ELECTRICAL, ELECTRONICS AND COMMUNICATIONS ENGINEERING

INFN - Ultra low-power CMOS sensors for charged particles and X-rays

Funded By	ISTITUTO NAZIONALE FISICA NUCLEARE

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Context of the research activity	The aim of the research is to develop novel ultra-low power CMOS sensors to be used for charged particles and X-ray detection. The target applications are instruments employed in future space-born scientific missions, such as those looking at gamma and X-rays sources, and future detectors used in nuclear and particle physics. A sensor and electronics co-design approach will be followed to reduce the power consumption to 1 mW/cm2 or possibly even below.

Objectives	CMOS sensors are today dominating the imaging market. Their potential in high-performance scientific instruments has been recognised since several years and first complex systems based on this technology are being deployed. For instance, the new inner particle tracker of the ALICE experiment at CERN will be entirely based on CMOS sensors fabricated in a 180 nm CMOS technology. Several square meters are arranged in different layers around the interaction point where particle collisions take place. A key difference between sensors employed in visible imaging and those used for imaging charged particles or highly energetic photons is that the frame rate is usually much higher, while often it is required to readout only the subset of pixels which have been hit in a given time-frame. This requires front-end architecture that allows for sparse readout, which are thus more complex than the standard 4-T approach used in most visible imaging devices. For accelerator instrumentation and space-born missions, radiation tolerance is also a concern. The need of following the guidelines for radiation-aware design lead to larger transistors and more logic (due, for instance, to the use of triplication with majority voting and/or other mitigation strategies) that in turns imply more power consumption. In previous space mission, like the AMS detector attached to the International Space Station and the Fermi gamma-ray observer, silicon strip sensors have been used. Low-power has been achieved by ganging several sensors together with wire-bonding, thus reducing the number of readout channels to a minimum. For the successors of these missions, the use of CMOS sensors is very appealing, as it reduces

	the weight and simplifies the construction and improve reliability, as much less interconnection are needed. However, the power of the sensors must be reduced by at least one order of magnitude compared to today standards, while maintaining a frame-rate capability of at least a few hundred of Hertz or higher. Such sensors would be of course very interesting also for future accelerator-based instrumentation, in particular those needed in lepton colliders, where material budget has to be kept to a minimum. Here low power is critical to achieve much lighter systems, as the cooling and power distribution infrastructure can be greatly simplified. The reduction of the power consumption entails several aspects: novel front-end and readout concepts should be envisaged as well as smarter power management schemes. One of the keys to reduce the power in the front-end electronics, which often takes half of the total power budget, is to improve the sensor quality. This can be achieved by reducing the sensor capacitance and by increasing the signal yield. A very interesting possibility is to add a gain layer, so that the number of charges is multiplied inside the silicon. A proportional multiplication should be achieved, as the total charge released by an event is often an information of interest. The addition of a well controlled gain layer to standard CMOS sensors will thus be a central part of this research.

Skills and competencies for the development of the activity	In order to effectively contribute to the research activity, the candidate should have a good back ground in at least one of the following fields: 1-Sensor design and simulation with TCAD tools 2-Analog circuit design 3-Digital circuit design 4-Firmware development and in lab device characterisation.