Facets of alpha particles in D−He plasmas in preparation for deuteron-tritium at the Joint European Torus


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INTRODUCTION

Experiments aimed at the generation of alpha particles in D−He plasmas with radio-frequency (RF) heating [1] were conducted at JET. The experiments had two aims:

1) Maximization of alpha particle production via the d+He→p+p reaction

2) Observation and studies of alpha particles and fast ions with the upgraded suite of fast ion diagnostics at JET

Besides these main goals, the experiments showed peculiar plasma regimes which allowed studying novel aspects of fast ion physics and their interplay with transport and confinement at JET.

ALPHA PARTICLE GENERATION WITH THE ‘THREE-ION’ RF SCHEME AT JET

- 50.25% D+He plasmas

- The three ion (RF) scheme [2] is used to accelerate D−NBI ions in the core from 100 keV to the MeV range

- D+He fusion occurs due to reactions between MeV range deuterons and thermal He, which acts as the target.

The poloidal cross-section of the JET tokamak with off-axis location of the ion cyclotron resonance for thermal D and He ions for 3-ion (ICF) fast-ion experiments in D−He plasmas [7-10] is shown. The coloured image is a tomographic reconstruction of the neutron emissivity for discharge 495679. The dashed lines are the lines of sight of the JET neutron camera.

EXPERIMENTAL RESULTS

- Two-fold increase of the plasma energy suggests RF power is efficiently absorbed by the plasma in the core.

- Two-fold increase of the 4s neutron rate, accompanied with the stabilization of the sawtooth period, indicates the production of MeV range deuterons.

- Depending on the plasma conditions, the (stabilized) sawtooth period can range from 100 ms to > 1 s.

REFERENCES


OBSERVATION OF CO-PASSING DEUTERONS IN THE MEV RANGE AND ALPHA PARTICLES WITH GAMMA-RAY SPECTROSCOPY

- Gamma-ray spectroscopy measurements with improved instruments provide direct evidence of the production of co-passing MeV range deuterons and fusion born alpha particles by the d+He and u+He nuclear reactions.

- Alpha particle camera determines an experimental image of the alpha particle source after tomographic inversion of the 16.4 MeV gamma-ray emission.

RICH SPECTRUM OF ALFVEN EIGENMODES

- A rich spectrum of Alfven Eigenmodes (AE) has been observed in the RF+NBI phase, including Toroidal (T), Elliptical (E) and Reversed Shear (RS) instabilities.

- RSAEs imply q-profile reversal, which may be linked to the generation of MeV range co-passing deuterons. RSAEs are more easily observed when the sawtooth period is > 1 s.

- Mode number analysis show instabilities with n = 1, 2, 3 but also n=2,-1,0. The latter may be associated to alpha particle drive [3].

TURBULENCE STABILIZATION BY THE FAST IONS

- Careful T measurements with charge exchange reveal TAE, despite the dominant electron heating from the MeV range fast ions. A >60% improvement of the Hα confinement factor is observed with respect to similar plasmas w/o MeV range ions.

- Gyrokinetic simulations reveal the key role of fast ions in turbulence stabilization (low (drift wave) and high (TAE-range) frequency instabilities [4].

Illustration of the electron and ion temperature profiles in JET experiments at D−He plasmas, in which the 3-ion D+He RF+ICF scenario accelerated D−NBI ions to MeV range energies. The example shows T_e and T_i profiles in plasma 494500 at t=10 s (Te,ni=0.5 MW, B=1.5 TM, j=125 m−1).