CWP Meeting

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Fast simulation(s) in LHCb

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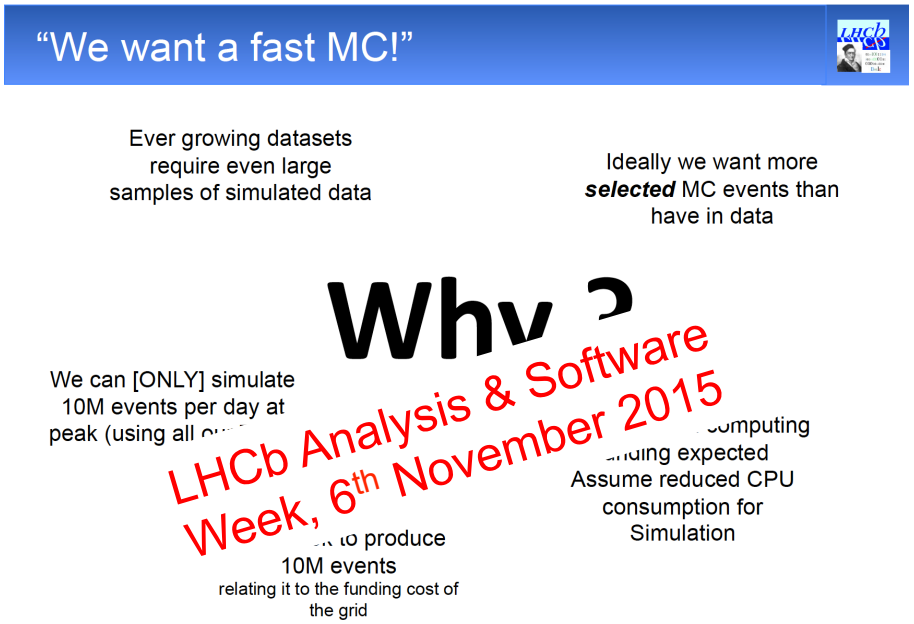
An emerging need in LHCb

- Need to further speed up the simulation became more apparent in the last years



- New developments including **Fast Simulations** in view of the needs for the LHCb Phase I Upgrade in Run3

- But options have been deployed in production as they became available and are in use since

Fast simulations

- Many options have or are being worked on
  - Deployed as they become available for current detector
- No single size fits all but pick and choose most appropriate with multiple options organized under a unique framework
  - Build on and 'upgrade' the Gauss framework to mix simulation flavors, including for different particles in the same event
- Benchmarks and performance to choose baseline combination

Summary of options

- Modified detector
  - Reduced detector: RICHless and tracker only – *In production*
  - Calorimeter Shower libraries – *Under development*
- Partial event
  - Signal particle gun – *In production*
  - ReDecay – *Being commissioned in production*
- Parametric
  - Muon low energy background – *In production*
  - Delphes fully parametric – *Under development*

Customizing the detector

- RICHless production
  - PID in simulation not used in some analysis and in other rely on PIDCalib
  - RICH simulation take a sizable fraction of the CPU, O(20-30%)
  - Care need to be taken on trigger: HLT lines including PID have to be switched off
  - Full processing option available in production environment
  - Used mostly when huge samples are needed and by a few Physics WG
- Tracker only production
  - Huge reduction in time, O(90%)
  - Cannot run any trigger, limited application
  - Processing setup in production upon request

Calorimeter Shower Libraries

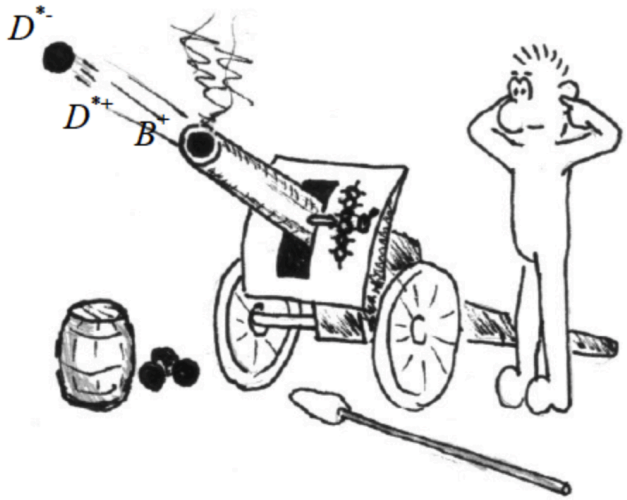
- Fast simulation of the Calo System first candidate for ‘detector’ replacement
  - ECAL+HCAL takes large fraction of total time
  - Aim to gain a factor of 3 to 10 with similar accuracy
- Approach chosen
  - Parametrise Calo response as function of incident particle kinematics and type and replace Geant4 with these look-up tables
  - Create MCCaloHits based on shower library in identical format as those from Geant4
  - All the rest, from Boole digitization onward is the same
- Status
  - Tool to characterize properties of particles hitting calorimeter and prototype of shower library ready
  - Extensive work on tuning and validation started – now focusing on binning needed
  - Aim for deployment for current detector for stress tests at the end of the year

A simulation with only the signal

- Simulate only what interests the most, i.e. particles belonging to the 'signal' and ignore the rest
  - Considerable CPU saving, O(95-99%) as well as disk space
  - Cannot reconstruct Primary Vertex and very limited trigger info
  - Too good to be true but more than sufficient for some studies, e.g. CEP
  - Production configurations available
  - Used in private productions

For one exclusive D* decay

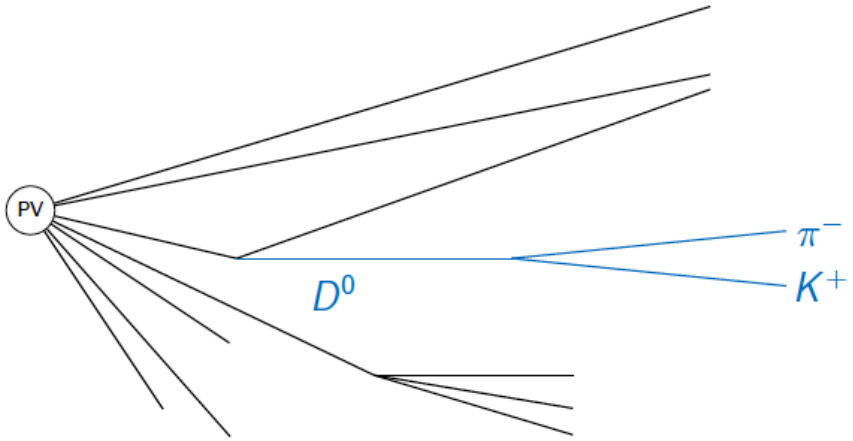
	Full Simulation	Particle Gun
Initialisation	174s	119s
Generation	0.3s/event	0.015s/event
Simulation	66s/event	2.7s/event



ReDecay

- Combine full simulation and particle gun approach

The idea illustrated for $D^0 \to K^-\pi^+$



- Hadronisaton stays the same.
- Kinematics of the redecayed particle stay the same.
  → Correct correlation with the underlying event.
- Same efficiencies and resolution as nominal simulation.
- Example use-cases: efficiencies in high dimensional amplitude analyses, templates for $R(something)$.
- Large number of redecays: **almost the same speed as particle gun.**

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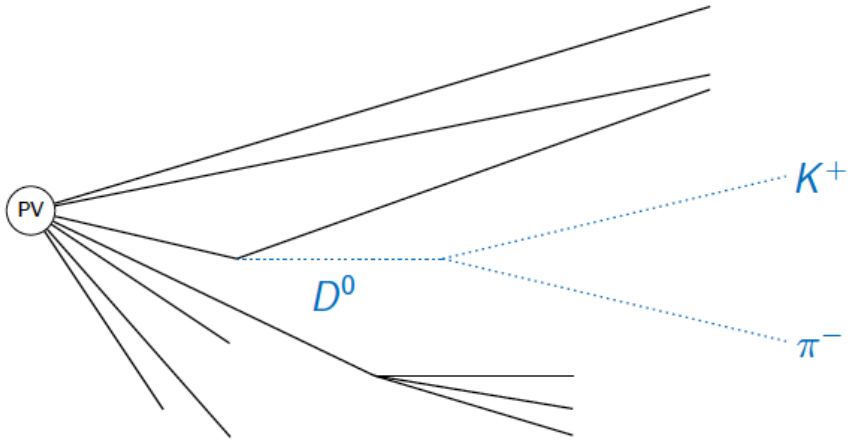

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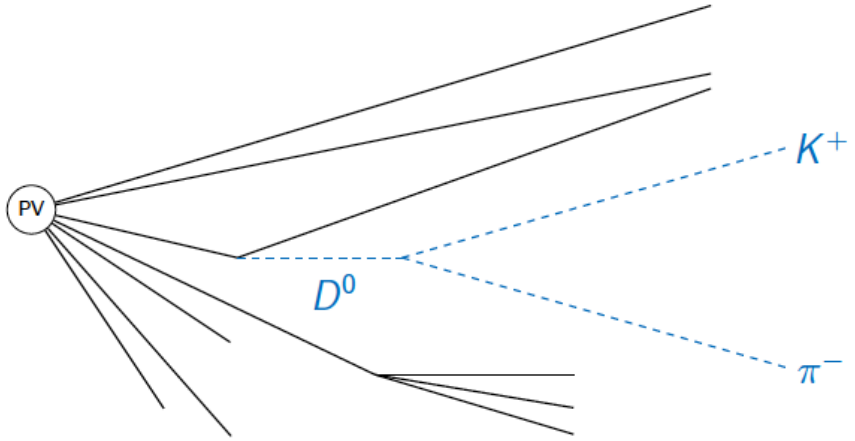

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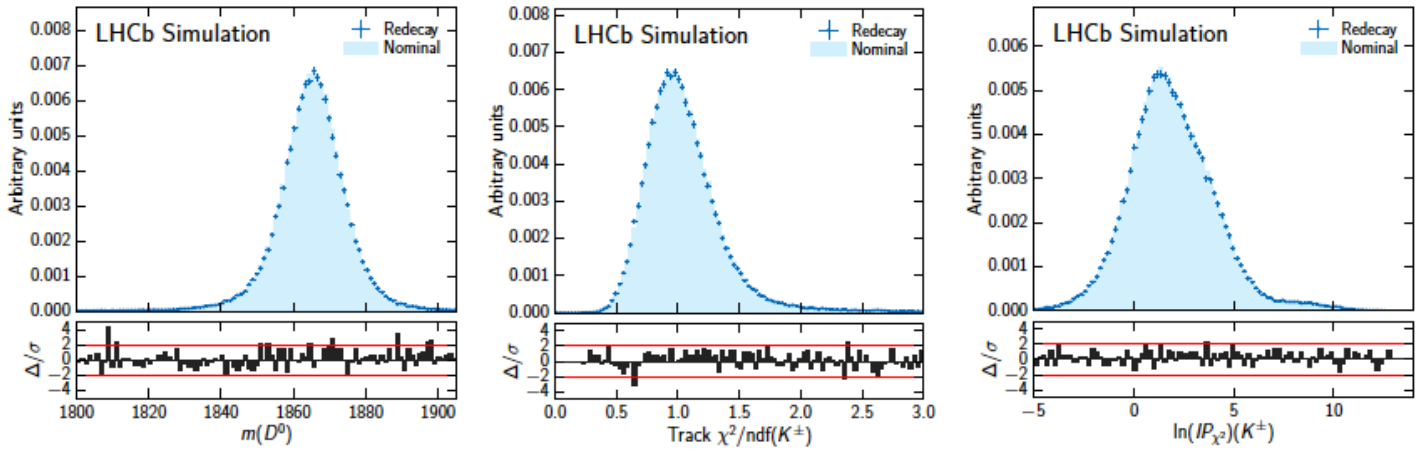
ReDecay

- Very good CPU perfomance, 10-50 time faster then nominal
  - Almost the same speed as particle gun with large number of redecay
  - Need to handle the non independence of the events in the analysis as it depends on the variable
  - Commissioning in productions for physics analysis just started after extensive debugging and validation



Muon low energy background

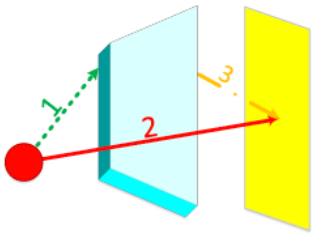
- In the Muon System prohibitive to obtain the same hit rates as in the data with full simulation for physics studies: it would be O(x10) slower
  - Low energy background specific to the Muon System, it requires also simulating cavern and nearby LHC elements
  - Thresholds in simulation are as low as KeV for γ/e± and eV for neutrons to get a reasonable hits rate
- Ad-hoc solution in place: fast simulation of low energy background *tracklets*
  - Parameterization of low energy background hits obtained from comparison of dedicated to standard simulation
  - Additions of fast-simulated background hits in the digitization
- Will need to understand how to combine it with Calo showers

Delphes: fully parametric option

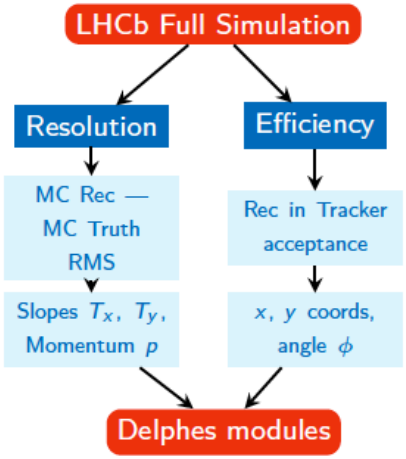
- Parameterizing not only the detector response but also the reconstruction
  - Useful for feasibility and systematics studies
  - Fully integrated in the LHCb Gauss simulation framework

Modified Particle Propagator

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

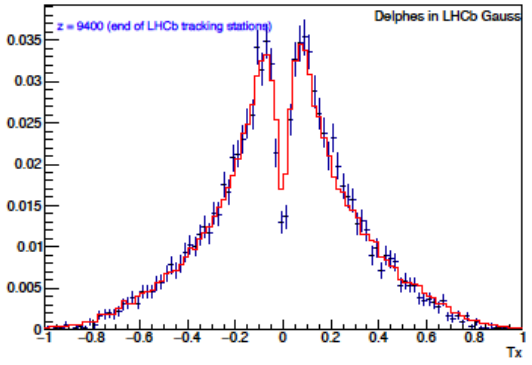


Resolution and efficiency



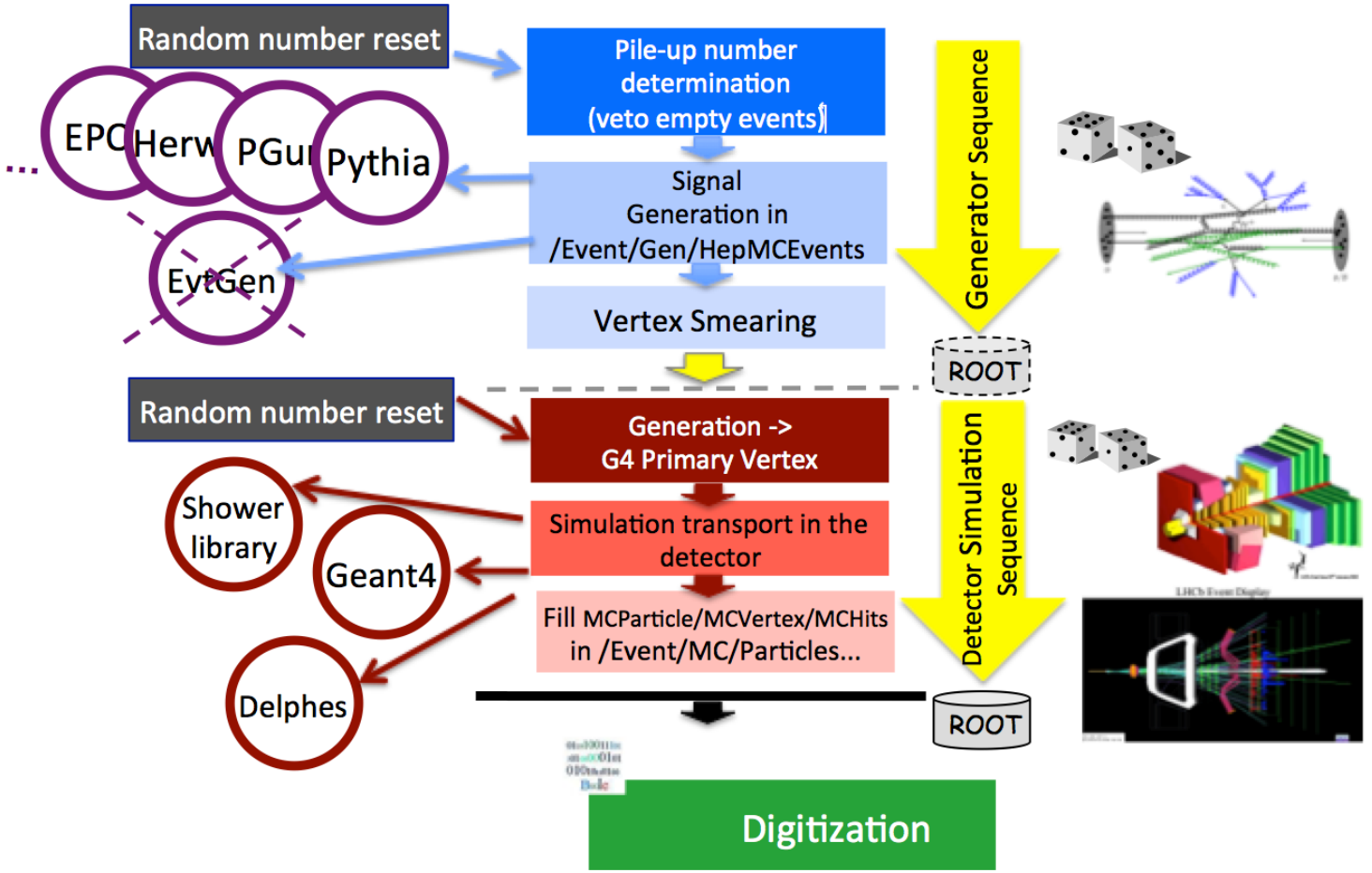
Example LHCb acceptance

Nominal Delphes



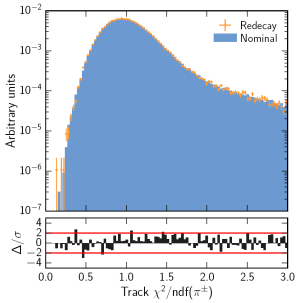
- Work in progress with prototype
  - Tuning of the efficiency ongoing, then add PID and Calo objects

Gauss as an integrated simulation framework



We are already using it for the existing options at the event level
BUT we need to make it work at the particle level and easy and fail-safe at the same time

Fast simulations options



ReDecay

Decay signal N times with same underlying event

Under code review for release

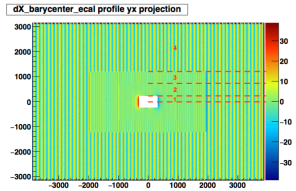
CPU: O(2-10%) of FullSim

Calo Shower Library

Prototype of library set up

Studying shower characteristics

Next use and tune showers



Aim: CPU O(20-40%) of FS

Signal ParticleGun

In use (CEP & other)

CPU and disk: O(1-5%) FS

Partial detector

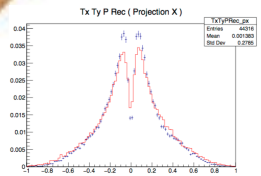
RICHless or Trackers only

In use (special HLT, no L0)

CPU: O(70-80%) FS

O(10-20%) FS

Other…



Delphes

Fully parametric ultra-fast

Written LHCb propagator

Efficiency and resolution from full sim

Under development

Aim: CPU O(0.1-0.5%) of FS

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