High Power Heating of Magnetic Reconnection for High-Beta ST Formation in TS-3 and UTST ST Merging Experiments

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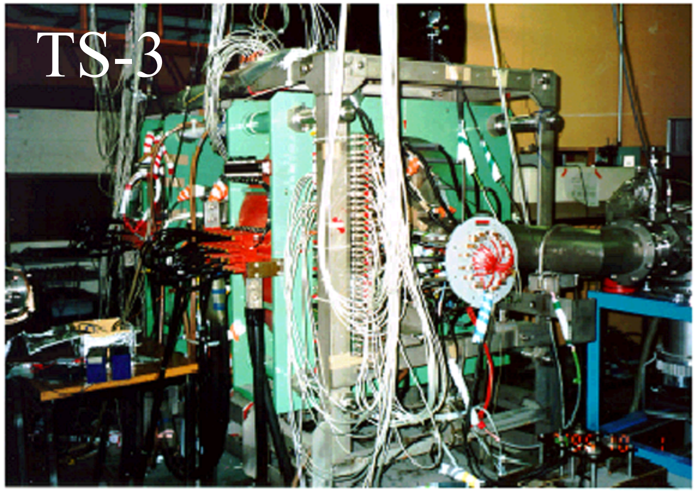
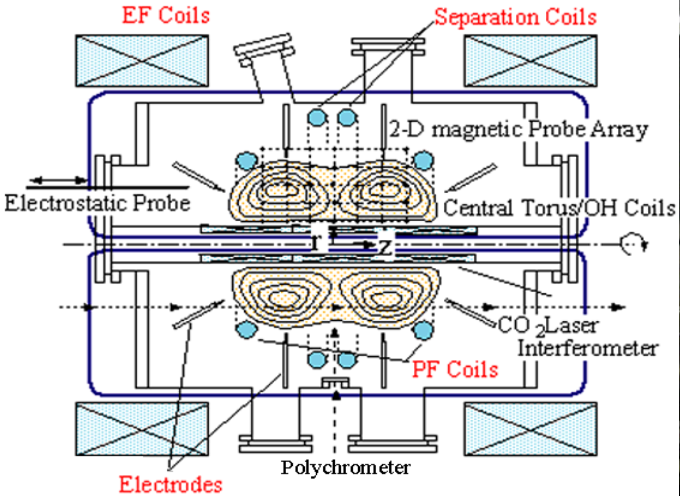
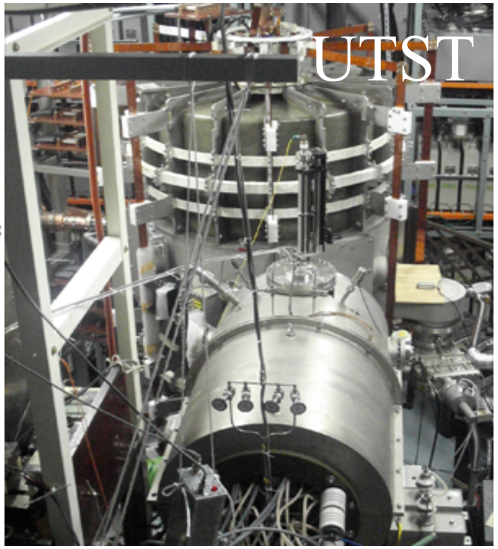
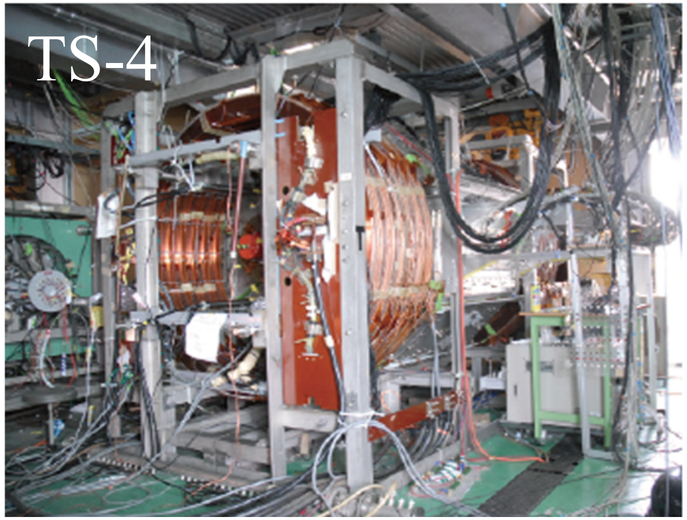
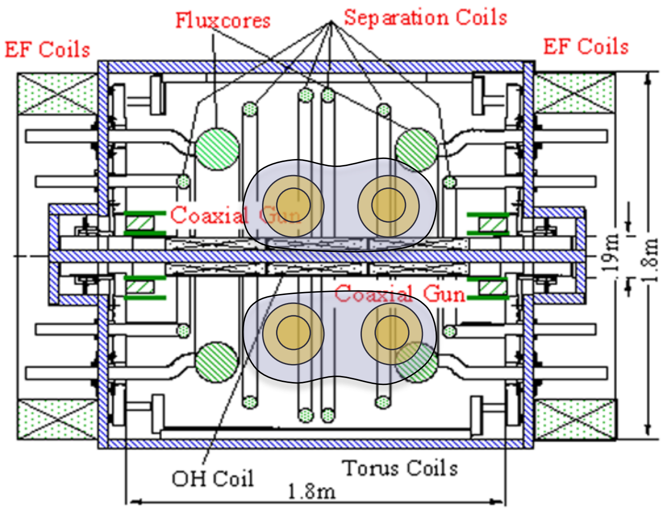
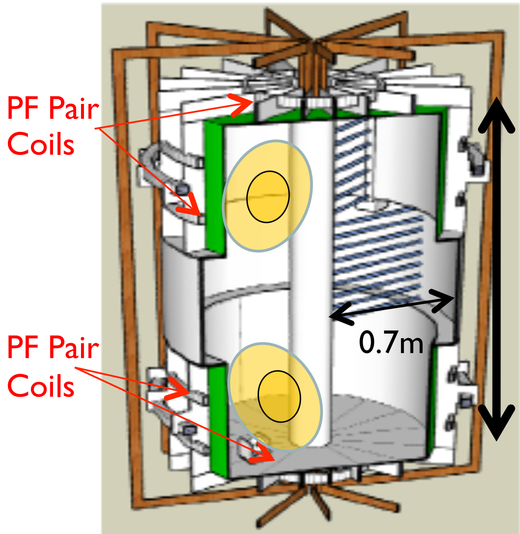






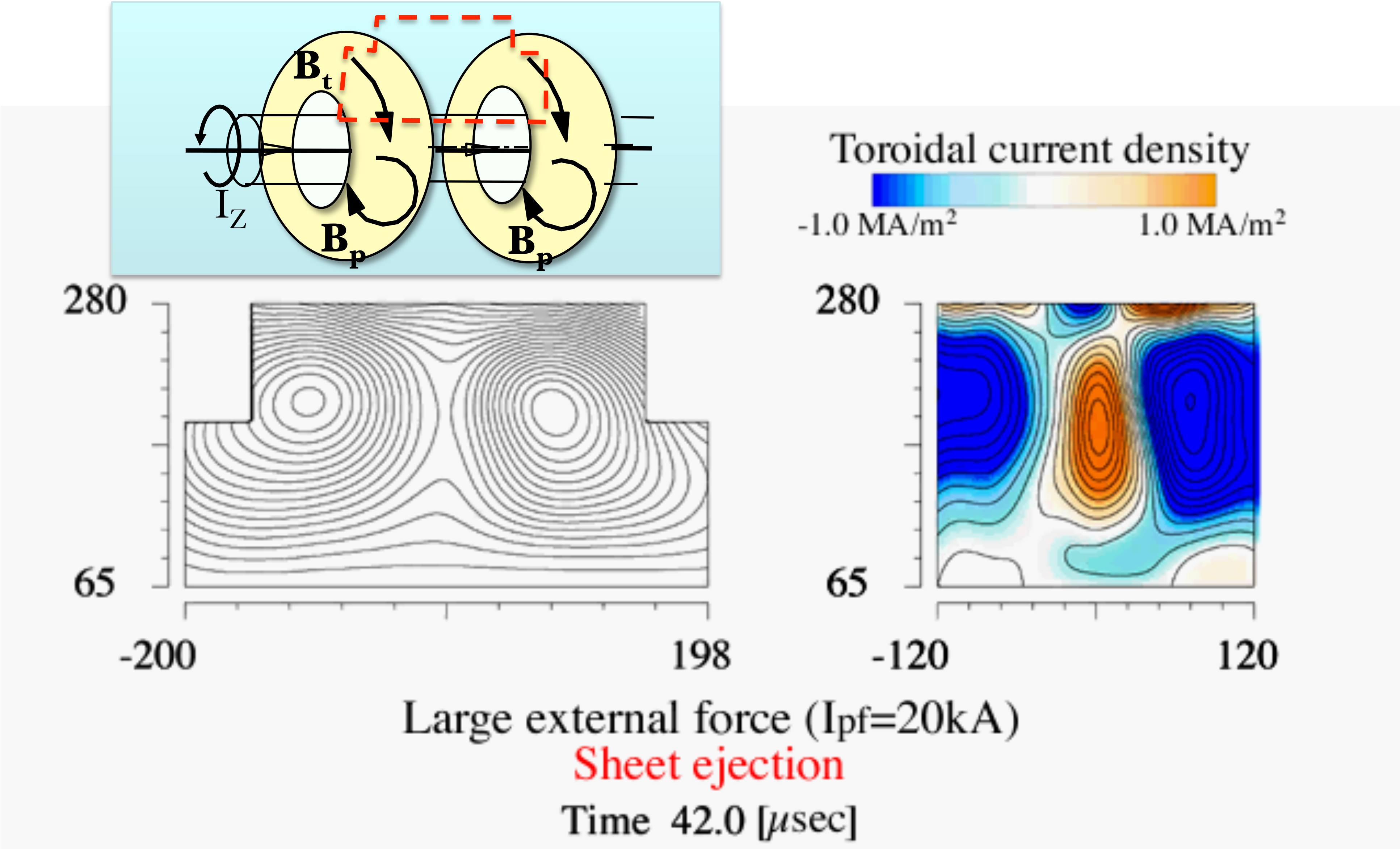






Magnetic reconnection of two merging toroidal plasmas

B field lines and j_t measured by 2-D magnetic probe array.



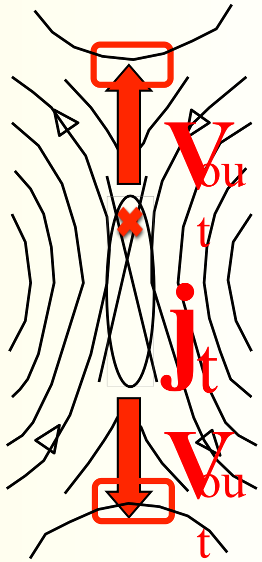
ST Merging for Reconnection Heating

● Why, Where and How much reconnection heats ions and electrons?

→ 2D T_i and T_e measurements

Outflow heating of T_i in downstream

Ohmic heating of T_e in current sheet



→ 1D T_i, V_i probe, Mach probe array

Fast shock in the downsteam

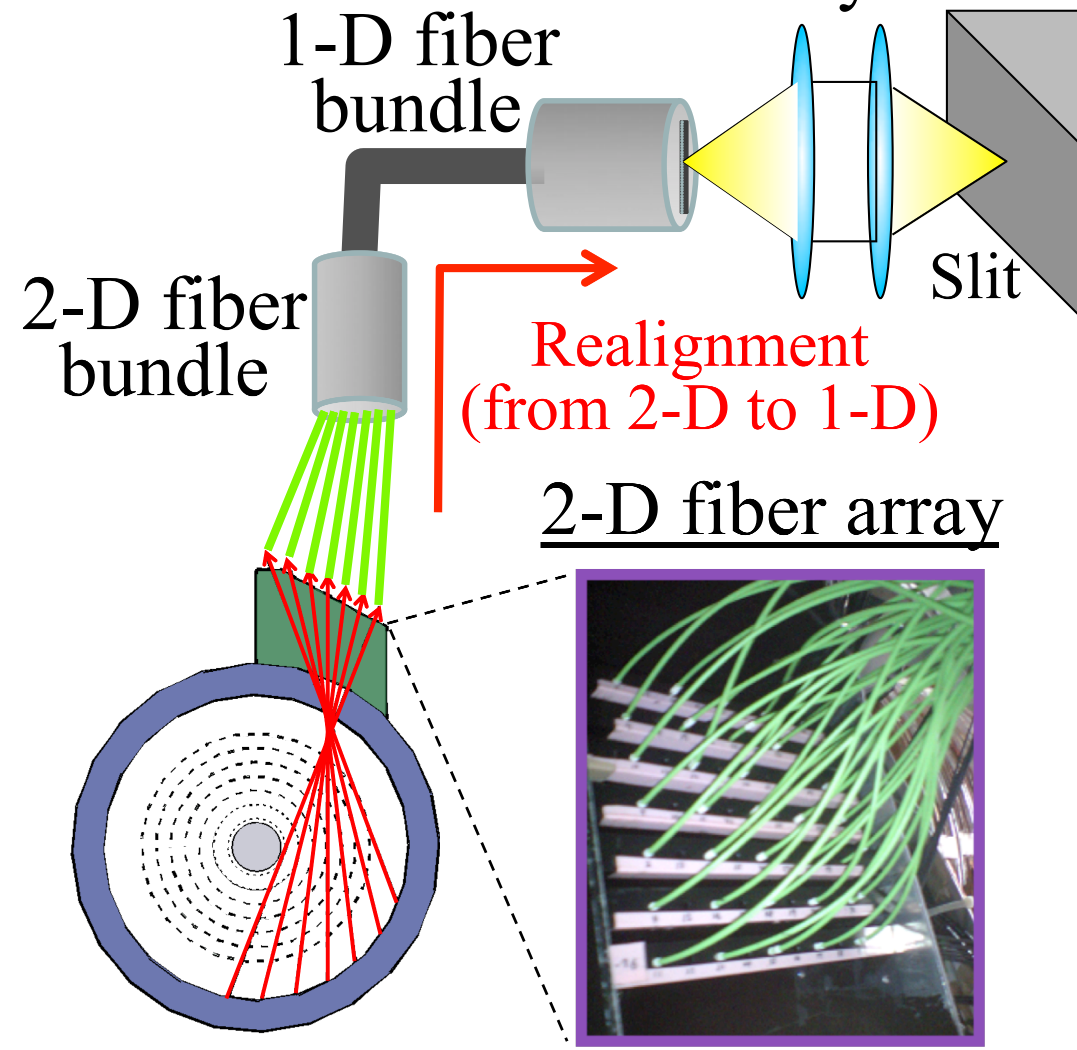
Scaling of rec. heating → T_{ie}>1keV in MAST rec. exp.

●Merging formation of abs. min-B profile

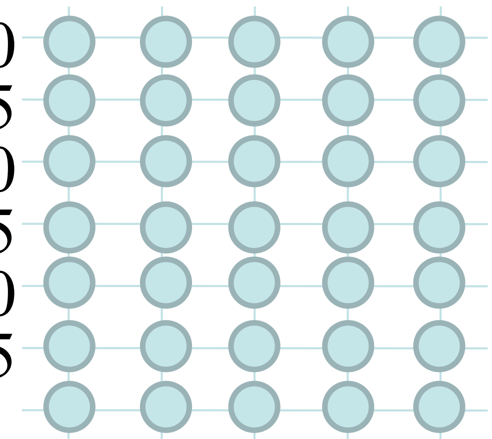
Fast formation of ST with ß>0.3 in 2nd-stability

2D T_i Doppler Measurement System

2011 RSI by Tanabe et al.

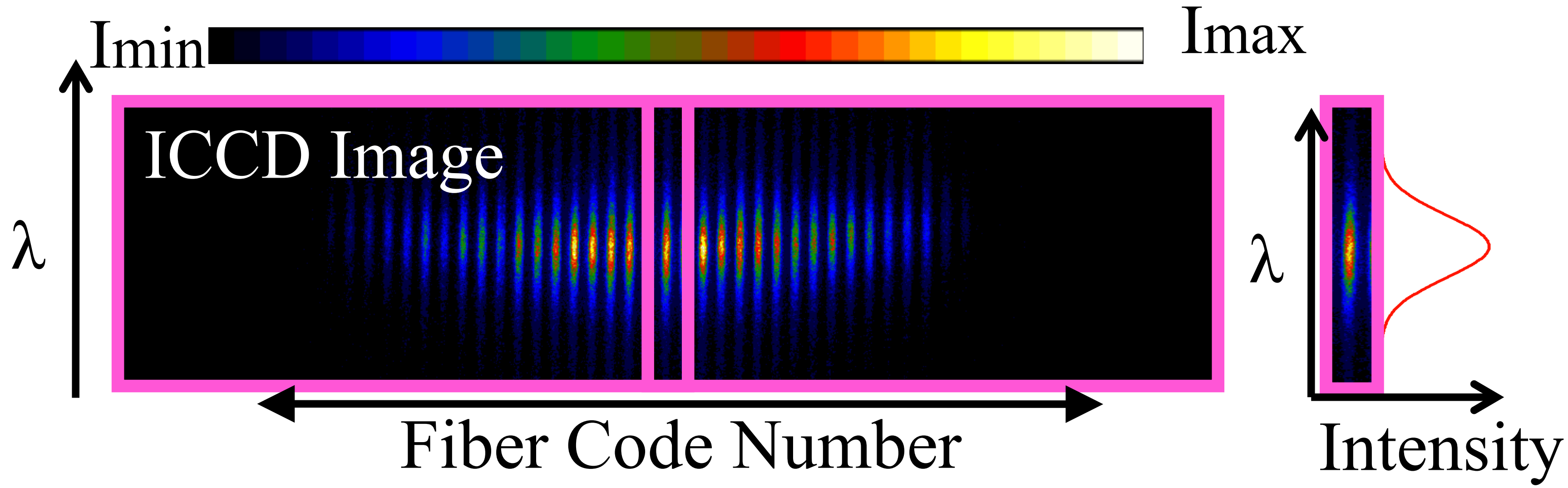


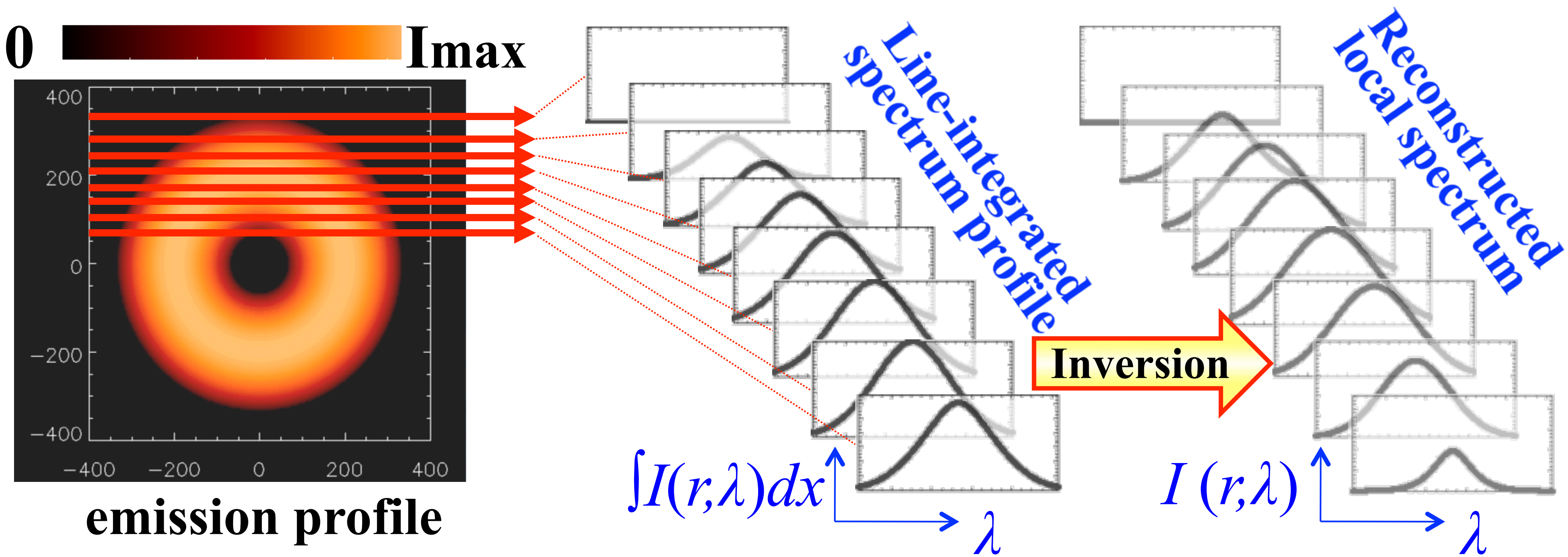
2-D Optical fiber position



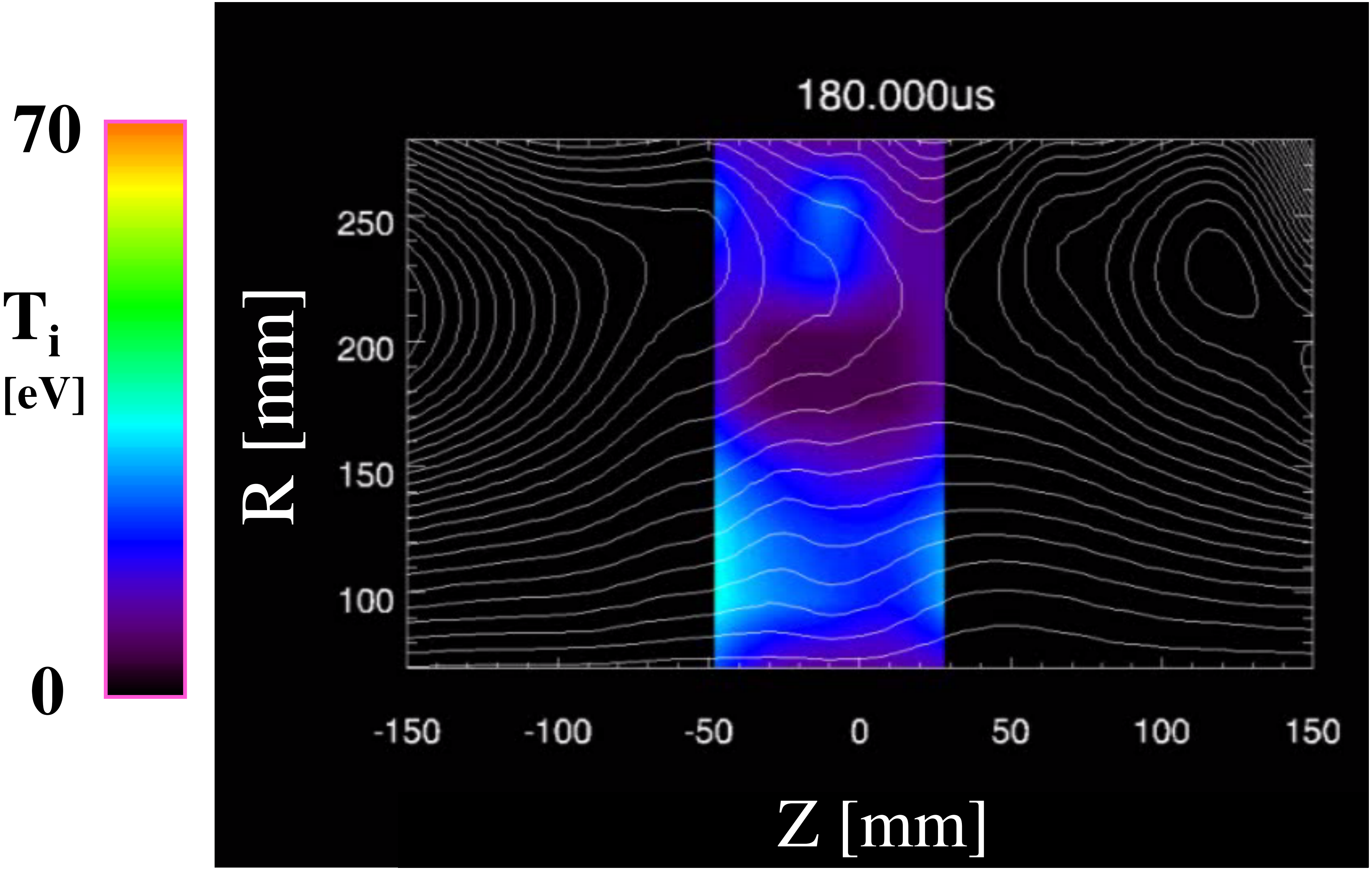
ICCD Image Reconstruction to measure 2D T_i Profile

1. Extract each code spectrum from ICCD Image



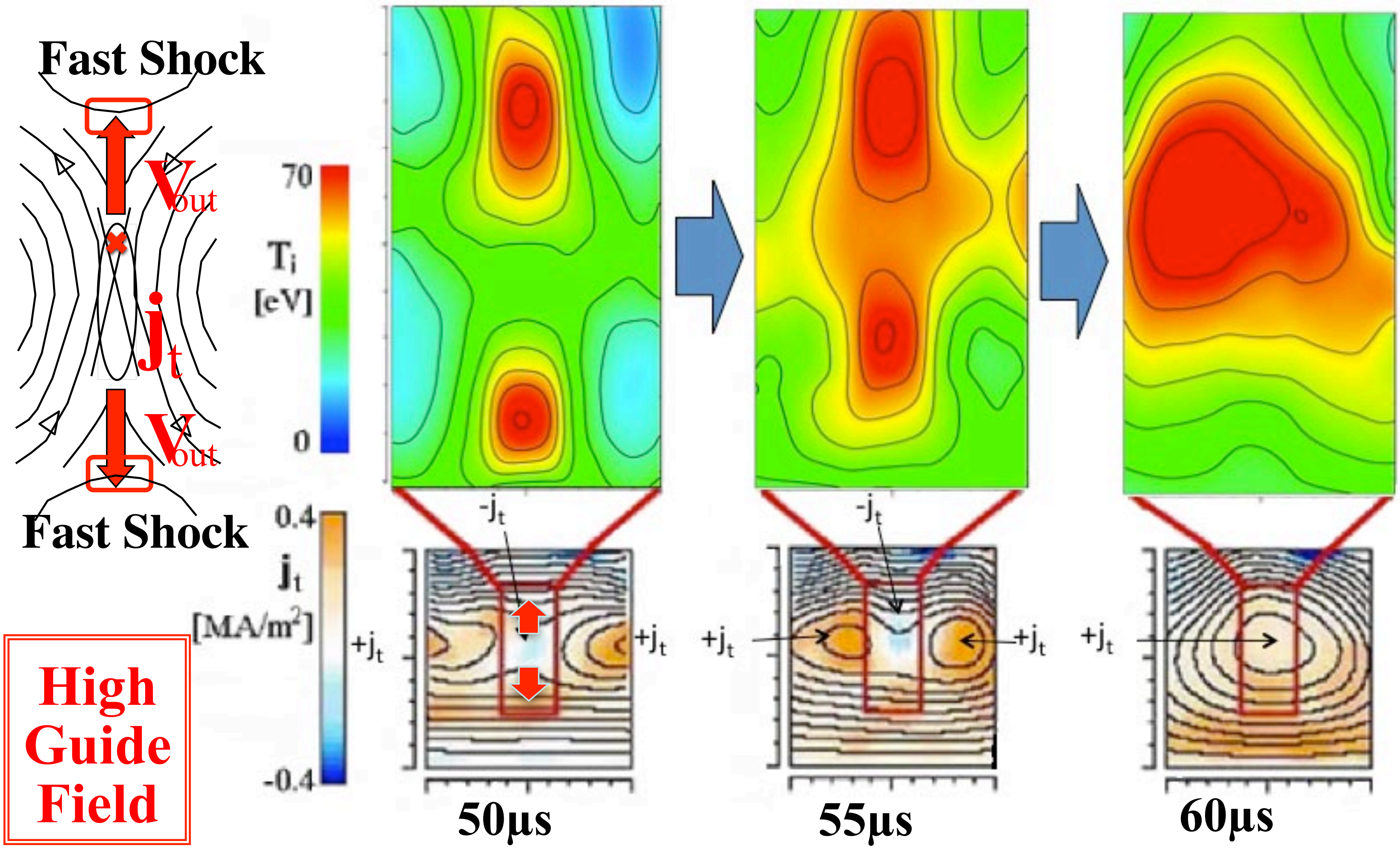


Significant ion heating of no-guide field reconnection (Merging of two toroidal plasma with opposing B_t)



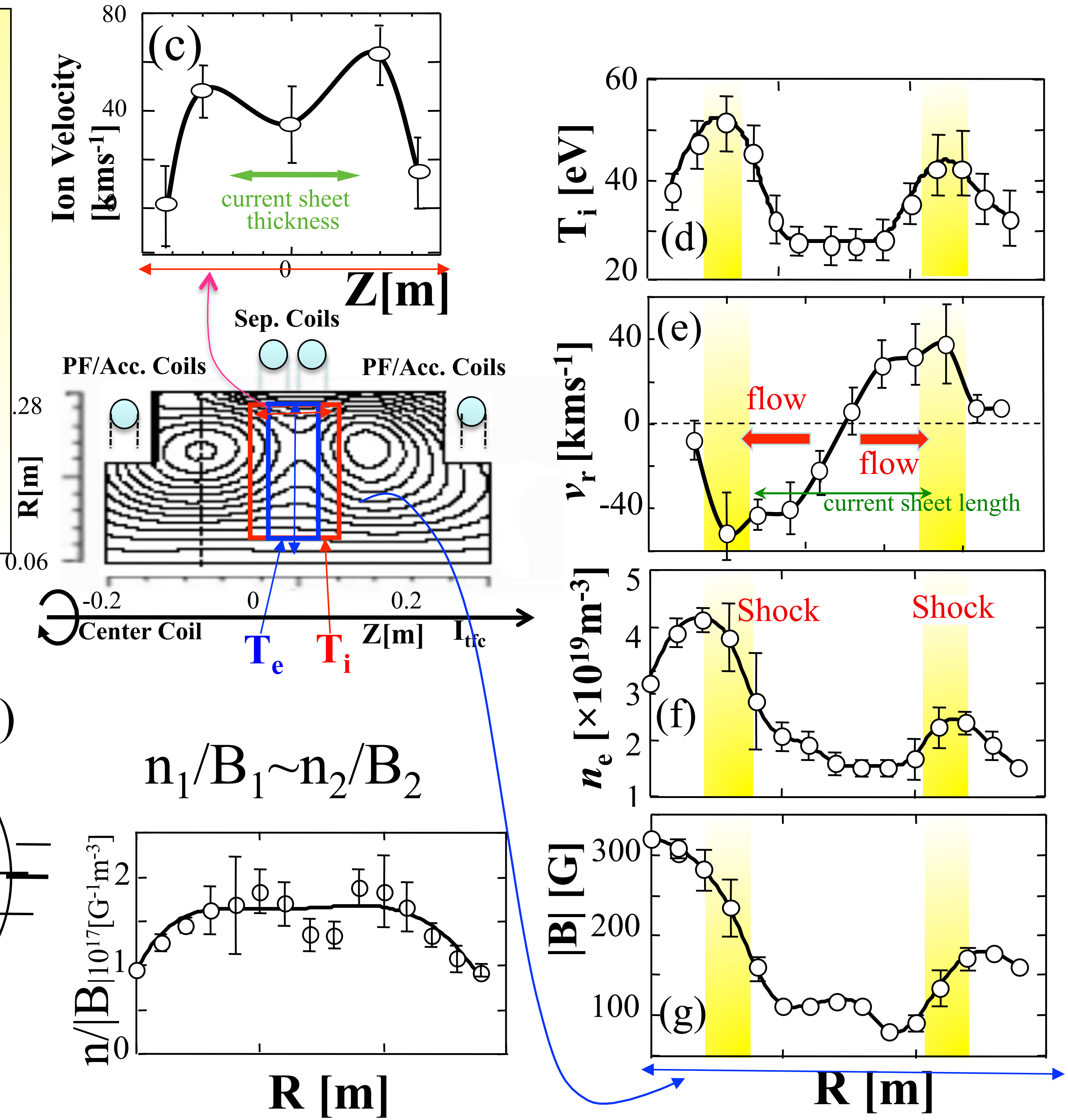
First 2-D T_i measurement of reconnection

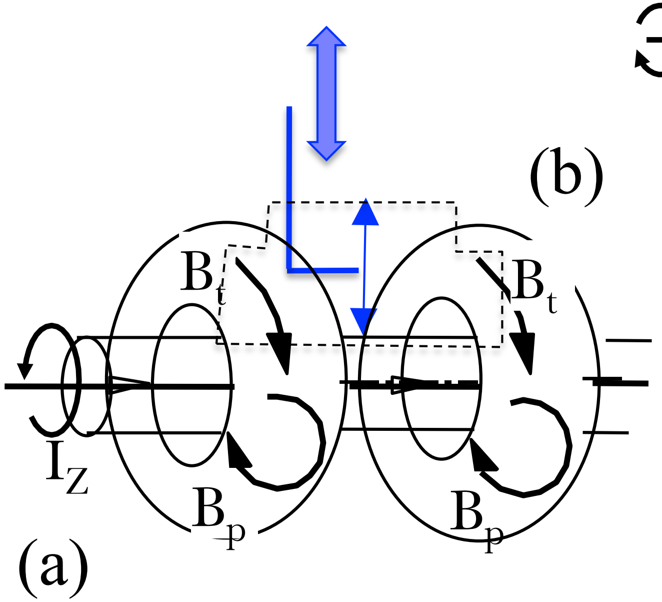
Clear evidence of ion heating by outflow!



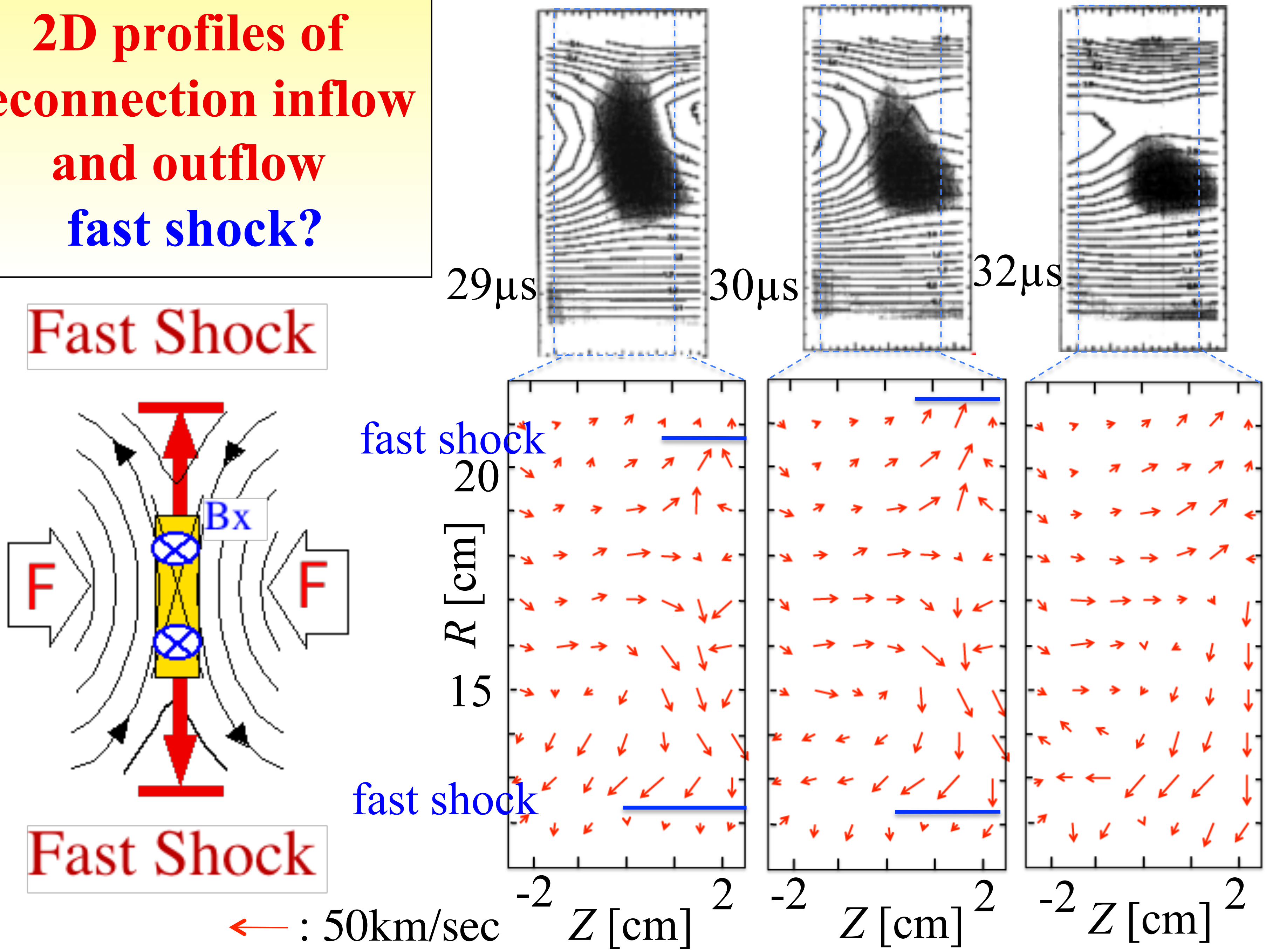
High Guide Field

At down-stream, hot T_i spot, steep increase in n_e and dumping of ion flow appear, indicating fast shock formation .



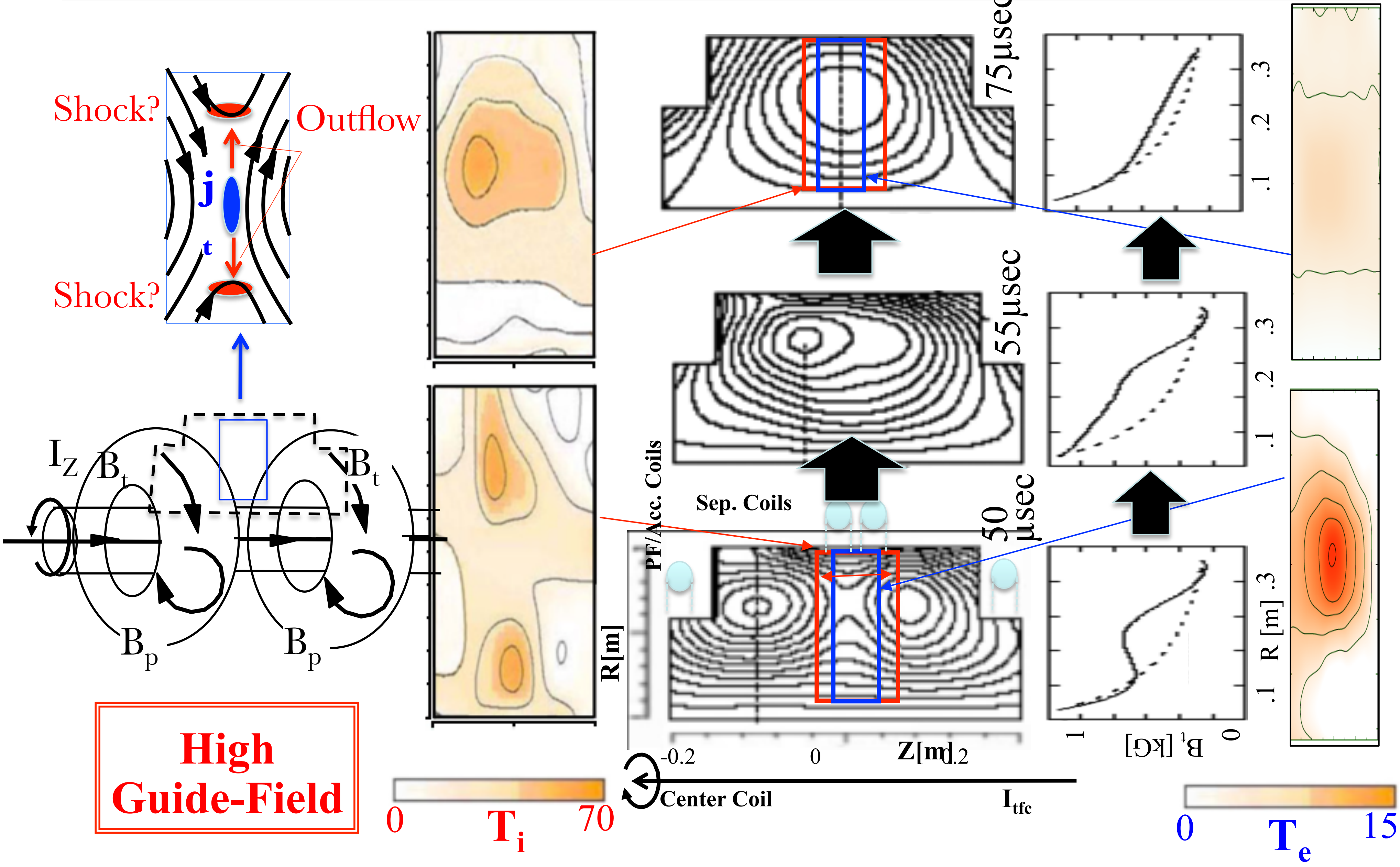


2D profiles of reconnection inflow and outflow
fast shock?



Significant ion heating in downstream and localized electron heating inside the current sheet.

High power heating suppresses paramag. B_t, increasing plasma beta.



Energy Flow during Reconnection

High Guide-Field

Magnetic Energy Dissipation **≈ 145J**

Outflow Energy

Current Sheet Heating

$\int\int E \bullet J dV dt$ **≈ 13J**

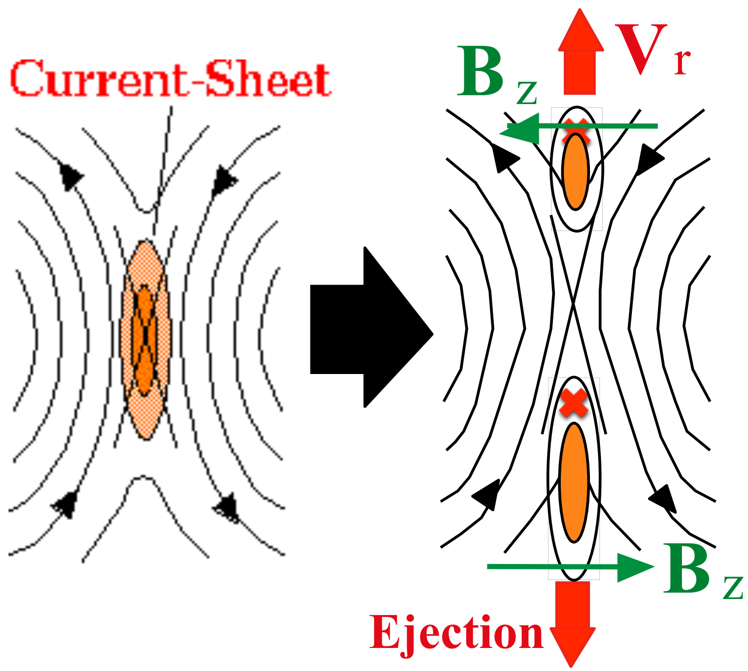
Large ion heating **»** **Small electron heating**

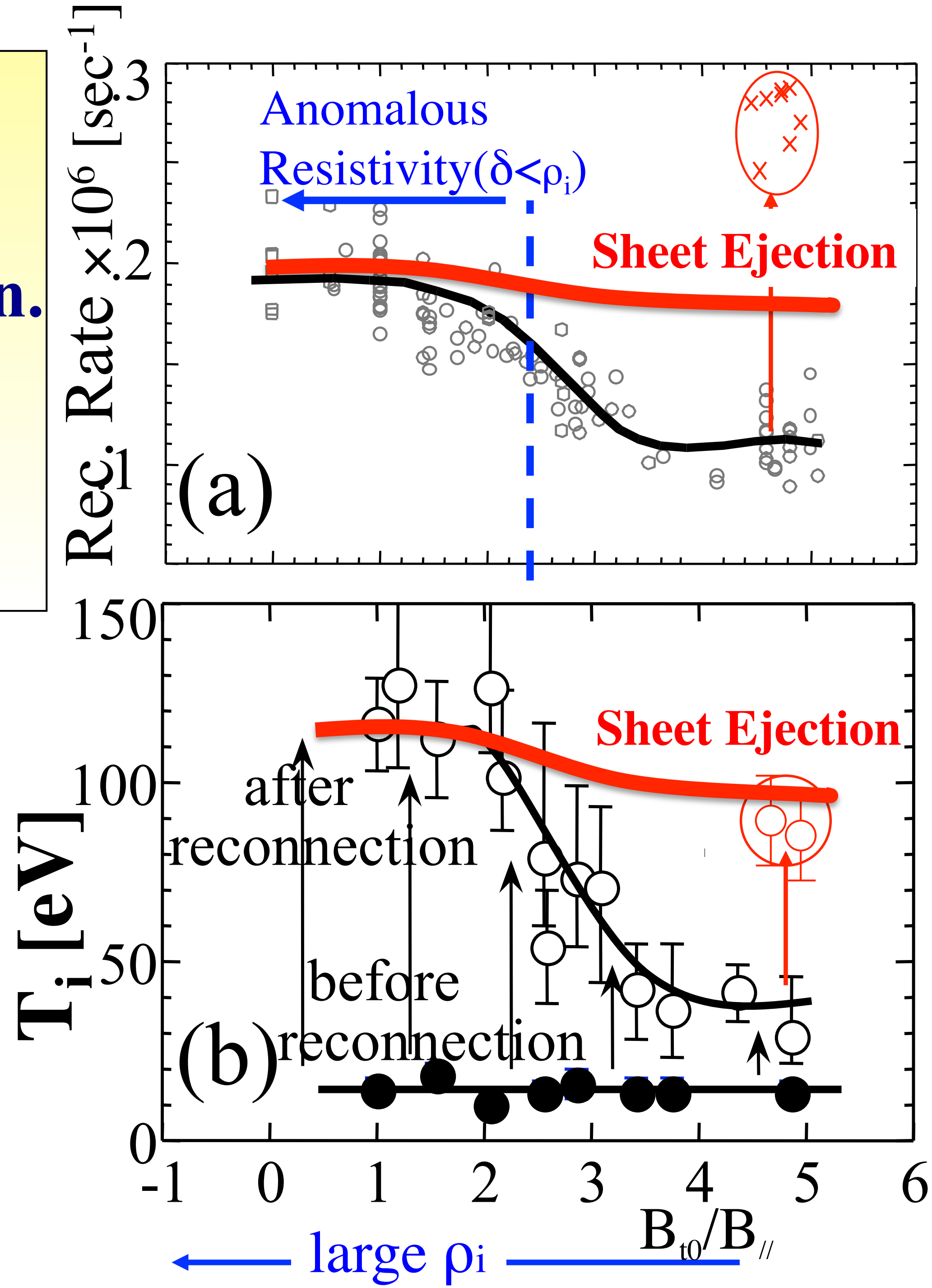
Increment of Ion thermal Energy **≈ 128J**

Smaller reconnecting B field than that of counterhelicity merging.

1) Rec. rate and ΔT_i decrease with B_t before plasmoid ejection.

2) Rec. rate and ΔT_i increase significantly after plasmoid ejection.

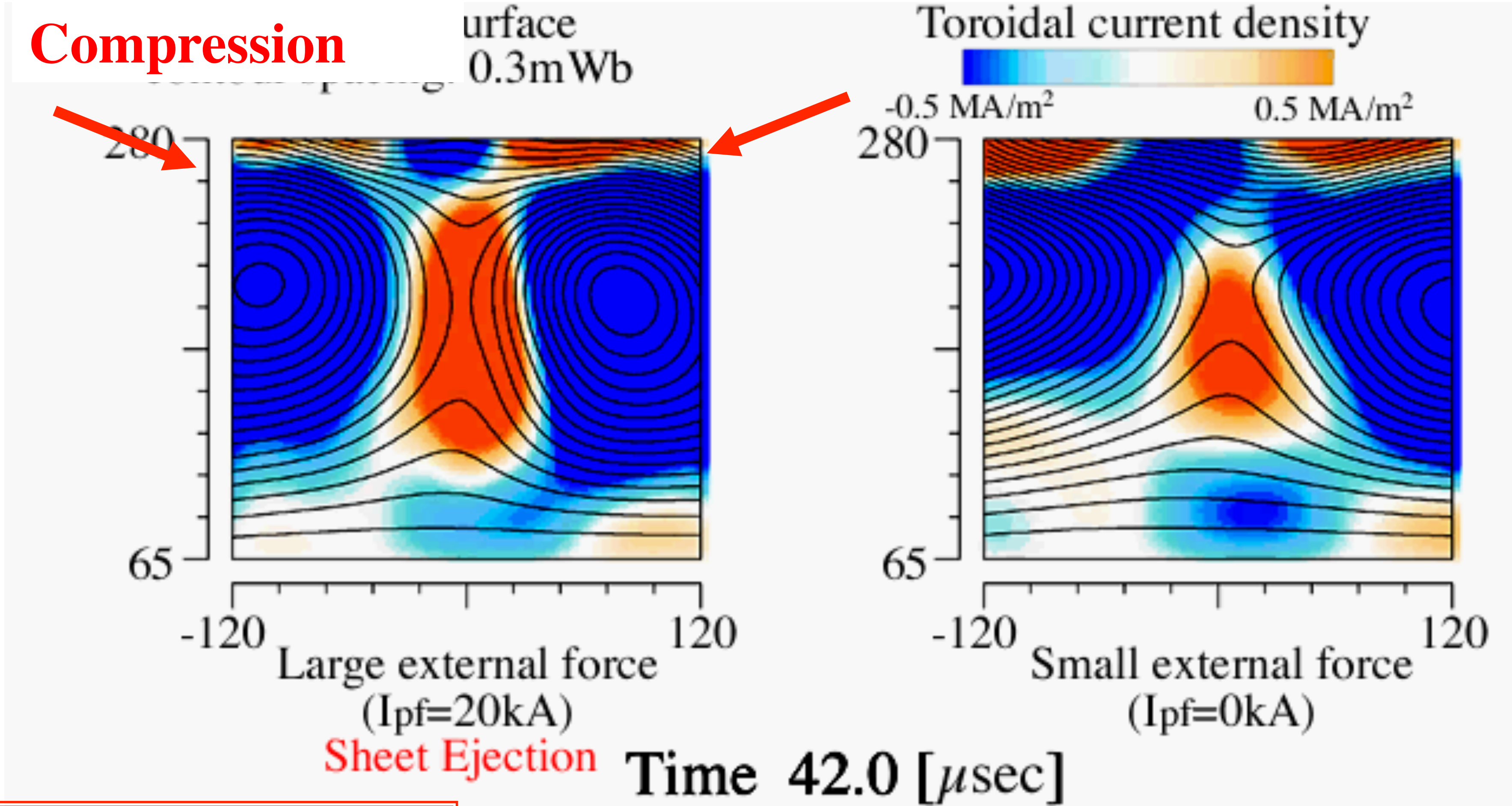




Plasmoid Ejection increases rec. speed and T_i.

(a) Fast inflow reconnection

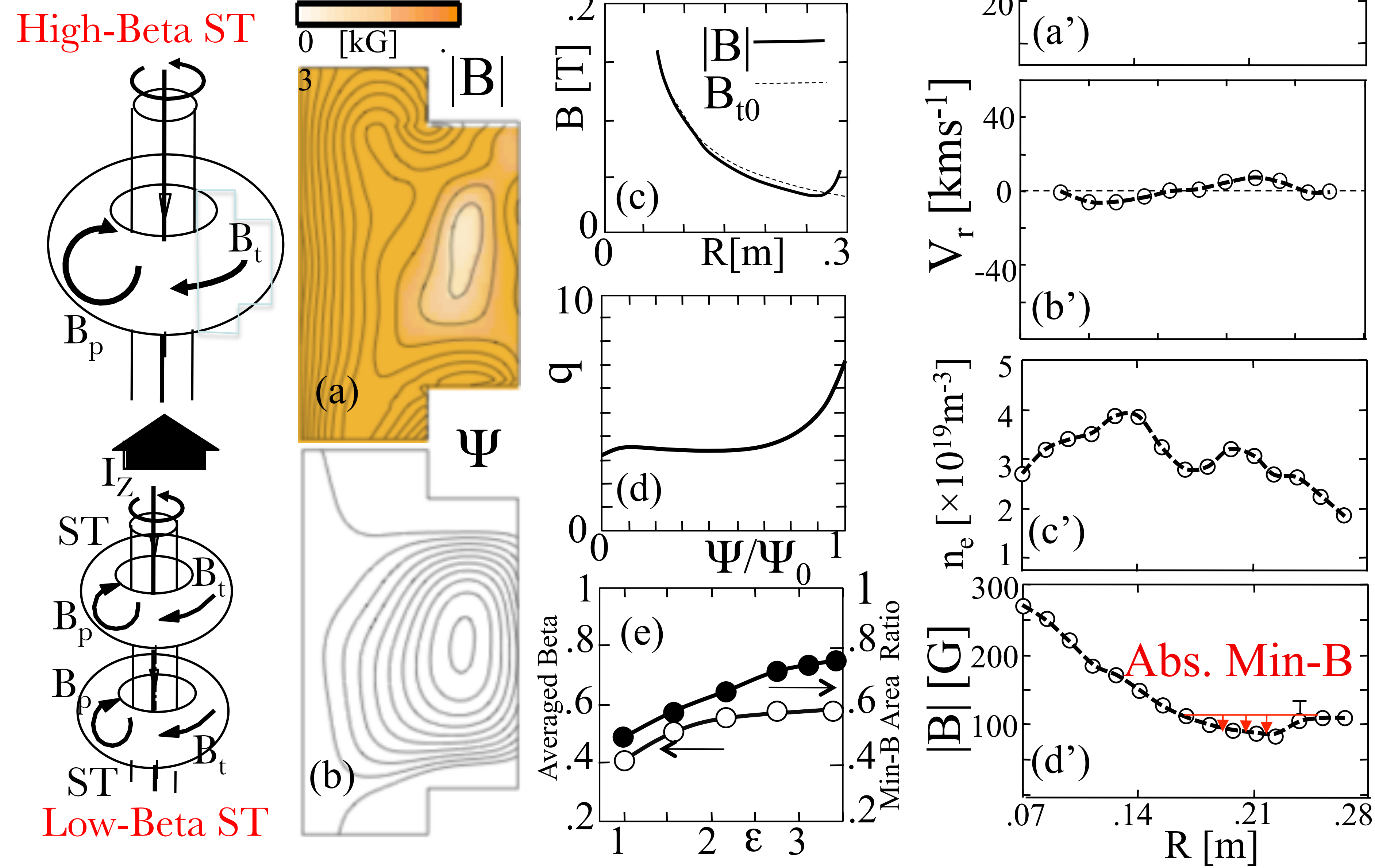
(b) Slow inflow reconnection



High Guide-Field

Formation of Absolute Min.-B

The rec. heating transforms paramagnectic merging STs to diamag. ST with abs min-B.



Comparison with Troyon Scaling

Merging Formation of Ultra-High ß ST with $ß_N$<20

A: 2nd stable

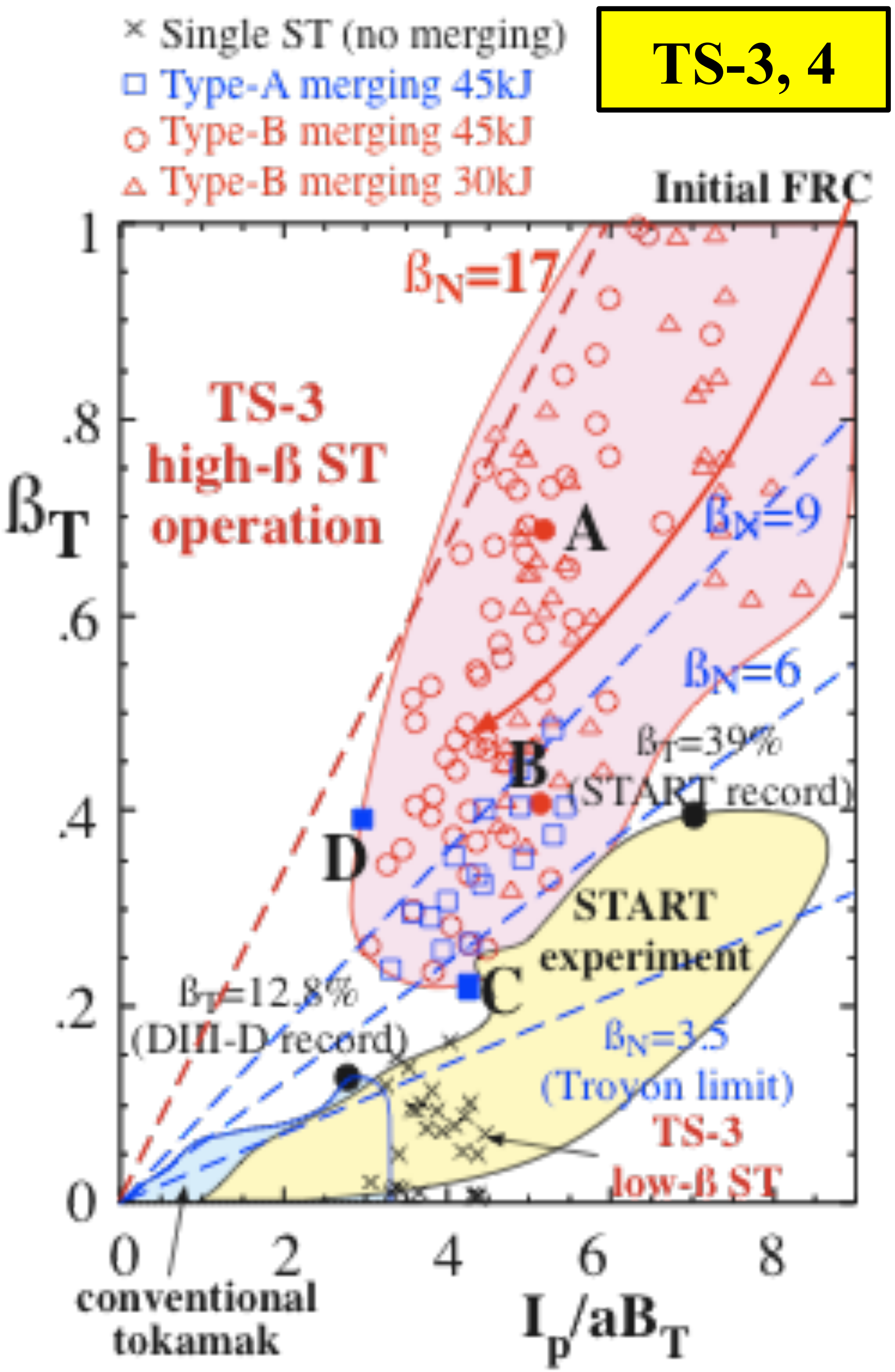
B: unstable

C: 1st stable

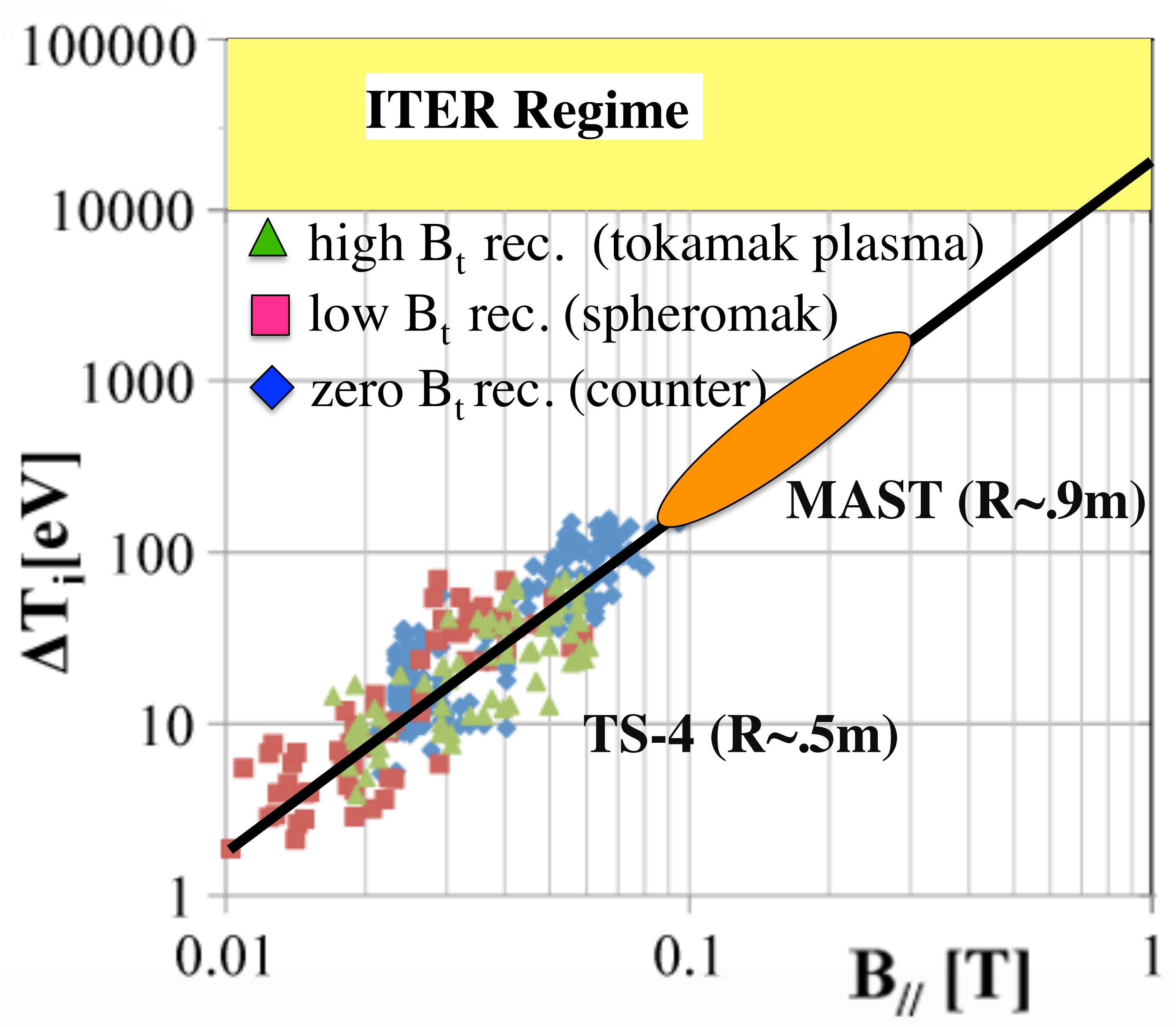
D: unstable

Reconnection Time < Growth Time of Instabilities

TS-3, 4



$B_{//}^2$-scaling for ion heating of reconnection

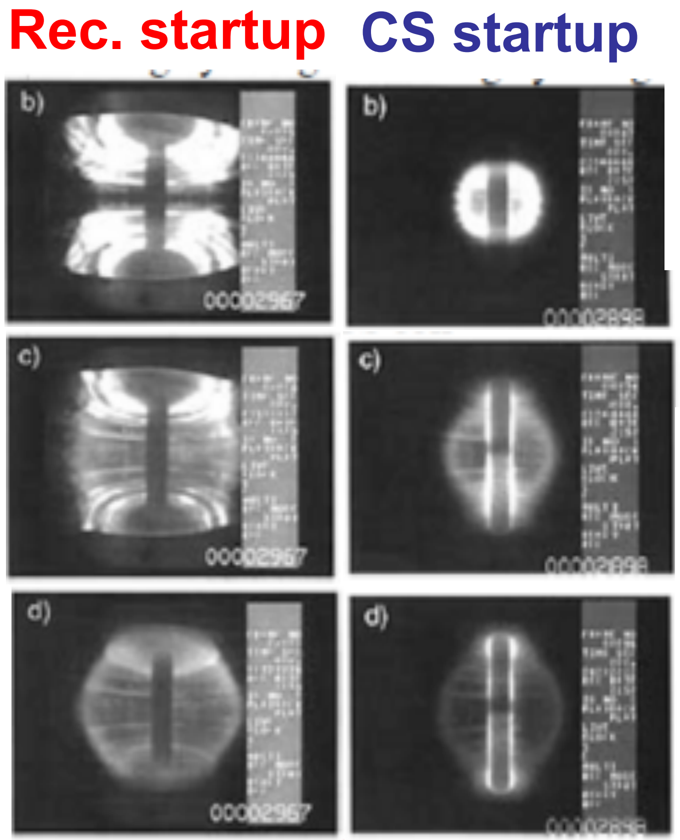


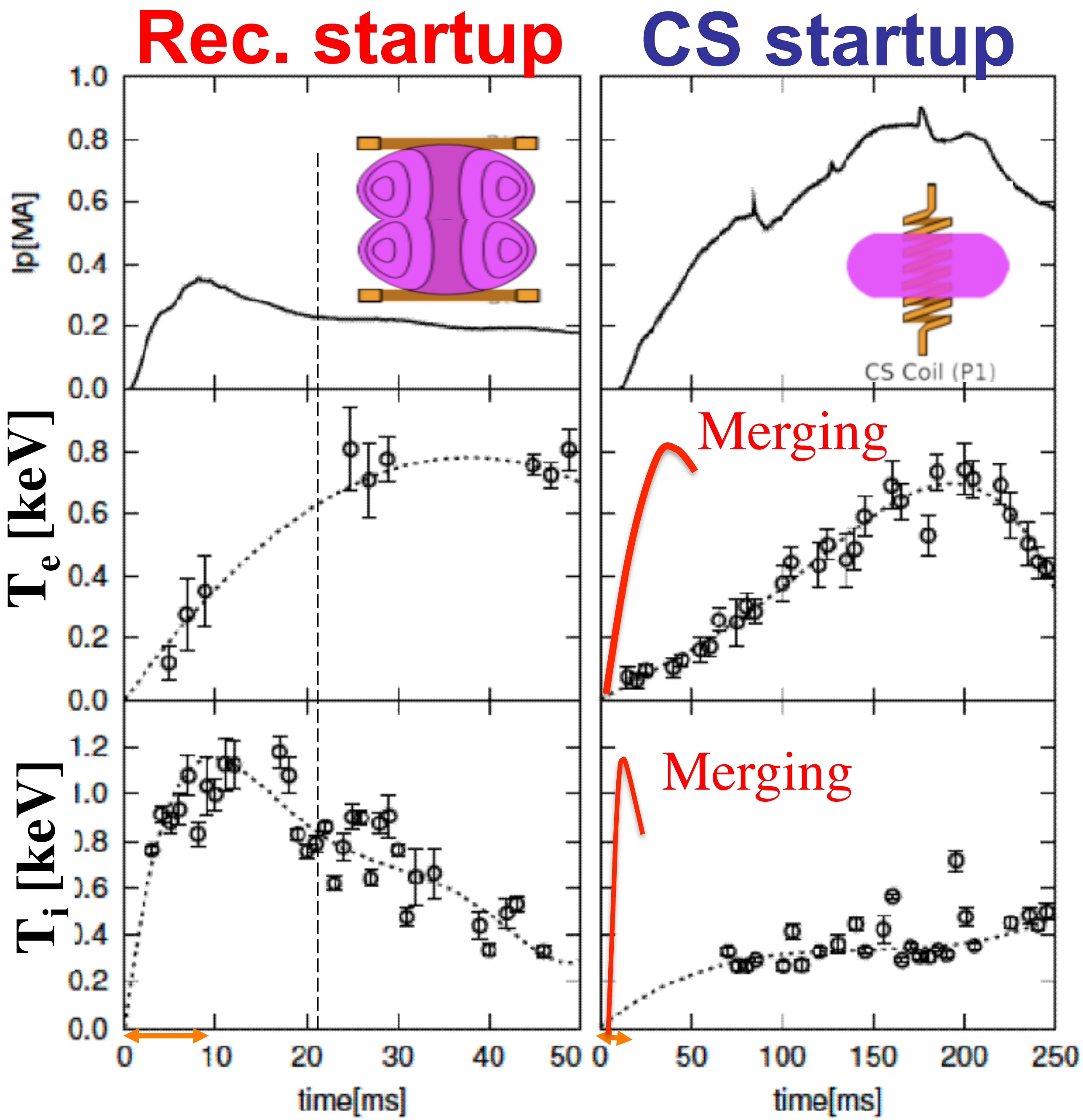
Y. Ono et al. to be published in PPCF

MAST

MAST-TS Collaboration
M. Gryaznevich, R. Scannel

The reconnection start-up heats ions and electrons much higher than the conventional CS startup.





Summary and Conclusions

1) Reconnection outflow heats ions by fast shock in two downstream regions where T_i peaks.
2) Electron heating occurs inside current sheet and T_e peaks at X-point.
3) Ion heating power >> Electron heating power
4) Ion heating energy and T_i increase with $B_{//}^2$.
5) The high-power rec. heating forms high-ß ST with absolute minimum B profile.

➡ Reconnection heating power in MAST is much higher (> keV) than TS-3 and 4 due to its higher reconnecting field $B_{//}$ and better energy confinement.

Direct ion heating by rec. is a promising method for heating ions > 10keV for fusion plasmas.