First results of LH coupling and current drive in WEST full metallic environment and commissioning of the new ELM resilient ICRF antenna

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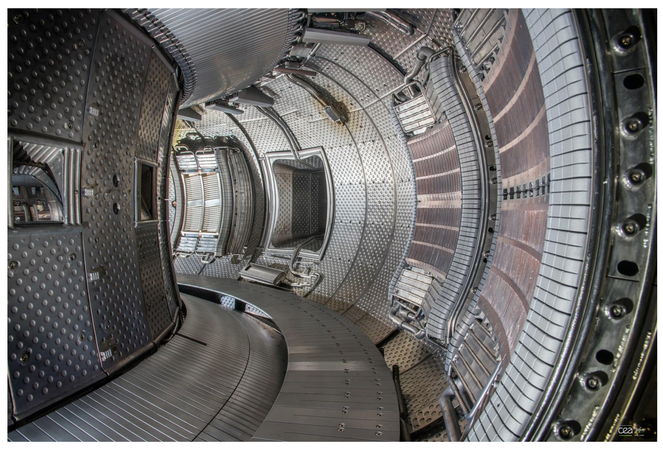
Introduction

WEST (tungsten-**W** **E**nvironment in **S**teady-state **T**okamak) has produced L-mode X-point plasmas since end 2017 *[J. Bucalossi et al., this conference, paper PD/1-2]* .



I_p (q_{95}~2.5)	1 MA
B_T	3.7 T
R	2.5 m
a	0.5 m
A	5-6
κ	1.3-1.8
δ	0.5-0.6
V_p	15 m^3
n_{GW} (1MA)	1.5 $10^{20} m^{-3}$
P_{ICRH}	9 MW
P_{LHCD}	7 MW
$T_{flattop}$ (0.8 MA)	1000 s

C2: Nov.17-Feb.18	Routine operation at 0.7 MA with diverted plasmas *[Nardon, EPS 2018]* Two LHCD antennas conditioned *[Ekedahl, EPS 2018]*
C3a: July18	LHCD up to 2.7 MW; One new ICRF antenna up to 0.6 MW Two boronisations: higher density ➔ better RF coupling

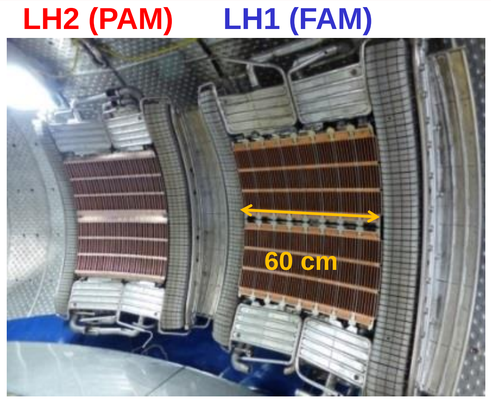
LH coupling and current drive results

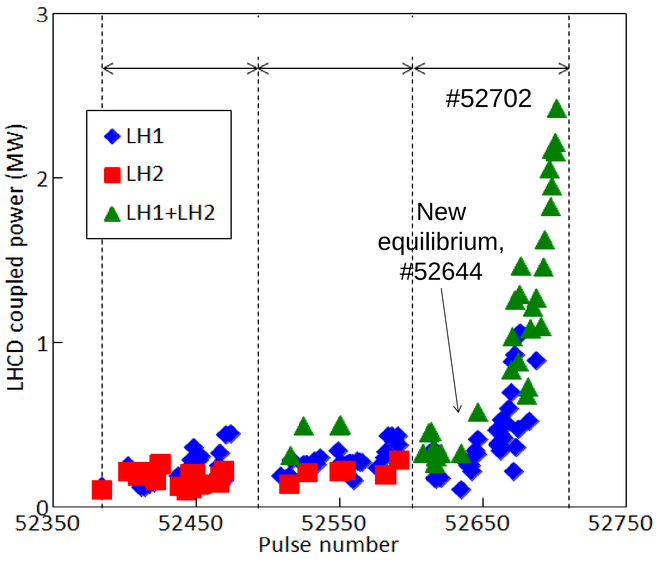
High power, CW LHCD system (f = 3.7 GHz):
16 klystrons, 9 MW at generator

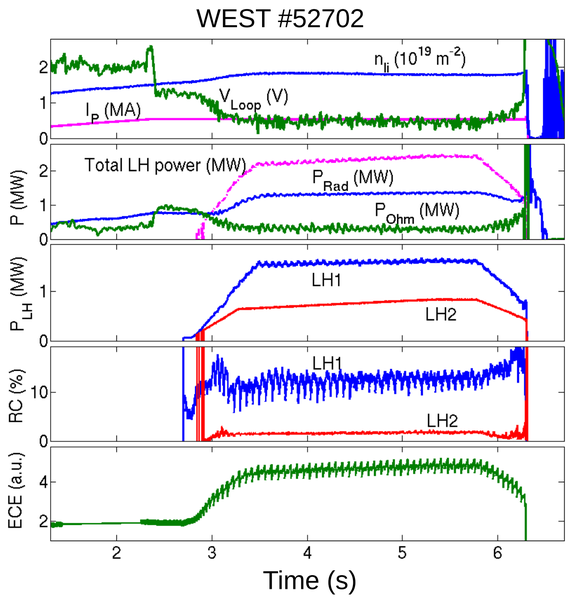
Two actively cooled antennas:
Fully-Active-Multijunction **(LH1 - FAM)**
Passive-Active-Multijunction **(LH2 - PAM)**

- LHCD commissioning took place in Feb 2018.
- Once adequate plasma equilibrium developed, the power could be increased rapidly, in two days only.

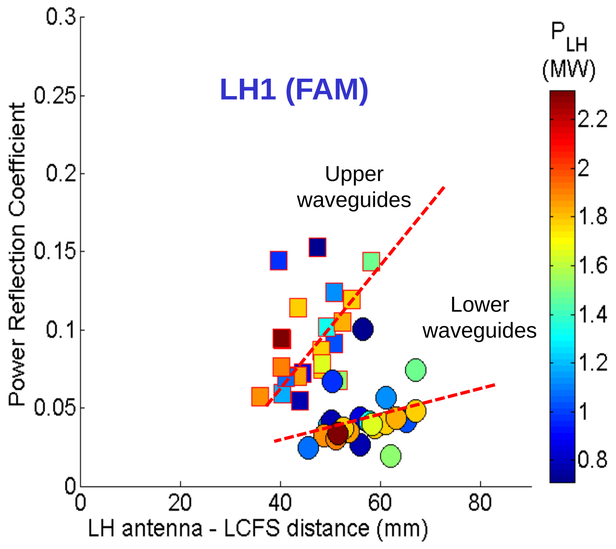
LH2 (PAM) **LH1 (FAM)**

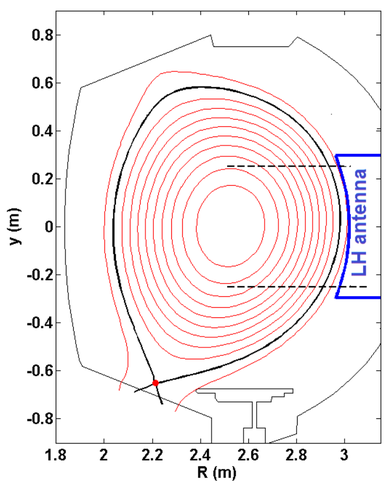






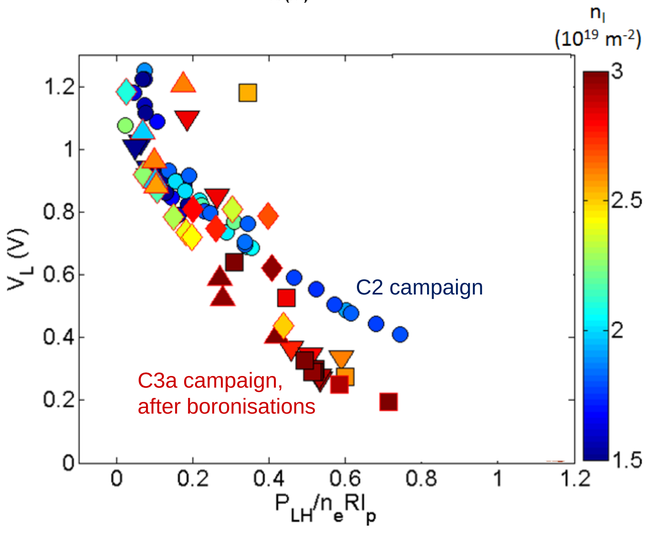
- Good LH wave coupling is obtained (RC < 15% on LH1 and < 3% on LH2).
- Poloidal asymmetry in RC observed: better coupling on lower rows.





LH antenna - LCFS distance is measured at ± 25 cm.

- Larger loop voltage drop with LHCD is observed in the last campaign (C3a), compared to the earlier campaign (C2).
- Better LHCD efficiency possibly due to cleaner plasma after boronisations, better LH coupling (i.e. higher spectrum directivity), lower peak $n_{//}$ on LH1 (1.8 instead of 2.0).

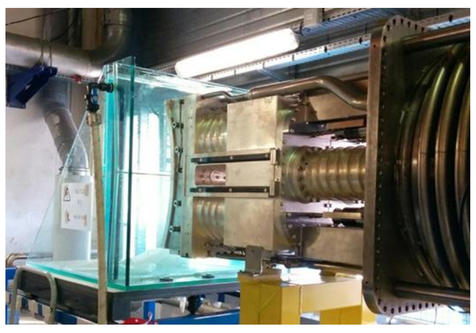


ICRH commissioning and plasma operation results

Three actively cooled ELM-resilient ICRF antennas have been fabricated for WEST, in collaboration with ASIPP *[J.M. Bernard et al., FED 2017].*

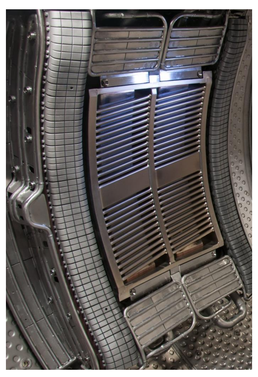
Two antennas have been tested on TITAN and then installed on WEST
[Bernard, SOFT 2018; Helou, SOFT 2018]

✓Low level test (mW range) → matching capability
✓High level test (27 kV) → voltage standoff capability
✓Leak test before introduction to the Tokamak → avoid risk of water leak in the machine

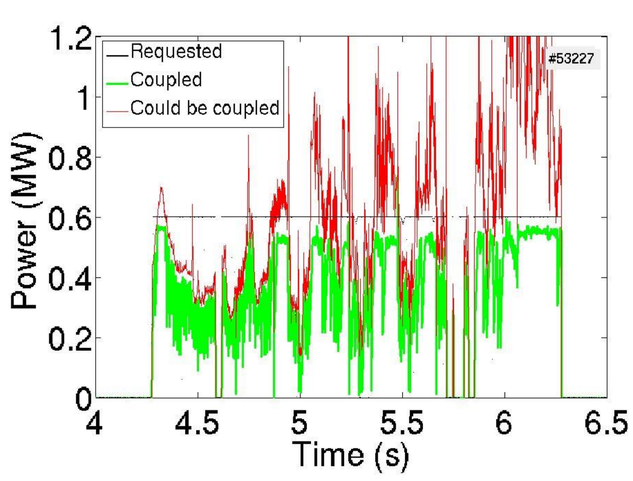


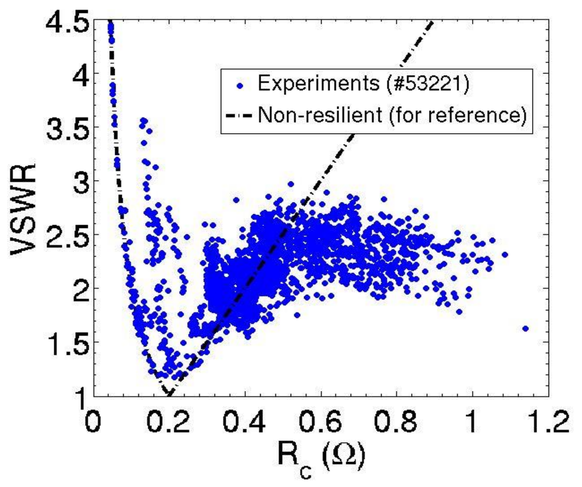
Set-up: aquarium with salted water
Distance aquarium ↔ straps is adjustable

One antenna has operated on plasma: load resilience demonstrated

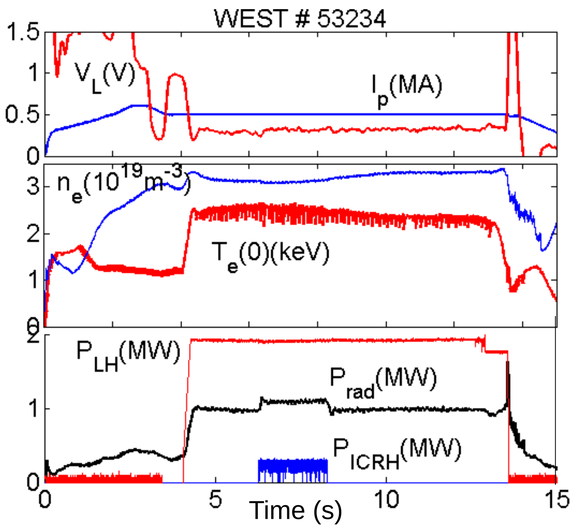


- ~ 40 shots with ICRH on plasma.
- Generators to antenna successfully restarted.
- CODAC & protection systems validated.
- Tuning on vacuum & plasma assessed.
- Load-resilience demonstrated on plasma.
- Peak ICRH power reached 600 kW.

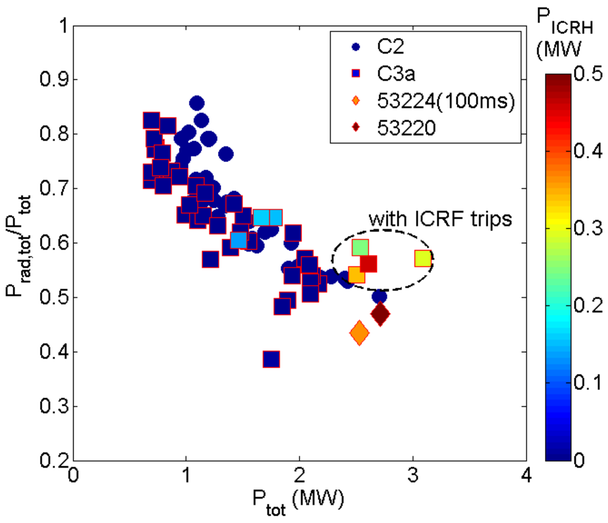




Latest achievements



- L-mode discharges lasting up to 15 s have been obtained.



- In discharges with LHCD alone, P_{rad}/P_{tot} decreases with P_{tot}.
- This trend needs to be confirmed at higher ICRH power.

Summary

- Long L-mode discharges (~ 15 s) have been obtained on WEST.
- LHCD power of 1.9 MW has been injected during 9.5 s; and 2.7 MW for 2 s.
- LH current drive efficiency is improved with respect to the previous WEST campaign.

- Two WEST ICRF antennas have been tested in the TITAN testbed and installed on WEST.
- One antenna has been commissioned on plasma.
- Load resilient feature has been confirmed during plasma movements.
- The peak coupled ICRH power has reached 600 kW.

- **New WEST campaign (C3b) has just started: 2 ICRF + 2 LHCD antennas**