Mid-Scale Drift Chamber Prototype: Beam Test and Preliminary Results

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on behalf of

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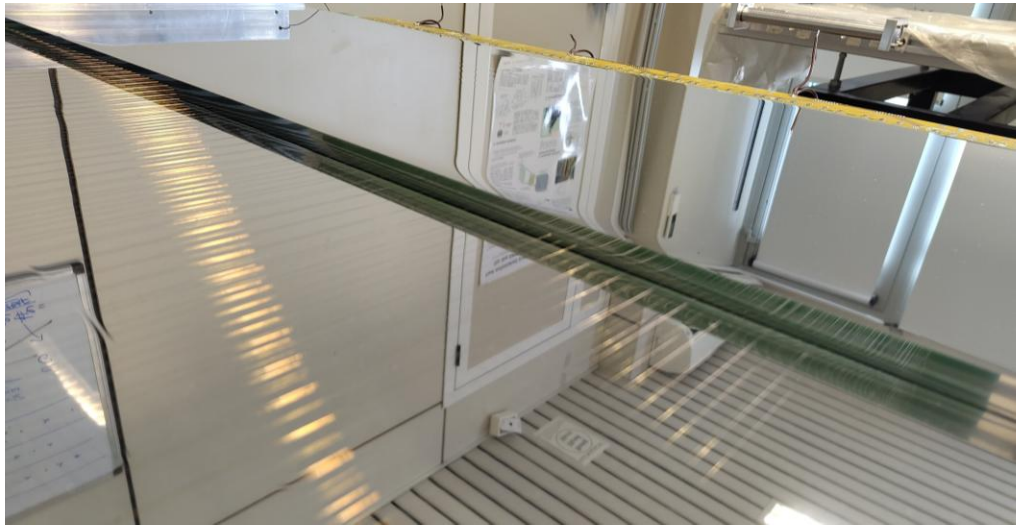
Dune Italia Meeting
10-12 November - LNF

DUNE

Beam Test Objectives

- **Study** the drift chamber prototype **performance** through:
  - **Cell efficiency**
  - **Drift velocity**
  - **Spatial resolution**
- Test their **uniformity** across the prototype volume
- **Validate** the mechanical design



Test Setup

*Thanks to DRD1 collaboration for the organisation and support during the test beam

CERN-SPS H4 beamline* **(~220 GeV muons)**

Beam Tracking performed by:

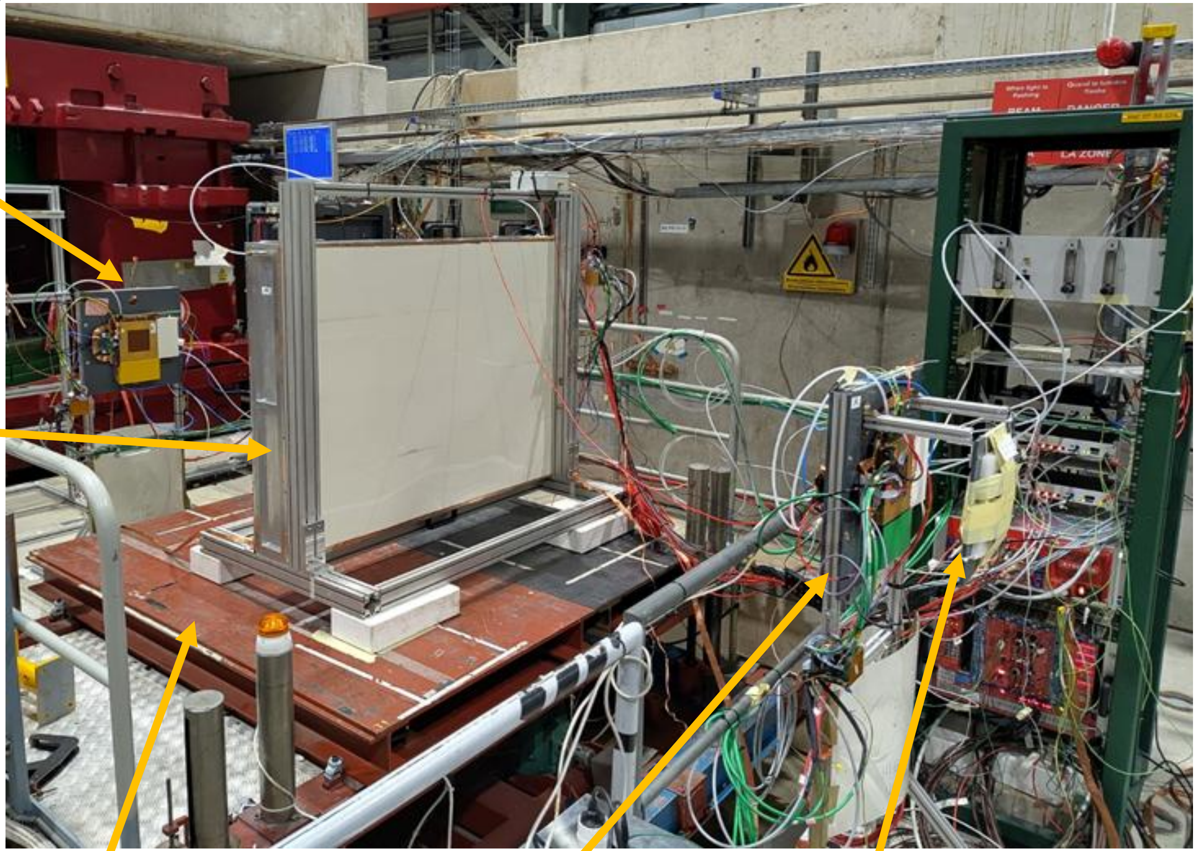
- 4 **GEM** detectors
  - ~10x10 cm^2 active area
  - σ_x=100 μm
  - **Thanks to Ferrara BESIII group!**

Trigger:

- 2 **plastic scintillators**
  - 15x15 cm^2 size
  - 1 cm thick
  - readout: 1 PMT Hamamatsu R9880 directly coupled

2 **GEM** (front)

DUT : **drift chamber**



Movable table

2 **GEM** (back)

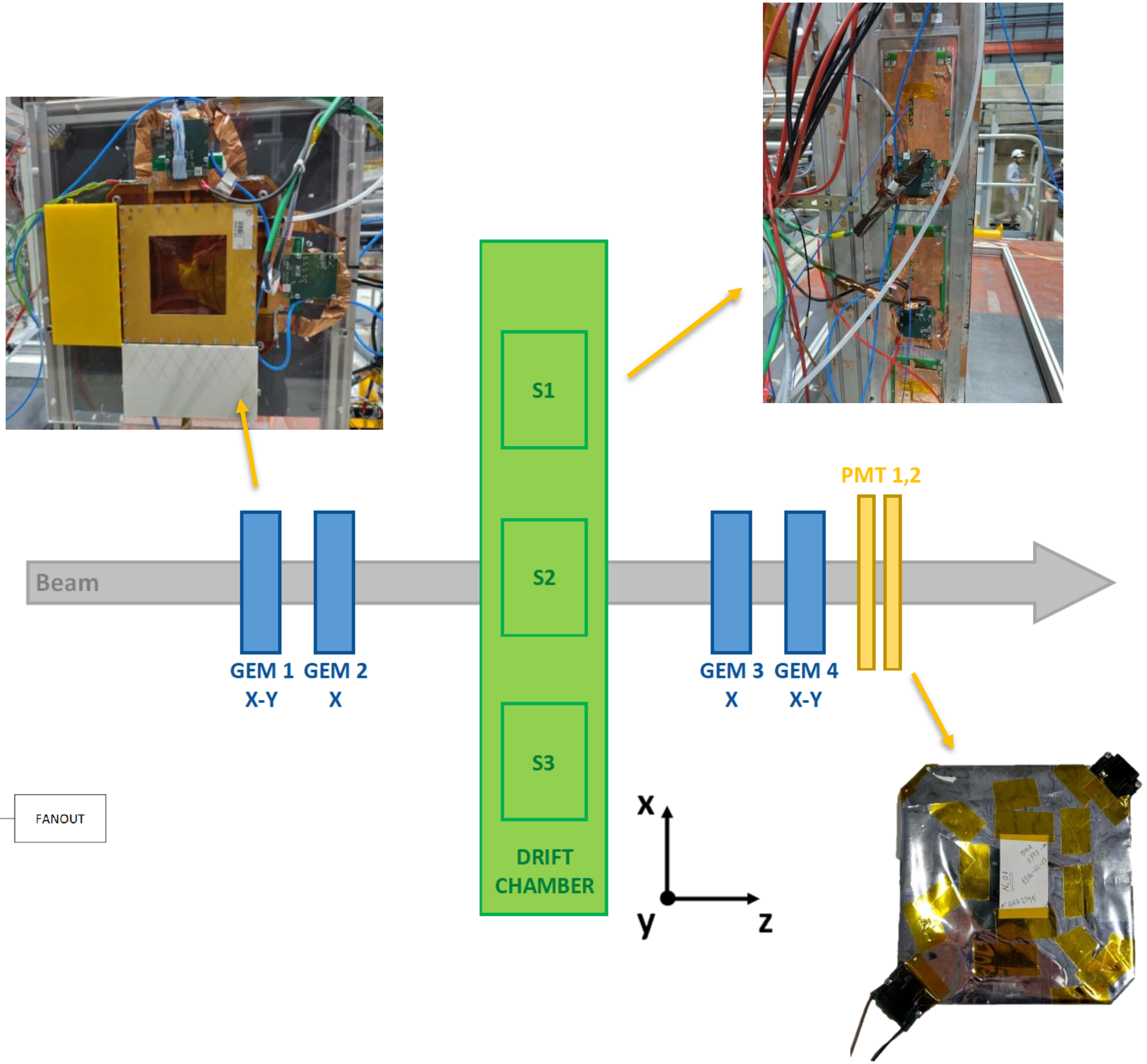
2 **scintillators**

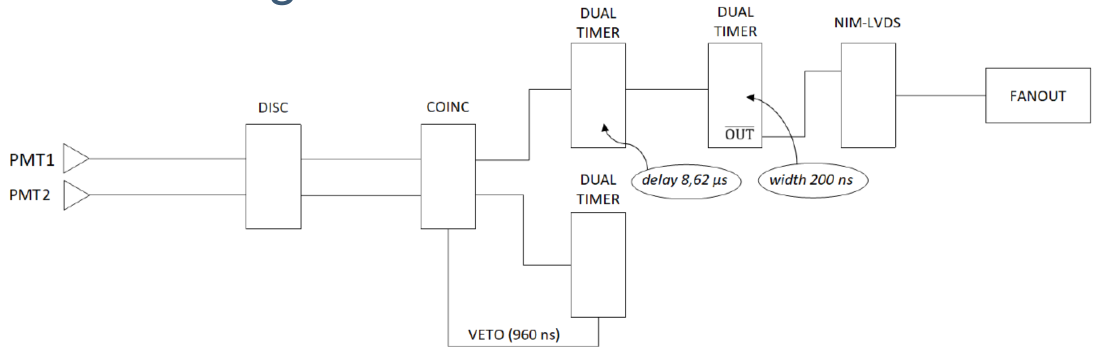
Test Setup

Drift chamber:
- wires **parallel to the y** axis
- only sectors **S1** and **S2** were read

Tracks reconstructed with:
- **4** points for **x** coordinate
- **2** points for **y** coordinate

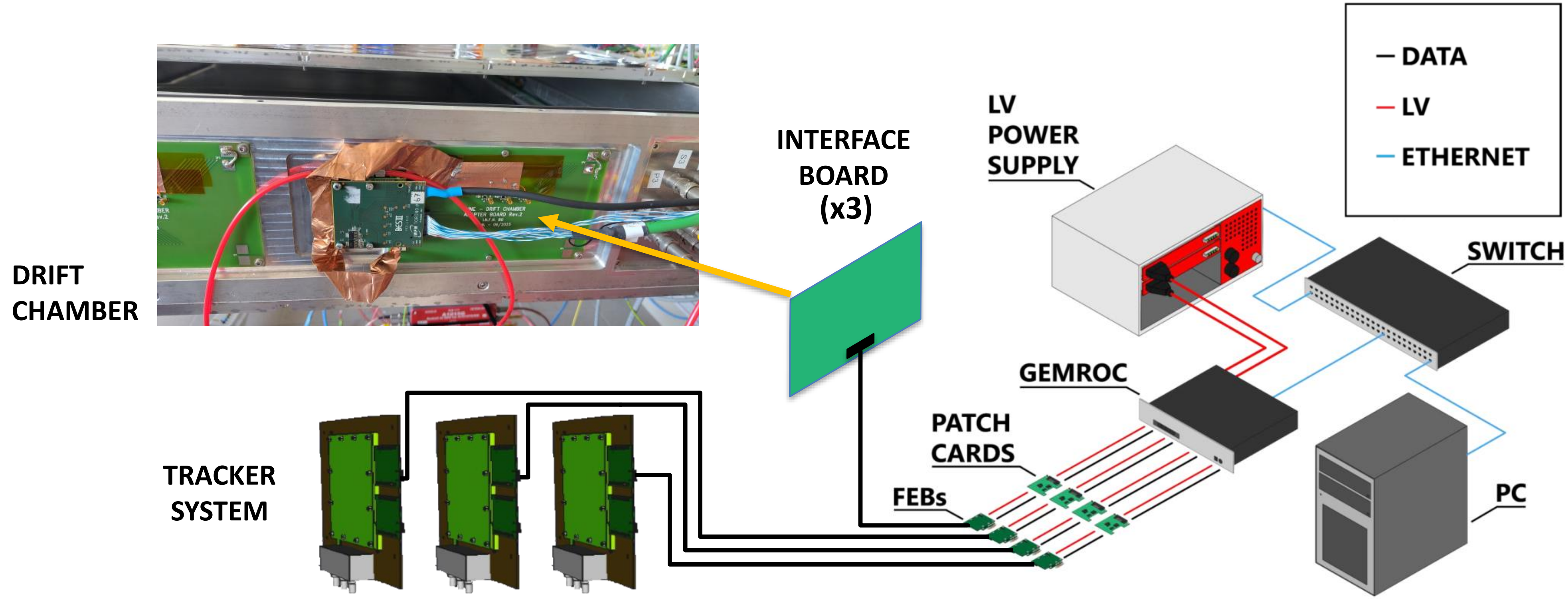
Acquisition triggered by the **coincidence** of 2 PMT signals





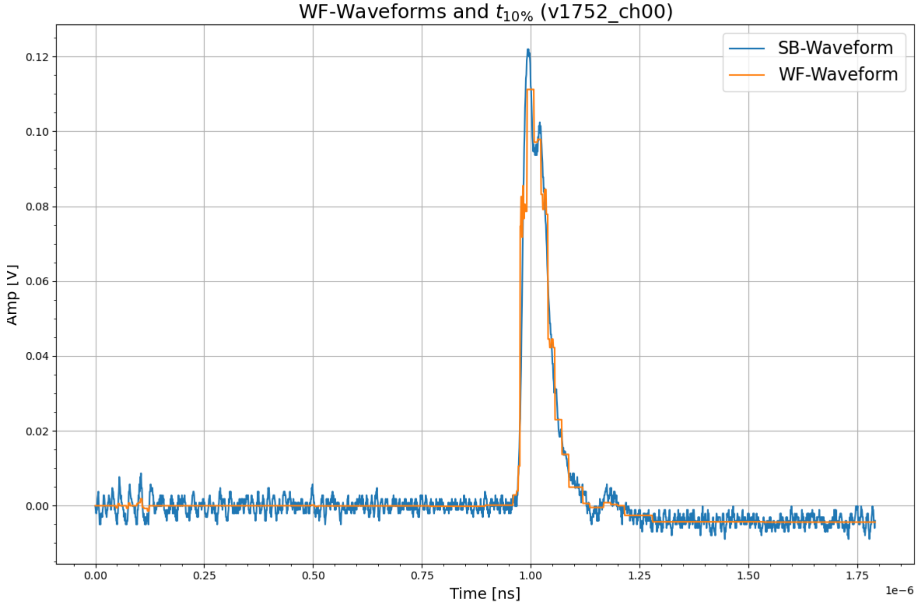
TIGER-GEMROC Readout

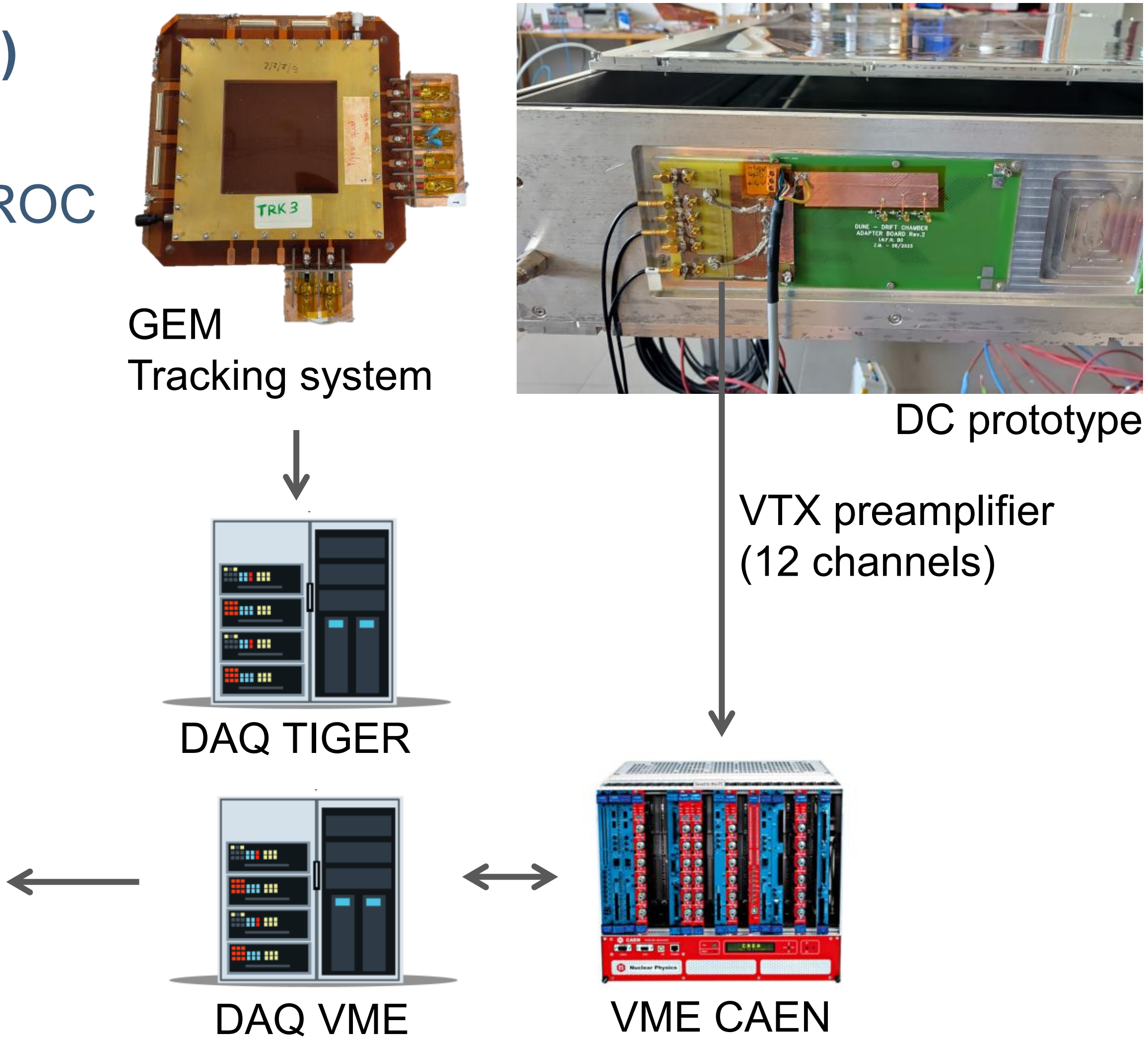
- GEMs and DCH are read out by the **TIGER ASIC**
- For the DCH, an **interface card** routes 64 channels to a Front-End Board mounting TIGER
- **3** interface cards are necessary to read all DCH channels
- **GEMROC** off-detector electronics



VME Readout Electronics

- **Board** with 2 **VTX preamplifiers (12 channels)**
- **VME V1751 digitizer** (1GS/s)
- **Trigger** propagated from VME to TIGER-GEMROC readout
- **Offline signal processing**





Test Plan

DCH read out with TIGER

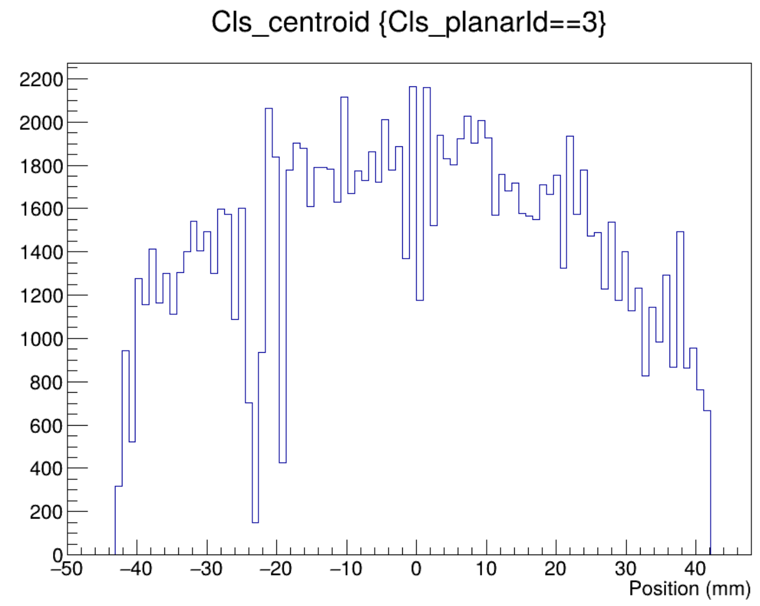
▪ **Muon** run: scan over different HV values, from **1100V to 1700V** (50V steps)	✔	[8M events]
• In 6 different positions of the chamber wrt the beam		[8M events]x6
▪ Muon run: scan over Field voltage from 1500V to 2100V, Mylar fixed at 1500V	✔	[2.9M events]
▪ **Muon run low rate** (< 1kHz): HV scan from 1100v to 1700V	✔	[3.3M events]
▪ **Pion** run	✔	[6M events]

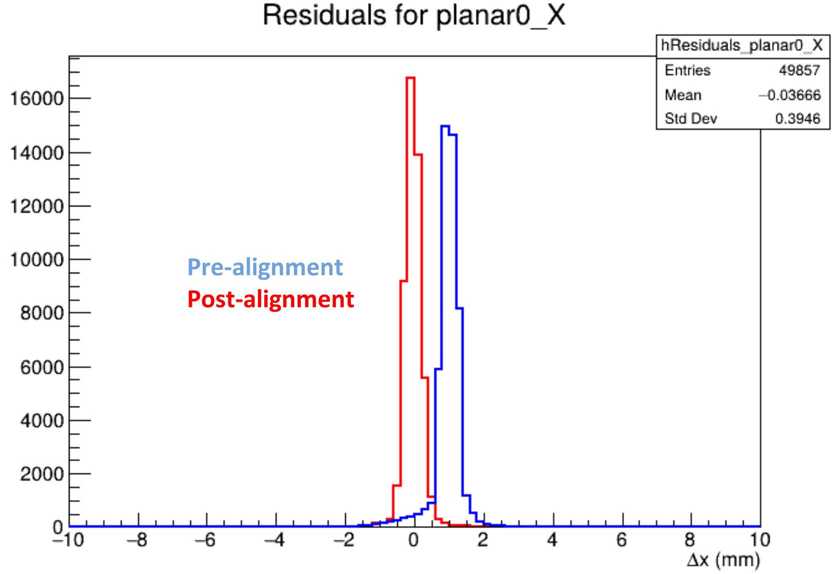
DCH read out with Digitizer

▪ **Waveforms** acquired with VME digitizer, HV scan from 1100V to 1700V	✔	[1M events]

Data Analysis

- A custom **analysis framework** is being developed
- **Alignment** and **tracking** implemented
- Quick-look plots available for:
  - Clusters
  - Tracks
  - Drift Chamber layers
- The goal is to reconstruct a sample of good tracks to **study drift chamber performance** *e.g.* **efficiency**, **drift velocity, spatial resolution**



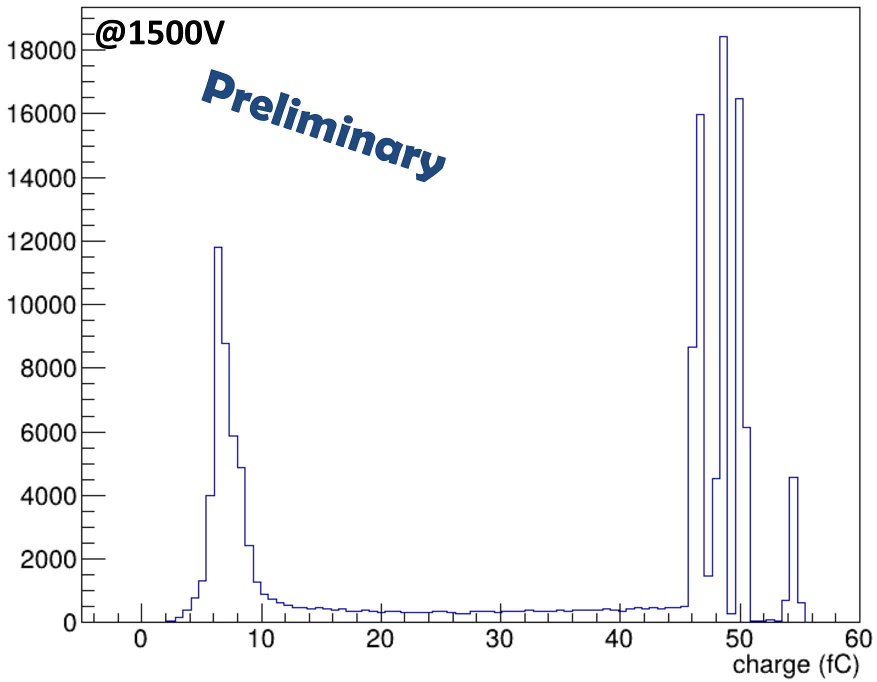


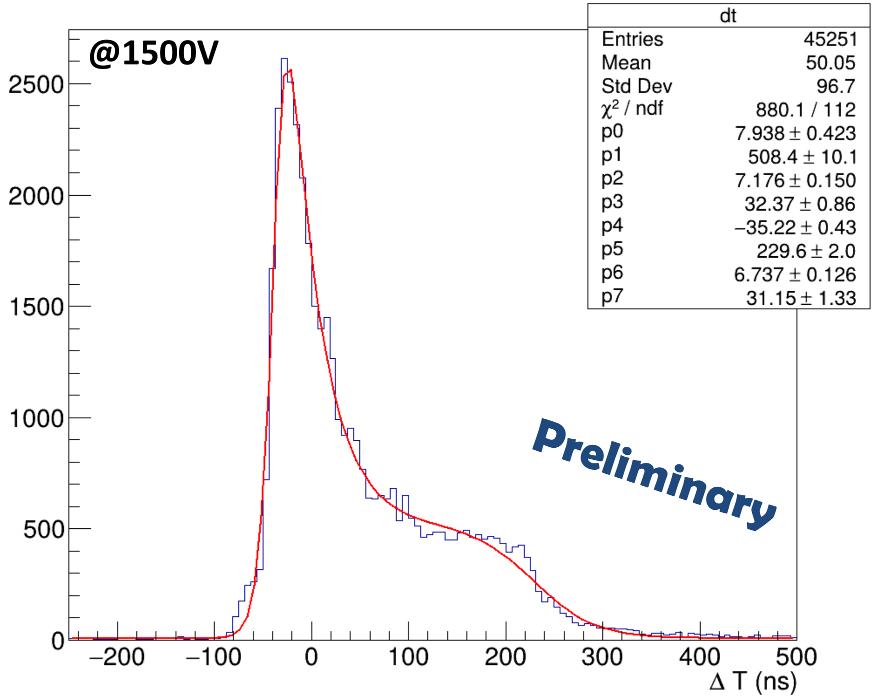
Time and Charge Distributions

- TIGER channels **saturate** at **~50 fC**
- At 1500V most of the signals are saturated

- **ΔT** = Time(PMT) – Time(Drift)
- Fitted with two Fermi-Dirac

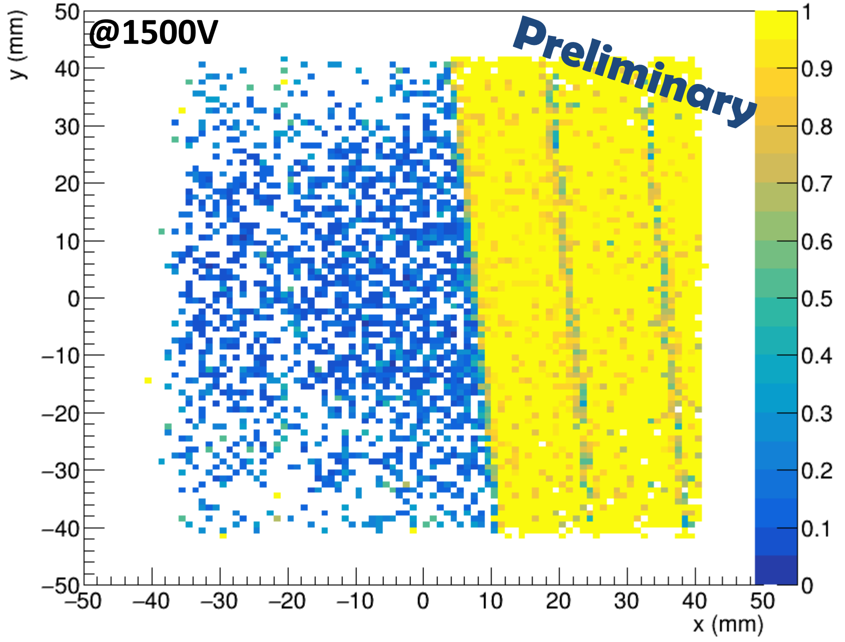
$$f(t) = p_1 + \frac{p_2\left(1 + p_3 e^{-\frac{t-p_5}{p_4}}\right)}{\left(1+e^{\frac{-t+p_5}{p_7}}\right)\left(1+e^{\frac{t-p_6}{p_8}}\right)}$$

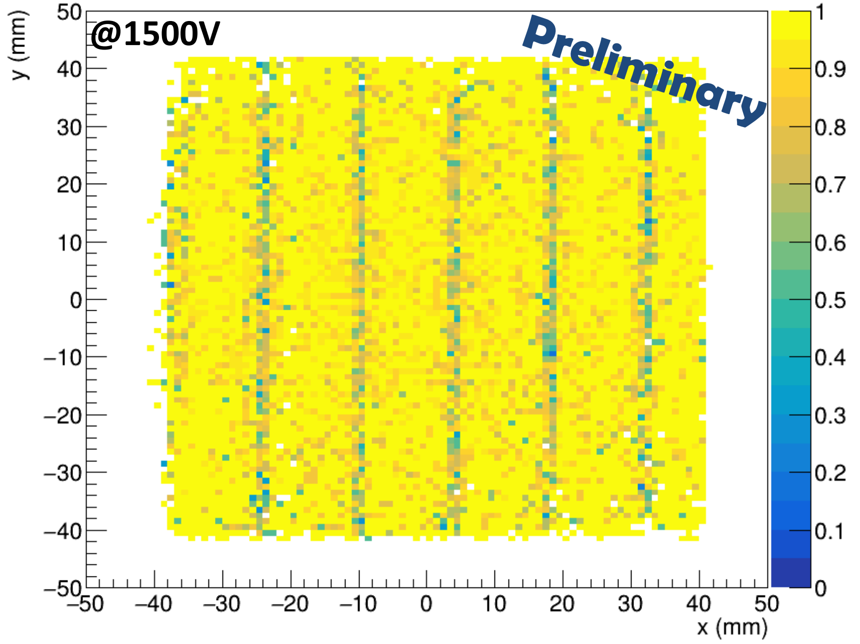




Channel Efficiency

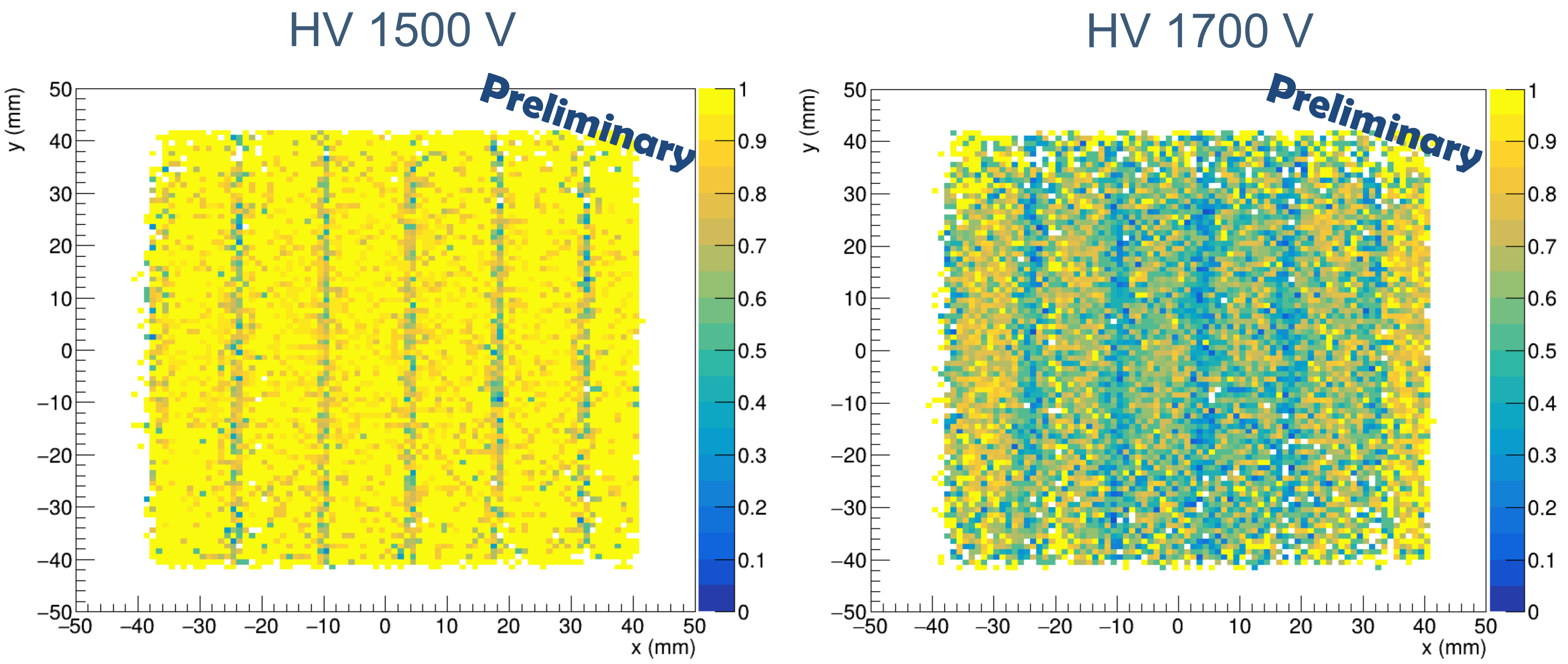
- One cluster in each tracker + DCH signal above threshold
- Efficiency **exceeds 95%** across most of the area, with **lower values** observed **near the cell edges** possibly due to reduced charge collection near the boundaries.





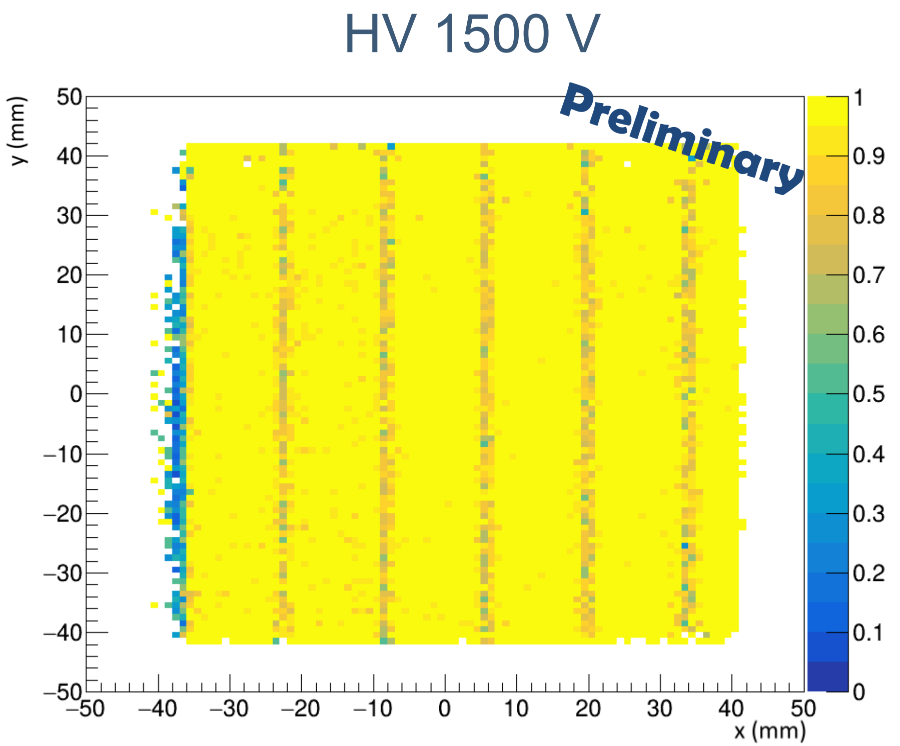
Channel Efficiency

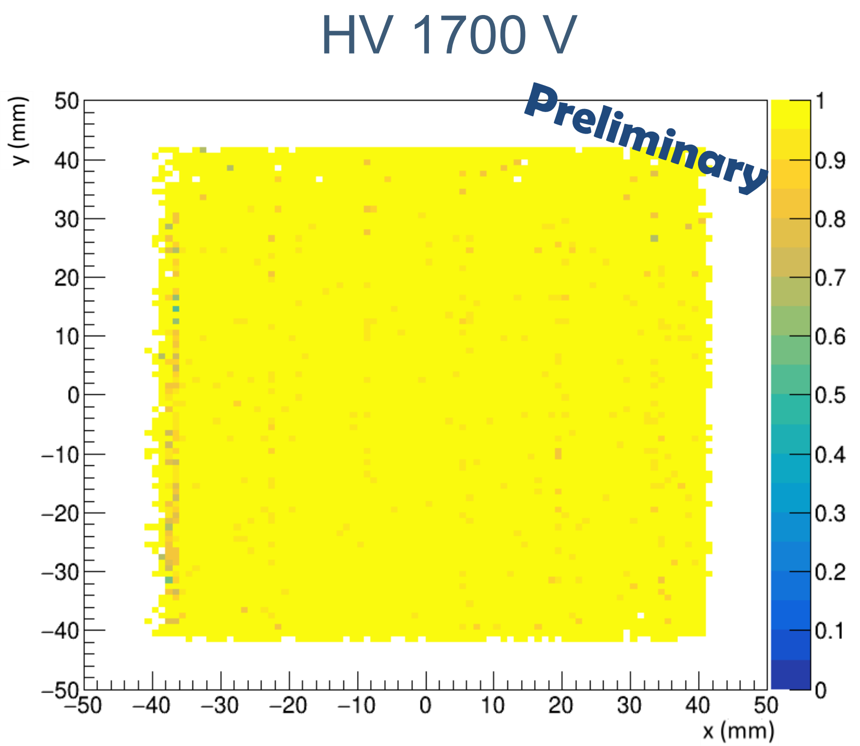
- **Loss off efficiency** above 1600 V due to a combination of high charge and high rate



Channel Efficiency

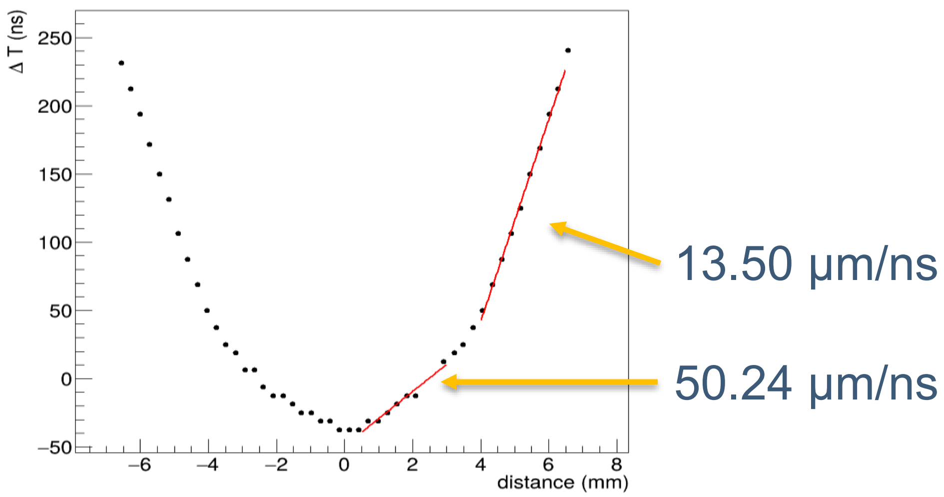
- **Full recovery** lowering the beam rate (<1k muon/cm^2)

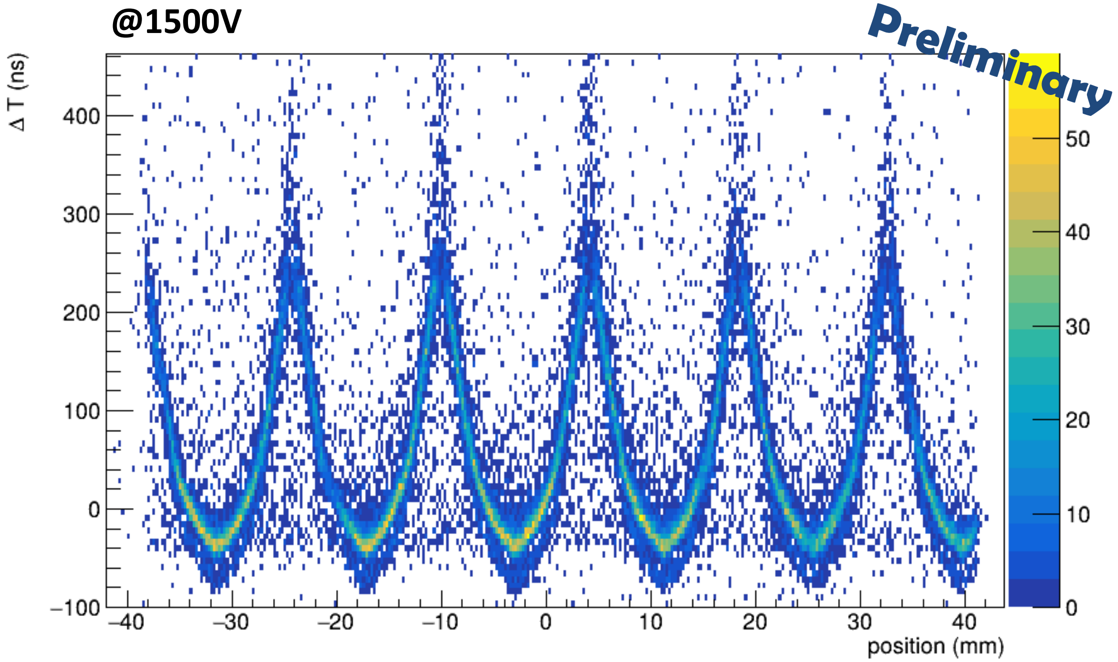


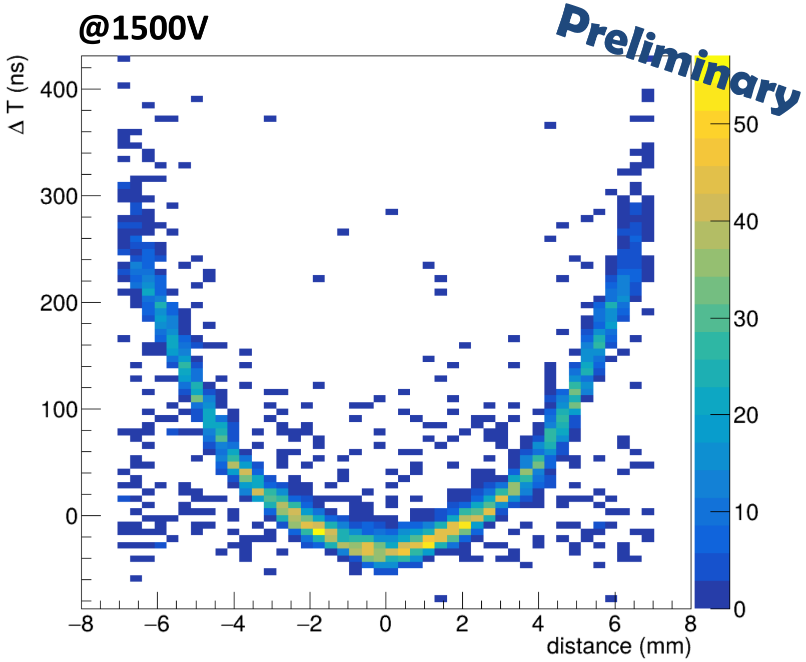


Time-Distance Relation

- Preliminary plot of ΔT vs. Track Position
- **ΔT** = Time(PMT) – Time(Drift)
- **Position** = x coordinate provided by the GEM tracker
- Drift velocity **not saturated** at 1500 V.

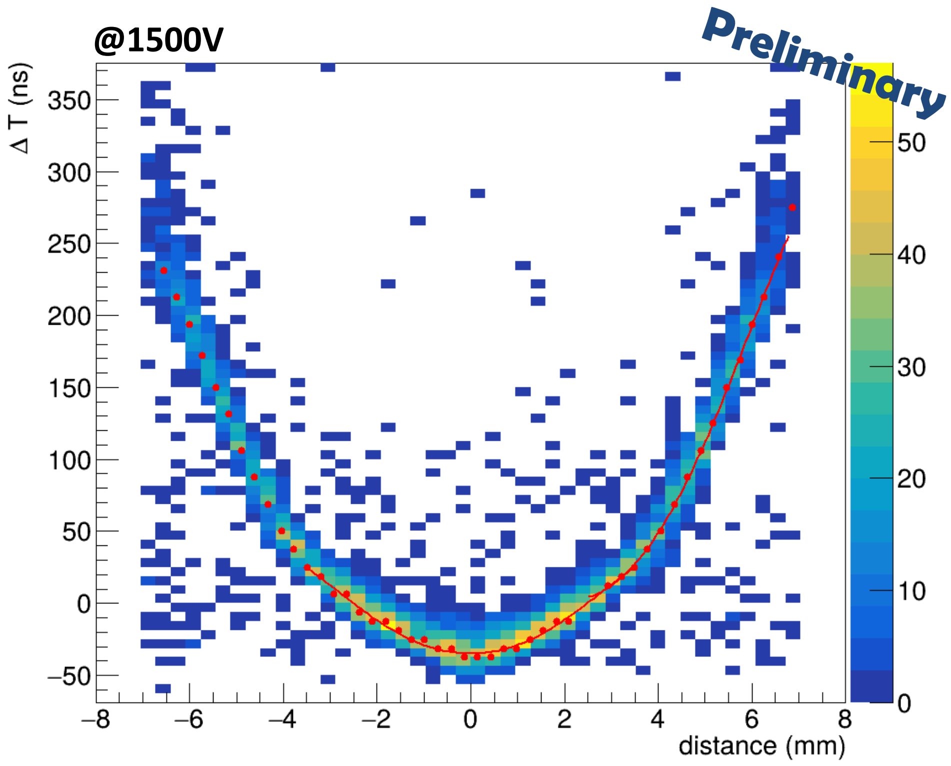


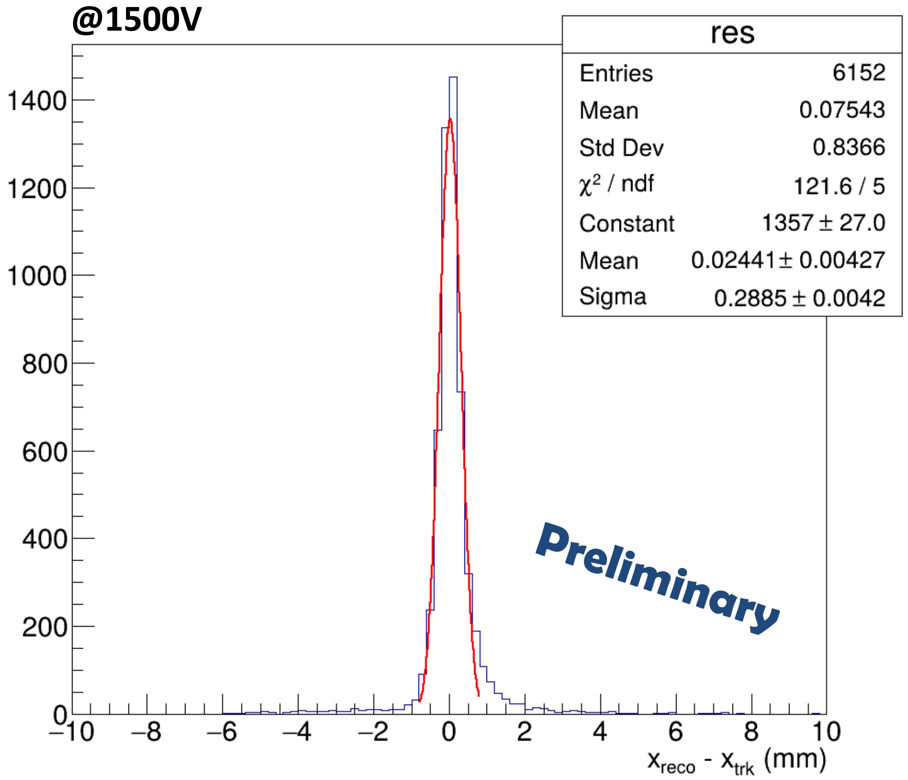




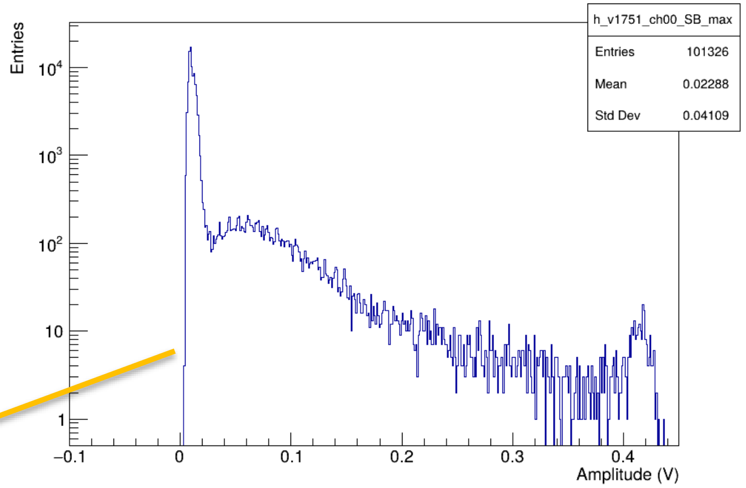
Position Residuals

- Time-distance distribution fitted with $t = N \cdot \text{atan}(ar^2 + br) + c$
- σ_x ~290 µm





Waveform Analysis

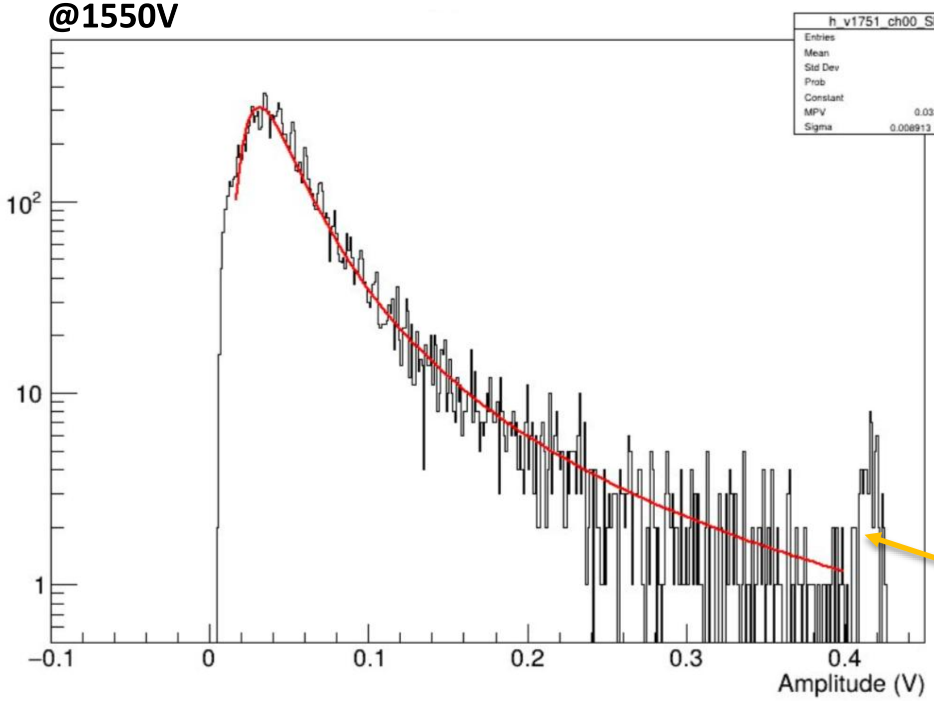


DCH READ OUT WITH DIGITIZER

- **12** drift chamber **channels: 4** from each wire plane
- Peak amplitude distribution fitted with Landau function

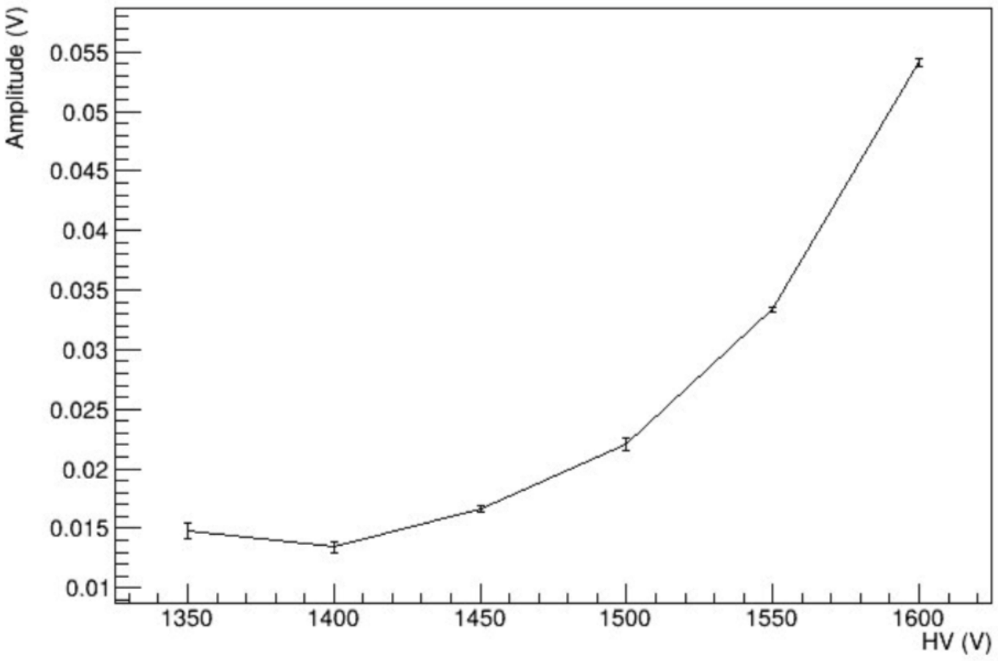
Pedestals excluded at 3σ

@1550V



Amplifier saturation at 400mV

Landau MPV vs HV



Conclusions and Outlooks

- **Analysis is ongoing** and **plots** are **preliminary**
- Test Beam Operations **limited** by TIGER **saturation** and ASIC **loss of efficiency** above 1600V
- Results are promising till now

Next steps:

- **Further study of full signal shape (more channels)** with VTX preamplifiers and digitizers
- **Beam test** @ BTF (Frascati)
- Start design of a full-scale prototype and a related R&D
- Use a **different electronics** for the chamber readout (TORA?)

Thank you

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Backup

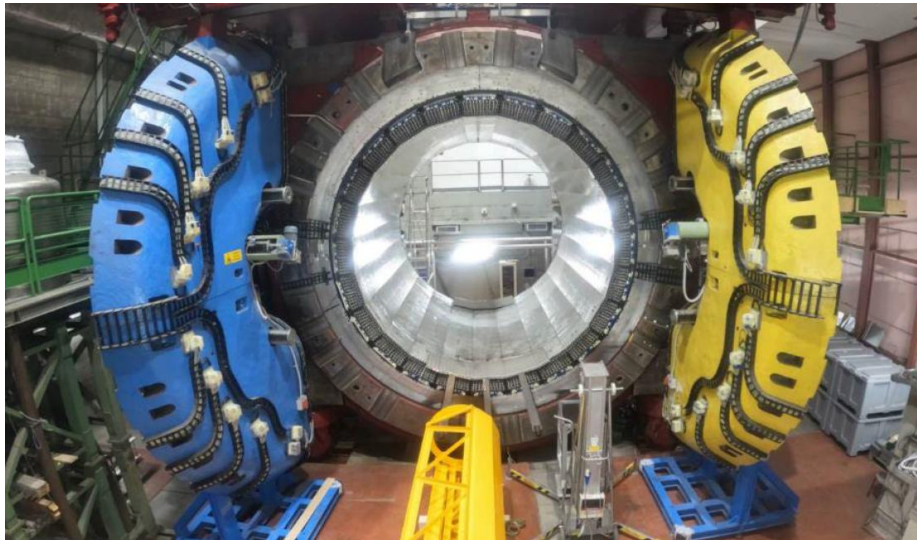
SAND

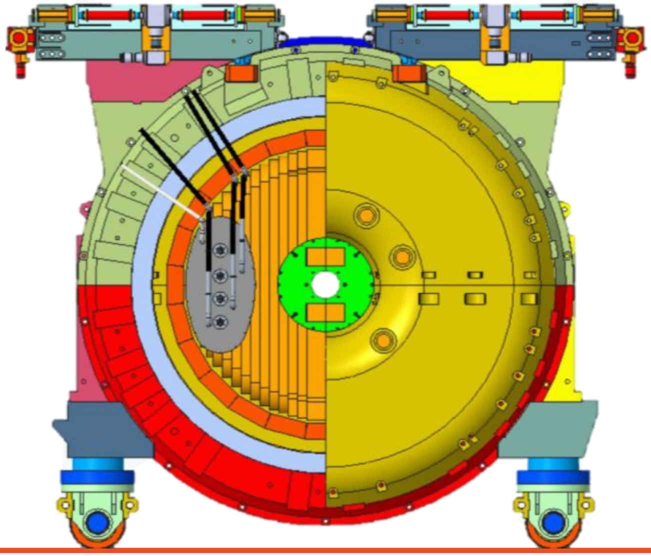
System for on-Axis Neutrino Detection

- Permanently on-axis
- **ECAL**: Pb + scintillating fibers

$$\sigma_E/E \cong 5\%/\sqrt{E(GeV)}$$
$$\sigma_t \cong 40ps/\sqrt{E(GeV)}$$

- **GRAIN** : 1t LAr active target
- **Inner Tracker**



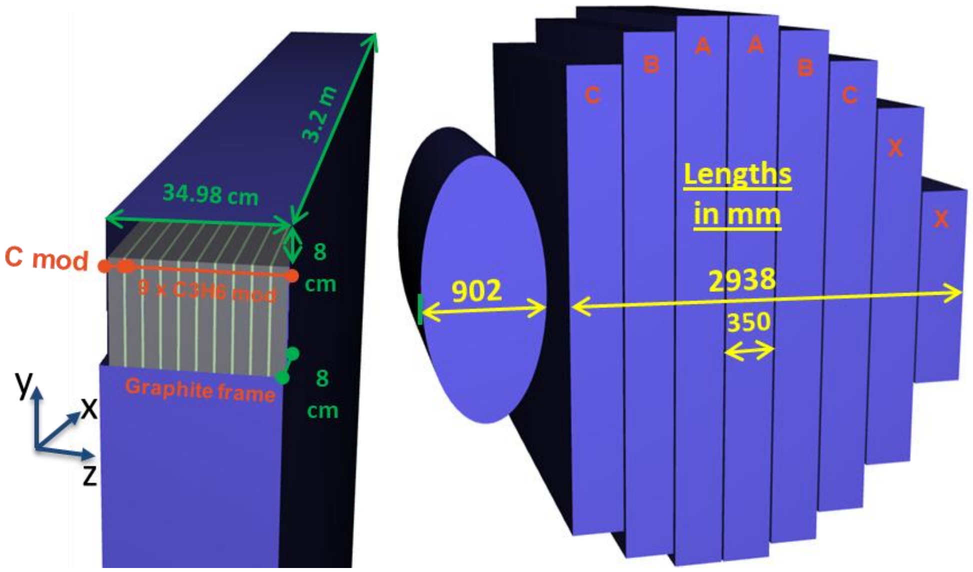


Objectives:

- Measurement of $\boldsymbol{\nu/\bar{\nu}}$ **flux** (absolute and relative)
- Measurement of ν **cross sections on Ar, CH_2, C (→H)**
- **Calorimetry**
- **High precision tracking**

The Inner Tracker

- 4.7 t tracker composed of **8 super-modules**
- Each super-module contains 10 modules
  - 9 with **polypropylene** (C_3H_6) targets, used as C-H target
  - 1 with **graphite** target
- A single module is composed by
  - a drift chamber with **3 wire planes**
  - the **target** material

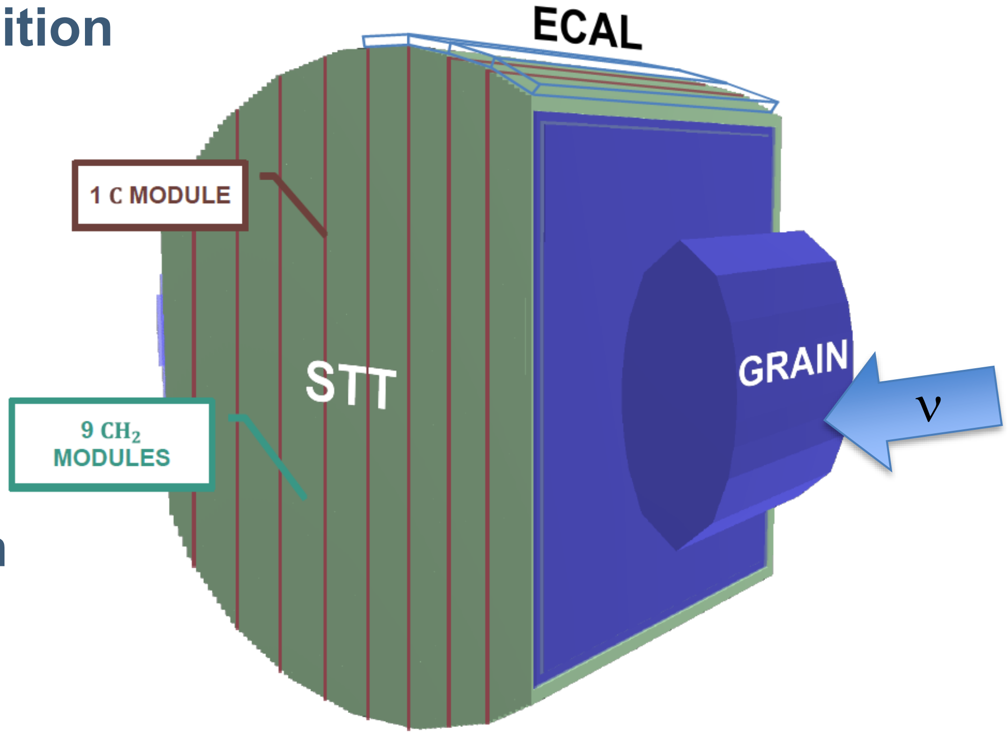


- Modules height varies **from 1.2 to 3.8 m**, for a fixed width of **3.2 m**
- **~220 drift planes**
- From $3.6 \cdot 10^4$ to $5.2 \cdot 10^4$ **readout channels,** depending on the cell geometry

The Inner Tracker

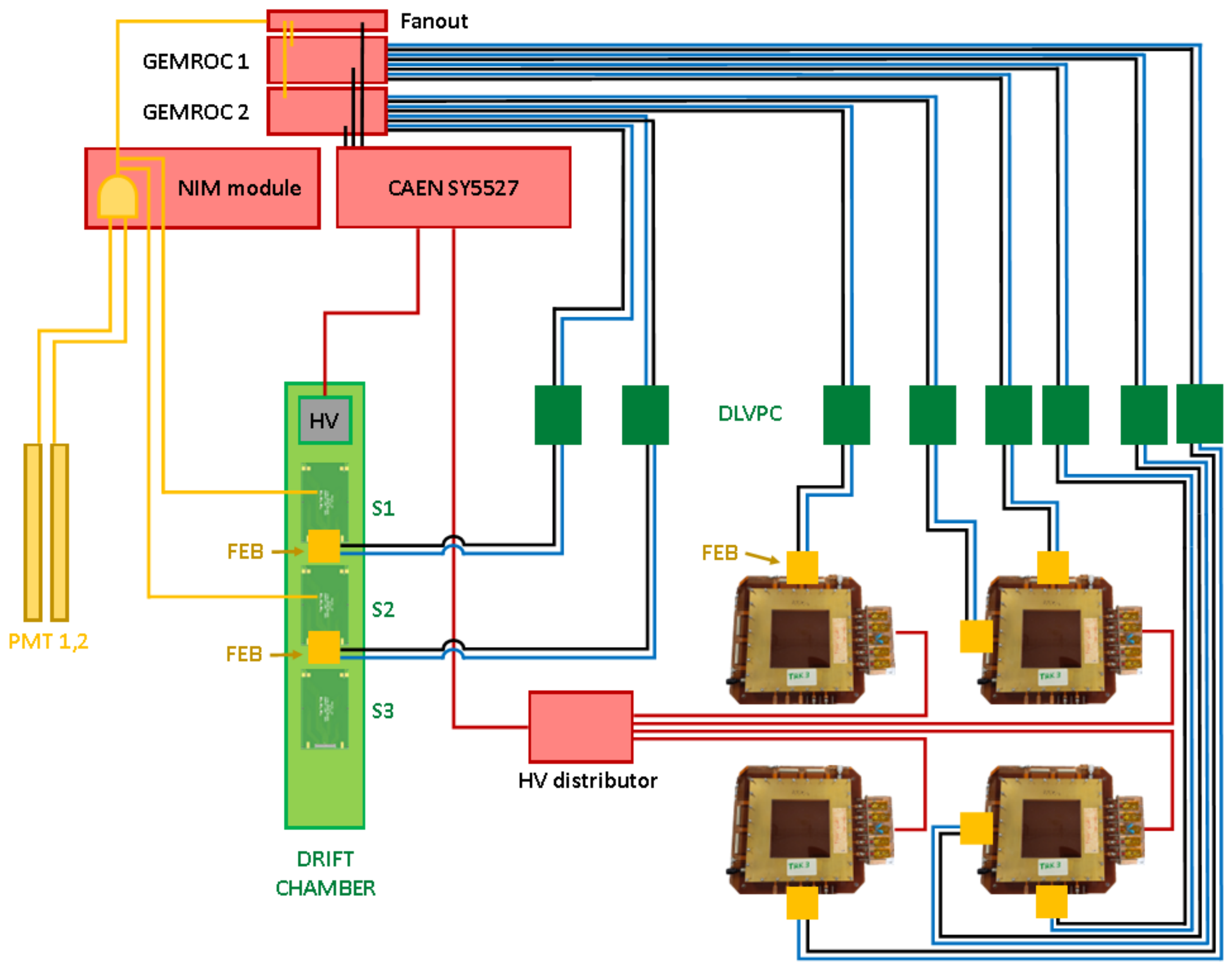
Objectives:

- Separate **neutrino and antineutrino events** (charge ID)
- Identify **beam flavor composition**
- Measure the **energy** of **charged** and **neutral particles*** (π_0, n)
- **Correct systematic errors** combining H and Ar cross sections
- Localize **neutrino interaction vertices** in the target material (precision < 5 cm)
- Timing resolution **< 10 ns**



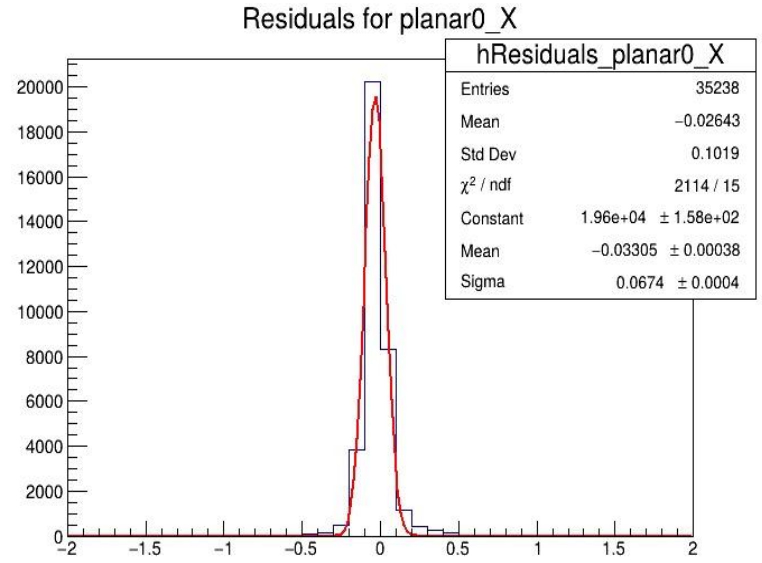
* with the help of the calorimeter

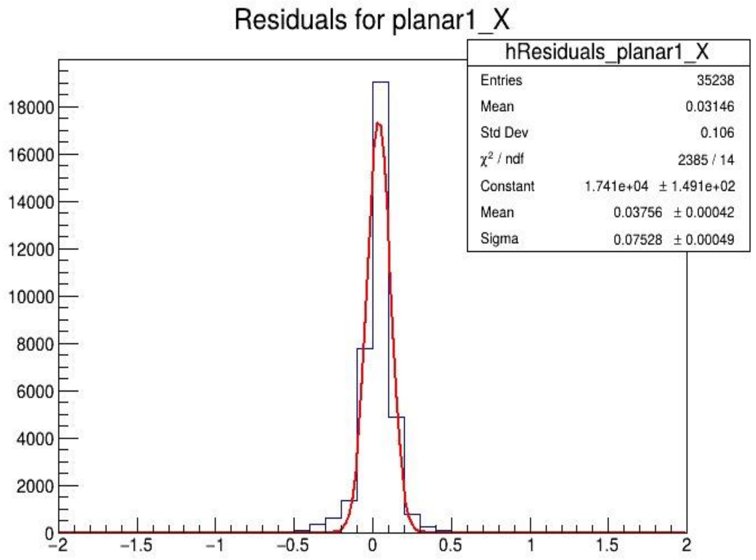
TIGER-GEMROC Readout

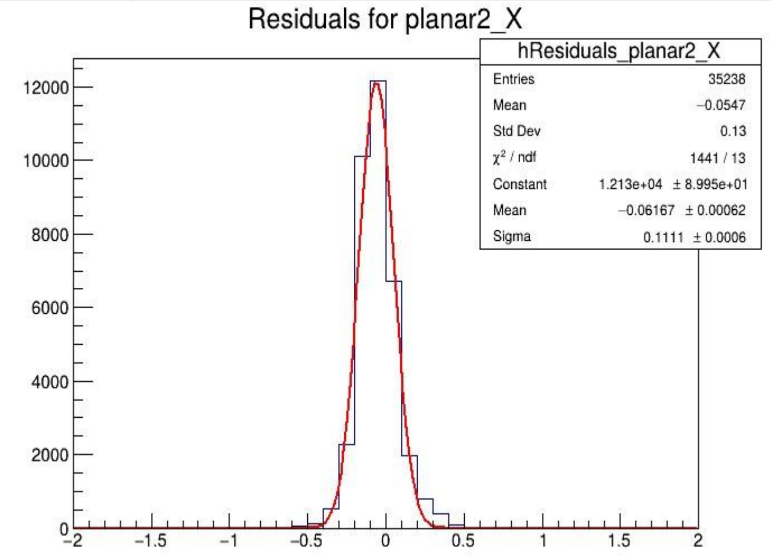


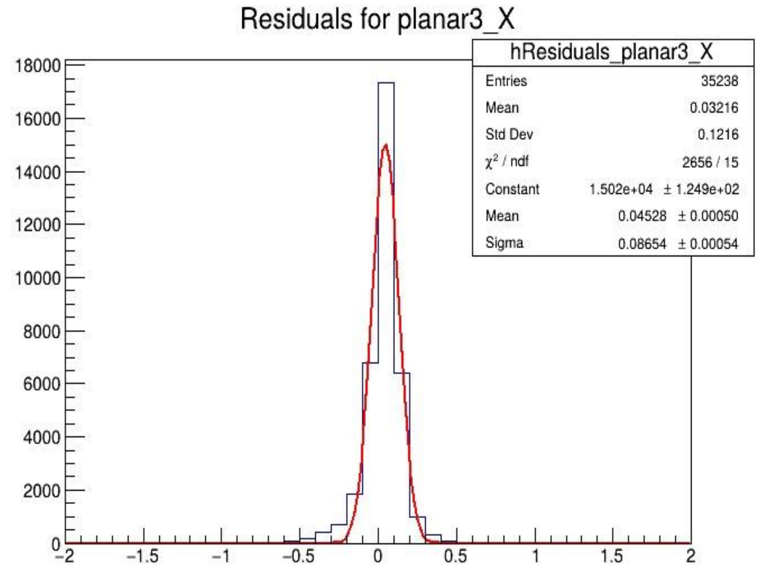
Tracker resolution

- Only 2 points for the **y** coordinate
- 4 points for the **x** coordinate



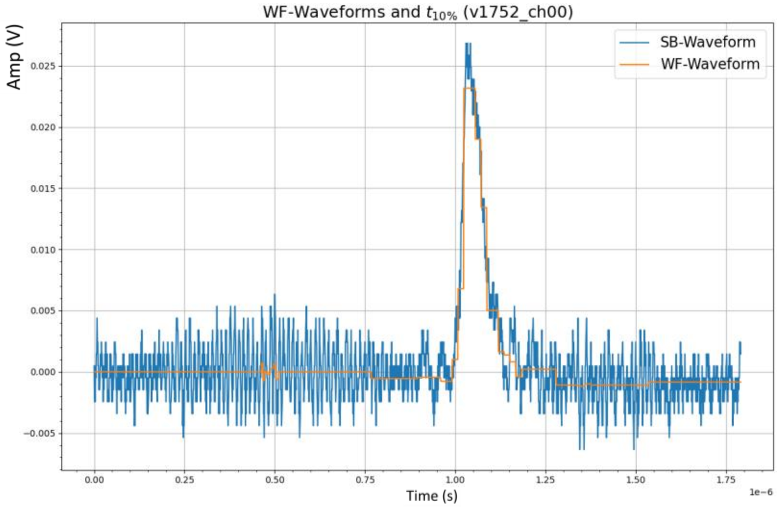


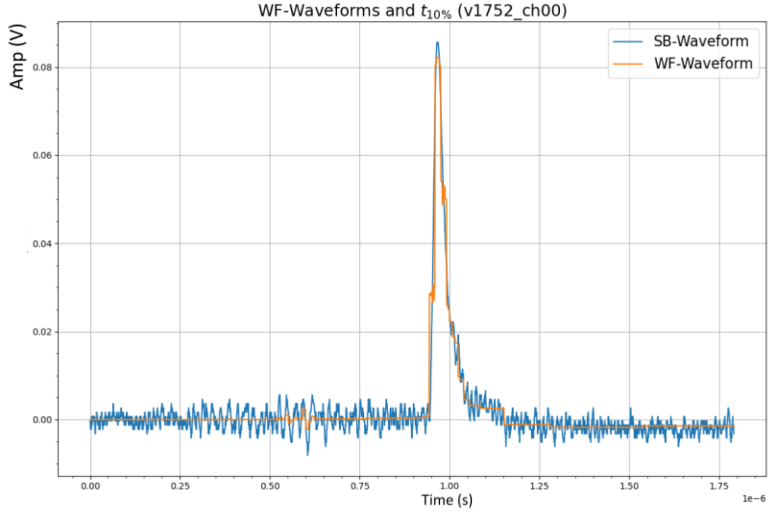


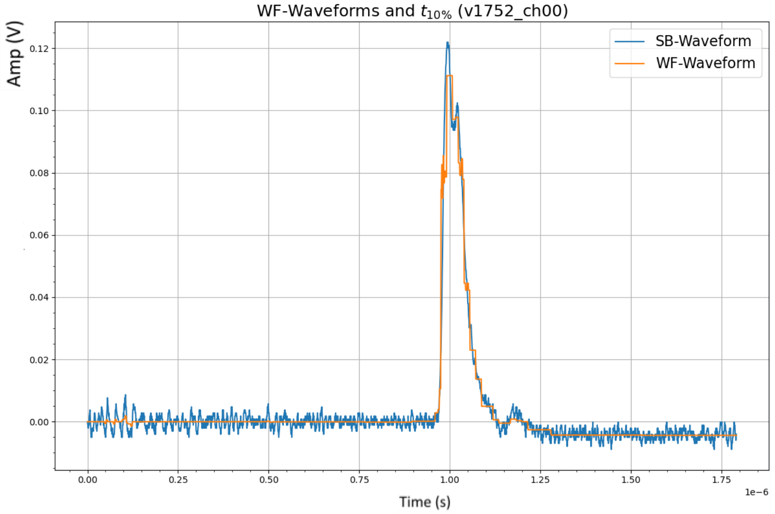


Drift Chamber Signals

- From Garfield++ a 3×10^4 gain is expected at 1600V
- Signals taken with VTX amplifier + VME digitizer
- Gain: 1.5 mV/fC

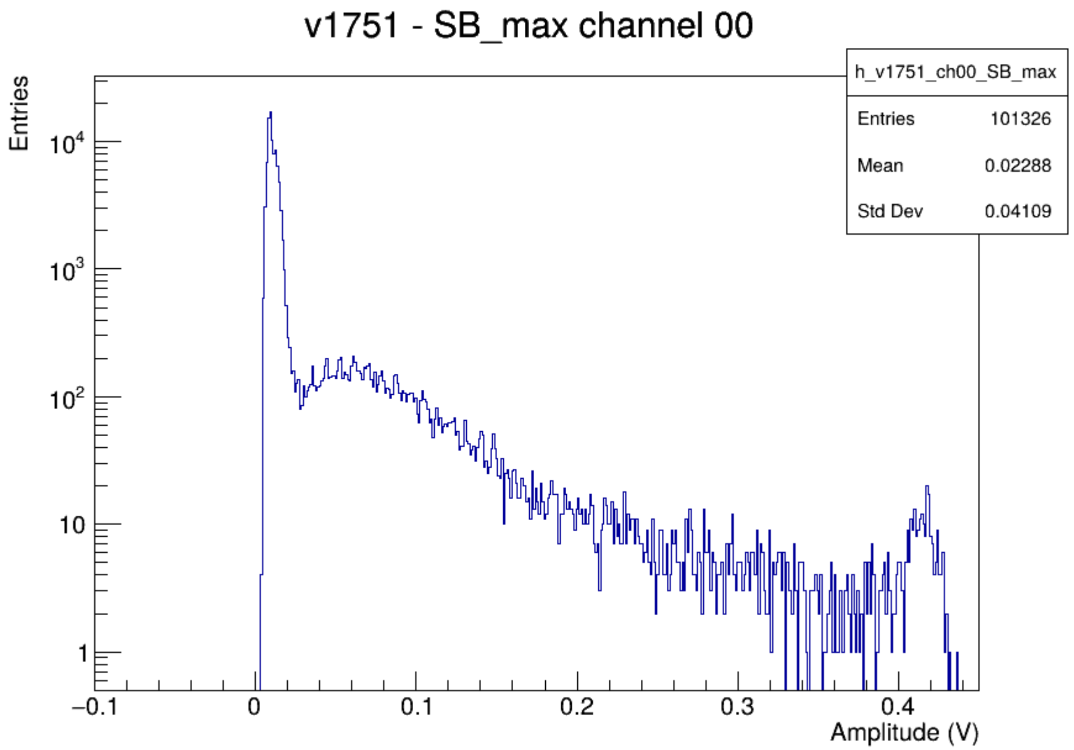


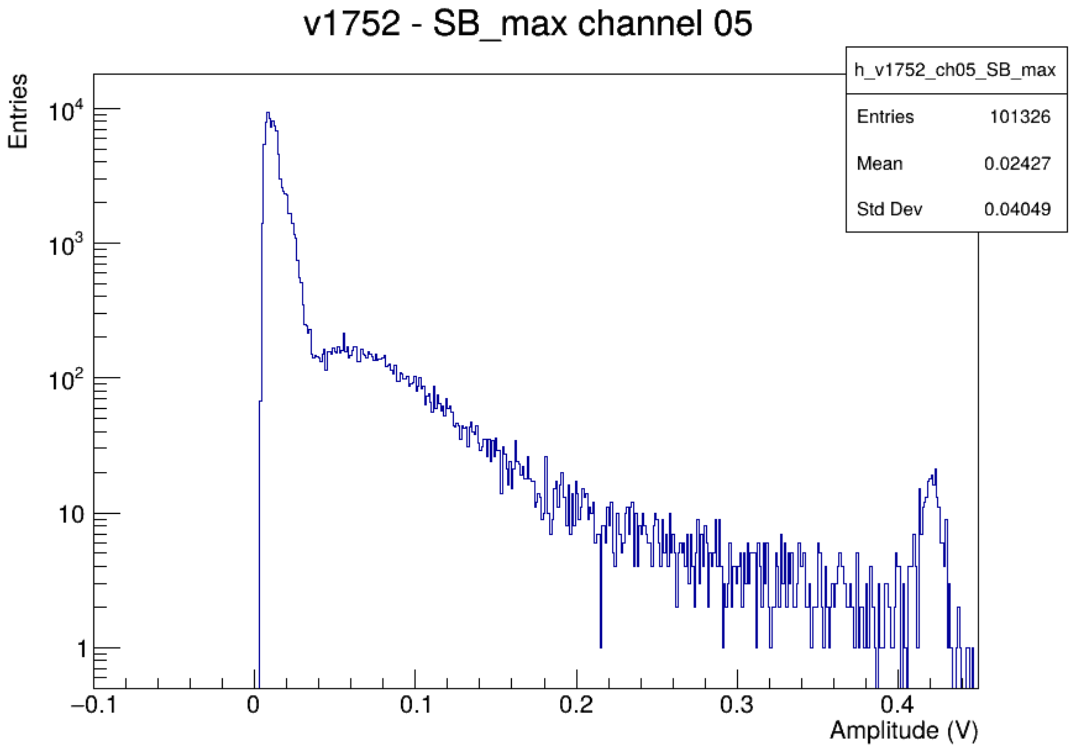




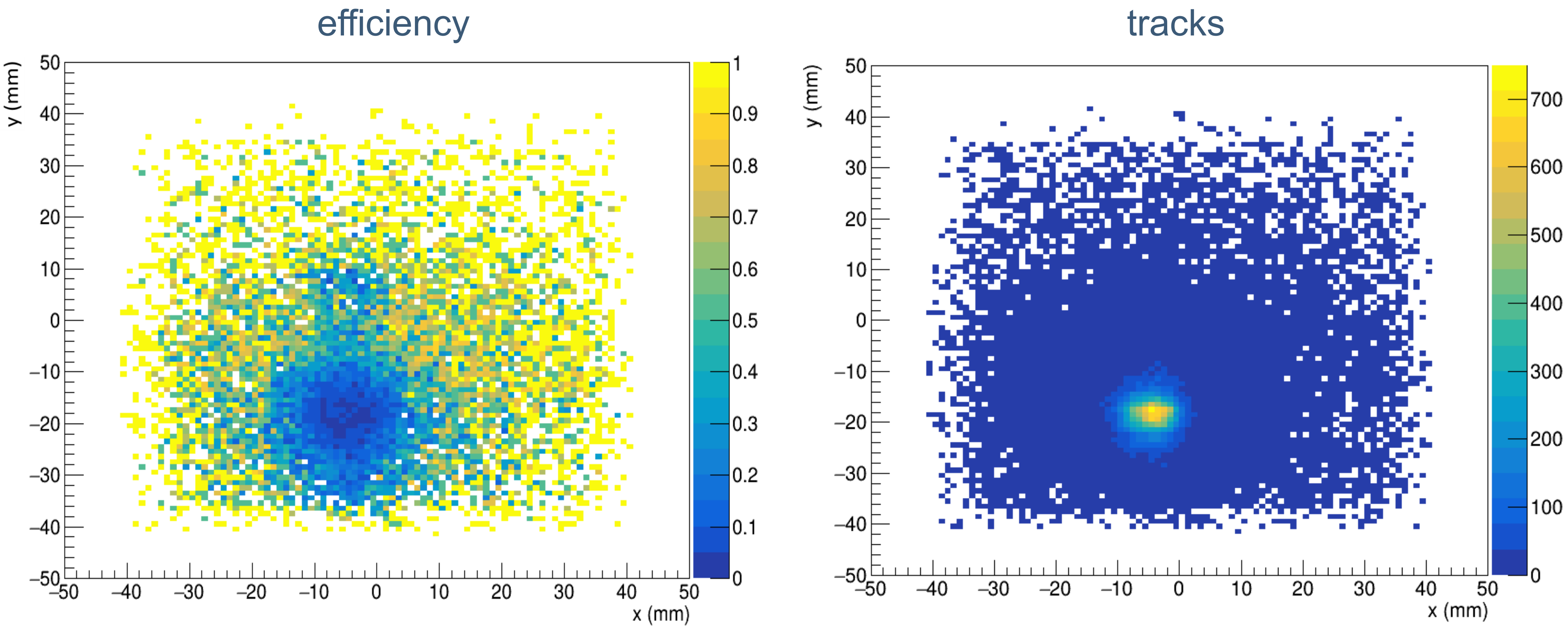
Drift Chamber Signals

- For some reason (not yet understood) channels **gradually became more noisy** form ch00 of digitizer 1 to ch05 of digitizer 2
- Probably it is a feature introduced by the grounding scheme of the VTX board





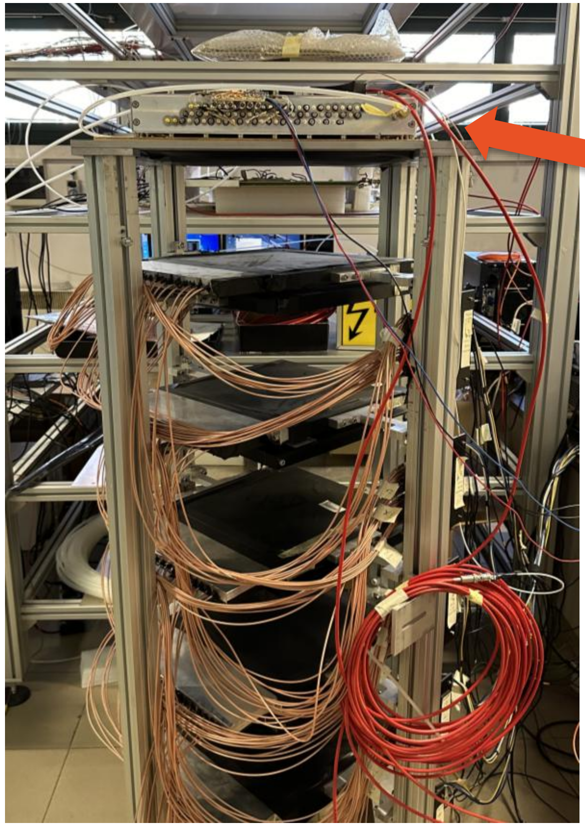
Pion Run

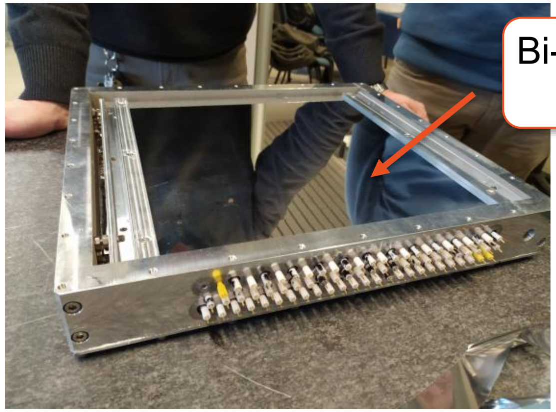


efficiency
tracks
y (mm)
x (mm)
50
40
30
20
10
0
−10
−20
−30
−40
−50
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
100
200
300
400
500
600
700

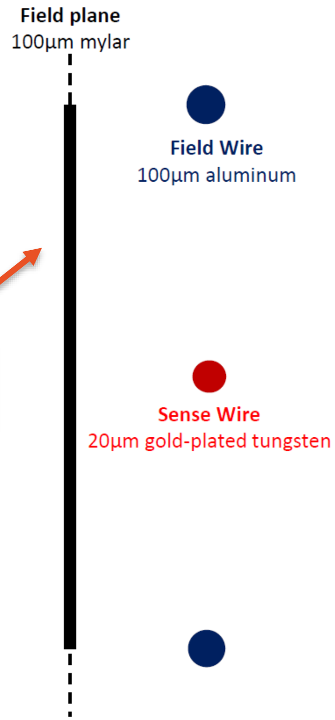
First Drift Chamber Prototype

- **30x30 cm** prototype with **3 multiwire layers** separated by **mylar foils**
- Allowed to study E-field configuration and 3d track reconstruction
- Tested with cosmic muons



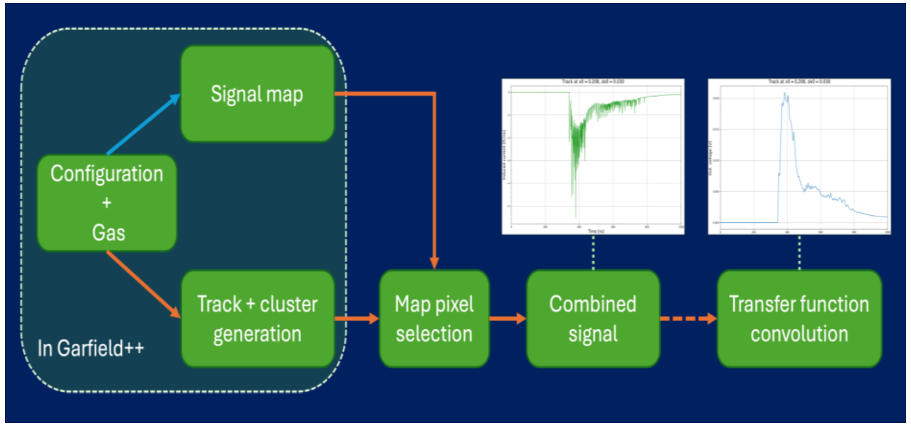


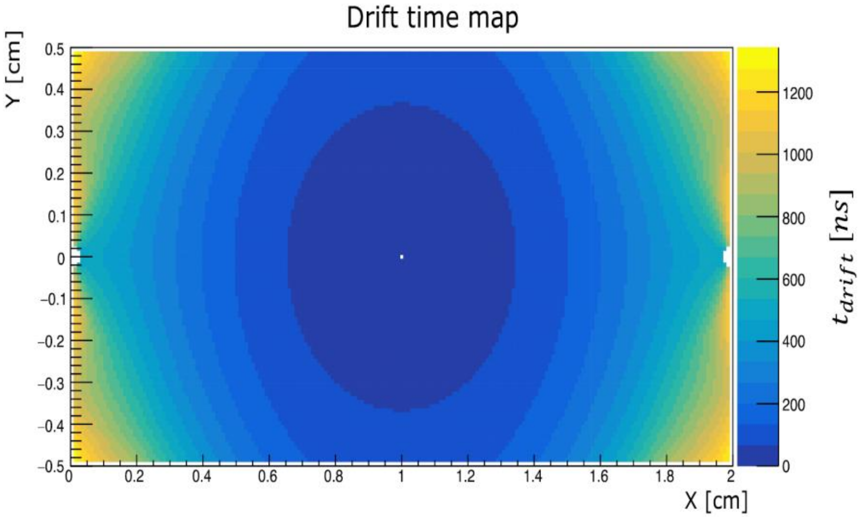
Bi-aluminized
mylar foil

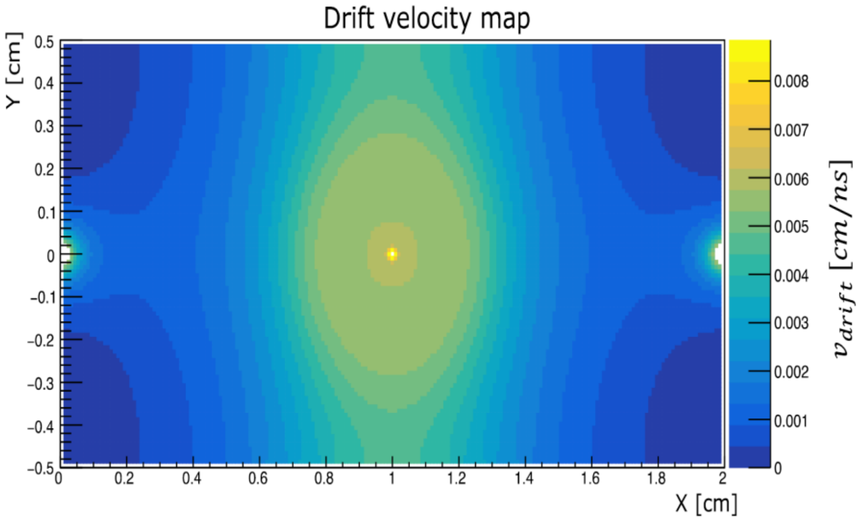


Cell Simulation

- **Garfield++** model for studying drift properties and signal production
- Full track simulation in Garfield++ is **too slow → signal maps**
- Particle signal obtained **combining mapped electron signals**.



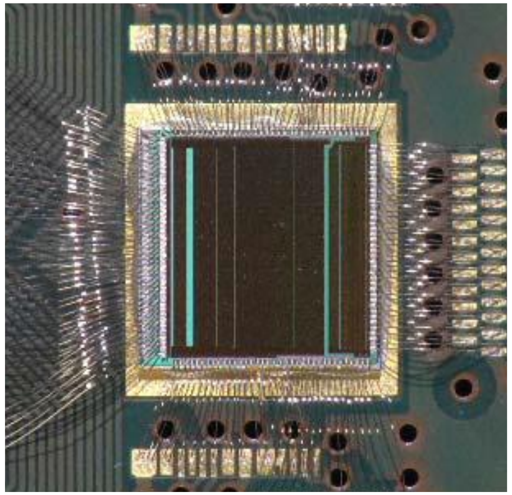




The Readout

ASIC Requirements:

- Must **measure** deposited **charge** and **time**
- Timing resolution better than **1 ns**
- Low threshold to **identify** charge from a **single ion pair**
- **Dynamic range better than 1000** for charge
- **Low power** to reduce heat



➡ **2 ASIC candidates** are considered: **VMM3a** and **TIGER**

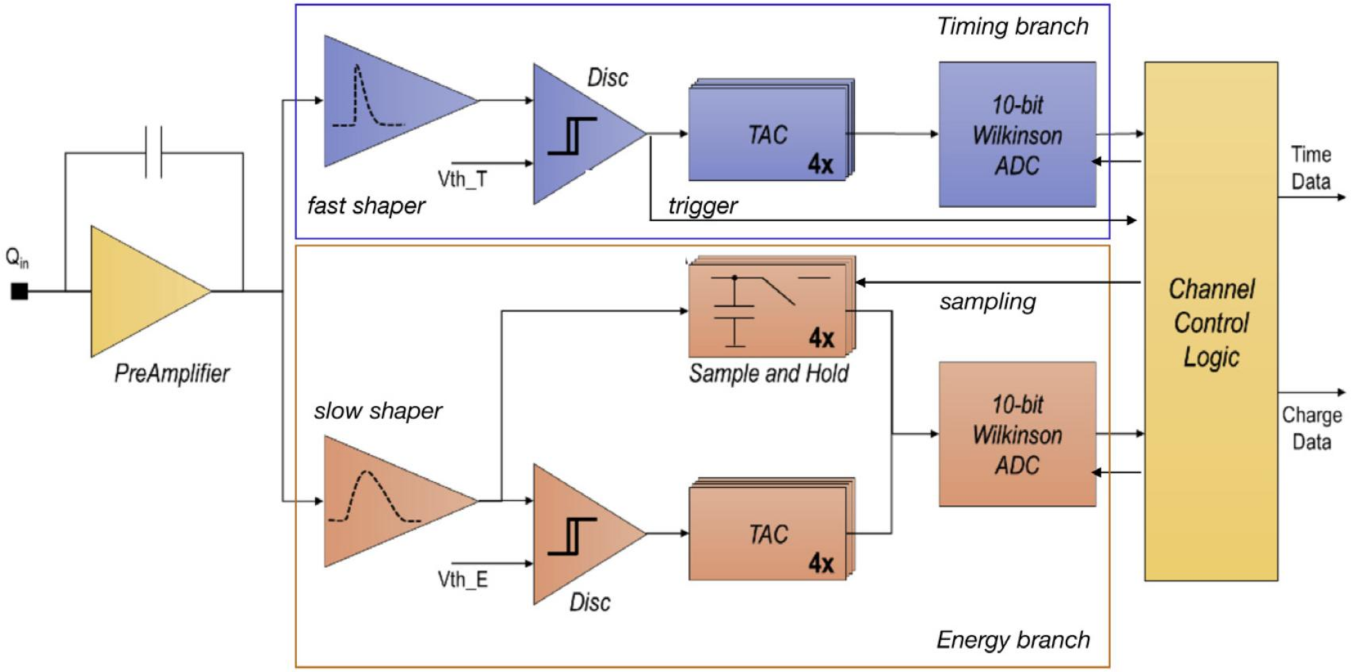
Both feature:

- **Independent** branches optimized for **time** and **charge** measurement
- **64** channels
- **~10 mW/ch** power consumption

TIGER

Turin Integrated Gem Electronics for Readout

- Developed for Cylindrical GEM readout for the BESIII experiment
- **Charge measurement**: **Sample & Hold** or **ToT** modes
- **Time measurement**: **timestamp** on rising edge
- **Dynamic range needs to be adapted**



VMM3a vs TIGER

	VMM3a	TIGER
Number of channels	64	64
Clock frequency	10-80 MHz	160-200 MHz
Input capacitance	< 300 pF	< 100 pF
Dynamic range	Linear within ±2% up to 2 pC	2-50 fC
Gain	0,5, 1, 3, 6, 9, 12, 16 mV/fC	12 mV/fC
ENC (energy branch)	< 3000 e^-	< 1500 e^-
TDC binning	~ 1 ns	50 ps
Maximum event rate	4 MHz/ch *	60 MHz/ch *
Consumption	15 mW/ch	12 mW/ch

* Expected rate << 1 kHz