Integrated Scenario Modeling for Steady State and Hybrid Scenario in DIII-D and ITER

By

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Presented at
48th Annual Meeting
American Physical Society
Division of Plasma Physics
Philadelphia, PA

October 30 – November 3, 2006

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Integrated Scenario Modeling Is Applied to DIII-D and ITER

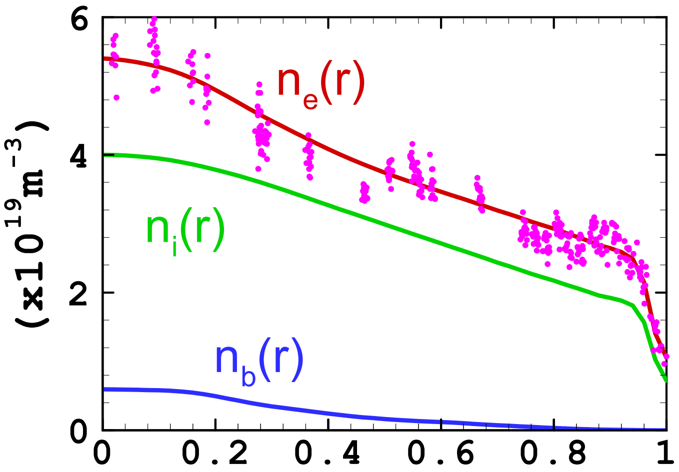
This talk will discuss:

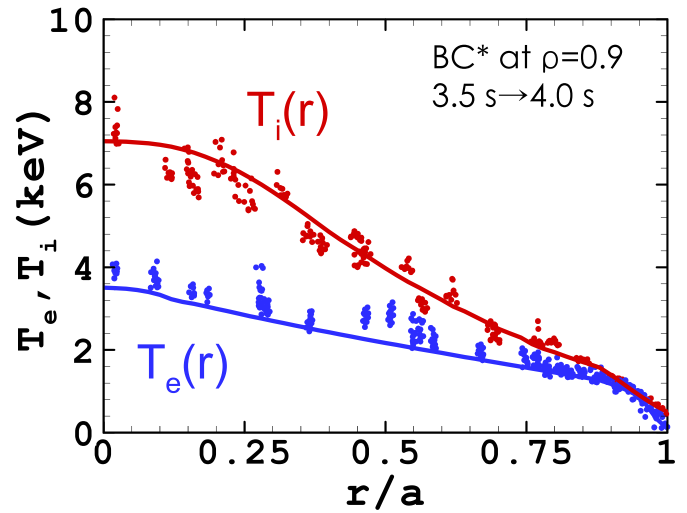
- **Progress of Integrated Scenario Modeling**
  - Density evolution using GLF23, fast ion diffusion, parallel computation

- **Validation of the Modeling Against DIII-D Experiments**
  - Hybrid and AT discharges

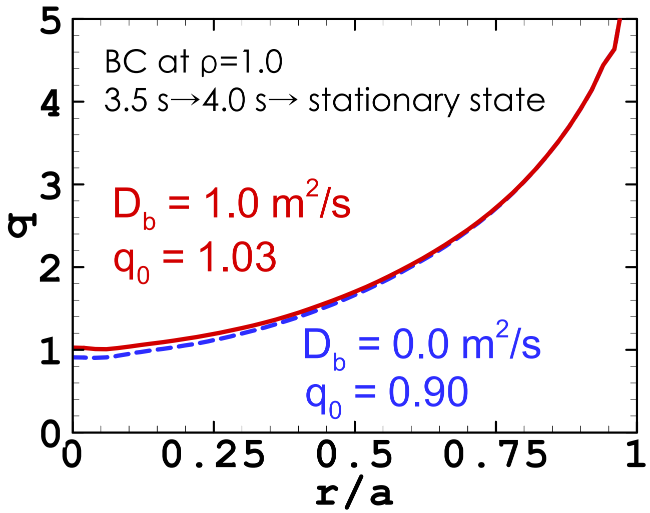
- **Application to ITER Prediction Using ITER 'Day-1' H&CD Capabilities**
  - Hybrid: Demonstration of high fusion performance (Q>10) with extended burning duration (t>5000 s) and q_0>1
  - Steady-state: Existence of full noninductive scenario at f_{NI}≥100 % and Q≈5 Possibility of better performance with Internal Transport Barrier (ITB)

ONETWO/GLF23 Reproduces Experimental Profiles Reasonably Well for DIII-D Hybrid Discharges





* Experimental data chosen in stationary phase Independent of ELM timing



- **Solve (n, Te, Ti, v, J) equations using GLF23 model**
- **Main ion particle diffusivity = GFL23 + neoclassical + background ($D=0.2\ m^2/s$)**
- **Ad-hoc assumed fast ion D_b**

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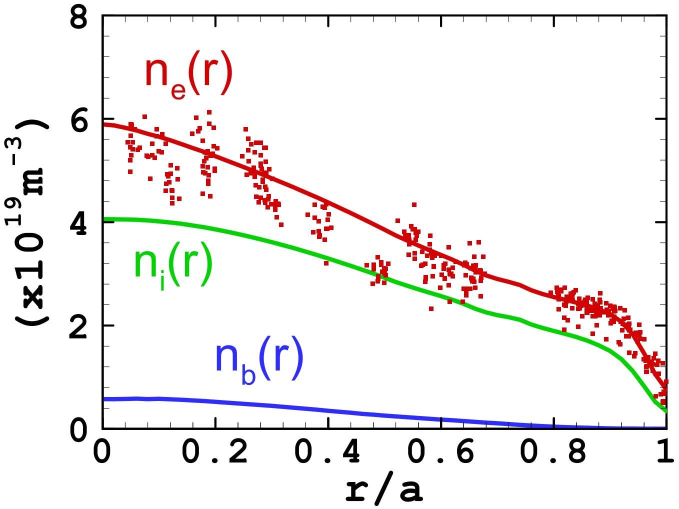
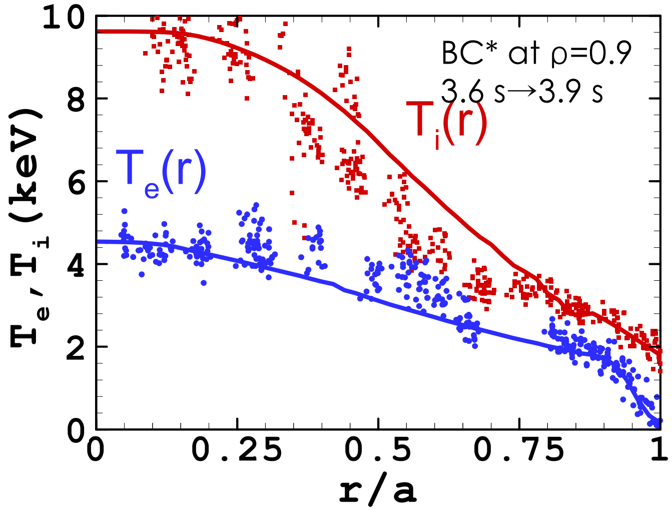
ONETWO/GLF23 Reproduces Experimental Profiles Reasonably Well for DIII-D AT Discharges





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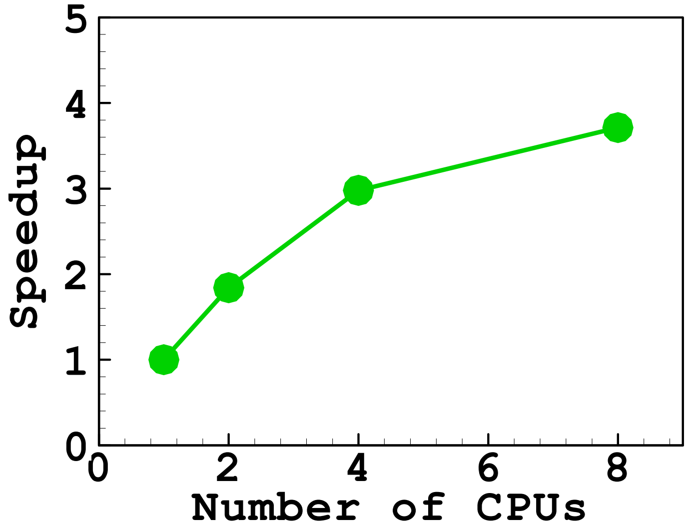
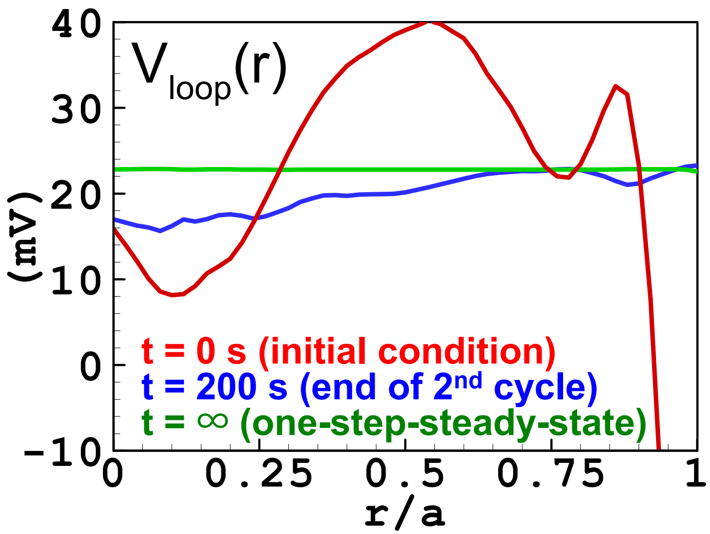
Computational Efficiency of ONETWO/GLF23 Has Been Improved for ITER Simulation by Parallel Computation and GCNM Solver





- **Parallelization of ONETWO/GLF23 by Domain Decomposition Method**
- **Stationary state with fully penetrated current profile by interleaving:**
  - Time stepping calculation of all the transport equations for over 100 s
  - "One Step Steady State" solution (δ / δt = 0) of J evolution using GCNM (Globally Convergent Newton Method) **[H.E. St. John, JP1.00130]**

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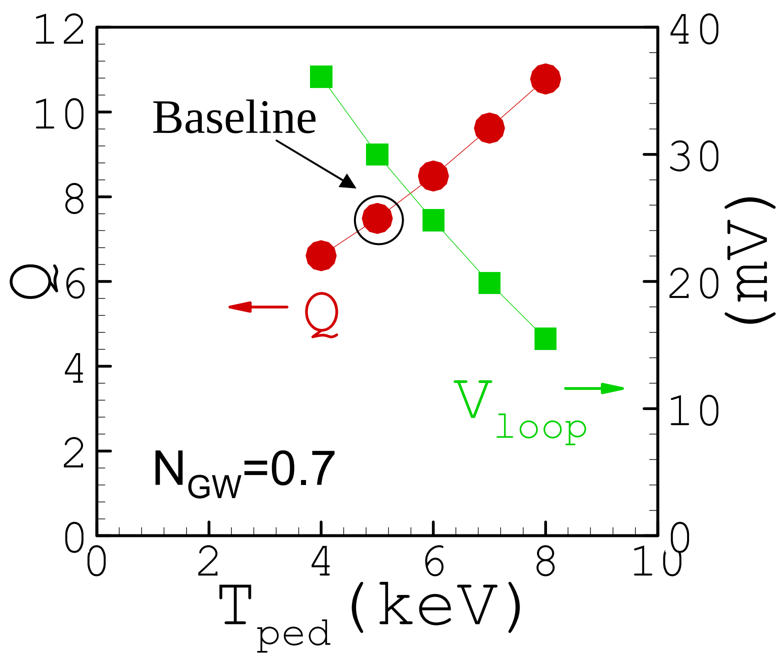
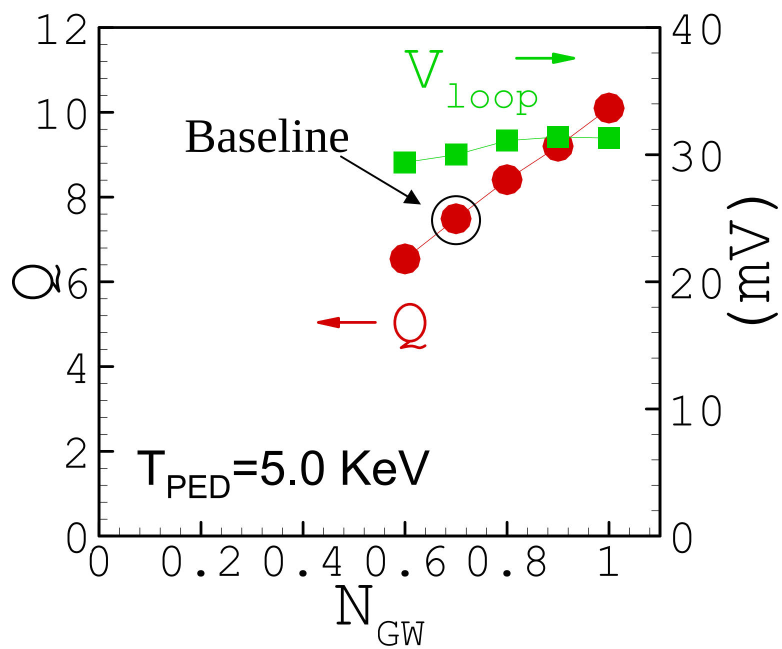
High Fusion Performance (Q>10) with Extended Burning Duration (t >5000 s) Can Be Achieved Using ITER 'Day-1' H&CD Capability

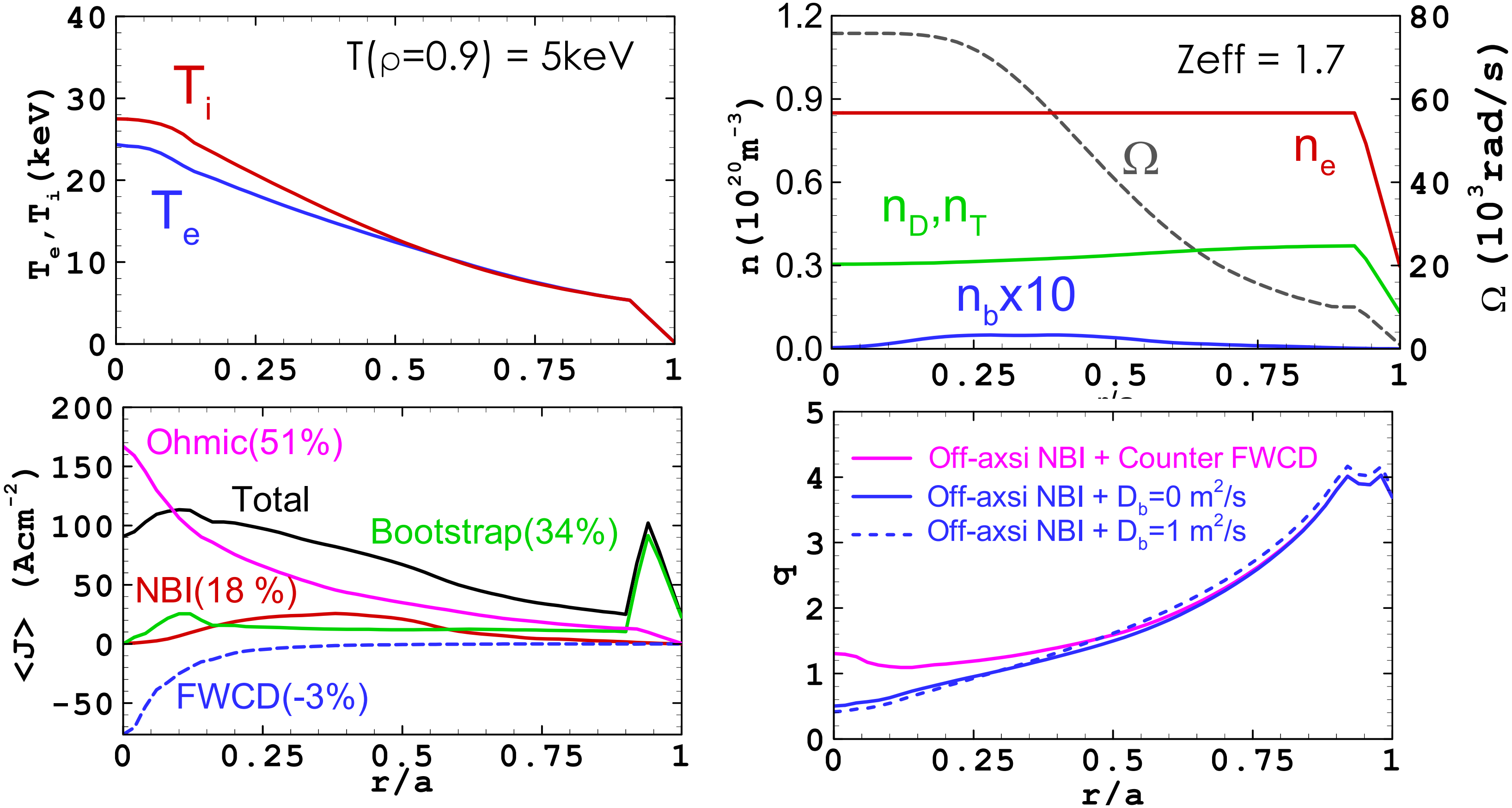
B_T = 5.3 T, I_p = 12 MA, P_{NB} = 33 MW @ 1 MeV, P_{RF} = 20 MW @ 56 MHz





- **Low V_{loop} provides extended burning duration**
- **Q ≈ 10 with (T_{ped} = 7 keV, N_{GW} = 0.7) or (T_{ped} = 5 keV, N_{GW} = 1.0)**

Stationary State with q_0>1 Is Demonstrated for the ITER Hybrid Scenario



- **Stationary state with fully penetrated J profile**
- **Q = 8, β_N = 2.3**
- **$q_0 \approx 1.2$, $q_{min} \approx 1.05$ using counter FWCD**

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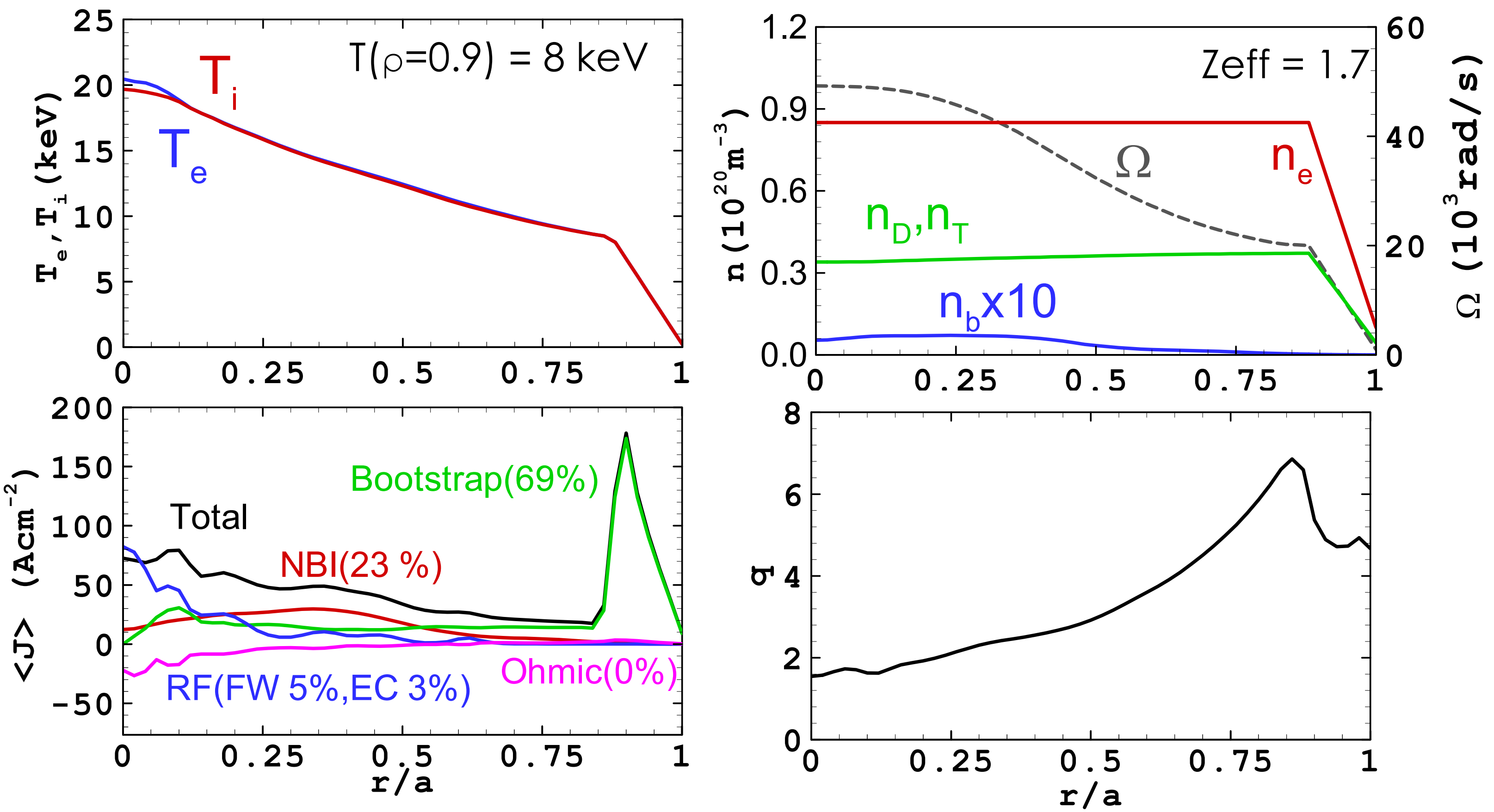
Existence of Full Noninductive (f_{NI}=100%) Scenario with Q≈5 is Established for the ITER Steady-State Scenario

B_T = 5.3 T, I_p = 9 MA, P_{NB} = 33 MW @ 1 MeV, P_{RF} = 20 MW @ 56 MHz, P_{EC} = 20 MW



- **Q = 5.5, β_N = 3.0**
- **Safety factor is monotonic with q(0) ≈ 1.5**

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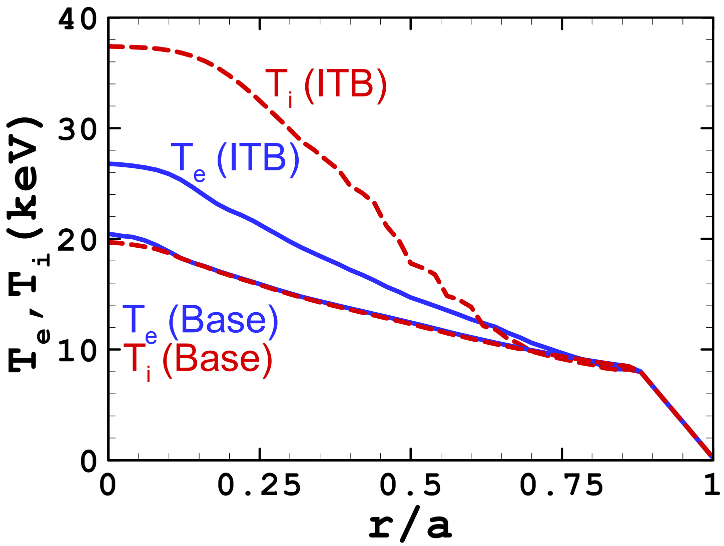
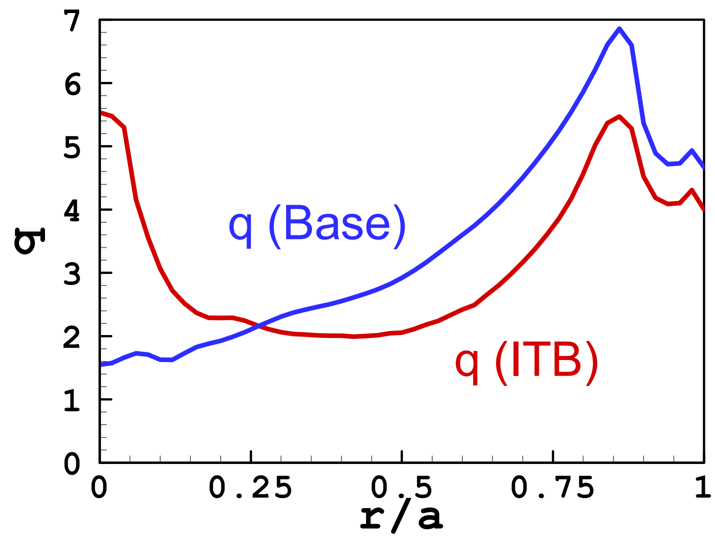
ITB Formation is Observed with a Broader Initial Current Profiles Otherwise under the Same Conditions





- **Substantially better parameters, though not equilibrated:**

	f_{NI} (%)	f_{BS} (%)	Q
Base case	100	69	5.5
ITB	110	73	7.7

- **Simulation efforts to sustain the broad current profile using off-axis ECCD for a long period are in progress**

Conclusion

- Integrated scenario modeling based on ONETWO/GLF23 has been successfully validated against DIII-D experiments with new modeling capabilities including density profile evolution using GLF23, fast ion diffusion and parallel computation.
- ONETWO/GLF23 simulation for the ITER Hybrid scenario Indicates high fusion performance (Q>10) and extended burning duration (t > 5000 s) can be achieved with q_0>1 using ITER 'Day-1' H&CD capability.
- Existence of full noninductive scenario ($f_{NI} \geq 100\%$) at $Q \approx 5$ Is established for the ITER Steady-State scenario with possibility of better performance by Internal Transport Barrier.

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