Fast simulation options in LHCb from ReDecay to fully parametrised

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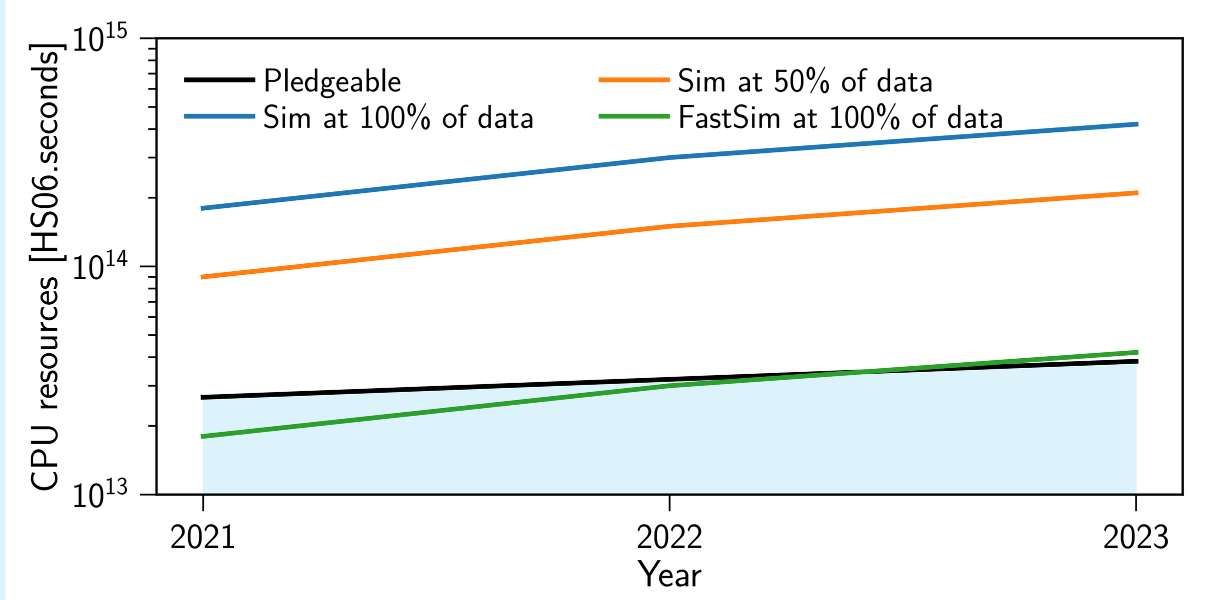
on behalf of the LHCb collaboration

Introduction

- For LHCb upgrade will need to simulate more complex events and in a bigger amount
  - ⇒ estimated resources will not be enough (see plot).
- Simulation time completely **dominated by detector transport** ($\mathcal{O}(95\%–99\%)$)!
- Increased CPU resources and new Geant versions will not suffice
  - ⇒ dedicated fast simulation options necessary
- Existing fast simulation options in LHCb:
  - Customize used subdetectors to the analysts needs ($\mathcal{O}(40\%–90\%)$ reduction.)
  - Only simulate the exclusive final state of interest ($\mathcal{O}(95\%–99\%)$ reduction.)
- Currently in development: shower libraries for the calorimeters, ReDecay and Delphes.
  - To be implemented in the official simulation of LHCb, Gauss [M. Clemencic et al. 2011 J. Phys. Conf. Ser. 331 032023]

Estimated CPU resources needed by LHCb with different simulation options

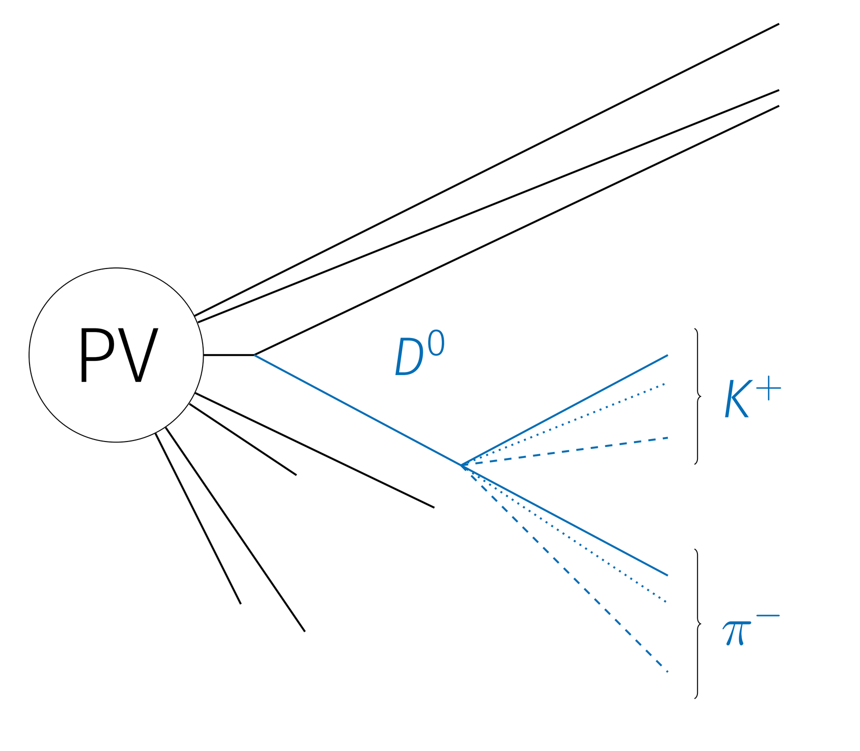


ReDecay

Motivation

- Many LHCb analyses involve exclusive decays, e.g. $D^0 \to K^-\pi^+$
  - ⇒ relevant quantities from decay products, not from the rest of the event.
- Simulating only signal decay products already implemented
  - ⇒ significant discrepancies with data: higher efficiencies and better resolutions.

Idea: re-use underlying event

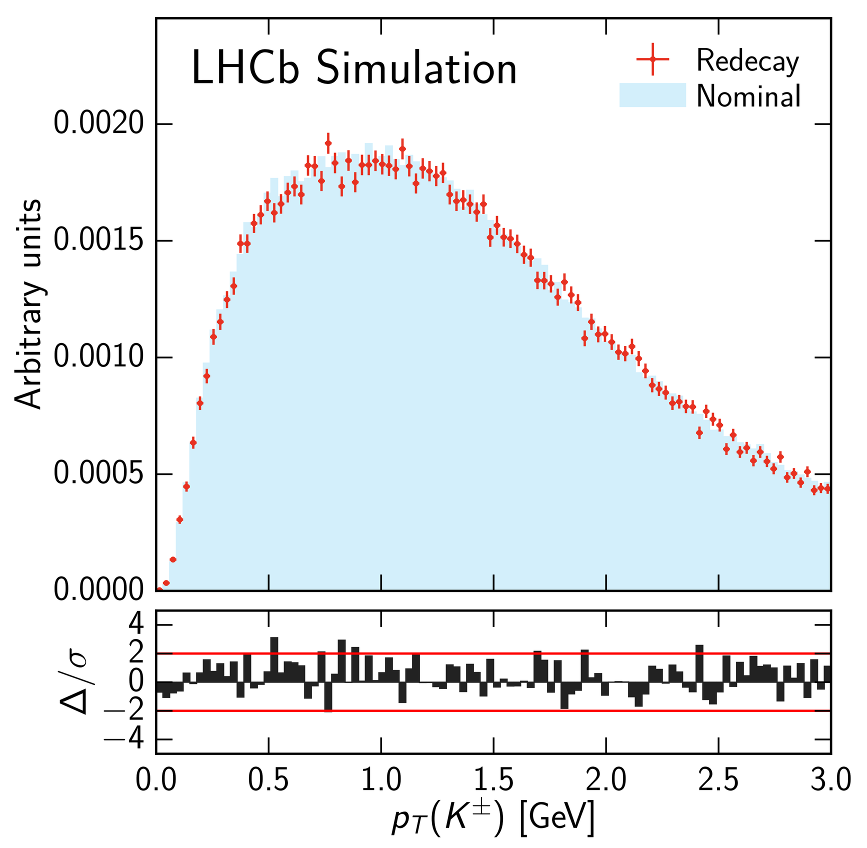


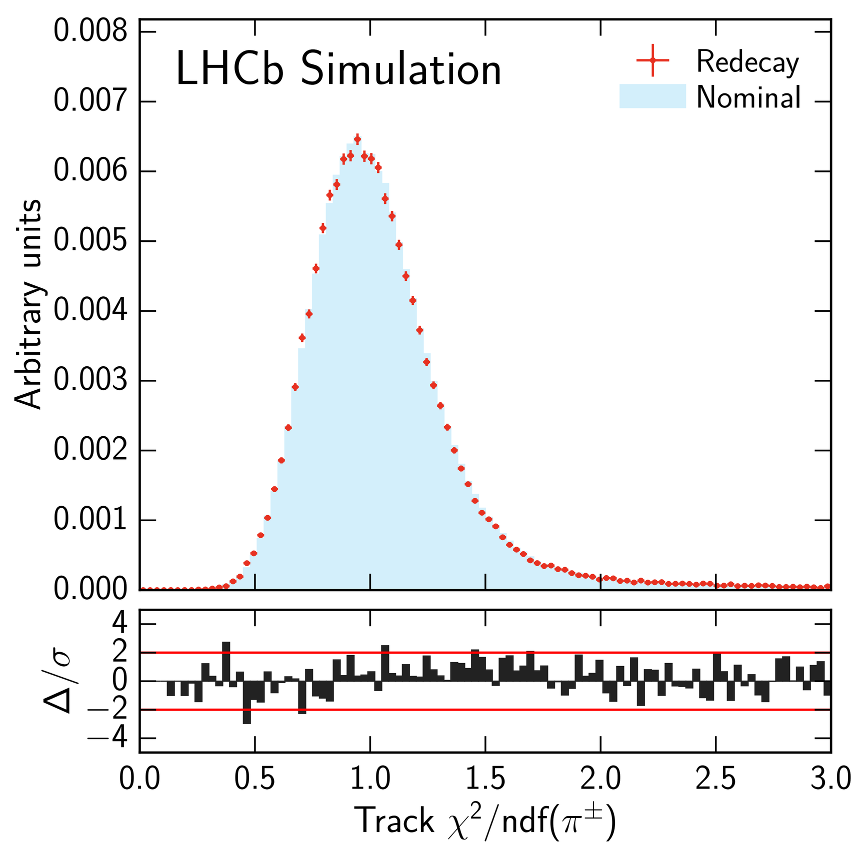
1. Generate full event.
2. Take out the signal.
3. Simulate the remaining event.
4. Generate and simulate multiple signals.
5. Combine simulated signal with stored underlying event.

- Independent of used generator.
- Complementary with general improvements to the LHCb detector simulation.
- **Same precision** on simulated detector response.

10 — 50 times faster

Example: $D^0 \to K^-\pi^+$

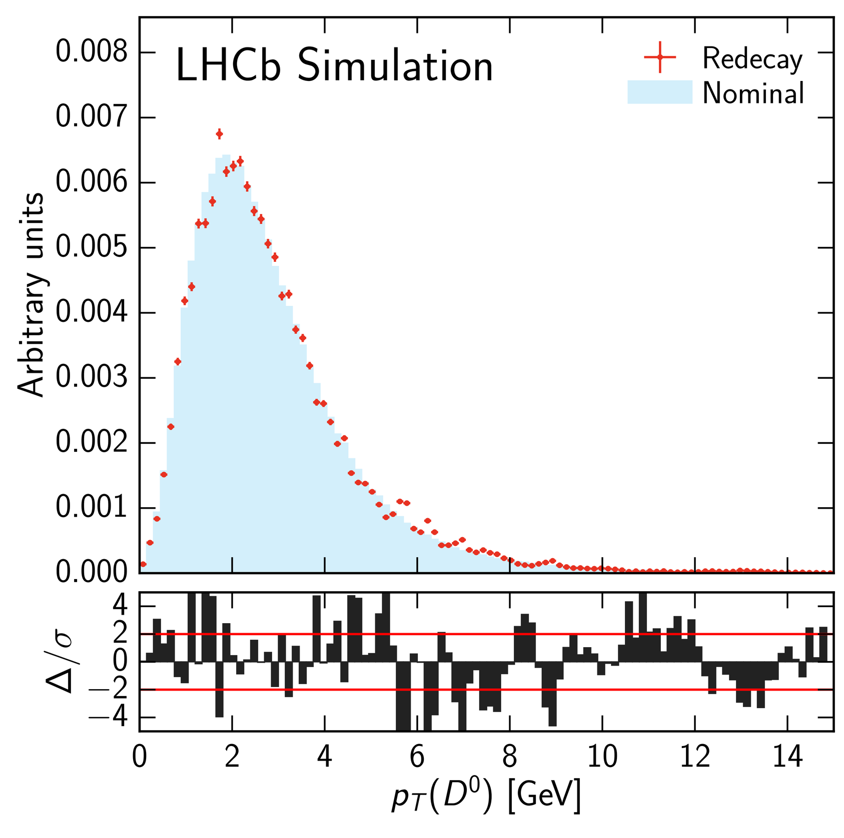




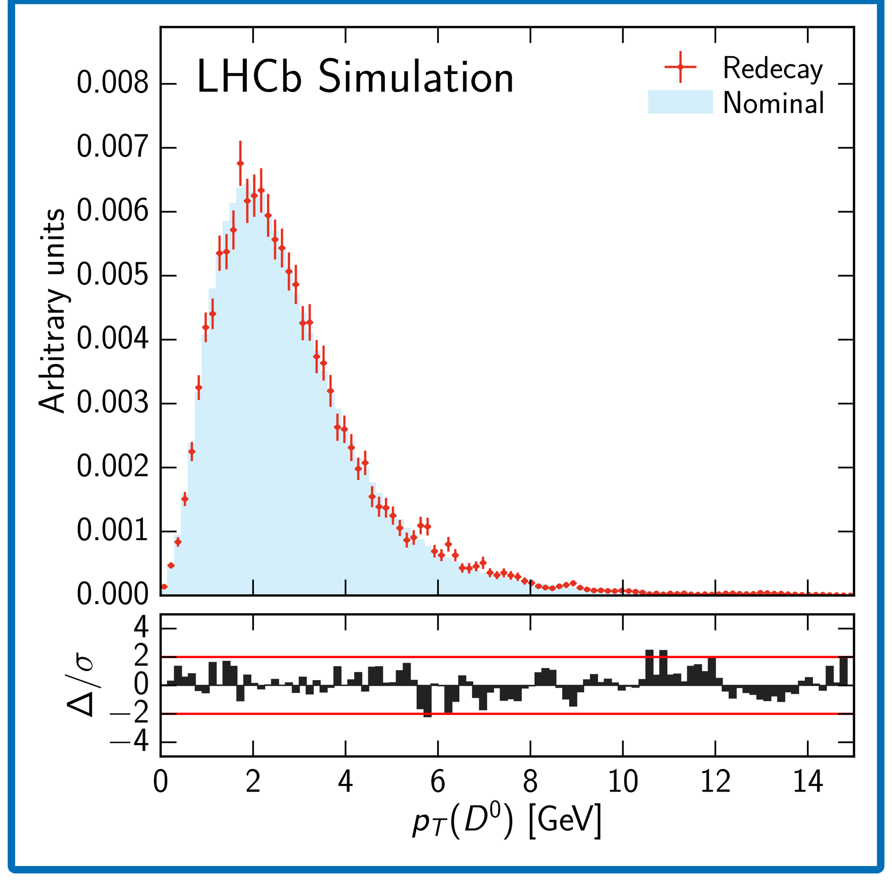
Challenge: Statistical uncertainty

- Events are not independent.
- Depends on studied variable:
  - No problem for child track variables (e.g. $p(K^+)$)
  - Large problem for global event variables (e.g. number of PVs)
- Sample with replacement (bootstrapping).

Naive $\sqrt{N}$



Bootstrapped



Parametric simulation using Delphes

Motivation

- Feasibility studies for physics analysis.
- Useful for study of systematics due to MC statistics.
- Can be used to explore different detectors for the upgrade

Delphes [de Favereau, J., Delaere, C. et al. J. High Energ. Phys. (2014) 2014:57]

Is a modular framework that parametrizes the response of a multipurpose detector and the reconstruction algorithms.

It includes:

- Tracking system, embedded into a magnetic field;
- Calorimeters with electromagnetic and hadronic sections;
- Muon system;
- Very forward detector arranged along the beam-line

It performs:

- Propagation of stable particles;
- "Interaction" with detector (parametric approach to efficiency and resolution convolution);
- "Reconstruction" of physics objects.

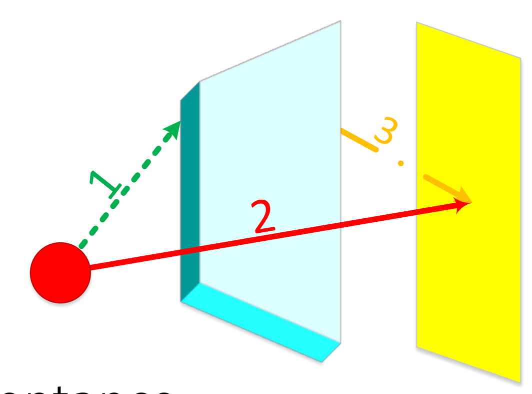
Goal: 100 — 1000 times faster

Customizations for LHCb

- Fully integrated in LHCb simulation framework GAUSS.
- Replace GEANT4 and reconstruction algorithms after LHCb generator.

Modified Particle Propagator

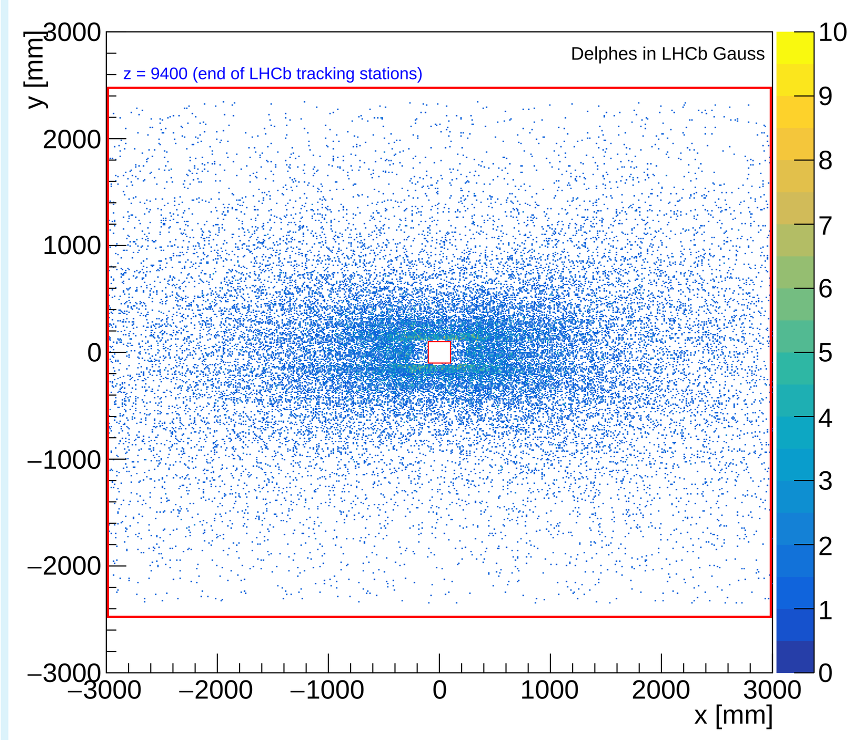
- LHCb acceptance.
- Simple transport in a dipole field.
- 3 different acceptance regions for charged particles.



In acceptance:

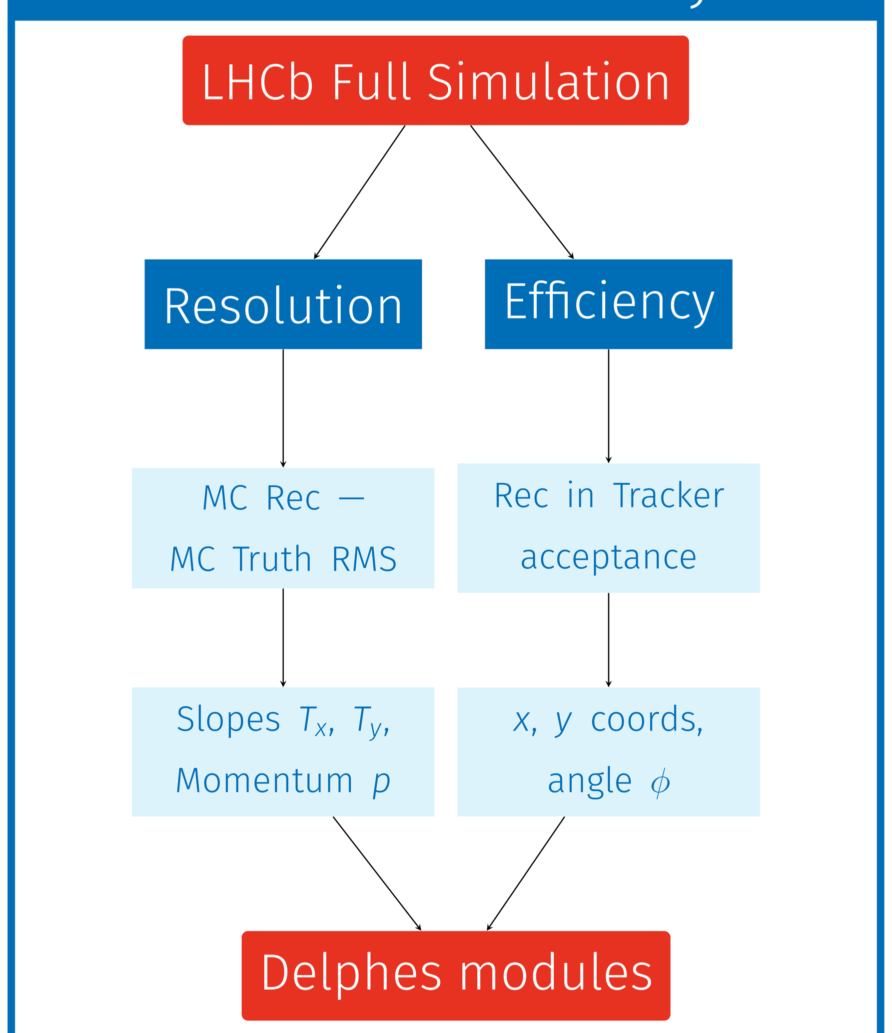
1. before the magnet only.
2. after the magnet only.
3. before and after the magnet.

Example LHCb acceptance

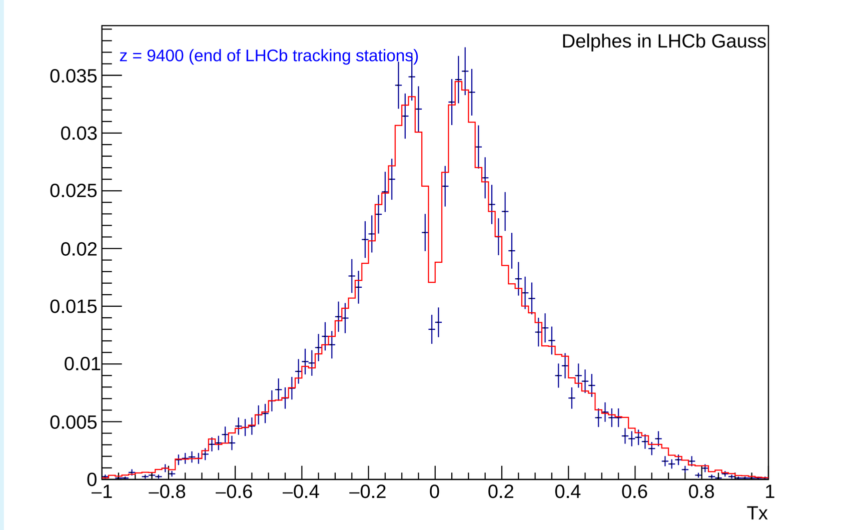


- Track distribution generated by Delphes using the new Particle Propagator module.

Resolution and Efficiency



Example



- Distribution of slope T_x, blue Delphes, red full Simulation