Stanford Linear Accelerator Center

Defining Material and Geometry

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Geant4

Contents

- G4VUserDetectorConstruction class
- Material
- Solid and volume
- Various ways of placement
- Visualization attributes
- Defining a field
- Geometry optimization ("voxelization")
- Geometry checking tools

G4VUserDetectorConstruction

Describe your detector

- Derive your own concrete class from G4VUserDetectorConstruction abstract base class.
- Implementing the method Construct()

1) Construct all necessary materials
2) Define shapes/solids required to describe the geometry
3) Construct and place volumes of your detector geometry
4) Instantiate sensitive detectors and set them to corresponding volumes
5) Associate magnetic field to detector
6) Define visualization attributes for the detector elements
7) Define regions

- Set your construction class to G4RunManager
- Modularize it w.r.t. each detector component or sub-detector for easier maintenance of your code

Definition of material

Geant 4

Definition of Materials

- Different kinds of materials can be described:
  - isotopes <-> G4Isotope
  - elements <-> G4Element
  - molecules, compounds and mixtures <-> G4Material
- Attributes associated to G4Material:
  - temperature, pressure, state, density
- Single element material

```
double density = 1.390*g/cm3;
double a = 39.95*g/mole;
G4Material* lAr =
  new G4Material("liquidArgon",z=18.,a,density);
```

- Prefer low-density material to vacuum

Material: molecule

- A Molecule is made of several elements (composition by number of atoms)

```
a = 1.01*g/mole;
G4Element* elH  =
   new G4Element("Hydrogen",symbol="H",z=1.,a);
a = 16.00*g/mole;
G4Element* elO  =
   new G4Element("Oxygen",symbol="O",z=8.,a);
density = 1.000*g/cm3;
G4Material* H2O =
   new G4Material("Water",density,ncomp=2);
H2O->AddElement(elH, natoms=2);
H2O->AddElement(elO, natoms=1);
```

Material: compound

- Compound: composition by fraction of mass

```
a = 14.01*g/mole;
G4Element* elN  =
   new G4Element(name="Nitrogen",symbol="N",z= 7.,a);
a = 16.00*g/mole;
G4Element* elO  =
   new G4Element(name="Oxygen",symbol="O",z= 8.,a);
density = 1.290*mg/cm3;
G4Material* Air =
   new G4Material(name="Air",density,ncomponents=2);
Air->AddElement(elN, 70.0*perCent);
Air->AddElement(elO, 30.0*perCent);
```

Material: mixture

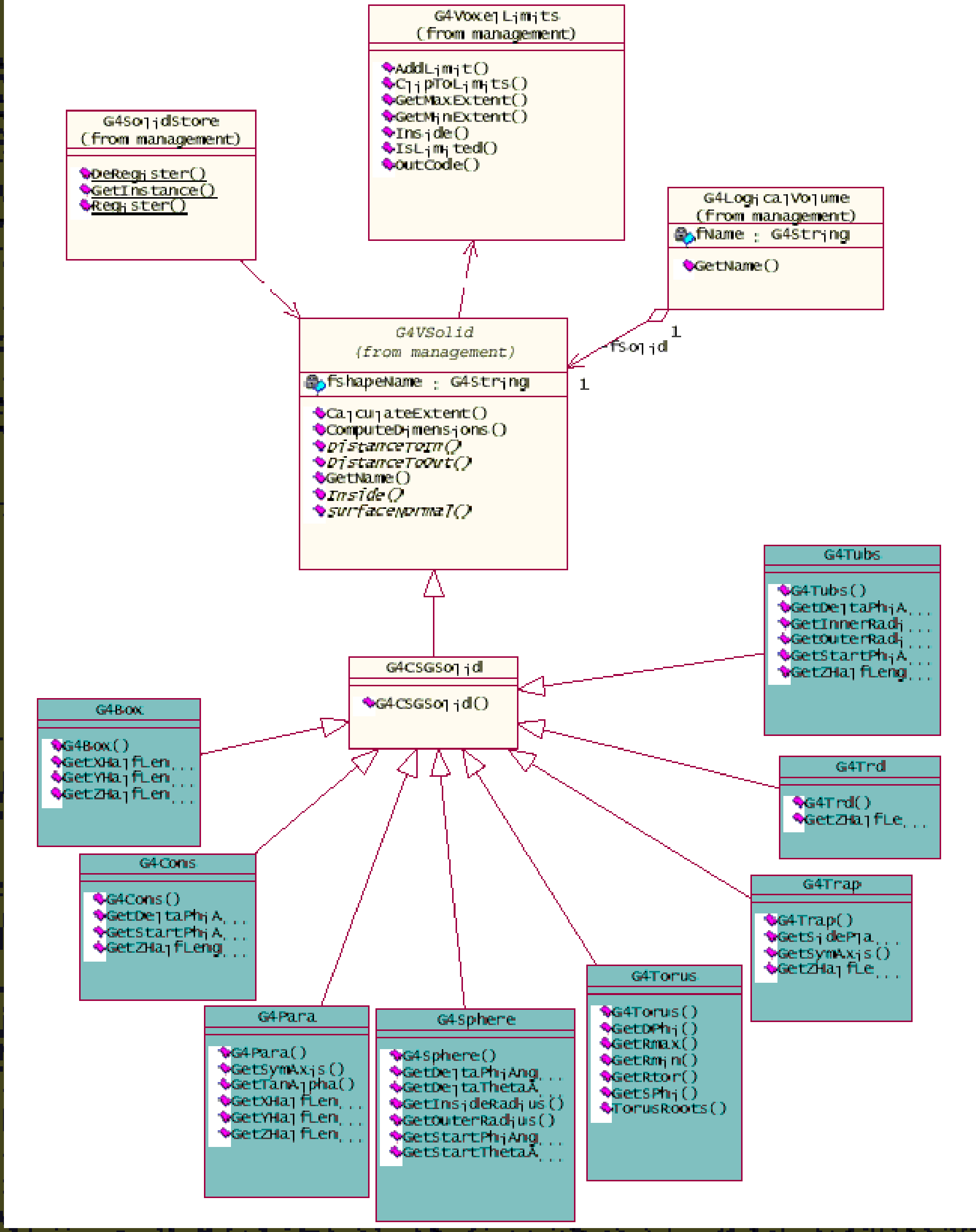
- Composition of compound materials

```
G4Element* elC  = …;   // define “carbon” element
G4Material* SiO2 = …;  // define “quartz” material
G4Material* H2O = …;   // define “water” material

density = 0.200*g/cm3;
G4Material* Aerog =
   new G4Material("Aerogel",density,ncomponents=3);
Aerog->AddMaterial(SiO2,fractionmass=62.5*perCent);
Aerog->AddMaterial(H2O ,fractionmass=37.4*perCent);
Aerog->AddElement (elC ,fractionmass= 0.1*perCent);
```

Solid and shape

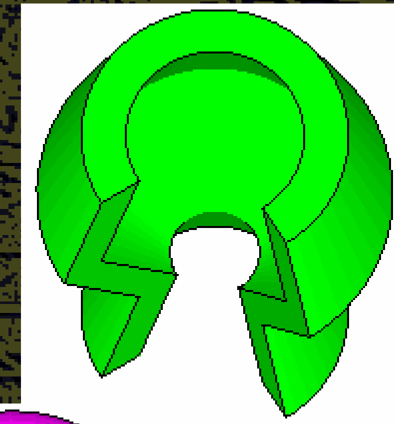
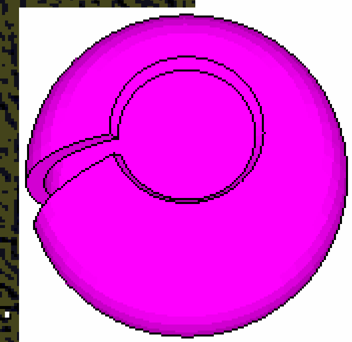
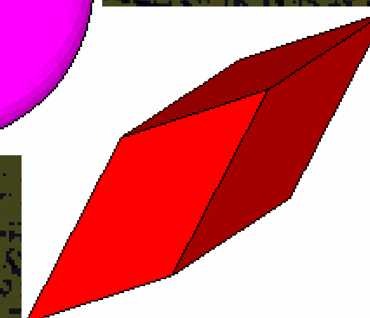
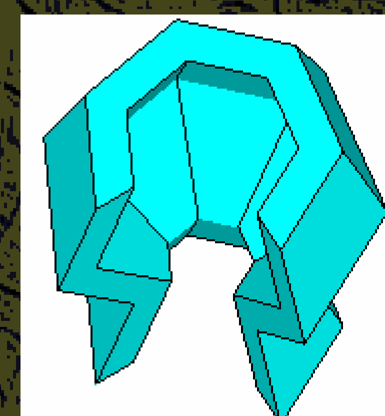
G4VSolid

- Abstract class. All solids in Geant4 derive from it
- It defines but does not implement all functions required to:
  - compute distances between the shape and a given point
  - check whether a point is inside the shape
  - compute the extent of the shape
  - compute the surface normal to the shape at a given point
- User can create his/her own solid class



Solids

- Solids defined in Geant4:
  - CSG (Constructed Solid Geometry) solids
    - G4Box, G4Tubs, G4Cons, G4Trd, ...
    - Analogous to simple GEANT3 CSG solids
  - Specific solids (CSG like)
    - G4Polycone, G4Polyhedra, G4Hype, ...
  - BREP (Boundary REPresented) solids
    - G4BREPSolidPolycone, G4BSplineSurface, ...
    - Any order surface
  - Boolean solids
    - G4UnionSolid, G4SubtractionSolid, ...
  - STEP interface
    - to import BREP solid models from CAD systems - STEP compliant solid modeler

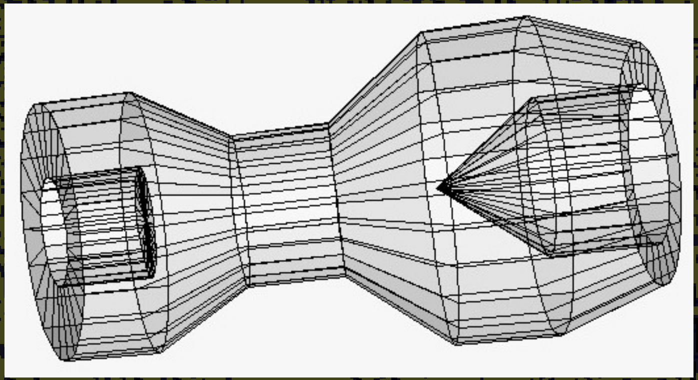





CSG: G4Tubs, G4Cons

```
G4Tubs(const G4String &pname,  // name
             G4double  pRmin,  // inner radius
             G4double  pRmax,  // outer radius
             G4double  pDz,    // Z half length
             G4double  pSphi,  // starting Phi
             G4double  pDphi); // segment angle

G4Cons(const G4String &pname,  // name
             G4double  pRmin1, // inner radius -pDz
             G4double  pRmax1, // outer radius -pDz
             G4double  pRmin2, // inner radius +pDz
             G4double  pRmax2, // outer radius +pDz
             G4double  pDz,    // Z half length
             G4double  pSphi,  // starting Phi
             G4double  pDphi); // segment angle
```

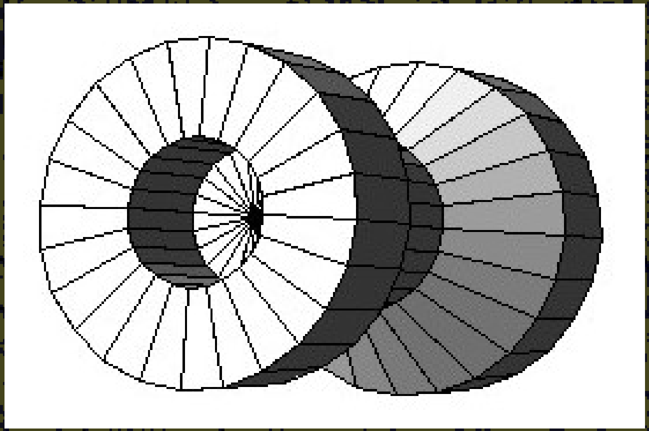
Specific CSG Solids: G4Polycone

```
G4Polycone(const G4String& pName,
           G4double phiStart,
           G4double phiTotal,
           G4int numRZ,
           const G4double r[],
           const G4double z[]);
```



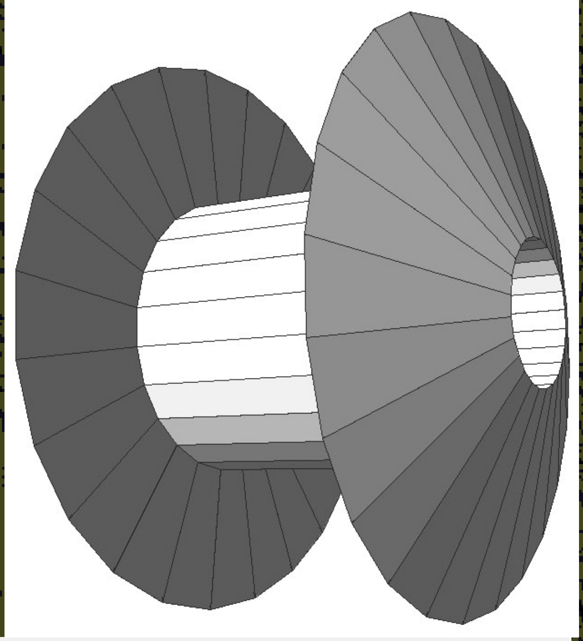
- **numRZ** - numbers of corners in the **r,z** space
- **r, z** - coordinates of corners

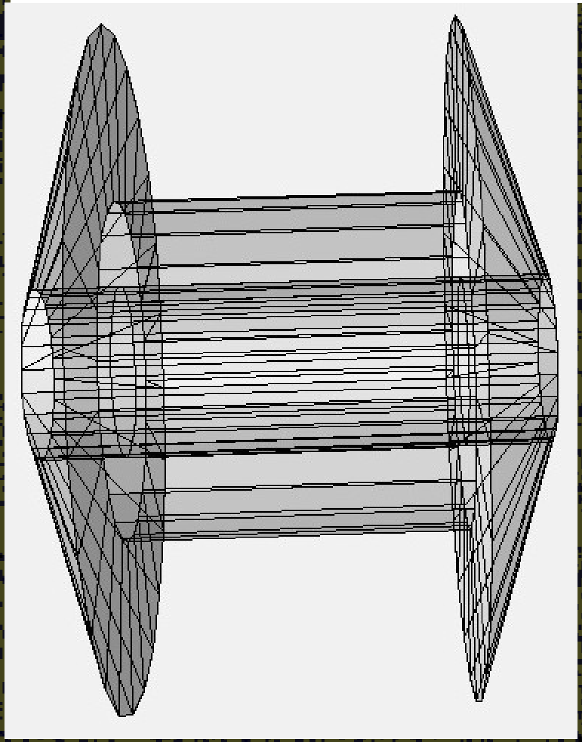
- Additional constructor using planes



BREP Solids

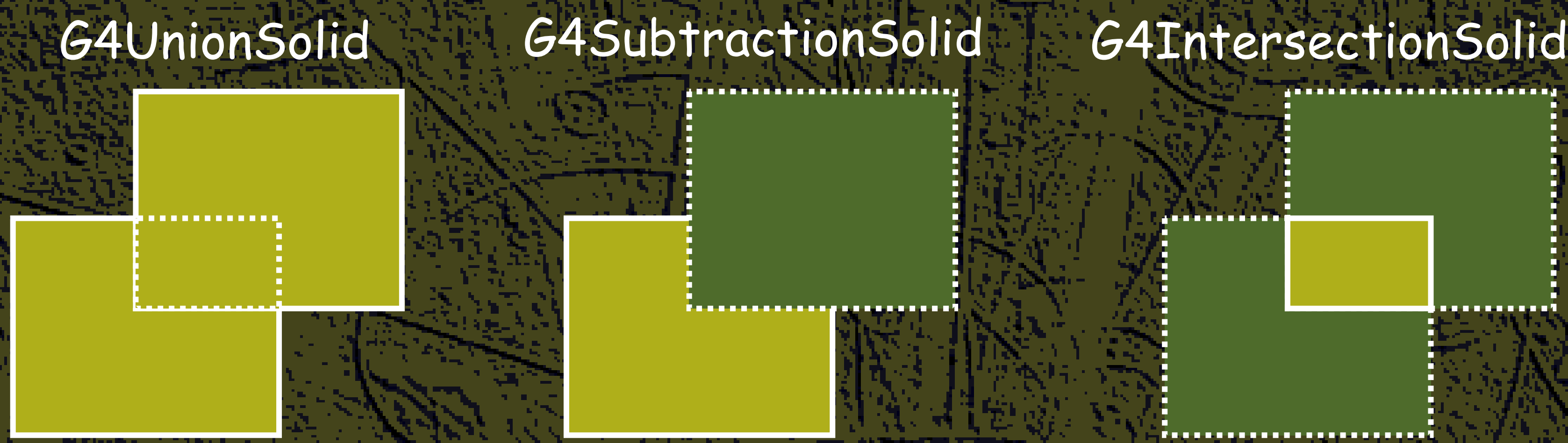
- *BREP = Boundary REPresented Solid*
- Listing all its surfaces specifies a solid
  - e.g. 6 planes for a cube
- Surfaces can be
  - planar, 2^{nd} or higher order
    - elementary BREPS
  - Splines, B-Splines,
    NURBS (Non-Uniform B-Splines)
    - advanced BREPS
- Few elementary BREPS pre-defined
  - box, cons, tubs, sphere, torus, polycone, polyhedra
- Advanced BREPS built through CAD systems





Boolean Solids

- Solids can be combined using boolean operations:
  - **`G4UnionSolid, G4SubtractionSolid, G4IntersectionSolid`**
  - Requires: 2 solids, 1 boolean operation, and an (optional) transformation for the 2nd solid
  - 2nd solid is positioned relative to the coordinate system of the 1st solid
  - Result of boolean operation becomes a solid. Thus the third solid can combined to the resulting solid of first operation.
- Solids can be either CSG or other Boolean solids
- Note: tracking cost for the navigation in a complex Boolean solid is proportional to the number of constituent solids



Boolean Solids - example

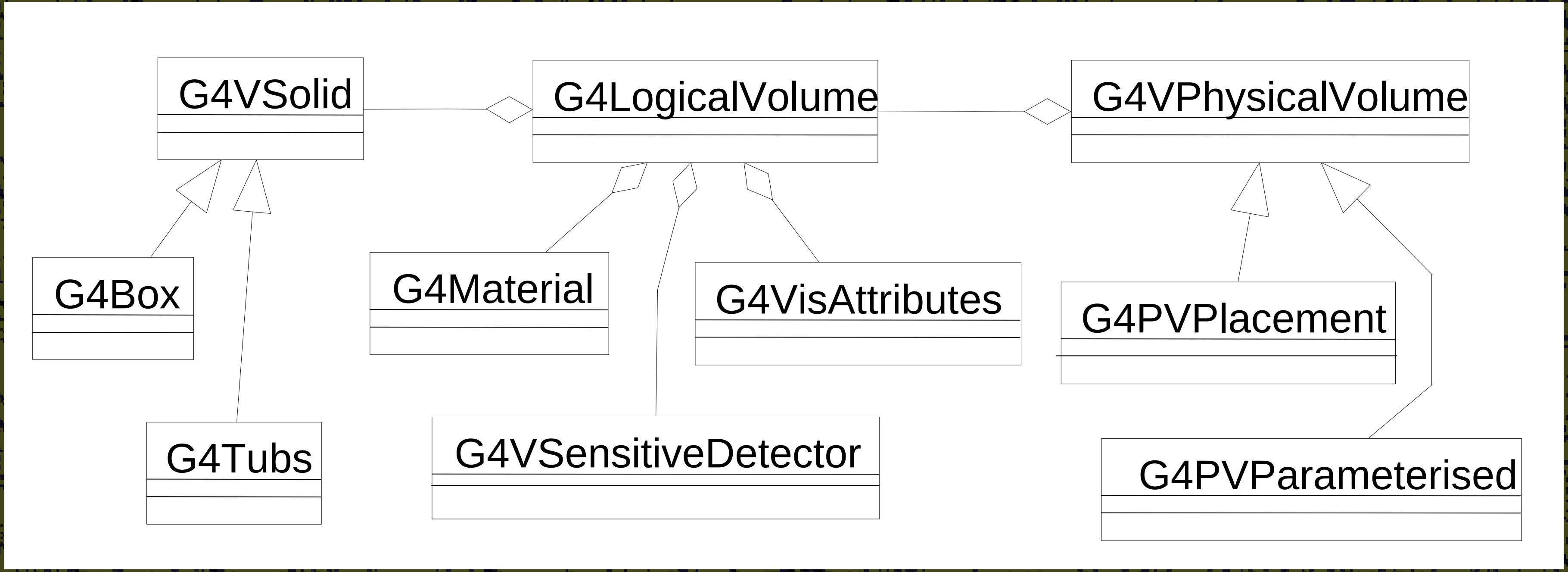
```
G4VSolid* box = new G4Box(“Box",50*cm,60*cm,40*cm);
G4VSolid* cylinder
 = new G4Tubs(“Cylinder”,0.,50.*cm,50.*cm,0.,2*M_PI*rad);
G4VSolid* union
 = new G4UnionSolid("Box+Cylinder", box, cylinder);
G4VSolid* subtract
 = new G4SubtractionSolid("Box-Cylinder", box, cylinder,
       0, G4ThreeVector(30.*cm,0.,0.));
G4RotationMatrix* rm = new G4RotationMatrix();
rm->RotateX(30.*deg);
G4VSolid* intersect
   = new G4IntersectionSolid("Box&&Cylinder",
       box, cylinder, rm, G4ThreeVector(0.,0.,0.));
```

- The origin and the coordinates of the combined solid are the same as those of the first solid.

Defining a geometry

Define detector geometry

- Three conceptual layers
  - G4VSolid -- *shape, size*
  - G4LogicalVolume -- *daughter physical volumes,*
    material, sensitivity, user limits, etc.
  - G4VPhysicalVolume -- *position, rotation*



Define detector geometry

- Basic strategy

```
G4VSolid* pBoxSolid =
   new G4Box("aBoxSolid", 1.*m, 2.*m, 3.*m);
G4LogicalVolume* pBoxLog =
   new G4LogicalVolume( pBoxSolid, pBoxMaterial,
                        "aBoxLog", 0, 0, 0);
G4VPhysicalVolume* aBoxPhys =
   new G4PVPlacement( pRotation,
      G4ThreeVector(posX, posY, posZ), pBoxLog,
      "aBoxPhys", pMotherLog, 0, copyNo);
```

- A unique physical volume which represents the experimental area must exist and fully contains all other components
  - The world volume

G4LogicalVolume

```
G4LogicalVolume(G4VSolid *pSolid,
                G4Material *pMaterial,
                const G4String &name,
                G4FieldManager *pFieldMgr=0,
                G4VSensitiveDetector *pSDetector=0,
                G4UserLimits *pULimits=0);
```

- Contains all information of volume except position, rotation
  - Shape and dimension (G4VSolid)
  - Material, sensitivity, visualization attributes
  - Position of daughter volumes
  - Magnetic field, User limits
  - Shower parameterization
- Physical volumes of same type can share a logical volume.
- The pointers to solid and material must NOT be null
- It is not meant to act as a base class

Visualization attributes

- Each logical volume can have associated a **`G4VisAttributes`** object
  - Visibility, visibility of daughter volumes
  - Color, line style, line width
  - Force flag to wire-frame or solid-style mode
- For parameterized volumes, attributes can be dynamically assigned to the logical volume
  - indexed by the copy number
- Lifetime of visualization attributes must be at least as long as the objects they are assigned to

Physical volume

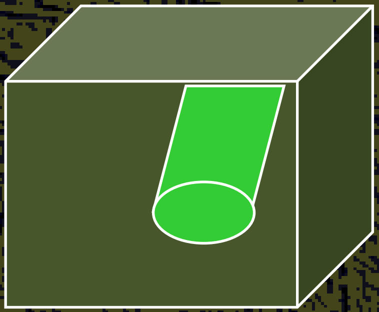
- G4PVPlacement 1 Placement = One Volume
  - A volume instance positioned once in its mother volume
- G4PVParameterised 1 Parameterized = Many Volumes
  - Parameterized by the copy number
    - Shape, size, material, position and rotation can be parameterized, by implementing a concrete class of *G4VPVParameterisation*.
  - Reduction of memory consumption
  - Currently: parameterization can be used only for volumes that either

    a) have no further daughters, <u>or</u>

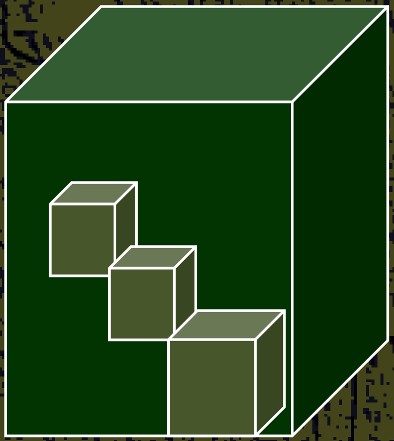
    b) are identical in size & shape.
- G4PVReplica 1 Replica = Many Volumes
  - Mother is filled by daughters of same shape
- G4ReflectionFactory 1 Placement = a set of Volumes
  - generating placements of a volume and its reflected volume
  - Useful typically for end-cap calorimeter
- G4AssemblyVolume 1 Placement = a set of Placements
  - Position a group of volumes

Physical Volumes

- Placement: it is one positioned volume
- Repeated: a volume placed many times
  - can represent any number of volumes
  - reduces use of memory.
  - Parameterised
    - repetition w.r.t. copy number
  - Replica
    - simple repetition, similar to G3 divisions
    - it is not slicing but filling a mother volume with daughters of same shape
- A mother volume can contain either
  - many placement volumes
  - or, one repeated volume



placement



repeated

G4PVPlacement

```
G4PVPlacement(G4RotationMatrix* pRot,
              const G4ThreeVector &tlate,
              G4LogicalVolume *pDaughterLogical,
              const G4String &pName,
              G4LogicalVolume *pMotherLogical,
              G4bool pMany,
              G4int pCopyNo);
```

- Single volume positioned relatively to the mother volume
  - In a frame rotated and translated relative to the coordinate system of the mother volume
- Three additional constructors:
  - Using **G4Transform3D** instead of rotation matrix and transformation vector to represent the direct rotation and translation of the daughter solid instead of the mother frame
  - A simple variation: specifying the mother volume as a pointer to its physics volume instead of its logical volume.
  - The combination of the two variants above

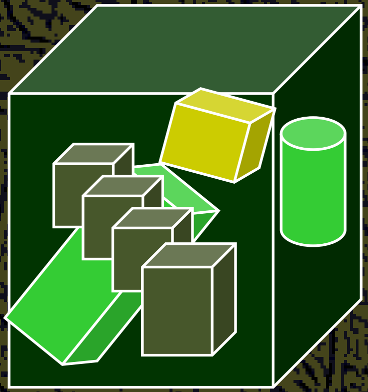
G4PVParameterised

```
G4PVParameterised(const G4String& pName,
                  G4LogicalVolume* pLogical,
                  G4LogicalVolume* pMother,
                  const EAxis pAxis,
                  const G4int nReplicas,
                  G4VPVParameterisation *pParam);
```

- Replicates the volume **`nReplicas`** times using the paramaterisation **`pParam`**, within the mother volume **`pMother`**
- **`pAxis`** is a suggestion to the navigator along which Cartesian axis replication of parameterized volumes dominates
- As mentioned previously, G4PVParameterised is a kind of G4VPhysicalVolume.
  - By one single object, this object represents many volumes as a function of copy number.

Parameterised Physical Volumes

- User should implement a class derived from G4VPVParameterisation abstract base class and define followings as a function of copy number
  - the size of the solid (dimensions)
  - where it is positioned (transformation, rotation)
- Optional:
  - the type of the solid
  - the material
- Limitations:
  - Applies to simple CSG solids only
  - Granddaughter volumes allowed only for special cases
  - Consider parameterised volumes as “leaf” volumes
- Typical use-cases
  - Complex detectors
    - with large repetition of volumes, regular or irregular
  - Medical applications
    - the material in animal tissue is measuredas cubes with varying material



G4PVParameterized : example

```
G4VSolid* solidChamber =
   new G4Box("chamber", 100*cm, 100*cm, 10*cm);
G4LogicalVolume* logicChamber =
   new G4LogicalVolume
   (solidChamber, ChamberMater, "Chamber", 0, 0, 0);
G4VPVParameterisation* chamberParam =
   new ChamberParameterisation();
G4VPhysicalVolume* physChamber =
   new G4PVParameterised("Chamber", logicChamber,
        logicMother, kZAxis, NbOfChambers,
        chamberParam);
```

G4VPVParameterisation : example

```
class ChamberParameterisation
: public G4VPVParameterisation
{
  public:
    ChamberParameterisation();
   ~ChamberParameterisation();
   void ComputeTransformation
     (const G4int copyNo,G4VPhysicalVolume* physVol)
      const;
   void ComputeDimensions
     (G4Box& trackerLayer, const G4int copyNo,
      const G4VPhysicalVolume* physVol) const;
   …
}
```

G4VPVParameterisation : example

```
void ChamberParameterisation::ComputeTransformation
(const G4int copyNo, G4VPhysicalVolume* physVol) const
{
  G4double Xposition = … // w.r.t. copyNo
  G4ThreeVector origin(Xposition,Yposition,Zposition);
  physVol->SetTranslation(origin);
  physVol->SetRotation(0);
}

void ChamberParameterisation::ComputeDimensions
(G4Box& trackerChamber, const G4int copyNo,
 const G4VPhysicalVolume* physVol) const
{
  G4double XhalfLength = … // w.r.t. copyNo
  trackerChamber.SetXHalfLength(XhalfLength);
  trackerChamber.SetYHalfLength(YhalfLength);
  trackerChamber.SetZHalfLength(ZHalfLength);
}
```

Replicated Physical Volumes

- The mother volume is completely filled with replicas, all of the same size and shape.
- As mentioned previously, G4PVReplica is a kind of G4VPhysicalVolume.
  - By one single object, this object represents many volumes as a function of copy number.
- Replication may occur along:
  - Cartesian axes (X, Y, Z) – slices are considered perpendicular to the axis of replication
    - Coordinate system at the center of each replica
  - Radial axis (Rho) – cons/tubs sections centered on the origin and un-rotated
    - Coordinate system same as the mother
  - Phi axis (Phi) – phi sections or wedges, of cons/tubs form
    - Coordinate system rotated such as that the X axis bisects the angle made by each wedge

a daughter logical volume to be replicated

mother volume

G4PVReplica

```
G4PVReplica(const G4String &pName,
            G4LogicalVolume *pLogical,
            G4LogicalVolume *pMother,
            const EAxis pAxis,
            const G4int nReplicas,
            const G4double width,
            const G4double offset=0);
```

- `offset` may be used only for tube/cone segment
- Features and restrictions:
  - Replicas can be placed inside other replicas
  - Normal placement volumes can be placed inside replicas, assuming no intersection/overlaps with the mother volume or with other replicas
  - No volume can be placed inside a radial replication
  - Parameterised volumes cannot be placed inside a replica

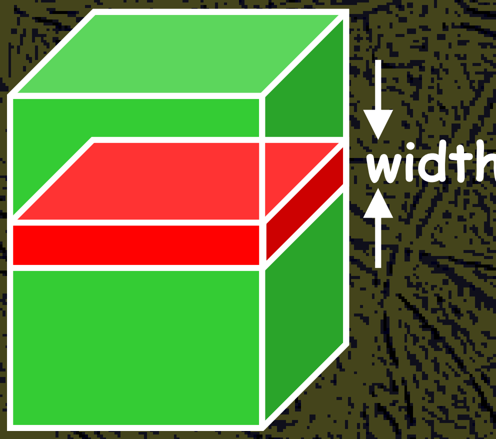
Replica - axis, width, offset

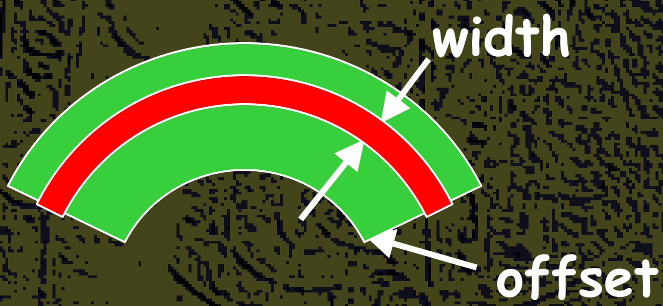
- Cartesian axes - **`kXaxis, kYaxis, kZaxis`**
  - offset shall not be used
  - Center of n-th daughter is given as

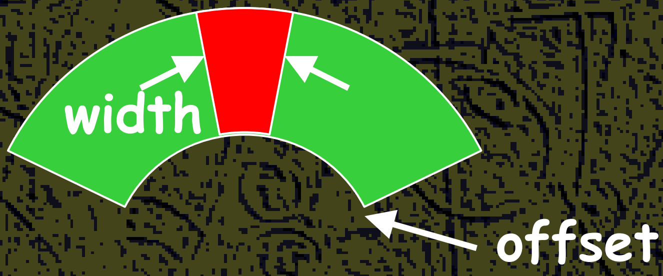
    `-width*(nReplicas-1)*0.5+n*width`
- Radial axis - **`kRaxis`**
  - Center of n-th daughter is given as

    `width*(n+0.5)+offset`
- Phi axis - **`kPhi`**
  - Center of n-th daughter is given as

    `width*(n+0.5)+offset`

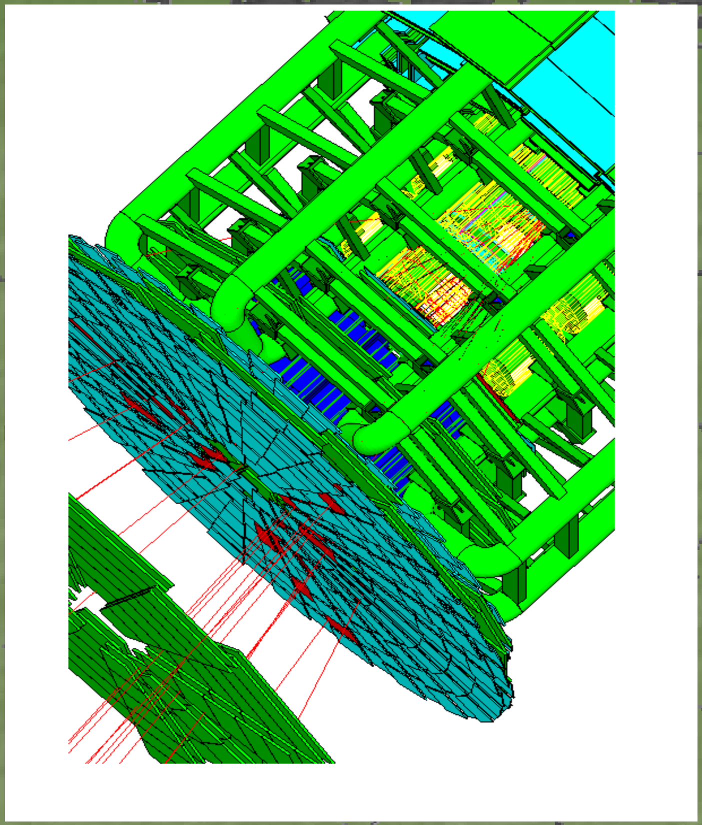






G4PVReplica : example

```
G4double tube_dPhi = 2.* M_PI * rad;
G4VSolid* tube =
   new G4Tubs("tube",20*cm,50*cm,30*cm,0.,tube_dPhi);
G4LogicalVolume * tube_log =
   new G4LogicalVolume(tube, Ar, "tubeL", 0, 0, 0);
G4VPhysicalVolume* tube_phys =
   new G4PVPlacement(0,G4ThreeVector(-200.*cm,0.,0.),
            "tubeP", tube_log, world_phys, false, 0);
G4double divided_tube_dPhi = tube_dPhi/6.;
G4VSolid* div_tube =
   new G4Tubs("div_tube", 20*cm, 50*cm, 30*cm,
        -divided_tube_dPhi/2., divided_tube_dPhi);
G4LogicalVolume* div_tube_log =
   new G4LogicalVolume(div_tube,Ar,"div_tubeL",0,0,0);
G4VPhysicalVolume* div_tube_phys =
   new G4PVReplica("div_tube_phys", div_tube_log,
   tube_log, kPhi, 6, divided_tube_dPhi);
```

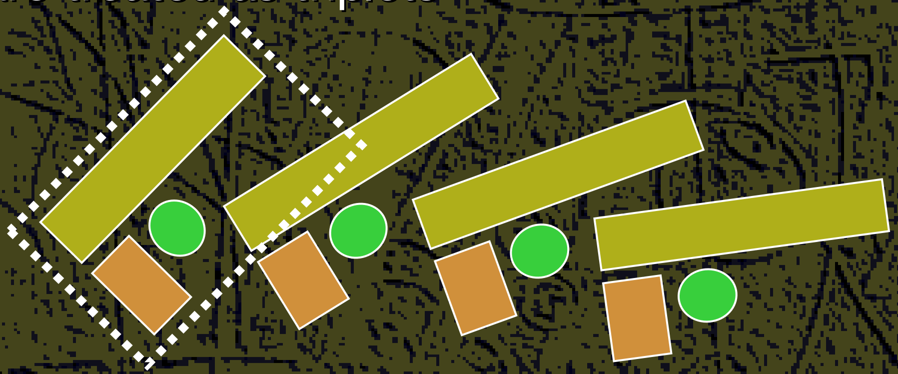


Defining a geometry advanced features

Geant 4

Grouping volumes

- To represent a regular pattern of positioned volumes, composing a more or less complex structure
  - structures which are hard to describe with simple replicas or parameterised volumes
  - structures which may consist of different shapes
  - Too densely positioned to utilize a mother volume
- Assembly volume
  - acts as an *envelope* for its daughter volumes
  - its role is over once its logical volume has been placed
  - daughter physical volumes become independent copies in the final structure
- Participating daughter logical volumes are treated as triplets
  - logical volume
  - translation w.r.t. envelop
  - rotation w.r.t. envelop



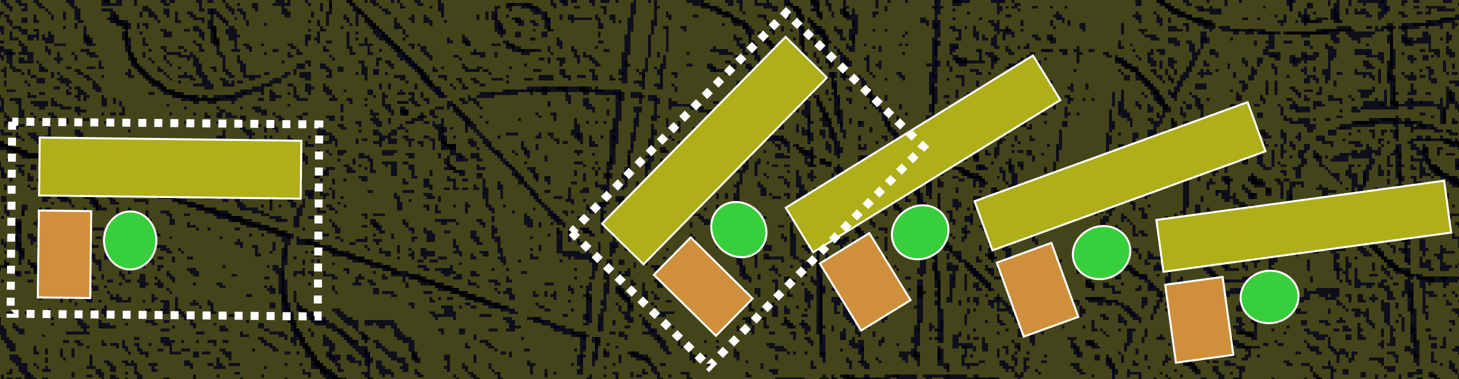
G4AssemblyVolume

```
G4AssemblyVolume::AddPlacedVolume
                   ( G4LogicalVolume* volume,
                     G4ThreeVector& translation,
                     G4RotationMatrix* rotation );
```

- Helper class to combine daughter logical volumes in arbitrary way
  - Imprints of the assembly volume are made inside a mother logical volume through **`G4AssemblyVolume::MakeImprint(…)`**
  - Each physical volume name is generated automatically
    - Format: **`av`**`_WWW_`**`impr`**`_XXX_YYY_ZZZ`
      - **`WWW`** – assembly volume instance number
      - **`XXX`** – assembly volume imprint number
      - **`YYY`** – name of the placed logical volume in the assembly
      - **`ZZZ`** – index of the associated logical volume
  - Generated physical volumes (and related transformations) are automatically managed (creation and destruction)

G4AssemblyVolume : example

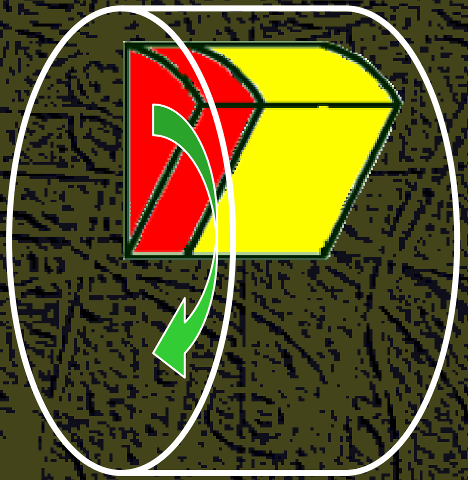
```
G4AssemblyVolume* assembly = new G4AssemblyVolume();
G4RotationMatrix Ra;
G4ThreeVector Ta;
Ta.setX(…); Ta.setY(…); Ta.setZ(…);
assembly->AddPlacedVolume( plateLV, Ta, Ra );
  … // repeat placement for each daughter

for( unsigned int i = 0; i < layers; i++ ) {
  G4RotationMatrix Rm(…);
  G4ThreeVector Tm(…);
  assembly->MakeImprint( worldLV, Tm, Rm );
}
```



Reflecting solids

- Let's take an example of a pair of endcap calorimeters.
  - They are mirror symmetric to each other.
- Such geometry cannot be made by parallel transformation

  or 180 degree rotation



- G4ReflectedSolid (derived from G4VSolid)
  - Utility class representing a solid shifted from its original reference frame to a new mirror symmetric one
  - The reflection (G4Reflect[X/Y/Z]3D) is applied as a decomposition into rotation and translation
- G4ReflectionFactory
  - Singleton object using G4ReflectedSolid for generating placements of reflected volumes
- Reflections are currently limited to simple CSG solids
  - will be extended soon to all solids

Reflecting hierarchies of volumes - 1

```
G4PhysicalVolumesPair G4ReflectionFactory::Place
 (const G4Transform3D& transform3D, // the transformation
  const G4String&   name,             // the name
  G4LogicalVolume* LV,                // the logical volume
  G4LogicalVolume* motherLV,          // the mother volume
  G4bool            noBool,           // currently unused
  G4int             copyNo)         // optional copy number
```

- Used for normal placements:
  1. Performs the transformation decomposition
  2. Generates a new reflected solid and logical volume
     - Retrieves it from a map if the reflected object is already created
  3. Transforms any daughter and places them in the given mother
  4. Returns a pair of physical volumes, the second being a placement in the reflected mother
- **G4PhysicalVolumesPair** is **std::map<G4VPhysicalVolume*,G4VPhysicalVolume*>**

Reflecting hierarchies of volumes - 2

```
G4PhysicalVolumesPair G4ReflectionFactory::Replicate
  (const G4String&  name,       // the actual name
   G4LogicalVolume* LV,         // the logical volume
   G4LogicalVolume* motherLV,   // the mother volume
   Eaxis            axis        // axis of replication
   G4int            replicaNo   // number of replicas
   G4int            width,     // width of single replica
   G4int           offset=0)   // optional mother offset
```

- Creates replicas in the given mother volume
- Returns a pair of physical volumes, the second being a replica in the reflected mother

GGE (Graphical Geometry Editor)

- Implemented in JAVA, GGE is a graphical geometry editor compliant to Geant4. It allows to:
  - Describe a detector geometry including:
    - materials, solids, logical volumes, placements
  - Graphically visualize the detector geometry using a Geant4 supported visualization system
  - Store persistently the detector description
  - Generate the C++ code according to the Geant4 specifications
- GGE can be downloaded from Web as a separate tool:
  - **`http://erpc1.naruto-u.ac.jp/~geant4/`**

Defining a field

Geant4

Magnetic field (1)

- Create your Magnetic field class
  - Uniform field :
    - Use an object of the G4UniformMagField class

```
G4MagneticField* magField= new
   G4UniformMagField(G4ThreeVector(1.*Tesla,0.,0.);
```

  - Non-uniform field :
    - Create your own concrete class derived from G4MagneticField and implement **GetFieldvalue** method.

```
void MyField::GetFieldValue(
  const double Point[4], double *field) const
```

    - Point[0..2] are position, Point[3] is time
    - field[0..2] are returning magnetic field

Magnetic field (2)

- Tell Geant4 to use your field
  1. Find the global Field Manager

```
G4FieldManager* globalFieldMgr =
   G4TransportationManager::GetTransportationManager()
     ->GetFieldManager();
```

  2. Set the field for this FieldManager,

```
globalFieldMgr->SetDetectorField(magField);
```

  3. and create a Chord Finder.

```
globalFieldMgr->CreateChordFinder(magField);
```

- /example/novice/N04/ExN04 is a good starting point

Global and local fields

- One field manager is associated with the 'world' and it is set in G4TransportationManager
- Other volumes can override this
  - An alternative field manager can be associated with any logical volume
    - Currently the field must accept position global coordinates and return field in global coordinates
  - By default this is propagated to all its daughter volumes

```
G4FieldManager* localFieldMgr
      = new G4FieldManager(magField);
logVolume->setFieldManager(localFieldMgr, true);
```

where '**`true`**' makes it push the field to all the volumes it contains.

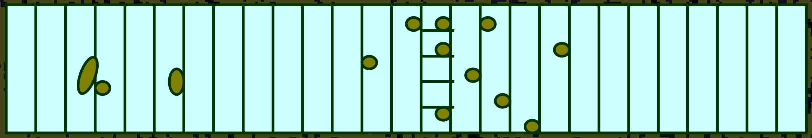
- Customizing the field propagation classes
  - Choosing an appropriate stepper for your field
  - Setting precision parameters

Geometry optimization ("voxelization")

Geant4

Smart voxelization

- In case of Geant 3.21, the user had to carefully implement his/her geometry to maximize the performance of geometrical navigation.
- While in Geant4, user's geometry is automatically optimized to most suitable to the navigation. - "Voxelization"
  - For each mother volume, one-dimensional virtual division is performed.
  - Subdivisions (slices) containing same volumes are gathered into one.
  - Additional division again using second and/or third Cartesian axes, if needed.
- *"Smart voxels"* are computed at initialisation time
  - When the detector geometry is *closed*
  - Does not require large memory or computing resources
  - At tracking time, searching is done in a hierarchy of virtual divisions



Detector description tuning

- Some geometry topologies may require ‘special’ tuning for ideal and efficient optimisation
  - for example: a dense nucleus of volumes included in very large mother volume
- Granularity of voxelisation can be explicitly set
  - Methods **`Set/GetSmartless()`** from **`G4LogicalVolume`**
- Critical regions for optimisation can be detected
  - Helper class **`G4SmartVoxelStat`** for monitoring time spent in detector geometry optimisation
    - Automatically activated if **`/run/verbose`** greater than 1

```
Percent     Memory    Heads    Nodes   Pointers    Total CPU    Volume
-------     ------    -----    -----   --------    ---------    -----------
  91.70         1k        1       50         50         0.00    Calorimeter
   8.30         0k        1        3          4         0.00    Layer
```

Visualising voxel structure

- The computed voxel structure can be visualized with the final detector geometry
  - Helper class **`G4DrawVoxels`**
  - Visualize voxels given a logical volume

    `G4DrawVoxels::DrawVoxels(const G4LogicalVolume*)`
  - Allows setting of visualization attributes for voxels

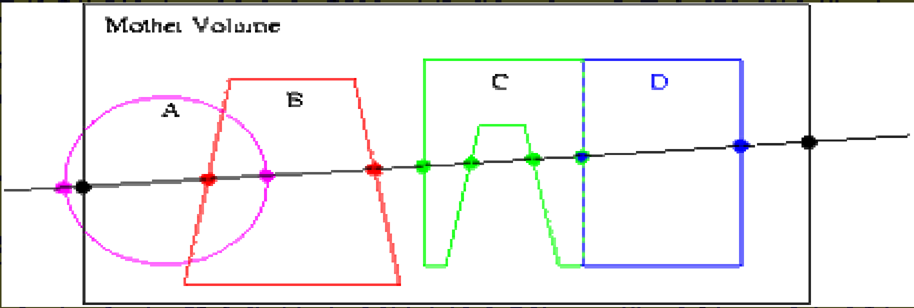
    `G4DrawVoxels::SetVoxelsVisAttributes(…)`
  - useful for debugging purposes

Geometry checking tools

Geant 4

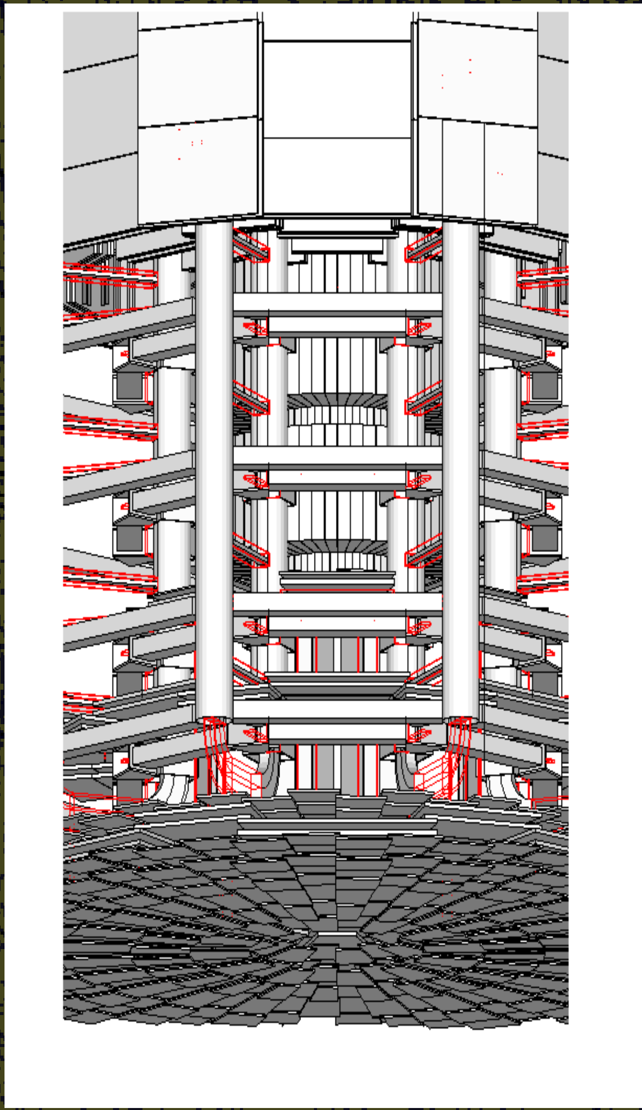
Debugging geometries

- An *overlapping* volume is a contained volume which actually protrudes from its mother volume
  - Volumes are also often positioned in a same volume with the intent of not provoking intersections between themselves. When volumes in a common mother actually intersect themselves are defined as overlapping
- Geant4 does not allow for malformed geometries
- The problem of detecting overlaps between volumes is bounded by the complexity of the solid models description
- Utilities are provided for detecting wrong positioning
  - Graphical tools (DAVID, OLAP)
  - Kernel run-time commands



Debugging tools: DAVID

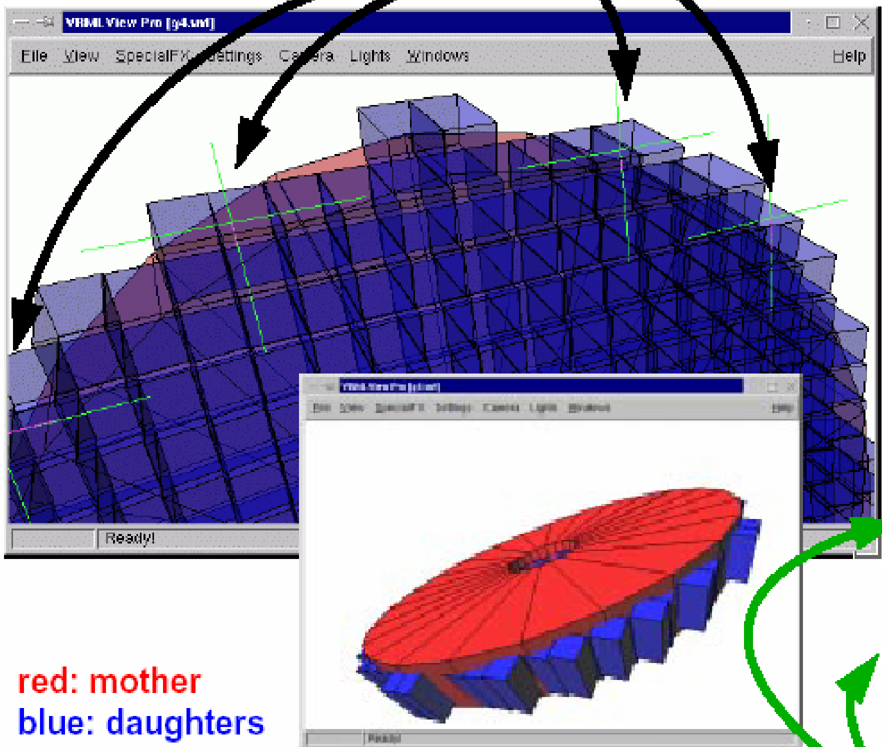
- DAVID is a graphical debugging tool for detecting potential intersections of volumes
- Accuracy of the graphical representation can be tuned to the exact geometrical description.
  - physical-volume surfaces are automatically decomposed into 3D polygons
  - intersections of the generated polygons are parsed.
  - If a polygon intersects with another one, the physical volumes associated to these polygons are highlighted in color (red is the default).
- DAVID can be downloaded from the Web as external tool for Geant4
  - http://arkoop2.kek.jp/~tanaka/DAWN/About_DAVID.html



Debugging tools: OLAP

- Stand-alone batch application
  - Provided as extended example
  - Can be combined with a graphical environment and GUI

graphical indication of detected overlaps



red: mother
blue: daughters

daughters are protruding their mother

Geant4 Macro:

```
/vis/scene/create
/vis/sceneHandler/create VRML2FILE
/vis/viewer/create
/olap/goto ECalEnd
/olap/grid 7 7 7
/olap/trigger
/vis/viewer/update
```

Output:

```
delta=59.3416
vol 1: point=(560.513,1503.21,-141.4)
vol 2: point=(560.513,1443.86,-141.4)
A -> B:
[0]:   ins=[2]   PVName=[NewWorld:0]  Type=[N] ...
[1]:   ins=[0]   PVName=[ECalEndcap:0]  Type=[N] ..
[2]:   ins=[1]   PVName=[ECalEndcap07:38]  Type=[N]

B -> A:
[0]:   ins=[2]   PVName=[NewWorld:0]  Type=[N] ...
```

NavigationHistories of points of overlap
(including: info about translation, rotation, solid specs)

Debugging run-time commands

- Built-in run-time commands to activate verification tests for the user geometry are defined

  geometry/test/run or **geometry/test/grid_test**
- to start verification of geometry for overlapping regions based on a standard grid setup, limited to the first depth level

  geometry/test/recursive_test
- applies the grid test to all depth levels (may require lots of CPU time!)

  geometry/test/cylinder_test
- shoots lines according to a cylindrical pattern

  geometry/test/line_test
- to shoot a line along a specified direction and position

  geometry/test/position
- to specify position for the **line_test**

  geometry/test/direction
- to specify direction for the **line_test**

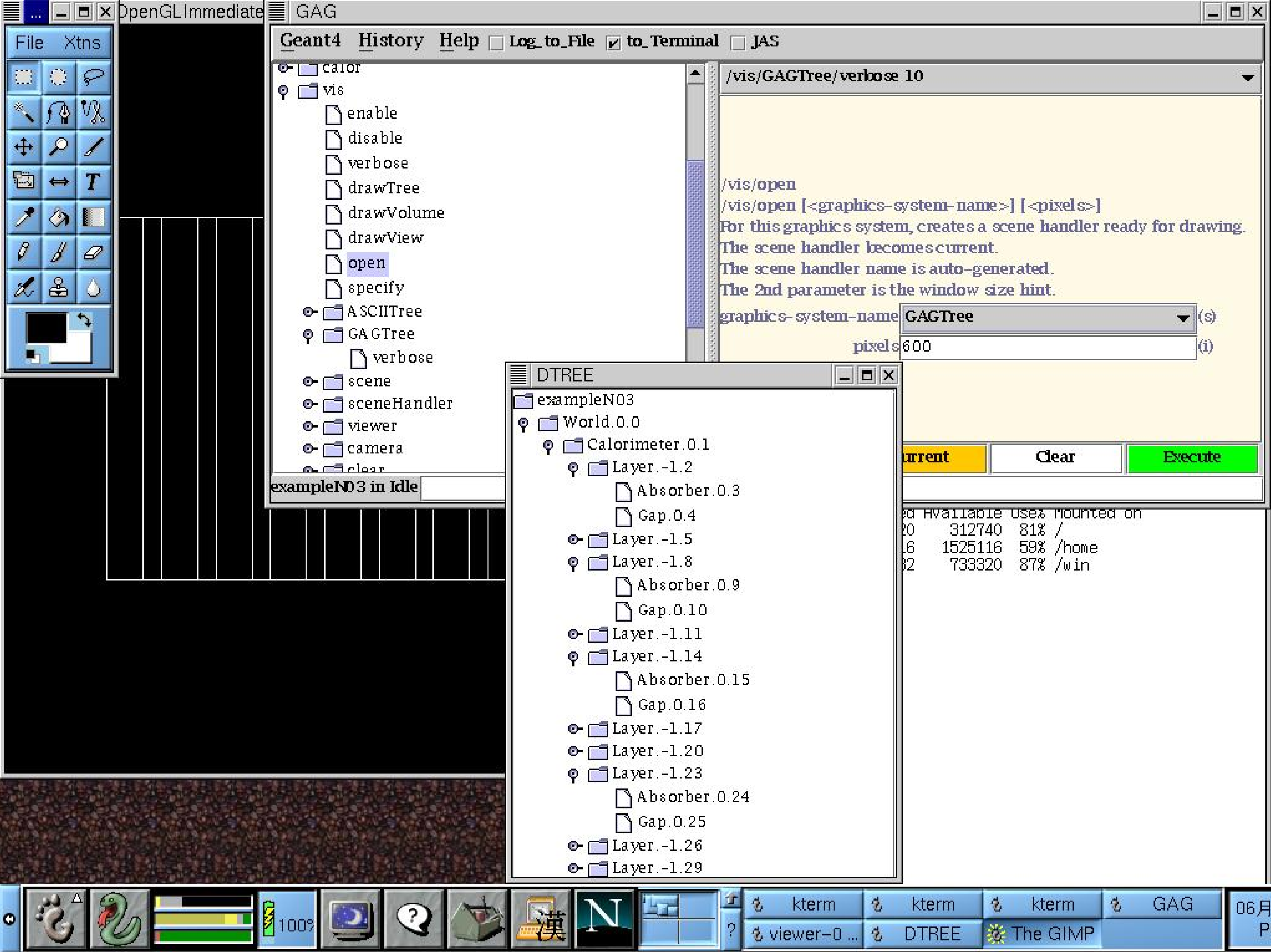
Debugging run-time commands

- Example layout:

```
GeomTest: no daughter volume extending outside mother detected.
GeomTest Error: Overlapping daughter volumes
    The volumes Tracker[0] and Overlap[0],
    both daughters of volume World[0],
    appear to overlap at the following points in global coordinates: (list
   truncated)
  length (cm)    ----- start position (cm) -----  ----- end position (cm) -----
    240           -240      -145.5      -145.5     0         -145.5      -145.5
Which in the mother coordinate system are:
  length (cm)    ----- start position (cm) -----  ----- end position (cm) -----
    . . .
Which in the coordinate system of Tracker[0] are:
  length (cm)    ----- start position (cm) -----  ----- end position (cm) -----
    . . .
Which in the coordinate system of Overlap[0] are:
  length (cm)    ----- start position (cm) -----  ----- end position (cm) -----
    . . .
```

Visualizing detector geometry tree

- Built-in commands defined to display the hierarchical geometry tree
  - As simple ASCII text structure
  - Graphical through GUI (combined with GAG)
  - As XML exportable format
- Implemented in the visualization module
  - As an additional graphics driver
- G3 DTREE capabilities provided and more



OpenGLImmediate
File Xtns
GAG
Geant4 History Help Log_to_File to_Terminal JAS
calor
vis
enable
disable
verbose
drawTree
drawVolume
drawView
open
specify
ASCIITree
GAGTree
verbose
scene
sceneHandler
viewer
camera
clear
exampleN03 in Idle
/vis/GAGTree/verbose 10
/vis/open
/vis/open [<graphics-system-name>] [<pixels>]
For this graphics system, creates a scene handler ready for drawing.
The scene handler becomes current.
The scene handler name is auto-generated.
The 2nd parameter is the window size hint.
graphics-system-name GAGTree (s)
pixels 600 (i)
Clear
Execute
DTREE
exampleN03
World.0.0
Calorimeter.0.1
Layer.-1.2
Absorber.0.3
Gap.0.4
Layer.-1.5
Layer.-1.8
Absorber.0.9
Gap.0.10
Layer.-1.11
Layer.-1.14
Absorber.0.15
Gap.0.16
Layer.-1.17
Layer.-1.20
Layer.-1.23
Absorber.0.24
Gap.0.25
Layer.-1.26
Layer.-1.29
312740 81% /
1525116 59% /home
733320 87% /win
kterm
kterm
kterm
GAG
viewer-0 ...
DTREE
The GIMP