The Current OLYMPUS Solid Model for Simulation and Reconstruction

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Analysis of our data relies on an accurate description of our detectors and any other material that may lie in a primary particle's path. Information about the construction of each detector element is maintained in the Geometry Description Mark-up Language (GDML) files used for Monte Carlo simulation and for tracking. While the GDML also records element positions and orientations, this note is focused on the material composition and geometrical shape of each physical component of OLYMPUS as it is currently modeled.

1 Introduction

A GDML file contains a description of the physical solid and gaseous elements that make up the relevant parts of the OLYMPUS detectors and related structures. The file format was developed at CERN as a common standard that interfaces well with both ROOT and GEANT4. Since our simulation and analysis are based on GEANT4 and our Event Display visualizer is based on ROOT, this is a natural choice for OLYMPUS.

The terminology used in GDML files is fairly simple. Each geometrical shape is a "solid." An element (made of a single defined material) that is placed at some location in space, whose shape is defined by a solid, is a "volume." If there are two volumes named A and B such that A totally contains B, then A is B's "mother" and B is A's "daughter." (No volume should ever partially contain another volume—it should contain other volumes totally or not at all. Failure to follow this rule can lead to unexpected or unwanted behavior.) The top-level volume in the hierarchy is known as World. All other volumes are totally contained by World.

In the OLYMPUS geometry, the global coordinate system is one where the X axis points toward the left sector, the Z axis points along the beamline, and the Y axis points up. The exact definitions of these axes are given relative to the Target Cell. The axis of the Target Cell is equal to the Z axis by definition, and the major and minor axes of an elliptical cross-sectional slice of the Target Cell are the definitions of the X and Y axes, respectively.

The current standard GDML file for simulations is named Geant4_survey2013.gdml and is the default used by the Monte Carlo propagator. It is located in each OLYMPUS git repository under *~/src/gdml/gdml_files/*. Other GDML files exist in this folder that each have their own special use, such as for the Track Fitter and for the Event Display. Additional GDML files can be created upon request based on your particular needs and specifications. When you run *make install* from any git repository's top-level directory, the GDML files that exist in that repository are copied to *$HOME/.olympus/shared/gdml/*, where *$HOME* refers to your personal home directory on the machine you're using.

The rest of this document will be divided into one section for each group of elements in OLYMPUS. Those elements will be explained exactly as they appear in the GDML, including where their local coordinate systems are centered for the purpose of placement in World and whether or not they are registered as sensitive detectors for GEANT4. This document is not intended as an overview or introduction to the GDML, but will give some level of detail about how each solid and volume is constructed and arranged. If you need an introduction, please see my talk from the July 2012 collaboration meeting, or read the GDML User's Guide, which can be obtained from CERN's website. If you need greater detail than you see in this document, you may either read the GDML files directly or contact me with specific questions.

2 Target Chamber

Description of Solids, Volumes, and Daughters

The OLYMPUS Target Chamber is a trapezoidal prism 1200mm long and 254mm tall, with a width of 114.3mm at its downstream face and 245mm at its upstream face. It is represented by a wrapper volume made of "Beam Gas," which is a low-pressure (10^{-6}Pa) version of air. Its daughters are the Frame, Target Cell, Collimator, and Downstream Wakefield Suppressor.

The Frame represents the solid aluminum piece we think of as "the Target Chamber." It has various holes subtracted away from it to make room for the Beamline and for Windows.

The Target Cell is an elliptical tube made of aluminum. It is 300mm long and 0.0375mm thick with inner semiminor (vertical) axis 2.25mm and inner semimajor (horizontal) axis 6.75mm.

The Collimator is a cylinder of tungsten with radius 82.55mm and height 152.4mm, with internal space hollowed out to represent the Countersink and Rear Flare.

The Downstream Wakefield Suppressor is an aluminum piece that transitions from a small elliptical opening to a large circular opening in a smooth fashion, looking something like a cone. In the GDML, it is represented as sixteen pieces, each 10mm thick along Z except for the most downstream piece, which is 8.75mm thick along Z, for a total length of 158.75mm. Each piece is an elliptical cone whose proportions are taken from the elliptical cross-section of the real Wakefield Suppressor at a point along its length equal to the center of the given piece. All of these together approximate the Wakefield Suppressor well, and they are contained in a cylindrical wrapper volume made of Beam Gas.

The real OLYMPUS Target Chamber includes thin aluminum Windows. In the GDML, these pieces are represented by separate volumes which are not daughters of the Target Chamber volume, but they are placed appropriately in the World volume so that the complete Target Chamber is represented accurately. Each Window is an oval of aluminum 0.254mm thick. It is a rectangle 692.15mm long by 88.9mm tall capped on each end with a semicircle of diameter 88.9mm. Each Window is encircled by an aluminum frame 9.91mm thick and 38.1mm wide as a border.

Local Coordinate System, Survey Data, and Sensitive Detectors

The OLYMPUS Global Coordinate System is defined relative to the Target Cell. For this reason, the Target Cell has its center at (X,Y,Z) = (0,0,0) and its length lies exactly along the Z axis. All other elements described in this section are placed in a static and permanent way relative to the

Target Cell and are assumed not to move relative to one another, since we have no survey data which could make this distinction. The only survey data we have for these parts is for the Target Chamber Frame, and we assume a well-defined and known translation between this and the Target Cell. Note that the center of the Target Cell is 50mm along Z directly downstream of the center of the Target Chamber Frame. The Target Chamber wrapper volume, in the GDML, coincides with the Target Chamber Frame.

None of the Target Chamber elements are sensitive detectors.

3 Beampipe Elements

Description of Solids, Volumes, and Daughters

The OLYMPUS Beampipe, consisting of elements designed for our experiment and installed on the DORIS ring, is represented in the GDML by 18 distinct volumes that meet with one another at their planar upstream and downstream faces. Starting upstream and working towards our Target Chamber, there are six pieces numbered from U6 to U1. Starting at the Target Chamber and proceeding downstream, pieces are numbered from D1 to D12, so that the Target Chamber itself sits between U1 and D1. These are the pieces:

U6 — The narrow incoming pipe, 1142.97mm long, 1.5875mm thick, inner radius 30.1625mm, made of stainless steel.

U5 — Part of the upstream bellows, 97.6376mm long, 1.651mm thick, inner radius 30.1625mm, made of stainless steel.

U4 — Part of the upstream bellows, 51.2064mm long, 2.3749mm thick, inner radius 27.7876mm, made of stainless steel.

U3 — Part of the upstream bellows, 44.45mm long, 1.651mm thick, inner radius 30.1625mm, made of stainless steel.

U2 — The upstream Beam Position Monitor, 91.567mm long, 1.5875mm thick, inner radius 30.1625mm, made of stainless steel. Four blocks representing the electronic components are placed around its perimeter at the middle.

U1 — A short pipe connecting to the Target Chamber, 107.95mm long, 3.0861mm thick, inner radius 28.6639mm, made of aluminum.

D1 — A short pipe connecting to the Target Chamber, 69.85mm long, 3.225mm thick, inner radius 28.575mm, made of aluminum.

D2 — The downstream Beam Position Monitor, 91.567mm long, 1.5875mm thick, inner radius 30.1625mm, made of stainless steel. Four blocks representing the electronic components are placed around its perimeter at the middle.

D3 — Part of the upstream bellows, 44.45mm long, 1.651mm thick, inner radius 30.1625mm, made of stainless steel.

D4 — Part of the upstream bellows, 51.2064mm long, 2.3749mm thick, inner radius 27.7876mm, made of stainless steel.

D5 — Part of the upstream bellows, 97.6376mm long, 1.651mm thick, inner radius 30.1625mm, made of stainless steel.

D6 — First conical expander, 65.151mm long, 1.651mm thick, inner radius expands from 30.099mm to 36.449mm, made of stainless steel. Includes a 14.224mm-long lead-in pipe and a 12.7mm-long lead-out pipe.

D7 — Second conical expander, 167.64mm long, 3.048mm thick, inner radius expands from 35.052mm to 73.152mm, made of stainless steel. Includes a 31.75mm-long lead-in pipe and a 25.4mm-long lead-out pipe.

D8 — Long wide downstream pipe, 1278.33mm long, 3.048mm thick, inner radius 73.152mm, made of stainless steel.

D9 — Conical reducer, 266.7mm long, 1.5494mm thick, inner radius reduces from 69.85mm to 20.574mm, made of stainless steel. Oval slits consisting of a rectangle 25.4mm tall by 83.9724mm long with each end capped by a semicircle of radius 11.9888mm are cut out of the cone to allow the passage of symmetric Møller and Bhabha scatters. Includes an 18.288mm-long lead-in pipe and a 12.7mm-long lead-out pipe.

D10 — Container pipe around the conical reducer, 285.496mm long, 2.7686mm thick, inner radius 73.4314mm, made of stainless steel. includes a 44.704mm-long, 101.219mm-radius downstream flange as a cap. The flange has a 22.225mm-radius hole on each side (left and right) of the beamline to allow for the passage of symmetric Møller and Bhabha scatters.

D11 — Two extension pipes, one on each side (left and right) of the beamline, 105.892mm long, 1.651mm thick, inner radius 20.574mm, made of stainless steel. These are the final point of exit for symmetric Møller and Bhabha scatters, so they each include a 23.876mm-long, 34.671mm-radius downstream flange that houses a 0.254mm-thick, 22.225mm-radius window made of aluminum.

D12 — The narrow outgoing pipe, 1007.62mm long, 1.651mm thick, inner radius 20.574mm, made of stainless steel.

Every Beampipe element is filled with Beam Gas.

Local Coordinate System, Survey Data, and Sensitive Detectors

The Beampipe elements are placed according to their nominal positions, since we have no survey data on any of these pieces. Therefore, their longitudinal axes all lie directly along the Z axis. This is believed to be reasonable since the metal of the pipes should always be distant from the actual particle beam relative to the spread of the beam.

The only exception is the Beam Position Monitors. Both the upstream and downstream Beam Position Monitors were surveyed, and these are placed and rotated in the GDML according to their survey measurements.

None of the Beampipe elements are sensitive detectors.

4 Lead Blocks

Description of Solids, Volumes, and Daughters

Four Lead Blocks were placed in each sector, all made of lead. One on each side was laid flush against the downstream portion of the left or right face of the Target Chamber. This Lead Block was shaped like a box with some material cut away in the shape of a semicircle to make room for the Target Chamber Window frame, which it was set flush against. This Lead Block measured about 120mm by 254mm with a thickness of 10mm. The material cut away to make room for the Target Chamber Window was in the shape of a circular sector with a radius of 82.55mm.

Of the other three Lead Blocks in each sector, all of them are simple box solids. Two measure 442mm by 150mm with a thickness of 12.5mm and the third measures 300mm by 100mm with a thickness of 25mm. Each of these Lead Blocks was laid at an angle, resting against the Beampipe downstream of the Target Chamber.

Local Coordinate System, Survey Data, and Sensitive Detectors

The center of each Lead Block's coordinate system is simply the center of the solid. There is not survey data for the Lead Blocks, but the positions and angles of each were measured by hand and they are placed according to these measurements.

None of the Lead Blocks are sensitive detectors.

5 Toroid Coils

Description of Solids, Volumes, and Daughters

Each of the eight Coils is identical in shape. The shape is moderately complex: it can be thought of like a border around a capital 'P' and is made up of seven pieces, each 88.9mm-thick, 533.4mm-wide solid copper.

Rectangle 1 — The spine of the P, 2574.8mm long.

Rectangle 2 — The right side of the top half of the P, 447.5mm long.

Rectangle 3 — The right side of the bottom half of the P, 1127.3mm long.

Curve 1 — The bottom of the P, inner radius 255mm.

Curve 2 — The top of the P, inner radius 430mm.

Curve 3 — The upper part of the midpoint of the P, inner radius 531.9mm.

Curve 4 — The lower part of the midpoint of the P, inner radius 538mm.

Local Coordinate System, Survey Data, and Sensitive Detectors

The placement of each Coil is based on a best fit to our magnetic field data. In the fit, each Coil is modeled as a loop of current. For more details, see the OLYMPUS internal note on our magnetic field. The Coil that sits immediately above a Wire Chamber in each sector has been artificially elevated by 20–30mm as an *ad hoc* correction to prevent overlap between the Coils and the Wire Chambers.

None of the Coils are sensitive detectors.

6 Wire Chambers

Description of Solids, Volumes, and Daughters

In each sector, the GDML has one wrapper volume representing a Wire Chamber (WC). Each WC contains several protective sheets—Windows, Lightguards, Foils, and Shields—as well as three Frames. Each Frame contains a Gas volume, which contains a Chamber volume. Each Chamber contains two Superlayers, each Superlayer contains three Layers, and each Layer contains some number of Wires. In total, there are 36 layers in the GDML, among which are distributed 954 Wires.

The shape of a WC is a trapezoidal frustum. Its inner face is a trapezoid 1460.52mm tall with bases of 241.617mm and 584.443mm and its outer face is a trapezoid 3162.95mm tall with bases of 707.832mm and 1450.28mm. The centers of these faces are connected by a line that makes a 31.72° angle with their mutual normal, in the plane formed by their normal and their heights. The faces are separated by a distance of 1092.866mm measured along their normal. The size of this wrapper volume was designed to allow for a 20mm cushion on each the inner and outer face to account for protective sheets, and a 7.5mm cushion on the upstream and downstream faces and 5mm cushion on the top and bottom faces to account for Frames shifting according to survey data.

The trapezoidal sheets that cover the inner and outer faces of a WC are, starting from the first (gas-adjacent) layer and working outward: 0.05mm-thick Mylar Windows, 0.14mm-thick Polyethelene Lightguards, and 0.045mm-thick aluminum Foils. Beyond this, the inner face also has a 5.9mm-thick Plexiglass Shield.

The Outer Frame is a piece of aluminum with 38mm-thick side walls and varying thickness on the top and bottom, from 103.5mm at the outer face to 84.9mm at the inner face. The Inner and Middle Frame pieces are constructed similarly, with 38mm-thick side walls and varying tops and bottoms, becoming thinner monotonically toward the inner face of the Inner Frame, where they are 19.2mm thick. These two pieces, the Inner and Middle Frame, also include Interconnecting Regions that cover the area in between Chambers. These have 38mm-thick side walls but 3.175mm-thick tops and bottoms, since no Wires are contained in these Interconnecting Regions.

Each Frame follows the trapezoidal frustum shape, growing from the inner face of the Inner Frame, which is 1476.68mm tall with bases of 576.34mm and 229.72mm, to the outer face of the Outer Frame, which is 3116.79mm tall with bases of 1434.86mm and 703.25mm. They are made of aluminum, and the entire space that each one contains corresponds to a Gas volume, made of "WC Gas with Ethanol." This gas is an 87.3:9.7:3 mixture of Ar:CO_2:CH_3CH_2OH at room temperature and atmospheric pressure.

The daughter volumes of Gas, and each of their daughters on down the line, are constructed as cross-sections of Gas that are parallel to the inner and outer faces and of nonzero thickness. Chambers are 100mm thick, Superlayers are 40mm thick, and Layers are 0.001mm thick. Wires are as thick as Layers, but each only 78mm wide instead of spanning the entire width of a Gas. In this way, each Wire corresponds to the approximate range of gas in which a particle would be detected by a particular sense wire, but is only as thick as a sense wire itself is. Note that even the

Wires are represented as WC Gas with Ethanol, so that the GDML does include any metal in the WCs to account for the metal sense and field wires.

Local Coordinate System, Survey Data, and Sensitive Detectors

Based on survey data showing that both WCs sat roughly 10mm lower than their nominal positions, these container volumes have been placed 10mm below nominal. This is a coarse correction for survey data. Finer corrections that incorporate the complete survey data are applied at the level of Frames. The local coordinate system of a Frame has its center at the body center of the thick-walled portion of the Frame, ignoring any Interconnecting Region. Note that the center of a chamber is between 4mm and 4.5mm further from the Target than the center of its respective Frame is.

Every Wire is a sensitive detector.

7 Time of Flight Detectors

Description of Solids, Volumes, and Daughters

In each sector, the four most forward Time of Flight detectors (TOFs) are 1193.8mm tall and about 178mm wide while the remaining fourteen in each sector are 1800mm tall and about 261mm wide. Otherwise, the designs are all nominally identical. The center is a Scintillator bar 25.4mm thick made of vinyl toluene. On the Target-side face is a sheet of Lead about 0.5mm thick. These are wrapped together in aluminum Foil 0.09mm thick, which is then wrapped in polyethelene 0.14mm thick. These wrappers cover four sides, but do not cover the top or bottom of a bar. All TOF materials for a single bar are contained within a TOF volume made of air.

It was found during surveying that there is some significant variation among TOF bars. For this reason, each bar's Scintillator has an individually-set width, and each bar's Lead has an individually-set thickness. For a few bars, there is no Lead.

Local Coordinate System, Survey Data, and Sensitive Detectors

Survey data was used to place each TOF, using the center of the Scintillator as the center of the local coordinate system. The TOFs line up into three panels in each sector. The most forward and most backward bar in each middle panel, as well as the most backward bar in each backward panel, constitute a special case. These six bars were not completely surveyed, so their placements involve a little bit of guesswork, under the assumption that they are positioned similarly to other bars in their own panel.

Each Scintillator is a sensitive detector.

8 Gas Electron Multipliers

Description of Solids, Volumes, and Daughters

Each sector contains three Gas Electron Multipliers (GEMs), which are identical except that the most downstream of them faces in the opposite direction (away from the Target). When I refer to "Target side" and "away side," I refer to the upstream or middle GEM design, and these should be reversed when considering the downstream GEM.

Each GEM is a box solid measuring 125mm by 125mm by 15mm and made of "GEM Gas," which is a 70:30 mix of Ar:CO_2 at room temperature and a density of 0.0017g/cm^3. Its daughters are a NemaG10 (fiberglass) Frame, a Drift volume, and seven sheets of metal: two PVs, an HV, three Foils, and a Readout Board. In reality, many of these metal sheets are perforated in special ways to create the detectors, but in the GDML each sheet is approximated as a solid layer of metal whose total volume is equal to the real volume of actual metal after holes are subtracted off.

The Frame is a border of 12.5mm around the central gas volume, which measures 100mm by 100mm. Both are 15mm long.

Each PV is a window made of 0.05mm-thick Mylar. This is really aluminized Mylar, but the 100$\AA$ layer of aluminum is neglected in the GDML.

The HV includes 0.05mm of Kapton and 0.005mm of copper.

Each Foil includes 0.045mm of Kapton and 0.008mm of copper.

The Readout Board includes 0.05mm of Kapton and 0.0045mm of copper.

Starting from the Target side and working toward the away side, the GEM is structured in this way:

- PV
- 3mm of GEM gas
- HV
- 3mm of GEM gas, which is the Drift volume
- Foil
- 2mm of GEM gas
- Foil
- 2mm of GEM gas
- Foil
- 2mm of GEM gas
- Readout Board
- 3mm of GEM gas
- PV

Local Coordinate System, Survey Data, and Sensitive Detectors

The center of a GEM's local coordinate system is the center of its Drift volume. Each GEM is placed according to survey data.

Each Drift volume is a sensitive detector.

9 Multi-Wire Proportional Chambers

Description of Solids, Volumes, and Daughters

Each sector contains three Multi-Wire Proportional Chambers (MWPCs), which are represented by container volumes made of air. These containers consist of two boxes stuck together: one to make room for the detector, and another on the downstream side to make room for the Electronics. We can consider these two parts separately, since the detector has much more detailed structure.

The detector is surrounded by a Frame, which is a box measuring 180mm by 180mm by 50mm. The Frame is a border of 34mm around the central Gas volume, which measures 112mm by 112mm. The most upstream 10mm of the Frame are made of aluminum, as are the most downstream 10mm, with the 30mm in between made of NemaG10 (fiberglass).

Other daughter volumes of the MWPC container include two Windows, two Foils, and the Gas. The upstream and downstream faces are each covered by a 0.05mm Window made of Mylar, then covered by a 0.045mm Foil made of aluminum. As with the GEMs, the Windows are really aluminized but there is not a 100$\AA$ aluminum layer in the GDML.

The Gas is made of "MWPC Gas," which is a 65:30:5 mixture of Ar:CO_2:CF_4. It contains as daughters the Drift volume and nine layers of metal. Each metal layer is a solid sheet which represents a set of wires. Individual wires with appropriate spacing are not built into the GDML. Instead, a layer of wires is replaced by a solid sheet of metal that has the same total volume as the sum of all the wires it stands for. The cathode layers are therefore 0.0127235mm-thick beryllium bronze while the sensing anode layers are 0.000490874mm-thick tungsten. Starting from the Target side and working toward the away side, the GEM is structured in this way:

- Foil
- Window
- 10mm of MWPC Gas, which is the Drift volume
- 2.5mm of MWPC Gas
- Cathode
- 2.5mm of MWPC Gas
- Anode (U layer)
- 2.5mm of MWPC Gas
- Cathode
- 5mm of MWPC Gas
- Cathode
- 2.5mm of MWPC Gas
- Anode (X layer)
- 2.5mm of MWPC Gas
- Cathode
- 5mm of MWPC Gas
- Cathode
- 2.5mm of MWPC Gas
- Anode (V layer)
- 2.5mm of MWPC Gas
- Cathode
- 12.5mm of MWPC Gas
- Window
- Foil

Making a “>” shape on the away side of each MWPC are two boxes of Electronics. Each is represented by a solid block of carbon measuring 335mm by 52mm by 50mm.

In each sector, there are two Support Beams that are placed near the MWPCs. The Support Beams are independent volumes whose mother is the World. They represent the real support beams that hold the MWPCs and GEMs in place. In the GDML, these are boxes measuring 30mm by 30mm by 1200mm, made of aluminum. They are placed nominally, since there is no available survey data for them.

Local Coordinate System, Survey Data, and Sensitive Detectors

The center of the Drift volume is the center of the local coordinate system for its MWPC. The MWPCs are placed according to survey data.

Each Drift volume is a sensitive detector.

10 Silicon Photomultipliers

Description of Solids, Volumes, and Daughters

The 12° luminosity monitoring system also includes the Silicon Photomultiplier detectors (SiPMs). These are each represented by a wrapper volume made of air, which has two daughters: an aluminum Foil and a vinyl toluene Scintillator.

The Foil is a layer 0.045mm thick surrounding the Scintillator on all sides.

The Scintillator is a box solid measuring 120mm by 120mm by 8mm.

Local Coordinate System, Survey Data, and Sensitive Detectors

The center of the Scintillator is the center of the local cooridnate system. There is no precise survey data for the SiPMs. The downstream SiPM in each sector is placed halfway between the most downstream GEM and the most downstream MWPC as an approximation. The upstream SiPM in each sector is placed along the line of the other monitors (at about 12°) at a distance from the most upstream GEM that corresponds to a measurement made by hand with a tape measurer.

Each SiPM Scintillator is a sensitive detector.

11 Lead Glass

Description of Solids, Volumes, and Daughters

The final component of the 12° luminosity monitoring system is the Lead Glass detectors (LGs). There are three independent LGs in each sector. Each one is a box solid measuring 65mm by 65mm by 300mm, made of lead glass. There is no additional structure accounted for in the LGs.

Local Coordinate System, Survey Data, and Sensitive Detectors

Each LG has its own local coordinate system centered at its own center. The central LG in each sector is placed exactly along the 12° line on the away-side face of the K-beams, and the other two are placed on either side of it with a 0.5mm gap in between. There is no survey data for the LGs.

Each LG is a sensitive detector.

12 Symmetric Møller/Bhabha Detectors

Description of Solids, Volumes, and Daughters

Each sector contains one Symmetric Møller/Bhabha Detector (SYMB), which is represented by a wrapper volume made of air. The wrapper contains as daughters a Collimator Block, a Sheet of Mu Metal, and nine Crystals.

The Collimator Block is a simple box solid made of lead with a compound Collimator Hole cut out of it. The Block measures 200mm by 120mm by 100mm. The hole is of very slightly different dimensions in each sector, so I will explain it using the left sector Collimator Hole's dimensions. Initially, a cylindrical hole of radius 10.225mm is taken out of the block all the way through. Then, an additional cylinder of material is removed from each the front (Target-side) face and the back (away-side) face, both being concentric with the initial cylinder. From the front face, the extra material removed is of radius 15.5mm and depth 1.8mm. From the back face, the extra material removed is of radius 15.5mm and depth 2.4mm.

The Sheet of Mu Metal sits between the Collimator Block and the Crystals, and measures 200mm by 120mm with a thickness of 0.1mm.

Each of the Crystals is an identical block measuring 25mm by 25mm by 160mm and is made of lead fluoride scintillator. They are arrayed in each sector in a three-by-three grid shape, with the central crystal very nearly in line with the axis of the Collimator Hole.

Local Coordinate System, Survey Data, and Sensitive Detectors

The center of the local coordinate system is defined by the intersection of the Collimator Hole's axis with the plane of the Collimator Block's front face. The SYMBs are placed according to survey data.

Each Crystal is a sensitive detector.

13 No Other Volumes

All of the volumes described above are placed as daughters (or granddaughters, etc.) of the overall container, World. No other elements exist in the GDML. Any objects which ought to exist but are not described here do not currently exist, and a request must be submitted for them to be created and added to the GDML.