Impact of electron density profile on core impurity behaviour in NBI-heated LHD plasmas

MAX-PLANCK-INSTITUT FÜR PLASMAPHYSIK

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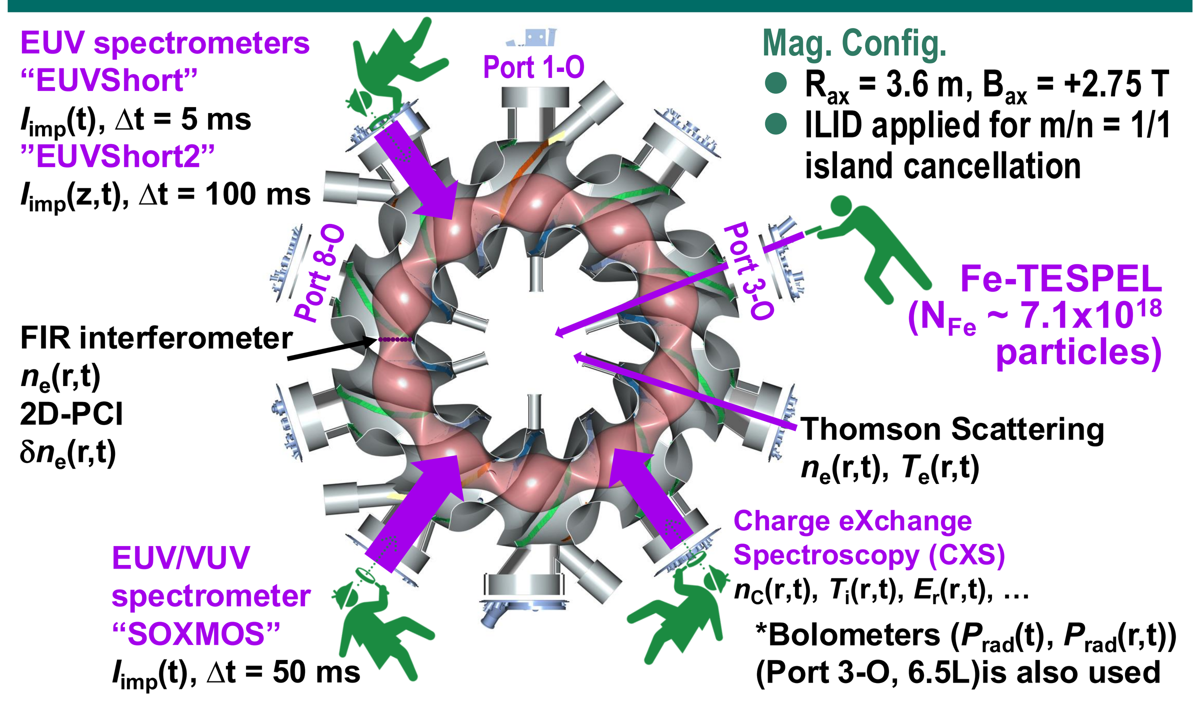
HIGHLIGHT

- Impact of the electron density profile shape on Fe impurity transport was investigated in NBI-heated LHD plasmas
- A significant reduction in the core Te was observed only when Fe impurities penetrated deeply into plasmas with a peaked n_e profiles
- However, when comparing cases with shallow Fe deposition, the Fe line emission intensity decayed more rapidly in plasmas with a peaked n_e profile than in plasmas with a flat n_e profile, contrary to expectations
- When impurities were injected into plasmas with a flat n_e profile, low-frequency fluctuations were suppressed regardless of the impurity deposition location

EXPERIMENT SETUP

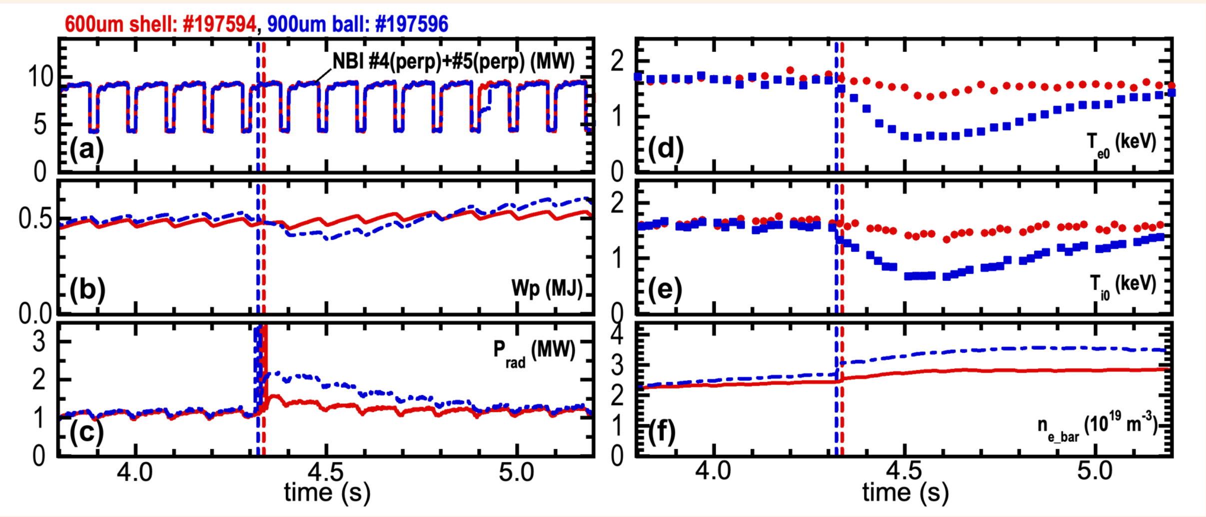


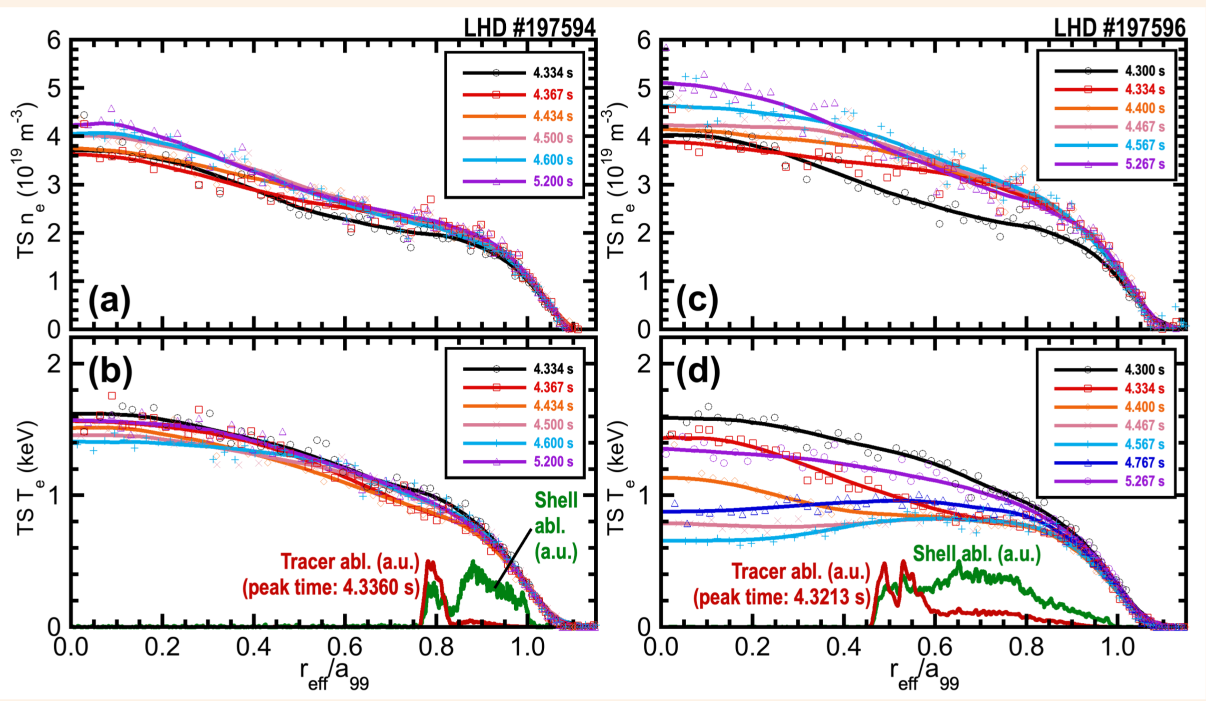
CONCLUDING REMARKS

- Impact of the n_e profile shape on Fe impurity transport was investigated in NBI-heated LHD plasmas using Fe-TESPEL injection
- A significant degradation of the core T_e was observed only when Fe impurities were deposited deeply into plasmas with a peaked n_e profile, indicating enhanced impurity accumulation in the core region
- In contrast, for shallower impurity deposition, Fe line emissions decayed more rapidly in the peaked-density plasma than in the flat-density plasma, suggesting that impurity transport cannot be explained solely by the density profile shape
- Distinct responses of low-frequency n_e fluctuations were observed between the two density-profile configurations, implying a possible coupling between impurity transport and turbulence
- These results indicate that both the impurity deposition location and the background density profile play important roles in determining impurity confinement in LHD plasmas

EXPERIMENTAL RESULTS

PEAKED DENSITY CASE





DISCUSSION

TEMPORAL BEHAVIOURS

- To modify the electron density profile shape, different combinations of NBIs were employed
  - ✓ Peaked profile: Flat Perp. #5 + Mod. Perp. #4
  - ✓ Flat profile: Flat Tang. #3 + Mod. Perp. #4
- Although the NBI combinations were different, the total injected heating power was nearly identical in both cases
- However, plasmas including tangential NBI (flat n_e case) exhibited slightly higher T_e due to stronger electron heating
  - ✓ In contrast, plasmas heated only by perpendicular NBIs (peaked n_e case) showed slightly higher T_i because of enhanced ion heating
- To investigate the effect of impurity deposition location, two TESPELs containing the same amount of impurity but having different sizes (600 μm shell and 900 μm ball) were injected
- A significant reduction in the central T_e was observed only when the 900 um TESPEL was injected into the peaked-density plasma

PROFILE RESPONSES

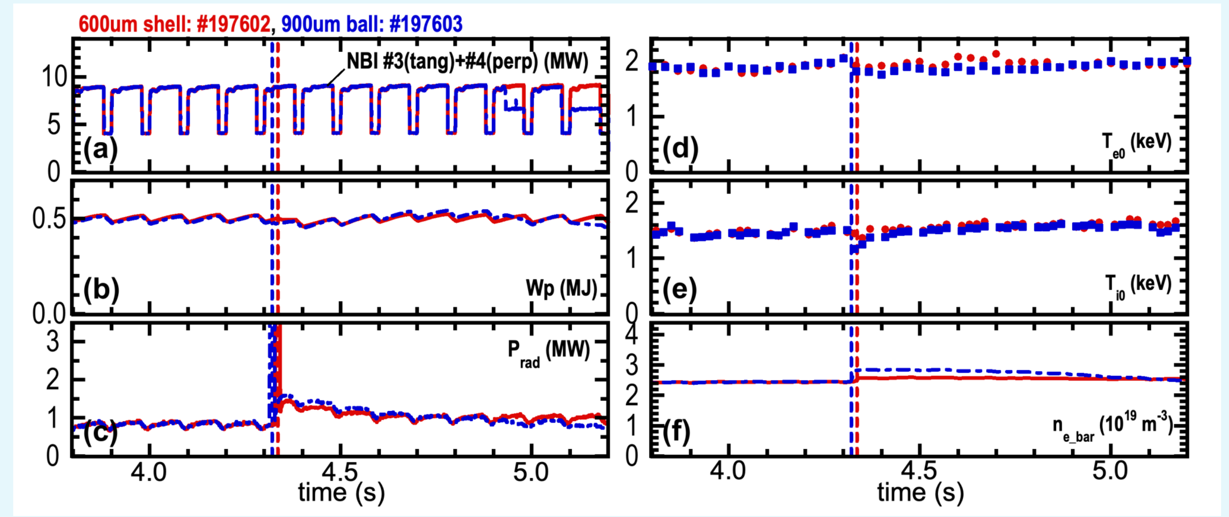
Peaked profile case

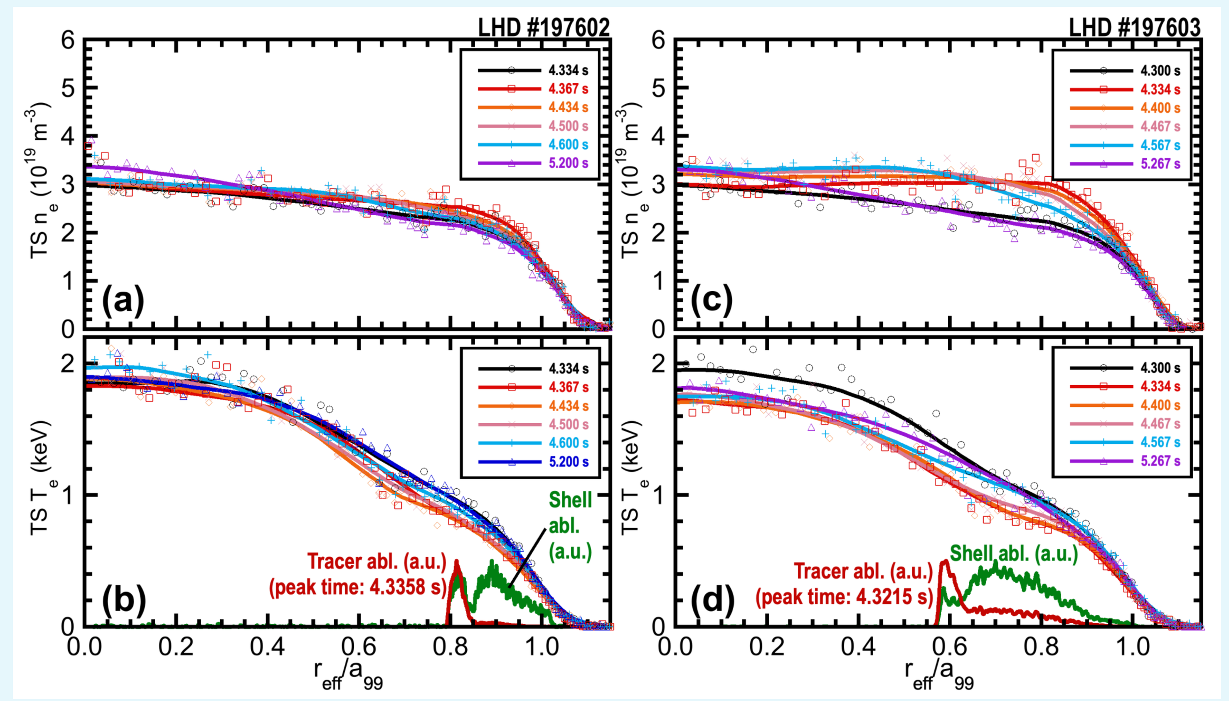
- For the 600 um TESPEL, the impact on the plasma profile was very limited
- For the 900 um TESPEL, the T_e profile gradually flattened from the TESPEL penetration region toward the plasma core

Flat profile case

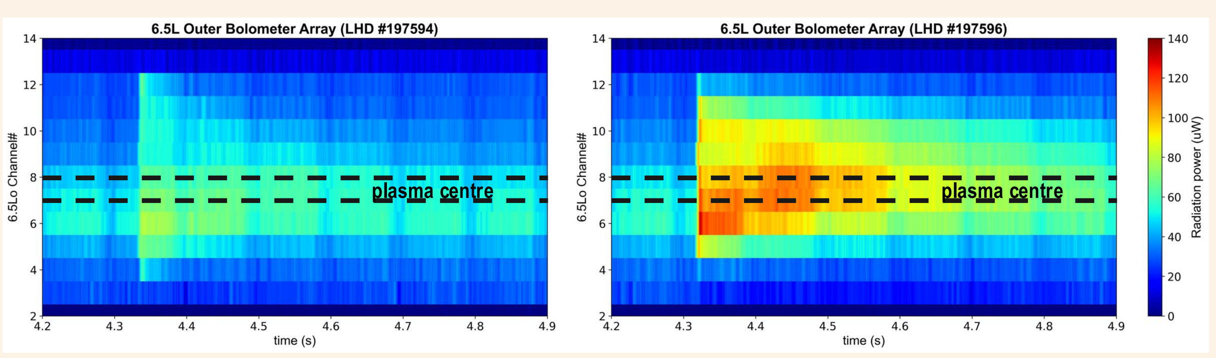
- For the 600 um TESPEL, the impact was similarly very limited
- For the 900 um TESPEL, the T_e decreased in the region where the TESPEL deposited. However, this effect did not propagate into the plasma core

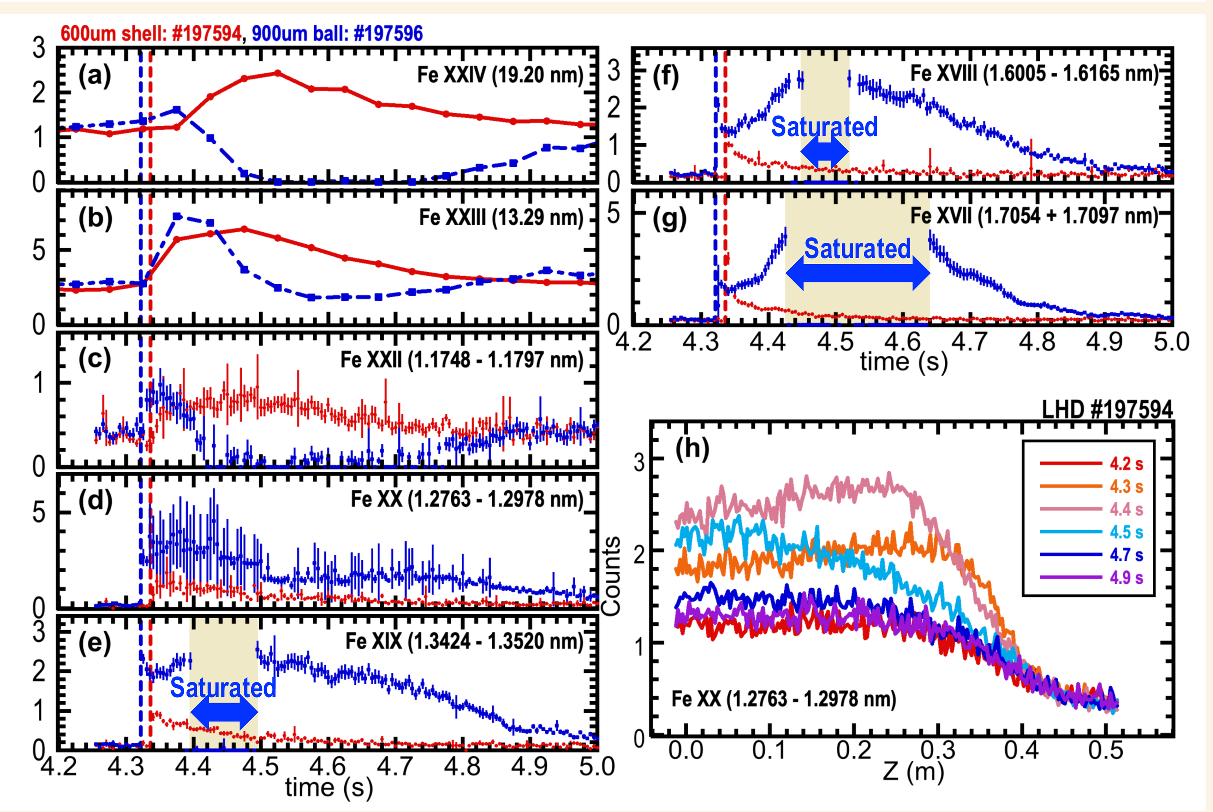
FLAT DENSITY CASE





IMPURITY BEHAVIOURS





PLASMA RADIATION

- Initial radiation response was stronger when impurities were deposited deeper in the plasma by the larger TESPEL
- In the plasma with a peaked n_e profile plasma, the radiation region shifted toward the plasma center after the 900 um TESPEL, indicating impurity accumulation in the core region

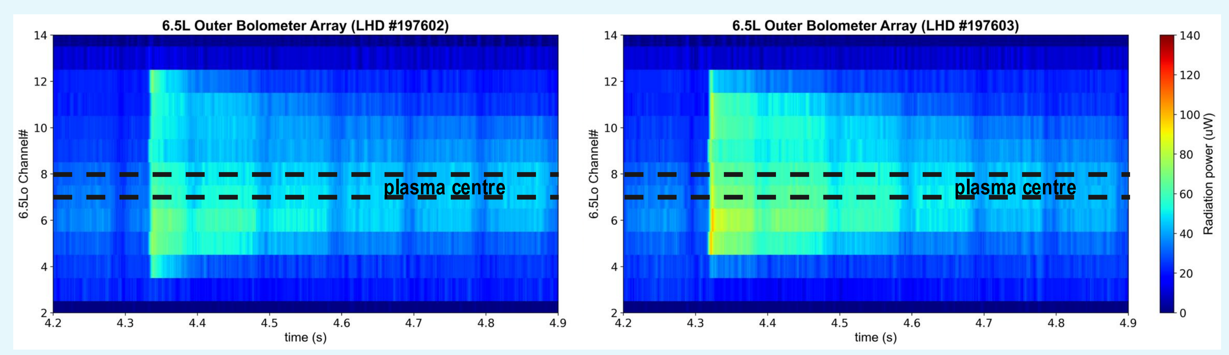
Fe LINE EMISSIONS IN EUV/VUV DOMAINS

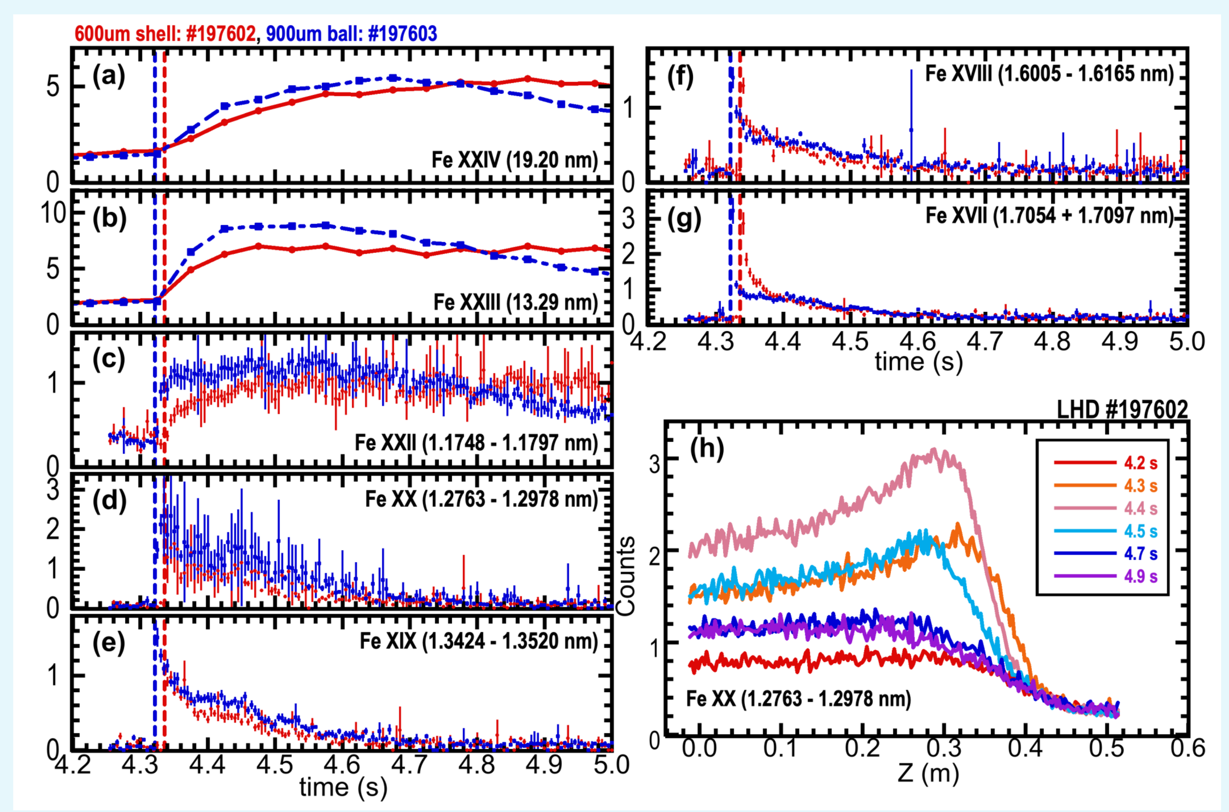
Peaked profile case

- For the 600 μm TESPEL, the Fe line emission gradually decayed to its pre-injection level. This is inconsistent with the expected impurity accumulation in a plasma with a peaked n_e profile
- For the 900 um TESPEL, the dominant charge state of Fe ions shifted from higher charge-states to lower charge-states as the T_e profile became flatter

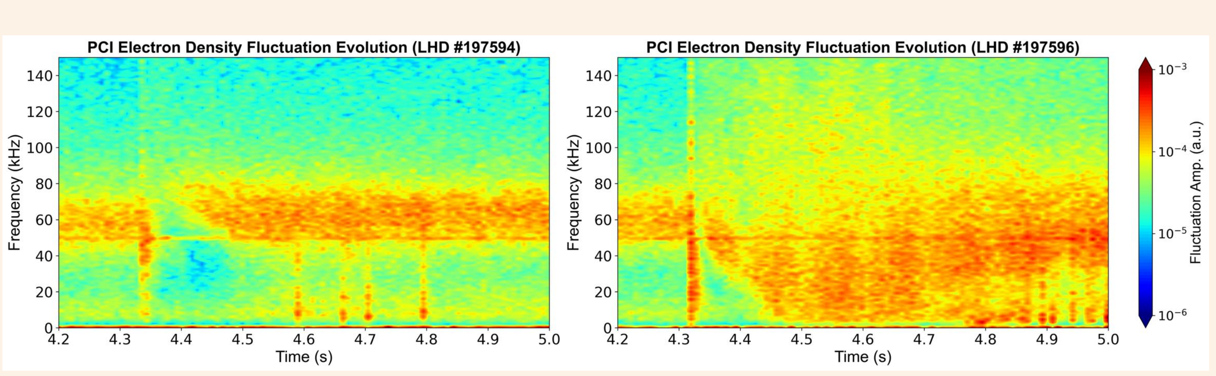
Flat profile case

- Differences in the temporal evolution were observed depending on the TESPEL size, i.e., the impurity deposition location
- For the 600 um TESPEL (shallower deposition), the intensities of line emissions from higher charge-states increased more gradually than for the 900 um TESPEL (deeper deposition)
  ➔ Assuming that the impurity transport coefficients do not vary strongly in space, impurities deposited farther from the plasma centre would require a longer time to accumulate in the core and subsequently diffuse outward
  ➔ Time delay observed may provide information on the spatial structure of impurity transport coefficients





TURBULENCE RESPONSES



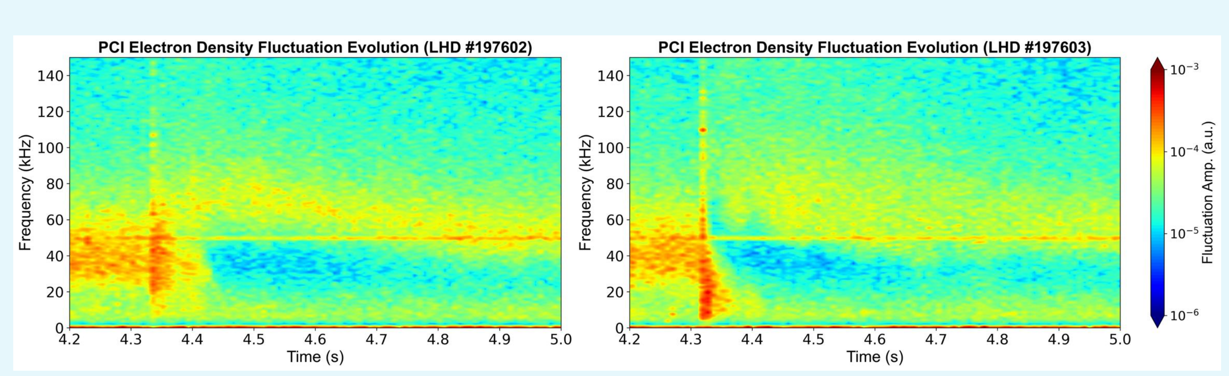
- For the injection of the larger TESPEL into the plasma with a peaked n_e profile, n_e fluctuations in the lower-freq. range increased simultaneously with the flattening of the T_e profile

Peaked profile case

- For the 600 um TESPEL, the reduction of the ~20 kHz n_e fluctuations lasted only about 0.1 s

Flat profile case

- The reduction of the ~20 kHz n_e fluctuations persisted for a much longer period, although it started earlier for the larger TESPEL
  ➔ When considered together with the impurity behavior, these observations suggest that the presence of impurities may be responsible for the reduction of the fluctuations
  ➔ Indicating an impact of impurities on turbulence?



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