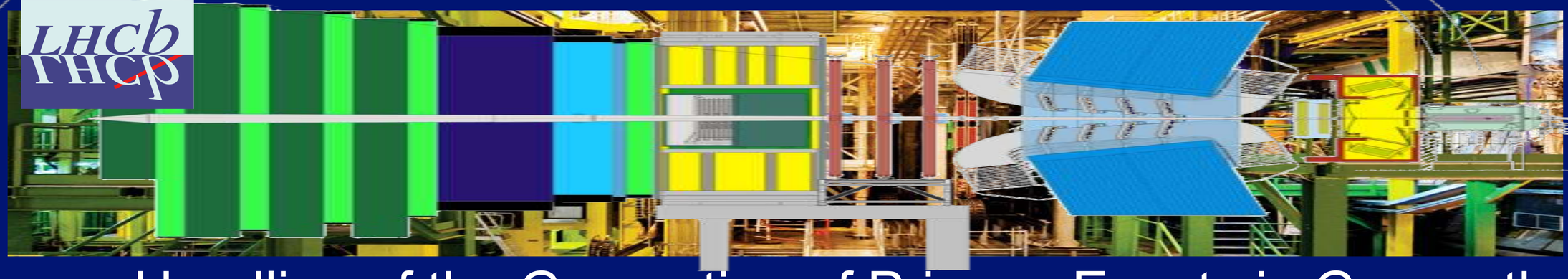

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Handling of the Generation of Primary Events in Gauss, the LHCb Simulation Framework

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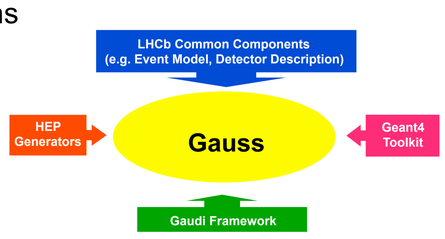
The simulation application, Gauss, is a collection of "User Code" specialized for physics simulation

- A sequence of algorithms configured via the properties in job options



based on LHCb common OO framework Gaudi, making use of its general services

- JobOptions Service, Message Service, Particle Properties Service, Event Data Service, Histogram Service…

LHCb common software

- LHCb Event model, Detector Description, Magnetic Field Service, …

dedicated simulation software based on external libraries

- Generator algorithms and tools (Pythia, EvtGen, …), GiGa (Geant4 Service)

Alternative Generators:

Particle Guns: for cosmics, calibrations, beam…

Machine Background: beam halo, … (N25-5)

Pile-Up Tool

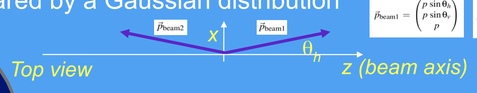
Determines the number of interactions *N* per event.

- Fixed Luminosity (default), *N* follows a Poisson law of mean value ν, where $\nu = \frac{\mathcal{L}\sigma_{tot}}{f}$, and with $N \neq 0$.
- Fixed N Interactions: *N* is constant.
- Fixed Luminosity For Rare Process: used for generation of rare events. (*N*-1) follows a Poisson distribution with mean value ν

Beam Tool

- Colliding Beams: generates 2 colliding beams with a crossing angle which is smeared by a Gaussian distribution

$\vec{p}_{beam1} = \begin{pmatrix} p\sin\theta_h \\ p\sin\theta_v \\ p \end{pmatrix}$ $\vec{p}_{beam2} = \begin{pmatrix} p\sin\theta_h \\ p\sin\theta_v \\ -p \end{pmatrix}$



where θ_h and θ_v follow Gaussian distributions with a defined mean value and $\sigma = \sqrt{\frac{\varepsilon}{\beta^*}}$

- Fixed Target: generates one single beam:

$\vec{p}_{beam1} = \begin{pmatrix} p\sin\theta_h \\ p\sin\theta_v \\ p \end{pmatrix}$ $\vec{p}_{beam2} = \vec{0}$

Sample Generation Tool

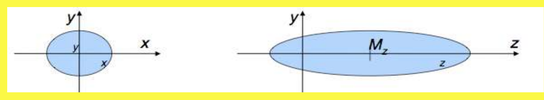
In LHCb, 4 different types of event samples can be produced:

- Minimum Bias: keep all events generated.
- Inclusive: keep events generated with at least one b-(or c) hadron in 400 mrad w/r to the z axis.
  If all of these hadrons have $p_z < 0$, flip the whole interaction
- Signal: keep events generated containing one B^+ or one B^- (or one $B^0/\bar{B}^0$, J/ψ, D_s^+/D_s^-, …) in 400 mrad.
  If there are several candidates, choose randomly one.
  If it has $p_z<0$, flip the whole interaction.
  To speed up generation, if the interaction contains a b quark, repeat the hadronization process until the interaction contains the B^+/B^-.
  Decay will be taken care by the decay tool.
- Special (Higgs, top, W, Z, …): keep all events generated by Pythia with special settings and passing specific generator level cuts (p_T(lepton) > 4 GeV, …)

Vertex Smearing Tool

Generates profiles of luminous region (position and size).

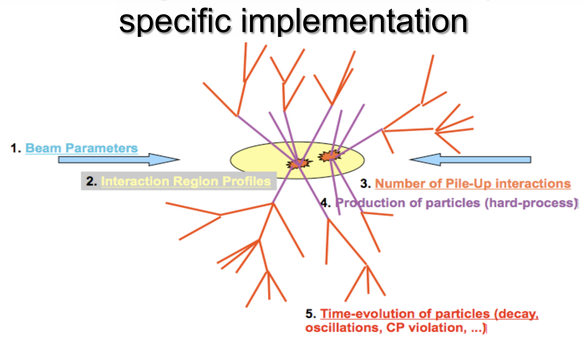
- **Beam Spot Smear Vertex**: the primary vertex position follows Gaussian distributions in (*x*,*y*,*z*) and has a fixed time *t*.



- **Flat Z Smear Vertex**: the primary vertex position follows Gaussian distributions in (*x*,*y*), a flat distribution in *z* and has a fixed time *t*.

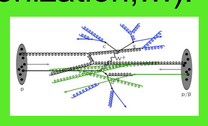
Generation of Physics Events

Generation algorithm uses tools, i.e. pieces of code realizing specific actions of the generation sequence. Each tool has a generic interface and (at least) one specific implementation



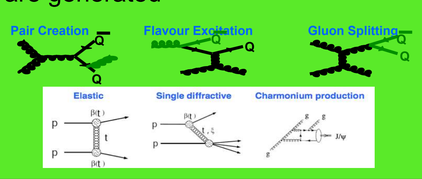
Production Tool

It is used to generate the *pp* collisions (hard process, hadronization,…). Delegated to generators on the market.



Pythia6: (6.4 default in LHCb productions, LHAPDF …)
http://www.thep.lu.se/~torbjorn/pythia/lutp0613man2.pdf

- All configuration switches are available to Gauss through Python options
- Default options constitute « **LHCb tuning** », which is done to extrapolate at higher energies charged track multiplicities seen at the UA1 experiment.
- The activated physics processes are the dominant ones for LHC energies. They define LHCb « **minimum bias** » out of which all major samples are generated



Cut Tool

To obtain more interesting samples, a cut is also performed at generator level to keep only useful events. Accept or reject an event based on generator level quantities.

- LHCbAcceptance: cut on signal direction: $0 \leq \theta_{signal} \leq 400$ mrad.
- DaughtersInLHCb: cut on direction of decay products of signal particle:
  - 10 mrad ≤ $\theta_{charged}$ ≤ 400 mrad, 5 mrad ≤ $\theta_{neutral}$ ≤ 400 mrad
  - No cut on Λ and K_s^0 daughters, and on neutrinos.
  - Only cut on γ if they come from π^0 or η.

Variations of this cut (DaughtersInLHCbAndFromB, ListOfDaughtersInLHCb, …) are available.

Decay Tool

It is used to decay all particles, and to generate correct time dependance (CP violation, mixing), correct angular correlations, etc…

EvtGen: (default in LHCb)
http://lhcb-release-area.web.cern.ch/LHCb-release-area/DOC/gauss/generator/evtgen.php

package used in Gauss to generate the decay and evolution of all particles:

- B hadrons, generic and user/signal tables
- handles complicated decay chains involving correlations between different observables
- it uses decay amplitudes instead of probabilities
- ~8000 decays implemented (stored in DECFILEs)
- delegate to Pythia when decay not present (Higgs, top, W, Z,…) in decay table (called internally)
- delegate to Photos for QED radiative corrections (called internally)

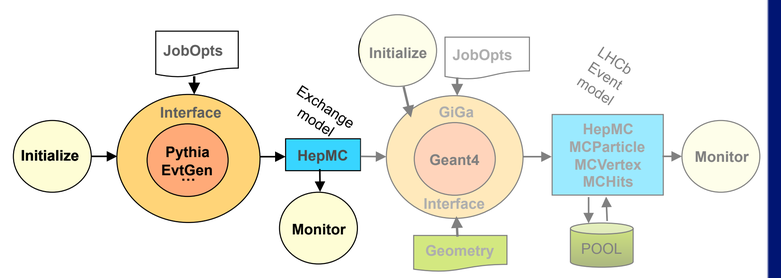
It was originally developed by David Lange and Anders Ryd from BaBar and CLEO **.

Sherpa Decay: (alternative in deployment)
http://projects.hepforge.org/sherpa/dokuwiki/doku.php

**adapted for LHCb.

N25-3: talk on Gauss

Two independent phases run in sequence::



- all generators "wrapped" into C++ code to make them callable and controllable" from within the framework
- events are stored in HepMC format (used also as exchange format between generation tools)

Alternative Production Tools:

Hijing: for p-gas events

BCVEGPY: for Bc production

Events from ASCII files with HepMC format

Pythia8: C++ Pythia version
http://home.thep.lu.se/~torbjorn/talks/tutorial81.pdf

HiddenValley

Sherpa: as both production and decay tool
http://projects.hepforge.org/sherpa/dokuwiki/doku.php

Herwig (+ Jimmy and MC) to be retired soon
http://hepwww.rl.ac.uk/theory/seymour/herwig

Herwig++: C++ version
http://project.hepforge.org/herwig

AlpGen

http://lhcb-release-area.web.cern.ch/LHCb-release-area/DOC/gauss/
lhcb-gauss-managers@cern.ch

2010 IEEE Nuclear Science Symposium, October 30 – November 6, 2010 Knoxville, Tennessee