Hadronic Interactions in GEANT 4

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Simulation of hadronic showers has been a field of strong activity for many years. Today we face the challenge to maintain through a change in software technology the knowledge and experience collected over time, and to use the advantages of the new technology to improve on the existing Monte Carlo codes, in order to match the stringent requirements of the LHC experiments.

Key words: Hadronic shower simulation; OO design; GEANT 4

1 Introduction

With the long time scale of the LHC experiments it seems appropriate, if not mandatory, to follow new developments in the field of computing science, and to apply them to LHC related software. The objectives of the GEANT 4[1] project are to re-design, and re-engineer a major CERN software tool (GEANT3.21[2]) used in HEP for an OO environment. A significant part of this effort is directed towards extending the functionality of the program, and the upgrade and extension of existing physics simulation processors. The implementation in C++ makes GEANT 4 an integral part of the LHC off-line software. Our focus is on the hadronic shower processors in the low and intermediate energy range. The effort involves three stages, each equally important to the quality of the final OO class library. Stage one is the rewriting of a widely used hadronic shower code in C++. We re–use the experience in algorithmic problem solving and the physics insight encapsulated in the code, while preparing the ground for stage two, the redesign of the program to match the Object Oriented paradigm. Here we maximize the possibility of extension and improvement of the underlying physics, and solve the problem of distributed development and maintainance. Stage three is the stepwise improvement, and extension of the underlying physics, and the implementation of alternatives in the OO environment.

2 Areas of research

2.1 OO Design

The requirements for the Object Model are to allow for distributed development and maintainance, and for maximum flexibility in terms of implementation of physics models, while maintaining performance. An Analysis and Design iteration has been completed successfully, allowing for full flexibility in process type, particle type, material, and energy range. We implement one process class per particle and process type. Each of the process classes has, via inheritance from a base class, the public interface to the tracking category, and an energy range manager object that is responsible for communicating the model object to use to the process class, depending on the incident particle energy, and the local detector material. Each process class has a member function that allows to register model objects into a list of pointers to models held by its energy range manager object. All model classes have a common base, and Get and Set functions for their respective validity range are enforced by pure virtual functions in the base class. The model classes share through their base class a set of class utilities holding phase space specific, target nucleus specific, or strangeness production related methods, that do not correspond to properties of individual particles or processes.

2.2 Re-engeneering

The re–engeneering of existing hadronic shower Monte Carlos is considered essential for the initial quality and reliability of the physics modeling, and debugging. The initial choice, in agreement with the original author, was GHEISHA. At the time of writing, the re–engeneering of the GHEISHA in C++ is all but completed. Extensive benchmarks of the C++ classes versus the original have been carried out at the level of the underlying cross-sections, and individual routines in order to ensure the correct re–use, and the reproduction of GHEISHA functionality. A typical example is shown in the left plot of Fig.1. The small differences visible have been traced back to the use of an upgraded set of random number generators in GEANT 4.

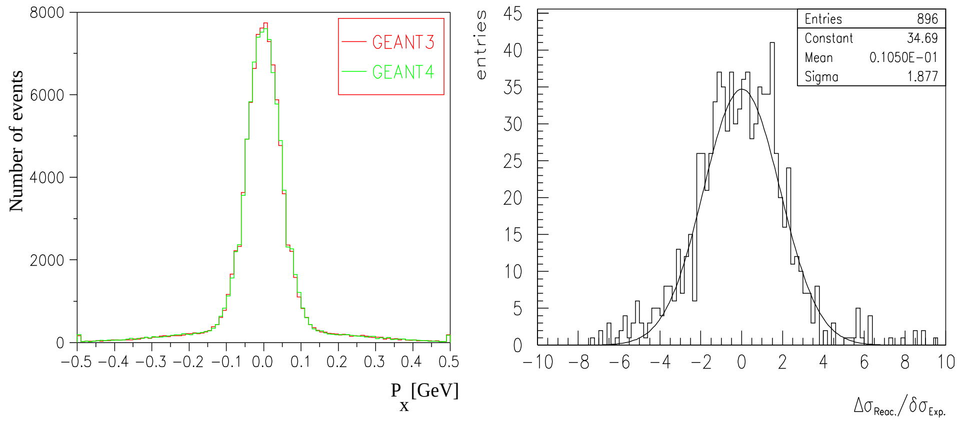

Fig. 1. Left: Comparison of GHEISHA[3] and GEANT 4 results for coherent elastic scattering of protons on Copper. Right: Comparison of parametrization prediction to data for the total reaction cross section of p–N scattering in the energy range from threshold to 20 GeV for materials heavier then Boron. We show the difference between prediction and experimental data normalized to the experimental errors.

2.3 New developments

Efforts to enlarge the underlying hadronic physics in the low and intermediate energy ranges have been launched. They show first successes in an increasingly large collection of experimental cross-section data. Having the application to simulation of hadron calorimetry in mind, the initial efforts focused on the interactions of protons, neutrons, and pions with matter. Improved empirical models have been developed in several areas, including p–N total reaction cross-sections, p–p elastic scattering, n–N total reaction cross-sections, and n–p elastic scattering, and are in the process of being published. An example of the target quality is shown in Fig. 1, right plot, for the case of p–N total reaction cross-sections [4].

3 Conclusions

Already after one year of work it has become increasingly clear that the approach of utilizing the flexibility of object oriented analysis, design, and programming to enhance the possibilities in the field of hadronic shower Monte Carlos both shows and promises significant successes.

References

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