



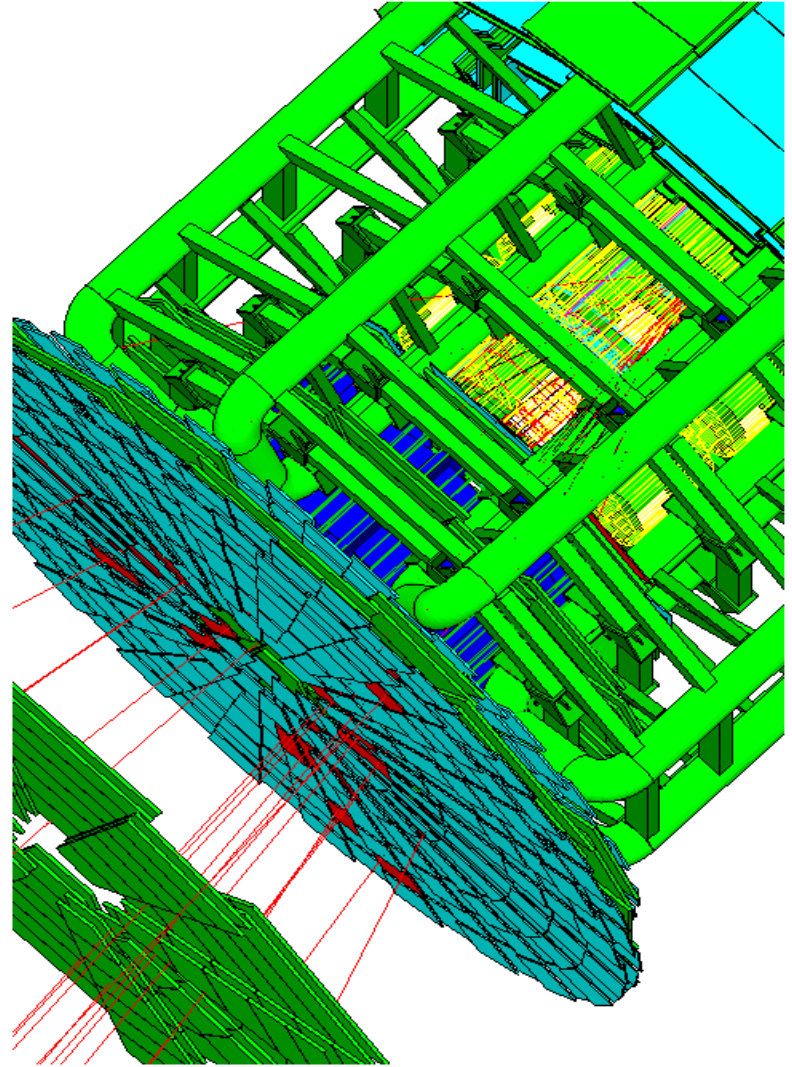
Version 10.4-p02

Geometry IV

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Geant4 Tutorial Course

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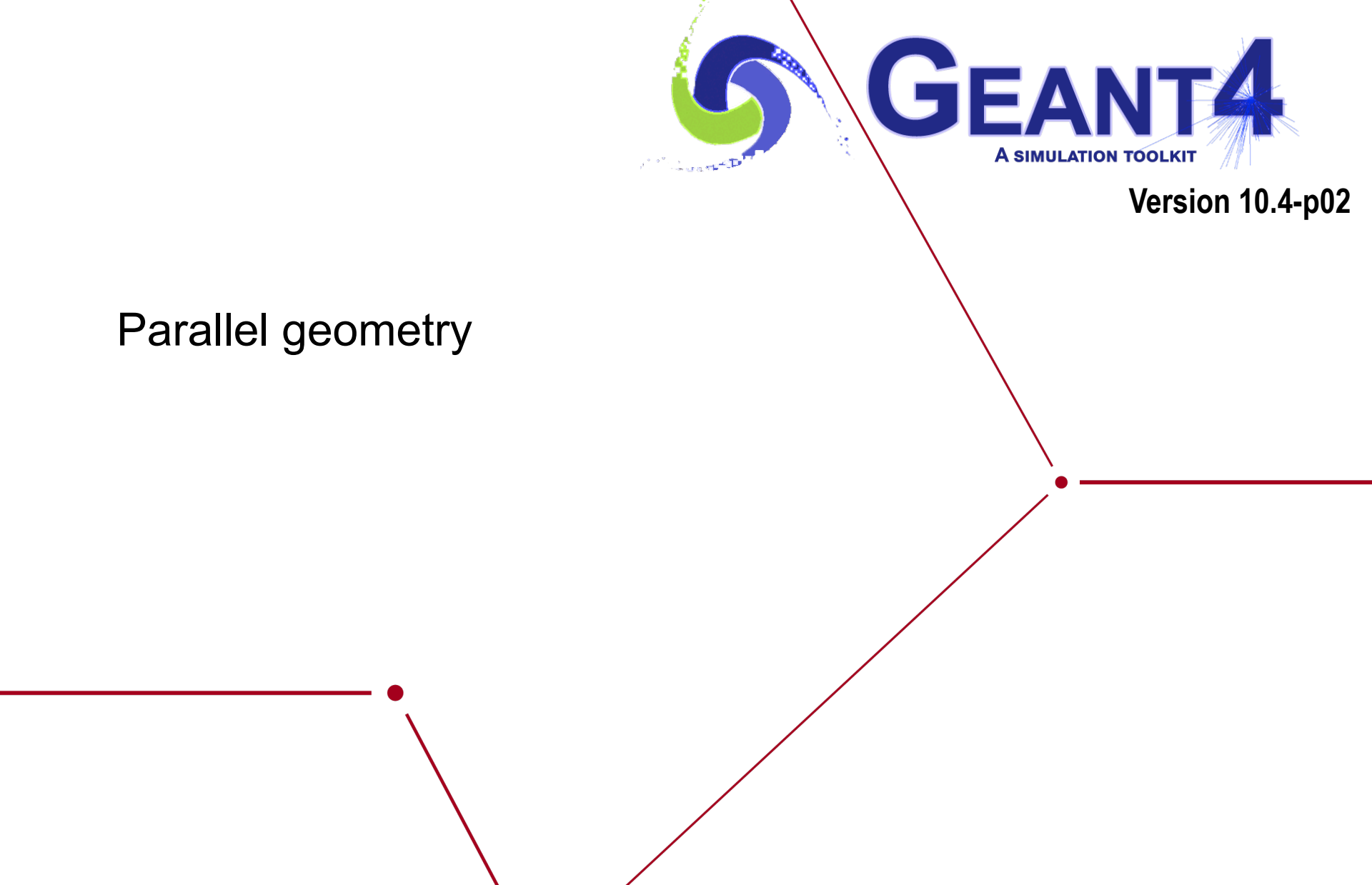
- Parallel geometry
- Layered mass geometry
- Moving objects





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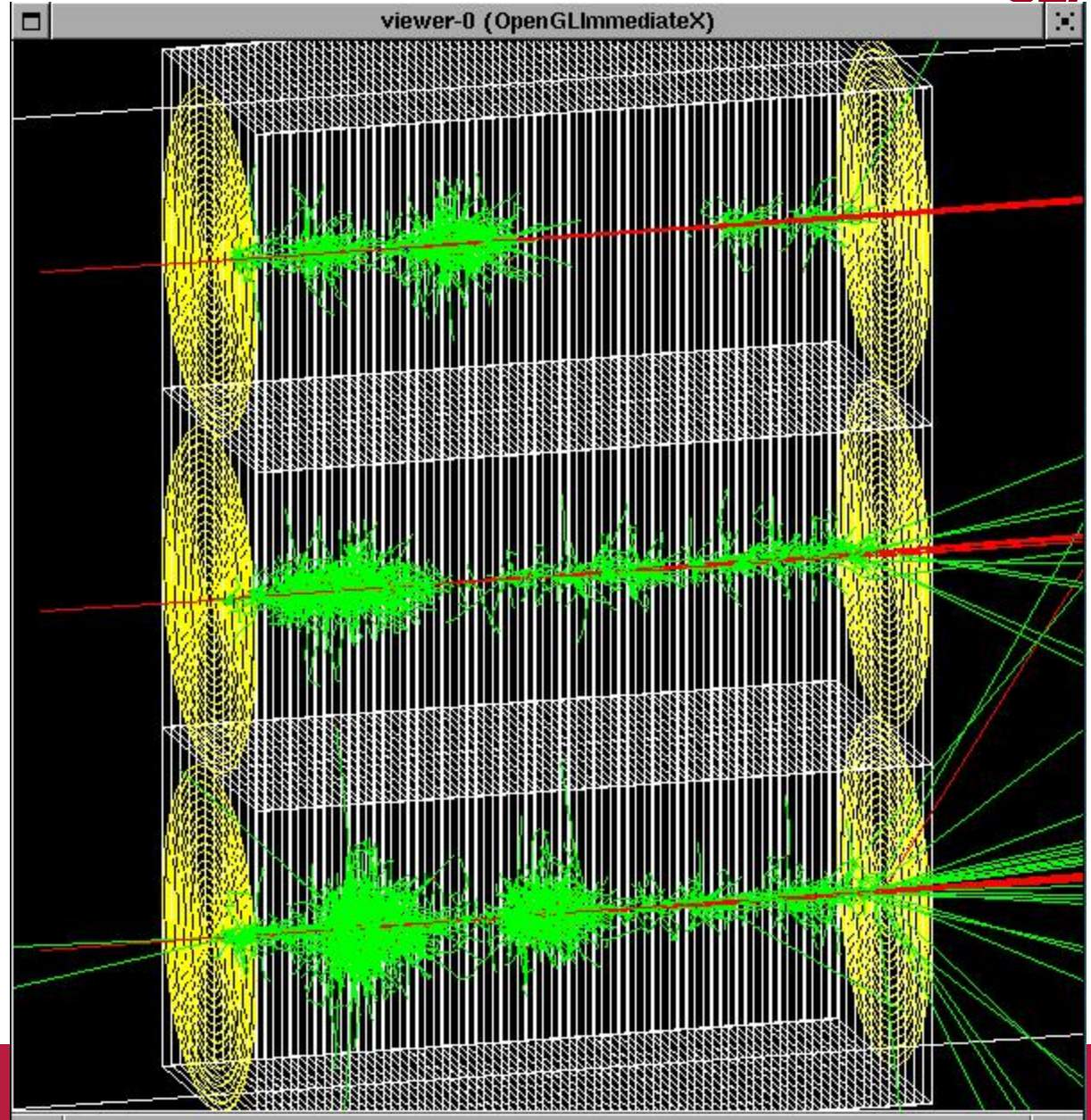
Parallel geometry

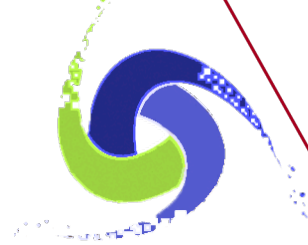


- Occasionally, it is not straightforward to define sensitivity, importance or envelope to be assigned to volumes in the mass geometry.
 - Typically a geometry built machinery by CAD, GDML, DICOM, etc. has this difficulty.
- New parallel navigation functionality allows the user to define more than one worlds simultaneously.
 - New G4Transportation process sees all worlds simultaneously.
 - A step is limited not only by the boundary of the mass geometry but also by the boundaries of parallel geometries.
 - Materials, production thresholds and EM field are used only from the mass geometry.
 - In a parallel world, the user can define volumes in arbitrary manner with sensitivity, regions with shower parameterization, and/or importance field for biasing.
 - Volumes in different worlds may overlap.

- **G4VUserParallelWorld** is the new base class where the user implements a parallel world.
 - The world physical volume of the parallel world is provided by G4RunManager as a clone of the mass geometry.
 - All UserParallelWorlds must be registered to UserDetectorConstruction.
 - Each parallel world has its dedicated G4Navigator object, that is automatically assigned when it is constructed.
- Though all worlds will be comprehensively taken care by G4Transportation process for their navigations, each parallel world must have its own process to achieve its purpose.
 - For example, in case the user defines a sensitive detector to a parallel world, a process dedicated to this world is responsible to invoke this detector. G4SteppingManager sees only the detectors in the mass geometry. The user has to have **G4ParallelWorldProcess** in his physics list.

- Mass geometry
 - sandwich of rectangular absorbers and scintillators
- Parallel scoring geometry
 - Cylindrical layers





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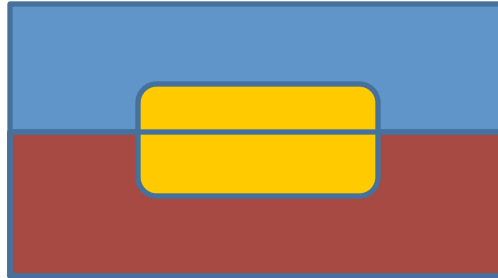
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Layered mass geometry

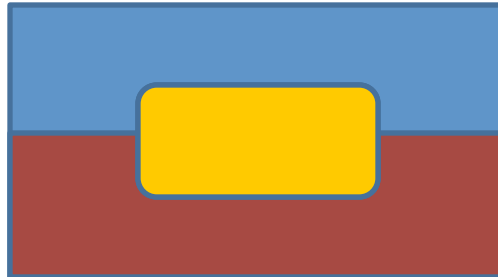


Layered mass geometries in parallel world

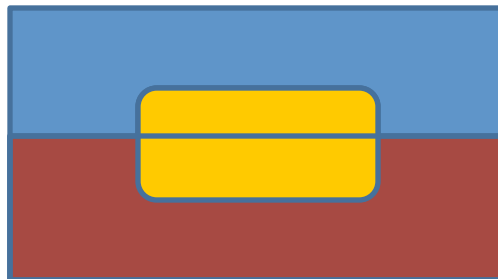
- Suppose you implement a wooden brick floating on the water.



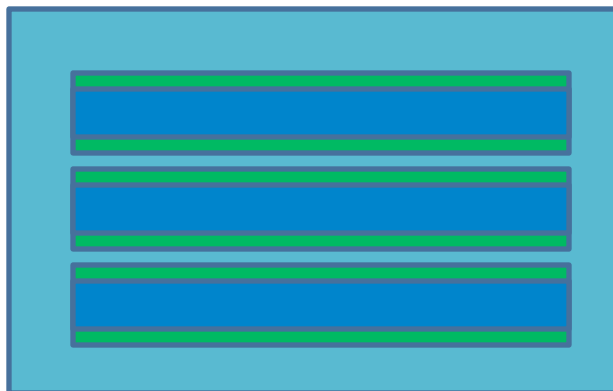
- Dig a hole in water...



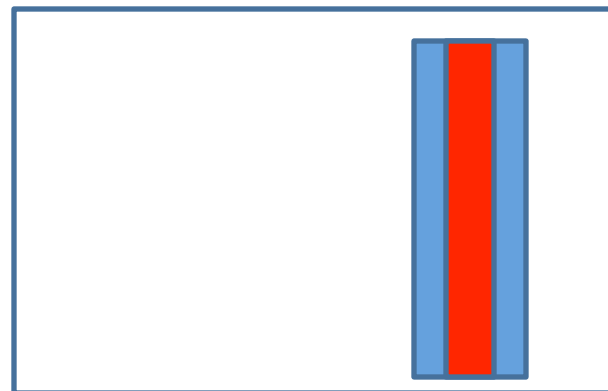
- Or, chop a brick into two and place them separately...



- Parallel geometry may be stacked on top of mass geometry or other parallel world geometry, allowing a user to define more than one worlds with materials (and region/cuts).
 - Track will see the material of top-layer, if it is null, then one layer beneath.
 - Alternative way of implementing a complicated geometry
 - Rapid prototyping
 - Safer, more flexible and powerful extension of the concept of “many” in Geant3



Mass world

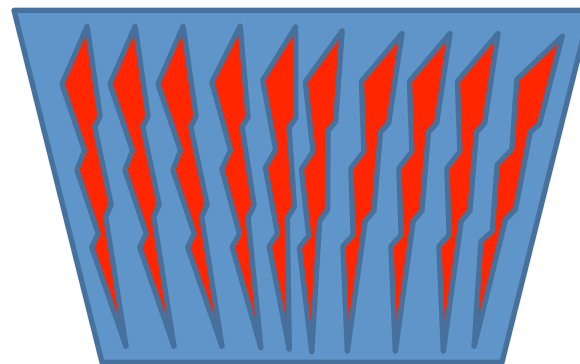


Parallel world

- A parallel world may be associated only to some limited types of particles.
 - May define geometries of different levels of detail for different particle types
 - Example for sampling calorimeter: the mass world defines only the crude geometry with averaged material, while a parallel world with all the detailed geometry. Real materials in detailed parallel world geometry are associated with all particle types except e^+ , e^- and gamma.
 - e^+ , e^- and gamma do not see volume boundaries defined in the parallel world, i.e. their steps won't be limited
 - Shower parameterization such as GFLASH may have its own geometry

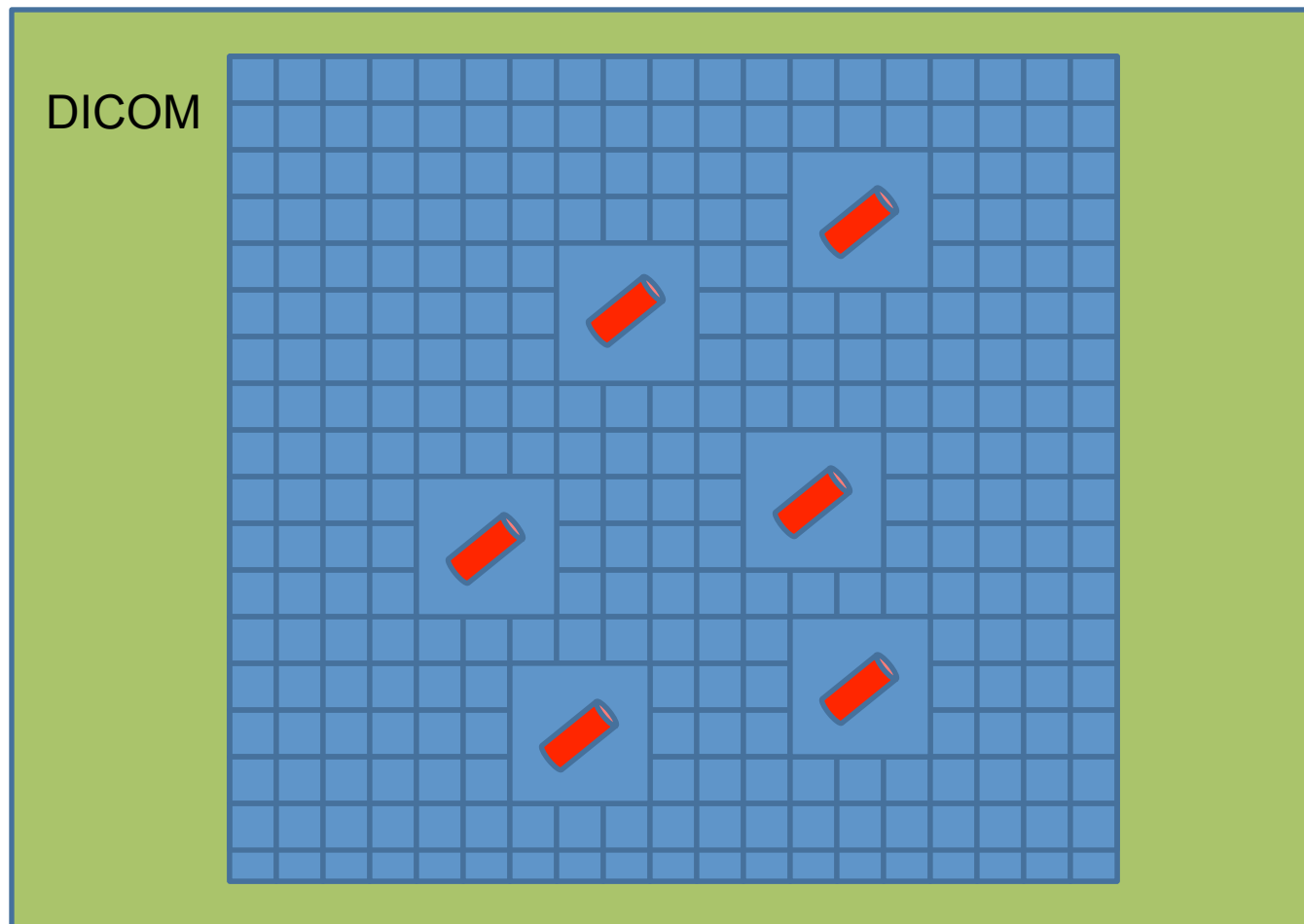


Geometry seen by e^+ , e^- , γ



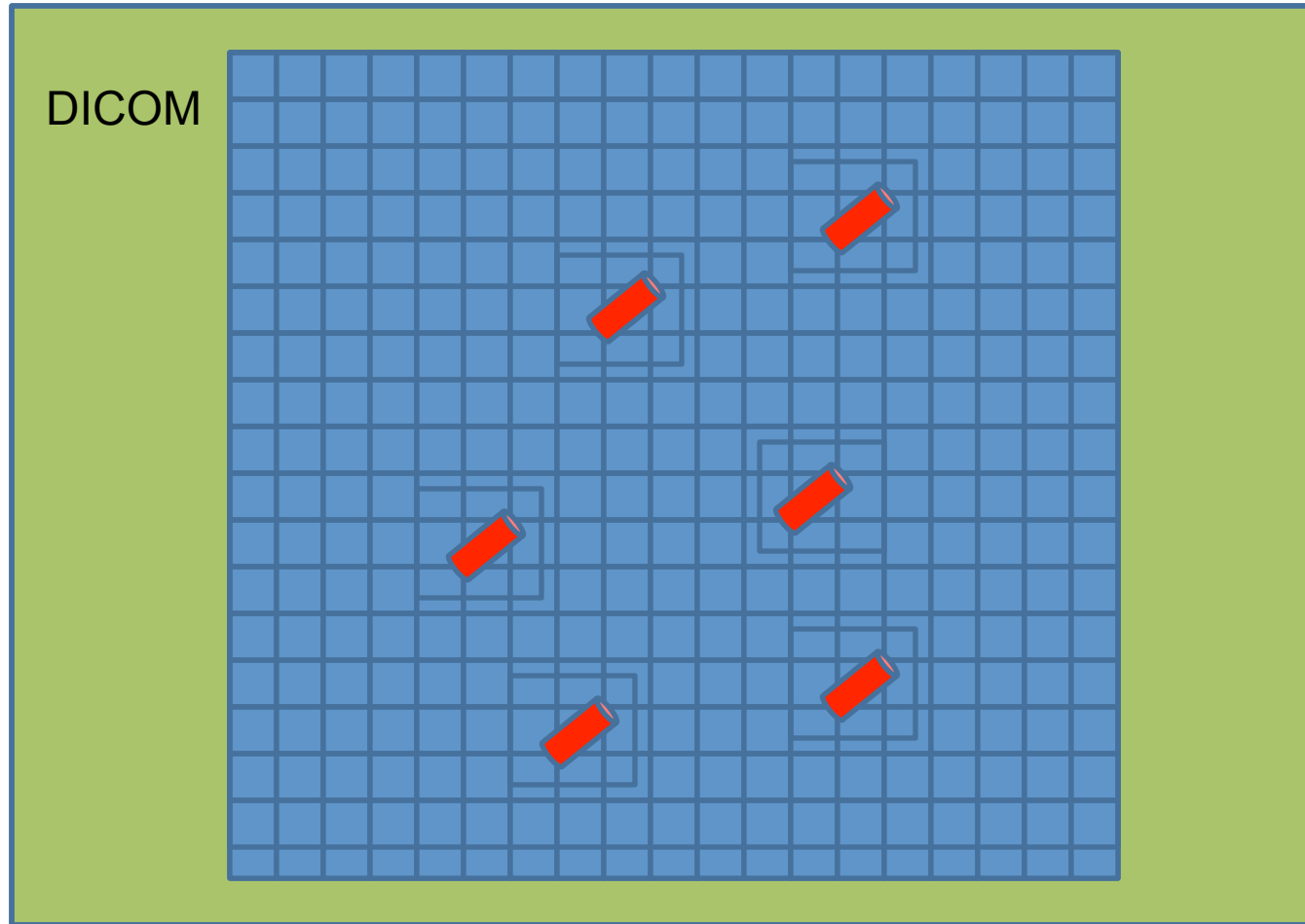
Geometry seen by other particles

- Brachytherapy treatment for prostate cancer.



A medical use case

- Instead, seeds could be implemented in an empty parallel world.
 - Seeds in the parallel world would be encapsulated in empty boxes for faster navigation



Another important use case in medicine

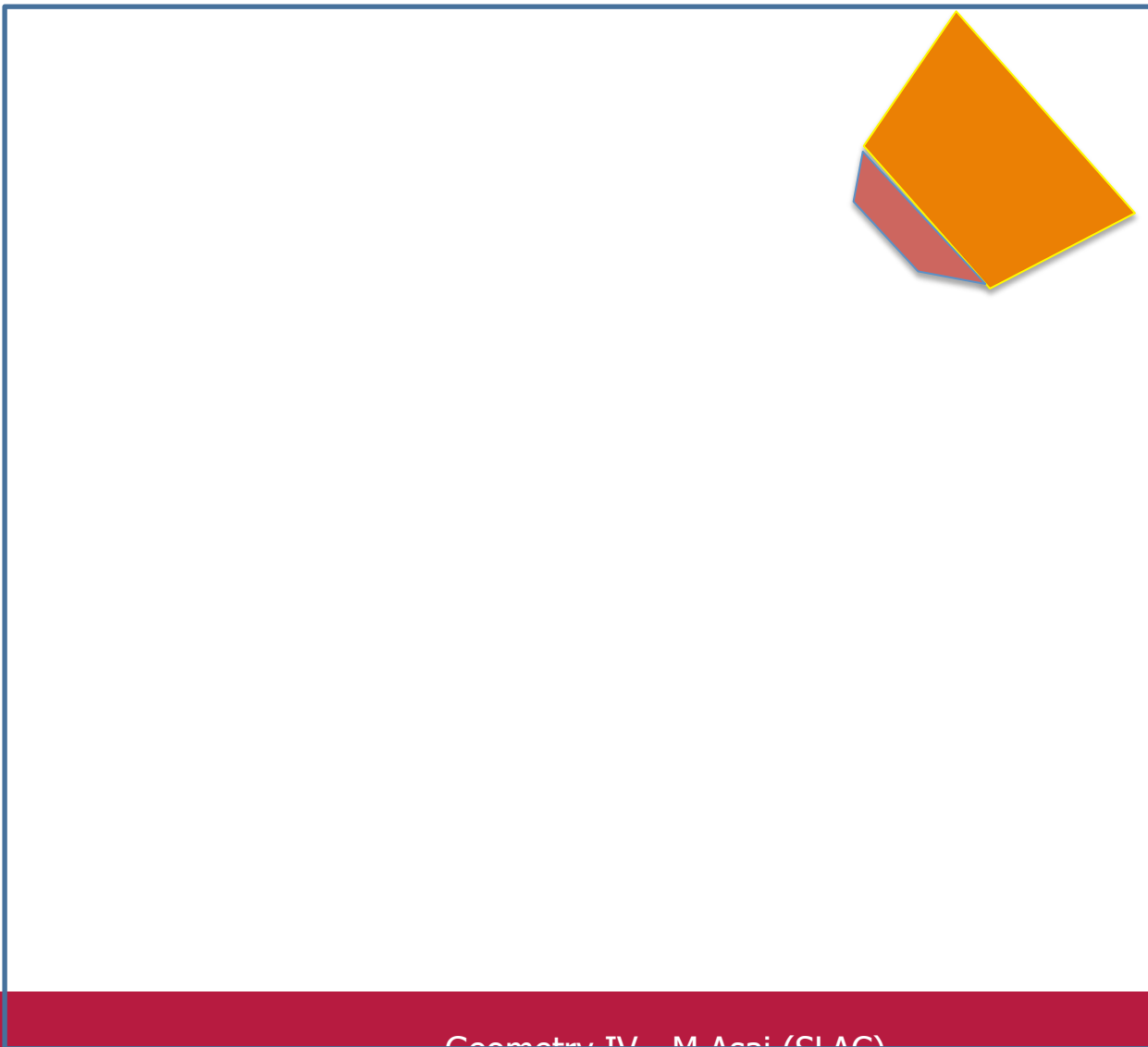
- DICOM data contain void air region outside of the patient, while the treatment head should be placed as close as patient's body.

DICOM



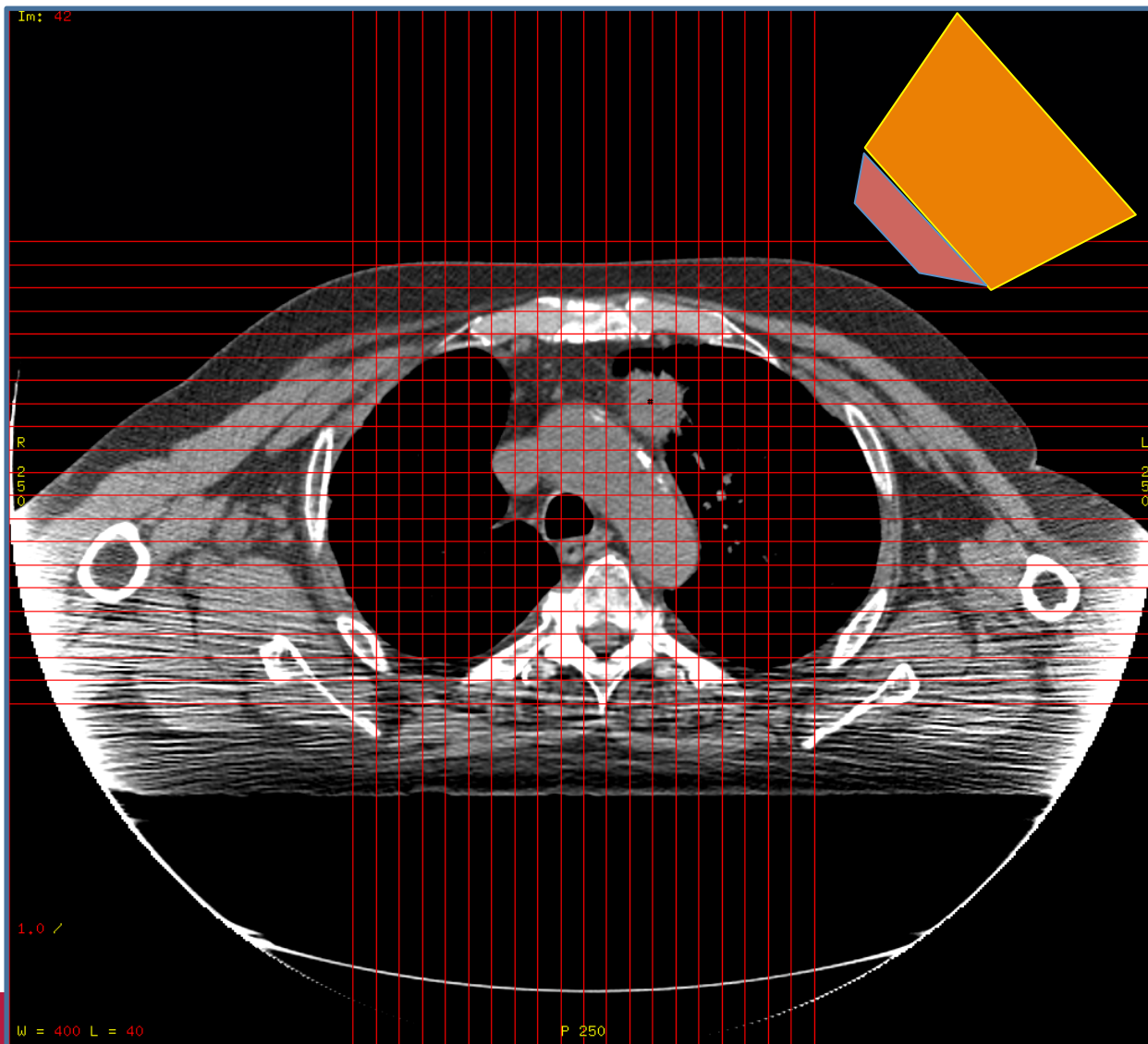
Another important use case in medicine

- Implement the treatment head in a parallel world.



Another important use case in medicine

- And overlay.



main() (RE04.cc)

```
G4String paraWorldName = "ParallelWorld";
G4VUserDetectorConstruction* realWorld = new RE04DetectorConstruction;
G4VUserParallelWorldConstruction* parallelWorld
    = new RE04ParallelWorldConstruction(paraWorldName);
realWorld->RegisterParallelWorld(parallelWorld);
runManager->SetUserInitialization(realWorld);
//
G4VModularPhysicsList* physicsList = new FTFP_BERT;
physicsList->RegisterPhysics
    (new G4ParallelWorldPhysics(paraWorldName,true));
runManager->SetUserInitialization(physicsList);
```

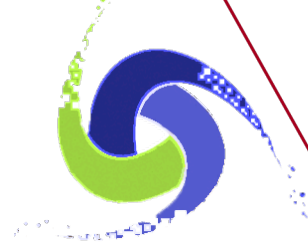
Switch of layered
mass geometry



- The name defined in the **G4VUserParallelWorld constructor** is used as the physical volume name of the parallel world, and must be given to G4ParallelWorldPhysics.


```
void RE04ParallelWorldConstruction::Construct()
{
  //
  // World
  G4VPhysicalVolume* ghostWorld = GetWorld();
  G4LogicalVolume* worldLogical = ghostWorld->GetLogicalVolume();
  //
  // material defined in the mass world
  G4Material* water = G4Material::GetMaterial("G4_WATER");
  //
  // parallel world placement box
  G4VSolid* paraBox = new G4Box("paraBox",5.0*cm,30.0*cm,5.0*cm);
  G4LogicalVolume* paraBoxLogical
    = new G4LogicalVolume(paraBox, water, "paraBox");
  new G4PVPlacement(0,G4ThreeVector(-25.0*cm,0.,0.),paraBoxLogical,
    "paraBox",worldLogical,false,0);
}
```

- The world physical volume of the parallel is provided as a clone of the world volume of the mass geometry. The user cannot create it.
- You can fill volumes regardless of the volumes in the mass geometry.
- Logical volumes in a parallel world may not have a material.



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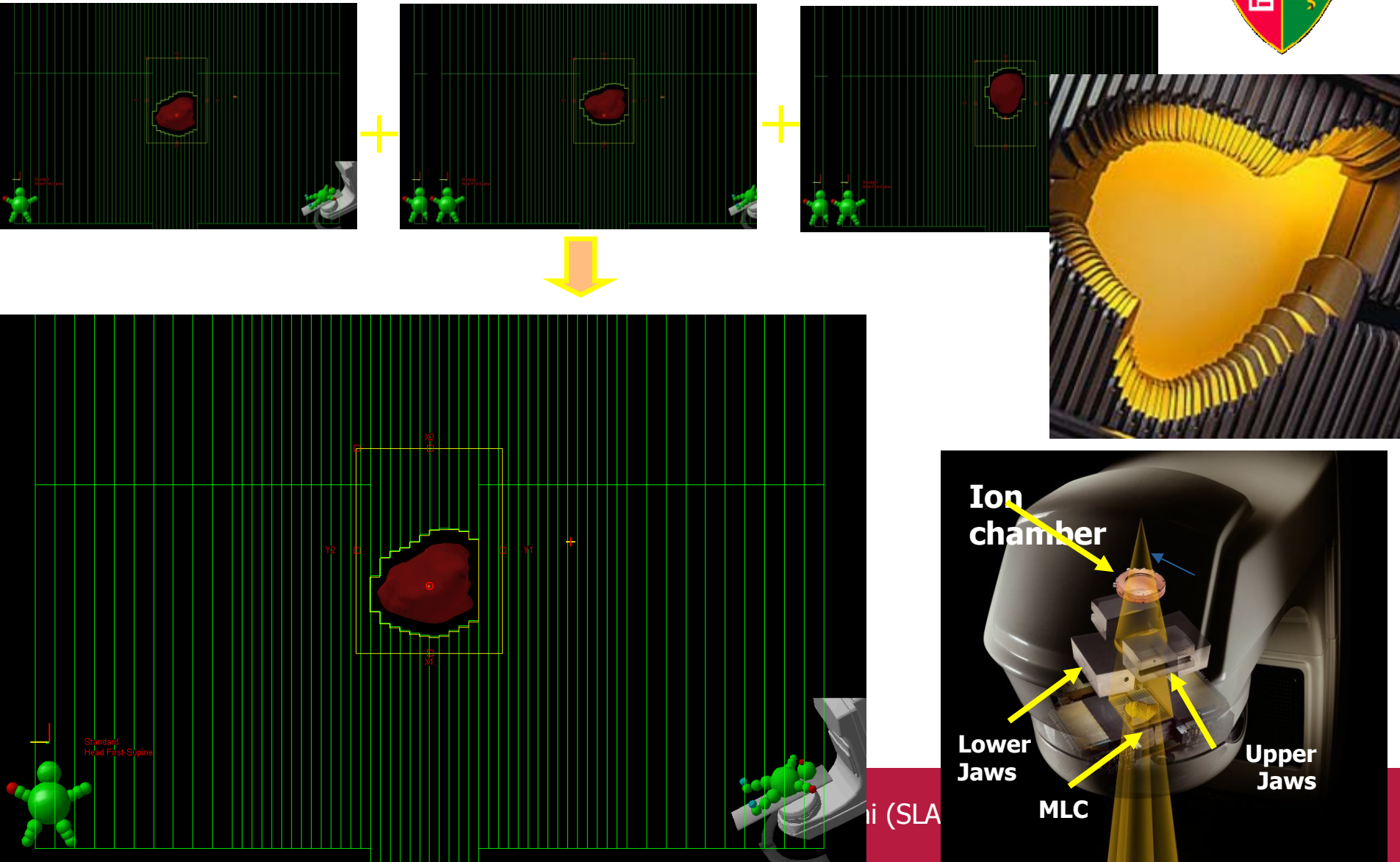
Moving objects



4D RT Treatment Plan



Source: Lei Xing, Stanford University



- In some applications, it is essential to simulate the movement of some volumes.
 - E.g. particle therapy simulation
- Geant4 can deal with moving volume
 - In case speed of the moving volume is slow enough compared to speed of elementary particles, so that you can assume the position of moving volume is still within one event.
- Two tips to simulate moving objects :
 1. Use parameterized volume to represent the moving volume.
 2. Do not optimize (voxelize) the mother volume of the moving volume(s).

Moving objects - tip 1

- Use parameterized volume to represent the moving volume.
 - Use event number as a time stamp and calculate position/rotation of the volume as a function of event number.

```
void MyMovingVolumeParameterisation::ComputeTransformation
```

```
(const G4int copyNo, G4VPhysicalVolume *physVol) const
```

```
{
```

```
static G4RotationMatrix rMat;
```

```
G4int eID = 0;
```

```
const G4Event* evt = G4RunManager::G4RunManager->GetCurrentEvent();
```

```
if(evt) eID = evt->GetEventID();
```

```
G4double t = 0.1*s*eID;
```

```
G4double r = rotSpeed*t;
```

```
G4double z = velocity*t+orig;
```

```
while(z>0.*m) {z-=8.*m;}
```

```
rMat.set(CLHEP::HepRotationX(-r));
```

```
physVol->SetTranslation(G4ThreeVector(z,0,0));
```

```
physVol->SetRotation(&rMat0);
```

```
}
```

Null pointer must be protected.

This method is also invoked while

Here, event number is converted to time.

(0.1 sec/event)

You are responsible not to make the moving volume get out of

(protrude from) t

Position and rotation are set as the function of event number.

- Do not optimize (voxelize) the mother volume of the moving volume(s).
 - If moving volume gets out of the original optimized voxel, the navigator gets lost.

motherLogical -> **SetSmartless**(**number_of_daughters**);

- With this method invocation, the one-and-only optimized voxel has all daughter volumes.
- For the best performance, use hierarchal geometry so that each mother volume has least number of daughters.