16th Topical Seminar on Innovative Particle and Radiation Detectors (IPRD23) 25-29 September 2023 Siena, Italy

Current status of Dual Readout calorimetry for future High Energy Physics experiments

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Future experiments at high energy e^+e^- colliders, such as FCC or CepC, will focus on extremely precise measurements of the properties of the Higgs boson. In addition a broad range of physics studies will be accessible to these machines, including ElectroWeak, QCD and Heavy Flavour Physics, as well direct searches for Beyond the Standard Model processes. This ambitious physics program poses very tight demands on the performance of the detectors. Among the main benchmarks there is the capability to resolve the W and Z bosons in their hadronic decays, based on the measurement of invariant mass of the two jets. This is translated into a target resolution for the measurement of the jet energy of $30\%/\sqrt{E}$, well beyond the performance achieved by running collider detectors. Another important feature of the next generation of calorimeters is high granularity: the capability to distinguish closely separated energy deposits will improve the calorimetric identification of impinging particles.

Dual-Readout calorimetry is a technique which aims to improve the energy resolution, specifically on hadronic jets, exploiting information produced by two different physical processes, namely scintillation and Cerenkov light emission. The IDEA detector, whose concept has been included in both FCC and CepC design reports, is based on a Dual-Readout fiber calorimeter, with each fiber independently readout using SiPMs. High-granularity capability is ensured by a stride between two SiPMs of about two millimeters, leading to a fine segmentation on the transverse direction with respect to the radial one. The longitudinal segmentation would then be recovered through the timing information from the SiPM. This large amount of data to store per each event, which offers interesting opportunities such as the usage of Particle Flow algorithms or different kinds of neural networks, requires an advanced readout and data acquisition system.

In order to demonstrate the feasibility of a Dual Readout calorimeter characterized by a highly granular design, the Dual Readout community has been working on the development of calorimeter prototypes. These prototypes are fundamental to evaluate the detector performances and validate the simulations, to reach a modular and scalable design for the IDEA calorimeter and also to identify the best construction techniques for this instrument. One electromagnetic shower-sized prototype has already been built and tested at electron beams at DESY (Germany) and SPS (CERN) in 2021, and a second test beam will take place in Summer 2023. An hadron shower-sized prototype, named HiDRa, is currently under development with the construction and beam test foreseen in 2024.

In this talk, after a brief resume of the physics motivations behind the need for Dual Readout calorimeters, I will discuss the Dual Readout technique and the choices for the design of these types of calormeters. I will present the 2021 test beam prototype and its results, as well as the preliminary results obtained from this summer's campaign. The Geant4 simulation of this prototype, once validated with the data from the test beam, has been used to estimate the expected performances for the hadron shower sized prototype and improve them. I will discuss these simulation-based studies in terms of energy and spatial resolutions, also for calorimeters with different dimensions such as a full-containing calorimeter for collider detectors. Finally, a presentation of the construction technique and quality of the HiDRa modules will also be given.