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Single photon counting pixel detector below 1 keV using LGAD sensors

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Soft X-rays (in the range of 200-2000 eV) are of great interest for imaging applications for a large variety of sectors. These include: imaging of organic samples, e.g., in the "water window"(between C and O, K-edges: 277 eV to 525 eV), anomalous scattering experiments around many K-edges of light elements, and L-edges of 3d transition metals (relevant to magnetic and superconducting materials). Many of the techniques performed at synchrotrons in the tender and hard X-ray regimes are currently hindered in the soft X-ray range by the lack of fast, large area, high dynamic-range detectors, sensitive to photons <2 keV [1].
To extend the application of the state-of-the art hybrid X-ray detectors to a lower energy range, PSI and FBK are developing silicon sensors based on Low Gain Avalanche Diodes (LGADs). These LGAD sensors are optimized for soft X-ray detection: they include a charge multiplication layer with a gain of ˜10 in order to amplify the signal and improve the signal-to-noise ratio, combined with a thin entrance window in order to increase the quantum efficiency at lower photon energies [2]. This contribution will present tests performed in the soft X-ray regime using the developed pixelated LGAD sensors with a pixel pitch of 75 µm, bump-bonded to the EIGER single photon counting read-out chip [3]. LGAD sensors with different multiplication layer designs and a large detection area of 4×4 cm2 have been characterized at the SIM beamline at SLS (PSI, Switzerland) between 200 eV and 900 eV. Additionally, as a proof-of-principle, ptychographic scans in the soft X-ray energy range have been performed. The high dynamic range, large area, fast frame rate, and low noise of the detector outdo the results previously obtained with hybrid charge-integrating detectors (such as Mönch), and allow to achieve a high resolution, mainly limited by the size of the detector [4]. Characterization results of the sensor performances will be presented, as well as preliminary ptychographic reconstructions obtained with 500-700 eV photons.

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[2] J. Zhang, et al., JINST 17.11 (2022).
[3] R. Dinapoli et al., NIM A 650.1 (2011): 79-83.
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