GDD
Gas Detectors Development Group

RD51 VMM3a/SRS Beam Telescope

Test Beam September 2024

Gaseous Detector Development Group

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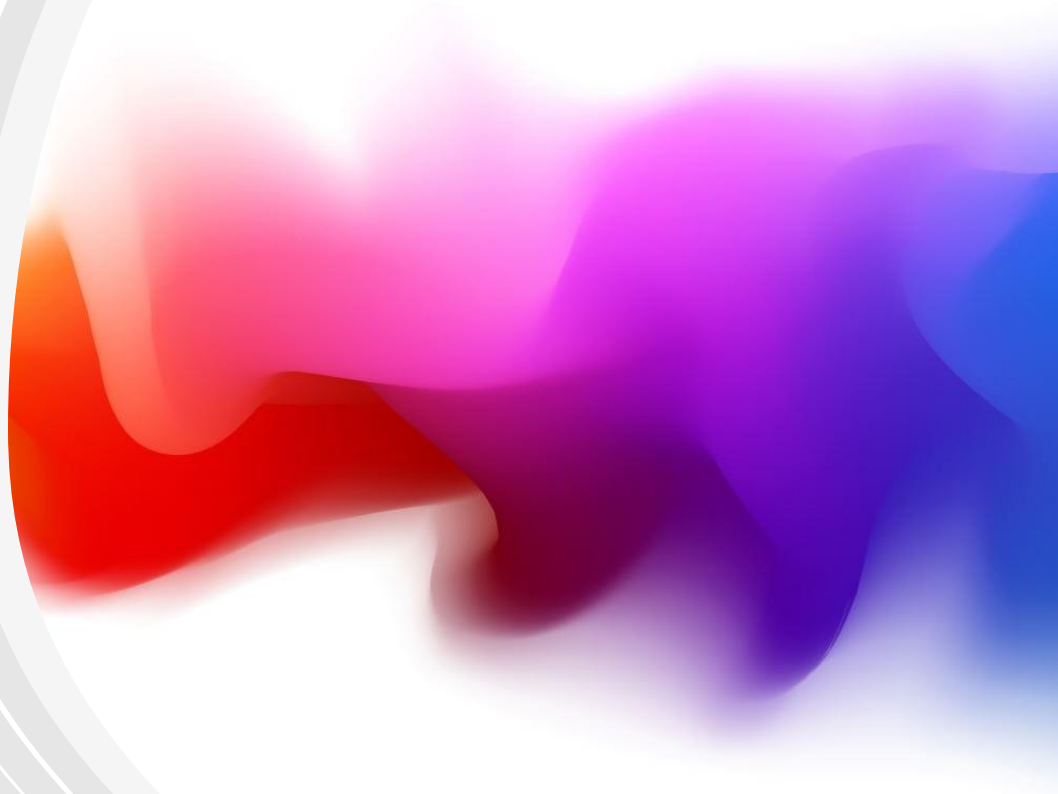
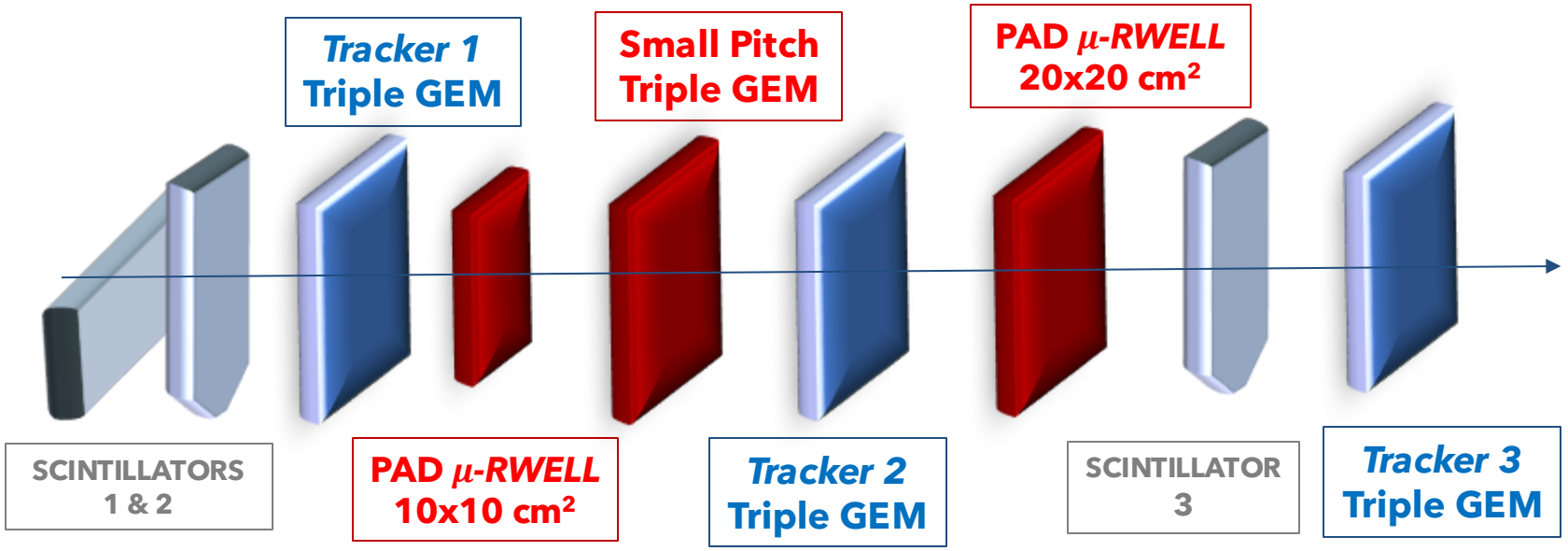
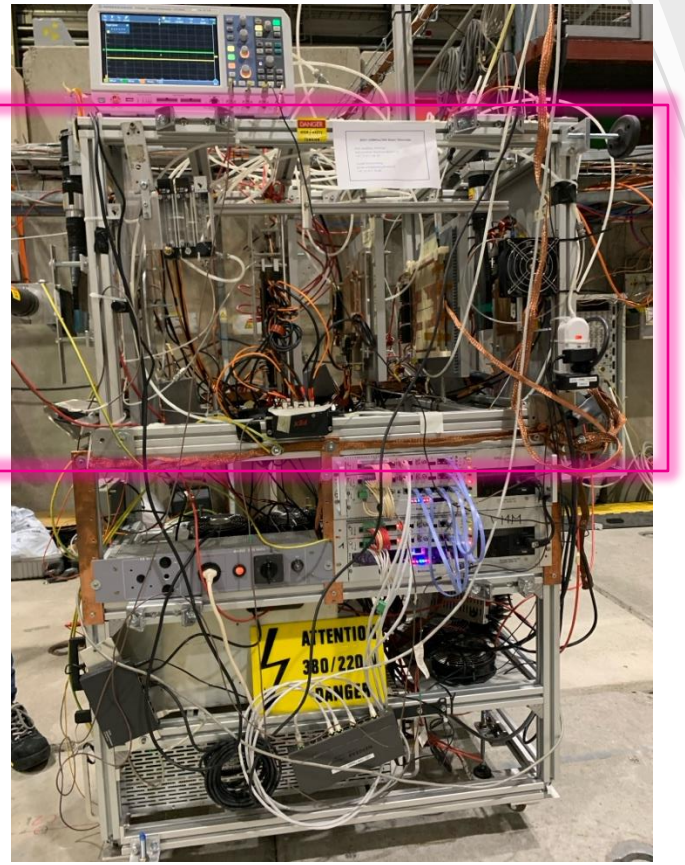


EXPERIMENTAL SETUP

RD51/DRD1 Telescope

- 3 scintillators in coincidence as the trigger
- 3 triple GEM trackers
- 3 detectors under test

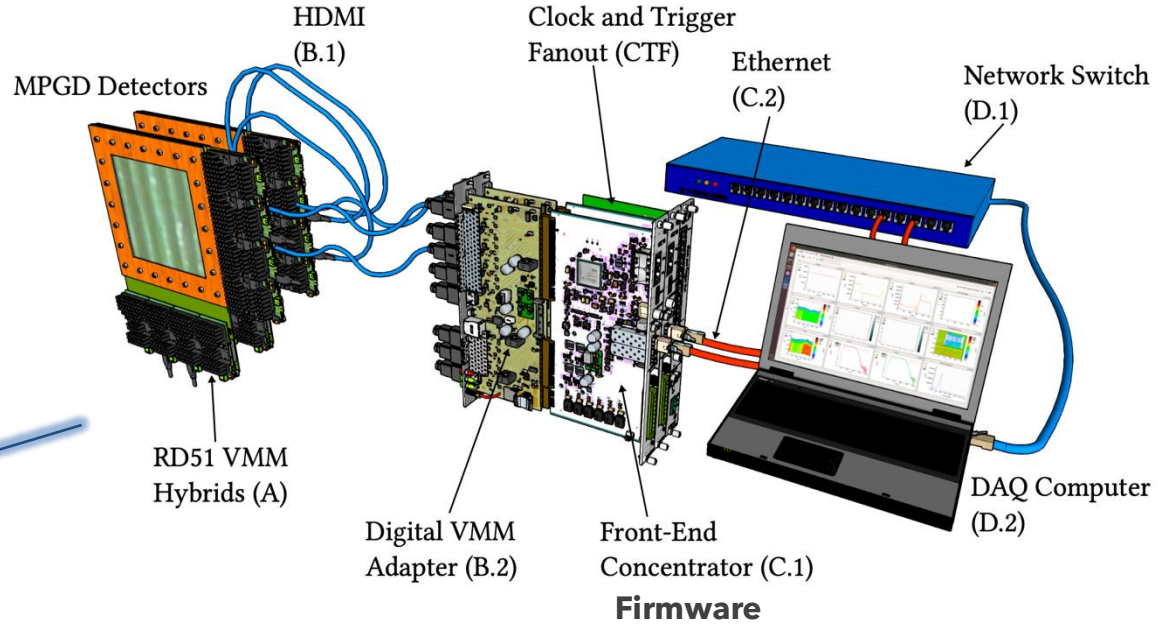




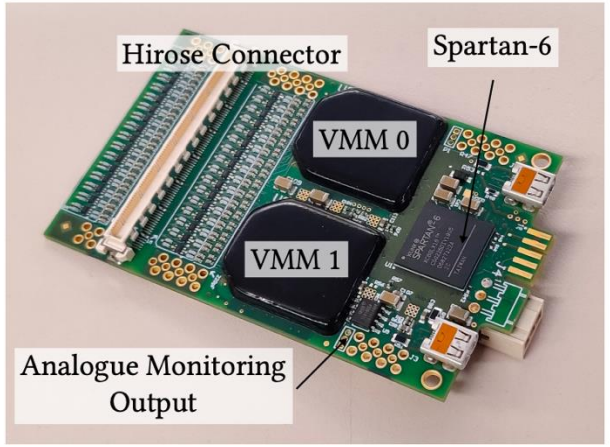
EXPERIMENTAL SETUP

VMM3a / Scalable Readout System (SRS)

Modular readout structure, consisting of a read-out chain :



VMM HYBRID



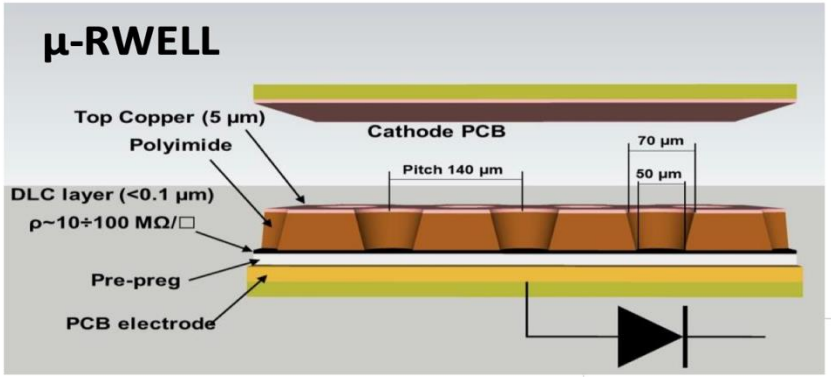
- 2 VMM chips each
- 64 channels per VMM
- All hybrids powered by an external power supply
- Except for those of the 20x20 cm^2 uRwell : internal HDMI powering in use
- Additional hybrid used to store trigger information

PAD μ-RWELL 20X20 CM^2

CONTEXT AND NEED

- On-going R&D on an MPGD-based sampling hadron calorimeter for a Future Muon Collider : → **uRwell prototype**
- Test beam campaign in 2023-2024: data acquisition performed with APV-based electronics
- **However :** challenging environment posed by the presence of BIB

  → new electronics needed to meet the requirements of :
  - time resolution of O(ns)
  - rate capability of O(MHz/cm^2) → alternative: **VMM-**based readout
    - time resolution better than **2 ns**
    - trigger rates in the **MHz** regime

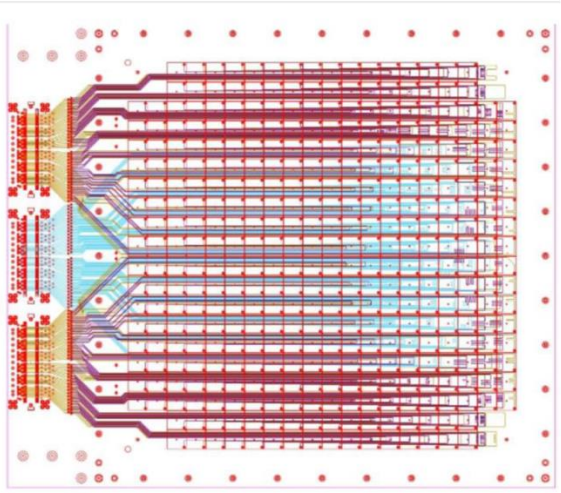


TASKS AND OBJECTIVES

Test of the VMM electronics on ***µ-RWell*** prototypes & Comparison with APV-based electronics

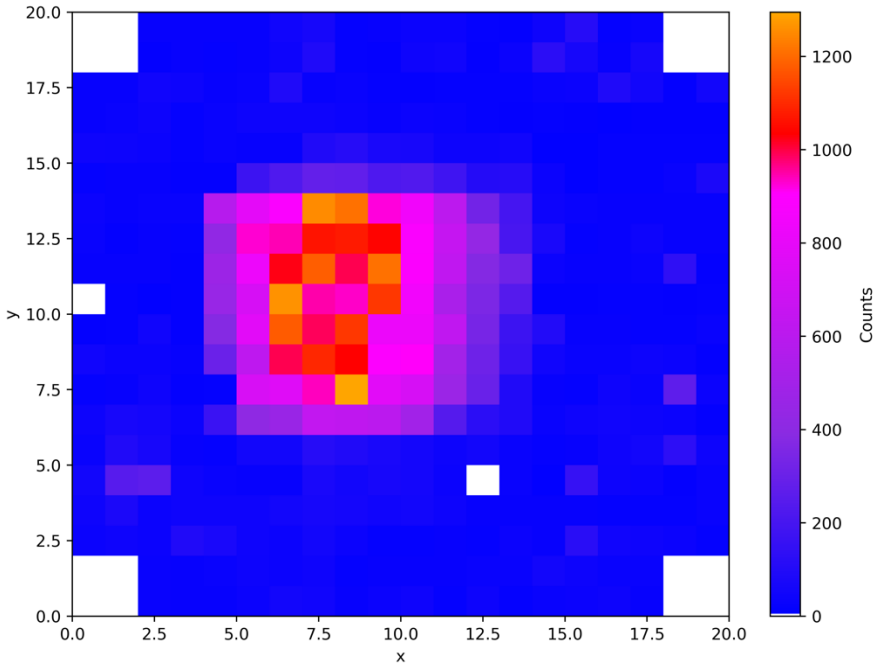
- Operation in gated mode at different threshold levels (THLs)
- Gain and Drift scans :
  - → Estimate cluster reconstruction efficiency
  - → Determine time resolution

PAD μ-RWELL 20X20 CM^2



- **1×1 cm^2 pad area**
- 384 pads → 3 hybrids
- Drift Gap: **6 mm**
- DLC grounded, TOP and DRIFT connected to HV
- Horizontal connecting vias
- Gas Mixture **Ar CO_2 CF_4 45:15:40** and **Ar CO_2 70:30**

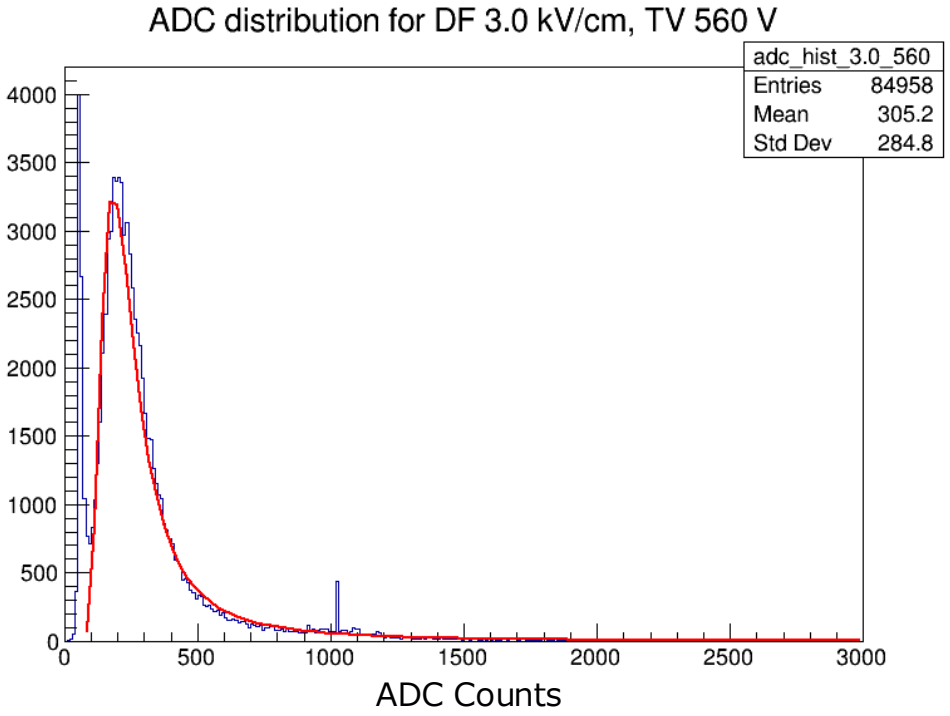
- Electronic Gain : 12 mV/fC
- Analog Threshold Levels: 0.8 fC, 1 fC, 2 fC
- Reconstruction of the beam profile
- Active area of the detector limited to the overlap of the triggering scintillators



PAD μ-RWELL 20X20 CM^2

Threshold Level 2 fC

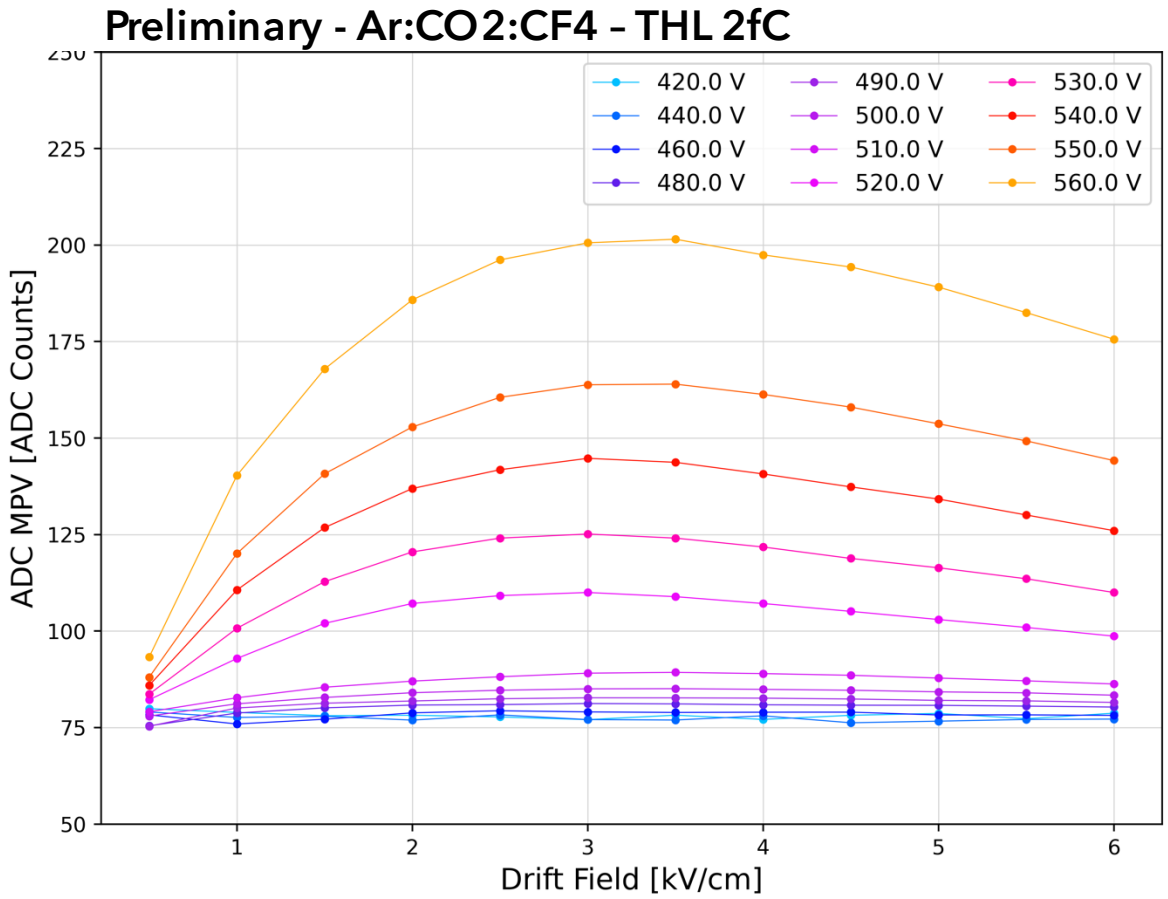
- Landau Fit of the ADC Charge distributions in the range 70-3000 ADC counts



- Noise peak at low ADCs
- Saturation peak around 1000 ADC

COLLECTED CHARGE

- Retrieve the **mpv** from the fit parameters

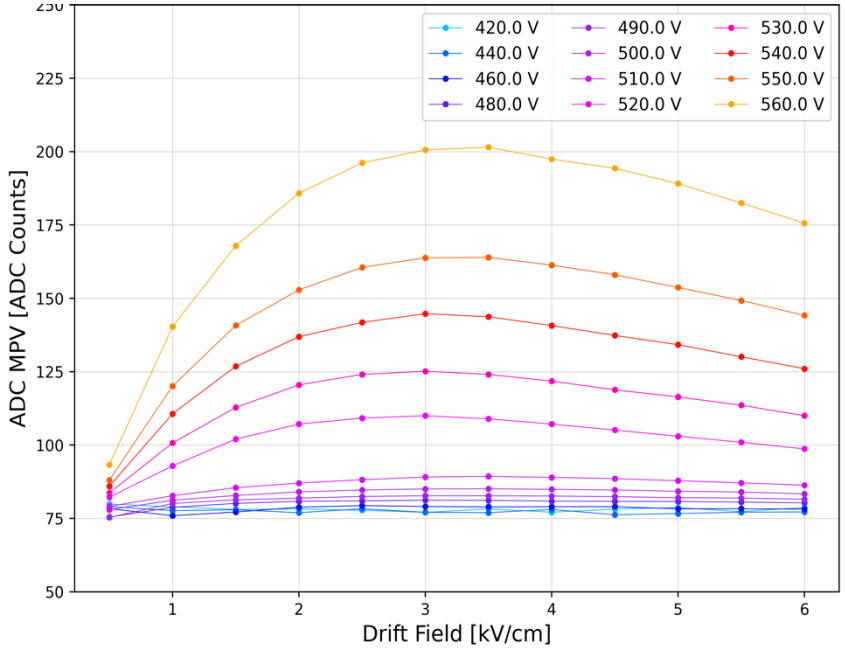


PAD μ-RWELL 20X20 CM^2

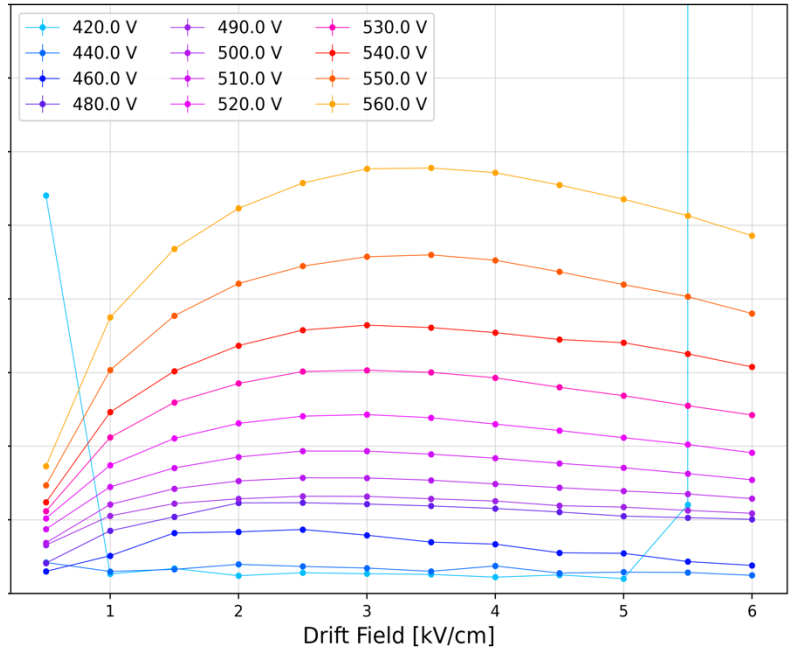
ADC MPV

- Results in agreement with measurements on a light-cathode uRwell with a picoammeter carried out by Silvia (*presented at the Common Project Meeting on 4/09/2024*)

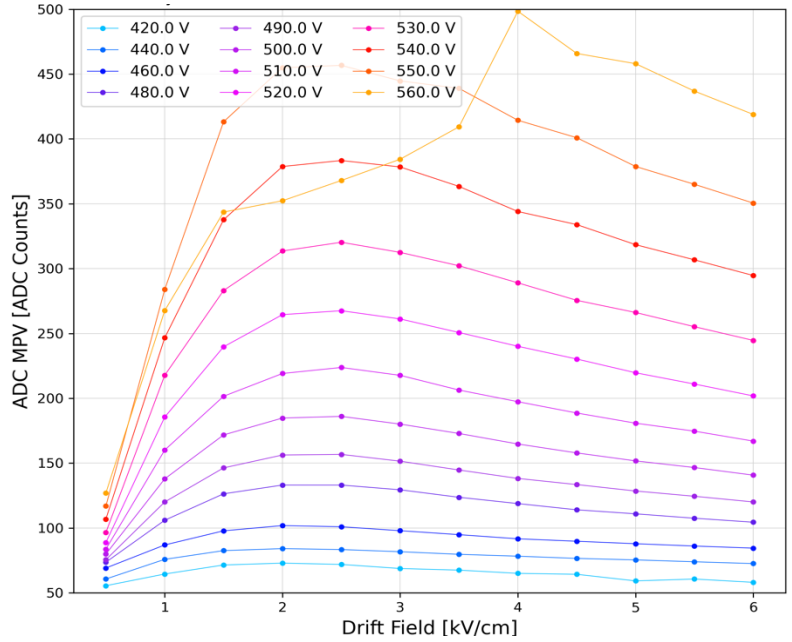
Preliminary – $ArCO_2CF_4$: - THL 2 fC



Preliminary - $ArCO_2CF_4$ - THL 1 fC



Preliminary – $ArCO_2$ - THL 1 fC



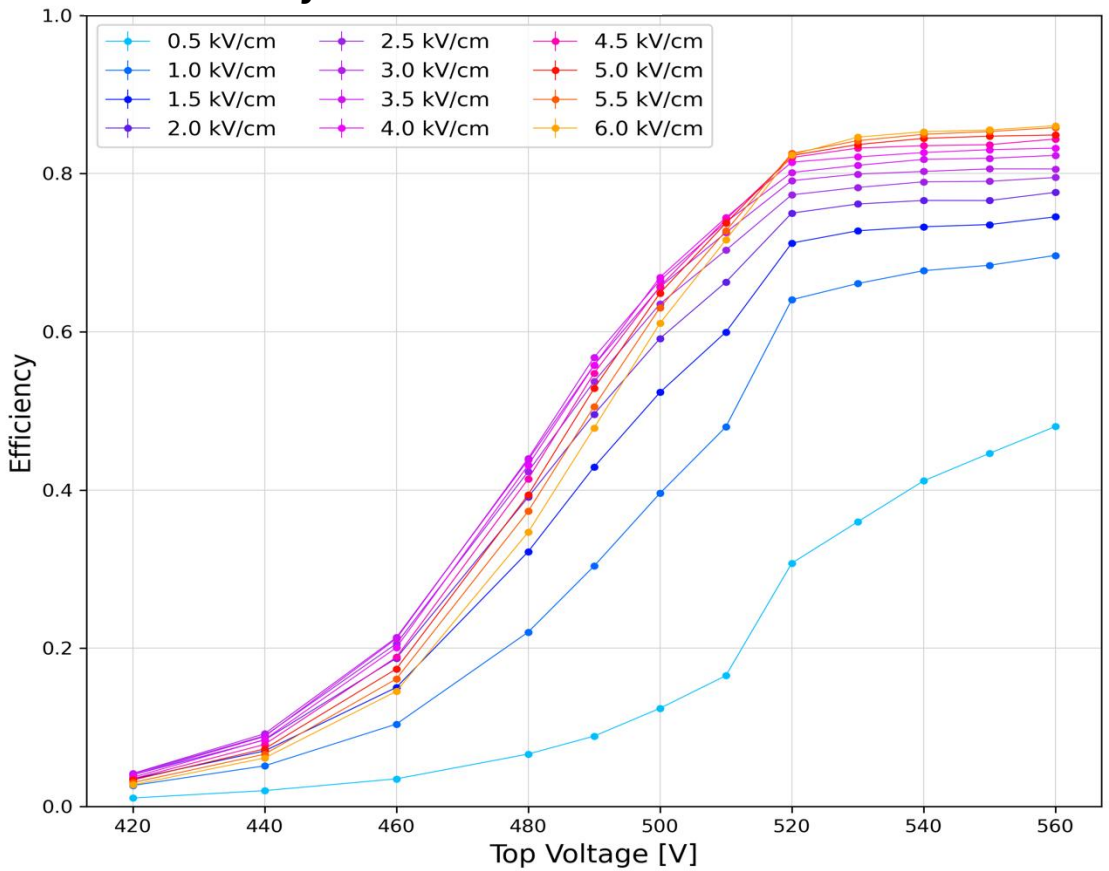
- Maximum ADC at ~ 3 kV/cm, then decreasing at larger values of the drift field (independent of the top voltage)
- **Increasing ADC at increasing Top Voltages for the whole drift range** (except for some ADC-saturating runs at 420 V)
- Same behavior with **$ArCO_2CF_4$** and **$ArCO_2$** : independent of the gas mixture, only dependent on the detector technology

PAD μ-RWELL 20X20 CM^2

Threshold Level 2 fC

- Compute the time difference between each reconstructed cluster and each trigger signal
- Ratio between number of events and number of triggers

Preliminary – Ar:CO2:CF4



EFFICIENCY BASED ON TIMING

- Consider as events the clusters with a time difference within [-500 ns, 500 ns]
- Ratio between number of events and number of triggers

- Plateau @ a top voltage of ~ 520 V
- The larger the drift field the higher the plateau level:

  ~ 90% @ 6 kV/cm

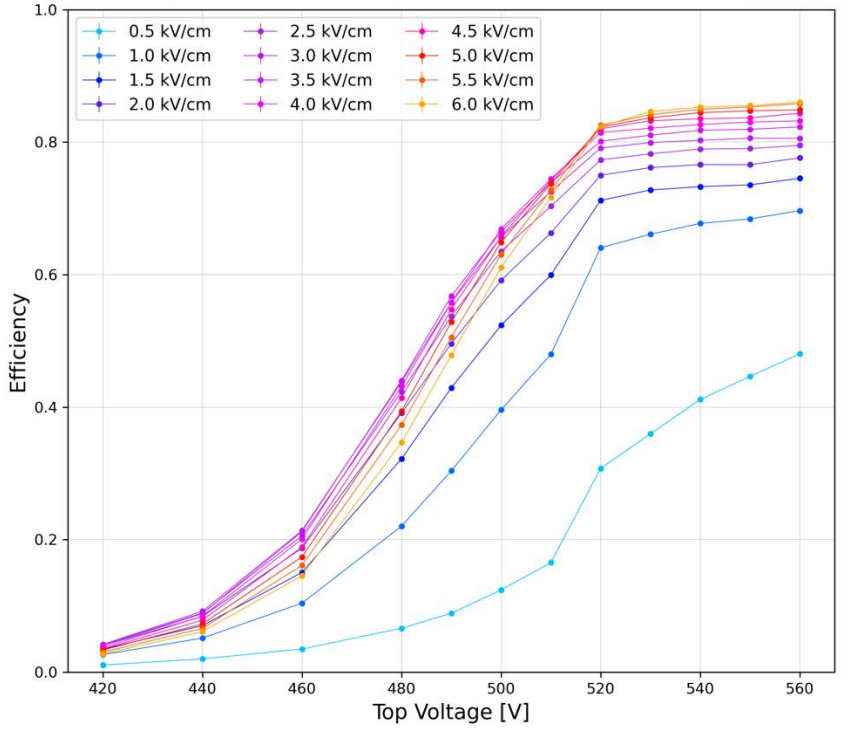
(expected : 10 % intrinsic detector inefficiency due to the groove structure)

PAD μ-RWELL 20X20 CM^2

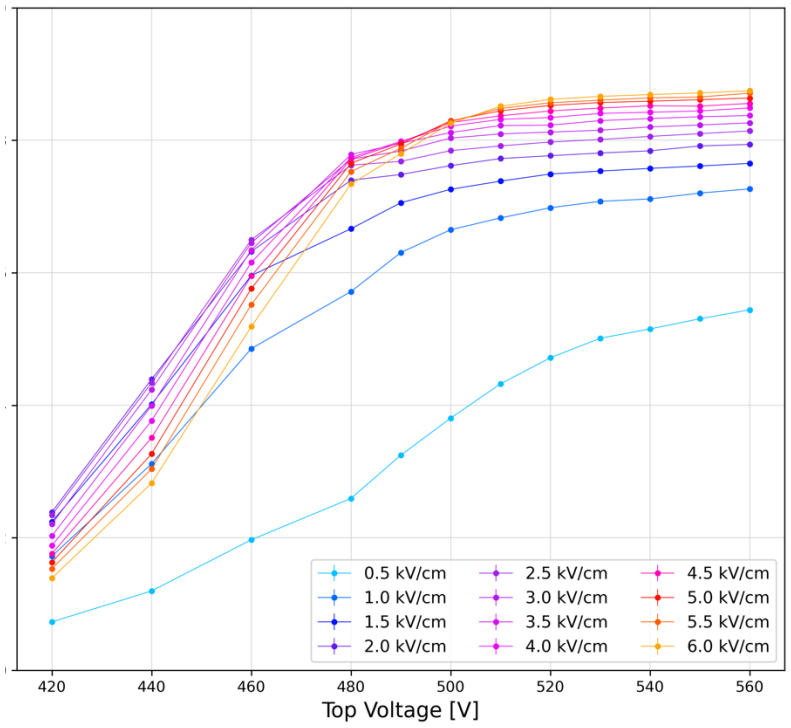
Efficiency vs Top Voltage

Ar:CO2:CF4

Preliminary - THL 2 fC

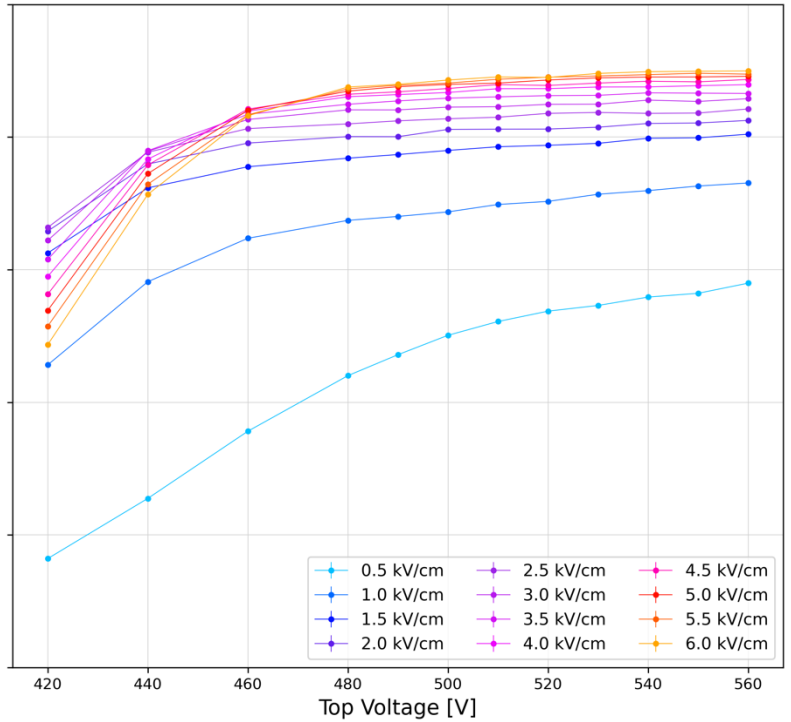


Preliminary - THL 1 fC



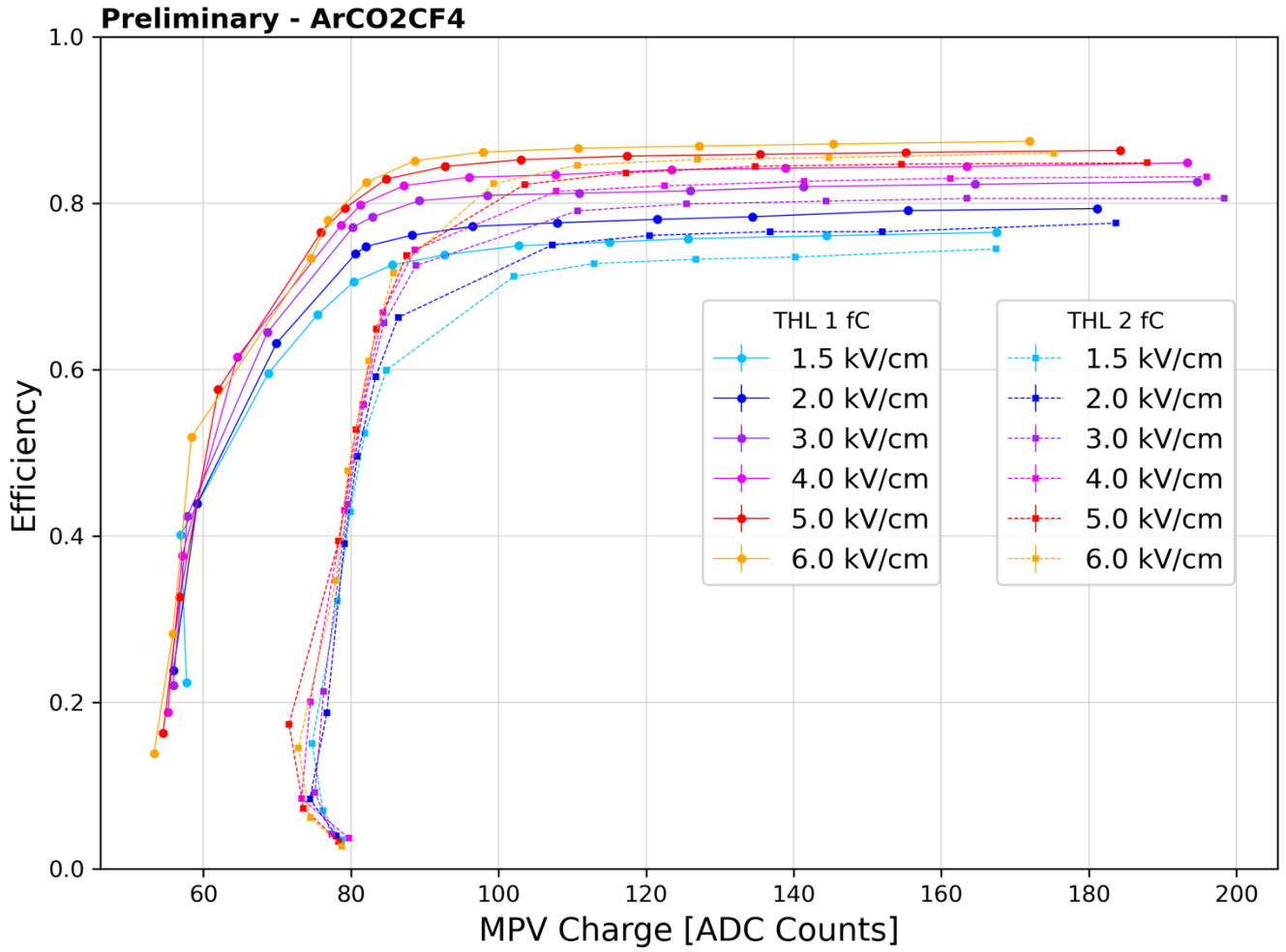
Ar:CO2

Preliminary – THL 1 fC



PAD μ-RWELL 20X20 CM^2

Efficiency - THL comparison



- Plateau reached almost for the same charge value, independently of the drift field :

  THL 1 fC @ ~80 ADC counts

  THL 2 fC @ ~100 ADC counts, but steeper turn-on rises

- The lower the THL the larger the saturating efficiency

- <u>The larger the drift field the larger the saturating efficiency</u>

  At best (D.F. 6 kV/cm)

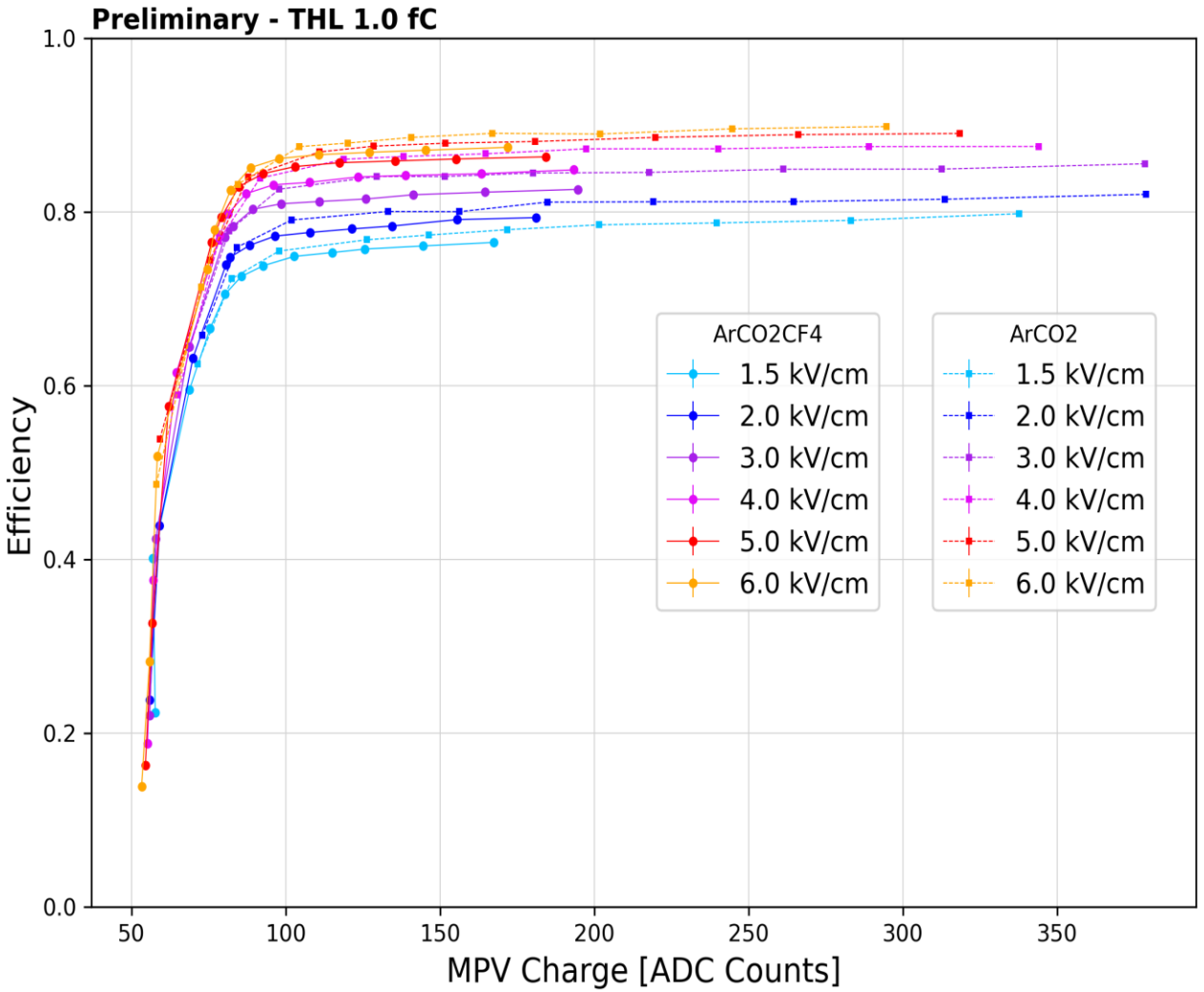
  THL 1 fC @ ~90%

  THL 2 fC @ ~87%

  Inconsistent with the decreasing trend of the charge as a function of the drift field !
  (shown later)

PAD μ-RWELL 20X20 CM^2

Efficiency – Gas comparison



Ar:CO_2 70:30 allows for higher charge multiplication → extended range of the gain is inspected

- Substantial overlapping of the turn-on curves at low charge values (below 100 ADC)
- Saturation value of the efficiency is about one tenth **larger** in **Ar:CO_2 than** in **Ar:CO_2 :CF_4**
- The larger the drift field the larger the saturating efficiency

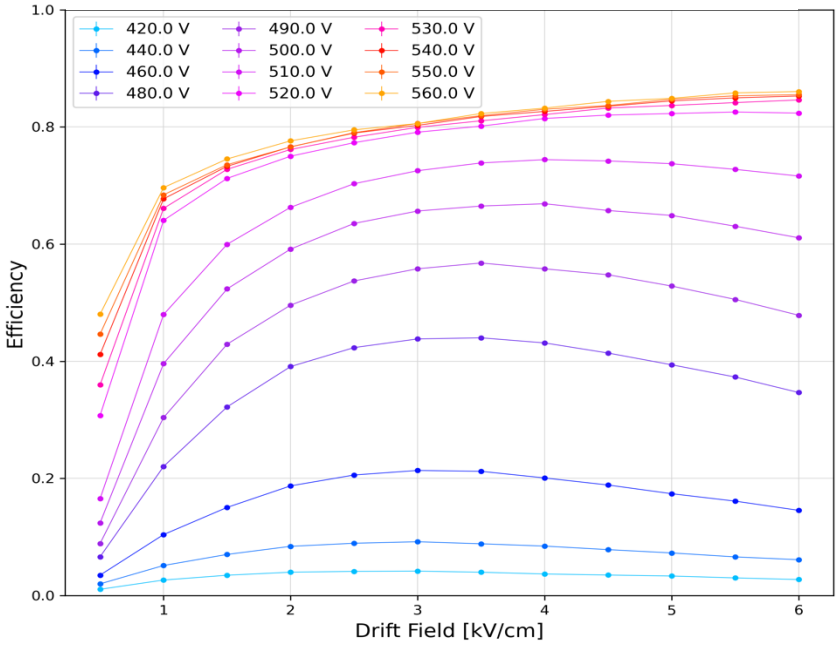
Inconsistent with the decreasing trend of the charge as a function of the drift field !

(shown later)

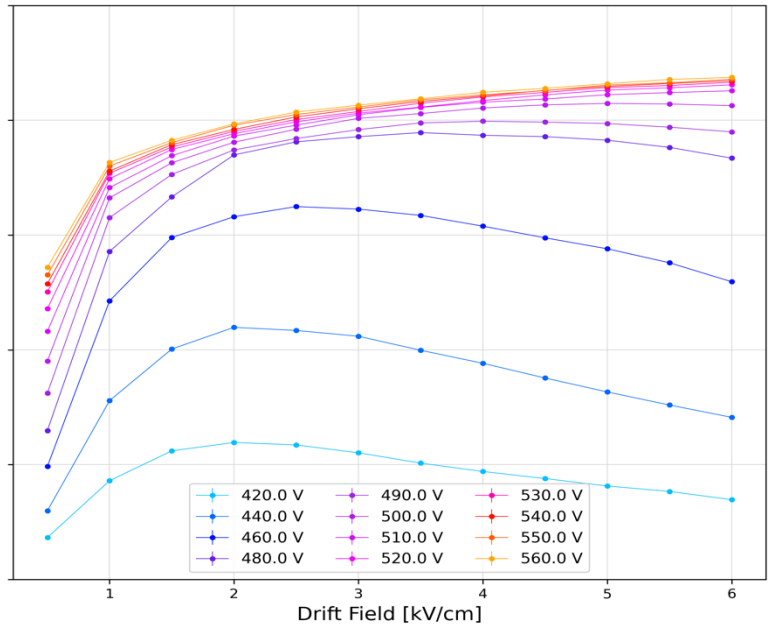
PAD μ-RWELL 20X20 CM^2

Efficiency vs Drift Field

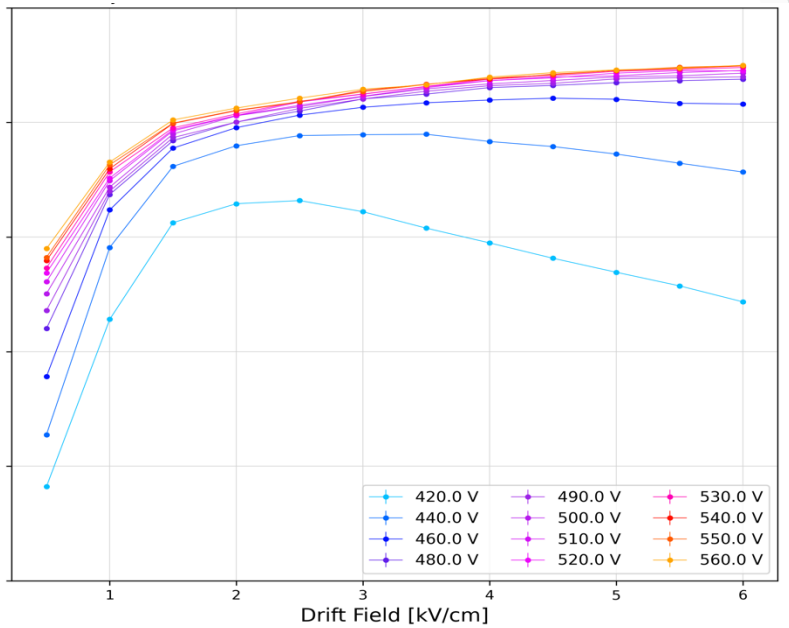
Preliminary – $ArCO_2CF_4$: - THL 2 fC



Preliminary - $ArCO_2CF_4$ - THL 1 fC



Preliminary – $ArCO_2$ - THL 1 fC



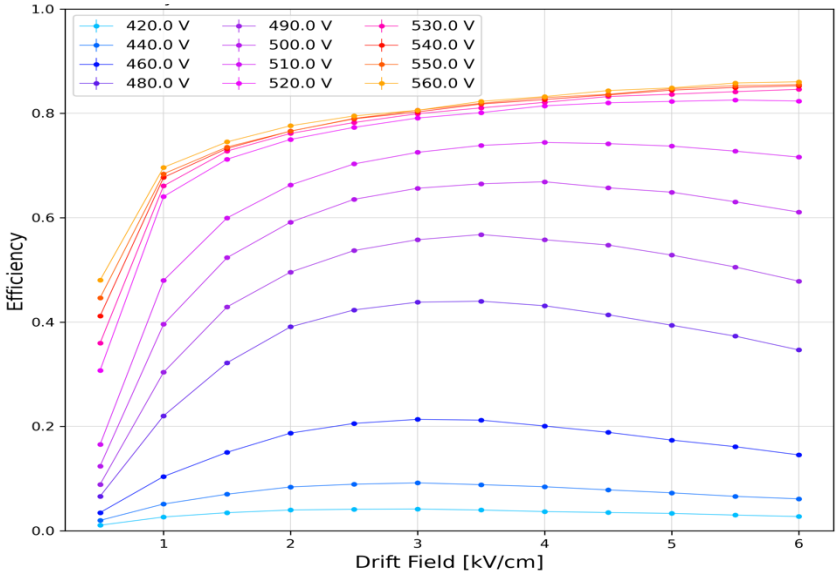
Low Top Voltage (~ low gain) :

- Maximum ADC at ~ 3 kV/cm, then decreasing at larger values of the drift field

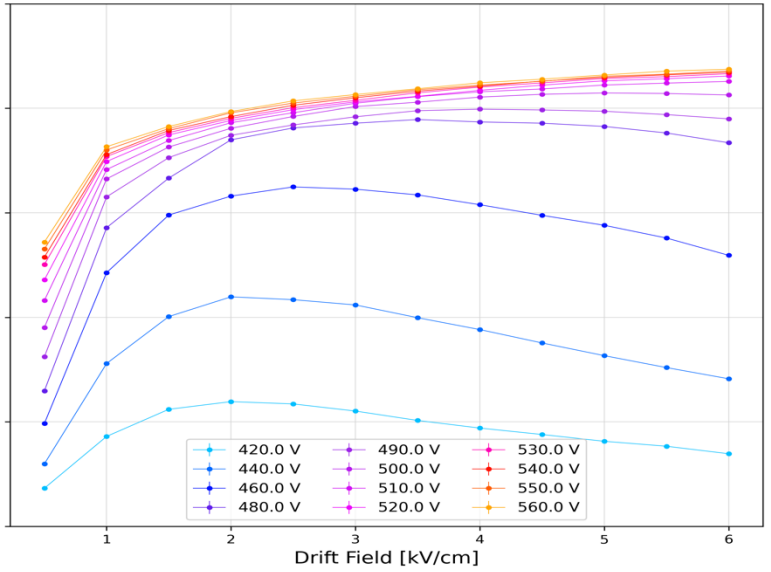
High Top Voltage (~ high gain) :

- Increasing trend in the whole drift range - **Inconsistent with the pulse height of the signal**

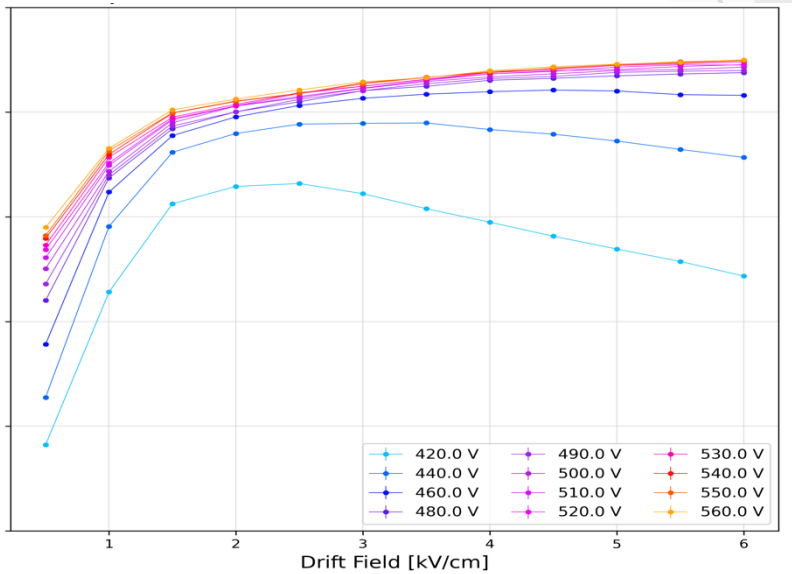
Preliminary – $ArCO_2CF_4$: - THL 2 fC

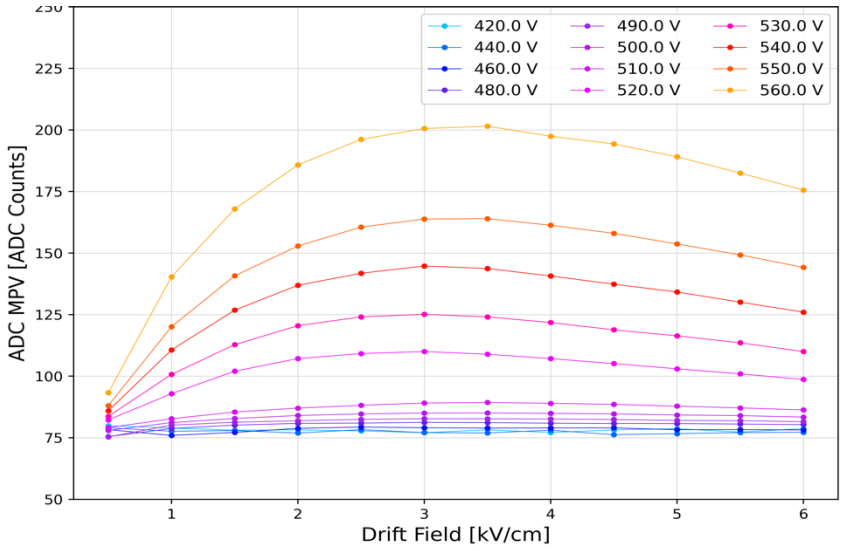


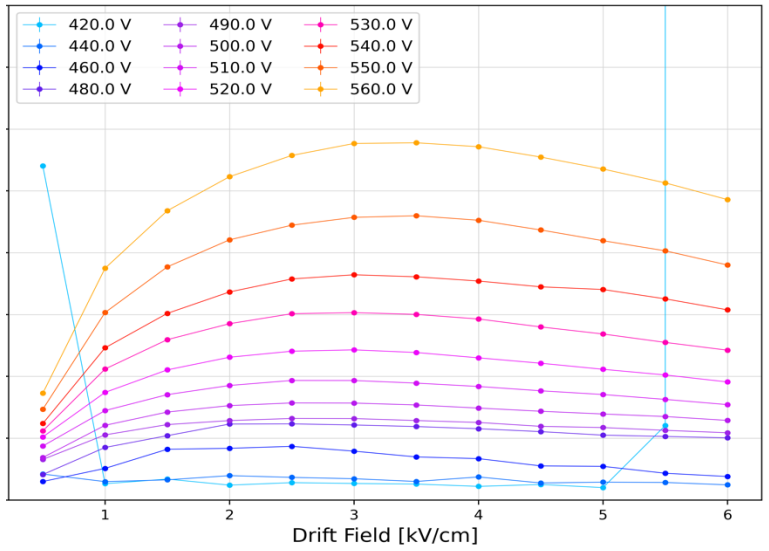
Preliminary - $ArCO_2CF_4$ - THL 1 fC

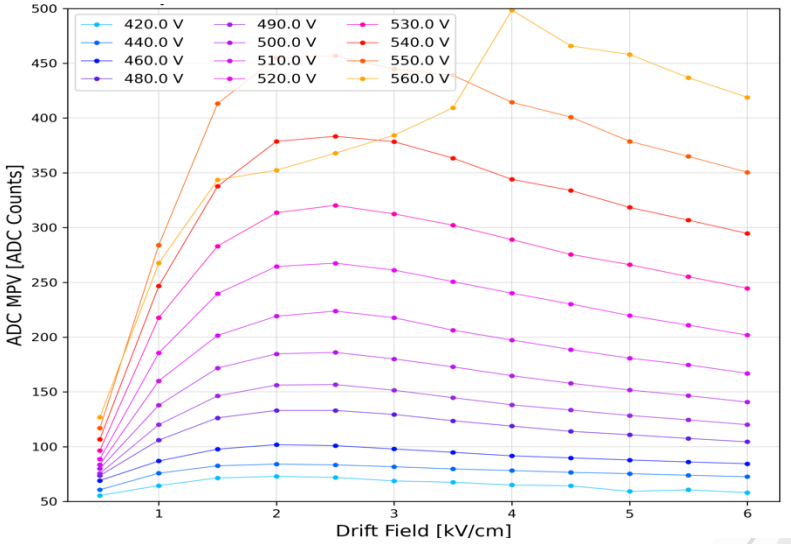


Preliminary – $ArCO_2$ - THL 1 fC







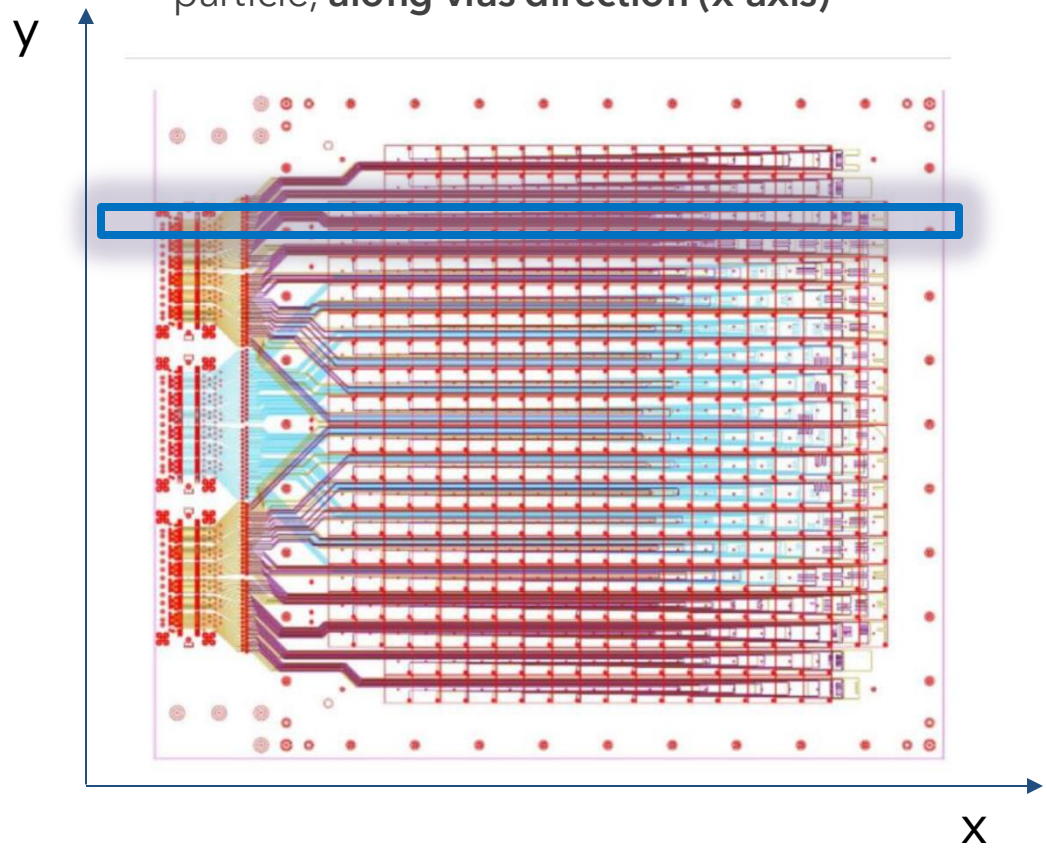


INSPECT FOR CROSS TALK

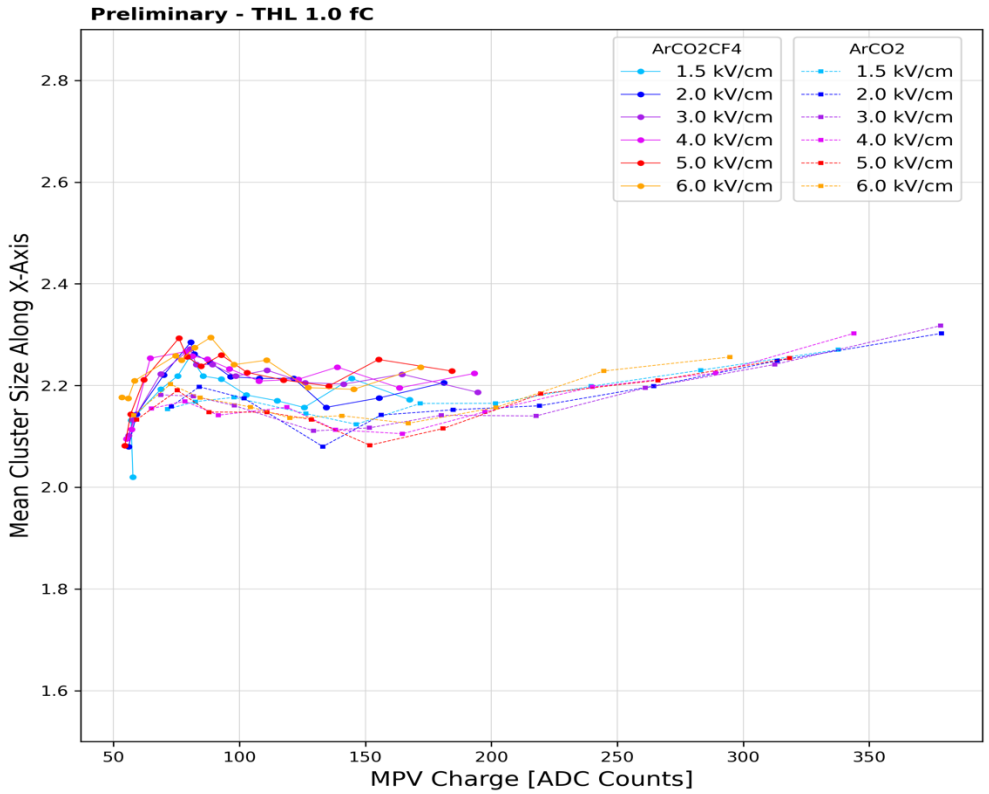
Cluster Size vs Pulse Height

- Search for **cross-talk effects** due to possible capacitive coupling of the connecting vias to the DLC layer

  → expected induction of charge in pads collinear to the one fired by the passing particle, **along vias direction (x-axis)**



- Most of the events have cluster size 1 → reject single-pad clusters to have a better understanding of the shape of the **multiple-pad clusters**
- Look separately at the **extension of the cluster along the x and y directions**
- Compute the **average cluster size along x and y** as a function of the pulse height (MPV)

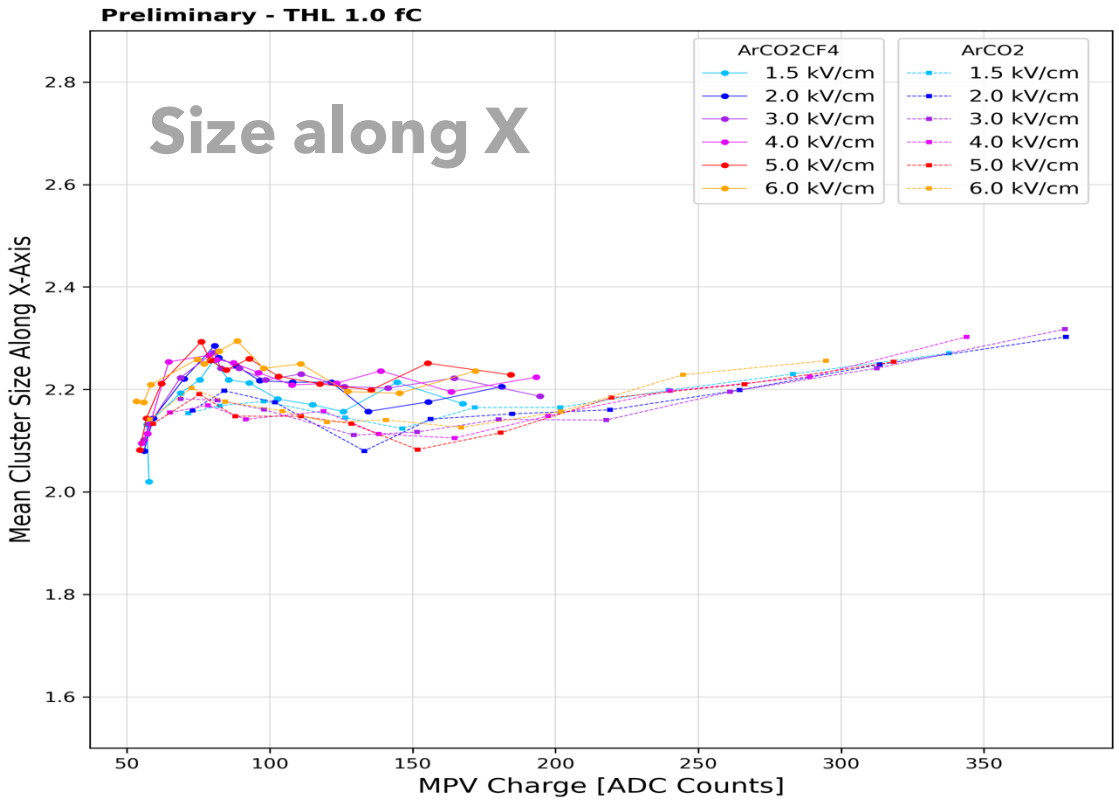


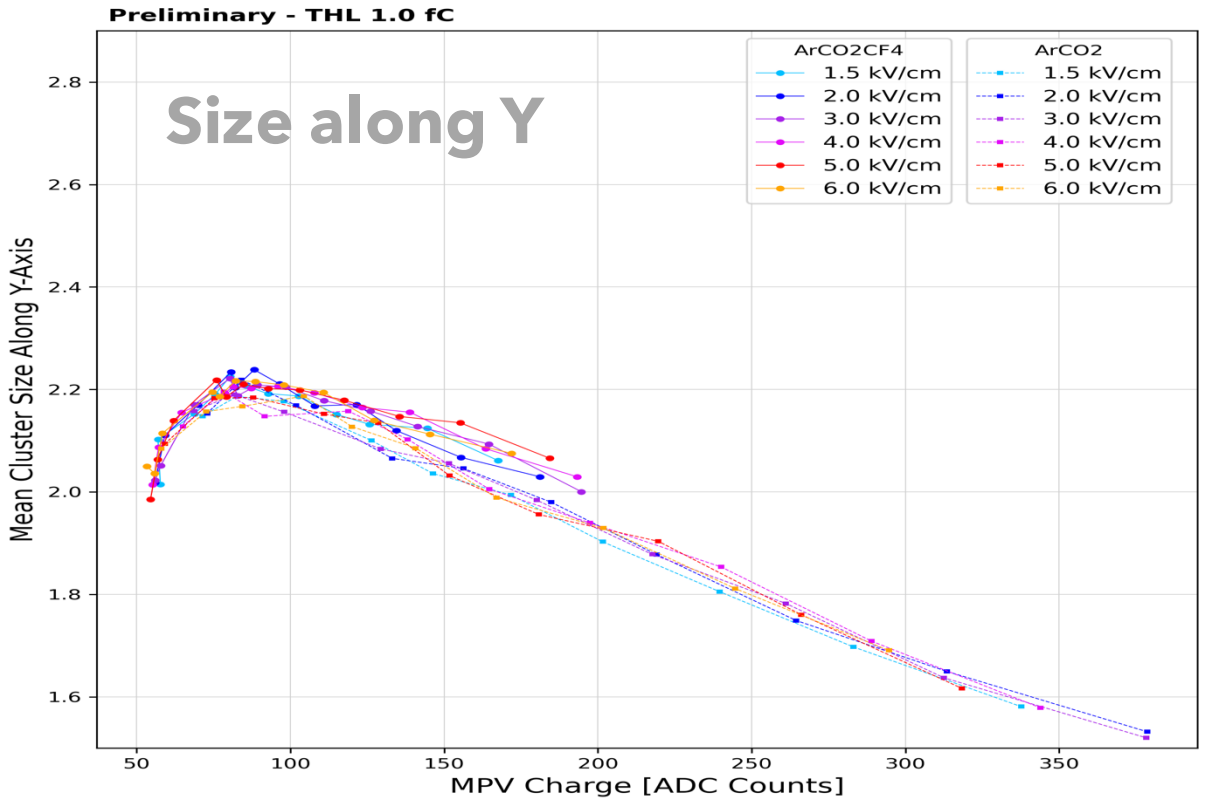
INSPECT FOR CROSS TALK

Cluster Size vs Pulse Height

- Different trends along the two axis
  - Below 70 ADC : common increasing trend
  - Above 70ADC : → **along x :** smooth decrease below 200 ADC, subsequent increase (possible **x-talk?**)

    → **along y :** steep decrease (to be understood …)





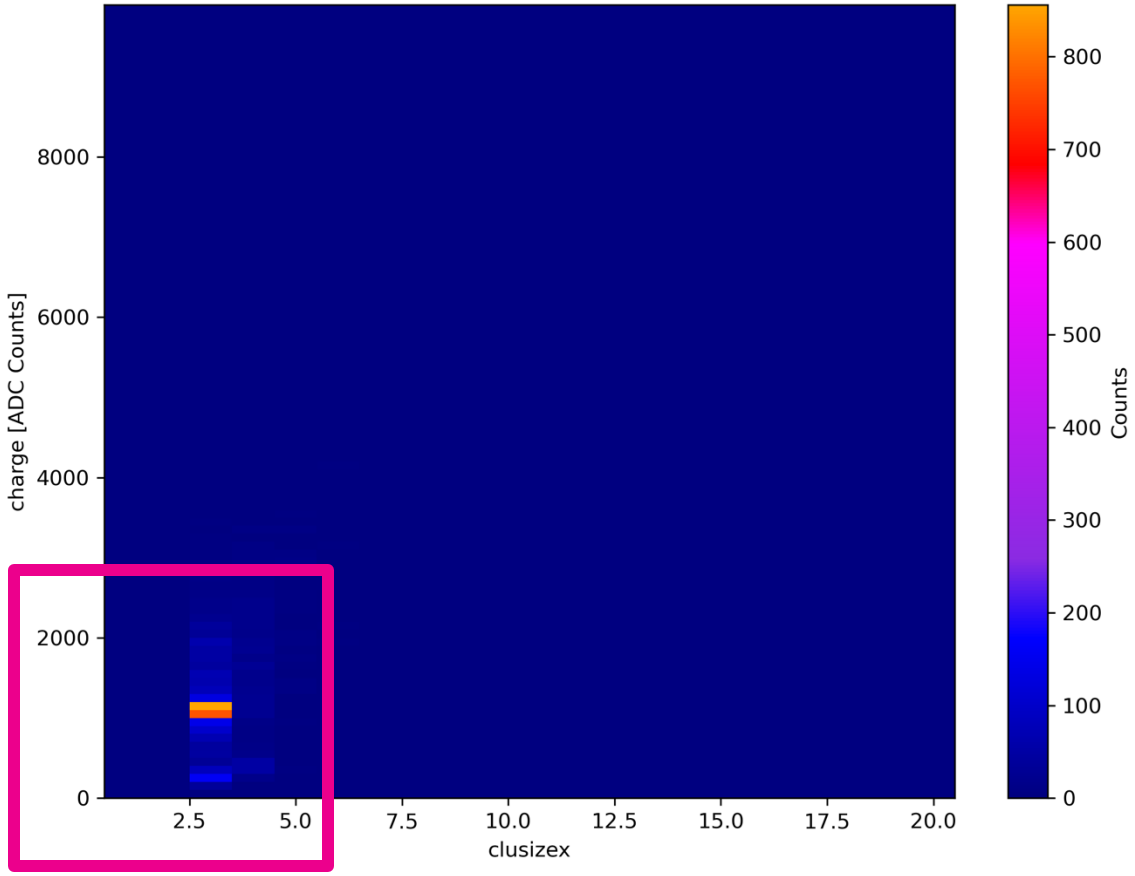
INSPECT FOR CROSS TALK

Cluster Size vs Pulse Height

- Study of the **pulse height** of the cluster wrt the **size along** x for clusters with an **x-extension > 2**

- Mostly cluster with an x-extension equal to 3
- Peak at a pulse height close to 1000 ADC counts (saturation limit for a single pad)

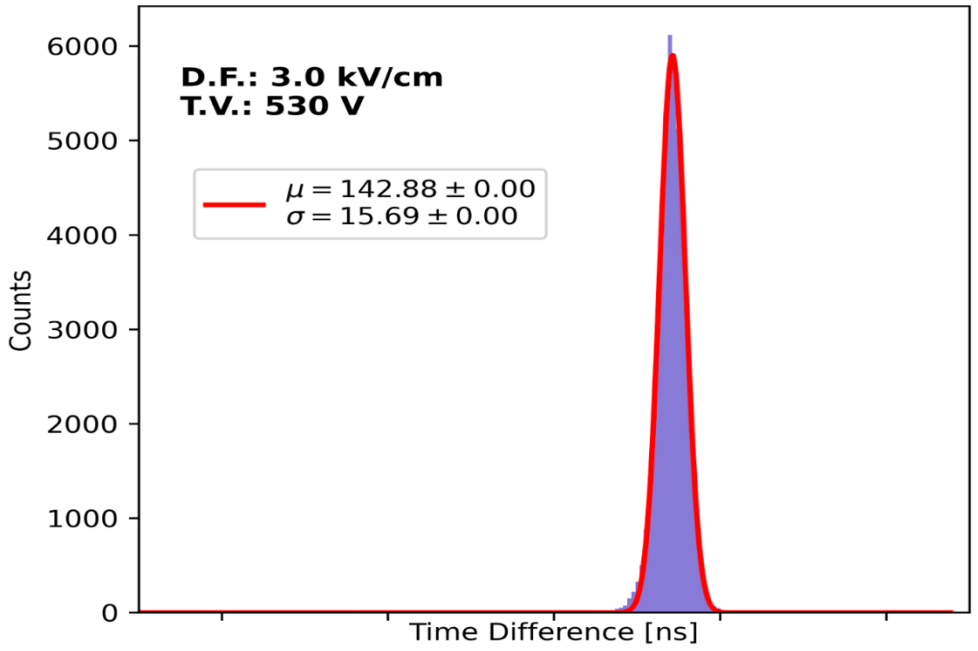
→ **Only one of the fired pads saturates**



PAD μ-RWELL 20X20 CM^2

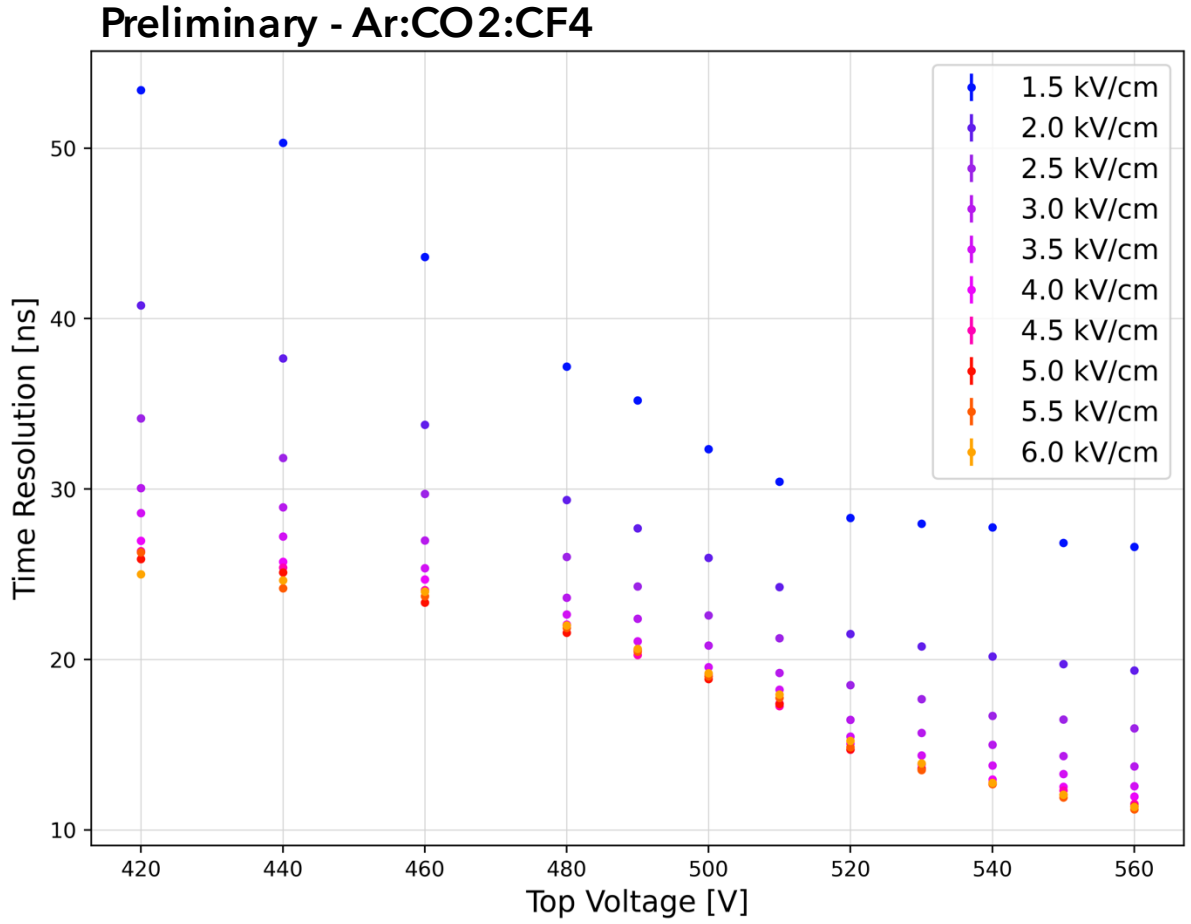
Threshold Level 2 fC

- Gaussian fit of the time difference distributions



- Gaussian fit of the time difference distributions
- The **sigma** provides an estimate of the convolution of detector and electronic **time resolutions**

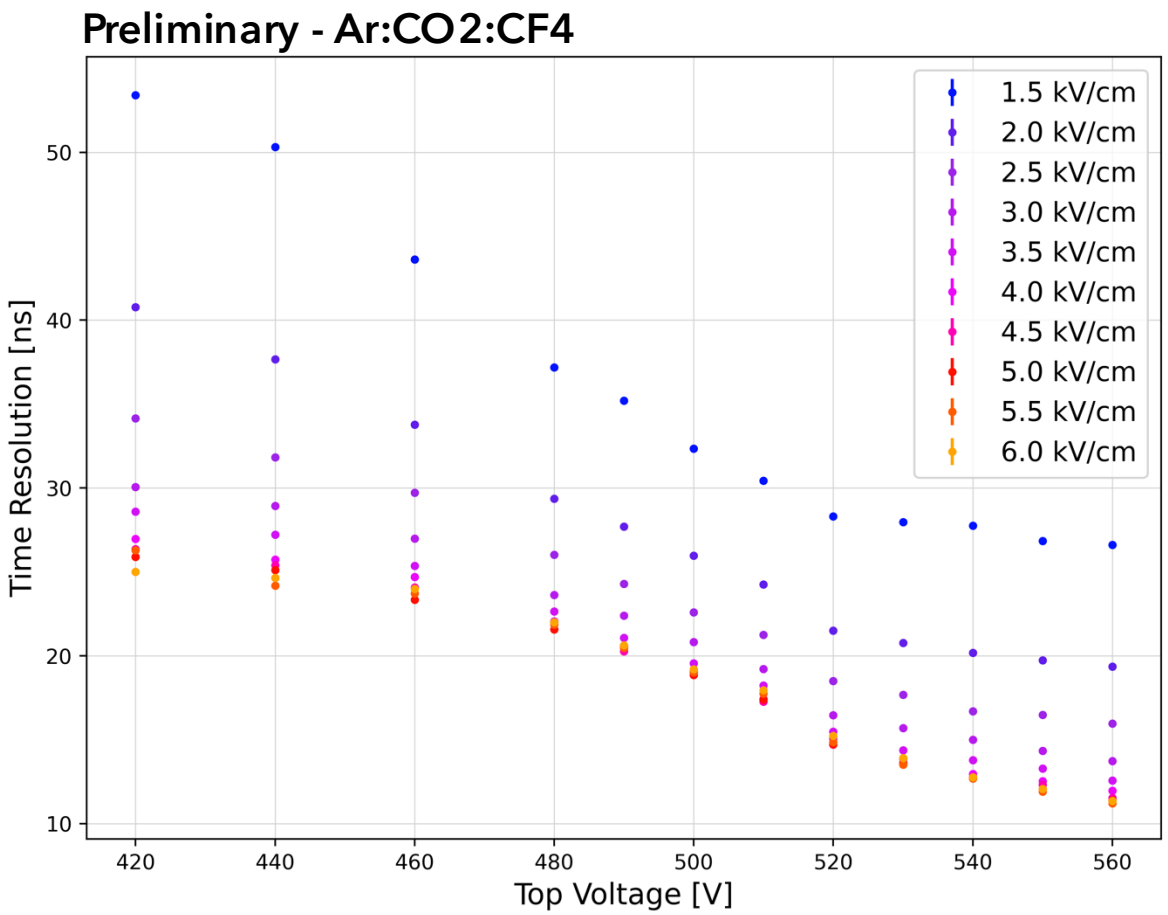
TIME RESOLUTION



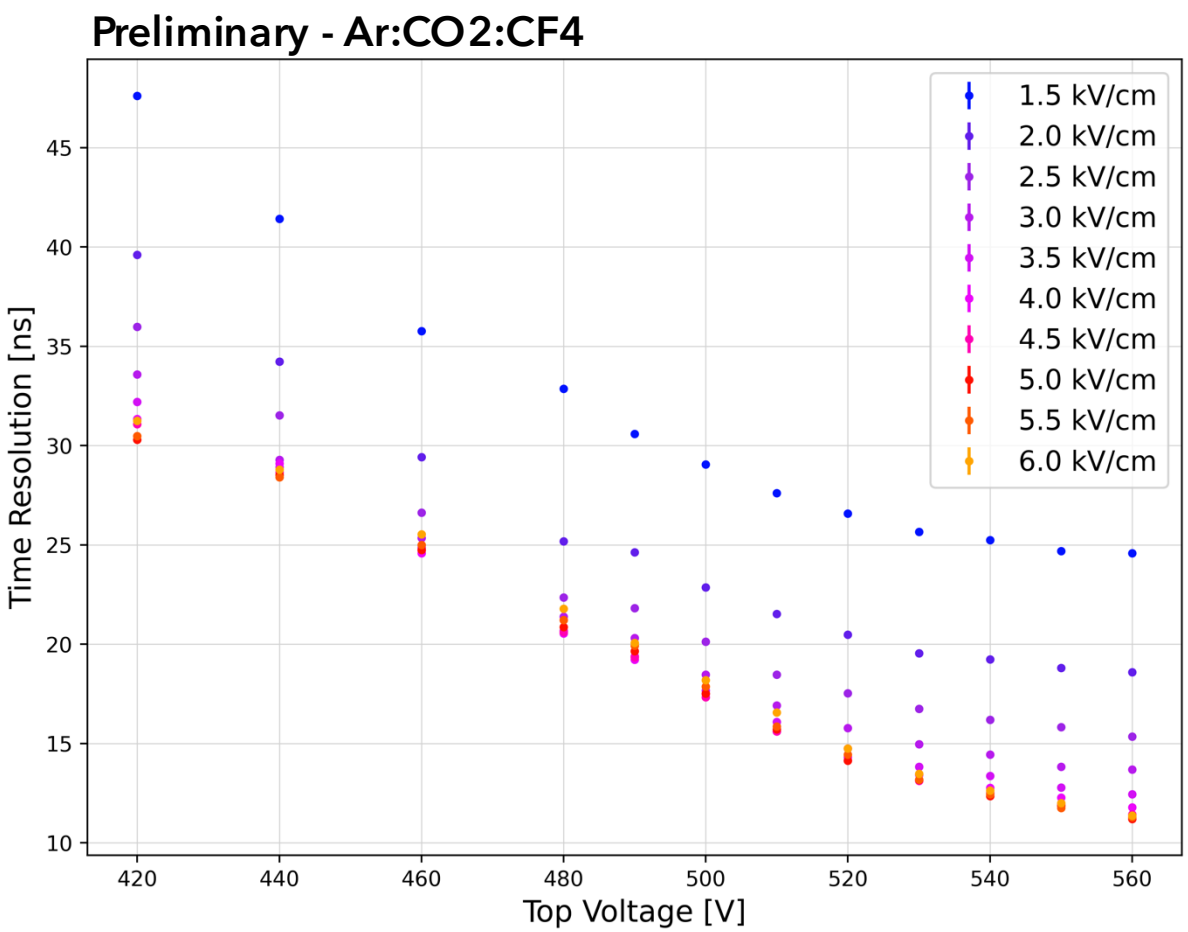
PAD μ-RWELL 20X20 CM^2

Time Resolution - THL comparison

Threshold Level 2 fC



Threshold Level 1 fC



NEXT STEPS

Implement tracking with Corryvreckan

- Analyzed high-statistics runs to observe **dead zones** of the detector due to the **groove** evacuating structure

  → Compute the **intrinsic inefficiency** of the chamber

- Compute a track-based efficiency to see if the **efficiency/pulse-height inconsistency** is solved with a more **refined selection of events**
- Analyze lower threshold runs (**0.8 fC**) for a better understanding of a possible **cross-talk effect**

THANK YOU

FOR THE ATTENTION

PAD μ-RWELL 20X20 CM^2

Cluster Size vs ADC

- Search for cross-talk effects due to possible capacitive coupling of the connecting vias to the DLC layer

  → expected induction of charge in pads collinear to the one fired by the passing particle