Geant-4's capabilities: kernel and auxiliary parts

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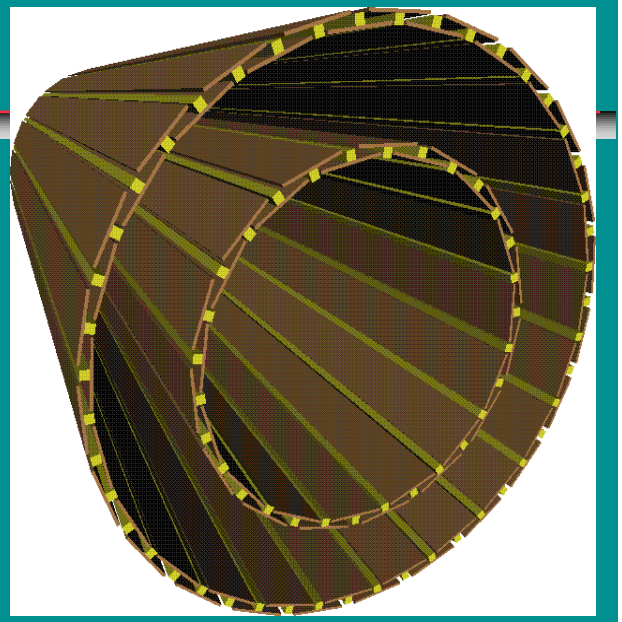
for Geant4 collaboration

Contents



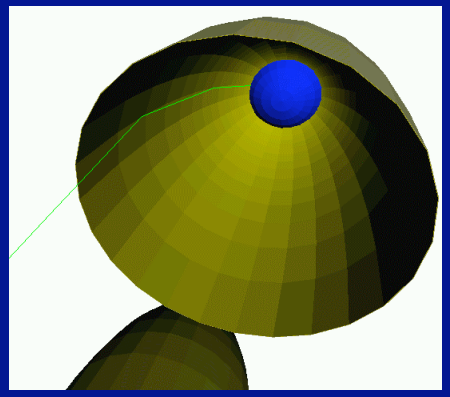
- Geant4: brief history
- Overview of Geant4
  - kernel's power
  - additional abilities
- Some experiences with ver. 4.0.0
- Status and plans

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

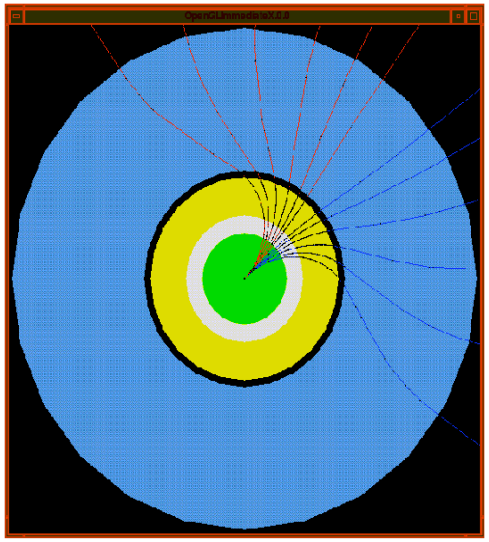


Geant4 kernel: run/event

- 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:

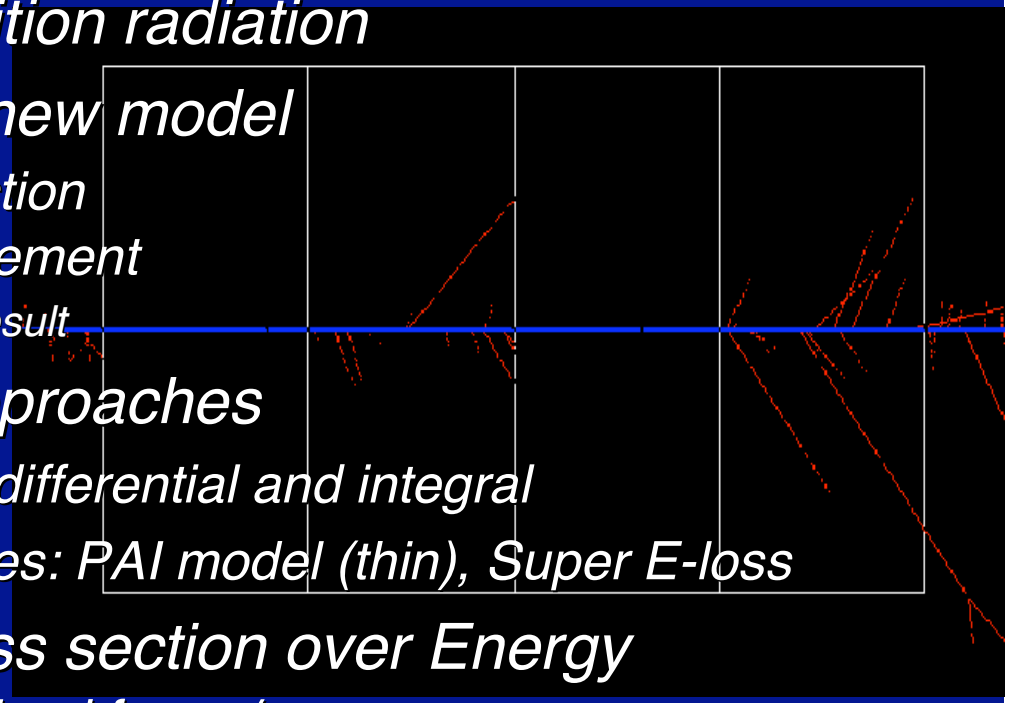
  Communicate
  - between categories,
  - from UI to kernel
- Geometry
  - hierarchy or flat
  - performant

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

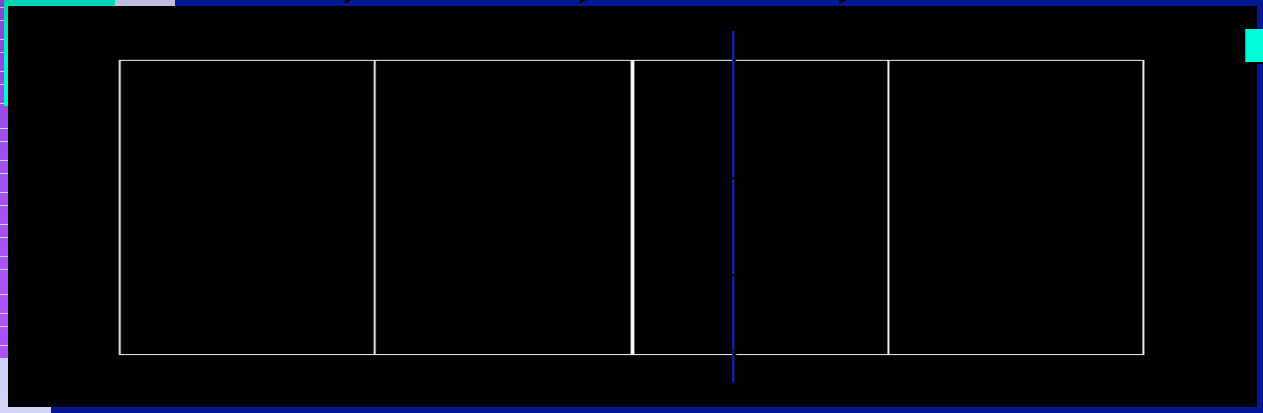
Electromagnetic processes

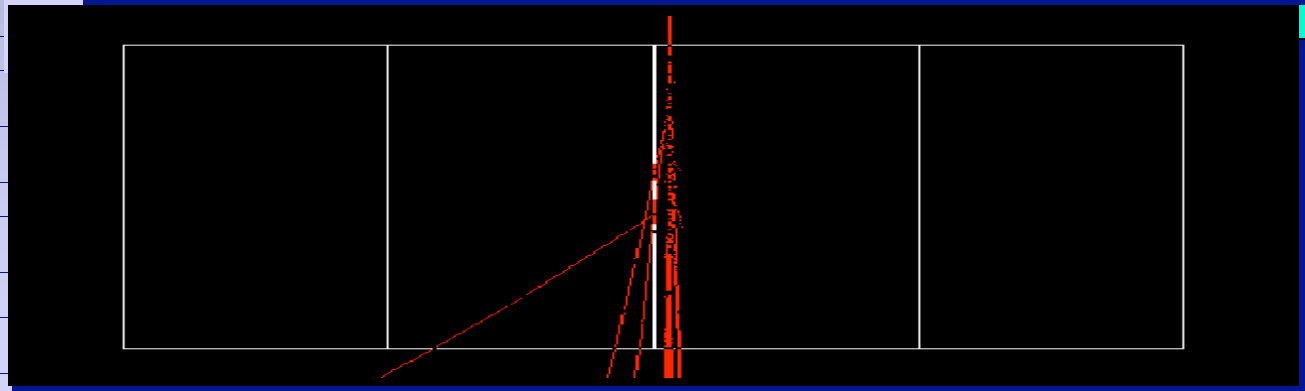
- All processes at least at level of Geant-3
- New process: Transition radiation
- Multiple Scattering: new model
  - no path length restriction
  - added lateral displacement
    - measured effect on result
- Energy Loss: two approaches
    - two approaches: differential and integral
    - several alternatives: 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

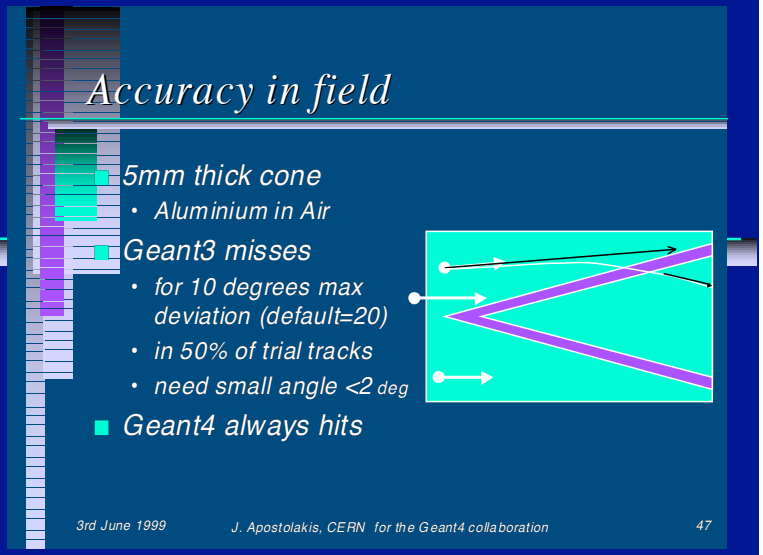
- Coherent "production cuts"
  - validity range of models fully exploited
  - kernel can enforce consistent production cuts
    - yet processes can ask to override when they need to.
  - treatment of boundary effects (Figures)
- Cuts in range rather than Energy
  - Geant3 used cuts in Energy - inefficient
  - significant gain in results quality vs CPU usage
- User can cut in Energy, track length, TOF ..

Parameterization/Fast Simulation

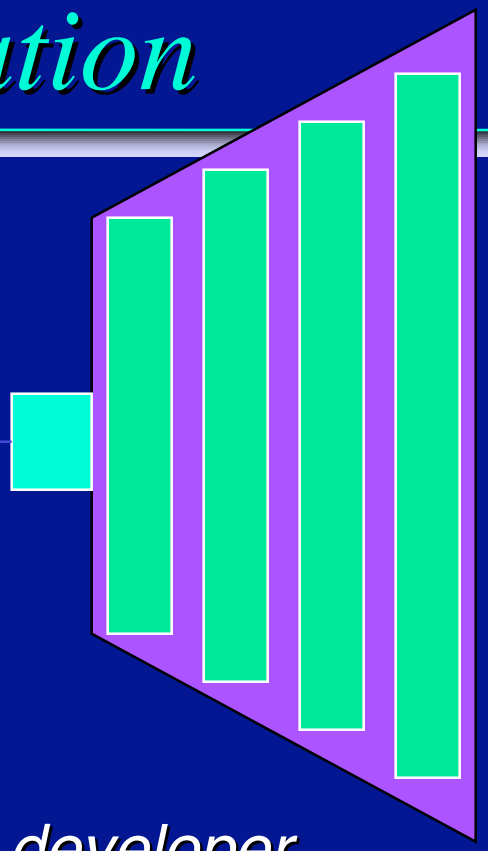
- *Fast Simulation Manager*
  - *Framework for parameterization*
  - *Takes over from detailed simulation*
  - *can return to detailed simulation (eg cracks)*
- *Can trigger on particle, volume, ..*
  - *Parallel geometrical description*
- *BaBar is developing Bogus based on this.*

Other processes

- Decay
- Optical processes
  - Reflection, refraction, absorption
- Transportation
  - interogates geometry, field motion
- Low energy extensions,
  - now to 1 Kev, eventually down to 1 eV
  - from ESA joint project



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

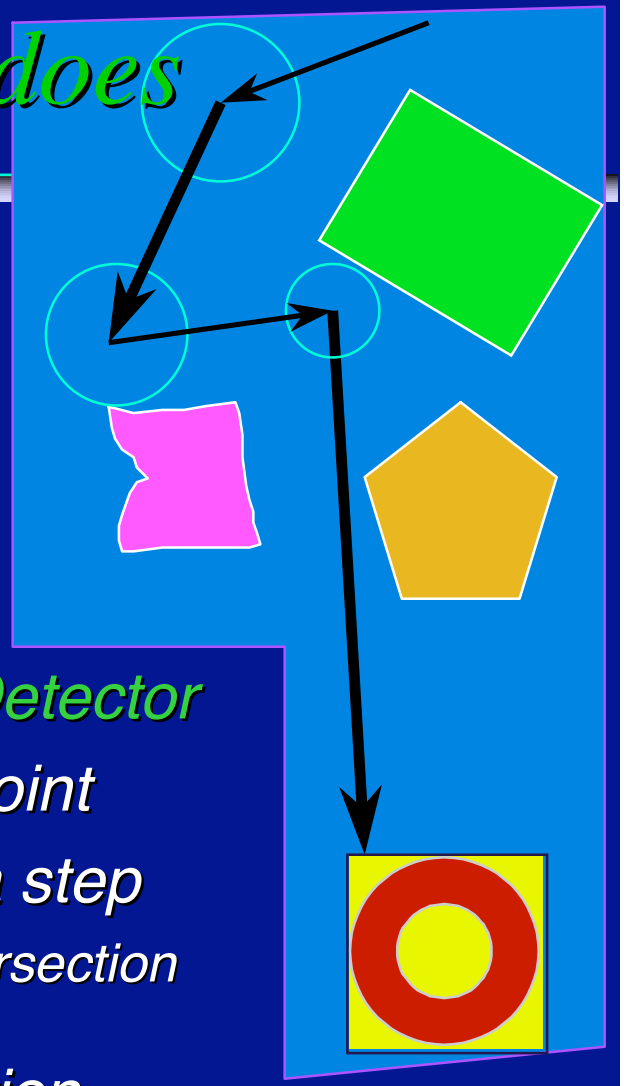
Describes a Detector

- 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

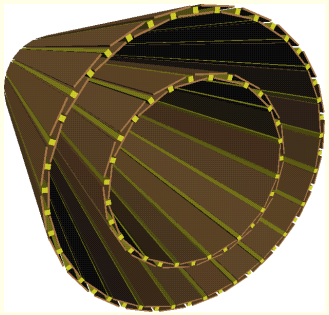
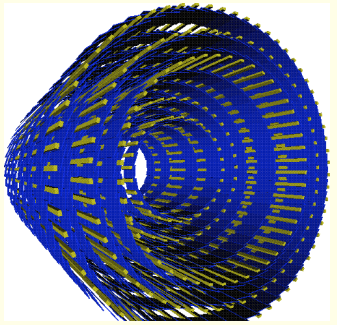
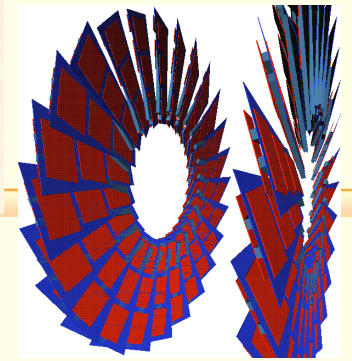
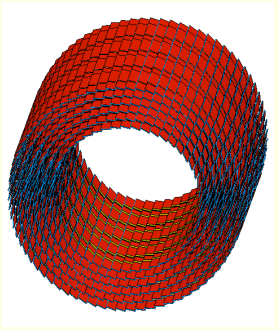
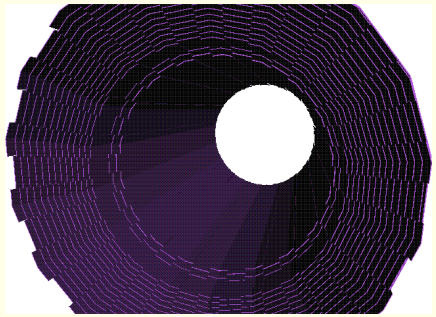
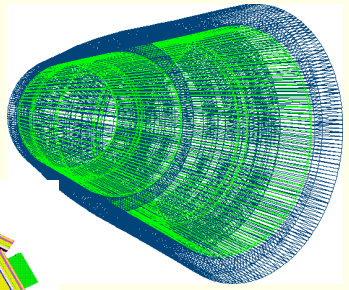
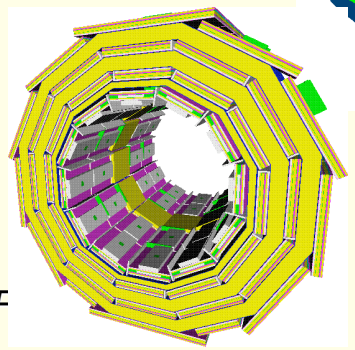
Field propagation



CMS Geometry in GEANT4

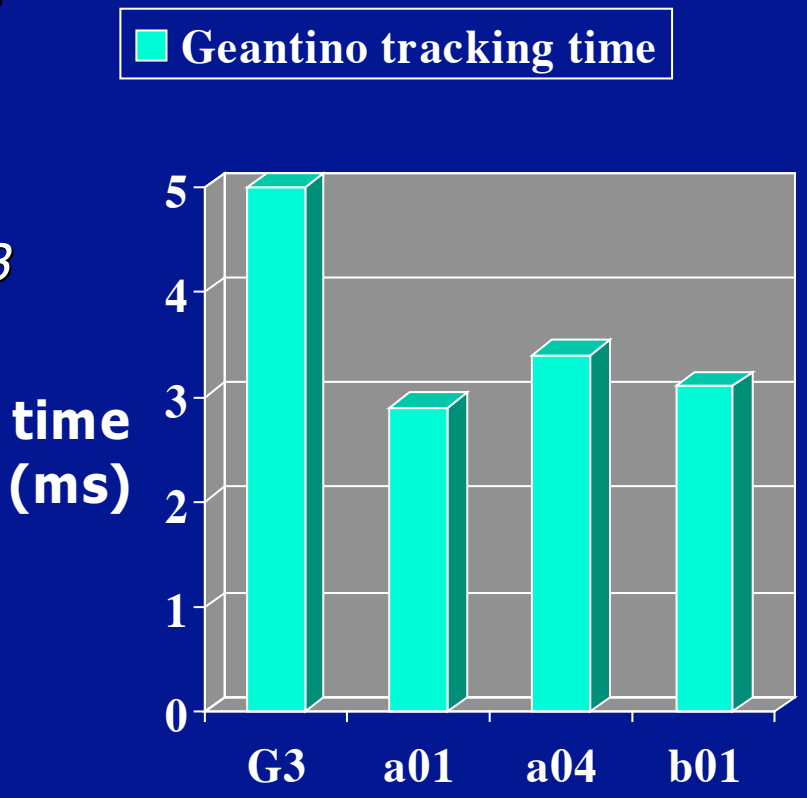
current status

- **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

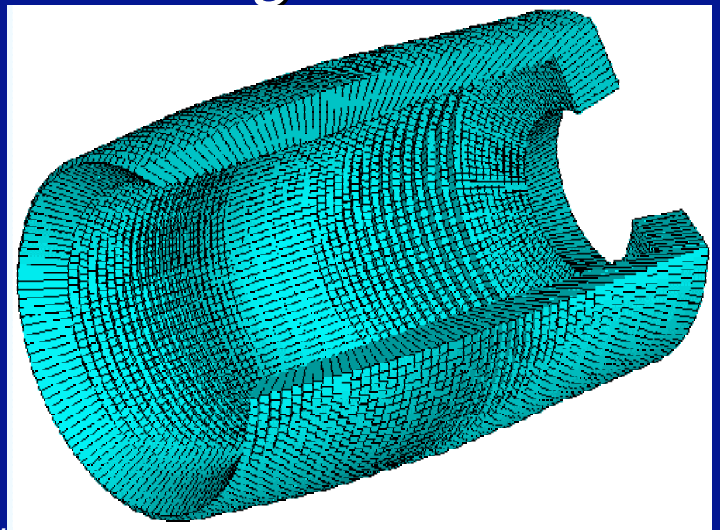
Full tracking performance

- Honeycomb calorimeter
  - shooting geantinos
- Geometry
  - hand optimised in Geant3
  - automatic in Geant4
- Tracking
  - specialised in Geant3
  - general in Geant4
- Tracking optimisation
  - since beta01



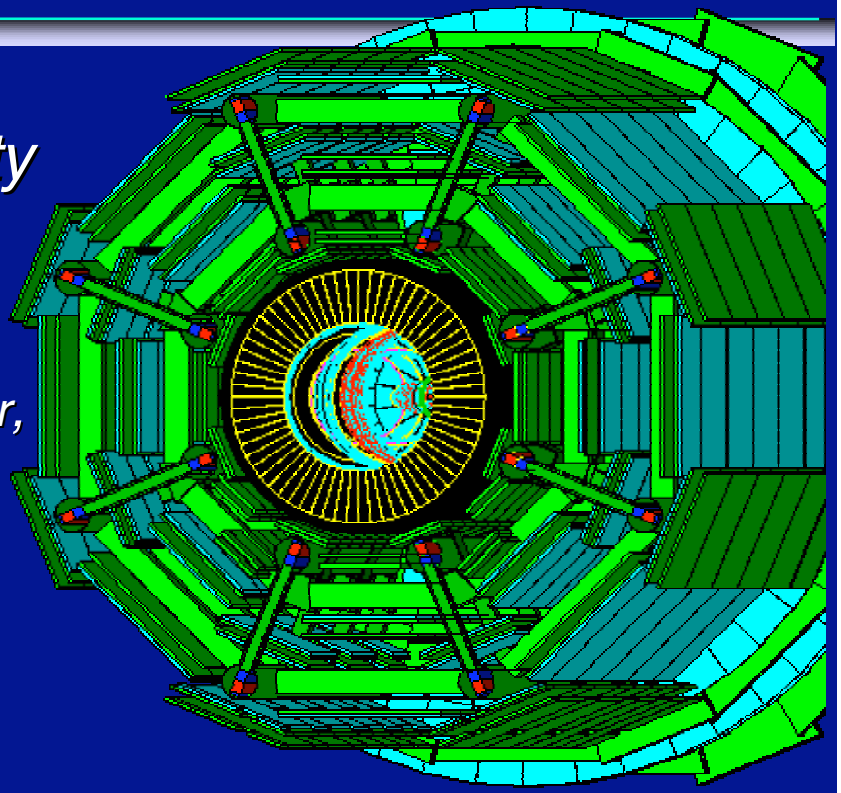
Object Persistency: Hits & other

- *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

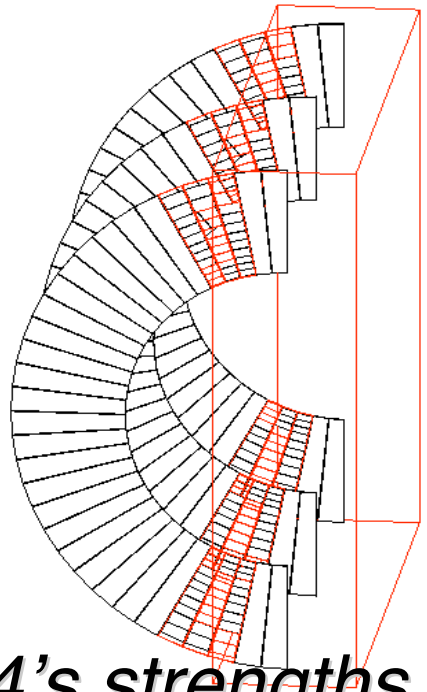


Visualization

- *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

- *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*

How we did it

- *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)*