東京大学 THE UNIVERSITY OF TOKYO

Status of the TST-2 Spherical Tokamak and Future Plans

Y. Takase, A. Ejiri, S. Shiraiwa

Graduate School of Frontier Sciences, University of Tokyo

for TST-2 and TST-2@K Groups

47th Annual Meeting of the APS Division of Plasma Physics

Denver, Colorado

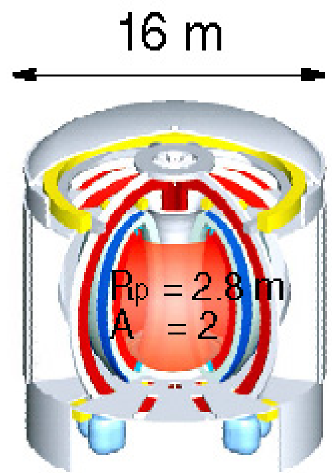
24-28 October 2005

Motivation for CS-less I_p Start-up

Compact, high β plasma with good confinement can be realized in ST

→ compact burning plasma experiment and fusion reactor

Lower aspect ratio and
elimination of central solenoid (CS)
improves economic competitiveness



VECTOR
(~9000 ton)
P_F = 3.7 GW

S. Nishio

TST-2 Spherical Tokamak

TST-2

Design parameters of TST-2:

R = 0.38 m / a = 0.25 (A = 1.6)

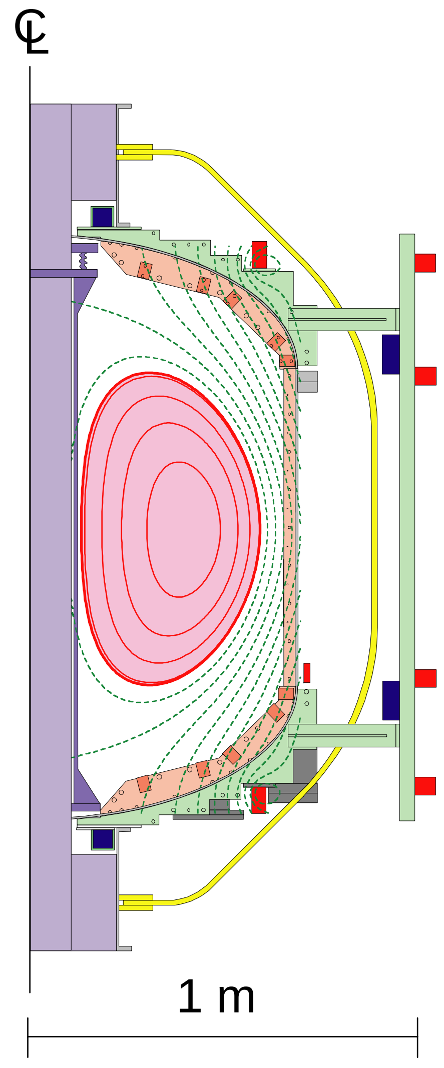
B_t = 0.3 T (0.3 T achieved)

I_p = 0.2 MA (0.14 MA achieved)

t_{pulse} = 0.05 s (0.3 s achieved)

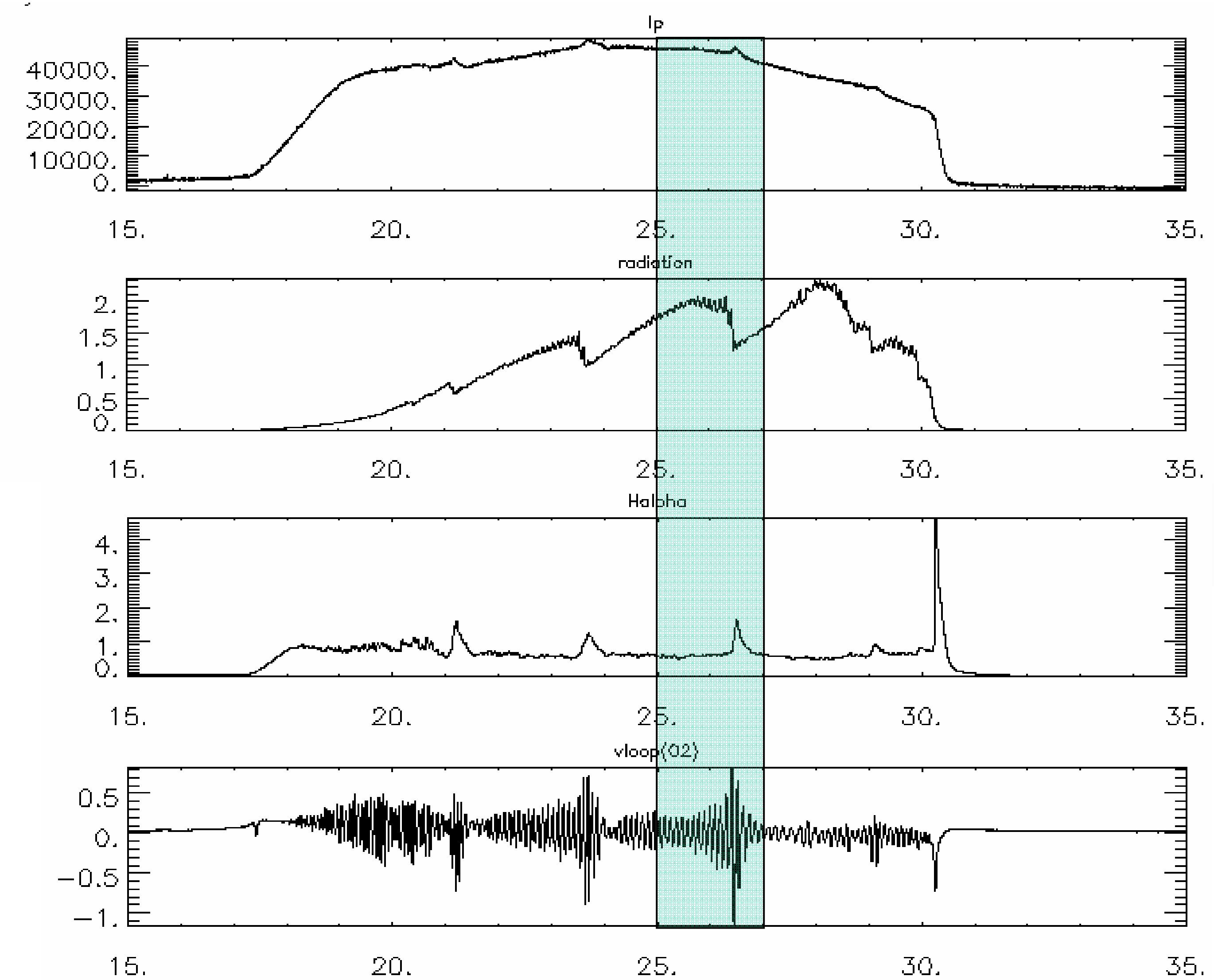
Main research topics:

- Plasma start-up optimization
- RF heating and wave physics
- MHD instability and reconnection
- Control of turbulence and transport

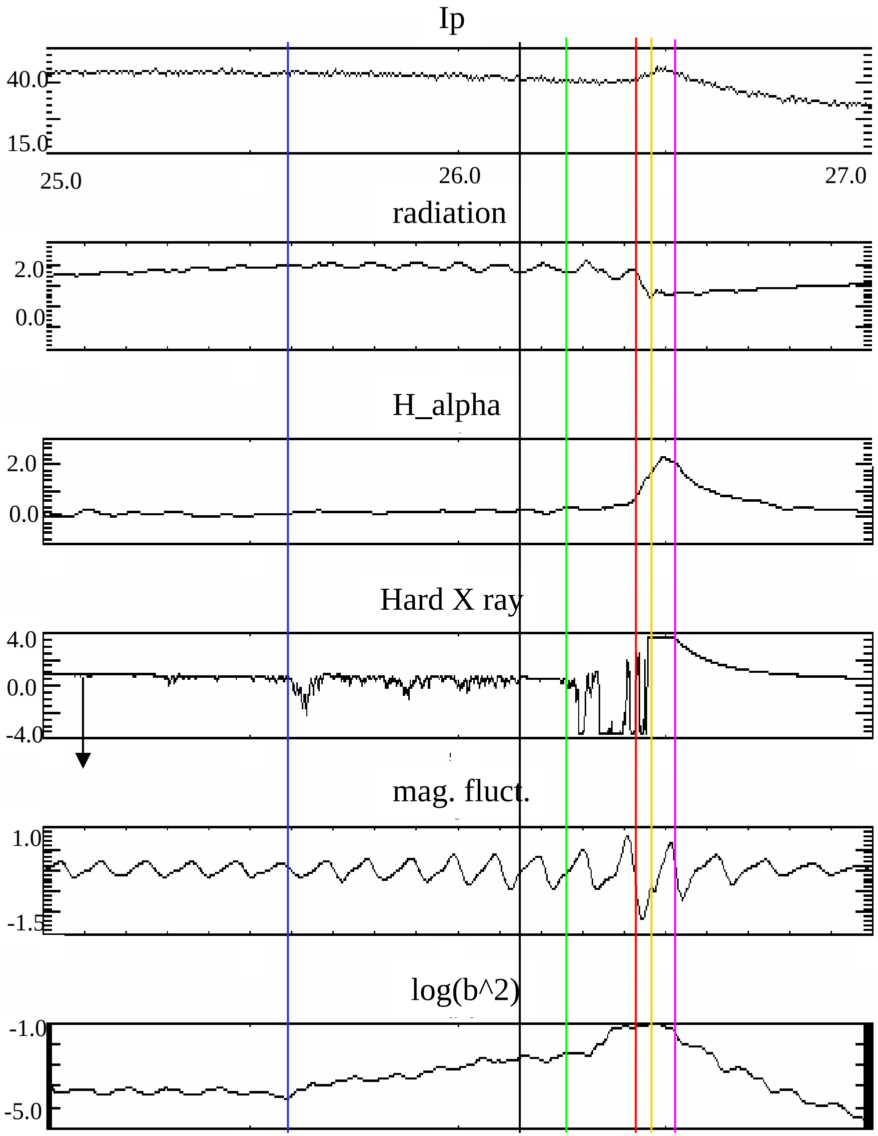


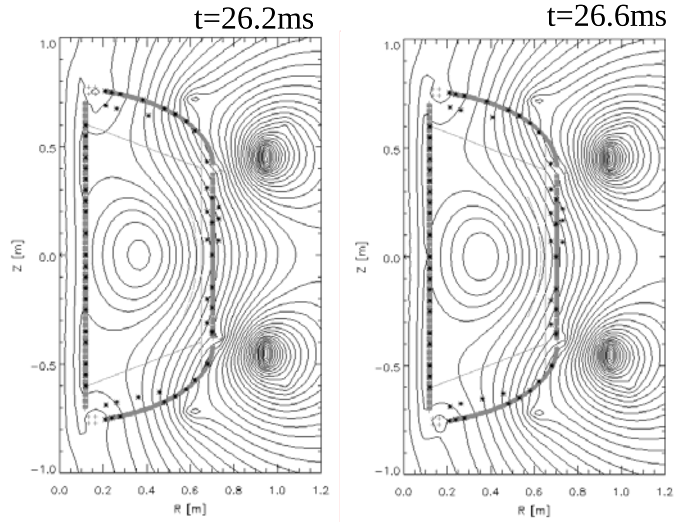
Reconnection Events

TST-2

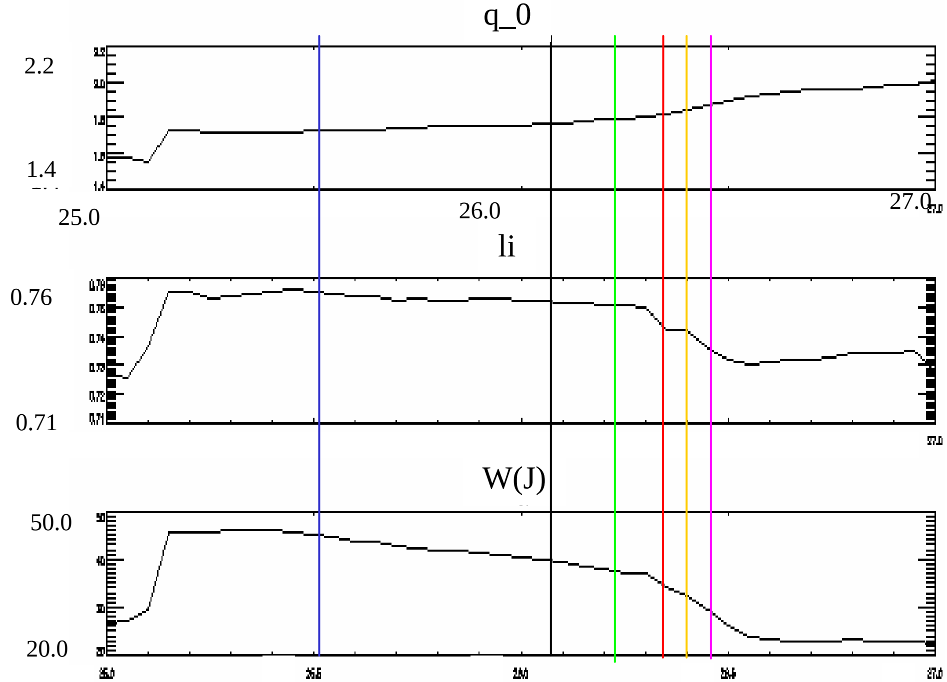


Detailed Time Evolution





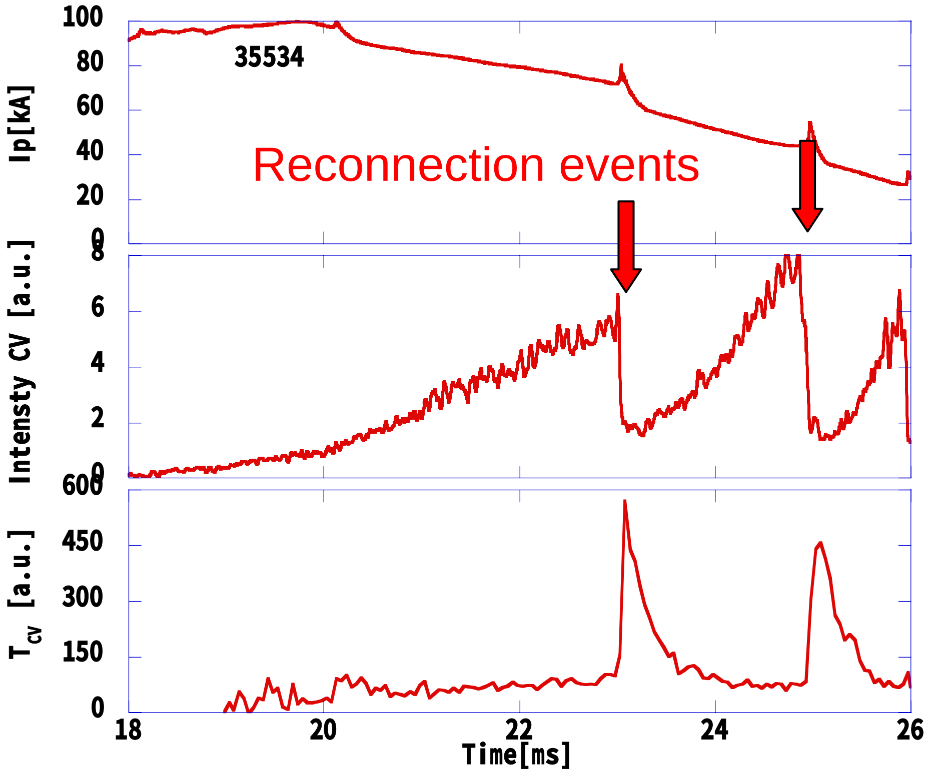
TST-2



Ion Heating Observed at Reconnection Events

TST-2

Conversion of magnetic energy
to ion kinetic energy



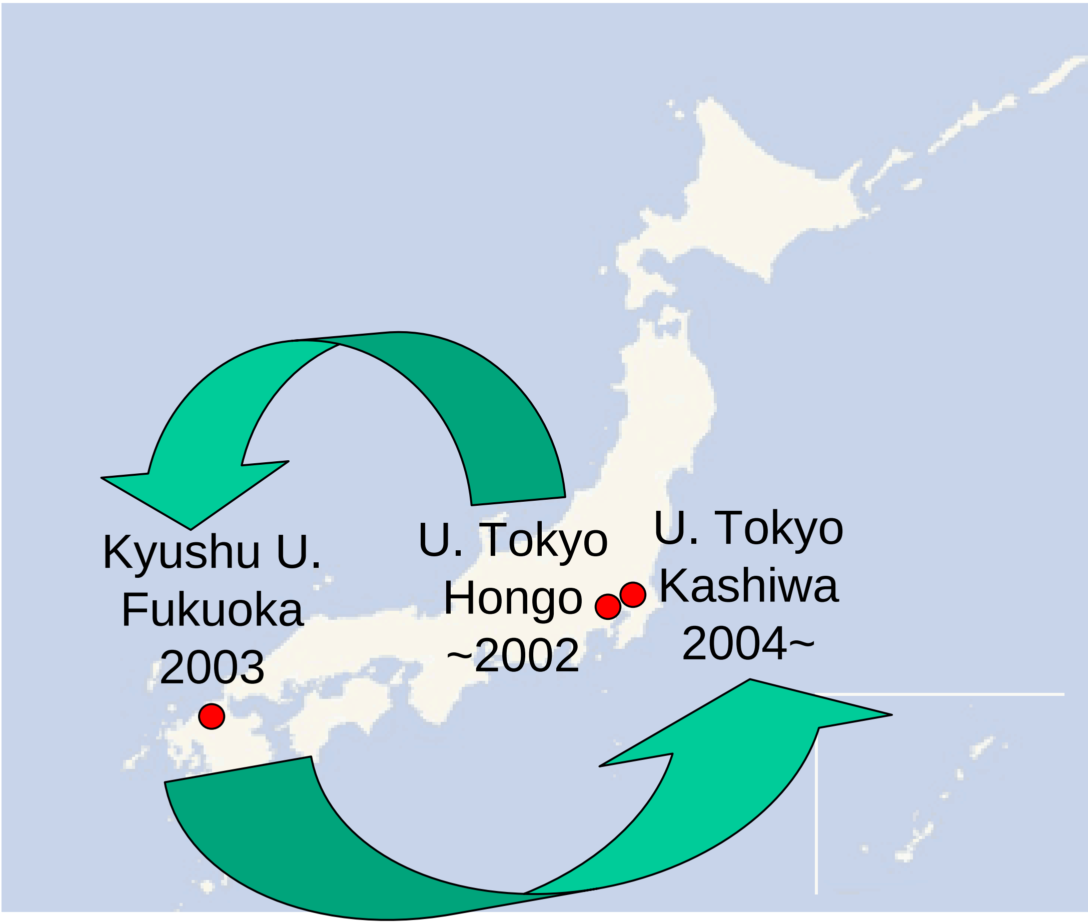
CV intensity decreases while CIII, OIII intensities increase (loss of electron energy)

CV (core) , and
OV, CIII, OIII (edge)
ion temperatures increase at reconnection events

A. Ejiri

Relocation of TST-2

(Twice in 2 Years)



TST-2 at Kyushu University (2003)

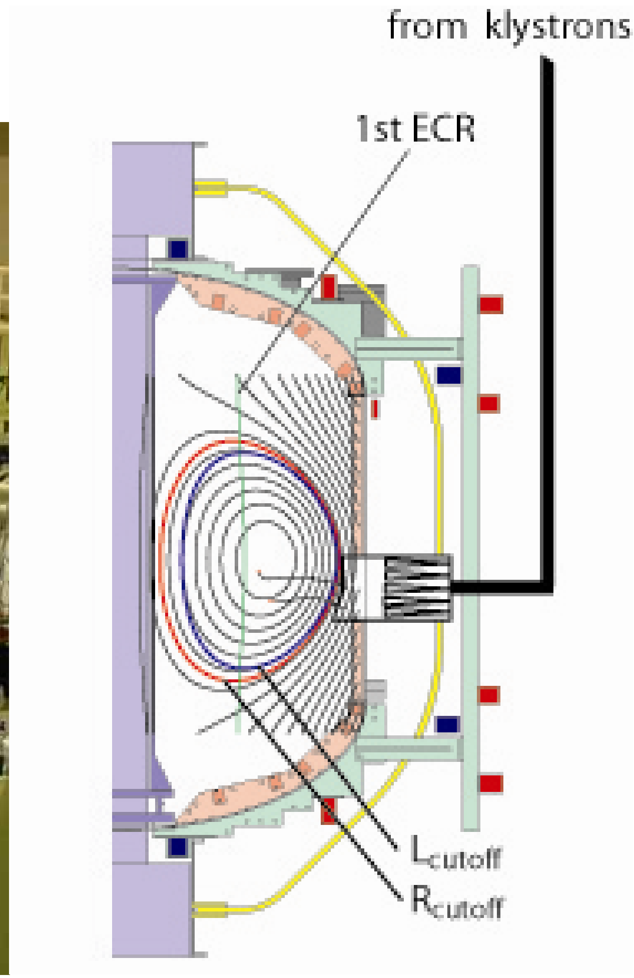
TST-2@K

Heating / current drive
By ECW and/or EBW

Waveguides from
8.2GHz klystrons

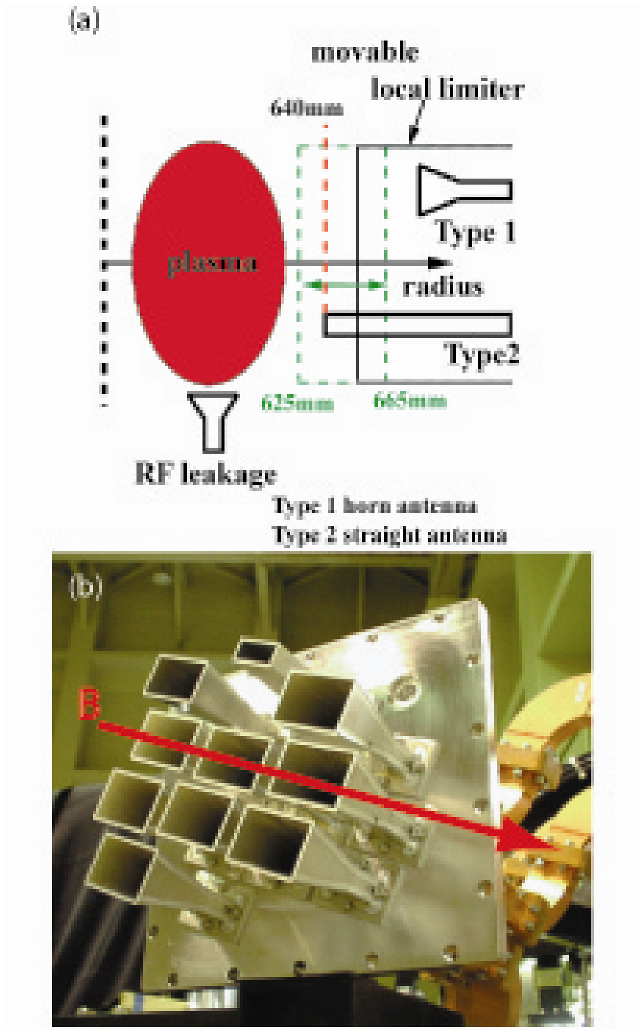
TST-2

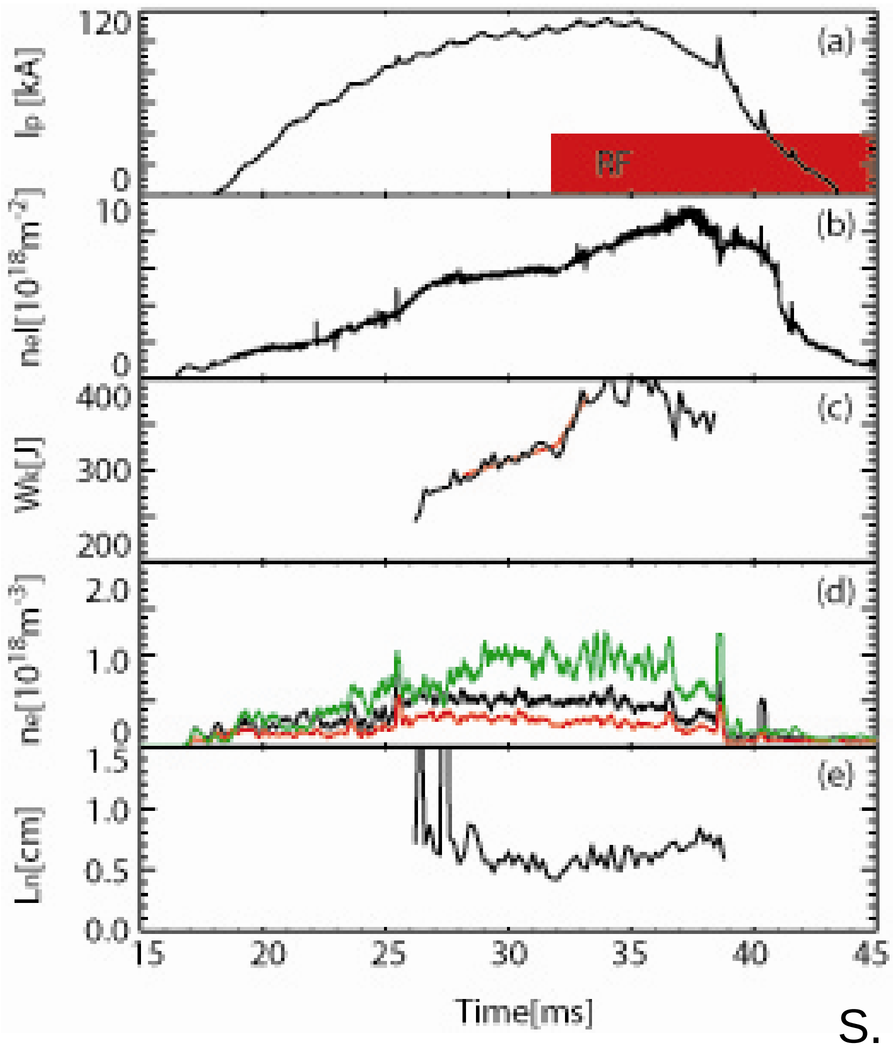
EBW Antenna



Typical plasma equilibrium

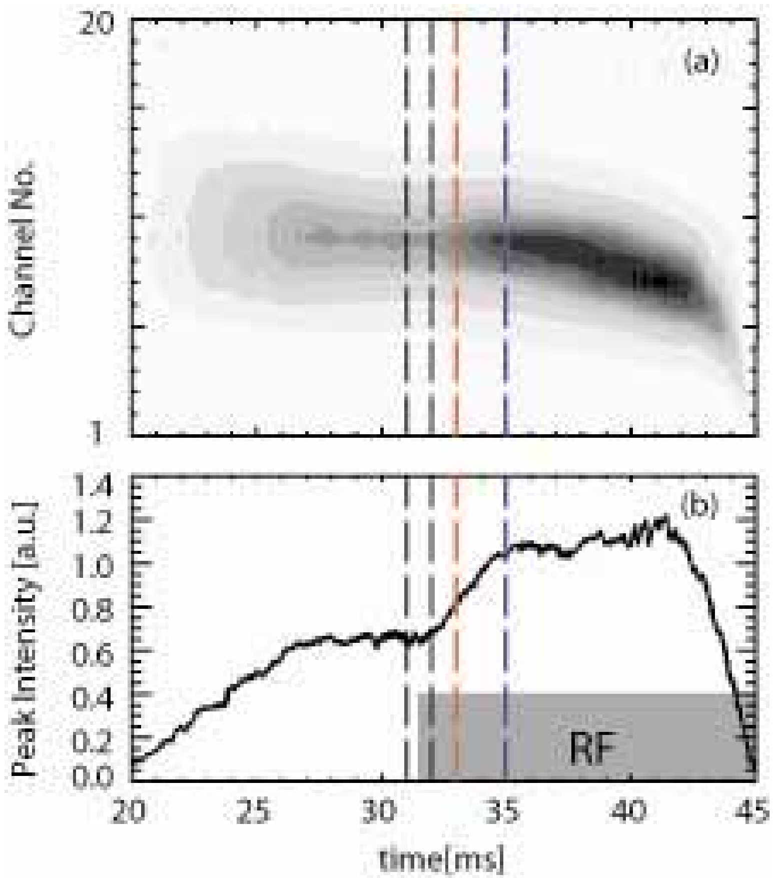
EBW Heating Experiment
Δ(dW/dt) Indicates Absorption > 50%

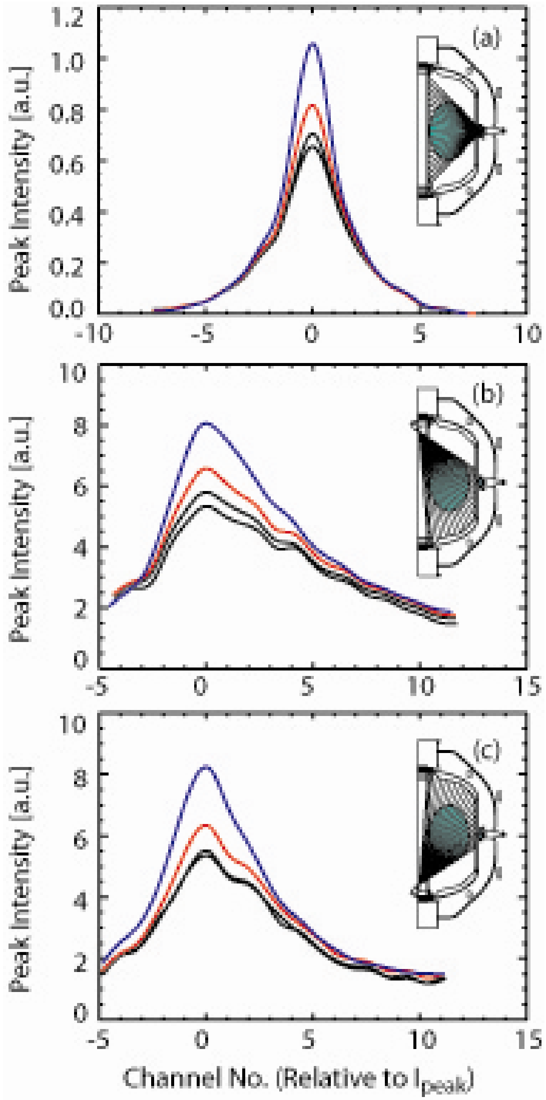




S. Shiraiwa

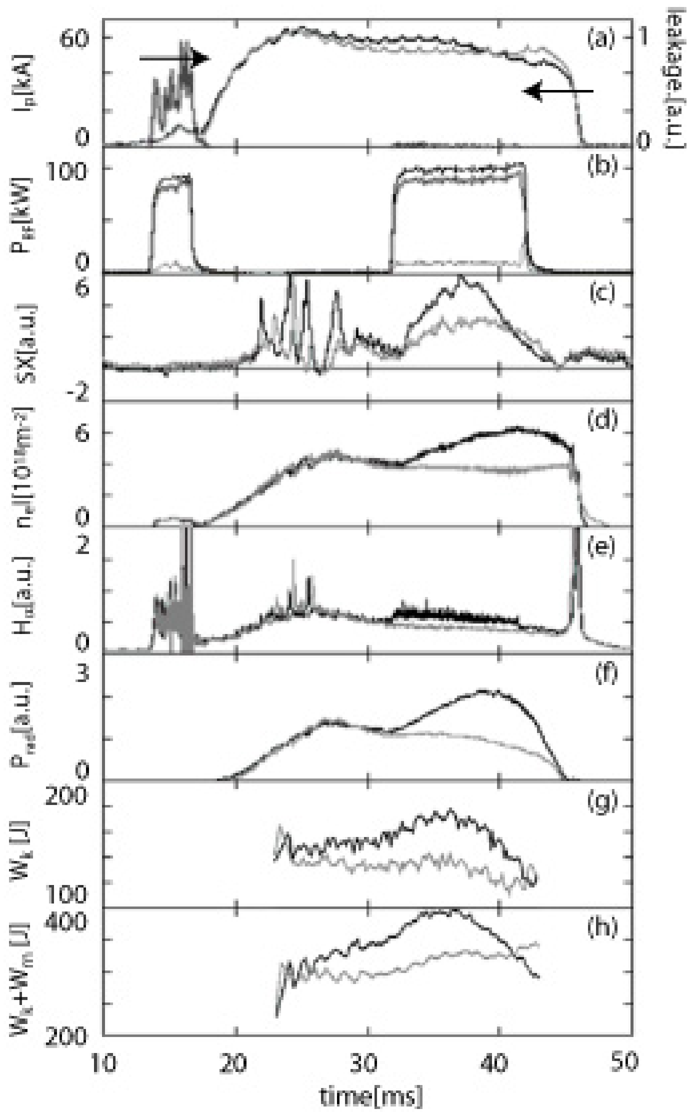
X-ray/Visible Emission Profile Indicates Central Electron Heating

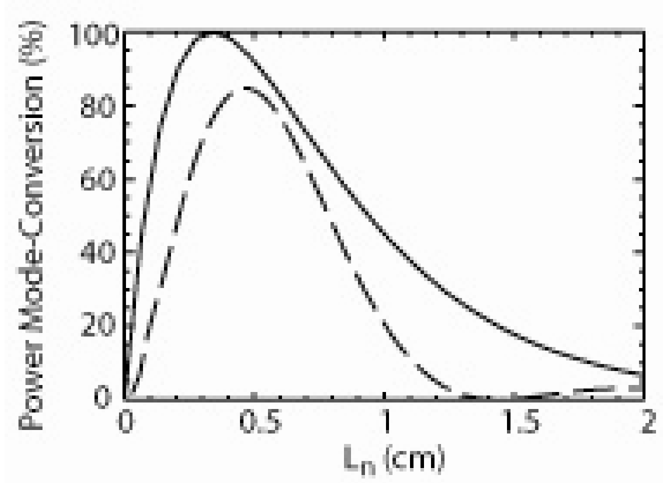


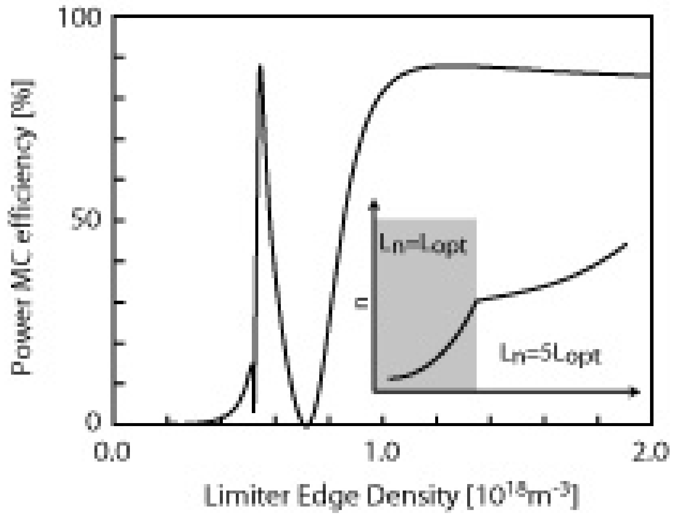


S. Shiraiwa

Absorption is Poor (< 20%) When the Density is Lower





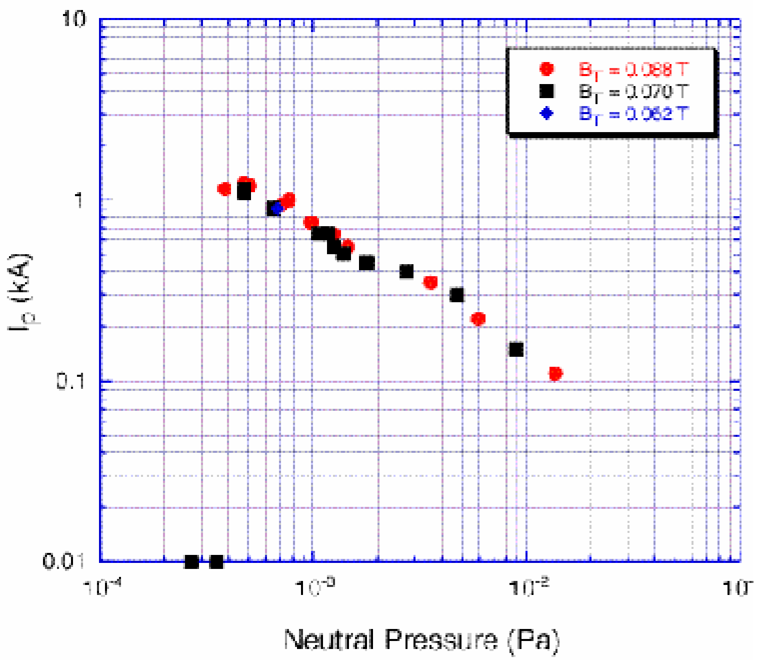


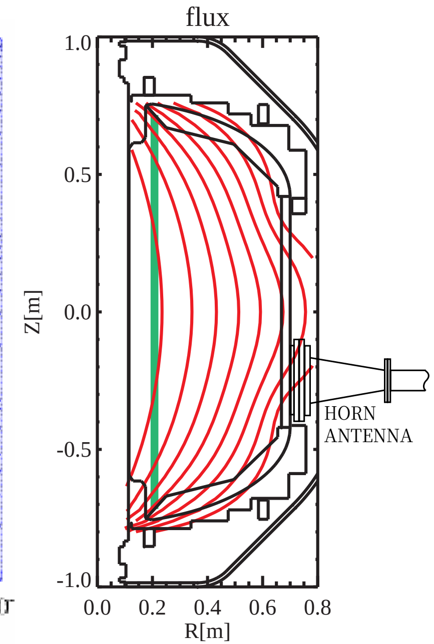
S. Shiraiwa

Plasma Current Formation by ECH

TST-2

- 1 kA / 1 kW achieved by ECH (2.45 GHz)
- Higher current for low gas pressure
  → low collisionality is important
- Requires vertical field with positive curvature
  → trapped particles are important

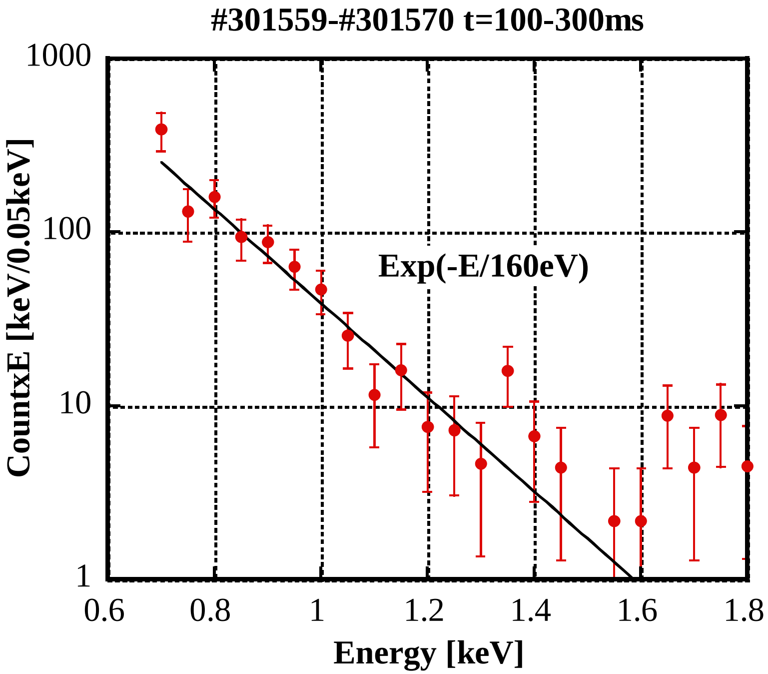




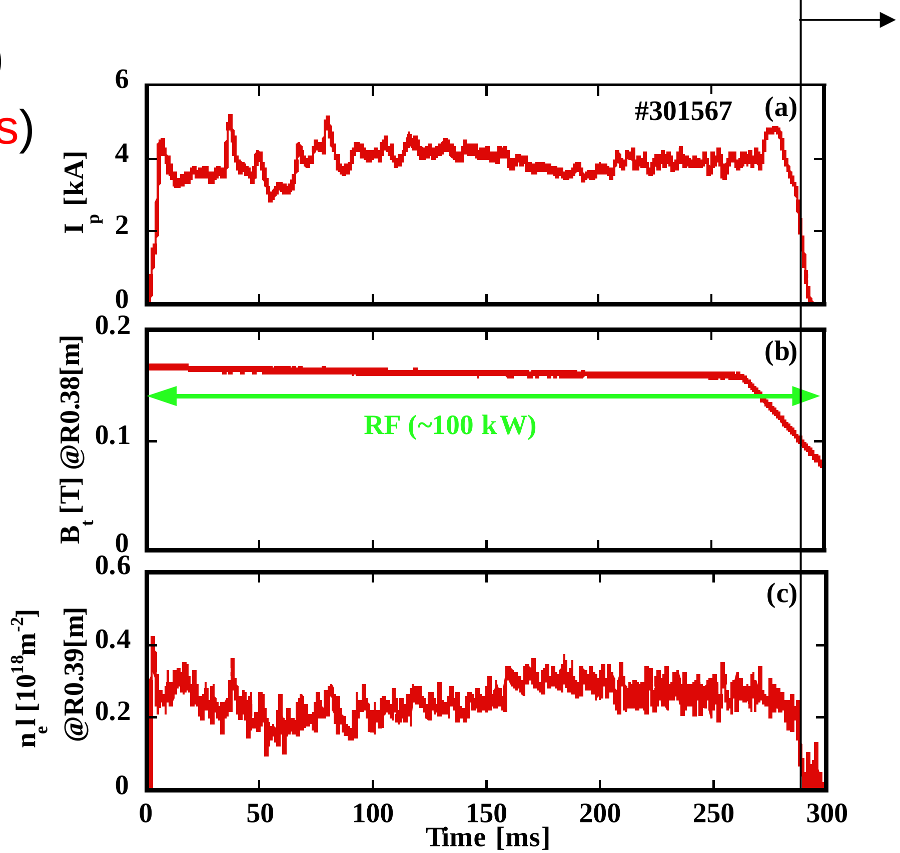
Solenoidless Start-up Experiments

TST-2@K

- Forest scenario
  - "pressure driven current" with mirror B_v
  - 4kA maintained for 0.27 s
    (with static B_v ~ 2 mT, no induction)
  - T_e = 160 eV (plasma is collisionless)



no $\omega = \omega_{ce}$ res.
inside vac.ves.



A. Ejiri

Reconstructed Equilibrium of the RF Start-up Plasma (I)

Plasma is limited by the outboard limiter,
j_ϕ is truncated at top and inboard

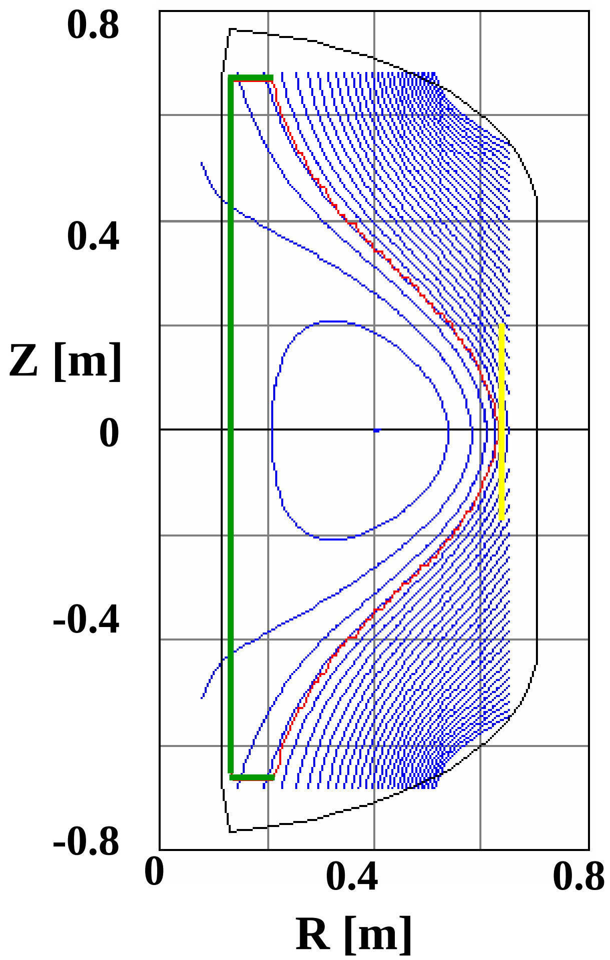
Flux function has free parametes β_{p0} and A.

$$j_\phi = r\frac{\partial p}{\partial \psi} + \frac{1}{r}\frac{\mu_0}{4\pi^2} f \frac{\partial f}{\partial \psi} \qquad \mu_0 f = 2\pi r B_\phi$$

$$= j_0\left(\beta_{p0}\frac{r}{r_0} + (1-\beta_{p0})\frac{r_0}{r}\right)\left(1 - \mathrm{A}\psi_n^{\ 2}\right)$$

Fitted to magnetic measurements (about 80 channels)

Obtained paramters are $\beta_{p0} \sim 1,\ A \sim 8$



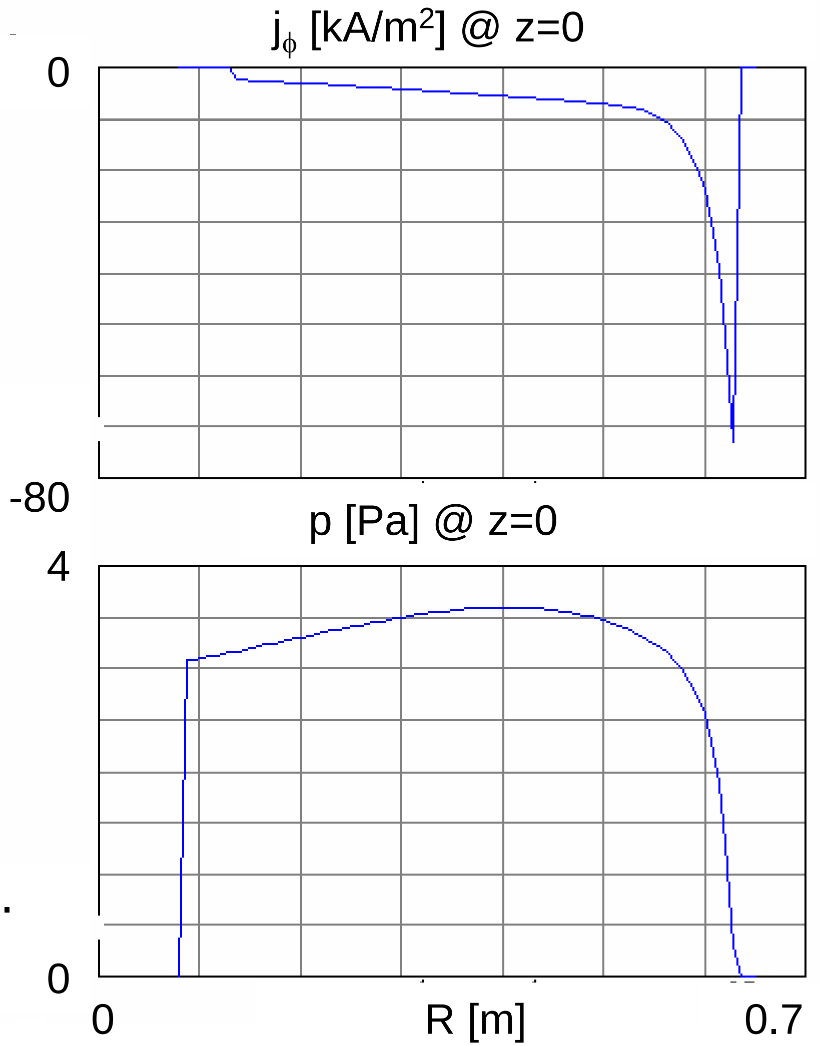
A. Ejiri

Features of RF Start-up Plasma Equilibrium

- high β_p
- large outboard boundary current

  Outboard co-PS current is dominant, while inboard counter-PS current is truncted.
- Steep pressure gradient at the outboard boundary

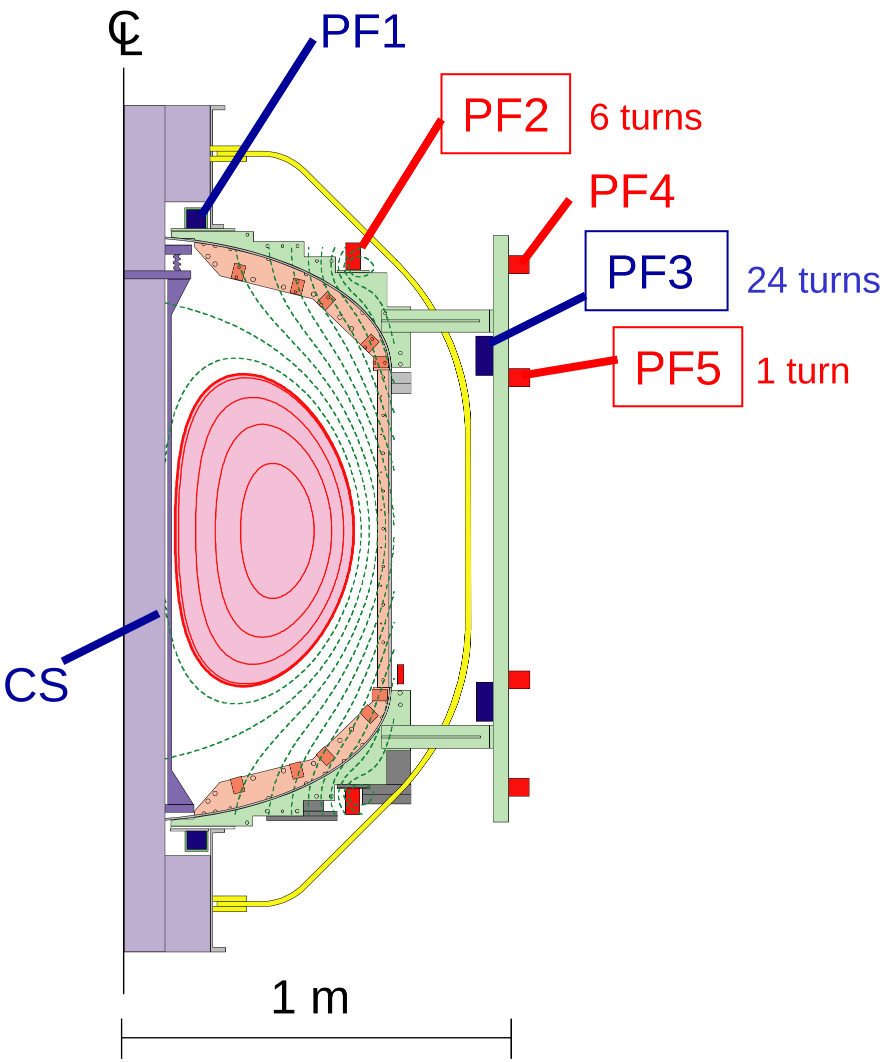
Soft X-ray flux and temperature are roughly consistent with the pressure deduced from equilibrium reconstruction.

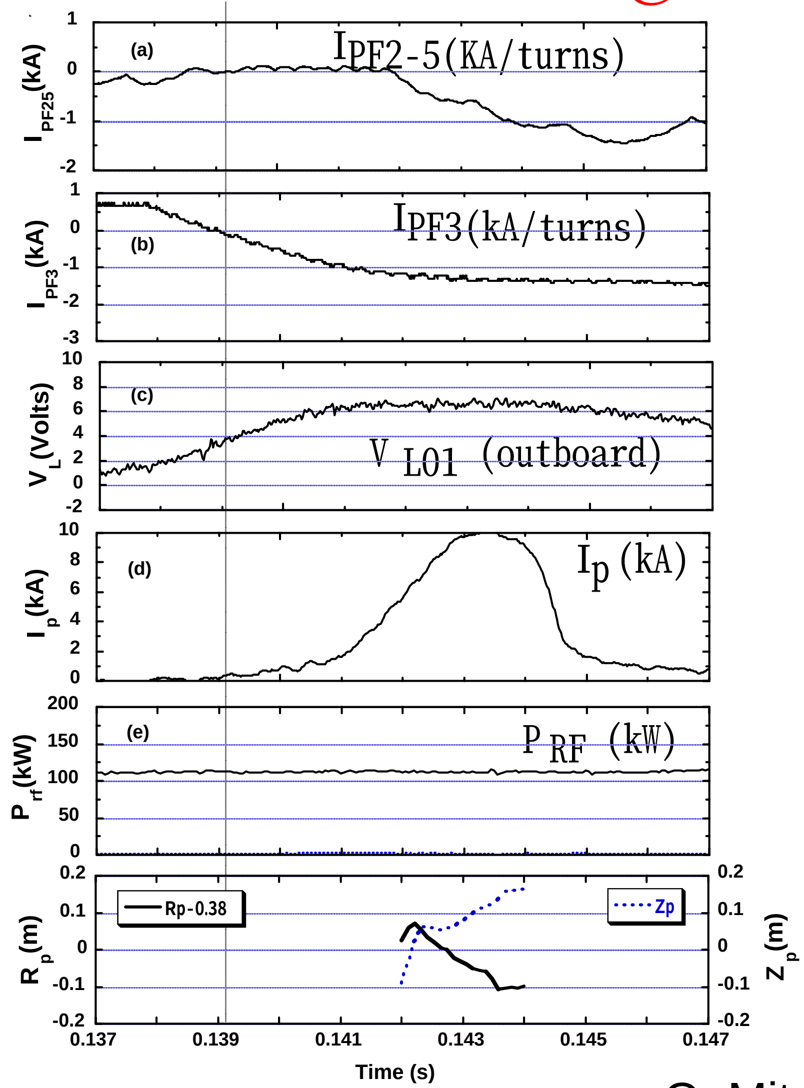


A. Ejiri

Completely CS-less Start-up to I_p = 10 kA Achieved in TST-2

TST-2@K





O. Mitarai

New Start at the Univ. Tokyo Kashiwa Campus

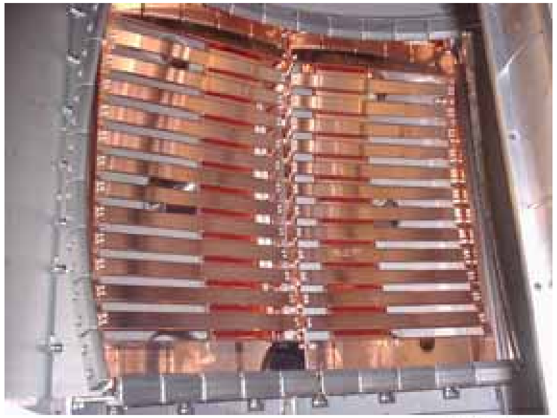
TST-2

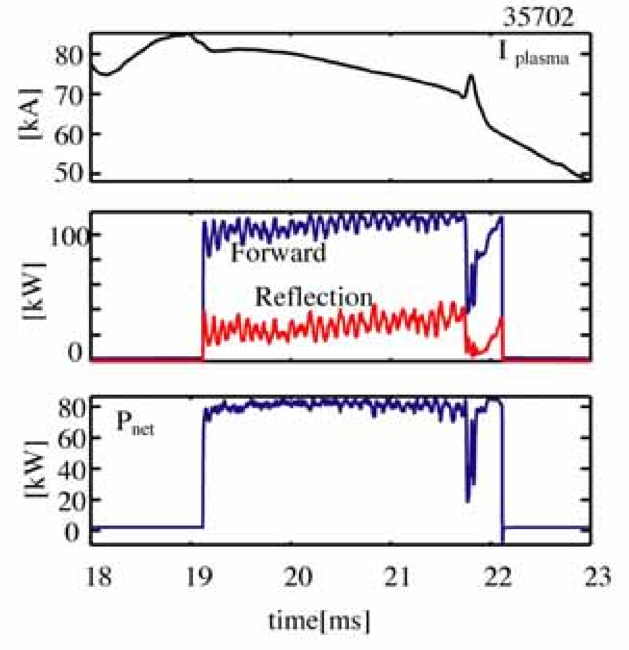
- Resume operation at Kashiwa
  - Solenoidless start-up
    - Based on results of JT-60U
  - Reconnection physics
    - Reconnection Events
    - Ion heating
  - Turbulence and transport
    - Develop fluctuation diagnostics
  - HHFW heating / current drive
    - 10-30MHz / 400 kW
    - $k_{||}$ control (new antenna)
  - Prepare LHCD system
    - 200MHz / 400kW (from JFT-2M)

100kW of RF Power Injected Successfully

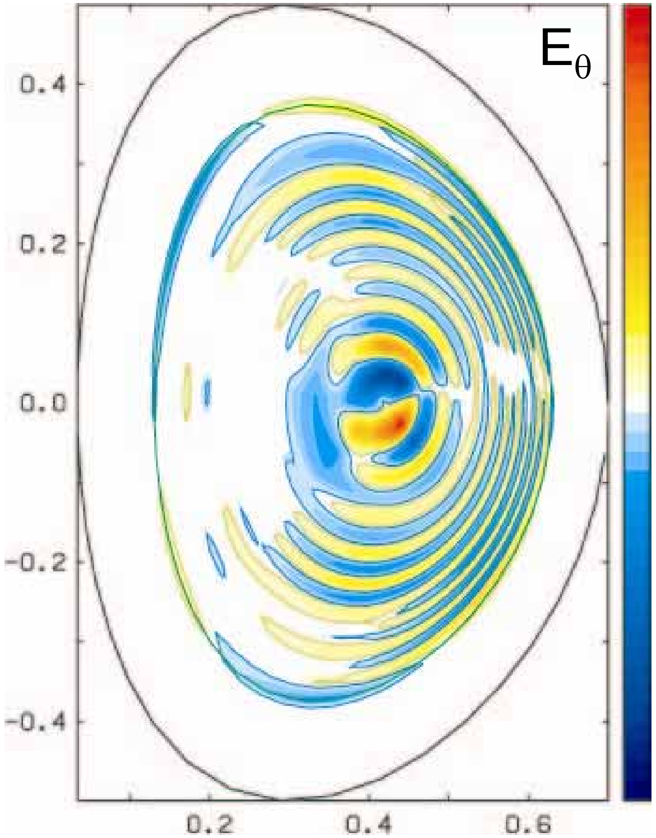
TST-2

HHFW Antenna





Full-wave calculation by TASK/WM



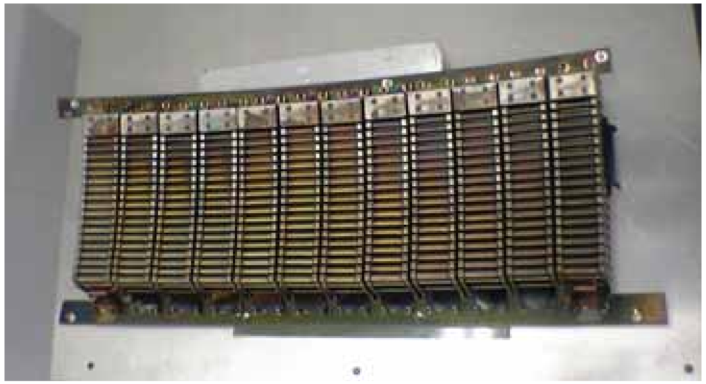
B_t = 0.3 T, f = 21 MHz, n = 10,
$n_e = 2 \times 10^{19}$ m^{-3}, T_e = 0.3 keV

Preparation in Progress for 200 MHz Experiments

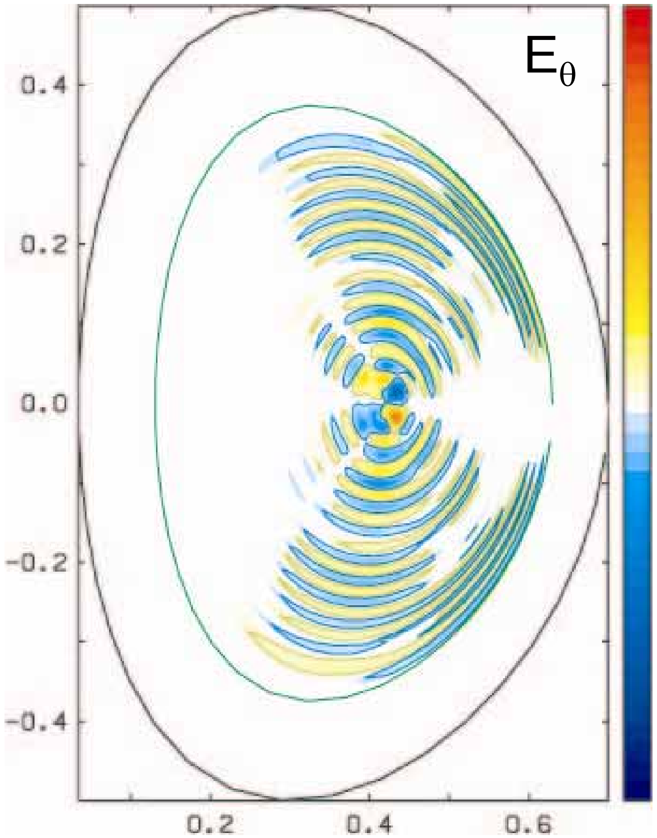
TST-2

200 MHz transmitters (from JFT-2M)

Combline antenna



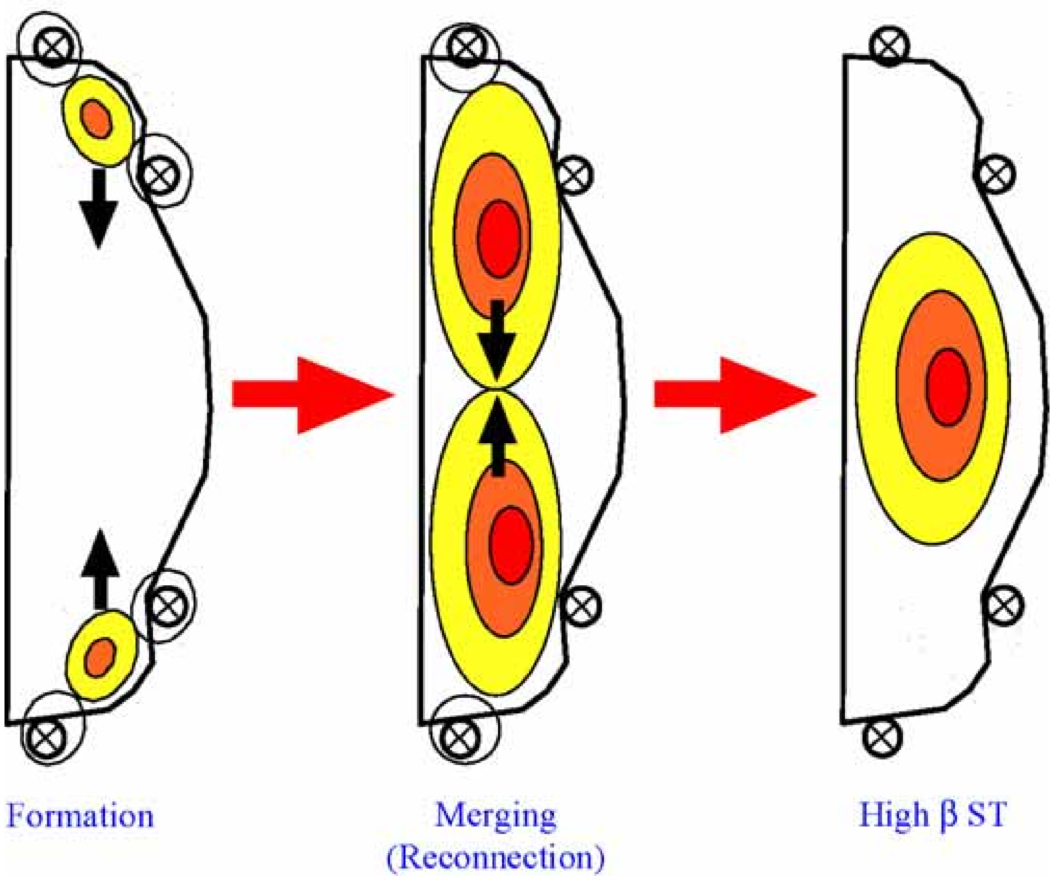
Full-wave calculation by TASK/WM



B_t = 0.3 T, f = 200 MHz, n = 10,
$n_e = 2 \times 10^{18}\ m^{-3}$, T_e = 0.3 keV

A New Experiment to Explore Ultra-High β Plasma Formation by Plasma Merging

UTST



Summary

- Successful EBW heating demonstrated
  - X-B mode conversion scenario
  - Absorption > 50% under favorable condition
- Solenoidless start-up demonstrated
  - 4kA for 0.3s (RF only)
    - Equilibrium with large current at the outboard boundary
  - 10kA (RF + induction by outer PF coils)
- Preparation in progress for RF experiments
  - 20MHz HHFW
  - 200MHz LH (from JFT-2M)
- New experiment in preparation (UTST)
  - Merging formation of high-β plasma (reconnection heating)
  - Sustainment by RF/NB