Recent Results from the CLAS12 μRWELL prototype

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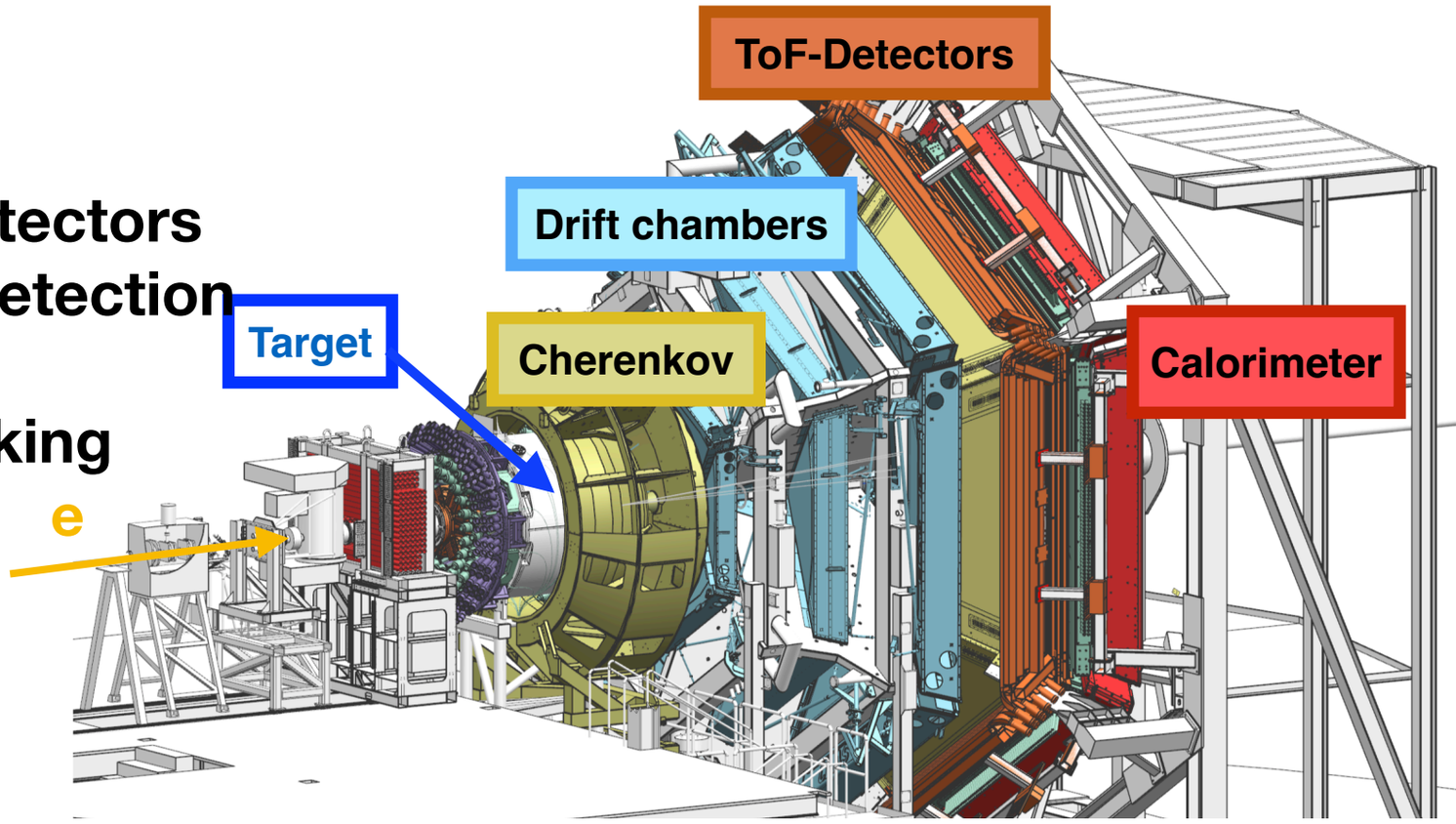
Dec 07, 2023

RD51 Collaboration Meeting, CERN

CLAS12 in HallB at Jefferson Lab

- **Large acceptance detector**
  - **different tracking and PID detectors**
  - **charge and neutral particle detection**
- **Solenoid magnet around target**
- **Toroidal magnet in forward tracking**
- **Various targets**
  - **H, D, He, C, …**
  - **unpolarized and polarized**



V. Burkert et al., NIMA 959 (2020), 163419

- **Standard luminosity 10^{35} $cm^{-2}s^{-1}$**
- **Broad physics program**
  - **Nucleon structure (GPDs, TMDs, …)**
  - **Hadron spectroscopy (N*, Λ, …)**
  - **Nuclear structure (CT, Short-range correlations, …)**

Why a μRWELL detector

- **Luminosity upgrade to ~2*10^{35}cm^{-2}s^{-1} with charged particle reconstruction efficiency > 85%**
  - **Catchup on statistics (existing data about factor two lower statistics than expected)**
  - **Gain time for long remaining physics program**
  - **Opportunities for new, low-rate reactions**

Why a μRWELL detector

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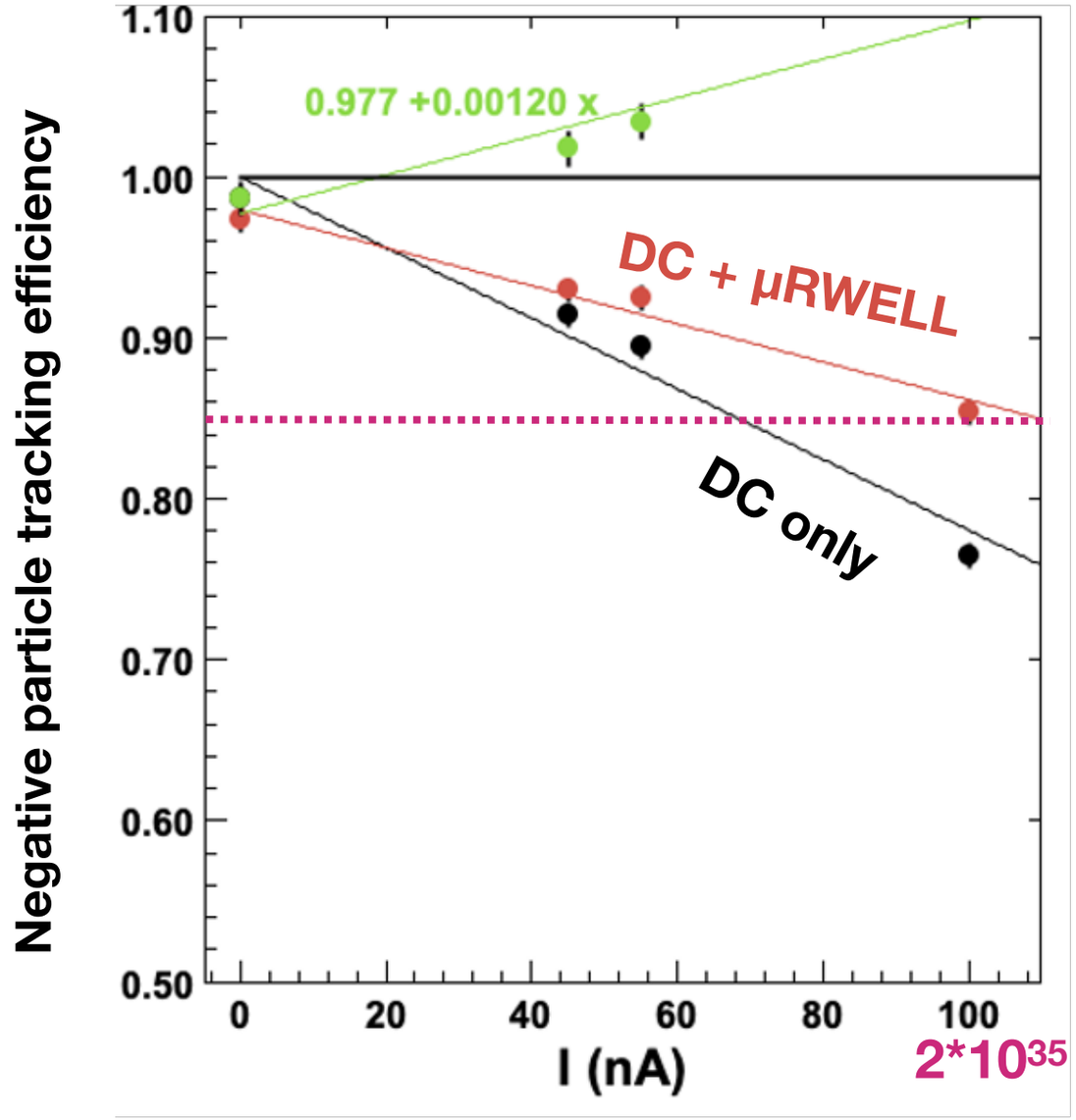
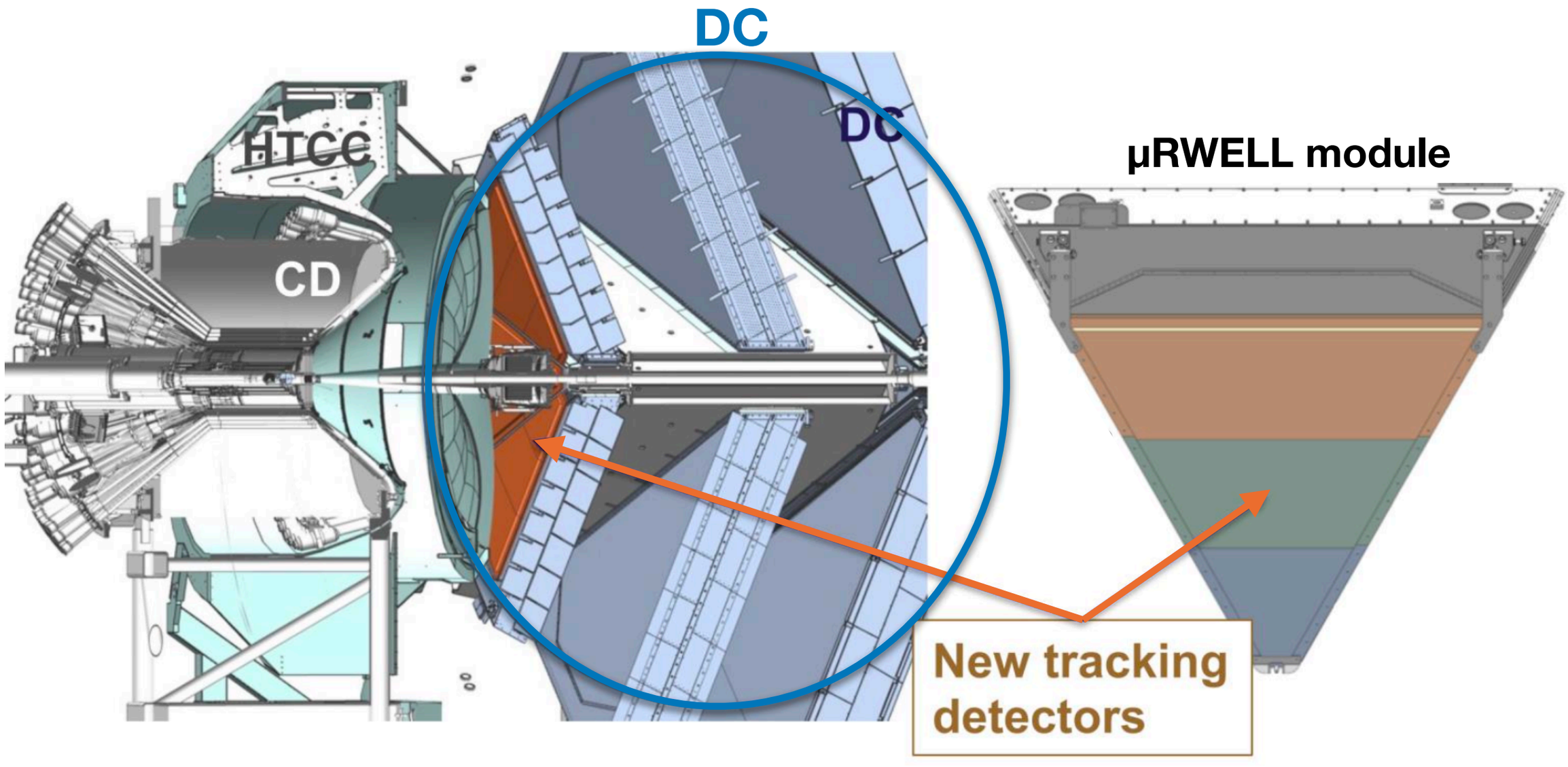
  - **Gain time for long remaining physics program**
  - **Opportunities for new, low-rate reactions**

- **Main Issue at higher luminosities**
  - **high occupancy in drift chambers —> single track efficiency < 80%**
- **Solution:**
  - **Add low-mass, high-efficiency, fast tracker with good resolution (~100um)**
  - **Simulations show required improvement on tracking efficiency**

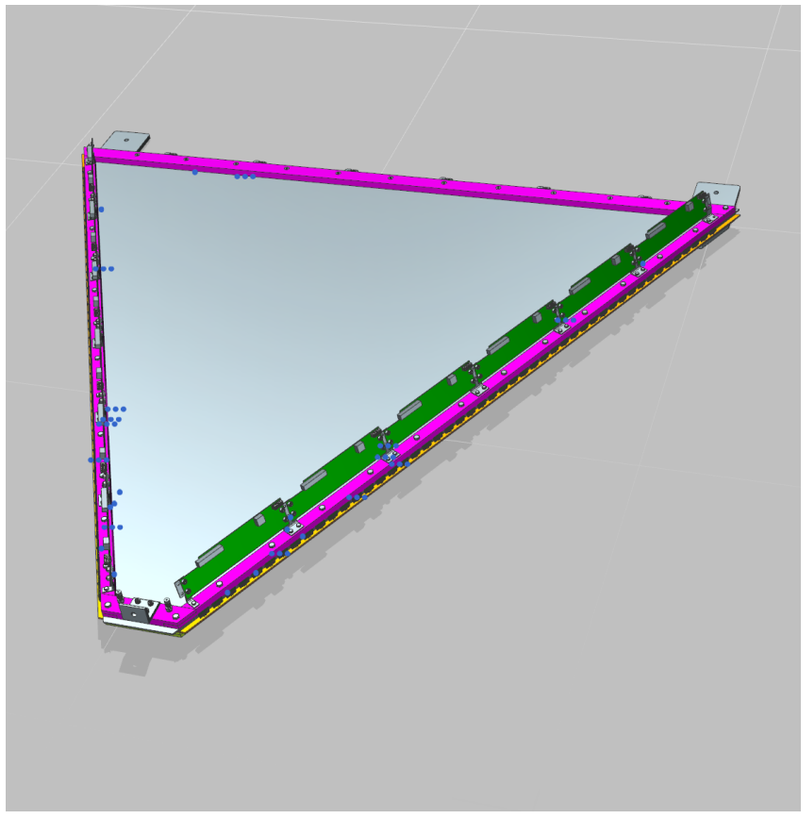


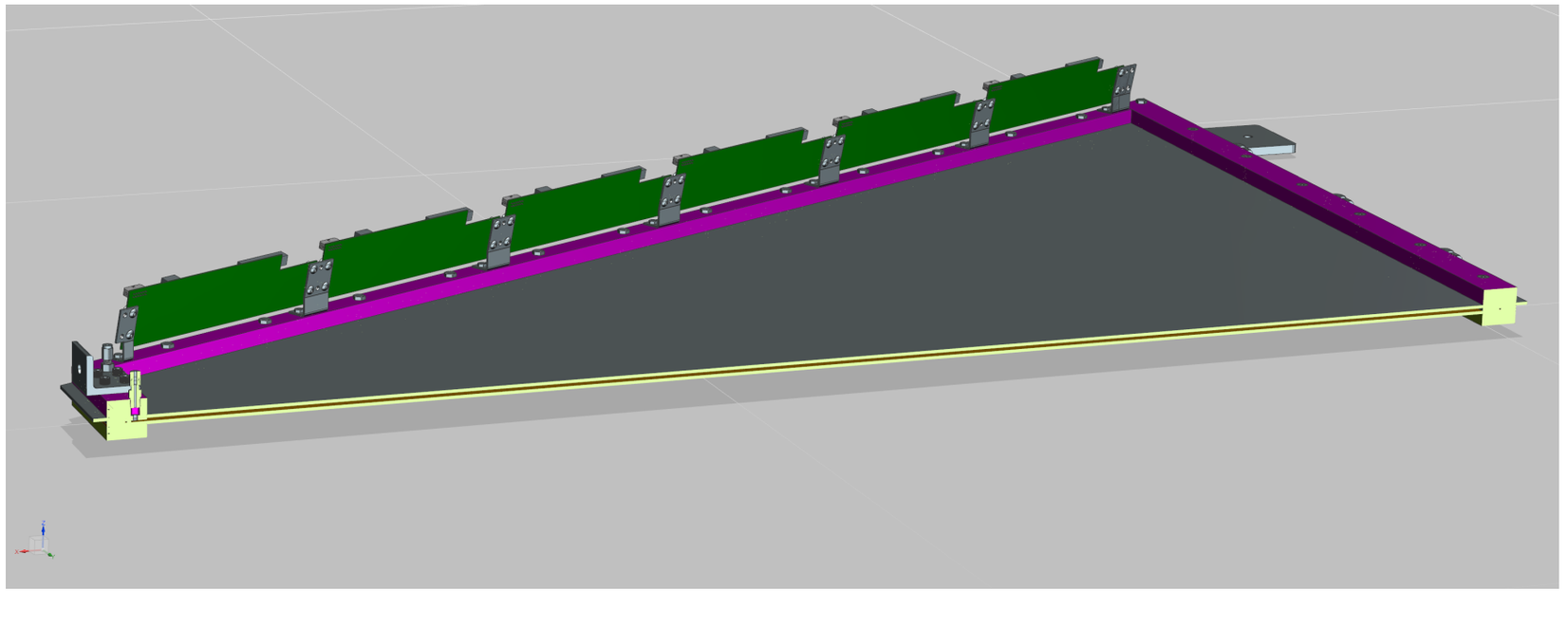
The CLAS12 μRWELL

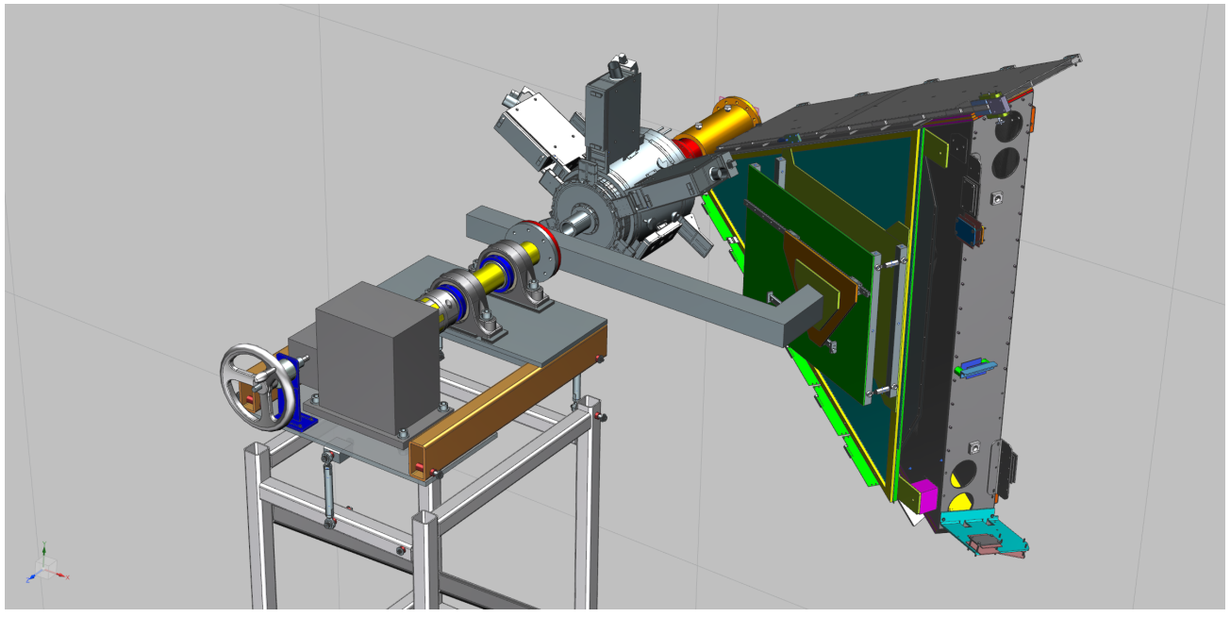
- **Add tracker before first drift chamber layers**
- **Size:**
  - **triangular shape**
  - **max. width ~1.4m**
  - **height ~ 1.2m**



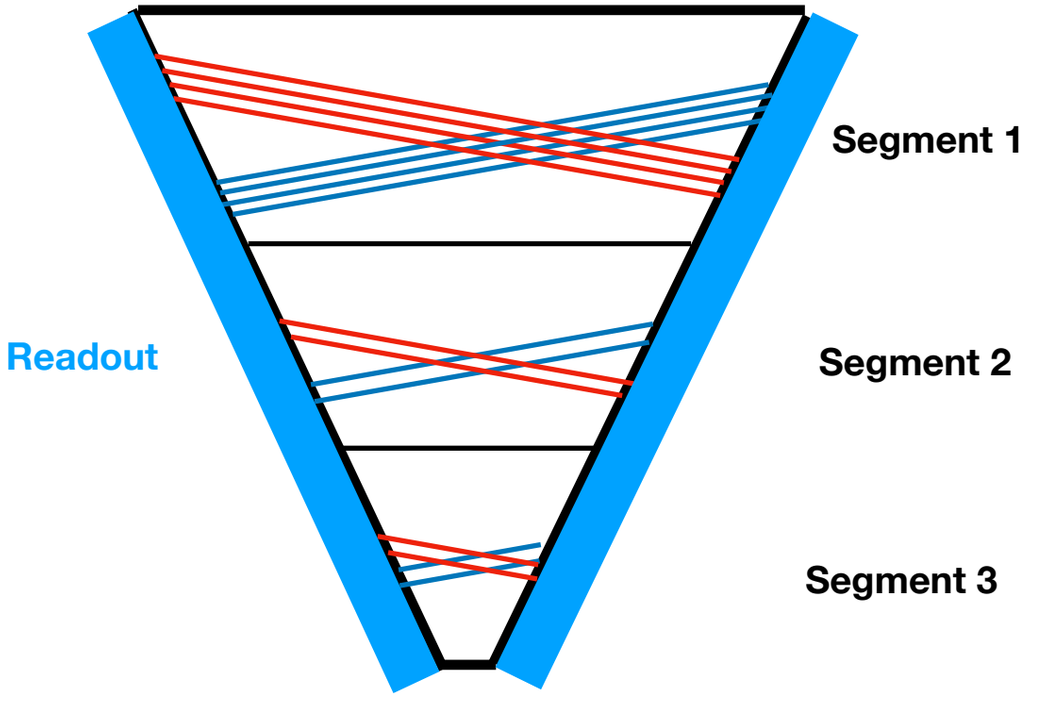
Full Design (in progress)





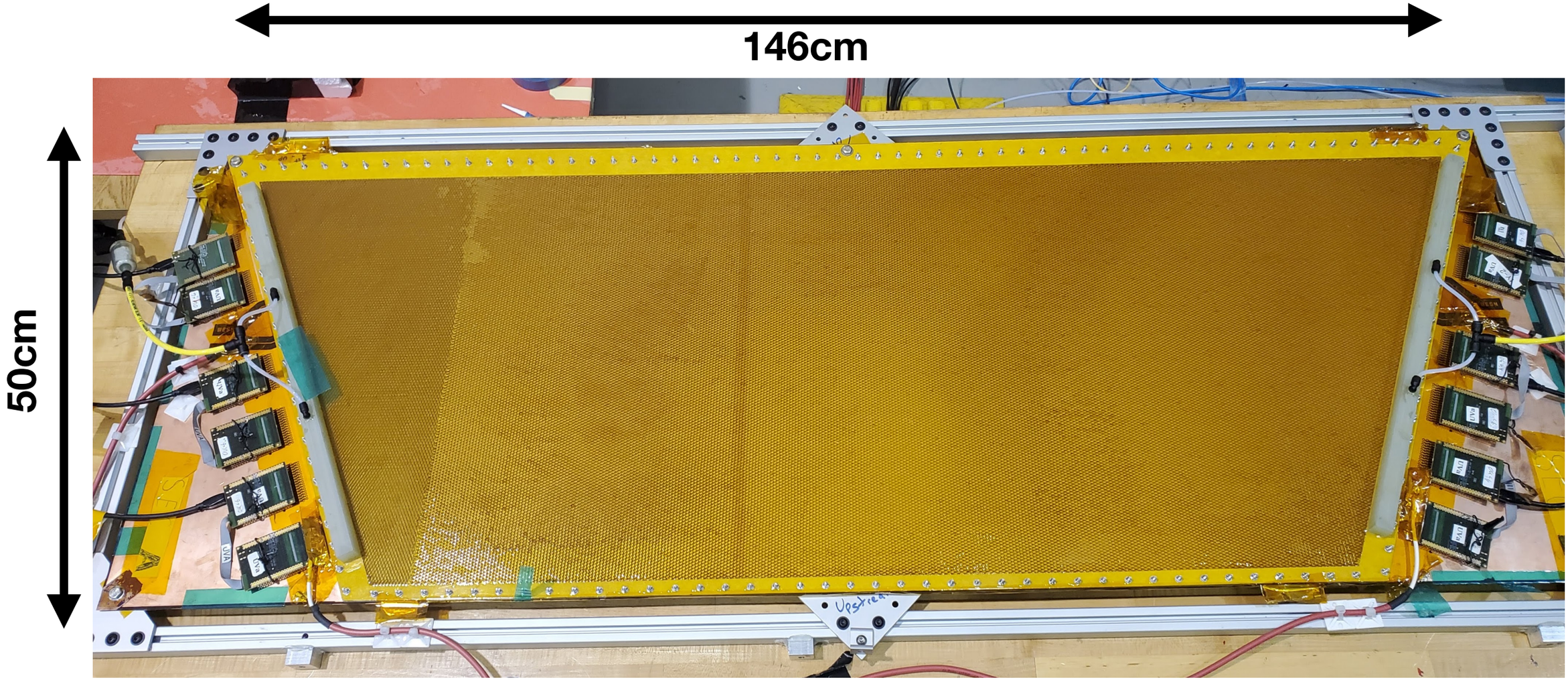


Installation

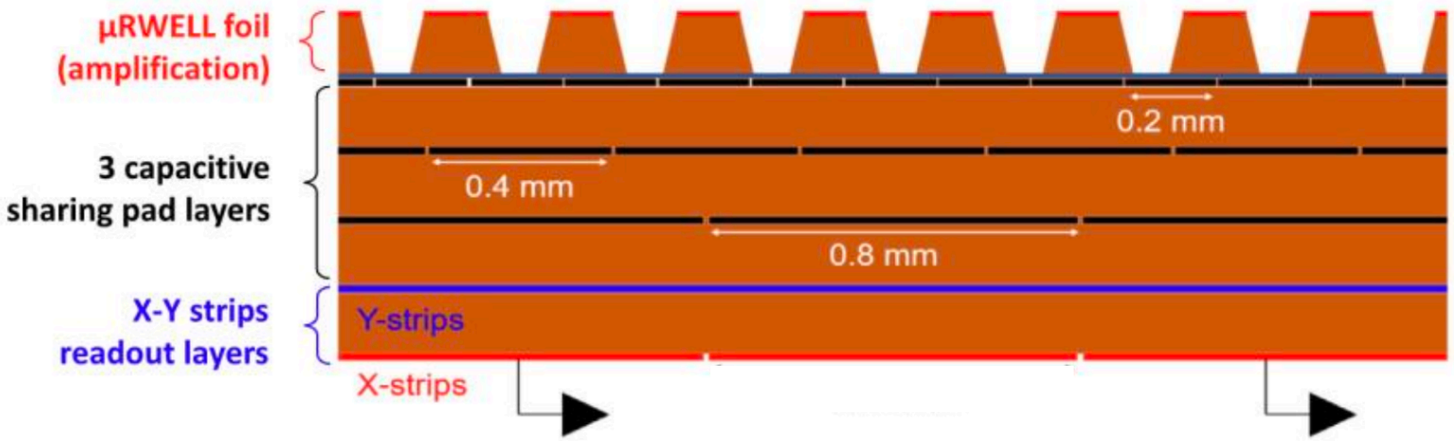


CLAS12 Prototype - Overview

- **Largest μRWELL build so far (thank you Rui, Bertrand and others at CERN)**
- **2D-U/V strip readout with 10 deg stereo angle**
  - **pitch 1mm**
  - **various strip widths (to find optimal combination)**
- **Capacitive sharing**
- **Electronics APV25 and SRS**

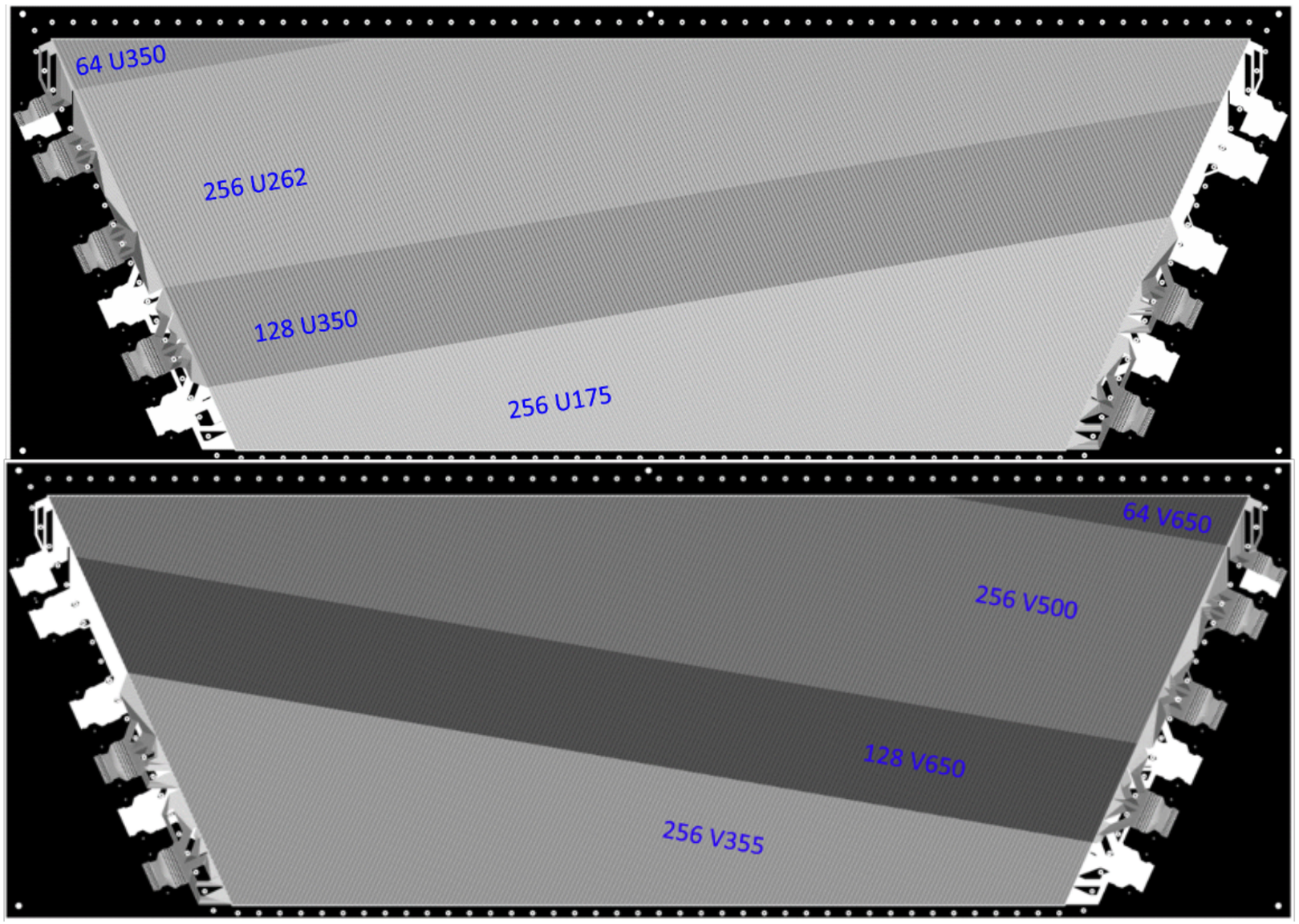


CLAS12 Prototype - Readout Structures



Capacitive sharing

K. Gnanvo, NIM A1047, 167782 (2023)



Readout Structures

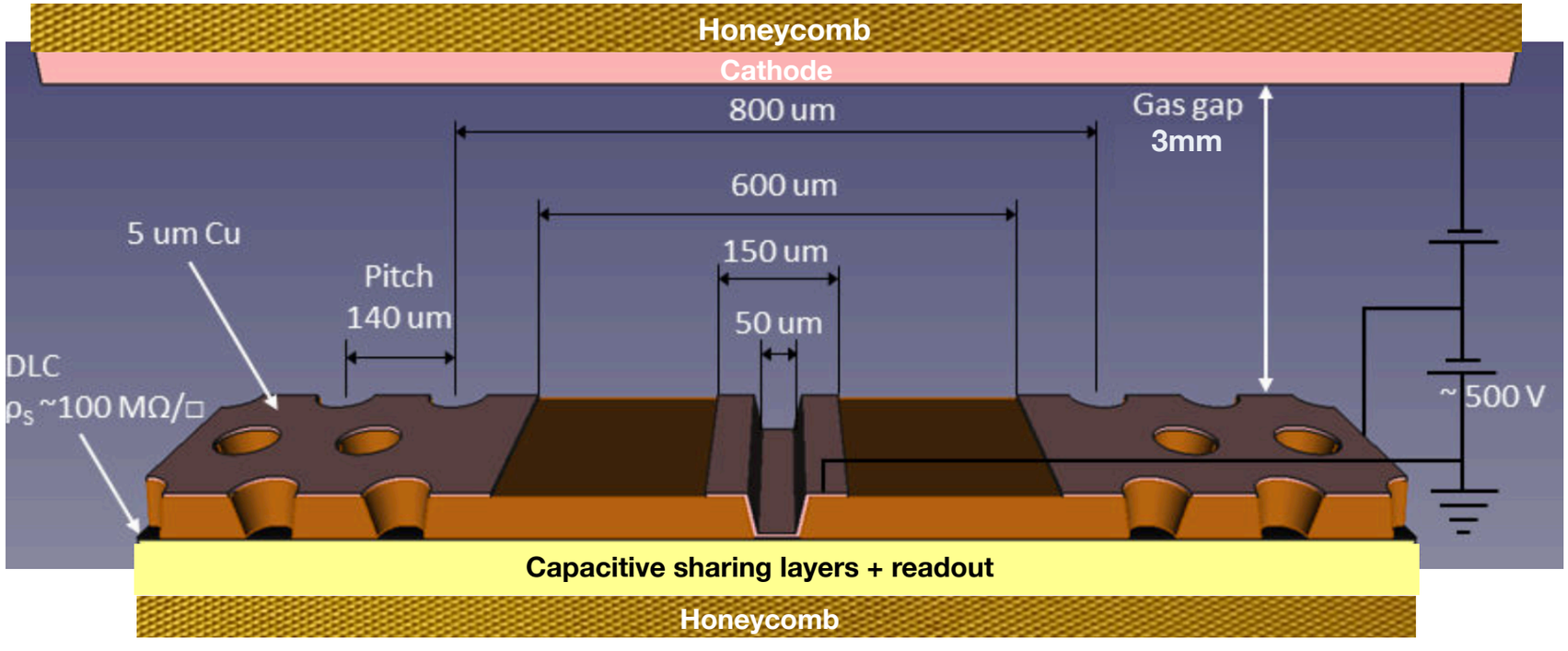
U-strips widths:

- **350µm**
- **262µm**
- **175µm**

V-strips widths:

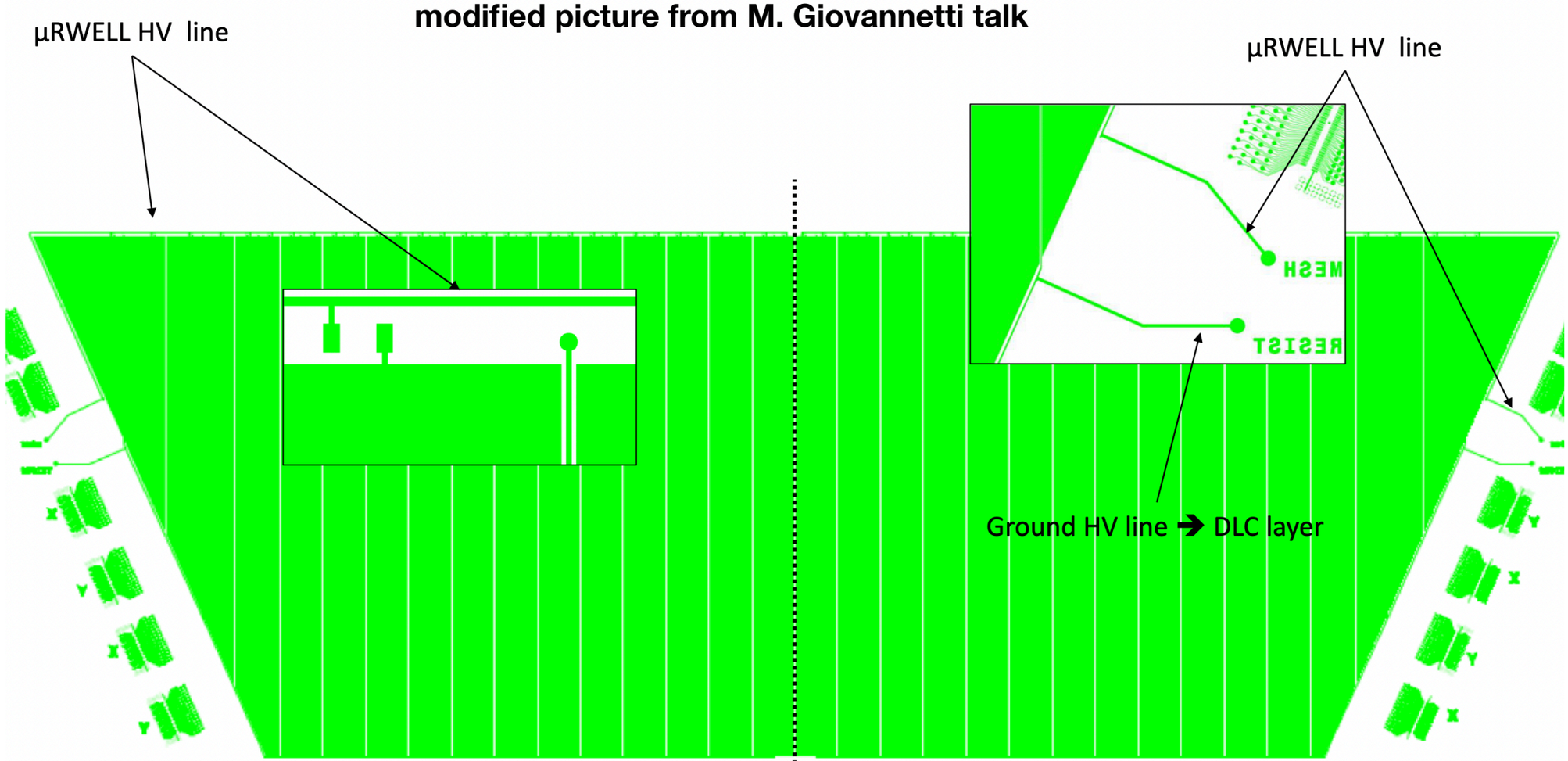
- **335µm**
- **500µm**
- **650µm**

CLAS12 Prototype - Detector Structures



Cross section of prototype

modified picture from M. Giovannetti talk



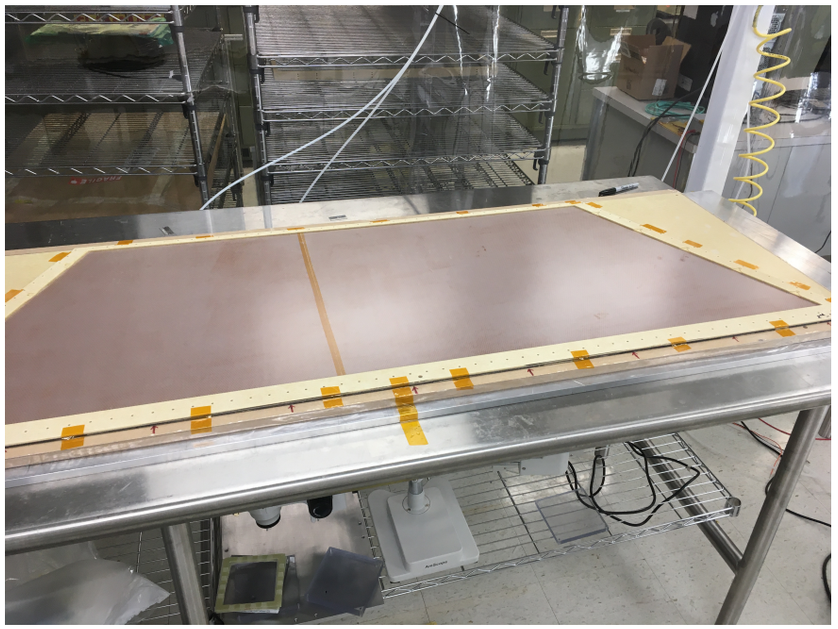
µRWELL foil HV lines

Split in two separate halfs

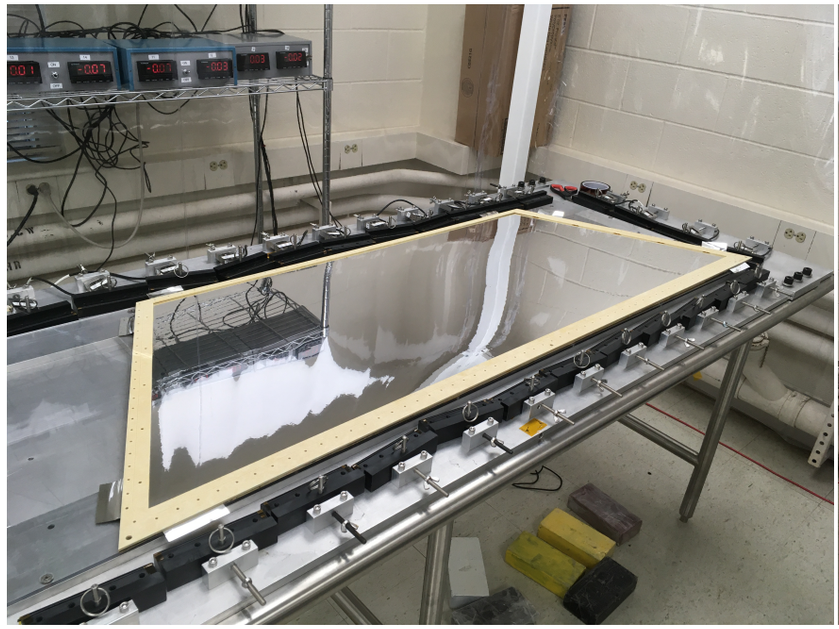
Pictures from Construction

Detector framing and cathode foil production at UVA (Many thanks to Huong, Nilanga and others)

Honeycomb base



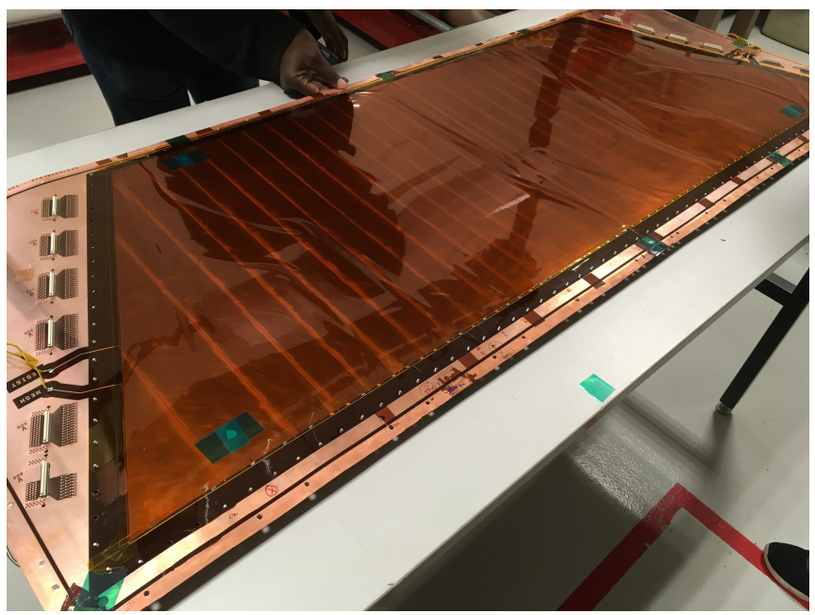
Cathode foil



pre-assembly

Final Assembly at CERN (Many thanks to Rui, Bertrand and others at CERN)

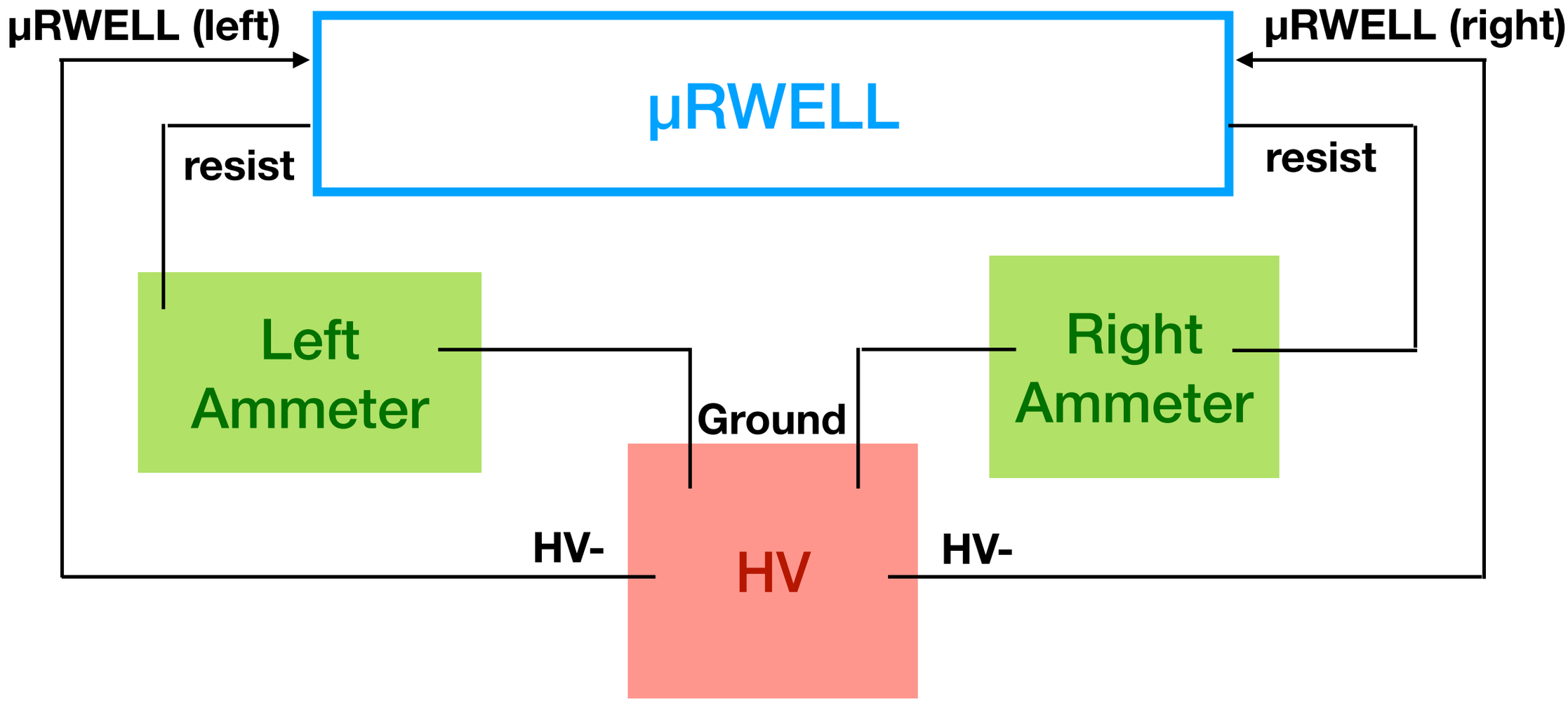
first look at μRWEL foil



before closing detector

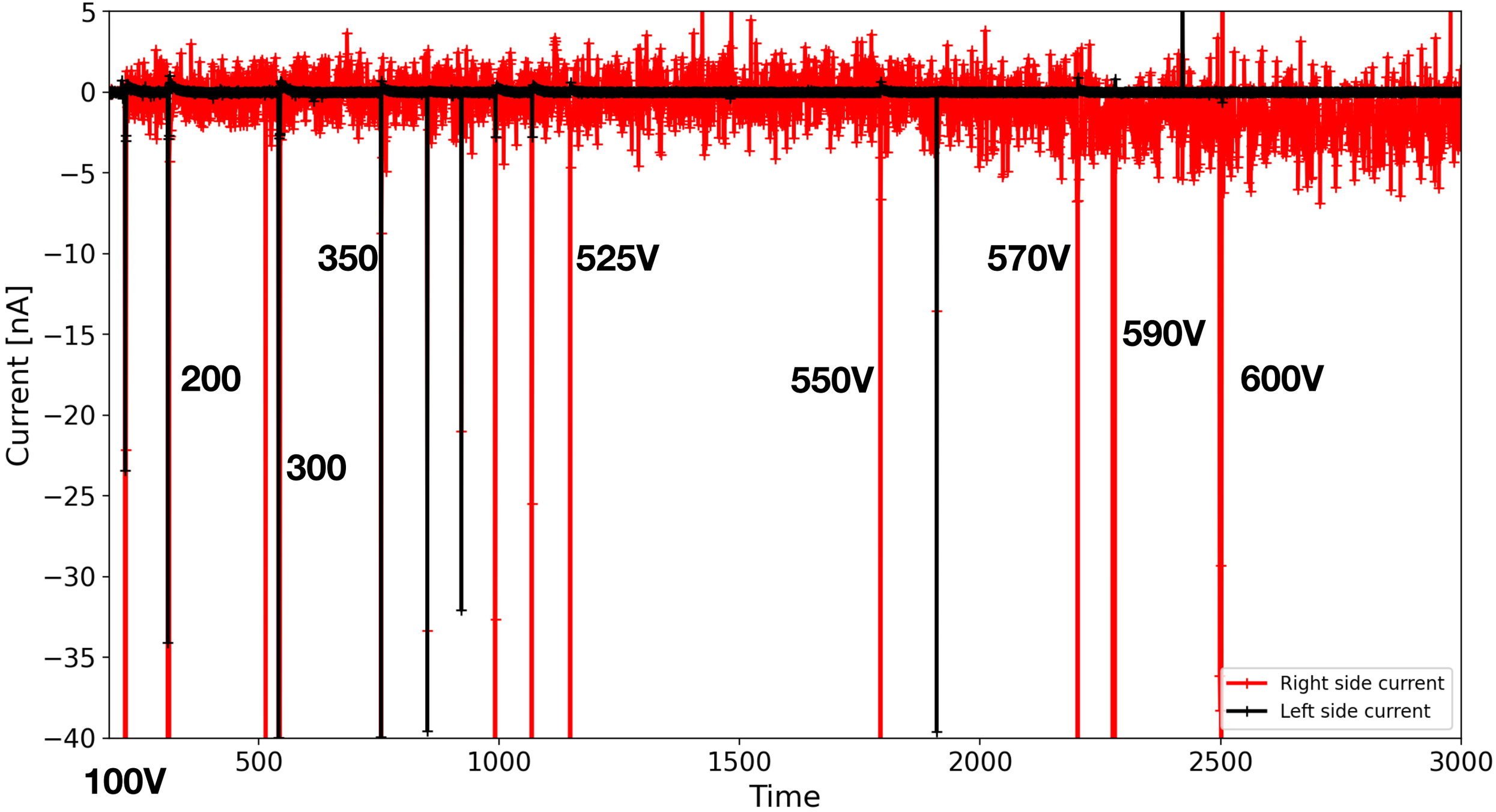
finished

Initial HV Testing of Prototype



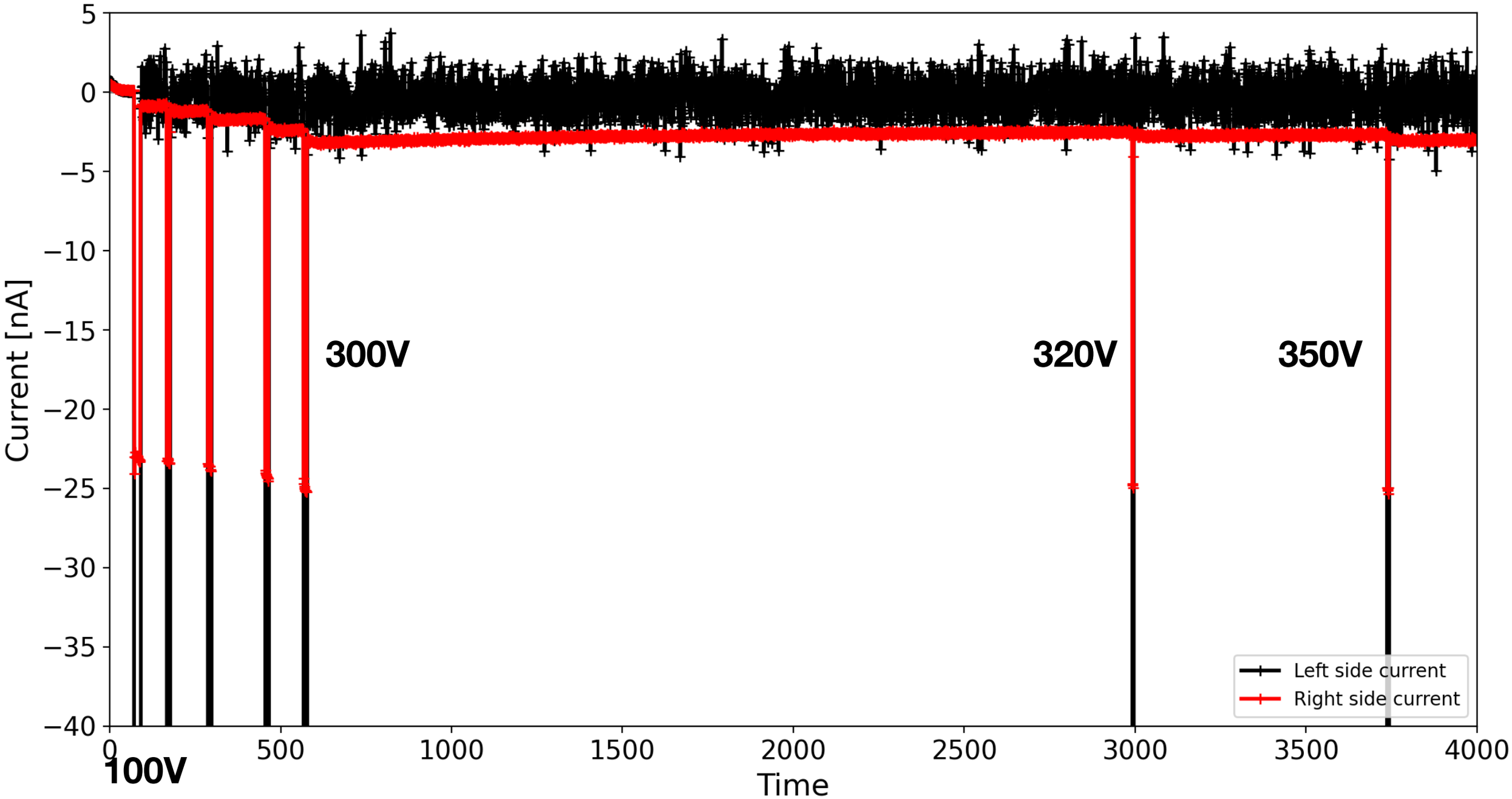
- **Gas in μRWELL: N2**
- **Slow increase of HV up to 600V with observation of currents.**
- **Expect leakage currents ~1-2nA**

Scan with HV on Right side



- **No current on left side as expected**
- **Leakage current on right side around 1-2nA above 550V**

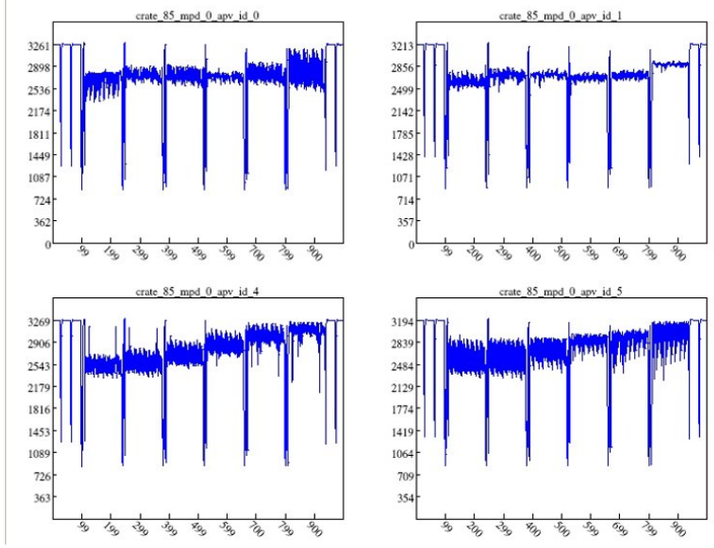
Scan with HV on Left Side



- **No current for left side**
- **Significant current for right side (did not want to go higher)**
- **Explanation: Leakage around the separation in the middle of detector**

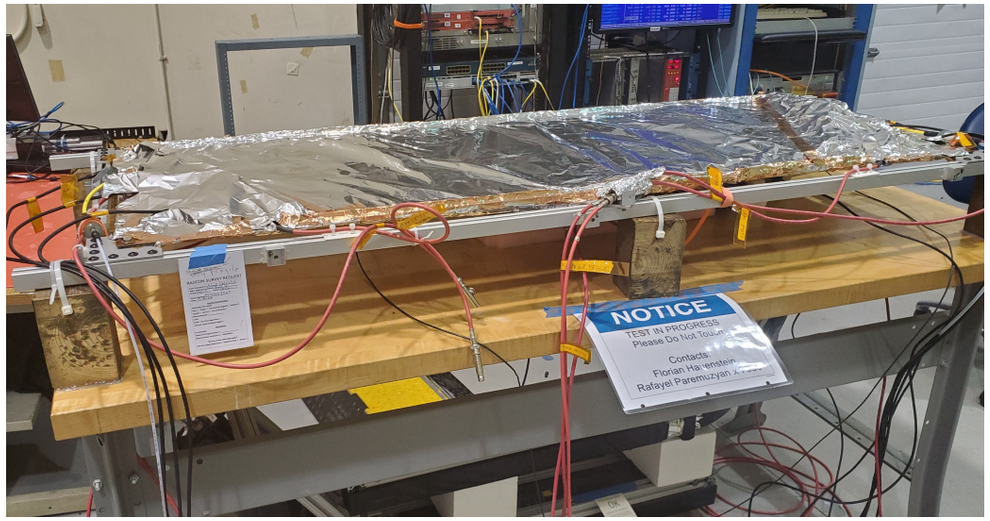
Further Issues resolved

- **Noisy readout**



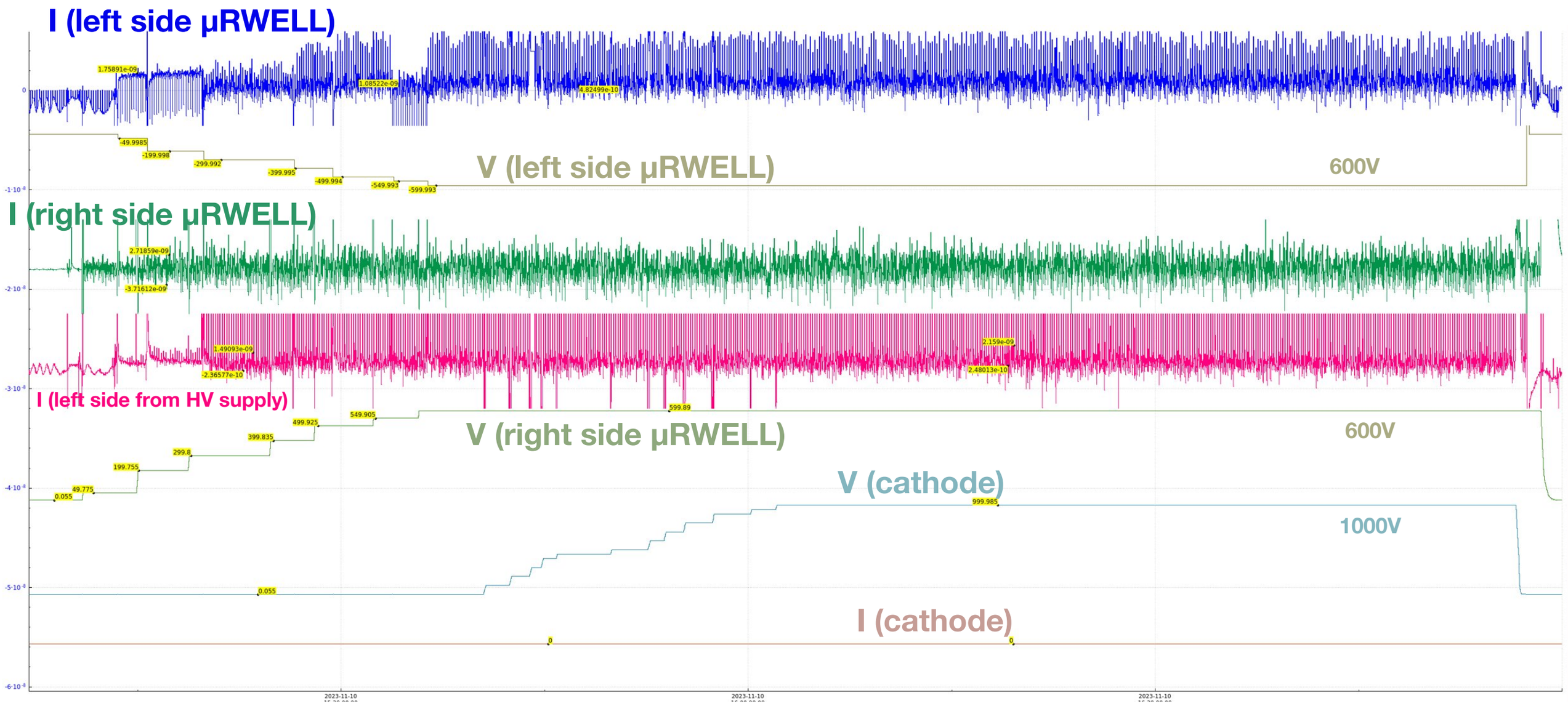
fixed with

- **Al wrapping (faraday cage)**
- **HV filter box**



- **High noise with ammeters connected —> data taking without them**
- **Bubbles at gas exhaust —> leak check and seal**
- **Detector back at CERN during summer**
  - **fix of leakage issue**
  - **long electrical cleaning by Rui**

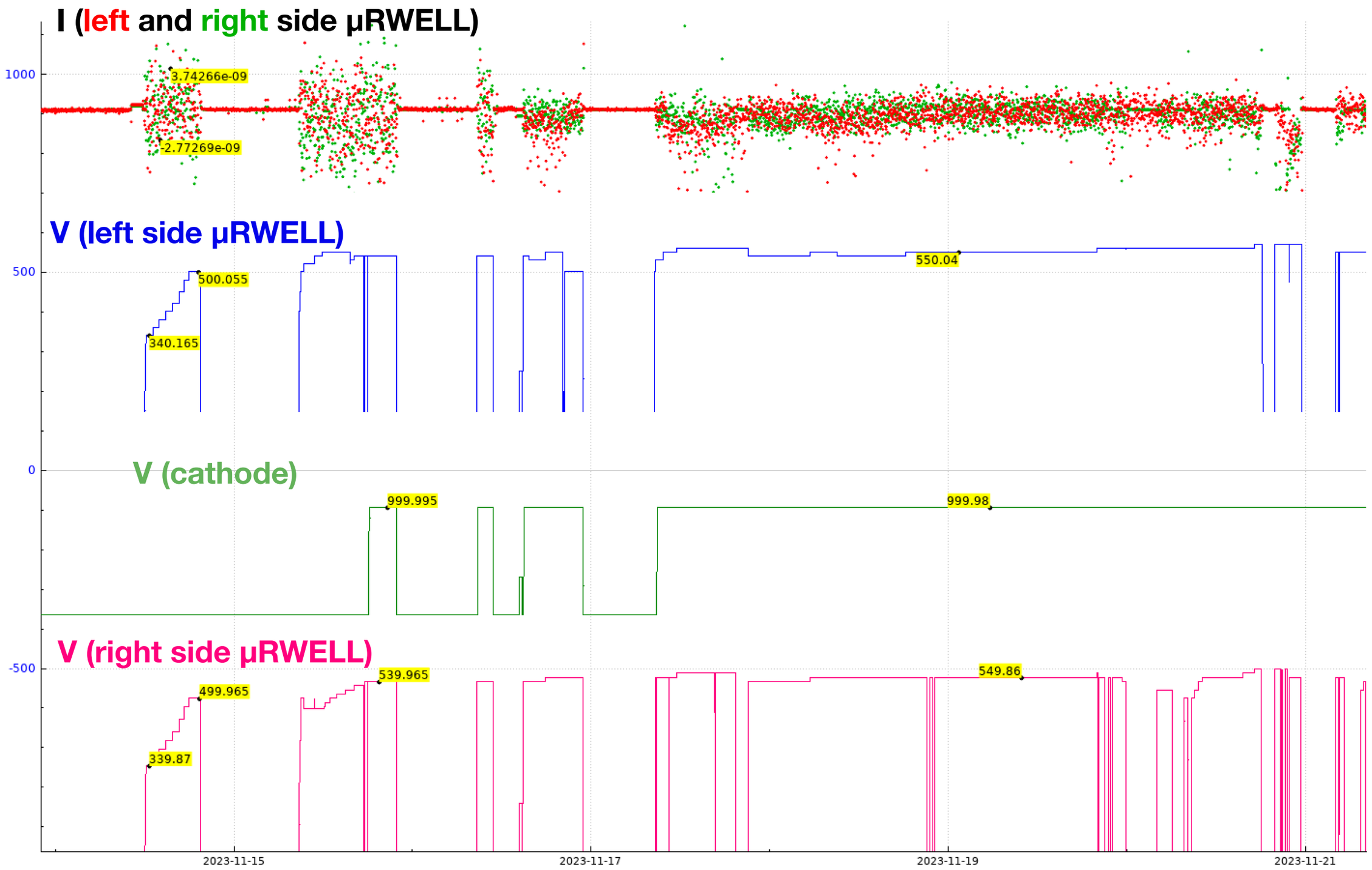
HV Test with Dry CO_2



- **µRWELL on both sides ramped up to 600V**
- **Cathode ramped up to 1kV**
- **Results:**
  - **currents fluctuating within +/-2nA**
  - **very stable operation under CO_2 for hours and days**

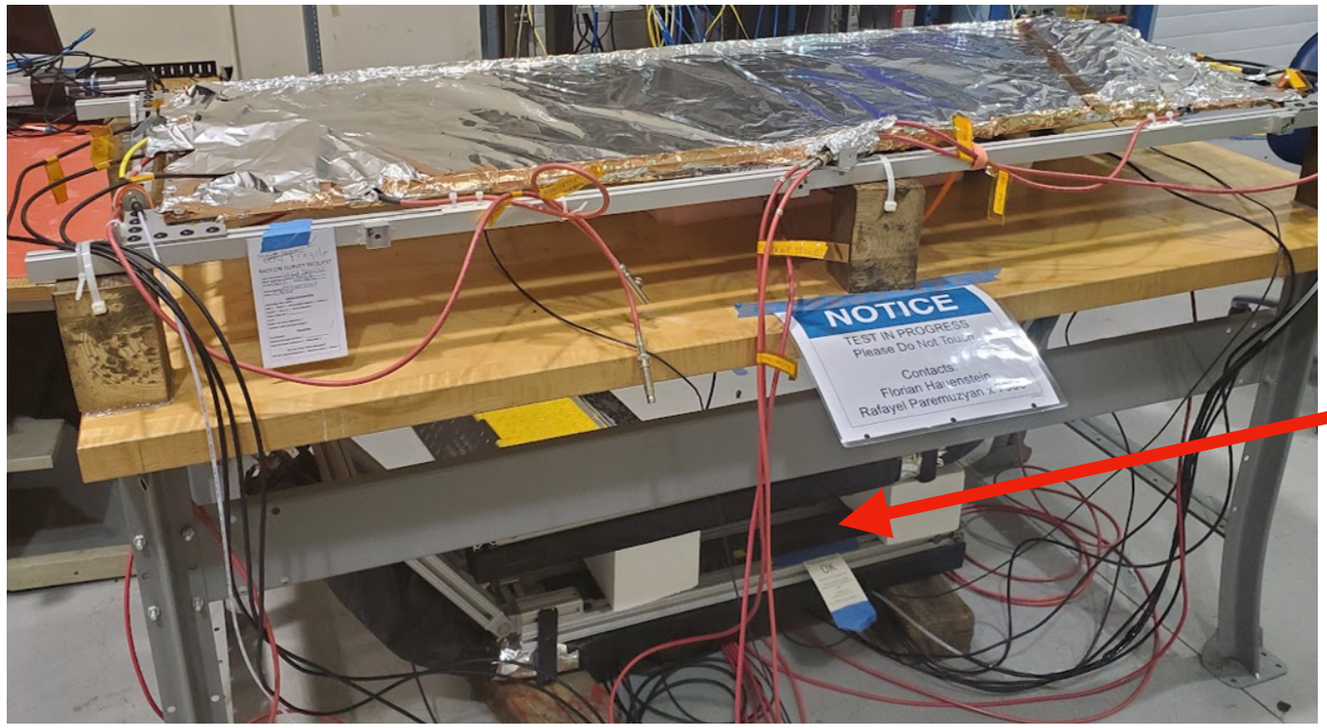
Note: the fluctuations on the left side current measurements are just due to a device issue and not real

HV Test with Ar:CO_2 (80:20)



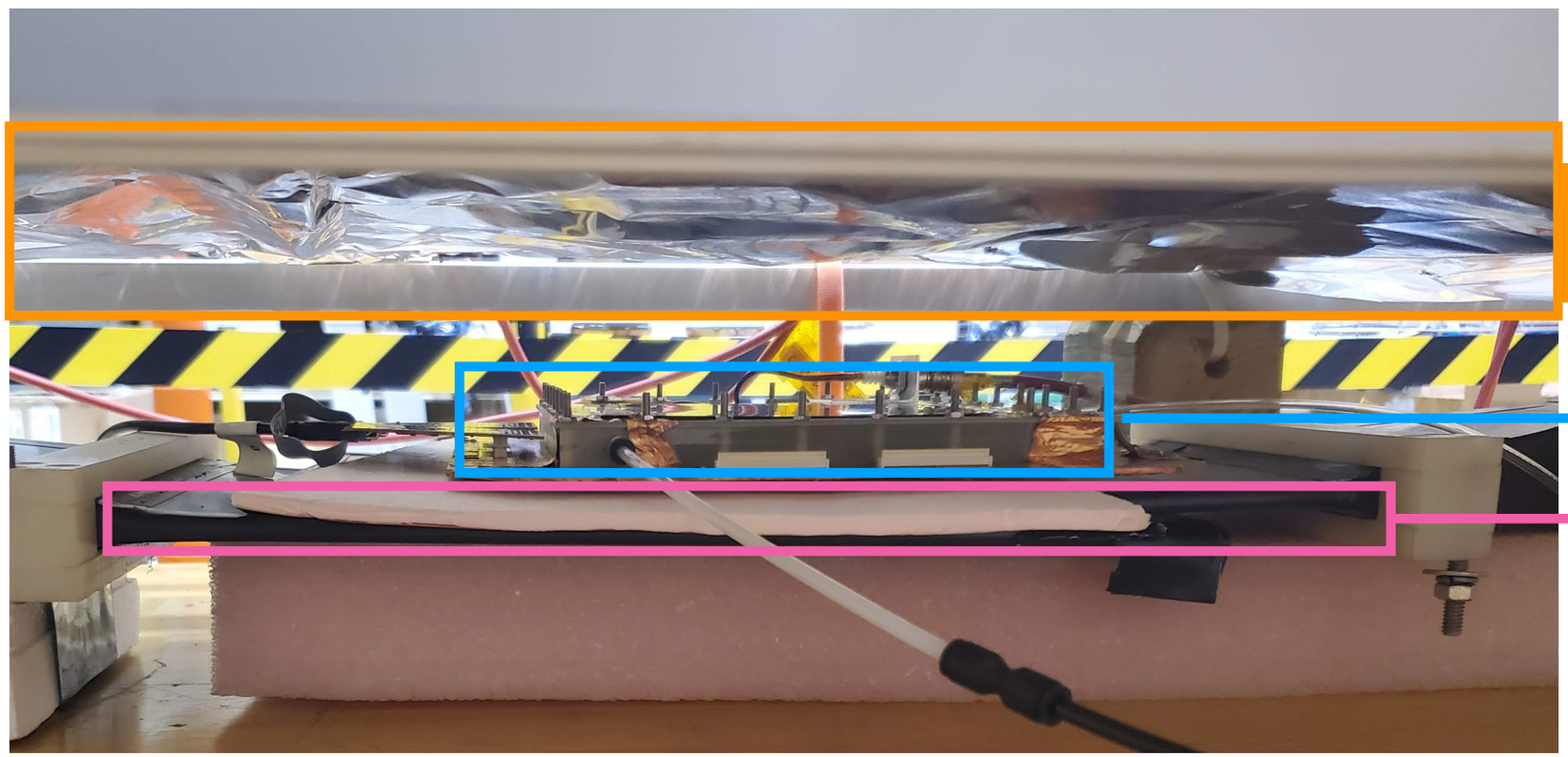
- **stable operation**
- **leakage currents <2-3nA up to 550V on µRWELL and 1kV on cathode**

Test Setup for Cosmic

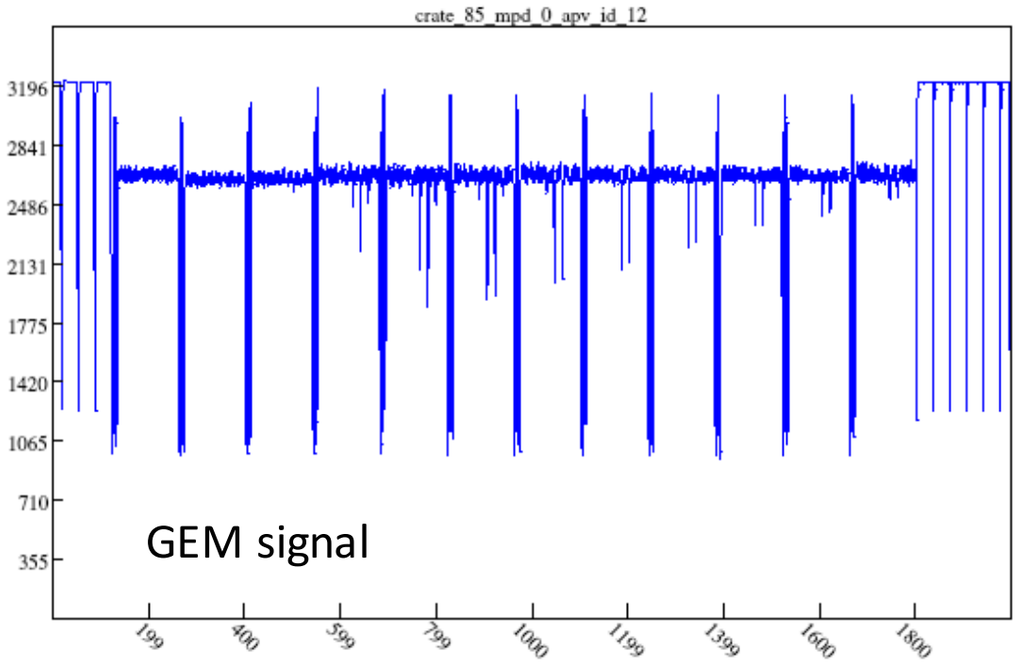


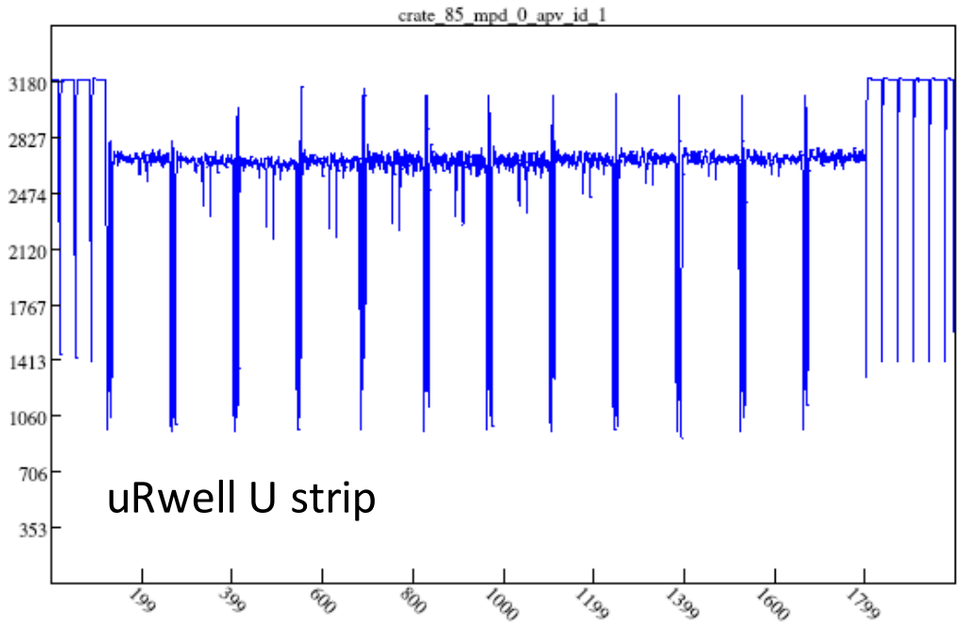
Pair of scintillators for trigger (covering whole detector)

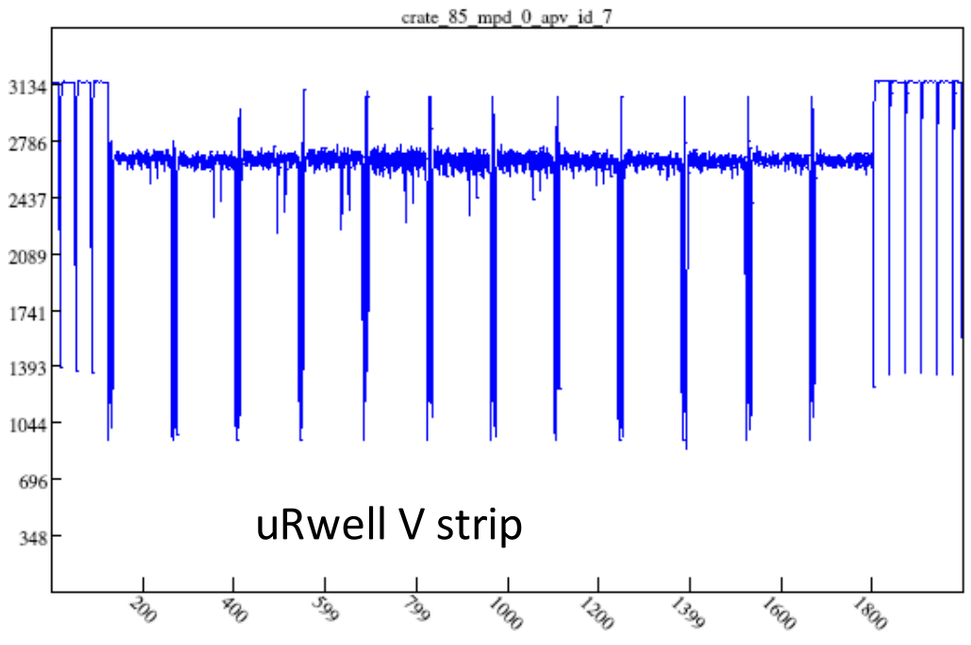
on the table under μRWELL



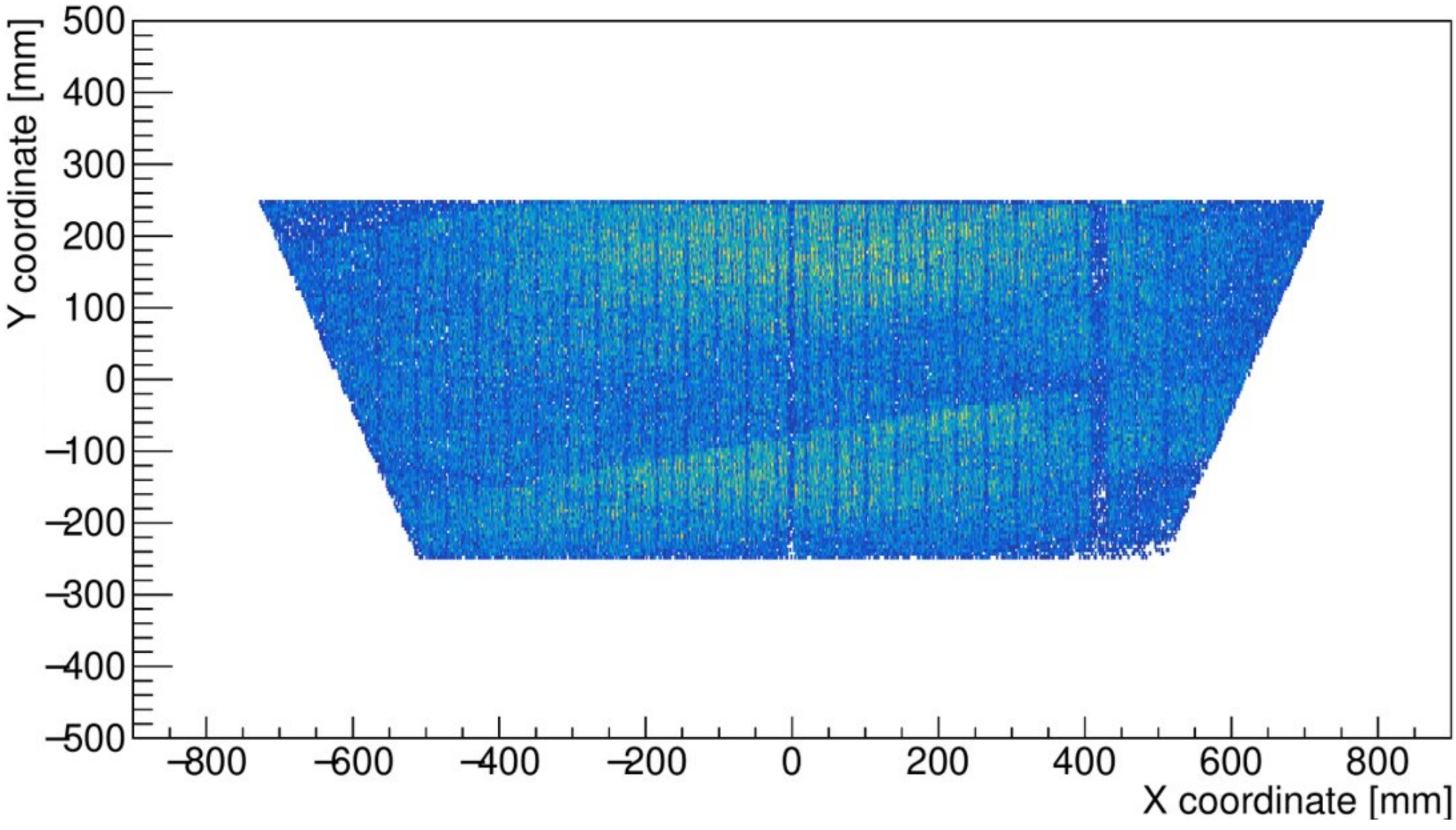
Cosmic Signal with uRWELL and GEM





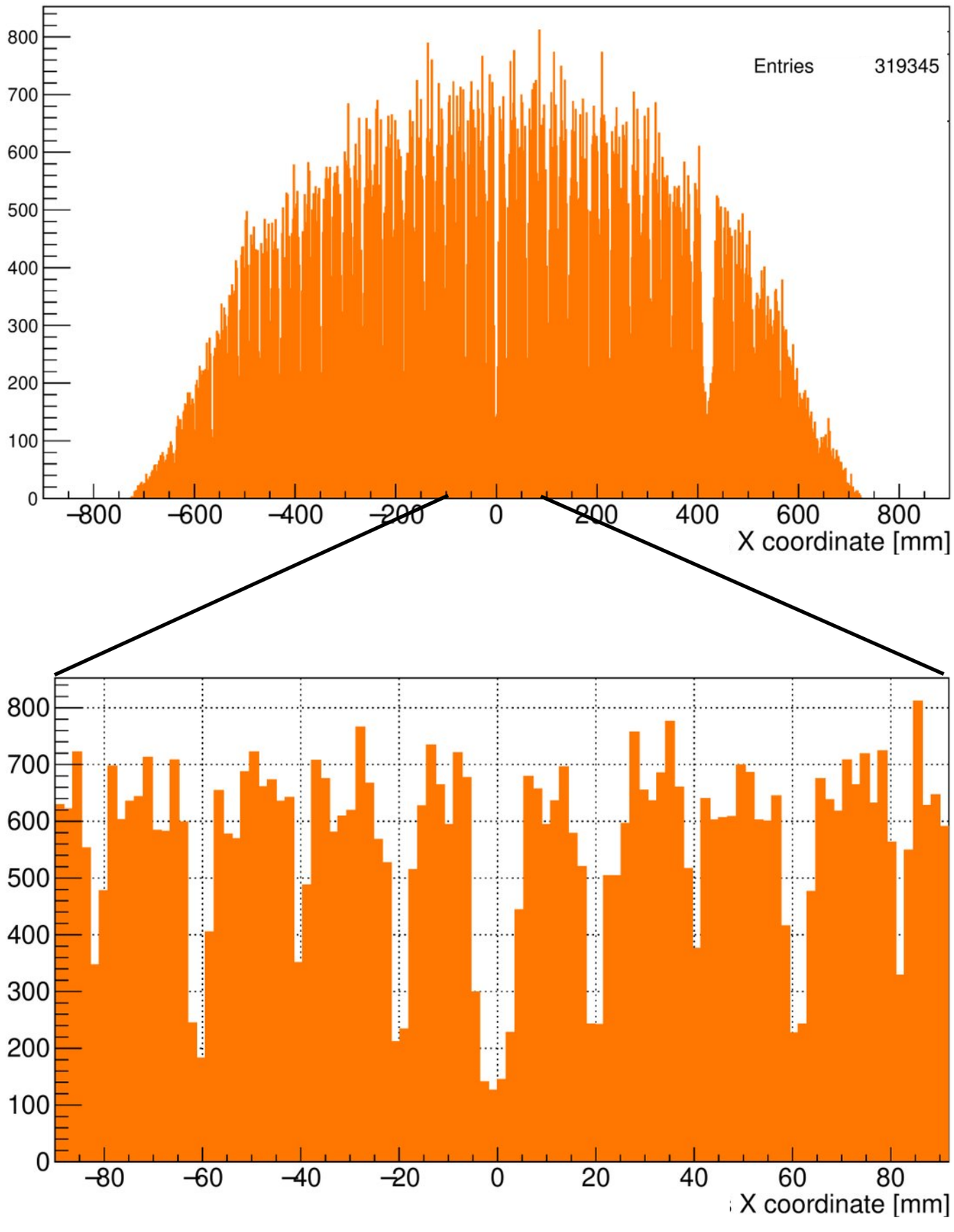


2D Hit Distribution - Detector works!

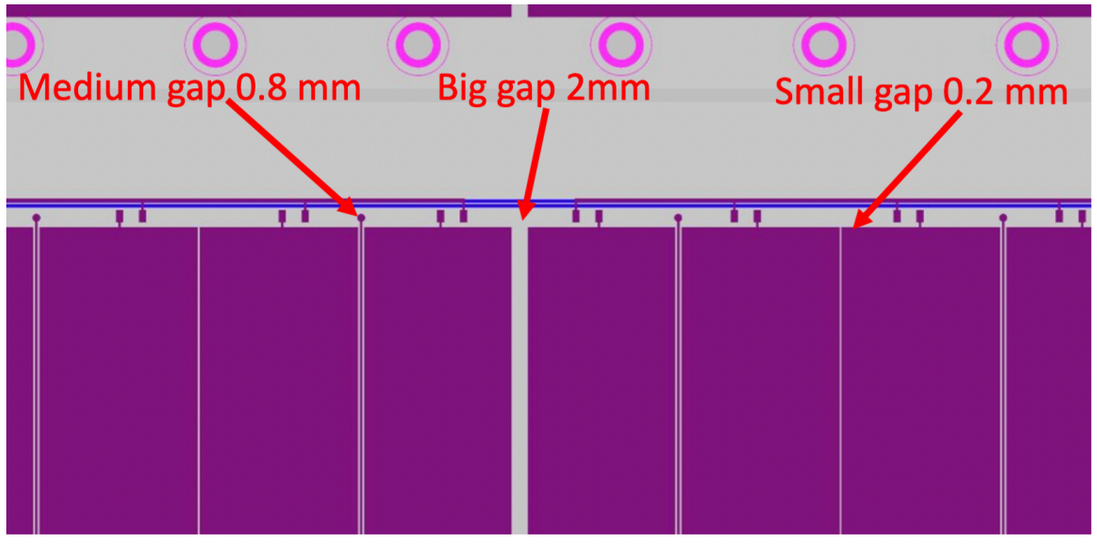


- **μRWELL at 570V, cathode at 1020V, Ar:CO_2 (80:20)**
- **Substructure from strips, HV segmentation and APVs visible (more statistics needed for detailed study)**

1D X-Distribution - HV sections visible!



- **Dip structure from gaps in foil between HV sections**
- **Width of gaps follow drawings**

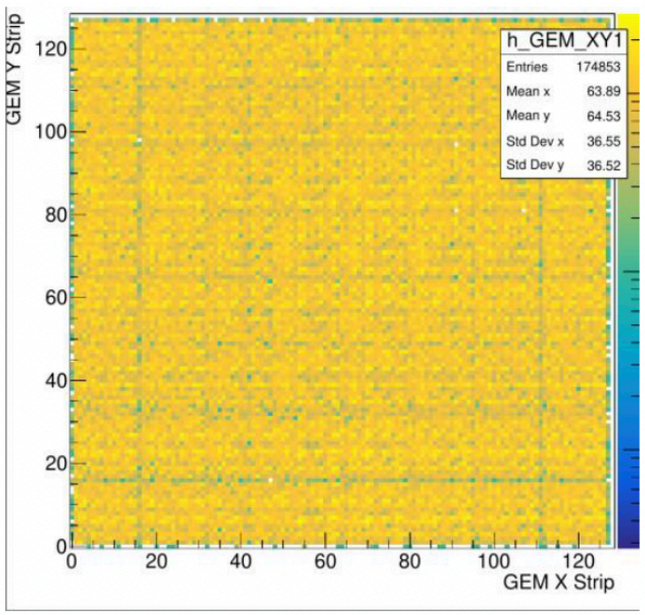


Analysis Procedure for (Relative) Efficiency

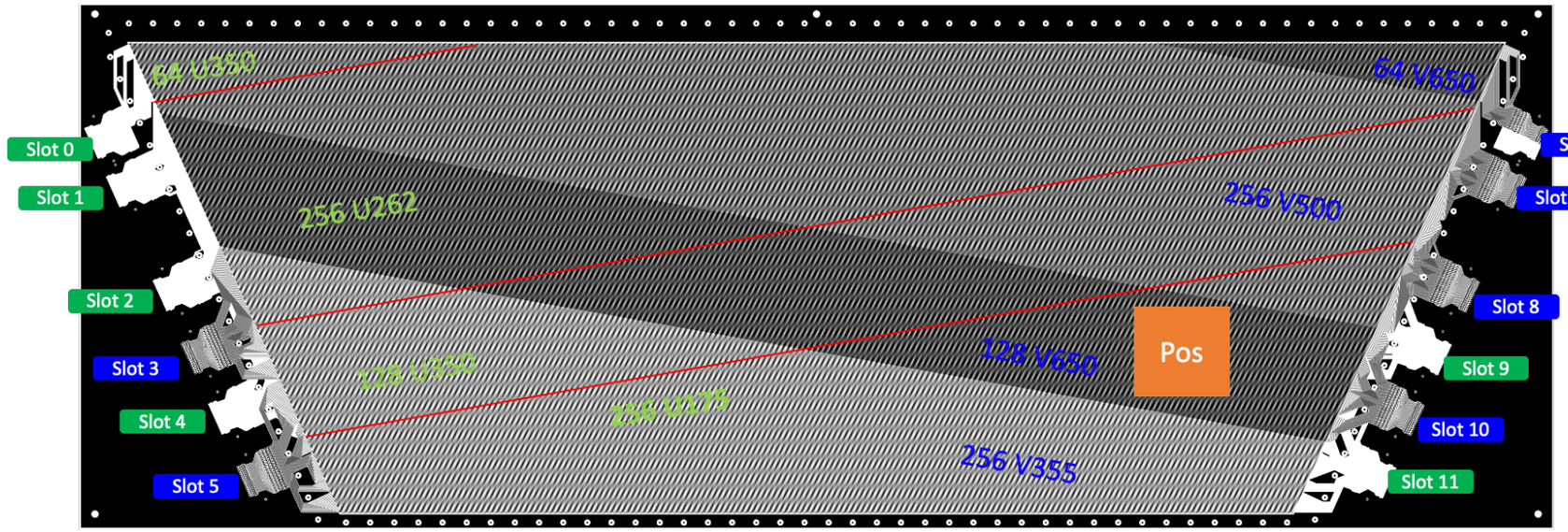
- **Pedestal run to determine noise and pedestal level per channel**
- **Signal in strip selected as x-σ away from pedestal**
- **Analysis selects cluster with at least 1 or 2 hits depending on σ-cut**

- **Efficiency determined with events which have hits in GEM and top scintillators —> GEM moved around to measure different μRWELL areas**

GEM XY distribution uniform as expected!



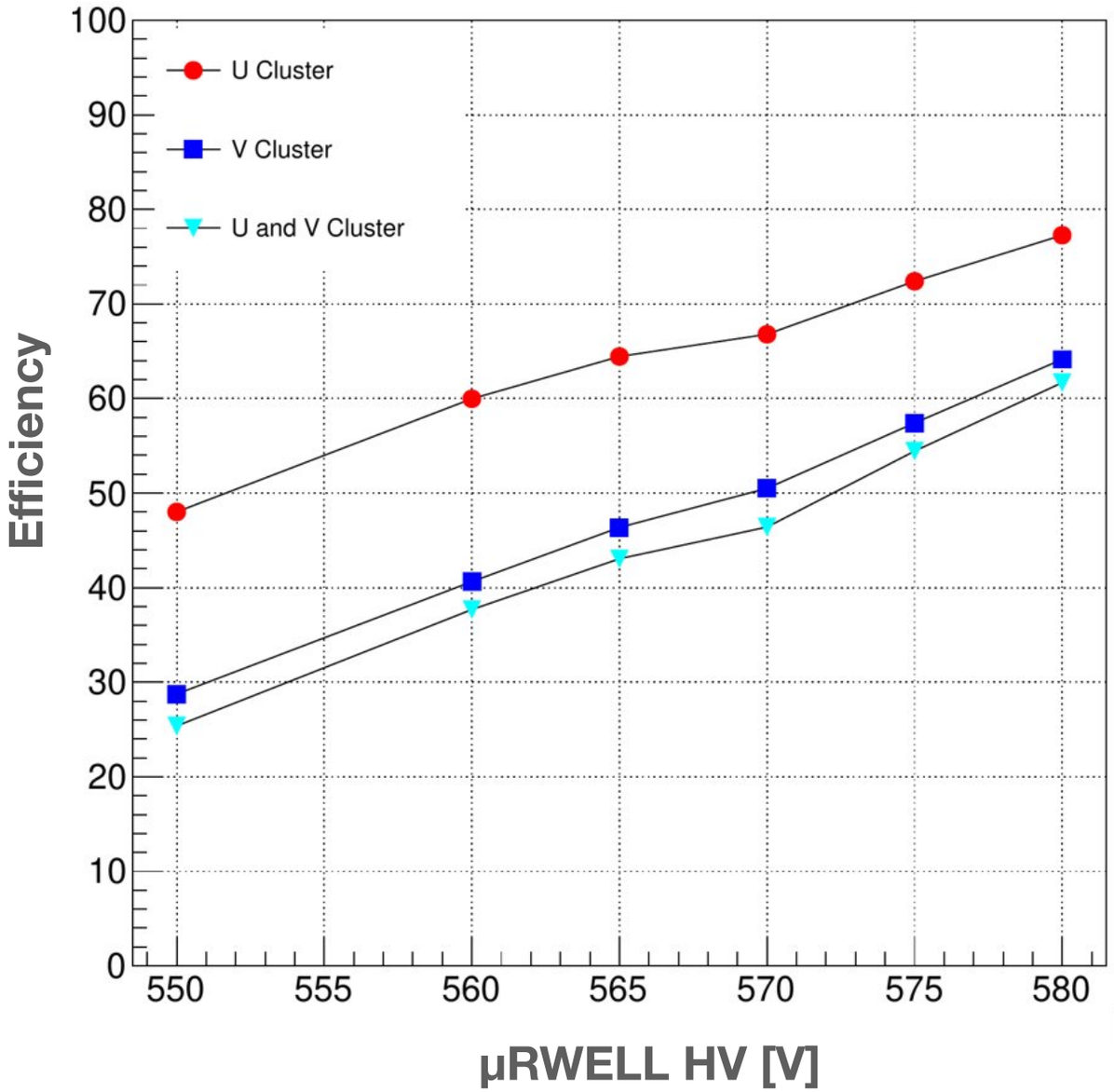
Position for efficiency measurement



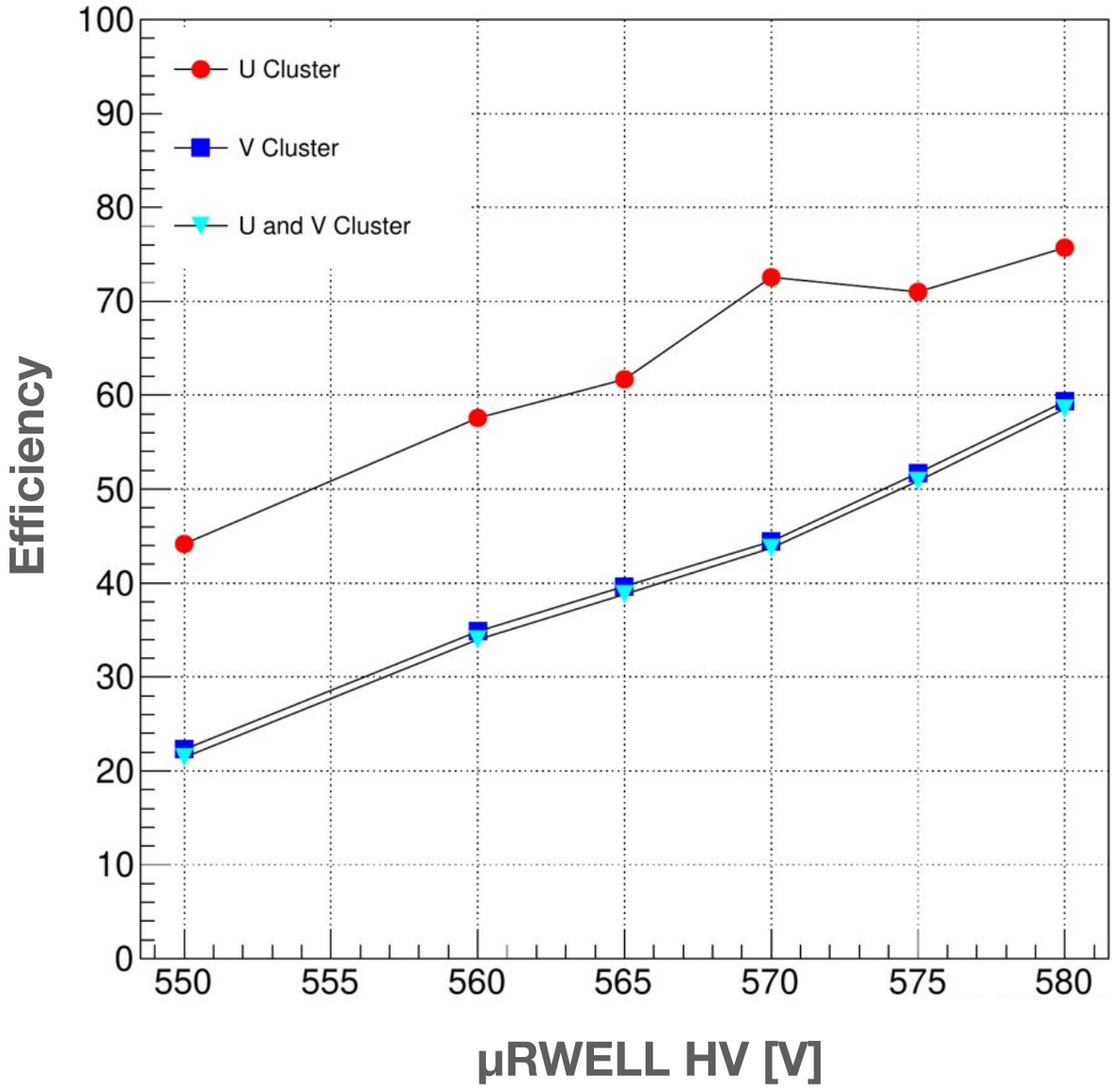
Efficiency Results

Ar:CO_2 80:20, Drift voltage 450V over μRWELL for each point

3σ, cluster with at least 2 hits



5σ, cluster with at least 1 hit

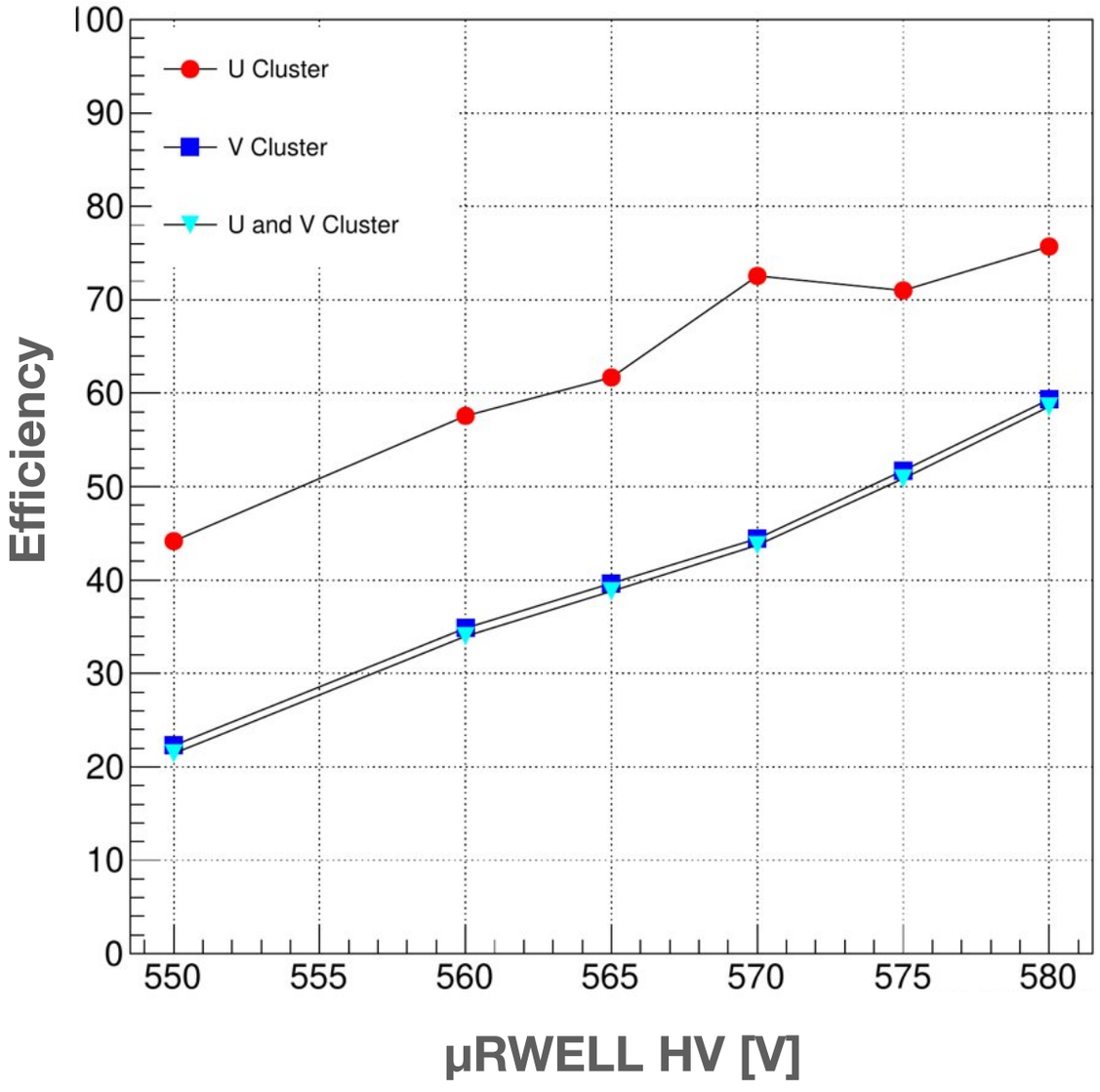


- **Increase of efficiency with voltage as expected**
- **More events have U and V cluster with 5σ cut**
- **Efficiency caps at around 80%, more events with U clusters only**

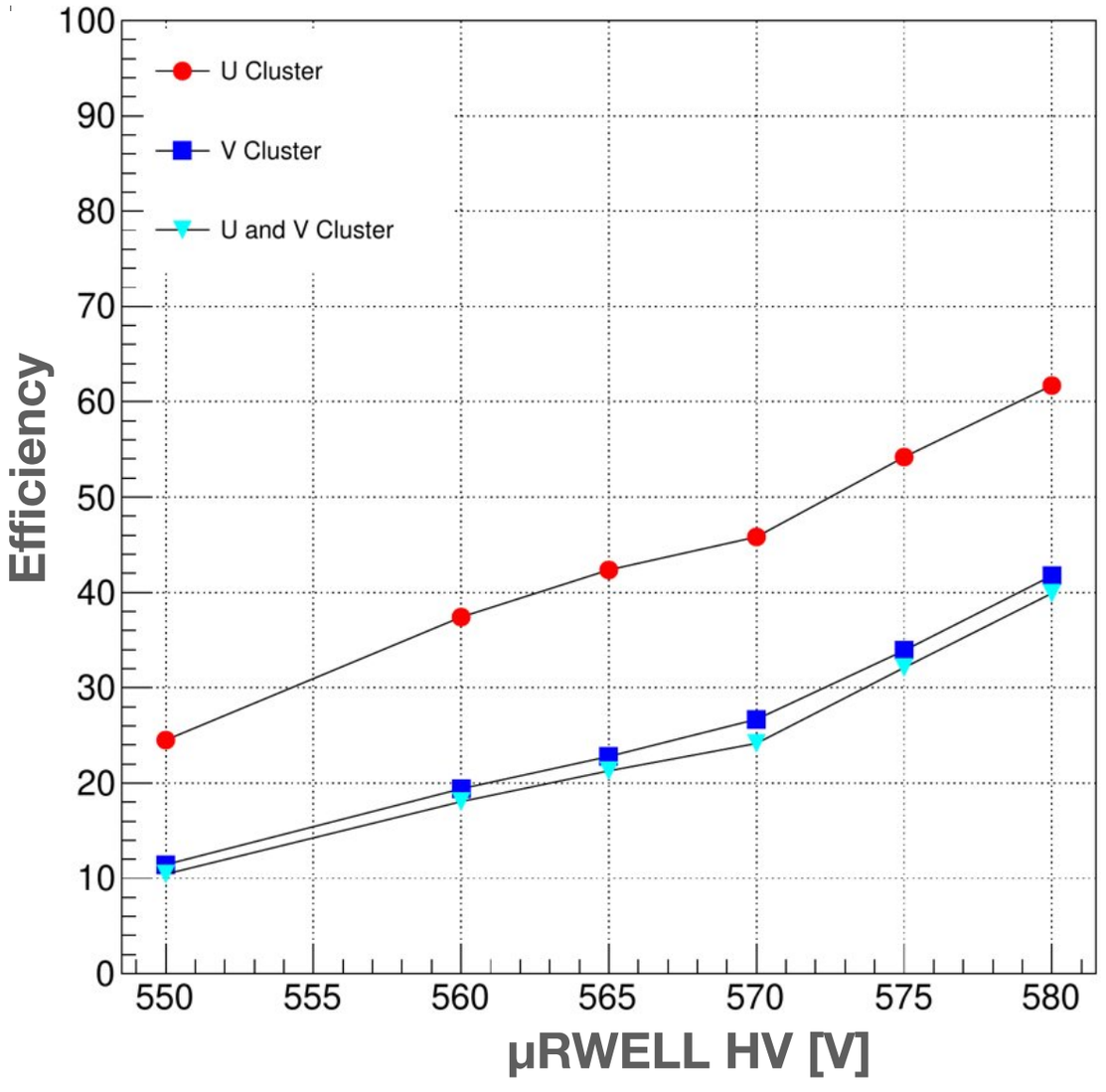
Efficiency Results

Ar:CO_2 80:20, Drift voltage 450V over µRWELL for each point

5σ, cluster with at least 1 hit



5σ, cluster with at least 2 hit



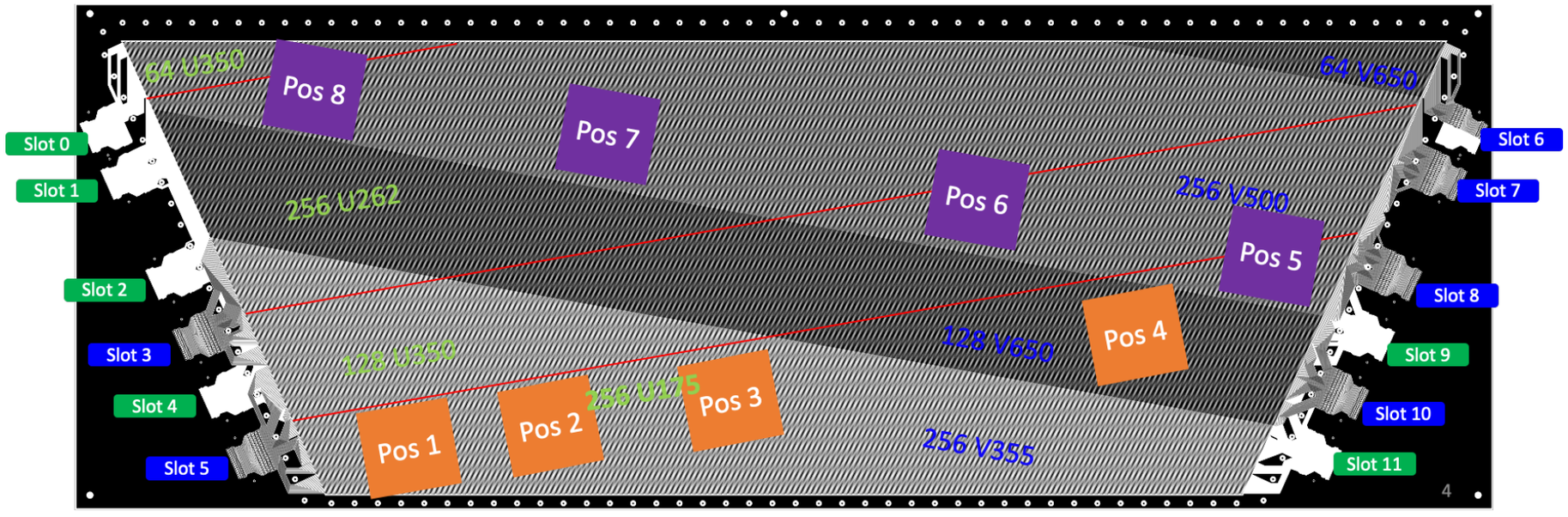
- **Cleaner events with 5σ and at least 2 hits**
- **But much lower efficiency (as expected)**

Conclusions and Next Measurements with Prototype

- **Detector operation is very stable!!!**
- **Initial issues resolved —> full detector is operational and collects data**
- **First measurements done with different μRWELL HV**

Planned measurements:

- **Efficiency scan with different cathode HV**
- **Position scan**



- **High statistics data of whole detector —> understand effect of different width**
- **Measurement with VMM3 instead of APV**
- **Study of other gas mixtures (Ar:CO_2 and Ar:C_4H_{10})**
- **Improve test setup with scintillator hodoscope**

Thank you

- **Large contribution from Nilanga Liyanage's group at UVA to the prototype**
  - **Huong, Minh and Bashita for the construction (cathode and frames)**
  - **Salina for the design work of the detector frames**

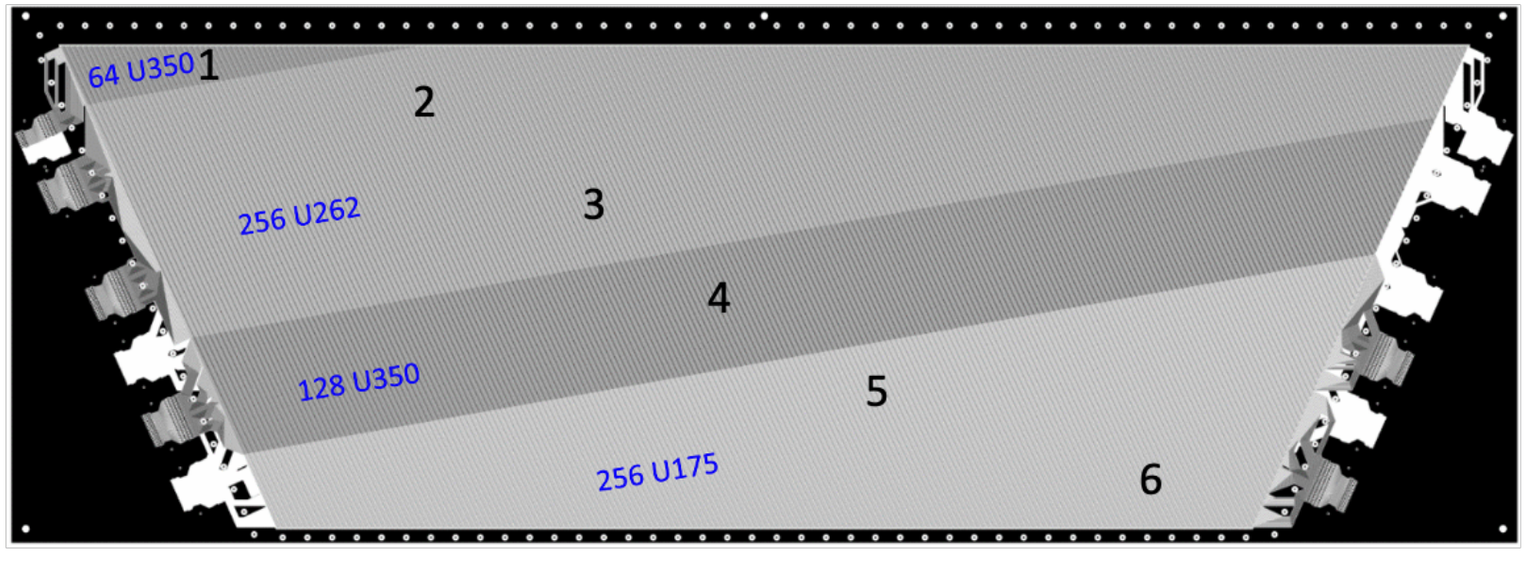
- **Rui, Bertrand and others at CERN for designing and building the so-far largest μRWELL foil (and answering our millions of question :))**

- **The technicians and engineers at Jefferson Lab for providing support in the testing of the detector**

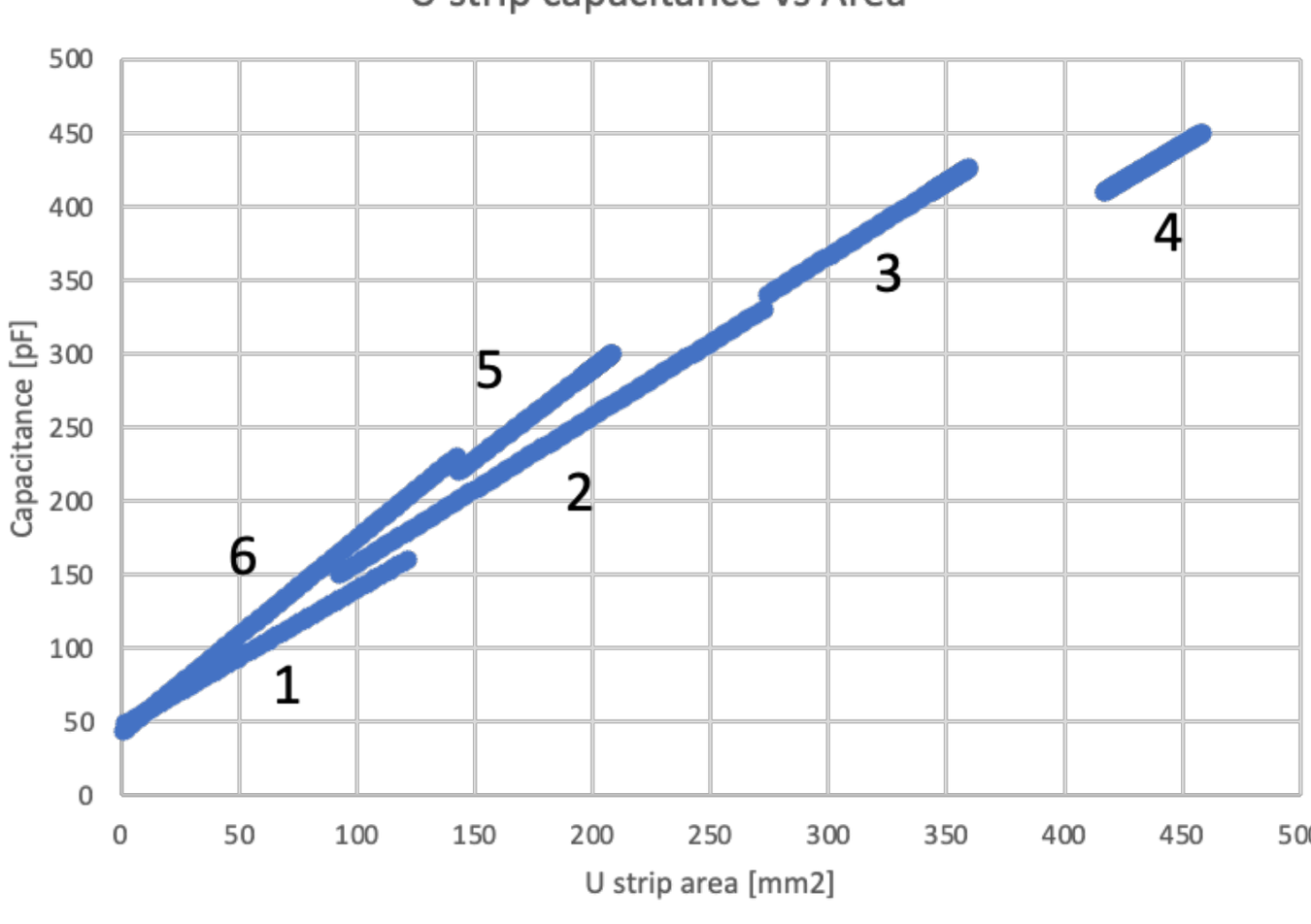
Questions?

Backup

U strip capacitance

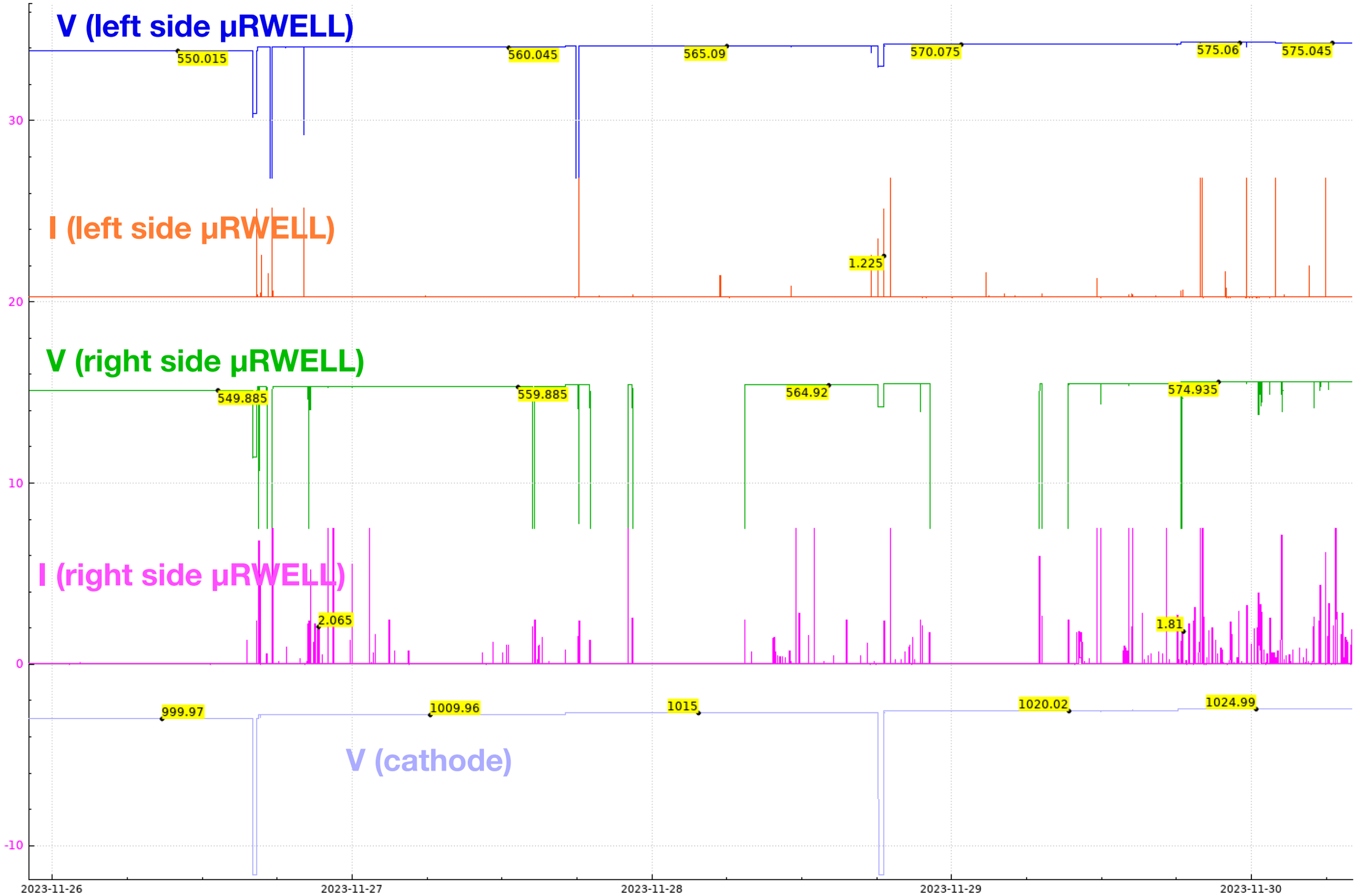


- **Capacitance is high - typical values for GEMs with APV readout are 100-200pF —> could explain lower overall efficiency —> loss of signal to noise**
- **More studies underway**



Plot by Rafo

HV Test with Ar:CO_2 (80:20)

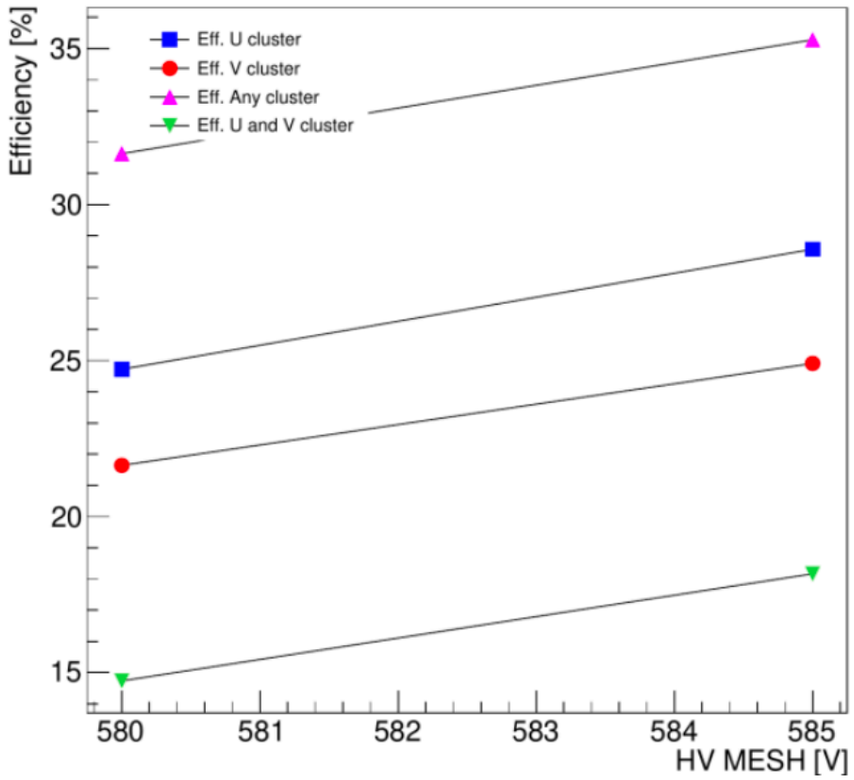


- **stable operation when slowly going up to 575V on µRWELL**
- **more activity for right side then left side**

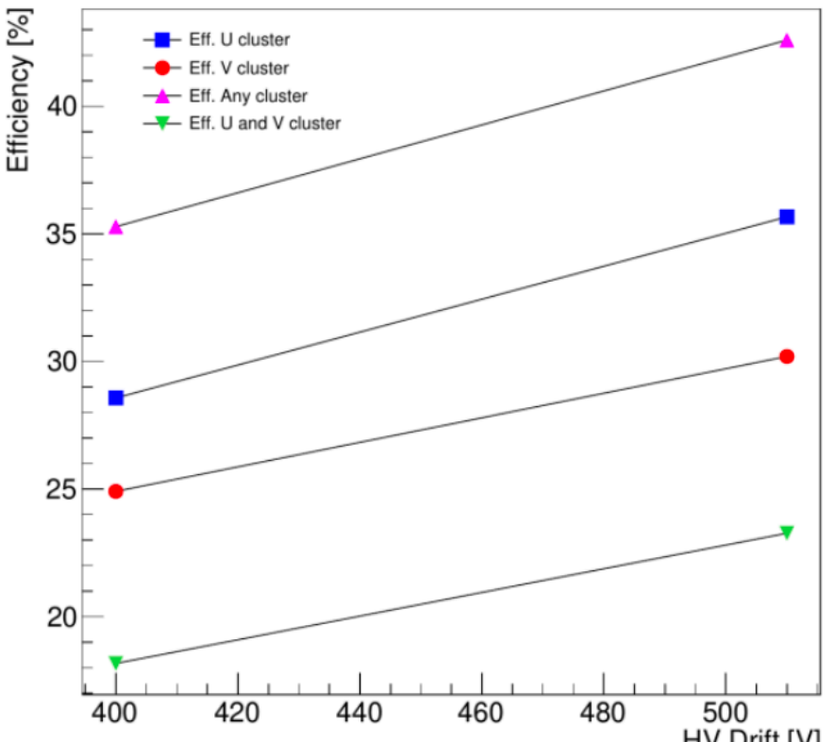
Old Efficiency Results

Ar:CO_2 75:25

Drift Voltage = 400 V

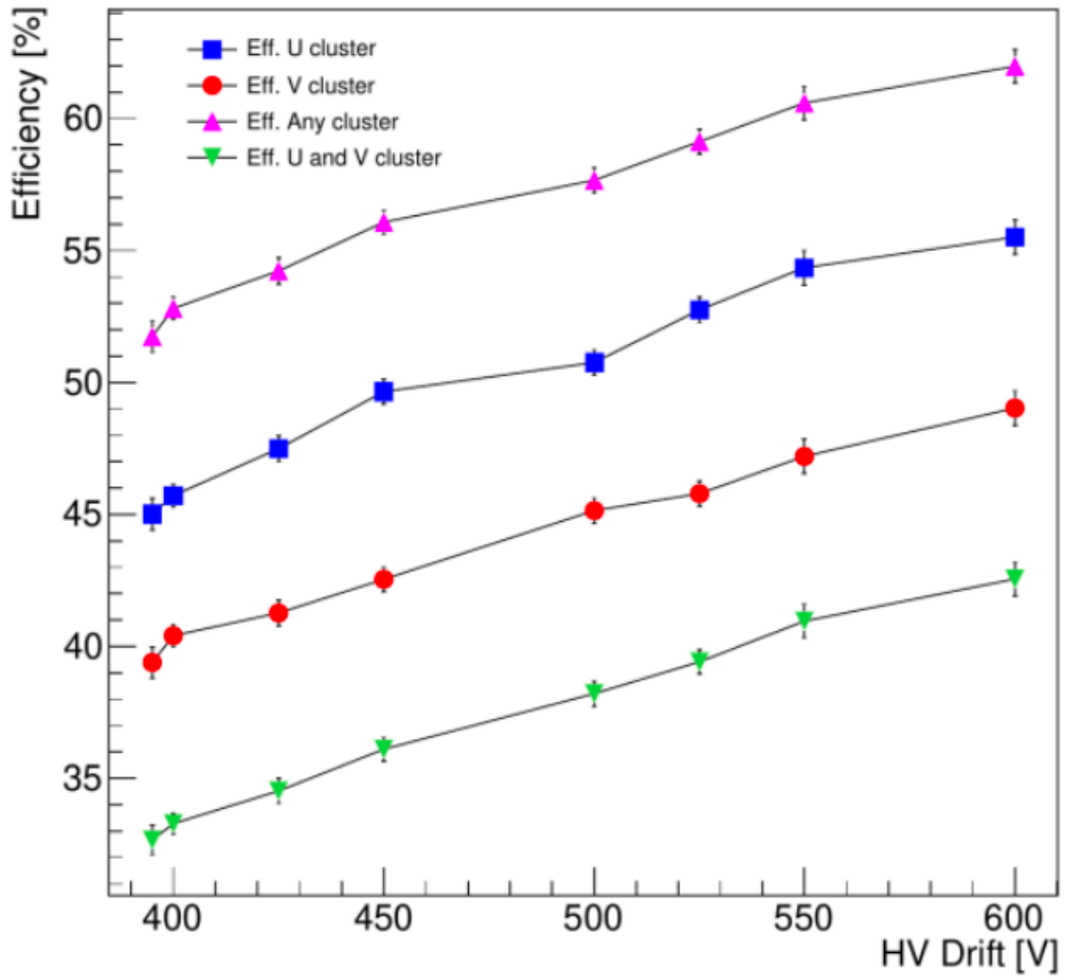


MESH HV = 585 V



Ar:CO_2 80:20

MESH HV = 575 V

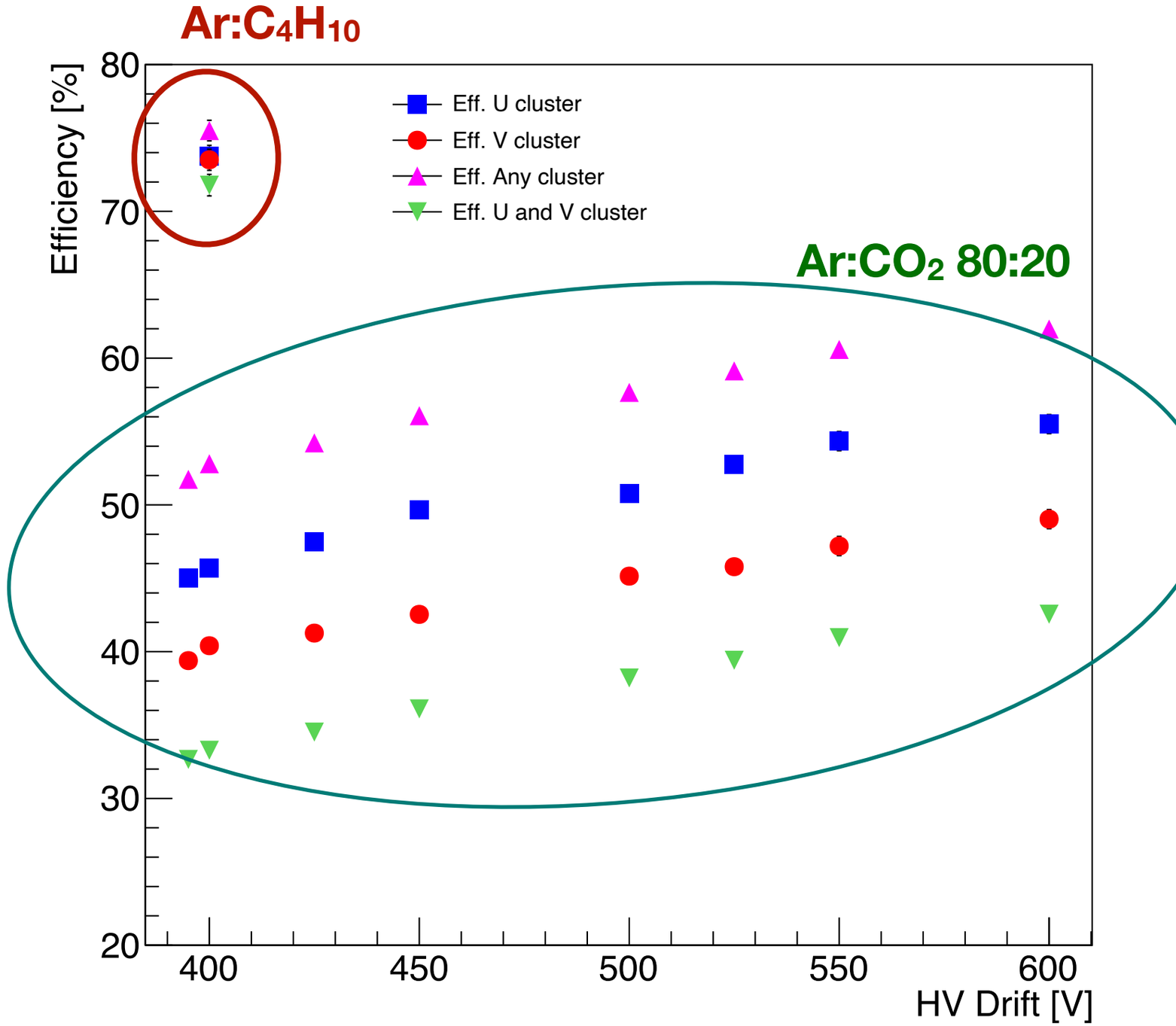


- **Larger efficiency for 80:20 due to more gain**
- **Difference between U and V efficiency**
- **Expected efficiency >90%!**

Old Test with $Ar:C_4H_{10}$ (Isobutane) 90:10

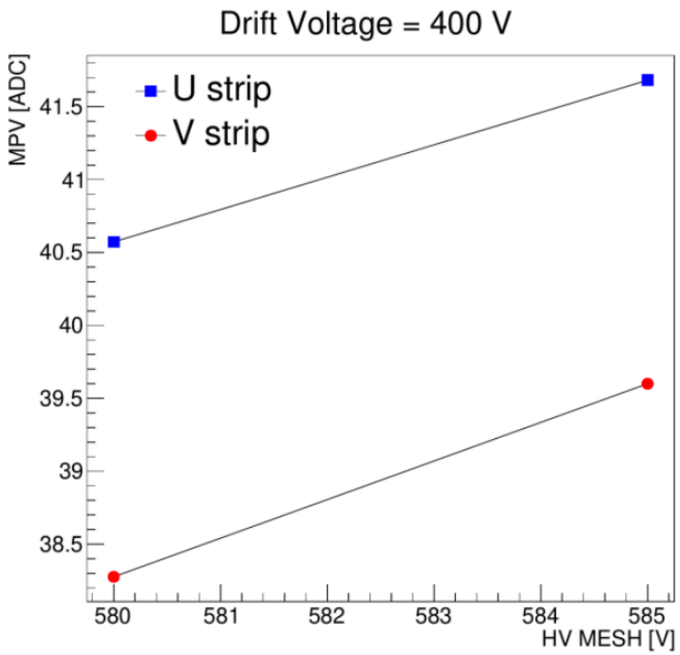
- **Mesh HV**
  - **575V for $Ar:CO_2$**
  - **500V for $Ar:C_4H_{10}$**

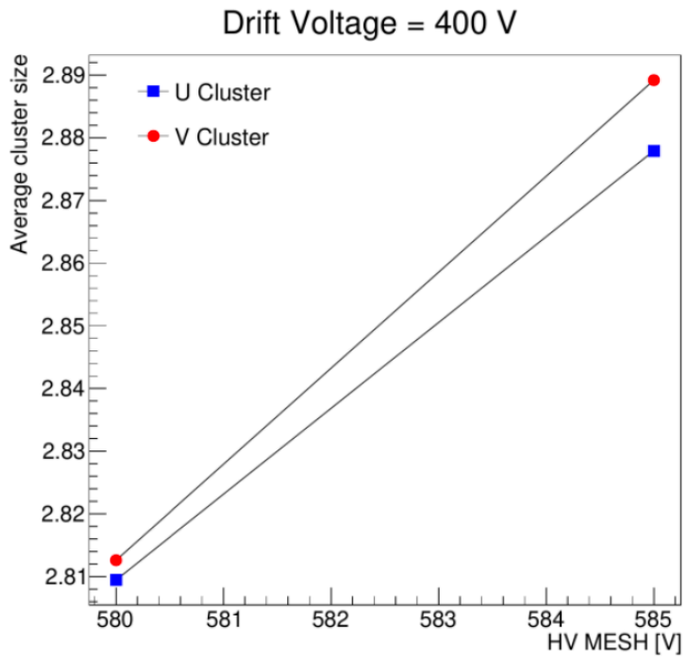
- **Result with $Ar:C_4H_{10}$**
  - **~2 times larger efficiency**
  - **U and V similar**
  - **BUT: unstable operation**

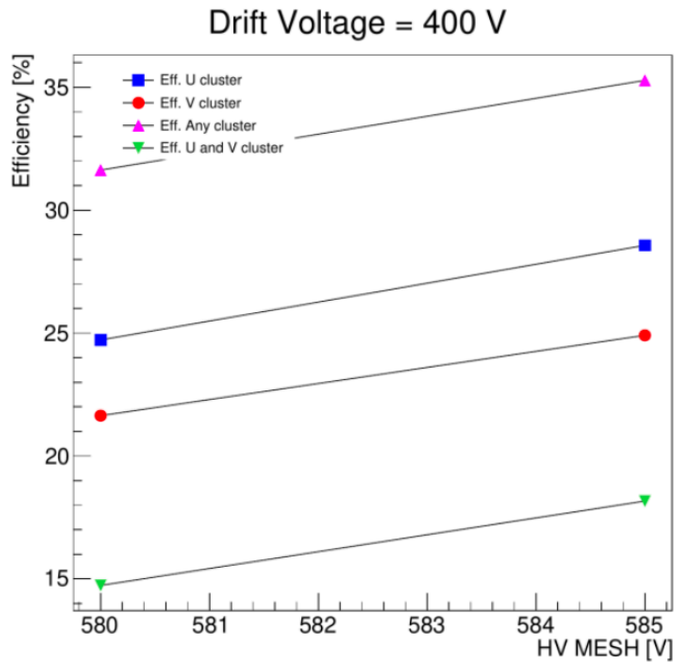


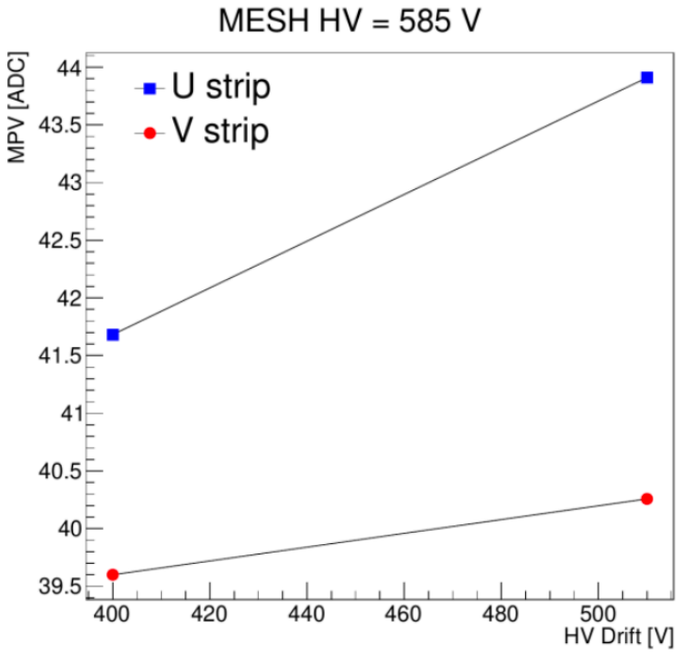
- **Note: No more measurements with different gas because detector was sent back to CERN for repairs (see later slide)**

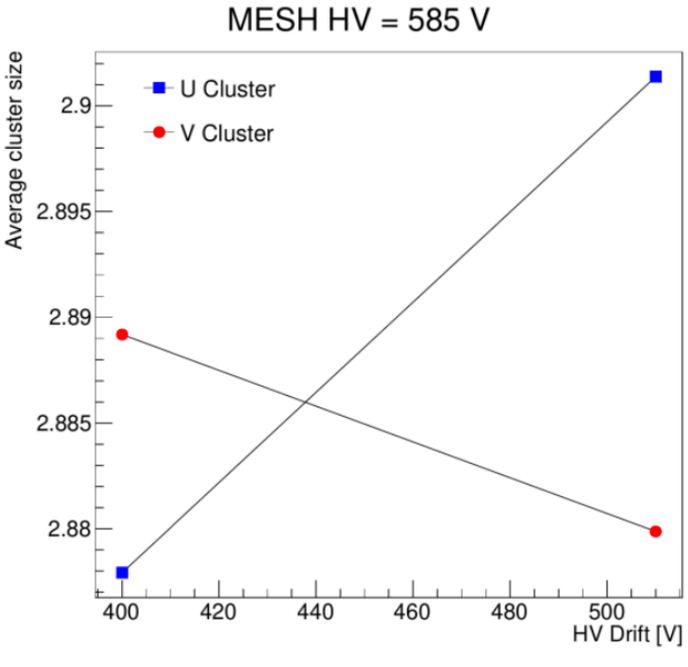
Old Results Ar/CO2 75:25

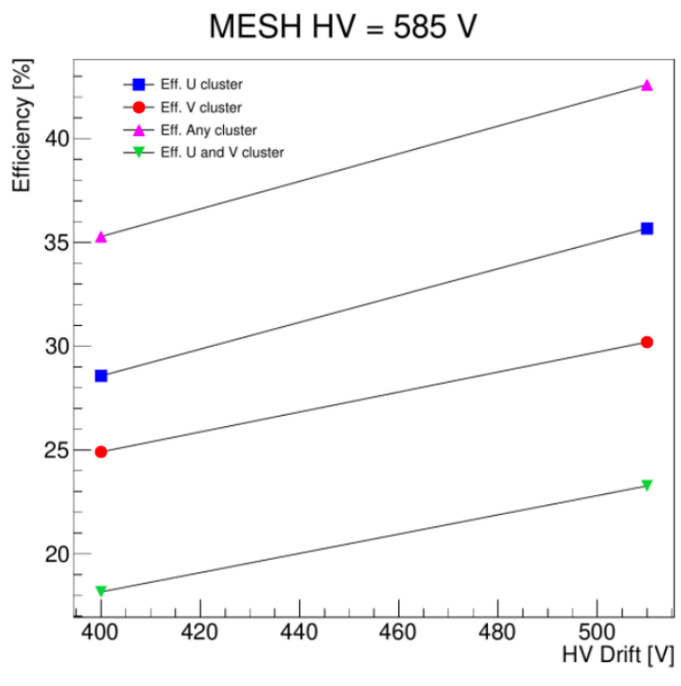












Old Results Ar/CO2 80:20