Ray Tracing Studies of HHFW Propagation and Damping in NSTX

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Parasitic damping of HHFW in the edge regions may degrade core heating efficiency

- **Launched waves may dump power onto vessel structures**
  - Use analytic cold plasma models to estimate onset density for propagation and exit angle of waves from launcher
    - Compare HHFW regime to conventional ICRF on C-Mod and ITER
  - Use GENRAY to follow direction of power flow of launched waves
    - Cold plasma model used for propagation

- **Core heating efficiency observed to depend on the launched $k_{//}$**
  - Use GENRAY to estimate a spatially averaged value for the single pass absorption rate
    - Approximate hot plasma model used for absorption

"Typical" scenario parameters used for comparisons of NSTX to ITER and C-Mod

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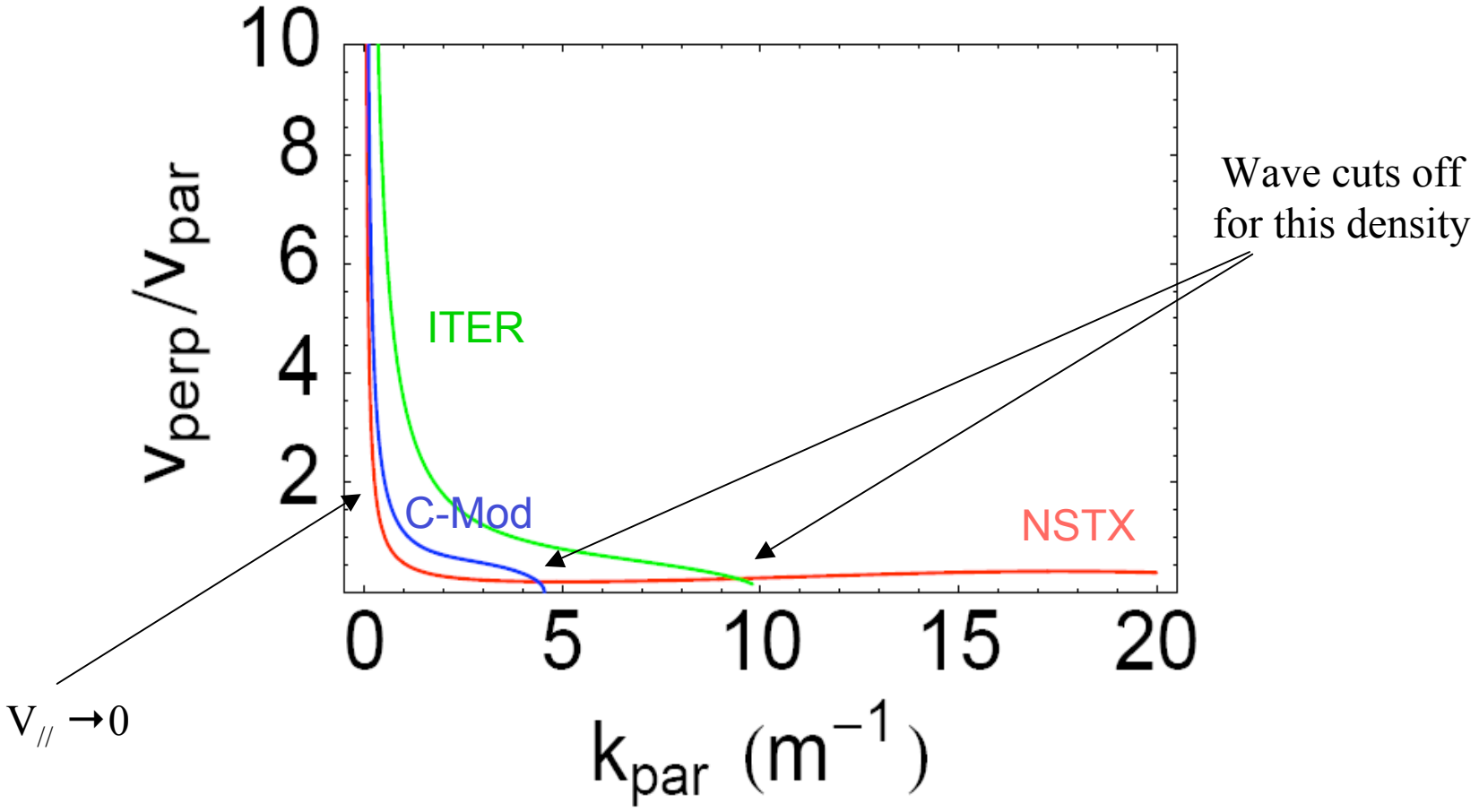
NSTX: D plasma; f = 30 MHz; $B_{edge} \sim 0.3$T; and $n_{edge} \sim 5 \times 10^{18}$ m^{-3}

ITER: D-T plasma; f = 53 MHz; $B_{edge} \sim 4$ T; and $n_{edge} \sim 6.5 \times 10^{18}$ m^{-3}

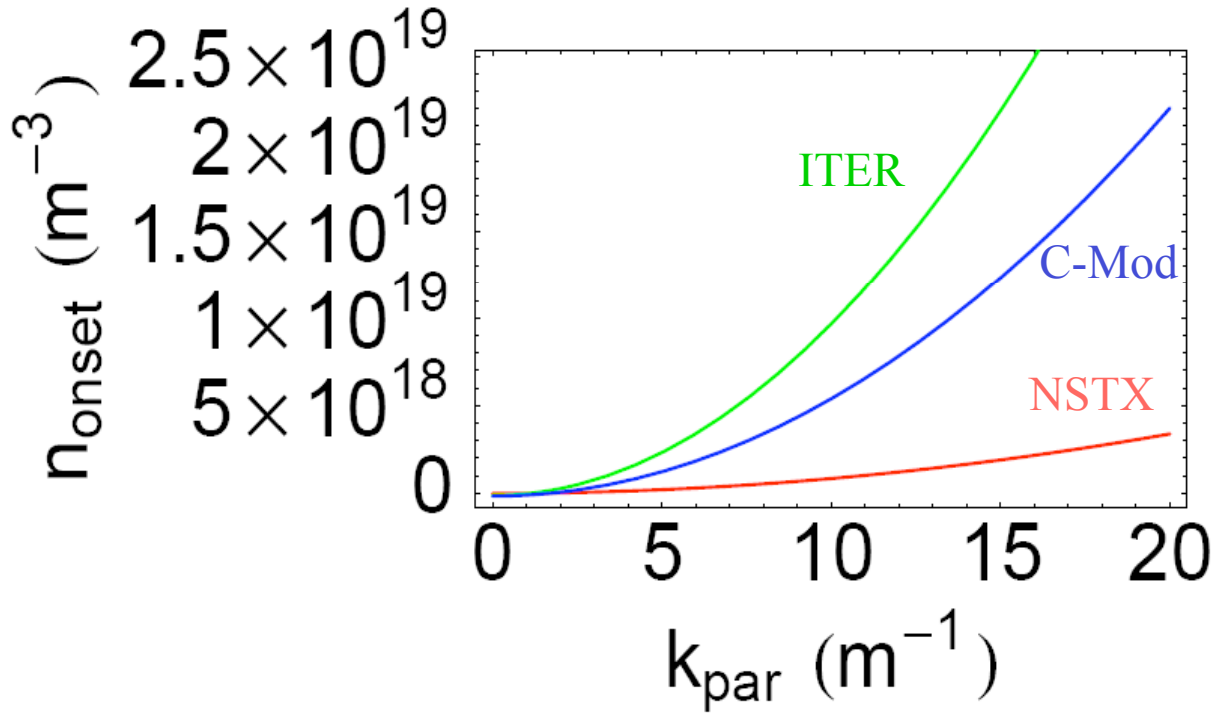
C-Mod: D(H) plasma; f = 80 MHz; $B_{edge} \sim 4$ T; and $n_{edge} \sim 10^{18}$ m^{-3}

Launched HHFW in NSTX travel more obliquely than conventional ICRF waves in C-Mod or ITER



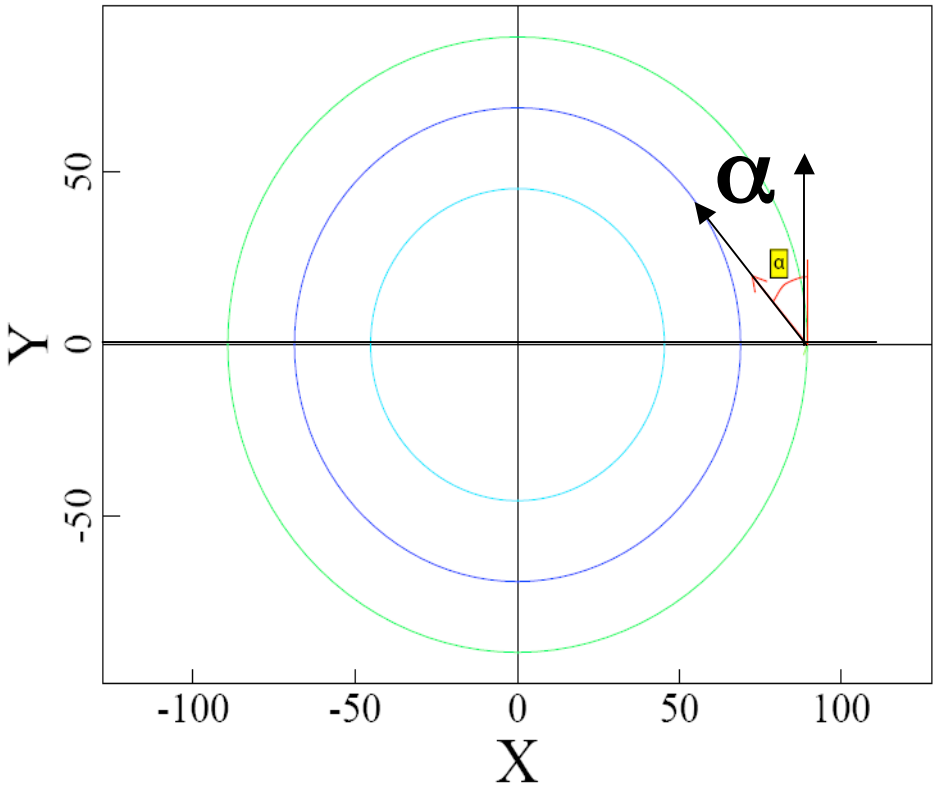
Evaluated with edge density and edge magnetic field

Onset density for propagation is lowest for the HHFW regime on NSTX

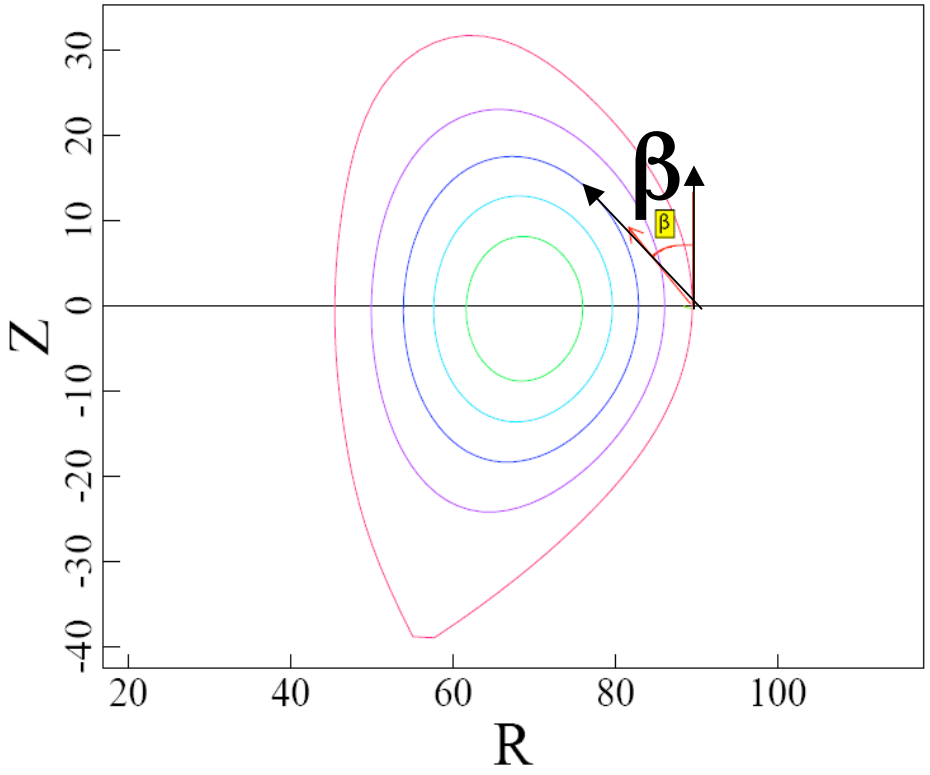


Onset density calculated from $n_{||}^2 = R$ with $n_{\perp}^2 = 0$

Exit angles of rays defined with respect to the toroidal (α) and poloidal (β) directions



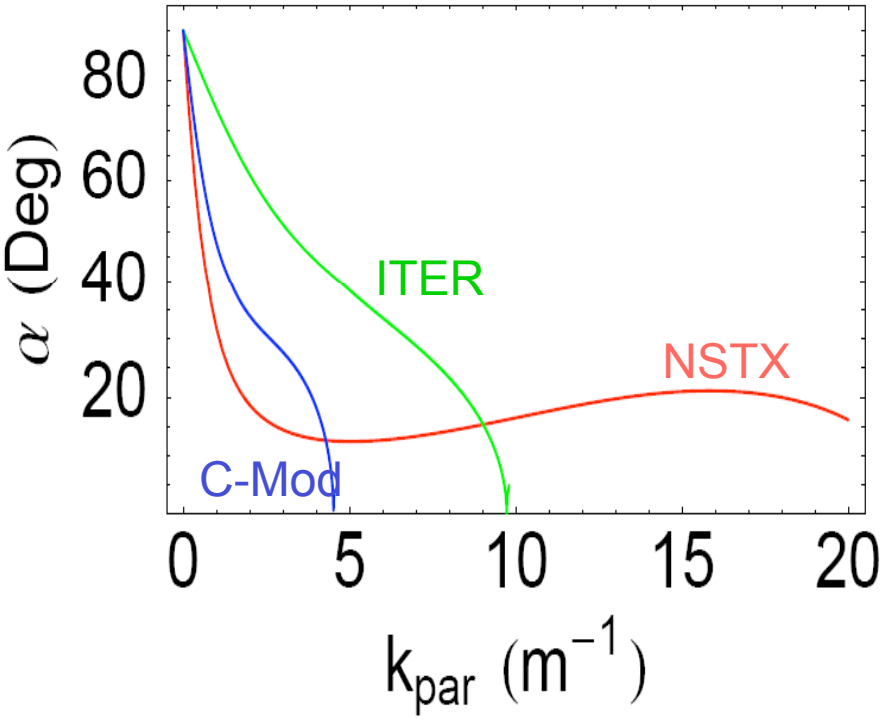
Toroidal view



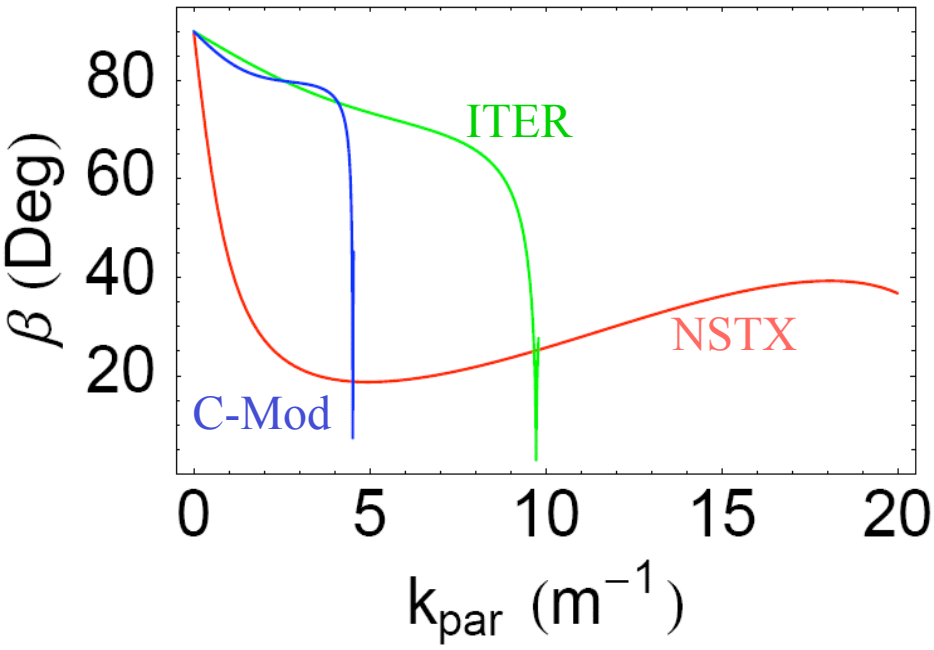
Poloidal view

For fixed edge density and B, the HHFW in NSTX are launched more obliquely than in C-Mod an ITER

Toroidal view

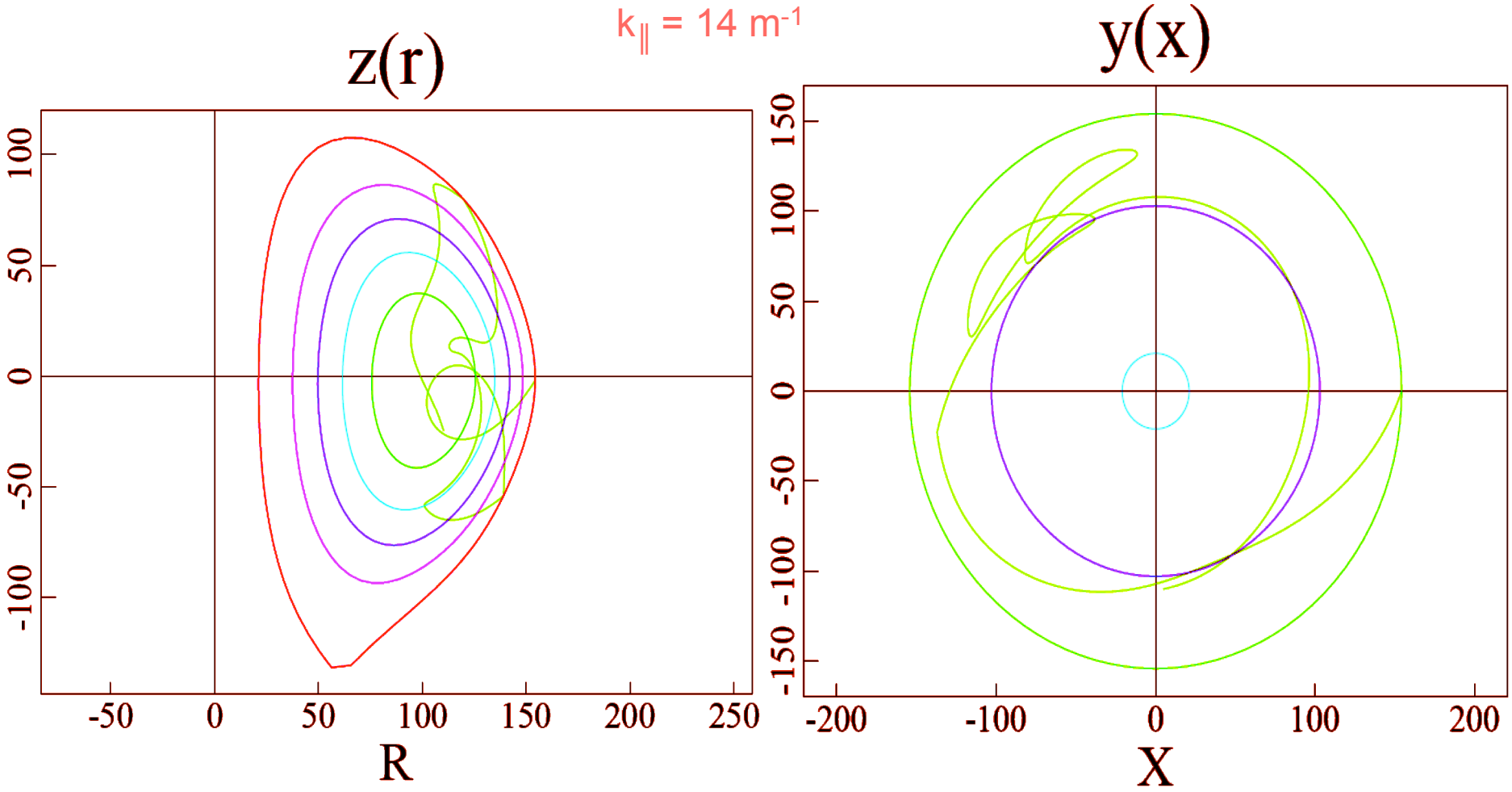


Poloidal view



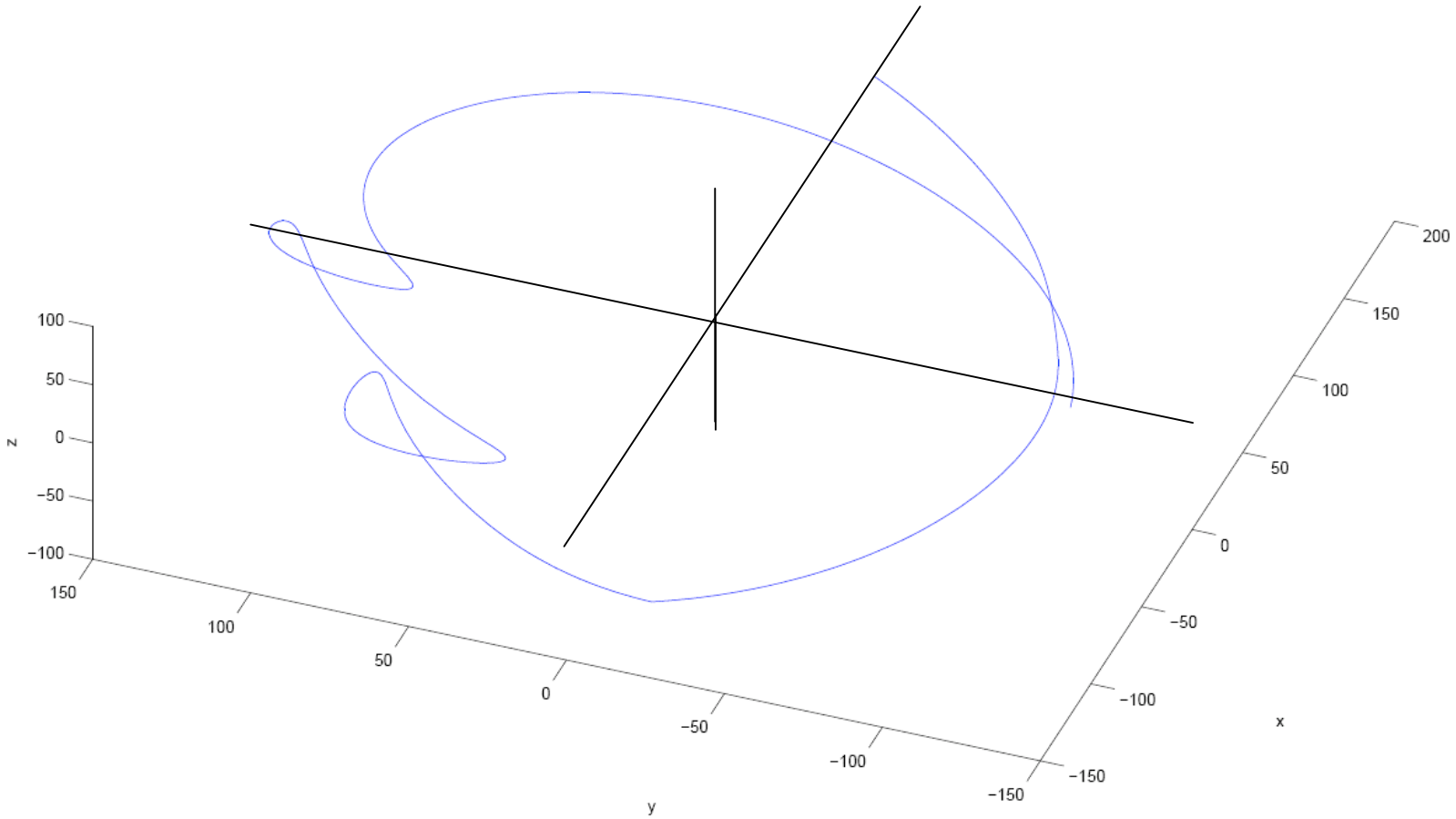
Future work: study propagation as function of edge density for fixed $k_{||}$

GENRAY confirms that launched HHFW in NSTX travel obliquely with respect to the vessel

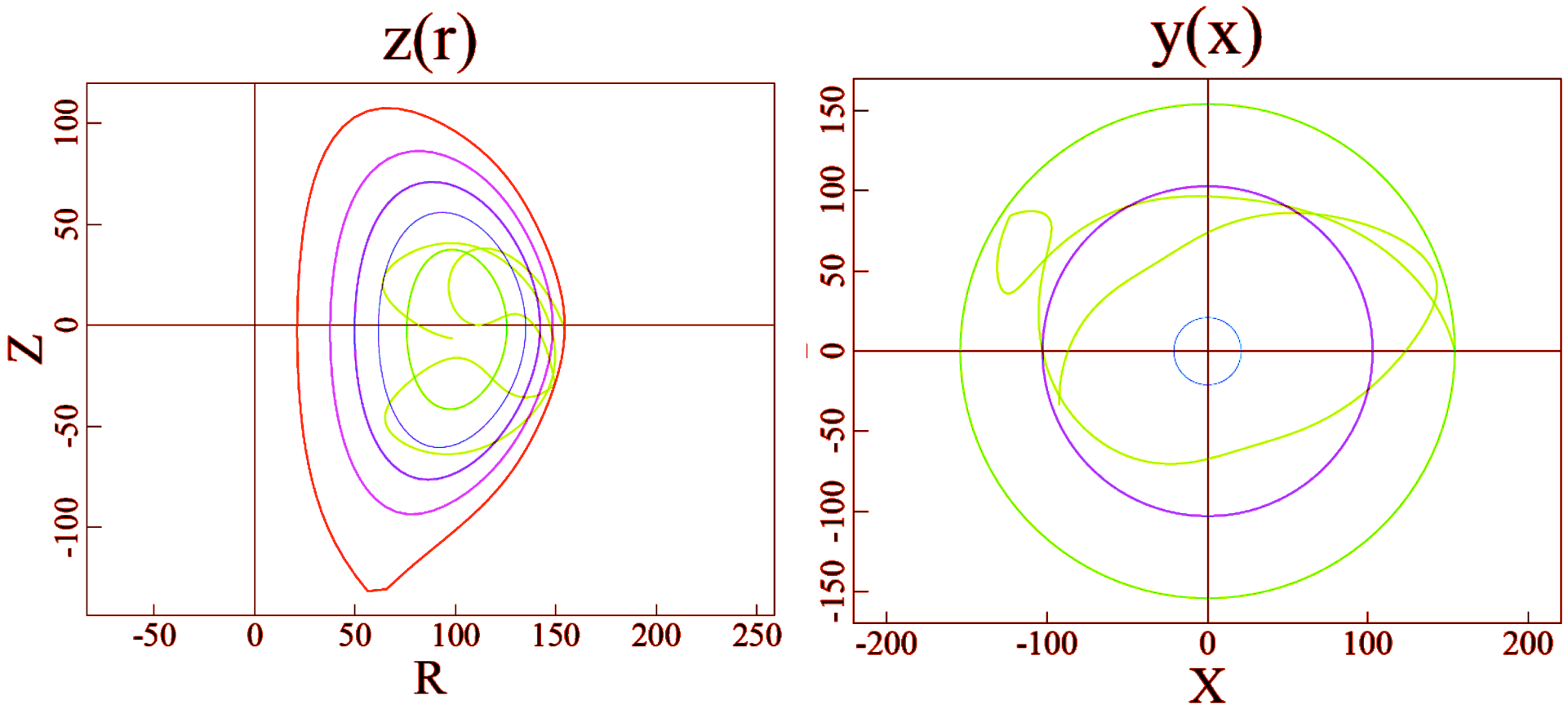


Toroidal extension of rays consistent with AORSA 3D field reconstructions

Ray travels all around torus for 14 m^{-1} case

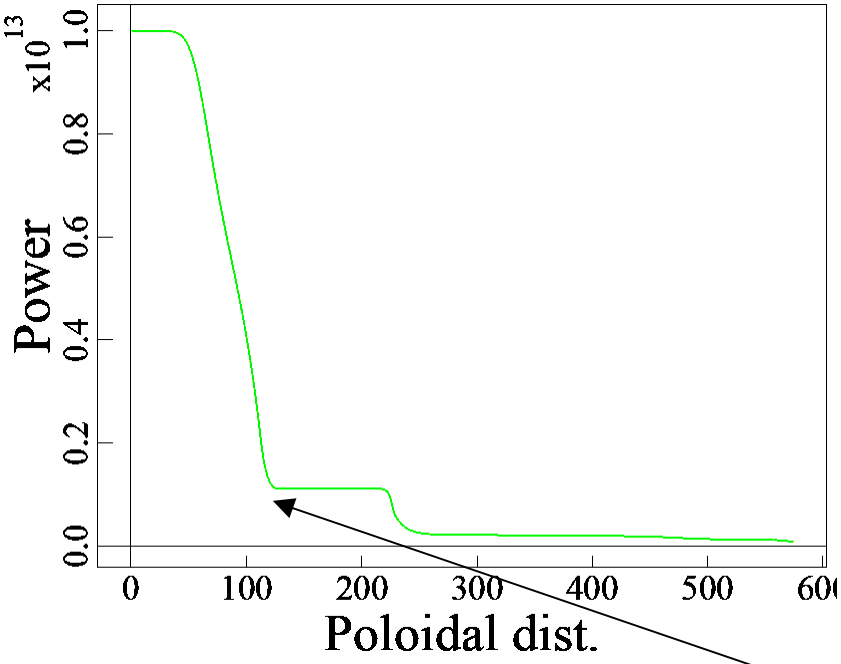


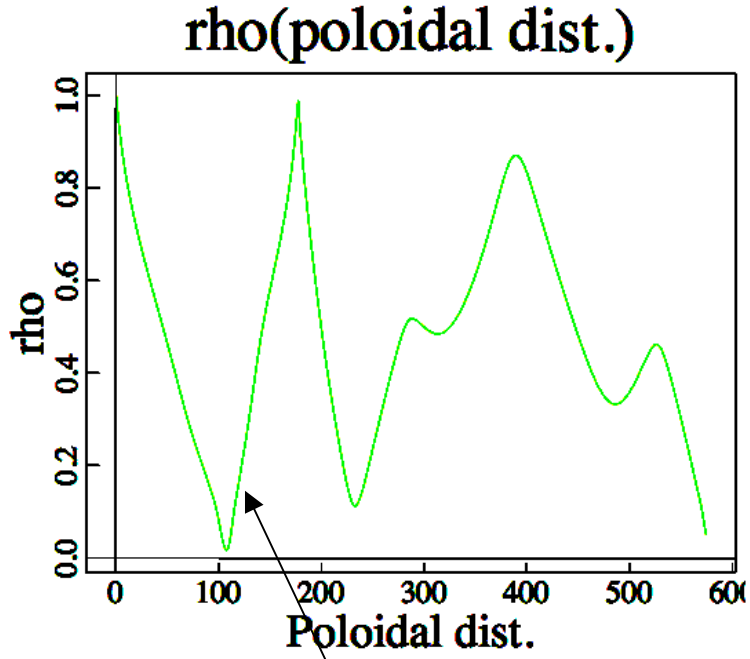
Ray passes ~ 5.5 times between cutoffs on the LFS and the HFS



$k_{\parallel} = -7\ m^{-1}$

Ray loses ~ 90% of power in two passes (in and out) for -7 m^{-1}

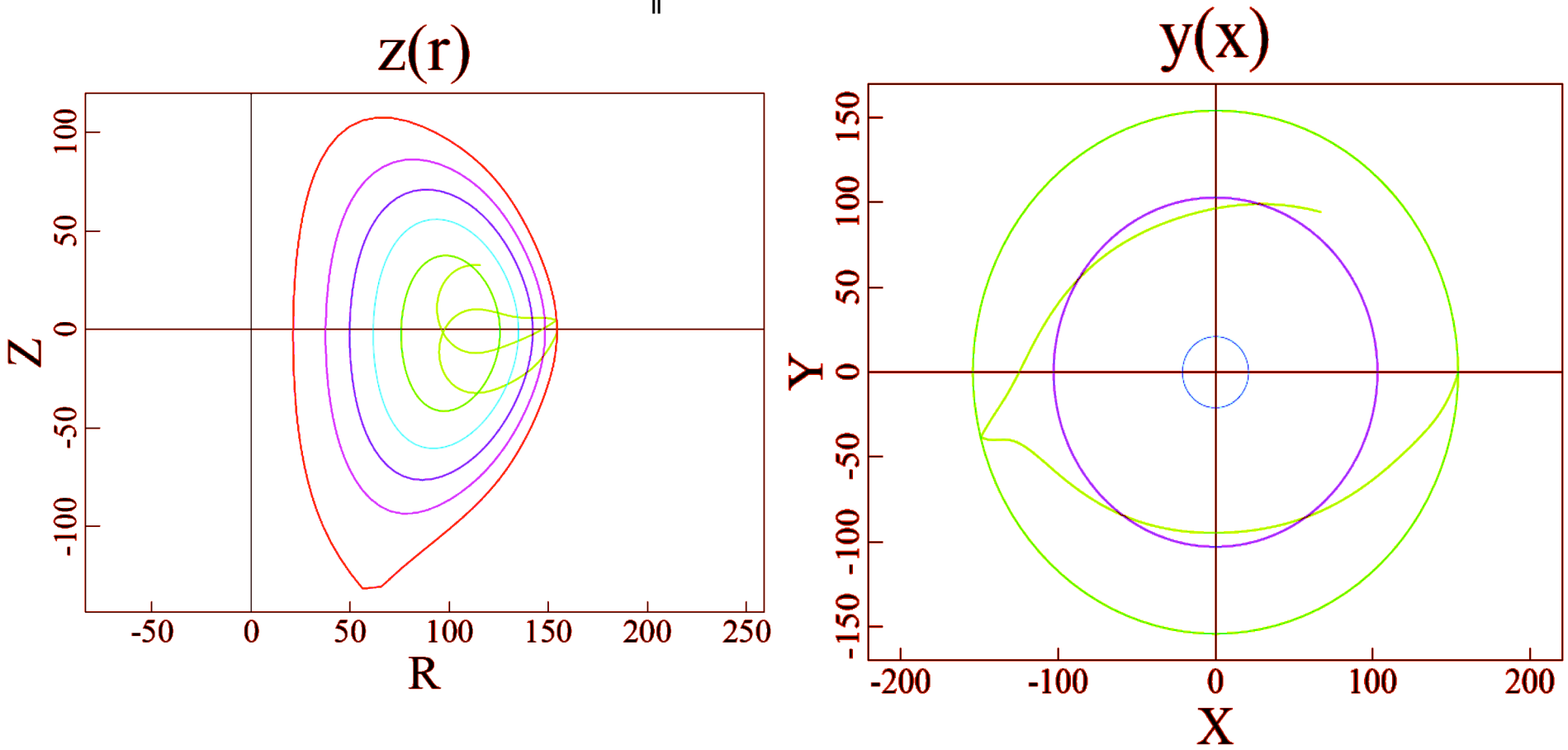




90% power lost

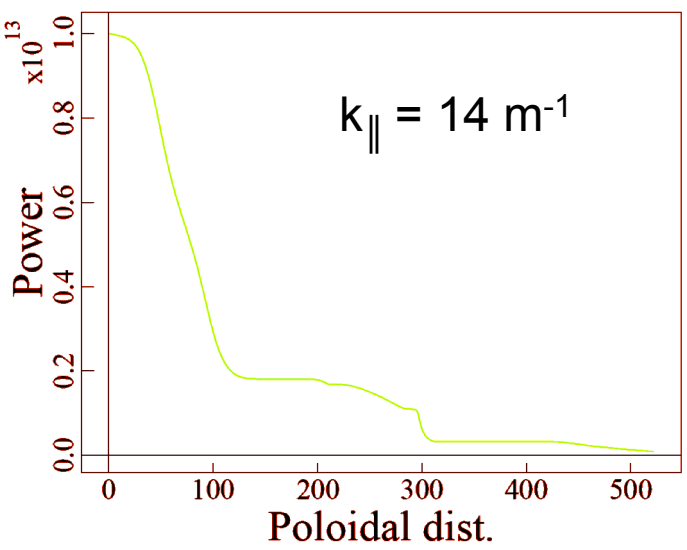
Ray hits wall far away from antenna in NSTX

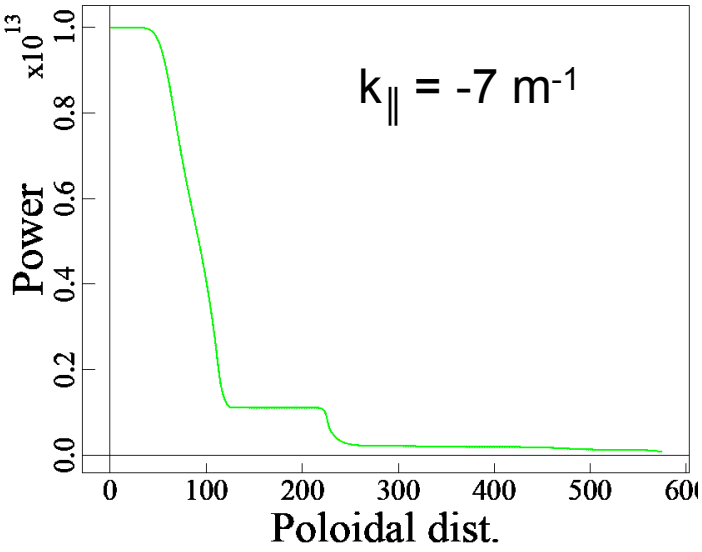
$k_{\parallel} = 3\ m^{-1}$

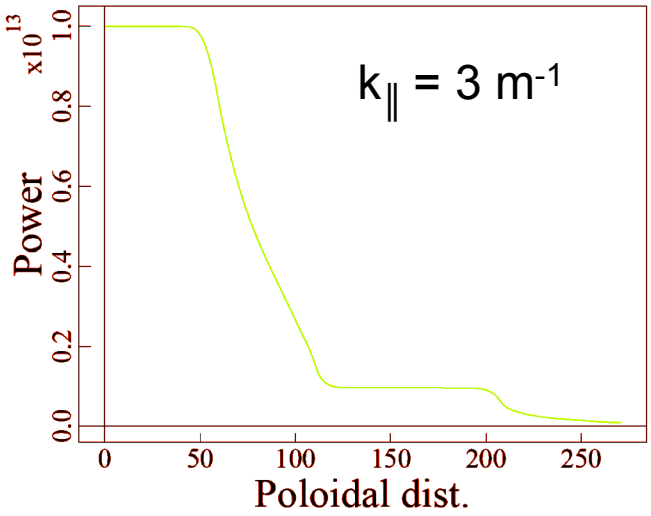


Could lead to “far field sheaths” or enhanced PDI losses

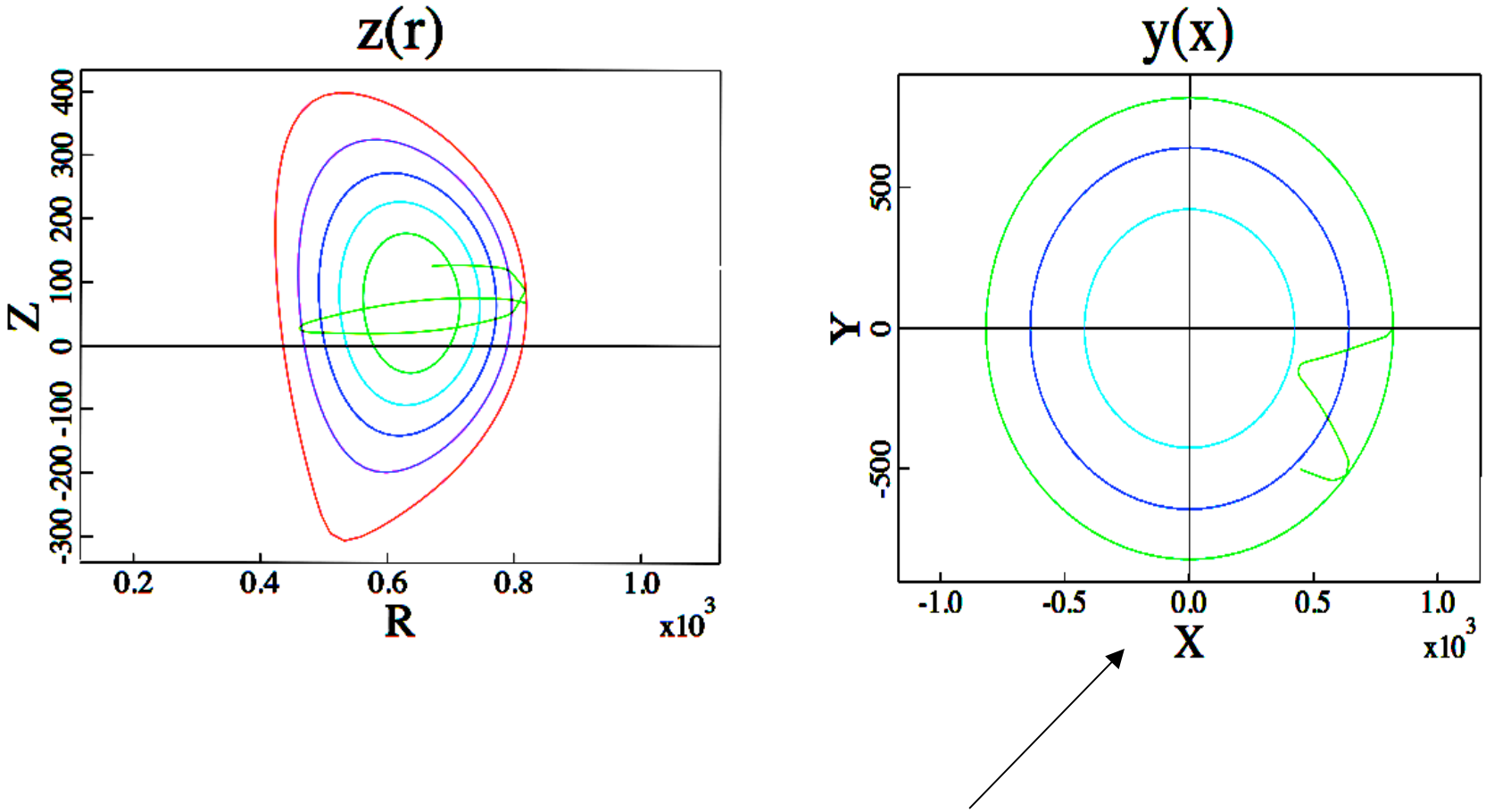
"First pass" power absorption rate somewhat lower for 14 m^{-1}







Waves propagate more radially in ITER



Less toroidal propagation, consistent with AORSA simulations

Future Work

- Use data for specific recent NSTX discharges
- Complete the C-Mod, ITER comparisons
- Use full wave code TORIC to produce 2D and 3D fields