MINISTERIO DE EDUCACIÓN Y CIENCIA

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

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On the relaxation physics of plasma potential and perpendicular flows in the plasma boundary of stellarator and tokamak plasmas

Presented by

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- Experimental set-up
- Effect of biasing on plasma parameters
- Decay time scales measured at TJ-II
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- Discussion
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Motivation

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- Driving and damping mechanisms of development of radial electric fields and plasma flows in the plasma boundary region of fusion devices are key elements to understand the improved confinement regimes in fusion devices.
- Both neoclassical (e.g. ion orbit losses) and anomalous mechanisms (i.e. anomalous stringer spin-up, Reynolds stress) have been considered as candidates to explain the generation of sheared flows.
- In biasing experiments carried out both in TJ-II stellarator and in Castor tokamak, the decay times of edge plasma potential and perpendicular flows measured in the edge plasma region have been investigated when electrode applied potential is turned off.
- Obtained results suggest the importance of anomalous damping rate mechanisms for radial electric fields and perpendicular flows in the plasma boundary of stellarator and tokamak plasmas.

Experimental Set-up

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- TJ-II is a four-field-period low-magnetic-shear stellarator.

$\langle R \rangle = 1.5$ m $\langle a \rangle \leq 0.22$ m

$B_T \leq 1.2$ T $\langle n_e \rangle \approx (0.35 - 1) \times 10^{19}$ m^{-3}

$P_{ECRH} \leq 400$ kW $f_{ECRH} = 53.2$ GHz

Langmuir/Mach Probes

$I_s \propto n T_e^{1/2}$ $V_f \approx V_p - \alpha T_e$

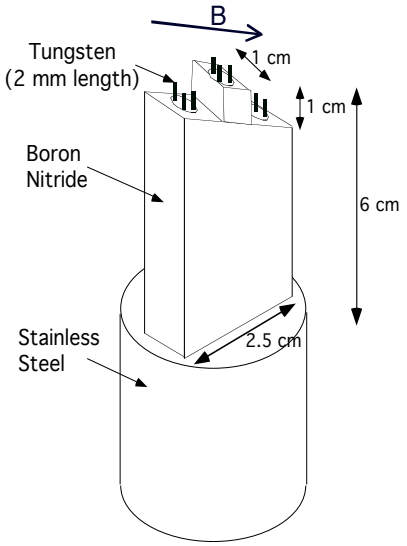
Electrode

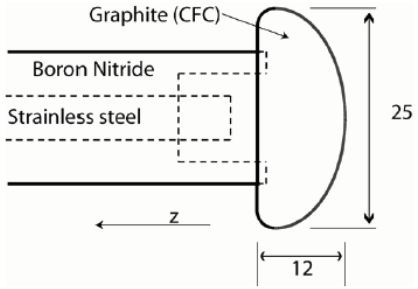
2-D Carbon (12 mm height and a diameter of 25 mm).

2 cm inside the LCFS

V= 160-400 V with respect to one poloidal limiter

I≈20-50 A





- Castor tokamak

$R = 0.4$ m $a = 0.085$ m

$B_t = 1$ T $I_p \approx 9$ kA $q_a \approx 10$

$n_e(a) \approx 1 \times 10^{12}$ cm^{-3} $T_e(a) \approx$ 10-20 eV

Rake probe

10 floating probes with 0.25 cm radial separation

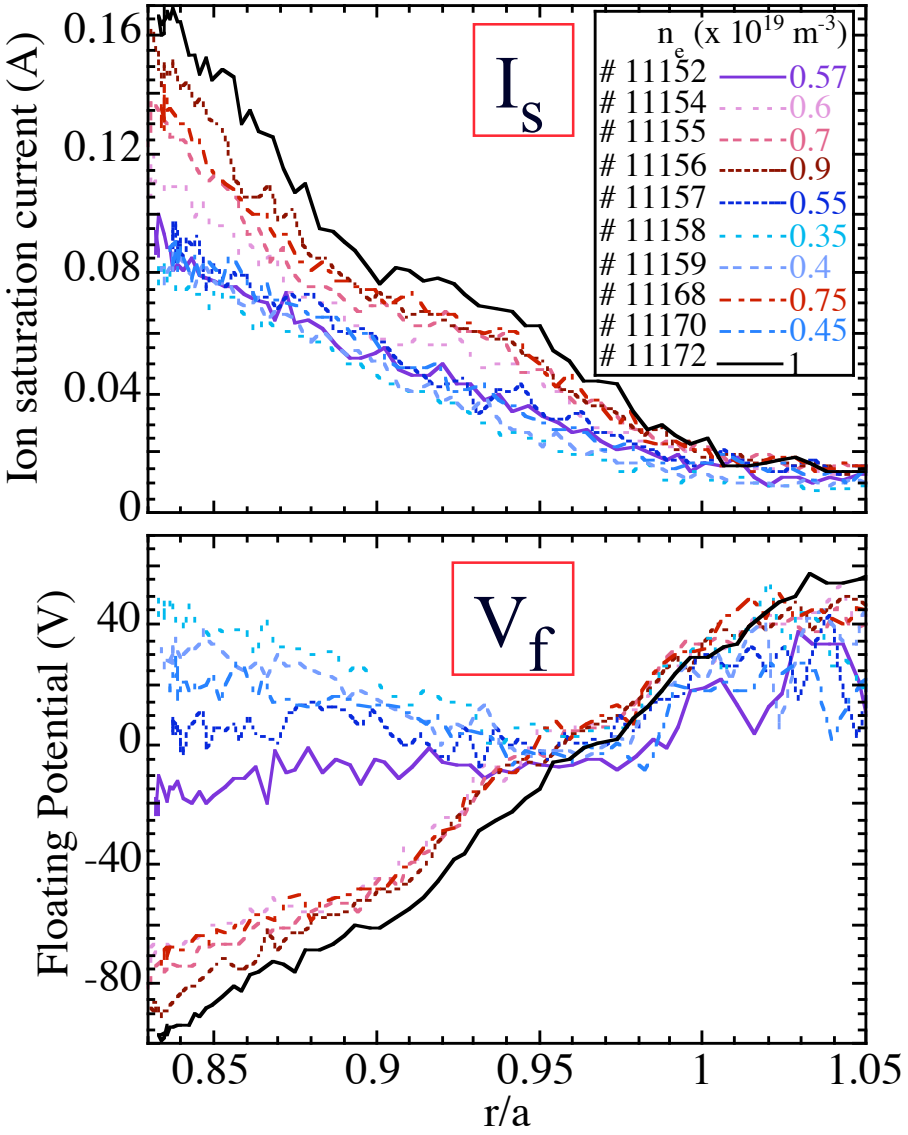
Electrode

$\rho = 0.75$

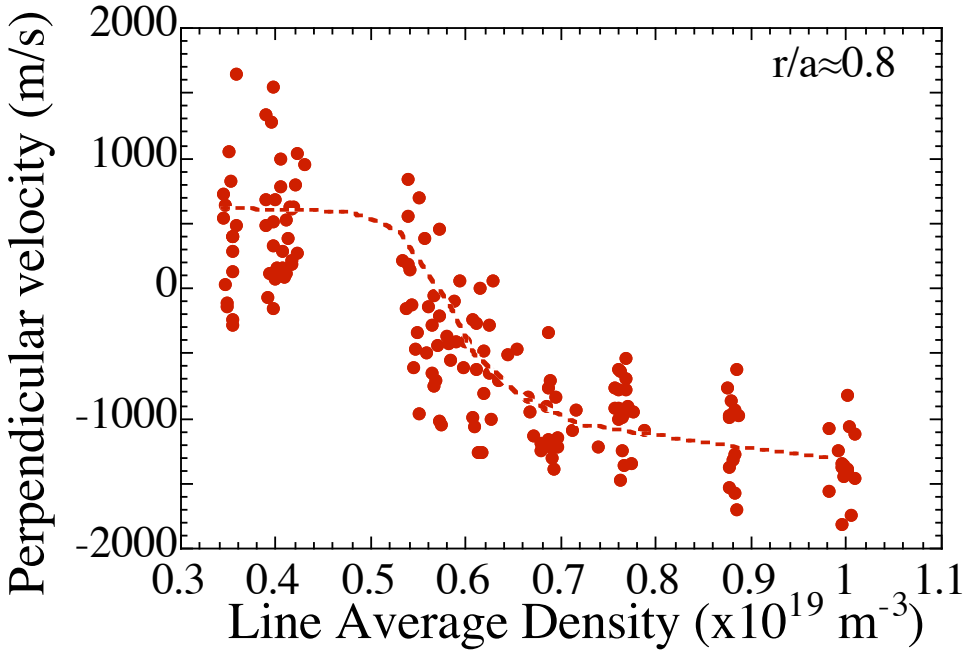
$U_b = 100 – 230$ V with respect to the vacuum vessel

I ≈ 30-40 A

Experimental results



The modifications in the plasma properties induced by electrode biasing depend on several parameters as the biasing voltage, the electrode location and plasma density.



Effect of biasing on plasma parameters

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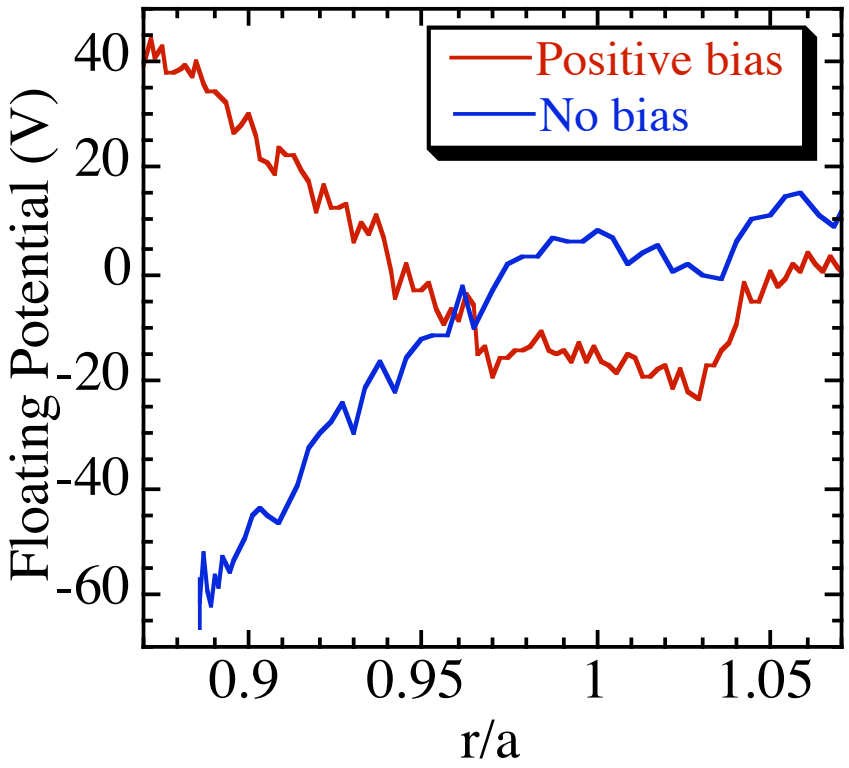
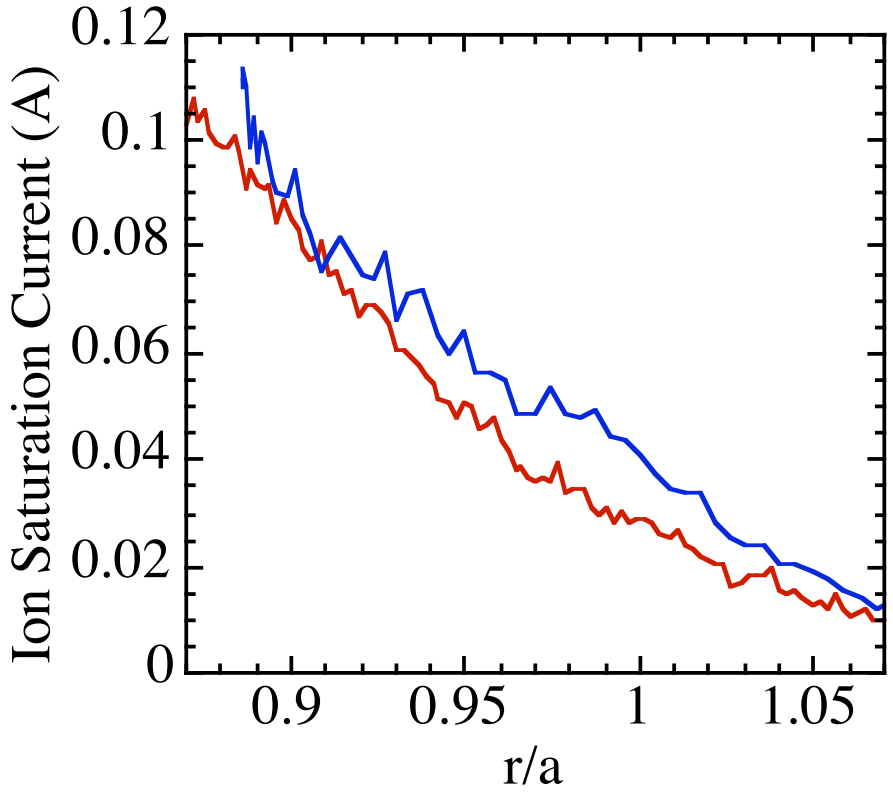
V_f profile is strongly modified by electrode bias in the region $r_{eff}/a<0.95$, leading to the formation of a strong radial electric field (up to 10 kV/m).

These results are consistent with the time evolution of the phase velocity observed, which increases during biasing.





Effect of biasing on plasma parameters

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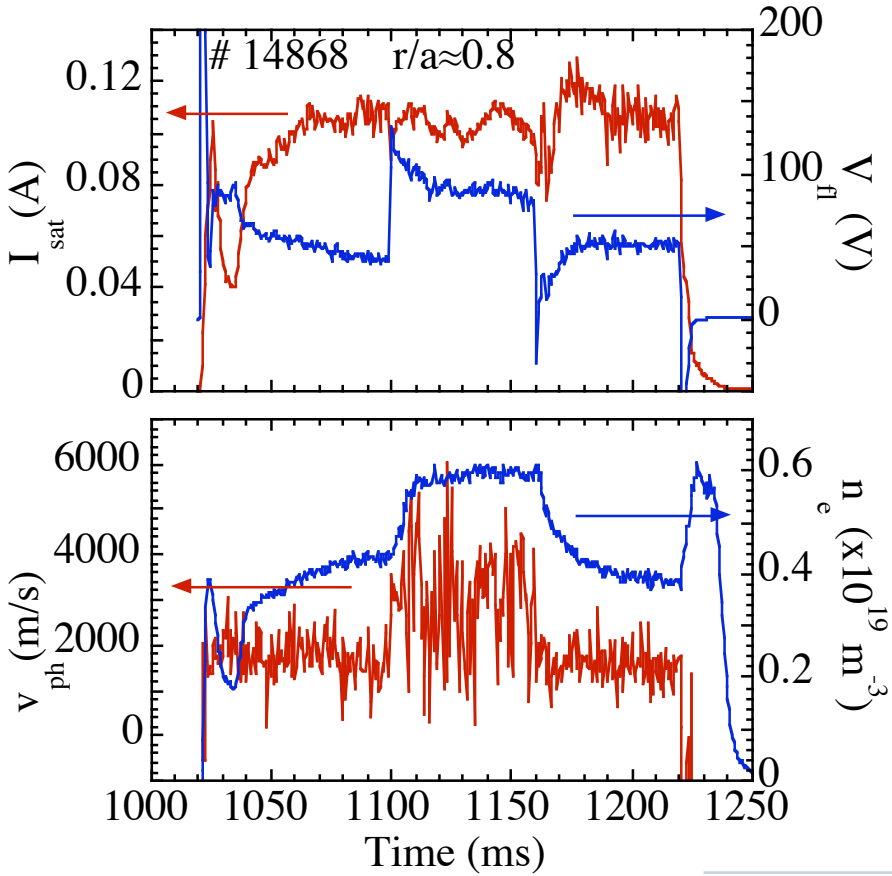
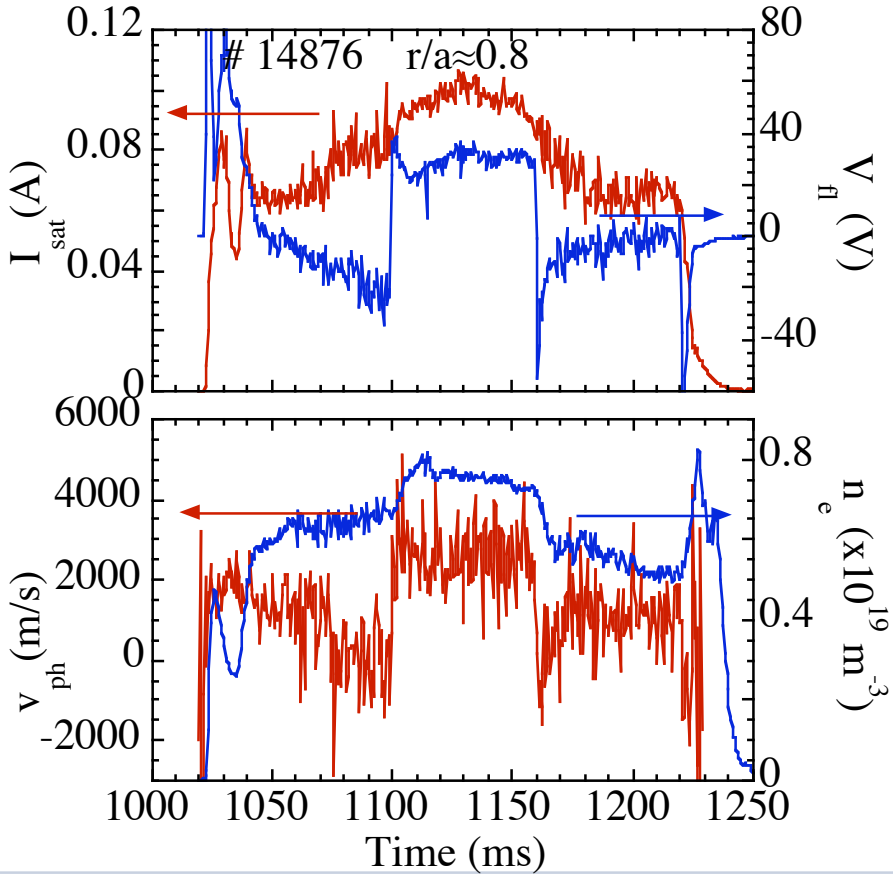
Below threshold density plasma potential fully controlled by external biasing.

Above threshold density edge plasma potential profiles are determined not only by external biasing but also by the electric fields spontaneously developed.

Two different time scales exist in TJ-II: slow time scale, in the range of the particle confinement time (10 ms), fast time scale in the range of turbulence time scales (10 – 50 μs)





Effect of biasing on plasma parameters

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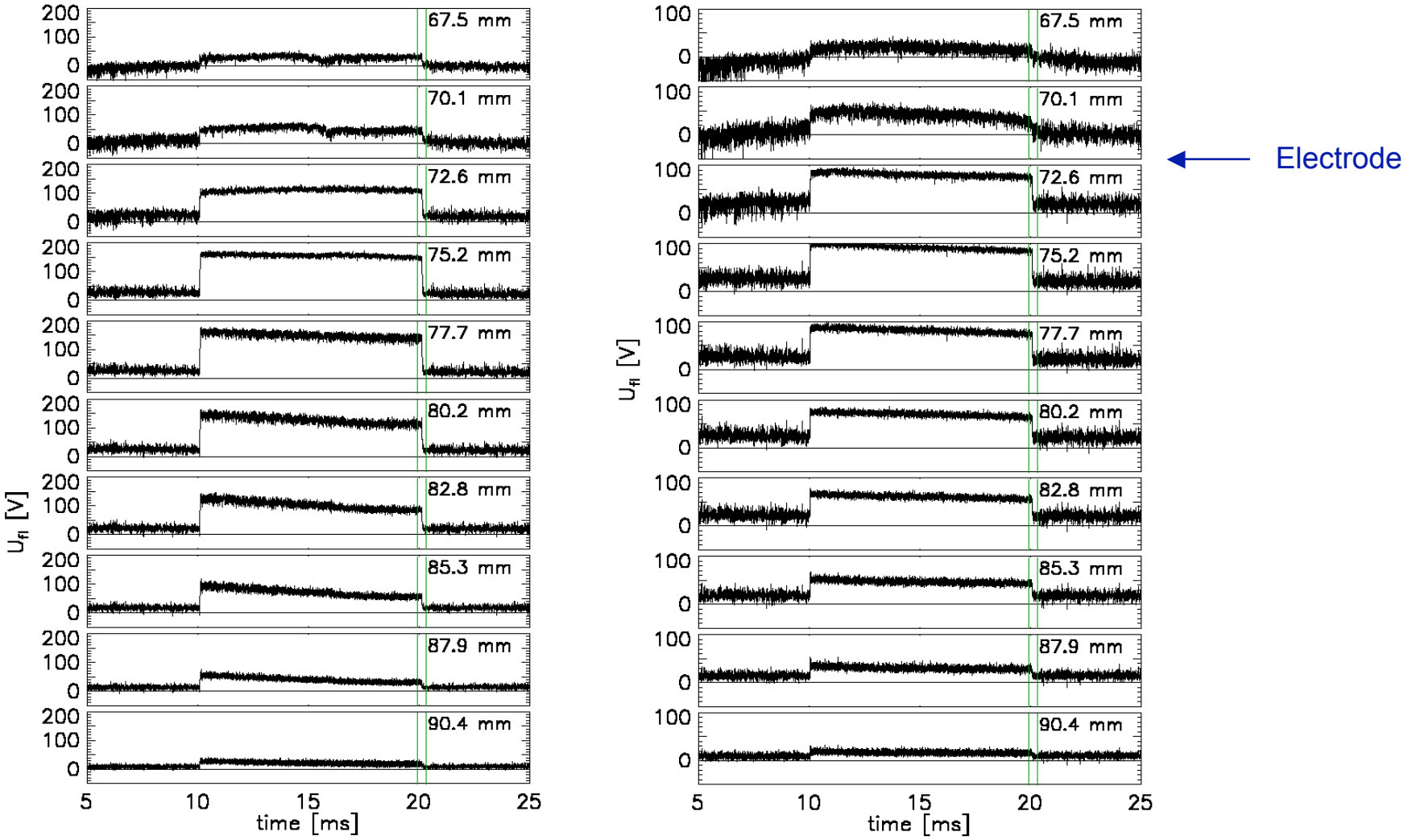
Time evolution of floating potential profiles during the biasing phase (10 – 20 ms) in the plasma boundary region of CASTOR



Effect of biasing on plasma parameters

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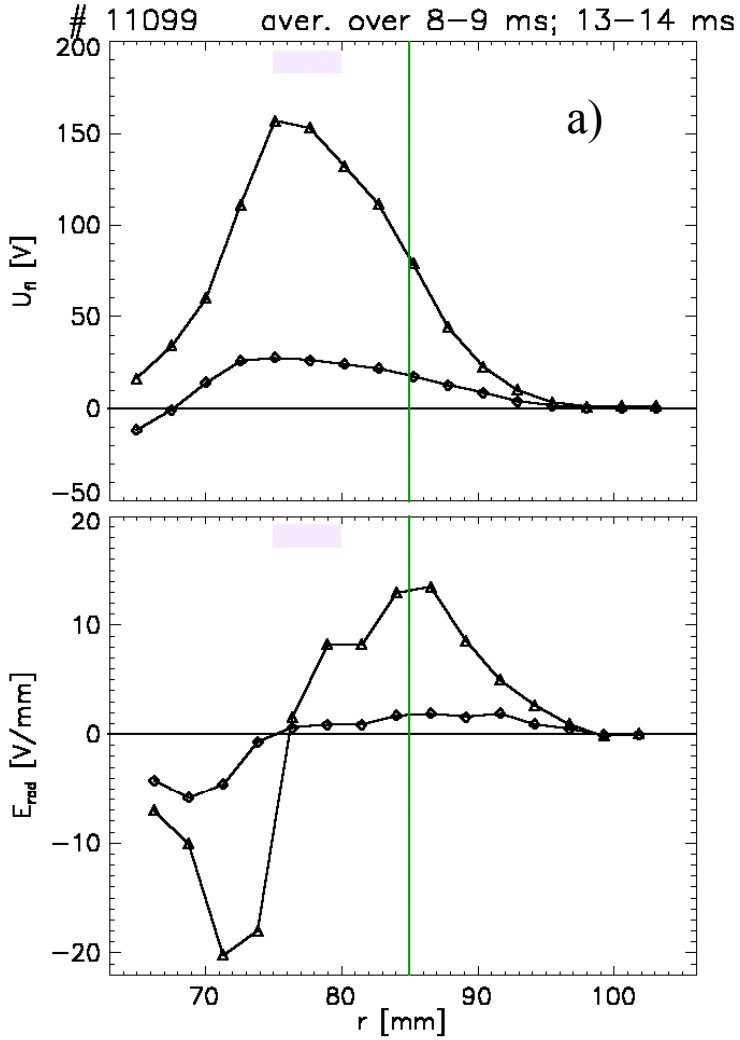
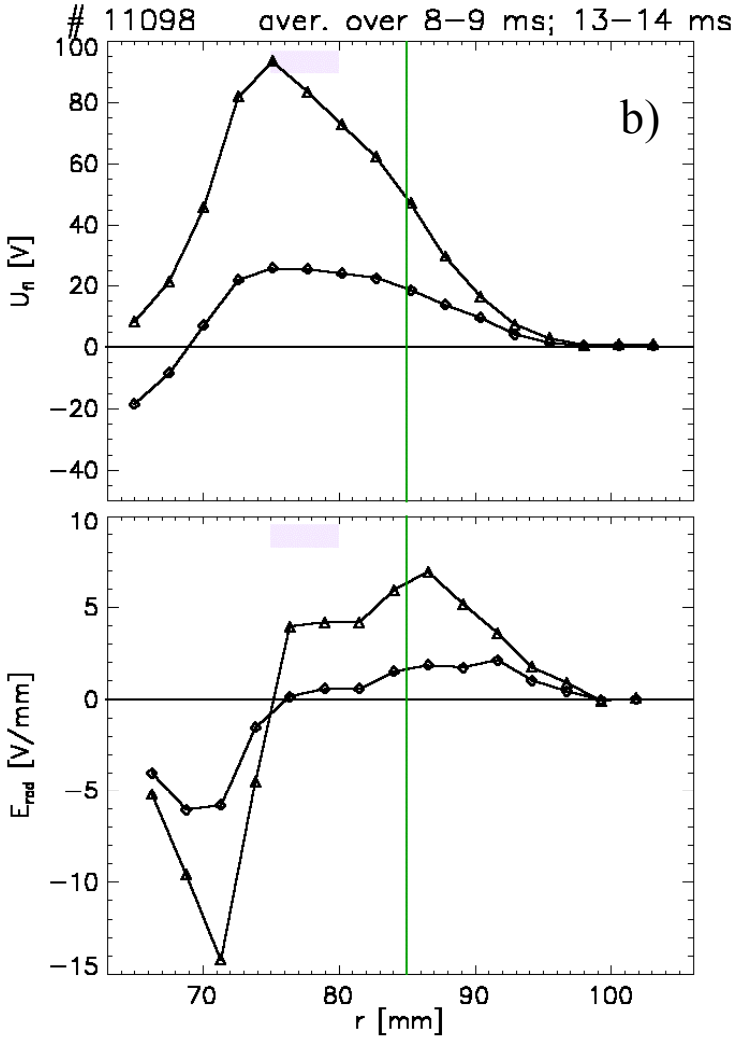
CASTOR: Radial profiles of floating potential and radial electric field in ohmic (diamonds) and biasing (triangles) phases with different biasing: a) 200 V, b) 100 V





Decay time scales measured at TJ-II

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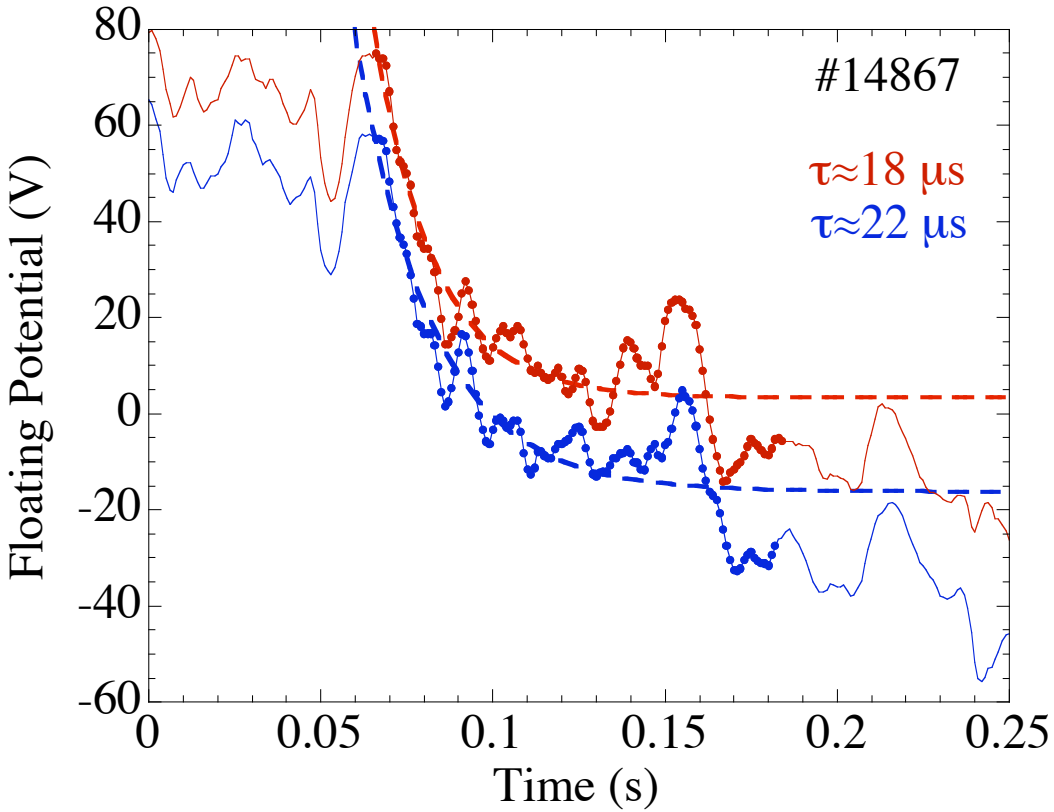
The time evolution of floating potential signals can be fitted to the function

$$U_{fl}(t) = U_{max} \exp(-t/\tau) + U_{min}$$

where τ is the exponential relaxation time



Decay time scales measured at TJ-II

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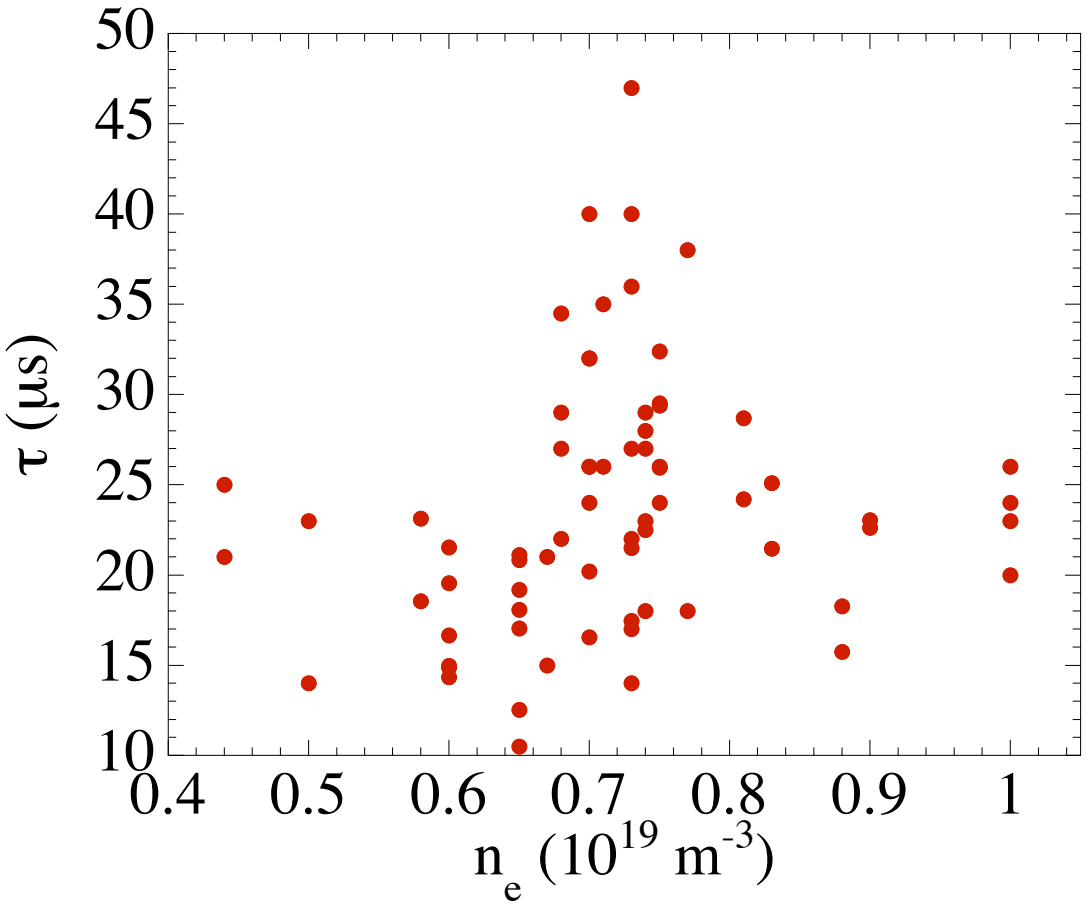
Decay times might be affected by the presence of sheared flows development near marginal stability, showing a tendency for longer decay times once edge sheared flows are fully developed.



Decay time scales measured at TJ-II

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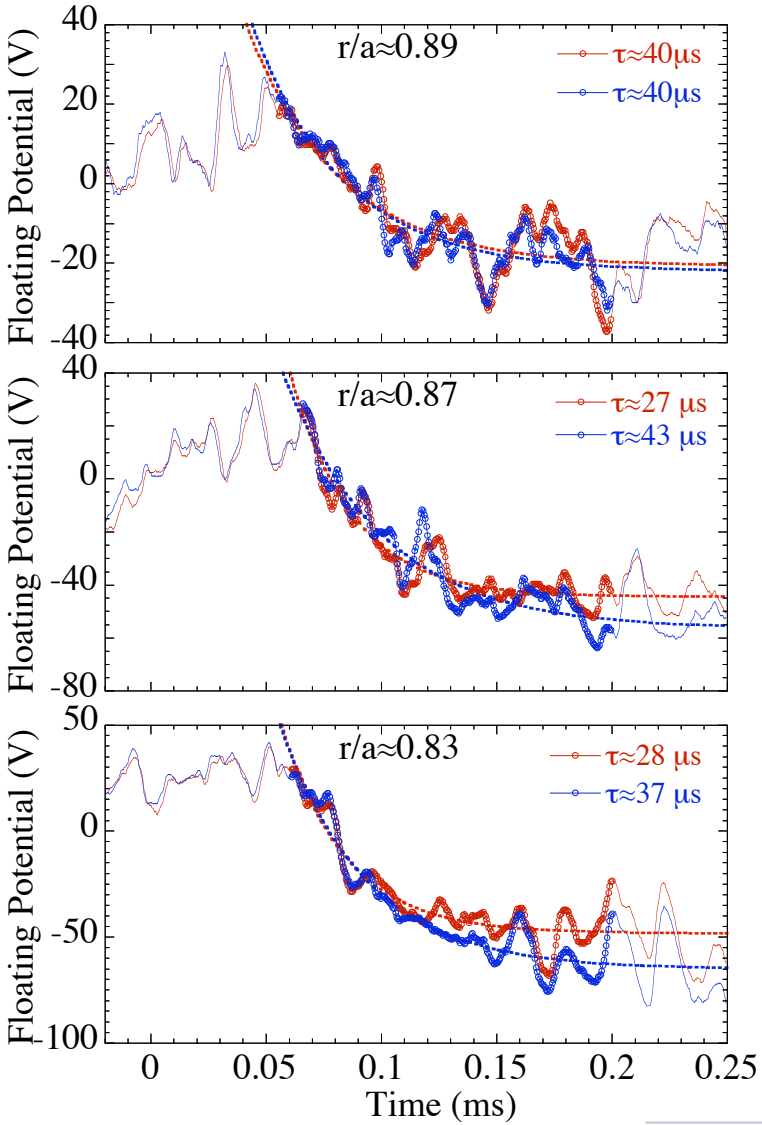
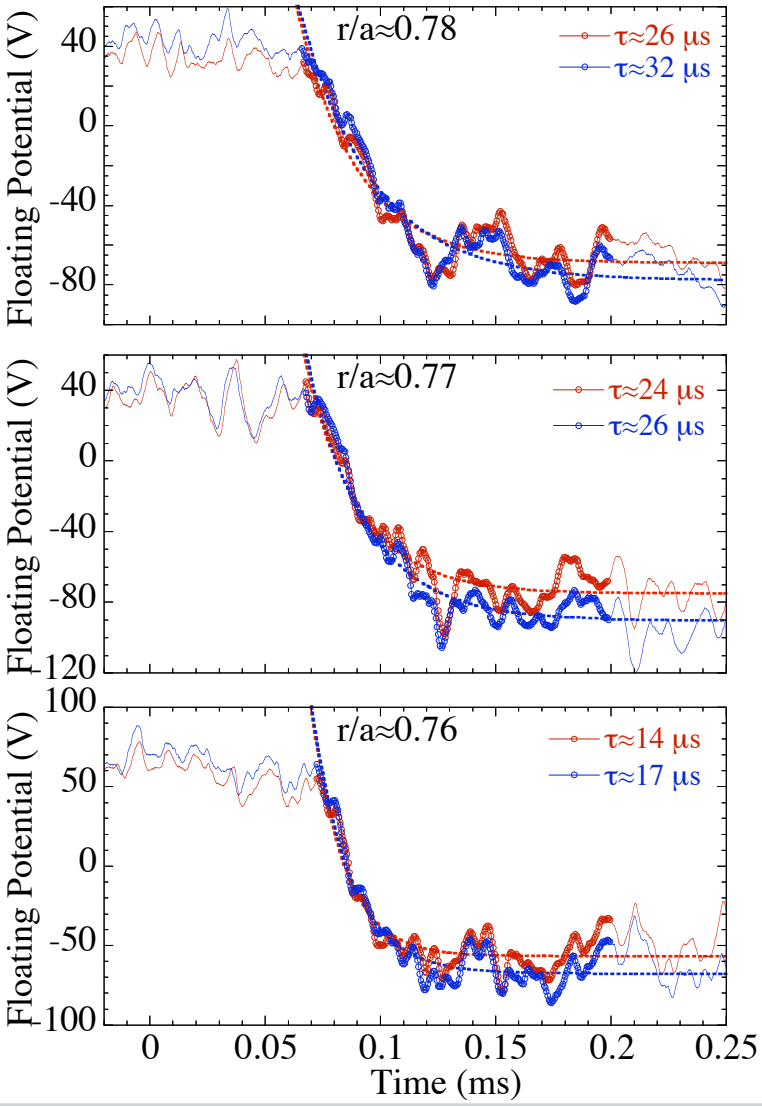
Decay times in TJ-II seem to decrease when going inside the plasma.





Decay time scales measured at TJ-II

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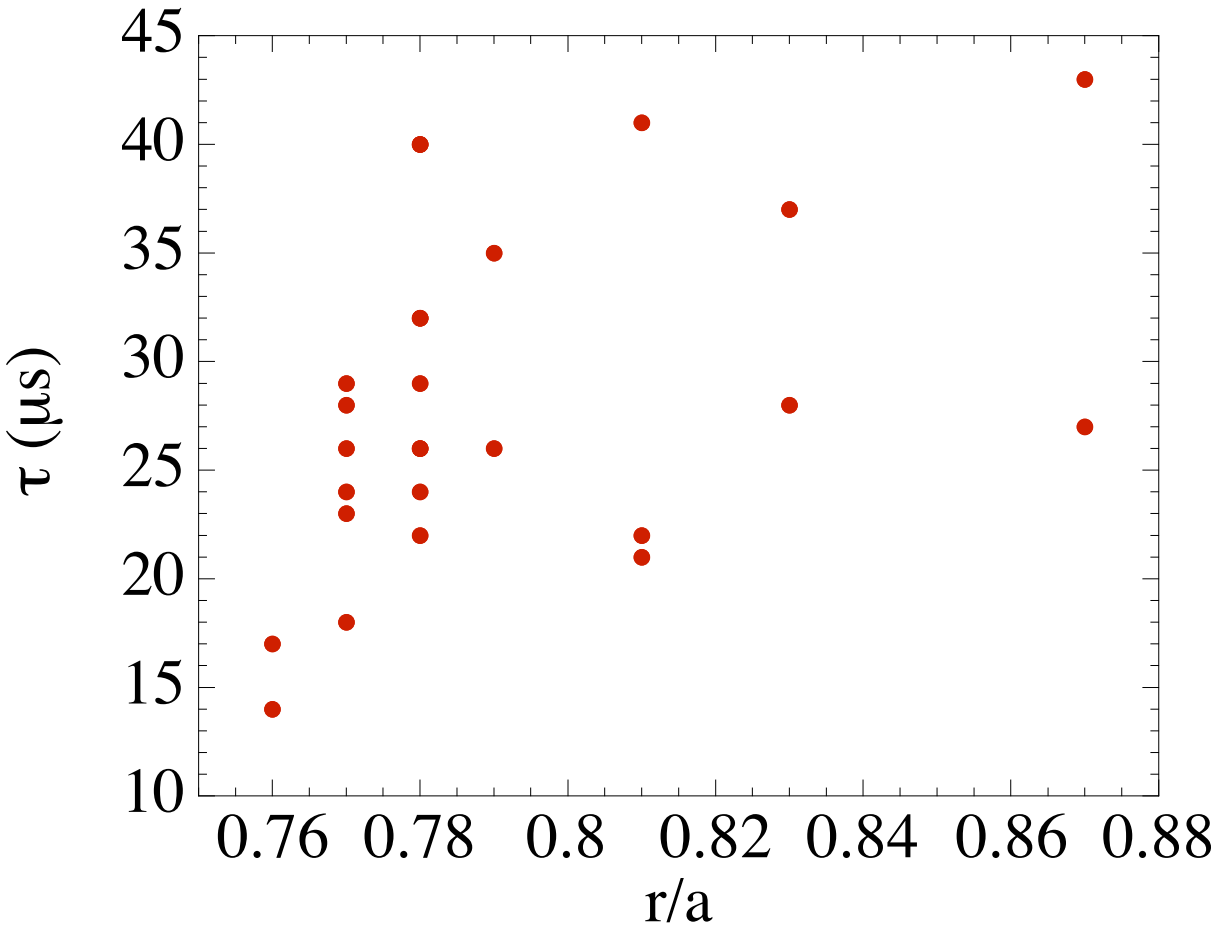
Decay times in TJ-II seem to decrease when going inside the plasma.



Decay time scales measured at TJ-II

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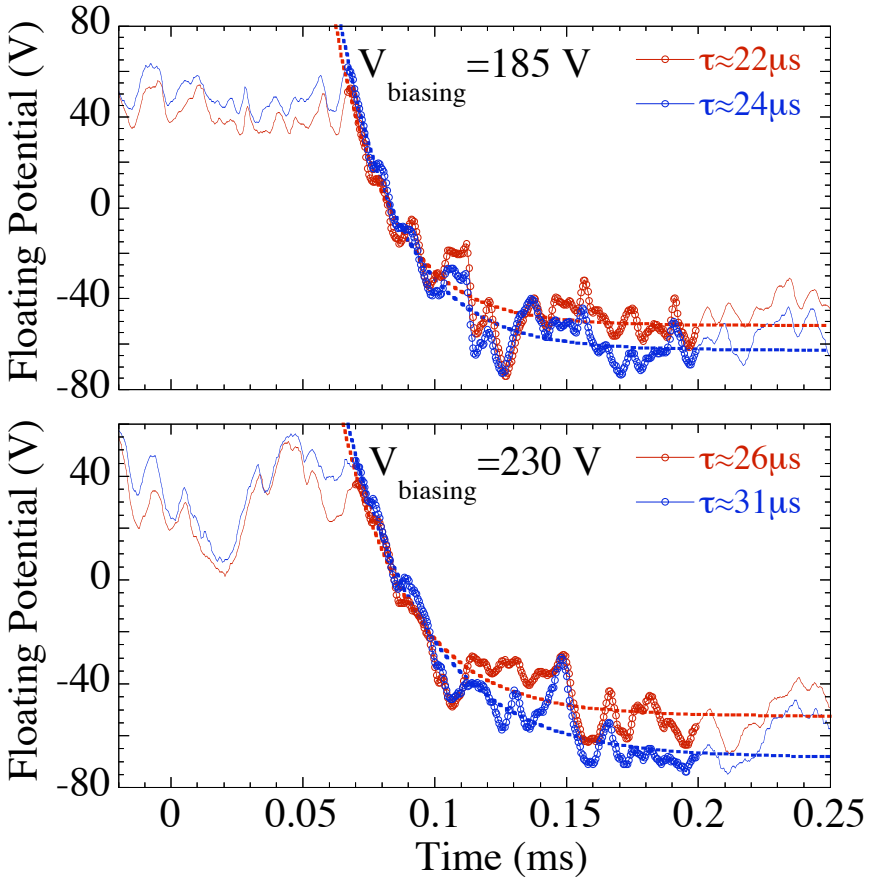
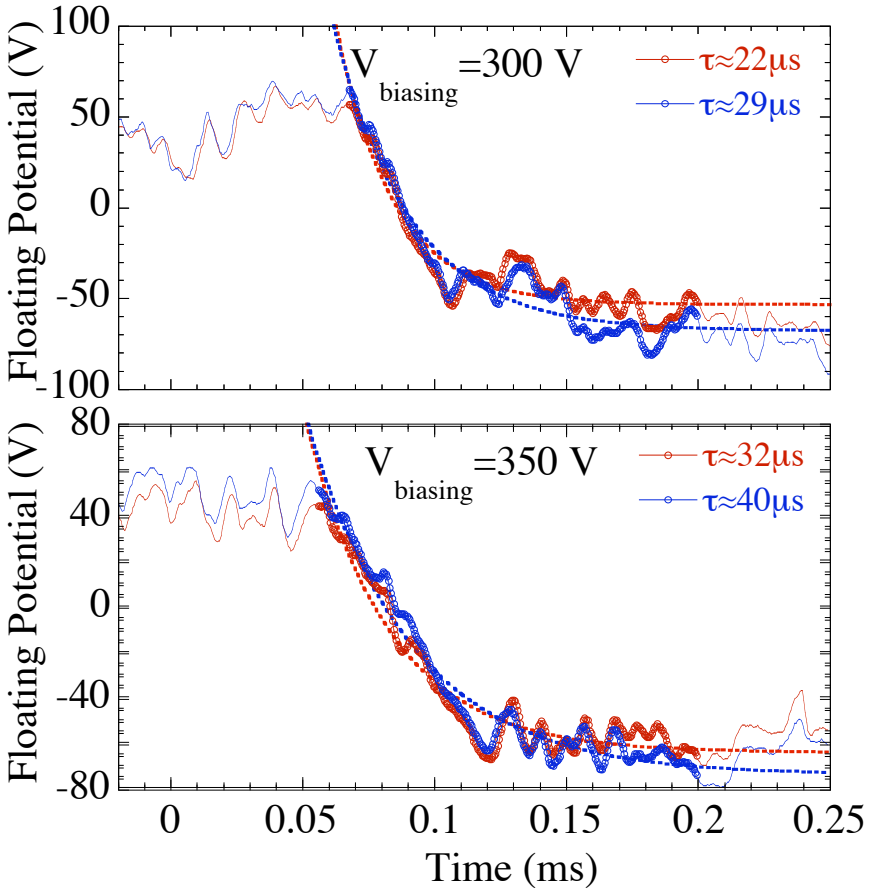
Decay times in TJ-II seem not to change with applied electrode voltage (175 - 400 V)

r/a≈0.8





Decay time scales measured at TJ-II

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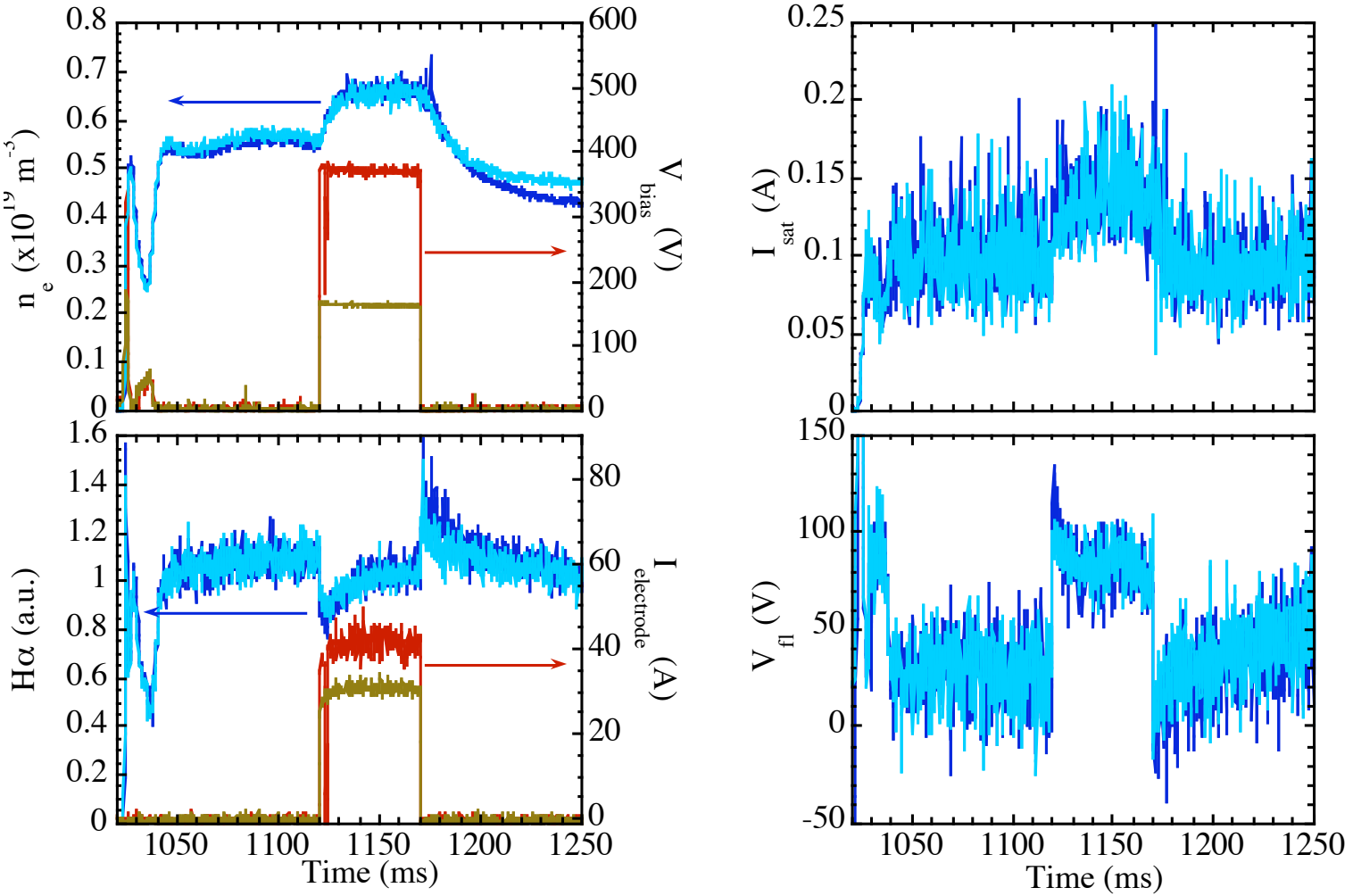
Comparison of probe response to electrode effect biased at 175 V and 400 V

r/a≈0.8



Decay time scales measured at Castor

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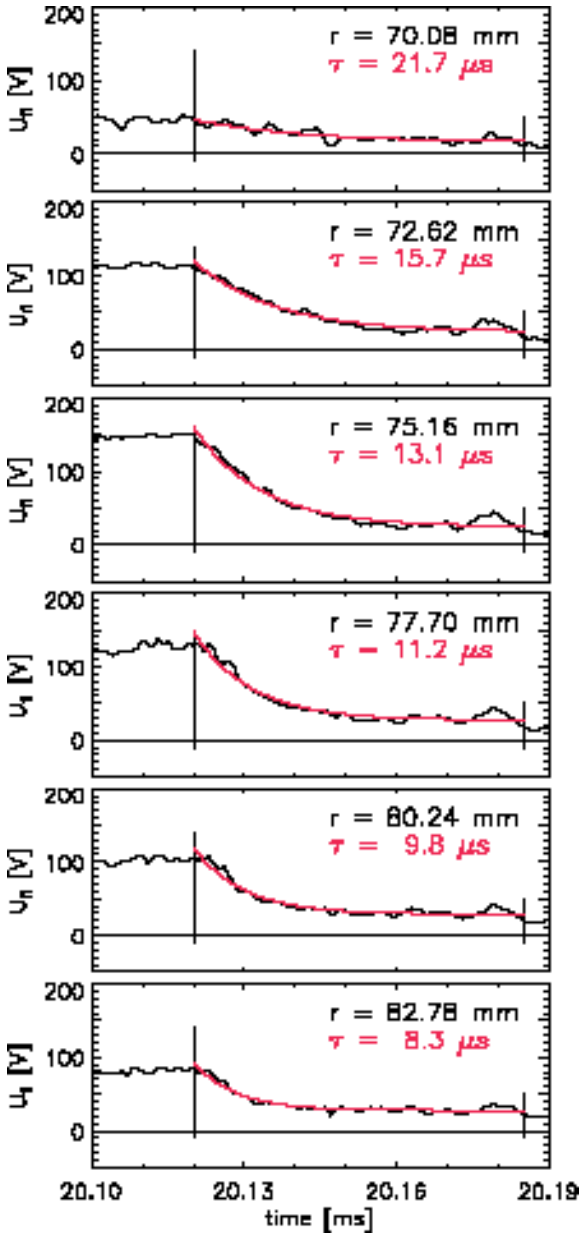
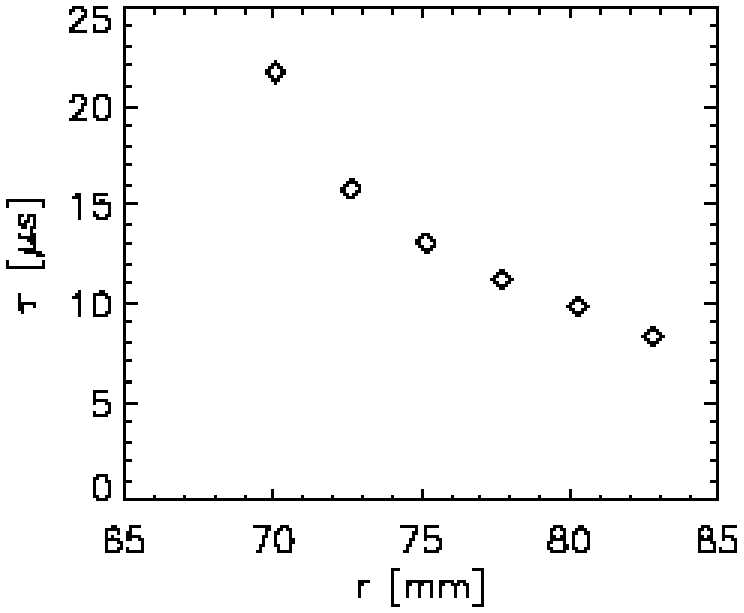


Decay times in Castor increase when going inside the plasma



SUMMARY

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- The similarity between decay time scales measured in TJ-II and Castor, with different values of ripple and consequently neoclassical viscosity, suggests the important effect of anomalous (turbulent) mechanisms in the damping rate of radial electric fields and poloidal flows in the plasma boundary of tokamak and stellarators plasmas.

- Results in TJ-II might be considered as the first experimental evidence of the influence of sheared flows on anomalous viscosity that can play a role in the bifurcation to the H-mode. In particular, these results call into a question the interpretation of the appearance of H-mode windows based on the influence of neoclassical viscosity.

- Parametric studies of the influence of different plasma regimes (e.g. collisionality, turbulence correlation times, magnetic configuration) on the damping time of poloidal flows and radial electric fields are clearly needed.

- This investigations would help to quantify the importance of anomalous versus neoclassical mechanisms on the damping physics of radial electric fields and poloidal flows in fusion plasmas.