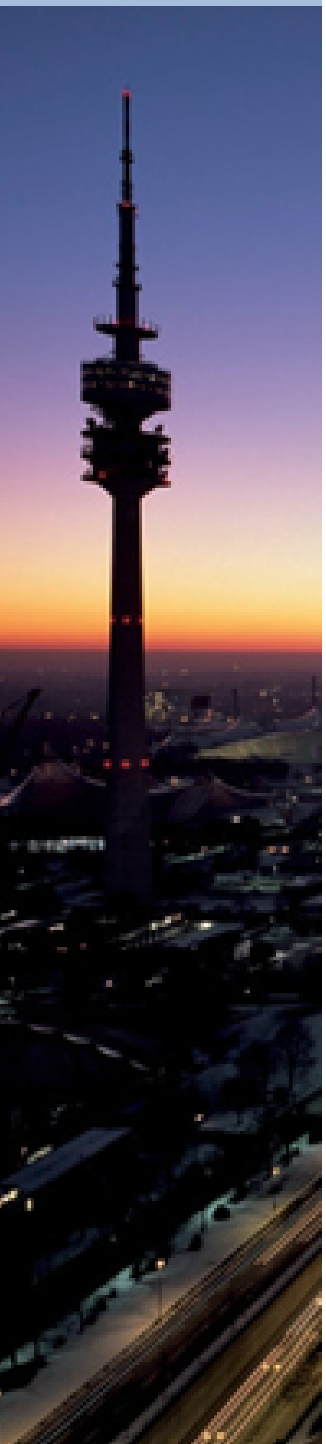

Delphes

A framework for fast simulation of a generic collider experiment

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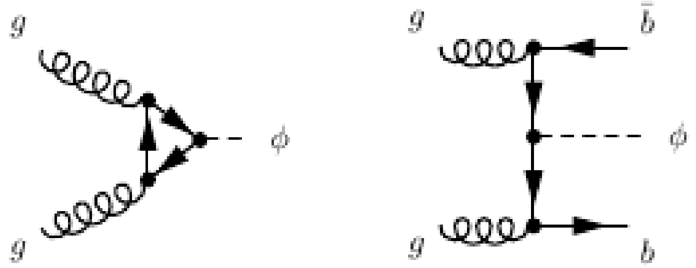
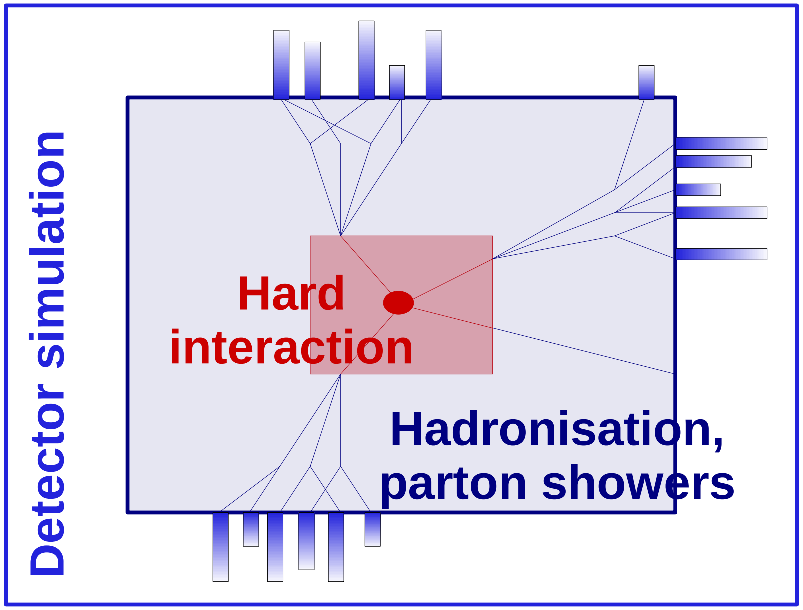
From theory to detectors...

Delicate to know if theoretical predictions will be visible and measurable in a high energy experiment:
this is complex and requires several steps

1° Development of a new model





2° Model implementation and generation of hard interaction

- MadGraph/MadEvent (MG/ME)
- CalcHep

3° Simulation of hadronisation and parton showers

- Pythia
- Herwig

4° Simulation of the response of a high energy experiment

- ATLAS
- CMS

Complexity of HE detectors...

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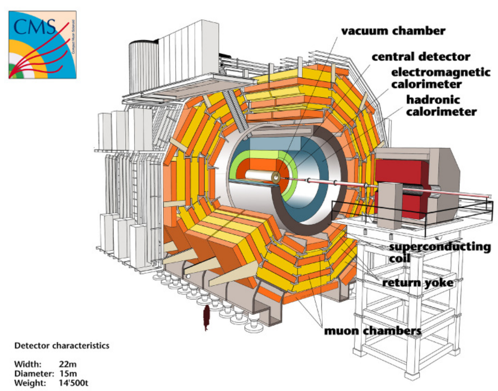
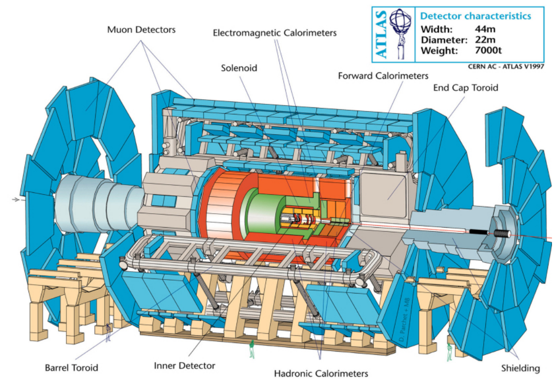
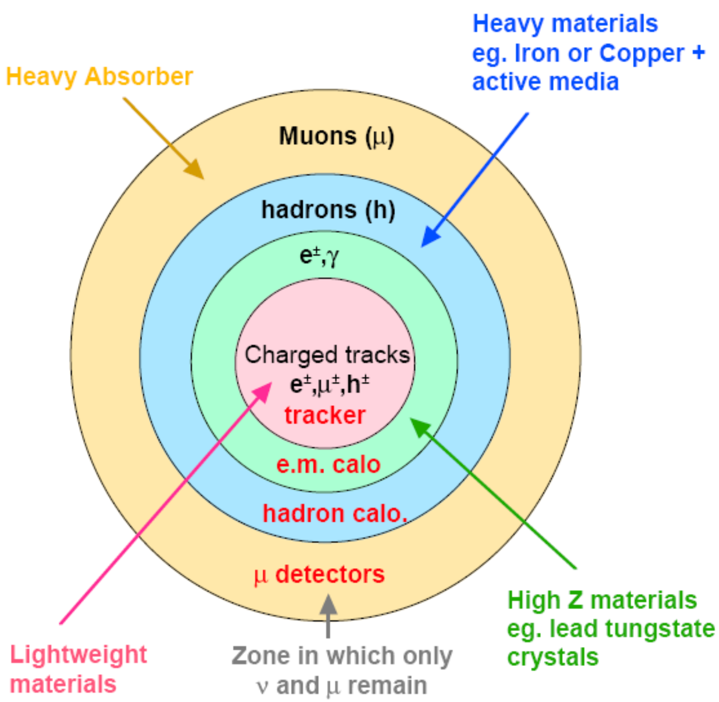
CMS





ATLAS

General structure



- Complexity of the related subdetectors
  - tracker
  - electromagnetic and hadronic calorimeters
  - muon chambers

- Requires the use of complex softwares to simulate
  - detail energy deposition from ionization, showering,...
  - secondary interactions
  - detector inefficiencies
  - multiple scattering
  - ...

Very complex simulation requiring a large CPU per event

DPG - München

23/03/2009

Fast simulation utilitiy

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Phenomenological studies may require only fast but realistic estimates of detector response → Delphes

Delphes provides:

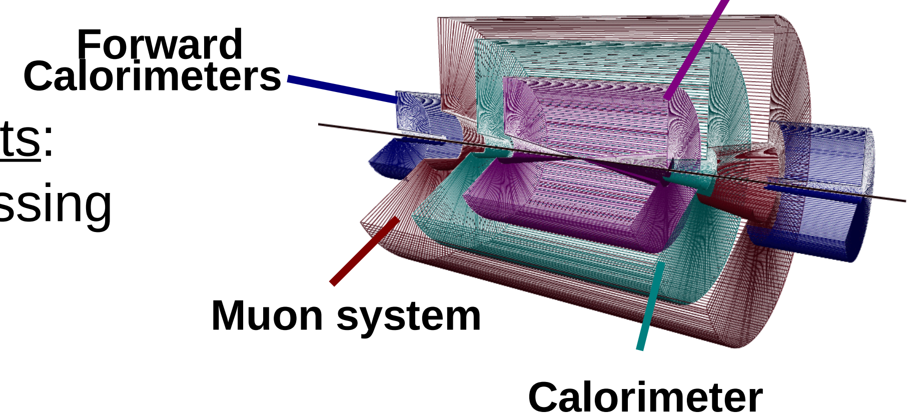
- Realistic simulation taking into account subdetector extensions, types, segmentations and resolutions

  - A tracker in a solenoidal magnetic field
  - Calorimeters with electromagnetic and hadronic sections
  - Muon system

- Reconstruction of physics objects: leptons, jets, b-jets, τ-jets and missing transverse energy

- Trigger emulation

- An event display



Delphes allows easy connection between theoretical and experimental *(distant)* worlds

Delphes flow

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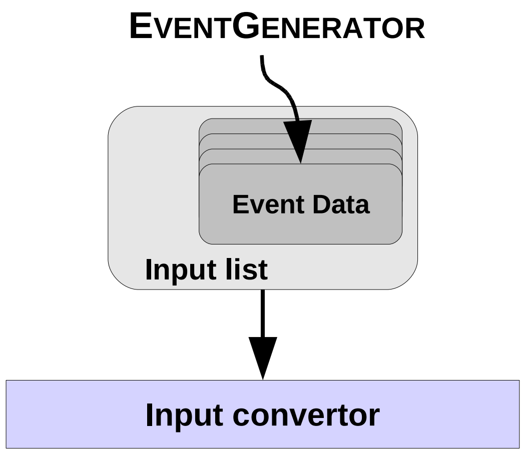
Interface:



- Input events : ***Delphes*** is interfaced to standard file formats

- StdHEP
- ROOT files obtained with h2root (hbook)
- Les Houches Event Format

➡ Compatible with MG/ME, Pythia,...

- ***Delphes*** is driven by two input cards defining

(a) detector parametrisation
(b) trigger definitions
(c) parameters on physics objects (cuts,...)

➡ Default detector cards and trigger tables available for ATLAS & CMS experiments

Delphes flow

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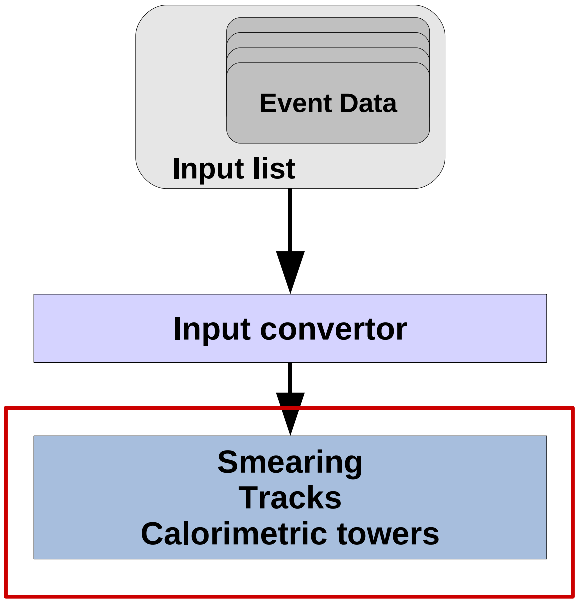


Smearing: Response of each subdetector parametrised as a function of the energy:

$$\frac{\sigma}{E} = \frac{S}{\sqrt{E}} \oplus \frac{N}{E} \oplus C$$

With different response to
- electromagnetic objects
- hadrons

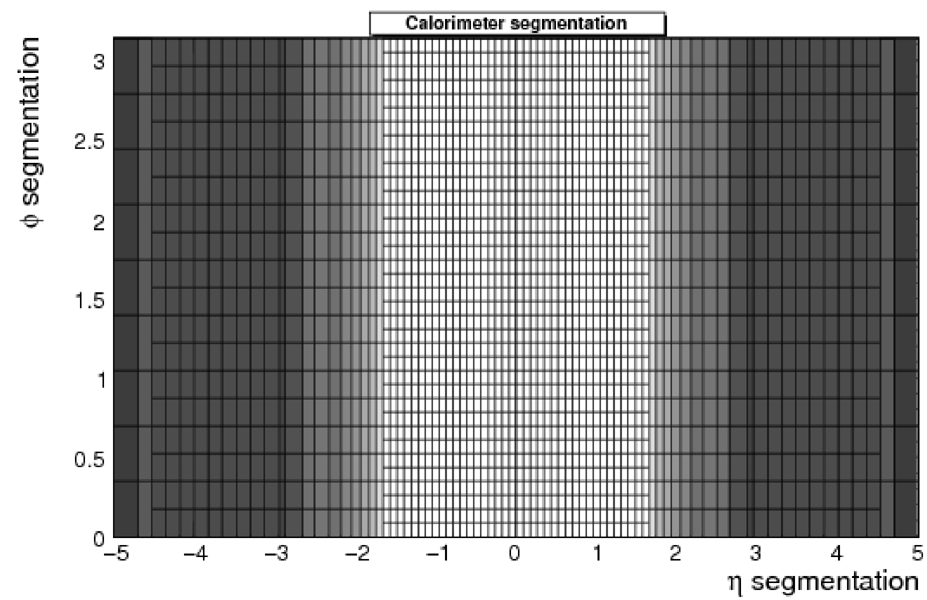
Muons: smearing on the p_T

Parameters controllable using the input datacard

Low level objects

Calorimetric towers :

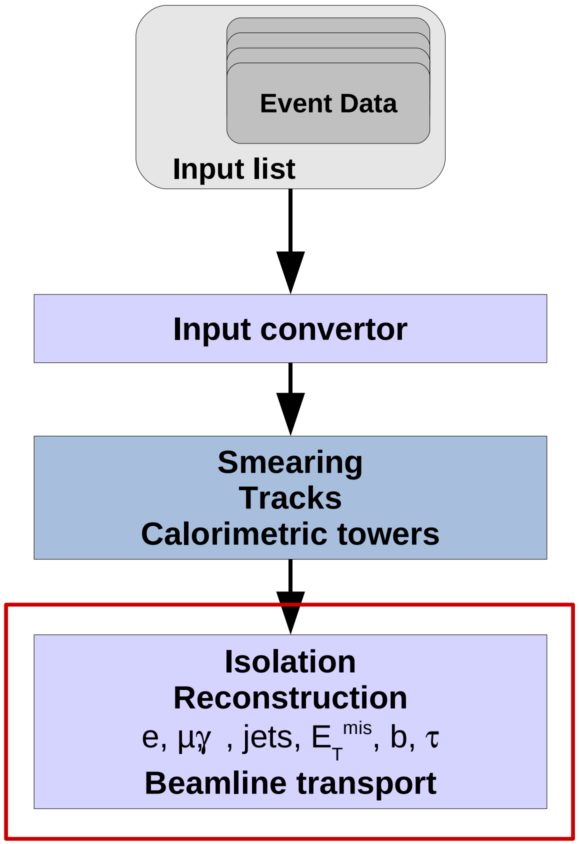
Segmentation in eta/phi, summing energy of multiple impacts in identical towers



Tracks:

For all charged particle in the tracking coverage, considering « energy flow »

Delphes flow



Delphes yields realistic observables for all reconstructed high level objects in two formats:

- Analysis tree in ROOT files,
- LHCO

using ExRootAnalysis, P. Demin

High level objects

Photons :

- reconstructed if they fall into the tracker coverage
- eta/phi variables correspond to the impact in the calorimeter

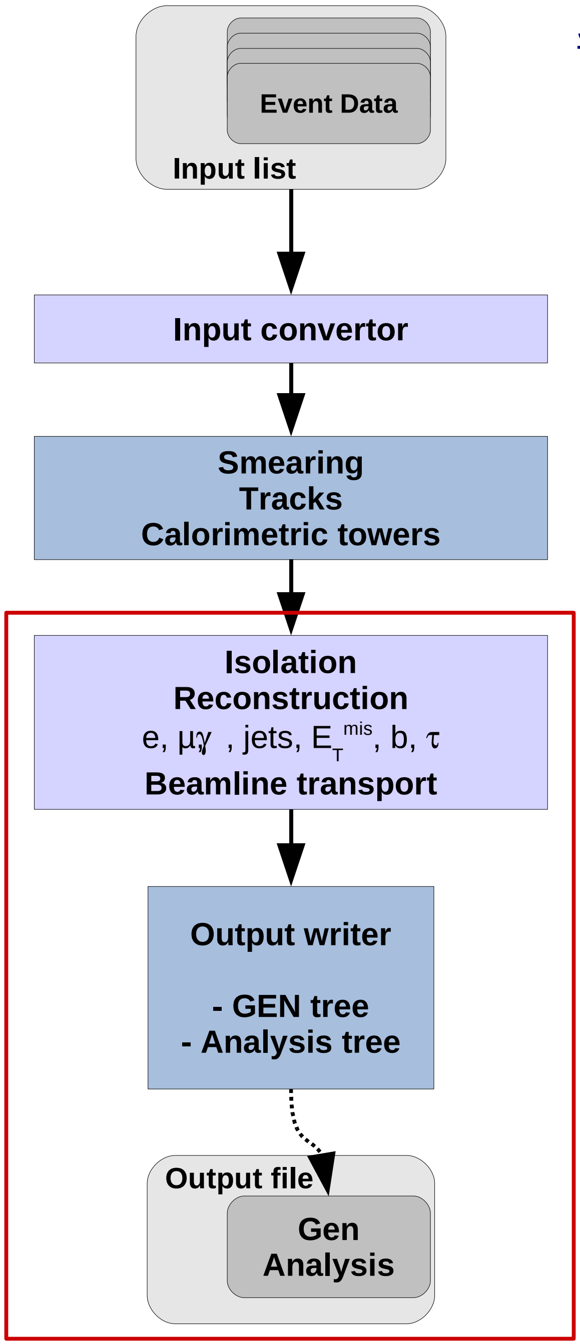
Electrons and muons :

- reconstructed if they fall into the tracker coverage
- isolation from charged particles using tracking information

↳ No other charge particles with p_T > 2 GeV within a cone

$$\Delta R = \sqrt{\Delta \eta^2 + \Delta \phi^2} < 0.5$$

Delphes flow



Jets :

- Treatement of particles which hadronise using jet reconstruction

- Uses reconstruction algorithms implemented in FastJet

  - CDF jet algorithm (cone)
  - CDF Midpoint algorithm
  - SIS Cone jets
  - Longitudinally invariant k_t jets
  - Cambridge / Aachen jets
  - Anti k_t jets

`FastJet`: M. Cacciari, G.P. Salam, Phys. Lett. B 641 (2006) 57.

- *b*-tagging

  - efficiency
  - misidentification of *c* and light jets

Choice of the jet algorithm, jet parameters and *b*-tagging efficiency in the detector datacard

Delphes flow

Delphes

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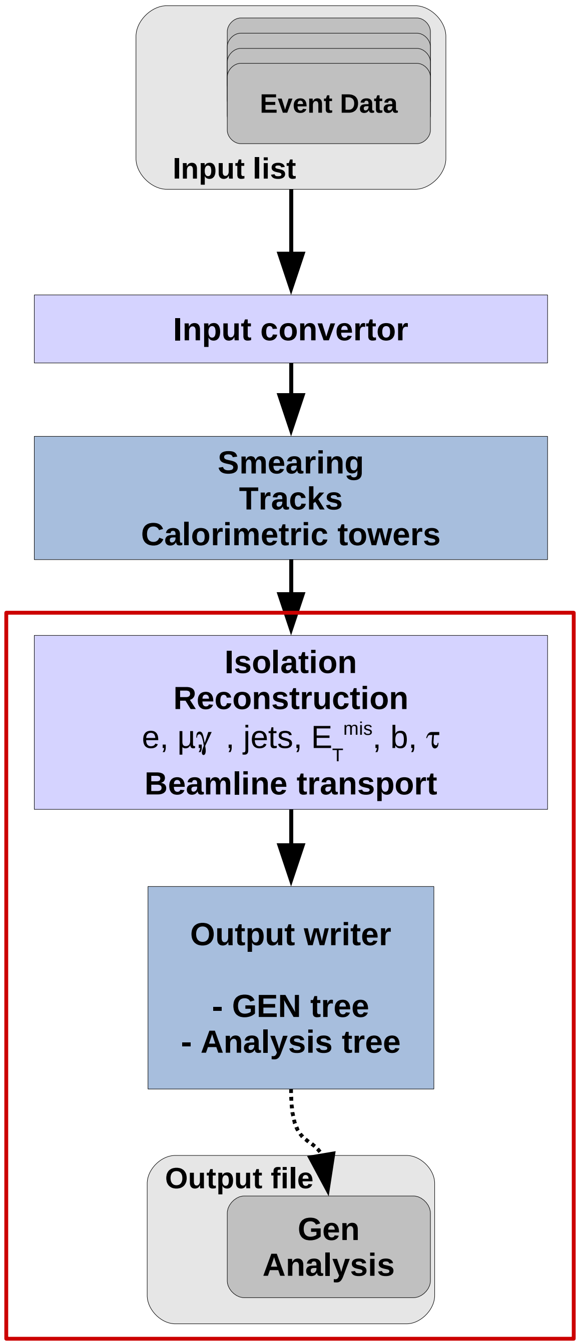
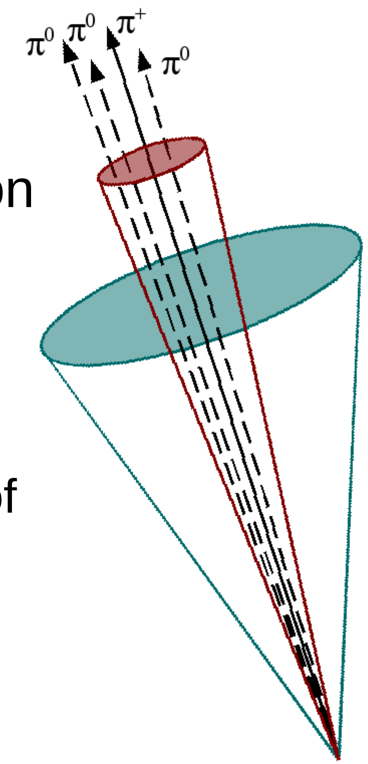


Tau-jets reconstruction:

Selected from the jet collection using a procedure consistent with the one applied in a full detector simulation



1) Use of the narrowness of the tau-jet

2) Requirement of tracking isolation

MET reconstruction:

Missing Transverse Energy (MET) calculation based on the calorimetric towers:

$$\vec{E}_T^{\,miss} = -\sum_{i}^{towers} \vec{E}_T(i)$$

Near-beam components

Most of recent experiments in HE physics have additional instrumentation along the beamline

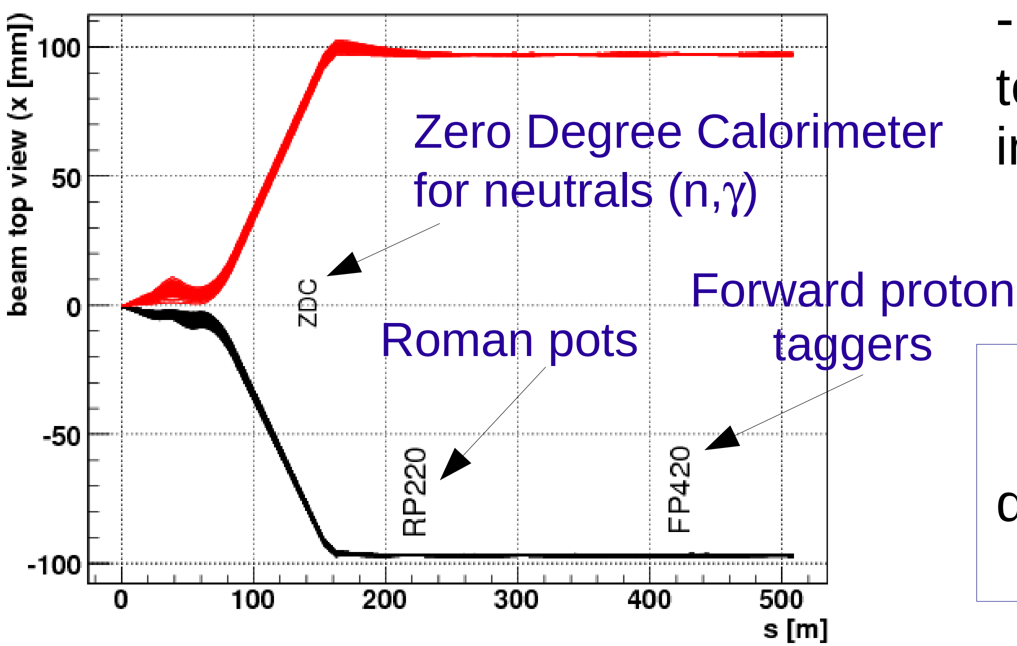
➡ In addition to the central detector, ***Delphes*** includes

- forward detectors to extend the eta coverage to higher values

  e.g. : Zero Degree Calorimeters

- (very) forward near-beam detectors

e.g. LHC beamline:

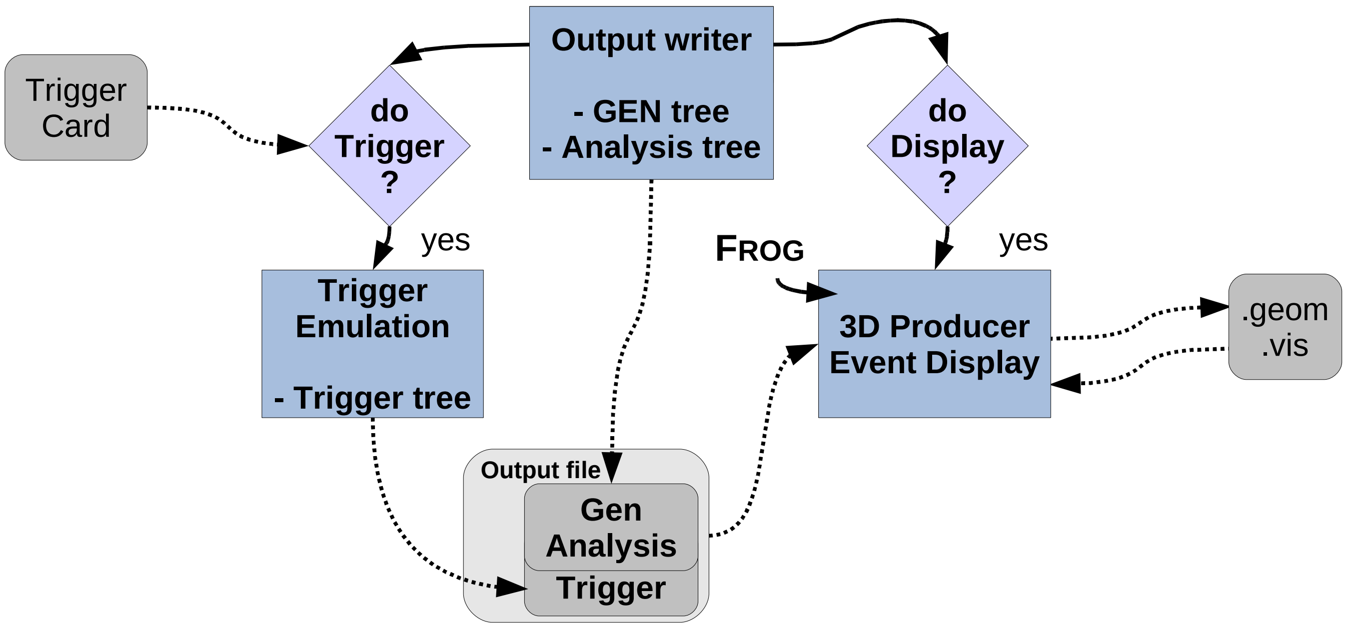


- ***Delphes*** uses HECTOR to perform particle transport in beamlines

Acceptance of the very forward and near-beam detectors are easily modified using the Detector card

X. Rouby, J. de Favereau and K. Piotrzkowski, JINST 2(2007) P09005

Additional features



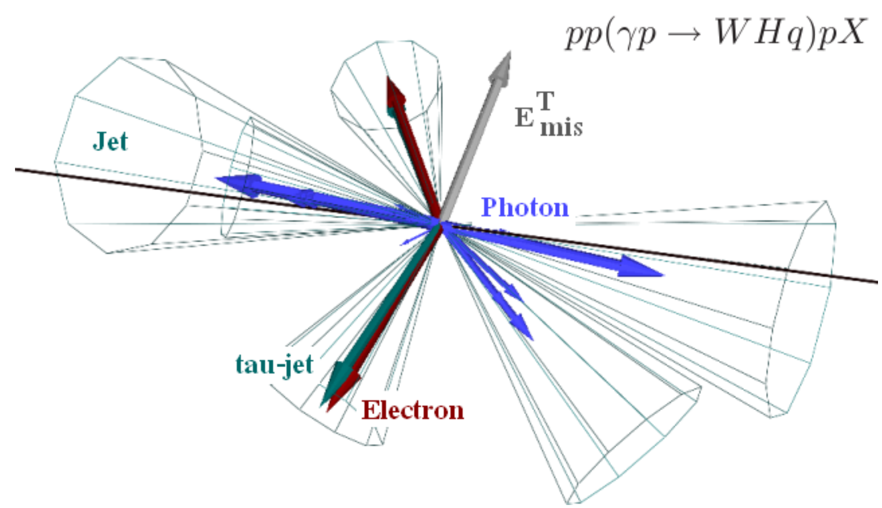
Trigger emulation

Application of user-defined trigger selection using the Trigger card

Result of the ***Delphes*** trigger selection is stored in the « Trigger tree » in the output root file

3D Event Display

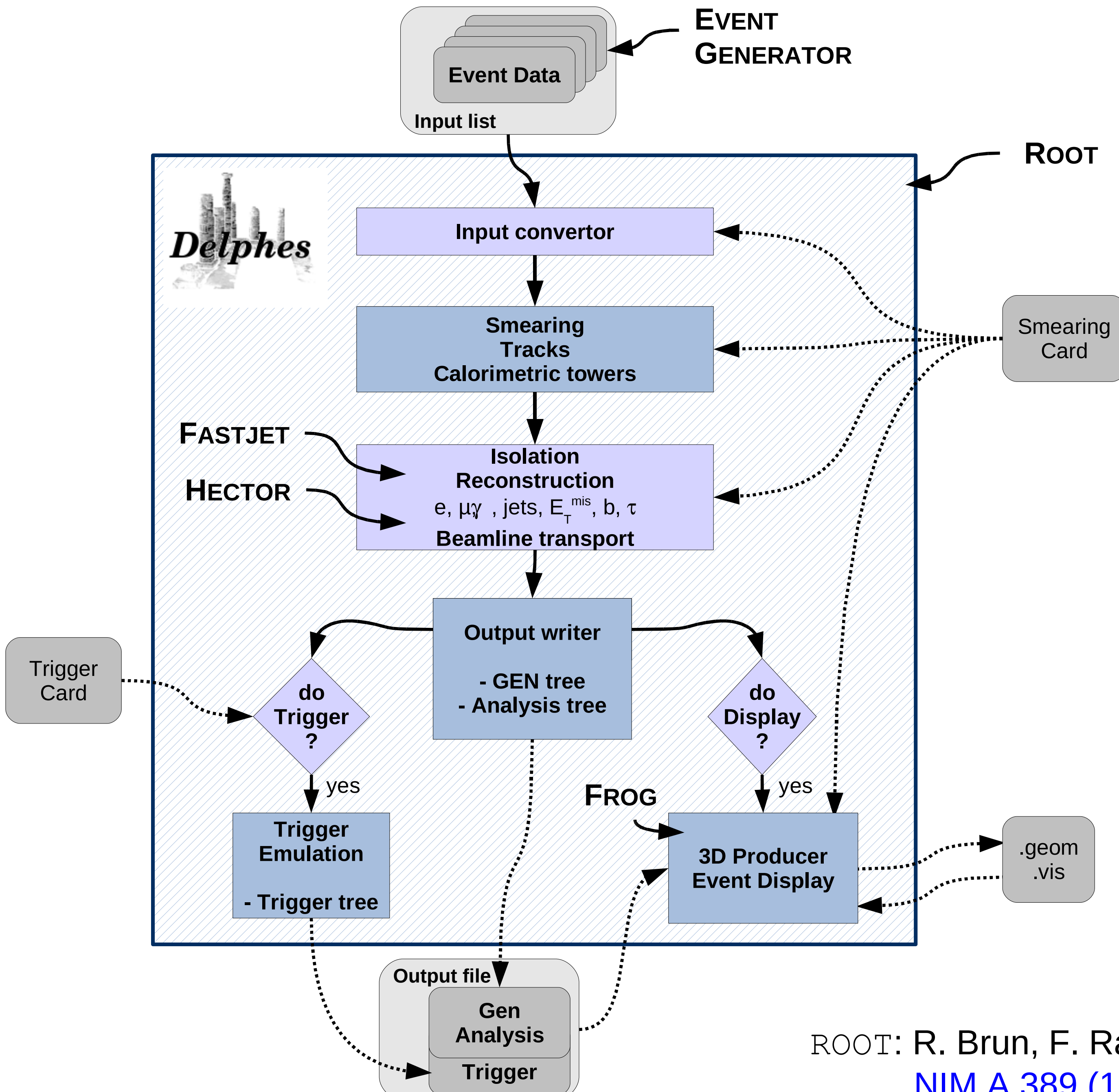
FROG interfaced to ***Delphes***



FROG: L. Quertenmont, V. Roberfroid, arXiv:0901.2718v1[hep-ex]

C++ / ROOT implementation

X. Rouby



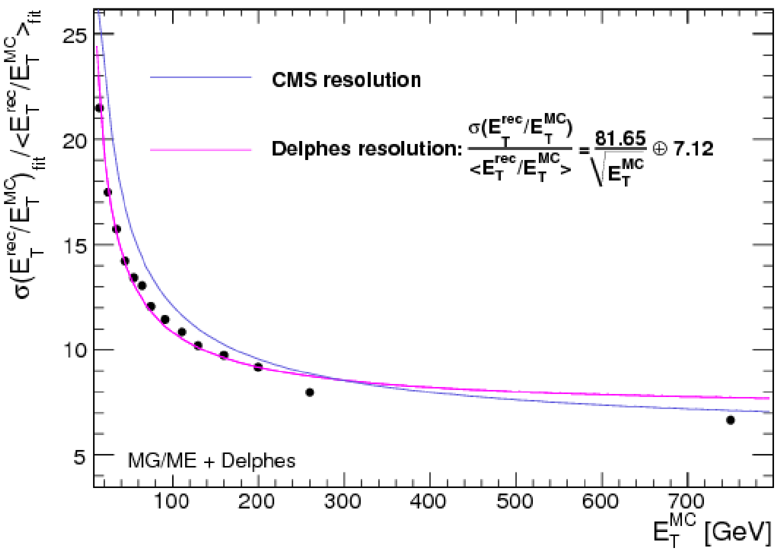
ROOT: R. Brun, F. Rademakers, NIM A 389 (1997) 81-86.

Validation

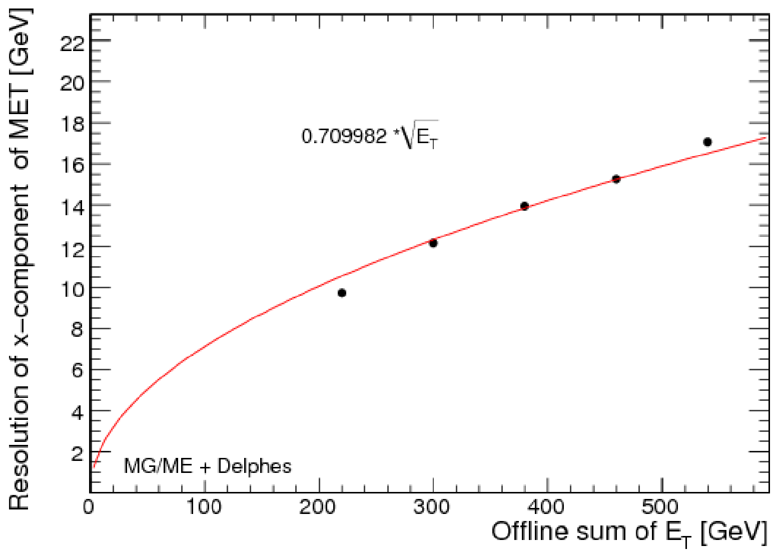
Validation procedures using CMS-like detector parameters

CMS resolution from: The CMS Collaboration, CERN/LHCC 2006-001.

1) E_T resolution of jets:



2) Resolution of MET:



Value expected by CMS:

$$\sigma_x = (0.6 - 0.7)\sqrt{\Sigma E_T}\ GeV^{1/2}$$

An excellent agreement is obtained comparing values of ***Delphes*** with the expectations of the general purpose CMS detector

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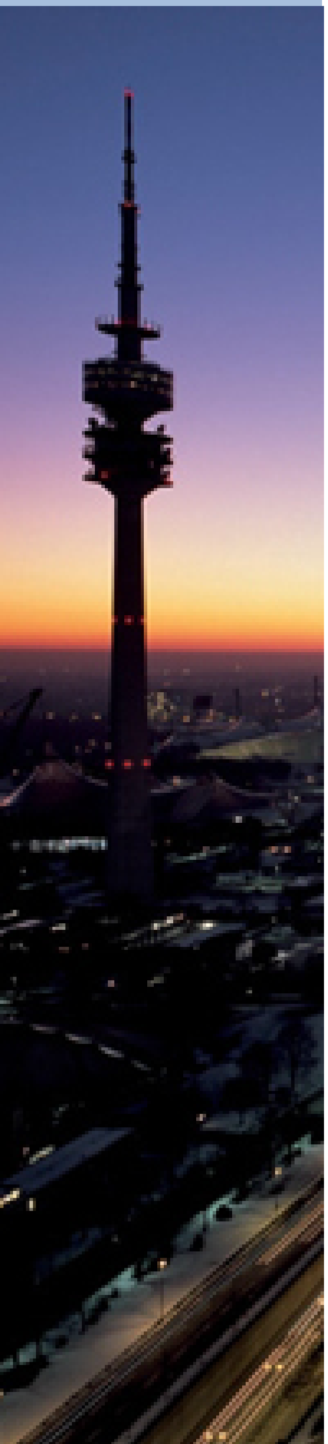
Summary and Outlook

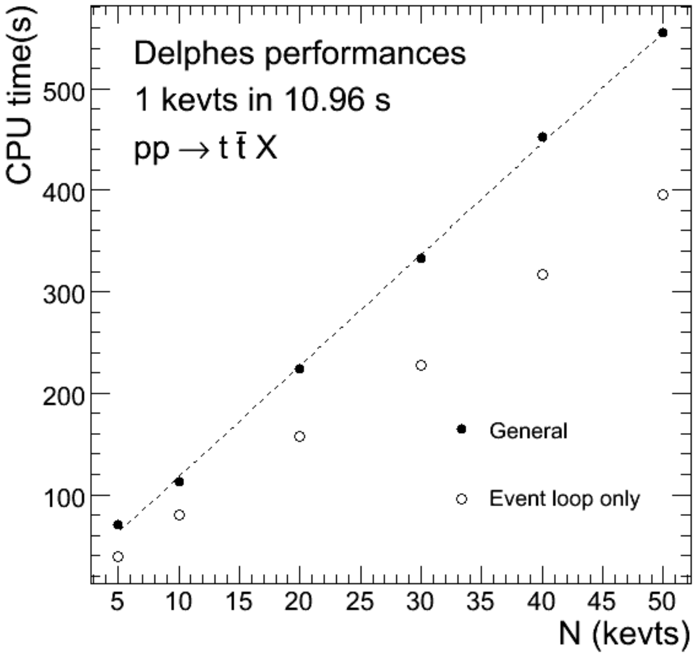


We present here a new framework for the fast simulation of a generic collider experiment

- Includes Trigger, forward near-beam detectors, 3D Event display

- ***Delphes*** performs a *fast* simulation:

10 000 events
109,6 s (regular laptop)
240 MB (physics dependent)



- ***Delphes*** stores output information in

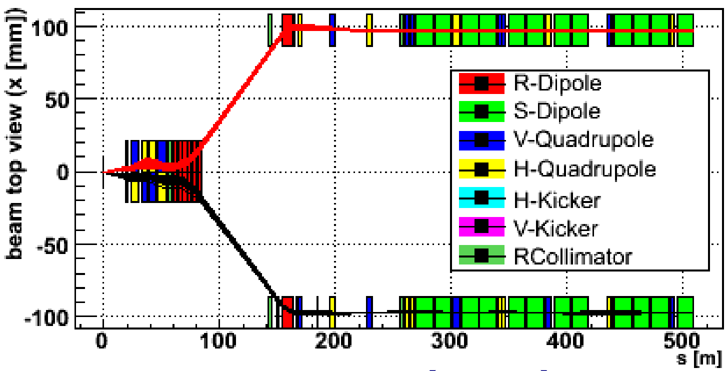
  - ASCII file of LHCO type
  - ROOT format

Can be used for fast evaluation of observability of new signals in phenomenology, as an illustration tool for tutorial sessions, ...

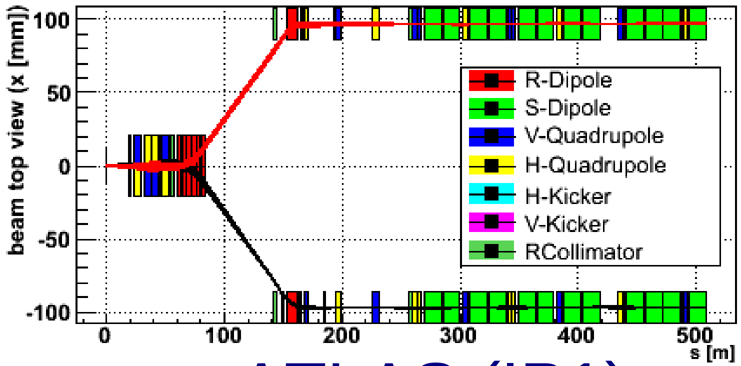
http://www.fynu.ucl.ac.be/delphes.html

Back-up slides

HECTOR: implementation

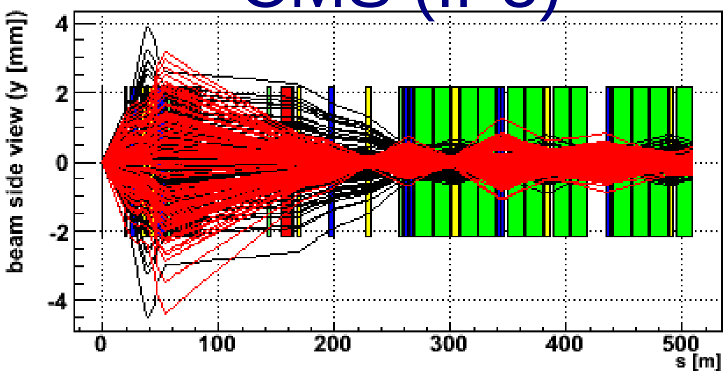


top

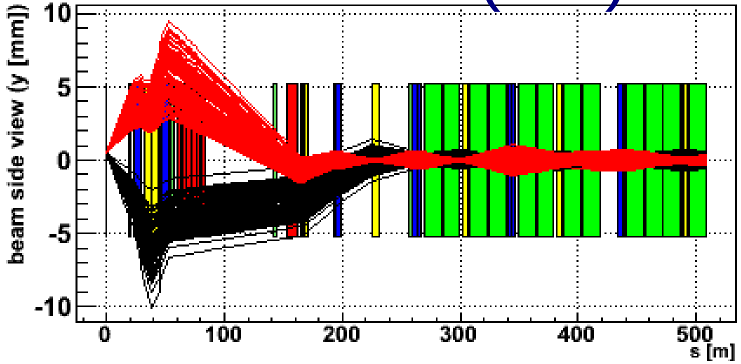


CMS (IP5)

ATLAS (IP1)



side



Horizontal crossing plane

Vertical crossing plane

Input Needed:

effective field strength / length

magnet position / aperture

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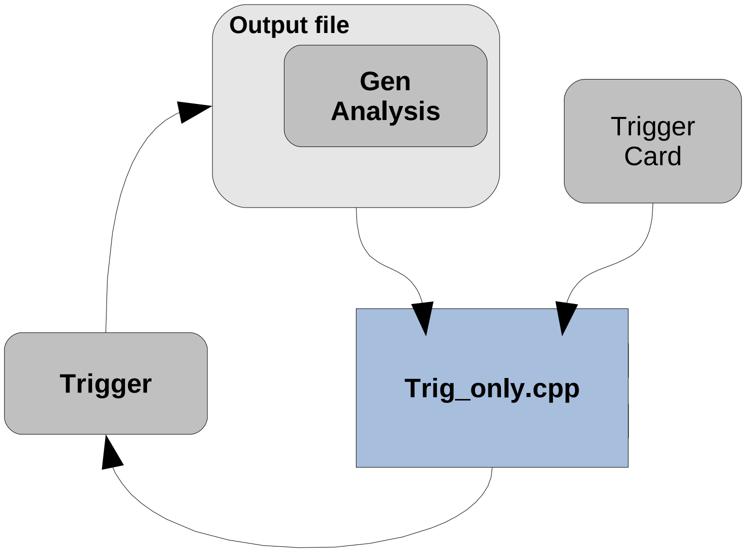
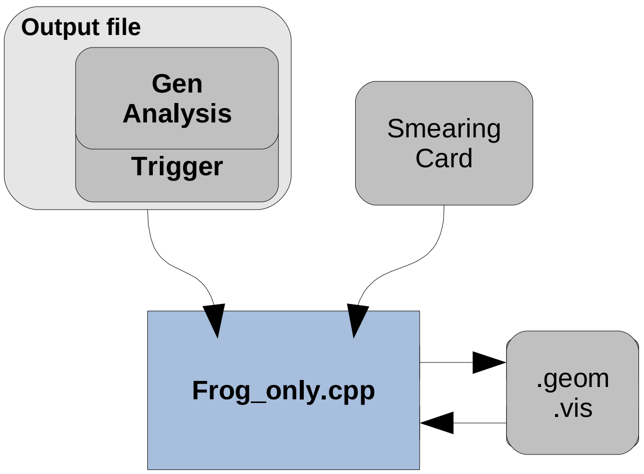
Back-up

- Calotowers
- Jet Algorithms
- Hector

Additional features





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Delphes flow

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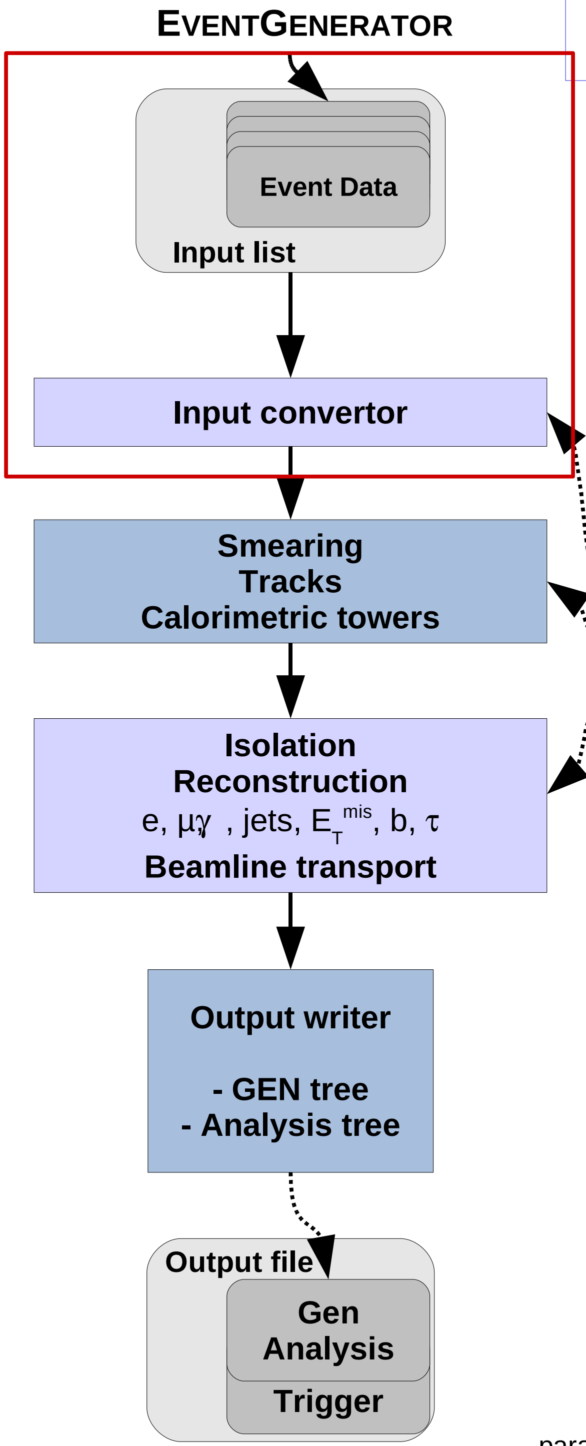

Smearing Card

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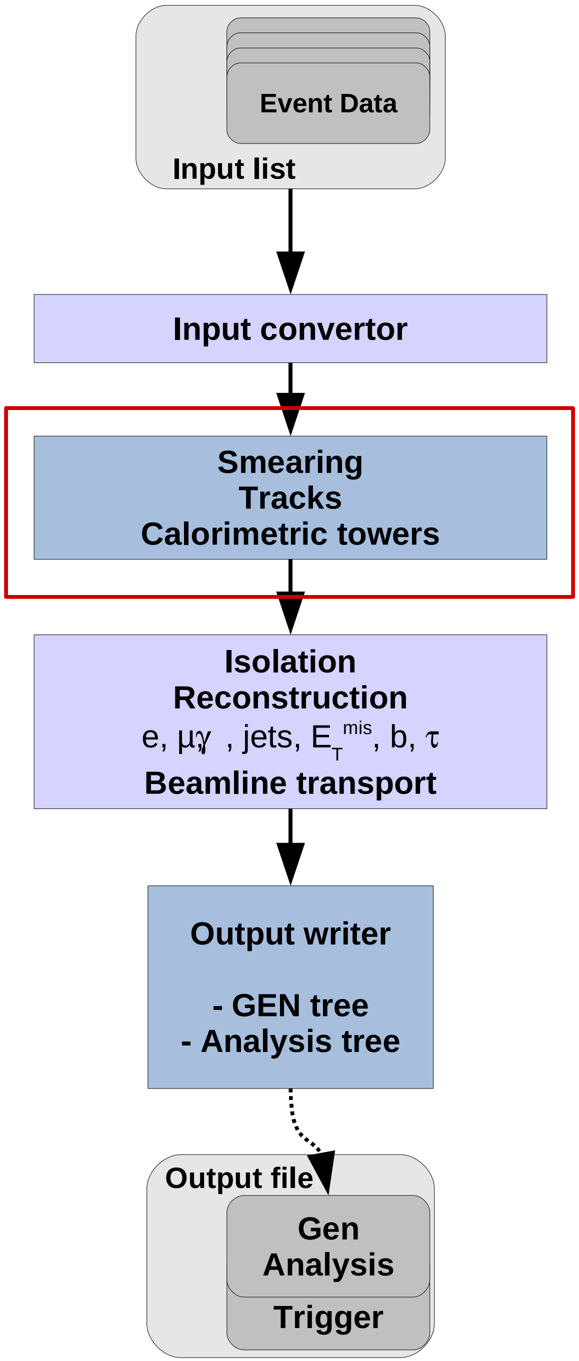

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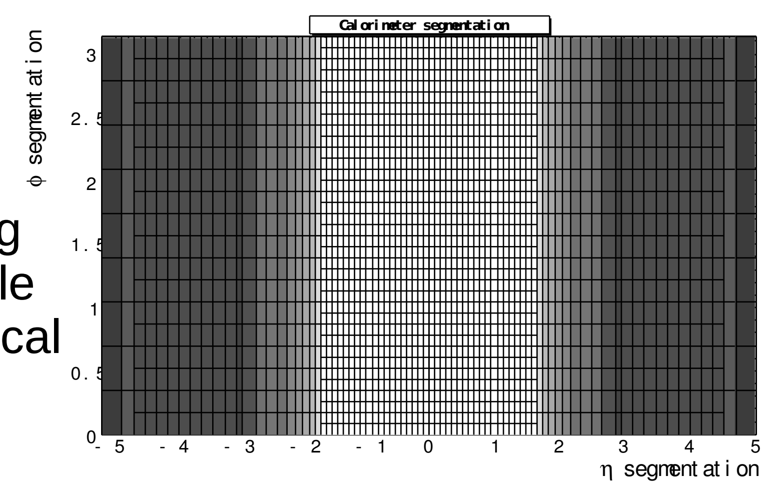

Tracks: for all charged particle in the tracking coverage, considering « energy flow »