DELPHES fast simulation status for the IDEA detector

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11th FCC-ee workshop

Thursday, 10 January 2019

OUTLINE

DELPHES
framework for Fast Simulation

→

IDEA
Baseline Detector description

→

Validation
of the Delphes IDEA card

→

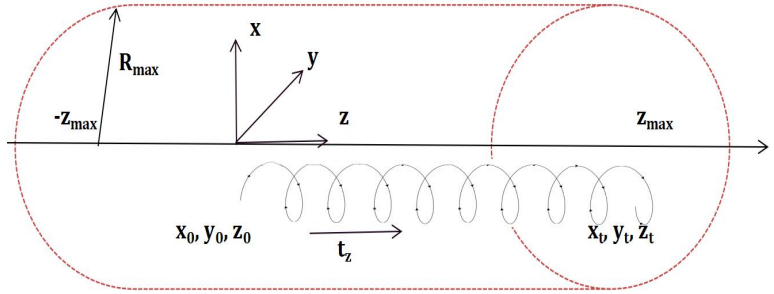
Comparison
between different detectors

compared with the **ILD card** validated with Full Sim

Fast Simulation

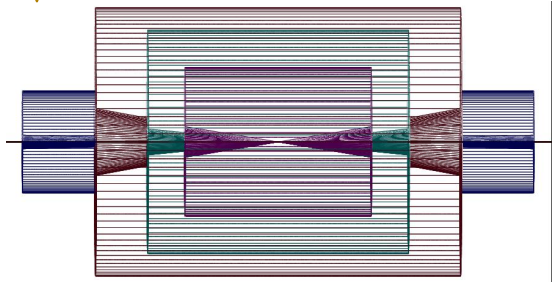
Fast Simulation of detector concept

Particle **trajectory** is followed in the detector. It only needs **general volumes** for acceptances, a **resolution driven segmentation**, resolution and response functions as obtained from Full Simulation or related to desired/studied performance.



Two frameworks for the fast simulation

DELPHES



Detector geometry: **implemented**

Validation: **on-going**

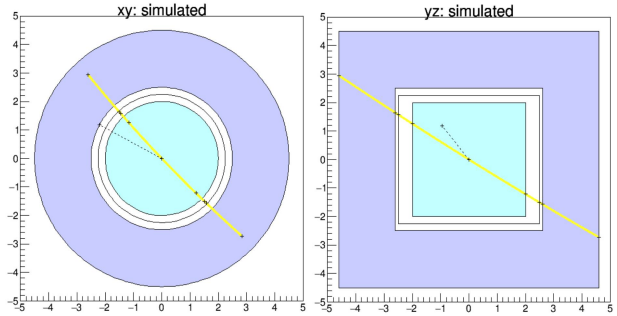
Benchmark studies: **to be done**

PAPAS

Detector geometry: **partially implemented**

Validation: **to be done**

Benchmark studies: **to be done**



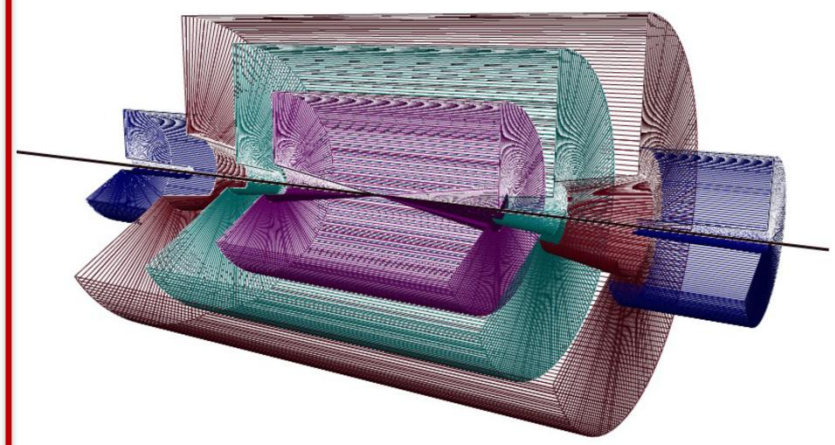
Focus on DELPHES to start fast simulation studies: more experience in the group

Goal: proceed in parallel working on PAPAS in the FCCSW once the details would be fixed

DELPHES Fast Simulation

Delphes provides a parametric **simulation of a detector** taking into account subdetector types (described as cylinders) with their extension, segmentation and resolution:

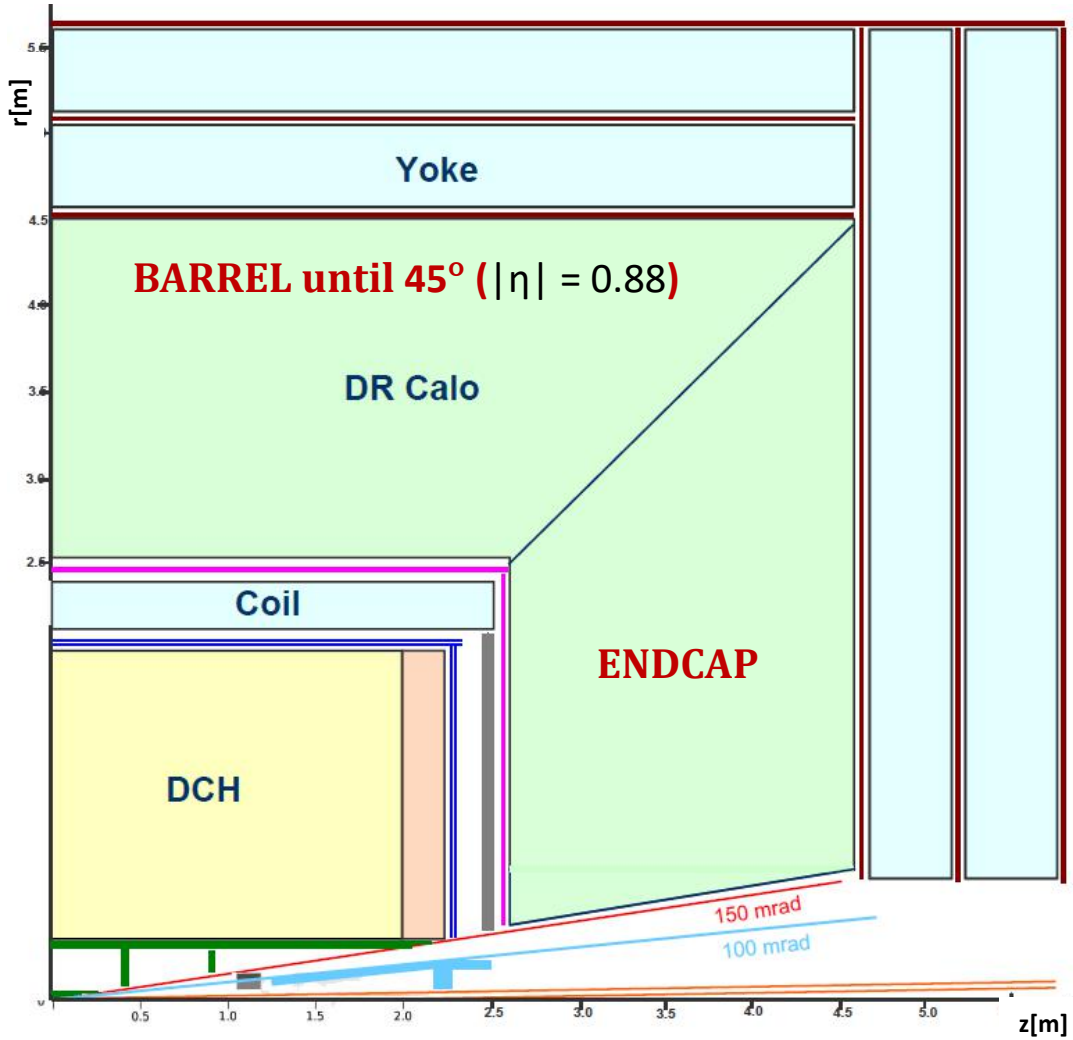
- a **tracker** in a solenoidal magnetic field,
- a **calorimeter** with electromagnetic and hadronic sections,
- a **muon system.**



Schematic view of the DELPHES detector

Finally, it provides **reconstruction of physics objects** (electrons and muons, jets, b-jets, τ-jets and MET) in the form of output ROOT files.

IDEA Baseline Detector



The real layout

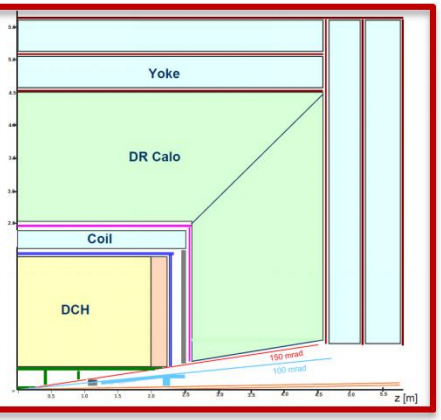
- A **magnetic field** of 2 T with
  - Solenoid length: 5 m
  - Solenoid inner radius: 2.1 m
  - Solenoid outer radius: 2.4 m
- A **Tracker** composed of
  - a drift chamber and a drift chamber service area (**DCH**);
  - **silicon pixels** and a **silicon strips** double stereo layer;
  - a μ-RWELL double layer as **preshower.**
- A **Dual-Readout calorimeter**
- A **muon system** composed of three μ-RWELL stations (each of them has a bidimensional view)

To understand if it is needed to extend the angular coverage of the detector from **150 mrad** to **100 mrad**, corresponding to η = 2.6 and η = 3.0, respectively.

IDEA Baseline Detector

Implementation in the Delphes card

The card has been validated assuming a total angular coverage of **100 mrad** (η = 3.0).



- **B field description** (*Particle Propagator* module)
  - Half length of the magnetic field coverage: **2.5 m**
  - Radius of the magnetic field coverage: **2.25 m**
  - Homogeneous magnetic field: **2 T**

- **Tracker description** (*TrackingEfficiency, MomentumSmearing*)
  - Half length: **2.6 m**

  The response of tracking detectors has been parametrized in the **same** way **for muons, electrons and charged hadrons** through an unique efficiency formula and a total resolution formula.

- **Dual-Readout (DR) calorimeter description** (*ECal, HCal*)
  - Half length: **2.6 m**

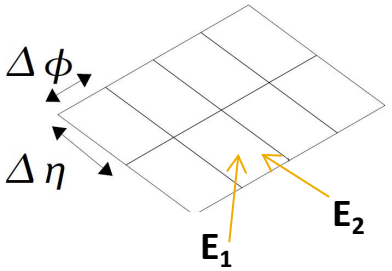
  The implementation in **two separated modules** is needed to describe the different response to electromagnetic (ECAL) and hadronic (HCAL) component of the showers. This implies:
  - **different segmentations** according to the different transverse dimensions of the showers;
  - **different energy resolution formula** for particles which deposit all their energy in ECAL ($e^{\pm}$, γ, π^0) or (*also) in HCAL.

WHY?
- Particle Flow algorithm
- No clustering in Delphes

* K_s^0 deposit 100% of their energy in ECAL (HCAL) with a probability of 30% (70%) and Λ deposit 30% (70%) of their energy in ECAL (HCAL).

DR Calorimeter

The geometry is given in Delphes as a segmentation of the cylinder in cells in η and φ directions:



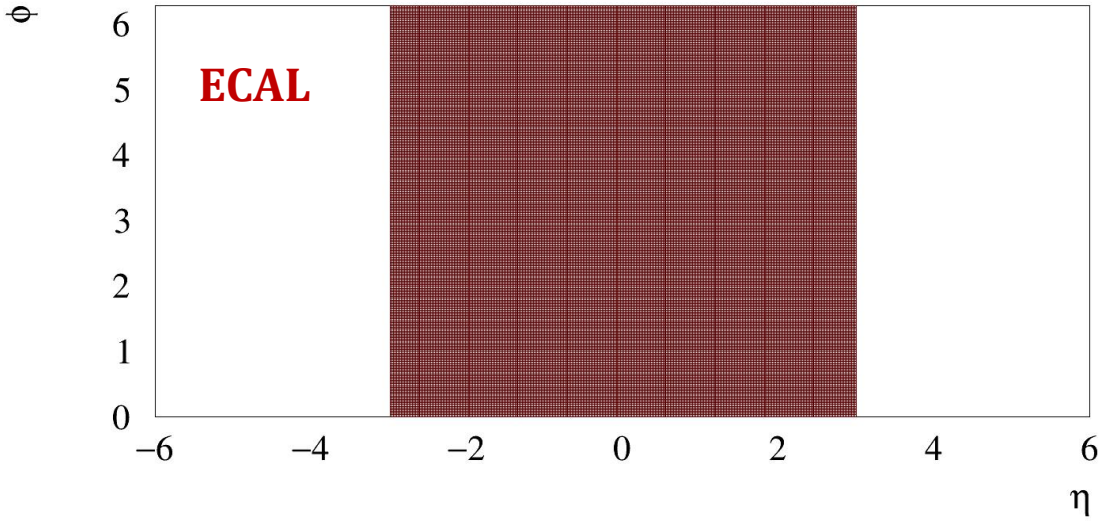
$$E_{tower} = E_1 + E_2$$

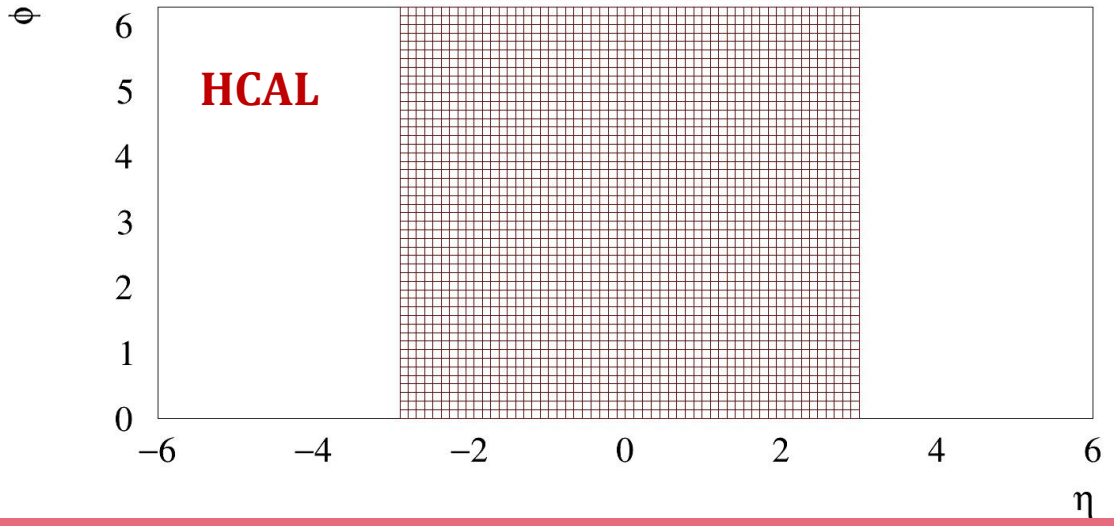
Since each tower reconstructed in the calorimeter corresponds to a single cell in Delphes work flow, the **granularity of the physics objects** is considered instead of the real granularity of the calorimeter.

ECAL cell size: **6 cm x 6 cm**
HCAL cell size: **~ 30 cm x 30 cm**

φ coverage: 360°
η coverage: 2.6 (150 mrad)

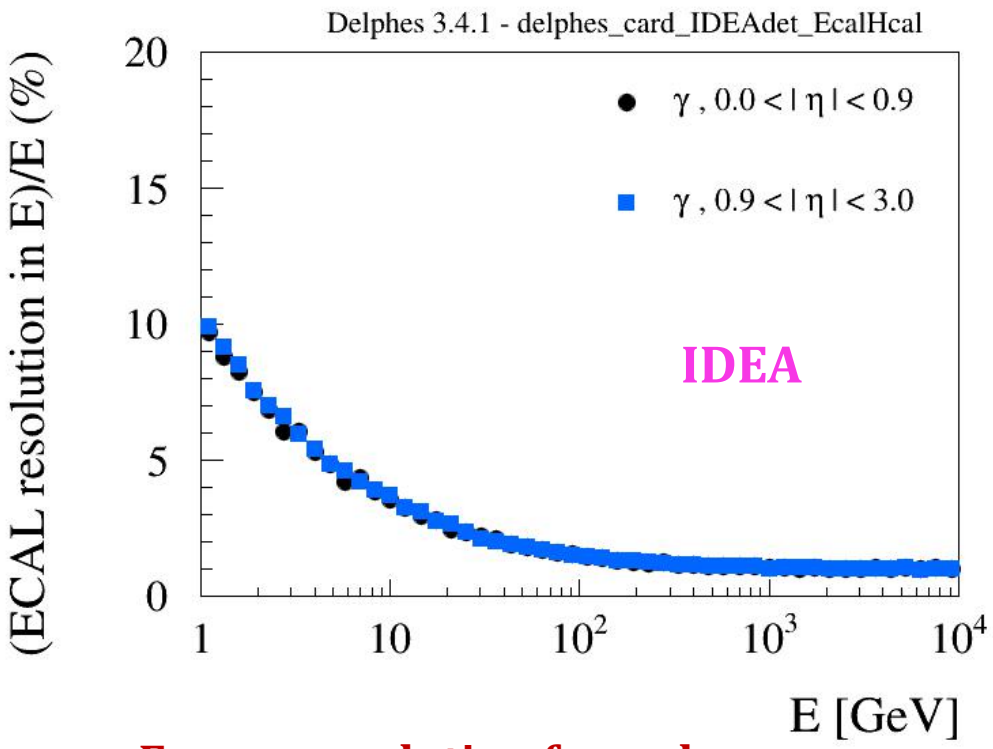
Extended to |η| = 3 to validate the card

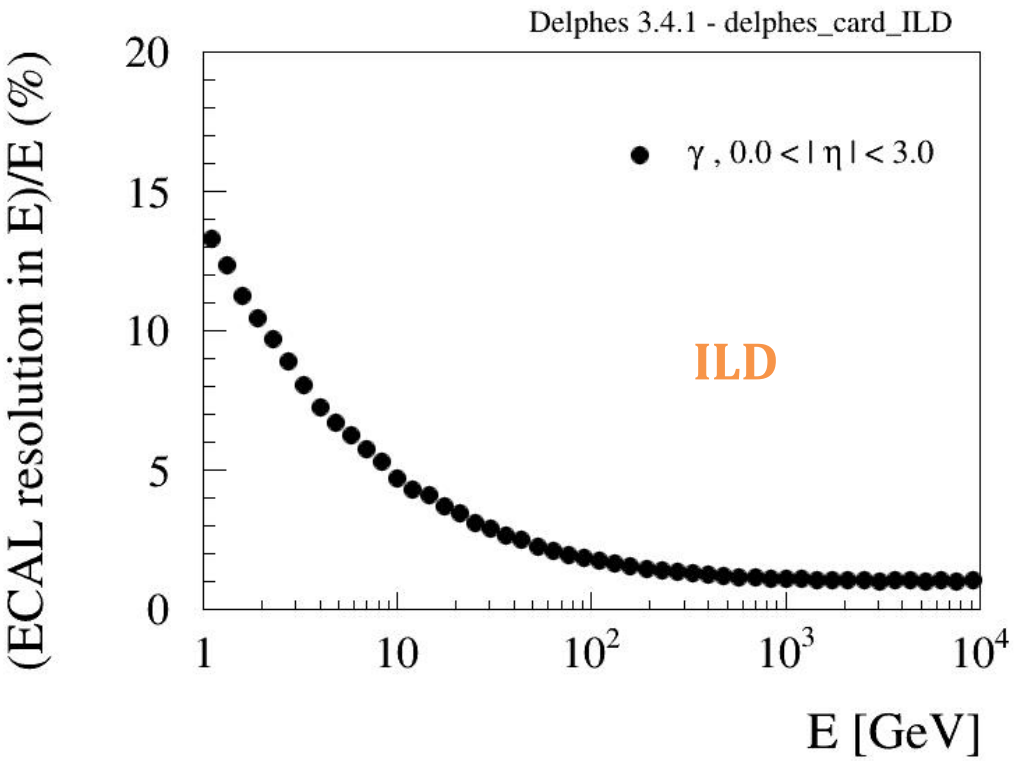




Validation

ECAL resolution





Energy resolution formula

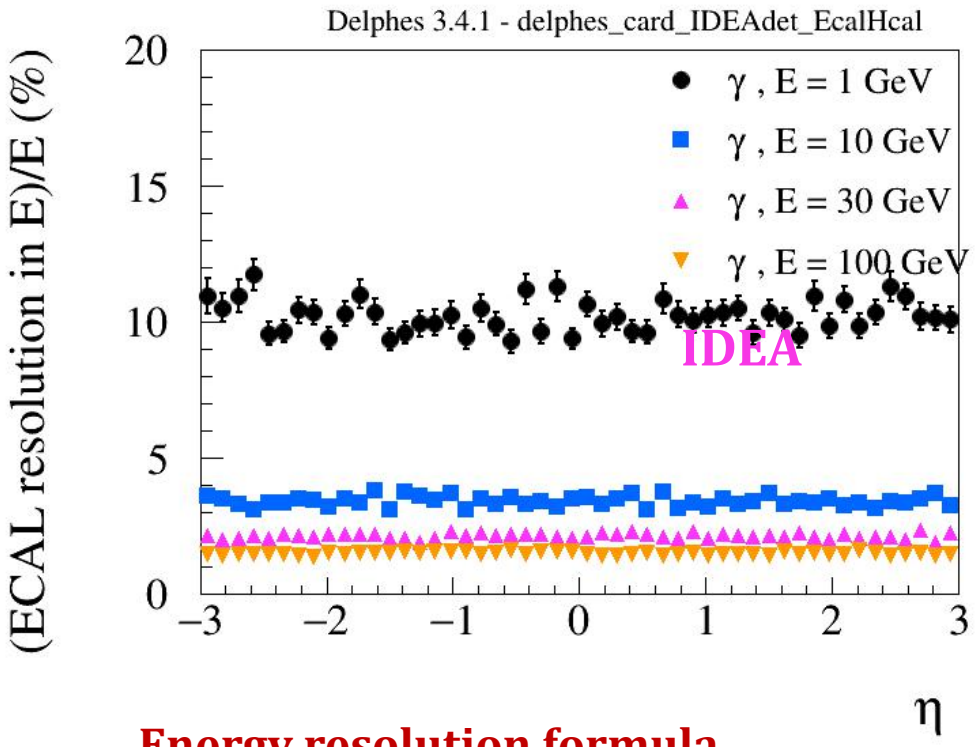
$$\sigma = \sqrt{(0.01^2 E^2 + 0.11^2 E)}$$

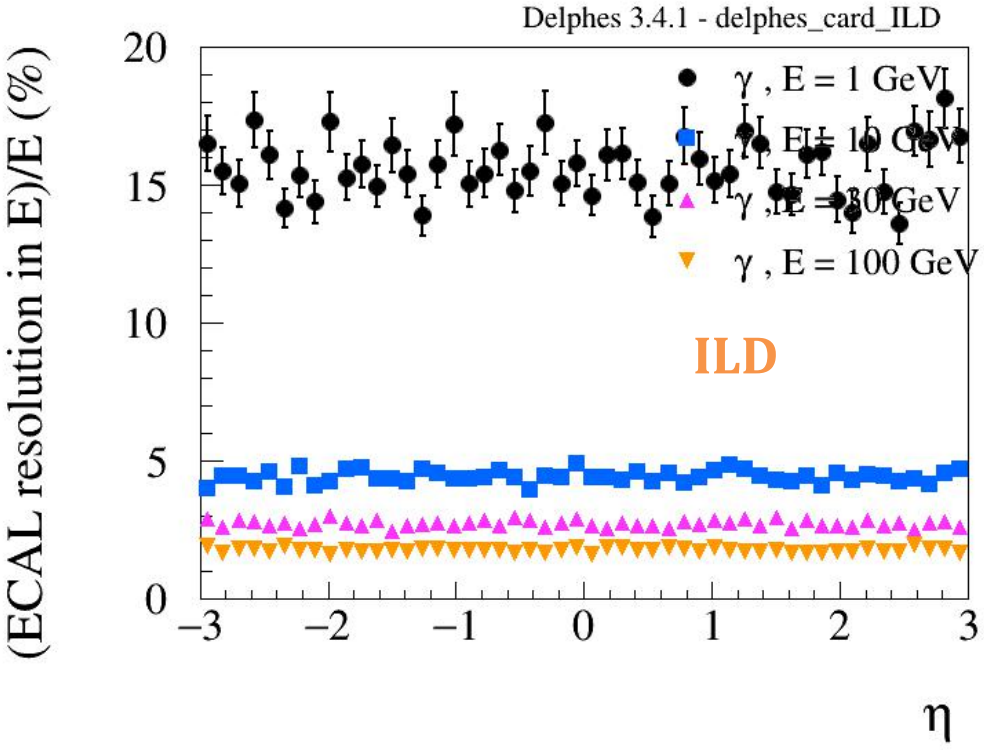
Same for barrel and endcap regions

The **high energy resolution** on ECAL is one of the most important strenghts of the IDEA detector thanks to its DR calorimeter

Validation

ECAL resolution





Energy resolution formula

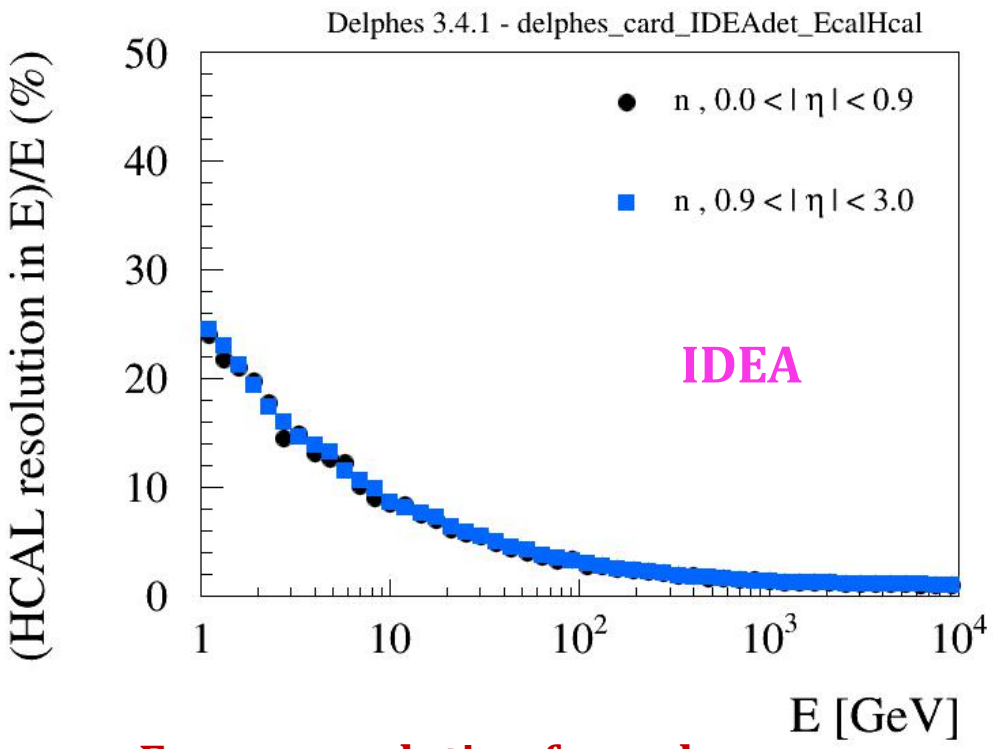
$$\sigma = \sqrt{(0.01^2 E^2 + 0.11^2 E)}$$

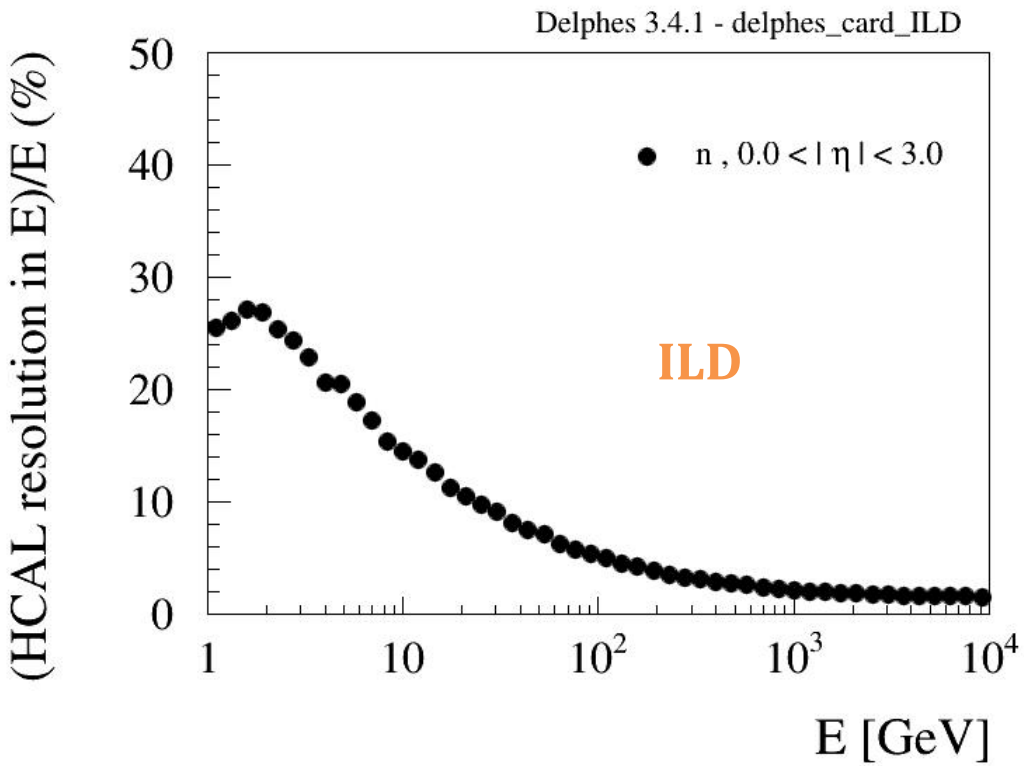
Same for barrel and endcap regions

- ✓ Good energy resolution on **photons** at different energy
- ✓ The resolution improves when particle energy increases

Validation

HCAL resolution





Energy resolution formula

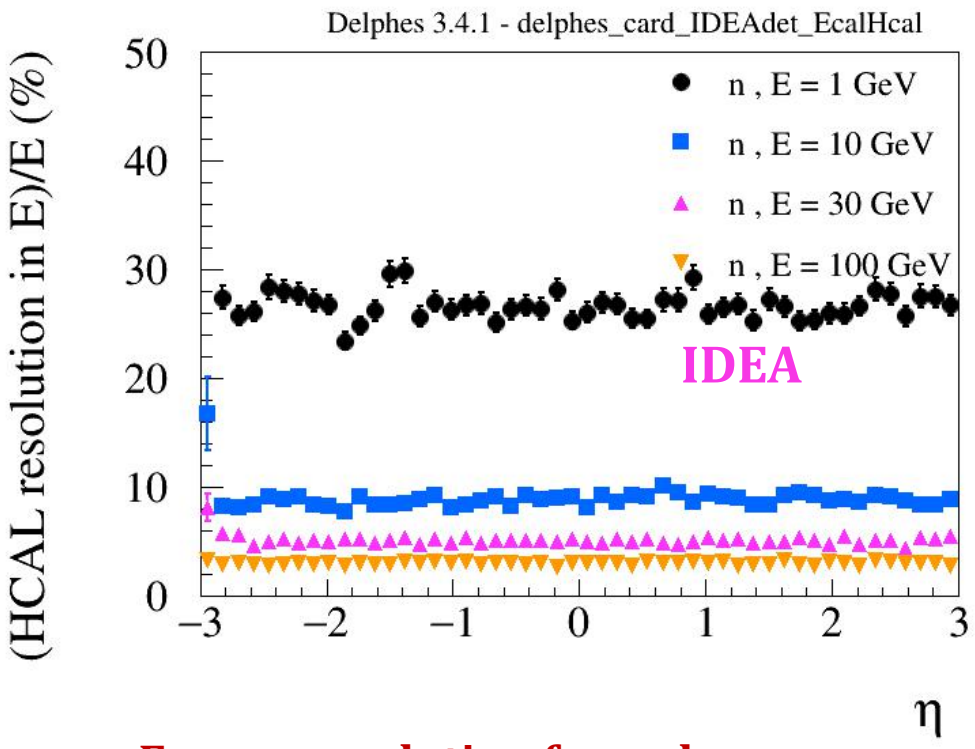
$$\sigma = \sqrt{(0.01^2 E^2 + 0.30^2 E)}$$

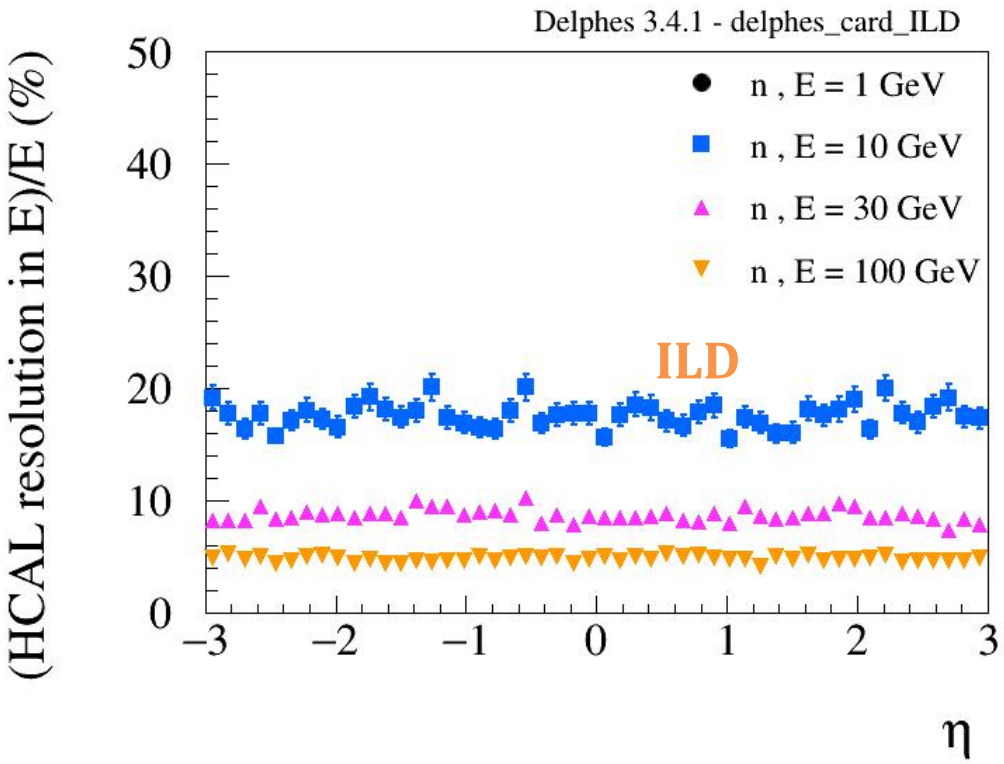
Same for barrel and endcap regions

Good energy resolution on the hadronic component of the showers

Validation

HCAL resolution





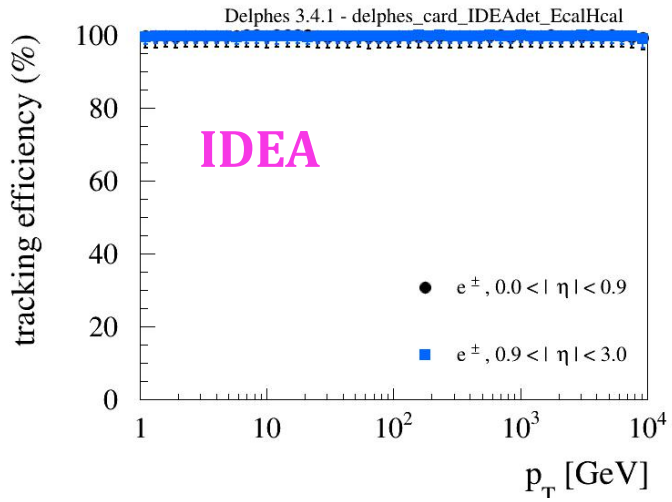
Energy resolution formula

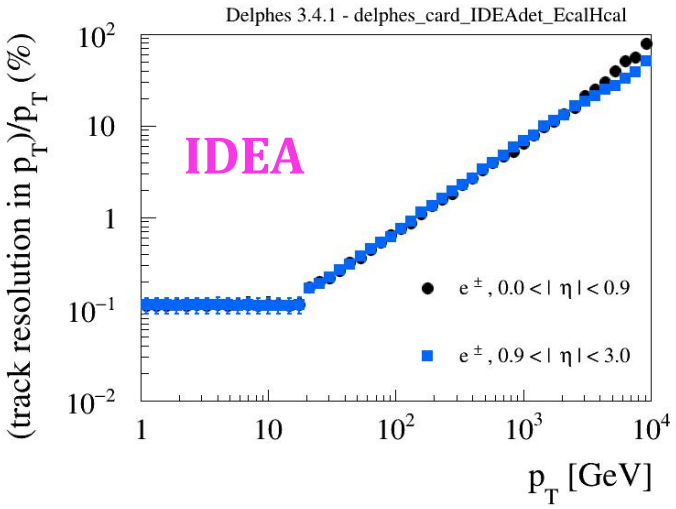
$$\sigma = \sqrt{(0.01^2 E^2 + 0.30^2 E)}$$

Same for barrel and endcap regions

- ✓ Better energy resolution on **neutrons** at different energy
- ✓ The resolution improves when increases particle energy

Tracker





The description of the Tracker is **preliminary** (waiting for an input from Full Simulation to have a total parametrization of efficiency and resolution):

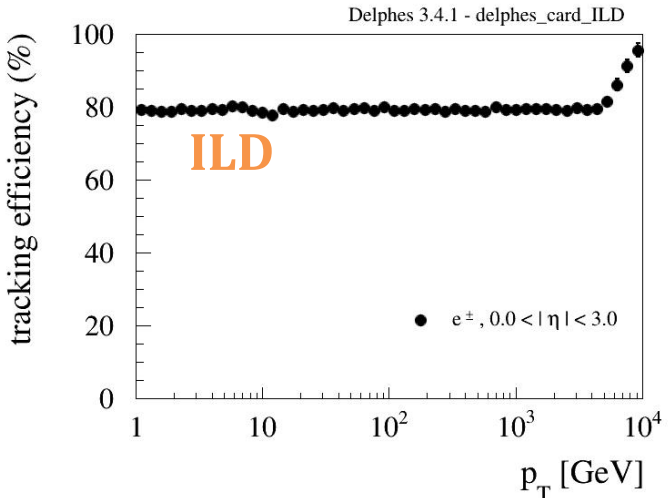
- The **same tracking efficiency** is assumed for electrons, muons and charged hadrons:

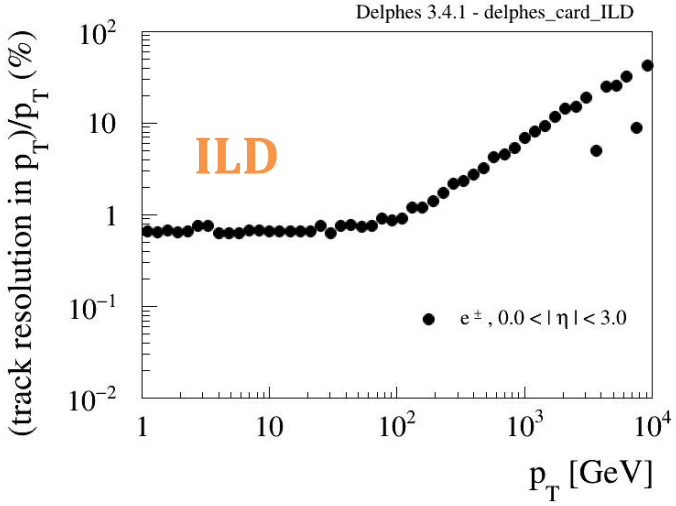
$\lvert\eta\rvert \geq 3.0$	0.00%
$E \geq 500$ MeV in $\lvert\eta\rvert \leq 3.0$	99.7%
$300 \leq E \leq 500$ MeV in $\lvert\eta\rvert \leq 3.0$	65%
$E \leq 300$ MeV in $\lvert\eta\rvert \leq 3.0$	6%

- The **same transverse momentum resolution** is assumed for electrons, muons and charged hadrons (**pessimistic**: only DCH contribution considered in the parametrization):

$$\sigma_{PT} / PT = \sqrt{[(7.e\text{-}07 * p_T)^2 + 0.0006^2]}$$

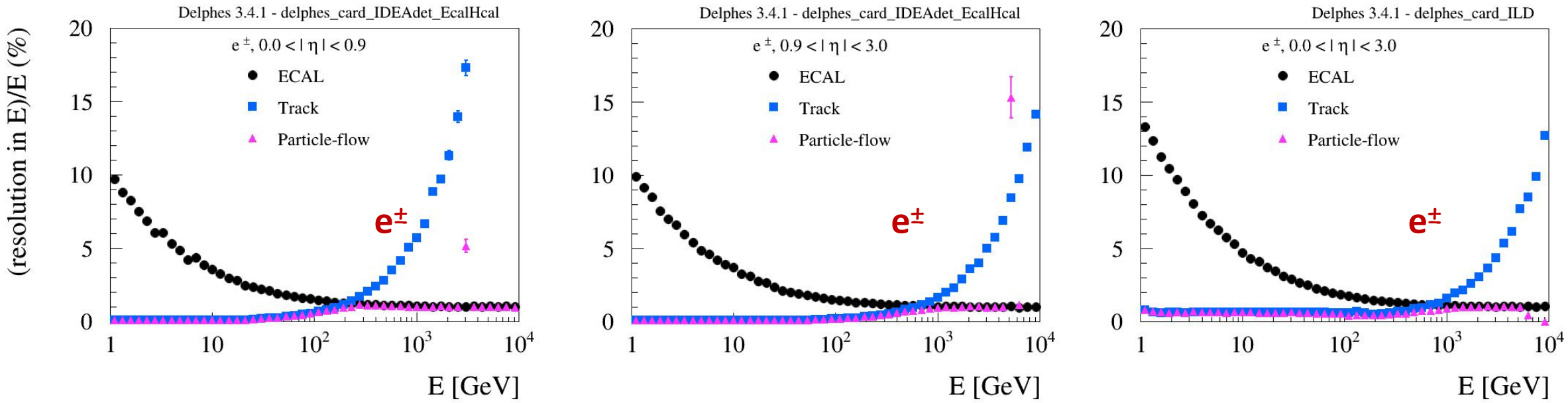
Same for barrel and endcap regions





Particle Flow Performance

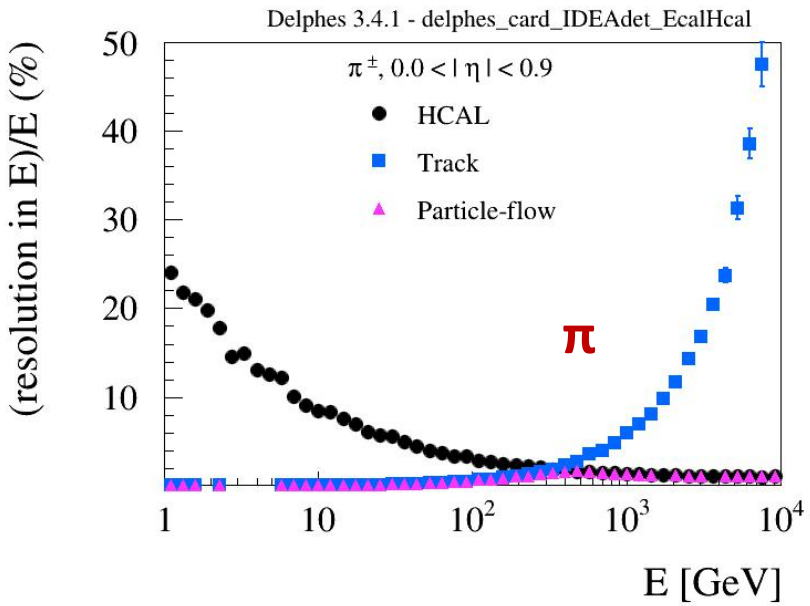
IDEA - Barrel **IDEA - Endcap** **ILD**



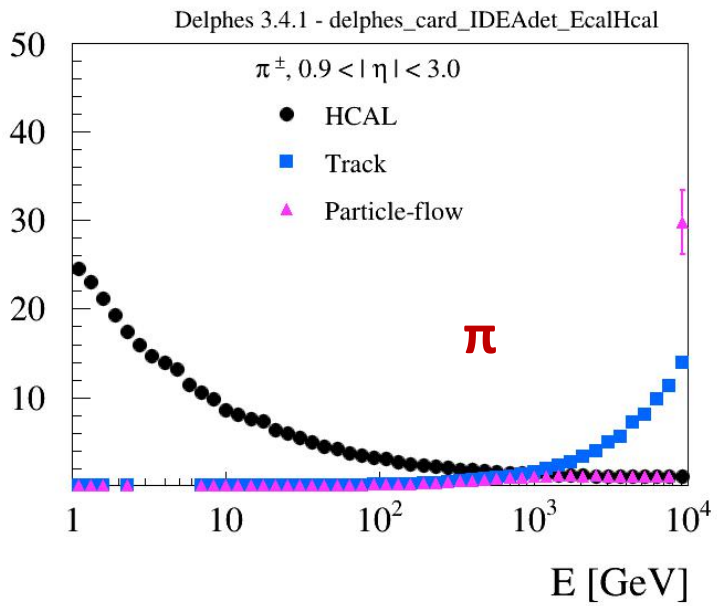
- ✓ The PF algorithm takes Tracks and calorimeter's Towers as input: in case of an excess of deposited energy wrt the considered track, it helps to evaluate if the excess corresponds to a neutral particle or not.
- ✓ It combines the information from tracker and calorimeter modules ⇨ it works correctly in **ECAL**.

Particle Flow Performance

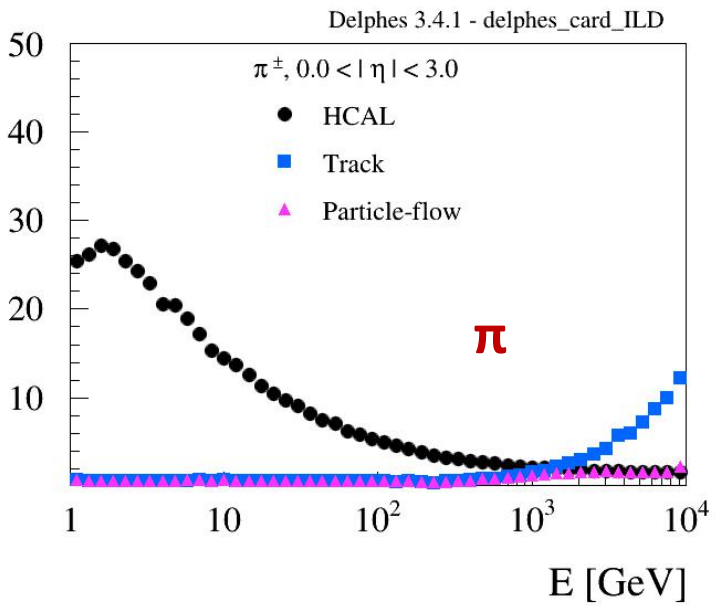
IDEA - Barrel



IDEA - Endcap



ILD

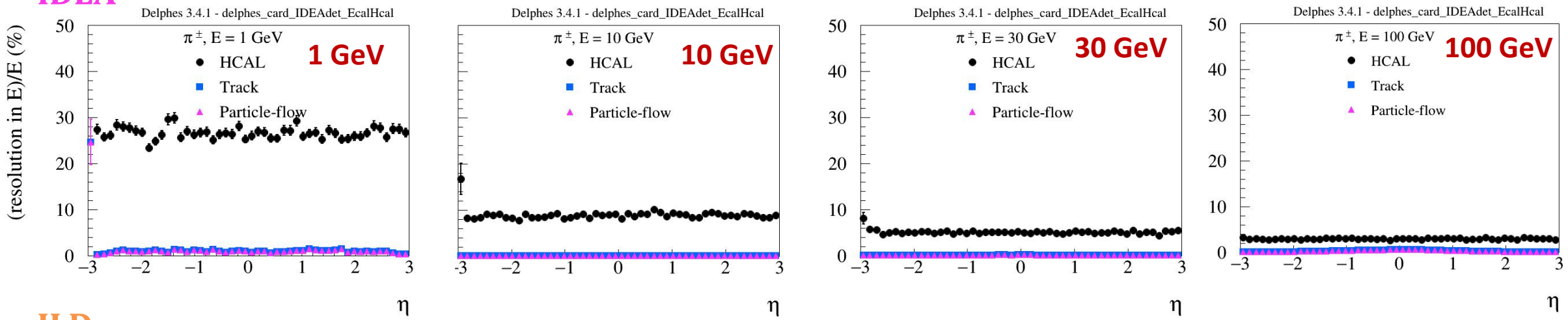


- ✓ The PF algorithm takes Tracks and calorimeter's Towers as input: in case of an excess of deposited energy wrt the considered track, it helps to evaluate if the excess corresponds to a neutral particle or not.
- ✓ It combines the information from tracker and calorimeter modules ⇨ it works correctly also in **HCAL**.

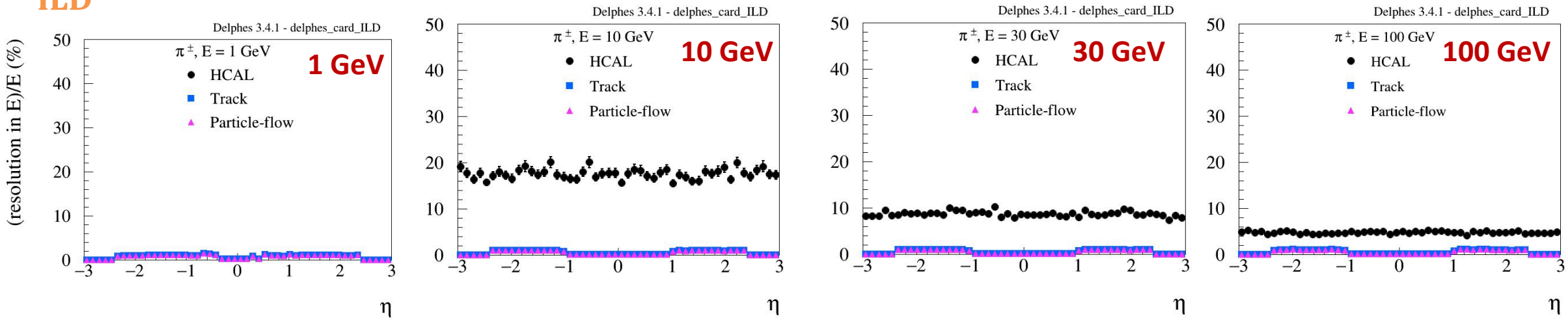
Validation

Particle Flow Performance

IDEA



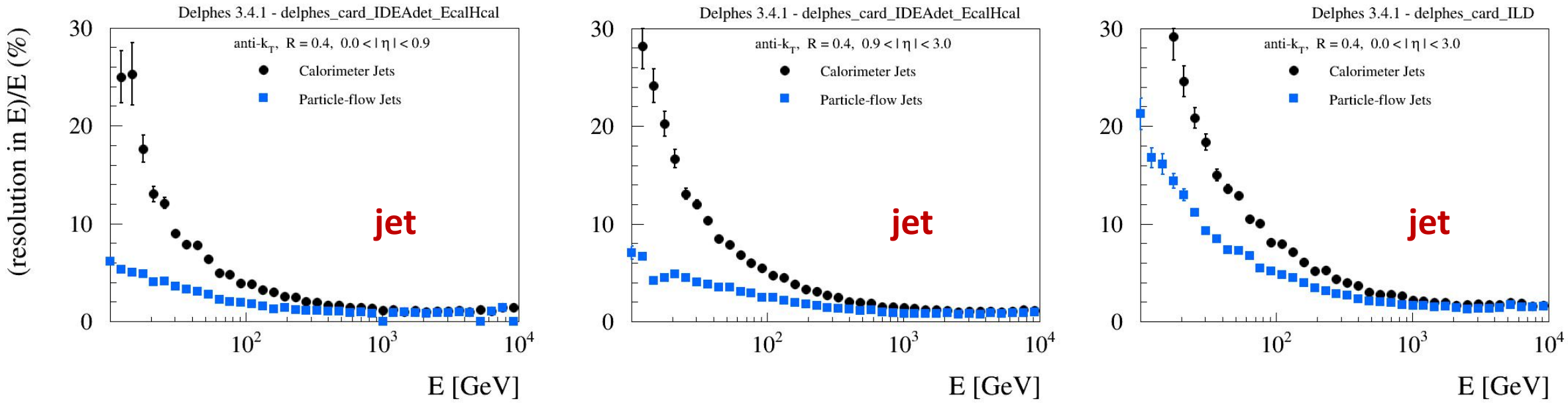
ILD



Validation

Particle Flow Performance

IDEA - Barrel | **IDEA - Endcap** | **ILD**

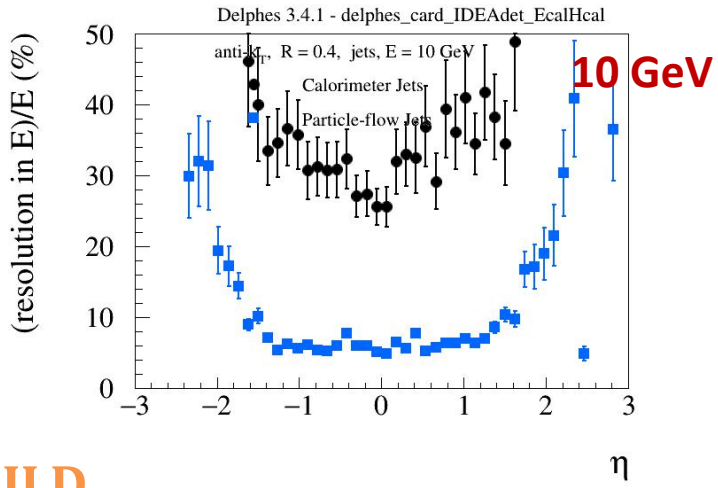


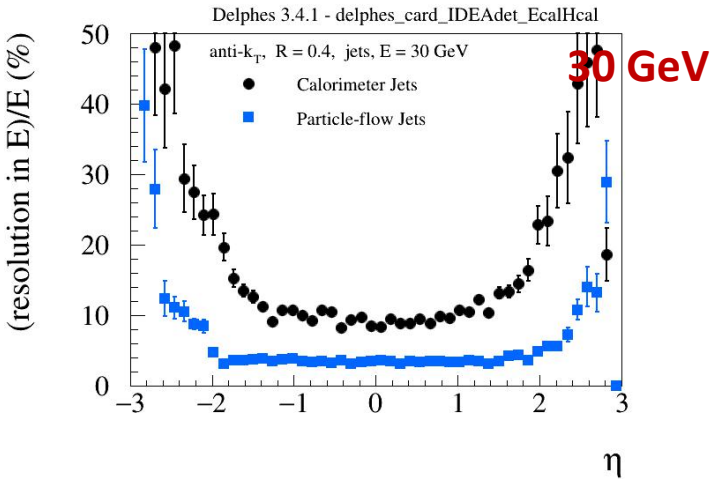
- Jets are reconstructed using the **anti-kt algorithm** requiring a **radius of 0.4**

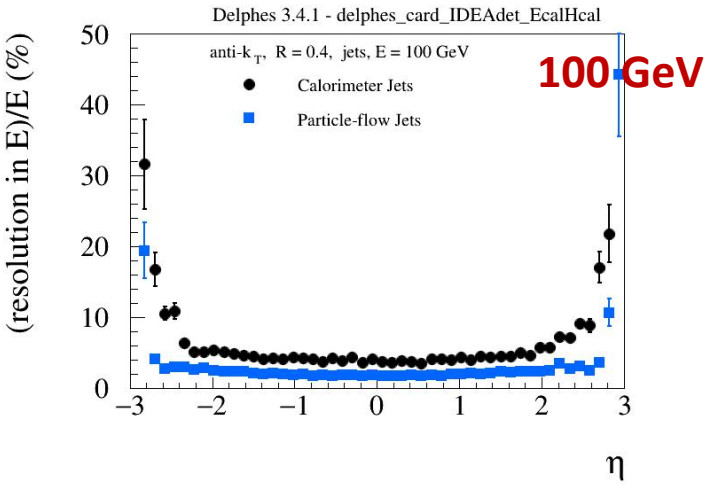
✓ Jets are reconstructed correctly both in the barrel and endcap region with a good energy resolution
✓ PF algorithm improves resolution on jets thanks to the tracker

Particle Flow Performance

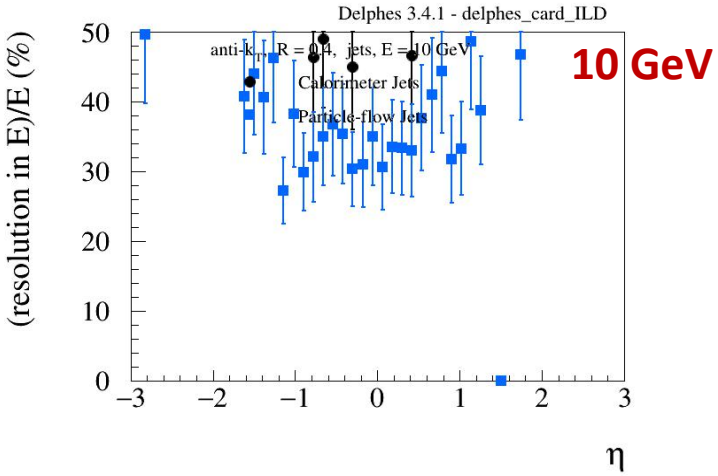
IDEA

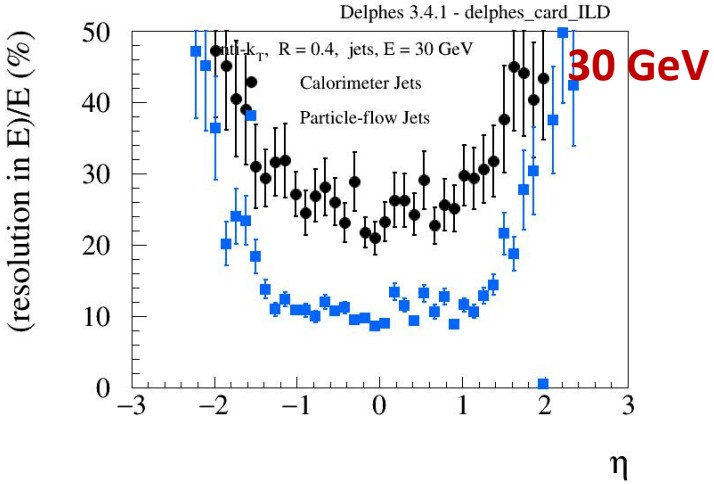


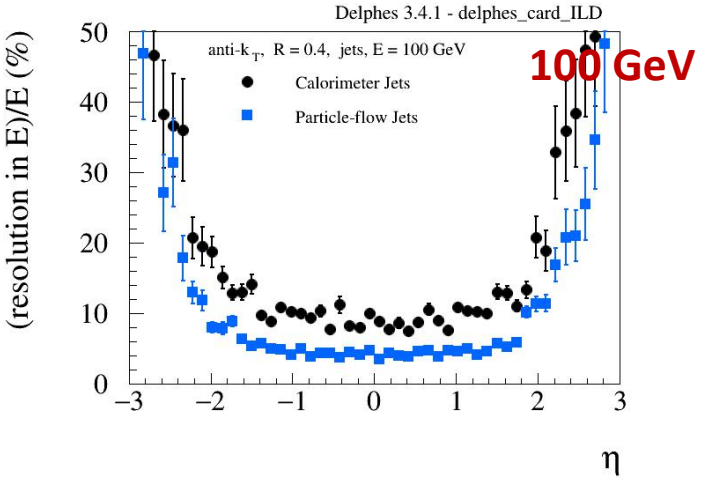




ILD

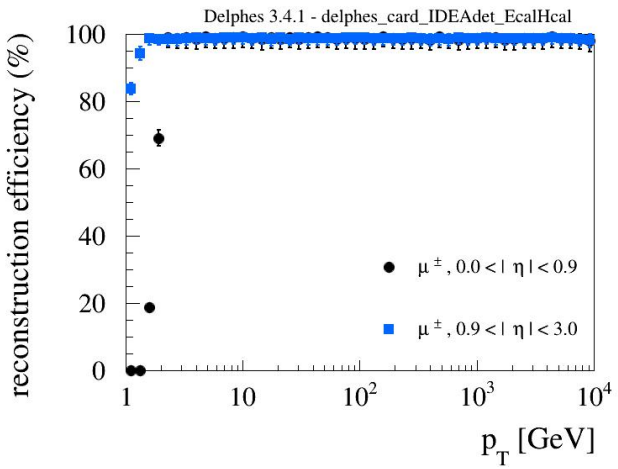




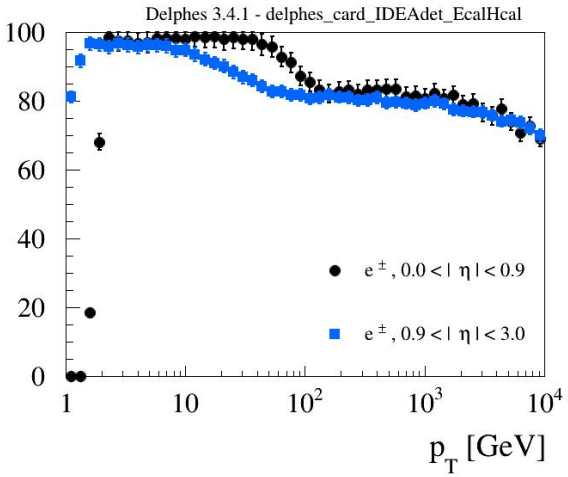


Reconstructed Objects

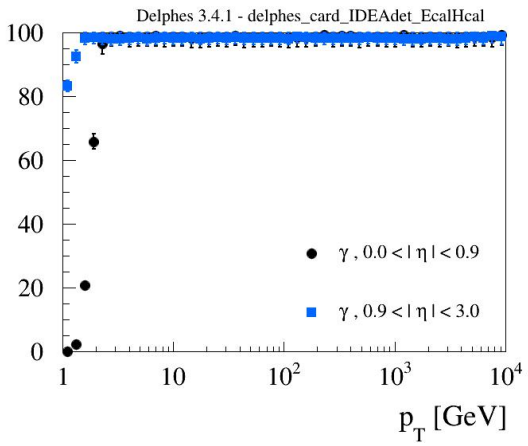
Muons



Electrons



Photons

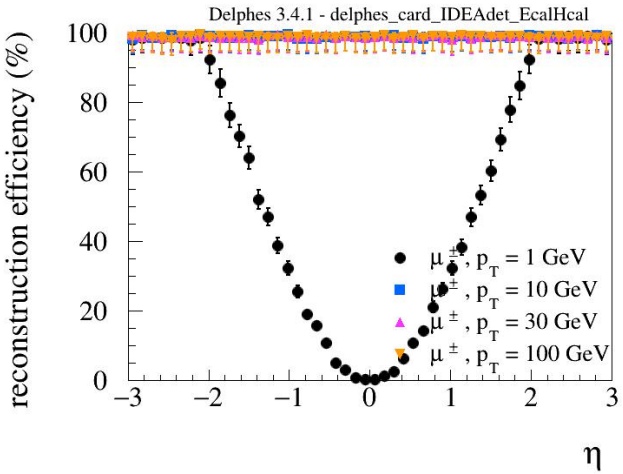


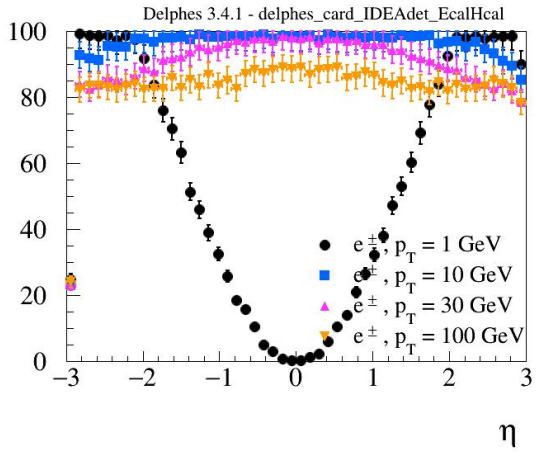
μ, e, γ

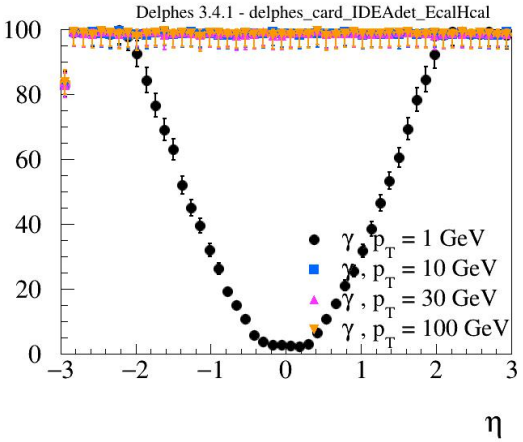
- isolated and identified with true PID
- reconstructed if they fall into the tracker coverage
- reco efficiency

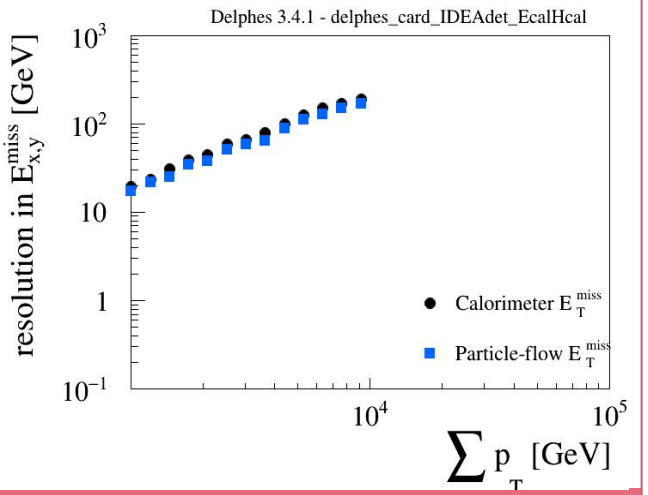
MET

calculation based on the calorimetric towers





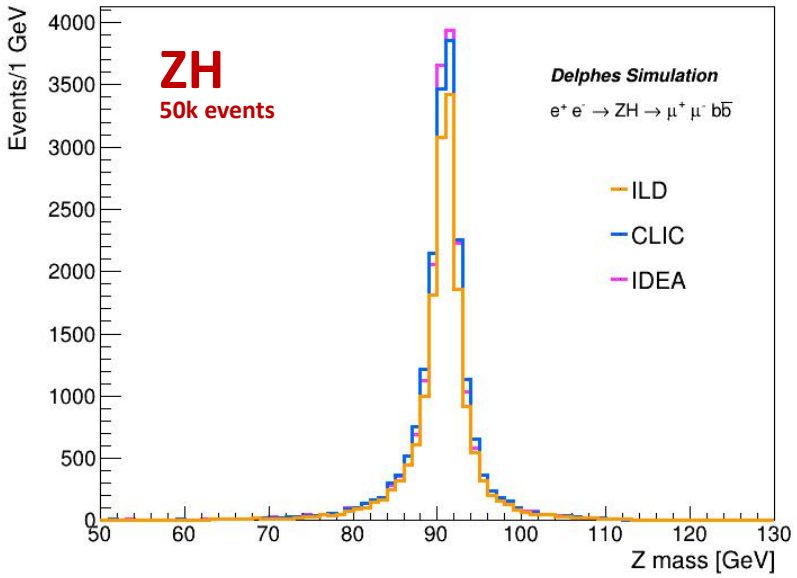


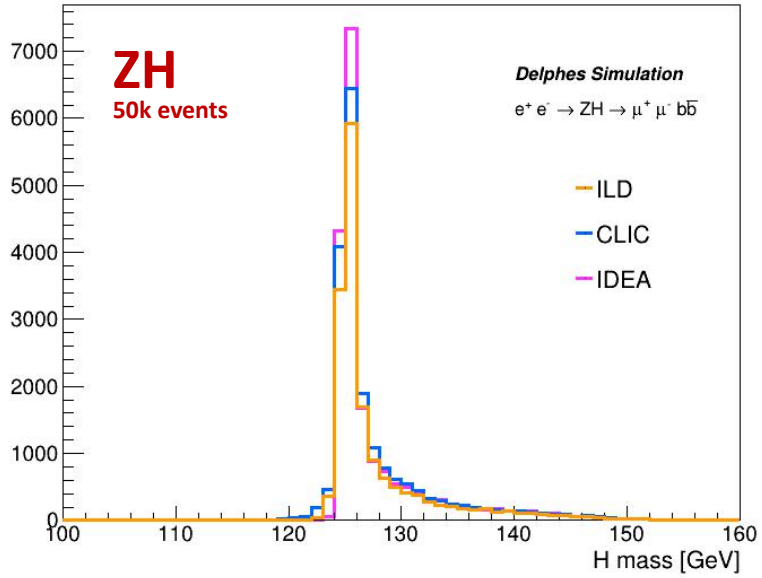


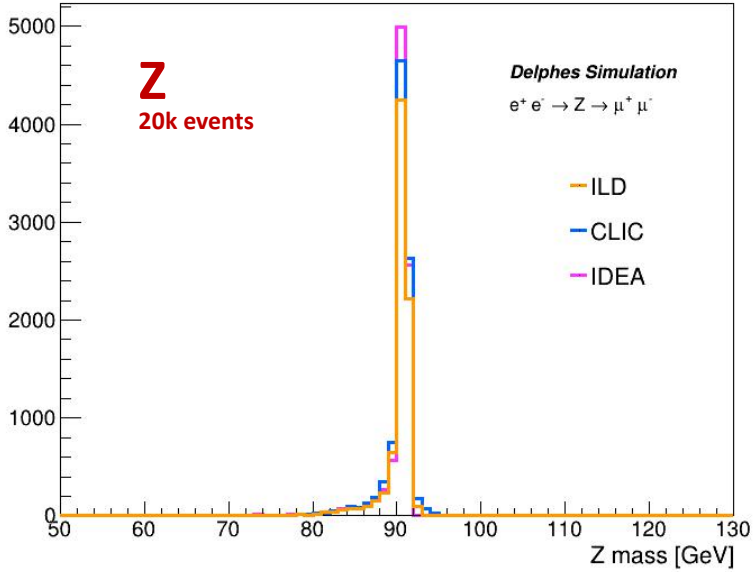
Detector comparison

IDEA configuration
until 150 mrad
$|\eta| = 2.6$

Muons







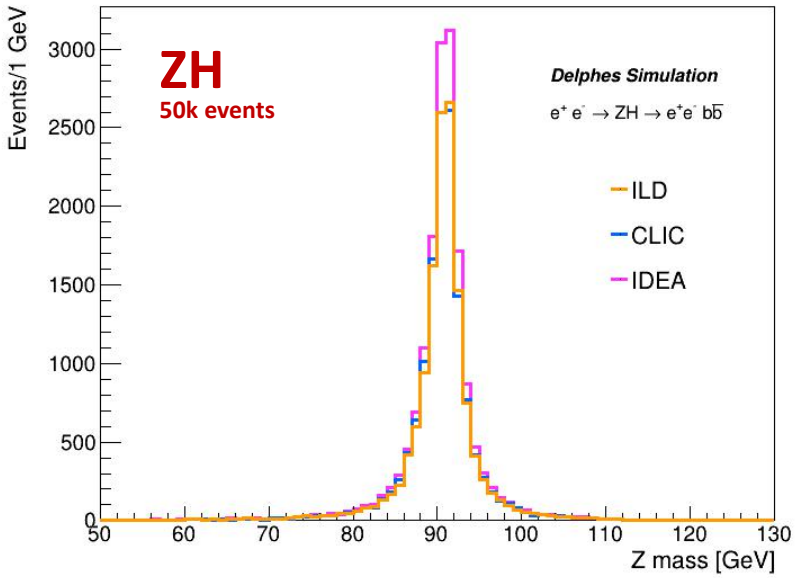
- The **Z invariant mass** and the **Higgs recoil mass** are reconstructed in a similar way by **ILD**, **CLIC** and **IDEA** detectors in the **muon final state**

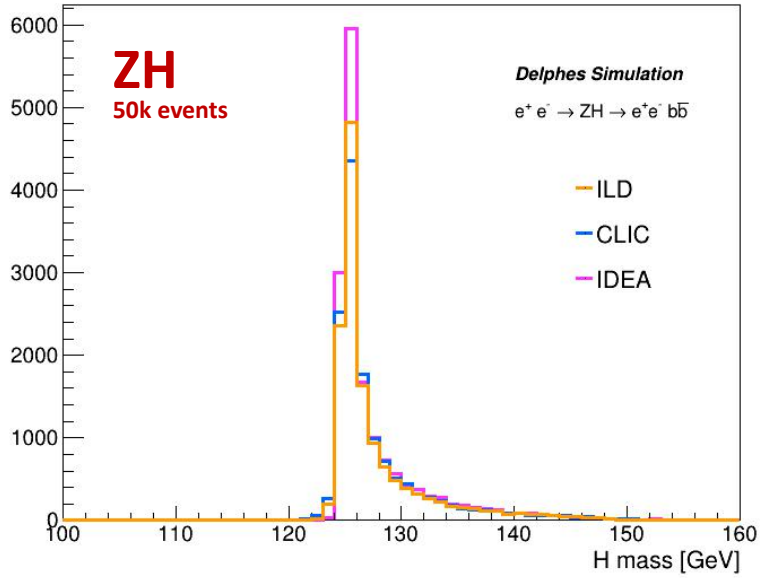
Detector	Z(μμ)H	Z(μμ)
IDEA	19191	9158
ILD	16577	8131
CLIC	19423	9471

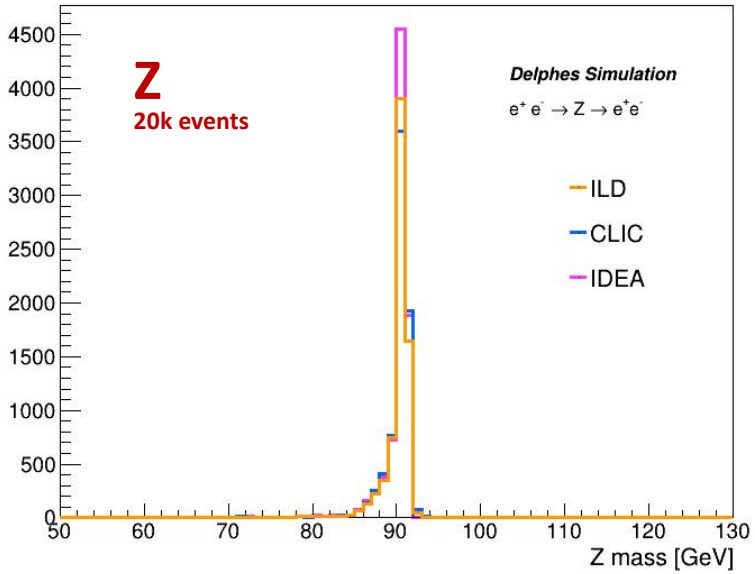
Detector comparison

IDEA configuration
until 150 mrad
$|\eta| = 2.6$

Electrons



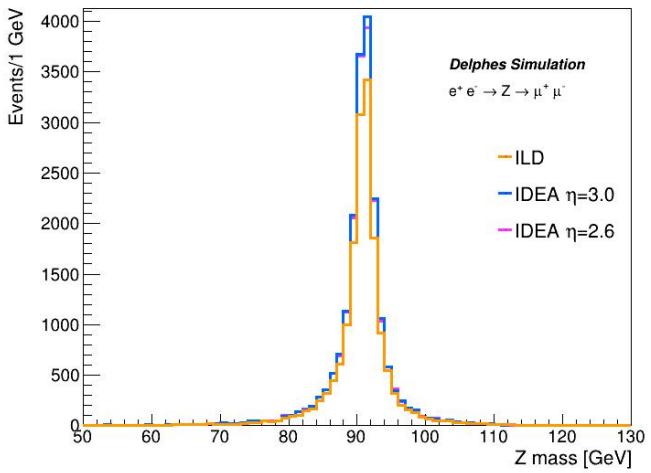




- The **reconstructed Z invariant mass** and the **Higgs recoil mass** are more different between the **IDEA** detector and **ILD** - **CLIC** in the **electron final state**: greater number of events in the mass peak

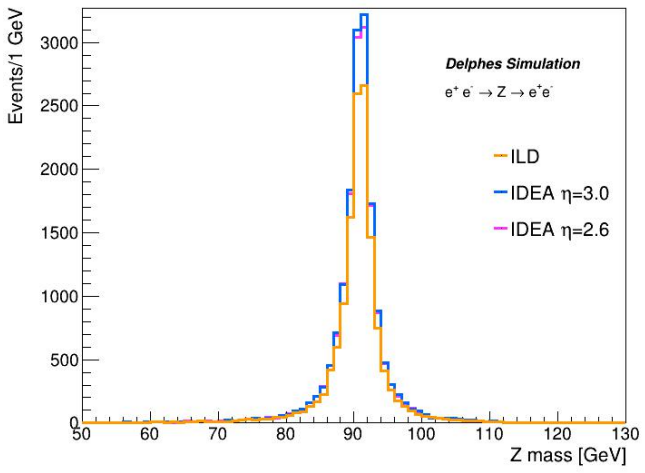
Detector	Z(ee)H	Z(ee)
IDEA	15937	8262
ILD	13673	7493
CLIC	13912	7289

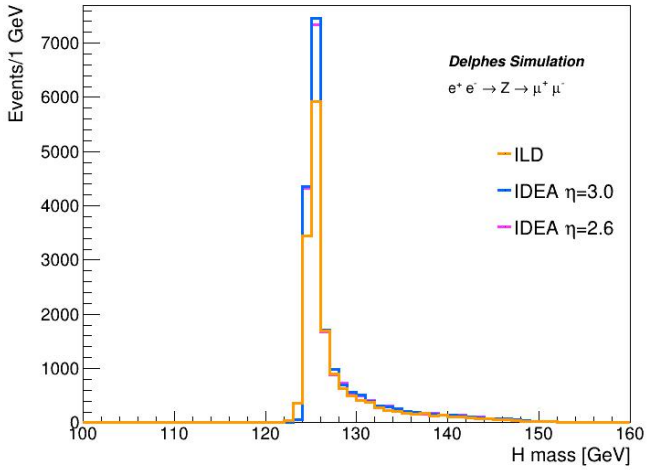
Configuration comparison



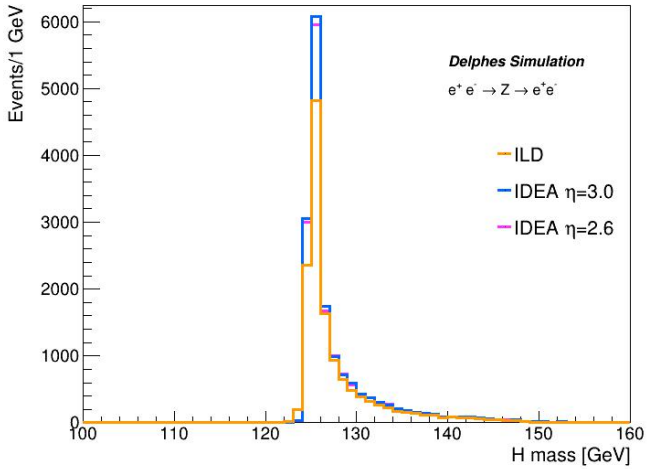
Comparison between two different configurations of the IDEA detector in two differen scenarios:

- |η| = **2.6**
- |η| = **3.0**
- REF: **ILD**





No significant improvement observed (around 1.5-2%):
need to study **proper benchmark analyses** sensible to particles at large acceptance



Conclusions & Plans

- Implementation of a **dedicated IDEA detector description** in a Delphes card
  - Focus on the **DR calorimeter** geometry and resolution
  - Preliminary **Tracker** description
- **Validation** of the card in comparison with the ILD detector description
  - checked the correct work flow of the card, efficiency and resolution of the subdetectors, object reconstruction
- **Comparison between different detector performance in basic analyses**
  - similar performance in muon final states
  - improvement in electron final states
- **Extension of the angular coverage of the detector to 100 mrad**
  - no significant improvement observed; need to study proper benchmark analyses.

TO DO:

- Implement a precise tracker performance description
  - overall efficiency and transverse momentum resolution considering all the sub-detectors
- Study more in detail object reconstruction and related algorithms
  (lepton isolation, jet reconstruction, b-tagging, τ-tagging, ...)

GOAL: Provide a complete card to perform physics analyses in order to study the IDEA detector performance and capabilities

Thank you for your attention

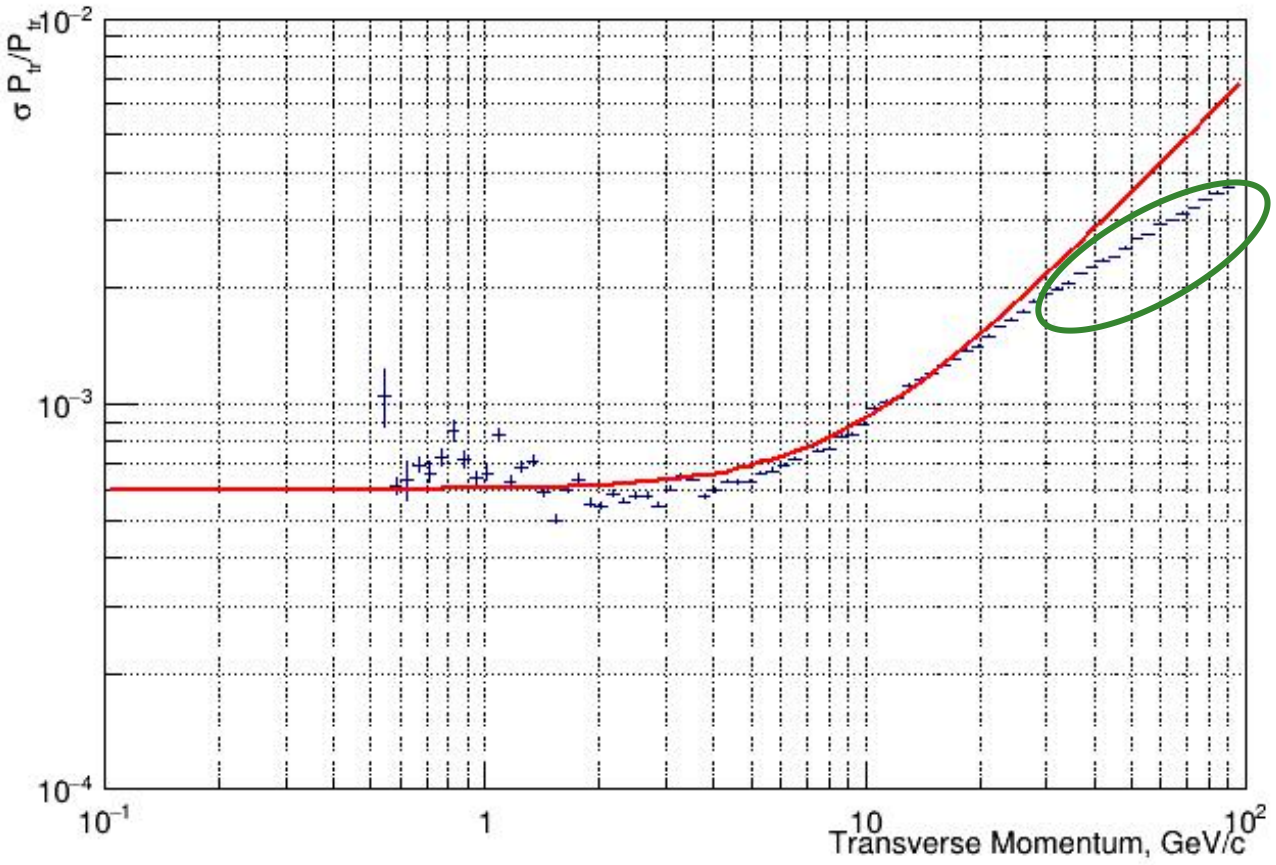
A special thanks to Michele Selvaggi for his help

BACKUP

Preliminary

Tracker

Transverse Momentum Resolution



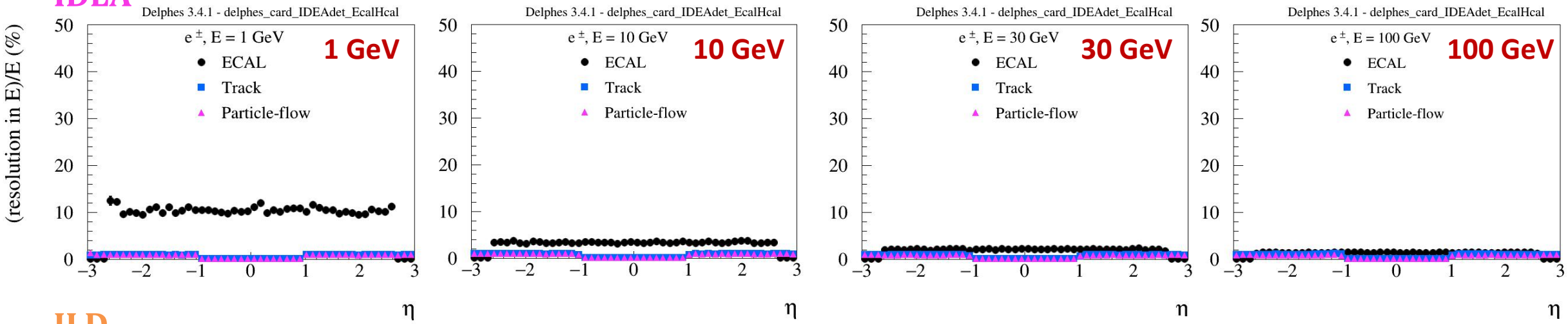
Effect given by the implementation of the other tracking sub-detectors in the Full Simulation.

For now the red fit has been implemented as Transverse Momentum Resolution parametrization in Delphes.

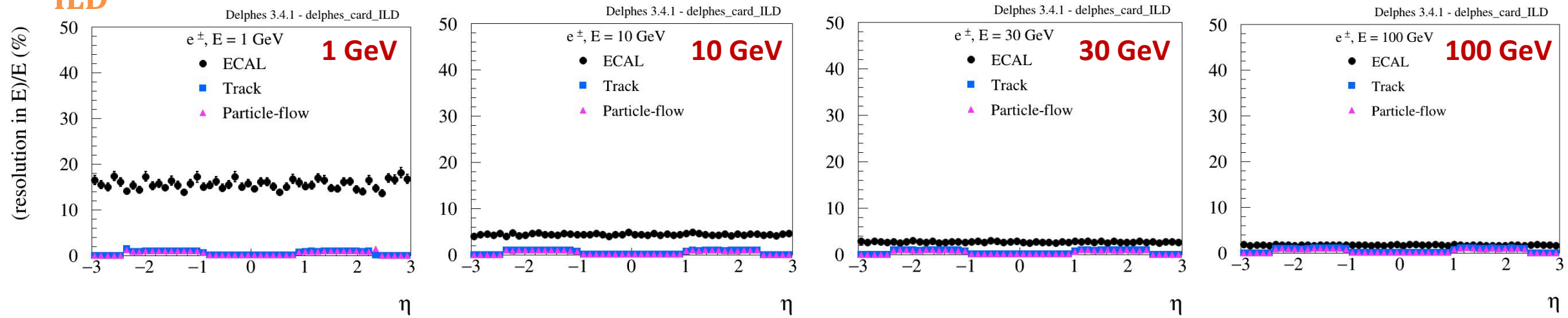
Validation

Particle Flow Performance

IDEA

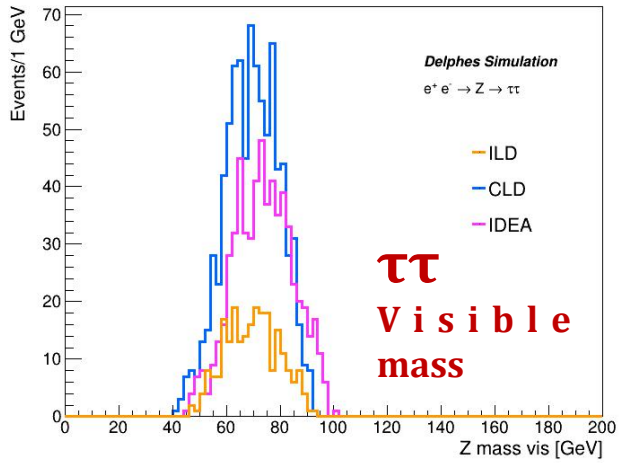


ILD



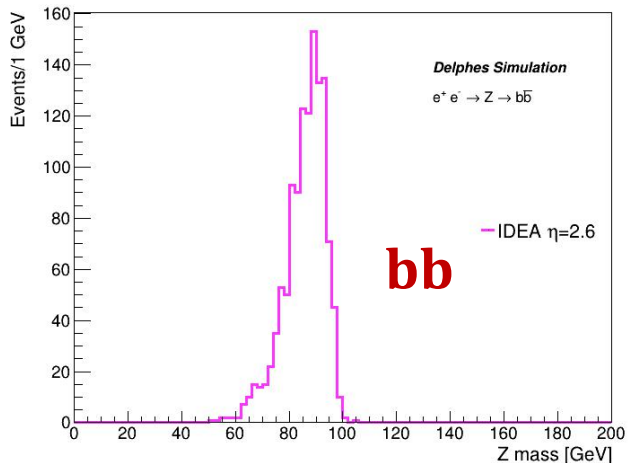
Preliminary

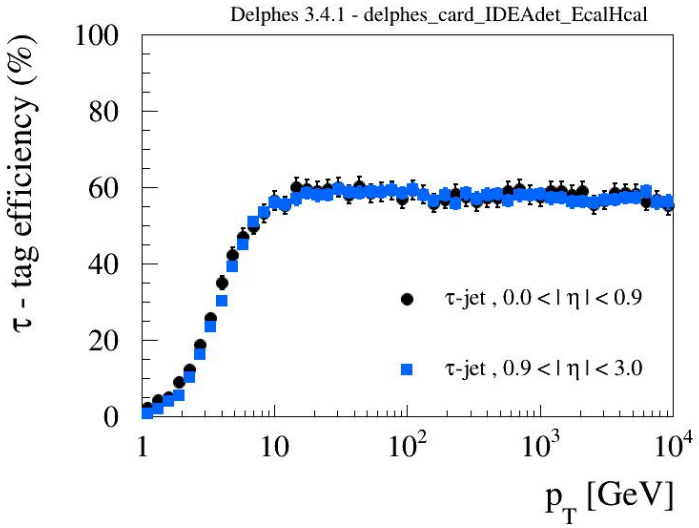
Reconstructed jets



Attempt to reconstruct the Z invariant mass in **final states with jets**:

- need to optimize the tagging algorithms (basic form)
- need to perform a targeted event selection (not so easy as with leptons)





- BUT the reconstructed objects are available