Geant4 ‘kernel’ at release 6.1

Highlights of developments & improvements

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for the Geant4 collaboration

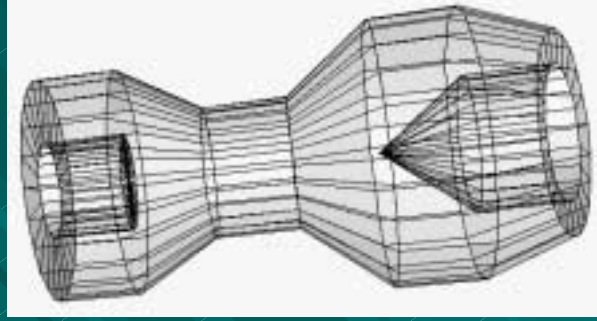
Outline

- The ‘kernel’
  - Its categories
- Highlights of previous changes
  - In releases 5.x and 6.0
- Recent changes in 6.1
  - and some upcoming in 6.2
- In Development (after 6.2)
  - Revision of ‘tolerance’

Categories

- Kernel categories
  - Run
  - Event
  - Tracking
  - Process Management
  - Track
  - Geometry
  - Particles
  - Materials
- Auxiliary modules
  - Visualisation
  - GUI / User Interfaces
  - Graphical representations

Run / Event



- Redesign of RunManager
  - Modularization
    - separation of ‘mandatory behaviour’ into G4RunManagerKernel class
  - Additional entries
    - For HEPMC event, track vector
    - Merging different kinds of primaries
- Maintain link between pre-assigned decay products and its primary particle

Process Management

Physics tables save/reload

- New requirement to cope with different setup on loading (compared to save)
  - Several stages
- First step: improved error reporting (on failure) [6.0]
- Second step: functionality improvement (6.1)
  - Can read tables with different ordering of materials
- Future refinements
  - In planning stages (no process changes)
  - Under discussion (others)

Geometry

- Abstraction of G4Navigator (G. Cosmo)
  - First level abstraction
  - First consolidation of interface
- Addition of Divisions (P Arce)
  - Extend capability of Replicas
    - Offsets available
- Fixes in Solids (V. Grichine)
  - Safety in Boolean & CSGs
  - Sphere ‘tolerance’ fix (W. Pokorski)

Propagation in EM Field

- Performance enhancement (5.2)
  - Refinement of integration driver
  - 15-20% improvement seen (benchmarks, CMS)
- Ability to specialize integration accuracy
  - ε_{min}, ε_{max} now for each FieldManager
    - Relative error for position, momentum direction, etc integration
- Choice of FieldManager by track
  - Eg you can use it choose more precision for muon or for tracks > 5 GeV

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Propagation in EM Field (cont)

- Ability to use variant ChordFinder (in 6.0)
  - Tailor to geometry
  - For improve performance
    - By avoiding extra steps

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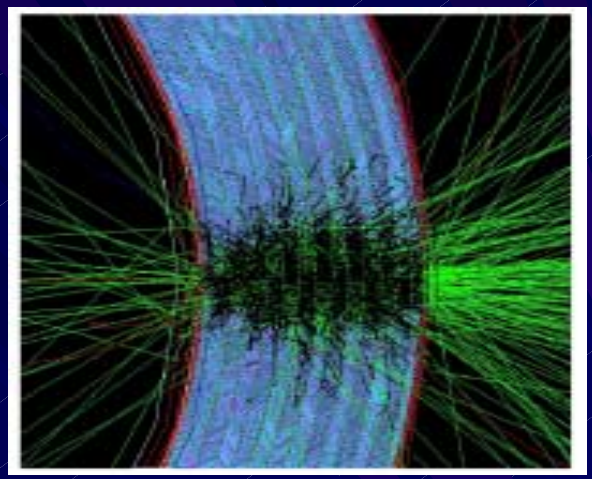
- Fixes for missing intersections (in 6.0)
  - Missing call to Navigator for chord (infrequent)
  - Repositioning error in rare conditions
- Default parameters changed for higher accuracy

$\delta_{intersection}$, ε_{min}, ε_{max},

Additional categories



- Visualization
  - Of ghost geometries for parameterization
  - New HepRep XML driver for HepRep
  - New visualization commands
  - Improved handling of auto-refresh at end of event/run
  - Removed obsolete OPACS driver.
- Environments
  - MOMO Java tools are now included
    - GGE (Geometry editor), GPE (Physics editor)

Biasing

- Geometrical / Importance biasing
  - In mass or ‘parallel’ geometry
  - Tailored for geometries of small to medium complexity
- Co-works with scoring
  - Simple but extensible
- New
  - First implementation of “weight-window” biasing technique

M. Dressel (form at CERN)

Major items for users' code migration

- Forced usage of touchable-history to retrieve information for the geometry hierarchy
  - Removed pointer to mother PV in **`G4VPhysicalVolume`**
- New default values (more accurate) for propagation in field
- 'Non-magnetic' fields require now their chord-finder and equation of motion initialized directly
- New interface for registration of cross-sections in hadronics, now registered directly with the process *(*)*
- Exception handling enabled in hadronic physics *(*)*
- Mandatory kernel functionalities of the run-manager are now grouped in the new **`G4RunManagerKernel`** class *(*)*
- New data set for low-energy EM processes

(*) for advanced users

Items of development (after 6.2)

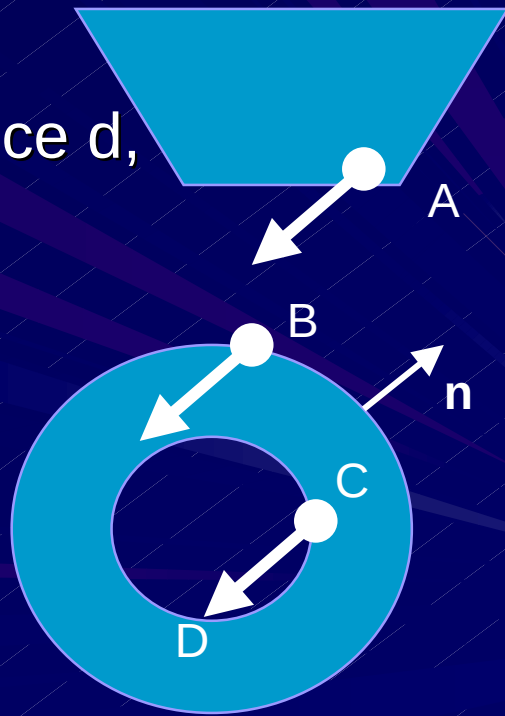
- Geometry
  - Physical volumes with a parameterisation and placements.
  - Revision of the ‘Cartesian’ tolerance
    - Proposal for adjusting it to problem size
    - For details see next slides
  - Customization of the volume registration
    - Enable user action on volume creation

Tolerance: what is it (for) ?

- Intersection of ray and surface
  - Should be point on surface
  - Yields imperfect ‘point’
    - With finite precision arithmetic
- Next step can encounter same surface
  - Giving extra, unnecessary, boundary crossings and steps
- In Geant4 the tolerance is used to avoid this:
  - An intersection at a distance d < tolerance / 2 is discarded, except to enter a solid.

Use of ‘tolerance’ in navigating

- Inside
  - If point is within tolerance/2 of exact surface, then it is considered on the surface
- DistanceToOut (point, direction, ..)
  - Do not consider an intersection at distance d, if |d| < tol / 2
    - No intersection
- DistanceToIn (point, direction)
  - If intersection distance is |d| < tol/2,
    - Ignore if $u_{dir} \cdot n^{exit}_{normal} > 0$



Tolerance today

- Different types, defined in geomdefs.hh
  - "Cartesian", absolute length: kCarTolerance = 10^{-9} mm
  - "Angular", relative: kAngTolerance= 10^{-9} rad
  - "Radial", absolute length: kRadTolerance= 10^{-9} mm
- Constants, determined at compile time
  - Must adapt G4 installation to problem size.
- Values chosen to be much
  - Smaller than any physically important length scale
  - Larger than machine precision (ε) for typical sizes (L)

$$\varepsilon L << t_{car} << \lambda$$

Difficulties with tolerance today

- Issues
  - Default values are not good for large (> 10Km) or small (< 1μm) setups
  - Corner problems for solids with large length ratios
  - Cannot use a single G4 installation for problem sizes with wide range of scales.

Current actions & proposals

- Relative tolerance for radius
  - Implemented in G4Orb already
    - A simple ‘full’ sphere
- Studied and are prototyping a revision of the tolerance
  - Changing it to a value that is fixed for a run
  - Adjusting it to the problem size L_{max}

$$t_{car} \cong \varepsilon L_{max}$$

Summary

- Geant4 kernel in release 5.1 to 6.1
  - Changed to accommodate regions and associated productions thresholds
  - Evolved ‘at the margin’, given its maturity
- Key areas of kernel evolution
  - Extension / orthogonalization of geometry creation capabilities
  - Performance and robustness improvements
  - Great benefit from User feedback (Thanks!)
- Refinements & further improvements and development are ongoing.

THE END

Thanks to all

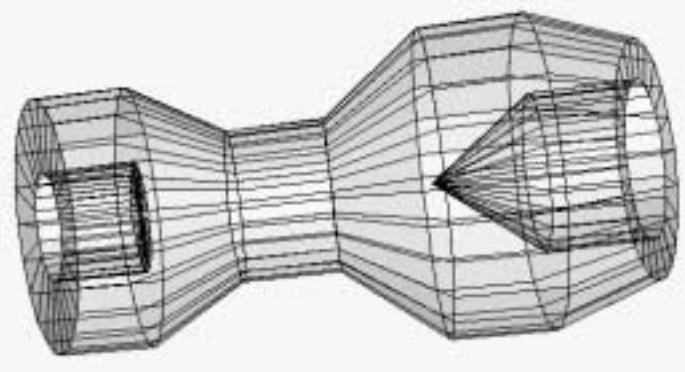
- Contributors
- Users

Also new in Geometry

- Reflection of a volume hierarchy — I Hrivnacova, G Cosmo, V Grichine
  - Eg to create endcap geometry
- Improved voxelisation for performant navigation — G Cosmo
  - 3-D voxels for parameterized volumes
    - Now equal performance to 'placed' volume
  - Option to avoid voxelizing some volumes
- 'Illegal' geometries detected & rejected — G Cosmo
  - E.g. incompatible daughters (placed & param. in one mother)
- XML binding: GDML 1.0 released — R Chytracek
  - Specification & Implementation
    - First 'input' module available'.

New Viz functionality

- New commands, with better control
- DTREE
  - Output of geometry tree
    - To ascii
- Visualisation of Boolean solids



- Future:
  - DCUT: slice view in multiple drivers
  - Improved DrawTrajectory()
    - Curved trajectory handling

Geant4 5.2: other issues

- Release 5.2 builds on the release 5.1 of end-April, which provided the "cuts/region" capabilities - a major development required by large experiments (on timescales agreed Sept 2002, which revised original ones of Feb 2002).
- Full release notes.
- ***Focus***:
  - priority to improvements to stability and performance
  - moved to full direct use of stl, taking out "g4stl" in code (was for non-std STL implement eg gcc/egcs)
- **Key fixes:**
  - Massless particles that caused NaNs & core dumps (found by CMS, using new physics lists)
  - Multiple scattering: fixes for muons, electrons at high energies (GLAST reports). To do: further revisions >100 MeV
  - Improved pion cross-sections
- **New in 5.2**
  - Alternative physics models for low-energy EM, implementing Penelope models
  - Example implementing TIARA-experiment setup for neutrons.

Cuts per region

- Production thresholds (‘cuts’) per region
  - Geometry, Kernel, EM processes, ..
  - First ‘full’ release in Geant4 5.1 (April)
  - Further refinements, validation (May-June 2003)

Examples of improvements

Fixes and improvements in Geant4 release X.y (month 200x)

- Geometry
  - Fix for
- EM
  - …
- Hadronics