2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Neutron-gamma measurements at the Madison Symmetric Torus

L. Cordaro[1], M. Zuin[1], J. K. Anderson[2], L. Stevanato[3], C. Fontana[3], I. Bonesso[3], J. Kim[2]
[1]Consorzio RFX, Padova [2]Department of Physics, University of Wisconsin-Madison
[3]Department of Physics, University of Padova
e-mail: luigi.cordaro@igi.cnr.it

The detection of high energy particles is widely considered as a crucial task for fusion reactors physics. A particular role, in this context, is owned by neutrons and photons which, being not charged, can leave the fusion machine and provide useful information about the plasma.
In this contribution, the energy calibration and the first experimental measurements of a new diagnostic for the neutron-gamma detection are presented.
The experimental system is composed of 6 scintillator cells coupled with flat photomultiplier tubes (PMTs) through silicon rubber interfaces. The output anode signals are fed into a CAEN DT5725 14 bit 250 MS/s Digitizer, equipped with algorithms for real-time analysis of each individual scintillation event. The PMTs are operated at relatively low voltage (~1kV), in order to avoid saturation effects, by means of a CAEN DT5533E HV power supply module.
One detector cell is based on NaI(Tl) crystal scintillator, the remaining ones use EJ-309 organic liquid scintillators. While the former, sensible only to high energy photons, is used for gamma-ray spectra analysis, the latter are used for fast neutron detection, thanks to their capability to separate neutrons from the gamma-ray component of the radiation field, by means of the Pulse Shape Discrimination (PSD) technique [1].
Each scintillator has been preliminarily characterized for its response to neutrons and gamma rays, at the Italian INFN laboratories in Legnaro. Energy calibration of the scintillation light has been performed with several calibrated radioactive sources (^{22}Na, ^{60}Co, ^{137}Cs, ^{241}Am), in the energy range from 59 keV to 1.33 MeV. Calibration of EJ-309 light output has been performed by fitting the experimental distribution of Compton scattering events of photons with a response function reconstructed by an expected model distribution [2]. The neutron response function has been analyzed as a function of the neutron time-of-flight, using a 10^6 fissions/s ^{252}Cf source tagged by an additional fast plastic scintillator. The Figure of Merit (FoM) has been estimated in order to measure the PSD capability to discriminate between neutrons and gamma ray events [1].
This set of detectors , which could provide the possibility to reconstruct an elemental image of the plasma emission, has recently been installed at the Madison Symmetric Torus (MST), a reversed field pinch device with minor radius a=0.52 m and major radius R=1.5m. MST is equipped with a 1MW Neutral Beam Injection (NBI) device that accelerates neutral particles towards the core plasma with an energy of approximately E_{NBI}=25 keV and a current of up to I_{NBI}=40 A [3].
The system has been operated in a wide range of plasma conditions, with and without neutral injection. Core plasma and NBI are fueled with hydrogen and deuterium.
The first experimental measurements have shown an excellent temporal resolution and the overall diagnostic has proved to withstand high gamma-ray and neutron flows, up to several Mcounts/ms^{-1}.
A high neutron flux has been detected in discharges operated with NBI. The fusion neutron flux decay, measured after the NBI switching off, allows an estimation of the fast ion confinement time in RFP plasmas, comparable to that found in [4].
Thanks to the high temporal resolution of the digitizer, the diagnostic is able to detect very fast transient phenomena, such as those detected during discrete plasma relaxation events. During these phenomena, fast transient peaks of both gamma and neutrons have been detected, allowing the study of fast particles induced by magnetic reconnection events in plasma.

References

[1] Cester D. et al., Nucl. Instr. Meth. Phys. Res., 748, 33-38 (2014)
[2] Stevanato L. et al., Applied Radiation and Isotopes 69 369-372 (2011)
[3] Waksman J., Anderson J. K. et al., Neutral beam heating of a RFP plasma in MST, Physics Of Plasmas 19, 122505 (2012)
[4] Anderson J. K. et al., Plasma Phys Control Fusion 56 094006, 2014