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Neutral Particle Diagnostics on MAST

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Introduction

A Compact Neutral Particle Analyser (CNPA) has been deployed on the MAST tokamak to study the ion heating and the energy distribution of the fast ions and is later foreseen to be used for determining the ion temperature in the Wendelstein 7-X (W7-X) stellarator. Neutron fluxes up to ~ 2 x 10^8 neutrons / cm^2 s and residual magnetic fields up to 50 mT are expected at the CNPA location during a representative MAST discharge and potentially might contribute to the errors in determining the ion temperature. These conditions are expected to become even more challenging at W7-X and after ongoing MAST neutral beam upgrades, where this type of diagnostic is expected to be used in the future.

The experimental set-up of CX-diagnostics on W7-X and MAST are shown in figures 1 and 2. More details can be found in [1] - [4].

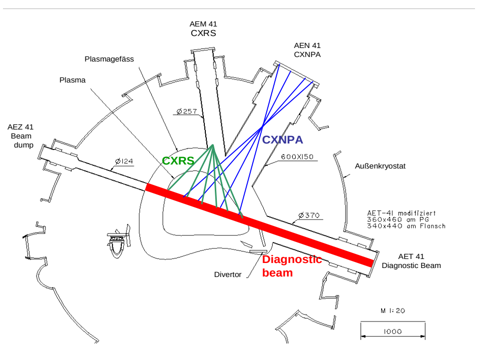


Figure 1: Setup of CX diagnostics on W7-X

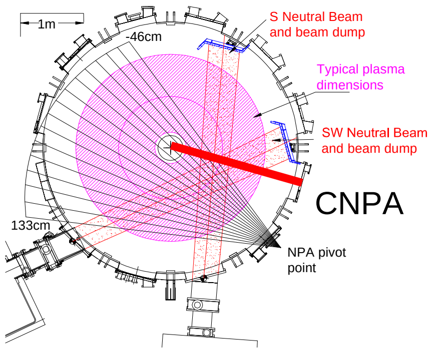


Figure 2: Set-up of NPA-diagnostics on MAST

Results

CNPA has been installed near proximity of the plasma device without any neutron and magnetic shielding. Measurements showing the influence of neutron irradiation on CNPA detectors have been presented in [4]. The signal to noise ratio is low and dominated by the neutron background. For detectors in the energy range of 2 – 5 keV this ratio was found to be about 2. The relation between neutron signal and the incoming neutron flux, measured by the fission chamber, is shown in figure 3. The expected linear dependence has been confirmed by the data and taken into account for further NPA studies.

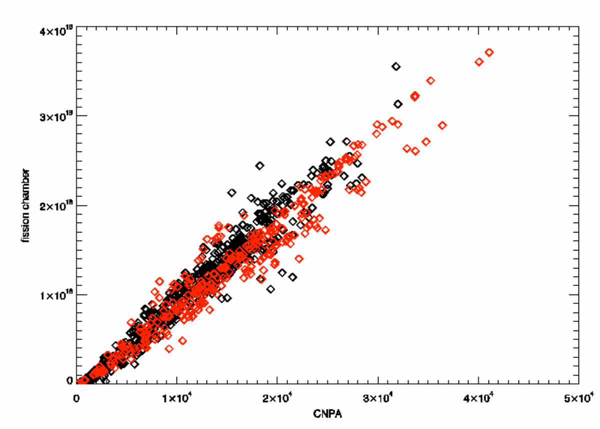
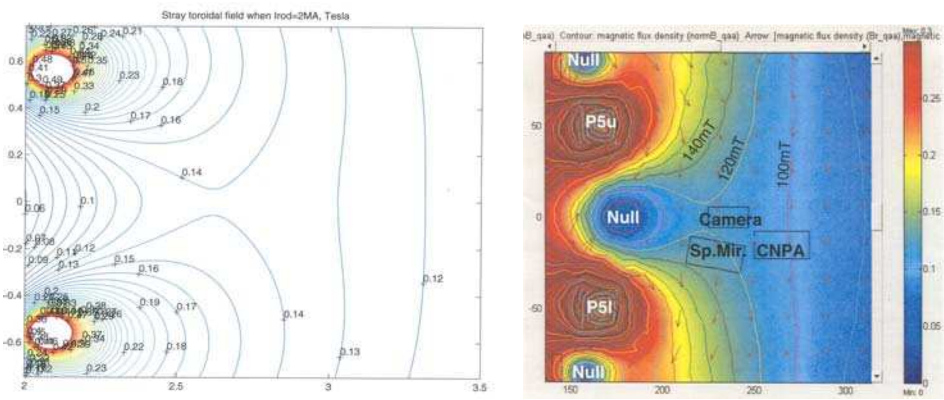


Figure 3: Relationship of neutron caused detector signal and incoming neutron flux

In order to minimise errors in the evaluation of ion temperature, it is also important to know the magnetic stray field at the analyser position and the influence of the outer magnetic stray field on the traces of Deuterium ions inside the analyser. Simulations of the residual magnetic fields on MAST in case of applying the highest coil currents has been done and are shown in figures 4a and 4b [5]. Their distributions are very inhomogeneous and magnitudes exceeding the recommended values by factor of 10 at the CNPA position.



a) b)

Fig. 4: Magnetic stray field of MAST around CNPA location: a) field lines, b) contour plot

Magnetic stray field distributions on W7-X for the plane of 2 m and 4 m over the plasma center are shown in figures 5a and 5b. The residual field strength at the planned CNPA position was found to be 6 – 8 mT [6].

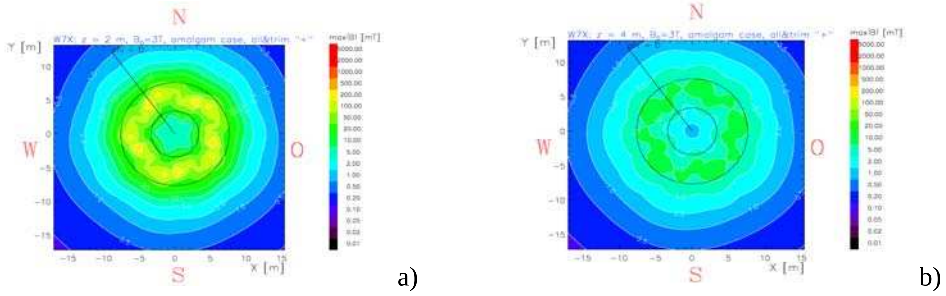


Figure 5: Magnetic stray field contour of W7-X: a) for the plane z = 2 m b) for z = 4 m

Because of the presence of the higher outer magnetic field compared with the threshold for an undisturbed analyser operation the NPA-results should be compared with other independent techniques. Figure 6 shows the temporal evolution of ion temperatures of the NBI heated MAST discharge #20637. In figure 7 the T_i-value for the discharge time of 0.2775 s determined with the CNPA is compared with ion temperature values obtained by CX-RS measurements and T_e-measurements from Thomson scattering.

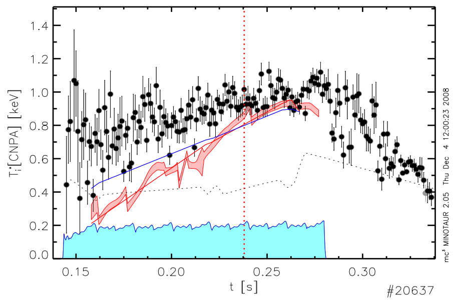


Figure 6: Temporal evolution of ion temperatures for MAST discharge # 20637

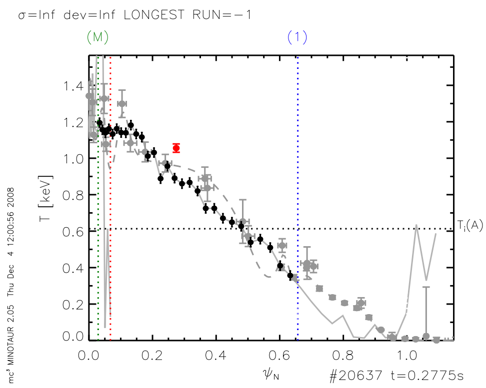


Figure 7: Radial temperature profiles from CX-NPA, CX-RS and Thomson scattering:
red point: CNPA
black symbols: CX-RS
blue symbols: Thomson scattering

Despite the fact that previous NPA-measurements were found in a good agreement with other diagnostics great attention should be paid to possible errors due to magnetic and neutron influence. The influence of neutrons on the signal rates of CNPA detectors is known in general and can be taken into account. The problem with high outer magnetic stray fields can be solved only by using a special magnetic shielding around the analyser, which is planned for future.

Summary and outlook

CX-NPA and CX-RS diagnostics are foreseen on W7-X in order to determine the ion temperature profiles and the fast ion behaviour. The operation of CNPA on MAST permits the study of these parameters under conditions of high magnetic stray fields and strong neutron fluxes. Simulations of the residual magnetic fields on MAST and W7-X at diagnostic locations have been presented. The CNPA should operate with an additional magnetic housing using ARMCO material after MAST neutral beam upgrade and during its later deployment on W7-X. The problem of shielding against an outer magnetic field becomes more essential for the deployment of 3 further ACORD-type analysers, which are foreseen in the NPA-analyser array on W7-X. For these ACORD-analyser an outer magnetic field up to 2 mT is allowed for reliable measurements [7]. Because of greater difficulties for shielding ACORD-analysers due to their dimensions and their additional pump, the influence of outer magnetic field on possible errors has to be studied. It is foreseen to test an ACORD-analyser inside Helmholtz coils by evaporating of Li^+- or Na^+- ions and to check the influence of the magnetic field on their traces to the detectors. Further, a modelling of these paths under the influence of an outer magnetic field up to 100 mT is envisaged. Previous T_i-measurements by means of CNPA on MAST have been found in relative good agreement with results from CX-RS.

Acknowledgements

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