Future Circular Collider (FCC) Dual Readout: a step closer to a scalable solution

A. Gabrielli1,2, D. Falchieri1,2, P. Giacomelli1, C. Veri1 on behalf of the Hidra-2 Collaboration
Research Units: BS, CT, MI, PV, RM1, TIFPA for the Hidra-2 Collaboration
1INFN Bologna, 2Physics and Astronomy Department University of Bologna (alesandro.gabrielli@bo.infn.it)

Step 1: The proposal of the Hidra-2 INFN project

Some Basics: Future Electroweak factories require unprecedentedly granular jet calorimeters energy resolution. This goal appears to be achievable only with an imaging calorimeter: it exploits parton field algorithms or a fiber sampling Dual Readout (DR) calorimeter, using scintillation and Cerenkov effects, the former produced by all incident particles, the latter only by relativistic charged particles. In both cases, many problems are still open and R&D is needed to build a benchmark prototype and evaluate the performance. Finally, new digital devices as SiPMs, currently not in the schedule, could lead to a simpler and innovative readout architectures.

The DR concept is based on the composition of sensitive readout, i.e. a transparent insulator. The latter are actinolite of all kinds of charged particles, to measure the total deposited energy, the latter are sensitive to Cherenkov Light or scintillating like photomultipliers. The Hidra-2 project aims to design, build and qualify prototype of fiber sampling calorimeter to evaluate:

- a stand-alone hadronic resolution around 30%/√E or better, for both single hadrons and pions, while maintain a resolution for isolated electromagnetic (em) showers close to 10%/√E;
- a transversal resolution of O(1%/√E);
- a longitudinal resolution of O(5%/√E);
- a large area, 10,000 cm² or bigger;
- a modular and scalable construction technique;
- an intensive parallel readout technology based on SiPMs;
- the performance of Deep Neural Network algorithms in exploiting such a large amount of CERN information.

Examples of tests already performed by some collaborations to test the DR approach. The pictures on the left show the use of "bucatini" shape absorber and scintillating fibers as detectors.

Step 2: The Design of a scalable approach to group the fibers for an optimized readout

The operation of a large number of SiPMs poses a series of system integration challenges: the reduced space available on the back of the calorimeter, the number of channels and the costs. The optimal solution would be the custom design of a SiPM with board intelligence. Channel grouping would allow to save space and costs. We are considering a flexible design based on a dedicated board compatible with future evolutions.

- Each SiPM is tested individually: crucial for the commissioning

Step 3: An evolved scalable approach for the electronic readout

We use a CAEN Front-End Readout System (FEFS) electronic cards designed to read out of large arrays of detectors.

Baseline solution

- Each bar of SiPMs will be operated at the same voltage
- The signals from 8 SiPMs are summed up in the grouping board

Step 4: Design for future Hidra-2 Hadronic Containment and DR integration

Design for future test beam in 2024 for a 10k channels Energy up to 30 GeV
2 out of 16 modules equipped with SiPMs

The challenge: We have 1040 SFPMs, fitting the back side of the detector, to be operated

- 640 FEE mini-boards

Summary

Highly granular dual readout calorimetry is one of the most promising technologies for future collider experiments. R&D is needed to assess dual readout performance and reach "production" maturity. The Hidra-2 project aims at testing a scalable solution using 10k channels in a "bucatini" shaped absorber and detector hosting Cerenkov and scintillating fibers. A test-beam at 30 GeV is scheduled in 2024 to extend the previous test carried out by some international collaborations. The Hidra-2 project focuses on a 5-year study to build and test a hadronic-containment prototype which features a first (real) assessment of dual readout hadronic system. Today’s main technical issues are related to the mechanical construction, and to the readout complexity.