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RADIAL MODE STRUCTURE OF CURVATURE-DRIVEN INSTABILITIES IN EBT

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FEATURES OF THIS CALCULATION:

- RETAINS NONLOCAL STRUCTURE OF MODES.
- CONNECTS INNER AND OUTER RING REGIONS TOGETHER IN ONE TREATMENT.
- A SELF-CONSISTENT FINITE β EQUILIBRIUM B FIELD IS USED. (including dB/dr and d^2B/dr^2)
- A WIDE RANGE OF EBT PARAMETERS HAVE BEEN EXAMINED.
- RELATIVISTIC EFFECTS ARE INCLUDED FOR THE HOT ELECTRON RING.

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ASSUMPTIONS OF PRESENT CALCULATION

- FINITE LARMOR RADIUS EFFECTS NEGLECTED.

- BALLOONING EFFECTS NEGLECTED AND

  $\vec{B} \cdot \vec{\nabla}$ (EQUILIBRIUM QUANTITIES) = 0

- Z – PINCH GEOMETRY LOCALIZED TO RING REGION USED WITH OUTGOING ENERGY BOUNDARY CONDITIONS (NATURAL CURVATURE DRIFT).

- DELTA – FUNCTION HOT ELECTRON DISTRIBUTION:

$$F_{Hot} = \frac{\gamma p_{\perp H}}{\mu_0 B^2} \delta(p_{\parallel}) \delta(\mu - \mu_0)$$

- WARM CORE ELECTRONS, COLD IONS.

BASIC EQUATIONS

- MOMENTUM BALANCE:

$$\rho_i \underline{v}_i = (\underline{\nabla} \times \underline{B}) \times \underline{B} - \underline{\nabla} \cdot \underline{P}$$

$$\underline{P} = \sum_i \int F_i \underline{v}\, \underline{p}\, d^3p$$

$$\underline{p} = m_e \gamma \underline{v}$$

- THE HOT ELECTRON PRESSURE TENSOR MAY BE WRITTEN AS:

$$\underline{P} = \sum_i \int \frac{dH\, d\mu\, B}{|p_\parallel|} F(r, H, \mu) \left[\mu B(\underline{I} - \underline{bb}) + p_\parallel^2 \underline{bb}\right]$$

where $c^2 p_\parallel^2 = H^2 - 2\mu B c^2 - m_e c^4$

$$\mu = \frac{p_\perp^2}{2B}$$

- F is obtained from the drift kinetic equation:

$$\frac{\partial F}{\partial t} + v_{\parallel} \underline{b} \cdot \nabla F + \underline{v}_D \cdot \nabla F + \dot{H}\frac{\partial F}{\partial H} = 0$$

where $$v_{\parallel} = \frac{p_{\parallel}}{\gamma} = \pm \frac{[H^2 - 2\mu B^2 c^2 - m^2 c^4]^{1/2}}{\gamma c^2}$$

$$\underline{v}_D = \frac{\mu\, \underline{b} \times \nabla B}{q_j m_j B\gamma} + \frac{p_{\parallel}^2}{q_j m_j B\gamma} \underline{b}\times(\underline{b}\cdot\nabla)\underline{b} + \frac{\underline{E\times b}}{B}$$

$$\dot{H} = q_j E_{\parallel} v_{\parallel} + q_j \underline{E}_{\perp} \cdot \underline{v}_D + \frac{\mu}{\gamma m_j}\frac{\partial B}{\partial t}$$

- These equations are then combined, transformed to z - pinch geometry, and linearized about perturbed fields $E_{\perp}$ and $B_{\parallel}$. These may be characterized by a "displacement" ξ:

$$\underline{\xi} = i\frac{\underline{E\times b}}{\omega B}\exp[-i\omega t + ikz]$$

THIS RESULTS IN A SECOND ORDER EQUATION FOR ξ_r:

$$\boxed{\frac{d}{dr}\left(r\, P \frac{d\xi_r}{dr} \right) - Q\, \xi_r = 0}$$

where $$P = \frac{\lambda B^2 (1 + G_1)}{D\, v_A^2}$$

$$Q = \frac{r B^2}{v_A^2}\left[\frac{k^2 \lambda (1 + G_1)}{D} - \frac{\omega^2 \lambda}{v_A^2 D}\right.$$

$$- \frac{k^2 \mu_0 v_A^2}{r B^2} \frac{d}{dr} (p_H + p_c) - \frac{k^2}{r^2} v_A{}^2 (\sigma + G_3)$$

$$+ \frac{2 \lambda \omega k (1 - G_2)}{r\, \omega_{ci}\, D} + \frac{k^2 v_A^2 (1 - G_2)^2}{r^2 D}$$

$$\left. + \frac{v_A{}^2}{r B^2} \frac{d}{dr} \left(\frac{r \lambda B^2 S}{v_A^2 D}\right)\right]$$

$$S = \frac{1 - G_2}{r} + \frac{\omega k (1 + G_1)}{\omega_{ci}}$$

$$D = 1 + G_1 - \frac{\lambda}{k^2 v_A^2}$$

$$\lambda = \frac{\omega^2 \omega_{ci}^2}{\omega_{ci}^2 - \omega^2}$$

G_1, G_2, G_3 ARE KINETIC INTEGRALS WHICH INVOLVE THE HOT ELECTRON DISTRIBUTION FUNCTION:

$$G_1 = -B \sum_i \int \frac{dp_* \, d\mu \, \mu^2}{\tau \, m_i} \left[\frac{1}{B} \frac{\partial F}{\partial \mu} + \frac{L_i^* F}{\tau \, \Omega}\right]$$

$$G_2 = - \sum_i \int \frac{dp_* \, d\mu \, \mu}{\tau \, m_i} p_{\parallel}^2 \left[\frac{1}{B} \frac{\partial F}{\partial \mu} + \frac{L_i^* F}{\tau \, \Omega}\right]$$

$$G_3 = - \sum_i \int \frac{dp_* \, d\mu \, p_{\parallel}^4}{8 \, \tau \, m_i} \left[\frac{1}{p_{\parallel}} \frac{\partial F}{\partial p_{\parallel}} + \frac{L_i^* F}{\tau \, \Omega}\right]$$

where $\Omega = \omega - \omega_{DB} - \omega_{cv}$

$$L_i^* = \left(\frac{k}{m_i \, q_i \, B} \frac{\partial F}{\partial r} + \frac{\tau \, \omega_{cv}}{p_{\parallel}} \frac{\partial F}{\partial p_{\parallel}}\right)$$

THE INTEGRALS G_1, G_2, G_3 DEPEND ON THE MODEL USED FOR THE HOT ELECTRON DISTRIBUTION.

FOR THE CASE OF A DELTA FUNCTION WITH NO PARALLEL ENERGY:

$$F_{Hot} = \frac{\gamma_0 \, p_{\perp H}}{\mu_0 \, B^2} \, \delta(p_\parallel) \, \delta(\mu - \mu_0)$$

$$1 + G_1 = (\omega - \omega_{DB})^{-1} \{ \omega \left[1 + \beta_\perp - \beta_{\perp H} \frac{\mu_0 \, B}{2 \, \gamma_0^2 \, m_e^2 \, c^2} \right]$$

$$- \omega_{cv\perp} \left[1 + r \frac{d}{dr} \left(\frac{p_{\perp c}}{B^2} \right) \right] \}$$

where $\omega_{cv\perp} = - \dfrac{k \, \mu_\theta}{e \, m_e \, \gamma_\theta \, r}$

$$\omega_{DB} = \frac{k \, \mu_\theta}{e \, m_e \, \gamma_\theta \, B} \frac{dB}{dr}$$

$$G_2 = \frac{\beta_{\parallel c}}{2} \qquad\qquad G_3 = \frac{3 \, \beta_{\parallel c}}{2}$$

Using these forms for G_1, G_2, G_3 which are accurate for arbitrary Δ_B / R_c and ω / ω_{db} one can make a local approximation:

$$\frac{d^2 \xi_r}{dr^2} = -k_r^2 \xi_r \quad , \quad k_r = \frac{2}{\Delta}$$

$$\frac{d\xi_r}{dr} = 0$$

$$\frac{1}{n_c} \frac{dn_c}{dr} = -\frac{1}{\Delta}$$

To obtain a fifth order dispersi relation:

$$y^5 + Ay^4 + By^3 + Cy^2 + Dy + E = 0$$

where $y = \frac{\omega}{\omega_{cvL}}$

A. High Frequency Modes

Compressional Alfven

Hot Electron interchange ($q_0 >> 1$)

Retaining A, B and C terms in the 5th order eqn., $B^2 = 4AC$ gives the marginal stability boundary:

$$p\left\{p^2\left(1+\frac{2\tilde{\beta}_c}{\tilde{\beta}_H}\right)^2 - 2p\left[\left(1+\frac{1}{q}+\tilde{\beta}_c\right)\left(1+\frac{2\tilde{\beta}_c}{\tilde{\beta}_H}\right)-\frac{4\tilde{\beta}_c}{\tilde{\beta}_H}\right] + \left(1-\frac{1}{q}-\tilde{\beta}_c\right)^2\right\} = 4\left(\frac{\Delta}{R}\right)^2(\tilde{\beta}-1)\tilde{\beta}_H\left[p\tilde{\beta}_c\left(1+\frac{2\tilde{\beta}_c}{\tilde{\beta}_H}-\frac{2}{\tilde{\beta}_H}\right) + \frac{1}{q}\left(1-\tilde{\beta}_c\right)\right]$$

→ Cubic in $p = n_H/n_i$

2 roots near $p \simeq 1$ → hot electron interchange

1 root at $p < (\Delta/R)^2 << 1$ → compressional Alfven

$\left(\tilde{\beta} = \frac{R_c}{2\Delta}\beta,\quad p = \frac{n_H}{n_i},\quad q = \left(\frac{k}{k_\perp}\right)^2 \frac{V_{cv\perp}}{\Delta\,\omega_{ci}}\right)$

Hot Electron Interchange

$p \simeq 1 \rightarrow$ neglect R.H.S. $\rightarrow$ quadratic in p: only one physical solution (i.e. with $p<1$):

$$p < p_1 = \left[1 - \left(\frac{1}{q} + \tilde{\beta}_c\right)^{1/2}\right]^2$$

note: if $q < (4-\tilde{\beta}_c)^{-1} \rightarrow p>1$ and this mode stabilizes (actually one goes over to low freq. hot interchange)

Compressional Alfven Mode

$p \ll 1$ root $\Rightarrow$ neglect p^2 and p^3 terms

$$p > p_2 = \frac{1}{q}\left(\frac{2\Delta}{R}\right)^2 \tilde{\beta}_H (\tilde{\beta}-1)(1-\tilde{\beta}_c)\left(1-\frac{1}{q}-\tilde{\beta}_c\right)$$

note: when $\tilde{\beta}_c = 1$ mode stabilizes

also, when $1 - \frac{1}{q} - \tilde{\beta}_c = 0$ $\quad p_2 \rightarrow \infty$

$\left(q = \left(\frac{k}{k_\perp}\right)^2 \frac{v_{ev}}{\Delta\omega_{ci}}\right)$ $\quad p_1 \rightarrow 0$

Low Frequency Modes ($\omega < \omega_{ci}$)

A. Low-frequency hot electron interchange ($q << 1$)

Keep B, C, D terms (justified when $q << 1$ and $\beta_c << \beta_H$)

$C^2 = 4BD$ gives:

$$p < p_3 = \frac{1}{4}(k_\perp \Delta)^2 q_0 (1 - \tilde{\beta}_c)^2$$

B. Low-frequency background interchange

Keep C, D, and E terms ($\beta_c << \frac{2\Delta}{R_c}$)

Stability acheived in 2 ways:

$$\beta_H > \frac{4\Delta}{R_c} - 2\beta_c \quad \text{(drift reversal)}$$

or

$$\frac{n_H}{n_i} \gtrsim 8 q_0 (k_\perp \Delta)^2 \left(\frac{\beta_c}{\beta_H}\right) \quad \text{for } \tilde{\beta}_H >> 1, \; \beta_c/\beta_H < 1$$

(charge uncovering, $n_{ce} \neq n_{ci}$ frequency shift $\propto (n_{ci} - n_{ce})/n_{ce} = p$)

C. Interacting Background Interchange ($\beta_c \sim 2\Delta/R_c$)

Keeping B, C, D and E terms:

$$[1 + q(1-\tilde{\beta}_c)]y^3 - (1-\tilde{\beta}_c)y^2$$

$$+ \tau\left(1 + \frac{2\tilde{\beta}_c}{\tilde{\beta}_H}\right)y + \tau\tilde{\beta}_c\left(1 + \frac{2\tilde{\beta}_c}{\tilde{\beta}_H} - \frac{2}{\tilde{\beta}_H}\right) = 0$$

where $\tau = p/q_0(k_\perp\Delta)^2$

note: $\tau < 1$ is stability condition for low-freq. hot electron interchange

assuming $\tau \ll (1-\tilde{\beta}_c)^2/3$ one finds that for $(1-\tilde{\beta}_c)$ small, 2 roots of the cubic coalesce and lead to instability if:

$$\boxed{1-\tilde{\beta}_c < 3\left[\frac{\tau}{4}\left(1 + \frac{2\tilde{\beta}_c}{\tilde{\beta}_H} - \frac{2}{\tilde{\beta}_H}\right)\right]^{1/3}}$$

NUMERICAL SOLUTION METHOD

- Radial equation: $\frac{1}{r}\frac{d}{dr}\left(rP\frac{d\xi}{dr}\right) - Q\xi = 0$

- Equivalent to 2 coupled first order equations:

$$\begin{cases} \frac{dy_1}{dr} = \frac{y_2}{r \cdot P} \\ \frac{dy_2}{dr} = rQy_1 \end{cases}$$

where $y_1 = \xi$, $y_2 = rP\frac{d\xi}{dr}$

- Solve as 2-point boundary value problems on intervals r_{min} to r_m and r_m to r_{max} using the SUPPORT code.

- Powell's hybrid method is used to solve for ω by matching:

$$\left.\frac{dy_1}{dr}\right|_{r=r_m^+} = \left.\frac{dy_1}{dr}\right|_{r=r_m^-}$$

PLASMA AND HOT ELECTRON PROFILES ARE CHOSEN WHICH ARE FLAT INSIDE AND OUTSIDE THE RING AND WHICH HAVE CONTINUOUS DERIVATIVES.

$$p_{\perp H}(r) = p_{\perp H0} \begin{cases} 0 & x < -x_0 \\ \dfrac{(x-x_0)^4 (x+x_0)^4}{x_0^8} & -x_0 < x < x_0 \\ 0 & x > x_0 \end{cases}$$

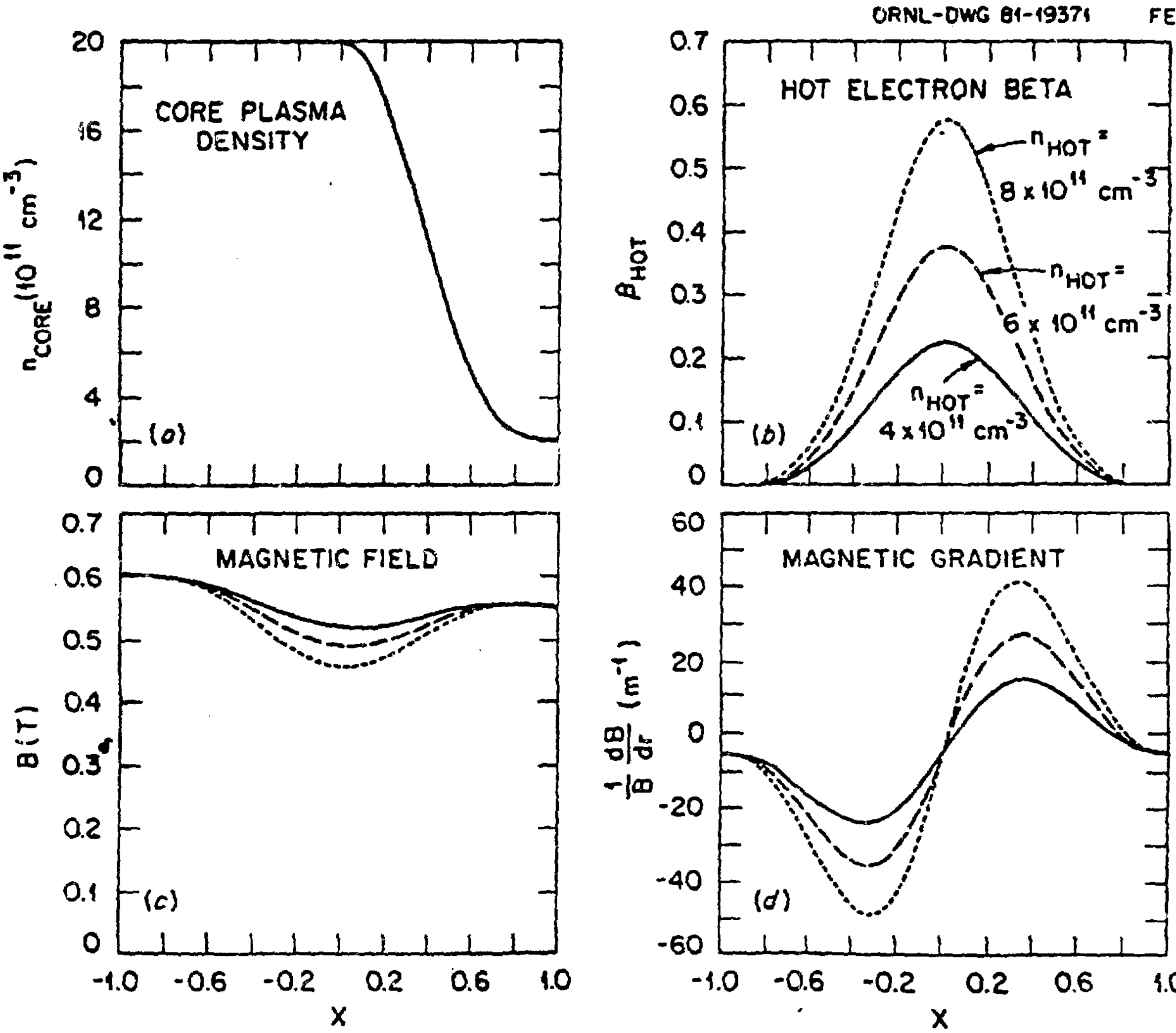
$$p_c(r) = p_{c0} \begin{cases} 1 & x < 0 \\ (1-s)\dfrac{(x-x_0)^4 (x+x_0)^4}{x_0^8} + s & 0 < x < x_0 \\ s & x > x_0 \end{cases}$$

where $x = \dfrac{r-r_0}{\Delta}$

$\Delta =$ hot electron annulus half-width

$x_0 =$ parameter which controls extent of pressure profile

$s =$ density shelf factor


ORNL-DWG 81-19371 FED
CORE PLASMA DENSITY
n_CORE (10^11 cm^-3)
(a)
HOT ELECTRON BETA
β_HOT
n_HOT = 8 x 10^11 cm^-3
n_HOT = 6 x 10^11 cm^-3
n_HOT = 4 x 10^11 cm^-3
(b)
MAGNETIC FIELD
B (T)
(c)
MAGNETIC GRADIENT
1/B dB/dr (m^-1)
(d)
X
X

A MAGNETIC EQUILIBRIUM MODEL IS USED WITH FIELD LINE CURVATURE APPROPRIATE TO Z-PINCH GEOMETRY ($\kappa = -1/r$).

FROM:

$$\vec{\nabla}\left(p_\perp + \frac{B^2}{2\mu_0}\right) = \vec{\kappa} B^2 \left[1 - \frac{\mu_0 (p_\parallel - p_\perp)}{B^2}\right]$$

ONE HAS:

$$\frac{1}{r^2}\frac{d}{dr}\left(r^2 \frac{B^2}{2\mu_0}\right) = -\frac{dp_\perp}{dr} - \frac{p_{\perp H}}{r}$$

WHICH CAN BE INTEGRATED:

$$B = \frac{1}{r}\left\{r_i^2 B_i^2 - 2r^2\mu_0 \left(p_{\perp H} + p_{\perp c}\right) - 2\mu_0 \int_{r_i}^{r} r'dr' \left(p_{\perp H} + 2p_{\perp c}\right)\right\}^{1/2}$$

OUTGOING ENERGY / EVANESCENT BOUNDARY CONDITIONS ARE USED AT INSIDE AND OUTSIDE OF ANNULUS.

$$\frac{d}{dx}\left(P\frac{d\xi}{dx}\right) - Q\xi = 0$$

OUTSIDE ANNULUS REGION,

$P, Q \simeq$ constant to $O\left(\frac{1}{r}\right)$

$\therefore$ solution is matched onto plane waves $\xi \sim e^{ik_x x}$

$$k_x = \pm i\sqrt{Q/P}$$

$\pm$ sign determined by:

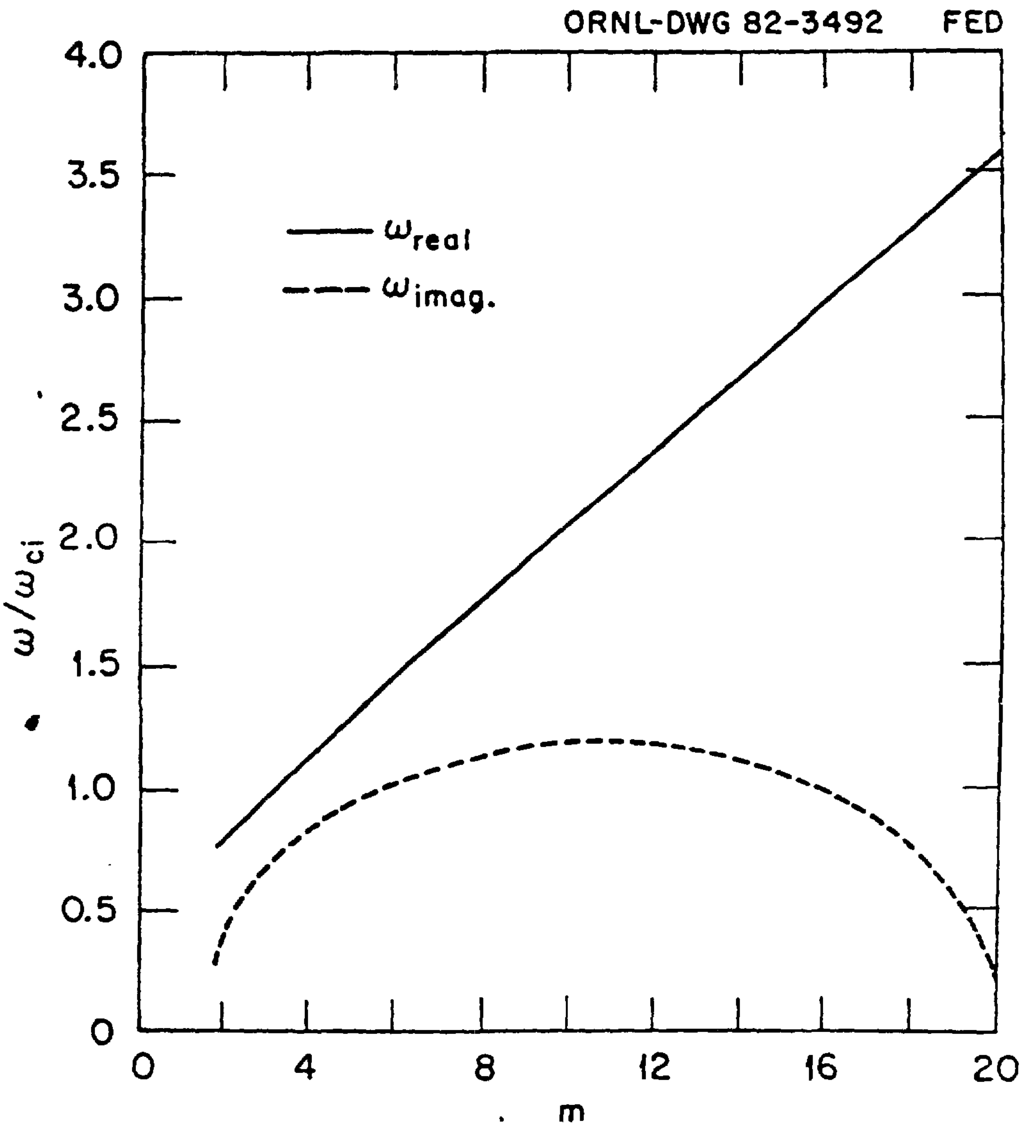
(1) $k_r > k_i$: outgoing energy

$$\frac{\partial w}{\partial k} \gtrless 0 \quad \text{for} \quad x \gtrless 0$$

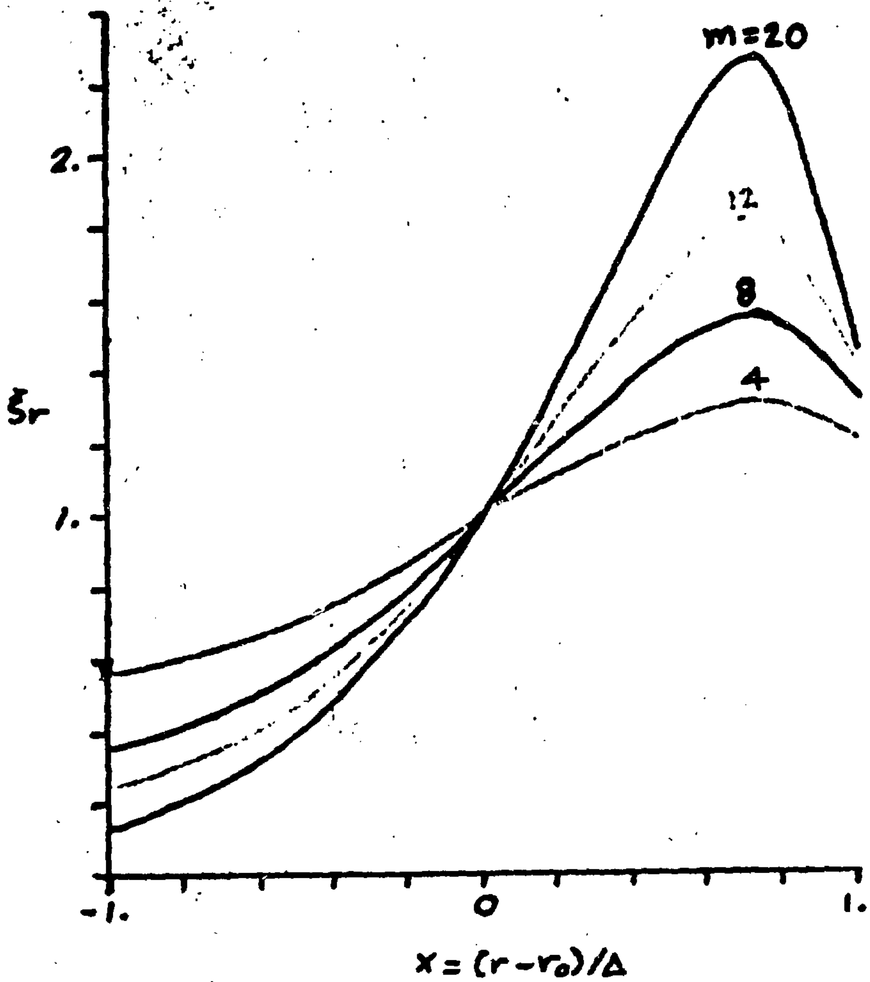
(2) $k_i > k_r$ evanescent

$$k_i \gtrless 0 \quad \text{for} \quad x \gtrless 0$$

DEPENDENCE OF FREQUENCY ON AZIMUTHAL MODE NUMBER FOR HOT ELECTRON INTERCHANGE ($N_{core, elec.} = 5 \times 10^{11}$ cm^{-3}, $N_{hot} = 5 \times 10^{11}$ cm^{-3}, $T_{core} = 0$, $T_{hot} = 500$ keV)

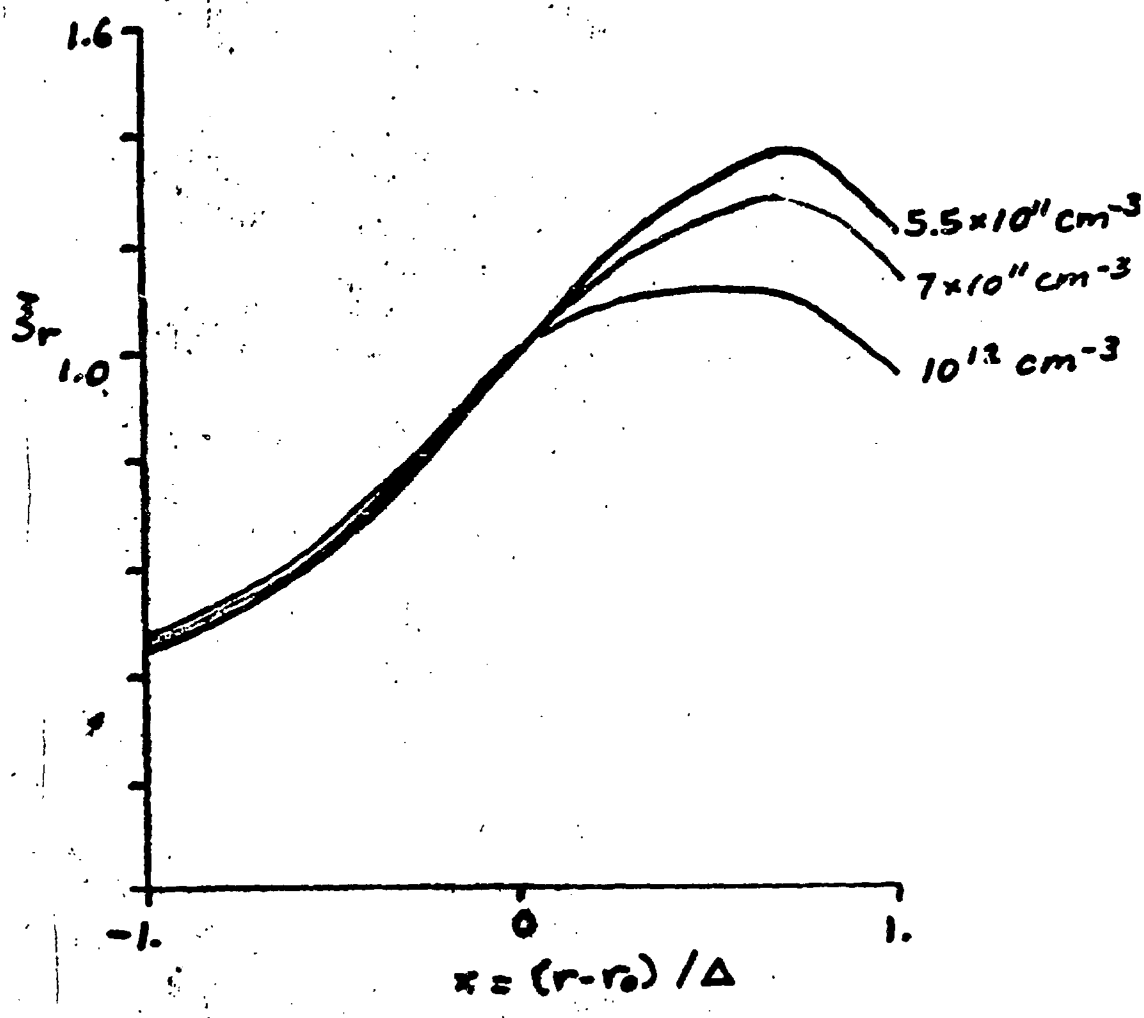


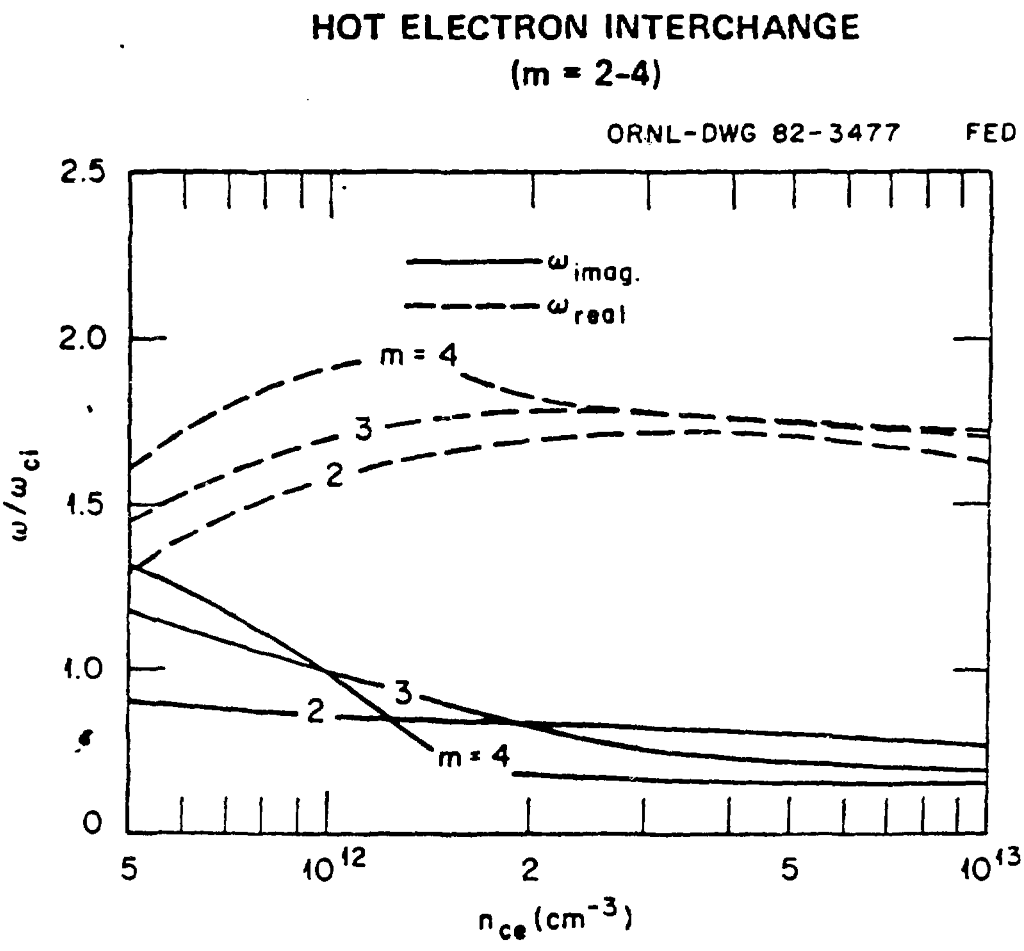
STRUCTURE OF HOT ELECTRON INTERCHANGE VS. MODE NO.

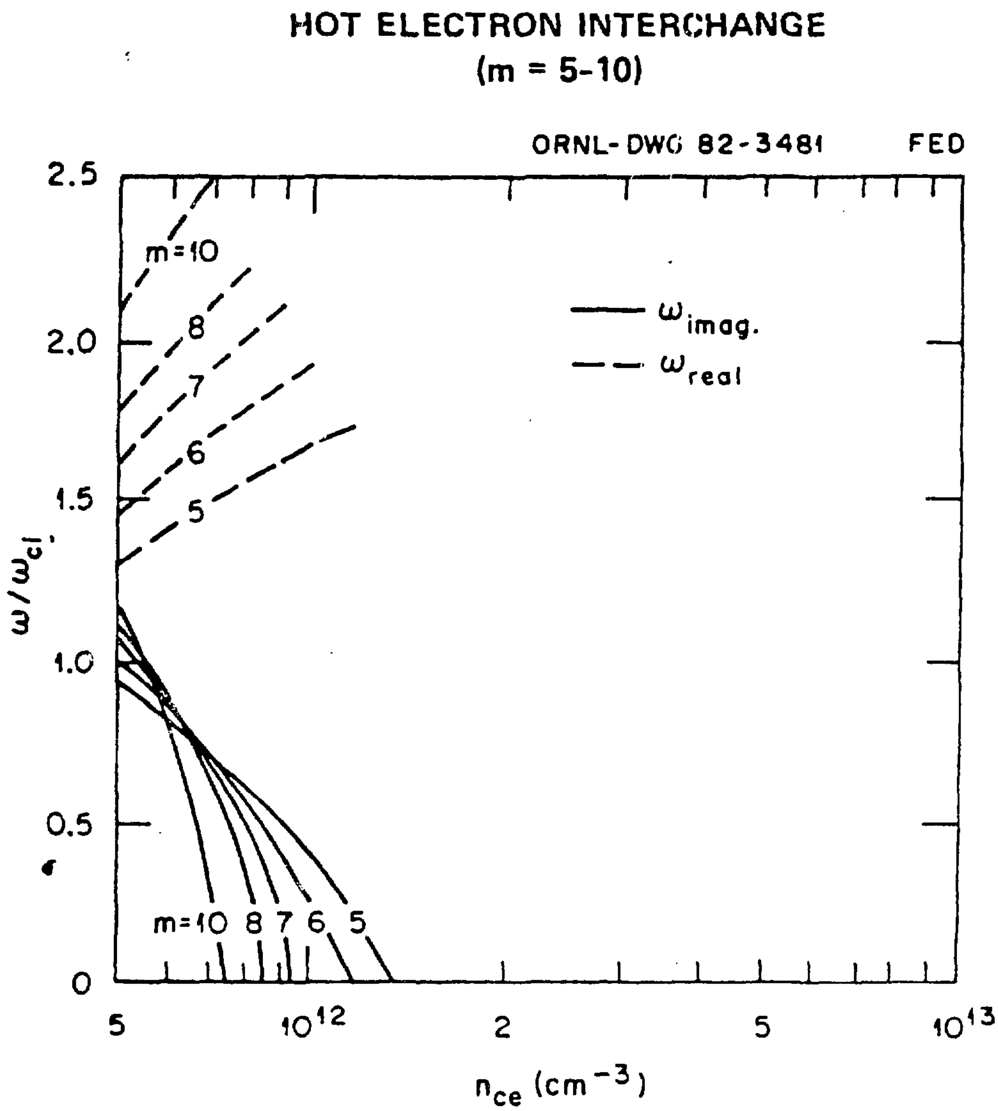


HOT ELECTRON INTERCHANGE MODE STRUCTURE VS. CORE DENSITY

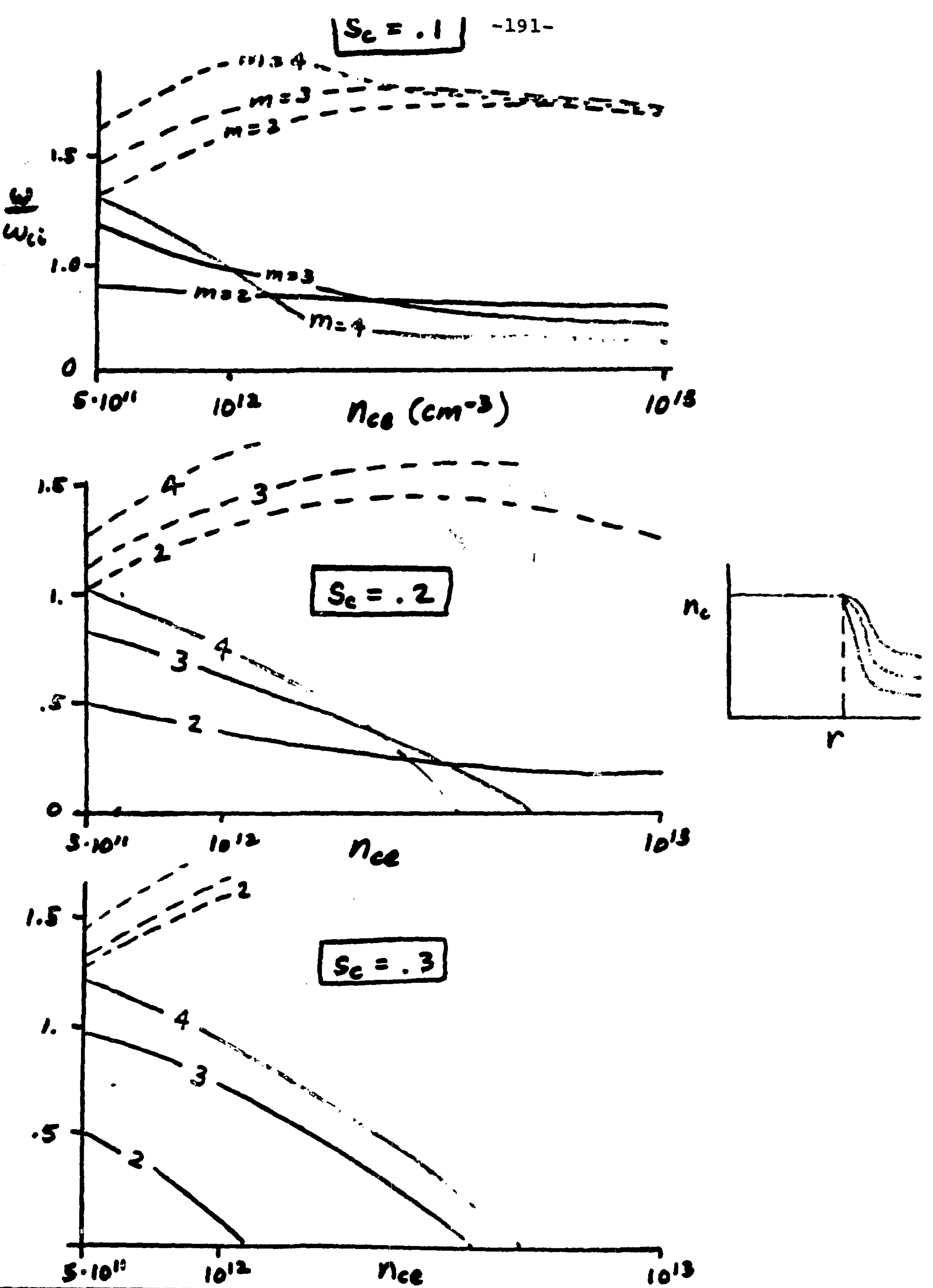
(m = 6)




HOT ELECTRON INTERCHANGE
(m = 2-4)
ORNL-DWG 82-3477 FED
ω imag.
ω real
m = 4
3
2
3
2
m = 4
ω/ω ci
2.5
2.0
1.5
1.0
0
5
10 12
2
5
10 13
n ce (cm -3)



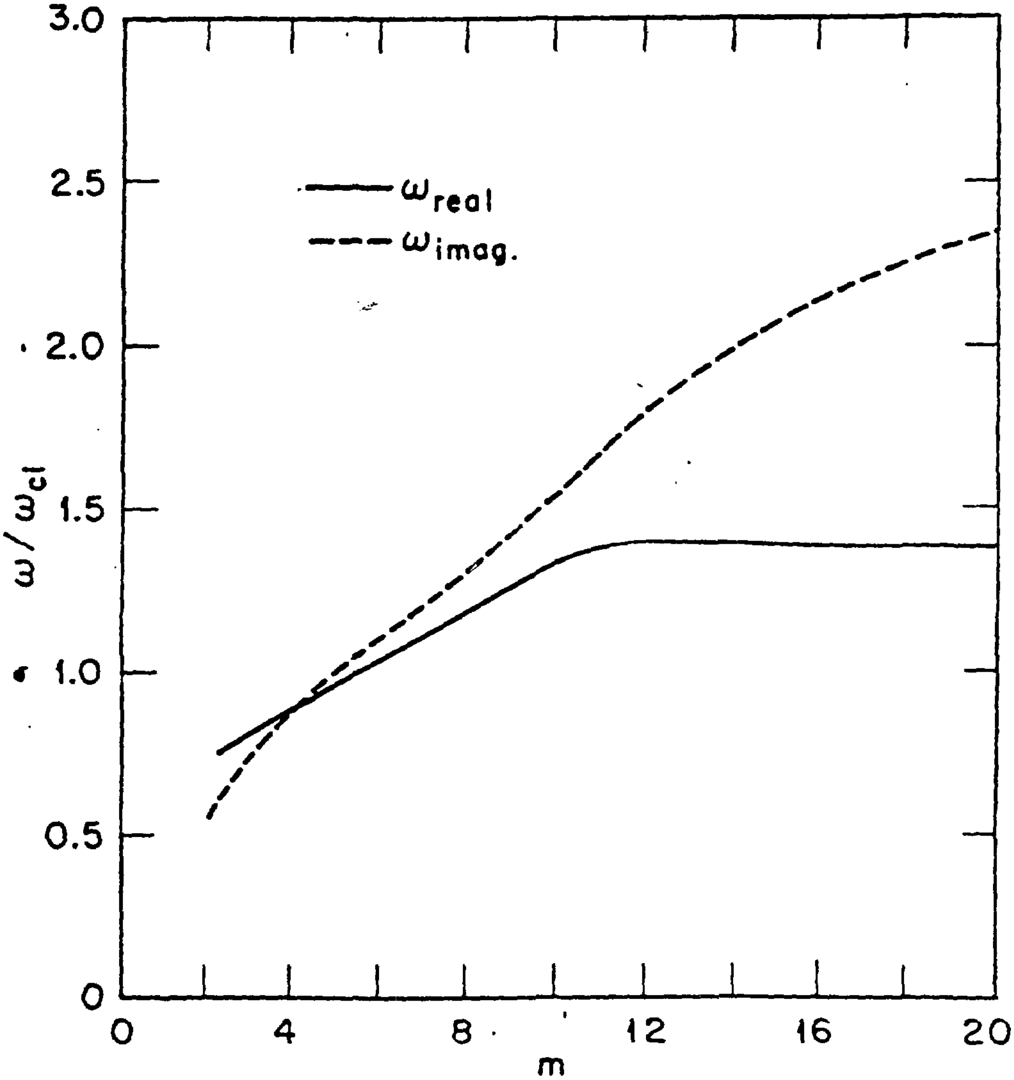
HOT ELECTRON INTERCHANGE
(m = 5-10)
ORNL-DWG 82-3481 FED
2.5
2.0
1.5
1.0
0.5
0
ω/ωci
m=10
8
7
6
5
ωimag.
ωreal
m=10 8 7 6 5
5
10^12
2
5
10^13
nce (cm^-3)



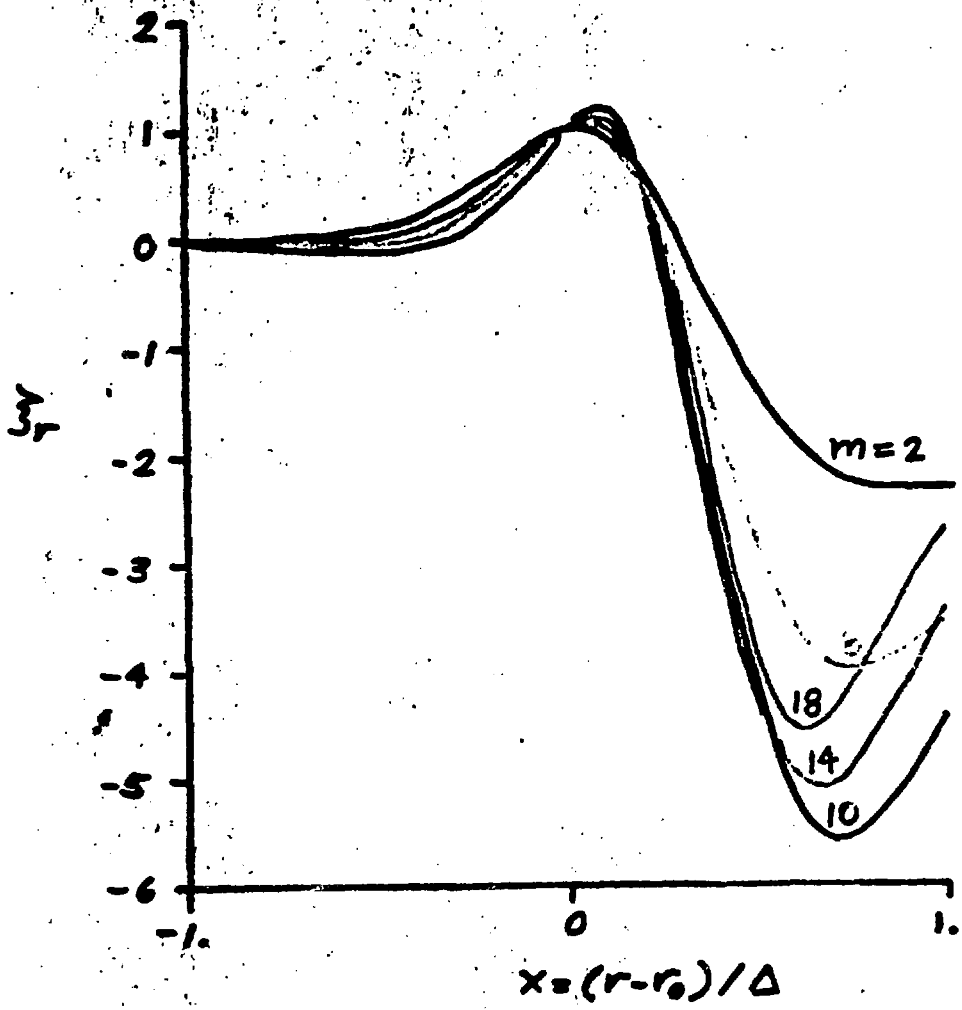
$S_c = .1$
m=4
m=3
m=2
1.5
$\frac{\omega}{\omega_{ci}}$
1.0
0
$5 \cdot 10^{11}$
10^{12}
10^{13}
n_{ce} (cm^{-3})
$S_c = .2$
4
3
2
1.5
1.
.5
$3 \cdot 10^{11}$
n_{ce}
n_c
r
$S_c = .3$

DEPENDENCE OF FREQUENCY ON AZIMUTHAL MODE NUMBER FOR COMPRESSIONAL ALFVÉN MODE (N_{core} = 7 x 10^{14} cm^{-3}, T_{core} = 0, N_{hot} = 5 x 10^{11} cm^{-3}, T_{hot} = 500 keV)

ORNL-DWG 82-3490 FED

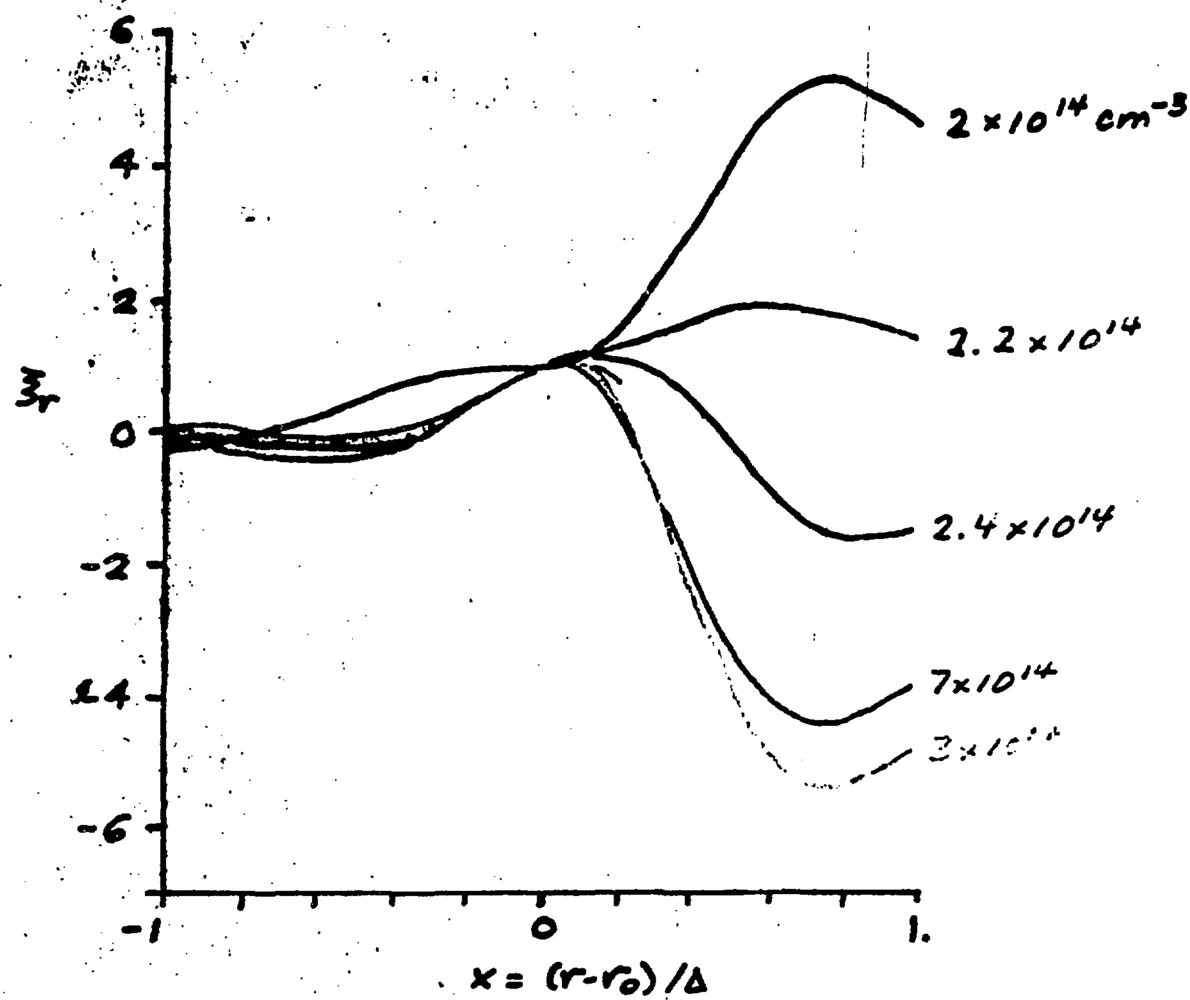


COMPRESSIONAL ALFVEN MODE STRUCTURE VS. MODE NO.



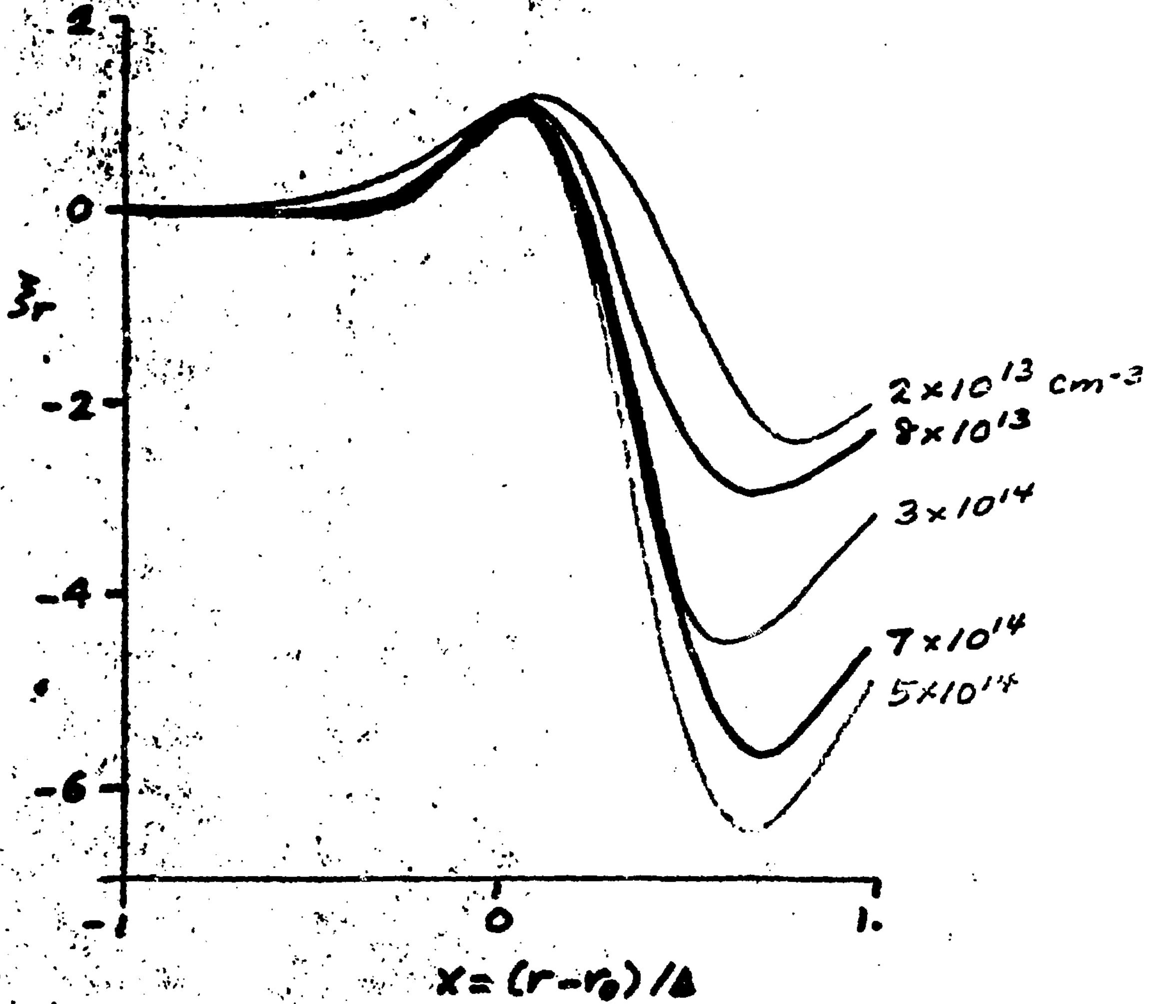
COMPRESSIONAL ALFVEN MODE STRUCTURE VS. CORE DENSITY

(m=7)

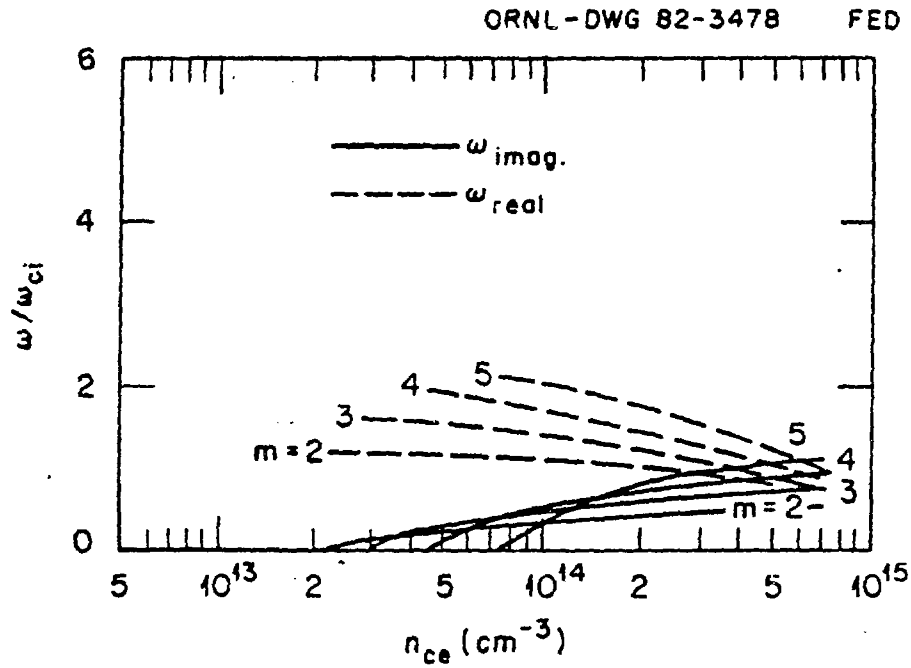


COMPRESSIONAL ALFVEN MODE STRUCTURE VS. CORE DENSITY

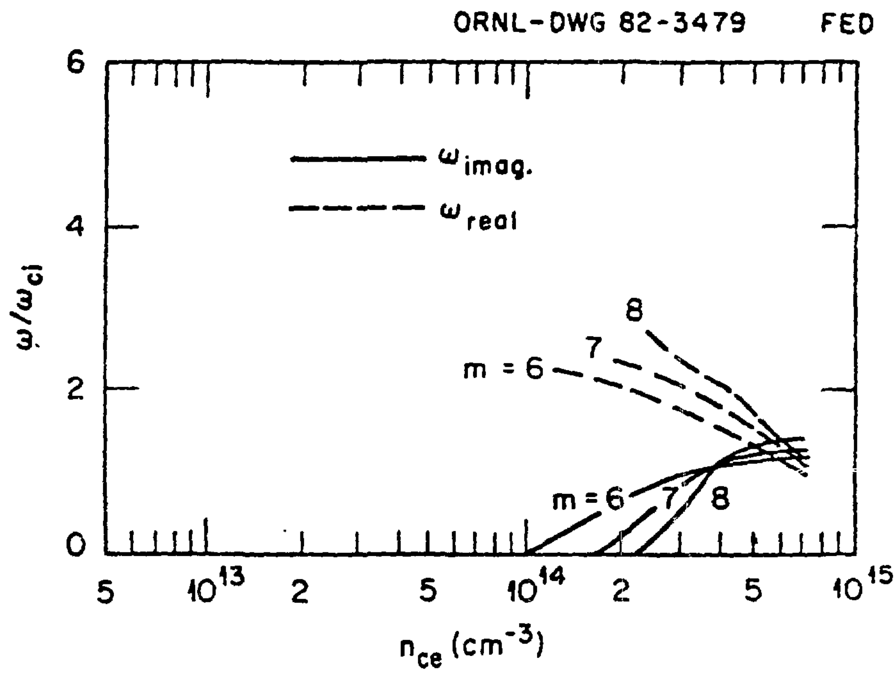
(m= 10)



COMPRESSIONAL ALFVÉN WAVE
(m = 2-5)

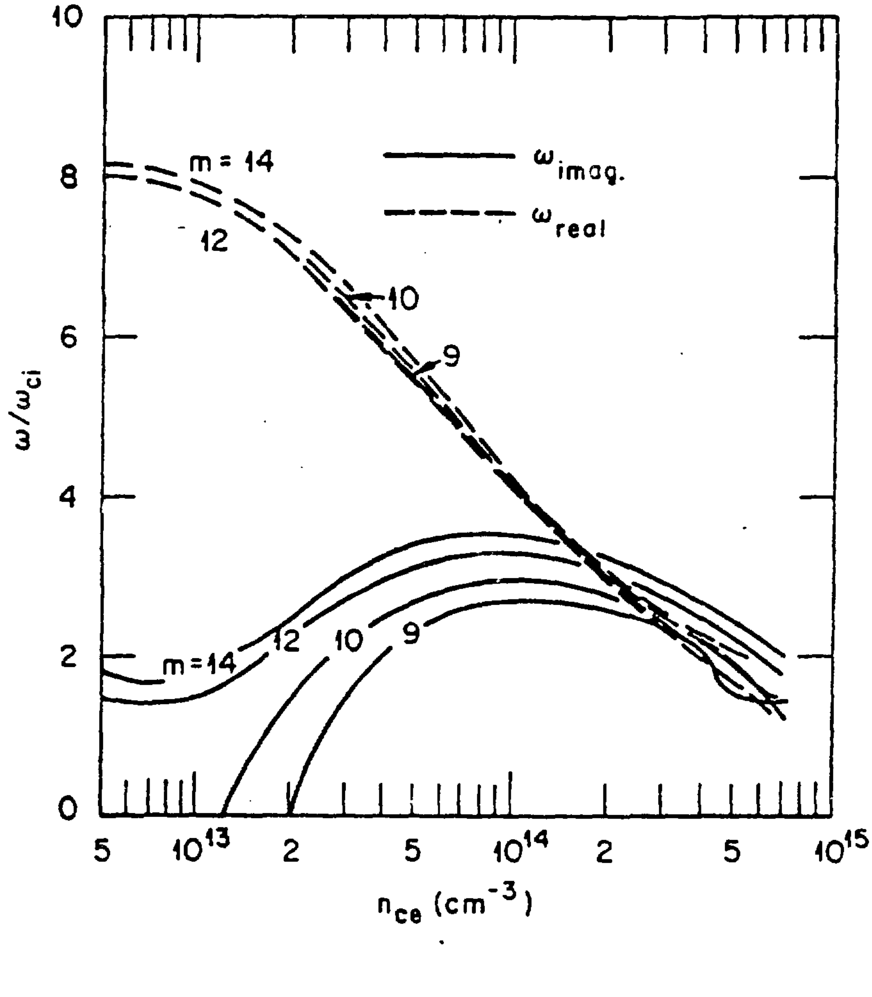


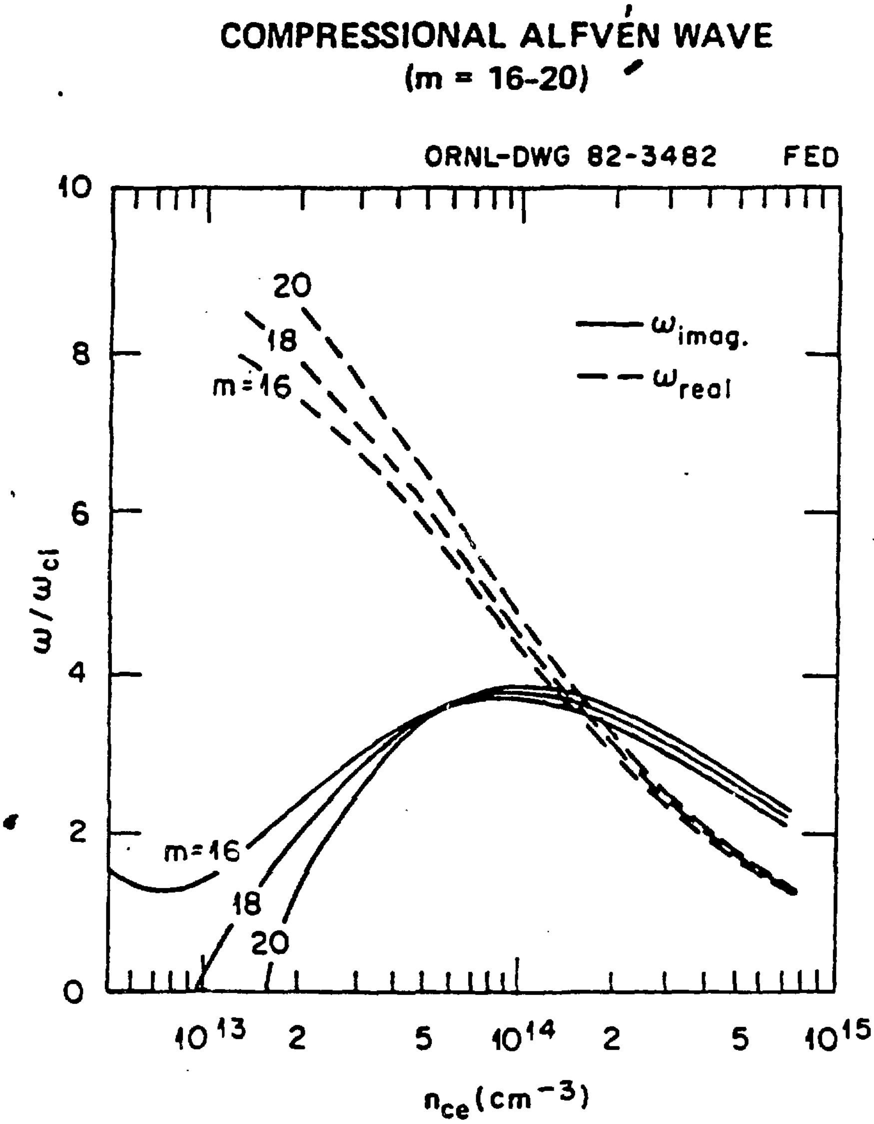
COMPRESSIONAL ALFVÉN WAVE
(m = 6-8)



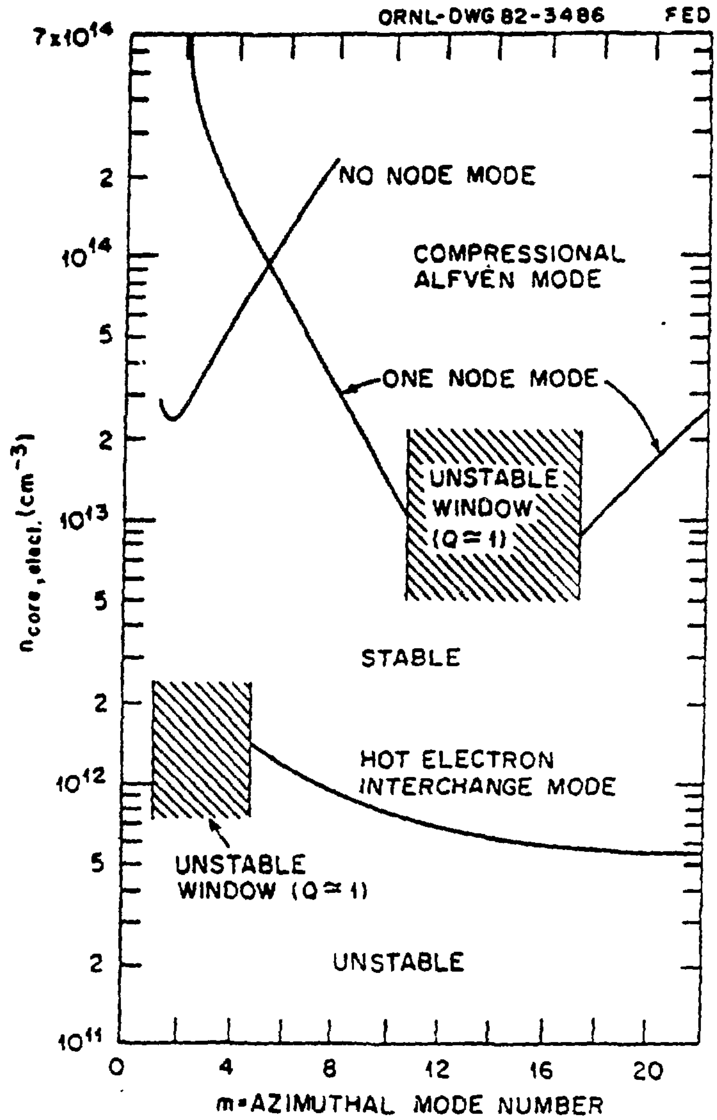
COMPRESSIONAL ALFVÉN WAVE
(m = 9-14)

ORNL-DWG 82-3480 FED

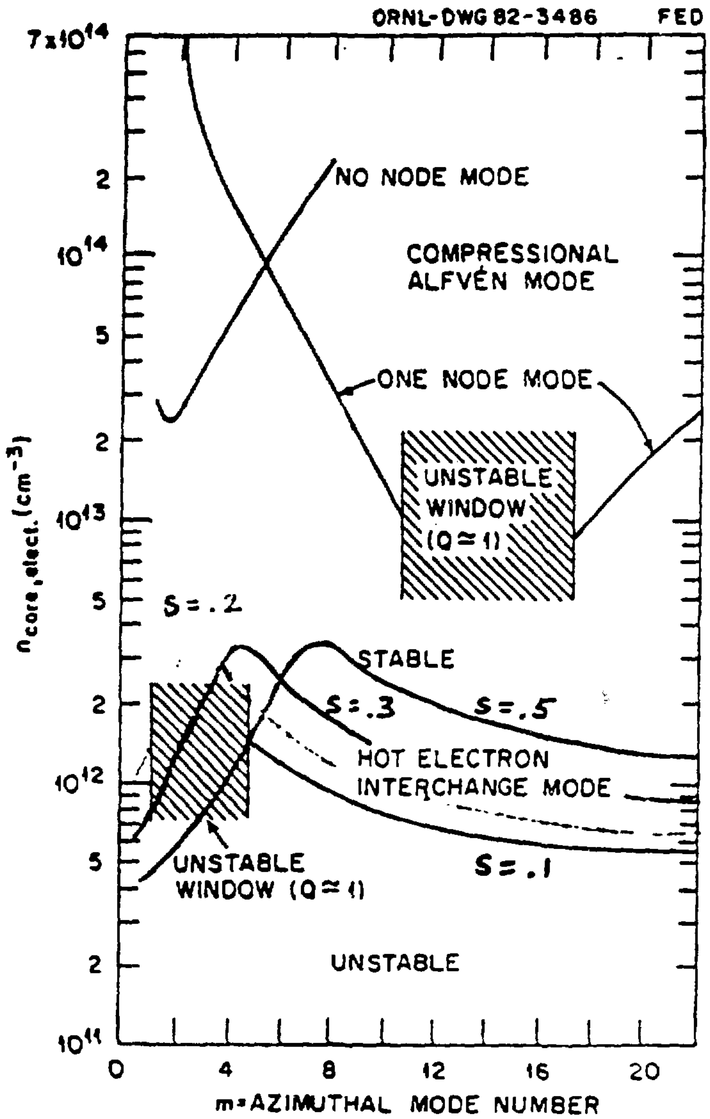



COMPRESSIONAL ALFVÉN WAVE
(m = 16-20)
ORNL-DWG 82-3482 FED
20
18
m=16
$\omega_{imag.}$
ω_{real}
m=16
18
20
ω/ω_{ci}
$n_{ce}(cm^{-3})$
10
8
6
4
2
0
10^{13}
2
5
10^{14}
2
5
10^{15}

HIGH FREQUENCY MODE STABILITY BOUNDARIES AS A FUNCTION OF m FOR $T_{core} = 0$, $N_{hot} = 5 \times 10^{11}$ cm^{-3}, $T_{hot} = 500$ keV

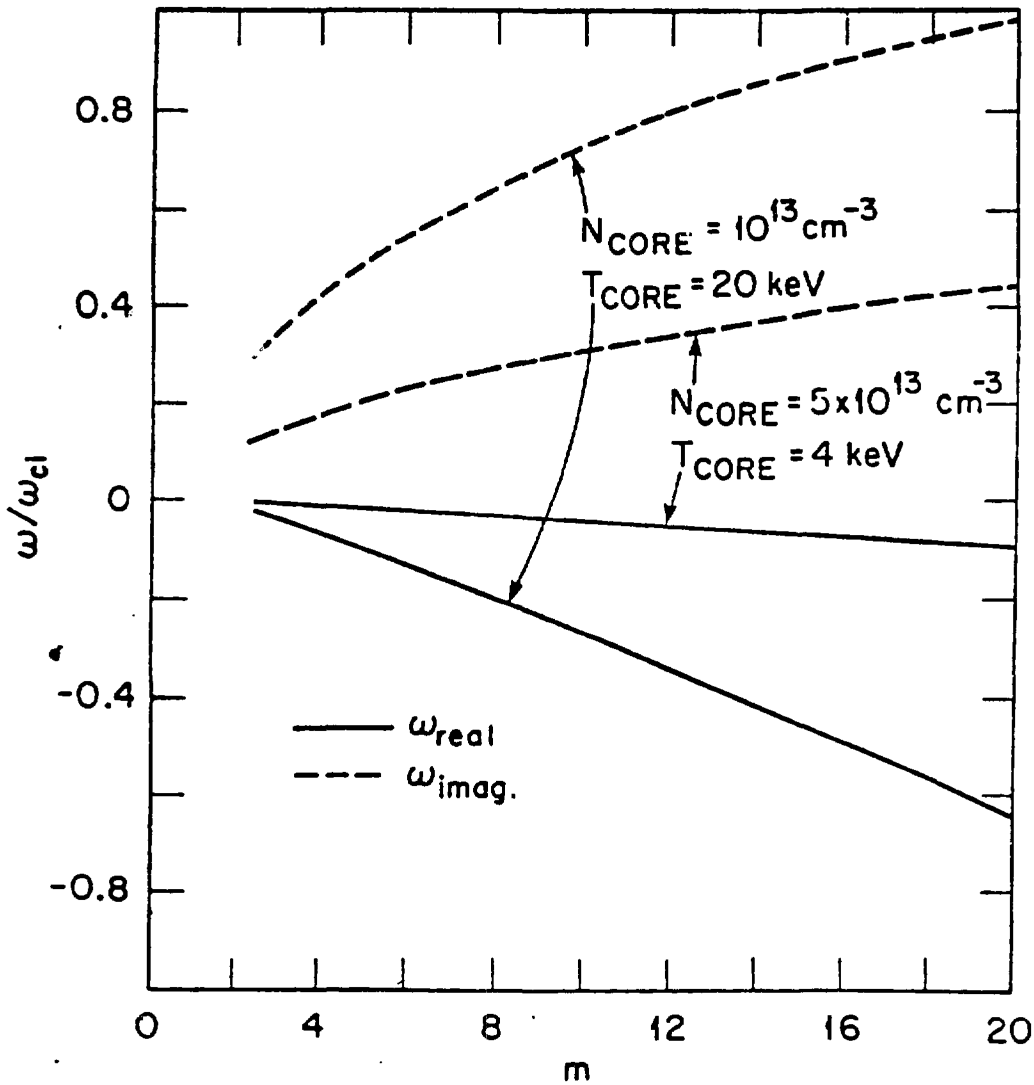


HIGH FREQUENCY MODE STABILITY BOUNDARIES
AS A FUNCTION OF m FOR $T_{core} = 0$,
$N_{hot} = 5 \times 10^{11}\ cm^{-3}$, $T_{hot} = 500\ keV$

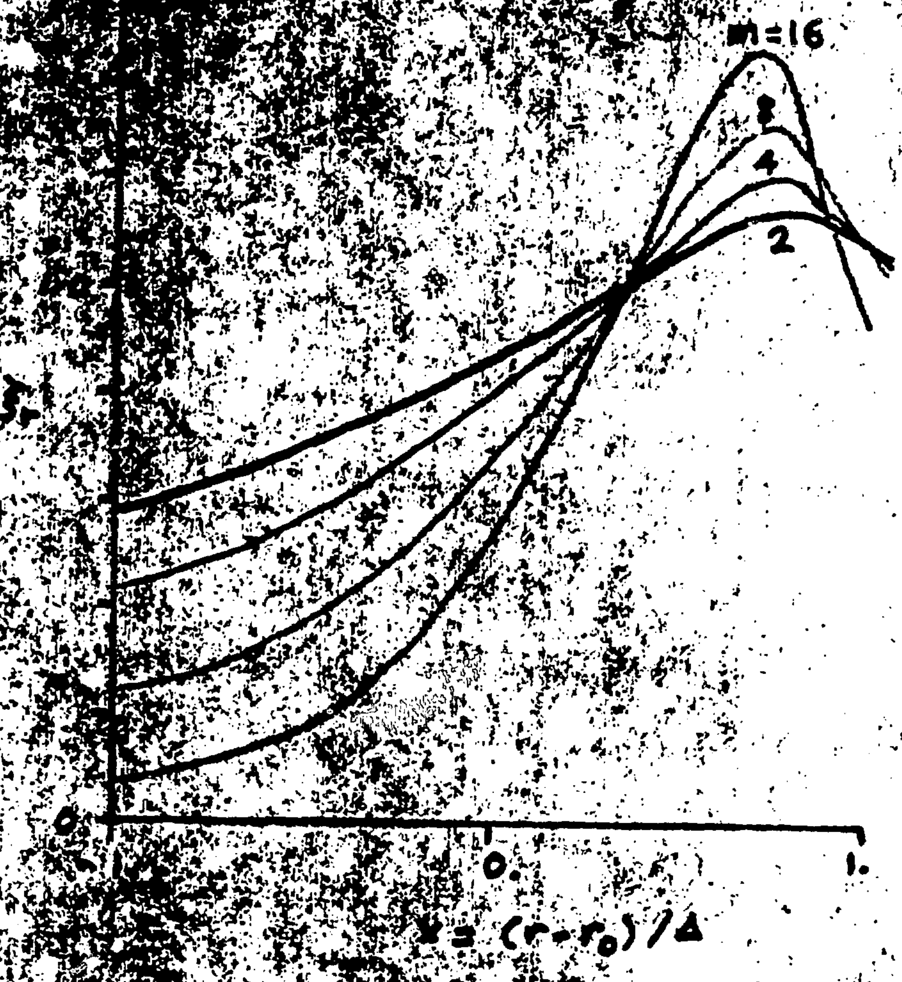


DEPENDENCE OF FREQUENCY ON AZIMUTHAL MODE NUMBER FOR INTERACTING CORE INTERCHANGE (N_{hot} = 5 x 10^{11} cm^{-3}, T_{hot} = 500 keV)

ORNL-DWG 82-3491 FED

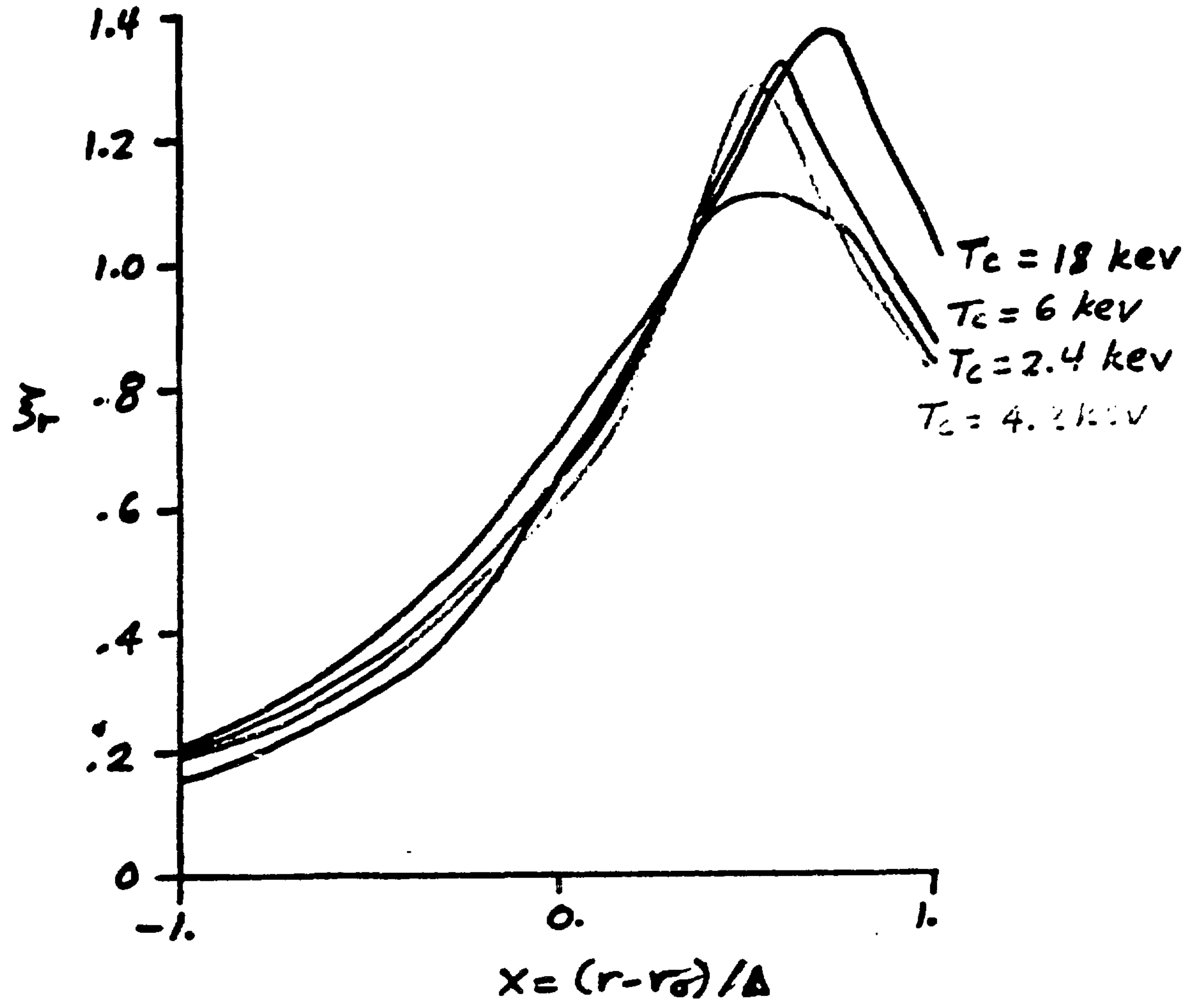


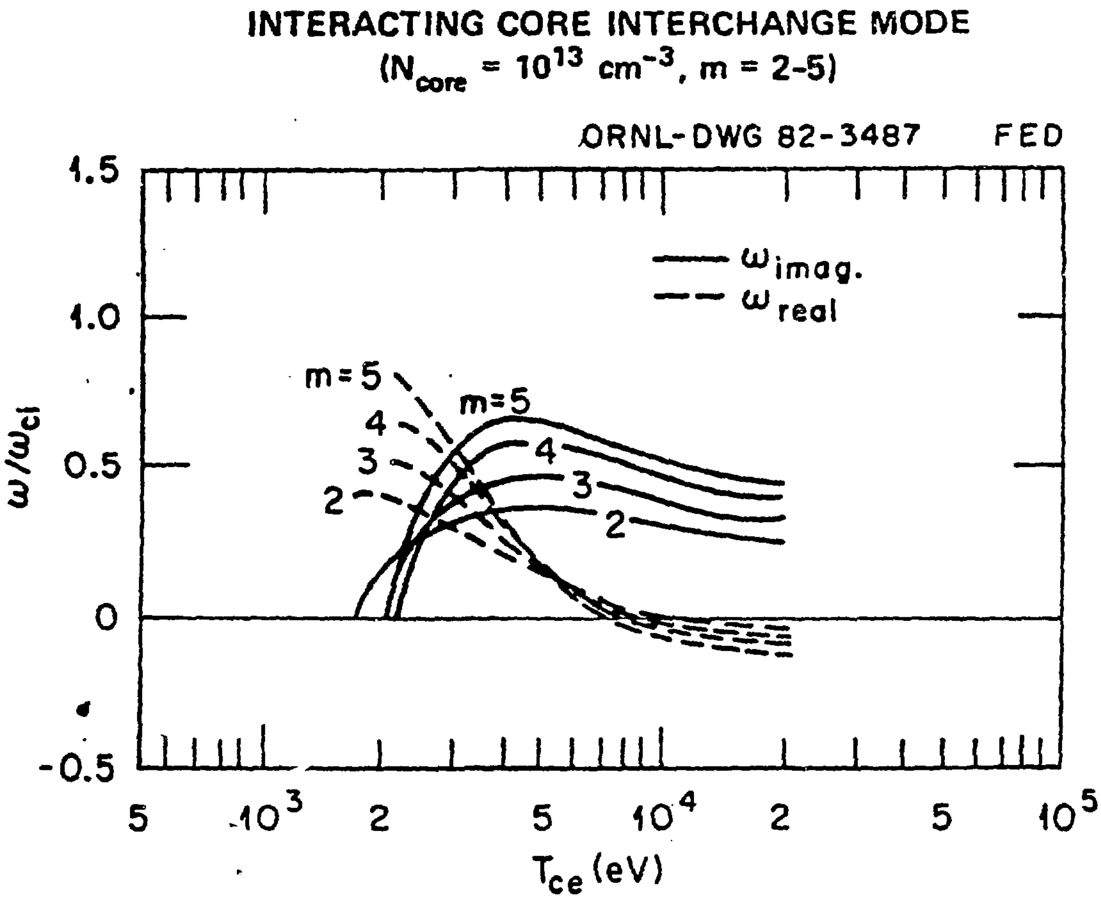
INTE[illegible]TING PRESSURE-DRIVEN INTERCHANGE [illegible]E STRUCTURE VS. M



INTERACTING PRESSURE-DRIVEN INTERCHANGE MODE STRUCTURE VS. CORE TEMPERATURE

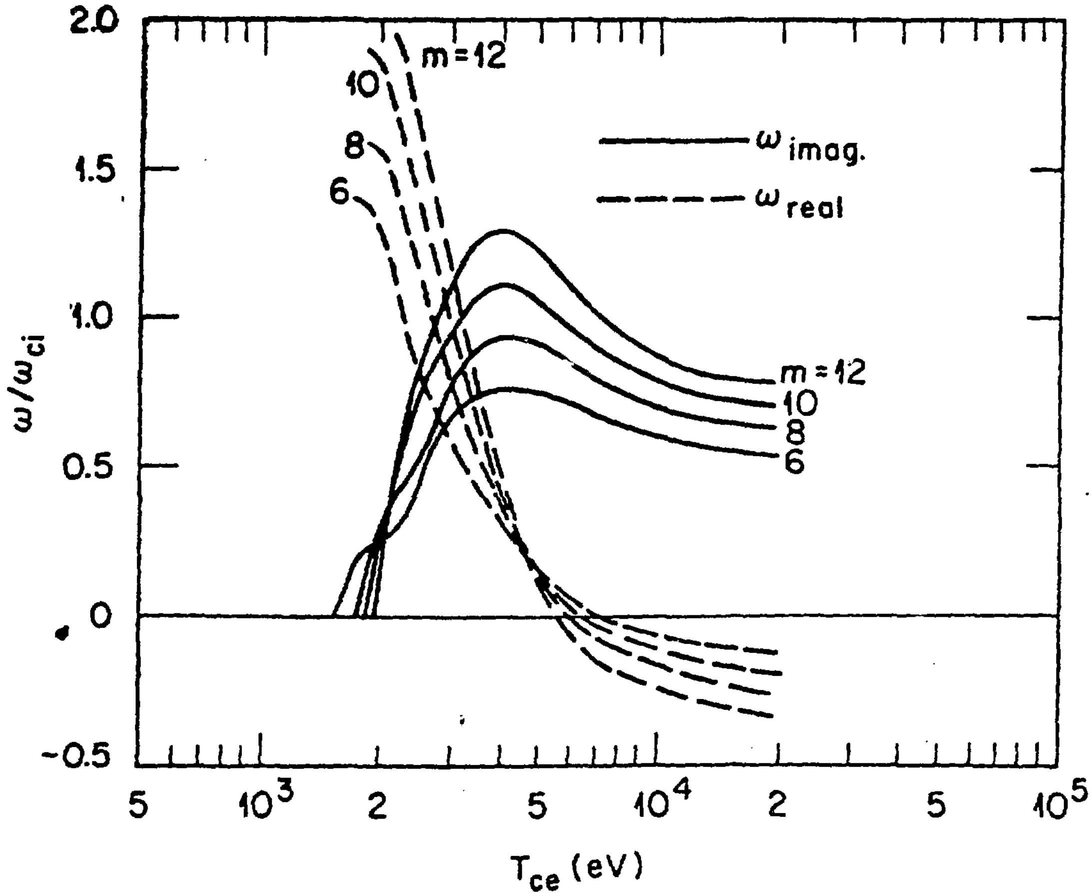
(m=11)

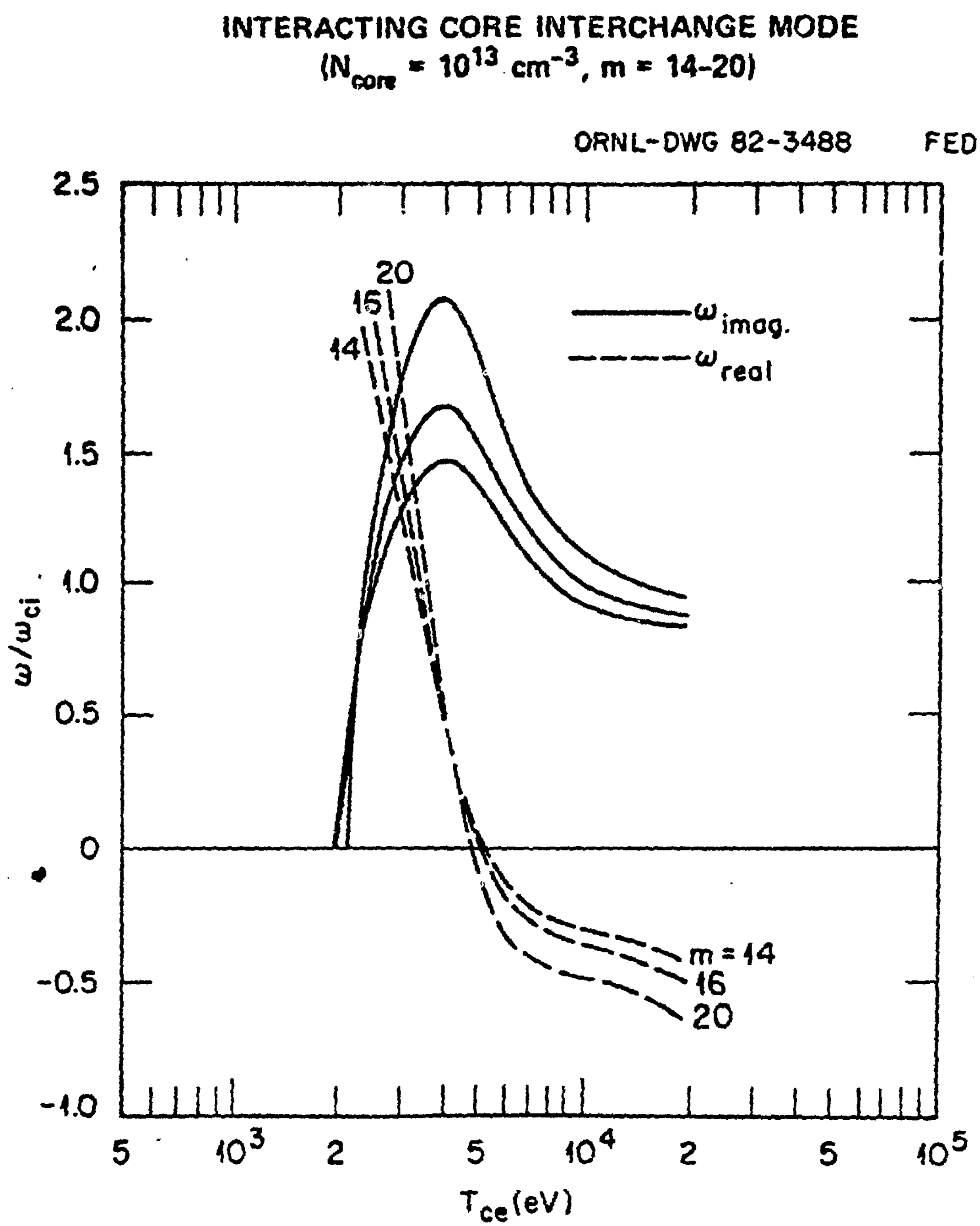



INTERACTING CORE INTERCHANGE MODE
(N_{core} = 10^{13} cm^{-3}, m = 2-5)
ORNL-DWG 82-3487 FED
$\omega_{imag.}$
ω_{real}
m=5
4
3
2
m=5
4
3
2
1.5
1.0
0.5
0
-0.5
ω/ω_{ci}
5
10^3
2
5
10^4
2
5
10^5
T_{ce} (eV)

INTERACTING CORE INTERCHANGE MODE
($N_{core} = 10^{13}$ cm^{-3}, m = 6-12)

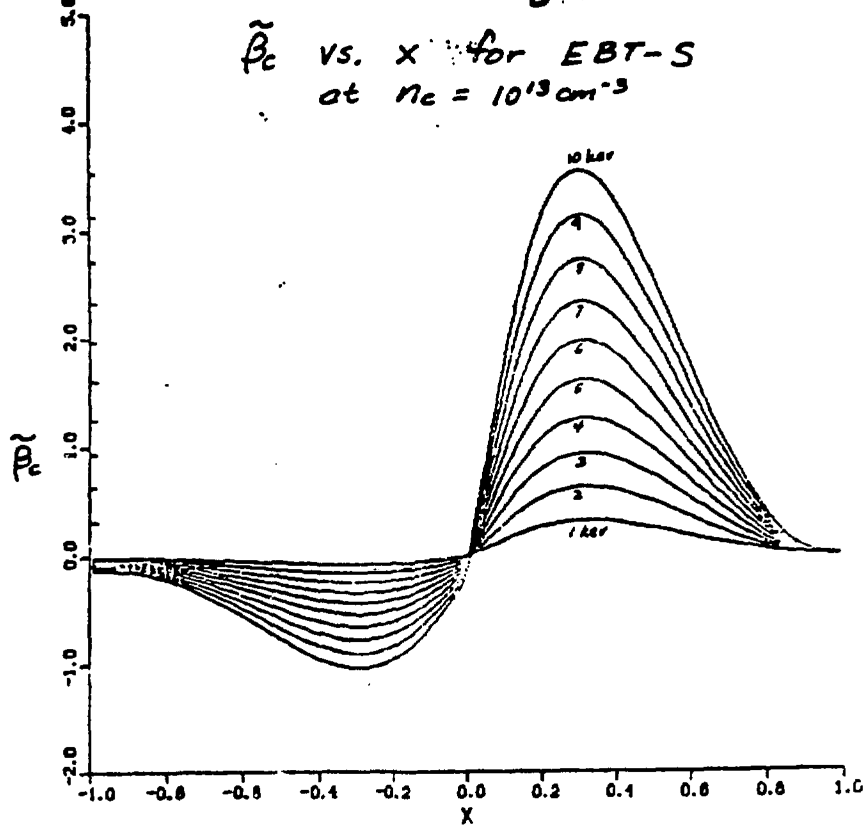
ORNL-DWG 82-3489 FED




INTERACTING CORE INTERCHANGE MODE
(N_core = 10^13 cm^-3, m = 14-20)
ORNL-DWG 82-3488 FED
ω imag.
ω real
20
16
14
m = 14
16
20
ω/ω_ci
T_ce (eV)
2.5
2.0
1.5
1.0
0.5
0
-0.5
-1.0
5
10^3
2
5
10^4
2
5
10^5

TYPICAL $\tilde{\beta}_c$ PROFILES USED IN RADIALLY - DEPENDENT CALCULATIONS

$$\tilde{\beta}_c = -r\frac{d}{dr}\left(\frac{p_c}{B^2}\right) \simeq \beta_c\left(\frac{r}{2\Delta}\right)(1+\beta_H)$$



HOT PLASMA DECOUPLING CONDITIONS:

- WKB ANALYSIS:

$$1-\tilde{\beta}_c < 3\left[\frac{?}{?}\tilde{\Omega}\left(1+\frac{2\tilde{\beta}_c}{\tilde{\beta}_H}-\frac{2}{\tilde{\beta}_H}\right)\right]^{1/3}$$

defining $\Omega_{cv} \equiv \dfrac{\omega_{kv}}{\gamma_{MHD}} = \sqrt{\dfrac{k\Delta g_0}{p}}$

$$\boxed{\Omega_{cv} < \frac{3(k\Delta)^{1/2}\tilde{\Omega}^{2}\sqrt{1+2\tilde{\beta}_c/\tilde{\beta}_H-2/\tilde{\beta}_H}}{(k_\perp\Delta)(1-\tilde{\beta}_c)^{3/2}}}$$

- LAYER ANALYSIS:

$\tilde{\beta}_c \ll 1$

$$\boxed{\Omega_{cv} < \mathrm{Max}\left[2\left(\frac{k}{K}\delta\right)^{1/4},\ 4\left(\frac{k}{K}\tilde{\beta}_c\right)^{1/2}\right]}$$

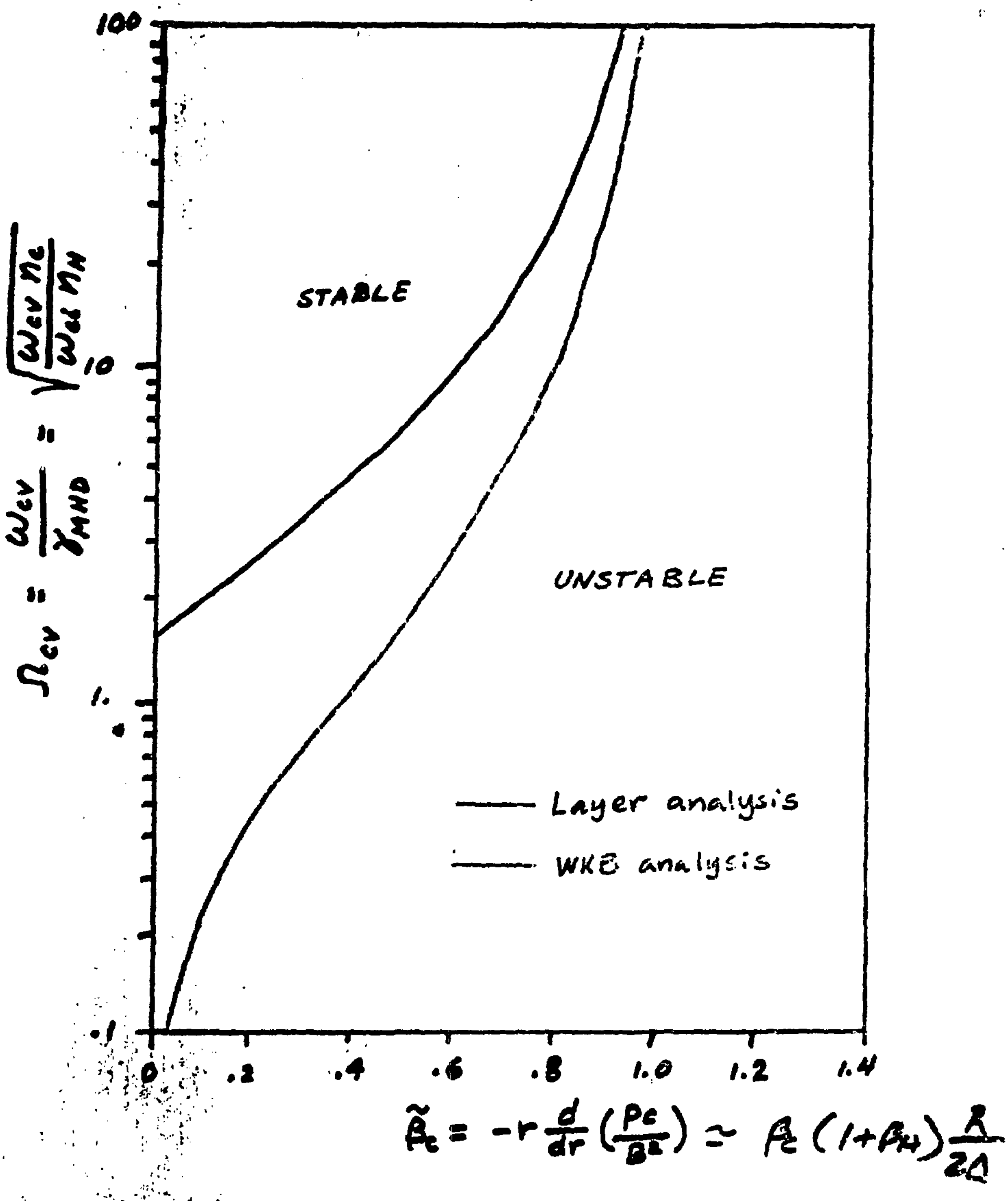
$$\delta \simeq |k|\Delta \qquad K = \frac{1}{\zeta(R-\Delta)}\frac{d\zeta(R-\Delta)}{dr} \sim |k|$$

$\tilde{\beta}_c \lesssim 1$

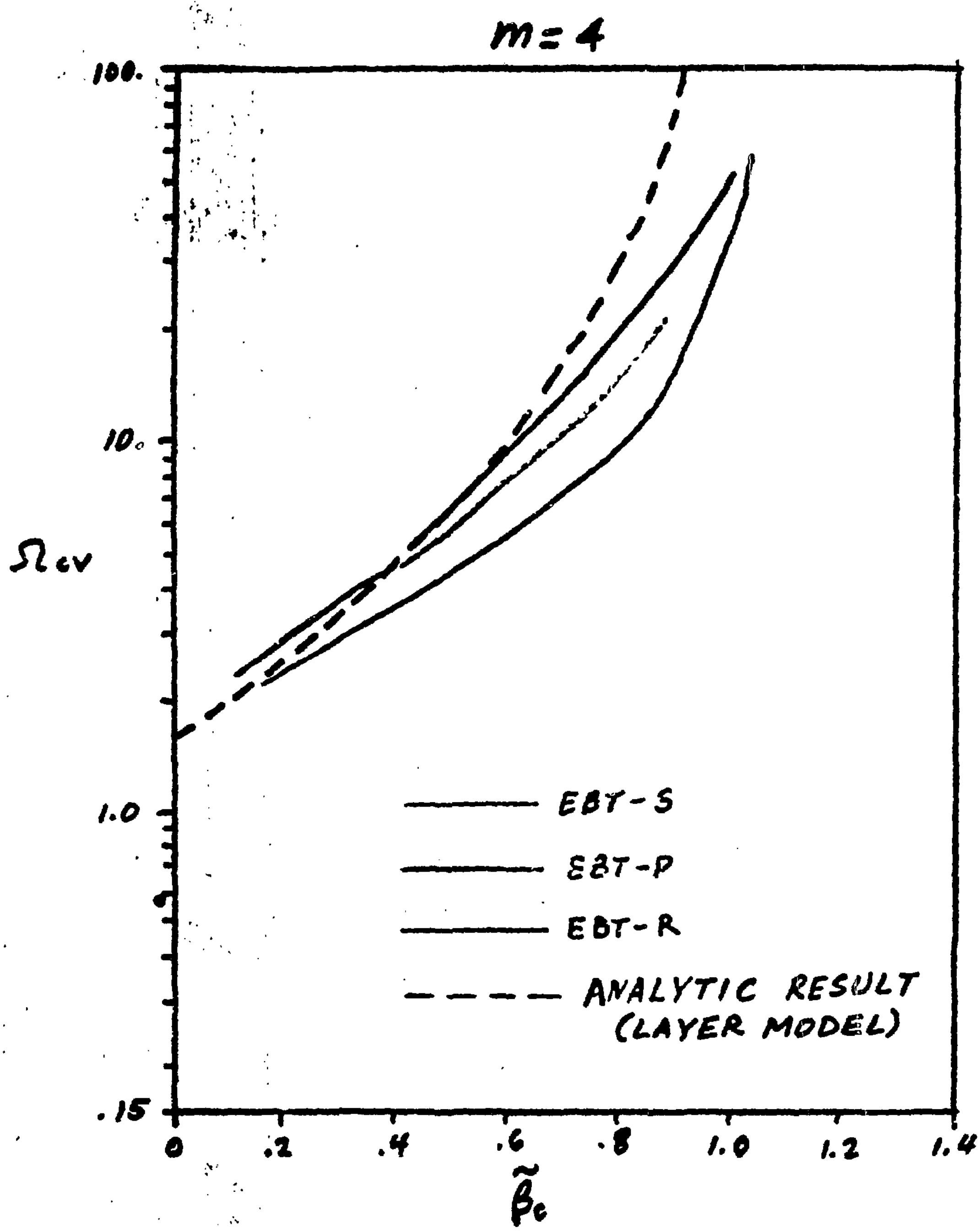
$$\boxed{\Omega_{cv} > \frac{\delta^{3/2}\,|k|}{2\,K^{3/2}(1-\tilde{\beta}_c)^{3/2}}}$$

HOT PLASMA DECOUPLING CONDITION FOR PRESSURE-DRIVEN INTERCHANGE

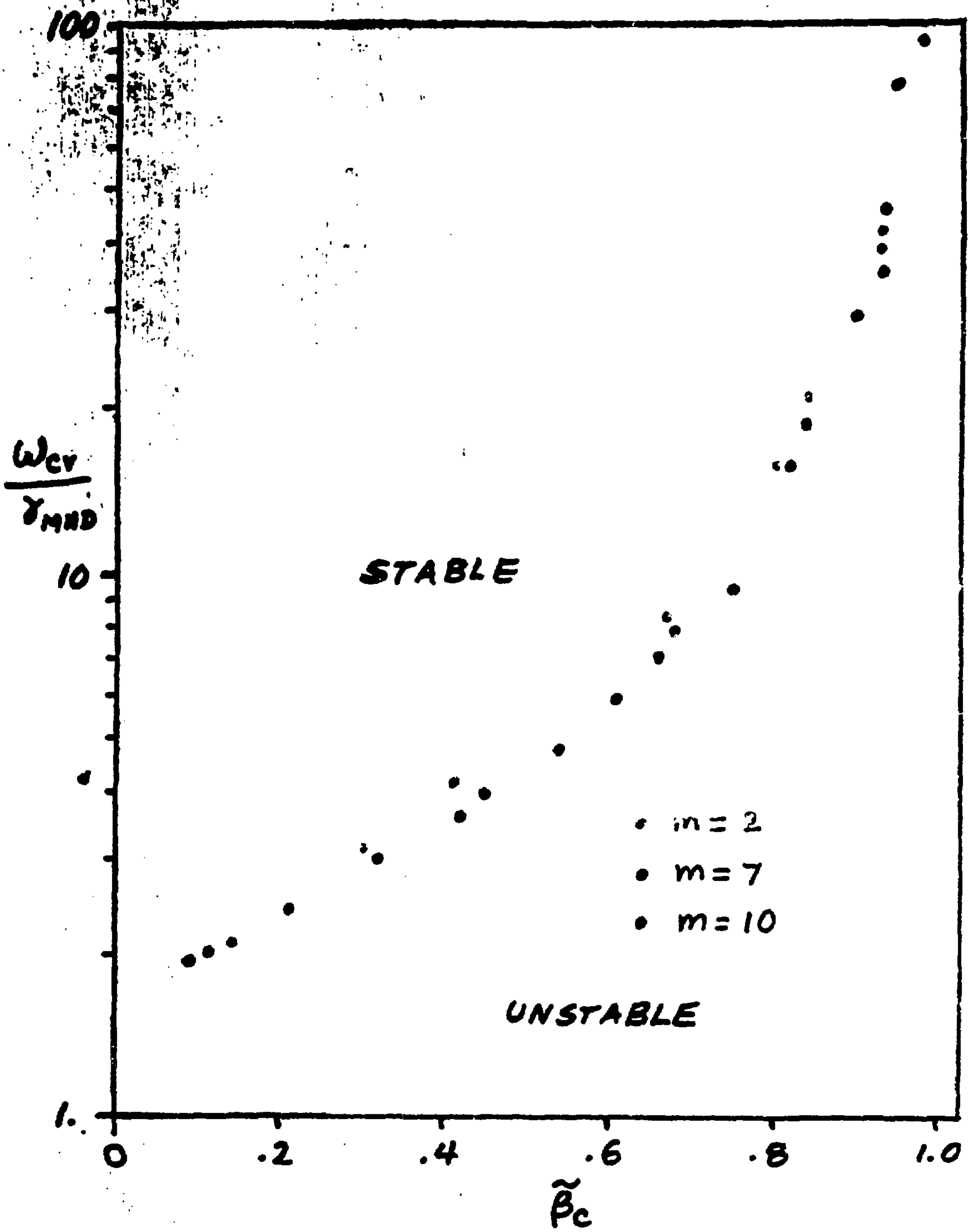
$m = 4$



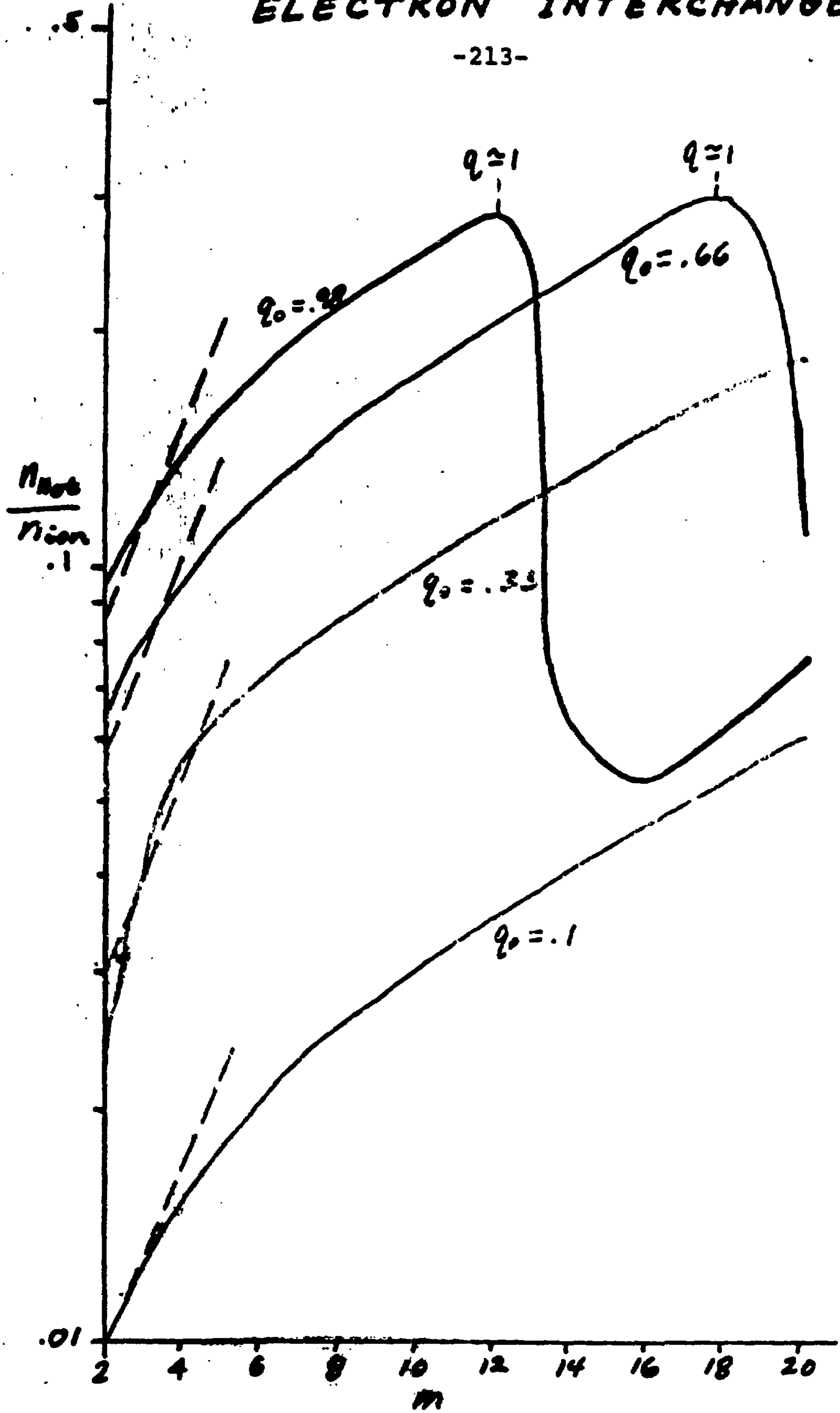
DECOUPLING CONDITION FROM NONLOCAL CALCULATION



THE HOT PLASMA DECOUPLING CONDITION IS NOT STRONGLY DEPENDENT ON M (except through $\frac{\omega_c}{\gamma_{MI}}$



ELECTRON INTERCHANGE



CONCLUSIONS:

- HOT ELECTRON INTERCHANGE

  $m \gtrsim 6$ somewhat more optimistic than local theory due to $k_r\Delta < 2$

  $m \lesssim 6$ instability band present ($q<1$) can be moved to $m<1$ by profile change (surface plasma)

  frequency and $(n_H/n_c)_{crit}$ in reasonable agreement with expt.

- COMPRESSIONAL ALFVEN

  stability determined by { no node mode for $m \lesssim 9$; one node mode for $m \gtrsim 9$ }

  $(k_r)_{eff.}$ higher than local theory → larger density threshold

  decoupling condition at different m than local theory due to radial mode structure

  one node unstable band at ~ 80MHz seen in expt. throughout T mode

CONCLUSIONS: (cont'd.)

- LOW FREQUENCY HOT ELECTRON INTERCHANGE

  SIMILAR TO HIGH FREQUENCY BRANCH, BUT WITH LOWER q_0

  LAYER SCALING FITS LOW m RESULTS.

- INTERACTING RING-CORE INTERCHANGE

  RELEVANT PARAMETER IS: $\tilde{\beta}_c = -r\frac{d}{dr}\left(\frac{P_c}{B^2}\right)_{MAX}$

  EBT-S (20 keV), EBT-P (1-2 keV) $\tilde{\beta}_c \lesssim .2$

  RING-CORE DECOUPLING LOST AT:

$$\frac{\omega_{cv}}{\gamma_{MHD}} \simeq 1.5$$