

Edge Biasing in RFX

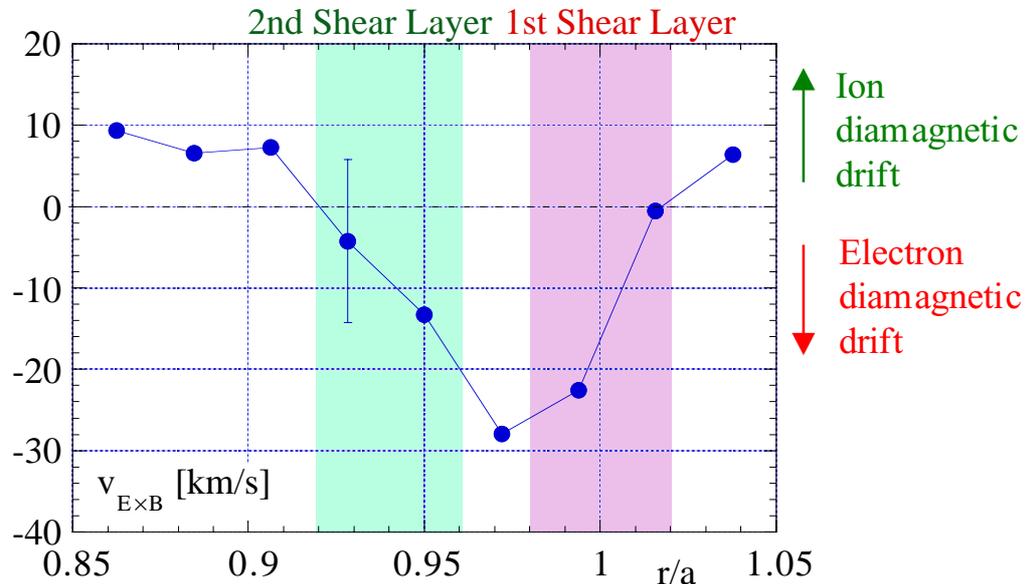
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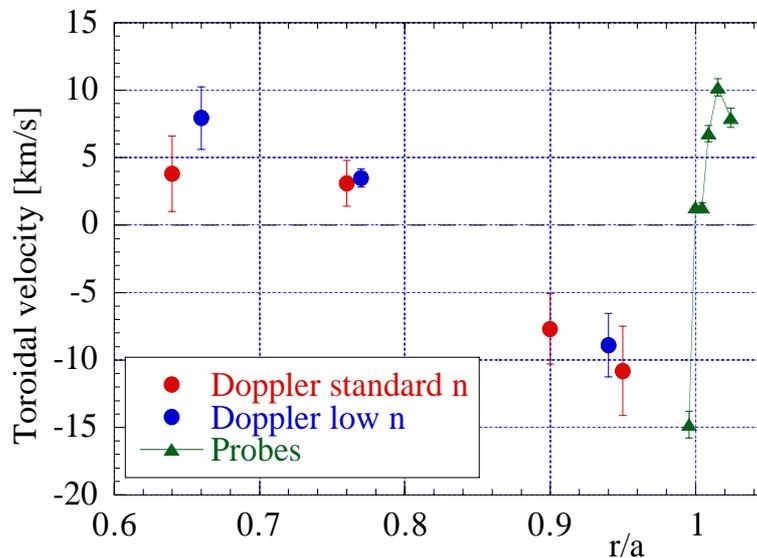
Outline

- Edge Biasing experiment in RFX
- Effects on electrostatic turbulence and related transport
- Momentum balance and modification of the ExB velocity at the edge
- Particle balance and effects on the global particle confinement time

RFX edge properties

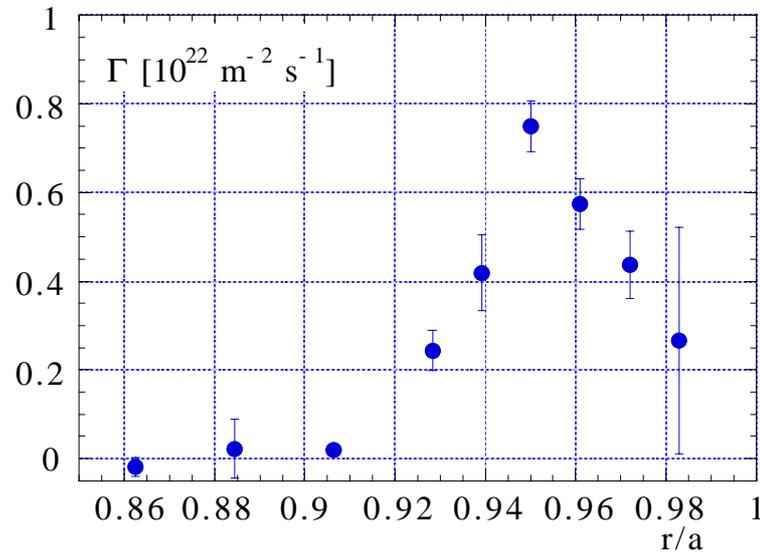


The RFX edge features a double ExB velocity shear layer. The shear in the second layer is marginal for turbulence decorrelation.

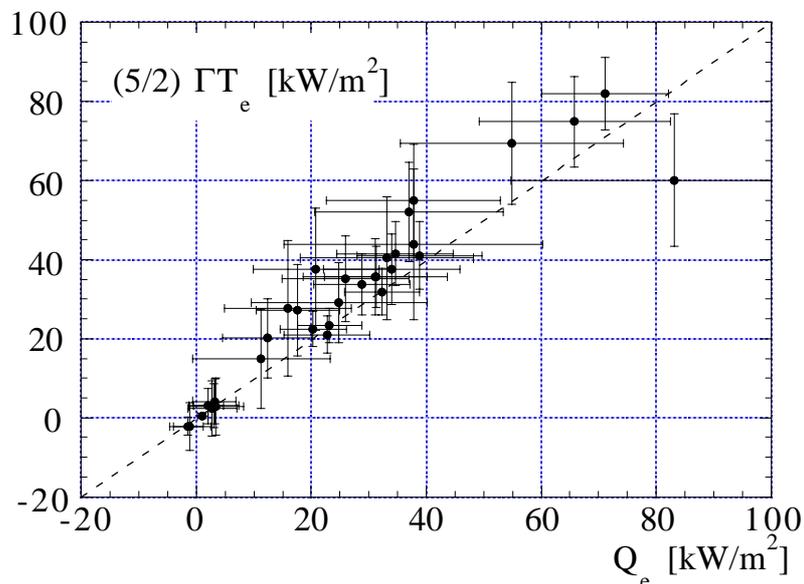


- Impurity line Doppler shift confirms the 2nd velocity shear layer.
- Mach probe confirm the 1st velocity shear layer.

RFX edge properties



Particle flux driven mostly by electrostatic turbulence and consistent with local particle balance.



The electrostatic energy flux is convective and $< 30\%$ of the total.

E. Martines et al., Nucl. Fusion, **39**, 581 (1999).

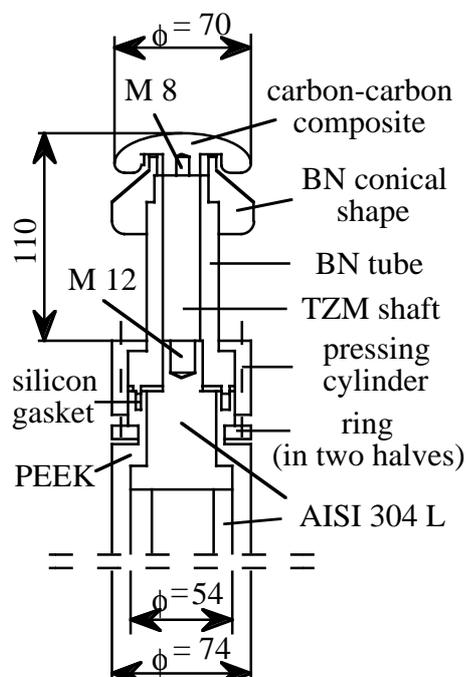
International RFP Workshop, Madison, 28Feb -1March 2000

Biasing electrodes

Two electrodes

Max current:
10 kA per electrode.

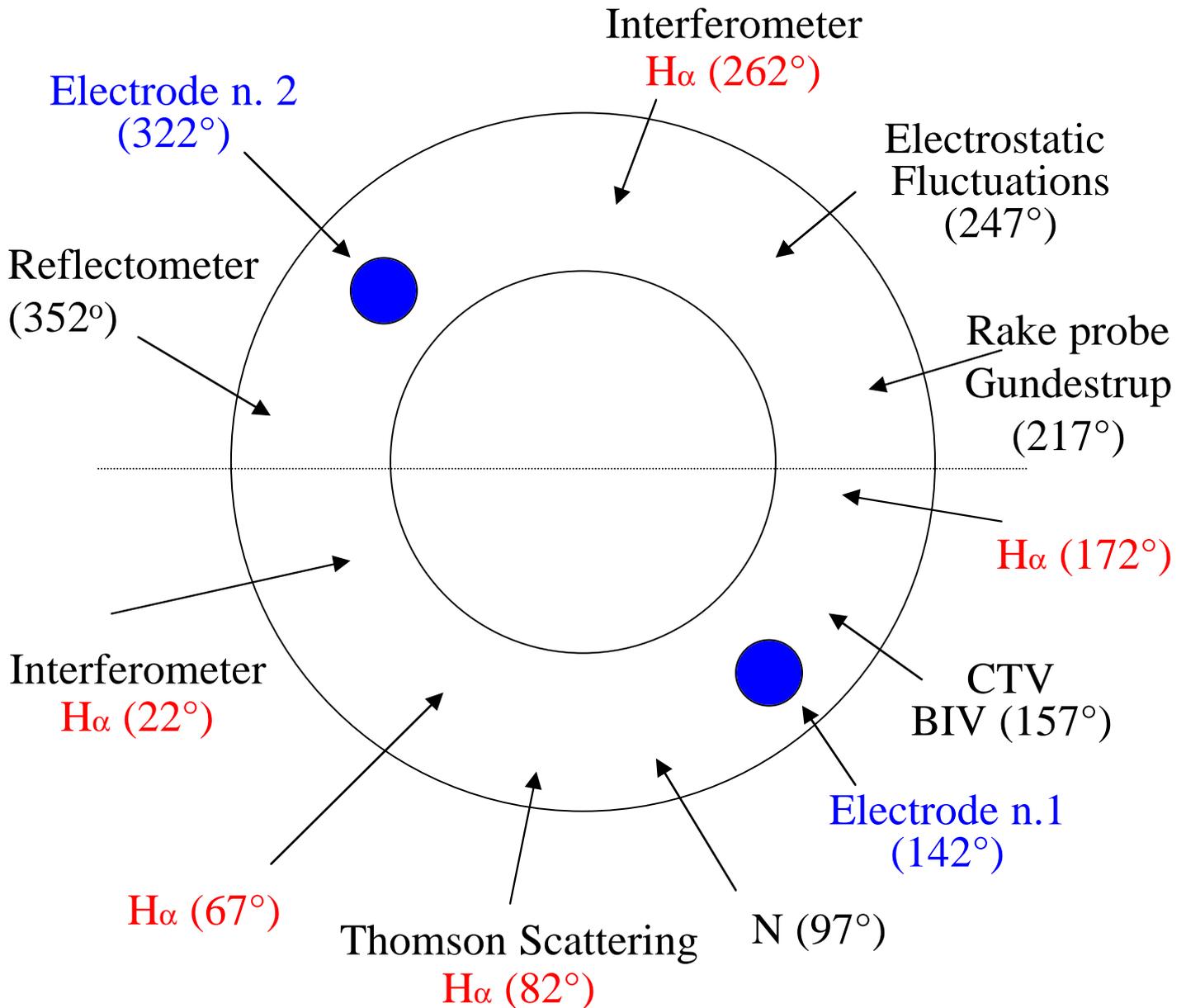
Current pulse length:
1-50 ms.



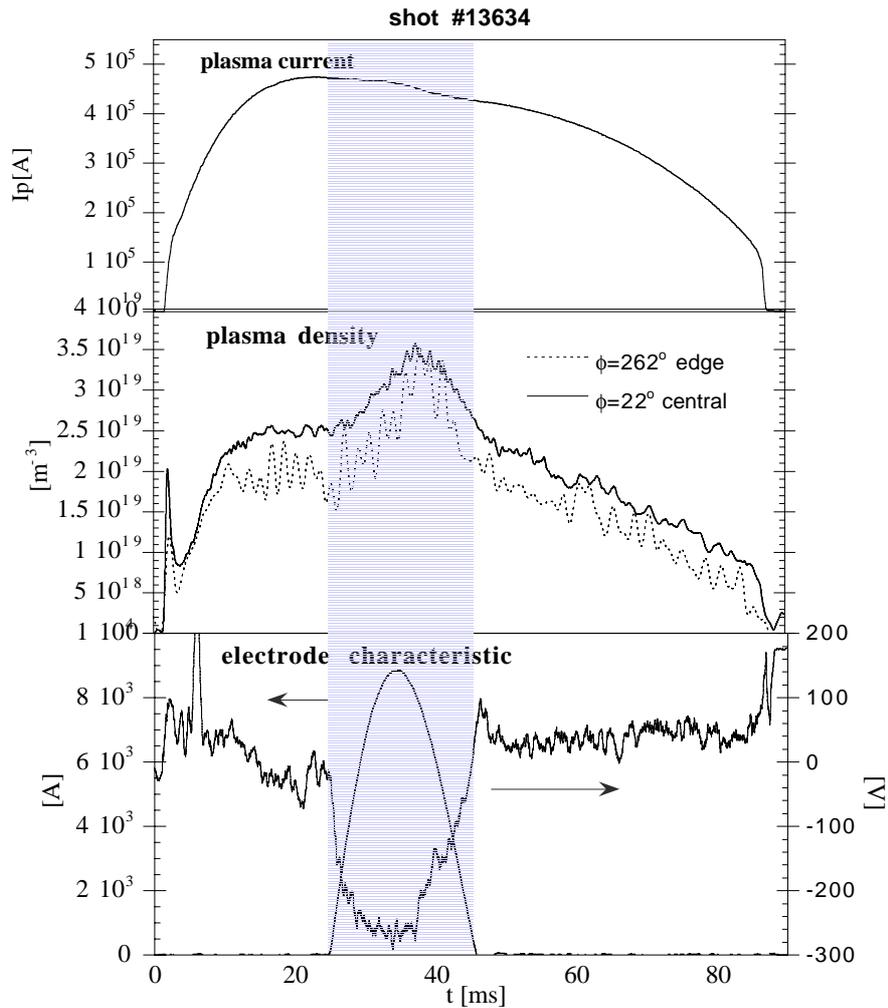
The electrodes have been negatively biased with a half-sine wave of current lasting 10-50 ms.

One or two electrodes have been inserted up to 9cm. Best performance at low density, after GDC, and with one electrode inserted at 7.5 cm ($r/a = 0.81$).

Experimental layout

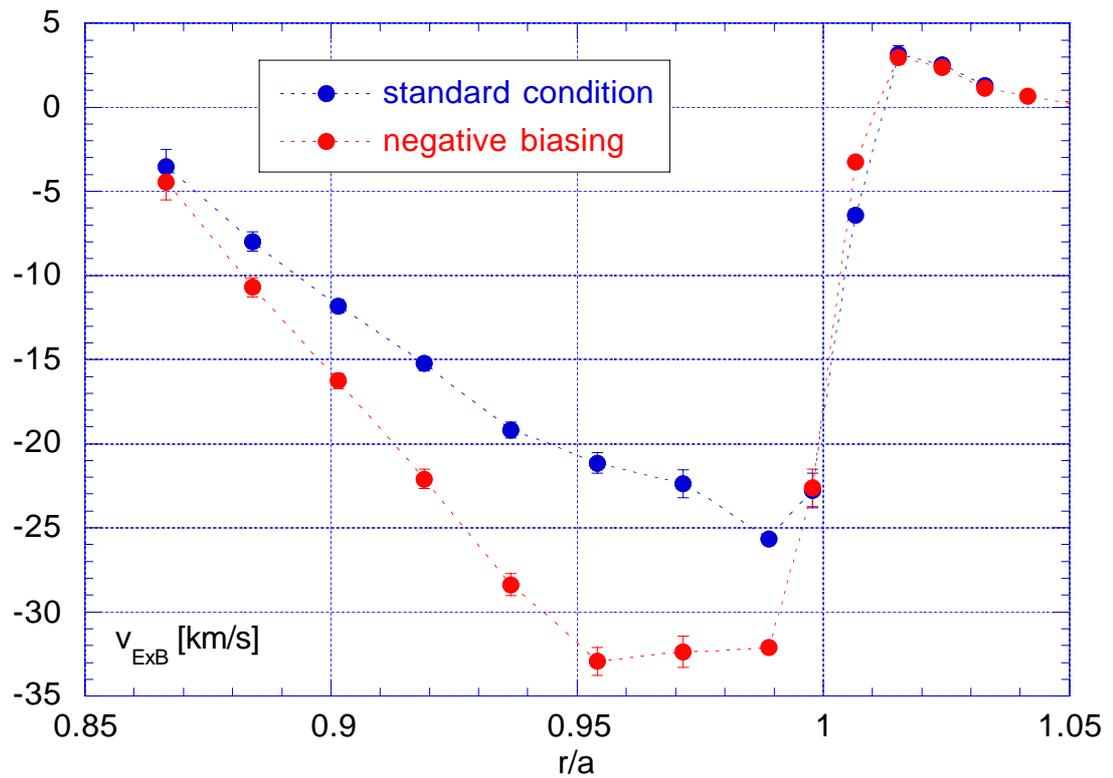


Biasing experiment



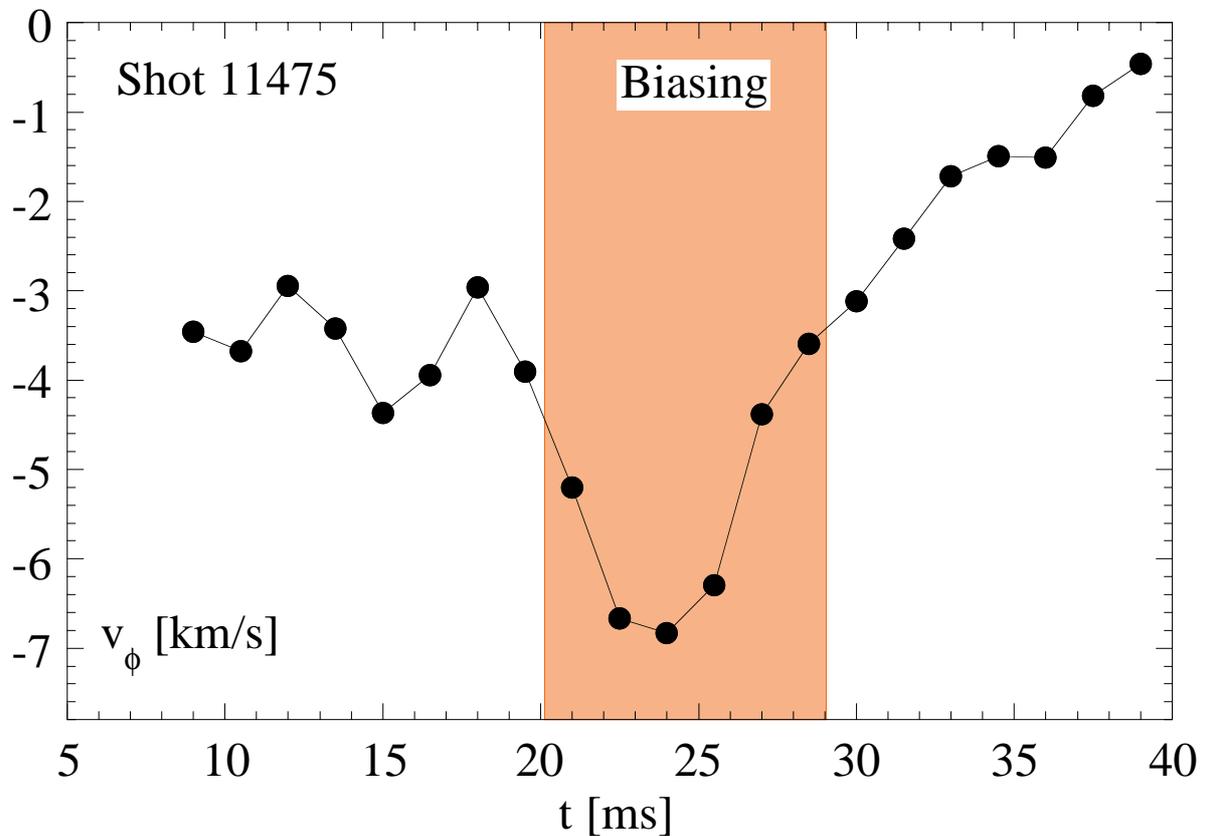
locations

Effect on the velocity shear



The $\mathbf{E} \times \mathbf{B}$ velocity increases and its shear is doubled.

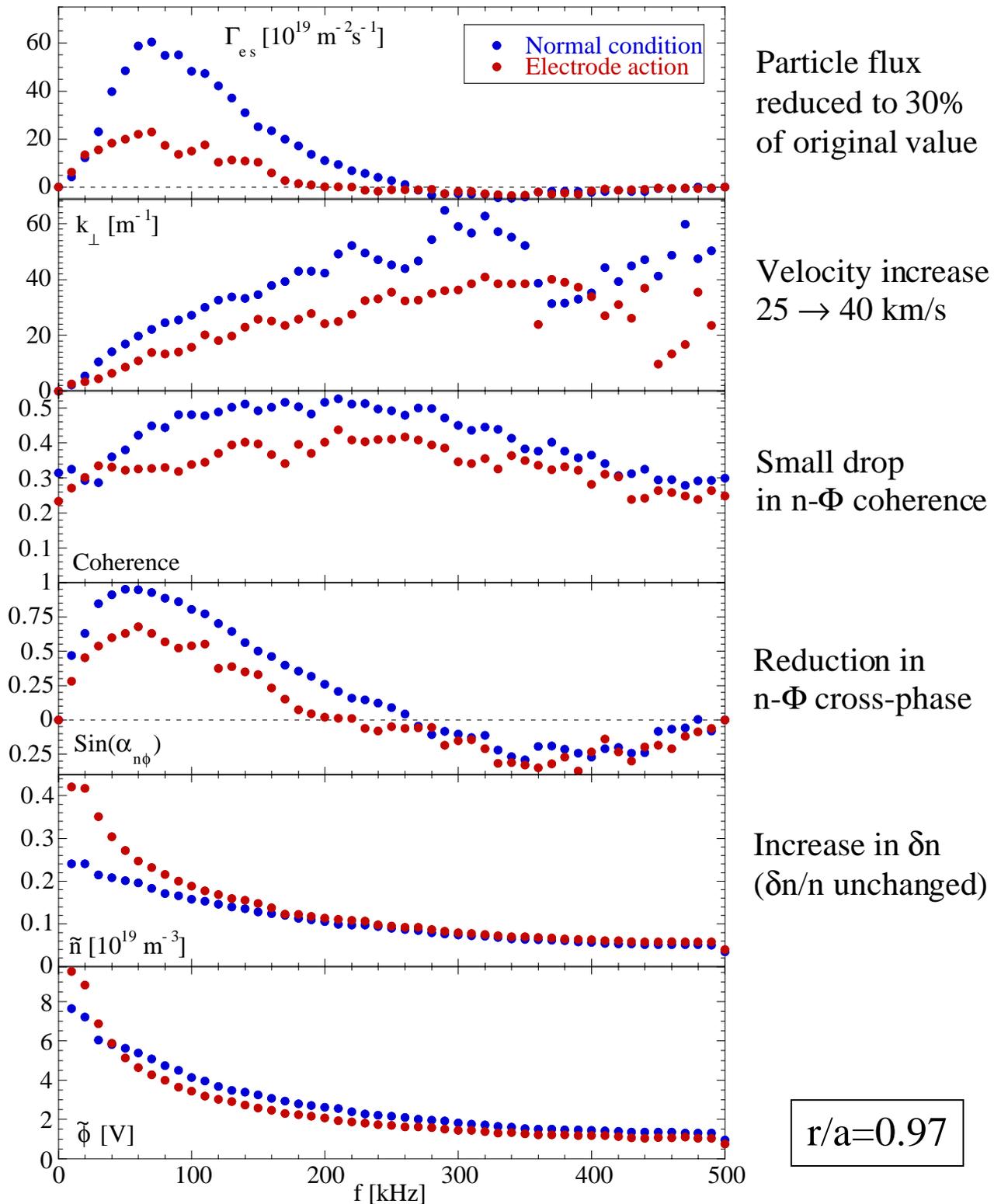
Effect on impurity flow



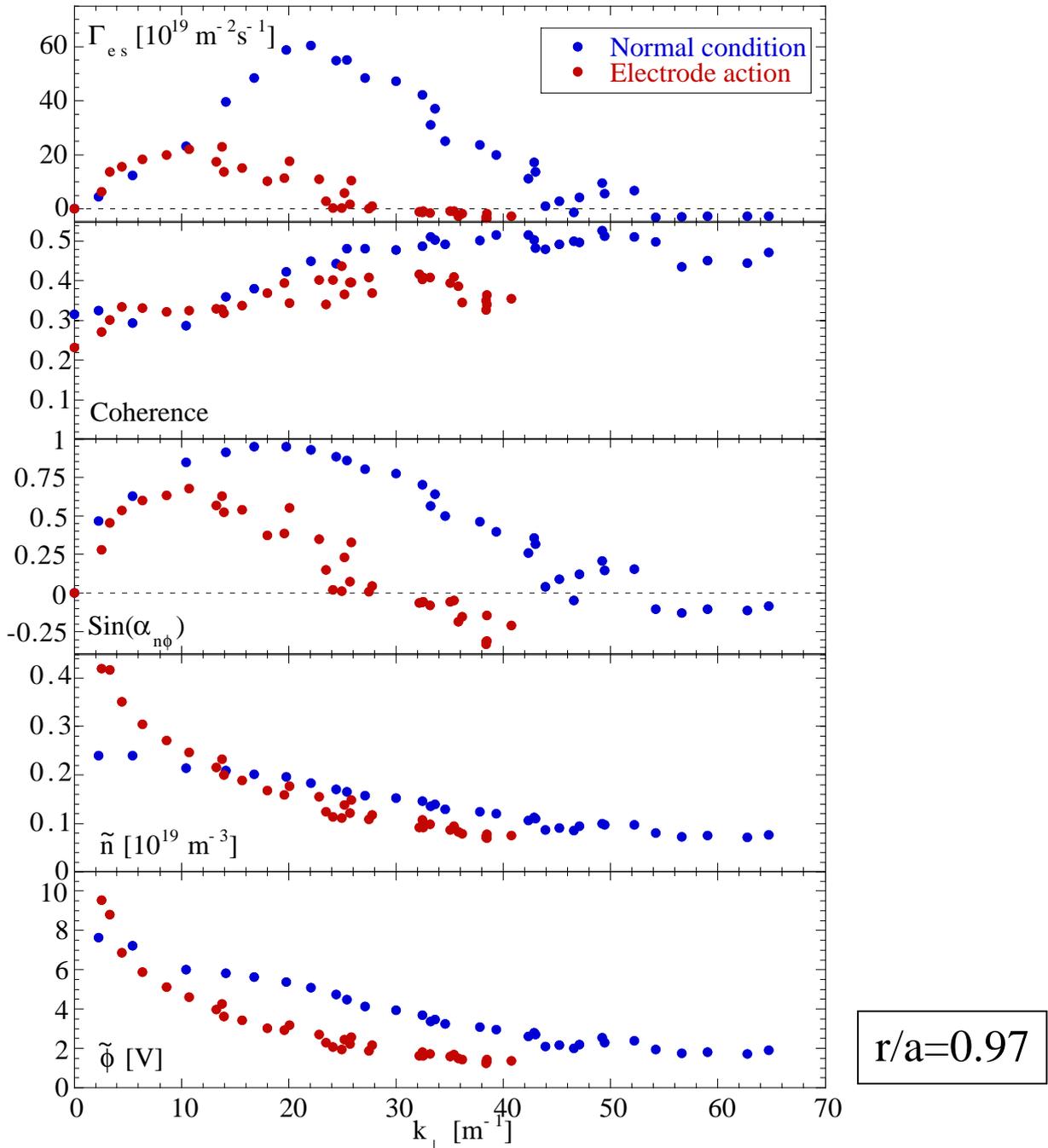
C III impurity rotation measured by Doppler shift of emission lines shows a doubling of the toroidal velocity during edge biasing, consistent with the increase in $\mathbf{E} \times \mathbf{B}$ velocity.

The location of C III ions is $0.9 < r/a < 1$ and does not change with biasing.

Particle flux (freq. domain)

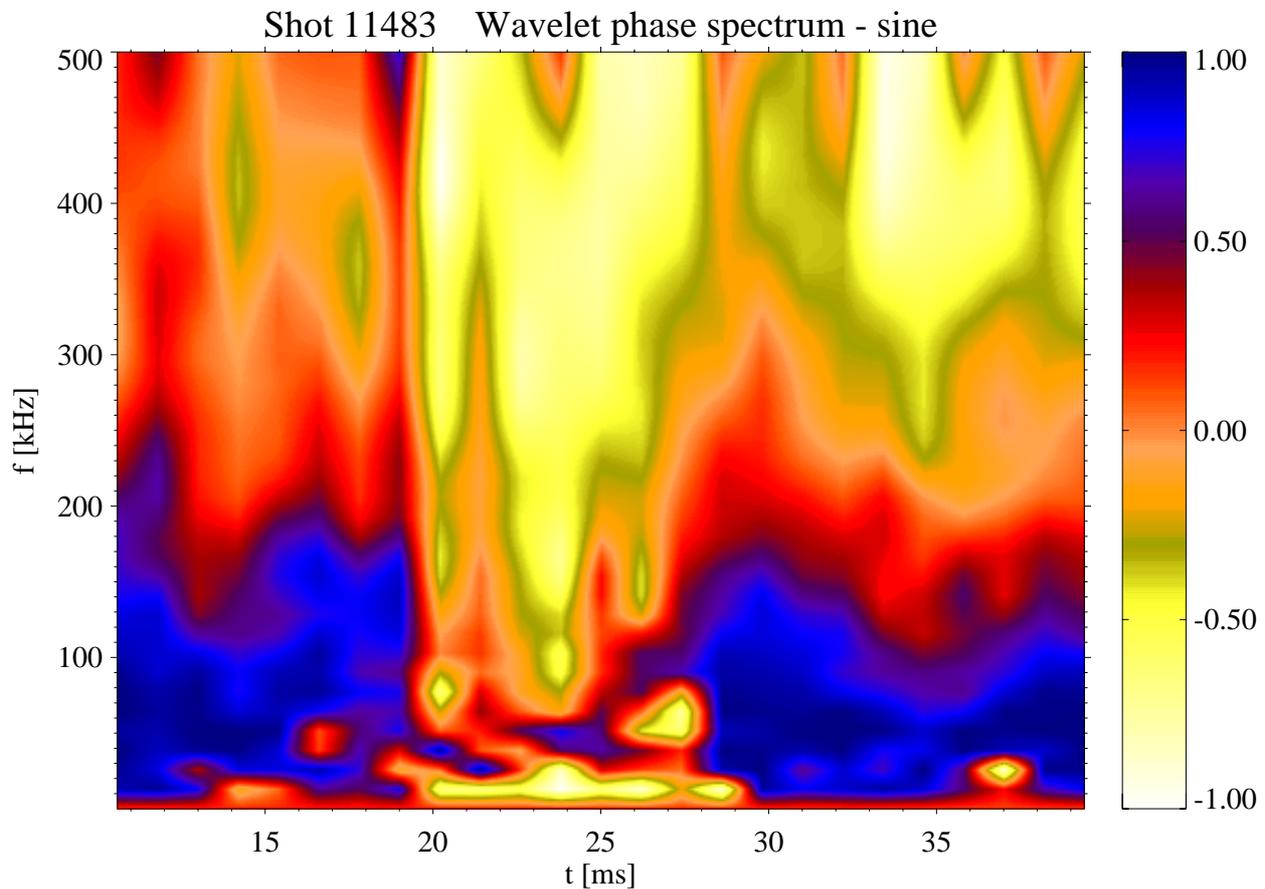


Particle flux (k-domain)



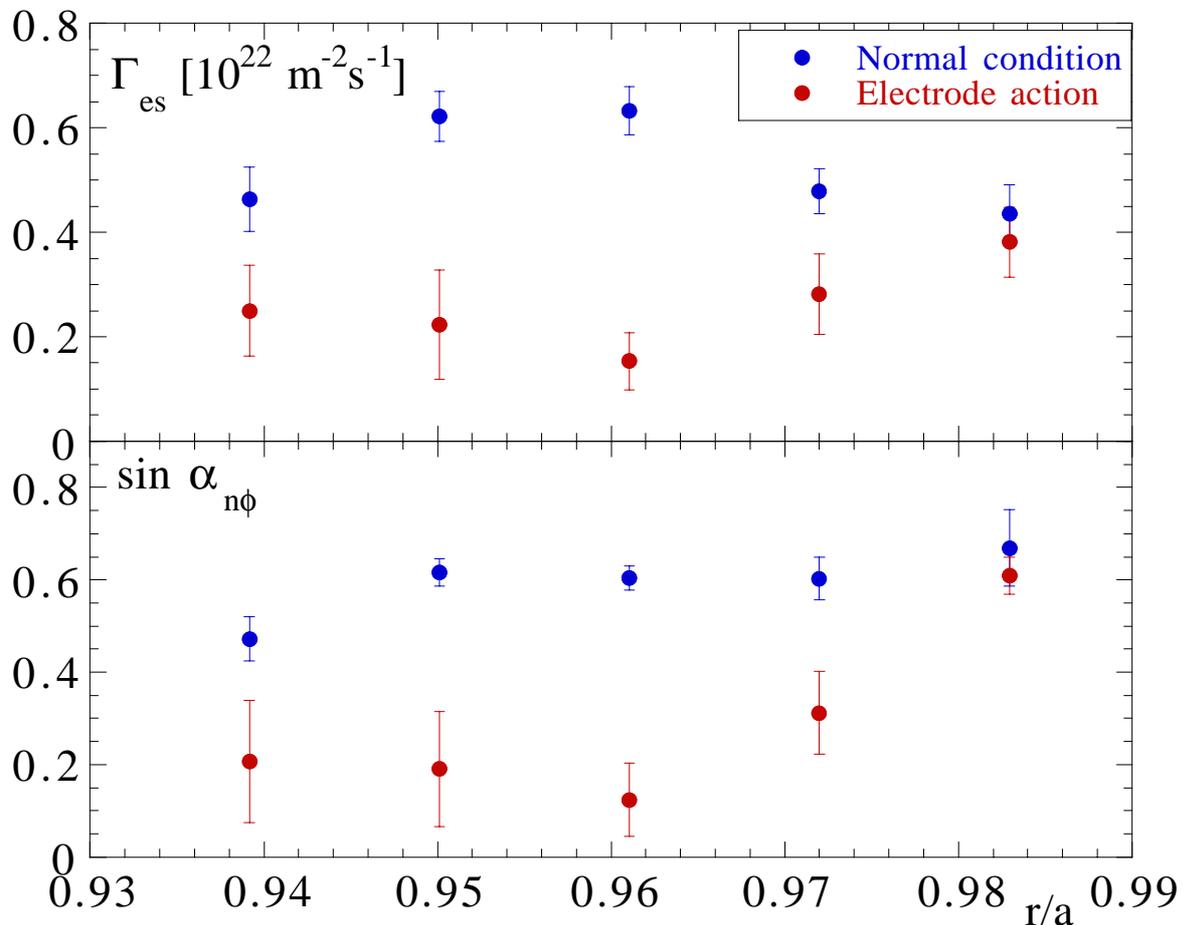
Flux reduction mostly due to a change in cross-phase.
Maximum transport-relevant k reduced from 50 to 25 m^{-1} .

Wavelet analysis



The sine of the phase between density and potential, which is normally near to 1 in the frequency range relevant for transport (20-200 kHz), is reduced during the edge biasing (20-30 ms).

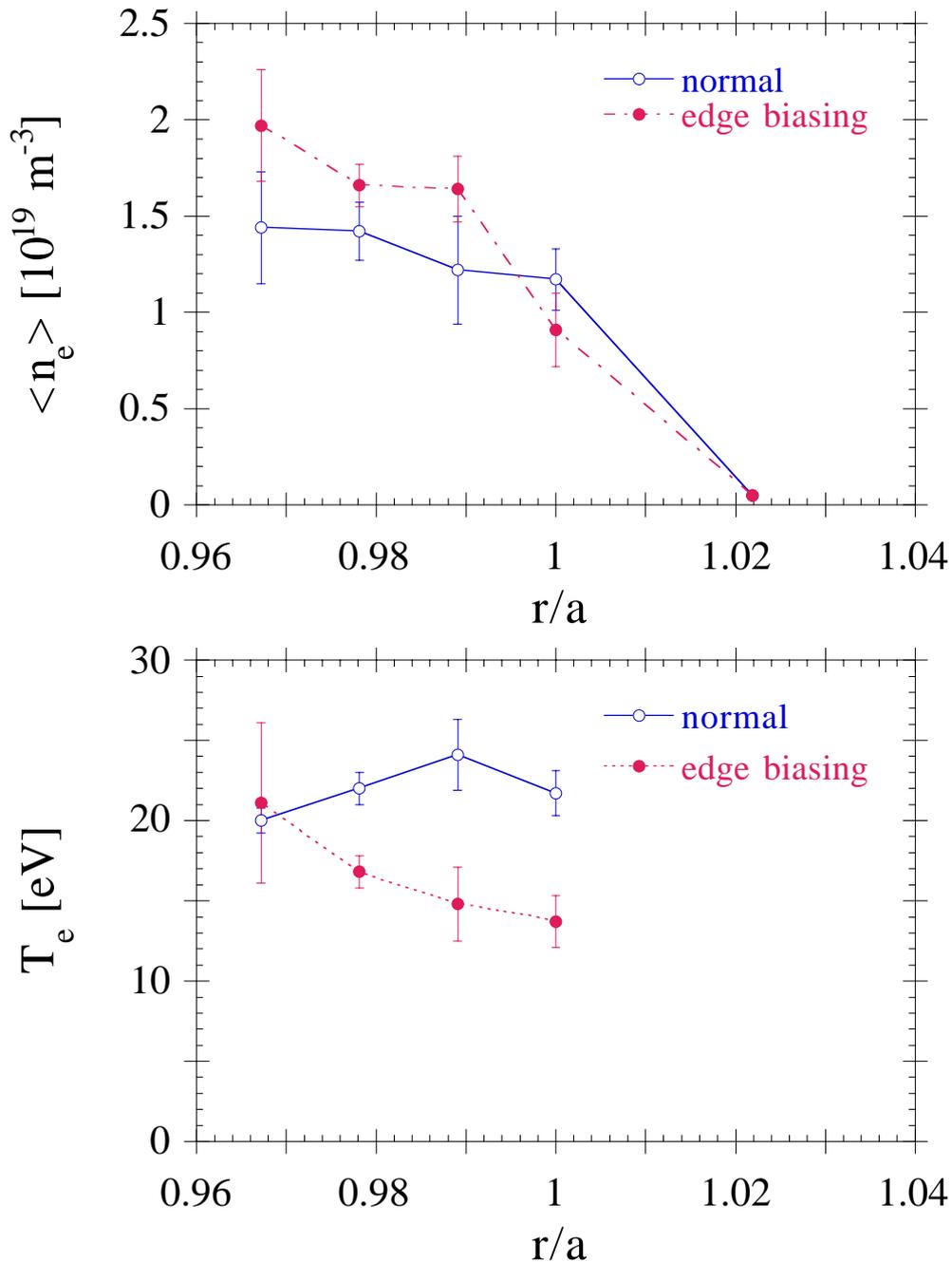
Particle flux radial profile



Particle flux reduction induced by phase decorrelation (as in DIID, TEXTOR, CASTOR) occurs over the whole plasma edge.

The electrostatic energy flux remains convective during the edge biasing.

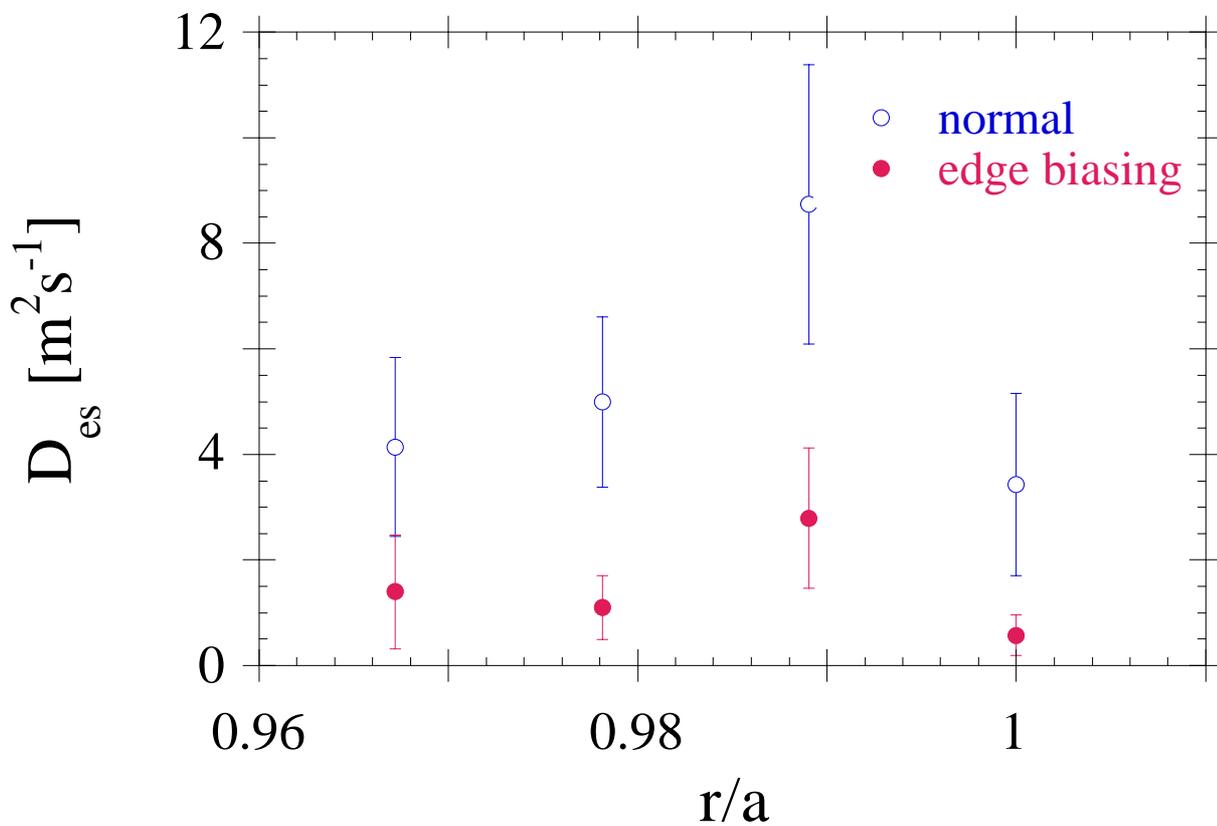
Edge n_e and T_e profiles



The edge density grows and the gradient increases
The edge temperature decreases.

Diffusion coefficient

$$\text{Fick's law: } \Gamma = - D \nabla n$$



The diffusion coefficient drops during the electrode action to values below the Bohm value.

Momentum balance

Single-fluid momentum balance equation in toroidal direction

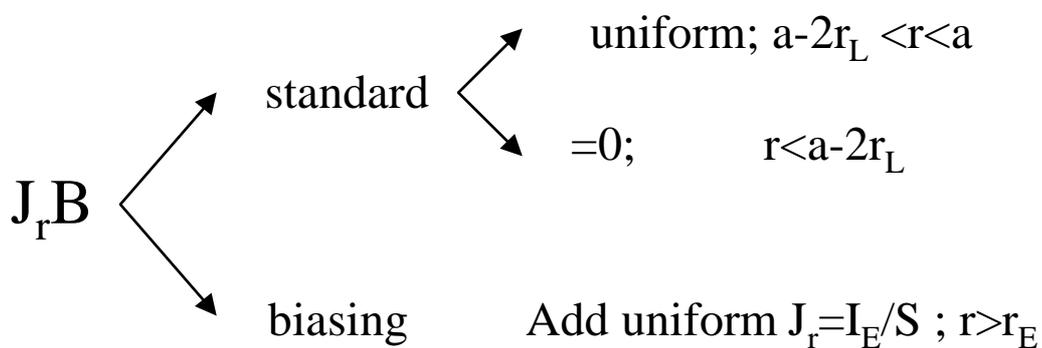
Ohm's law in the radial direction.

Hypothesis:

- $\partial/\partial t = 0 ; \partial/\partial z = 0 ; \partial/\partial \theta = 0 ;$
- $B \sim B_\theta$
- collision with neutrals : $n M v u_z$, $v = 10^{-14} T^{0.318} n_n$
- radial velocity is: $u_r = -D * \frac{dn}{dr}$

$$J_r B = n M v u_z - n M D * \frac{1}{n} \frac{dn}{dr} \frac{du_z}{dr} + (\nabla \cdot \Pi_i)_z$$

$$E_r = u_z B + T \left(\frac{1}{T} \frac{dT}{dr} + \frac{1}{n} \frac{dn}{dr} \right)$$



D. Desideri, et al, Czechoslovak Journal of Physics **49/S3**, 119(1999).

The viscous term

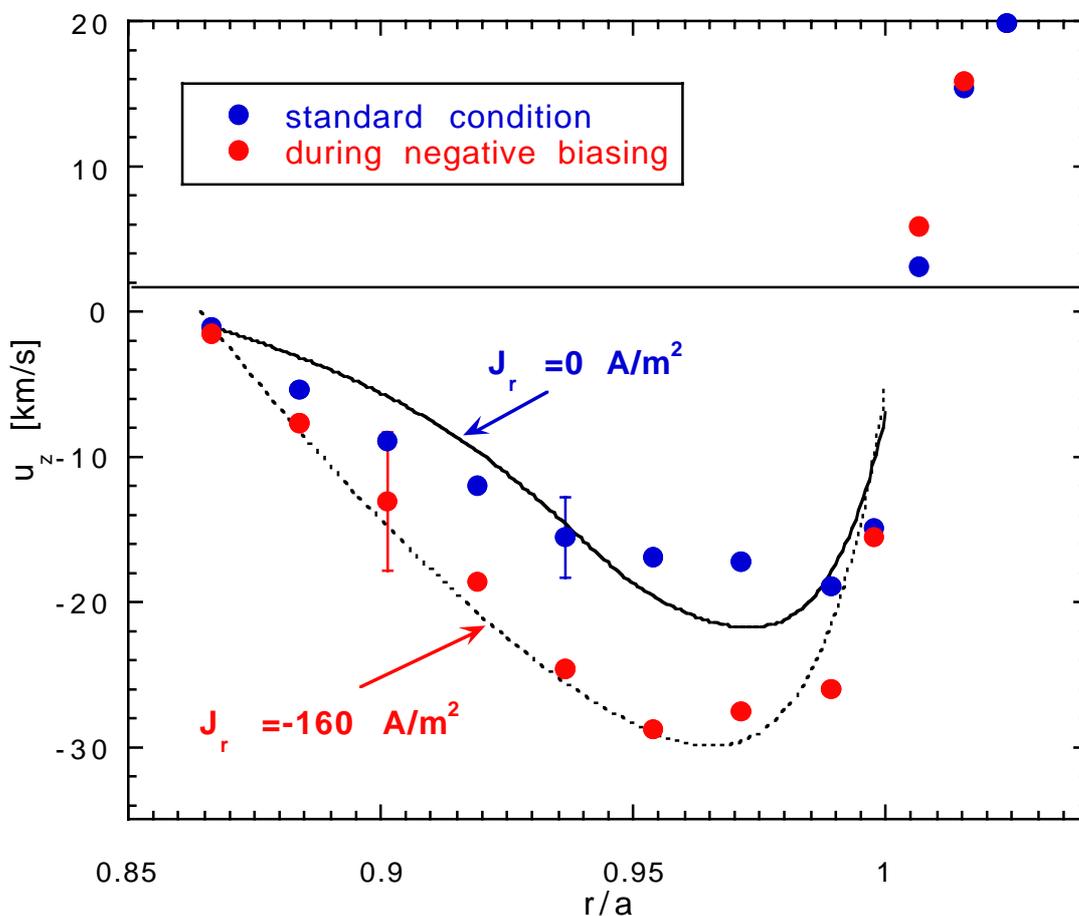
$$(\nabla \cdot \Pi_i)_z = \frac{d\Pi_{rz}}{dr} + \frac{\Pi_{rz}}{r}$$

$$\Pi_{rz} = -\eta_1 \frac{du_z}{dr} - \eta_3 \frac{du_r}{dr}$$

$$\eta_1 = n M D^*$$

Comparison with experimental profiles

Experimental profiles of density, temperature, diffusion coefficient + experimental boundary conditions on velocity

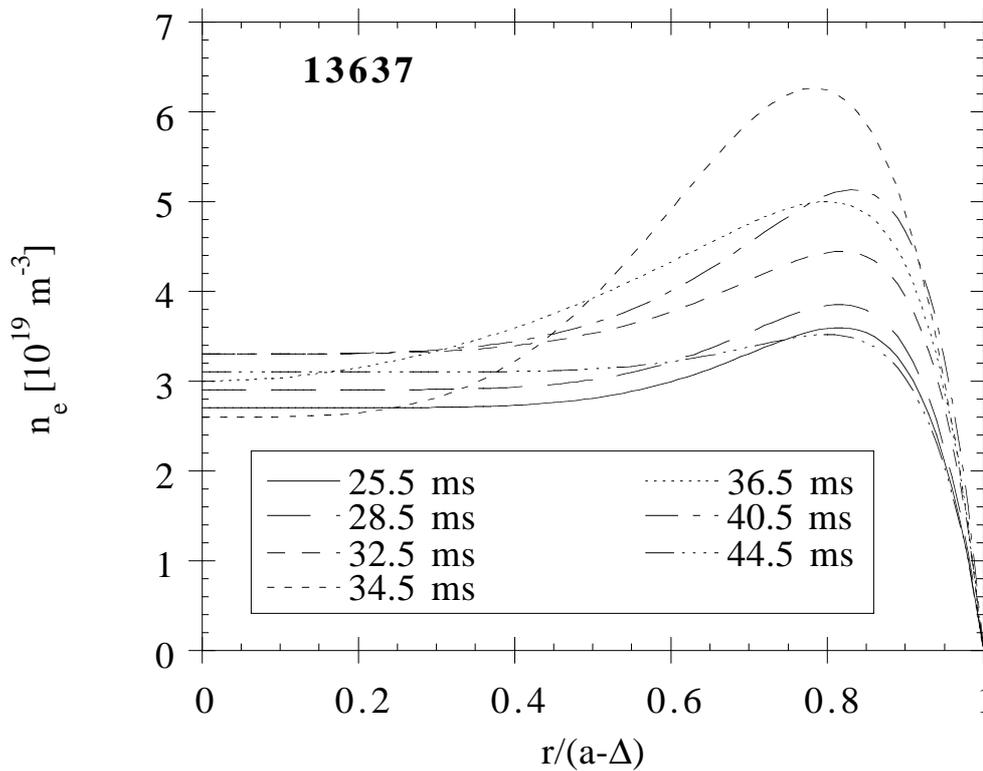


$$J_r (\text{ion losses}) = -30 \text{ A/m}^2$$

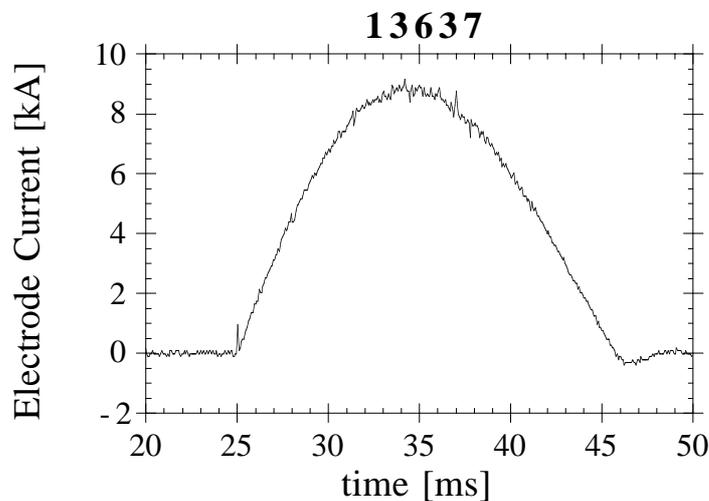
$$J_r (\text{electrode}) = -160 \text{ A/m}^2$$

corresponding to $I_E = 6.5 \text{ kA}$
(experimental $I_E = 8 - 10 \text{ kA}$)

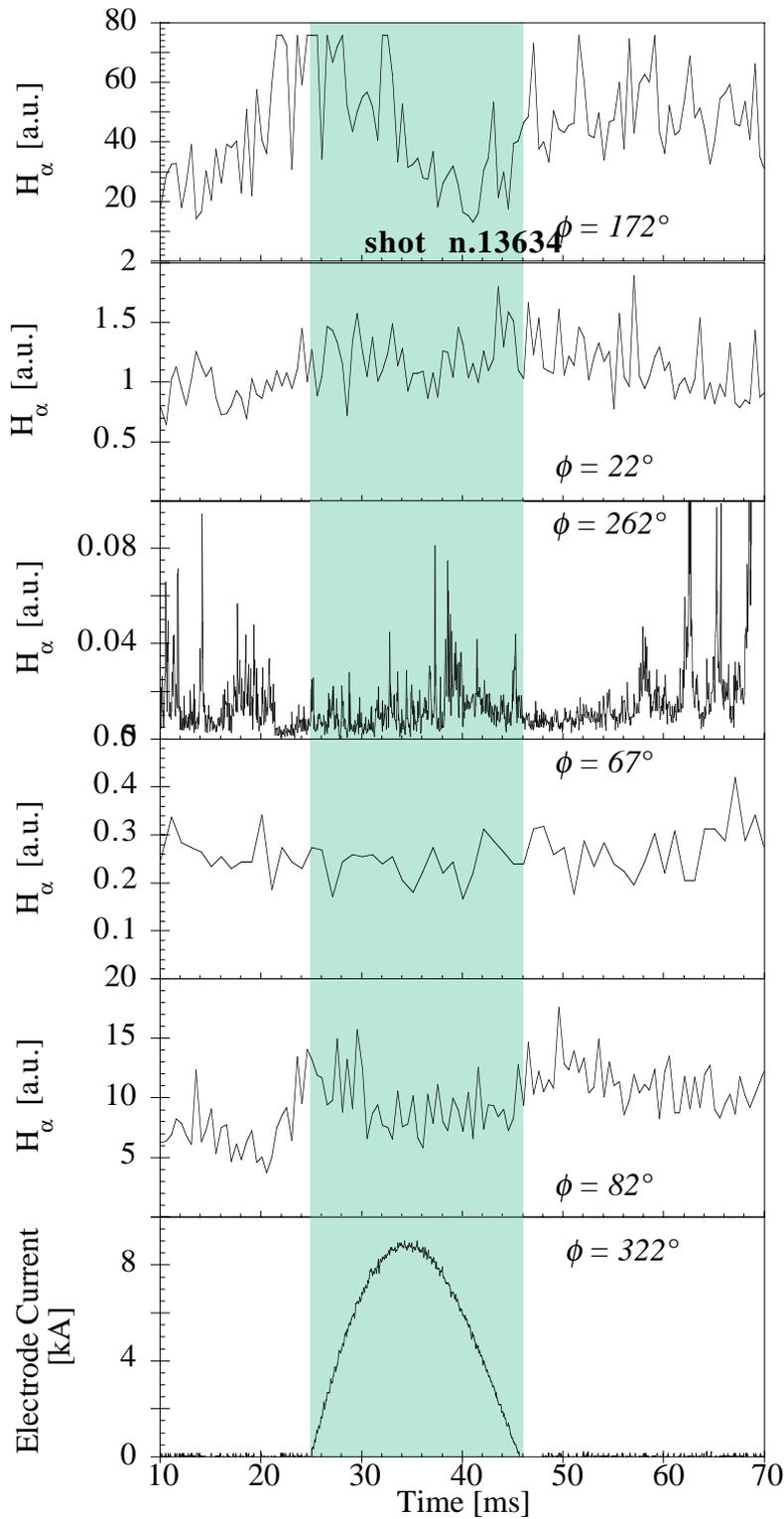
Density profile evolution



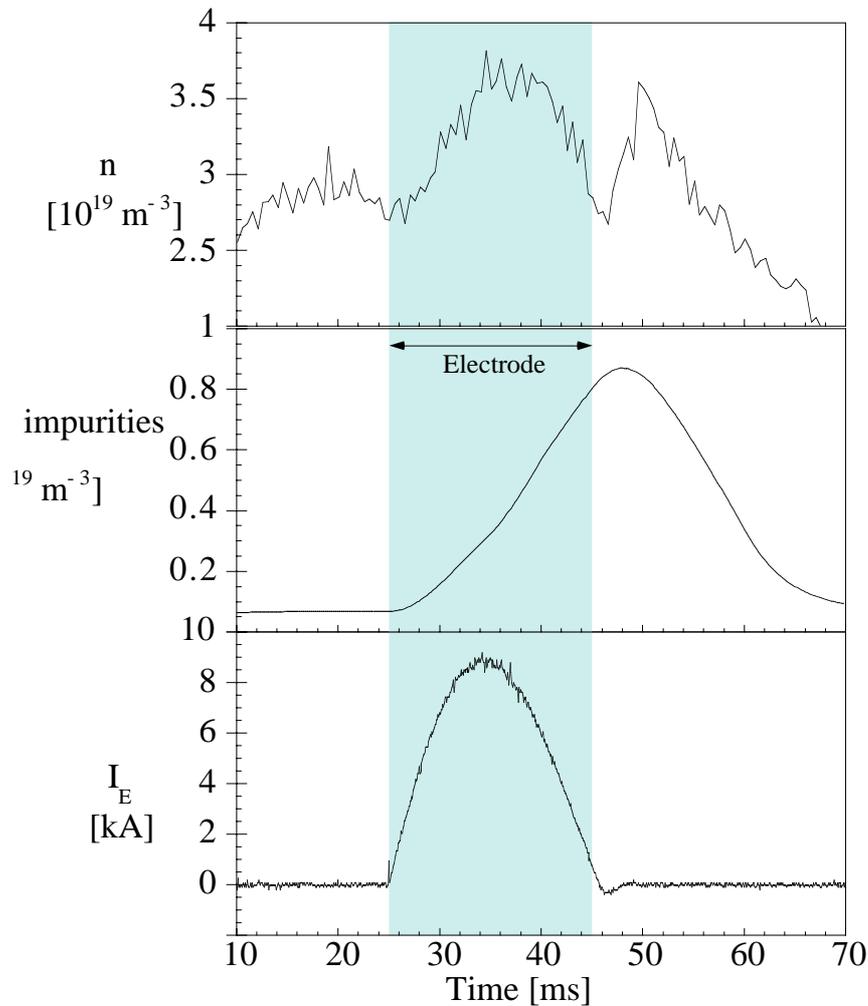
The electron density increases during the edge biasing.



H_α time and space evolution



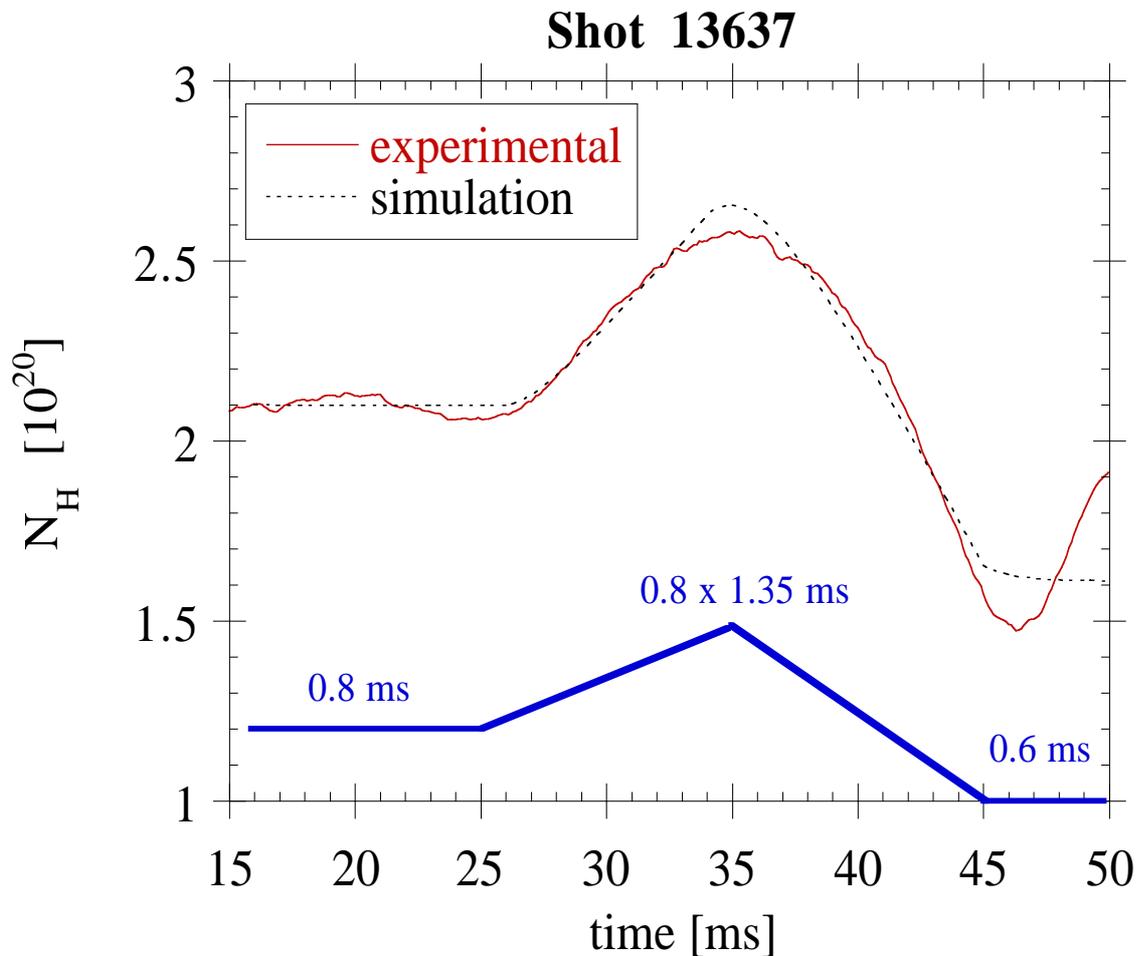
Impurity influx



Carbon inflow is a few percent of H inflow.
Most of the impurity influx comes from B
and N.

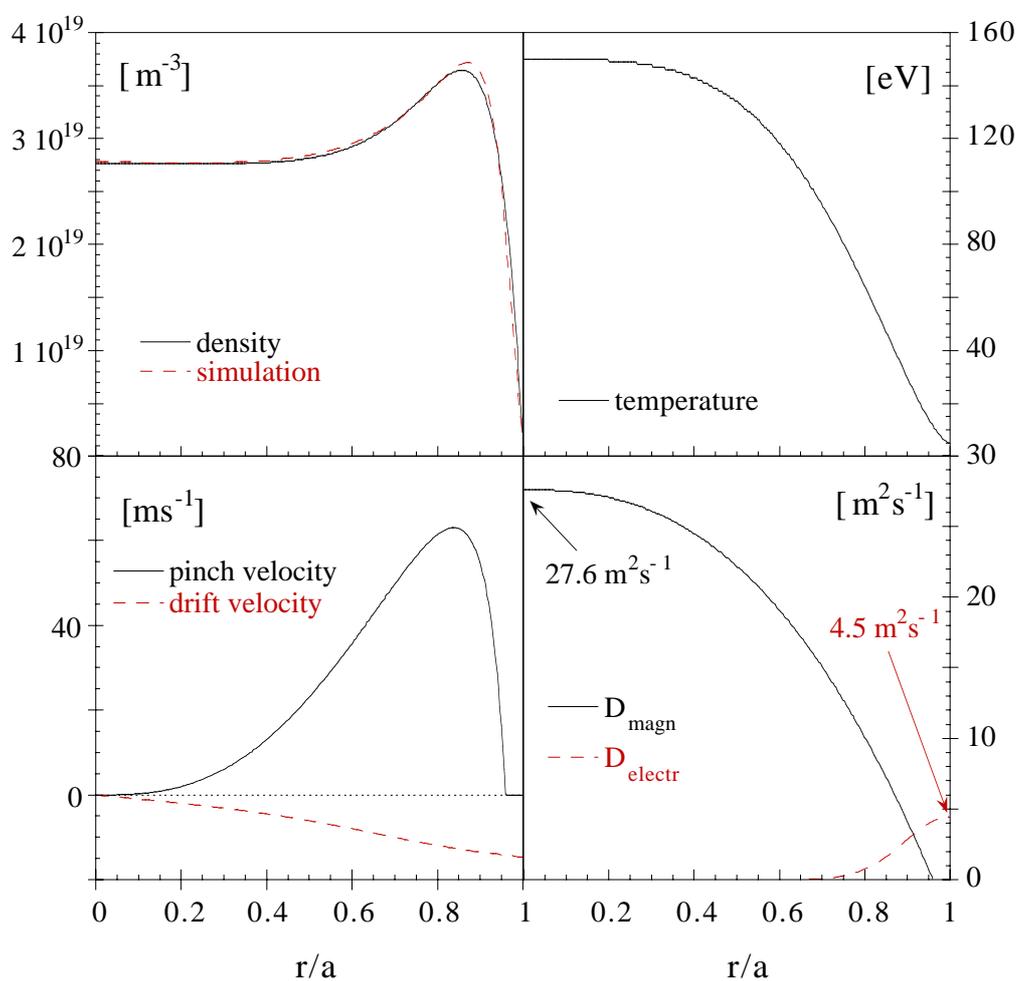
0-dimensional two-reservoir model

$$\frac{\partial N_p}{\partial t} = -(1-R)\frac{N_p}{\tau_p} + \frac{N_w}{\tau_w} \quad \text{and} \quad \frac{\partial N_w}{\partial t} = (1-R)\frac{N_p}{\tau_p} - \frac{N_w}{\tau_w}$$



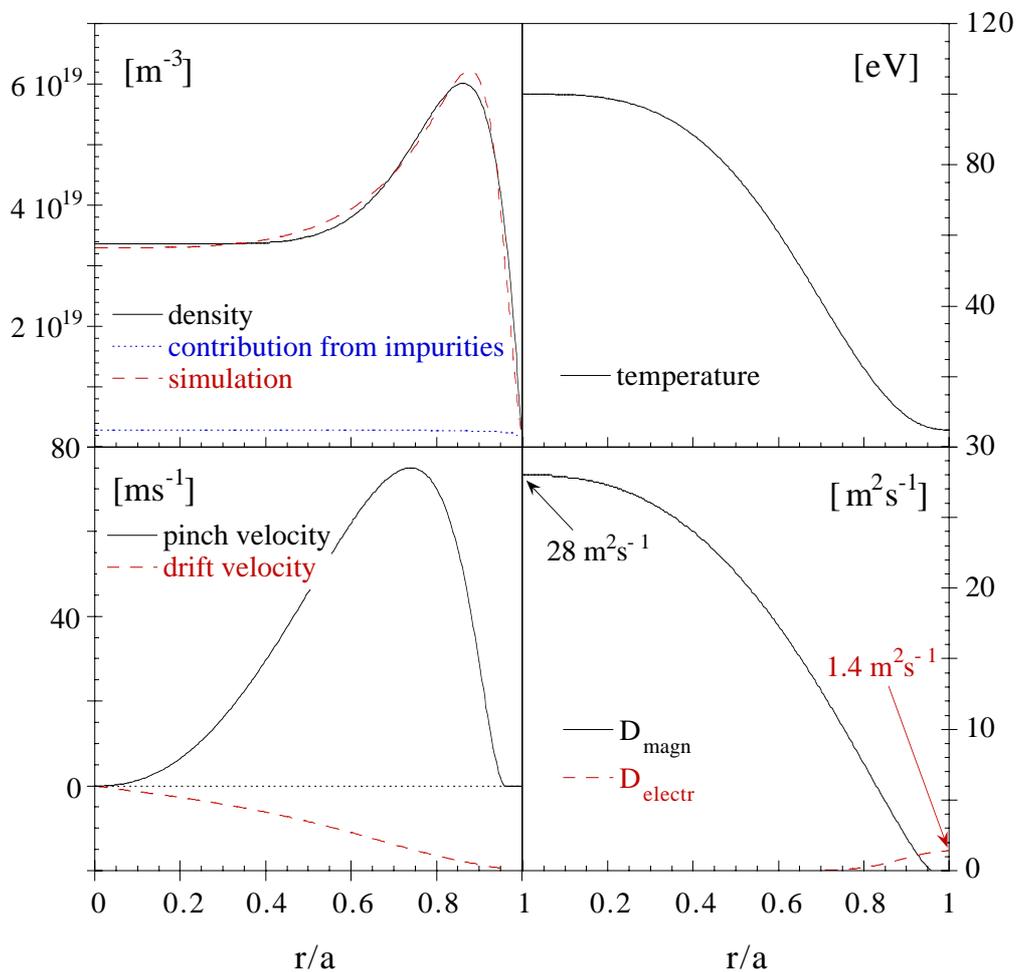
1-dimensional model

Before edge biasing
#13637, $t = 23$ ms



1-dimensional model

During edge biasing
#13637, $t = 33$ ms



Conclusions

- By edge biasing the edge $\mathbf{E} \times \mathbf{B}$ velocity and its shear have been increased.
- The increased shear reduces the transport driven by electrostatic turbulence, mainly through a phase decorrelation (as in tokamaks).
- Momentum balance at the edge shows that the toroidal velocity is controlled by **ion losses, anomalous viscosity** and **friction with neutrals**.
- The increase in density and reduction of electrostatic particle flux are consistent with an improvement of 30% of the particle confinement time. A complete particle balance must include the effect of the locked mode.