**Ph.D. in Information Technology**
**Thesis Defense**

**May 10th, 2024**
**at 17:00 p.m.**
**Room Alpha**

**Griseld DEDA** – XXXVI Cycle

# DEVELOPMENT OF READOUT ELECTRONICS FOR INNOVATIVE ENERGY-DISPERSIVE X-RAY DETECTORS BASED ON MONOLITHIC ARRAYS OF SDDS

Supervisor: Prof. Carlo Ettore Fiorini

**Abstract:**

The main goal of this thesis was the development and characterization of SCARLET (SDD-ASIC ARray for Large Event Throughput) Analog Pulse Processor (APP), a new high-density, multichannel X-ray detector for spectroscopic applications that can achieve both high energy resolution and high counting rate. The chip layout is compatible for bump-bonding assembly with 2 × 2, 2-mm pitch, monolithic arrays of Silicon Drift Detector (SDD), obtaining a so-called Hybrid Pixel Detector. This configuration comes with a set of challenges that need to be adressed. Reducing the pixel area of the detector can introduce challenges such as charge sharing. The adoption of flip-chip bump bonding technology introduces challenges like missing bonds, local shorts, temperature or lifetime reliability, verification procedures, and the presence of parasitic capacitance and resistance in the bump solder. Another critical challenge is the integration of the Charge Sensitive Amplifier (CSA) with the rest of the pulse processing electronics, which introduces mixed-signal issues. The ASIC development has been started from its predecessor, TERA (Throughput Enhanced Readout ASIC), designed in the same 0.35 μm CMOS technology node. Each channel includes the CSA, a 7th-order semi-Gaussian shaping amplifier with controllable shaping times and full scale ranges, followed by a peak stretcher and a switched capacitor analog-memory. Each channel is also equipped with a dedicated peak detector and a novel pile up rejection (PUR) logic. Each pair of channels is digitized by a 12-bit on-chip Successive-Approximation Register (SAR) ADC. The thesis also addresses the development and characterization of a new 1-mm thick 2×4 monolithic array of SDDs, with a pixel active area of 8×8 mm2, in the framework of SIDDHARTA-2 experiment. This experiment aims to deepen the knowledge of strong nuclear interactions. Moreover, the thesis presents the development of a novel detection module based on these SDDs, coupled with CMOS-based Charge Sensitive Amplifiers arranged in a stacked structure with the goal to enhance the detection efficiency in the hard X-ray range. This solution aims to further increase the absorption efficiency of the system without acting on the substrate thickness of the SDD.

## PhD Committee

Giacomo Borghi, **Politecnico di Milano**
Massimo Manghisoni, **Università Degli Studi Di Bergamo**
Dionisio Doering, **Stanford University**