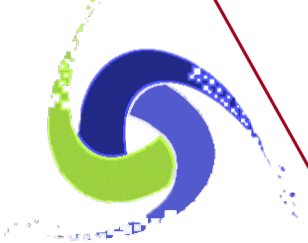

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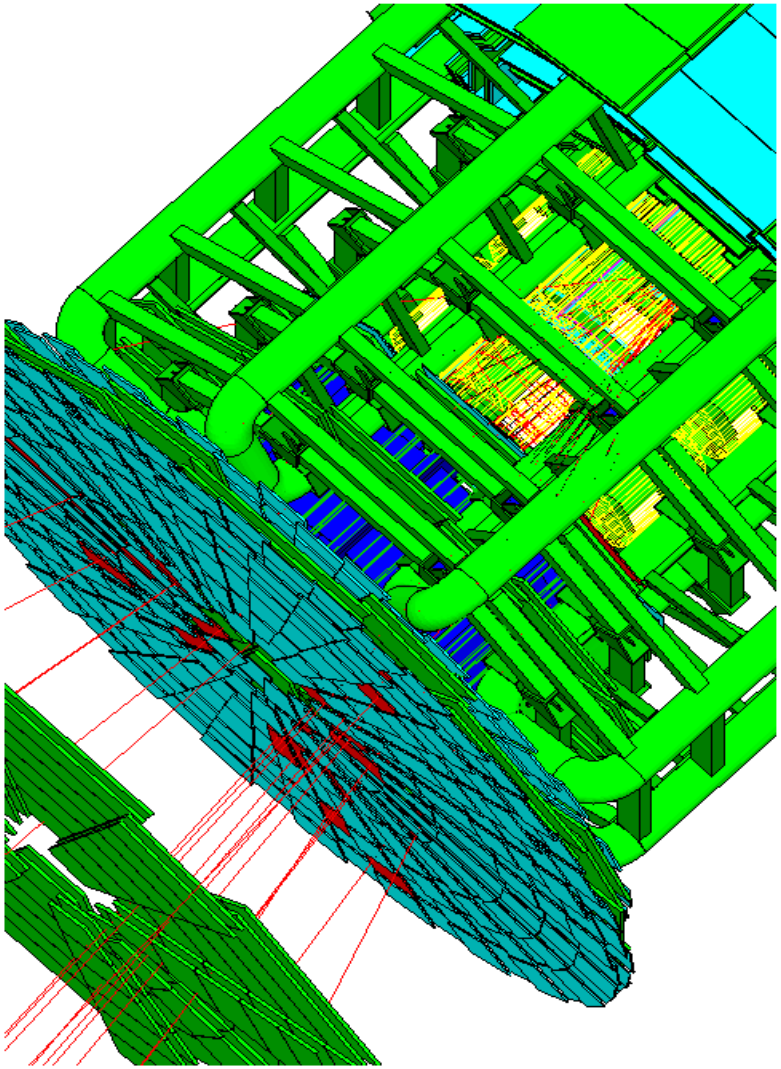
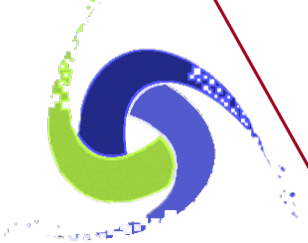
Geometry IV

Makoto Asai (SLAC)
Geant4 Tutorial Course

Contents

- Parallel geometry
- Layered mass geometry
- Moving objects





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Parallel geometry

Parallel navigation

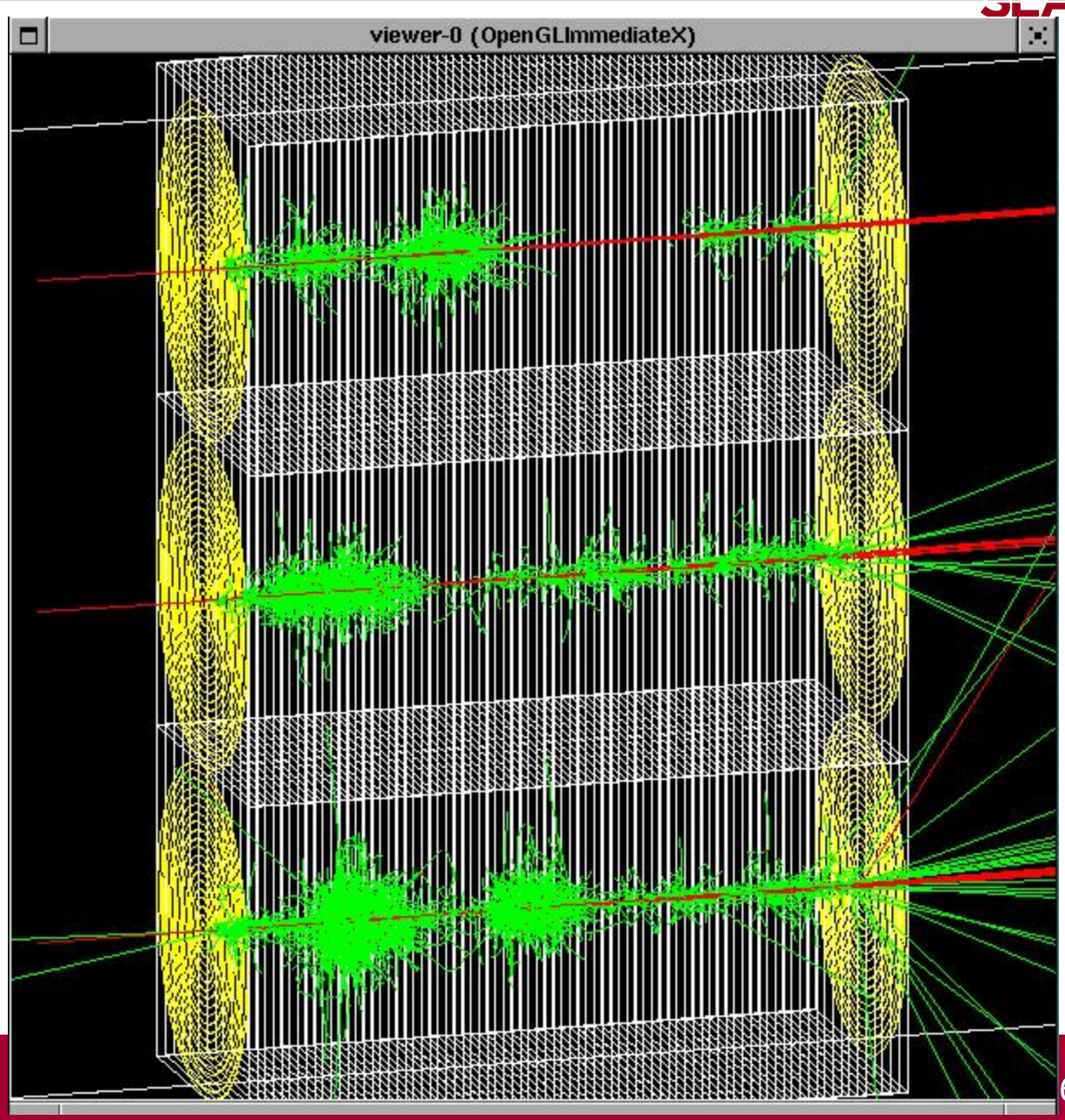
- Occasionally, it is not straightforward to define sensitivity, importance or envelope to be assigned to volumes in the mass geometry.
  - Typically a geometry built machinery by CAD, GDML, DICOM, etc. has this difficulty.
- New parallel navigation functionality allows the user to define more than one 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.

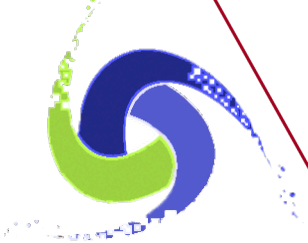
Parallel navigation

- G4VUserParrallelWorld 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.

example/extended/runAndEvent/RE06

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





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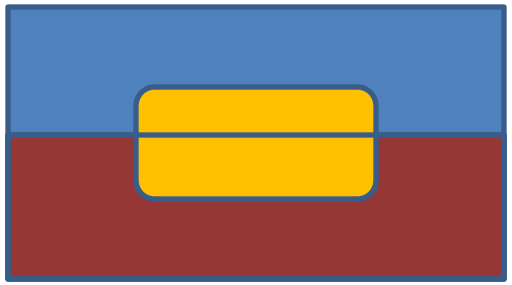
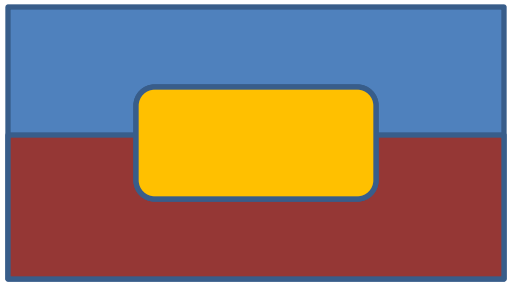
Layered mass geometry

Layered mass geometries in parallel world

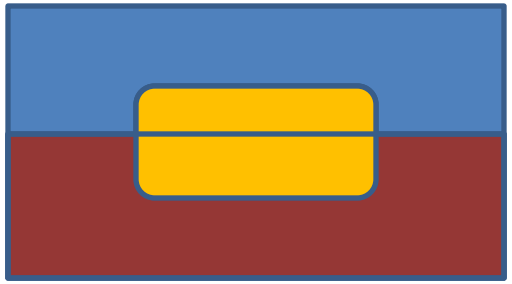
- Suppose you implement a wooden brick floating on the water.



- Dig a hole in water…

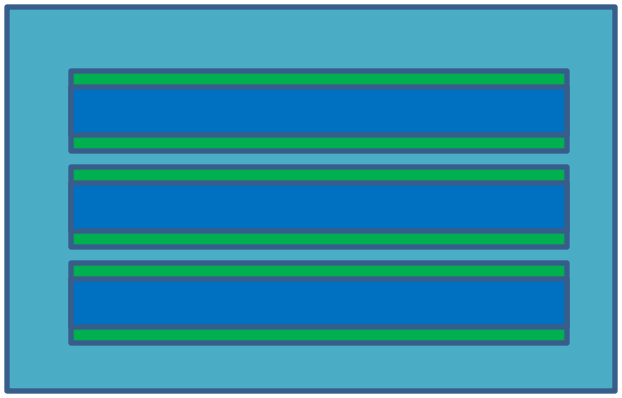


- Or, chop a brick into two and place them separately…

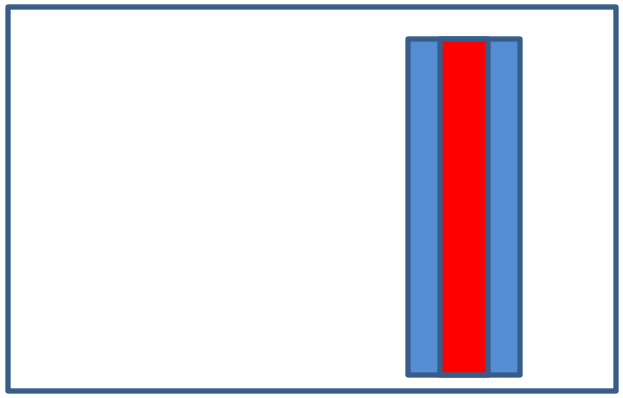


Layered mass geometries in parallel worlds

- 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

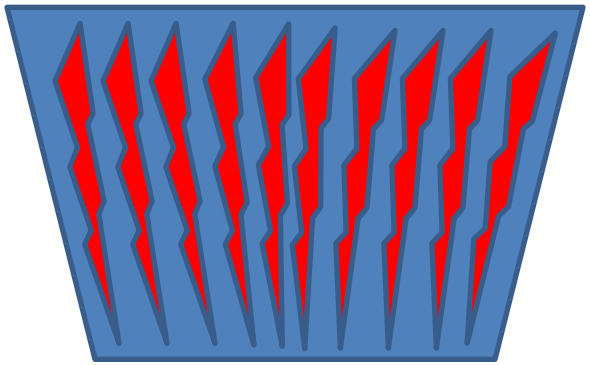


Parallel world

Layered mass geometries in parallel worlds - continued

- 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

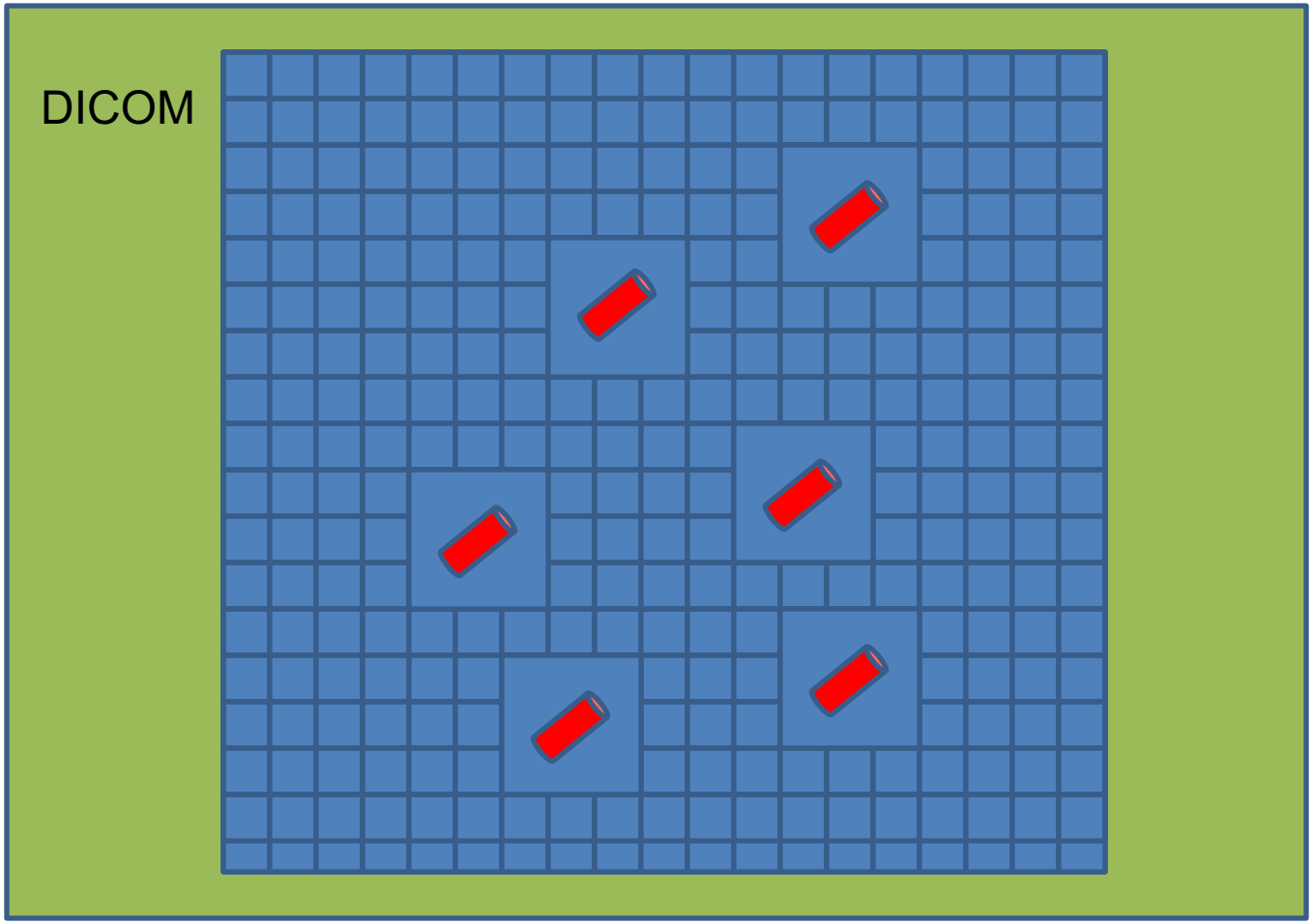
Geometry seen by e+, e-, γ



Geometry seen by other particles

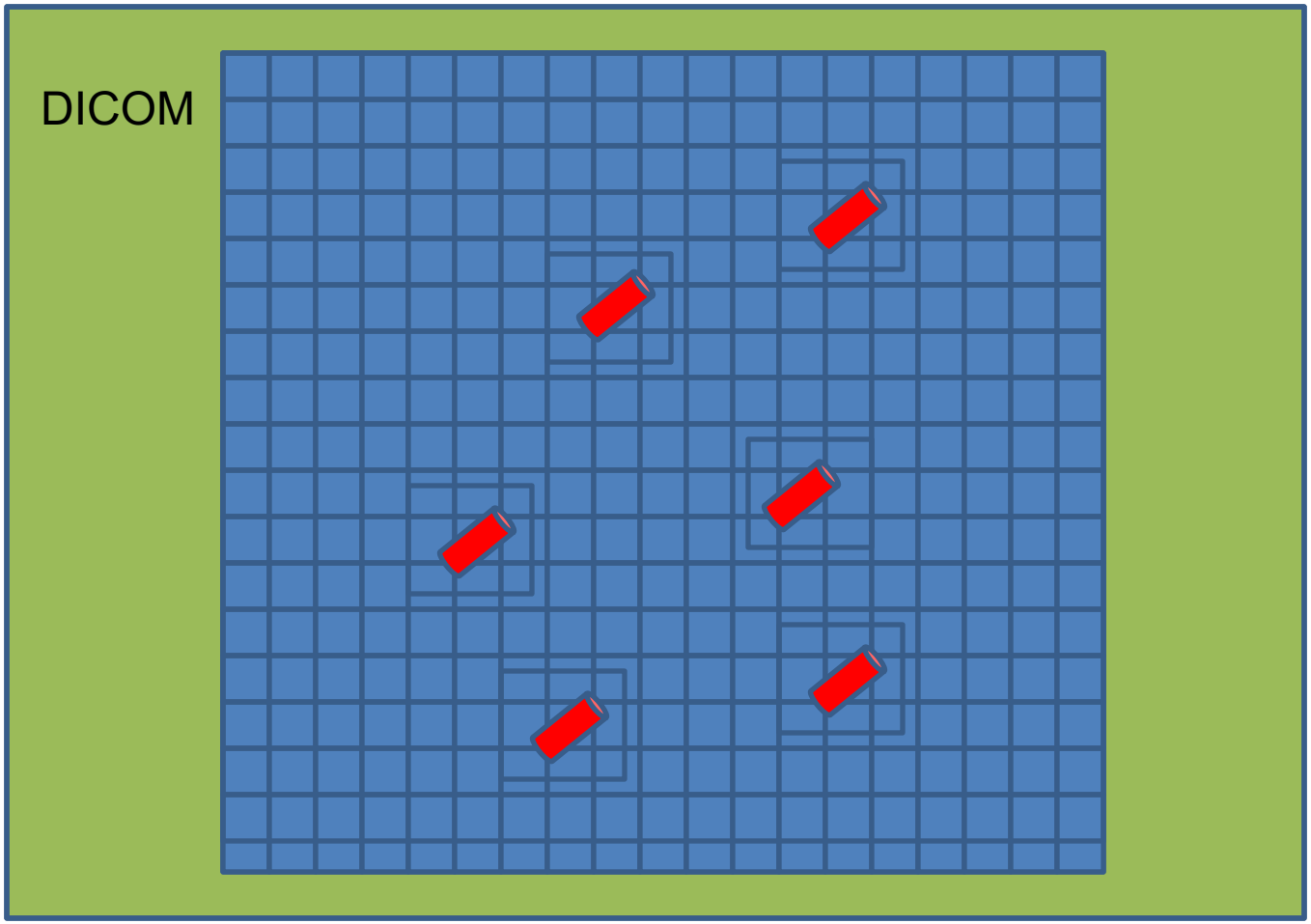
A medical use case

- Brachytherapy treatment for prostate cancer.



A medical use case

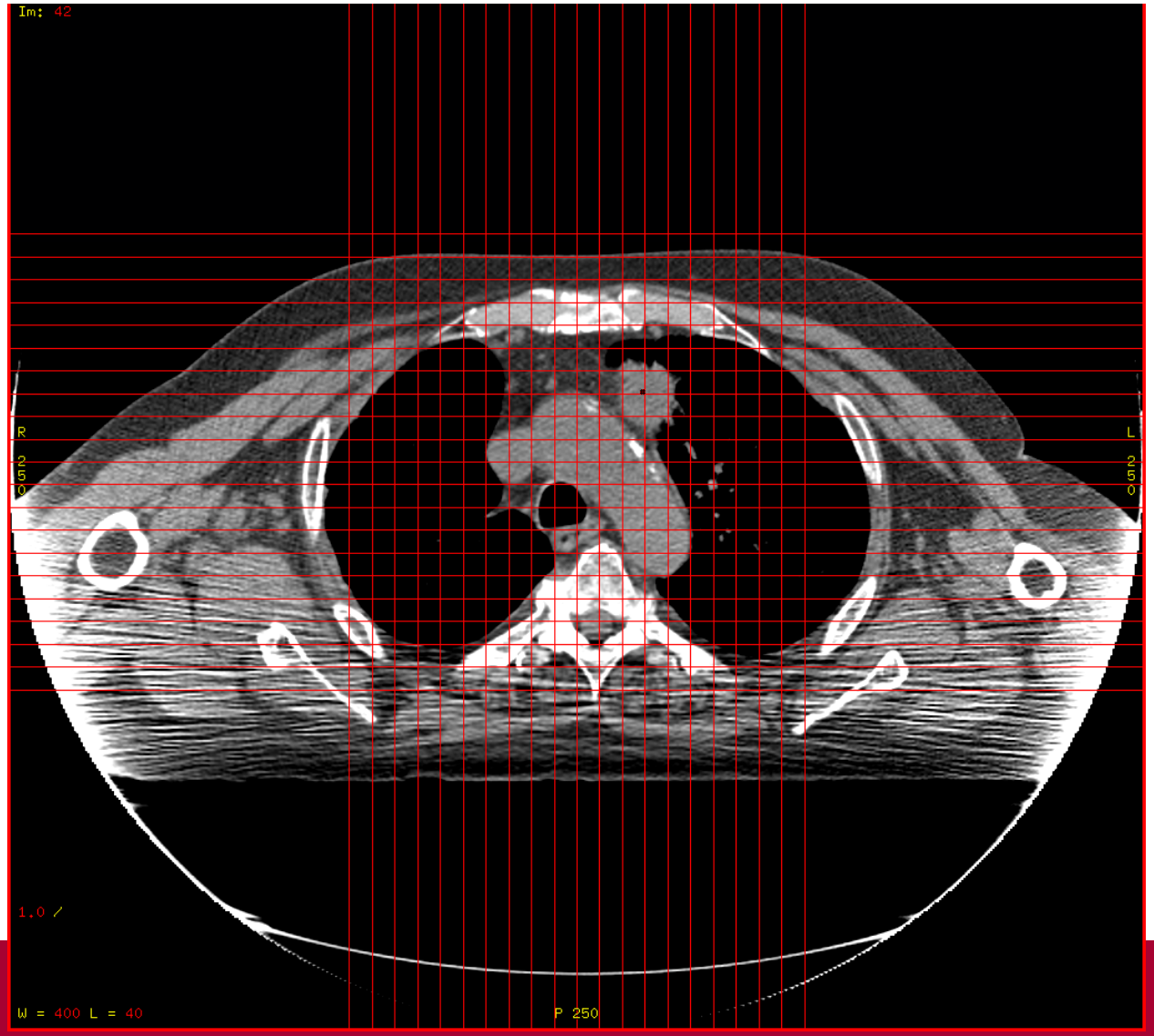
- Instead, seeds could be implemented in an empty parallel world.
  - Seeds in the parallel world would be encapsulated in empty boxes for faster navigation



Another important use case in medicine

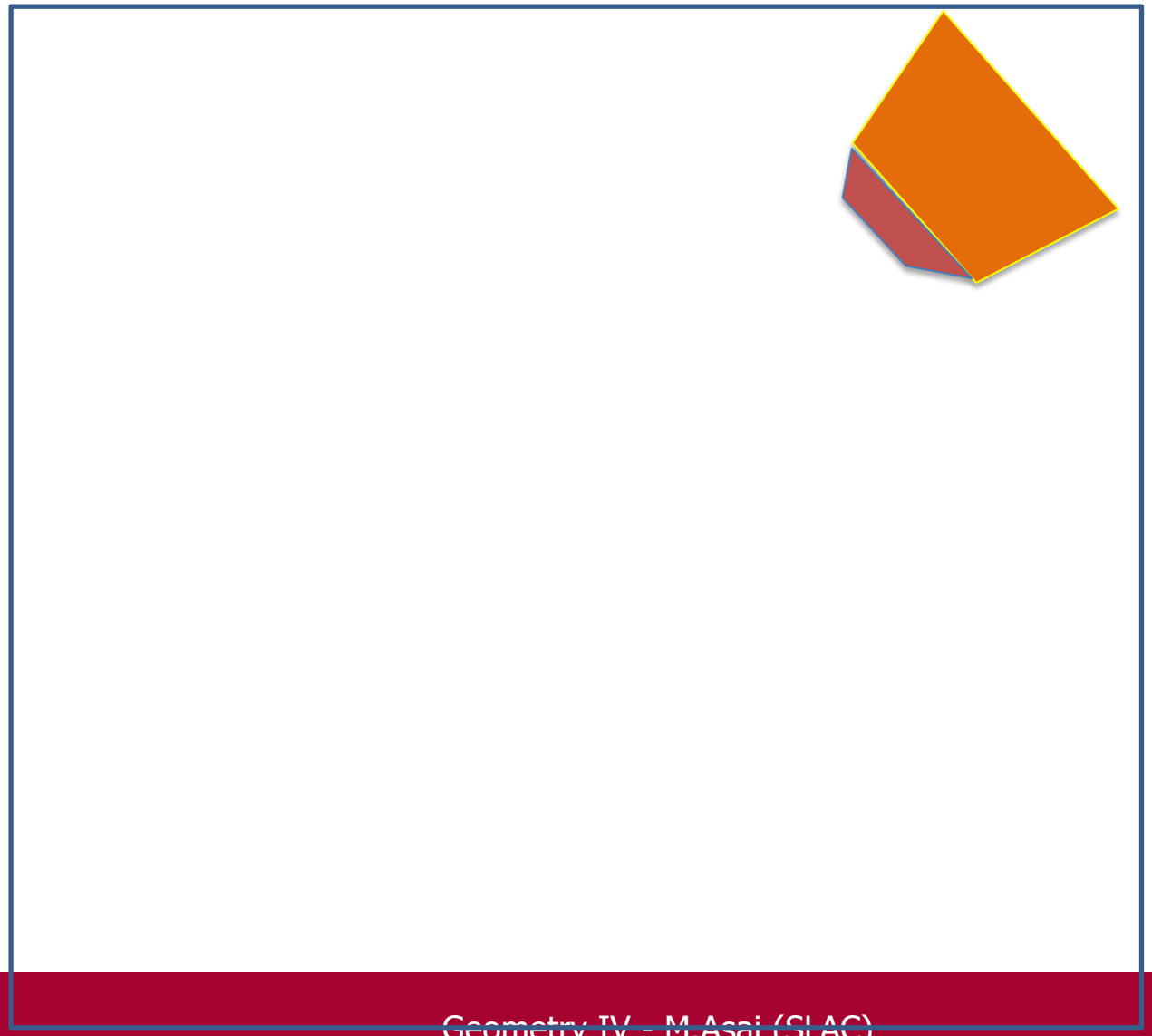
- DICOM data contain void air region outside of the patient, while the treatment head should be placed as close as patient's body.

DICOM



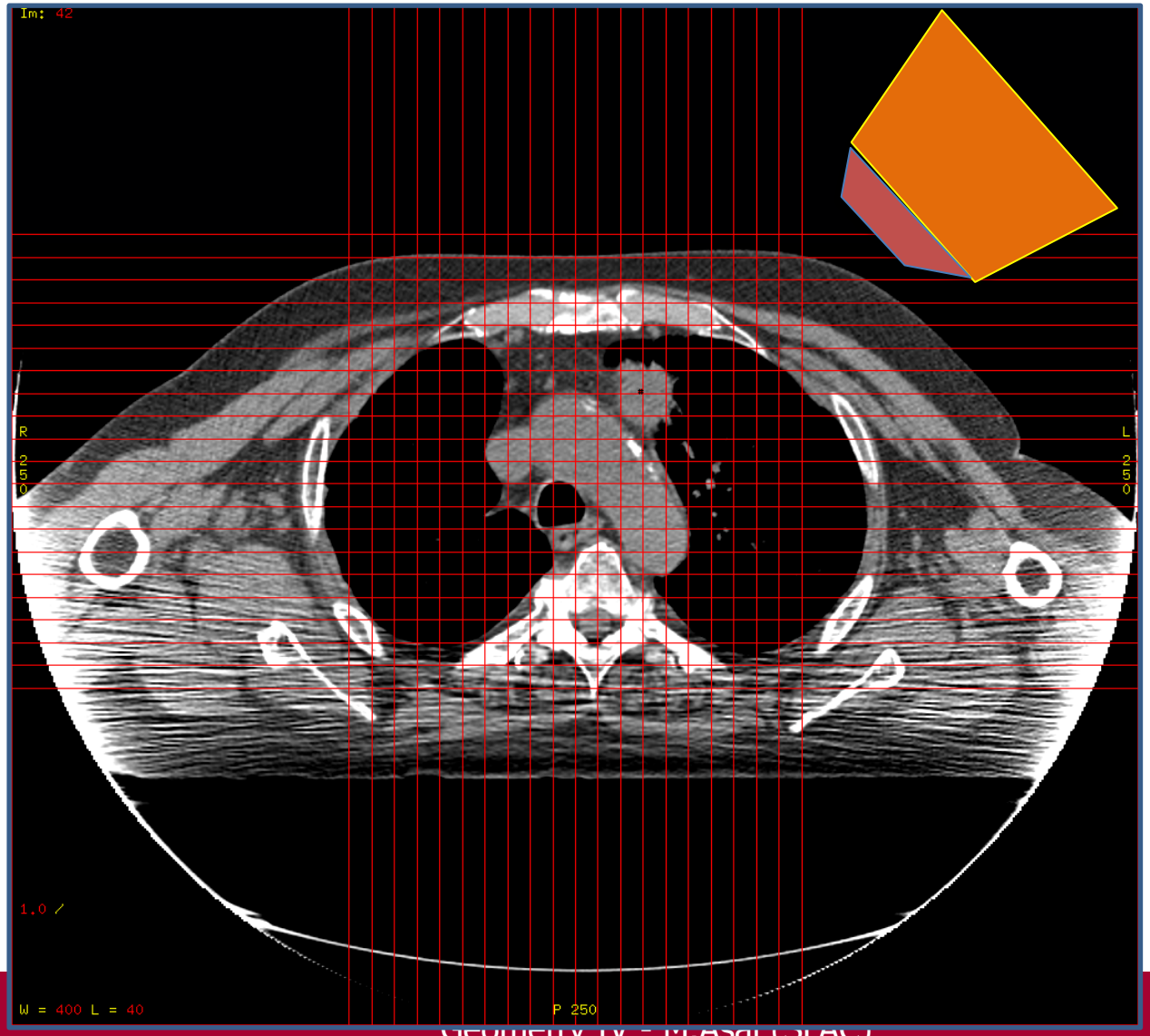
Another important use case in medicine

- Implement the treatment head in a parallel world.



Another important use case in medicine

- And overlay.

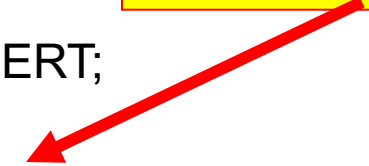


Defining a parallel world with layered mass geometry

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

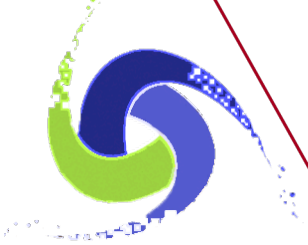


– The name defined in the G4VUserParallelWorld constructor is used as the physical volume name of the parallel world, and must be given to G4ParallelWorldPhysics.

Defining a parallel world

```
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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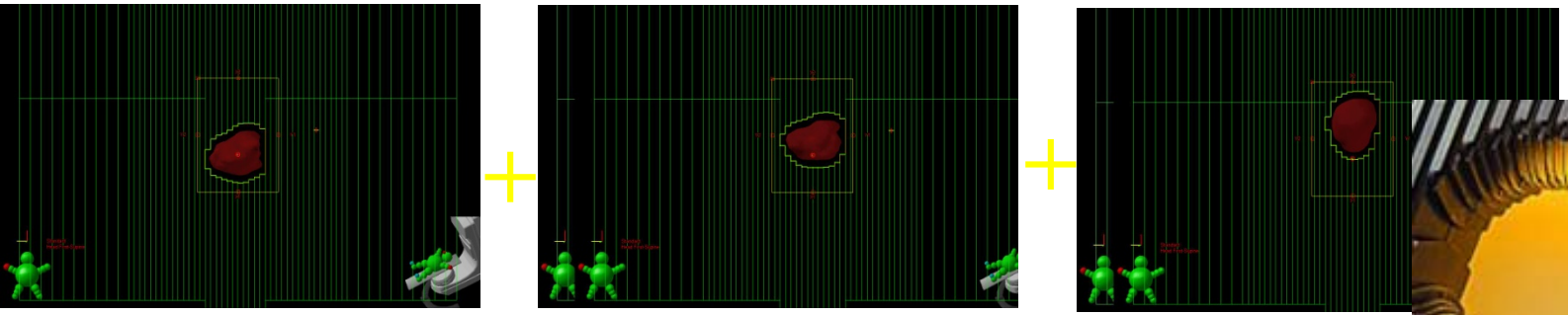
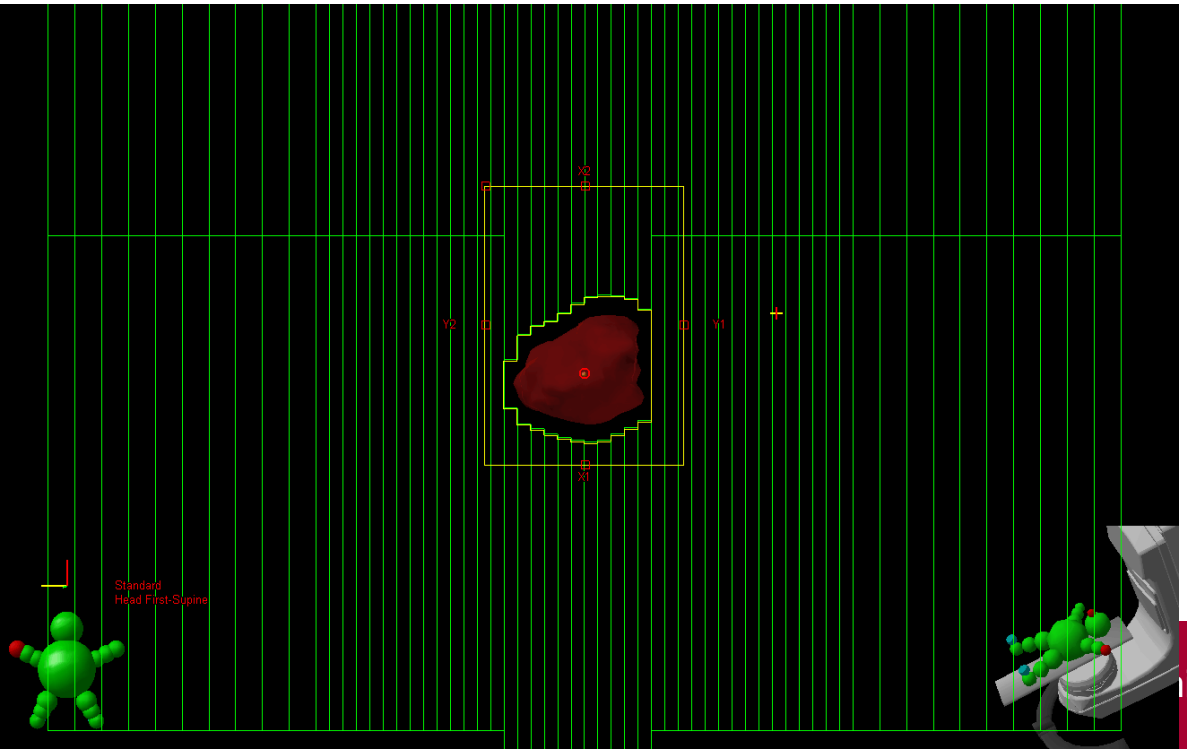
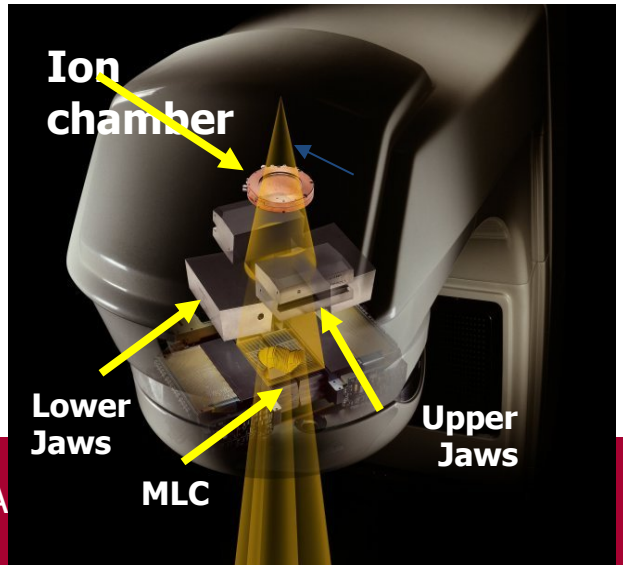
Moving objects

4D RT Treatment Plan

Source: Lei Xing, Stanford University







Moving objects

- 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::G
  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(G4ThreeVe
  physVol->SetRotation(&rMat0);
}
```

Null pointer must be protected.
This method is also invoked while
at

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.

Moving objects - tip 2

- 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.