Role of radial electric field shear at the magnetic island in the transport of plasmas

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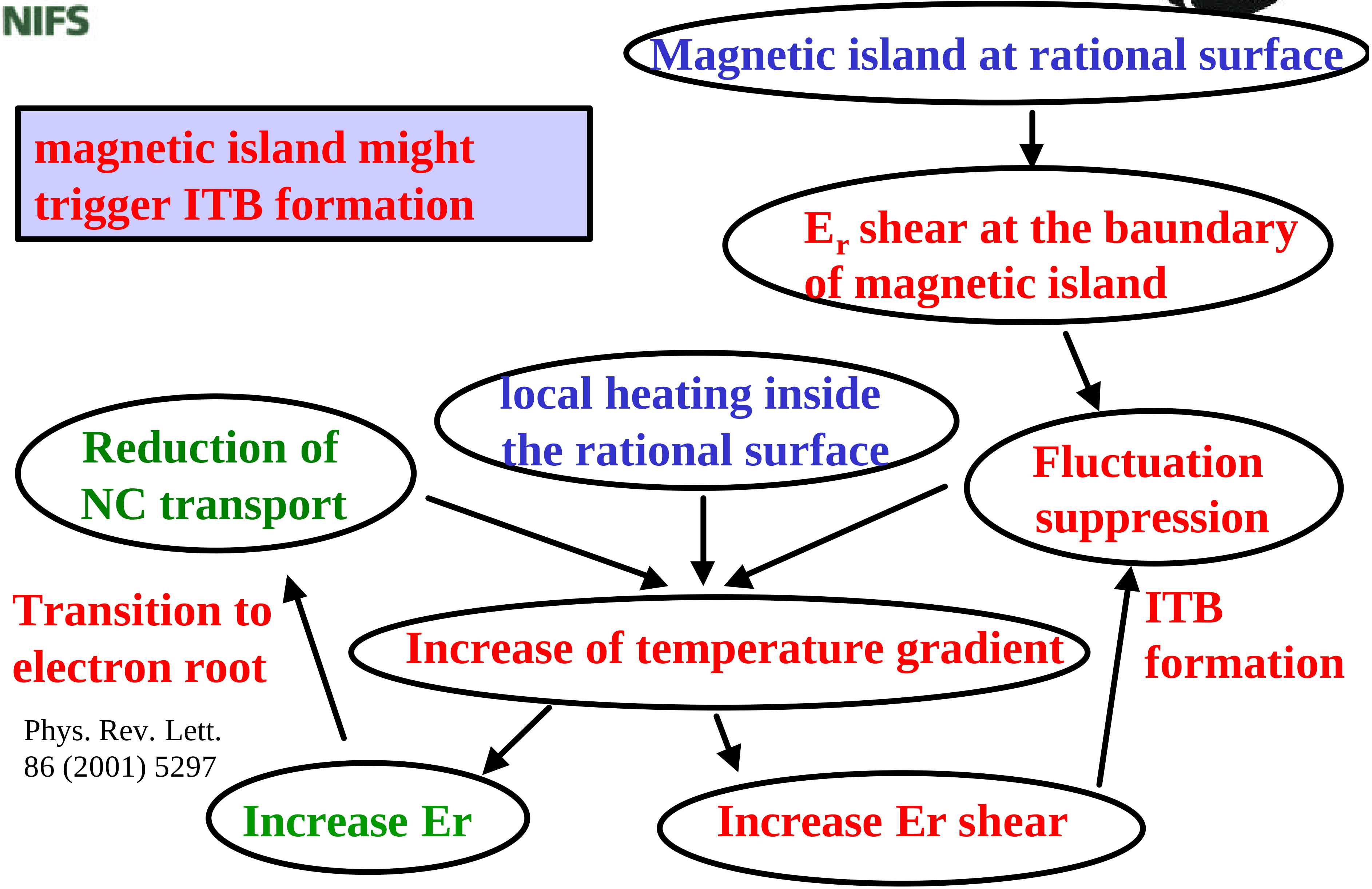
1 Introduction (The effect of magnetic island on transport)
2 E_r shear at the boundary of m=1 island
3 Reduction of local c_e at the boundary of m=1 island
4 ITB formation inside rational surface
5 Summary

Acknowledgement to Dr.C.Hidalogo (CIMAT)

Role of E_r shear at the magnetic island

magnetic island might trigger ITB formation



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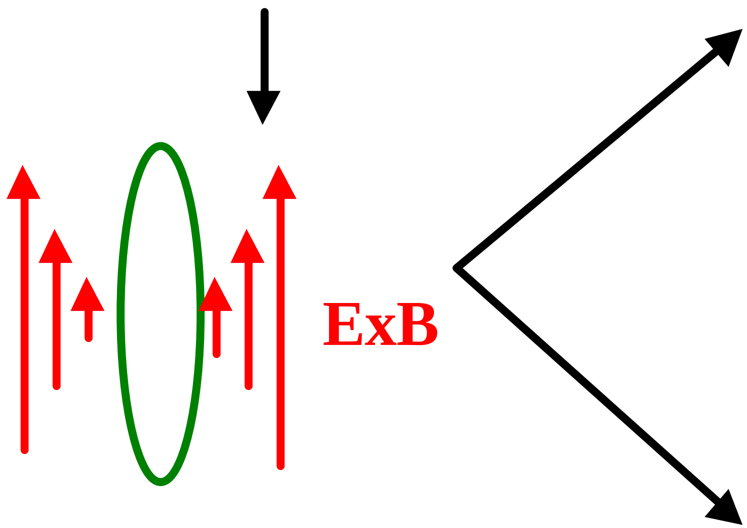
E_r shear and Transport at Magnetic island

NIFS

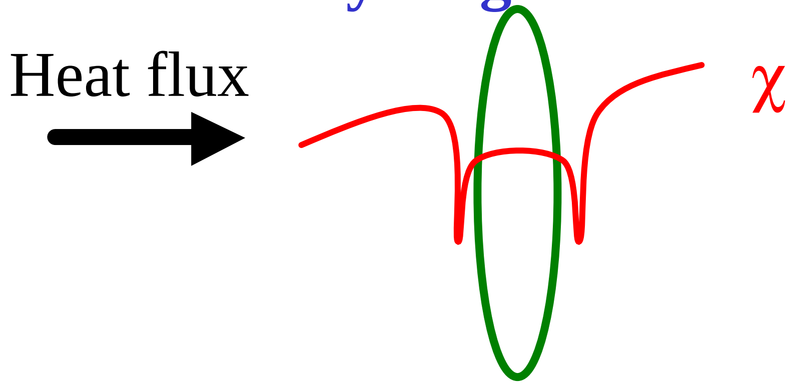
When the magnetic island is slipping



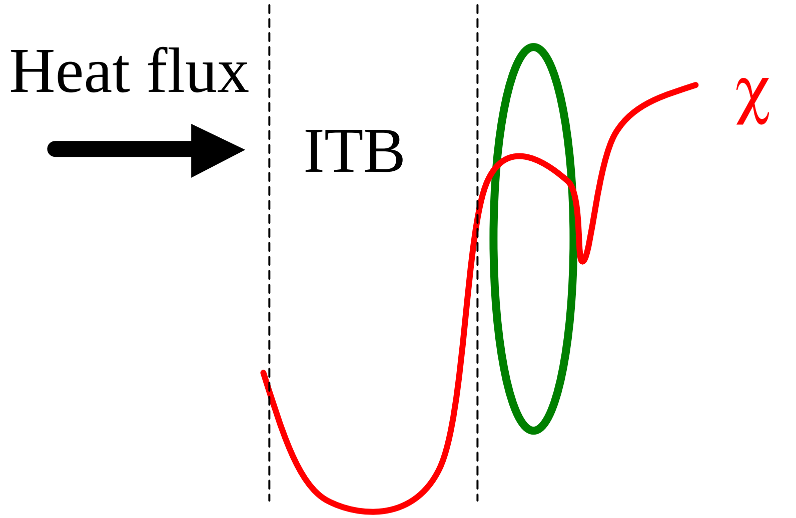
ExB shear is expected at the boundary of magnetic island.

There are two possible effect of E_r shear on transport

1 Narrow Transport Barrier at the boundary magnetic island

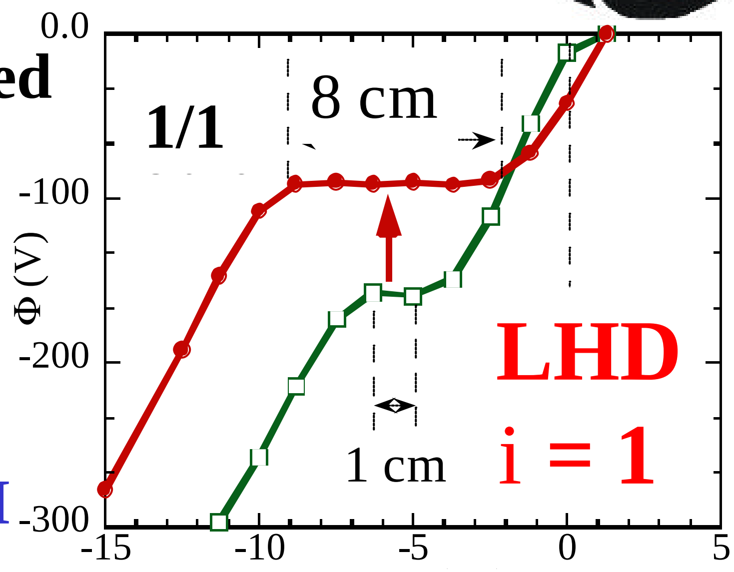


2 Internal Transport Barrier triggered by magnetic island



Plasma potential inside the island

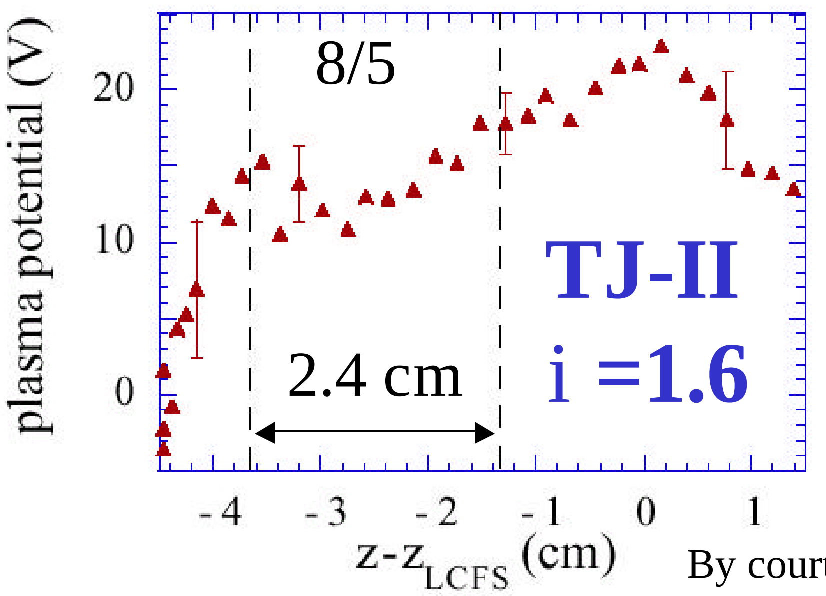
Flattening of space potential is observed at the rational surfaces in the wide range of rotational transform i

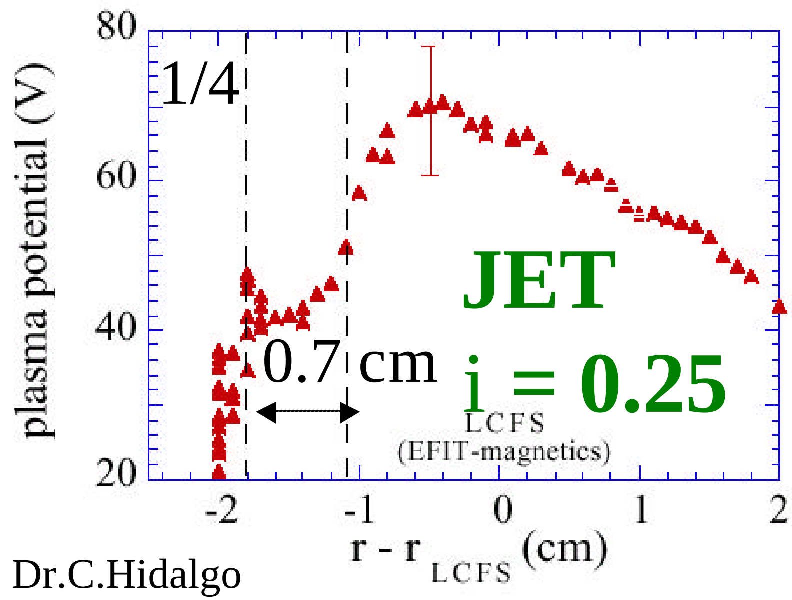


ι=0.25 (n/m=1/4: W <1cm) in JET

i =1.0 (n/m=1/1: W<10cm) in LHD

i =1.6 (n/m=8/5: W<few cm) in TJ-II

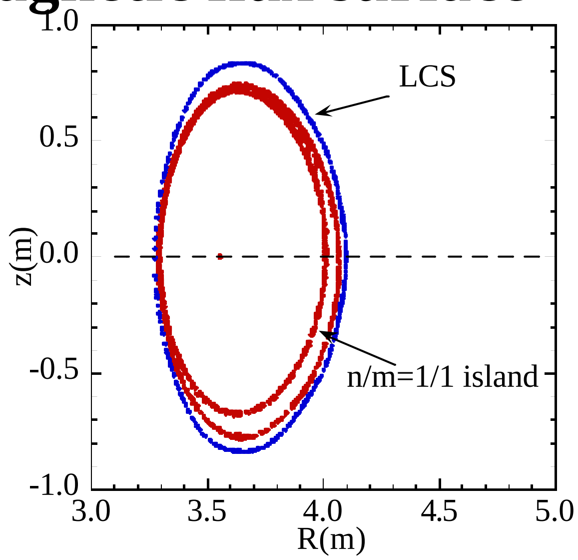




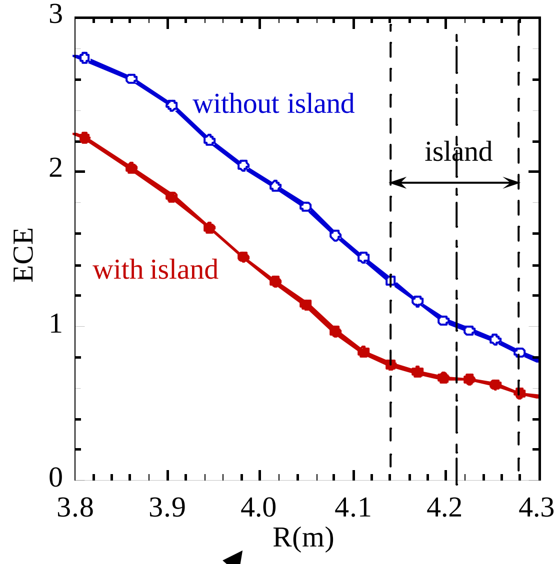
By courtesy of Dr.C.Hidalgo

n/m=1/1 magnetic island in LHD

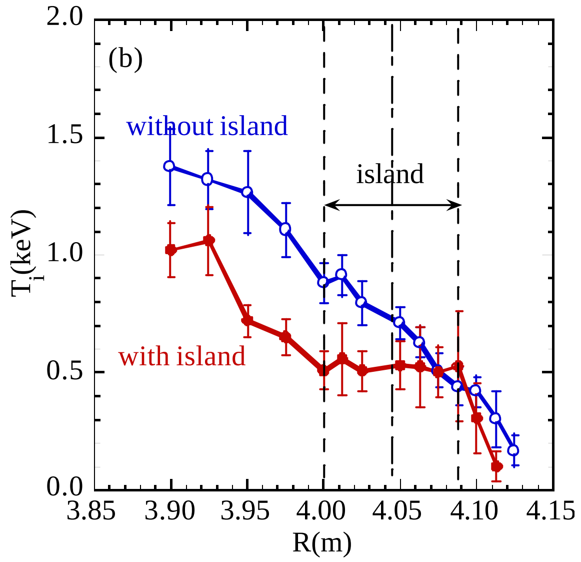
Magnetic flux surface

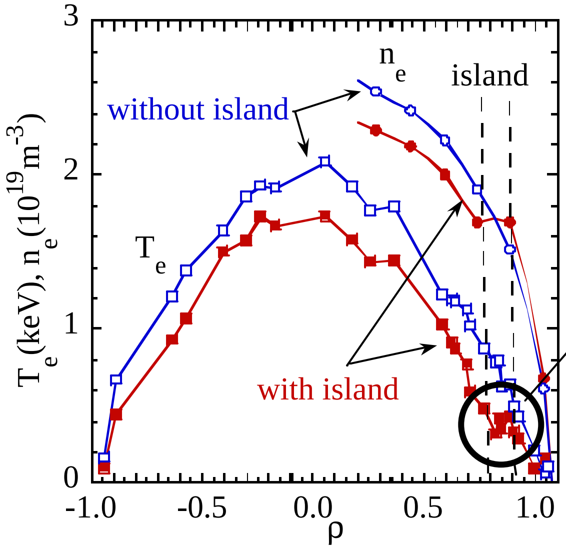


Electron temperature



Ion temperature

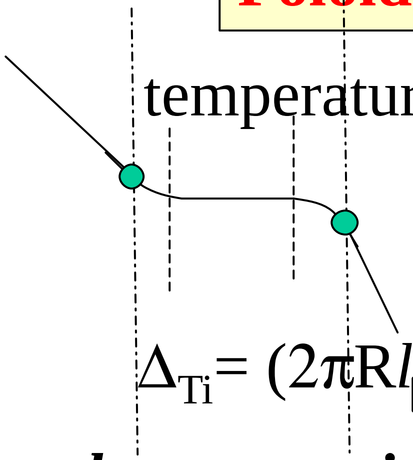


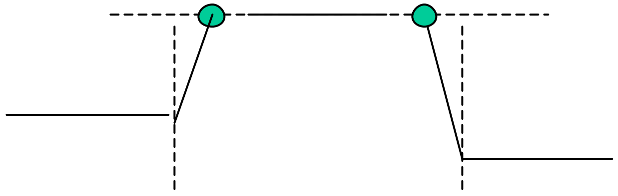


When the m/n=1/1 perturbation field is applied to the plasma, the size of magnetic island can be increased and the flattening of electron/ion temperature and density are observed

Ion temperature and radial electric field near the magnetic island

Poloidal flow is zero at the magnetic island

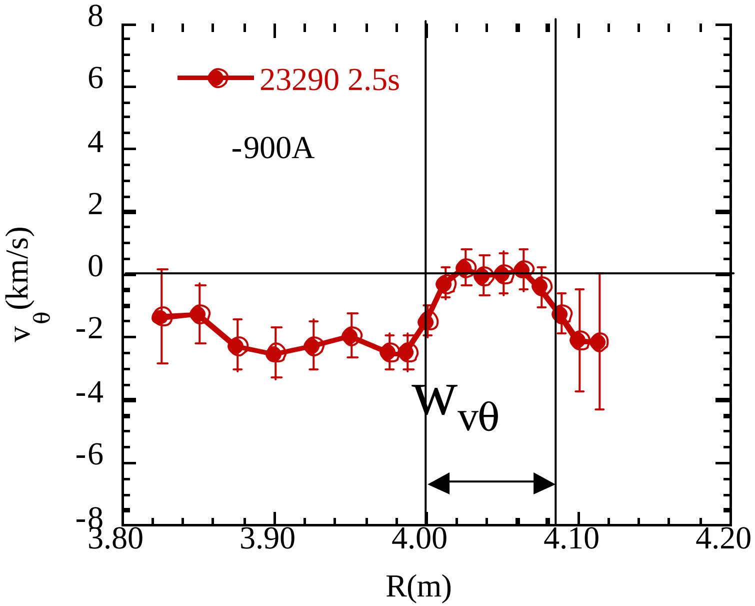


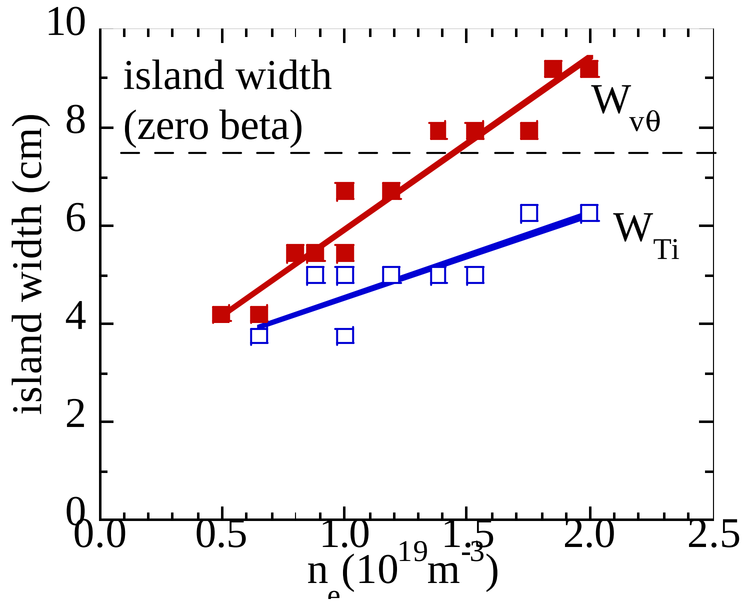


Width of T_i flattening is smaller than that of E_r

$$\Delta_{Ti} = (2\pi R l_{||}\chi_{\perp}/\chi_{||})^{1/2} \qquad \Delta_{Er} = (\mu\varepsilon_0\varepsilon_{\perp}E_r/J_r)^{1/2}$$

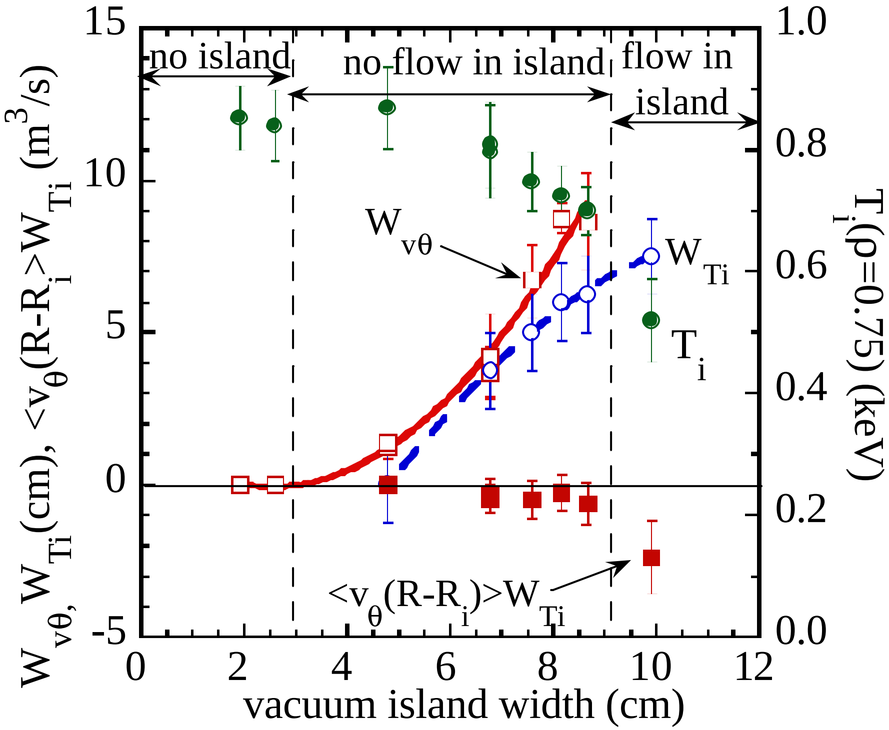
$l_{||}$ **: connection length** m **: viscosity coefficient**

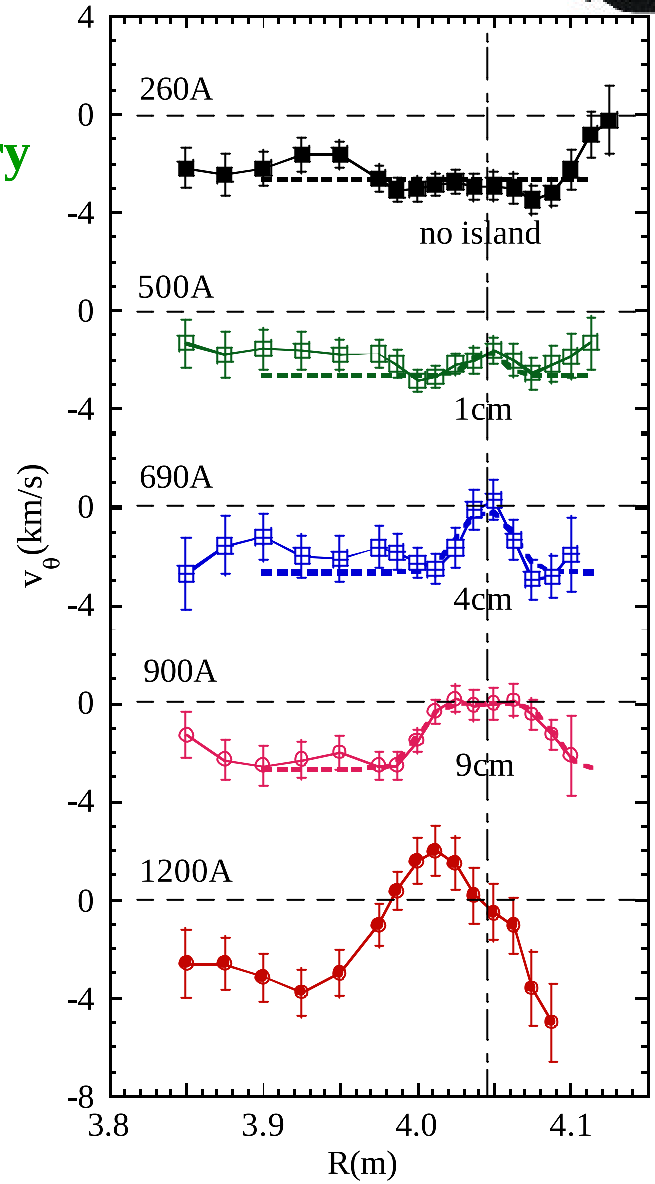




plasma flow spin up in the magnetic island

When the size of magnetic island is small, there are sharp flow gradient at the boundary of magnetic island.





However, the plasma flow along the magnetic flux surface inside the island suddenly appears (flow sin up) when the size of island exceed the critical value.

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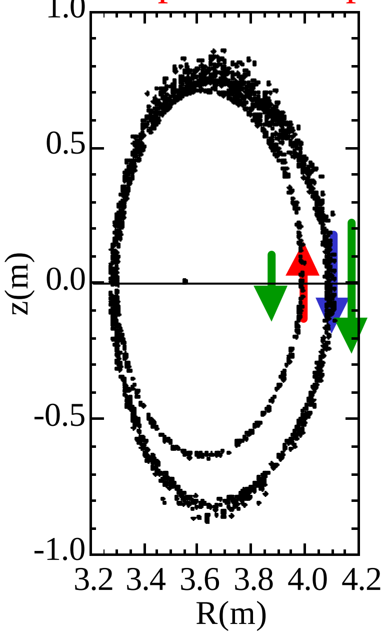
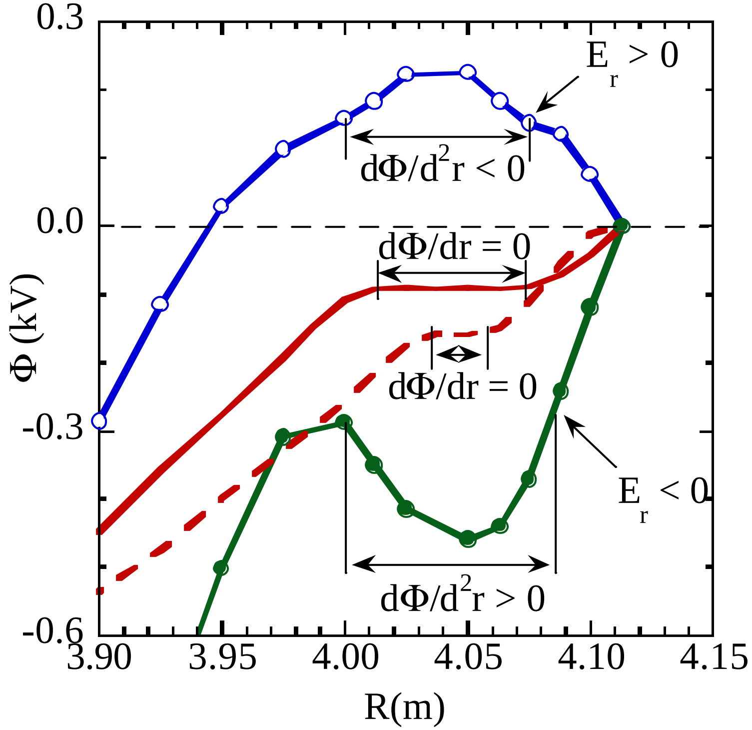
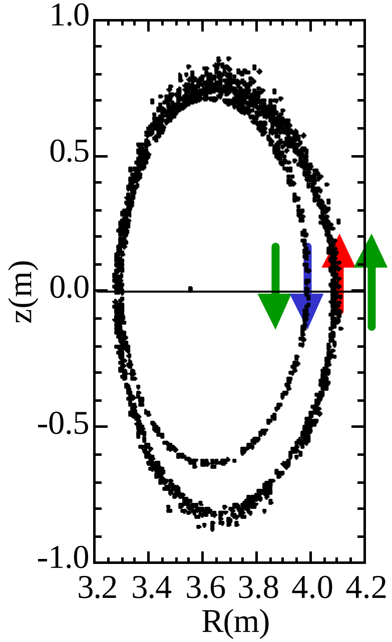
Potential structure at O-point

$E_r < 0 : E_r' < 0$





$E_r > 0$

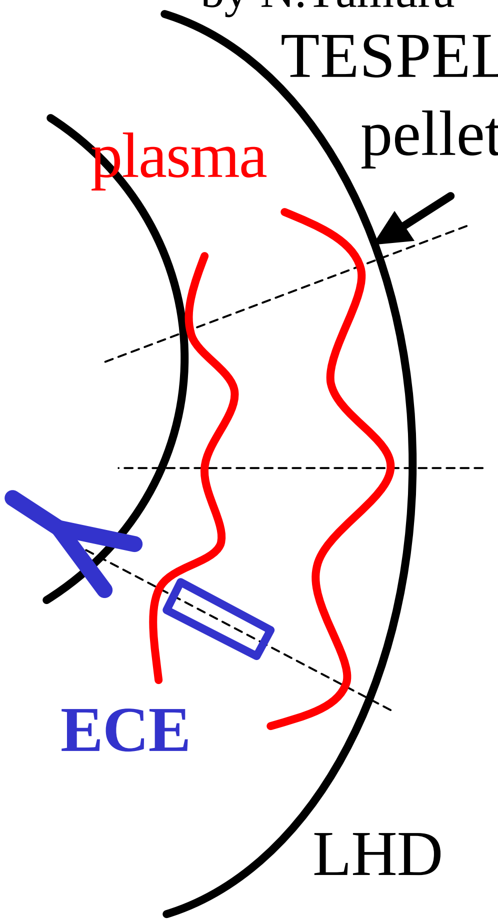


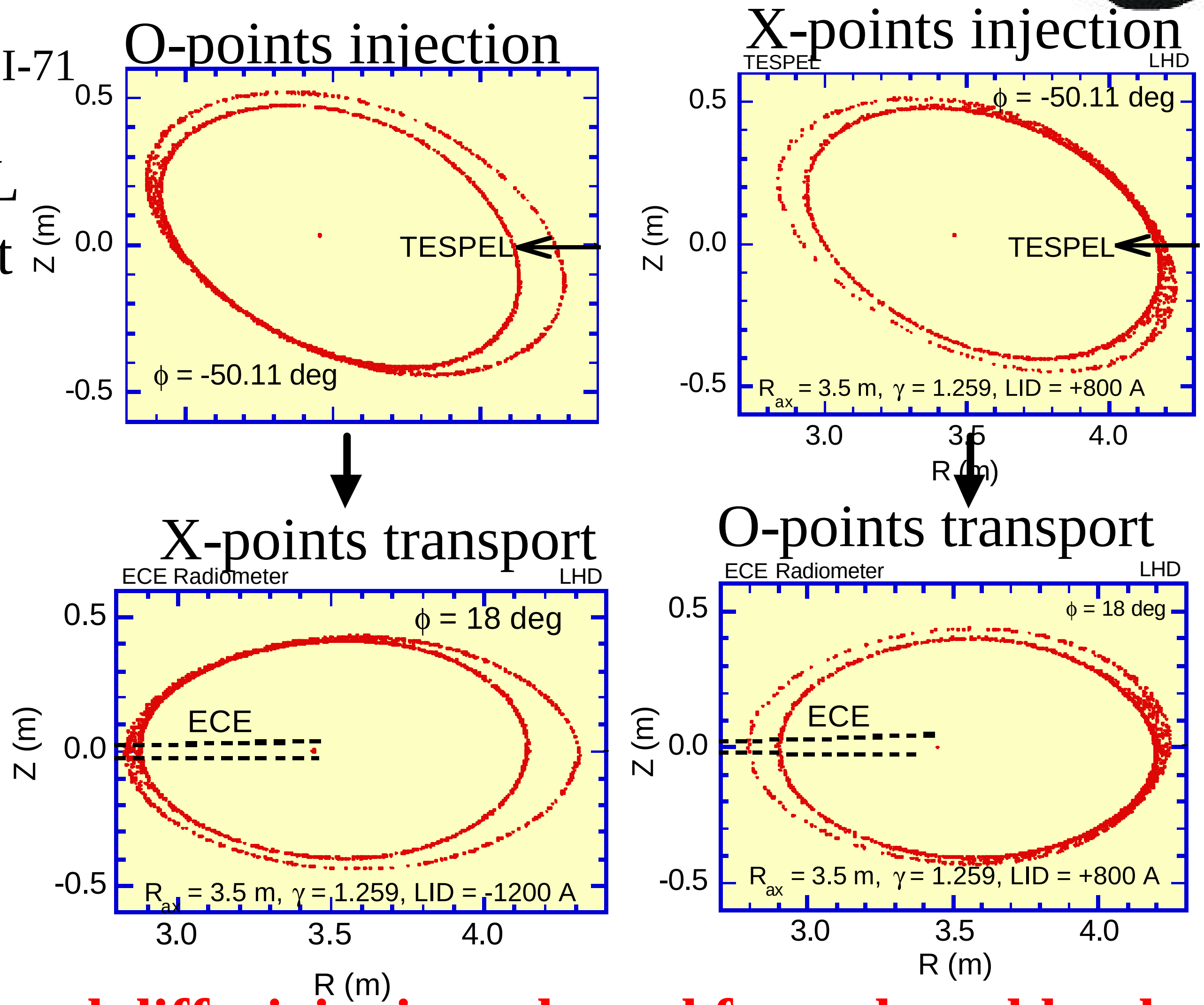
	Edge	X-point	O-point
Ion root	$E_r < 0$	$E_r' < 0$	$dF/d^2r > 0$
Electron root	$E_r > 0$	$E_r' > 0$	$dF/d^2r < 0$

Potential structure at O-point is determined by the E_r shear at X-point.

O/X-point cold pulse propagation

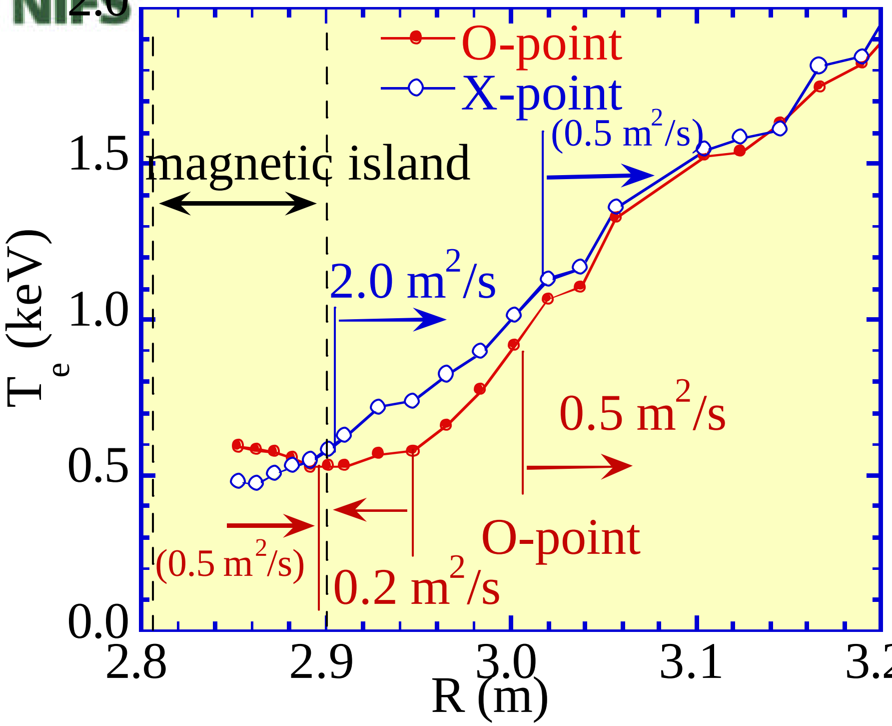
Presented at P-I-71
by N.Tamura

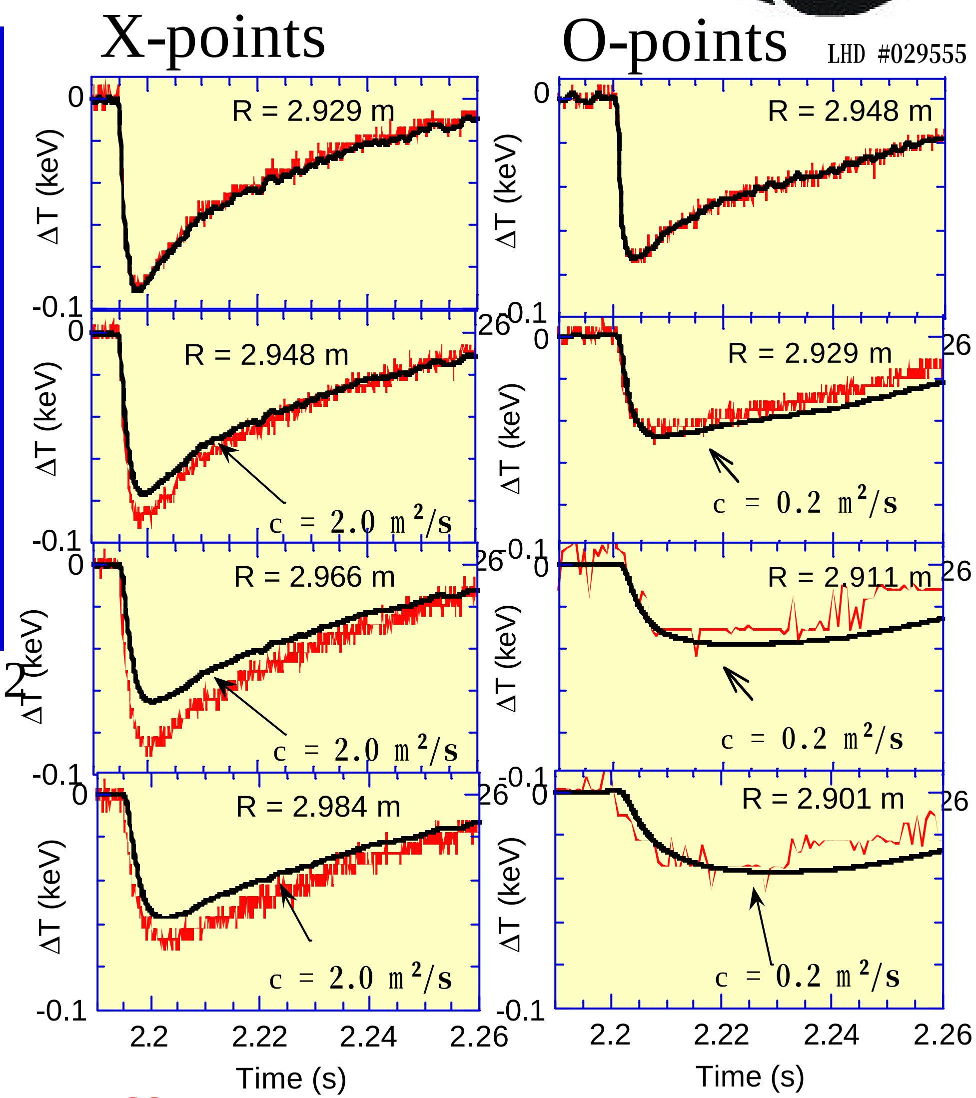




The electron thermal diffusivity is evaluated from the cold pulse propagation produced by small hydro-carbon pellet (TESPEL).

Heat transport near the magnetic island



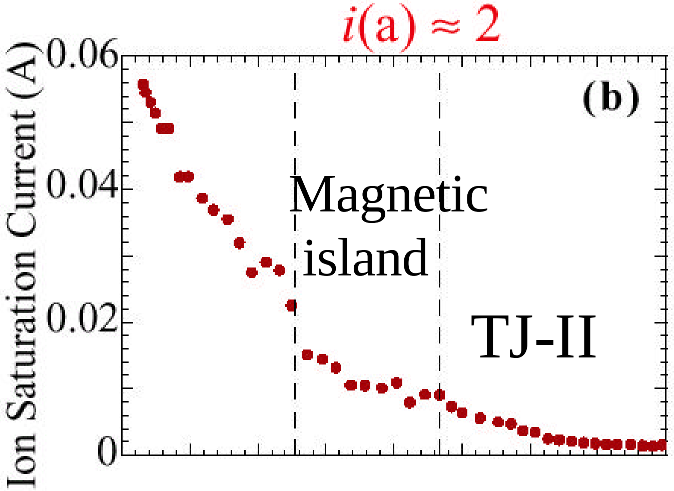


Presented at P-II-02 by S.Inagaki

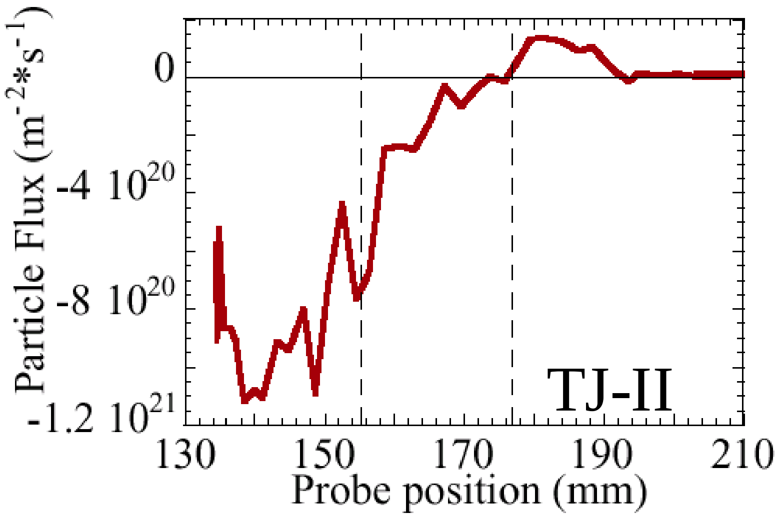
χ_e = 0.2 m²/s @ O-point
χ_e = 2.0 m²/s @ X-point

Significant reduction of thermal diffusivity is observed near or inside the magnetic island

Particle transport near the magnetic island



$$\Gamma_{ExB} = <\tilde{n}\,\tilde{v}_r>$$



By courtesy of Dr.C.Hidalgo

The ExB fluctuation particle flux is inwards at i = 2 resonant surface

Transport near the rational surface

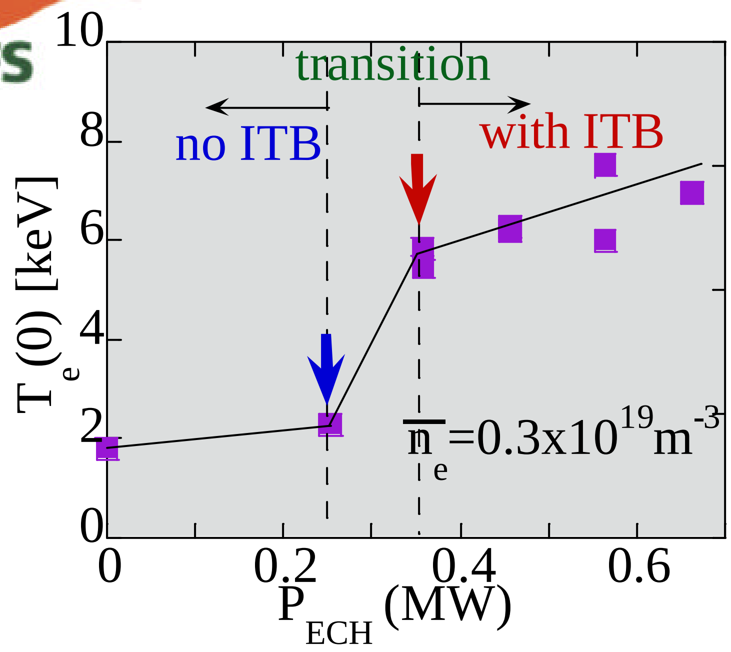
Particle transport → Inward flux
Heat transport → Reduction of c

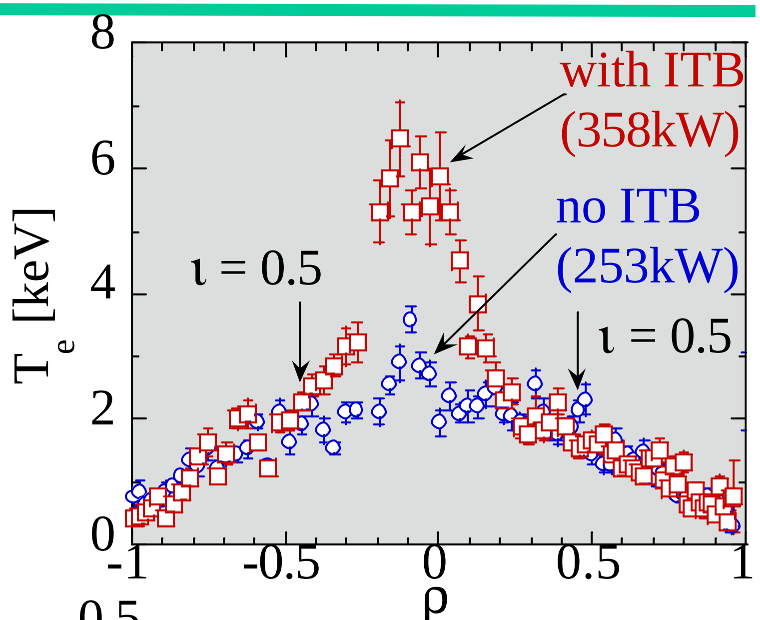
These improvement of transport near the magnetic island is localized to compensate the loss of confinement due to the flattening of pressure inside the island

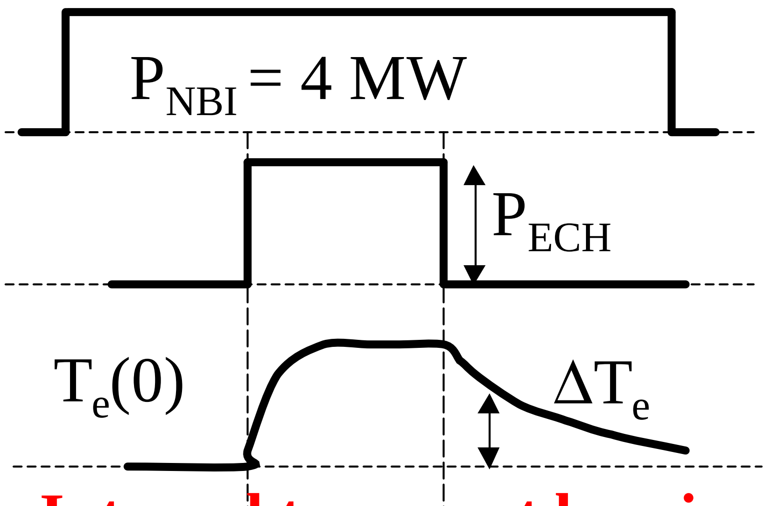
↓

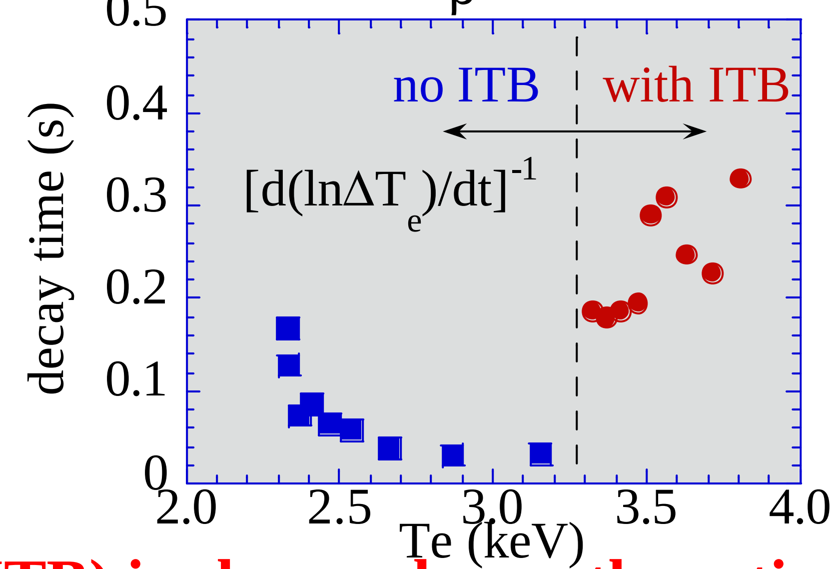
magnetic island at the rational surface might trigger the ITB formation

ITB near the ι=1/2 surface in LHD





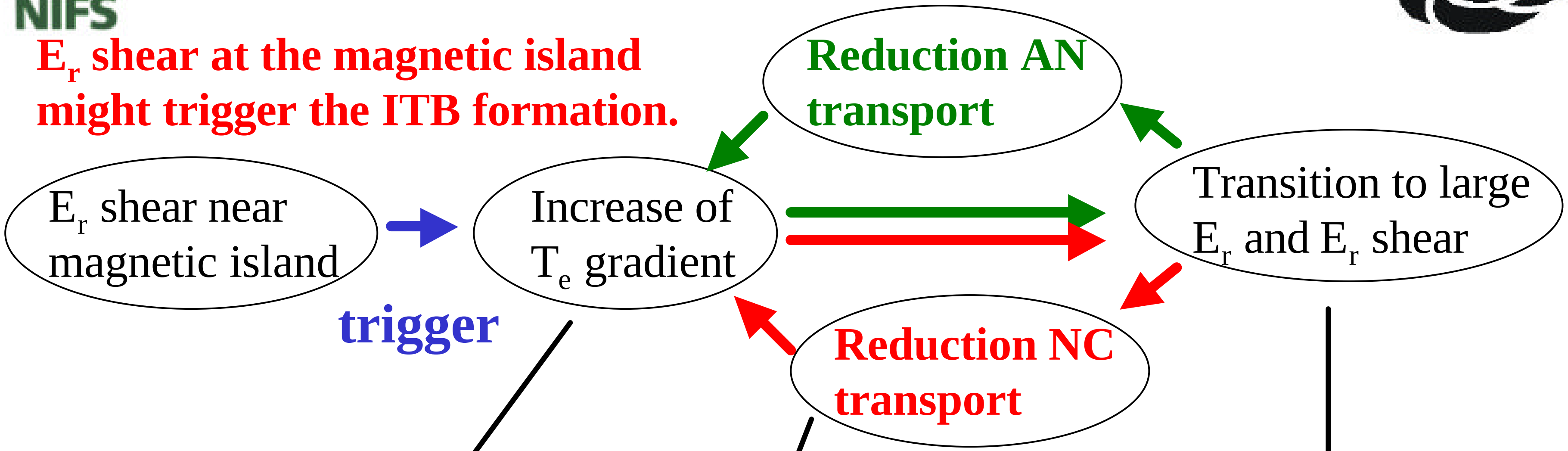


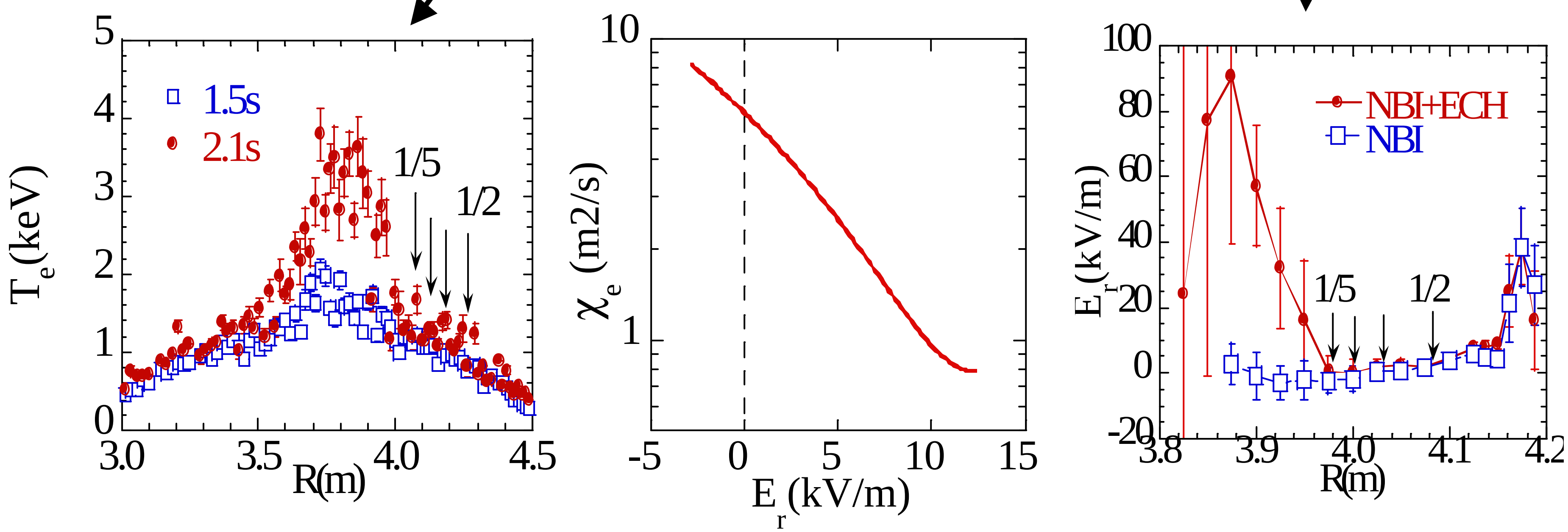


Internal transport barrier (ITB) is observed near the rational surface of ι = 1/2 (q=2).

E_r profiles of the plasma with ITB

E_r shear at the magnetic island might trigger the ITB formation.





Summary

Observations

1 The localized radial electric field shear (E_r shear) is observed at the boundary the magnetic island at the O-points. (The flow spin up start inside the magnetic island, when the island size is too large).

2 The electron thermal diffusivity near or inside the magnetic island at the O-point is much smaller than that at the X-point.

3 The internal transport barrier (ITB) appears near the rational surface.

Speculation ↓

These observations support the hypothesis that E_r shear near the boundary of magnetic island may trigger the ITB formation.