Impact of Runaway Electrons on WEST Tungsten Plasma Facing Components using radioactivity signature

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The components of the first wall in tokamaks are exposed to particle fluxes that can induce nuclear reactions, leading to the creation of radioelements. This study specifically examines nuclear activation in tungsten environment and particularly the divertor, which is the most exposed component to particle and heat fluxes. The WEST tokamak using divertor with actively cooled ITER grade PFCs (plasma facing components), provides a unique platform for investigating separately the activation volume caused by fusion neutrons and runaway electrons (RE). In WEST (a=0.5m; R=2.5m; I_p= 0.5-1MA; P_{in}=5-10MW) the contribution of RE to radioelement production in tungsten can exceed that of fusion neutrons. Experiments conducted in deuterium plasma on the WEST tokamak typically yield 3.10^6 and 3.10^3 neutrons/cm^2/s of 2.45 and 14 MeV, respectively. In these plasma conditions, RE can generate beams up to 150 kA. Upon impact with the divertor, this is equivalent to a flux of approximately 10^{13} electrons (> 8 MeV)/cm^2 falling on the components within tens of milliseconds.

The radioelements produced in natural tungsten are mainly ^{181}W and ^{185}W through nuclear reactions induced by neutrons or photoneutrons from RE. These isotopes half-life is 121 and 75 days respectively and can impose severe safety constraints to man access in the WEST device (maintenance, personnel protection, nuclear management, etc.). This can be the case even without the production of fusion neutrons and only because of RE.

The results presented here are based on gamma-ray spectroscopy measurements conducted on WEST tungsten PFCs and simulations carried out with the Monte-Carlo transport code TRIPOLI-4. In the reported experiments, it is observed that a single event of RE beam can induce localized mass activations of more than 50 kBq/kg in tungsten. This is in contrast to a diffuse mass activation inducing about 10^{-2} kBq/kg with a fluence of 10^{10} neutrons$_{2.45}$/cm^2 after 5 hours of plasma during the WEST 2023 campaign.

These radioactivity measurements, along with other diagnostics such as plasma current and position, neutron flux, and infrared videos, enable the identification and characterization of RE interaction events within the divertor tungsten components. This study provides an evaluation

of the activation of ITER tungsten components in the undesired case high current RE are produced in this machine.