Signal Shapes in the ALICE TPC

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GOETHE UNIVERSITÄT FRANKFURT AM MAIN

IKF Institut für Kernphysik Frankfurt

H-QM Helmholtz Research School Quark Matter Studies

ALICE

OUTLINE

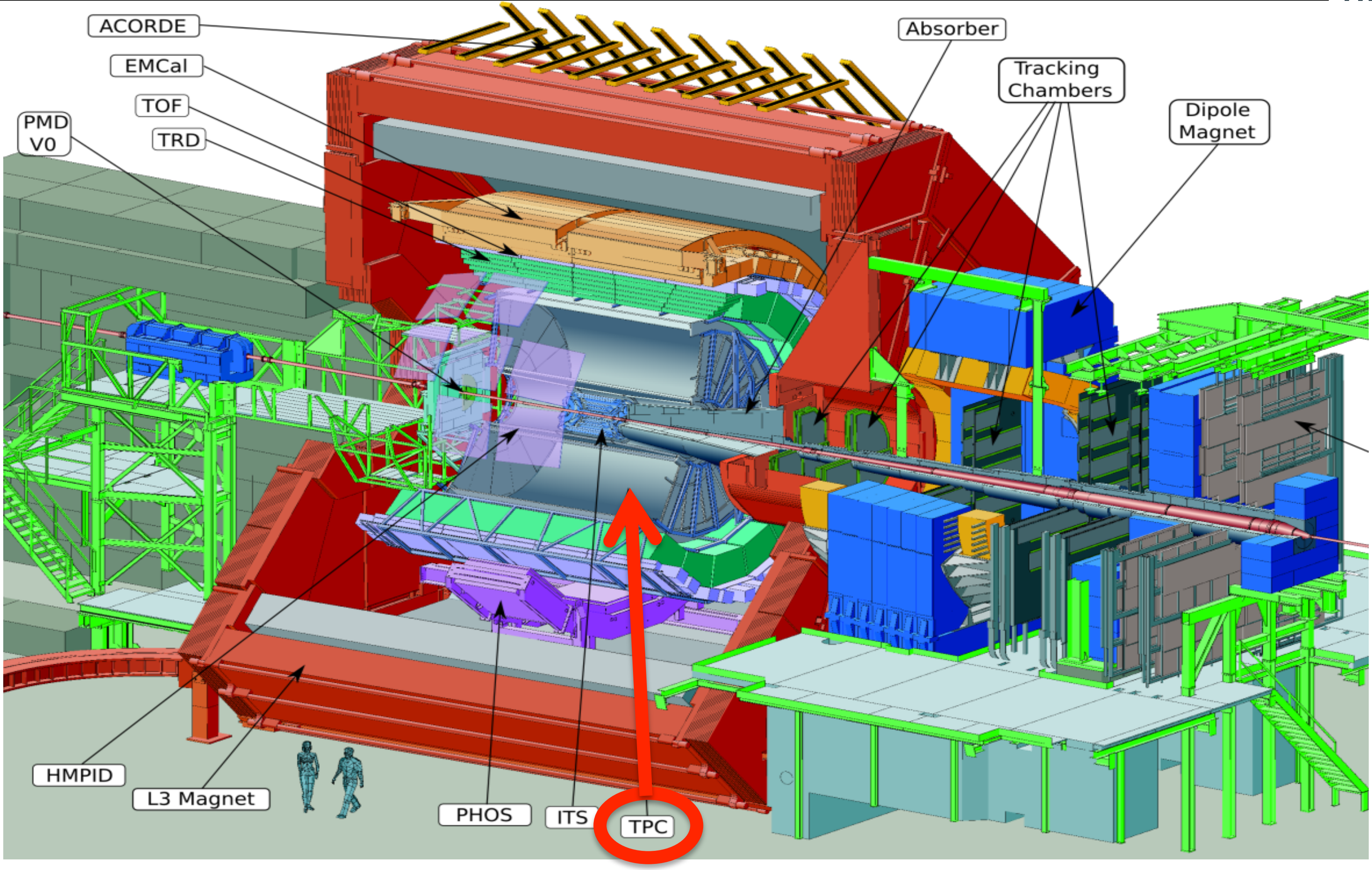
Introduction

- **A** **L**arge **I**on **C**ollider **E**xperiment, **ALICE**
- **T**ime **P**rojection **C**hamber, **TPC**
- TPC Laser System

ALICE TPC Signal Shape

- Motivation → **Ion-Tail and Common-Mode**
- Signal Shape studies with **Real Data**
- Ion-Tail: **Garfield Simulations**
- **Offline Correction Procedure**
- Results
- Summary

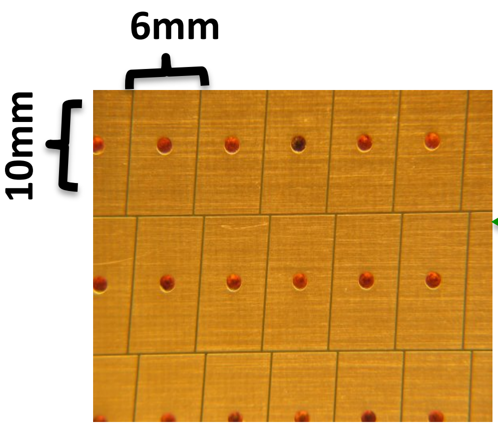
ALICE Detector Setup

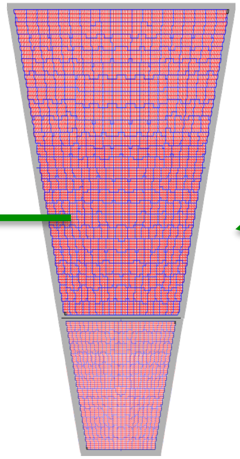


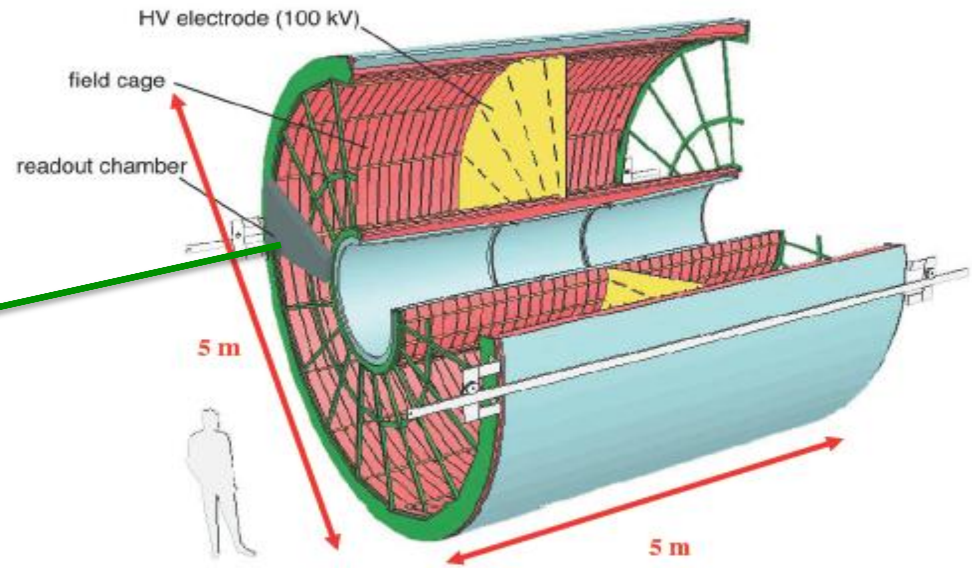
TPC: Main tracking and particle identification (PID) detector

Time Projection Chamber, TPC

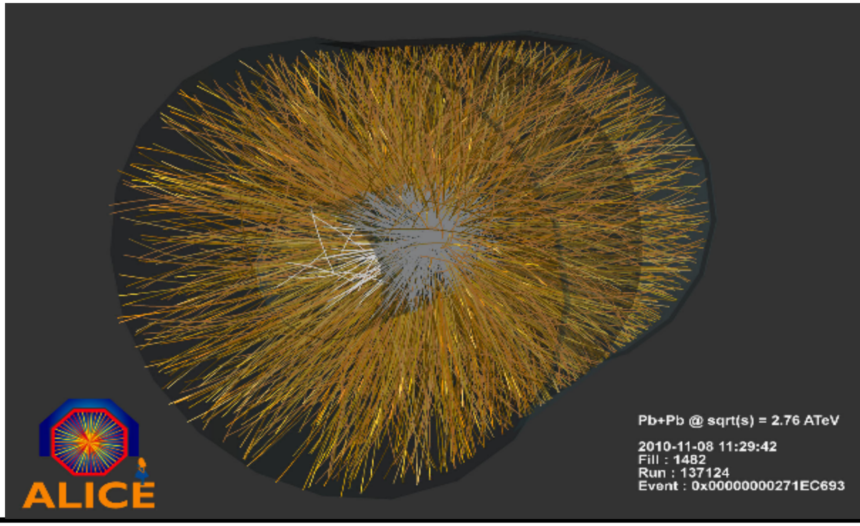
→ Designed to measure up to **20000 primary and secondary particles** in a single central Pb-Pb collision



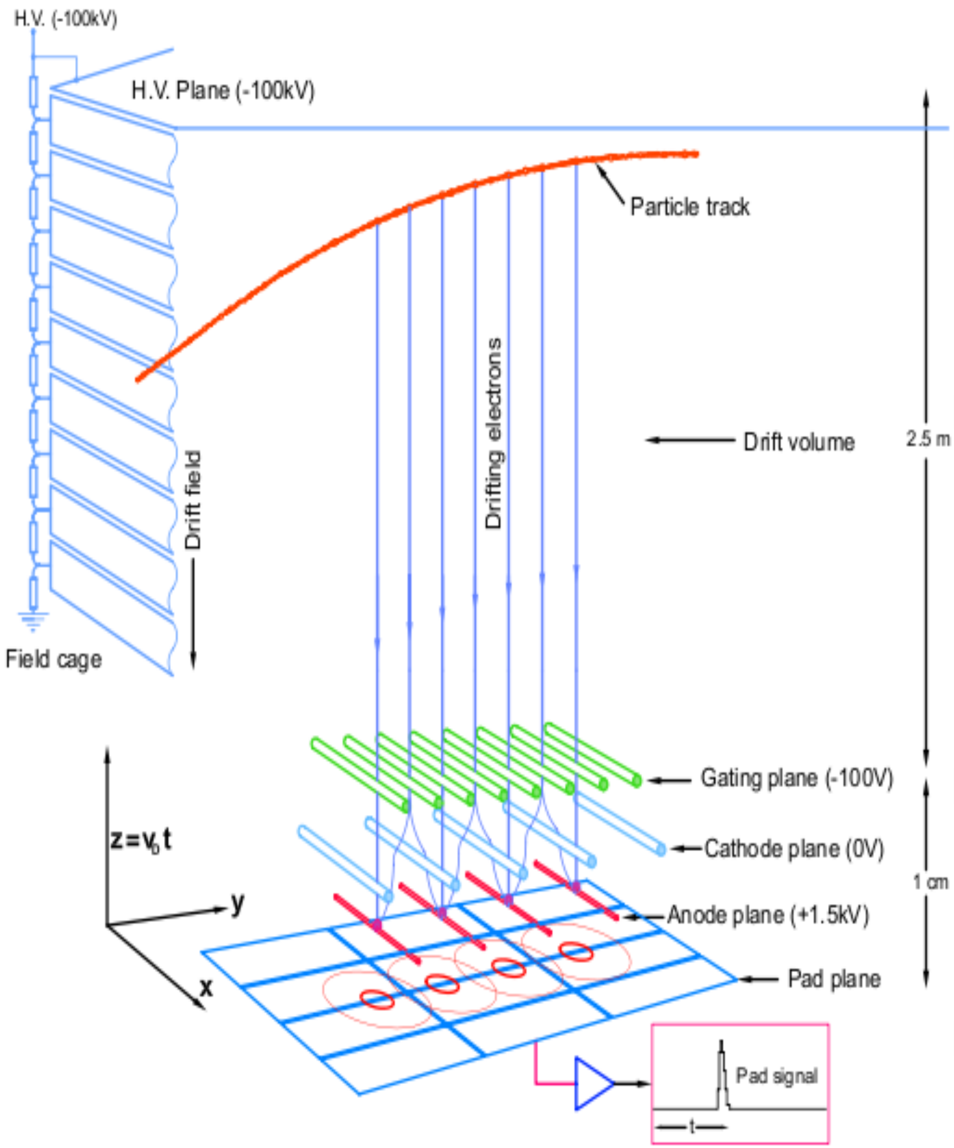




- **Ne-CO_2:** 90% -10%
- **Read-out chambers:** 72
- **159 rows** (maximum number of clusters per track)
- **Pads** (readout channels): 557 568
- **Time bins** (samples in z direction): 1000



Working Principle



Ionization

Electron Drift

Gas Amplification

MWPC (Multi-Wire Proportional Chambers**)**

→ Electrons with **~1000 larger drift velocity**

→ Original charge is multiplied by a factor of **several thousands**

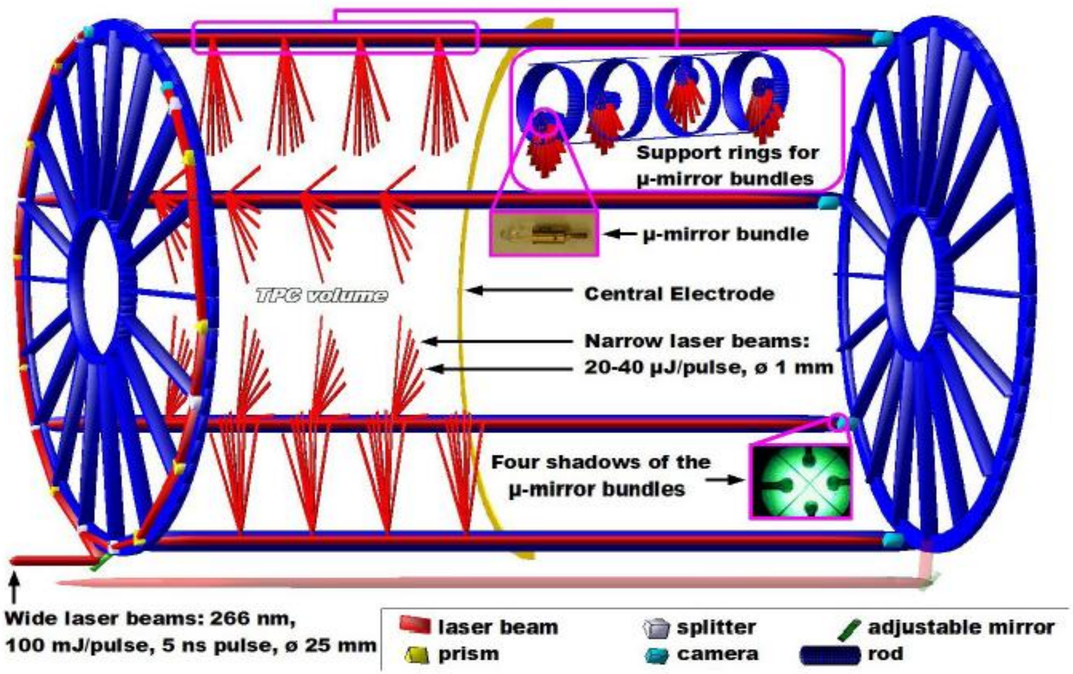
Signal Generation

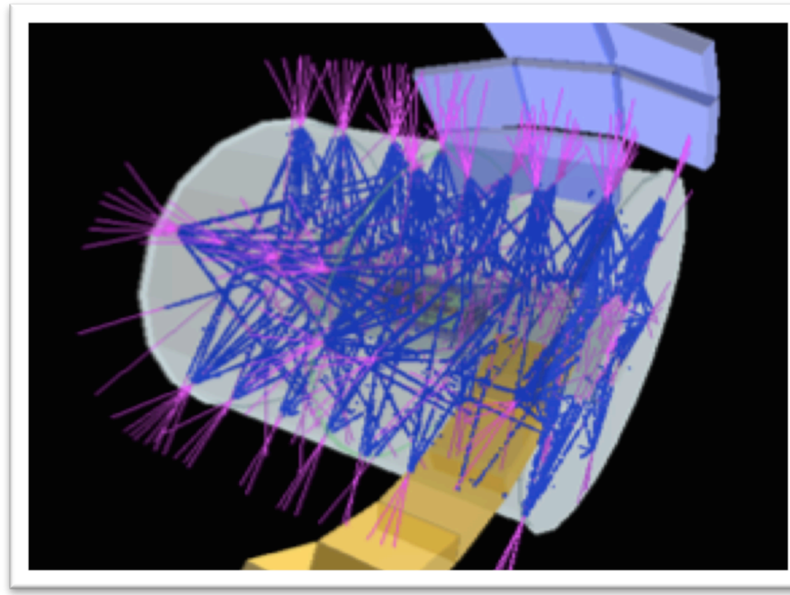
→ **Mirror charge of ions** induces the signal

→ **FEE** amplifies and shapes the induced signal of **each pad**

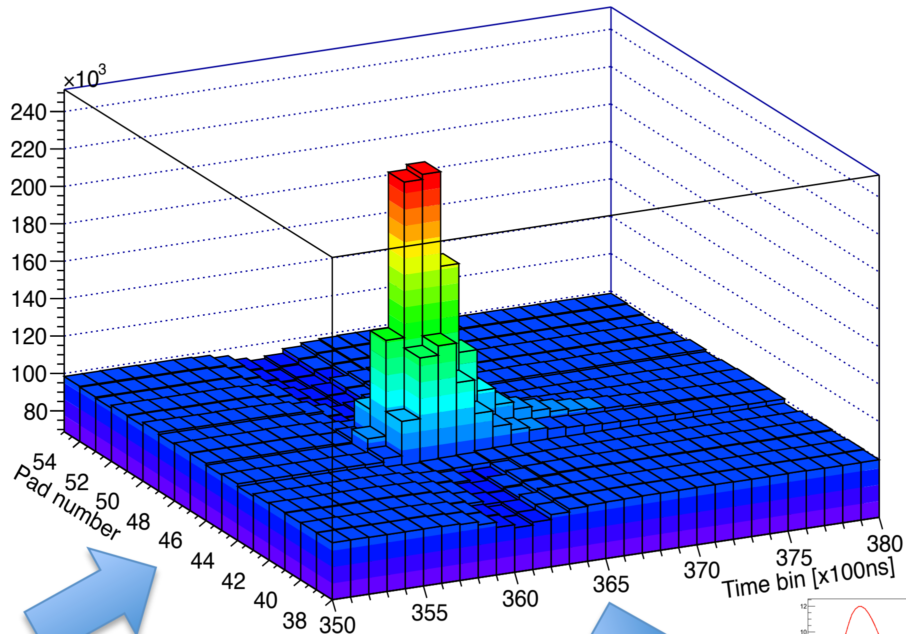
TPC LASER SYSTEM

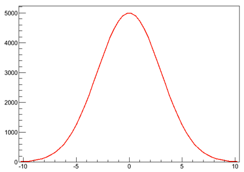
→ For the Signal Shape analysis TPC laser data was used.



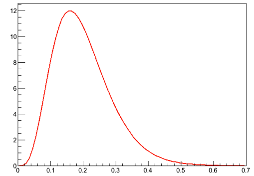


TPC cluster over a 5x5 pad-timebin matrix





Gauss



12*exp(4)*(t/0.16)^4*exp(-4*t/0.16)
(transfer function of PASA)

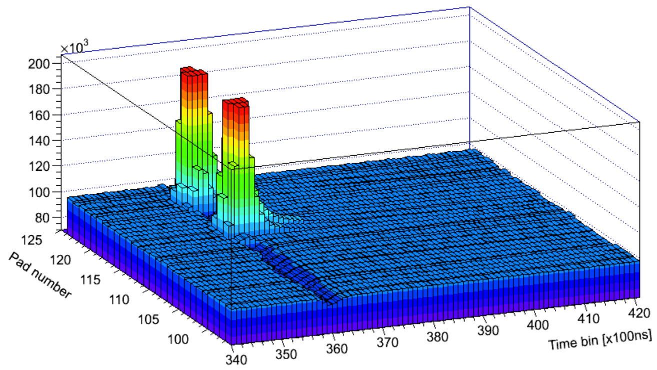
Laser Signal before pedestal subtraction → 2000 events

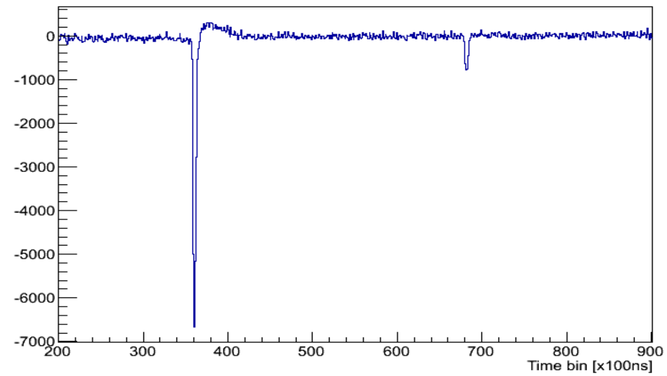
ALICE TPC
Signal Shape

MOTIVATION

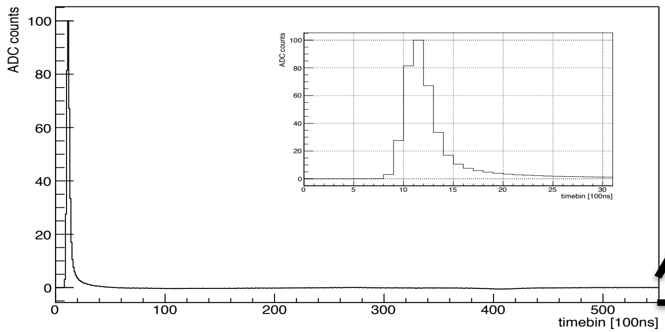
→ The **PID** is calculated from the **specific energy loss measurement (dE/dx)**, which is derived from the **pulse height distribution** of charged particle tracks

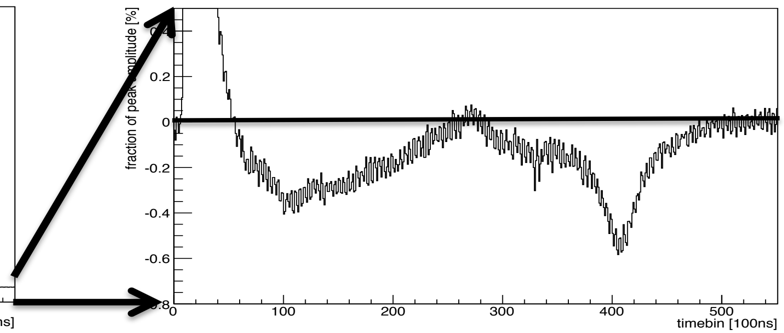
Common-Mode → Along pad direction





Ion-Tail → Along time direction

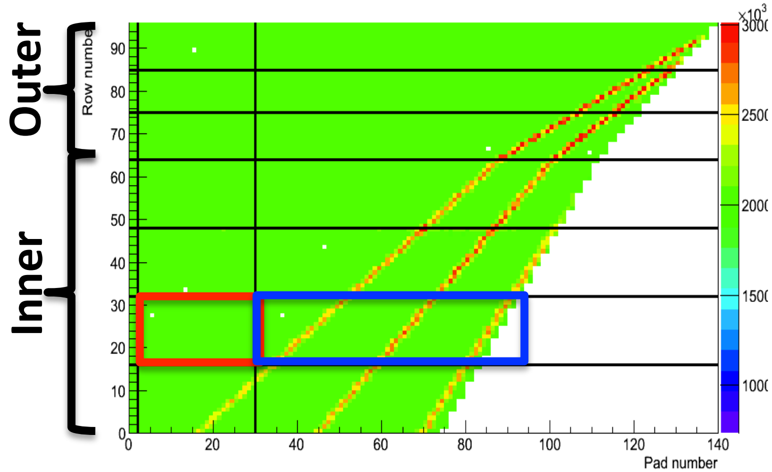




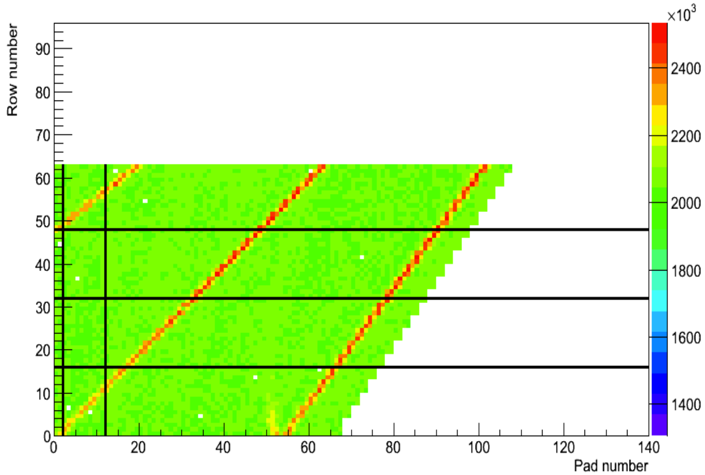
Worsening of dEdx resolution and cluster loss

Common-Mode Effect: Charge Conservation

OROC

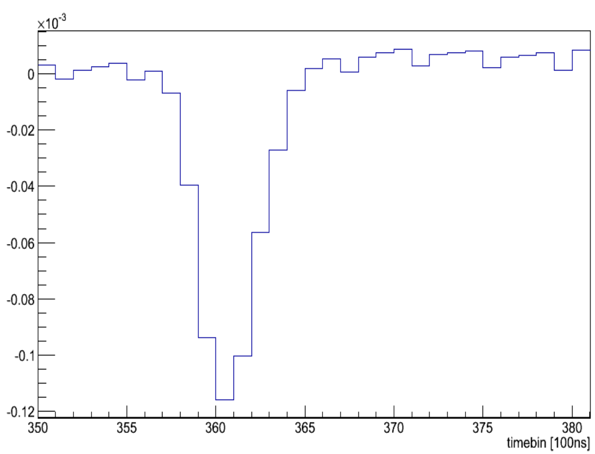


IROC

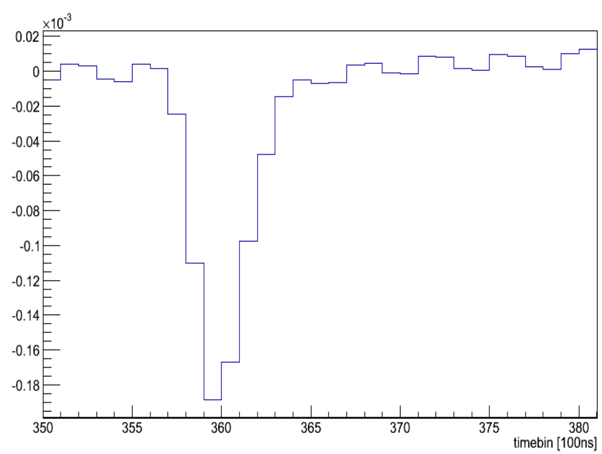


Anode wire segmentation

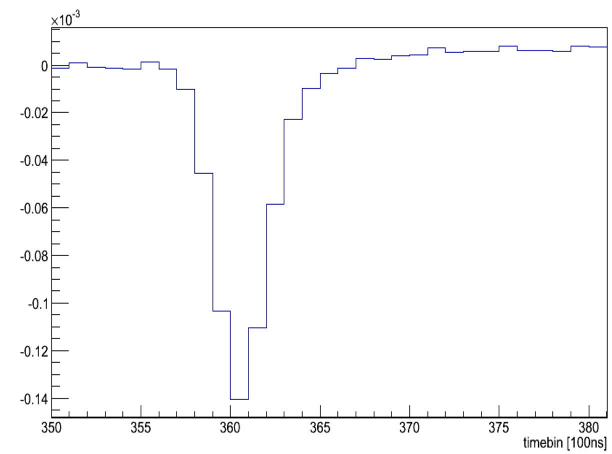
IROC



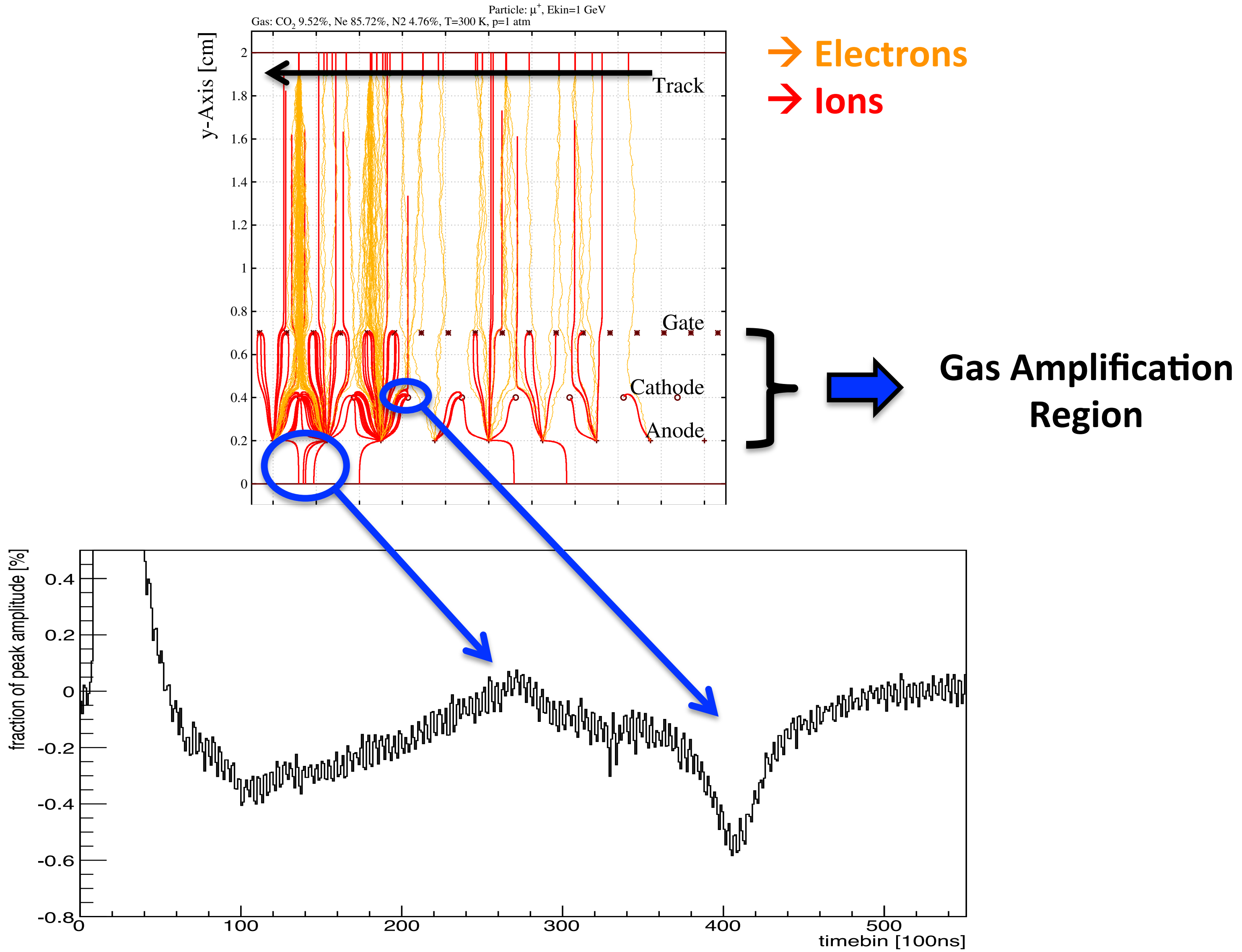
Inner OROC



Outer OROC



Ion Tail: Reason



Ion Tail: Dependencies

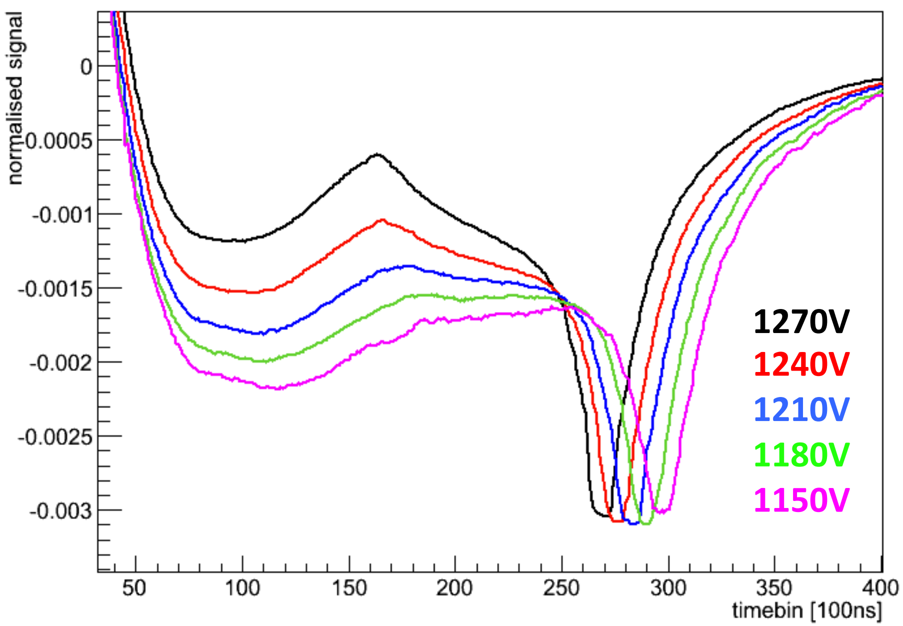
Ion tail signal shape depends on:

→ Anode **Voltage**

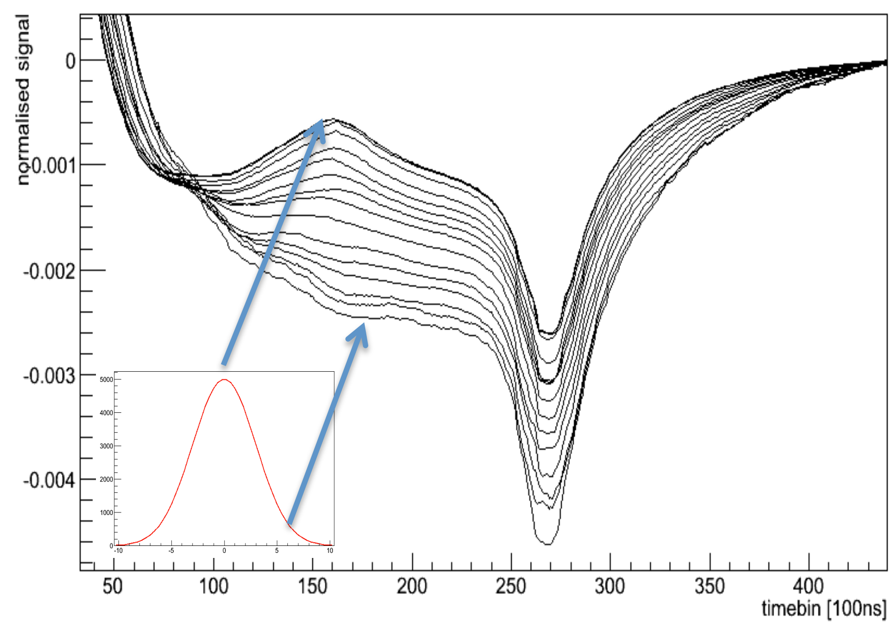
→ Signal **position** on a given pad wrt to the center of gravity of cluster

→ **Geometry**.

Voltage Dependence

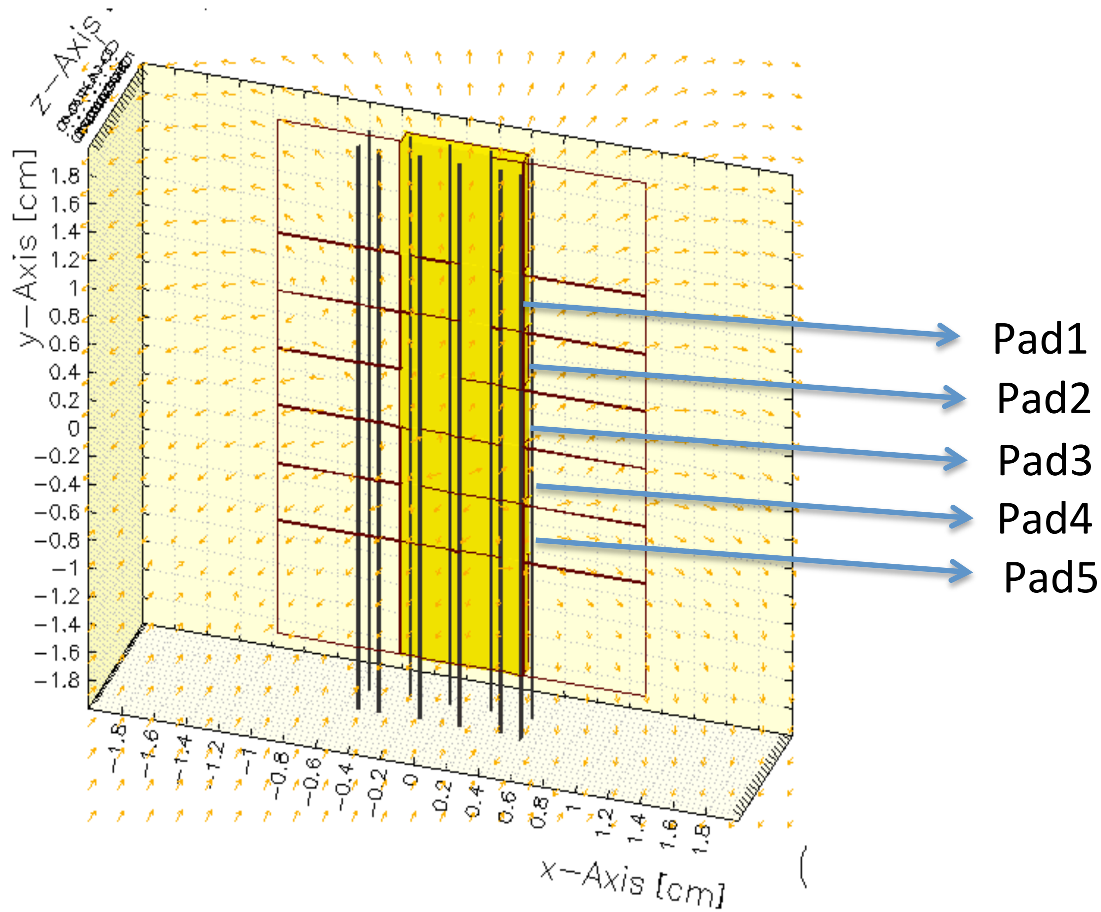


Position Dependence



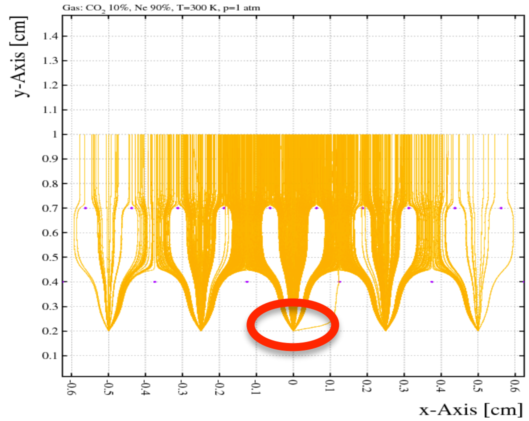
Ion Tail: Garfield Simulations

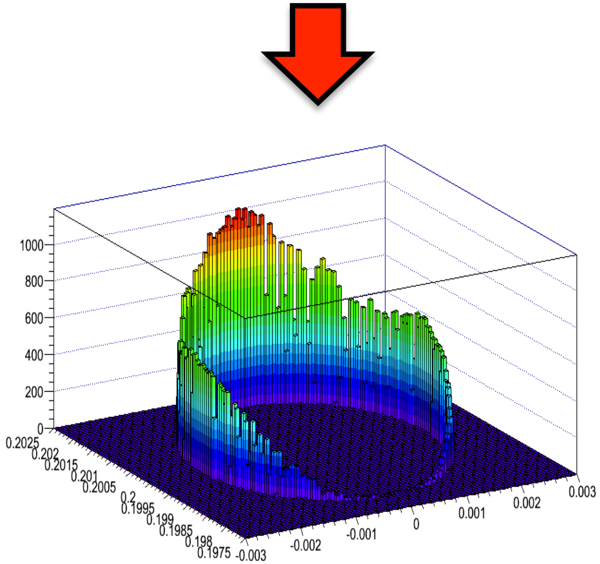
→ 3D setup which similar to the **IROC geometry of TPC**
→ Calculations were done with **NEBEM**
→ **Ne^+ ions are drifting in Ne gas**



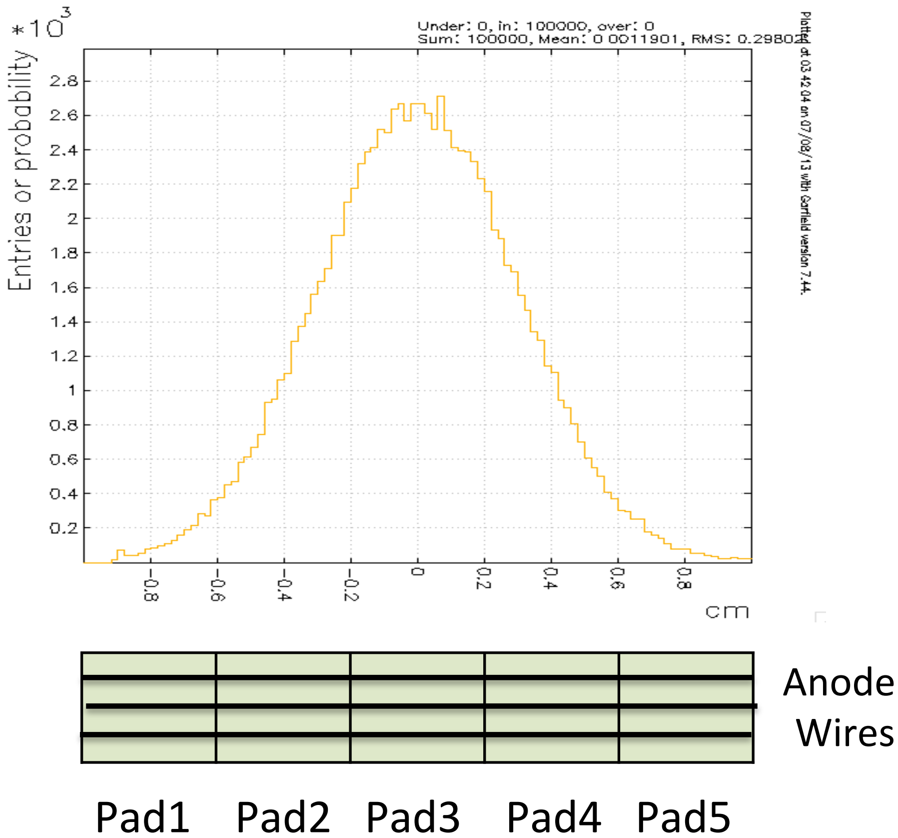
Ion Tail: Ion Distributions

Distribute ions around the wire as a triple gaussian profile

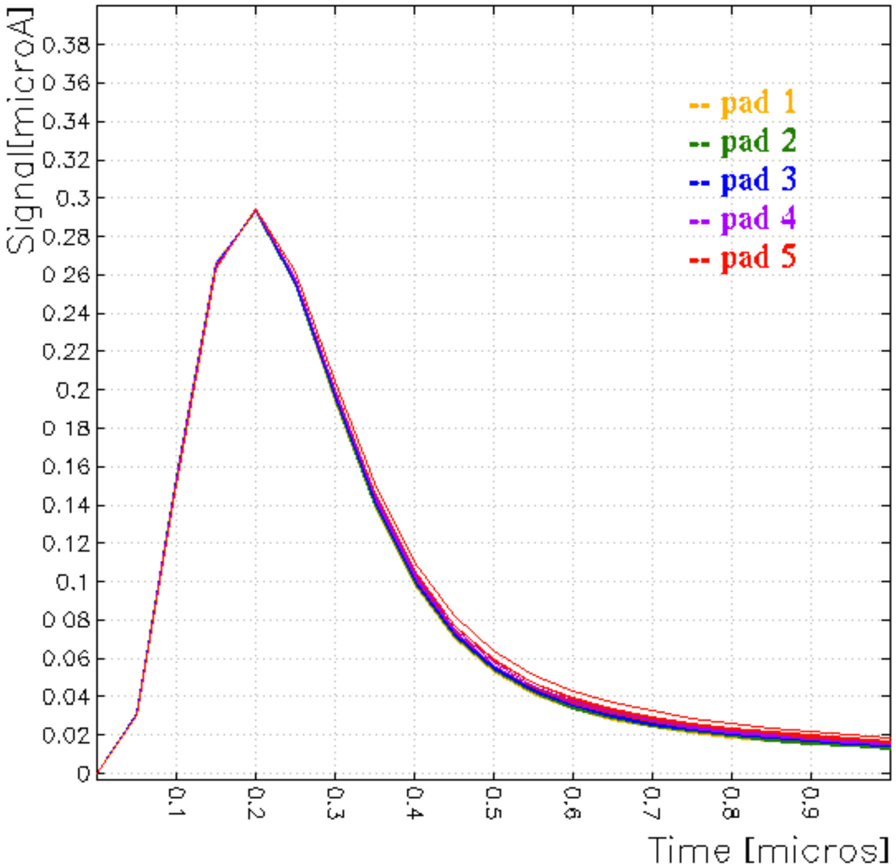


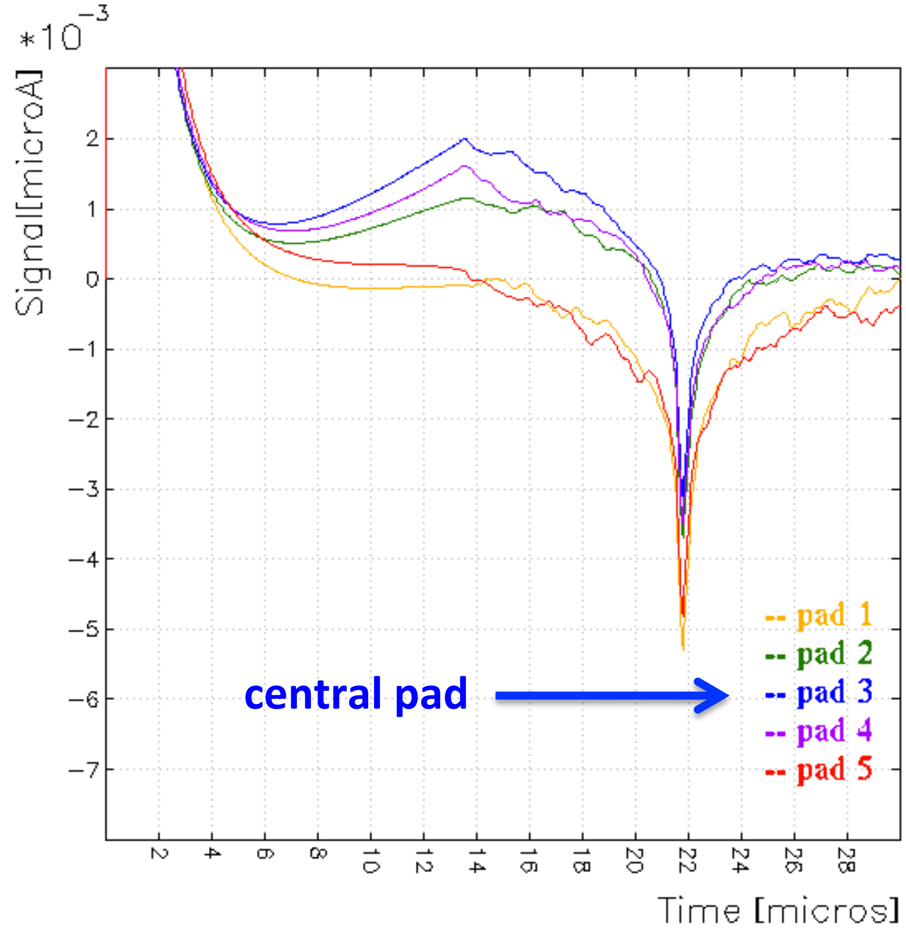


Distribute ions with the shape of Pad Response f. along the anode wires



Ion Tail: Garfield Simulation Results

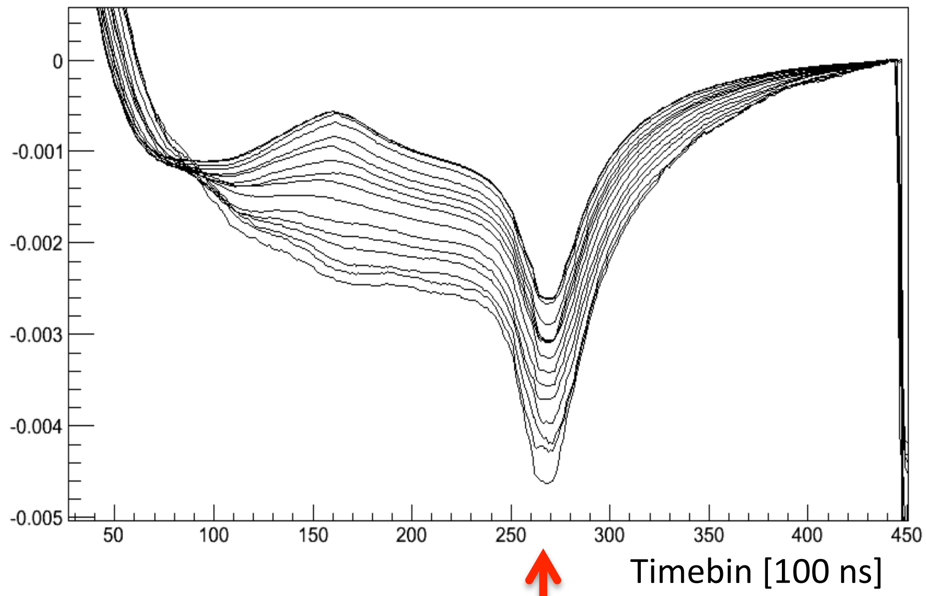




12*exp(4)*(t/0.16)^4*exp(-4*t/0.16)
(transfer function of PASA)

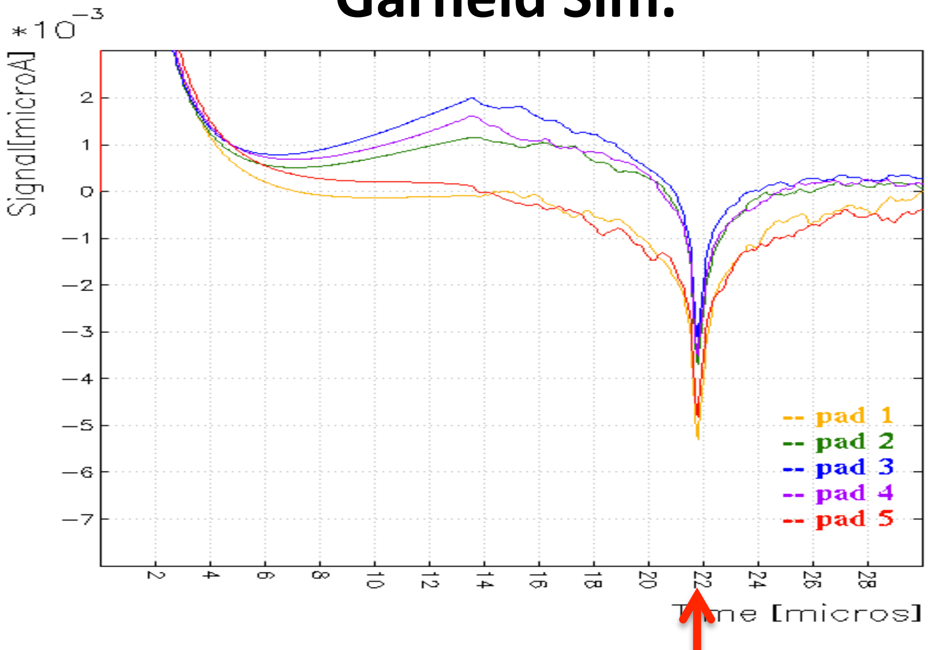
Ion Tail: Simulation vs Real Data

Data



Ion arrival is
~27 µs

Garfield Sim.



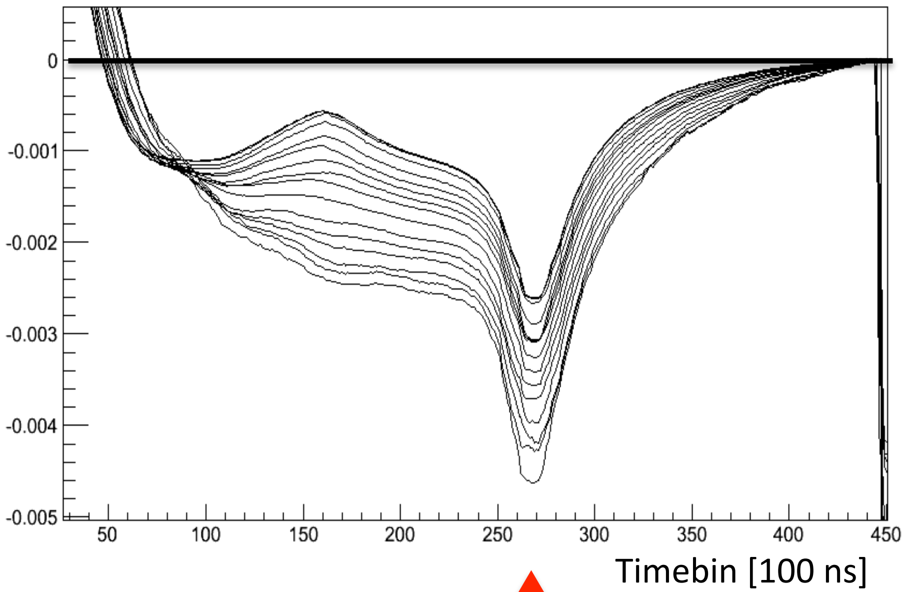
Ion arrival is
~22 µs

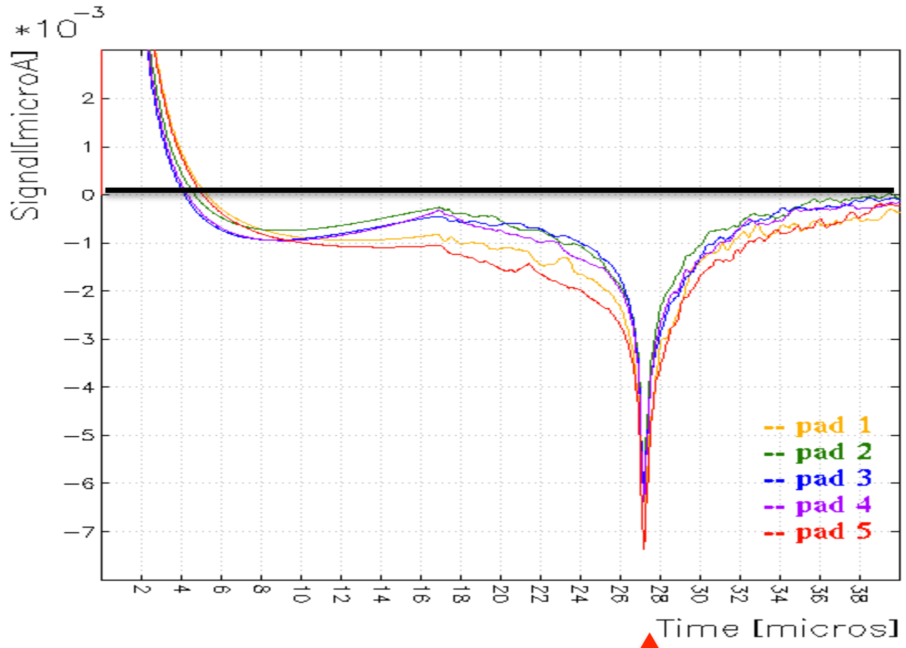
- **Baseline** → Distributions of **ions around wire**.
- **Ion arrival time** → Ne^{+} in Ne is not the right assumption.
  Ion mobility measurements for gas mixtures is needed.

Ion Tail: Simulation vs Real Data

→ Baseline is tuned playing with the **distribution of ions around the wire**

→ Ion mobility **scaled with a constant** factor to match ion arrival





Ion arrival is ~27 μs

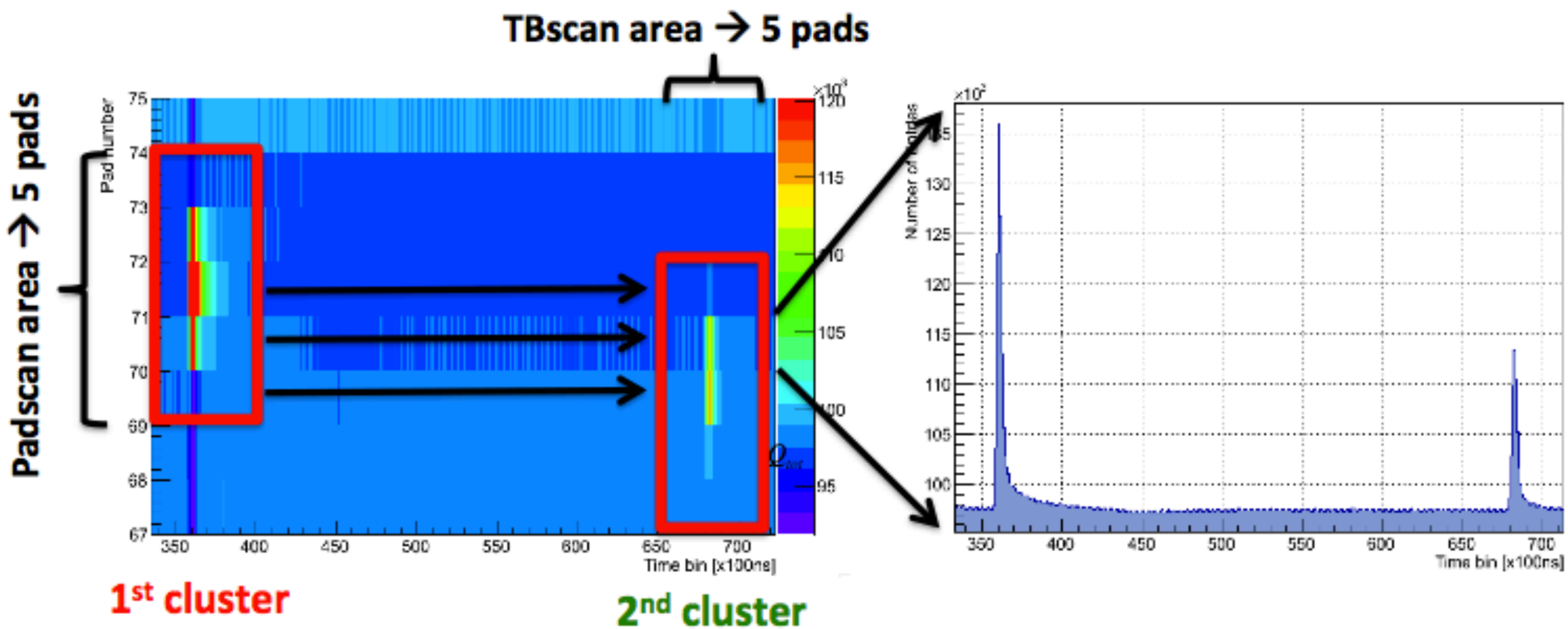
Ion arrival is ~27 μs

OFFLINE CORRECTION PROCEDURE

How to Correct ?

→ **Common-mode : Rely on charge conservation** on a given anode wire segment

→ **Ion-Tail:** Use **normalised Time Response Functions (TRF)**

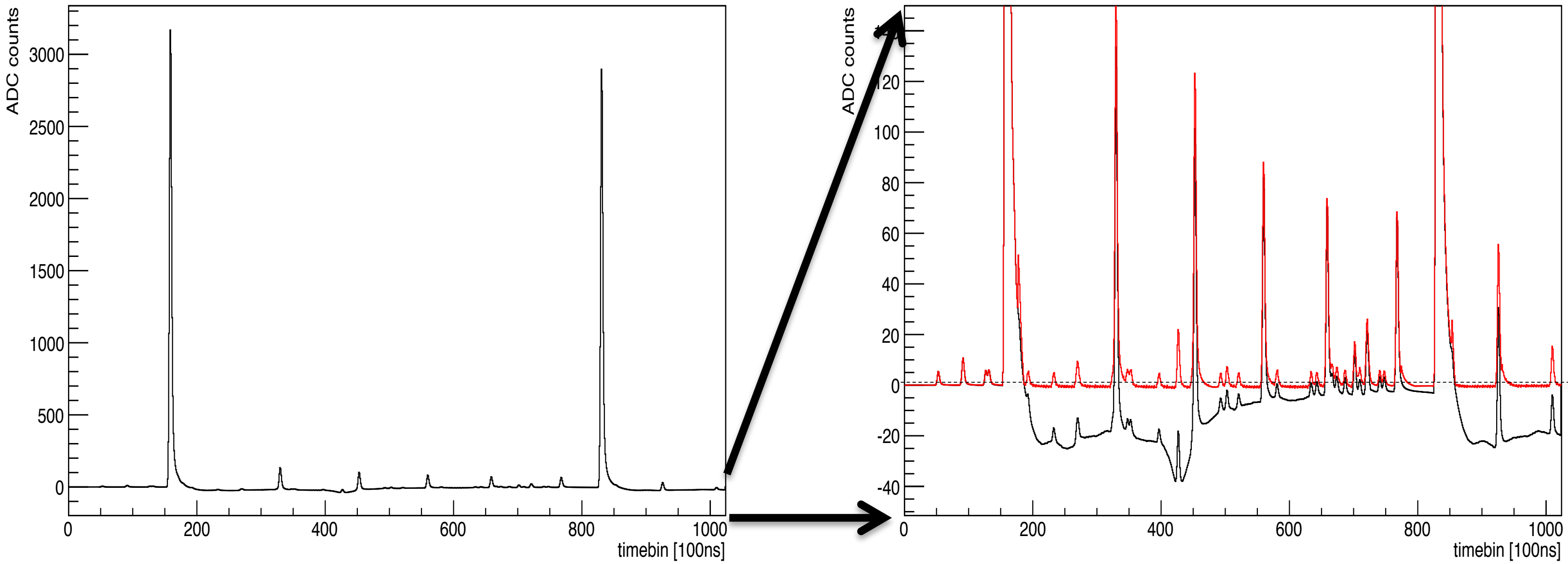


$$C_{timebin} = Q_{totpad} \times f \times TRF$$

f : Experimental factor, which compensates the missing charge.

How to Correct ?

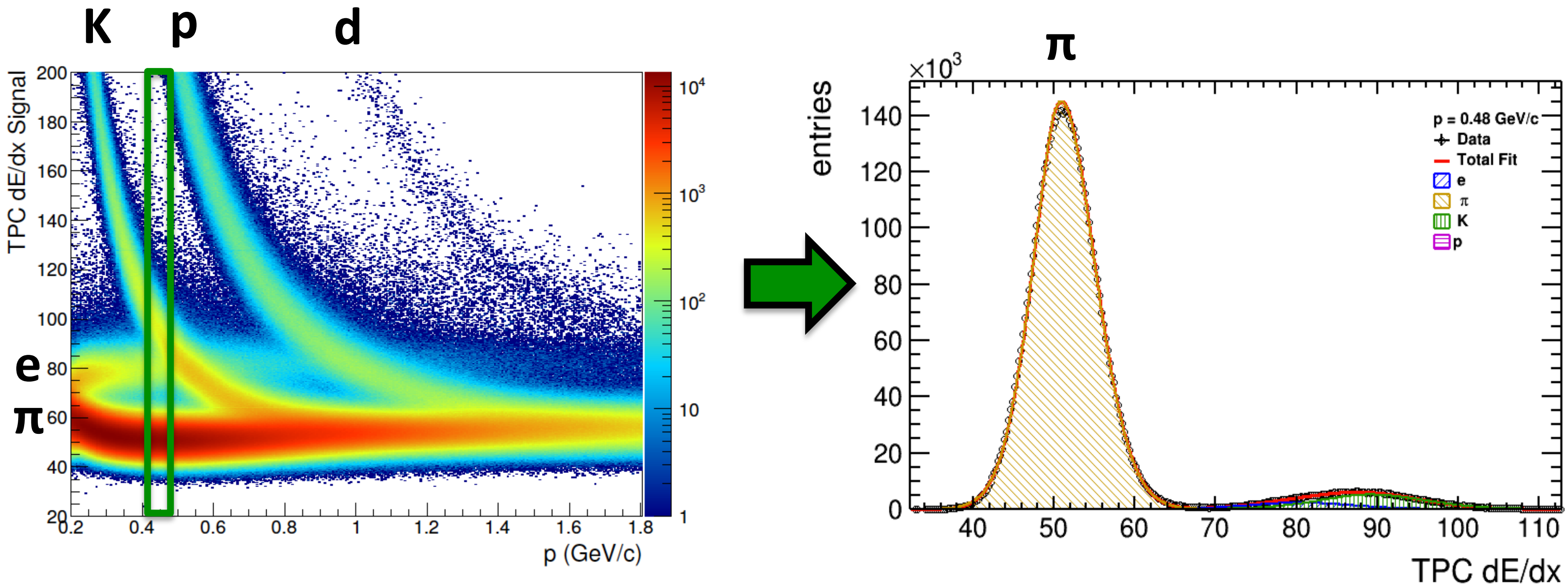
TOY MC



Real
Corrected

Zero suppression

How to judge ?



Judge by looking at;

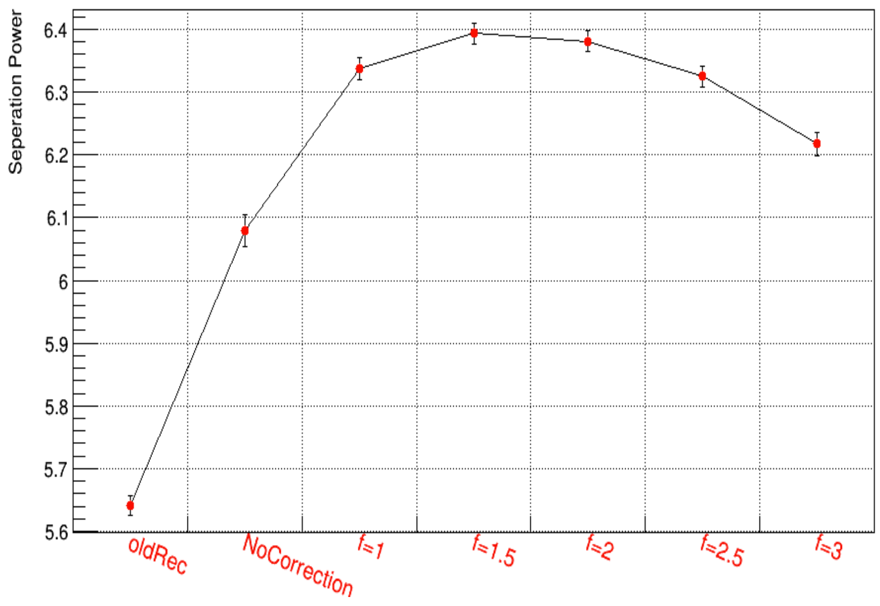
→ **MIP position**: Peak position of pions

→ **dE/dx resolution**: (sigmaPi/meanPi)

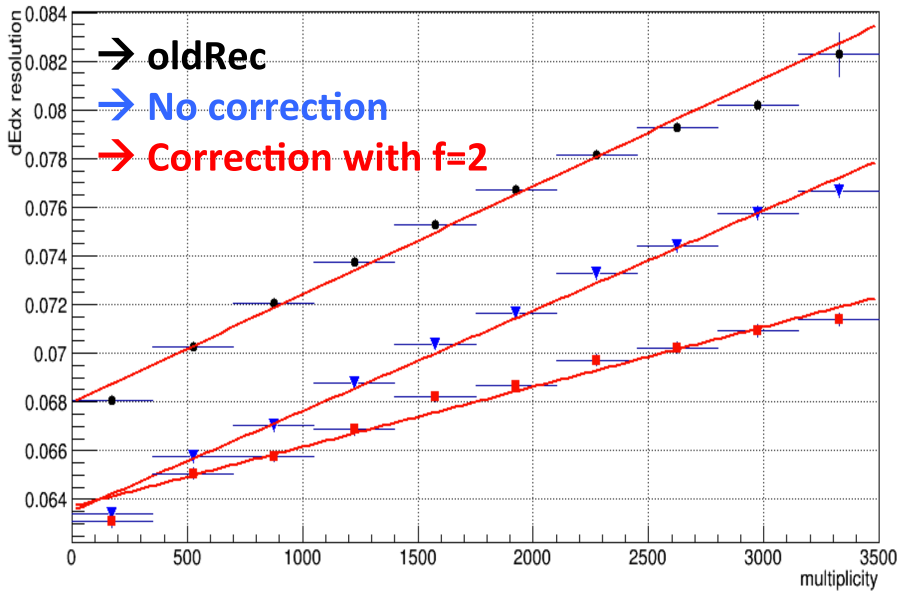
→ **Seperation power**: (meanEl – meanPi)/((sigmaEl+sigmaPi)*0.5)

Final Results: Real Data

Separation Power



dEdx Resolution

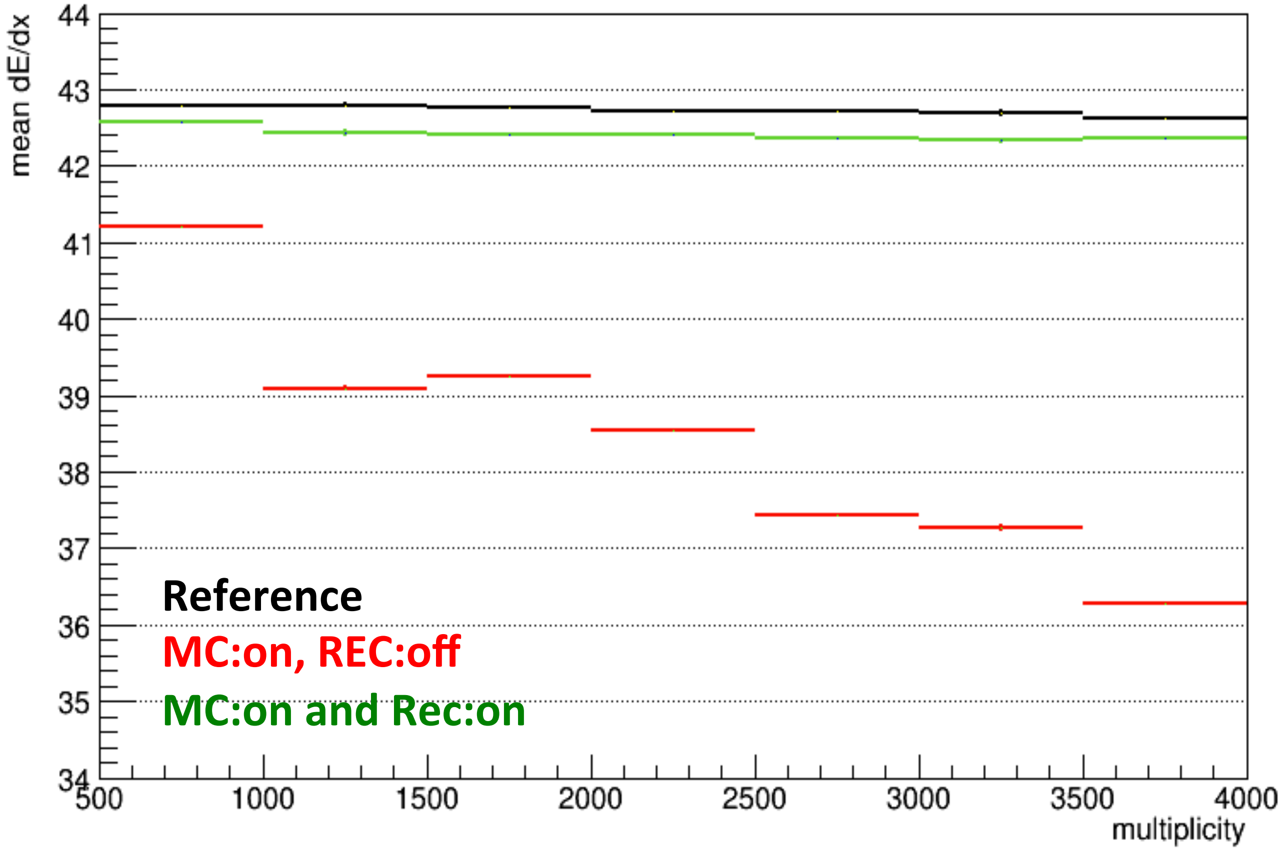


f : Experimental factor, which compensates the missing charge.

Final Results: MC

→ To obtain more **realistic MC description,** both effects should be added to the detector response.

MIP position



SUMMARY

- **TPC signal shape** was studied using Laser data.
- Ion tail is reproduced with **3D Garfield simulations**
  → **Ion mobility measurements for gas mixtures** would allow for a better matching between data and simulation
- Ion tail and common mode effects were simulated and **corrected successfully**
- It is proven that offline correction of both effects improves the dE/dx resolution thus the **PID quality** of ALICE.

BACKUP

- To obtain more realistic MC description for **RUN1,** ion tail should be added to the detector response.

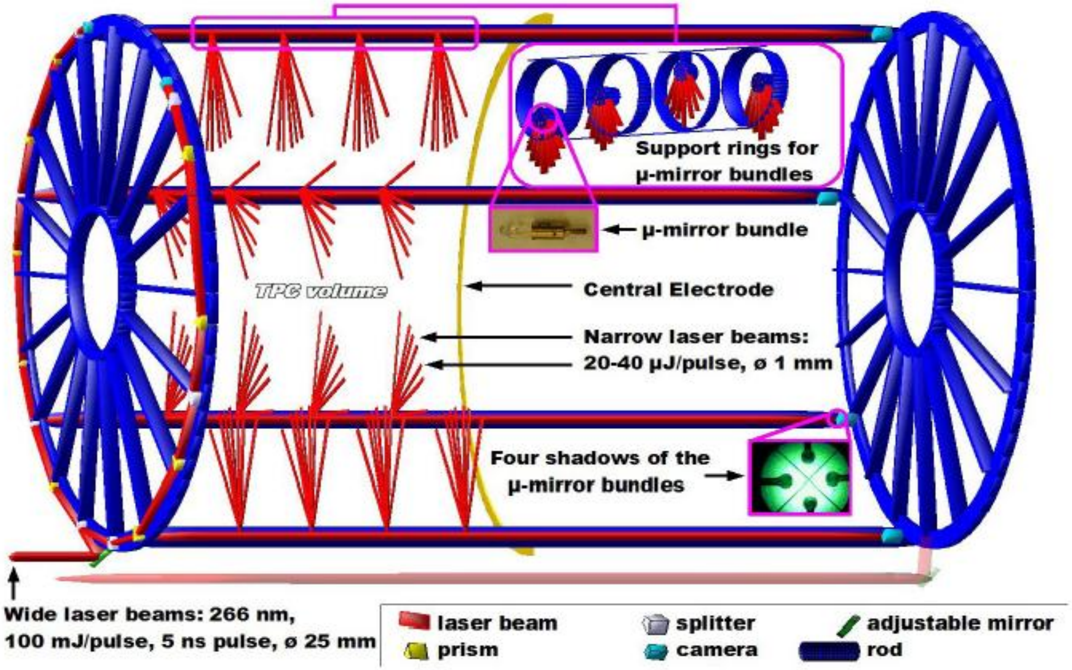
  → E.g number of observed signals, dEdx characteristic and the dependence on the track multiplicity is not described at all.

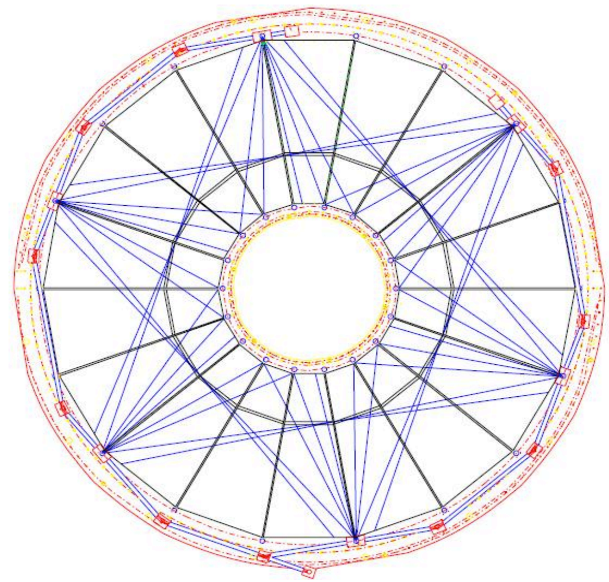
- In the TDR it was assumed that signal correction **(Ion Tail)** will be done on the hardware level **in ALTRO**. However, due to instabilities in software, given functionality was not enabled.
  → For **Run2** given problem should be already fixed.

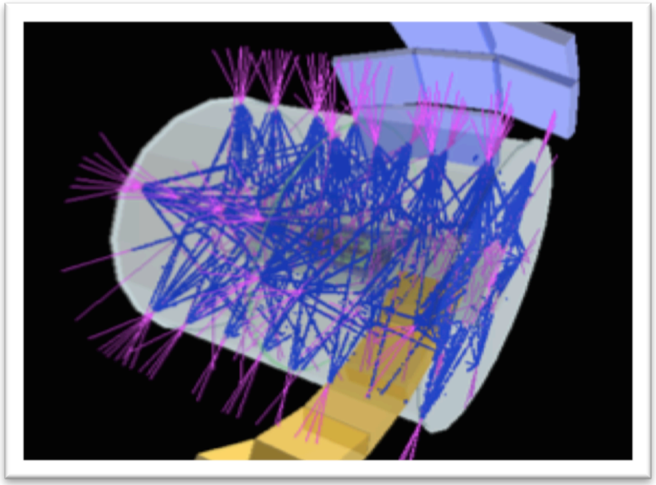
- **PbPb events:**
  → ~ 20 % of the clusters are lost
  → ~ 20 % shift of the mean dEdx
  → Fluctuations of the dEdx bias leads to worsening of dEdx resolution
  (Effects are linearly proportional to local track density)
- pPb events:
  → ~ 5 % effect for highest multiplicity events.

⇨ **MC should be dEdx calibrated in the similar way as the raw data**

TPC LASER SYSTEM





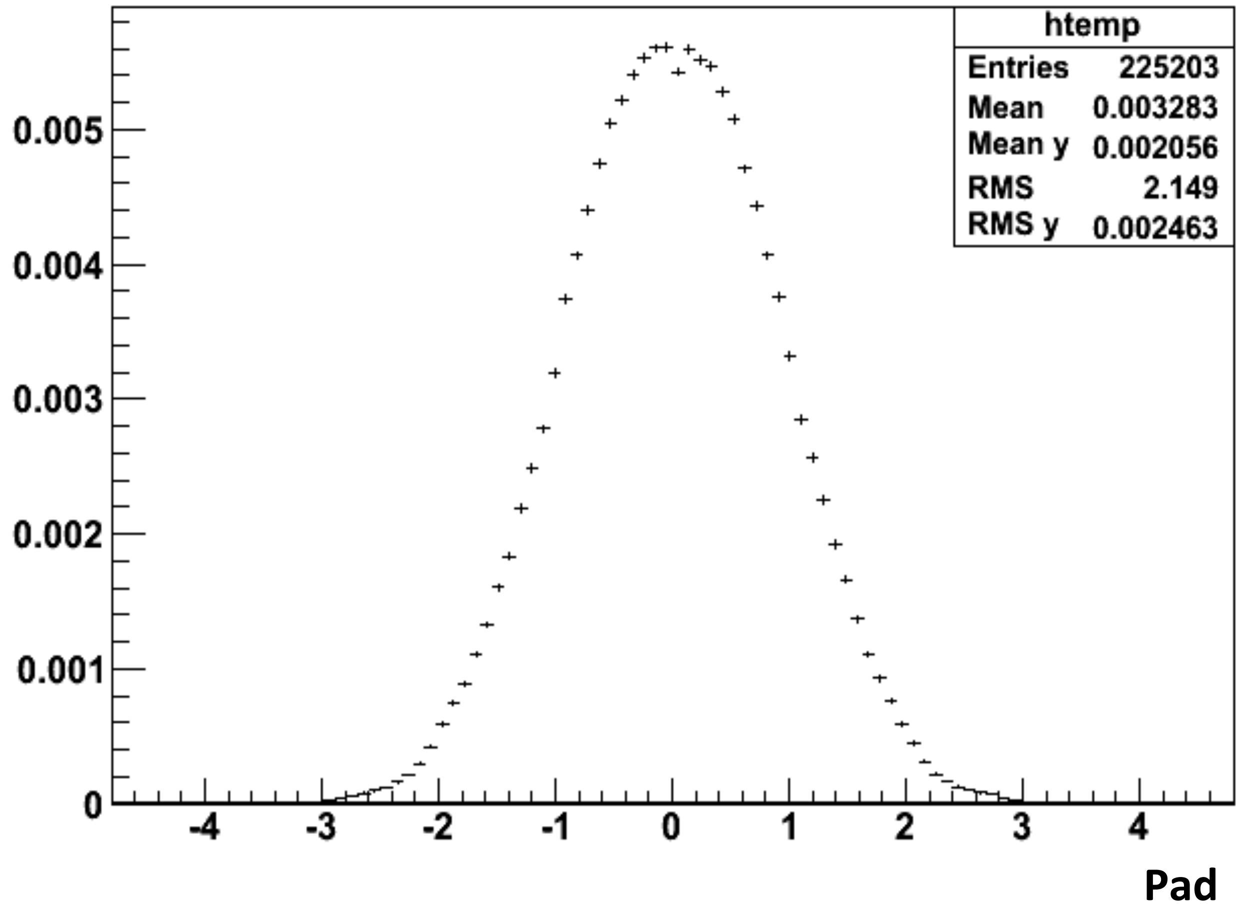


→ 336 Laser Rays (168 on each side)

→ 2 Sides, 6 Laser Rods, 4 Bundles, 7 micromirrors

→ z-Positions;
odd rods: ±130, 850,1690, 2470 mm
even rods: ±100, 790, 1630, 2410 mm

Pad Response Function

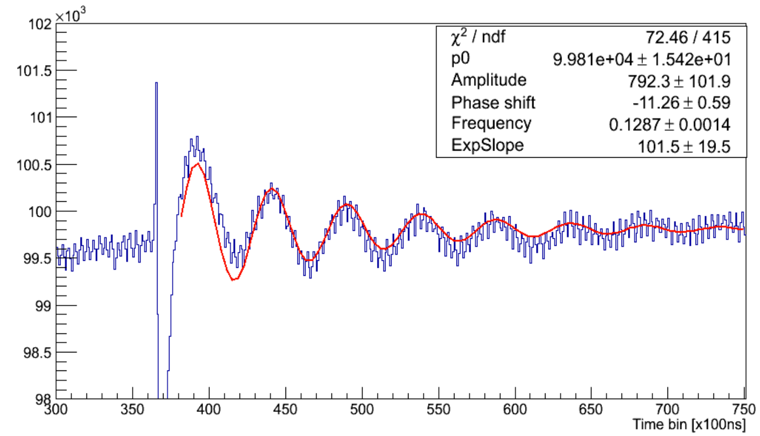


REMINDERS (III)

Preparation of the TRFs → Removal of frequencies + smoothing

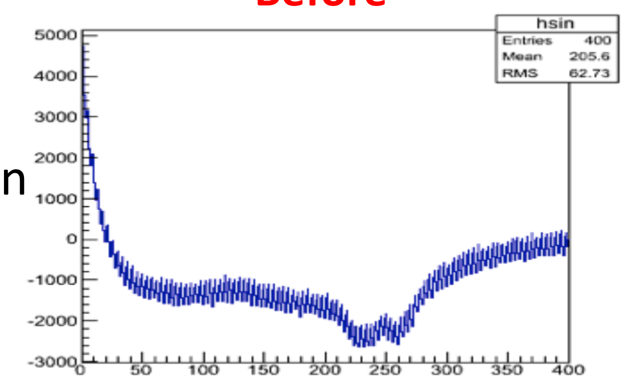
1) **Low freq** → **damping oscillator**

→ [0]+[1]*exp(-(x-380)/[4])*sin([2]+[3]*x)

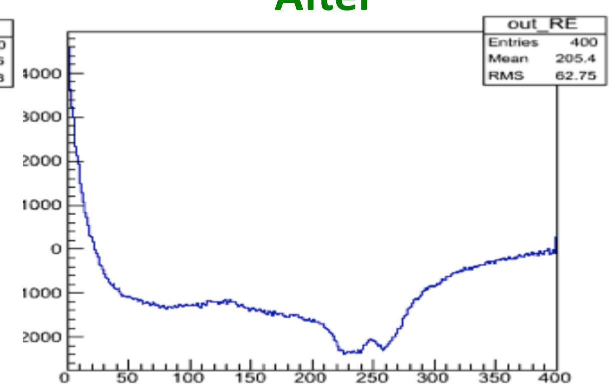


2) **High freq** → Fast Fourier Transformation

Before

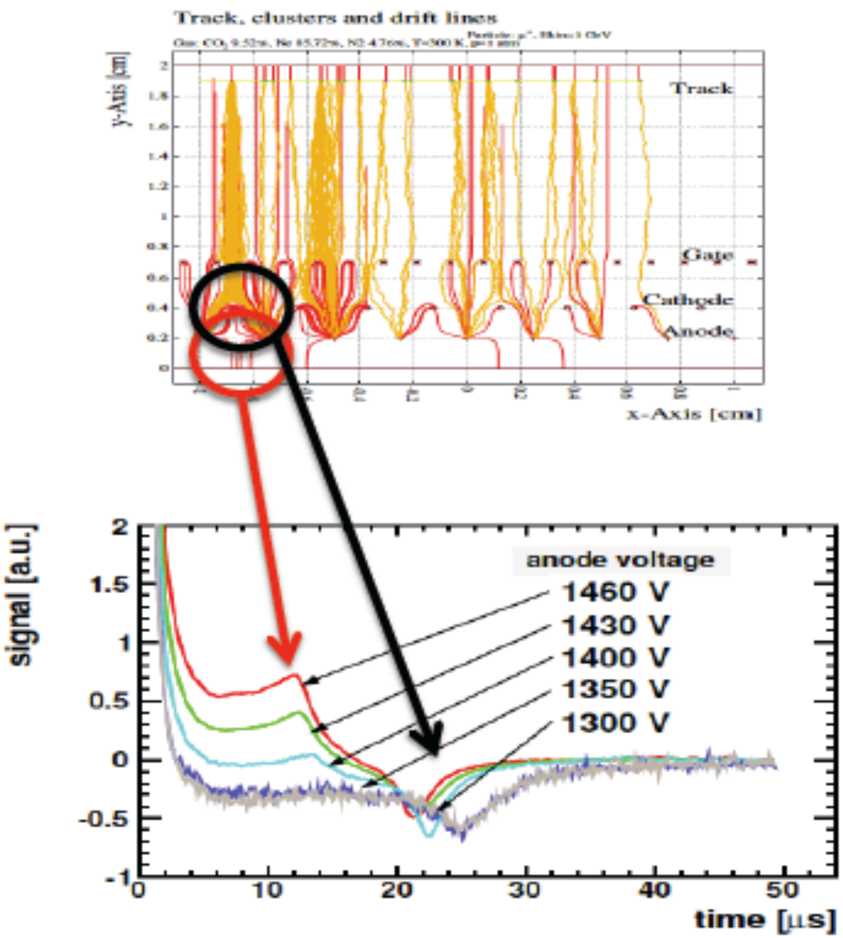


After

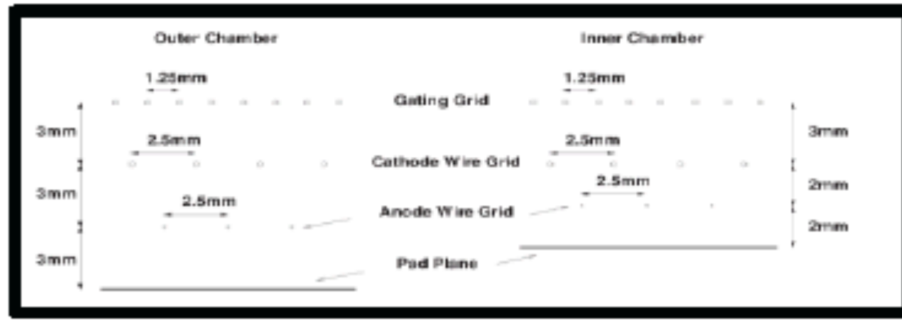


3) **Smoothing** with **TLinearFitter**

Garfield



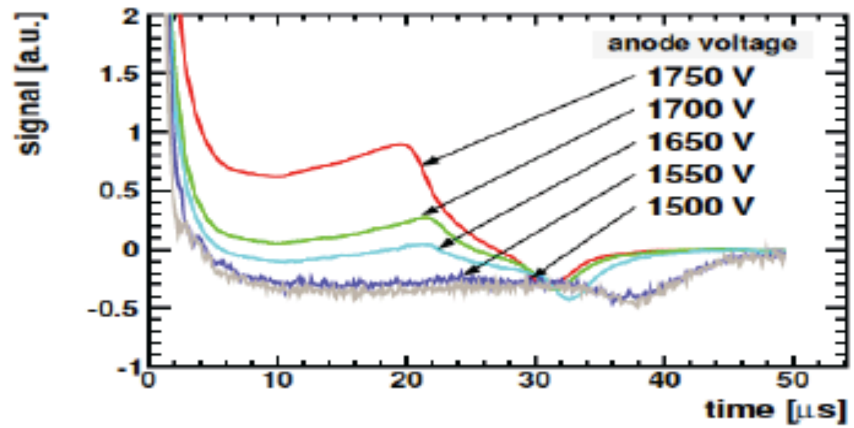
Wire geometries



$6 \times 10\ mm^2 \rightarrow$ inner OROC

$6 \times 15\ mm^2 \rightarrow$ outer OROC

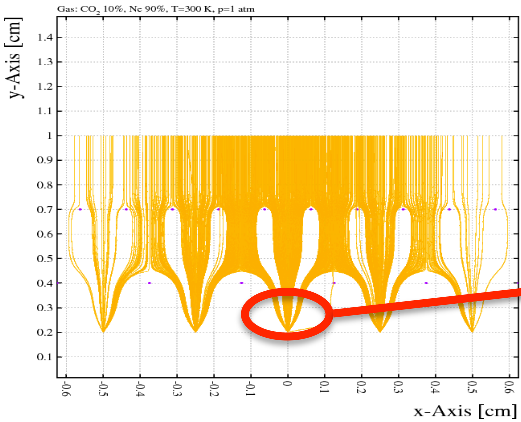
$4 \times 7.5\ mm^2$ → **Pad sizes**

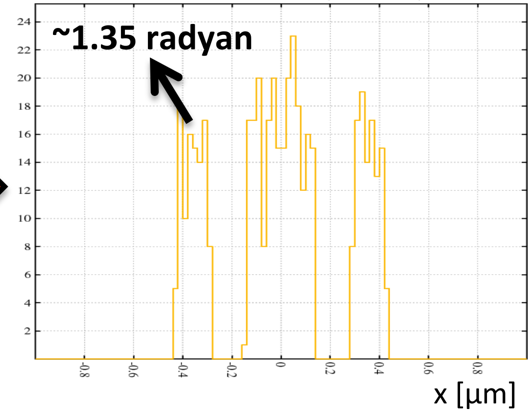


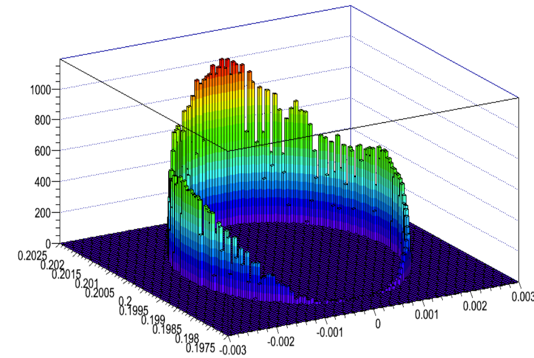
Cosmic data (2006-2008)

REMINDER (II)

→ Try to estimate the shape of distribution from the hit points of the electrons on the wire

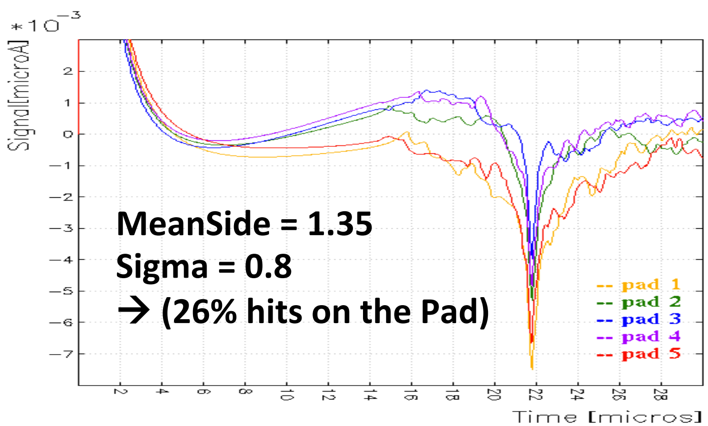


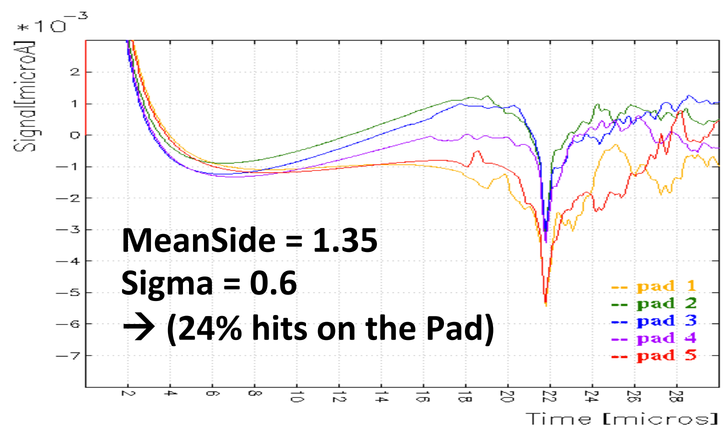




Sum of **3 Gaussians**

1. **Amplitude is fixed** (ampSide*(4/3) = ampCentral)
2. **MeanSide** = **Center of side peak**
3. **Sigma** = **Sigma of central peak** such that (middle peak sigma) = (side peak sigma)*2





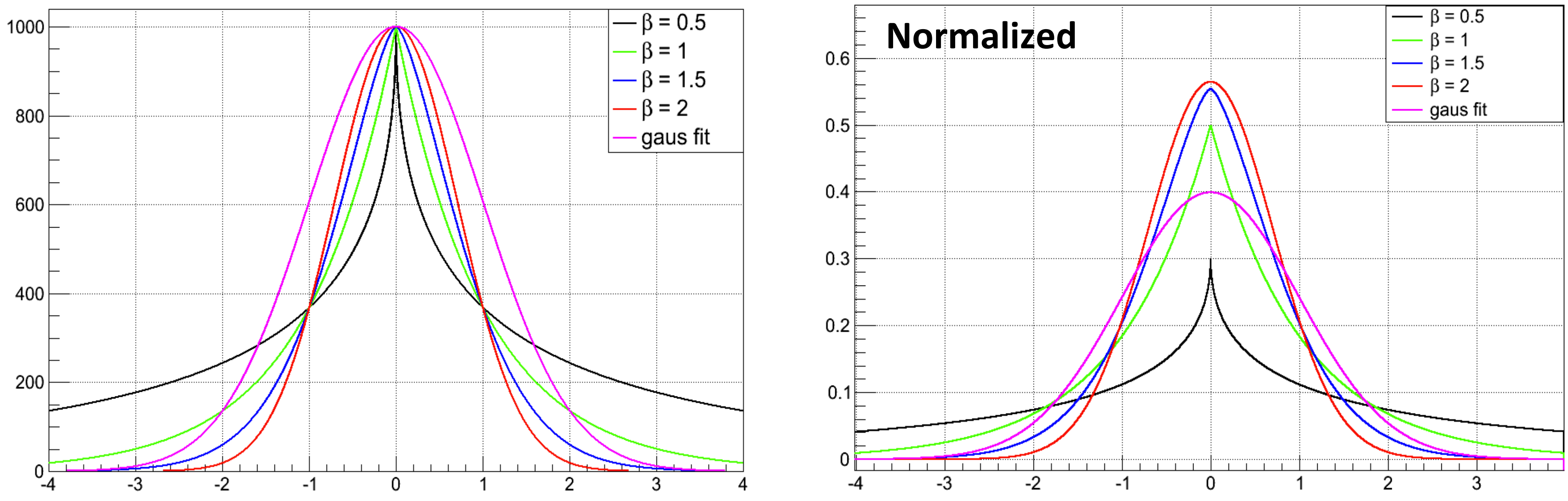
→ **Pad 3 is the central pad**

→ **Only 3000 ions were used.**

WHAT IS NEW ?

1) Use **generalized normal distribution**
→ new parameter β

$$\frac{\beta}{2\alpha\Gamma(1/\beta)}\, e^{-(|x-\mu|/\alpha)^{\beta}}$$



2) Vary the **number of ions** in the cluster

MOTIVATION

REAL DATA:

→ Time Response Functions (TRFs) for **different distances to COG of cluster**.
→ Central (top curve), outermost (bottom curve)
→ Each step is 0.4 mm