# Delphes 3

## Latest Developments

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github.com/delphes

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# Detector simulation

- Full simulation (GEANT):
  - **simulates** particle-matter interaction (including showers, nuclear int., brehmstrahlung, photon conversions, etc ...) → 100 s /ev
- Experiment Fast simulation (ATLAS, CMS ...):
  - **simplifies** and makes faster simulation and reconstruction → 1 s /ev
- Parametric simulation (**Delphes**, PGS):
  - **parameterize** detector response, reconstruct complex objects B field propagation, Jets, Missing ET → 10 ms /ev
- Object smearing (Atom, Falcon, TurboSim):
  - from parton to detector object (lookup tables)

# When Delphes?

- When to use FastSim?

  → test your model with detector simulation and you have limited resources
  → scan big parameter space (SUSY-like)
  → preliminary tests of new geometries/resolutions (future detectors)
  → educational purpose (bachelor/master thesis)

- When not to use FastSim?

  → very exotic topologies (HSCP, long-lived, ...) (NOT YET ...)

# The Delphes project

- Delphes project started back in 2007 at UCL as a side project to allow quick phenomenological studies

- Since 2009, its development is **community-based**
  - **ticketing system** for improvement and bug-fixes
    → user proposed patches, can be forked from github and make pull-requests

- In 2013, **DELPHES 3** was released (DELPHES 2 NOT SUPPORTED ANYMORE !!):
  - C++ modular software
  - Dependencies: gcc, tcl, ROOT
  - is shipped with FastJet

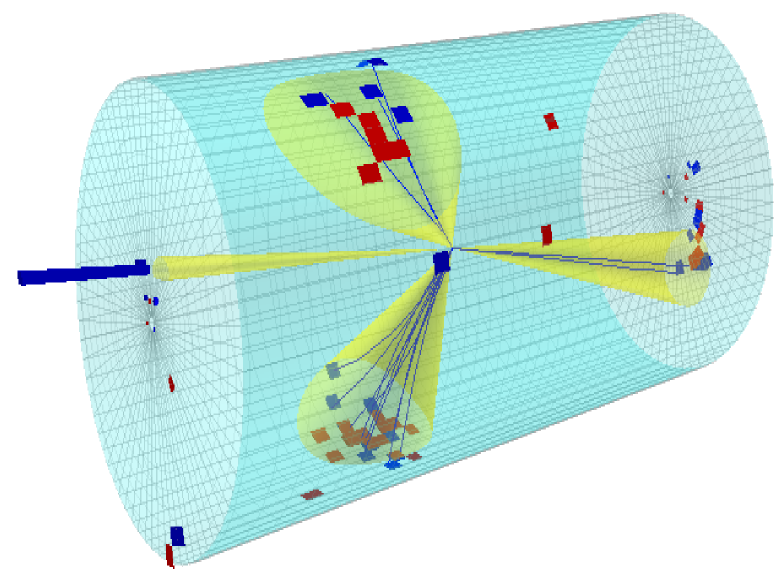
- Delphes is itself distributed by various tools: MadGraph, MadAnalysis, CheckMate
- **Widely** tested and used by the community (pheno, Snowmass, Recasting, FCC, CMS upgrades ...)

- Repository: github.com/delphes
- Website and manual: https://cp3.irmp.ucl.ac.be/projects/delphes
- Original publication: JHEP 02 (2014) 057 [1307.6346]

# What is Delphes?

- **Delphes** is a **modular framework** that simulates of the response of a multipurpose detector in a **parameterized** fashion

- **Includes**:
  - pile-up
  - charged particle **propagation** in magnetic field
  - electromagnetic and hadronic **calorimeters**
  - **particle flow**



- **Provides**:
  - leptons (electrons and muons)
  - photons
  - jets and missing transverse energy (particle flow)
  - taus and b's

# Run Delphes

- Install ROOT from root.cern.ch
- Clone Delphes from github or download from website
- Type in shell:

```
./configure
make -j 4
```

- Run Delphes:

```
./DelphesSTDHEP [configuration_file] [output] [input]
./DelphesHepMC [configuration_file] [output] [input]
```

- Input formats: HepMC, StdHep, ProMC, LHE
- Output: browsable ROOT tree

# New Features

# Run Delphes with Pythia 8

- You can now run the full MC/reconstruction chain with one simple command by linking Delphes with Pythia8 (more info here).
- Set PYTHIA8 path variable and recompile Delphes:

```
export PYTHIA8=[path_to_pythia8_installation]
make HAS_PYTHIA8=true DelphesPythia8
```

- You can then directly either directly use Pythia8 matrix element, or use external LHE (also with matching available).
- In both case the input to Delphes will be a Pythia8 "cmnd" file:

```
./DelphesPythia8 [detector_card] [pythia8_cmnd] [output]
```

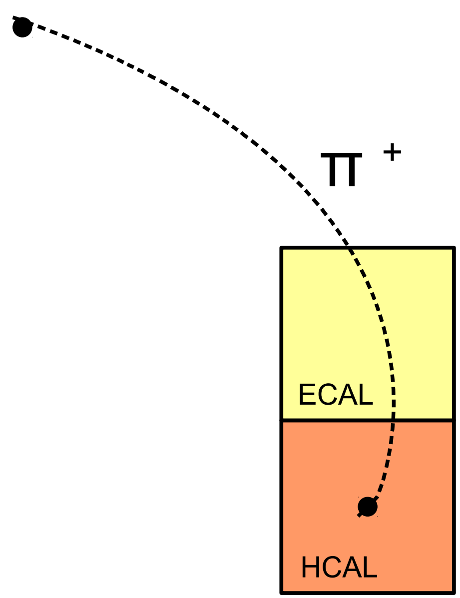
- Avoids storing huge intermediary event files (hepmc), all the parton/hadron-level information can accessed via the Particle branch in the output.
- If multiple weights were stored in LHE input, Delphes stores them in the Weights branch in a vector.

# Particle-Flow

- Given **charged track** hitting given **calorimeter cell**:

  - are deposits more **compatible** with **charged** or **charged + neutrals** hypotheses?
  - how to assign momenta to all resulting components ?

- We have **two** measurements $(E_{trk}, \sigma_{trk})$ and $(E_{calo}, \sigma_{calo})$
- Call $E_{neutral} = E_{calo} - E_{trk}$




<u>Algorithm:</u>

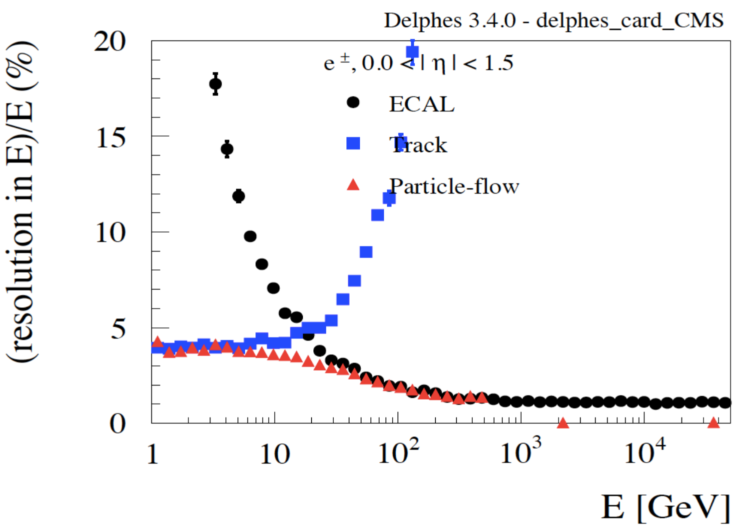
If $E_{neutral} / \sqrt{(\sigma_{trk}^2 + \sigma_{calo}^2)} > S$ :

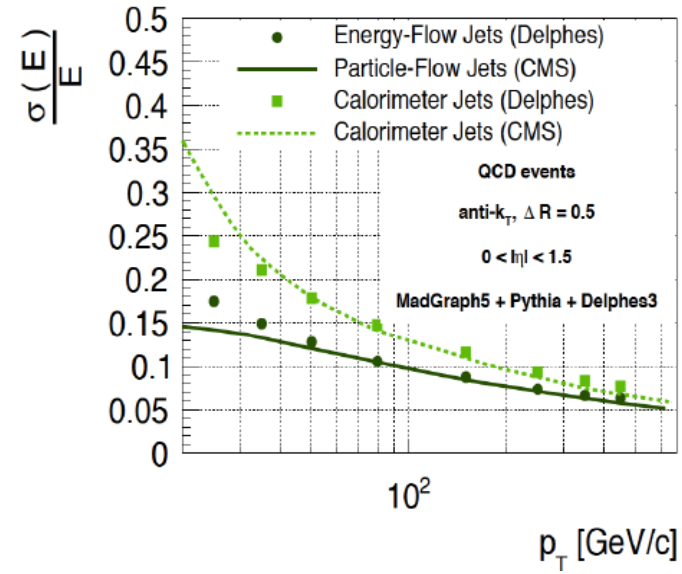
→ create PF neutral particle + PF track

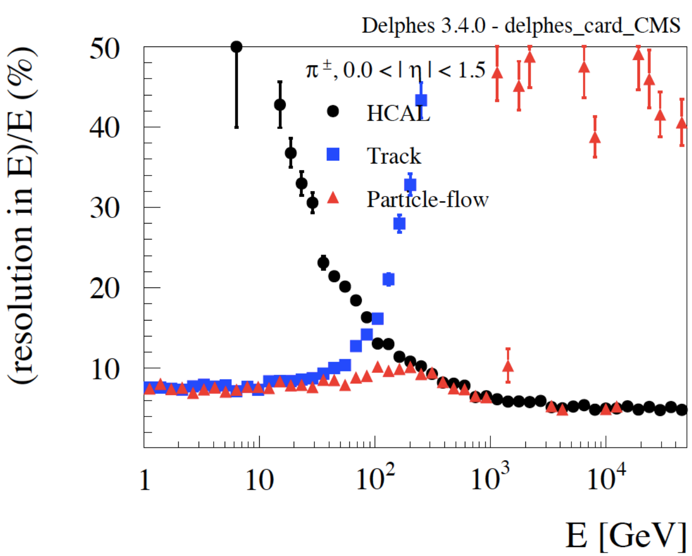
Otherwise:

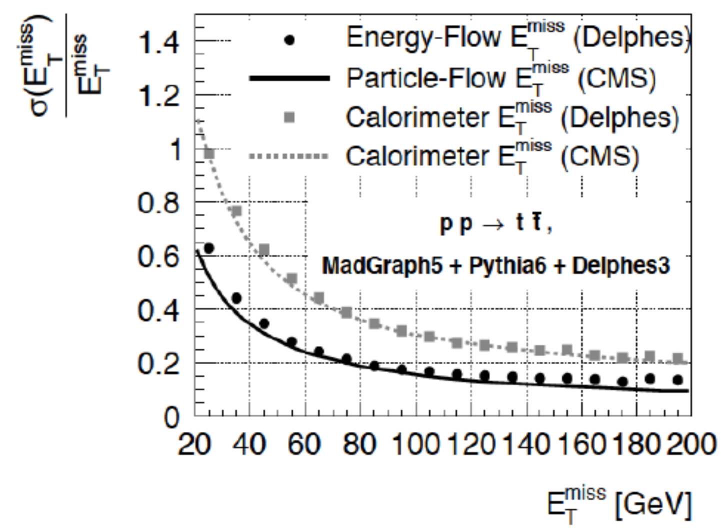
→ create PF track with (weighted) average energy $w_i = 1/\sigma_i^2$

# Particle-Flow



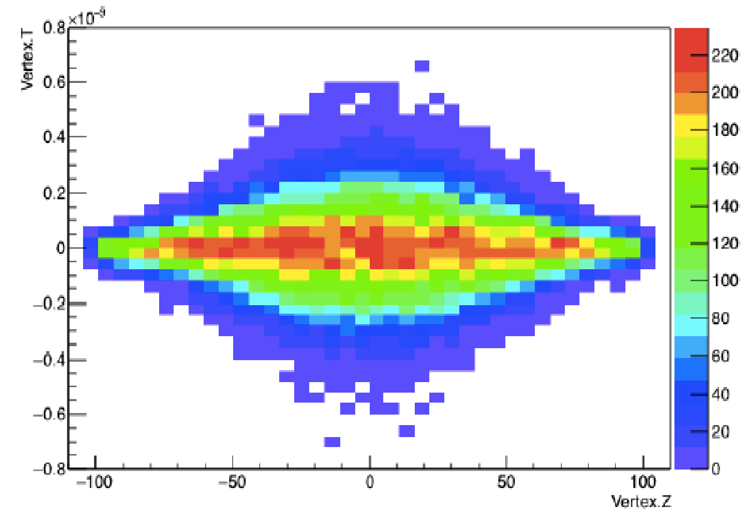






Particle flow makes optimal use of Tracker and Calorimeter information

# Timing

- Beamspot description with f(z,t) customizable profile has been included
- Time information is propagated up calorimeters, and then smeared
- Vertexing in 3D/4D has been included

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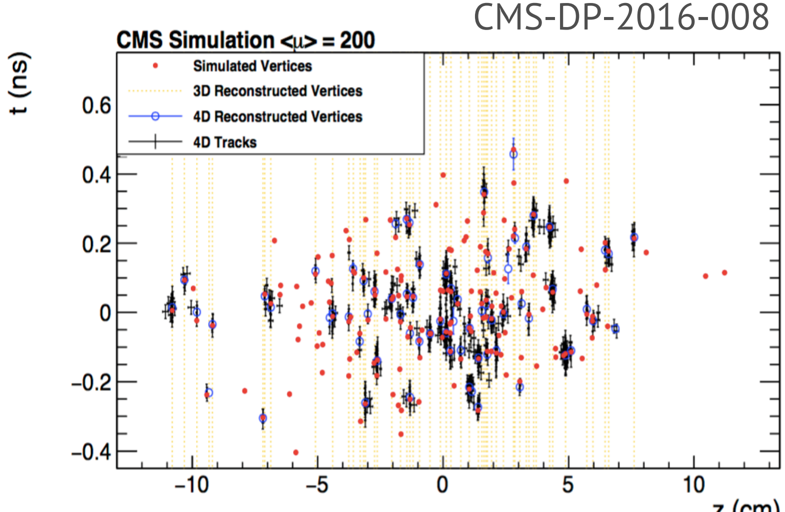
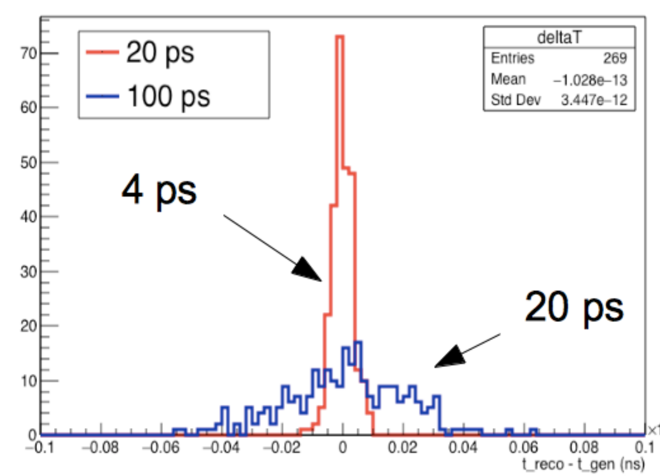




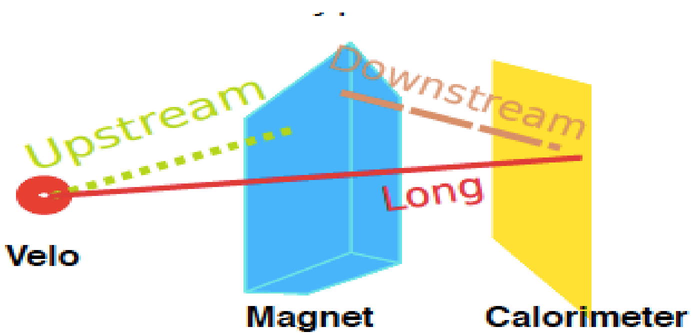

*Lindsey Gray, Andrew Hart*

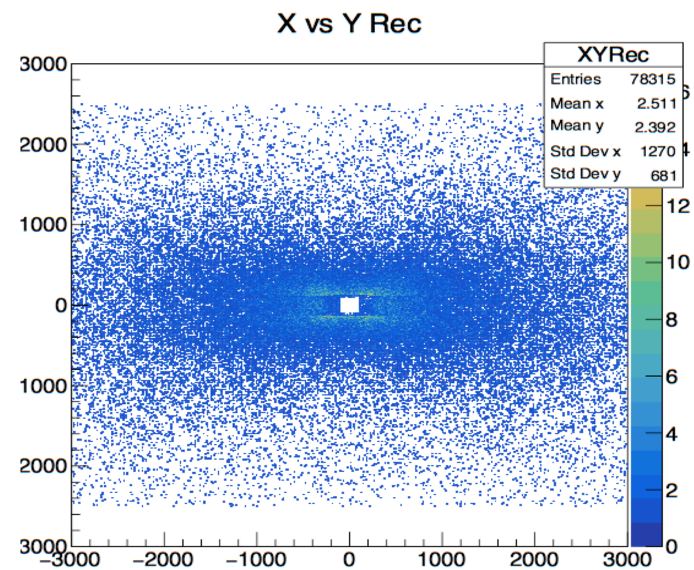
# Delphes in LHCb

- Integration of Delphes in LHCb framework has started in private branch
- Complete re-writing of ParticlePropagator module, accounting for:

  → asymmetric acceptance and non-rotational symmetry taken into account

  → account for $p_T$ kick in $B_y$ field




*Benedetto G. Siddi*

- A first implementation of a full chain analysis has been done
- Currently working on correct emulation of efficiency and resolution of the LHCb detector

# Conclusions

- **Delphes 3** has been out for two years now, with **major improvements**:

  - modularity
  - default cards giving results on par with published performance from LHC experiments
  - updated configurations for future e+e- and hh colliders
  - interfaced within MadGraph5/Py8, CheckMate/MadAnalysis

- Delphes 3 can be used right away for fast and realistic simulation for present and future collider studies
- **Delphes is used both by experimentalist and theorists**
- Continuous development (particle flow, vertexing, timing ...)
- Feel free to contribute!

# Back Up

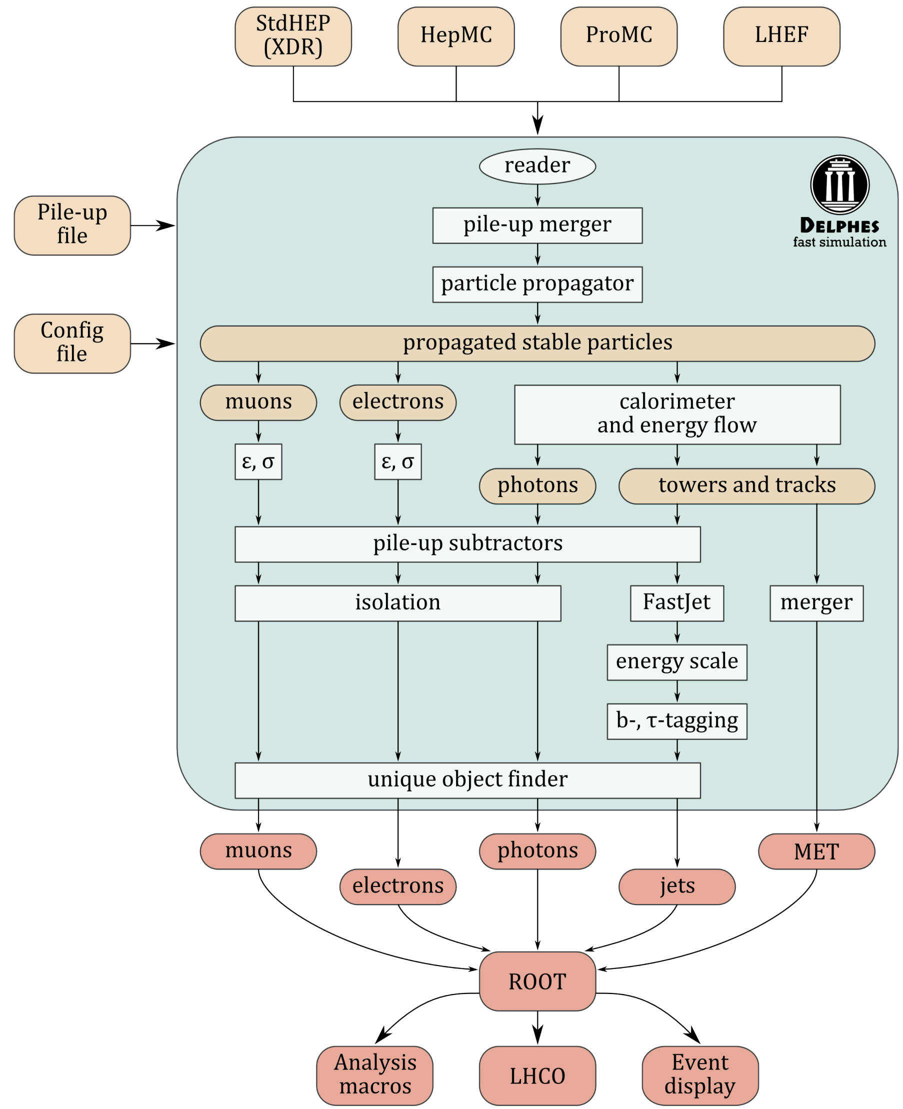
# Modular

- The modular system allows the user to configure and schedule modules via a configuration file (.tcl), add modules, change data flow, alter output information

- Modules communicate entirely via collections (vectors) of universal objects (TObjArray of Candidate four-vector like objects).

- Any module can access TObjArrays produced by other modules using ImportArray method:

```
ImportArray("ModuleName/arrayName")
```



# Configuration file

- Delphes configuration file is based on tcl scripting language
- This is where the detector, data-flow, and output tree is configured.
- Delphes provides tuned detector cards for some detectors:
  - ATLAS, CMS, ILD, FCC (LHCb in progress).
  - can find other tunes in CheckMate, MadAnalysis.
- Order of execution of various modules is configured in the Execution Path:

```
set ExecutionPath {
    ParticlePropagator
    TrackEfficiency
    ...
    Calorimeter
    ...
    TreeWriter
}
```

# Configuration file

```
##################
# Photon isolation
##################

module Isolation PhotonIsolation {
  set CandidateInputArray PhotonEfficiency/photons
  set IsolationInputArray EFlowMerger/eflow

  set OutputArray photons

  set DeltaRMax 0.5

  set PTMin 0.5

  set PTRatioMax 0.12
}


#####################
# Electron efficiency
#####################

module Efficiency ElectronEfficiency {
  set InputArray ElectronFilter/electrons
  set OutputArray electrons

  # set EfficiencyFormula {efficiency formula as a function of eta and pt}

  # efficiency formula for electrons
  set EfficiencyFormula {                                     (pt <= 10.0) * (0.00) +
                                         (abs(eta) <= 1.5) * (pt > 10.0)  * (0.95) +
                         (abs(eta) > 1.5 && abs(eta) <= 2.5) * (pt > 10.0)  * (0.85) +
                         (abs(eta) > 2.5)                                   * (0.00)}
}
```

input collection

output collection

parameters