Status Report for WPENR

3rd Theory Project Board | 10.03.2022
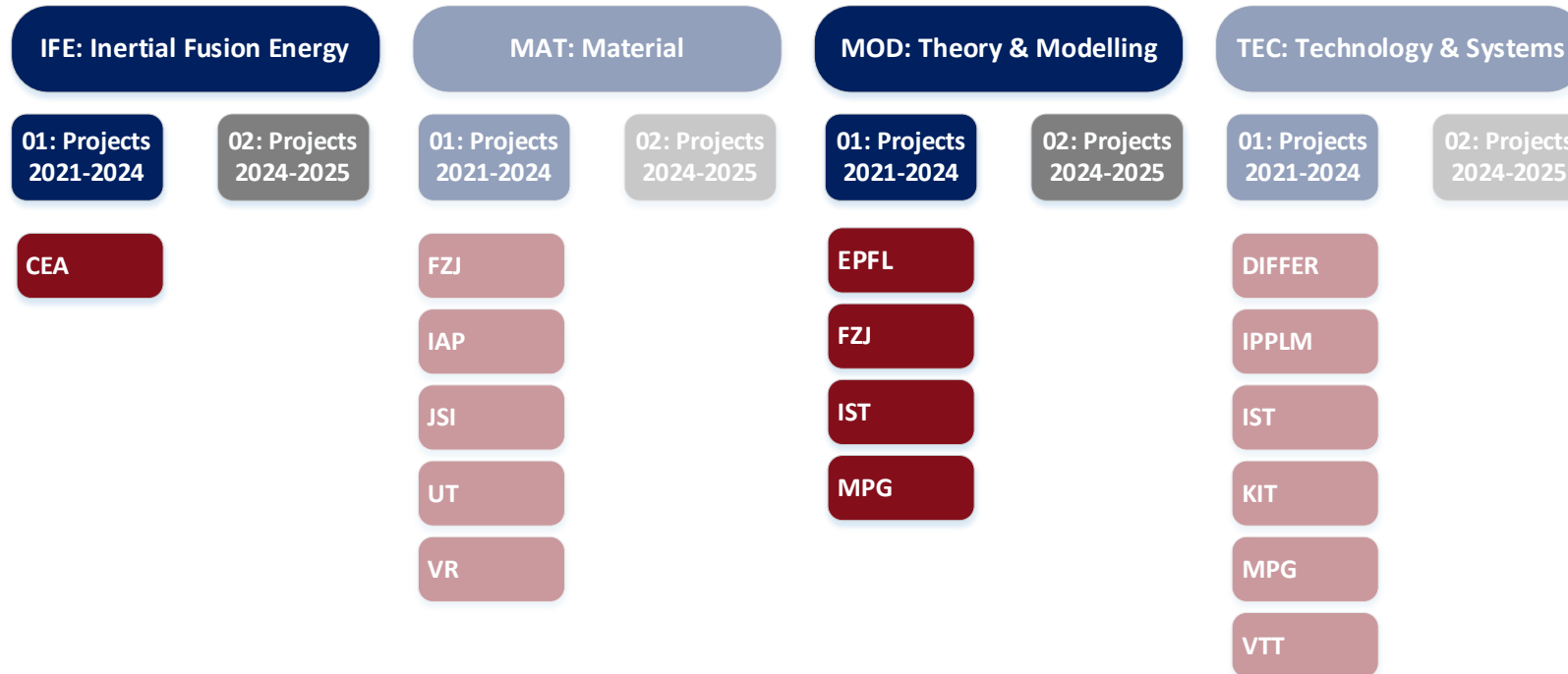
D.Kalupin

WP ENR: Enabling Research

IFE: Inertial Fusion Energy	MAT: Material	MOD: Theory & Modelling	TEC: Technology & Systems
01: Projects 2021-2024	01: Projects 2021-2024	01: Projects 2021-2024	01: Projects 2021-2024
02: Projects 2024-2025	02: Projects 2024-2025	02: Projects 2024-2025	02: Projects 2024-2025
CEA	FZJ	EPFL	DIFFER
	IAP	FZJ	IPPLM
	JSI	IST	IST
	UT	MPG	KIT
	VR		MPG
			VTT

ENR-MOD.01.IST

Energetic particle optimization of stellarator devices using near-axis magnetic fields

project (2yrs) started in Jan.2022

Late start: projects were running for 6 months in 2021

Overall progress
- Preparatory activities:
    - *Kick off (establishment of interactions within the project team)*
    - *Theory/literature reviews;*
    - *Definition of test/benchmark cases;*
    - *Collection of experimental data;*
    - *Preliminary simulations.*

- Reduced models:
    - *Benchmarking against more sophisticated models and codes*
    - *IMASification of I/O*

All scientific deliverables for 2021 are achieved.

ENR-IFE.01.CEA (D.Batani)
Advancing shock ignition for direct-drive inertial fusion

WP 1 - Characterization of hot electrons and hot-electron-driven SI
Preparation of a common experiment on the laser facility SG II UP in Shanghai

WP 2 - hydrodynamic instabilities and mitigation strategies in DD-SI, including use of foams
Development of dedicated numerical codes including model for simulating the interaction of high-power lasers with foams, Analysis of experimental results from campaigns performed in the framework of or previous ENR projects.

WP 3 - Bipolar SI: direct drive compression and bipolar spike irradiation
Preliminary model simulation of i) polar-direct-drive ignition-class targets, ii) bipolar ignition spike on symmetrically pre-compressed pellets, iii) new target concepts: homogeneous sphere (with wetted foam ablator) with dynamic formation of the fuel hollow shell

WP 4 - parametric instabilities and cross beam energy transfer, and their mitigation using broadband lasers
Development of dedicated numerical codes and analysis of experimental results from campaigns performed in the framework of or previous ENR projects. Preparation of a follow-up experiments in different laser facilities: Vulcan (UK), PALS (Prague), Gekko (Osaka)

**WP 5** - Magnetic-field-assisted implosion and ignition
Realization of a cylindrical compression experiment with embedded B- field to characterize strongly magnetized hot dense plasmas. Omega laser facility in Rochester (US). The experimental results are currently being analysed.

2nd SB.ENR-IFE (Monitoring of 2021 activities)
https://indico.euro-fusion.org/event/1352/
Annual report
https://idm.euro-fusion.org/?uid=2P4JDK
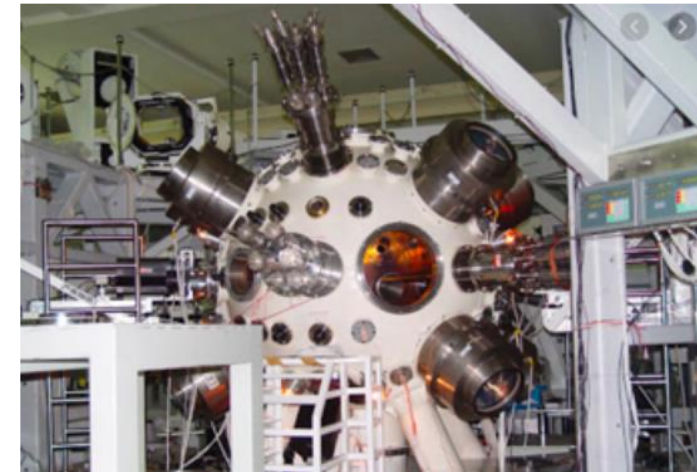
3. The two parts agree to perform common experimental work on laser facilities, including in particular the SG-II system at SIOM. The research groups from the EUROFusion Enabling Research Project ENR-IFE19.CEA-01 express the interest to perform experiments on the SG-II laser facility. Joint experimental proposals for physical experiments will be prepared and submitted for selection to the facility.

ENR-01.MOD.EPFL (J.Graves)
Operation limiting plasma instabilities in high performance tokamaks: fundamental understanding and solutions for critical problems
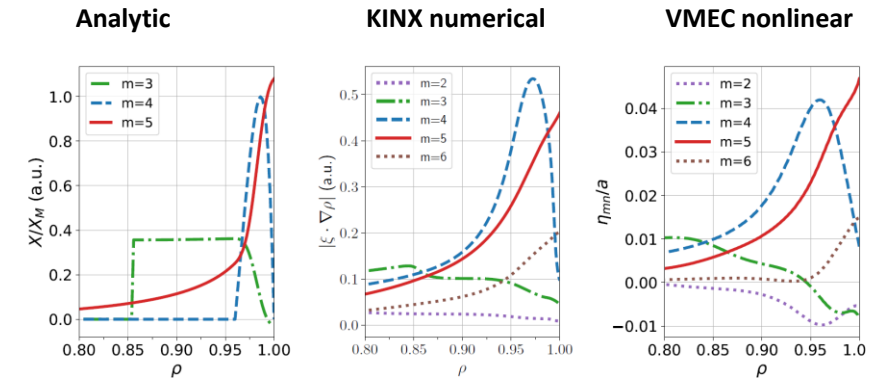
Scientific deliverable (annual scientific deliverables as specified in the Task Agreement)	Achieved: Fully/Partly/Not	Evidence for achievement, brief reason for partial or non-achievement
Codes will be written which solve for code resistive infernal modes	Fully achieved	Work published in PPCF: https://doi.org/10.1088/1361-6587/ac3496
Codes will be written for ideal exfernal modes (EHO's) with realistic magnetic shear.	Fully achieved	Work presented as invited talk and published in PPCF: https://doi.org/10.1088/1361-6587/ac2d77
Initial reporting will be provided on non-linear ballooning in slab geometry with imposed flows	Fully achieved	The model is a slab has been identified and the equations have been formulated. The work has been reported to the EnR collaborators and the PI has presented the work to the E-TASC committee in November.
Initial reporting will be provided on ideal wall RWMs with toroidicty	Fully achieved	The equations have been formulated and are ready for solving. The work has been reported to the EnR collaborators the PI has presented the progress to the E-TASC committee in November.
Work will be published on the validity of n=0 rigid-shift vertical displacement and the impact of X-point resonances for ideal MHD fluctuations	Fully achieved	Work presented at two conferences (oral and poster) and has been published in Letter format in NF: https://doi.org/10.1088/1741-4326/ac27c5
Recommendations will be given for improvements to linear ideal MHD kink-ballooning stability codes in order to capture the effects of full separatrix geometry.	Fully achieved	Two approaches for solving this problem have been identified. Work reported to the EnR collaborators and the PI has presented the progress to the E-TASC committee in November.

4th E-TASC Scientific Board (Monitoring of ENR-MOD 2021 activities)
https://indico.euro-fusion.org/event/1355/
Annual report:
https://idm.euro-fusion.org/?uid=2P3DUR

Analytic exfernal mode model extended to include magnetic shear effects everywhere.
Eigenfunction agreement with KINX and VMEC modes
These modes are robust by modelling separatrix, and with realistic shear.

ENR-01.MOD.FZJ (S.Wiesen)

Development of machine learning methods and integration of surrogate model predictor schemes for plasma-exhaust and PWI in fusion

4th E-TASC Scientific Board (Monitoring of ENR-MOD 2021 activities)
https://indico.euro-fusion.org/event/1355/
Annual report
https://idm.euro-fusion.org/?uid=2P26L4

SP1 Development of a surrogate model for power & particle exhaust
A first standard SOLPS-ITER case for a JET discharge has been setup.

**SP2** Development/improvement of ML/ANN methods for training based on experimental data for pedestal physics
Good progress was made in assessing the status of the JET database through. Additional selected parameters will be added to the database soon (Psep, Prad, Pradcore, and Ti,PED). The work on the evaluation ne,SEP and pedestal profiles has begun. The inclusion of full profiles (full HRTS information) facilitates a first comparison between ML methods for tabular data vs. interpolation of full profiles. The work has started to assess the status of the AUG database. TSV and MAST-U data bases will follow

SP3 Model discovery for erosion yields through ML methods
In 2021 the main focus of this subproject was on the identification of model parameters from plasma irradiated surface profiles.

SP4 Towards time-dependent surrogate models for exhaust
In the first task of this subproject a 1D divertor model development and data generation has been setup.
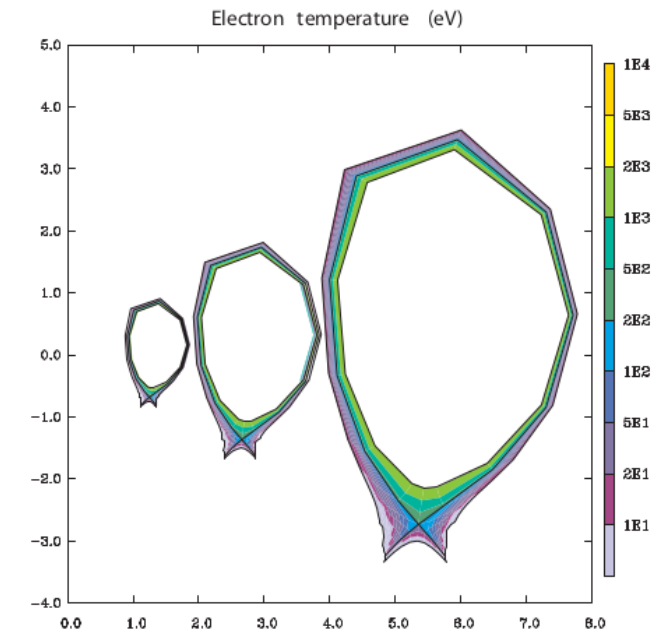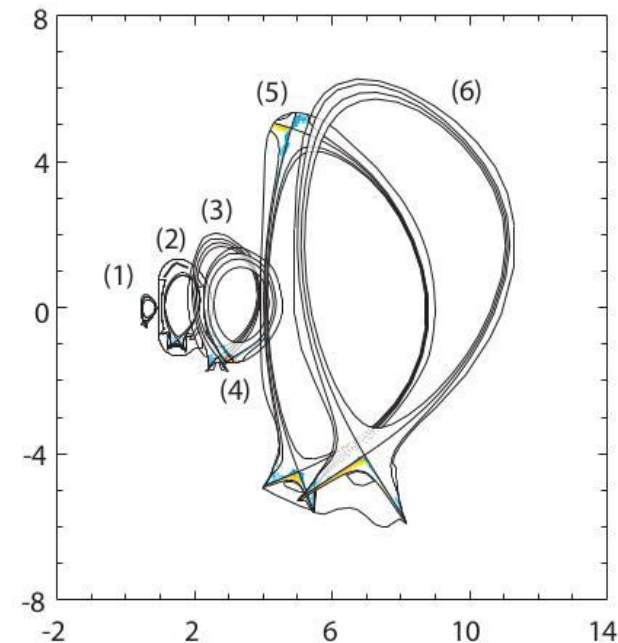
Conformal scaling of one geometry
-More work to implement
-Surrogate output valid for imaginary experiments
-Makes some assumption on scenario(eg. use baseline at fixed q_{95} and w/ similar flux exp.)
+Parameters can be changed independently
+Same parameters can be used as surrogate input
+Effect contribution to specific results is clear

ENR-01.MOD.MPG (Ph.Lauber)
Advanced energetic particle transport models (ATEP)

WP1. ATEP theoretical framework
A theoretical framework, based on nonlinear gyrokinetic theory, has been established to characterize fluctuation induced EP transport on long time scales in realistic tokamak plasmas. As planned, the 2D and 3D formulation of PSZS transport equations, and definition of ZS with corresponding equations for ZFS have been finalized. A complete transport theory describing the ZS evolution has been delivered

WP2. Advancing various building blocks according to WP1
Various test cases - including a JET-like case where the trapped particle contributions were shown to be crucial - for benchmarking with the (slower) numerical model have been prepared. First conceptual steps concerning a 3d version of a local GK solver have been taken. Parts of the CAS3D-K infrastructure (e.g. passing orbit expressions etc) were shown to be adequate for the construction of the local 3D model.

WP3. Implementation, application and verification of reduced EP transport models
The 1-D reduced plasma beam model has been successful extended to general Tokamak geometry (milestone fully achieved).

**WP4.** Preparation of time-dependent reference cases
The AUG data has been fitted (IDA) and written into the IMAS data-base on the Eurofusion Gateway system. Automated modelling with the EP-WF (LIGKA) has been already performed (MHD limit) for 160 time slices during the transition. This prototype of a fully-IMAS based workflow can now be extended to various models developed within ATEP.

4th E-TASC Scientific Board (Monitoring of ENR-MOD 2021 activities)
https://indico.euro-fusion.org/event/1355/
Annual report:
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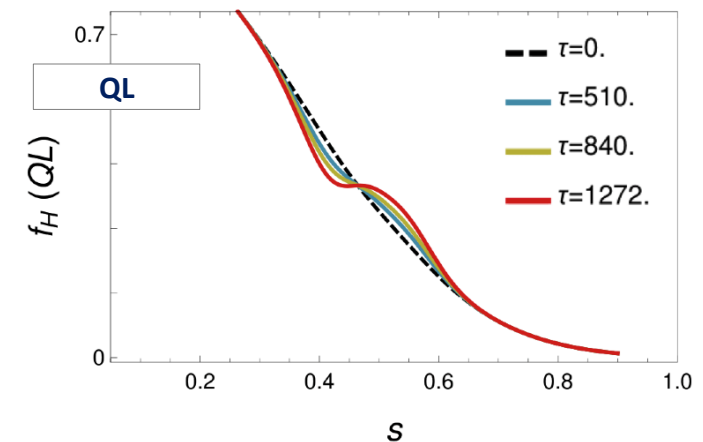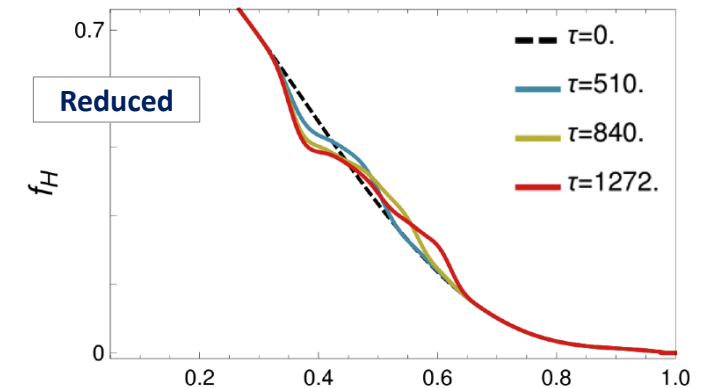
GA Deliverable No.	Title	Due Date	Status	Details on Status (in case of delays or issues)
D07.01	Joint progress report on the Enabling Research projects 2021	31/12/2021	**Completed**	

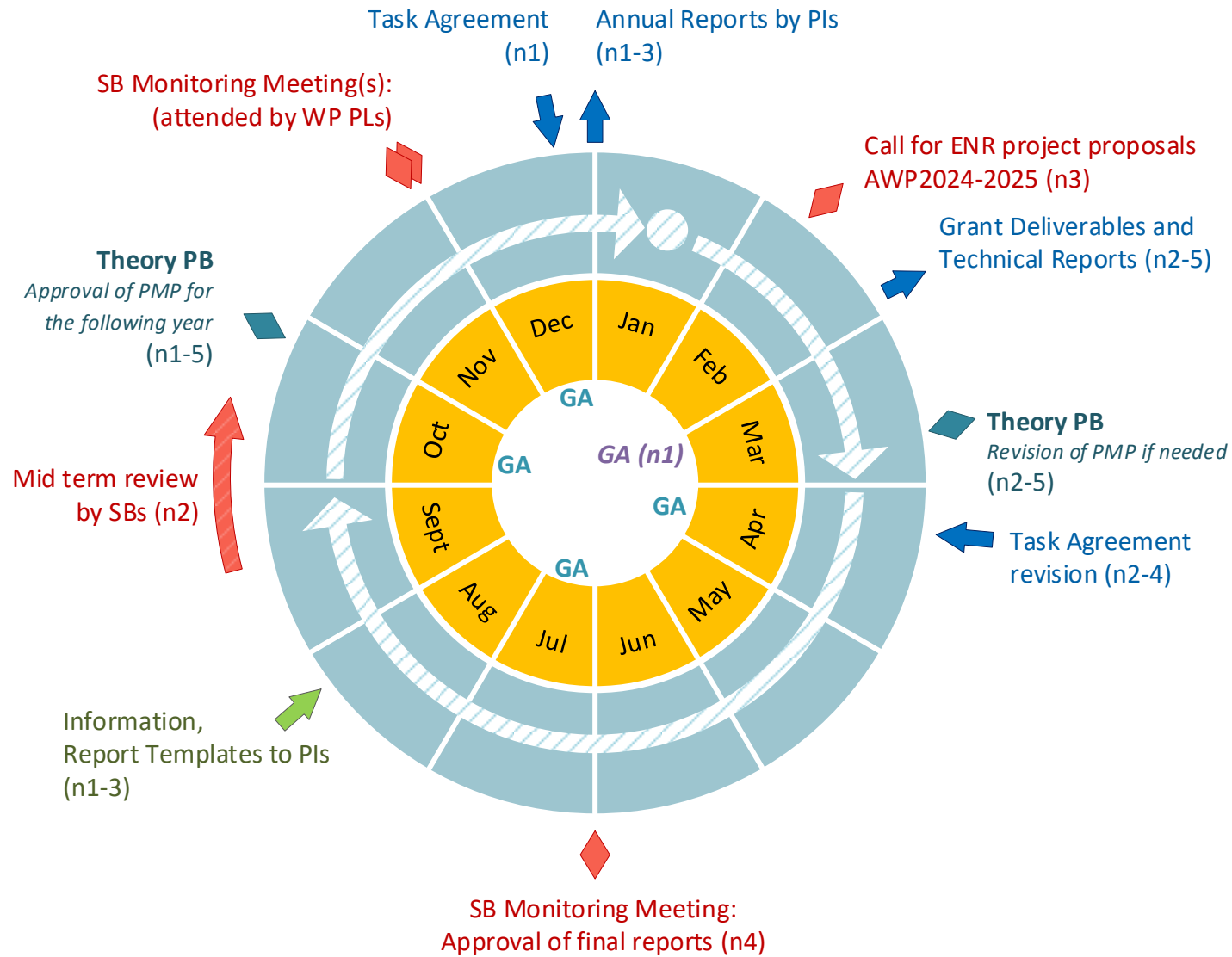| GA Milestone No.	Title	Due Date	Status	Details on Status (in case of delays or issues)
n/a				

Description of Risk	Severity	Likely hood	Proposed Mitigation Action	Risk materialized?	Mitigating Measures applied?	Comments
n/a					n/a	

Decisions on PCRs

PCR Number	PCR Title	PCR Status	Comments
none			

At the end of 2022 the **Mid-term Review** of projects will be done by **SBs**

End of PB-Presentation slides