Integrated Modelling and High Fidelity Pulse Simulator overview introducing the 1st training on the HFPS open to all EUROfusion

C. Bourdelle for the TSVV11 team

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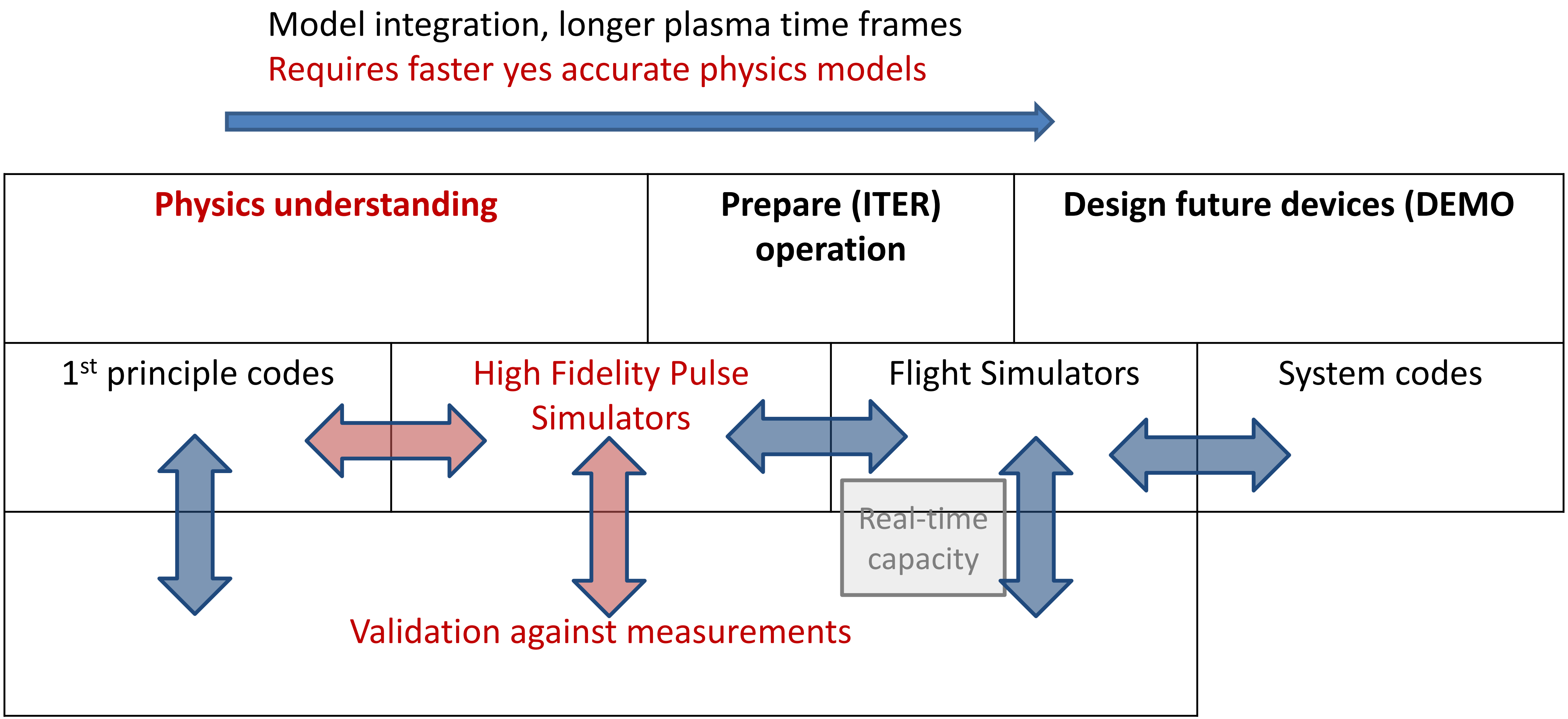
Context of this talk: 1st training on the High Fidelity Pulse Simulator

Wed. Jan. 25th **10.30-12.30 CET**	**General introduction and overview (open to all, no registration needed)**: · Recent achievements of integrated modelling · What is the High Fidelity Pulse Simulator?
Wed. Jan. 25th **14.30-17.30 CET**	**2.30 CET: all, Intro/demo interpretative case: F. Casson** **Breakout rooms as needed (ref. supervisor see table below)** **5 pm CET: all, update on progresses/issues**
Thur. Jan. 26th **9.30-12.30 CET**	**9.30 CET: all, intro/demo predictive case with QLKNN** **Breakout rooms as needed (ref. supervisor see table below)** **12.00 CET: all, update on progresses/issues**

Registered participants only

This training will be repeated yearly by the TSVV11 members.

Integrated modelling landscape:
focus of Today’s talk on the physics understanding aspects



The ultimate goal of integrated modelling is to prepare more reliably tokamak operation.
The focus of Today’s talk is on the physics understanding side of the coin.

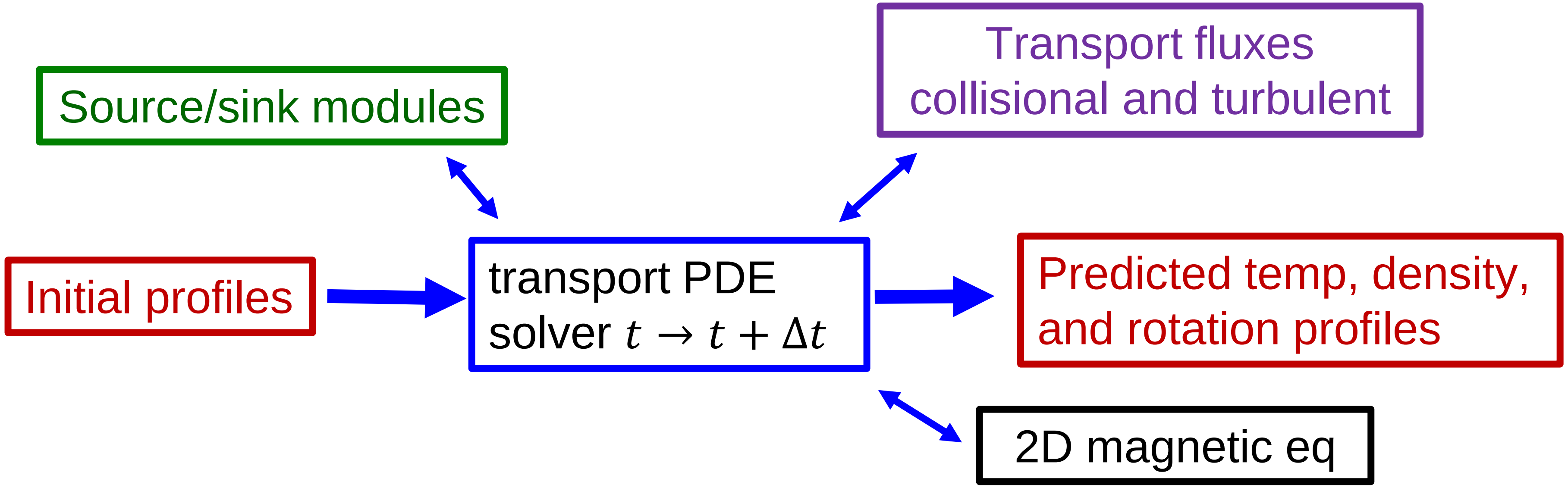
outline

- Overviewing some (not exhaustive!) recent progresses on physics based High Fidelity Integrated Modelling
  - Integrating complex non-linear retroaction loops up to a radial boundary condition
  - Moving the boundary condition outward, from the core to the SOL
- ‘The’ High Fidelity Pulse Simulator and its tools within the TSVV11 EUROfusion programme
- Some (not exhaustive!) remaining challenges

High Fidelity Integrated Modelling of the plasma core: framework

Integrate our physics understanding: radiation, heating, transport, MHD stability, equilibrium, neutrals in a time evolving framework

Multi-scale (spatial&temporal) and multi-physics problem



Particle flux — Particle sources/sinks

Particle density: $$\frac{\partial n_s}{\partial t} + \frac{1}{r}\frac{\partial}{\partial r}(r\Gamma_s) = S_s$$

Energy: $$\frac{3}{2}\frac{\partial P_s}{\partial t} + \frac{1}{r}\frac{\partial}{\partial r}(r q_s) = Q_s$$

Heat flux — heat sources/sinks

$$t_{integrated\ sim.} = t_{turb.fluxes} \times \frac{t_{discharge}}{\Delta t_{transp.\ solver}} \times N_{iterations}$$

$t_{discharge}$: 1-1000 s; $\Delta t_{transp.\ solver}$: 10^{-3} s; $N_{iterations}$: 1-10

$$t_{integrated\ sim.} \approx 10^4 \times t_{turb.fluxes} < \sim 24\text{h}$$

$t_{turb.fluxes}$: ~<10s

Multiple such modelling frameworks in use, JINTRAC, ASTRA, ETS, TOPICS, PTRANSP among others

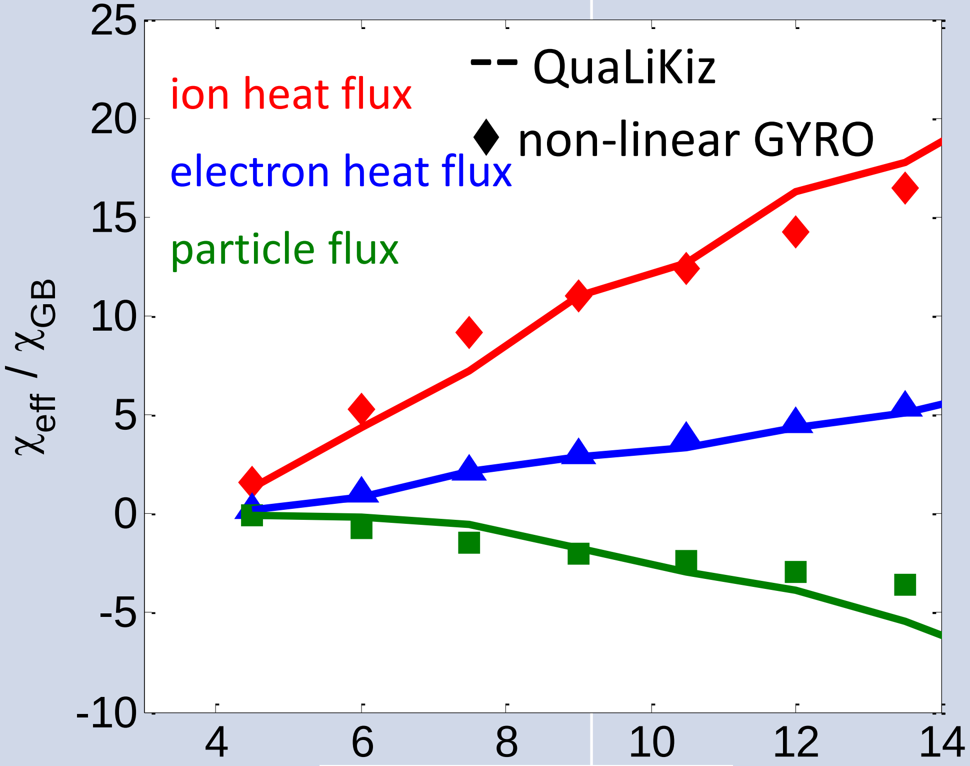
Requires faster yet accurate physics models
ex. Turbulent flux prediction speed up: one trillion times faster

www.qualikiz.com

10^6 times faster

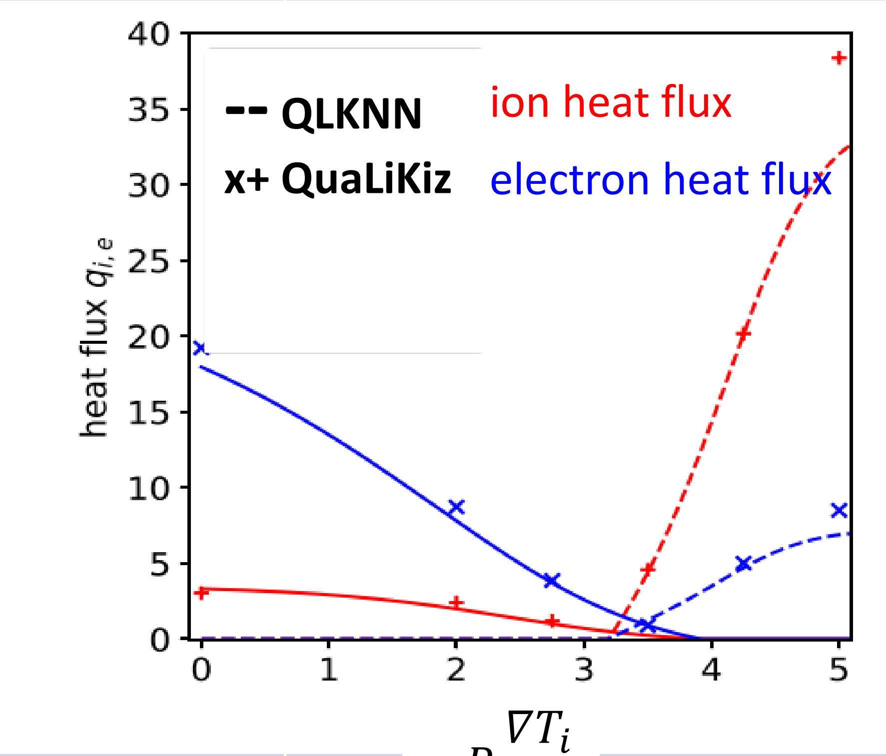
10^6 times faster

Anchoring non-linear gyrokinetic simulations	Quasilinear approximation Eigenfunction in fluid limit	Neural Network regression



[Casati NF09]

$$-R\frac{\nabla T_e}{T_e} = -R\frac{\nabla T_i}{T_i}$$



[van de Plassche PoP20]

$$-R\frac{\nabla T_i}{T_i}$$

Temporal and spatial non-linear interactions between multiple transport channels, current/equilibrium, sources and sinks

Interpretative modelling:

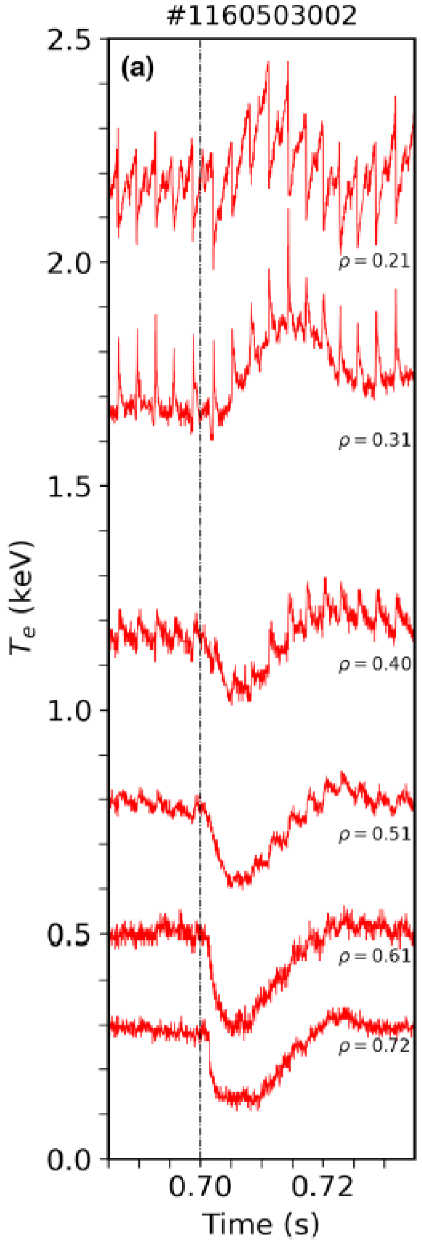
- Level 0: **j** (interpretative, without turbulence predictions)
  - – Important due to sensitivity of q-profile and mag. shear on stability

Flux driven multiple confinement times predictive modelling:

- Level 1: **j, Ti, Te**
  - – Forgiving: transport driven by temp. gradients and is “stiff”
  - – Always predict T_i and T_e, otherwise turbulence amplitude wrong
- Level 2: **j, Ti, Te, ne**
  - – Non-trivial: particle transport not stiff (off-diagonal transport)
  - – Depends sensitively on turb. spectra, collisions, kinetic resonances
- Level 3: **j, Ti, Te, ne, Vtor**
  - – Challenging: momentum transport from symmetry breaking
  - – Feedback potential for barrier formation (ExB shear)
- Level 4 : **j, Ti, Te, multi-ion (isotopes, impurities), Vtor**
  - – Exciting territory, complex non-linear interplays
  - – Heavy Impurity transport needs all L3 channels (sets neoclassical transport and poloidal asymmetries), and provides radiation feedback

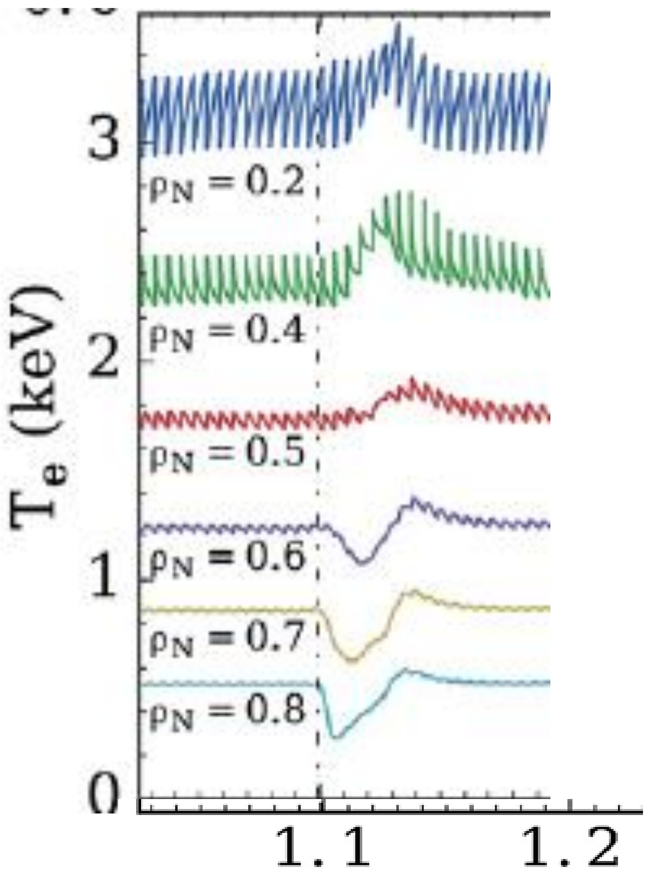
Level 1: Transport dynamics of ‘cold pulses’ in tokamak plasmas captured by the standard paradigm of local transport

Example of
‘cold pulse’
Alcator C Mod



Prediction: from core ρ=0.9.
PTRANSP, TGLF-SAT1
Heat and current in ohmic plasmas
Density increased as in experiments

Explained by a reduction of the electron conducted power, a consequence of the stabilization of TEM modes when they are the primary electron heat exhaust mechanism.



[Rodriguez-Fernandez, Angioni, White, Reviews of Modern Plasma Physics 2022]

Level 1: Healing plasma current ramp-up by Nitrogen seeding in the full Tungsten environment of WEST

W radiation peaks at T_e~1.5 keV

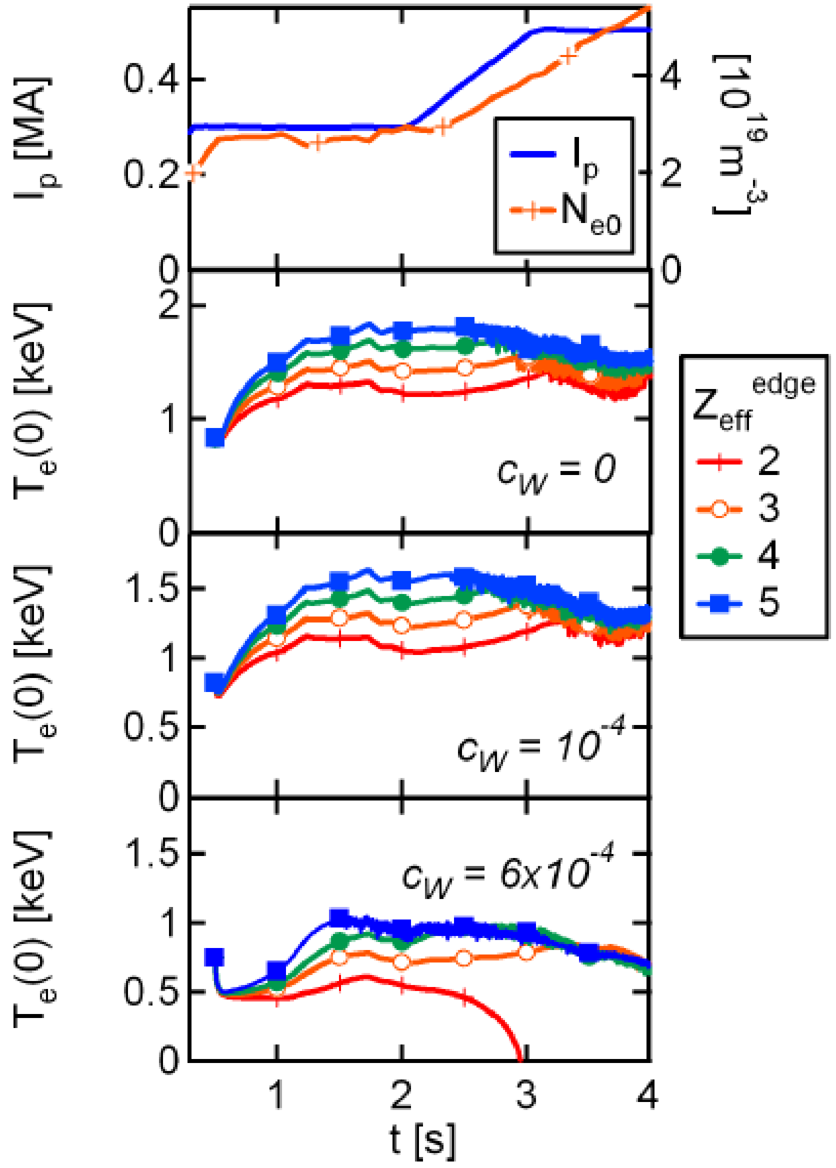
During Ip ramp up, need to guarantee core heating > core cooling to avoid hollow Te leading to broad/hollow j prone to MHD.
In absence of RF, early core ohmic heating mandatory

RAPTOR-QLKNN (heat only)-ADAS for rad. Ohmic heating, current diffusion
0.5 to 4 s
Predictive from core up to ρ=0.8

Early core ohmic heating / peaked current profile due to:

- edge radiation cooling
- improved confinement due to ITG stabilization by larger Zeff

WEST



[Maget PPCF2022]

Level 4: Predictive JET current ramp-up modelling in D and T

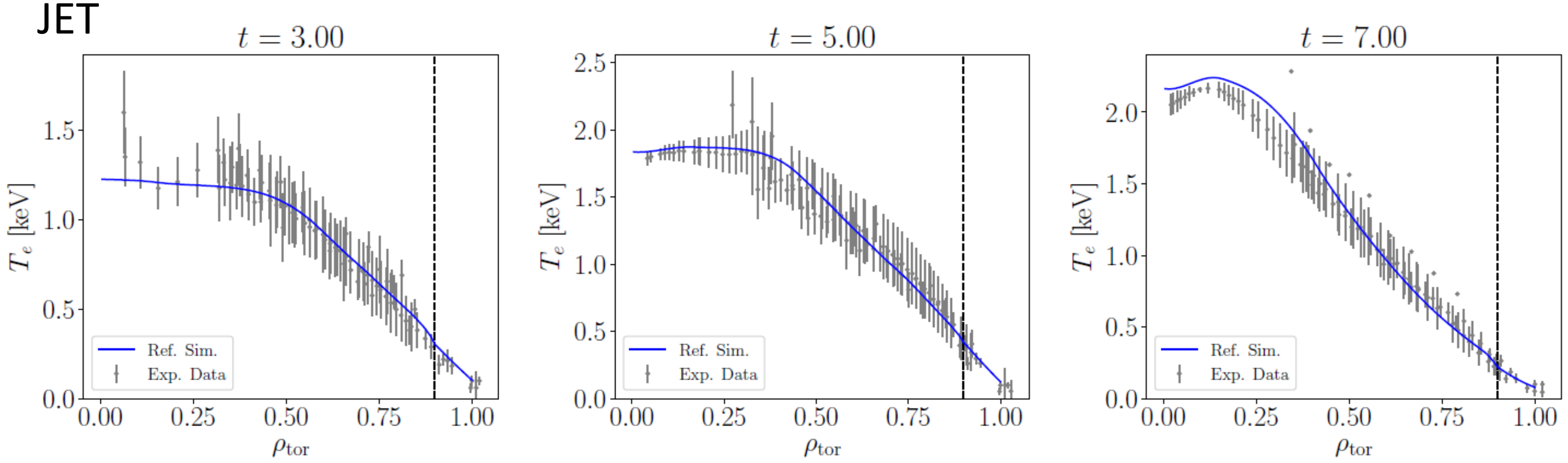
JETTO settings, 7.25 s of plasma evolution, using QLKNN

[A. Ho accepted NF 2023]

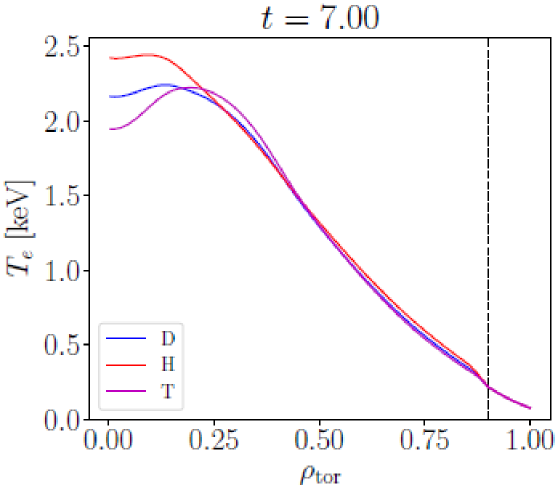
	JET#97776
Description	Ohmic ramp-up
Predicted quantities	j, T_e, T_i, n_e, n_{Be}, n_{Ni}, n_W
# of radial grid points	101
Plasma time[1]	1.77 – 9.0 s
Maximum plasma time step	0.001 s
Simulation boundary (ρ_{tor})	0.9
QuaLiKiz region (ρ_{tor})	0.03 – 0.9
Equilibrium model	ESCO – fixed boundary
Neutral particle model	None
Impurity transport model	SANCO
Radiation model	ADAS cooling factors
ADAS year	Be: 89, Ni: 96, W: 50
Neoclassical transport model	NCLASS
Turbulent transport model	QLKNN-jetexp-15D
NN particle transport option[2]	1 – see Equation (1)
QuaLiKiz E×B option	0 – no E×B suppression
QuaLiKiz collisionality multiplier[3]	0.25

The chosen scenario exhibits a hollow Te profile captured by modelling
Need to model predictively the light impurity (Be) impacting Z_{eff} / resistivity and the heavy impurities (Ni, W) impacting P_{rad}.

JET



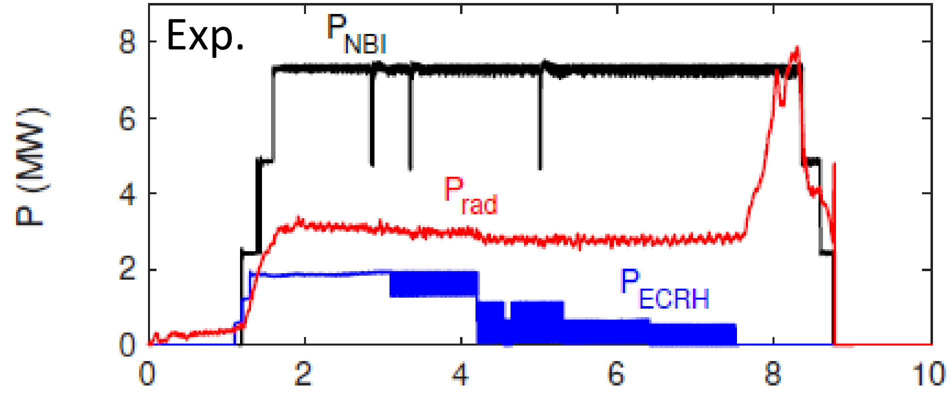
T_e more hollow in T, more challenging MHD stable I_p ramps [Challis NF2020]

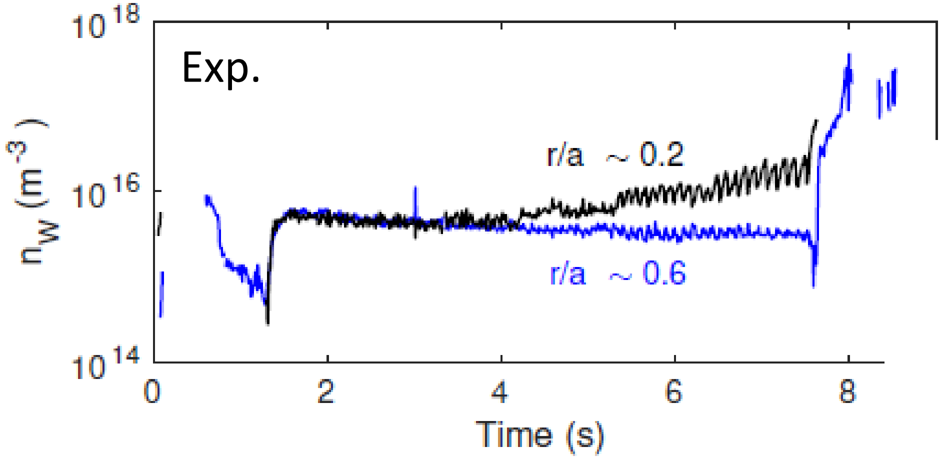


Level 4: W-accumulation avoidance at AUG tokamak thanks to ECRH density flattening, reducing W inward neoclassical flux

[Manas IAEA 2020]

AUG #32408

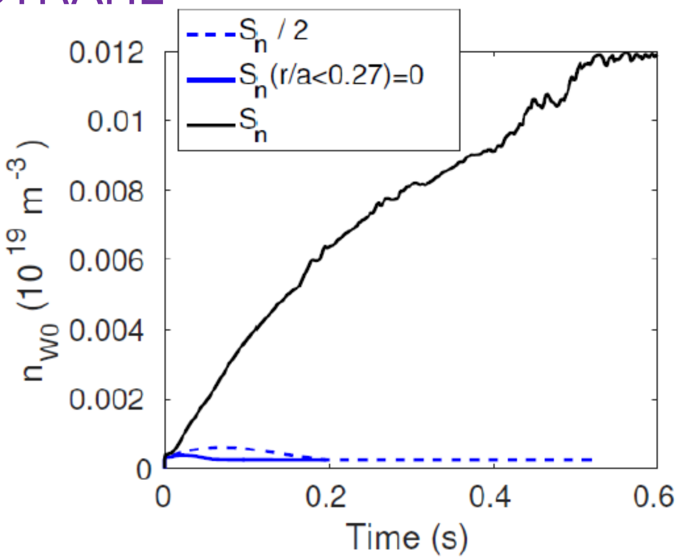




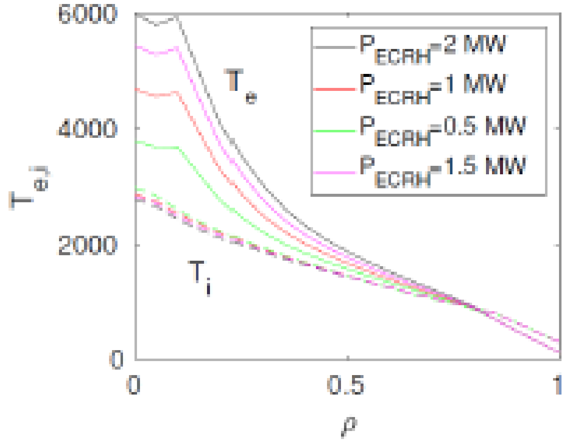
ASTRA-QuaLiKiz-NEO-TORBEAM-STRAHL
Predictive from pedestal top inward

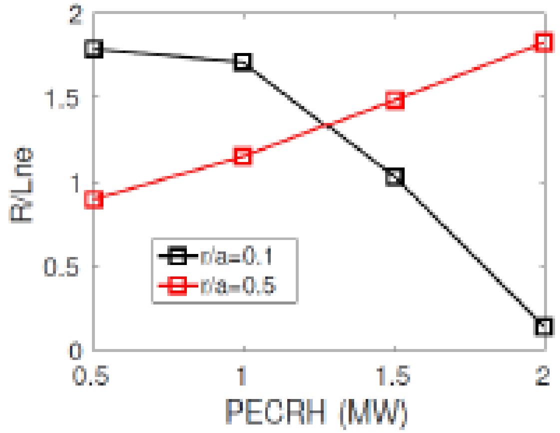
$$\Gamma_W = ZD\left[\frac{1}{Z}\frac{\nabla n_W}{n_W} - \frac{\boldsymbol{\nabla n_D}}{\boldsymbol{n_D}} + \frac{1}{2}\frac{\nabla T_D}{T_D}\right]$$

NBI particle source enhances W inward neoclassical convection



large Te/Ti can compensate this unfavorable scenario by increasing turbulent particle diffusion, reducing W inward neoclassical flux

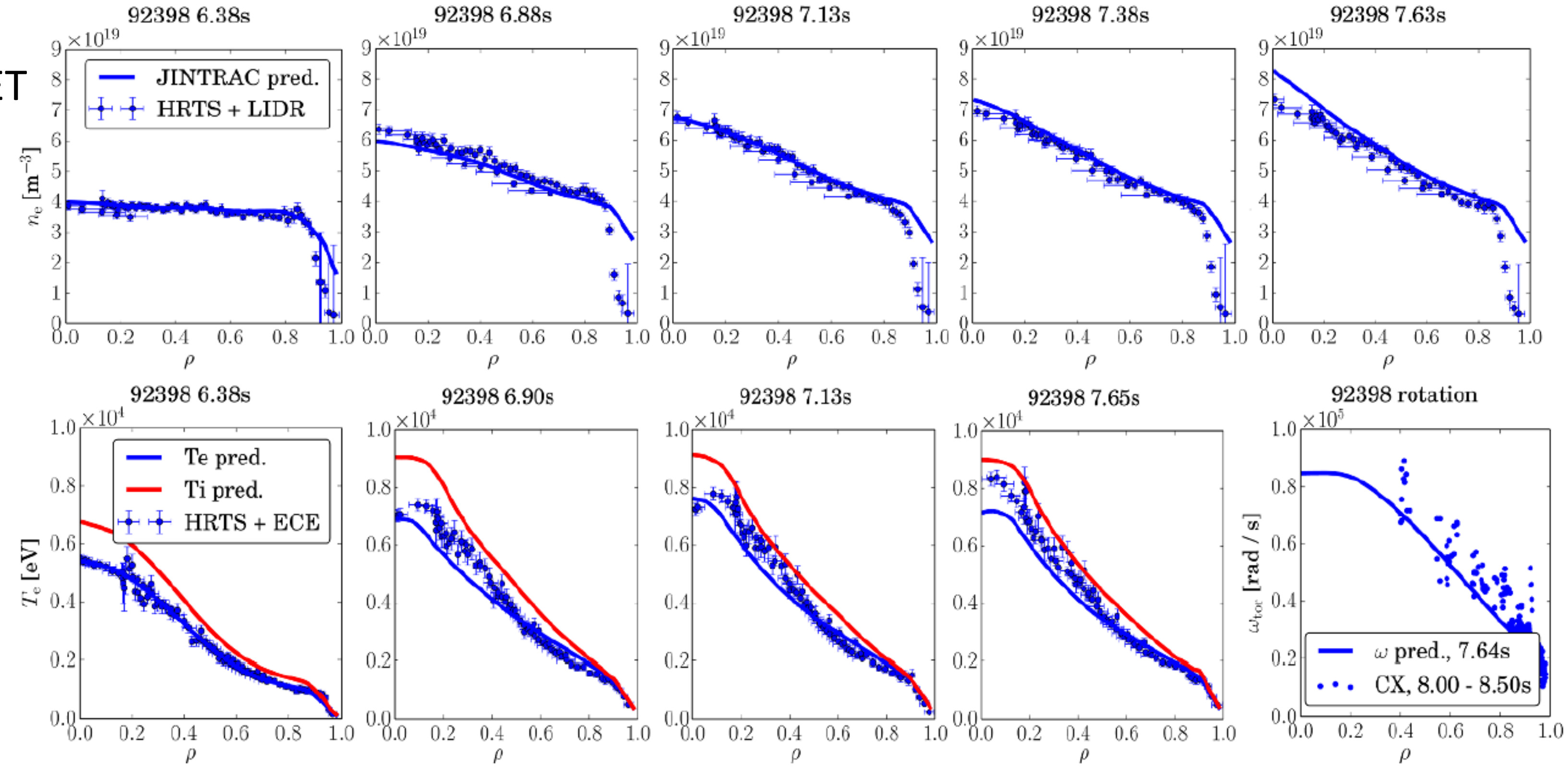




Level 4: W-accumulation at JET tokamak due to density peaking, and avoidance with ICRH

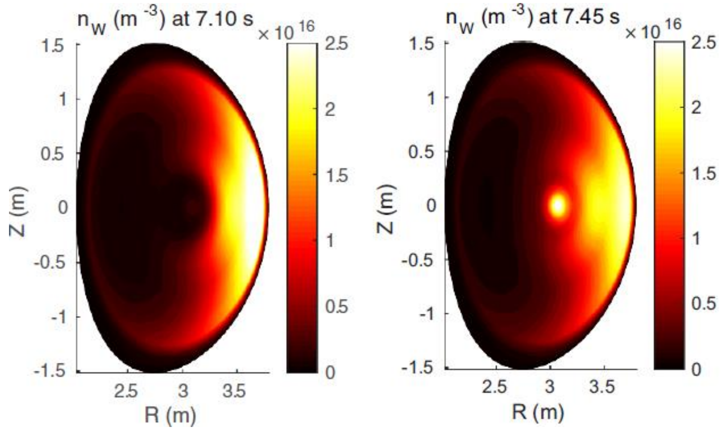
Prediction: from pedestal top inward. Over 1.5 s of plasma evolution.

JET



W-radiation emission peaks at later time due to inward neoclassical W transport driven by density peaking.

Mitigated by on-axis ICRH heating (not shown for brevity)



JETTO-SANCO-QuaLiKiz-NEO-PENCIL-FRANTIC-PION successfully described core W-accumulation due to NBI particle source and momentum Breton NF 2018 Casson NF 2020
Mitigation strategy with ICRH heating due to density peaking reduction [Casson NF 2020].

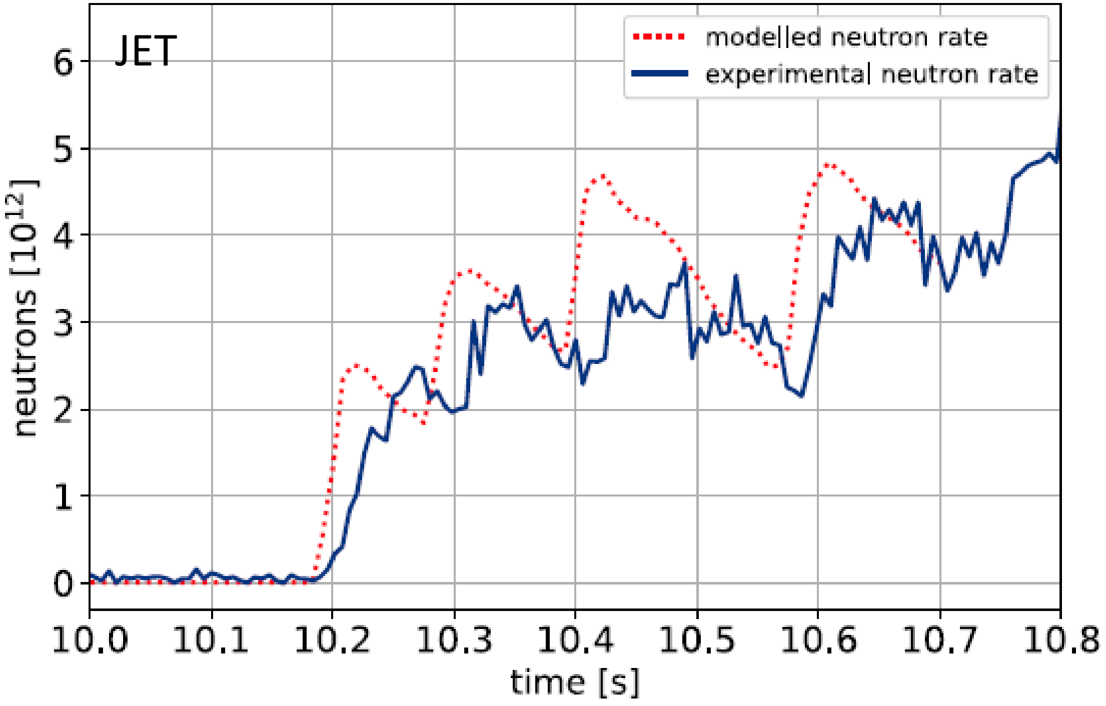
State-of-the-art core plasma integrated modelling evolving j, T_e, T_i, n_D, n_{Be}, n_{Ni}, n_W, ω, rad., NBI, ICRH

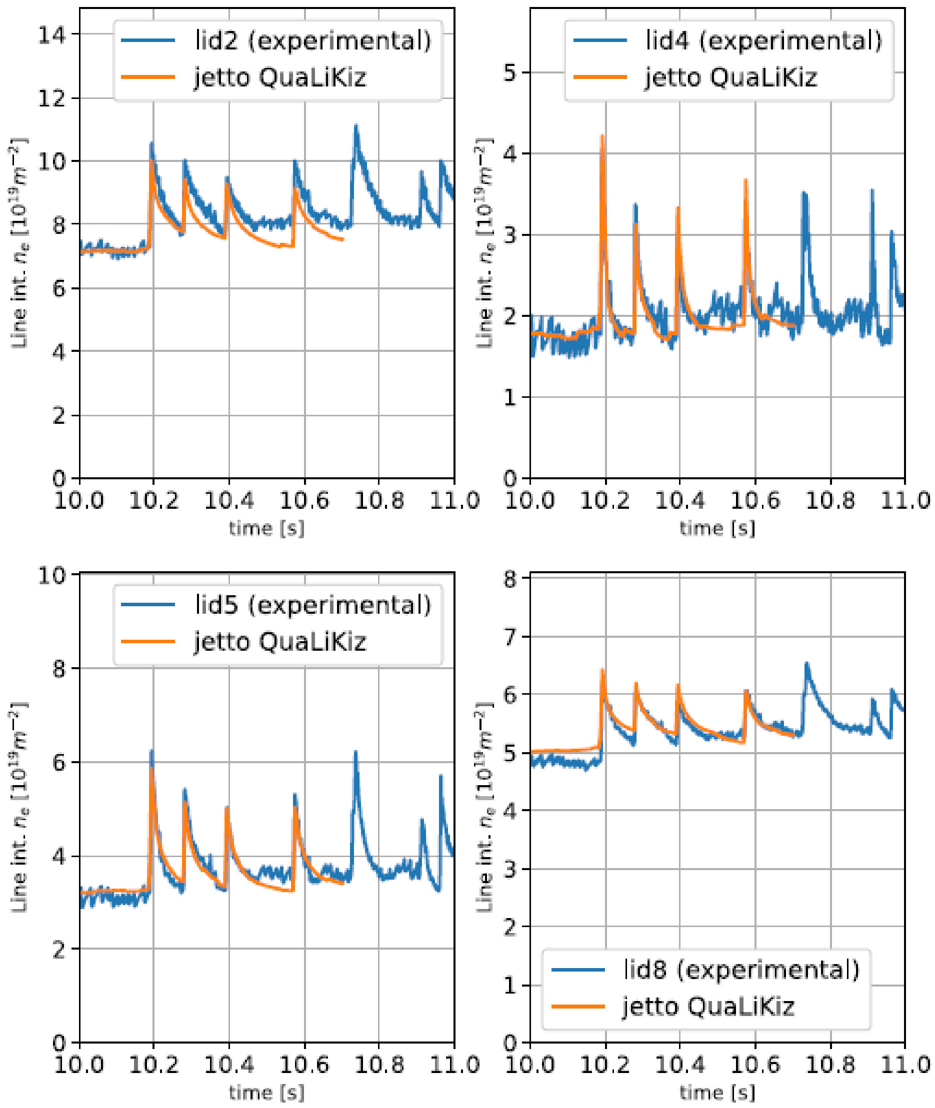
Multiple-isotope pellet cycles captured by turbulent transport modelling in the JET tokamak

Prediction: from core to pedestal top.
Over 0.7 s of plasma evolution, 4 pellets.

JETTO-SANCO-QuaLiKiz-NCLASS-PENCIL-PION-FRANTIC-HPI2

The fast timescale of isotope mixing D pellet in H plasma captured by the modelling

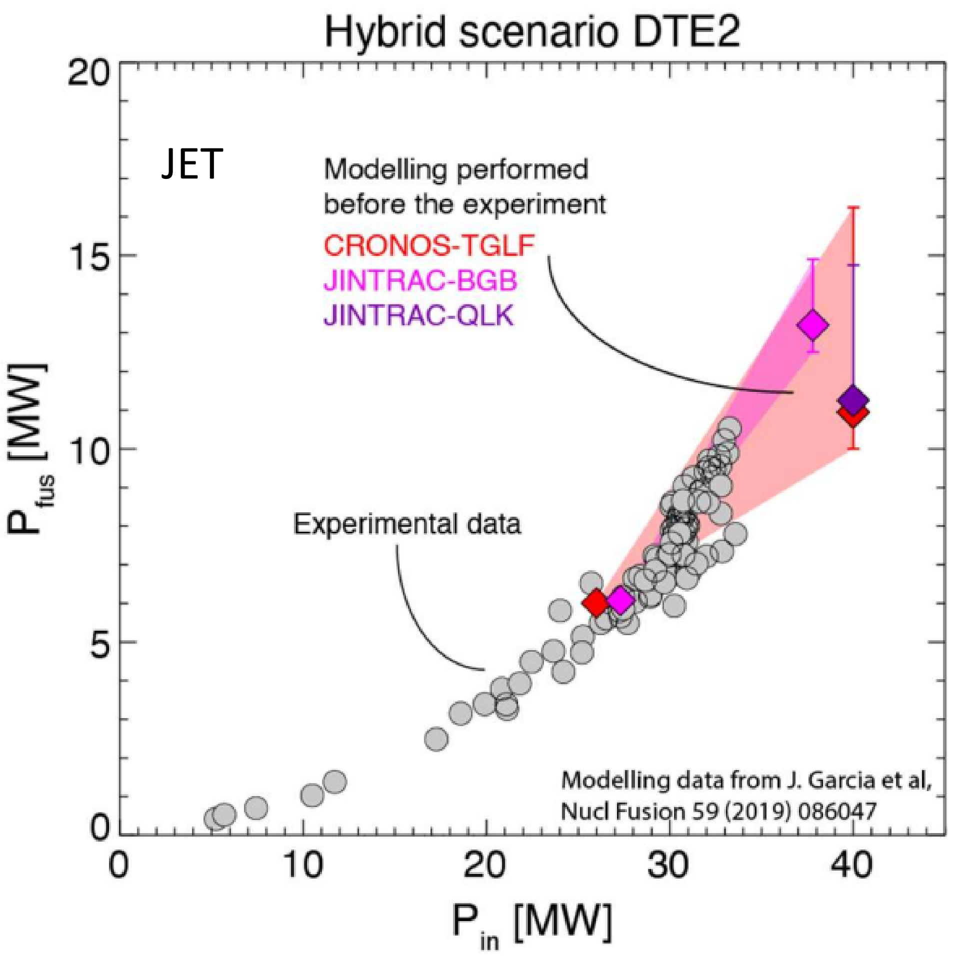




[Marin NF 2021]

Predict first: Integrated modelling used for JET DT preparation

Predictions: 1/ from core to pedestal top. Level 4 with JINTRAC-QuaLiKiz
2/ From core to separatrix: Level 2 with CRONOS-TGLF-Ped:Cordey's scaling



- Strong predict first modelling performed since 2010
- D-T fusion power achieved is in broader agreement with predictions
- Simplified models can be improved with new DT data.
- Essential for ITER and future reactors predictions.

[Garcia APS-DPP 2022]

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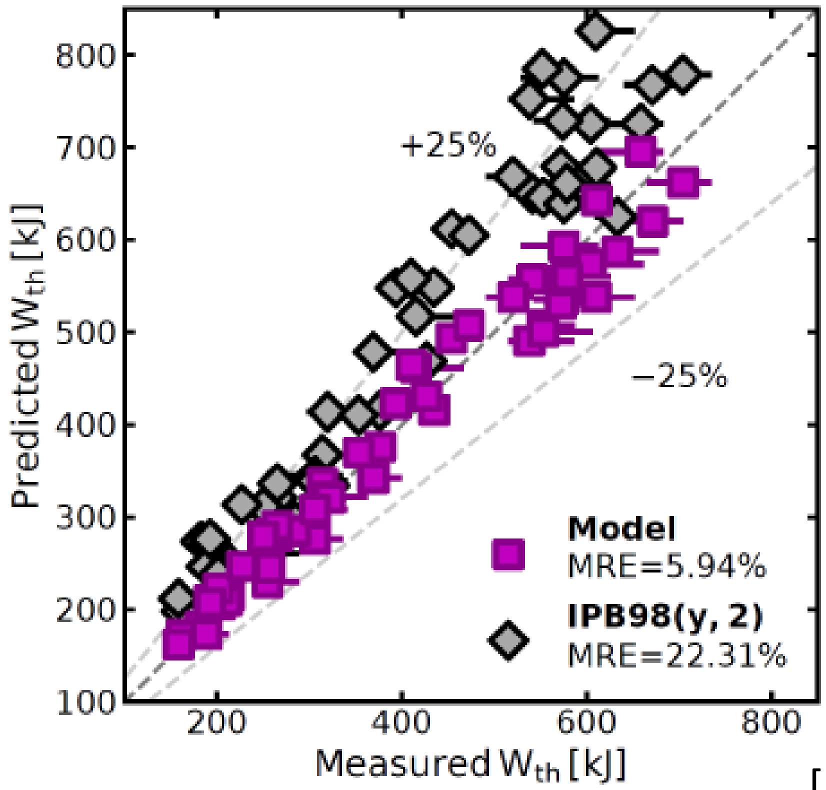
Extending the boundary condition to the SOL: 50 AUG H modes better than empirical scaling laws, quantitavely and qualitatively

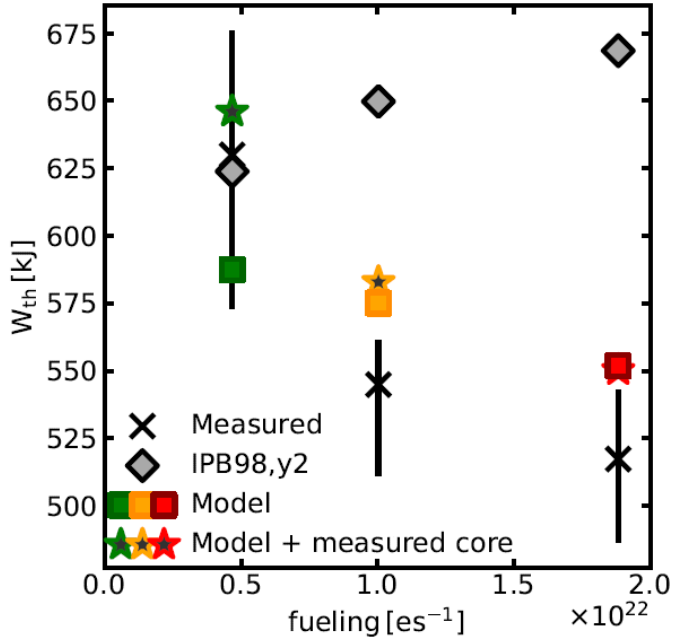
ASTRA-TGLFsat2-NCLASS-IMEP
prediction from core to SOL, mixing physics based and exp. scalings
Core: quasilinear fluid code TGLF sat2
Pedestal: ideal MHD stability + ad-hoc $R < \nabla T_e > / T_{e,top} = -82.5$
Separatrix: T_{sep} from 2 point model using λq scaling [Eich], n_{sep} machine specific scaling, on AUG $\propto \Gamma_D^{0.2}$

better than empirical scaling laws, quantitatively ….



[Luda NF 2021]

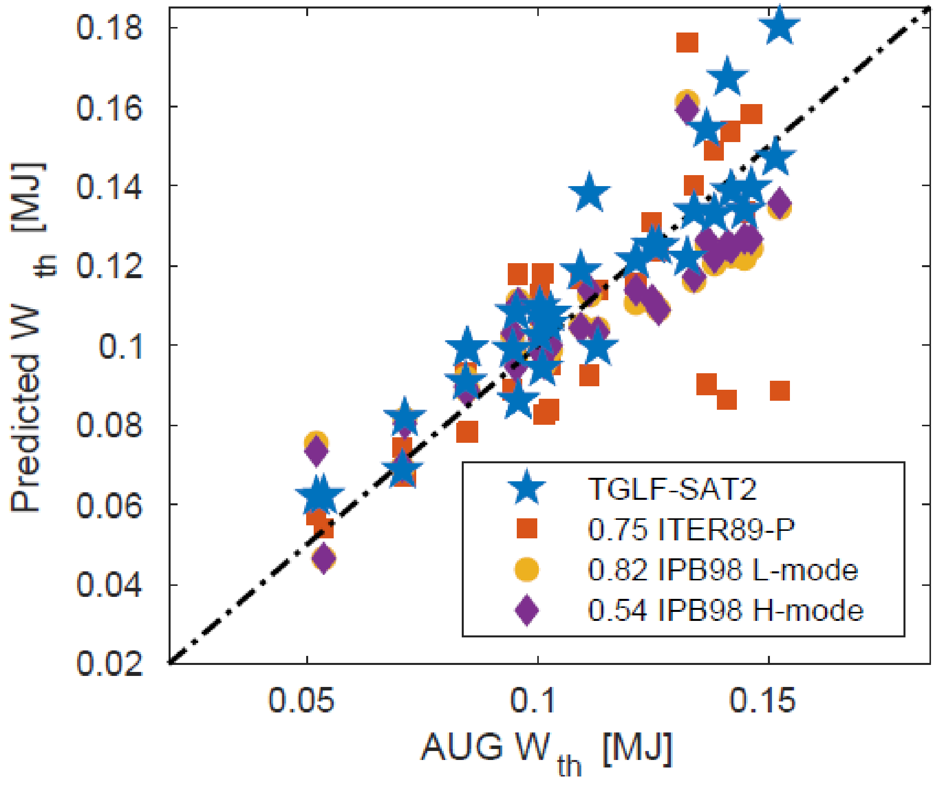
and qualitatively!
Explain the energy content degradation when increasing gas fuelling: n_{sep} higher, $\alpha = \alpha_c$ for narrower pedestal (higher q near sep.), lower P_{ped}



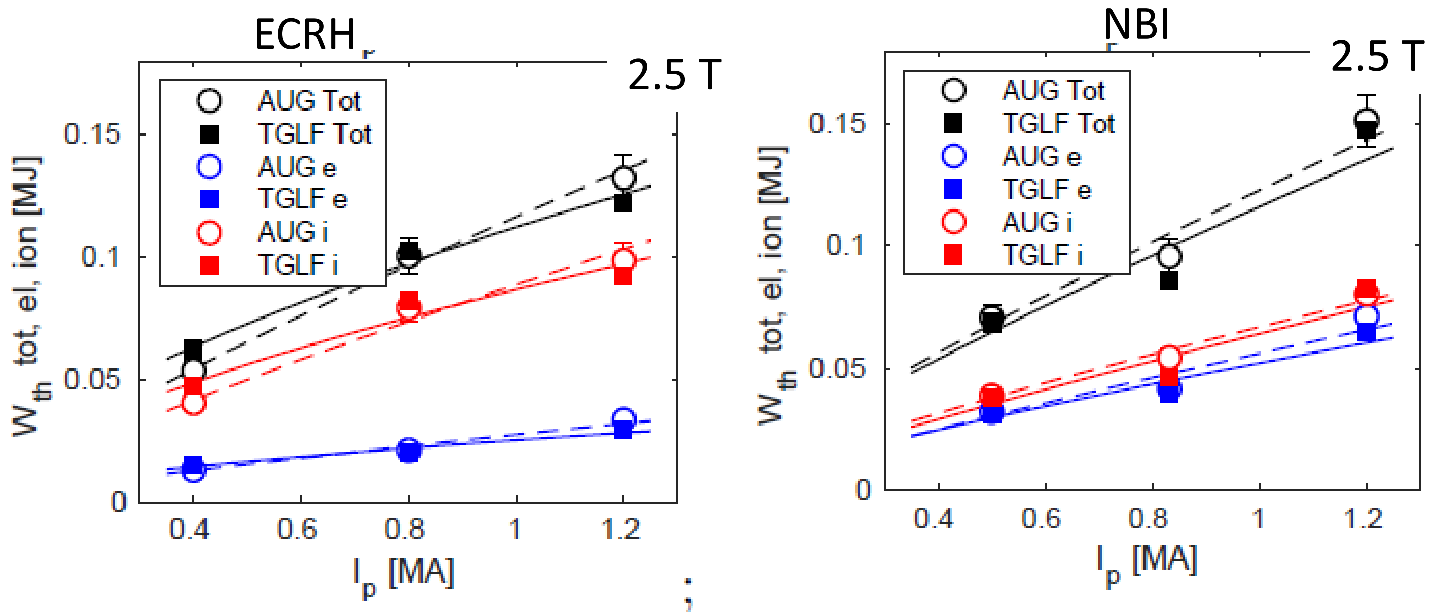
Extending the boundary condition to the SOL: AUG L mode database better than empirical scaling laws, quantitavely and qualitatively

ASTRA-TGLFsat2-NCLASS-TORBEAM-RABBIT
prediction from core to SOL
Core up to LCFS: quasilinear fluid code TGLF sat2
Separatrix: T_{sep} from 2 point model using λ_q scaling [Goldston], n_{sep} =0.3<n> with feedback on <n>
frozen current profile

better than empirical scaling laws, quantitatively ….



and qualitatively!
Explains the I_p impact on confinement by q stabilization of turbulence

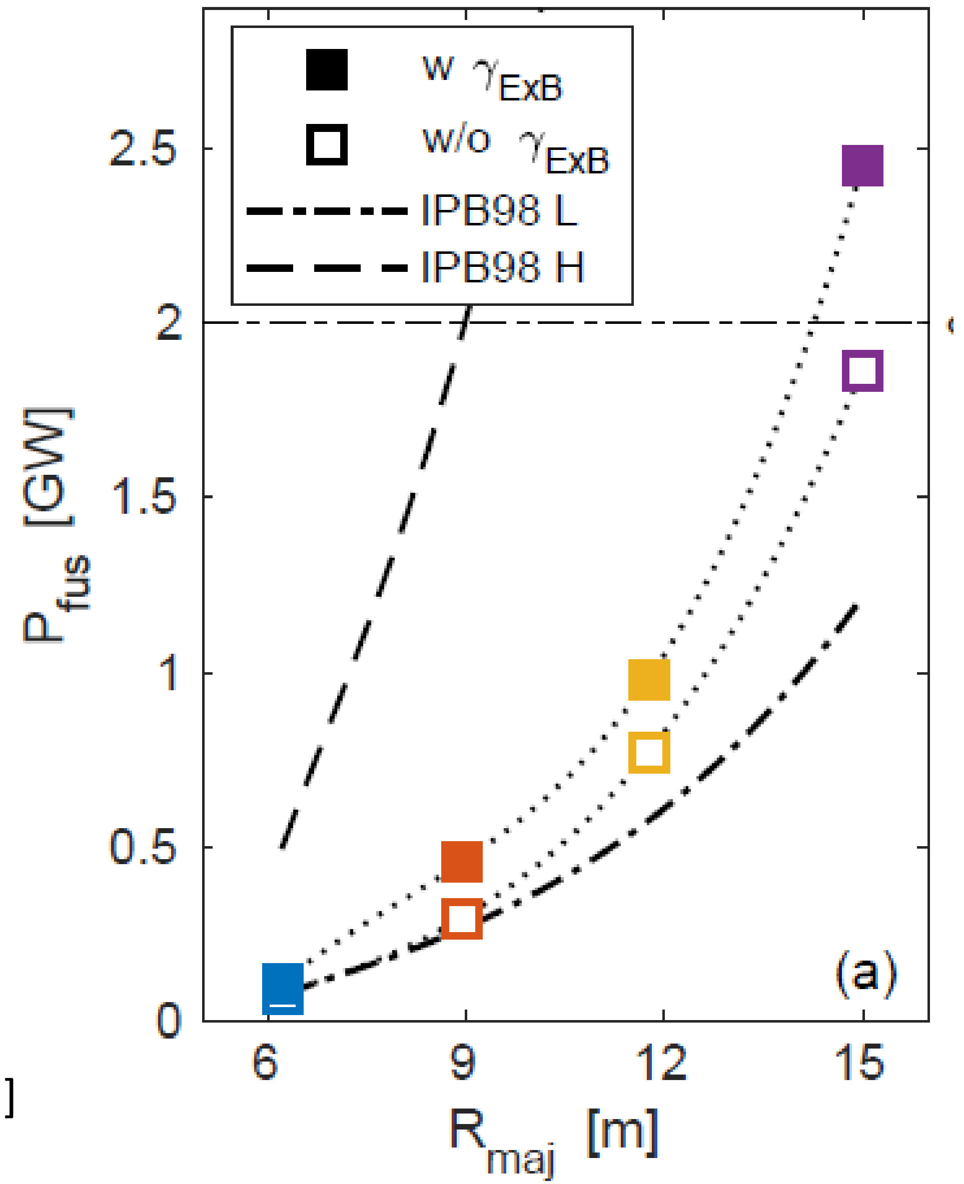


[Angioni NF2022]

Predictions of fusion power and confinement of an L–mode fusion reactor ("curiosity driven exercise")

ASTRA/TGLF–SAT2
T_{sep}=170 eV
n_{sep} =0.3<n> with feedback such that density at ρ = 0.85 to go below Greenwald limit

5.7 T and 50 MW of central ECRH



[Angioni sub. to NF 2023]

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What is the High Fidelity Pulse Simulator?

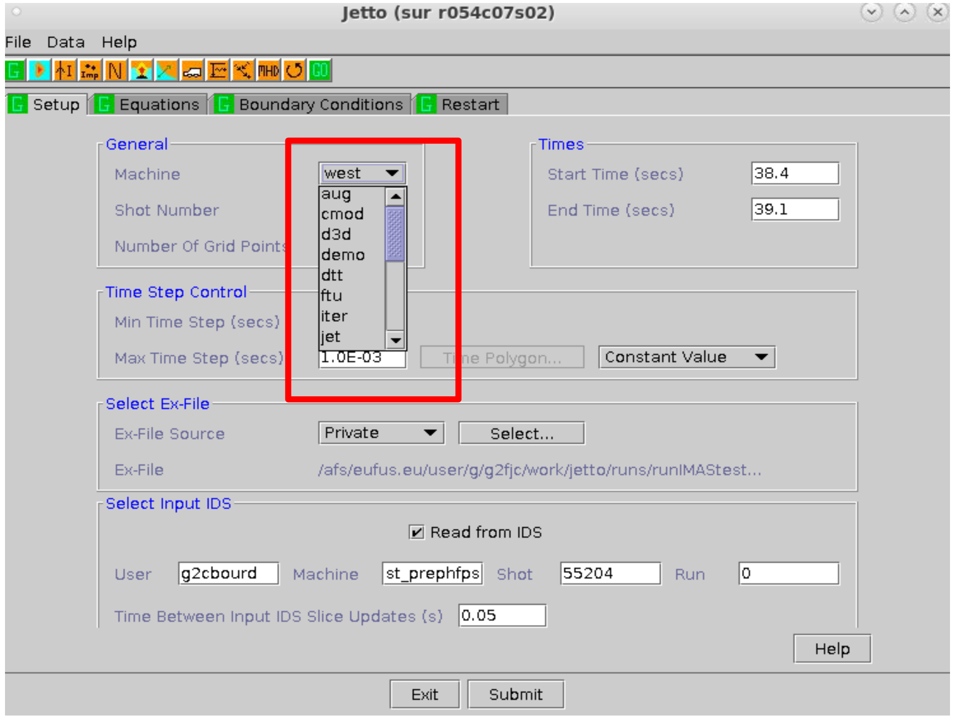
Python-driven workflow based on **IMASified JINTRAC (i.e. JETTO+EDGE2D, from the core to the SOL)**

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**

Automated run generation and analysis pipelines being developed for uncertainty quantification



A key tool: IMAS data structure

IMAS : **I**ntegrated **M**odelling and **A**nalysis **S**uite Data Dictionary.

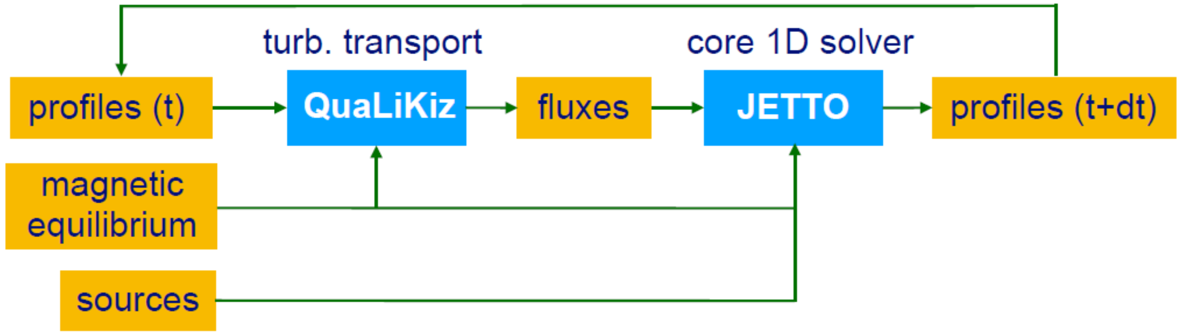
Chosen by IO **for ITER future experimental data** and present modelling in/output.

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

IMAS infrastructure includes:

- **Data Dictionary** : machine generic
  - What data exist ?
  - What are they called ?
  - How are they structured ?
- **Data Access** : functions to read/write objects
- **Workflow component generator** : encapsulate physics codes to turn them into components that can be coupled in a workflow



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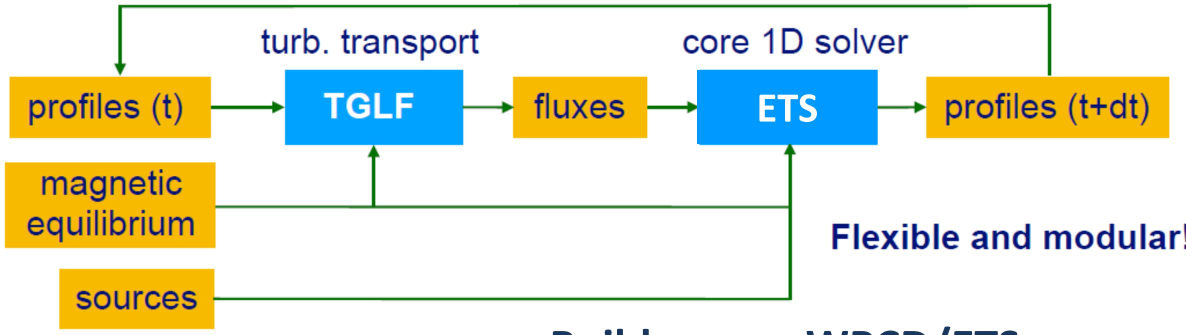


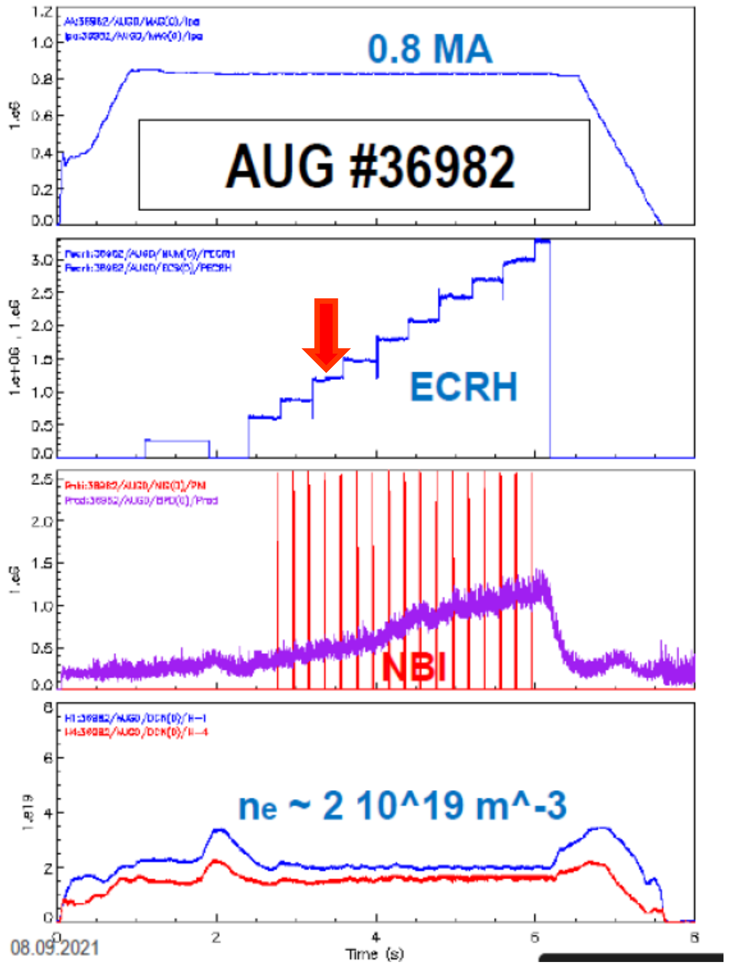
Flexible and modular!

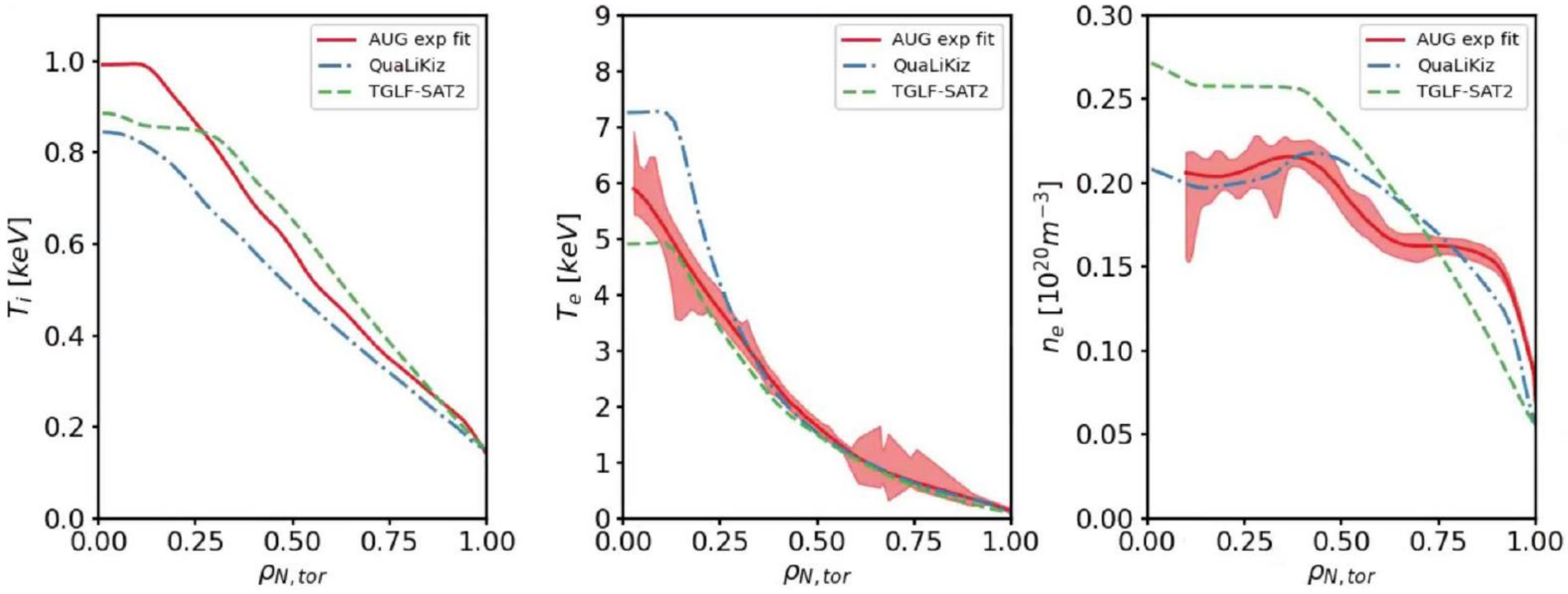
Builds up on WPCD/ETS approach

IMAS AUG data modelled by the HFPS
L mode up to the LCFS

L mode on AUG, 1.2 MW of ECRH

HFPS-QuaLiKiz **or** TGLFsat2-FRANTIC (neutrals at 5eV)
Predictive modeling up to separatrix, heat and particle





C.Angioni, NF 2022
C.K. Kiefer, NF 2021

[Citrin ITPA Oct. 2022]

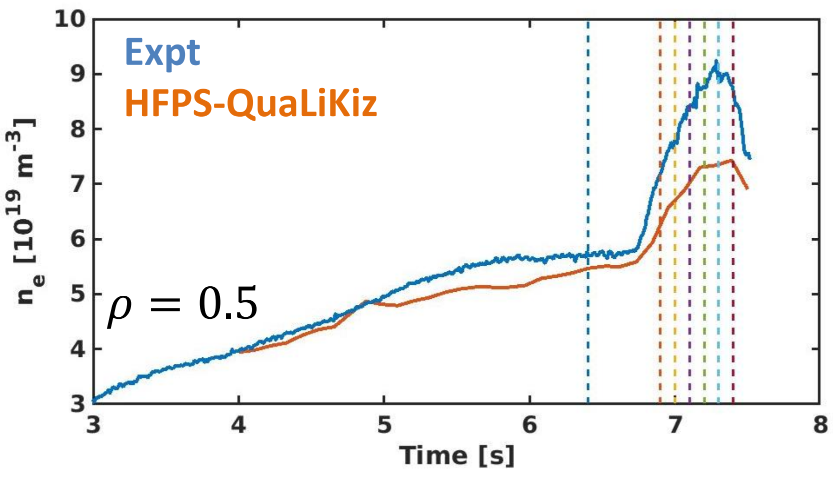
IMAS WEST data modelled by the HFPS
Boron dropper enhancing L mode confinement

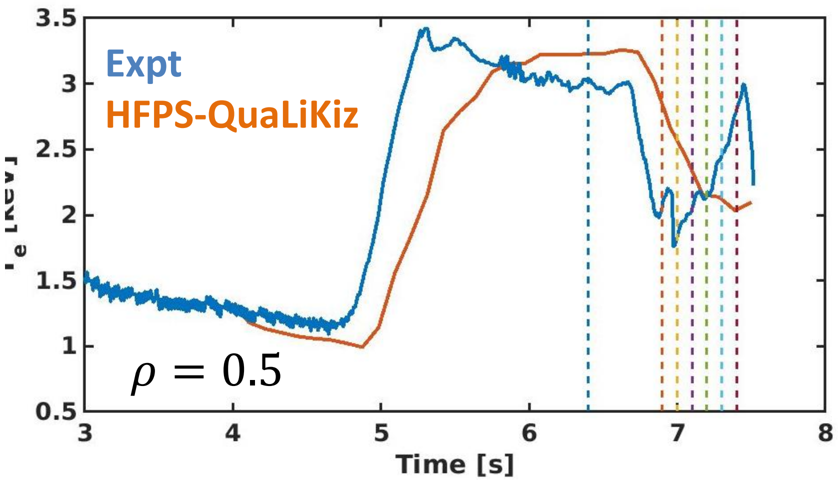
HFPS-QuaLiKiz

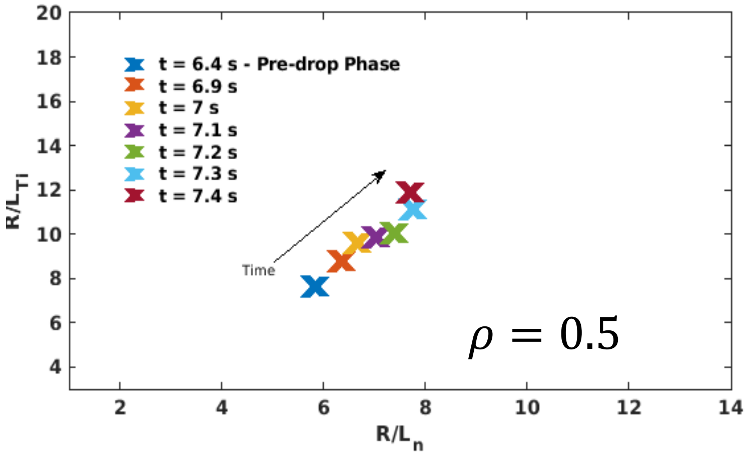
Predictive modeling up to ρ=0.9, heat and particle over 3.5 s of plasma evolution

Largest Boron powder injection in WEST LHCD heated L mode,
leads to increased energy content [Bodner NF2022]
Key role of enhanced Z_{eff} and collisionality on turbulence stabilization

#56920







[G. Bodner, P. Manas et al]

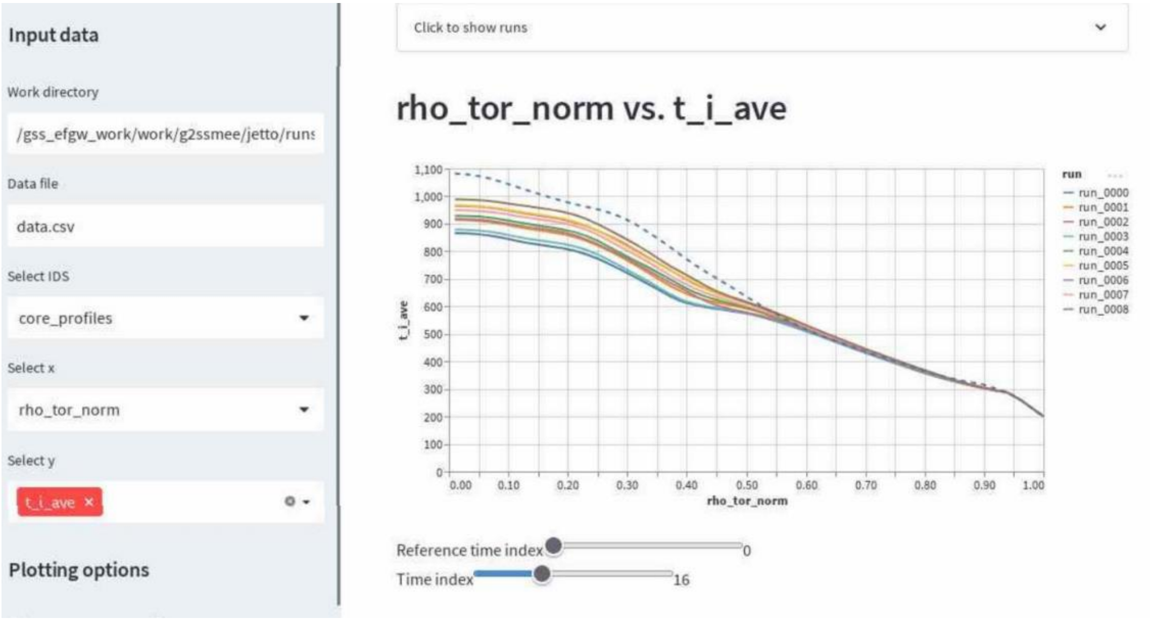
Large scale validation tools (on-going) requires sampling on uncertainties of initial and boundary conditions

netherlands eScience center

- Set up 100s of simulation runs from a single template
- Launch standard sets of sensitivity tests with minimal programming
- Batch job submission and status tracking
- Supports the Standardized Interface Data Structures (IDSs) data directory
- Compare and visualize 100s of simulations in one overview
- Display and merge simulation results as confidence ranges and distributions

duqtools

a tool for Dynamic Undertainty Quantification for Tokamak reactor simulations modelling



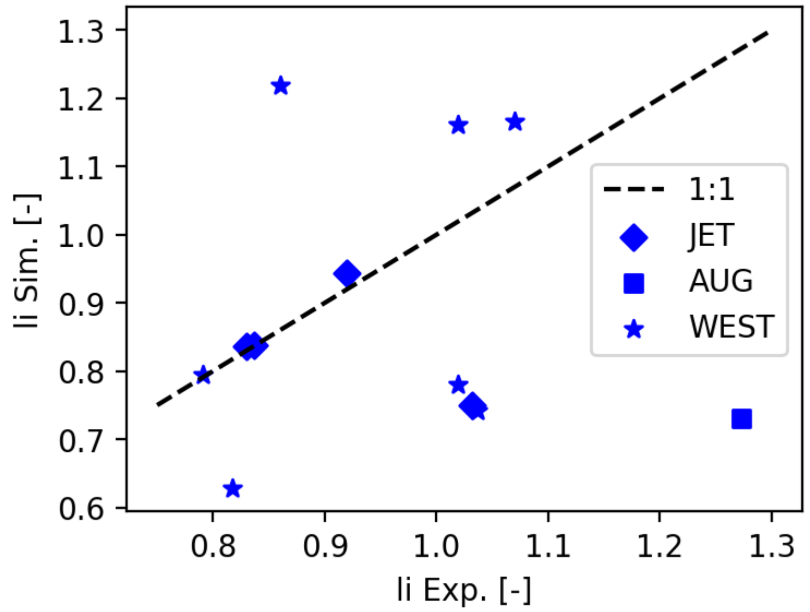
[Smeets, Azizi, TSVV11 meeting Nov 2022]

Large scale validation tools (on-going)
requires synthetic diagnostics 0D, 1D and 2D

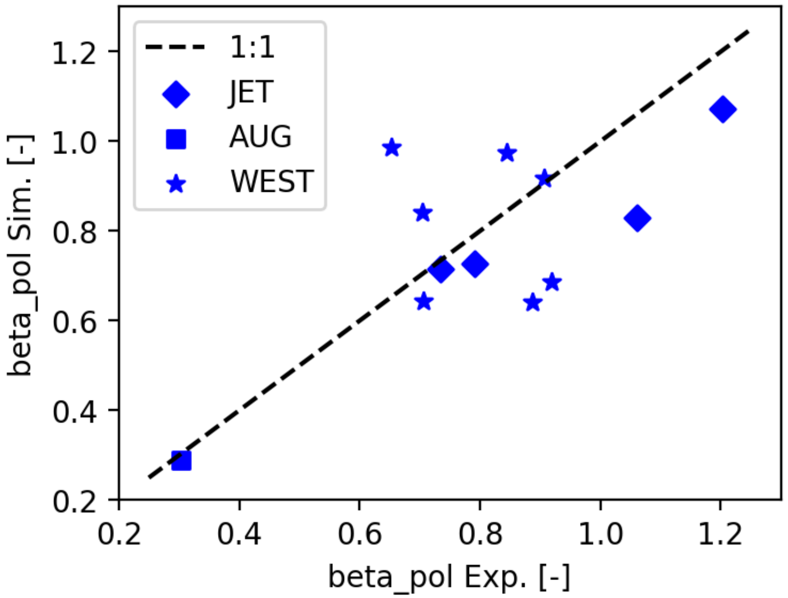
Validation metrics (steady-state analysis)

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

- To be implemented via a **hierarchy** of modelling use-cases and simulation fidelities



Using HFPS on Gateway
JET, AUG and WEST
Intrepretative HFPS simulations with ESCO equilibrium reconstruction and current diffusion only at this preminiary stage



[Ho EPS 2022]

TSVV11 : « *Validated frameworks for the Reliable Prediction of Plasma Performance and Operational Limits in Tokamaks* »

All the physics that we master now has to be available from ITER control room

Guiding principles:

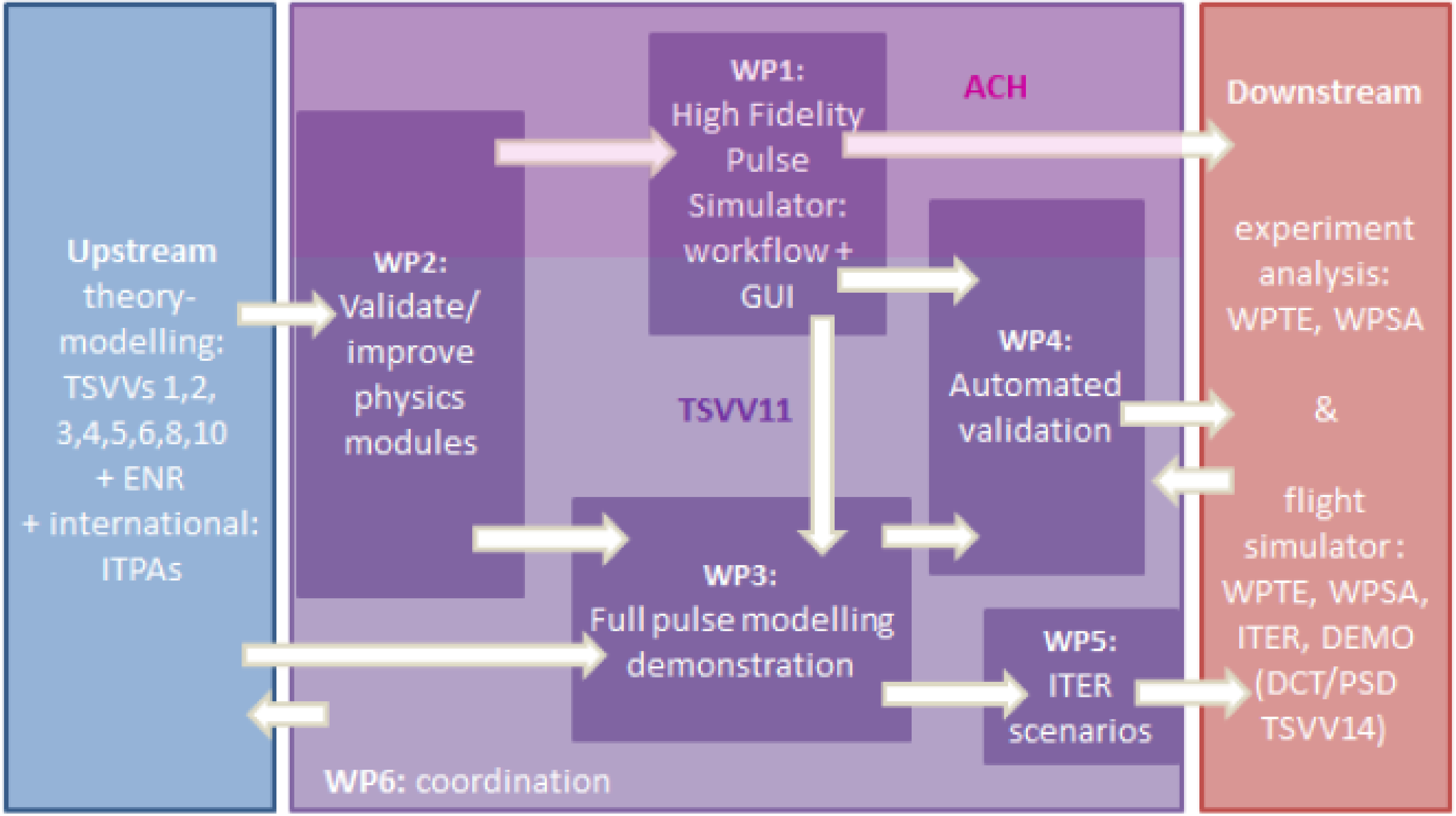
- Align with ITER technical choices in terms of integrated modelling workflow and database management
- Improve and validate advanced physics modules focusing on high priority modelling extensions that will be needed for multi-physics full predictive modelling, with the help of other TSVV activities and in coherence with WPTE priorities
- Demonstrate validation of full pulse predictive modelling from breakdown to termination, including a realistic assessment of operational limits
- Support extended validation against EU operating tokamaks by providing to users outside this TSVV yearly training on the integrated modelling workflow, a detailed and clear documentation on the workflow and the embedded physics modules, a user friendly interface and automated validation tools

integrate and validate all the physics that we master

Upstream: Join our expertises for **physics based reduced models**

Within TSVV11: **integrate** physics based reduced models
Validate on targeted issues, develop automated large scale validation tools, demonstrate **full pulse** modelling from breakdown to termination, contribute to ITER scenario preparation

Dowstream: Thanks to smooth GUI, workflows and validated physics have **more users** (WPTE **@JET**, WPSA, ITER, DEMO…)



TSVV11 structure

PI: C. Bourdelle

- **WP1: HFPS Workflow orchestration and module coupling framework** (coordinator: F.J. Casson, 2.5 ppy incl. 1.5 ACH)
- **WP2: HFPS key physics modules validation** (3.5 ppy incl. 1 from ACH)
  - WP2-D1 Turbulent transport reduced models targeted validation (coordinator: Y. Camenen)
  - WP2-D2 Core-edge-SOL coupling targeted validation (coordinator : C. Bourdelle)
  - WP2-D3: Impurity transport, development of reduced models, verification and targeted validation (coordinator: C. Angioni)
  - WP2-D4: MHD modules targeted validation (coordinator: P. Maget)
  - WP2-D5: Plasma initiation (Breakdown and burn-through and MHD equilibrium) integration and validation (coordinator: J-F Artaud)
- **WP3-HFPS full pulse modelling capability demonstration** (coordinator: E. Fable, 2 ppy)
- **WP4-HFPS systematic validation** (coordinator: A. Ho, 1ppy incl. 0.5 from ACH)
- **WP5- HFPS initial ITER phase modelling** (coordinator: J. Citrin, total effort 0.5 ppy)

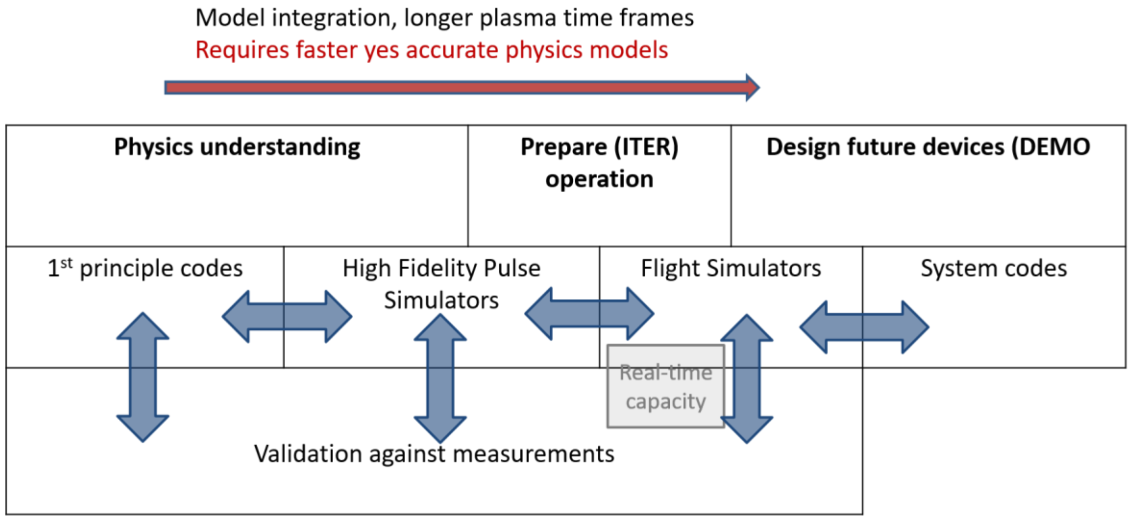
wikipage:
https://wiki.euro-fusion.org/wiki/TSVV-11

Total : 7ppy + 3ppy from ACH

outline

- Overviewing some (not exhaustive!) recent progresses on physics based High Fidelity Integrated Modelling
  - Integrating complex non-linear retroaction loops up to a radial boundary condition
  - Moving the boundary condition outward, from the core to the SOL
- 'The' High Fidelity Pulse Simulator and its tools within the TSVV11 EUROfusion programme
- Some (not exhaustive!) remaining challenges

Faster yet accurate physics: needed for all modules



Faster:
- **Smarter physics approximation**

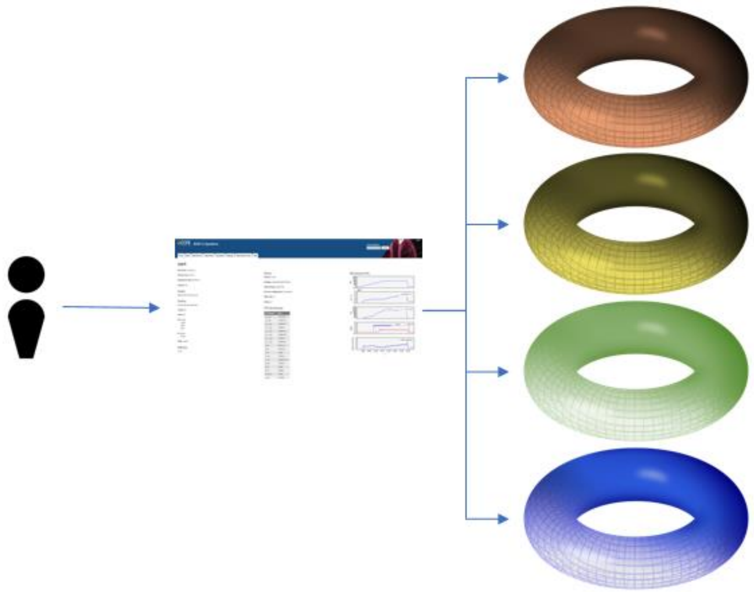
and/or
- **Machine Learning surrogates**

and in all cases mandatory :
Professional software support

- **Turbulent transport** models:
  - need to include electromagnetic stabilization, role of fast ions [Citrin Mantica PPCF2022]
  - Low, high Z impurity transport to be validated further against higher fidelity codes
- **Fueling**:
  - Pellet model HPI2 physics/numerical optimization
  - Neutral particle sources, impact on n_{sep}, see hierarchy of models [WPAC/WPTE meeting 2022]
- **Heating**:
  - ICRH: interplay with W directly ($T_{\perp}$ /$T_{//}$, induced rotation, etc) or by impacting background. Hierarchy of codes towards faster options?
- From **breakdown** to I_p ramp up with free-boundary equi. [HT Kim NF 2022]
- Interplay transport, MHD and neutrals **in pedestals:** IMEP [Luda NF2021], Europed [Saarelma sub. to NF 2023]
- Etc, etc

Easier experimental data access for larger scale validation

- Findable:
- Accessible:
- Interoperable
- Re-usable:



https://fair4fusion.eu/

4 implementation scenarios have been established by FAIR4Fusion and proposed to EUROfusion:

A : Share physics metadata within the community (central catalogue)

B : Central access point for full data of all EU experiments

C : Add PIDs, links to publications + provenance

D : Opening data to the general public

For large scale validation: need simulation database

- Align with ITER simDB

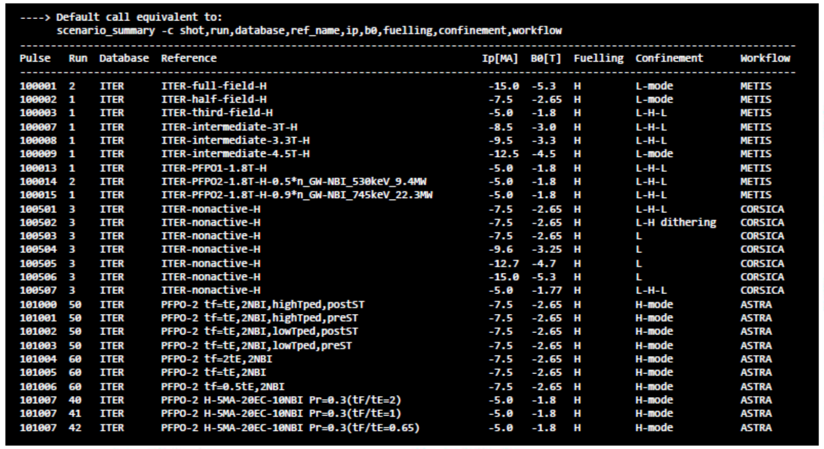
- Ready on the gateway
- But… Need EF **software and hardware support**: Long Term Storage Facility see Gateway expert group 07/21 recommendation #6

STORAGE LIMITATION

RESPONSIBILITY FOR ONGOING MAINTENANCE

IMAS scenario database

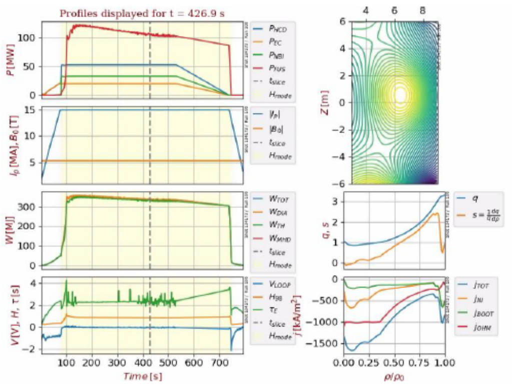
- ~2300 simulations for core and/or edge scenarios, among which 900 are active

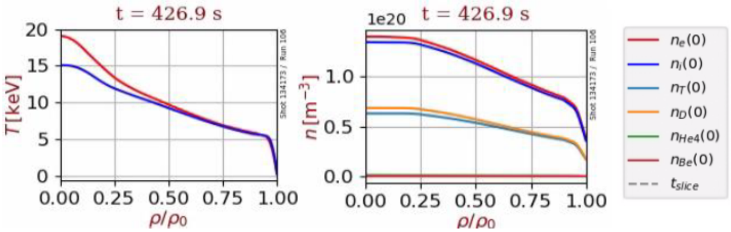


```
----> Default call equivalent to:
      scenario_summary -c shot,run,database,ref_name,ip,b0,fuelling,confinement,workflow
```

Pulse	Run	Database	Reference	Ip[MA]	B0[T]	Fuelling	Confinement	Workflow
100001	2	ITER	ITER-full-field-H	-15.0	-5.3	H	L-mode	METIS
100002	1	ITER	ITER-half-field-H	-7.5	-2.65	H	L-mode	METIS
100003	1	ITER	ITER-third-field-H	-5.0	-1.8	H	L-H-L	METIS
100007	1	ITER	ITER-intermediate-3T-H	-8.5	-3.0	H	L-H-L	METIS
100008	1	ITER	ITER-intermediate-3.3T-H	-9.5	-3.3	H	L-H-L	METIS
100009	1	ITER	ITER-intermediate-4.5T-H	-12.5	-4.5	H	L-mode	METIS
100013	1	ITER	ITER-PFPO1-1.8T-H	-5.0	-1.8	H	L-H-L	METIS
100014	2	ITER	ITER-PFPO2-1.8T-H-0.5*n_GW-NBI_530keV_9.4MW	-5.0	-1.8	H	L-H-L	METIS
100015	1	ITER	ITER-PFPO2-1.8T-H-0.9*n_GW-NBI_745keV_22.3MW	-5.0	-1.8	H	L-H-L	METIS
100501	3	ITER	ITER-nonactive-H	-7.5	-2.65	H	L-H-L	CORSICA
100502	3	ITER	ITER-nonactive-H	-7.5	-2.65	H	L-H dithering	CORSICA
100503	3	ITER	ITER-nonactive-H	-7.5	-2.65	H	L	CORSICA
100504	3	ITER	ITER-nonactive-H	-9.6	-3.25	H	L	CORSICA
100505	3	ITER	ITER-nonactive-H	-12.7	-4.7	H	L	CORSICA
100506	3	ITER	ITER-nonactive-H	-15.0	-5.3	H	L	CORSICA
100507	3	ITER	ITER-nonactive-H	-5.0	-1.77	H	L-H-L	CORSICA
101000	50	ITER	PFPO-2 tf=tE,2NBI,highTped,postST	-7.5	-2.65	H	H-mode	ASTRA
101001	50	ITER	PFPO-2 tf=tE,2NBI,highTped,preST	-7.5	-2.65	H	H-mode	ASTRA
101002	50	ITER	PFPO-2 tf=tE,2NBI,lowTped,postST	-7.5	-2.65	H	H-mode	ASTRA
101003	50	ITER	PFPO-2 tf=tE,2NBI,lowTped,preST	-7.5	-2.65	H	H-mode	ASTRA
101004	60	ITER	PFPO-2 tf=2tE,2NBI	-7.5	-2.65	H	H-mode	ASTRA
101005	60	ITER	PFPO-2 tf=tE,2NBI	-7.5	-2.65	H	H-mode	ASTRA
101006	60	ITER	PFPO-2 tf=0.5tE,2NBI	-7.5	-2.65	H	H-mode	ASTRA
101007	40	ITER	PFPO-2 H-5MA-20EC-10NBI Pr=0.3(tF/tE=2)	-5.0	-1.8	H	H-mode	ASTRA
101007	41	ITER	PFPO-2 H-5MA-20EC-10NBI Pr=0.3(tF/tE=1)	-5.0	-1.8	H	H-mode	ASTRA
101007	42	ITER	PFPO-2 H-5MA-20EC-10NBI Pr=0.3(tF/tE=0.65)	-5.0	-1.8	H	H-mode	ASTRA

DINA-JINTRAC free boundary core-edge ITER DT scenario 15 MA / 5.3 T





Tools are available to list and visualise all available simulations in the scenario database, described in https://confluence.iter.org/display/IMP/Scenario+Database

[Schneider, ITER Org. ITPA diags 2022]

conclusions

- Over the past ~5 years, flux driven integrated modelling using multiple plateforms on various tokamaks allowed
  - Explaining dynamical phases of tokamak plasmas: interplay W and RF/NBI heating, W and ohmic during ramp up
  - Capturing main confinement scaling trends in L and H modes (impact of fueling, I_p, etc)

- Since April 2021 the TSVV11 physics driven activity within EUROfusion joins efforts on
  - A common modular IMASified integrated modelling platform: the High Fidelity Pulse Simulator
  - Developing tools for automated large scale validation

- A lot remains to be coordinated:
  - supporting all physics modules (software management, improved physics, ML surrogates)
  - Allowing a FAIR data access to all EU devices
  - Simulation database hard and software support

- Nonetheless… we are ready to start our 1st training on the HFPS open to all EUROfusion on the Gateway! NB: It will be repeated yearly.