Energy and Particle Balance under boron and lithium coated walls in TJ-II

(searching for specific Li effects)

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CIEMAT

Outline

- Background
- Energy Balance
- Profile evolution and control
- Impurity production
- Conclusions

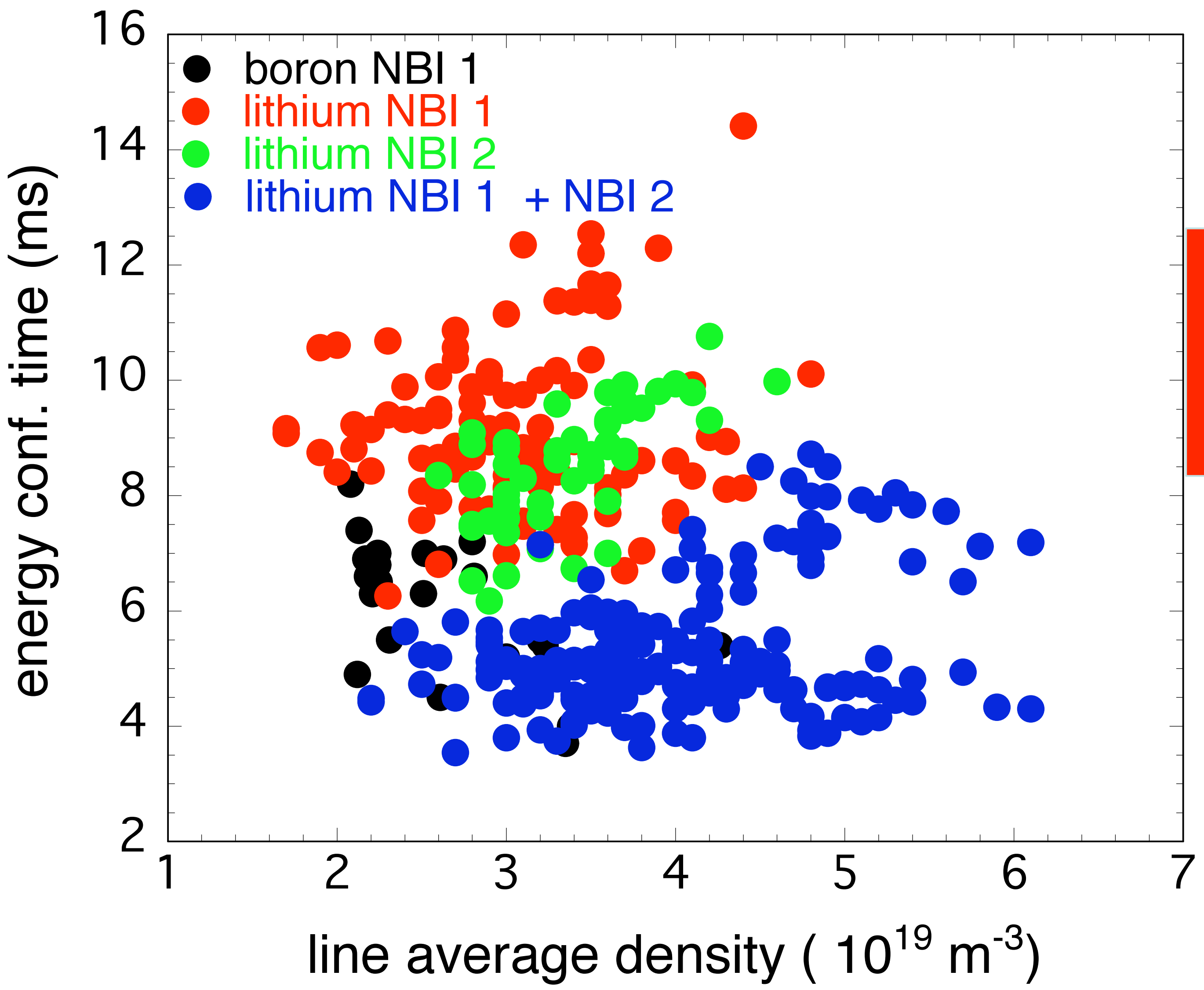
Background

- Two years of operation of TJ-II under Li walls (first report at ISHW Toki) : ~6000 shots
- Reference campaign with B walls: one NBI+ ECRH
- Improvement of coating lifetime by underlying B coating
- Presently, refreshing of Li coating from containers under vacuum: up to 6 coating cycles
- Experiments with B coating on top of Li (2009)

Main results: (F. *Tabarés et al PPCF 08, J.Sánchez et al, NF 2009)*

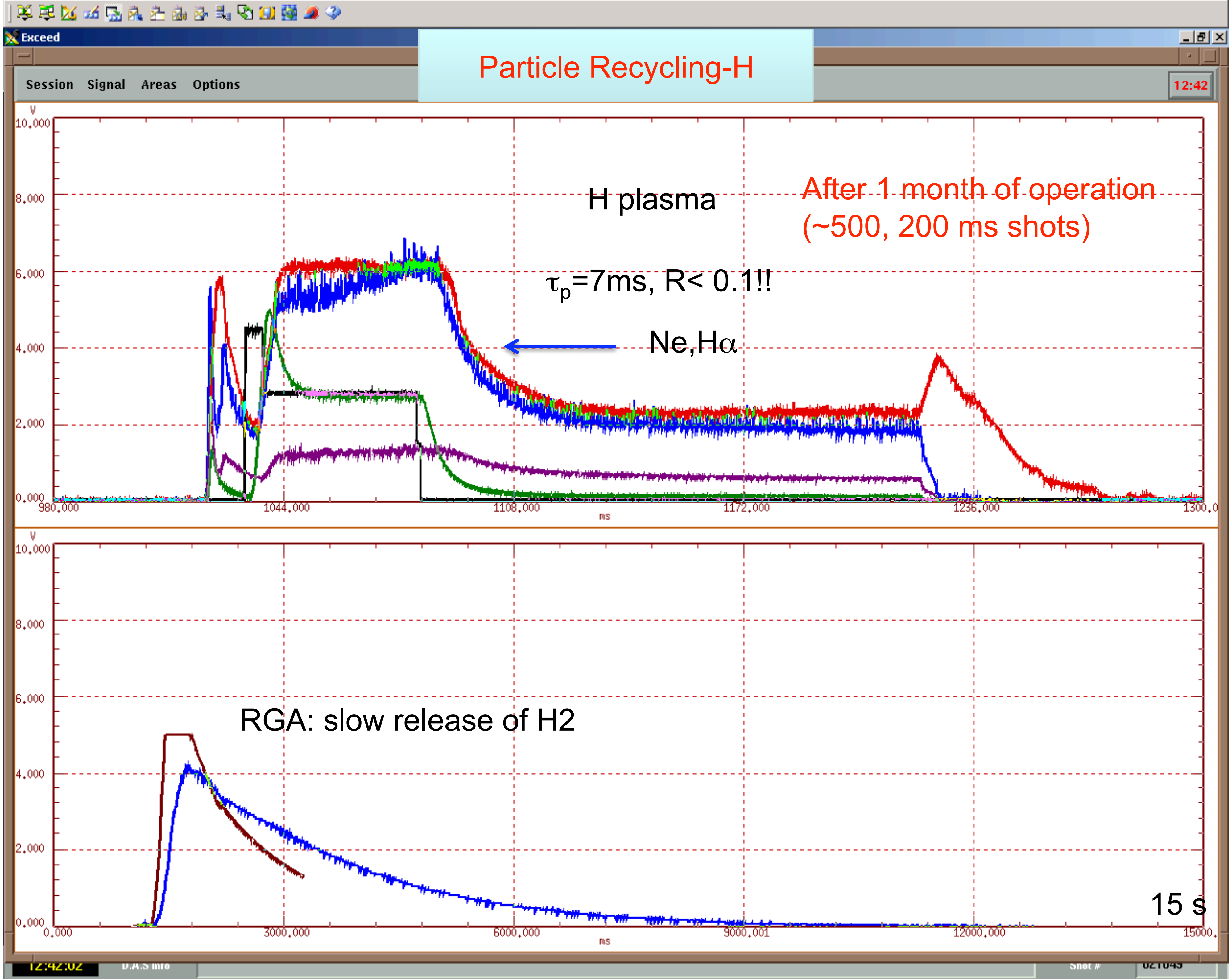
- Highly improved density control
- Routine operation under 2 NBI heated plasmas
-Transition to H mode (T. Estrada et al. I-23, M.A. Pedrosa, I-27 Thursday)
- Improved Confinement/E content (E.Ascasibar et al, P2-04, TJ-II poster PD-04)
- Development of peaked Profiles (this talk)
- Decreased LI sputtering yield (this talk)

Global E Confinement : B vs Li

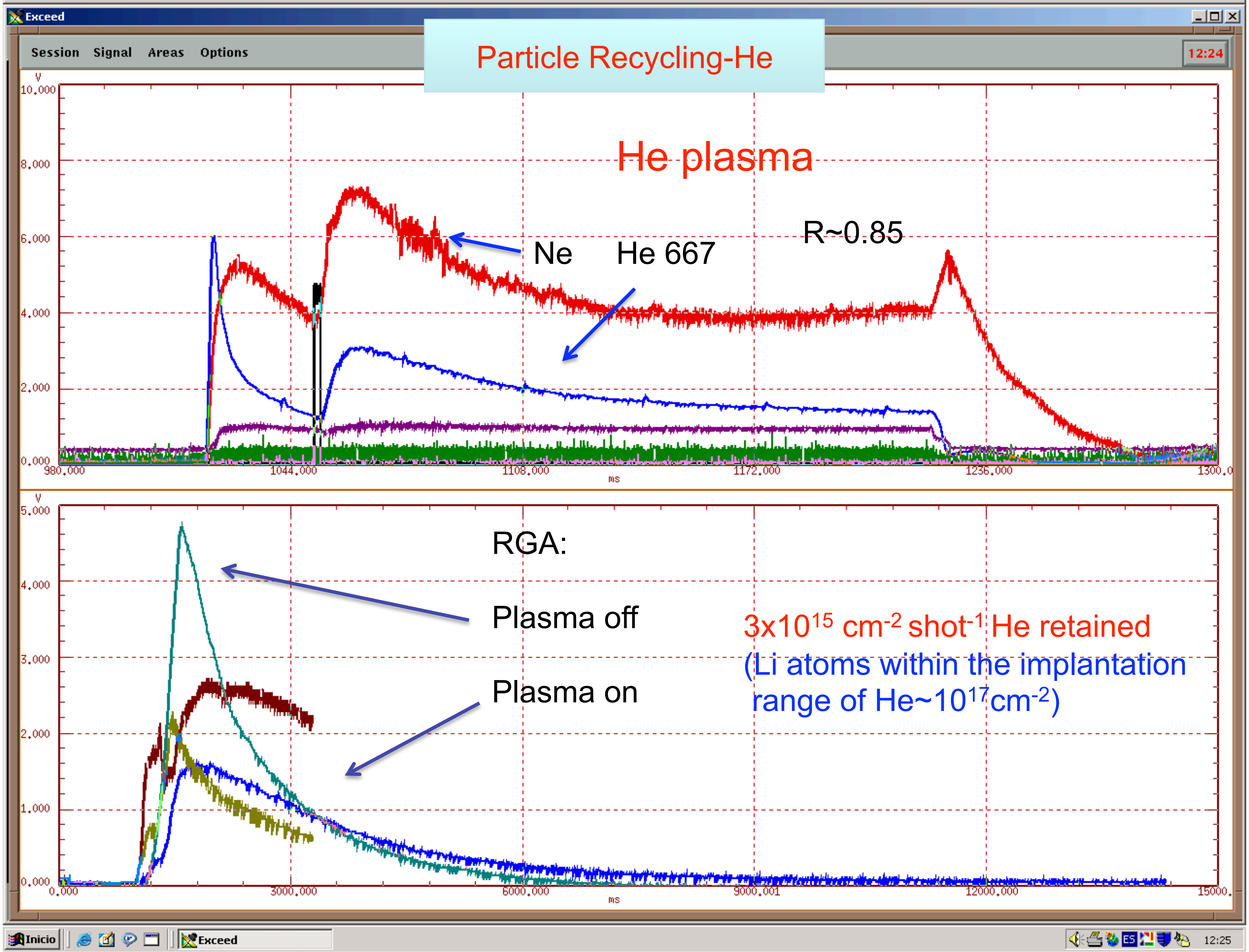


But:
Specific effects due to Li?

Particle Recycling-H

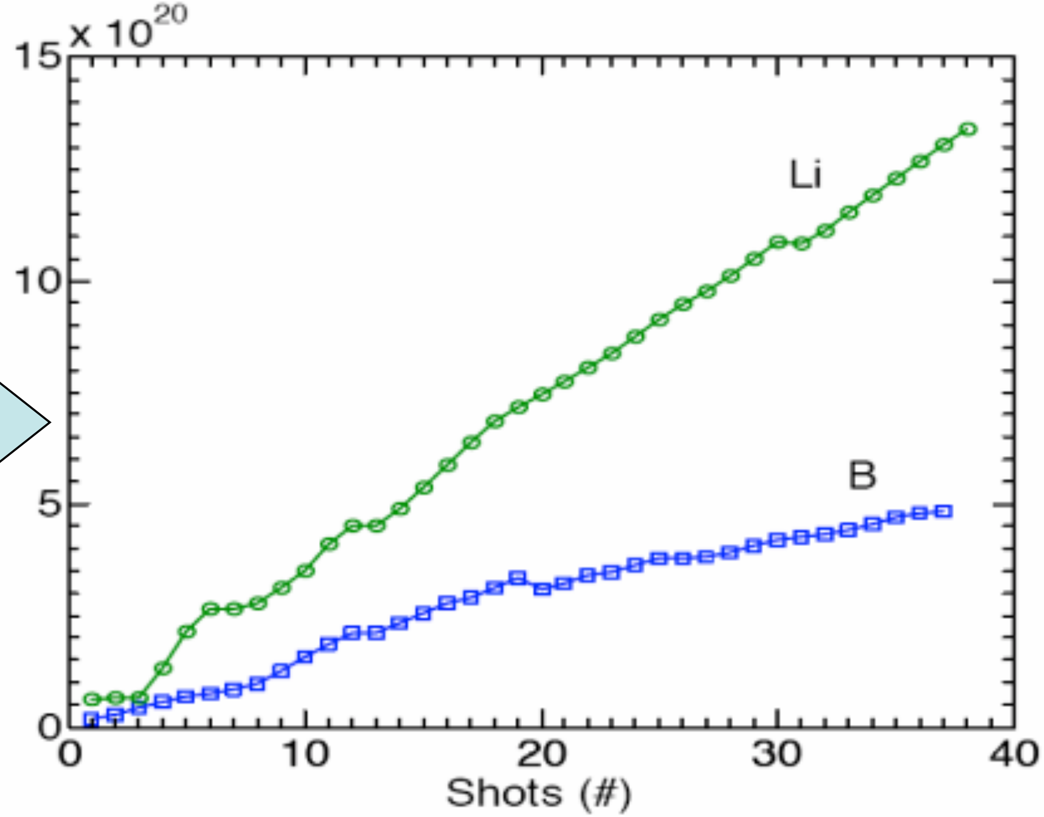


Particle Recycling-He

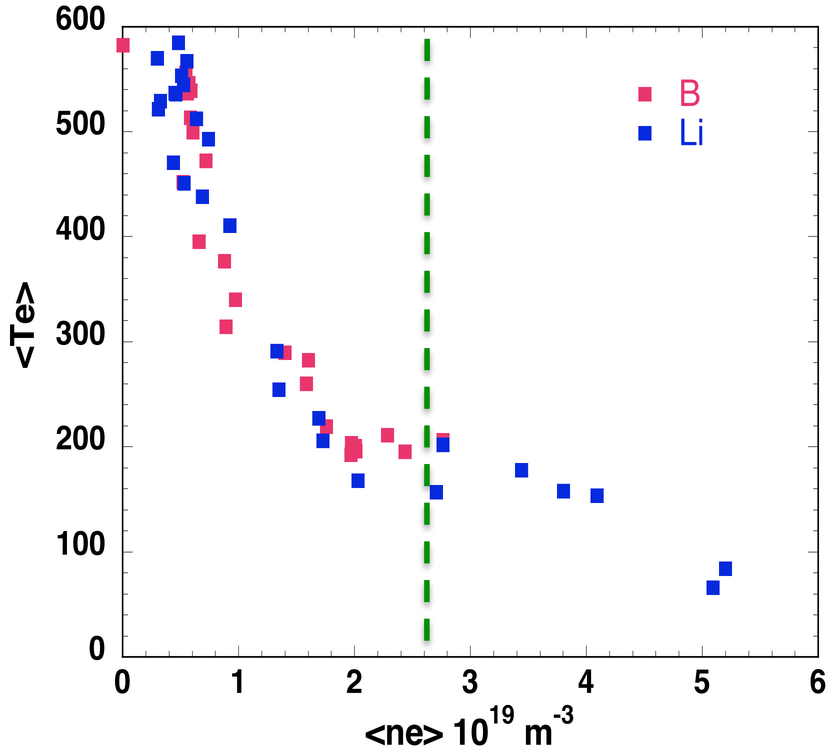


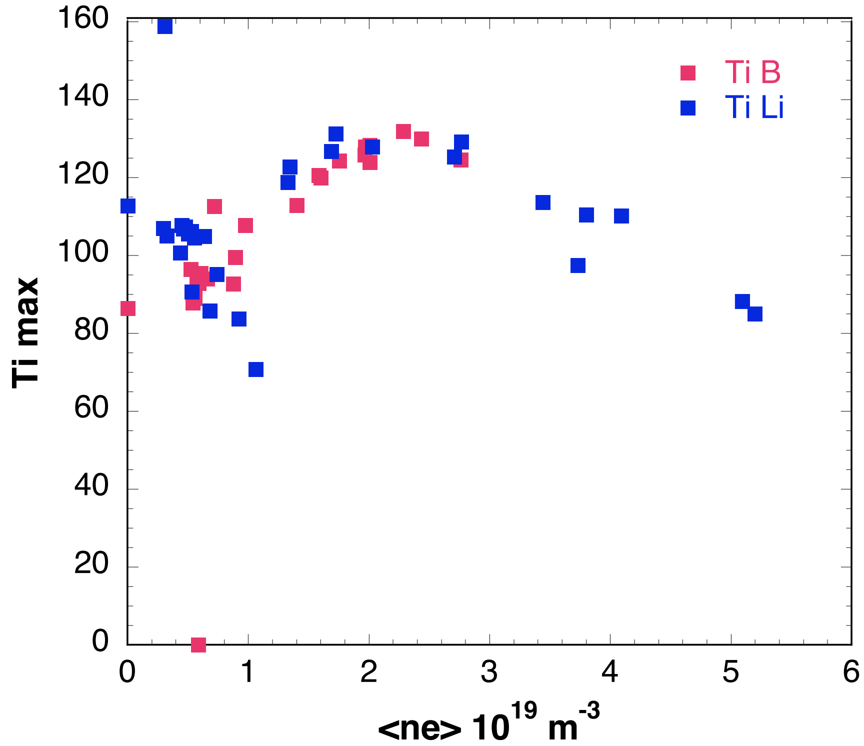
Particle inventory Li vs B

Wall inventory
>Factor 3, no
sign of saturation



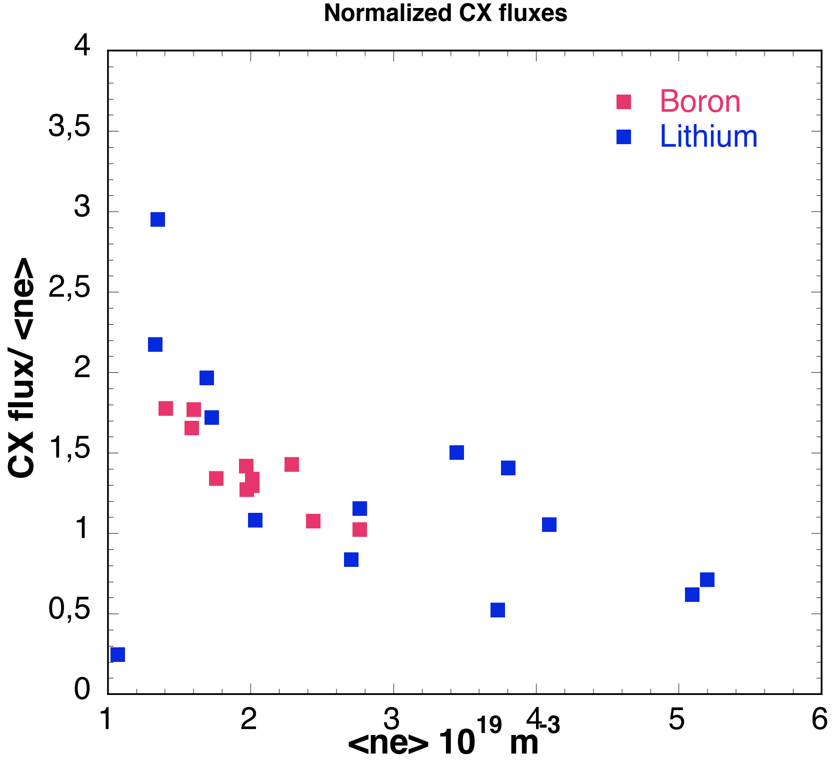
0-D Energy Global Balance: B vs Li

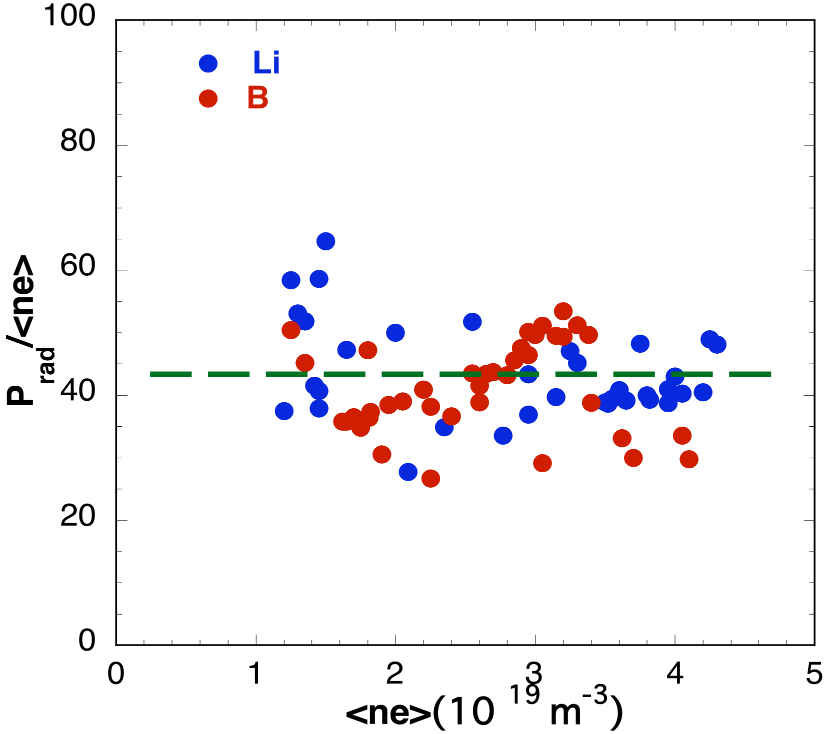




Similar values of Te and Ti for both coatings

Energy Losses



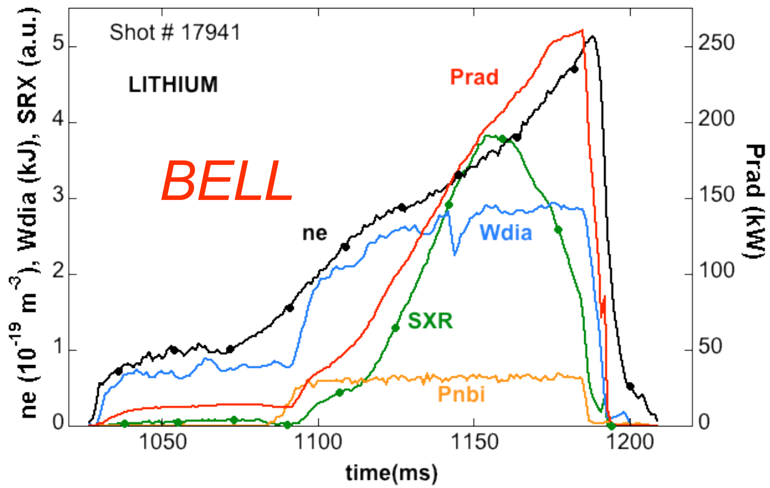


Similar values of electron and ion energy losses in both coatings

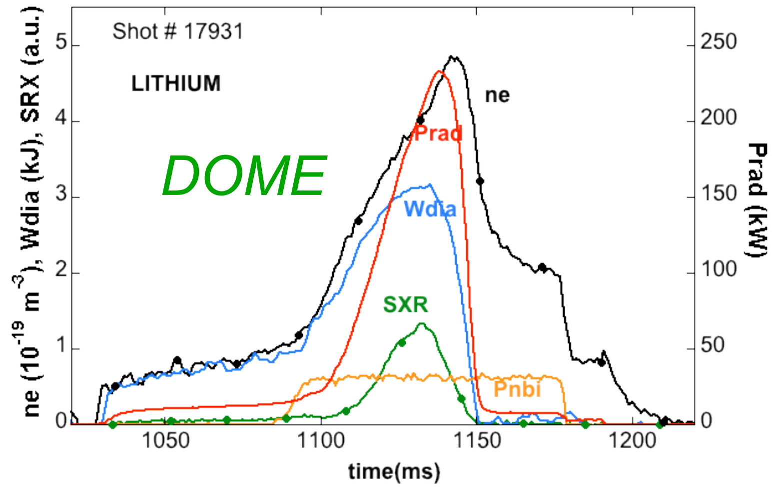
1-D effects: Plasma Profiles

same global parameters but...

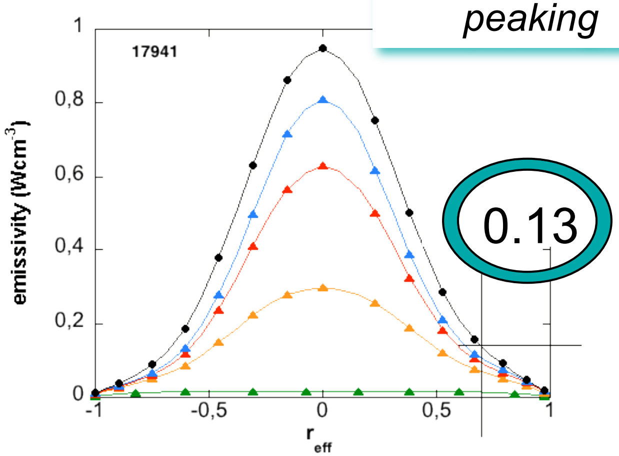
non collapsing

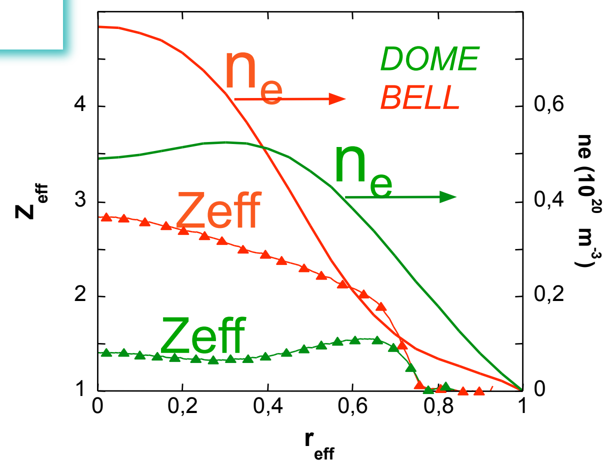


Prone to collapse

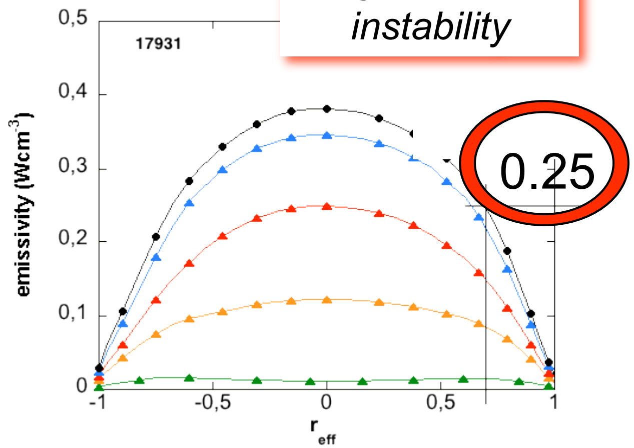


central impurity peaking



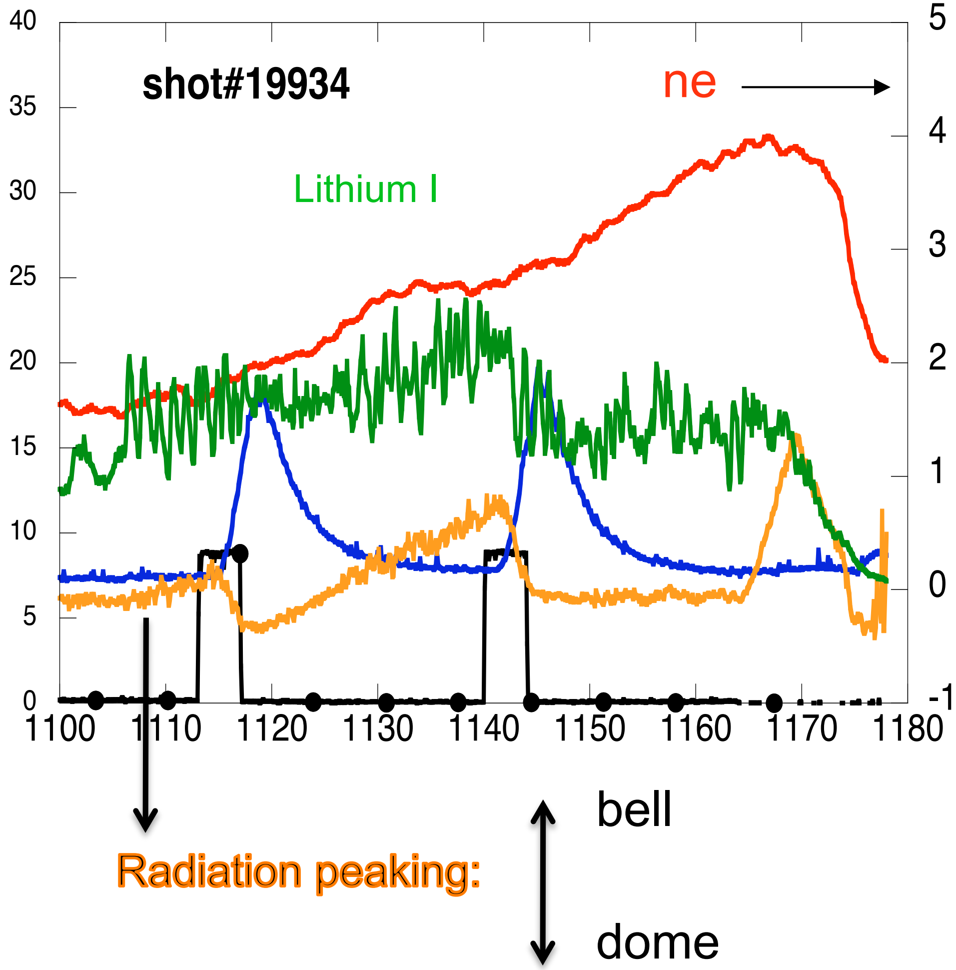


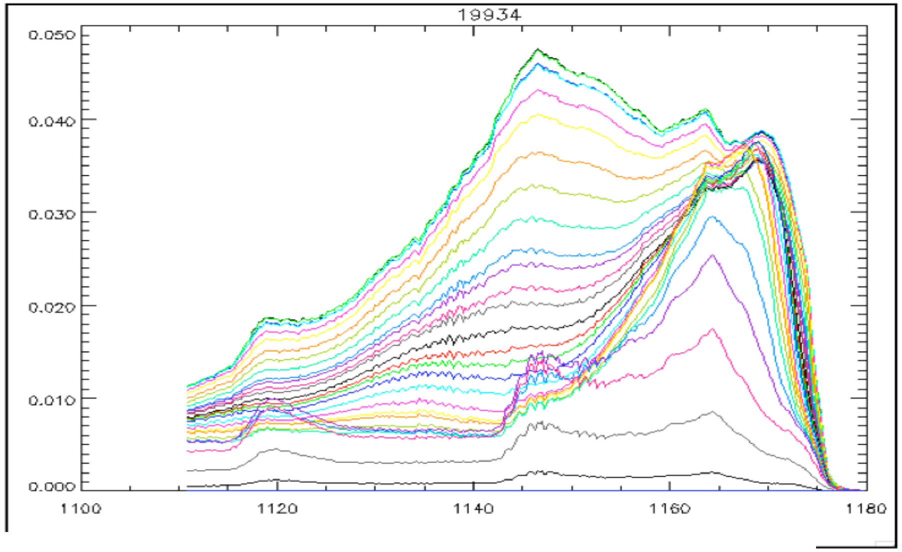
edge thermal instability

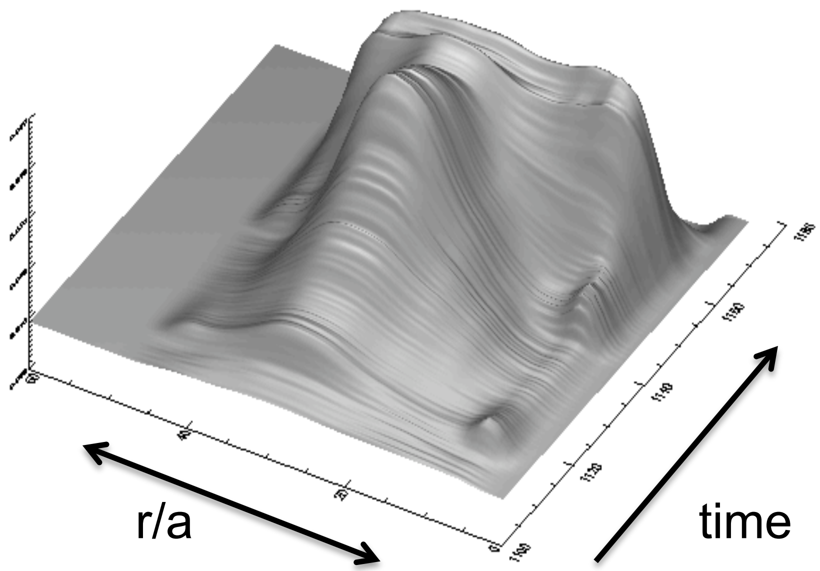


Controlling the plasma profile by small puffing-1

** Tabarés, Ochando, Medina et al, EPS 2009*







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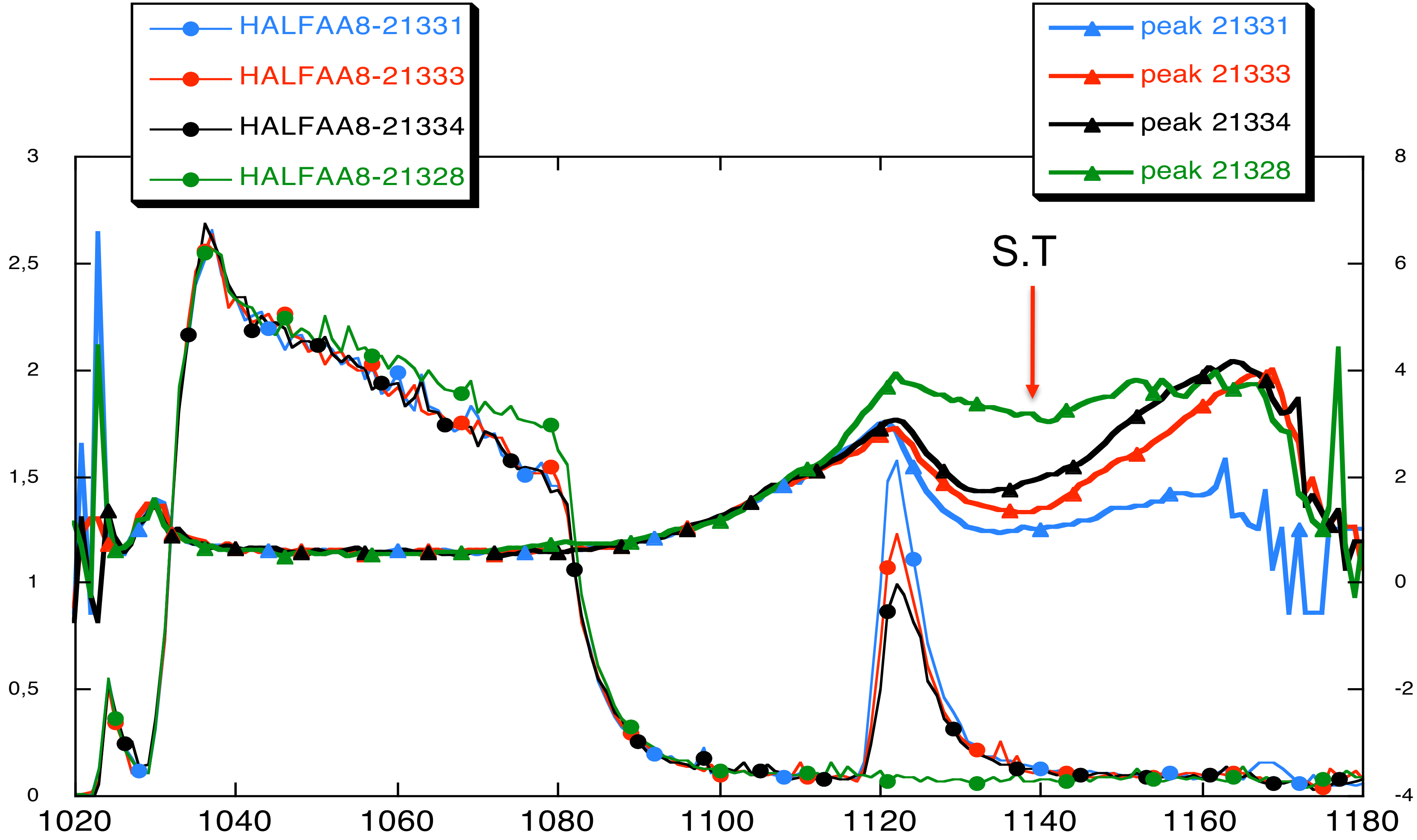
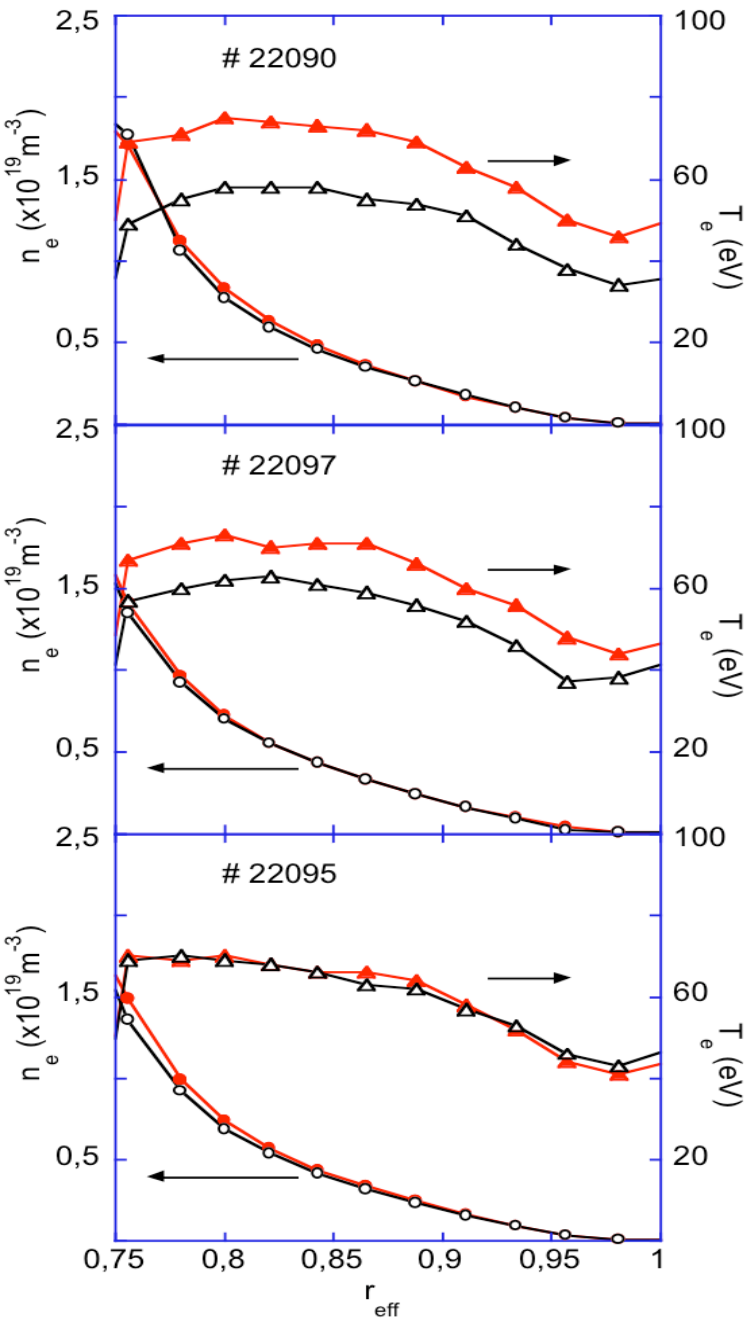
Controlling the plasma profile by small puffing-2





Edge effects

Correlation between edge cooling and transition to broad profiles

No difference (up to 15% seeding) in Ne/H_2 vs pure H_2 injection (?)

No significant increase of ne at the edge (but seen in ST profiles)

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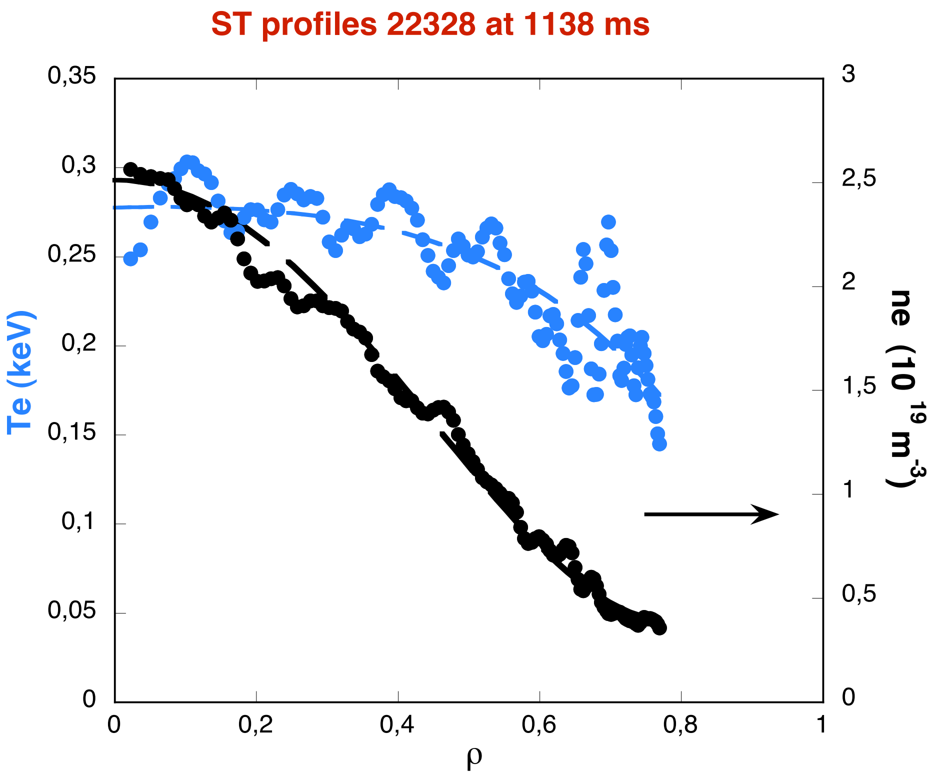
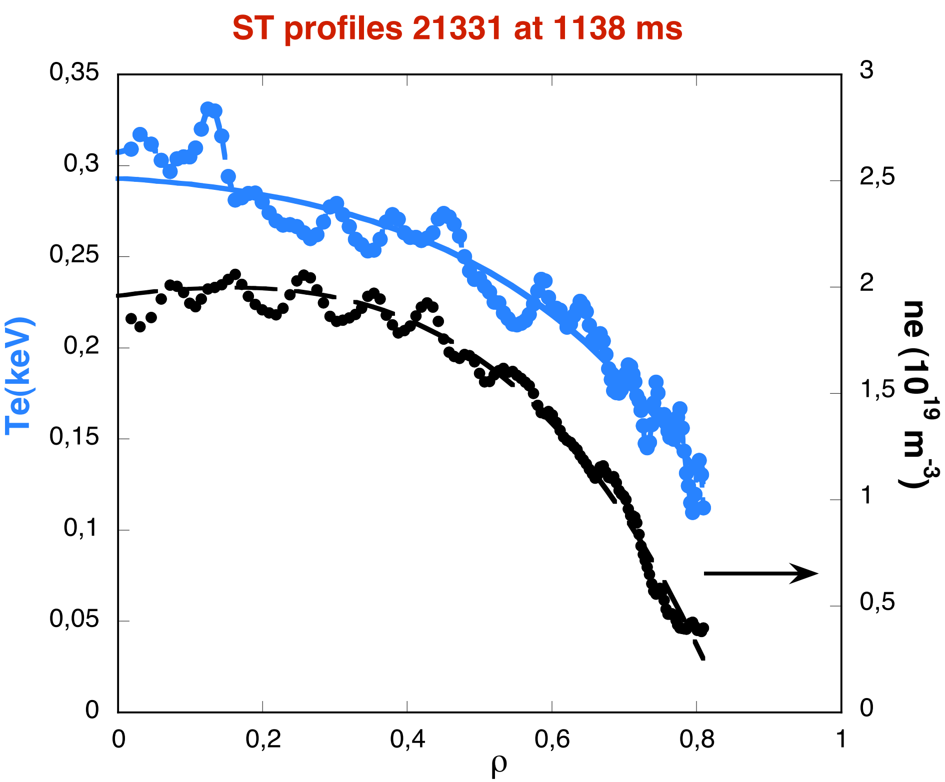
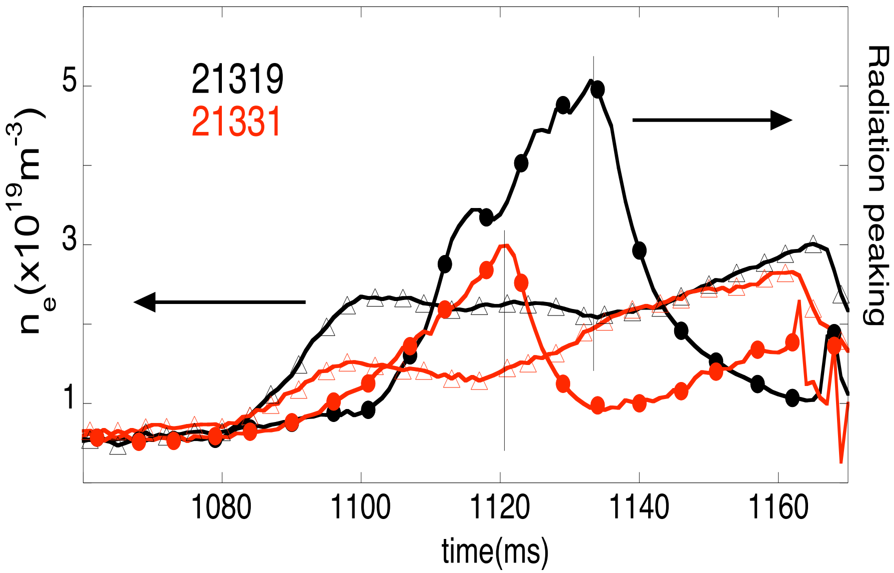
Bell

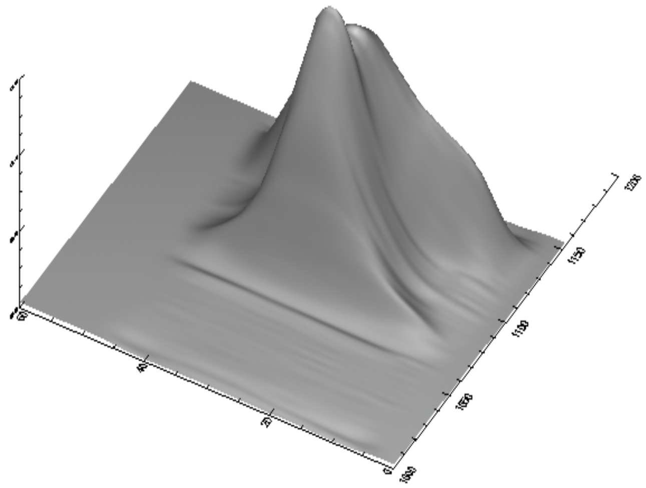


Dome

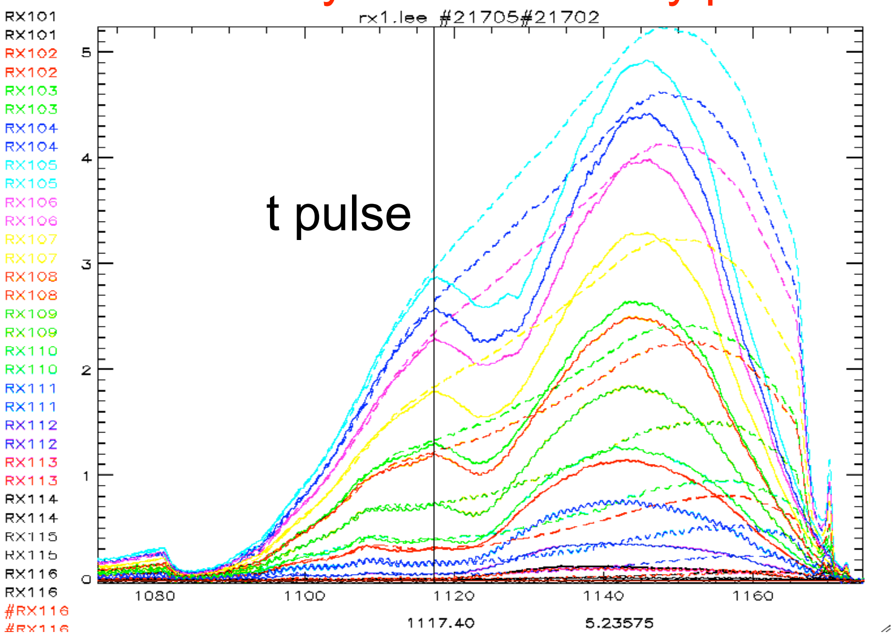


Effect of gas pulse:
Broadening of density profile+ electron cooling at r> 0.6





SXR array local emissivity profile



- Fast (~ τ_E) decay of peaking upon gas puffing
- Same for spontaneous an driven transitions
- Central channels quickly respond to cooling effect

Transition driven by decay of NBI central heating?

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Impurity Generation: Lithium Sputtering studies

Specific diagnostics:

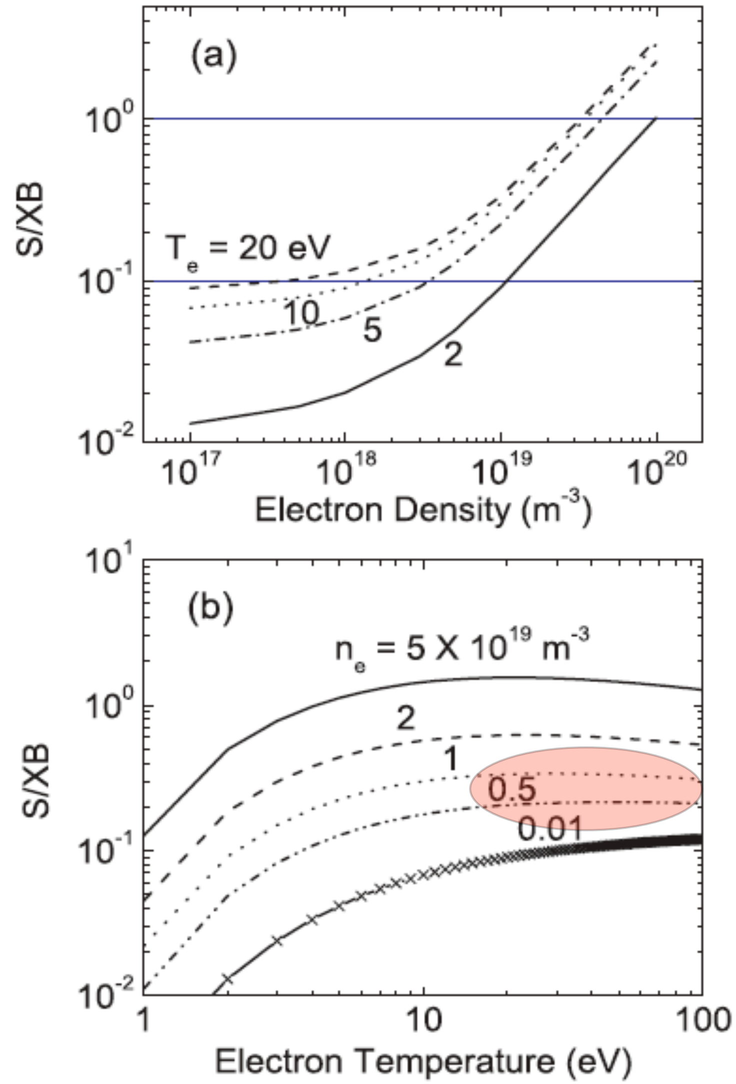
- Li emission at 671nm at the edge *Rel. Calibrated in situ*
- 6 Hα monitors
- Array of Li+ emmision at the edge: r/a: 1.05 to 0.75
- Edge ECE (ECRH plasmas)
- Supersonic He beam for ne and Te at the edge
- NPA for CX Ti determination

- ECRH and NBI plasmas: up to 800 kW heating power
- H and He plasmas
- Li/B and B/Li coatings

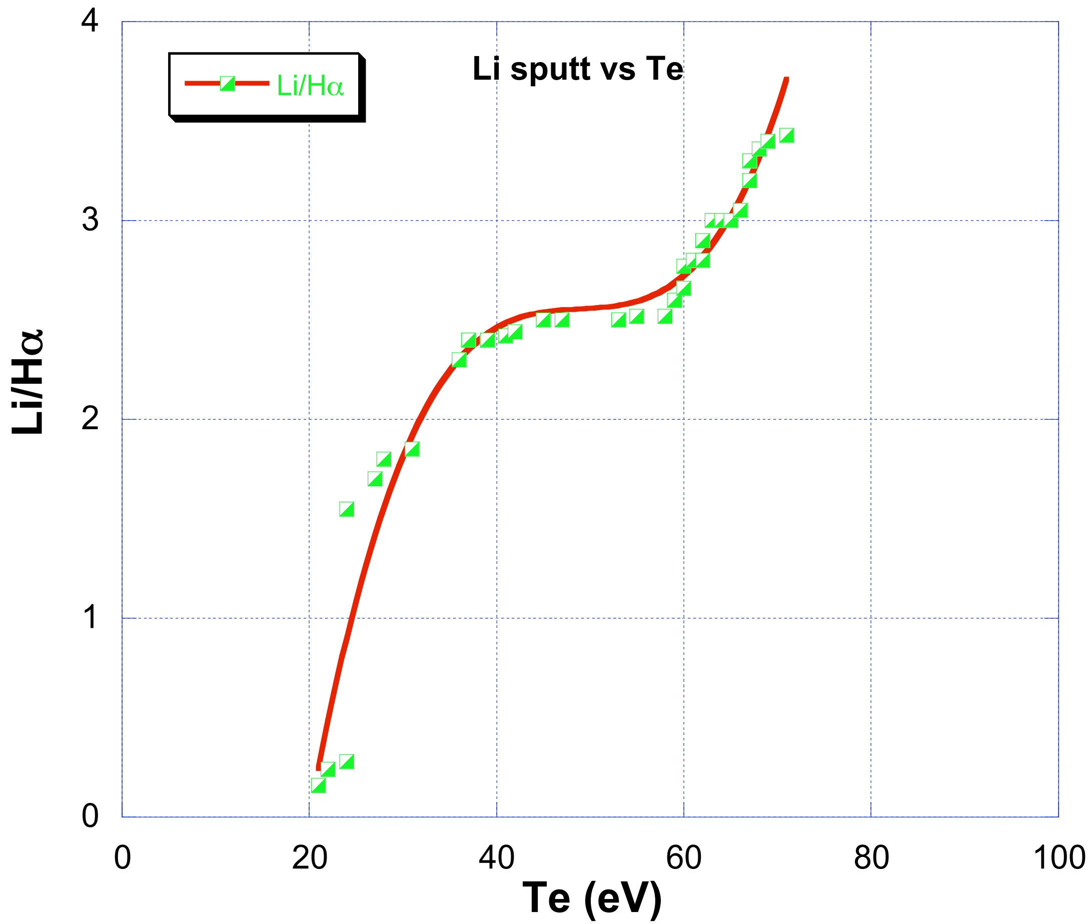
\+ Laboratory experiments (sputtering and recycling)

Li sputtering yield in TJ-II

- $\Phi_{Li}=I_{671}.S/XB_{671}$
- $\Phi_H=I_{Ha}.S/XB_{656}$
- $\Phi_{Li}/\ \Phi_H = I_{Li}/I_{Ha}.(0.2/15)$
- I_{Li}/I_{Ha}(exp)~0.33, $\Phi_{Li}/\ \Phi_H$ ~2%
- But: R_H~10%!!
- So Φ_H~10x. ,
- Li/H ~2.10^{-3}!!
- Li/H= $S_H/1-S'_{ss}$, $S'_{ss}= S_{ss}-(1-Rn)$
- Sputt theoretic: 3.3.10^{-2} (2/3 ions)



Results



Sputtering yield >6 times lower than expected:
- E ions?
- Li+ screening?

Strong Te dependence!!!

Larger bonding E ?

GDC: mixing??

Previous reports

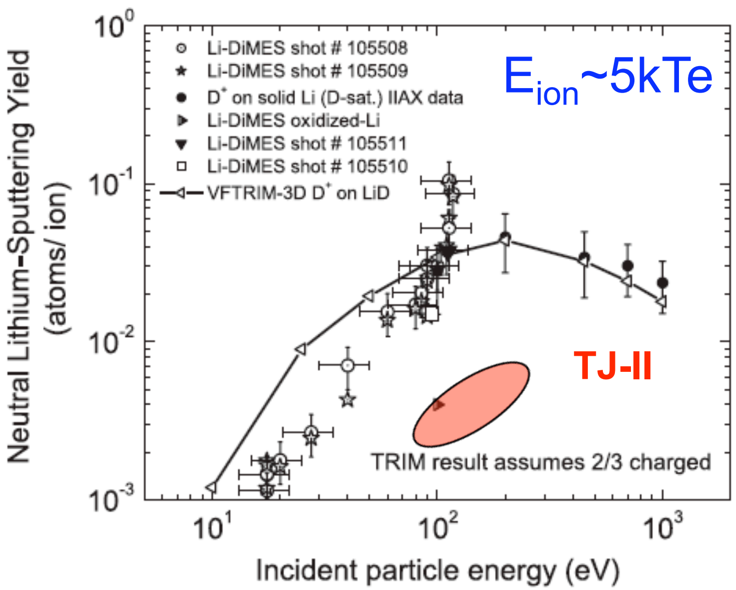
a: 0-D model

- $dX/dt = A.\Phi_H.S_H - X/\tau_p - X/\tau_p.S_{ss} = 0$

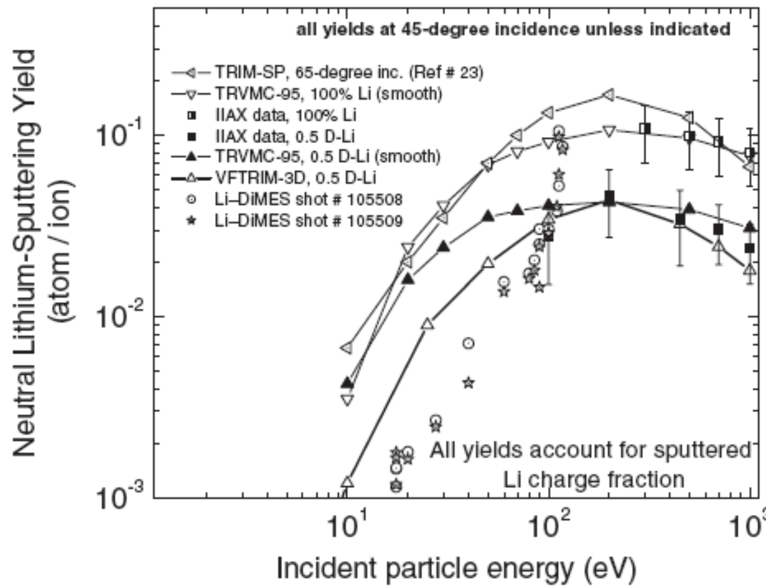
→ $x/n_e = S_H/1-S_{ss}$, with $S_{ss} = S_x-(1-R_n)$,

Rn=self-reflexion coeff, SH, Sss dep on E and angle of incidence

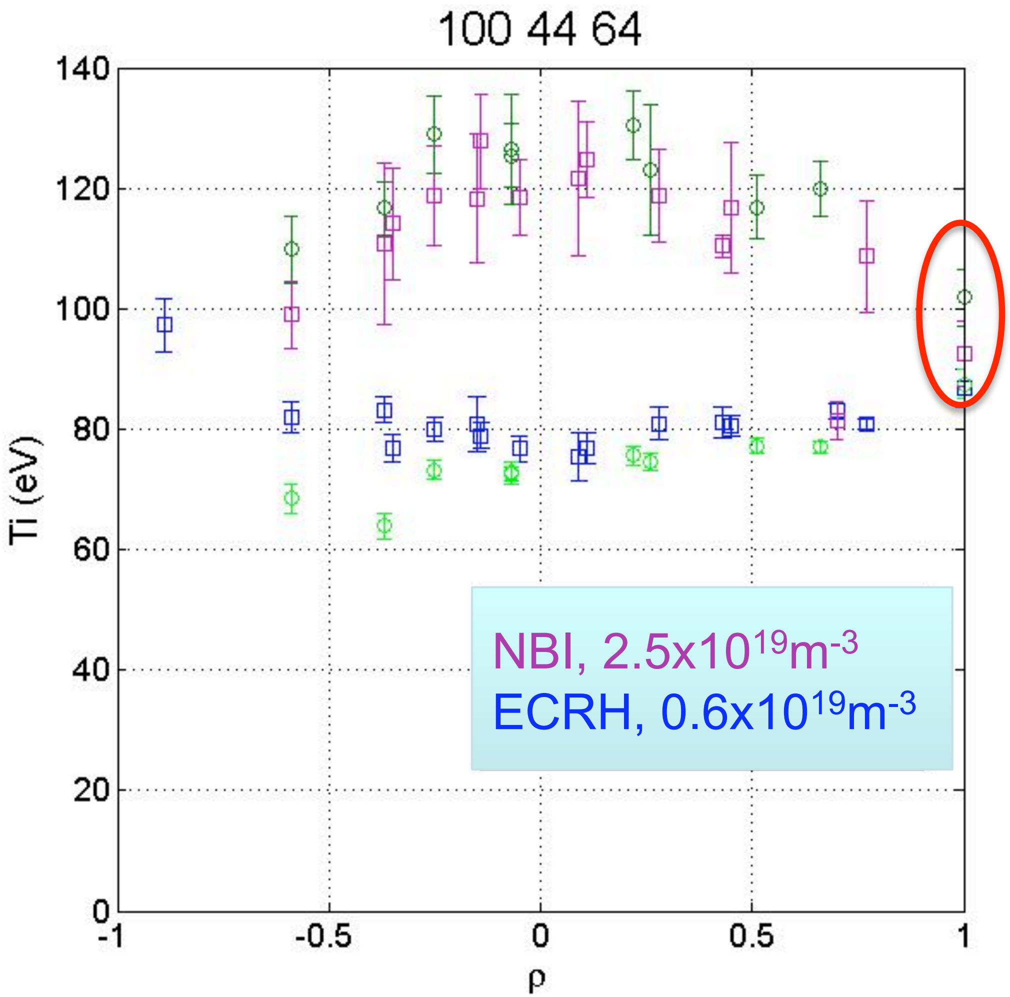
DIII-D results



Lab experiments



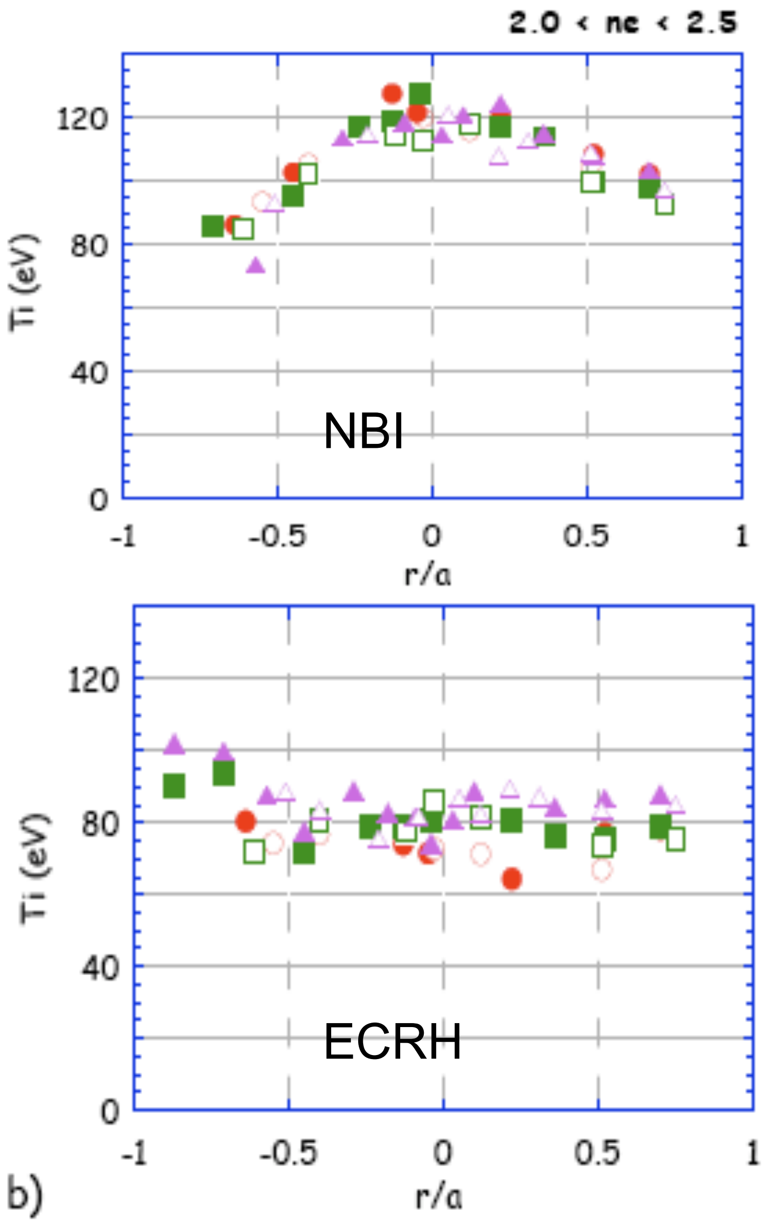
NPA Ti profiles



But: Not so suitable for edge Ti

Other methods in progress:

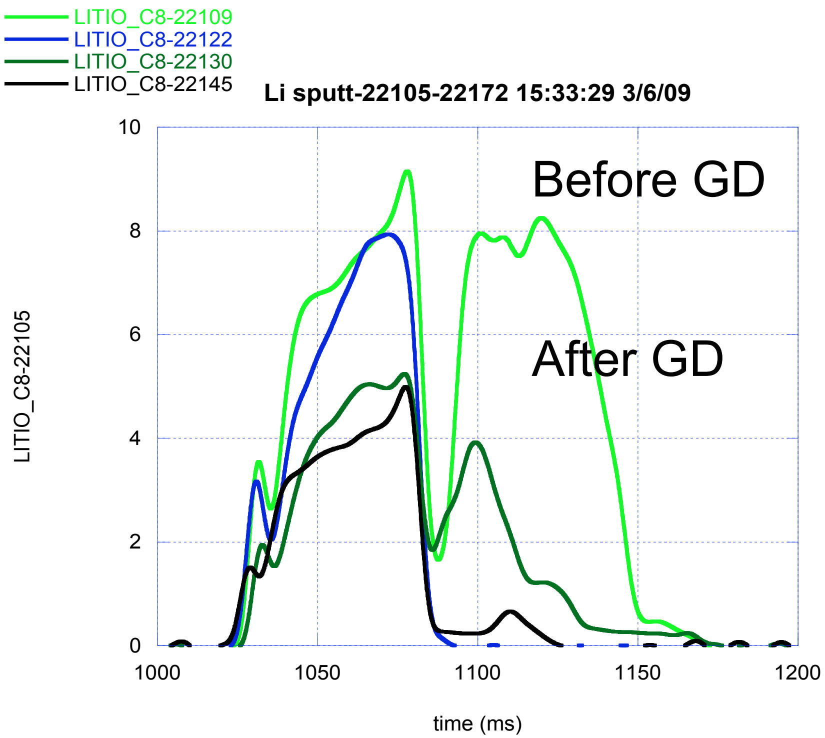
- -CXRS
- -Spectroscopy
- -RFA
- -He Beam (Guzmán et al JNM 2009)

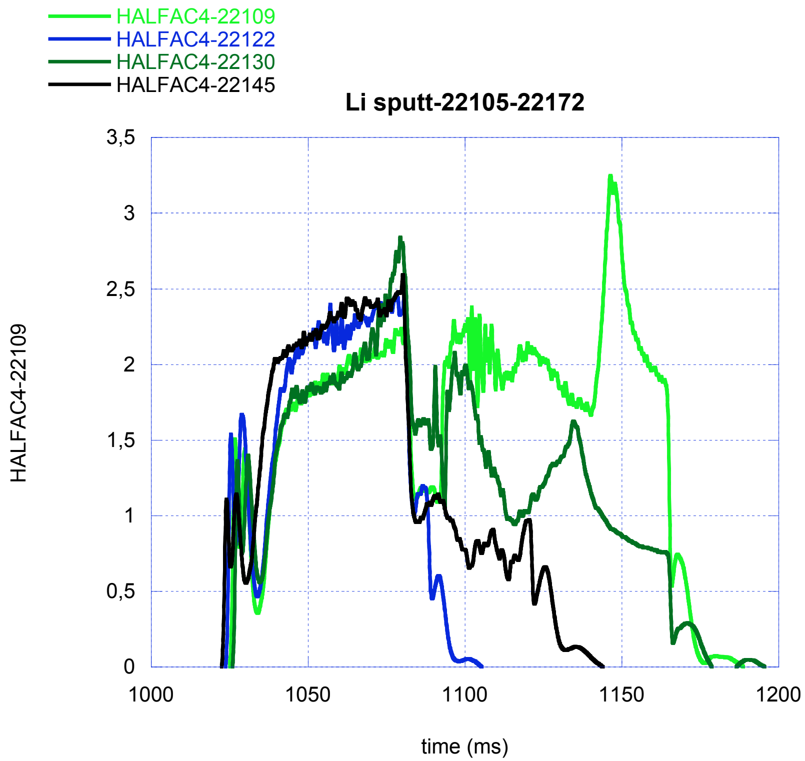


Similar Ti radial profiles for B wall

R. Balbín et al, EPS 2005

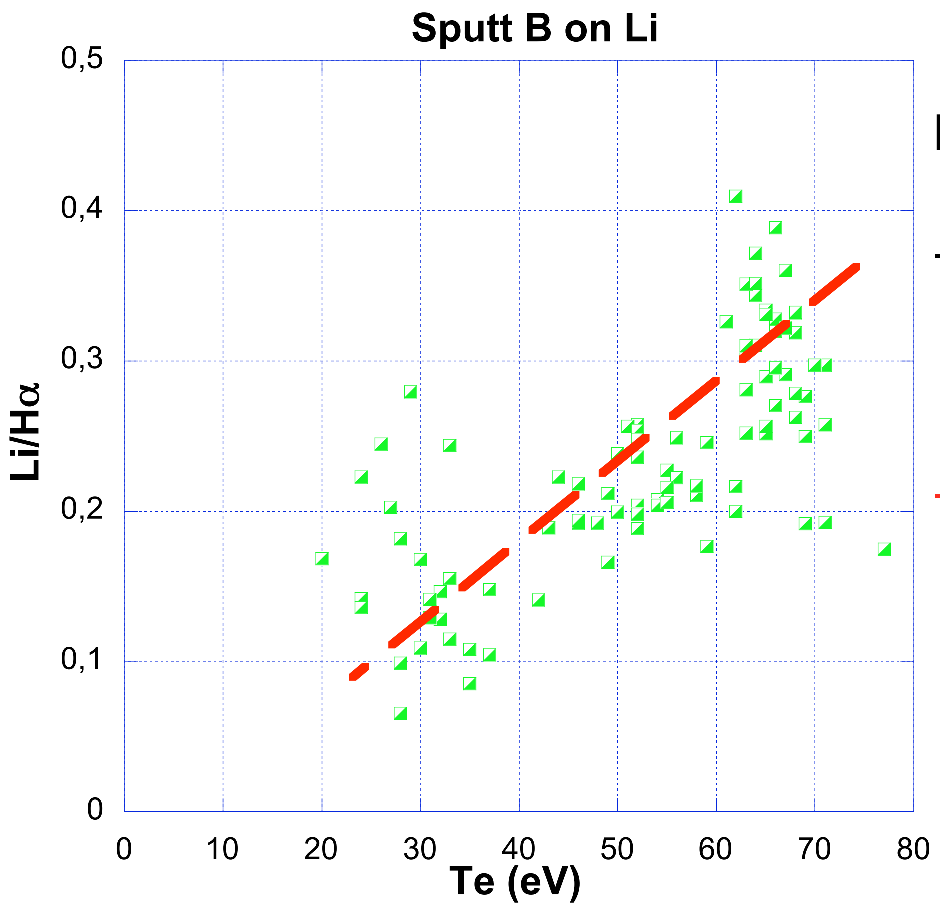
Layer (B/Li) mixing effects





Li sputtering yield lower by ~2 after He GDC

Boron layer (~50 nm) on top of Li



Much lower yields:

- E bonding ??

→But good recycling!!

- Role of bulk vs surface Li on recycling?

Conclusions

• Similar Parameters for Global E balance found for Li and B walls at ne< $2.5 \times 10^{19}\ m^{-3}$

• Self development of two different plasma radial profiles under Li walls at high ne

•Transition between them triggered by short gas pulse

•NBI absorption /central heating modified by plasma profile (?)

•No evidence of flatter Ti profiles for Li walls yet found

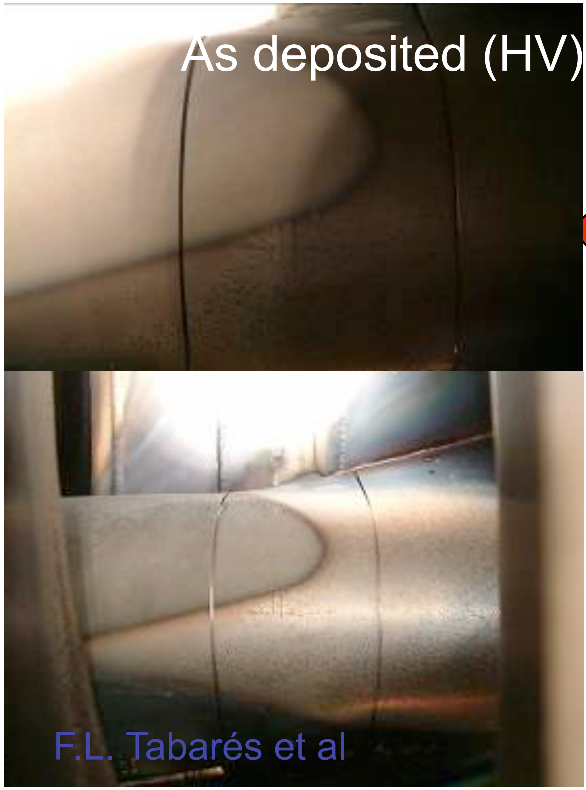
•Low sputtering yield for Li associated to material mixing

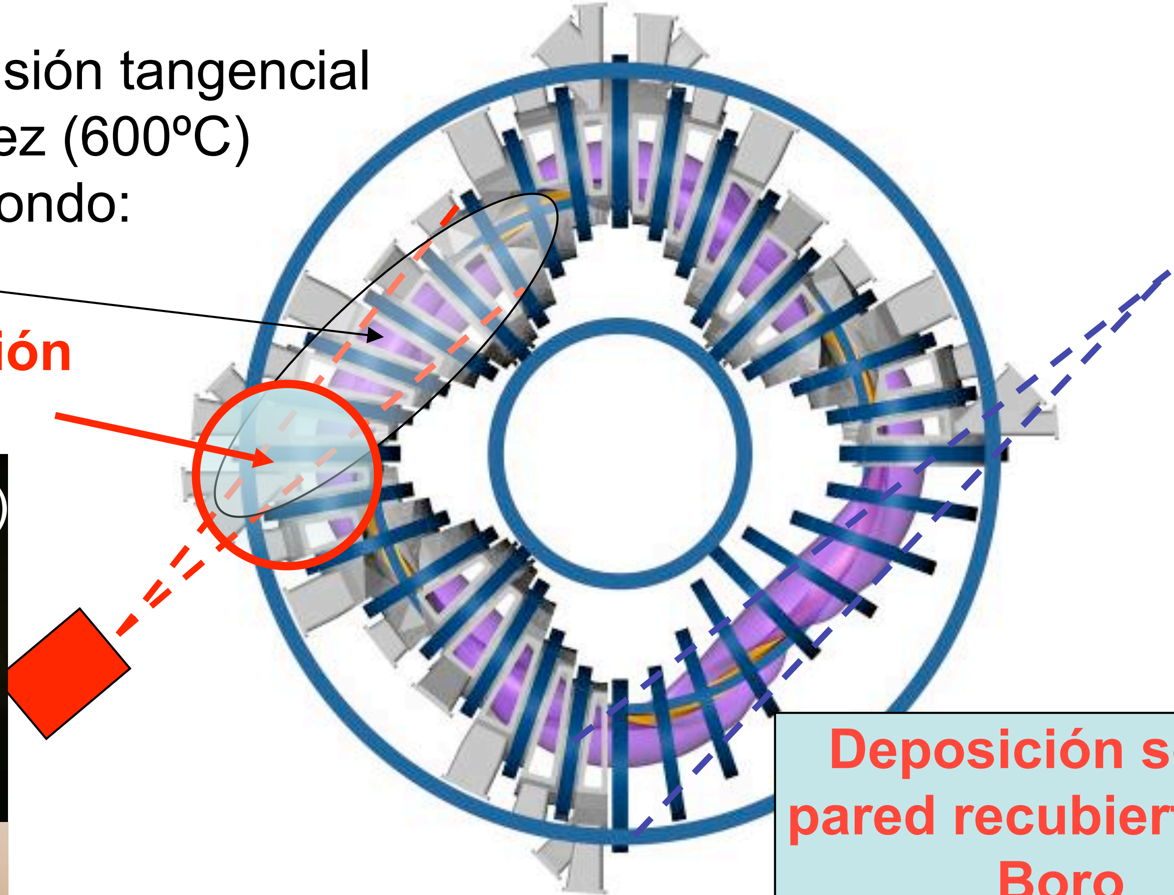
•Good recycling found even by covering the Li layer with B


Thanks for your attention!

Deposición de Litio

- **4 hornos**, simétricos, visión tangencial
- 4 g depositados cada vez (600ºC)
- pepel de la presion de fondo:
    - **HV: línea de visión**
    - **10^{-3}-10^{-5}mbar: difusión**
    - **Ne GD+ hornos**

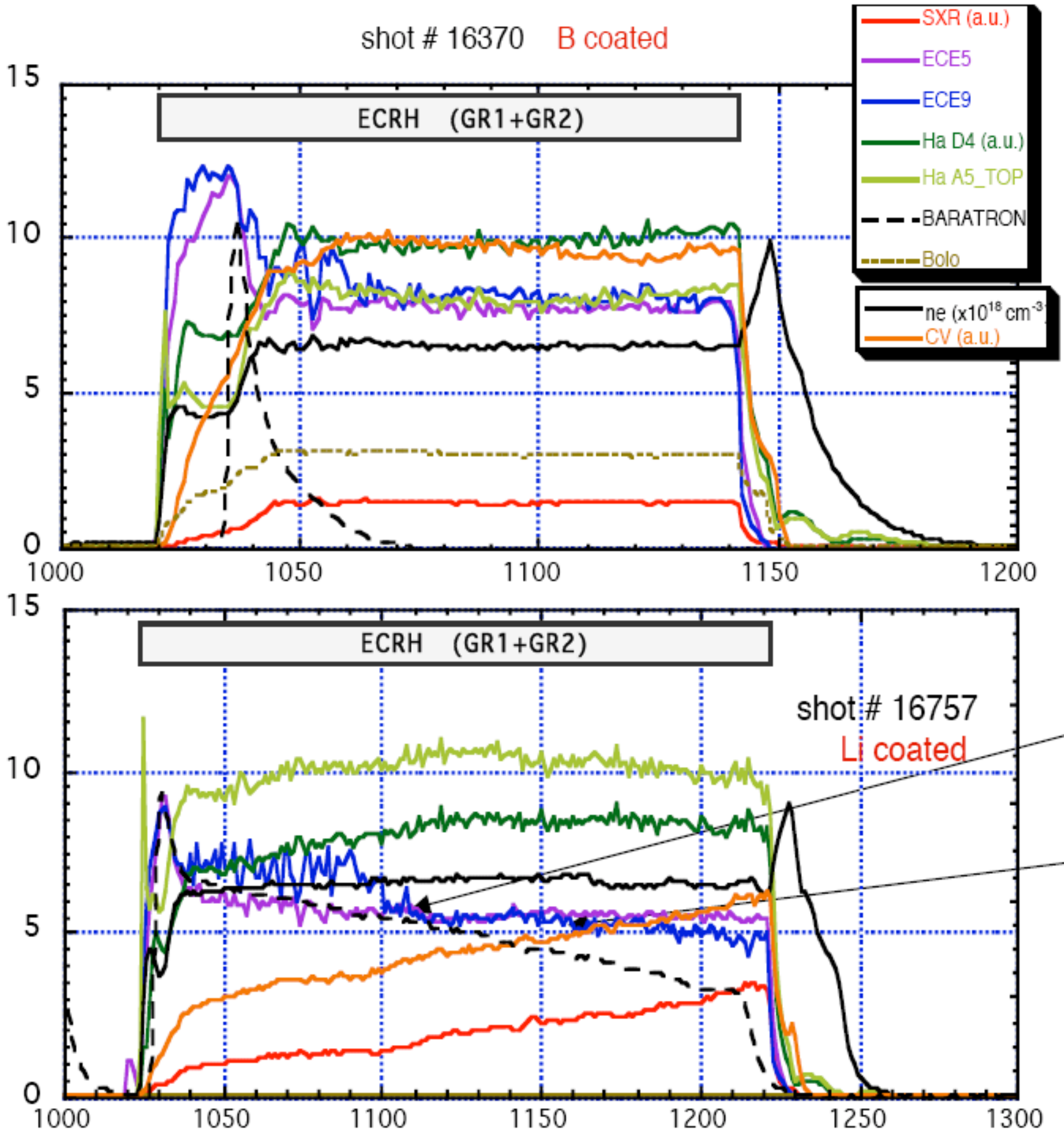




Deposición sobre pared recubierta con Boro

Redistribución por el plasma: mejora con el tiempo de uso!

Energy and Particle balance studies in the full lithiated TJ-II stellarator 17th ISHW, Princeton Oct 2009



Pared de B

Se requiere mayor inyección de gas

Menor emisión de C V

Pared de Li

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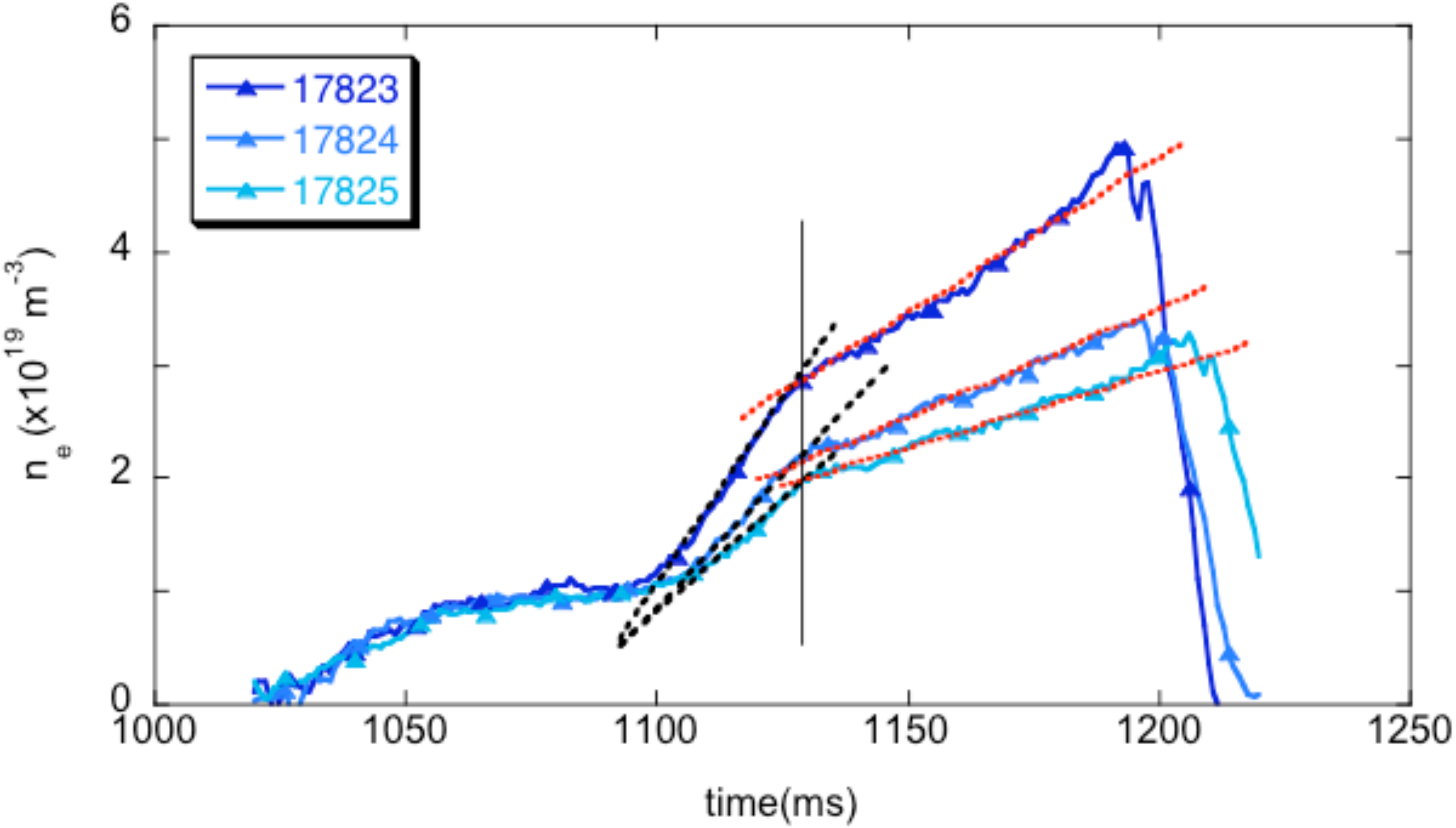
Energy and Particle balance studies in the full lithiated TJ-II stellarator 17th ISHW, Princeton Oct 2009

Control de la rampa de densidad



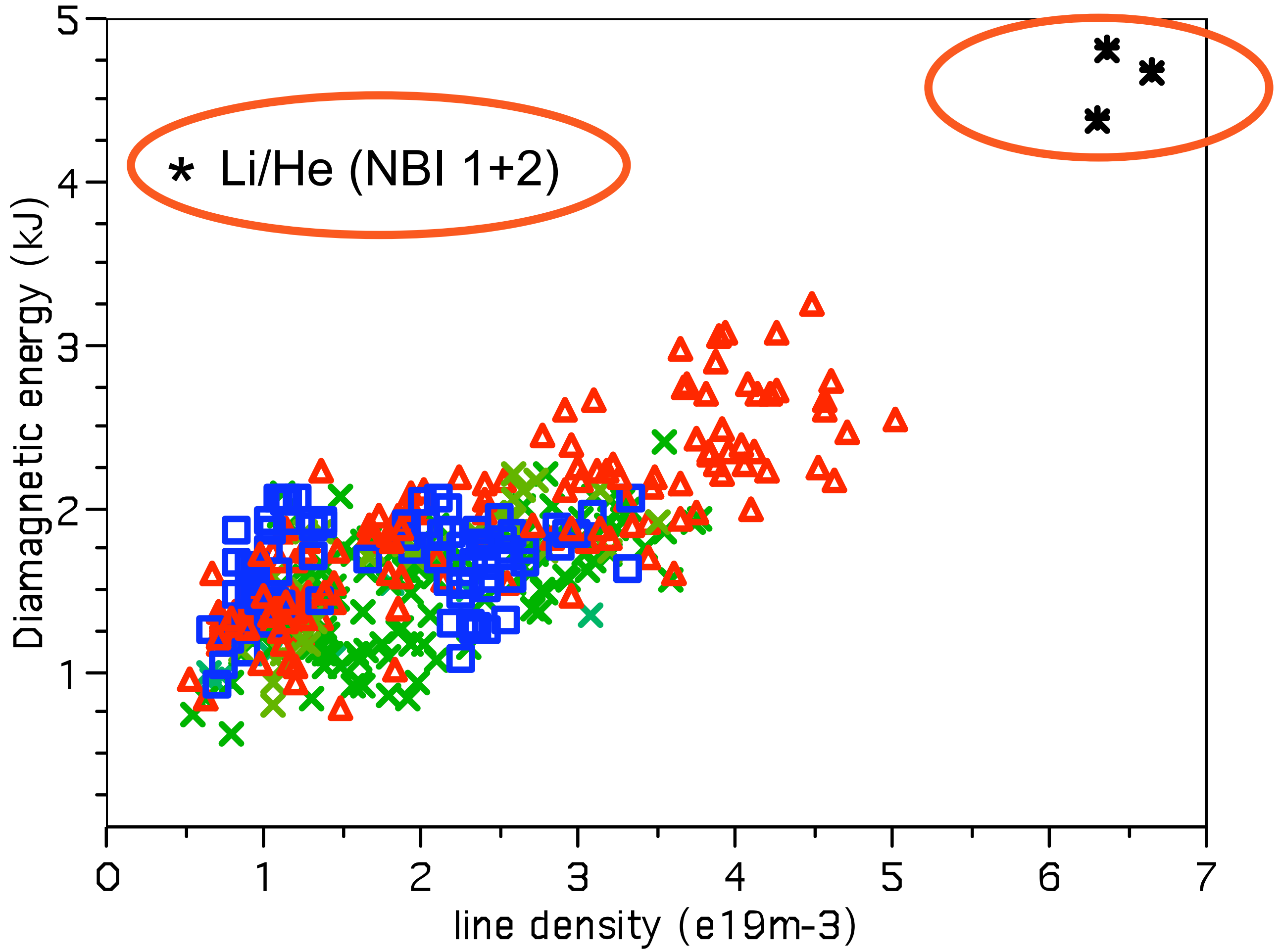
New extended operational window

Wall/ Plasma

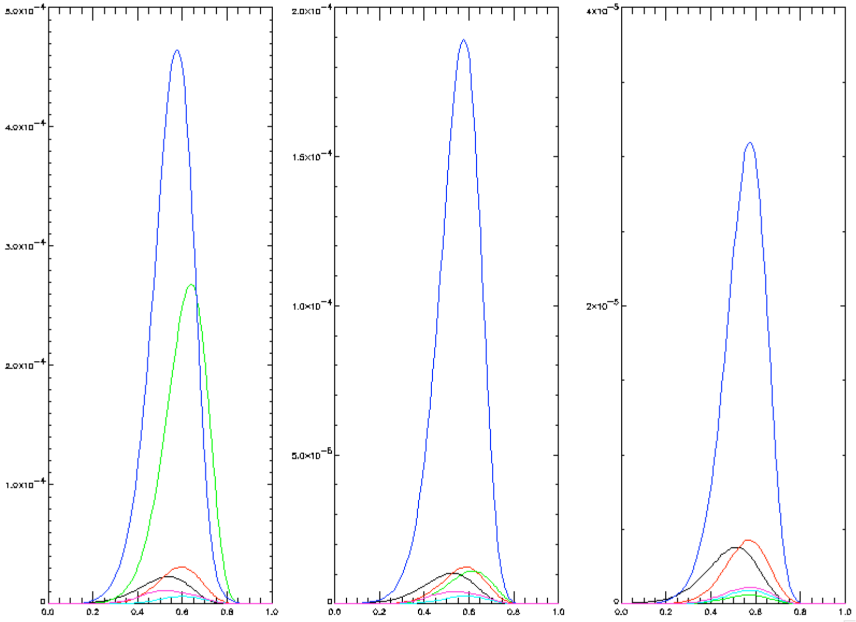
x B / H

Δ Li / H

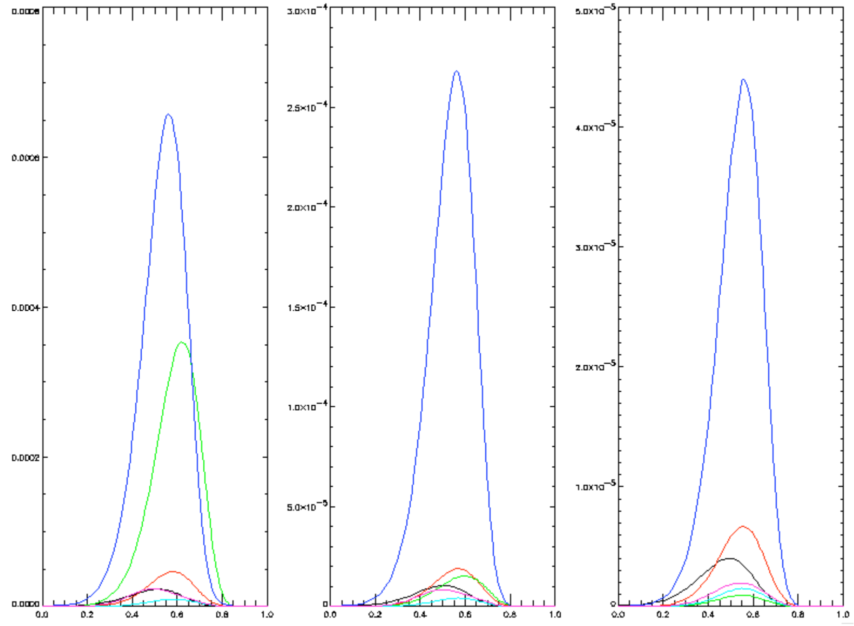
□ Li / He



T=5ms



T=10ms



Pulso de impurezas de 3ms observado

Difc=2000 cm^2/sec

Vdac=-2   2D/A

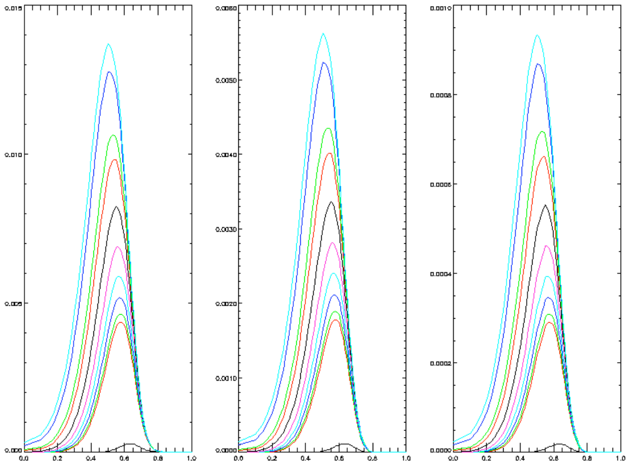
Vex=2 (V(R)=V(A)*(R/A)**VEX)

Flx=1e10   *============>

H	C	O	Ne	Ar	Fe
100	1	0.1	0.1	0.1	0.1

La emisión del Fe baja mucho (no se ioniza lo suficientemente rápido). Se mantienen altas la del O (con el filtro de 8μm) y la del Ne

Evolución temporal de un pulso de Ne.



Pulso de impurezas de 3ms observado

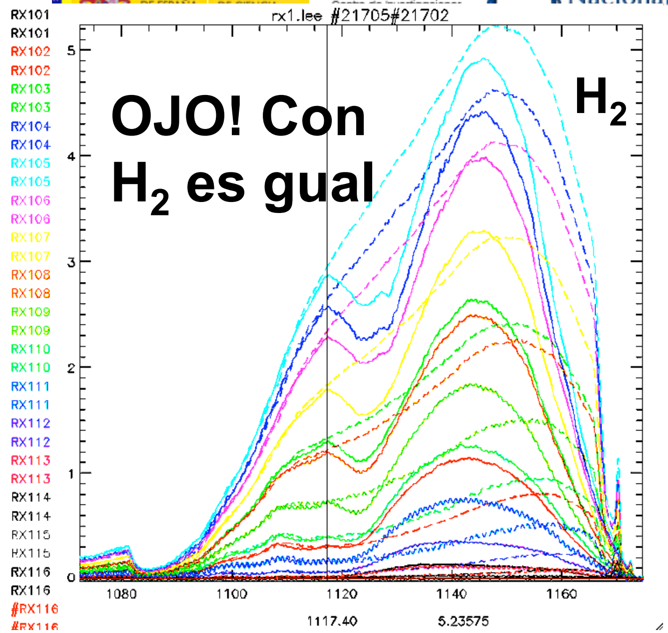
Difc=2000 cm^2/sec

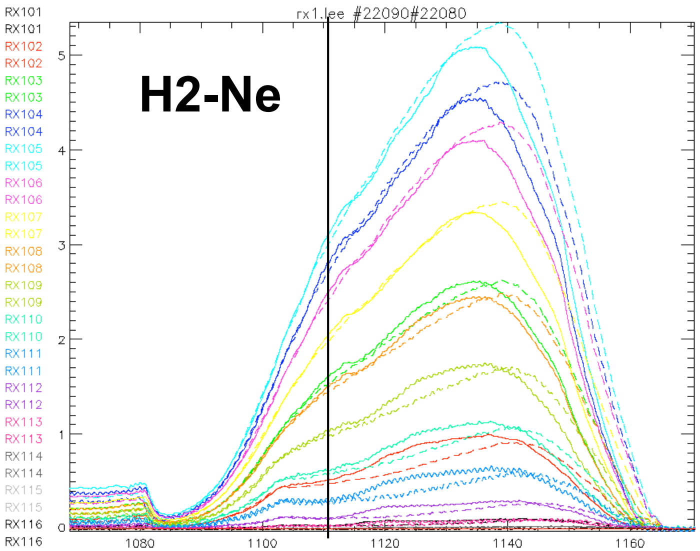
Vdac=-2   2D/A

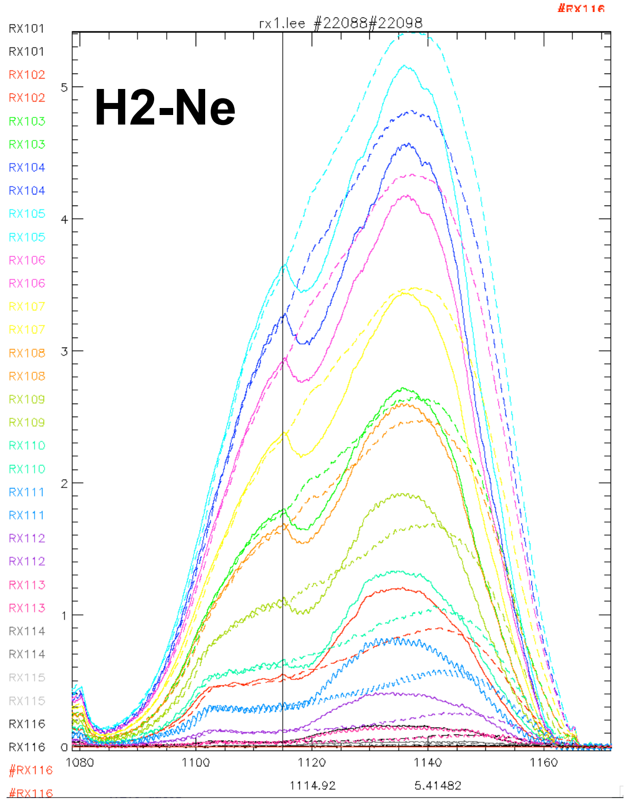
Vex=2 (V(R)=V(A)*(R/A)VEX)**

Flx=1e10

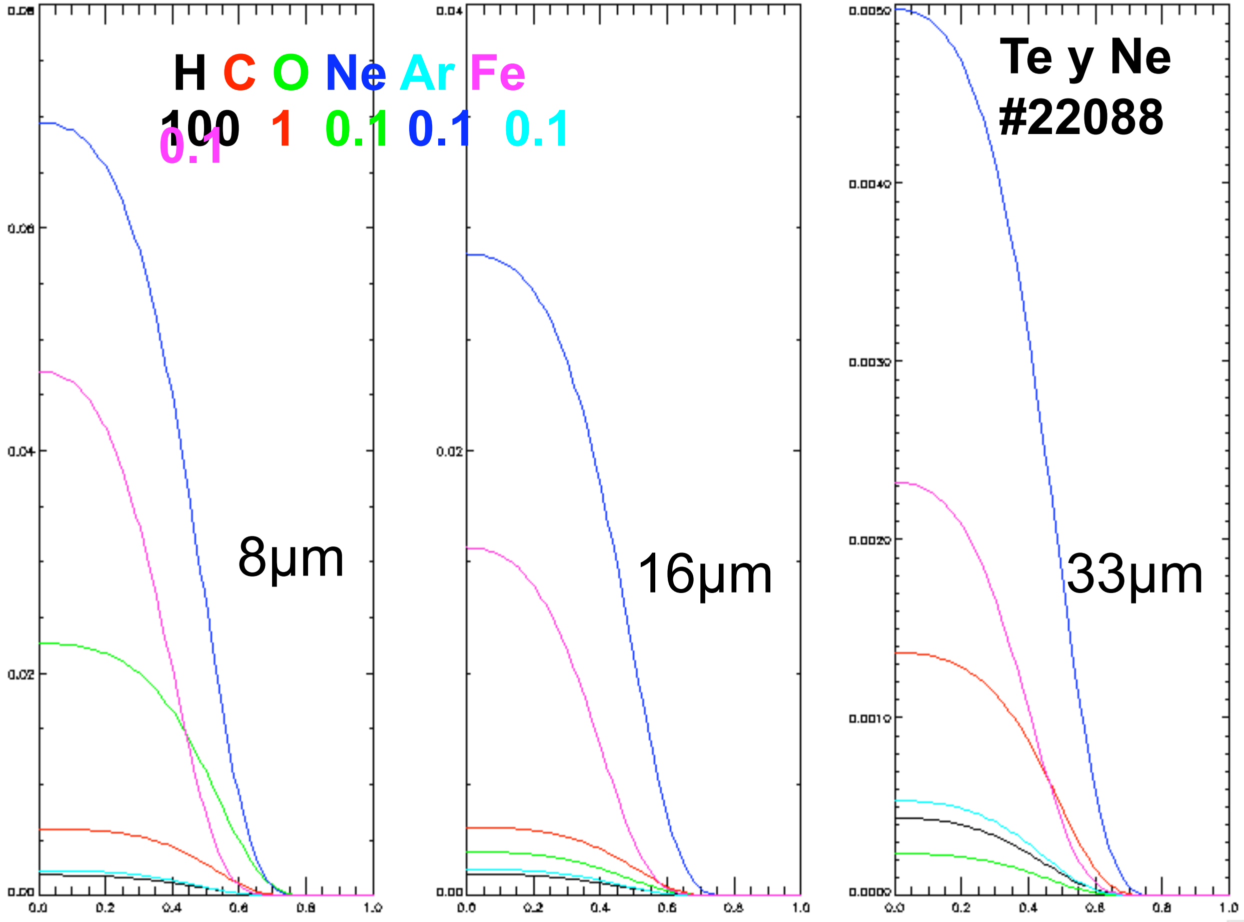
t0=0.001 y dt=0.002





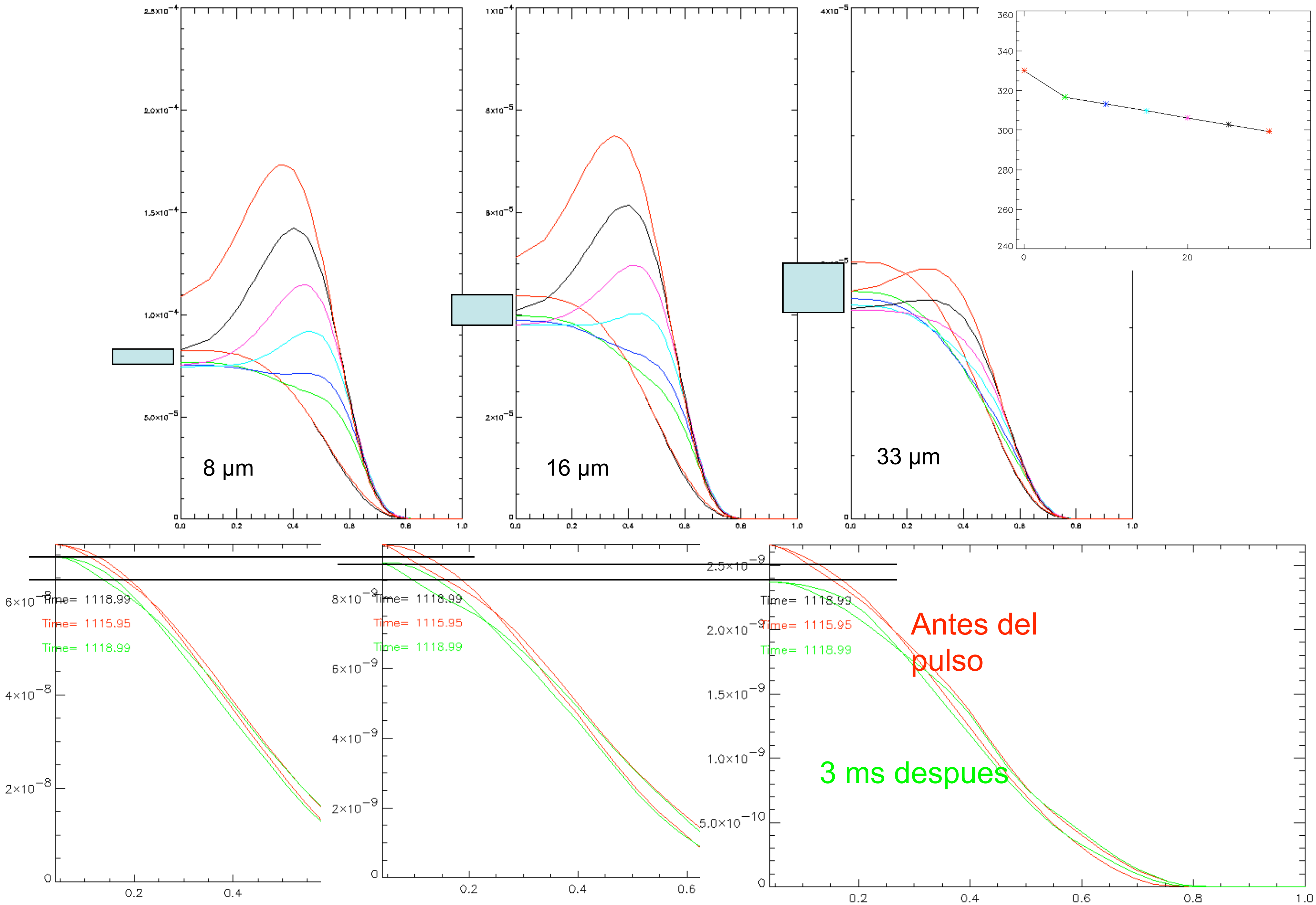


Experimentalmente la penetracion del pulso de Ne parece verse en los canales exteriores como un aumento de señal que se propaga hacia el centro. Mientras, los canales mas interiores o no aumentan nada o incluso disminuyen antes de que el Ne puda llegar al centro

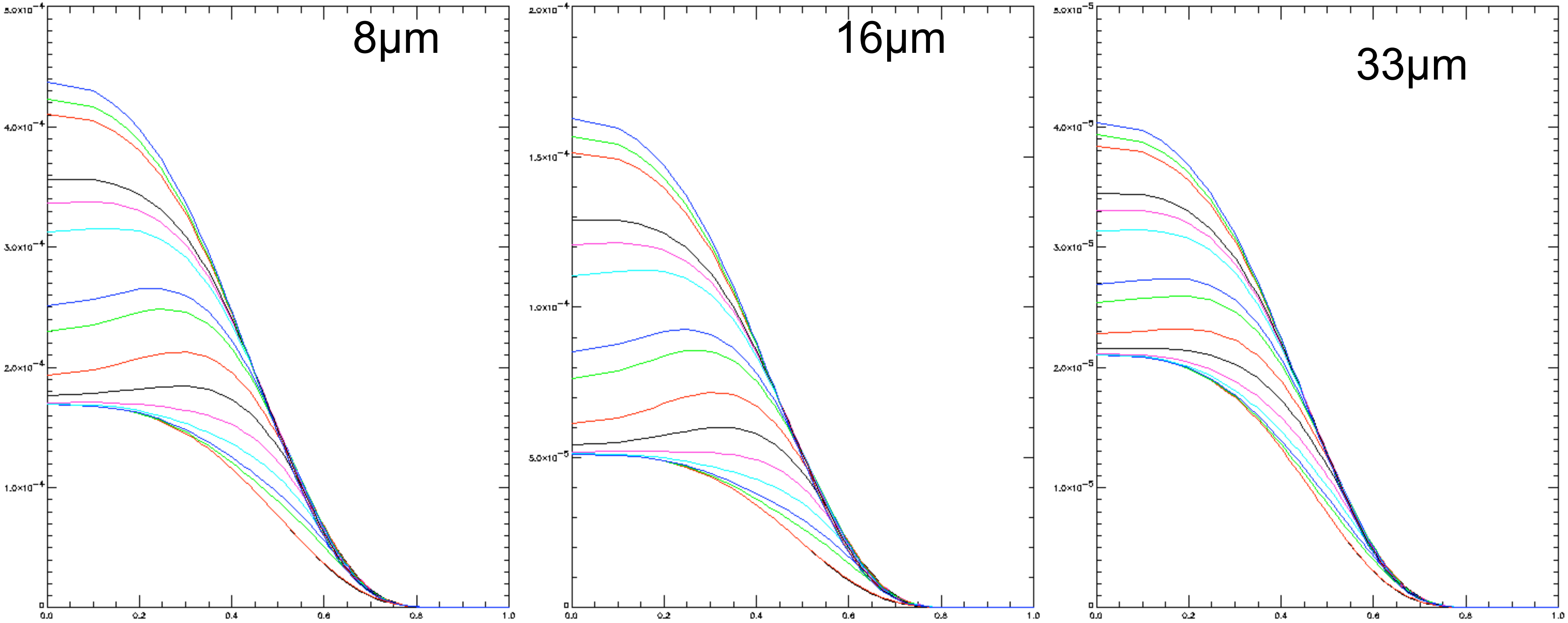


Simulación de la contribución a la emisión r x blandos a través de varios filtros y distintas impurezas

Simulando la bajada de señal en el centro #22088



Simulación completa de la entrada de Ne.



Pulso de impurezas de 3ms observado

Difc=2000 cm^2/sec

Vdac=-2   2D/A

Vex=1 **(V(R)=V(A)*(R/A)**VEX)**

Flx=5e9

t0=0.001 y dt=0.005

Te y Ne
#22082

Plasma base

H C O
100 2 0.06 %