Photosensor Options of Dual-Readout Calorimetry for the 4th Concept

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The 4th Concept calorimeter design is built upon criteria that result from the DREAM prototype: by using two types of fibers, scintillator and quartz, to sample a shower, its electromagnetic fraction can be determined, and strong fluctuations of this fraction in the overall energy resolution can be suppressed. The next foreseen steps are to extend the dual-readout principle to homogeneous calorimeters (for instance scintillating crystals containing heavy elements) and to tackle another source of fluctuation in hadronic showers, originating from binding energy losses in nuclear break-up (measuring low energy neutrons, which often remain unobserved in standard calorimeters). A new generation of photodetectors with suitable properties, may represent a special asset for dual-readout calorimetry, making it simple, reliable and cheap.

1 Introduction

The 4th Concept design proposes a calorimeter system of a relatively simple construction and moderate costs, however with excellent properties, built upon experience gained with the extensively beam-tested DREAM (Dual REAdout Module) prototype [1]. The main idea of dual(/multiple) readout (DR) calorimetry is to independently measure for each hadronic shower those physical quantities that have large fluctuations and lead to large spread in energy response, mainly the electromagnetic content of a shower, and the binding energy losses, but to sum over the depth development of the shower, that should not affect the energy response in case of sufficient containement.

This choice is quite different from the currently popular trend in calorimetry, based on Particle Flow Analysis (PFA)[2], that emphasizes a high degree of transverse and longitudinal segmentation. The 4th Concept, with one longitudinal calorimeter section, has relatively few channels, about 20K, contrasted with about 50M for PFA. Even reading each channel twice (scintillating and quartz fibers separately) the DR system would be much simpler and cheaper. Furthermore it should be possible to apply the DR principle by distinguishing scintillation and Cherenkov light in a single radiator coupled to a single photodetector, according to their different time characteristics: very fast Cherenkov signal (few ns) - slower scintillation pulse (tens ns); low energy neutrons from nuclear fragmentation would produce a signal much later, on a scale of hundreds ns.

Therefore the two different methods emphasize different experimental aspects: redundancy and fine granularity in space for PFA, and high resolution in the time domain for DR. Almost all related R&D activities are widely different for these two calorimetric approaches; however at least one item is of common interest, and may have promising perspectives for both methods: new photodetectors with high quantum efficiency, photon counting capability and no sensitivity to magnetic fields. In particular this last requirement rules out the classic vacuum photo-multiplier tubes (PMT).

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2 New Developments

An interesting alternative to PMT's has been recently developed [3] and a number of different types of solid state photon counting devices (SiPM) from various manufacturers are presently becoming commercially available. The potential of these photo-detectors has become soon clear but work still needs to be done towards a detailed specification and evaluation in view of different applications and in particular the application of these photo-sensors to calorimetry. In Italy this development has been undertaken by FBK-IRST [4] in Trento, with the support of INFN, where a number of research groups have launched activities for using SiPM in medical applications (PET), astrophysics, calorimetry, large area scintillatorbased muon counters and scintillation fiber trackers.

One of these projects (FACTOR), with participation of people involved in DREAM and 4th Concept, is engaged in a campaign of R&D and tests in Messina, Trieste and Udine laboratories and on test beams at CERN and FNAL. Static and dynamic measurements of various IRST devices compare well with other manufacturers' products, and show reduction of the dark count rate. IRST has also made considerable progress in the design and on the geometric efficiency of SiPMs for their application to calorimetry. Sensitivity of the IRST SiPM in the blue region may be another important advantage for the readout of quartz (Cherenkov emitting) fibers. Present progress and future plans for the collaborative effort of FBK-IRST and INFN have been presented and discussed at a recent meeting in Perugia. The two partially overlapping comunities of DREAM and 4th are carrying on intense R&D and test activities. The plans and objectives for the these activities are described in documents [5]. Some tasks for the 4th Concept design group are listed in [6]: these include construction of a cubic-meter dual-fiber readout module to overcome the leakage fluctuations that limit the performance of the 1-tonne DREAM module. When this new module will be constructed (provided enough money becomes available) it will be also a benchmark for the design criteria of a full-scale ILC multiple-readout calorimeter prototype. One realistic option could involve using the upgraded SiPM from IRST for the readout of this module; initial tests will be performed on a smaller-scale tower.

References

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