Snowmass 2021 Letter of Interest

Developments Towards a SiPM-on-Tile Based Analogue Hadron Calorimeter (AHCAL)

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August 30, 2020

Introduction

The CALICE collaboration has pioneered the development of the SiPM-on-Tile technology for highly granular calorimeters. The construction and operation of an AHCAL *Physics Prototype* established the performance, in terms of energy and topology reconstruction, of the approach in principle, as well as the adequacy of detailed simulations; for an overview see Ref.[1] An AHCAL *Technological Prototype*[2], which demonstrates the viability of engineering solutions for a large collider detector, has been built and successfully tested in beams at CERN in 2018.

The design has been guided by the ILD detector concept for the ILC, but variations are being proposed for SiD at the ILC, CLICdet at CLIC and CLD at FCCee as well. Moreover, it has inspired the design chosen for the scintillator section of the upgrade of the CMS endcap calorimeter (HGCAL)[3] for the high-luminosity phase of the LHC, which is on-going with a strong participation of US groups.

With this LoI we propose to

- use the Snowmass process to define, together with interested US groups, an R&D programme for the CALICE AHCAL;
- use the existing AHCAL prototype for a continuation of the test beam programme and as a test bed for new component developments.

Note that this document complements two separate CALICE LoIs, which also, but not exclusively, relate to the AHCAL, and which are not covered here:

- *CALICE R&D for compact read-out systems for highly granular calorimeters* (K. Krüger, R.Poeschl, T. Suehara)
- *Physics potential and prototyping technological solutions for timing layers highly granular calorimeters* (F.Simon, D. Zerwas)

Test beam programme

While the data recorded with the *Technological Prototype* in 2018 show excellent quality, analysis is at an early stage. More beam tests are planned, to address the following goals:

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[1] F. Sefkow, A. White, K. Kawagoe,, R. Pöschl, J. Repond, Experimental Tests of Particle Flow Calorimetry, Rev. Mod. Phys. 88, 015003 (2016)
[2] CALICE Coll., F. Sefkow, F. Simon, A highly granular SiPM-on-tile calorimeter prototype, J.Phys.Conf.Ser. 1162 (2019) 1, 012012
[3] CMS Coll., The Phase-2 Upgrade of the CMS Endcap Calorimeter, CERN-LHCC-2017-023, CMS-TDR-019

- Exploit the *ns* timing capabilities of the technological prototype readout electronics: The fast timing mode, using maximum clock speed, has shown a resolution better than 1 ns in small tests, but still needs to be commissioned for the full system. The data will be used to evaluate the performance, investigate shower physics in the timing domain and explore reconstruction techniques for a 5D calorimeter.
- Data taking with an existing tungsten absorber structure: This will open up studies of shower evolution and detector response with plastic scintillator in a neutron-rich absorber, which offer a richer timing phenomenology and contribute to the understanding of hadron shower evolution in tungsten-based electromagnetic sections as proposed in almost all detector concepts.
- Test of a combined ECAL and HCAL system with a silicon tungsten prototype in front of the AHCAL, to study the performance for energy and topology reconstruction in a realistic configuration.
- Hardware tests of new components: The AHCAL prototype can be used as a test bed for new types of scintillators, SiPMs, front end electronics and back-end interfaces, providing a realistic environment and, by virtue of the reconstruction of the shower start location, enabling the test of components in different stages of the shower evolution.
- Precision Timing: Timing layer prototypes with tens of ps resolution could be integrated in the prototype to study their interplay with the rest of the detector showing more moderate resolution.

The test beam programme is open to new collaborators[4] and to additional proposals.

Further R&D to advance the SiPM-on-Tile technology an HCAL at a Higgs factory

Several areas require intensified R&D. A non-exhaustive list is given here:

- Optimisation of Megatile design and production scenarios for 8 million channels, about a factor 20-30 above the channel count of the CMS HGCAL
- Exploration of scintillator materials for energy and time measurements
- Evaluation of new generations of SiPMs
- Development, engineering evaluation and prototyping of endcap geometries, as most prototyping for the ILC so far has been guided by barrel calorimeter designs, including the implications of different geometrical segmentations on component type multiplicity, interface integration, signal and service routing as well as angular coverage
- Absorber structural studies for the detector endcaps

Additional topics need to be addressed for the application at circular colliders:

- Read-out electronics architectures (front-end ASICSs and data concentration) for the continuous read-out of circular colliders
- Integrated cooling concepts for continuous read-out

In addition to these more incremental development lines, more radical extensions of the highly granular tile technology may be conceptually explored, e.g. the inclusion of elements sensitive to UV Cerenkov light for the application of dual read-out techniques.

[4] The institutes currently active in the CALICE AHCAL effort are IPASCR Prage (Czech Republic), OMEGA Palaiseau (France), DESY Hamburg, MPP Munich, Universities Göttingen, Hamburg, Heidelberg, Mainz and Wuppertal (Germany), University of Tokyo (Japan), University of Bergen (Norway), LPI and MEPHI, Moscow (Russia), CERN (Switzerland), Northern Illinois University and University of Texas at Arlington (USA)