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Proton irradiation effects on superconducting properties of Nb3Sn

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In order to predict the irradiation effects in the MQXF quadrupoles in view of HL-LHC at CERN during operation up to a luminosity of 4'000 fb-1, an irradiation program was carried out on industrial, Ta and Ti added Nb3Sn wires. Wire samples from the same batch were irradiated with high energy protons (65 MeV and 24 GeV, up to 1.4 × 1021 p/m2) and neutrons (1 MeV, up to 1.8 × 1022 n/m2). The values of Tc and Jc were reported as a function of particle fluence. After replacing the fluence by the number of displacements per atom, dpa, determined using the FLUKA code, it was found that the variation of Tc in Nb3Sn wires as a function of the dpa value for both, proton and neutron irradiation, falls on the same curve, reflecting an universal behavior. This result reflects the fact that the variation of Tc is uniquely governed by the change in atomic ordering, S. Both the measured value, Tc, and the calculated one, dpa, depend essentially on the number of Frenkel defects. With the new relationship between Tc and dpa for both, protons and neutrons, the decrease of Tc in the quadrupoles at the maximum luminosity can be estimated to ˜ 0.3 K. The variation of Jc vs. dpa shows some similarities between proton and neutron irradiation, too, but the analysis is more complex, the observed enhancement of Jc with irradiation being due to enhanced point pinning caused by the radiation induced defect clusters.

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