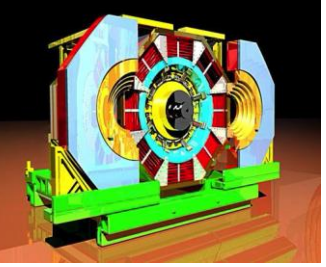
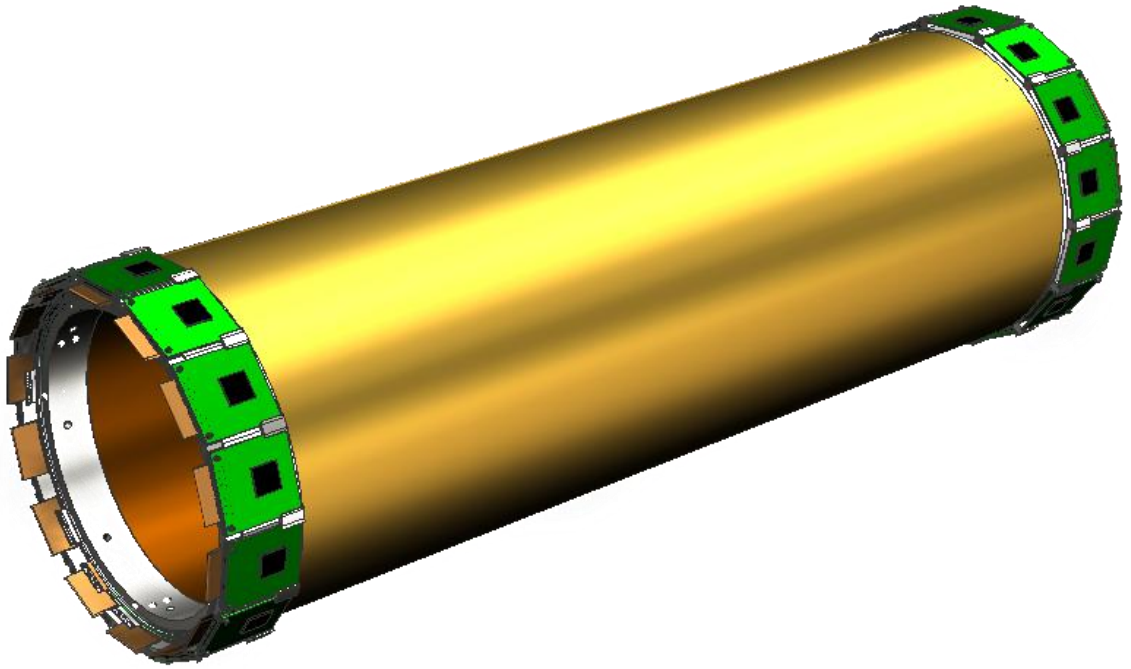




Full triple-GEM digitization in magnetic field

Riccardo Farinelli & Lia Lavezzi & Liangliang Wang

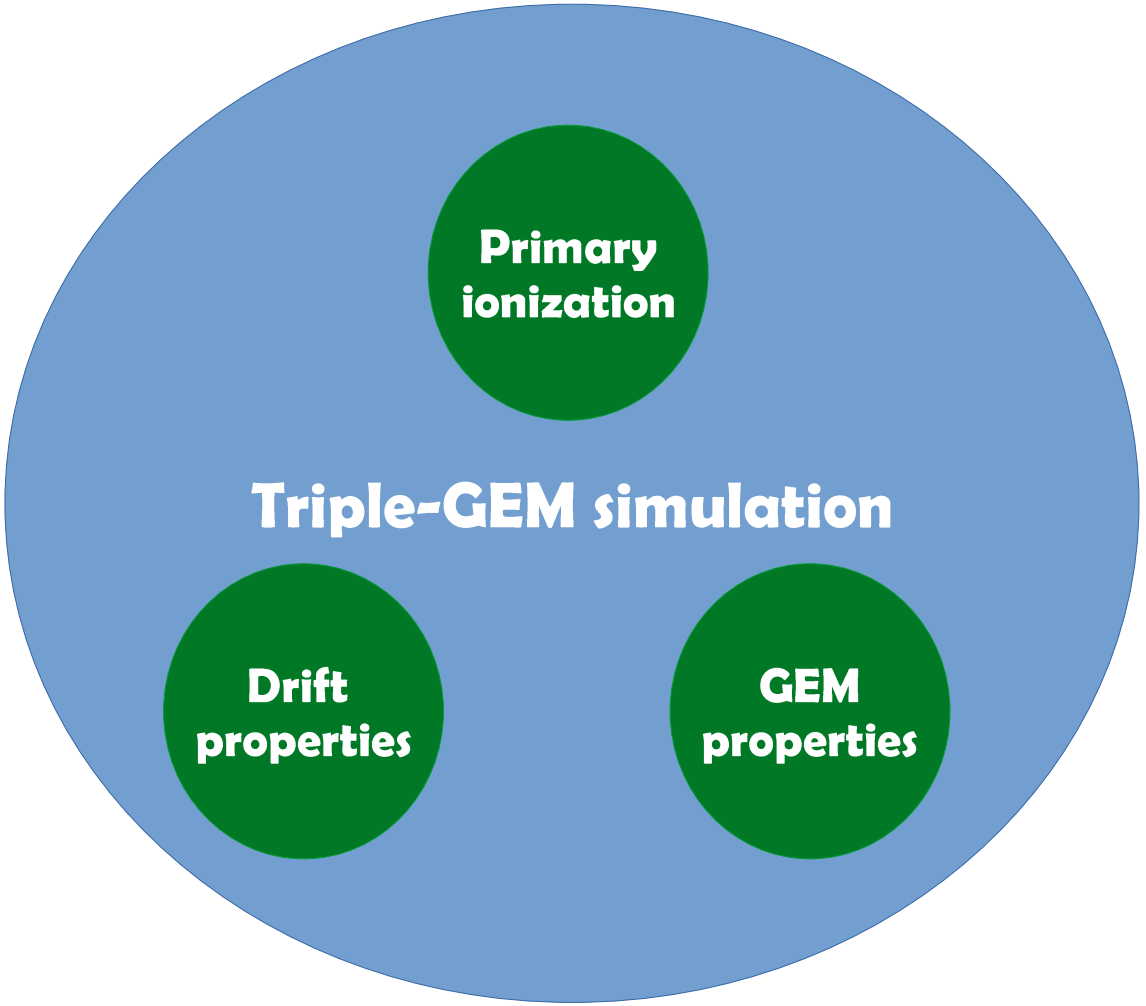
Outline

- Simulation technique
- Primary ionization
- Transparency & Avalanche
- Drift properties
- Signal clusterization

Simulation technique - I

GARFIELD is too time demanding to simulate the full triple-GEM signal formation due to a ionizing particle → divide the simulation into 3 parts:

1. Ionization
2. Gain
3. Diffusion



The 3 topics are indipendent, then we can study them separately

Primary ionization - I

GOAL – parametrize the **number & position** of primary/ secondary electrons produced in the drift gas

- The ionizing particle interacts with the gas and create primary electrons
- If their energy is sufficient, each primary electron can create secondary electrons:
  - we assume that the position of the secondary electrons is the same of the primary one
  - We call this agglomerate of electrons *"electron cluster"*

Primary ionization - II

We need [from GARFIELD]

- # of electrons generated in the Drift gap
- Their generation position

They depend on:

- gas mixture
- particle momentum
- particle path

Primary ionization - II

We need [from GARFIELD]

- # of electrons generated in the Drift gap
- Their generation position

They depend on:

- gas mixture ⟶
- particle momentum ⟶
- particle path ⟶

We use:

- Argon:iC_4H_{10}
- 1 GeV/c
- (For now) only orthogonal tracks

Primary ionization - II

We need [from GARFIELD]

- # of electrons generated in the drift gap
- Their generation position

They depend on:

- gas mixture ⟶
- particle momentum ⟶
- particle path ⟶

We use:

- Argon:iC_4H_{10}
- 1 GeV/c
- (For n… …thogonal

Same dE/dx

Always 5 mm of drift gap

Same distribution of energy loss /simulated track

1 Note on the primary ionization

For now, the dE/dx of the track **is simulated**

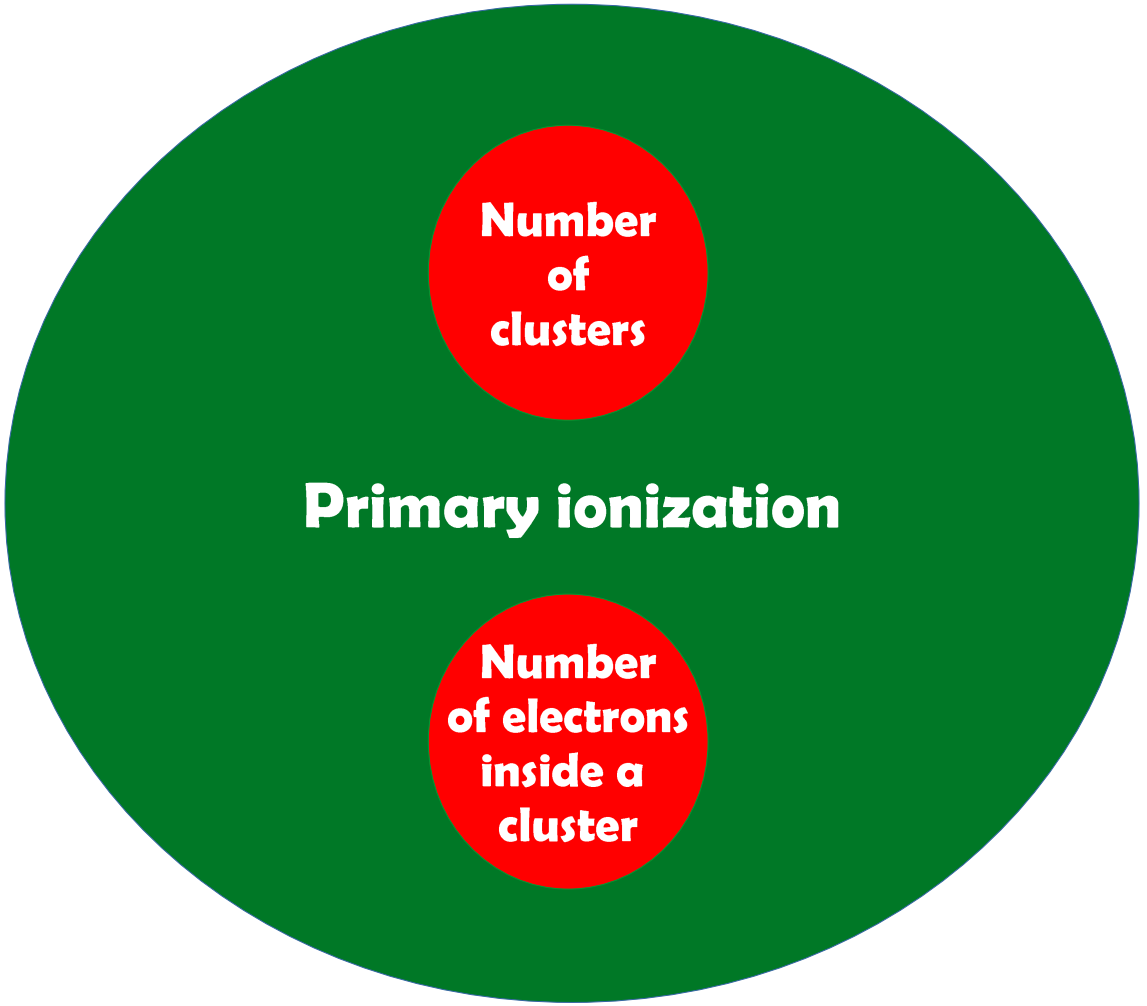
- ELOSS = # total[*] electrons **×** mean energy needed to create an electron-ion pair

[*] primary + secondary

In the final version of the digitization, the energy loss will be **input from GEANT4**...

...we will take care of this later

Primary ionization - III



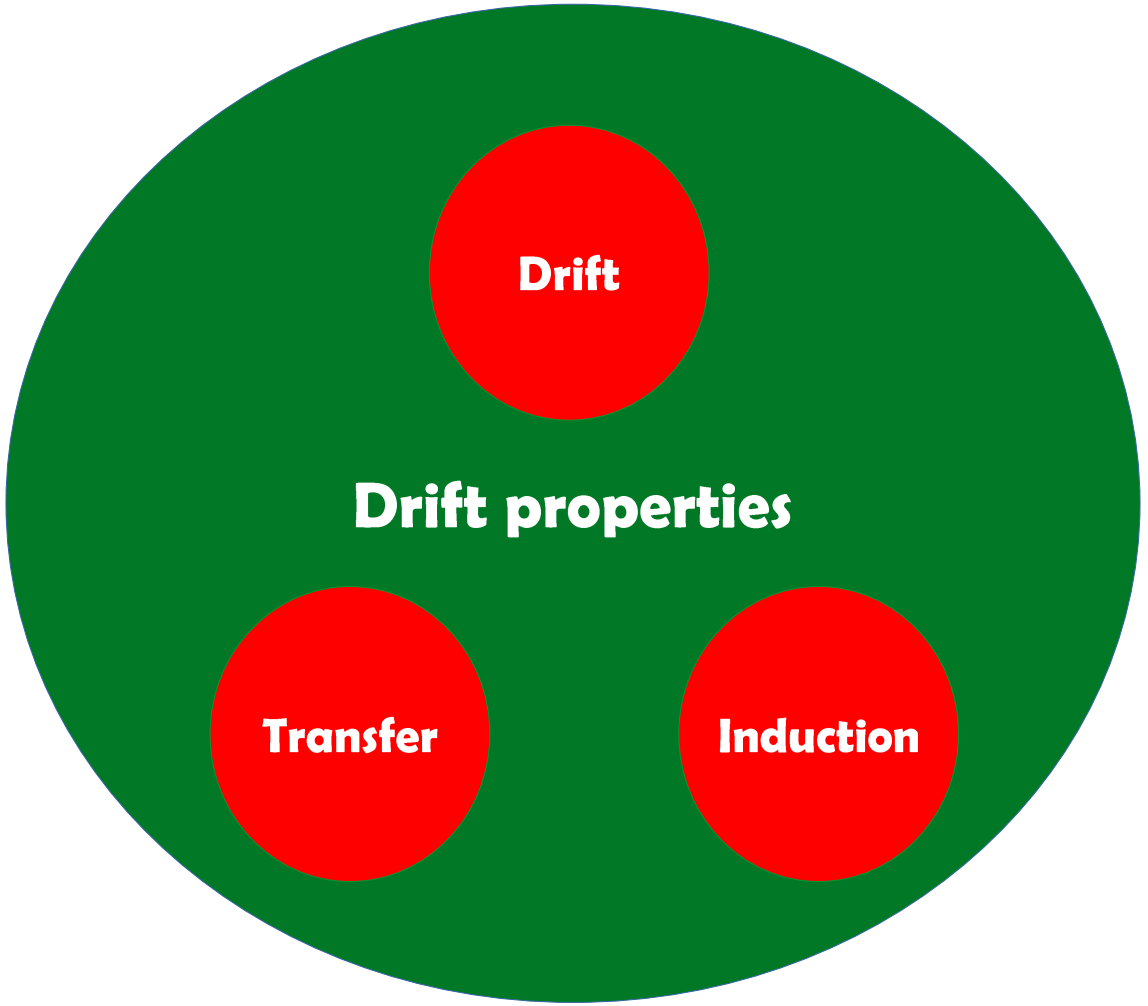
The 2 topics are indipendent, then we can study them separately

2

Drift properties - I

- Given an electron generated in the Drift gap, we have to know its final position and time on the anode
- We have three types of gas region:
  - Drift
  - Transfer
  - Induction

Drift properties - II

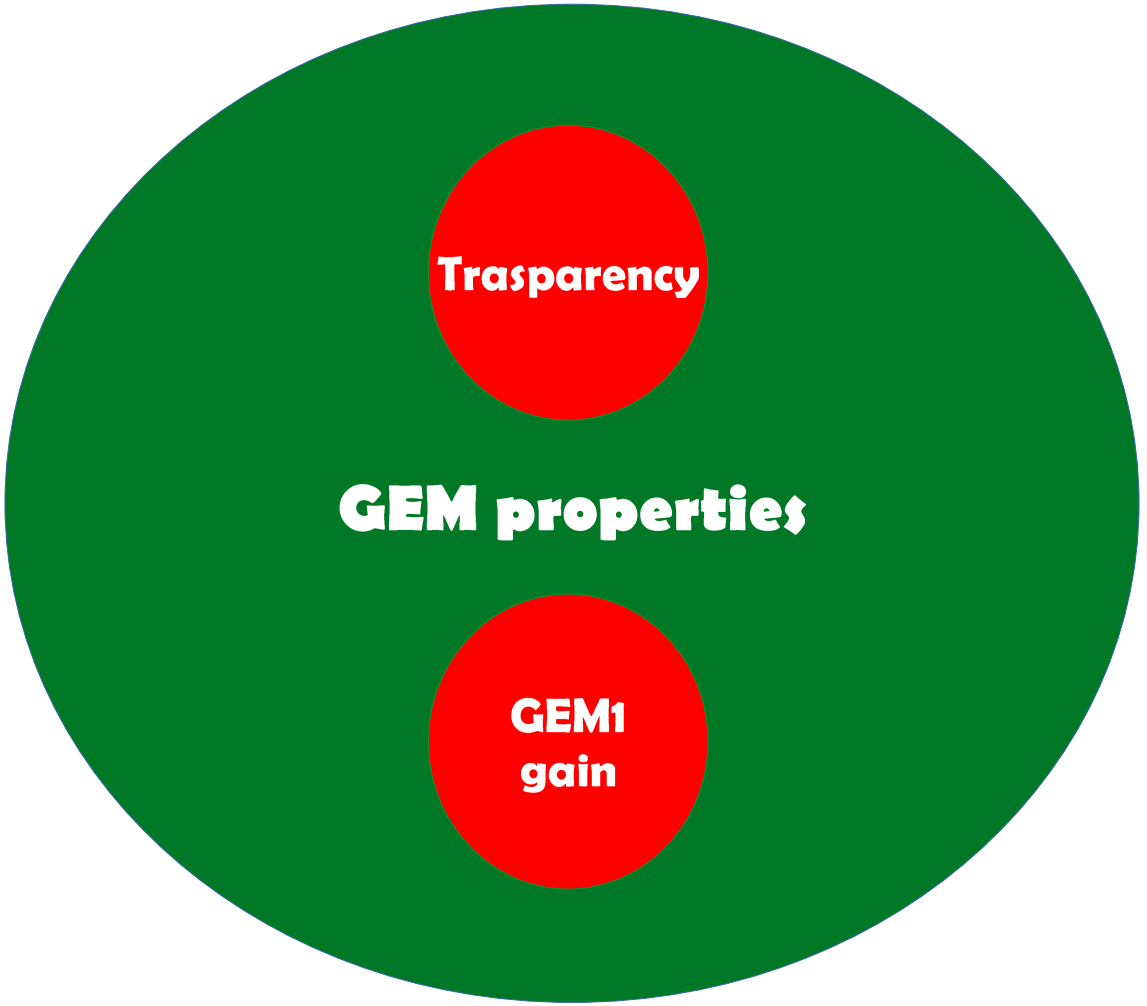


The 3 topics are indipendent, then we can study them separately

GEM properties - I

- Each electron crossing a GEM plane generates an avalanche, if it does not fall on the electrodes
- The gain depends on the applied HV: in this simulation we use HV = 270V/GEM
- The capability of an electron to pass on the other side of the GEM plane depends on the applied fields in Transfer and Induction gaps
- The gain of each GEM shows a Landau distribution
- Only the first GEM gain fluctuation influences the distribution at anode. We can consider a mean value for the gain in GEM2 and GEM3

GEM properties - II



The 2 topics are indipendent, then we can study them separately

Digitization ingredients

1. # generated electron clusters
2. # electrons inside a cluster
3. Spatial shift in the Drift gap
4. Spatial shift in the Transfer gap
5. Spatial shift in the Induction gap
6. GEM1 trasparency
7. GEM1 gain

Digitization ingredients

1. # generated electron clusters
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7. GEM1 gain

From GARFIELD

10k orthogonal μ tracks

e- drift in the DG

e- drift in the TG

e- drift in the IG

e- avalanche in a GEM

Digitization recipe

a) *Generate* the electron clusters

b) *Generate* the # electrons inside the cluster

c) *Simulate* the gain

d) *Obtain* the final position of each electron taking into account the smearing and displacement

Preparation to step a)

Generate the electron clusters

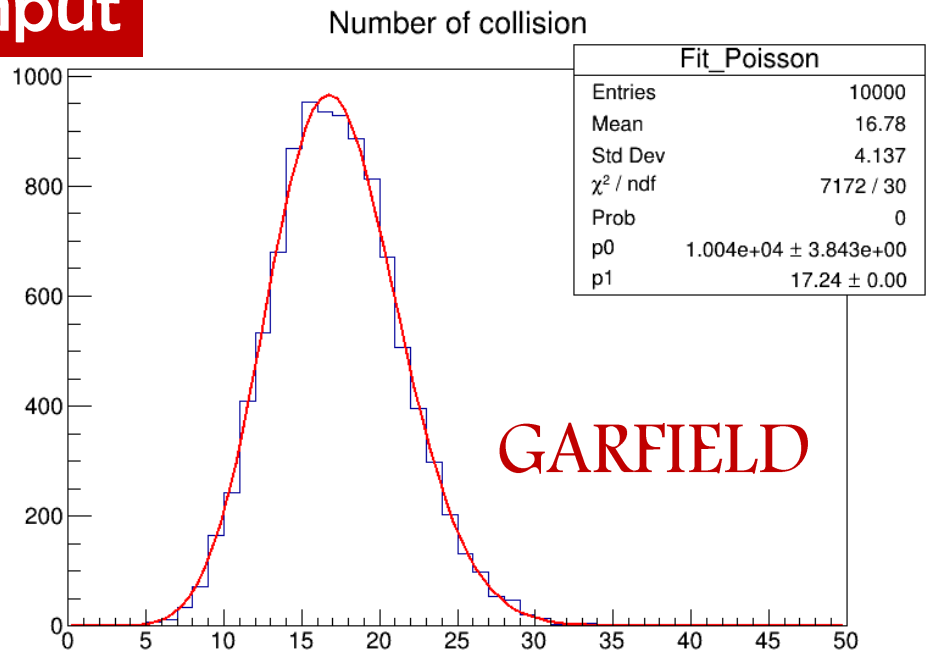
The generation of the electron clusters is a Poisson process

→ sample from an **exponential probability:**

$$p(dz) = A * N * \exp(-N * dz)$$

where N = mean # clusters in 5mm of Ar:iC_4H_{10}

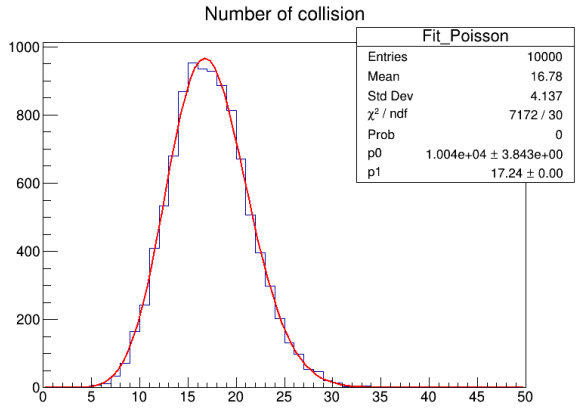
input



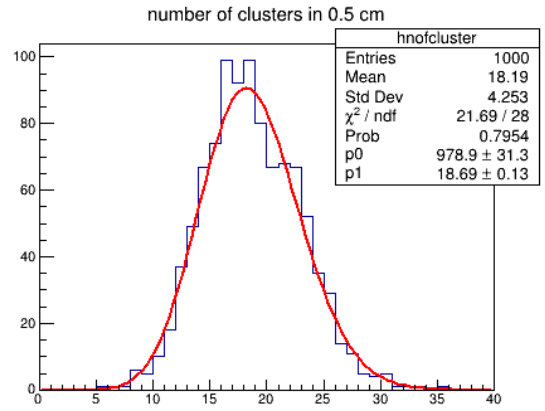
An exponential probability gives the dz between two consecutive clusters. The z position is incremented after each cluster and when > 5mm the loop stops

Check of the step a)

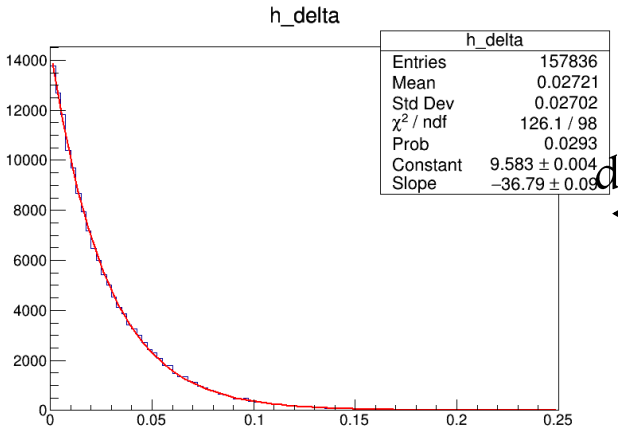
GARFIELD



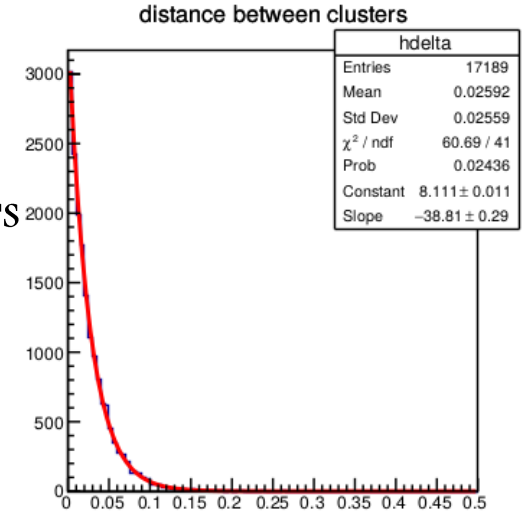
OUR SIMULATION



Number of clusters ↔

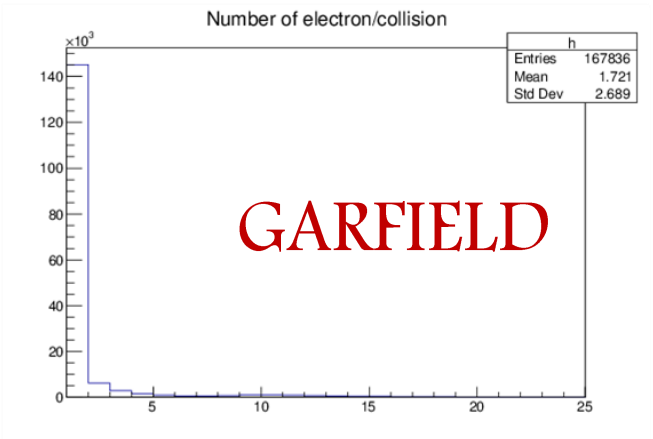


dz between consecutive clusters ↔

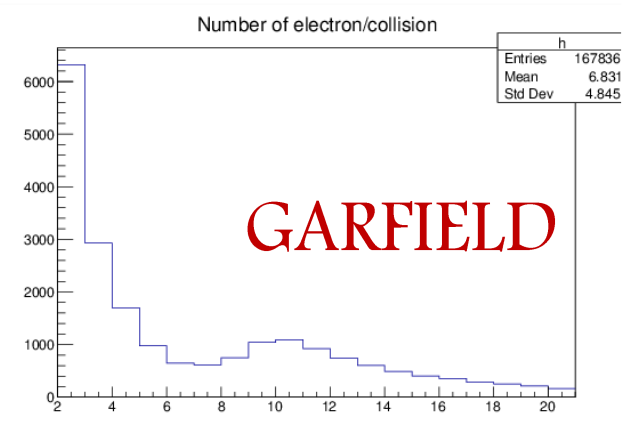


Preparation to step b)

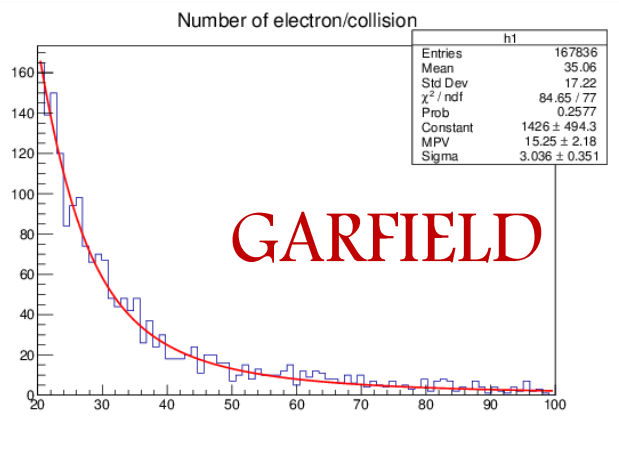
Generate the number of electrons inside the cluster



Range 1-25



Range 2-20



Range 20-100

→ We have recorded the probability in [1, 100]

input

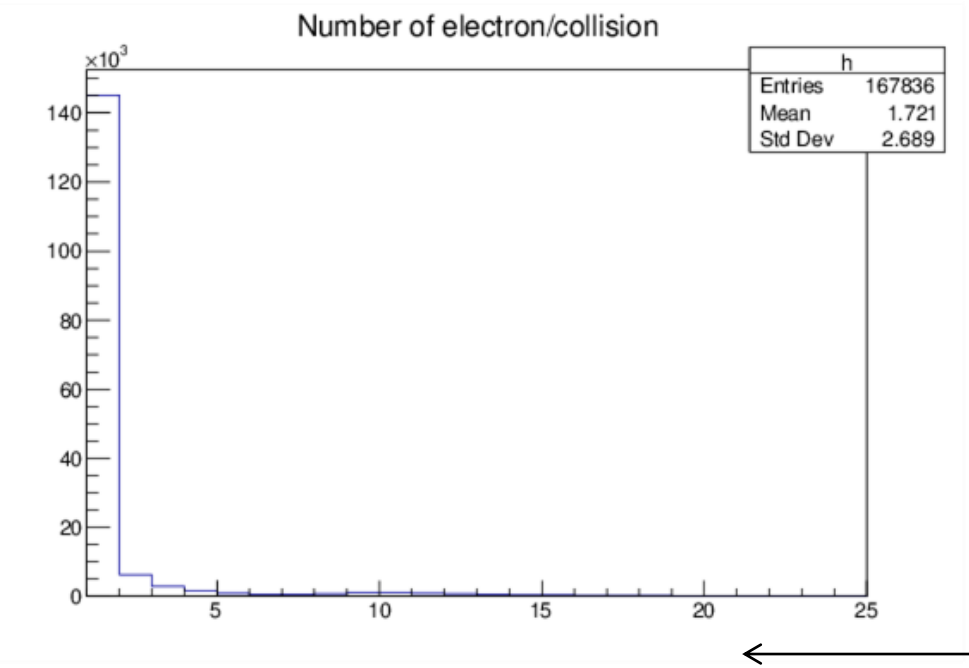
We use:

- the simulation discrete value between in [1, 20]
- the sampled value from the Landau fit in [21, 100]

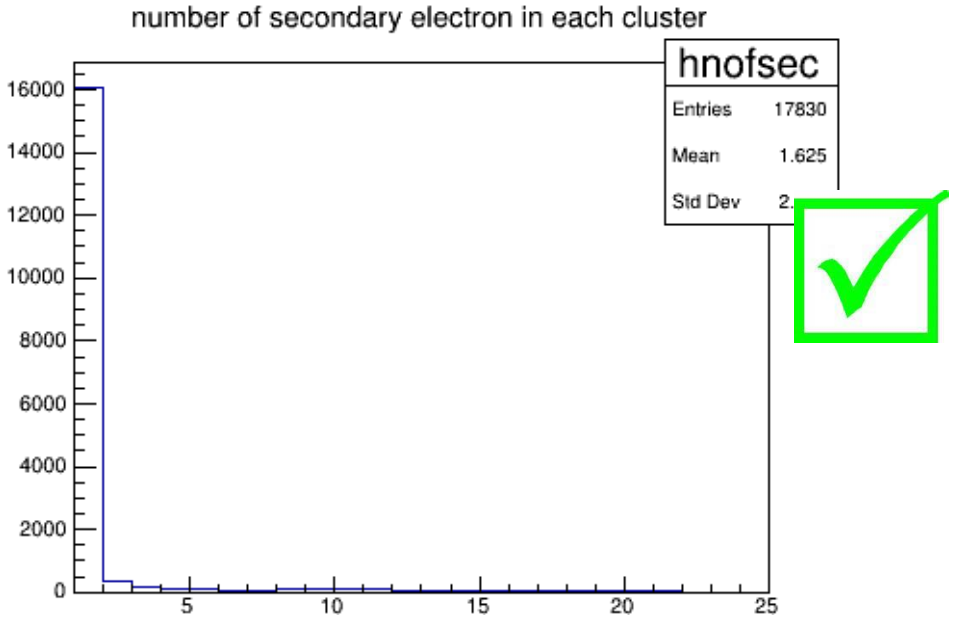
Approximation: # electron limit set to 100.

Check of the step b)

GARFIELD



OUR SIMULATION



Number of electrons inside a cluster

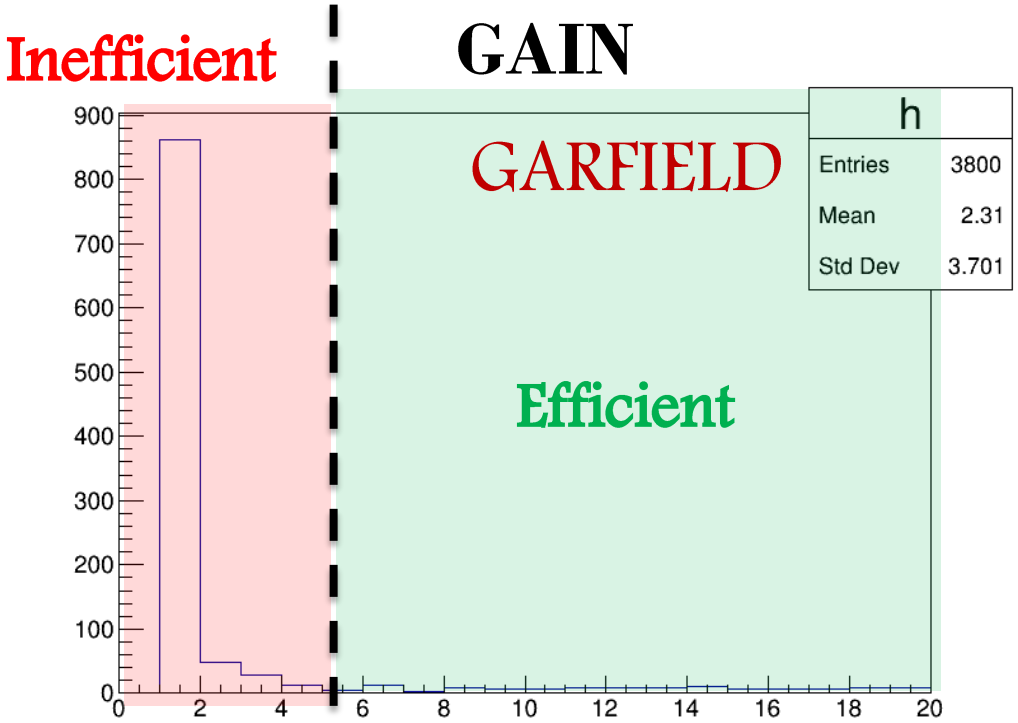
Preparation to step c)

Simulate the gain

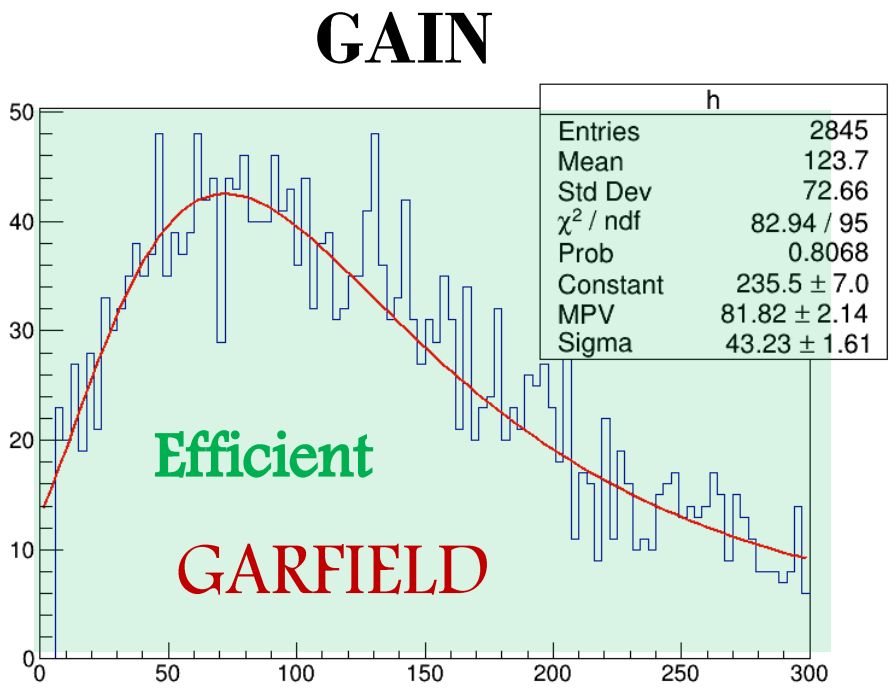
- To evaluate the **gain** and the **trasparency** we simulate an electron avalanche from 150 μm *before* GEM1 to 150 μm *after* GEM1
- The number of generated electrons has two behaviors:
  - a peak at the values 0, 1, 2, 3, 4, 5
  - For gains > 5 → Landau shape
- We consider the electron *inefficient* if the gain is below 5 →

  transparency = #efficient electrons / #total electrons

Preparation to step c)



Range 1 - 20



Range 5 - 300

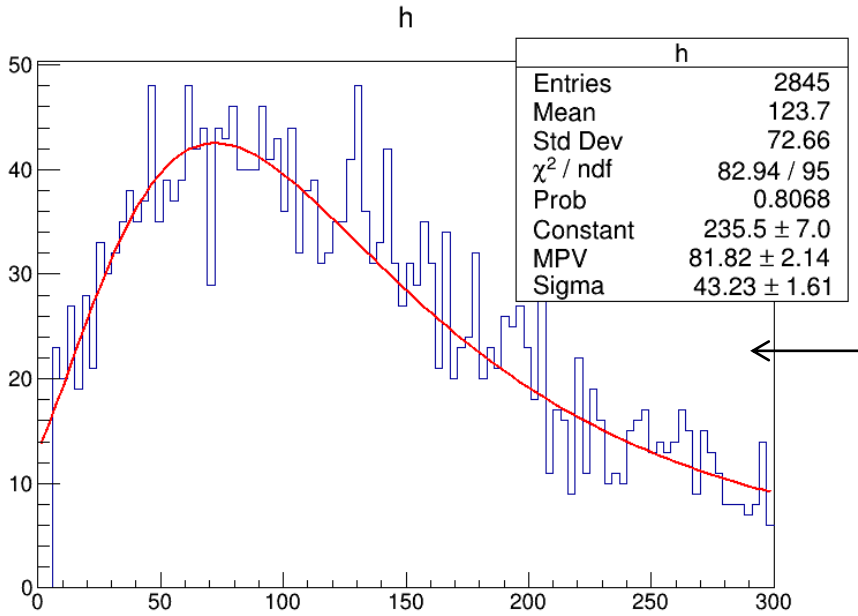
input Measured trasparency = 74.5 %

Step c)

- The electrons that survive to the GEM1 (given by the transparency) are amplified
- The gain of the GEM1 is sampled from a Landau
- For GEM2 and GEM3 the gain is set **constant** because the fluctuations there are not important
- We currently use a low gain value in GEM2 and GEM3 otherwise it takes too much time

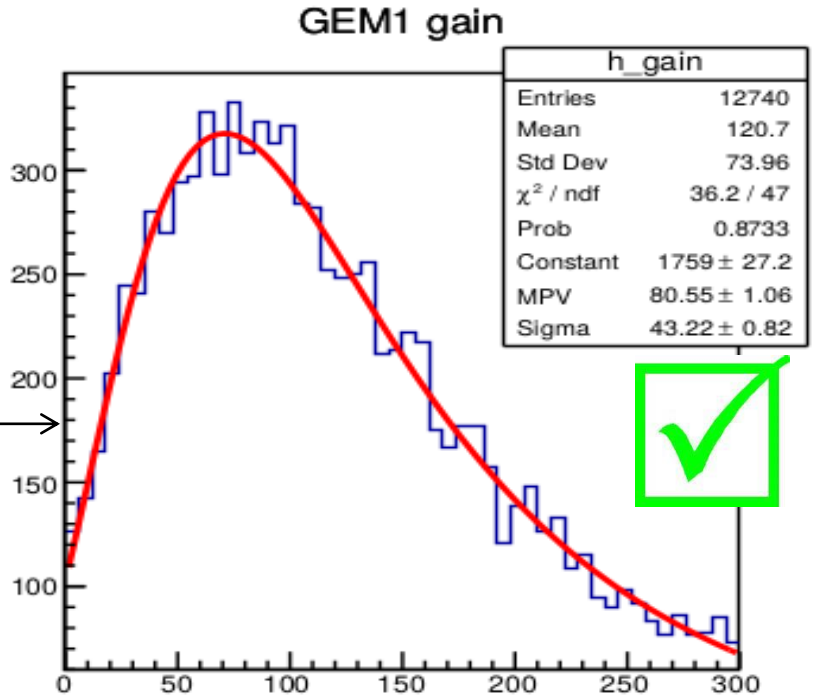
Check of the step c)

GARFIELD



GEM1 gain

OUR SIMULATION



Preparation to step d)

Get the final position of each electron

To obtain the complete transport from the Drift gap to the anode we simulate the entire triple-GEM (no empty steps) in separate stages.

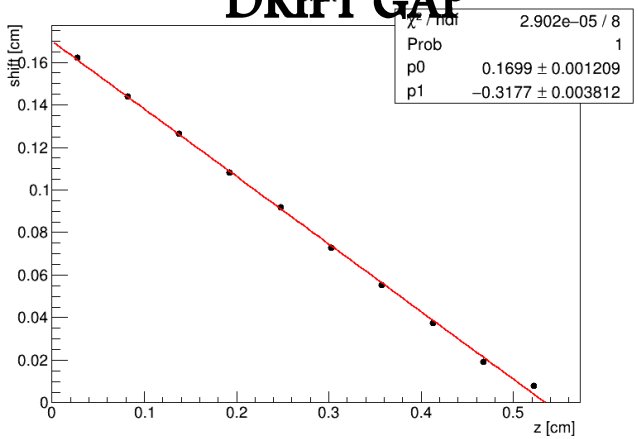
The shift depends:

- [in the Drift gap] on the z of the electron cluster generation. Its drift is simulated to 150 μm after GEM1 to consider the displacement due to the passage through the GEM hole
- [in the Transfer gap] NOT on z of the cluster. The electrons drift from 150 μm after GEM1 to 150 μm after GEM2 to consider the displacement due to the passage in the GEM hole
- [in the Induction gap] → same as TG

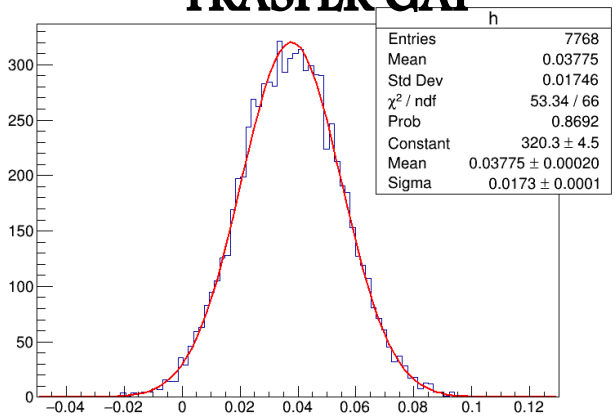
GARFIELD

Preparation to step d)

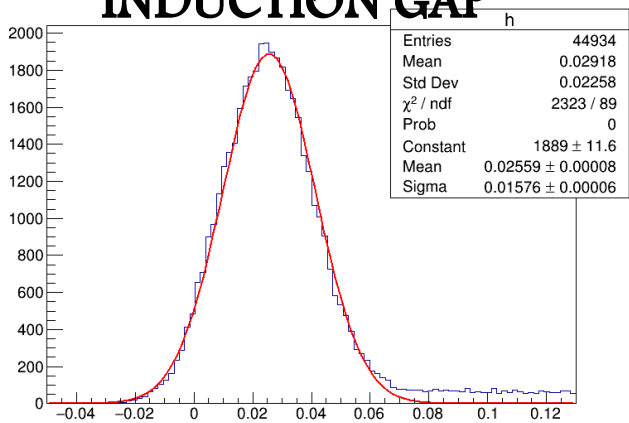
DRIFT GAP



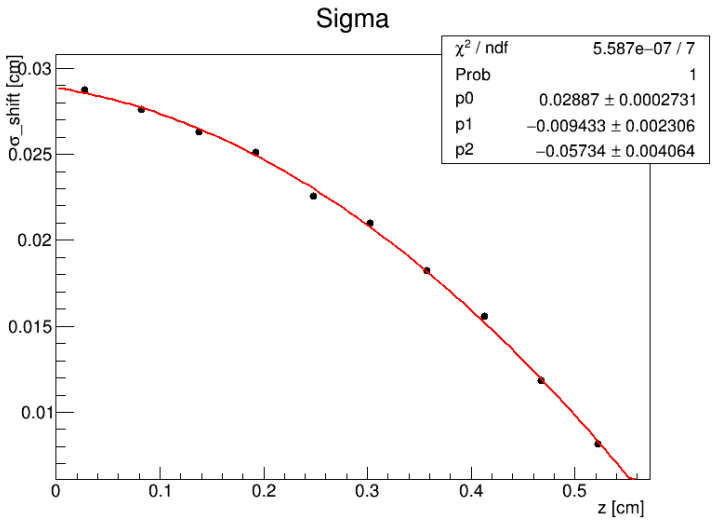
TRASFER GAP



INDUCTION GAP



input $\mu\_shift\_tot(z) = shift\_DG(z) + 2*shift\_TG + shift\_IG$



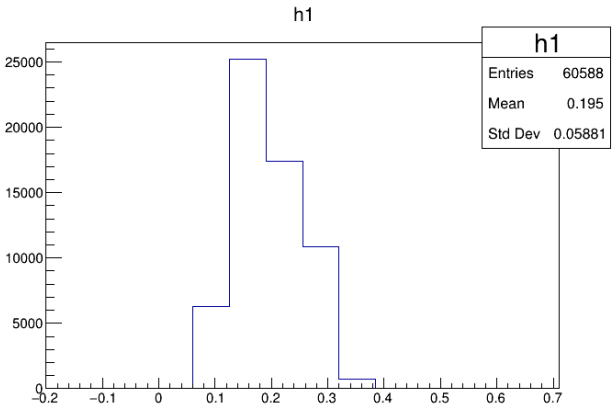
input $\sigma\_shift(z) = \sqrt{[\sigma_{x\_DG}(z)^2 + 2*\sigma_{x\_TG}(z)^2 + \sigma_{x\_IG}(z)^2]}$

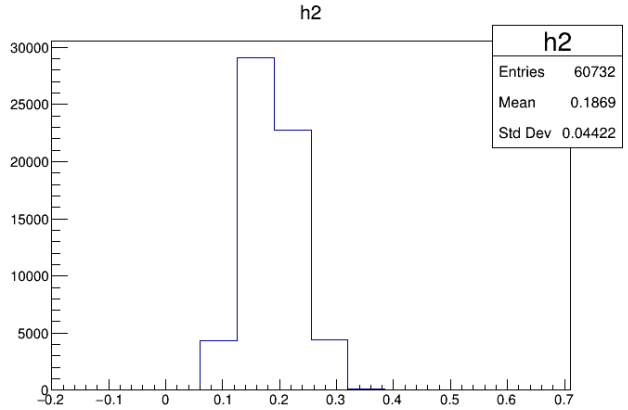
Step d)

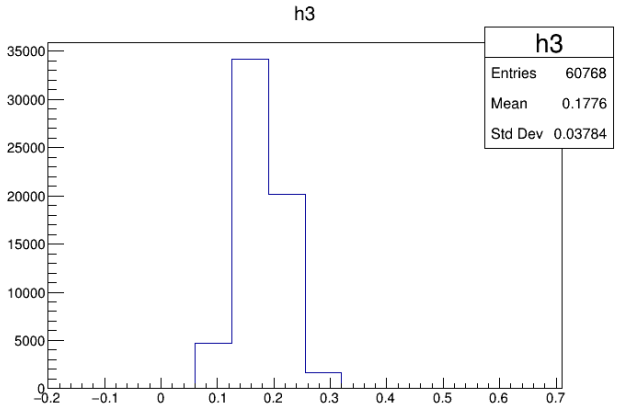
Generate a random Gauss number around **μ_shift (z)** and smear it by **σ_shift (z)** for **each** electron

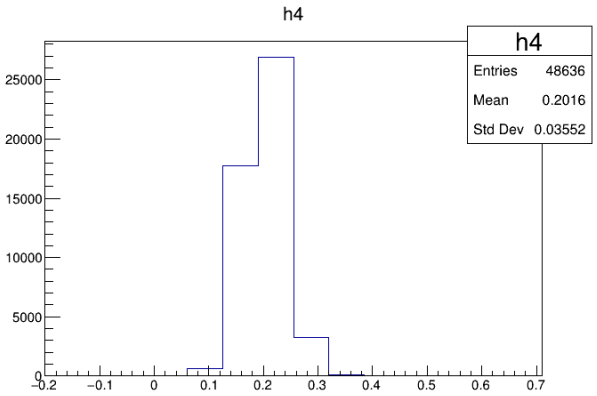
now cook everything together
at 180°C for 30 minutes using
1k simulations …

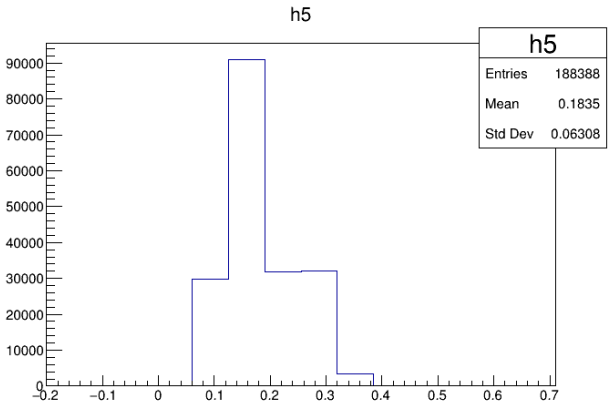
charge distribution @ anode











Next to do

- Simulation of the signal formation on the anode
  - Maxwell?
  - APV simulation on 1° step
  - Interact with the TIGER group for eventual electronics
- μTPC reconstruction
- Noise (info from testbeams)
- Charge threshold
- Test on tracks @ different angles
- Tune the simulation with testbeam results
- Use dE/dx from Geant4 as input

Next to do

- Simulation of the signal formation on the anode (!)
  - Maxwell?
  - APV simulation on 1° step
  - Interact with the TIGER group for eventual electronics
- µTPC reconstruction (!)
- Noise (info from testbeams)
- Charge threshold
- Test on tracks @ different angles
- Tune the simulation with testbeam results (!)
- Use dE/dx from Geant4 as input

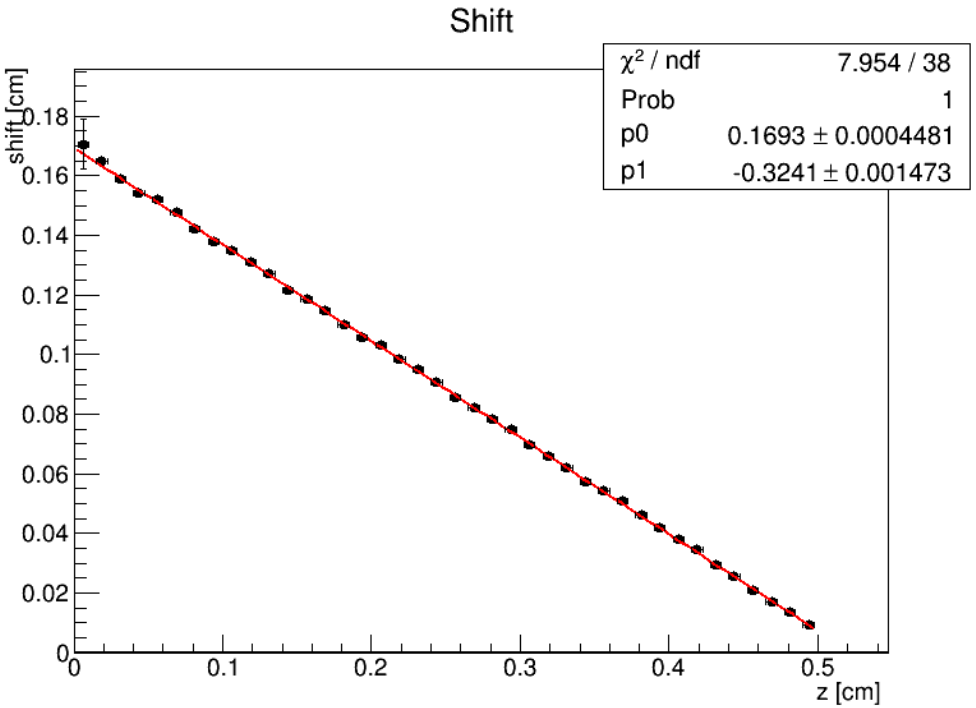
- Anything else?

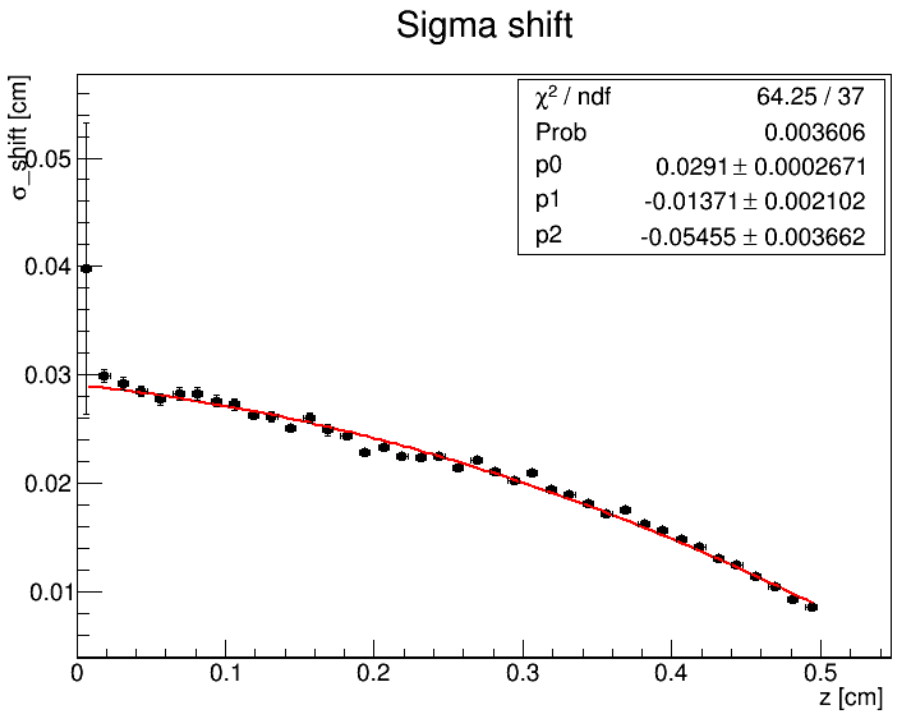
IMPORTANT – deadline may 2017

spare

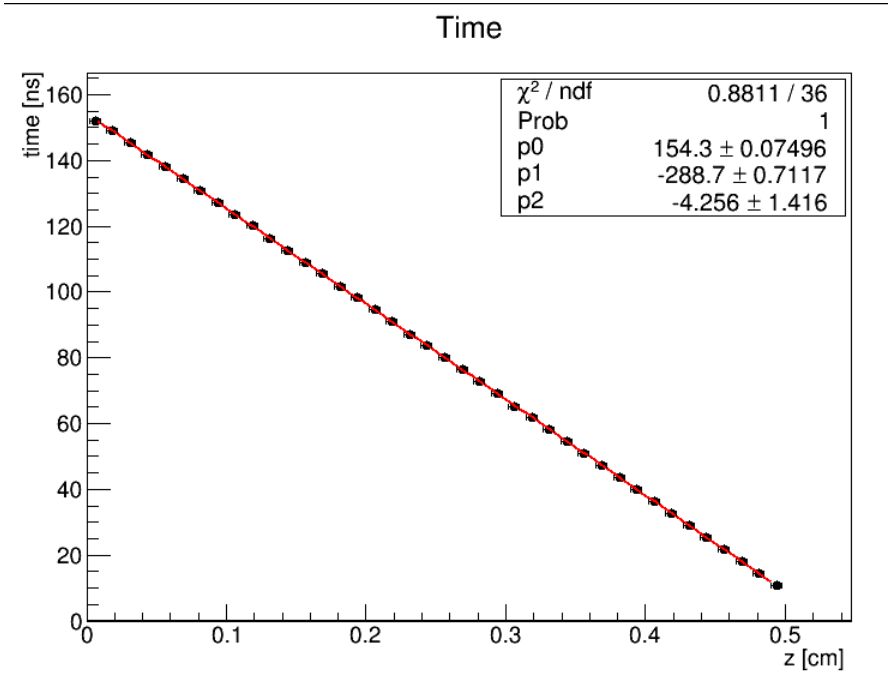
x position

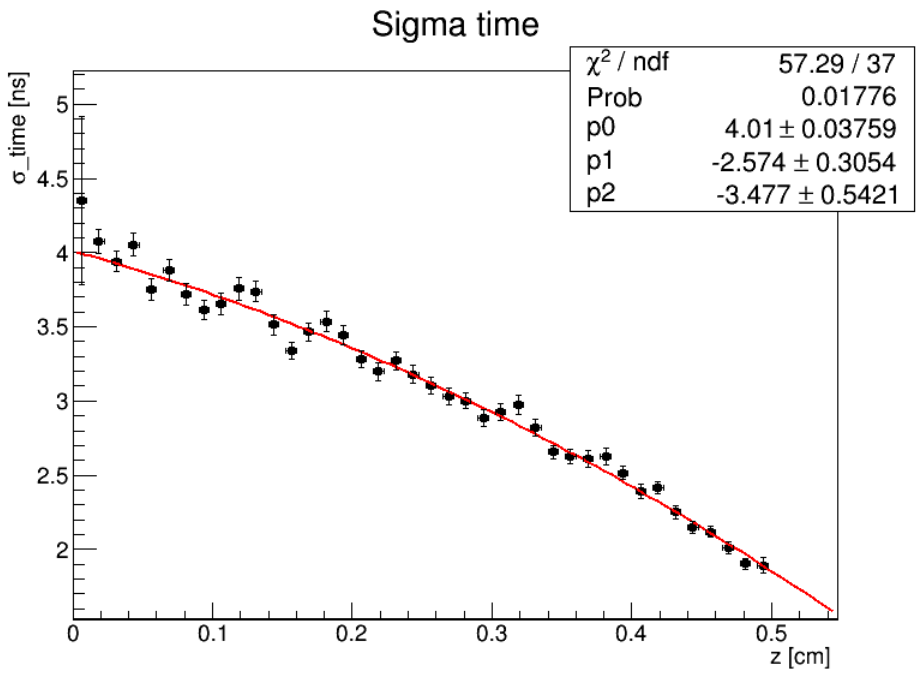
250 run



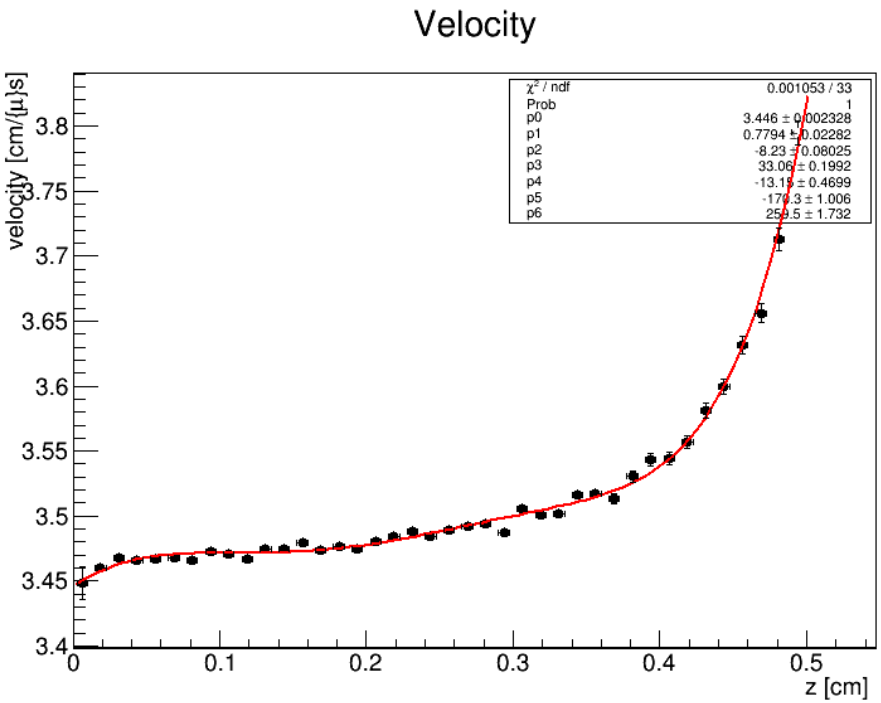


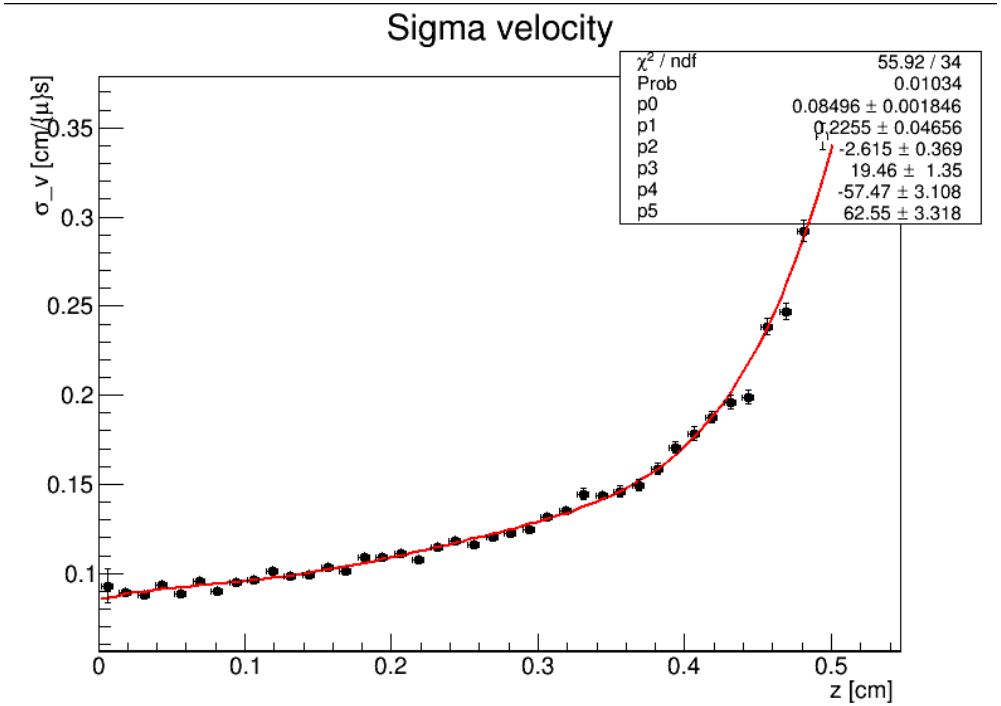
time of arrival on anode





drift velocity





$$[\text{HERE}]\ V\_drift = \frac{(x\_anode - x\_generation)}{(t\_arrival - t\_generation)}$$