State of the art of nuclear diagnostics for fusion reactors

A. Dal Molin,[1,*] G. Marcer,[2] A. Muraro,[1] M. Nocente,[2] E. Panontin,[2] E. Perelli Cippo,[1] O. Putignano,[2] M. Rebai,[1] D. Rigamonti,[1] M. Tardocchi,[1] G. Gorini,[2] and JET Contributors.[3]

[1] *Istituto per la Scienza e la Tecnologia dei Plasmi, CNR, Milan, Italy*

[2] *Università degli Studi di Milano-Bicocca, Milan Italy*

[3] *See the author list of 'Overview of JET results for optimising ITER operation' by J. Mailloux et al. to be published in Nuclear Fusion Special issue: Overview and Summary Papers from the 28th Fusion Energy Conference (Nice, France, 10-15 May 2021)"*

* *Corresponding author: andrea.dalmolin@istp.cnr.it*

Nuclear fusion research is one of the most prominent fields set to revolutionize the energy market in the medium-long term period. Recent scientific achievements, such as the ones obtained at JET [1] and NIF [2], have renewed public and private interest in this topic, sparking the creation of numerous new projects and reactor concepts.

Nuclear diagnostics are an essential tool to assess any deuterium-tritium machine performance. Absolute neutron counting is the gold standard technique to measure fusion power. Neutron emission spectroscopy grants access to the fuel ion physics providing information on the fuel ion temperature and energy distribution, the fuel ion ratio and the thermal to non-thermal neutron fraction. Gamma-ray and hard X-ray spectroscopy are the most direct way to obtain information on the fast particle energy distribution and their interaction with the plasma.

Fusion nuclear diagnostics need to be carefully designed to operate in extreme scenarios, both in terms of operational capabilities (energy range, energy resolution, counting rate potential, etc.) and in terms of robustness in the harsh environment of a nuclear reactor. In this work, we present the state of the art for nuclear measurements in fusion experiments and we discuss possible solutions for the next-generation reactors.

[1] Gibney, E. (2022). Nuclear-fusion reactor smashes energy record. In Nature (Vol. 602, Issue 7897, pp. 371–371). Springer Science and Business Media LLC. https://doi.org/10.1038/d41586-022-00391-1

[2] Zylstra, A.B., Hurricane, O.A., Callahan, D.A. *et al.* Burning plasma achieved in inertial fusion. *Nature* 601**,** 542–548 (2022). https://doi.org/10.1038/s41586-021-04281-w