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Physics model development and extensive validation of predictive integrated modelling within the new EU framework programme 2021-2027 (TSVV11 activity)

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EU context “a strong theory and modelling programme is essential because empirically based predictions are uncertain in unexplored environments like ITER and particularly DEMO, and this will be a stronger focus than foreseen earlier” [2018 Fusion Roadmap]

In EUROfusion Work Package Advanced Computing, 14 ‘Theory, Simulation, Verification and Validation’ activities, **TSVV11 to extend & validate state-of-the-art in predictive integrated tokamak simulation, combining both technical framework and physics-module advances.**

Guiding principles:

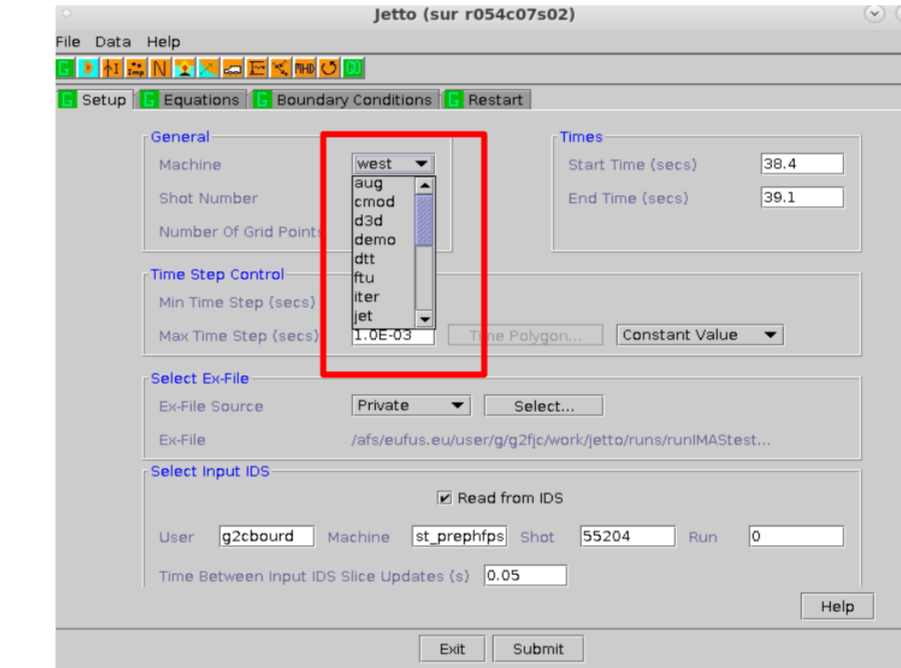
- **Align with ITER technical choices** workflow and database management
- **Improve and validate advanced physics modules** focusing on extensions needed for multi-physics full pulse
- **Demonstrate validation of full pulse predictive modelling** on multiple tokamaks
- Support extended validation against EU operating tokamaks: yearly training, documentation, user friendly interface and **automated validation tools**
- Apply to ITER scenarios. Provide **validated models to flight (or pulse design) simulator** developed in parallel to operate ITER and design DEMO

Why IMAS Data structure?

IMAS : **I**ntegrated **M**odelling and **A**nalysis **S**uite Data Dictionary
chosen by IO for ITER future experimental data and present modelling in/output machine and code generic. Capable of covering all experiment subsystems and plasma physics, **extensible**
promoted as the standard to access all experimental results within EUROfusion in a unique data format in the FAIR and open science requirements for FP9

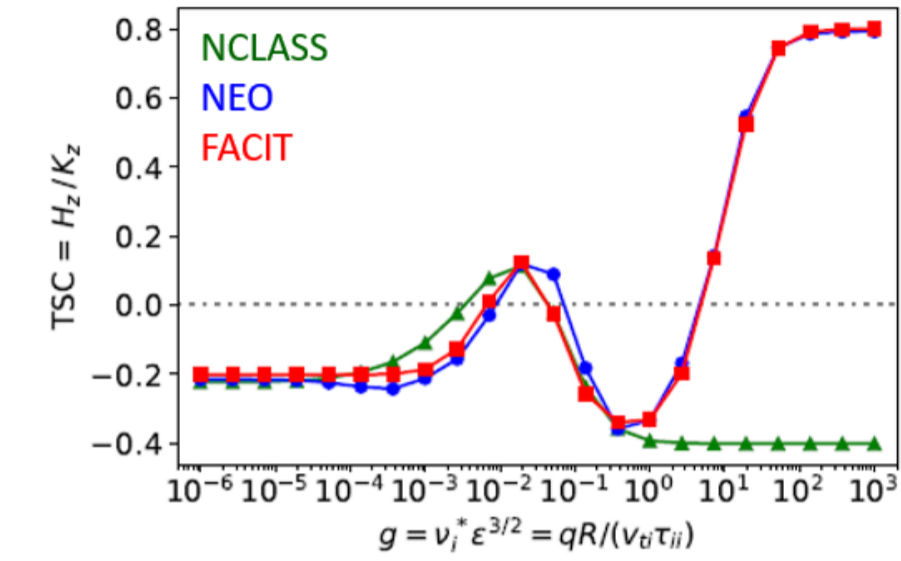
What is the High Fidelity Pulse Simulator?

Python workflow based on **IMASified JINTRAC (i.e. JETTO+EDGE2D)**
 workhorse for scenario preparation in ITER Physics Dept.
any IMASified physics module can be included
 Coupled to experimental IMAS data from AUG, JET, TCV, WEST, on the EUROfusion GateWay



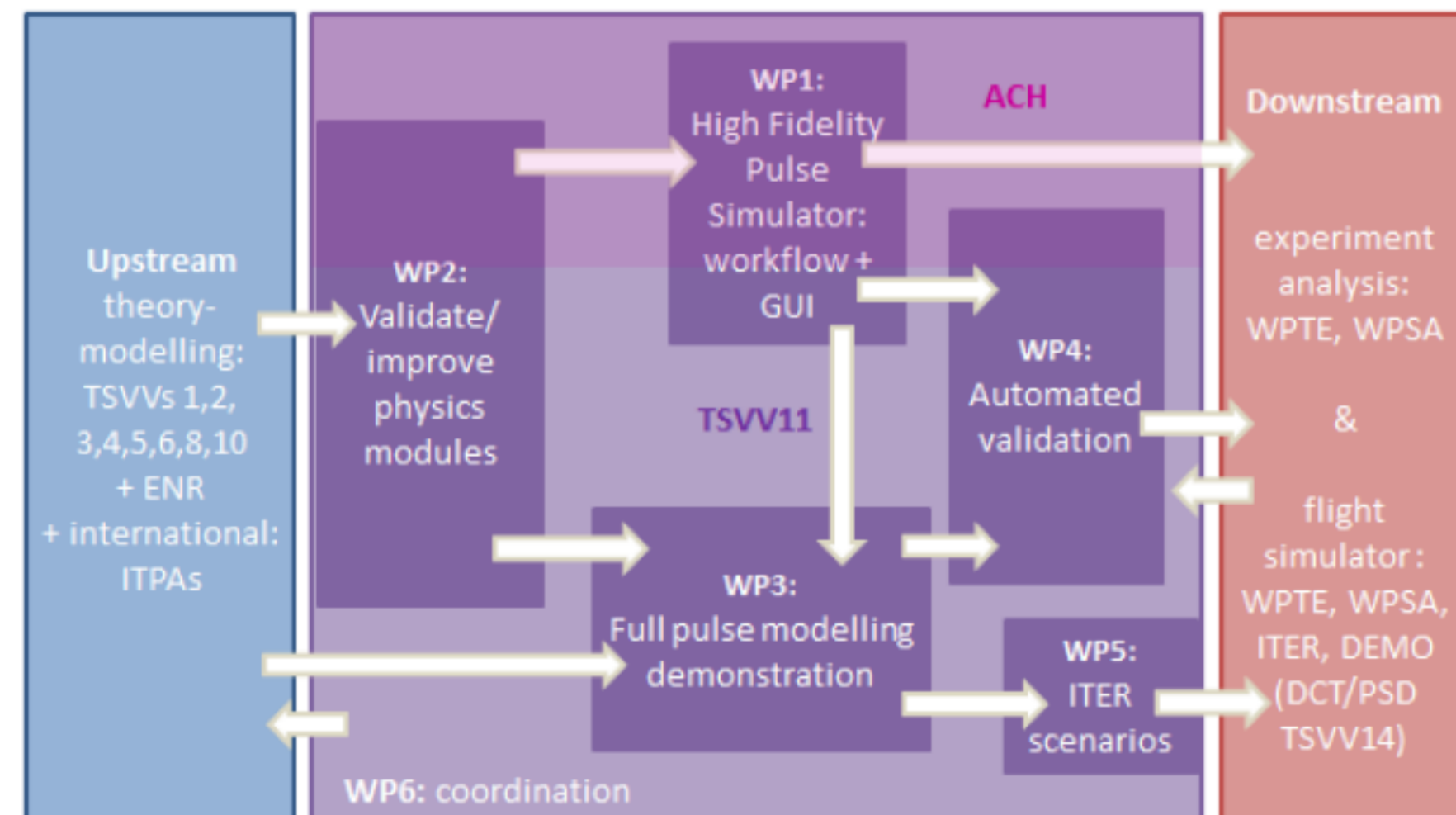
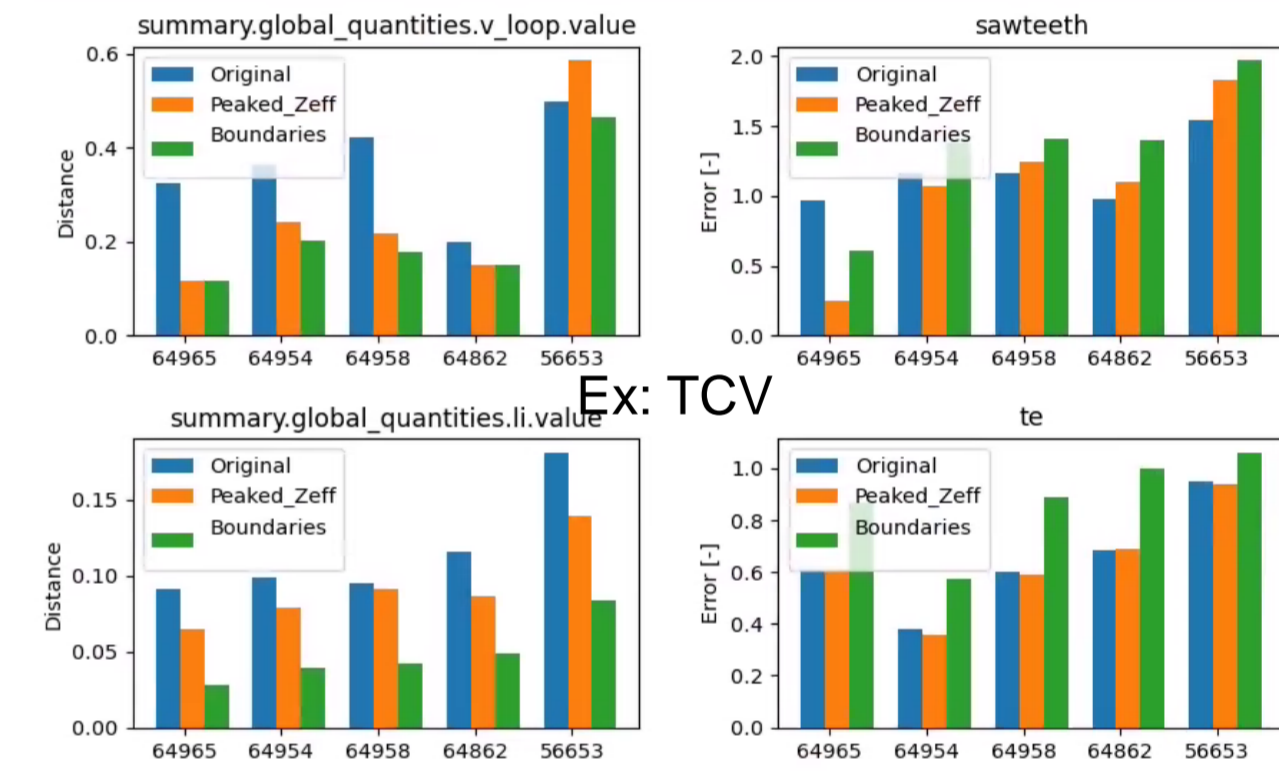
physics module improvement: faster and as accurate

Ex: neoclassical heavy+light impurity transport (FACIT) reproduces NEO while gaining 3 to 5 order of magnitude in terms of CPU. [D. Fajardo, C. Angioni, P. Maget, P. Manas, PPCF2022]



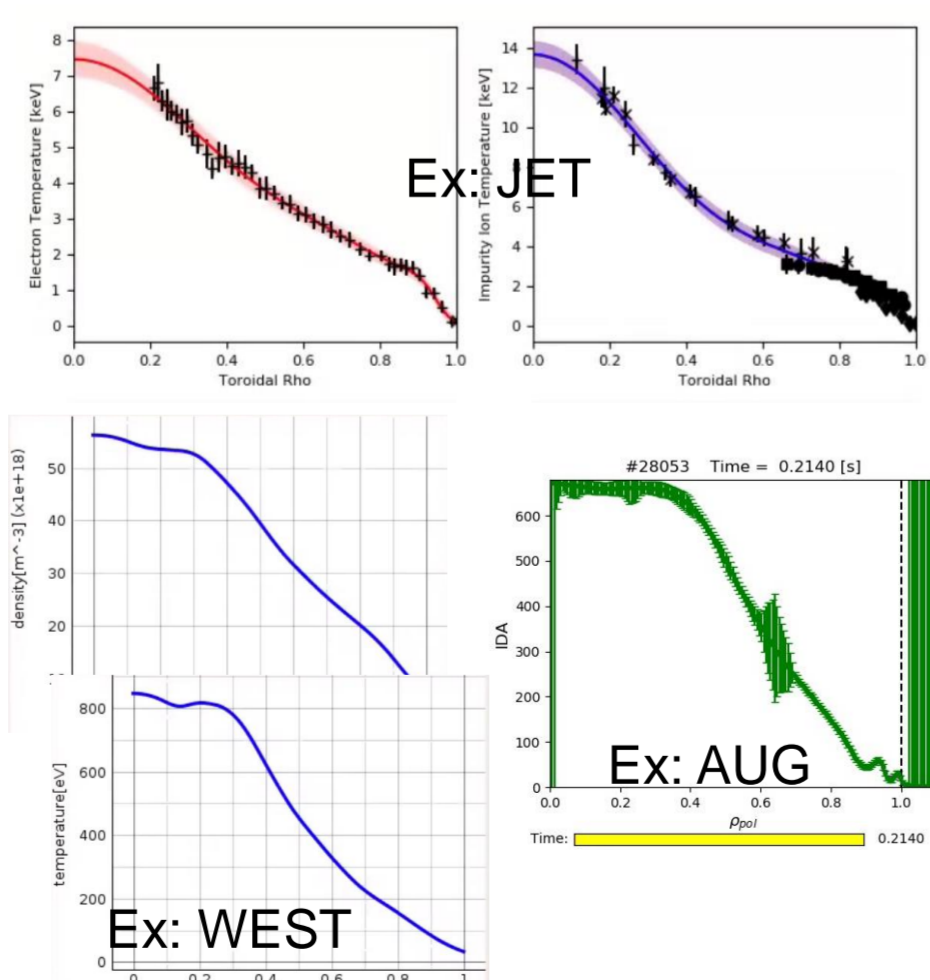
I_p ramp-up on multi-machines

Can we always reproduce the experimental V_{loop} , l_i , first sawtooth with “reasonable” free parameters?
 $T_e(1)$, $Z_{eff}(\rho)$...



Large-scale validation

generate **IMAS IDS** format inputs



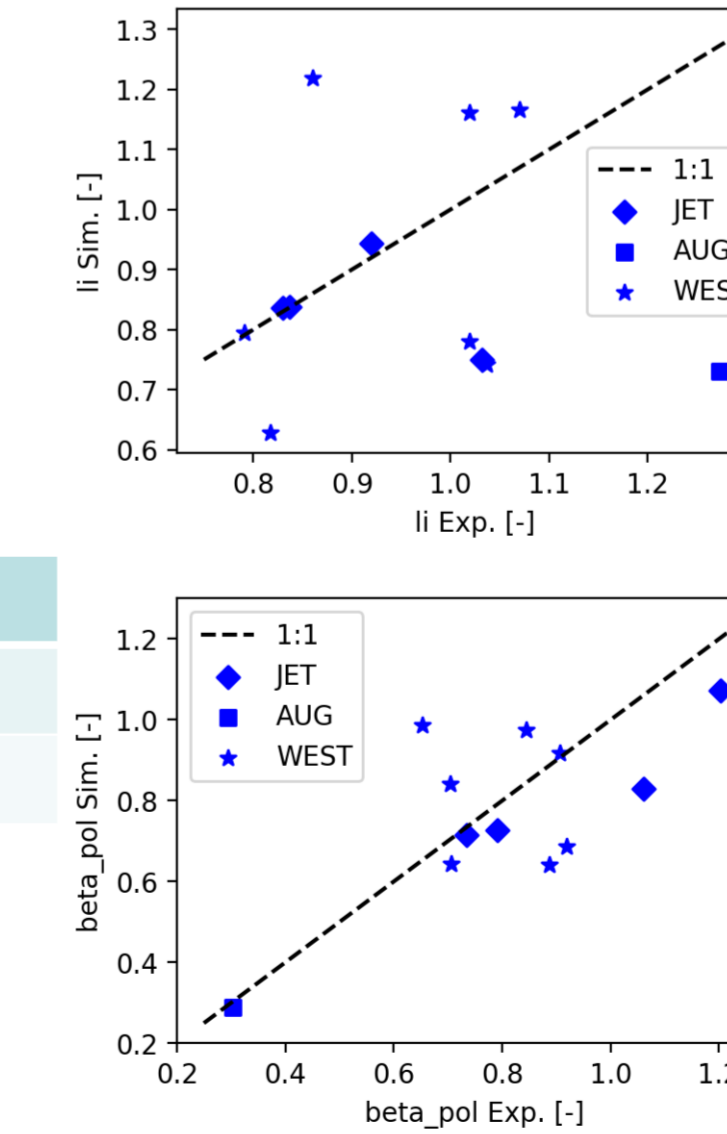
Validation metrics (steady-state analysis)

0D	$l_i, W_{MHD}, V_{loop}, R_n, P_{rad}, \bar{Z}_{eff}, \bar{n}_e, \langle n_e \rangle, \langle T_e \rangle,$
1D	n_e, T_e, T_i (at $\rho = 0, 0.3, 1.0$), $\overline{\Delta n_e}, \overline{\Delta T_e}, \overline{\Delta T_i}$ (av. RMS)
2D	Synthetic line-of-sight diagnostics

implemented via a **hierarchy** of use-cases

Tier 1	No evolution	Input sanity check
Tier 2	+ current and equilibrium	q profile relaxation
Tier 3	+ kinetic profiles	Transport validation

Uncertainty quantification on tiers 2 & 3



full pulse modelling capability demonstration

proof-of-principle of full pulse modelling from breakdown to termination using FENIX [Fable PPCF2022] to be pursued with the HFPS

