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T.C.Hender, R.J. Buttery, E. de la Luna, J.S. Ferreira, D.F. Howell, D. McDonald,
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T.C.Hender[1], R.J. Buttery[1], E. de la Luna[2], J.S. Ferreira[3], D.F. Howell[1],
D. McDonald[1], M.F.F. Nave[3], J.D. Strachan[4], A.D. Whiteford[5], K-D Zastrow[1]
and JET EFDA Contributors*

[1]*EURATOM/UKAEA Fusion Association, Culham Science Centre, Abingdon, Oxon, OX14 3DB, UK*
[2]*Asociacion Euratom-CIEMAT para Fusion, CIEMAT, Spain*
[3]*Associação EURATOM/IST, Centro de Fusão Nuclear, 1049-001 Lisbon, Portugal*
[4]*Princeton Plasma Physics Laboratory, Princeton University, Princeton, N.J., USA*
[5]*Dept. of Physics, University of Strathclyde, Glasgow, UK*
** See annex of J. Pamela et al, "Overview of Recent JET Results and Future Perspectives", Fusion Energy 2002 (Proc. 19th IAEA Fusion Energy Conference, Lyon (2002).*

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## INTRODUCTION

Results are presented on measurements of particle confinement in JET using trace amounts of tritium, in the presence of m=3, n=2 magnetic islands induced by Neo-classical Tearing Modes (NTMs). 3/2 NTMs are generally correlated with an energy confinement degradation of ~10-20% and this is understood as being due flattening of the pressure across the magnetic island. The recent JET trace tritium campaign allowed us to study the influence of the NTM on particle transport, from the observed evolution of the 14MeV neutron emission profile following puffs of trace amounts (2.5 to 5mg) of tritium.

## 1. EXPERIMENT DETAILS

Nearly identical JET discharges in terms of equilibrium parameters and NBI heating power were established, in one case with a 3/2 NTM, and in the other without. Avoidance of the NTM was achieved by having a higher Toroidal Field (TF) as the NBI power was applied, when longer period sawteeth tend to trigger the NTM. The TF was then ramped to a lower value (Fig.1). Conversely formation of an NTM was facilitated by a reduced, or constant TF. In these matched discharges an 11% degradation of confinement was observed in the NTM pulse, of which 7% is due to reduced density confinement. Charge exchange ion temperature measurements show that energy confinement is predominantly degraded within q=3/2 (Fig.2) and this seems related to substantial flux surface distortions within q=3/2 (as well as smaller flux surface distortions at q=2, 5/2 etc, Fig.3). Phase analysis of the Electron Cyclotron Emission (ECE) data shows ~$180^{o}$ phase inversions, consistent with magnetic islands, at both q=1 and 3/2, when the NTM is present.

## 2. NEUTRON RESULTS

Between 2.5 and 5mg of tritium was puffed at a time (26.5s) at which the NTM amplitude had become approximately constant (and into no-NTM discharges at the same time). The rate of penetration of the tritium was observed by a 19 chord horizontal/vertical measurement of the 14MeV D-T neutrons. The temporal behaviour of the 14MeV neutrons, following the T-puff, showed essentially no change on the outer chords due to the 3/2 NTM, but peaked earlier and decayed sooner in the core (Fig.4), in the NTM discharges. In Fig.5 the innermost chords, along which no change due to the NTM in 14MeV neutron emission is observed, are highlighted.

The volume bounded by these chords is approximately that within the q=3/2 surface; here the location of q=3/2 is identified both from EFIT [1] reconstructions including MSE data and from the ECE location of the 3/2 magnetic islands.

## 3. INITIAL TRANSPORT SIMULATIONS

Simulations have been conducted to determine the tritium transport diffusion coefficient DT and relative pinch velocity VT/DT, that give the best c 2 -fit to the 19 channels of the 14MeV neutron camera, using the UTC code [2]. The UTC simulations are based on an underlying TRANSP code [3] fit to each discharge, which allows the results of the sophisticated models for 14MeV neutron emission in TRANSP to be reproduced in UTC; fuller details of this, and other aspects of UTC, are given in Ref [2].

UTC simulations have been made for a discharge with a 3/2 NTM (Pulse No: 61359) and an otherwise equivalent discharge without an NTM (Pulse No: 61362). Two simple forms for the radial variation of the tritium transport coefficients have been assumed:-

(i) Within q = 3/2 (r/a<0.58) $D_T$ = constant and $V_T$ = 0, and outside q = 3/2 DT, VT are piecewise continuous (Fig.6(a)).

(ii) As (i) but an extra constant zone of constant DT, VT is inserted around q = 3/2 (to allow directly for the effect of m = 3, n = 2 island); see Fig.6b.

In the simulations shown in Figs.6(a) and (b), it is assumed that the tritium transport coefficients outside q = 3/2 are the same for the NTM pulse, as those which are optimal in the no-NTM pulse; this assumption is consistent with the observation that the NTM only significantly affects flux surfaces (Te-surfaces, see Fig.3) within q = 3/2. From Fig 6(a) it can be seen that when the simpler transport model (i) is employed that the effect of the NTM is to increase DT within q = 3/2 by 20%, which given the volume in this region is consistent with the observed 7% reduction in average electron density due to the NTM. The slightly more sophisticated model (ii) shows the predominant tritium transport change, due to the NTM, is a reduction in the inward pinch within the q = 3/2 island region. Rather counter-intuitively in this case the DT is lower in the core when the NTM is present, but this is more than countered by the 54% reduction in VT in the vicinity of q = 3/2. In these transport simulations it has been plausibly assumed that the transport outside q = 3/2 is unaffected by the NTM; as a test this assumption has been removed in the case of transport model (ii) and the transport coefficients outside q = 3/2 (as well as inside) allowed to vary to achieve an optimal $\chi^2$-fit to the 14MeV neutron data. It is found that although the transport coefficients vary slightly outside q = 3/2 the dominant change, relative to the no-NTM pulse, remains the change in' VT in the vicinity of q = 3/2 (shown in Fig 6(b)). As might be expected there is an improvement to the fit quality in going from transport model (i) to (ii); for the NTM pulse, with transport outside q = 3/2 constrained to the no-NTM result, the $\chi^2$ of the fit to the 14MeV neutron data decreases from 1.97 to 1.85 (a small but significant improvement).

It should be noted that the results presented are initial simulations and do not necessarily represent the best interpretation of the tritium particle transport. Another issue which needs to be addressed in the future is that the effect of the 3/2 NTM, which would be expected to enhance diffusion of the NBI ions, is not included. Since the D-T neutrons arise dominantly from D-beam/thermal triton reactions, this could be a significant effect in the UTC simulations.

## SUMMARY

Matched pulses with, and without, a 3/2 NTM have been used to study the effect of this instability on tritium particle transport. The transport of trace quantities of puffed tritium is monitored using 19 chord horizontal and vertical 14MeV neutron cameras. Direct analysis of the data shows that the primary change to the 14MeV neutron emission, following the tritium pulse, is within q=3/2. Initial transport simulations show the change in the 14MeV, neutron data due to the NTM, can be accounted for by increased tritium diffusion within the q = 3/2 surface, or a more local reduction in pinch velocity in the vicinity of q = 3/2. These transport results are not yet conclusive; further studies are needed including consideration of the enhanced diffusion of fast NBI ions due to the 3/2 NTM.

## ACKNOWLEDGEMENTS

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## REFERENCES

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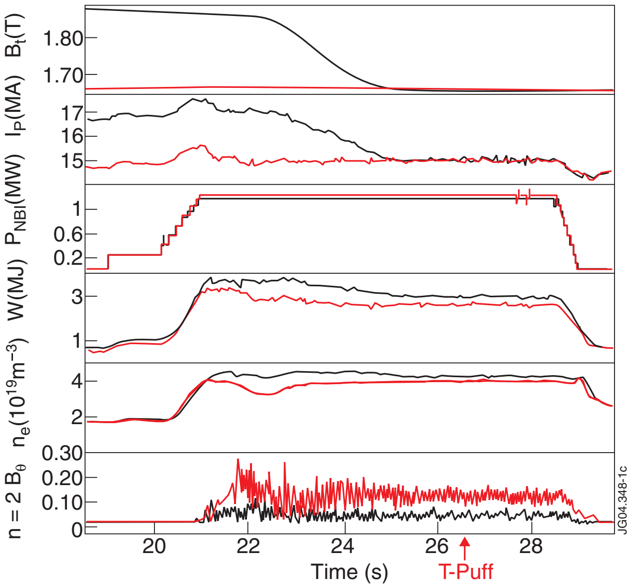


*Figure 1: In Pulse No: 61362 (black curves) an NTM is avoided by an initially higher TF. At the time of the T-puff (26.5s) the discharges are nearly identical except one (61359, red curves) has an NTM.*

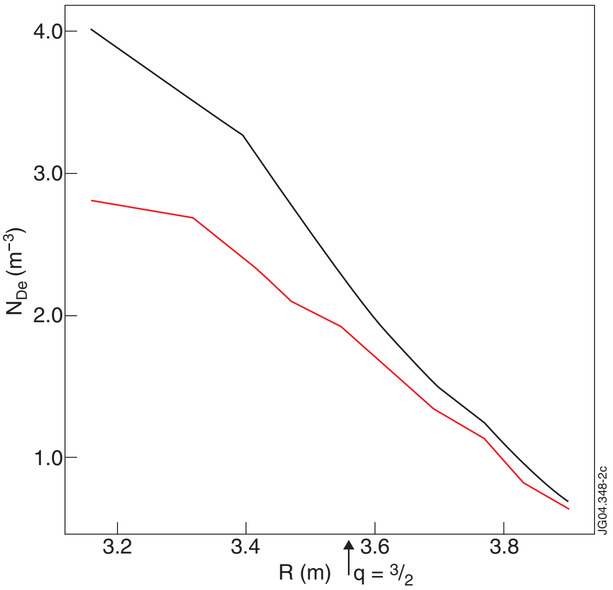
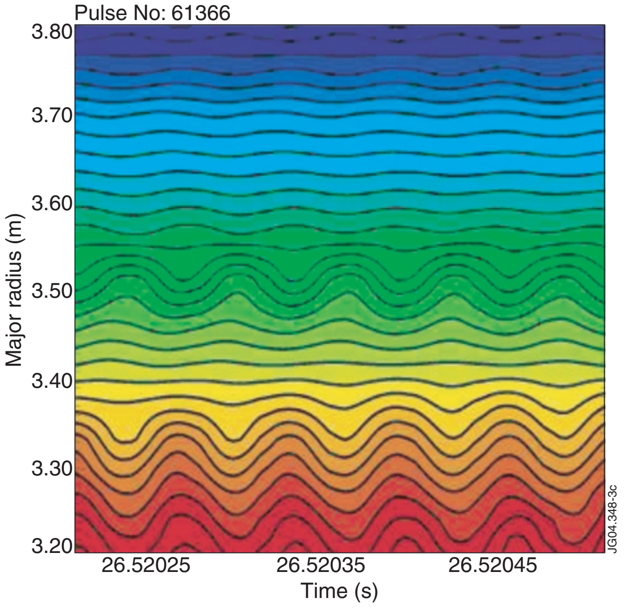


*Figure 2: $T_i$ for no-NTM pulse (61362, black) and a 3/2 NTM pulse (61359, red) at the time of the T-puff. Confinement is dominantly degraded within q=3/2.*

*Figure 3: $T_e$ contours showing significant distortions within q=3/2 for an NTM pulse. The locations of rational-q values are determined from MSE and are consistent with the MHD activity. For clarity the data is frequency filtered to the frequency range of the NTM + the time averaged value.*



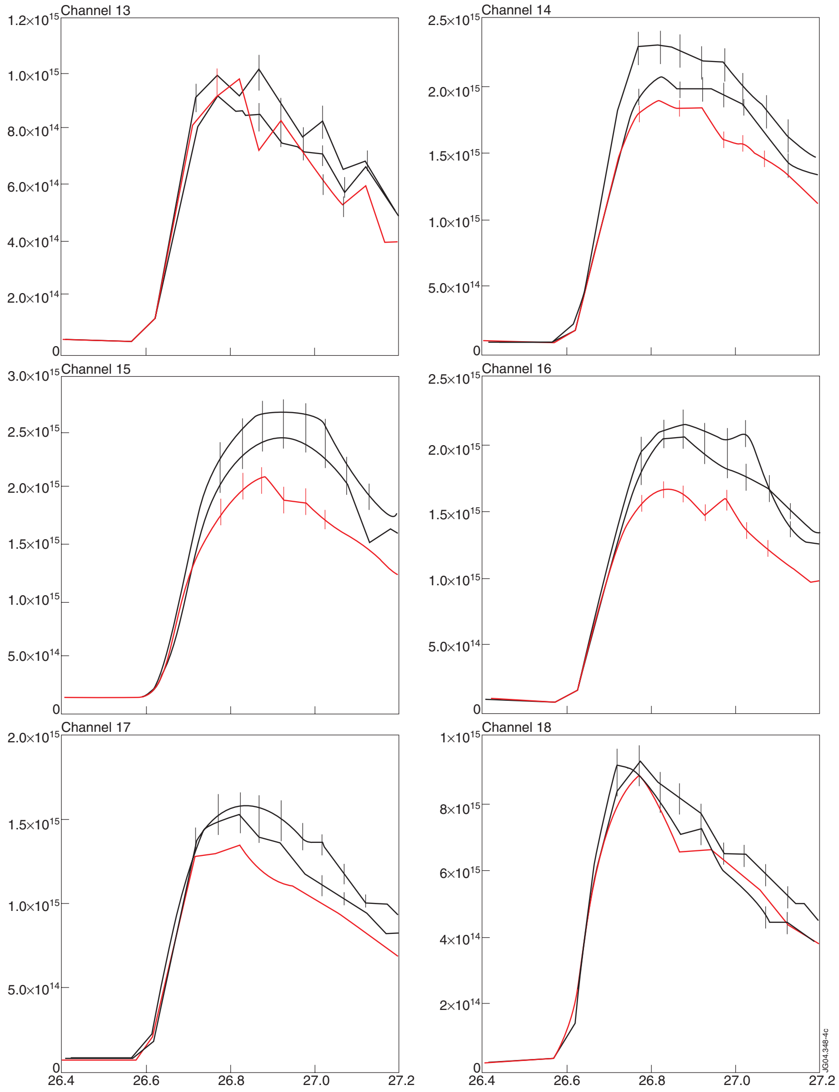


*Figure 4: Vertical neutron camera data for pulses in with (red line) and without 3/2 NTMs (black lines). The channels near the plasma axis (channels 15 and 16, see Fig.5) show the greatest effect from the NTM.*

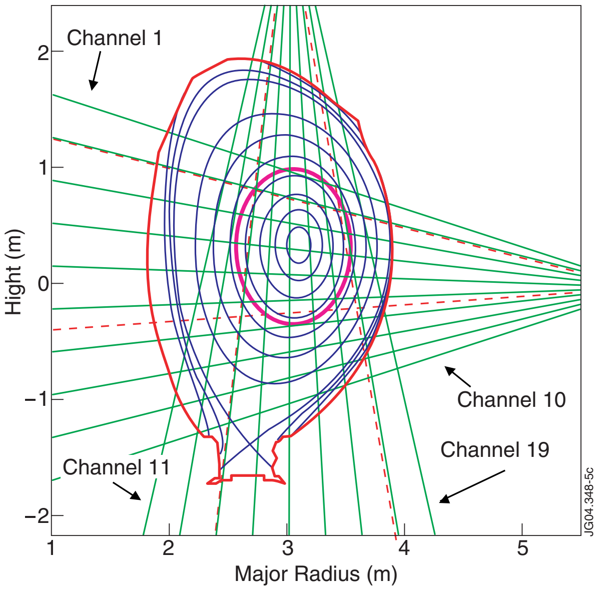


*Figure 5: The innermost chords of the 14MeVneutron camera for which there is no significant change in emission due to the NTM are highlighted in red. The flux surface highlighted in purple is q~3/2.*

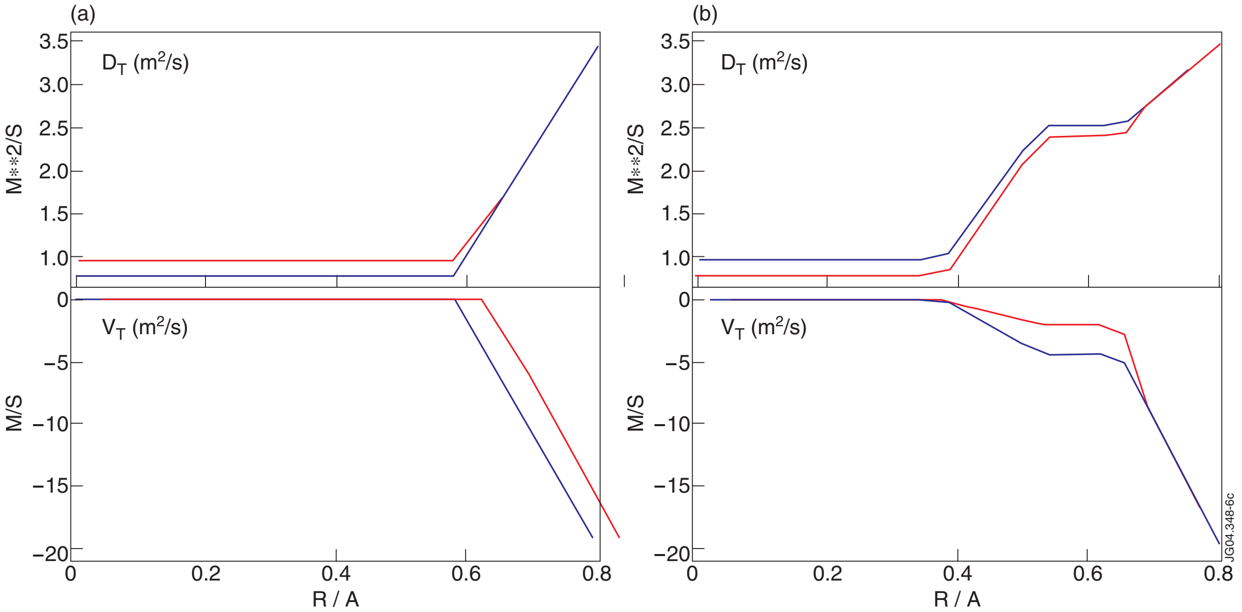


*Figure 6: UTC transport simulation results. In both (a) and (b) the red curves are the NTM discharge and the blue the no-NTM discharge. The simple transport model (i) results are shown in (a) and results with the transport model (ii) including variation of parameters near q=3/2 are shown in (b).*