OPERATION OF ITER OVER A RANGE OF TOROIDAL FIELDS POSES CHALLENGES FOR THE ECH SYSTEM

- Operation from the design field of 5.3 T to as low as 3.0 T claimed by ITER team

  What can the ECH system do at different toroidal fields?

- Self-consistent equilibria were generated at 5.3, 4.9, 4.5, 3.6, and 3.2 T with constant q-profile (I_p=15.4, 14.2, 13.1, 10.4, and 9.3 MA) using TEQ
  - Pressure profile consistent with the equilibrium was generated
  - Pressure profile was scaled with B^2 to keep beta constant
  - Density profile was scaled with B to keep n/n_{GW} constant
  - $\Rightarrow$ T_e+T_i scaled with B to keep beta constant

- TORAY-GA was run for the anticipated steering range for each ECH antenna, using 170 GHz power with beam divergence characteristic of the top launcher

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CALCULATION OF ELECTRON CYCLOTRON CURRENT DRIVE FOR ITER

- The ITER project calls for ECH to heat and ECCD to control the current profile and to control neoclassical tearing modes
  - 4 antenna locations: 3 near the midplane and 1 near the vessel top
- The performance of the antennas can be well predicted by using ray tracing or beam propagation codes
  - Benchmarking of codes has been carried out under the ITER/ITPA process
    - ★ Similar (but not identical) results are obtained
  - Some codes have been carefully tested against experiment
- In this study the TORAY-GA code is used to explore the potential uses of the 4 ECH launchers over a range of toroidal magnetic fields using the same equilibrium

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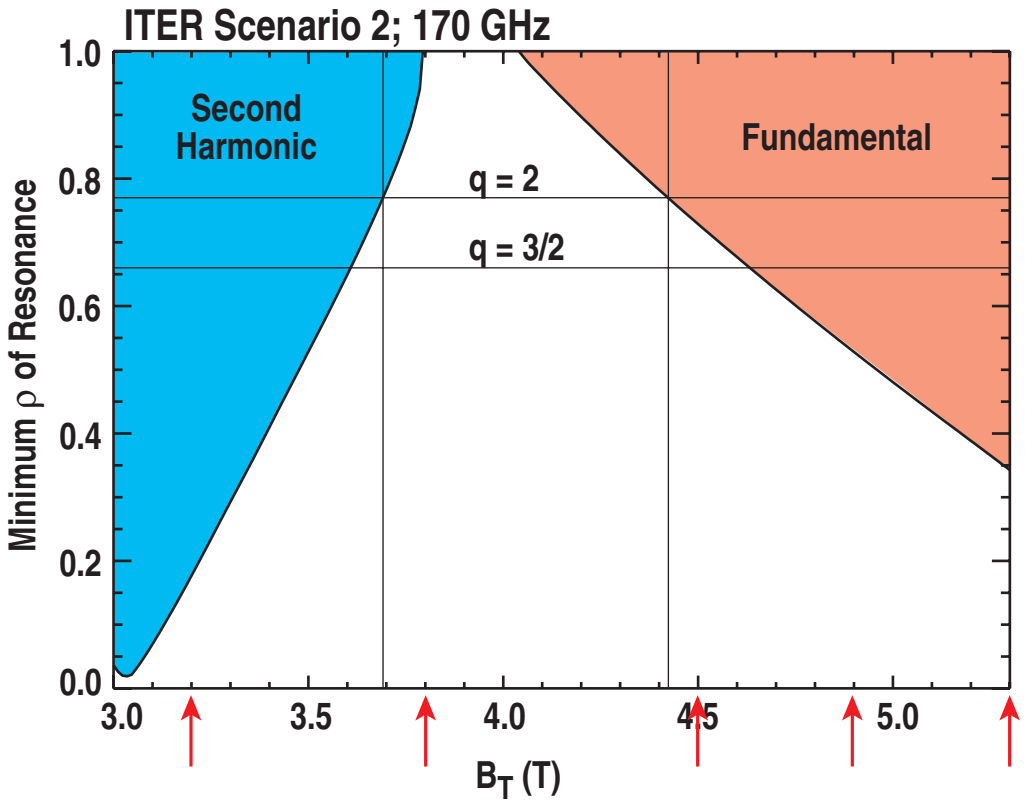
APPLICABILITY OF ECCD IN ITER IS STRONGLY AFFECTED BY LOCATION OF RESONANCE



- Fundamental resonance intersects q = 2 surface for $B_T > 4.4$ T
- Second harmonic resonance intersects q = 2 surface for $B_T < 3.7$ T

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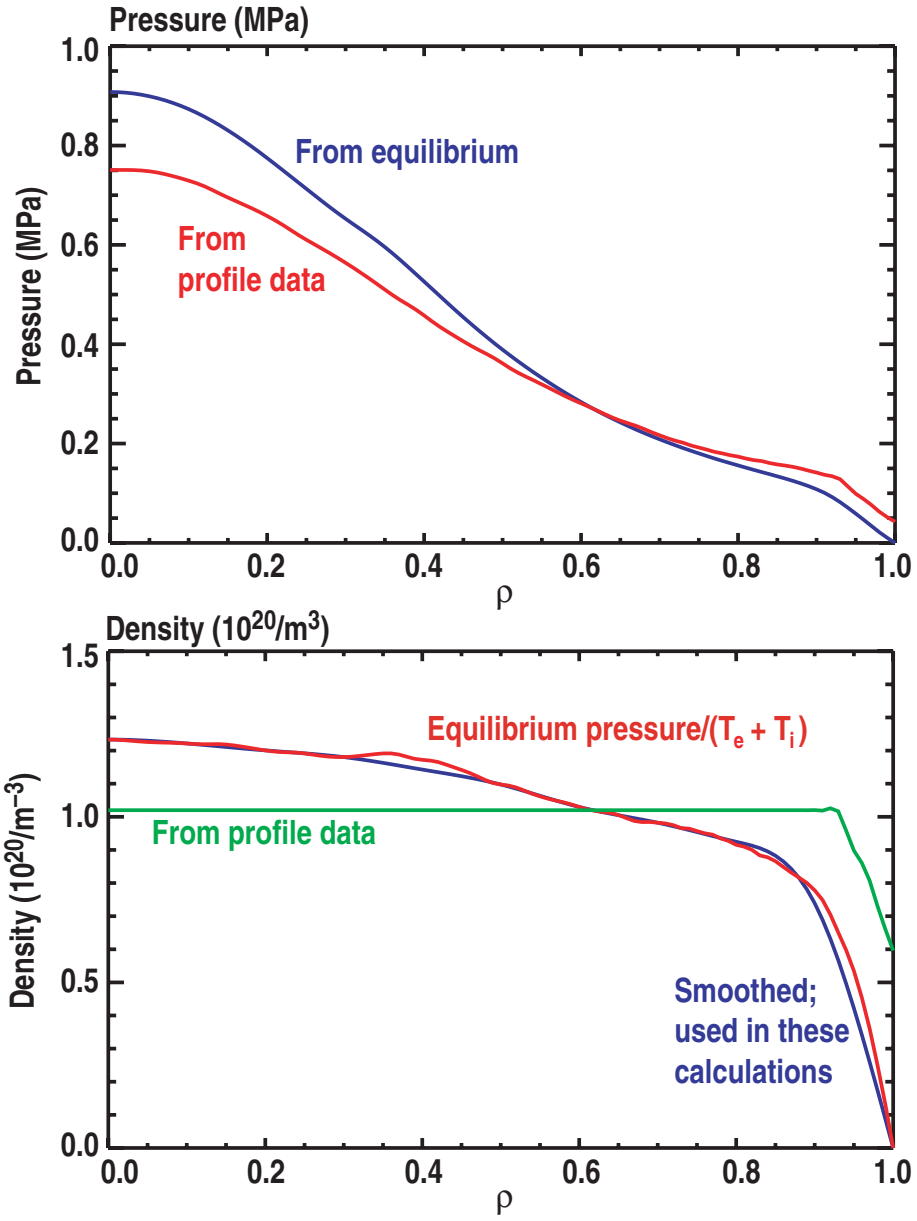
ITER SCENARIO 2 PRESSURE PROFILE FROM EQUILIBRIUM INCONSISTENT WITH KINETIC DATA



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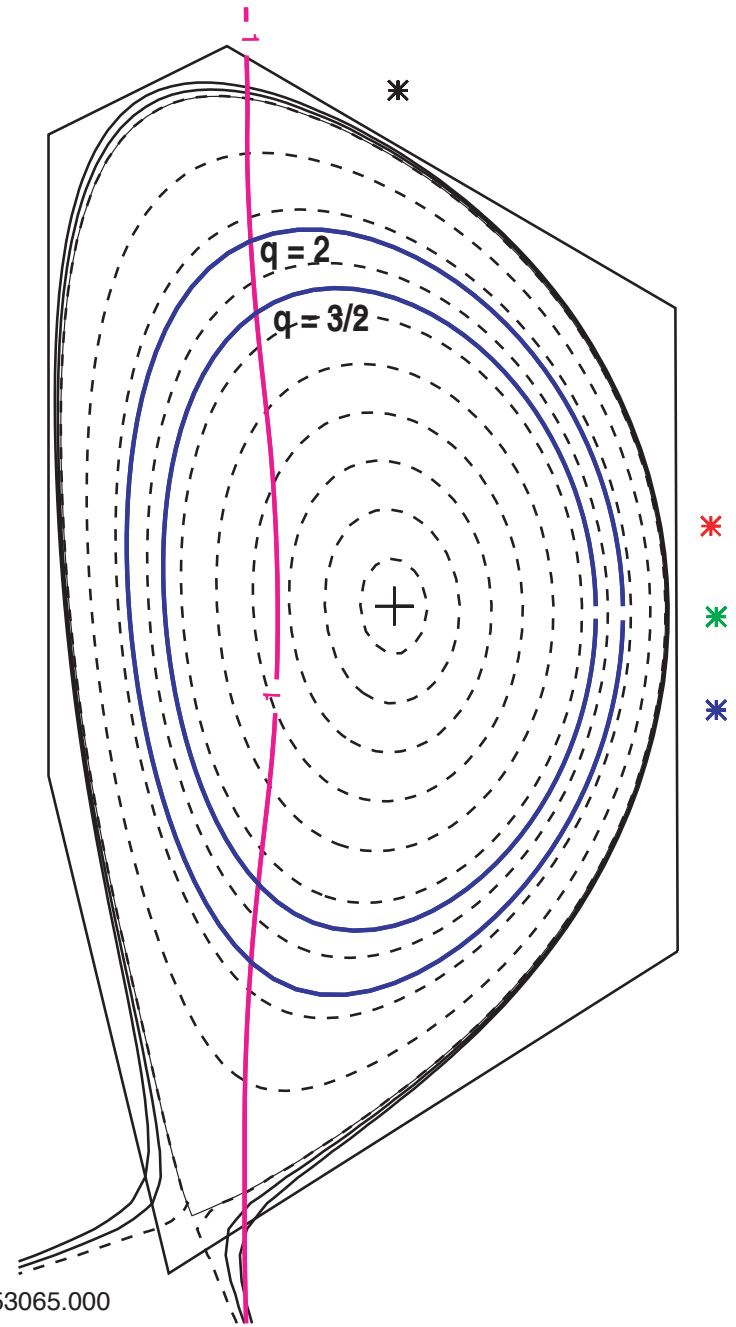
ITER SCENARIO 2 EQUILIBRIUM AT FULL FIELD (5.3T)



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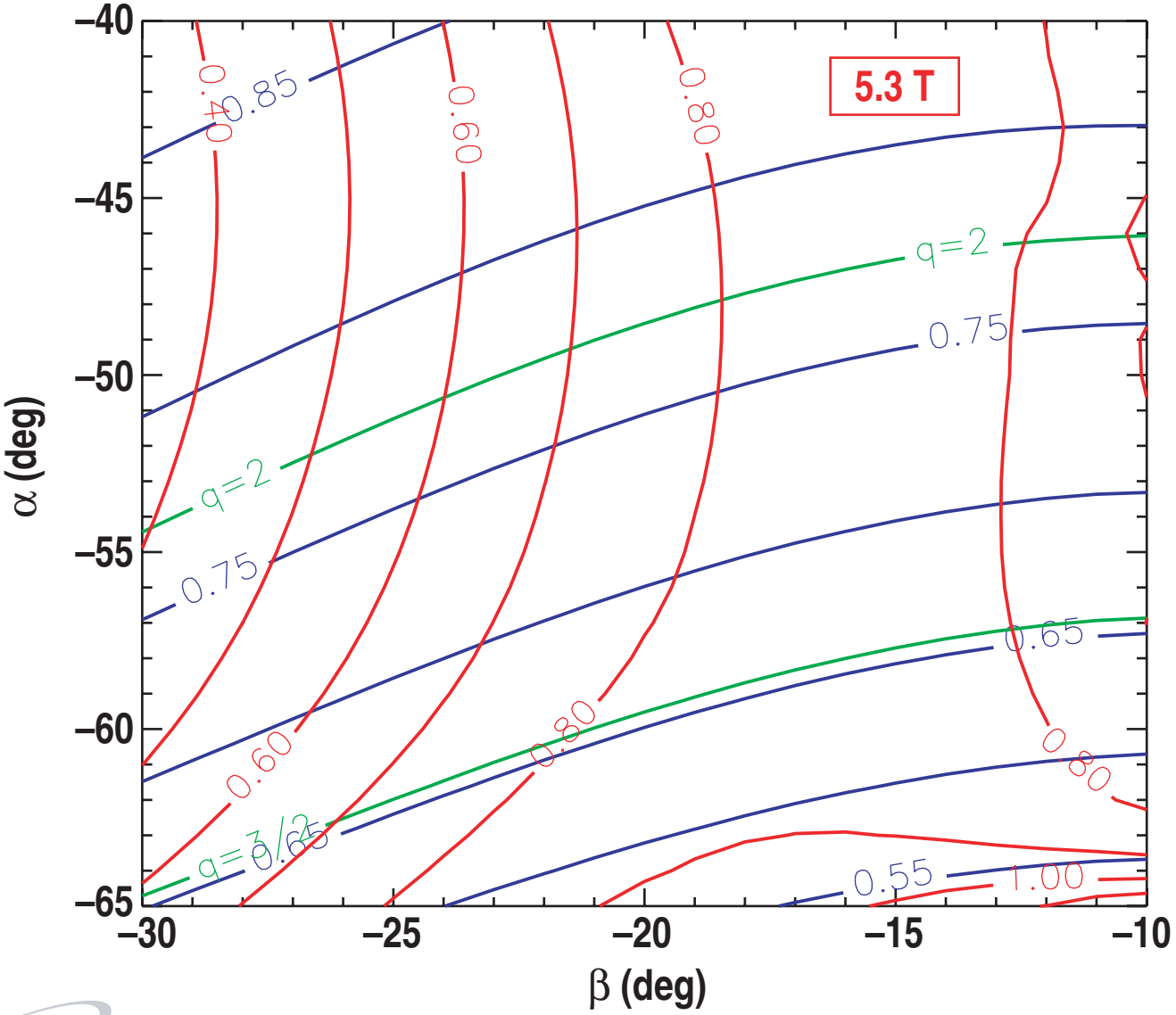
CONTOURS OF PEAK j_{CD} (A/cm^2/MW) AND PEAK ρ OF j



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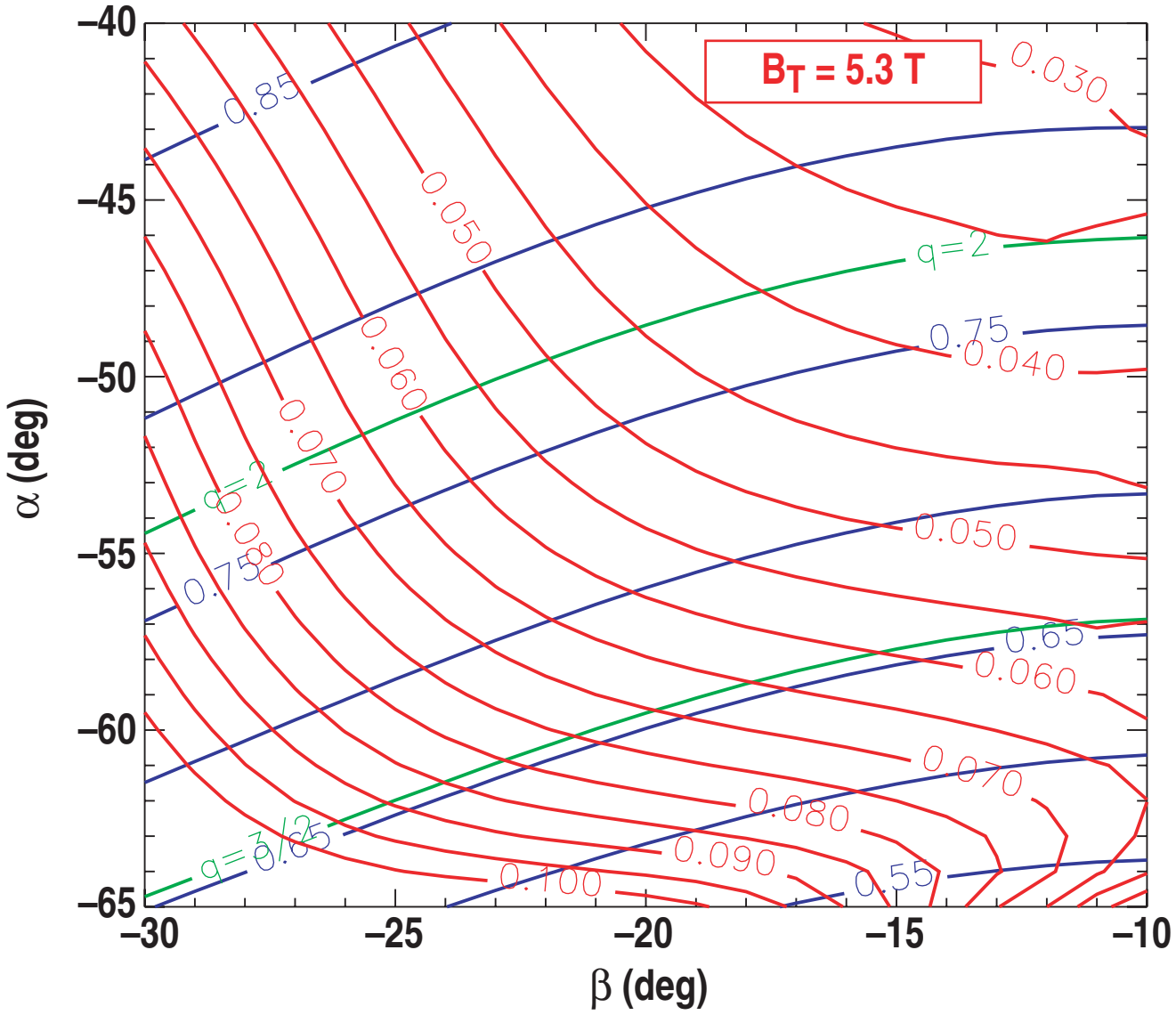
CONTOURS OF $\delta\rho$ AND PEAK ρ OF j_{EC}



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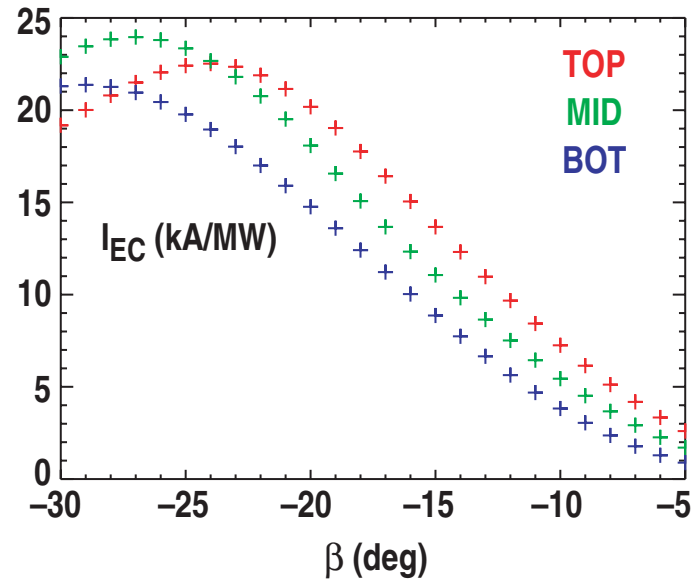
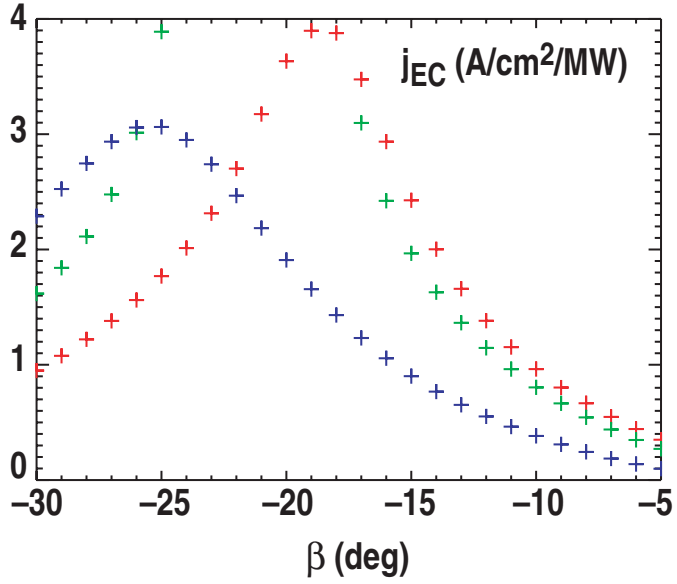
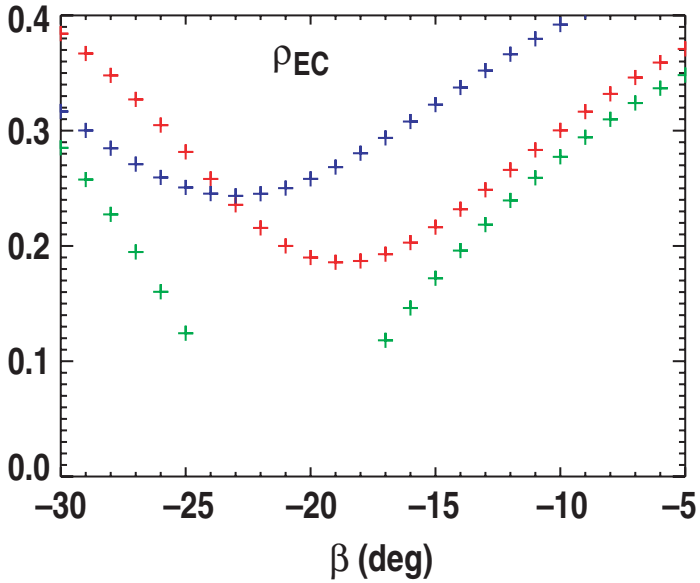
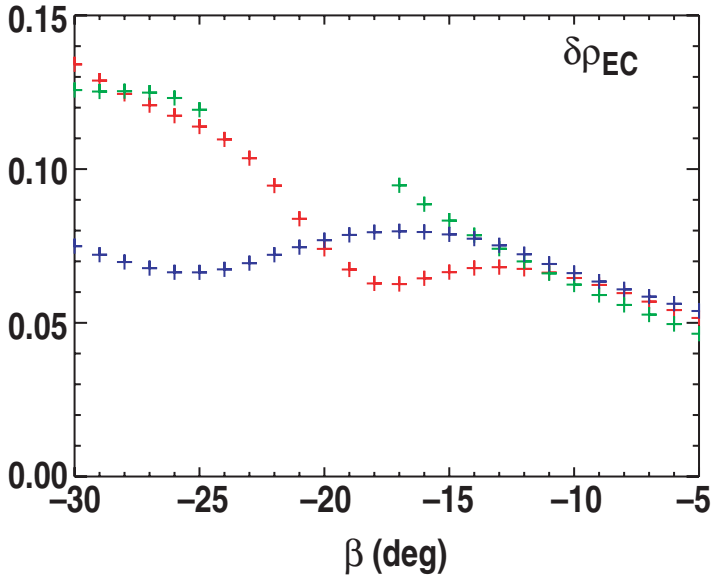
MIDPLANE LAUNCHERS, B_T = 5.3 T









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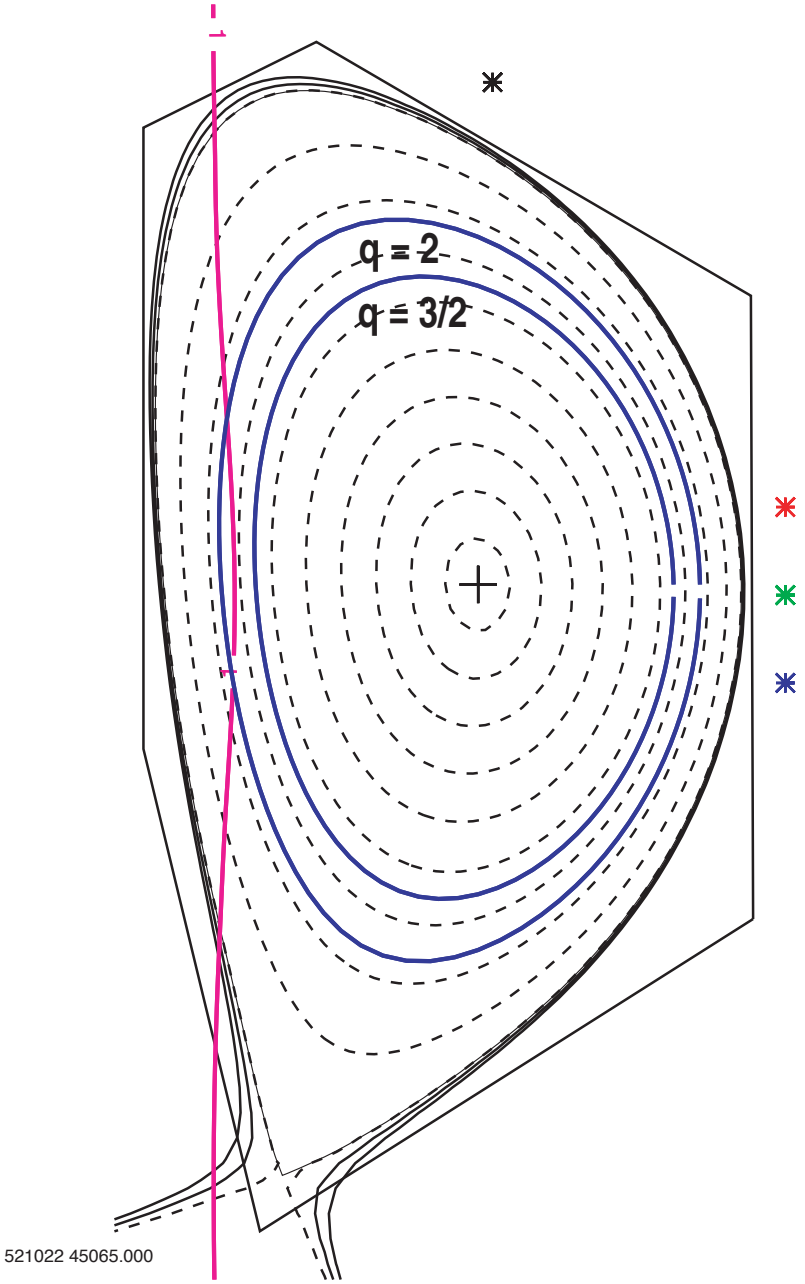
ITER SCENARIO 2 SCALED TO 4.5 T



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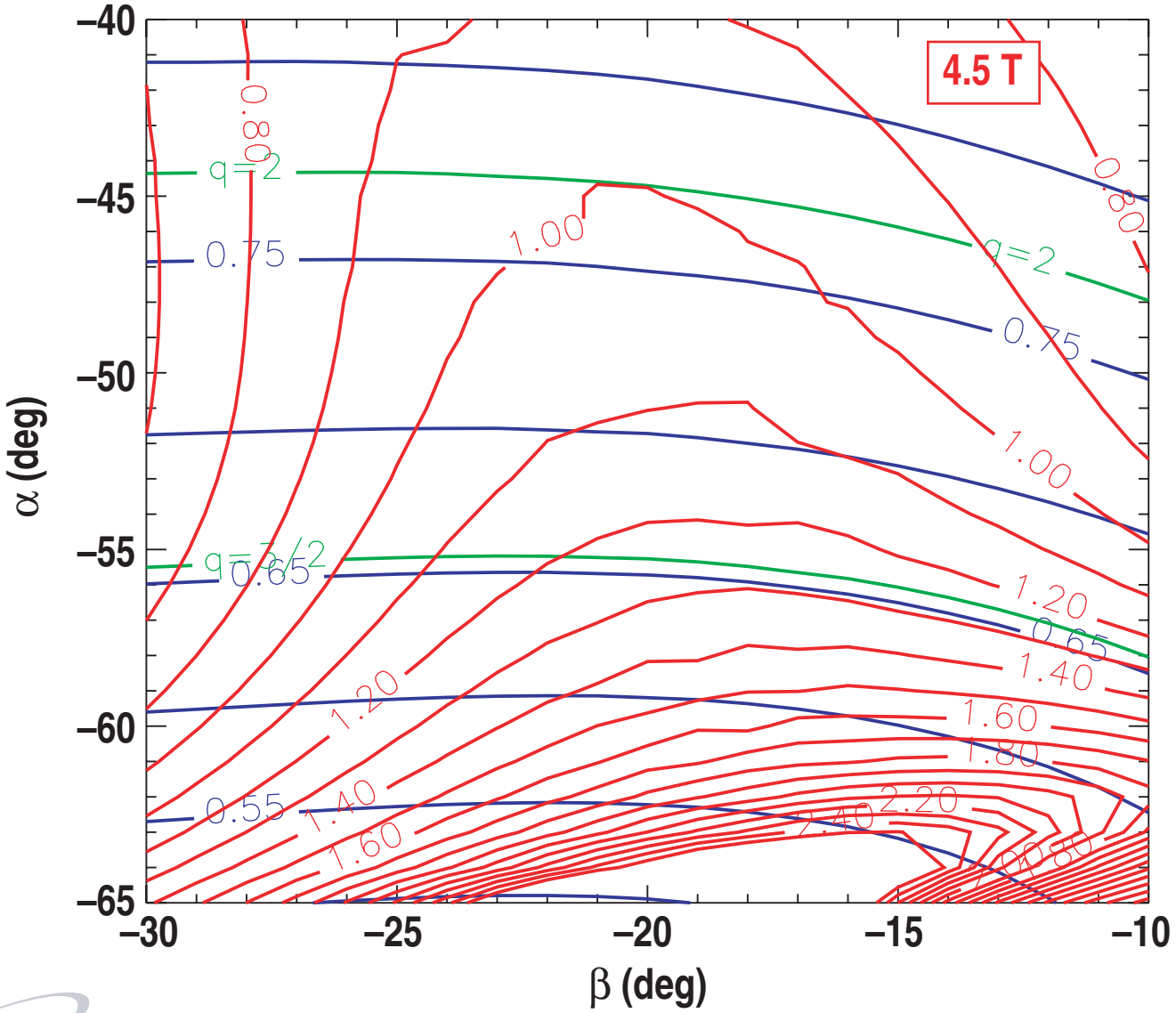
CONTOURS OF PEAK j_{CD} (A/cm^2/MW) AND PEAK ρ OF j



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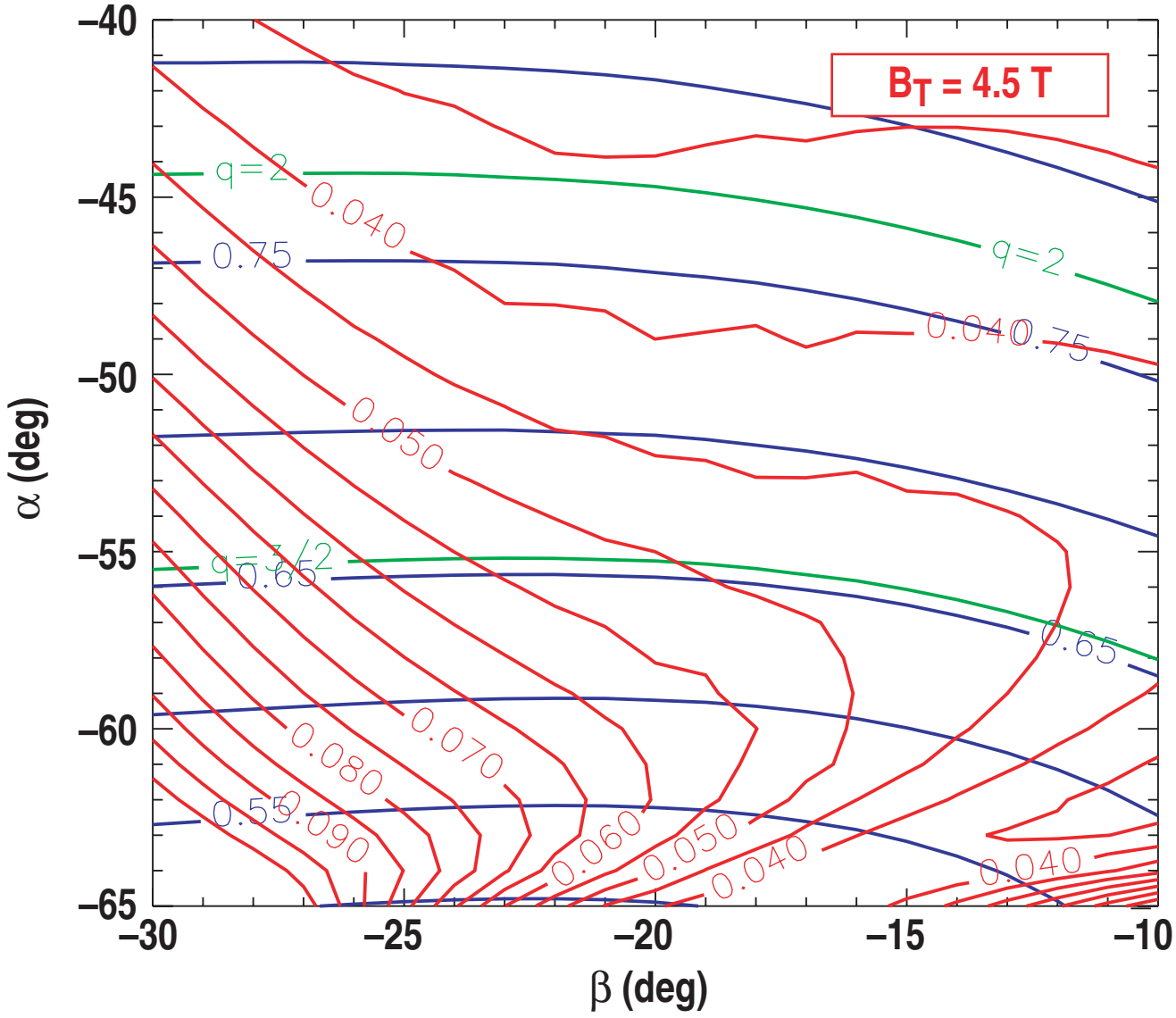
CONTOURS OF $\delta\rho$ AND PEAK ρ OF j_{EC}



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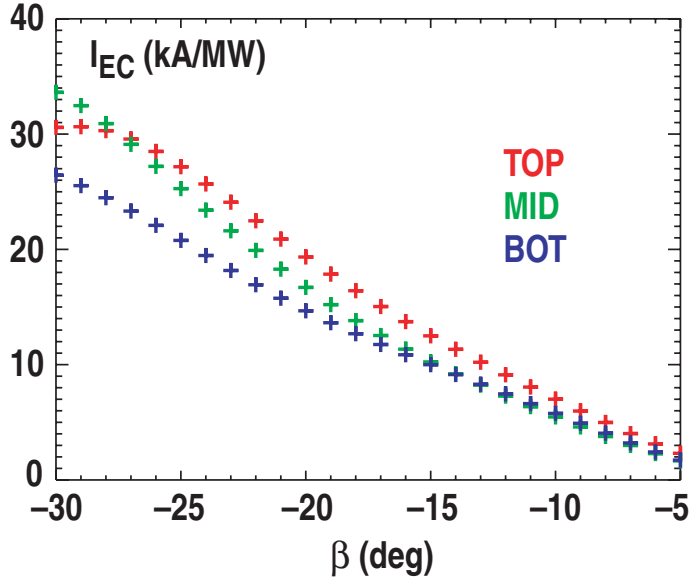
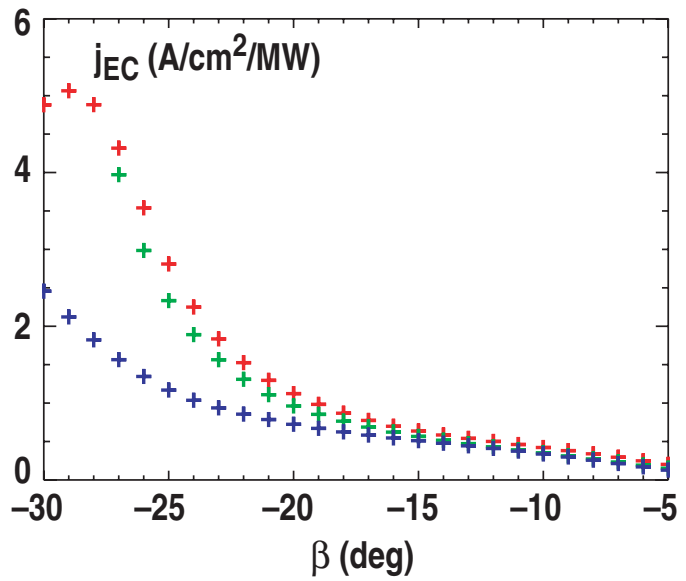
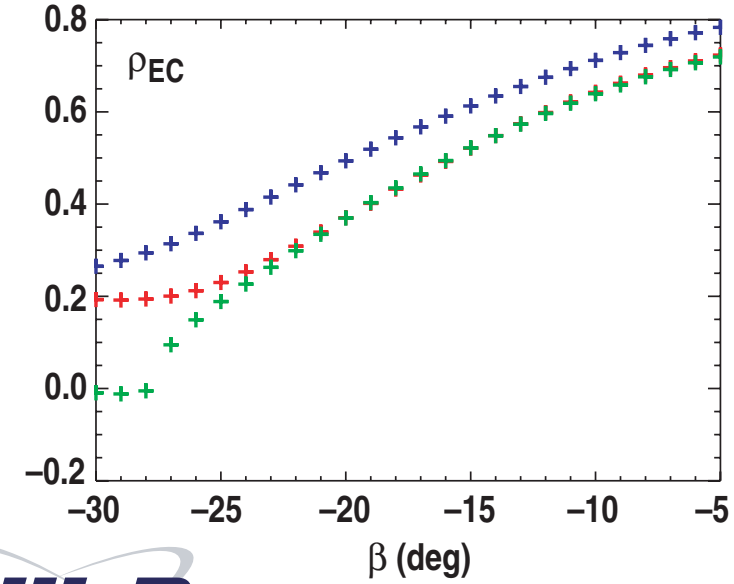
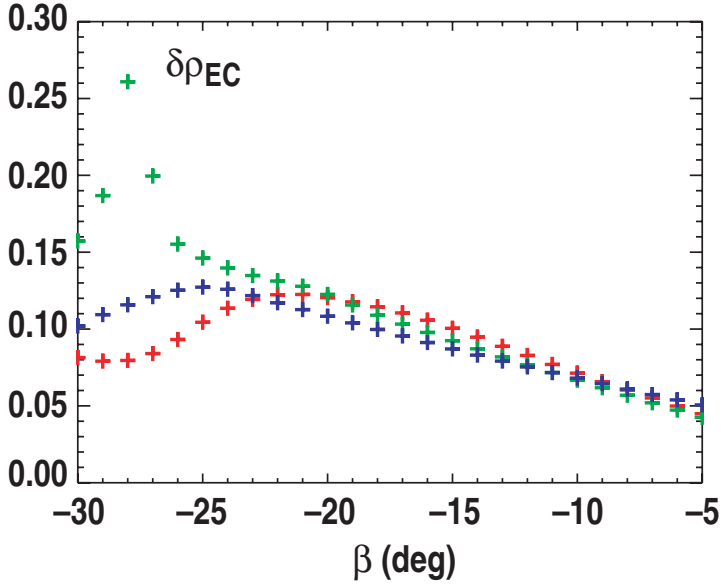
MIDPLANE LAUNCHERS, B_T = 4.5 T









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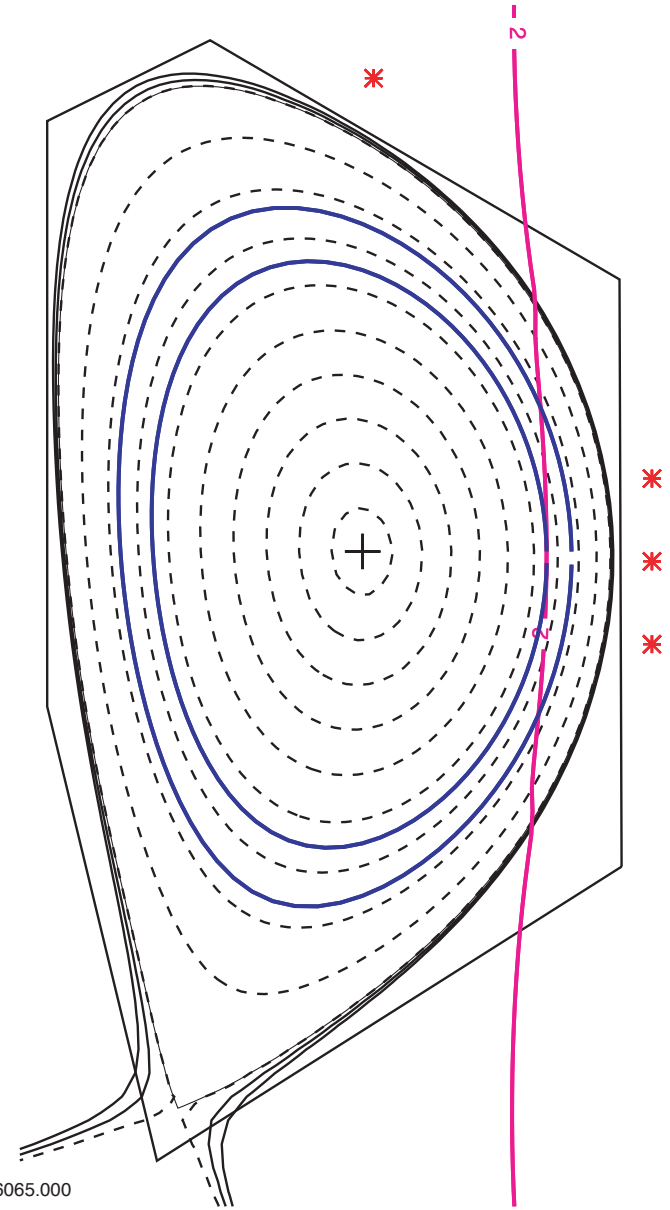
ITER SCENARIO 2, SCALED TO 3.6 T



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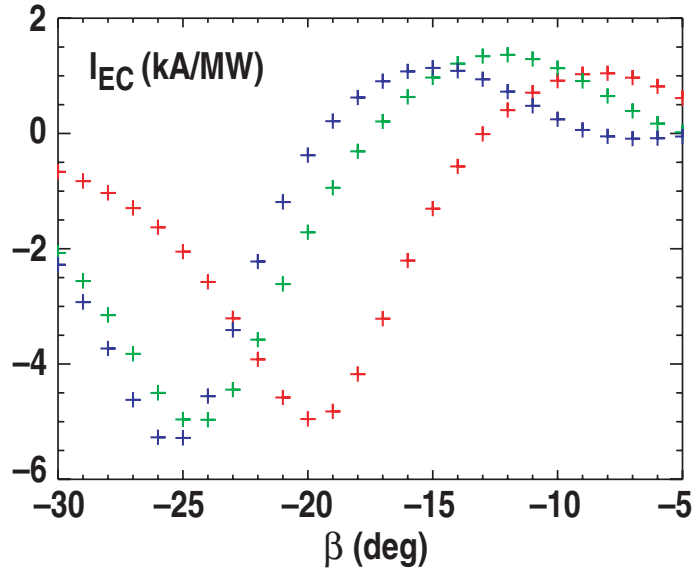
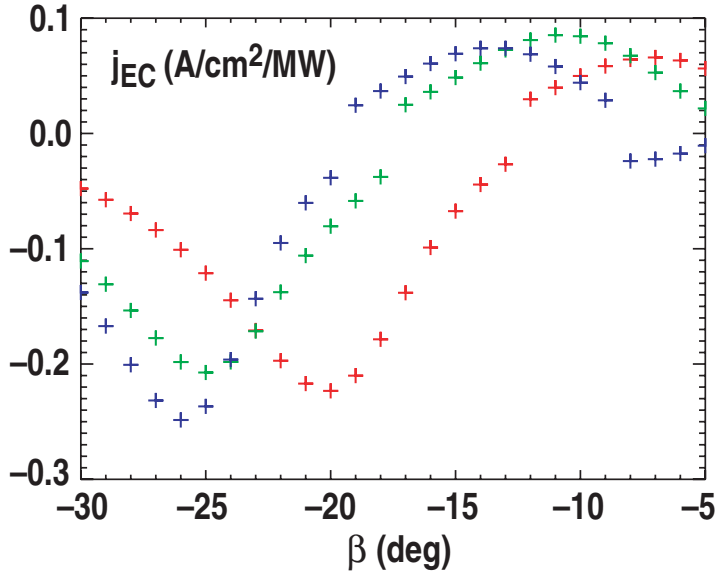
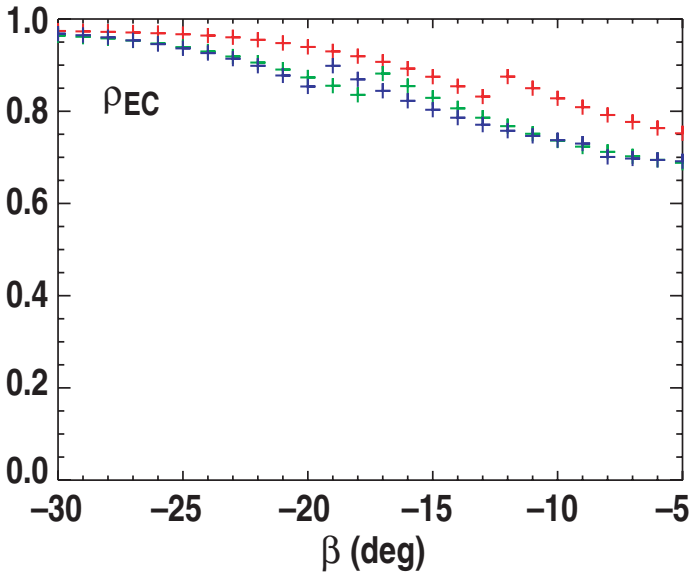
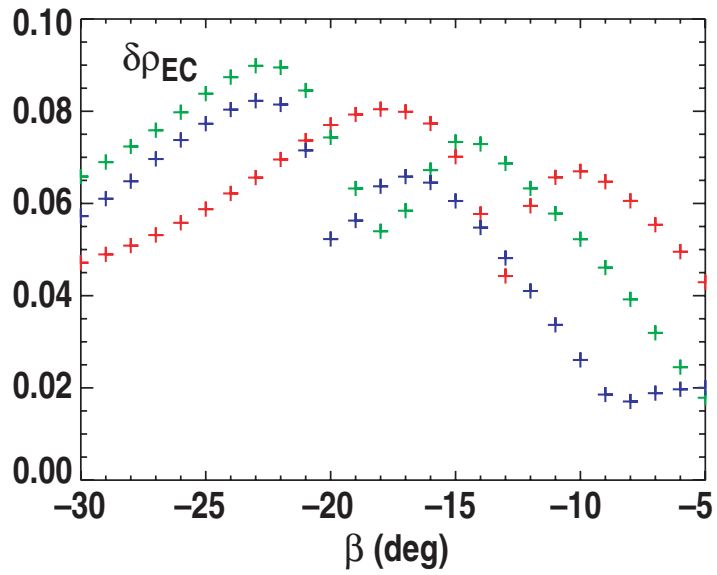
MIDPLANE LAUNCHERS, B_T = 3.6 T









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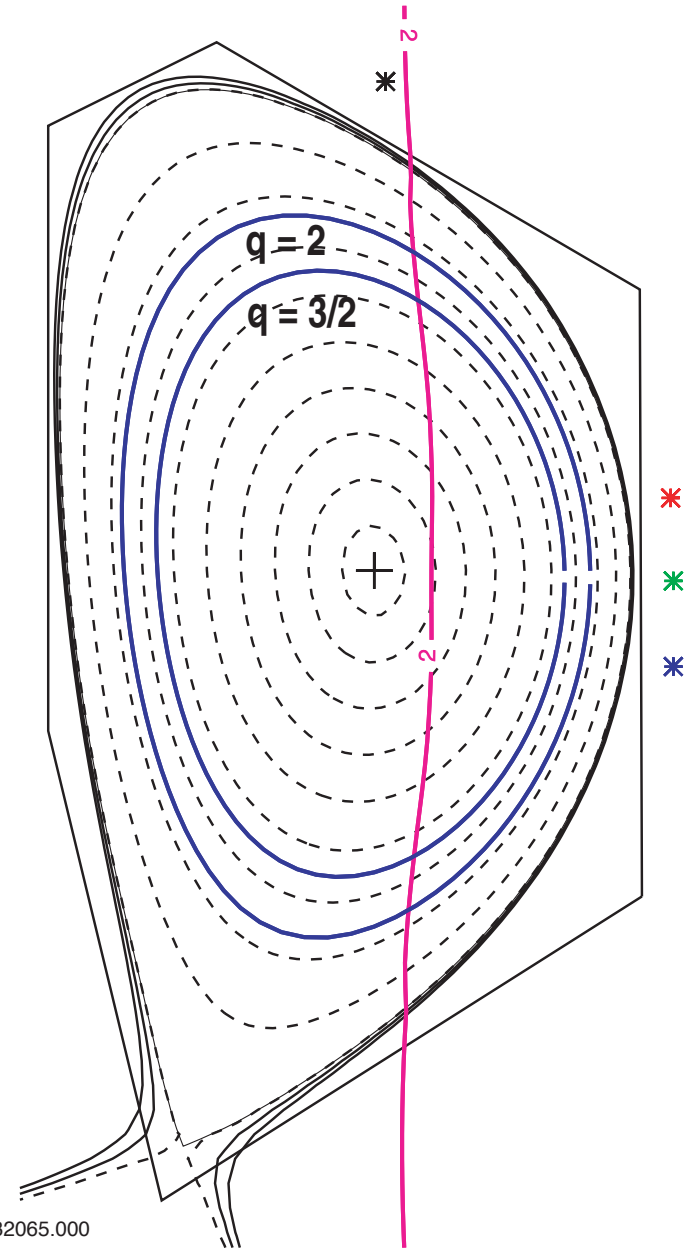
ITER SCENARIO 2 SCALED TO 3.2 T



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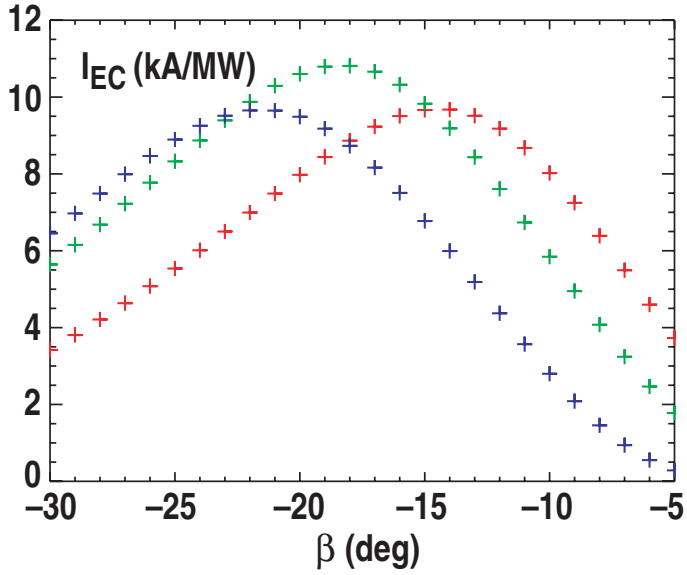
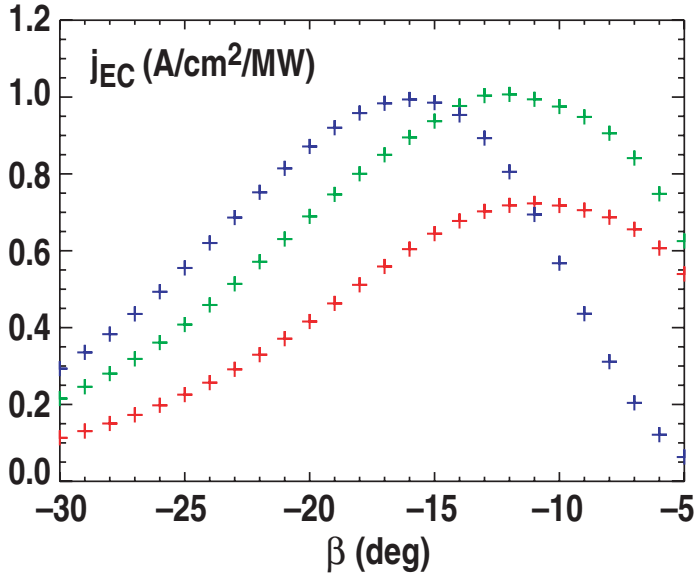
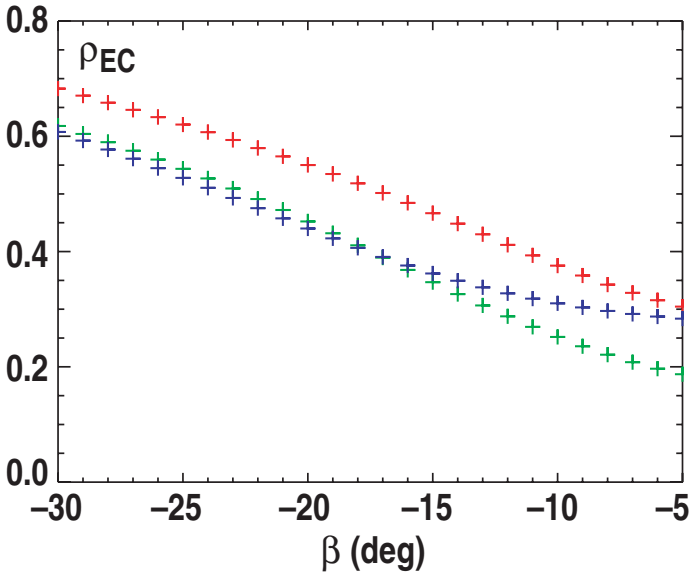
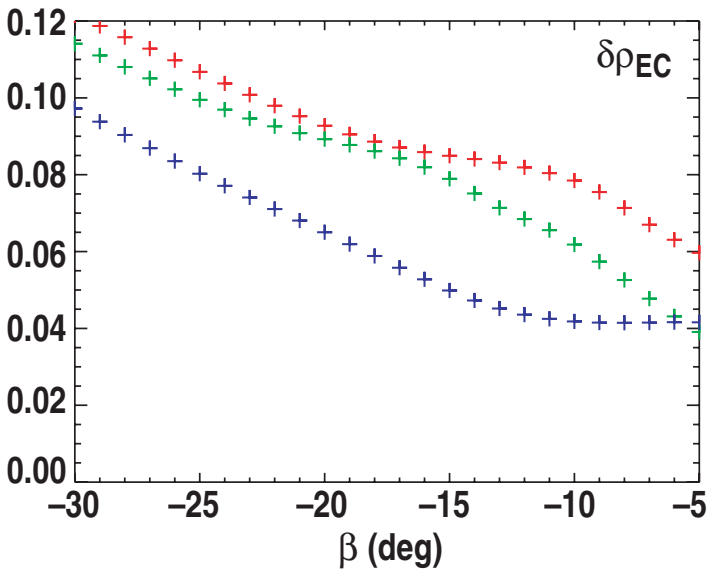
MIDPLANE LAUNCHERS, B_T = 3.2 T









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CONCLUSIONS

- The upper launcher is useful only for B greater than 4.5 T or B less than 2.65 T
- For 5.3 T > B > 4.5 T, the peak current density and total driven current for the top launcher are not strongly affected over this range
- For B < 4.5 T, only the midplane launchers will be useful
- For B ~ 4.0 T, the midplane launch may be effective at driving current on the inboard side although second harmonic absorption may reduce the efficiency; this case not yet examined
- At 3.6 T the midplane launch is very inefficient due to the cancelling effects of the Fisch-Boozer and the Ohkawa currents
- At 3.2 T the midplane launch can't reach sufficiently large minor radius to be useful for driving current at q=2 surface (ρ=0.77)
- For B ~ 3.4 T there may be an island of effectiveness for 2/1 NTM suppression

Planned launchers may be effective at driving localized currents near the q=2 surface for B > 4.5 T or B ~ 4.0 T or B ~ 3.4 T or B < 2.65 T

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