

Ion-Tail and Common-Mode Effect Corrections for the ALICE TPC

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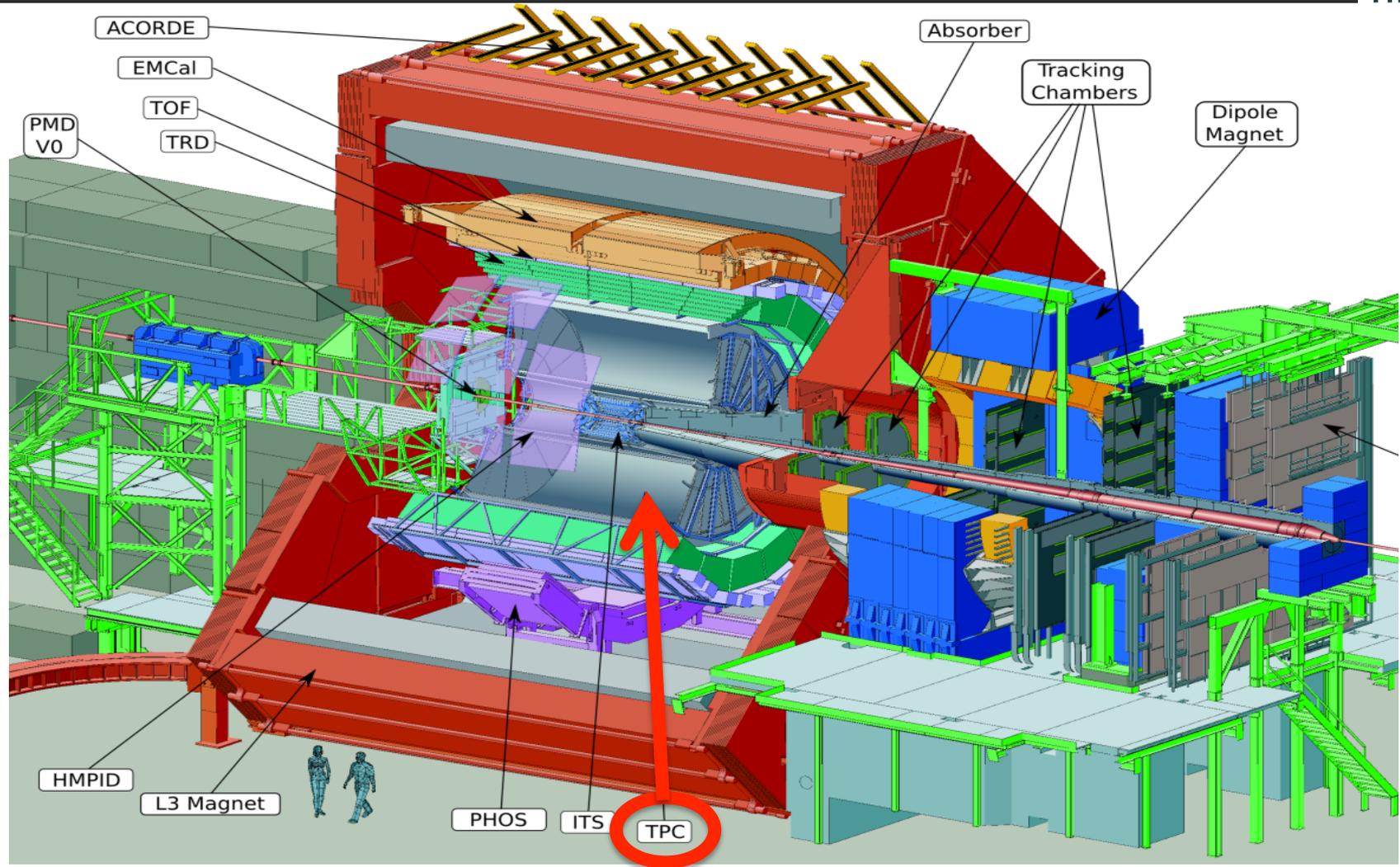
Introduction

- **A Large Ion Collider Experiment, ALICE**
- **Time Projection Chamber, TPC**
- **TPC Laser System**

Common-Mode and Ion-Tail Correction

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

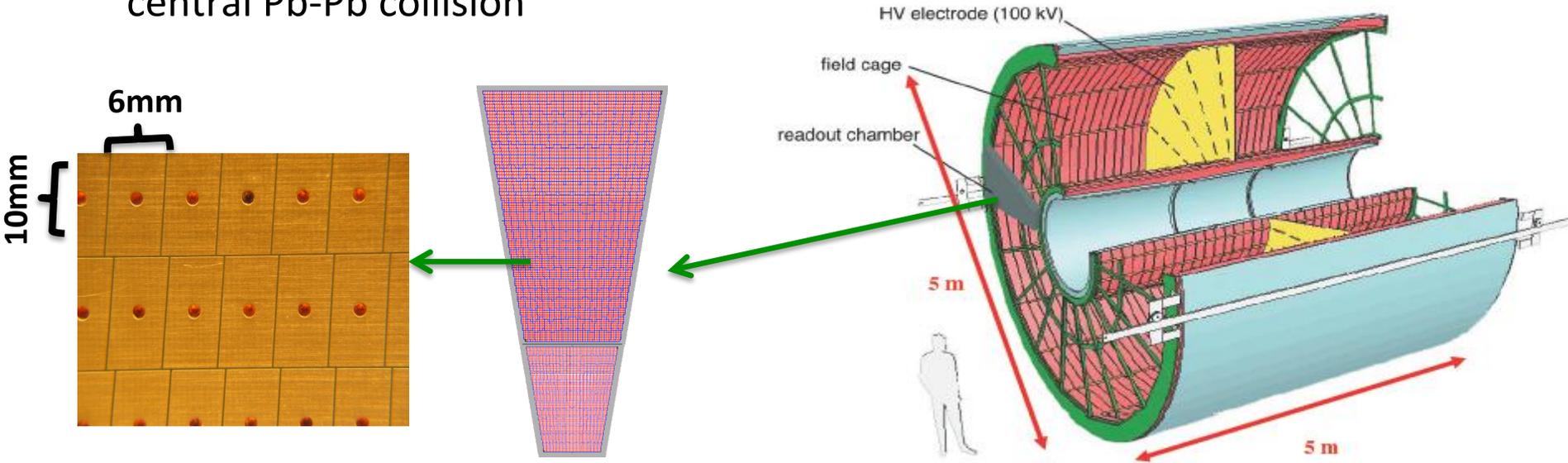
ALICE Detector Setup



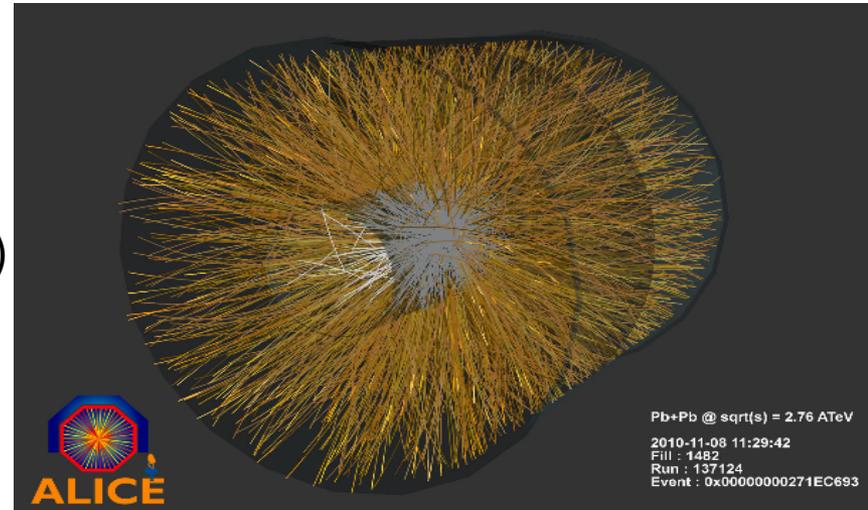
TPC: Main tracking and particle identification (PID) detector

Time Projection Chamber, TPC

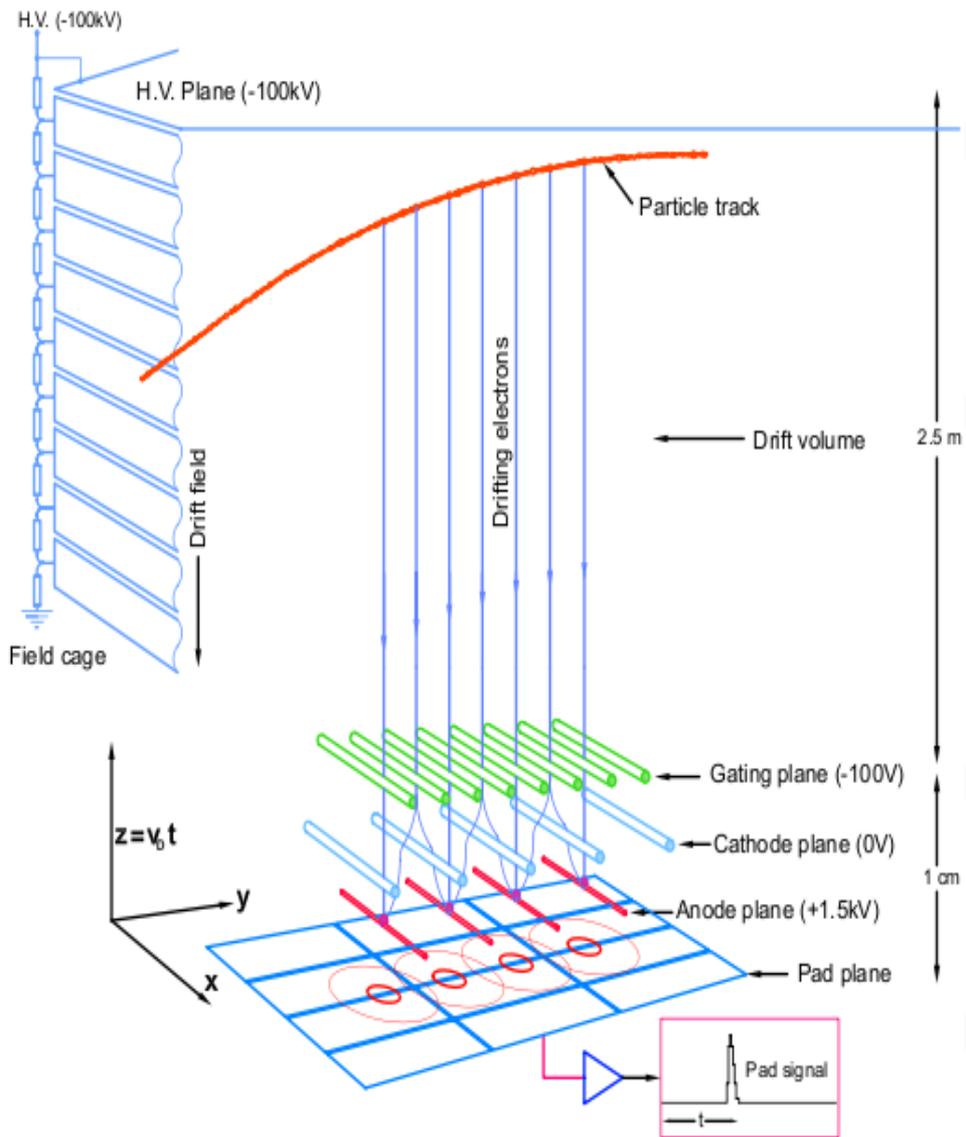
→ Designed to measure up to **20000 primary and secondary particles** in a single central Pb-Pb collision



- **Ne-CO₂**: 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**

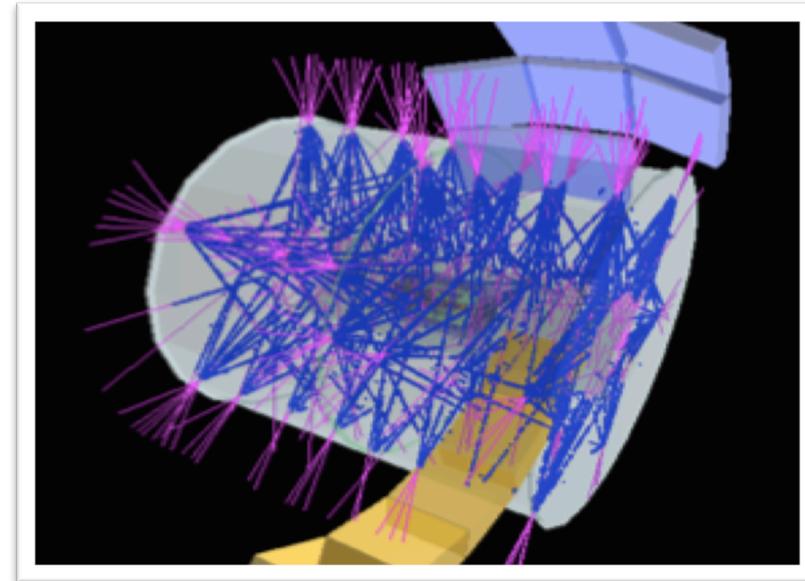
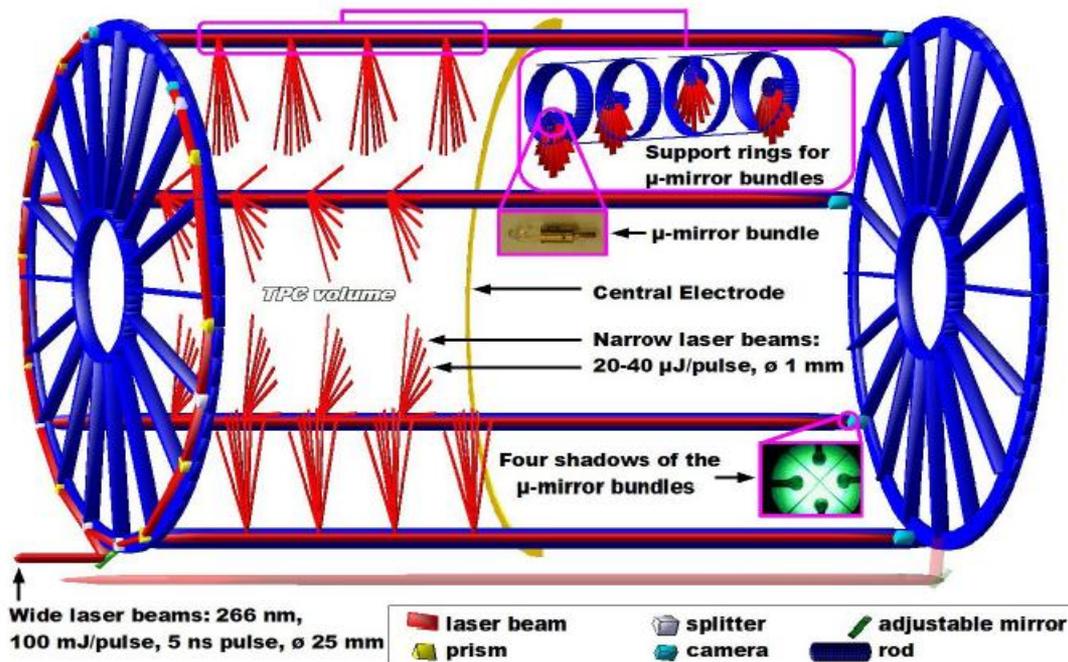
Signal Generation

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

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

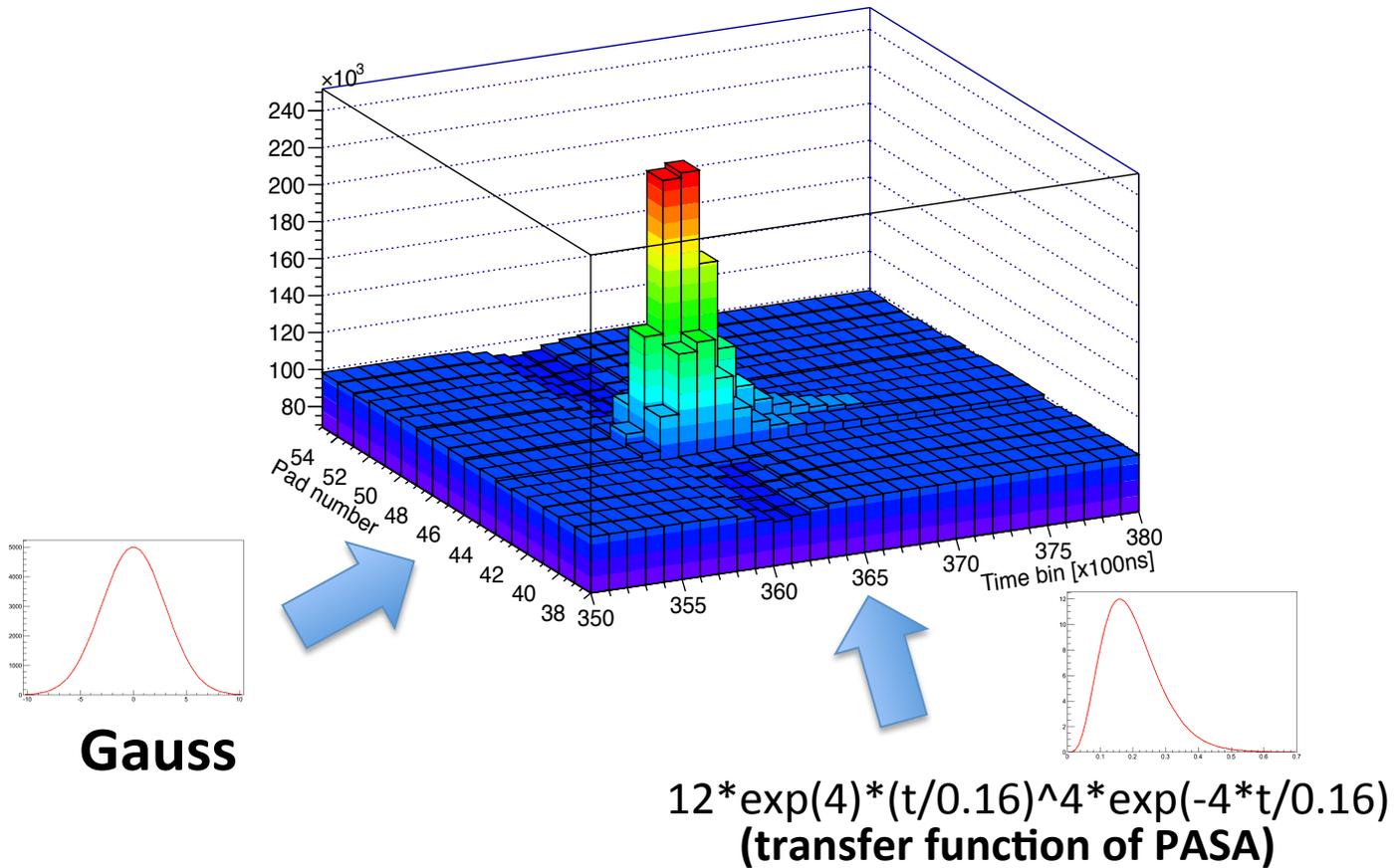
TPC LASER SYSTEM

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



ALICE TPC Signal Shape

TPC cluster over a 5x5 pad-timebin matrix



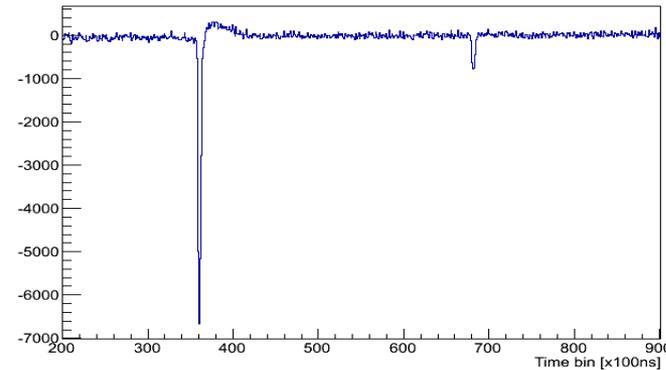
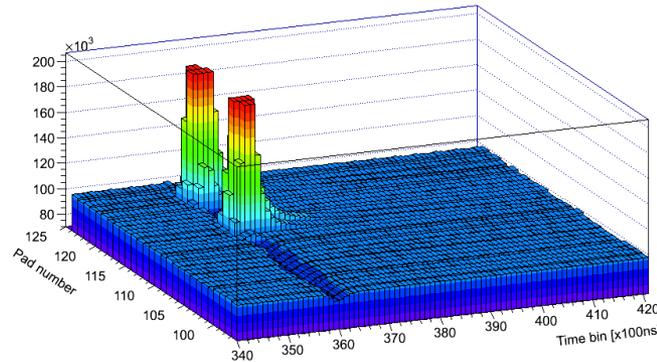
Laser Signal before pedestal subtraction → 2000 events

Common-Mode and Ion-Tail Correction

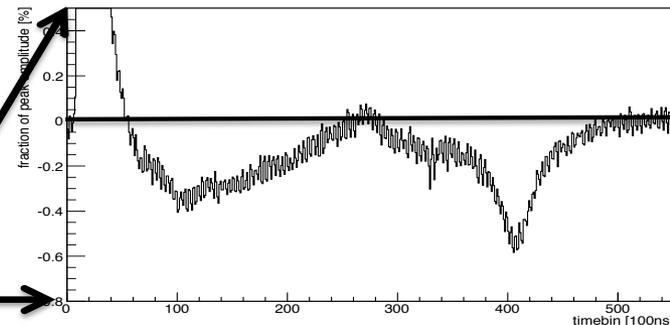
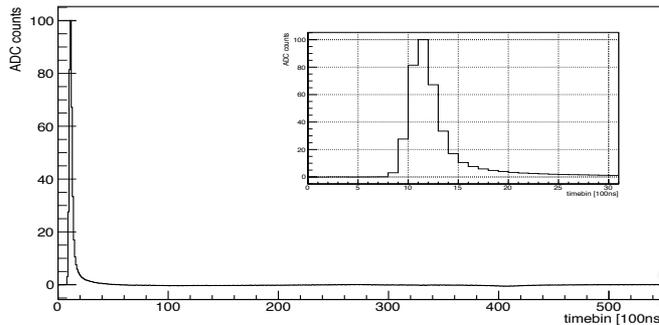
MOTIVATION

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

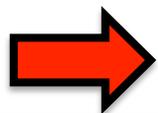
Common-Mode → **Along pad direction**



Ion-Tail → **Along time direction**

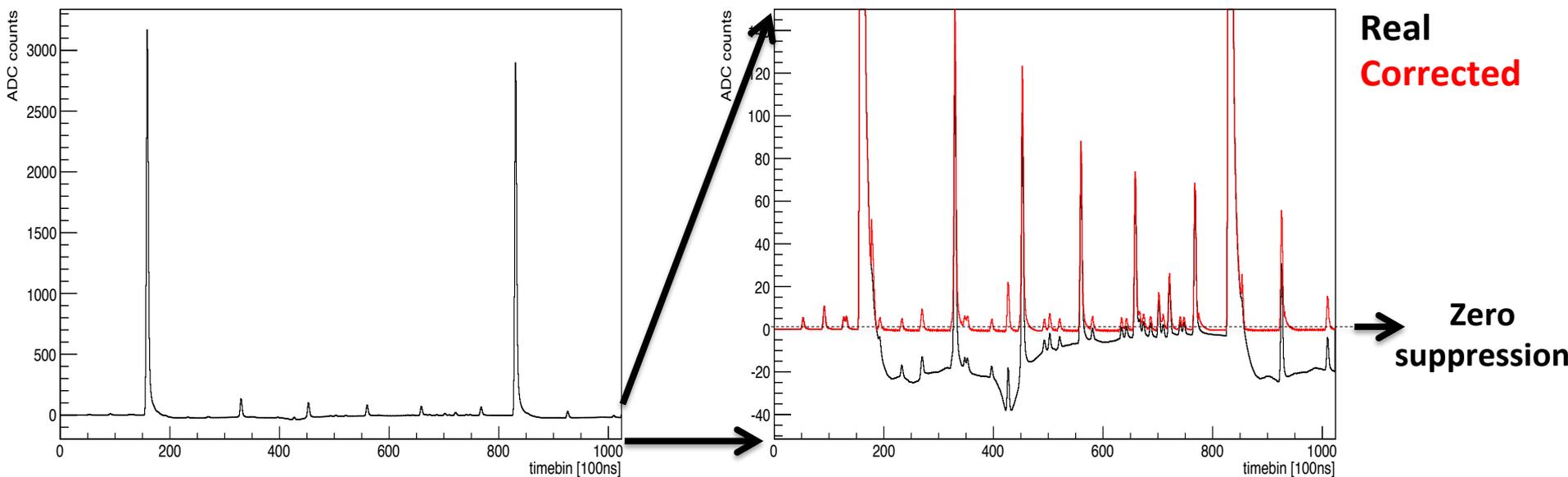


→ **Zero suppression**



Charge and cluster loss → **Worsening of dE/dx**

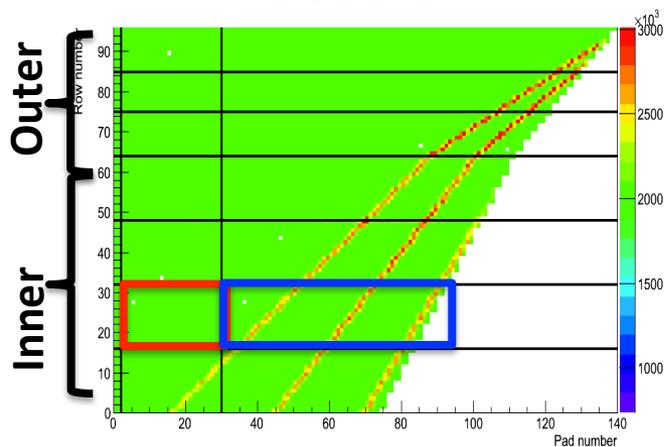
TOY MC



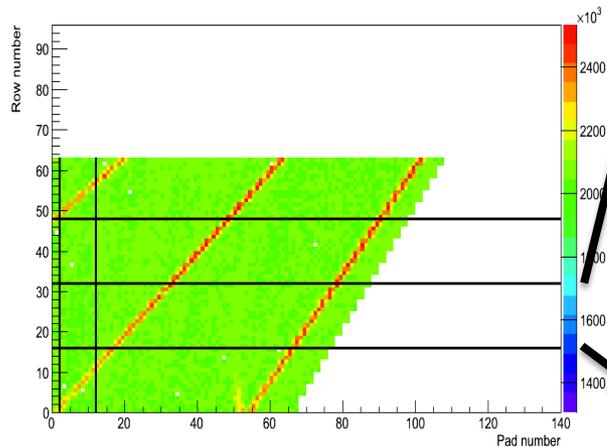
Common-Mode Effect

Common-Mode Effect: Charge Conservation

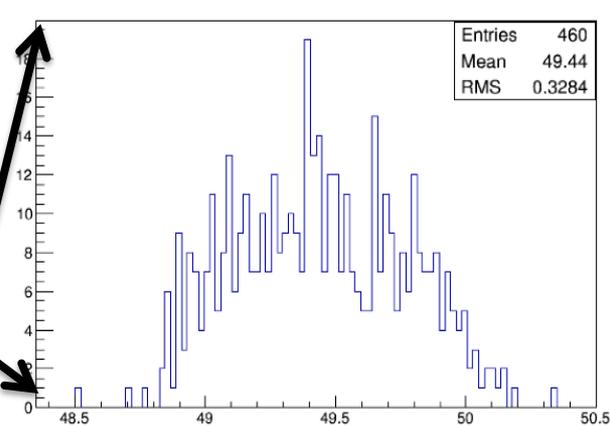
OROC



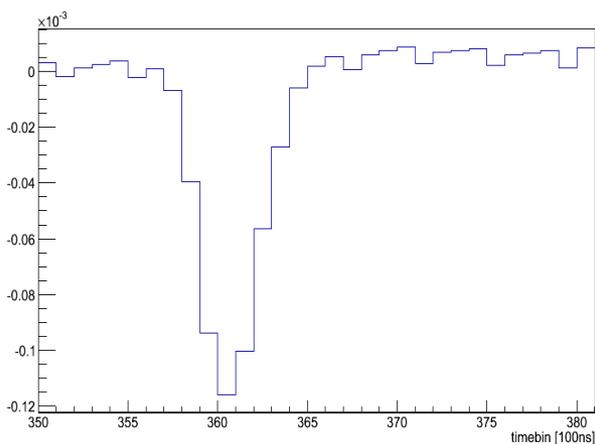
IROC



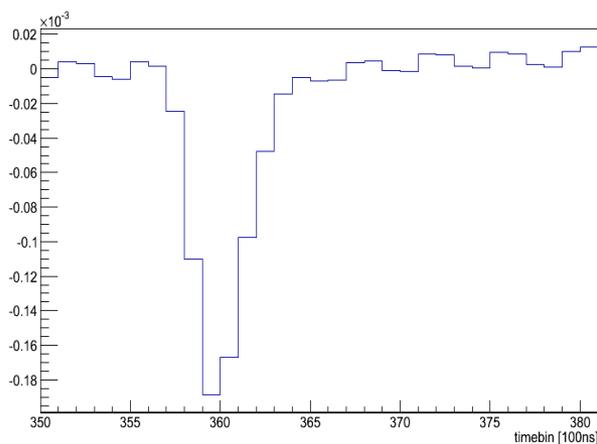
Total Charge



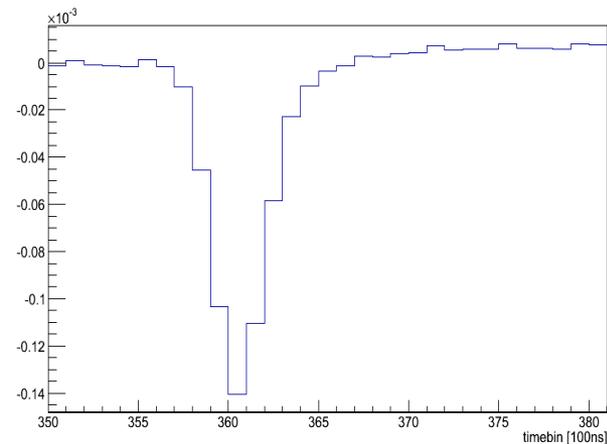
IROC



Inner OROC

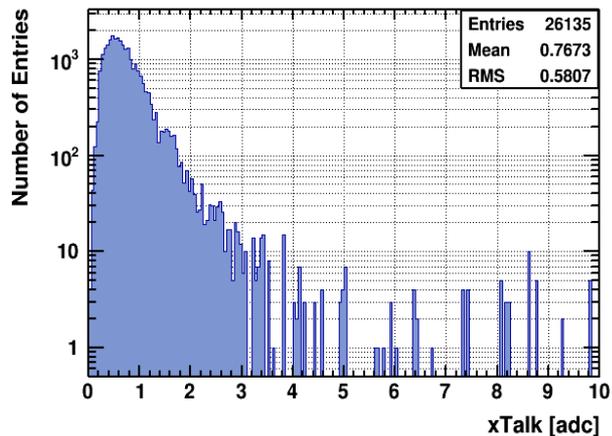
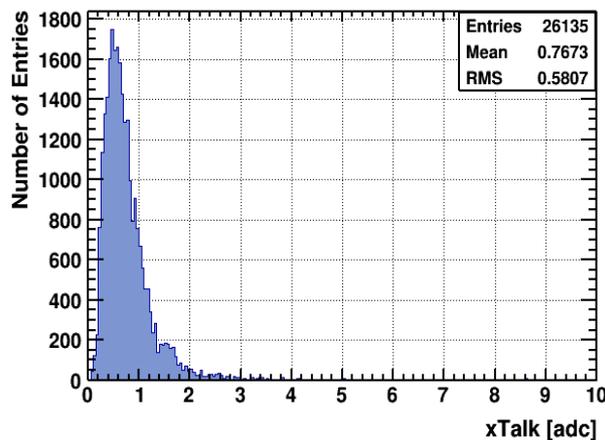
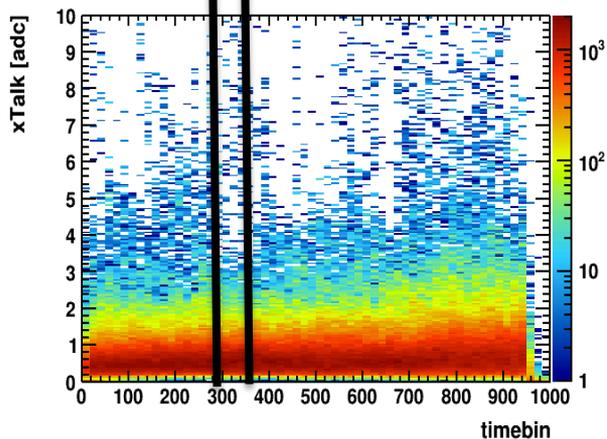
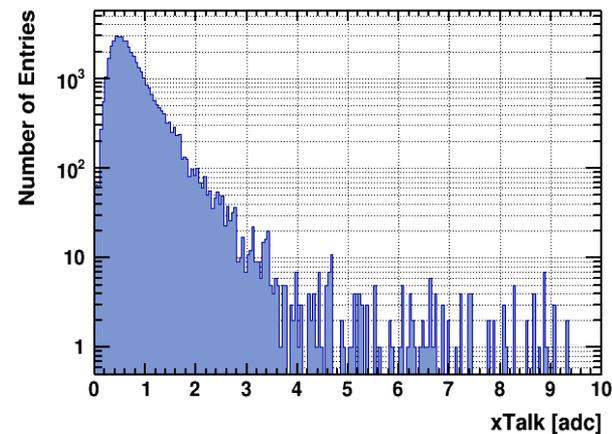
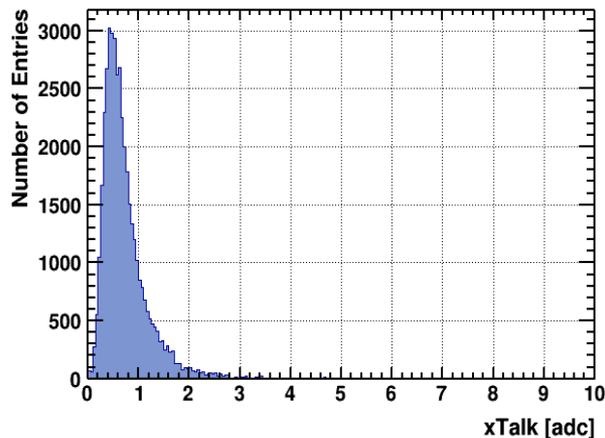
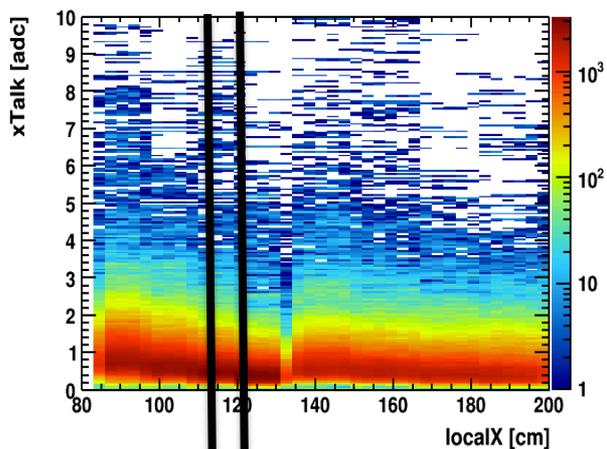


Outer OROC



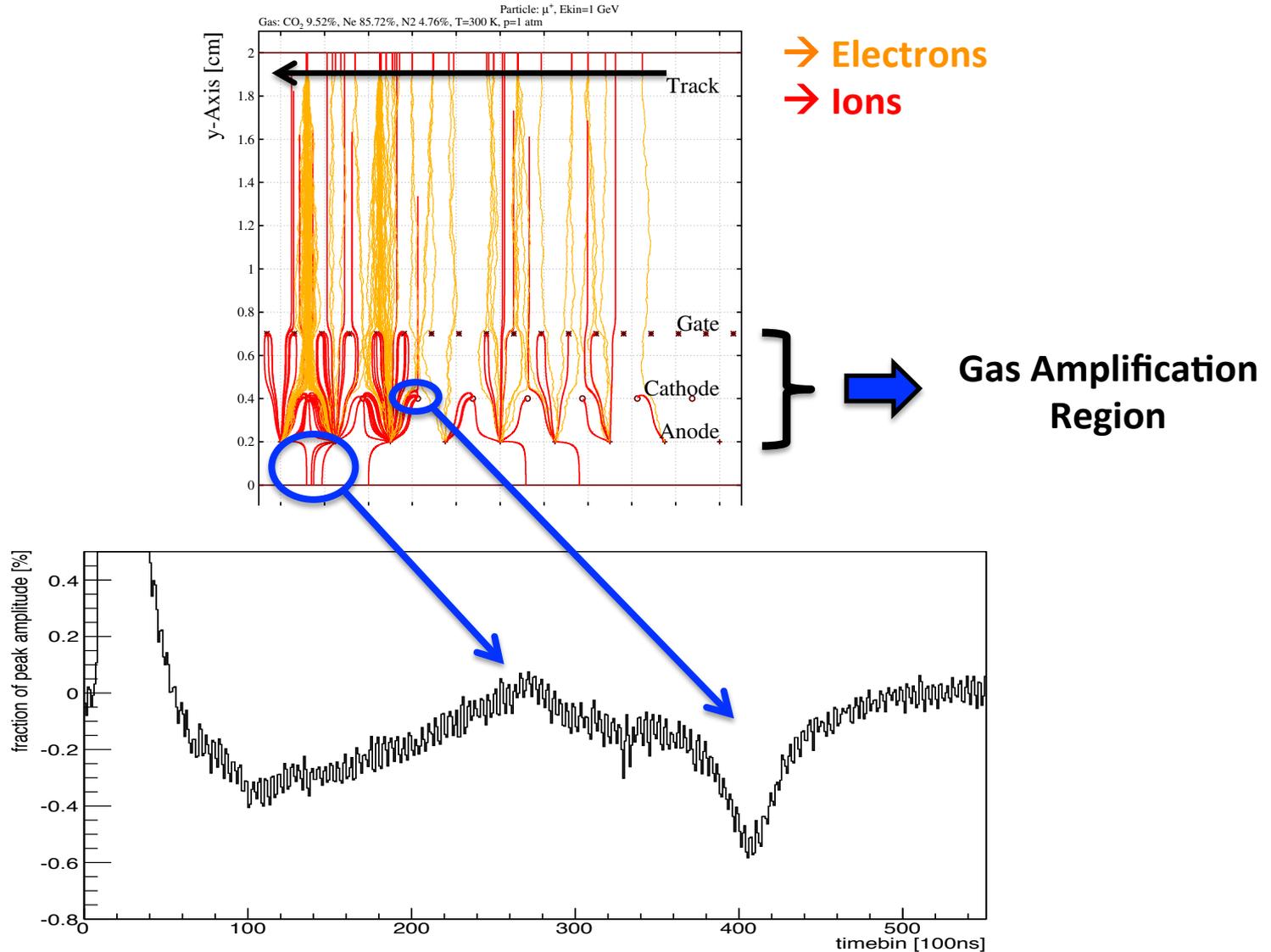
Common-Mode Implementation on MC

→ Based on **charge conservation** → **Important for GEMs as well**



Ion-Tail Effect

Ion Tail: Ion Drift in the Amplification Region

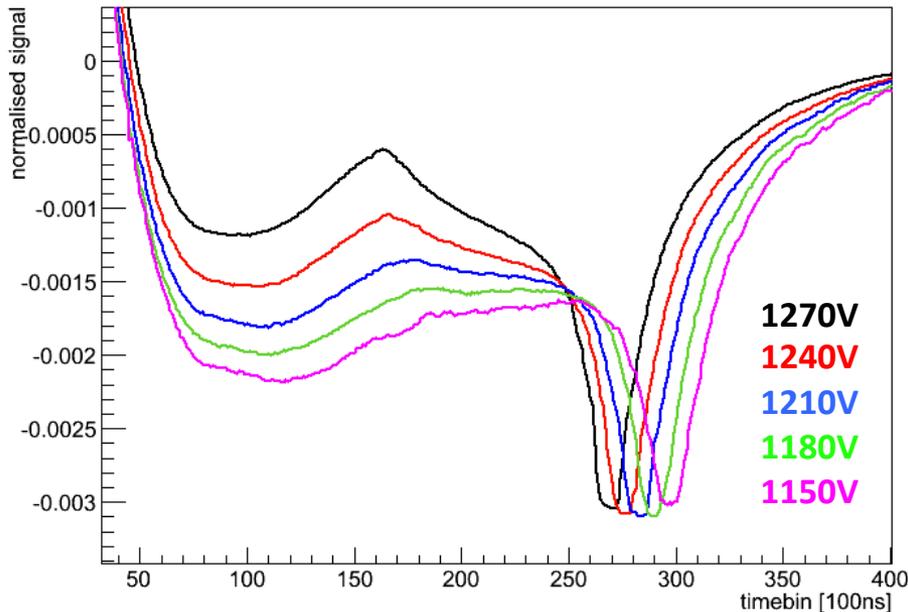


Ion Tail: Dependencies

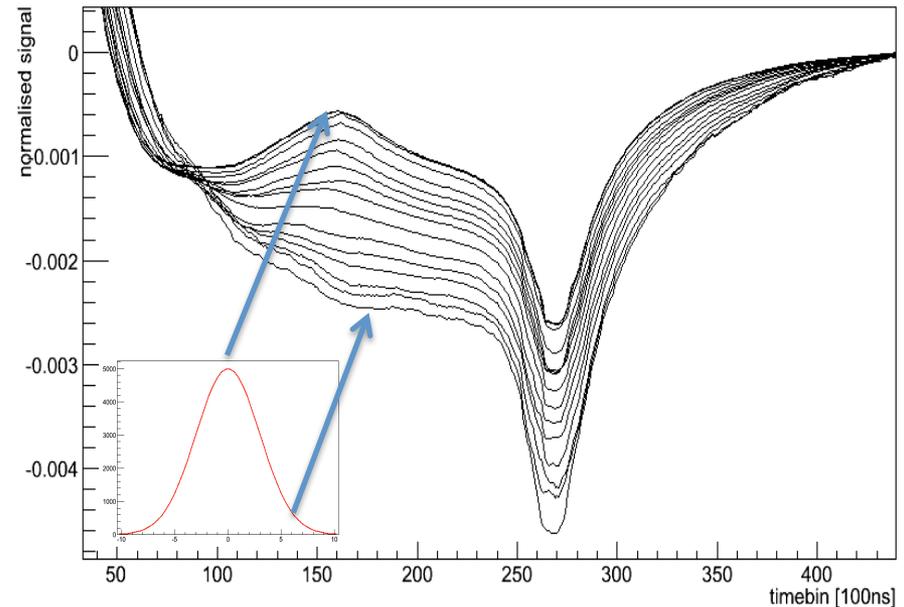
Ion tail signal shape depends on:

- Anode **Voltage**
- Signal **position** on a given pad wrt to the center of gravity of cluster
- **Geometry.**

Voltage Dependence



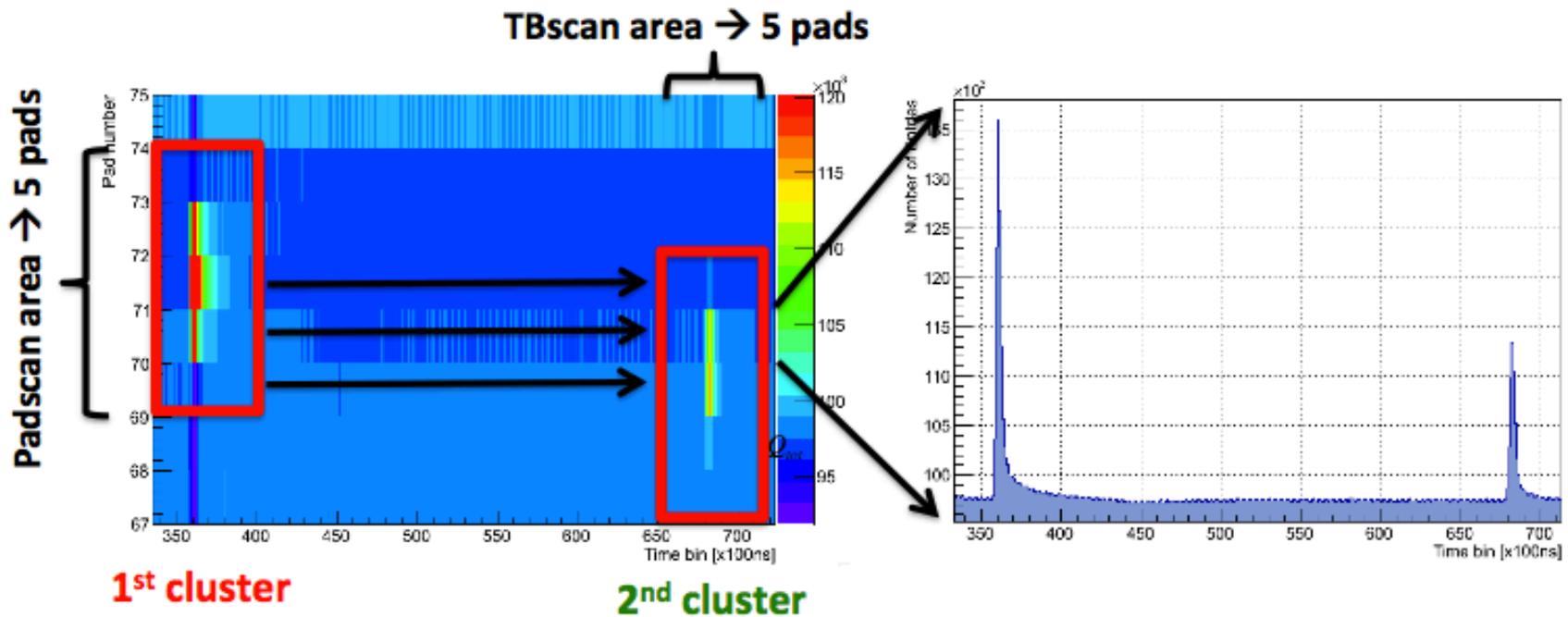
Position Dependence



OFFLINE CORRECTION PROCEDURE

How to Correct ?

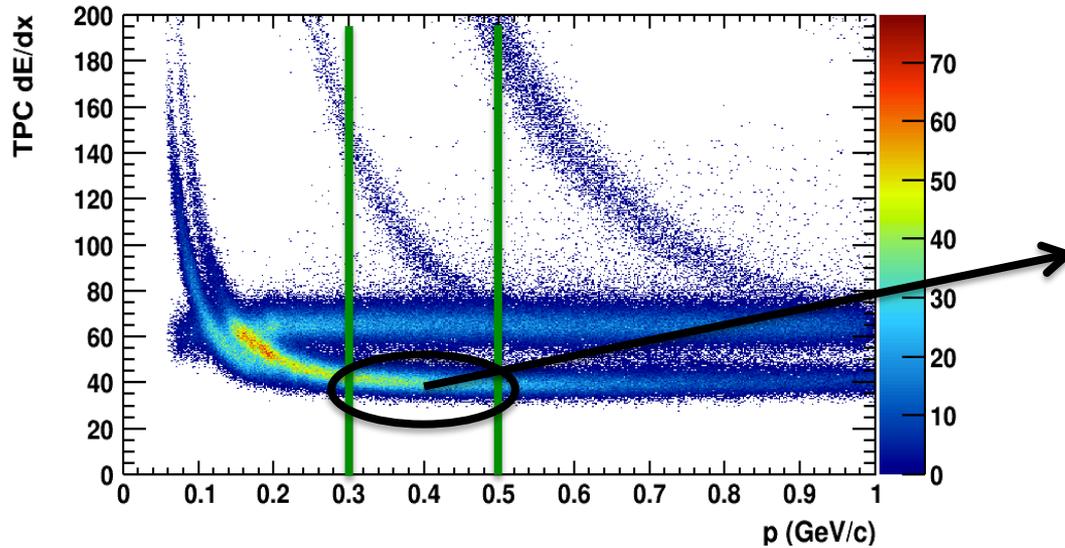
- **Common-mode** : Rely on charge conservation on a given anode wire segment
- **Ion-Tail**: Use normalised Time Response Functions (TRF)



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

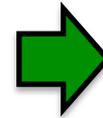
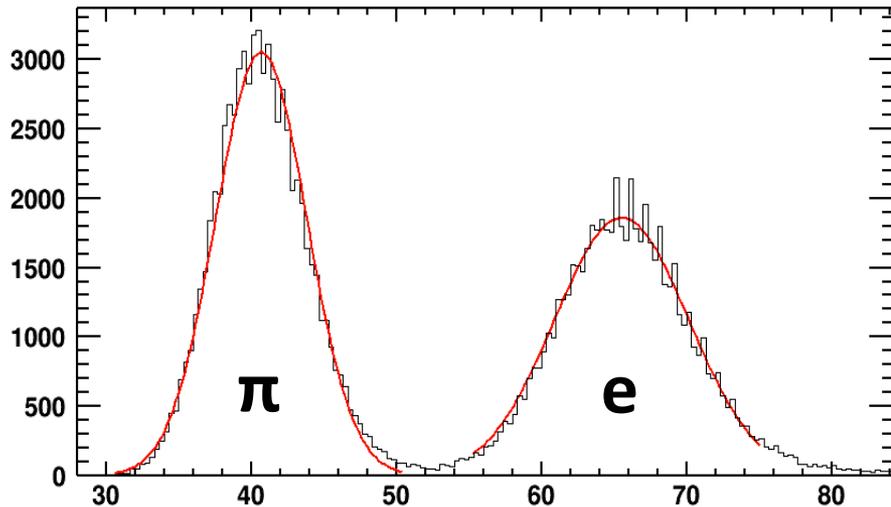
f : Experimental factor, which compensates **the missing charge**.

How to judge ?



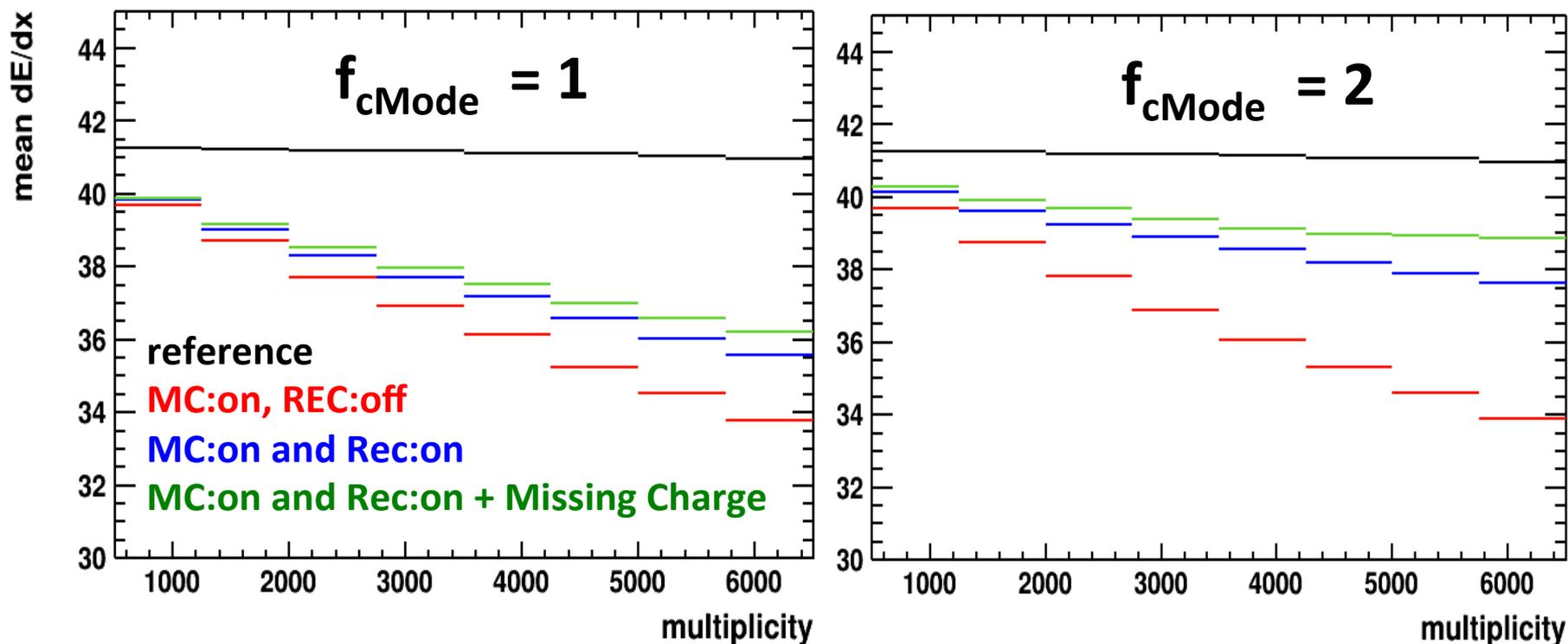
1) Mean dE/dx of Pions at MIP

2) Separation power



$$S = \frac{\mu_e - \mu_\pi}{\left(\frac{\sigma_e + \sigma_\pi}{2}\right)}$$

Mean dE/dx vs Multiplicity

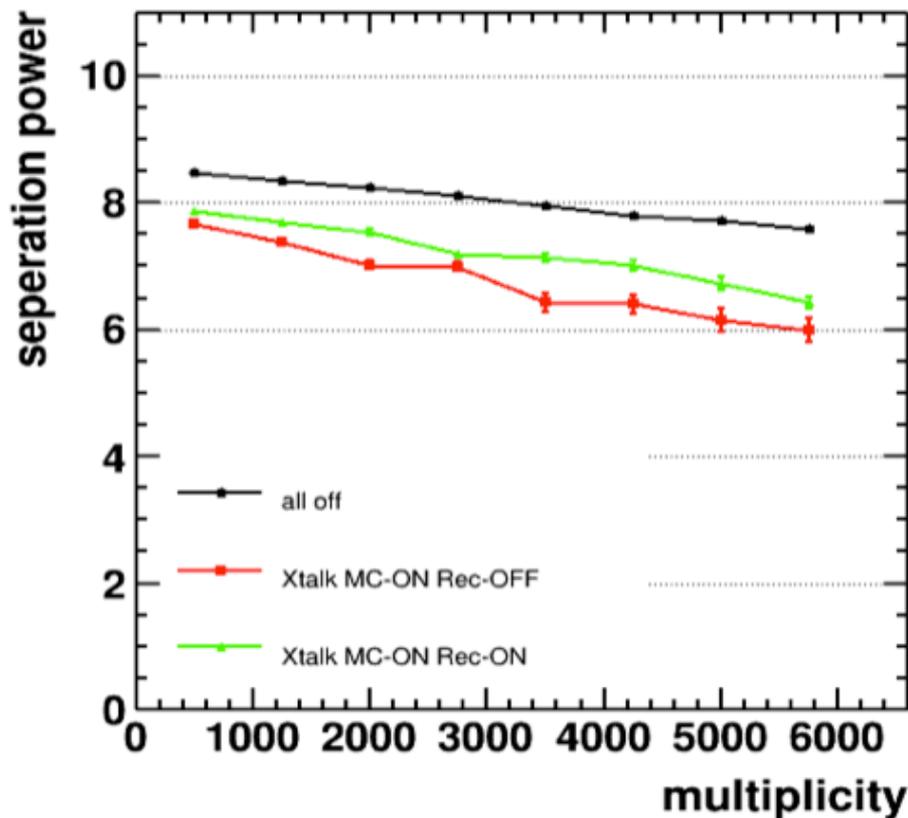


→ Scaling factor is needed for the missing clusters

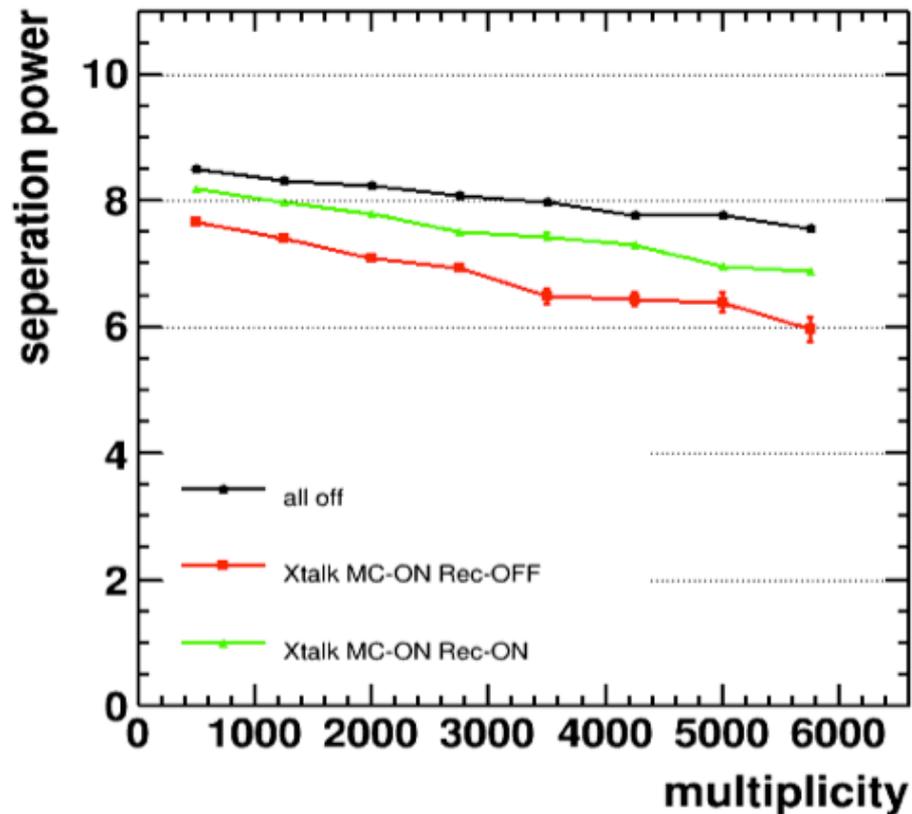
RESULTS: Common-Mode (MC)

Seperation Power vs Multiplicity

$f_{\text{cMode}} = 1$

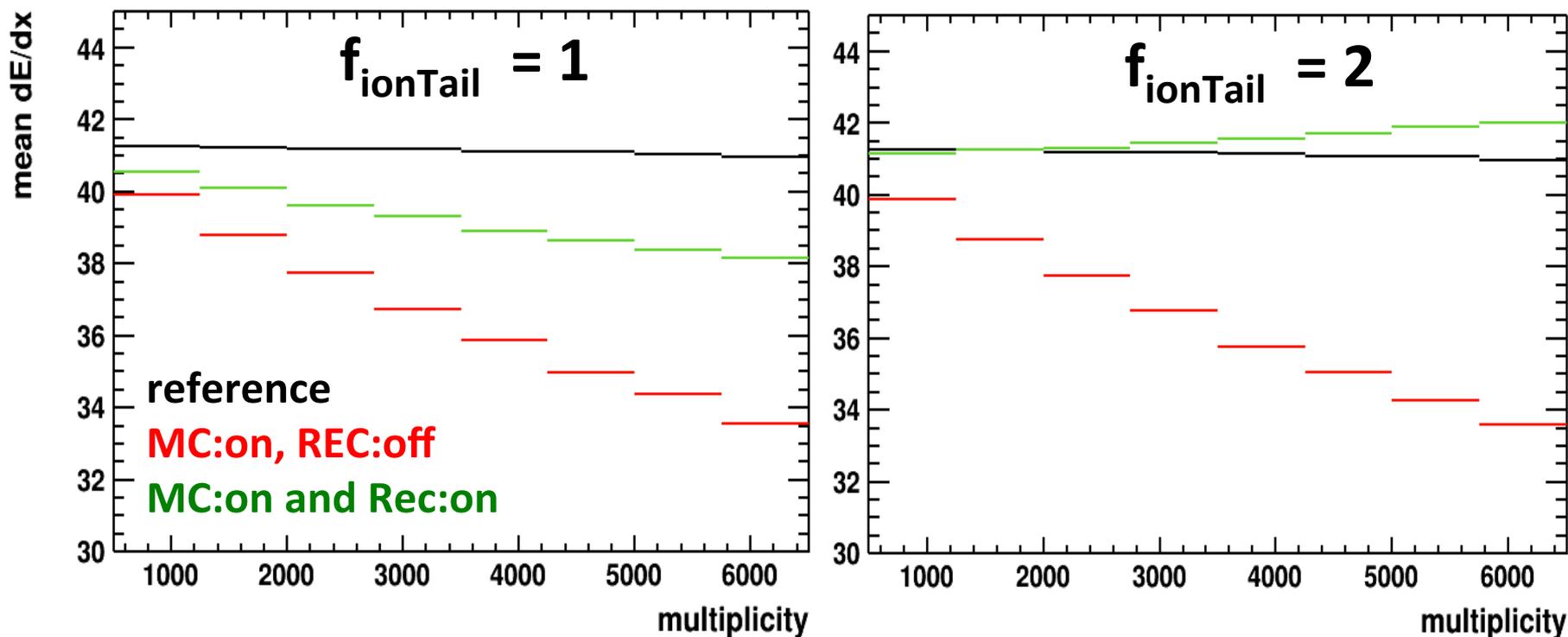


$f_{\text{cMode}} = 2$



RESULTS: Ion-Tail (MC)

Mean dE/dx vs Multiplicity

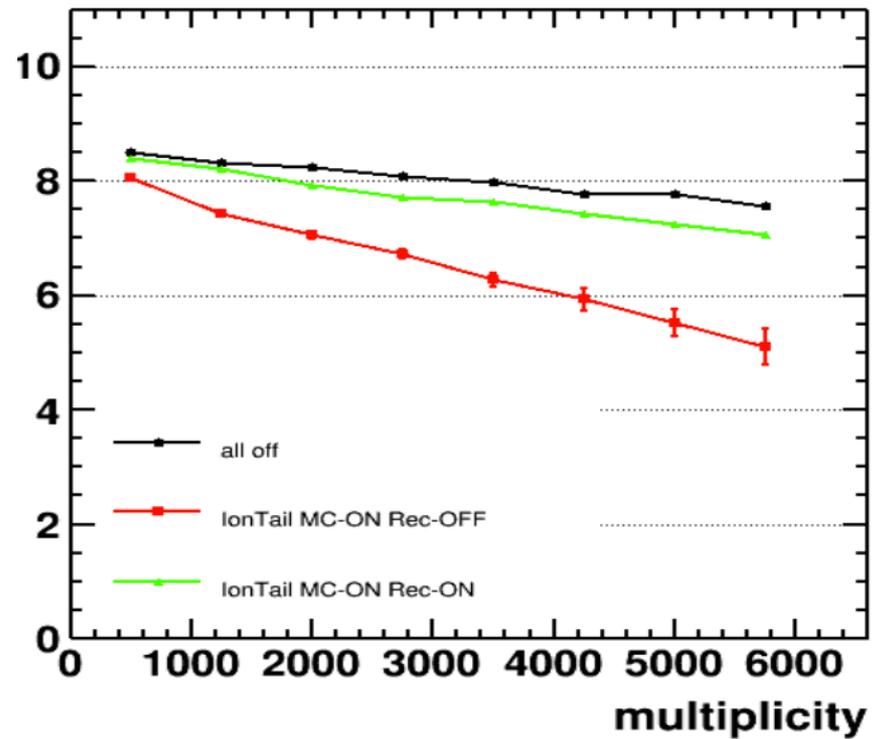
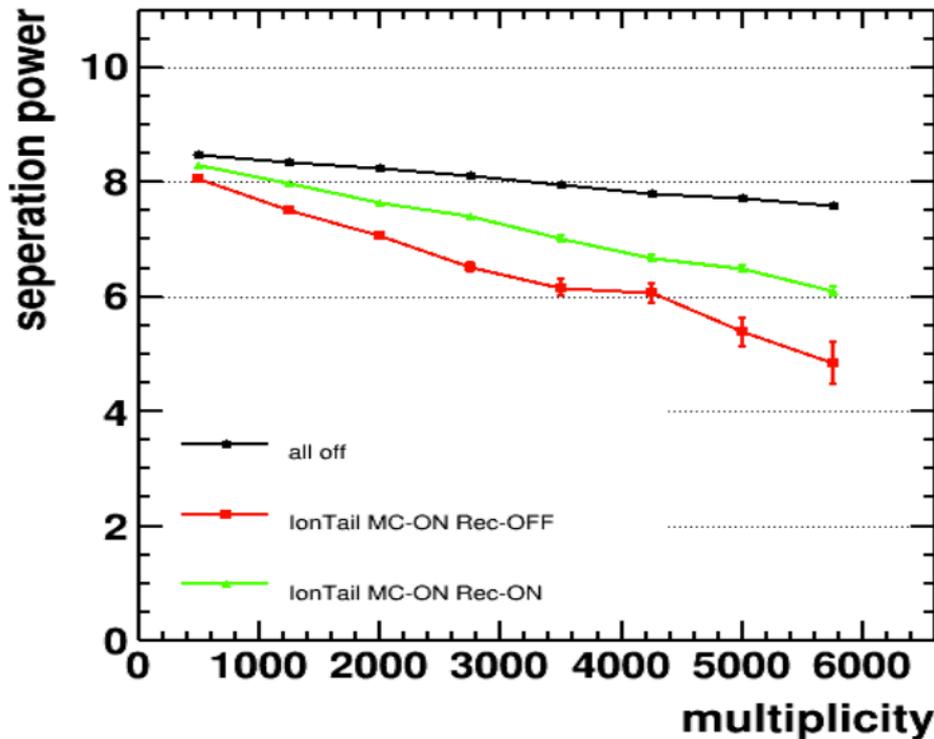


RESULTS: Ion-Tail (MC)

Seperation Power vs Multiplicity

$f_{\text{ionTail}} = 1$

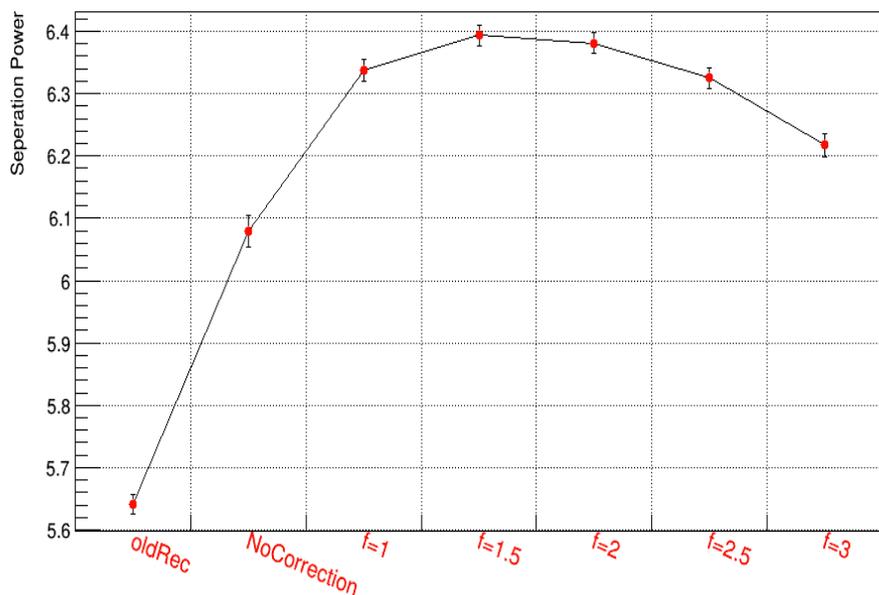
$f_{\text{ionTail}} = 2$



Results (Real Data)

Ion-Tail Correction

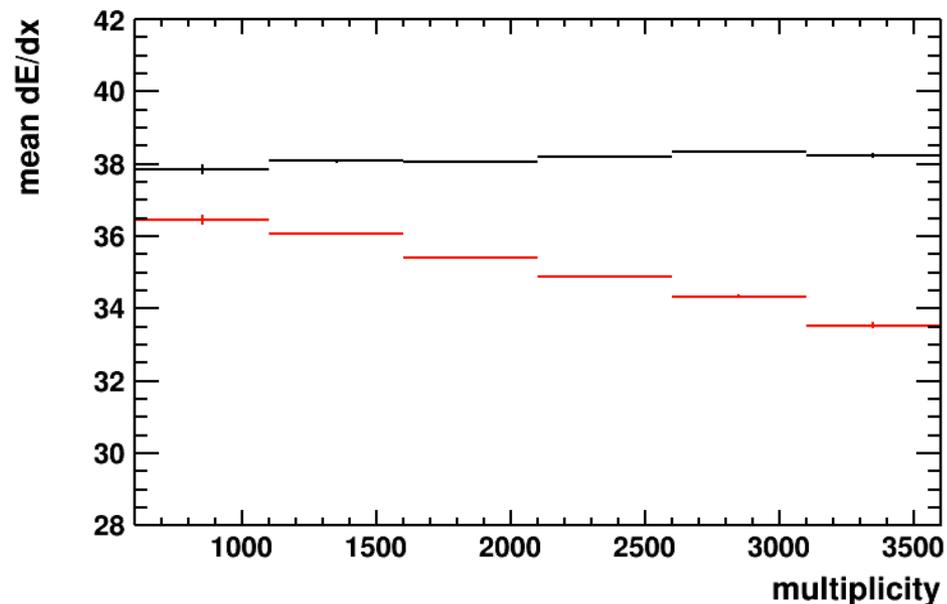
Separation Power



2010 PbPb data

IonTail + Common-mode Correction

Mean dE/dx vs multiplicity



2013 pPb data

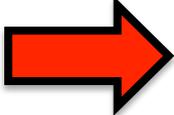
SUMMARY



- **Comprehensive study** of common-mode and ion-tail effects was performed using the Laser data of ALICE TPC.
- Since **common-mode effect** is based on the charge conservation, it has to be considered for **both GEMs and MWPCs**.
- Both effects are linearly proportional to the **local track density**.
- Both effects were **implemented in the MC** and corrected in the **reconstruction** successfully.
- It is proven that an offline correction of both effects improves the dE/dx performance thus the **PID quality** of ALICE.

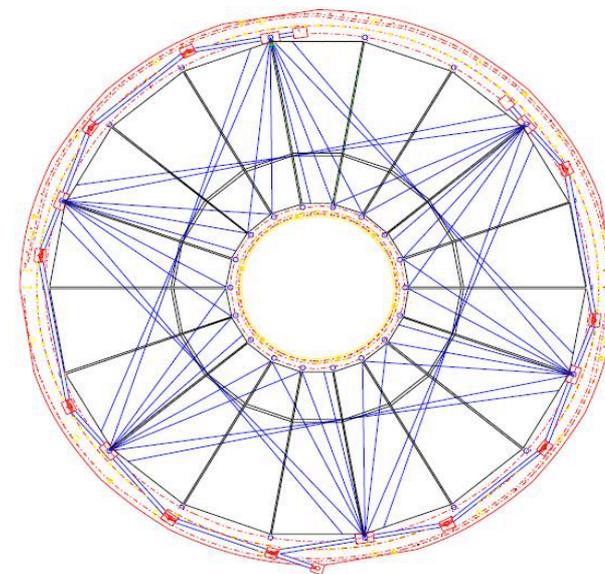
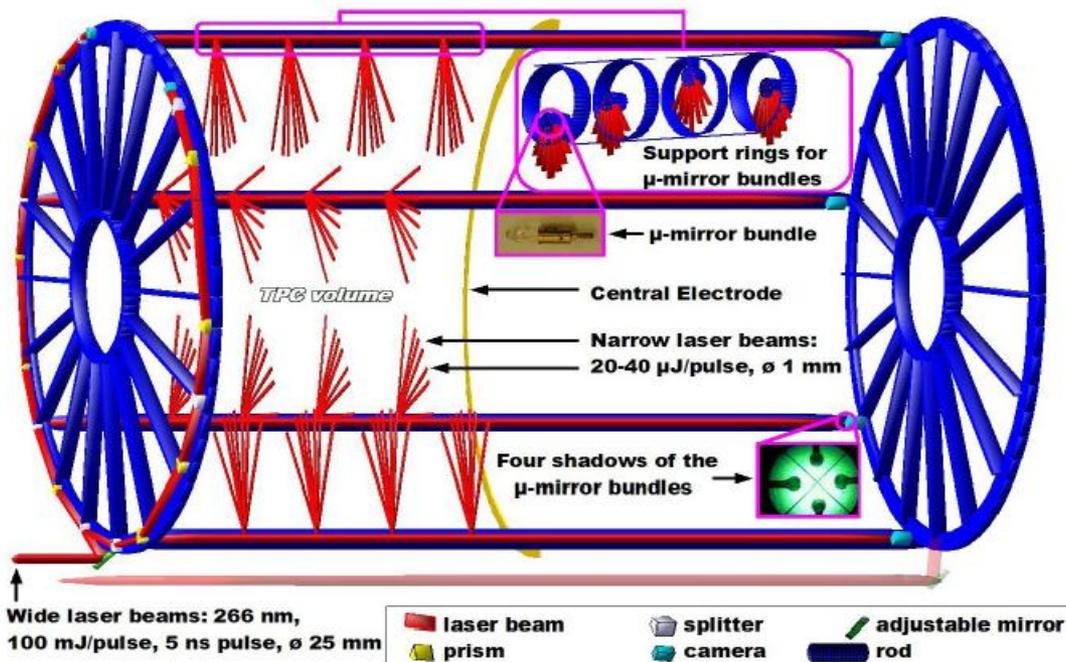
BACKUP

- 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



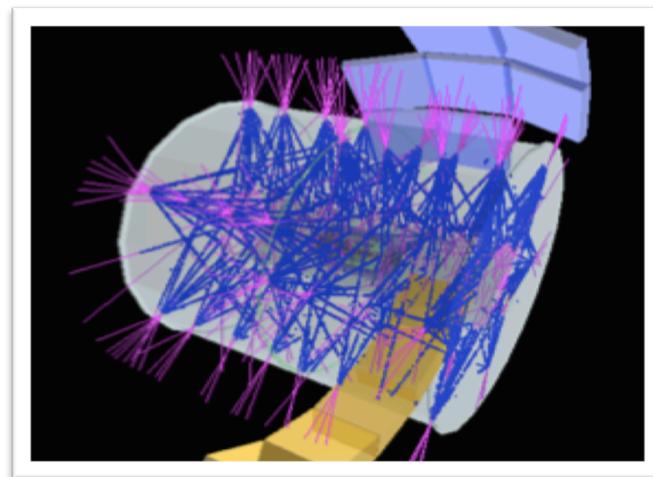
→ 336 Laser Rays (168 on each side)

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

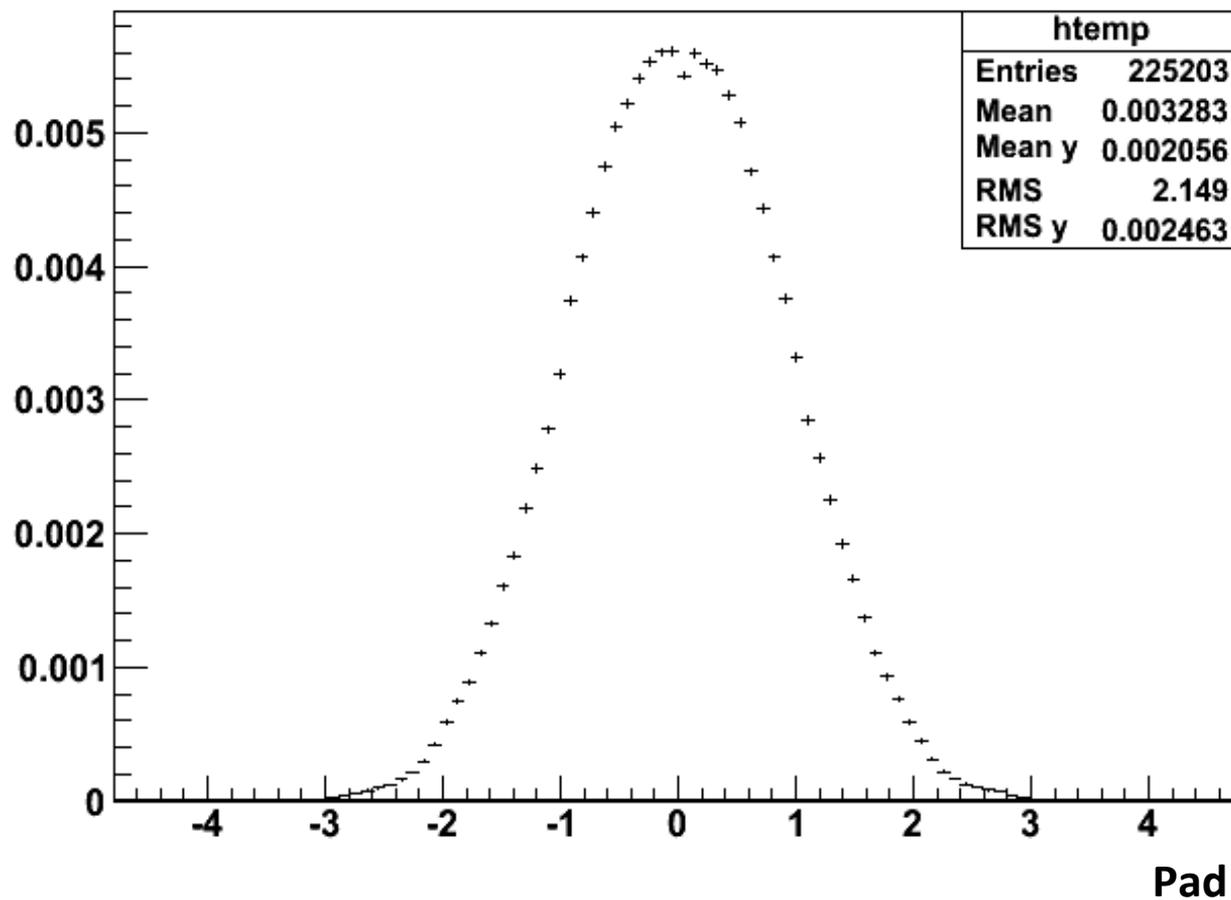
→ z-Positions;

odd rods: $\pm 130, 850, 1690, 2470$ mm

even rods: $\pm 100, 790, 1630, 2410$ mm



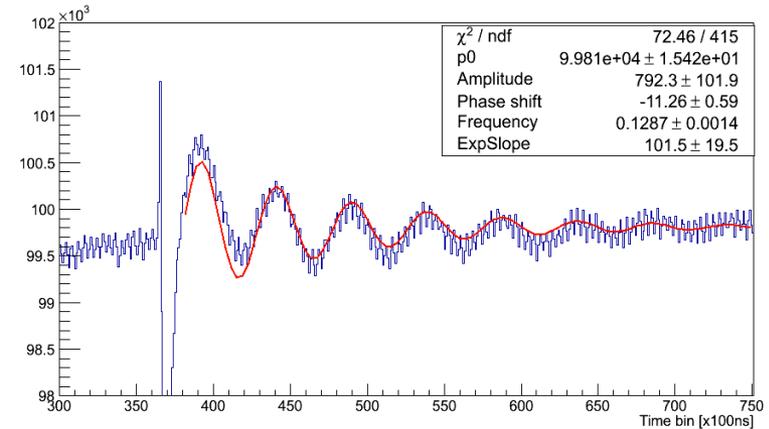
Pad Response Function



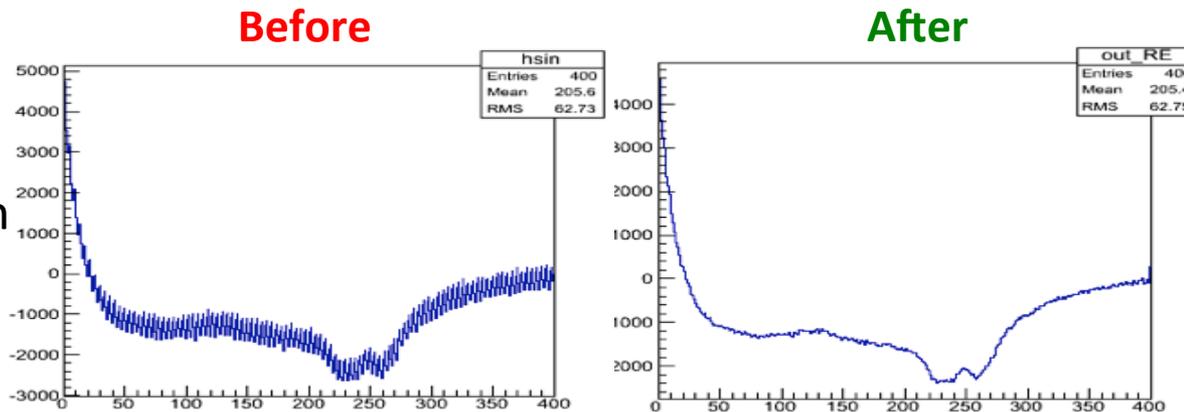
REMINDERS (III)

Preparation of the TRFs → Removal of frequencies + smoothing

- 1) **Low freq** → damping oscillator
→ $[0] + [1] * \exp(-(x-380)/[4]) * \sin([2] + [3] * x)$

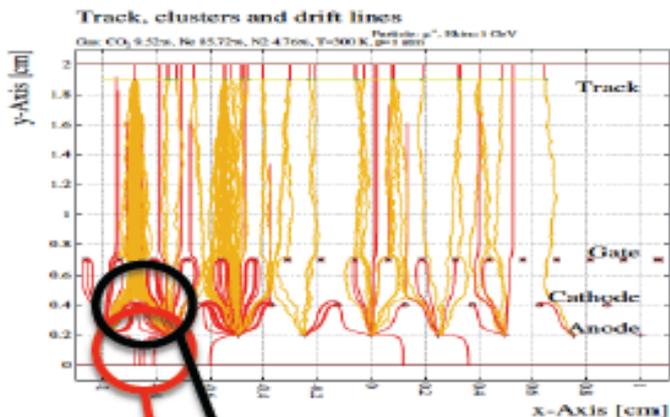


- 2) **High freq** → Fast Fourier Transformation

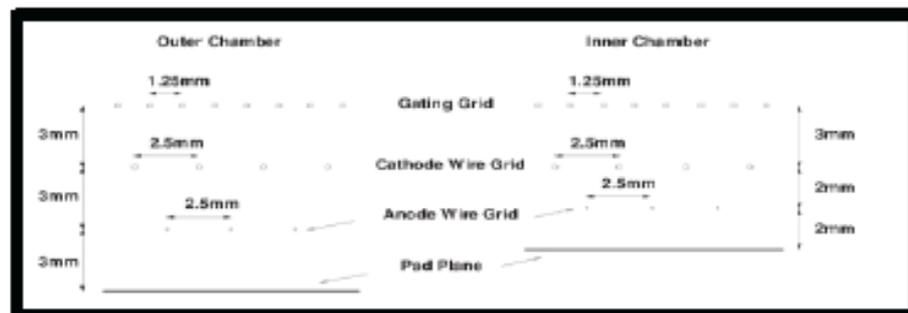


- 3) **Smoothing** with TLinearFitter

Garfield

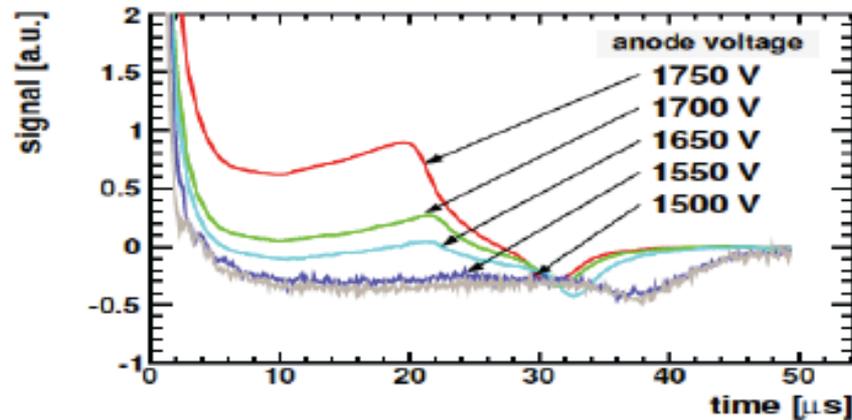
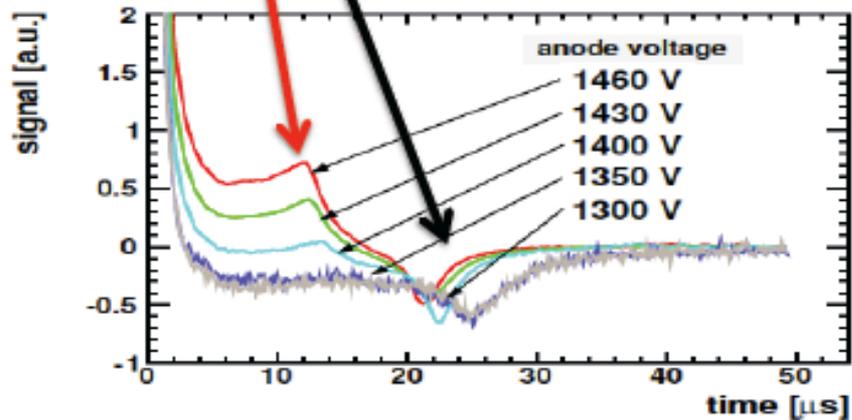


Wire geometries



6x10 mm² → inner OROC
6x15 mm² → outer OROC

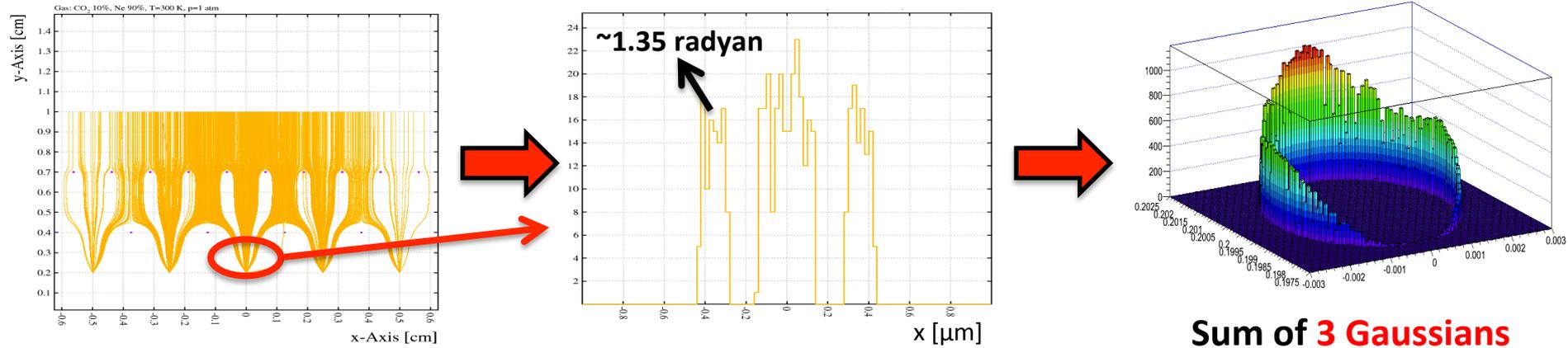
4x7.5 mm² → **Pad sizes**



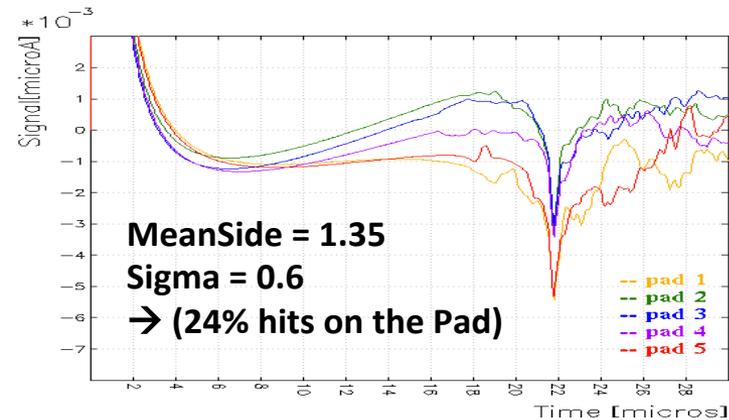
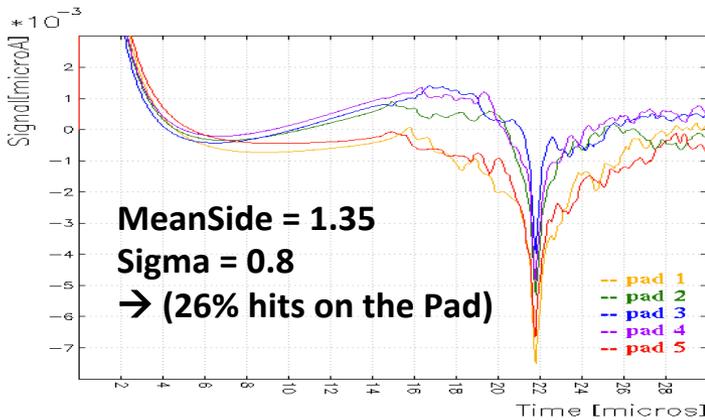
Cosmic data (2006-2008)

REMINDER (II)

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



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



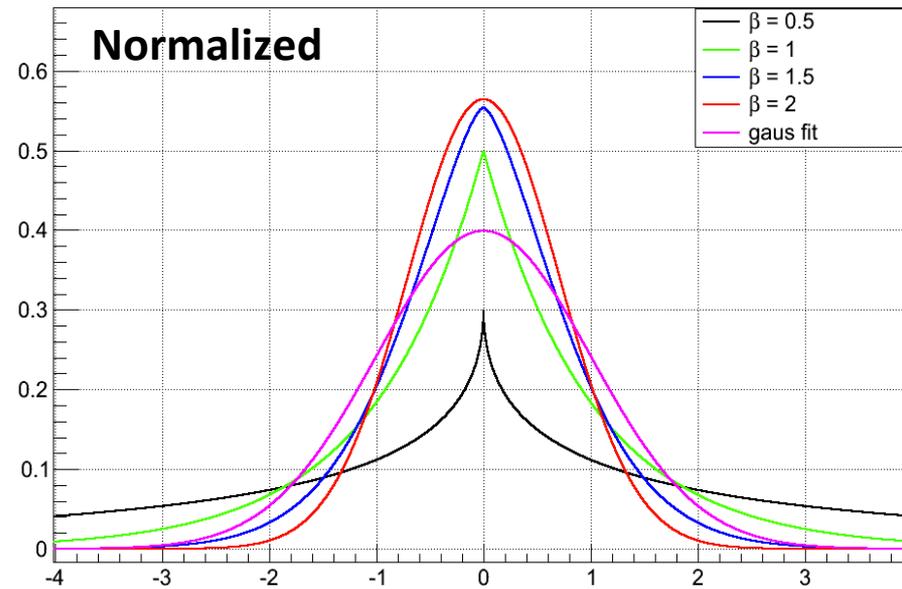
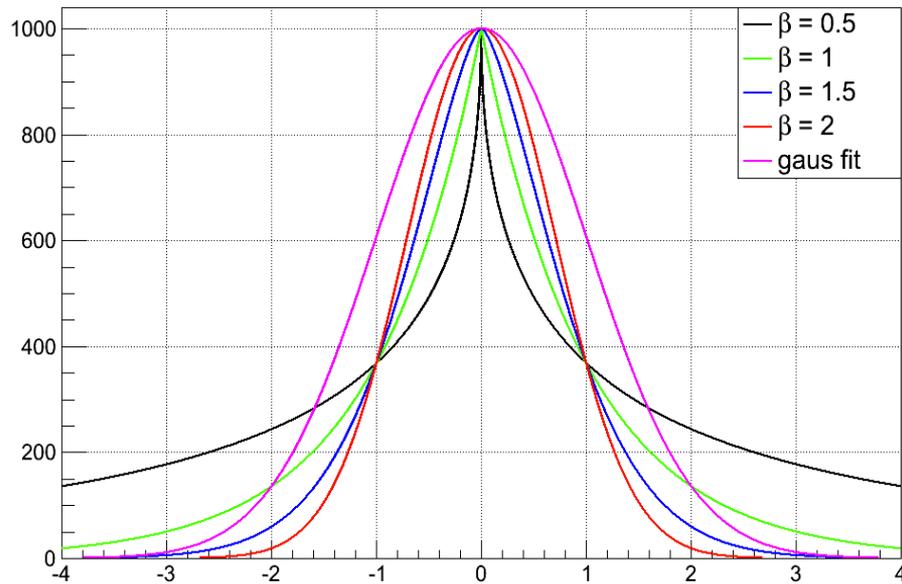
→ Pad 3 is the central pad

→ Only 3000 ions were used.

WHAT IS NEW ?

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

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

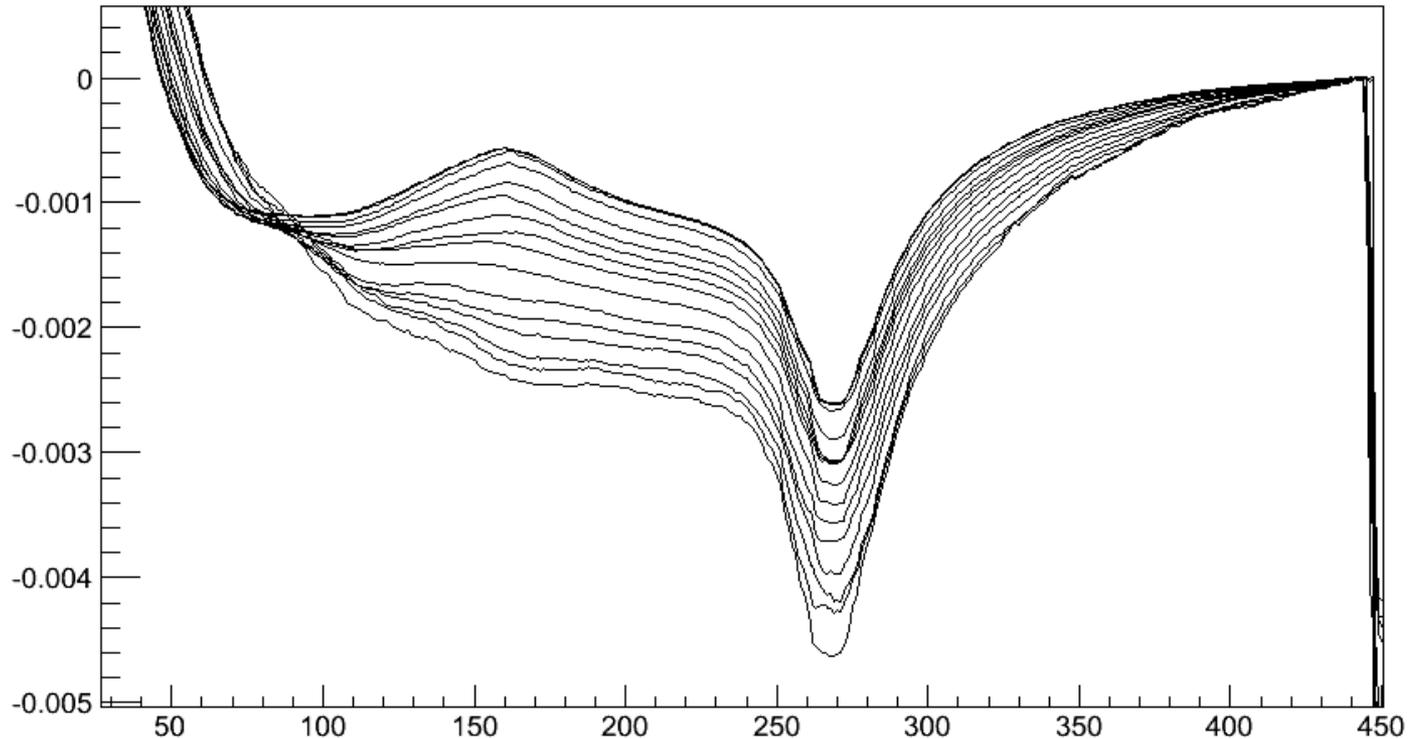


- 2) Vary the **number of ions** in the cluster

MOTIVATION

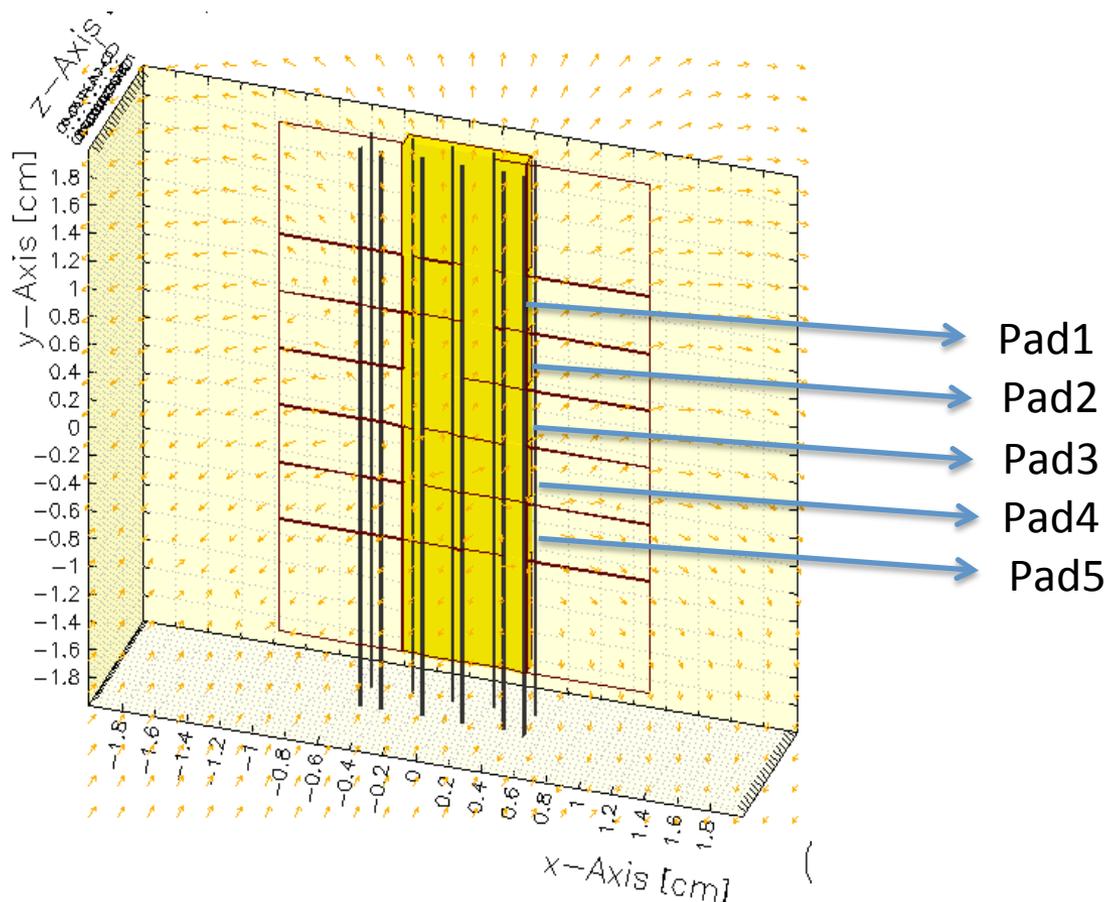
REAL DATA:

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



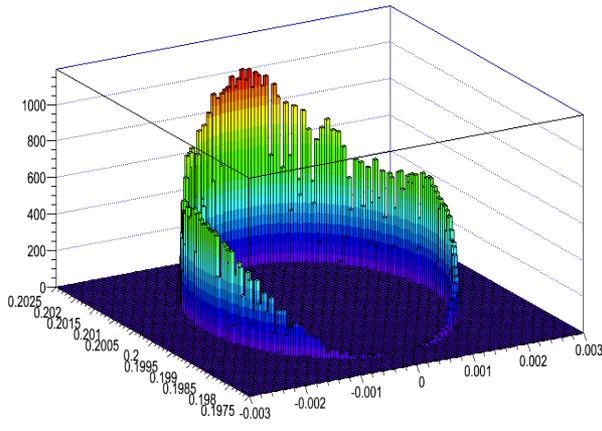
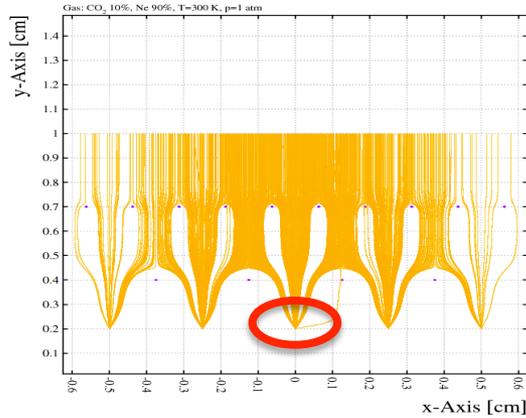
Ion Tail: Garfield Simulations

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

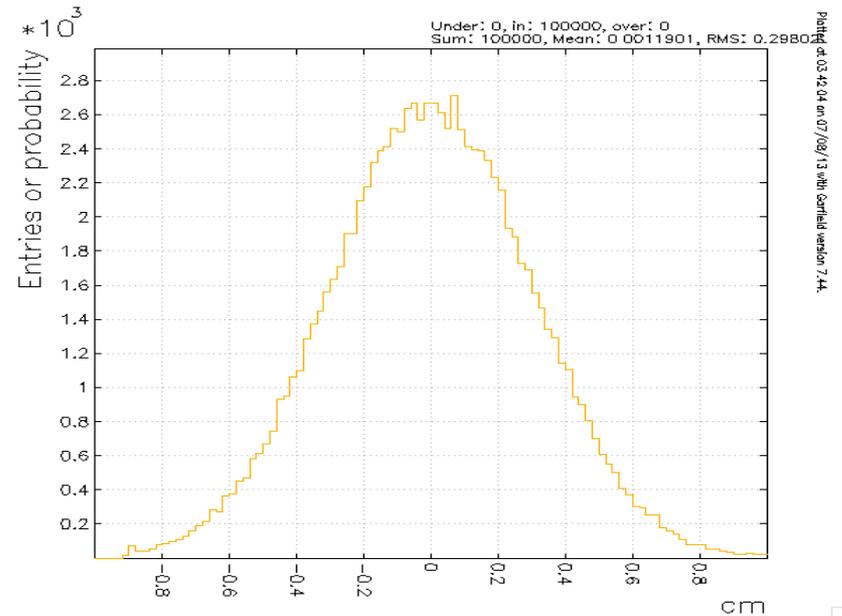


Ion Tail: Ion Distributions

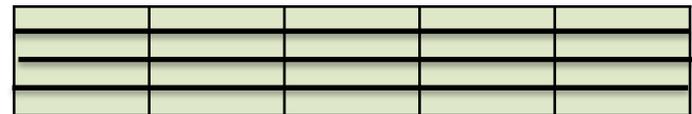
Distribute ions around the wire as a triple gaussian profile



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



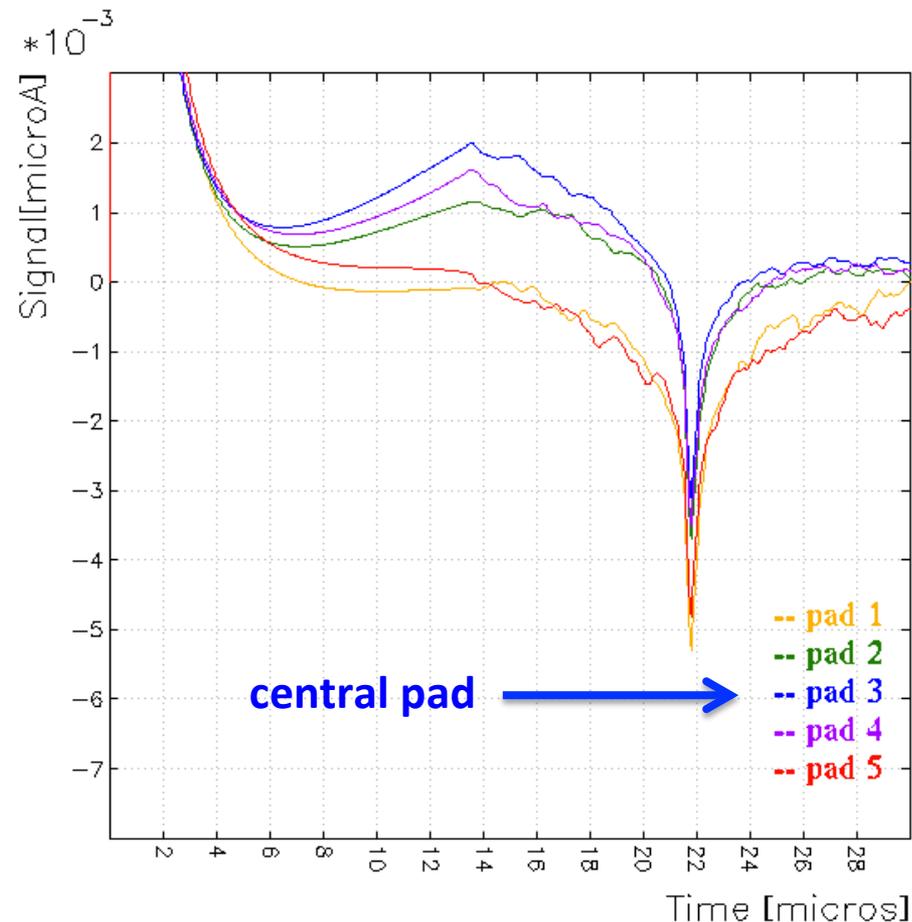
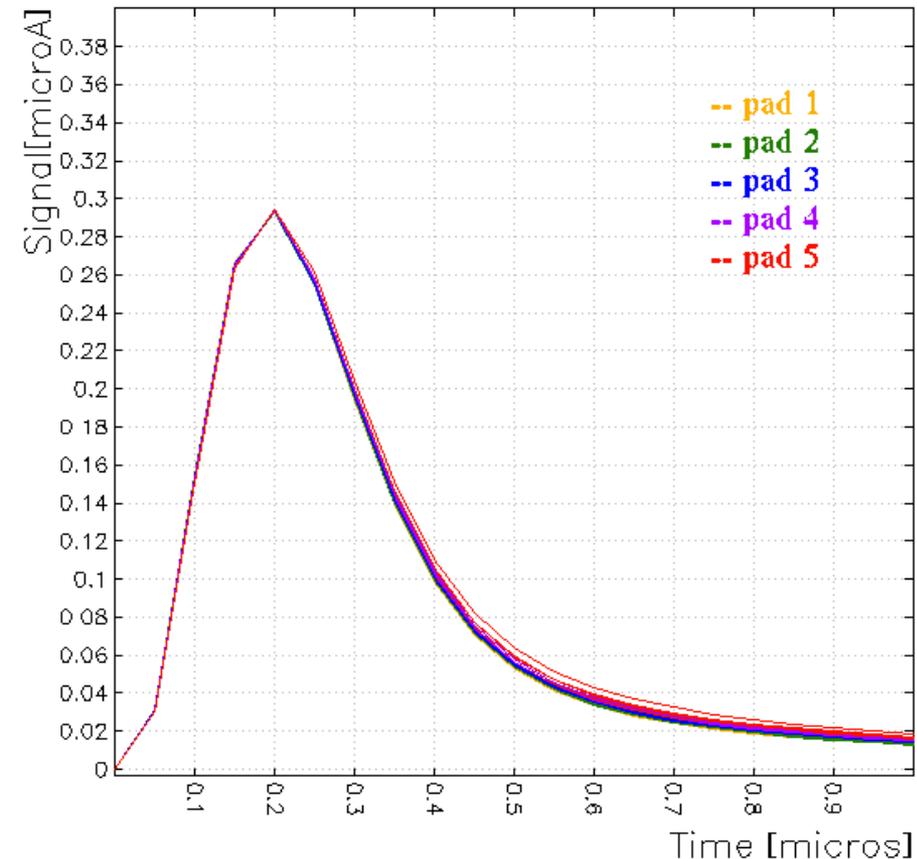
Plotted at 03:42:04 on 07/08/13 with Canvas version 7.44.



Anode Wires

Pad1 Pad2 Pad3 Pad4 Pad5

Ion Tail: Garfield Simulation Results

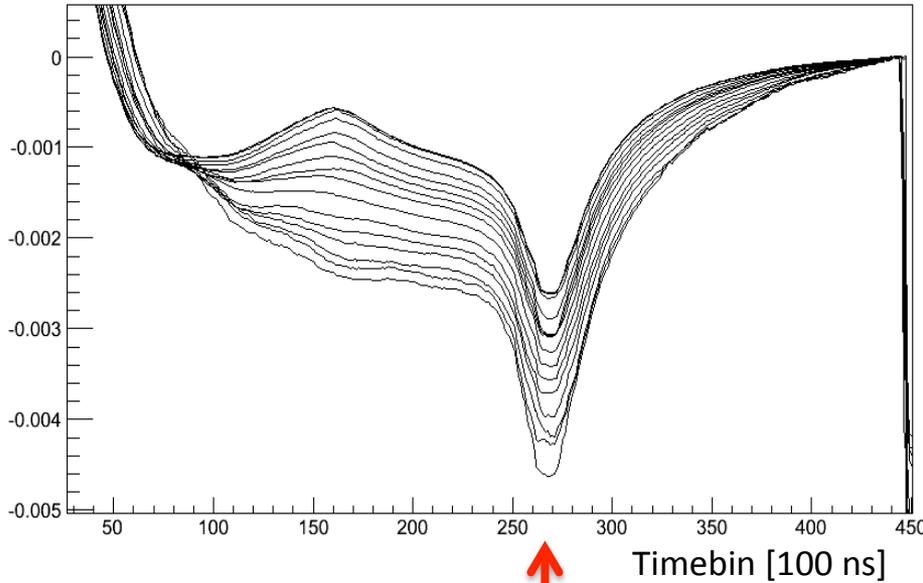


$$12 * \exp(4) * (t/0.16)^4 * \exp(-4 * t/0.16)$$

(transfer function of PASA)

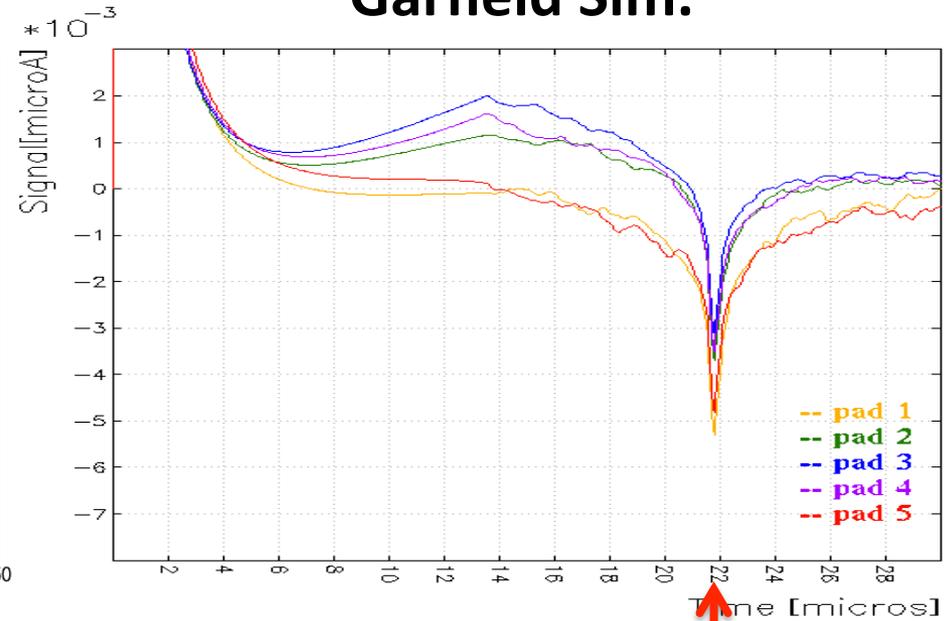
Ion Tail: Simulation vs Real Data

Data



**Ion arrival is
~27 μ s**

Garfield Sim.

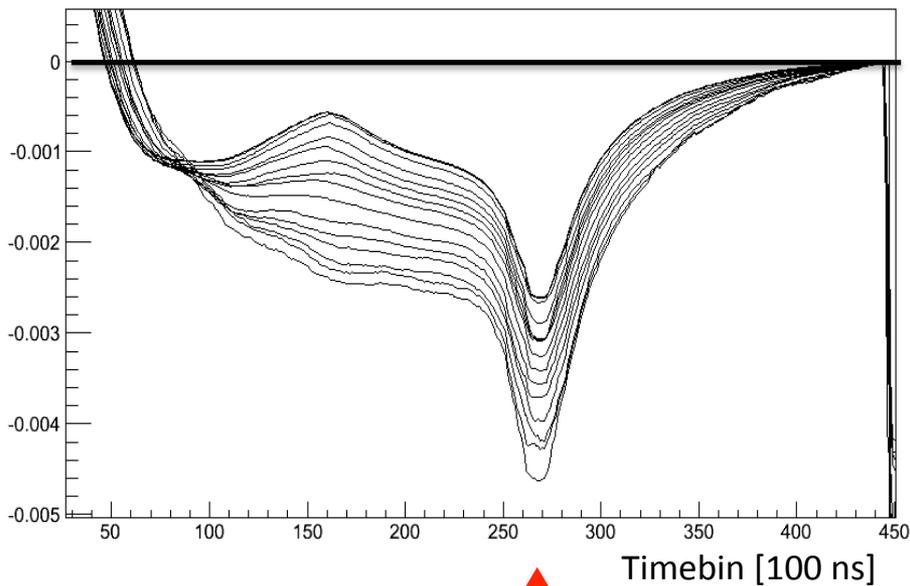


**Ion arrival is
~22 μ s**

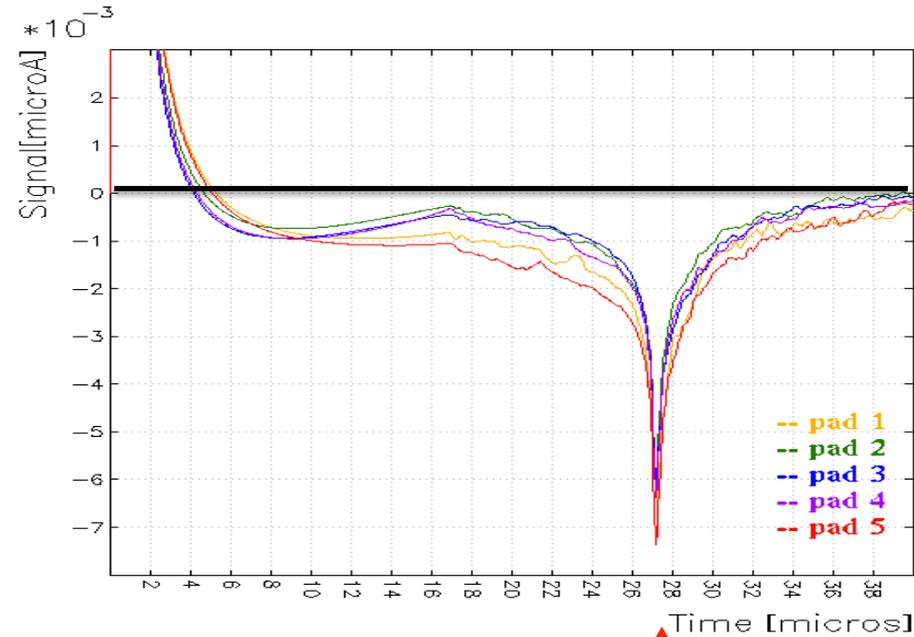
- **Baseline** → Distributions of ions around wire.
- **Ion arrival time** → Ne⁺ in Ne is not the right assumption.
Ion mobility measurements for gas mixtures is needed.

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 μ s**



↑
**Ion arrival is
~27 μ s**