PhD course of National Interest in Technologies for Fundamental Research in Physics and Astrophysics

Annual report

Name and surname: Sami Ullah Khan
Cycle and a.a.: 40th & 2024/2025
Supervisor: Manuel Dionisio Da Rocha Rolo

- **Research activity carried out during the year**

Aim of the Project

The main goal of my research is to evaluate and optimize the performance of the ARCADIA MD3 CMOS sensor for advanced X-ray imaging applications, including phase contrast imaging. The project focuses on analysing the sensor's response under various X-ray conditions and developing self-calibration methods to improve uniformity and detection efficiency.

Research Activities Performed

During this year, I successfully set up a hard X-ray experimental station using a molybdenum filament X-ray tube and a (220) silicon crystal, operating at 35 kV, to generate and detect $K\alpha_1$ diffraction peaks. A lead slit was used to collimate the beam, and the Bragg angle was carefully aligned to observe characteristic lines. Through these measurements, I analysed cluster size distributions to study charge sharing and localization of events. Further experiments were performed using soft X-rays and Bremsstrahlung radiation, here we used an aluminium filter to suppress characteristic lines. The spatial distribution of hits and variations in cluster size under different energy regimes were used to evaluate the detector's sensitivity and charge diffusion behaviour. To address pixel-level non-uniformities, a Python-based self-calibration algorithm is developed. This tool adjusts bias and VCASN values across the sensor columns by comparing signal levels with defined thresholds. It improved stability, reduced noise, and led to more consistent pixel response across the array.

Difficulties and Actions Taken

One major challenge was the initial misalignment of the slit and crystal, which produced unclear diffraction patterns. This was resolved by realigning the setup using geometric modelling and reference measurements. Another issue was non-uniform signal response across the sensor, which complicated data interpretation. The calibration algorithm helped mitigate this by tuning local parameters based on real-time signal feedback. In soft X-ray tests, I observed increased noise and pile-up effects, especially at low thresholds. These were addressed by optimizing exposure conditions and applying aluminum filtering to improve event clarity. A Python-based self-calibration algorithm is introduced for dynamic tuning of bias and VCASN values across the sensor array. This algorithm compares real-time pixel signal distributions with defined tolerance ranges and iteratively adjusts operating parameters to stabilize the response.

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- **List of attended courses and passed exams**

  Courses attended:

  1: Programmable SOCs (4 CFU, **exam passed**)

  2: Microelectronics for radiation detector II (3 CFU, **exam passed**)

  3: Design of readout integrated circuits for particle detectors (2.5 CFU, **exam passed**)

  4: Introductory course to VHDL and HLS programming (5 CFU, **exam passed**)

  5: Fundamental of FPGA based digital design (2.5 CFU, **exam remaining**)

- **List of attended conferences, workshops and schools, with mention of the presented talks**

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- **List of published papers/proceedings**

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- **Thesis title (even temporary)**

  Development and characterization of CMOS sensors for X-ray Imaging in space and medical applications

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Date: 10-09-2025 **Signature:**

Seen, the supervisor