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Tritium Transport Studies with JET ISEP NPA During the Trace Tritium Experimental Campaign

M.Mironov[1], V.Afanasyev[1], A.Murari[2], M.Santala[3], P. Beaumont[4]
and JET-EFDA contributors

[1]A.F.Ioffe Physical-Technical Institute, Russian Academy of Sciences, St.Petersburg, Russia
[2]Consorzio-RFX Associazione ENEA-Euratom per la Fusione, C.so Stati Uniti 4,30127 Padova, Italy
[3]Helsinki University of Technology, Association Euratom – Tekes, Espoo, Finland
[4]EURATOM/UKAEA Fusion Association, Culham Science Centre, Abingdon,UK

One of the advanced applications of neutral particle analysis is to study the transport of main ion component of the plasma [1]. The Tritium Trace Experimental (TTE) campaign at JET [2] presented almost optimal conditions for these experiments in plasma discharges when small fraction of tritium was introduced by gas puffing. Special features of the experiment such as the low tritium background in the plasma, the small tritium influxes from the wall and the purity of deuterium neutral beam injection all contributed to the very high contrast of the neutral tritium fluxes due to T_2 puffing. In particular, in these favorable conditions it was possible to obtain a more than satisfactory signal to noise ratio even with reduced T_2 puffs, i.e. injecting an amount of particles so small that it did not alter the main plasma parameters, a situation ideal for perturbative transport studies.

Fluxes of neutral particles leaving JET plasma were detected with the low energy neutral particle analyzer ISEP NPA (Ion Separator) explicitly designed to operate under high neutron and gamma emission rates [3]. The NPA is installed 28 cm above the tokamak mid-plane and its light of sight views the plasma centre in the horizontal direction. The analyzer provides simultaneous measurement of all the hydrogen isotope neutral fluxes (H_0,D_0,T_0) with a good mass resolution (10^{-3}).

Typical time evolution of tritium neutral fluxes in JET discharges with reduced T_2 puff is presented in Fig.1. It has been observed for the first time for tritium neutral fluxes that the delay from the beginning of the T_2-puff to the peak of the fluxes increases with the particle energy. There are two processes that could explain observed neutral fluxes behavior: heating and/or transport of tritium ions. To evaluate a contribution of the former process we estimated the tritium thermal equilibration time. For considered JET discharge #61161

($n_D(0)=3x10^{19}$ m^{-3}, $T_D(0)=10$ keV) thermal equilibration time is ≤ 30 ms, which is an order of magnitude lower than characteristic time of the tritium neutral flux temporal evolution. In other words the growth of neutral tritium fluxes is too slow to be explained by tritium heating. Therefore it is considered that lower growth rate of higher energy neutral fluxes is mainly determined by the tritium ion transport.

The neutral fluxes of higher energies come from the deeper plasma region. This is due to ion temperature increasing towards the centre and the better plasma transparency for more energetic particles. This is illustrated by source functions for different neutral flux energies shown in Fig.2. It can be seen from the figure that 4 keV neutral fluxes represent the peripheral plasma (0.7-0.9) *a*, and 28 keV fluxes – the deeper region (0.2-0.6) *a*. After the puff as ionized tritium atoms penetrate from plasma edge to the centre they give rise to more energetic neutral fluxes. Thus the observed dependence of the delay on the particle energy can be interpreted as propagation of the tritium ions into the plasma.

It should be noted that we consider the plasma heated by the neutral beam, which can produce additional neutralisation target for the plasma ions. However since the beam and the analyser are located far enough from each other in the toroidal direction the contribution of the beam-induced neutralisation into ISEP NPA signals is negligible and is not accounted for in the modelling.

To reconstruct the tritium ion density profile and its temporal evolution the DOUBLE code [3] simulating the neutral particle fluxes emitted by plasma was used. The results for three time points are shown in Fig.3 by solid lines. For comparison in the figure the similar tritium density profiles reconstructed from neutron diagnostic data are presented by dashed lines [4]. It is seen that the shape and time evolution of the compared profiles are in a good agreement. However it is found that absolute value of tritium density obtained with two methods differ by factor of 10, the NPA giving higher tritium density. There is no satisfactory explanation of this discrepancy at present.

To estimate the tritium transport coefficients a simple transport model was applied. Tritium flux is expressed as sum of tritium diffusion and inward pinch terms $\Gamma = -D\frac{\partial n}{\partial r} + Vn$. The coefficients D and V are assumed to be constant over the plasma radius. Results for the simulation for several time points are shown in Fig.4. For tritium diffusion coefficient the best fit gives the value of 0.2 m^2/s, for inward pinch velocity the best fit gives the value of 1.5 m/s.

Conclusions.

1. It has been observed for the first time for tritium neutral fluxes that the delay from the beginning of the T_2-puff to the peak of the fluxes increases with the particle energy.
2. The observed evolution of neutral fluxes is interpreted as tritium propagation into the plasma and tritium profile time evolution reconstructed.
3. The shape and time evolution of the reconstructed tritium profiles show good agreement with neutron diagnostics data. On the other hand, the absolute value of tritium density given by NPA is 10 times higher than the value from neutron diagnostics. The reason for the discrepancy is being investigated.
4. To estimate the tritium transport coefficients a simple transport model is applied to reconstructed tritium profiles. The best fit gives 0.2 m^2/s for tritium diffusion and 1.5 m/s for inward pinch velocity.

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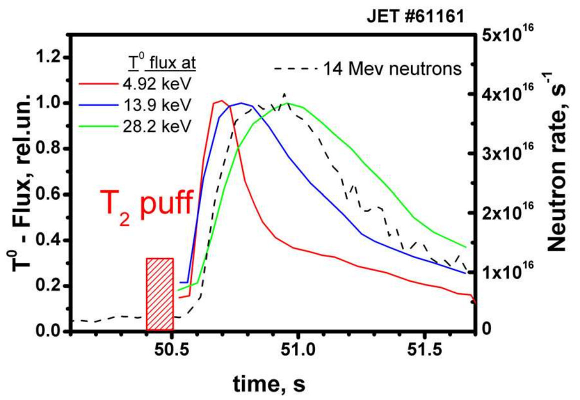

Fig.1 ISEP NPA and 14 MeV neutrons traces. Tritium gas puff in JET shot #61161.

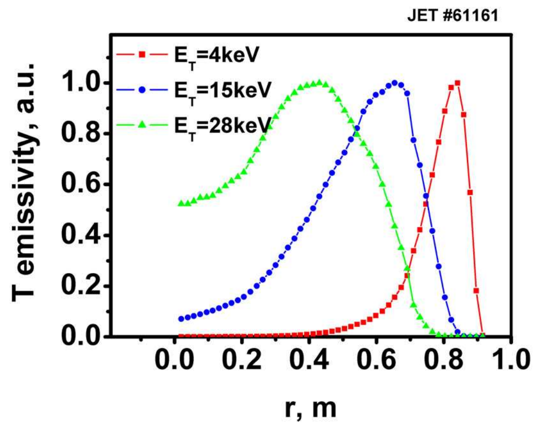

Fig.2 Source functions for tritium neutral fluxes of different energies.

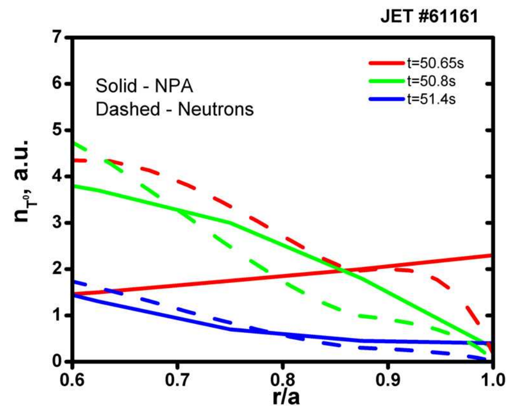

Fig.3 Comparison of tritium profile evolution obtained from NPA and neutron data.

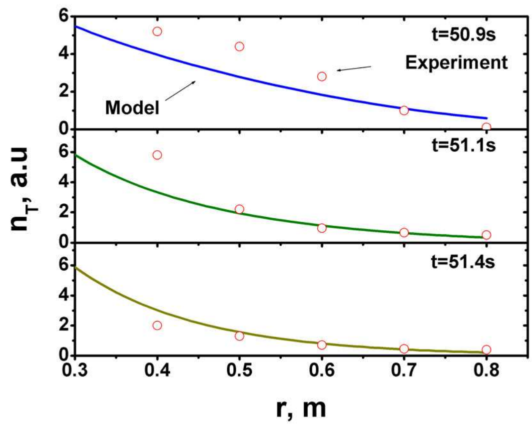

Fig.4 Modelling of tritium profile evolution