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Delphes

A framework for fast simulation of a generic collider experiment

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References

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Website :

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

News / Download / User manual / FAQ

Paper + User manual :

arXiv:0903.2225[hep-ph]

Delphes, a framework for fast simulationof a generic collider experiment, S. Ovyn, X. Rouby and V. Lemaître

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Getting started...

Getting started : download

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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_1.7.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.

For Mac-OSX users:

In ***Delphes***' genMakefile.tcl, you should add "`-Dmacos` " in the `CXXFLAGS` definition (line 219):

```
CXXFLAGS += $(ROOTCFLAGS) -Dmacos -DDROP_CGAL -I. ...
```

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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_1.7.tar.gz
```

Compile the sources

```
cd Delphes_V_1.7
./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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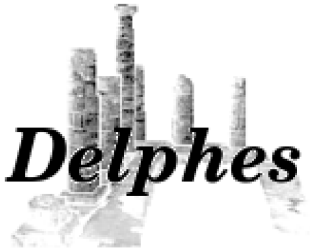
If you are running from the server...

Thanks to your comments this morning, Delphes is running smoothly on your server. If you plan to use this version during this tutorial, shoud still need to copy the `data` folder into your home:

```
mkdir myDelphes
cd myDelphes
cp -r /usr/local/Delphes_V_1.5/data .
```

This simply copies all the detector cards, trigger card, beam files so that you can play with them...



Input files from MC generator

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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:

```
ls *list
TEST_small_tt.list
```

TEST_small_tt.list :

tt_jj_small.hep

- text file containing one input data file per line
- all data files must be of the same type

Getting started : run

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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 of 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

Getting started : run

Running *Delphes* :

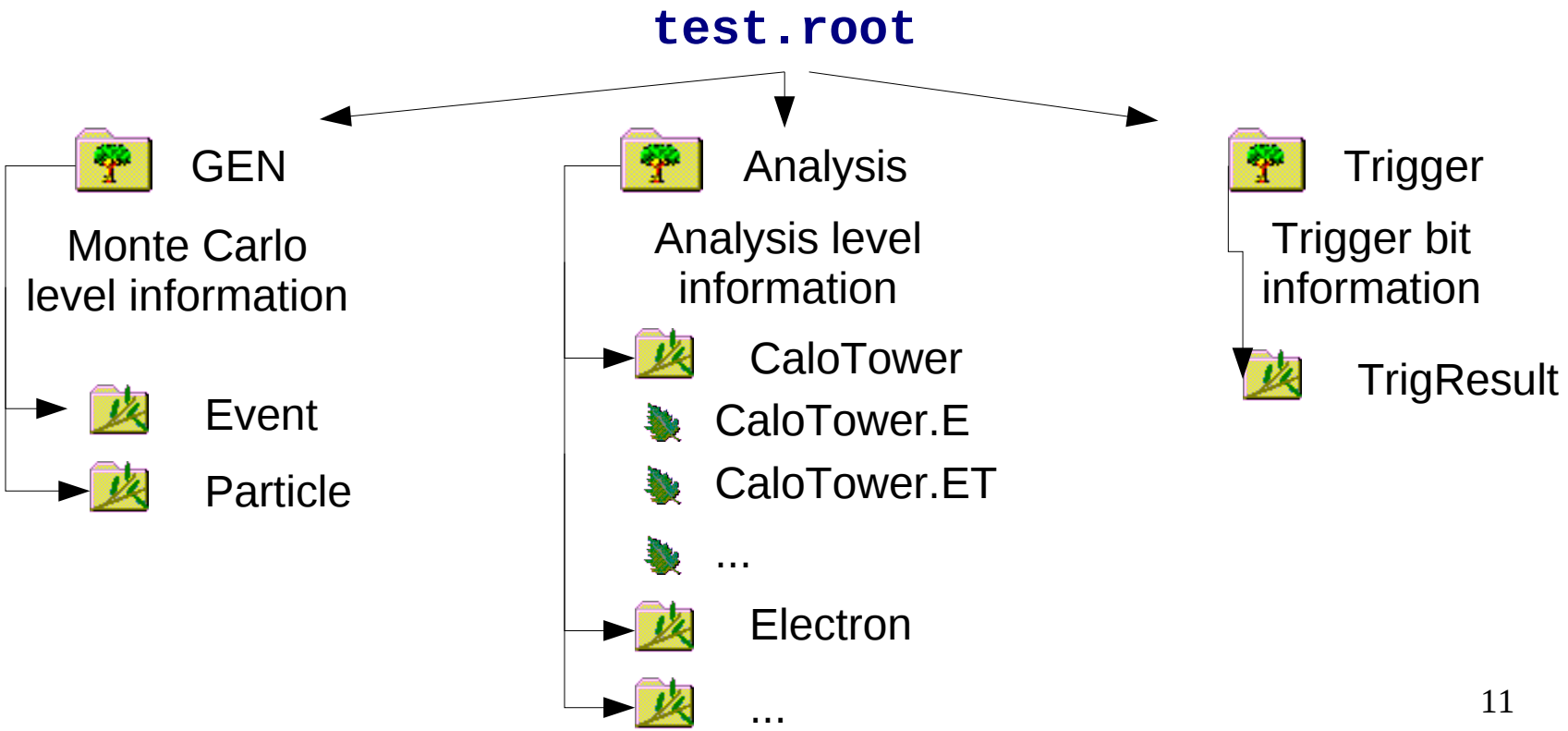
```
./Delphes  TEST_small_tt.list  test.root

**********************************************************************
**********************************************************************
**                                                                  **
**                          Welcome to                              **
**                                                                  **
**                                                                  **
**     .ddddddd-             lL             hH                     **
**     -Dd` `dD:            Ll             hH`                     **
**     dDd   dDd    eeee.   lL  .pp+pp    Hh+hhh`   -eeee- `sssss   **
**    -Dd   `DD   ee. ee   Ll   .Pp. PP   Hh. HH.   ee. ee  sSs     **
**    dD`   dDd  eEeee:    lL.  pP.  pP  hH   hH` eEeee:` -sSSSs.   **
**   .Dd  :dd    eE.      LlL   PpppPP   Hh  Hh   eE         sSS    **
**   dddddd:.     eee+:   lL.  pp.      hh.  hh    eee+  ssssssS    **
**                        Pp                                        **
**                                                                  **
**           Delphes, a framework for the fast simulation           **
**                 of a  generic collider experiment                **
**                    arXiv:0903.2225v1 [hep-ph]                    **
**                                                                  **
...
**                                                                  **
**                       Exiting Delphes ...                        **
**                                                                  **
**********************************************************************
**********************************************************************
```

Running *Delphes* :

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

This creates the following output file test.root

```
root -l  test.root
root [0]
Attaching file test.root as _file0...
Warning in <TClass::TClass>: no dictionary for class TRootGenEvent is available
...
root [1] TBrowser t
```



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Running *Delphes* :

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

This creates the following output file test.root

```
root -l  test.root
root [0]
Attaching file test.root as _file0...
Warning in <TClass::TClass>: no dictionary for class TRootGenEvent is available
...
root [1] Tbrowser t
```

A log file is also created, with all parameters test_run.log

```
#  Input PDG table : data/particle.tbl                                  *
*                                                                       *
#*********************************                                    *
# Central detector caracteristics                                      *
#*********************************                                    *
*                                                                       *
* Maximum tracking system:                    2.5                       *
* Maximum central calorimeter:                3                         *
...
```

This log file contains the input parameters from data card, and triggers.

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Interlude: ROOT...

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Some useful commands in ROOT:

```
root -l  test.root
root [0]
Attaching file test.root as _file0...
Warning in <TClass::TClass>: no dictionary for class TRootGenEvent is available
...
```

This command opens ROOT and at the same type opens the test.root file

```
root [1] TBrowser t
root [2] .ls
root [3] Analysis->GetEntries()
root [4] GEN->GetListOfBranches()->ls()
root [5] Analysis->GetListOfLeaves()->ls("Electron")
```

Browser for the file contents

Number of events in the tree

Branch/leaf contents

Quickly drawing distributions:

```
root [6] Analysis->Draw("Jet.E")
root [7] Analysis->Draw("Jet.Pt : Jet.Eta")
root [8] Analysis->Draw("Photon.Phi","Photon.E>15")
root [9] Trigger->Draw("TrigResult.Accepted")
```

Energy

Pt vs Eta

Phi with a cut on energy

Trigger result

Getting started : ROOT

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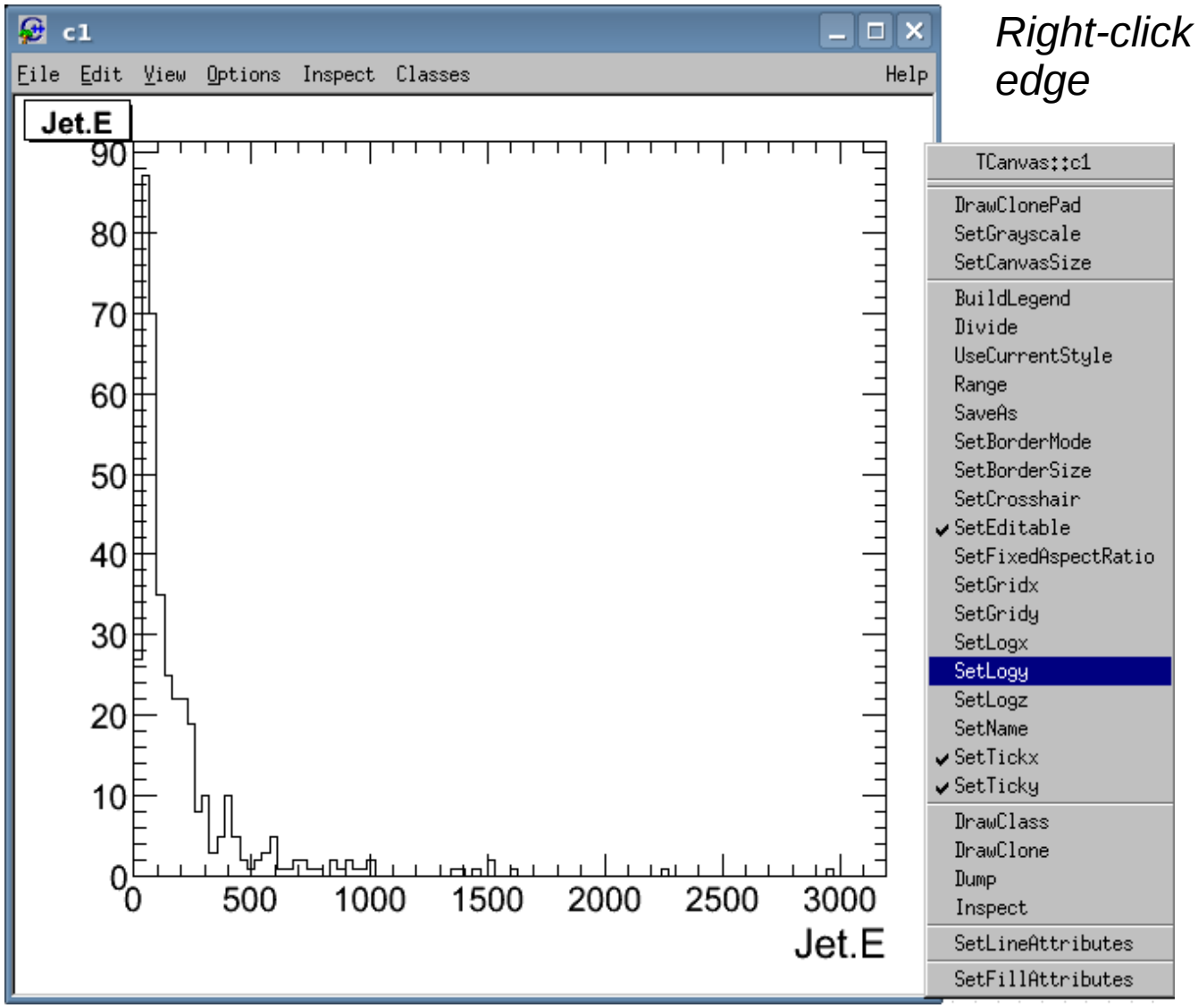
```
root [6] Analysis->Draw("Jet.E")
```



Right-click in the white edge

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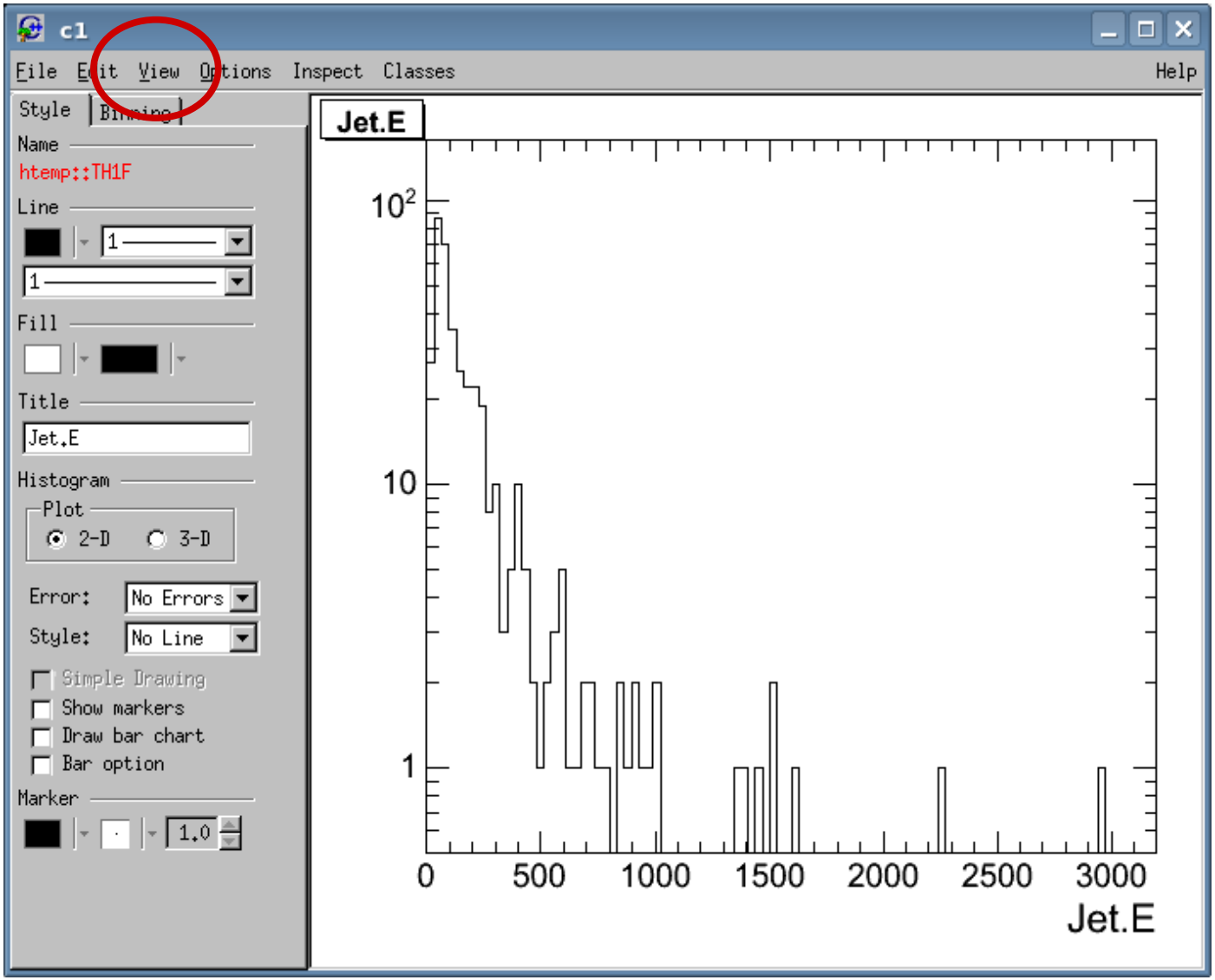
root [6] **Analysis->Draw("Jet.E")**

View → Editor



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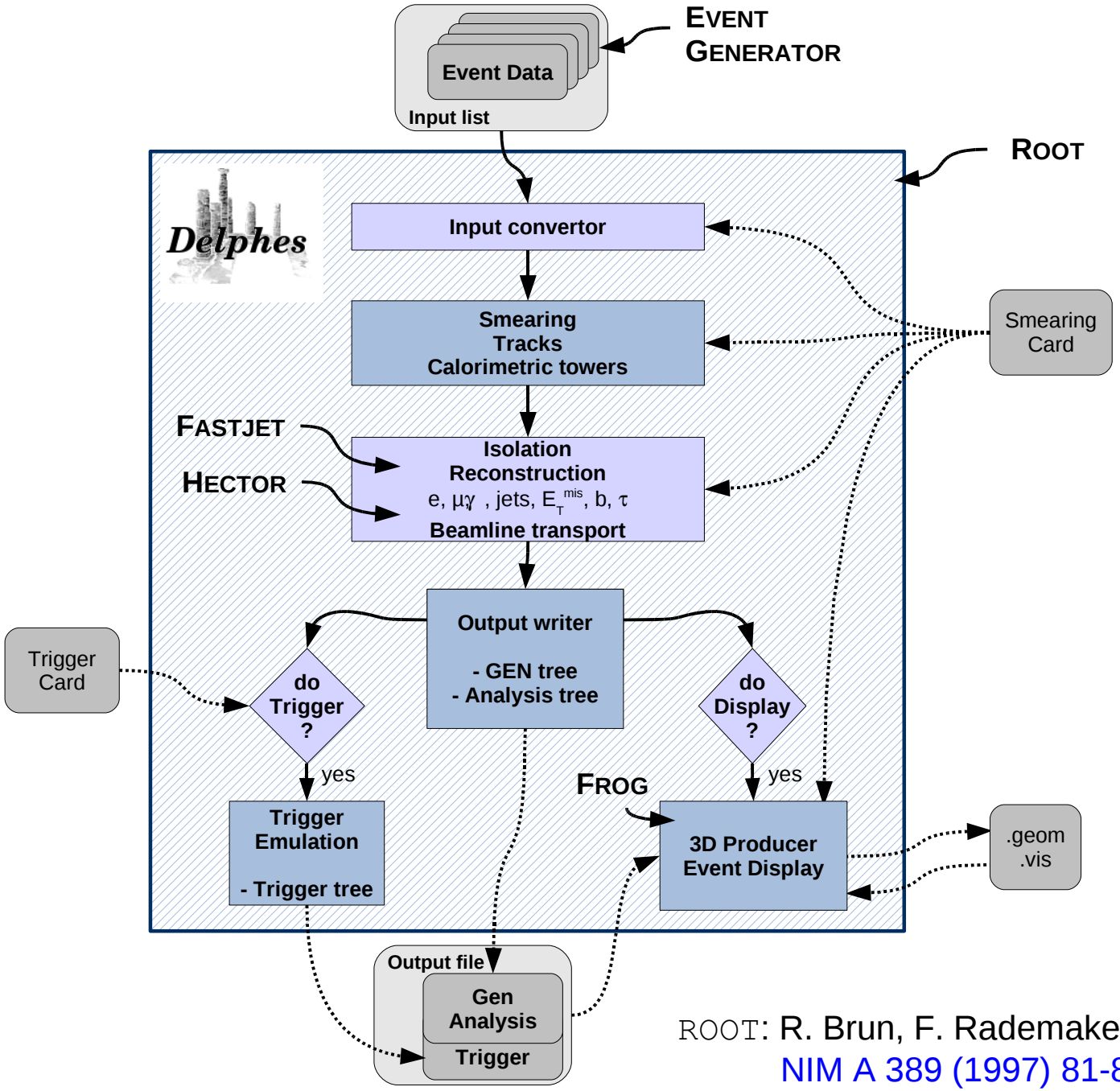
Back to Delphes parameters...

C++ / ROOT implementation



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

Detector Card : layout

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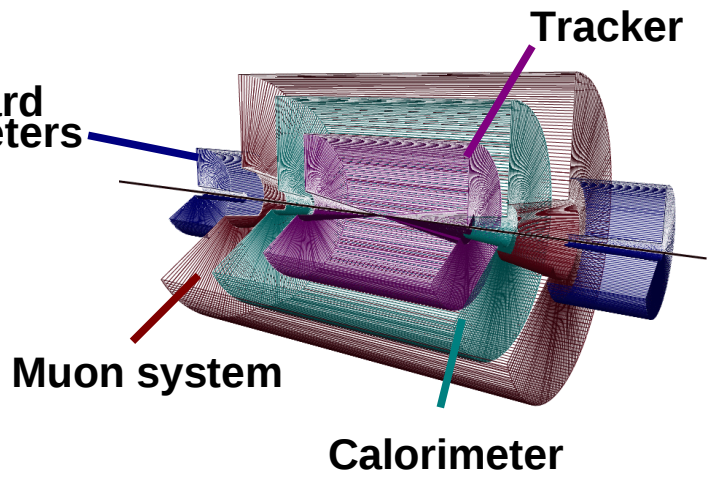
Delphes simulates a generic HEP detector:

All parameters describing the detector are defined in the **detector card**:

- Subdetector extensions/parameters
- Expected resolutions
- Paths to external input files (beam optics, PDG particles)
- ...



Central detector components:

```
DETECTOR CARD      # DO NOT REMOVE THIS IS A TAG!

# Detector extension, in pseudorapidity units
CEN_max_tracker    2.5   // Maximum tracker coverage
CEN_max_calo_cen   3.0   // central calorimeter coverage
CEN_max_calo_fwd   5.0   // forward calorimeter pseudorapidity coverage
CEN_max_mu         2.4   // muon chambers pseudorapidity coverage
```

Symmetries :

η >0 ↔ η <0 (pseudorapidity)

All-φ (azimuth)

Detector Card : layout

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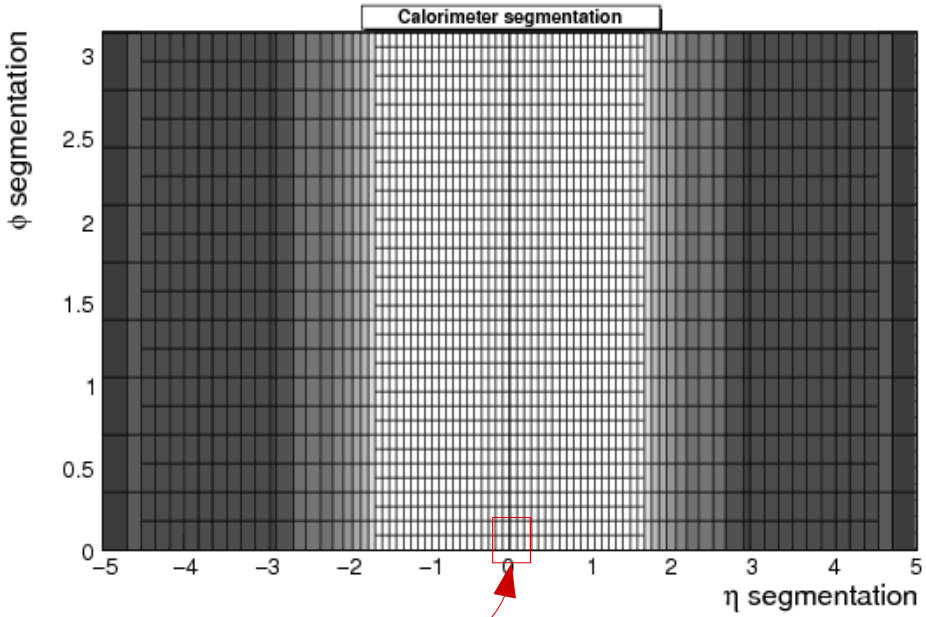
Central detector components:

calorimetric tower segmentation

List of calotowers:

- edges in eta
- size in phi (degrees)




```
# Calorimetric towers
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
## list of the edges of each tower in eta for eta>0 assuming
a symmetric detector in eta<0

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 10 10 10 20 20
### list of the tower size in phi (in degrees)
```

Detector Card : layout

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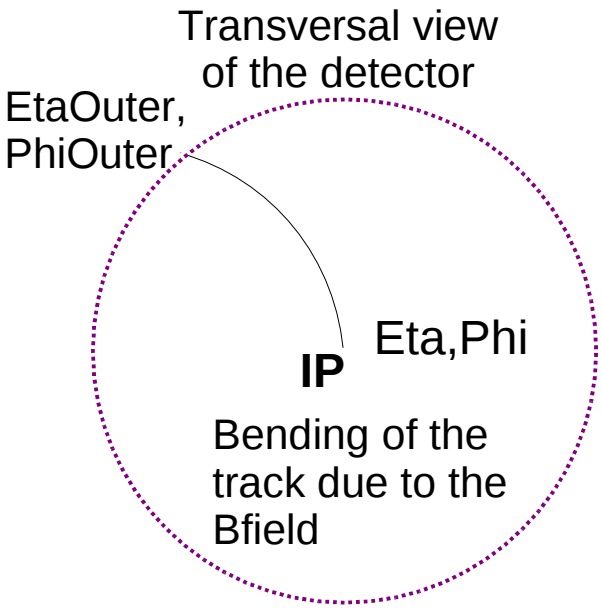
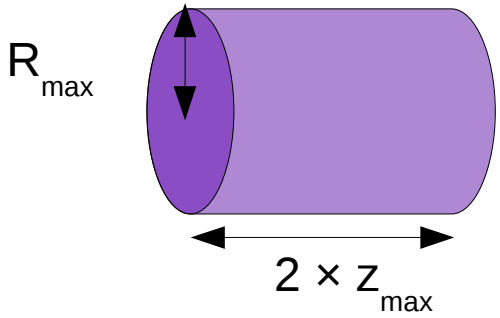
Central detector components:

Solenoidal magnetic field parameters, for the tracking system:

```
# In case BField propagation allowed

TRACK_radius      129  //radius of the BField coverage, in cm
TRACK_length      300  //length of the BField coverage, in cm
TRACK_bfield_x    0    //X component of the BField, in T
TRACK_bfield_y    0    //Y component of the BField, in T
TRACK_bfield_z    400  //Z component of the BField, in T
```





Detector Card : layout

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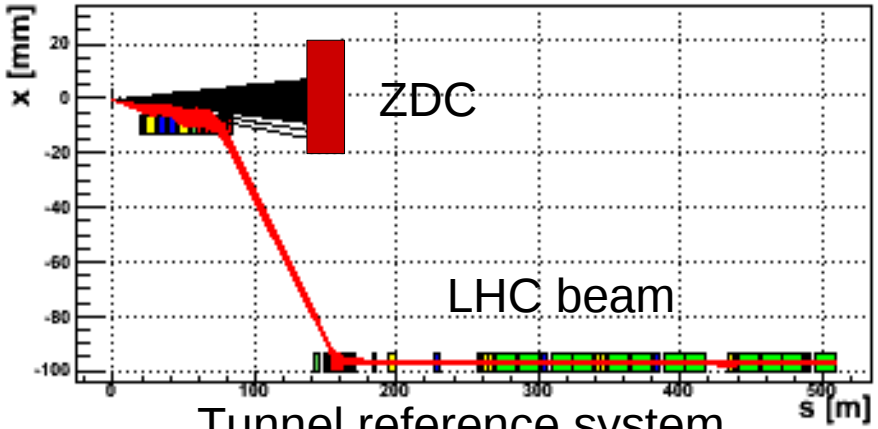
Forward detectors: zero-degree calorimeters (ZDC)

```
VFD_min_zdc   8.3   // zero-degree neutral calorimeter coverage, in eta
VFD_s_zdc     140   // distance to the IP, in meters
```

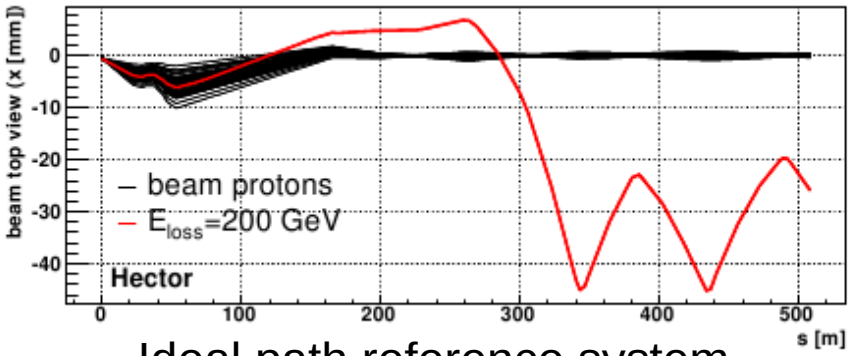
Zero degree calorimeters are located after the beam separation : see all neutrons/photons directly coming from the IP



Tunnel reference system

Forward detectors: roman pots (RP220) / taggers (FP420)

Roman pots and forward taggers see beam particles *elastically* scattered with some energy loss, at the IP



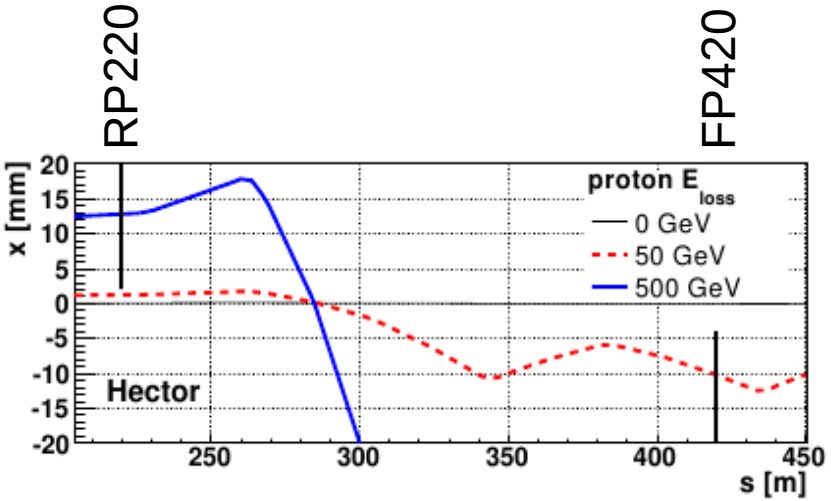
Ideal path reference system

Detector Card : layout

Forward detectors: roman pots/taggers

```
#Hector parameters
RP_220_s            220     // distance of the RP to the IP, in meters
RP_220_x            0.002   // distance of the RP to the beam, in meters

RP_offsetEl_x       0.097   // hor. separation between both beam, in meters
RP_offsetEl_y       0       // ver. separation between both beam, in meters
RP_offsetEl_s       120     // distance of beam separation point, from IP
RP_cross_x          -500    // IP offset in horizontal plane, in micrometers
RP_cross_y          0       // IP offset in vertical plane, in micrometers
RP_cross_ang_x      142.5   // half-crossing angle in hor. plane, in microrad
RP_cross_ang_y      0       // half-crossing angle in ver. plane, in microrad
```



Parameters for Hector

Time resolution

```
ZDC_T_resolution   0 // in s
RP220_T_resolution 0 // in s
RP420_T_resolution 0 // in s
```

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Detector Card : layout

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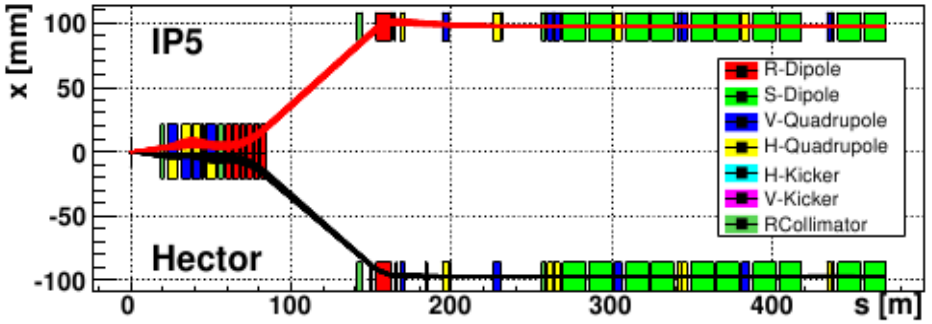
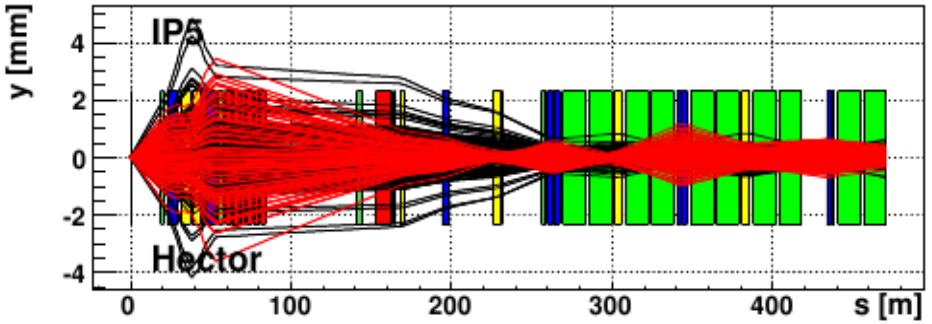
Forward detectors:

roman pots/taggers

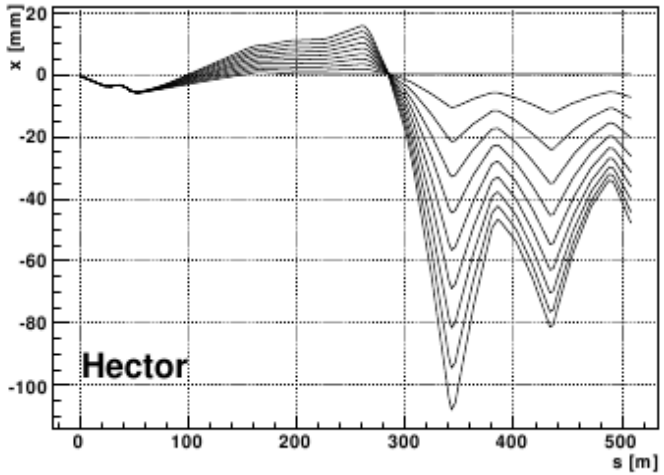
List of beam magnets:

- effective length,
- field strength,
- position,
- geometrical aperture






```
RP_beam1Card      data/LHCB1IR5_v6.500.tfs // beam optics file, beam 1
RP_beam2Card      data/LHCB2IR5_v6.500.tfs // beam optics file, beam 2
RP_IP_name        IP5    // tag for IP in Hector ; 'IP1' for ATLAS
```



LHC beam 1 or 2
Interaction region 1 (ATLAS)
or 5 (CMS)
7 TeV proton beams
in collision mode

Detector Card : resolutions

All calorimeters are simulated according to their **resolution**, parametrised with this formula:

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

Stochastic term | Noise term | Constant term

```
# Energy resolution for electron/photon
# \sigma/E = C + N/E + S/\sqrt{E}, E in GeV
ELG_Scen            0.05     // S term for central ECAL
ELG_Ncen            0.25     // N term for central ECAL
ELG_Ccen            0.005    // C term for central ECAL
ELG_Sfwd            2.084    // S term for FCAL
ELG_Nfwd            0.0      // N term for FCAL
ELG_Cfwd            0.107    // C term for FCAL
ELG_Szdc            0.70     // S term for ZDC
ELG_Nzdc            0.0      // N term for ZDC
ELG_Czdc            0.08     // C term for ZDC

# Energy resolution for hadrons in ecal/hcal/hf
# \sigma/E = C + N/E + S/\sqrt{E}, E in GeV
HAD_Shcal           1.5      // S term for central HCAL
HAD_Nhcal           0.       // N term for central HCAL
HAD_Chcal           0.05     // C term for central HCAL
HAD_Shf             2.7      // S term for FCAL
HAD_Nhf             0.       // N term for FCAL
HAD_Chf             0.13     // C term for FCAL
HAD_Szdc            1.38     // S term for ZDC
HAD_Nzdc            0.       // N term for ZDC
HAD_Czdc            0.13     // C term for ZDC
```

electromagnetic sections:

- Central
- Forward
- ZDC

hadronic sections:

- Central
- Forward
- ZDC

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Detector Card : resolutions

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Time resolution for forward detectors

```
# Time resolution for ZDC/RP220/RP420
ZDC_T_resolution    0  // in s
RP220_T_resolution 0  // in s
RP420_T_resolution 0  // in s
```

In reality, neither RP220 (Totem/IP5) nor ALFA (Atlas/IP1) can measure time of flight

Pt resolution on muons

```
MU_SmearPt         0.01 // in GeV
```

It is foreseen to have input distributions instead of flat probabilities for the smearing in future versions of ***Delphes***.

Tracking efficiencies

```
# Tracking efficiencies
TRACK_ptmin 0.0 // minimal pt needed to reach the calorimeter in GeV
TRACK_eff   100 // efficiency associated to the tracking (%)
```

Reconstruction thresholds (Pt or E)

```
PTCUT_elec         10.0  // in GeV
PTCUT_muon         10.0
PTCUT_jet          20.0
PTCUT_gamma        10.0
PTCUT_taujet       10.0

ZDC_gamma_E        20
ZDC_n_E            50
```

Real experiments can *not* reconstruct complex objects at a too small scale (Pt / E).

Detector Card : misc.

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Various flags to switch on/off some components

```
FLAG_bfield      1  //1 to run the bfield propagation else 0
FLAG_vfd         1  //1 to run the very forward detectors else 0
FLAG_RP          1  //1 to run the very forward detectors else 0
FLAG_trigger     1  //1 to run the trigger selection else 0
FLAG_frog        0  //1 to run the FROG event display
FLAG_lhco        0  //1 to run the LHCO
```

It is possible *a posteriori* to run the trigger, to create the LHCO output file or to generate the input files for FROG

./Trigger_Only

```
 Usage: ./Trigger_Only input_file output_file [detector_card]
[trigger_card]
 input_file - file in Delphe root format,
 trigger_card - Datacard containing the trigger algorithms
(optional)
```

./LHCO_Only

```
 Usage: ./LHCO_Only input_file [runlog_file]
 input_file - file in Delphes root format,
 [runlog_file] - the corresponding log file (optional)
```

./Frog_on_analysis_output

```
 Usage: ./Frog_on_analysis_output input_file [N_events]
 input_file - root file containing the events to display
 detector_card - Datacard containing resolution variables for the
detector simulation (optional)
```

Detector Card : misc.

Similarly, it is possible *a priori* to run the converter stage, to translate the input data (*hep, *hepmc, *root, *lhe)

into a ***Delphes*** ROOT file (GEN tree).

./Convertors_Only

```
 Usage: ./Convertors_Only input_file output_file PDG_Table
 input_list - list of files in Ntpl, StdHep of LHEF format,
 output_file - output file,
 PDG_Table - file with PDG particle table
```

./Convertors_Only TEST_small_tt.list test.root data/particle.tbl

...

root -l test.root

...

.ls

```
TFile**         test.root
 TFile*         test.root
  KEY: TTree    GEN;1   Analysis tree
```

Jet algorithms.

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Many parameters are used for the jet definition/tuning

```
JET_coneradius    0.7   // generic jet radius ; not for tau's !!!
JET_jetalgo       1     // 1 for Cone algorithm, 2 for MidPoint algorithm,
                        // 3 for SIScone algorithm, 4 for kt algorithm
                        // 5 Cambridge/Aachen, 6 anti-kt
JET_seed          1.0   // minimum seed to start jet reconstruction, in GeV
JET_Eflow         1     // Perfect energy assumed in the tracker coverage
```

1 is on (Energy flow) ; 0 is off

b-tagging / misindentification: flat distributions

```
BTAG_b            40    // b-tag efficiency (%)
BTAG_mistag_c     10    // mistagging (%)
BTAG_mistag_l     1     // mistagging (%)
```

Leptons + misc.

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Lepton isolation

```
# Charged lepton isolation. Pt and Et in GeV
ISOL_PT          2.0      //minimal pt of tracks for isolation criteria
ISOL_Cone        0.5      //Cone  for isolation criteria
ISOL_Calo_ET     2.0
//minimal tower transverse energy for isolation criteria. 1E99 means "off"
ISOL_Calo_Grid   3        //Grid size (N x N) for calorimetric isolation
```

For the leptons, a tracking isolation is applied, with such parameters.

In particular, for muons, some information is also available on the Calorimetric isolation.

Others...

```
PdgTableFilename data/particle.tbl

NEvents_Frog     100
```

Trigger Card

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```
# 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'
```

Cuts on Pt in GeV

logical AND operator

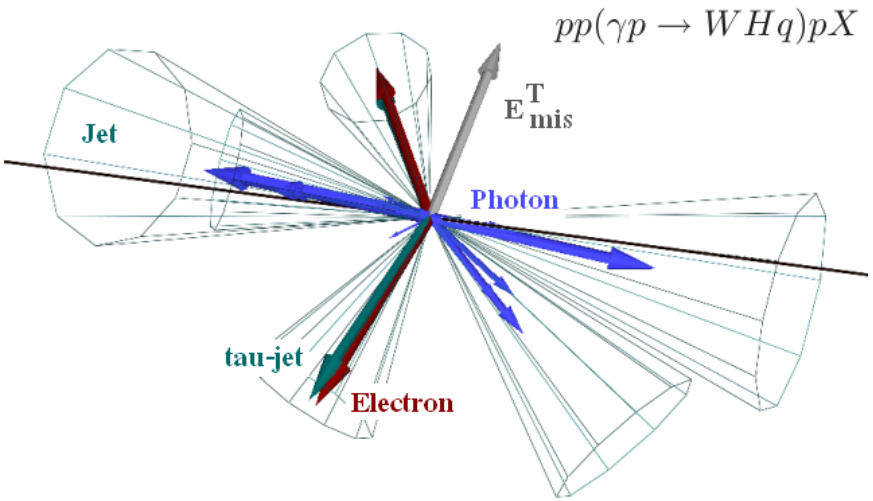
Trigger code	*Corresponding object*
ELEC_PT	electron
IElec_PT	isolated electron
MUON_PT	muon
IMuon_PT	isolated muon
JET_PT	jet
TAU_PT	τ -jet
ETMIS_PT	missing transverse energy
GAMMA_PT	photon
Bjet_PT	b-jet

FROG

X. Rouby

3D Event Display

FROG interfaced to ***Delphes***



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

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

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

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
```

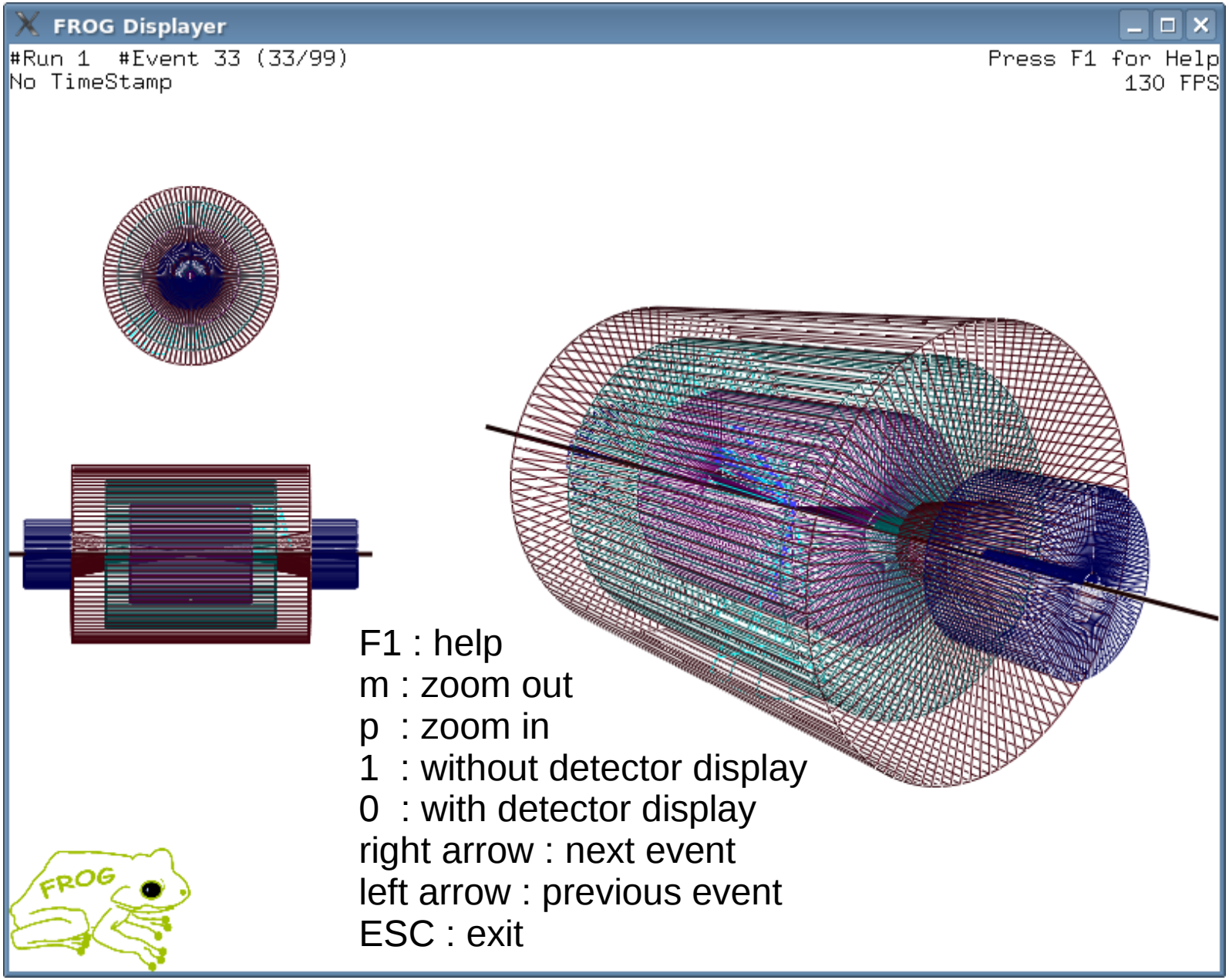
Compile it...

...Run it

FROG

Delphes

X. Rouby



That's all for today...

All comments and feedback are welcome!