High-Z core radiation effects in DIII-D and JET plasmas

by

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DIII-D Wall Change Community Forum

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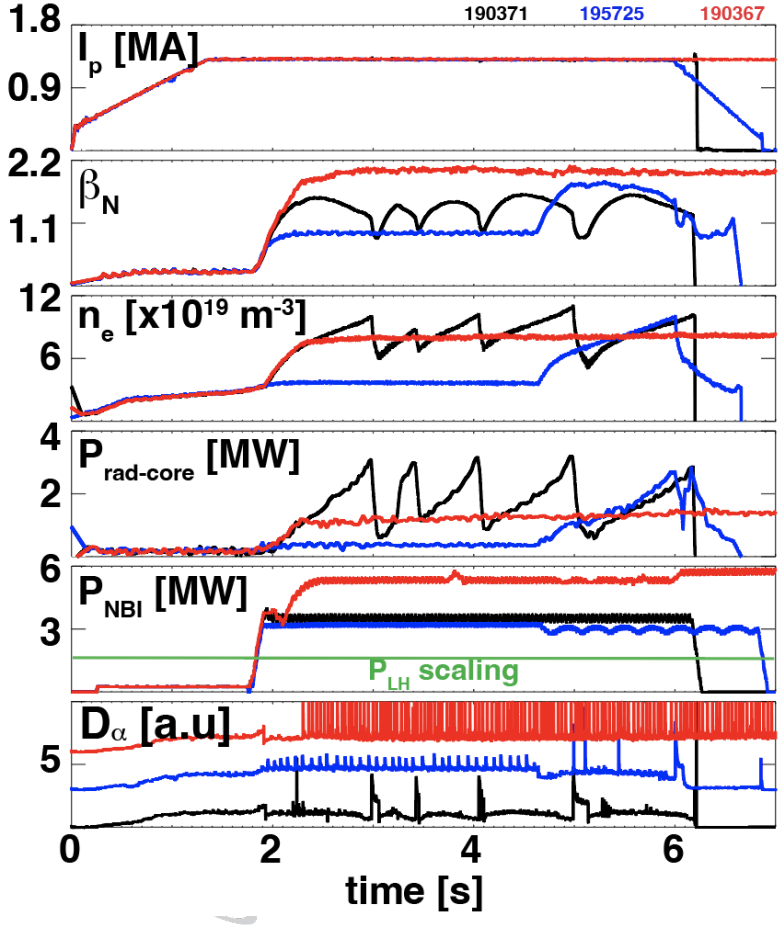
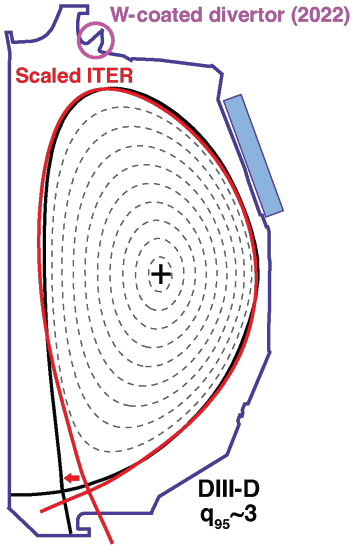
- ✓ 22 years @ JET
  - 14 with C-Wall, 8 with Be/W Wall
- ✓ 9 years @ ASDEX Upgrade
  - 4 with C-Wall, 5 with W-Wall
- ✓ 3.5 years @ DIII-D
  - All with C-Wall…..
- ✓ Chair of ITPA integrated scenario TG for 12 years

DIII-D core radiation collapses just from W deposits on the carbon wall (from SAS VW operation on other days)





ITER baseline scenario tests at DIII-D, access power scan (not using the SAS-VW). W core radiation collapse when C_W ~1x10^{-5}

A.C.C. Sips et al, Nucl. Fusion 64 (2024) 076037

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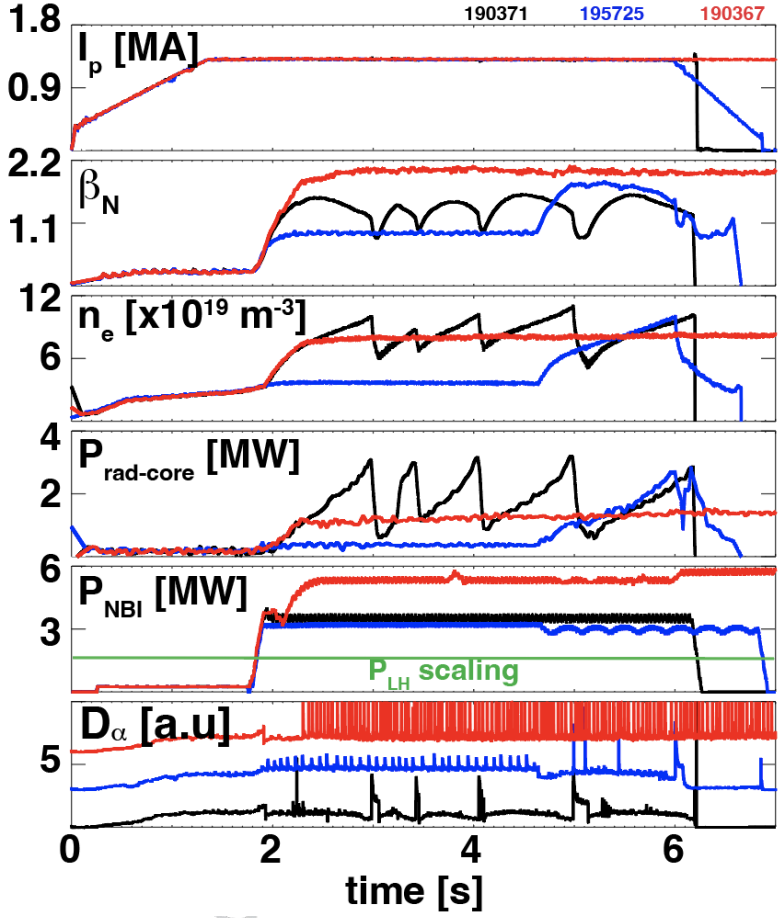

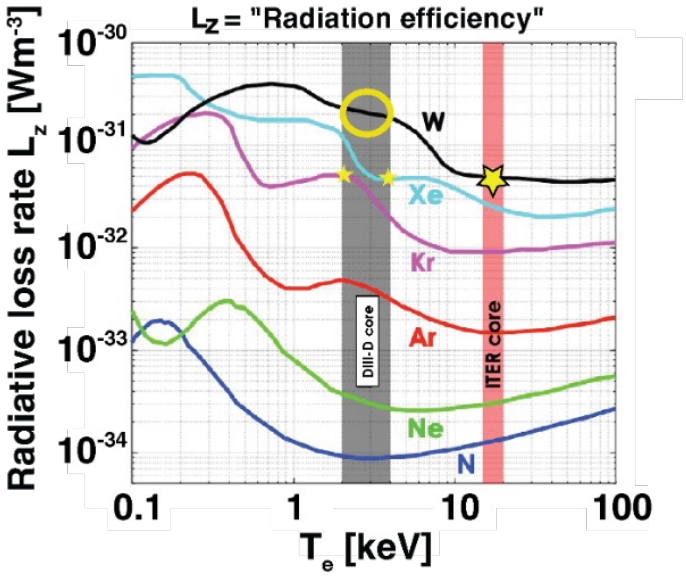

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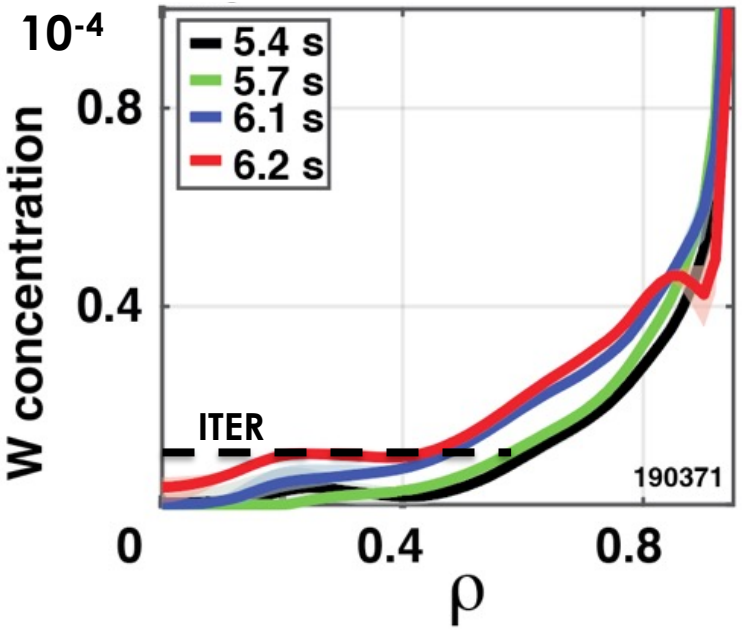
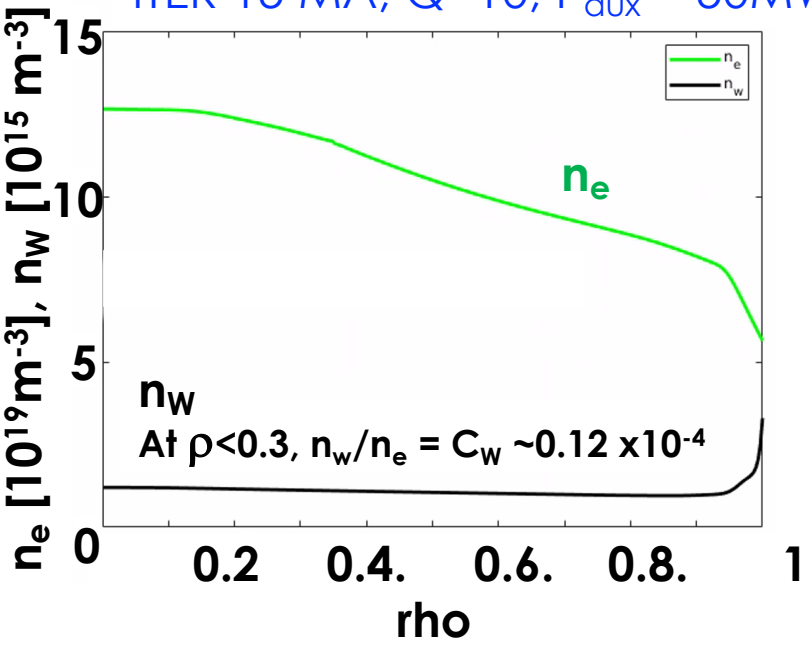
C_W in DIII-D with tiny W coverage is the same as in ITER predictions for a full W-wall

DIII-D with core collapses

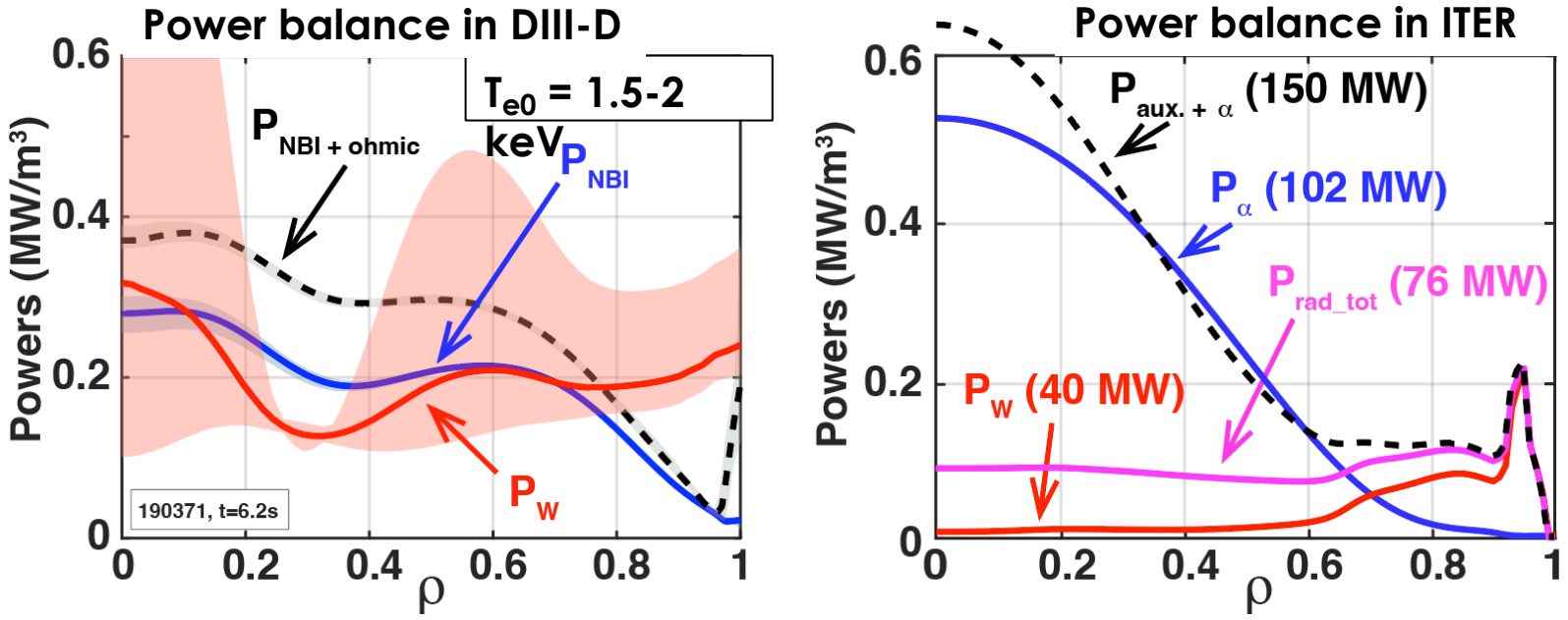


ITER 15 MA, Q~10, P_{aux} = 50MW



1. W transport/screening in DIII-D is different compared to a reactor
2. P_{rad} ~10x higher per W-atom (DIII-D: T_{e0}~ 3keV, ITER/FPP: T_{e0}~ 20 keV)

Power balance is Different in ITER When Using the Same W-Concentration Profile as in DIII-D @ C_W ~10^{-5}



DIII-D has a core radiation collapse, but ITER would not:

- W radiates ~10x less at ITER core temperatures (**T_{e0} = 18 keV, Q = 10**)
- ITER, at higher C_W > (few)x10^{-5}, more input power required, reducing Q

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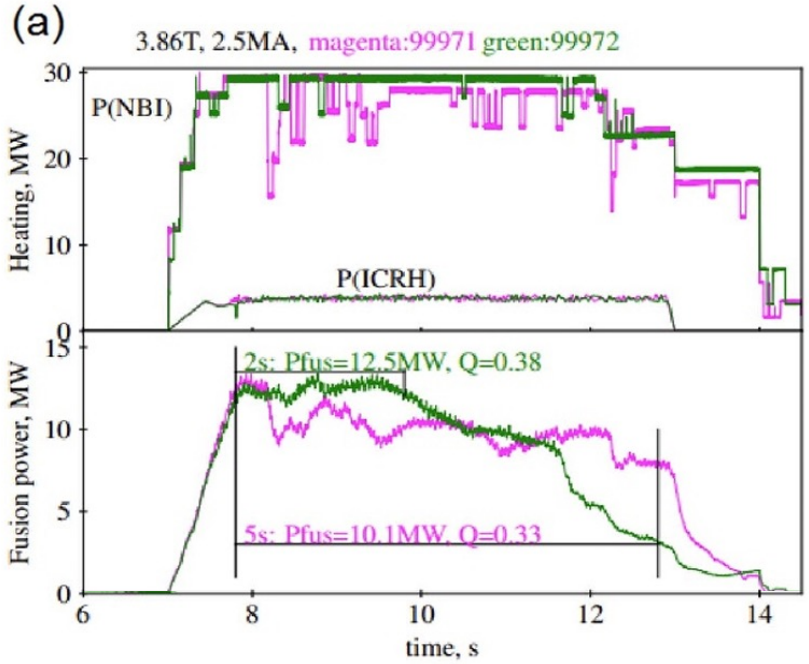
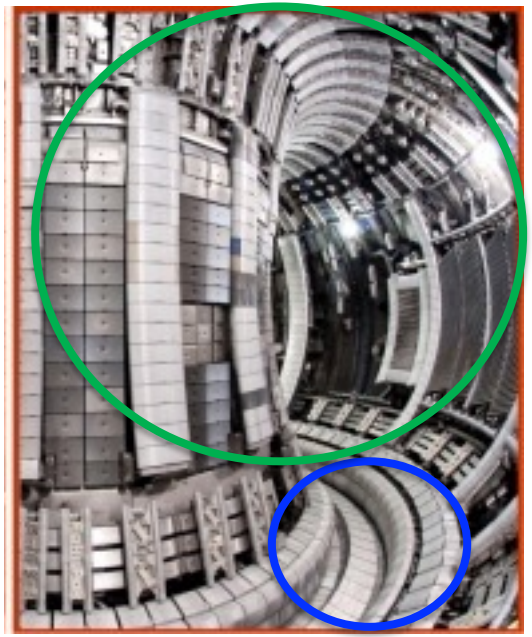
JET with Be/W wall at T_{e0} ~8-10 keV has high core W radiation compromising fusion performance & survival



JET

max P_{fus} shot



Be Wall

W divertor

"Core impurity accumulation was the main factor limiting the stationarity of the pulses, which was partially mitigated by increasing the gas fuelling rate at the cost of fusion performance"

M. Maslov et al, Nucl. Fusion 63 (2023) 112002

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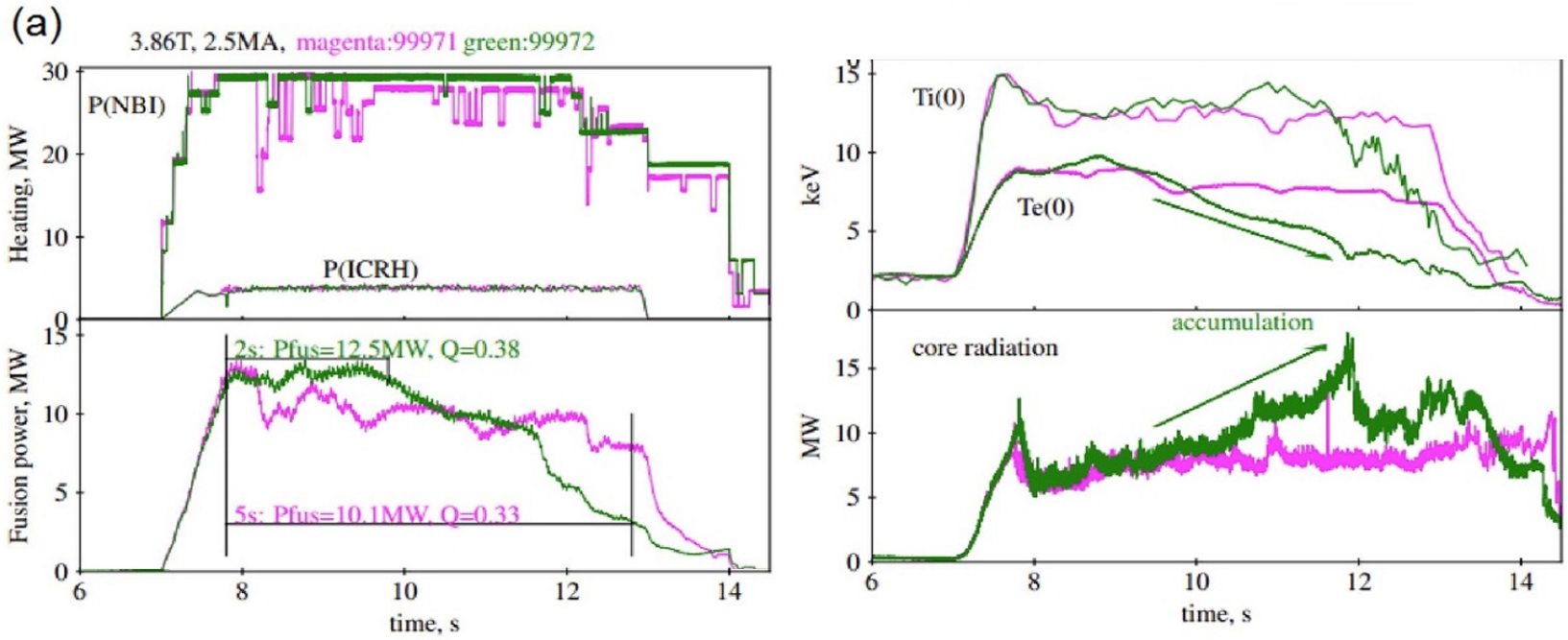

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Mitigating actions required to prevent W core collapses are severe (JET & ASDEX Upgrade)

Compared to carbon, a high-Z wall, in medium size devices*:

- Requires increasing SOL or divertor density, thus increasing ν^*
- Some plasma scenarios are not possible (core radiation collapse)
  - Need for core ECH or RF power in all plasmas scenarios
  - Despite core heating, restriction in operating space
- Appling a Boronization will cover high-Z surfaces in contact with the plasma for a few days (not studying the high-Z wall):
  - This is not reactor relevant
- All the above done for ~20 years → High high-Z wall at DIII-D would not be unique

***DIII-D before having Carbon wall (late 1980's) – non-stationary plasmas (Inconel Wall)**

Operation limits for solid-W and coated-W divertor tiles give lower input power limits compared to carbon wall

Tile surface temperature limits will be more restrictive compared to carbon wall (see JET):

- W-coating cracks and carbon migrates to surface above 1200°C
- Bulk-W, e.g. segmented tile at JET, has temperature limits set by Inconel tile clamps and fixings: ~400°C bulk and 1100°C surface

This reduces (compared to carbon) the allowed input power and input energy to the tiles AND need monitoring/protection in real-time (to be assessed and implemented for DIII-D)

No He-GDC for intershot conditioning – or next shot has 2-5% He

- DIII-D is "hooked" on He-GDC