Status of Electron Bernstein Wave (EBW) Research on NSTX and CDX-U

Presented by

Gary Taylor

Plasma Physics Laboratory, Princeton University

In collaboration with

P.C. Efthimion, B. Jones, J.R. Wilson

Plasma Physics Laboratory, Princeton University

J.B. Wilgen, G.L. Bell, T.S. Bigelow, D.A. Rasmussen

Oak Ridge National Laboratory

A.K. Ram, A. Bers

Plasma Science and Fusion Center, Massachusetts Institute of Technology

R.W. Harvey

CompX, Del Mar, California

44th American Physical Society, Division of Plasma Physics Meeting

Orlando, Florida

November 11-15, 2002

PPPL PRINCETON PLASMA PHYSICS LABORATORY

EBWs May Enable Local Heating, Current Drive and $T_e(R,t)$ Measurements on ST Plasmas

- Electron cyclotron heating, CD and radiometry not viable for spherical torus (ST) plasmas, where $\omega_{pe} >> \omega_{ce}$
- EBWs propagate when $\omega_{pe} >> \omega_{ce}$ and strongly absorb at EC resonances, allowing EBW heating, CD and radiometry in STs
- Local EBW heating and CD are potentially important for non-inductive startup and MHD suppression in an ST
- EBWs can couple to electromagnetic waves near the upper hybrid resonance (UHR) that surrounds ST plasmas

PPPL
PRINCETON PLASMA PHYSICS LABORATORY

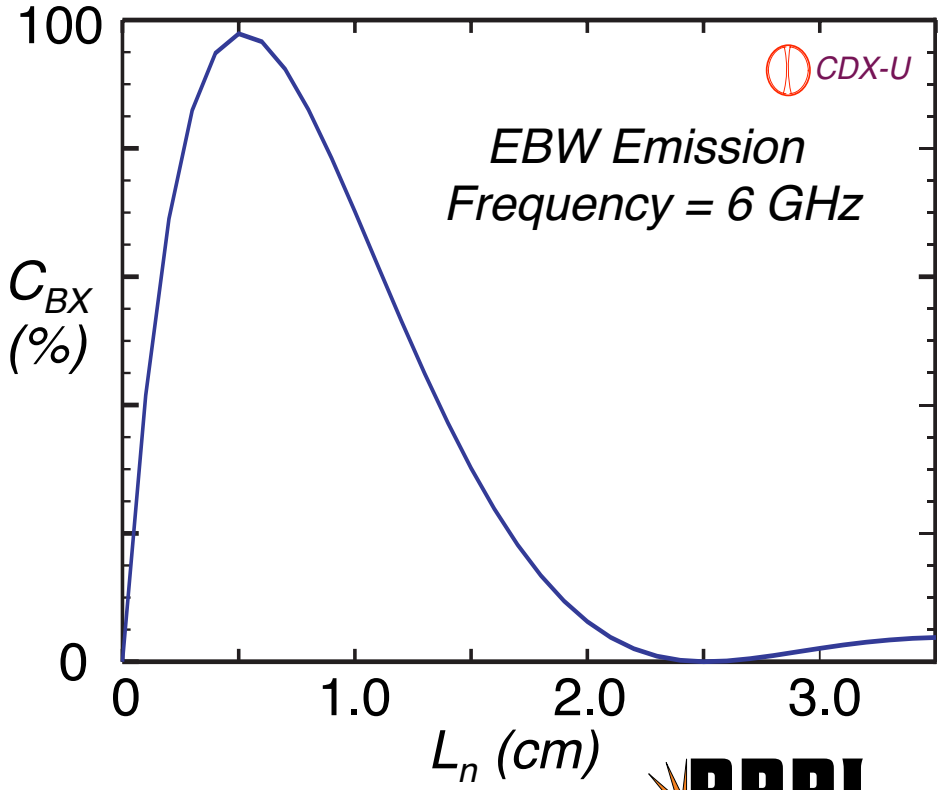
EBW Experiments on CDX-U and NSTX Have Focused on Maximizing EBW Conversion to X-Mode (B-X)

- If L_n is short at the UHR, EBWs tunnel to the fast X-mode:

$$C_{BX} = 4e^{-\pi\eta}(1-e^{-\pi\eta})\cos^2(\phi/2 + \theta), \quad \eta \propto L_n$$

- Measurement of B-X emission evaluates the efficiency of the X-B process for heating and current drive

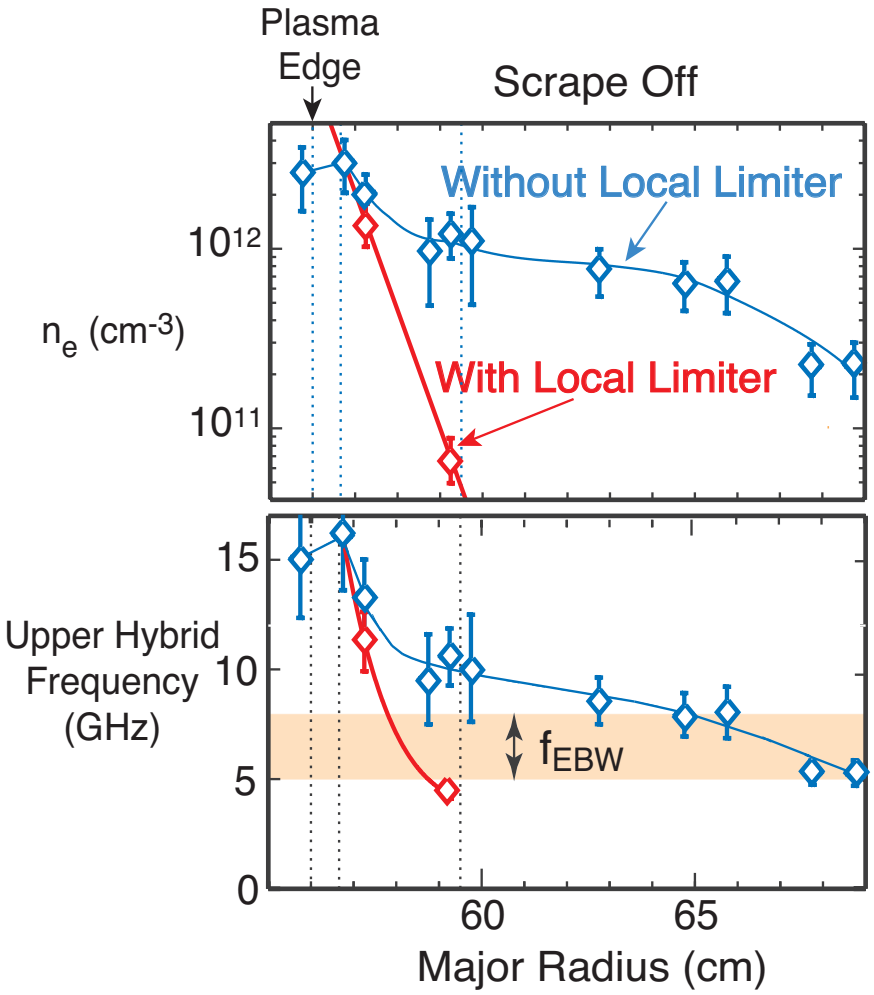
- Mode conversion to the O-mode (B-X-O) also possible; studied on W-7AS and MAST



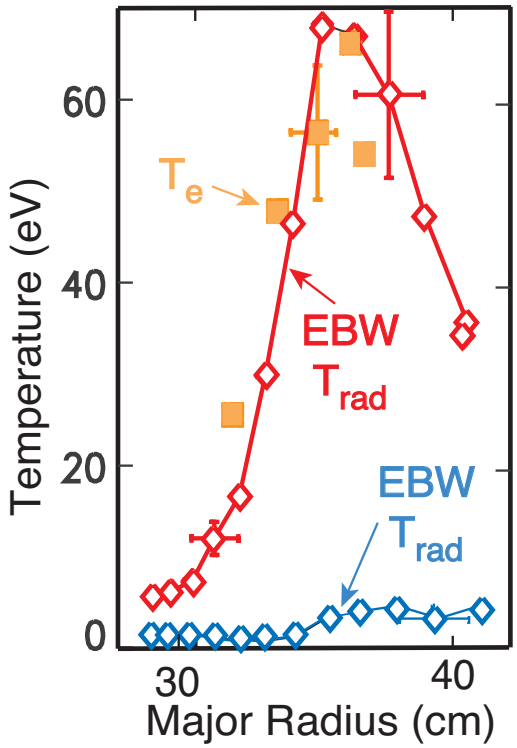
PPPL
PRINCETON PLASMA PHYSICS LABORATORY

On CDX-U, Limiter Shortened L_n to 0.7cm, Increasing C_{BX} to > 95%, in Good Agreement with Theory

CDX-U



Poster KP1.098 on Wednesday morning for more CDX-U results



PPPL PRINCETON PLASMA PHYSICS LABORATORY

Need C_{BX} > 80% for Viable EBW Heating and Current Drive System on NSTX

NSTX

- Measured C_{BX} < 5% for NSTX L-Mode plasmas, 10-15% during H-Modes

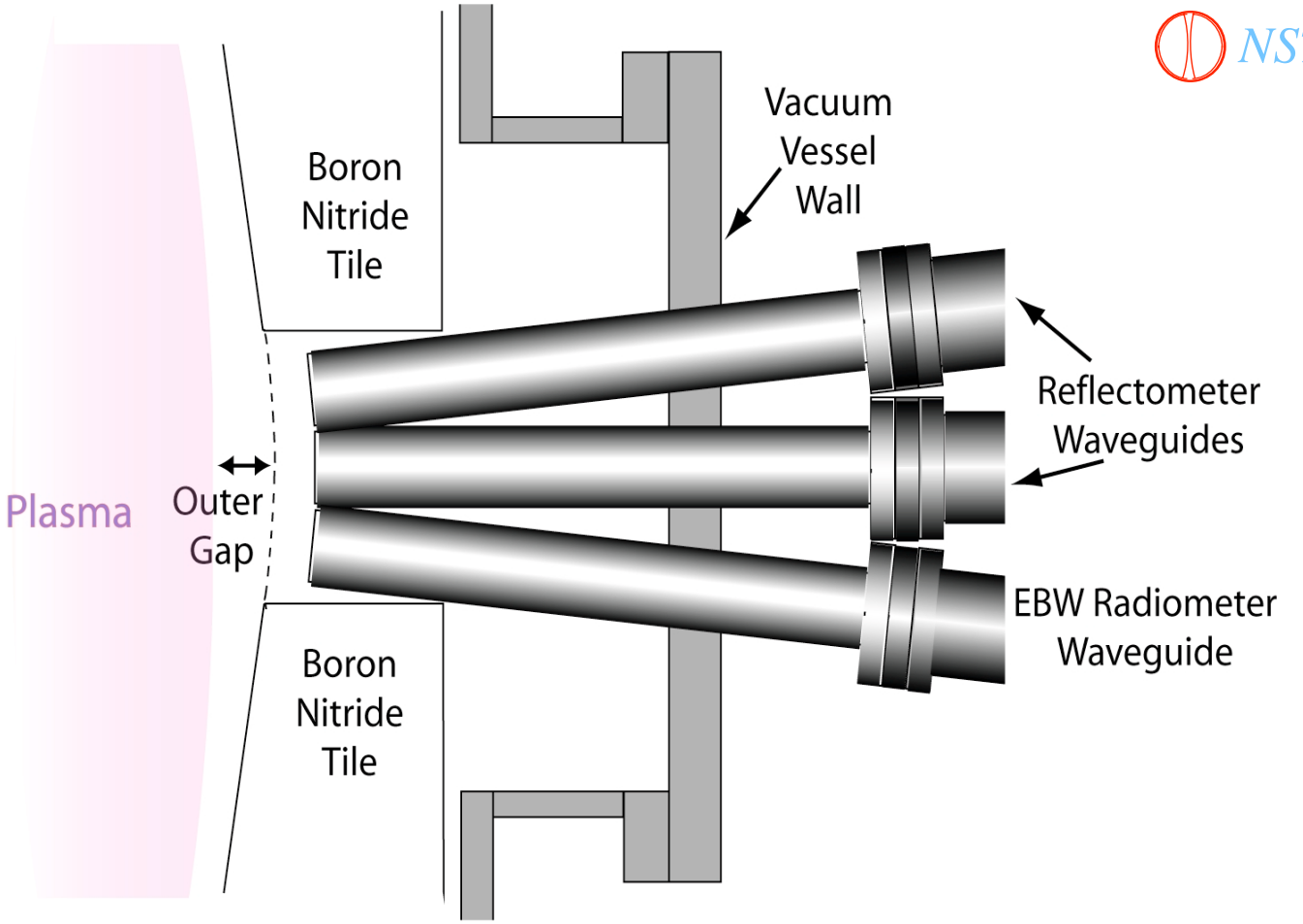
- Reproduce CDX-U experiments with local limiter on NSTX next year, for both B-X and B-X-O conversion

- Results from experiment on NSTX using HHFW antenna tiles to shorten L_n this year were very encouraging:

  - achieved $C_{BX} \leq 50\%$

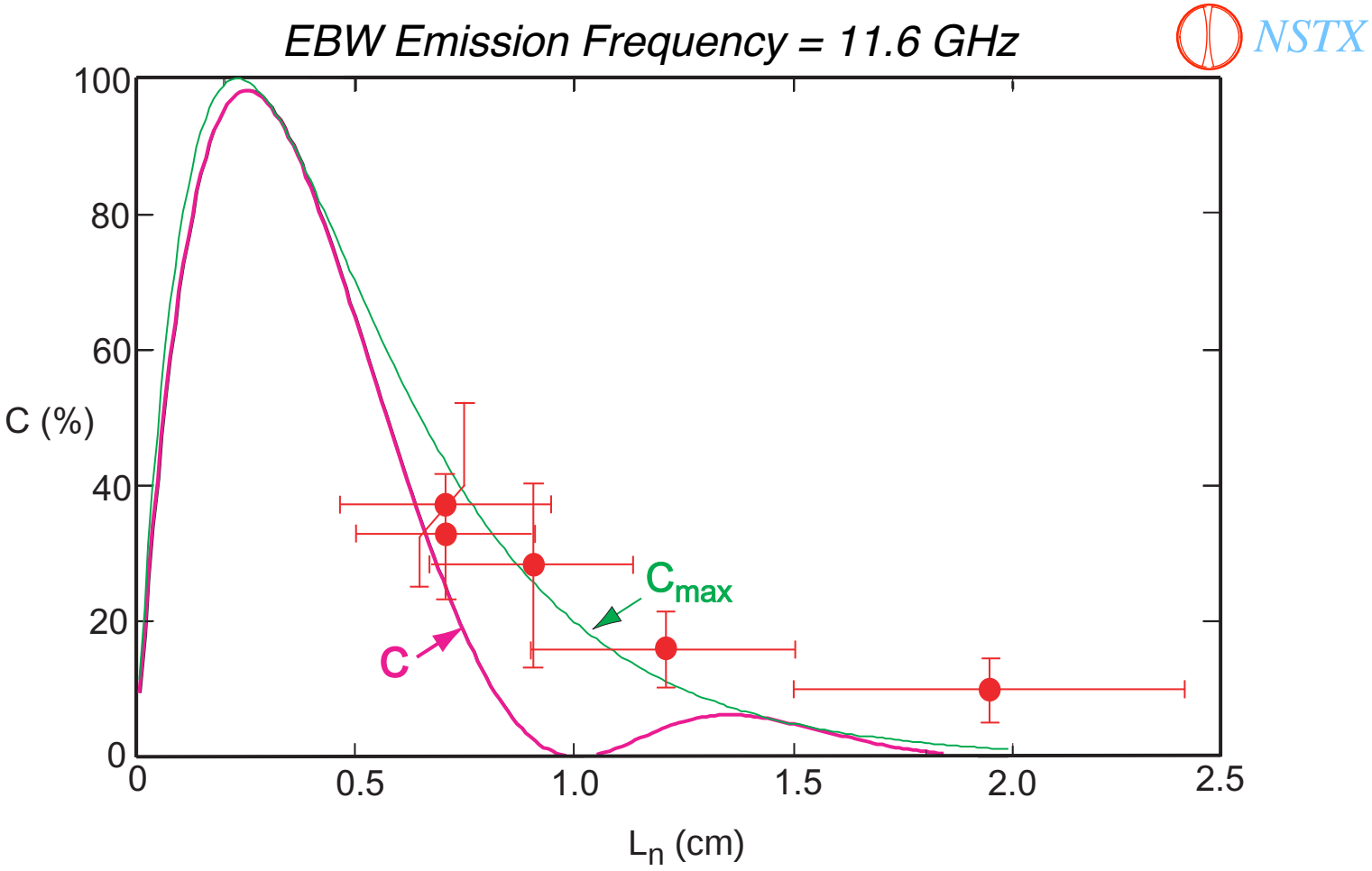
PPPL PRINCETON PLASMA PHYSICS LABORATORY

Increased C_{BX} by Using Tiles in HHFW Antenna as Local Limiter to Shorten L_n at UHR and Increase C_{BX}



- Measure L_n with X-Mode Reflectometer

C_{BX} Increased from 10% to 50% as L_n Shortened from 2 to 0.7 cm, Agreeing with Theory



- Will attempt similar experiment with O-Mode antenna next year

EBW Heating and Current Drive May Optimize Equilibrium for High β Plasmas by Suppressing MHD

NSTX

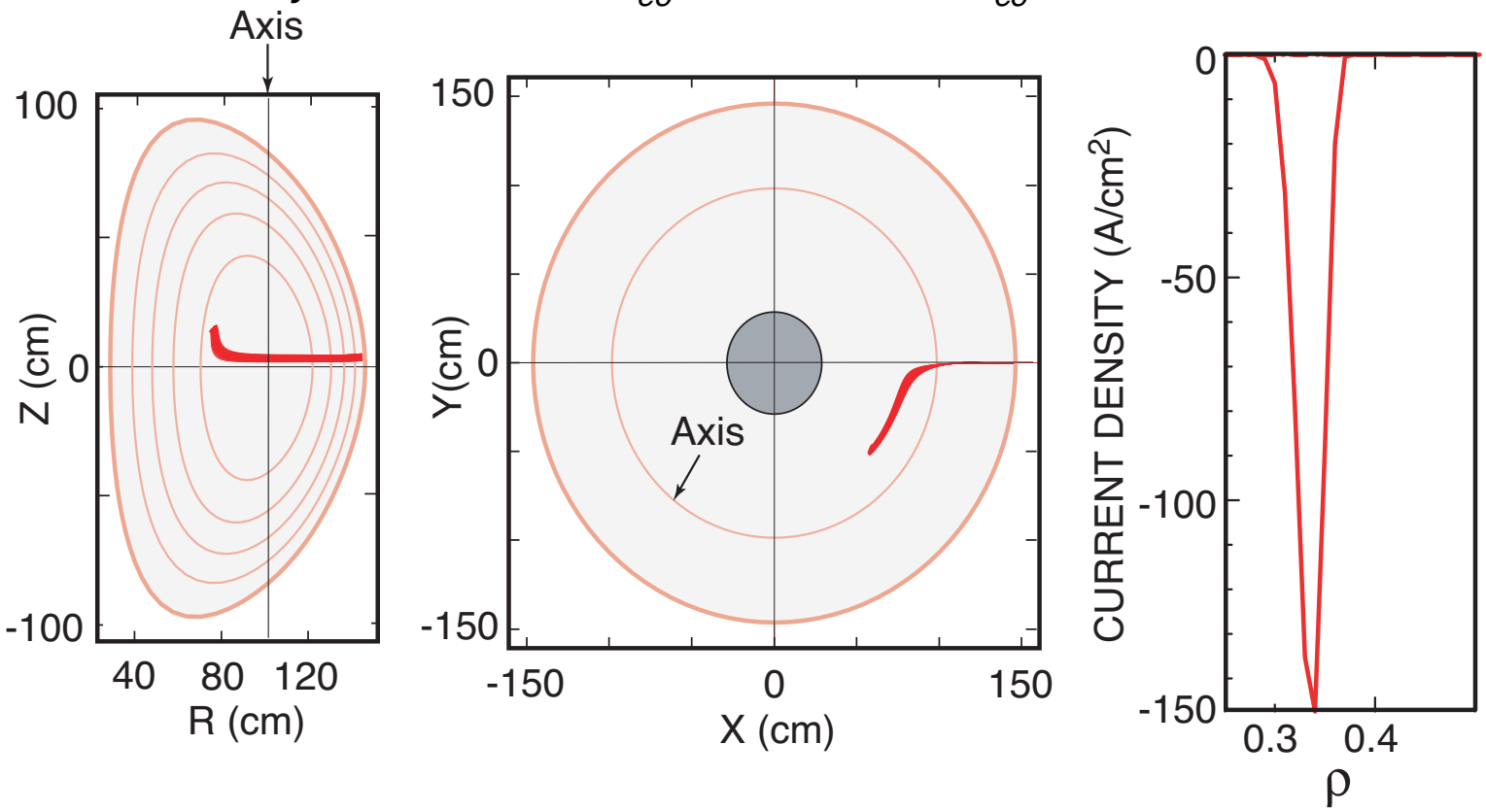
- Trapped particle effects make high field side (HFS) EBW power deposition more attractive
- Greatest access to HFS for fundamental EBW frequencies
- EBW heating and current drive modeling with GENRAY ray tracing and CQL3D bounce-averaged Fokker-Planck codes

CompX ORNL Oak Ridge National Laboratory PPPL Princeton Plasma Physics Laboratory

In β ~ 20% NSTX Plasma, EBWCD Efficiency Comparable to ECCD and Very Localized

1 MW 14.5 GHz RF at 5° above mid-plane, -0.1 < $n_{//}$ < 0.1

CD efficiency = 0.065 A/W, n_{eo} = 3x10^{19} m^{-3}, T_{eo} = 1keV



- CD localization supports requirements for NTM suppression

Summary

- Limiter in CDX-U scrape-off shortened L_n to increase C_{BX} from ~10% to > 95%
- Similar technique on NSTX shows a five-fold increase in C_{BX} to ~ 50% ; Limiter can also widen B-X-O transmission window
- Measured C_{BX} are in good agreement with theoretical predictions that use measured L_n on both CDX-U and NSTX
- EBWCD modeling of NSTX β ~ 20% plasma, shows good localization, suitable for NTM suppression, and CD efficiencies at least as good as ECCD
- Next year will attempt to achieve C_{BX} and C_{BXO} > 80% as a prerequisite to installing ~ 1 MW EBW heating system

PPPL
PRINCETON PLASMA PHYSICS LABORATORY