FreeCAD (and Free CAE) Users Conference - March 2023

GDML Workbench - Keith Sloan

- Main Developers
  - Keith Sloan
  - Munther Hindi

Introduction

- Monte Carlo Simulations
- GDML / Geant4 Geometry
- GDML Workbench
  - Arrays & Mirrors
  - GDML Objects from FreeCAD sketches
  - GDML Tessellated Solids
- Users
- Summary

Monte Carlo Simulations

- Physics of particle interaction with materials
- High energy, Nuclear & Accelerator Physics, Space, Medical
- Software
  - Geant4
  - ROOT (CERN)
  - Others Geant5, GRAY
- Experiment Written in C++
- Optionally Geometry defined in markup XML
  - GDML - Geometry Description Markup Language

Geant4 Geometry and CAD

- Geant4 (Physicists)
  - Solid Graphics
  - Tessellated (Brep, STEP shapes)
    - Longer times for simulations
- CAD (Engineers)
  - Brep shapes
  - Sketches
    - Extrusions - Pockets
    - Revolve

Geant4 / GDML Geometry

- Define section
- Materials
- Solids
- Volumes
  - Defines One Solid
  - One Material
  - Optional a number of Physvols
- Physvols
  - Position, Rotation
- Assembly
  - Multiple Volumes
- Rules
  - No overlapping volumes
  - No duplicate Names - Volumes, Assembly, Solids

GDML/Geant4 Solids

- Over 30 GDML/Geant4 solid types (FC Part has 6)
  - Constructive Solid Geometries CSG
    Box, Tube, Cones, etc
  - CSG Like
    Polygon, Polyhedra
- Implemented as Part::FeaturePython Objects
- Properties the same a GDML definition

GDML Workbench History

- CAD-GDML - Meeting at SLAC Sept 2011
    - C++ Workbench started by Emmanuel Delage
- Initial Workbench FreeCAD_Python_GDML
        - Geant4 python library which at the time was still under development
        - Now GitHub retired / archived
- GDML workbench
        - Different approach
        - GDML Solids implemented as FreeCAD FeaturePython Objects
        - Recent enhancements - Thanks to Munther Hindi
            - Arrays, Mirrors
            - Extruded and Revolved Sketches

Relationships

GDML/Geant4

Materials

Volume
Solid, Material

PhysVol
Position Rotation

Assembly

Workbench

Materials

App::Part
Volume Assembly
Placement

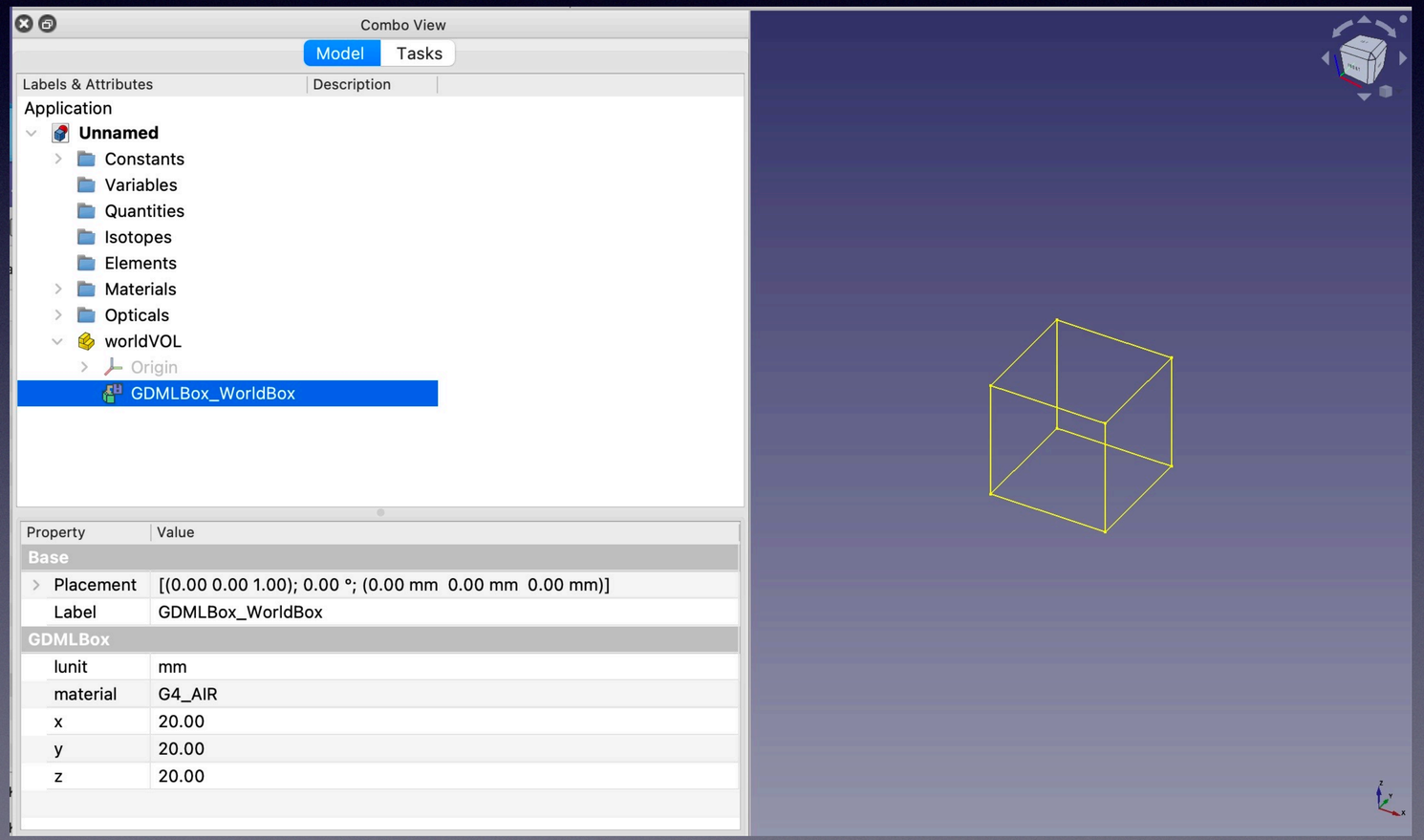
GDML Objects
Solid (Material)
Placement

FreeCAD GDML workbench

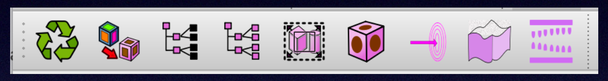
- Part (Geant4 / GDML - Volume, Assembly)
- Solids as Part::Python Features
  - Object properties as per GDML parameters
- Part initially one Solid but now export now creates appropriate PhysVols

Activate GDML Workbench

- Open New File
- Import XML file of any user defined materials
- Create
  - Parts
    - Volumes
    - Assemblies
  - Solids
    - Set Properties
    - Set Material
- Export
  - Select ‘worldVol’
  - File | export
  - Filetype - gdml or GDML



Icons / Commands

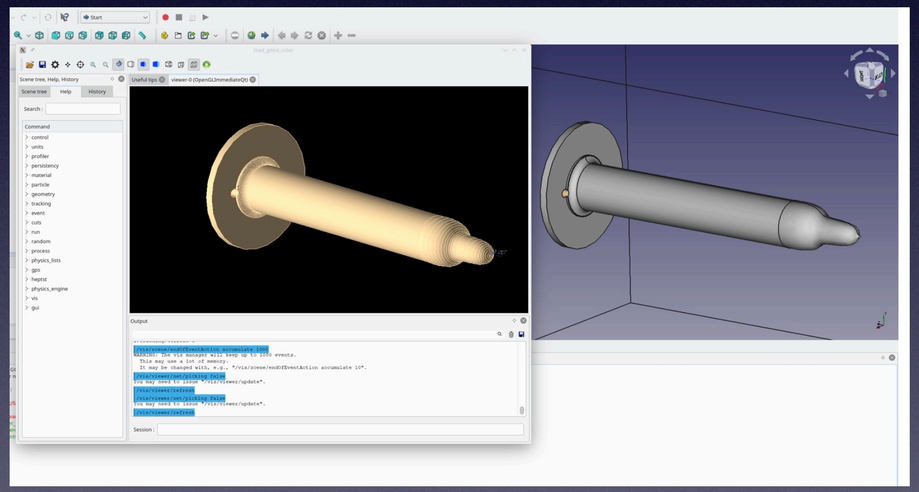
- Utility - 
- Solids - 
- Sketch and Applicable Functions 
- Booleans 
- Tessellated / Mesh 

Extruded & Revolved Sketches

- Create Sketch
  - Sketcher Workbench
  - Import SVG to Sketch
- Extrude or Revolve
- Set Material

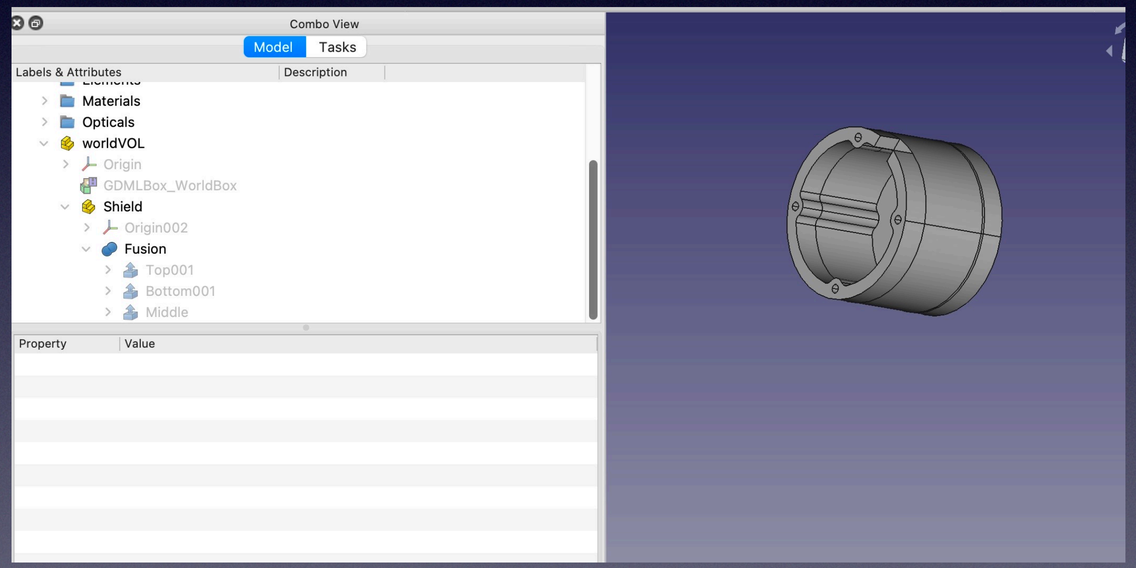
Revolved Sketch

- Revolved Sketch
- See GDML workbench wiki
- In this example exported as
  - Tube
  - genericPolycone



Extruded Sketch

- Create sketch
  - Sketch workbench
  - Import SVG
  - toSketch (Addon workbench)
- Extrude
- This example (see wiki for files)
  - Imported STEP file
  - Used toSketch to create three sketches
  - Extrude sketches
  - Boolean (Fuse) three extrusions.



Arrays & Mirrors

- Arrays
  - Types supported
    - Orthogonal
    - Polar
    - Path
    - Point
  - Exported as MultiUnion
  - Scripts for separate volumes
    - Root
    - G4Opt
- Mirrors

Tessellated Solids

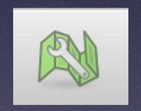
- Tessellate FC Object

- Tessellate using Gmsh

- Mesh
  - FC Object to Mesh

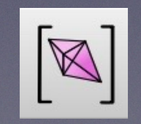
  - Tessellate from Mesh

  - Mesh Toolbox



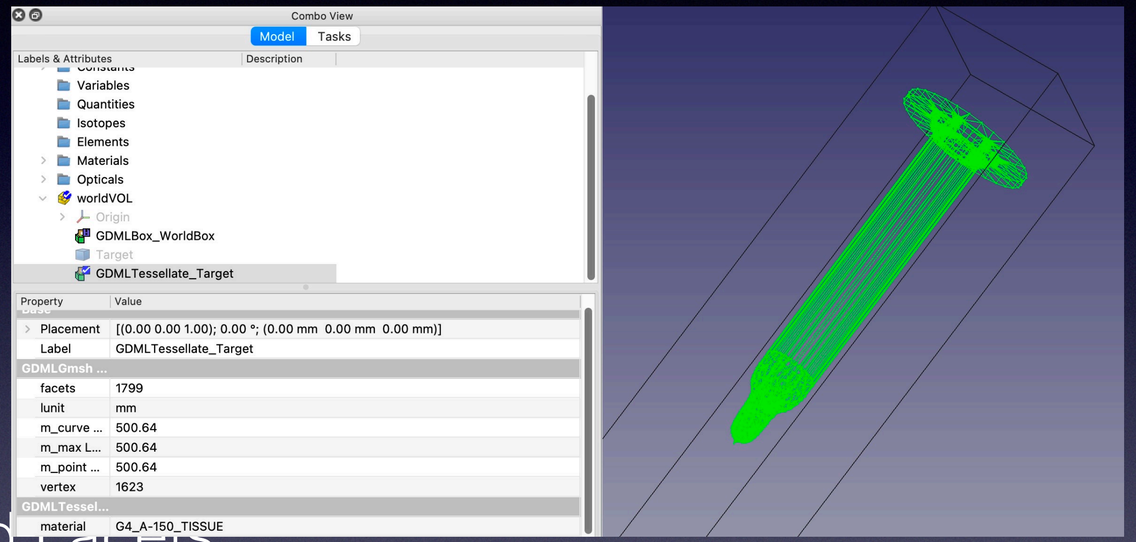
  - Decimate Tessellation

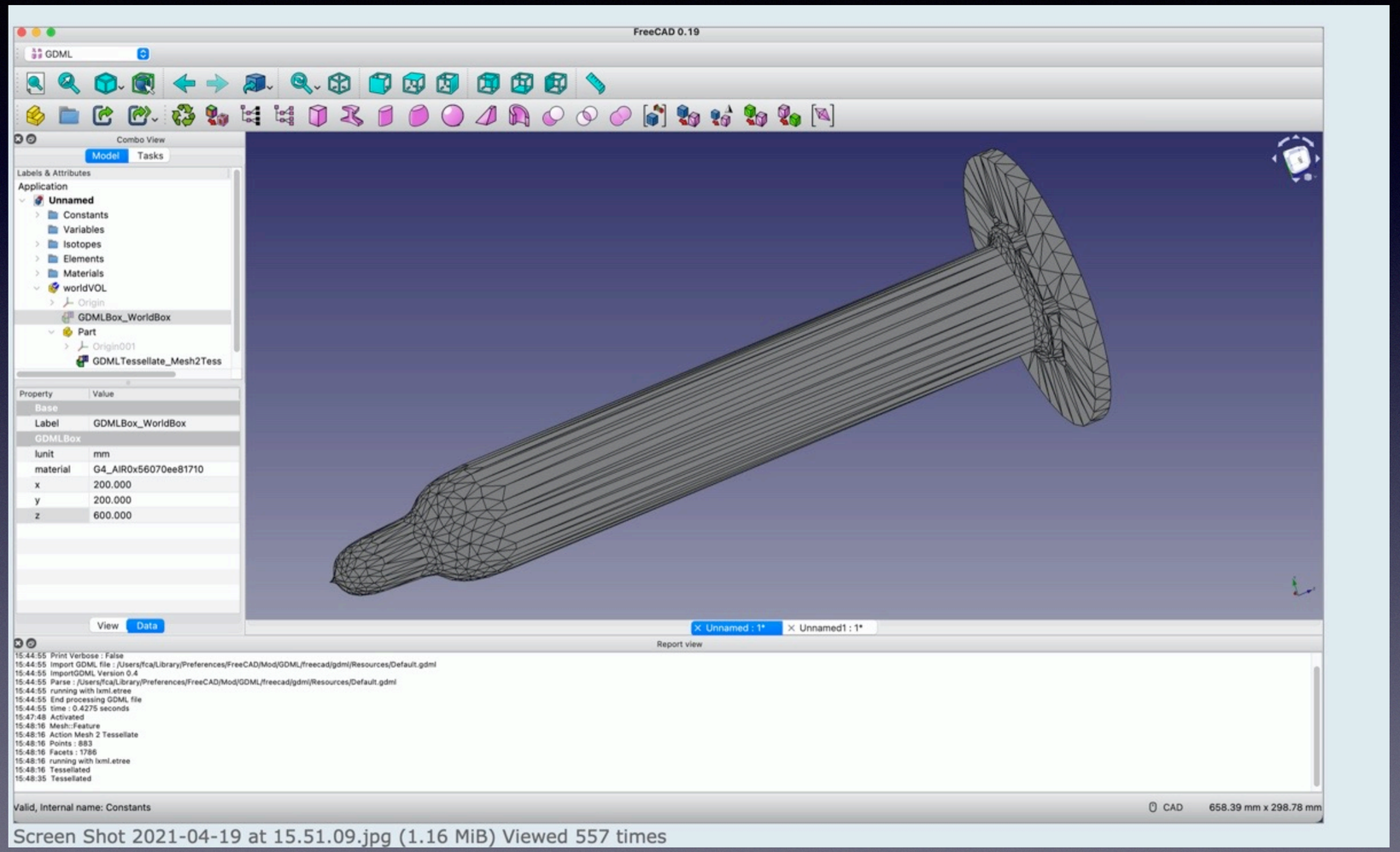
- Tetrahedron



Gmsh Min

- Creates a Tessellated Mesh
- Choose Mesh parameters based on Bounding Box
- Uses Gmsh Recombine
  - Triangulate Facets combined to Quad Facets
  - In example shown - Facets 1799 Vertex 1623
- Note: Gmsh shared library needs to be installed in FreeCAD Resources/lib





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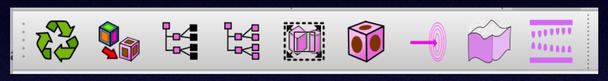
Icons / Commands

- Utility - 
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Modes of Working

- Create GDML Solids. 
- FC Sketches (More akin to CAD design) 
  - Extrude 
  - Revolve 
- Create FC PartDesign - Body
  - Tessellate PartDesign Body 
  - Set Tessellated Material 
- Import STEP
  - Options : Use Colour Map to Materials 
  - Tessellate 
  - Allocate material 

Optical Support

- With GDML workbench activated, open new file
  - Creates GDML file structure
    - Matrix
    - Surfaces
- Import matrix.xml file see example freecad/gdml/Resources/matrix.xml
  - Matrix is a number of spreadsheets within the Opticals/Matrix Group
- Import optical.xml file see example freecad/gdml/Resources/optical.xml
  - Definition of a number of surfaces

- Icons/Commands
  - Set Skin Surface 
  - Set Border Surface 

Import / Export files

- Filetype - xml
  - Import will add to current FreeCAD structure
    - Materials
    - Volume / Solid
  - Exporting
    - Materials
- Can Select World or Individual Volume
  - Export gdml - Single file with gdml definitions
  - Export GDML - directory with gdml sections as includes

Other Information

- Installation - see README
  - Gmsh shared library needs to be installed in FreeCAD Resources/lib see README
- Use - see Wiki
- Geant Materials - Resources/Geant4Materials.xml

Users

- 22 - Github Stars
- 8-10 users - Github regularly cloning after updates
- One citation
    - Conceptual design report for the LUXE experiment Abramowicz, H. et al 2021
      (Thanks - Louis Helary)
- Researchers
    - Paolo Dondero - Geant4 Collaboration
    - Amirreza Hashemi - Harvard Medical
- Phd’s
        - Siyao Gu - University of Texas

Thanks

- Munther Hindi
- Jim Austin (icon designs)
- Emmanuel Delage, Wouter Deconnick, Louis Helary
- Damian Lambert, Paulo Dondero, Ami Hashemi
- John Watts, Frederico-Carminati
- Hilden Timo, Atanu Quant, Masaki Morita
- Large number from the FreeCAD community
  Please see github README
- See also GitHub Contributors

Future

- Mentor
- Command line scripts
- User defined materials
- GUI creation of more solids
- Check for overlapping Solids

Summary

- GDML Workbench is for creating Geometries that can be import into
  - Geant4 and ROOT for for MonteCarlo simulations.
- Workbench enables creation via
  - Creating Solid Constructed Graphic Objects CSG
  - CSG’s plus Array, Mirror, Point Cloud
  - FC Sketchs - exported as booleans of CSG’s
  - Facilities to Tessellate