EUROfusion

Extrapolation to JET-DT plasmas using a combination of empirical scaling and the ASCOT neutral beam heating code

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BACKGROUND

JET DTE2 in 2021: Goals (KPIs)

Best performing plasmas
- target power of 40 MW of auxiliary heating
- thermal stored energies in the range 10-13 MJ
- DD neutron rate of $5{\times}10^{16}$ n/s was an objective in the development of hybrid and baseline scenarios for DTE2

DT neutron rate goal

A DT neutron rate of $5.3{\times}10^{18}$ n/s corresponds to a fusion power P_{DT}=15 MW. [1]

Need for flexible and quick tool for standard analysis and DT scenario development

TOOLS & COUPLING

JETPEAK [2]
- database currently includes some 15000 samples from stationary phases in all JET-ILW experiments and more than 1000 structured variables, from diagnostics and a variety of modelling codes

ASCOT [3,4]
- has been used at JET for analysis actively since late 1990's and during campaigns in 2016 (C36-37) it was extended with a complete fusion product module AFSI [5] and coupled with synthetic neutron diagnostics
- testing and validation against neutron production data was published in [2]
- Matlab interface for JETPEAK-ASCOT, in which ASCOT has been coupled to the JETPEAK database

Allows intershot analysis within ~10 minutes and DT extrapolation over larger datasets (~10^2 samples), presented in this paper, to be completed overnight.

PROFILE DEFINITION AND SCALING FOR EXTRAPOLATIONS

- Input data source: JETPEAK experimental data profiles for T_e, n_e
- As charge exchange data for most of the samples were unavailable, T_i profiles based on X-ray crystal spectrometry were used together with the observation that the fraction of thermal equipartition to the deposited ion power is close to constant throughout the radius
- T_i/T_e scaling: $T_{i,ext} = f_i T_{i0}$ and $T_{e0} = f_e\, T_{e0}$
- $f_e = a_w\, a_n^{-1}\, (T_{e0} + T_{i0})/\,(T_{e0} + a_T T_{i0})$ and $f_i = a_T f_e$

	Thermal energy	Density	Temperature ratio
Baseline	$W_{th} \propto P^{0.86} n_e^{0.63} I_p^{-0.19}$	$\langle n_e\rangle \propto I_p^{0.4}\, P_{tot}^{0.3}$	$T_i/T_e \propto (P_{tot}/\langle n_e\rangle)^{0.25}\, I_p^{-0.28}$
Hybrid	$W_{th} \propto P^{0.7} \langle n_e\rangle^{0.98} I_p^{0.0}$	$\langle n_e\rangle \propto I_p^{0.4}\, P_{tot}^{0.3}$	$T_i/T_e \propto (P/\langle n_e\rangle)^{0.25}\, I_p^{-0.28}$
AT	$W_{th} \propto P^{0.7} \langle n_e\rangle^{1} I_p^{0.0}$	$\langle n_e\rangle \propto I_p^{0.4}$	$T_i/T_e \propto (P/\langle n_e\rangle)^{0.5}\, I_p^{-0.25}$

CONCLUSIONS AND FUTURE WORK

- **Flexible and easy-to-use tool for JET DTE2 scenario development is demonstrated by performing large sets of empirically scaled DT extrapolations for best performing and DTE2 ref shots from baseline, hybrid and AT experiments**
- **All highest DD neutron rate pulses have not been included in the DTE2 ref list, so the extrapolations will be run for more extensive data sets.**
- **P_{aux} = 40 MW cannot be likely achieved, so the extrapolation routines can be updated with the most realistic assumption of P_{NBI}**

DATA SETS for DT extrapolations

First set – until Feb 2020

Baseline (q_{95}≈3, $I_p \le 4$ MA), target auxiliary power P_{tot} = 40 MW, target I_p= 4 MA

Hybrid (q_{95}≈4-4.5, $I_p \le 3.1$ MA) target auxiliary power P_{tot} = 40 MW, target I_p=2.5 MA

AT (q_{95}≈4, $I_p \le 3$MA) target auxiliary power P_{tot} = 30 MW, target I_p= 2.8 MA

Second set – updated with DTE2 references

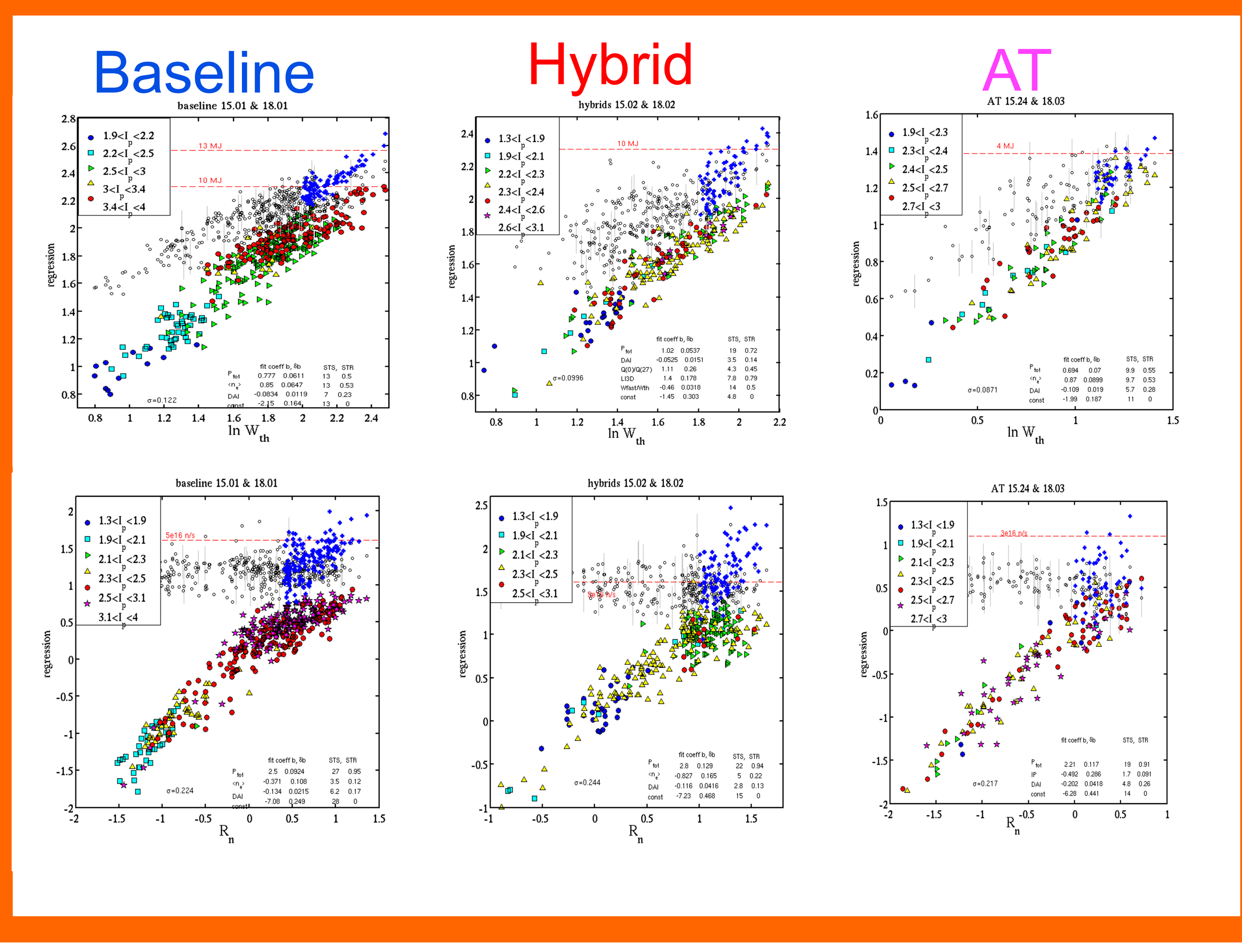
Plasma current not changed

Third set – DTE2 references + highest neutron rate plasmas from latest campaigns

Plasma current not changed, NBI power in more realistic level

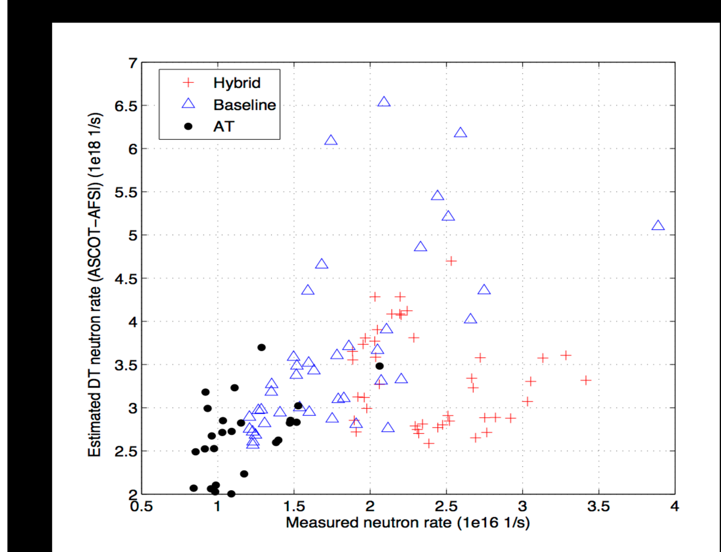
NEXT

Empirical baseline regression (coloured symbols) and extrapolation (o,**+**) to DTE2 target parameters using a scaling with power in MW and a proxy for edge fuelling (Balmer-α emission).
Top: for thermal stored energy. Bottom: for DD neutron rates.

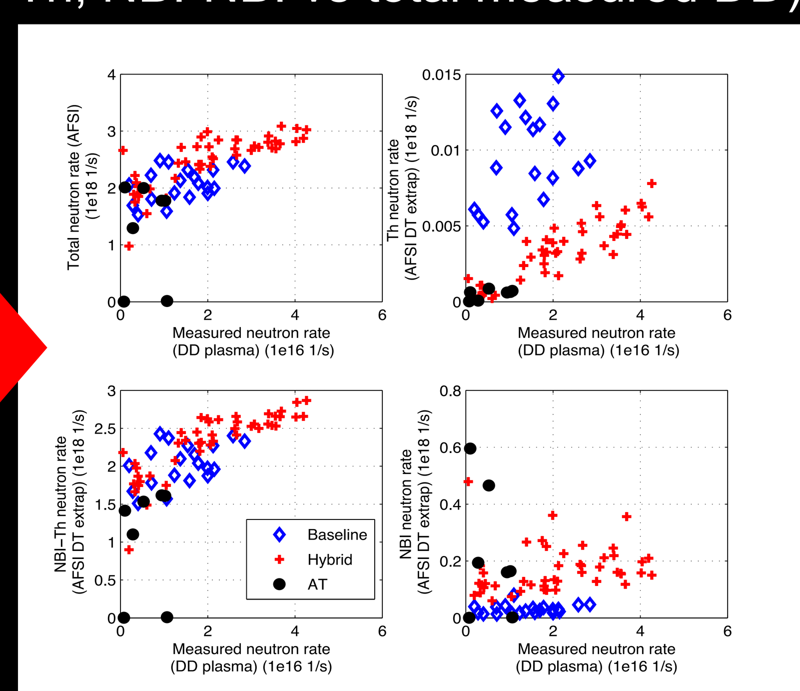


EXTRAPOLATED NEUTRON RATES

SET 1 (total DT neutron rates vs measured DD)



SET 2 (by components: total, Th, NBI-Th, NBI-NBI vs total measured DD)



References
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