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Demonstration of real time wall conditioning and plasma control through impurity powder injection in LHD

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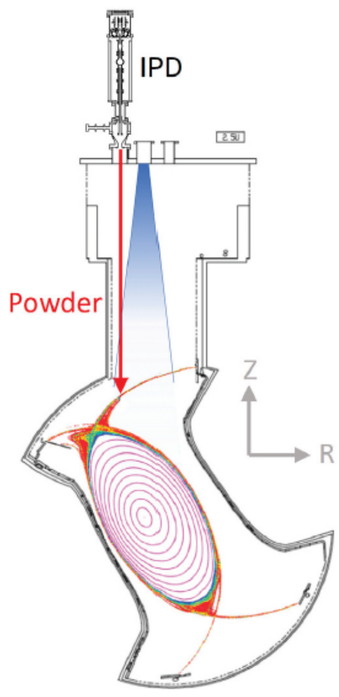
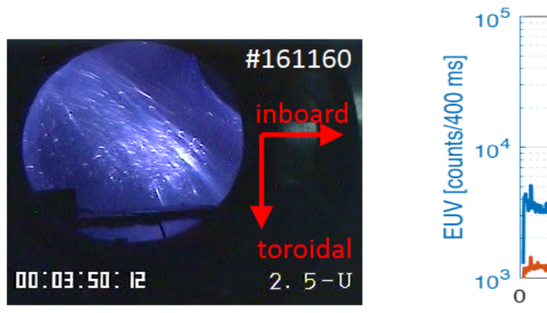
ABSTRACT

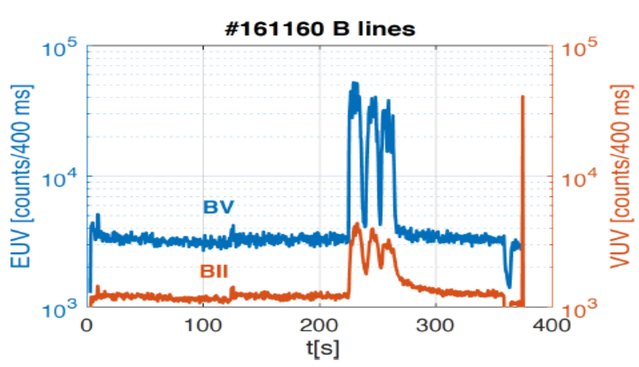
- The Impurity Powder Dropper (IPD) [1], developed and built by PPPL, is installed on LHD
- Boron (B) and Boron Nitride (BN) powder is successfully injected in the helical plasma
- Reduction of wall recycling and impurity content due to deposition of B on the plasma facing component is observed, both on a shot-to-shot basis, and in real time

BACKGROUND



- Injection of B (and its composites) powder into the plasma allows for real-time boronization. Advantages with respect to the traditional glow discharge boronization: no toxic diborane gas (B_2H_6), no interruption of plasma operation.
- Technique already tested in tokamaks [2,3]
- IPD installation on LHD guided by EMC3-EIRENE and DUSTT simulations [4]
- Successful injection of B and BN powder demonstrated, confirmed by multiple diagnostics
- for different heating schemes and magnetic configuration (R_{ax}=3.6, 3.9 m)
- Plasma response characterized in Ref [5]

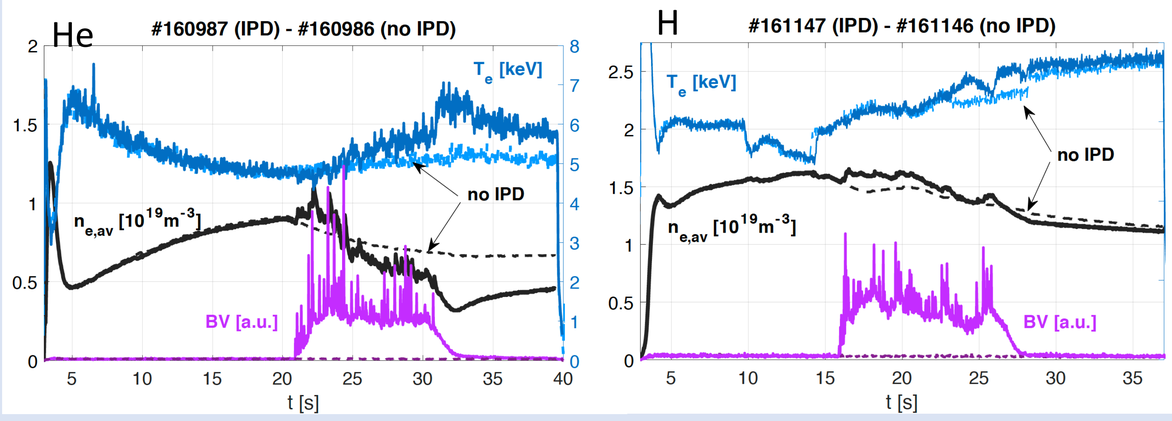




Real time reduction of recycling

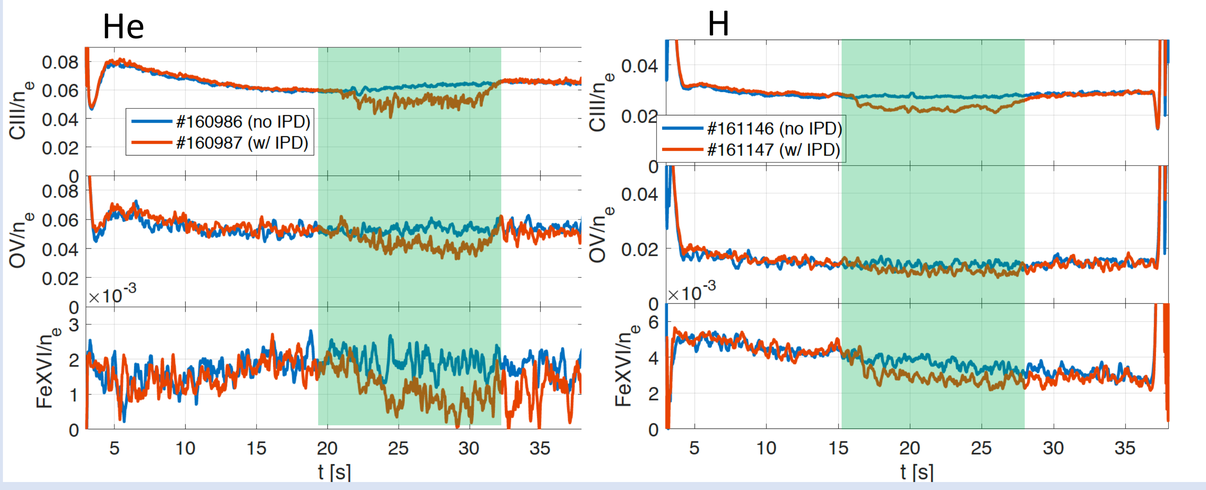
10 s long B injection in ECH heated He and H plasma, constant gas puff:

- Initial increase of n_e with respect to no powder case (dashed) due to extra electron source
- After a few s, n_e decreases: change in recycling
- Radiation from neutrals decreased (He_I, H_α)
- T_e increased (P_{in}=const)
- Further n_e decrease after B electron source removed

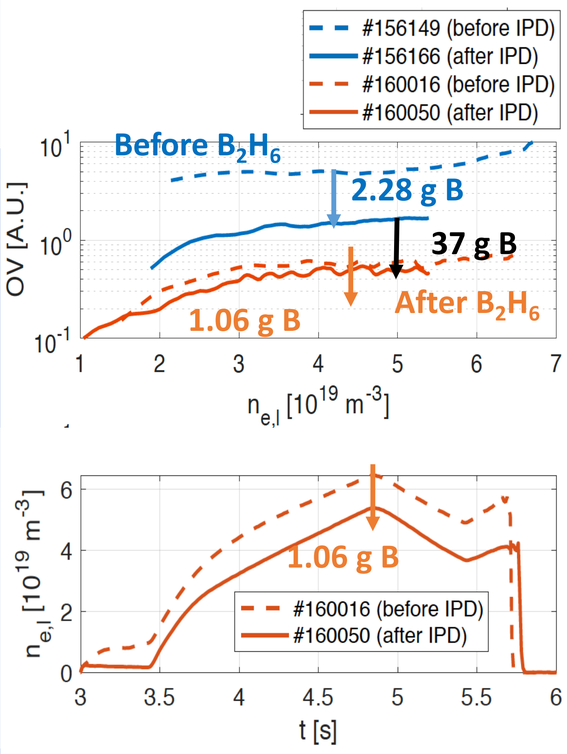


Real time reduction of impurity concentration

Concentration of impurities generated at the divertor plates (C) and first wall (O, Fe) is also observed to decrease in real time during boron powder injection



Reduction of impurity content and wall recycling



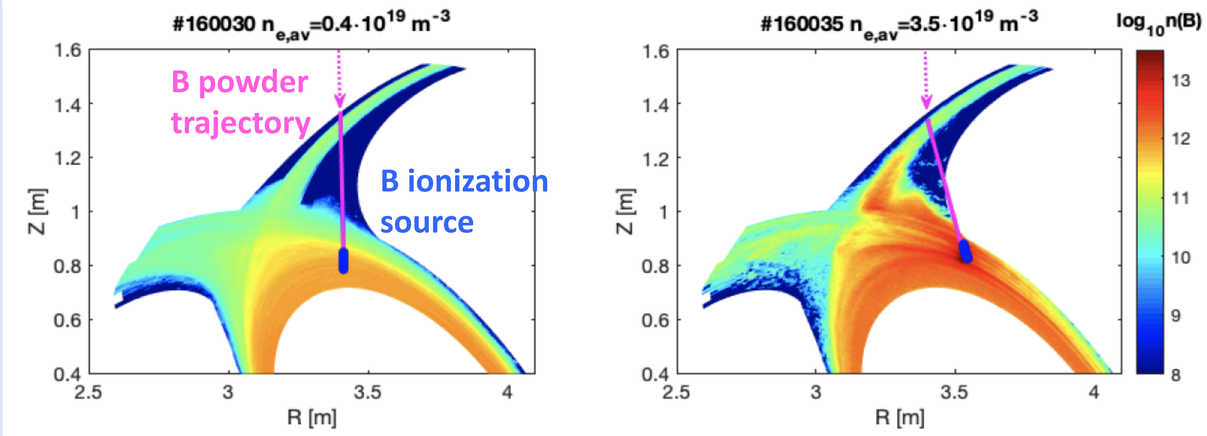
- Control discharge: density ramp without IPD. Performed before (dashed) and after IPD experiments (cumulative B and BN injection)
- **Before B_2H_6** boronization:
- Oxygen level in LHD drops by a factor 5 (spectroscopy measurement of OV line)
- Carbon level drops by a factor 2
- Radiated power decreased
- Similar results at R_{ax} = 3.6 m and R_{ax} = 3.9m

- No impurity level reduction for experiments **after B_2H_6** (37g B in 7h)
- Still, reduction of recycling: ~ 20% lower n_e with same gas puff

Modeling with EMC3-EIRENE-DUSTT

Interpretative simulations are performed with coupled EMC3-EIRENE and DUSTT codes, confirming trend of prior predictive simulations [4].

- For high density, the powder grains are deflected by the plasma flow in the divertor leg
- Deeper penetration for low density plasmas
- Predictive simulations suggest more even deposition of injected B on the wall [6], due to reduced impurity friction [7]



REFERENCES

[1] A. Nagy et al., RSI 2018
[2] R. Lunsford et al., NF 2019
[3] A. Bortolon et al., NF 2020
[4] M. Shoji et al., CPP 2019
[5] F. Nespoli et al., NME 2020
[6] M. Shoji et al., NME 2020
[7] F. Effenberg et al., NME 2020

CONCLUSION

- Boron and boron nitride powder is injected in LHD
- Wall conditioning effects (reduction of recycling and impurity content) are demonstrated both on a shot-to-shot basis and in real time
- Predictive simulations suggest low density plasmas might lead to more efficient boronization of the wall.