

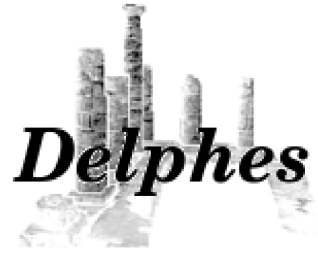
Delphes

A framework for fast simulation of a
generic collider experiment

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Freiburg*



Website :

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

News / Download / User manual / FAQ

Current version: Delphes V 1.7b

Paper + User manual :

[arXiv:0903.2225\[hep-ph\]](https://arxiv.org/abs/0903.2225)

DELPHES, a framework for fast simulation
of a generic collider experiment

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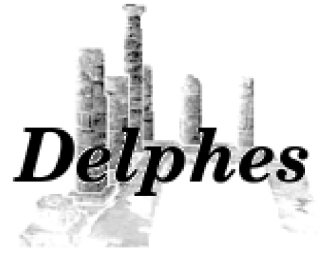
xavier.rouby@cern.ch



S. Oryn, UCL-CP3

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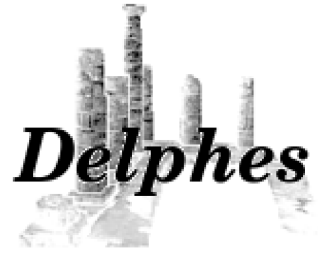
Motivations
Simulation
BUT also...
Tutorial
Conclusion



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*Motivation: from theory to
detectors...*

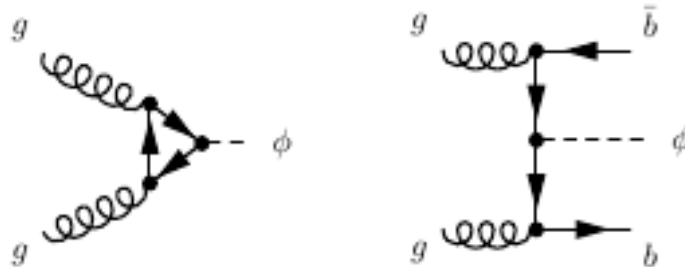
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Knowing if theoretical predictions will be visible and measurable in a high energy experiment is complex and requires several steps:

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1° Development of a new model

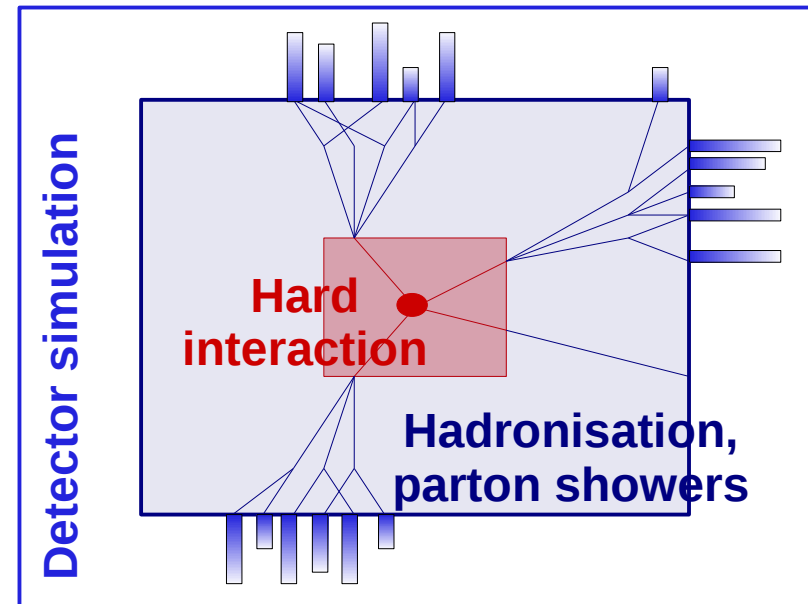


2° Implementation and generation of hard interaction

- MadGraph/MadEvent (MG/ME)
- CalcHep

3° Simulation of hadronisation and parton showers

- Pythia
- Herwig

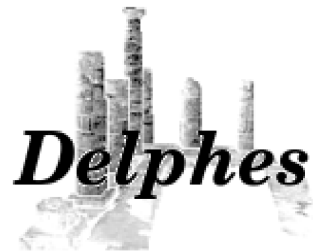


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Complexity of HE detectors...

4° Simulation of the response of a high energy experiment

- ATLAS
- CMS



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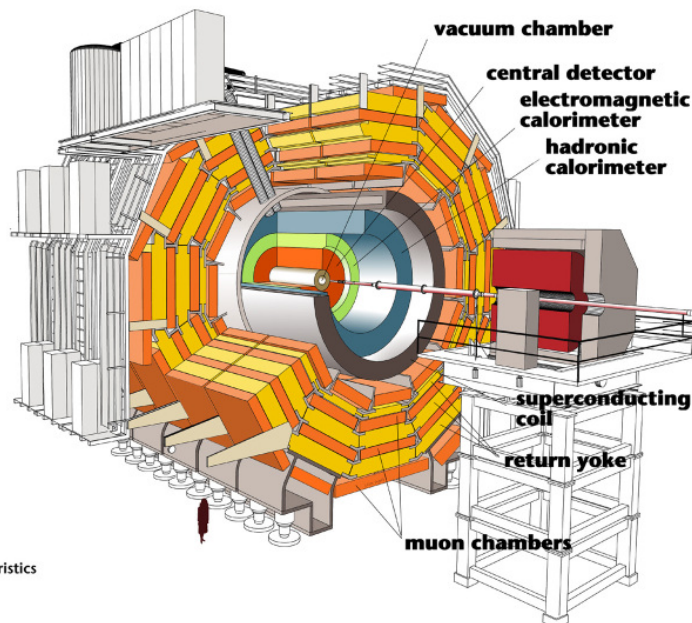
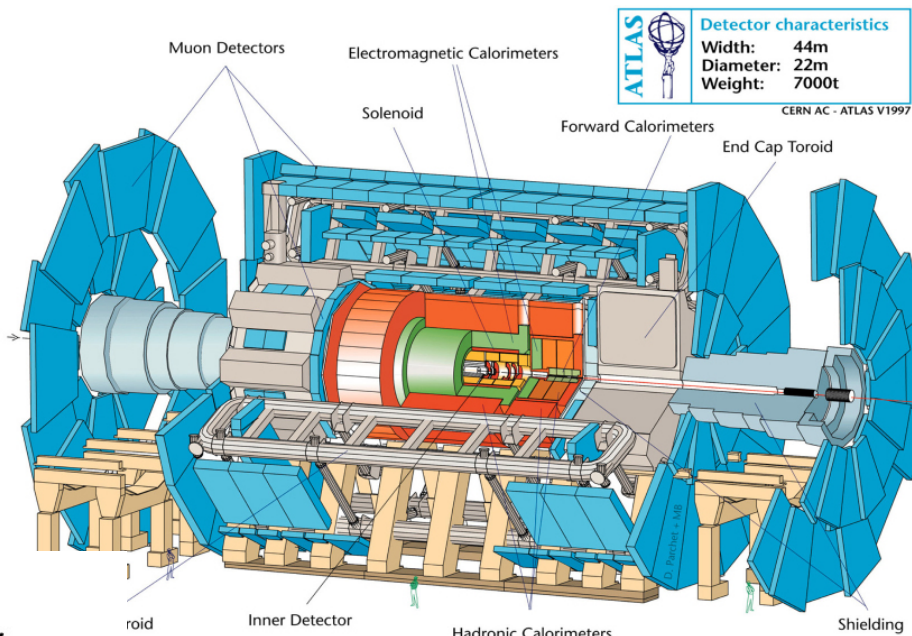


Detector characteristics
Width: 22m
Diameter: 15m
Weight: 14'500t

ATLAS

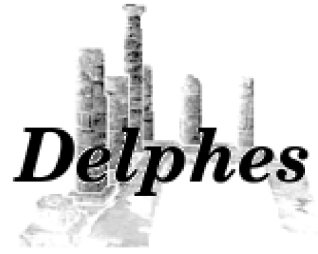


Athena, ATLFast I & II

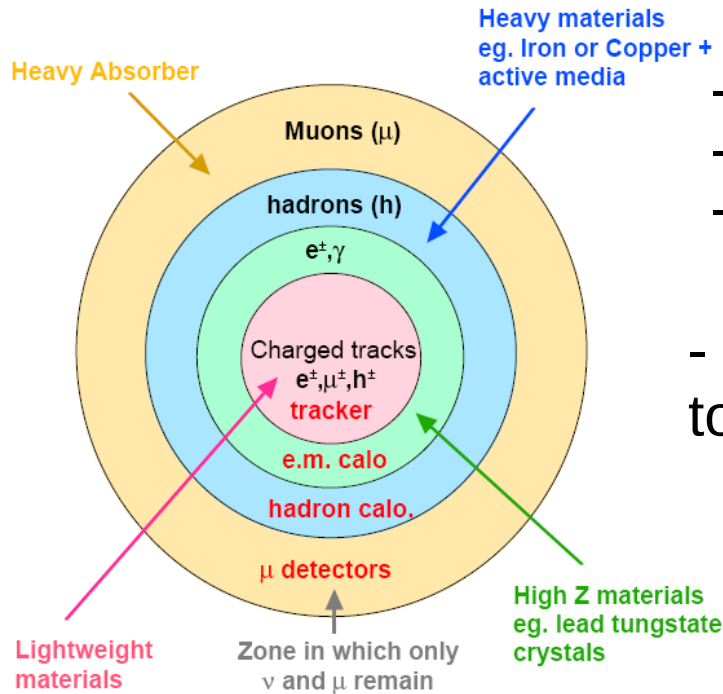


CMS

CMSSW, FastSim



General structure



- Complexity of the related subdetectors
 - tracker
 - electromagnetic and hadronic calorimeters
 - muon chambers
- Requires the use of complex softwares to simulate
 - detailed energy deposition from ionization, showering
 - secondary interactions
 - detector inefficiencies
 - multiple scattering
 - ...

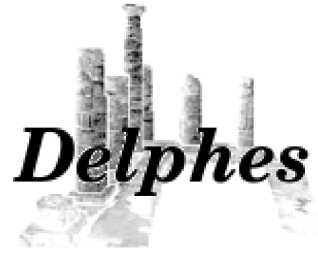
Such a simulation is very complex and a large CPU per event

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



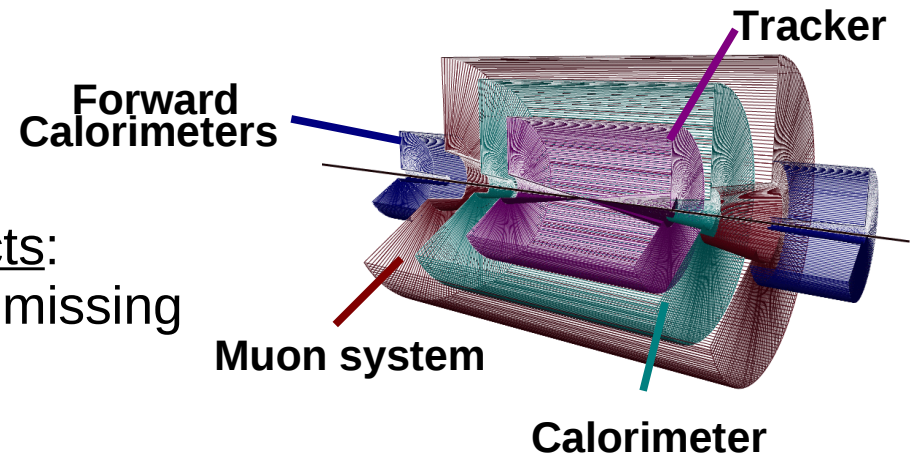
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Delphes provides:

- 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



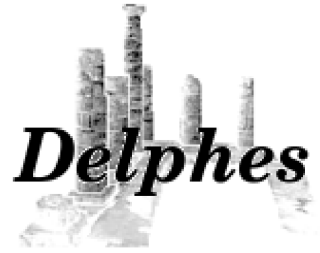
- Reconstruction of physics objects: leptons, jets, b-jets, tau-jets, and missing transverse energy
- Trigger emulation
- An event display

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

The code is also independent from any collaboration

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C++ implementation of the simulation

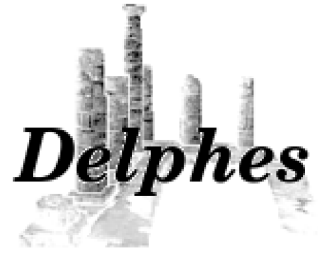
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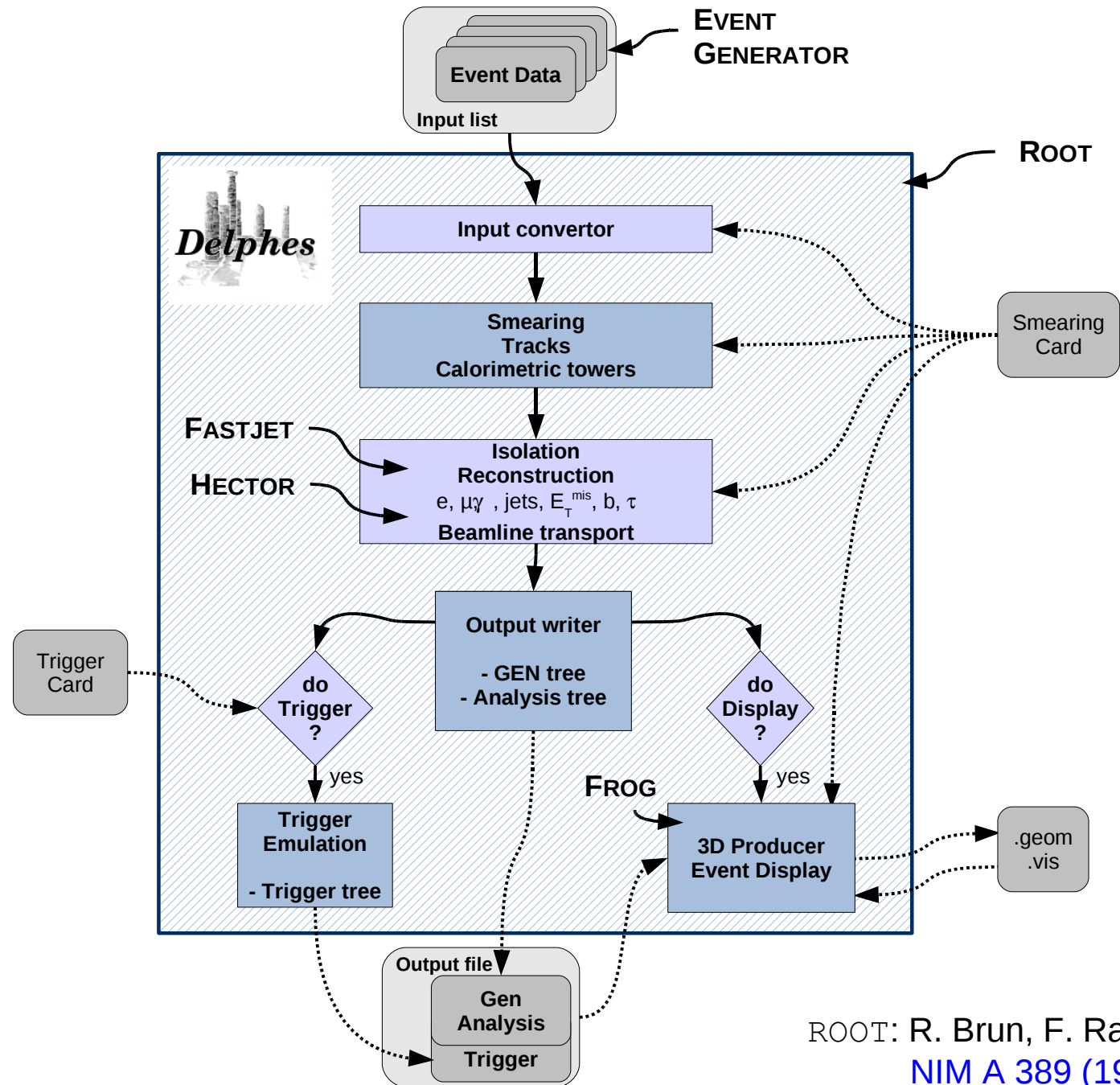
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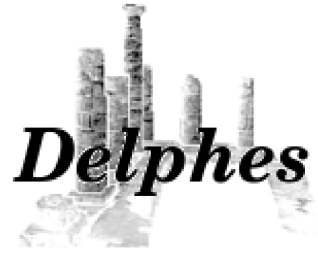


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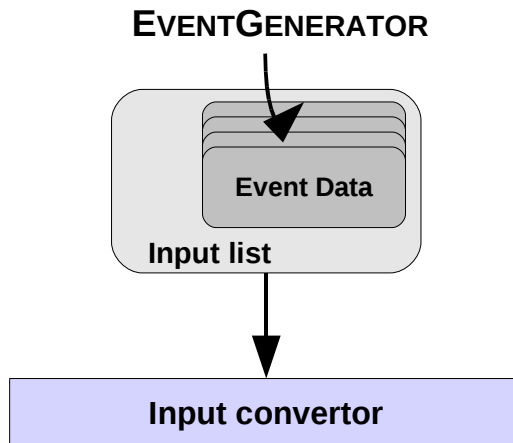
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ROOT: R. Brun, F. Rademakers,
NIM A 389 (1997) 81-86.



Interface:



First step of *Delphes*: conversion of input events into a ROOT tree readable by the rest of the code

➔ Result of the conversion stored in a **GEN tree**

➔ Allow easy checks between various generators

```
./Delphes inputlist.list OutputRootFileName.root
data/DetectorCard.dat data/TriggerCard.dat
```

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

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

➔ Compatible with - MG/ME, Pythia, Herwig,...

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Tower-tracks
photon-e/μ

jets

tau-jets-MET

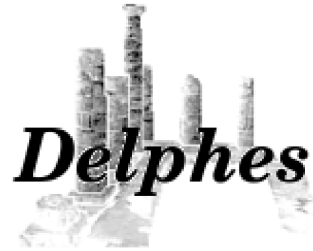
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Interface:

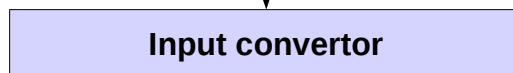
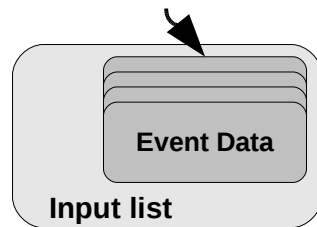
The input file list contains the location of the input files with one file per line!

```
/nfs/cms/mass10/o/ovyn/Analysis2/Wt_2l/apatWt_an_1.root
/nfs/cms/mass10/o/ovyn/Analysis2/Wt_2l/apatWt_an_2.root
/nfs/cms/mass10/o/ovyn/Analysis2/Wt_2l/apatWt_an_3.root
```

➔ Automatic detection of the file extension (.lhe, .hep, .root, .hepmc)

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

EVENTGENERATOR



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

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

```
./Delphes inputlist.list OutputRootFileName.root
data/DetectorCard.dat data/TriggerCard.dat
```

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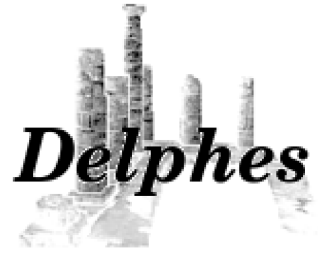
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Output file format: *Delphes* yields realistic observables for all reconstructed high level objects in two formats:

1°) Analysis tree in **ROOT files**, using ExRootAnalysis, P. Demin

- GEN tree (Monte Carlo level information)
- Analysis tree (detector level information)
- Trigger tree (trigger acceptance)

2°) **LHCO**

<http://v1.jthaler.net/olympicswiki/doku.php>

Column format

```
# typ eta phi pt jmass ntrk btag had/em dummy dummy
```

Typ: 0 = photon , 1 = electron , 2 = muon , 3 = tau-jet , 4 = jet , 6 = MET

Ntrk: number of tracks associated with the object. For of a lepton, this number is multiplied by the charge of the lepton.

For muons: The integer part is the identity of the jet that is closest ot this μ in ΔR

had/em: ratio of the hadronic versus electromagnetic energy deposited in the calorimeter cells associated with the object; it is typically > 1 for a jet and $\ll 1$ for an electron or γ .

For muons: the format is xxx.yy. The 'xxx' is **ptiso**, the summed p_T in a $R=0.4$ cone (excluding the μ). The 'yy' is **etrat**, is the ratio of the transverse energy in a 3×3 grid surrounding the μ to the p_T of the muon.

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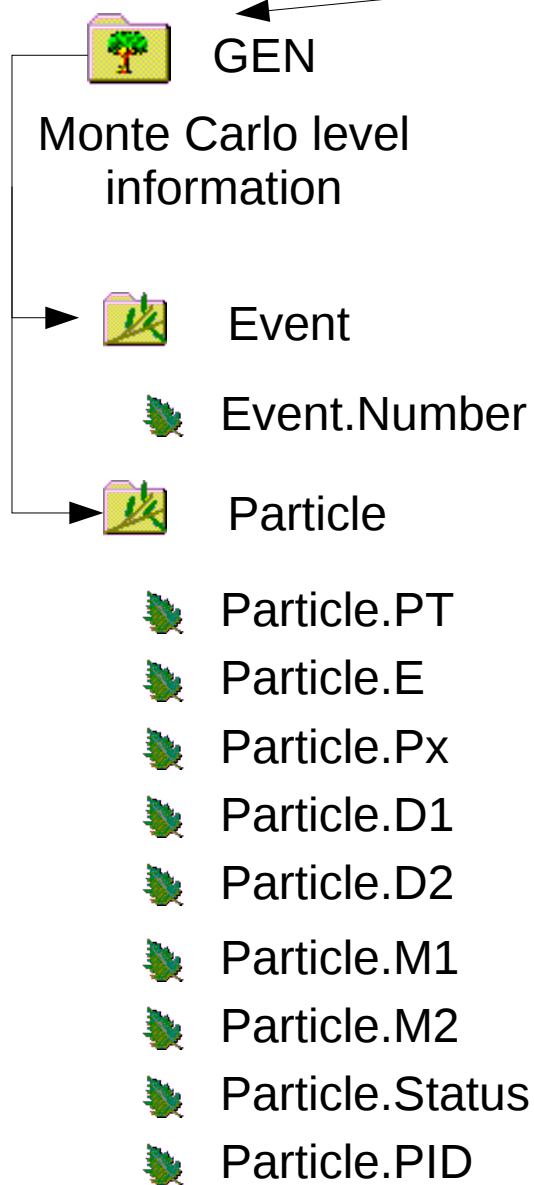
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Trees in the output ROOT file



Delphes.root



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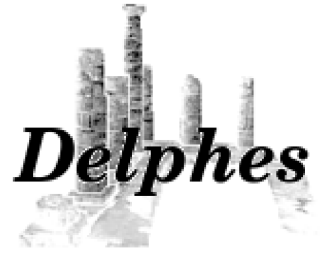
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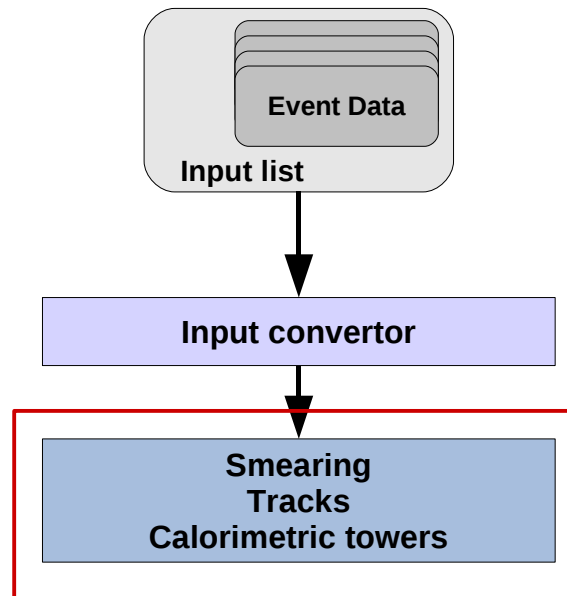
Conclusion

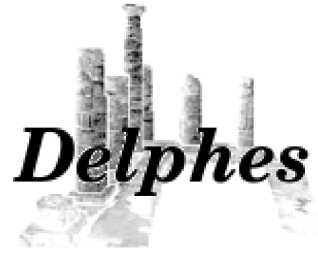


Low objects, detector level information

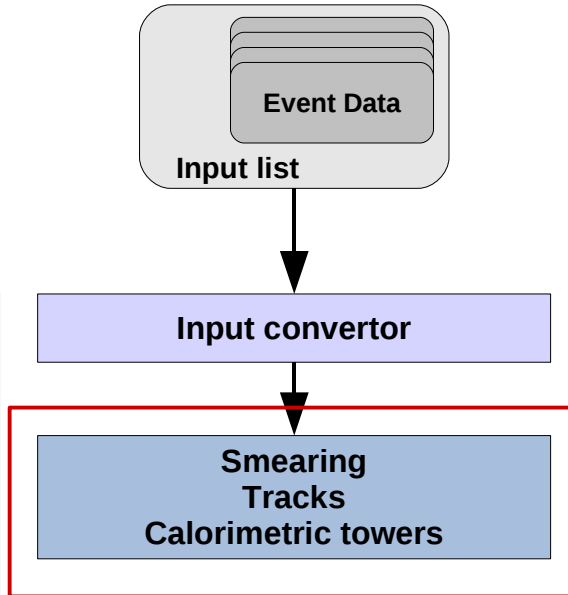
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Smearing: Response of each subdetector parametrised as a function of the energy:

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

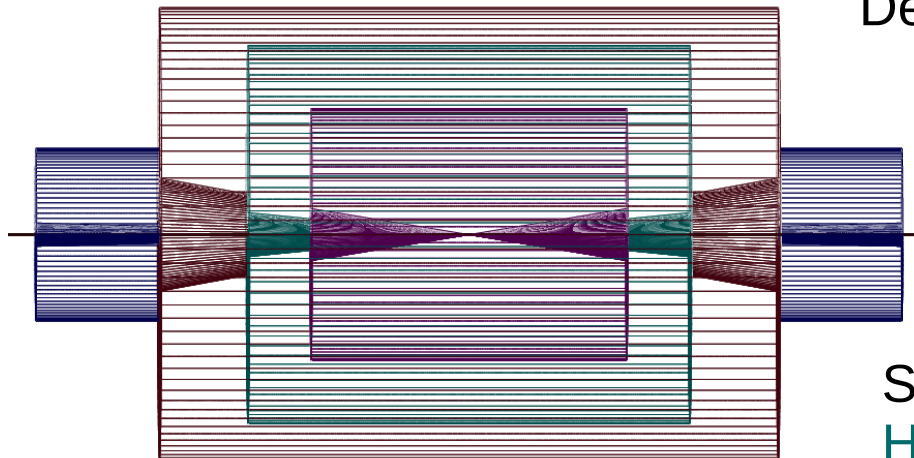
With different response to

- electromagnetic objects
- hadrons

Muons: smearing on the p_T

Parameters controllable using the input datacard

Schematic view of the *Delphes* detector

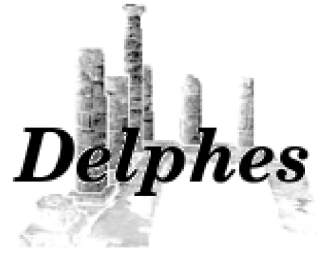


Detector extension in pseudorapidity

- tracker coverage
- central calorimeter coverage
- forward calorimeter coverage
- muon chambers coverage

S, N and C term of the ECAL, HCAL, FCAL

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Low level objects : Tracks

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

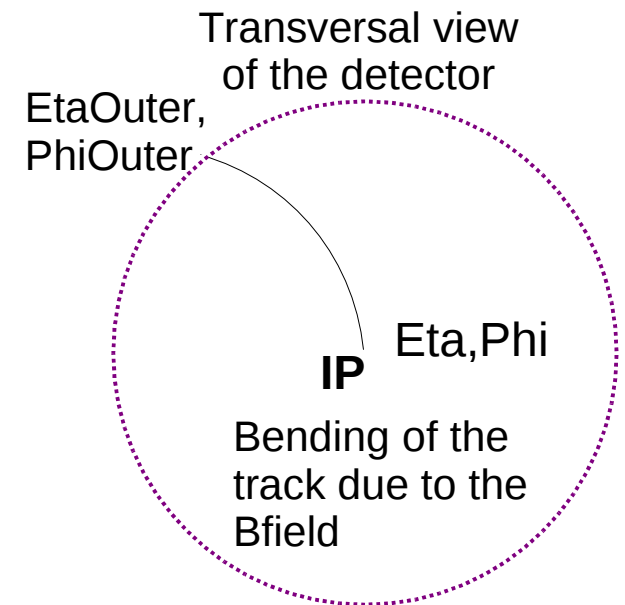
The tracker is embedded in a magnetic **B** field

- Position of charged particles is modified
- The values of the length and radius of the tracker are important parameters

Impact of the η modification important when the p_T of the particle is too small to reach the central calorimeters

The inner and outer value of the tracks are stored in the Tracks branch of the *Delphes* ROOT file

➔ Eta, Phi, EtaOuter, PhiOuter



!! The particle energies are smeared according to the resolution of the calorimeter subdetector they reach !!

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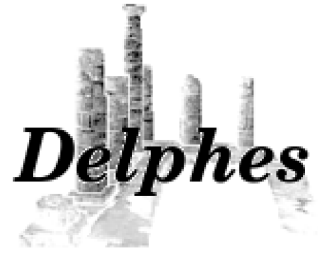
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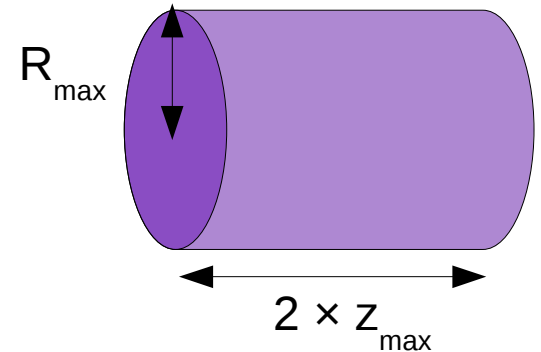
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Simulation of the magnetic field

$B_x = B_y = 0$ → Exact calculation of the transport of a charged particle

The magnetic field is supposed to be

- homogeneous
- constant inside a cylinder of length $2 \times z_{max}$ and of radius R_{max} .



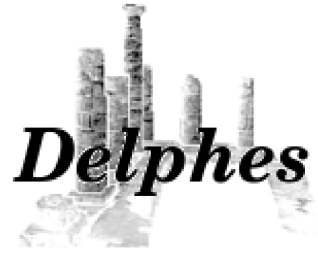
To make the code faster, the **time** of flight needed to exit the cylinder is computed

$$\rightarrow t_{max} = \min(t_T, t_z) \quad \begin{cases} t_z \text{ such that } |z(t_z)| = z_{max} \\ t_T \text{ such that } R(t_T) = R_{max} \end{cases}$$

$B_x \neq 0$ $B_y \neq 0$ → iterative method step by step until the particle exits the tracker region **Method slower than for a pure solenoidal B field**

Disclaimer: magnetic field of muon chambers such as for ATLAS not simulated with **Delphes**

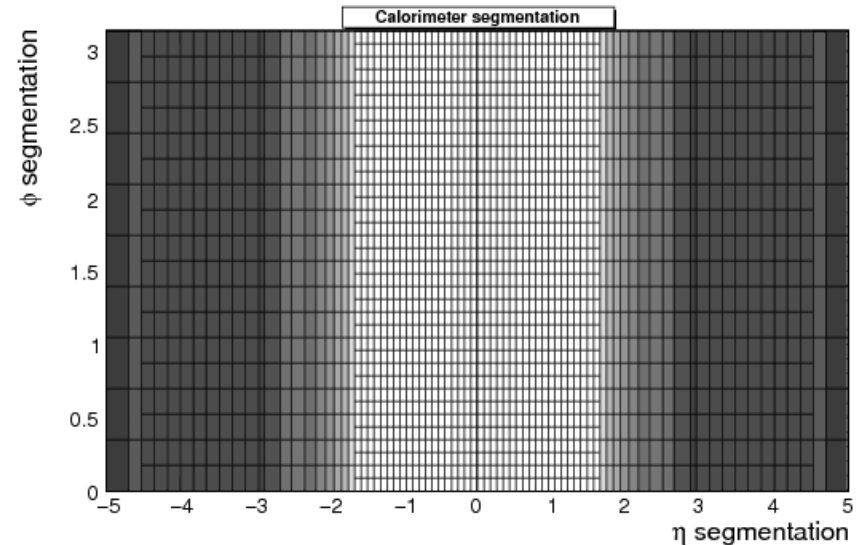
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Calorimetric towers

Segmentation in eta/phi

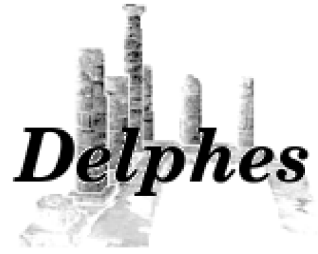
Need to enter in the datacard the number of towers in pseudorapidity as well as the edges of the towers in eta/phi



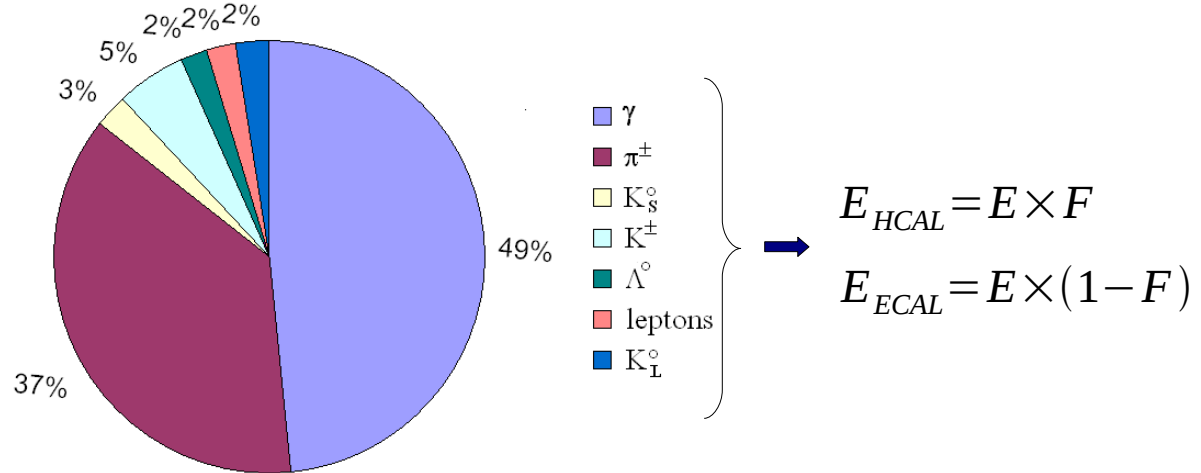
- Definition of positive towers only because the detector is supposed to be **symmetric in η** !
- **Delphes** assumes that all towers are similar in ϕ for a given η value

```

TOWER_number      40
TOWER_eta_edges  0. 0.087 0.174 0.261 0.348 0.435 0.522 0.609 0.696 0.783 0.870
0.957 1.044 1.131 1.218 1.305 1.392 1.479 1.566 1.653 1.740 1.830 1.930 2.043 2.172
2.322 2.500 2.650 2.868 2.950 3.125 3.300 3.475 3.650 3.825 4.000 4.175 4.350 4.525
4.700 5.000
TOWER_dphi 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 20 20
    
```



- Charged and neutral final-state hadrons interact with the ECAL, HCAL and FCAL



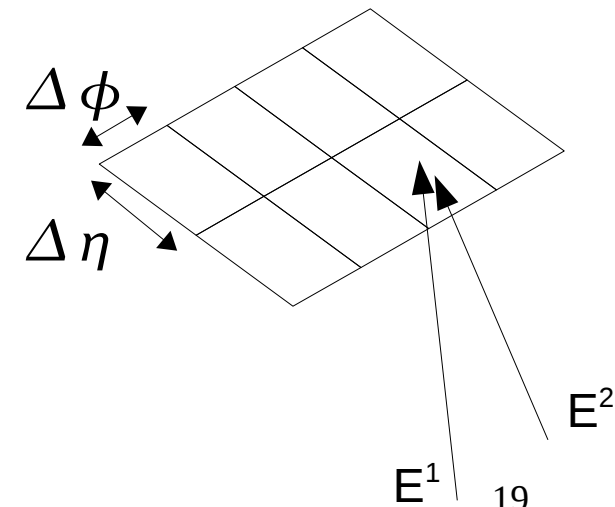
Smearing of particles performed using the expected fraction of the energy, determined according to their **decay products**, that would be deposited into the ECAL (E_{ECAL}) and into the HCAL (E_{HCAL})

- Summing energy of multiple impacts in identical towers

$$E_{ECAL}^{tower} = E_{ECAL}^1 + E_{ECAL}^2 \quad \text{and} \quad E_{HCAL}^{tower} = E_{HCAL}^1 + E_{HCAL}^2$$

➔ Smearing of the corresponding energies

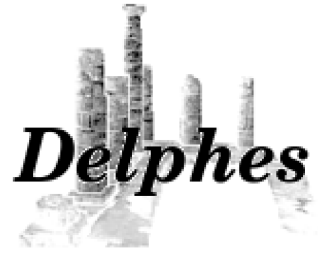
$$E^{tower} = E_{SHCAL}^{tower} + E_{SECAL}^{tower}$$



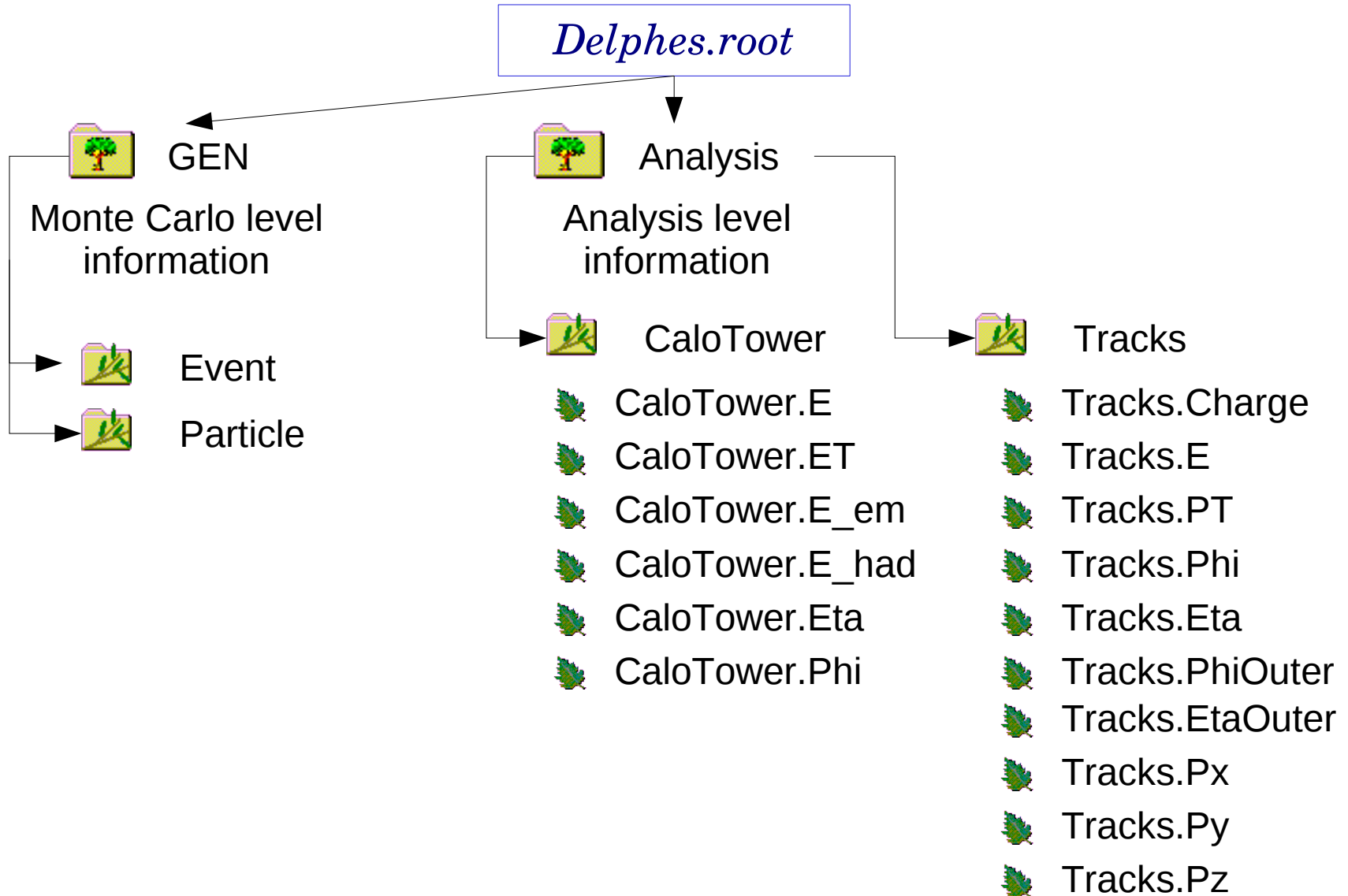
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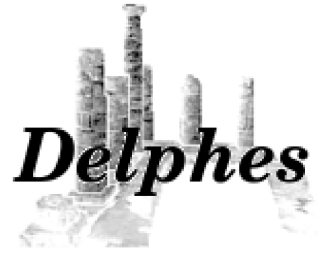
Trees in the output ROOT file



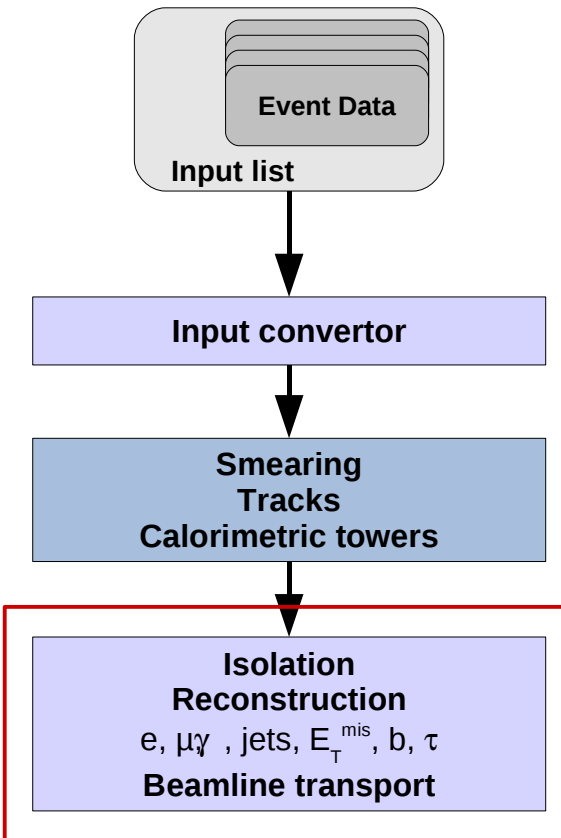
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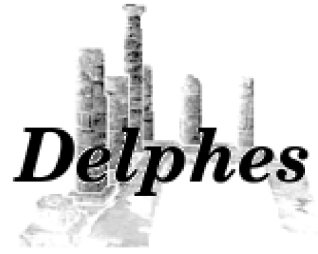


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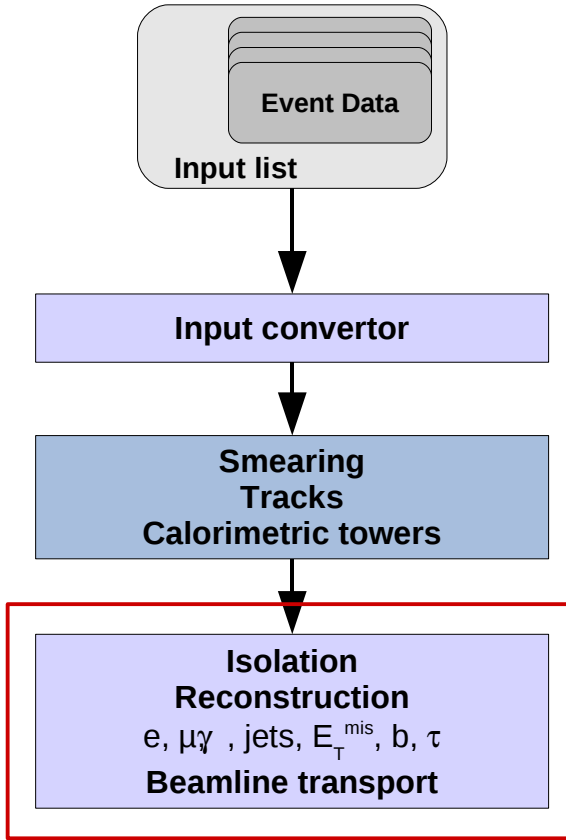


*High level objects,
final reconstructed
information*

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Photons :

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

Electrons and muons :

- reconstructed if they fall into the tracker coverage
- muons do not leave a deposit in the calorimeters

Isolation implemented:

- Isolation of charged particles using tracking information
- ↳ No other charge particles with $p_T > 2$ GeV within a cone

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

- Additional information available for calorimetric isolation

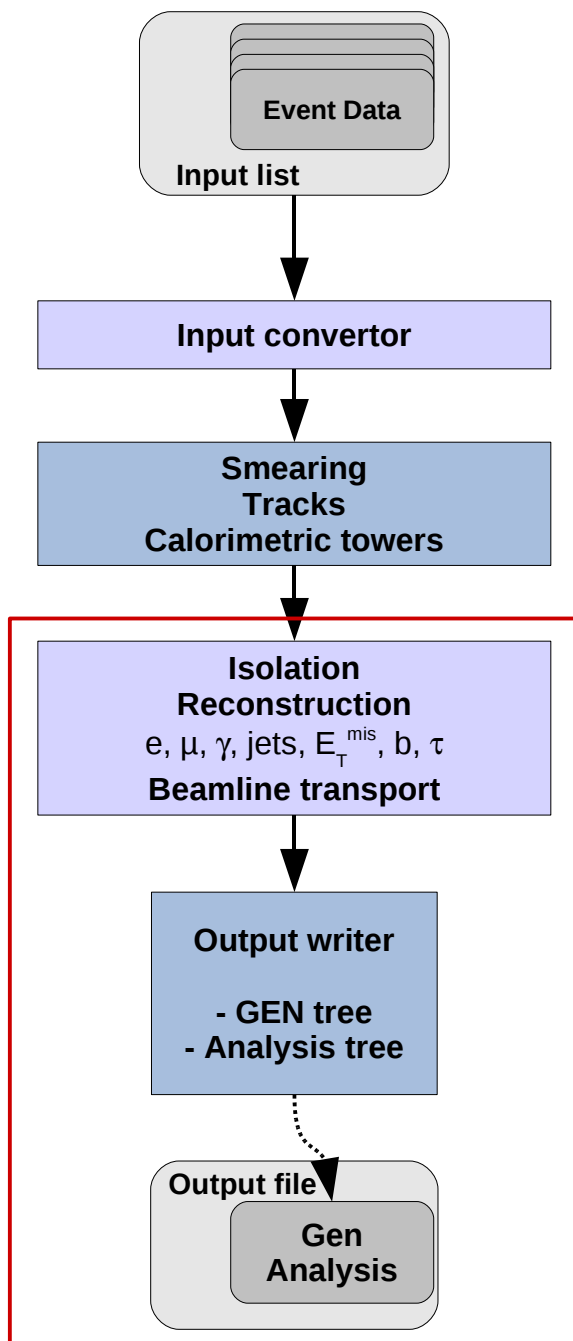
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22/06/2009



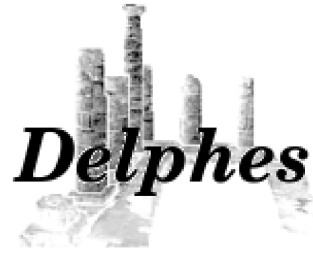
Jets :

- Treatment 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

Jet algorithms differ

- in their sensitivity to soft particles or collinear splittings
- their computing speed performances.

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



Choice of the jet algorithm, jet parameters in the detector datacard

In addition to the standard E, P_x, P_y, P_z, Eta, Phi variables, the jet collections also contains

- The **number of tracks** associated to the jet
- The ECAL value ont the HCAL value of the jet
- A **b-flag** indicated if the jet has been b-tagged

- *b*-tagging

- identical in the entire tracker coverage
- independent of the p_T of the jet
- efficiency controlable in the datacard (default= 40%)
- mis-identification of c (10%) and light jets (1%)

Final remark

The user can choose if a perfect energy reconstruction is applied in the tracker coverage (perfect energy flow).

If not, jets are taking as input the calorimetric towers

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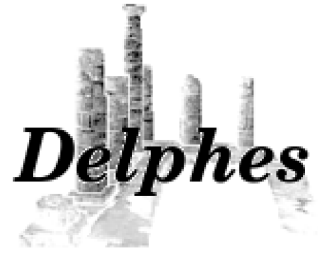
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Validation

BUT also...

Tutorial

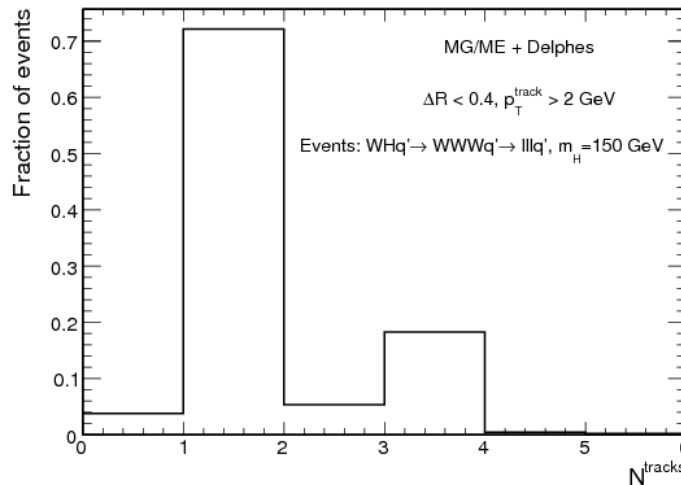
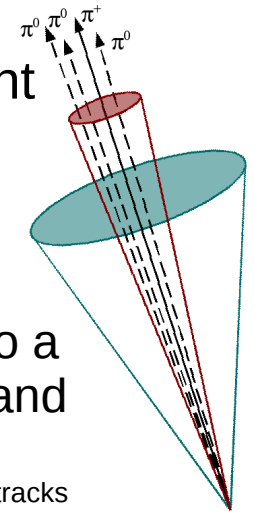
Conclusion



Tau-jets reconstruction:

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

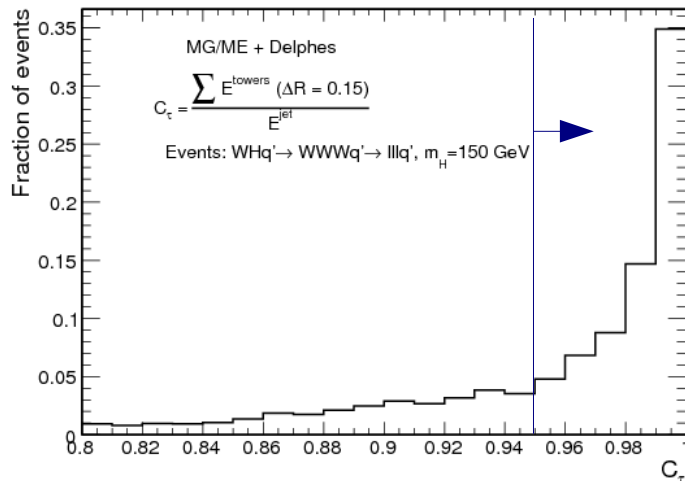
2) Requirement of **tracking isolation**



Number of tracks associated to a particle with $p_T > 2 \text{ GeV}$ is one and only one in a cone of radius R_{tracks}

- ➡ - 3-prong τ dropped.
- Cone should be entirely incorporated into the tracker

1) Use of the **narrowness** of the tau-jet

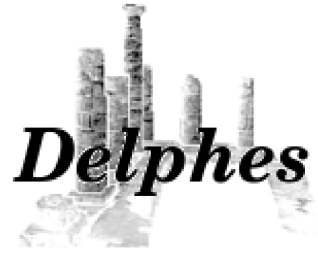


C_τ = sum of the energy of towers in a small cone of radius R_{em} around the jet axis, divided by the energy of the reconstructed jet.

- ➡ C_τ expected to be large

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- Motivations
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- Tower-tracks
- photon-e/ μ
- jets
- tau-jets-MET**
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- Measurement of Missing Transverse Energy (MET) in an ideal detector

Momentum conservation imposes the transverse momentum of the observed final state (p_T^{obs}) to be equal to the vector sum of the invisible particles,

$$\vec{p}_T = \begin{pmatrix} p_x \\ p_y \end{pmatrix} \text{ and } \begin{cases} p_x^{miss} = -p_x^{obs} \\ p_y^{miss} = -p_y^{obs} \end{cases}$$

- MET reconstruction in *Delphes*

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

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

Remarks:

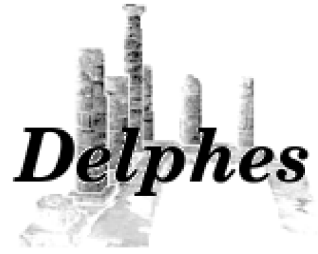
- dead channels, misalignment, noisy towers, cracks of the detector that worsen directly the MET not taken into account
- based on the calorimetric towers only

➡ muons not used to reconstruct MET

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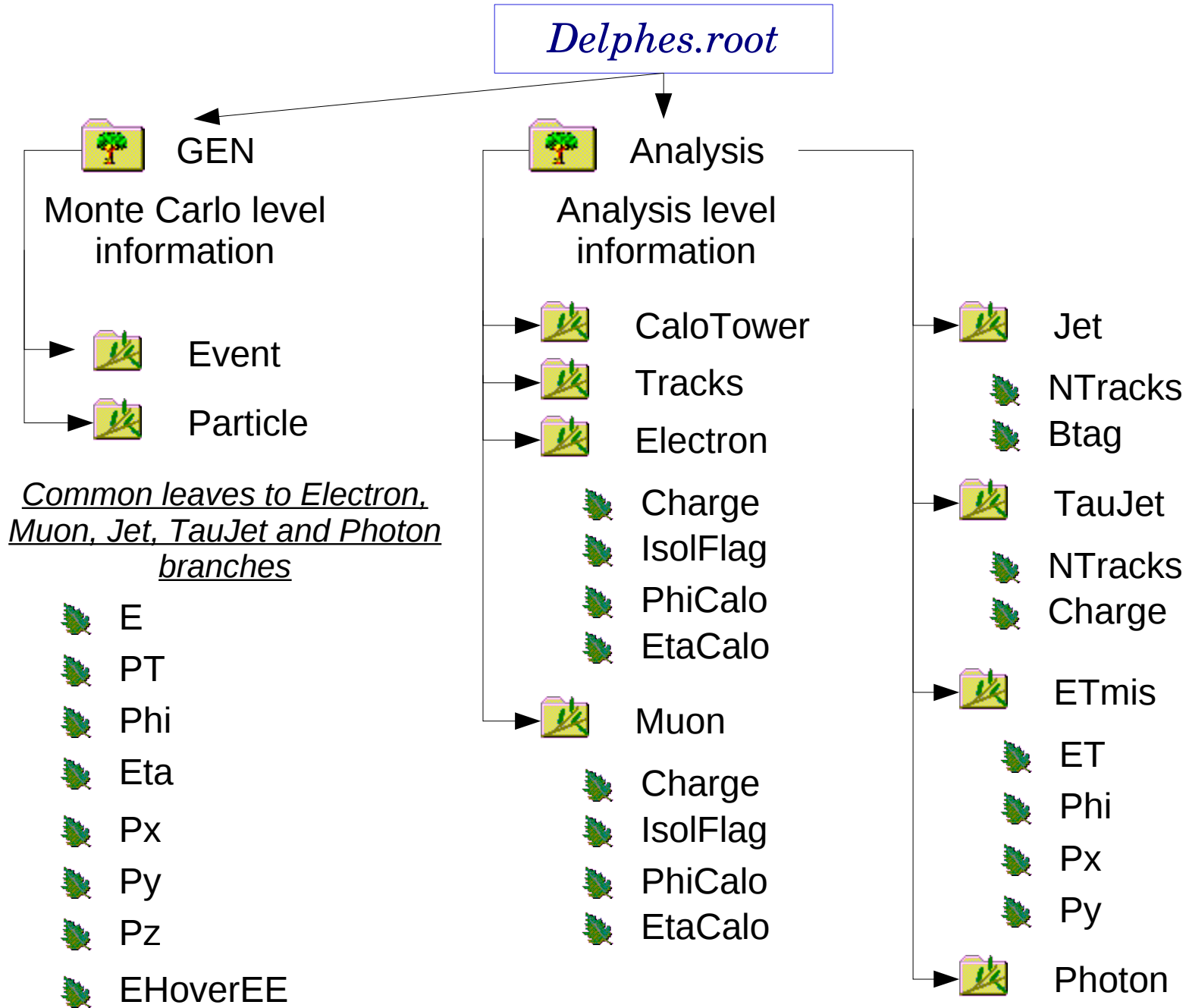
- Motivations
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- jets
- tau-jets-MET
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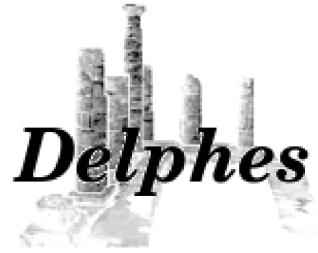
Trees in the output ROOT file



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- tau-jets-MET
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Very forward detector information

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

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Motivations

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Interface

Tower-tracks

photon-e/μ

jets

tau-jets-MET

Forward det.

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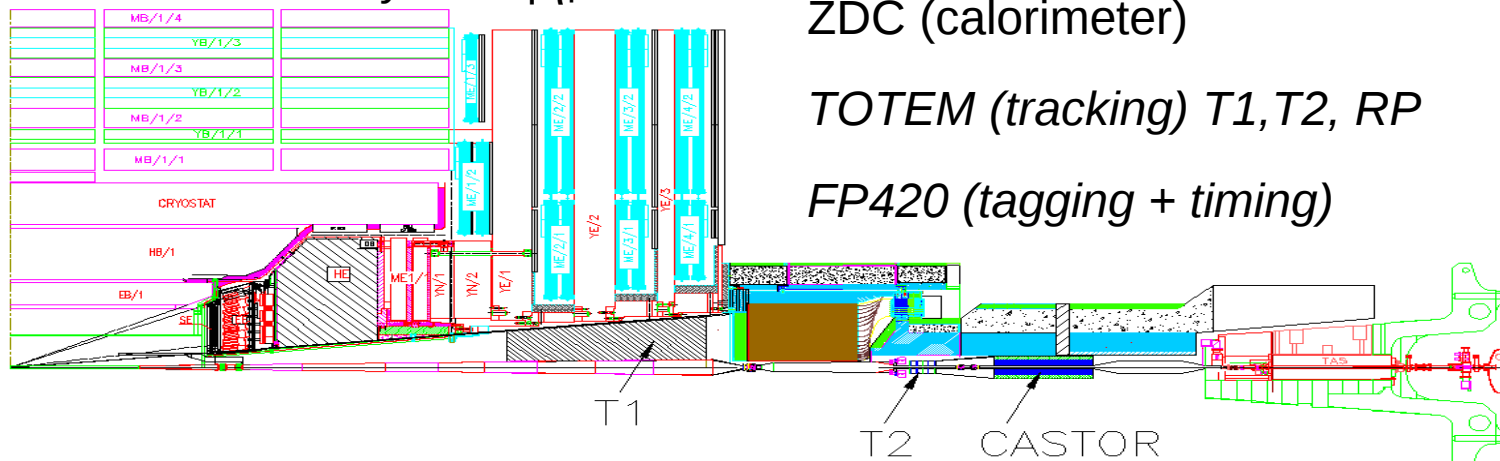
Conclusion

22/06/2009

Central detector coverage

CMS tracking : $0 < |\eta| < 2.5$

CMS calorimetry : $0 < |\eta| < 5$



Very forward extensions

CASTOR (calorimeter)

ZDC (calorimeter)

TOTEM (tracking) T1, T2, RP

FP420 (tagging + timing)



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

Delphes

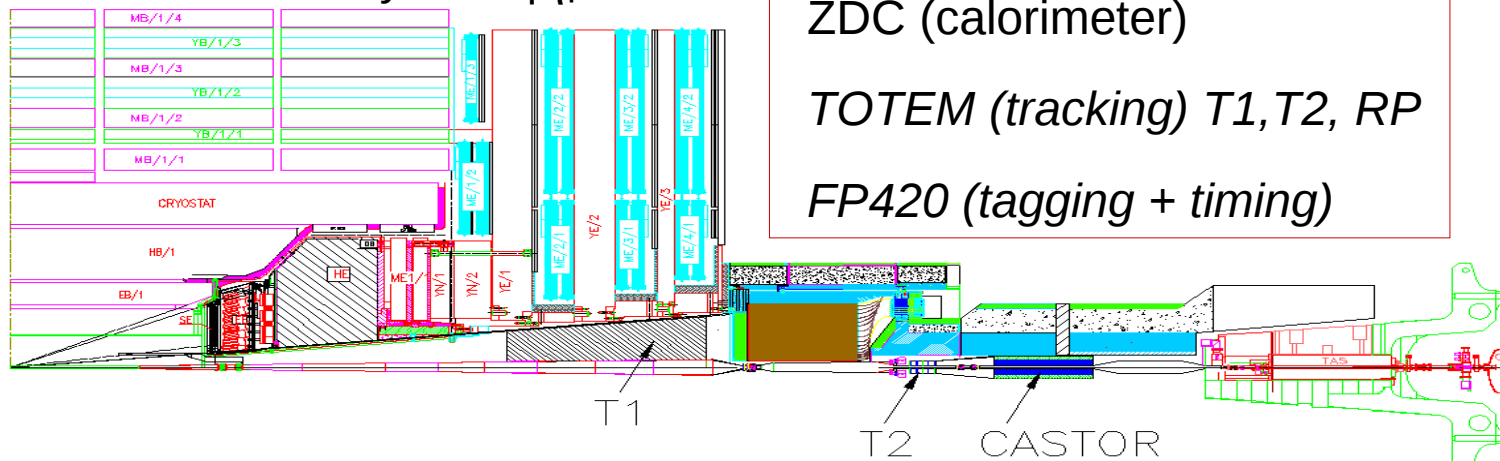
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S. Oryn

- Motivations
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- jets
- tau-jets-MET
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Central detector coverage

CMS tracking : $0 < |\eta| < 2.5$

CMS calorimetry : $0 < |\eta| < 5$



Very forward extensions

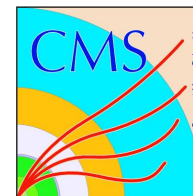
CASTOR (calorimeter)

Delphes

ZDC (calorimeter)

TOTEM (tracking) T1, T2, RP

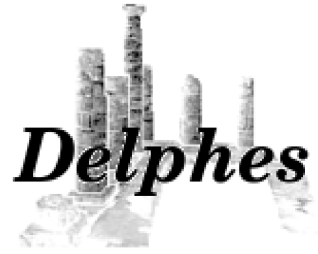
FP420 (tagging + timing)



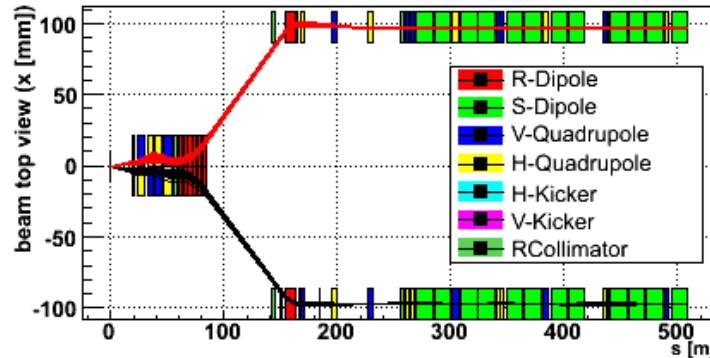
HECTOR implementation

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

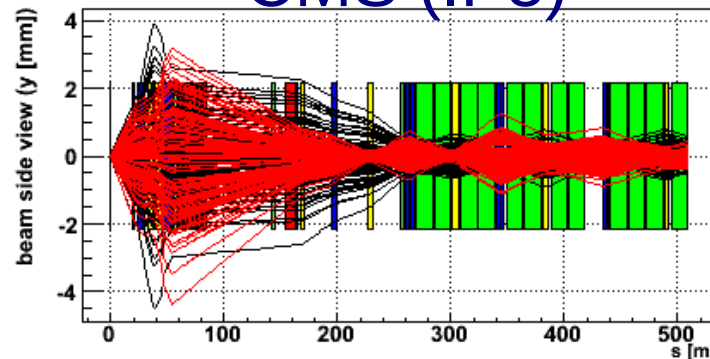
X. Rouby, J. de Favereau and K. Piotrkowski, *JINST* 2(2007) P09005



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S. Ovn

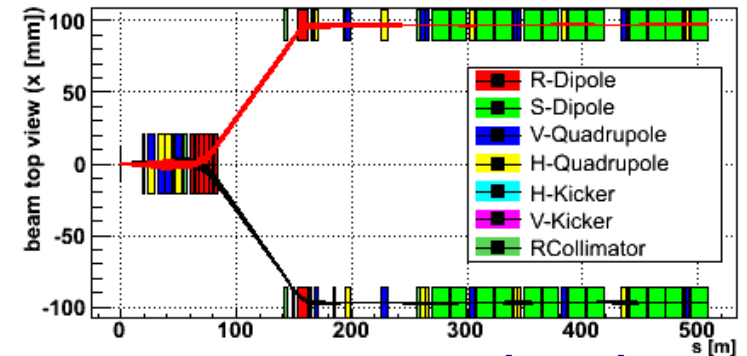


CMS (IP5)

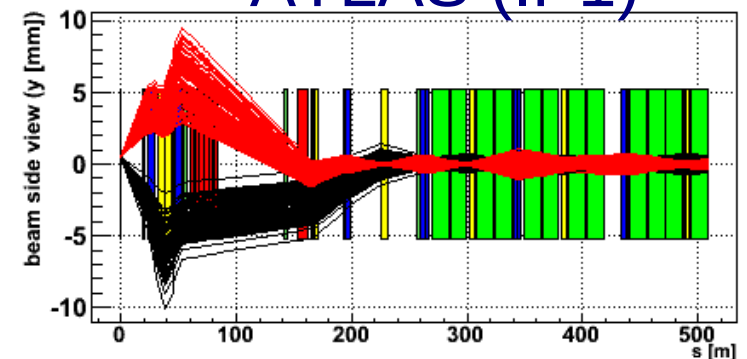


Horizontal crossing plane

top



ATLAS (IP1)



Vertical crossing plane

side

Input needed:

- effective field strength / length
- magnetic position/aperture

➔ data/LHCB1IR5_v6.500.tfs
data/LHCB2IR5_v6.500.tfs

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

- Motivations
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- Forward det.

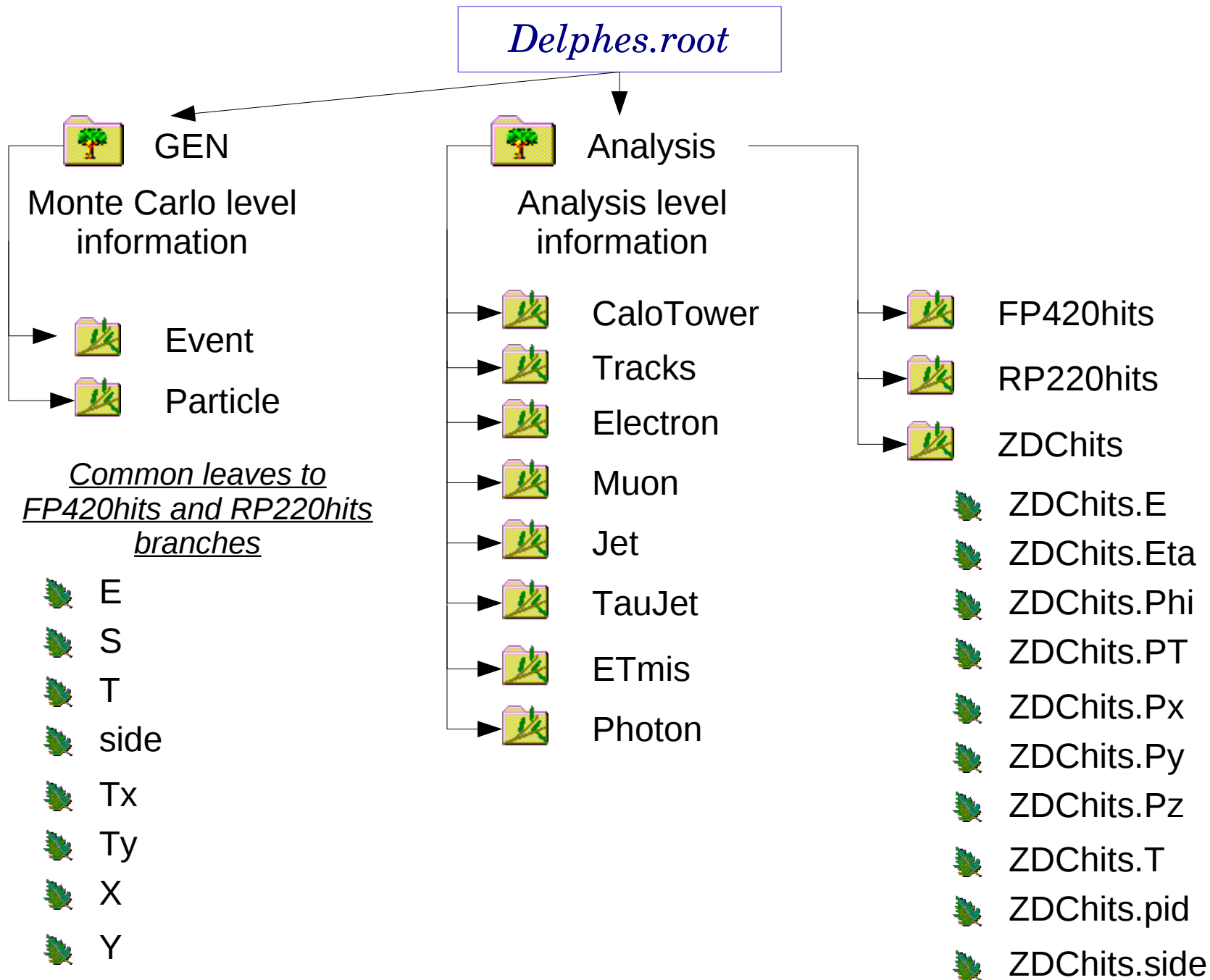
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Trees in the output ROOT file

Delphes

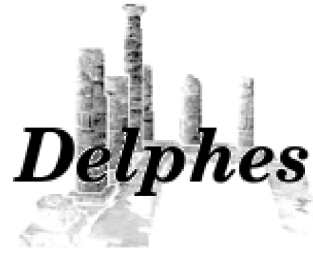
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- Motivations
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Validation procedures using CMS-like detector parameters

CMS resolution from: The CMS Collaboration, [CERN/LHCC 2006-001](#).



The majority of interesting processes contain jets in the final state.

➔ The **jet resolution** is therefore a crucial point

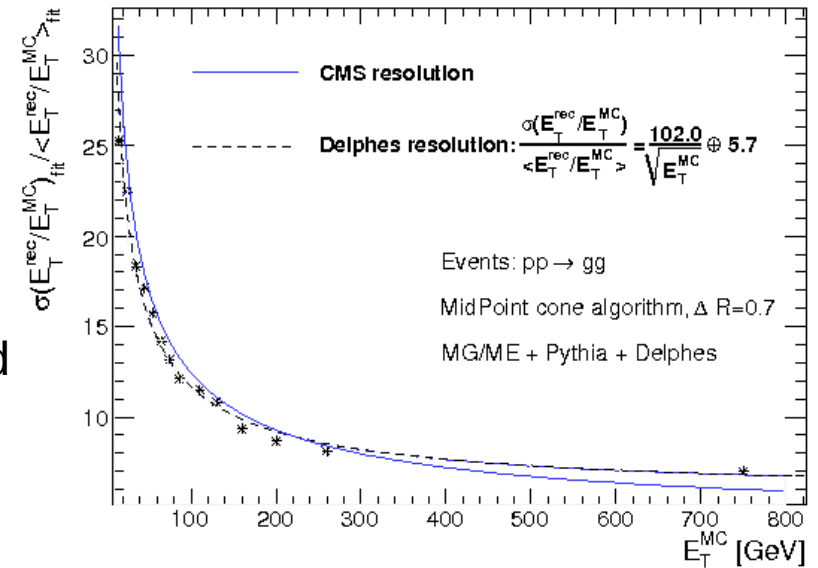
Sample used: pp → gg

- Arranged in 14 bins of gluon p_T .
- In each p_T bin, Delphes jets are matched to the closest GEN jet using

$$\Delta R = \sqrt{(\eta^{rec} - \eta^{MC})^2 + (\phi^{rec} - \phi^{MC})^2} < 0.25$$

- E_T^{rec}/E_T^{MC} histograms fitted with a Gaussian distribution in the interval ± 2 rms centred around the mean value. The resolution in each p_T bin is obtained by

$$\frac{\sigma \left(\frac{E_T^{rec}}{E_T^{MC}} \right)_{fit}}{\left\langle \frac{E_T^{rec}}{E_T^{MC}} \right\rangle_{fit}} (\hat{p}_T(i))$$



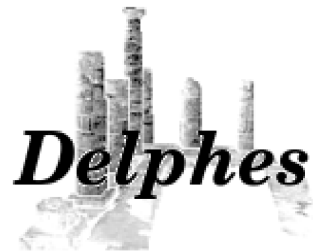
An excellent agreement is obtained comparing values of **Delphes** with the expectations of the general purpose CMS detector

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- Motivations
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Validation procedures using CMS-like detector parameters

CMS resolution from: The CMS Collaboration, [CERN/LHCC 2006-001](#).



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HEP detectors designed to be as much hermetic as possible

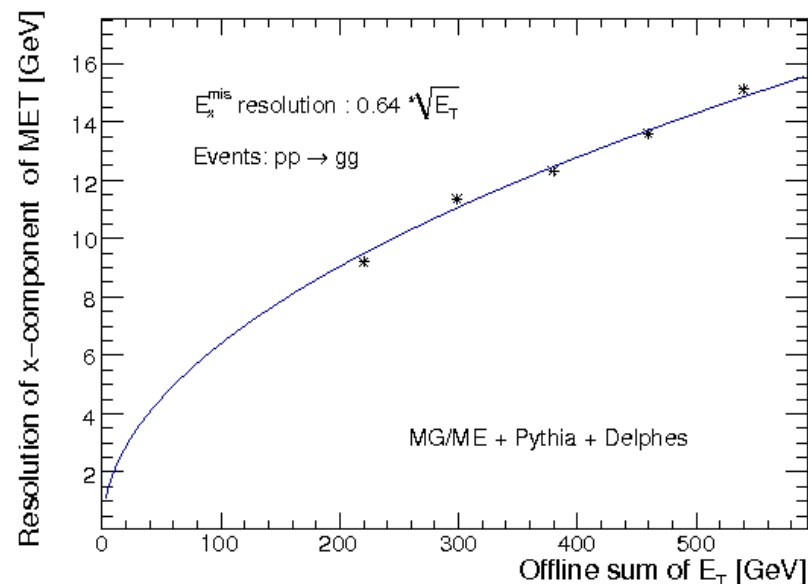
➔ **MET resolution** is a crucial point

Sample used: pp → gg : muon contribution is negligible

- Arranged in 5 bins of scalar E_T sum

Quality of the MET checked via the resolution on its horizontal component E_x^{miss}

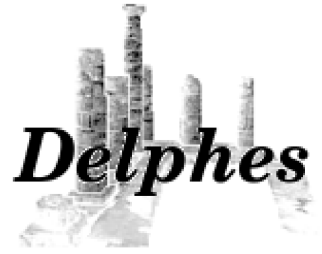
- Difference between the *Delphes* and the GEN E_x^{miss} fitted with a Gaussian distribution in the interval ± 1 rms centred around the mean value.



Value expected by CMS: $\sigma_x = (0.6 - 0.7) \sqrt{E_T} \text{ GeV}^{1/2}$

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

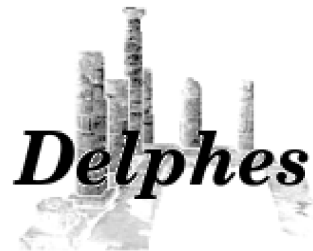
- Motivations
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- Interface
- Tower-tracks
- photon-e/ μ
- jets
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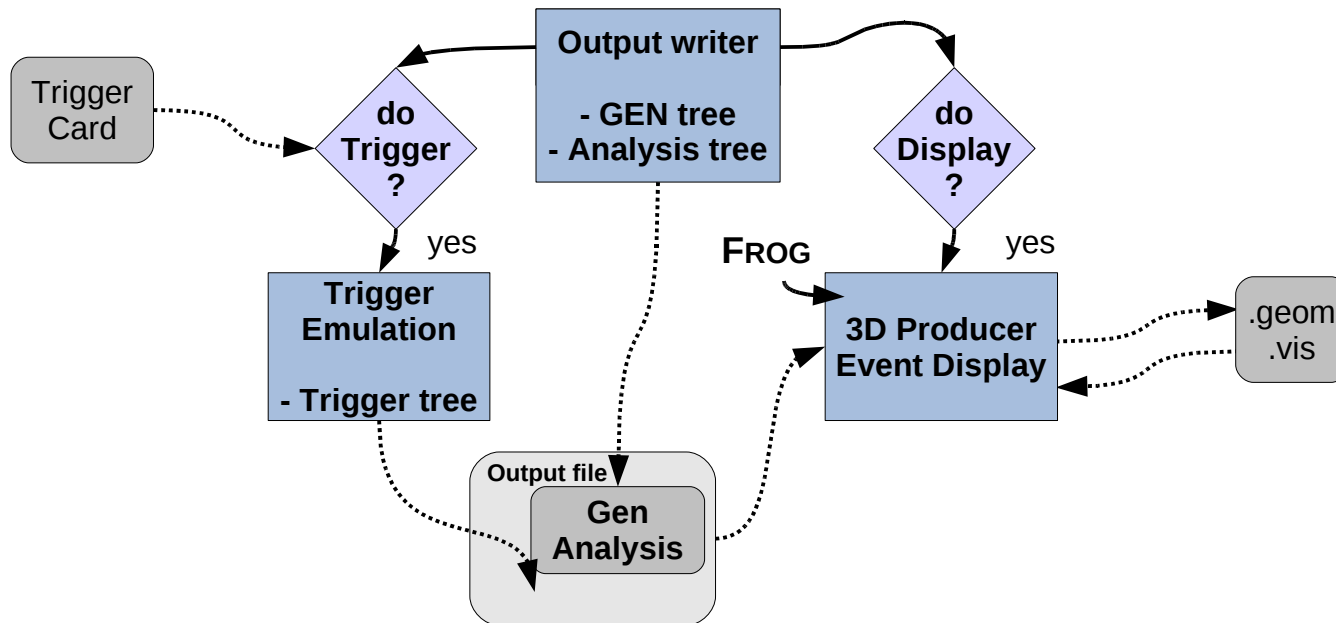
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Additional features



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S. Olyn



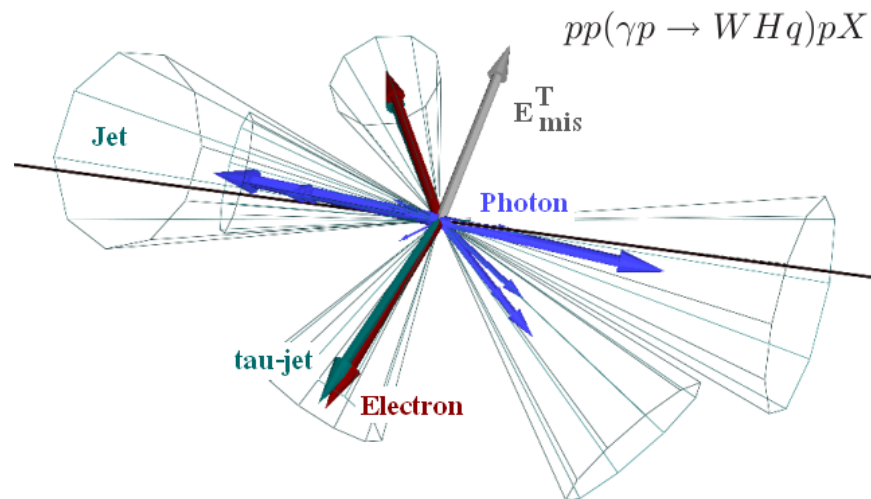
Trigger emulation

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

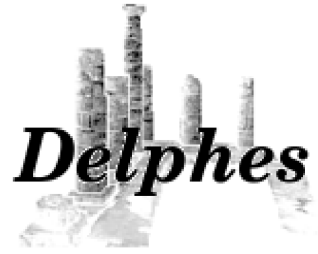
FROG interfaced to *Delphes*



FROG: L. Quertenmont, V. Roberfroid,
[arXiv:0901.2718v1](https://arxiv.org/abs/0901.2718v1)[hep-ex]

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- Trigger selection in a real experiment

New physics often characterised by low σ of new physics compared to values of Standard Model ones

➡ High statistics are required for data analyses ➡ high luminosity

BUT only a tiny fraction of the observed events can be stored for subsequent offline analyses,

- ↳ - large data rejection factor using dedicated algorithms
- Selection should be fast and very efficient

A trigger emulation is included in *Delphes*, using a **fully parametrisable trigger table**

```
Inclusive electron >> ELEC1_PT: '29'
di-electron >> ELEC1_PT: '17' && ELEC2_PT: '17'
```

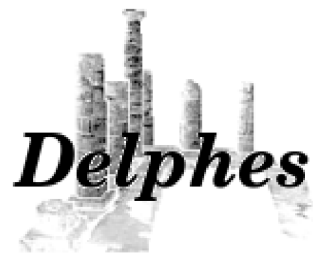
- select events containing objects (i.e. jets, particles,met) with a p_T above some threshold.
- Logical combinations (AND) of several conditions are also possible.
- Default trigger tables available for ATLAS & CMS experiments

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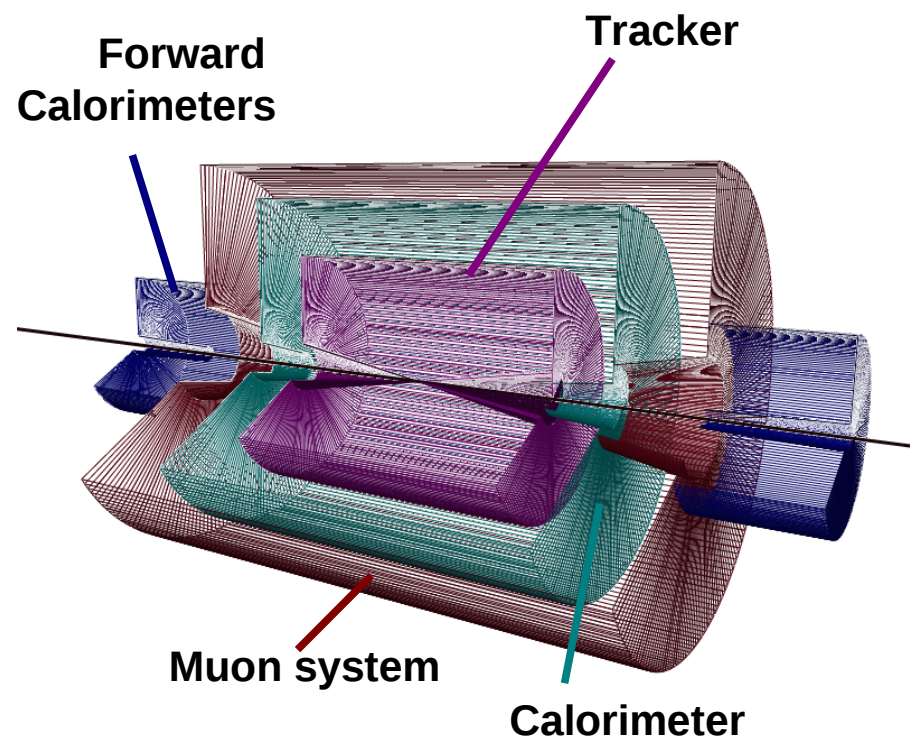


FROG: L. Quertenmont, V. Roberfroid, [arXiv:0901.2718v1\[hep-ex\]](https://arxiv.org/abs/0901.2718v1)

Visualisation is useful to convey information about the detector layout and the event topology in a simple way.

➔ The *Fast and Realistic OpenGL Displayer* FROG interfaced in *Delphes*

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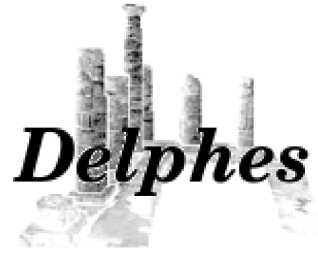
Reminder

- Detector assumed to be strictly symmetric around the beam axis.
- Only the geometrical coverage: towers are not drawn

Utility of the detector visualisation

- Communication purpose
- Geometric coverage of the different detector subsystems clearly visible.

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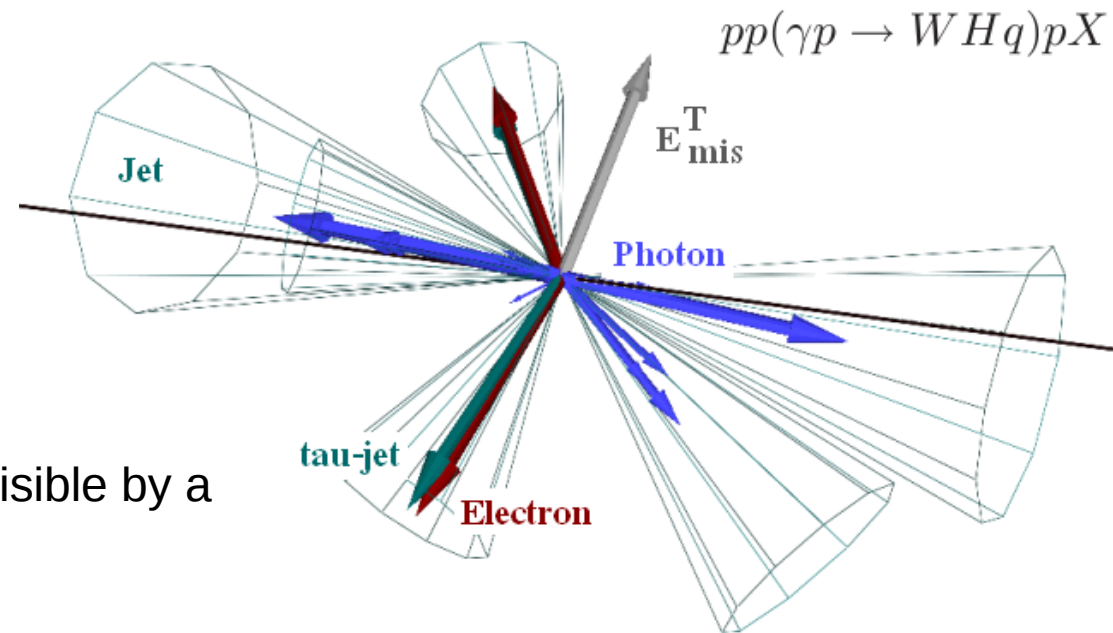


FROG: L. Quertenmont, V. Roberfroid, [arXiv:0901.2718v1\[hep-ex\]](https://arxiv.org/abs/0901.2718v1)

Visualisation is useful to convey information about the detector layout and the event topology in a simple way.

➔ The *Fast and Realistic OpenGL Displayer* FROG interfaced in *Delphes*

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- Visibility of each objects (e^\pm , μ^\pm , τ^\pm , jets, MET) enhanced by a colour coding.

- Kinematics information is visible by a simple mouse action.

Utility of the event visualisation

- Deeper understanding of interesting physics processes

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- FROG**
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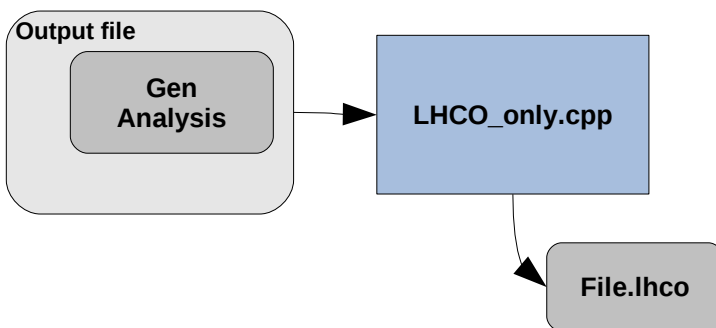
Additional features



Forgotten to run the trigger selection, the LHCO output or the preparation for the event visualisation?

➔ Stand-alone running programs are available

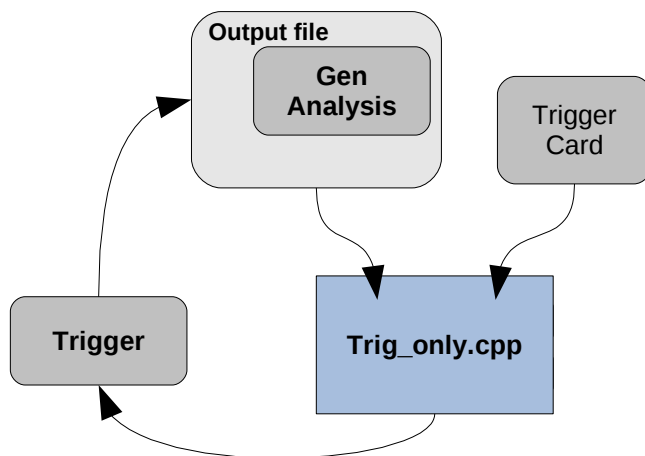
LHCO running



The input Delphes root file should contain all the GEN and Analysis information

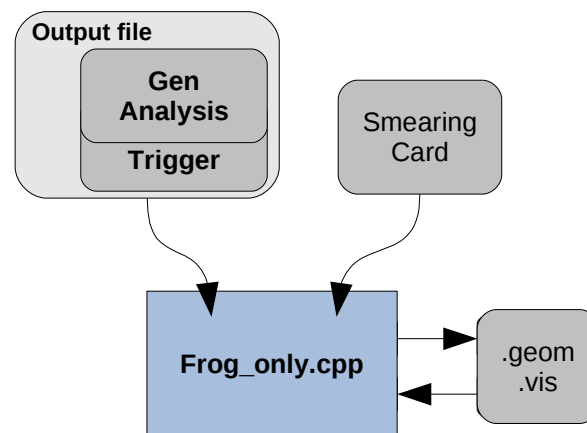
➔ Creation of the text file

Running the trigger



Using the *Delphes* file, the code adds the Trigger branch in the input file

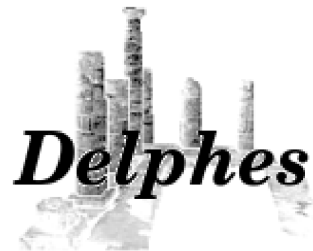
Running the preparation for FROG



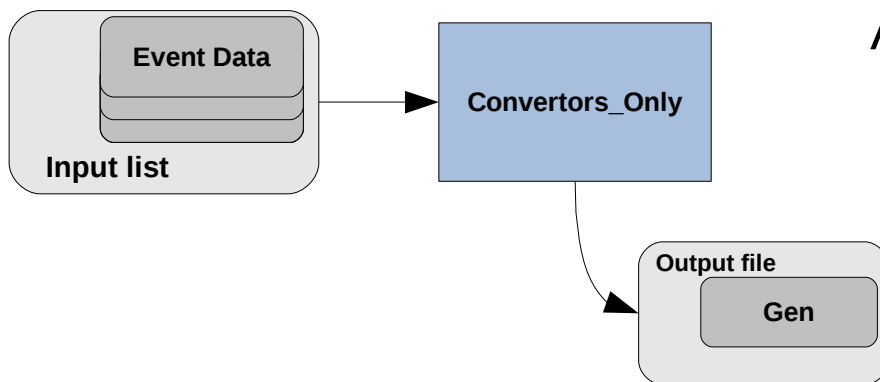
Using the *Delphes* file, the code creates the .vis files

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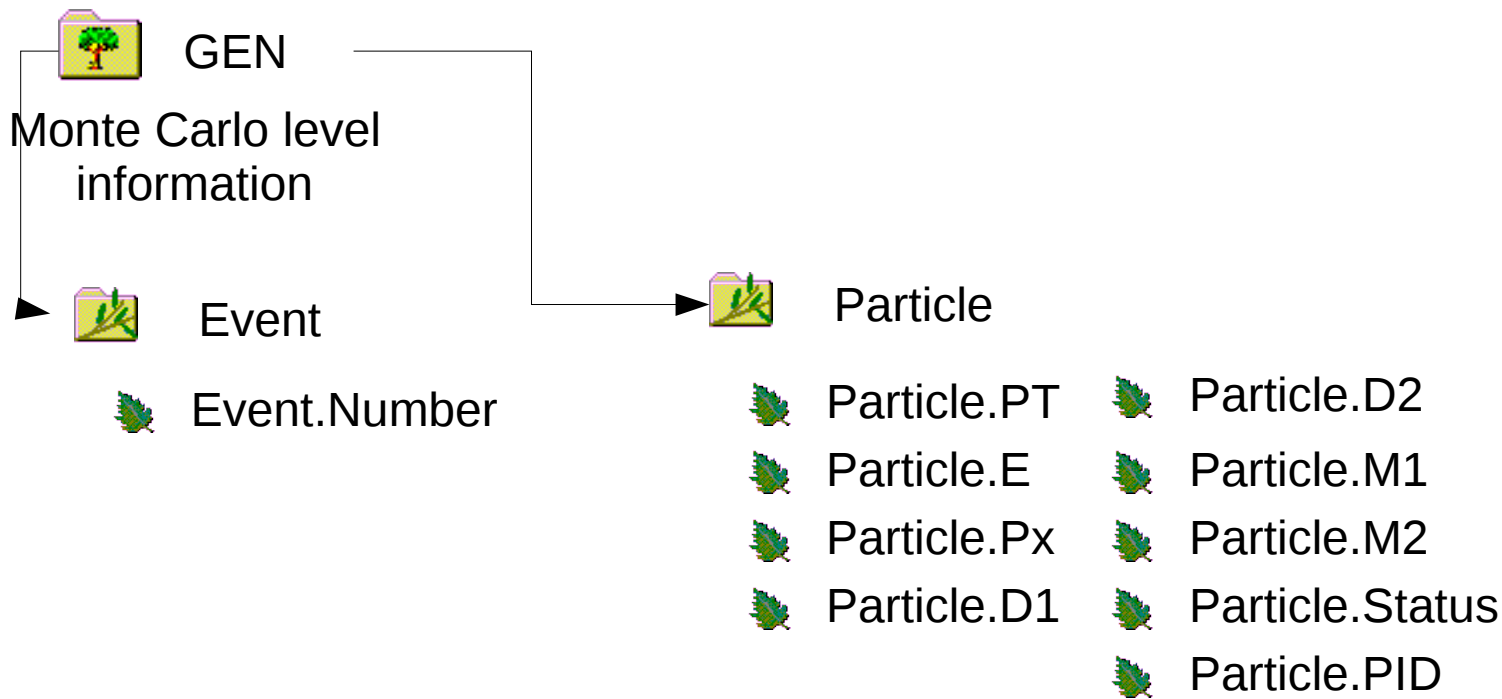
Convertor



All types of input files accepted by *Delphes*

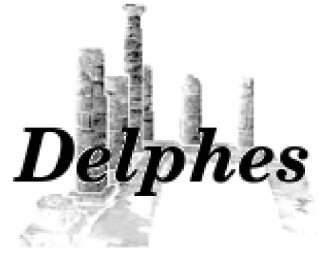
- StdHEP
- ROOT files
- Les Houches Event Format
- HepMC

Allow easy checks between various generators



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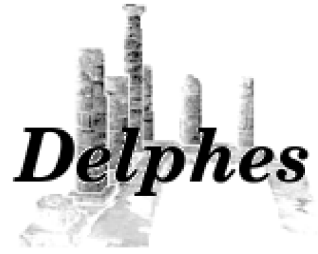
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Small tutorial...



Code download

from the website : « *download* » link

Delphes tar-ball is self-sufficient, it contains every dependencies needed for the physics.

or from a command line :

```
wget http://www.fynu.ucl.ac.be/users/s.ovyn/Delphes/files/Delphes_V_1.7b.tar.gz
```

Requirements

A recent working ROOT version (<http://root.cern.ch>)

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

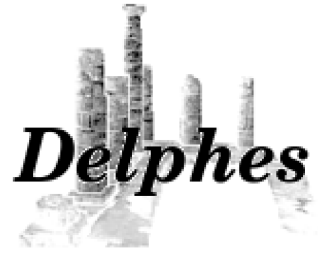
Delphes has been developped on ROOT > 5.18 on Linux with GNU gcc/g++ > 4.1.2, but any recent version should be fine.

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Requirements

Checking ROOT installation

```
echo $ROOTSYS
```

If empty, check that the environment variables are defined.

In *bash* shell, check that these variables are in the `.bashrc`:

(e.g. assuming ROOT is in `/usr/bin/root`)

```
export ROOTSYS=/usr/bin/root
export PATH=$PATH:$ROOTSYS/bin
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:$ROOTSYS/lib
```

Test it :

```
root
```

If the FROG event display is to be run:

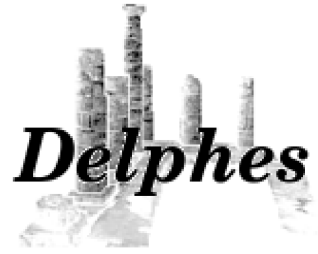
3D-OpenGL libraries are not included in the `tar.gz`, but required only if FROG is used. These libraries can be downloaded from here: <http://curl.haxx.se/download.html>

More on FROG requirements:

<http://projects.hepforge.org/frog/index.php?page=Starting.php>

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Untar – decompress the code sources

```
tar -xzf Delphes_V_1.7b.tar.gz
```

Compile the sources

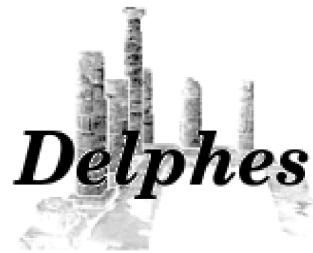
```
cd Delphes_V_1.7b
./genMakefile.tcl > Makefile
make
>> Compiling tmp/Utilities/ExRootAnalysis/src/BlockClassesDict.cc
>> Compiling tmp/src/TreeClassesDict.cc
...
>> Building Analysis_Ex
Delphes has been compiled
Ready to run
```

Many lines are printed during the compilation.

In particular, the dependencies (like FastJet, mcfio, stdhep) lead to a few warning messages. This is normal and harmless.

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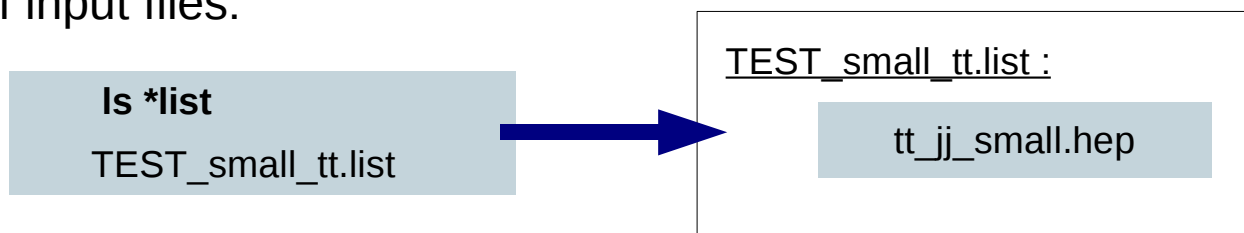
Input files from MC generator

Suggested samples for this introduction:

```
wget http://www.fynu.ucl.ac.be/users/s.ovyn/Delphes/files/tt_jj_small.hep.tar.gz
tar -xzf tt_jj_small.hep.tar.gz
mv samples/* .
```

These events are $\gamma p \rightarrow ttX$,
generated with MadGraph/MadEvent and
hadronised with Pythia
saved into StdHEP file format (*hep).

List of input files:

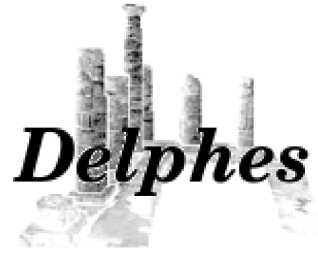


text file containing one input data file per line

all data files must be of the same type

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Delphes

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Running *Delphes* :

```
./Delphes
```

```
Usage: ./Delphes input_file output_file [detector_card] [trigger_card]
```

```
input_list - list of files in Ntpl, StdHep or LHEF format,
```

```
output_file - output file.
```

```
detector_card - Datacard containing resolution variables for the detector  
simulation (optional)
```

```
trigger_card - Datacard containing the trigger algorithms (optional)
```

Main things needed:

input_list : e.g. TEST_small_tt.list

List of input MC files

output_file : e.g. test.root

Output ROOT filename

Some options:

detector_card : e.g. data/DetectorCard_CMS.dat

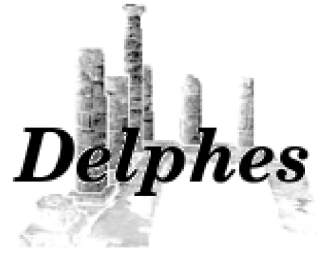
Detector parameters

trigger_card : e.g. data/TriggerCard_CMS.dat

Trigger definitions

Try it:

```
./Delphes TEST_small_tt.list test.root
```



X. Rouby
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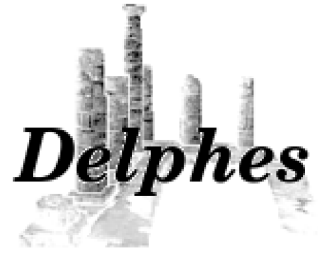
- Motivations
- Simulation
- BUT also...
- Tutorial
- Conclusion

# trigger_name	>> algorithm	#comments
Inclusive electron	>> ELEC1_PT: '29'	
di-electron	>> ELEC1_PT: '17'	&& ELEC2_PT: '17'
Inclusive Photon	>> GAMMA1_PT: '80'	
di-Photon	>> GAMMA1_PT: '40'	&& GAMMA2_PT: '25'
Inclusive muon	>> MUON1_PT: '19'	
di-muon	>> MUON1_PT: '7'	&& MUON2_PT: '7'
Taujet and ETmis	>> TAU1_PT: '86'	&& ETMIS_PT: '65'
di-Taujets	>> TAU1_PT: '59'	&& TAU2_PT: '59'
Jet and ETmis	>> JET1_PT: '180'	&& ETMIS_PT: '123'
Taujet and electron	>> TAU1_PT: '45'	&& ELEC1_PT: '19'
Taujet and muon	>> TAU1_PT: '40'	&& ELEC1_PT: '15'
Inclusive b-jet	>> Bjet1_PT: '237'	
Inclusive 1 jet	>> JET1_PT: '657'	
Inclusive 3 jets	>> JET1_PT: '247'	&& JET2_PT: '247' &&
JET3_PT: '247'		

Trigger code

Corresponding object

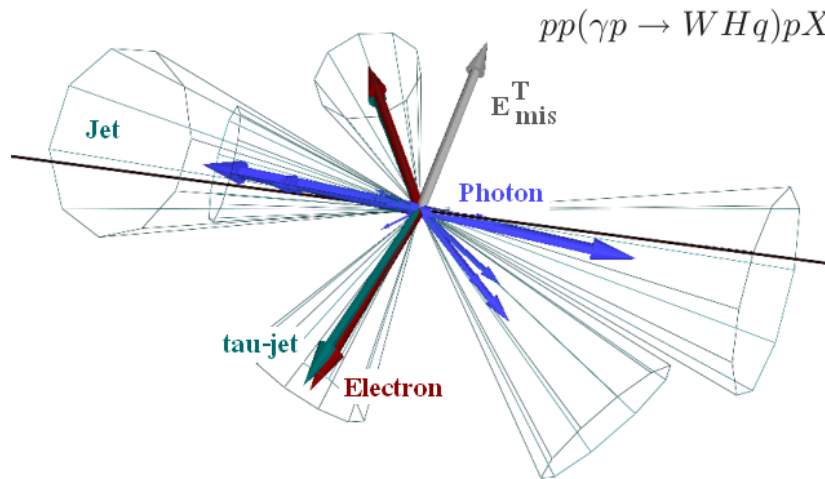
Cuts on p_T in GeV	ELEC_PT	electron
	IElec_PT	isolated electron
logical AND operator	MUON_PT	muon
	IMuon_PT	isolated muon
	JET_PT	jet
	TAU_PT	τ -jet
	ETMIS_PT	missing transverse energy
	GAMMA_PT	photon
	Bjet_PT	b-jet



3D Event Display

FROG interfaced to *Delphes*

To run FROG, some libraries are needed, as it uses the OpenGL free libraries, which are not in Delphes



FROG: L. Quertenmont, V. Roberfroid,
[arXiv:0901.2718v1\[hep-ex\]](https://arxiv.org/abs/0901.2718v1)

FROG runs on two files : *geom and *vis, which are created if the flag is ON

```
FLAG_frog      1 //1 to run the FROG event display
```

Then compile the source (NOT done automatically when Delphes is compiled)

```
cd Utilities/FROG
make
...
cd ../..
./Utilities/FROG/frog
```

Compile it...

...Run it

OpenGL:

```
xorg-x11-Mesa-libGL-6.8.2-1.EL.33.0.2
xorg-x11-Mesa-libGLU-6.8.2-1.EL.33.0.2
```

GLUT:

```
freeglut-2.2.0-14
freeglut-devel-2.2.0-14
```

X11-devel:

```
xorg-x11-devel-6.8.2-1.EL.33.0.2
```

CURL:

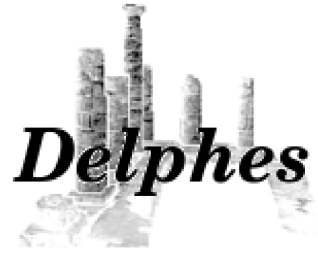
```
libcurl
```

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Motivations
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Conclusion



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

- Includes Trigger, forward near-beam detectors, 3D Event display
- Several input file types accepted by *Delphes*

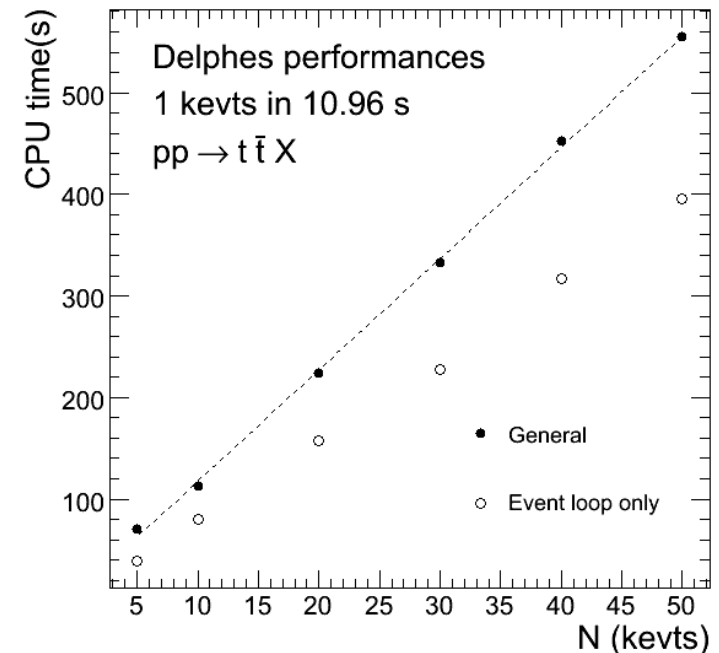
- StdHEP
- ROOT files
- Les Houches Event Format
- HepMC

- *Delphes* stores output information in

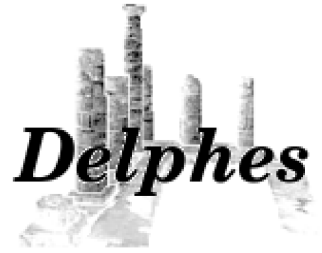
- ASCII file of LHCO type
- ROOT format

- *Delphes* performs a *fast* simulation:

- 1 000 events, 10.96 s (regular laptop), 240 MB (physics dependent)



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



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Backup slides

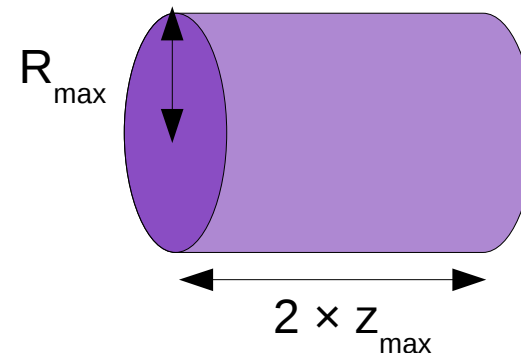
Simulation of the magnetic field

Delphes

$B_x = B_y = 0$ → Exact calculation of the transport of a charged particle

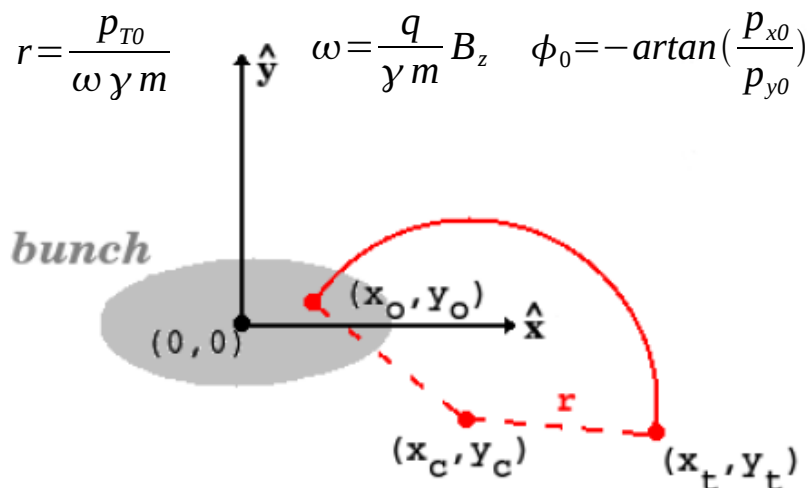
The magnetic field is supposed to be

- homogeneous
- constant inside a cylinder of length $2 \times z_{\max}$ and of radius R_{\max} .



Based on
$$\frac{d\vec{p}}{dt} = q\vec{v} \times \vec{B}, \quad \frac{d\vec{x}}{dt} = \vec{v} \quad \text{and} \quad \vec{p} = \gamma m \vec{v} = \gamma m \frac{d\vec{x}}{dt}.$$

Expression of the position and momentum of the charged particle at any time t .



$$\begin{cases} x(t) = x_c + r \cos(\omega t + \phi_0) \\ y(t) = y_c + r \sin(\omega t + \phi_0) \\ z(t) = z_0 + \frac{p_{z0}}{\gamma m} t \end{cases}$$

$$\begin{cases} R(t) = \sqrt{R_c^2 + r^2 + 2r R_c \cos(\Phi_c - (\phi_0 + \omega t))} \\ \Phi(t) = \arctan\left(\frac{y(t)}{x(t)}\right) \\ \Theta(t) = \arctan\left(\frac{R(t)}{z(t)}\right) \end{cases}$$

To make the code faster, the **time** of flight needed to exit the cylinder is computed

1°) t_z : time needed to reach the end of the tracker longitudinally

$$t_z = \frac{y m}{p_{z0}} (-z_0 + z_{max} \times \text{sign}(p_{z0}))$$

2°) t_T : time to exit the volume by the side once $R(t) = R_{max}$

$$t_T = \frac{1}{\omega} \left[\Phi_c - \phi_0 + \arctan\left(\frac{R_{max}^2 - (R_c^2 + r^2)}{2rR_c}\right) \right]$$



$$t_{max} = \min(t_T, t_z)$$

$$\begin{cases} t_z \text{ such that } |z(t_z)| = z_{max} \\ t_T \text{ such that } R(t_T) = R_{max} \end{cases}$$

$B_x \neq 0$ $B_y \neq 0$ iterative method step by step until the particle exits the tracker region **Method slower than for a pure solenoidal B field**

Disclaimer: magnetic field of muon chambers such as for ATLAS not simulated with **Delphes**

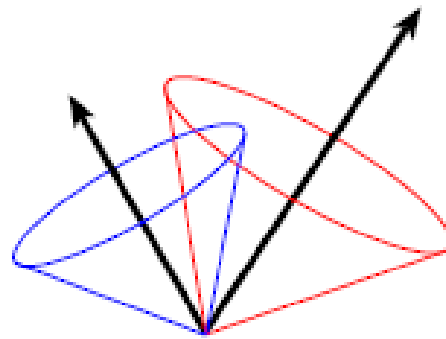
Cone algorithms

1° CDF jet algorithm - cone (also named « JetClu cone jet algorithm »)

- Associates together towers lying within a circle in the (η, ϕ) space.
- Used by the CDF experiment in Run II.
- Towers with a E_T higher than a given threshold (default: $E_T > 1 \text{ GeV}$) used as seeds for the jet candidates.

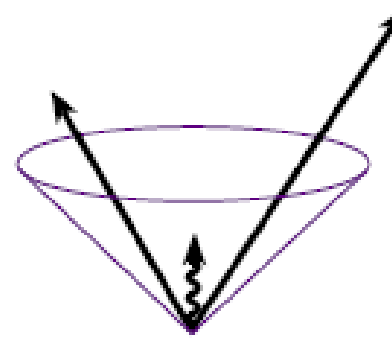
The existing FastJet code has been modified to allow **easy modification of the tower pattern** in η, ϕ space.

JetClu is not infrared safe



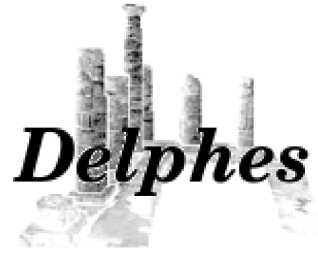
Identified as 2 jets

With addition of a soft gluon



Identified as 1 jets

➔ More performant algorithms are also available in Delphes



Cone algorithms

1°) CDF jet algorithm - cone (also named « Jetclu cone jet algorithm »)

- Associates together towers lying within a circle in the (η, φ) space.
- Used by the CDF experiment in Run II.
- Towers with a E_T higher than a given threshold (default: $E_T > 1$ GeV) used as seeds for the jet candidates.

The existing FastJet code has been modified to allow **easy modification of the tower pattern** in η, φ space.

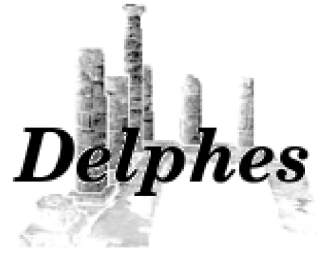
2°) CDF Midpoint algorithm

- Identical jet procedure than the CDF jet cone algorithm
- Algorithm that reduces infrared sensitivity
- Adds 'midpoints' (energy barycentres) in the list of cone seeds.

3°) SIS Cone jets : NO seed!

- Simultaneously insensitive to additional soft particles and collinear splittings,
- Fast enough to be used in experimental analysis.

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S. Oryn



Recombination algorithms

- Infrared and colinear **safe**
- Merge successive calorimeter tower pairs
- Similar jet running except for the definition of distances d

↳ distance d_{ij} between each pair of towers (i, j)
variable d_{iB} (beam distance) depending on the p_T of the tower i.

Algorithm:

- Browses the calotower list
- Starts by finding the minimum value d_{\min} of all d_{ij} and d_{iB} .
- $d_{\min} = d_{ij}$ towers i and j merged into a single tower with $p^\mu = p^\mu(i) + p^\mu(j)$
- $d_{\min} = d_{iB}$ the tower is declared as a final jet

4°) k_t jets: $d_{ij} = \min(k_{ti}^2, k_{tj}^2) \Delta R_{ij}^2 / R^2$ and $d_{iB} = k_{ti}^2$

5°) Cambridge / Aachen jets: $d_{ij} = \Delta R_{ij}^2 / R^2$ and $d_{iB} = 1$

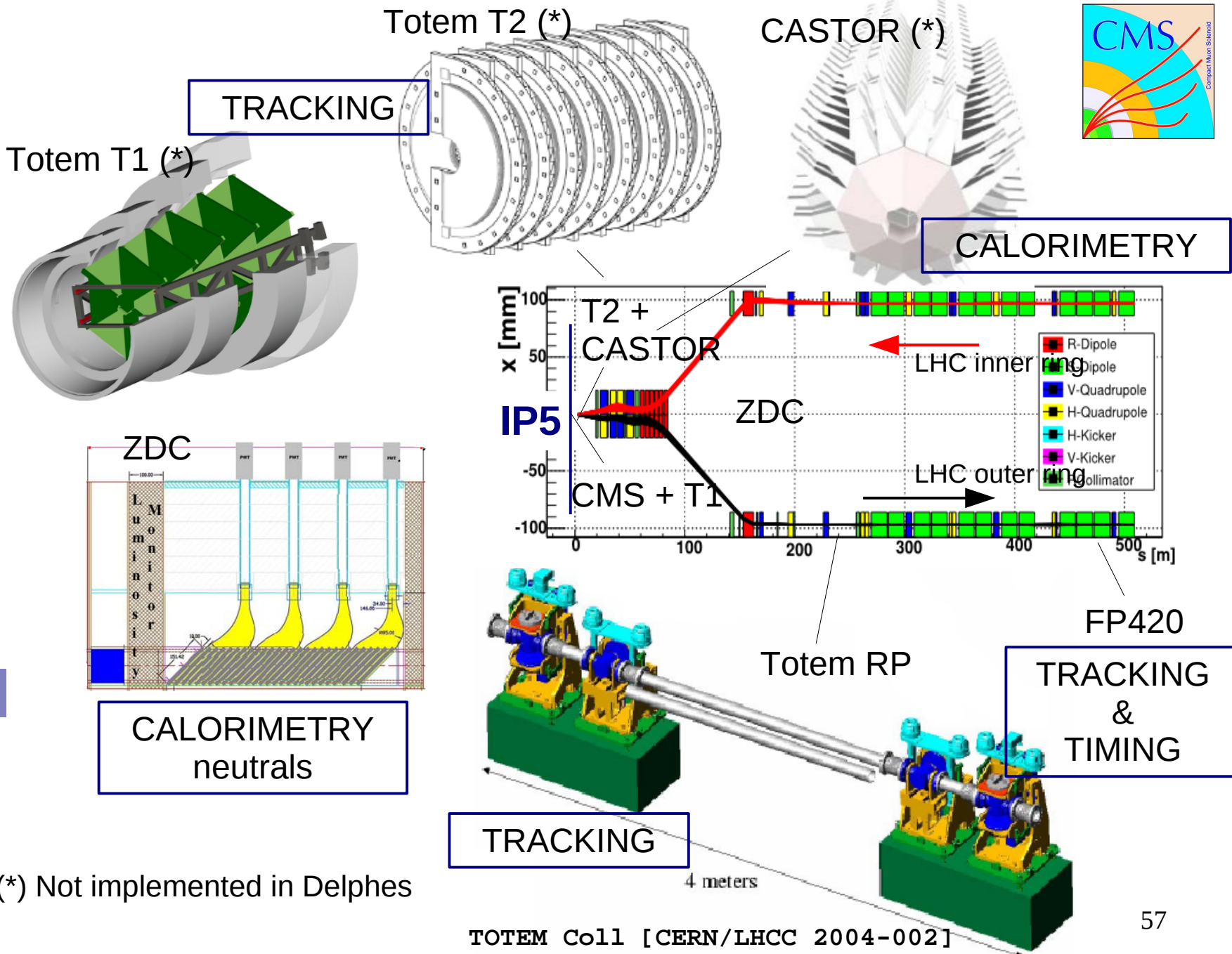
6°) Anti k_t jets: $d_{ij} = \min(1/k_{ti}^2, 1/k_{tj}^2) \Delta R_{ij}^2 / R^2$ and $d_{iB} = 1/k_{ti}^2$

Delphes

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- Motivations
- Simulation
- Interface
- Tower-tracks
- photon- e/μ
- jets
- tau-jets-MET
- Forward det.**
- Validation
- BUT also...
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- Conclusion

22/06/2009



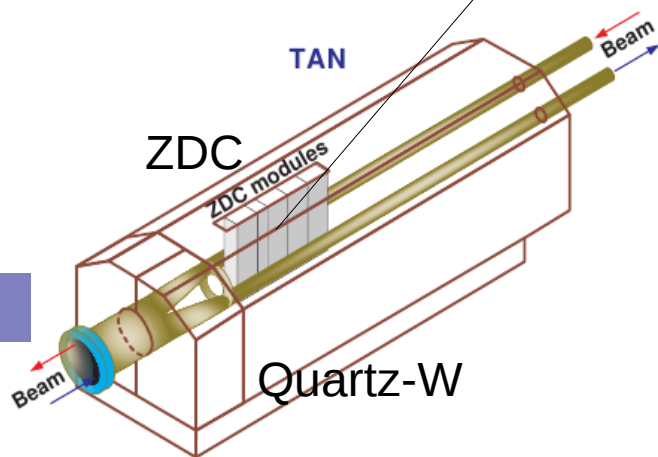
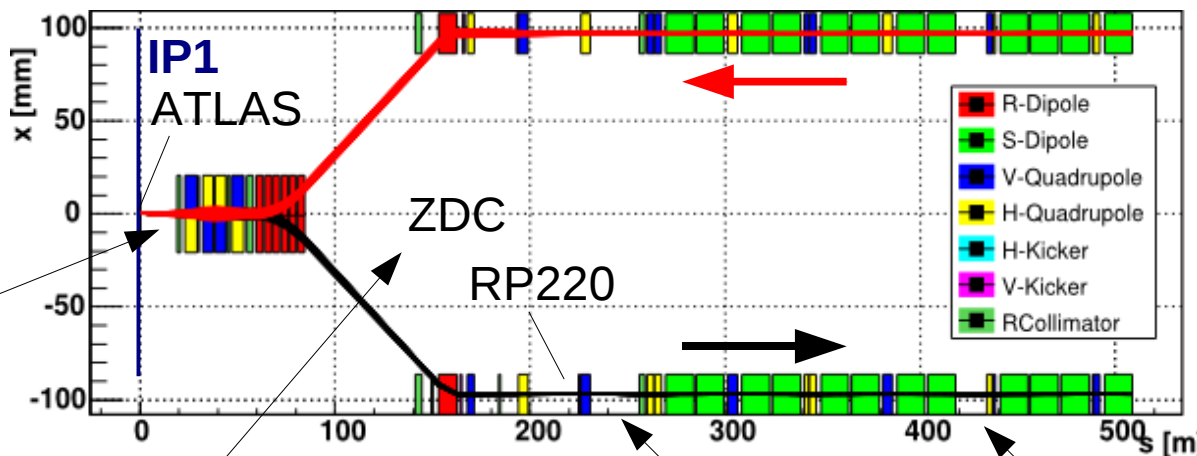
Delphes

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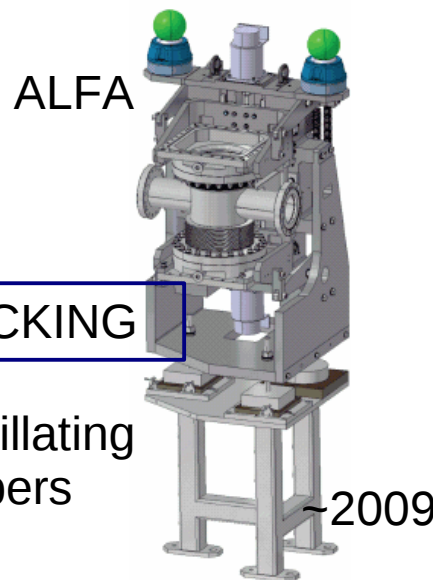
- Motivations
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Adapted from
Rouby, de Favereau, Piotrkowski [JINST 2 P09005]



CALORIMETRY
neutrals



FP420
Si + Cerenkov

TRACK & TIMING

~2010

(*) Not implemented in Delphes