A fully parametric option in the LHCb simulation framework

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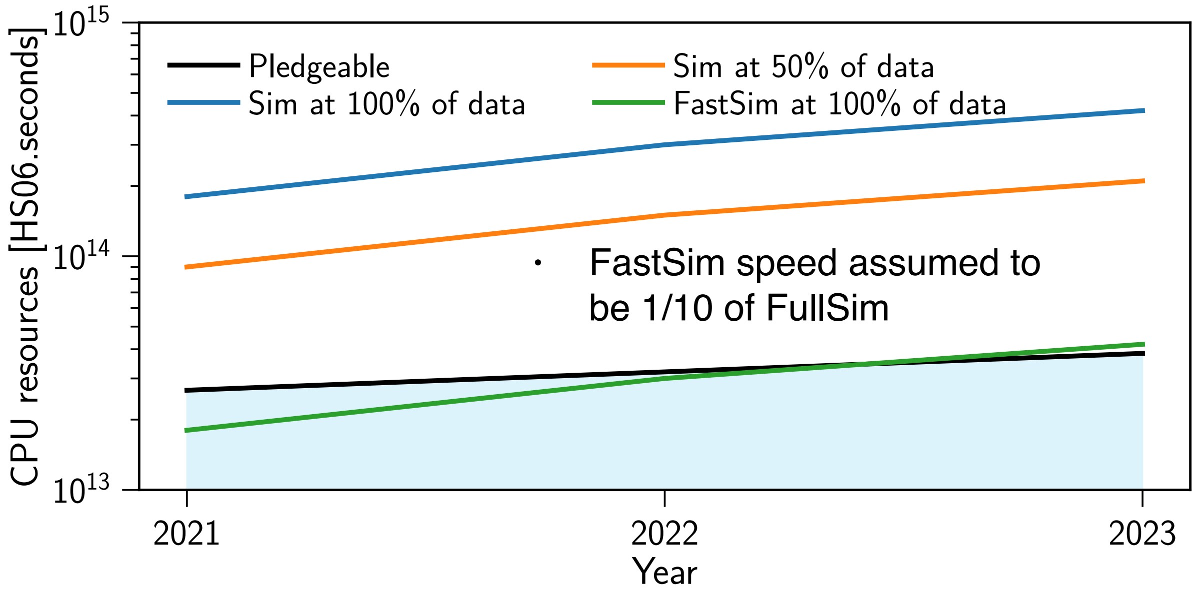
The Monte Carlo problem

- 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

- Monte Carlo is an important component of the systematic uncertainties in analyses
- Large MC samples → Large resources
- In the LHCb upgrade huge amount of data will be taken → Need to produce corresponding Monte Carlo
- Upgrade studies
- New simulation options needs to be investigated



- Requirements for a FastMC:
  - Less CPU consuming
  - Reconstructed particle information in order to use the standard LHCb tools for analysis
  - As close as possible to the full simulation in physics output

FastSimulation options in LHCb

- Broad investigation deploying solutions when mature for physics

- Simplified detector simulation:
  - Reduced detector: RICH-less or tracker-only (In production)
  - Calorimeter showers fast simulation. (Under development)
    - See next talks: Matteo Rama and Viktoriia Chekalina
  - Muon lower energy background, used with full muon detector simulation (In production)

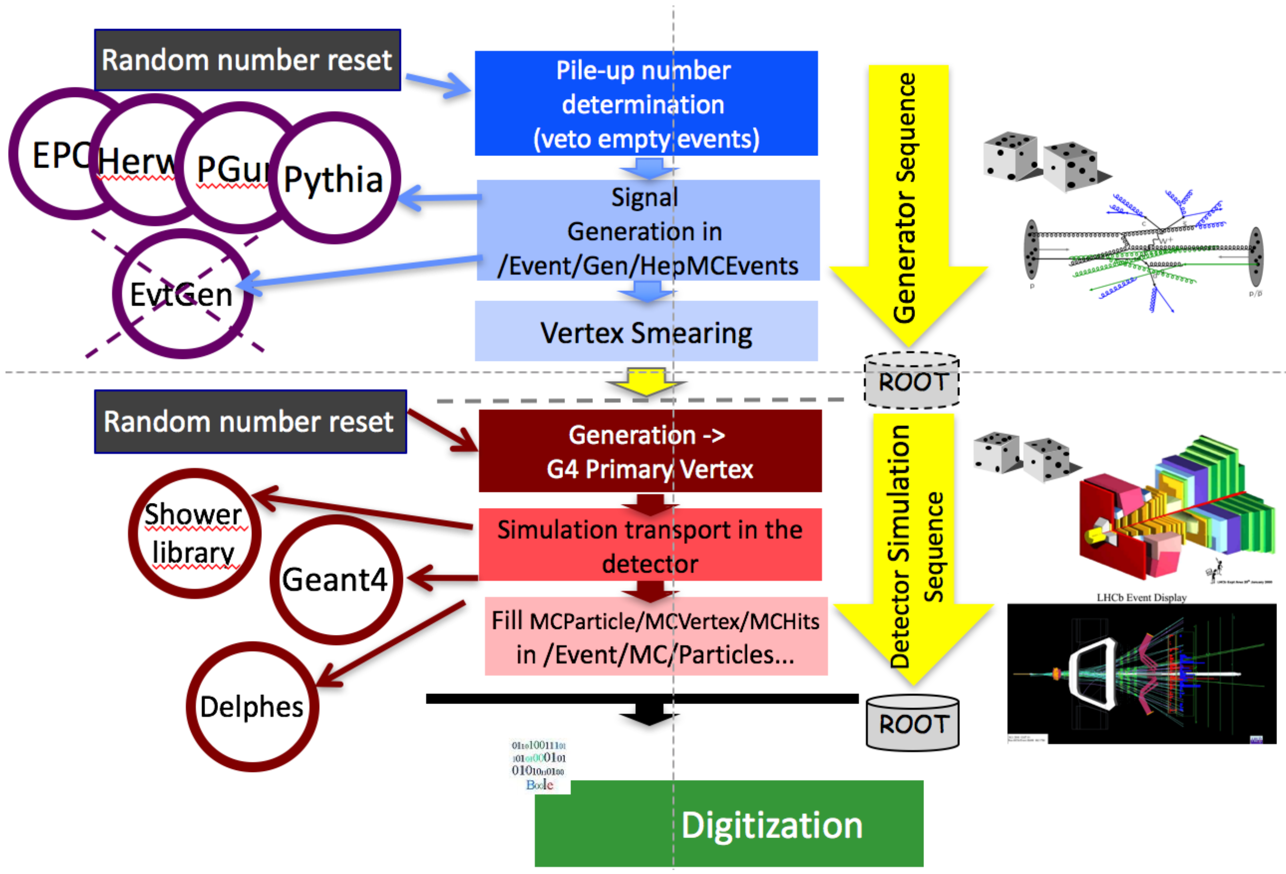
- Simulation of partial event:
  - Simulate only particles from signal decay (In production)
  - ReDecay, e.g. use N-times the non-signal decay part of the event (In production)

- Fully parametric simulation:
  - Parametrized tracking, calorimeter and particleID objects with a DELPHES-based infrastructure (Under development)

FastMC: Integration of Delphes in LHCb simulation framework

- No single solution for all needs but different simulation options organised under the Gauss unique framework

- Building an integrated, easy to use and safe simulation framework
  - Working fast simulation solutions for the whole event
  - Prototypes allowing a mix of simulation flavours for different detectors and particles
  - Output compatible with what expected by later processing

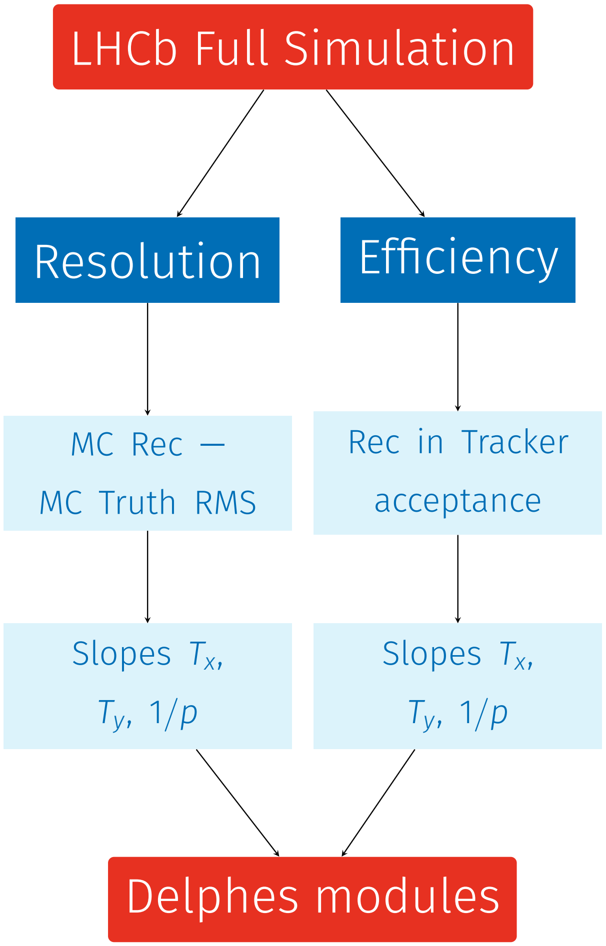


- Benchmark and physics performance measurements to choose baseline production settings

Fully parametric fast simulation: Delphes

- Work on fully parametric ultra-fast simulation based on the DELPHES package
  - Delphes is a modular framework for fast simulation. [10.1007/JHEP02(2014)057]
  - It is written in C++ and is available as library.
  - Originally written for LHC central colliders
  - Parametrizes not only the detector response but also the reconstruction

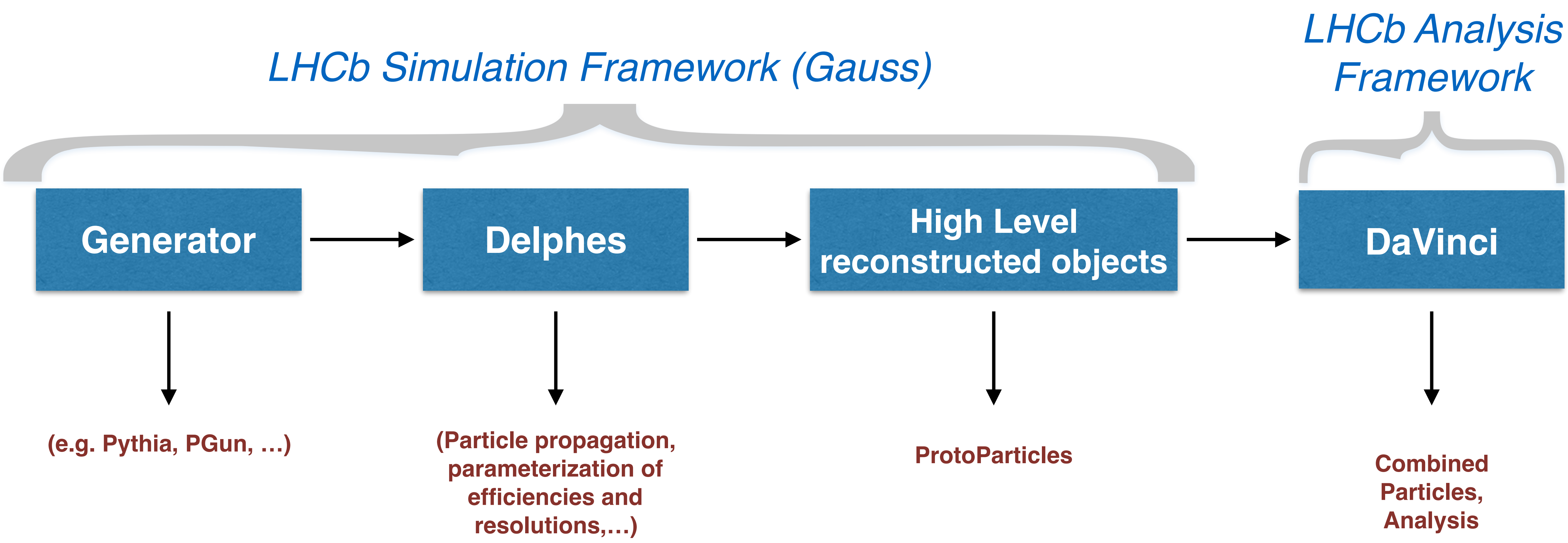
- Crucial to cope with large amount of simulated statistics needed for Run3 and future Upgrade II. Goal: $O(100)$x faster then full simulation.



- Functional prototype integrated in the current LHCb Simulation framework (Gauss)
  - Tracking efficiency and resolution
  - Primary vertices reconstruction
  - Photon calorimetric objects
  - Output LHCb reconstructed high level objects,
  - Compatible with the experiment analysis tools

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.



Output for LHCb Analysis framework (DaVinci)

What is the minimal output to do analysis in LHCb?

No lower level reconstructed objects!

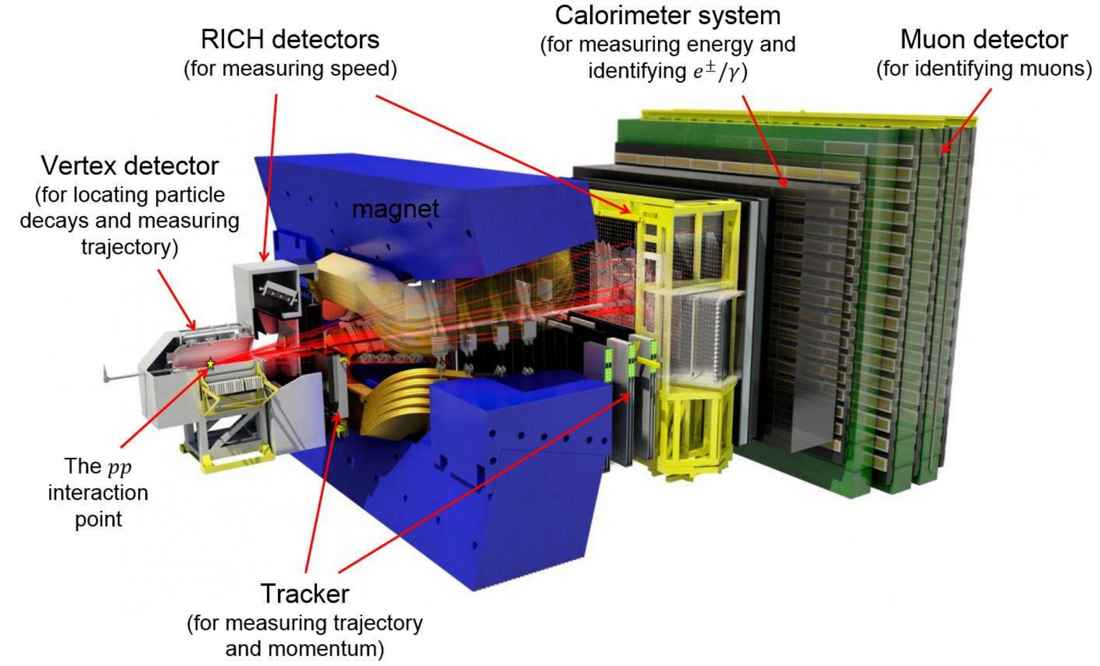
- **Proto Particles**
  - Links with tracks
  - At least one particle ID information
  - Calo objects
  - Rich
  - Get Slopes error for tracks

Smearing primary (collision) vertex

- **We want to be able to do a simple analysis with Delphes output using as much as possible existing LHCb Analysis tools**

Status of the Tracking parameterisation

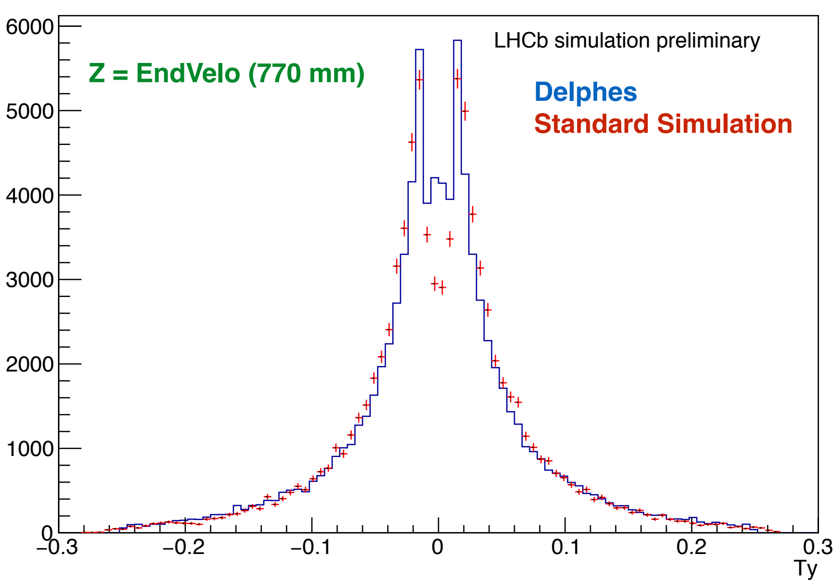
- Extensions to Delphes to be setup as a patch to the source include:
  - Propagation inside the LHCb acceptance
    - Simple transport in a dipole field
    - Parameterisation of the Magnet Center as function of 1./p
  - Parameterisation of the Efficiencies and Resolution for charged particles:
    - Binning variables: track slopes dp_x/dz and dp_y/dz, 1./p

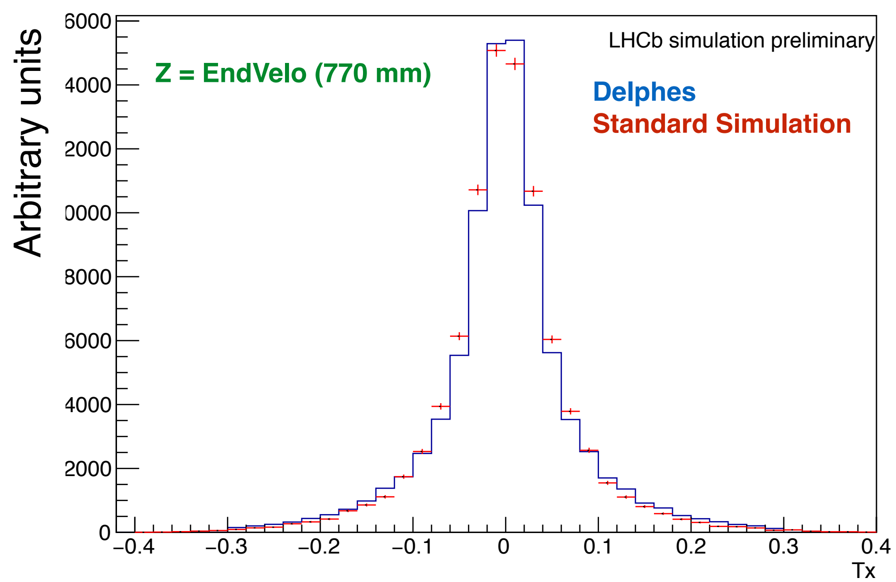


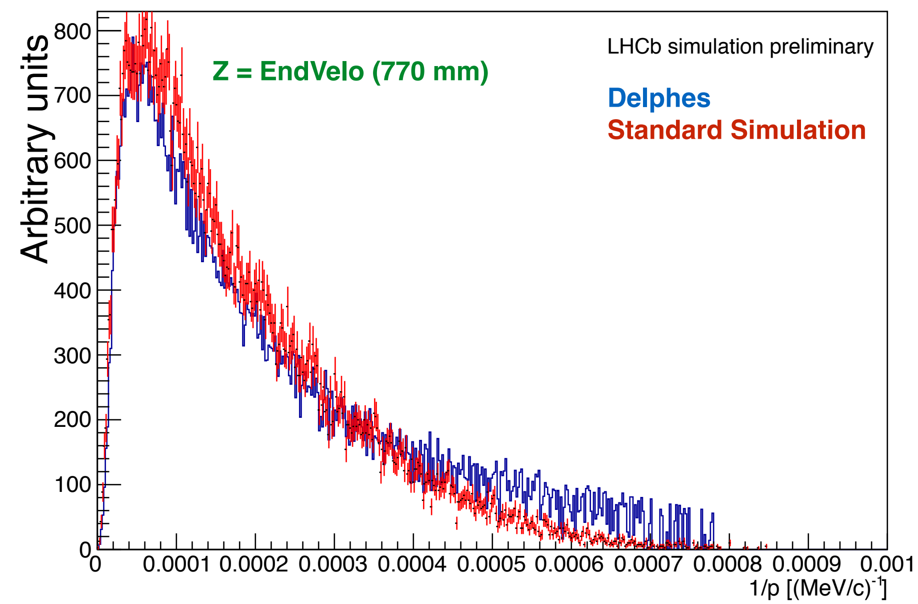
- Covariance Matrix of the track parameterised with a lookup table
  - Profile of the single matrix element as function of 1./p
  - -> Translation in to a lookup table
- Track quantities, i.e. ghostProb, likelihood, chi2, nDoF, also parameterised with a lookup table
  - Same procedure of the Covariance Matrix

Status of the Tracking parameterisation

- Comparison between Delphes and full simulation output for the variables used for parameterization





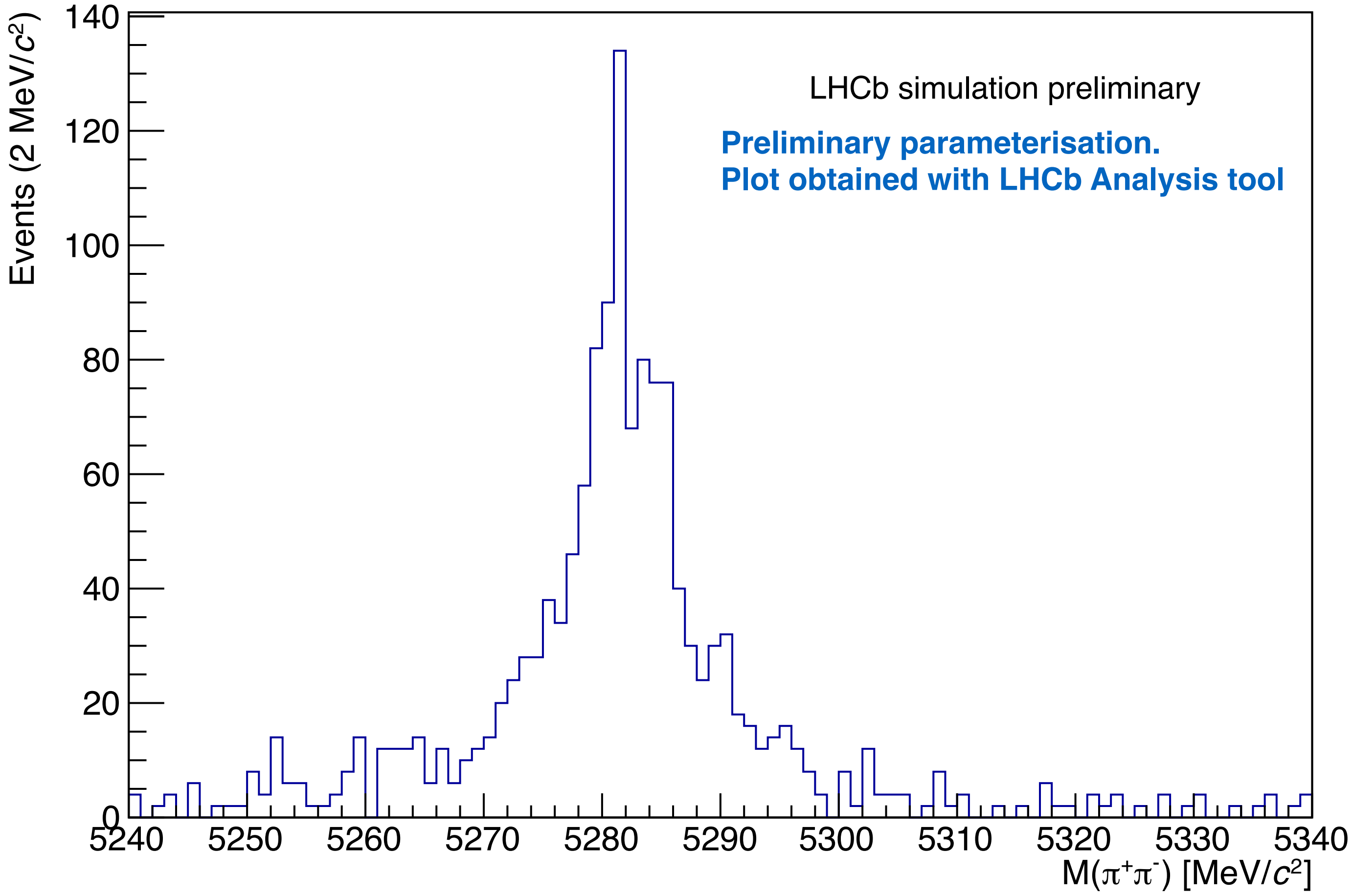


- Slope dp_x/dp_z
- Slope dp_y/dp_z
- 1./p

- Parameterisation specific for each data taking period and detector conditions

Status of the Tracking parameterisation

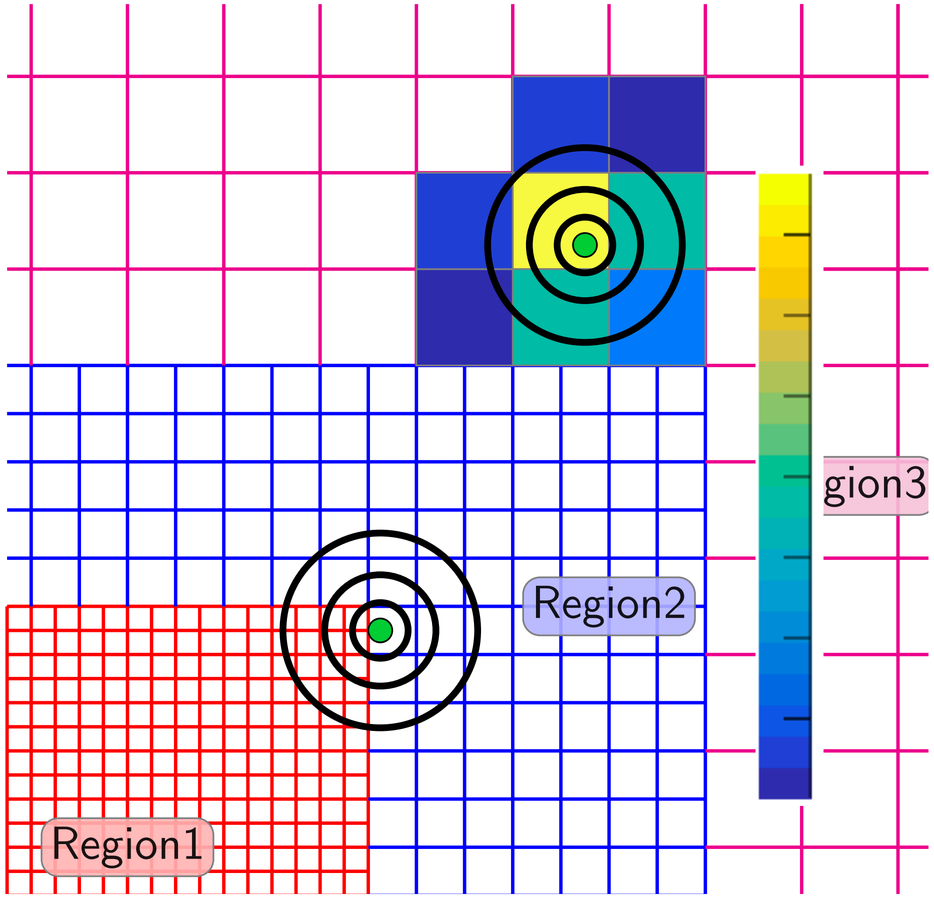
- It is possible then to provide final reconstructed objects and process them with standard LHCb analysis framework



Status of the Calorimeter parameterisation

- Calorimeter parameterisation in Delphes almost complete for neutrals

- Customizable geometry based on simple loops within Delphes
- Gives the 3 regions of the current LHCb Calorimeter
- As output reconstructed ProtoParticles

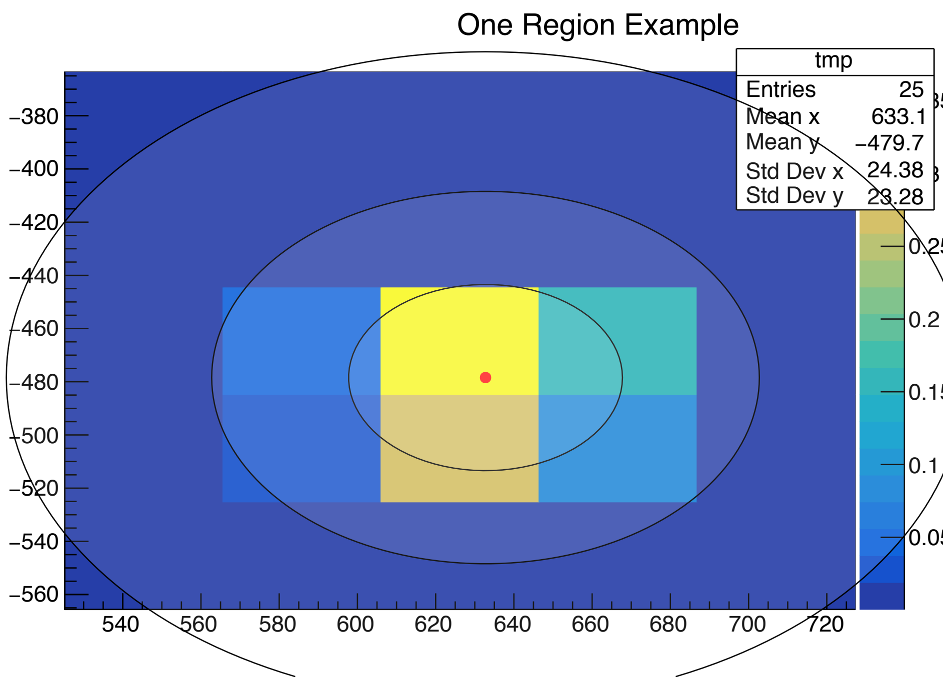


- Clusterization in Delphes in order to get the particles energy:
  - Take individual MC hits(*) and get calorimeter response from Delphes
  - Draw circles of 1, 2 and 3.5 R_M to get 90, 95 and 99% of the energy

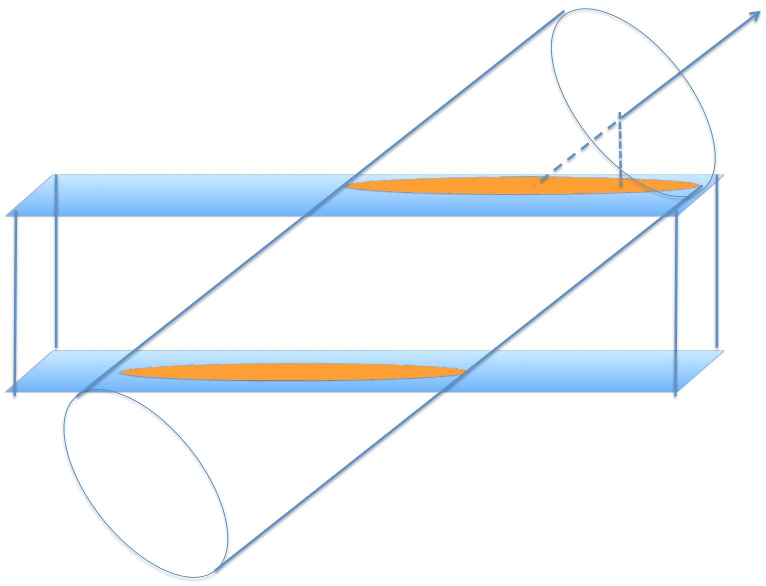
*particles crossing the calorimeter face

Status of the Calorimeter parameterisation

- Building the ProtoParticle:
  - Covariance matrix of the calo cluster (E, X, Y)
  - Z position of the calorimeter cluster (measure of the shower)
  - All CaloCellIDs for every tower (built from position)
  - CaloDigit (CellID + energy of the cell)
  - The calo cluster itself (collection of digits + z position)
  - PID hypothesis (start PID as only photon, will be updated later)

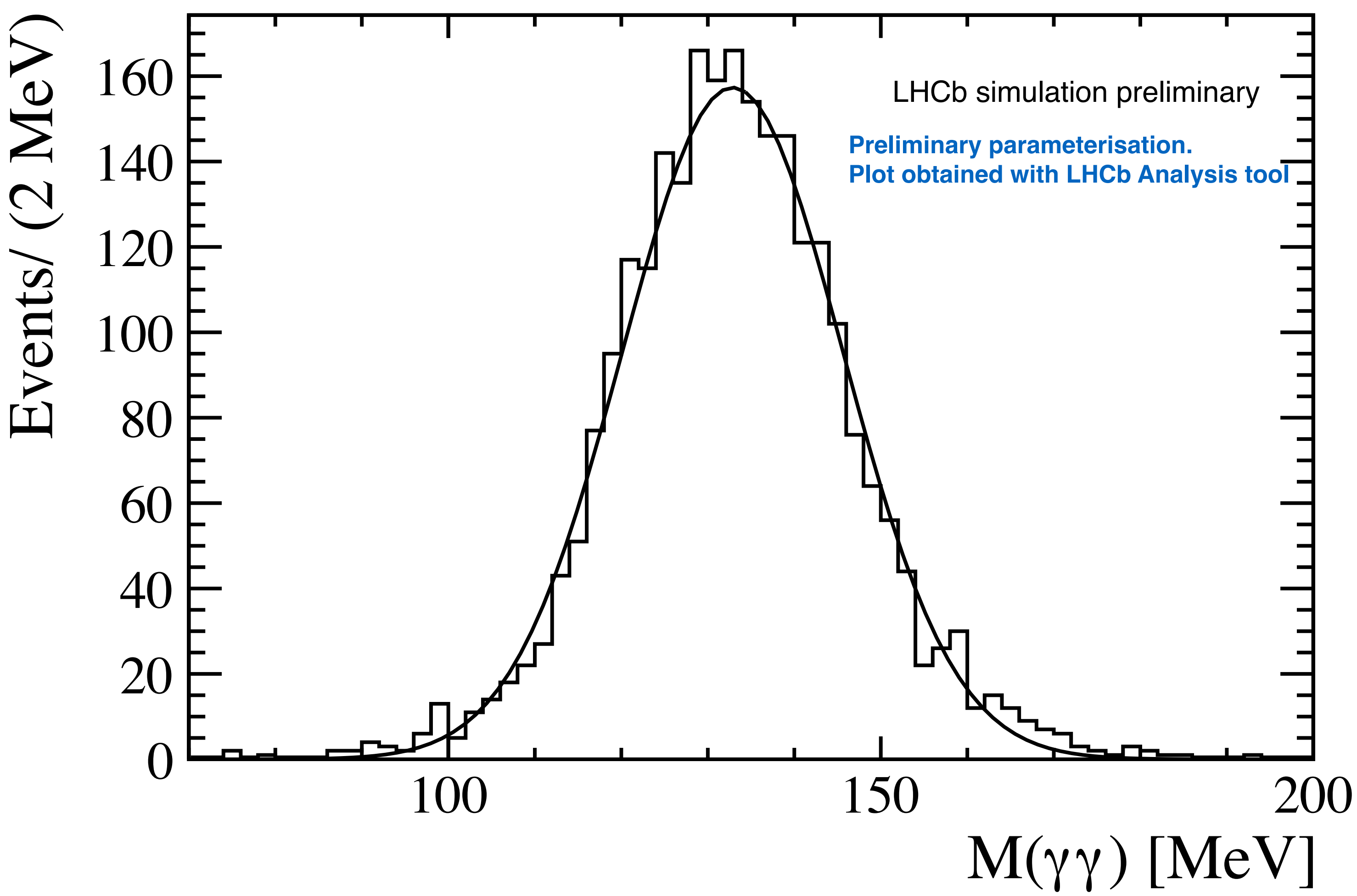


- Next steps are the generalization of the Moliere radii to an ellipse and include the calorimeter parameterisation for charged particles



Status of the Calorimeter parameterisation

- Using the standard Analysis tools of the LHCb it is possible to reconstruct the π^0 peak from the $\gamma\gamma$ invariant mass



Conclusions

- Fast simulations are crucial in LHC experiments to cope with the large amount of Monte Carlo statistics needed in the future
- Delphes has been integrated within the LHCb simulation framework Gauss
- Delphes has been extended for LHCb with:
  - A simple propagator for propagating particles inside the LHCb acceptance and magnetic field;
  - Particle efficiencies and resolution smearing according to the LHCb full simulation
  - Parametric calorimeter response for neutral particles
- A complete analysis chain has been exercised and Delphes output could be used for physics analysis
- Aim to be 100 times faster than the full standard simulation based on GEANT4

Thank you