Geant-val: a web application for validation of detector simulations

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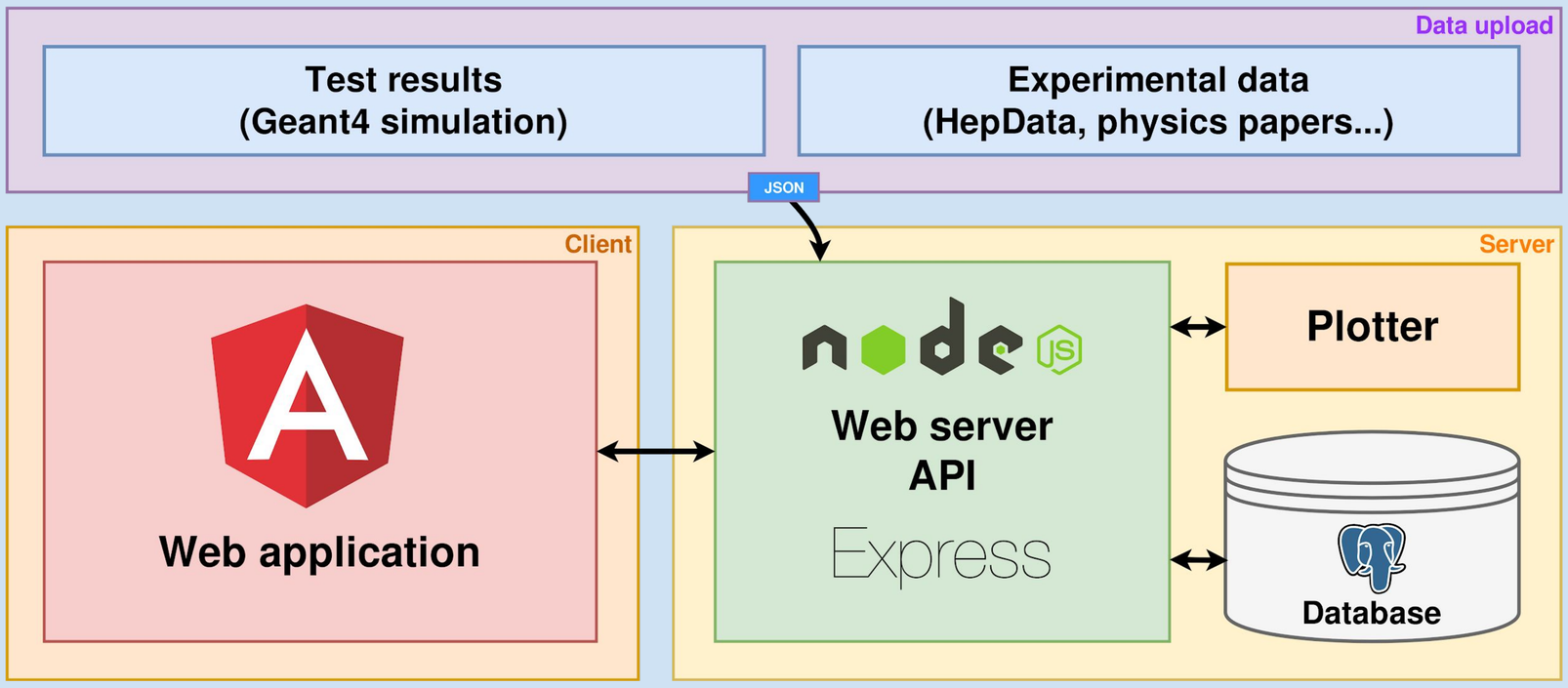
Abstract

One of the key factors for the successful development of physics Monte-Carlo is to properly organize regression testing and validation. Geant4, the world-standard toolkit for HEP detector simulation, heavily relies on this activity. The CERN/SFT group, which contributes to the development, testing, deployment and support of the toolkit, is also in charge of running on a monthly basis a set of community-developed tests using the development releases of Geant4.
We present the Web application geant-val developed for visualizing the results of these tests so that comparisons between different Geant4 releases can be made. The application is written using Express.js, Node.js and Angular frameworks, and uses PostgreSQL for storing test results. Test results are visualised using ROOT and JSROOT. In addition to pure visual comparisons, we perform different statistical tests (chi squared, Kolmogorov-Smirnov, etc) on the client side using Web Workers (JavaScript).



NodeJS/Express server

This server is the core of the geant-val system.

- Provides a web API:
  - allowing clients to access the database,
  - responding to the Angular app's requests.
- Generates high quality plots on the fly using ROOT whenever they are requested.

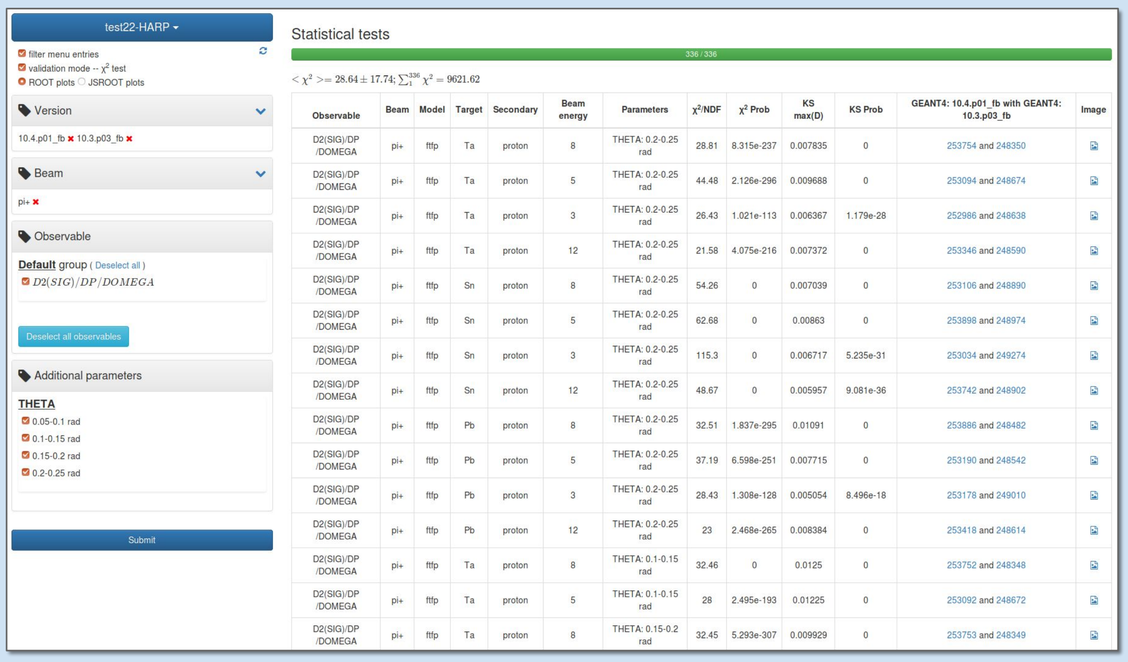
Angular application

The main interface users will interact with:

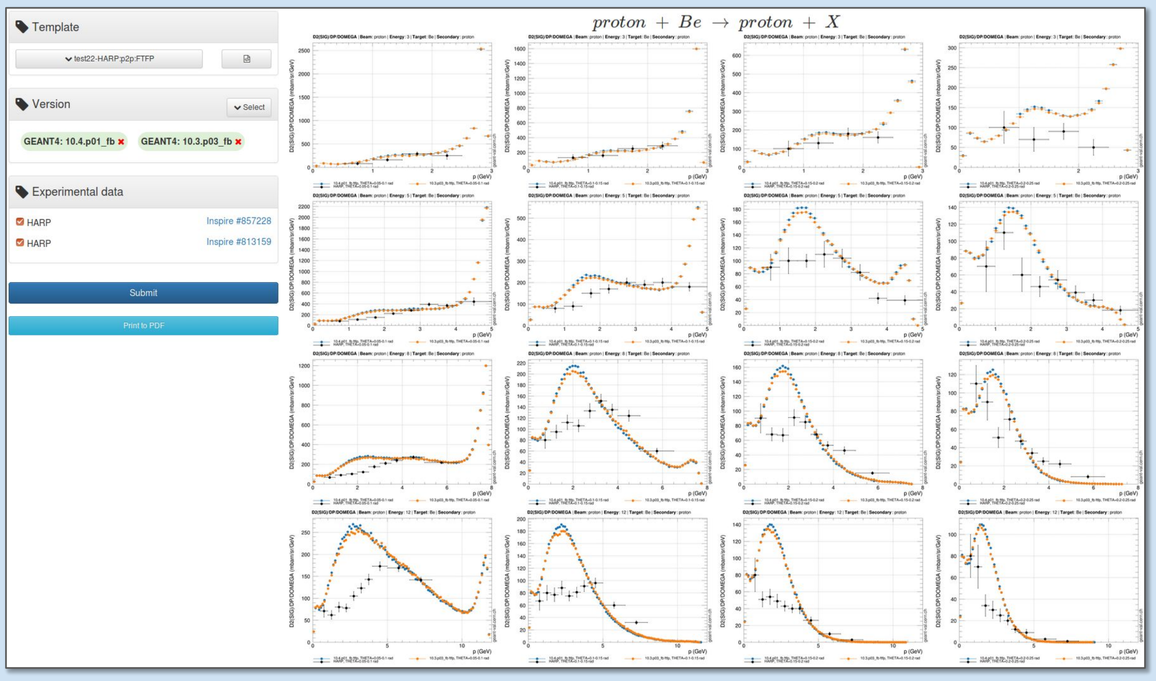
- Allows statistical comparison of histograms to be performed.
- Allows visual comparison of plots:
  - using a selection menu.
  - using pre-defined templates.
- Allows produced plots in PNG, ROOT and EPS formats to be downloaded.

Statistical comparison

χ^2 and Kolmogorov-Smirnov statistical tests allows test results for different **versions of Geant4 to be compared**. The calculations are performed on the client side using JavaScript workers. χ^2/NDF, χ^2 probability, KS Max(D) and KS probability are displayed.



Observable	Beam	Model	Target	Secondary	Beam energy	Parameters	χ^2/NDF	χ^2 Prob	KS max(D)	KS Prob	GEANT4: 10.4.p01_fb with GEANT4: 10.3.p03_fb	Image
D2(SIG)/DP /DOMEGA	pi+	fttp	Ta	proton	8	THETA: 0.2-0.25 rad	28.81	8.315e-237	0.007835	0	253754 and 248350	
D2(SIG)/DP /DOMEGA	pi+	fttp	Ta	proton	5	THETA: 0.2-0.25 rad	44.48	2.126e-296	0.009688	0	253094 and 248674	
D2(SIG)/DP /DOMEGA	pi+	fttp	Ta	proton	3	THETA: 0.2-0.25 rad	26.43	1.021e-113	0.006367	1.179e-28	252986 and 248638	
D2(SIG)/DP /DOMEGA	pi+	fttp	Ta	proton	12	THETA: 0.2-0.25 rad	21.58	4.075e-216	0.007372	0	253346 and 248590	
D2(SIG)/DP /DOMEGA	pi+	fttp	Sn	proton	8	THETA: 0.2-0.25 rad	54.26	0	0.007039	0	253106 and 248890	
D2(SIG)/DP /DOMEGA	pi+	fttp	Sn	proton	5	THETA: 0.2-0.25 rad	62.68	0	0.00863	0	253898 and 248974	
D2(SIG)/DP /DOMEGA	pi+	fttp	Sn	proton	3	THETA: 0.2-0.25 rad	115.3	0	0.006717	5.235e-31	253034 and 249274	
D2(SIG)/DP /DOMEGA	pi+	fttp	Sn	proton	12	THETA: 0.2-0.25 rad	48.67	0	0.005957	9.081e-36	253742 and 248902	
D2(SIG)/DP /DOMEGA	pi+	fttp	Pb	proton	8	THETA: 0.2-0.25 rad	32.51	1.837e-295	0.01091	0	253886 and 248482	
D2(SIG)/DP /DOMEGA	pi+	fttp	Pb	proton	5	THETA: 0.2-0.25 rad	37.19	6.598e-251	0.007715	0	253190 and 248542	
D2(SIG)/DP /DOMEGA	pi+	fttp	Pb	proton	3	THETA: 0.2-0.25 rad	28.43	1.308e-128	0.005054	8.496e-18	253178 and 249010	
D2(SIG)/DP /DOMEGA	pi+	fttp	Pb	proton	12	THETA: 0.2-0.25 rad	23	2.468e-265	0.008384	0	253418 and 248614	
D2(SIG)/DP /DOMEGA	pi+	fttp	Ta	proton	8	THETA: 0.1-0.15 rad	32.46	0	0.0125	0	253752 and 248348	
D2(SIG)/DP /DOMEGA	pi+	fttp	Ta	proton	5	THETA: 0.1-0.15 rad	28	2.495e-193	0.01225	0	253092 and 248672	
D2(SIG)/DP /DOMEGA	pi+	fttp	Ta	proton	8	THETA: 0.15-0.2 rad	32.45	5.293e-307	0.009929	0	253753 and 248349	



User layouts

User-defined layouts can be used for fast visual validation of Geant4. Some predefined templates are already available in the application. User can define their own XML template to generate the plots and the layout they need.

Our ROOT-based **plotting tool** is used server-side to generate high quality graphs.

- Written in C++ for high performance.
- Executed on the Node server, the output is cached for future requests.

Produces:

- 1D histograms (with labels).
- Scatter plots.
- Ratio plots (histograms and scatter plots supported).

Outputs:

- PNG images for lightweight display.
- ROOT JSON files for interactive display.
- ROOT and EPS files for user download.

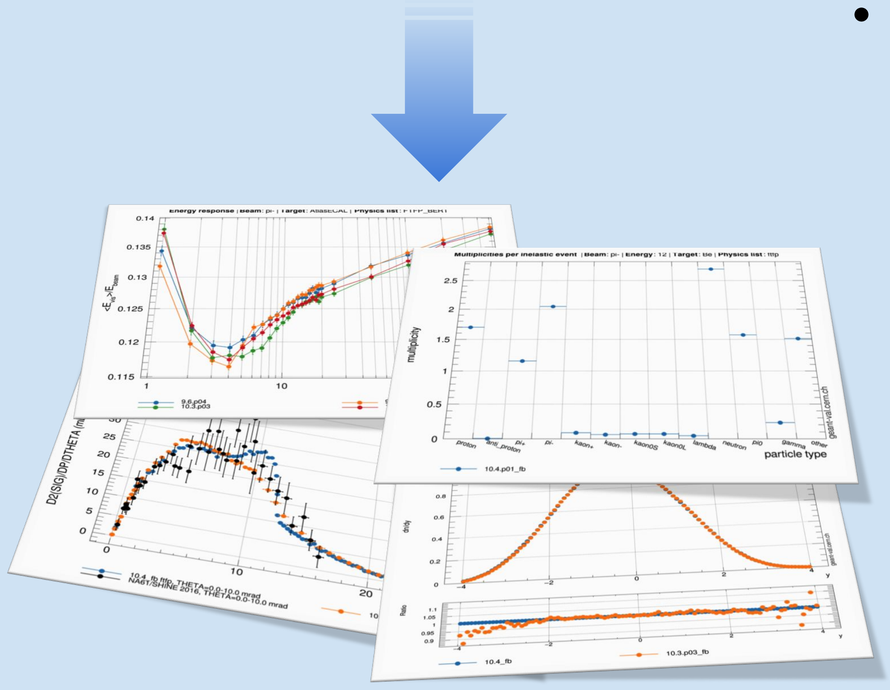
Supports:

- LaTeX for labels and titles.
- Linear and $\log_{10}$ axes scales.
- Automatically adapted or manual axes ranges.
- Different marker and line styles.

Available tests

At the moment the project uses results produced by 11 tests. They are used for reference and stable release validation of Geant4.

Test name	Project	Author	Description
FluctTest	GEANT4	Vladimir Ivanchenko	Example for investigation of G4 fluctuation models is on the base of TestEm8 (Ionisation in thin absorbers and gaseous detectors). Simulation data are compared with experimental ones.
MscHanson	GEANT4	Vladimir Ivanchenko	The tests simulates multiple scattering distributions of 15.7 MeV electrons transmitted through thin foils of the indicated materials.
TestEm3-Energy	GEANT4	Vladimir Ivanchenko	TestEm3 simulates energy resolution and visible energy in hecatlas, zeus calorimeters
TestEm3-cutTest	GEANT4	Vladimir Ivanchenko	TestEm3 produces plots showing impact of production cut on energy resolution and visible energy
hadr00	GEANT4	Vladimir Ivanchenko	Application demonstrating Geant4 hadronic cross sections
simplified calorimeter	GEANT4	Andrea Dotti, Alberto Ribon	The simulation program is implemented as a simplified geometry of sampling calorimeters. The calorimeter geometry consists of a cylinder with a radius of 5 (interaction lengths of the absorber material) and 10 length. These large dimensions ensure that the leakage is kept as small as possible and the full hadronic shower is absorbed. The axis of the cylinder is parallel to the beam one. For sampling calorimeters the layers of active materials are perpendicular to beam axis, the geometrical sampling fraction is as close as possible to the real one. The read-out of the deposited energy is obtained measuring the energy released in the active material. The simplified version of the CMS electromagnetic calorimeter (a lead tungsten crystal calorimeter) is composed of active material only. The read-out allows to measure the energy deposited in the sensitive volumes and, grouping together read-out planes, to measure the longitudinal shower profile. Concentric cylinders are also defined to read-out the transverse shower profile.
test15	GEANT4	Alexander Howard	Comparison of Geant4 simulation against the TARC experiment. This test is a validation of the production, transportation and interaction of neutrons with a large (~3.3m) volume of lead. Protons with momenta 2.5GeV/c are impinged on the lead volume through a semi-blind hole and the resulting neutron fluences are measured at various radii within the volume.
test22-HARP	GEANT4	Vladimir Uzhinsky	Double-differential proton production cross sections in the proton momentum range 0 to 8 GeV at angles 0.05 to 0.25 radians from collisions of charged pions and protons with nuclei (BE, C, AL, CU, SN, TA and PB), double differential PI+- production cross sections in PI+ and PI- interactions with BE, C, AL, CU, SN, TA and PB nuclei at incident momentum from 3 to 12 GeV/c.
test22-NA49	GEANT4	Vladimir Ivanchenko	
test22-NA61	GEANT4	Vladimir Uzhinsky	double differential PI+, PI-, proton production cross section in the laboratory system for p+C interactions at 31 GeV/c in different polar angle intervals (THETA).
test146	GEANT4	Vladimir Ivanchenko	Simulation of simplified combined calorimeter. Crystal electromagnetic (ECAL) calorimeter and sampling hadronic calorimeter (HCAL) are built. Geometry options: - ECAL may be not constructed; - preshower may be constructed consisting of thin layers of all materials from Geant4 material DB. Analysis is done only using ROOT histograms for energy deposition in ECAL and HCAL, transfer shape in ECAL, total calorimeter response.



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