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Development and deployment of a fast Monte Carlo simulation in LHCb

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Summary. — With the steady increase in the precision of flavour physics measurements with data from Run 2 of the LHC, the LHCb experiment requires simulated data samples of ever increasing magnitude to study the detector response in detail. However, relying on an increase of computing resources available for the production of simulated samples will not suffice to achieve this goal. Therefore, multiple efforts are currently being investigated to reduce the time needed to simulate an event. This document presents a summary of those efforts in LHCb, focusing on the newest developments: re-using parts of previously simulated events and a fully parametric detector description using the DELPHES framework.

1. – Introduction

For LHCb upgrade, more complex events and larger samples will need to be simulated. The computing resources deemed to be available will not be enough. The simulation time is dominated by the transport of particles inside the detector ($\mathcal{O}$ 95%–99%). For this reason increased CPU resources and new GEANT [1] versions will not be sufficient and dedicated fast simulation options will be necessary. Currently, some fast simulation options are available in the LHCb framework. One of them consists in the customization of the used detectors, in this way a $\mathcal{O}$ 40%–90% of time reduction can be achieved. Another possibility is to simulate just the decay of interest without including the underlying event, in this case the time reduction is $\mathcal{O}$ 95%–99%. Other fast simulation options are currently under development and will be implemented in the LHCb simulation framework, GAUSS [2], such as fast shower libraries for calorimeters, ReDecay and DELPHES [3].

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2. – ReDecay

Many LHCb analyses involve exclusive decays, *e.g.* $D^0 \to K^-\pi^+$ in which the only relevant parts are the decay products and not the rest of the event. The goal is to be 10–50 times faster than the nominal simulation. This option consists in generating the full event, taking out the signal, simulating the remaining part, and then regenerating and simulating the signal multiple times. Multiple signal decays are combined with the same underlying event. This approach is independent of the used generator and has the same detector response. The agreement with the nominal simulation is good but events are not independent anymore and the statistical uncertainty depends on the studied variable. The decay products variables are still independent, *e.g.* $p(K^-0)$ and $p(\pi^+)$, but global variables, such as number of primary vertices, or $p_T(D^0)$, are statistically correlated among different events. It is possible to avoid this using a different approach, *i.e.* the bootstrap method, to estimate the true variance in each bin and the correlation.

3. – DELPHES

Is a modular framework that parametrizes the response of a multipurpose detector and the reconstruction algorithms. It includes: the tracking system, embedded into a magnetic field, calorimeters with electromagnetic and hadronic sections, a muon system and very forward detector parts arranged along the beam-line. It performs the following: the propagation of stable particles, the interaction with detector using a parametric approach, the reconstruction of physics objects. The goal is to be from 100 to 1000 times faster than the full simulation. DELPHES has been customized to be integrated in the LHCb simulation framework, with the purpose to replace GEANT4 and the recontruction algorithms after the LHCb generator. A new particle propagator has been written to match the LHCb acceptance, that includes a simple transport inside the dipole magnet. Resolutions and efficiencies are parameterized from full simulation. The former is defined as the difference between the reconstructed quantities and the Monte Carlo true values. The sampled variables are the two track slopes T_x and T_y, and the momentum P. Efficiencies are taken from the reconstructed quantities in the tracker acceptance. The related variables are the two coordinates x and y, and the angles between them, ϕ.

4. – Conclusion

Fast simlulation is a crucial topic for LHC experiments, that need large amounts of Monte Carlo events. ReDecay and DELPHES have been integrated in the LHCb simulation framework. ReDecay is a powerful tool to get the large samples needed for exclusive decays. DELPHES is useful in cases where a less detailed approach is sufficient, in order to have large Monte Carlo samples to study systematic uncertainties and possible detector developments.

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