Detector and Event Visualization with SketchUp at the CMS Experiment

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Introduction

We have developed *Ruby scripts* [1] to create 3D computer models of the *CMS detector* and *CMS events* in *SketchUp* [2] via its *Ruby API*. These models have many applications related to 3D representation of the CMS detector and events. Figures produced based on these models were used in conference presentations, journal publications, technical design reports for the detector upgrades, and other formal and informal presentations.

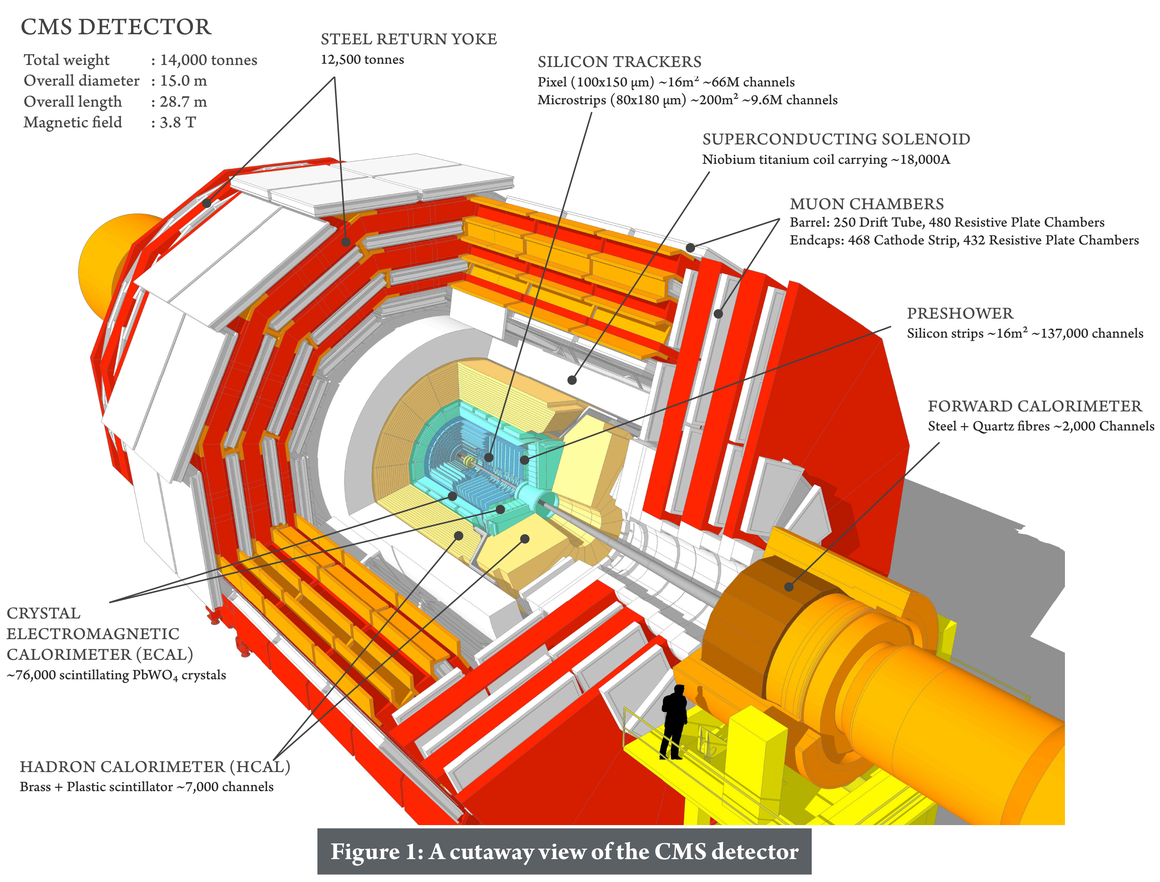

Figure 1: A cutaway view of the CMS detector

Detector Visualization

The *geometry* of the CMS detector is obtained from the *CMS Detector Description* [3]. The CMS Detector Description, written in *XML*, is the master source of the CMS detector geometry used in the *event reconstruction* and the *detector simulation*. The CMS Detector Description describes the CMS detector as a *directed tree*. Each *vertex* of the tree corresponds to a *component* with a size, shape, material, and density. Each *edge* connects from a component to its subcomponent; it specifies the position and angle of the subcomponent within the component.

First, the Ruby scripts that we developed parse the XML files and recognize the directed tree of the detector geometry. Second, they build each component as a *solid* with the given size and shape. Then, for each edge from the *leaves* of the tree to the *root*, the scripts place the *tail* component in the *head* component as a subcomponent at the given position and angle.

Figure 1 is one of the CMS detector cutaway images often used in public presentations. The 3D model in this figure was created in SketchUp. This figure is used in the CMS official website [4] and the *Higgs boson discovery summary* published in *Science* [5].

The level of the detail to draw can be adjusted by choosing subcomponents to include in the model. For example, Figure 2 shows more detailed geometry of innermost subsystems, *silicon strip* and *pixel trackers*. This figure is part of the exhibition "*ZOOOM*" [6], displayed at *Point 5*, a CERN site in Cessy France, where the CMS detector is installed.

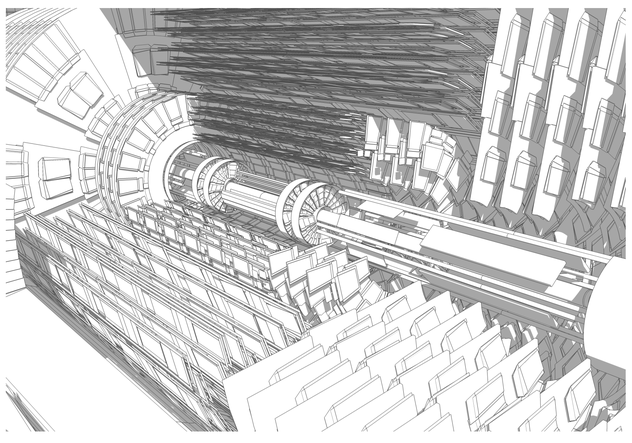

Figure 2: A detailed geometry of the CMS tracker

In addition to the geometry of the current CMS detector, we can draw geometries for CMS detector upgrades [7]. In Figure 3, one half of each model has the current geometry of the CMS pixel tracker and the other half has the geometry for the upgrade. These two images were used to illustrate the difference between the current CMS pixel tracker and its *Phase 1* upgrade in many public documents, including the *CMS Technical Design Report for the Pixel Detector Upgrade* [8].

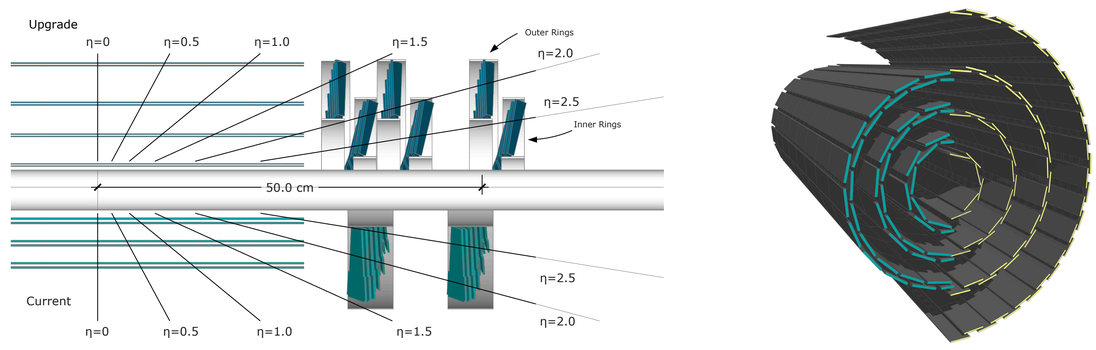

Figure 3: Models of the CMS pixel tracker consisting of half current and half upgrade geometries

Event Display

We can also visualize CMS events in SketchUp. We use event data stored in the *ig* files, which were originally developed for the *iSpy event display* [9]. The ig files are *JSON* files which contain four momenta of reconstructed particles, positions and energies of calorimeter deposits, and other event information. *Tracks* are rendered as *cubic bézier splines*, calorimeter deposits as scaled rectangles with six faces, muons as *polylines*, and hit *muon chambers* as rectangular boxes. Figure 4 shows an example image of a candidate Higgs boson decaying into two photons.

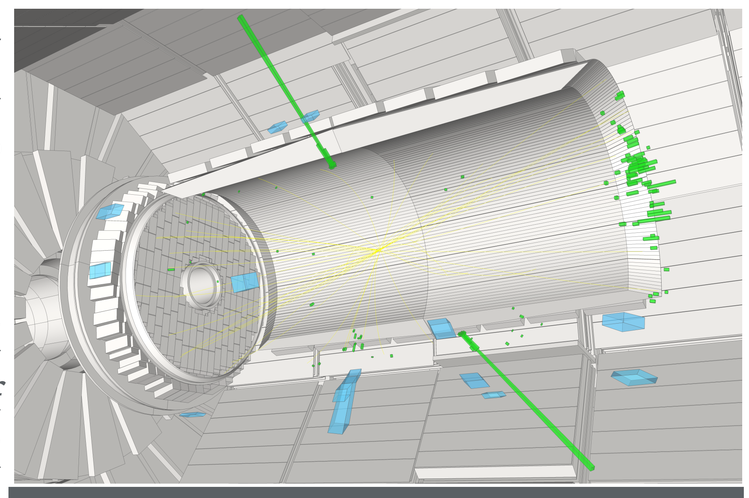

Figure 4: An event display of a Higgs boson production candidate event

Summary

We have created accurate 3D models of the CMS detector and events in SketchUp. These models allow us to produce high quality images and exportable 3D models of the CMS detector and events, which are used in a variety of public presentations. In addition, these models can be used to validate geometries for CMS detector upgrades. Furthermore, several art projects, exhibitions, outreach programs using these models are being planned.

[1] GitHub repo SketchUpCMS, ***http://github.com/SketchUpCMS/SketchUpCMS***
[2] SketchUp official website, ***http://www.sketchup.com***
[3] M. Case *et al.*, "CMS Detector Description: New Development," CHEP 2004
[4] "CMS detector design," ***http://cms.web.cern.ch/news/cms-detector-design***
[5] CMS Collaboration, "A New Boson with a Mass of 125 GeV Observed with the CMS Experiment at the Large Hadron Collider," *Science* **338** (2012) 1569.
[6] "ZOOOM: CMS visualized in 3D," ***http://cms.web.cern.ch/news/zooom-cms-visualised-3d***
[7] I. Osborne *et al.*, "CMS geometry through 2020," CHEP 2013
[8] CMS Collaboration, "CMS Technical Design Report for the Pixel Detector Upgrade," CERN-LHCC-2012-016 (2012).
[9] G. Alverson *et al.*, "iSpy: A powerful and lightweight event display," *J. Phys. Conf. Ser.* **396** (2012) .

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