Overview of TJ-II experiments

Presented by
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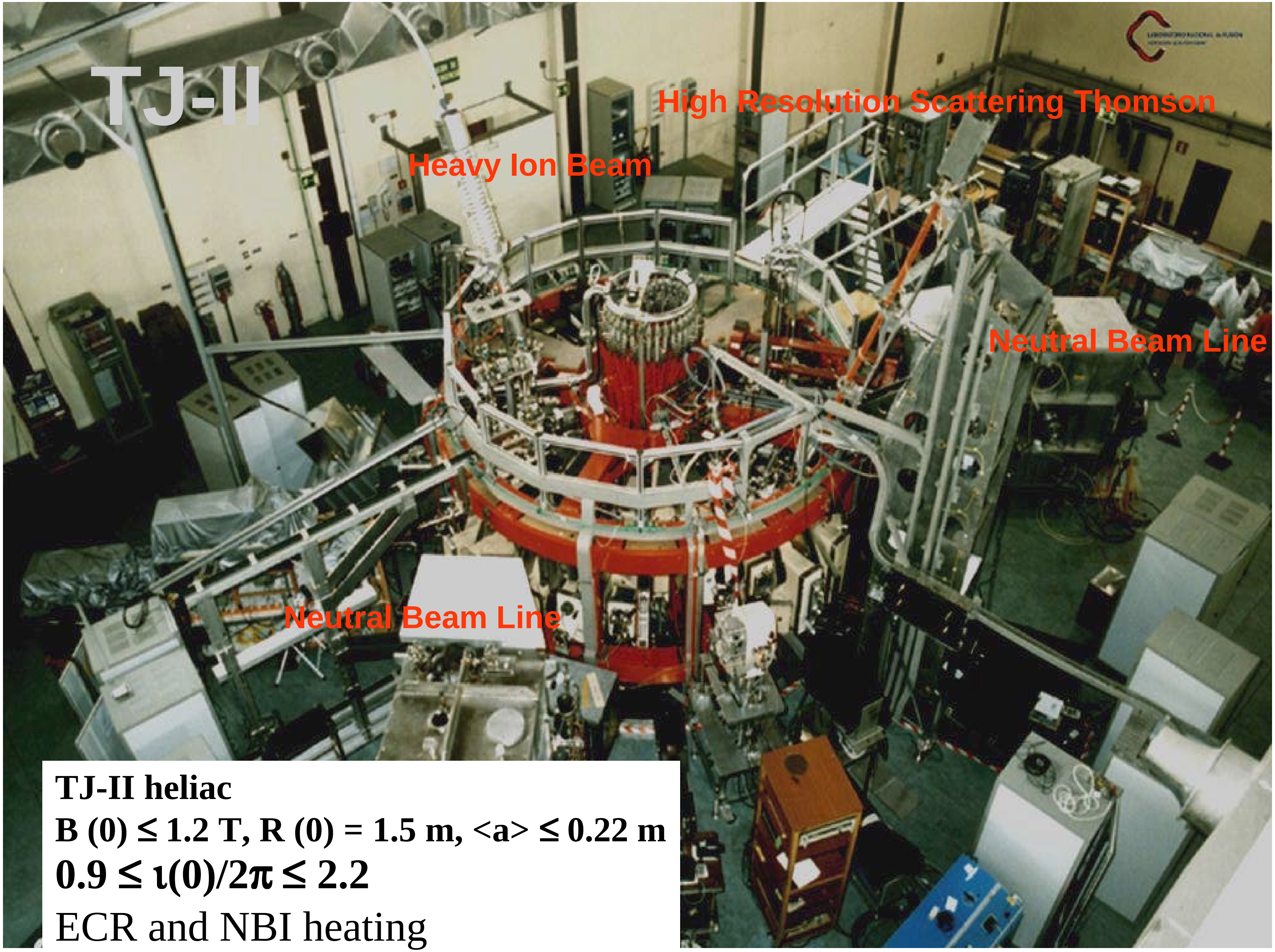

TJ-II heliac

$B(0) \leq 1.2$ T, $R(0) = 1.5$ m, $\langle a \rangle \leq 0.22$ m

$0.9 \leq \iota(0)/2\pi \leq 2.2$

ECR and NBI heating

OUTLINE

Global confinement scaling and Enhanced confinement modes:

Spontaneous transitions and development of ExB sheared flows

Biasing induced improved confinement regimes

Effect of transformer induced toroidal current in confinement.

Electron internal transport barriers and role of rationals

Transport studies

Impurity and particle transport studies

Radial electric fields and transport

Plasma – wall studies

divertor like configurations

NBI plasmas

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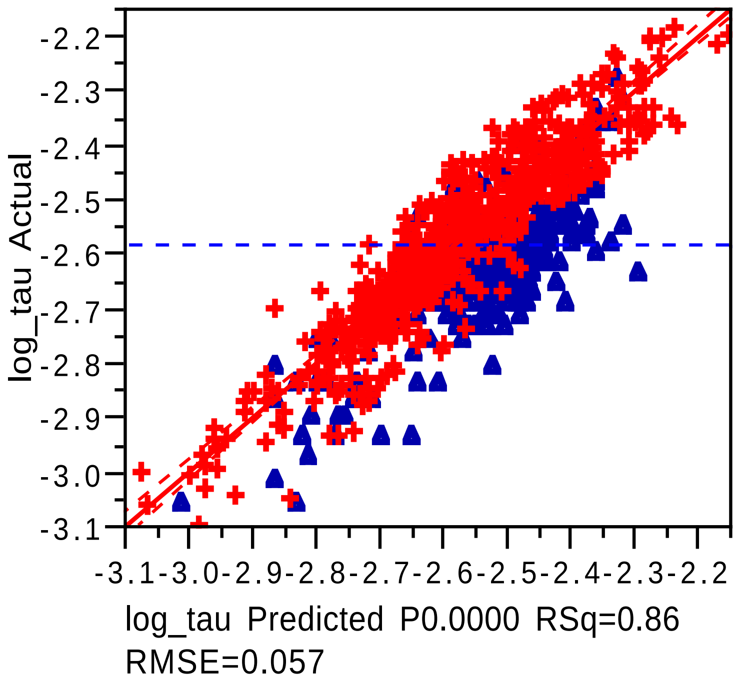
TJ-II vs ISS95 scaling



•Previous experiments in all-metal wall conditions are consistent with ISS95 predictions.

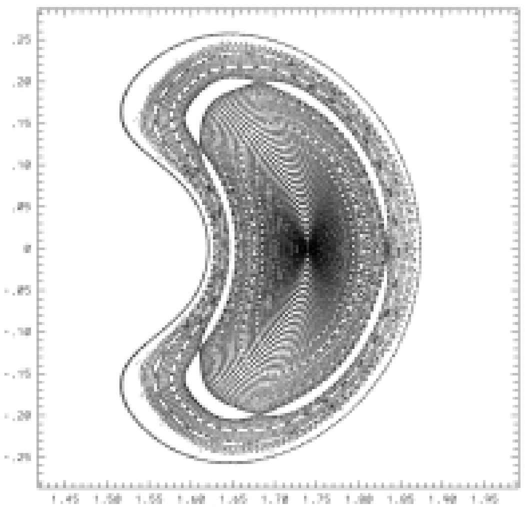
•Plasma discharges, produced in boronised wall conditions, yield different dependences on rotational transform and on plasma density.

•The possible physical origins: impact of improved confinement regimes as well as plasma-wall interaction on TJ-II global confinement.

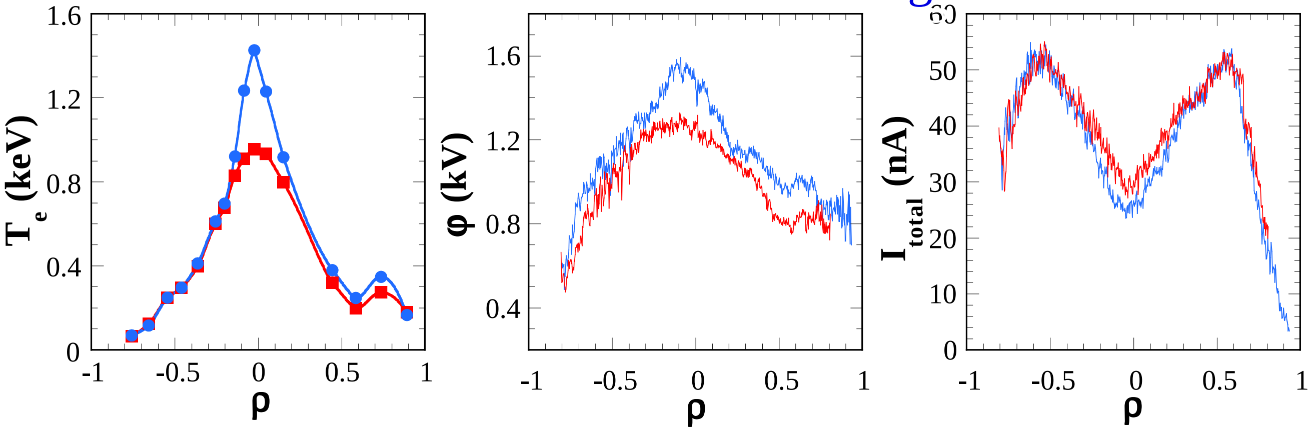
	Nr. shots	α_P	α_n	α_iota
All-metal set	368	-0.75±0.03	**0.63±0.04**	**0.5±0.1**
Boron set	762	-0.62±0.02	**1.06±0.02**	**0.35±0.04**
ISS95	859	-0.59±0.02	0.51±0.01	0.40±0.04

E. Ascasibar et al., (2003)

Triggering of e-ITB in stellarator: role of rationals



before & during e-ITB



•The rational 3/2 has to be positioned inside the plasma for the e-ITB to appear.

•Is the presence of rational surfaces in the plasma essential to e-ITB formation or does it simply modify the power threshold?

Great flexibility of stellarator devices in magnetic configuration (3/2, 4/2, 8/5,…)

T. Estrada et al., Plasma Physic and Controlled Fusion (2004)

F.Castejón et al., IAEA-2004 (EX/8-1)

Why do rationals trigger ITBs?

Due to the triggering of ExB sheared flows in the proximity of rationals

Hidalgo PPCF-2000 / Pedrosa 2000/ Carreras 2001/ Ochando 2001 / Ida 2002 /Shaing 2003/ Estrada 2004 / Castejón 2004:

•kinetic effect.

•Viscosity

•Neoclassical effects

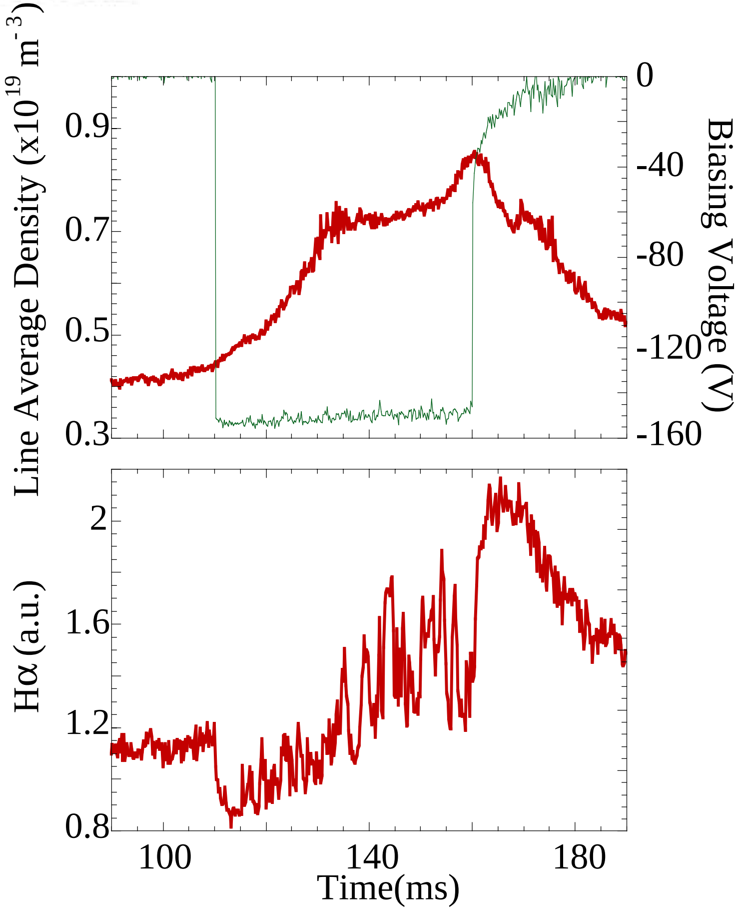
•Turbulence driven flows

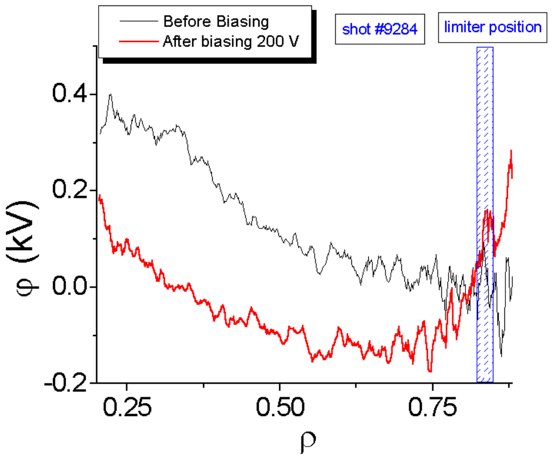
TJ-II experiments

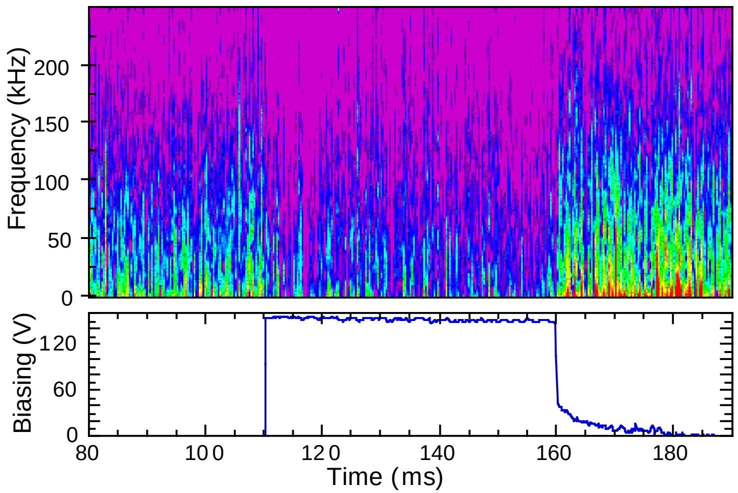
Due to a rarefaction of resonant surfaces in the proximity of low order rationals which is expected to decrease turbulent transport.

Romanelli PoP- 1993 / L. Cardozo 1997 / Brakel 2002 / Garbet 2001

Biasing induced H-mode like transition in TJ-II







- **Modification of edge radial electric fields by limiter biasing.**
- **Improvement in particle confinement time and reduction of turbulence**
- **No significant impurity influx.**
- **Bursty behaviour in H_α**

C. Hidalgo et al., PPCF-2004

Sheared flow development and threshold plasma density

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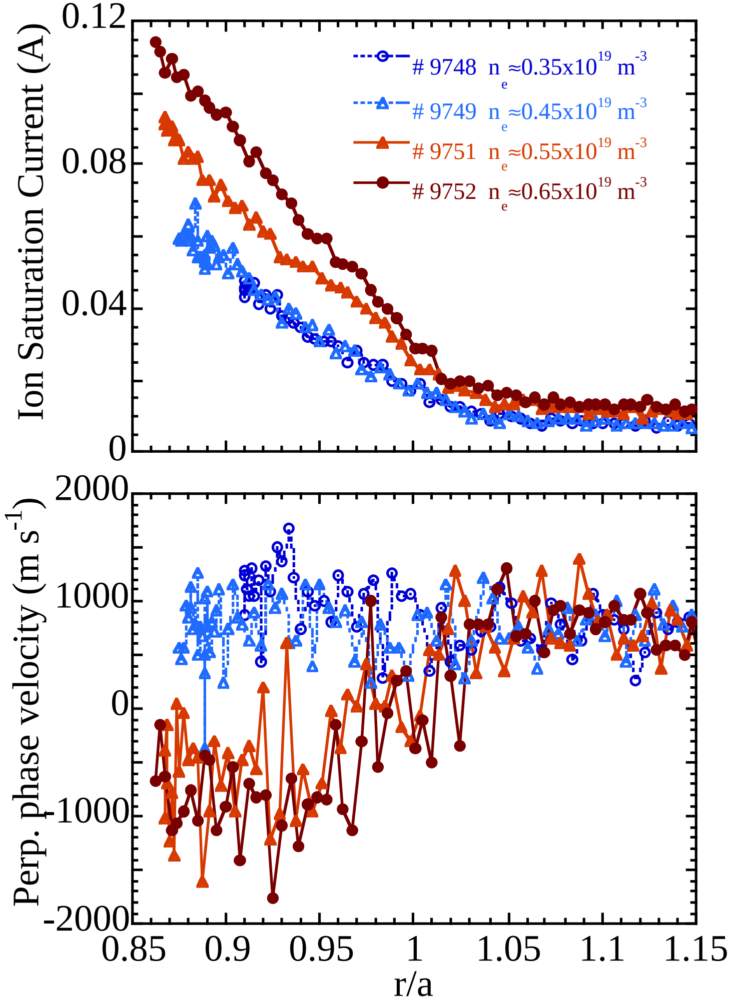
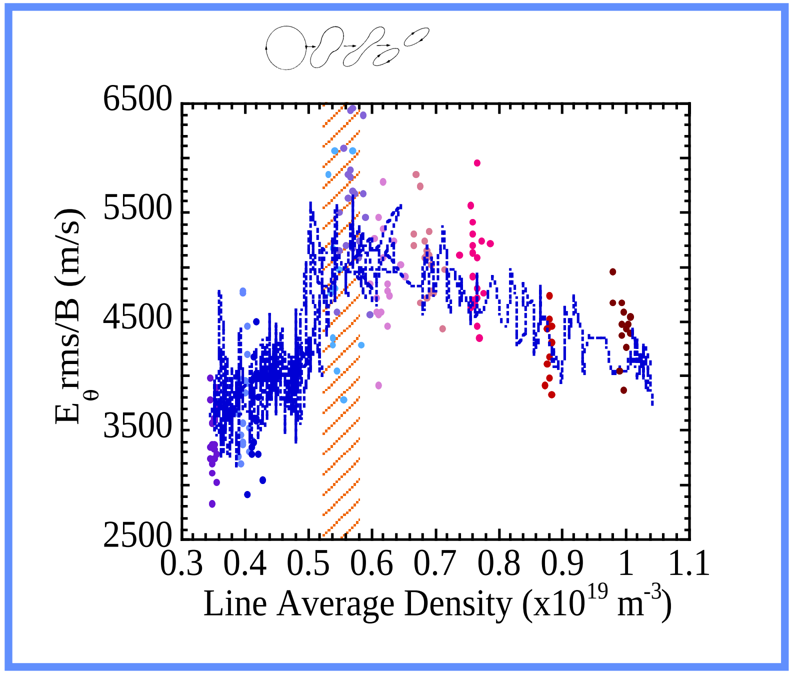


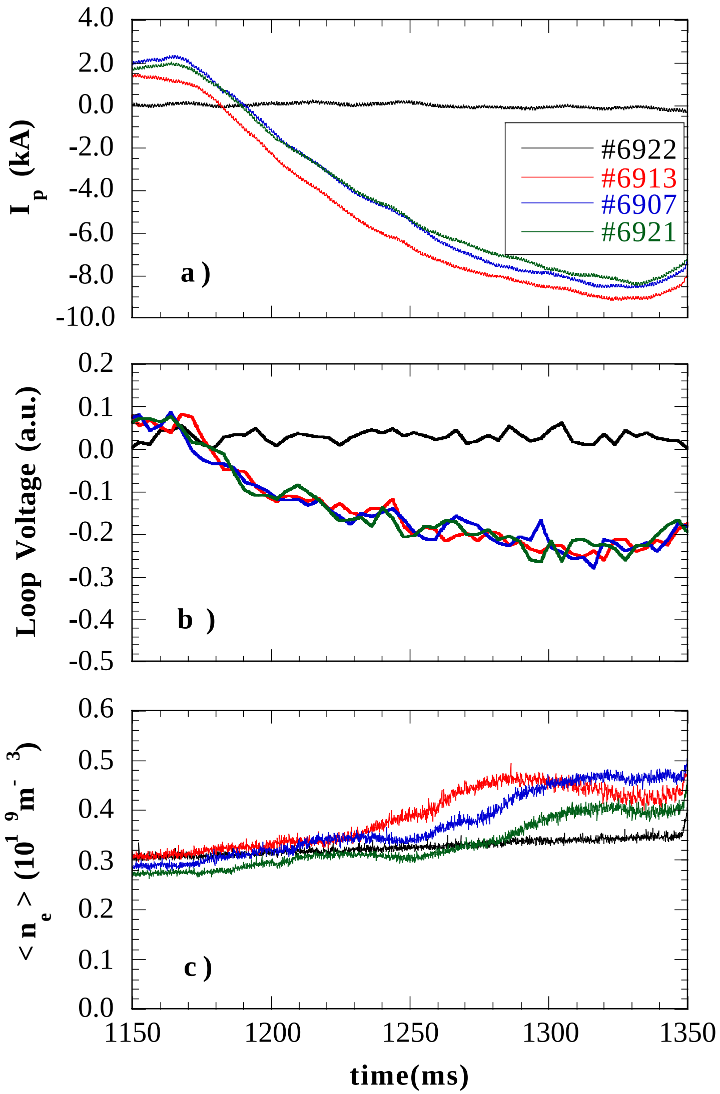
- **The development of the naturally occurring velocity shear layer requires a minimum plasma density.**
- **There is a coupling between the onset of sheared flow development and the level of turbulence.**
- **This mechanism can explain spontaneous improved confinement in TJ-II**



C. Hidalgo et al., Phys. Rev. E (2004);

M.A. Pedrosa et al., IAEA-2004 (EX/P6-21)

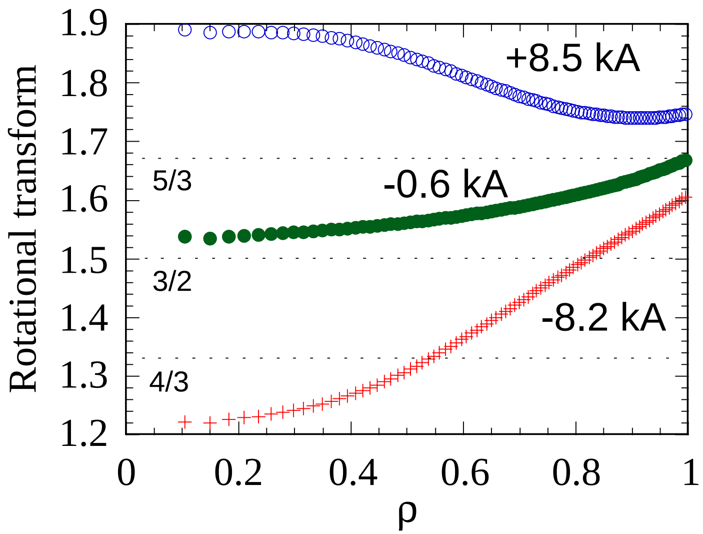
Effects of Plasma Current: magnetic shear



- **TJ-II plasmas confinement under transformer induction conditions responds to plasma current.**
- **Plasma density: decreases/increases smoothly for values of positive/negative plasma current**
- **These observations show the link between magnetic configuration (magnetic shear) and transport.**

D. López Bruna et al., Nuclear Fusion (2004)

J. Romero et al., Nuclear Fusion 43 (2003) 386



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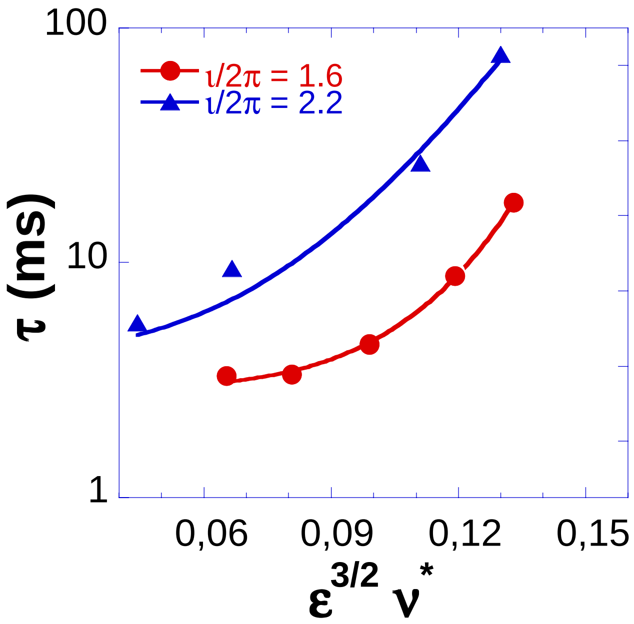
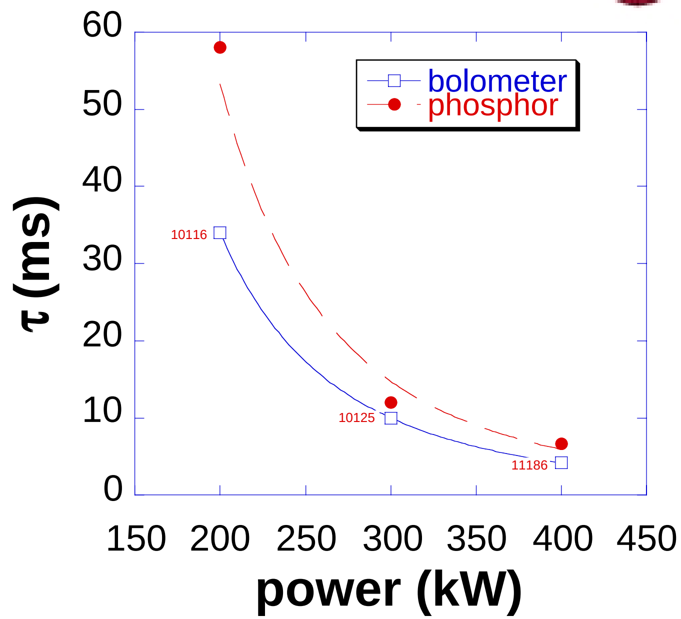
Inpurity transport studies





Influence of density / collisionality:

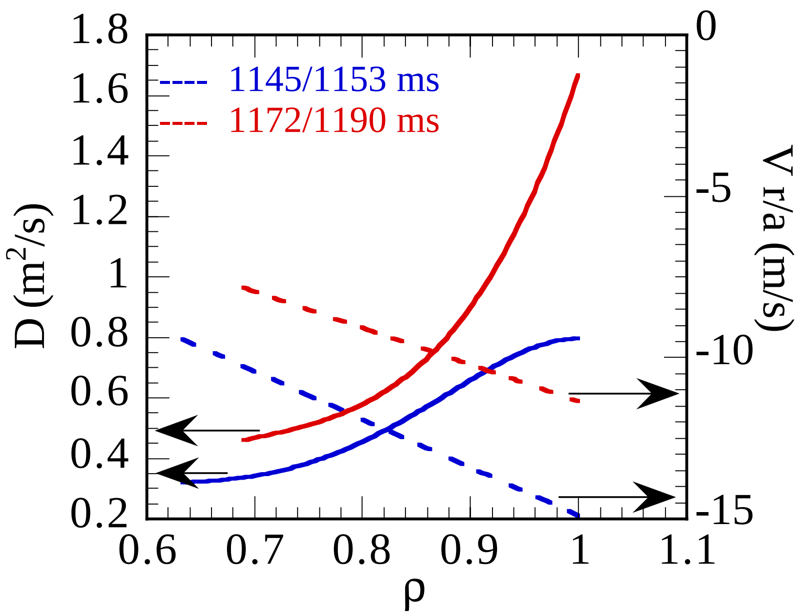
Impurity confinement time (τ) slowly increases with density / collisionality up to a value where it increases more rapidly. The threshold density / collisionality increases with iota.

Influence heating power:

Confinement time shows a strong dependence with ECRH heating power ($\tau \approx P^{-3}$) which turns out to be stronger than the one observed in the global energy confinement time ($P^{-0.5}$).

Zurro B. et al., IAEA-2004 (EX/P6-32)

Particle transport and perturbative experiments

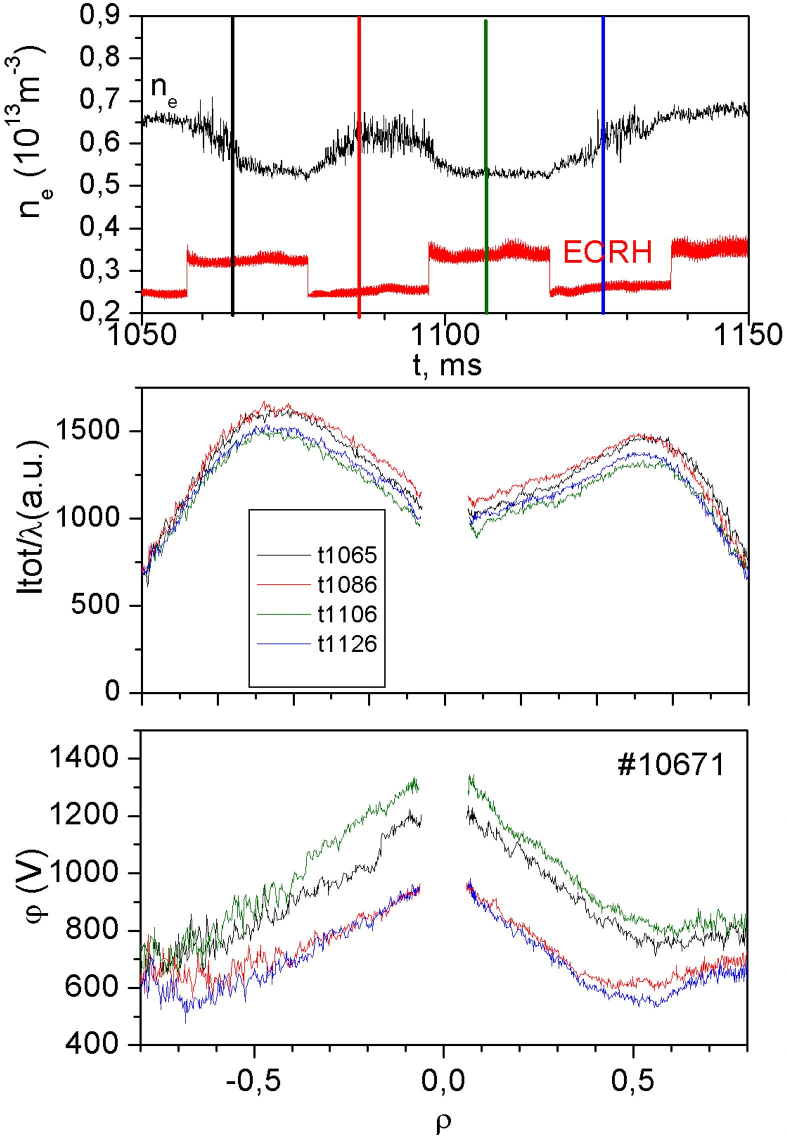


•Particle diffusivities are about 0.3 m^2/s ($r \approx 0.6$), increasing radially outwards. An inward pinch is necessary to explain bulk particle transport.(S. Eguilor et al., 2004)

•However, evidence of non-diffusive transport mechanisms has been observed during the propagation of edge cooling pulses experiments. (B. van Milligen et al., Nuclear Fusion 2002)

•A model has been developed, incorporating a critical gradient mechanism that separates a sub-critical diffusive and a super-critical anomalous transport channel, depending on the local value of the gradient.
(B. Van Milligen et al., IAEA-2004 (TH/P6-10)

Electric fields: neoclassical and kinetic effects



- The positive values of the radial electric field (50 V/cm) measured by the HIBP system at low density plasmas are of the order of the neoclassical estimations

Krupnik et al., EPS-2004.

- Coupling between ECRH input power density, plasma potential and the energy of the suprathermal electron tail.

F.Medina el et EPS-2004.

- An approach based on Langevin equations has been recently introduced to estimate this ECH induced flux.

F. Castejón et al., PPCF 2003 /

IAEA (2004) EX/8-1

Ion energy confinement and electric fields

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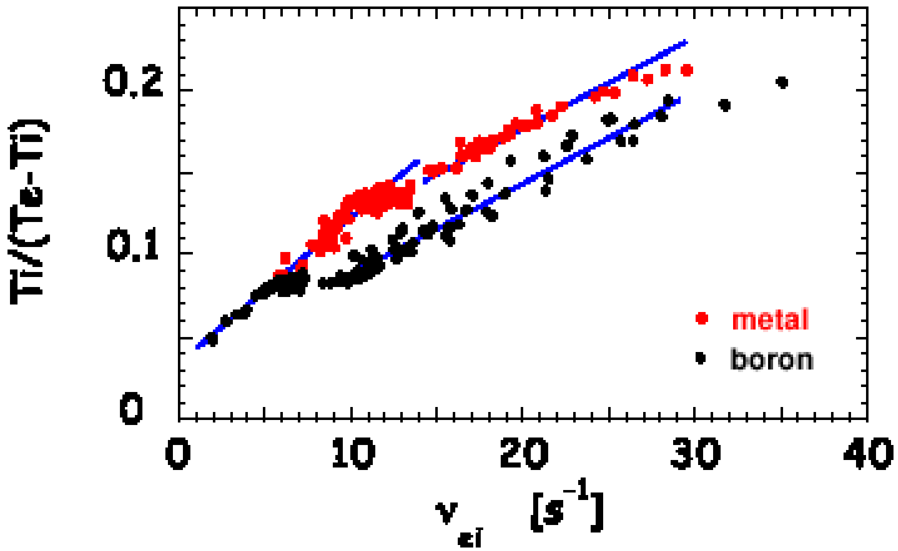
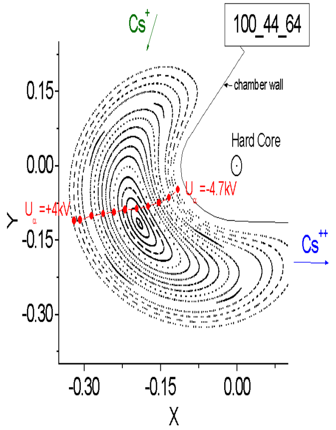


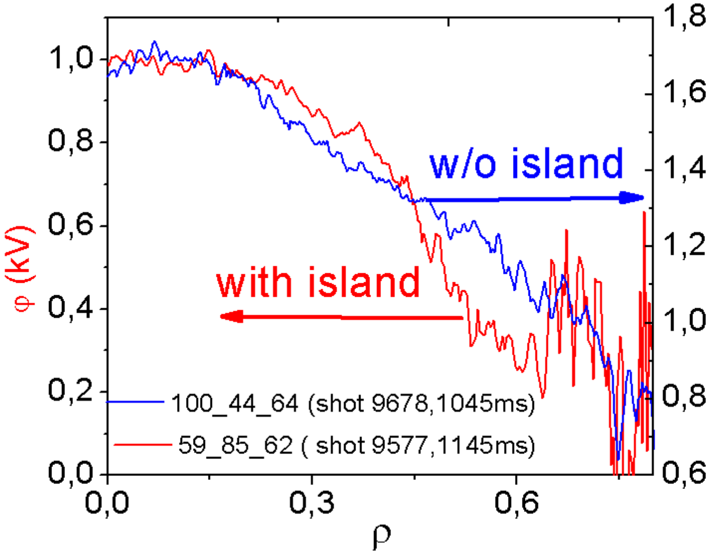
- The ion power balance equation shows different confinement regimes characterized by different ion energy confinement times.
- **Results are compatible with changes in the ambipolar electric field computed from neoclassical calculations.**

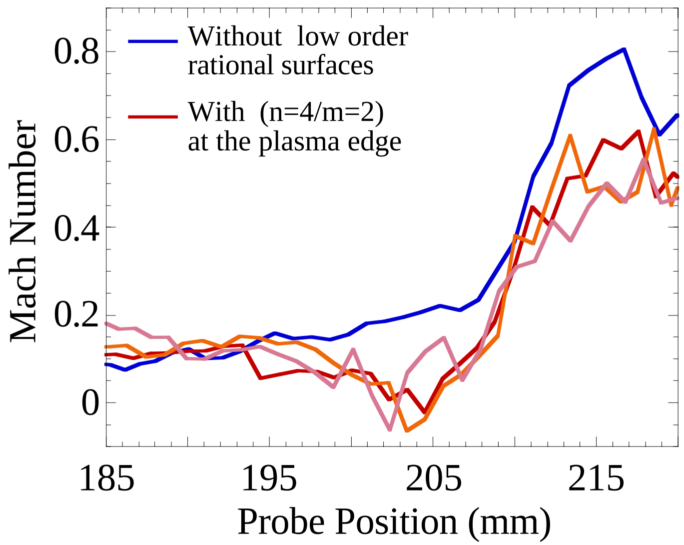
$$\nu_{ei}\left(T_e - T_i\right) n_e - \frac{T_i}{\tau_{Ei}} n_i = 0$$

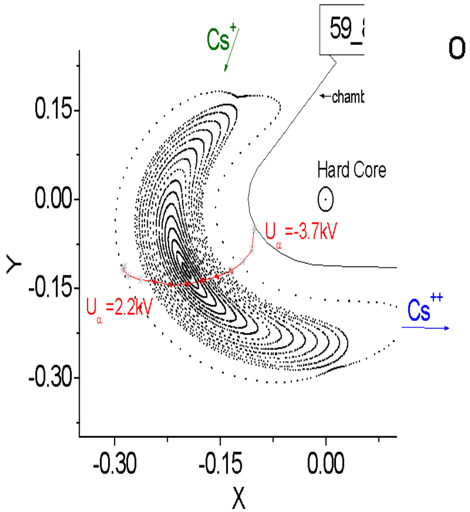
R. Balbín et al., 2004

Plasma potential, flows and rational surfaces









Radial profiles of plasma potential and flows show evidence of "structures" in configurations with low order rationals.

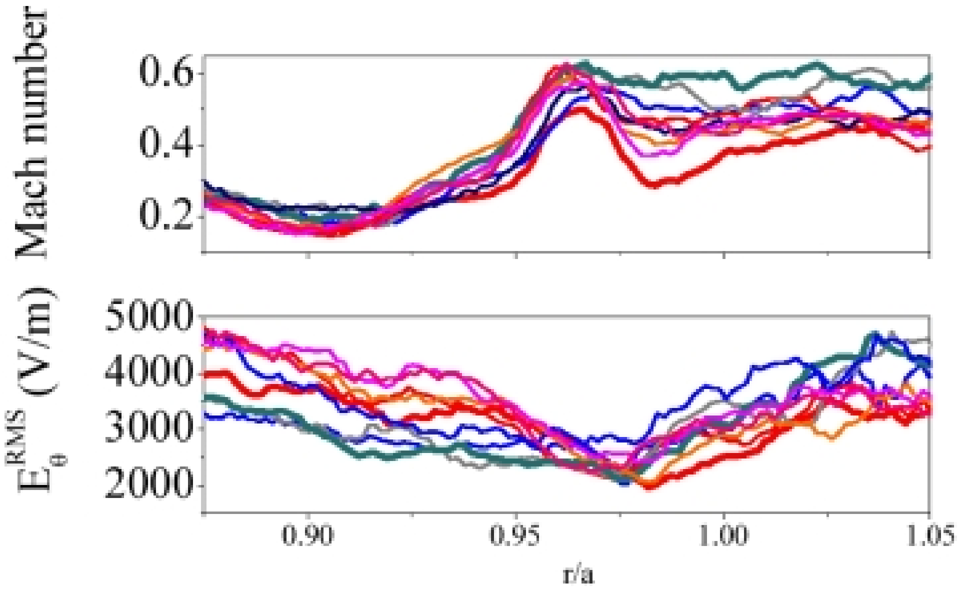
M.A. Pedrosa et al., PPCF-2004

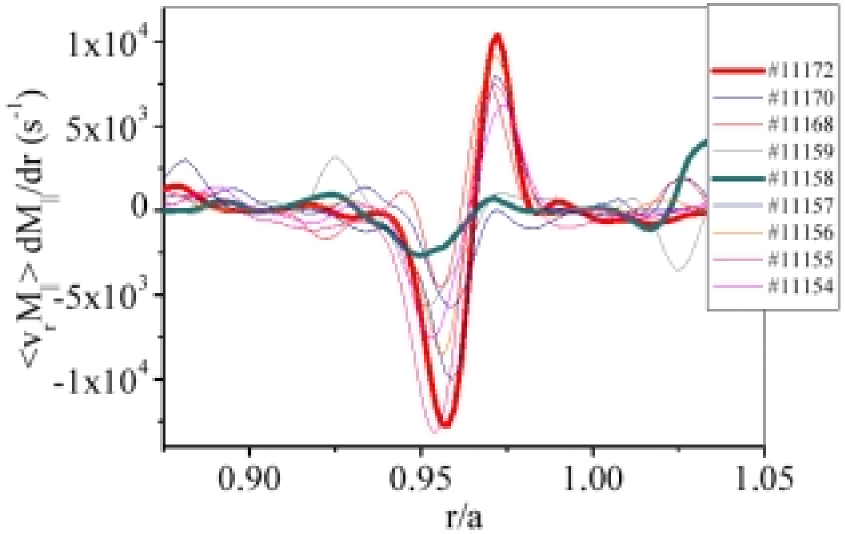
L. Krupnik et al., EPS-2003

Magnetic topology: momentum re-distribution via turbulence

Energy transfer:

$$P = < \tilde{v}_r \tilde{M}_{||} > \frac{\partial M_{||}}{\partial r}$$





Experiments carried out in the plasma boundary of TJ-II stellarator and JET tokamak have shown the existence of significant gradients in the cross-correlation between parallel and perpendicular flows near the LCFS.

(B. Gonçalves et al., IAEA-2004)

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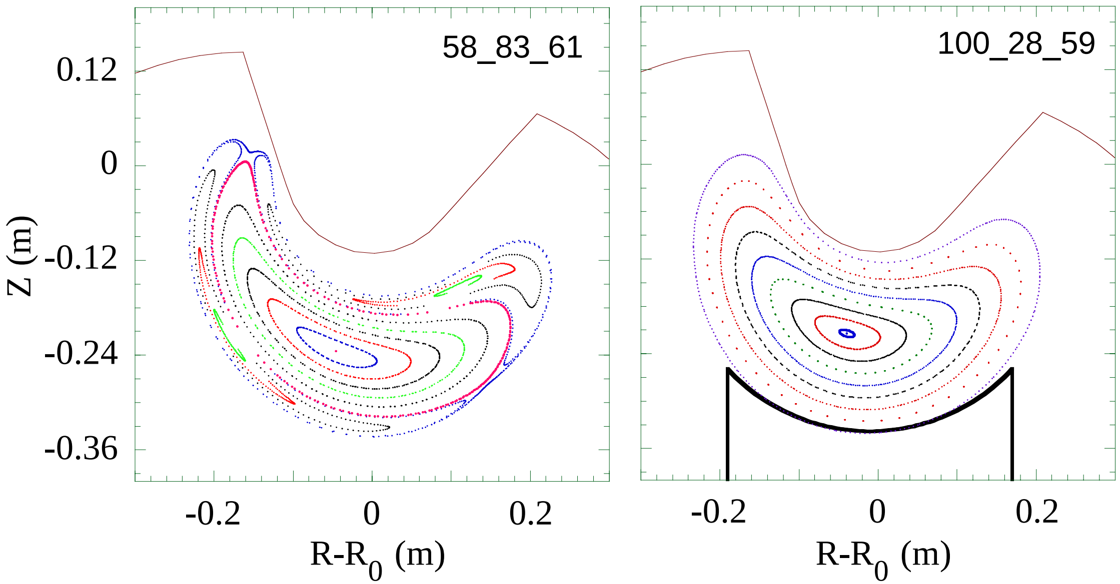
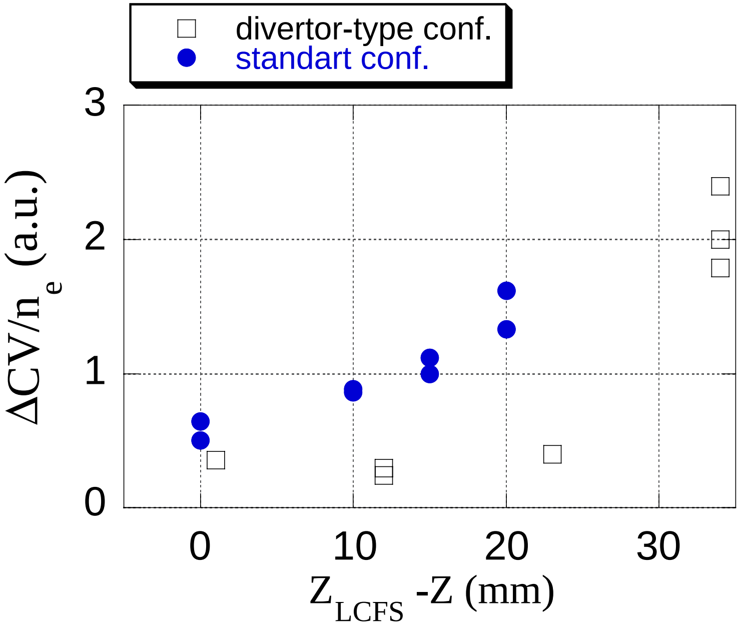
Plasma wall studies: configurations with edge islands





- **Enhanced screening of injected impurities in edge island configurations takes place.**
- **These results indicate that configurations with rational numbers that give rise to island chains at the edge are good candidates for application as divertor-type plasmas in TJ-II.**

I. García-Cortés et al., JNM-2004

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NBI plasmas: profile evolution

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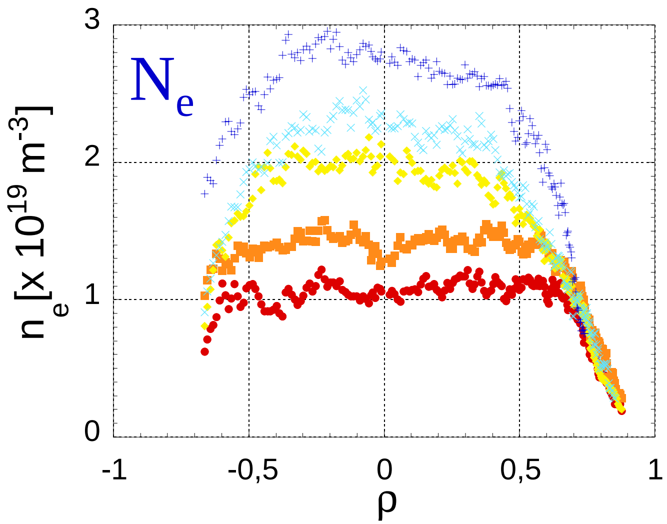
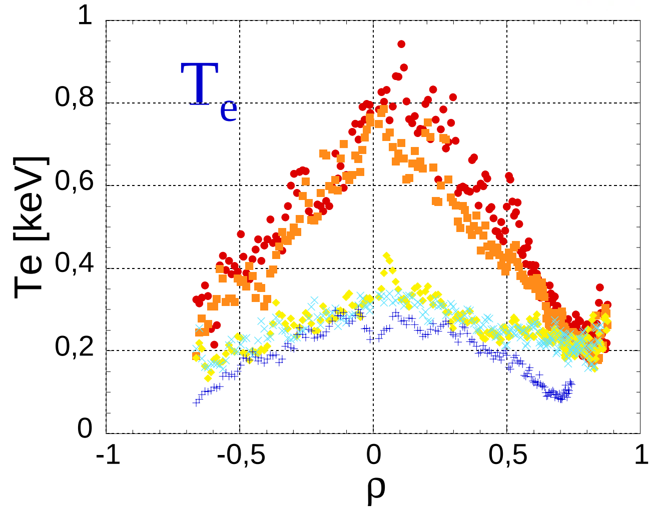
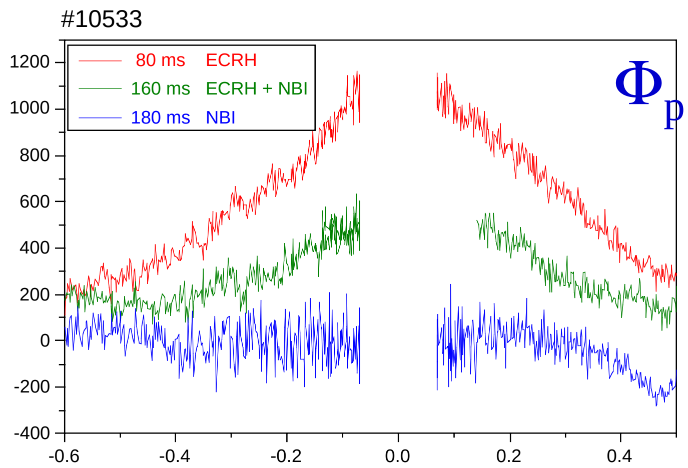




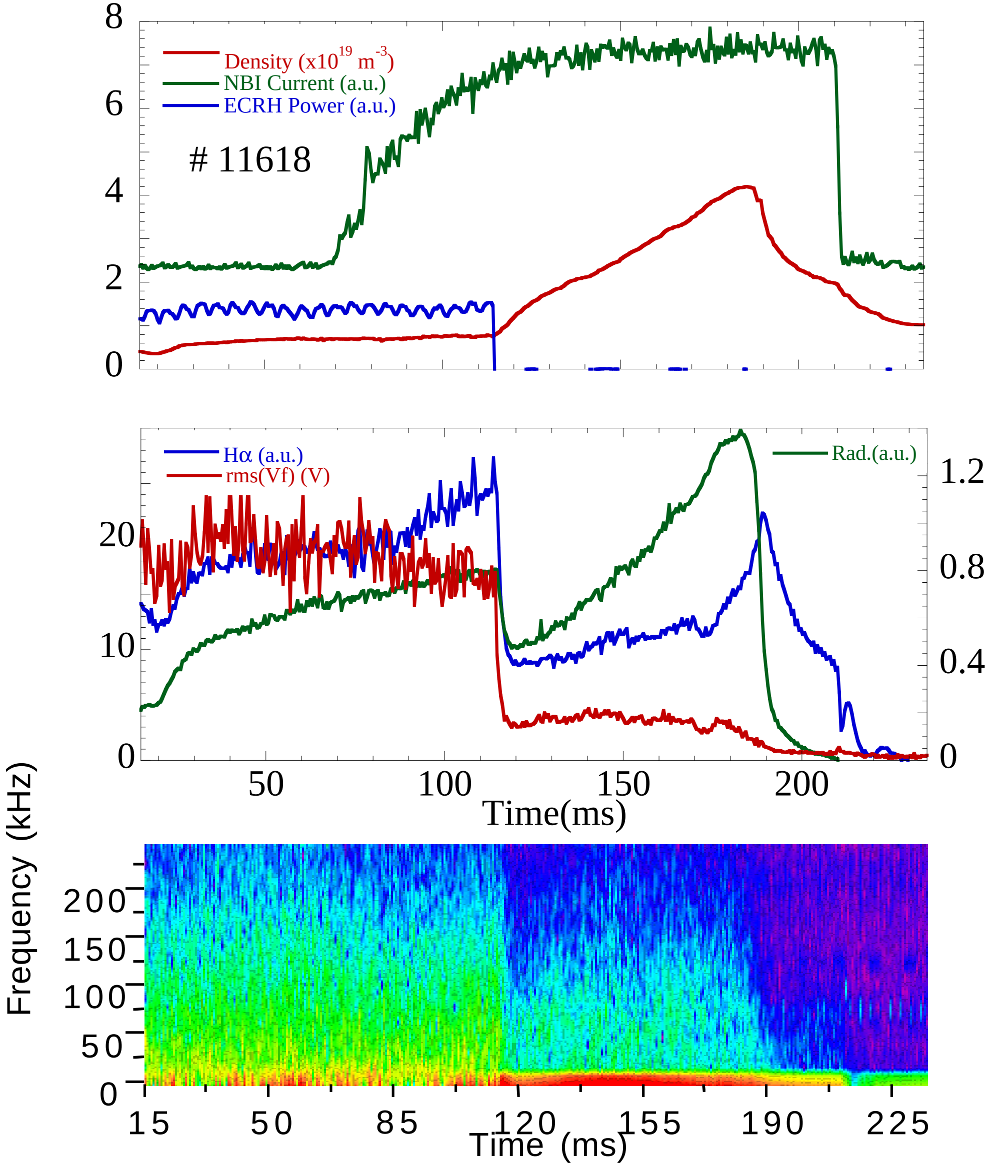


M. Liniers et al., EPS-2004
L. Krupnik et al., EPS-2004

•The electron and density profiles show a gradual evolution from the hollow shape typical of ECH plasmas (on-axis) to bell-shaped profiles at the NBI phase (400 kW).

•Measurements of plasma potential show the evolution of the electric field from positive at ECH plasmas to near sign reversal at the NBI regime.

NBI plasmas:confinement and fluctuations



Combined ECRH and NBI experiments reveal that, once ECRH heating power is switched-off, a confinement regime characterized by:

•a strong reduction in ExB turbulent transport

•significant increase in the ratio between density (n) and particle transport (H_α) is achieved.

Final Conclusions

- **Global confinement studies have revealed a positive dependence of energy confinement on the rotational transform and plasma density.**

- **Spontaneous and biasing-induced improved confinement transitions, with some characteristics that resemble those of previously reported H-mode regimes in other stellarator devices, have been observed.**

- **Magnetic configuration scan experiments have highlighted the interplay between magnetic topology, transport and electric fields.**

- **Experiments configurations with a low order rational located in the proximity of the LCFS have shown the impurity screening properties related to the expected divertor effect.**

- **The evolution of transport and turbulence at the transition from ECRH to NBI plasmas plasmas points in the direction of an improved particle confinement regime.**