PROGRESS IN THE INTEGRATION OF THE PHYSICS BASED MHD STABILITY MODELS INTO THE ONETWO TRANSPORT CODE

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MOTIVATION

- H-mode and ITB formation of modern tokamak make it necessary to analyze the pressure and current profiles and to analyze and control the instabilities associated with them
- Self-consistent integration of MHD stability models in transport analysis is essential for simulation and development of AT scenarios for DIII-D and new tokamak devices such as EAST
- High accuracy equilibrium calculations are required for stability studies

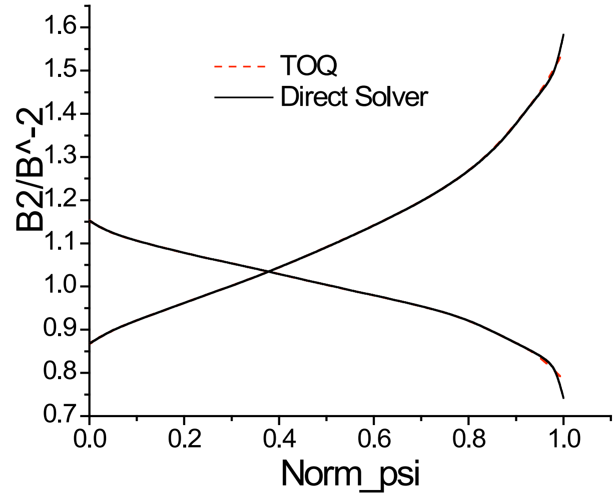
  ---- Use of inverse solver can provide direct input to stability codes and avoid inaccuracy associated with the interpolation of flux coordinates and mapping

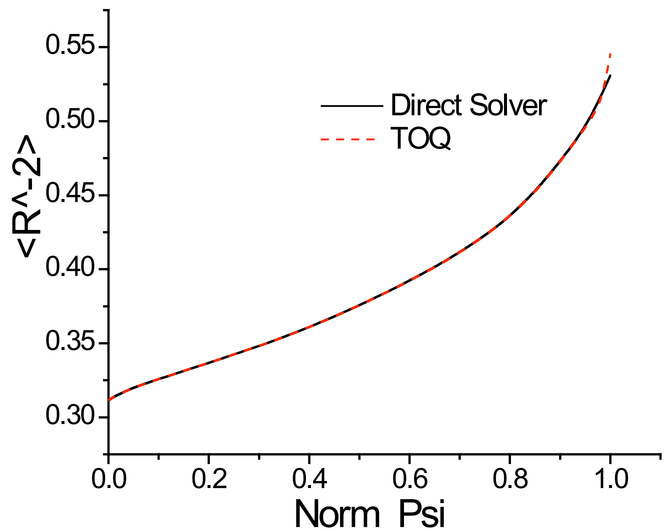
OUTLINE

- The inverse equilibrium code TOQ has been integrated into ONETWO
- A non-resonant magnetic damping model due to error magnetic field has been implemented into ONETWO to model the observed plasma slowing down in DIII-D RWM discharges
- The ONETWO transport package is being applied to develop AT scenarios for the EAST (Experimental Advanced Superconducting Tokamak) being constructed at ASIPP, Hefei China.

TOQ HAS BEEN INTEGRATED INTO ONETWO

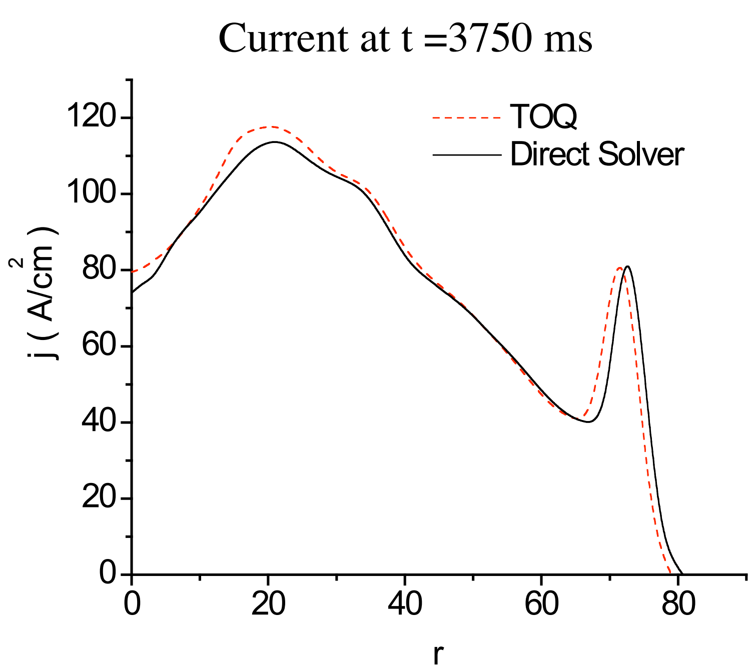
- TOQ is a fixed boundary, equal-arc-length, inverse equilibrium solver for the Grad-Shafranov equation. Different choices are available to parameterize the current profiles in the Grad-Shafranov equation
- It was originally written by B. Miller of General Atomics(B. Miller et. al, NF, p2101, 1987). The latest version TOQ4.1 is contributed by Dylan Brennan,and is available at http://fusion.gat.com/toq/
- We check the calculated geometric parameters by TOQ against the direct equilibrium solver in ONETWO. They are in good agreement (right).

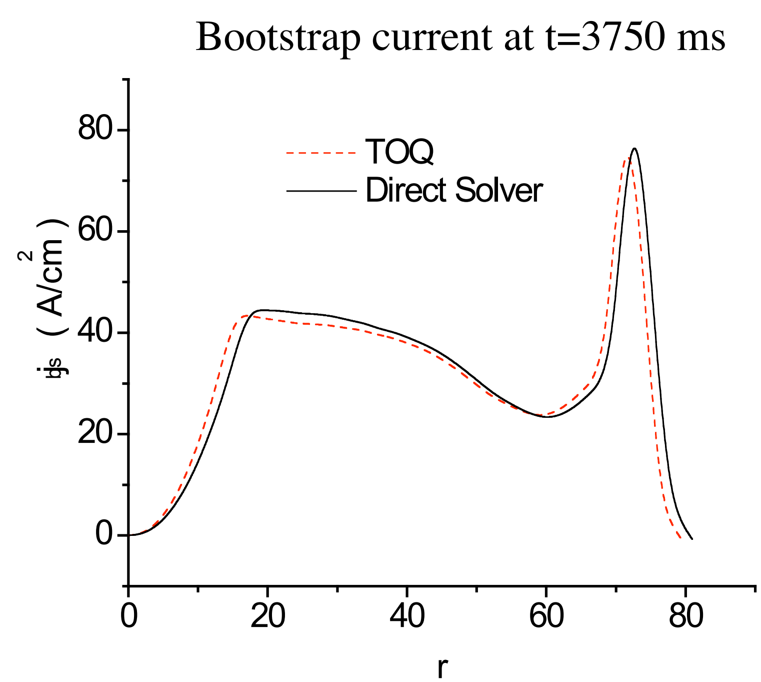




TOQ BENCHMARKS WELL AGAINST THE EXISTING DIRECT EQUILIBRIUM SOLVER IN ONETWO

- **TOQ, as an independent code, is called by ONETWO to calculate the geometric parameters of flux surface and other neoclassic transport related parameters at each time point and to present a series of output files for stability analysis. To benchmark, a sample current evolution case for shot 111221 has been run from t=3.7s using both TOQ and the direct solver.**





ONETWO HAS BEEN MODIFIED TO INCLUDE MAGNETIC DRAG EFFECTS DUE TO NON-RESONANT ERROR FIELD

- **The magnetic drag effects on plasma rotation are simulated in ONETWO**

------ Toroidal rotation evolution equation

$$\sum_i < R^2 > \frac{\partial m_i n_i \omega_\phi}{\partial t} + \frac{1}{H\rho}\frac{\partial H\rho\Gamma_\omega}{\partial \rho} = S_\omega - S_{Drag}^{R} - S_{Drag}^{NR}$$

S_ω Momentum source

S_{Drag}^{R} Momentum sink due to resonance error magnetic field

S_{Drag}^{NR} Momentum sink due to non-resonance error magnetic field.

THE RESONANCE DRAG EFFECT IS MODELED USING THE INDUCTIVE MOTOR MODEL

$$S^R_{Drag} = C_B \frac{B^2{}_{err\_qn}}{\omega_{\phi\_qn}} e^{-\frac{(\rho-\rho_{qn})^2}{\lambda^2{}_{qn}}}$$

C_B Resonance magnetic drag coefficient

B_{err_qn} Error magnetic field at q_n

ρ_{qn} Radius of q_n surface

λ_{qn} Drag half width

(R. Fitzpatrick, POP, 5, 3325, 1998)

NON-RESONANT MAGNETIC DRAG

- **The non-resonant magnetic drag from the (m,n) component of error field is modeled as**

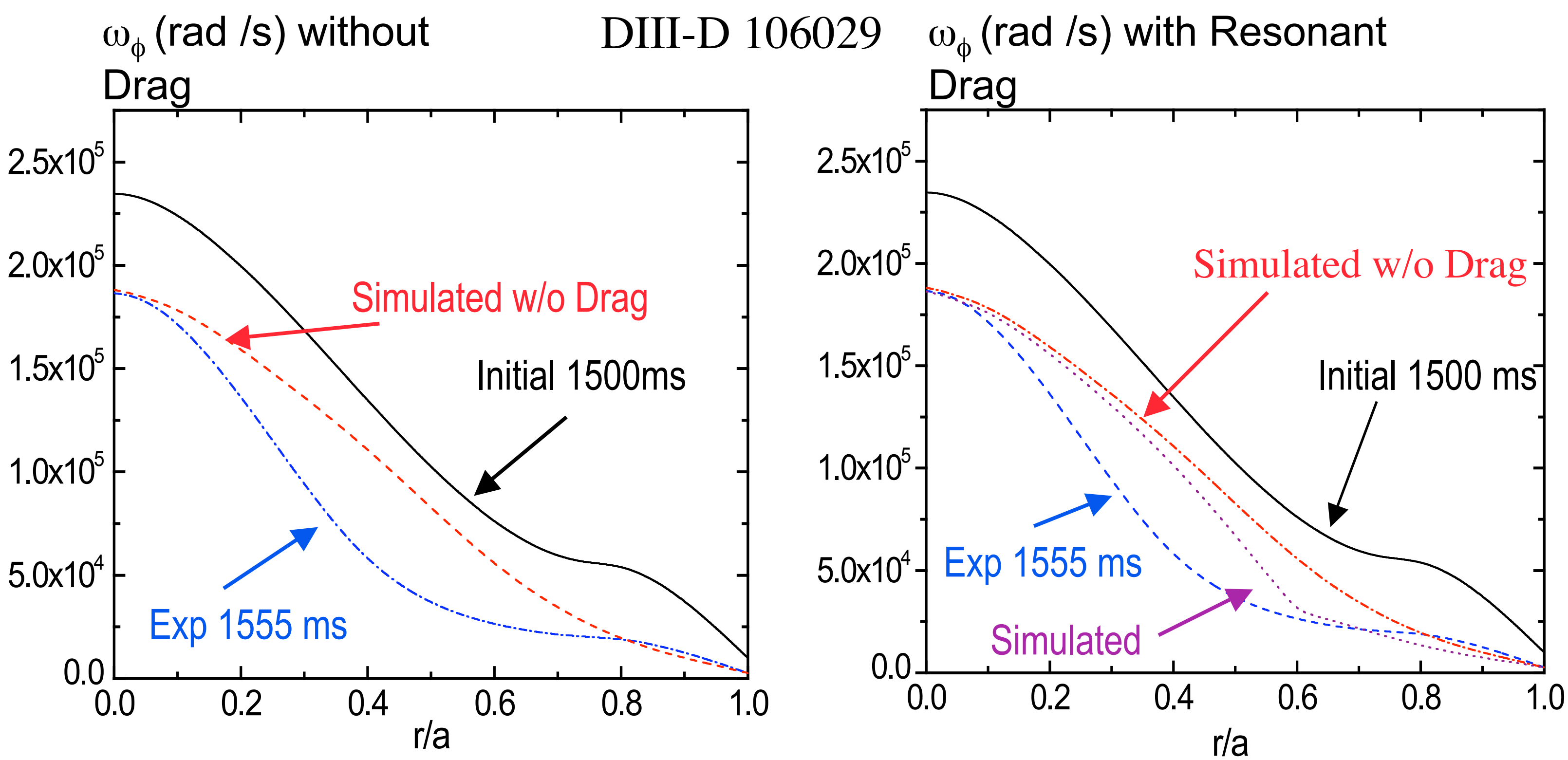
$$\frac{\partial \omega_\phi}{\partial t} = -\pi^{\frac{1}{2}} \left(V_{Ti} / R_0 \right) \left(n B_{mn} / B_0 \right)^2 \omega_\phi / \left(2 \,|\, n - m/q \,|\right)$$

B_{mn} The Fourier component of error magnetic field

(K.C. Shaing, POP, 10, 1443, 2003 and R. J. La Haye et al, POP, 9,2051,2002)

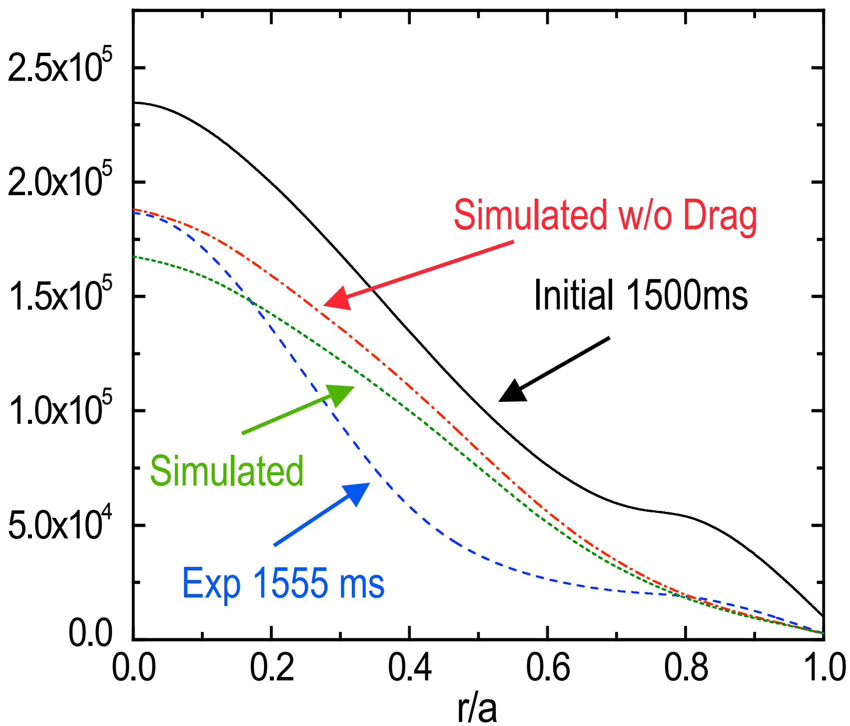
RESONANT MAGNETIC DRAG CAN QUALITATIVELY DESCRIBE REDUCTION OF PLASMA ROTATION IN RWM DISCHARGE

- **ONETWO simulations of toroidal rotation using measured temperature and density data**
- **Magnetic drag + 3500 Neoclassic background**

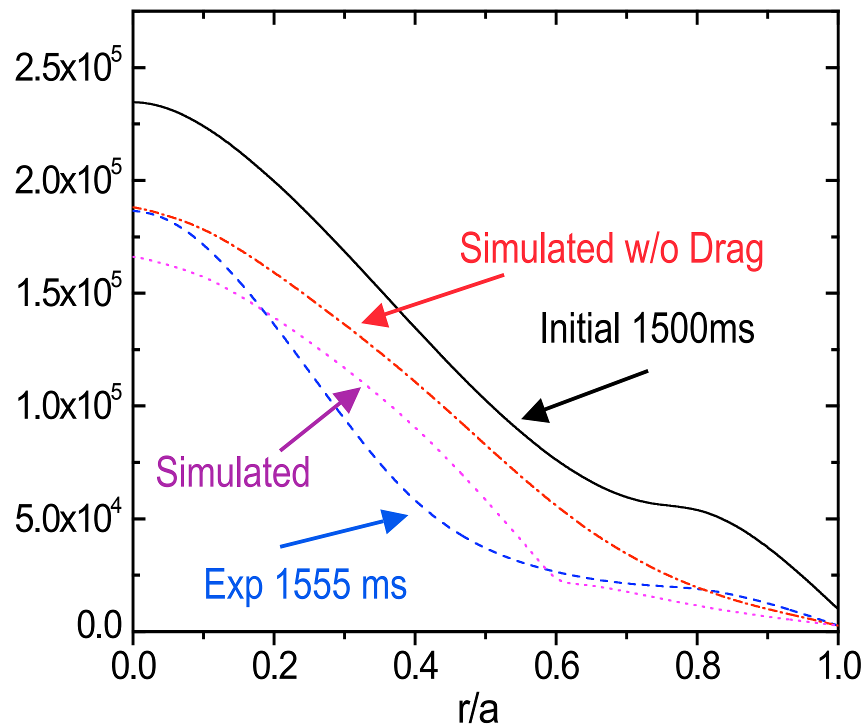


NON-RESONANCE MAGNETIC DRAG EFFECTS APPEAR TO BE MODEST

ω_ϕ (rad /s) with Non-resonant Drag



ω_ϕ (rad /s) with both Resonant and Non-resonant Drag



EAST IS A SUPERCONDUCTOR TOKAMAK BEING CONSTRUCTED IN HEFEI

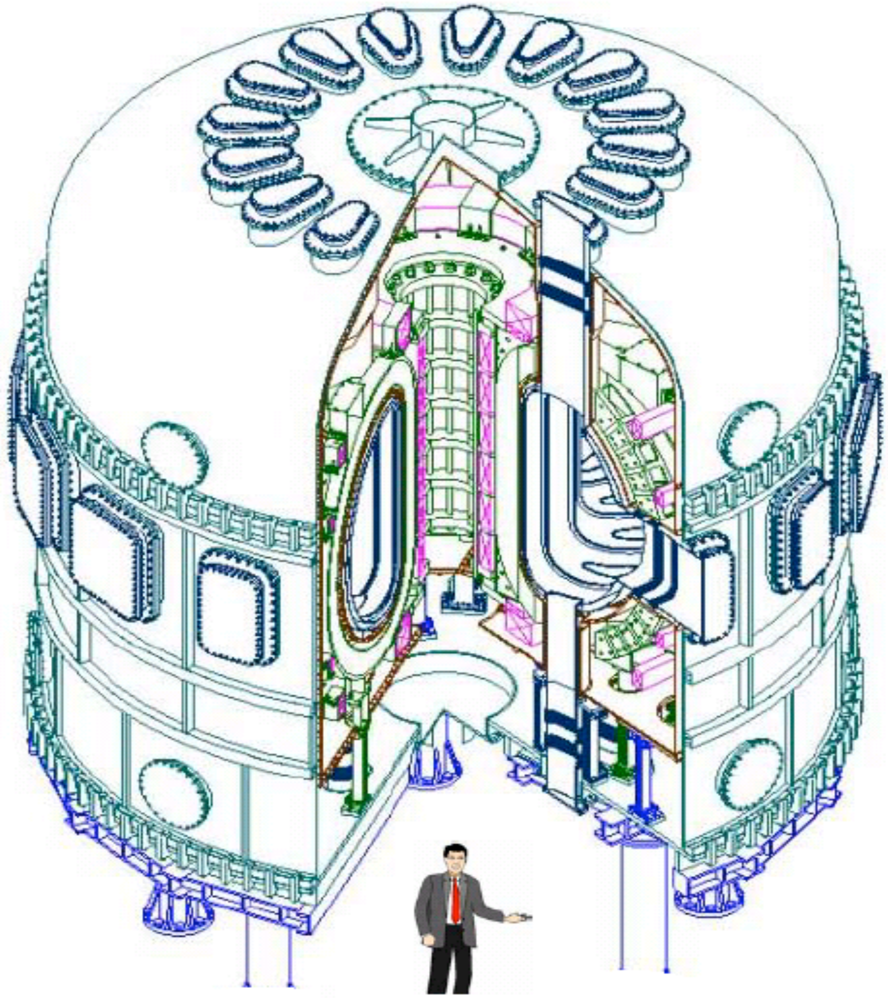
- **The missions of EAST (Experimental Advanced Superconducting Tokamak) include**

  ----Demonstrate steady-state operation with full non-inductive current drive, i.e. with external current drive and bootstrap current.

  ----Investigate advanced tokamak physics and demonstrate stationary high plasma operation performance operation by strong plasma shaping, profile control and divertor optimization.

- **The EAST machine is under construction at ASIPP, Hefei, China. First plasma is expected by late 2005.**

EAST PARAMETERS



Major radius R_0 1.75-1.95 m

Minor radius a 0.4-0.5 m

Toroidal field B_0 3.5(4) T

Plasma current I_p 1(1.5) MA

Elongation κ_x 1.6-2

Triangularity δ_x 0.4-0.8

Heating and current drive

- ICRF 1.5-3-6 MW
- LHCD 2-3.5-8 MW
- ECRH 0.2-1-1.5 MW
- NBI 0-4-8 MW

EAST VACUUM CHAMBER

PRE-ASSEMBLING OF EAST SUPERCONDUCTING TOROIDAL FIELD COILS

PRELIMINARY EAST SIMULATION USING ONETWO

- **A double null plasma configuration with 1 MA fixed total current and NBI, ECH, and fast wave heating and current drive is simulated using the GLF23 transport model until T_e, T_i, and ω reach steady state.**
- **Then the Faraday equation is solved to find the steady state current density, J, with flat electric field profile.**

$P_{NBI} = 2$ MW $\quad I_{tot} = 1.0$ MA

$P_{ECRF} = 1.5$ MW $\quad I_{ohm} = 0.101$ MA

$f_{ECRF} = 1.7$ GHz $\quad I_{bs} = 0..432$ MA

$P_{FW} = 1.5$ MW $\quad I_{beam} = 0.35$ MA

$f_{FW} = 30$ Mhz $\quad I_{RF} = 0.117$ MA

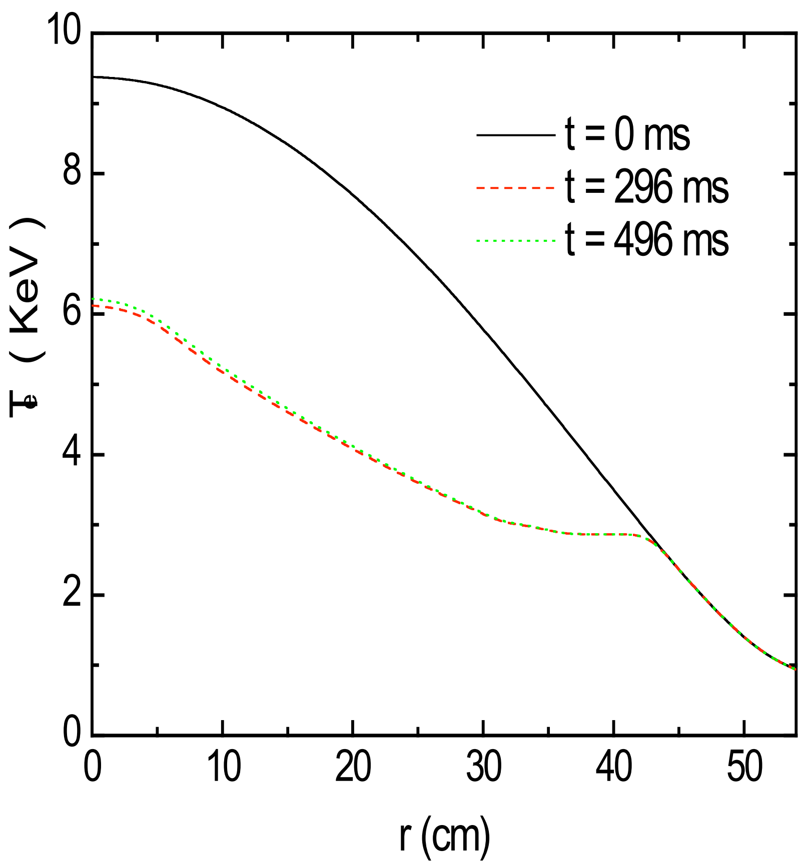
$$< n_e >= 3.3 \times 10^{19} m^{-3}$$

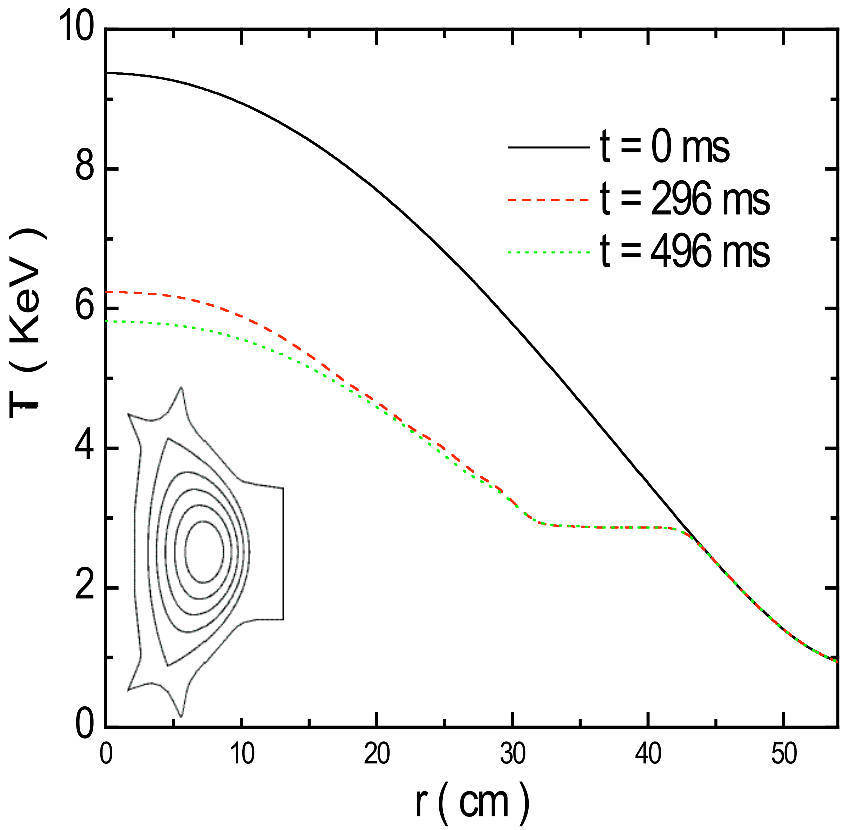
$$< \beta_T >= 1.5\%$$

$$\beta_N = 2.84$$

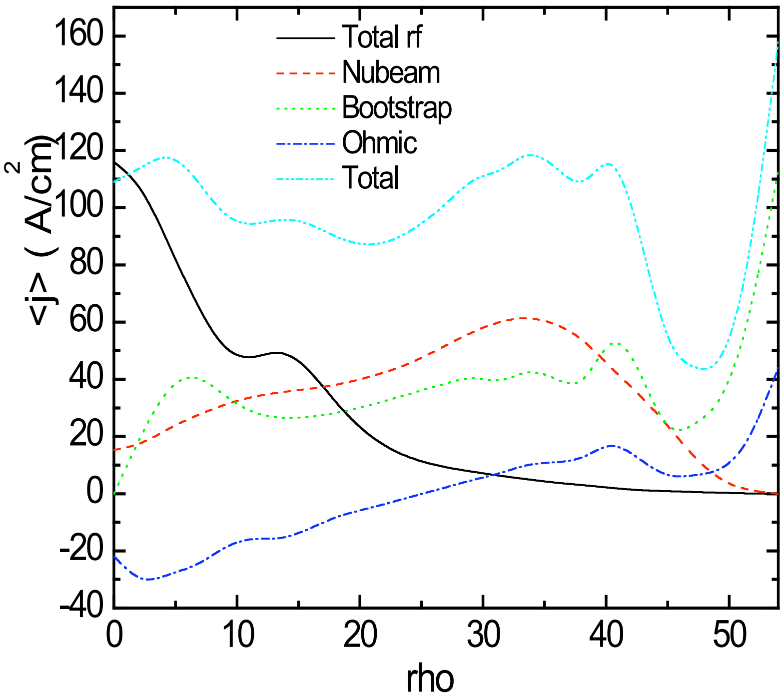
$$q(0) = 1.9 \qquad q_{95} = 4.3$$

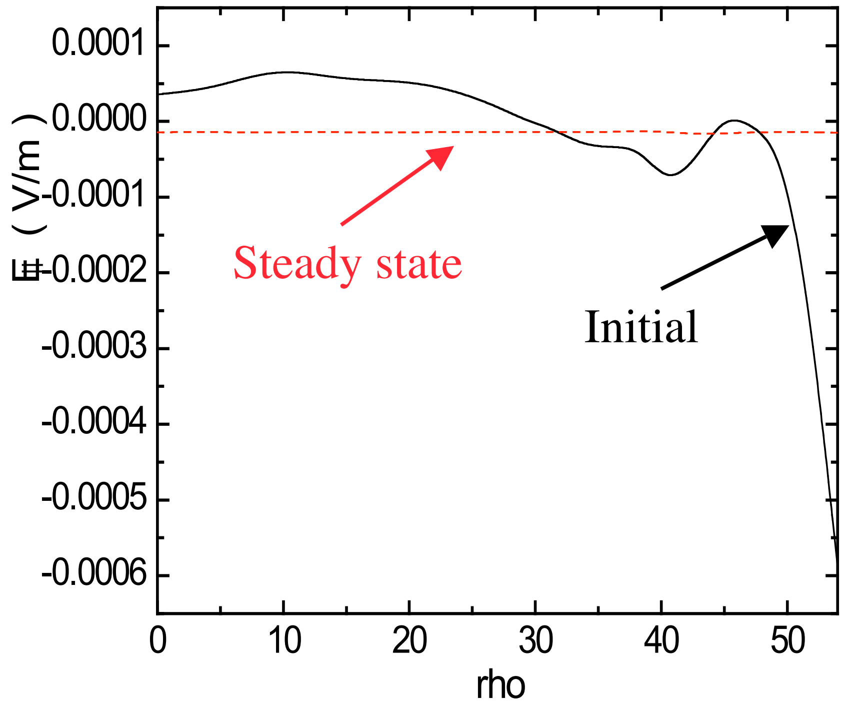
ELECTRON AND ION TEMPERATURE PROFILES EVOLVE INTO STEADY STATE IN 0.5 S





STEADY STATE CURRENT AND ELECTRIC FIELD PROFILES





More work is required to optimize the current profile and to obtain $E_{||} \approx 0.0$ by adjusting RF, NBI .

SUMMARY / PLAN

Summary

- The inverse equilibrium solver TOQ has been integrated into ONETWO. It is the basis for the integration of MHD instability codes and ONETWO.
- The slowing down of a DIII-D RWM discharge due to error magnetic field has been modeled using ONETWO. Magnetic drag due to error field can qualitatively describe the plasma slowing down.
- ONETWO is being applied to model EAST.

Future direction

- Integrate stability codes (ELITE, BALOO) into ONETWO and simulate the plasma evolution self-consistently with stability analyses.
- Use ONETWO to simulate EAST AT discharges: achieve high β with optimized current profiles and full non-inductive current drive.

** D. Zhou would like to thank Dr Jim Leuer for the EAST equilibrium calculations.