Electron Cyclotron Current Drive at High Electron Temperature on DIII–D

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in collaboration with

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GENERAL ATOMICS

306-04/CP/jy

MOTIVATION

- Electron cyclotron current drive (ECCD) is strongly dependent on electron temperature (T_e)
- Nearly all experimental tests of ECCD theory have been done with T_e an order of magnitude lower than ITER regime
- High rf power, low density experiments on DIII–D have measured ECCD profiles for thermal $T_e \approx 10$ keV but radiation temperatures > 20 keV from electron cyclotron emission (ECE)
- Experimental results from this challenging regime are found to generally agree with theoretical calculations using the CQL3D quasi-linear Fokker-Planck code

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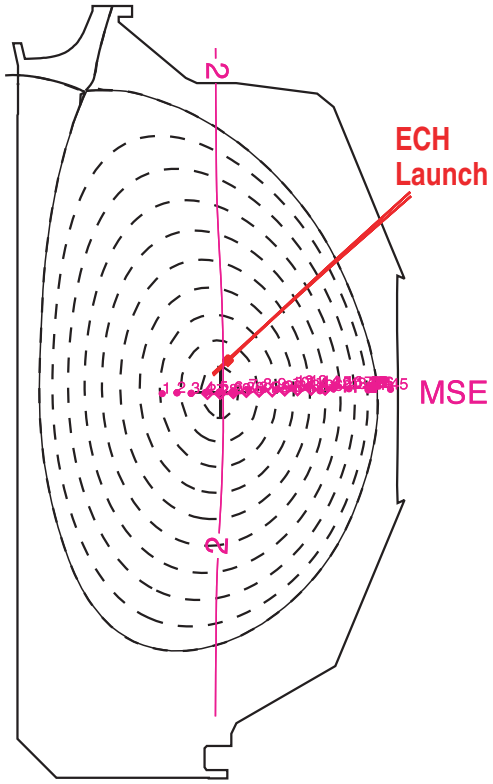
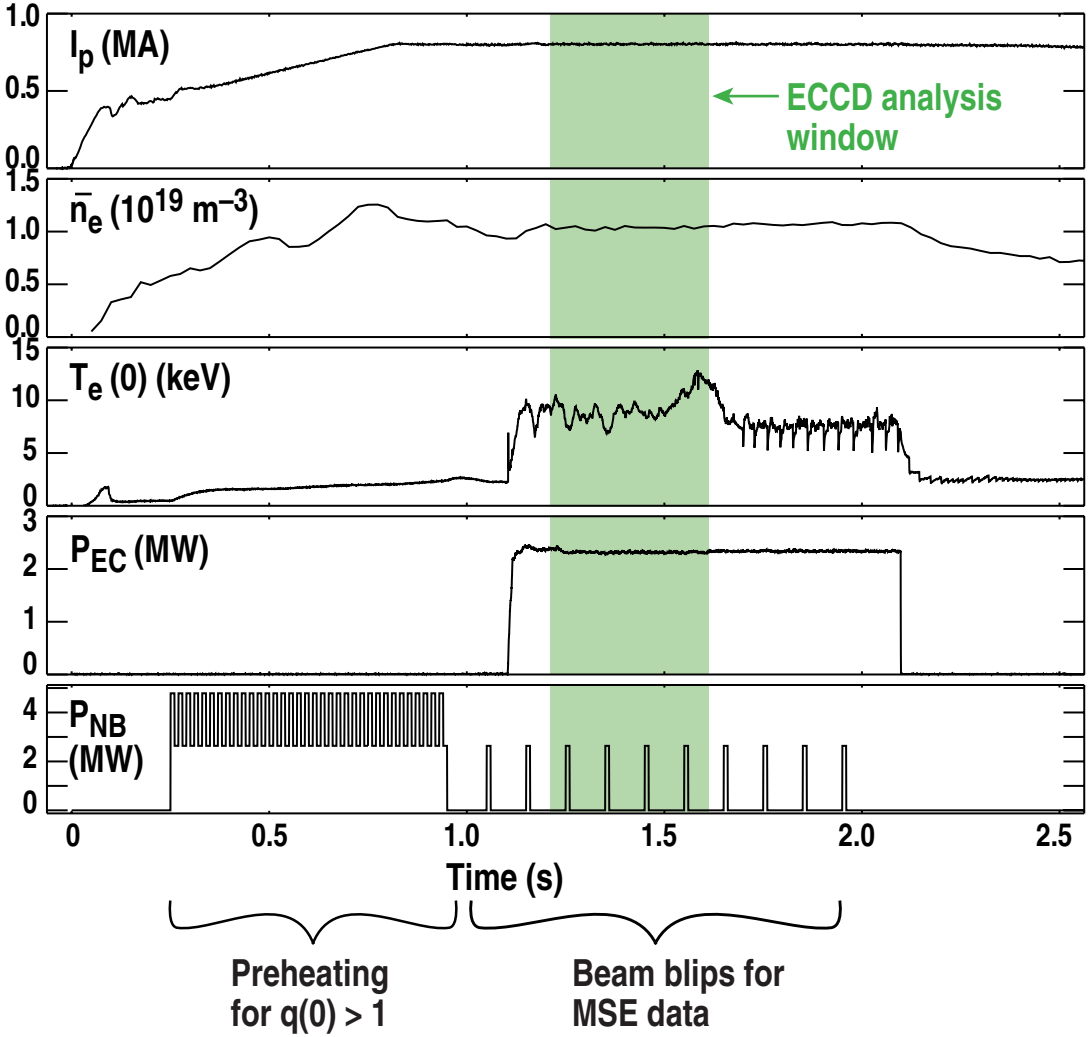
NEARLY CENTRAL ECCD MEASURED IN LOW DENSITY L–MODE PLASMAS DURING SAWTOOTH-FREE PERIOD



2nd harmonic
X–mode launch
$N_{||} = \pm 0.23$



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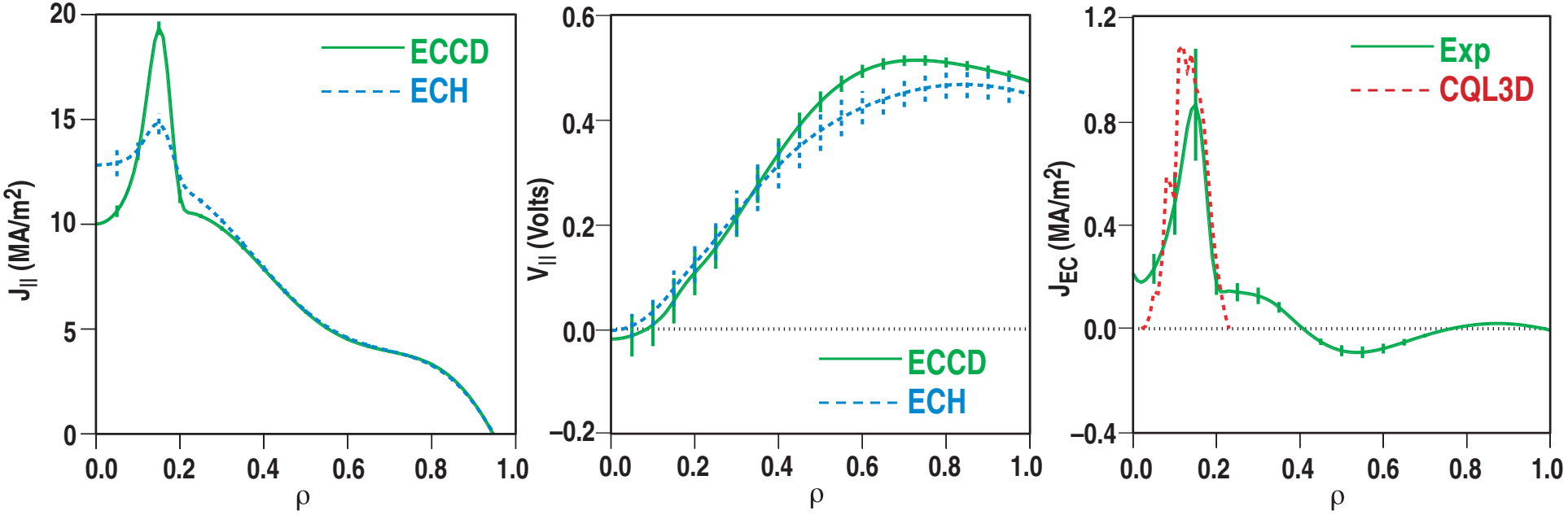
NARROW ECCD PROFILE IS MEASURED BY LOOP VOLTAGE ANALYSIS OF MSE EFITs FOR SINGLE GYROTRON CASE

$J_{NI} = J_{||} - \sigma_{neo} E_{||}$ $J_{EC} = J_{NI}(ECCD) - J_{NI}(ECH)$



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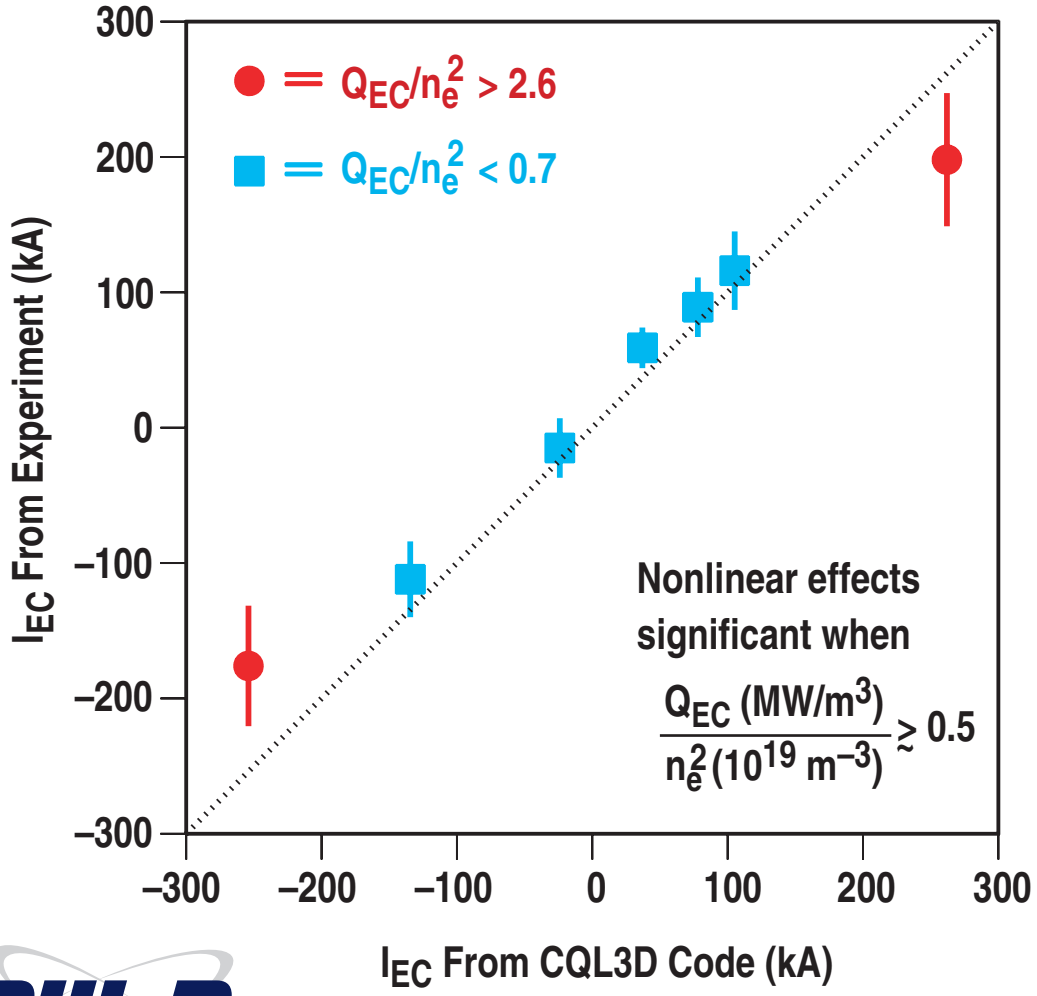
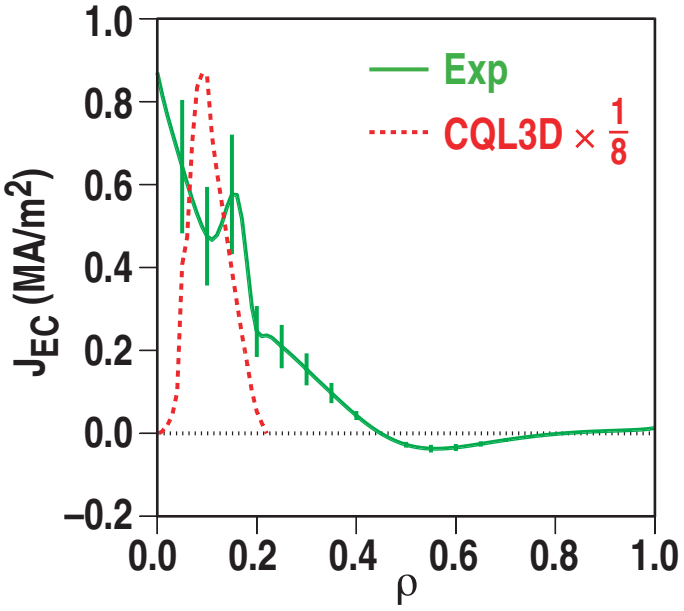
EXPERIMENTAL ECCD AGREES WITH CQL3D FOKKER-PLANCK CODE EXCEPT FOR HIGHEST RELATIVE POWER DENSITY CASES



$T_e = 6 - 11$ keV
$n_e = 1 - 3 \times 10^{19}$ m^{-3}
$P_{CD} = 0.6–2.3$ MW

Radial transport may explain lower ECCD for high Q_{EC}/n_e^2 cases



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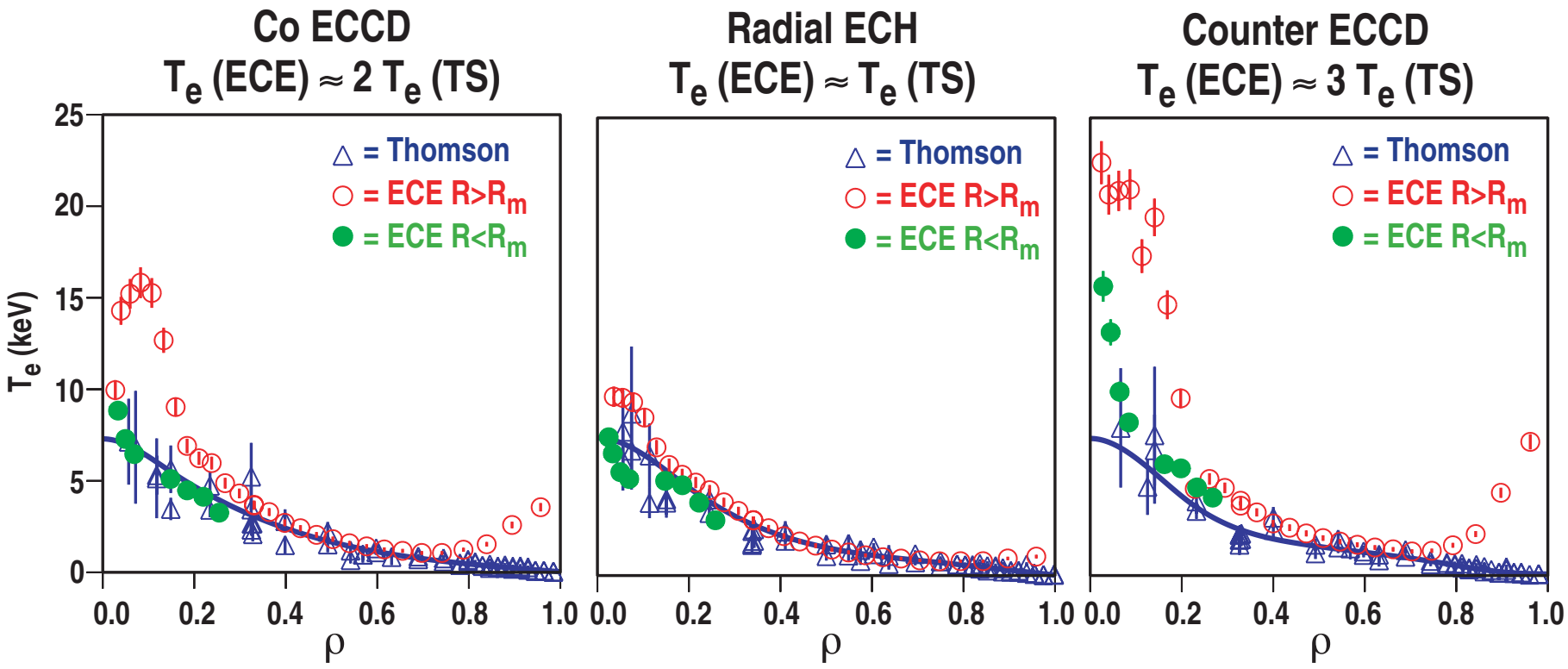
ANOMALOUSLY HIGH RADIATION TEMPERATURE INDICATES POPULATION OF NON-THERMAL ELECTRONS



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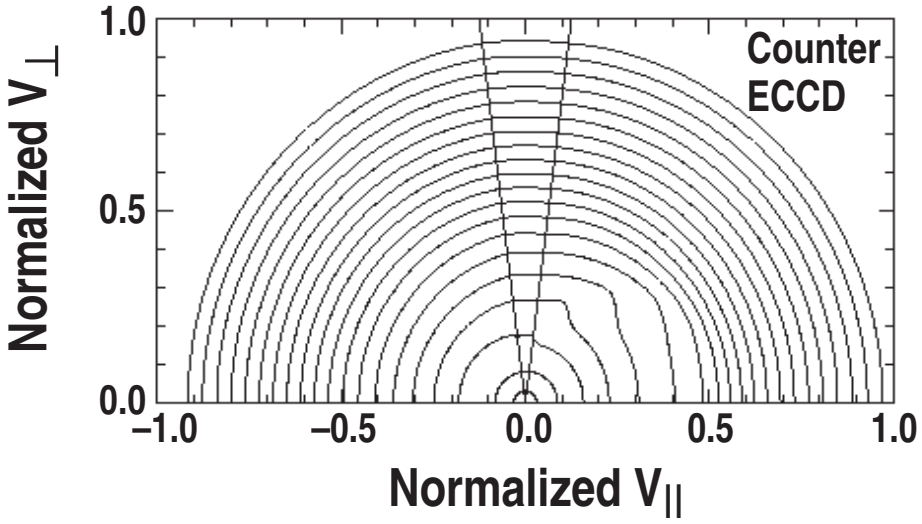
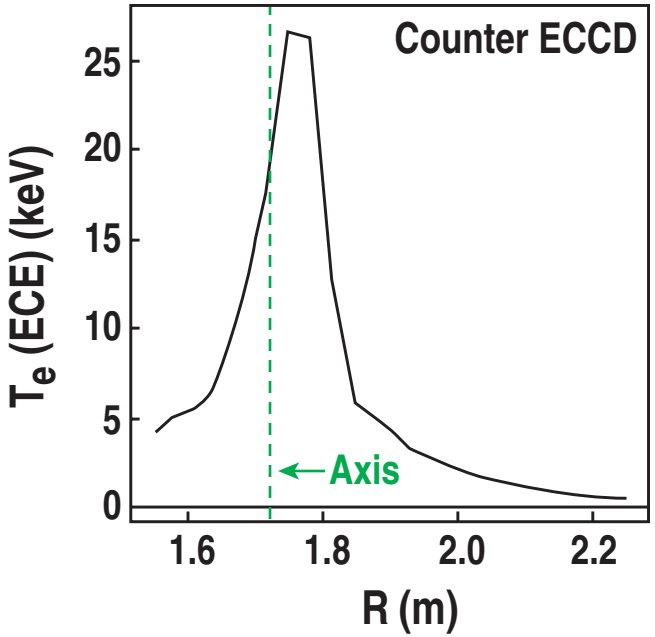
SIGNIFICANT NON-THERMAL EFFECTS ARE PREDICTED BY CQL3D FOKKER-PLANCK CODE FOR HIGH RELATIVE POWER DENSITY CASES

2D electron distribution function from CQL3D shows flattening at low velocities



Radiation temperature calculated using CQL3D distribution function is 4× Thomson scattering



- Quasi-linear enhancement to ECCD ≈ 30% for all cases
- Non-thermal effects on bulk are not yet fully accounted for in CQL3D

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SUMMARY

- Experiments on DIII–D have measured up to 200 kA of ECCD at high electron temperture ($T_e \approx 10$ keV)
- Experimental ECCD is in agreement with CQL3D quasi-linear Fokker-Planck code except when $Q_{EC}/n_e^2 >> 1$
- Anomalously high radiation temperature (> 20 keV) from non-thermal electron population is reproduced by Fokker-Planck code
- Future work on CQL3D will implement full transport modeling (real space and velocity space) than may bring theory and experiment closer together for $Q_{EC}/n_e^2 >> 1$

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