Contribution ID: **239** Type: **Oral Communication**

Low Gain Avalanche Silicon Detectors: an experimental study and modeling for high resolution X-ray spectroscopy

Tuesday 2 July 2024 15:30 (20 minutes)

Radiation and particle semiconductor detectors incorporating electron-hole multiplication layers have received a growing interest within the scientific community in the last decade [1-4]. In particular, devices operating in the proportional charge multiplication region with moderate gains (< 50), commonly called Low Gain Avalanche Detectors (LGAD), have been found very challenging for high resolution timing and for their spectroscopic and position sensitive possibilities [5-6].
It is anyhow well known that the charge multiplication via impact ionization introduces an additional noise source [7] and reduces the weight of some noise components of the overall system, but a comprehensive study for the noise of LGAD in the very low gain region still needs investigation and modeling. In this work, we present an experimental study on the noise power spectral density of the reverse current of an LGAD, which has allowed to quantify its noise components under various bias conditions. The excess noise factor has been determined as function of the multiplication gain. Extremely low excess noise factors have been found and a comparison with the available theoretical model is presented, showing its limits of application, together with an empirical model with excellent agreement with the experimental data. A comprehensive model for the electronic noise of a system employing a LGAD will be presented, showing the effects of the different noise components on the achievable signal to noise ratio. On the basis of this model, it is possible to precisely determine the optimum multiplication gain of the LGAD to be chosen to achieve the best system performance for each given set of detector's and front-end electronics'parameters. The model has been verified with the experimental data of X-ray spectroscopy up to 60 keV. This experimental and theoretical study allows to identify the potentialities and the field of applications of silicon detectors with internal multiplication charge gain, in particular in X-ray spectroscopy, opening perspectives for their potential implementation on radiation imaging devices.

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Session Classification: Sensor Materials