Popular science abstract

Quantum electrodynamics (QED) describes the interaction of electrically charged particles with electromagnetic fields. It is often thought of as the most accurate description of nature and impacts many fields of research in physics. It is also the most precisely tested theory in the regime of weak fields where perturbative calculations are applicable. With the advance of laser technology which provide access to strong fields, new phenomena will appear, predicted long time ago, like for example the sparking vacuum, whereby a spontaneous production of electron positron pairs, e^+e^-, can occur. For that to happen, the electrical field has to be above a critical value of $E_{\text{crit}} = 1.3 \cdot 10^{18}\,\text{V/m}$ also called the Schwinger limit. This limit defines a new regime of QED - the non-perturbative regime. While such high laser fields may become available in the future, the value of the Schwinger limit can be presently probed in interactions of high energy electron beams with easily achievable laser power in excess of 300 TW by measuring the rate of created e^+e^- pairs. This is the core of the LUXE experiment proposed at DESY with the 16.5 GeV electrons of the European XFEL Facility. The electron beam will be used to either interact directly with the intense laser beam or to produce a flux of bremsstrahlung photons which will then collide with the laser. A precision of better than 10% on the determination of the Schwinger limit will be achieved. The LUXE experiment, expected to be operational in the second half of 2024, has the potential to open a window into the largely unexplored regime of non-perturbative QED.

For the proper identifcation and counting of signal positrons produced in the beam-laser interactions, a fine-grained compact electromagnetic calorimeter is necessary. The AGH and TAU (Tel Aviv University, Israel) teams propose to build such a sandwich type calorimeter, consisting of 20 tungsten plates (3.5 mm thick, with a surface of $55 \times 5.5\,\text{cm}^2$) interspersed with ultra thin sensor planes. The signals from sensors will be read by a dedicated front-end electronics placed close to sensors, reading in total above 20 000 sensor channels. The AGH group has many years of experience in the development of compact electromagnetic calorimeters, and in particular in the design of a dedicated front-end electronics in advanced CMOS technologies for such calorimeters. AGH and TAU teams have built within the FCAL collaboration a prototype of a compact luminometer for future high-energy linear e^+e^- colliders. For the present proposal, the AGH group aspires to develop new thin dedicated front-end electronics module and connect it closely to the thin tungsten-sensor module. In next step 20 such modules will be integrated in a complete electromagnetic calorimeter. The success of this proposal will ensure a novel compact calorimeter, capable to perform under harsh conditions.

A key component of front-end electronics is a dedicated multi-channel ASIC (Application Specific Integrated Circuit) designed in advanced CMOS technology. For the readout of electromagnetic calorimeter a 32-channel ultra-low power ASIC will be designed in CMOS 130 nm technology. The design architecture and technology choice will assure ultra-low power needed to integrate the front-end and sensors, without additional cooling. The front-end architecture will allow to read calorimetric signals in wide range, starting from few femtocoulombs for mimimum ionising particles (MIP) up to several hundred of femtocoulombs for sensors placed in the showe centre. The AGH group has long experience in the design of dedicated readout ASICs in sub-micron CMOS technologies, gained during development of such ASICs for high energy physics experiment like LHCb at LHC or PANDA at FAIR.