# Modelling of JT-60SA Operational Scenarios

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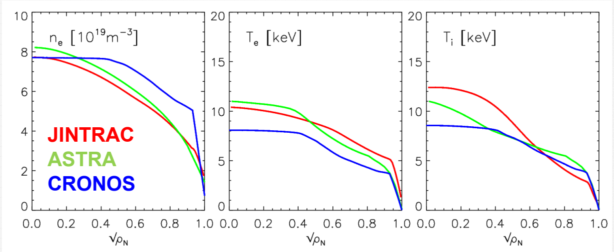
## Introduction

- Aim of the simulations was to assess steady state conditions estimated with 0-dimensional codes and provide a profile database for further physics studies.
- Three scenarios considered: standard H-mode, hybrid, advanced steady-state.
- Codes deployed: ASTRA, CRONOS, JINTRAC.
- Core transport models: TGLF (CRONOS), CDBM (CRONOS), GLF23 (ASTRA, CRONOS), Bohm/gyro-Bohm (ASTRA, JINTRAC).
- Edge transport barrier models: continuous ELMs (JINTRAC), Cordey scaling + EPED1 (CRONOS).
- Boundary conditions imposed at separatrix (CRONOS JINTRAC) or top of the pedestal (ASTRA).
- Fully predictive simulations of current density, ion density (CRONOS and JINTRAC, density not evolved in ASTRA), ion and electron temperature. No rotation.
- Equilibrium solver SPIDER or three moments (ASTRA), HELENA (CRONOS) and ESCO (JINTRAC).

## Standard H-mode (scenario2)

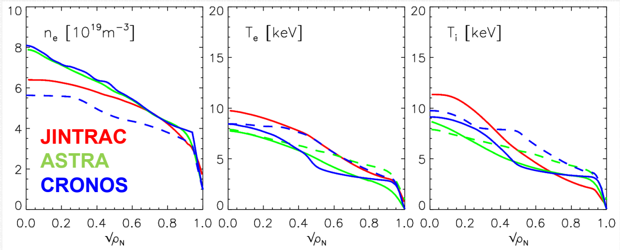
- JINTRAC: Bohm/gyro-Bohm, $\alpha_c$=1.3. Tends to underestimate height of density pedestal.
- ASTRA: SPIDER equilibrium solver and JET-like Bohm/gyro-Bohm. Boundary conditions at top of ETB. Reasonable agreement with JINTRAC results. (Density not simulated).
- CRONOS: CDBM+GLF23. Underestimates on axis electron and ion temperatures.
- Generally all codes give values for zero-dimensional quantities close to nominal scenario.
- Integrated core/SOL simulations with COREDIV indicate that $n_e$=2 $10^{19}$ $m^{-3}$ (instead of $10^{19}$ $m^{-3}$ used in these simulations) is a boundary condition more compatible with the assumption $Z_{eff}$=1.5. This could have an effect for stiff transport models like GLF23 (higher core density, lower core temperatures).



| Scenario 2 | JINTRAC | CRONOS | ASTRA | Reference |
|---|---|---|---|---|
| $B_T$ [T] | 2.25 | 2.25 | 2.25 | 2.25 |
| $I_p$ [MA] | 5.5 | 5.5 | 5.5 | 5.5 |
| $f_{bs}$ [%] | 34 | 28 | 35 | 28 |
| $q_{95}$ | 3.5 | 3.0 | 3.3 | 3.0 |
| $P_{NBI}$ [MW] | 33 | 33 | 32.5 | 34 |
| $P_{ECRH}$ [MW] | 7 | 7 | 7 | 7 |
| $n_{e0}$ [$10^{19}$ $m^{-3}$] | 8.2 | 7.5 | 8.2 | 6.3 |
| $<n_e>$ [$10^{19}$ $m^{-3}$] | 5.1 | 6.2 | 5.4 | 5.6 |
| $T_{e0}$ [keV] | 10.3 | 8.1 | 11.2 | 13.5 |
| $<T_e>$ [keV] | 7.2 | 5.4 | 7 | 6.3 |
| $T_{i0}$ [keV] | 12.4 | 8.5 | 11.2 | 13.5 |
| $<T_i>$ [keV] | 6.5 | 5.8 | 6.4 | 6.3 |
| $W_{th}$ [MJ] | 23 | 22.5 | 23.3 | 22 |
| $\tau_E$ [s] | 0.60 | 0.61 | 0.58 | 0.64 |
| $Z_{eff}$ | 1.5 | 1.5 | 1.5 |  |

## Hybrid scenario (scenario 4-2)

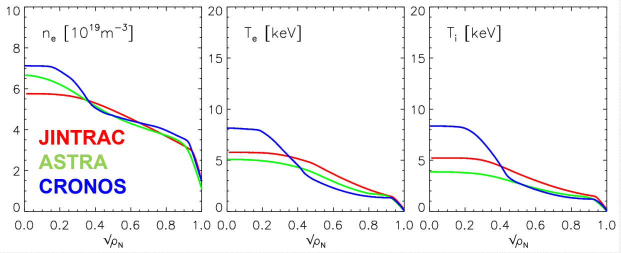
- JINTRAC: Bohm/gyro-Bohm. $\alpha_c$=1.5. Fully predictive. Density slightly underestimated (adjust fuelling, introduce inward pinch).
- ASTRA: with SPIDER and JET-like Bohm/gyro-Bohm (solid line), less energy content than JINTRAC. With analytical equilibrium and GLF23 (dashed line), less energy content, but volume is different. (Density not evolved).
- CRONOS: CDBM+GLF23 (solid line) ITB on electron and ion temperature, TGLF (dashed line).



| Scenario 4-2 | JINTRAC | CRONOS CDBM+GLF23 / TGLF | ASTRA BgB / GLF23 | Reference |
|---|---|---|---|---|
| $B_T$ [T] | 2.28 | 2.28 / 2.28 | 2.28 / 2.28 | 2.28 |
| $I_p$ [MA] | 3.5 | 3.5 / 3.5 | 3.5 / 3.5 | 3.5 |
| $f_{bs}$ [%] | 48 | 40 / 39 | 51 / 43 | 40 |
| $q_{95}$ | 4.6 | 4.6 / 4.5 | 4.8 / 4.8 | 4.4 |
| $P_{NBI}$ [MW] | 29 | 29 / 29 | 29 / 32 | 30 |
| $P_{ECRH}$ [MW] | 6.8 | 7 / 7 | 7 / 7 | 7 |
| $n_{e0}$ [$10^{19}$ $m^{-3}$] | 6.4 | 8 / 6.1 | 7.9 / 7.9 | 8.4 |
| $<n_e>$ [$10^{19}$ $m^{-3}$] | 4.7 | 5 / 4.1 | 5 / 5 | 6.2 |
| $T_{e0}$ [keV] | 9.7 | 8.2 / 8.5 | 7.8 / 10 | 7.5 |
| $<T_e>$ [keV] | 5.2 | 3.8 / 5.1 | 4 / 3.6 | 3.7 |
| $T_{i0}$ [keV] | 11.3 | 9.0 / 9.8 | 8.7 / 13 | 7.5 |
| $<T_i>$ [keV] | 4.6 | 4.3 / 5.4 | 4.1 / 4.3 | 3.7 |
| $W_{th}$ [MJ] | 14.2 | 12.5 / 13 | 12.6 / 13.4 | 13.4 |
| $\tau_E$ [s] | 0.4 | 0.4 / 0.42 | 0.35 / 0.4 | 0.42 |
| $Z_{eff}$ | 1.7 | 1.7 | 1.7 |  |

## Advanced steady-state scenario (scenario 5-1)

- JINTRAC: Bohm/gyro-Bohm, fixed $D_{ETB}$ and $\chi_{ETB}$ (corresponding to $\alpha_c$=1.0). Higher pedestals give too much bootstrap current. No ITB on electron or ion temperature. Profiles less peaked. Ion temperature underestimated.
- ASTRA: with three-moment equilibrium and JET-like Bohm/gyro-Bohm transport, lower energy content, but volume is different. Ion and electron temperature lower than in JINTRAC.
- CRONOS: CDBM+GLF23. ITBs on density, electron and ion temperature. (High pressure gradient and low shear).



| Scenario 5-1 | JINTRAC | CRONOS | ASTRA | Reference |
|---|---|---|---|---|
| $B_T$ [T] | 1.72 | 1.72 | 1.72 | 1.72 |
| $I_p$ [MA] | 2.4 | 2.3 | 2.3 | 2.3 |
| $f_{bs}$ [%] | 62 | 67 | 53 | 68 |
| $q_{95}$ | 6.3 | 6.5 | 6.6 | 5.8 |
| $P_{NBI}$ [MW] | 29 | 29 | 31 | 30 |
| $P_{ECRH}$ [MW] | 6.5 | 7 | 7 | 7 |
| $n_{e0}$ [$10^{19}$ $m^{-3}$] | 6.0 | 7.0 | 6.7 | 6.6 |
| $<n_e>$ [$10^{19}$ $m^{-3}$] | 4.2 | 4.4 | 4.2 | 4.2 |
| $T_{e0}$ [keV] | 5.9 | 8.0 | 5.1 | 6.7 |
| $<T_e>$ [keV] | 3.3 | 3.0 | 2.8 | 3.3 |
| $T_{i0}$ [keV] | 5.5 | 8.2 | 3.9 | 7.1 |
| $<T_i>$ [keV] | 2.9 | 3.0 | 2.2 | 3.4 |
| $W_{th}$ [MJ] | 8.9 | 9 | 7.2 | 8.4 |
| $\tau_E$ [s] | 0.24 | 0.25 | 0.19 | 0.23 |
| $Z_{eff}$ | 1.7 | 1.7 | 1.7 |  |

## Conclusions and future work

- JT60-SA scenarios have been simulated with different codes and transport models.
- Results are close to those obtained with zero-dimensional codes.
- Detail of the profiles differ from code to code.
- Electron and ion temperatures assumed in zero-dimensional calculations seem to be optimistic for most scenarios.
- For all scenarios normalized pedestal pressure ($\alpha_c$) seems to be below MHD stability limit.
- Further analysis of pedestal stability is required.
- Analysis of time dependent scenarios (density and current ramp up and down) planned.

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To obtain further information on the data and models underlying this paper please contact publicationsmanager@ccfe.ac.uk.