VecGeom Navigation in Geant4: an update

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Geometry Parallel Session - *Geant4 Collaboration Meeting* - 13 Sept 2021

Why use VecGeom Navigation in Geant4 ?

VecGeom Navigation offers a number of new features vis-a-vis G4(Voxel) navigation:

- Custom/separate types of navigation (compute step) via VNavigator interface
  - which can be customised / selected for each volume at runtime
- BVH-based ‘HybridNavigator’ which (can) use VecCore-accelerated operations to eliminate multiple candidate volumes via their (axis-aligned) bounding boxes.
- Custom safety calculation - selectable on per (mother logical) volume (at runtime)
  - Plus innovative method to calculate safety - using pre-computed lists of candidate volumes in the ‘subtraction’ volume of mother minus all daughters (beta - can require substantial computation for mother volumes with many daughters)
- Potential speedup of 10% seen in benchmarks of first version (2019)
- Ability to exploit features of VecGeom not available in current G4Solids ‘bridge’: shape specialisations, placed solids

Key elements

G4VecGeomNavigation library

- G4VecGeomConverter: convert G4 geometry and create VecGeom in memory
- TG4VoxelVecGeomNavigation: replacement for G4VoxelNavigation
- VecGeomG4Solid: wrapper for G4VSolid (for solid types not yet converted.)

G4VecGeomConverter

This class converts a Geant4 geometry in memory to a VecGeom Geometry

G4Placement	VPlacedVolume
G4LogicalVolume	LogicalVolume
G4VSolid	VUnplacedSolid

Converts most G4VSolids, including Box, Trap, ... Polycone.

Does NOT handle Replica / ParameterisedVolume / Division etc

G4VecGeomVoxelNavigation

Takes over navigation in ‘voxelised’ volumes (if activated)

- Called ONLY if G4 criteria for **G4VoxelNavigation** are met: #daughters>= 3
- Can operate in ‘solo’ or ‘comparison’ mode - the latter compares answers with G4VoxelNavigation (and returns G4 answer by default.)

Status in December 2020

- Initial implementation and benchmarks - presented at CHEP 2019
- Conversion supported most popular G4VSolid types (box, trap, .. polycone) -
- Initial benchmarks promising - 10% CPU improvement for (artificial) test case with large number of daughter volumes
- Some capabilities not yet robust, or not implemented:
  - Geometries with touching surfaces caused navigation errors
  - Multiple VSolid types used in LHC experiments not (yet) converted

Updates (summary)

G4VecGeomConverter: fixes + expanded types that can be converted

G4VecGeomVoxelNavigation & VecGeom Navigators: extensions / fixes

Geant4 example demonstrating its use in release 11.0-beta (June 2021)

- extended/geometry/vecGeomNavigation - requires recent VecGeom release

Updates

G4VecGeomConverter - update

Fixes for Trap,

Convert more G4VSolid types: Para, Orb, Generic Polycone, Tet, Polyhedra, CutTubs.

Separate files for ‘GenericPlacedVolume’ and ‘VecGeomG4Solid’ & added default methods

Latest branch/MR (work in progress):

- set MaterialPointer to index of G4HepEM material.
- set MaterialCutPointer to index of G4HepEM material cuts couple.

To be investigated:

- Interface also existing VecGeom Replica / Division capability

G4VecGeomVoxelNavigation - update

- Cope with points on common surface between touching volumes
  - uses new implementations in VecGeom's navigators to ignore a just-exited volume
- 'Comparison mode' reports differences in detail and ignores small differences
  - Critical to understand origin of difference - e.g. is different answer of G4 vs VecGeom solid ?

‘Modes’

- Runtime Check (or not) the compatibility with answers of G4(Voxel)Navigation
- Compile time: does G4 installation use G4Solids, VecGeom solids or mixture?

Note: most recent testing (JA) was using G4Solids for Geant4, not VecGeom solids => this can account for differences (some? / most?)

Test cases

New test cases:

- ’NTST’ geometry (D. Williams, UCSF) Inner Detector of Babar (ca 2001)
- FullCMS - imported from cms2015.gdml or cms2018.gdml
- ATLAS - gdml files from FullSimLight (Marilena Bandiaramonte)

Current results:

- NTST: runs reliably in either mode
- FullCMS: reports differences in ‘comparison’ mode; fails standalone
- ATLAS: under testing …

‘Applications’

You can try these capabilities out in two ways:

- Use the example FullCMS in vecgeom/G4VecGeomNavigation repository
- Use (or copy) the G4 example in examples/extended/geometry/vecGeomNavigation

Please try it out. Feedback welcome:

- reports of success or problem with other geometries
- problems with fixes are super welcome !!

New extended example

In release 11.0-beta the new examples/extended/geometry/vecGeomNavigation directory includes a simpler setup which:

- Reads in a GDML file into Geant4
- Converts the geometry to create the equivalent VecGeom setup
- Navigates in either both setups depending on configuration
  - In ‘comparison’ mode it reports differences verbosely

This example imports a selected version of the VecGeom/G4VecGeomNavigation repository, compiles and links it

- thanks to Ben Morgan for rewriting this capability to make it robust.

A (few) more details in Extended Examples parallel session (Thursday).

Caveats / pitfalls - or where care is needed

It can be tricky to configure this capability currently, as it requires:

- VecCore (testing configured to use Vc on SSE4)
- VecGeom (using VecCore) - recent version (30 June 2021 or later)
- Geant4 configured to use above (11.0-beta or 10.7-ref-07+)
- G4VecGeomNavigation (from VecGeom gitlab account)

If your head is not spinning yet, wait until you get a linking error after you have configured all these …

So simplifying this configuration (stack) should be a near-term goal !!

Next steps / plans

- (Pre-condition:) Improved VecGeom ‘integration’ in G4
- Extend test cases
- Improve robustness: identify cause(s) of differences between G4 & VecGeom answers
- Performance testing for mid and high complexity setups (NTST, LHC det.)
- Embed converter & Voxel-Navigation capability/code inside G4 (tbc)

Details

Adapted to separate library TGeo2VecGeom library

- for Root<-> VecGeom conversions
- allows builds of VecGeom without Root

G4VecGeomConverter

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Already converted many G4VSolids, from Box to Polycone.

Added methods in G4VSolids to access missing parameters (G4Trap)

Extended to additional solids: