# Status of EBW Emission Measurements on NSTX

S.J. Diem

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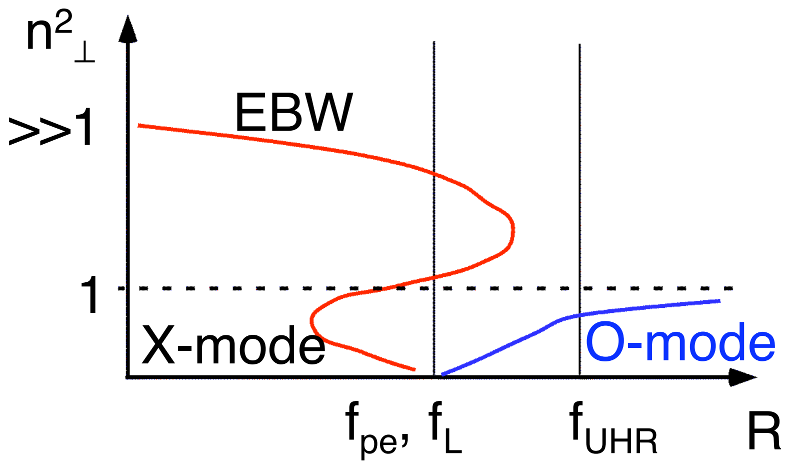
# Outline

- Electron Bernstein wave emission background
- Overview of EBW diagnostic and goals for 2007 NSTX run campaign
- Recent results from 2007 run campaign
  - H-mode scan results
  - Scan of plasma vertical position
  - LITER scan

# EBW coupling to electromagnetic waves



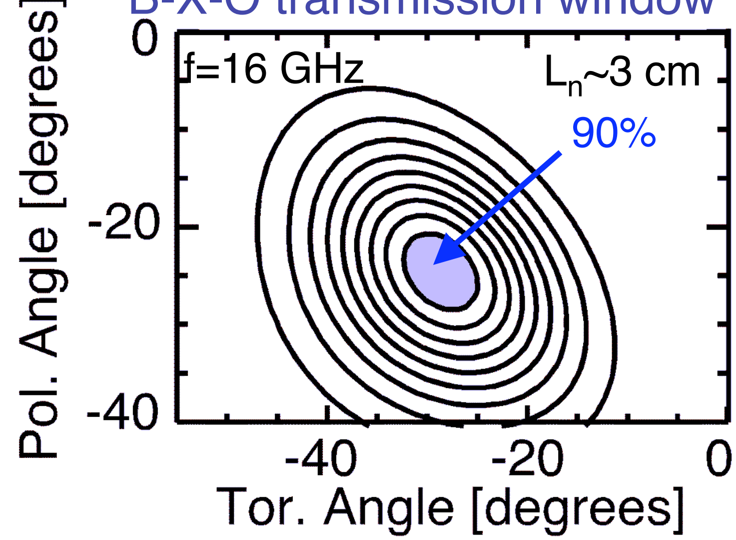



- EBW emitted at EC harmonic converts to the X-mode near UHR and then O-mode at $f=f_{pe}$
- Emission will be elliptically polarized (~1.6) due to oblique view of plasma

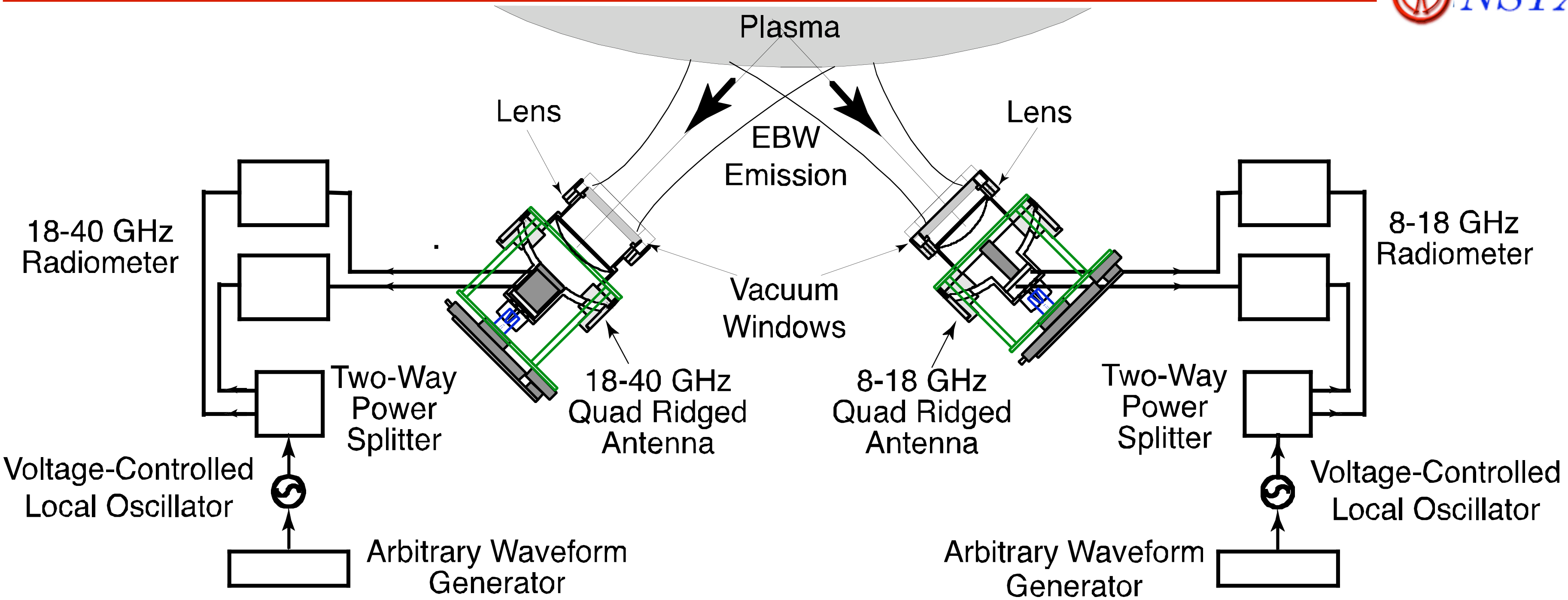
- B-X-O transmission window depends on:
  - Magnetic field pitch (~30-45% in NSTX)
    - determines location of window
  - Density scale length
    - determines width of window
- Experimental transmission defined as:

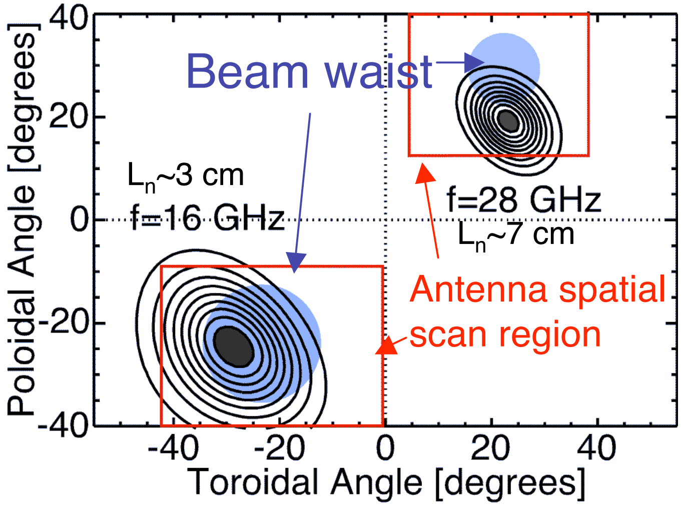
$$Transmission_{EBW} = \frac{T_{rad}}{T_{e,\mathrm{Thomson}}\left(R_{emission}\right)}$$

B-X-O transmission window



# Steered EBW antennas allow spatial mapping of B-X-O emission window




- ±10° scan in poloidal and toroidal directions
- Acceptance angle:
  8-18 GHz antenna ~ 22°
  18-40 GHz antenna ~ 14°

*S.J. Diem, et al, Rev. Sci. Instrum.* ***77*** *(2006)*

# XP 720: EBW emission in H-mode plasmas

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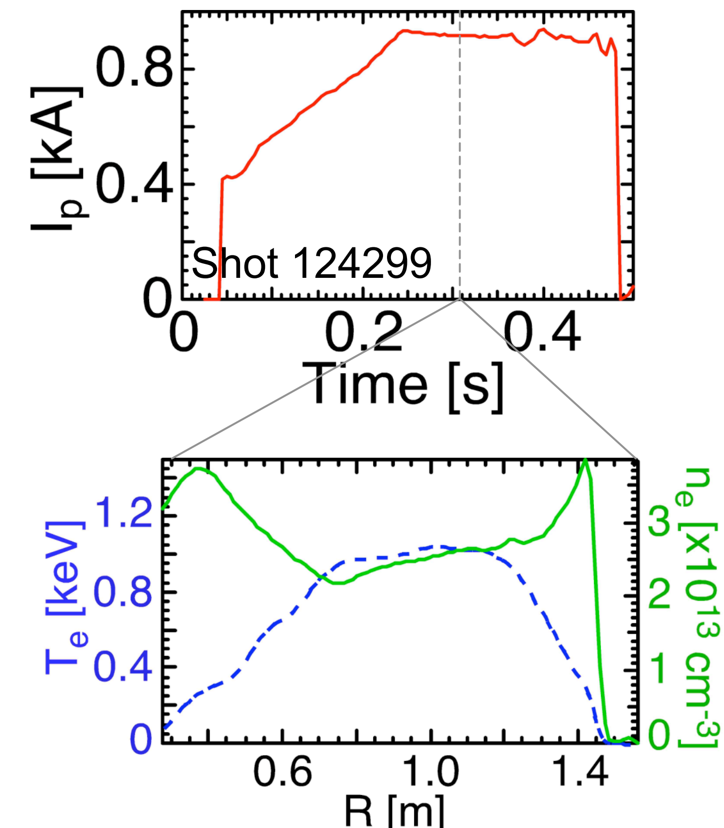
- Measure 8-36 GHz thermal EBW emission via oblique B-X-O coupling
- Study behavior of EBWs emitted from H-mode plasmas at $f_{ce}$, $2f_{ce}$, and $3f_{ce}$
- Experiment had three objectives:
  - Study effect of collisions on B-X-O mode coupling
  - Investigate dependence of B-X-O coupling on plasma parameters
  - Map experimental transmission efficiency in H-mode plasmas

# B-X-O transmission efficiency mapping in H-modes plasmas

- Repeat target discharge: $I_p$~0.9 MA, $T_e(0)$~1 keV
- Antenna pointing direction scanned between shots
- Experimental transmission efficiency defined as:

$$Transmission_{EBW} = \frac{T_{Rad}}{T_{e,\mathrm{Thomson}}\left(R_{emission}\right)}$$




- Compare experimental and theoretical transmission efficiencies
  - Theoretical does not account transmission losses of EBW from emission to mode conversion

# Measured B-X-O transmission of 40-50% in H-mode plasmas with Li conditioning, high κ

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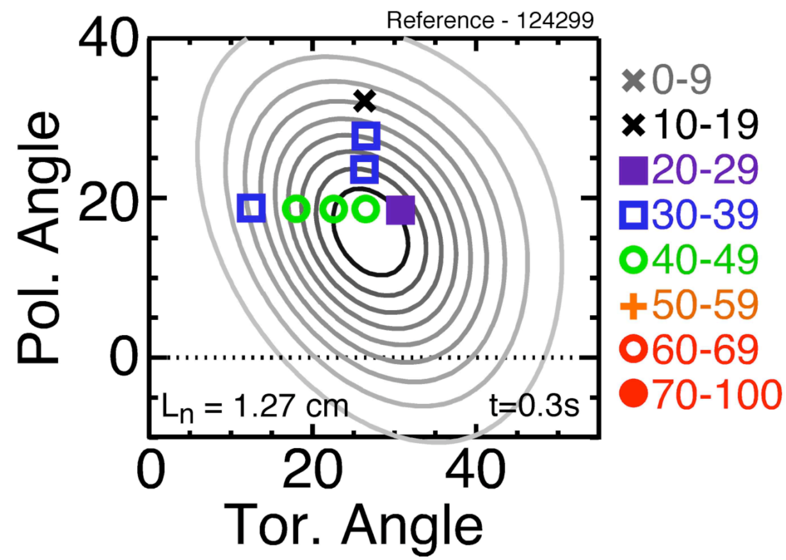
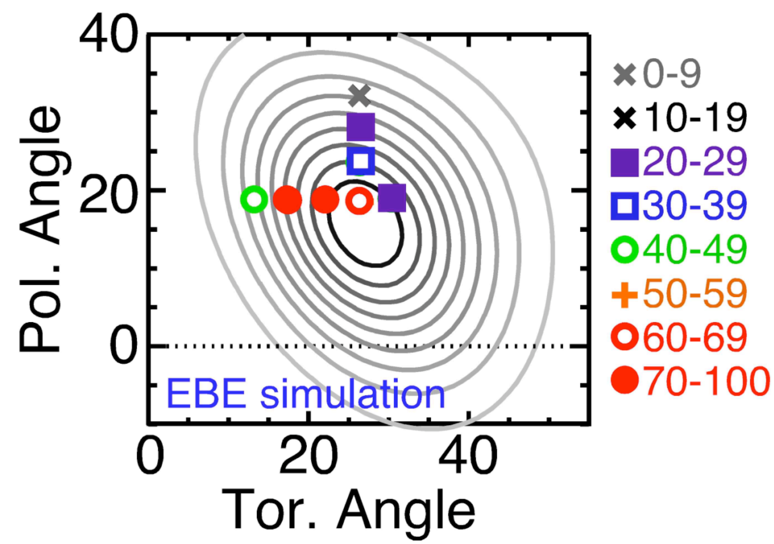
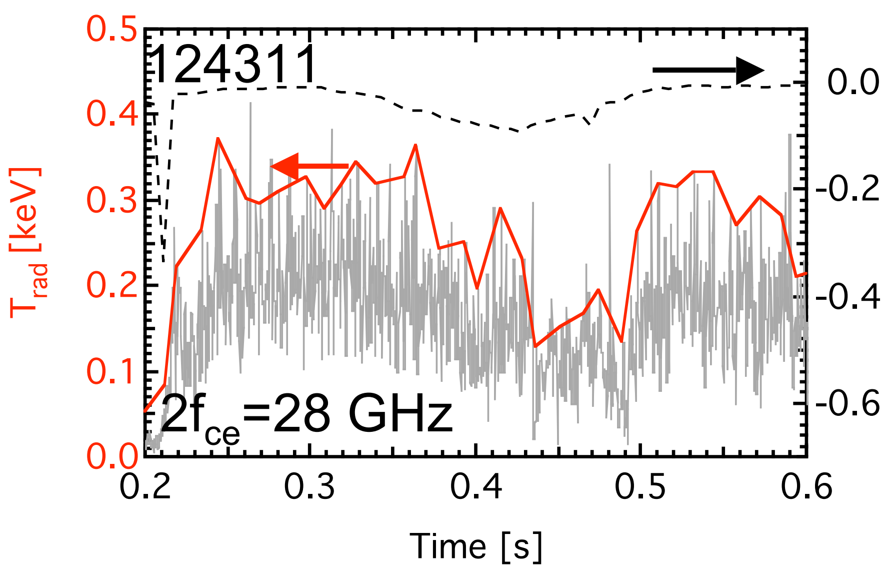
- Maximum experimental B-X-O transmission for $2f_{ce}$=28 GHz was 45%
- Peak in measured B-X-O transmission similar to predicted location
- Simulated B-X-O transmission for $2f_{ce}$=28 GHz was ~100%
- Measurements for $f_{ce}$=18 GHz available but awaiting modifications to EBE code

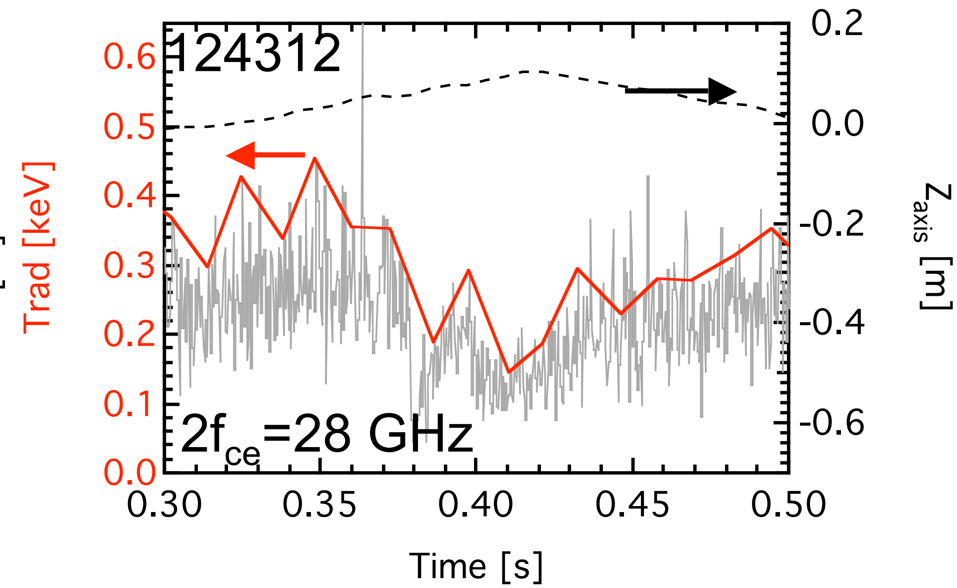


# Change in vertical position of magnetic axis decreased measured $T_{rad}$

- Scan in the vertical position of the plasma magnetic axis was achieved by changing $Dr_{sep}$
  - 124311 $z_{maxis}$ went from 0 cm to -8 cm to 0 cm
  - 124312 $z_{maxis}$ went from 0 cm to +6 cm to 0 cm
- Target plasma: $I_p$=0.8 MA, $T_e(0)$~1 keV, $n_e(0)$~$3x10^{13}$ $cm^{-3}$



# EBE measurements/simulation show decrease in emission with change in $Z_{maxis}$

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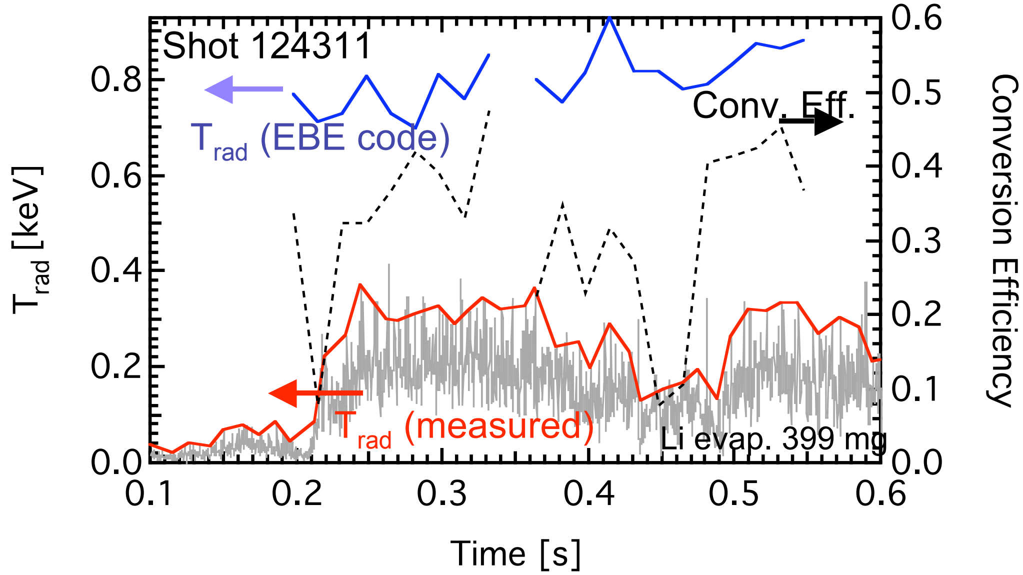
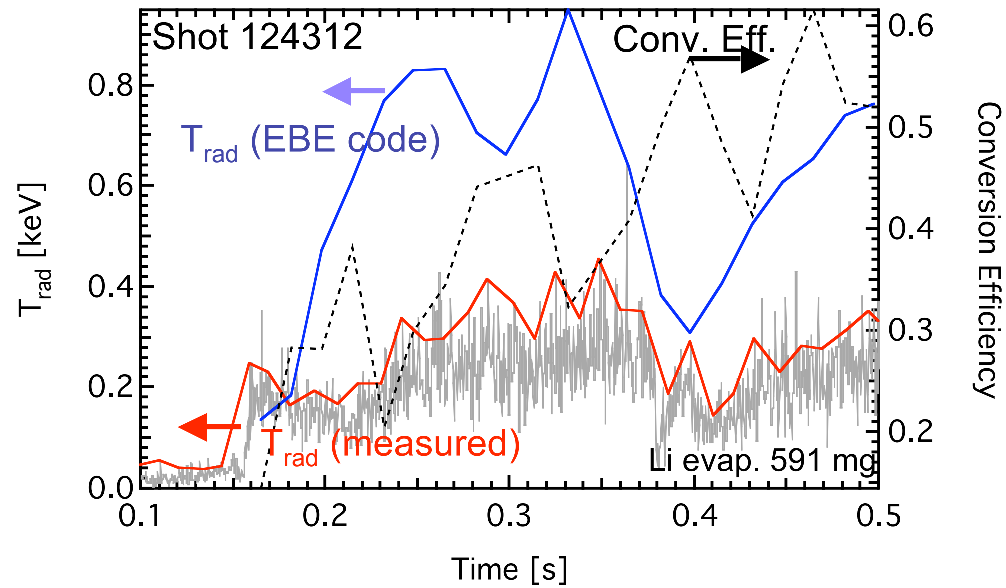
- $Z_{maxis}$ decrease lead to ~150 eV drop in measured $T_{rad}$
- EBE simulation shows drop in conversion efficiency occurs at $Z_{maxis}$ drop



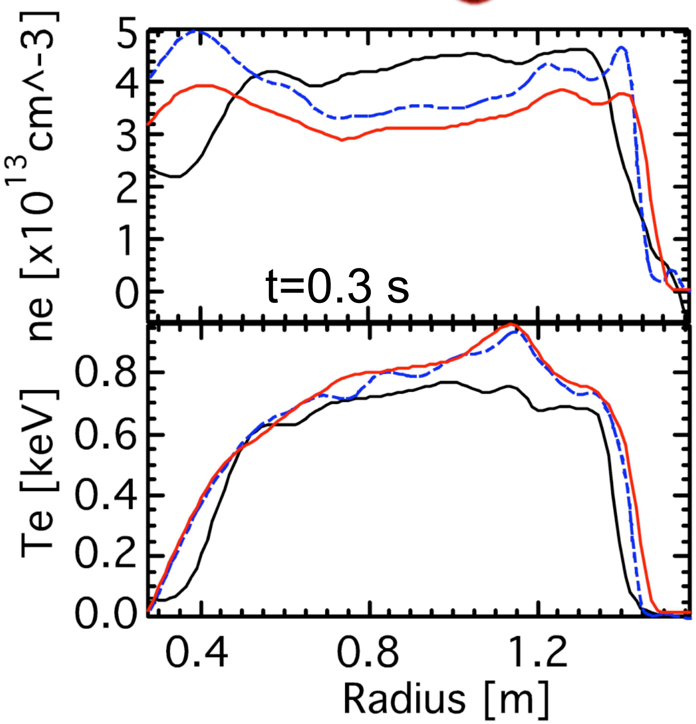

- $Z_{maxis}$ increase lead to ~200 eV drop in measured $T_{rad}$
- EBE simulation shows increased Doppler broadening effects occurs at $Z_{maxis}$ increase

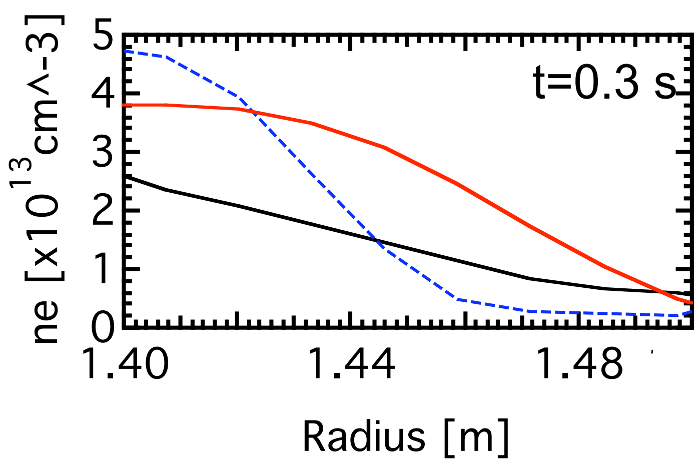


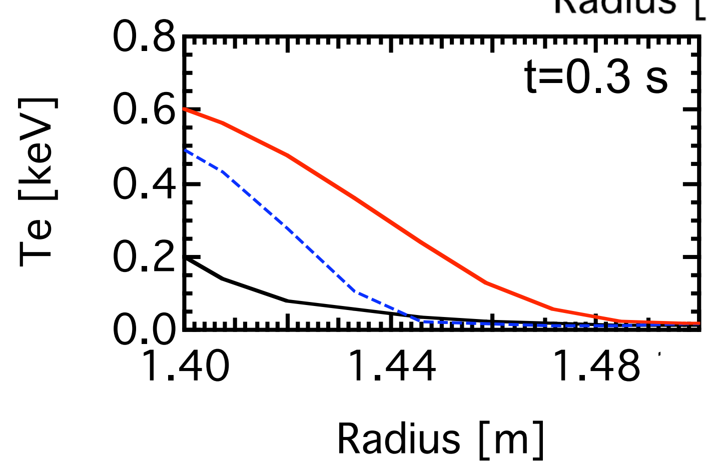
# LITER scan investigates effect of edge parameters on $T_{rad}$

- Target plasma: $I_p$=0.8 MA, $T_e(0)$~0.7 keV, $n_e(0)$~4x$10^{13}$ cm-3

- Increased LITER evaporation rate to observe effects on EBE
  - 124284 - ref. shot with 0 mg
  - 124290 - 171 mg of Li
  - 124309 - 286 mg of Li



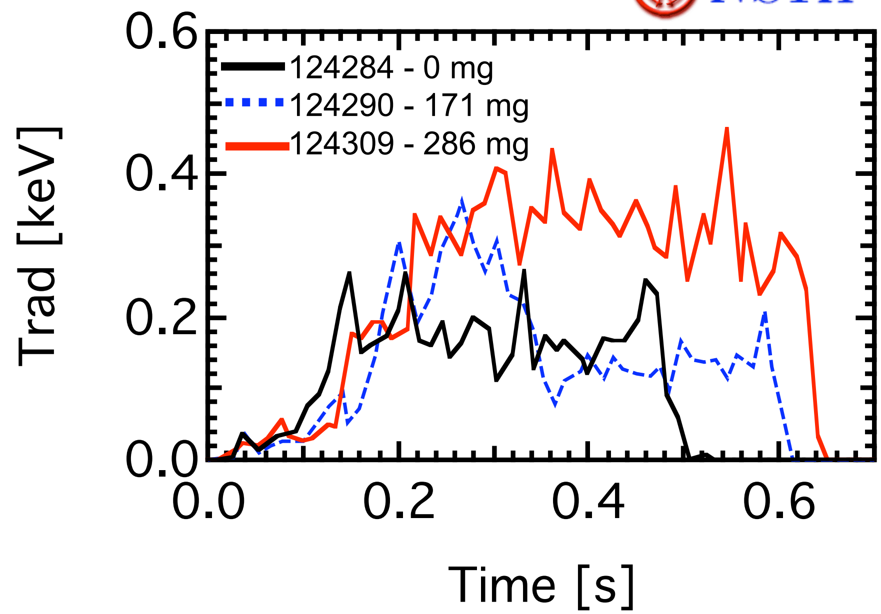



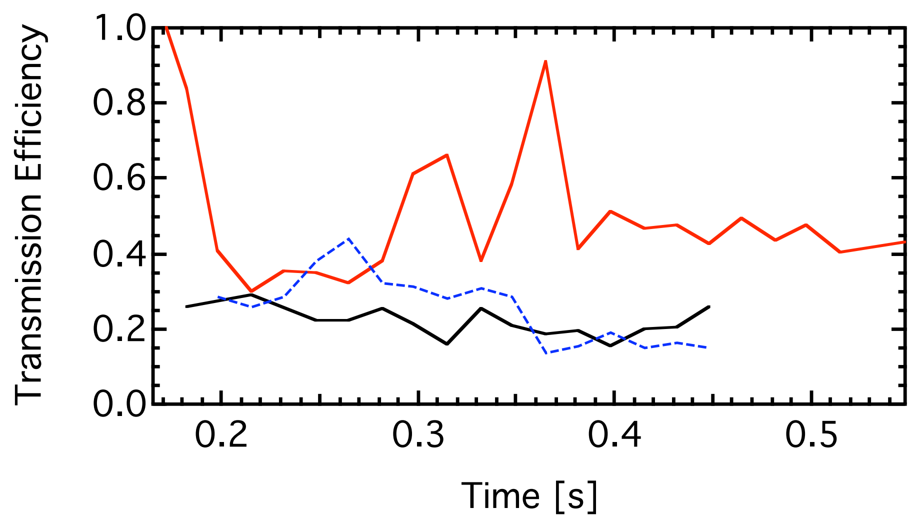
# Increase in measured $T_{rad}$ observed with increase in Li evaporation

- Measured $T_{rad}$ increased from ~200 eV to ~350 eV with increased Li evaporation

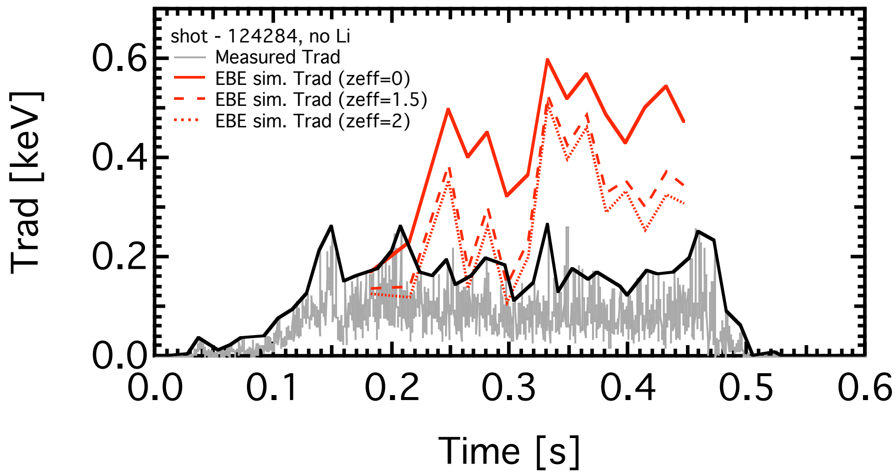
- Lithium conditioning decreased $L_n$ (3 ➔2 cm) and increased edge $T_e$

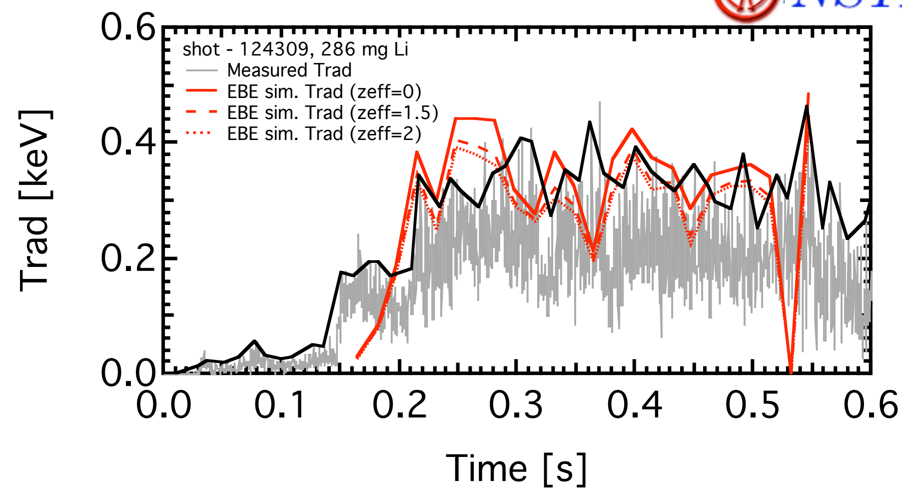
- Measured EBE transmission efficiency increased from ~20% to ~45% with lithium



# Good $T_{rad}$ agreement with EBE simulation in shot with highest Li evaporation rate

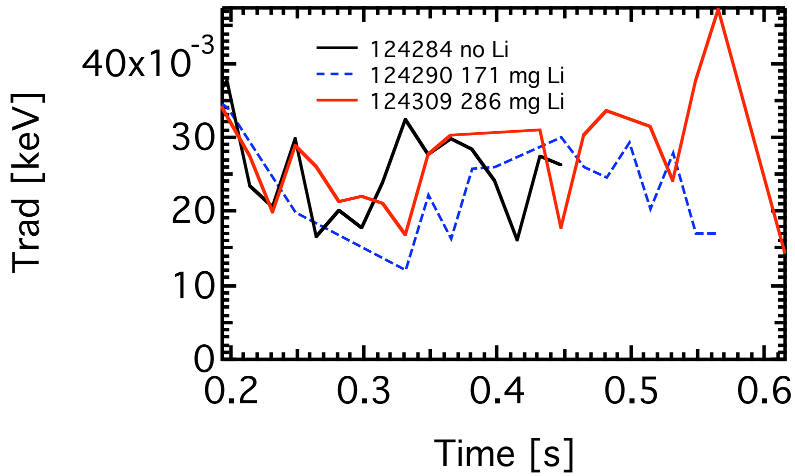


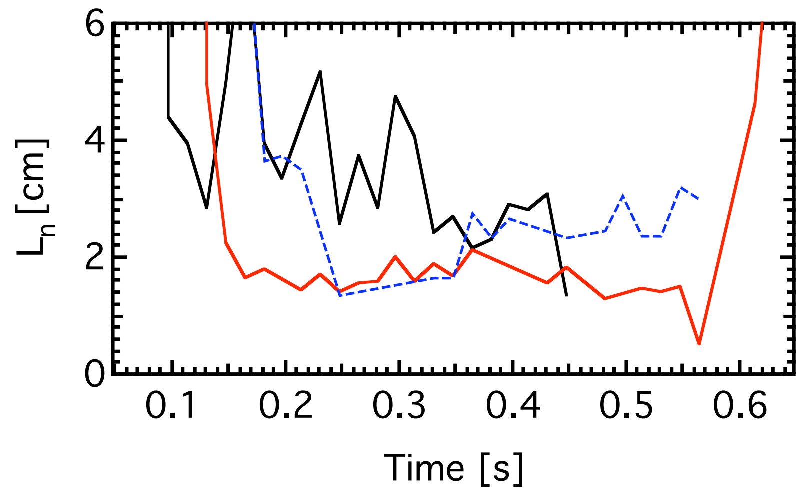




- For 0 mg of Li conditioning - measured $T_{rad}$~200 eV, simulation $T_{rad}$~400-600 eV
- For highest Li evaporation rate (286 mg) - measured and simulated $T_{rad}$ agree
- Increased agreement between with and without collisional damping simulations may indicate reduction of collsional damping observed with lithium conditioning

# Summary of LITER scan results

- Measured transmission efficiency increased from 20-45% with 286 mg of evaporated lithium




- Decrease in $L_n$ (3→2 cm) with lithium conditioning
- No significant increase in $T_e$ near the mode conversion region observed
  - However, EBE simulation results with/without collisions has best agreement with 286 mg of lithium evaporation

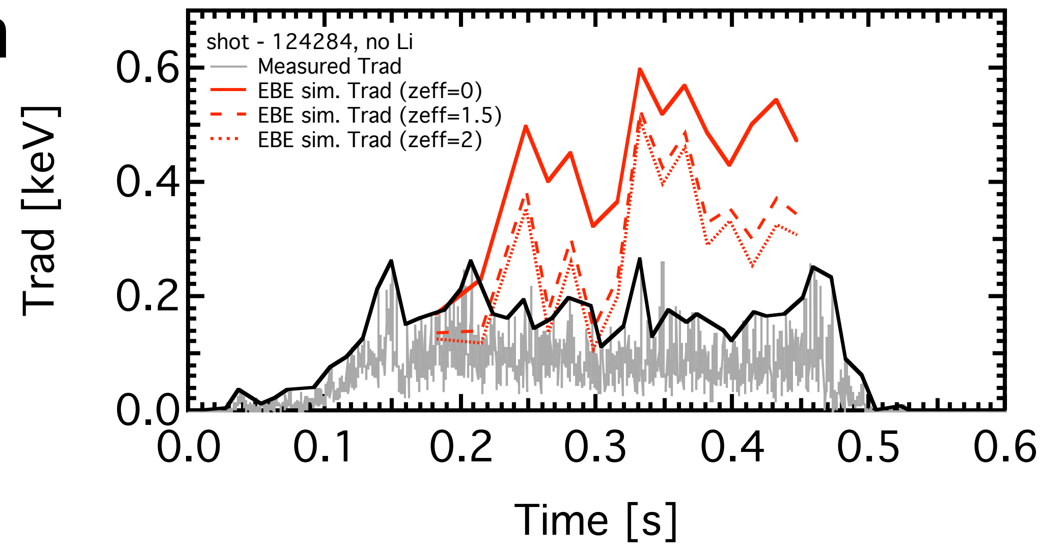
# Conclusions and future work

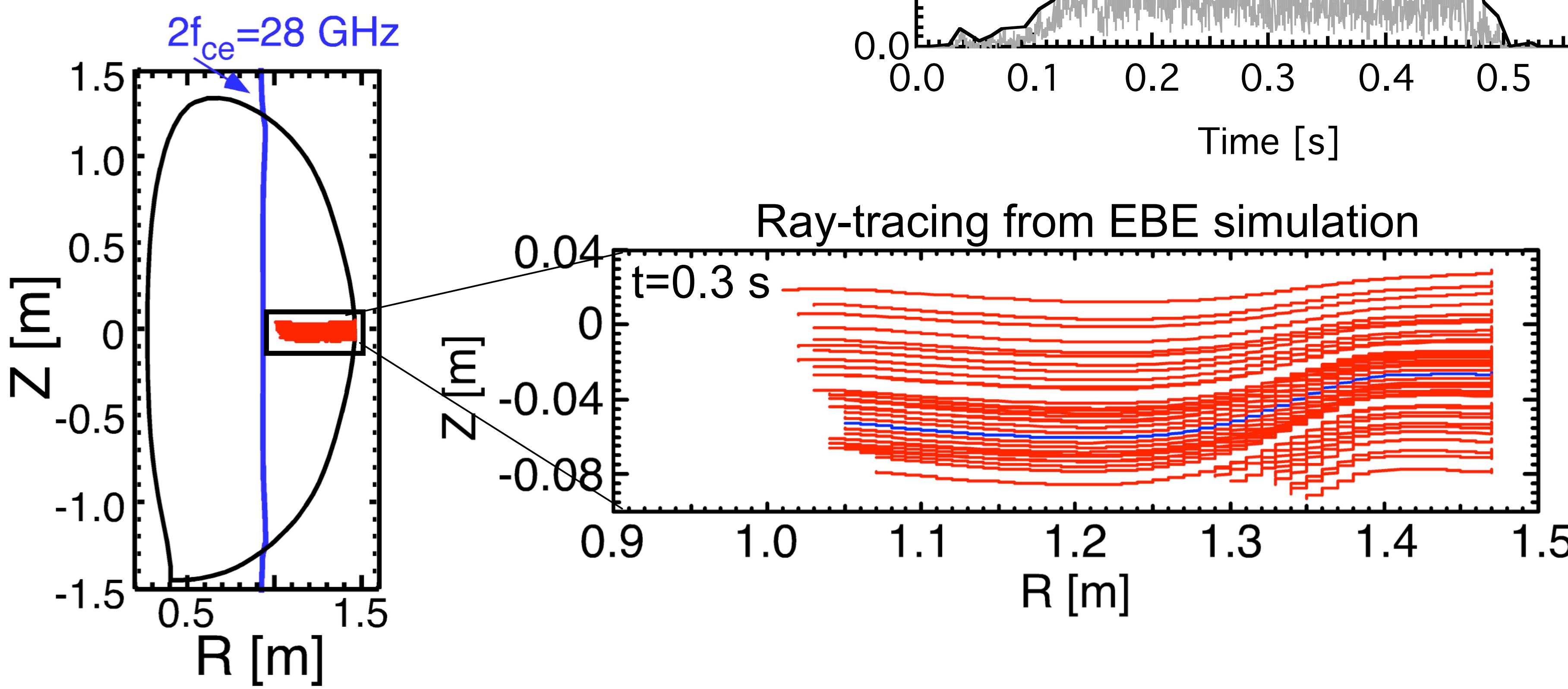
- Measured transmission efficiency for H-mode plasmas for $2f_{ce}$=28 GHz was 40-50%
- $Dr_{sep}$ scan allowed for controlled scan in $z_{maxis}$
  - Increase in $z_{maxis}$ lead to decrease in measured $T_{rad}$ due to increase in Doppler broadening
  - Decrease in $z_{maxis}$ lead to decrease in measured $T_{rad}$ due to increase in $L_n$
- Lithium conditioning scan increased measured $2f_{ce}$=28 GHz transmission efficiency from 20-45%
- Future work will focus on comparing emission from 2006 and 2007 H-mode plasmas to understand increase in $T_{rad}$ in 2007

# 124284 - 0 mg lithium



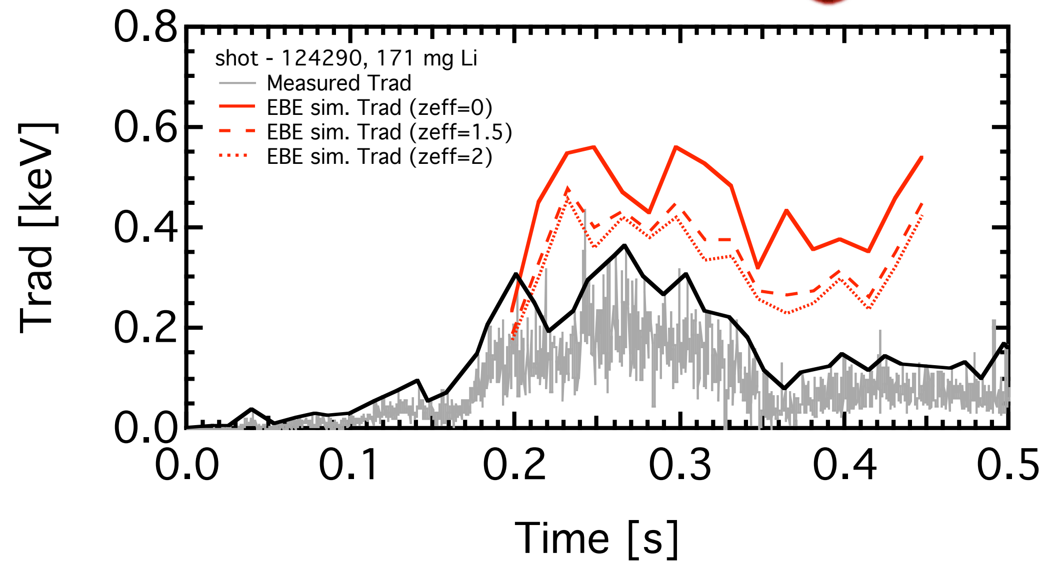
- $2f_{ce}$=28 GHz emission from axis ~1.0-1.1 m
- Max transmission efficiency ~ 20%

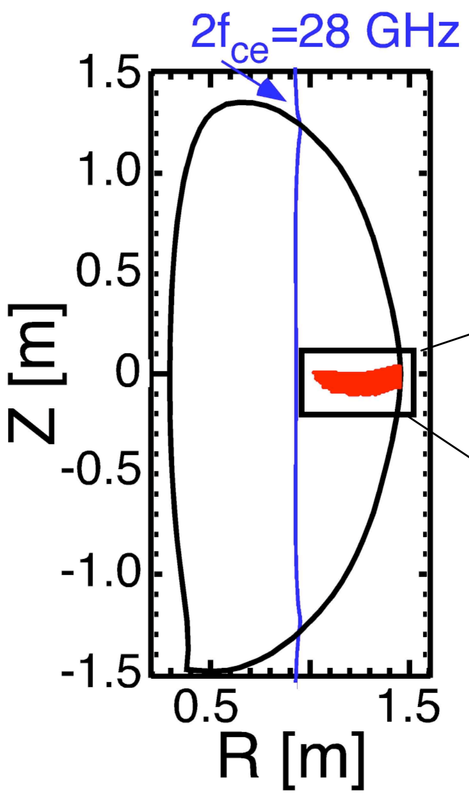


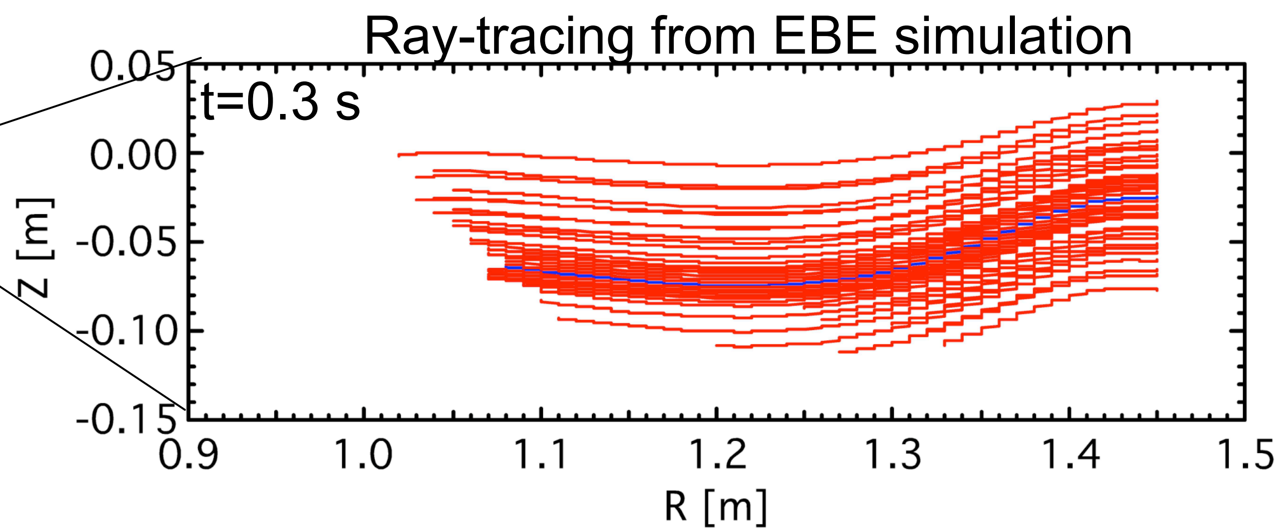



# 124290 - with 171 mg of Li

- $2f_{ce}$=28 GHz emission from axis ~1.0-1.1 m
- Max transmission efficiency ~ 30%

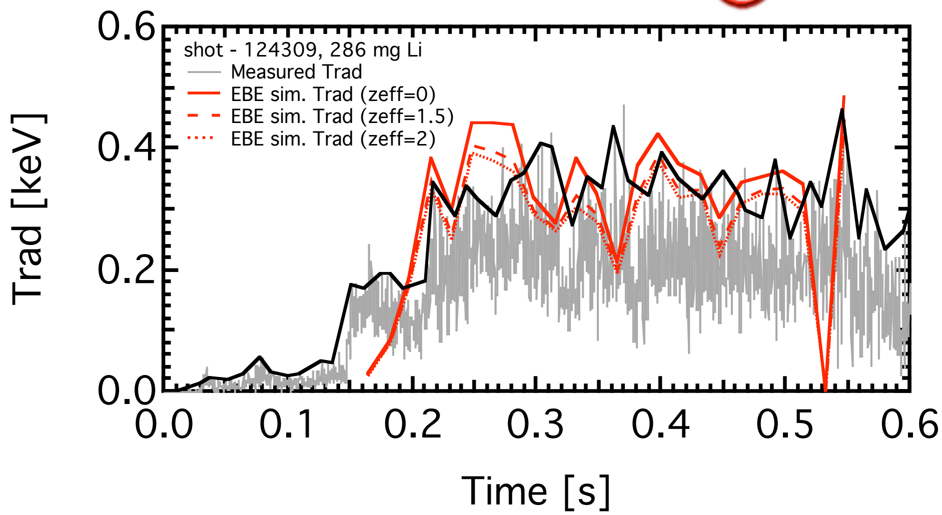


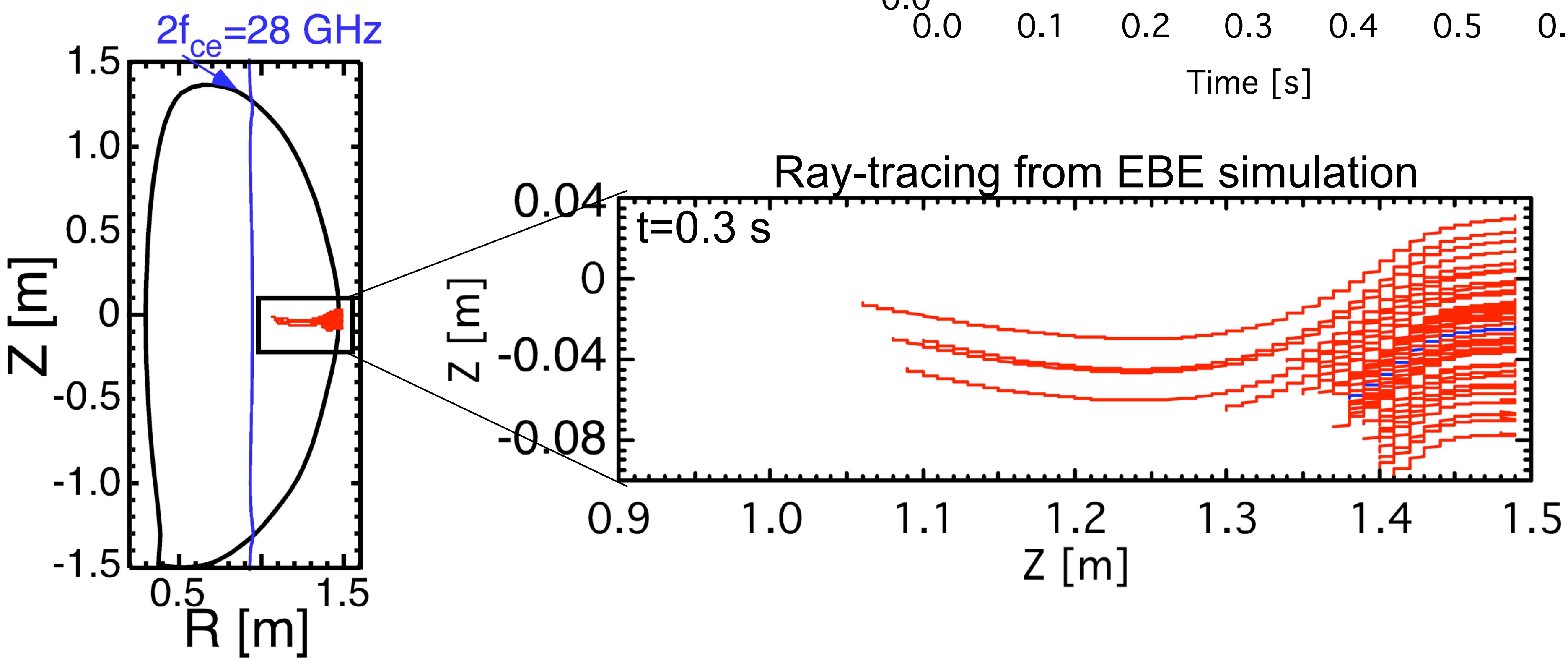



# 124309 - with 286 mg of Li

- $2f_{ce}$=28 GHz emission from axis ~1.0-1.4 m
- Max transmission efficiency ~ 40-50%



# Li conditioning effects on emission location

- 0, 171 mg of evaporated lithium - emission primarily from core
- 286 mg of evaporated lithium - emission location oscillated between core and edge of plasma
  - Yielded emission from both $2f_{ce}$ (core) and $3f_{ce}$ (edge)