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# Development and Testing of an Upgrade to the CMS Level-1 Calorimeter Trigger

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The LHC will restart in 2015 with a higher centre-of-mass energy and luminosity. To allow the CMS physics programme to fully exploit these increases the CMS Level-1 trigger must maintain similar efficiencies for searches and precision measurements to those achieved in 2012. With an average of 50 interactions occurring in each bunch-crossing, it will be challenging to select interesting physics events within the readout bandwidth limitations. The CMS calorimeter trigger is being upgraded to enable the more sophisticated algorithms needed to handle the high-luminosity conditions and to add the flexibility to adapt to changing LHC performance and physics priorities.
The design of the upgraded system is summarised, performance of the prototype hardware presented, and the results of integration tests between subcomponents shown.

## Summary

When the LHC resumes operation in 2015, the higher centre-of-mass energy and high-luminosity conditions will require significantly more sophisticated algorithms to select interesting physics events within the readout bandwidth limitations.
The planned upgrade to the CMS calorimeter trigger will achieve this goal by implementing a modular and flexible system based on the micro-TCA electronics standard with Advanced Mezzanine Card (AMC) modules based on the latest Xilinx Virtex 7 FPGAs with up to 144 high-speed optical serial links, running at speeds up to 10 Gbps. Two variants of AMC modules are planned for the upgrade differing principally in the configuration of optical link I/O.
The upgrade will improve the energy and position resolution of physics objects, enable much improved isolation criteria to be applied to electron and tau objects and facilitate pile-up subtraction to mitigate the effect of the increased number of interactions occurring in each bunch crossing.
The design of the upgraded system is summarised, including hardware, software and firmware. Particular emphasis is placed on the results of prototype testing and the experience gained which is of general application to the design of such systems. For example, studies of high-speed signal integrity, advanced firmware systems for link alignment and monitoring, and novel version management tools for firmware.
The integration of prototype cards into a test system with Ethernet communication, trigger data-flow, timing control and a data-acquisition path is presented. Software and firmware for upgraded calorimeter trigger algorithms have been developed and results on their performance, including latency and FPGA resource usage will also be presented.
First results from integration tests between subcomponents are also included and finally future plans are summarised.

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