Electron Bernstein Wave Research on CDX-U and NSTX

Presented by

Gary Taylor

In collaboration with

Phil Efthimion and Brent Jones

- EBWs offer potential for local heating, current drive and $T_e(R,t)$ diagnostic in ST plasmas

- EBW emission yields information about viability of EBW heating and current drive

**PPPL**
PRINCETON PLASMA
PHYSICS LABORATORY

Outline

- Brief review of EBW conversion to X-mode

- Initial CDX-U EBW emission results without local limiter

- EBW emission enhancement during NSTX H-modes

- CDX-U EBW emission results with a local limiter

- Plans for EBW current drive and heating

PPPL
PRINCETON   PLASMA
PHYSICS LABORATORY

EBW Emission Measured on CDX-U and NSTX via Mode Conversion to Fast X-Mode
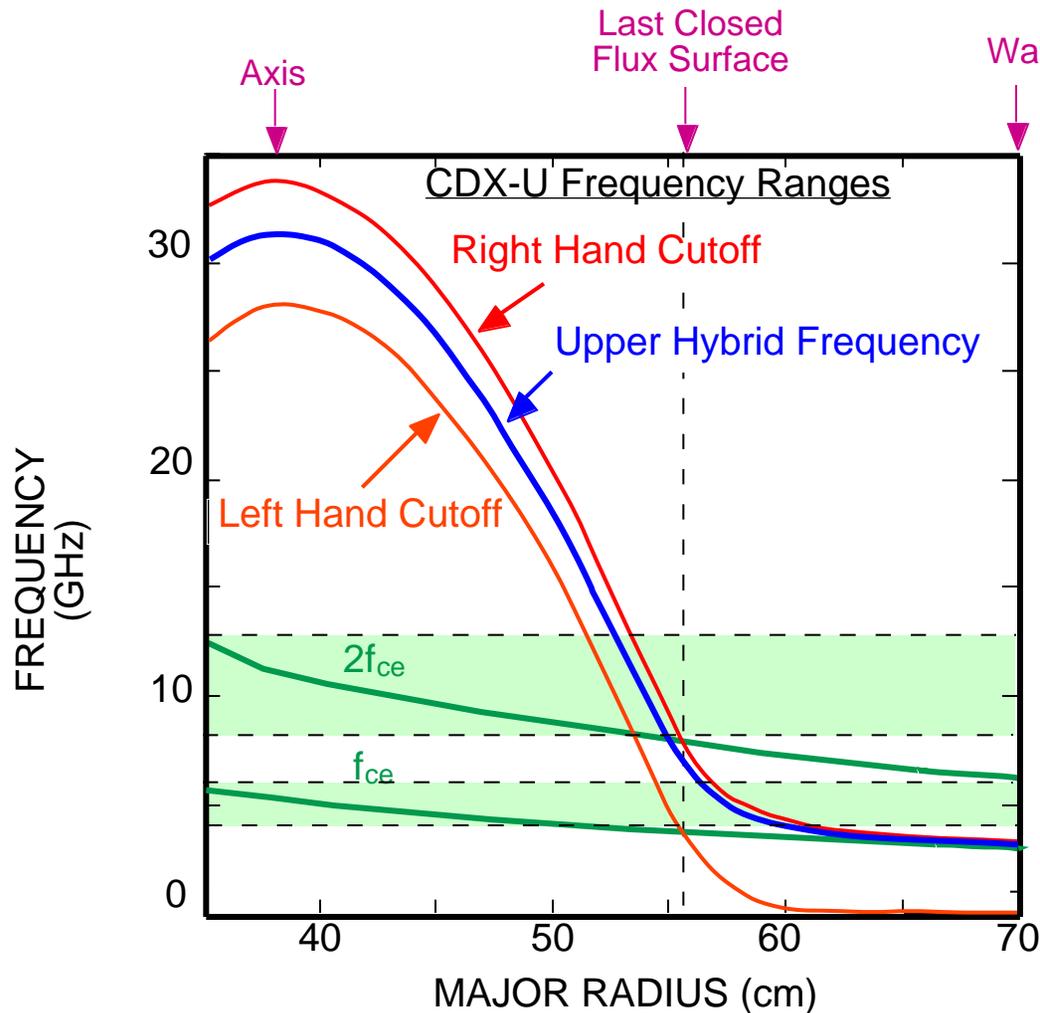
- If L_n is steep at UHR, EBW tunnels to fast X-mode
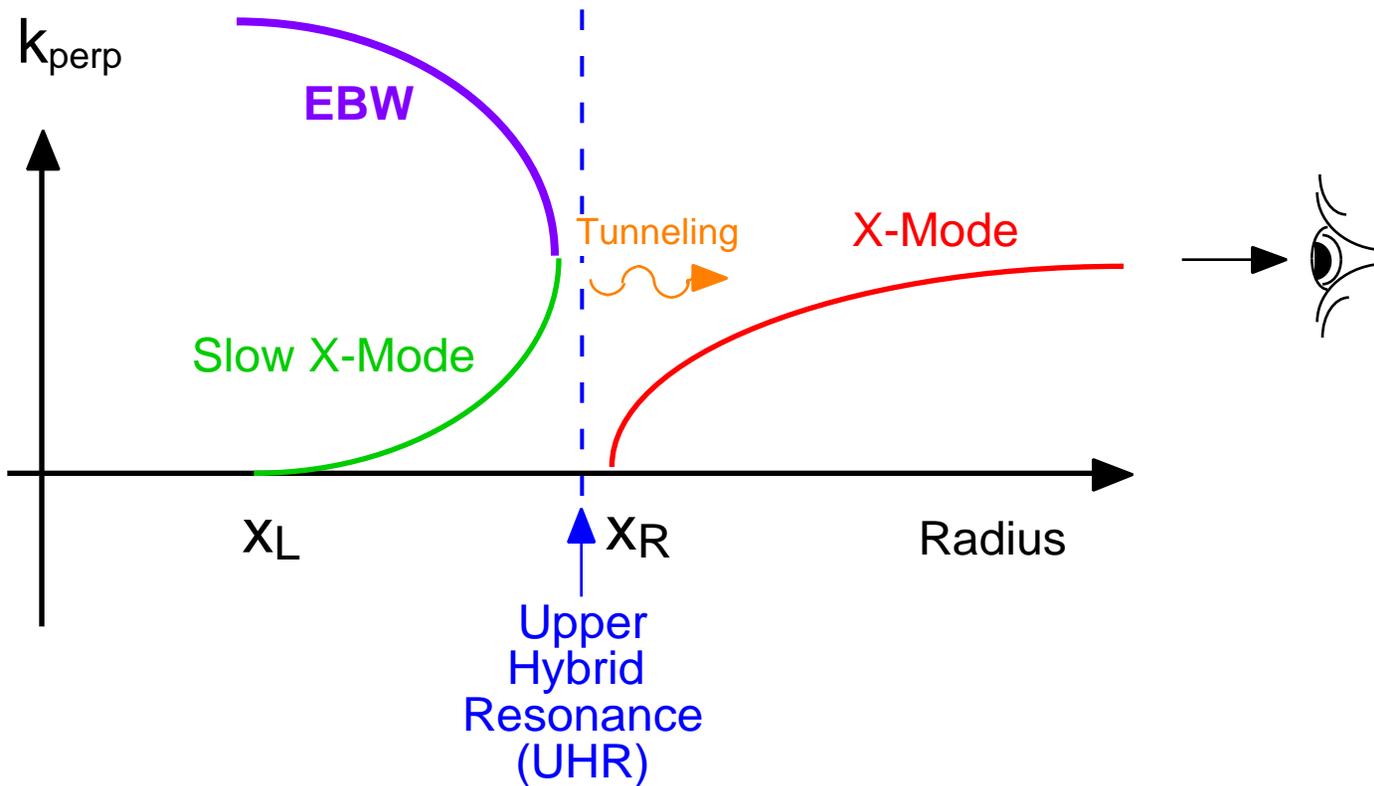
# Conversion Efficiency Very Sensitive to L_n at Upper Hybrid Layer. On CDX-U C_{max} ~ 1 for L_n ~ 0.5 cm
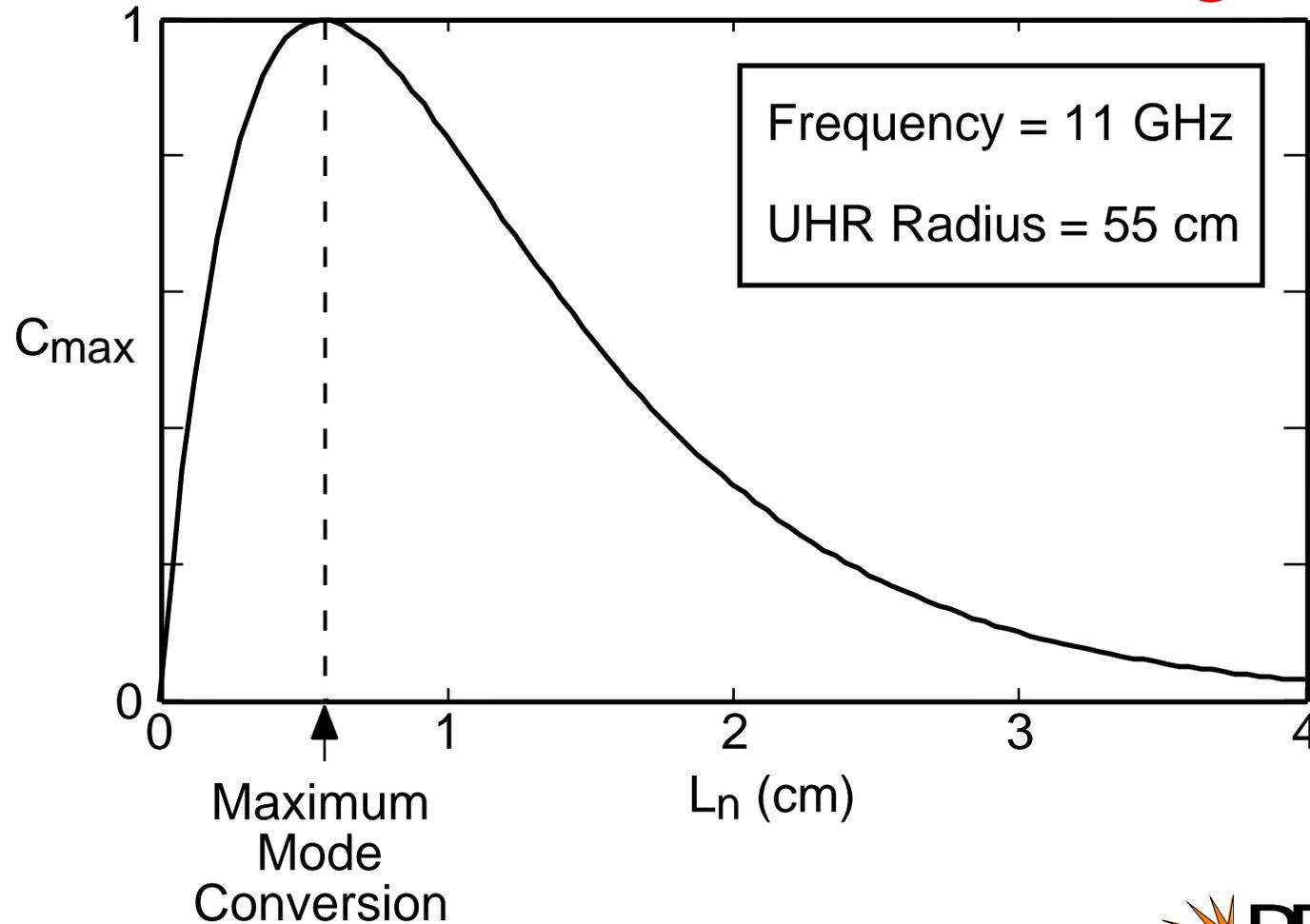
On CDX-U, Fundamental EBW Converts to X-Mode Between Last Closed Flux surface and Wall

CDX-U

Axis

Last Closed Flux Surface

Wall

CDX-U Frequency Ranges

Right Hand Cutoff

Upper Hybrid Frequency

Left Hand Cutoff

$2f_{ce}$

f_{ce}

FREQUENCY (GHz)
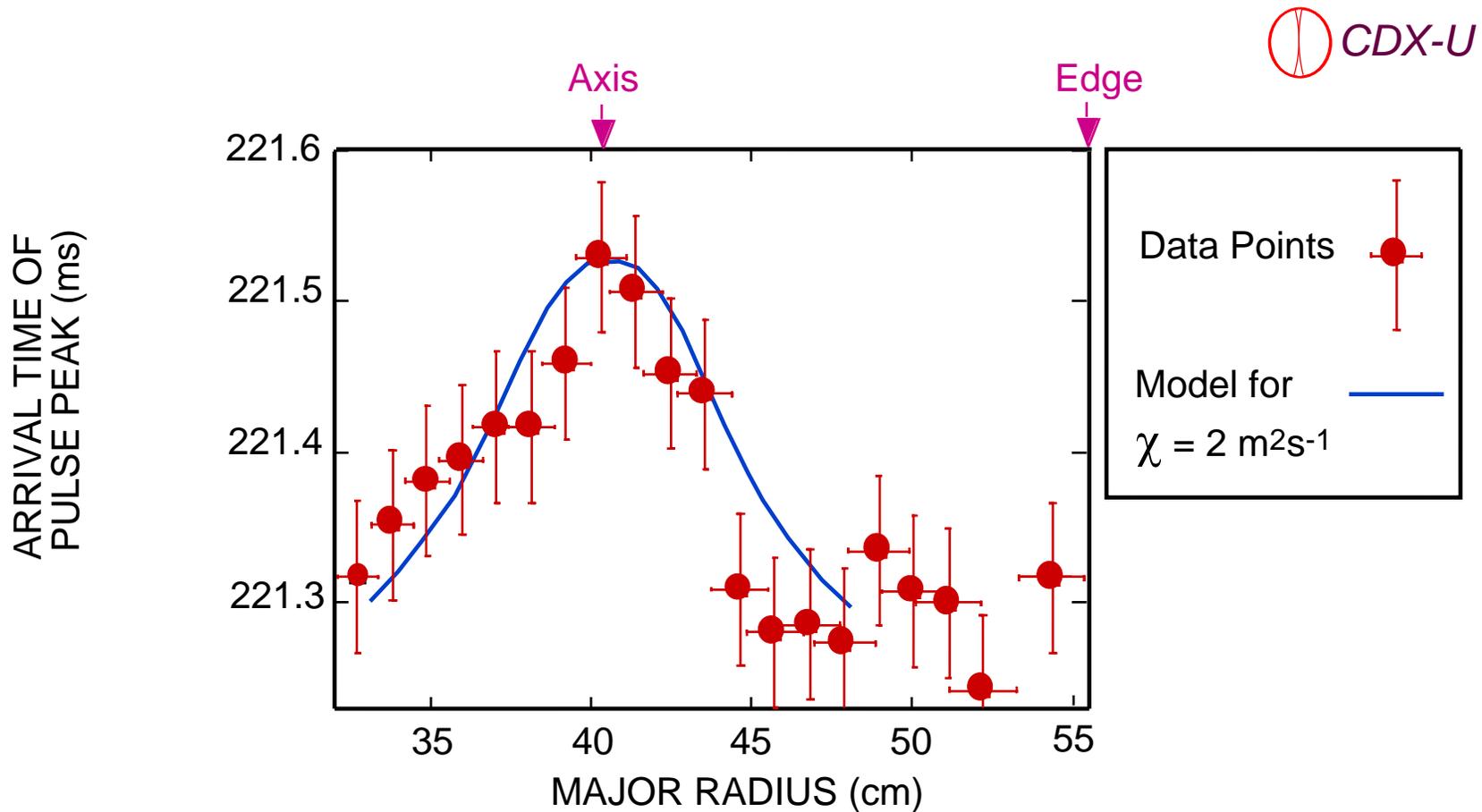
30

20

10

0

40　　50　　60　　70

MAJOR RADIUS (cm)

● Second harmonic EBW mode converts to X-mode near last closed flux surface
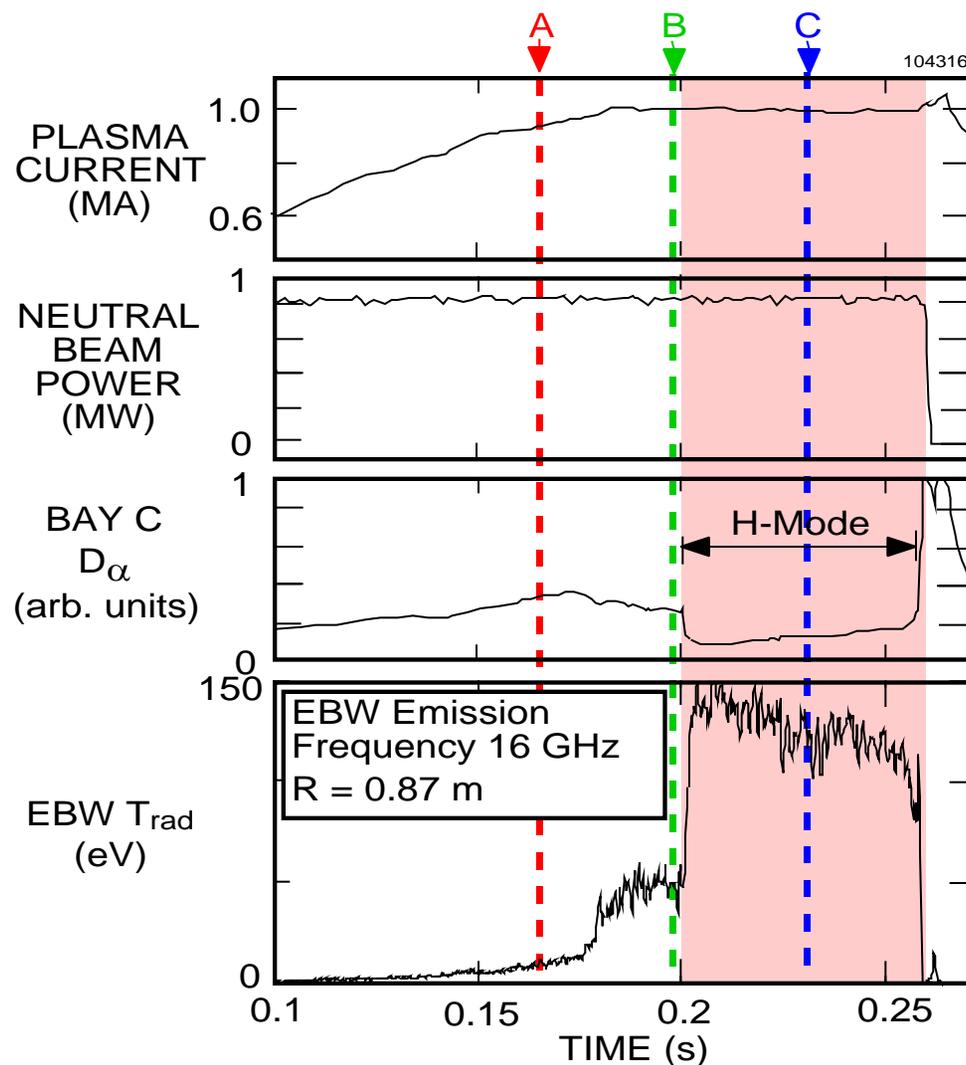
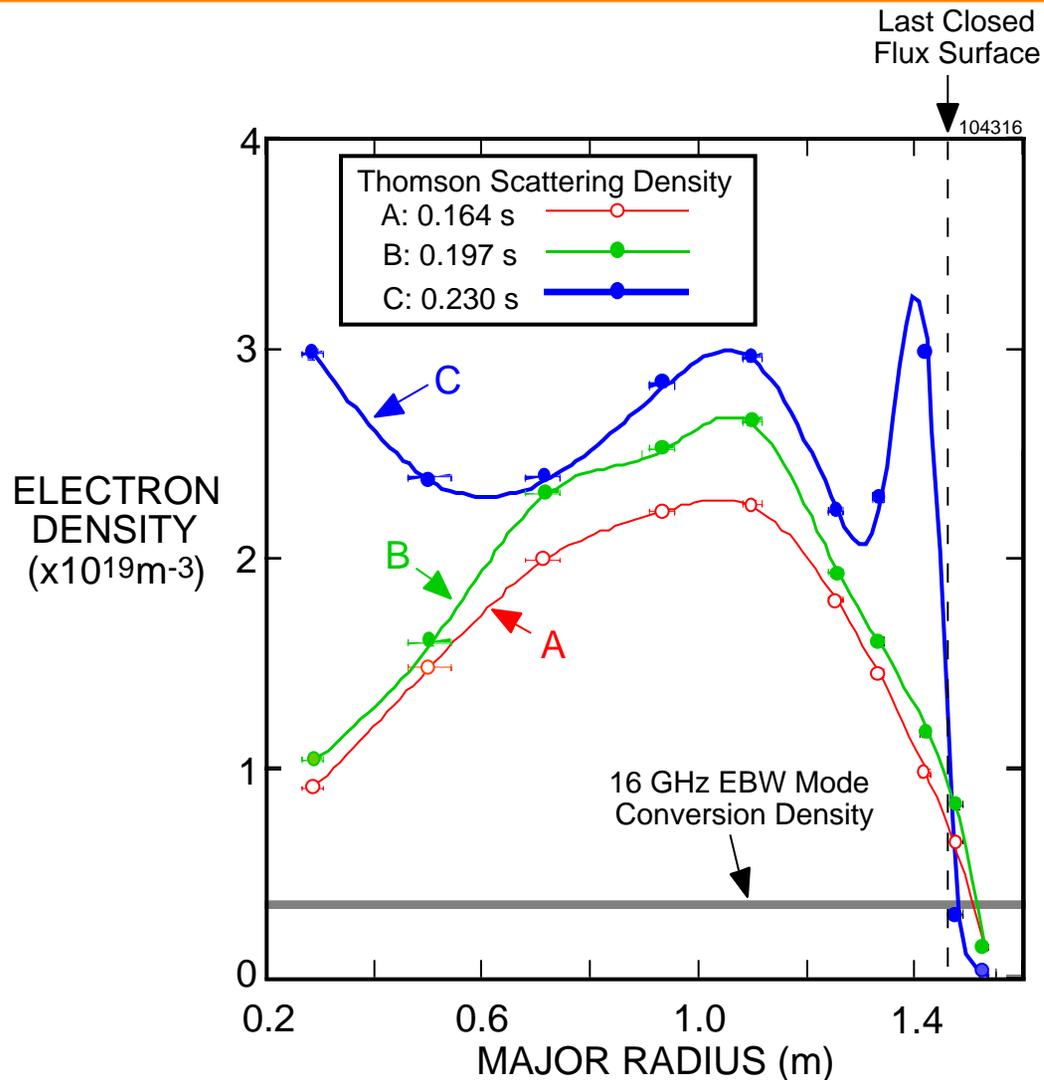# Gas Puffs Used to Determine Radial Localization of EBW Emission
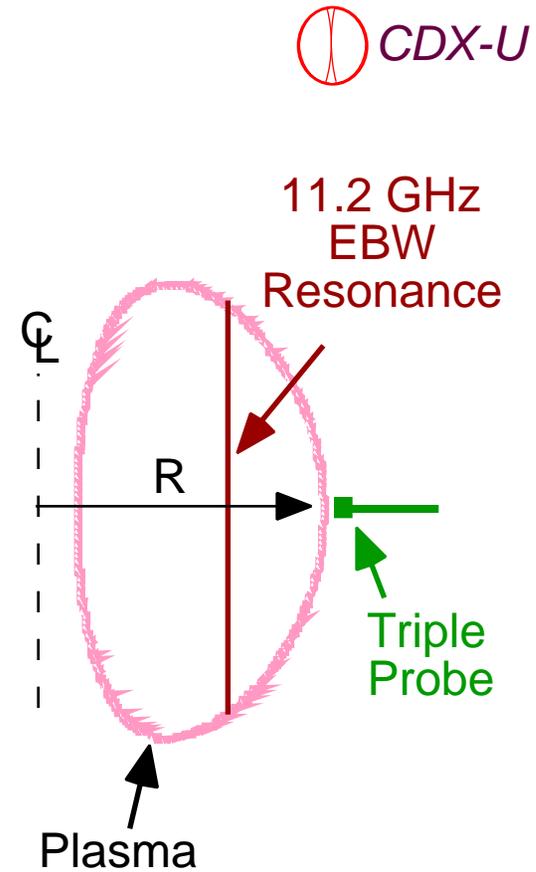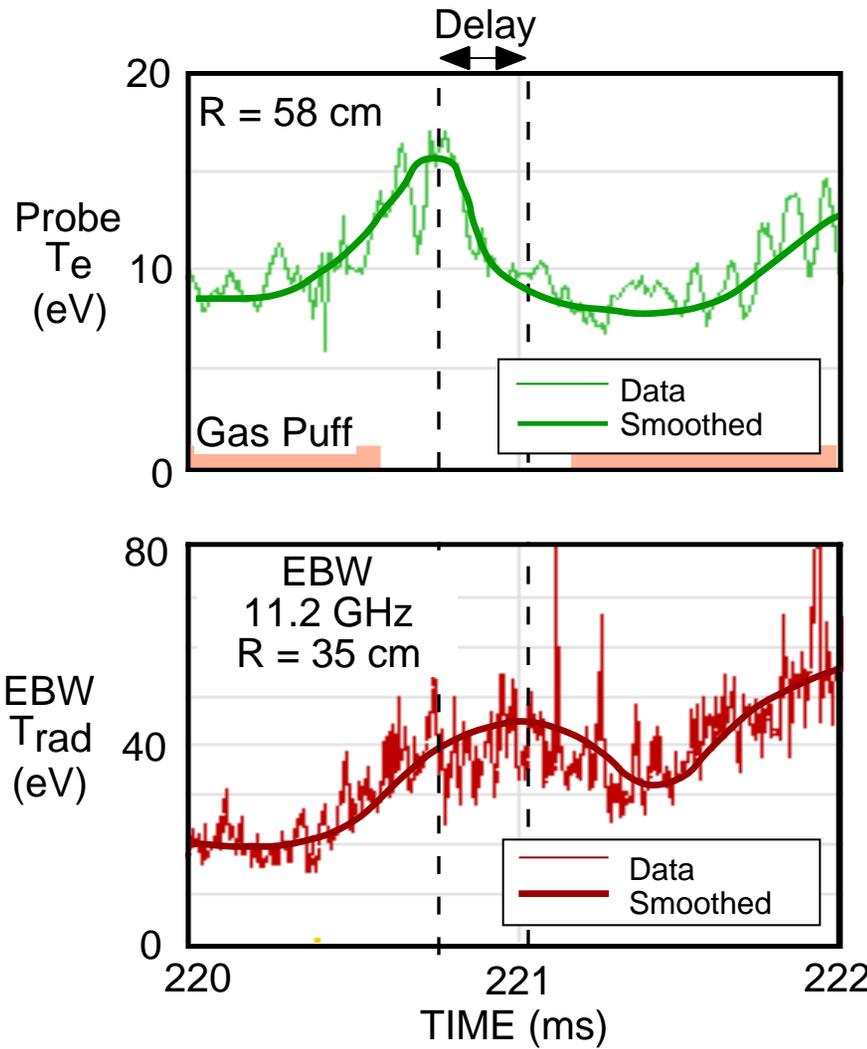
EBW Emission Source is Localized in Radius Allowing Study of Radial Diffusion
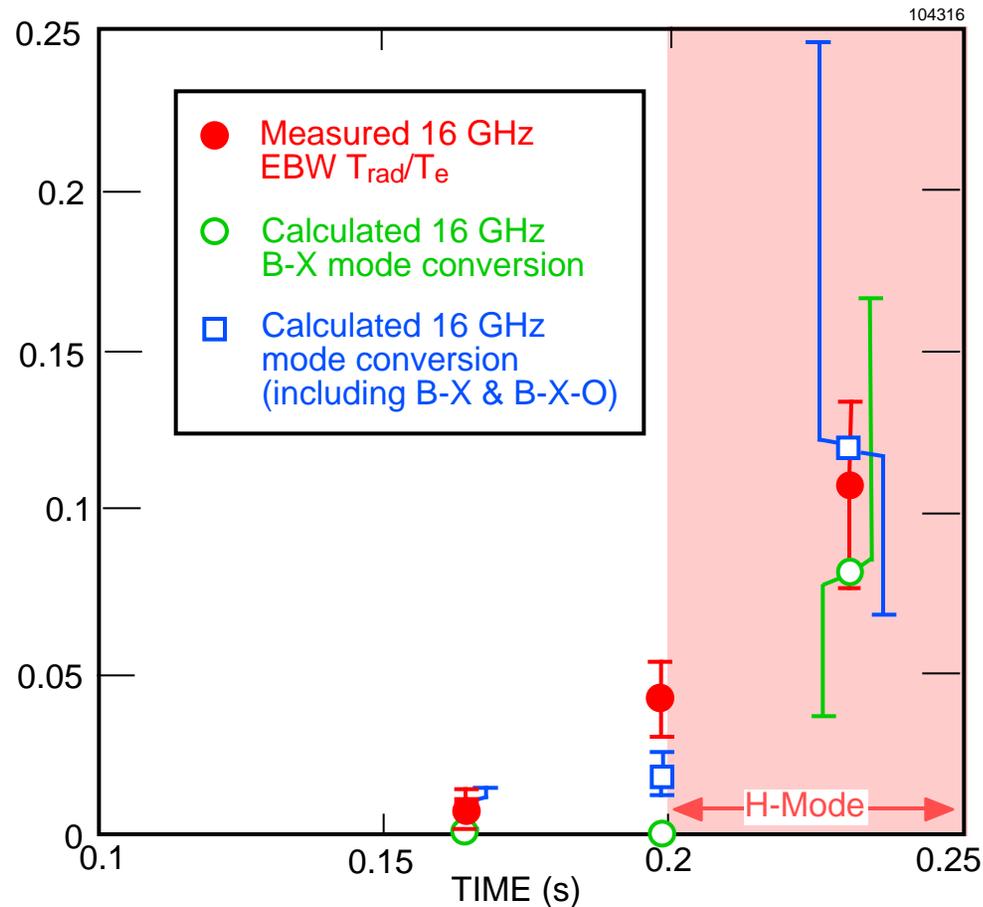
EBW Mode Conversion Efficiency Increases at L-H Transition when Edge Density Profile Steepens

Mode Conversion of Fundamental EBW Emission from Core Occurs in Scrape Off During H-Mode

Measured EBW Conversion Efficiency Agrees Relatively Well with Calculated Efficiency


- B-X-O mode conversion can contribute to measured emission if there is depolarization

# Measured EBW Mode Conversion Efficiency on CDX-U & NSTX is 10-20%

- Low conversion efficiency consistent with measured L_n

- Smaller L_n needed to achieve 100% conversion

PPPL

PRINCETON   PLASMA
PHYSICS LABORATORY

In-Vacuum EBW Antenna and Limiter to Optimize L_n for High Mode Conversion

CDX-U
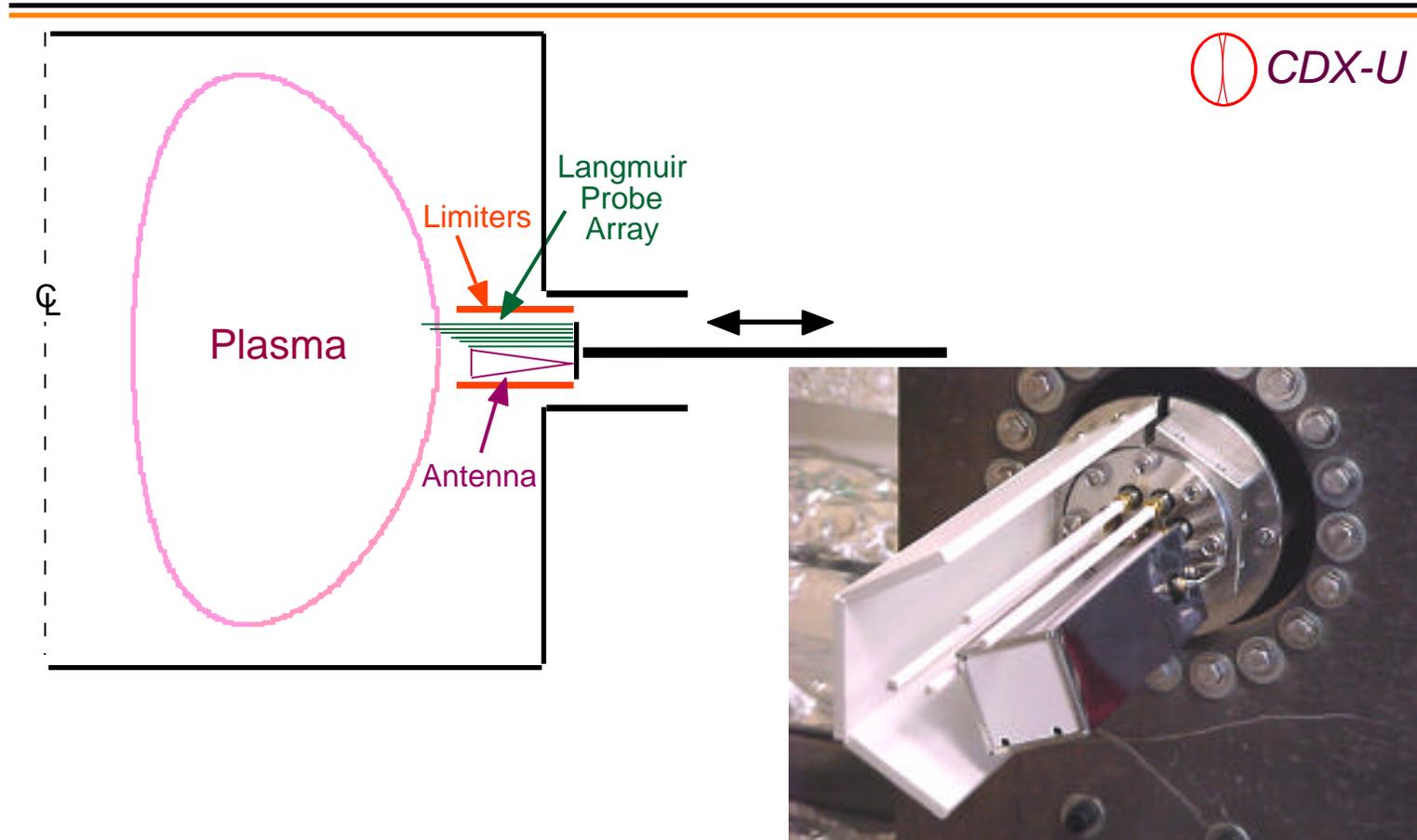
- Local limiters to define L_n in front of antenna

- Probes measure L_n and EBWs directly

PPPL
PRINCETON PLASMA
PHYSICS LABORATORY

Local Limiter Steepens L_n for High Mode Conversion Efficiency

CDX-U
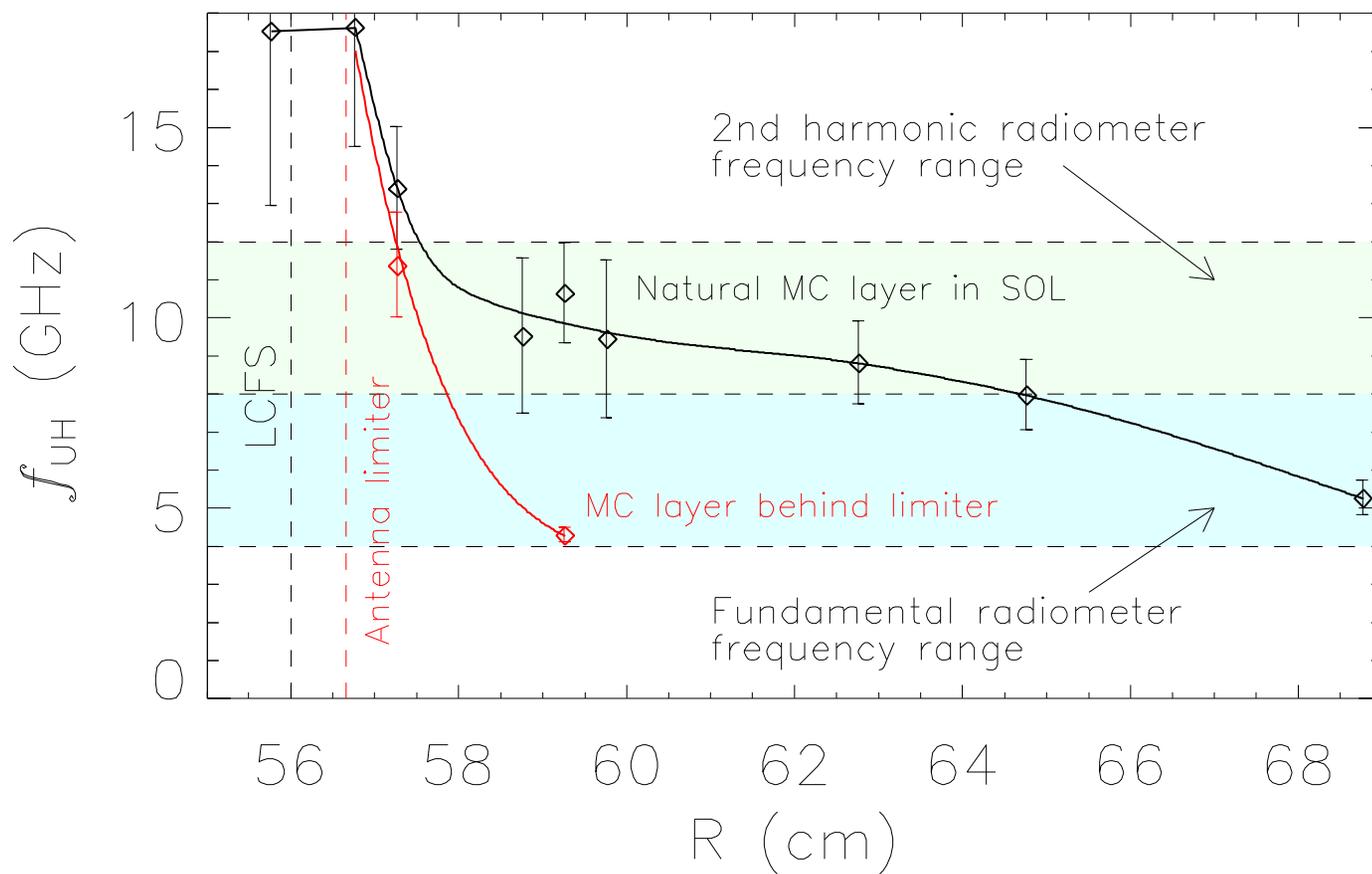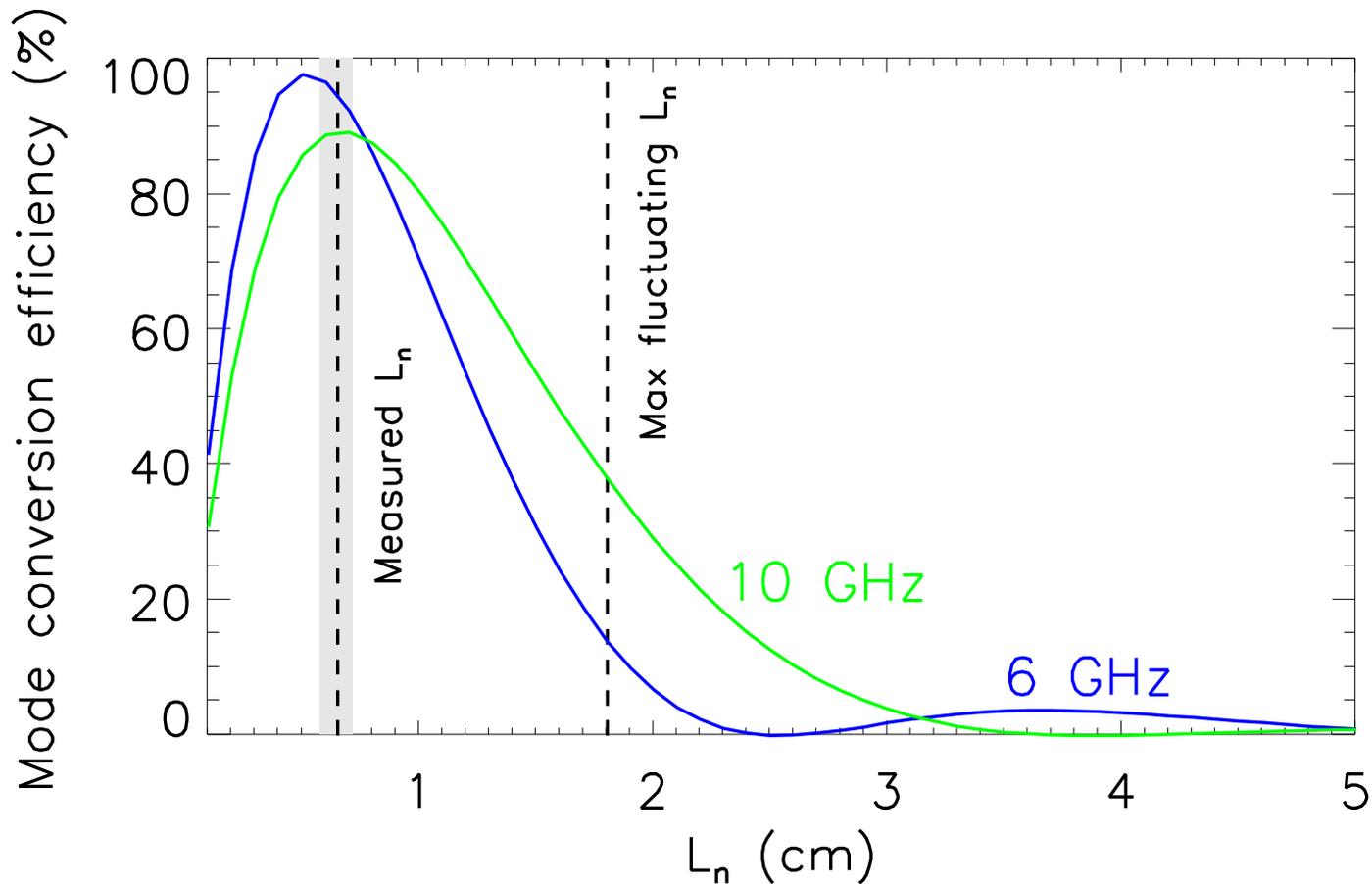
Achieved Order of Magnitude Increase in B-X Conversion to T_{rad}/T_e ~ 100% with Local Limiter
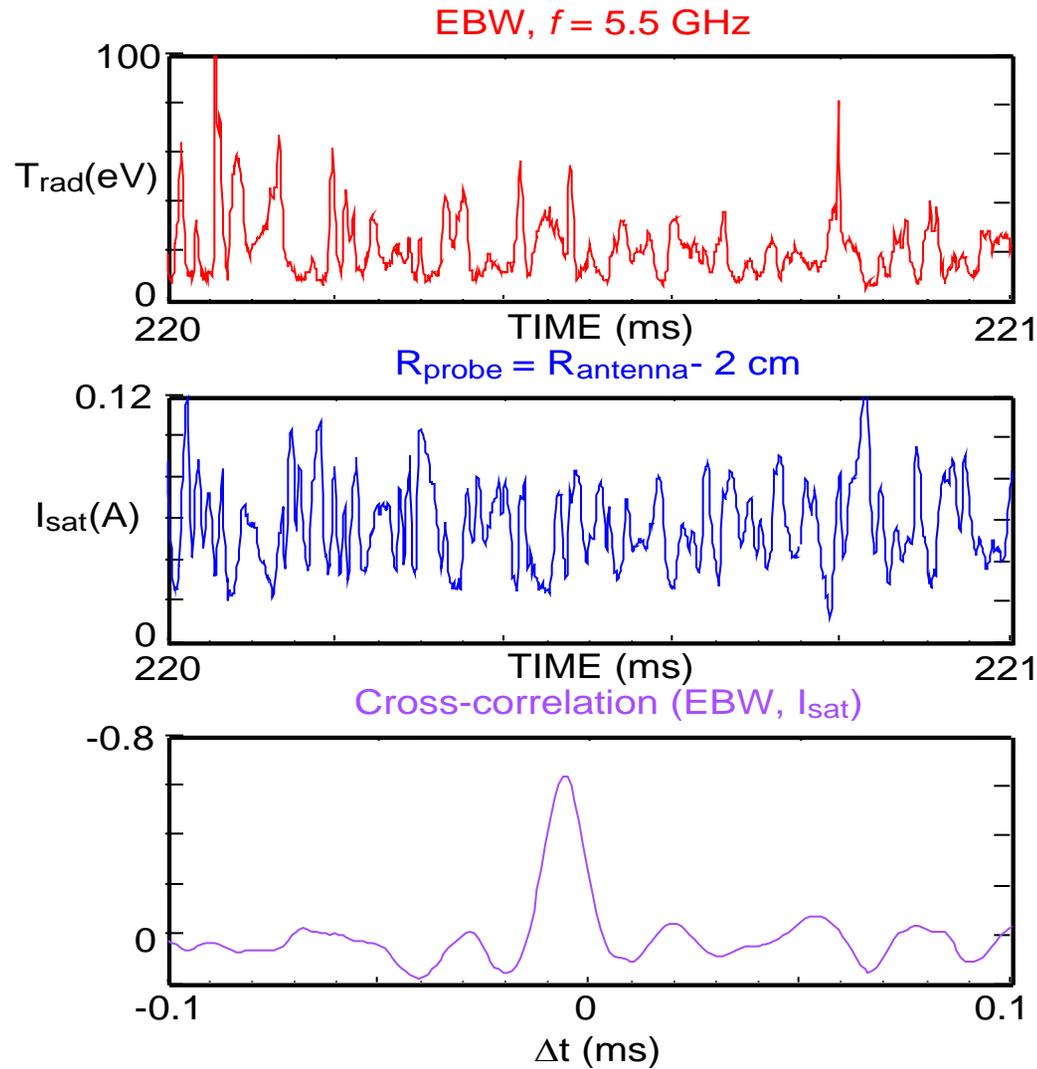
CDX-U
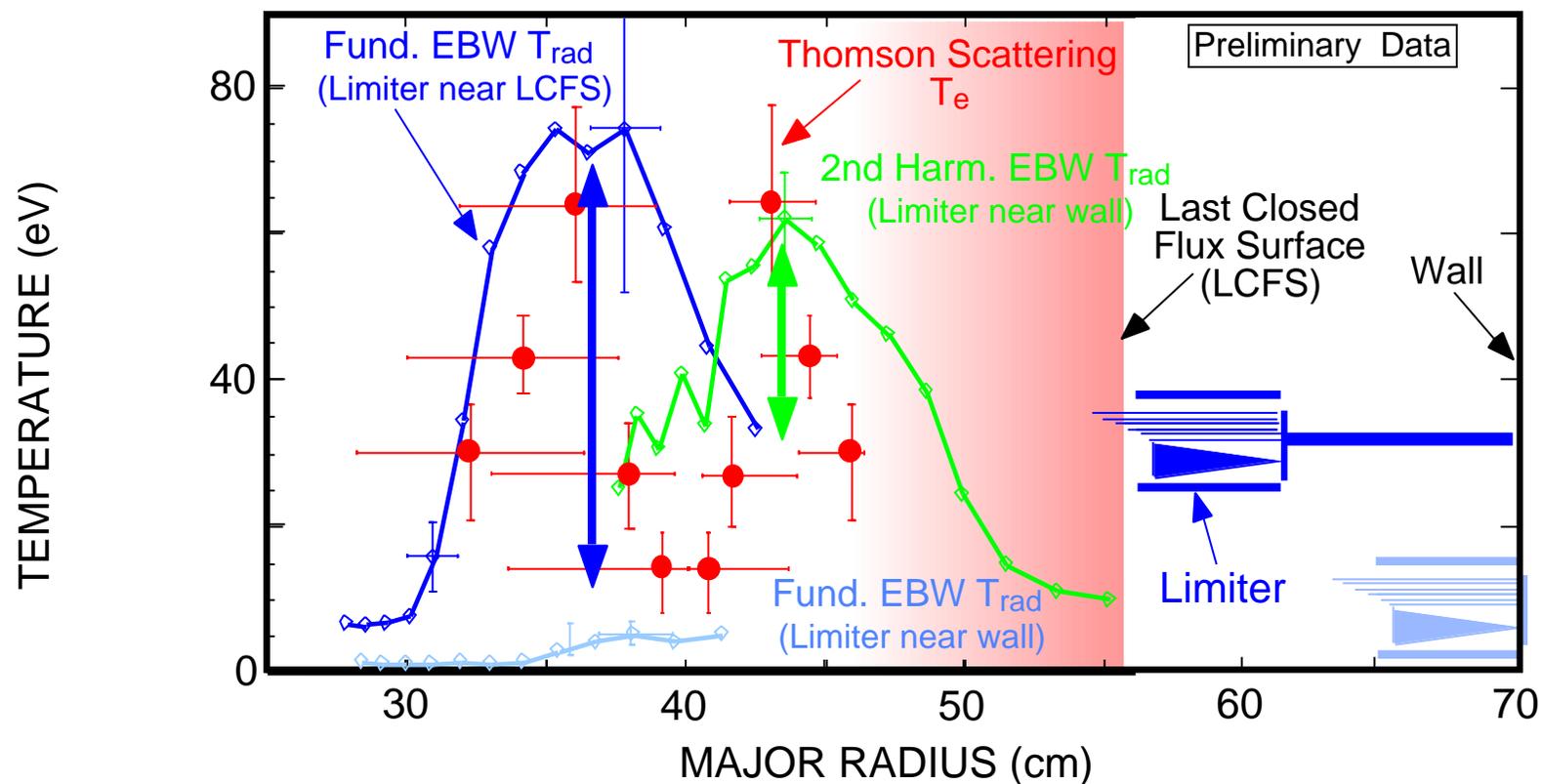
- Local limiter allows efficient coupling to EBWs for current drive and heating

PRINCETON PLASMA
PHYSICS LABORATORY

Relative Fluctuation Amplitude at 6 GHz and 10 GHz Consistent with Theory

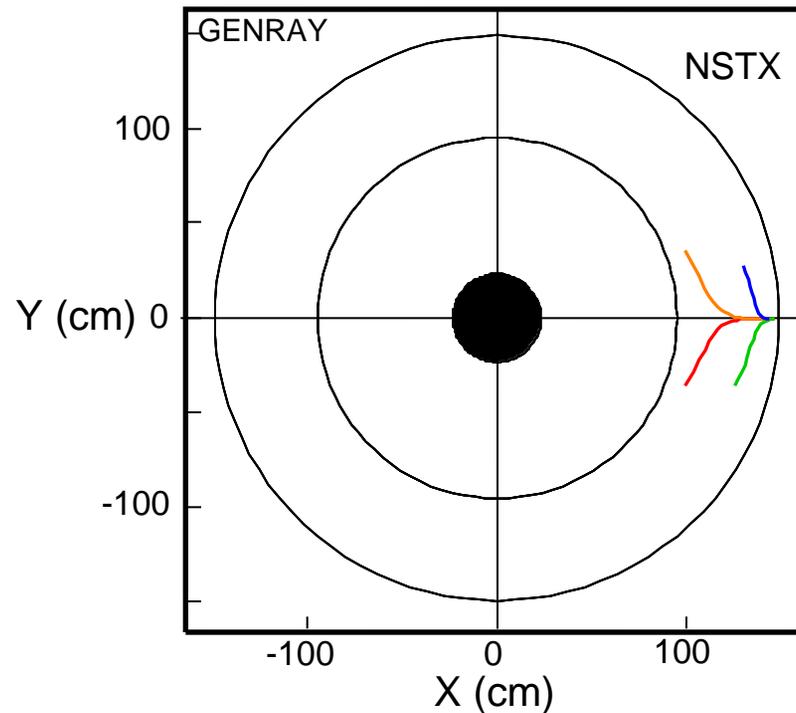# EBW T$_{rad}$ Fluctuations Correlate with Density Fluctuations Near Probe Limiter

EBW, f = 5.5 GHz

R$_{probe}$ = R$_{antenna}$ - 2 cm

Cross-correlation (EBW, I$_{sat}$)

PRINCETON PLASMA PHYSICS LABORATORY

EBW Heating and Current Drive Deposition
Changed via Poloidal Launch Angle and Frequency

GENRAY - *B. Harvey, CompX*

NSTX n$_{//}$=0 Launch

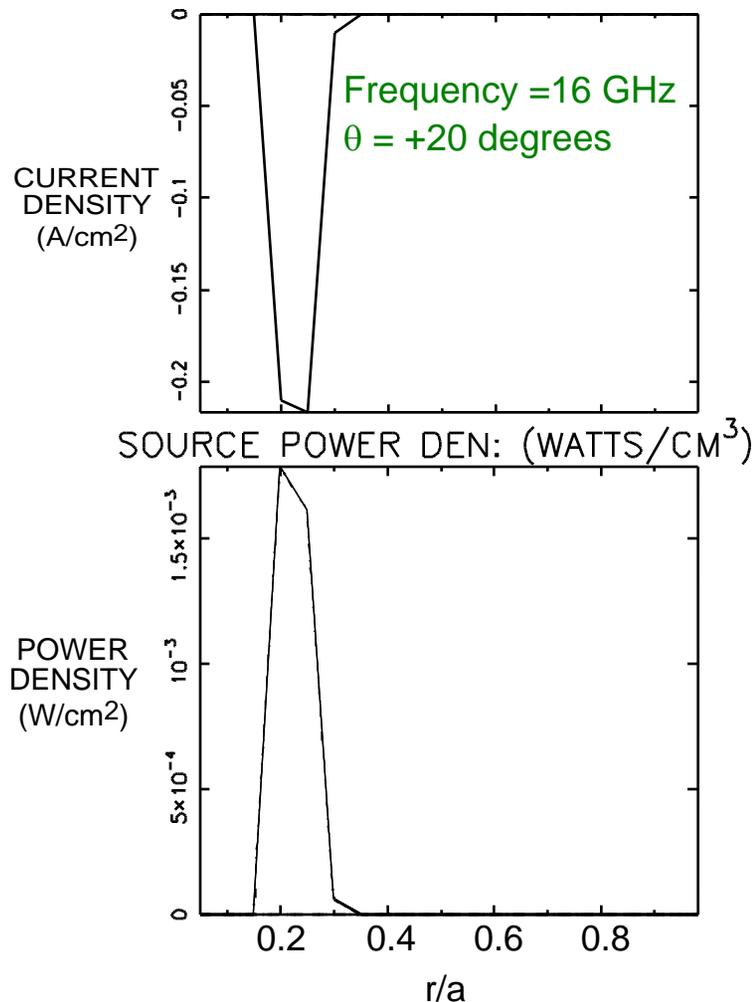f = 12 GHz, θ = + 20$^\text{o}$
f = 16 GHz, θ = + 20$^\text{o}$
f = 12 GHz, θ = - 20$^\text{o}$
f = 16 GHz, θ = - 20$^\text{o}$
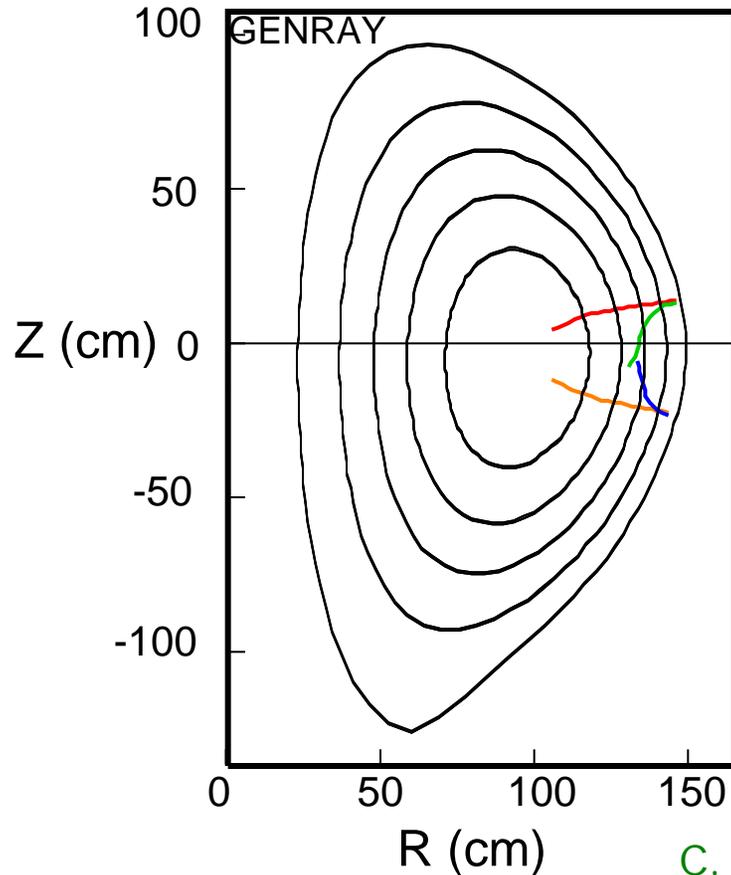
C. Forest *et al* , Phys. Plasmas **7**, 1352 (2000)

PPPL
PRINCETON PLASMA
PHYSICS LABORATORY

NSTX EBW Current Drive Efficiency ~ 0.1A/W for $n_e \sim 3 \times 10^{19} m^{-3}$ and 50% Mode Conversion Efficiency

FLUX SURF. AV. CURNT. (AMPS/CM^2)

total current = −0.215542E+03 Amps

Frequency =16 GHz

θ = +20 degrees

CURRENT DENSITY (A/cm2)

SOURCE POWER DEN: (WATTS/CM^3)

POWER DENSITY (W/cm2)

r/a

- Large absorptivity ensures localized current drive

- Current drive studied with CQL3D Fokker-Planck code

PPPL
PRINCETON PLASMA
PHYSICS LABORATORY

Summary

- EBW emission source radially localized, as expected

- Measured B-X conversion efficiency consistent with theory

- Initial data with limiter show order of magnitude increase in fundamental B-X conversion to $T_{rad}/T_e \sim 100\%$

- Mode-converted EBW emission data supports the viability of EBW heating and current drive

- CDX-U EBW current drive experiments to begin this year

PPPL
PRINCETON   PLASMA
PHYSICS LABORATORY