EUROfusion

Thrust 1: Pedestal & SOL Turbulence

N. Vianello and M. Wischmeier
On behalf of the Thrust # 1 Members

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Thrust 1 - TSVVs Overview

TSVV1: Physics of the L-H Transition and Pedestals	TSVV3: European boundary plasma modelling towards reactor relevant simulations	TSVV4: Plasma Particle/Heat Exhaust: Gyrokinetic/Kinetic Edge Codes
• GBS • GENE • GYSELA • HAGIS • ORB5 • QuaLiKiz • SOLEDGE3X • TSVV4 Code	• BIT1/BIT3 • EBC • FELTOR • GBS • GRILLIX • SOLEDGE3X	• GENE-X • GyselaX • PICLS • BIT1/BIT3 • VOICE

- There are natural synergies since same codes exploited in different TSVVs as well common physical problems:
  - Neutrals
  - Gyro-Kinetic, kinetic, gyrofluid and fluid limits and validity
  - Boundary conditions
  - …

TSVV1- Objectives and deliverables

- **The long-term mission (objectives)**
  - Capability to carry out self-consistent, robust & validated GK simulations of L-H transitions & to accurately predict pedestal profiles; extension to QH-/I-modes.
  - Validated & fast reduced transport models for multi-channel core-edge predictive modelling.
  - Applications of GK simulations & reduced models to small/no ELM regimes, studying their transferability to ITER and DEMO.
- **The quests (deliverables)**
  - Validated local & global (EM collisional) GK simulations of ion-/electron- & multi-scale turbulent transport in the H-, QH-, I-, and L-mode edge.
  - Extension of these simulations to self-consistently include relevant macroscopic (MHD-like) instabilities & development of a radial electric field.
  - Consistent application of a TSVV4 code – bridging core, pedestal & SOL regions including neutral physics – to the L-H transition problem.
  - An interpretative & predictive capability of L-H transitions accurately capturing the observed edge plasma dynamics in various machines.
  - Reduced transport models for the pedestal on the basis of GK simulations, involving electron-/ion- scale, & macroscopic (MHD-like) instabilities.

TSVV3 – objectives and deliverables

- Long term goal:
  - Provide EUROfusion partners with a set of **reference fluid tools to model the boundary plasma of magnetic fusion devices**, ultimately allowing applications to **reactor relevant devices** such as ITER and DEMO
  - Key features:
    - Improve **predictive capabilities and/or numerical cost** w/r existing tools
    - **Hierarchy of approaches** from gradient-diffusion to gyro-fluid turbulence direct numerical simulations
- 2-step strategy:
  - 2021-2023: use existing fluid turbulence codes to evaluate models and numerical approaches to integrate edge physics (PWI, neutrals, impurities…) in fluid turbulence codes and extend the validity of plasma models to reactor relevant conditions
  - 2024-2025: progressively integrate and optimize most promising/mature approaches in a reduced set of tools co-developed/maintained by partners and apply to experiments
- Key deliverables by end of 2023:
  - A gyro-fluid model valid across the range of reactor relevant collisionalities including boundary conditions, multi-species and neutrals physics
  - A reduced turbulence model capturing main features of turbulence transport at significantly reduced numerical cost, implemented in existing mean-field codes
  - A 3D mean-field edge plasma code based on a finite-element HDG approach (equilibrium independent grid)
  - Fluid edge turbulence codes integrating edge physics capabilities currently only found in mean-field codes such as SOLPS-ITER (e.g., self-consistent neutrals recycling, impurities, realistic wall geometry…) and optimized to run effectively on HPCs
  - Codes made available to the community (documentation, public repositories, training sessions…) including tools to facilitate validation against experiments (IMAS, synthetic diagnostics)

Setup of TSVV Task 4

Key deliverables:

1) Develop highly scalable **gyrokinetic / fully kinetic codes for the plasma edge**. Provide first versions to TSVV T1 asap.
2) Develop new methods for **dealing with open field lines**. Find improved boundary conditions via FK studies, potentially coupling of GK/FK approaches
3) Explore **limitations of gyrokinetics:** Compare GK/FK, e.g. for strong gradients. Extensions to GK needed?
4) Code coupling methods for handling interaction with **neutrals and impurities** Methods for **coupling GK and fully kinetic** approaches, plus **GK and fluid/gyrofluid** approaches

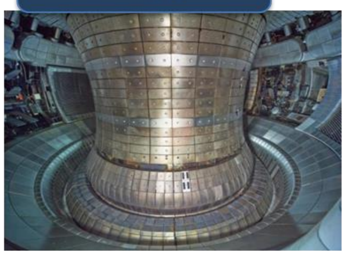
Our setup:

1) Advance three codes in parallel: **GENE-X (IPP), PICLS (SPC), GyselaX (CEA)**
2) Combined numerical and analytical efforts: **BIT1**, **VOICE** simulations, **semi-analytical model** (grazing incidence)
3) Hybrid/fully kinetic codes **ssV** and **GEMPIC/AMReX**; **Moment-based** edge GK model
4) **Inclusion of neutrals planned for all main codes**, gradually moving from simple source terms to more realistic models. Treat impurities either in-model, or by coupling to external simplified models. Coupling kinetic/fluid offered by moment-approach.

The WP Tokamak Exploitation

Main objective of WPTE is to provide the **physics basis** for ITER and DEMO operational scenarios in a **unique integrated approach** profiting of machines of different capabilities, sizes and parameters

ASDEX Upgrade



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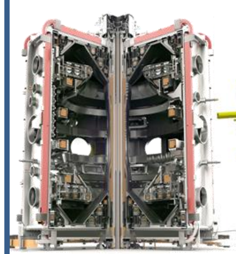
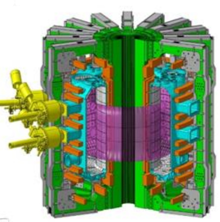


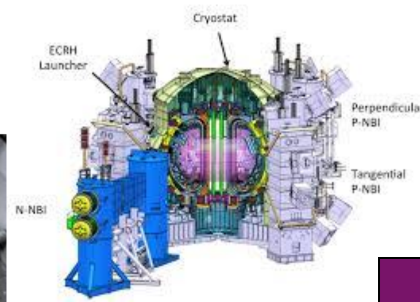


MAST-U

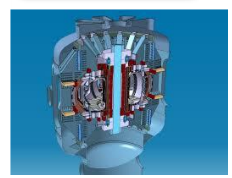
TCV

In 2021

JET from 2022

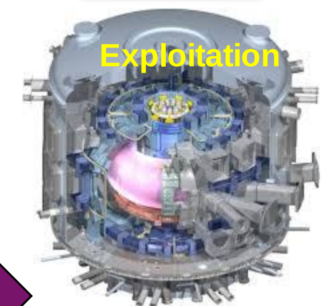


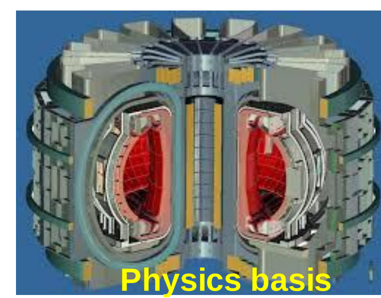
JT-60SA
From 2023



COMPASS-U
(from 2023)

ITER (2025)





DEMO

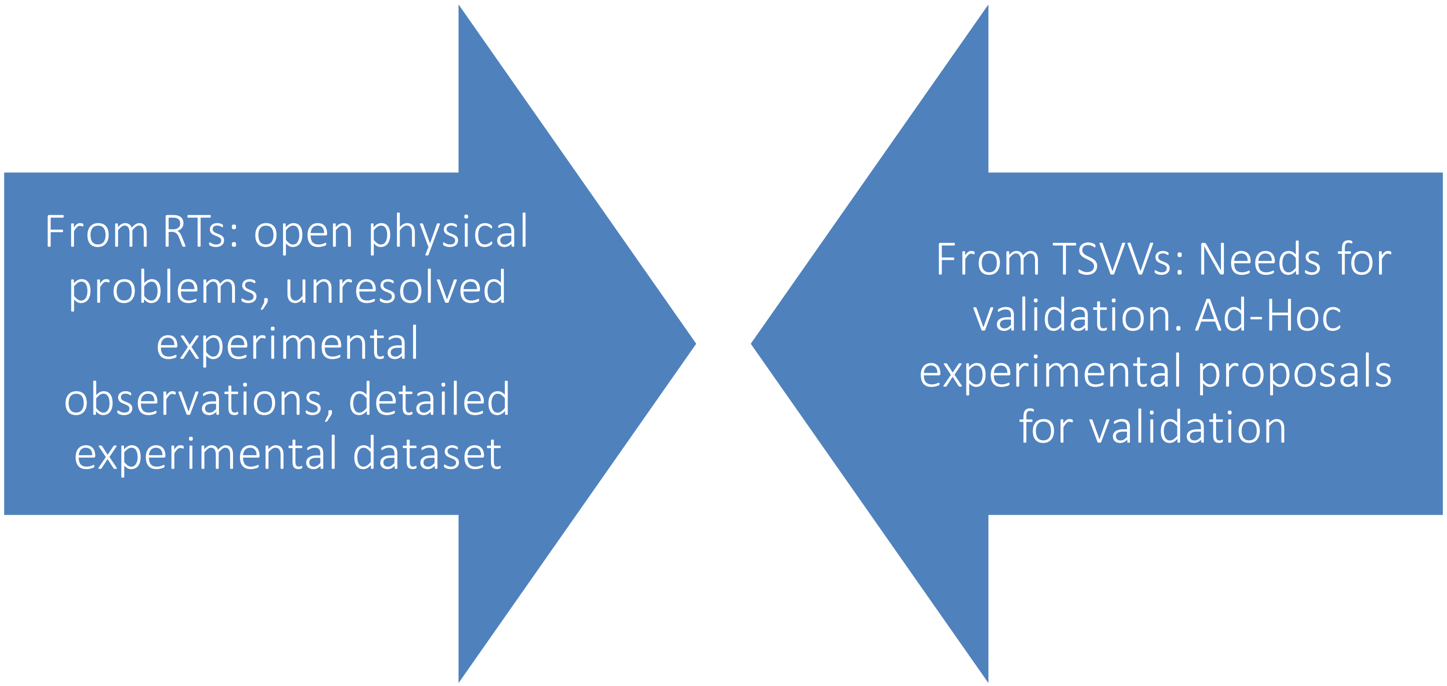
For TSVV WPTE can offer different size machines for step-ladder validation process

The WPTE Research Topics

	TFLs	Title	SC	SC	SC
RT1	EJ/BL	IBL scenarios towards low collisinality and detachment	O. Sauter,	T. Puetterich	L. Piron
RT2	NV/BL	H-mode entry and pedestal dependence with impurities and isotopes	M. Dunne,	L. Frassinetti	
RT3	EJ/BL	RF-assisted breakdown and current ramp-up optimization	D. Ricci,	T Wauters	
RT4	EJ/MW	Disruption avoidance and control for ITER and DEMO	F. Felici,	M. Maraschek	O. Kudlacek
RT5	EJ/AH	Run-away electron generation and mitigation	U. Sheikh,	C. Reux,	O. Ficker
RT6	NV/AH	ELM mitigation and suppression in ITER/DEMO relevant condition	W. Suttrop	D. Ryan	
RT7	NV/BL	Negative triangularity scenarios as an alternative for DEMO	T. Bolzonella		
RT8	NV/BL	QH-mode and I-mode assessment in view of DEMO	E. Viezzer	A.Merle	
RT9	MW/BL	Extension of EDA and QCE performance towards DEMO	M. Faitsch	L. Gil	
RT10	ET/AH	Fast-ion physics with dominant ICRF heating	Y. Kazakov	R.Bilato	
RT11	NV/BL	Impact of MHD activity on fast ion losses and transport	M. Vallar	M. Garcia-Munoz	
RT12	EJ/NV	Development of the steady state scenario	S. Coda,	C. Piron	
RT13	MW/AH	X-point radiation and control	M. Bernert,	S. Wiesen	
RT14	MW/ET	Physics of plasma detachment / impurity mix/ heat load patterns	O. Février,	S. Henderson	A. Jarvinen
RT15	NV/ET	Extrapolation of SOL transport to ITER and DEMO	D. Brida,	G. Harrer	
RT16	ET/AH	PFC damage evolution under tokamak conditions	Y. Corre,	K. Krieger	
RT17	ET/AH	Material migration and fuel retention mechanisms in tokamaks	T. Loarer,	J. Likonen	
RT18	MW/EJ	Alternative divertor configurations	A. Thornton	C. Theiler	

The validation process: where interactions occur

Theory, Simulation, **Validation** and Verification



- Foster integration with experimental activities and open issues
- Envisage validation step-ladder exercise
- Reduced model and usability after validation/verification

Thrust 1: Discussion outcome

- Step-ladder approach to validation procedure. Use the unique capability of WPTE in exploring wide operational space
- Fostering the interaction between WP and TSVVs in order to identify the needs (physical parameters, observables …) for validation and eventually theory oriented experimental proposal
- Build "Thrust wide" timeline to underline the interactions between the TSVVs and possible availability for the EUROfusion community (i.e. DEMO team)
- Discussion about ACH needs and priority to provide a possible unified needs (where synergies can be found)