Delphes card status

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Fast Simulation

From Federico's presentation…

Recommendations

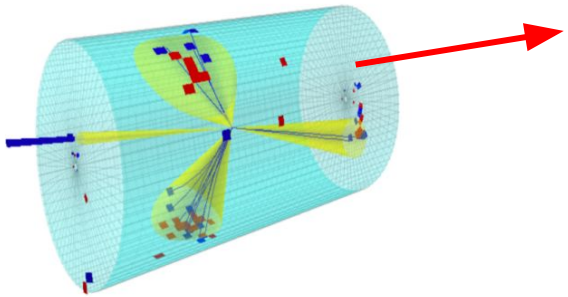
- IMCC should centrally provide up-to-date Delphes cards for phenomenology studies
- The centralised cards should reflect the "Baseline" and "Aspirational" scenarios described in the "Interfaces" chapter of the Interim report (or the analogous location in future documents)
  - Each detector concept is welcome to provide a "state-of-the-art" card reflecting the currently achieved performances in full simulation (but this is not considered mandatory)
  - Should be labelled with detector concept name to avoid confusion with central IMCC cards
- IMCC should also provide tools to produce Delphes cards given a geometry description + simulated datasets
  - These could be distributed as a part of the mucoll-benchmarks repository
- A note with "Terms and conditions" should be distributed with the cards to avoid misuse where fake objects become relevant
  - Develop "BIB object libraries" for overlay (for tracks and calo clusters) to address this in the long-term
- Cadence of maintenance: at least once per major report
- Maintenance responsibilities: synthetic "baseline" and "aspirational" cards to be provided by IMCC, detector-concept-specific by concept teams

How does it work?

Delphes in a nutshell

DELPHES
fast simulation

- **Delphes** is a modular framework that simulates the response of a **multipurpose detector** in a parameterised fashion
- Includes:
  - pile-up
  - charged particle propagation in B field
  - EM/Had calorimeters
  - particle-flow
- Provides:
  - leptons, photons, neutral hadrons
  - jets, missing energy
  - heavy flavour tagging



- designed to deal with hadronic environment
- well-suited also for e+e- studies
- detector cards for: CMS (current/PhaseII) - ATLAS - LHCb - FCC-hh - ILD - CEPC - FCCee (IDEA/CLD) - CLICdet

```
#####################################
# Order of execution of various modules
#####################################

set ExecutionPath {
    ParticlePropagator

    ChargedHadronTrackingEfficiency
    ElectronTrackingEfficiency
    MuonTrackingEfficiency

    TrackMergerPre

    TrackSmearing

    TrackMerger

    ECal
    HCal

    Calorimeter
    EFlowMerger

    PhotonEfficiency
    PhotonIsolation

    ElectronFilter
    ElectronEfficiency
    ElectronIsolation

    ChargedHadronFilter
    MuonFilter

    MuonEfficiency
    MuonIsolation

    EFlowFilter

    NeutrinoFilter


    GenJetFinder
    FastJetFinderKt

    TreeWriter
}
```


Slide credit: M. Selvaggi

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- As of now, concentrated on MUSIC detector
- Started from CLIC delphes card
  - Cleaned a lot of stuff (possible to add them back if needed)
- Implemented parametric tool for track smearing implemented by M. Selvaggi and F. Bedeschi
- Prepared a preliminary card with “aspirational” performance

```
set DetectorGeometry {
    1 PIPE -100 100 0.0228 0.0012 0.35276 0 0 0 0 0 0
    1 VTX -0.13 0.13 0.029 5e-05 0.0937 2 0 1.5708 5e-06 5e-06 1
    1 VTX -0.13 0.13 0.04 5e-05 0.0937 2 0 1.5708 5e-06 5e-06 1
    1 VTX -0.13 0.13 0.05 5e-05 0.0937 2 0 1.5708 5e-06 5e-06 1
    1 VTX -0.13 0.13 0.073 5e-05 0.0937 2 0 1.5708 5e-06 5e-06 1
    1 VTX -0.13 0.13 0.101 5e-05 0.0937 2 0 1.5708 5e-06 5e-06 1
    1 ITK -0.4816 0.4816 0.164 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    1 ITK -0.4816 0.4816 0.354 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    1 ITK -0.6923 0.6923 0.554 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    1 OTK -1.2642 1.2642 0.819 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    1 OTK -1.2642 1.2642 1.153 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    1 OTK -1.2642 1.2642 1.486 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    1 MAG -2.5 2.5 2.25 0.05 0.0658 0 0 0 0 0 0
    2 VTXDSK 0.065 0.112 -0.366 5e-05 0.0937 2 0 1.5708 5e-06 5e-06 1
    2 VTXDSK 0.053 0.112 -0.298 5e-05 0.0937 2 0 1.5708 5e-06 5e-06 1
    2 VTXDSK 0.041 0.112 -0.23 5e-05 0.0937 2 0 1.5708 5e-06 5e-06 1
    2 VTXDSK 0.032 0.112 -0.18 5e-05 0.0937 2 0 1.5708 5e-06 5e-06 1
    2 VTXDSK 0.032 0.112 0.18 5e-05 0.0937 2 0 1.5708 5e-06 5e-06 1
    2 VTXDSK 0.041 0.112 0.23 5e-05 0.0937 2 0 1.5708 5e-06 5e-06 1
    2 VTXDSK 0.053 0.112 0.298 5e-05 0.0937 2 0 1.5708 5e-06 5e-06 1
    2 VTXDSK 0.065 0.112 0.366 5e-05 0.0937 2 0 1.5708 5e-06 5e-06 1
    2 ITKDSK 0.277 0.56 -2.19 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 ITKDSK 0.257 0.56 -1.946 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 ITKDSK 0.239 0.56 -1.741 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 ITKDSK 0.215 0.56 -1.457 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 ITKDSK 0.191 0.56 -1.173 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 ITKDSK 0.156 0.56 -0.888 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 ITKDSK 0.106 0.41 -0.604 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 ITKDSK 0.106 0.41 0.604 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 ITKDSK 0.156 0.56 0.888 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 ITKDSK 0.191 0.56 1.173 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 ITKDSK 0.215 0.56 1.457 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 ITKDSK 0.239 0.56 1.741 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 ITKDSK 0.257 0.56 1.946 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 ITKDSK 0.277 0.56 2.19 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 OTKDSK 0.6175 1.4302 -2.19 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 OTKDSK 0.6175 1.4302 -1.933 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 OTKDSK 0.6175 1.4302 -1.667 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 OTKDSK 0.6175 1.4302 -1.41 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 OTKDSK 0.6175 1.4302 1.41 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 OTKDSK 0.6175 1.4302 1.667 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 OTKDSK 0.6175 1.4302 1.933 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 OTKDSK 0.6175 1.4302 2.19 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
    2 OTKDSK 0.6175 1.4302 2.19 0.000956 0.0937 2 0 1.5708 7e-06 9e-05 1
}
```

This depends on the chosen detector configuration

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ECAL

```
# set ECalResolutionFormula {resolution formula as a function of eta and energy}
# sqrt(energy^2*c^2 + energy*a^2) where a is the stochastic term and c the constant term
set ResolutionFormula {
(abs(eta) <= 2.5) * sqrt( energy^2*0.01^2 + energy*0.10^2  )}
```

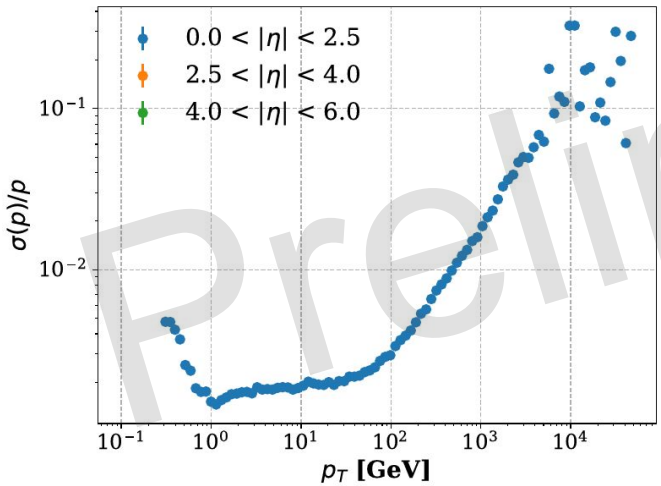
HCAL

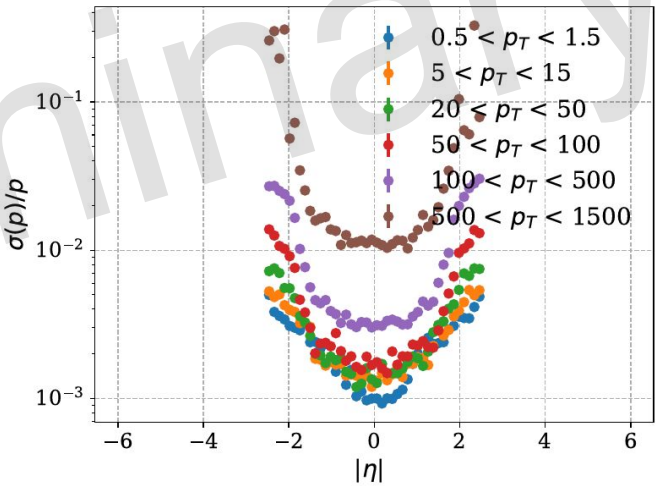
```
# set HCalResolutionFormula {resolution formula as a function of eta and energy}
# sqrt(energy^2*c^2 + energy*a^2) where a is the stochastic term and c the constant term
set ResolutionFormula {
    (abs(eta)<= 2.5) * sqrt(energy*0.308^2  + energy^2*0.050^2)
}
```

Delphes card status - validation

- The new version of the code allows for validation of the Delphes card

$\mu^{\pm}$ track resolution: p





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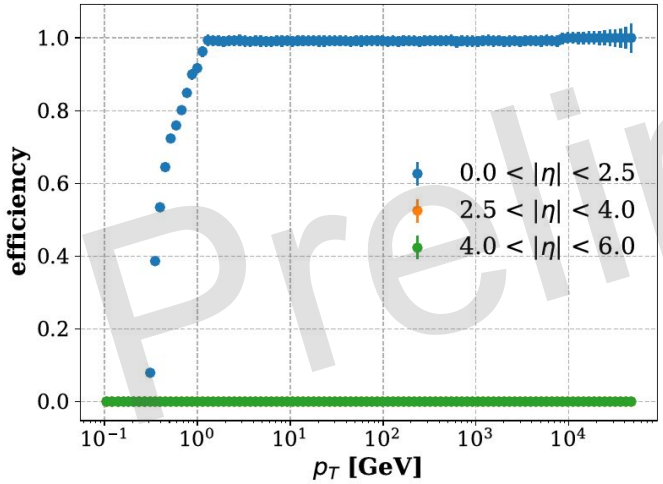
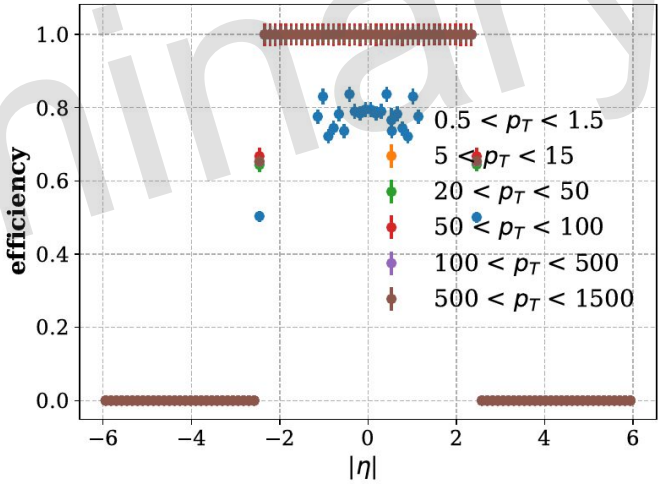
$\mu^{\pm}$ track efficiency





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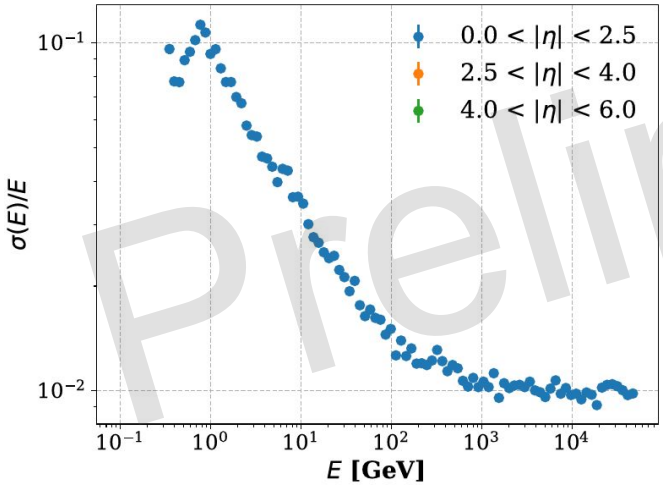
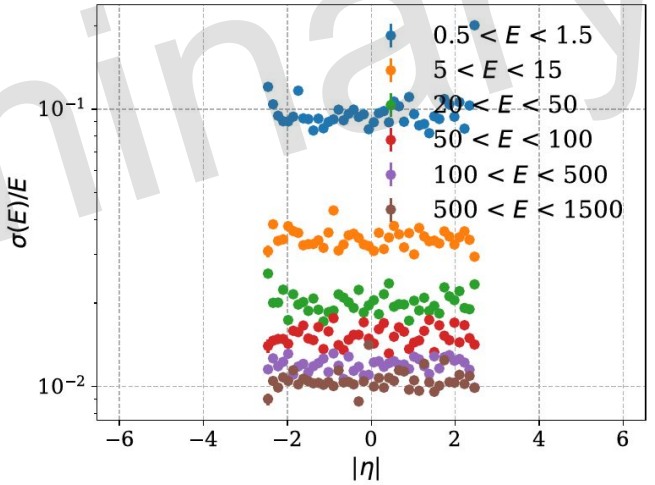
  γ calorimeter resolution: E

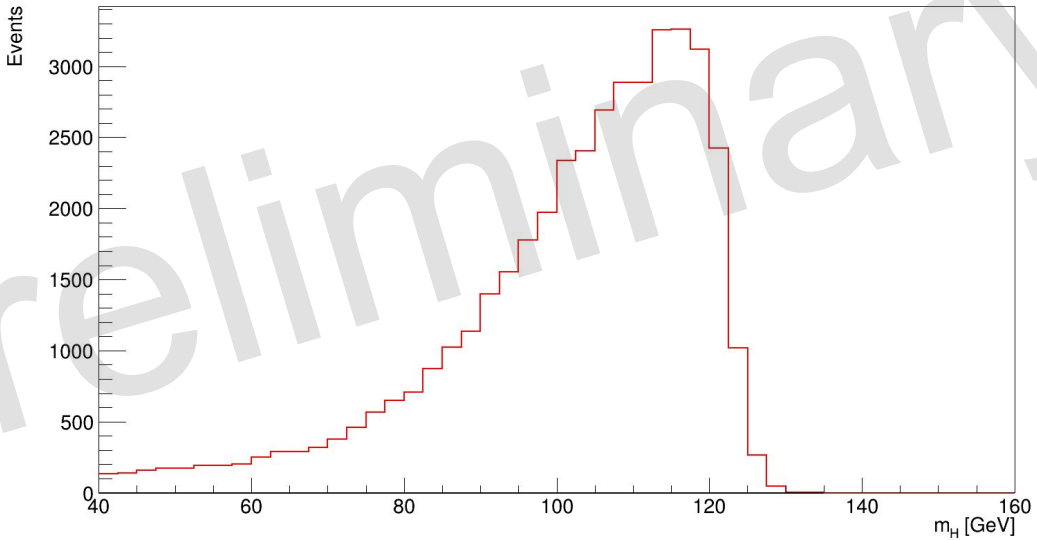




Analysis with Delphes card - an example

- 100k events of μμ→H(→bb)νν simulated at 10 TeV with MadGraph5 + Pythia
- Processed through MUSIC Delphes card
- Quick analysis taking the first 2 jets with highest p_T

Results are similar to the ones obtained with CLIC Delphes card



Next steps

- Still running validation of this card, but up to now everything seems fine

- What's missing:
  - Adding several different jet clustering algorithms
  - Tune efficiencies to match what we had in https://arxiv.org/pdf/2303.08533 (possibly from plots)

  - **+ all the steps mentioned by Federico in the roadmap :)**
  - BONUS: in principle, everything can be embedded in an analysis framework (as done by FCC: https://github.com/HEP-FCC/FCCAnalyses)
    - It needs lcio→edm4hep conversion, but this is what we are aiming to