

Fast parameterised simulation option in LHCb simulation framework

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On behalf of the LHCb Collaboration

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Who am I?

- Benedetto Gianluca Siddi
- Started my PhD in Ferrara in 2015 working on Lepton Flavour Universality Tests
 - Topic of my PhD thesis
 - Two articles (PRD and PRL) came out from the analysis
- In the meantime started to work on the implementation of a Parametrized Fast Simulation option to be integrated in the LHCb Simulation framework
- PhD thesis defended in February 2018
- INFN Fellow in scientific computing in Ferrara from January 2018
 - Continuing the work on FastSimulation and future upgrades for LHCb and simulation part of TimeSpot project

Test of lepton flavor universality by the measurement of the $B^0 \rightarrow D^{*-} \tau^+ \nu_\tau$ branching fraction using three-prong τ decays

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The ratio of branching fractions $\mathcal{R}(D^{*-}) \equiv \mathcal{B}(B^0 \rightarrow D^{*-} \tau^+ \nu_\tau) / \mathcal{B}(B^0 \rightarrow D^{*-} \mu^+ \nu_\mu)$ is measured using a data sample of proton-proton collisions collected with the LHCb detector at center-of-mass energies of 7 and 8 TeV, corresponding to an integrated luminosity of 3 fb^{-1} . The τ lepton is reconstructed with three charged pions in the final state. A novel method is used that exploits the different vertex topologies of signal and backgrounds to isolate samples of semitauonic decays of b hadrons with high purity. Using the $B^0 \rightarrow D^{*-} \pi^+ \pi^- \pi^+$ decay as the normalization channel, the ratio $\mathcal{B}(B^0 \rightarrow D^{*-} \tau^+ \nu_\tau) / \mathcal{B}(B^0 \rightarrow D^{*-} \pi^+ \pi^- \pi^+)$ is measured to be $1.97 \pm 0.13 \pm 0.18$, where the first uncertainty is statistical and the second systematic. An average of branching fraction measurements for the normalization channel is used to derive $\mathcal{B}(B^0 \rightarrow D^{*-} \tau^+ \nu_\tau) = (1.42 \pm 0.094 \pm 0.129 \pm 0.054)\%$, where the third uncertainty is due to the limited knowledge of $\mathcal{B}(B^0 \rightarrow D^{*-} \pi^+ \pi^- \pi^+)$. A test of lepton flavor universality is performed using the well-measured branching fraction $\mathcal{B}(B^0 \rightarrow D^{*-} \mu^+ \nu_\mu)$ to compute $\mathcal{R}(D^{*-}) = 0.291 \pm 0.019 \pm 0.026 \pm 0.013$, where the third uncertainty originates from the uncertainties on $\mathcal{B}(B^0 \rightarrow D^{*-} \pi^+ \pi^- \pi^+)$ and $\mathcal{B}(B^0 \rightarrow D^{*-} \mu^+ \nu_\mu)$. This measurement is in agreement with the standard model prediction and with previous results.

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I. INTRODUCTION

In the Standard Model (SM) flavor universality (LFU) is an only by the Yukawa interaction expected branching fraction of s three lepton families originate from the charged leptons. Further development of physics processes measurements, are compatible with 1 standard deviation difference element of the branching fraction decay with respect to those of $W^+ \rightarrow \mu^+ \nu_\mu$ and $W^+ \rightarrow e^+ \nu_e$. Since uncertainties due to large extent, the SM prediction branching fractions of semitau relative to decays involving high

Measurement of the Ratio of the $B^0 \rightarrow D^{*-} \tau^+ \nu_\tau$ and $B^0 \rightarrow D^{*-} \mu^+ \nu_\mu$ Branching Fractions Using Three-Prong τ -Lepton Decays

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The ratio of branching fractions $\mathcal{R}(D^{*-}) \equiv \mathcal{B}(B^0 \rightarrow D^{*-} \tau^+ \nu_\tau) / \mathcal{B}(B^0 \rightarrow D^{*-} \mu^+ \nu_\mu)$ is measured using a data sample of proton-proton collisions collected with the LHCb detector at center-of-mass energies of 7 and 8 TeV, corresponding to an integrated luminosity of 3 fb^{-1} . For the first time, $\mathcal{R}(D^{*-})$ is determined using the τ -lepton decays with three charged pions in the final state. The $B^0 \rightarrow D^{*-} \tau^+ \nu_\tau$ yield is normalized to that of the $B^0 \rightarrow D^{*-} \pi^+ \pi^- \pi^+$ mode, providing a measurement of $\mathcal{B}(B^0 \rightarrow D^{*-} \tau^+ \nu_\tau) / \mathcal{B}(B^0 \rightarrow D^{*-} \pi^+ \pi^- \pi^+) = 1.97 \pm 0.13 \pm 0.18$, where the first uncertainty is statistical and the second systematic. The value of $\mathcal{B}(B^0 \rightarrow D^{*-} \tau^+ \nu_\tau) = (1.42 \pm 0.094 \pm 0.129 \pm 0.054)\%$ is obtained, where the third uncertainty is due to the limited knowledge of the branching fraction of the normalization mode. Using the well-measured branching fraction of the $B^0 \rightarrow D^{*-} \mu^+ \nu_\mu$ decay, a value of $\mathcal{R}(D^{*-}) = 0.291 \pm 0.019 \pm 0.026 \pm 0.013$ is established, where the third uncertainty is due to the limited knowledge of the branching fractions of the normalization and $B^0 \rightarrow D^{*-} \mu^+ \nu_\mu$ modes. This measurement is in agreement with the standard model prediction and with previous results.

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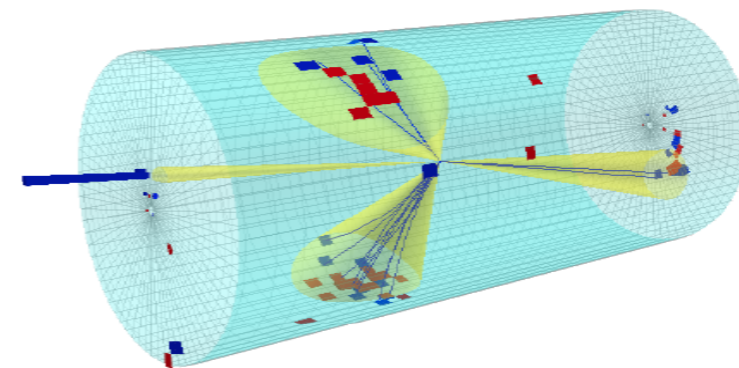
In the standard model (SM) of particle physics, flavor-changing processes such as semileptonic decays of b hadrons are mediated by a W boson with universal coupling to leptons. Differences between the expected branching fraction of semileptonic decays into the three lepton families originate from the different masses of the charged leptons. Lepton universality can be violated in many extensions of the SM with nontrivial flavor structure. Since uncertainties due to hadronic effects cancel to a large extent, the SM prediction for the ratios between branching fractions of semitauonic decays of B mesons relative to decays involving lighter lepton families, such as $\mathcal{R}(D^{*-}) \equiv \mathcal{B}(B^0 \rightarrow D^{*-} \tau^+ \nu_\tau) / \mathcal{B}(B^0 \rightarrow D^{*-} \mu^+ \nu_\mu)$ and

Collaborations in final states involving electrons or muons from the τ decay. The LHCb Collaboration published a determination of $\mathcal{R}(D^{*-})$ [12], where the τ lepton was reconstructed using leptonic decays to a muon. The first simultaneous measurements of $\mathcal{R}(D^{*-})$, $\mathcal{R}(D^0)$, and τ polarization, using τ decays with one charged hadron in the final state, has recently been published by the Belle Collaboration [13]. All these measurements yield values that are above the SM predictions with a combined significance of 3.9 standard deviations [14].

This Letter reports the first determination of $\mathcal{R}(D^{*-})$ using the three-prong $\tau^+ \rightarrow \pi^+ \pi^- \pi^+ \nu_\tau$ and $\tau^+ \rightarrow \pi^+ \pi^- \pi^0 \nu_\tau$ decays. A more detailed description of this measurement is given in Ref. [15]. The D^{*-} meson is $\gamma^* \rightarrow \bar{D}^0 (\rightarrow K^+ \pi^-) \pi^-$ decay consists of six charged tracks; this analysis. A data sample of responding to an integrated with the LHCb detector at $\sqrt{s} = 7$ and 8 TeV is used. Central systematic uncertainties, τ is chosen as a normalization measurement of the ratio

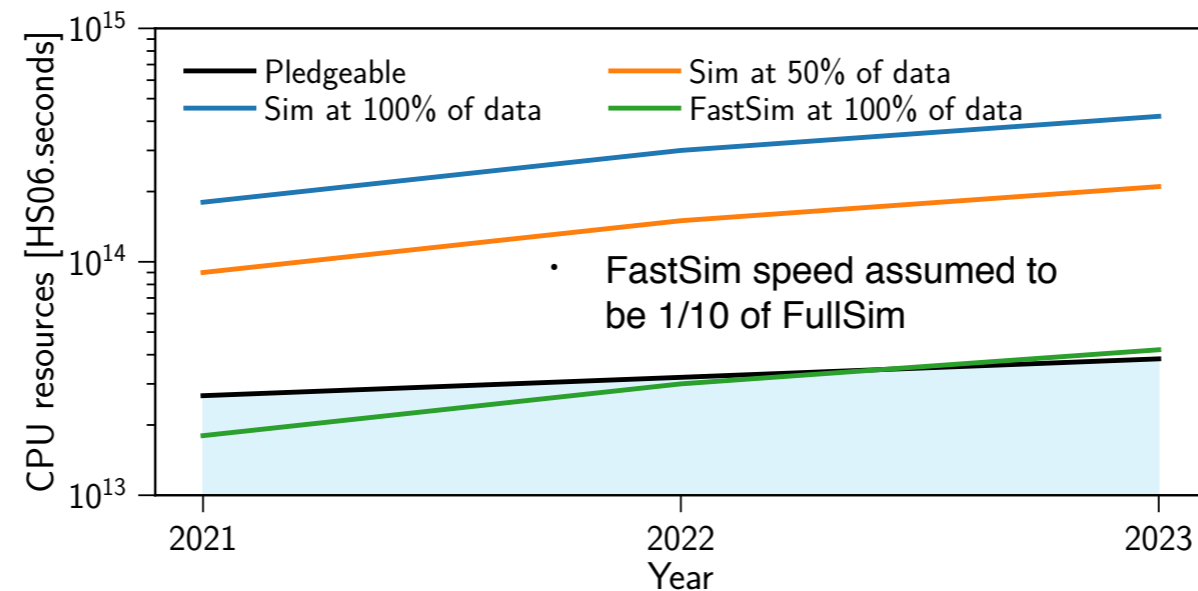
$$\mathcal{R}(D^{*-}) = \frac{\mathcal{B}(B^0 \rightarrow D^{*-} \tau^+ \nu_\tau)}{\mathcal{B}(B^0 \rightarrow D^{*-} \mu^+ \nu_\mu)} = \frac{1}{3\pi\tilde{\nu}_\tau + \mathcal{B}(\tau^+ \rightarrow 3\pi^0 \nu_\tau)} \quad (1)$$

for the LHCb Collaboration



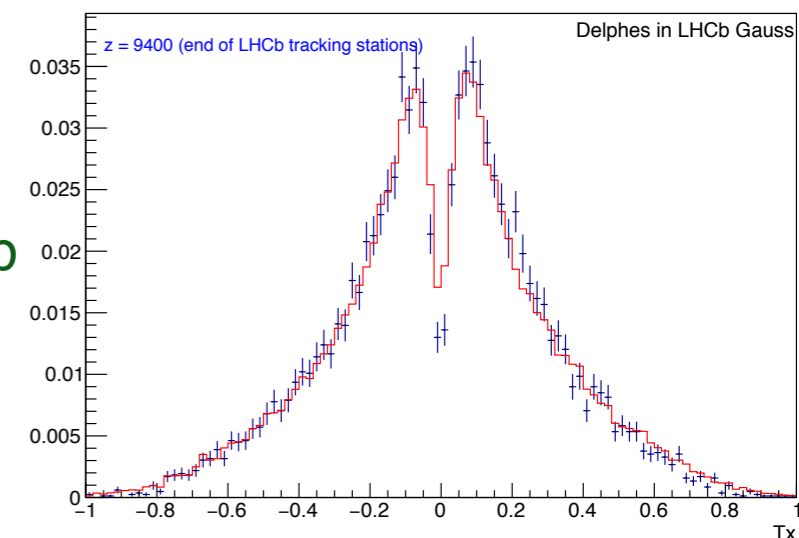
FastMC: Integration of Delphes in LHCb simulation framework

- The role of Monte Carlo simulation in high energy physics experiment is to mimic the behaviour of a detector to understand experimental conditions and performance
- Systematics uncertainties in most of the analysis are dominated by the MC
- Large MC samples → large resources
- New simulation options needs to be investigated

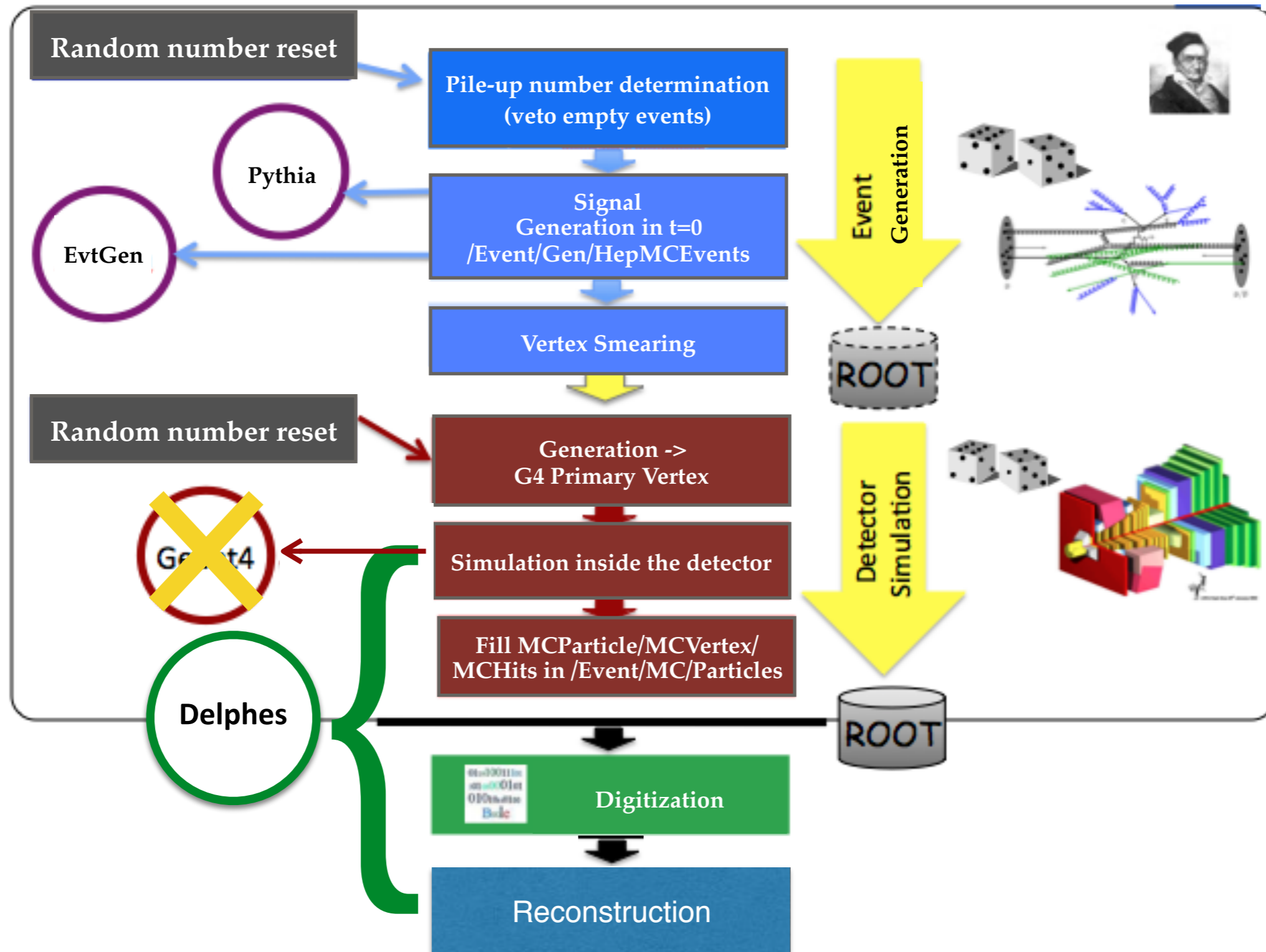


Requirements for a FastMC:

- Two orders of magnitude faster than GEANT4
- Less CPU consuming
- Reconstructed particle information in order to use the standard LHCb tools for analysis
- As close as possible to the full simulation

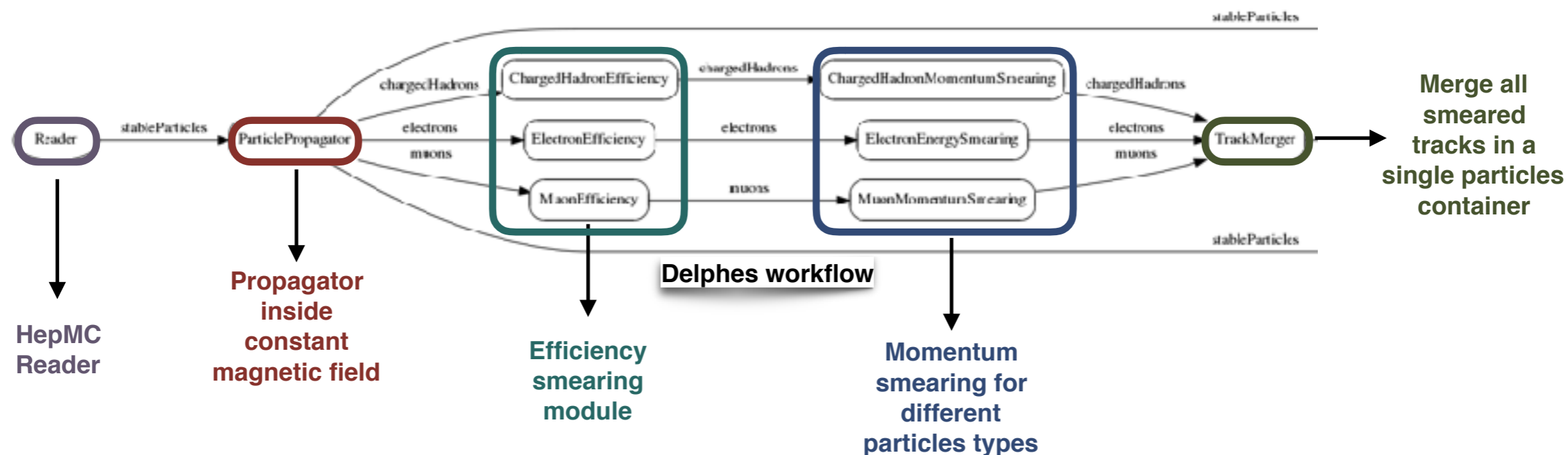


Fast simulation with Delphes in LHCb



Delphes

- Delphes + modifications for LHCb, has been integrated in LHCb simulation framework Gauss.
 - It takes in input particles generated from the generator part of Gauss,
 - It writes as output objects in the format necessary for LHCb analysis framework.
- No lower level reconstructed objects!



- Working on implementing relevant quantities of reconstructed tracks, e.g., covariance matrices, fit χ^2 , ghost probabilities
- Work to be done :
 - Particle Identification probabilities, calorimeter response for charged and neutral particles.
 - Finalize the output of the objects filled with the information needed to be used in the LHCb analysis framework in order to perform physics analyses
 - Review the code in order to make it thread safe and multithreading to be used in the new LHCb Framework.