Electron Bernstein wave diagnostic development on the TST-2 spherical tokamak

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Outline

- Overview of TST-2
- Motivation of EBW research
- Radio-reflectometer
- Experimental results
- Summary

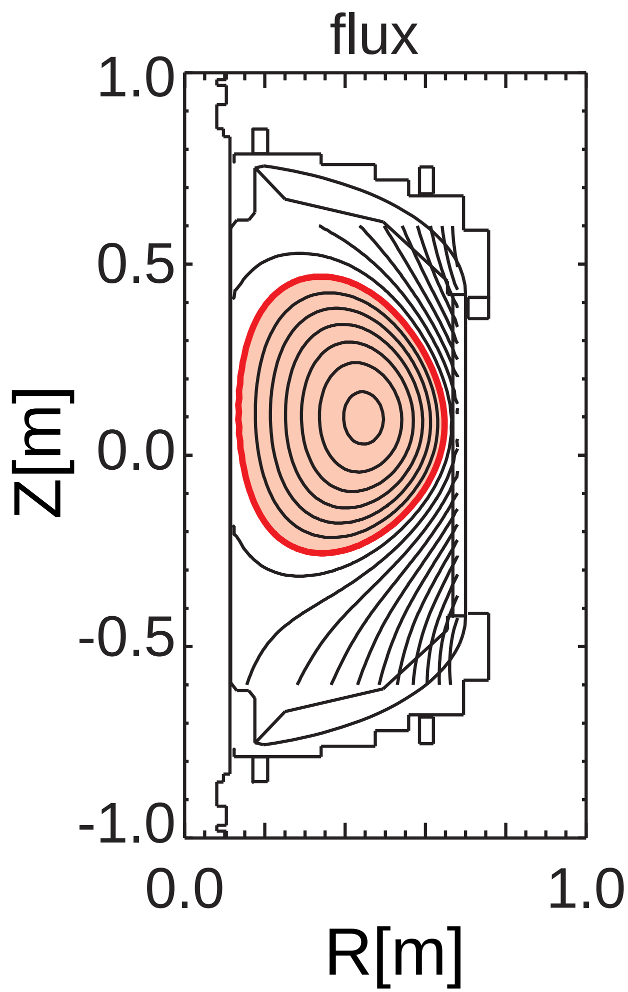
TST-2 spherical tokamak

Plasma Parameters

Bt	0.21T
R	~ 0.38m
a	~ 0.25m
A	> 1.5
κ	1.2~1.8
Ip	< 120kA
$t_{discharge}$	20ms
n_e	~ $10^{19}m^{-3}$
T_i	50-100eV
T_e	400eV (from preliminary PHA measurement)

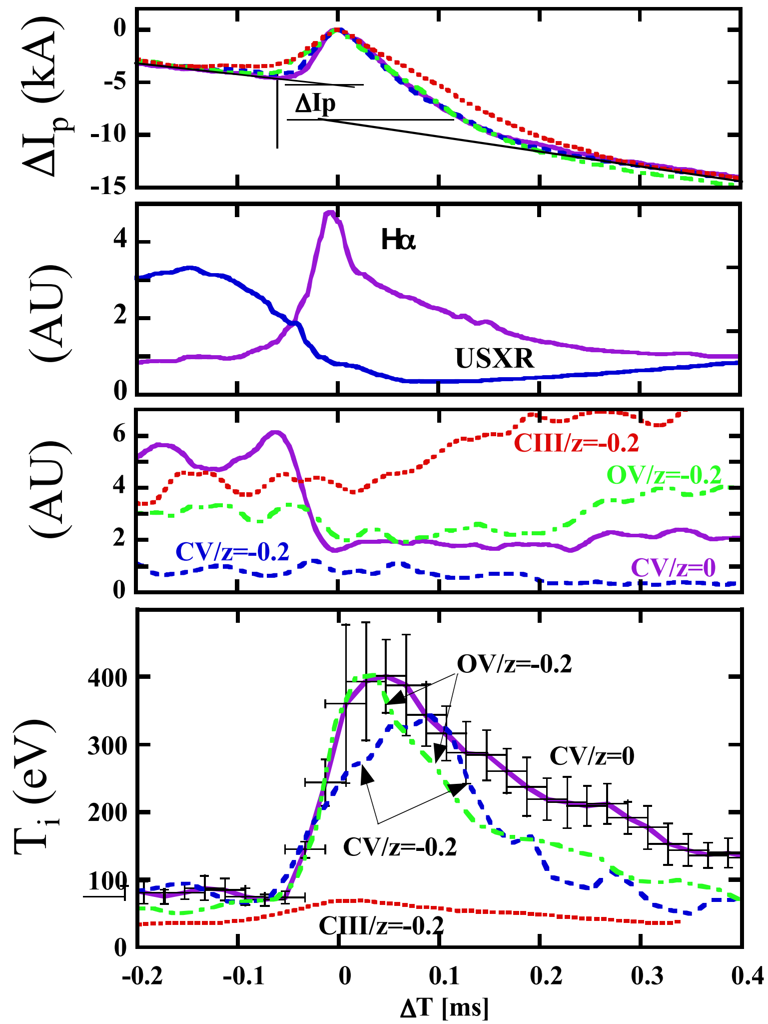
Equilibrium reconstruction shows β_T = 5.7% (β_N = 2.7); W = 610 J (τ_E = 3 ms)

I_{plasma}[kA]	89
R_{axis}[m]	0.43
Z_{axis}[m]	0.1
a[m]	0.24
A	1.53
κ	1.41
ψ_{diamag}[mWb]	-1.1
q_0	1.2
q_{edge}	4.6
l_i	0.6
$<\beta_{t0}>$[%]	5.7
β_p	0.46
β_N	2.7
E[Joule]	606



Ion temperature increase during a strong reconnection event

	ρ	T_i
CV / z = 0	< 0.3	Increase then slow decay
CV / z = - 0.2 OV / z = - 0.2	~ 0.7	Increase then fast decay
CIII / z = - 0.2	edge	No change



Motivation

Electron temperature diagnostics in ST

- overdense ($\omega_{pe} \gg \Omega_{ce}$)
- Electron cyclotron emission is not possible

Electron Bernstein wave (EBW)

- can propagate in overdense plasmas
- High optical thickness Å@Ålocal (and fast) T_e measurement
- electrostatic wave (mode-conversion is required)

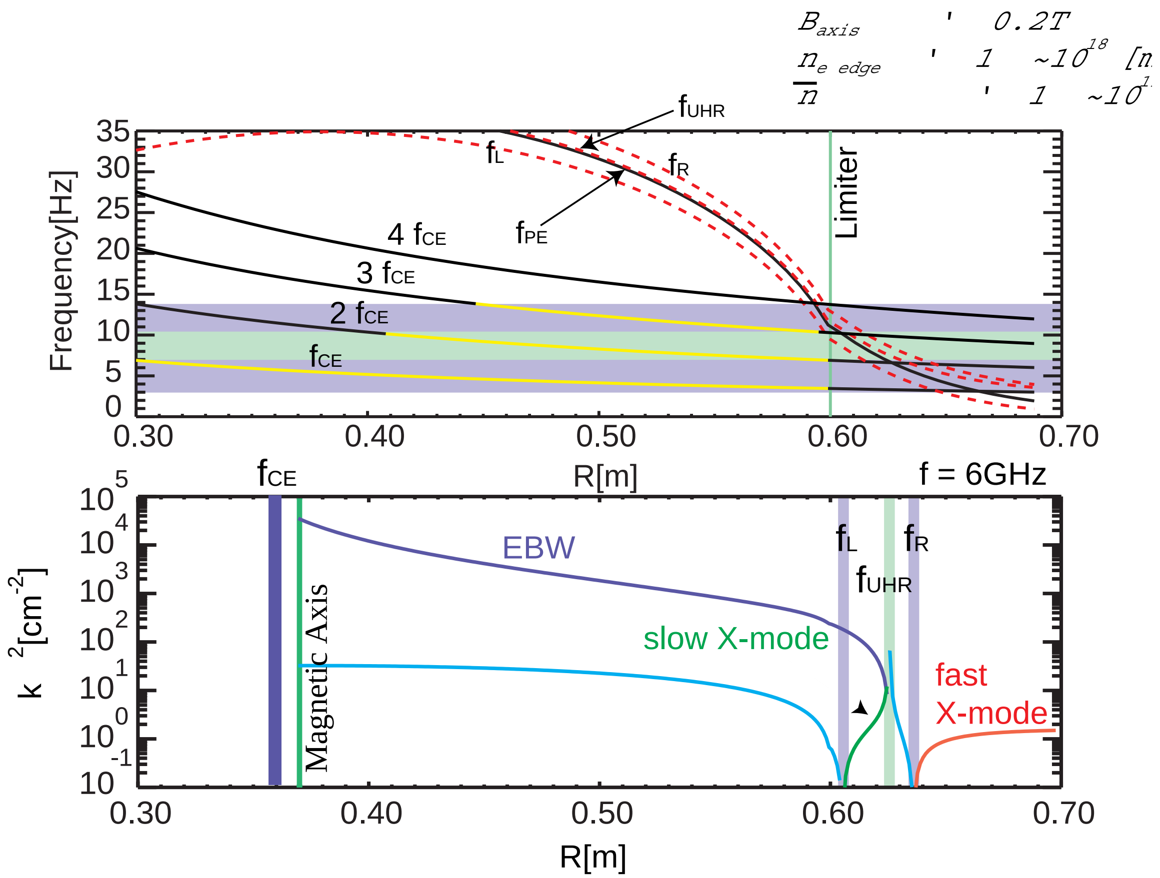
  So far, two mode conversion (MC) scenarios are proposed

  - EBW-SX-O scenario
  - EBW-SX-FX scenario

Is it possible to obtain T_e from EBW ?

Simultaneous measurement of EBW emission and MC efficiency is necessary

Location of critical layers



- Critical layers exist in the plasma edge region within several cm.
- ~100% MC can be expected if optimum density gradient is realized.

Radio-reflectometer

- Radiometer
  - Heterodyne detection
  - frequency range (5-12GHz)
  - IF bandwidth100MHz
  - absolutely calibrated with liquid nitrogen
  - $k_{//}=0$
- Reflectometer
  - Amuplitude Modulation
  - IF frequency 150MHz
  - frequency range 5-12GHz

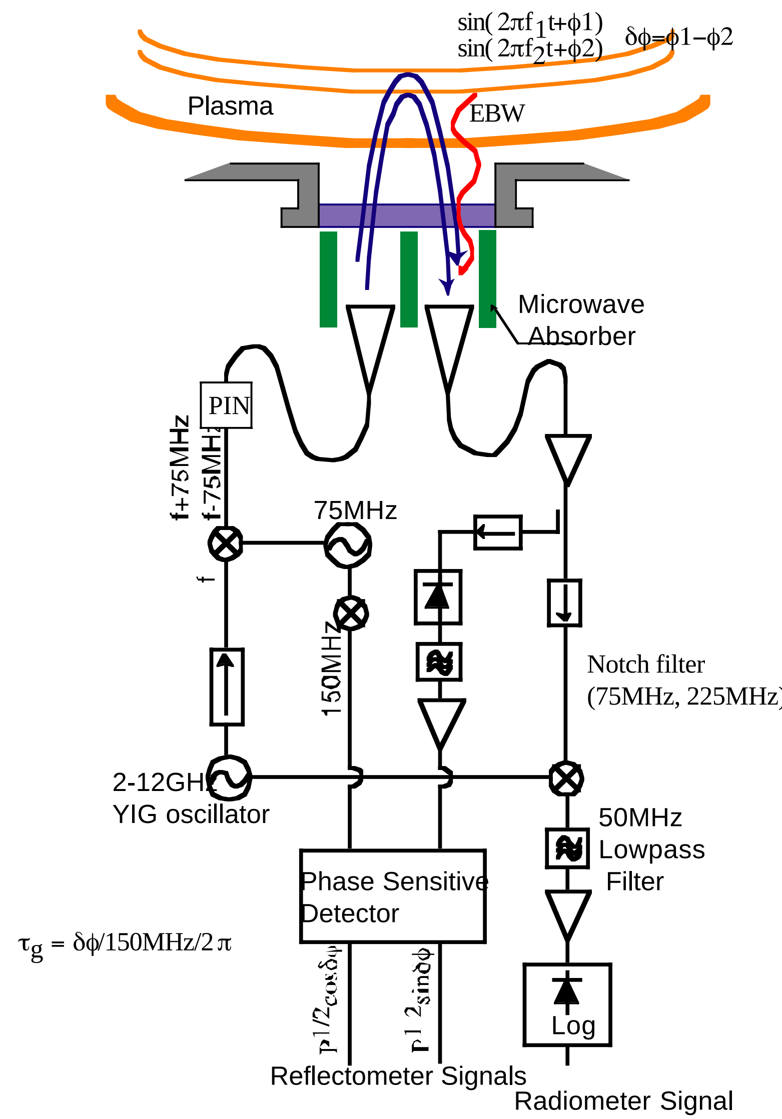
Simultaneous measurement

T_{rad}

density gradient at UHR

Direct measurement

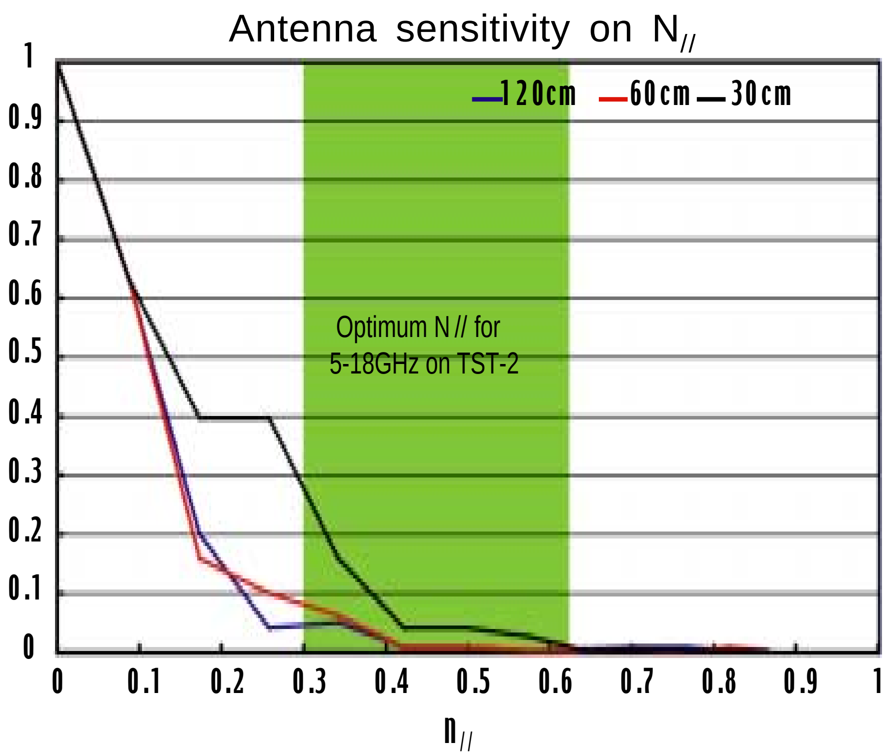
MC efficiency by reflectivity



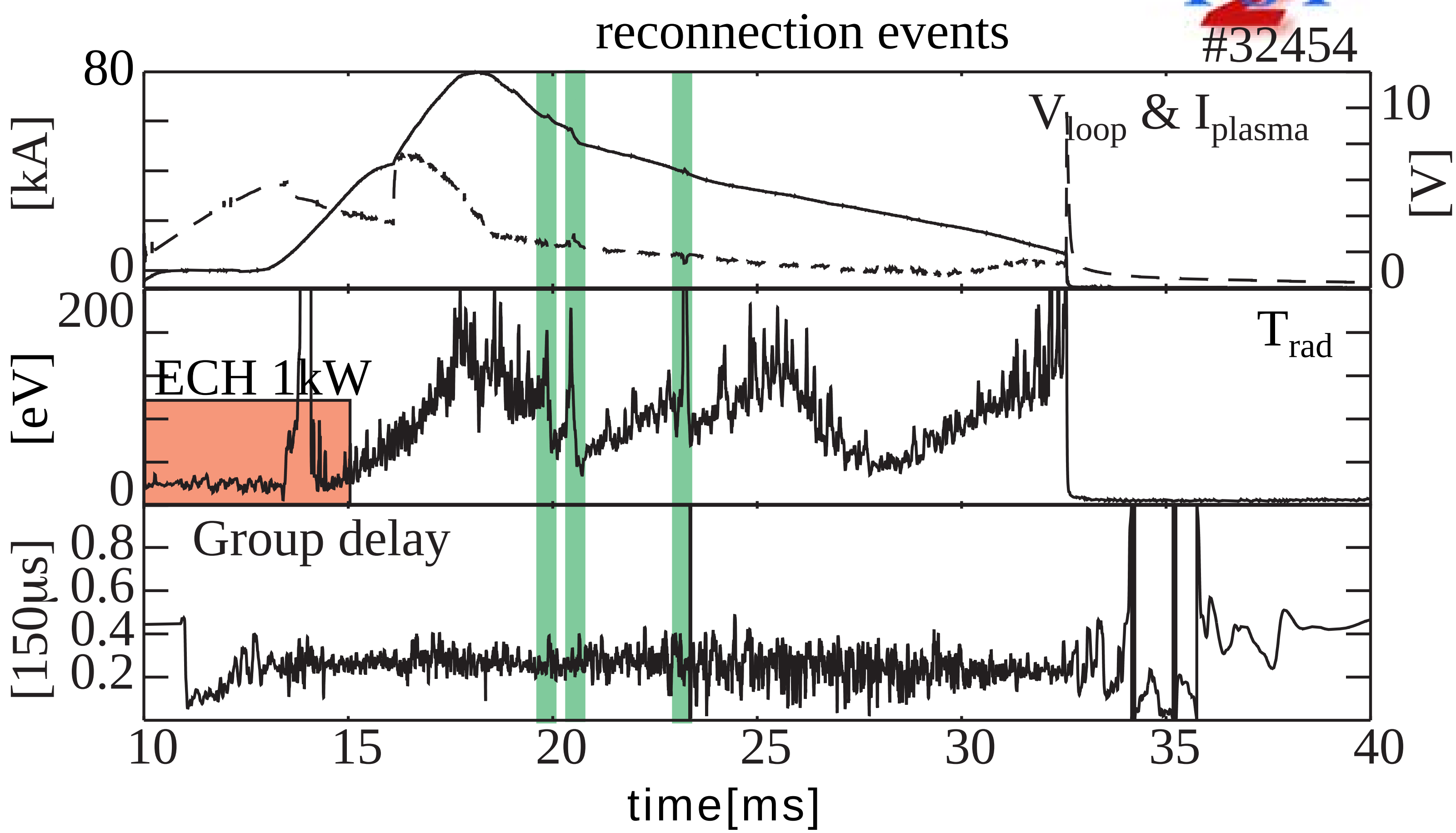
Distance between the antenna and vacuum window is important to measure EBW-SX-X process emission

- Mockup of vacuum vessel segment is used to decide the minimum distance to avoid the unfavorable emission generated via EBW-SX-O process.

- The antenna does not receive $N_{//}$> 0.2 emission, when the distance is more than 60cm.

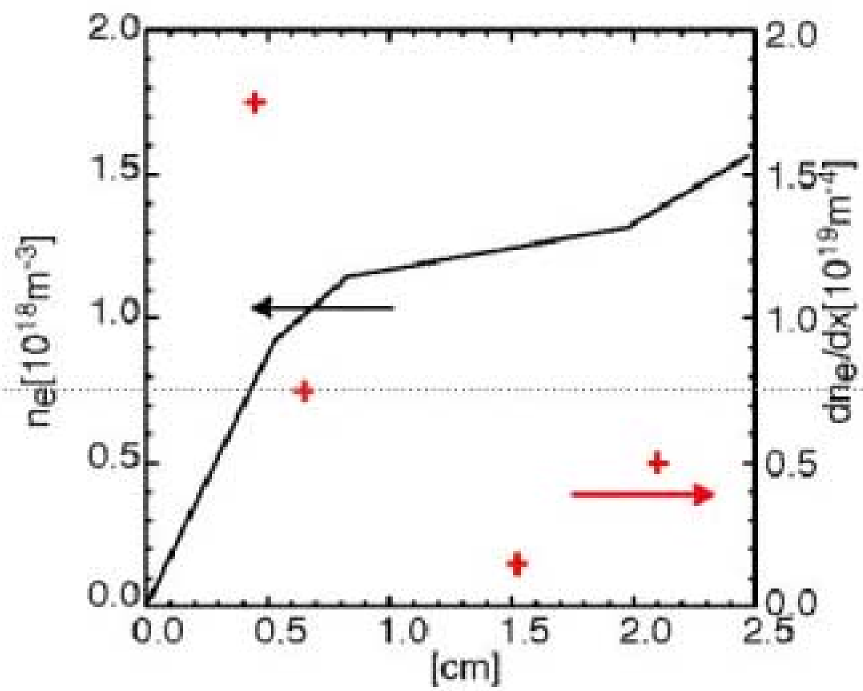


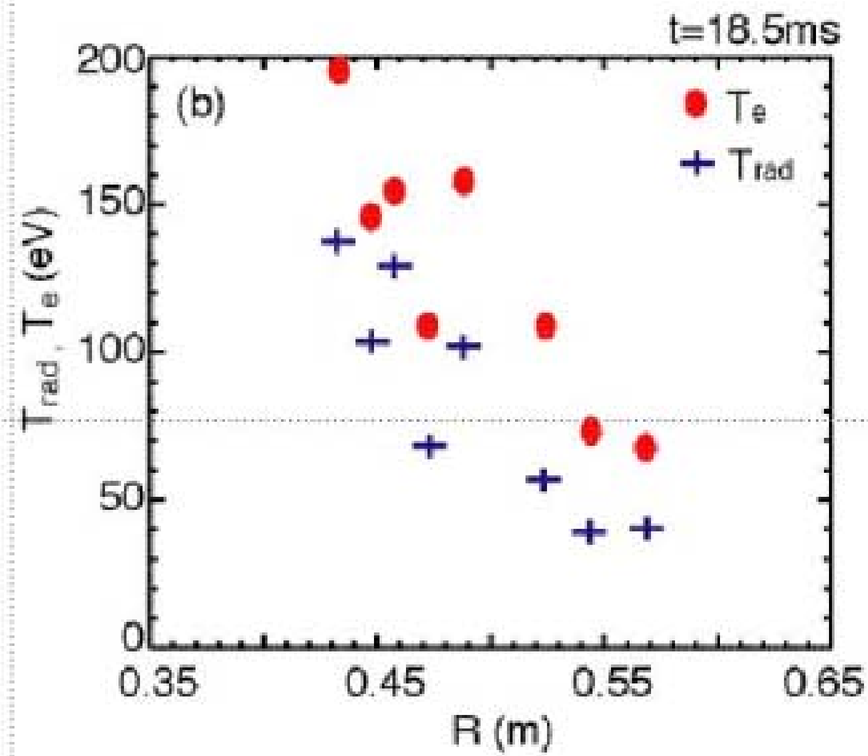
Example of simultaneous measurement



- T_{rad} from the core region is 100-150eV
- T_{rad} drops at IREÅ@Åno obvious change in group delay

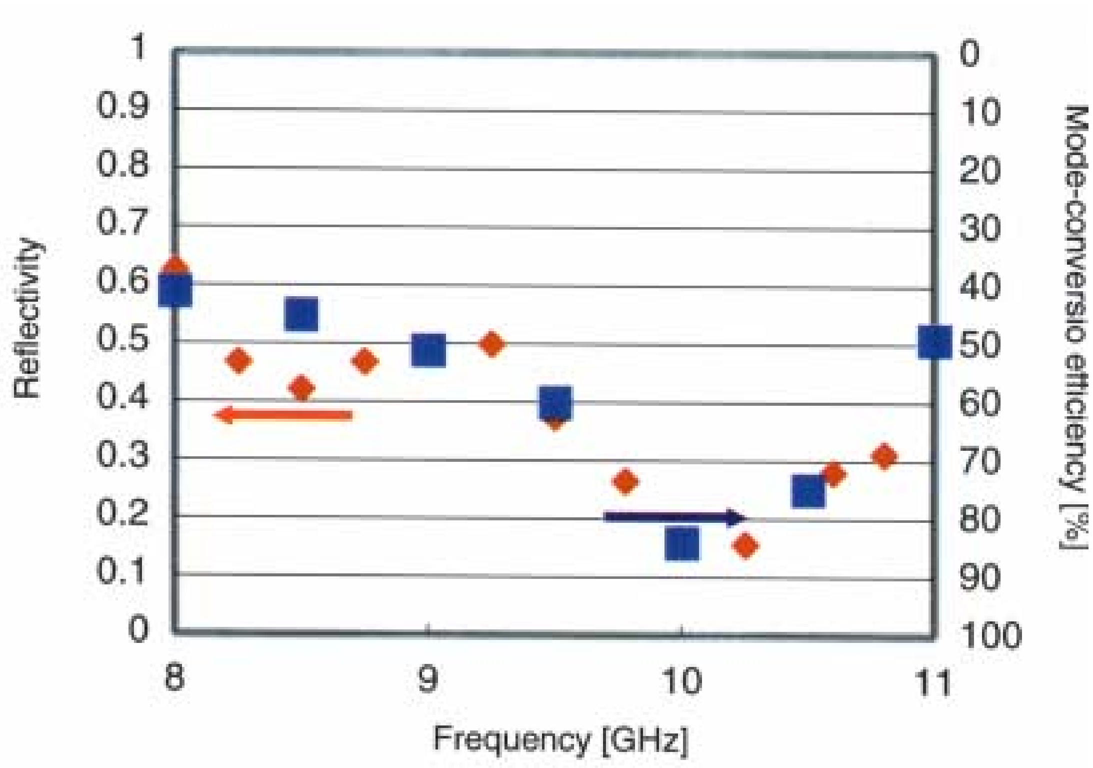
Spatial profiles of n_e, T_{rad} and T_e (at I_p maximum)





- dn_e/dxÅ~Å10^{19}[m^{-4}]
- A simple |B| profile of B_t~1/R and B_pÅ a is assumed to map the radiometer frequency to the spatial location.

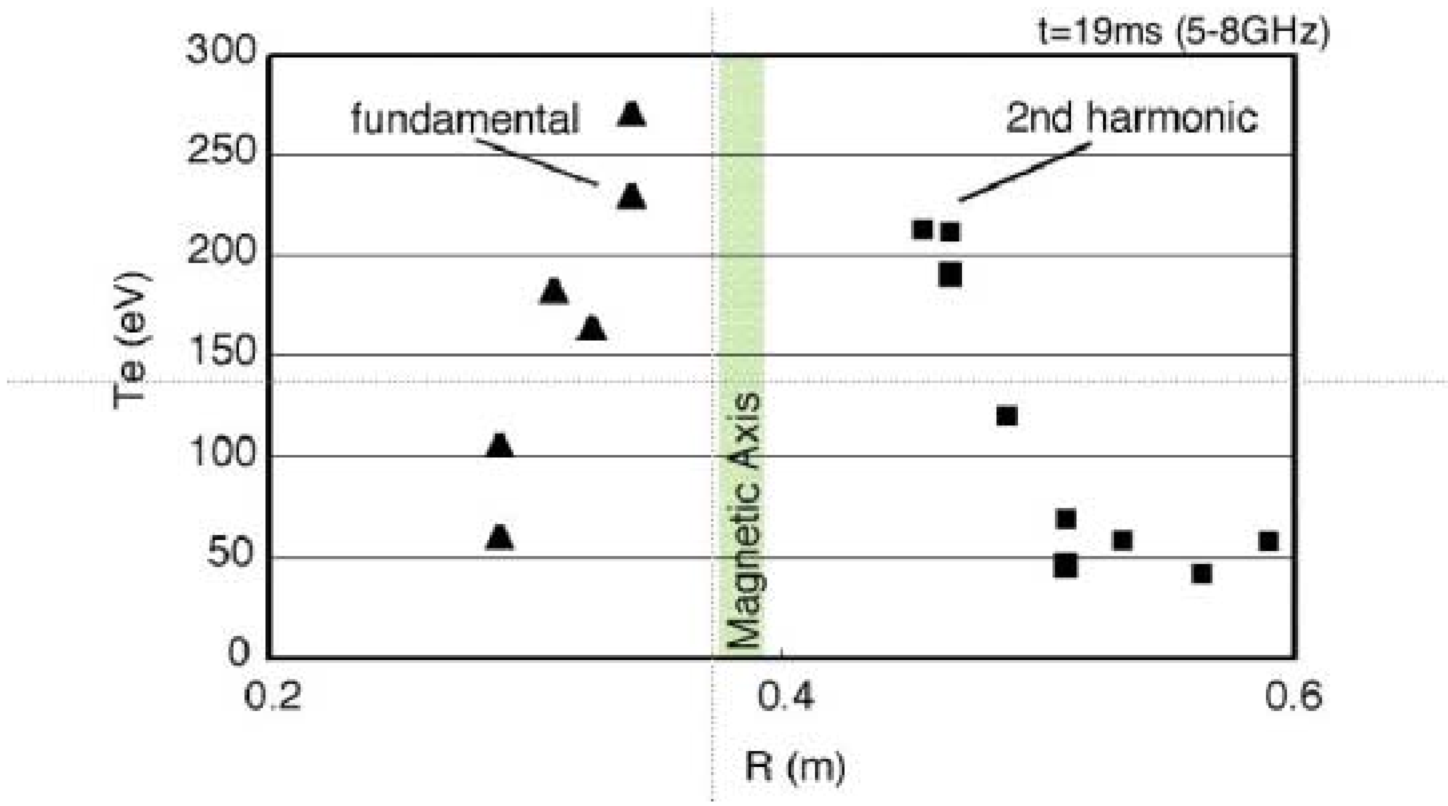
Comparison between MC efficiency and reflectivity



Reflectivity= (reflected power with plasma)/(reflected power with Al plate on the window)

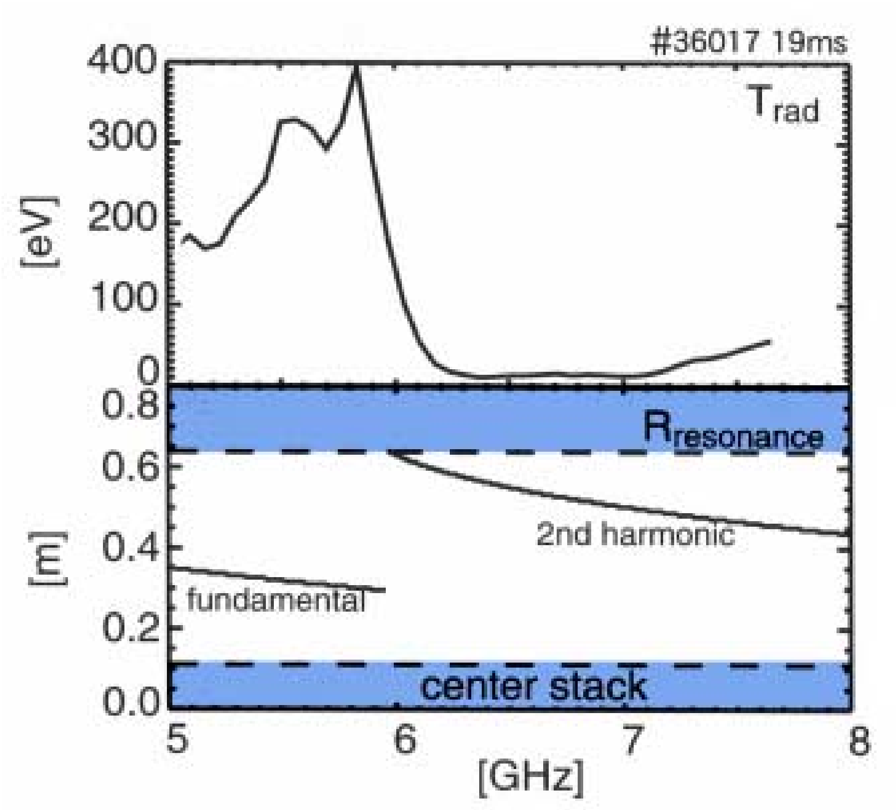
MC efficiency is calculated by full-wave code using the measured density profile

T_e obtained from fundamental and 2nd harmonic emission



- MC efficiency is estimated from the reflectivity.
- T_e profile is symmetric about the magnetic axis.

Overlap of cyclotron harmonics are clearly observed by the scanning measurement



EBW emission profile by 10kHz frequency scan

- Since ω_c emission comes from the core region and $2\omega_c$ emission comes from the peripheral region, the EBW intensity changes clearly at the overlap frequency.
- 3 overlap frequencies can be identified between 5-12GHz, although the changes of EBW intensity become small at higher frequency.

Conclusions

- T_e diagnostic of overdense plasmas
  - an alternative to ECE diagnostic
  - X-mode emission mode-converted from EBW
- Radio-reflectometer
  - simultaneously measures of T_{rad} and n_e profile around UHR
  - possible direct measurement of MC efficiency from reflectivity
- 5-12GHz Radio-reflectometer is installed on TST-2 spherical tokamak
  - the fundamental to 3rd harmonic emission coverage.
  - mode-conversion region located within 1~2cm from plasma edge
  - $dn_e/dx \sim 10^{19}[m^{-4}]$
  - T_{rad}~ 100-150eV and T_e around 200eV from the core region
  - Good consistency between MC efficiency and the reflectivity
- Fast scanning VCO is introduced recently
  - Frequency coverage is extended to 5-16GHz
  - Overlaps of cyclotron harmonics are clearly observed from the scanning profile measurements