Fast simulation

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Geant4 webpage

- Updated tasks #6 and #8

Electromagnetic shower parametrisation

The increase of the luminosity of particle accelerators will create unique opportunities in particle physics research by collecting orders of magnitude more data. At the same time, the demand for detector simulation will grow accordingly. However, the computing resources will not suffice if the current detector simulation is to be used. Development of faster simulation became an important topic, and many techniques are explored [1].

Fast simulation techniques that are currently employed by experiments are very detector specific and often deeply embedded in the software framework of the experiment. It is therefore very costly to introduce the same type of fast simulation to every new detector or experiment, as lots of work needs to be dedicated to the reimplementation. In order to minimise the work necessary to use fast simulation in the existing experiments and also the future ones, it is vital to work on the extraction of the common part of fast simulation implementation and to make it shared between different communities.

Simulation of the electromagnetic showers is often the most time consuming part of the simulation. In order to reduce the time spent in the calorimeters, the detailed simulation of the incoming particle can be replaced with directly created energy depositions representing the deposited energy of all particles from the shower development. One of the possible "recipes" for the creation of those energy deposits is to parametrise the shape of the shower based on the incoming particle type and its energy. Such parameterizations are already in use in the simulation production, however, are specific to the experiments, and they depend on parameters' values that were meticulously tuned to those detectors. Any change of those detectors, or application to a different device, would require a time-consuming re-tuning procedure. A simplification, automation and a more general procedure are needed in order to make the shower parameterization reusable.

Geant4 offers fast simulation hooks that enable overtaking the simulation for particles that fulfill given conditions. However, it is up to the user to implement how energy is deposited for those particles. There is one generic model implemented in Geant4 based on the GFlash parametrisation [2]. The parameters used to describe the showers are a function of the particle's energy and the material of the detector. The price for such a general solution is the accuracy of the simulation.

In order to increase the accuracy, the parameters ought to be extracted from the detailed simulation of the same detector. The on-going work is carried out on the development of the tools that simplify the tuning procedure and automate it as far as possible. It should also offer the possibility to alter the granularity of the calorimeter, as the larger the number of the created energy deposits, the longer it takes to look up the volumes in the geometry hierarchy.

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Pointers to information:

[1] HSF-CWP-2017-07 https://arxiv.org/abs/1803.04165
[2] G. Grindhammer and S. Peters, https://arxiv.org/abs/hep-ex/0001020

Validation tools for fast simulation of electromagnetic showers

Assessment of the accuracy of the fast simulation is vital for the development and employment of those techniques. As fast simulation is used to replace the detailed (so-called full) simulation, the comparison is done against the detailed simulation. It could be applicable both for the traditional shower parametrisation (more on shower parameterization), and the machine learning methods.

Since the most time-consuming part is most commonly the electromagnetic shower simulation, the fast simulation techniques focus on particle showers. Therefore, the validation is performed on the properties of the showers, such as:

- deposited energy
- shower profiles (longitudinal = along the initial particle momentum direction; transverse)
- number of cells with deposits above the threshold
- cell energy distribution
- simulation time

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Where & what

Geant4 application:

- for production of data for ML training;
- for ML and parametrisation validation;
- for extraction of parameters;

can be found on GitHub.

It also includes:

- validation tools,
- translation to/from HDF5 in C++ for quicker Python (numpy) access for ML training,
- tuning of parameters (prototyping the tuning procedure to be put in Geant4).

Data for ML training is on EOS - ideally this could be made more accesible publicly to encourage external contributions (opendata?)

To-do list

- Go back to the transverse profile parametrisation (more difficult than longitudinal);
- Investigate & introduce start-of-shower parametrisation;
- Investigate coarser granularity for energy deposition and how deposits should be created (currently $N \sim E$);
- Measure time spent in simulation of low-energetic parts of shower (below certain energy threshold -> core of shower fully simulated, parametrisation of the rest) to assess the gain;