How to Characterise a Reactor Relevant Fusion Plasma: JET Diagnostics.

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Fusion plasmas are complex non linear systems, continuously driven away from equilibrium in order to achieve better performances in energetic terms. The need to carefully explore the operational parameter space and to find the best compromise between total energy output and sufficient stability, requires the simultaneous determination of a vast series of quantities, obtained with measuring systems called diagnostics. In magnetic confinement fusion the highest emphasis falls on the determination of the magnetic field topology, essential not only for the physics but also for the real time control of the experiments. To quantify the energetic performances of the plasma, the kinetic properties, density and temperature, of both the ion and electron fluid have to be carefully determined. In this perspective, the level of impurities (particles of non reacting species diluting the main plasma) and the radiation emission have also to be closely monitored, because they strongly affect the power balances of the magnetic configuration. The fusion products, alpha particles and neutrons, which constitute the ultimate indicator of the plasma fusion reactor relevance, have to be detected with high time and energy resolution. Since in present fusion devices plasmas with temperatures of millions of degrees are confined very close to material surfaces and not far from vacuum panels kept at the temperature of liquid helium, plasma wall interactions and the related themal stresses constitute one of the main problems for the operation of the future fusion reactor. The power loads on the plasma facing components, erosion redeposition and recycling are some of the elements which have to be efficiently monitored for the operation of the devices and the understanding of the edge physics. To determine all these quantities with the required accuracy, in a Tokamak machine practically all the main measurement techniques of the physical sciences are represented.

In JET, the biggest and most relevant Tokamak in the world, the diagnostics now produce a peak of more than 10 Gigabytes of data per shot. All the basic measuring techniques used in physics, from interferometry to scattering, from spectroscopy to tomography, from radar to thermography, are represented and refined to cope with the very challenging environment of a fusion device. Given the high neutron yield, new technologies are also being pursued to develop radiation hard sensors applicable also to the next generation of fusion devices. Several techniques are normally used to measure the same quantity in order to cross validate the results and exploit the synergies between various techniques. In the last years significant efforts have also been performed in the direction of improving the data analysis methods. New methods, based on Bayesian statistics and graph theory, are being developed to improve the data analysis and integrate the results of various measurements, Soft computing approaches, such as fuzzy logic, and non algorithmic methods, such as Cellular Neural Networks, are finding useful applications in various aspects of the signal processing, particularly in the field of real time control.