# Geant 4

## *Detector Description: Basics*

**http://cern.ch/geant4**

PART II

# Describing a detector - I

- *Detector geometry modeling*
- *The basic concepts: solids & volumes*

# Describe your detector

- Derive your own concrete class from `G4VUserDetectorConstruction` abstract base class.
- Implementing the method `Construct()`:
  - Modularize it according to each detector component or sub-detector:
    - Construct all necessary materials
    - Define shapes/solids required to describe the geometry
    - Construct and place volumes of your detector geometry
    - Define sensitive detectors and identify detector volumes which to associate them
    - Associate magnetic field to detector regions
    - Define visualization attributes for the detector elements

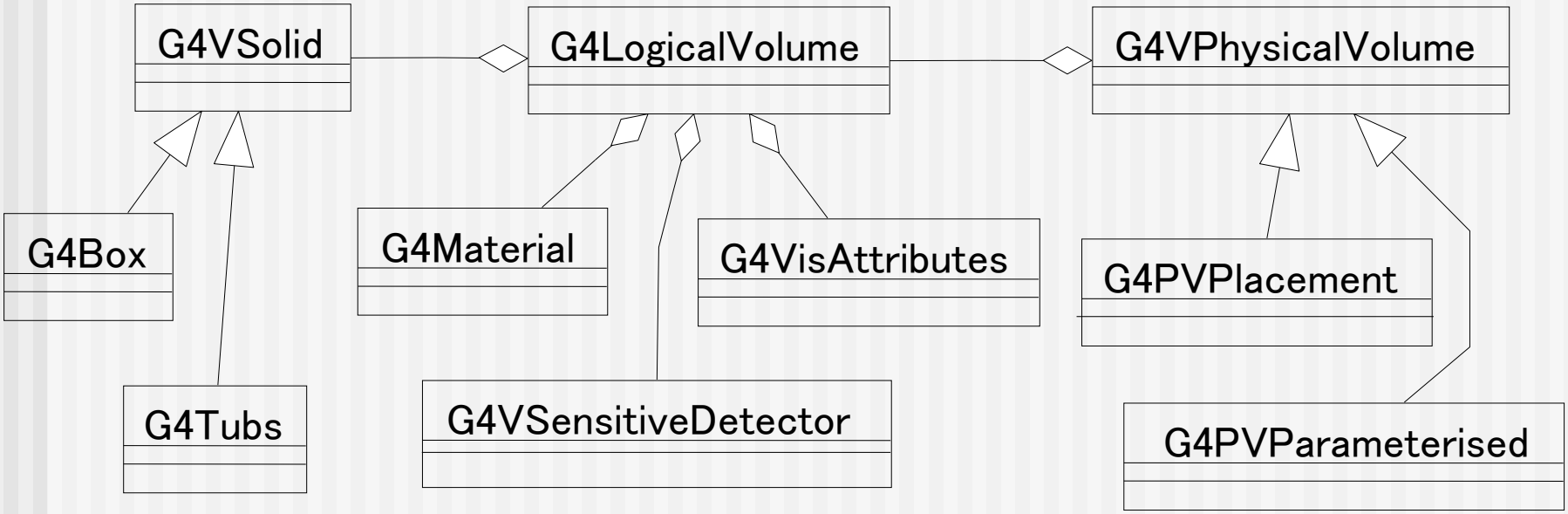
# Creating a Detector Volume

- Start with its Shape & Size
  - Box 3x5x7 cm, sphere R=8m
- Add properties:
  - material, B/E field,
  - make it sensitive
- Place it in another volume
  - in one place
  - repeatedly using a function

- *Solid*
- *Logical-Volume*
- *Physical-Volume*

# Define detector geometry

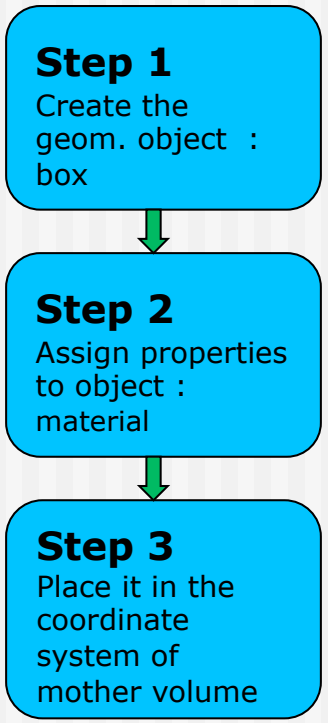
- Three conceptual layers
  - **G4VSolid** -- *shape, size*
  - **G4LogicalVolume** -- *daughter physical volumes, material, sensitivity, user limits, etc.*
  - **G4VPhysicalVolume** -- *position, rotation*



# 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

PART II

# Describing a detector - II

- *Logical and Physical Volumes*

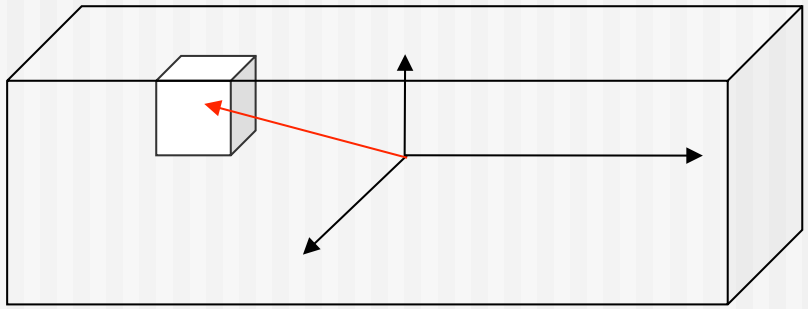
# G4LogicalVolume

```
G4LogicalVolume(G4VSolid* pSolid, G4Material* pMaterial,
                const G4String& name, G4FieldManager* pFieldMgr=0,
                G4VSensitiveDetector* pSDetector=0,
                G4UserLimits* pULimits=0,
                G4bool optimise=true);
```

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

# Geometrical hierarchy

- Mother and daughter volumes
  - A volume is placed in its mother volume
    - Position and rotation of the daughter volume is described with respect to the local coordinate system of the mother volume
    - The origin of the mother's local coordinate system is at the center of the mother volume
    - Daughter volumes cannot protrude from the mother volume
    - Daughter volumes cannot overlap
  - One or more volumes can be placed in a mother volume

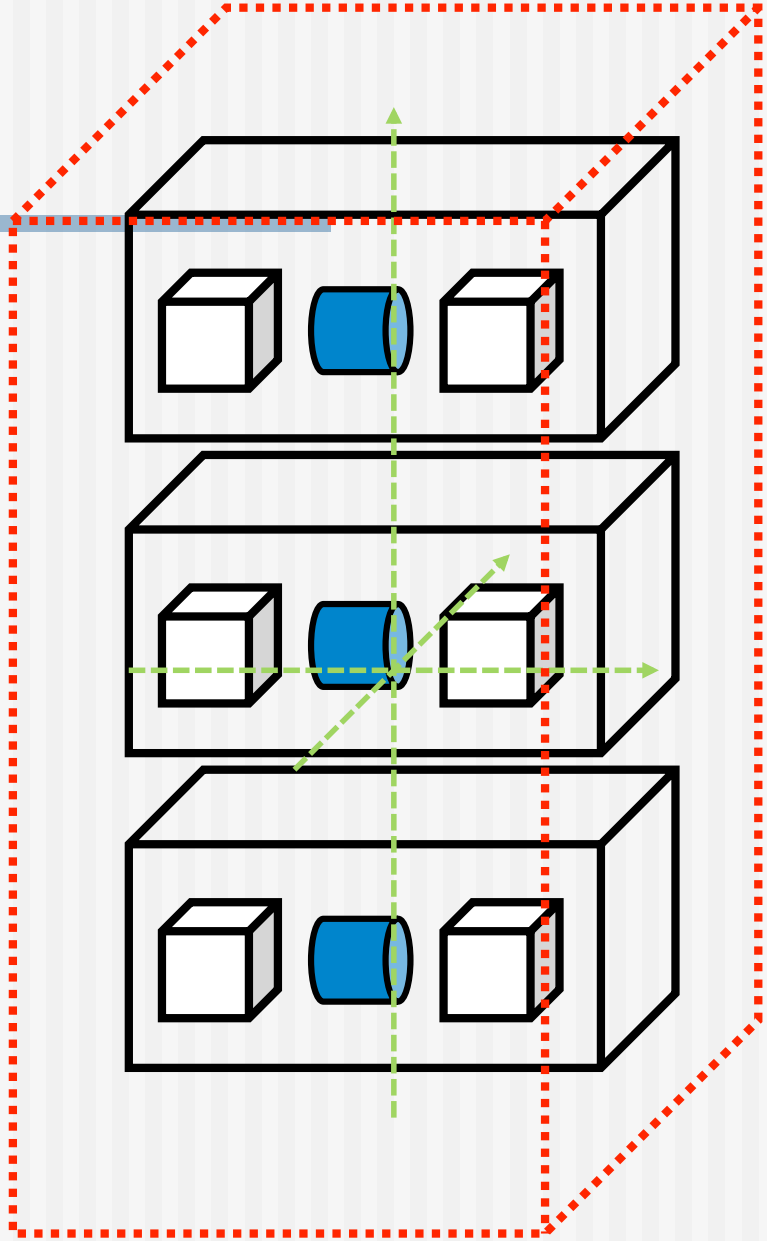


# Geometrical hierarchy

- Mother and daughter volumes (cont.)
  - The logical volume of mother knows the daughter volumes it contains
    - It is uniquely defined to be their mother volume
    - If the logical volume of the mother is placed more than once, all daughters appear by definition in all these physical instances of the mother
- World volume is the root volume of the hierarchy
  - The world volume must be a unique physical volume which **fully contains with some margin** all other volumes
    - The world defines the global coordinate system
    - The origin of the global coordinate system is at the center of the world volume
    - Should not share any surface with contained geometry

# Geometrical hierarchy

- One logical volume can be placed more than once. One or more volumes can be placed in a mother volume
- Note that the mother-daughter relationship is an information of **`G4LogicalVolume`**
  - If the mother volume is placed more than once, all daughters by definition appear in each placed physical volume
- The world volume must be a unique physical volume which fully contains with some margin all the other volumes
  - The world volume defines the global coordinate system. The origin of the global coordinate system is at the center of the world volume
  - Position of a track is given with respect to the global coordinate system

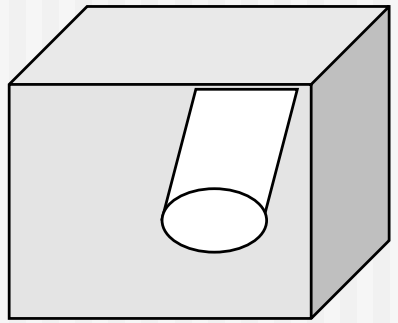


# G4VPhysicalVolume

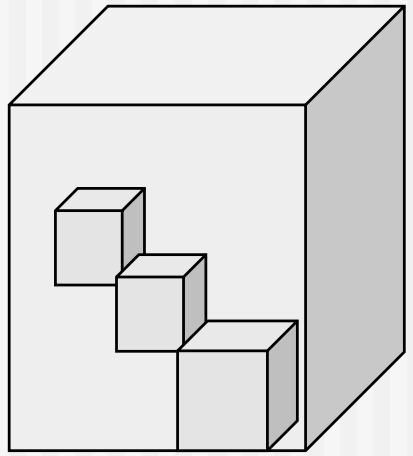
- G4PVPlacement — 1 Placement = One Volume
  - A volume instance positioned once in a mother volume
- G4PVParameterised — 1 Parameterised = Many Volumes
  - Parameterised by the copy number
    - Shape, size, material, position and rotation can be parameterised, by implementing a concrete class of **`G4VPVParameterisation`**.
  - Reduction of memory consumption
    - Currently: parameterisation can be used only for volumes that either a) have no further daughters or b) are identical in size & shape.
- G4PVReplica — 1 Replica = Many Volumes
  - Slicing a volume into smaller pieces (if it has a symmetry)

# Physical Volumes

- Placement: it is one positioned volume
- Repeated: a volume placed many times
  - can represent any number of volumes
  - reduces  use of memory.
  - Replica
    - simple repetition, similar to G3 divisions
  - Parameterised
- A **mother** volume can contain **either**
  - **many placement** volumes **OR**
  - **one repeated** volume



*placement*



*repeated*

# G4PVPlacement

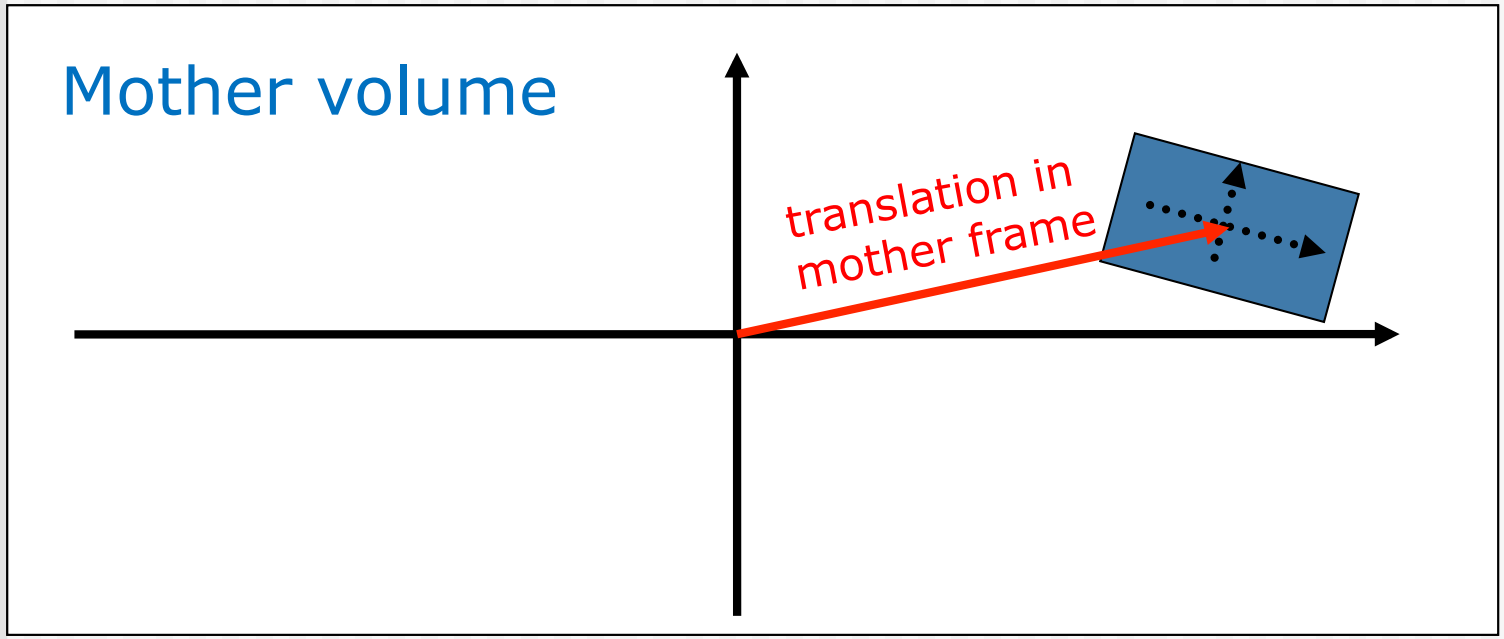
```
G4PVPlacement(G4RotationMatrix* pRot,      // rotation of mother frame
              const G4ThreeVector& tlate, // position in rotated frame
              G4LogicalVolume* pCurrentLogical,
              const G4String& pName,
              G4LogicalVolume* pMotherLogical,
              G4bool pMany,               // not used. Set it to false…
              G4int pCopyNo,              // unique arbitrary index
              G4bool pSurfChk=false);     // optional overlap check
```

- 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:
  - A simple variation: specifying the mother volume as a pointer to its physical volume instead of its logical volume.
  - Using `G4Transform3D` to represent the direct rotation and translation of the solid instead of the frame (*alternative ctor*)
  - The combination of the two variants above

# G4PVPlacement
## Rotation of mother frame …

```
G4PVPlacement(G4RotationMatrix* pRot,     // rotation of mother frame
              const G4ThreeVector& tlate, // position in mother frame
             G4LogicalVolume* pCurrentLogical,
              const G4String& pName,
              G4LogicalVolume* pMotherLogical,
              G4bool pMany,              // not used. Set it to false…
              G4int pCopyNo,             // unique arbitrary index
              G4bool pSurfChk=false ); // optional overlap check
```

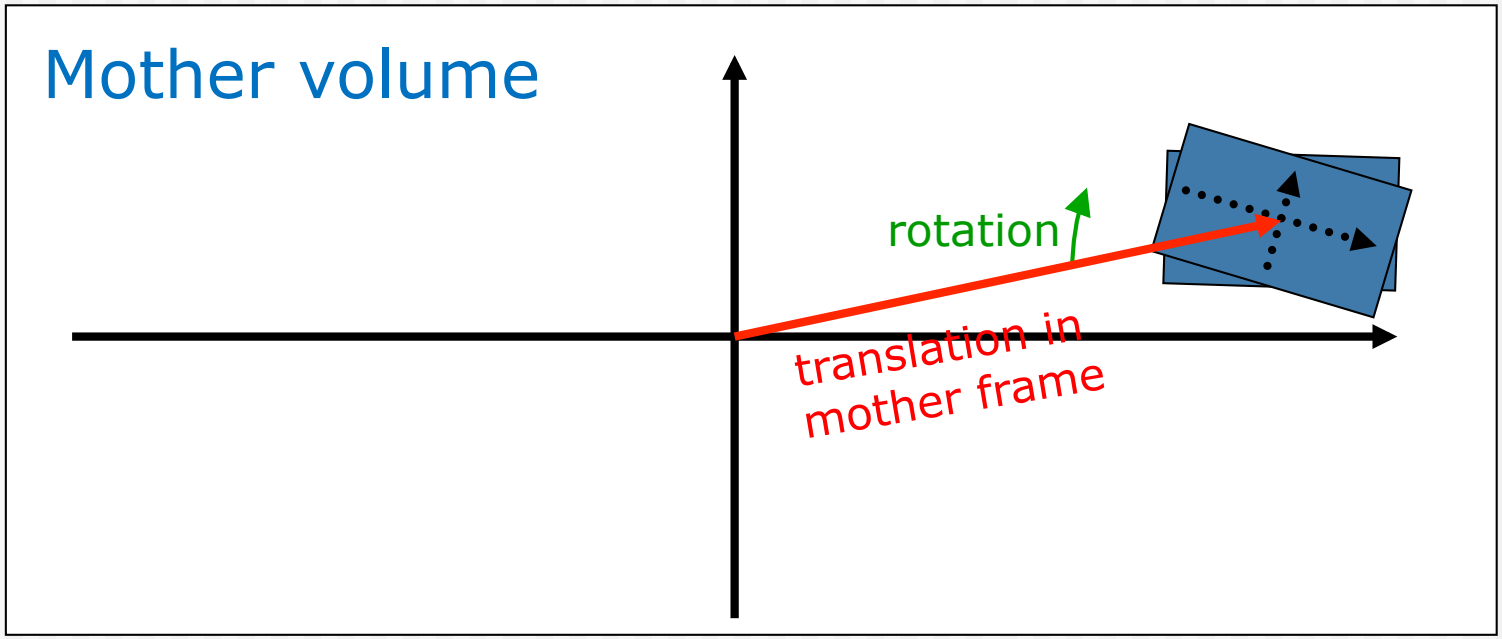
- Single volume positioned relatively to the mother volume



# G4PVPlacement

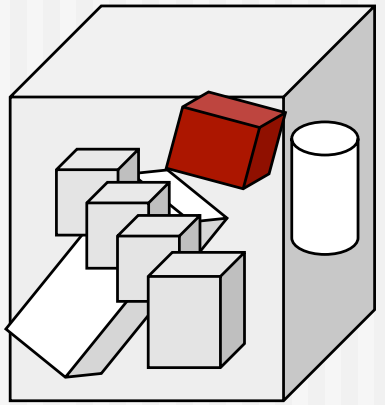
## Rotation in mother frame …

```
G4PVPlacement( G4Transform3D( G4RotationMatrix &pRot,      // rotation of daughter frame
                              const G4ThreeVector &tlate), // position in mother frame
               G4LogicalVolume *pDaughterLogical,
               const G4String &pName,
               G4LogicalVolume *pMotherLogical,
               G4bool pMany,              // not used, set it to false…
               G4int pCopyNo,             // unique arbitrary integer
               G4bool pSurfChk=false ); // optional overlap check
```



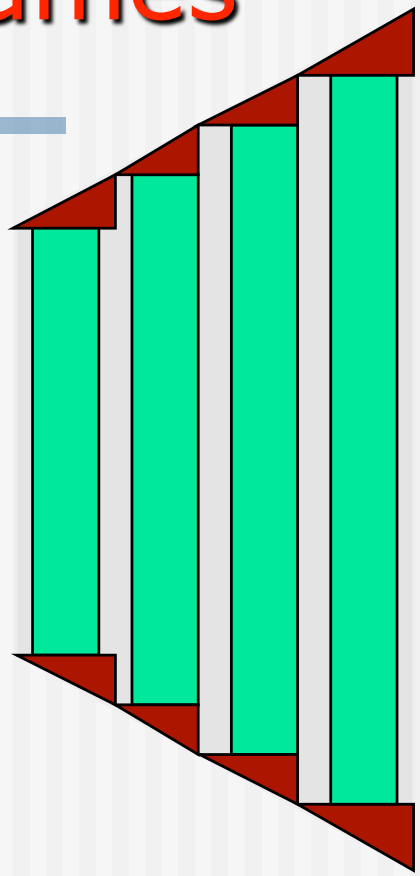
# Parameterised Physical Volumes

- User written functions define:
  - the size of the solid (dimensions)
    - Function **`ComputeDimensions(…)`**
  - where it is positioned (transformation)
    - Function **`ComputeTransformations(…)`**
- Optional:
  - the type of the solid
    - Function **`ComputeSolid(…)`**
  - the material
    - Function **`ComputeMaterial(…)`**
- Limitations:
  - Applies to a limited set of solids
  - Daughter volumes allowed only for special cases
- Very powerful
  - Consider parameterised volumes as “leaf” volumes



# Uses of Parameterised Volumes

- Complex detectors
  - with large repetition of volumes
    - regular or irregular
- Medical applications
  - the material in animal tissue is measured
    - cubes with varying material

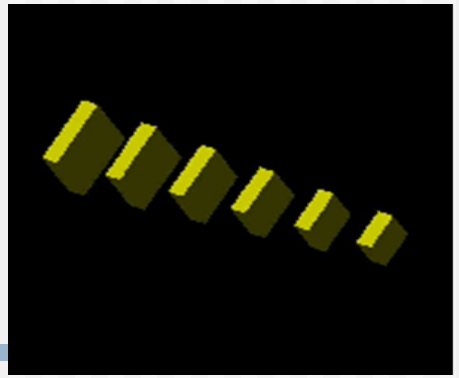


# G4PVParameterised

```
G4PVParameterised(const G4String& pName,
                  G4LogicalVolume* pCurrentLogical,
                  G4LogicalVolume* pMotherLogical,
                  const EAxis pAxis,
                  const G4int nReplicas,
                  G4VPVParameterisation* pParam,
                  G4bool pSurfChk=false);
```

- Replicates the volume `nReplicas` times using the parameterisation `pParam`, within the mother volume
- The positioning of the replicas is dominant along the specified Cartesian axis
  - If `kUndefined` is specified as axis, 3D voxelisation for optimisation of the geometry is adopted
- Represents many touchable detector elements differing in their positioning and dimensions. Both are calculated by means of a `G4VPVParameterisation` object
- Alternative constructor using pointer to physical volume for the mother

# Parameterisation
## example - 1



```
G4VSolid* solidChamber = new G4Box("chamber", 100*cm, 100*cm, 10*cm);
G4LogicalVolume* logicChamber =
   new G4LogicalVolume(solidChamber, ChamberMater, "Chamber", 0, 0, 0);
G4double firstPosition = -trackerSize + 0.5*ChamberWidth;
G4double firstLength = fTrackerLength/10;
G4double lastLength  = fTrackerLength;
G4VPVParameterisation* chamberParam =
   new ChamberParameterisation( NbOfChambers, firstPosition,
                                ChamberSpacing, ChamberWidth,
                                firstLength, lastLength);
G4VPhysicalVolume* physChamber =
   new G4PVParameterised( "Chamber", logicChamber, logicTracker,
                          kZAxis, NbOfChambers, chamberParam);
```

Use **kUndefined** for activating 3D voxelisation for optimisation

# Parameterisation
## example - 2

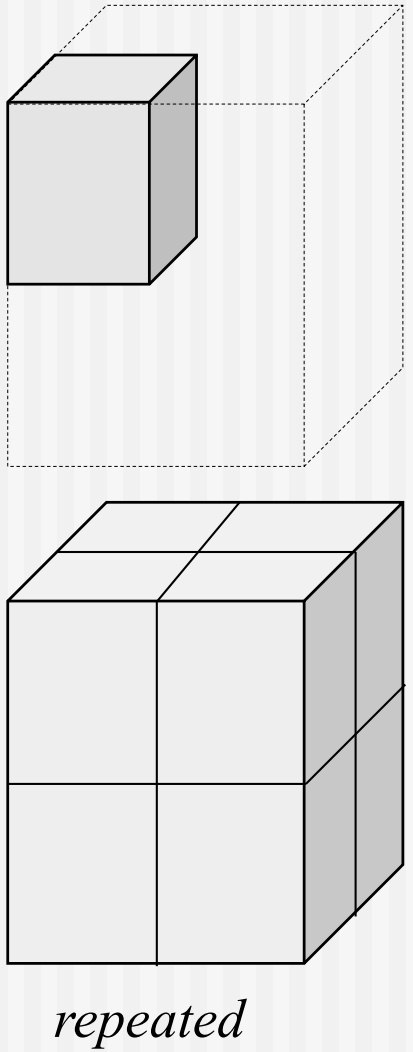
```
class ChamberParameterisation : public G4VPVParameterisation
{
  public:
    ChamberParameterisation( G4int NoChambers, G4double startZ,
                             G4double spacing, G4double widthChamber,
                             G4double lenInitial, G4double lenFinal );
   ~ChamberParameterisation();
   void ComputeTransformation (const G4int copyNo,
                               G4VPhysicalVolume* physVol) const;
   void ComputeDimensions (G4Box& trackerLayer, const G4int copyNo,
                           const G4VPhysicalVolume* physVol) const;
}
```

# Parameterisation
## example - 3

```
void ChamberParameterisation::ComputeTransformation
(const G4int copyNo, G4VPhysicalVolume* physVol) const
{
  G4double Zposition= fStartZ + (copyNo+1) * fSpacing;
  G4ThreeVector origin(0, 0, Zposition);
  physVol->SetTranslation(origin);
  physVol->SetRotation(0);
}
void ChamberParameterisation::ComputeDimensions
(G4Box& trackerChamber, const G4int copyNo,
 const G4VPhysicalVolume* physVol) const
{
  G4double  halfLength= fHalfLengthFirst + copyNo * fHalfLengthIncr;
  trackerChamber.SetXHalfLength(halfLength);
  trackerChamber.SetYHalfLength(halfLength);
  trackerChamber.SetZHalfLength(fHalfWidth);
}
```

# Replicated Physical Volumes

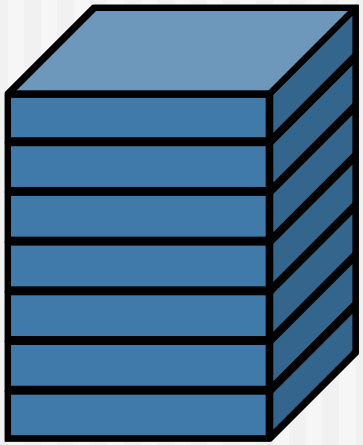
- The mother volume is sliced into replicas, all of the same size and dimensions.
- Represents many touchable detector elements differing only in their positioning.
- Replication may occur along:
  - Cartesian axes (X, Y, Z) – slices are considered perpendicular to the axis of replication
    - Coordinate 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



# G4PVReplica

*a daughter logical volume to be replicated*

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



*mother volume*

- Alternative constructor:
  - Using pointer to physical volume for the mother
- An `offset` can be associated
  - Only to a mother offset along the axis of replication
- 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

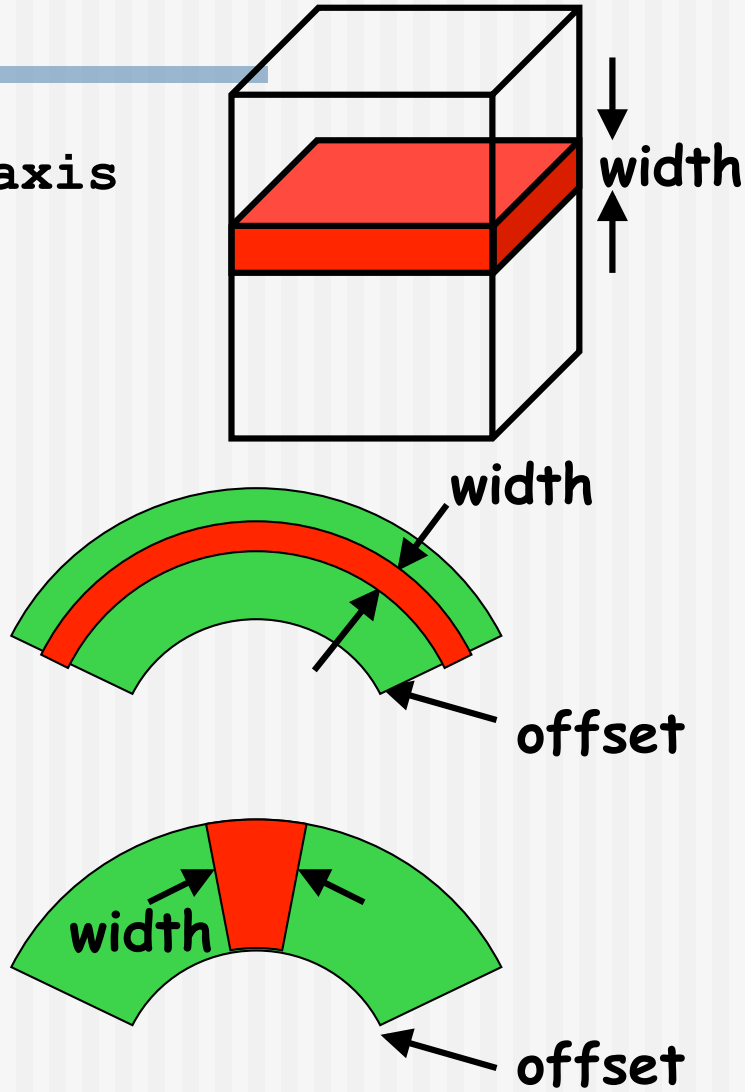
# Replica – axis, width, offset

- 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

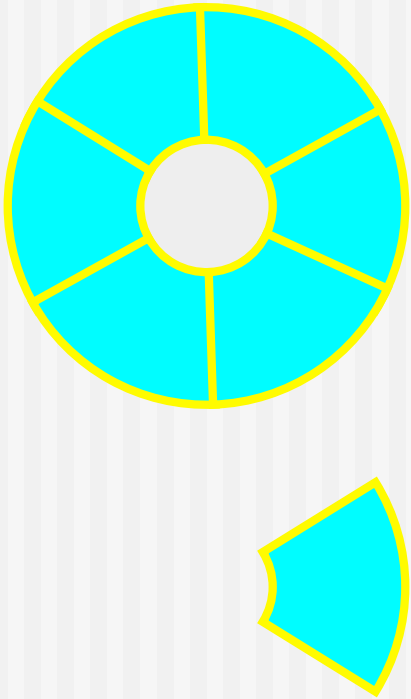
    **`width*(n+0.5)+offset`**
- Phi axis - **`kPhi`**
  - Center of n-th daughter is given as

    **`width*(n+0.5)+offset`**



# Replication
## 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, Air, "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,Pb,"div_tubeL",0,0,0);
G4VPhysicalVolume* div_tube_phys =
   new G4PVReplica("div_tube_phys", div_tube_log,
   tube_log, kPhi, 6, divided_tube_dPhi);
```

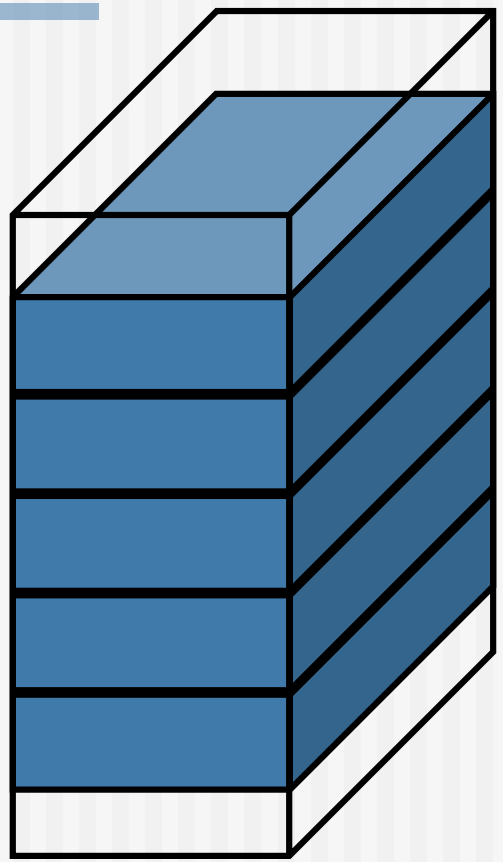


# Divided Physical Volumes

- Implemented as "special" kind of parameterised volumes
  - Applies to CSG-like solids only (box, tubs, cons, para, trd, polycone, polyhedra)
  - Divides a volume in identical copies along one of its axis (copies are not strictly identical)
    - e.g. - a tube divided along its radial axis
    - Offsets can be specified
- The possible axes of division vary according to the supported solid type
- Represents many touchable detector elements differing only in their positioning
- **`G4PVDivision`** is the class defining the division
  - The parameterisation is calculated automatically using the values provided in input

# Divided Volumes - 2

- **`G4PVDivision`** is a special kind of parameterised volume
  - The parameterisation is automatically generated according to the parameters given in **`G4PVDivision`**.
- Divided volumes are similar to replicas but …
  - Allowing for gaps in between mother and daughter volumes
    - *Planning to allow also gaps between daughters and gaps on side walls*
- Shape of all daughter volumes must be same shape as the mother volume
  - Solid (to be assigned to the daughter logical volume) must be the same type, but different object.
- Replication must be aligned along one axis
- If no gaps in the geometry, **`G4PVReplica`** is recommended
  - For identical geometry, navigation in pure replicas is faster



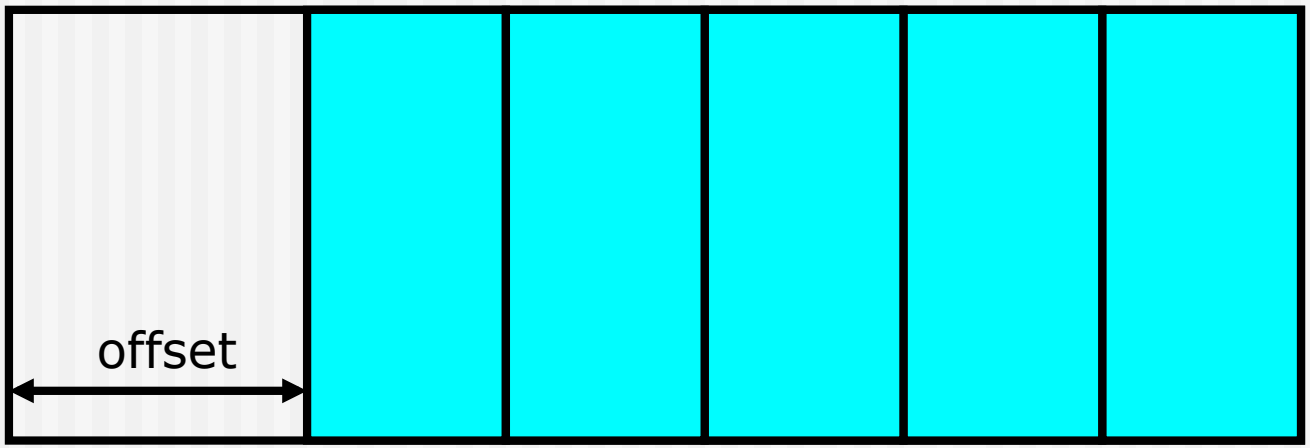
mother volume

# Divided Volumes - 3

```
G4PVDivision(const G4String& pName,
             G4LogicalVolume* pDaughterLogical,
             G4LogicalVolume* pMotherLogical,
             const EAxis pAxis,
             const G4int nDivisions,     // number of division is given
             const G4double offset);
```

- The size (width) of the daughter volume is calculated as

  `( (size of mother) - offset ) / nDivisions`



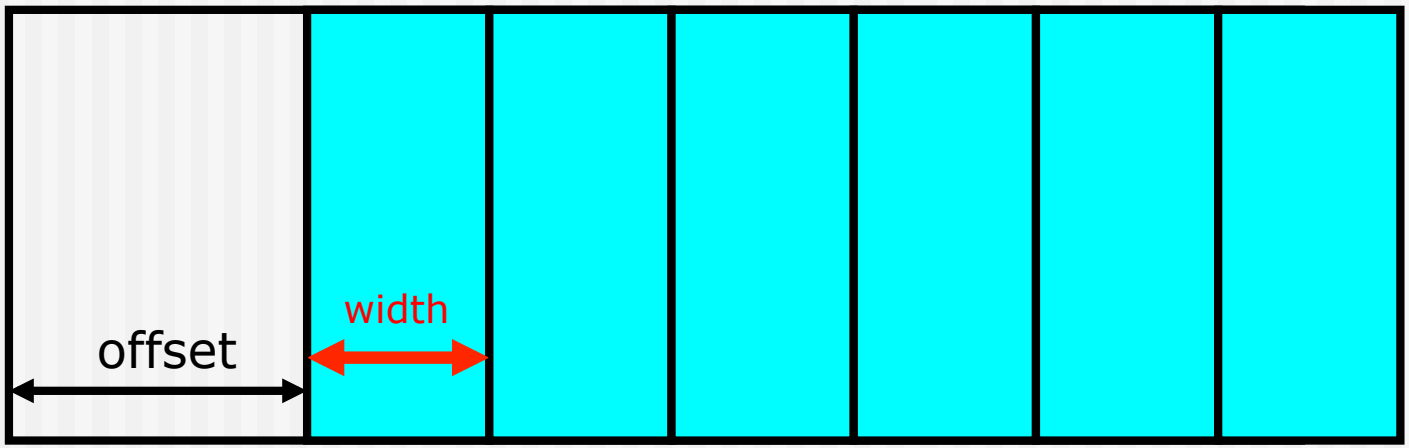
# Divided Volumes - 4

```
G4PVDivision(const G4String& pName,
             G4LogicalVolume* pDaughterLogical,
             G4LogicalVolume* pMotherLogical,
             const EAxis pAxis,
             const G4double width,   // width of daughter volume is given
             const G4double offset);
```

- The number of daughter volumes is calculated as

  `int( ( (size of mother) - offset ) / width )`

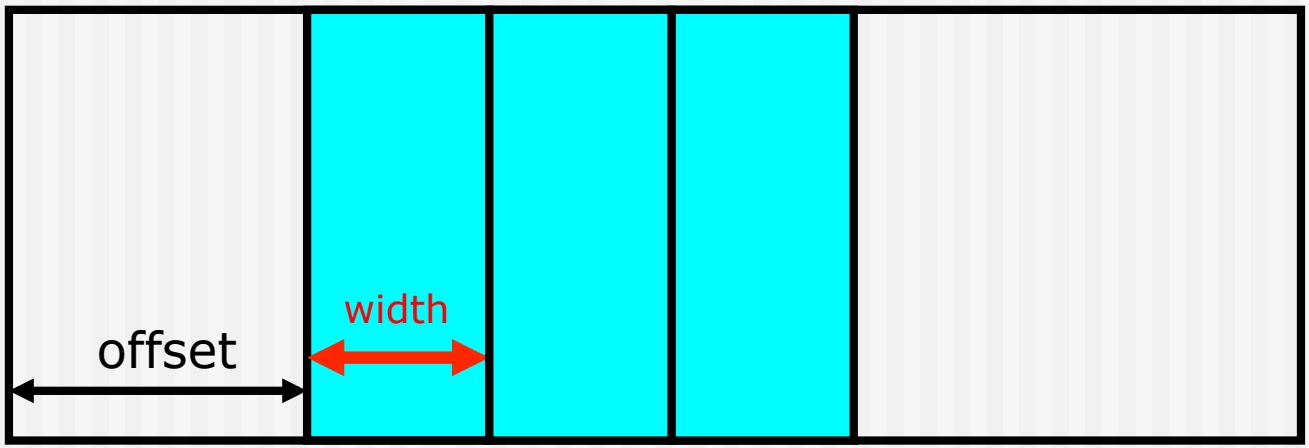
- As many daughters as width and offset allow



# Divided Volumes - 5

```
G4PVDivision(const G4String& pName,
             G4LogicalVolume* pDaughterLogical,
             G4LogicalVolume* pMotherLogical,
             const EAxis pAxis,
             const G4int nDivisions,  // both number of divisions
             const G4double width,    // and width are given
             const G4double offset);
```

- *nDivisions* daughters of *width* thickness



# Divided Volumes - 6

- Divisions are allowed for the following shapes / axes:
  - **`G4Box : kXAxis, kYAxis, kZAxis`**
  - **`G4Tubs : kRho, kPhi, kZAxis`**
  - **`G4Cons : kRho, kPhi, kZAxis`**
  - **`G4Trd : kXAxis, kYAxis, kZAxis`**
  - **`G4Para : kXAxis, kYAxis, kZAxis`**
  - **`G4Polycone : kRho, kPhi, kZAxis`**
  - **`G4Polyhedra : kRho, kPhi, kZAxis`**
    - **`kPhi`** - the number of divisions has to be the same as solid sides, (i.e. **`numSides`**), the width will not be taken into account
- In the case of division along **`kRho`** of **`G4Cons, G4Polycone, G4Polyhedra`**, if width is provided, it is taken as the width at the **`-z`** radius; the width at other radii will be scaled to this one

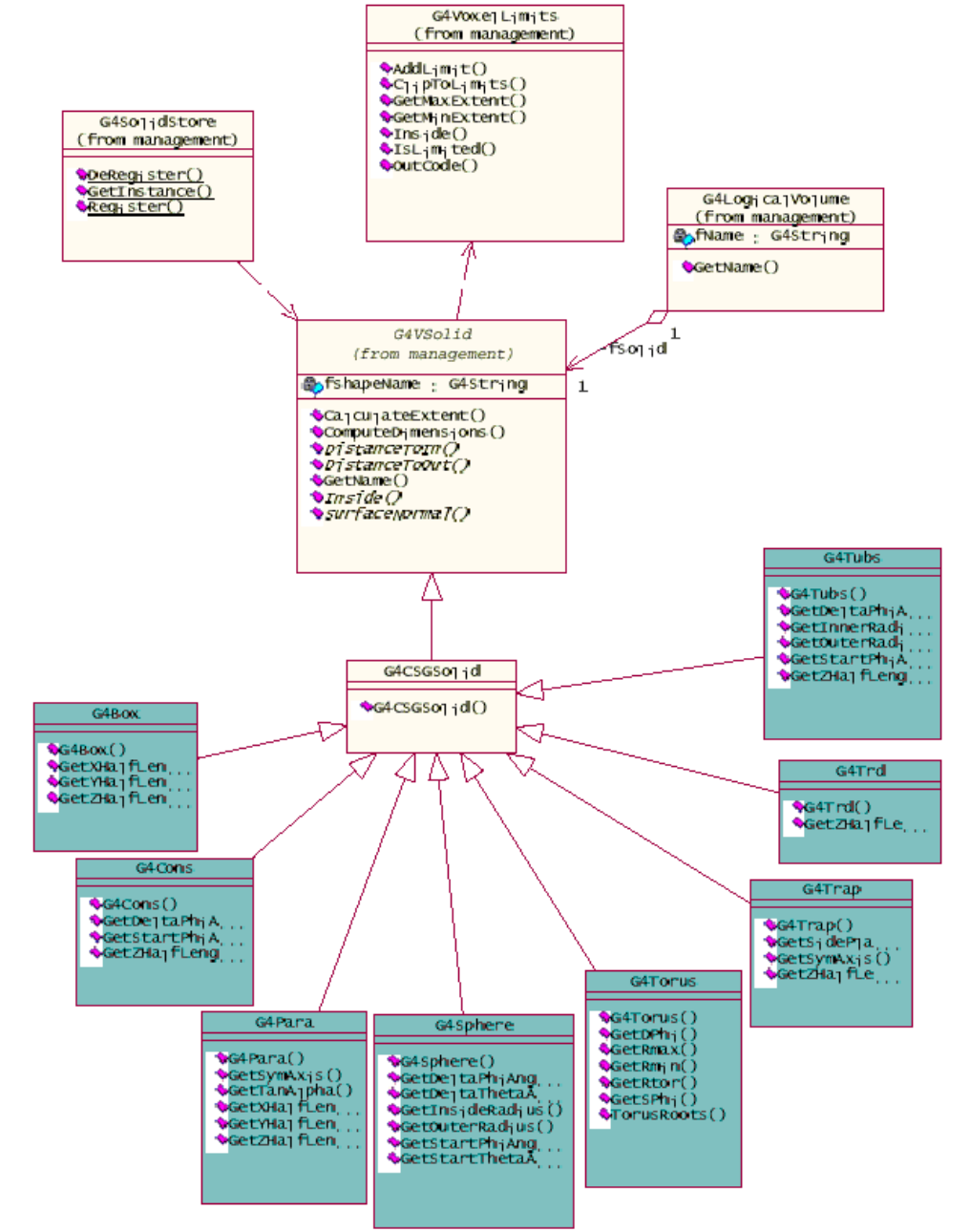
PART II

# Describing a detector - III

- *Solids & Touchables*

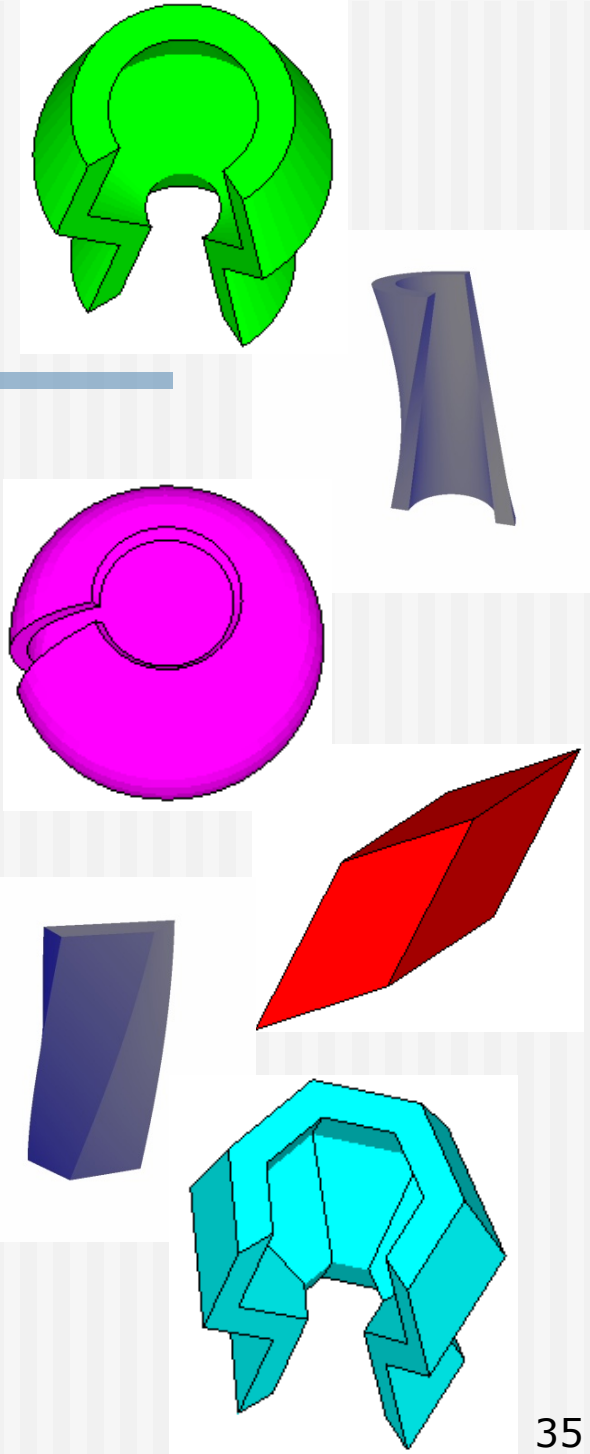
# G4VSolid

- Abstract class. All solids in Geant4 derive from it
  - Defines but does not implement all functions required to:
    - compute distances to/from the shape
    - 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
- Once constructed, each solid is automatically registered in a specific solid store



# Solids

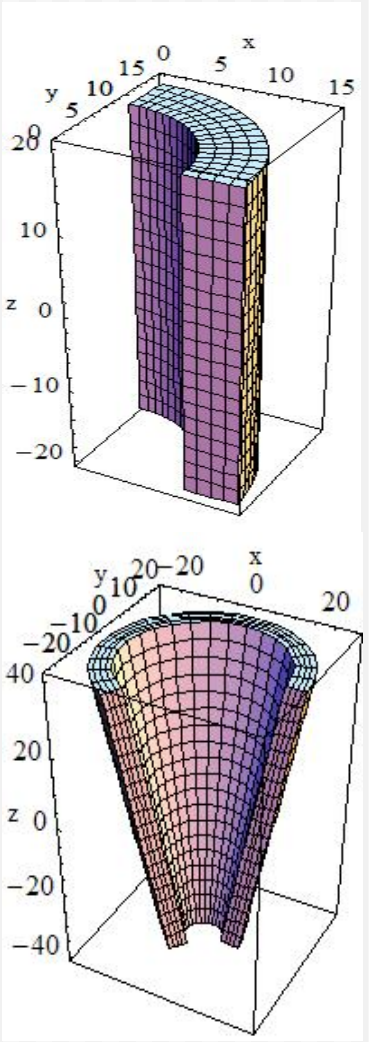
- Solids defined in Geant4:
  - CSG (Constructed Solid Geometry) solids
    - G4Box, G4Tubs, G4Cons, G4Trd, …
    - Analogous to simple GEANT3 CSG solids
  - Specific solids (CSG like)
    - G4Polycone, G4Polyhedra, G4Hype, …
    - G4TwistedTubs, G4TwistedTrap, …
  - BREP (Boundary REPresented) solids
    - G4BREPSolidPolycone, G4BSplineSurface, …
    - Any order surface
  - Boolean solids
    - G4UnionSolid, G4SubtractionSolid, …



# CSG: G4Tubs, G4Cons

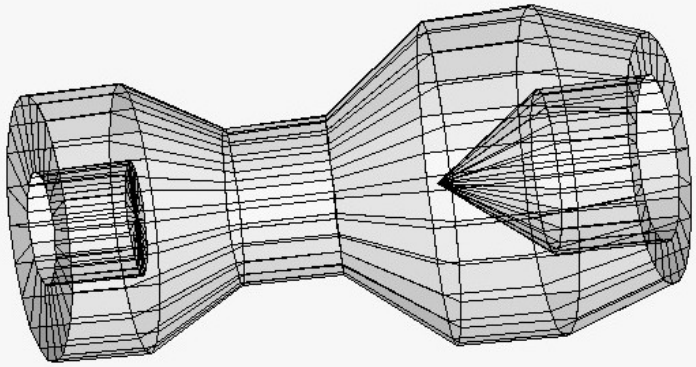
```
G4Tubs(const G4String& pname,   // name
               G4double  pRmin,   // inner radius
               G4double  pRmax,   // outer radius
               G4double  pDz,     // Z half length
               G4double  pSphi,   // starting Phi
               G4double  pDphi); // segment angle

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
```

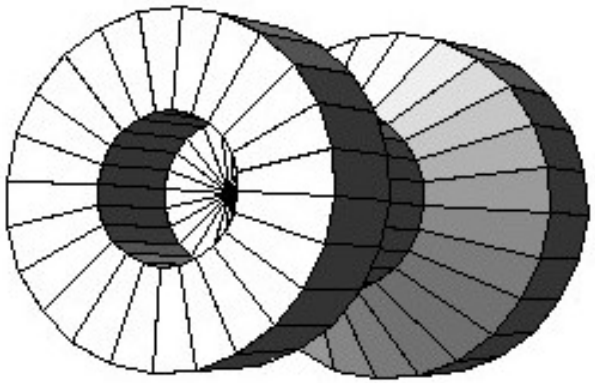


# Specific CSG Solids: G4Polycone

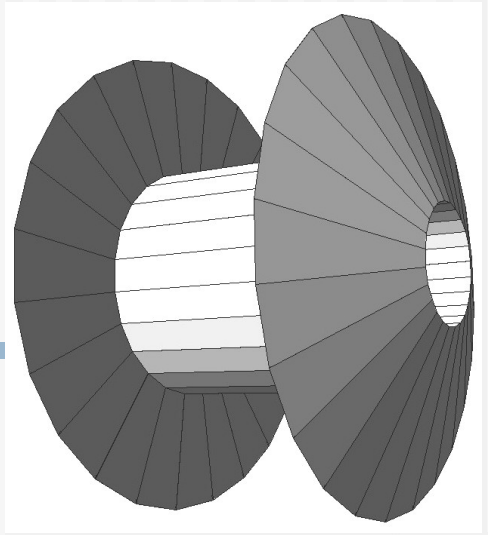
```
G4Polycone(const G4String& pName,
                 G4double phiStart,
                 G4double phiTotal,
                 G4int numRZ,
           const G4double r[],
           const G4double z[]);
```

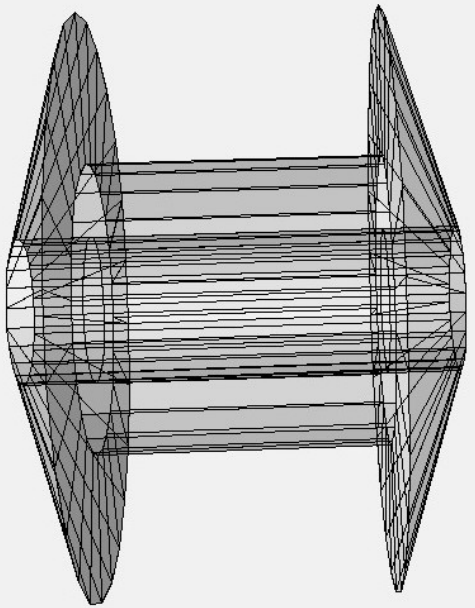


- `numRZ` - numbers of corners in the `r,z` space
- `r, z` - coordinates of corners
- Additional constructor using planes



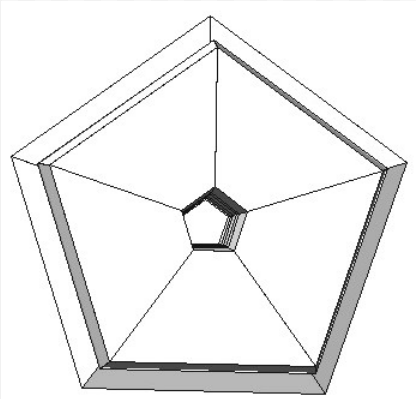
# BREP Solids

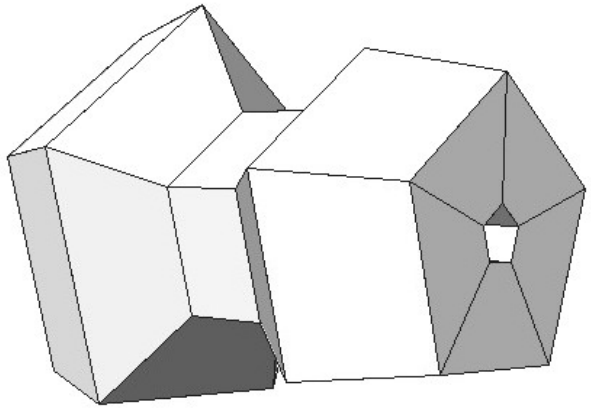




- *BREP = Boundary REPresented Solid*
- Listing all its surfaces specifies a solid
  - e.g. 6 squares for a cube
- Surfaces can be
  - planar, 2nd or higher order
    - elementary BREPS
  - Splines, B-Splines,
    *NURBS (Non-Uniform B-Splines)*
    - advanced BREPS
- Few elementary BREPS pre-defined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

# BREPS example:
## G4BREPSolidPolyhedra

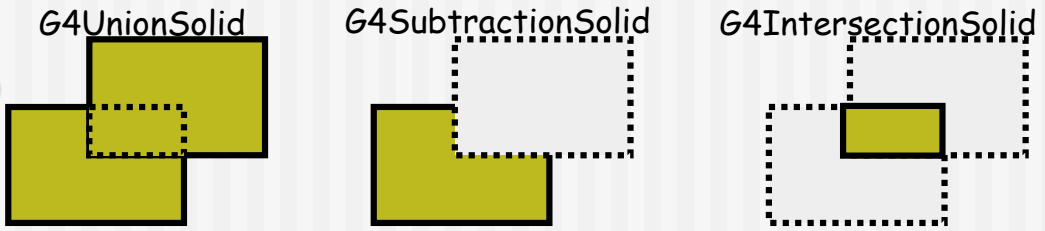




```
G4BREPSolidPolyhedra(const G4String& pName,
                     G4double phiStart,
                     G4double phiTotal,
                     G4int sides,
                     G4int nZplanes,
                     G4double zStart,
               const G4double zval[],
               const G4double rmin[],
               const G4double rmax[]);
```

- **sides** - numbers of sides of each polygon in the **x-y** plane
- **nZplanes** - numbers of planes perpendicular to the **z** axis
- **zval[]** - **z** coordinates of each plane
- **rmin[], rmax[]** - Radii of inner and outer polygon at each plane

# 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
    - Component solids must not be disjoint and must well intersect

```
G4Box box("Box", 20, 30, 40);
G4Tubs cylinder("Cylinder", 0, 50, 50, 0, 2*M_PI);  // r:     0 -> 50
                                                    // z:   -50 -> 50
                                                    // phi:   0 ->  2 pi
G4UnionSolid union("Box+Cylinder", &box, &cylinder);
G4IntersectionSolid intersect("Box Intersect Cylinder", &box, &cylinder);
G4SubtractionSolid subtract("Box-Cylinder", &box, &cylinder);
```

- 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

# Areas, volumes and masses

- Surface area and geometrical volume of a generic solid or Boolean composition can be computed from the **solid**:

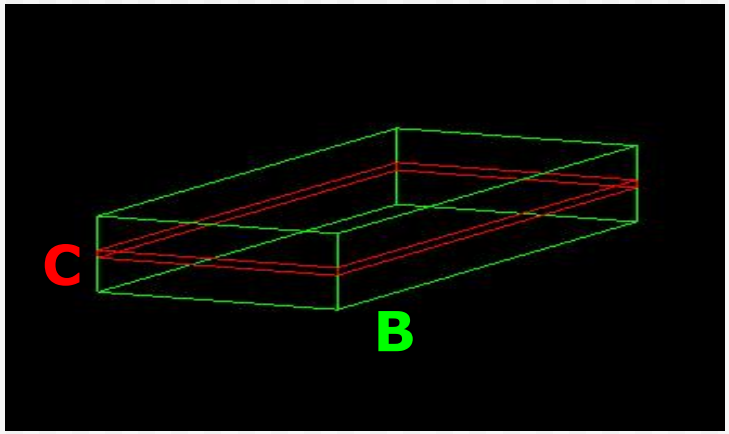
```
G4double GetSurfaceArea();
G4double GetCubicVolume();
```

- Overall mass of a geometry setup (sub-detector) can be computed from the **logical volume**:

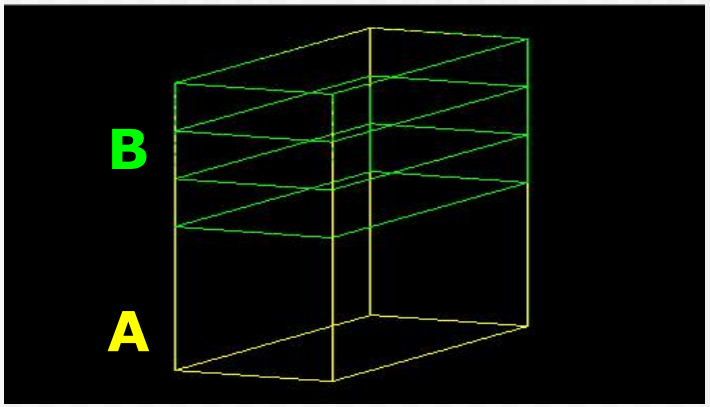
```
G4double GetMass(G4Bool forced=false,
                 G4Material* parameterisedMaterial=0);
```

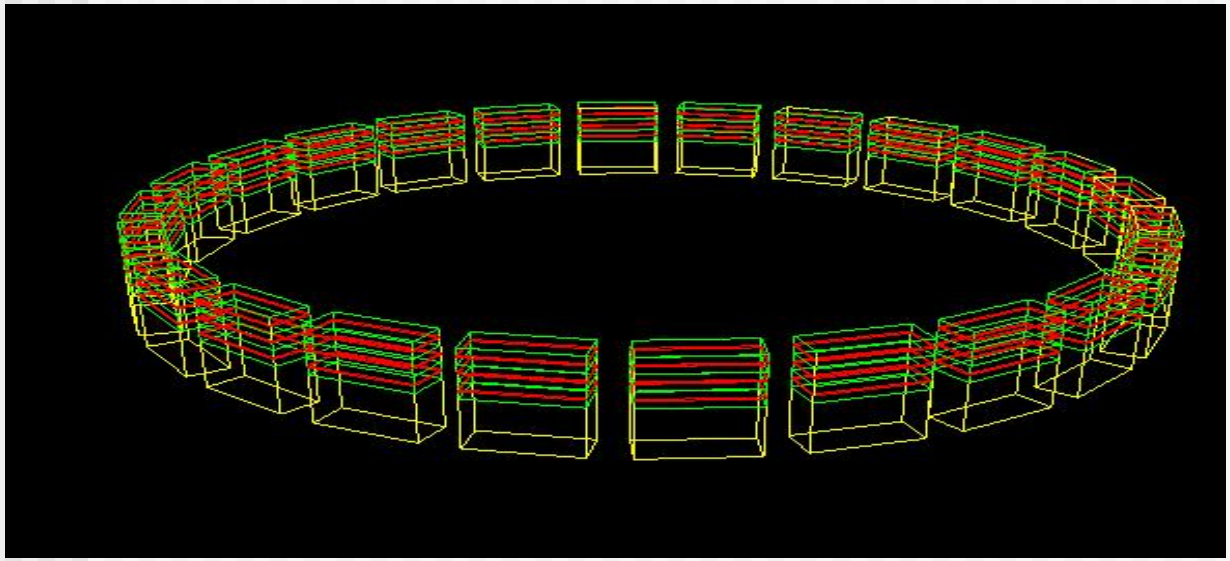
# How to identify a volume uniquely?

- Suppose a geometry is made of sensitive layers C which are placed in a volume B




- Volume B is a daughter volume of a divided volume *A*

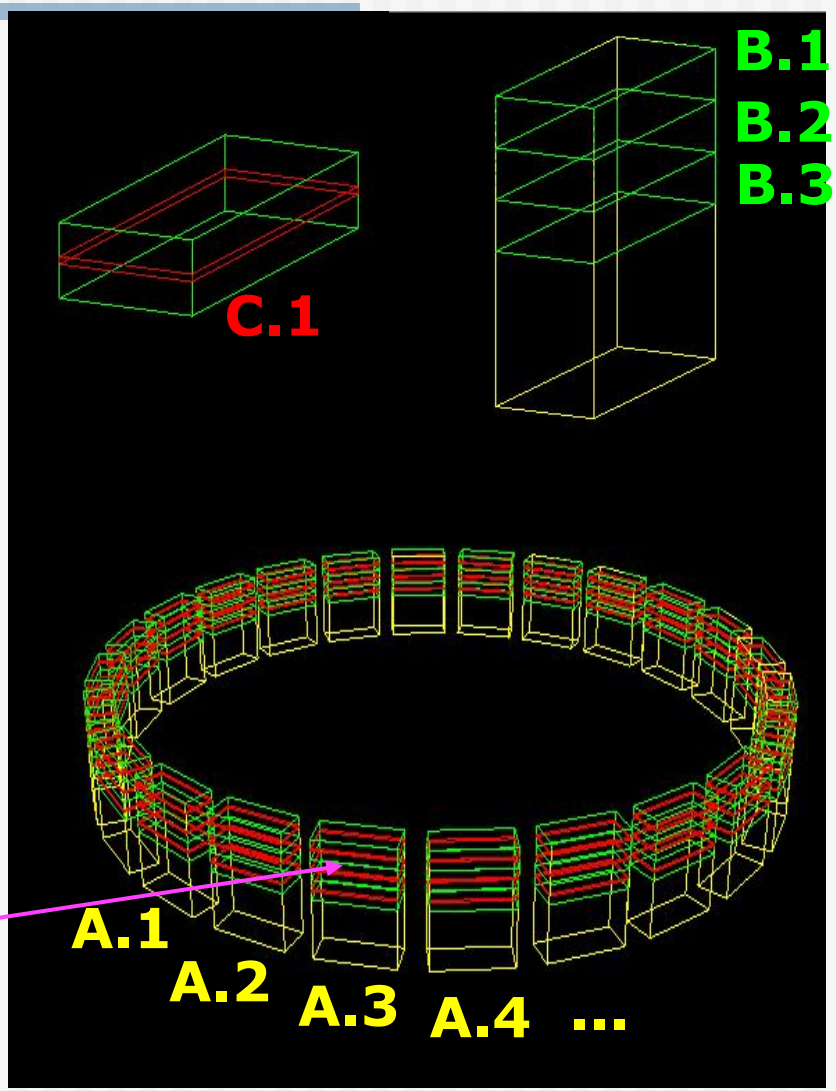


- Volume *A* has 24 positions in the world
- While in the 'logical' geometry tree volume *C* is represented by just one physical volume, in the real world there are many *C* 'volumes'
- *How can we then identify these volumes C ?*

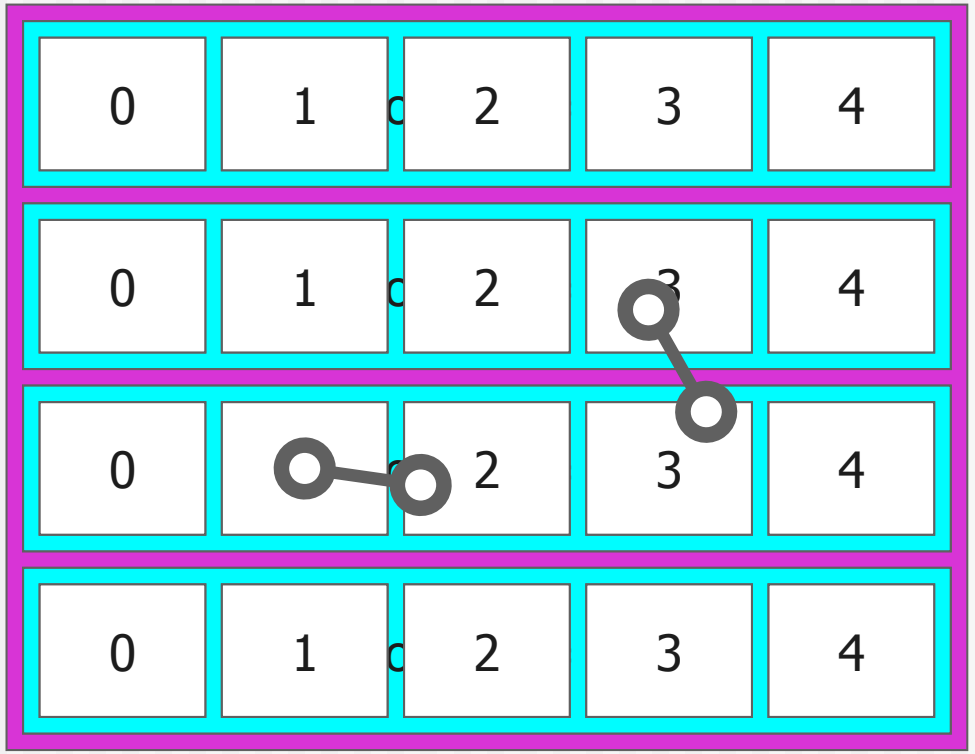
# Basics of Touchables

- A touchable for a volume serves the purpose of providing a unique identification for a detector element
- It is a geometrical entity (volume or solid) which has a unique placement in a detector description
  - It can be uniquely identified by providing the copy numbers for all daughters in the geometry hierarchy
  - In our case these are
    - CopyNo of C in B: **1**
    - CopyNo of B in A: **1,2,3**
    - CopyNo of A in the world: **1, .., 24**
  - Example of touchable identification:
    - **A.3/B.2/C.1**



# Copy numbers

- Suppose a calorimeter is made of 4x5 cells
  - and is implemented by two levels of replica
- In reality, there is only one physical volume object for each level. Its position is parameterized by its copy number
- How to get the copy number of each level, when a step belongs to two cells ?
  - *Remember*: geometrical information in **`G4Track`** is identical to "PostStepPoint". You cannot get the correct copy number for "PreStepPoint" if you directly access to the physical volume
- Use touchable to get the proper copy number, transformation matrix,…

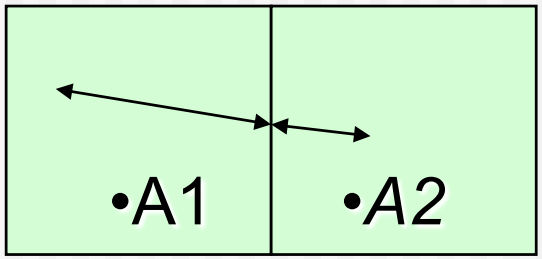


# What a touchable provides ?

- **`G4VTouchable`** - a base class for all touchable implementations – defines the following 'requests' (methods) which all touchable have to respond, where depth means always the number of levels up in the tree to be considered:
  - depth = 0 : the bottom level (volume C in B)
  - depth = 1 : the level of its mother volume (volume B in A)
  - depth = 2 : the grandmother volume (volume A in world)
- **`GetCopyNumber(G4int depth =0)`**
  - **returns the copy number of the given level**
- **`GetTranslation(G4int depth = 0); GetRotation(G4int depth=0)`**
  - **return the components of the volume's transformation**
- **`GetSolid(G4int depth =0)`**
  - **returns the solid**
- **`GetVolume(G4int depth =0)`**
  - **returns the physical volume**

# Benefits of Touchables in track

- Full geometrical information available
  - to processes, to sensitive detectors, to hits
- All the geometrical information of the particular step should be taken from "`PreStepPoint`"
  - Available in `G4TouchableHistory` object
    - Copy-number, transformations
  - Accessible via Handles (or *smart-pointers*) to touchables
  - Note: the geometrical information associated with `G4Track` is basically the same as "`PostStepPoint`"



# Touchable & Steps

- **`G4Step`** has two **`G4StepPoint`** objects as its starting and ending points. All the geometrical information of the particular step should be got from "**`PreStepPoint`**"
  - Geometrical information associated with **`G4Track`** is basically same as "**`PostStepPoint`**"
- Each **`G4StepPoint`** object provides:
  - position in world coordinate system
  - global and local time
  - Material
  - Associated **`G4TouchableHistory`**
    - Touchable to be used for geometrical information
    - Copy-number, transformations
- *Handles* (or *smart-pointers*) to touchables are intrinsically used. Touchables are reference counted

# How to use Touchables …

- **`G4TouchableHistory`** has information of the geometrical hierarchy at the point

```
G4Step* aStep = ..;
G4StepPoint* preStepPoint = aStep->GetPreStepPoint();
G4TouchableHandle theTouchable =
                  preStepPoint->GetTouchableHandle();
G4int copyNo = theTouchable->GetReplicaNumber();
G4int motherCopyNo = theTouchable->GetReplicaNumber(1);
G4ThreeVector worldPos = preStepPoint->GetPosition();
G4ThreeVector localPos = theTouchable->GetHistory()->
    GetTopTransform().TransformPoint(worldPos);
```

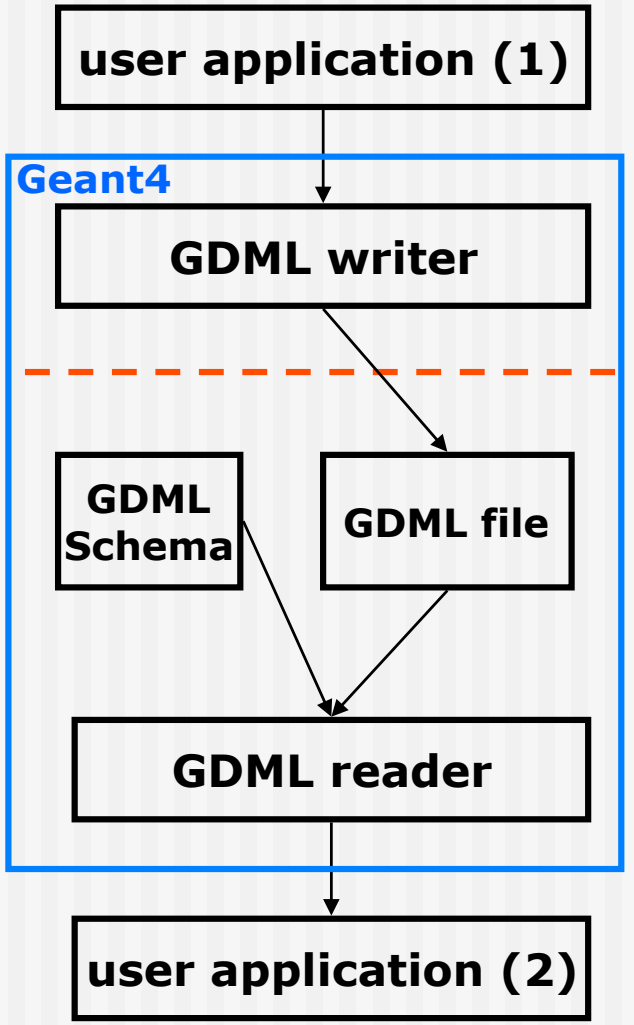
# PART II

# GDML

- *Importing and exporting detector descriptions*

# GDML components

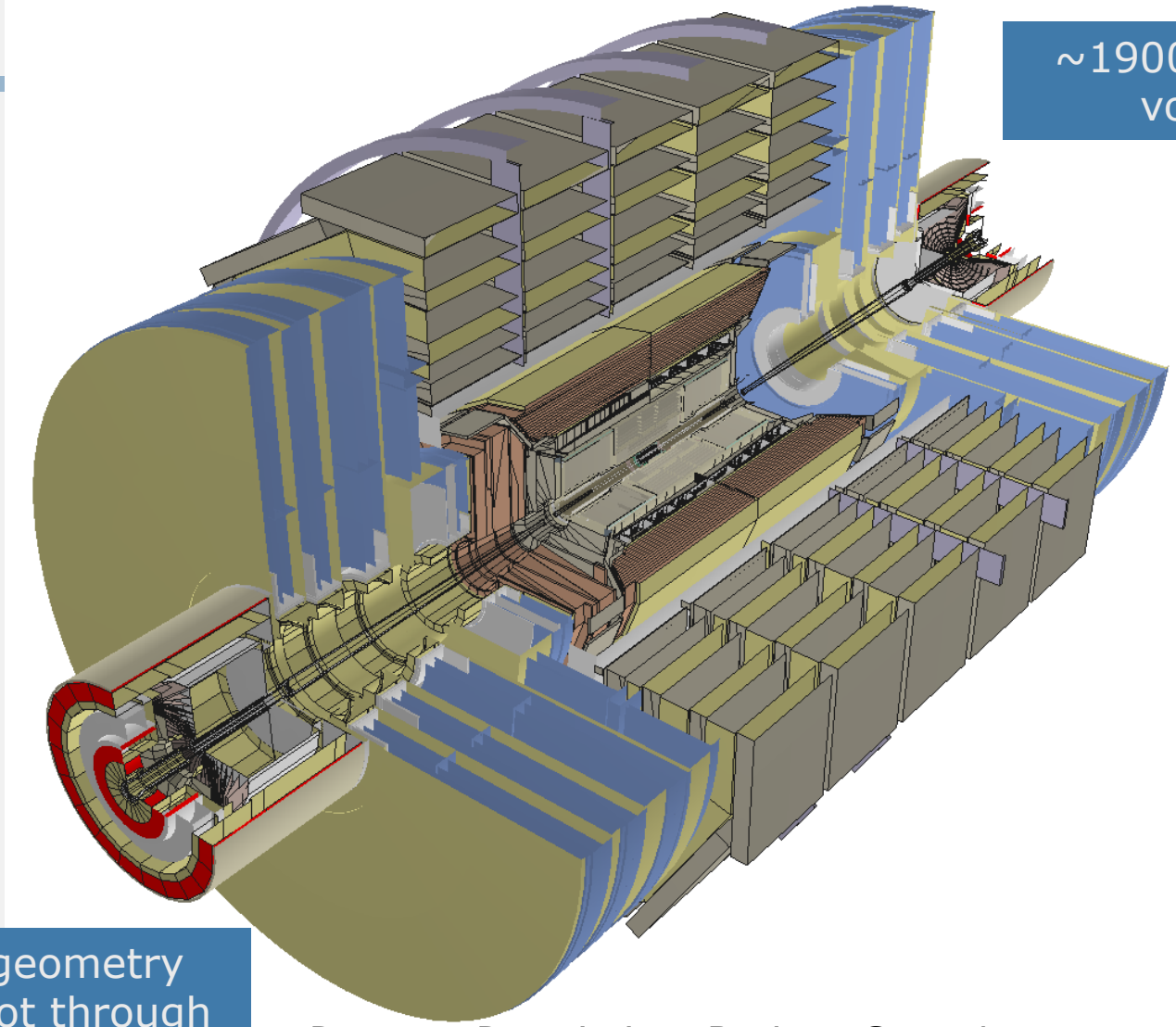
- GDML (Geometry Description Markup Language) is defined through XML Schema (XSD)
  - XSD = XML based alternative to Document Type Definition (DTD)
  - defines document structure and the list of legal elements
  - XSD are in XML -> they are extensible
- GDML can be written by hand or generated automatically in Geant4
  - 'GDML writer' allows exporting a GDML file
- GDML needs a "reader", integrated in Geant4
  - 'GDML reader' imports and creates 'in-memory' the representation of the geometry description



# GDML – Geant4 binding

- XML schema available from http://cern.ch/gdml
  - Also available within Geant4 distribution
    - See in **`geant4/source/persistency/gdml/schema/`**
  - Latest schema release GDML_3_0_0 (as from 9.2 release)
- Requires XercesC++ XML parser
  - Available from: http://xerces.apache.org/xerces-c
  - Tested with versions 2.8.0 and 3.0.1
- Optional package to be linked against during build
  - **`G4LIB_BUILD_GDML`** and **`XERCESCROOT`** variables
  - Examples available: **`geant4/examples/extended/persistency/gdml`**

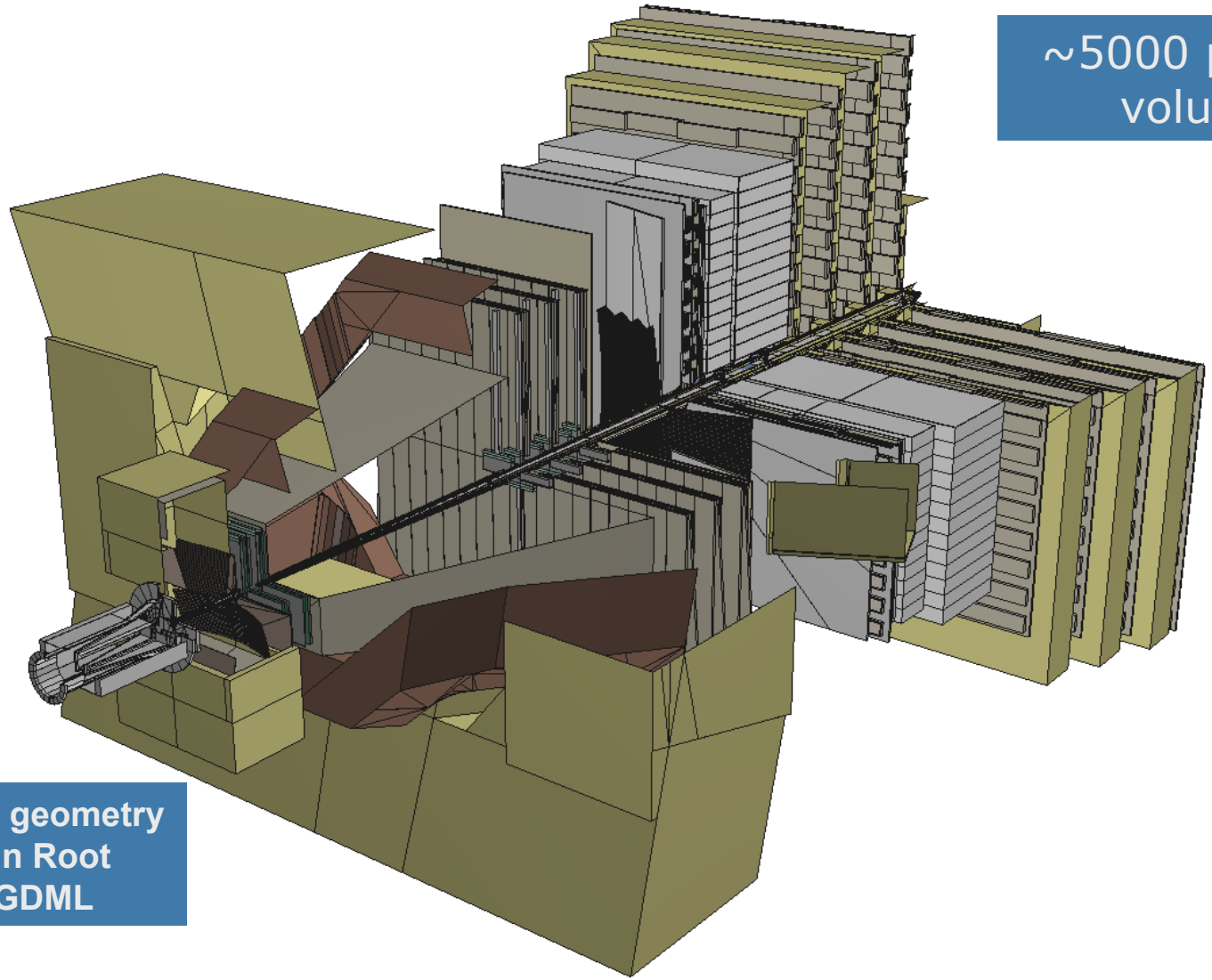
# CMS detector through GDML



~19000 physical volumes

Geant4 CMS geometry imported in Root through GDML

# LHCb detector through GDML



~5000 physical volumes

**Geant4 LHCb geometry imported in Root through GDML**

# Using GDML in Geant4

to write:

```
#include "G4GDMLParser.hh"
G4GDMLParser parser;
parser.Write("g4test.gdml", pWorld, true, "path_to_schema/gdml.xsd");
```

**instantiate GDML parser**

**Concatenate or not pointers to entity names**

**pass the 'top' volume to the writer**

**Activate or de-activatate schema validation**

to read:

```
parser.Read( "g4test.gdml", true );
```

**get pointer to 'top' world volume**

```
pWorld = GDMLProcessor::GetInstance()->GetWorldVolume();
```

➡ GDML examples in: **`geant4/examples/extended/persistency/gdml`**

# Using GDML in Geant4 - 2

- Any geometry tree can be dumped to file
  - … just provide its physical volume pointer (**`pVol`**):

```
parser.Write("g4test.gdml", pVol);
```

- A geometry setup can be split in modules
  - … starting from a geometry tree specified by a physical volume:

```
parser.AddModule(pVol);
```

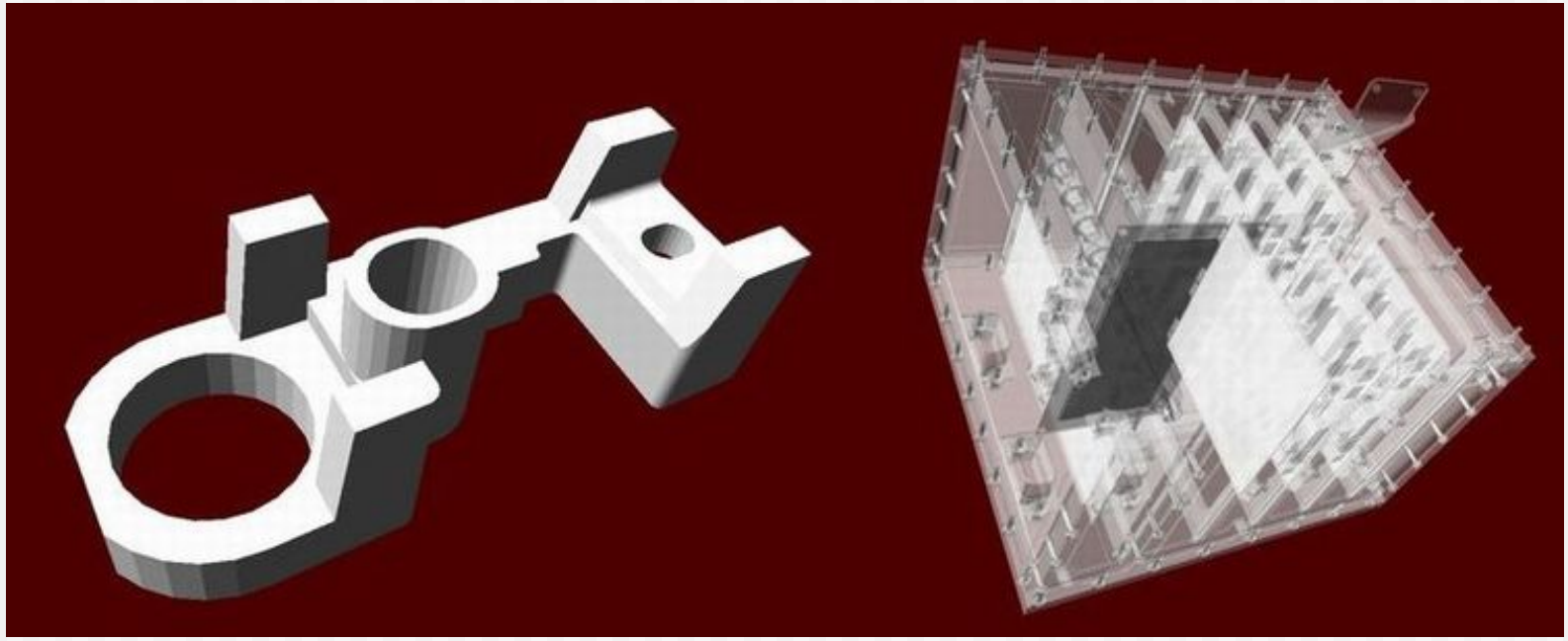
  - … indicating the depth from which starting to modularize:

```
parser.AddModule(depth);
```

- Provides facility for importing CAD geometries generated through STEP-Tools
- Allows for easy extensions of the GDML schema and treatment of auxiliary information associated to volumes
- Full coverage of materials, solids, volumes and simple language constructs (variables, loops, etc…)

# Importing CAD geometries with GDML

- CAD geometries generated through STEP-Tools (**`stFile.geom`**, **`stFile.tree`** files) can be imported through the GDML reader:
  - `parser.ParseST("stFile", WorldMaterial, GeomMaterial);`



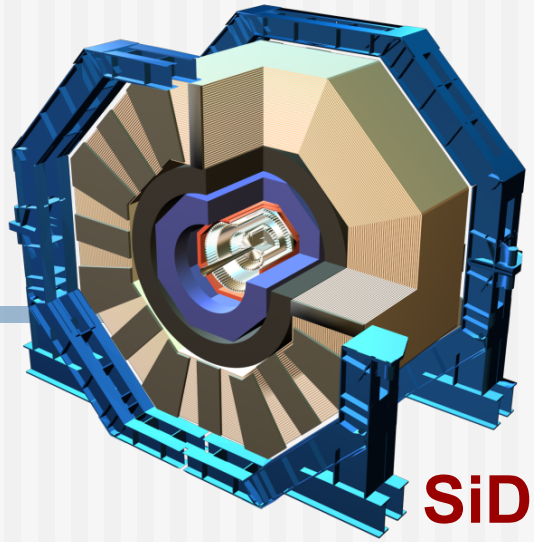
- Tool like FastRad allow for importing CAD STEP files and directly convert to GDML

# GDML processing performance

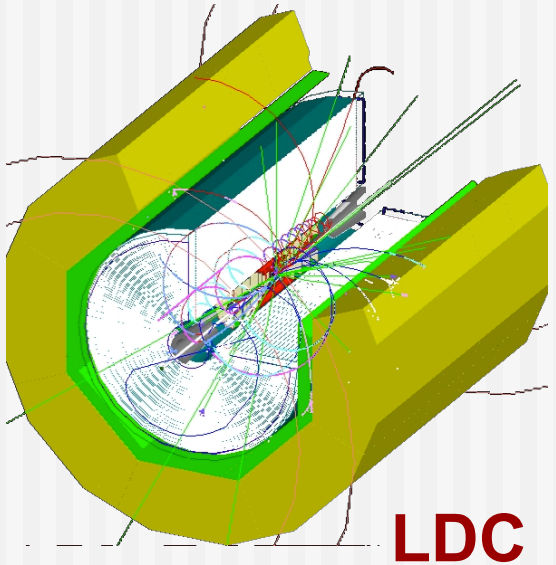
- GDML reader/writer tested on
  - complete LHCb and CMS geometries
  - parts of ATLAS geometry
    - full ATLAS geometry includes custom solids
- for LHCb geometry (~5000 logical volumes)
  - writing out ~10 seconds (on P4 2.4GHz)
  - reading in ~ 5 seconds
  - file size ~2.7 Mb (~40k lines)
- for CMS geometry (~19000 logical volumes)
  - writing out ~30 seconds
  - reading in ~15 seconds
  - file size ~7.9 Mb (~120k lines)

# GDML as primary geometry source

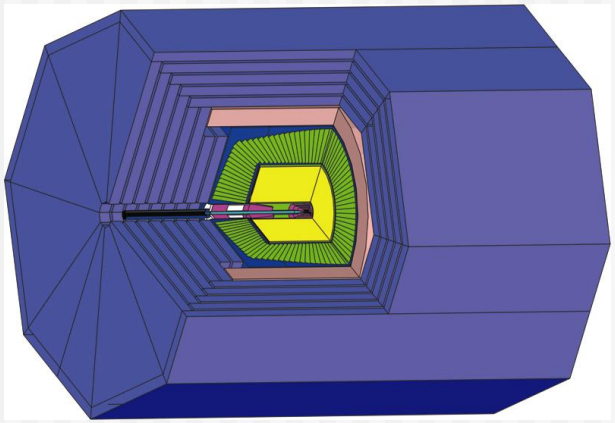
- Linear Collider
  - Linear Collider Detector Description (LCDD) extends GDML with Geant4-specific information (sensitive detectors, physics cuts, etc)
  - GDML/LCDD is generic and flexible
    - several different full detector design concepts, including SiD, GLD, and LDC, where simulated using the same application



SiD



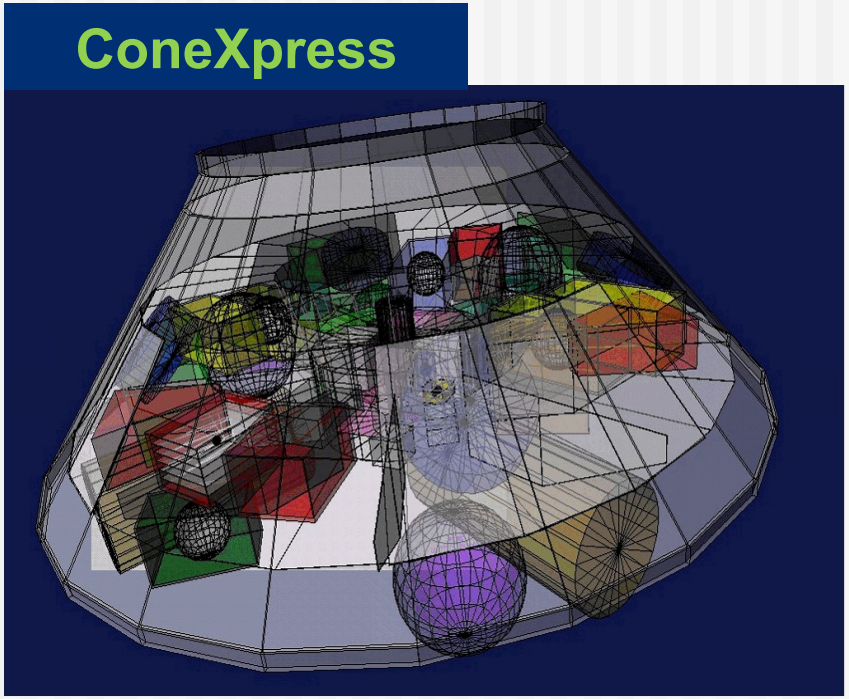
LDC



GLD

# GDML as primary geometry source

- Space Research @ ESA
  - Geant4 geometry models
    - component degradation studies (JWST, ConeXpress,...)
    - GRAS (Geant4 Radiation Analysis for Space)
  - enables flexible geometry configuration and changes
  - main candidate for CAD to Geant4 exchange format



# GDML as primary geometry source

- Anthropomorphic Phantom
  - Modeling of the human body and anatomy for radioprotection studies
  - no hard-coded geometry, flexible configuration