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Investigation of low gain avalanche detectors exposed to proton fluences beyond 1015 neq/cm2

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The High Luminosity Large Hadron Collider upgrade will increase the luminosity of the LHC by a factor of 10. Low gain avalanche detectors (LGADs) promise excellent timing resolution, which can mitigate the pileup associated with high luminosity. The most highly irradiated LGADs will be subject to 2.5×10^{15}neq /cm2 of hadron fluence during Run 4; their timing performance must tolerate this. Hamamatsu Photonics K.K. (HPK) and Fondazione Bruno Kessler (FBK) LGADs have been irradiated with 400 and 500 MeV protons respectively up to the Run 4 hadron equivalent fluence. Measurements of the irradiated LGADs' leakage current, capacitance, charge collection, and timing performance are presented. A timing resolution better than 70 ps is observed for all fluences. Charge collection is below 10 fC for the HPK sensors after $(0.9\pm0.5)\cdot10^{15}$neq/cm2, and for the FBK sensors after $(1.7\pm1.0)\cdot10^{15}$neq/cm2 for all operating voltages below 600 V. 2x2 arrays of both the FBK and HPK LGADs were produced to study the inter-pad characteristics. The inter-pad resistance for the HPK LGADs stayed slightly above 10 MΩ for $5\cdot10^{14}$neq /cm2, and the inter-pad resistance of the FBK LGADs fell slightly below 1 MΩ after 10^{15}neq/cm2. Observations of the punch-through voltage and inter-pad isolation for fast signals are reported.

Authors: SORENSON, Josef Daniel (University of New Mexico (US)); HOEFERKAMP, Martin (Department of Physics and Astronomy); KRAMBERGER, Gregor (Jozef Stefan Institute (SI)); SEIDEL, Sally (University of New Mexico / ATLAS); SI, Jiahe (University of New Mexico (US))

Presenter: SORENSON, Josef Daniel (University of New Mexico (US))

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