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The Geant4 physics validation repository

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Abstract. The Geant4 collaboration regularly performs validation and regression tests. The results are stored in a central repository and can be easily accessed via a web application. In this article we describe the Geant4 physics validation repository which consists of a relational database storing experimental data and Geant4 test results, a java API and a web application. The functionality of these components and the technology choices we made are also described.

1. Introduction

Geant4 [[1]-[3]] is a toolkit for the simulation of the passage of particles through matter. Its areas of application include high energy, nuclear and accelerator physics, studies in medical and space science. The Geant4 collaboration regularly performs validation and regression tests. A validation test compares results obtained with a specific Geant4 version with data obtained by various experiments. A regression test compares results of two or more versions of Geant4 for any observable.

There are two categories of validation tests thin- and thick-target tests. Thin-target tests allow a detailed study of specific observables from a single physics process for a given configuration of projectile particle type, projectile kinetic energy and target material. A large set of published thin-target data, collected over several years, is used roughly once per month to validate each internal development release. These data can also be used for tuning some of the parameters of the physics models. This is particularly true for the hadronic models, many of which are phenomenological.

Thick-target tests are mainly based on test beam setups. These tests allow the assessment of the physics accuracy of Geant4 simulations in realistic configurations, which involve several physics processes and multiple energy scales. A notable example is the measurement of the properties of electromagnetic and hadronic showers in calorimeter test beam setups. Test beam simulations are in general complex and time-consuming, and are therefore repeated by experimenter only for some Geant4 public releases. To get more frequent and regular feedback, Geant4 developers have created a set of simplified test beam setups which are used for regression testing. When a statistically significant difference is detected, for instance if the hadronic shower becomes wider than that observed in a previous Geant4 version, the code changes responsible for the difference are investigated.

As the areas of application expand, tests are improved and new tests are developed to insure that the physics processes are modeled correctly. As the number of regularly performed validation tests increases and the collection of results grows, storing them and making them


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available to the Geant4 collaborators and user community in general becomes a challenge. Therefore the Geant4 collaboration decided to reconcile and organize the materials in one central repository and to make this data easily available via a web application [4]. This application should be of general interest to the collaborators and users community. For example it should help experimenters to find answers to questions like:

- What data is used to validate Geant4 physics?
- How well does Geant4 describe the data of interest for the experiment?
- Which model provided by Geant4 describes the data of interest for the experiment best?
- What are the benefits of switching to the latest improved version of Geant4?...

The web application described here replaces and enhances a previous JSP (Java Server Pages)[5] based web application which could only display static plots and meta-data.

2. Requirements

Below we briefly list the requirements and the desired functionality. The list resulted from discussions within the Geant4 collaboration especially in the "Physics Lists and Validation Tools" working group.

- the application should preserve the functionality to display static plots and meta data,
- it should be possible to store experimental data used for Geant4 validation as arrays and simulation results as histograms,
- reuse and extend the existing Java API to deal with data stored as histograms and arrays,
- the application should provide meaningful search functions and easy to navigate menus,
- the web application should allow the user to select and overlay tests with experimental data. In this case the actual plots are created on the fly and sent to the display.
- the application should be based on modern Internet technologies and industry standards,
- the application should provide a fresh modern look.

3. Software Components

The Geant4 validation repository framework consists of a database, a web interface and a Java API. The software components are shown in Figure 1. One important reason for choosing this set of modern internet technologies is the fact that all components are very well integrated in, well documented and supported by the IDE (integrated development environment) of our choice: NetBeans [6] which really simplifies the development effort.

- **PostgreSQL:** relational database [7] stores completed plots in form of images with meta-data, simulation results as histograms, and experimental data as arrays. Images of final plots (gif, jpeg etc.) are stored as blobs (binary large objects) while histograms and data points are stored as arrays in the database. The meta-data describes the test, lists references to the experimental data, as well as other parameters that describe the test (e.g. Geant4 version, beam particle, beam energy/momentum, reaction, target material, secondaries etc.). In case the mandatory parameters are not sufficient to completely describe a test one can supply additional tags to provide more information. NetBeans provides a database browser which can be used to navigate the database, add/delete/modify entries and directly execute SQL (Structured Query Language) statements.
- **Java API:** is based on the data access object (DAO)[8] software design pattern and provides an abstract interface to the database.

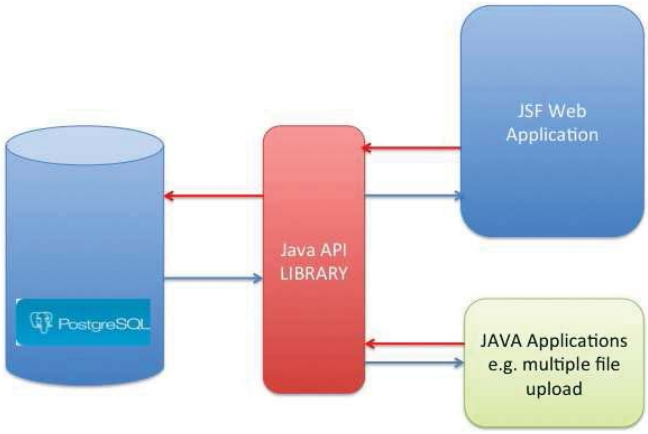


Figure 1. Software components.

- **Web Application:** offers easy to navigate menus, to interactively select and overlay compatible data. Compatible data means the results belong to the same type of test and we are comparing the same observable and measurement variables. Examples are shown in Figure 3 and 4. The application logic is such that only compatible data can be selected via the provided menus. The web application also provides security and authentication to grant access to groups of functions and data that are internal to the Geant4 collaboration, e.g. viewing results from development releases, upload of new tests and modification of selected tests. The Web Application is based on Java Platform, Enterprise Edition (Java EE) [9] and utilizes the PrimeFaces [10] open source JSF (Java Server Faces) component suite. The database is accessed using the classes provided by the **Java API**. It is deployed on a GlassFish Application server [11] running on the FermiCloud service [12]. A GlassFish Application server is included in the Netbeans distribution we are using, allowing the developer to localy deploy, debug and view the web application on the machine or laptop used for development.
- **Multiple File Upload Application** is an example java application making use of the **Java API**. It allows authorized Geant4 collaborators and production jobs to submit multiple entries to the repository.

4. Showcase

In this section we want to showcase the functionality provided by the web application and show a few select views provided. Figures [2-5] show examples of different views that can be selected by the main menu on the left.

- Figure 2: **Display Tests** allows to select static plots with meta-data. Here the completed plot is stored as an image file with meta-data in the database. Therefore it is not possible to refine selections or overlay different results.
- Figure 3: **Experimental Data Browser** allows to select different experimental data sets and shows the selected data overlayed in one plot. As we can see data can be selected by

target material, reaction, type of beam, beam energy, secondaries and the quantity plotted. The user can also select logarithmic axis and if the data should be displayed as a table.

- Figure 4: **Test Result Browser** allows to select various Geant4 simulations and overlays the results to available experimental data. As for the Experimental Data Browser data can be selected by target material, reaction, type of beam, beam energy, secondaries and the quantity plotted. In addition the user can choose the Geant4 version as well as the physics model or physics list used to obtain the simulation result.
- Figure 5: **Experiments Statistics** provides statistics about the experimental data sets available in the database. We are in the process of transitioning to store more data in form of histograms but at the time of writing most of the test results from the 24 tests are still stored as plots with meta-data. Of the total number of 22480 test results 8618 are available for public viewing while 13870 are only accessible to authenticated Geant4 collaborators. The internal test results are performed with pre-release versions of Geant4 which are not released to the public. At the time being we have only results of 4 tests in form of histograms available in the database giving 409 entries. Currently the results of 14 experiments are stored as raw data points in the database which corresponds to 311 data curves.

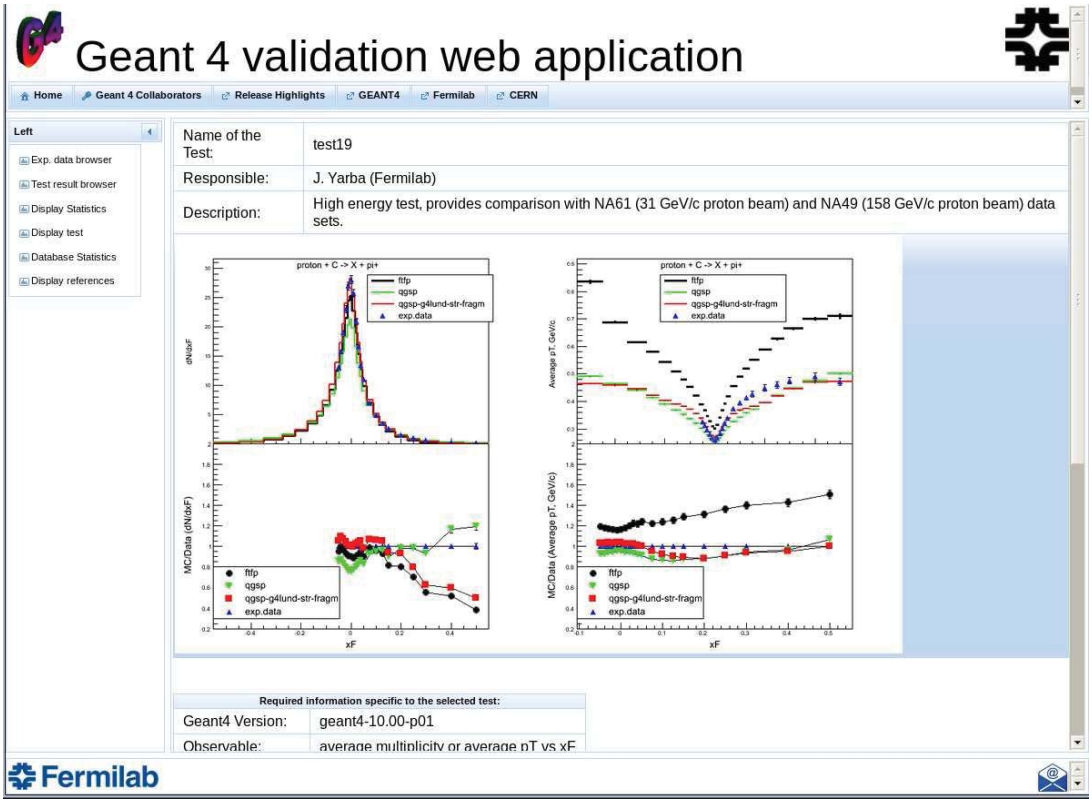


Figure 2. Display of static images with meta-data. Here the completed plot is stored as an image file with meta-data in the database. Therefore it is not possible to refine selections or overlay different results. Shown here are different properties of π^+ produced by 158 GeV/c incident protons on a thin Carbon target. The results obtained with different Geant4 models (FTFP, QGSP, QGSP-G4LUND-STR-FRAGM) are compared to data from the NA49 experiment [13].

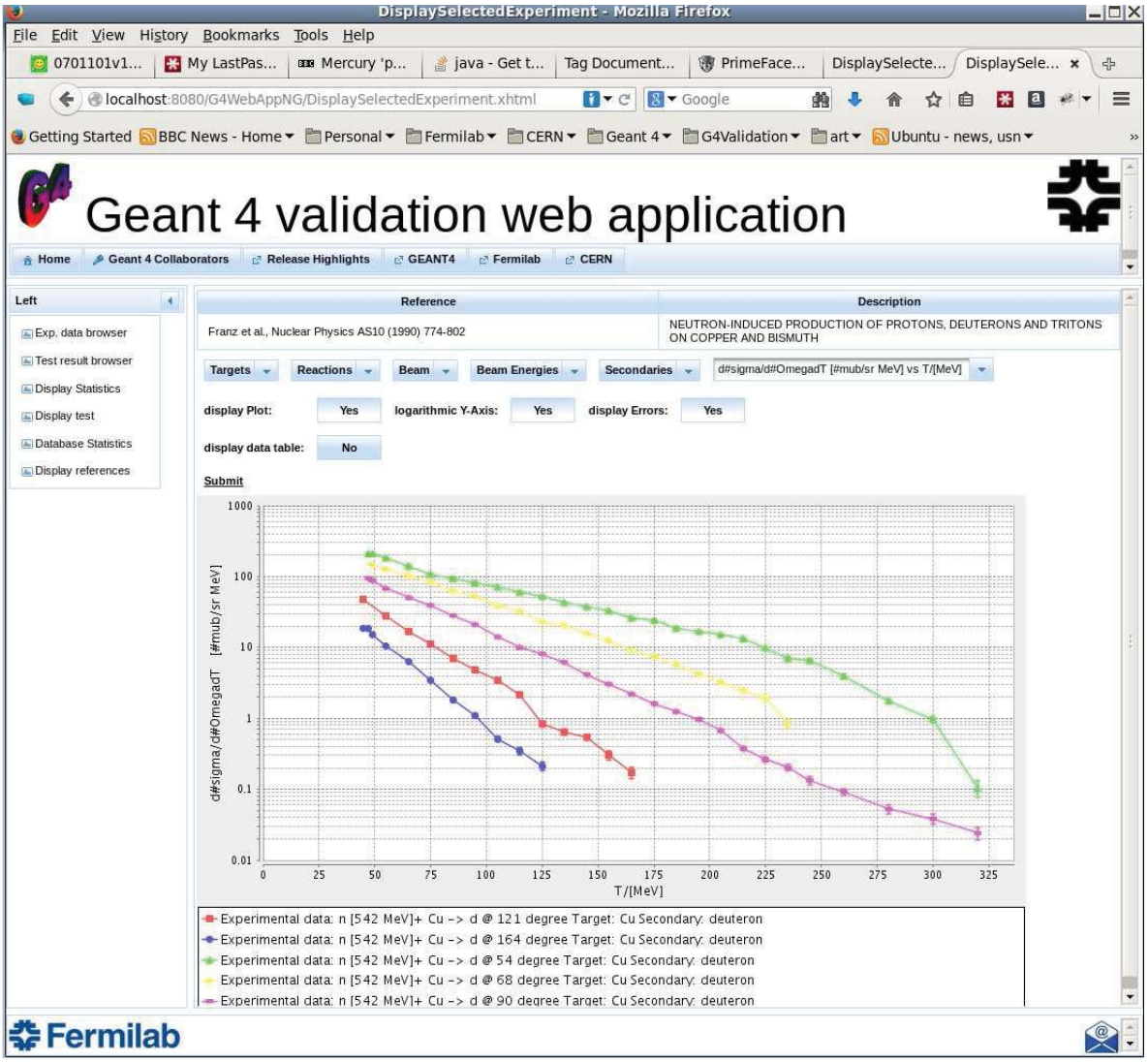


Figure 3. Display of experimental data. Menus on the top allow to select data by target material (Cu), reaction (n [542 MeV]+ Cu → d), type of beam (neutrons), beam energy (542 MeV), secondaries (deuterons) and the quantity (cross section) plotted. The user can also select linear or logarithmic axis and request the data to be displayed as a table. Shown here are the differential cross sections of neutron-induced production of deuterons on a thin Copper target at a specific angle as a function of the outgoing deuteron energy for different production angles [14].

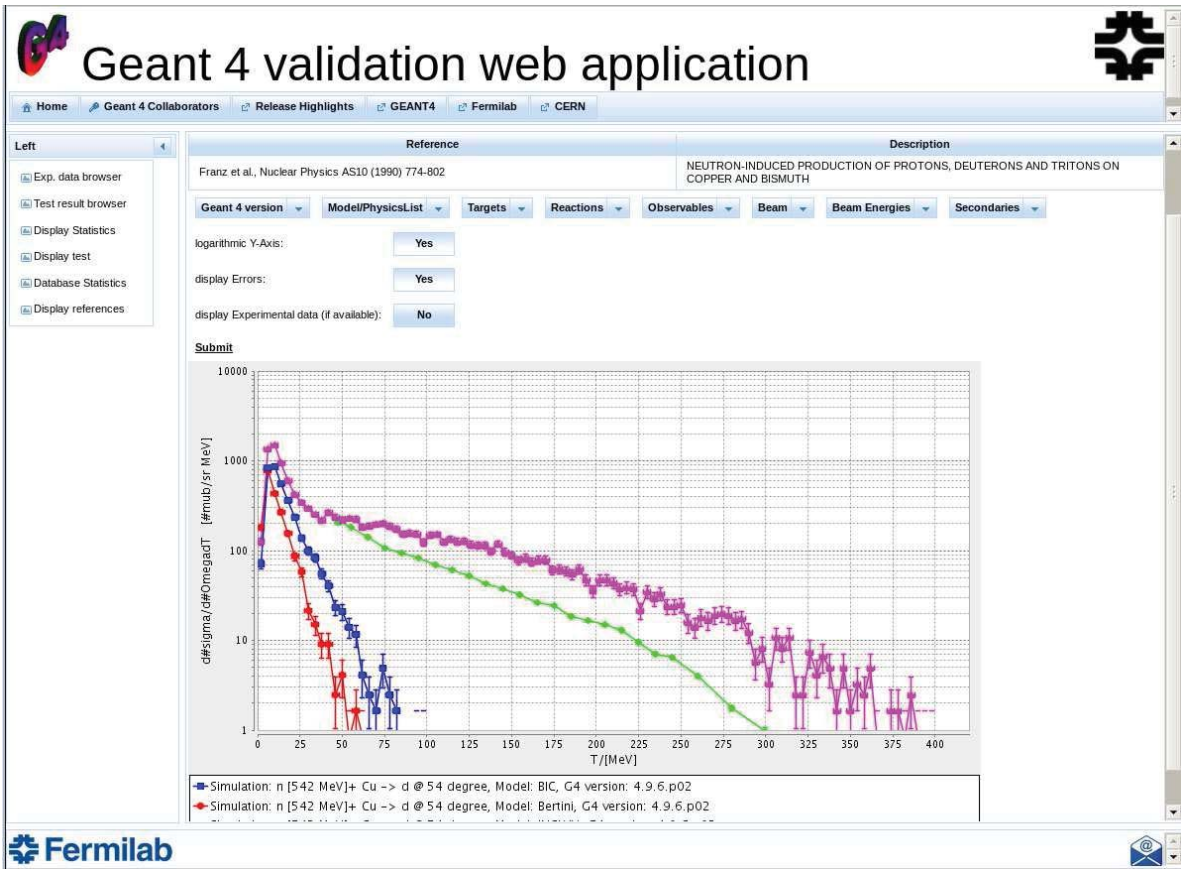


Figure 4. Comparison of experimental data (green) [14] with three different Geant4 models (Bertini, BIC, INCLXX). Shown here are the differential cross sections of neutron-induced production of deuterons on Copper at an specific angle as a function of the outgoing deuteron energy. The deuteron spectra produced by the BIC and Bertini model are much too soft compared to the experimental data.

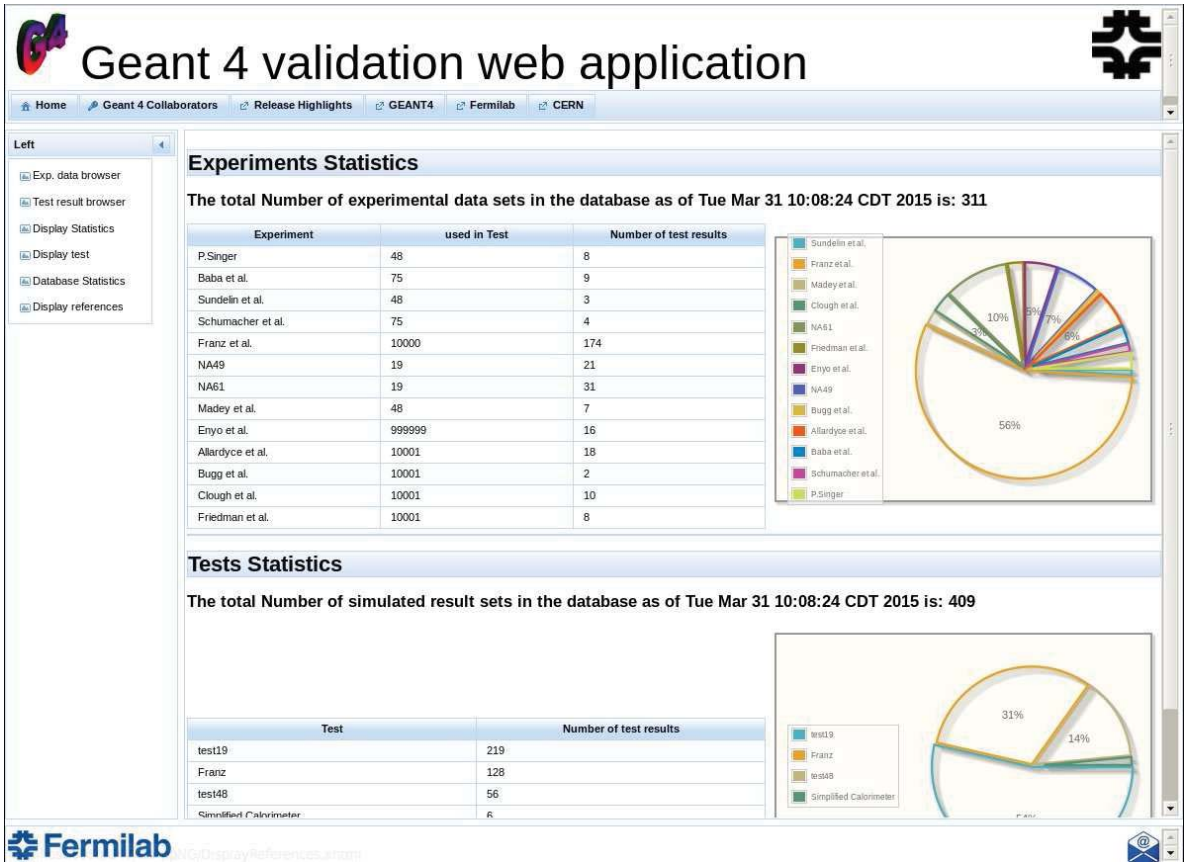


Figure 5. The Web application provides various database statistics pages. Shown here are statistics about the experimental data curves by experiment and the simulation results stored as histograms.

5. Conclusions and Outlook

A repository to collect and organize Geant4 validation and regression test results as well as the experimental data used for validation has been designed and implemented. A Web application allows easy access to the information for Geant4 collaborators and the general user community. The Geant4 collaboration continually includes more tests and experimental data to the repository. Originally we concentrated on tests of hadronic and electromagnetic physics that are of interest for high energy physics experiments. But in the future we hope to include tests that are of interest for other areas such as medical and space science where Geant4 is applied.

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