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Neutral Particle Diagnostics at MAST with a Compact Energy Analyser and Comparison with Charge Exchange Recombination Spectroscopy

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Introduction

Charge exchange-neutral particle analysis (CX-NPA) and charge exchange-recombination spectroscopy (CX-RS) will be employed at the stellarator W7-X after its commissioning at Max-Planck-Institute of Plasma Physics Greifswald. In the meantime a compact neutral particle analyser (CNPA) with a thin diamond-like foil for stripping of hydrogen atoms has been installed at the Mega Amp Spherical Tokamak MAST in Culham Science Centre, U.K. The CNPA was developed at the IOFFE-Institute St. Petersburg in cooperation with Max-Planck-Institute Garching and is characterised by a pronounced compactness and low weight compared with conventional analysers. It will be used in combination with three ACORD-type analysers in a pivoting analyser unit in order to measure the core and edge plasma temperatures in W7-X as radial temperature profiles. In addition, CX-RS using the Doppler broadening of radiation of C^{5+} impurities and others like He and Ne will be employed at plasma positions as seen in Fig.1 in order to get independent results for ion temperatures, for determining toroidal rotation velocities and ion densities of impurities. Now the CNPA is being tested at MAST with the intention of comparing its results with those of the Princeton analyser and with results from CX-RS. At the later W7-X device a 60keV neutral beam injector RUDI-X will be installed enabling locally resolved active CX-NPA and CX-RS measurements.

Experimental

The experimental set-up of CX-diagnostics of the stellarator W7-X, which is presently under

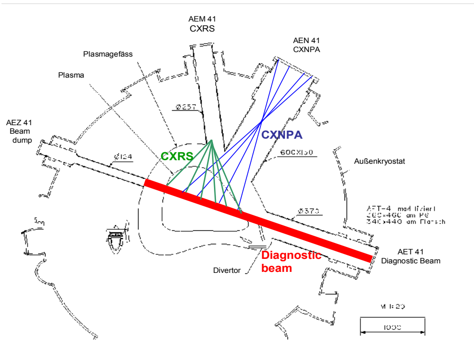


Figure 1: Setup CX diagnostics at W7-X

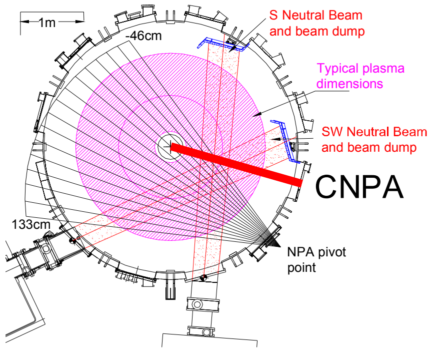


Figure 2: Set-up of NPA's and neutral heating beams at MAST

construction, is shown in Figure 1.

Figure 2 shows the positions of the Princeton analyser, of the CNPA on MAST and their lines of sight. The position for CX-RS measurements on MAST meets the positions of sight lines of the CNPA at radial positions about 0.3 m from the plasma centre.

The functional principles of the Princeton analyser are explained in [1]. More details of the CNPA and its position at MAST can be found in [2] and [4]. The sightlines of the applied CX-recombination spectrometer and experimental details of this spectrometer are described in [5].

A number of features at MAST and W7-X are expected to be similar, e.g., residual magnetic stray fields are of the same order of magnitude in both devices. At present, the influence of neutrons at MAST on the neutral particle analysers (NPA's) is less by one order of magnitude, but it will be increased after upgrading the beam heating system and will be expected to reach values of W7-X of about 10^{15} neutrons/s. A typical NBI heated MAST discharge with a heating power of 1.6 MW is characterised by electron temperatures of about 1.2 keV and electron densities of about 2.2 x 10^{19} m^{-3}.

First of all the CNPA was installed close to the plasma device without any neutron shielding. During a test of the influence of neutron irradiation on analyser detectors [3] counting rates of the detectors caused by the neutron flux were observed reaching up to $7x10^{13}$ neutrons per second. This corresponds to the level of neutron noise induced in the Princeton NPA, though the CNPA was closer to the MAST-torus.

Results

The results of measurements using the CNPA and the Princeton analyser were found to be

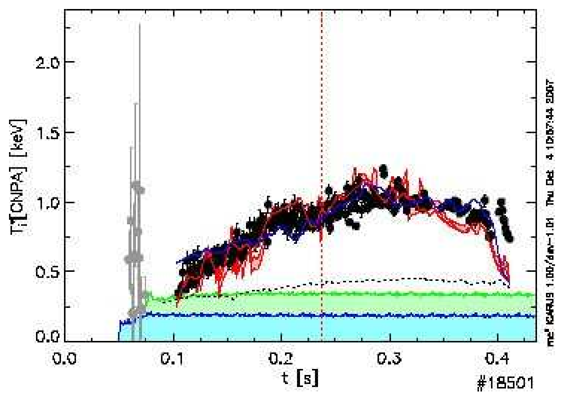


Figure 3: Temporal evolution of ion temperature for MAST discharge #18501

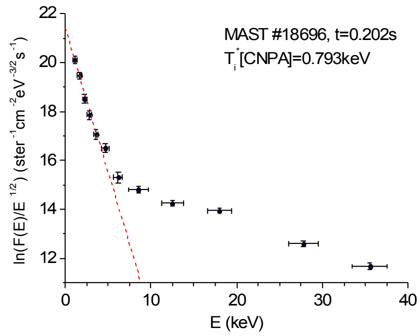


Figure 4: Decay of hydrogen flux with energy for a NBI heated MASTdischarge. Fluxes at energies above 5 keV result from slowing down spectrum of particles injected by NBI [4]

in a good agreement and they are also consistent with results from measurements applying charge exchange recombination spectroscopy. Fig. 3 and 4 represent CNPA data yielding an ion temperature of about 800 eV during discharge #18501 at 0.2 s after discharge ignition. The sightlines of the applied CX-recombination spectrometer and experimental details of this spectrometer are described in [5]. Figure 5 and 6 show results from CX-RS of an H-mode and an L-mode discharge. These results are shown together with the radial temperature distribution obtained by Thomson scattering measurements. Figure 7 shows the temporal evolution of ion temperature for discharge # 13695 measured by CX-RS. Finally, the comparison of CX-NPA, CX-RS and Thomson Scattering is presented in Figure 8. It can be seen, that all techniques applied, CX-NPA, CX-RS and Thomson scattering, yield a temperature value of about 900 eV for MAST discharge #18501 at the radial position of about 1.2 m. This can be considered as a very satisfactory result.

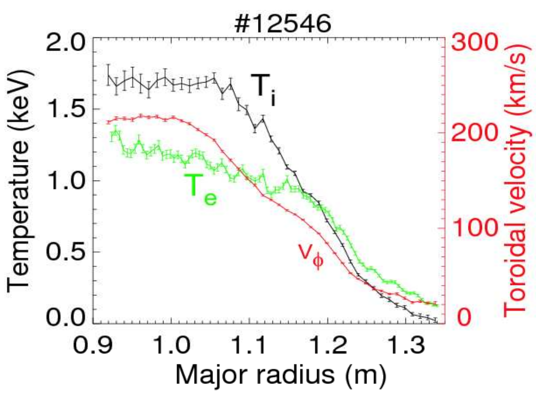


Figure 5: Radial temperature and velocity distribution of H-mode discharge

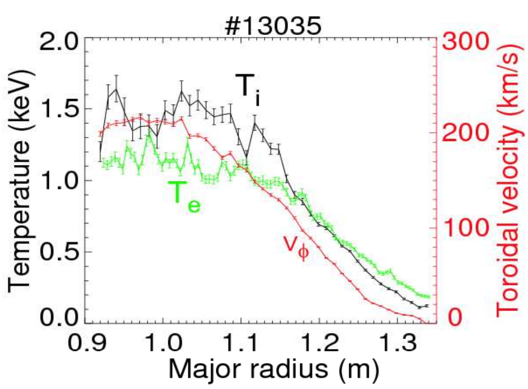
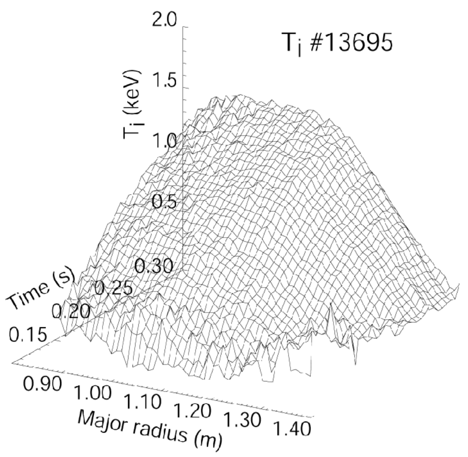


Figure 6: Radial temperature and velocity distribution of L-mode discharge



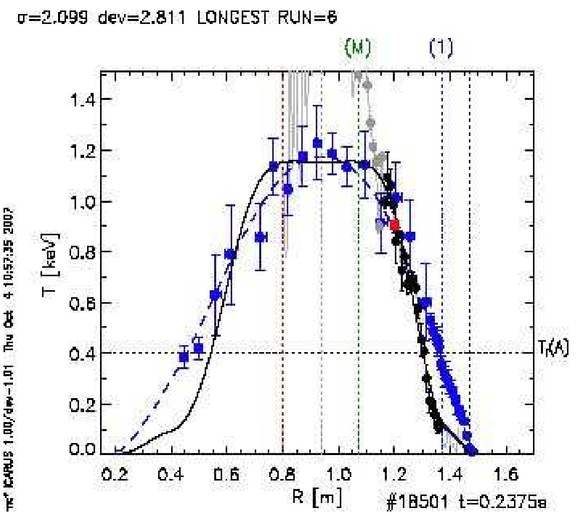


Figure 7: Temporal evoluation of ion temperature distribution

Figure 8: Radial profiles of ion temperatures from CX-NPA, CX-RS and Thomson Scattering:
red Point: CNPA
black symbols: CX-RS
blue symbols: Thomson Scattering
grey symbols: CX-RS -outside validation range of modelling

Summary

The tests of the CNPA has been shown promising results at MAST, which are in good agreement to measurements with the Princeton NPA and CX-RS measurements. The CNPA is very reliable and requires low maintenance. A further upgrade of MAST diagnostics is going on in order to realise ion temperature measurements deeper in the plasma centre.

Acknowledgements

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