Predictive modelling of D-T fuel mix control with gas puff and pellets for JET 3.5 MA baseline scenario

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Motivation for studying fuel mix control in the baseline scenario:

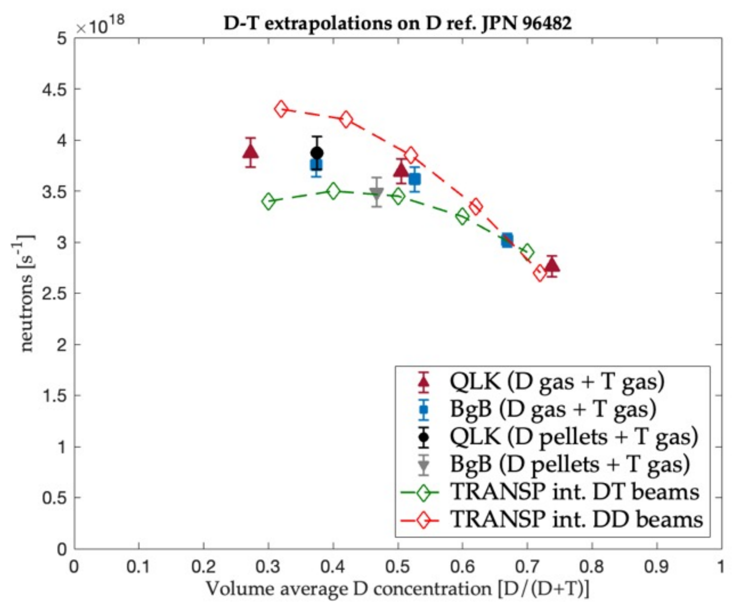
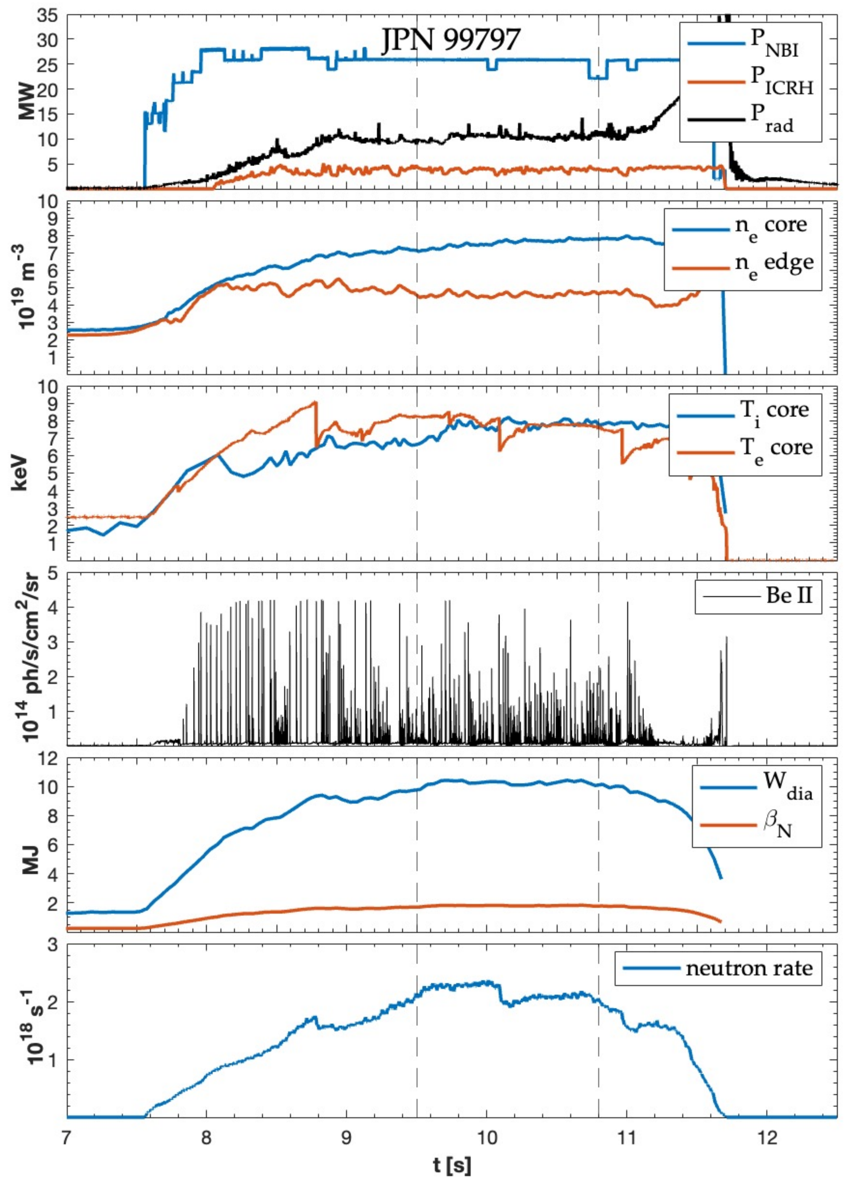


Figure 1. Sensitivity of the (3.5 MA / 3.3 T) baseline scenario to the plasma composition, comparing the results of fully predictive simulations done with QuaLiKiz or Bohm gyro-Bohm transport model in presence of D-T balanced beams (full markers) to TRANSP interpretative analysis (open markers) with D-T balanced beams or D-D beams.

- In preparation to JET DTE2 campaign we developed a wide database of fully predictive simulations [1].
- Before DTE2 we studied the sensitivity of the baseline performance to the D-T main ion plasma mixture.
- D ELM-pacing pellets (2 mm) at 35 Hz are required for ELM triggering and medium/high-Z impurity influx control in the (3.5 MA, 3.3 T) baseline scenario [2].
- Gas recipe for baseline in D-T features a balanced D-T gas puffing during the ramp-up and T gas puff with D pellets during the flat-top phase, neutral beam injection is D-T balanced.
- Validation of QuaLiKiz on actual D-T data.



JINTRAC-QuaLiKiz-SANCO simulations on D-T JPN 99797 (3.5 MA / 3.3 T):

Predicted quantities:

- Electron density profiles
- Electron temperature profiles
- Ion temperature profiles
- D ion density profiles
- T ion density profiles
- Be ion density profiles
- Ni ion density profiles
- W ion density profiles
- Current density profiles

Models used:

- QuaLiKiz [3,4]: turbulent transport
- SANCO: impurity transport
- ESCO: equilibrium
- PENCIL-PION: heating
- FRANTIC: ionization sources

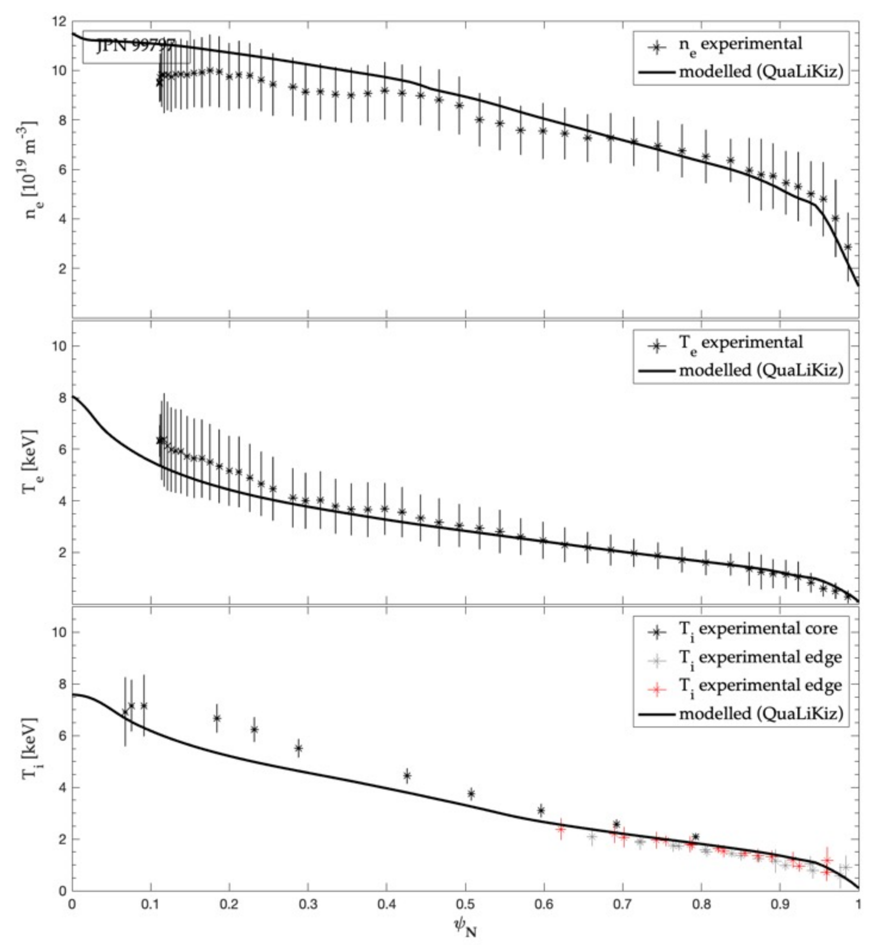


Figure 2. Comparison between experimental and modelled profiles, with electron density and temperature measured by the high-resolution Thompson scattering and ion temperature measured by charge exchange spectroscopy.

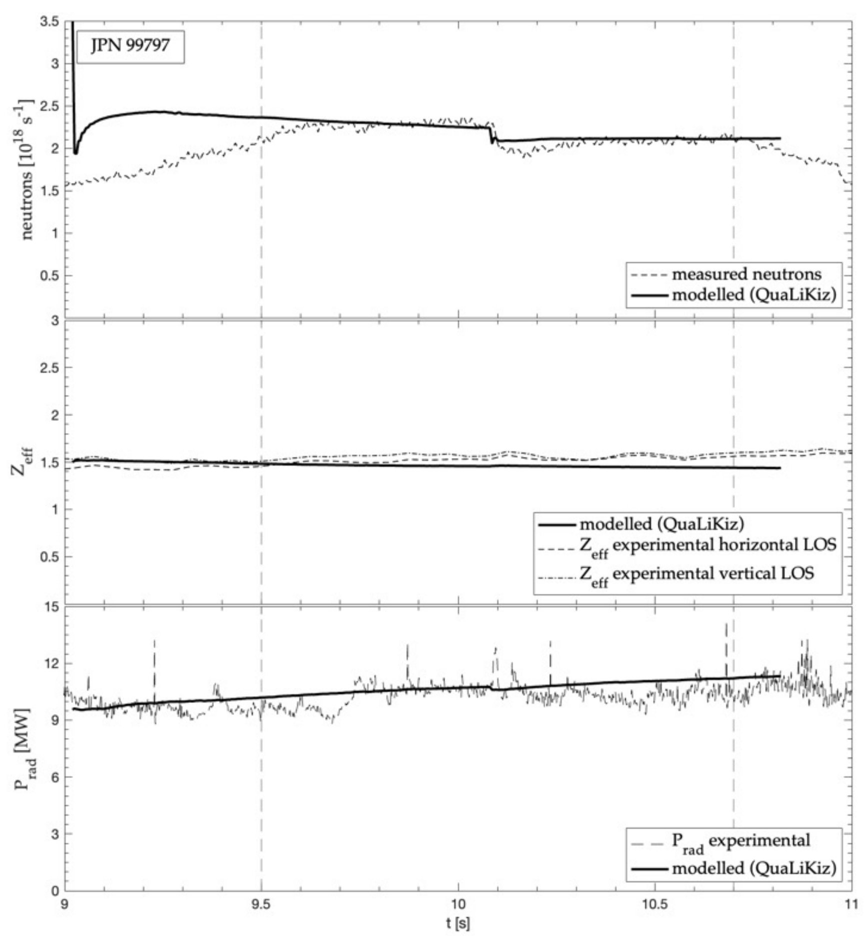


Figure 3. Comparison between experimental and modelled neutron rate, effective charge, and bulk radiative power for the JPN 99797 in the flat-top phase.

Modelling pellets, balancing particle sources to reproduce the experimental T concentration:

- **First set of simulations:** the plasma mixture is imbalanced unbalancing the particle sources simulated as gas puff ("gas only")
- **Second set of simulations:** pellets are modelled with the "Continuous pellet model" [5] assuming a gaussian source centred at the normalised toroidal flux radius ρ_n = 0.9 with a width equal to 0.15. Gas puff particle sources are tuned to reproduce the experimental T concentration. Despite the absence in the experiment of D gas puffing, we found a lower limit of the pellet fuelling efficiency which requires the presence of a residual D gas puffing in the modelling. We call it **"D wall ionization source"**.

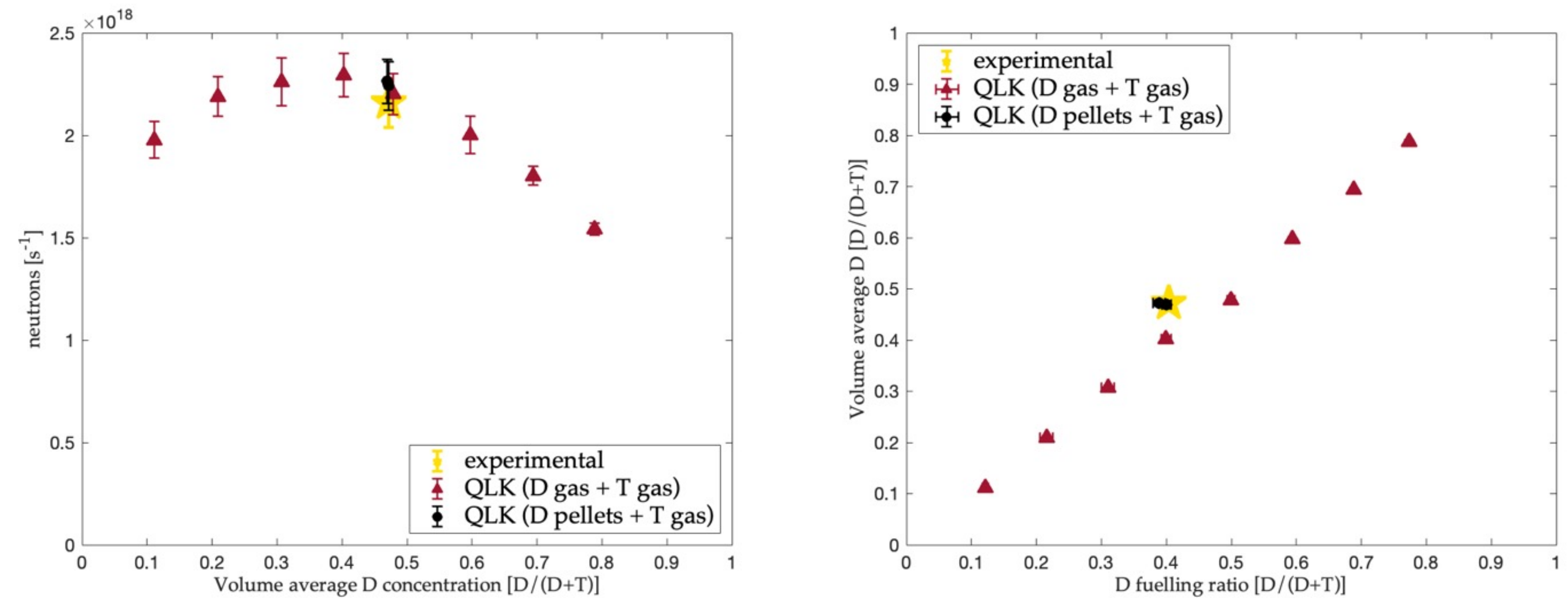


Figure 4. Comparison between experimental and modelled main ion plasma mixtures, the dependence of neutron yield (left) and the fuelling ratio required to achieve the desired plasma composition (right).

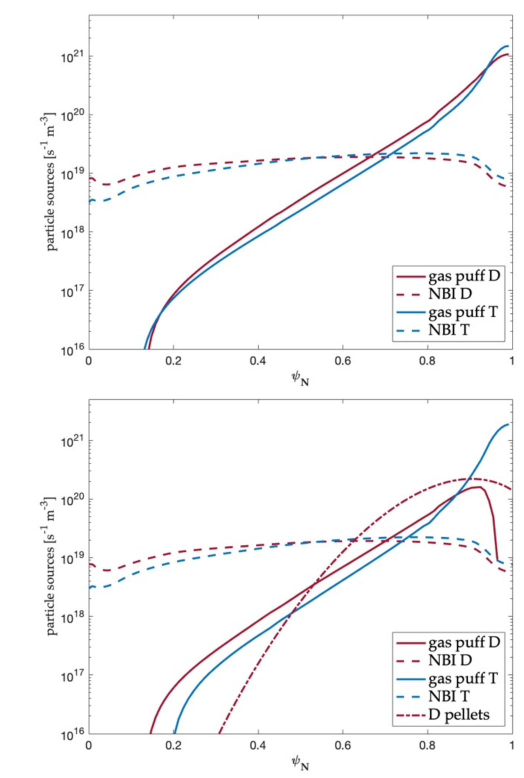


Figure 5. Particle deposition profiles for D and T from gas puff and NBI when modelling the gas puff source and pellet source both as gas puff (top), and pellets and gas puff separately (bottom).

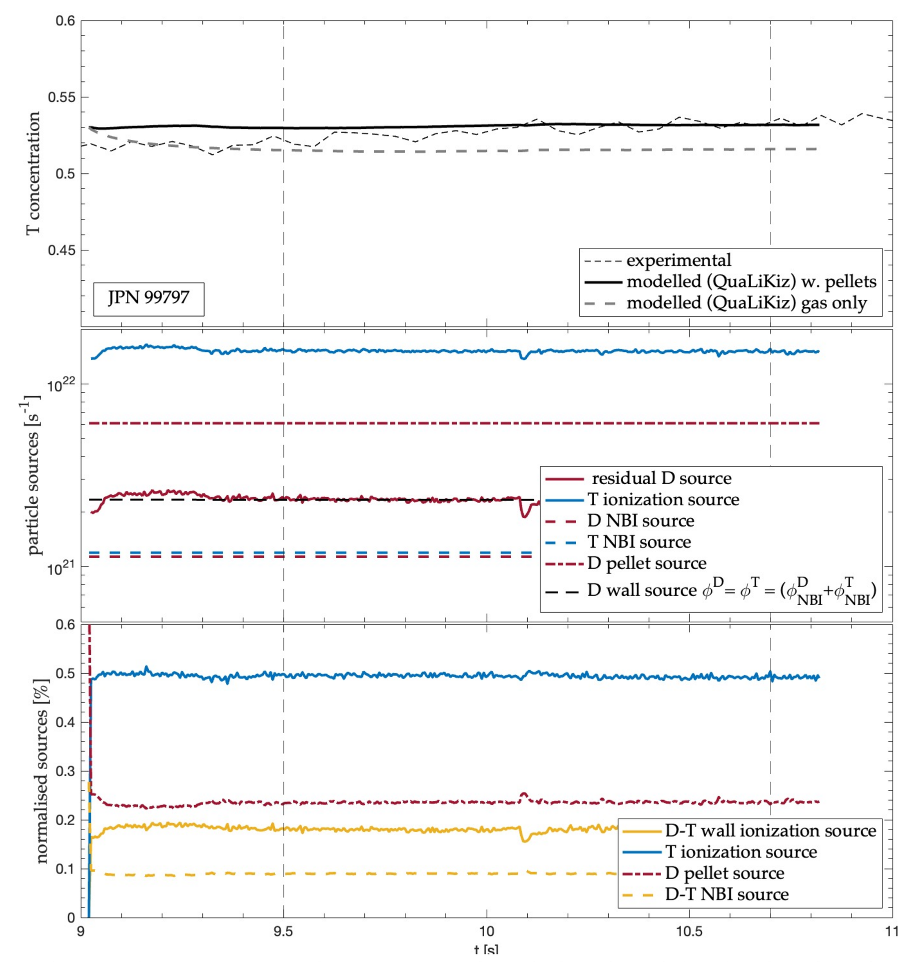


Figure 6. T concentration measured and simulated (top), simulated particle sources (middle), normalised particle sources with respect to the total particle sources (bottom).

CONCLUSIONS:

- JETTO – QuaLiKiz – SANCO predictive simulations show a good agreement with measurements of the D-T baseline JPN 99797;
- Modelling pellets and tuning the gas puff sources we are able to reproduce the experimental evolution of the T concentration;
- We have isolated a residual D ionization source which corresponds to the lower limit of the pellet fuelling;
- The particle flux associated to of the residual D ionization source is in agreement with the D wall particle flux computed with the method proposed in [6];
- Assuming the nominal pellet fuelling source the residual D ionization source is reduced to less than 1% of the total particle sources;
- Further work will investigate the sensitivity of these results to the assumptions done in the pedestal modelling, with the possibility of using EIRENE for a more accurate estimate of the cold neutral sources;

Essential References: [1] Zotta V. K. et al Nucl. Fusion 62 076024, [2] Garzotti L. et al 2019 Nucl. Fusion 59 076037, [3] Bourdelle C. et al 2016 Plasma Phys. Control. Fusion 58 014036, [4] Citrin J. et al 2017 Plasma Phys. Control. Fusion 59 064010, [5] Parail V. et al 2009 Nucl. Fusion 49 075030, [6] Jones T. T. C. et al 1998 25th EPS Conference.

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