Core versus edge confinement in JET with ILW compared to CFC first-wall.

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See appendix of F. Romanelli et al., Fusion Energy, 2010 (23rd IAEA Intern. Conference, Daejeon, 2010).

INTRODUCTION

The baseline type I ELMy H-mode and Hybrid scenarios have been re-established in JET with the new W MKII-HD divertor and Be-main wall (hereafter called ITER-like wall, ILW).
The aim of this work is to compare the confinement in the ILW and CFC plasmas, to discuss their differences and to clarify the role of the pedestal and core confinement. The electron density and temperature parameters (pedestal heights and profiles) are obtained from the High Resolution Thomson Scattering diagnostic [1] and the plasma thermal energy is obtained from the diamagnetic energy corrected for the fast particle losses.

THE DATABASE

The database is composed of ≈114 CFC shots [2,3] and ≈400 ILW shots with NBI heating only. Shots and time windows are selected with the following criteria:

- Type I ELMy shots
- constant power and H98 for a few τ_E
- no NTMs

The main parameter ranges are shown in Table 1.

	scenario	δ	Ip (MA)	P_{NET} (MW)	q_{95}
CFC	BL low δ	~0.28	1.0-2.5	5-20	2.8-3.5
CFC	BL high δ	0.4-0.45	1.0-2.5	5-20	3.3-3.6
CFC	Hyb. low δ	~0.23	1.7-2.0	5-20	3.6-4.0
CFC	Hyb. high δ	0.35-0.4	1.3-2.0	5-20	3.6-4.5
ILW	BL low δ	0.25-0.30	1.2-3.5	3-25	2.8-3.6
ILW	BL high δ	0.38-0.42	1.7-2.5	5-20	3.3-3.6
ILW	Hyb. low δ	0.26-0.30	1.7-2.0	3-25	3.6-4.0
ILW	Hyb. high δ	0.35-0.4	1.5	10-25	3.6-4.5

Table 1. Parameter range of the four analyzed scenarios

CONFINEMENT OVERVIEW

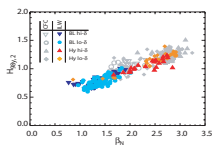

Figure 1: H98 versus normalized beta

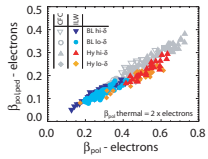

Figure 2: Pedestal versus total beta

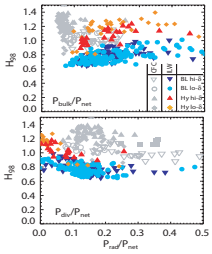

Figure 3: H98 versus power radiated by the bulk plasma normalized to Pnet.

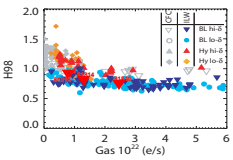

Figure 4: H98 versus gas rate.

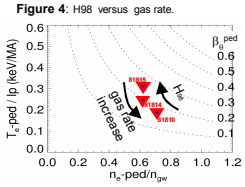

Figure 5: Normalized pedestal Te vs normalized pedestal Ne for three ILW high δ BL with similar Ip, Bt and Pnet but different gas rate.

Global confinement H_{98} and β_N

The confinement factor H_{98} as a function of β_N for the CFC and the ILW database is shown in Figure 1. For both walls a beta scaling is observed

- The baseline CFC plasmas have a higher H_{98}~1 than the baseline ILW plasmas H_{98}~0.8.
- The hybrid CFC plasmas have a similar confinement enhancement factor as achieved in the CFC plasmas H98≤1.3
- Note the same trend of H_{98} versus the normalized beta for both CFC and ILW.

- For the baseline scenarios the pedestal contribution to the total confinement is similar with both walls (Figure 2)
- For the hybrid scenarios, ILW plasmas show a lower pedestal contribution to the total confinement than the CFC plasmas.

THE RADIATED POWER

Due to the different impurities in ILW and CFC plasmas, the radiation distribution is expected to differ between the two walls. In the CFC wall carbon (which radiates at the edge) is the main radiator, whereas in the ILW W and Ni (which radiate in the core) are the main radiators power might be an important parameter.

In general the core radiation is increased in the ILW with respect to the CFC wall

- In ILW shots a weak positive trend between P_{bulk}/P_{net} the H_{98} is present.
- Baseline ILW shots with P_{bulk}/P_{net} ≈ 0.1-0.2 have H_{98} lower than the corresponding CFC shots.
- The increased core radiation does not seemingly affect the hybrid plasma performance in the ILW compared to the CFC shots
- The edge radiation is signficantly reduced in the ILW as expected because of the absence of carbon, but without a clear implications on the confinement
- This observations suggest that P_{rad}/P_{net} may not be a key factor in the difference between CFC and ILW plasmas.

THE DOSING LEVEL

An important role in obtainining high H_{98} in ILW plasmas is played by the dosing level.

- A clear negative trend is present for the low δ baseline ILW shots.
- For high δ baseline ILW shots and the ILW hyrids the trend is less clear. The large sperad of the data is related to the fact that plasmas with different Ip, Bt and P_{net} are considered.

To minimize this problem, three high δ baseline ILW shots with Ip=2.0MA, Bt=2.2T and Pnet=10-11MW have been analyzed. A negative trend of H_{98} with gas rate is present:
The increase of H_{98} as the gas rate is reduced can be ascribed to increase of the pedestal presure.
- The gas rate reduction produces a weak redeuction of N_e^{ped}, but a strong increase of T_e^{ped}.
- β_θ^{ped} increases from ≈0.18 to ≈0.26.

The increase occurs also in the core but, as shown in Figure 6 from the normalized kinetic profile, the main confinement improvement is related to the pedestal.

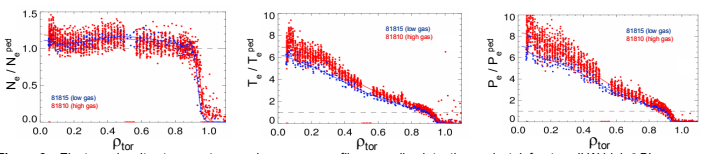

Figure 6: Electron density, temperature and pressure profile normalized to the pedestal for two ILW high δ BL shots with same Ip, Bt and Pnet but different gas rate.

CORE and PEDESTAL CONFINEMENT

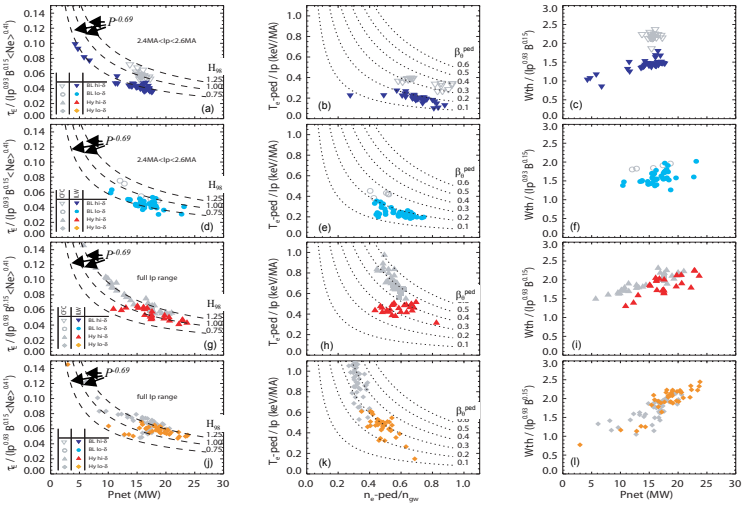

Figure 7: Normalized energy confinement vs input power, normalized pedestal Te versus pedestal Ne and thermal energy versus input power for high δ BL plasmas (first row), for low δ BL plasmas (second row) and hybrid plasmas (third row).

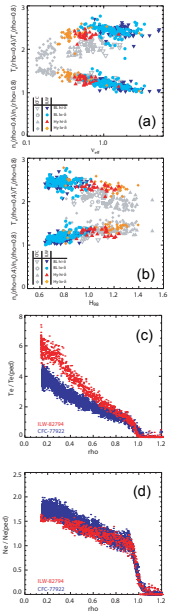

Figure 8: gradient length (a) versus ν_{eff} and (b) H_{98} (c&d) normalized Ne and Te profile for a ILW (blue) and a CFC (red) shot at ν_{eff}=0.3-0.6

GLOBAL AND PEDESTAL CONFINEMENT

The normalized τ_E versus P_{net} is shown in the first column of Figure 7.

- High δ BL have H_{98} lower in ILW than in the CFC shots, Figure 7(a).
  This is related to lower T_e^{ped}, as N_e^{ped} is similar, Figure 7(b).
  β_θ^{ped} ≈ 0.1-0.2 in ILW
  β_θ^{ped} ≈0.2 0.3 in CFC.
- Low δ BLs have confinement relatively similar in ILW and CFC.
  ILW and CFC shots with similar N_e^{ped} have similar T_e^{ped}
  Both ILW and CFC shots lie on the same β_θ^{ped} ≈0.2 curve
- Low and high Hybrids ILW plasmas have H_{98} comparable to the CFC hybrids. ILW shots have lower T_e^{ped}, but slightly higher N_e^{ped} (h&k). However, the thermal energies are comparable, Figure 7(i&l).

GRADIENT LENGTH

- CFC shots have a negative trend of R/Ln_e with the collisionality [2,3,5]. The ILW shots follow the same trend, Figure 8a. A positive trend is present for R/LTe in CFC shots, while no trend is present for ILW shots, Figure 8a.

- As a consequence the ILW shots feature more peaked pressure profiles at low collisionality than the CFC shots, thus CFC Hybrids have a larger pedestal contribution to confinement compared to the ILW plasmas

Two high-δ Hybrids with a similar confinement (ILW: H_{98}~1.25, CFC: H_{98}~1.3) show a clear difference in R/LT_e between ILW and CFC shots. Figures 8(c) and 8(d) show the normalized Ne and Te profiles for two high δ hybrid shots with ν_{eff}=0.3-0.6.

- Normalized density profiles are similar.
- Normalized temperature profile is more peaked for the ILW shot.

→ Rotation velocity measurements not yet available, but good food for critical gradient studies...

CONCLUSIONS

- **High δ BL** plasmas have lower H_{98} with the ILW .
  The reduced performance is mainly related to a lower pedestal T_e.
- **ILW Low δ BL** plasmas can reach the same pedestal parameters as CFC plasmas. In this case the confinement are relatively similar.
- Low gas rate seems necessary to reach high H_{98}.
- **ILW Hybrids** plasmas have confinement similar the corresponding CFC plasmas. But distribution core/pedestal has changed
- Profile peaking: - n_e peaking in ILW and CFC are consistent and follow the same trend with ν_{eff}.
  - T_e peaking is different: at the same collisionality, ILW plasma are more peaked.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Pasqualotto R. Et al., Rev. Sci. Instrum. **75**, 3891 (2004)
[2] Frassinetti et al., 37th EPS Conference, 2010 Dublin, Ireland, P1.1031.
[3] Beurskens et al., submitted to Nucl. Fusion
[4] Saibene et al., Nucl. Fusion **45**, 297 (2005).
[5] Maslov M. et al., Nucl. Fusion **49**, 075037(2009)