IPP INSTITUTE OF PLASMA PHYSICS OF THE CZECH ACADEMY OF SCIENCES

Pre-conceptual design of LMD tiles for COMPASS-U:

Activities in 2023 & Plans for 2024

R. Dejarnac on behalf of IPP.CR

+

[UKAEA, UK] & [IST, Portugal] & [CIEMAT, Spain]

8.2.2024

MINISTRY OF EDUCATION, YOUTH AND SPORTS

OUTLINE

- Status of the COMPASS-U project
- Activities in 2023
  - Design
  - Modeling
- LMD plans for 2024
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COMPASS-U PROJECT (1/3)

COMPASS-U is a fully **new device** under construction in **IPP Prague**

Main parameters

- **Toroidal magnetic field** — **B_t = 5 T**
- **Plasma current** — **I_p = 2 MA**
- **Major radius** — **R_g = 0.9 m**
- Minor radius — a = 0.27 m
- Metallic (inertial) first wall + **Divertor manipulator**
- **Vacuum vessel operation temperature up to 500°C**

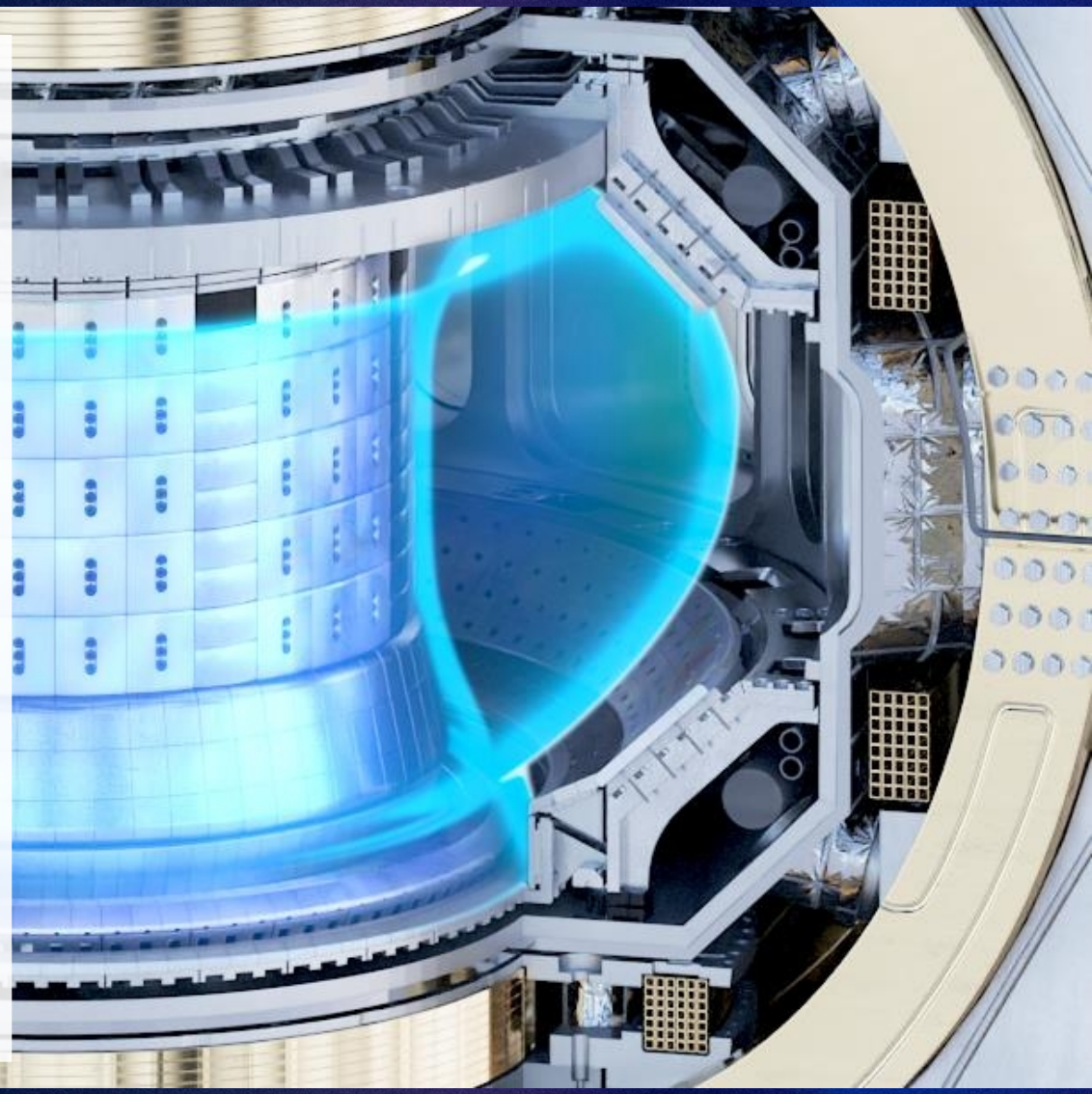
Plasma heating power

- Initial phase — P_{NBI} >= 3 MW, P_{ECRH} = 1 MW
- Later phase — P_{NBI} = 6 MW, P_{ECRH} = 8 MW
- 3 s flattop discharges

Scientific objectives

- Power exhaust + Advanced confinement + **LM** (full-ring divertor)

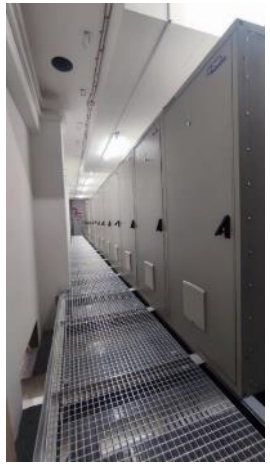
First plasma expected in 2026



COMPASS-U PROJECT (2/3)

Torus hall

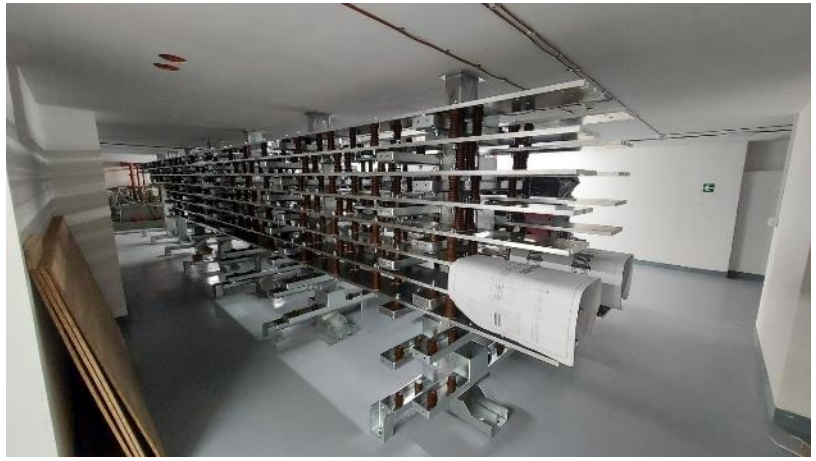
Installation of IGBT power supplies for PF coils



TF coils thyristor convertors

Assembly hall

1st fly-wheel during the FAT tests



Installation of the PF coils bus-bars

COMPASS-U PROJECT (3/3)

Three-floor new hall for power supplies, diagnostics and gyrotrons

Basement for two fly-wheel generators

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LMD activities 2023: Design (1/2)

Conceptual Design in collaboration with UKAEA

- Team led by **D. Horsley**
- **CAD models** of **COMPASS-U OVT tile + support structure** were shared w/ mechanical eng. (M. Bastar)
- **Documents based on DEMO design templates** were produced:
  - *Stakeholder Requirements Document* (SHRD) to identify and capture the stakeholder requirements for the COMPASS-U LMD tile design and future experiments – **C-U will be test bed for LM and open for EF experts**.
  - *Outcomes Requirements Document* (ORD) to define the expected research outcomes of the future COMPASS-U experiments using the LMD tile as these outcomes should influence its design.
  - *Design requirements* against which any future design will be compared.

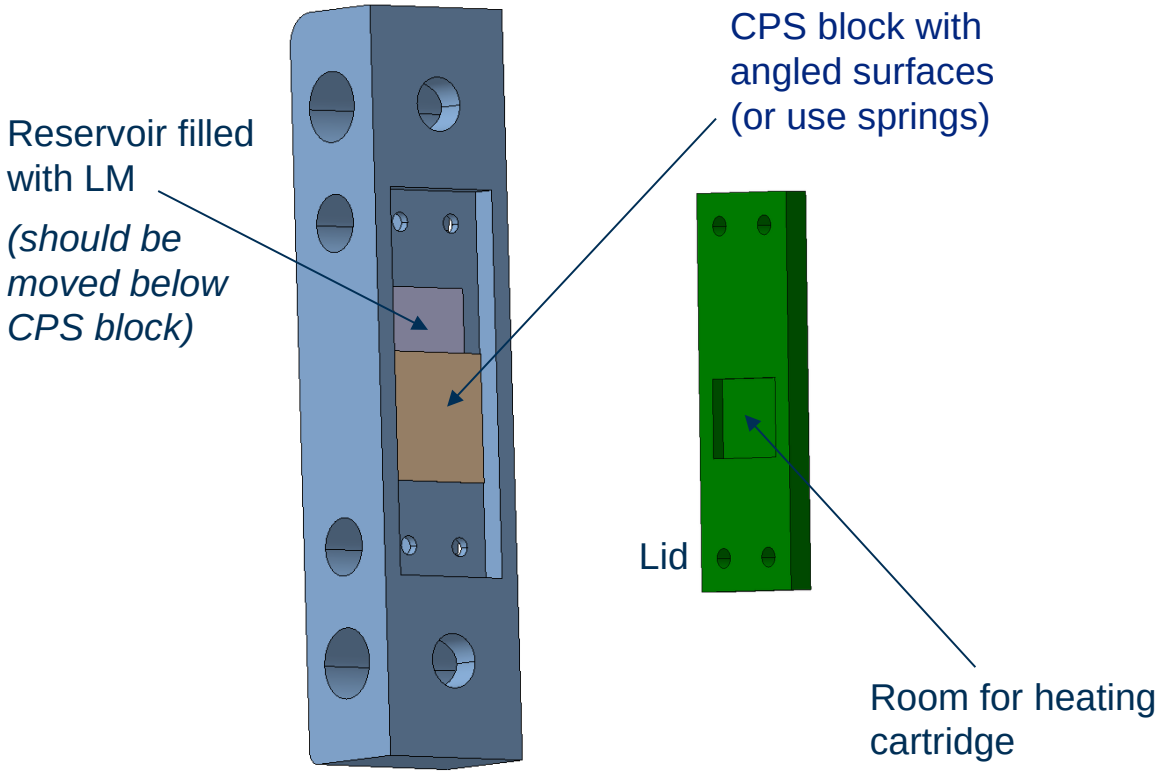
Workshop organized (18.01.2024)

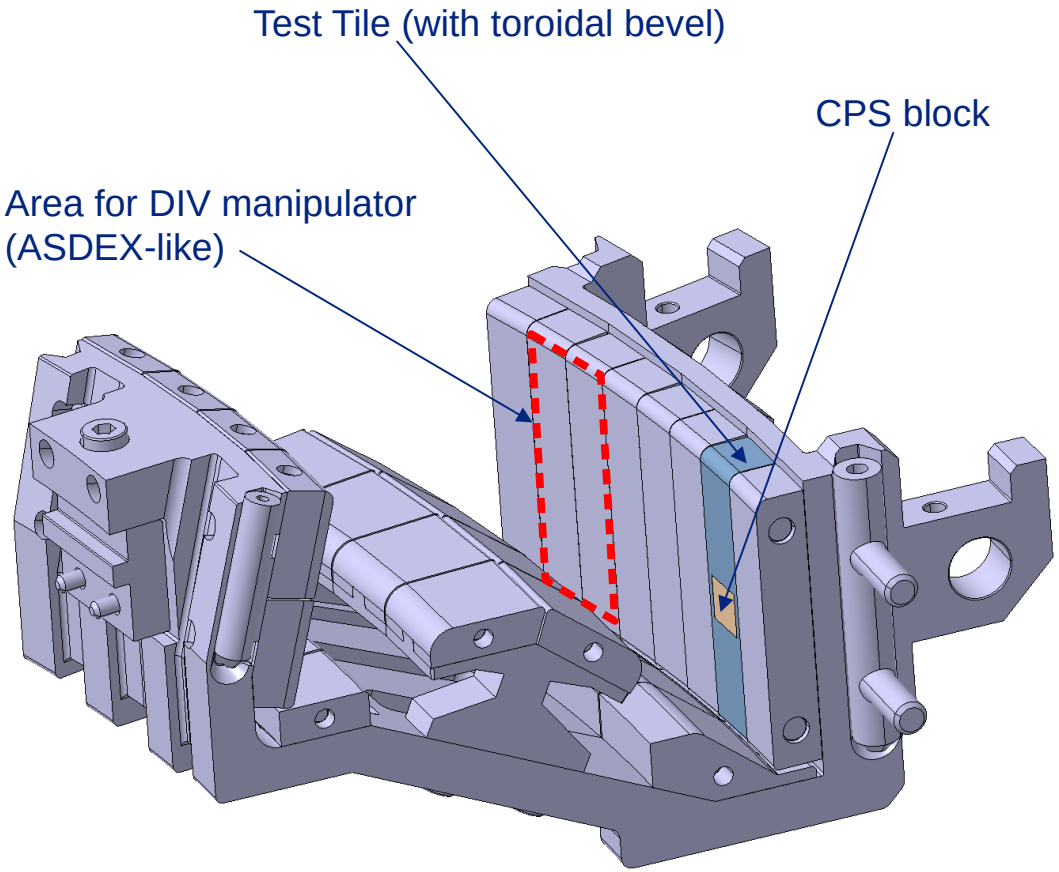
- Discuss the design strategy and requirements prioritization *(technology demonstration + extrapolation to DEMO)*
  - *Main goal?* Is it engineering or physics?
    - **Engineering:** Mechanical robustness, best CPS techno (mesh, felt, 3D-printed), hard stops, which LM (?), replenishment, cold trap, etc...
    - **Physics:** Erosion, redeposition, vapor shielding efficiency, core pollution, validation of modeling (how?), etc...
- Comment on the present conceptual design

LMD activities 2023: Design (2/2)

Design Concept *(brief overview – see D. Horsley's talk)*

- A pre-conceptual design of a "CPS block" and its implementation in one COMPASS-U OVT tile was created
- Divertor manipulator should cover 2 OVT tiles





LMD activities 2023: Modeling (1/2)

2023 modeling activities

- **Simulations of the 2022 AUG experiment using HeatLMD code (IPP.CR)** => 2 publications:
  - J.G.A. Scholte et al., NME **37** (2023) 101522.
  - J. Cecrdle et al., Fusion Eng. and Design **194** (2023) 113886.
- **J. Cecrdle [PhD student]:**
  - experiments on Nano-PSI (DIFFER) to quantify the (so far unknown) tin (thermally enhanced) sputtering yield.
  - HeatLMD simulations of ITER-like 15 MJ/$m_{||}^2$ unmitigated ELMs presented at ISFNT15.
  - parallelization of HeatLMD code in progress [**HeatLMD** = IPP.CR in-house code developed by J. Horacek for plasma-LM interactions].
- **S. Lukes [PhD student]:**
  - learning ERO2.0 from experts in FZJ (J. Romazanov, A. Kirshner, Ch. Baumann, S. Rode). Using the resources of the Karolina IT4I supercomputer.
  - implementation of Li into the code and first results (next slide).
  - results presented at the ITER summer school and at the IT4I user's conference.
- **In collaboration with Charles University:**
  - investigation of Sn Removal for Liquid Metal Tokamak Divertor by Low Pressure Argon Arc with Hot Tungsten Cathode System
  - published in Journal of Fusion Energy **42** 36 (2023) but no national funding for continuation.

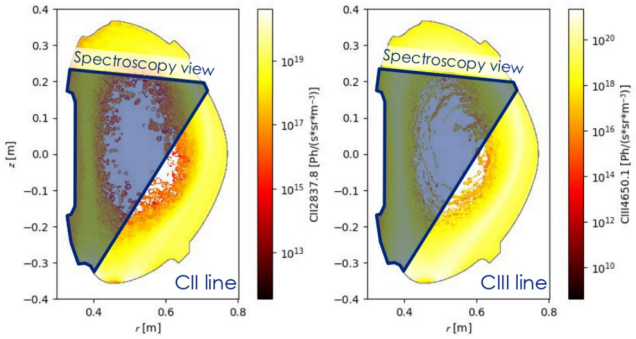
LMD activities 2023: Modeling (2/2)

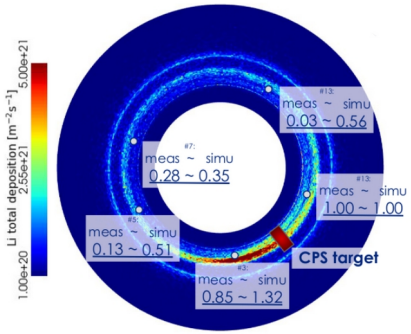
HeatLMD + COREDIV integrated modeling for COMPASS-U *(see I. Stanik's talk)*

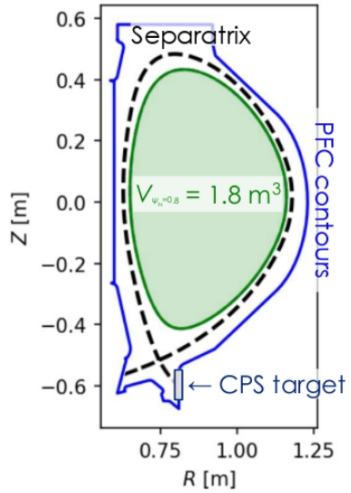
- **COMPASS-U H-mode discharge** simulated by **Fiesta+METIS** (half field scenario = 2.5 T, 0.8 MA)
- **Plasma-LMD interactions** by **HeatLMD** coupled to **COREDIV =** self-consistent 1D radial transport of impurities to plasma core & 2D multi-fluid transport in the SOL
- **Li** and **Sn** LM were considered yielding core concentrations:
  - **C^{Li} < 10-11%,** corresponding to **$P^{rad,Li}$ < 0.13 MW**
  - **C^{Sn} < 0.025%,** corresponding to **$P^{rad,Sn}$ < 1.1 MW**
- **Article by Irena Stanik** submitted to PoP *(see her presentation for more details)*

First ERO2.0 simulations of Li (& W) redeposition in COMPASS-U

- **Verification on COMPASS experimental data**
  - spectroscopy of carbon CII & CIII lines
  - 2019 LMD experiment Li redeposition on 14 screws
- **Predictions for COMPASS-U**
  - background plasma from SOLPS-ITER, H-mode scenario at 4.3 T, 1.2 MA
  - model ready to use, simulations on-going







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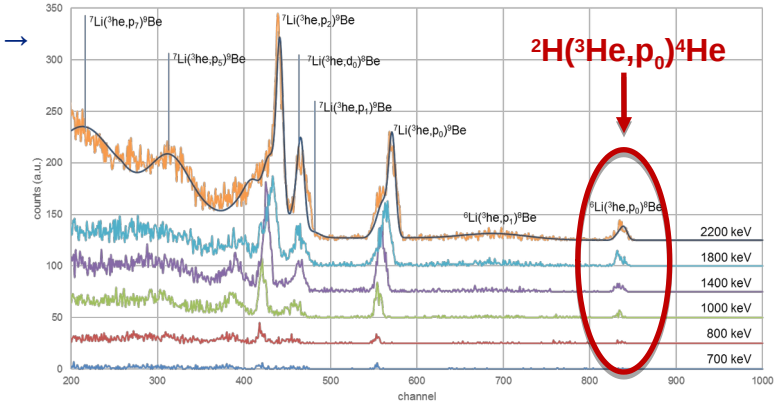
LMD activities 2024: Design & Experiments

COMPASS-U LMD tile design plans for 2024

- **Design**
  - Modification of the present design according the outcomes of the workshop
  - Integration of the LMD tile design into the COMPASS-U divertor
  - Structural analysis from EM loads (W tile + CPS block)

Follow-up from 2019 COMPASS LMD experiments

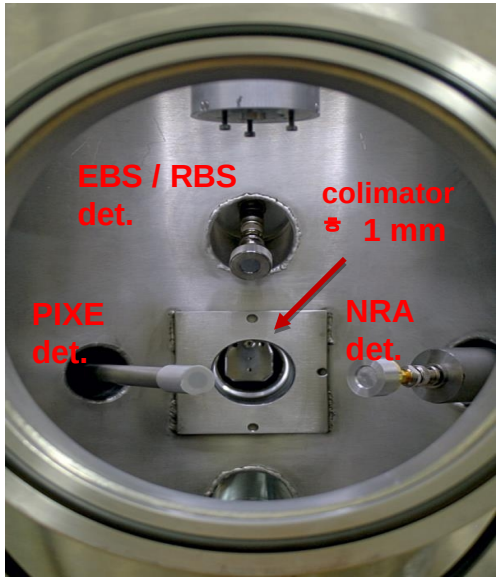
- **D retention in Li and LiSn alloy** (75% Sn) **during ELMy H-mode** exposures in COMPASS divertor
  - NRA analysis at **IPFN, Portugal** [R. Mateus, N. Catarino]
  - using IPFN JET chamber & 2300 keV $^{3}He^{+}$ beam
  - competing ^{2}H, ^{6}Li & ^{7}Li NRA emissions →



- **Exposure of LiSn module in OLMAT**
  - experiment TBP after NRA analysis
  - main goal = behavior of LiSn under HHF
    - Quantify erosion
    - Stability of LM
    - Vapor cooling effect
    - Change in Li depletion

R. Mateus et al., Nucl. Instrum. Methods Phys. Res. B 486 (2021) 55

JET chamber / Detector geometry



LMD activities 2024: Modeling

Modeling plans for 2024

- **Participation in OLMAT LiSn experiment + associated HeatLMD modeling:** J. Horacek, J. Cecrdle, A. de Castro
- **Coupled HeatLMD / COREDIV simulations of (Fiesta+METIS) COMPASS-U discharges:** J. Horacek, I. Stanik
  - preliminary results showed that a more rigorous assessment is needed by including into the workflow the following:
    - SOLPS-ITER (for divertor background);
    - ERO2.0 for the impurities (Li, Sn) transport inside LCFS and their deposition study assuming Marconi-Fusion cluster resources;
    - BIT1 (D. Tskhakaya's PIC code) for better prompt redeposition;
    - Possibly also ASTRA modeling of the central plasma Sn removal by 1 MW ECRH.
- **Coupling HeatLMD with a vapor cooling power model**
  - work in collaboration with G. Nallo from PoliTo
  - TBP after parallelization of HeatLMD