# Development of the ALICE FIT FT0-A Detector Frame in ROOT Geometry for Simulation

A Senior Project

Jason Pruitt
With Advisor Dr. Jennifer Klay

Department of Physics
California Polytechnic State University San Luis Obispo
United States

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**Author: Jason Pruitt**

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Senior Project Advisor: Dr. Jennifer Klay

Signature

Date

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# 1 Abstract

CERN's ALICE experiment aims to investigate the strong nuclear force through the study and production of Quark Gluon Plasma via Pb-Pb collisions. ALICE's Fast Interaction Trigger, a group of several detectors concerned with analyzing collision events, is outfitted with the necessary materials and software for both online and offline data analysis. We simulate the detectors and all the materials in ROOT geometry to understand both machine performance and particle interactions. This allows for the analysis of secondary particle production from collision events, as well as ensuring correct placement and compatibility with other detectors and collision simulation software. This paper describes and details the development and completion for the FT0-A support structure, where measurements from the CAD files of the structure are translated into ROOT Geometry.

# 2 Introduction

CERN's ALICE experiment is the section of the Large Hadron Collider principally concerned with the investigation of heavy ion collisions for the purpose of better understanding the production and behavior of quark gluon plasma (QGP) and its relation to the study of quantum chromodynamics. We are particularly interested in investigating QGP because of the insight it affords to properties of the early universe, as QGP's production necessitates the high energy density conditions that were present microseconds after the Big Bang. In order to produce such conditions in a laboratory setting, ALICE runs at center-of-mass-energies as high as 5.5 TeV/nucleon, accelerating nuclei to relativistic speeds. ALICE is composed of many sub-detectors each centered at the investigation of different collision event properties, with the subject of our focus being the Fast Interaction Trigger (FIT) detector system. The objective of this project was to correct the overlaps in the simulation of the FIT T0-A detector geometry [1], composed of a grid of sensitive elements and an aluminum frame to seat them. Since the simulation and analysis of collision events are concerned with the material of both the involved particles and the material of the detector, any overlaps would simulate the particles passing through more material than necessary and result in incorrect data. Additionally, an overlap could lead to the multiple different materials simulated at a given position, where the software's choice between the materials would also lead to unreliable data.

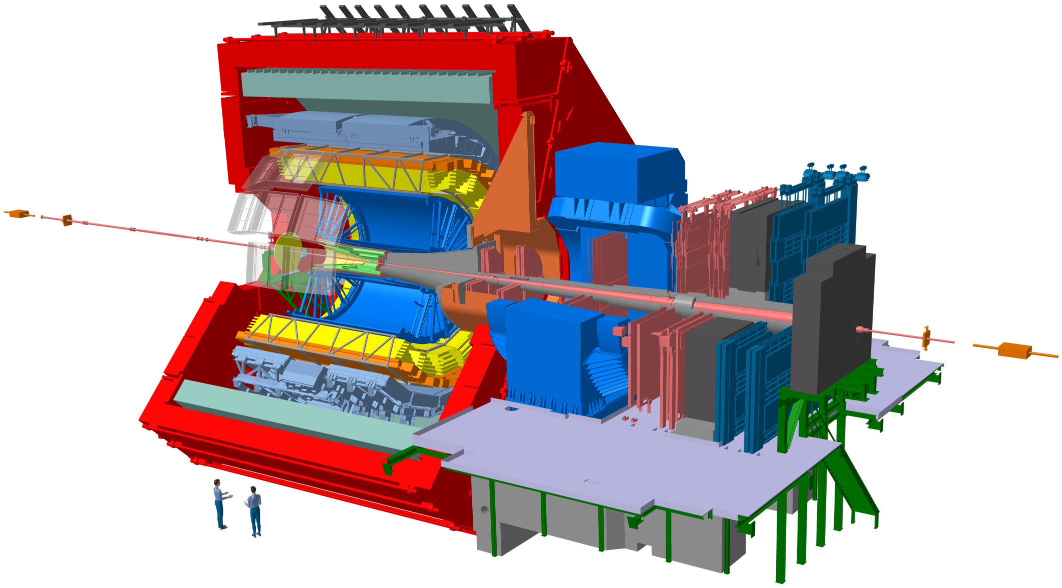


Figure 1: Diagram of ALICE at Run 3, with human size comparison. [2]

# 3 ALICE-FIT

A trigger system in particle physics experiments determines which events of a collision to consider based on certain criteria in order to circumvent data storage limitations. With such an ability to discriminate and select events, a trigger system is particularly useful for tagging certain rare events or events of special interest. The Fast Interaction Trigger system was designed as an upgrade to the existing ALICE detector framework in order to accommodate for the LHC's increase in heavy-ion luminosity and collision rate in run 3. With this update both the ALICE hardware and software received upgrades. The Online-Offline (O2) software framework provided means for ALICE data to be analyzed both at the time of data collection (online) and later after the fact (offline). O2 works in conjunction with Alidock [3], a Docker [4] container intended to simplify the deployment of the ALICE software suite. With Alidock, all of the external dependencies (e.g. ROOT or Python) and version control are managed in one install, providing a streamlined experience across different operating systems.

Three detectors exist in this system, the Forward Diffraction Detector (FDD), V0, and T0. The FDD is designed to trigger and study the physics of diffractive and ultra-peripheral collisions, where the amount of surface area of the particles involved is of special interest. The V0 measures the reaction plane, or the plane formed by the collision axis and the impact parameter. [5]

The T0, where our focus lies, is a two subdetector system with FT0-A and FT0-C, where the sensitive elements of both (displayed in Figure 3) are a combination of Cherenkov quartz radiators and Photonis photomultipliers [6]. The A-side is an array of 24 sensitive elements with flat geometry, whereas the C-side is an array of 28 sensitive elements in a curved geometry due to the work of Noah Miller [7].

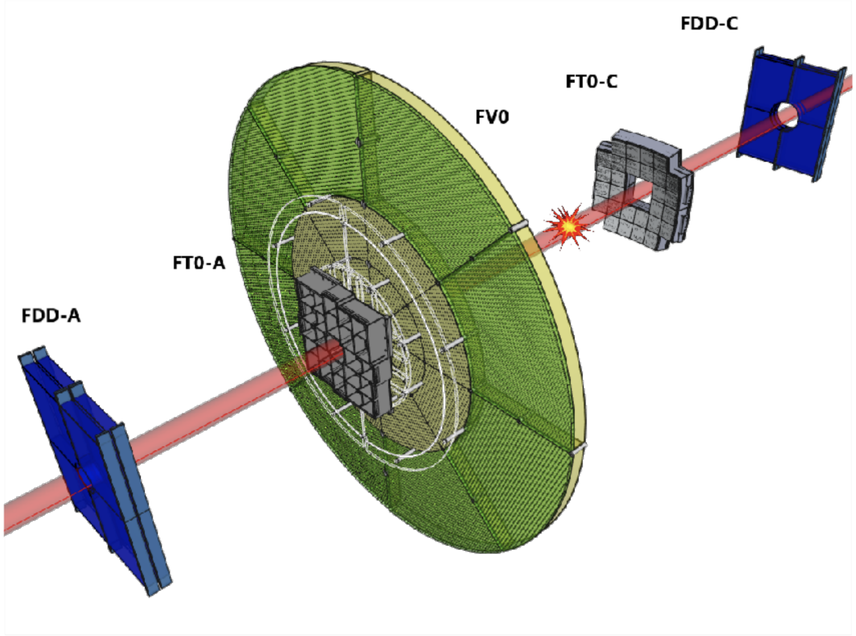


Figure 2: Diagram of ALICE-FIT

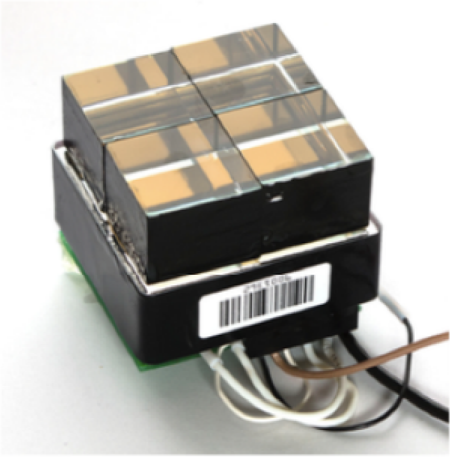


Figure 3: T0+ Sensitive element module

# 4 Methods/Process

By modeling the detector in a CAD file, we obtain accurate real-life measurements of how large each detector component is, using Autodesk Fusion 360 [8]. With these specifications, we create objects in ROOT Geometry [9] to match, and place them in space as they are oriented in the CAD file. The ROOT objects created are specified in both dimension as well as material to allow the simulated detector to interact with particle collision simulators GEANT [10] and PYTHIA [11]. As a means to test the detector's performance before its construction and integration into ALICE, events are generated in these collision simulators which sets theoretical expectations for collision interactions. At first, only the sensitive elements are simulated as a control, and then passive elements such as the frame or cables are simulated to analyze their influence on what particles reach the sensitive elements. Particles interacting with passive material can slow down, completely stop, or can create new particles. All of these events impact the ability to accurately measure properties of particles produced in a collision.

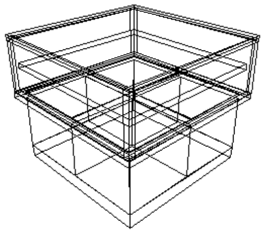


Figure 4: wireframe of a single sensitive element, 0INS, geometry in ROOT

## 4.1 Sensitive Element Simulation

Since the FT0-A detector is an array of 24 sensitive elements, the elements' individual components of the quartz radiator and photomultiplier are represented as rectangular boxes combined in ROOT, as shown in Figure 4. Each element is placed onto a grid of x and y positions in the shape of Figure 5. since a saturation of electronic signal near the beam pipe was observed when a collision event contained a high number of particles, a shift was introduced to the elements lying on the x and y axes.

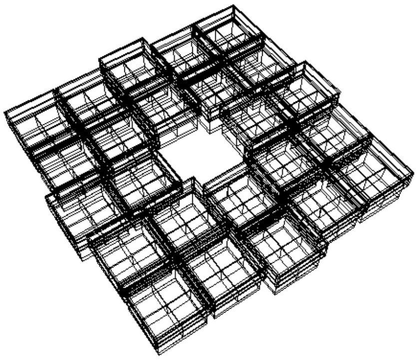


Figure 5: wireframe of FT0-A sensitive element grid

The first iteration of the simulation placed the sensitive elements into the grid based on an estimate of their locations. The positions of the sensitive elements were found to conflict with the centers of the sockets they would sit inside. To rectify this, the aluminum frame's front plate measurements were taken using Autodesk's inspect tool (Shown in Figure 6) to find the x and y locations of their centers. Then the estimated measurements of the sensitive element positions and the positions of the frame plate centers were subtracted to find a potential universal offset difference. The offset was found and applied, reducing the number of unique overlap values.

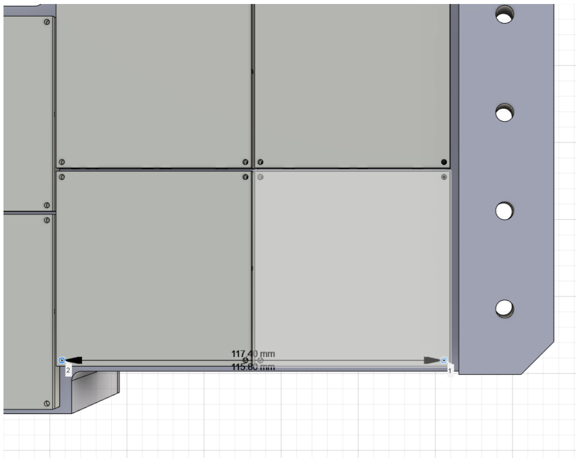


Figure 6: Measuring the dimensions of the CAD document to be translated into ROOT using Autodesk Fusion 360's inspect tool

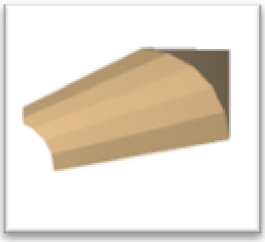


Figure 7: OpenGL visualization of corner subtraction to simulate rounded corners

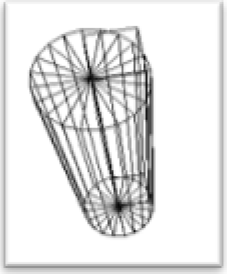


Figure 8: Wireframe of corner subtraction to simulate rounded corners

## 4.2 Frame Construction

The specifications of the dimensions of the detector frame used in ROOT geometry are based on measurements from the CAD document of the frame. An example of a measurement taken is shown in Figure 6.

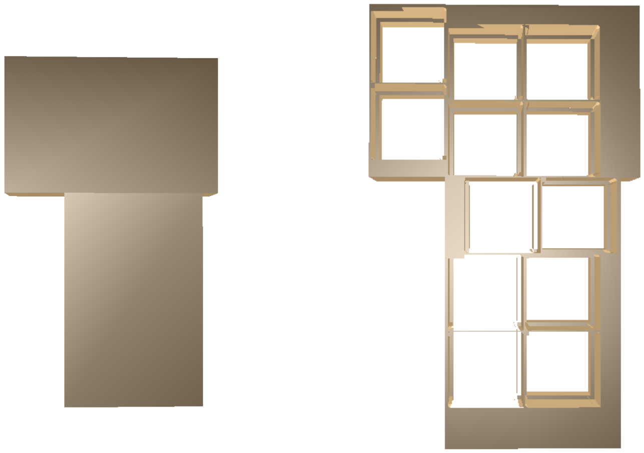
The frame construction process is as follows; First, one half of the frame is approximated with two rectangles - one horizontal stacked atop a vertical. Six sockets the size of the sensitive elements are subtracted from each rectangle to seat the sensitive elements, where the dimensions of both the PMTs and quartz radiators are taken into account. To simulate rounded corners, a corner piece is made by the subtraction of a tube from a rectangular box.(Seen in Figures 7 and 8) To better simulate the shape of the rims of the detector, the extra aluminum from the estimation via the initial rectangles is subtracted with eight small rectangular subtractions. The numbering of both the socket subtractions and extra aluminum are shown in Figures 11 and 12. The plates are then added on the opposite side of the holes' opening. The constructed frame object forms an L shape that is reflected in x and y to form the other side of the frame. The entire process is displayed in Figure 11.

```
// ---------
// |       |                 <-----Rectangle 1 removed here
// |   1   |----------------- ^
// |       |        |       | |
// ---------    3   |   5   | |
// |       |        |       | | Rectangle 2 removed here
// |   2   |----------------- |
// |       |        |       | |
// --------|    4   |   6   | |
//         |        |       | v
//    ^    ------------------  <------Rectangle 3 removed here
//    |
//    |
//    Rectangle 4 removed here
//
```

Figure 9: ASCII documentation within Detector.cxx to visualize the socket and extra aluminum subtraction from the initial horizontal rectangle estimation

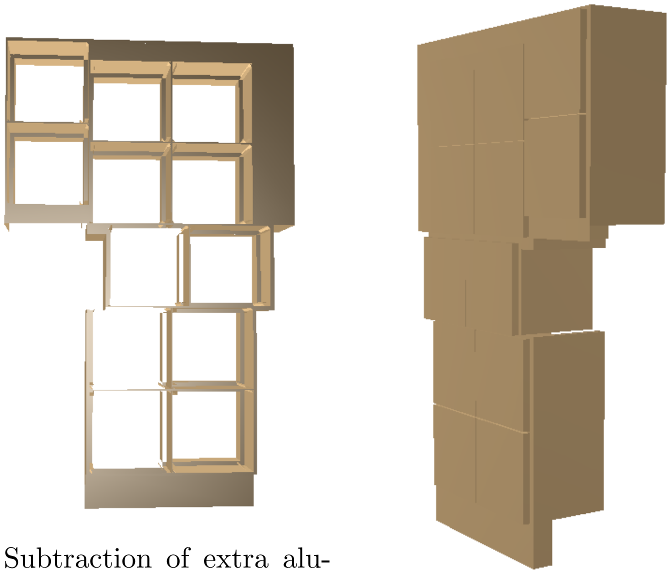
```
//                  -----------------
//                  |       |       |
//  Rectangle-->    |   8   |   7   |
//     8            |       |       |
//  removed      --------------------
//    here       |       |       | ^
//               |  10   |   9   | |
//               |       |       | | Rectangle 5 removed here
//               ----------------- |
//               |       |       | |
//               |  12   |  11   | v
//               |       |       |  <-----Rectangle 6 removed here
//               -----------------
//              <---------------->
//            Rectangle 7 removed here
//
```

Figure 10: ASCII documentation within Detector.cxx to visualize the socket and extra aluminum subtraction from the initial vertical rectangle estimation



(a) Estimation by rectangles of half of the frame

(b) Subtraction of sensitive element seats



(c) Subtraction of extra aluminum around rims

(d) Addition of plates

Figure 11: Stages of frame construction in ROOT Geometry

### 4.3 Software Development Details

The ALICE O2 software framework in which the geometry description is embedded is a large and complex piece of software that can be cumbersome to work with, especially for incoming collaborators unfamiliar with object oriented programming styles and practices. In order to better understand the construction process of the geometry in ROOT as well as to provide more control over different individual components of the frame, a standalone macro was created that would run independently of the detector framework, and would not necessitate the simulation of a collision event in order to view and construct the geometry. This macro also allowed faster edits of the geometry and visual feedback, and produced the following figures that detail the construction process of the A-side detector frame geometry. Once the geometry was finished in the standalone macro, the code and its documentation were incorporated into the ALICE O2 framework Detector.cxx file. [12]

## 5 Concluding Remarks and Future Work

The work done here on the FT0-A side will allow for the implementation of cabling and electronic materials, as well as enable the analysis of secondary particle effects on the future design of the FoCal [13]. After having corrected the A-side overlaps, we are now ready to implement a similar routine for the C-side given proper understanding and documentation of the geometry construction. These tools will prove both critical for other future detectors and indispensable references for the maintenance of the ALICE O2 software.

## 6 Acknowledgements

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