

SYNCHRONIZING GEANT AND 3D CAD - A COLLABORATIVE ENGINEERING STUDY AT ILD

B. List[#], L. Hage, S. Eucker, S. Suehl, N. Welle, DESY, Hamburg, Germany

Abstract

The design of a high energy physics detector involves highly complex optimizations during the design phase. These optimizations are driven by the goal of the best possible physics performance, which is evaluated by physicists on the basis of Geant based simulations, and by the need to design a detector that can actually be built and operated, which is studied by engineers with the help of detailed engineering models. Synchronizing the work of these two communities with their very different tools and file formats is far from trivial. Based on an Engineering Data Management System and industrial tools for 3D model inspection we propose an collaborative design process that is being developed for the ILD detector.

INTRODUCTION

Detectors for experiments in high energy physics are highly complex apparatus that are designed, built and operated by hundreds or even thousands of engineers, technicians and physicists over a time of several decades. During the design phase, the detector evolves from a strawman drawing on a napkin to a full-fledged technical design. This process involves the work of dozens of working groups around the world who try to identify the right mix of particle detection techniques and technologies to get the detector with the best physics performance that can be built with the available technology and resources.

During this optimization process, physicists use simulation programs based on software packages like Geant4 [1] to evaluate the physics performance of the detector, decide between possible design alternatives and identify areas where improvements are desirable; in parallel, engineers develop detailed designs that address all problems such as mechanical stability, power distribution, cooling, signal cable routing. It is important that these parallel design and optimization processes are kept synchronized, so that the engineers design what the physicists want, and the physicists simulate what the engineers can build.

Thus, the exchange and comparison of the 3D models used in the physics simulation and the engineering process are of high importance. However, while it is possible to use engineering CAD models as basis to perform e.g. structural analysis like FEM calculations of mechanical deformation and stability in an efficient way, it is still not possible to automatically translate CAD models of complete detectors into models suitable for a Geant4 simulation. In particular, for performance reasons Geant4 uses internal representations of 3D volumes that

are quite different from the way solid modelling CAD programs work.

In this contribution we present the approach that is pursued at DESY to improve this information exchange and establish collaborative engineering methods in detector design.

SOLUTION CONCEPT

The proposed approach to collaborative engineering, which is currently being studied in the context of the ILD detector development, is based on experience with a similar process employed in the construction of the European Free Electron Laser XFEL. It is based on a process where the detailed design of individual subsystems (such as the tracker or the calorimeter) is performed within the space allocated by a dedicated placeholder model. Only this placeholder model is maintained centrally for the whole detector, whereas the detailed models of the components are kept separate. Thus the placeholder model decouples the development of the subdetectors. The detail models are collected in regular intervals and checked against the placeholder model. When necessary, the placeholder model is refined to define the space allotted to a subdetector more precisely, thus preventing overlaps and collisions between the various parts of the detector.

The 3D CAD models of individual subdetectors are stored in the Engineering Data Management System (EDMS) operated by DESY. Data from different CAD programs can be efficiently imported via STEP files. All CAD models are also made available as JT files [2]. JT is a 3D visualization file format developed by Siemens PLM Software. Rendering software based on JT can efficiently display and manipulate 3D scenes which would be far too complex for efficient rendering within a CAD program. By combining the detailed models of the subdetectors with a JT viewing program, a complete model of a detector can be displayed and inspected (including the possibilities to show cuts and perform measurements) without the need to integrate the detailed CAD models themselves.

The GEANT simulation model, on the other hand, can be transformed to JT via the VRML [3] file format, for which an output driver exists in Geant4. The VRML file is then translated into JT format.

The industrial 3D visualization software VisView from Siemens is a powerful tool to inspect JT files. Of particular interest is its ability to overlay two JT models and mark surfaces that are common between both models or present in either model in different colors. This feature allows very efficient checks of whether a component fits

[#] Benno.List@desy.de
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into its allotted space by comparing the detailed model with the placeholder, and to efficiently compare the geometries of subsystems between the engineering model and the implementation in Geant4.

FIRST RESULTS AND OBSERVATIONS

Figure 1 illustrates how the different models of the ILD detector look like, namely the placeholder model, the detailed engineering model and the simulation model as implemented in the Mokka simulation program.

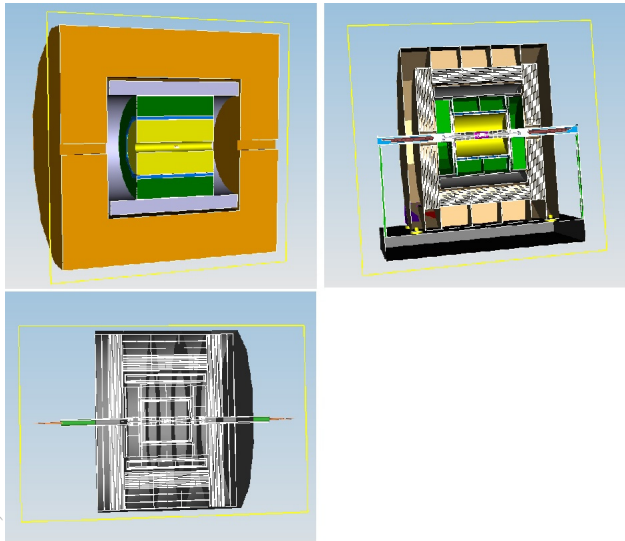


Figure 1: Different models of the ILD detector: Placeholder model (upper left), detailed engineering model (upper right), and Mokka simulation model (bottom).

Figure 2 shows how model files of a single subdetector, in this case the muon system, can be overlaid in a single application for a direct visual comparison of the geometries. This capability is useful on the one hand to check detailed engineering models against their respective placeholders, on the other hand it is used (as shown here) to directly compare engineering and simulation models. In the example shown here, which is based on an old version of the simulation geometry, it was found that different conventions were used for the spacial orientation of the muon system's parts. Also it is clearly visible that mechanical support structures were not included in that version of the simulation geometry.

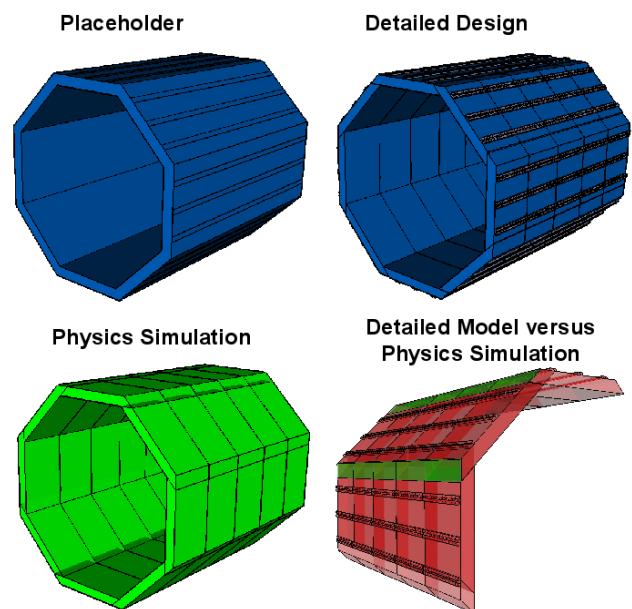


Figure 2: Different models of the muon system. The bottom right shows a direct comparison between the detailed design model (in red) versus the physics simulation model (in green).

DESIGN STANDARDS

In order to make efficient use of the opportunities that arise from the detailed comparison of engineering and Geant models, it is necessary that both communities adhere to a number of design standards.

Most important, a compatible hierarchy of detector parts has to be developed. Engineering models tend to have structures that put group components according to their mechanical relationships, e. g. which parts are bolted together, while the simulation model will be organized according to functional relationships. For example, in a detector design which consists of several movable rings, such as the CMS or the ILD detector, an engineering model will typically have the rings as top level of the hierarchy, and below that e.g. a section of the muon system in each ring segment, whereas the simulation model will probably have "muon system" and "calorimeter" on the top level. Thus, care has to be taken that both models are composed of structures that can be compared to each other, which does not necessarily mean that the hierarchies need be identical. For example, "Muon system ring 1" may be a part of "Muon system" in the Geant4 model and a part of "Ring 1" in the engineering model; as long as both models have equivalent entities at some level, a meaningful comparison can be performed.

In general, attention has to be paid to have proper hierarchies in all models. This applies also to Geant

models where it is advisable to group the components of a subdetector logically by putting them into enclosing volumes that belong to the respective subdetector only.

Another important issue for the integration of separate models is the establishing of a common reference system. Obviously, all models have to adhere to a common standard for the coordinate axes orientation; however, in some CAD programs it is clumsy to work with a model that is not centered at the coordinate system origin. Therefore, to facilitate model integration, by convention each CDA model needs to have a reference object, e.g. a sphere centered at the interaction point, present in the top level of the model hierarchy, so that during integration differences in the origins of the models' coordinate systems can be unambiguously detected and removed.

CONCLUSIONS

We have presented an collaborative engineering process that is based on the creation and maintenance of three types of models: A placeholder model for overall space allocation, detailed engineering models of subdetectors, and the Geant4 model used for physics simulations. Keeping these models synchronized requires collaborators with a certain process discipline, and a

commitment from the whole collaboration. The benefit of the placeholder model is that it decouples design activities (on the engineering and the physics simulation side) of different components, and still allows an efficient use of available space. Regular checks of the engineering versus the physics simulation models leads to more realistic simulation results, in particular regarding the amount and distribution of dead material or the location of insensitive detector regions such as gaps. At the same time, these checks make sure that changes to the detector geometry that are initiated by the physics requirements, such as adding more layers to a calorimeter, are correctly incorporated in the mechanical design.

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