Divertor power loads and scrape off layer width in the large aspect ratio full tungsten tokamak WEST

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DIVERTOR POWER LOADS AND SCRAPE OFF LAYER WIDTH IN THE LARGE ASPECT RATIO FULL TUNGSTEN TOKAMAK WEST

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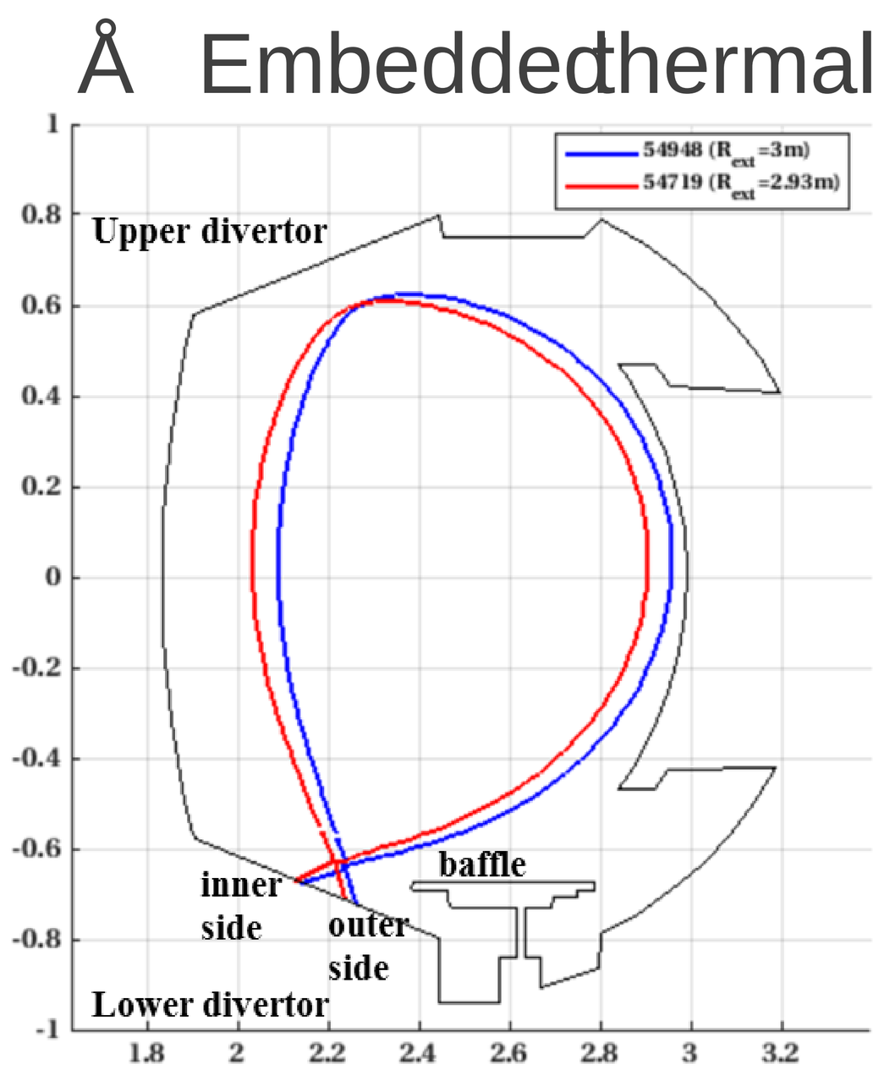
ABSTRACT

• A large database including different magnetic equilibrium and input power is investigated to compare the heat load pattern (location, amplitude of the peak and heat flux decay length) on the inner and outer regions as function of the continuous progress achieved in WEST: from the first ohmic diverted plasma (obtained during the second experimental campaign C2 in 2018) up to the high power (up to 8 MW total injected) and high energy (up to 90 MJ injected energy in lower single null configuration) steady state experiments performed in the last experimental campaign (C4 in 2019).

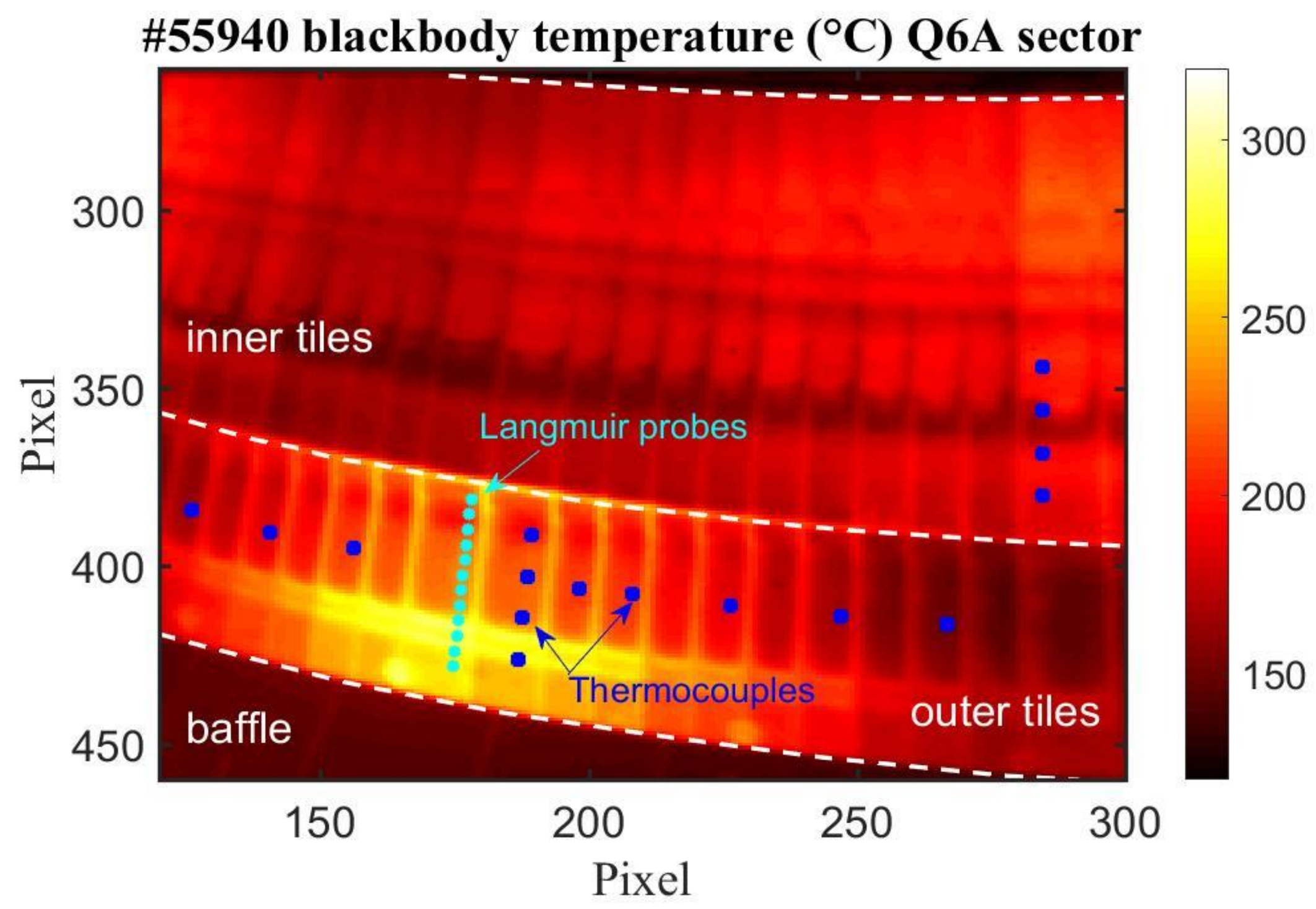
Diagnostic set-up

WEST: full metallic tokamak + extensive set of diagnostics for heat load measurement on lower divertor W tiles (W coated uncooled graphite tiles):

- Flush mounted Langmuir probes (LP) ńץץ ...with ...
- Infra-red (IR) thermography ńǁ estimated with TEDDY code
- Embedded thermal sensors (TC & FBG) ...



Estimated parameters though inversion



Heat flux comparison FBG/TC/LP/IR

Database

165 L-mode Lower Single Null (LSN) discharges with P_{tot} from 1 to 8 MW B_T = 3.7 T and Ip from 300 to 700 kA (corresponding q_{95} from 3.2 to 7.8)

FBG
TC Q6A
TC Q1A
LP
+ D plasma
O He plasma

a)

FBG
TC Q6A
TC Q1A
LP
IR
+ D plasma
O He plasma

b)

FBG
TC Q1A
LP
IR
+ D plasma
O He plasma

c)

Crosscheck

IR inversion and LP measurement fitted with Eich formula (see above) with averaged data over 1s to extract q_{peak}, λ_q and S for comparison to TC/FBG

Fig a): good agreement for q_{peak} with all diagnostics in the range ± 20%

Fig b): Inward shift from 1 to 2 cm between the diagnostics and the magnetic reconstruction

Fig c): 3 groups of λ_q appears

- TC_{Q6A} & LP(Q6A) (consecutive PFCs) [middle]
- IR (same PFC as TC_{Q6A}) [-40%]
- FBG (Q3A) & TC_{Q1A} [+40%] (180° and 60° toroidally spaced with other diag)

Divertor heat load steady progress during WEST phase 1

Divertor heat flux increase over the campaigns from about 0.2 MW/m² with 2.3 MW of Low Hybrid Current Drive (LHCD) during C2 to 6 MW/m² with 4MW of LHCD during C4 (Fig d)). 10MW/m² can be reached with ... The ... (Fig d)), despite equivalent plasma parameters (Ip, density, magnetic field) and estimated λ_q (Fig e)).

C4 OSP
C4 ISP
C3 OSP
C3 ISP
C2 OSP

d)

Only pulses at 500kA

C4 OSP
C3 OSP
C2 OSP

e)

Fig f) and g): The divertor heat load increase is also observed with the increase of absorbed energy for 1272 pulses of the different campaigns (E calculated from the cooling phase of the inertial PFC).

Same trend for C3 & C4 for the absorbed energy versus Einj in USN → equivalent radiated and neutral loads in USN

C4 OSP
C3 OSP
C2 OSP
+ D plasma
O He plasma

f)

C4 OSP
C3 OSP
C2 OSP
+ D plasma
O He plasma

g)

Fig h): Peak $q_{//}$ asymmetry about 3 (3/4 1/4) and equivalent for the whole database, no depency found with Pdiv, density or q95 but pulses mainly at 500kA and 300kA with small density variation at same Ip.

Fig i): E_{outer}/E_{inner} equivalent for the campaigns but affected by the baffle screening

C4 OSP
C3 OSP
+ D plasma
O He plasma

h)

C4 OSP
C3 OSP
+ D plasma
O He plasma

i)

CONCLUSION

- q_{peak} from the whole set of diagnostics is in good agreement in the ± 20% range
- λ_q and S scale quite linearly with the X-point height as expected
- But λ_q shows significant discrepancy between diagnostics and location in the machine (± 40% range) → improve IR processing (ε(s,T)) and post-mortem analysis TC/FBG
- q_{peak} has followed the continuous progress achieved in WEST and increase over the campaigns from 0.2MW/m² to 6MW/m² → 10 MW/m² steady state accessible with ~ 7 MW of additional power in L-mode discharge
- Heat load distribution is clearly asymmetric with a 3/4 and 1/4 distribution for $q_{//}$ higher on the outer region as commonly observed in forward-B configuration

ACKNOWLEDGEMENTS

• This work has been carried out thanks to the support of the A*MIDEX project (n° ANR-11-IDEX-0001-02) funded by the « Investissements d'Avenir » French Government program, managed by the French National Research Agency (ANR).
• This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.