STATUS OF IDEA SOFTWARE FOR SIMULATION AND RECONSTRUCTION

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ON BEHALF OF THE IDEA SOFTWARE GROUP

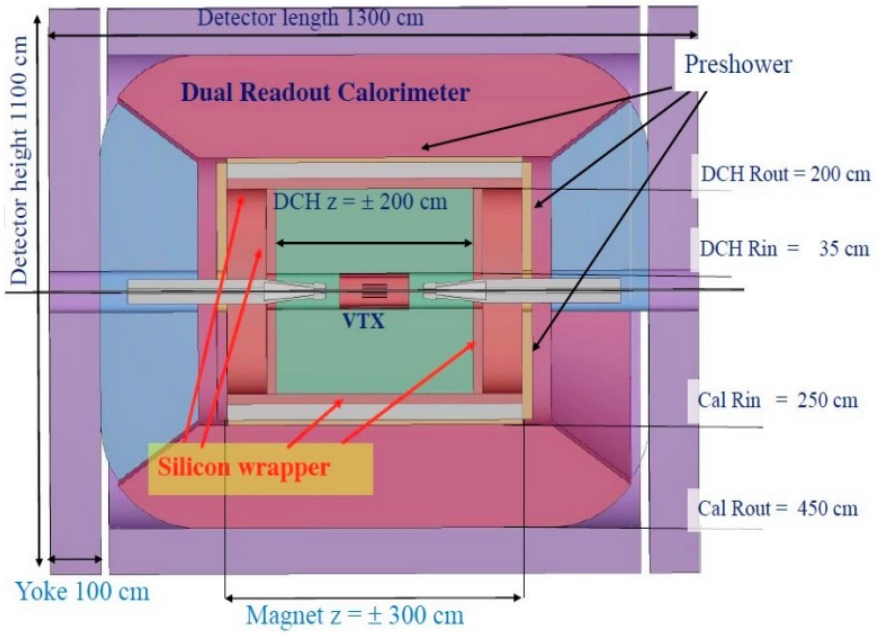
THE 2022 INTERNATIONAL WORKSHOP
ON THE HIGH ENERGY CIRCULAR ELECTRON POSITRON COLLIDER
2022/10/24–28, NANJING, PRC

IDEA SPECTROMETER

Innovative **D**etector for **E**lectron–positron **A**ccelerator

Subsystems

- silicon vertex tracker (pixel)
- light drift chamber (wire, He:iC4H10 90:10)
- silicon wrapper (micro–strip)
- superconducting solenoid (2T, low mass)
- pre-shower (μRWELL)
- dual–readout calorimeter (scintillation+Čerenkov)
- muon chambers (μRWELL)

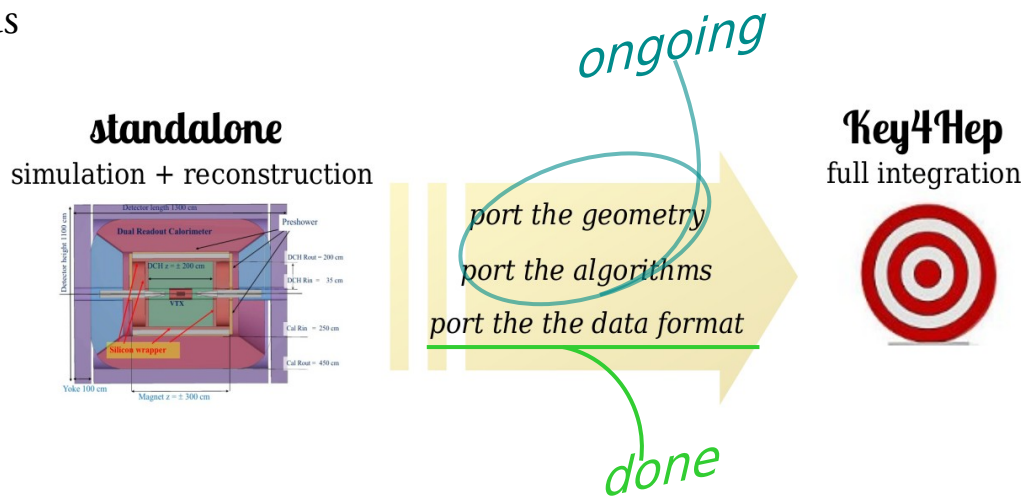


IDEA detector concept is proposed both to C*ep*C and to FCC–*ee*

INTEGRATION INTO FRAMEWORK

GEANT4 STANDALONE CODE @ HTTPS://GITHUB.COM/HEP-FCC/IDEADETECTORSIM

- adapted for compilation **on Key4hep stack**
- works with the latest Key4hep stack on CERN lxplus machine
- easy installation through bash script
- run instructions in the README
- **fully interfaced to Key4Hep through EDM4Hep**
  - DR calo hit
  - tracker hits
  - tracks reconstructed with ROME code
    [M. Schneebeli et al, ROME - A universally applicable analysis framework generator, proc. CHEP06]

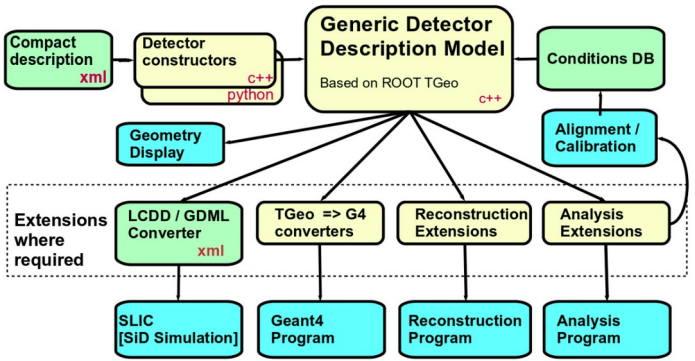


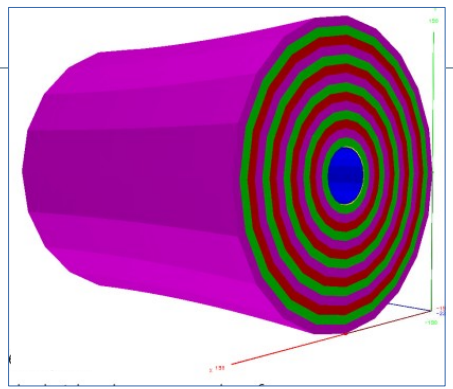
DD4HEP GEOMETRY

SINGLE SOURCE OF DETECTOR INFORMATION TO PERFORM **ALL DATA PROCESSING APPLICATIONS** (SIMULATION, RECONSTRUCTION, ONLINE TRIGGER AND DATA ANALYSIS)

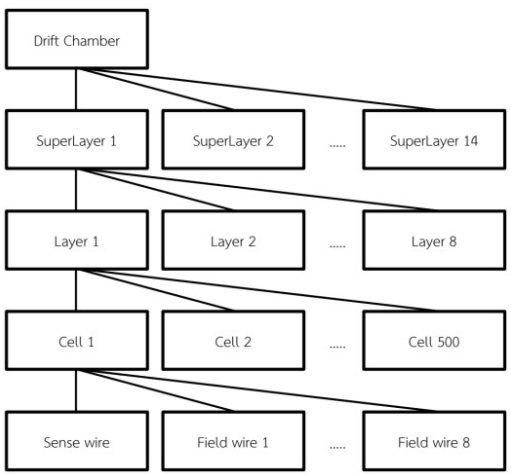
IDEA DD4Hep geometry description

- DR calorimeter already available
- **New! Drift Chamber available**

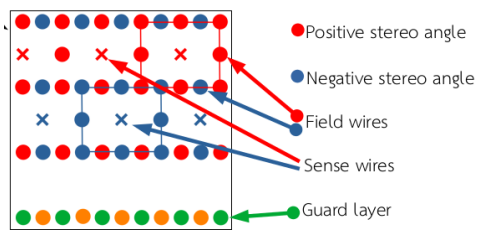




basic volume (super–layer) = hyperboloid with given radius and stereo angles, containing all wire cells @ given radius

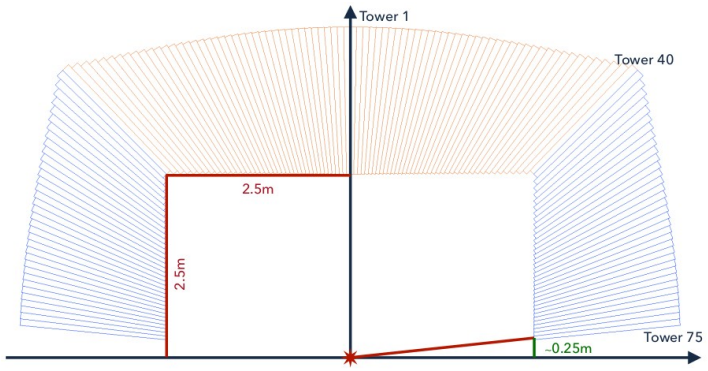


14 SuperLayers
- hyperboloid volumes made of gas
- each contains 8 layers
- one layer = one row of cells



FIBER DUAL READOUT CALORIMETER

Simultaneous measurement of
- **Sintillation** signal
- **Čerenkov** signal



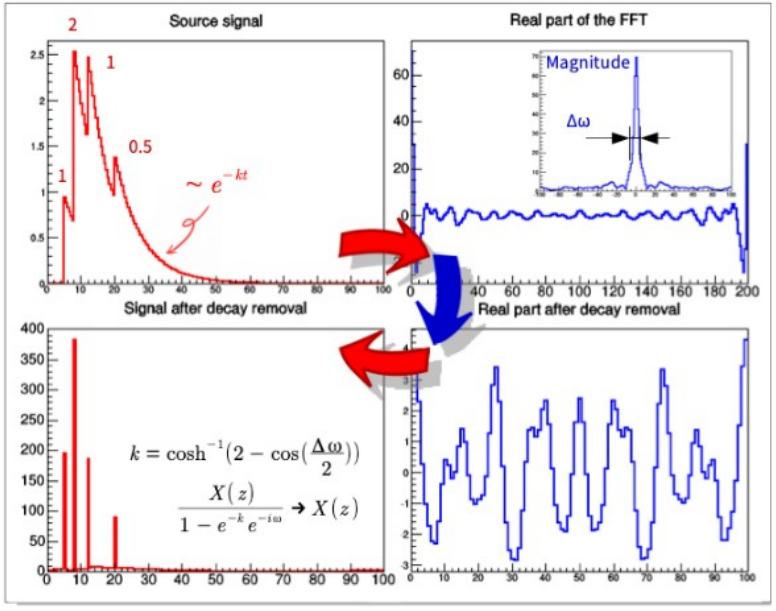
Benchmark implementation
- 5400 towers ($\Delta\vartheta = 1.125°$, $\Delta\phi = 10.0°$)
- inner radius: 2.5 m
- outer radius: 4.5 m @ 90°
- 36 rotations around beam axis

From simulation, energy resolution:
- 10% – 15 % / √E electromagnetic
- 25% – 30 % / √E single hadrons (also neutrals)
- 5 % jets @ 50 GeV

GEANT4
- Cu absorber, 1 mm fibers, 1.5 mm pitch
- full simulation including drift chamber and solenoidal magnetic field available
- already based on EDM4hep

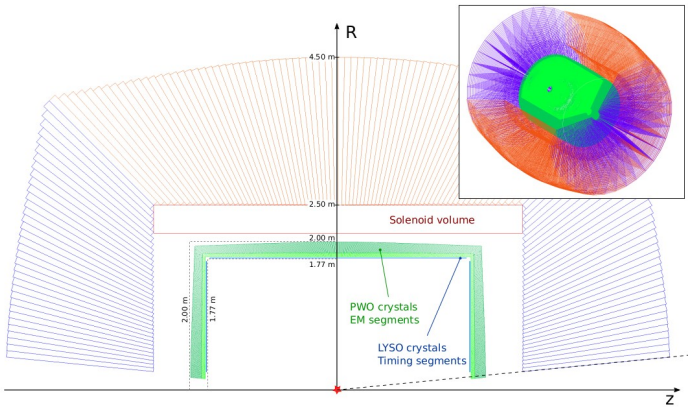
Longitudinal segmentation via timing
- Possible, if full signal is readout by SiPM sampled at 10 GHz.

→ SiPM response integrated in simulation/digitization output



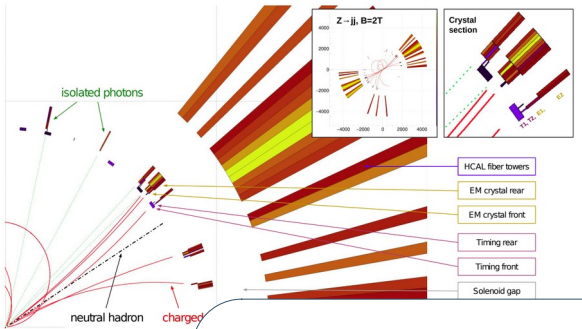
CRYSTAL ECAL + FIBER HCAL OPTION

INCLUDE CRYSTAL ECAL IN FRONT OF DRCALO FOR HIGH RESOLUTION ON EM COMPONENT



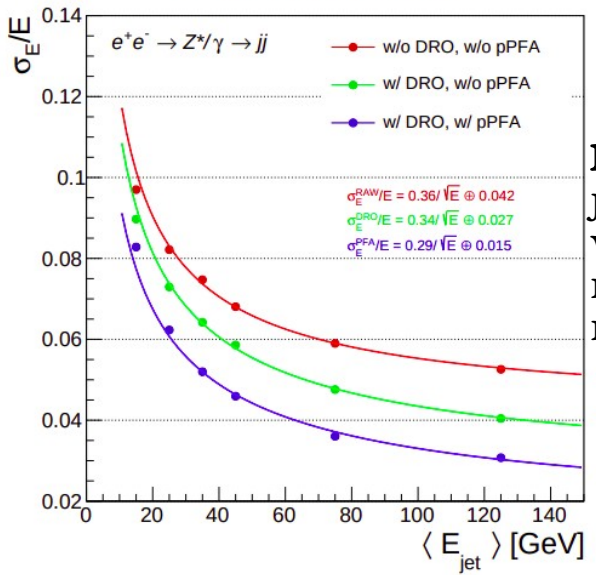
- barrel crystal section inside solenoid volume
- LYSO (timing layer)
- 2 layers of PWO (1 cm²)
- crystals readout by SiPM

From simulation, energy resolution:
- **electromagnetic → improved to 3% / √E**
- hadronic & jet → ~ unaltered w.r.t. full fiber DRcalo



- jets reconstruction via Durham Algorithm
- energy of clusters corrected with the Dual Readout (DRO) equation
- Particle Flow Algorithm reconstruction

Simulation of events: $e^+e^- \rightarrow Z / \gamma^* \rightarrow$ jet jet



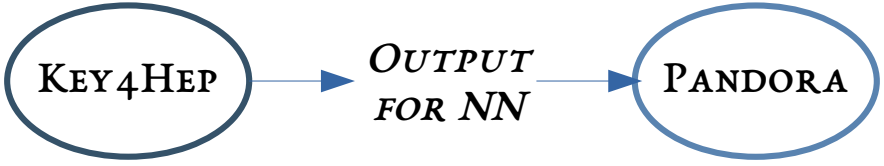
RESOLUTION ~ 3% - 4% FOR JET ENERGIES ABOVE 50 GEV, WITHIN MOST PHYSICS REQUIREMENTS AT HIGGS FACTORIES **WITH DRO & PFA**

[M.T. Lucchini]

FIBER DR CALO ➞ NEURAL NET & PARTICLE FLOW

PROJECT FOR DEVELOPMENT OF ALGORITHMS OF PARTICLE FLOW ALGORITHMS BASED ON NEURAL NETWORKS FOR JET RECONSTRUCTION IN DUAL READOUT CALORIMETERS (AIDAINNOVA)

- code @ https://github.com/HEP-FCC/IDEADetectorSIM/tree/master/ParticleFlow_k4pandora
- based on Pandora → Pandora integrated into Key4Hep succesfully & tested

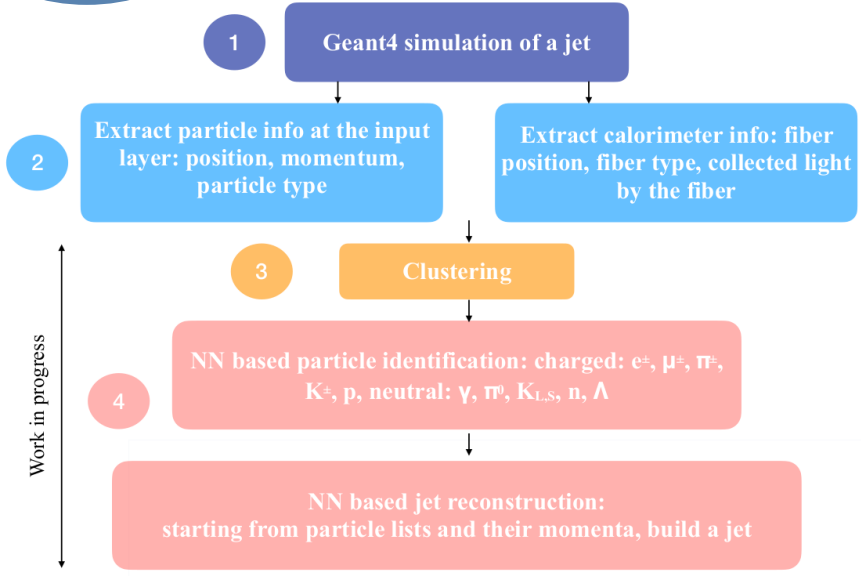


All algorithms based on NN, for:

- **clustering**
  - available algorithms, interfaced with Pandora using Torch Data format (*e.g.* cluster reconstruction of LAr TPC of DUNE)

- **particle identification**, to identify every particle in the jet
  - ML with the open–source platform Tensor Flow
  - dedicated CPU/GPU installed in Roma3 cluster

- **jet reconstruction**
  - Regression algorithms for particle–to–jet assignment & jet energy reconstruction

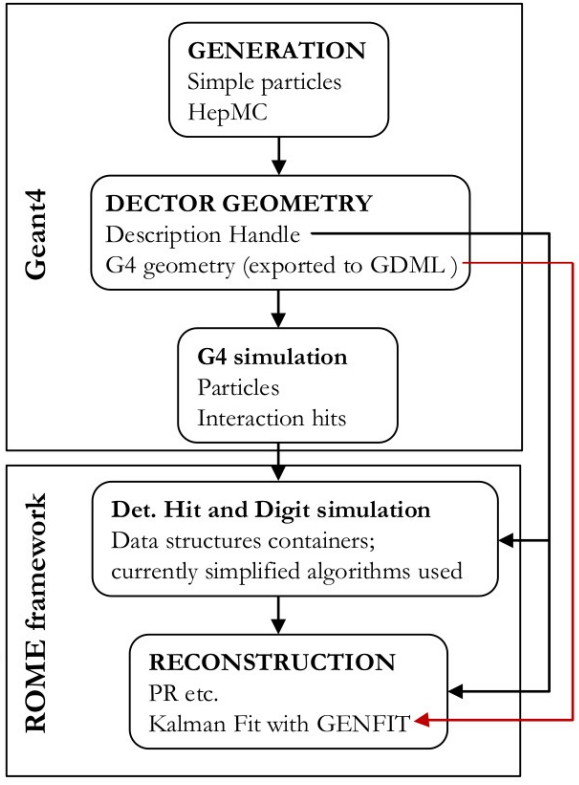


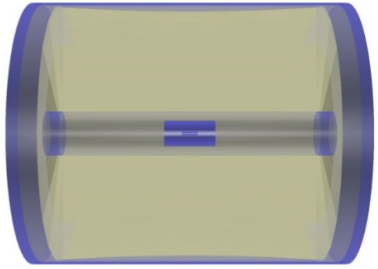
[INFN (Roma3, Pavia, Padova, Roma1) + CERN (S. Vallecorsa) + Sussex (I. Vivarelli)]

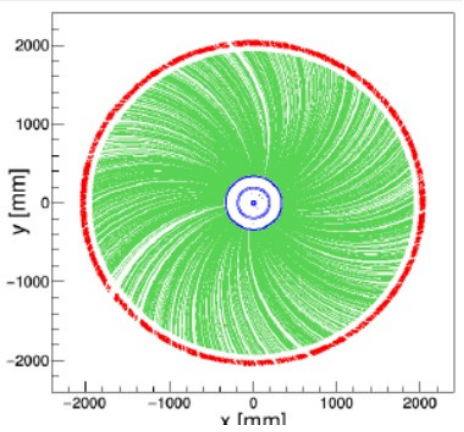
DRIFT CHAMBER & TRACKERS

DRIFT CHAMBER + SILICON VERTEX + SILICON WRAPPER + PRE-SHOWER

- Geometry implemented in GEANT4 with good level of detail
- Reconstruction with ROME framework (MEGII)
- Interfaced with Key4Hep

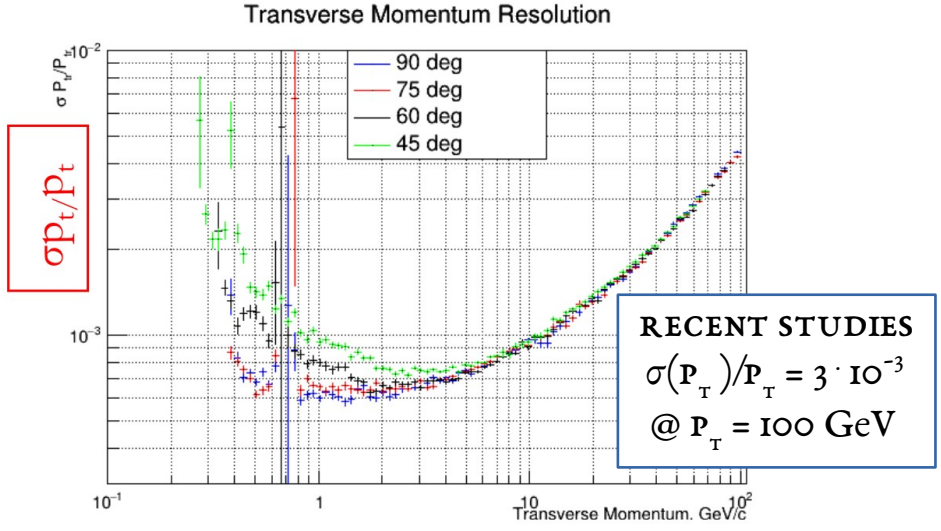






Simulation & Reconstruction

- DCH geometry includes wires and detailed description of the end-caps → simplified digitization
- Si-vertex/wrapper and pre-shower simulated as a layer of overall equivalent material → smearing hits
  - σ_{DCH} = 100 μm
  - σ_{Si} = pitch/√12 μm (conservative)



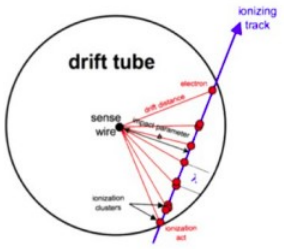
RECENT STUDIES

$\sigma(P_T)/P_T = 3 \cdot 10^{-3}$ @ P_T = 100 GeV

[GF. Tassielli, W. Elmetenawee)]

CLUSTER COUNTING IN DCH

PARTICLE IDENTIFICATION BY MEANS OF CLUSTER COUNTING TO **IMPROVE PID CAPABILITIES** BY A FACTOR 2



dE/dx RESOLUTION

$$\frac{\sigma_{dE/dx}}{dE/dx} = 0.41 \cdot n^{-0.43} \cdot \left(L\,[\mathrm{m}] \cdot p\,[\mathrm{atm}]\right)^{-0.32}$$

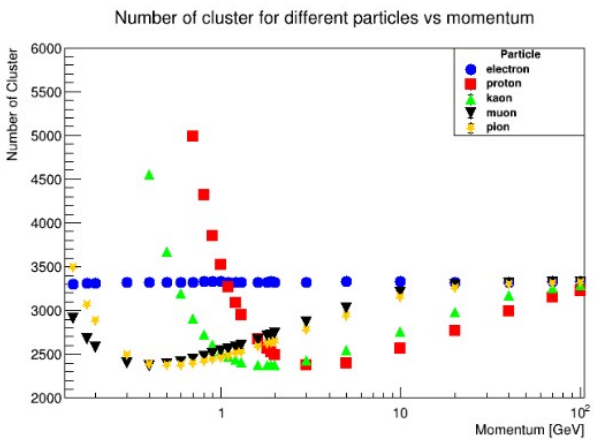
Walenta parametrization

CLUSTER COUNTING RESOLUTION

$$\frac{\sigma_{dN_{CL}/dx}}{dN_{CL}/dx} = \frac{1}{\sqrt{\rho_{CL} \cdot L}}$**

Poisson statistics

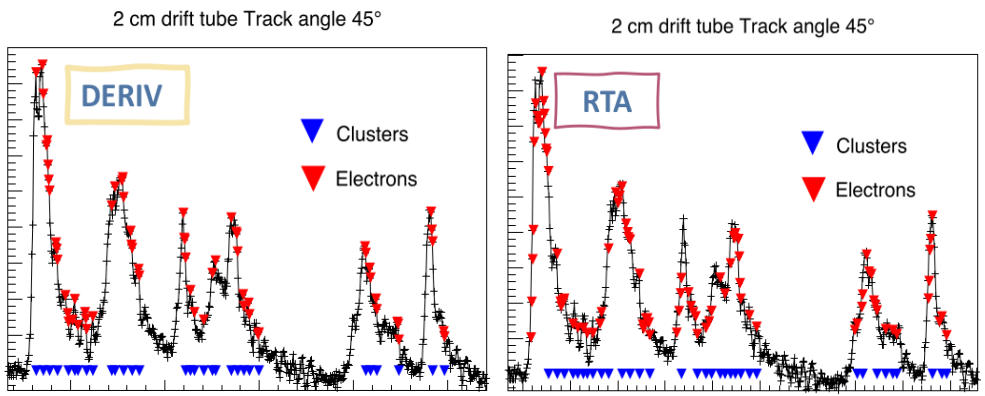
Simulation with GEANT4 and GARFIELD++ to associate energy loss to number of clusters → add electronics → simulate signals



Reconstruction of e^- peaks in the signal via 2 algo:

DERIV = 1st and 2nd derivatives

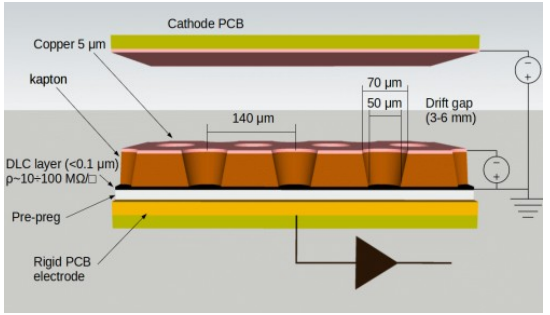
RTA = running template algorithm

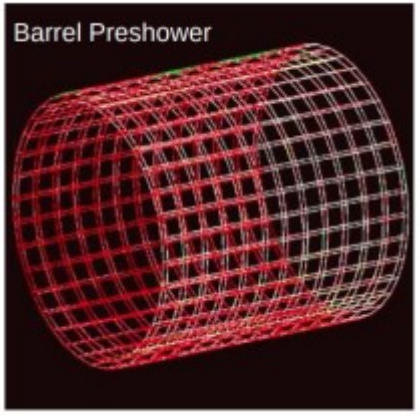


[F. Cuna, B. D'Anzi, F. Grancagnolo, N. De Filippis]

PRE–SHOWER & MUON COUNTERS

- BOTH BASED ON μRWELL TECHNOLOGY
- PRE–SHOWER → BETWEEN THE SOLENOID AND THE DRCALO
- MUON CHAMBERS → THREE LAYERS IN THE MAGNET RETURN YOKE

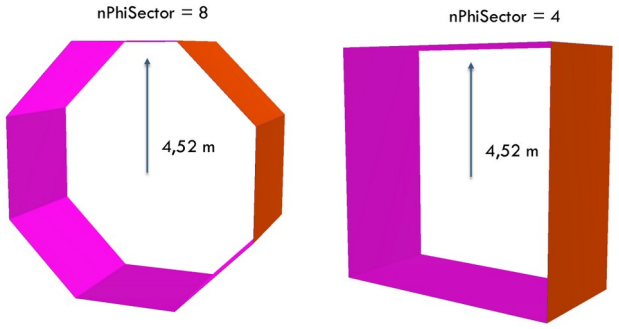




Pre–shower

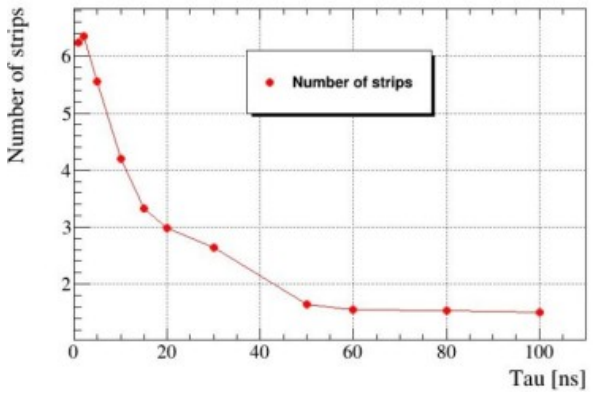
- implemented as a cylinder
- hits are smeared

```
vector<double> muspc.Brl.LayersInRad     = {4520};  //mm
```



Muon chambers

- **now in the official framework**
- one layer completed, two to go
- material stratification implemented



Digitization

- standalone code (PARSIFAL) [LL, R. Farinelli]

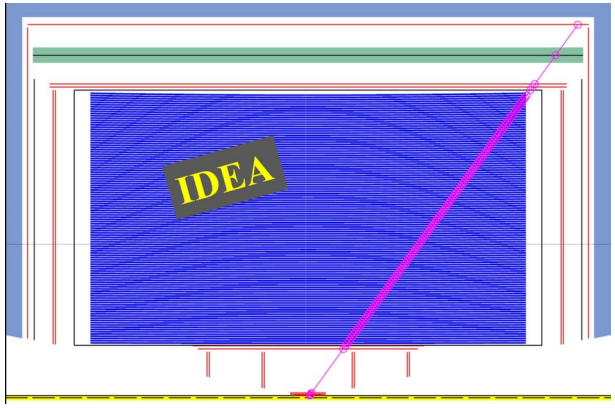
[I. Garzia, GF. Tassielli, E. Fontanesi]

DELPHES

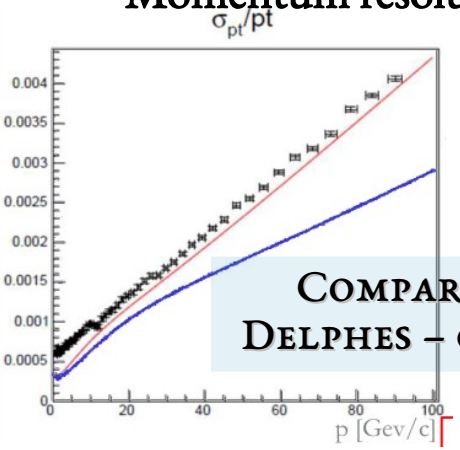
FRAMEWORK FOR **FAST SIMULATION** OF THE RESPONSE OF A FULL DETECTOR IN A **PARAMETERIZED** WAY

IDEA card available → IDEA detector fully implemented in DELPHES

Modules
- tracking & vertexing
- timing
- PID information via dE/dx
- PID information via cluster counting



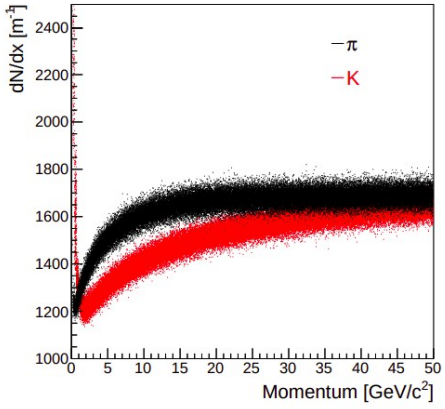
Momentum resolution

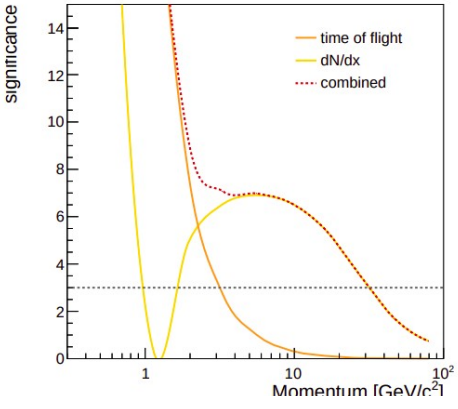


full simulation
DELPHES with Si resolution as full sim
DELPHES with a more realistic Si resolution

COMPARISON DELPHES – GEANT4

K/π separation power dE/dx





[F. Bedeschi, F. Cuna]

NEXT FUTURE

Grid Infrastructure

- Virtual Organization created for FCC
  Admin: G. Ganis
- Setup (user interface, computing element, storage) for FCC Virtual Organization @
  - T1 CNAF
  - T2 ReCaS Bari
- Disk space on the storage @ CNAF = 100 TB
  - TB2021 and TB2022 for DCH (@ CERN)
  - TB2022 for DRCalo (@ DESY & CERN)

Forecast for 2023

- Preliminary full simulation & reconstruction of IDEA by Fall 2023
  - Inside Key4hep and with tools provided by it (ACTS, Pandora ...)
- Organization of hands–on tutorial/school for physics analyses & software
- Group growing as the software becomes more mature and easier to use

THANK YOU FOR THE ATTENTION

... and thanks to the software experts who contributed to this talk