Ion and Electron Heating during Magnetic Reconnection in TS-3, TS-4 and MAST Torus Plasma Merging Experiment

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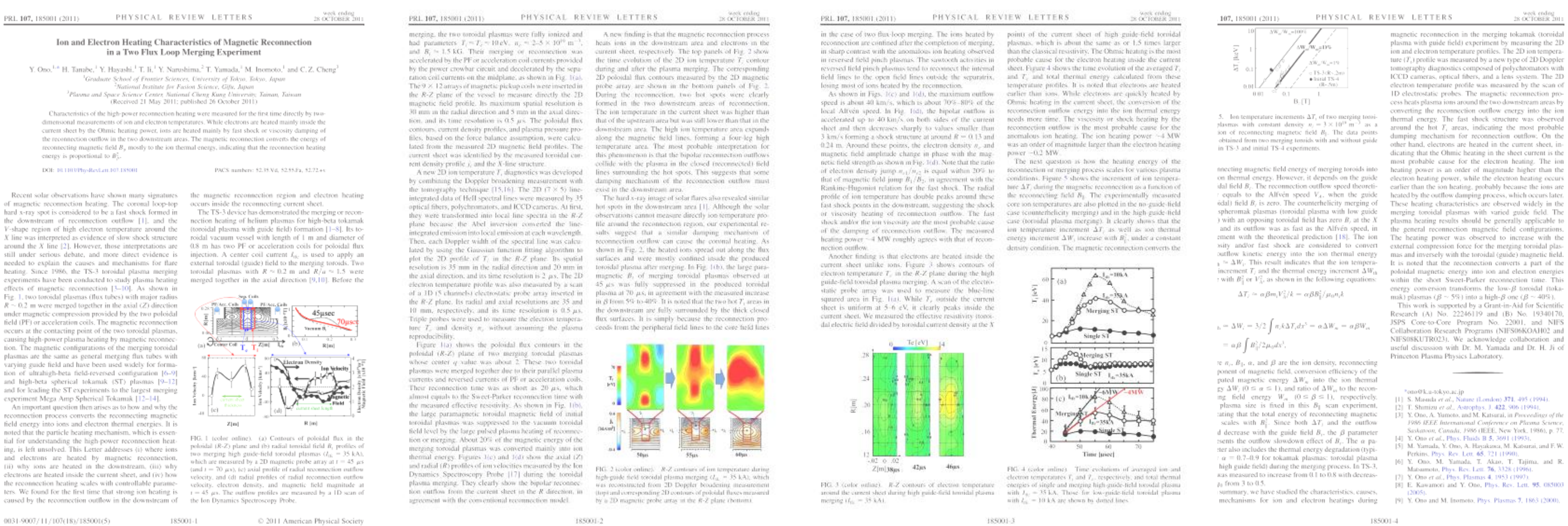
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Ion and Electron Heating Characteristics of Magnetic Reconnection in a Two Flux Loop Merging Experiment

THE UNIVERSITY OF TOKYO

CCFE
CULHAM CENTRE FOR FUSION ENERGY

Outline

Target physics of this talk:

Profiles of ion / electron heating

1: TS-3 & TS-4 case (Y. Ono group)

(2-D measurement around X point)

2: MAST case (thanks to M. Gryaznevich)

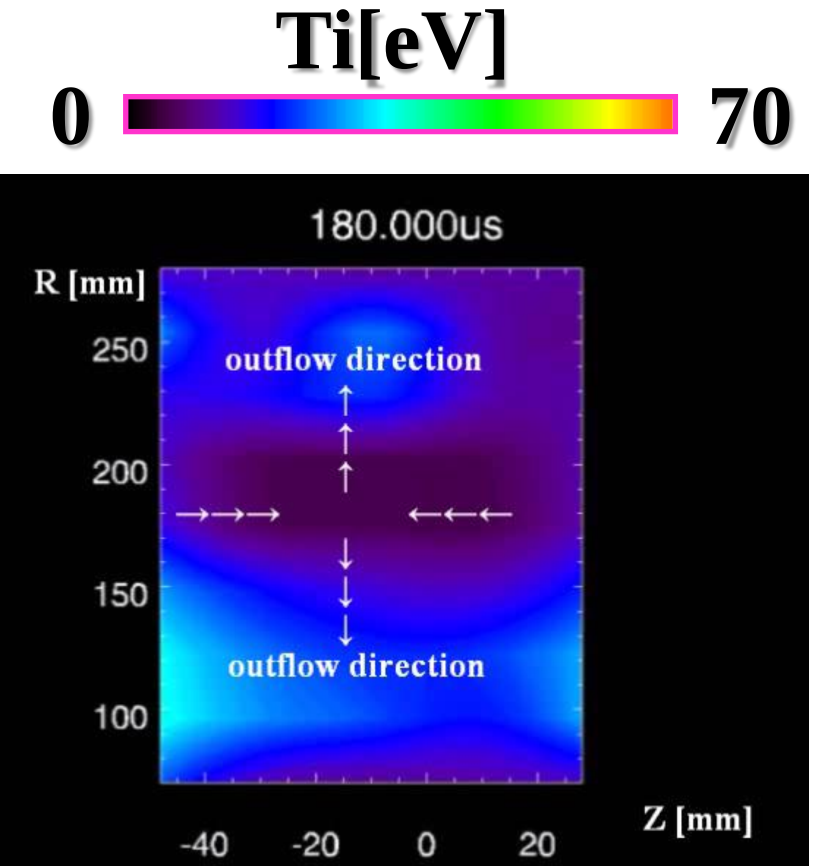
(~1keV regime high power experiment)

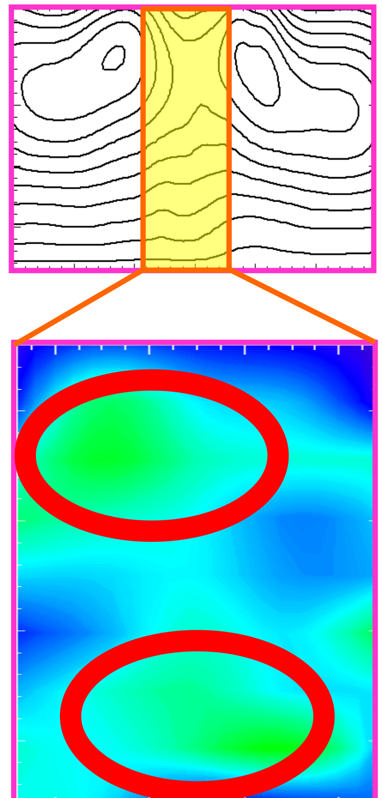
(130 points 1-D Te, ne diagnostics)

(Ti –Te energy relaxation is detected)

Ion heating in downstream and electron heating at X-point in TS-3&4 merging experiments

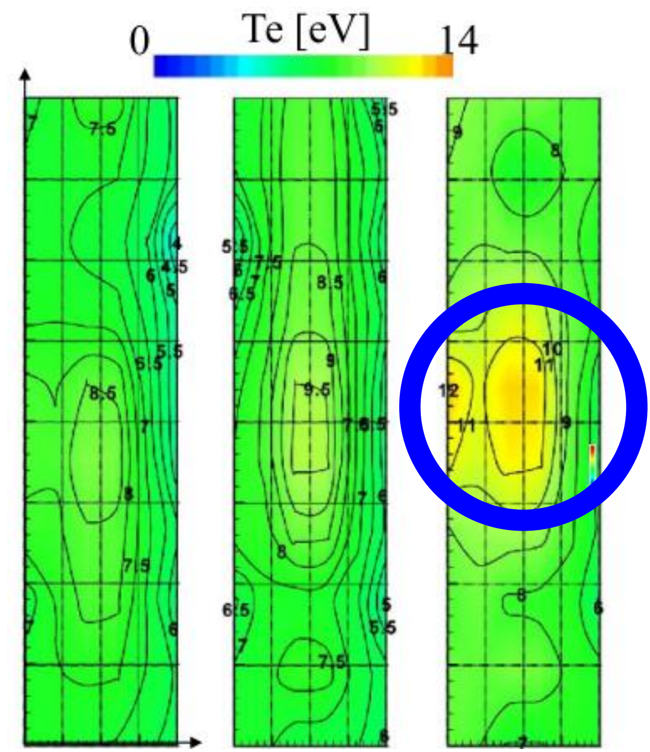
Ion heating in the downstream





R-Z contour of T_i by ion Doppler tomography

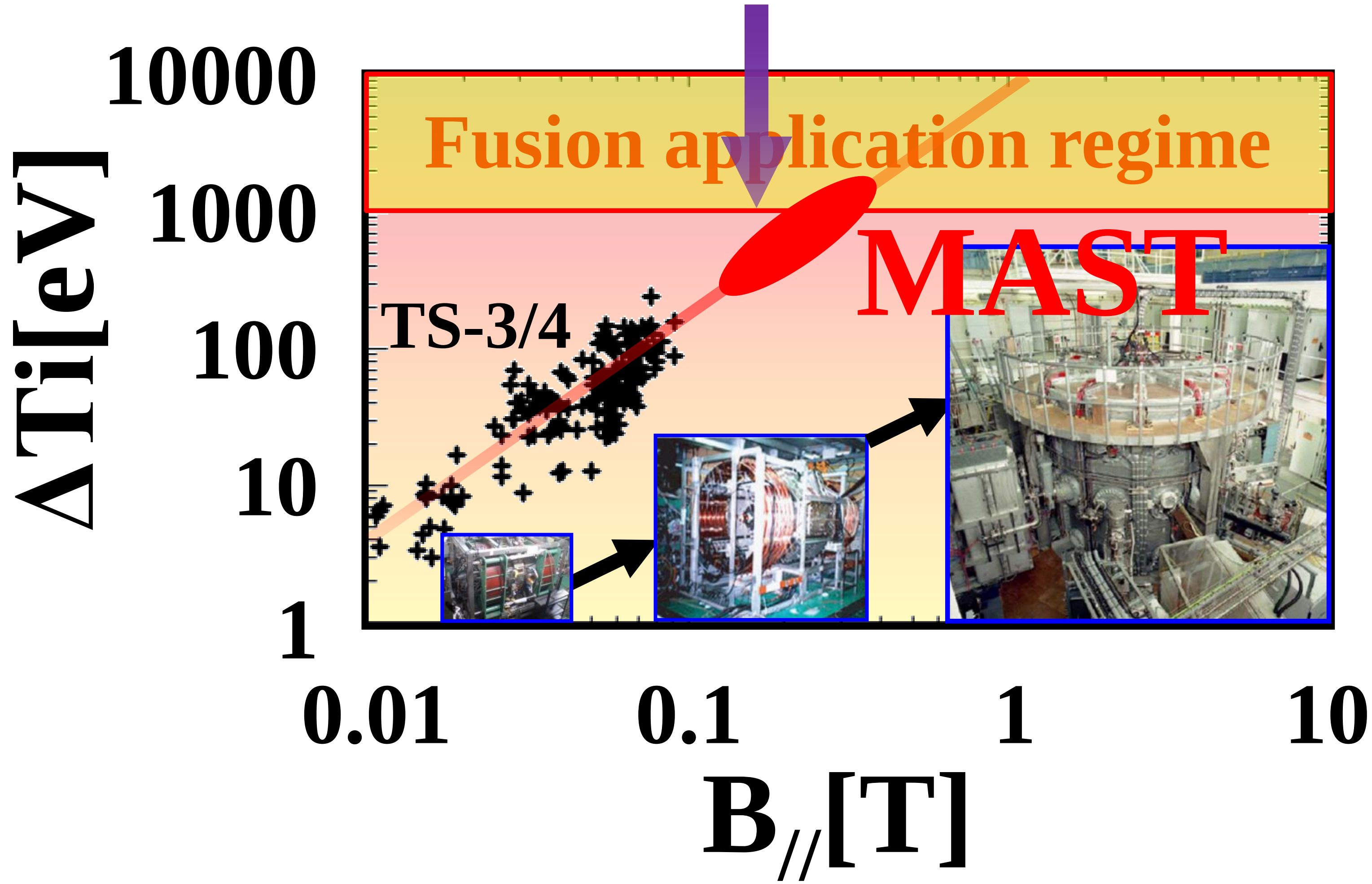
Electron heating at X-point



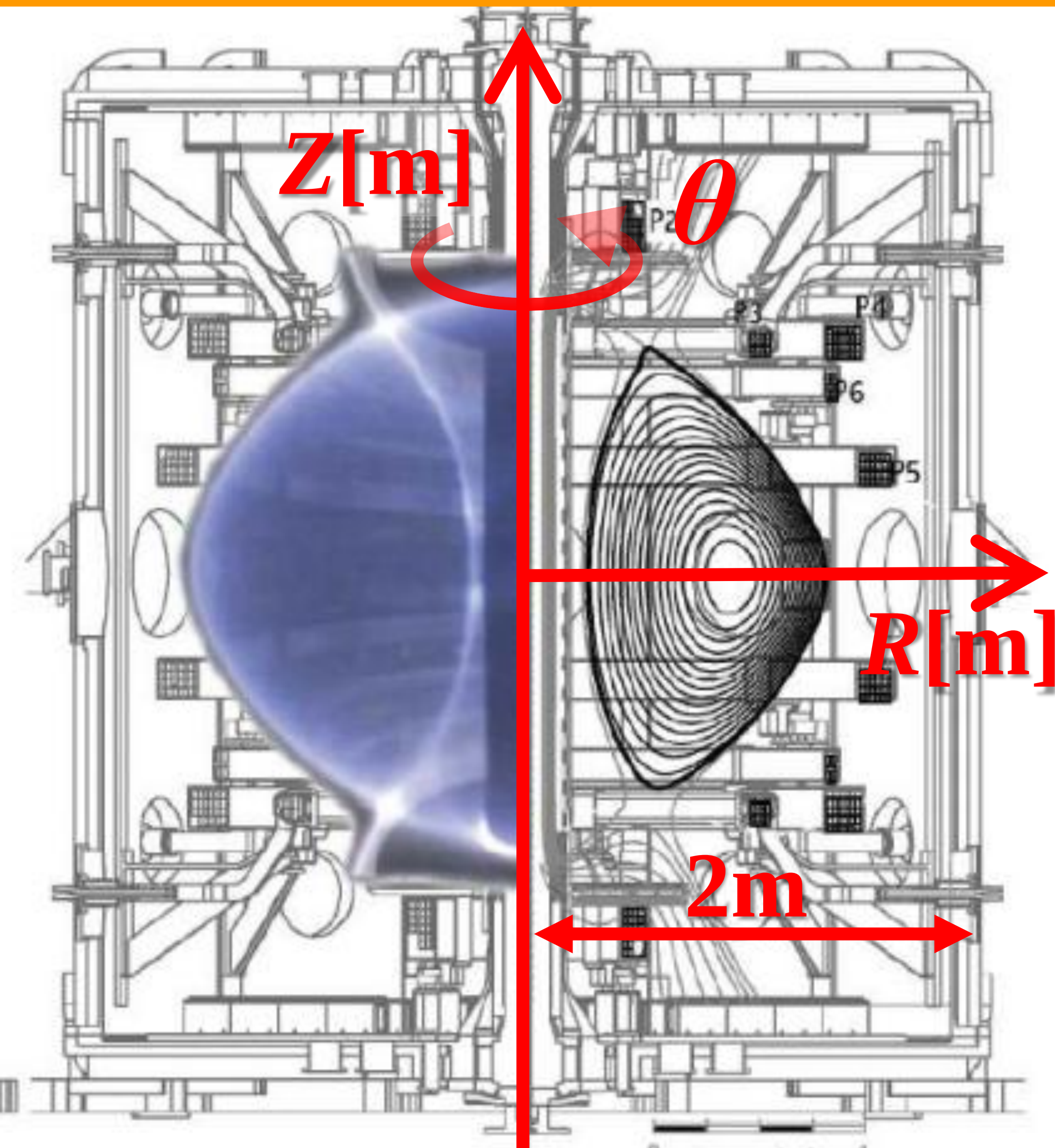
R-Z contours of T_e by electrostatic probe array

Dependence of reconnection ion heating on reconnected magnetic field energy $B_{//}^2$

Collaborative study for high-field reconnection heating in MAST using Doppler tomography diagnostics developed in Univ. Tokyo.

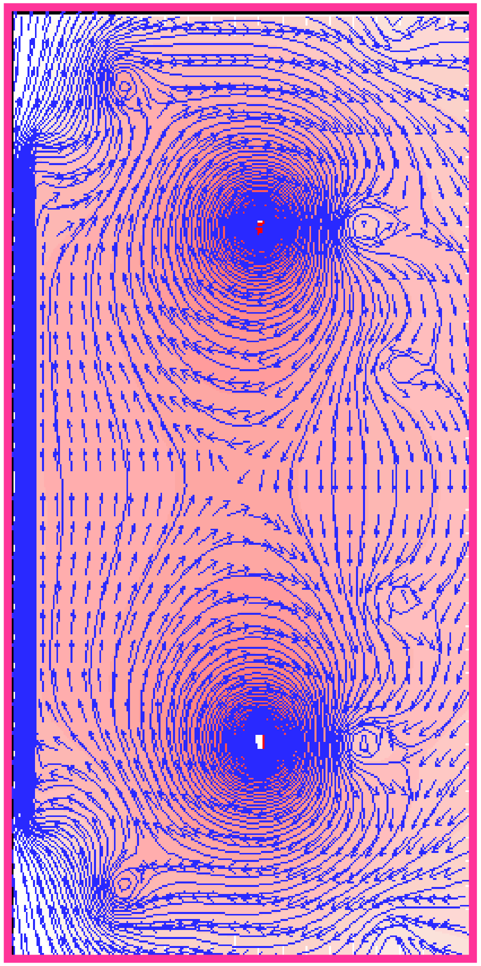


Vertical cross-section of MAST tokamak merging device and its typical discharge

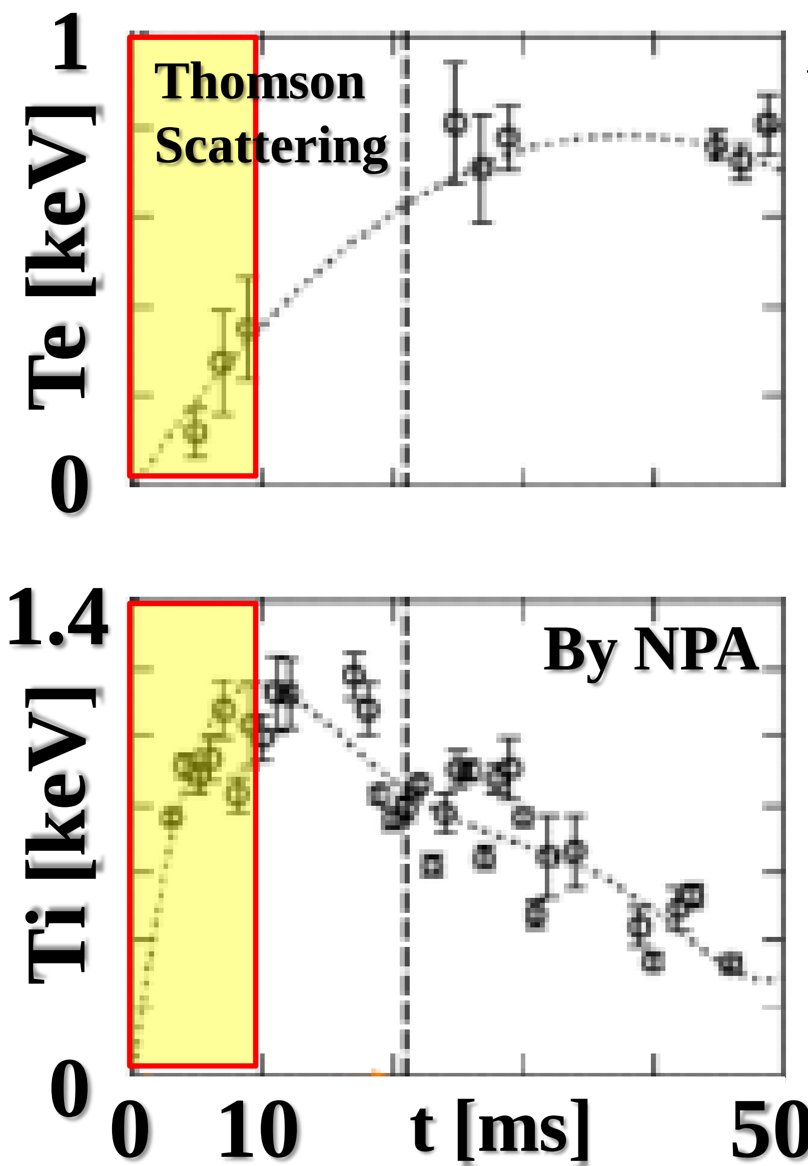


The MAST rec. experiment documented T_i~1keV as predicted in the TS-3 & 4 rec. experiments.

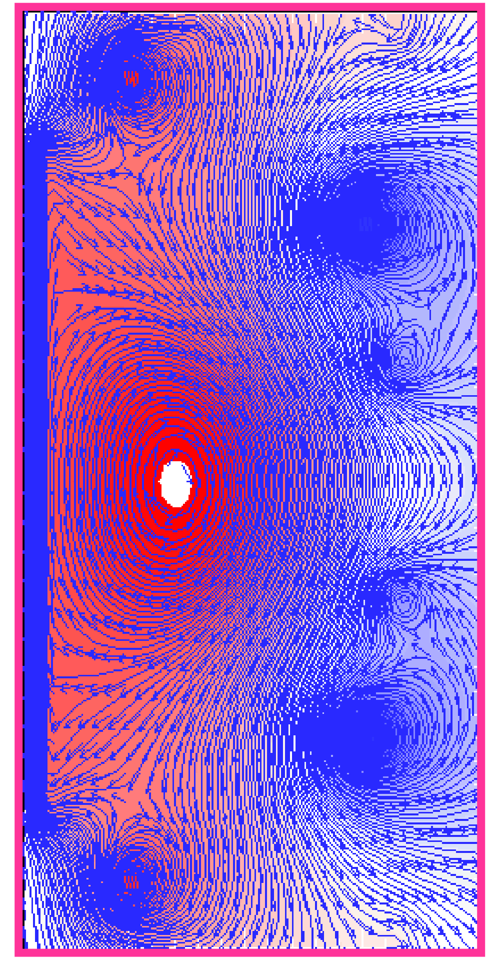
Before reconnection



(t = 0 ms)

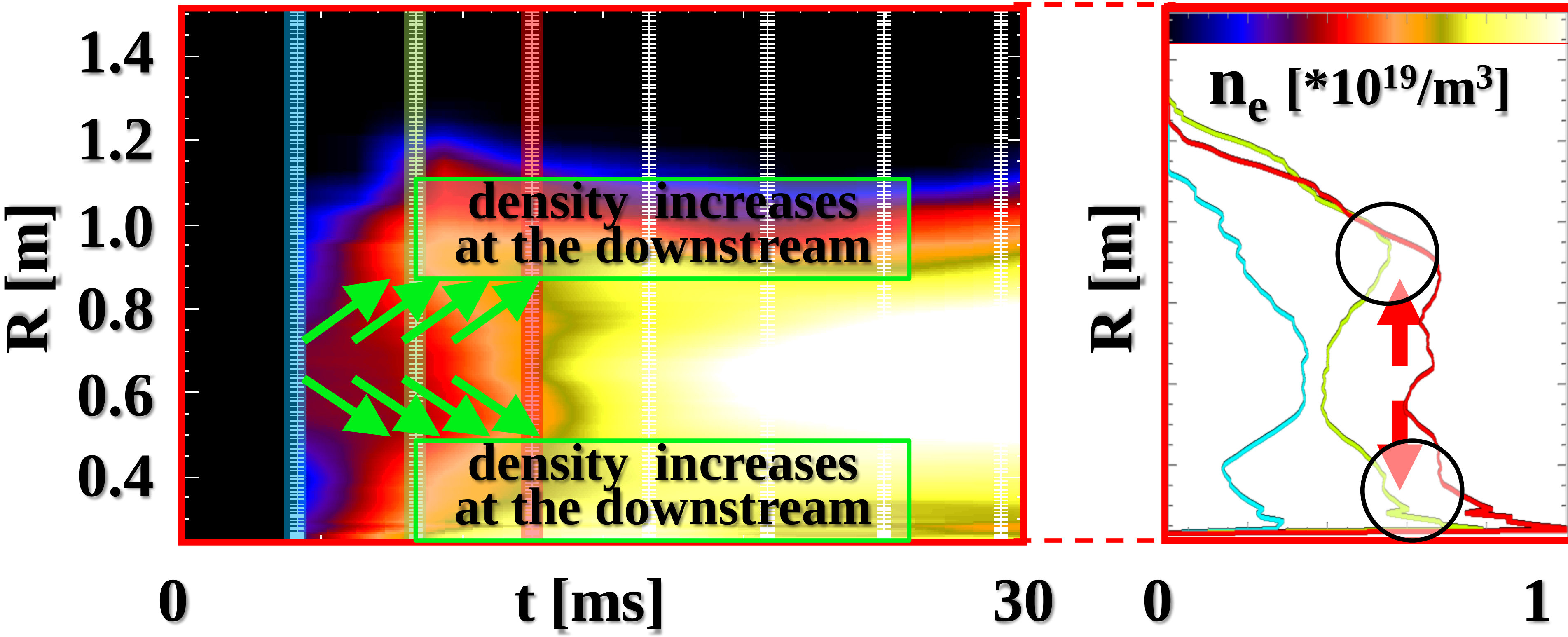


After reconnection



(t = 10 ms)

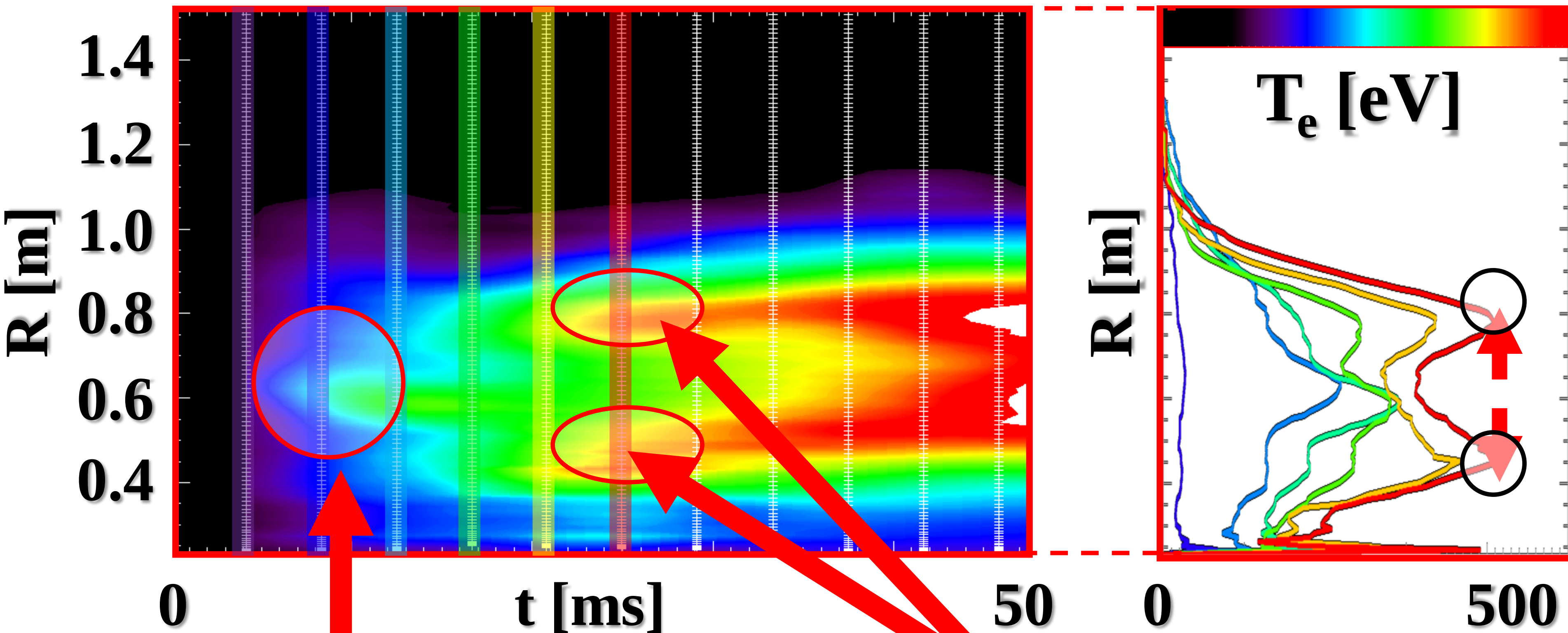
The electron density is observed to pile-up in the down-stream of current sheet.



Electron density profile during/after reconnection measured 130 chords high resolution Thomson scattering system

Strongly peaked T_e profile during reconnection

Double-peaked T_e profile after the reconnection



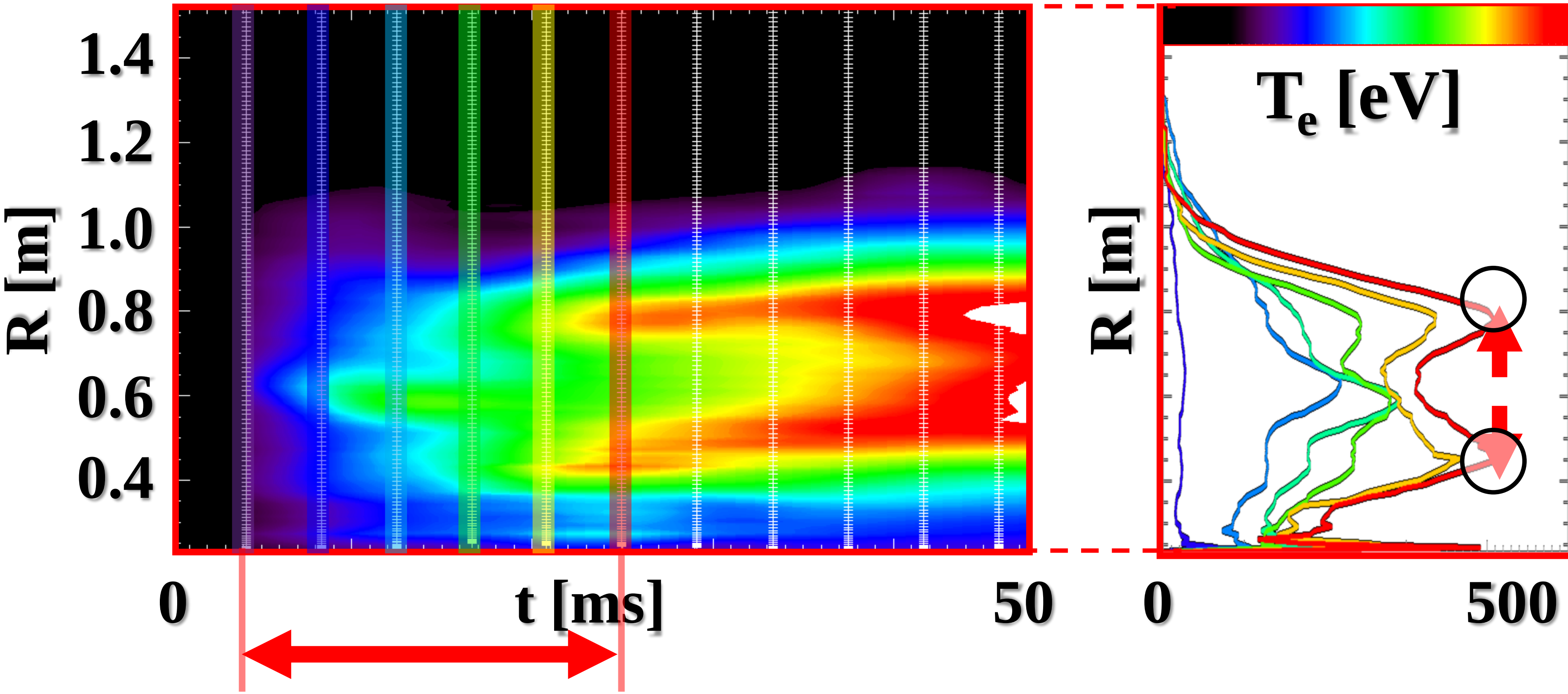
Electron heating at the X-point

$T_i \rightarrow T_e$ energy transfer dominates electron heating in the periphery?

Strongly peaked T_e profile during reconnection

↓

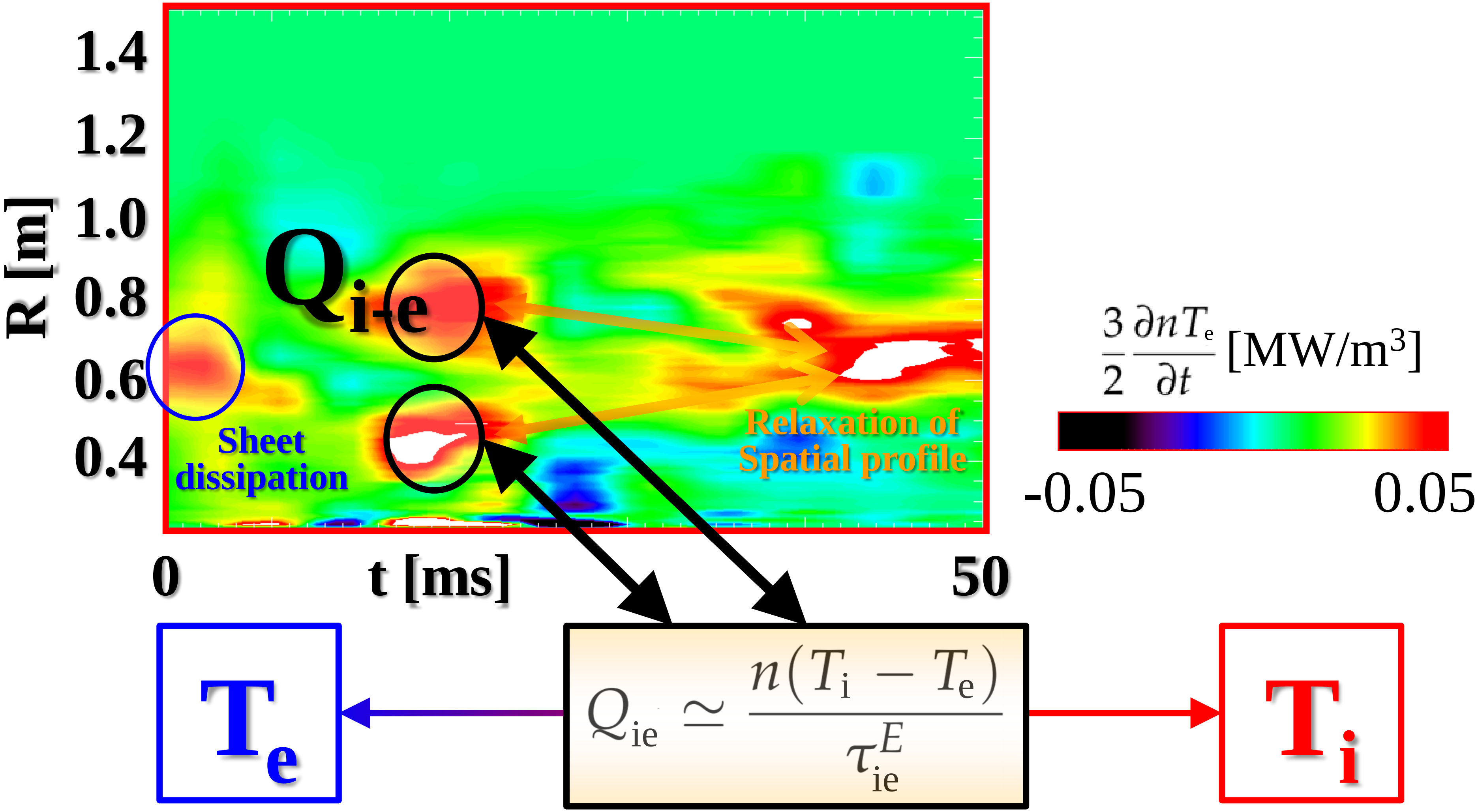
Double-peaked T_e profile after the reconnection



- Te=100eV : τ^E_{ei} ~ 4ms
- Te=200eV : τ^E_{ei} ~ 11ms
- Te=300eV : τ^E_{ei} ~ 20ms

This heating timescale of ~20ms agrees with T_i-T_e energy relaxation time.

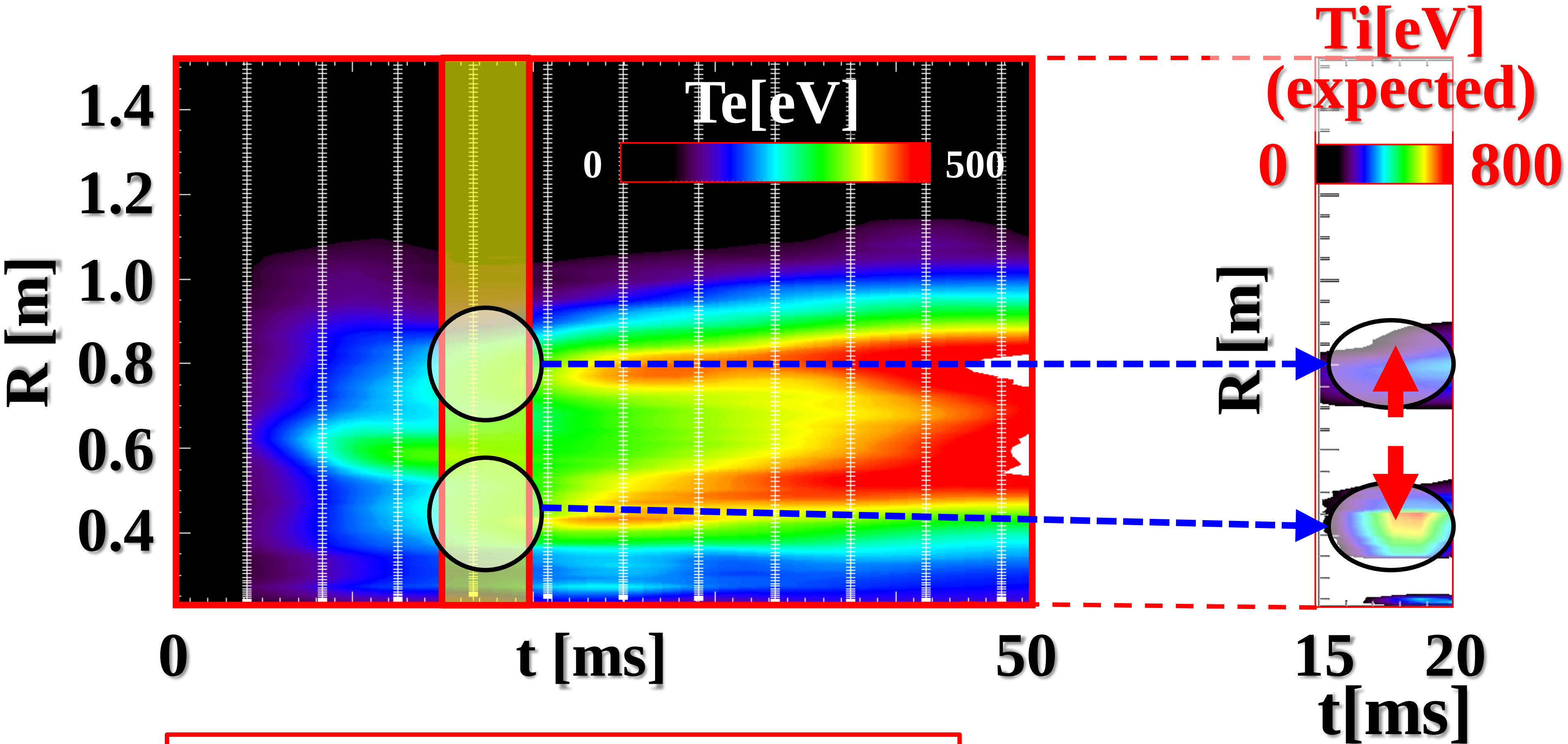
Profile of electron heating power[MW/m^3] for estimation of T_i-T_e energy relaxation



Estimation of T_i based on the assumption:

$$dnTe/dt = Q_{i-e} = n(Ti-Te)/\tau_{e-i}$$

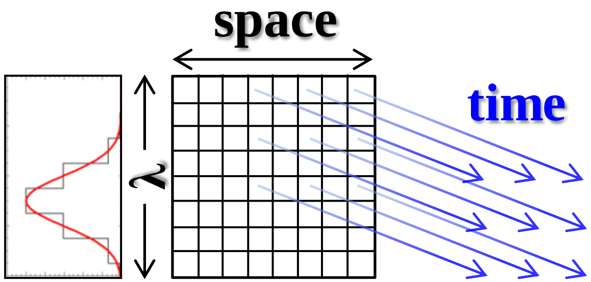
➡ T_i (maximum) ~ 800eV in the downstream



$$T_i = (dTe/dt)\,\tau_{e-i} - Te$$

We are now installing new Doppler tomography diagnostics for direct T_i measurement in MAST (coming soon!)

We are now constructing,



1: 8 x 8 PMT Doppler system

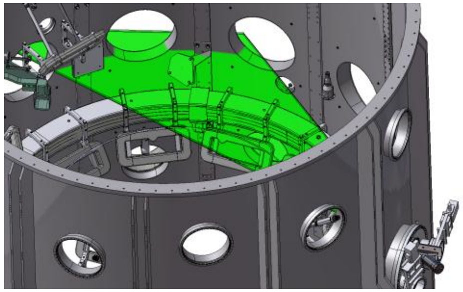
(for space & time resolution / rough wavelength resolution)

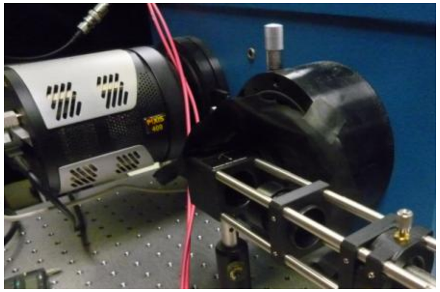
2: 1 chord CCD fast kinetics mode measurement

(for time & wavelength resolution / no spatial resolution)

3: 24 ~ 32 chords Doppler tomography system

(for space & time resolution / only one frame in a pulse)



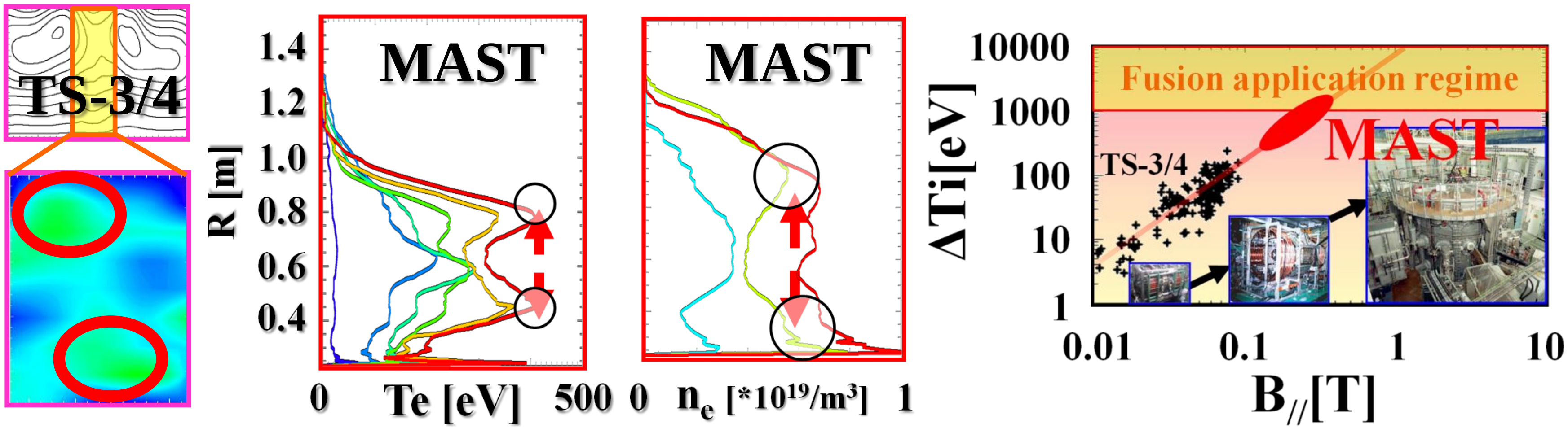


This profile measurement starts from 2012 – Nov. (at the end of this year)

Summary & Future Work

■Summary (TS-3/4 and MAST):

- ✓ Ion is heated at the downstream of outflow
- ✓ Electrons are heated around X point and those in periphery may be heated by i-e energy relaxation.
- ✓ The heating power scales with $\propto B_{//}^2$



■future work:

- ✓ TS-3/4: T_e profile measurement under high τ_E operation (Study of i-e energy relaxation in the periphery)
- ✓ MAST: T_i profile measurement by a new Doppler tomography.