Ph.D. in Information Technology
Thesis Defense

September 25th, 2026
At 02:30 p.m.
Room Alpha - Building 24

Christian Riboldi – 38th Cycle

DEVELOPMENT OF READOUT ELECTRONICS AND DATA ACQUISITION SYSTEM FOR GAMMA RADIATION DETECTORS IN HADRONTHERAPY APPLICATIONS
Supervisor: Prof. Marco Carminati

Abstract:

This doctoral project is dedicated to the development of advanced electronics readout for gamma radiation detection in the medical field, focused on the realization of a prompt gamma ray camera for real-time monitoring of the interaction depth of the beam in hadrontherapy as part of the REALPATH project. Hadrontherapy uses accelerated charged particles, such as protons and carbon or helium ions, for the targeted treatment of tumors. Compared to conventional X-ray radiotherapy, it allows for highly localized energy deposition within the tumor volume, minimizing damage to surrounding healthy tissue. However, to fully exploit the potential of this technique, accurate monitoring of the Bragg peak, i.e., the point of maximum dose deposition in the tissue, is necessary in order to improve treatment accuracy and reduce safety margins in treatment planning. The system developed is based on pixelated LYSO scintillators coupled with SiPM arrays and read out via dedicated multi-channel ASICs, specifically optimised for the detection of prompt gamma rays. In particular, the work involves the experimental characterisation and integration of the SITH ASIC, which is capable of simultaneously measuring the energy and timing of gamma photons. A key contribution of this doctoral research concerns the development of a modular FPGA-based data acquisition architecture, designed to operate at high count rates. The implemented electronics consist of 32-channel modules that integrate front-end electronics, signal digitisation and real-time data management within the FPGA. Two front-end boards are combined into a single 64-channel acquisition unit, whilst the complete camera architecture can scale up to 512 channels through a modular approach. Particular attention has been paid to the management of high counting rates, which represent one of the main technological challenges of Prompt Gamma Imaging (PGI) systems. The acquisition chain developed has been experimentally validated up to counting rates exceeding 1 Mcps per channel, whilst maintaining stable spectroscopic performance and excellent energy resolution for the application (7.9-11.4% at 662 keV). The system has also been designed to support future developments towards 10 Gb/s data transmission and synchronised multi-camera acquisitions via White Rabbit-based time synchronisation. The detector and electronics developed were experimentally characterised both under laboratory conditions and under proton beam irradiation at the CNAO (National Centre for Oncological Hadrontherapy), demonstrating the feasibility of compact, scalable, high-rate prompt gamma imaging systems for clinical applications in range verification for hadrontherapy.

PhD Committee

Prof. Carlo Ettore Fiorini, **Politecnico di Milano**

Prof. Marco Riboldi, **Università Ludwig Maximilian di Monaco**

Prof. Stefano Riboldi, **Università degli Studi di Milano**