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Representing Range Compensators in the *TOPAS* Monte Carlo System

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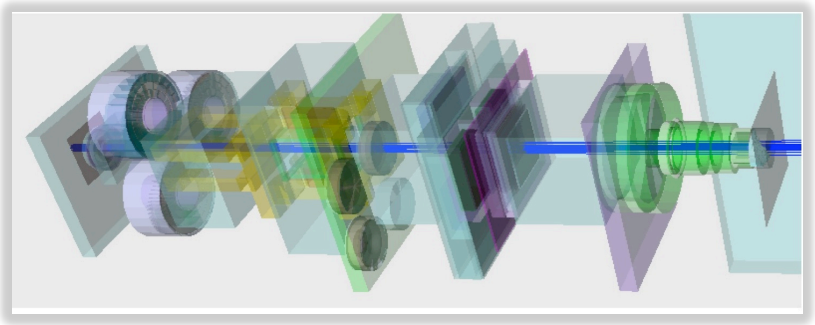
Overview

- Introduction to *Tool for Particle Simulation* (TOPAS)
- Range compensator overview
- Boolean Solid geometry
- Modeling compensators with Boolean Solids
- Approximation using Hexagonal Prisms for faster performance
- Comparison of Boolean Solids and Hexagonal Prisms
  - Performance results (computation time)
  - Accuracy

Introduction to TOPAS

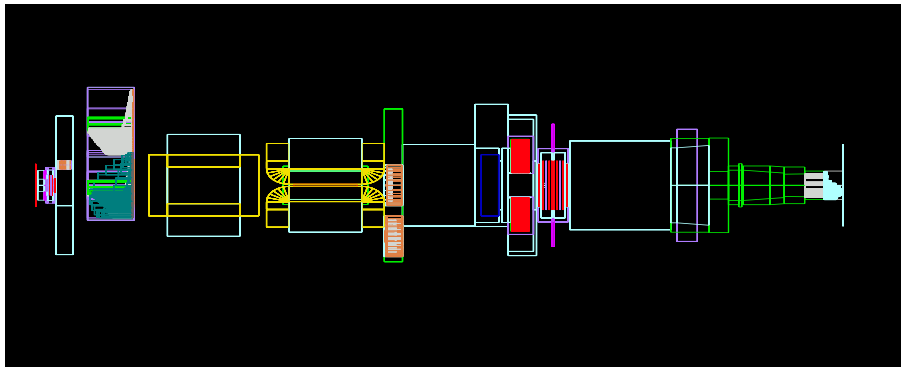
TOPAS (Tool for Particle Simulation)



- TOPAS aims at making **proton** Monte Carlo particle transport simulation easier to use
- User can easily customize beamline for specific treatment facilities
- TOPAS uses Geant4 for the underlying physics processes

Introduction to TOPAS

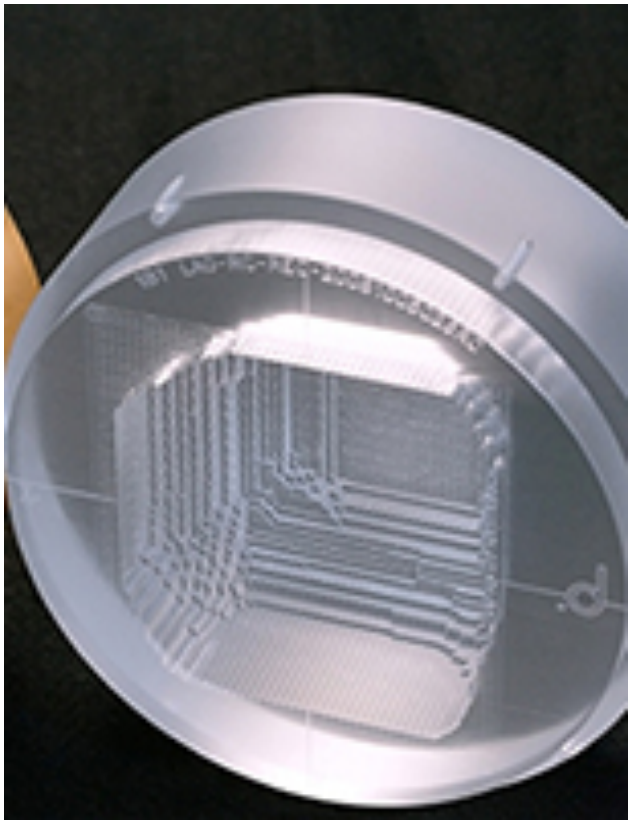
TOPAS (Tool for Particle Simulation)



- TOPAS provides numerous pre-built and customizable components. *For example:*
  - Propeller wheel for double scattering
  - Ion chamber
  - *Range compensators*

Overview of Range Compensators

- Range compensator produces a patient-specific energy spread
- Often designed in treatment planning software
  - Varian Eclipse
  - Elekta XiO
- Construction: drill a number of holes out of a cylinder of lucite
- Each drill hole may have a unique depth



Boolean Solids

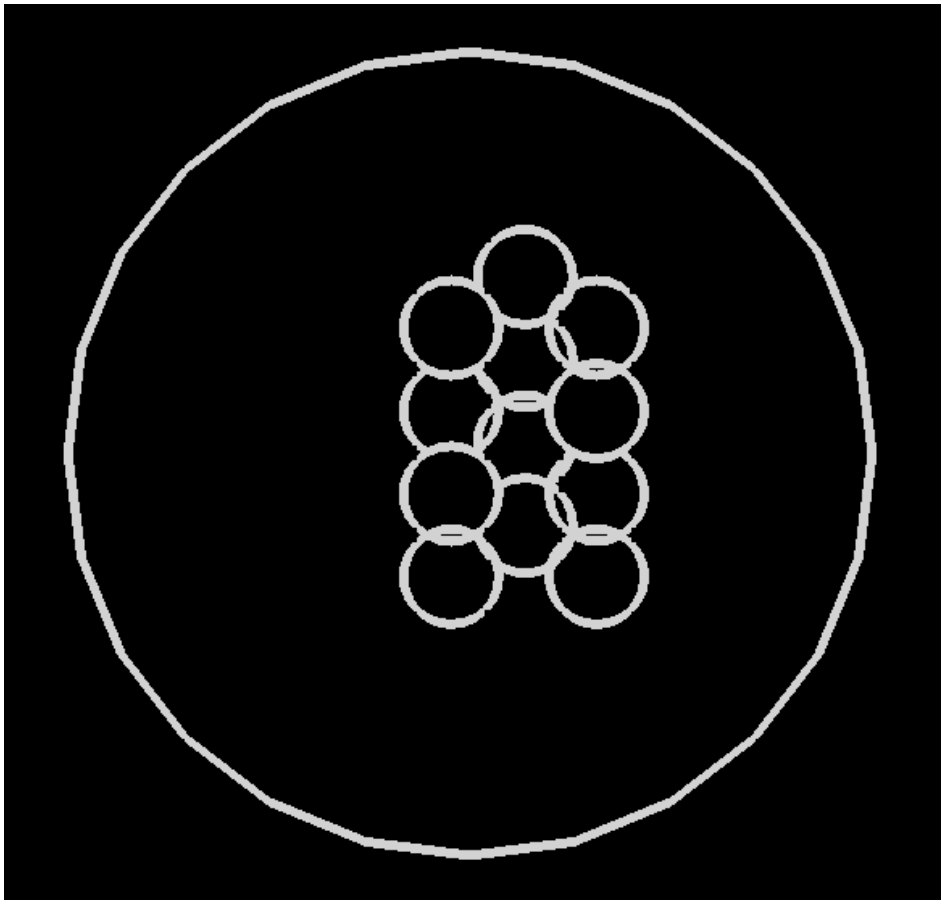
- Geant4 supports boolean solid combinatorial geometry
  - Subtraction solids
  - Union solids
- It's as simple as

```
newSolid = Solid1 union Solid2
```

or, `newSolid = Solid1 minus Solid2`

- Overlap among boolean solids is acceptable

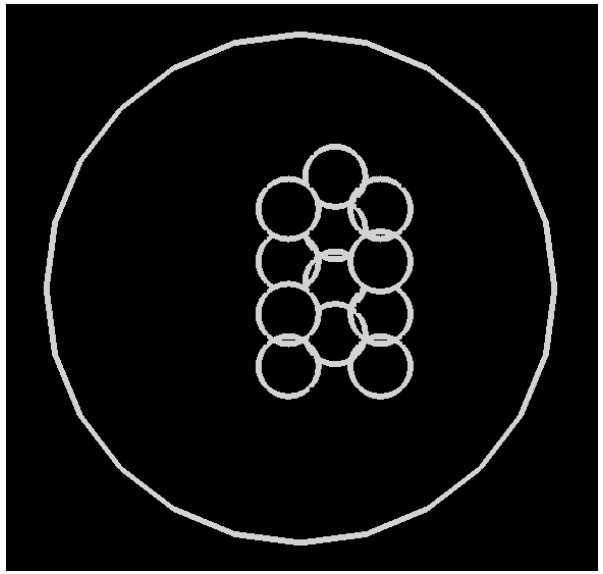
Compensator with Union Solids



Compensator with Union Solids

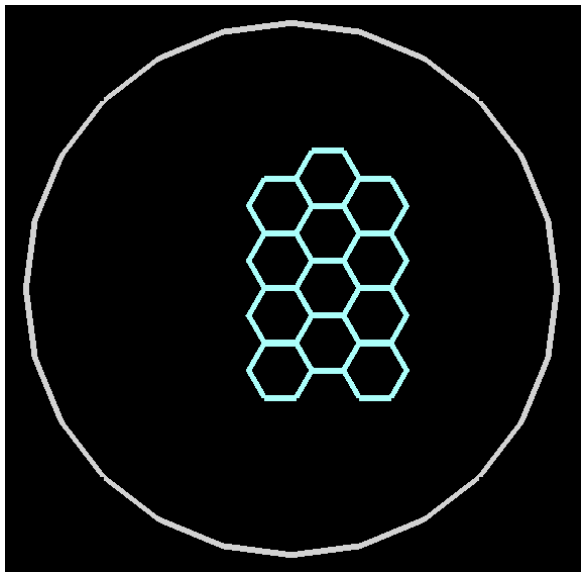
Compensator comprised of a bigCylinder with *n* holes unioned:

```
newSolid_1 = smallCylinder_1 union smallCylinder_2
newSolid_2 = newSolid_1 union smallCylinder_3
…
newSolid_(n-1) = newSolid_(n-2) union smallCylinder_(n-1)
Compensator = bigCylinder minus newSolid_(n-1)
```

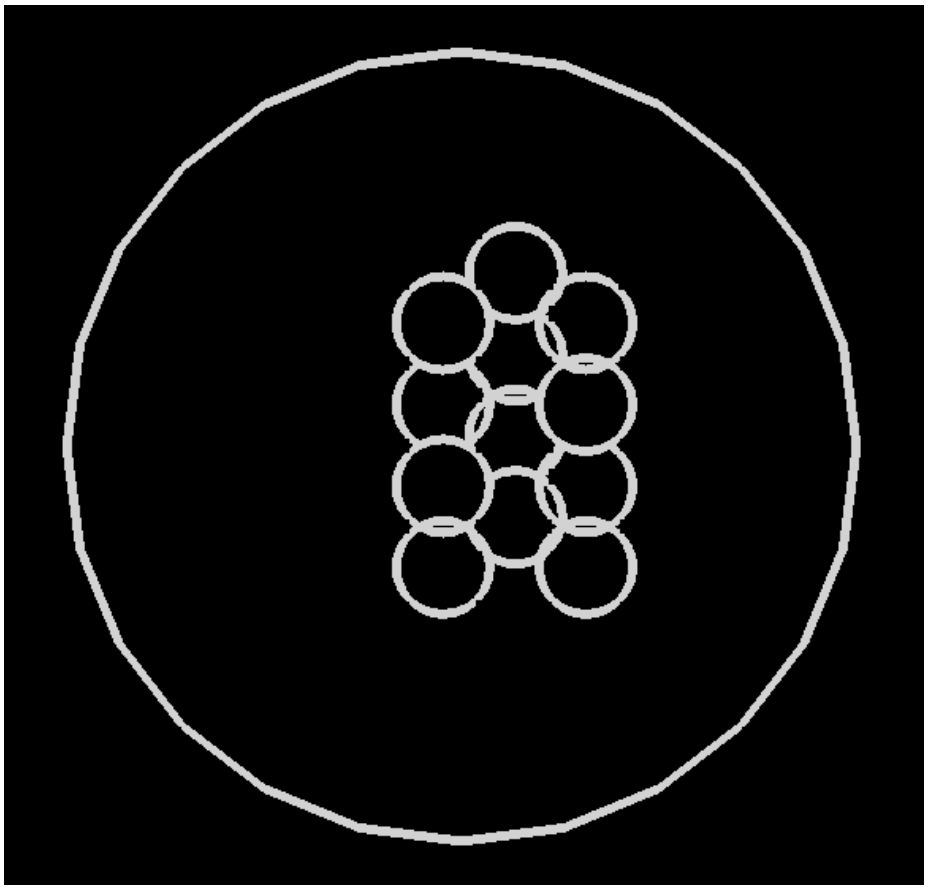


Approximation for Performance Gains

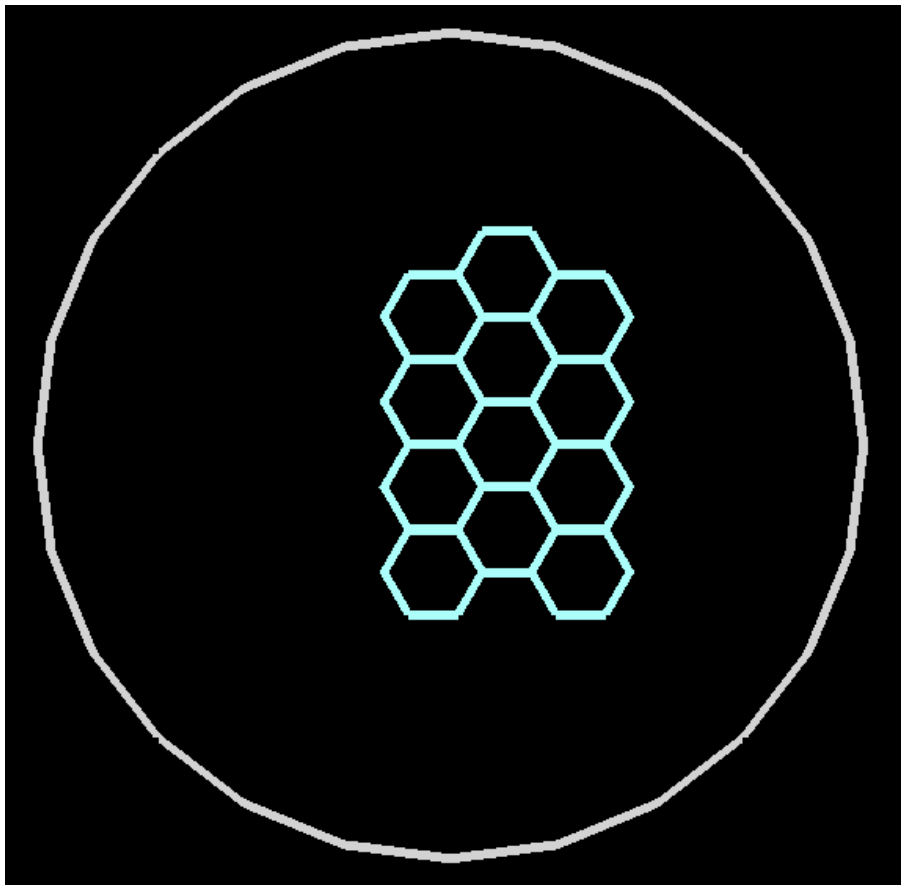
- Goal: reduce computation time
  - Want to exploit Geant4's navigation optimizations; this requires solids not to overlap
- Solution: Approximate the drill holes with hexagonal prisms
  - Easy to "nest" hexagons without overlap



Approximation for Performance Gains



Union Solids

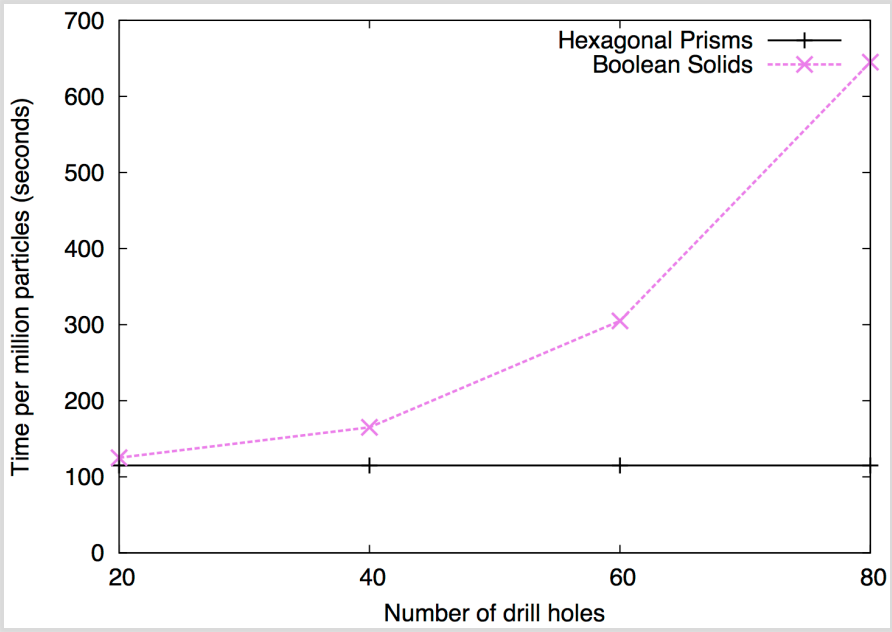


Hexagonal Prisms

Performance results

- Fixed number of particles; vary the number of drill holes
- With hexagonal prisms, navigation only looks at nearby boundaries in geometry
- With UnionSolids (boolean solids), navigation system traverses entire set of unioned cylinders

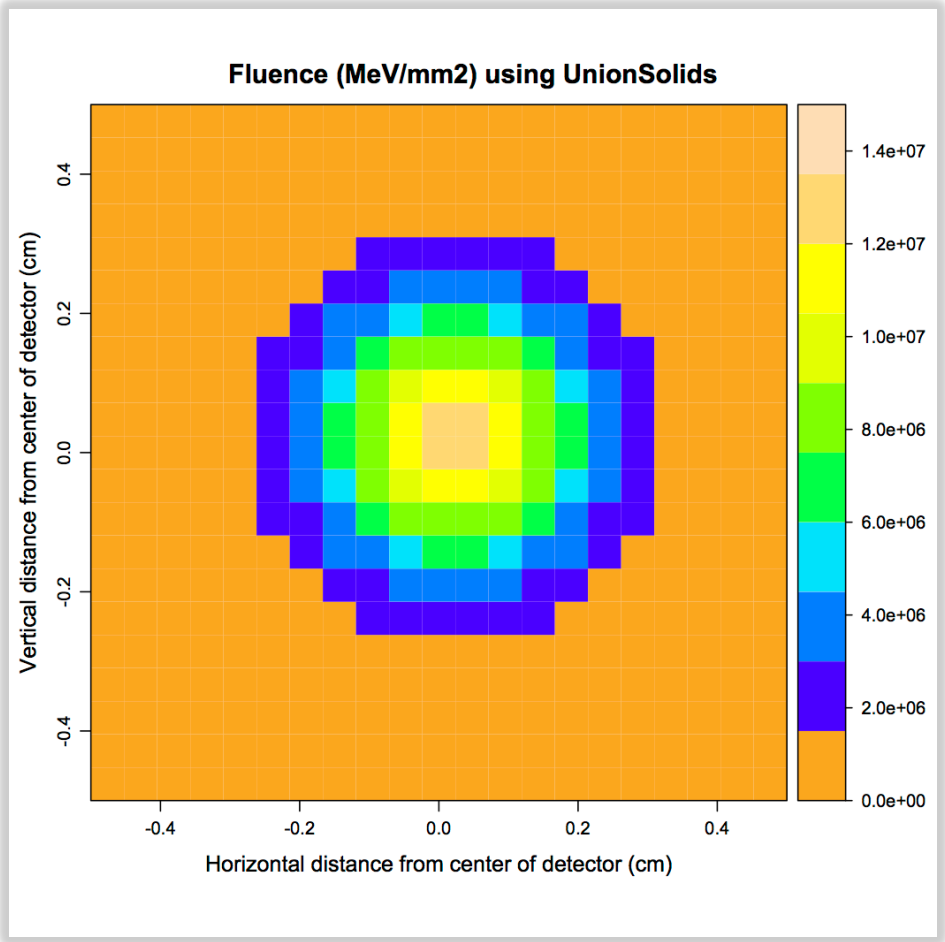
System specifications
- 2.6 GhZ AMD Opteron
- Used one core
- 8GB RAM



Accuracy results

Simulation setup:

- Real compensator from a treatment
  - Drill hole size: 0.475 cm
- 200 million protons
- Simulated in MGH FHBPTC beamline
  - 169.23 MeV
- Scored inside a volume of water
  - Water is placed 2cm beyond end of beamline

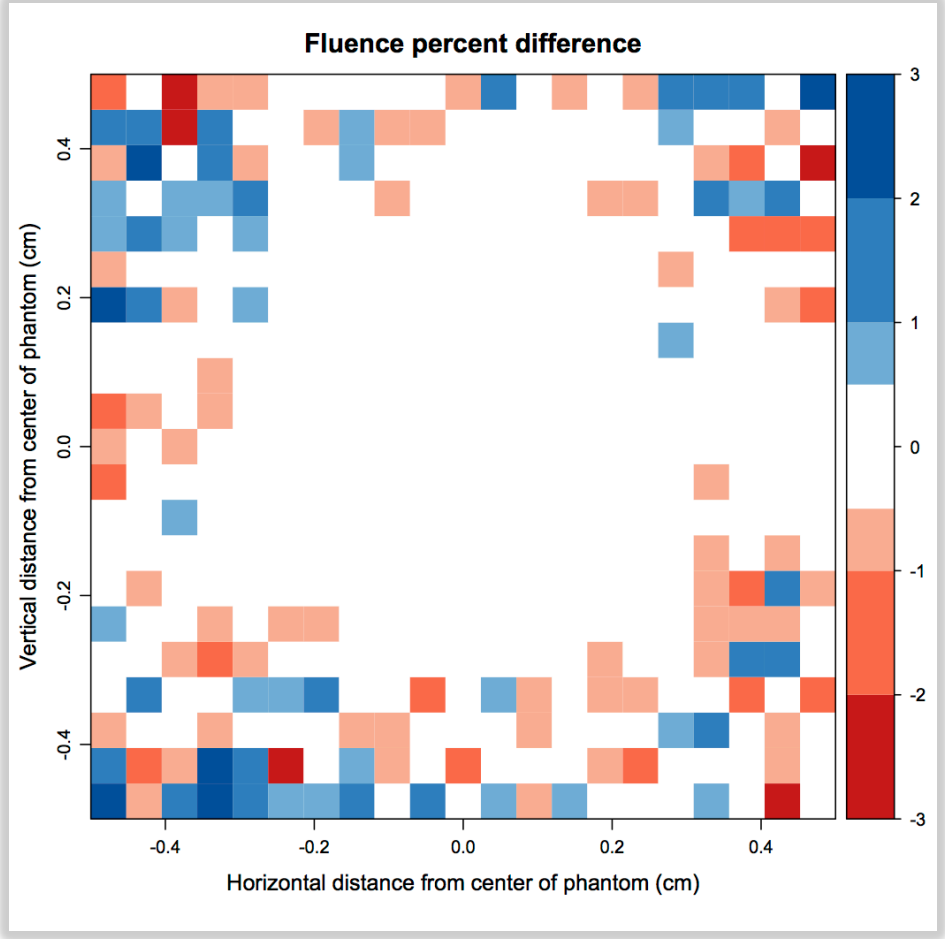


Accuracy results

Simulation setup:

- Real compensator from a treatment
- 200 million protons
- Simulated in MGH FHBPTC beamline
- Scored inside a volume of water
- *Results: within 3 percent difference*

UnionSolids vs. Hexagonal Prisms



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Conclusions

- Geant4 UnionSolids enable a *precise* model of patient-specific range compensators
- Approximation with Hexagonal Prisms provides significant performance gains
- The work discussed in this talk is implemented in *Tool for Particle Simulation* (TOPAS)

Acknowledgements

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