GEANT4: a world-wide collaboration to build Object-Oriented HEP simulation software

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RD44 collaboration

GEANT4 is a world-wide collaboration of about 100 scientists producing the simulation software for the next generation of High Energy Physics experiments. CERN, KEK, TRIUMF, FNAL, SLAC, LBL, DESY and many other institutes are contributing to it. The aim is to provide a flexible and extendible software toolkit exploiting Object-Oriented methodologies and C++ implementation technology. Particular emphasis is put on the software development process and on the transparency of the physics models. Important aspects of world-wide distributed software development will also be covered. GEANT4 has been approved by the CERN/DRDC at the end of '94 with the milestone of producing a general OO Analysis&Design and a tracking prototype, in order to benchmark its performance. After meeting such a milestone by the end of '95, the project has been renewed for another year and a half with the milestones of delivering an alpha-version providing roughly the same amount of functionality as GEANT3.21.

Key words: GEANT4; Simulation; Object Oriented; OODBMS; Object persistency; CAD; LHC; World wide collaboration; OO Design;

1 Introduction

The GEANT4 project (RD44) has the objective of producing an Object-Oriented framework for the simulation of future and LHC experiments. It was started in '94 by a few tens of scientists, from different labs and experiments, aiming to apply a rigorous approach to HEP simulation software construction. Today GEANT4 is a world-wide collaboration, formed by about 100 researchers including physicists, engineers and computer scientists, working in different areas of expertise. A high relevance is given to the study of the software process in such a large, geographically dispersed, development effort; the use of design and Quality Assurance tools has proven to be a decisive factor during the lifetime of the project. The connection between open/transparent software and the scientific validation of the produced results has been emphasised.

GEANT4 is managed in close collaboration with RD45, an R&D project which is demonstrating the suitability of Object Data Base Management Systems for HEP data storage and selection, and with analogous projects ongoing in the experiments to create an Object Oriented framework for reconstruction and analysis.

2 Historical overview

RD44 was approved at the end of '94 by the CERN/DRDC, with the milestones of producing an Object Oriented design of the new simulation toolkit and a prototype to make performance studies. In the first year of work, the Object Oriented technology and several methodologies were studied and analysed; a decomposition of the problem domain was achieved, and this lead to the creation of several working groups which delivered a detailed design of all the major components of the GEANT4 toolkit; a prototype of geometry and tracking was realized and gave impressive results in terms of performance, showing that the current technology can allow a truly Object Oriented design without compromising the execution speed (in comparison with FORTRAN).

GEANT4 was re-approved at the end of '95 for the following 18 months, with the milestones of realizing an alpha-version reproducing the basic functionality of GEANT321 in terms of geometry, tracking and physics; the HITS/DIGI component was also required to work already with an OODBMS solution, as provided by RD45. Particular emphasis was put on the requirement of transparency of the physics models design and implementation, so that the users should be able to understand how the physics results are generated.

3 Functionality and Developments

A global view of the functionality realized in the different subdomains is presented in this section. Also hints of the on-going developments are given for the different GEANT4 components.

3.1 Geometry and fields

The GEANT4 geometry solid modeler is based on the ISO STEP standard and it is fully compliant with it, in order to be able to exchange geometrical information with CAD systems. A key feature of the GEANT4 geometry is that the volumes definitions are independent from the solid representation (CGS+booleans, BREPS, SWEPT are allowed by STEP); thanks to an abstract interface for the G4 solids, the tracking component works identically for NURBS (NonUniformRationalBSplines) based solids and for simple boxes. The treatment of the propagation in the presence of fields has been deeply revised to provide propagation and volume intersections within specified accuracy. Again, an Object Oriented design allows us to exchange different numerical algorithms and/or different fields (not only B-field), without affecting any other component of the toolkit. An automatic converter of GEANT3 geometries to the G4 C++ description is continuously being developed.

3.2 Tracking

The tracking component has been basically delivered with full functionality. The design is such that a generalized G4 physics process (or interaction) can perform actions, along a tracking step, either localized in space, or in time, or distributed in space and time (and all the possible combinations that can be built from these cases). This allows us to implement in the same framework detailed physics processes, fast parameterisations (and different levels of parameterisations), field interactions, multiple scattering, etc. In the near future, it is planned to consider the possiblity of removing any kind of "cuts" for the users wishing to exploit this option.

3.3 Hits and persistency

The design and implementation of the HITS and DIGI class category has been realized, and also several prototypes, test cases and scenarios have been developed. Volumes (not necessarily the ones used by the tracking) are aggregated in sensitive detectors, while hits collections represent the logical read out of the detector. Different ways of creating and managing hits collections have been delivered and tested, notably for both single hits and calorimetry hits types. In all cases, hits collections have been successfully stored into and retrieved from an Object Data Base Management System, with different optimisations for queries according to the different cases.

3.4 Events

The Event Management and Event Generators Interface categories have been completed. A flexible design for the "stacking" mechanism allows the users to simulate trigger selections, without compromising performance. For the short term, an interface to existing event generators (i.e. PYTHIA) has been developed through the ASCII format file of HEPEVT, in order to keep GEANT4 independent from FORTRAN common blocks.

3.5 Physics

The abstract interface of physics processes allows multiple implementations of physics models per interaction or per channel. Classes data encapsulation and polymorphism have made it possible to give transparent access to the cross sections (independently of the choice of reading from an ascii file, or of interpolating from a tabulated set or of computing analytically from a formula). Electromagnetic and hadronic physics are handled in a uniform way in such a design, opening up (as opposed to packaging in "black boxes") the physics to the users. The alpha version is meant to reproduce the basic functionality of the GEANT3 and EGS electromagnetic physics, and the development of low energy processes and optical photons tracing is well on the way. Concerning the hadronic physics, a three-phased approach is being followed: at first, the HEP most widely used hadronic package (GHEISHA) has been selected and re-engineered to the OO GEANT4 design (also allowing the developer to overlay different models for energy ranges and/or materials), with the purpose of exactly reproducing its results; then, improvements and extensions in every energy range will be implemented to test the flexibility of the physics design; finally, original new parameterisations (practically ready) and theoretical models (such as from FRITIOF/PYTHIA) would be plugged in to fully exploit the G4 design. Radiation transport will be released during the lifetime of the alpha version and it is exclusively based on standard and acknowledged (ENDF-B6 and MENDL-2) neutron scattering cross-sections. After the first alpha-version, a working group will develop the gamma&lepton–hadron interactions.

3.6 Visualisation and GUI

The basic and most frequently used graphics functionality has been implemented in the alpha-version. The Object Oriented design of the visualisation component has allowed us to develop several drivers independently, such as for OpenGL, OpenInventor, X11, Postscript and DAWN. The same strategy has been successfully adopted for the Graphical User Interfaces (OPACS, TCL/TK, XVT). More developments are foreseen during '97.

4 Conclusions

GEANT4 has reached the stage where the first alpha version has been produced, and it contains an amount of functionality comparable to GEANT3. The alpha version will continuosly evolve, being constantly developed and compared to data in order to drive it towards a public beta version before spring of next year.

5 References

References

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