Predictions of ECCD and ECH in ITER

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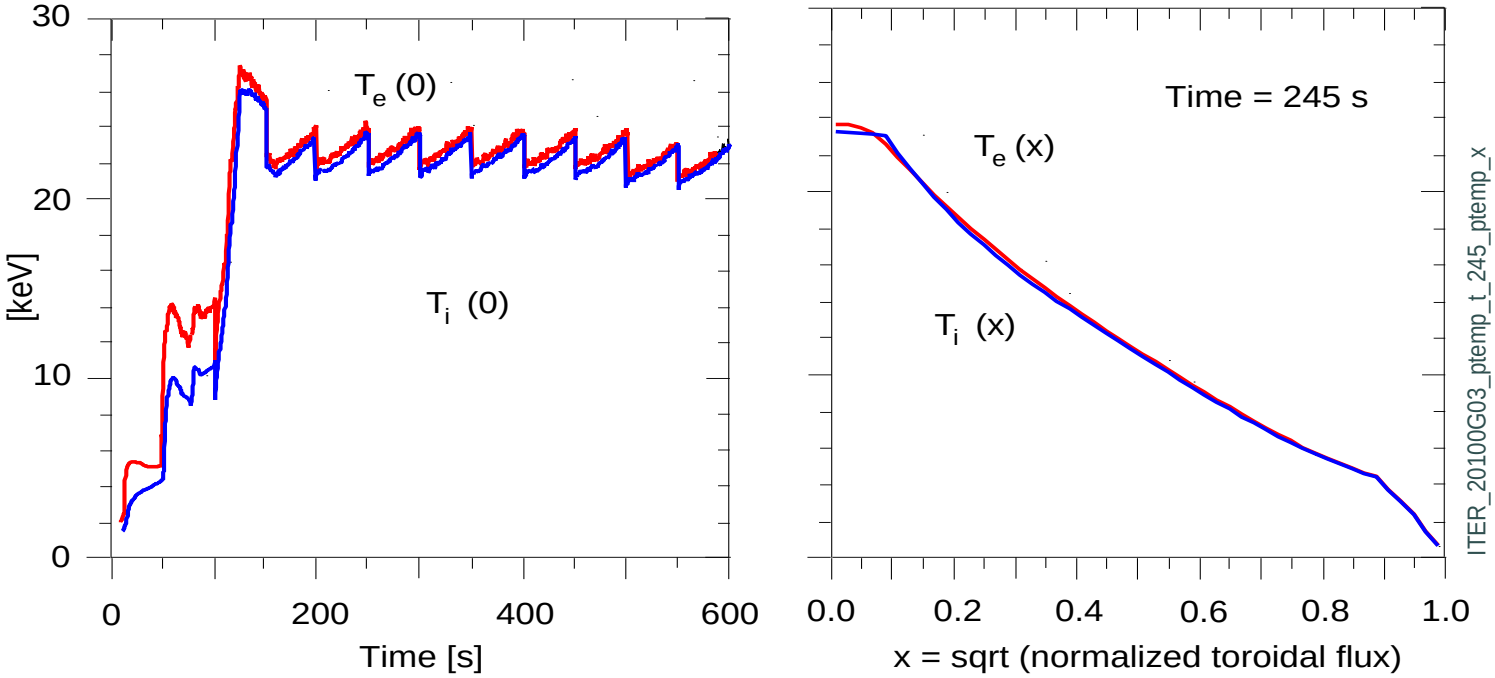
- ECCD and ECH offer important services for ITER and DEMO
  - Current drive needed for long durations
  - Heating needed especially during startup and L$\longrightarrow$H transition
  - Control of MHD
- Detailed predictions of ECCD and ECH effects needed to design systems
  - Start with integrated, self-consistent predictions of target plasmas

PTRANSP predictions of ITER plasmas

- PTRANSP $\equiv$ new version of TRANSP with improved predictive capabilities
- Collaboration of PPPL, Lehigh U, LLNL, Tech-X, GA
- PTRANSP generates self-consistent time-dependent integrated modeling
  - TSC establishes plasma boundary, startup, feedback control, termination
  - NUBEAM for negative ion neutral beam heating, torquing, shine through
  - NUBEAM for alpha heating, slowing down, losses
  - TORIC for ICRH
  - GLF23 for predicting T_i, T_e
  - TEQ for equilibria
  - TORAY for ECCD, ECH
- detailed predictions of H-mode and Hybrid ITER plasmas
  - sawteeth
  - alpha ash accumulation
  - plasma rotation

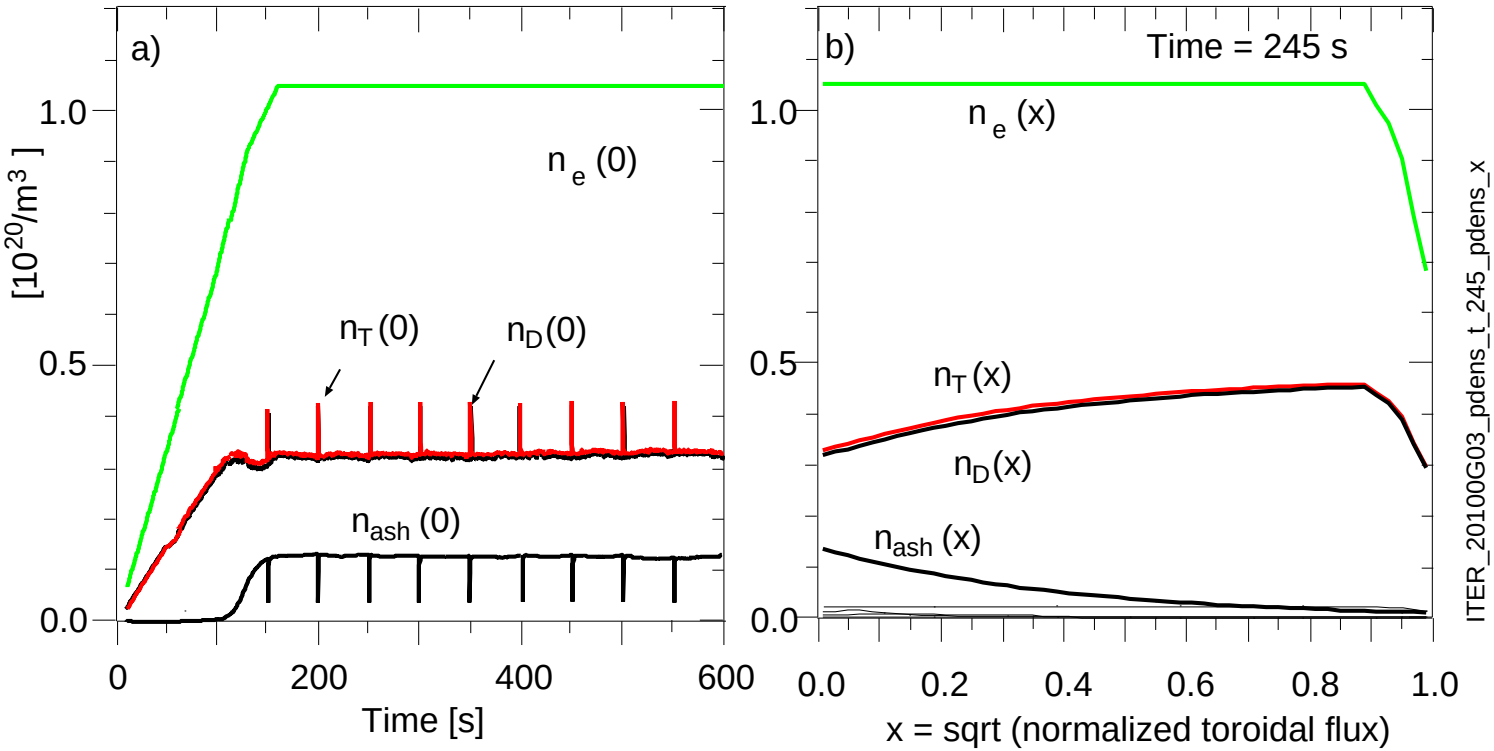
Example of ITER H-mode

- $B_{TF} = 5.3$ T, $I_p = 15$MA, κ_{98} =1.75, δ_{98} =0.5-0.6
- $P_{NNBI} = 33$MW, P_{ICRH} = 20 MW, f_{GW} =0.86, β_n =1.7-1.8
- GLF23 predicts T_i and T_e up to assumed values at r/a=0.9



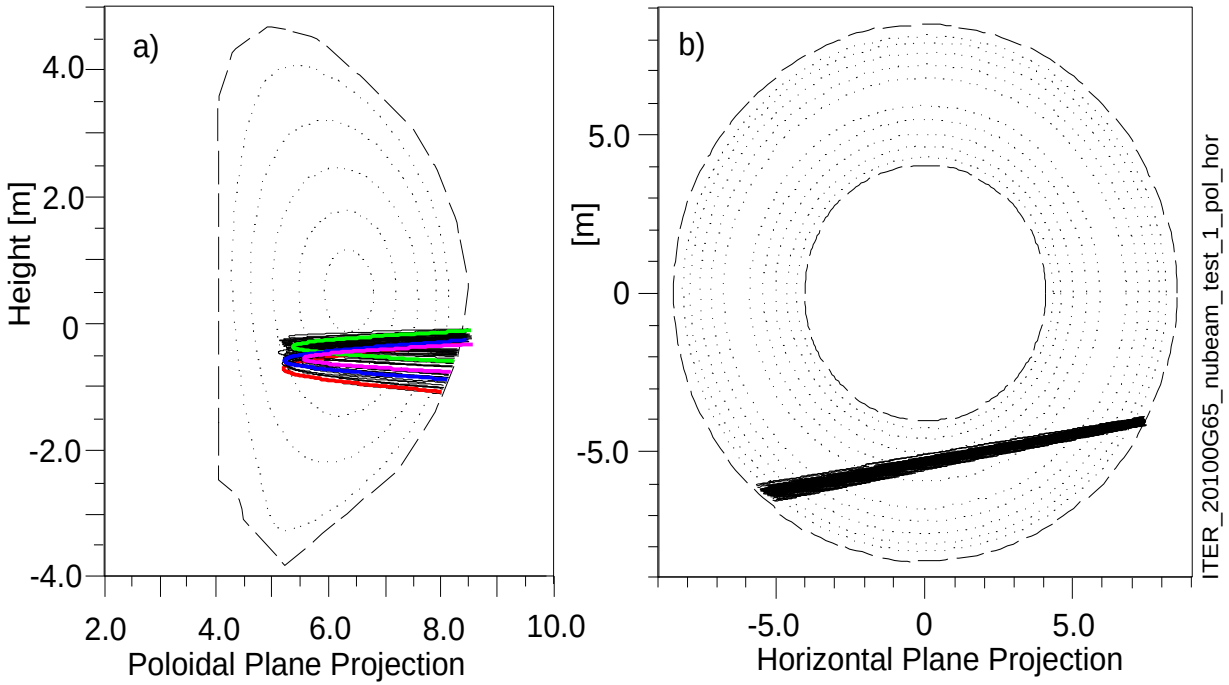
Densities in standard ITER H-mode

- Assume n_e, n_{Be}, n_{Ar}
- compute n_D, n_T, n_{NNBI}, n_α, n_{ash}



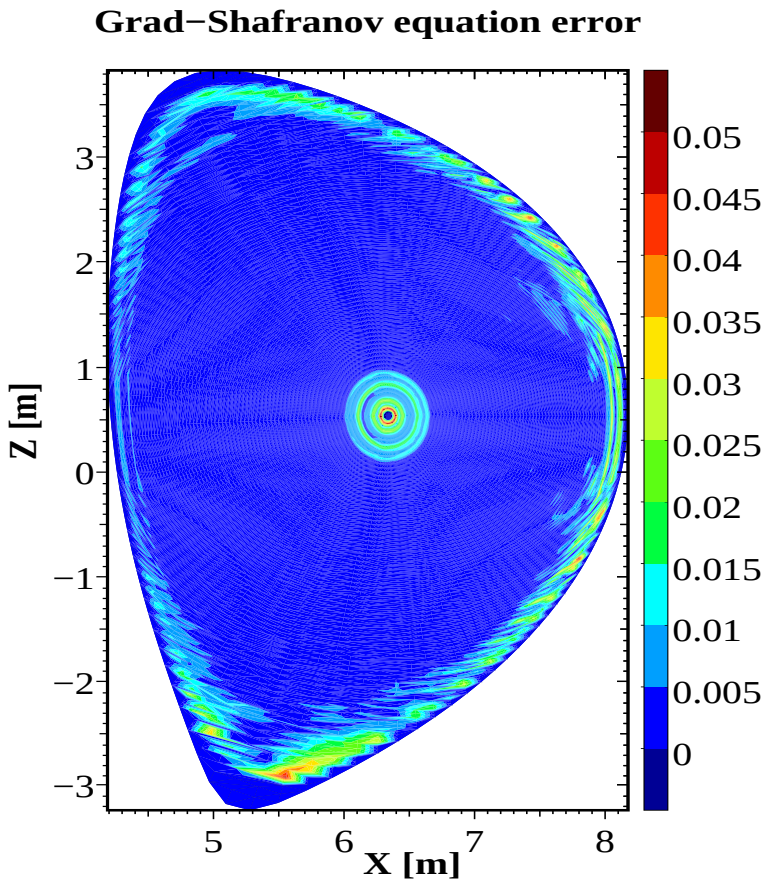
Careful treatment of Negative Ion Neutral Beam Injection

- 3D geometry modeled
- Example of Monte Carlo flights for case of below-axis NNBI



Accurate time-evolving equilibrium solutions

- Contours of (RHS - LHS) / RHS



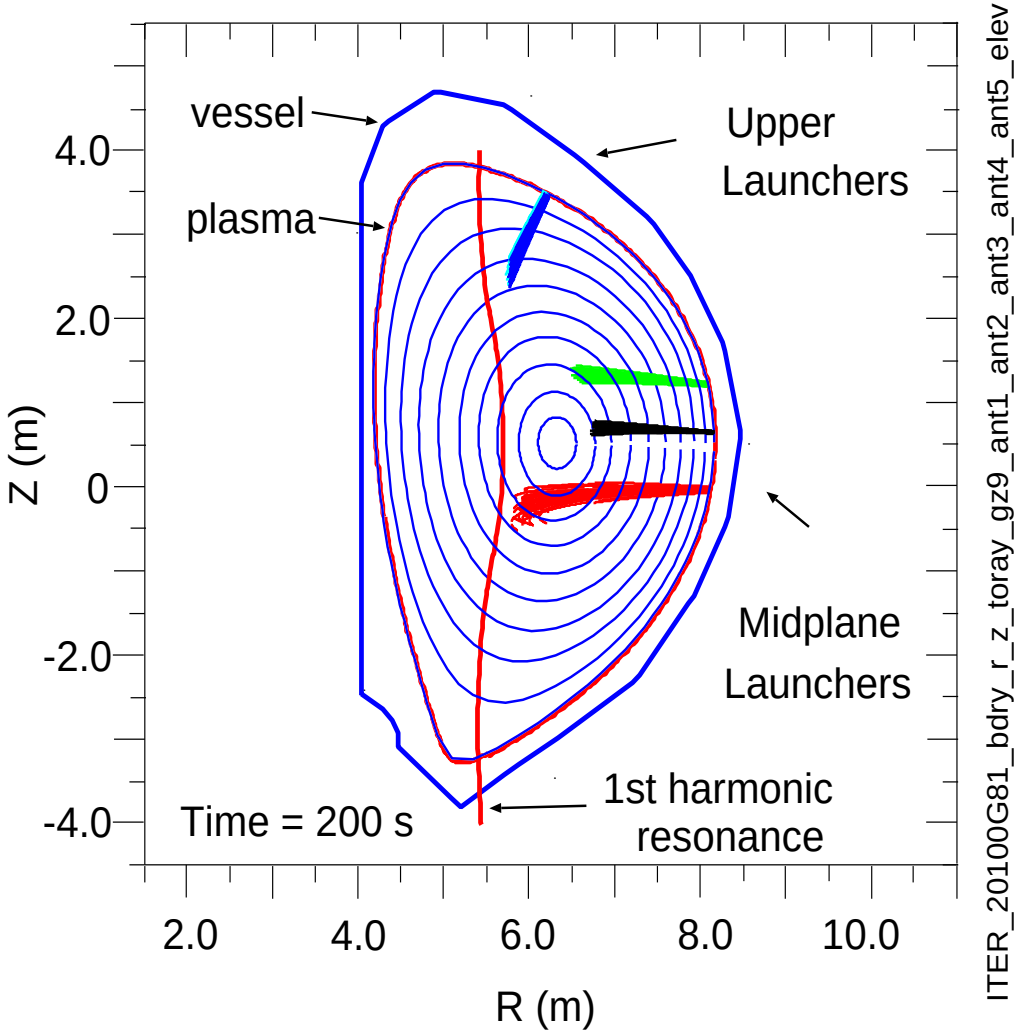
Example of assumed Launchers and angles

- Assume three midplane and two upper launchers
- Assume 170 GHz, 1.2 deg divergence
- Assume angles for H-mode case

Launcher	Midplane 1	Midplane 2	Midplane 3	Upper 1	Upper 2
Major Radius [m]	8.50	8.50	8.50	6.48	6.45
Height [m]	0.01	0.61	1.21	4.11	4.20
Poloidal angle [deg]	90.0	90.0	90.0	146.0	150.0
Toroidal angle [deg]	40.0	38.0	32.0	42.0	25.0

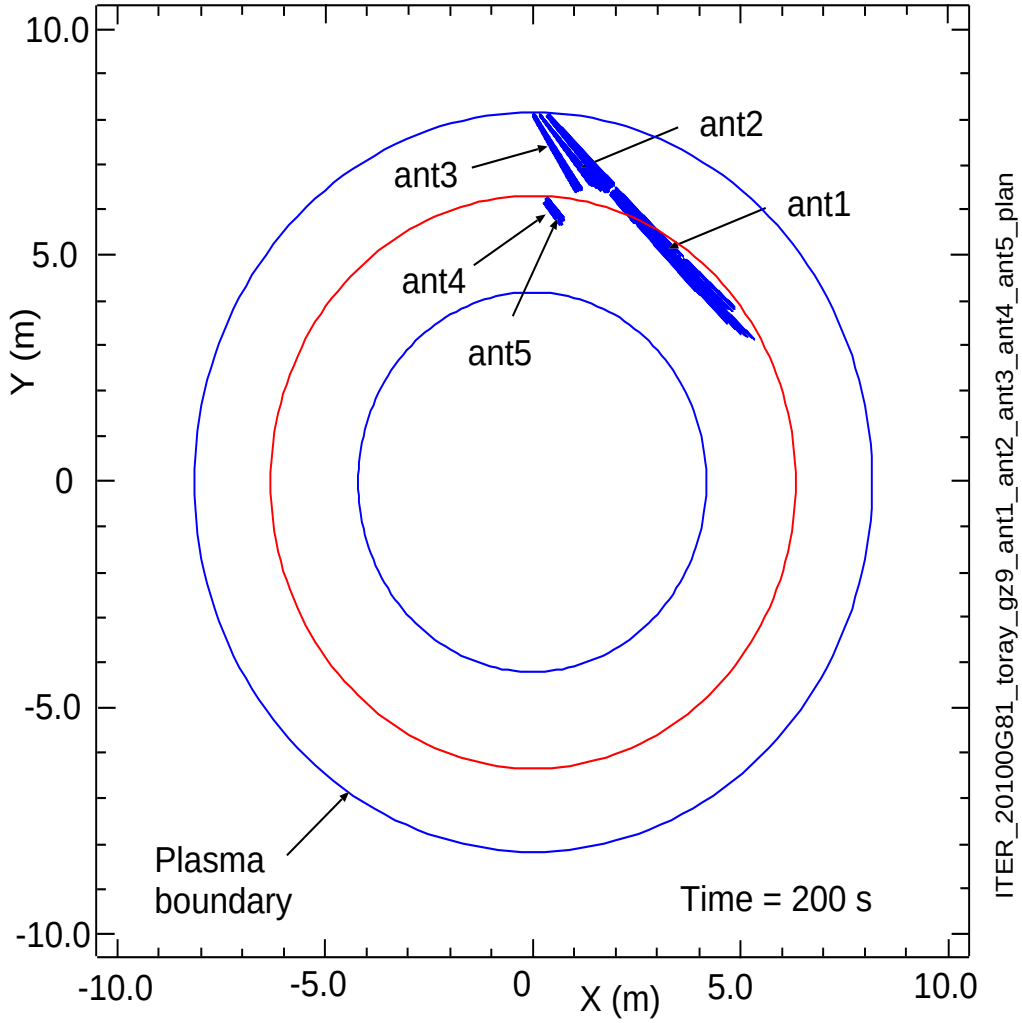
Elevation view of examples of TORAY rays

- 20 rays launched for each antenna at each time



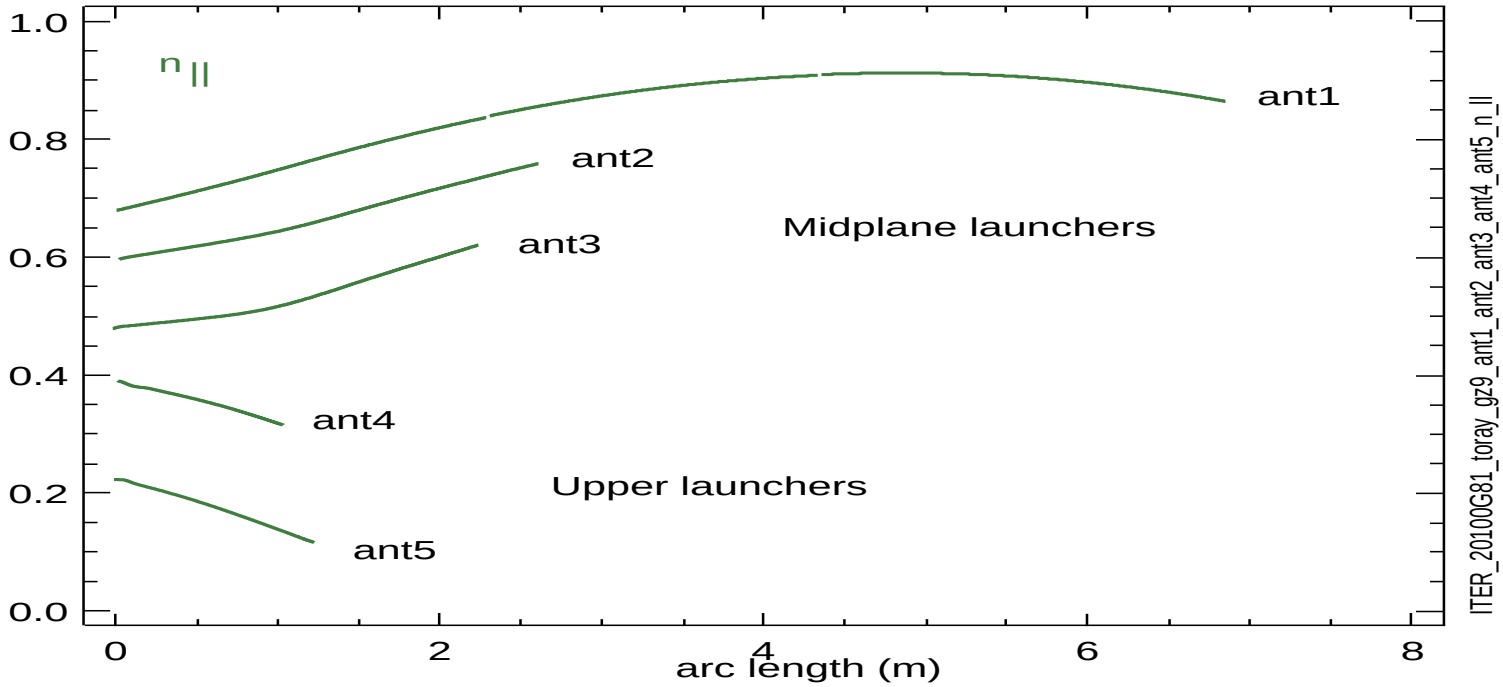
Plan view of examples of TORAY rays

- Clockwise I_p and B_{TF} in ITER

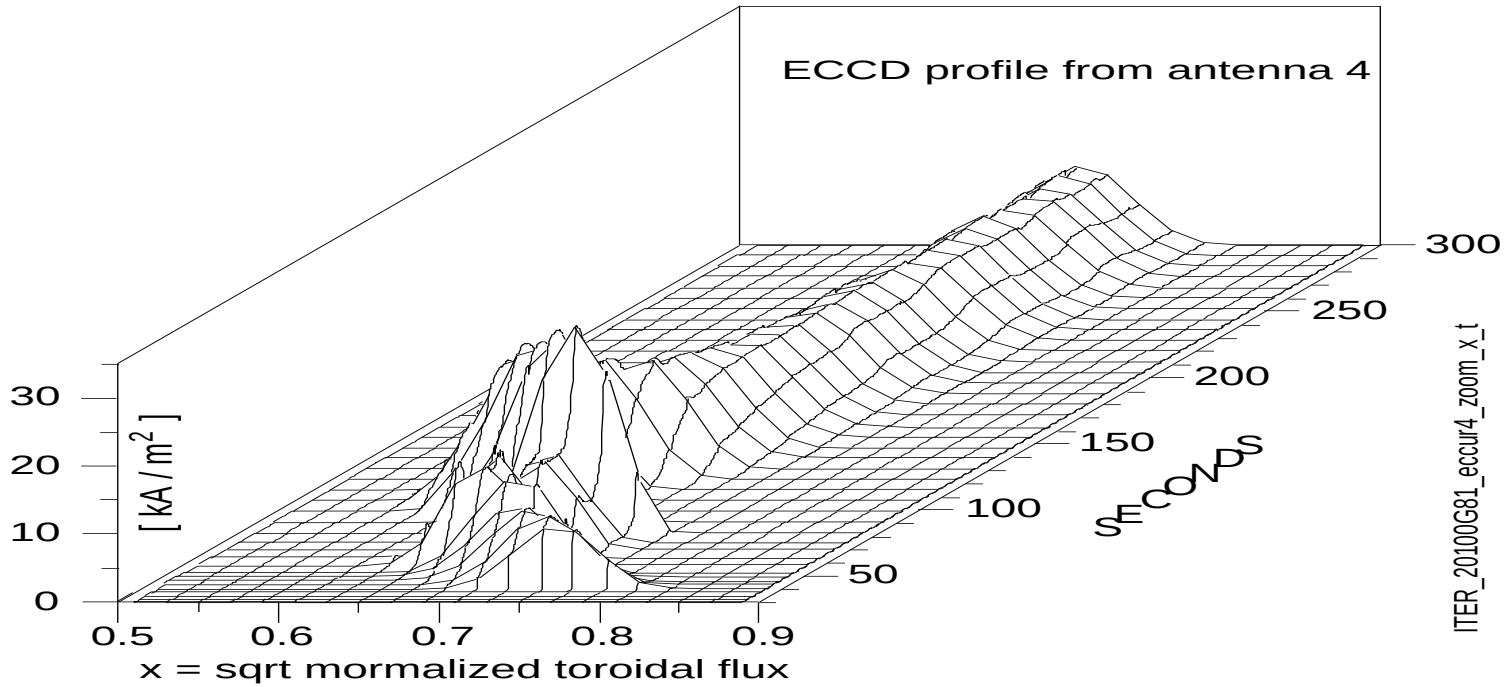


Profiles of $n_{||}$ along rays

- Parallel index of refraction



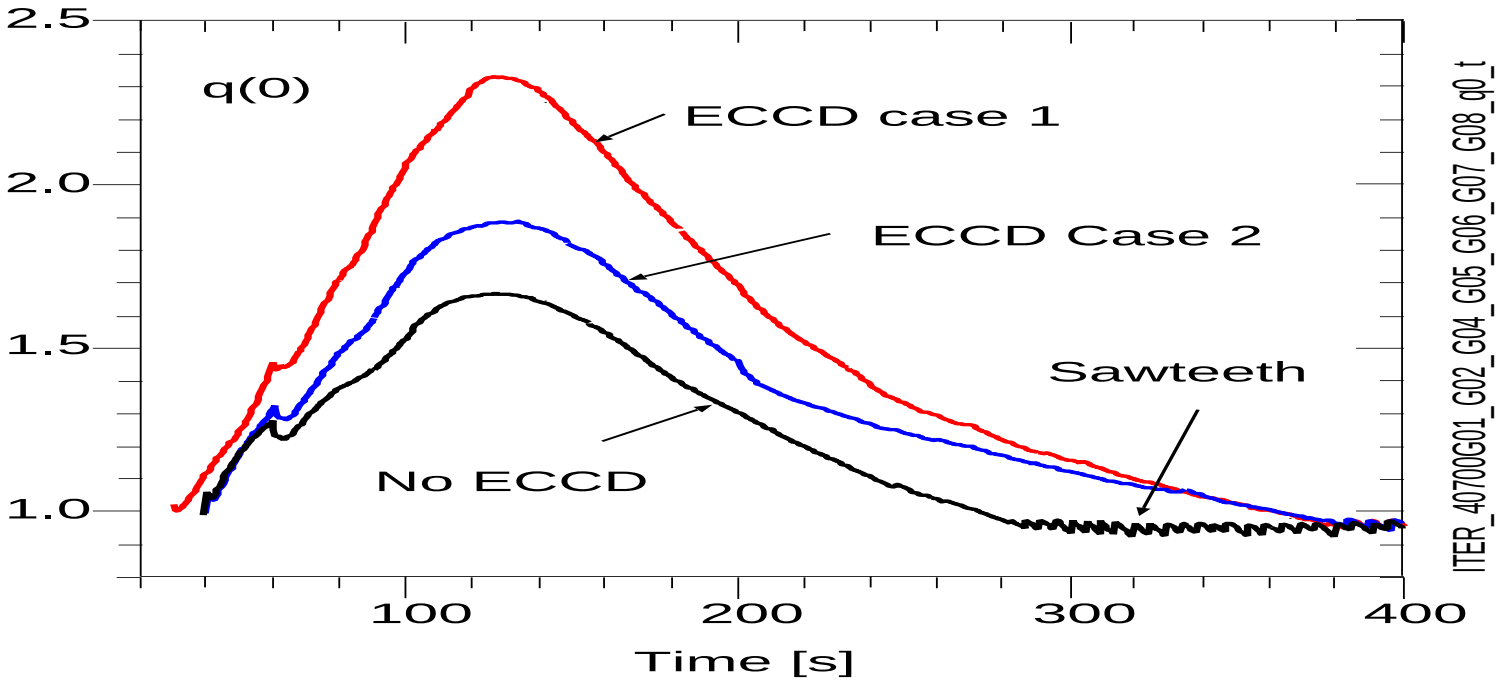
Example of evolving $j_{ECCD}(x,t)$



- Location of $q = 3/2$ is at $x = 0.60$ at 50 s, 0.68 at 200 s.
- Location of $q = 2/1$ is at $x = 0.70$ at 50 s, 0.79 at 200 s.

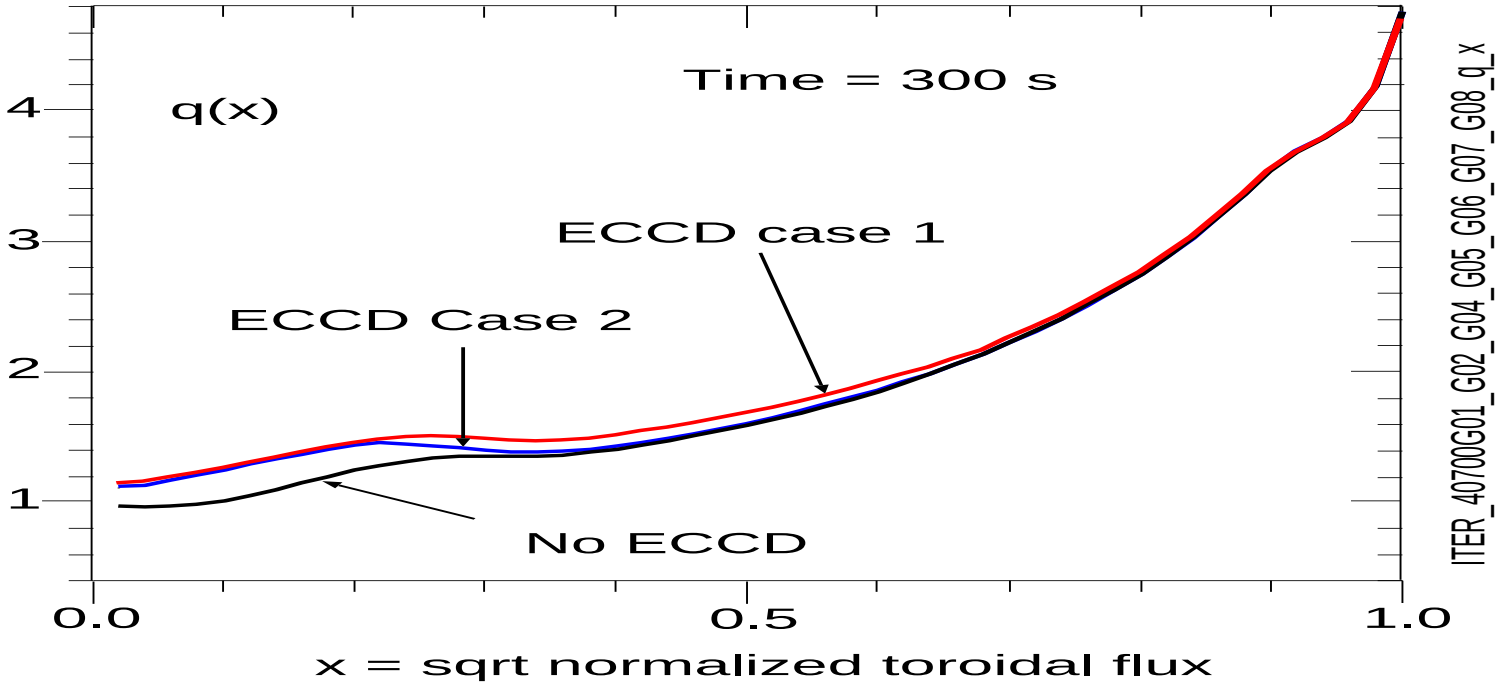
Example of ECCD effects on $q(0)$ evolution

- Hybrid plasmas have $q(0)$ above or near unity

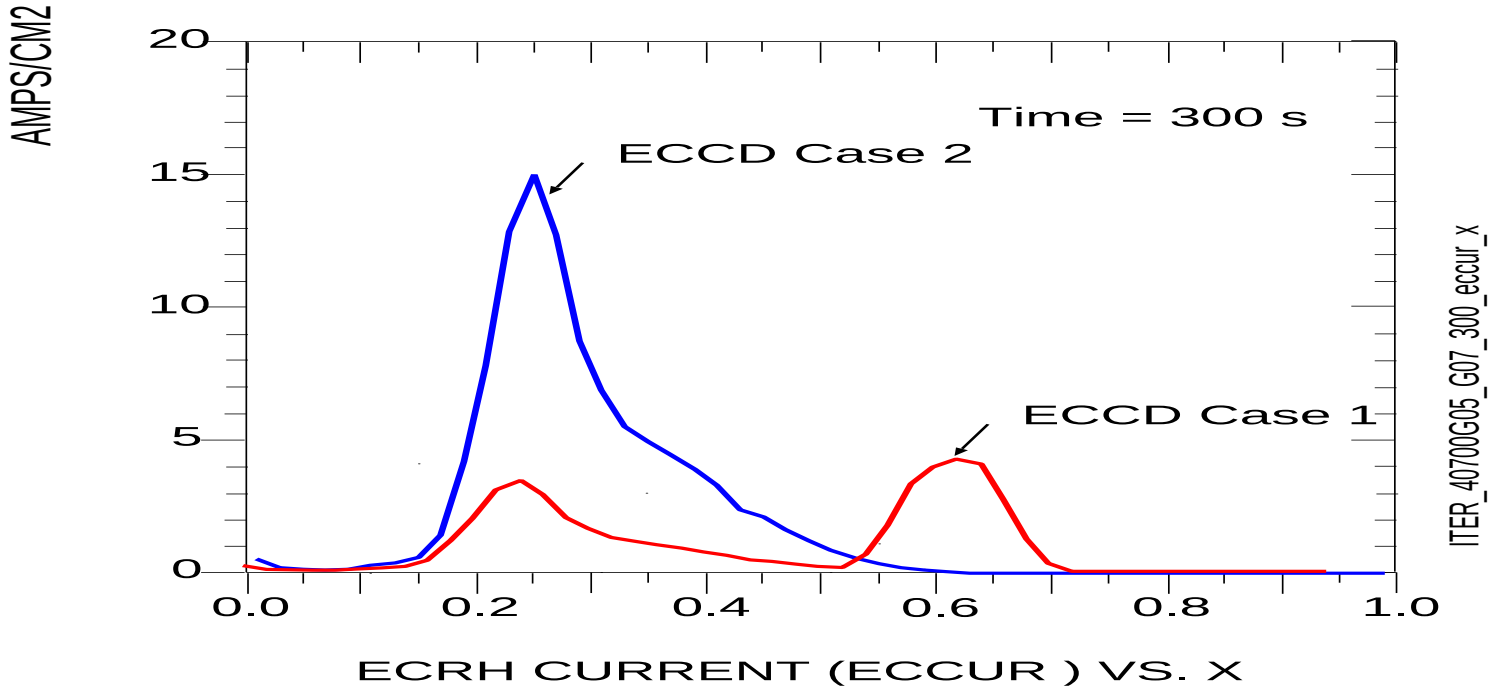


- ECCD delays decrease below unity

Profiles of $q(x)$ in Hybrid plasmas



Profiles of j_{ECCD}



Summary

- The PTRANSP code has been used to generate self-consistent, time-dependent predictions of H-mode and Hybrid plasmas in ITER
- Effects of ECCD and ECH are shown by comparing predictions with and without
- Effects studied:
  1. Added heating
  2. Control of $q(x)$
- ECCD and ECH not yet optimized