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Integration Design Issues in HEP Experiments

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The global design process of high-energy physics experiments typically follows three overlapping stages consisting of detector modeling, detector integration and services implementation phases.

This process sometimes results in unexpected interactions between subsystems. At the CMS experiment at CERN we have had over two years of operational experience during which time we have observed several instances of unexpected behavior attributable to the complexity of detector integration design.

This presentation will examine the mechanisms and consequences of these behaviors, as well as considering their origins in the three level design process common to such experiments.

Summary

The global design process of high-energy physics experiments typically follows three overlapping stages consisting of detector modeling, detector integration and services implementation phases.

The detector modeling phase consists of successive optimizations of physics performance using Monte Carlo simulation. Based on a set of target processes, subdetector assemblies are added and modified until an acceptable cost to performance ratio of the complete detector is achieved, at which point the global design of the detector is fixed. Rarely are the practical details of detector construction addressed at this stage.

The inevitable conflicts arising from competing subdetector requirements are addressed during the detector integration phase, at which point issues such as cable routing, power dissipation and interaction between subdetectors result in design changes which often affect the subdetectors themselves and result in a further cycle of detector simulation.

Detector services can be explicit, such as detector readout, electrical power, cooling, safety systems and radiation shielding. They can also be implicit, such as mechanical support, maintenance access and lighting, which are not immediately obvious as part of the detector design and are often added late in the construction phases of an experiment.

Provision of the necessary services is implemented in part by subdetector groups and also by central support teams that provide services for several experiments at the same time. The design personnel for these systems are typically familiar with industrial systems and not with the special sensitivities of high-energy physics detectors. The resulting systems are designed for a contemporary industrial environment, often independently from the design process of the detector.

In addition, service requirements at the subdetector level are frequently specified in terms not directly addressable by support crews, such as detector temperature limits rather than coolant flow rate, which can result in the need for system modifications during the installation phase.

It should come as no surprise that such a design process sometimes results in unexpected interactions between subsystems. From a practical point of view, the organizational aspects of HEP detectors and laboratories are sufficiently complicated that achieving tighter integration between design teams remains a distant goal, so the detector commissioning and operation phases are marked by iterations of emerging design issues and subsequent modifications to the detector design.

At the CMS experiment at CERN we have had over two years of operational experience during which time we have observed several instances of unexpected behavior attributable to the complexity of detector integration design, issues that could be expected in any detector of comparable scale.

This presentation will examine the mechanisms and consequences of these behaviors, as well as considering their origins in the three level design process common to such experiments. There are common features in the issues we have observed so far which can guide diagnostic methods and serve as a benefit of experience.

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