Status of the IDEA Drift Chamber software

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Physics requirements: Higgs, EWK and Heavy Flavour

- **Tracking:**
  - Momentum resolution for Z recoil (and $H \rightarrow \mu\mu$)
    - Comparatively low momenta involved → transparency is important
  - Vertex resolution/transparency to separate g, c, b, τ final states
- **Calorimetry:**
  - Jet-jet invariant mass resolution to separate W, Z, H in 2 jets
  - Good π^0 ID for τ and HF reconstruction

Higgs boson sector

- **EWK:**
  - Extreme definition of detector acceptance
  - Extreme EM resolution (crystals) under study
    - Improved π^0 reconstruction
    - Physics with radiative return
- **Heavy Flavour:**
  - PID to accurately classify final states and flavor tagging

EWK and Heavy Flavour

The IDEA detector at e^+e^- colliders (1)

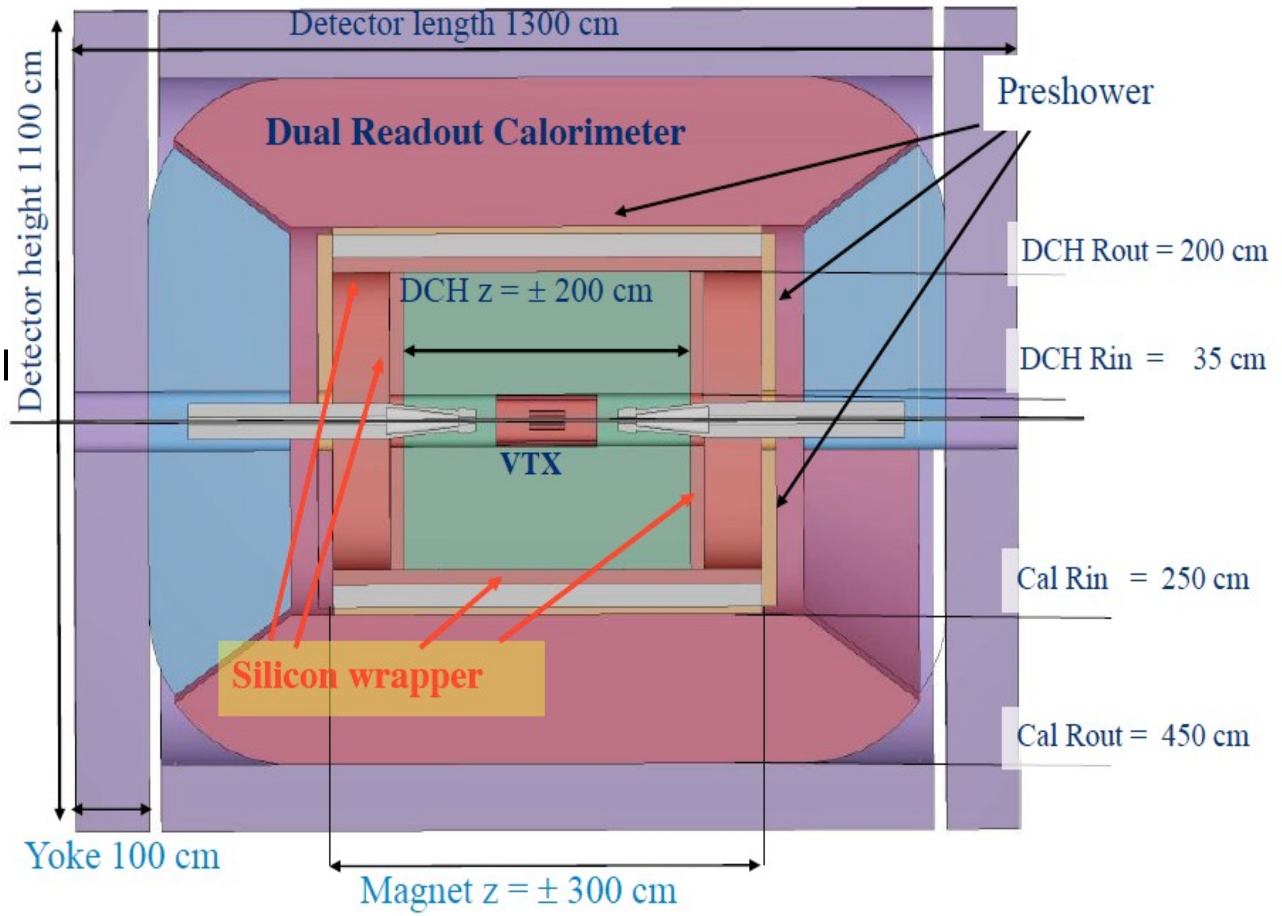
Innovative Detector for E+e- Accelerator

FCC-ea at CERN

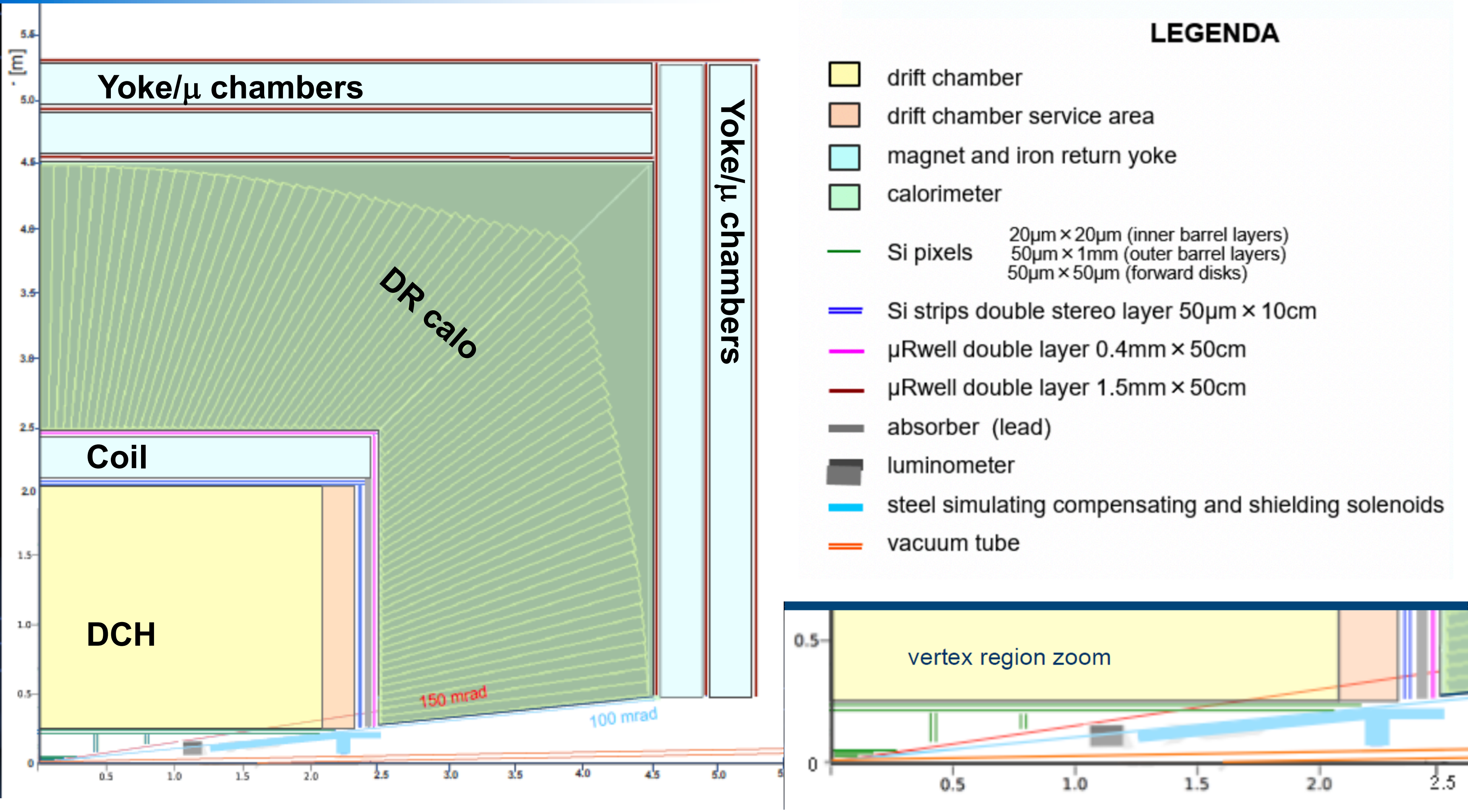
IDEA consists of:

- a silicon pixel vertex detector
- a large-volume extremely-light drift wire chamber
- surrounded by a layer of layer of silicon micro-strip detectors
- a thin low-mass superconducting solenoid coil
- a preshower detector
- a dual read-out calorimeter
- muon chambers inside the magnet return yoke

Low field detector solenoid to maximize luminosity
→ optimized at 2 T

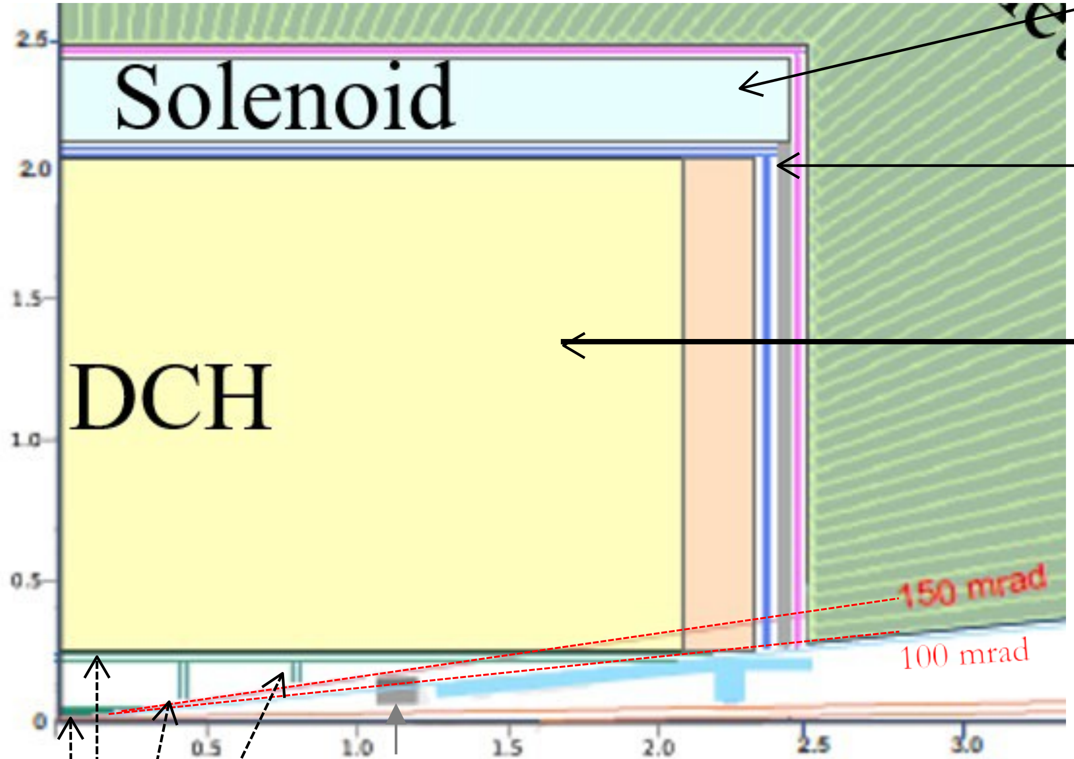


The IDEA detector at e^+e^- colliders (2)



Tracking → 150 mrad → No material in front of luminometer
Calorimetry → 100 mrad

The IDEA tracking system



Solenoid: 2 T, length = 5 m, r = 2.1-2.4 m, 0.74 X_0, 0.16 λ @ 90º

Si Wrapper:
2 layers of μ-strips (50 μm x 1 mm) both barrel and forward regions

DCH: 56448 (~1.2 cm) cells
He based gas mixture (90% He – 10% i-C_4H_{10})

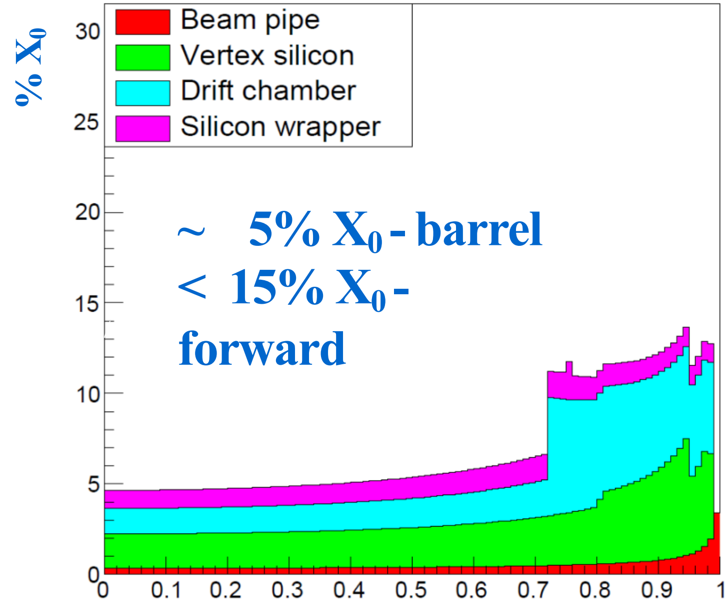
Vertex:

inner: 3 single Si pixel (20 μm x 20 μm) layers of 0.3% X_0

outer: 2 single Si pixel (50 μm x 50 μm) layers of 0.5% X_0

forward: 4 single Si pixel (50 μm x 50 μm) layers of 0.3% X_0

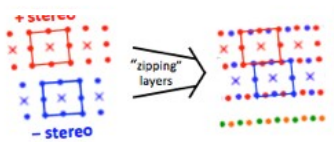
IDEA: Material vs. cos(θ)

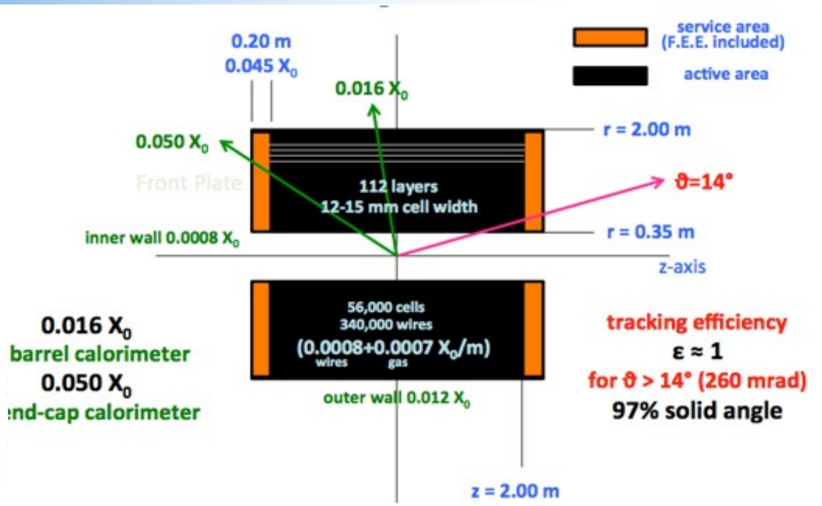


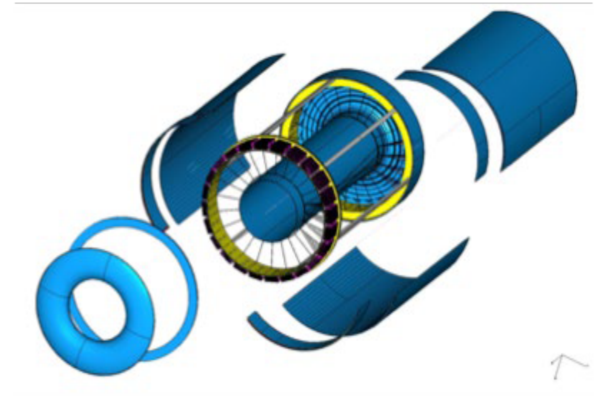
~ 5% X_0 - barrel
< 15% X_0 - forward

Design guideline: the Drift Chamber

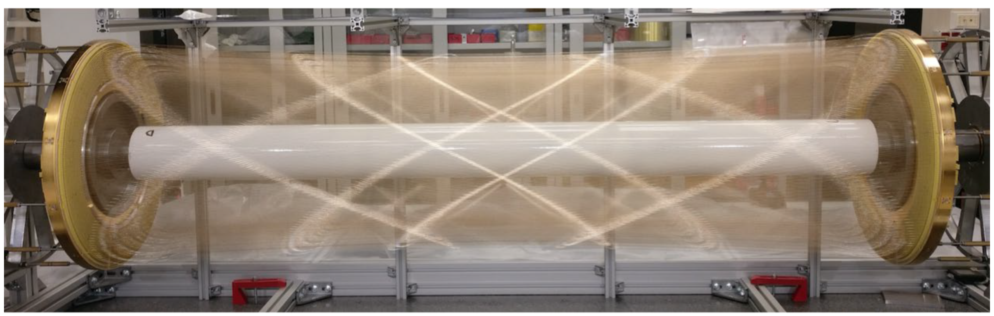
Drift Chamber







New concept of construction allows to reduce material to ≈ 10^{-3} X_0 for the barrel and to a few x 10^{-2} X_0 for the end-plates.



The wire net created by the combination of + and – orientation generates a more uniform equipotential surface

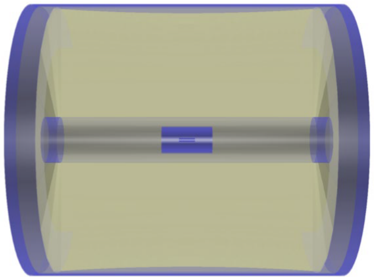
sense wires:	20 mm diameter W(Au) =>	56448 wires
field wires:	40 mm diameter Al(Ag) =>	229056 wires
f. and g. wires:	50 mm diameter Al(Ag) =>	58464 wires
	343968 wires in total	

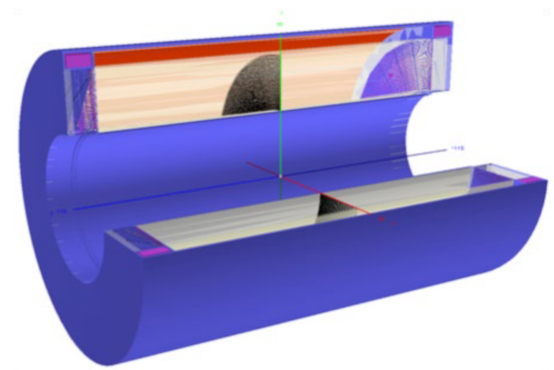
- High wire number requires a non standard wiring procedure and needs a feed-through-less wiring system.
- A novel wiring procedure developed for the construction of the ultra-light MEG-II drift chamber

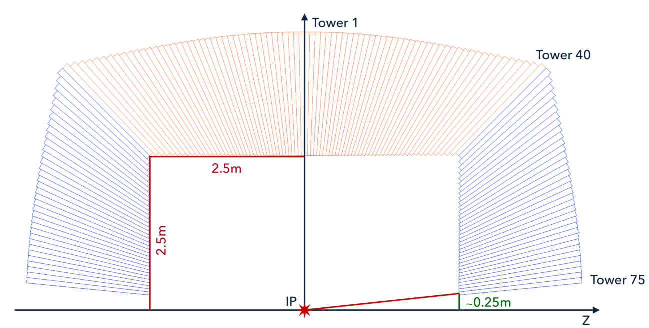
Geant4 full simulation of IDEA

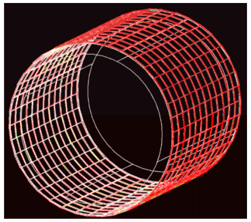
A full standalone geant4 simulation of the IDEA **Silicon Vertex (and Si wrapper), DriftChamber, DR Calorimeter (and Muon)**

- The DCH is simulated at a good level of geometry details, including detailed description of the endcaps; hit creation and track reconstruction code available
- SVX and Si wrapper are simulated as simple layer or overall equivalent material
- Dual readout calorimenter simulated with geant4 too
  - Towers are trapezoidal physical volumes with slightly different shapes changing with θ.
  - Fibers are 1mm diameter tubes, 0.5 mm of absorber material (copper) between two adjacent
  - → 130 milion fiber for the whole IDEA detector
- Muon detector





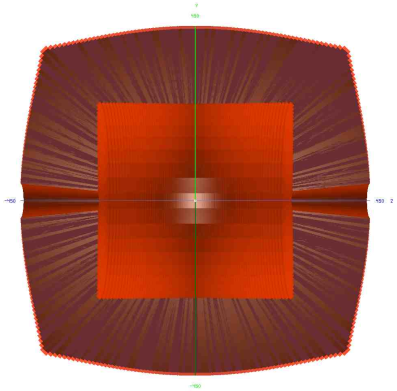




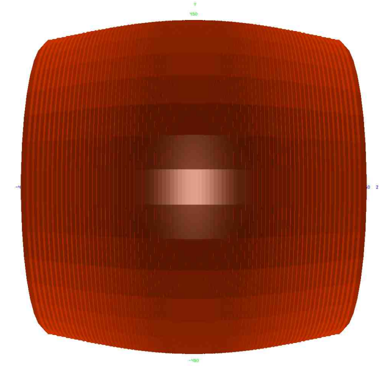
Integration of all the detectors on going

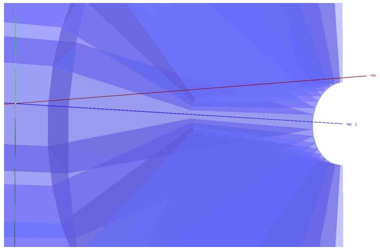
Integration of DCH and DR calo volumes

- **Standalone code for Drift Chamber already developed**
- **geometry of the dual readout calorimeter (courtesy of L. Pezzotti) adapted to cope with DCH geant4 framework :**
  - Towers are G4Trap() physical volumes with slightly different shapes changing with θ.
  - Fibers are 1mm diameter G4Tubs(), 0.5 mm of absorber material (copper) between two adjacent fibers is considered.
  - Barrel Inner length: 5m - Outer diameter: 9 m @ 90° .
  - 2 m long coper based towers: ~ 8.2 λ
  - 36 rotation around z axis
  - Number of Towers in the barrel: 40 × 2 × 36= 2880
  - Number of Towers in per endcap: 35 × 36= 1260



Calorimeter mother volume

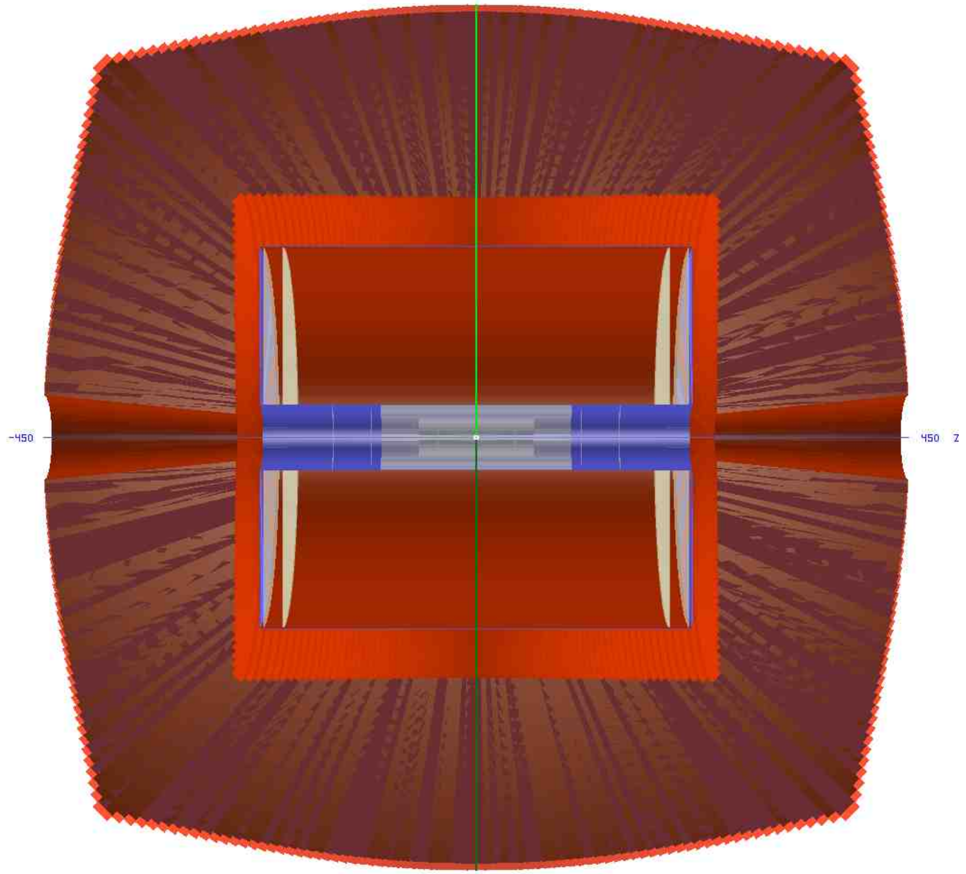




Code in: https://github.com/welmeten/DriftChamberPLUSVertex/tree/master

Integration of DCH and DR calo volumes

(calorimeter + Drift chamber)

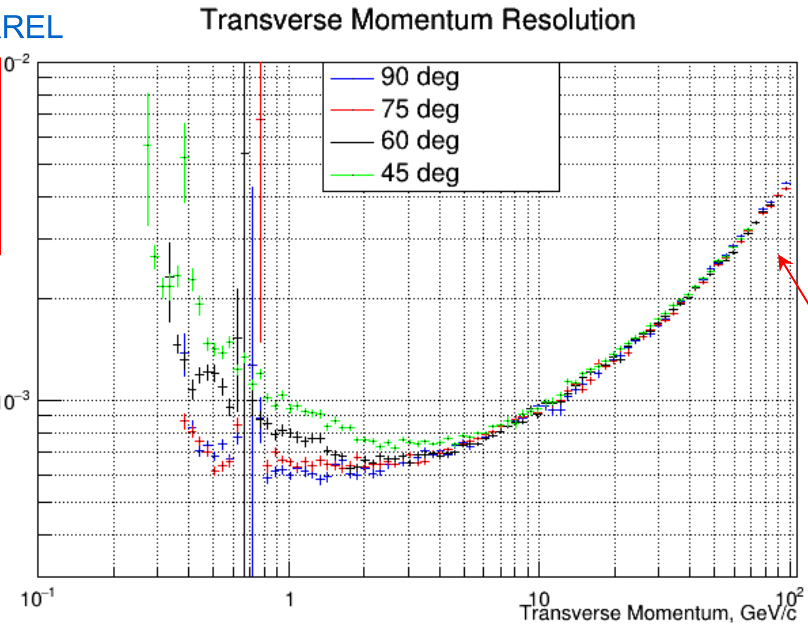


- On going check if there are any overlap between the calorimeter and the other detectors.
- Implementing the hits/tracks and reco also for the calorimeter.

Expected tracking performance: full simulation with Geant4

BARREL

$\sigma p_t/p_t$



DCH + SVX but no Si-Wrapper

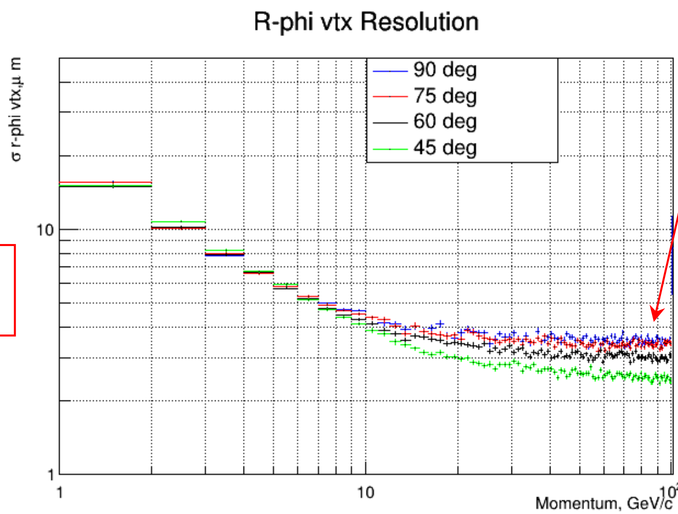
Recent studies with

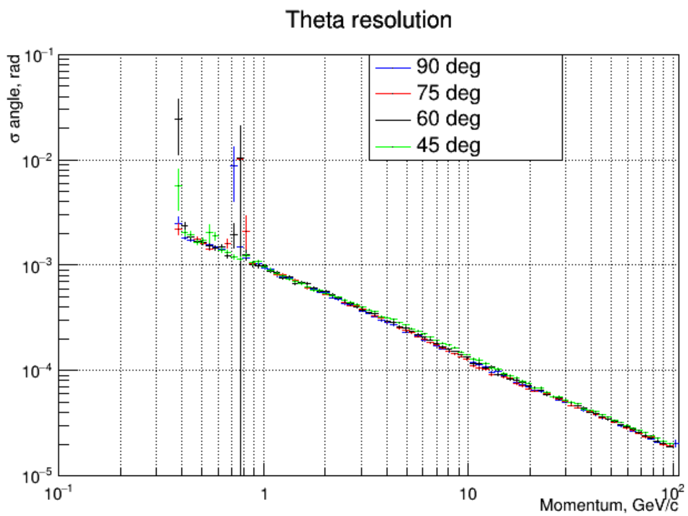
$\sigma(p_t)/p_t$ (100 GeV) = 3x10^{-3}

$\sigma(d_0)$ (100 GeV) = 2μm

BARREL

impact parameter

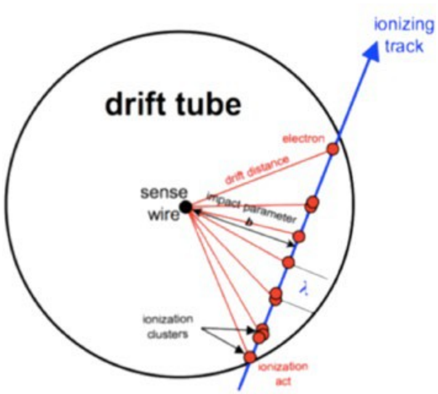


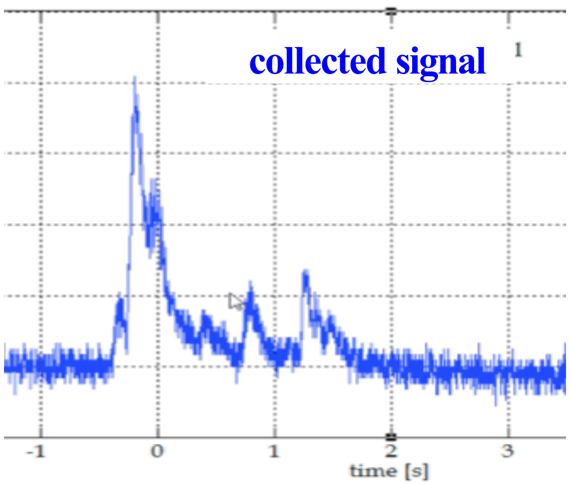


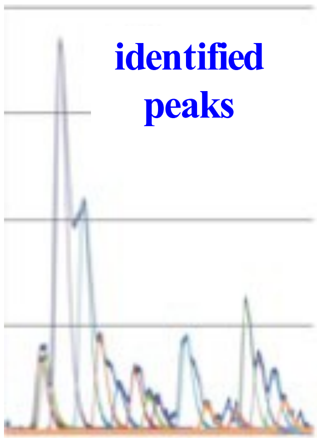
Cluster Counting/Timing and P. Id. principles

Principle: In He based gas mixtures the signals from each ionization act can be spread in time to few ns. With the help of a fast read-out electronics they can be identified efficiently.

- By counting the number of ionization acts per unit length (dN/dx), it is possible to identify the particles (P.Id.) with a better resolution w.r.t the dE/dx method.







- record the time of arrival of electrons generated in every ionisation cluster (≈12cm-1)
- reconstruct the trajectory at the most likely position

The cluster counting is based on replacing the measurement of an ANALOG information (the [truncated] mean dE/dX) with a DIGITAL one, the number of ionisation clusters per unit length:

dE/dx

Truncated mean cut (70-80%) reduces the amount of collected information. n = 112 and a 2m track at 1 atm give $\sigma \approx 4.3\%$

dN_{cl}/dx

δ_{cl}= 12.5/cm for He/iC_4H_{10}=90/10 and a 2m track give $\sigma \approx 2.0\%$

New studies about the Cluster Counting

Goal: Investigation of the potential of the C.C. (for He based drift chamber) with parametrization of the generation of ionization clusters

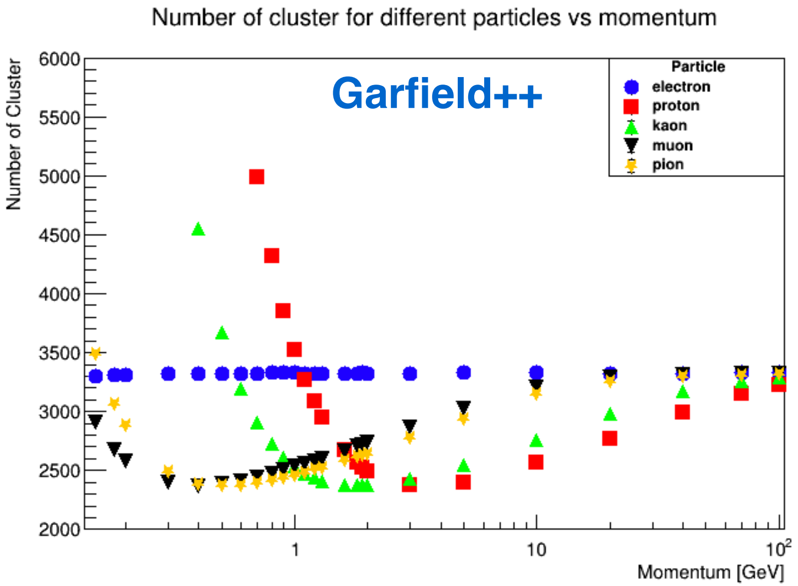
Studies done with 2m long tracks through a 1cm^3 box of gas (90% He and 10% iC_4H_{10})

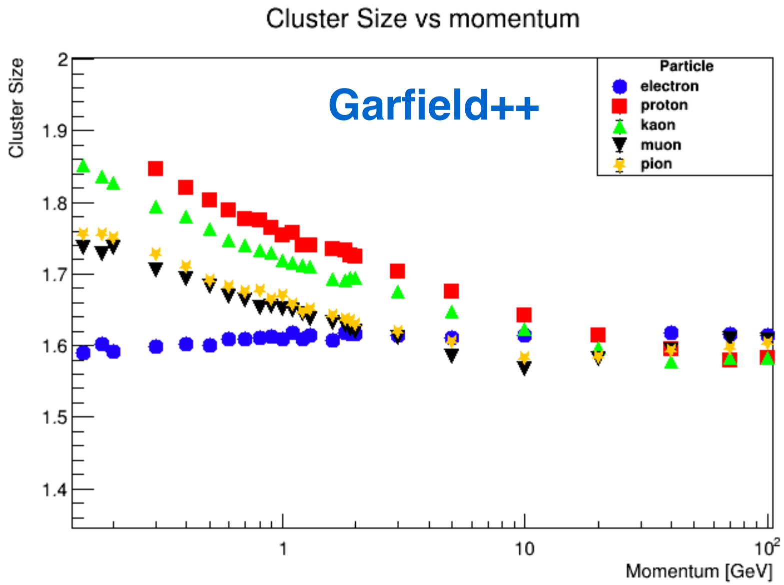
Garfield++:

- simulates the ionization process in a detailed way
- computes the gas properties (drift and diffusion coefficients as function of the fields value)
- solves the electrostatic planar configuration and simulates the free charges movements and collections on the electrodes.
- cannot simulate a full detector and collider events.

Geant4:

- simulates the particle interaction with material of a full detector.
- But...the fundamental properties and performance of the sensible elements (drift cells) are either parameterized or «ad-hoc» physics models have to be defined.





Garfield++ vs Geant4

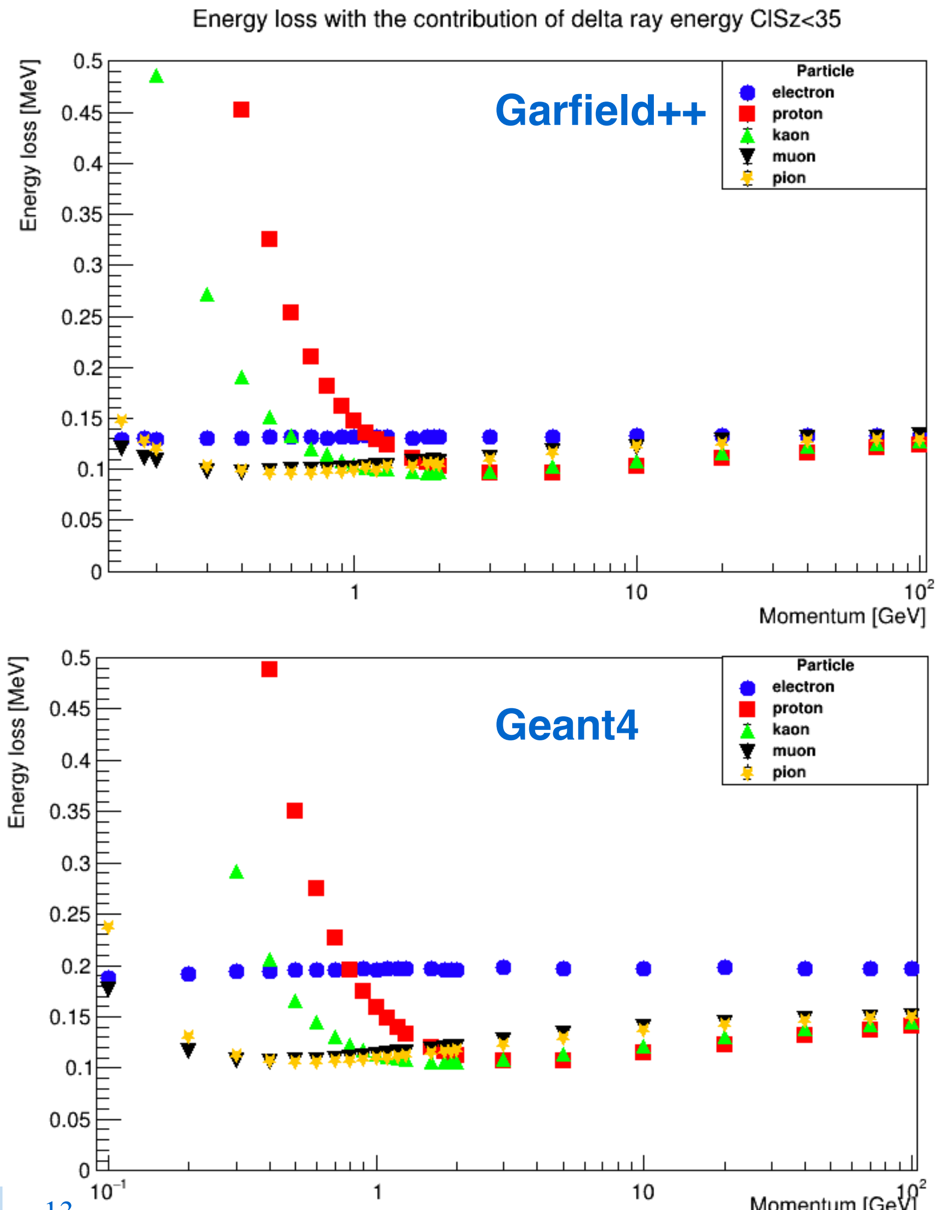
- Distribution of energy loss for different particles simulated from Garfield++ and from Geant4

- both derived without the contribution from delta rays energy also derived

Strategy:
studying the results from Garfield++ simulations, we can interpret correctly the results obtained from Geant4 simulations with the goal to reconstruct the number of cluster generated from different particles with different momenta passing through the tracker detector.

The strategy consists of :

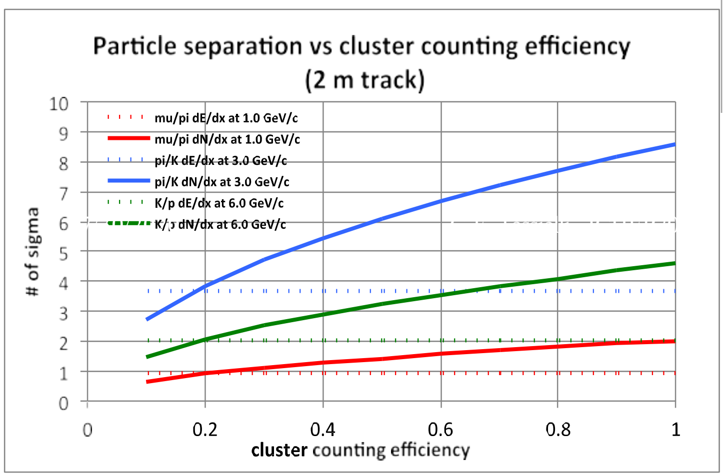
- Constructing a model of primary and secondary ionization energy.
- Using the model to reconstruct the number of cluster from energy loss simulated by Geant4.

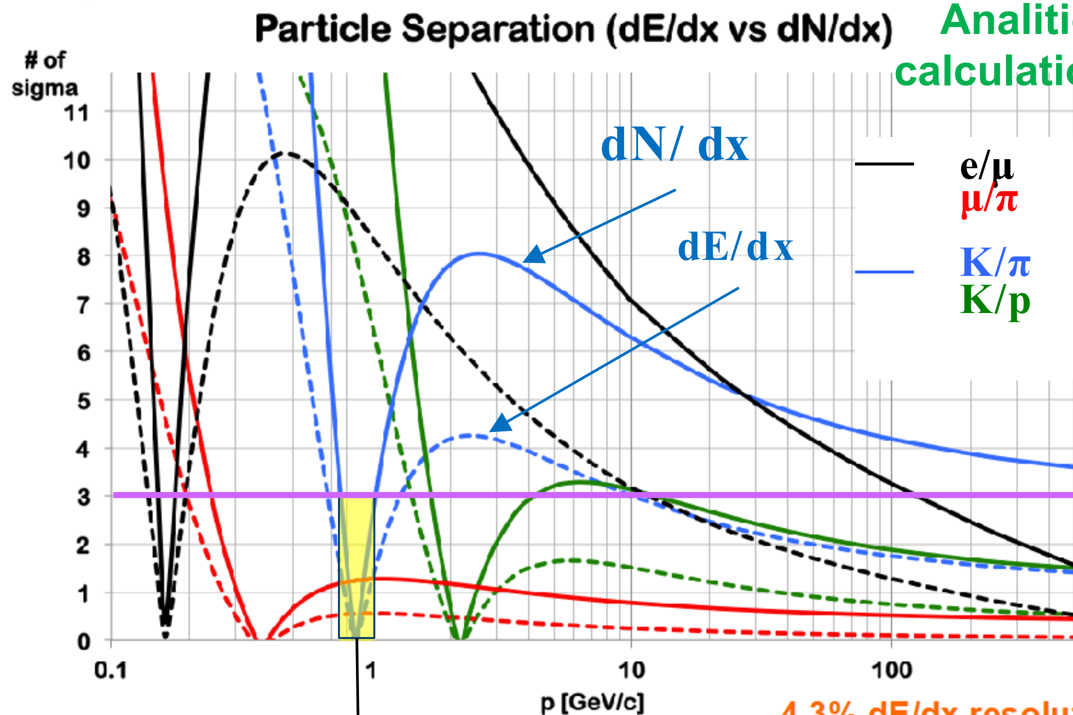


Design guidelines: particle identification

Cluster Counting/Timing in DCH for good P.Id. performance

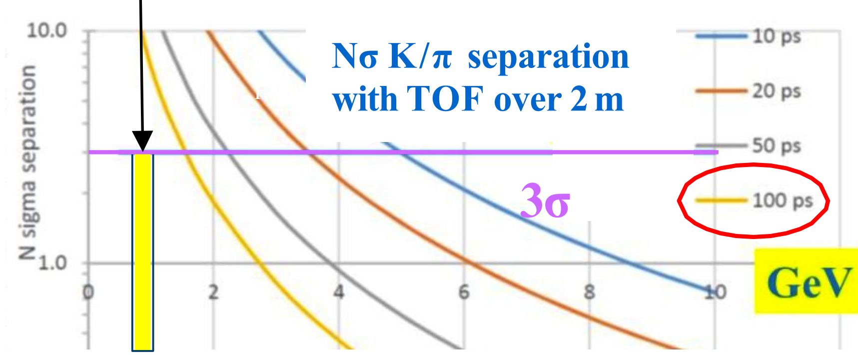
- Expected excellent K/π separation over the entire range except 0.85<p<1.05 GeV (blue lines)
- Could recover with timing layer





Analitic calculations

4.3% dE/dx resolution
80% cluster counting efficiency



Conclusions

- Physics requirements impose guiding principles for detector design and performance:
  - High precision vertex detector
  - High transparency and momentum resolution
    - Good integrated PID with cluster counting
  - Excellent calorimetry
  - Light solenoid and minimal yoke
  - Tracking muon system
  - Excellent performance at all energies: Z, WW, ZH, tt

- Performance studies with Geant4 full simulation using the DCH done

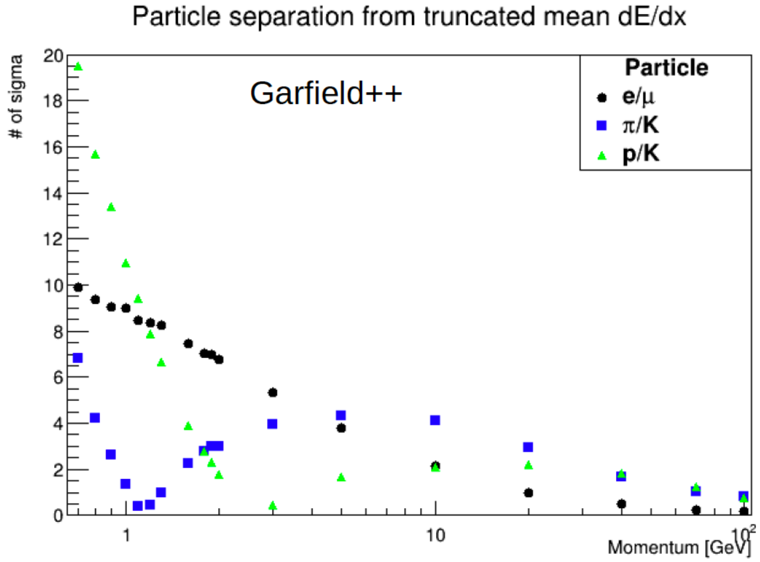
- Integration of DCH and DR Calo completed → moving to hits and tracks

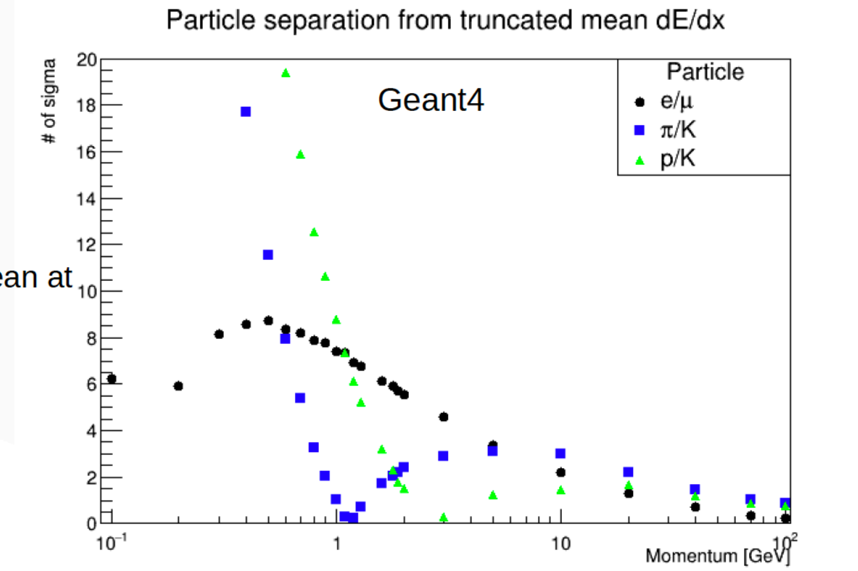
- studies of the PID capabilities of the DCH with the cluster counting

Backup

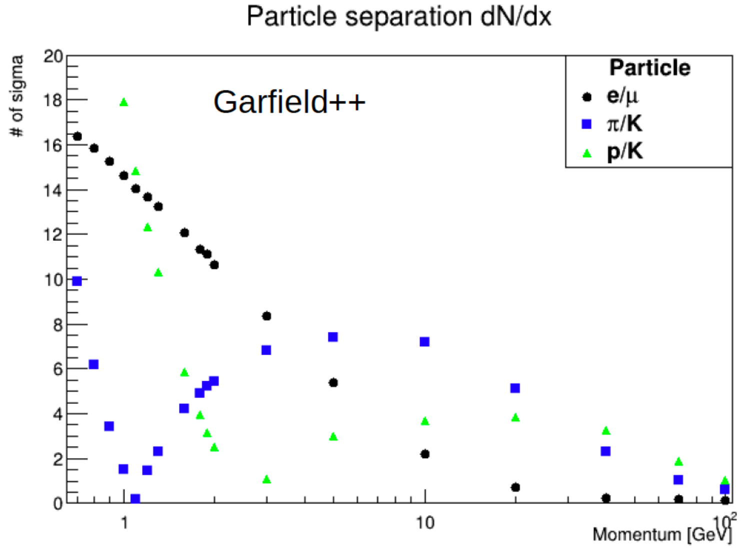
Garfield++ vs Geant4

Particle separation with traditional dE/dx method and cluster counting





Truncated mean at 70%

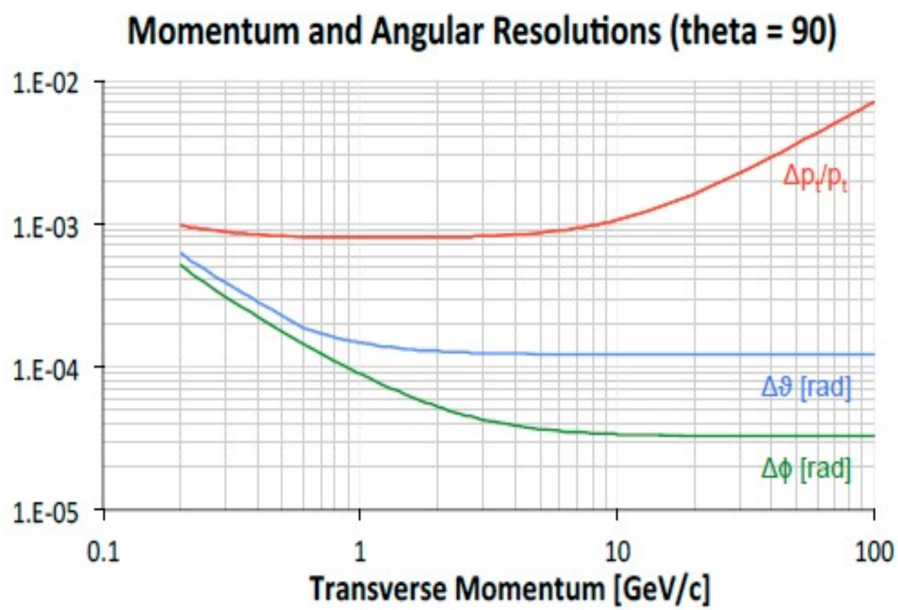


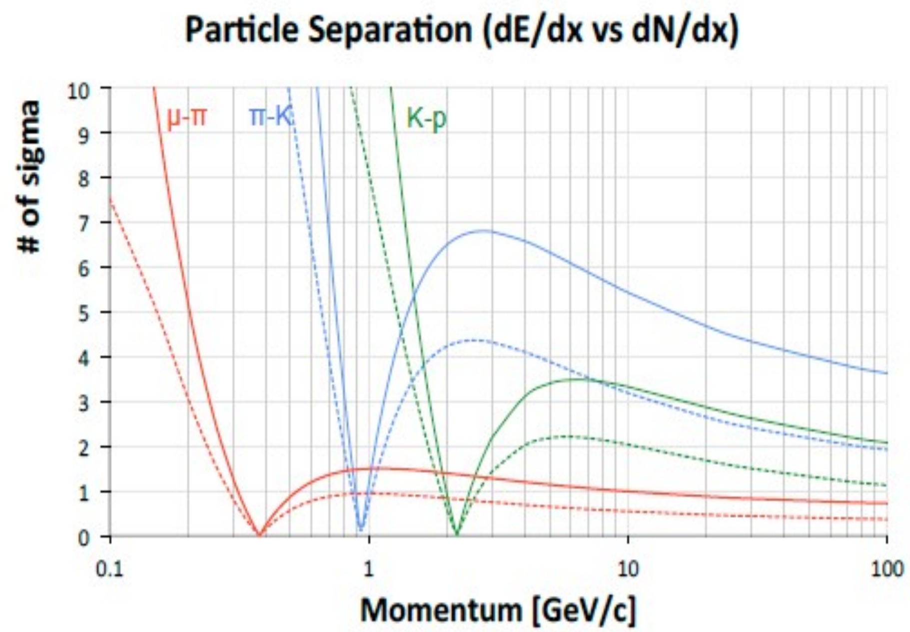
$$n_\sigma = \frac{\Delta_A - \Delta_B}{\langle \sigma_{A,B} \rangle}.$$

σ is the average of the two resolutions.

We are simulating 2m long tracks which pass through a 1 cm long side box of 90% He and 10% iC_4H_{10}, with Garfield++ and Geant4

The Drift Chamber for the IDEA experiment





$\Delta p_t/p_t = (0.7 p_t + 8.3) \times 10^{-4}$

$\Delta\vartheta = (1.1 + 9.4/p) \times 10^{-4}$ rad

$\Delta\varphi = (0.33 + 9.4/p) \times 10^{-4}$ rad

dE/dx = 4.3 %

dN/dx = 2.2 % (at ε_N = 80 %)