ELECTRICAL, ELECTRONICS AND COMMUNICATIONS ENGINEERING

INFN - Design and characterisation of novel cryogenic photon detection systems for fundamental physics and applications

Funded By	ISTITUTO NAZIONALE FISICA NUCLEARE

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Context of the research activity	The successful candidate will contribute to the development of novel photon detection systems that have to operate at liquid nitrogen temperature and below. The research will be focused on novel Geiger-mode silicon photon detectors (Silicon Photon multiplier, SiPM) mated to custom-designed front-end chips. These systems are primarily intended to equip the next generation of liquid noble detectors for neutrino and dark matter research, but they are expected to find use in many different areas.

	Liquid noble detectors based on Argon and Xenon will play a fundamental role in future research facilities investigating neutrino physics and direct dark matter detection. The interaction of the primary particles produce a few photons that need to be detected with the highest efficiency. In some cases, each photon must be time-stamped with an accuracy well below the ns. Sensitive areas of several square meters have to be instrumented with single-photon detection systems that combine the capability to operate at cryogenic temperature with excellent reliability and low power consumption. CMOS SPADs are today a reality, but the high dark count and low fill factor make them unsuitable in high-end applications. SPADs with single-cell access in which a sensor layer is vertically integrated with the readout electronics have been recently reported by major imaging sensors companies. Such devices are however geared towards small sensitive areas such as those typically covered by commercial imaging sensors and their use in large scale instrumentation where several square meters of sensors need to be deployed is problematic. Furthermore, the access to such proprietary technologies and their cost can be also an issue. Many applications do no need the granularity of an imaging pixel, which is a few micrometers in size. In nuclear and particle physics, in astrophysics as well as in nuclear medicine, pixel of few square millimetres are adequate. The actual sensor size is thus determined by the need of keeping the sensor

Objectives	capacitance low enough to not overload the front-end amplifier input. The aim of this research is to develop a new generation of photo-sensor systems particularly suited for high-end scientific applications that need to cover large areas. The research entails several aspects. First, dedicated SiPMs with high fill factor and adequate interconnection density have to be produced. Two approaches can be envisaged and will be pursued: the use of through-silicon vias and that of back-side illuminated devices. The interconnection between the sensor and the front-end electronics can be realised with direct bump-bonding between the sensor and the electronic wafers or with interposers. The sensor pitch will be kept coarse enough to allow the use of well-established and low cost flip chips techniques that allow the production of large sensor modules with high reliability and moderate cost. One of the key aspects of the research will be the design and characterisation of a custom-made front-end ASIC. The target device embed at least 1024 readout channels that can provide accurate time-stamping of the photons, measurement of the photon flux and embedded data processing and decimation, in order to reduce the number of cables to the back-end electronics. Smart power management strategies need to be used as the power consumption must be kept to a minimum. The full system must be properly engineered so that the transition from prototyping to large scale production is as smooth as possible. In accelerator-based experiments, the radiation tolerance of the equipment is a primary concern and radiation-aware design approaches need thus to be adopted. This will allow the use of the designed systems also in space-born missions, where the use of SiPMs is of increasing interest and where radiation tolerance is also an important requirement.

Skills and competencies for the development of the activity	The ideal candidate would have a good knowledge of basic electronics and semiconductor physics and a back ground in the use of CAD software for ASIC design. A good attitude to lab measurement and electronics testing is also necessary.