Control of H/D Isotope Mix by Peripheral Pellets in H-mode Plasma in JET

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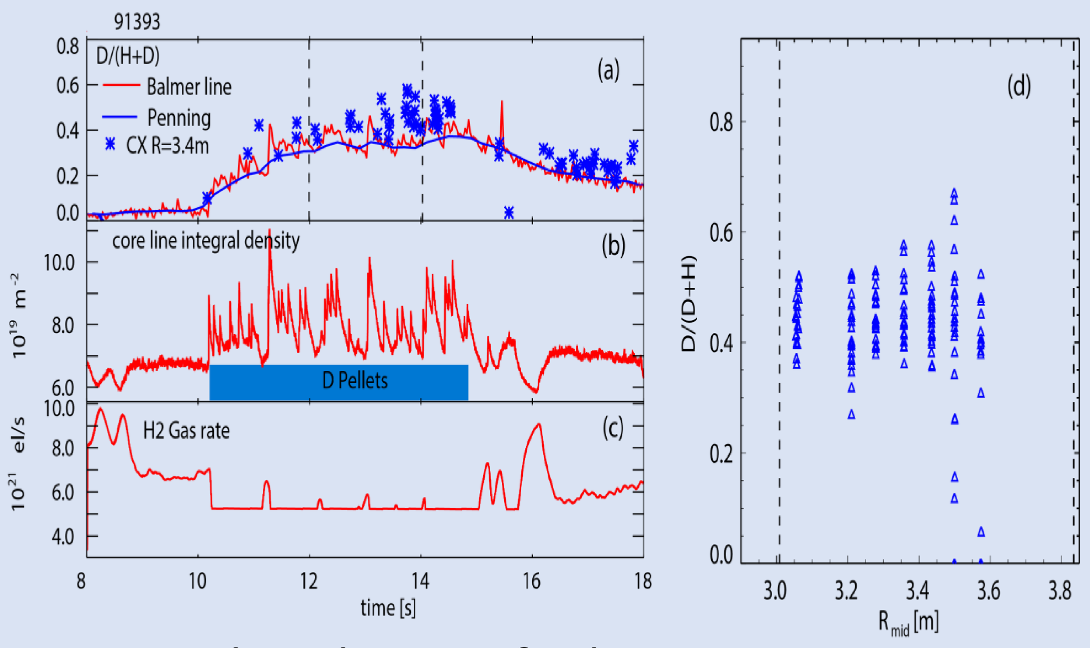
ABSTRACT

- Control of plasma H:D isotope mix using shallow pellets (in H or D) was demonstrated attaining ~50%:50% ratio.
- The isotope mix propagates to the core on the confinement timescale.
- Isotope dependence of energy confinement is within error bar to scalings.
- Dataset is collected for different pellet sizes, isotope content and plasma current, and including for the first time pellets with ITER-like ablation and relative pellet size.
- Data indicate high ablation efficiency for pellets with ablation depth r/a<0.95, but falling sharply for shallower pellet deposition.

BACKGROUND

- In ITER the density of deuterium and tritium will be controlled by injection of cryogenic pellets separately to allow active isotope ratio control.
- ITER pellet velocity is limited to 300m/s. This combined with high pedestal temperatures and small relative pellet size results in shallow pellet ablation. This paper presents unique pellet fuelling dataset from JET addressing aforementioned issues.

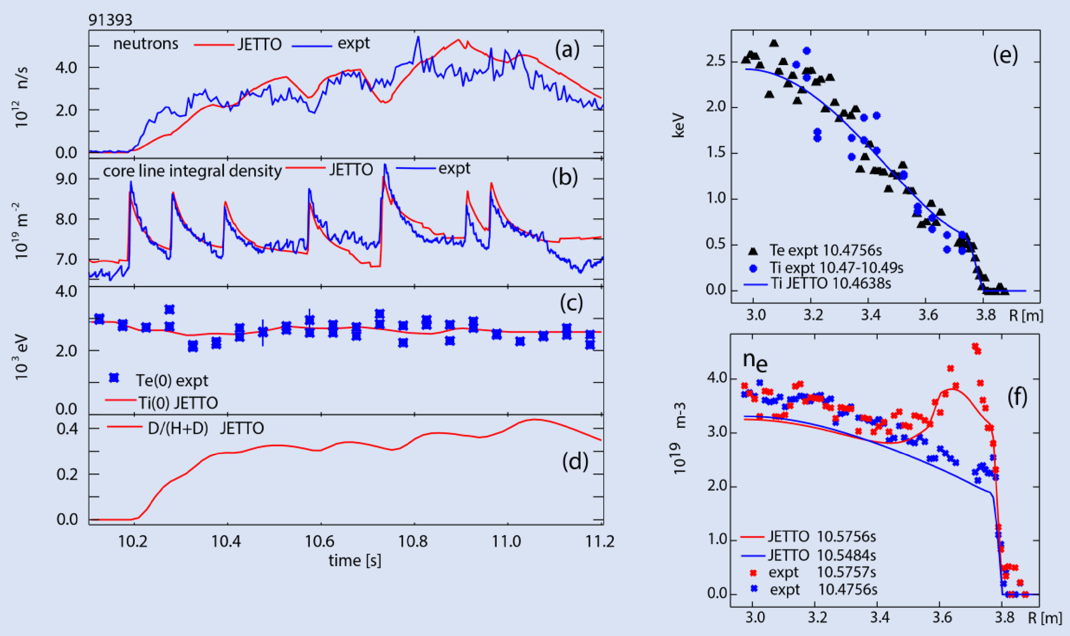
DEUTERIUM PELLETS INTO HYDROGEN PLASMA



Temporal evolution of relevant parameters during the isotope control experiment.

$I_p = 1.4MA$, $B_T = 1.7\,T$. of $P_{NB} = 6.3MW$, $\omega = 2\omega_{cH}$, 51MHz, $P_{RF} = 3.3MW$

fuelling by ~20mm^3 deuterium pellets ($N_{pel} = 8.5\times10^{20}\ at$) from the high field side, pellet rate of 9.7 Hz pellet velocity is~90m/s.



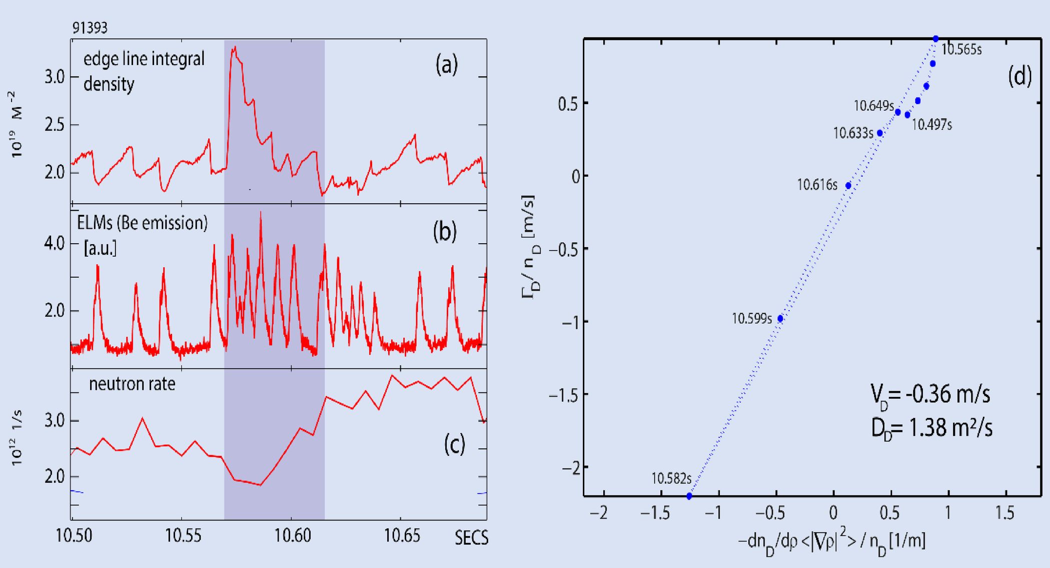
Isotope mix control by pellets. (a) total neutron rate R_(DD,th), (b) core line integrated density (d) calculated central isotope mix ratio.

The model evolves independently hydrogen and deuterium densities as a response to particle sources and particle transport. Temperature from experiment.

JINTRAC, PENCIL, HPI2 and FRANTIC codes.

$D = C_D \times \chi_{BgB}$, $v/D = -C_V r/a^2$. "continuous ELM model", outward convection in the form of $v = v_0 \times exp\{-(t-t_{pel})/\tau + (r/a-1)/\Delta\}$ /s.

Best fit: $C_D = 4.5$, $C_V = 0.4$, $v_0 = 7m/s$, τ = 50ms, Δ= 0.25 , and using the same values for hydrogen and deuterium.



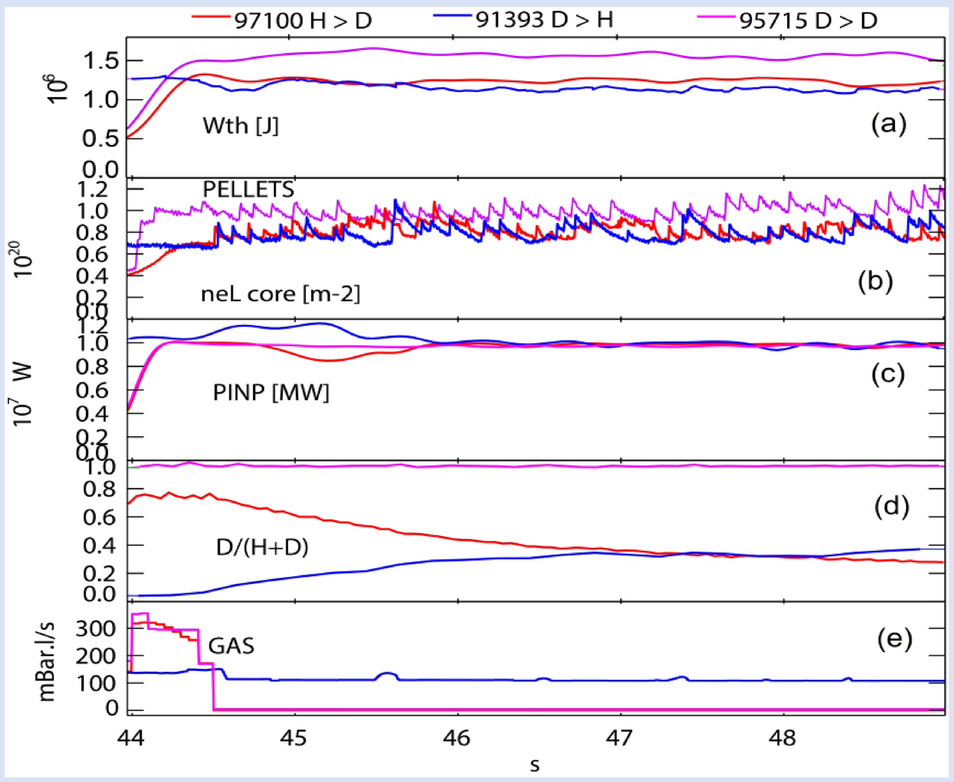
Detail of transient around the 4th pellet.

Pellet creates transiently a zone of reversed gradient.

at r/a=0.5: $D_D = 1.38m^2/s$, $D_D/\chi_{eff} = 0.41$. Here $\chi_{eff} = q/(n_e\nabla T_e + n_i\nabla T_i) = 3.3m^2/s$

The gyro-kinetic simulations show that in ion temperature gradient regime the diffusivities for both ion species are higher than the electron diffusivity $D_H \sim D_D > D_e$

INJECTION OF HYDROGEN PELLETS INTO DEUTERIUM PLASMA

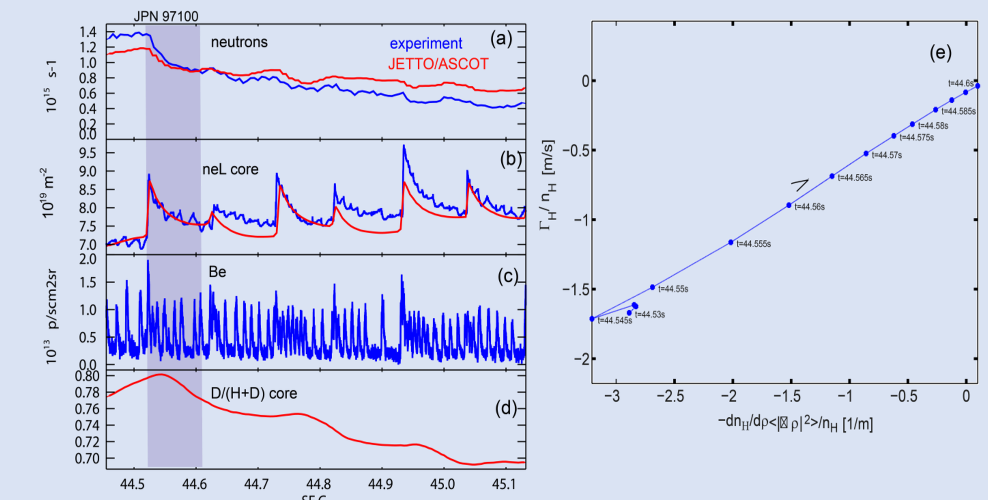


Comparison of pellet fuelling using different combinations of hydrogen isotopes

The shot with H pellets has slightly higher (15%) thermal energy content W_{th} compared to the shot 91393 with D pellets

Plasma with D-.D has higher W_{th} by a factor of ~1.2 compared to mixed isotope cases.

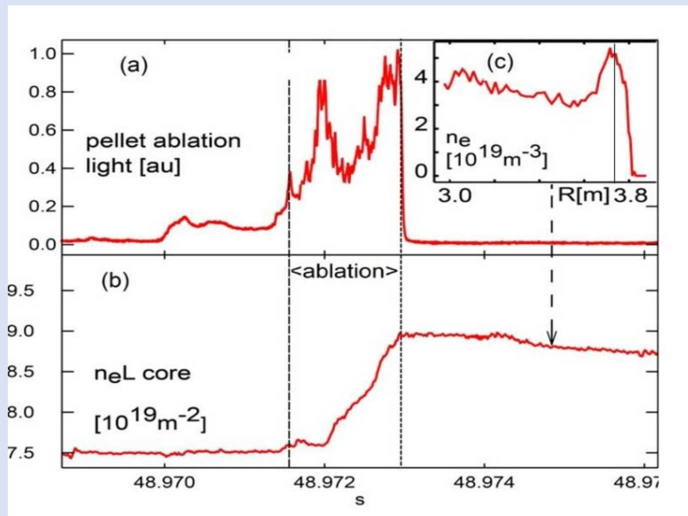
Such increase is within the error bar what is expected from scaling $\tau_E \propto n^{0.41} M^{0.19-0.4}$ $\propto 1.2^{0.41}(2/1.4)^{0.19\div0.4} =$ 1.15÷1.24. (IPB98y2 and from [6]).



Isotope mix control by hydrogen pellets, experiment and modelling

At r/a=0.5 :hydrogen diffusivity is $D_H = 0.53m^2/s.$, $\chi_{eff} = 2.7\,m^2/s$ so that $D_H/\chi_{eff} = 0.20$. This value is factor of two smaller than in case of deuterium pellets injected into hydrogen plasma.

PELLET DEPOSITION EFFICIENCY



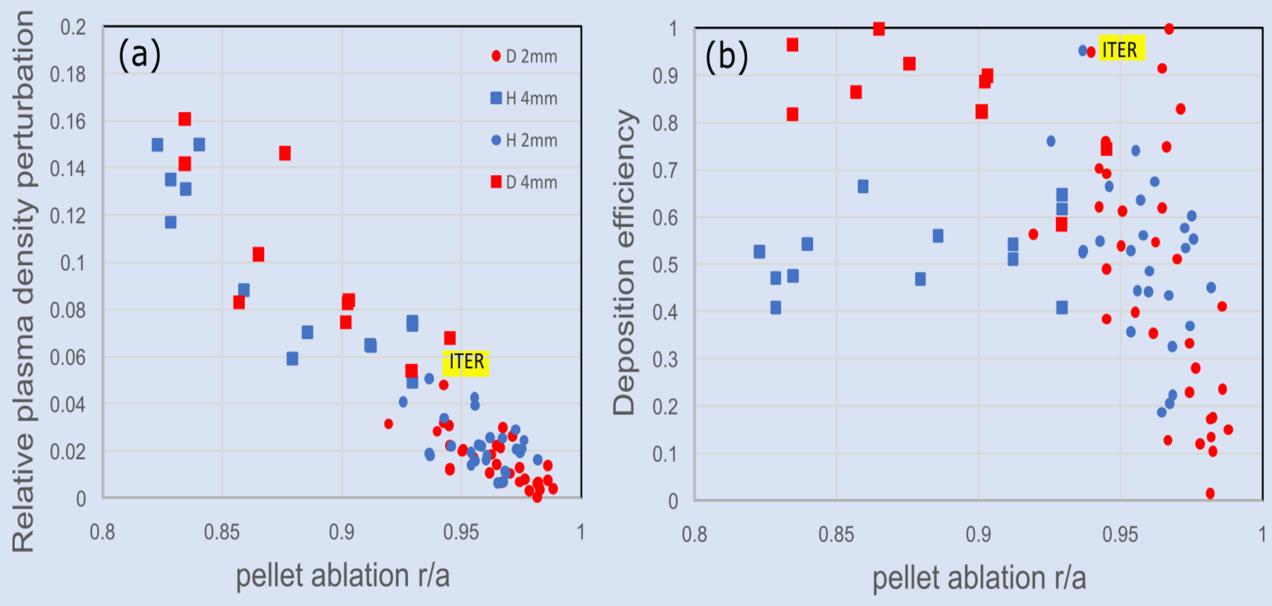
Temporal evolution of pellet ablation.

Pellet ablation depth can be calculated from the fast interferometer and ablation light signals.

JET dataset populate the region predicted for ITER,

The data indicate high injection efficiency for ablation depth r/a<0.95 and falling sharply for shallower pellets.

No difference between hydrogen and deuterium pellets. The exception is the lower efficiency for large hydrogen pellets.



(a) relative perturbation of plasma density by pellet and (b) pellet deposition efficiency, both as a function of ablation depth

ACKNOWLEDGEMENTS

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