# Digitization in the IDEA Drift Chamber FCC-ee


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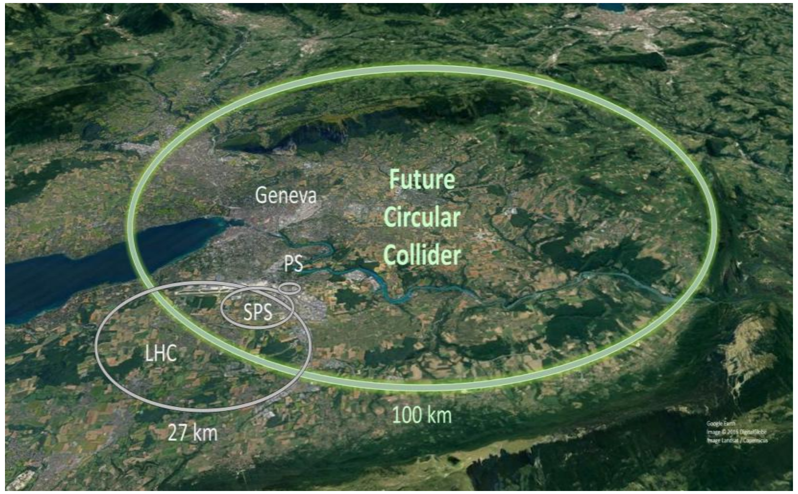
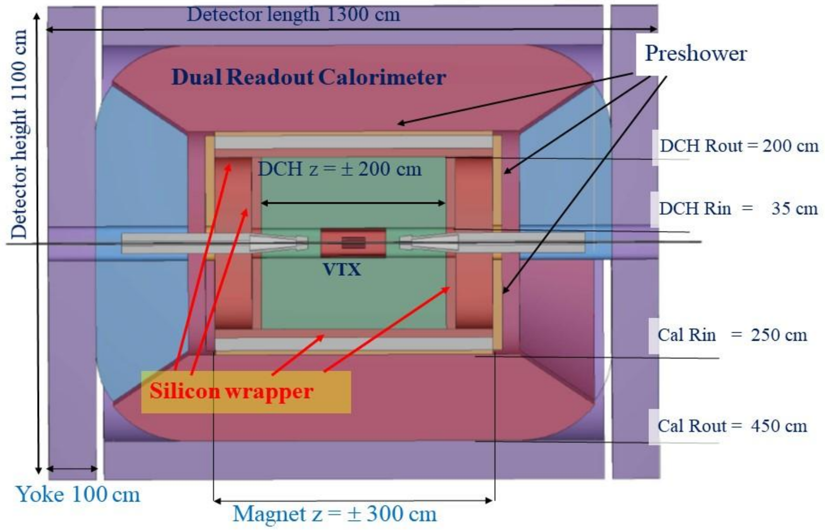
# Future Circular Collider and the IDEA Detector




- Next-generation particle collider.
- Circumference of 100 km
- Purpose: To collide particle with extremely high energy
- Runing Phases:
  1. **FCC-ee:** uses electrons positrons for collision
  2. **FCC-hh:** uses protons-protons collision for much higher energies.
- Requires new detector technologies.

**Inovative Detector for Electron-positron Collider (IDEA)**




- Silicon Pixel Vertex Detector
- Large volume, ultra-light Drift Chamber
- Silicon micro-strip detectors
- Thin low mass Superconducting Solenoid coil
- Preshower Detector
- Dua-Readout Calorimeter
- Muon system

# The IDEA Drift Chamber

The Drift chamber is a unique volume, high granularity, fully stereo, low mass cylinder

**Purpose:**

- Precise tracking of the charged particles
- Particle Identification

**Gas Mixture:**

He 90% - $iC_4H_{10}$ 10%

**Geometry:**

- Inner radius $R_{in}$ = 0.35m
- Outer radius $R_{out}$ = 2m
- Length L = 4m
- 112 co-axial layers arranged in 14 superlayers

**343968 wires in total**

- Sense vires: 20 μm diameter W(Au) = 56448 wires
- Field wires: 40 μm diameter Al(Ag) = 229056 wires
- f. and g. wires: 50 μm diameter Al(Ag) = > 58464 wires

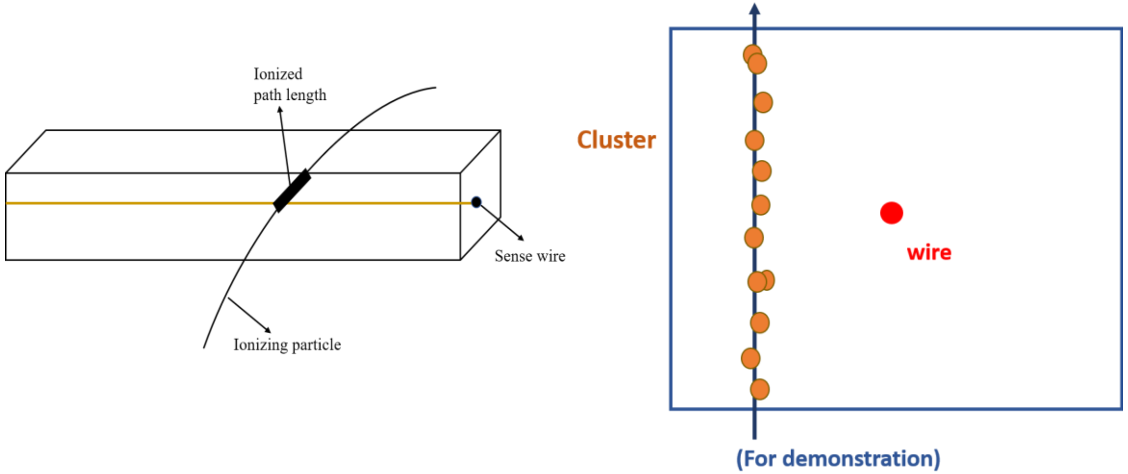
Fig: Drift Chamber of the MEG II Experiment

Thin wires → increase the chamber granularity → reducing both multiple scattering and the overall tension on the endplates

# Digitization in the IDEA Drift Chamber

Converts simulated energy deposits from Geant4 into realistic detector signals.

**1.** Particle–Cell intersection

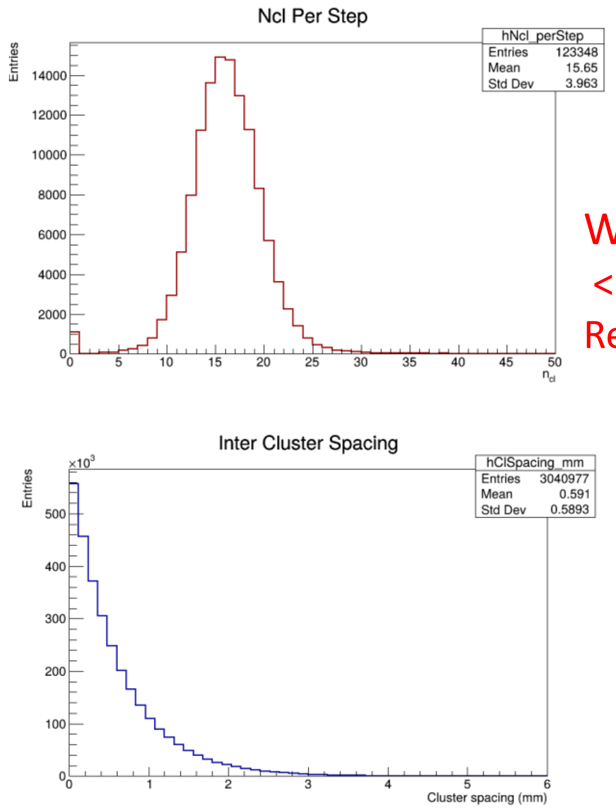



**Information:**

- Ionized Path length ℓ
- **βγ** from the MC particle
- μ = dNcl/dx (**βγ**)× ℓ

**2.** The # of clusters can be described by the Poisson distribution and the cluster spacing will follow the exponential distribution

$n_{cl}$ = pois(μ)

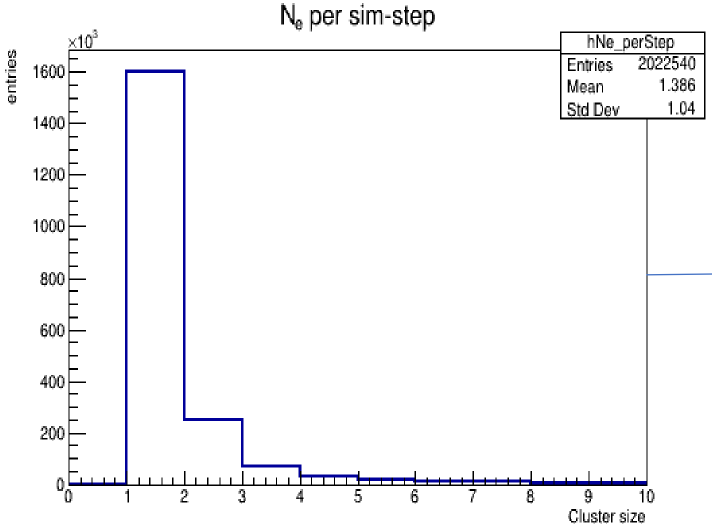



$W_{eff}$ = 41 eV,
<Ne> = 1.4 / cl
Ref: F. Sauli

Ref: Principles of Operation of Multiwire Chamber by F. Sauli

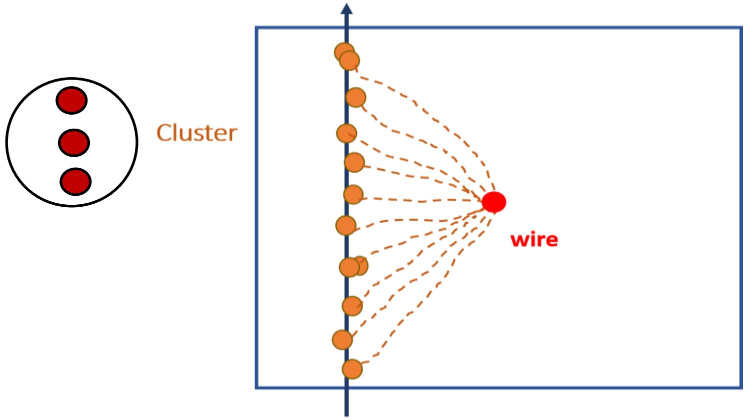
# Digitization in the IDEA Drift Chamber

**3.** For each number of cluster, assign the number of electrons **$n_e$** according to the probabilities ref: 1.

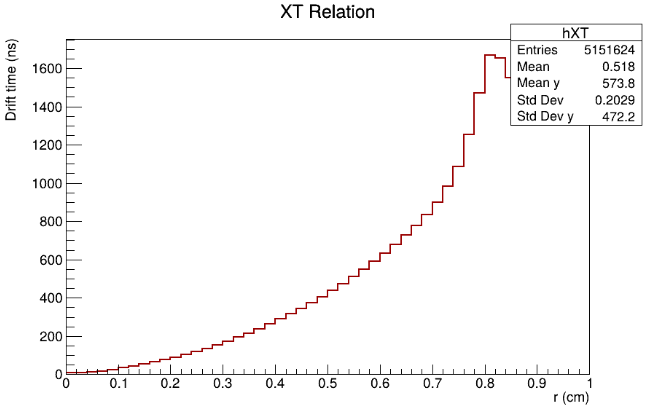



**4. Transport each of these electrons to the sense wire.**

- Each ionization electron is transported individually to the sense wire.
- The electron drift time is obtained from a tabulated distance-to-time (x–t) relation.
- The lookup table (LUT) is generated using Garfield++ simulations.
- Cell size (9 * 9) mm




(For demonstration)




1. The Probabilities are given in the ref: H. Fischle, J. Heintzeand B. Schmidt, Experimentaldeterminationof ionizationcluster size distributionsin countinggases, NIMA 301 (1991)

# Digitization in the IDEA Drift Chamber

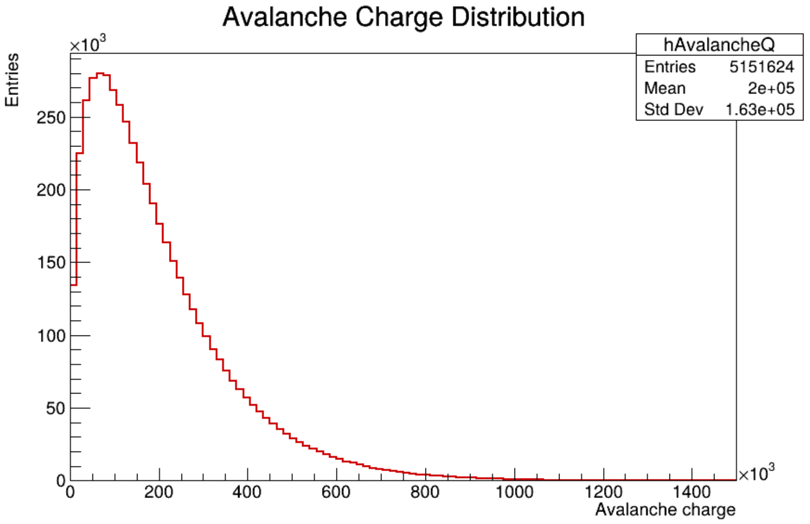
## 5. Define the amplitude of the signal generated by each of these electrons.

- For each drifted electron, the avalanche charge is sampled from a Polya distribution.
- The sampled charge defines the signal amplitude associated with the electron.
- The electron contributes to the signal with a given amplitude and drift time.

$G = 2 \times 10^5$

$\theta = 0.5$

Ref: Walaa

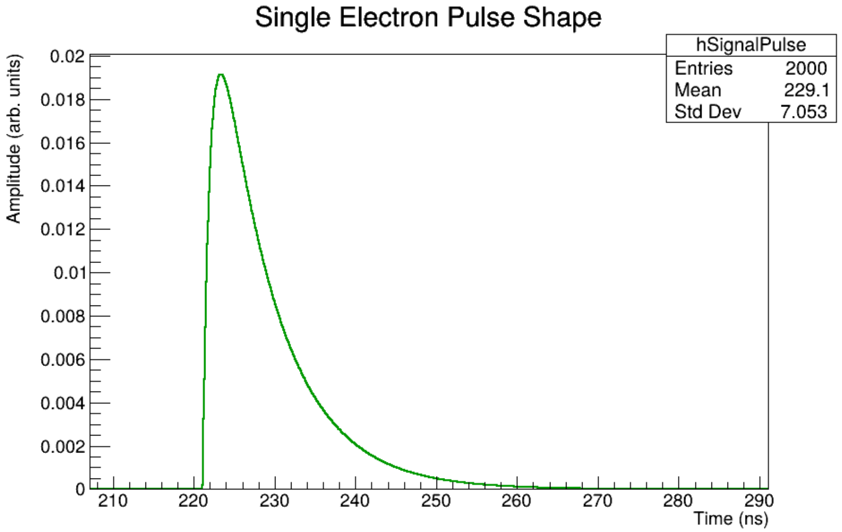



## 6. Single-Electron Pulse Generation:

For each electron, an individual pulse is generated at its arrival time.

The pulse shape includes rise and fall times using arbitrary values.

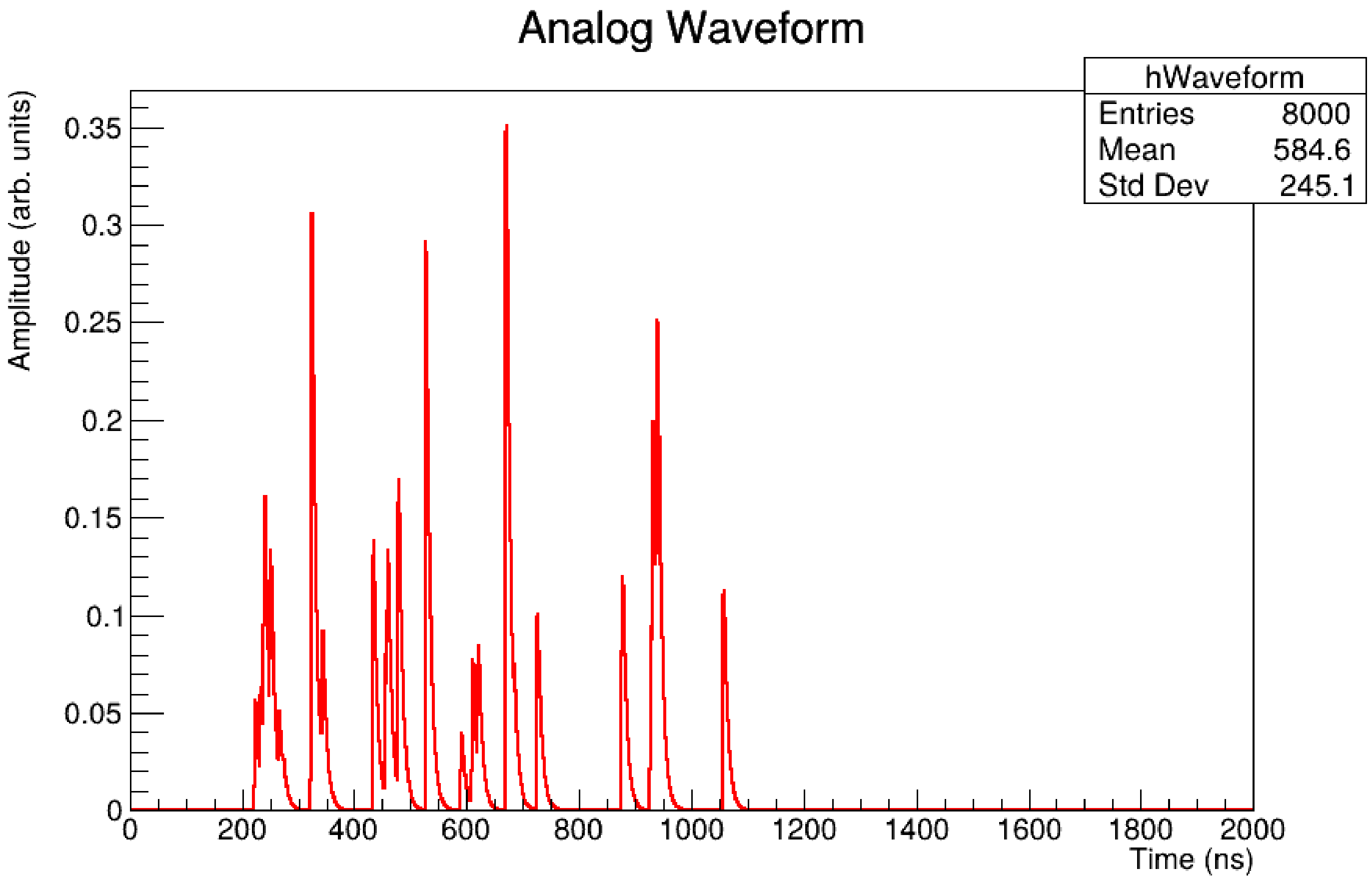
**Scale factor: $5 \times 10^{-6}$, Rise time: 1.0 ns, Fall time: 7.0 ns**




Ref: Enhancing Particle Identification in Helium-Based Drift Chambers Using Cluster Counting: Insights from Beam Test Studies

# Digitization in the IDEA Drift Chamber

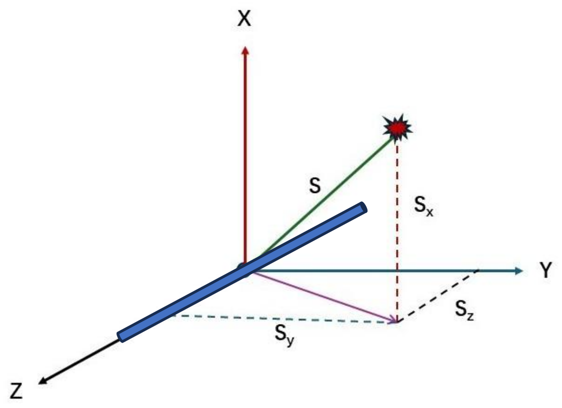
## Build the analog wave form by summing up the individual contributions of all single electrons



# Digitization in the IDEA Drift Chamber

## Propagate the Analog Waveform at both ends of the wire

- **Get distance to each end along the wire.**




$$d_L = L/2 + z\_hit\_mm$$
$$d_R = L/2 - z\_hit\_mm$$

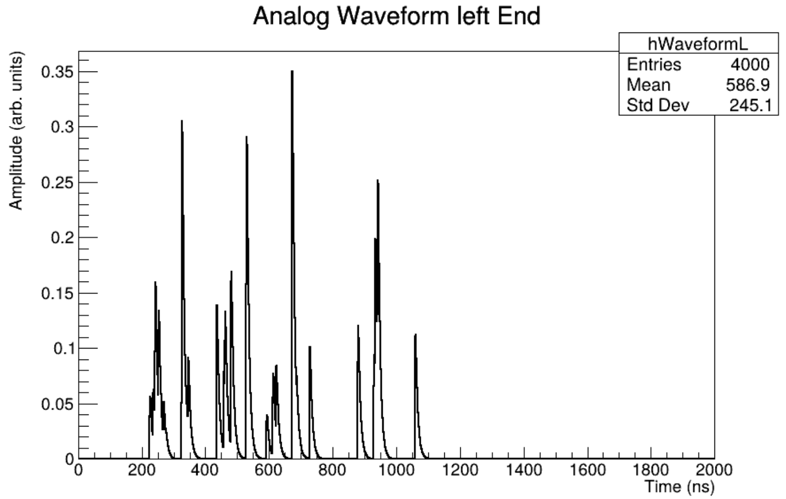
- **Convert distance to propagation delay.**

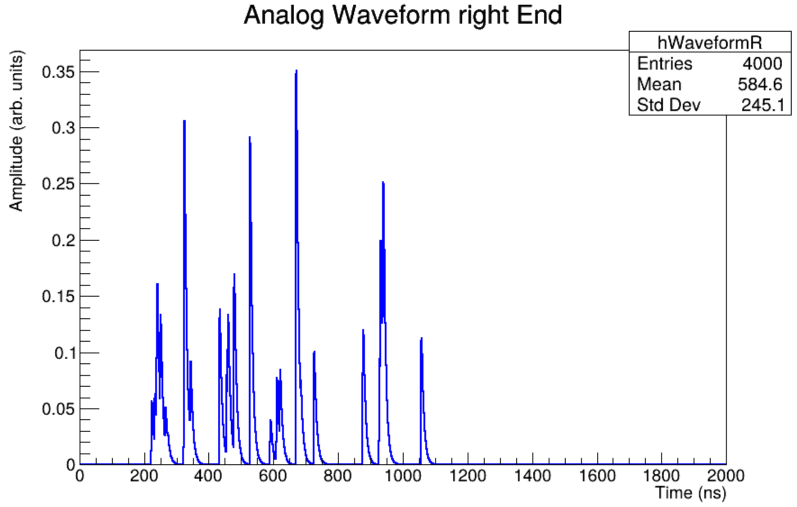
  Vs = 200 mm/ns ≈ 5 ns/m

  **Att(d) = exp(−d/λ), 1.0**

- **VR += singleElectronPulse(t, t0 + tpropR_ns, q * attR);**

- **VL += singleElectronPulse(t, t0 + tpropL_ns, q * attL);**



# Digitizatio of the Analog waveform

# Digitization in the IDEA Drift Chamber

## Applying the pre amplifier transfer functions

Apply impedance-mismatch amplitude scaling and electronics shaping (convolution) to the analog waveform to get the final readout signal.

- **Front-end gain:**

  Apply an overall scale to the output of the A.Waveform (L, R)

- **Impedance mismatch scaling:**

1. Compute a simple reflection coefficient (gamma):
2. Then rescale amplitude with 1-gamma

$$\Gamma = \frac{R - Z}{R + Z} \quad \longrightarrow \quad x(t) \leftarrow x(t) \times (1 - \Gamma)$$

- **Electronics transfer function:**

1. Build impulse-response by
2. Shape: rise * fall followed by a normalization factor

$$k(t) \propto \left(1 - e^{-t/\tau_r}\right) \left[ f \, \frac{e^{-t/\tau_{f1}}}{\tau_{f1}} + (1 - f) \, \frac{e^{-t/\tau_{f2}}}{\tau_{f2}} \right] \qquad (t > 0)$$

- **Discrete Convolution:**

$$y[i] = \Delta t \sum_j x[i - j] \; k[j]$$

**Parameters:**

R: MatchingRes  = 50 ohm -> 330 ohm

Z:TubeImpedance = 50 ohm

TauRise = 3.0 ns, TauFall1 = 9.0 ns, TauFall2 = 25 ns

# Digitization in the IDEA Drift Chamber

## Adding proper noise according to frequency response determined Experimentally

We add noise so the digitized waveform realistically includes the baseline fluctuations of the real readout electronics, making the simulated signal look and behave like measured data.

### ☐ Input (frequency-domain template)

1. Frequency bins
2. Magnitude Template
3. Normalization

### ☐ Match to waveform sampling:

1. Making the generated noise waveform compatible with our waveform
2. Waveform bin width, dt = 0.5 ns (2 Gsa/s)
3. Waveform sampling frequency:
4. Nyquist frequency:

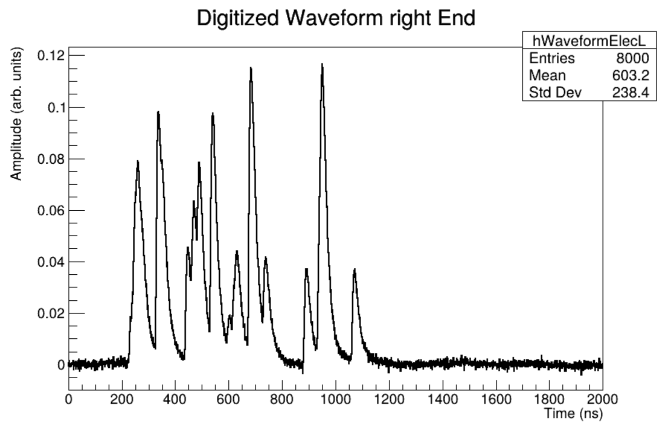
$f_s = 1/dt$,
$f_{Nyquist} = f_s/2$

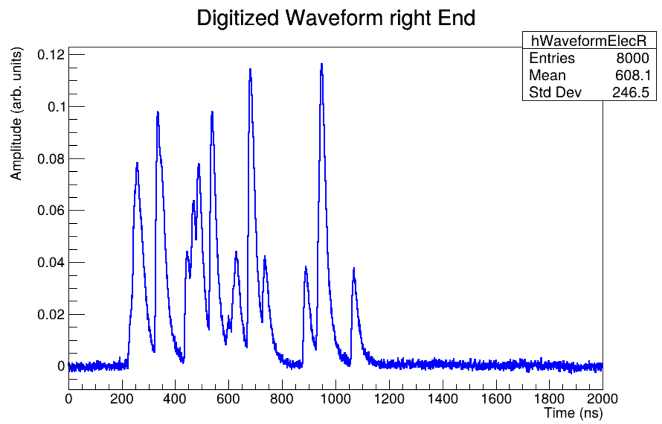
### ☐ Build random complex spectrum

1. Apply a random phase to every bin (0, 2π)
2. Builds the real and imaginary part

### ☐ Noise waveform into time Domin

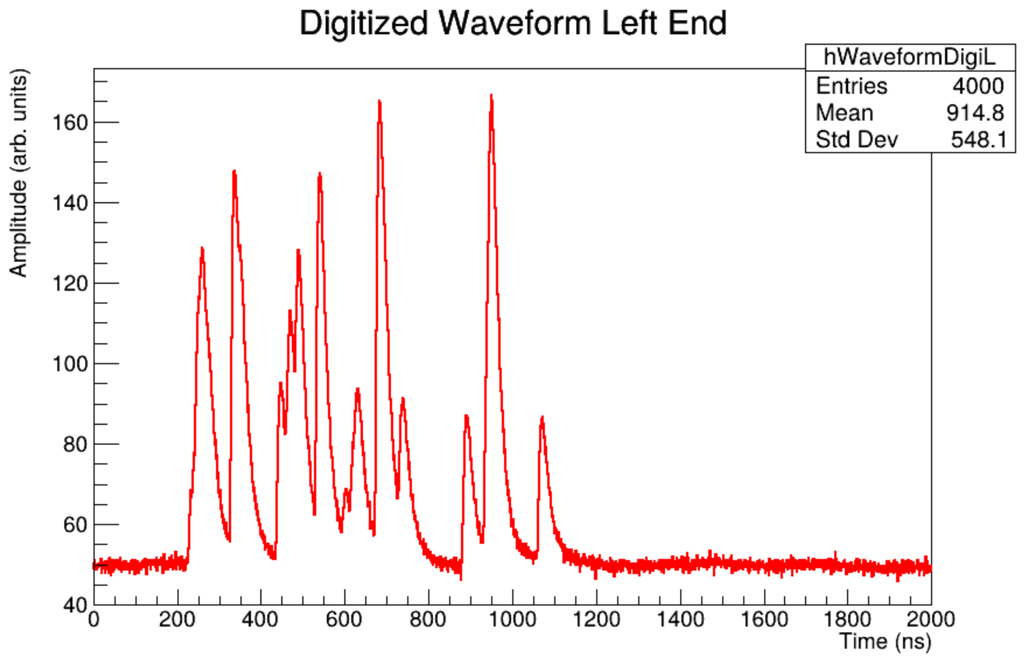
Appy inverse fast Fourier transform to convert it time domain.

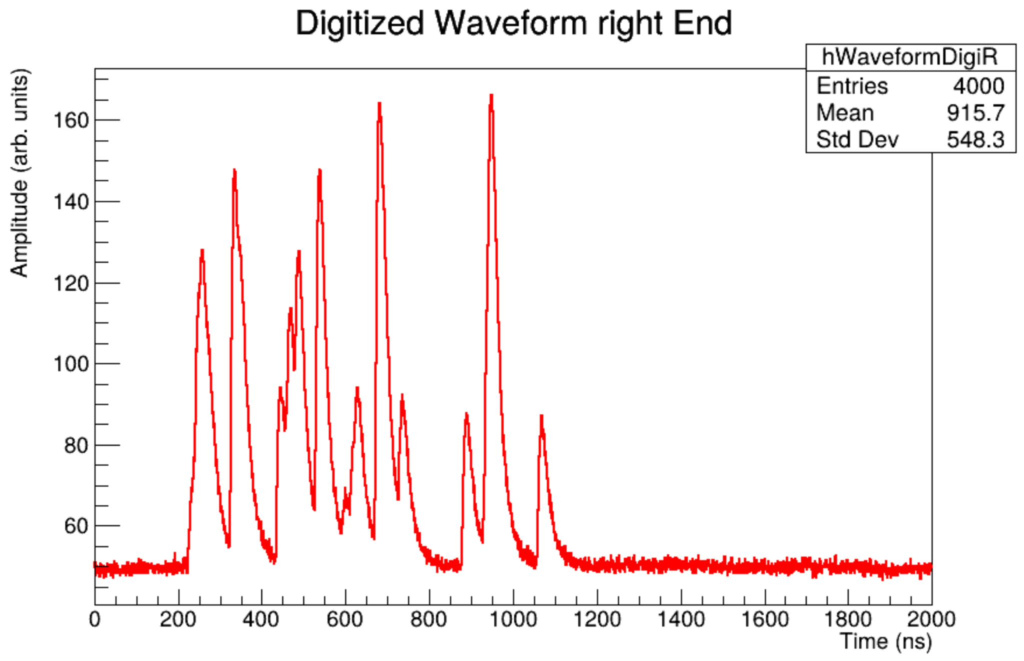


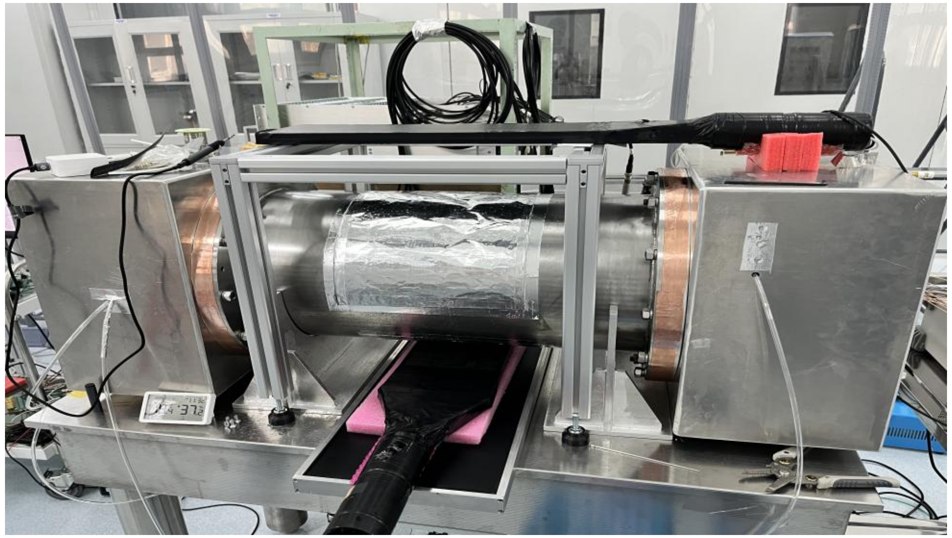
# Digitization in the IDEA Drift Chamber

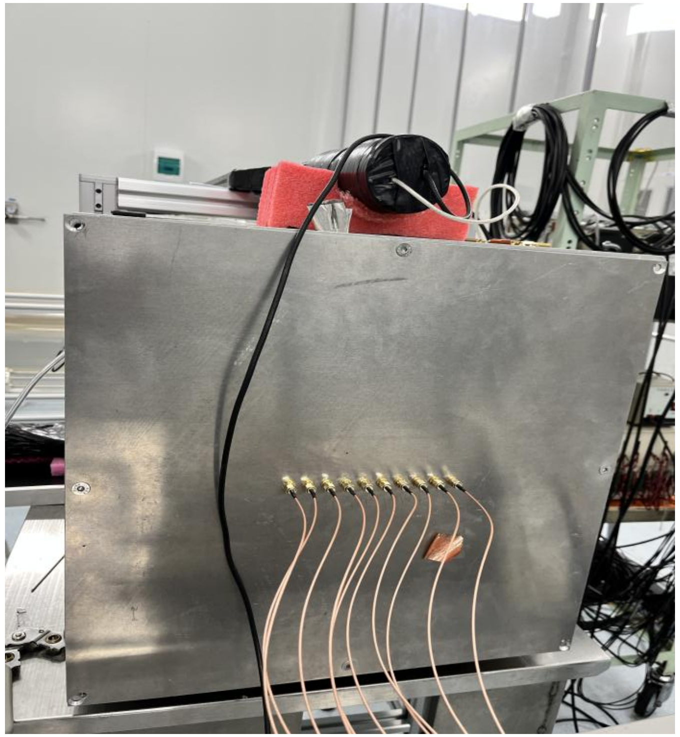
## Complete Digitized Waveform

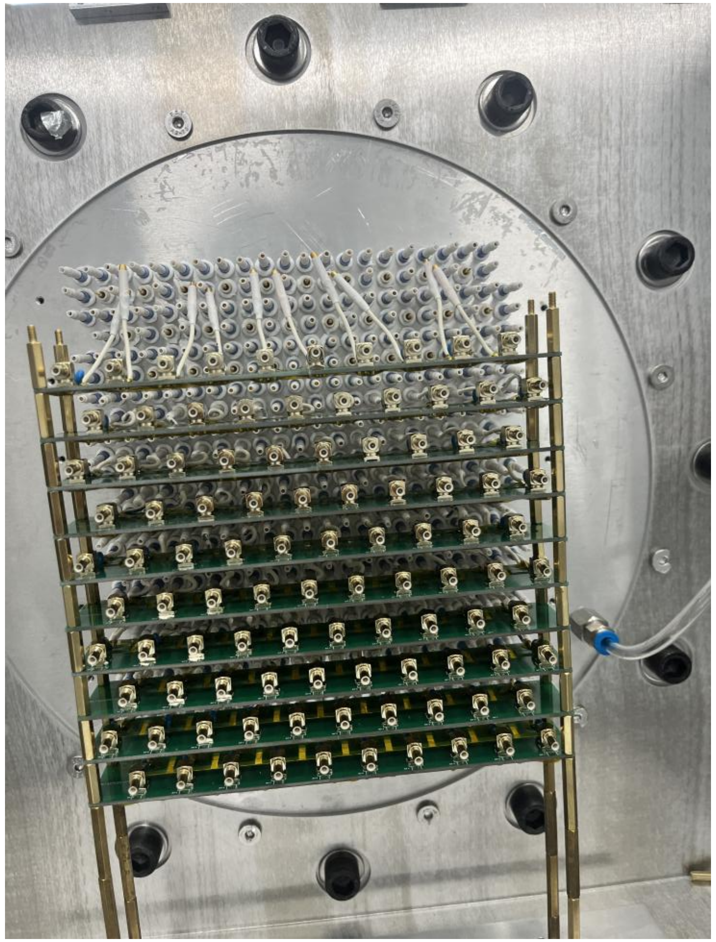


# CEPC Drift Chamber





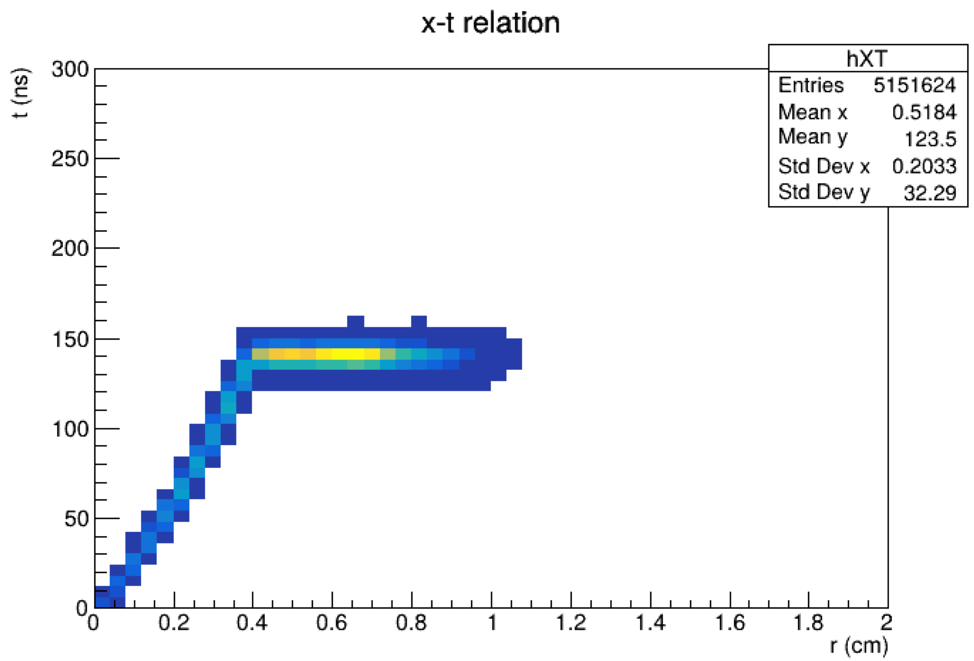


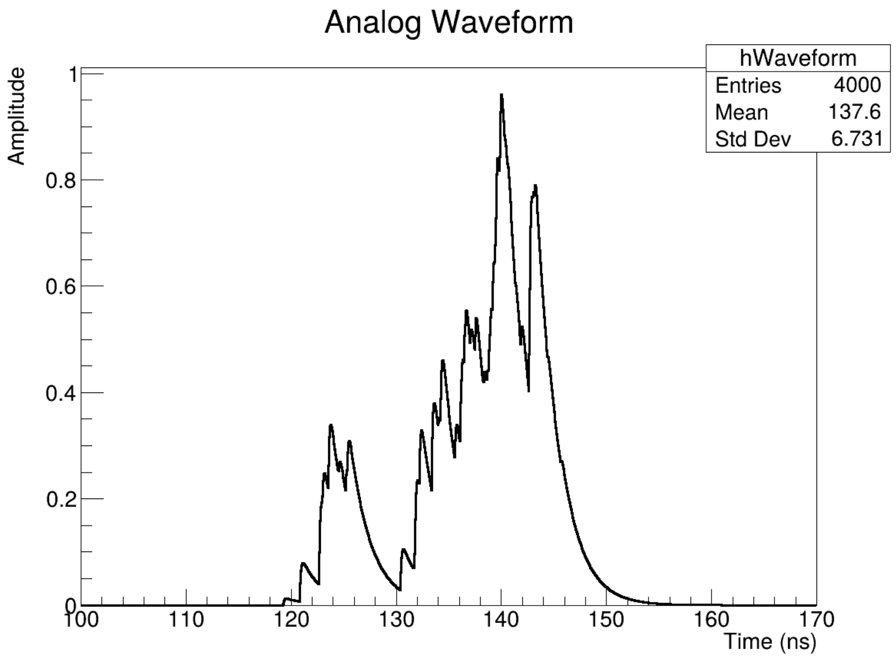
# CEPC Drift Chamber


# Thank you for your attention!

# Digitization in the IDEA Drift Chamber

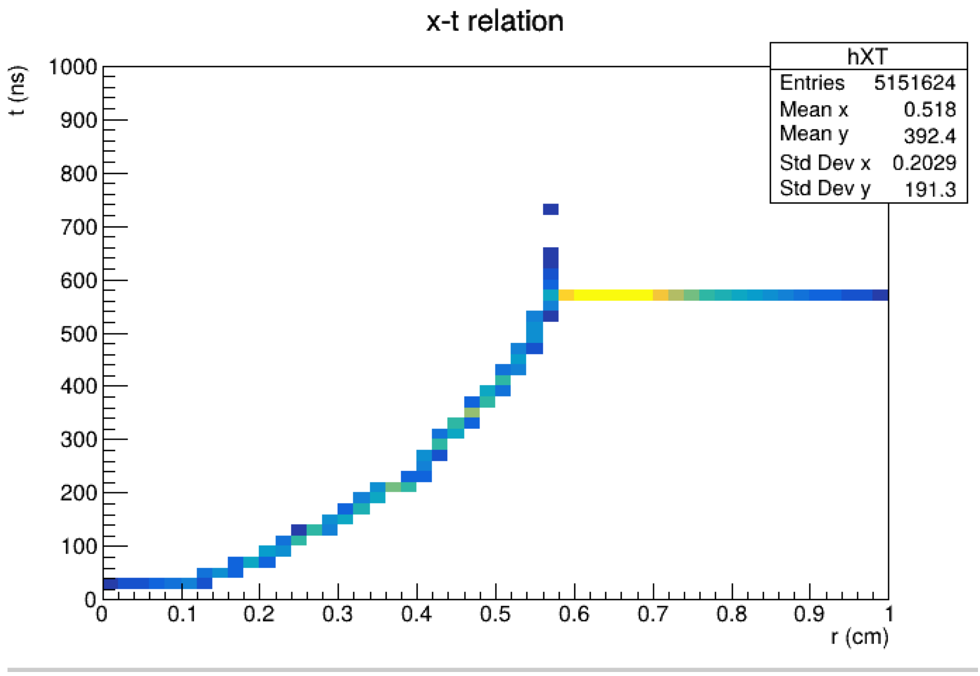
## Back Up slides

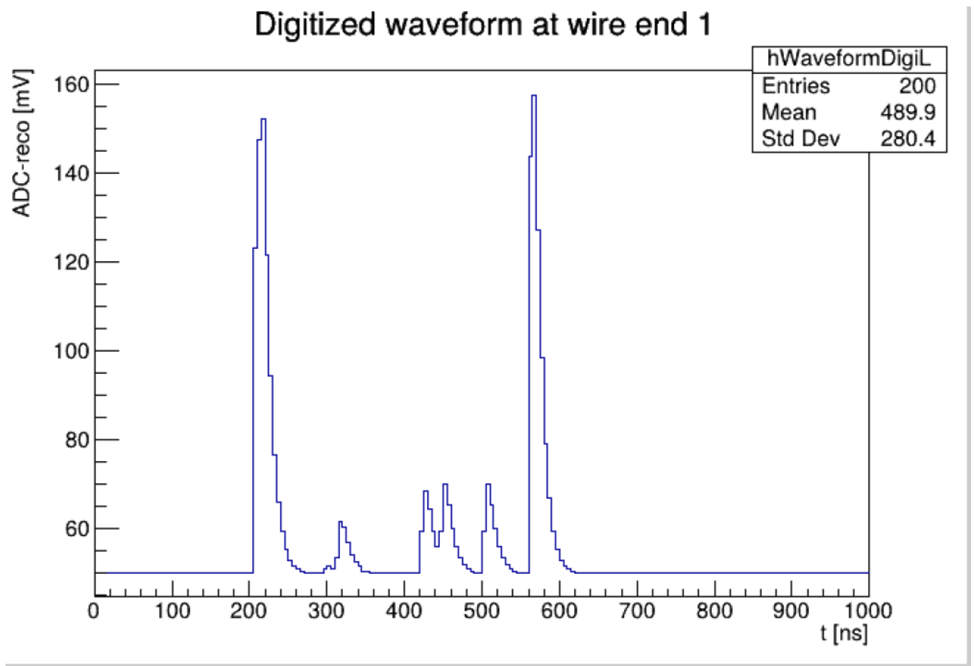


# Digitization in the IDEA Drift Chamber

## Back Up slides



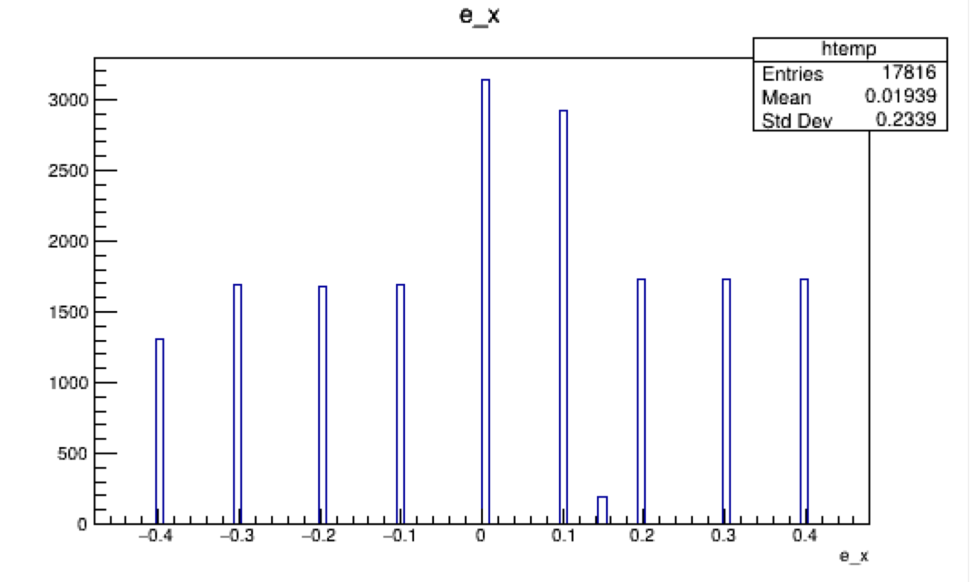



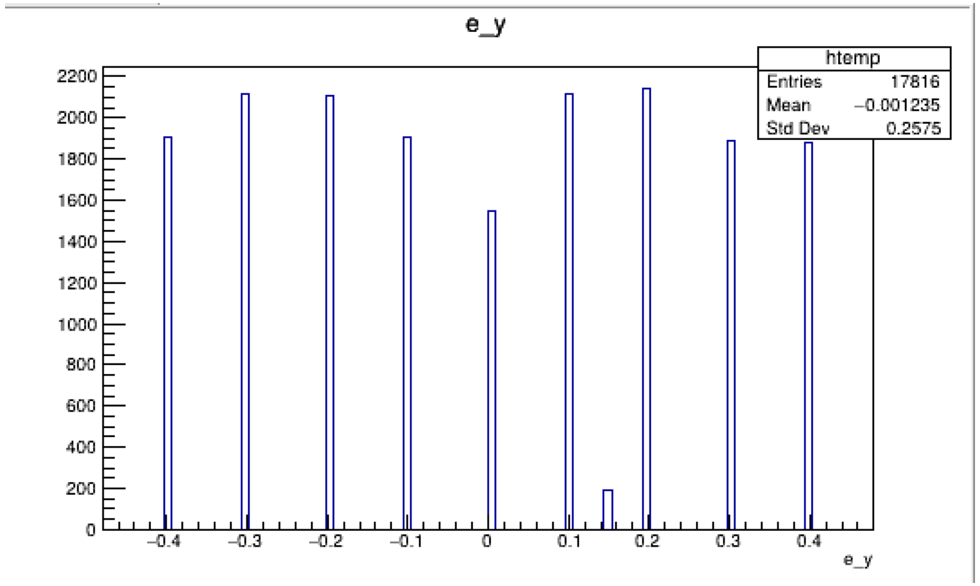
# Digitization in the IDEA Drift Chamber

## Back Up slides

Drift distances in x and y

- Problem: low statistics



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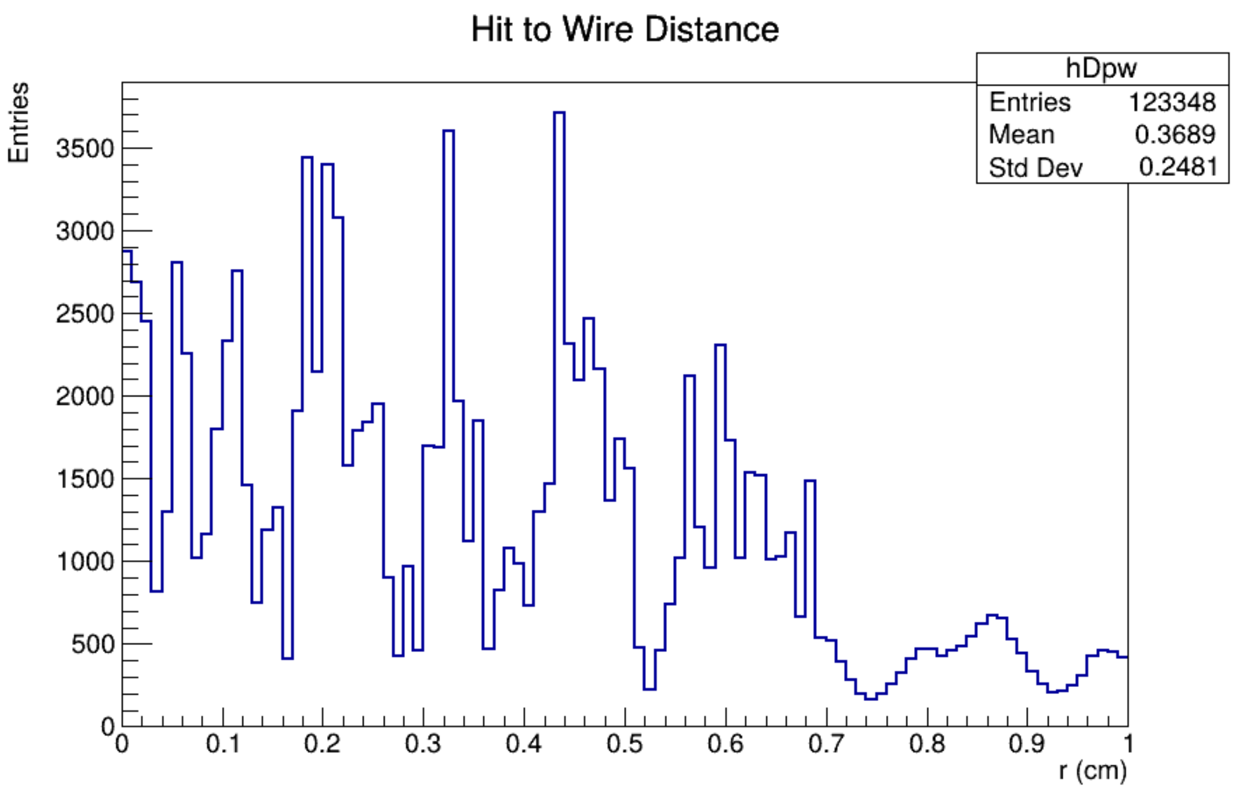
## Back Up slides



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