Overview of the COMPASS results

M. HRON, for the COMPASS Team*

Institute of Plasma Physics of the Czech Academy of Sciences, Prague, Czech Republic

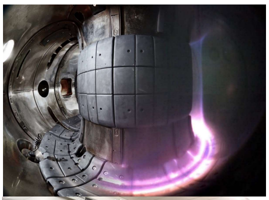
corresponding author: hron@ipp.cas.cz

*For the COMPASS Team list see Attachment 1 of the related IAEA FEC paper preprint https://conferences.iaea.org/event/214/contributions/17018/

COMPASS TOKAMAK MAIN FEATURES (2009 – 2021)

- ❑ ITER-like geometry (1:10)
- ❑ Ohmic & NBI-assisted H-mode
- ❑ Neutral beam injection (NBI) heating system
- ❑ Diagnostics focused on the edge plasma

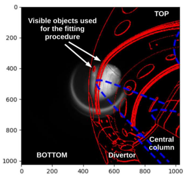
COMPASS parameters	
Major radius	0.56 m
Minor radius	0.20 m
Magnetic field	0.9 - 2.1 T
Plasma current	0.4 MA
NBI heating power	0.6 MW
Plasma volume	2 m³
Discharge length	0.3 – 1 s
Electron and ion temperature	1 keV



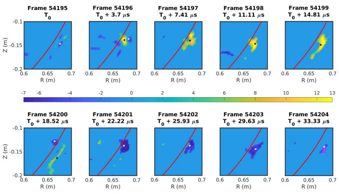
EDGE and SOL: TOMOGRAPHIC RECONSTRUCTION OF EDGE TURBULENCE

Idea of tomography with a single camera

- ➢ Observed objects (filaments) are 3D × Camera image is 2D ↔ **Missing one dimension**
  Assuming **helicoidal symmetry** → reduce the problem to 2D

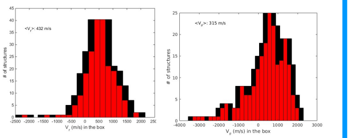


Representation of a field line in the visible camera view



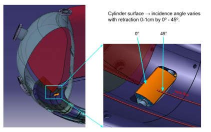
Tomography results
Poloidal planes (separatrix in red)
One positive & one negative blobs can be followed.

Structure detection and tracking

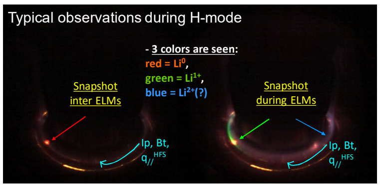


Velocity histogram single detection & tracking of structures in the pink rectangle

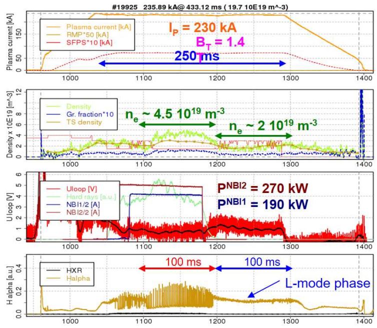
PLASMA – MATERIAL INTERACTION: Liquid Metal Divertor (LMD) experiments



To increase & control q_{dep} at target:
1) Module moved up into plasma using a manipulator *(shot-to-shot basis)*
2) Module surface is cylindrical
→ incidence angle increases gradually
(as the wetted area) w/ insertion into plasma



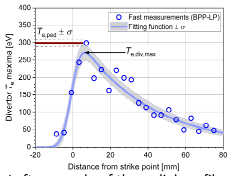
First experiments in a tokamak divertor using a CPS LMD module in ELMy H-mode conditions
No damage of CPS mesh + good power handling capabilities (both LM) up to **q_{dep} = 12 MW/m² & ε^{ELM}~15 kJ.m⁻²**
No droplet directly ejected from CPS surf. ; No efficient vapor shielding ; No contamination by Sn of core/SOL plasmas



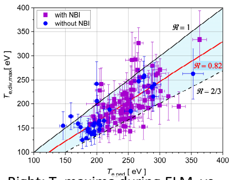
2 LMD modules filled w/ Li & w/ LiSn alloy *(25% Li, 75% Sn)* based on the CPS technology
Modules with mesh made of Mo wires with Ø = 100 µm and pore radius = 75 µm
Li module: 18 L-mode & 9 ELMy H-mode discharges:
L-mode → q_{dep} = 0.4 – 12 MW/m²
H-mode → q_{dep} = 0.5 – 18 MW/m²
LiSn module: 25 ELMy H-mode discharges:
average q_{dep} = 1 – 12 MW/m² & ELM relative energy~3%

ELM FILAMENTS IN THE SCRAPE-OFF LAYER

- ❑ T_e measurement with high temporal resolution during ELMs on the divertor
- ❑ Successfully resolved ELM filaments
- ❑ Representative maximum T_e at divertor obtained
  - ➢ close to the pedestal temperature
- ❑ Low energy transfer from electrons to ions observed
  - ➢ no enhancement of ELM ion energy →
  - ➢ → no physical sputtering of divertor material expected



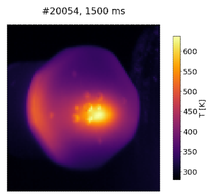
Left: Left: example of the radial profile of Te maxima during a single ELM on the outer divertor target.



Right: T_e maxima during ELM vs. corresponding pedestal temperature

RUNAWAY ELECTRONS (RE)

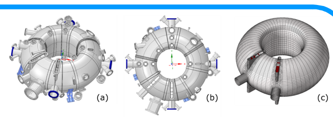
- ❑ Experimental & modelling studies of the RE generation, mitigation and suppression
- ❑ New diagnostics equipment obtained:
  - ➢ V-ECE heterodyne radiometer (monitoring of the early RE population phase)
  - ➢ semiconductor pixel detectors (bremstrahlung)
  - ➢ X-ray cameras (low energies)
  - ➢ HXR shielded photoneutrons and photodetectors (~100 keV – ~10 MeV)
  - ➢ room temperature solid state pellet injector (dynamics of RE losses)
  - ➢ calorimetry head in LFS protection limiter
- ❑ Effects of various mitigation strategies and control techniques studied
  - ➢ a) room temperature pellet injector; b) active RE radial position control
- ❑ Average RE energy detected by the calorimetry head spread from hundreds of Joules up to 15 kJ
- ❑ Active RE radial position control → average impact energy lowered by 40% (compared to RE drifting toward LFS)
- ❑ New attitude to combination of the RE beam position control, followed by a mitigation, were successfully tested
  - ➢ massive gas injection / impurity seeding / external magnetic perturbations / low-power elmg. waves



IR camera image of the RE impacting the calorimetry head

DISRUPTIONS

4 new MEMS accelerometers at 4 orthogonal positions (N, E, S, W) on equatorial ports of COMPASS.
2 displacement sensors (West-East).
→ Non-axisymmetric sideway disruption forces scaling for ITER

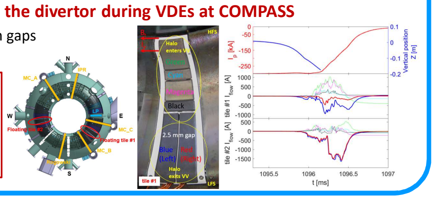


Sideways force on COMPASS might be caused by the vessel asymmetry (elongated ports)

Current flows towards the divertor during VDEs at COMPASS

2 special divertor tiles with gaps
→ eddy currents path

Tile segments measure:
- **Halo current**
- **Part of the eddy current** (flows along the divertor and through the gaps according to ATEC model)



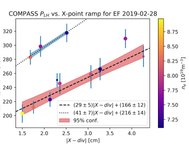
L-H TRANSITION

Dependence on the X-point height

- ❑ **P_{LH} increases** linearly **by 30-40 kW** (~18%) **per 1 cm** of the X-point height above the divertor
- ❑ Discharges with **q_{95}~3 - base value of P_{LH} larger by 50 kW**, i.e. 30% increase in P_{LH} around q_{95}~3, likely related to intrinsic error fields

Influence of the magnetic perturbation

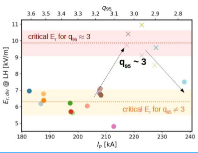
- ❑ Controlled HFS error field (EF)
  - ➢ simulates a **central solenoid displacement**
  - ➢ EF **correction from the LFS and top/bottom**
- ❑ L-H transitions with residual EF:
  - ➢ NBI-assisted - disruption rate ~ 50%
  - ➢ ohmic - disruptions were inevitable
- ❑ critical parameter: **low plasma rotation during ohmic L-H transitions** in COMPASS
  - ➢ small external momentum (P_{NBI} < 100 kW) sufficient to prevent the disruption.



← Density-normalized P_{LH} (|X-div|) as a function of the X-point height (left).

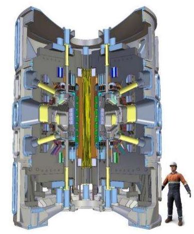
→ Critical E_r in the SOL at which the L-H transition occurs (right).

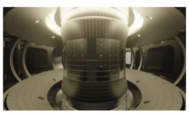
Several outliers are observed for q_{95} ~ 3.



CONCLUSIONS

- ❑ COMPASS tokamak was originally operated in CCFE (UK), reinstalled at IPP in Prague and scientifically exploited there since **2009**
- ❑ **COMPASS will be shutdown in 2nd Q/2021**
- ❑ Exploitation period - contributions to a number of „hot" topics in fusion research
  - ➢ improvement of understanding of various phenomena occurring in fusion plasmas
  - ➢ **contribution to the design of ITER**
- ❑ The knowledge gained at COMPASS – exploited in **construction of COMPASS-U**
  - ➢ B_T ≤ 5 T, I_p ≤ 2 MA, R = 0.89 m, t_{pulse} ≤ 5 s, Metallic first wall, high-temperature operation
  - ➢ presently in final design phase
  - ➢ first plasma planned for 2023
- ❑ More about COMPASS and COMPASS-U at this conference: posters by **M. Komm** (power exhaust), **V. Yanovskiy** (disruption forces), and **G. Zadvitskiy** (NBI modelling)





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