

EvtGen and Pythia developments

EvtGen

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Pythia

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EvtGen status

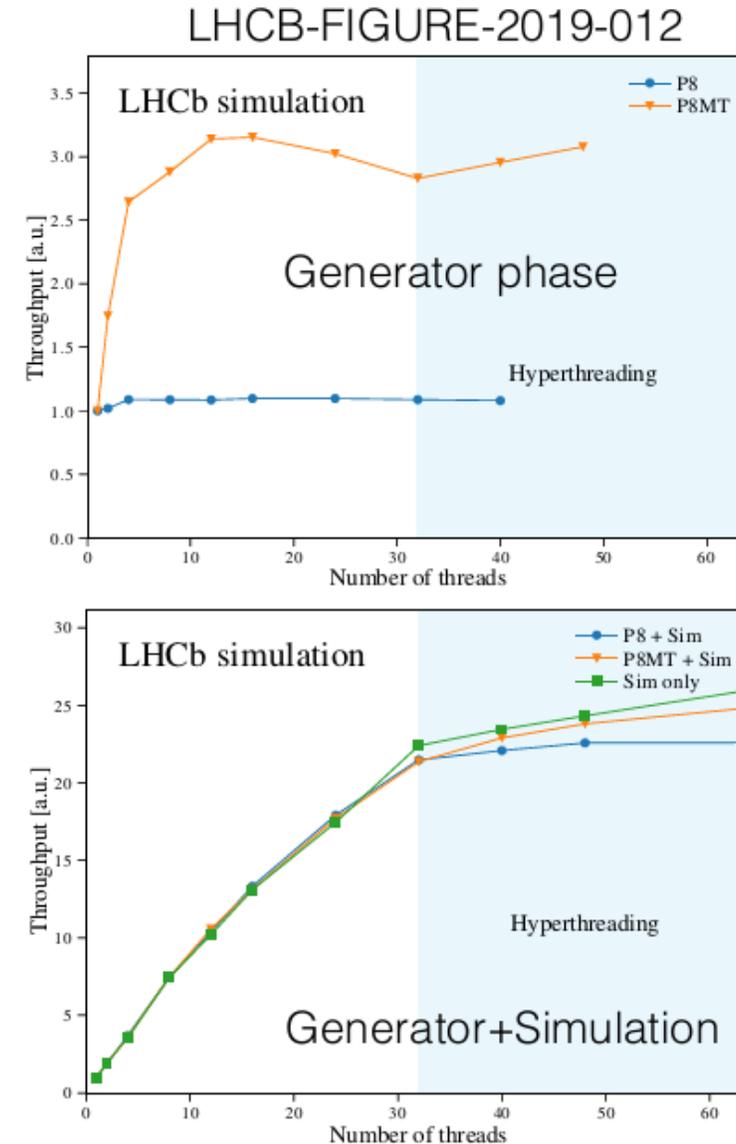
- Generator package specialised for heavy-flavor hadron decays
 - Used as well inside simulation of b jets
- Contains about 130 decay models implementing specific dynamics of various decays
- Maintains detailed decay table with large number of explicit decays
 - Known decay branching fractions do not add up to 100%, remainder is filled up by generating quark configurations and passing those to Pythia8 for fragmentation
 - Fraction of decays passed to Pythia8 depends on particle (b -baryons rely more on Pythia8 than others)
- τ decays simulated using TAUOLA
- PHOTOS used for simulation of final-state radiation (FSR)
- Source code stable over past 10 years (most changes due to addition of new models)
- Recently went through some modernisation and cleanup

Plans for EvtGen

- Physics wise no plan for changes in near future
- Currently working on code consolidation
 - Unify coding style, C++ modernisation
 - Plan to decrease code duplication within decay models
 - Improve/Update documentation (Doxygen and paper/guide)
- Plan to make EvtGen thread safe
 - Event $\hat{=}$ particle whose decay is simulated (through full decay chain)
 - Main blockers are Tauola and Photos, which are not yet thread safe
 - Work on source-code redesign currently ongoing with help of computing engineers
 - Full adaptation might be challenging (core code adaptation should be doable)

Multithreading environment within LHCb

- New version of simulation under development uses single EvtGen instance which is setup as needed
 - Using only the generator, there is a limitation using already a few threads
 - No visible effect however when detector simulation runs
 - LHCb runs Generator+Simulation by default in the same job
- ⇒ Might be different for other experiments
- ⇒ There could be a limit with more threads

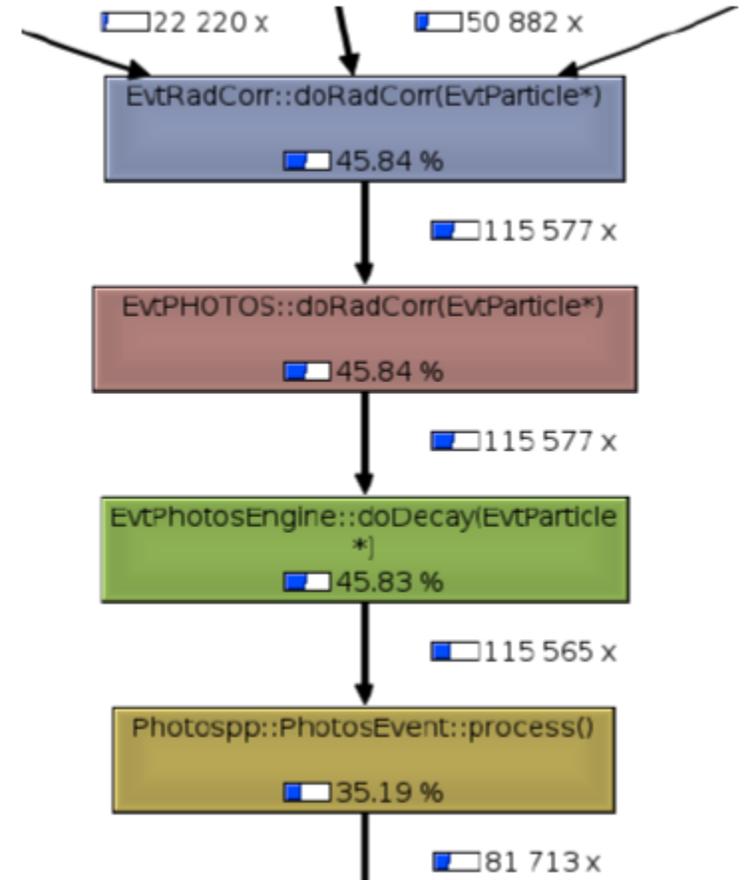


Issues with multithreading in EvtGen

- Structural limitations inside EvtGen for multithreading
 - Global instance of random number generator
 - Global instance of particle properties and decay table (less critical)
- Limitations from dependences
 - TAUOLA
 - PHOTOS
- Needed structural changes identified
- Overcoming limitations from dependences are more challenging as they are external
 - TAUOLA and PHOTOS authors currently exploring ways to enable thread safety
 - Replace Tauola with Pythia8
 - Look for an alternative to PHOTOS (discussing about porting FSR simulation from other generators)

Issues with multithreading in EvtGen

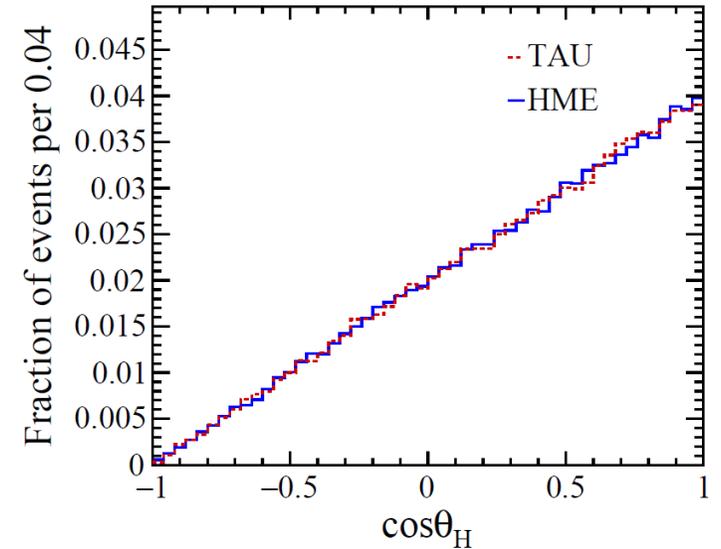
- PHOTOS is commonly used in almost every decay
 - Profiling shows a significant amount of CPU time consumption in PHOTOS itself
 - Conversion EvtGen \leftrightarrow HepMC also significant
 - Similar conversion happens inside PHOTOS
 - Probably half of CPU time effectively spent on conversion
 - Need to try bypassing HepMC to estimate possible gain
- ⇒ Usually $\sim 1/3$ of EvtGen CPU time spent on FSR simulation



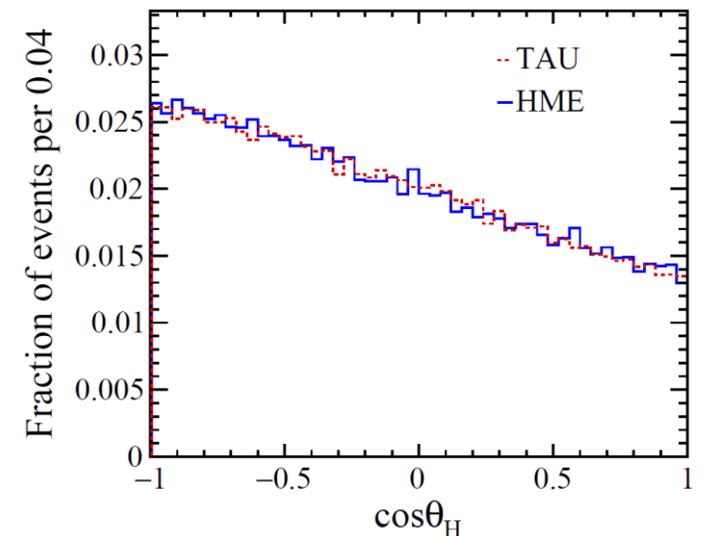
TAUOLA replacement

- In addition to multithreading limitations, spin-state information of τ not propagated between EvtGen and TAUOLA:
 - TAUOLA expects τ from W, Z, γ or H , not from B
 - needed for analyses sensitive to τ polarization
- Simulation of τ decays with spin-state propagation possible with PYTHIA8 using HME (helicity-matrix element) amplitude model.
- Main EvtGen \leftrightarrow Pythia interface ready
- Need to iron out a few details (helicity/spin basis, initialization)

$$B^+ \rightarrow \tau^+ (\rightarrow \pi^+ \bar{\nu}_\tau) \nu_\tau$$



$$B^+ \rightarrow \tau^+ (\rightarrow \mu^+ \nu_\mu \bar{\nu}_\tau) \nu_\tau$$



Pythia status and plans

- General purpose generator for simulation of collision events of particles (electrons, protons, photons, heavy nuclei) at high-energies.
- Contains models for several aspects: hard/soft interactions, parton distributions, initial/final-state parton showers, multiparton interactions, fragmentation and decay.

Currently working on different aspects aimed at making simulation of b -hadron faster:

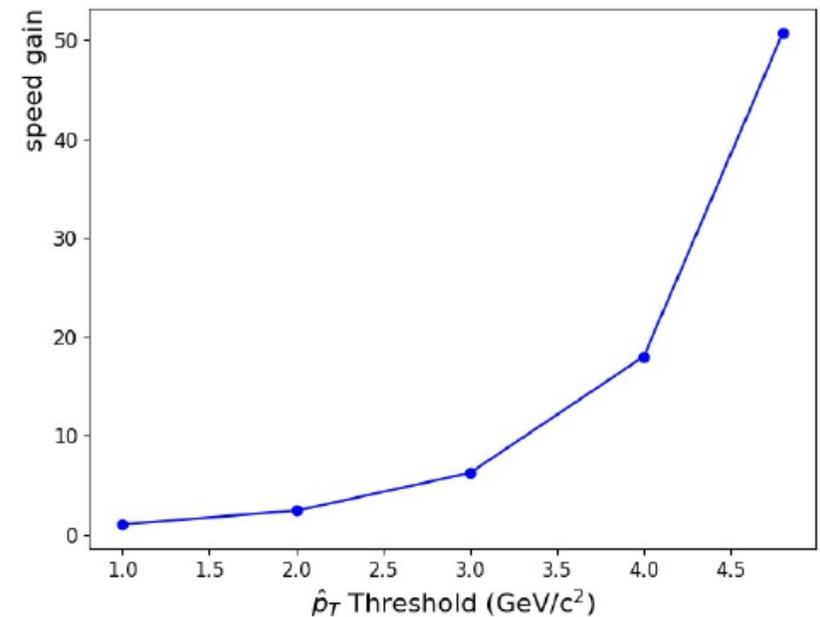
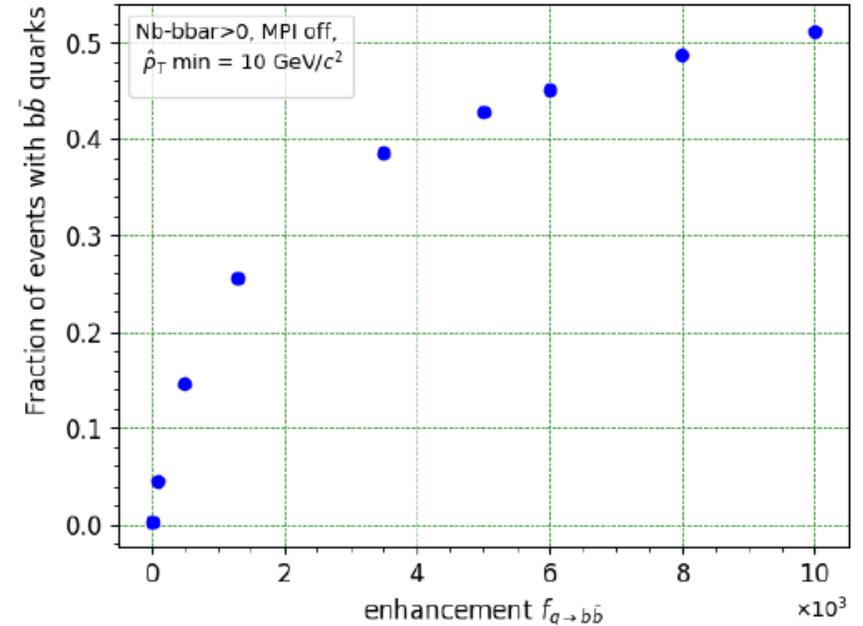
- B enhancement
- Doubly-heavy hadrons in Pythia

Plans for future developments:

- Forced hadronization
- Optimizing simulation with more than one heavy-quark pair

B enhancement

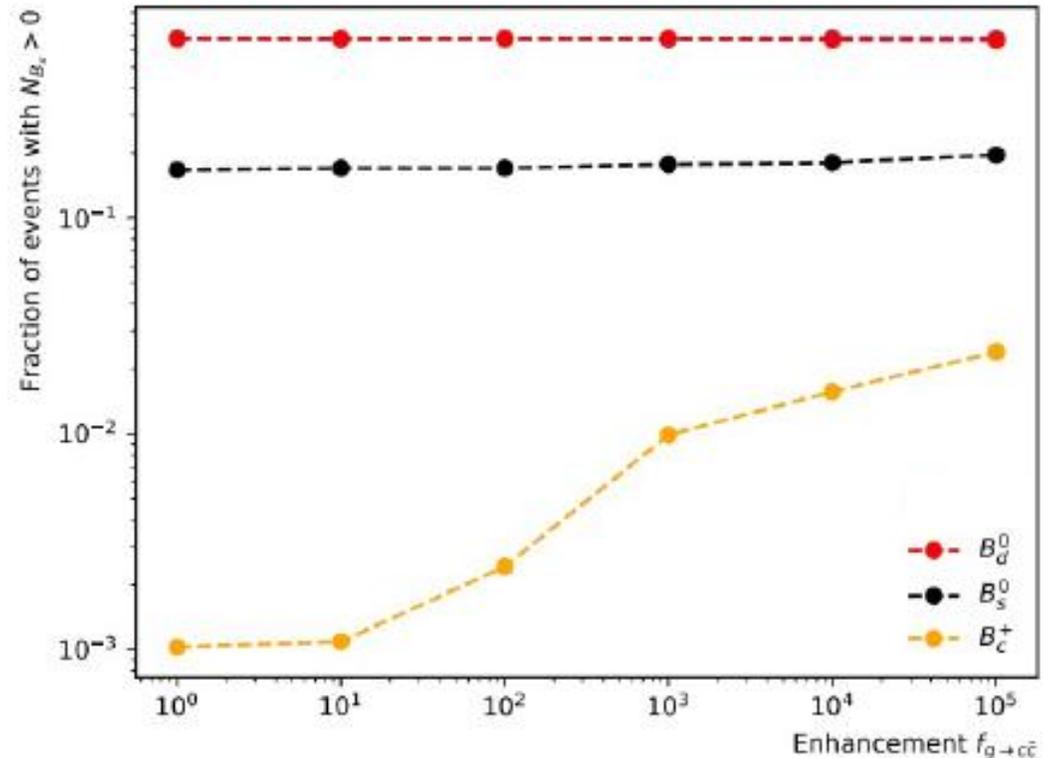
- **Goal:** make b -hadron production faster (in LHCb simulation)
- Particularly important for cases where generator consumes more CPU time than detector simulation
- **Examples:** production of $B_S, B_C, \Xi_{cc}, \Omega_{bb}$
- Produced b -hadrons should still be kinematically unbiased
- Currently exploring ways to enhance $g \rightarrow c\bar{c}, b\bar{b}$ splitting in an unbiased way



Proof of Principle via standalone Pythia

Double-heavy hadrons in Pythia

- Pythia currently not employed for B_c or other double heavy hadrons at LHCb
- Exploring ways to increase efficiency by vetoing events without desired heavy-quark composition at early simulation stage
- Possible vetoes based on presence of correctly colour-connected heavy quarks
- Will enable comparison with dedicated generators like BcVegPy which currently has a limited list of supported production processes



Future plans

- Forced hadronization
 - Implement forced hadronization rather than current repeated hadronization
 - Will make a considerable impact for events with baryons with multiple s like $\Omega_b(ssb)$
 - Less significant impact expected for B^\pm, B^0
- Simulation with more than one heavy-quark pair
 - Currently investigating ways to improve efficiency of simulation for events with more than one heavy-quark pair produced in multiparton interactions

Summary and outlook

EvtGen:

- Currently working on making EvtGen threadsafe
- ⇒ Full adaptation might be challenging but the plan is to converge on core within one year
- ⇒ Replacing final-state radiation simulation (currently using PHOTOS) is the main concern
- ⇒ Working in moving from TAUOLA to PYTHIA for τ simulation

Pythia:

- Currently working in enhancement of b -hadron production to make simulation faster
- Exploring how to improve efficiency for events with multiple heavy quarks