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TRITIUM PATHWAYS IN JET TRACE TRITIUM TRANSPORT EXPERIMENTS

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1. Introduction

Recent JET experiments with transient puffed injection of low tritium levels (< 1%) have permitted detailed analysis of the time- and space-dependent neutron emission to determine the ρ^*, ν^* and β scaling of particle transport in the core (normalized radius $\rho<0.8$) for ITB, ELMy H-mode and hybrid scenarios [1]. Such 'trace T' experiments could also characterize the influence of the SOL on particle transport in the edge/pedestal region ($0.8<\rho<1$), although not designed for this purpose, since the ELM averaged radial influx of T^+ ions at the edge of the core region ($\rho=0.8$) is provided by the neutron analysis and the external T_2 gas puff rate is also measured. To see what can be learned about systematic SOL effects on particle transport scaling, using the available partial data, we analyze three representative gas puffing cases using NBI heating only, from the JET trace T experimental database, with parameters as given in the Table. The cases considered cover a range in average core electron density, but don't represent a density scan since plasma current, magnetic field and shape also vary. Further, there are systematic differences in ELM behavior for these cases, as shown in Figure 1.

Table: Parameters for analyzed T puffing cases

Shot	$\langle n_e \rangle$ $10^{19} m^{-3}$	Γ_{puff}^{max} $(10^{22} pt/s)$	Γ_{inT}^{+max} $(pt/m^2/s)$	Γ_{outT}^{+} $(pt/m^2/s)$	N_{core} $(10^{19}\ pt)$	B_T (T)	I_p (MA)	P_{NB} (MW)
61132	2.4	1.1	3.6	2.2	16.0	1.9	2.35	2.3
61097	5.0	1.22	3.3	2.8	8.0	1.65	2.0	7.6
61138	9.5	1.12	2.7	2.4	4.6	2.25	2.5	13.6

**See the Appendix of J.Pamela et al., Fusion Energy 2004 (Proc. 20th Int. Conf. Vilamoura, 2004) IAEA, Vienna (2004)*

2. T saturation at the outer mid-plane

Previous analysis of trace T experiments [2] has shown that T recycling has a significant effect on deduced core particle transport, through the assumed T recycling coefficient (R_T), defined as the ratio of the returned T flux to that leaving the core. Plausible values ($0 < R_T^{core} < 1$ and $0.03 < R_T^{core} < 0.06$) have been used in previous analyses. Figure 2 illustrates the sequence of T puffing shots in the trace T campaign prior to those analyzed here, showing both the instantaneous puffing rate (the peak rate is $\sim 10^{22}$ s^{-1}) and the accumulated T injected by puffing. It should be noted that there was no T puffing 30 shots before the first shot considered (61097). For the considered cases, the measured core T content is found to be <10% of these injected T values, so core recycling occurs in a background of a much larger T recycling flux in the SOL and wall region. Thus, it is not clear *a priori* that the R_T^{core} should be small, or even <1. Also, the non-penetrating component of the injected flux can produce a localized cool, dense region near the inlet, as observed on Textor-94 [3]. Figure 3 shows results of an idealized multi-species simulation with the solps code (coupled b2 and Eirene) treating the species D, T, D_2, DT, T_2 using an Eirene model developed by D Reiter and D. Coster [4]. The distributions of T fluxes and energies to the wall in the near-inlet region (localized 20cm poloidally around the gas inlet) are shown for the shots in the Table, each for two cases, assuming total power crossing the separatrix P_{sptrx}= 0.5 and 0.75 P_{NB} An elevated flux of low energy atoms and molecules is found in the central region, distinguished from the low flux, high energy values for core CX particles in the wings. The particle flux values are toroidally averaged, although the calculation assumes an idealized point T source and is 3 dimensional. A 3-D Monte Carlo calculation using BBQ [5], calculating transport of a local gas jet from GIM15 through the port (0.6m wide) suggests a local flux peaking factor P_ϕ is ~5-20. For these values, the calculated T fluxes and energies would produce a saturated near-inlet surface region (local ratio $n_T/n_C > 0.4$) within ~ 25-100 msec. Figure 3 also shows a significant reduction in the T flux to the wall for the highest density case (61138), reflecting reduced mean free path (trapping in the SOL with flow to the divertor) and diminution of Franck-Condon neutral production. This is consistent with the decreased core T content (Table) for pulse 61138. Thus variations in wall saturation can be expected to play a systematic role in edge/pedestal particle transport scaling. Figure 4 shows the D and T concentrations in the SOL for the near-wall and separatrix for these cases. Strong local near-wall T enrichment is seen, decreasing toward the edge/pedestal. Comparison with the available partial divertor langmuir probe data shows that the solutions are in scale for the density variation considered.

3. Systematic effects: wall model and ELMs

The value of R_T^{core} is related to R_T^{wal} (ratio of T fluxes entering and leaving the wall). Figure 5 shows the calculated time evolution of the local surface in- and effluxes, and R_T^{wall}, for the near-inlet region, using the PTE wall saturation model and the calculated solps fluxes for 61097 in the 1-D WDIFFUSE code. The PTE model was deduced from previous JET species changeover experiments [6]. Transient values with $R_T^{wall} > 1$ are found (Fig. 5). The calculated results strongly depend on the assumed prior implantation history and on the assumed distribution of trapped T in the surface before the discharge. Note from Fig. 2 that the prior accumulated T puffing injection varies by a factor 3 for the cases considered.

ELM behavior (shown in Fig. 1) can also have a systematic effect on particle transport scaling. Calculations with the MIST radial transport code for these shots, assuming an explicit ELM model to replace ELM-averaged values, finds that the turbulent (excess over neo-classical) diffusivities which match the transient in the edge/pedestal region to be reduced by a factor 2-4 for the isolated / compound ELM cases (0.2 / 0.6 m^2s^{-1} reduced to 0.05 / 0.2 m^2s^{-1}, respectively) and by 5 fold for the grassy ELM case (2.5 to 0.5 $m^2 s^{-1}$). A D, T, D_2, DT, T_2 solps simulation has been used to estimate variation in wall fluxes during ELMs. Figure 6 compares the n_D^+ and n_T^+ evolution in the divertor (top) and in the SOL upstream of the x-point. A transient increase in local fluxes by 3-fold is found, which must be included in a first principles calculation of R_T^{core} and R_T^{wall}

4. Conclusions

Systematic effects on edge/pedestal particle transport scaling in puffing experiments depend on the status of saturation in the near inlet region, on the details of ELM –induced particle expulsion from both core and SOL, and on the degree of near-wall T enrichment. Progress in clarifying the roles of these processes could be achieved through dedicated experiments on edge/pedestal trace T transport, to complement previous core studies.

References

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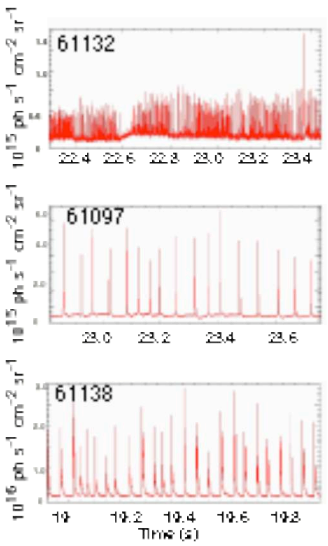

Figure 1. D_α (ELM) behavior away from gas inlet for analyzed cases

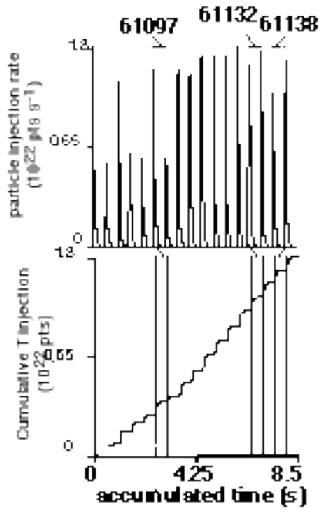

Figure 2. T puff history for shots in trace T campaign up to those analyzed. (top), Instantaneous puff rate; (bottom) accumulated T

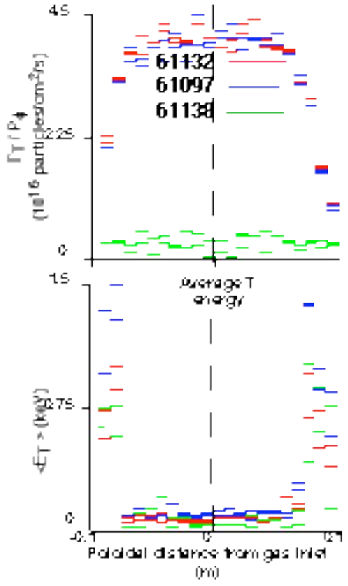

Figure 3. (top) Total T fluxes (from T, T_2 and DT) near inlet, (bottom) average T energy. each for $P_{sptrx} = 0.5, 0.75\ P_{NB}$

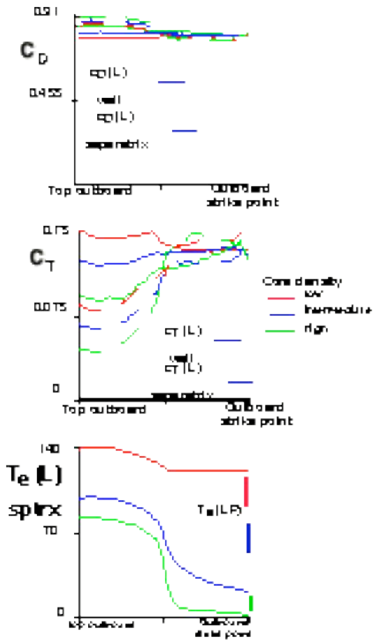

Figure 4 Poloidal variation of D^+, T^+ SOL concentrations (near-wall and separatrix) and electron temperature

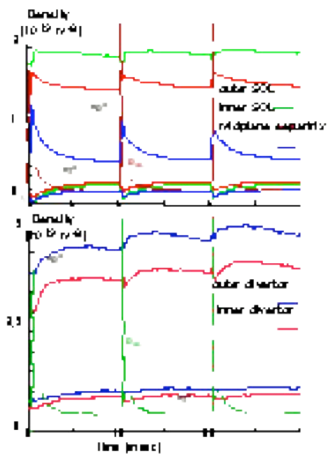

Figure 5. simulation of D^+, T^+ density during ELM transients with solps (top) edge/pedestal (bottom)inner, outer divertor

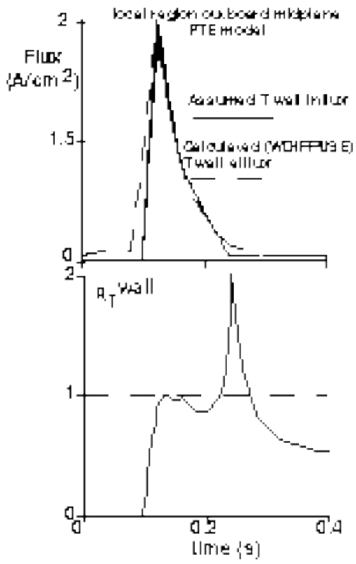

Figure 6 Wall recycling simulation (WDIFFUSE) calculation of R_T^{wall}