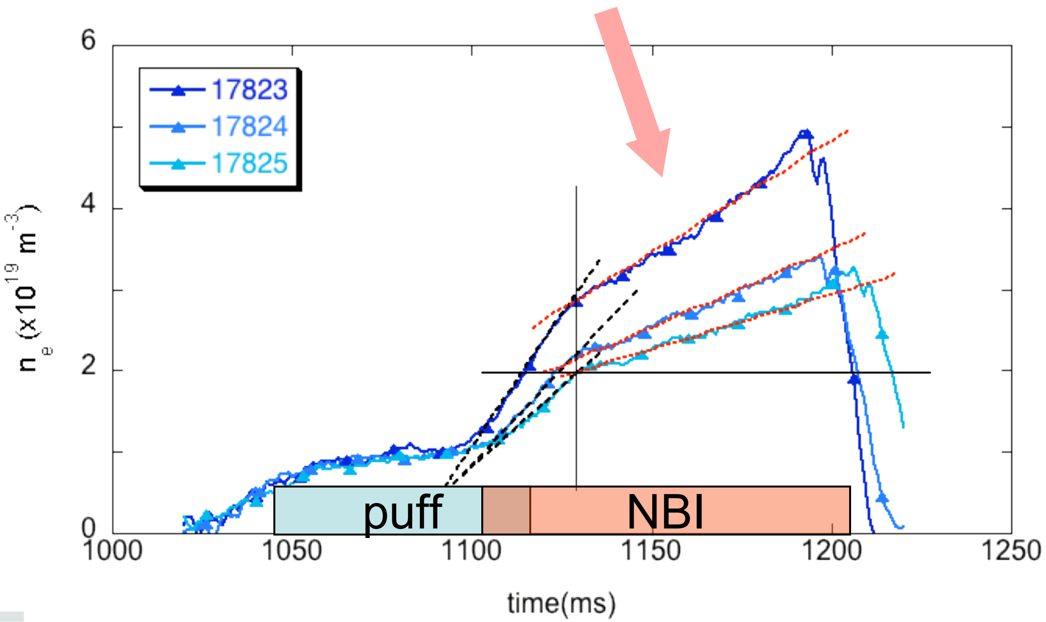
Density control evolution (2008)



approaching nominal beam fuelling rate! (~10^{20} e^{-}/s)

m_2=dne/dt



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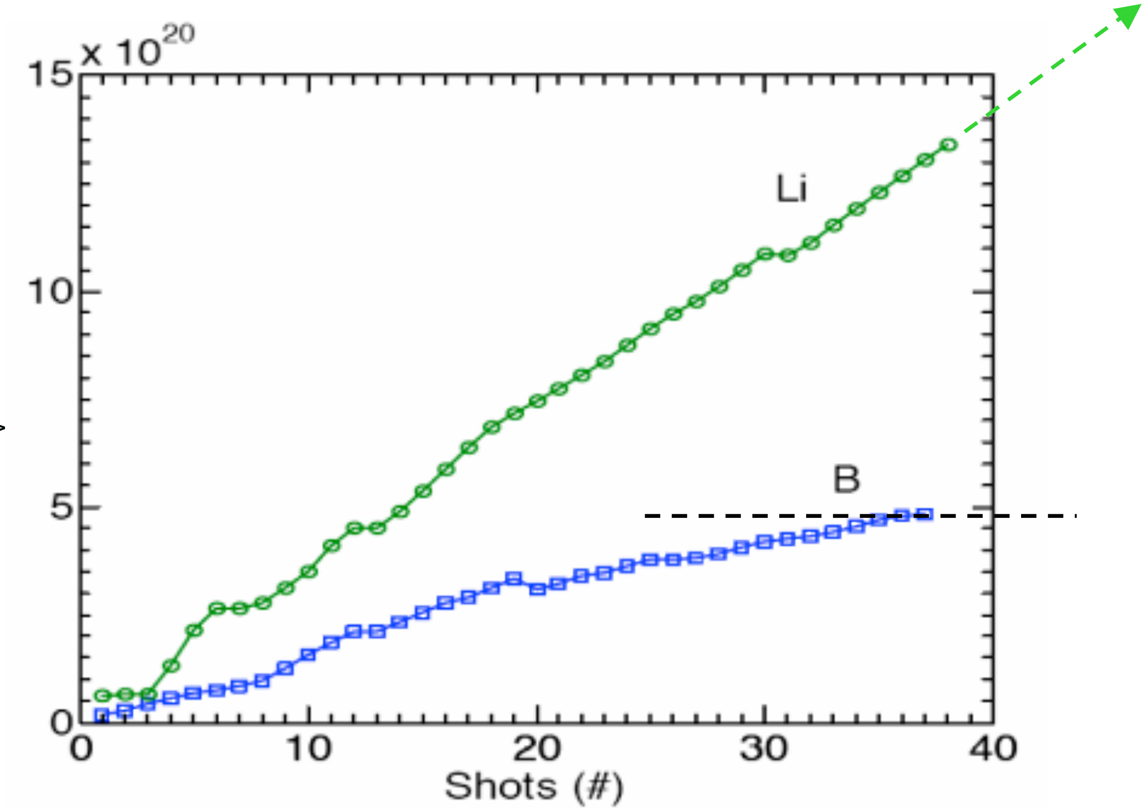
Particle Control Li vs B

Total wall inventory > 3 times, no sign of saturation



$H/Li \sim 4.10^{17} cm^{-2}$ → 80 nm, if H:Li=1!!

Lab. Experiments: 4.2 .10^{17} cm^{-2} @ 1.7 KeV (Sugai et al)

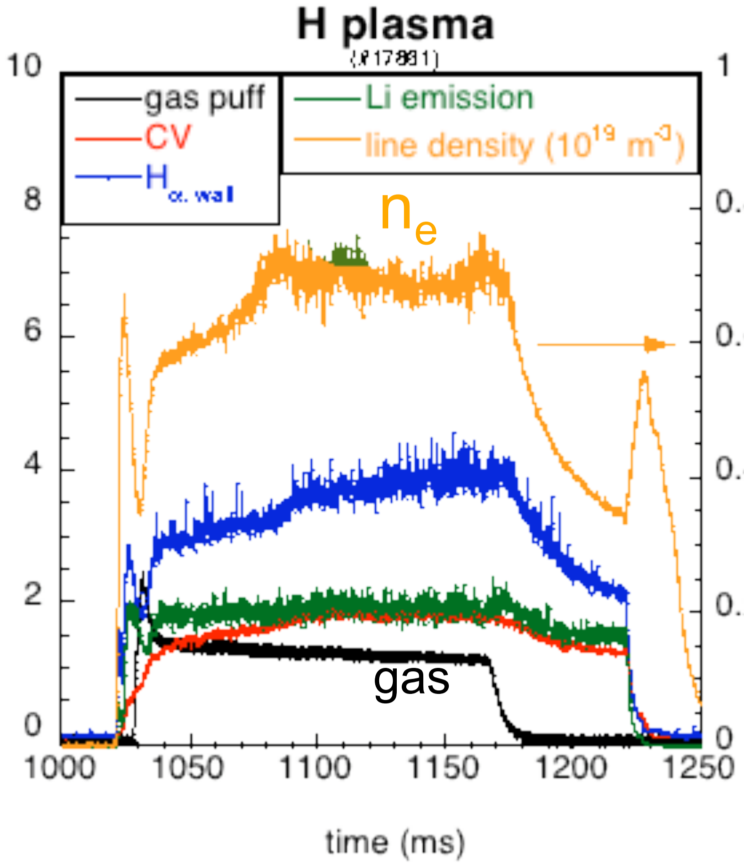
Dynamic particle balance

$$dN/dt= f.\ Qin-N/(\tau p/1-R)$$

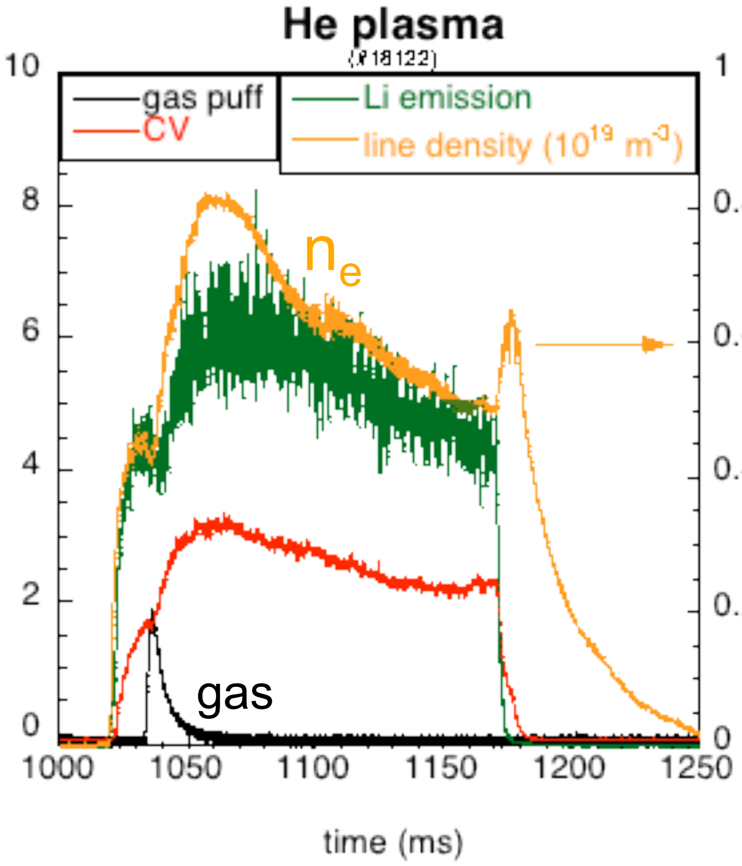
For ECRH plasmas:

f ~1, t $_{p}$eff ~8 ms, → R<0.2!!

He plasmas: R<1!!,
enhanced contamination



H plasma



He plasma

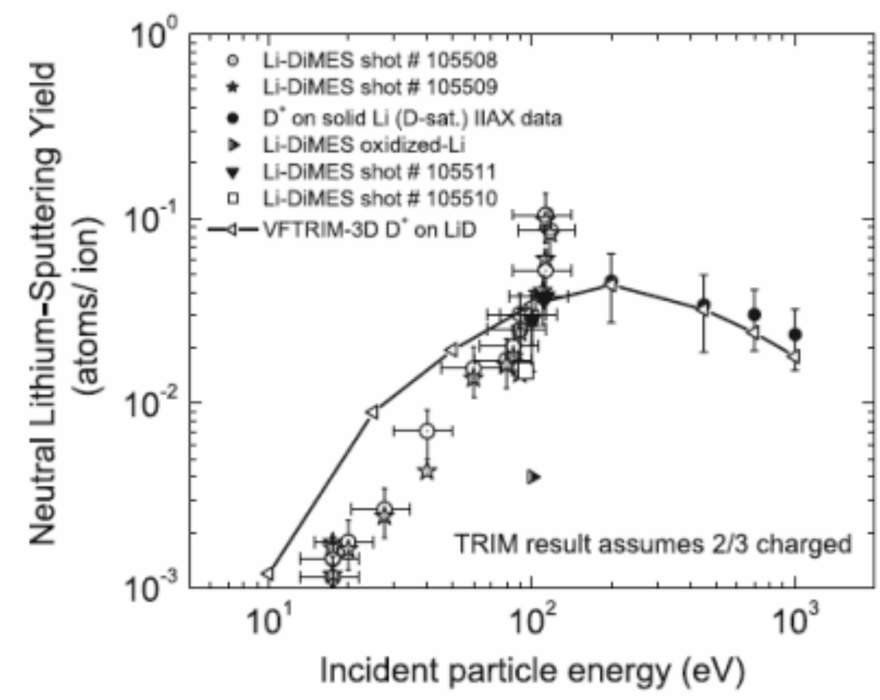
Impurity composition/generation

- From spectroscopy, Φ_{Li}/Φ_H ~0.44%
- for R=20%, Φ_{Li}/Φ_H ~9.10^{-4}

Impurity (Li) generation

But…expected?:

- $Li/H= S_H/1-S'_{ss}$, $S'_{ss}= S_{ss}-(1-Rn)$
- Li/H_{sputt}~3.10^{-2}



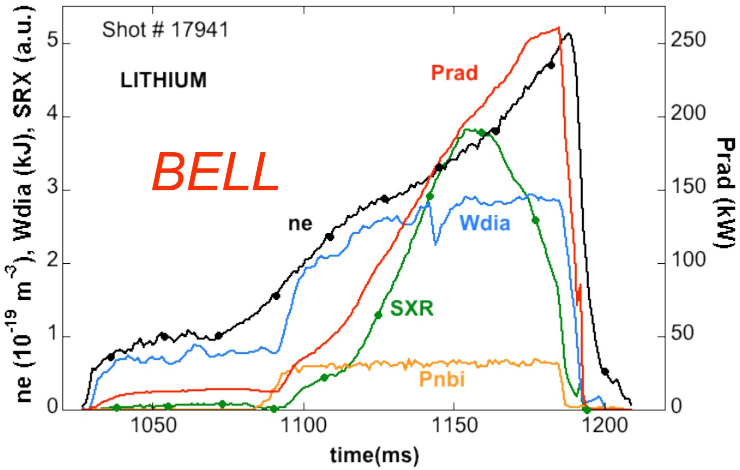
→ Reduction>30x!!

Efect of underlying coating?

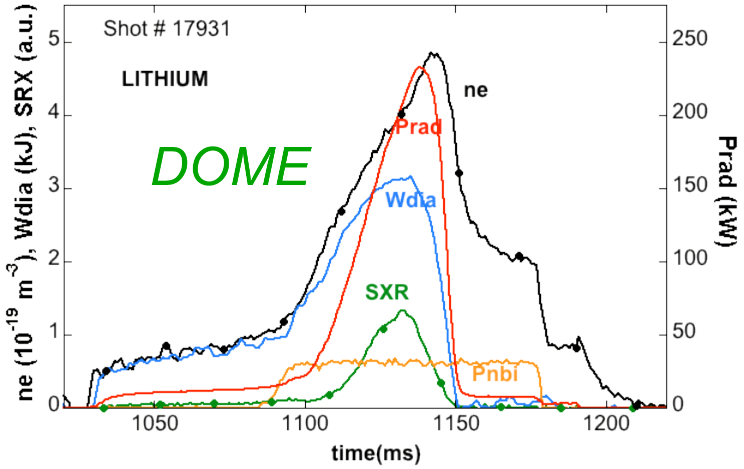
Profile shape: impurity & n_e behavior

same global parameters but...

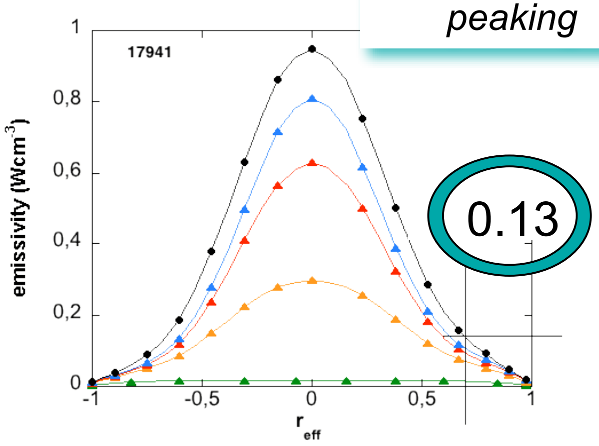
non collapsing

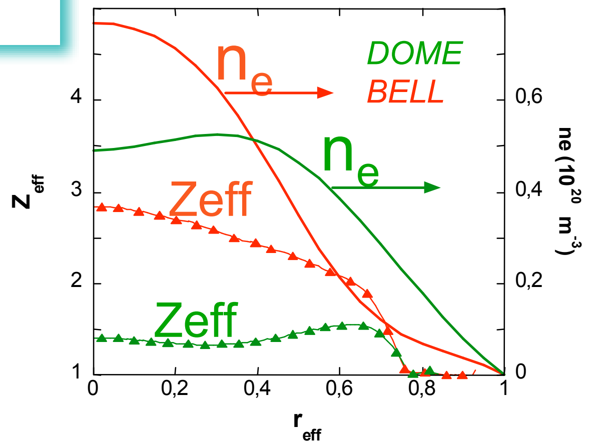


Prone to collapse

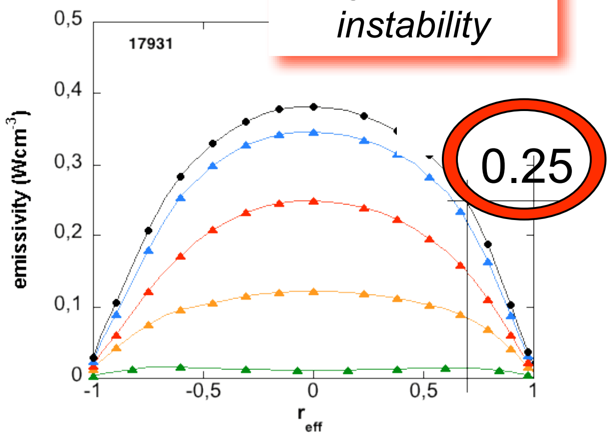


central impurity peaking

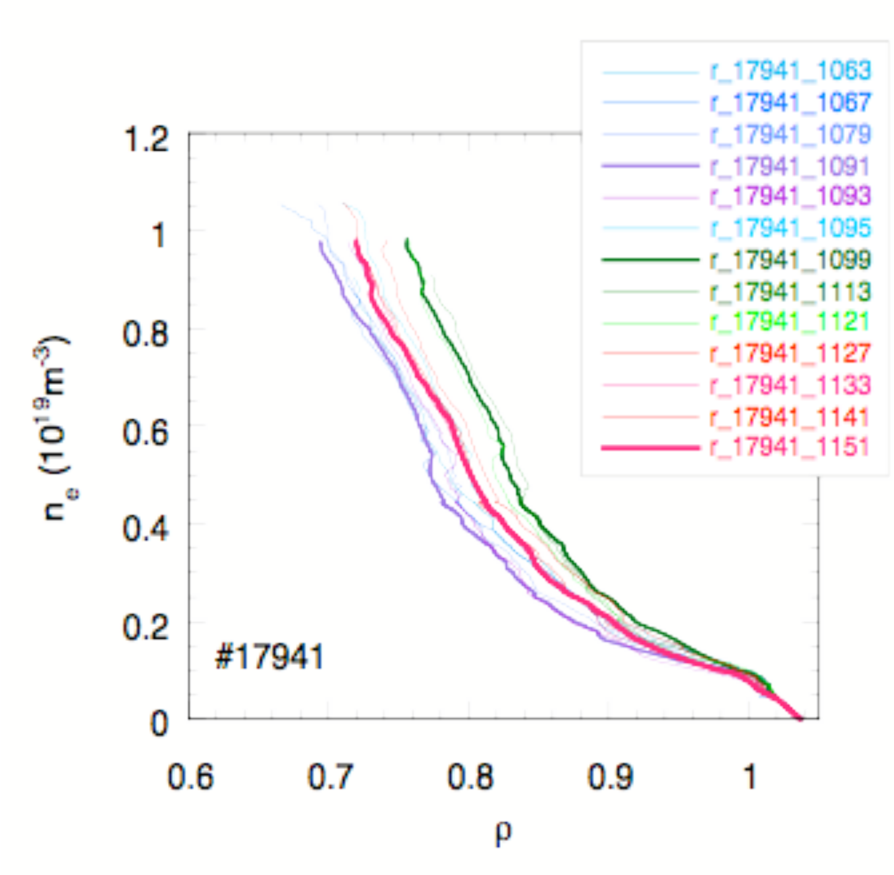




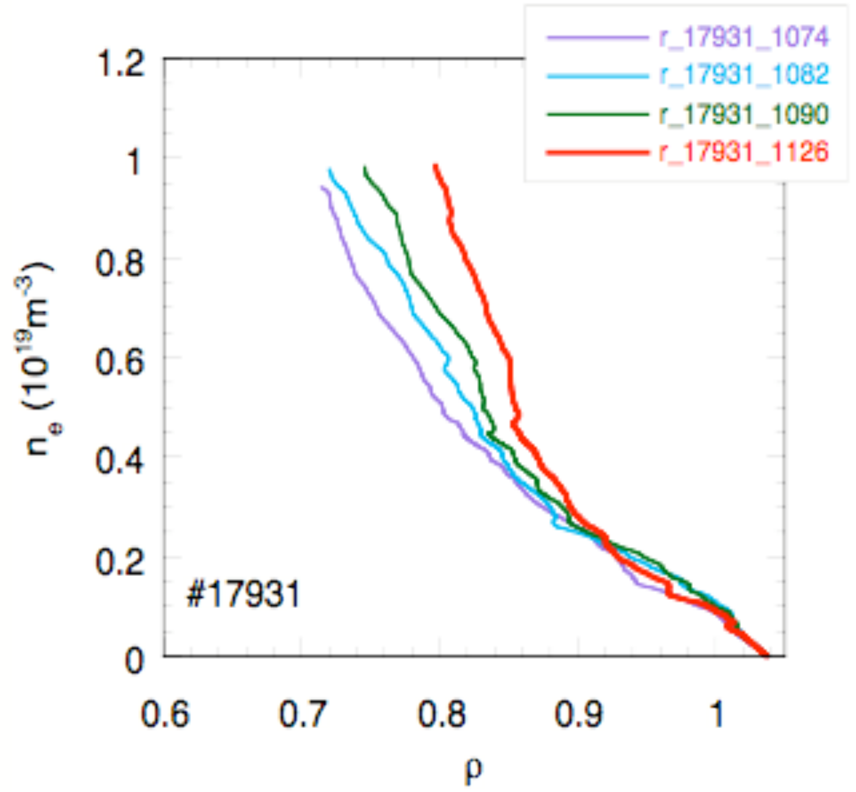
edge thermal instability



Edge profile evolution

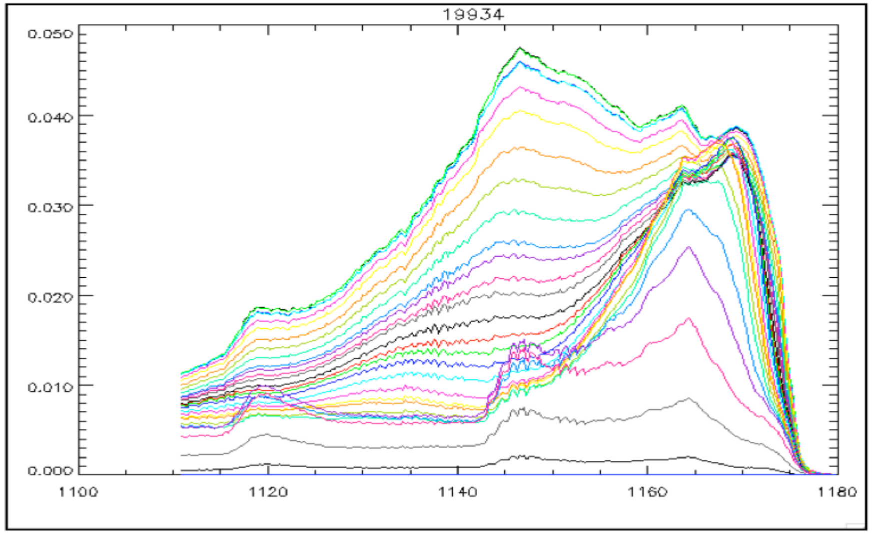


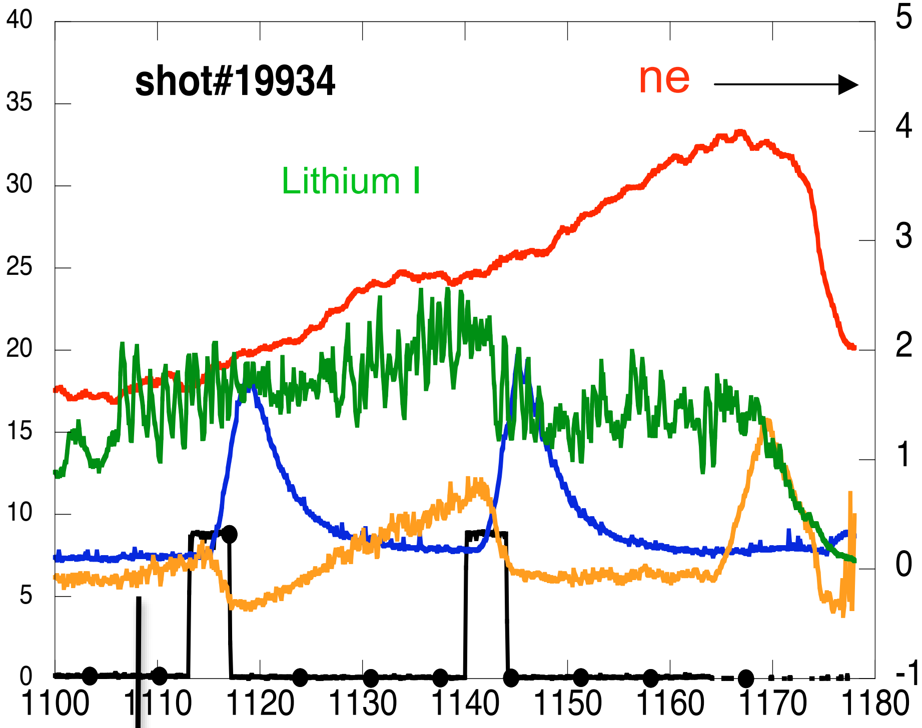
BELL



DOME

Plasma profile control by puffing

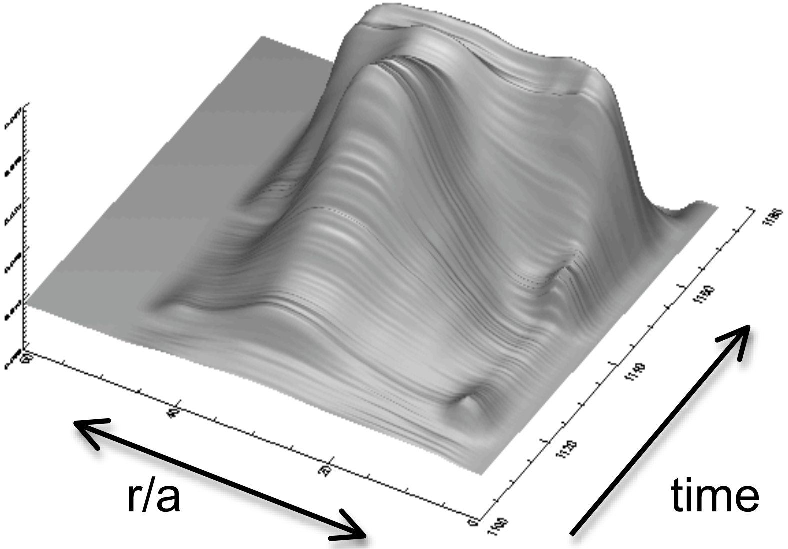




Radiation peaking:

bell

dome



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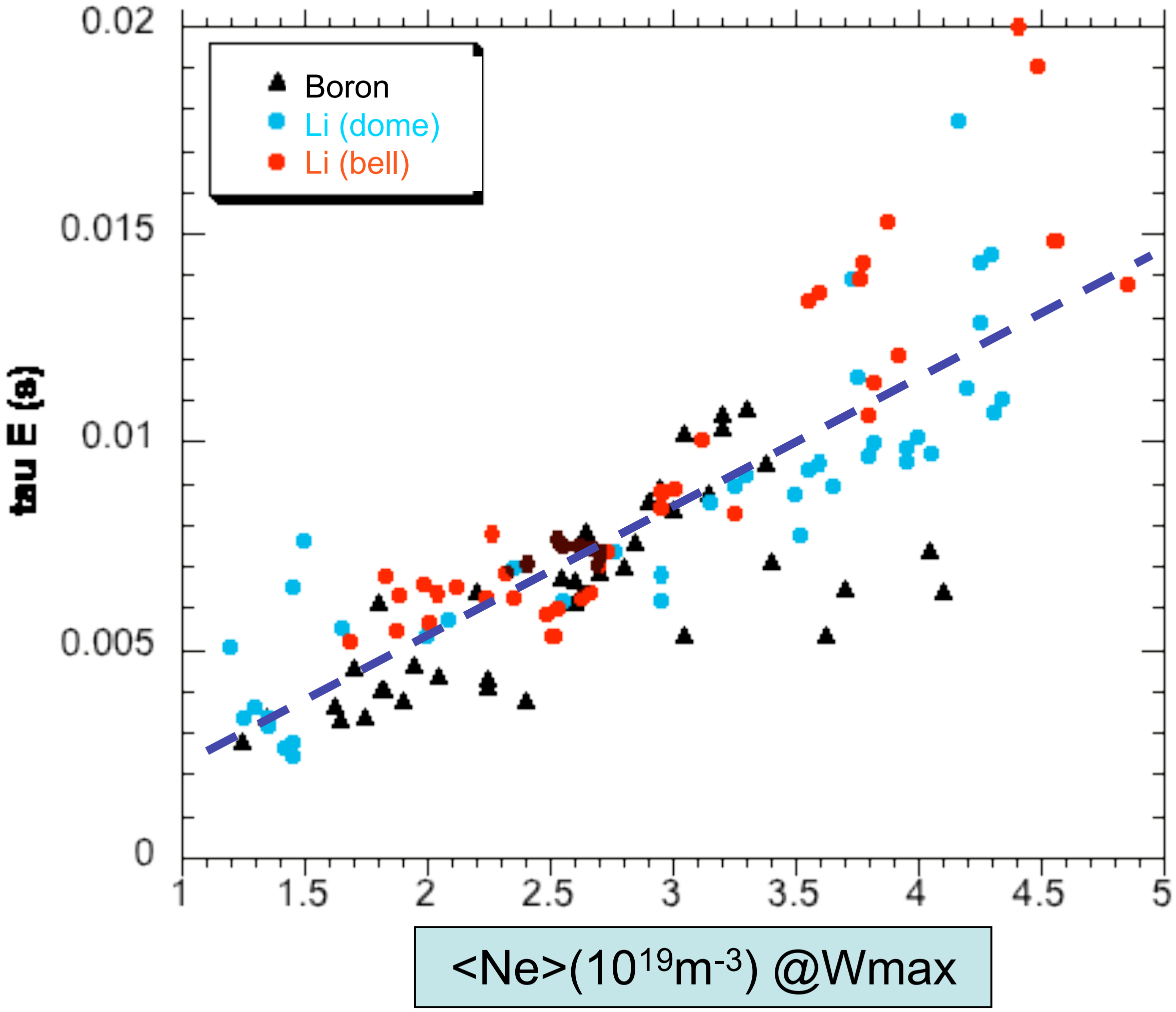
Energy Confinement



Energy Confinement

$$\tau_E=W_d/(P_{abs}-P_{rad})$$

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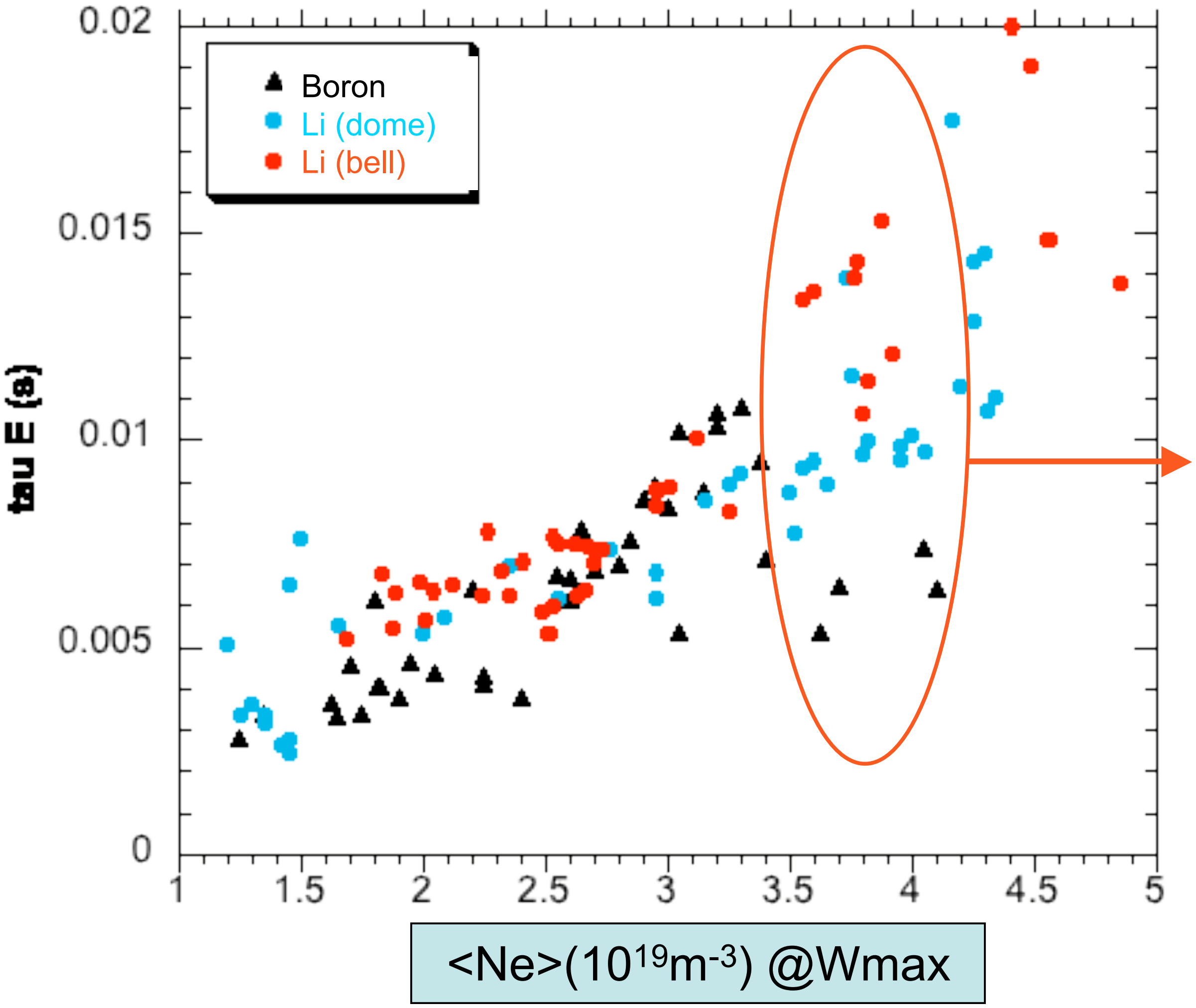
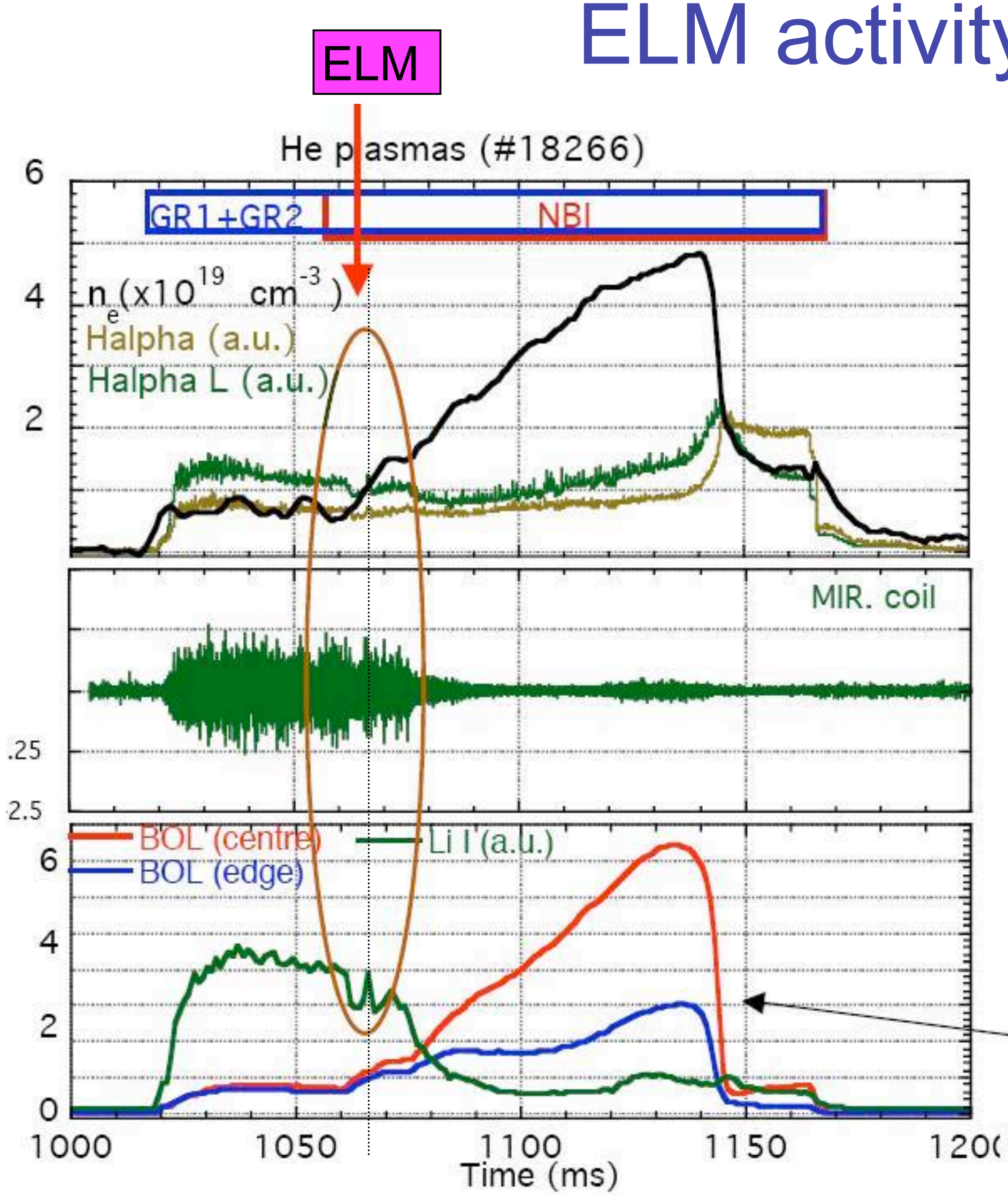


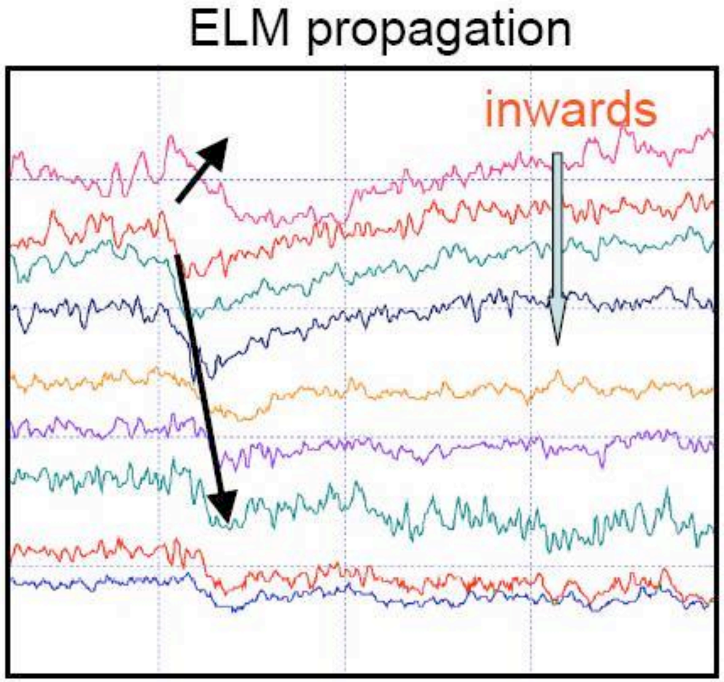
Energy Confinement

$\tau_E = W_d/(P_{abs} - P_{rad})$

B < Li Dome ~ Li Bell

ELM activity and transitions

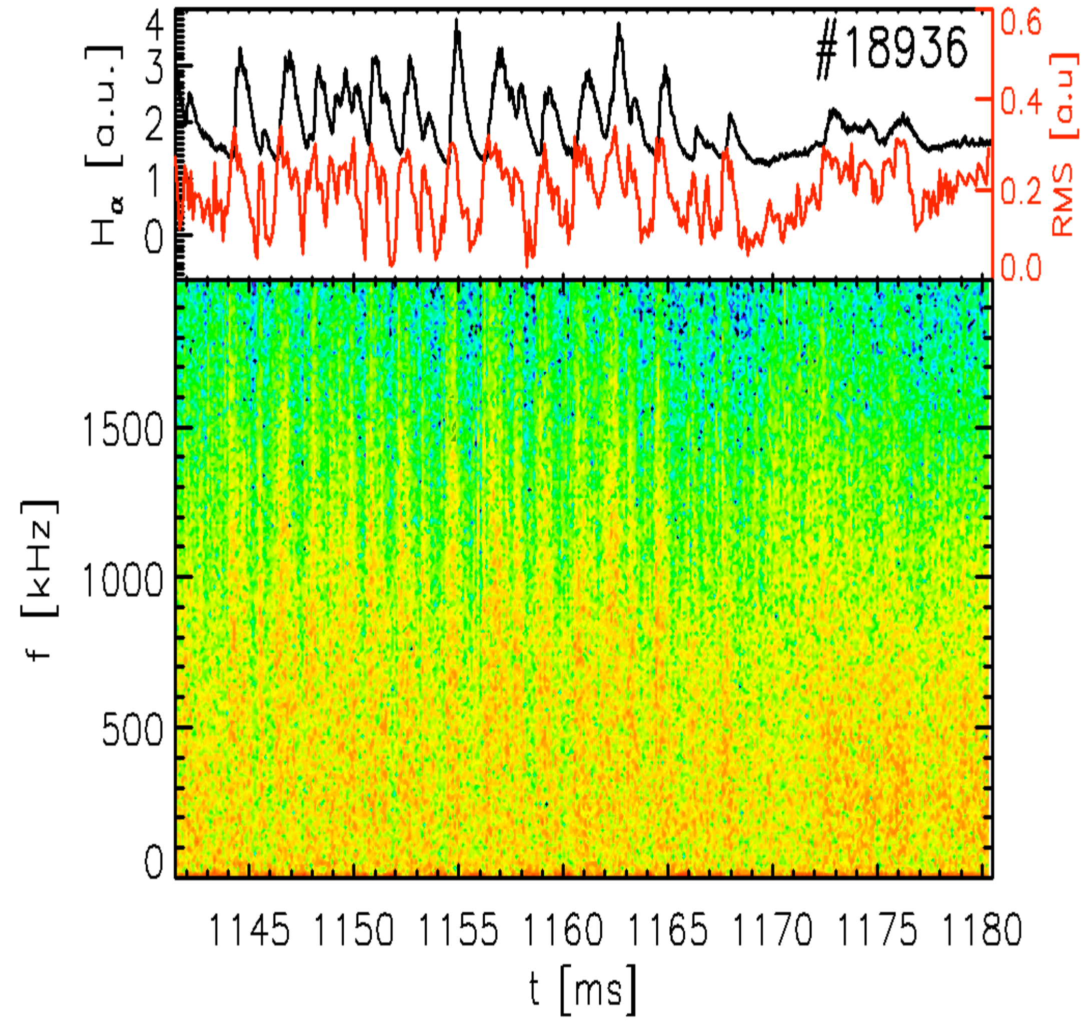


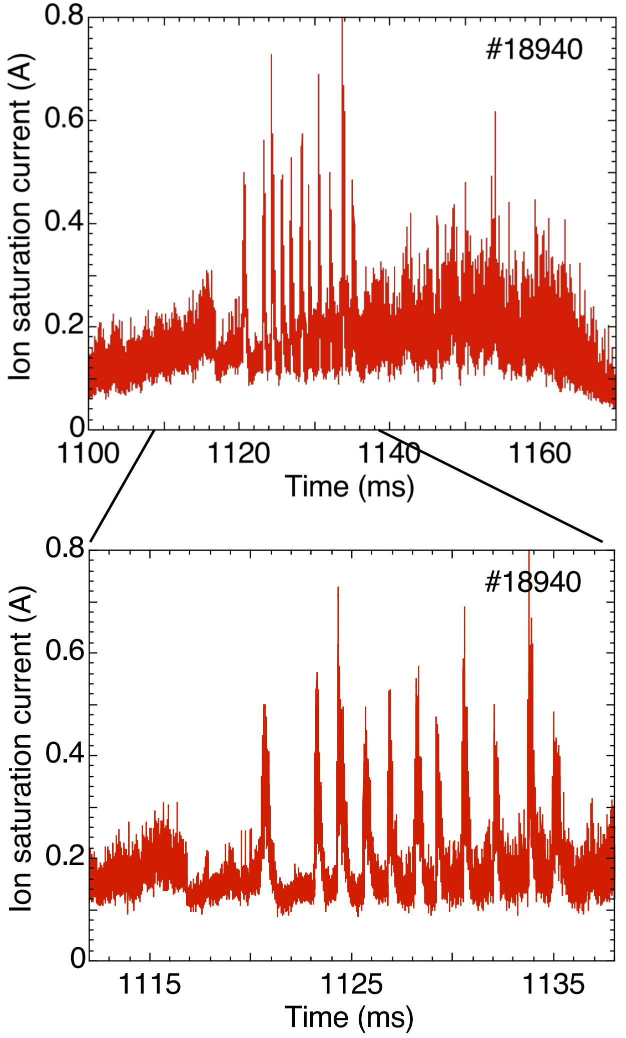


Ballistic cold pulse from r/a~0.6
Δt~300μs

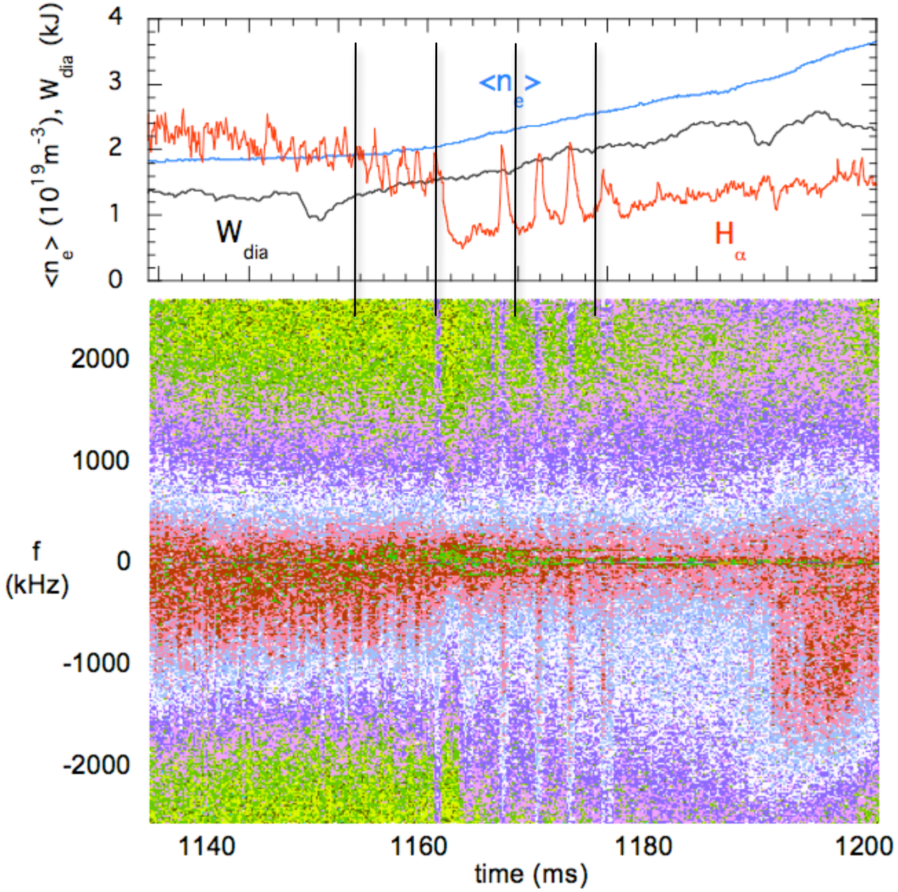
Ratio P_{rad} central/edge
strongly changing:
Profile peaking

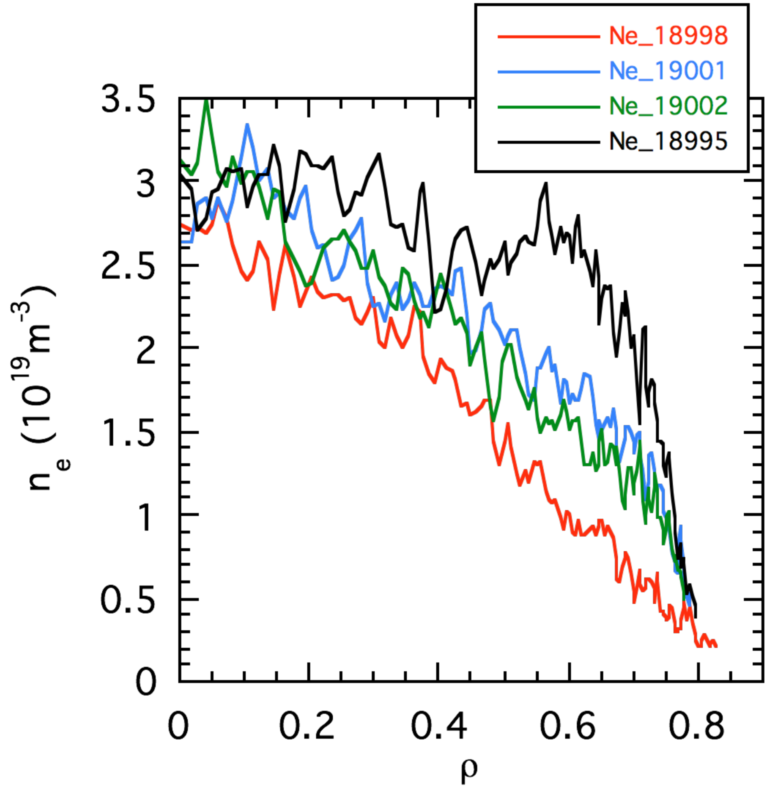
Density Fluctuations



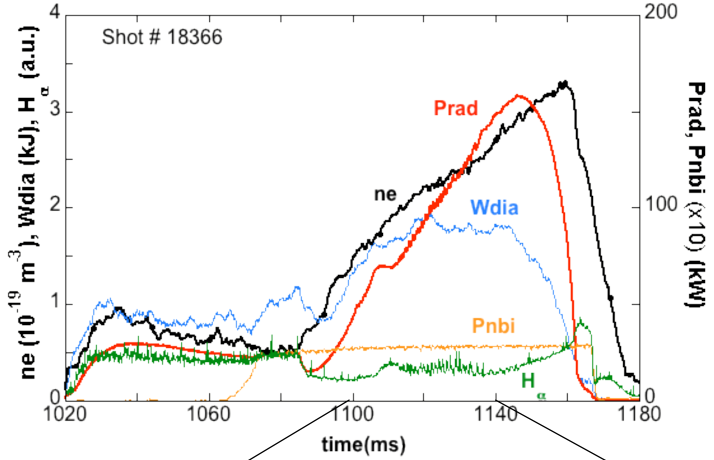


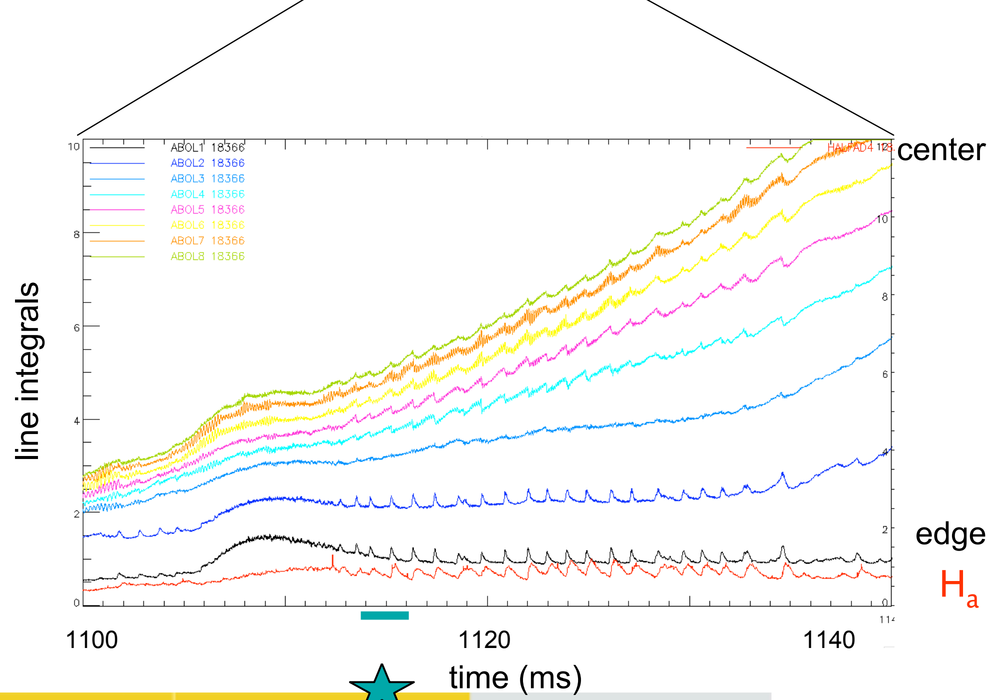
L-H Transition



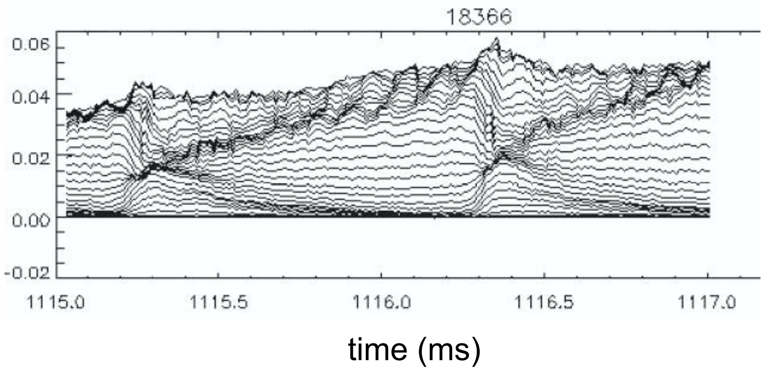


"*Sawtooth*" activity





sawtooth-like events



unfiltered photodiodes to visualize the whole plasma cross-section

+Toroidal rotation as a rigid body

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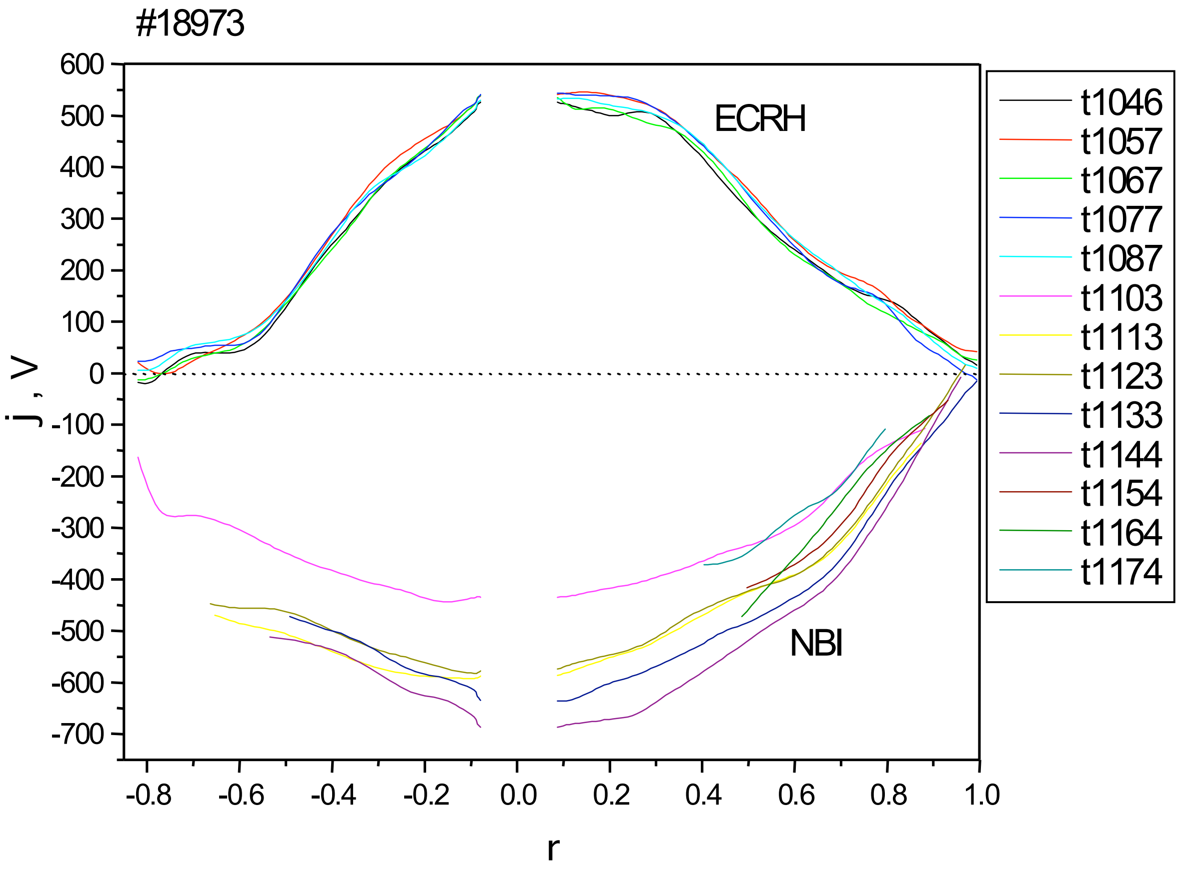
Radial electric field in ECRH and NBI regimes



NBI on

There is a transition in the structure of plasma potential from pure ECRH to NBI plasmas. Negative edge radial electric fields can reach values in the order of 100 V/cm in the NBI phase.

Conclusions

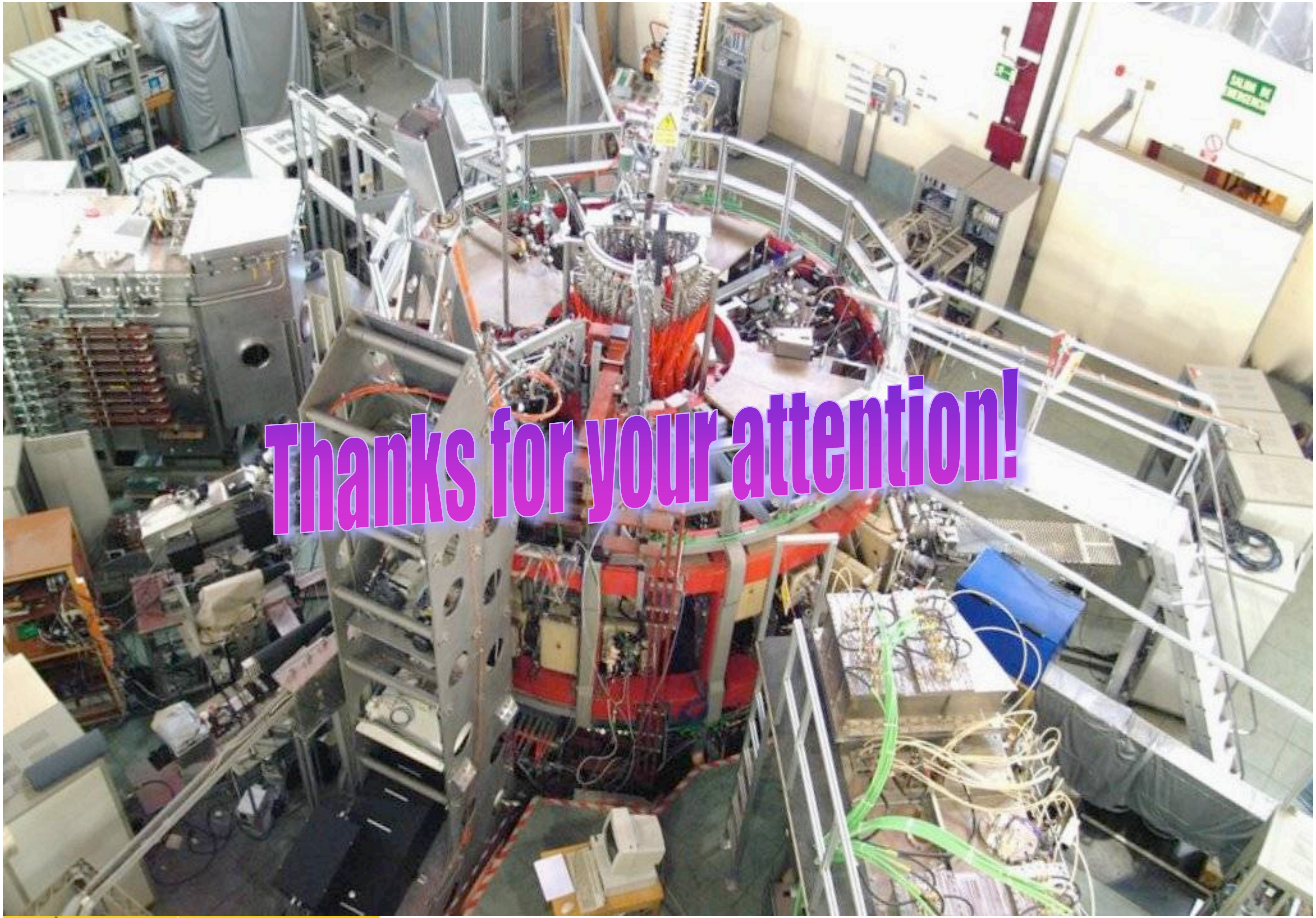
- Li coating by evaporation was performed in TJ-II.
- Only a partial coverage initially achieved, but evolved with plasma interaction
- Machine operation more reliable and reproducible

→ Extended operational window

- Density control highly improved, long lasting effect
- Strong change in particle recycling: very low R obtained!
- Good impurity control, but still C dominated (?)
- Strong confinement improvements in NBI plasmas.
- Sawtooth and ELM-like activity observed during transitions to enhanced confinement modes (L-H Transition)
- Change in plasma profiles controlled by fuelling strategy

Improvement of technique still possible:

Full Li wall (CPS?) + SMB fuelling in preparation



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