Geant-4’s capabilities:
kernel and auxiliary parts

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for Geant4 collaboration
Contents

- Geant4: brief history
- Overview of Geant4
  - kernel’s power
  - additional abilities
- Some experiences with ver. 4.0.0
- Status and plans
Geant4 Context

- **Geant4**: project & collaboration
  - was developed by **RD44 project**
  - **RD44 ended with first production release**
    - version 4.0.0 @ end 98

- **New Geant4 collaboration**
  - for production service, maintainance and to continue to develop Geant4
  - *is made of experiments, laboratories & institutes*
**Geant4 Capabilities**

- **Very powerful Geant4 kernel**
  - tracking, stacks, geometry, hits, ..

- **Extensive & transparent physics models**
  - electromagnetic, hadronic, … (next talk)

- **Additional capabilities/interfaces**
  - persistency, visualization, ...

- **Surpasses Geant-3**
  - in nearly every respect
Geant4 kernel: run/event

- Includes categories for run, event, track
- One computing process can have many runs

### Run

- each run has a fixed geometry & event-generator
- can do many runs in one job / process

### Event:

- Manages track creation
- Stacks for inactive tracks
  - 3 default stacks
  - very powerful
  - no cost!
Geant4 kernel: tracking

- Tracking is general
  - same for all particle types
  - different list of processes for each particle
- It messages
  - sensitive detectors and user actions

- So anyone can add their physics model
  - simply, without restrictions or problems
Geant4 kernel: other

- Hits & digitization
  - Experiment specific hits
  - Handles event pileup
    - using new readout category

- Materials
  - isotopes, elements,
  - compounds, ...

- Particles
  - properties from PDG

- Intercoms:
  - Communicate
    - between categories,
    - from UI to kernel

- Geometry
  - hierarchy or flat
  - performant
Electro-Magnetic physics

Gammas:
• Gamma-conversion, Compton scattering, Photo-electric effect

Leptons (e, mu) + charged particles (hadrons, ions):
• Ionisation, Bremstrahlung, Energy loss, Multiple scattering, transition radiation, Synchrotron radiation, PAI model energy loss

Photons:
• Cerenkov, Rayleigh, Reflection, Refraction, Absorption, Scintillation

High energy muons and lepton-hadron interactions

Implementation of physics to 1 KeV
• in development version
Electromagnetic processes

All processes at least at level of Geant-3

New process: Transition radiation

Multiple Scattering: new model
- no path length restriction
- added lateral displacement
  - measured effect on result

Energy Loss: two approaches
- two approaches: differential and integral
- several alternatives: PAI model (thin), Super E-loss

Integration of cross section over Energy
- $DE/E$ not constrained for $e^+/e^-$
- hadronic resonances can be seen (future)
Secondaries Produced or Not

Lead, CO$_2$, Lead, CO$_2$

- Range < safety
  - Secondaries will not leave Pb: not produced
- Range > safety
  - Secondaries leave Pb: produced
Cuts: production & user

Coherent “production cuts”

- validity range of models fully exploited
- kernel can enforce consistent production cuts
  - yet processes can ask to override when they need to.
- treatment of boundary effects (Figures)

Cuts in range rather than Energy

- Geant3 used cuts in Energy - inefficient
- significant gain in results quality vs CPU usage

User can cut in Energy, track length, TOF ..
Parameterization/Fast Simulation

- **Fast Simulation Manager**
  - Framework for parameterization
  - Takes over from detailed simulation
  - can return to detailed simulation (e.g., cracks)

- Can trigger on particle, volume, ..
  - Parallel geometrical description

- BaBar is developing Bogus based on this.
Other processes

- **Decay**
- **Optical processes**
  - Reflection, refraction, absorption
- **Transportation**
  - Interrogates geometry, field motion
- **Low energy extensions,**
  - Now to 1 Kev, eventually down to 1 eV
  - From ESA joint project

Accuracy in field

- 5mm thick cone
  - Aluminium in Air
  - Geant3 misses
    - For 10 degrees max deviation (default=20)
    - In 50% of trial tracks
    - Need small angle <2 deg
  - Geant4 always hits
Examples and Documentation

- **Six examples**
  - simple detectors
  - different experiment types
  - demonstrate essential capabilities

- **Documentation:**
  - Getting started & installation guide
  - User guide for application & toolkit developer
  - Software & physics reference manuals

- **G4 URL:**
  http://wwwinfo.cern.ch/asd/geant/geant4.html
Geant4 geometry: what it does

Describes a Detector
- Hierarchy of volumes
- Many volumes repeat
  - Volume & sub-tree
- Up to millions of volumes for LHC era
- Import detectors from CAD systems

Navigates in Detector
- Locates a point
- Computes a step
  - Linear intersection

Field propagation
CMS Geometry in GEANT4

current status

- Beam Pipe
- Tracker
  - Si Pixel Detectors
    - Barrel Si Pixel
    - Forward Si Pixel
  - Si Strip Detectors
    - Barrel Si Strip
  - MSGC
    - Barrel MSGC
- Calorimeters
  - Electromagnetic Calorimeter
    - Barrel ECAL
  - Hadron Calorimeter
    - Barrel HCAL
- Muon System
  - Barrel Muon
**Full tracking performance**

- **Honeycomb calorimeter**
  - shooting geantinos

- **Geometry**
  - hand optimised in Geant3
  - automatic in Geant4

- **Tracking**
  - specialised in Geant3
  - general in Geant4

- **Tracking optimisation**
  - since beta01

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*Geantino tracking time*

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Object Persistency: Hits & other

To store hits, use object persistency

Abstract interface

- ODBMS solution via RD45 (Objectivity)
- Tracker-type and calorimeter-type hits
- Saw minimal performance & storage overhead

Minimal modifications

- G4 kernel untouched

Also store:

- Trajectories, Runs,
- Events, Geometry

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Visualization

The most-used functionality is implemented

Several drivers:

- OpenGL, **VRML**, **Open Inventor**, **Opacs**, **DAWN renderer** (G4)
- Also choice of User Interfaces:
  - **Terminal (text)** or
  - **GUI: Momo** (G4), **OPACS**
Experiences with Geant4

- Production release in use
  - used, got feedback
    - from 5 experiments
  - first results confirm some of G4’s strengths
    - in EM physics, geometry, hadronic physics
  - First EM physics benchmarks
    - Geant4 gives better physics @ same speed
    - Geant4 gives better speed for same physics

- Consolidation release 4.0.1 imminent
Summary

How we did it

- Very powerful kernel
  - general tracking
  - stacking at no cost
  - user choice of
    - processes
    - actions (run, step, ...)

- Extensive physics models
  - EM, hadronic

- G4 URL:
  http://wwwinfo.cern.ch/asd/geant/geant4.html

- Software Engineering in HEP
- The software process: distributed development
- ESA PSS-05: URD v.06
- Object-Oriented methodology: Booch+unified
- OOA&D: Rational Rose CASE
- QA: Insure, Logiscope, code inspection, coding guidelines, scripts
- Testing at class-level (ex: 375 test-cases for processes)