



Contribution ID: 26

Type: **not specified**

Proton irradiation effects on superconducting properties of Nb₃Sn

Tuesday, 18 December 2018 10:10 (25 minutes)

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 1.4×10^{21} p/m²) and neutrons (1 MeV, up to 1.8×10^{22} n/m²). The values of T_c and J_c 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 T_c 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 T_c is uniquely governed by the change in atomic ordering. Both the measured value, T_c, and the calculated one, dpa, depend essentially on the number of Frenkel defects. With the new relationship between T_c and dpa for both, protons and neutrons, the decrease of T_c in the quadrupoles at the maximum luminosity can be estimated to ~ 0.3 K. The variation of J_c vs. dpa shows some similarities between proton and neutron irradiation, too, but the analysis is more complex, the observed enhancement of J_c with irradiation being due to enhanced point pinning caused by the radiation induced defect clusters.

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Session Classification: Radiation damage to materials status