MIP analysis of Si-sensor by electron beam for ALICE-FoCal

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A large ion collider experiment (ALICE)[1)] refers to a high-energy heavy ion collider experiment that uses the Large Hadron Collider (LHC) at CERN. The purpose of the experiment is to investigate the properties of quark gluon plasma (QGP). Previous results have indicated that the time to thermal equilibrium is much shorter than the theoretical expectation, and the color glass condensate (CGC) may explain this phenomenon. To investigate the CGC in detail, a detector, Forward Calorimeter (FoCal),[2)] will be installed to measures the direct photons emitted in the forward direction with high sensitivity to the CGC, into the ALICE experiment.

FoCal consists of FoCal-H and FoCal-E. FoCal-E has detection and absorption layers, with the detection layer comprising a high granularity layer (HGL) for position resolution and a low granularity layer (LGL) for energy measurement. The LGL consists of a 9×8 array of 1 cm^2 silicon sensors, and this study focused on this sensor. FoCal-E measures electromagnetic shower energy from photons and electrons over a wide range, making minimum ionizing particle (MIP) detection crucial. FoCal also experiences high neutron exposure, requiring durability of up to 7×10^{13} neutrons, making it essential to verify MIP detection after exposure. To investigate this, test beam experiments evaluated (1) MIP detection capability post-neutron exposure and (2) MIP behavior under varying neutron exposure, bias voltage, and temperature.

The test beam experiment was performed at ELPH with electron beam at energy of 800 MeV. The main sensor for LGL with neutron exposure was irradiated with the electron beam, and four sensors with different neutron exposures were analyzed. In Fig. 1, A is the fit of the composite function of the Gaussian and Landau functions, and B is the fit of Gaussian convolved with the Landau function. B describes the data better than A, and successfully extracts the MIP signal. Figure 2 shows the neutron dose dependence of MIP and voltage applied to the bias resistance at 13°C. The MIP is observed for all neutron exposures. The higher the voltage, the more constant the MIP is. Also, the higher the neutron exposure, the lower the MIP tends to be. As well-known, the higher the exposure dose of the sensor, the higher is the voltage required to achieve full depletion, making it necessary to evaluate the effect of neutron exposure by comparing the sensor with a non-exposed sensor. Figure 3 shows the temperature dependence of MIP and voltage applied to the bias resistance at 2.16×10^{13} neutrons. MIP shows no significant temperature dependence, requiring further measurements at more varied temperatures. This work was supported by the Research Program at the Research Center for Election Photon Science, Tohoku University.

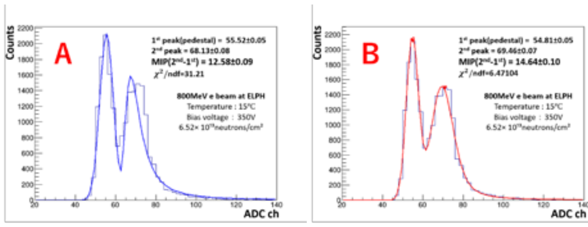

Fig. 1. A. Gaussian + Landau fit; while B. Gaussian convolved with Landau fit.

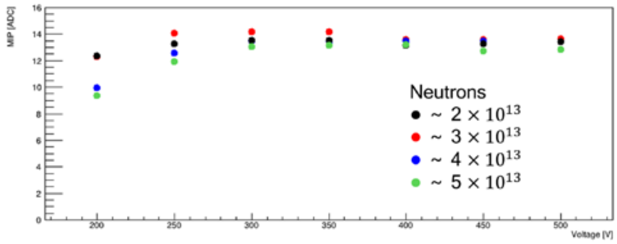

Fig. 2. Neutron dose dependence of MIP(ADC) positions vs. voltage applied to the bias resistance at 13°C.

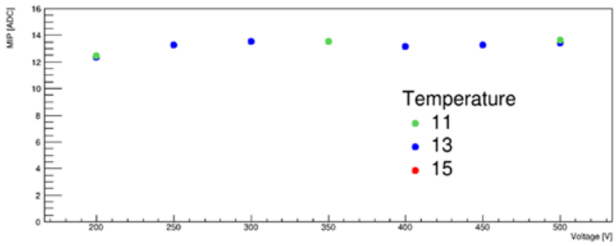

Fig. 3. Temperature dependence of MIP(ADC) positions vs. voltage applied to the bias resistance at neutron exposure of roughly 2×10^{13} [neutrons].

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2) ALICE collaboration, Technical Design Report of the ALICE Forward Calorimeter (FoCal) (2001).