An Analytic Scheme for CD Power Estimate -- An Update

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In ARIES-AT, on-axis Fast Wave CD and edge Lower Hybrid CD are required to maintain the plasma equilibrium.

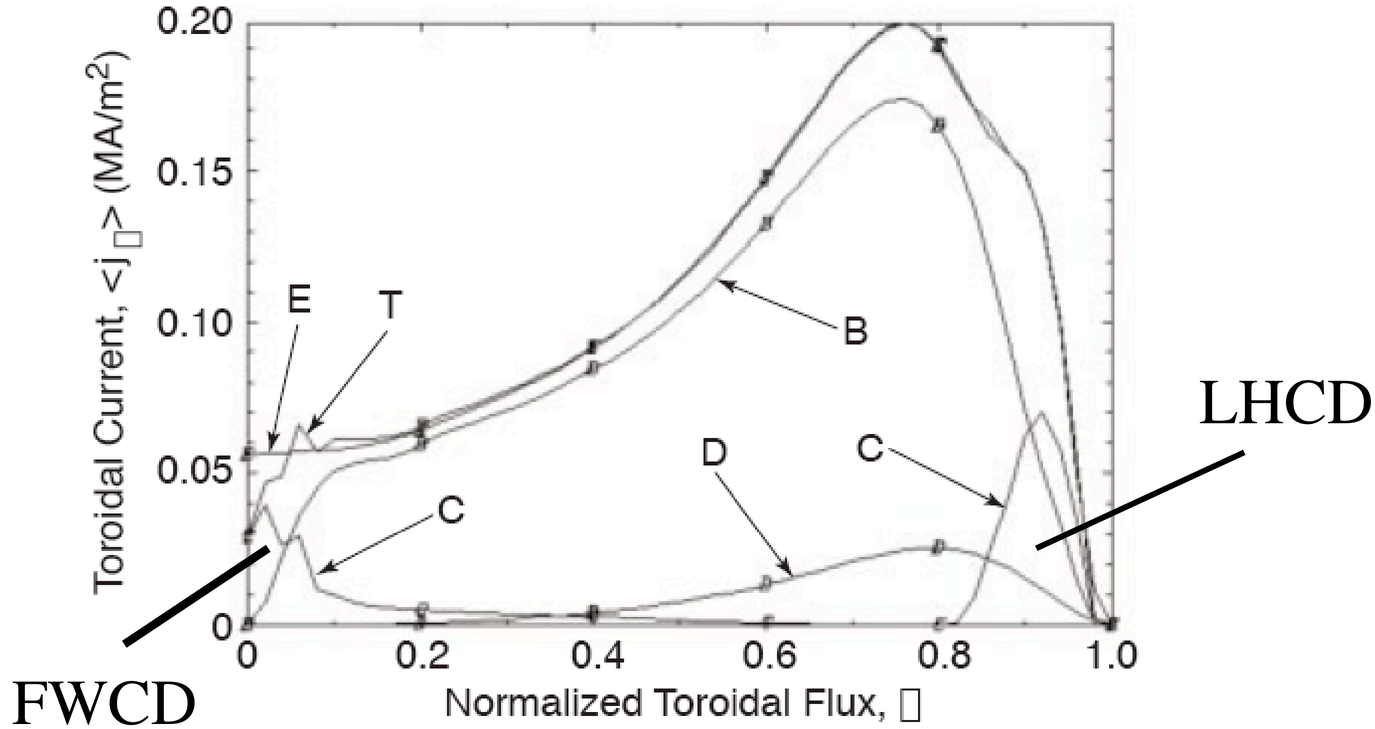


Figure 10: Toroidal components of the boostrap (B), diamagnetic (D), RF-driven (C) current densities vs. normalized toroidal flux for ARIES-AT. The equilibrium current profile (E) is well reproduced by the driven current (T).

CD Power Calculations in ARIES Studies

- The methodology was centered around a reference equilibrium with a fixed pressure profile and current profile.
- Variations of the n and T profiles and Zeff, with p = [?] nT, result in variations of the bootstrap current profile, which require different current profiles to be driven by noninductive means.
- For each case, CD calculations were performed using a ray tracing code to determine power requirements for the RF techniques.
- Thus a large database was obtained for P_{CD} for each current driver as a function of ne, Te (and their profile peakedness, a_N and a_T) and Zeff.
- In searching for a optimum operating point, the system code interpolates among the set of P_{CD} (ne, Te, a_N, a_T, Zeff).
- This process is computation-intensive and time-consuming.

For the ARIES Pathway project, a simpler method to estimate the CD power must be implemented for scoping analysis over a wide parameter range including the plasma size, while maintaining the correct parameter dependence.

An Analytic Estimate of CD Power

- First, the locations and magnitudes of currents to be driven inside the plasma are deduced from j_{CD} (r) = j_{eq} (r) - j_{BS} (r).
- Sets of n, T and Zeff consistent with the pressure at these locations are determined.
- At each location, determine the CD technique to be used. Usually FW in the ICRF is used for on-axis drive and LH slow waves are used for edge current drive.
- The normalized CD efficiency □(w,□,□,Zeff) for each technique at each location is calculated using the Ehst-Karney formula, where

  $w = V_{\parallel} / V_e = c / (N_{\parallel} V_e)$ with $V_e = (T_e/m_e)^{1/2}$

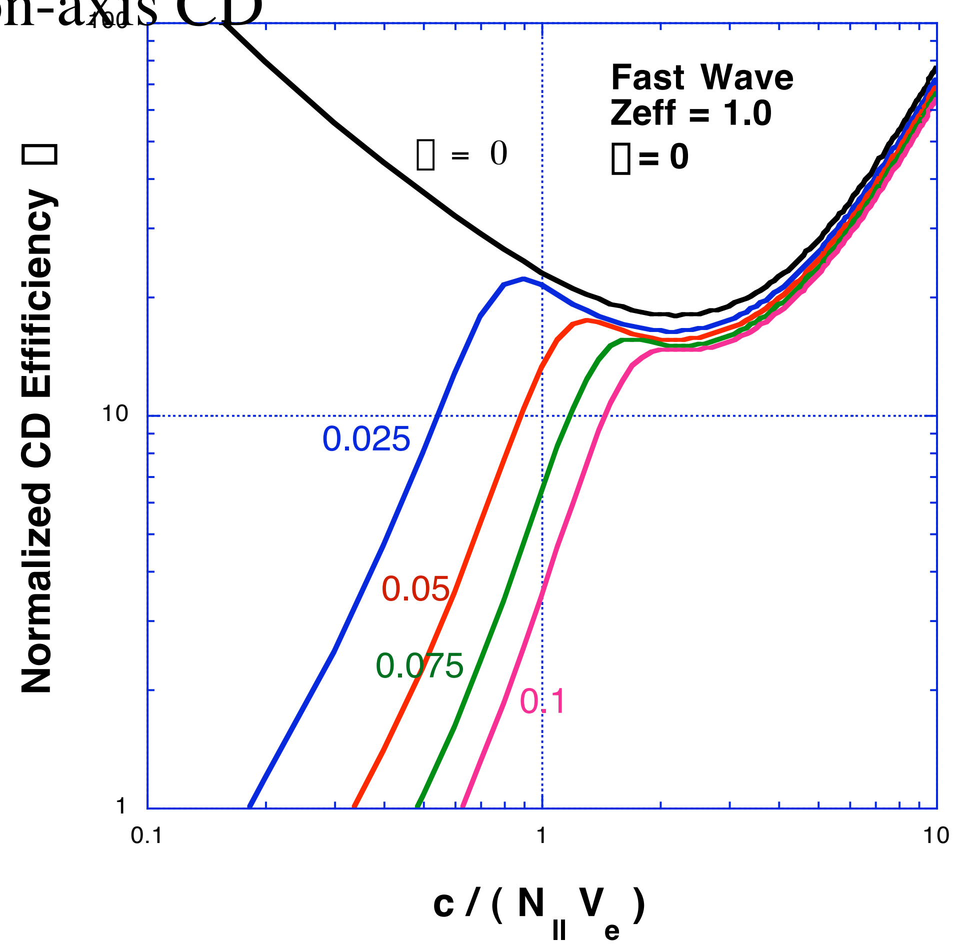
  □ ≈ r/R

  □ is poloidal location of wave abosrption
- The CD efficiency at each location is then

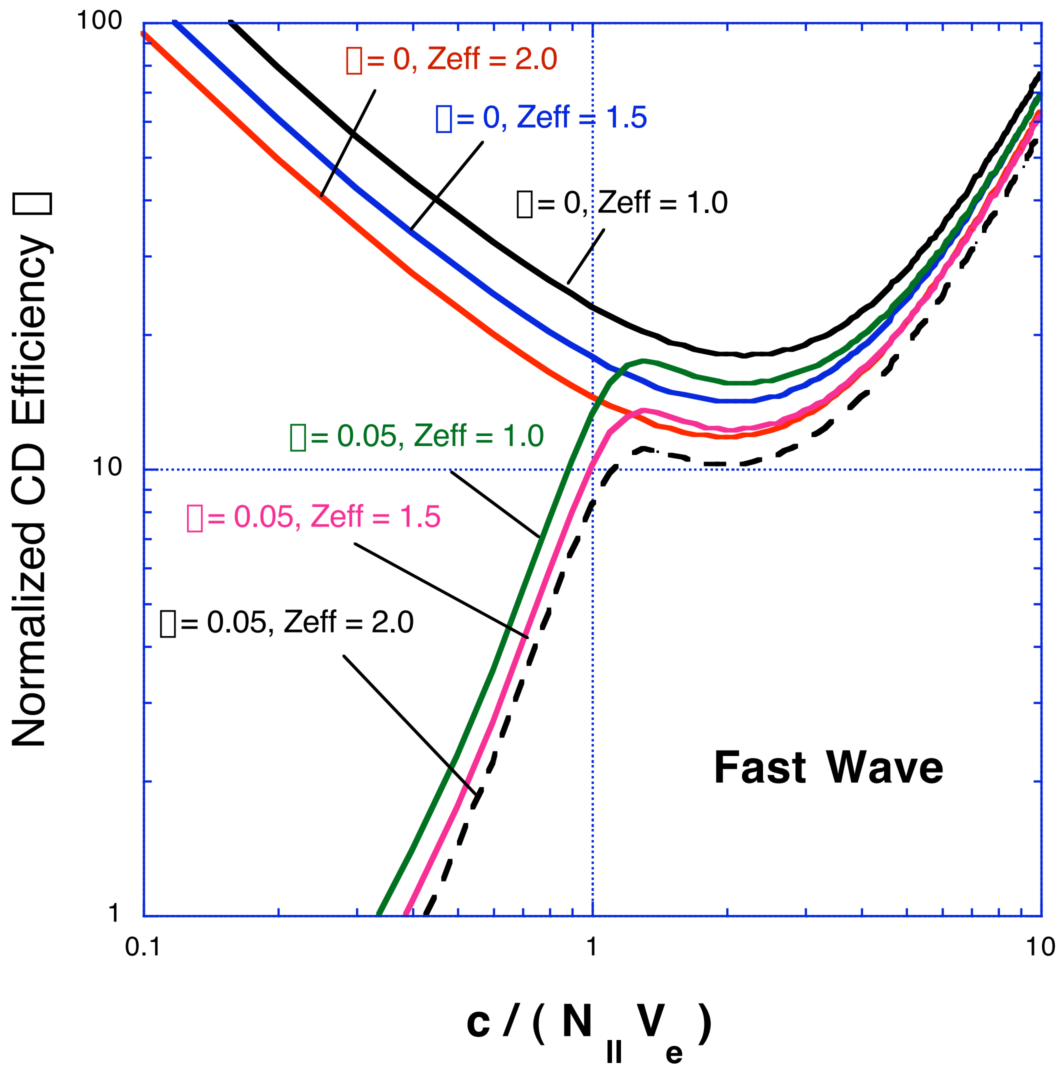
  I/P (A/W) = 3.05×10^{18}/ln□/R(m) T_e(keV)/n_e(m_{-3}) □
- Knowing I, one can then calculate P.
- The total CD power is then P_{CD} = □ P, summed over all current drive location.

Normalized CD Efficiency for Fast Waves

- From Ehst-Karney formula
- Includes trapped particle
effect.
- e ≤ 0.1   for on-axis CD

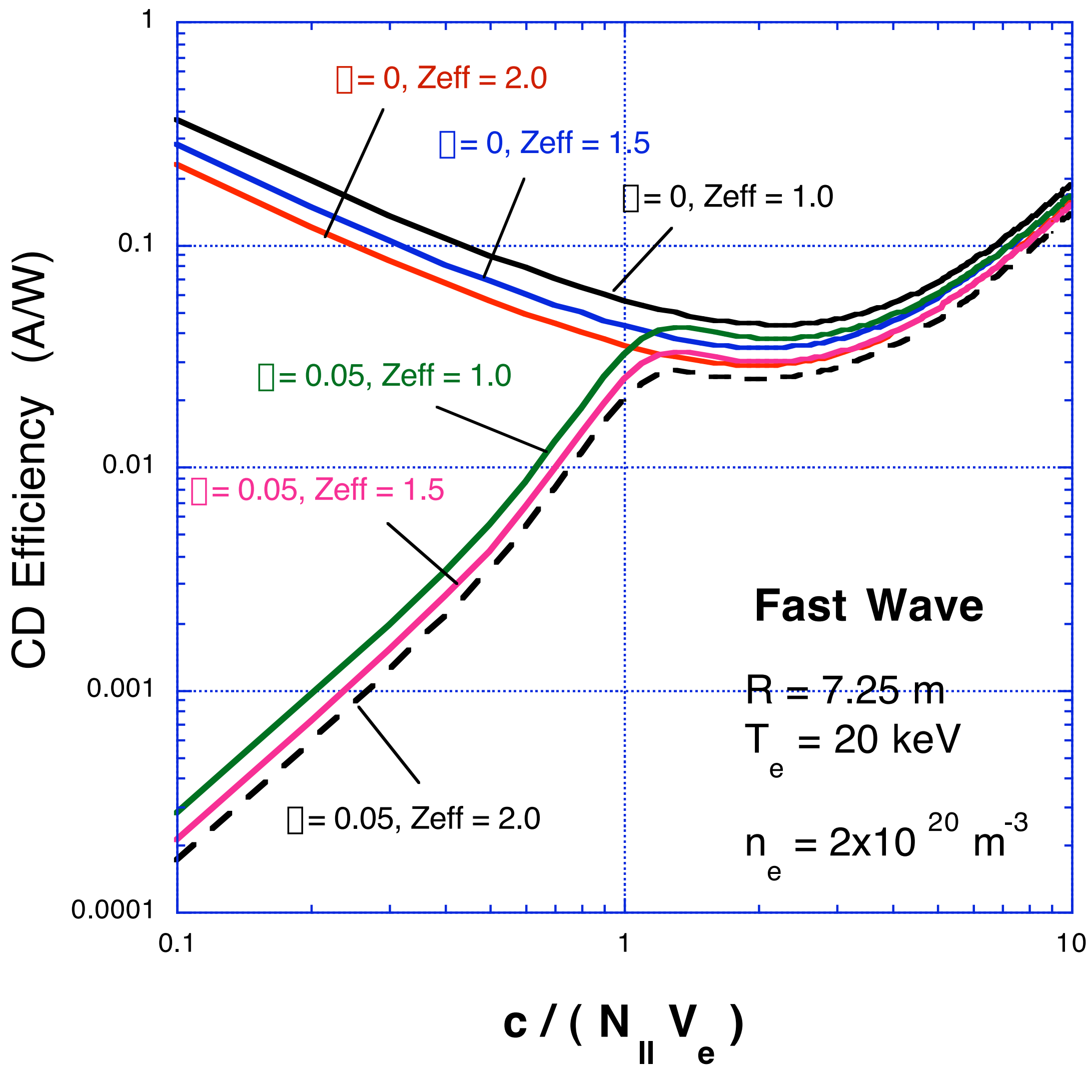


CD Efficiency degrades with Zeff



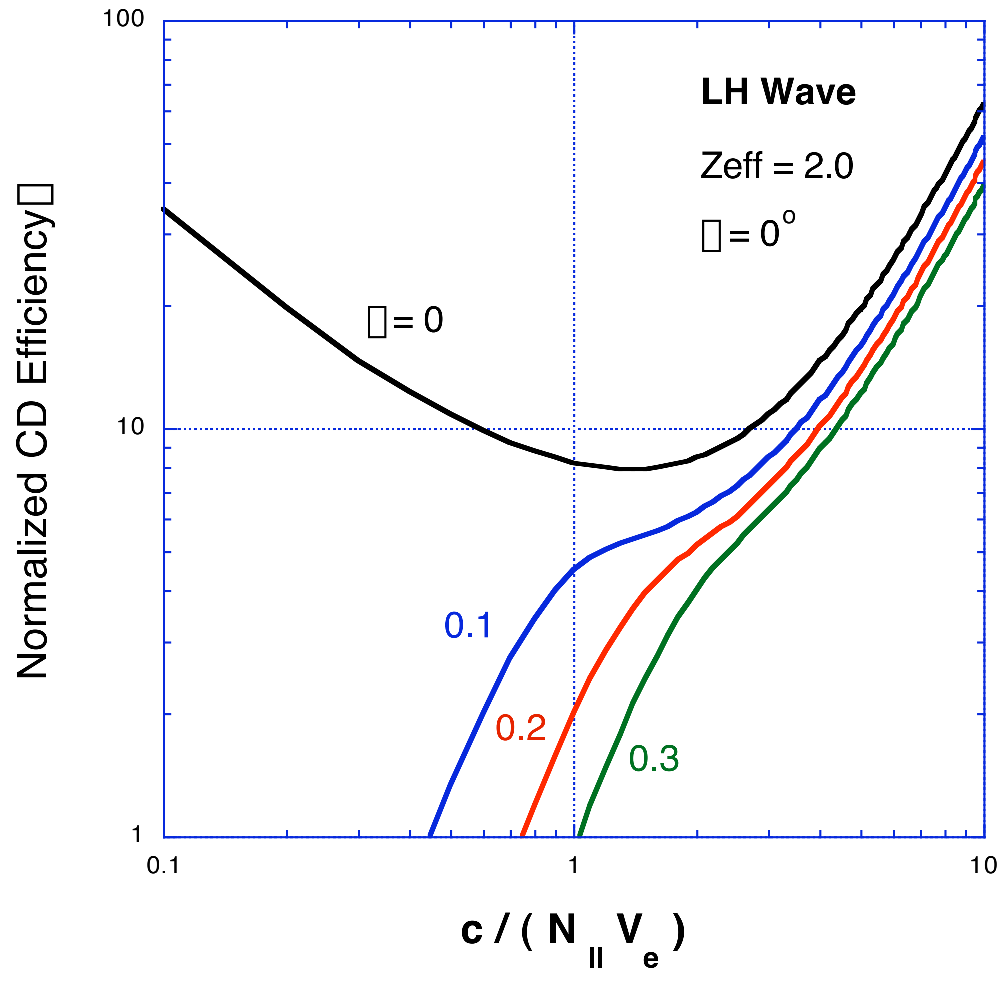
Ox-axis FWCD Efficiency I/P

- For a reactor, FWCD usually operates at w ≈ 1, I/P = 0.03 A/W.
  -- Strong single-pass absorption



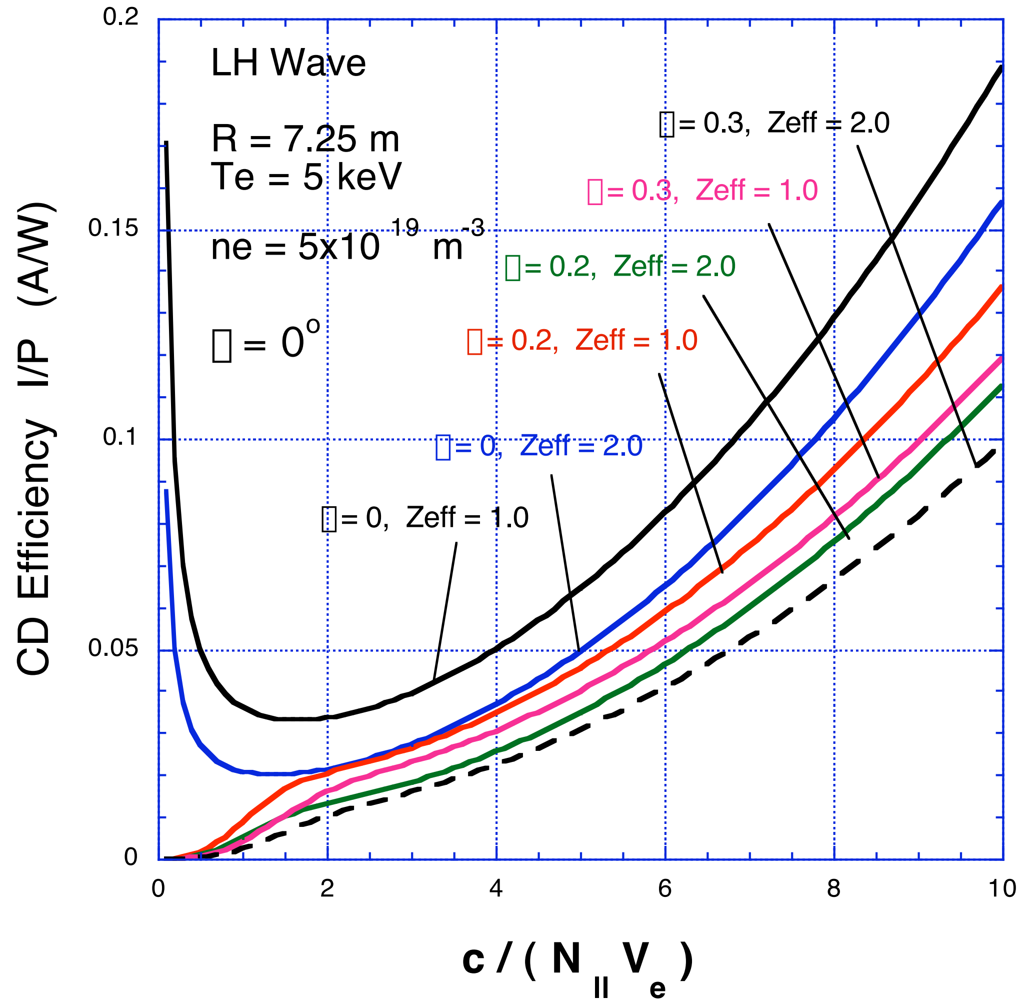
Normalized LHCD Efficiency at Outer Plasma

- For edge current drive



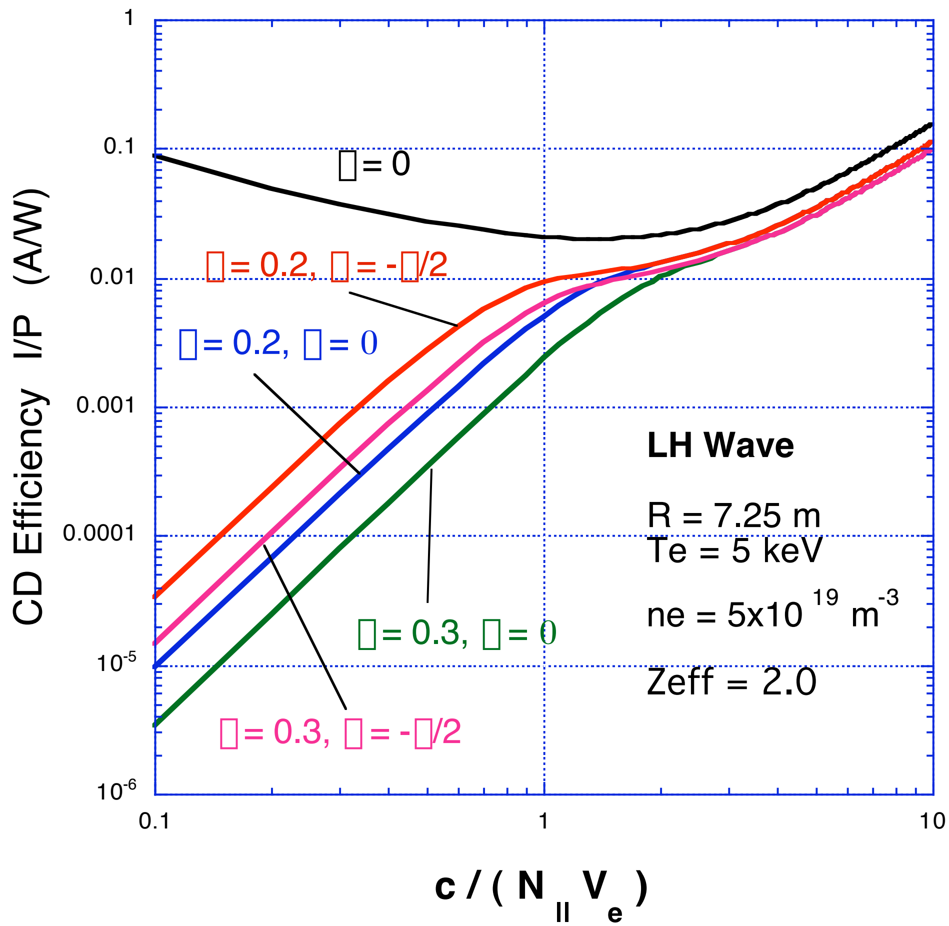
LHCD Efficiency degrades with Zeff

Usually, LHCD operates at w = 3, implying I/P = 0.04 A/W.



Trapped Particle Effect is weak at high phase velocities

This indicates that CD efficiency at □=0° may be sufficient.



Summary

- Progress has been made in developing an analytic scheme for estimating CD power requirement with the right parameter dependence.
- The next task is to compare this simple scheme with results from the ARIES-AT study.
- This scheme will be incorporated into the systems code.