Update from CLAS12 High-Luminosity TF

Florian Hauenstein
Nov 10, 2023
CLAS Collaboration Meeting

Why Higher Luminosity

Proposal Expectations

- $10^{35}cm^{-2}s^{-1}$ luminosity
- 100% detection efficiency
- Full geometric acceptance

Reality

- Lower luminosities due to DC occupancies —> lower track efficiency
- Less than 100% efficiency
- Acceptance gaps

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- 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

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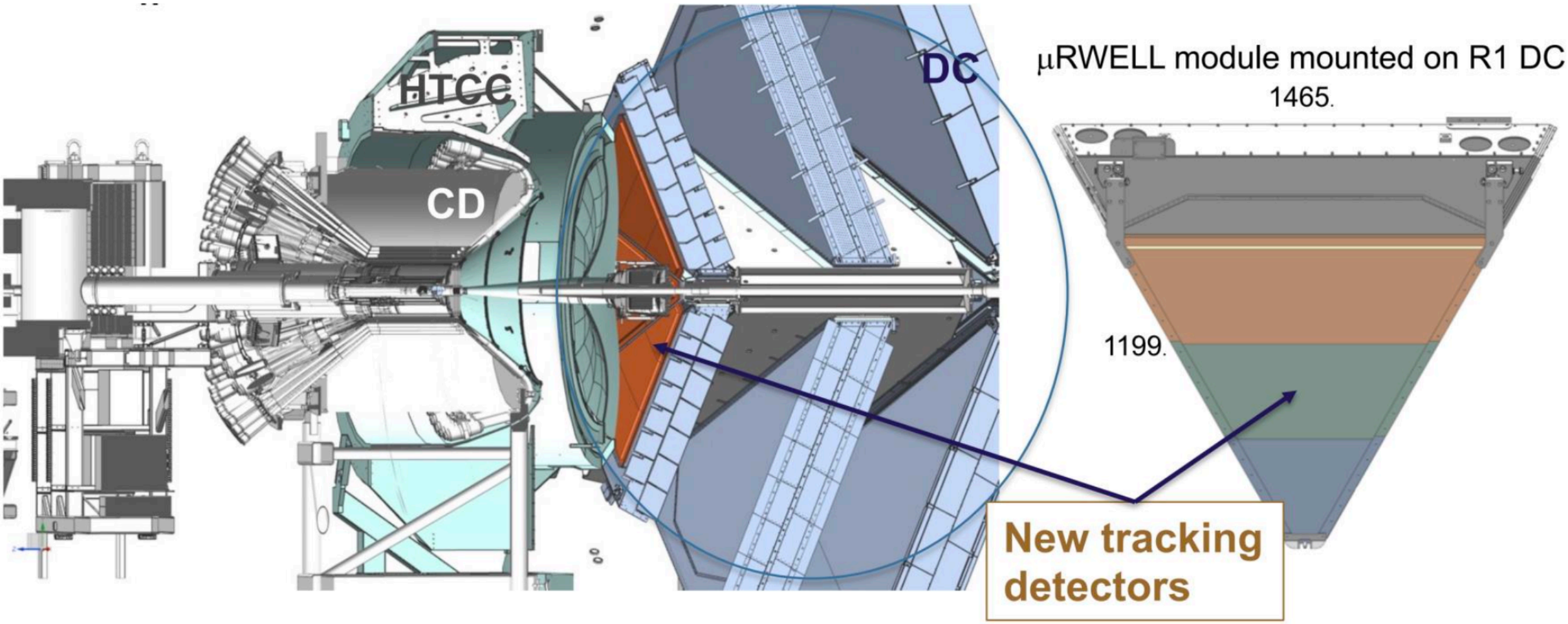
- **Phase-1 Upgrade:**

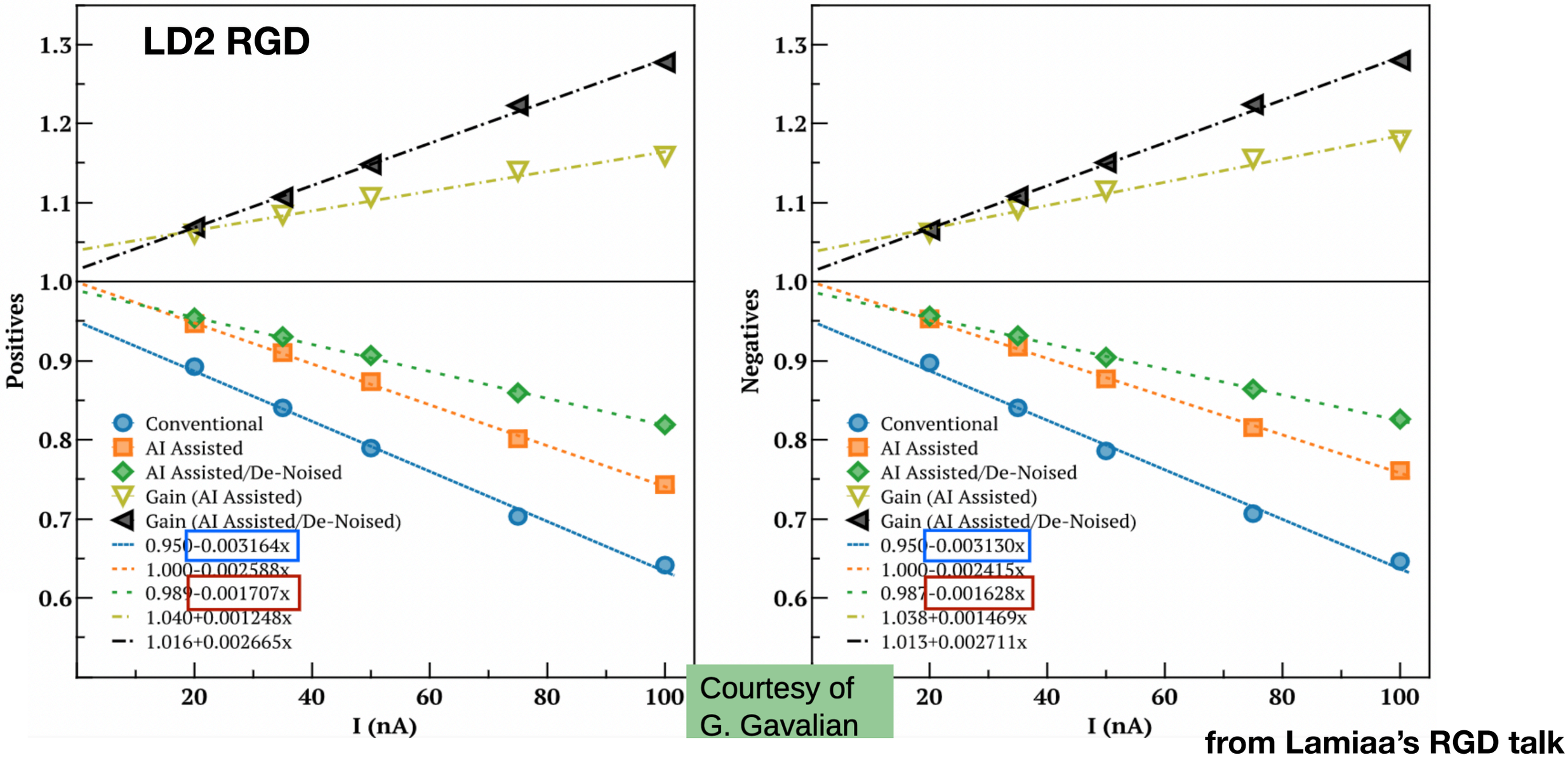
~$2*10^{35}cm^{-2}s^{-1}$ with charged particle reconstruction efficiency > 85%

How to Achieve Phase-1 Goals?

- **Improve FD Tracking with AI and Denoising**
- **Assessment of detector performances at higher luminosities**
- **New, fast μWELL tracker in front of R1 DC**



Improved FD Tracking with AI and Denoising



Courtesy of G. Gavalian

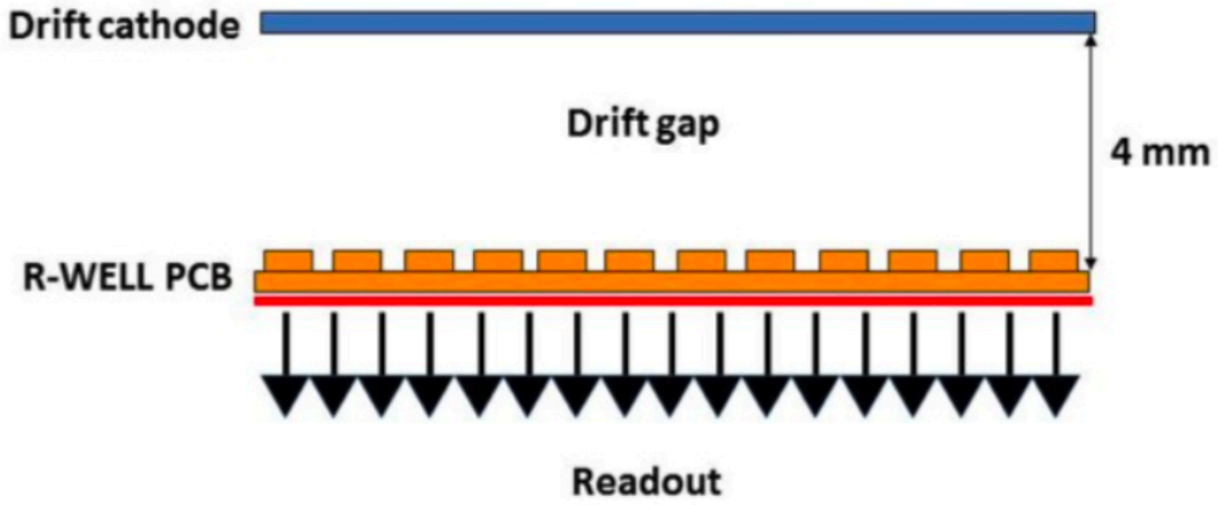
from Lamiaa's RGD talk

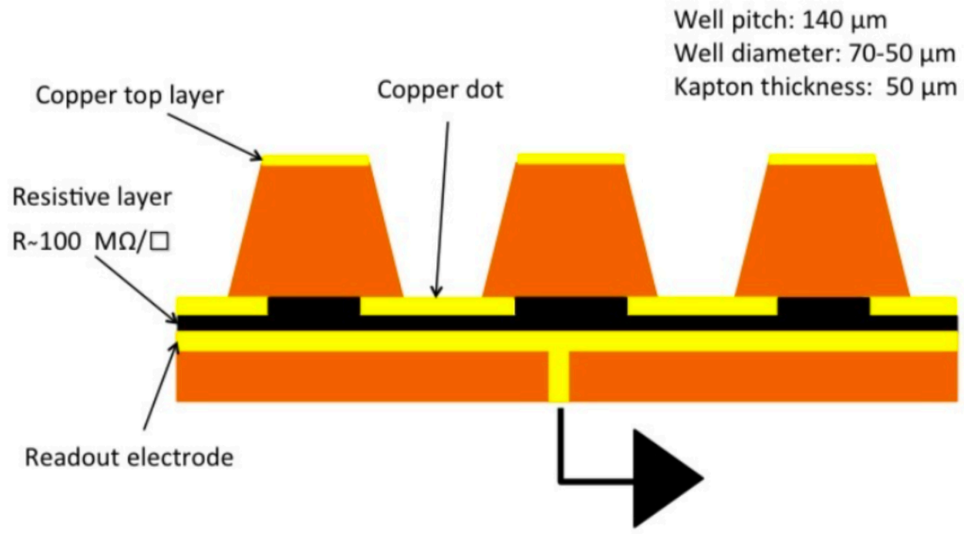
- **Close to required slope of 0.001/nA**
- **FD tracking without μRWELL ready for higher luminosities**

Detector Performance at Higher Luminosities

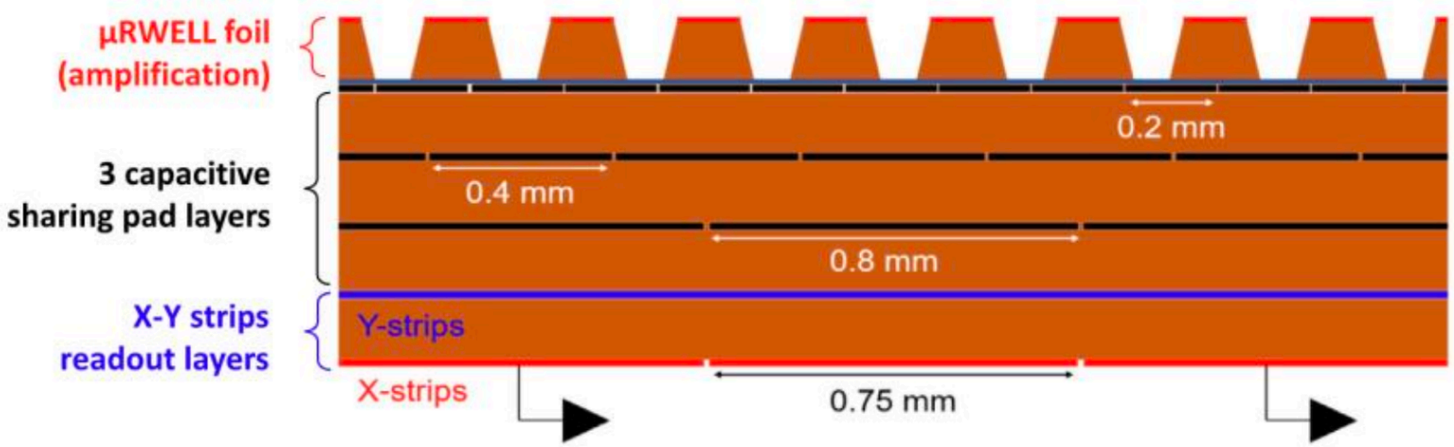
- **PMT Detectors (P/ECAL, C/FTOF, L/HTCC, CND, RICH)**
  - **Operational at x2 lumi**
  - **Main concern: Aging of PMTs (C/FTOF, ECAL) —> replacement plan in development**
  - **Non-linearity studies at higher luminosities planned for RGK (CTOF)**
- **DC**
  - **RGC and RGD study: Operational at x2 lumi**
  - **Concern: long term stability at x2 lumi -> monitoring in development**
  - **In progress: Study effect of higher luminosity on resolutions**
- **CVT**
  - **Improved stability of BMT at high lumi with new gas**
  - **SVT okay for x2 lumi**
  - **Main concern: Spare tiles for BMT —> plan for new tiles in development**
  - **Need: Improved tracking efficiency with AI based background rejection**
- **FT:**
  - **Operational at x2 lumi**
  - **Concerns:**
    - **FTC: Light reduction from radiation damage —> more frequent energy calibrations**
    - **FTH: Gain dependence of SiPm current —> Redesign of FTH FEE**

New μRWELL Tracker





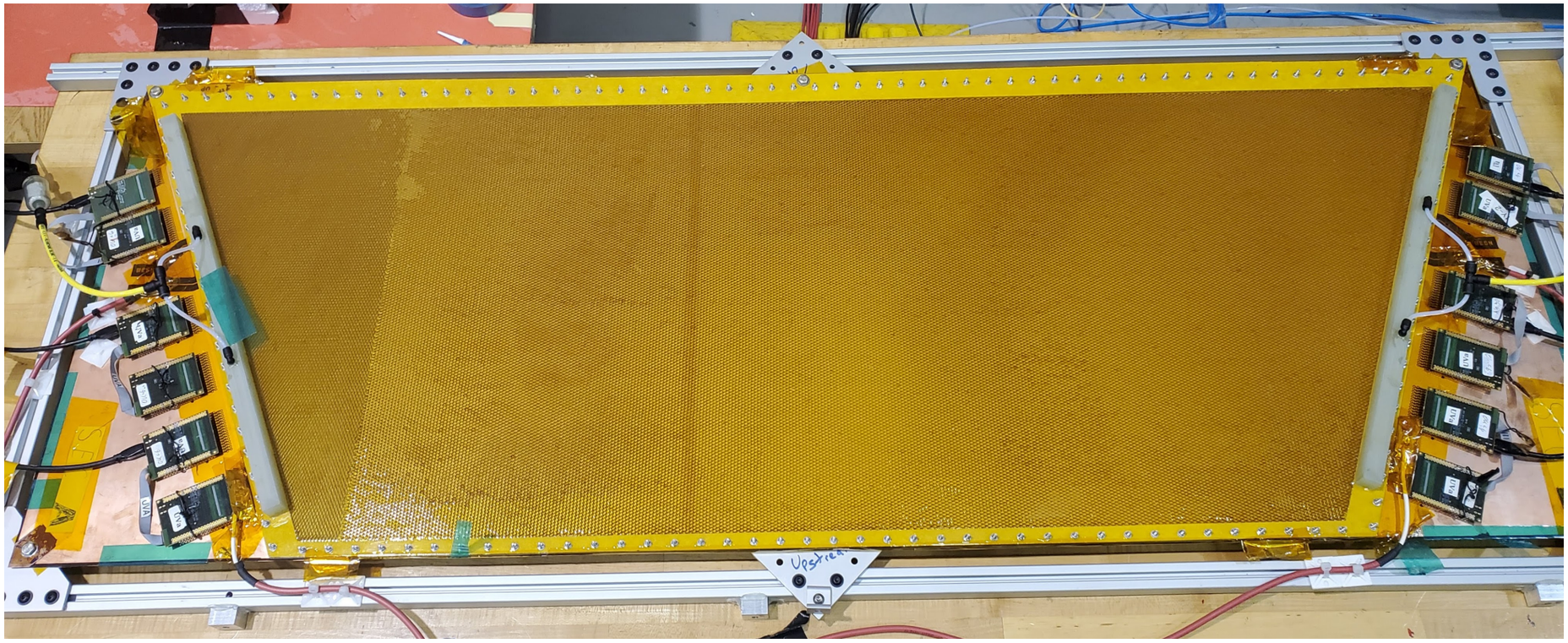
- **Micro-Pattern Gaseous Detector (MPGD)**
  - **Amplification in wells**
  - **Spark protection due to resistive layer**
  - **Low-mass, good spatial and timing resolution**
- **2D capacitive sharing readout**



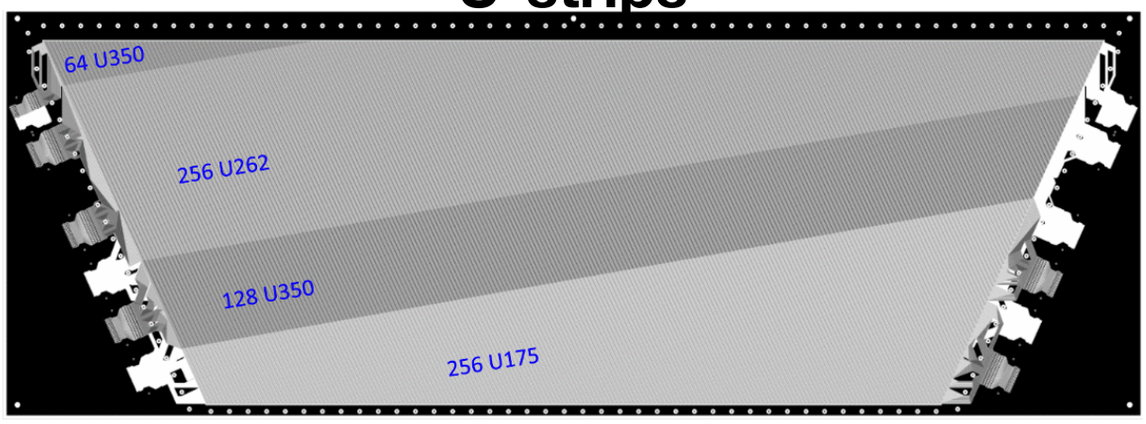
K. Gnanvo, NIM A1047, 167782 (2023)

Our Prototype

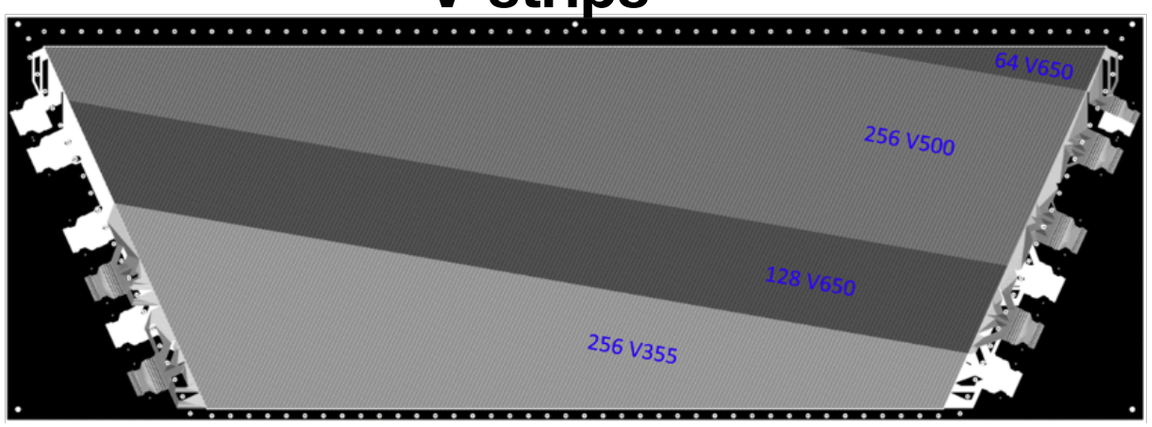
- **Largest μRWELL build so far**
- **2D-U/V strip readout with 10 deg stereo angle**
  - **pitch 1mm**
  - **various strip width (to find optimal combination)**
- **Electronics APV25 and SRS**



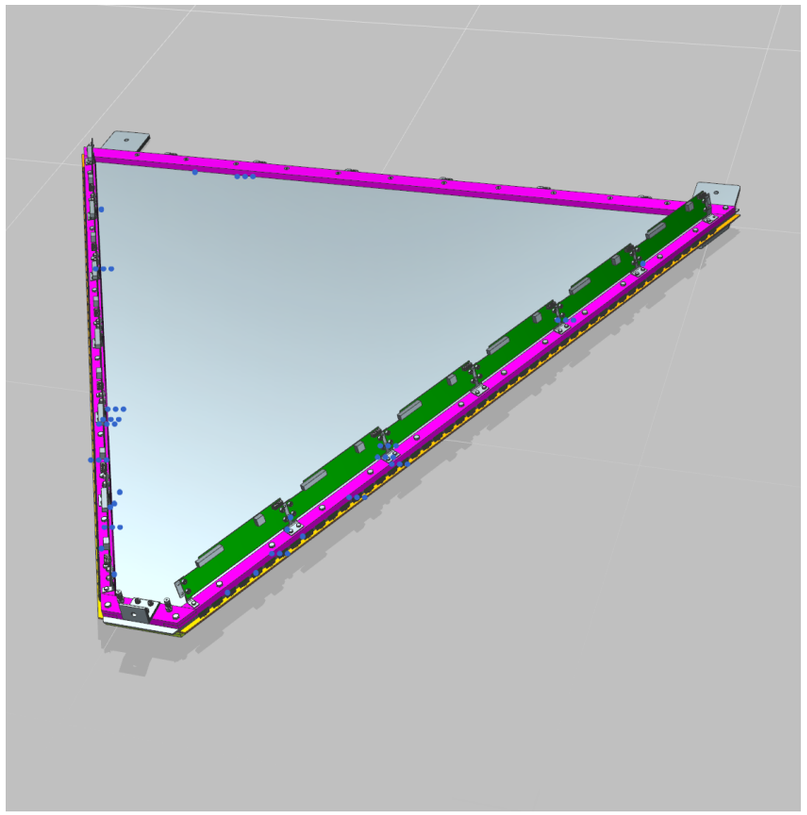
U-strips

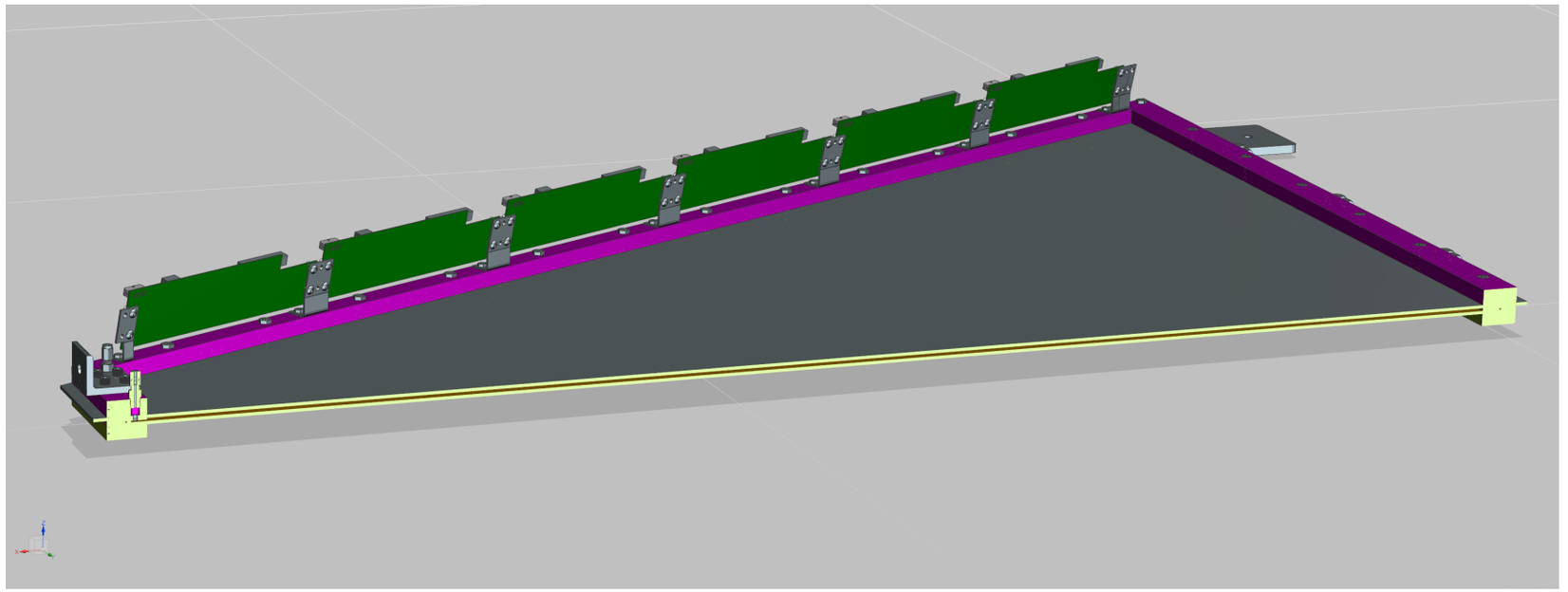


V-strips

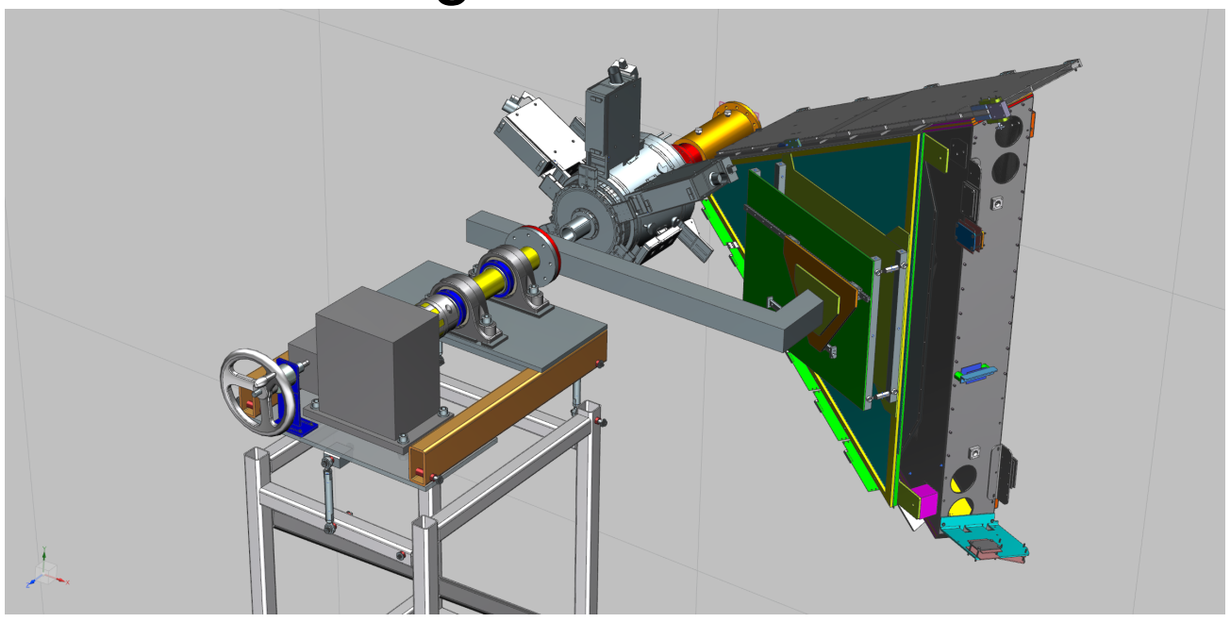


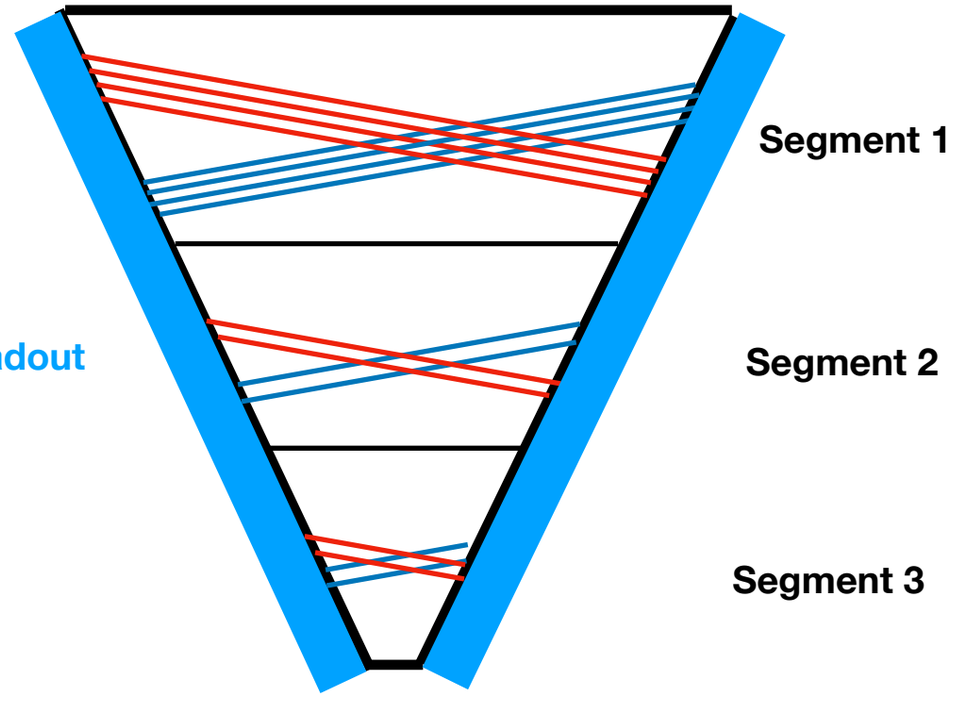
Full Design (in progress)





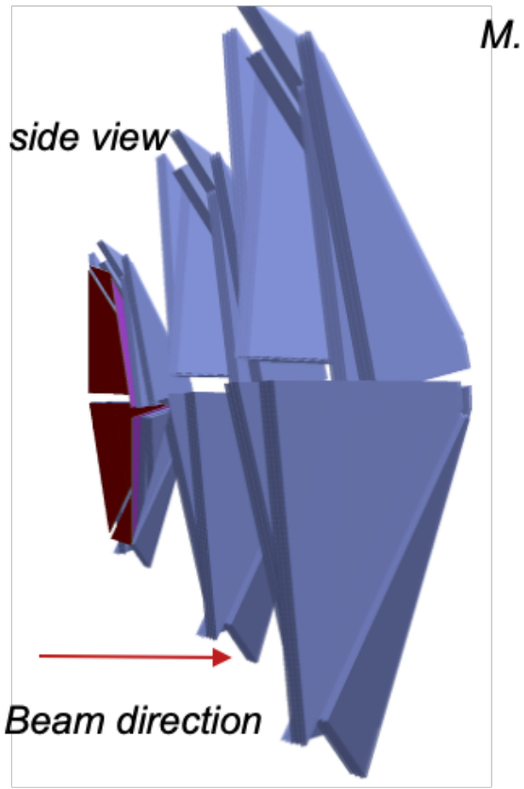
During Installation



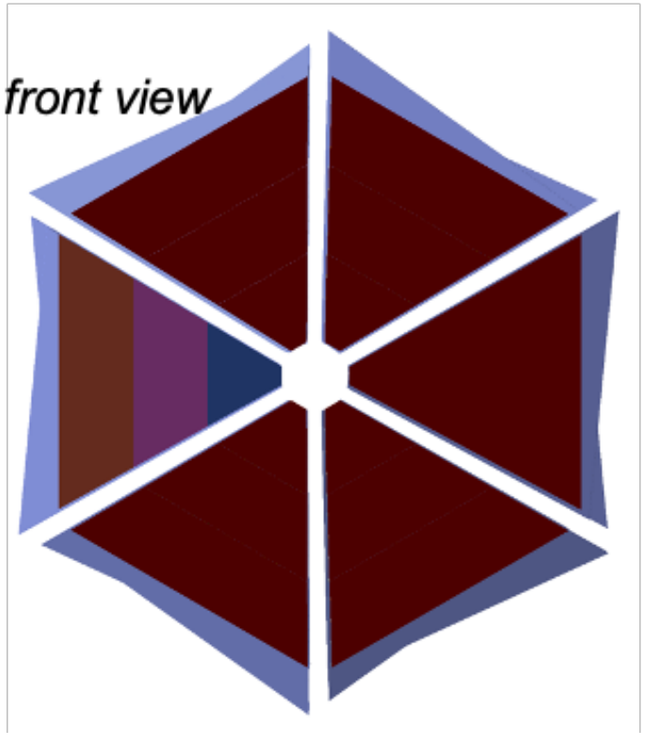


Figures from Chris Guthrie

μRWELL in GEMC

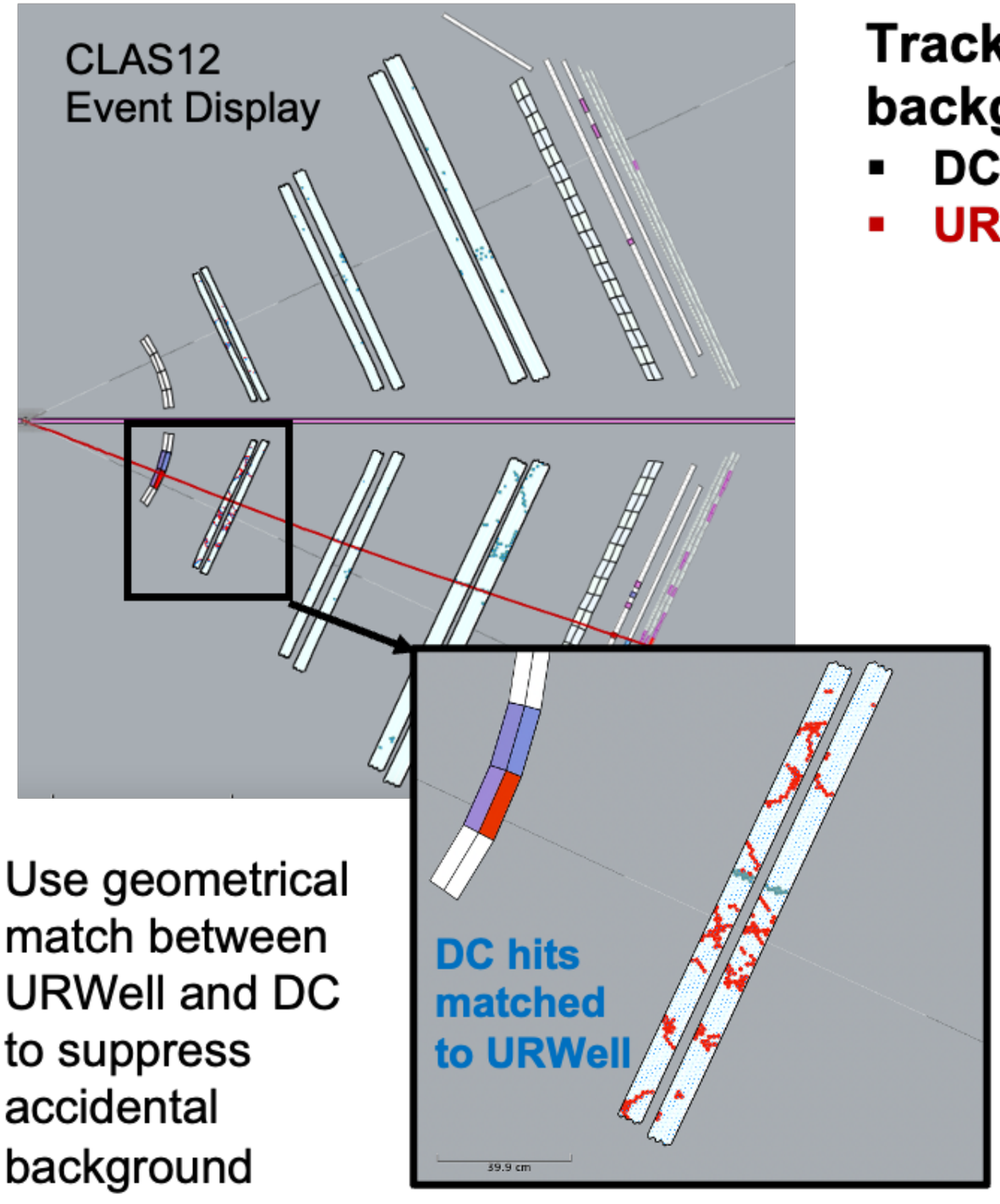


- **Implemented upstream of R1-DC (M. Bondi)**
  - **6 sectors with either 1 or 2 double-sided detectors**
  - **each detector: 3 layers capacitive sharing with U-V readout**
- **μRWELL simulations**
  - **Coatjava - geometry service:**
    - GEANT4 volumes for GEMC
    - Definition of strip lines in local and global frame
  - **GEMC:**
    - **Geometry** full detector completed and merged. Prototype geometry implemented
    - **Digitization** effective description of detector response. Implementation completed and included. More tuning to be done based on prototype and readout electronics tests.



Slide by Raffaella

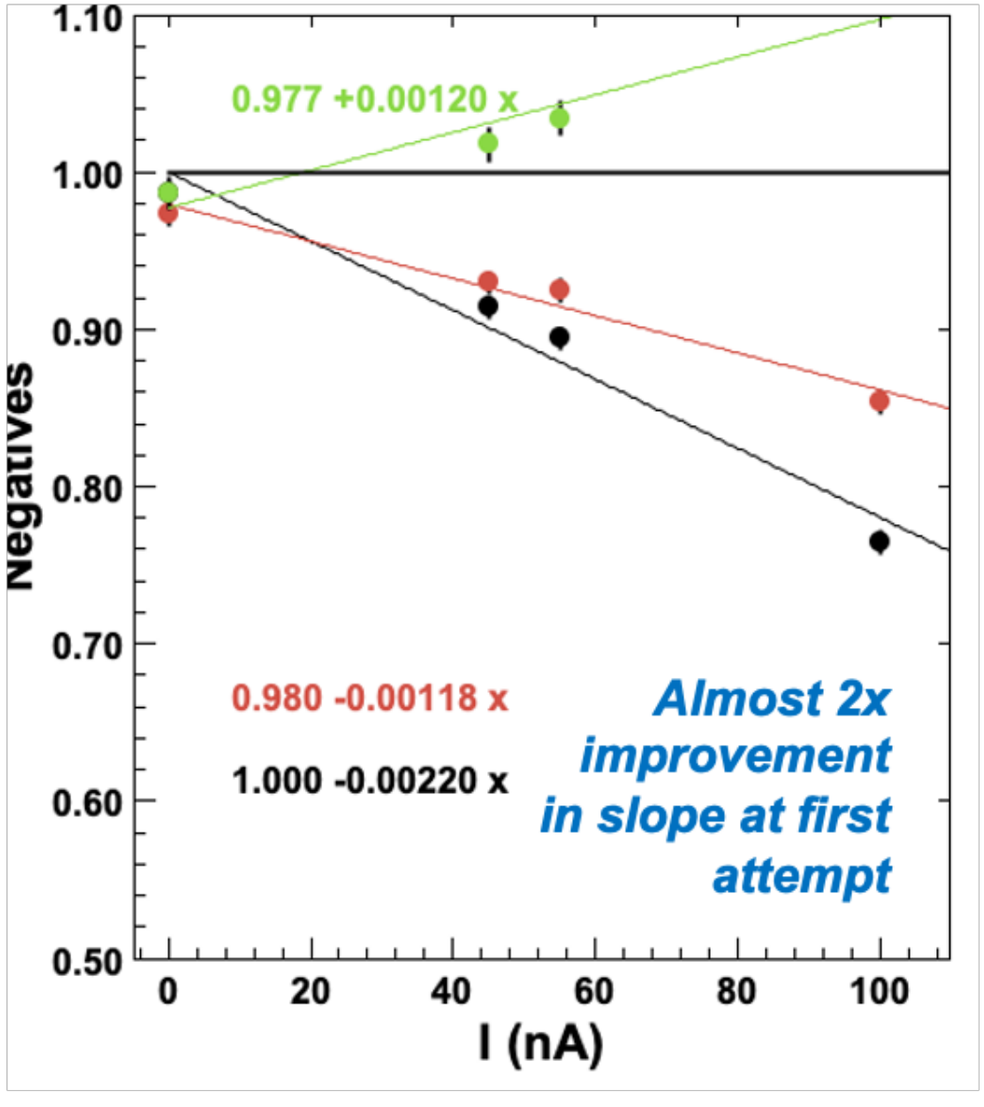
Combined μRWELL-DC Track Finding



Use geometrical match between URWell and DC to suppress accidental background

Tracking efficiency from MC with DC background from real data

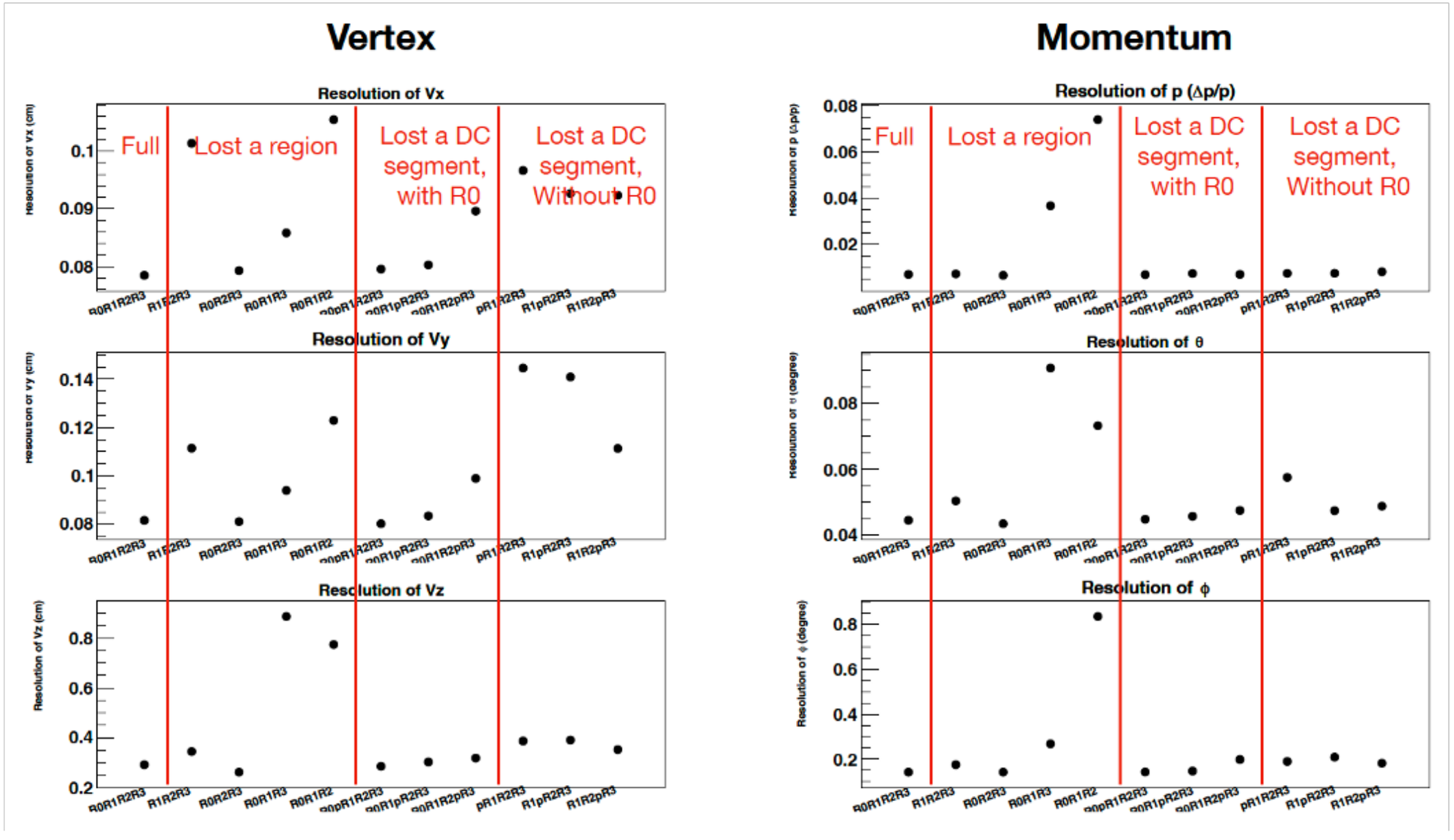
- **DC-only track finding**
- **URWell-DC track finding**



Slide by Raffaella

μRWELL+DC Tracking

- Forward Tracking modified to use URWell as an additional region (R0)
- First studies of impact on resolution in different tracking scenarios completed
- Waiting on GEMC background to continue track finding and fitting optimization



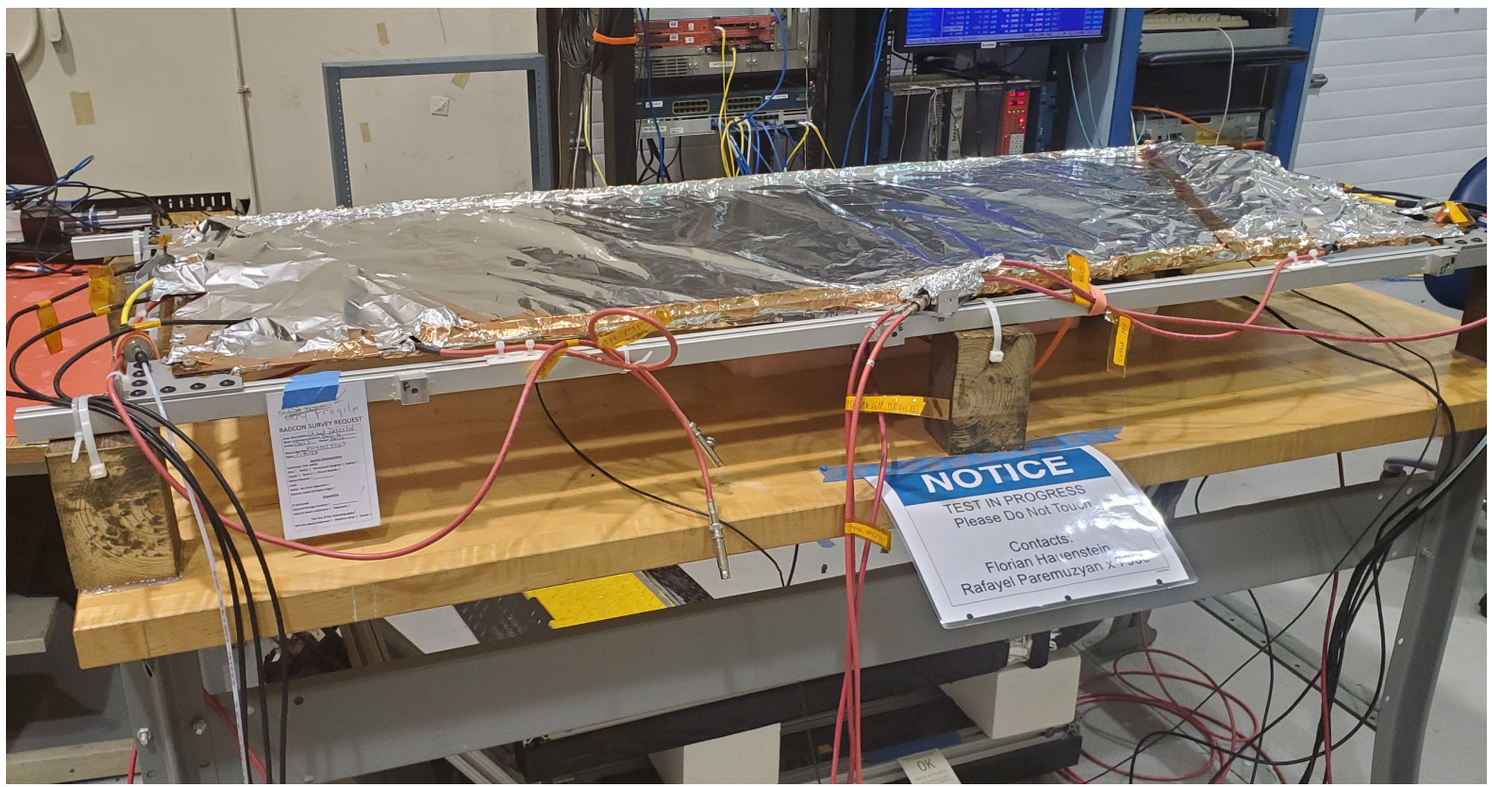
T. Cao

Slide by Raffaella

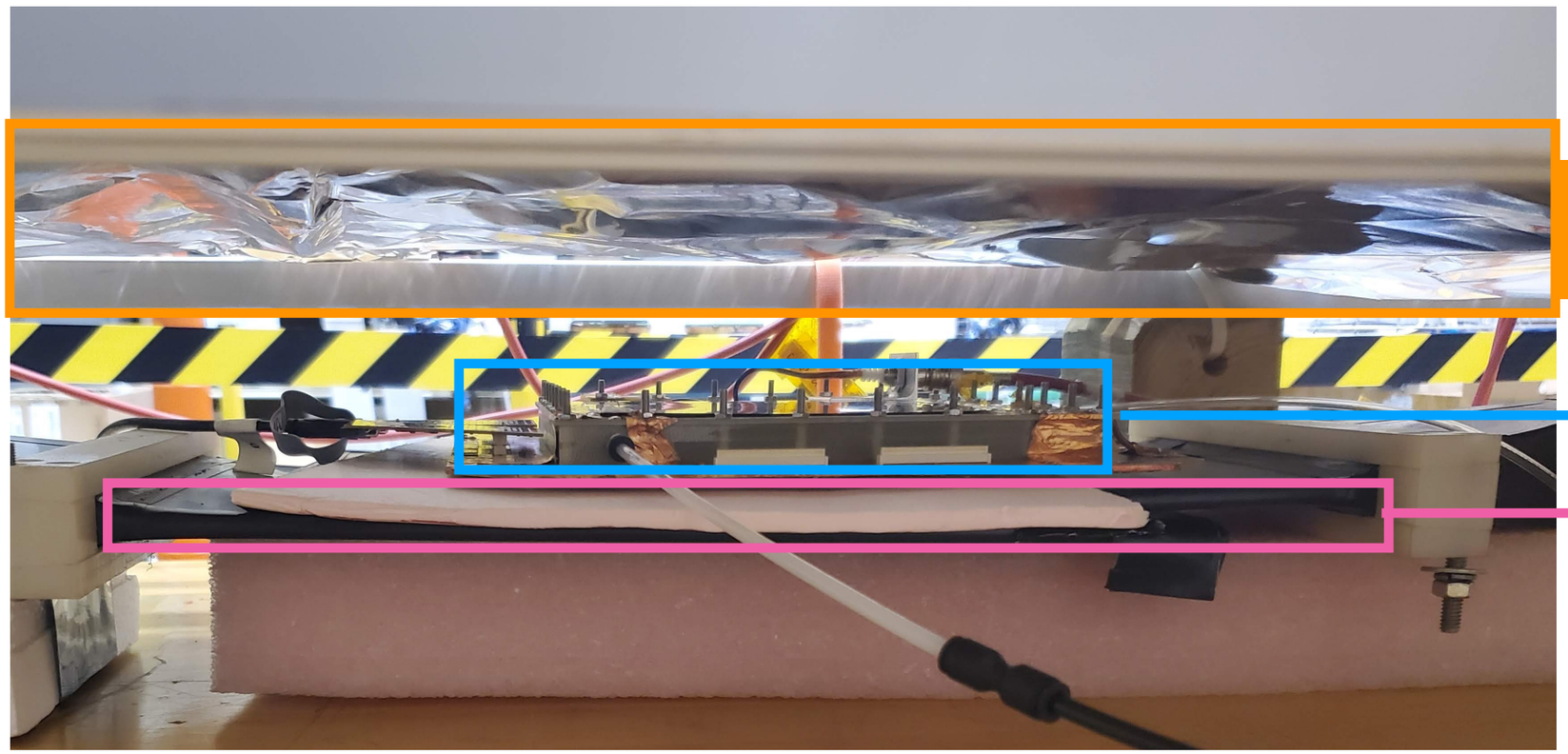
Prototype Testing- Status April

- **HV current leaks from left to right —> only half operational**
- **Low efficiency in cosmic setup —> 1%**
- **No clear signal during beam tests in HallB and high noise**

- **Improvements April - May:**
  - **seal of gas inlays —> bubbles observed on exit**
  - **improved trigger latency —> no signal clipping**
  - **improved cosmic setup —> GEM and trigger scintillators closer**
  - **HV filter box**
  - **signal noise suppression with faraday cage with wrapped Al foil**

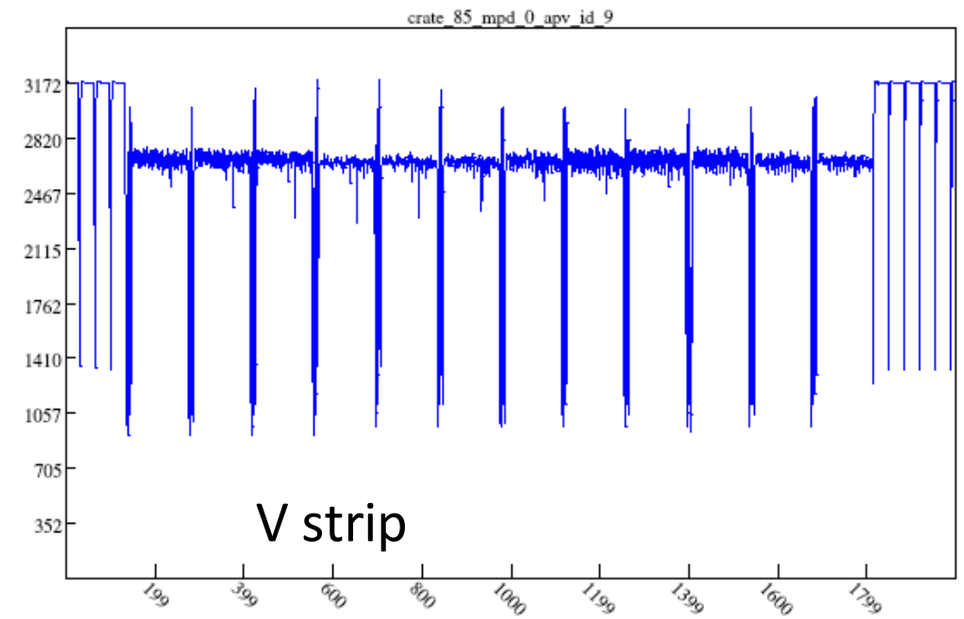


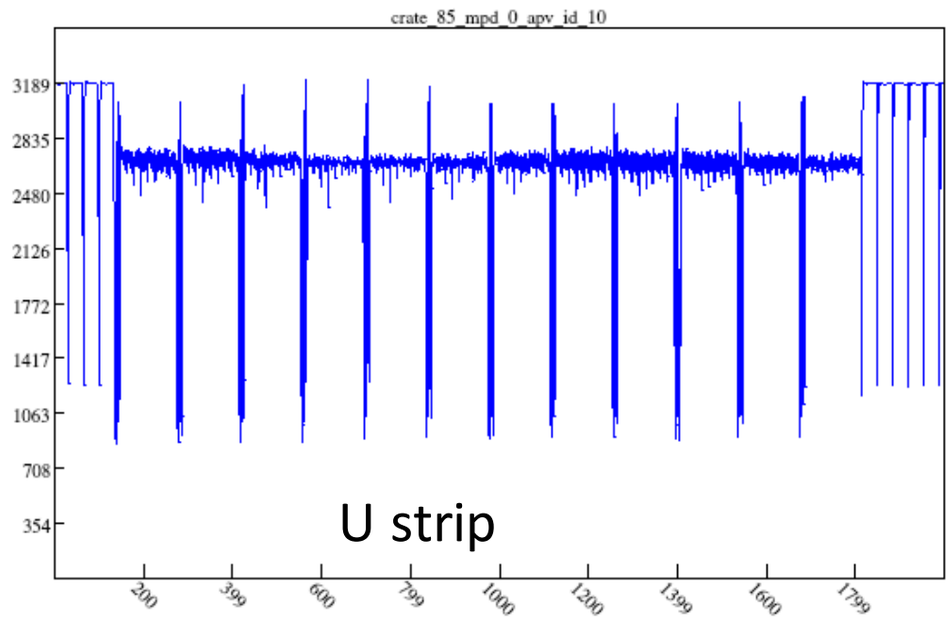
Setup at EEL

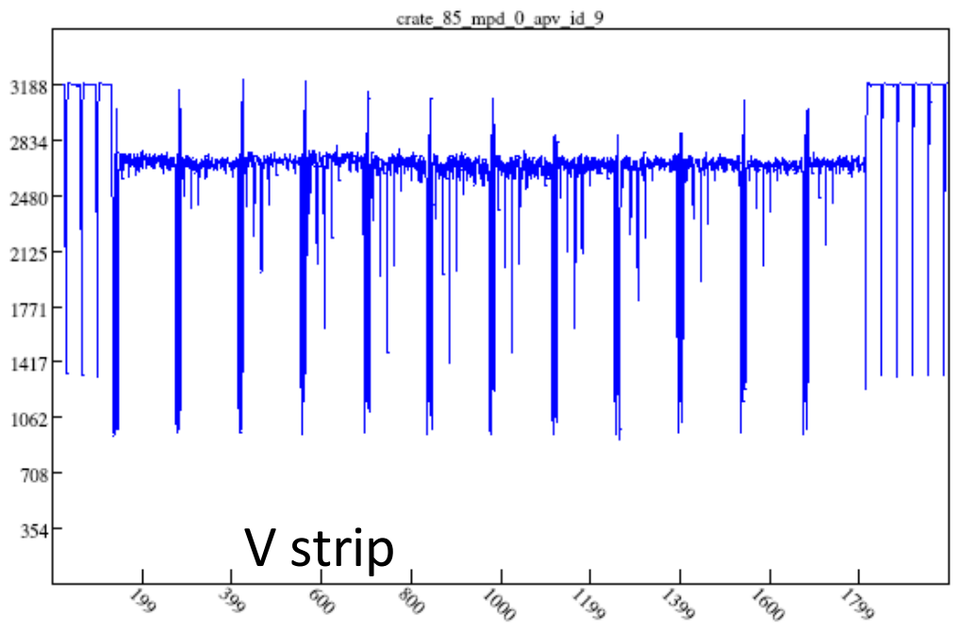


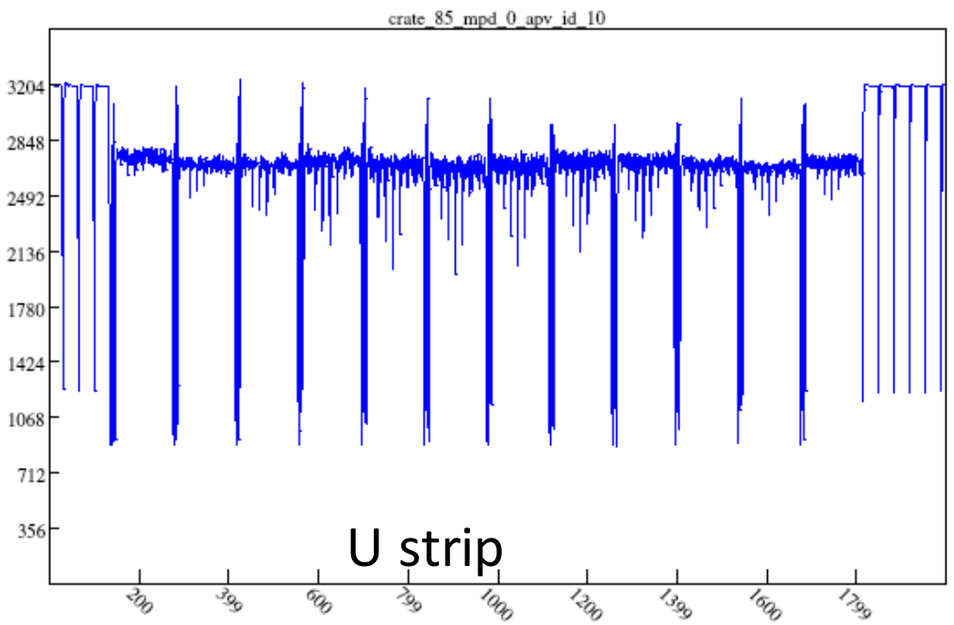
- **Particles need to pass 10x10 GEM and scintillators —> defines area of μRWELL**
- **Efficiency is relative to GEM which is assumed to be 100% efficient**

Cosmic Signal with uRWELL

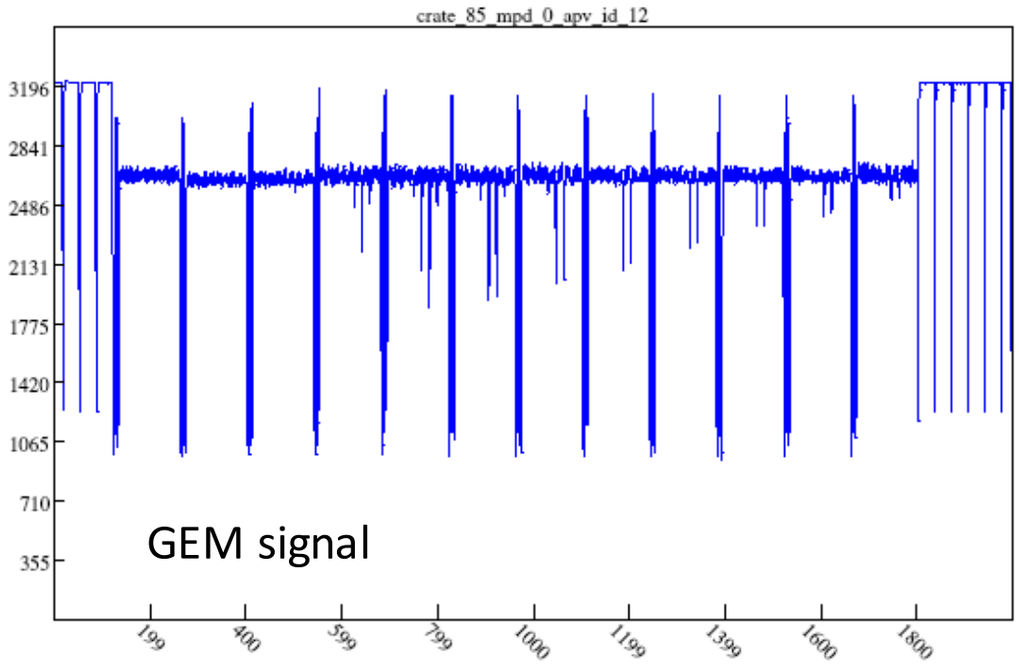


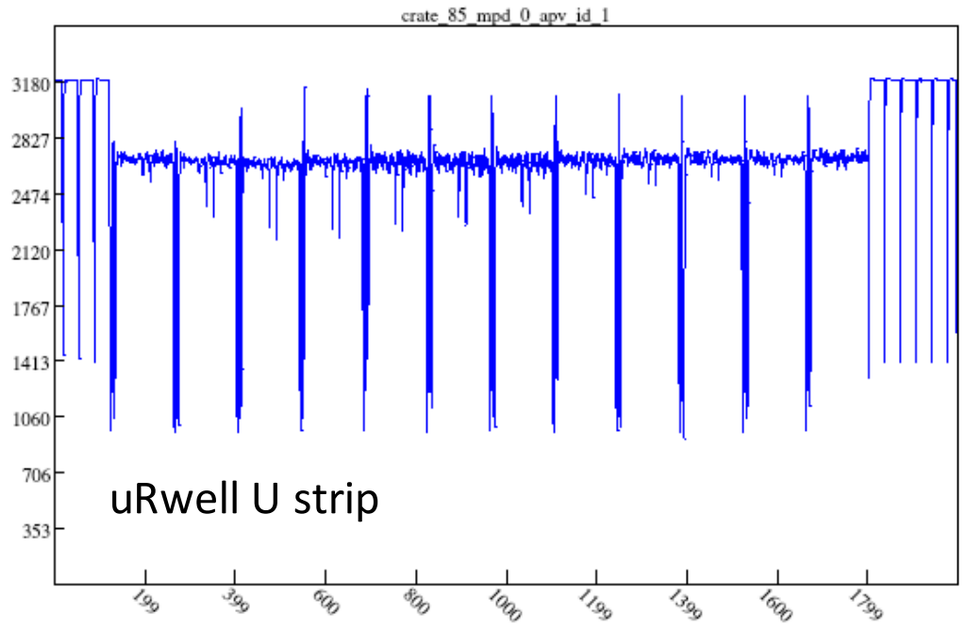


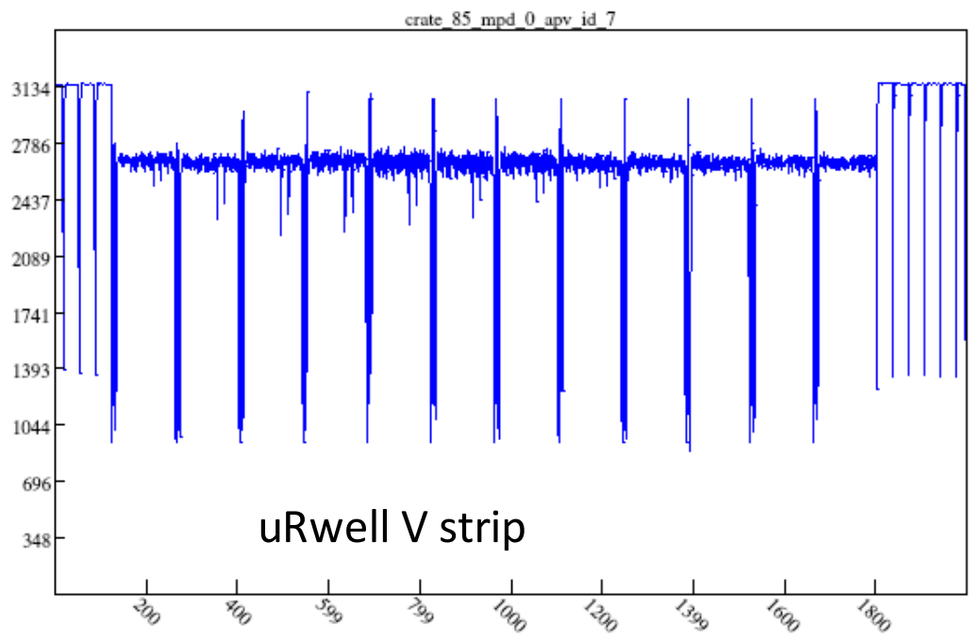




Cosmic Signal with uRWELL and GEM





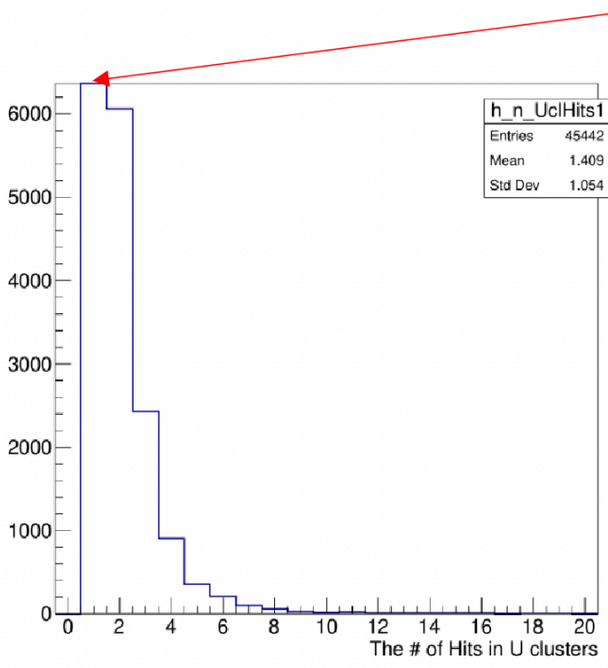


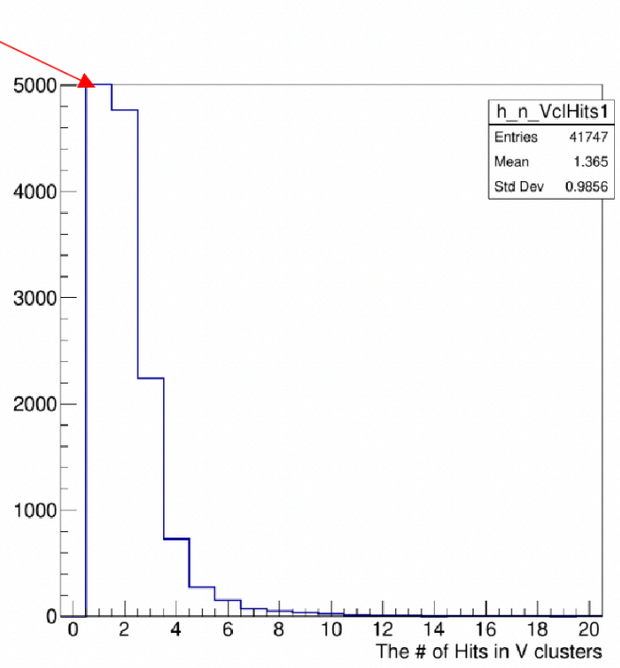
- **Some events have signal in both detectors**

Analysis Procedure (guidance from Kondo)

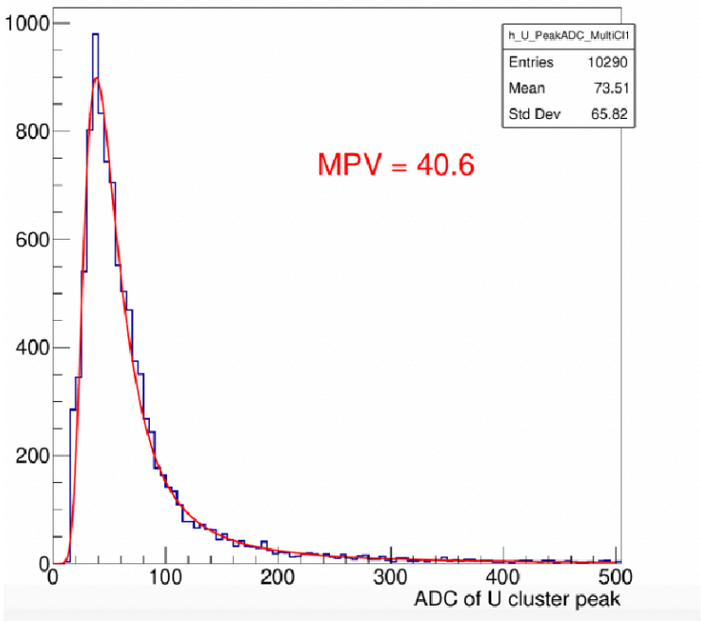
- **Select hits 3σ away from noise/pedestal**
- **Clusters with at least 2 hits**

Note: clusters with 1 hits are ignored in the analysis.

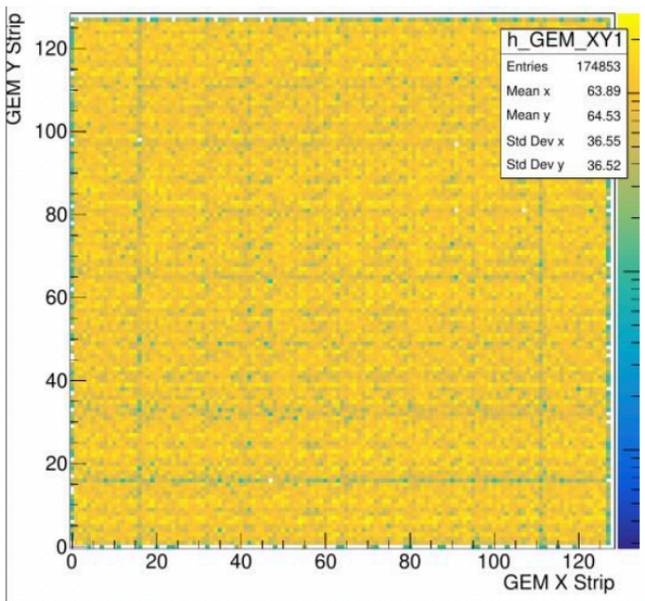




ADC U-clusters



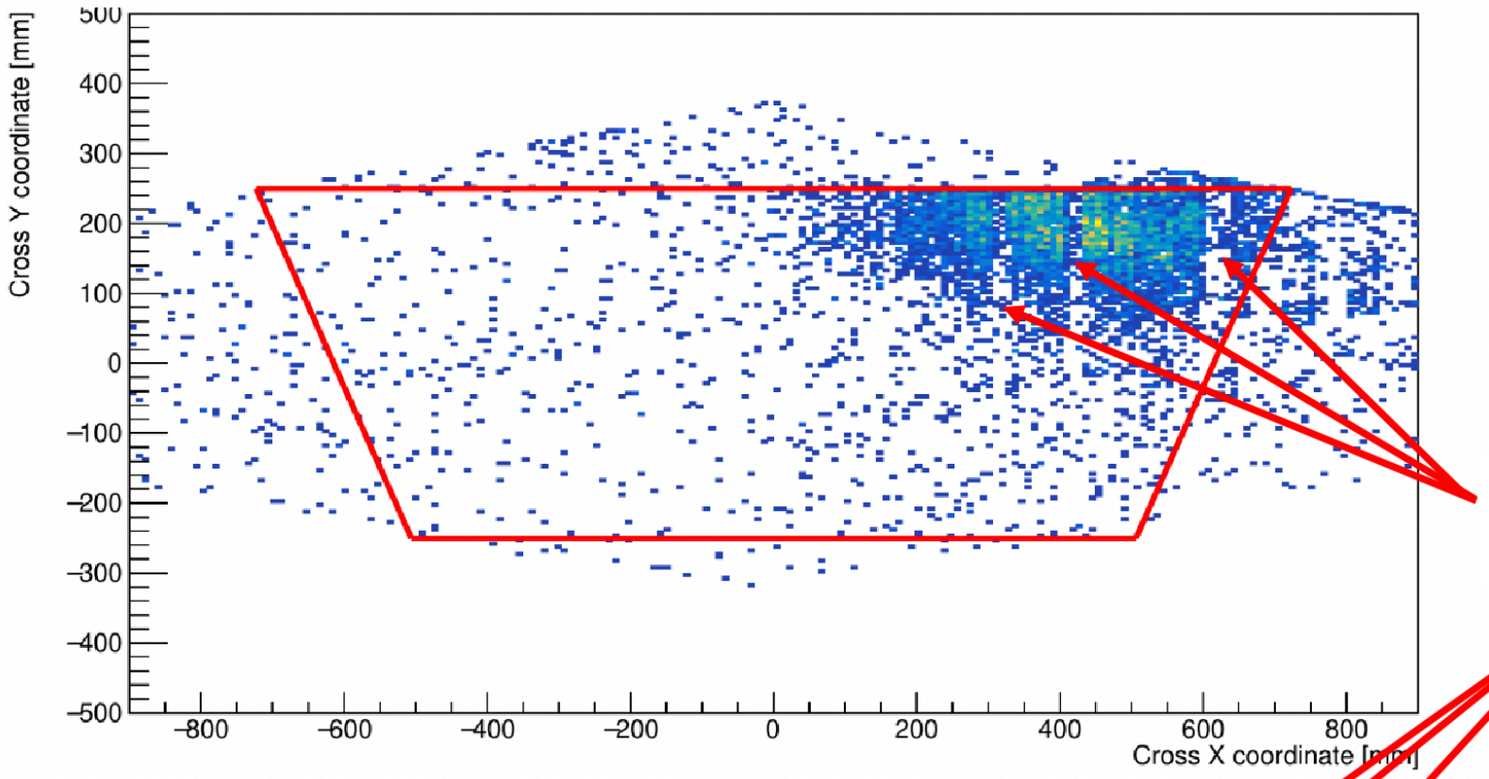
- **Event has at least two hits in GEM X and Y**



GEM XY distribution is uniform as expected!

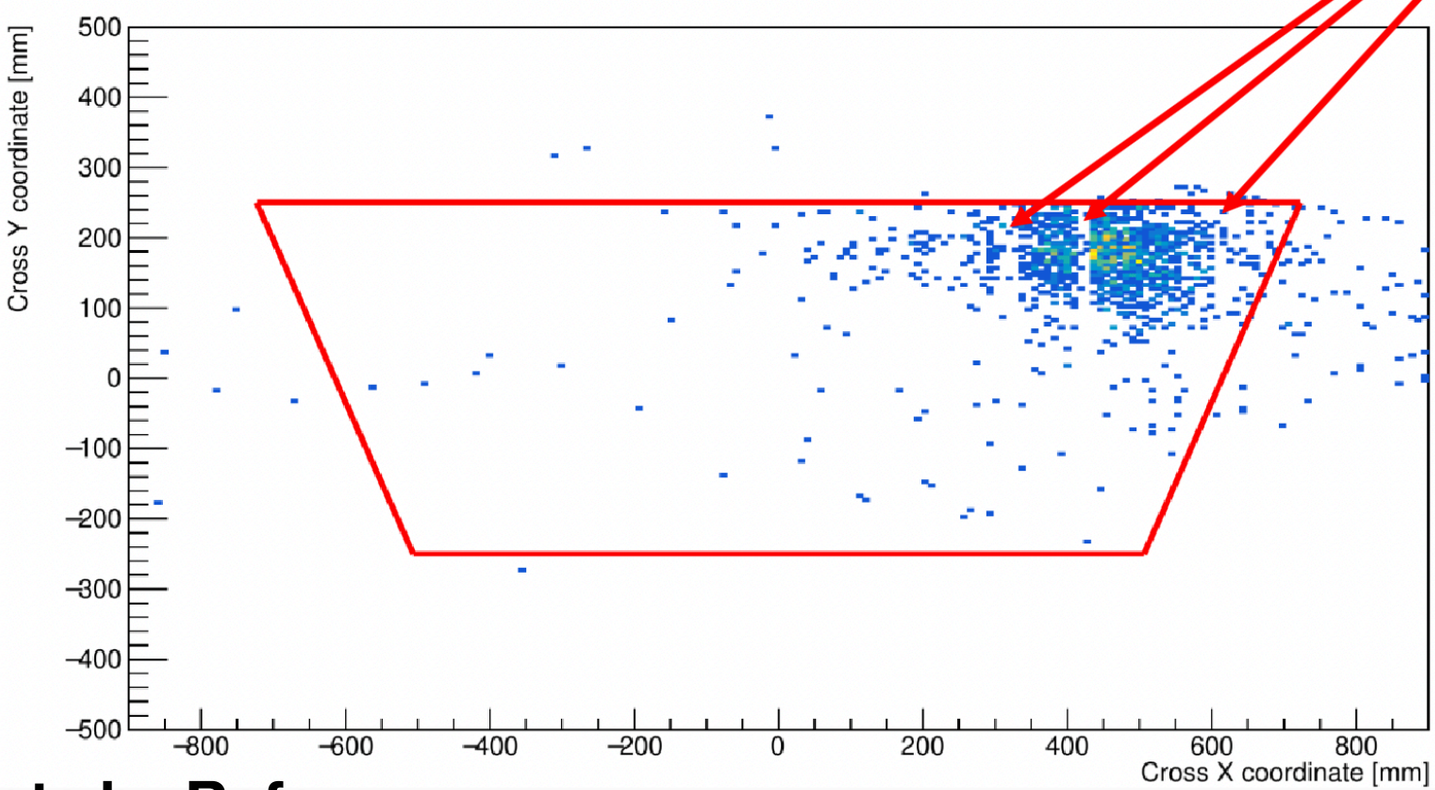
Plots by Rafo

2D Distribution



all events with μRWELL hit

disconnected μRWELL sections

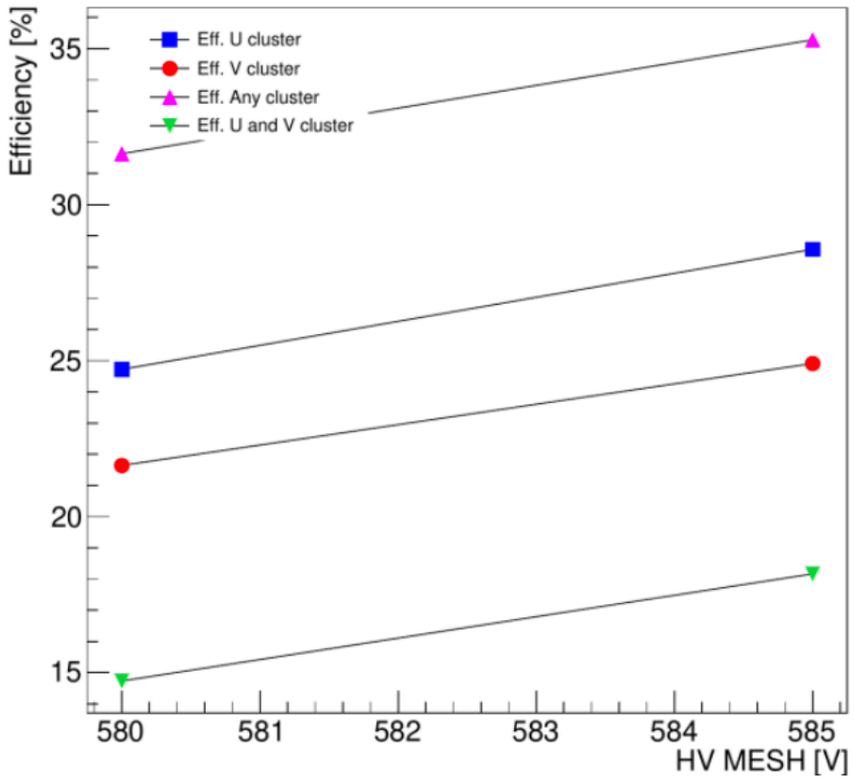


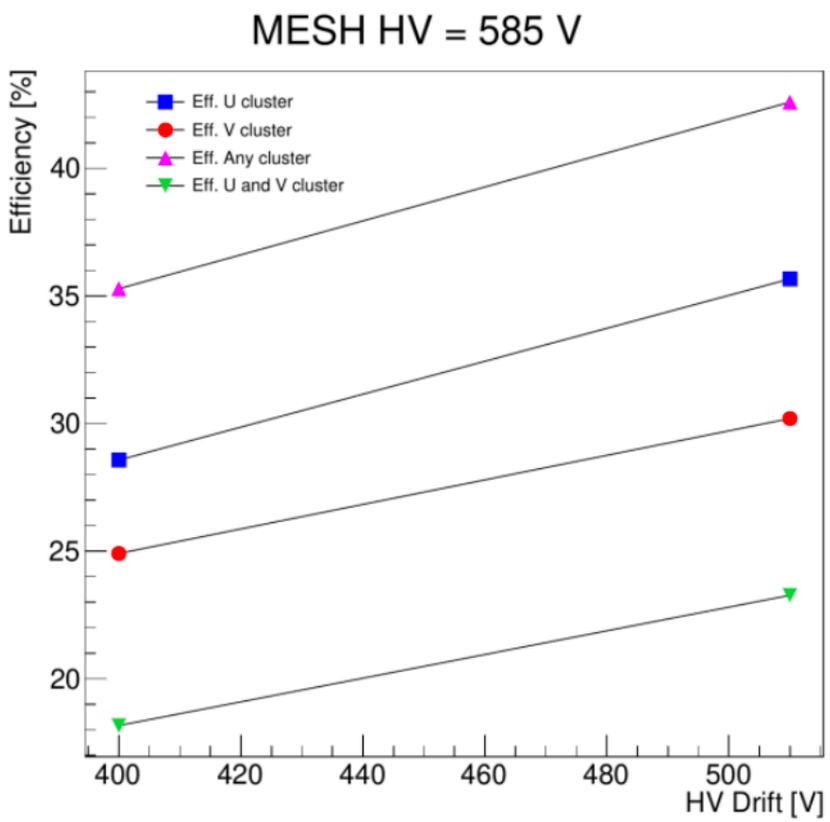
all events with μRWELL hit
and good hit in GEM

Plots by Rafo

Efficiency Results

Ar:CO_2 75:25



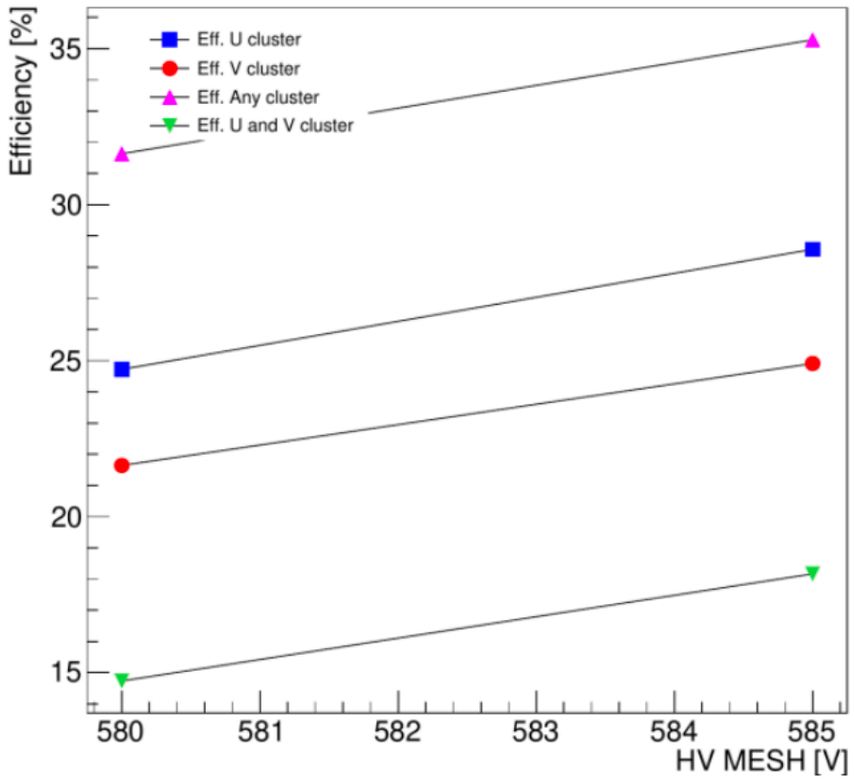


- **Increase of efficiency with voltage**
- **Difference between U and V efficiency**
- **BUT: low overall efficiency**

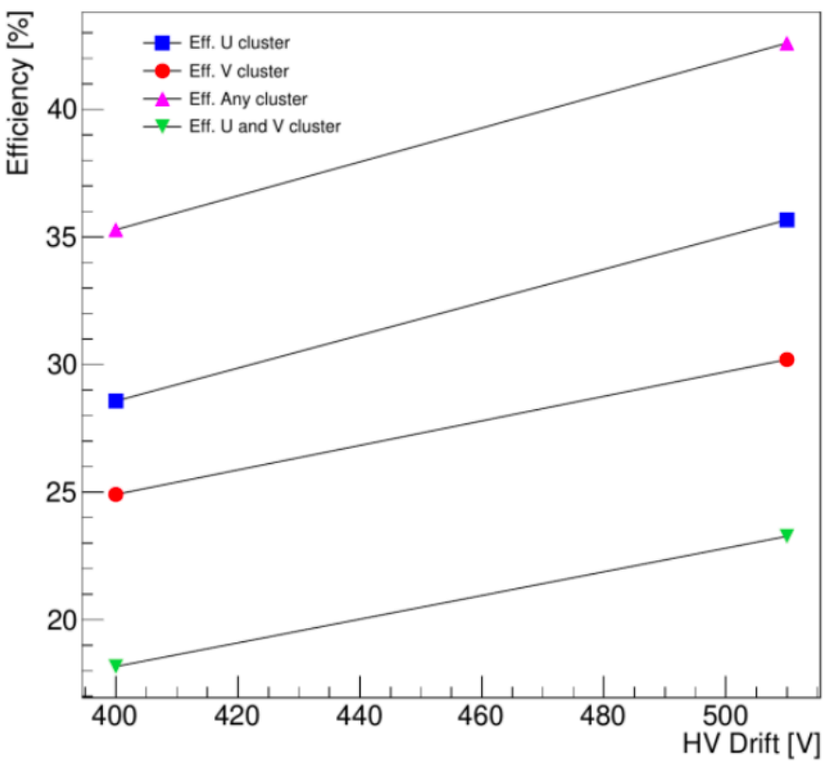
Efficiency Results

Ar:CO_2 75:25

Drift Voltage = 400 V

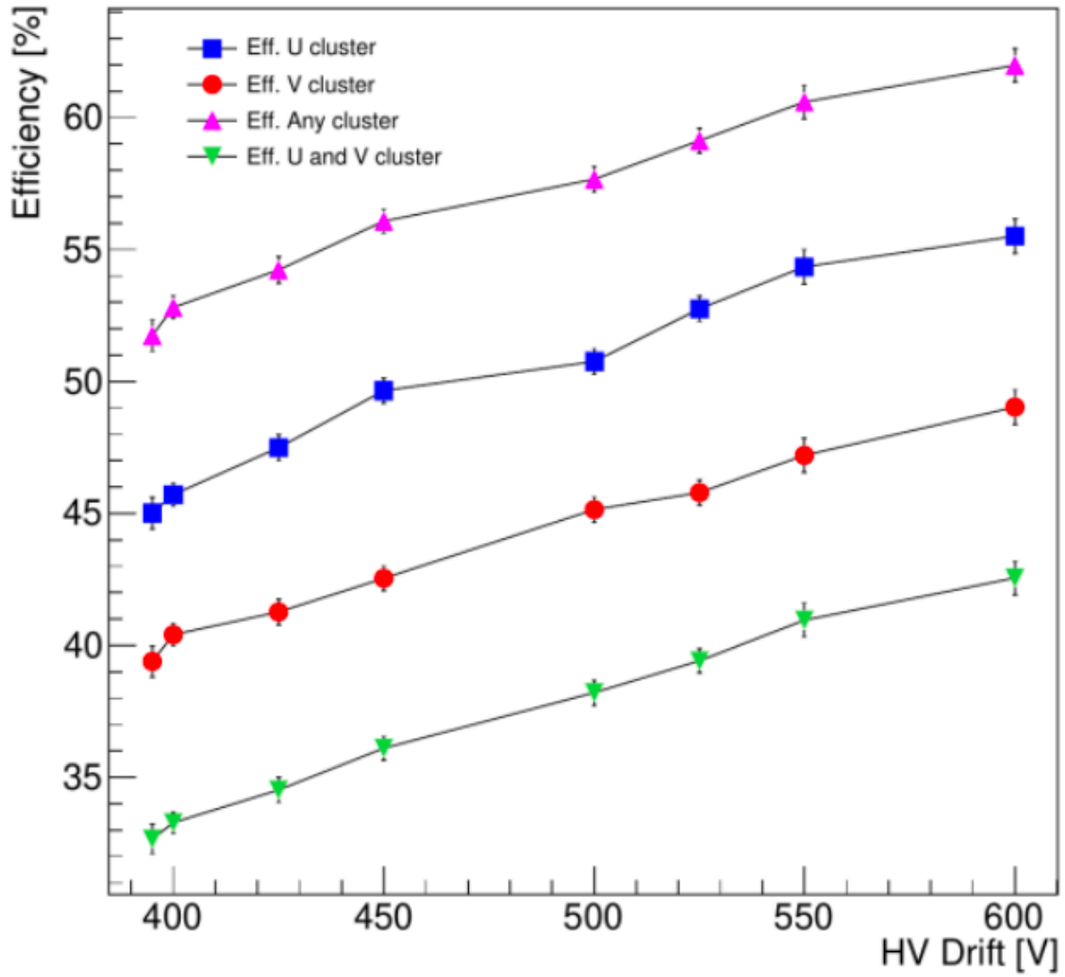


MESH HV = 585 V



Ar:CO_2 80:20

MESH HV = 575 V

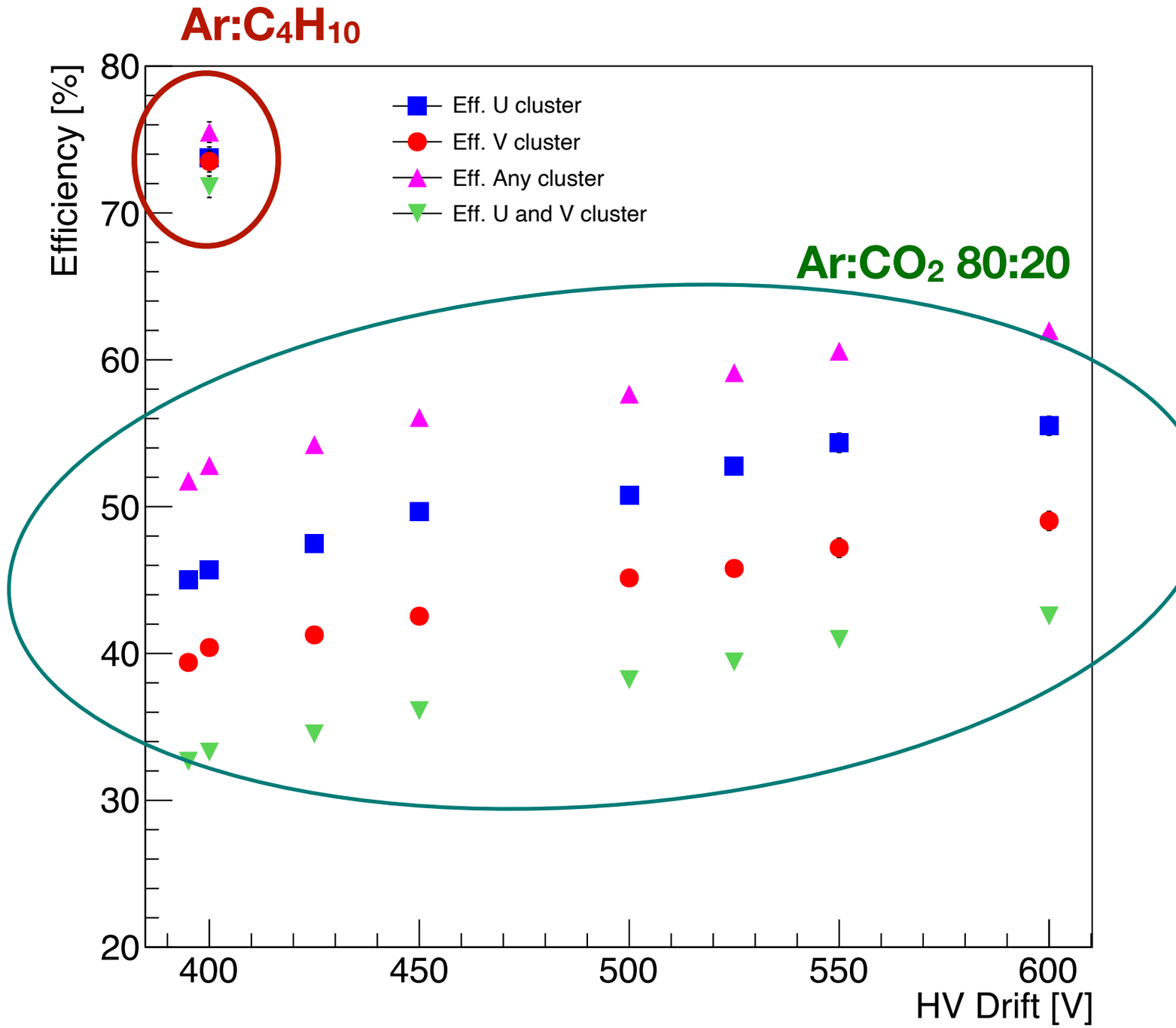


- **Larger efficiency for 80:20 due to more gain**
- **Still difference between U and V efficiency**
- **Expected efficiency >90%!**

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

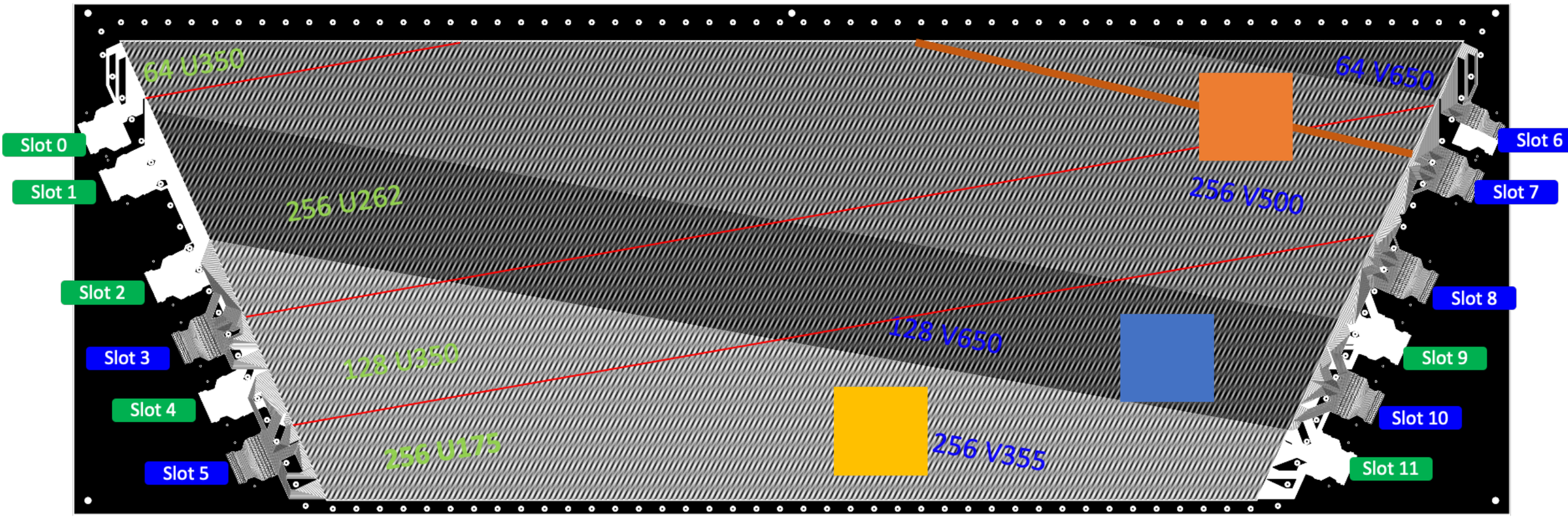
- **Mesh HV**
  - **575V for $Ar:CO_2$**
  - **500V for $Ar:C_4H_{10}$**

- **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)**

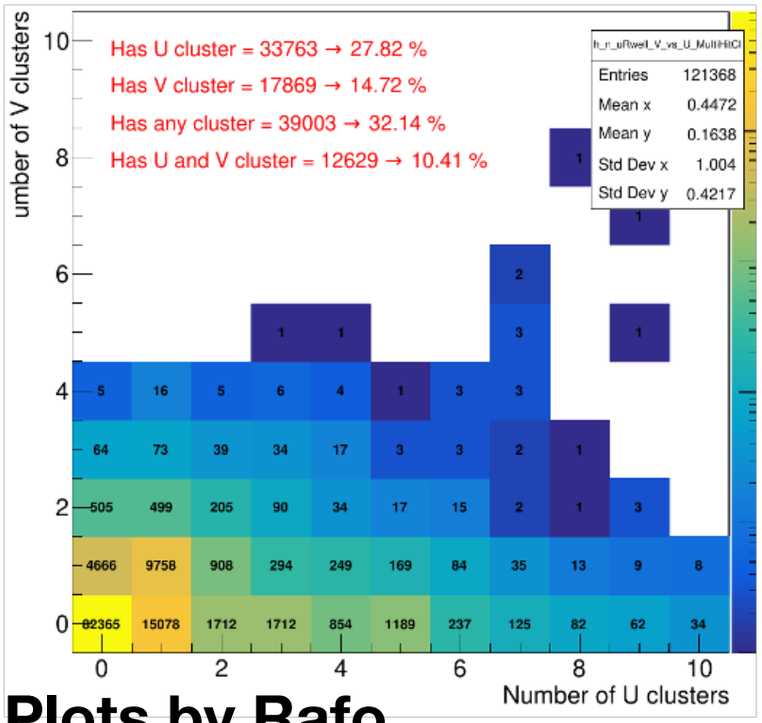
Efficiency Dependence of Strip Width/Length



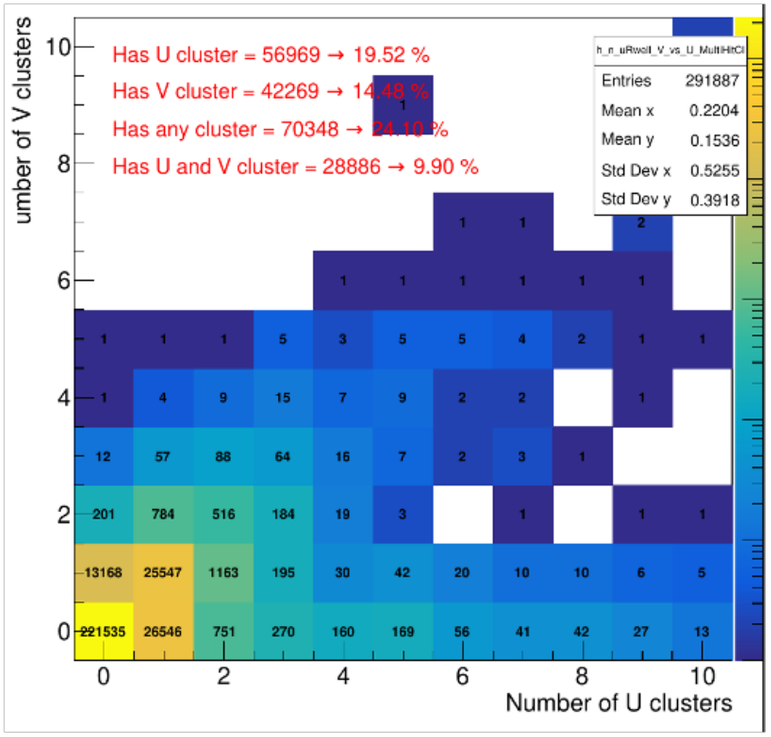
- **3 GEM positions**
  - **U175µm / V355µm crossing (run 1576)**
  - **U175µm / V550µm crossing (run 1574)**
  - **U550/262µm / V500µm crossing (run 1582)**
- **Ar:CO_2 75:25 and same HV on µRWELL**

Results for the Runs

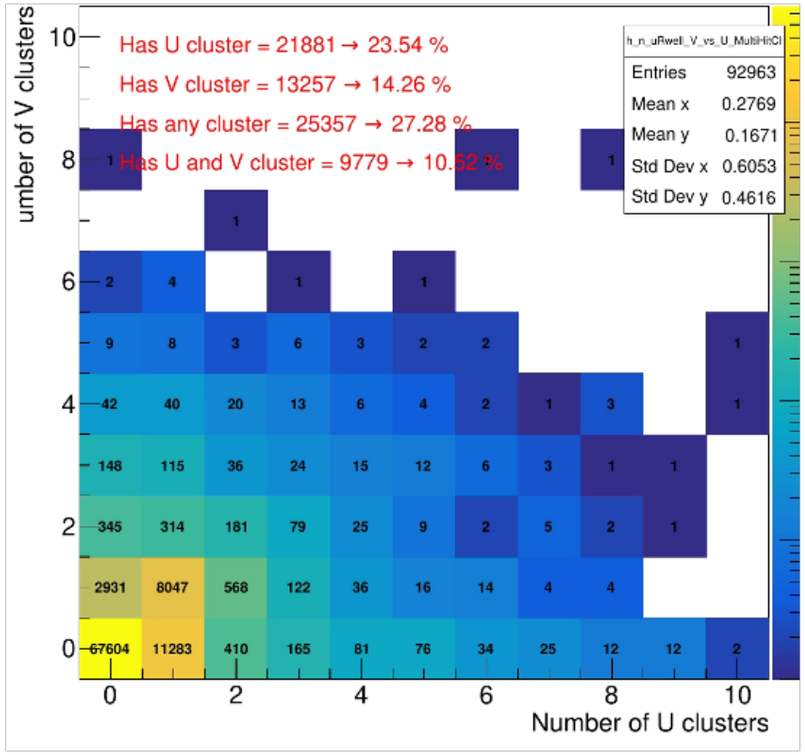
run 1576



run 1582



run 1574

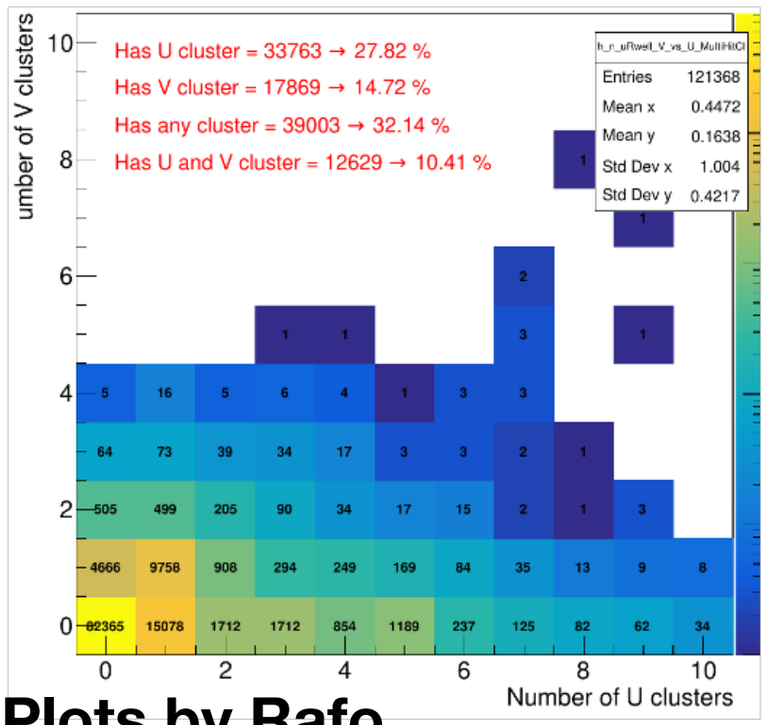


Plots by Rafo

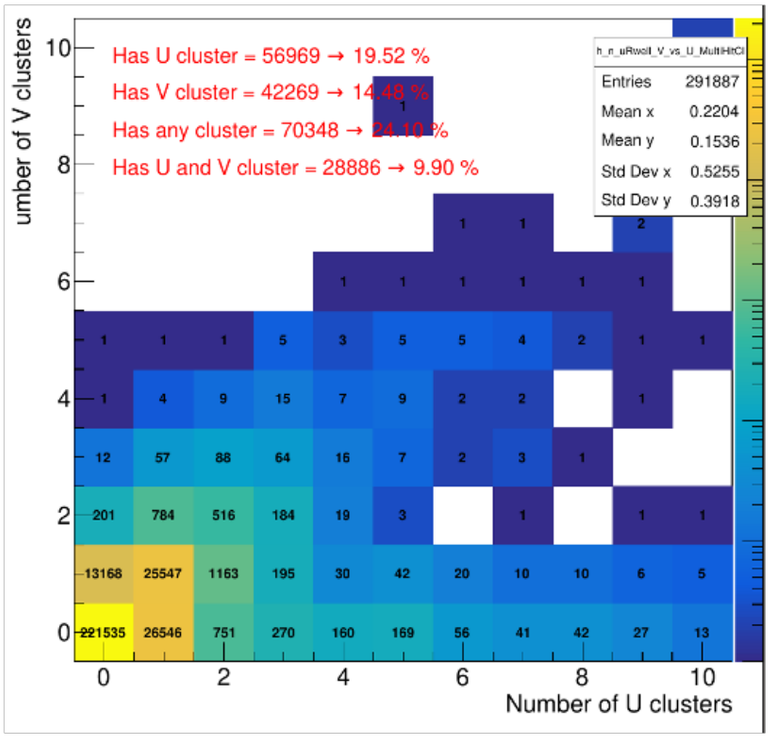
- **All “V” strips show the same efficiency (~14%), however the strips in 1574 are in average x2 longer than the one for 1582**
- **U strip efficiency dependence on strip width/length difficult to interpret**

Results for the Runs

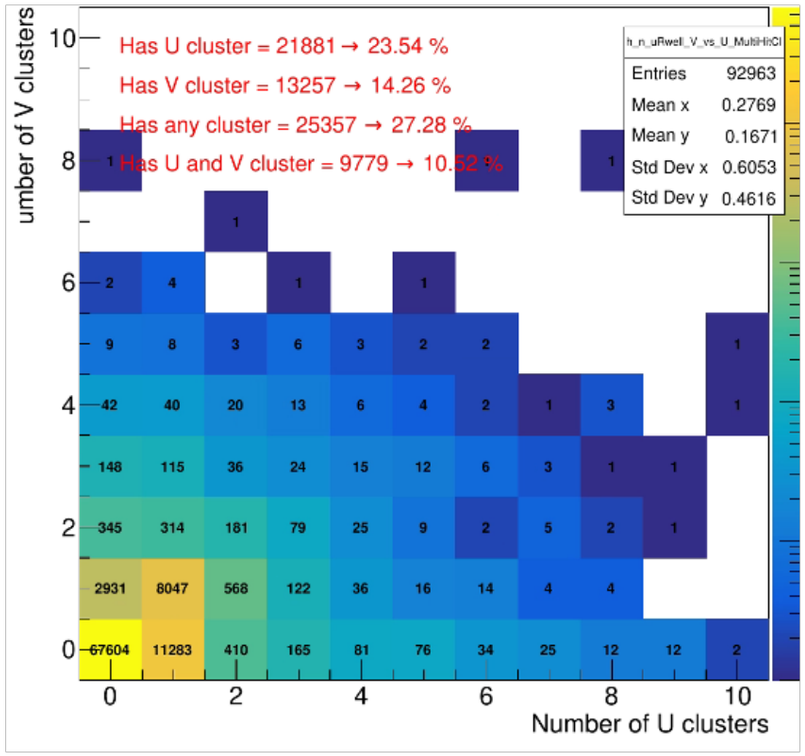
run 1576



run 1582



run 1574



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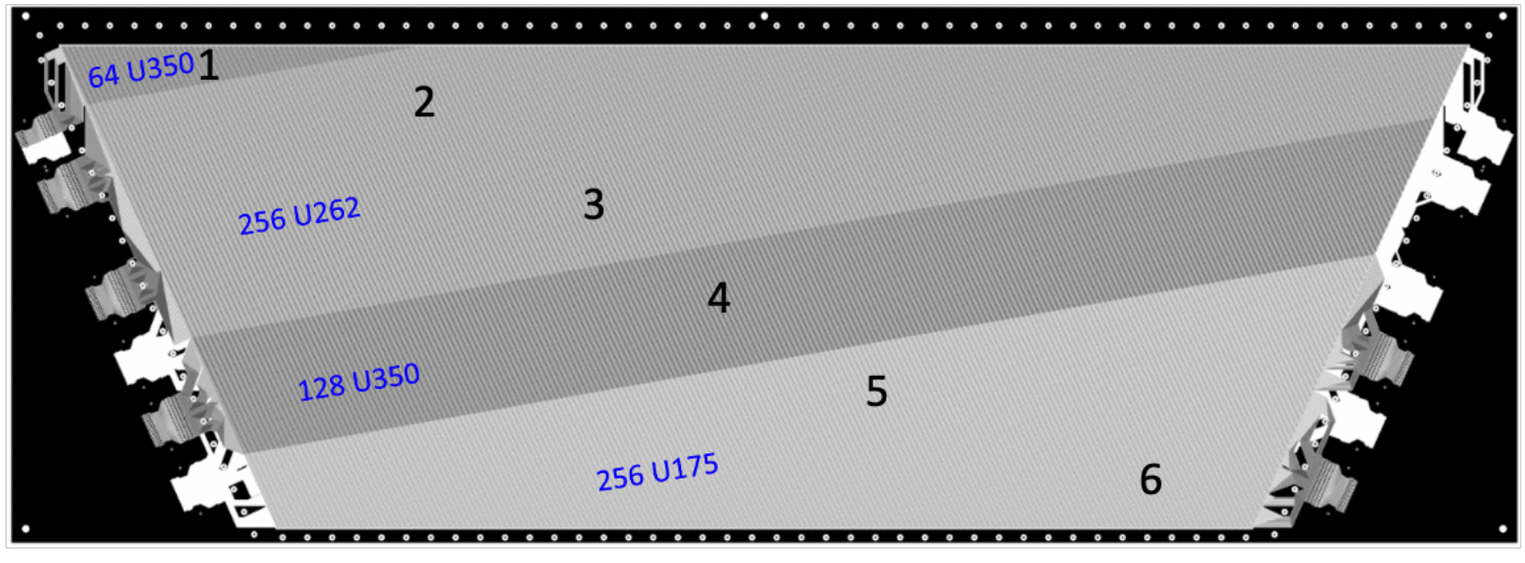
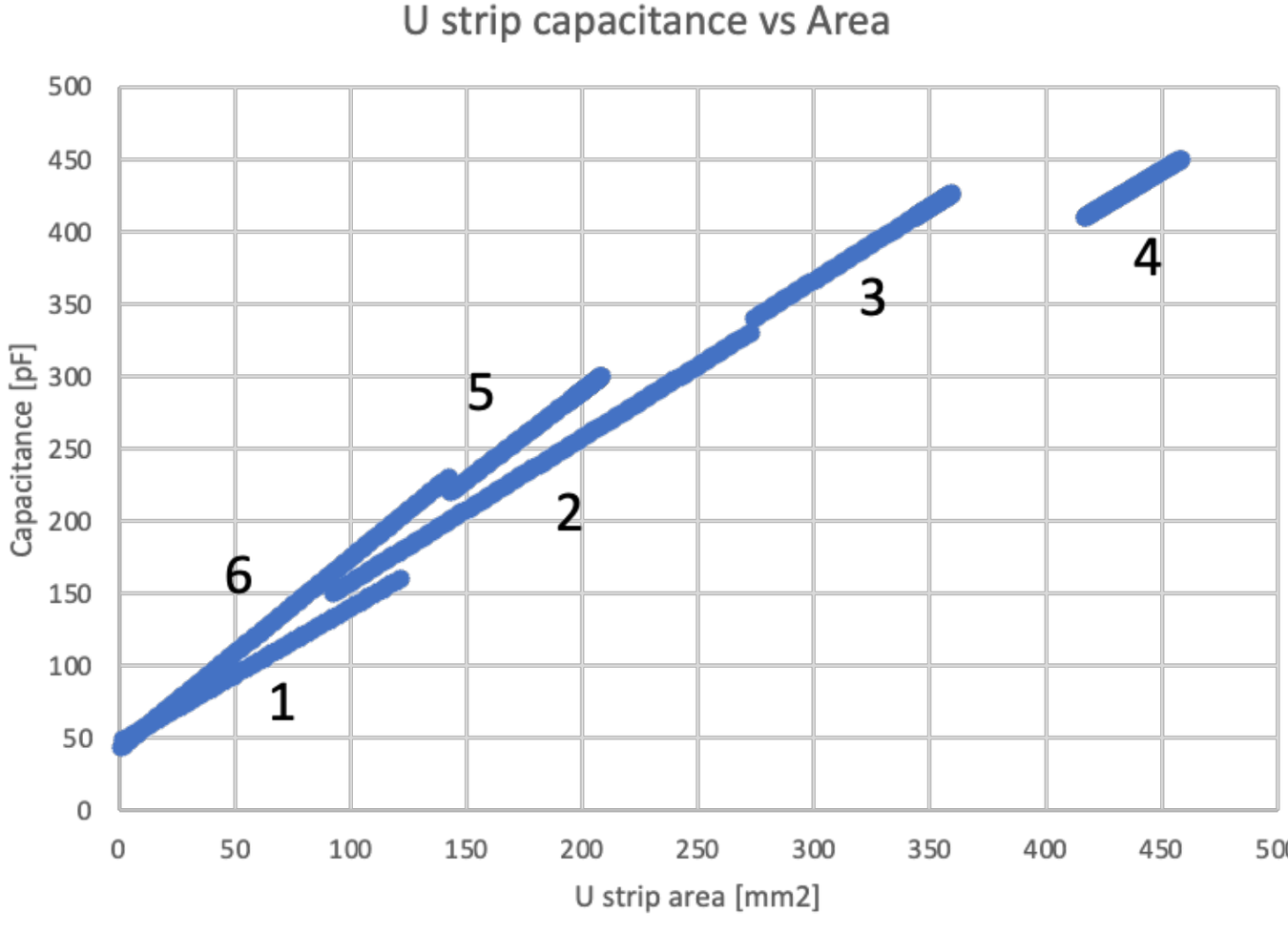
Dependence on capacitance of strips??

U strip capacitance



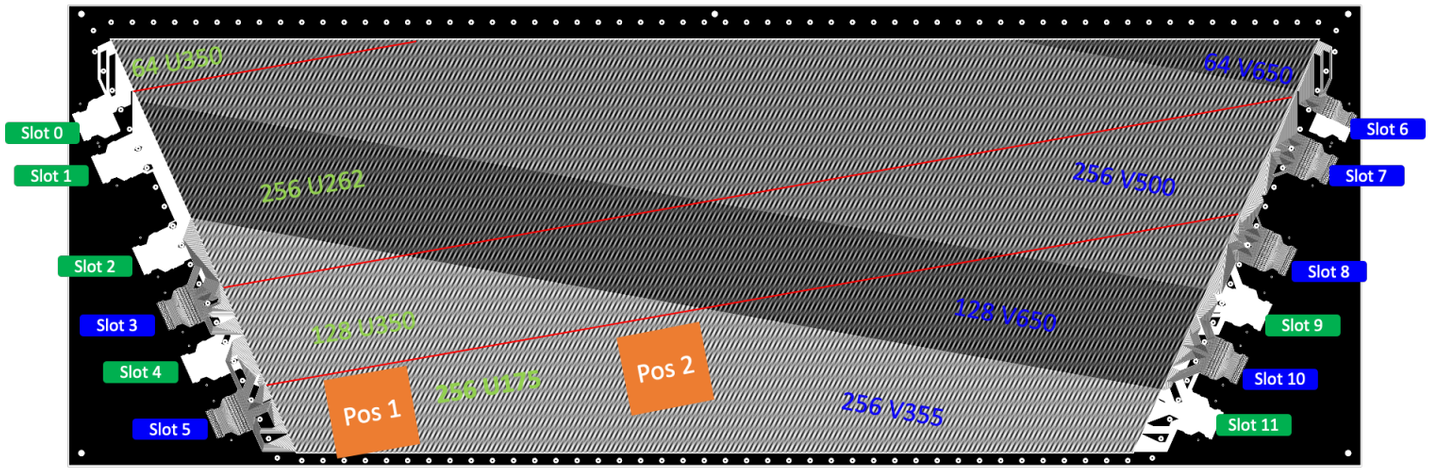
- **Capacitance is high - typical values for GEMs with APV readout are 100-200pF —> could explain lower overall efficiency —> loss of signal to noise**
- **More studies underway**



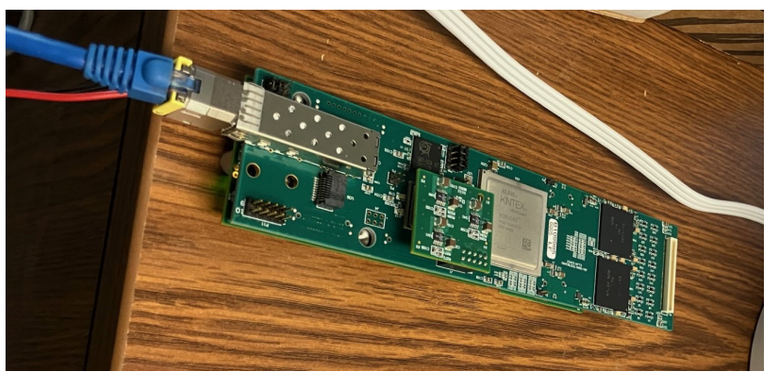
Plot by Rafo

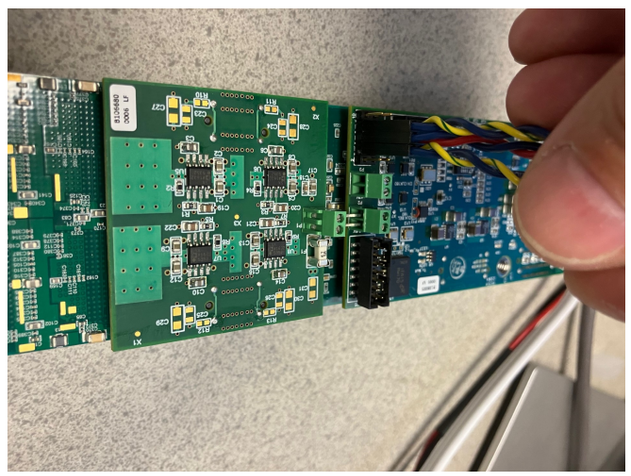
Upcoming Plans with Prototype

- **Detector repaired at CERN**
  - **leakage problem solved (confirmed in EEL)**
  - **recovered bad HV sectors**
- **Cosmic measurements on left side with lower capacitance**



- **Measurements with VMM3**





- **Study of other gas mixtures and HV**
- **Next year maybe again in the hall?**

μRWELL Prototype Tests at INFN

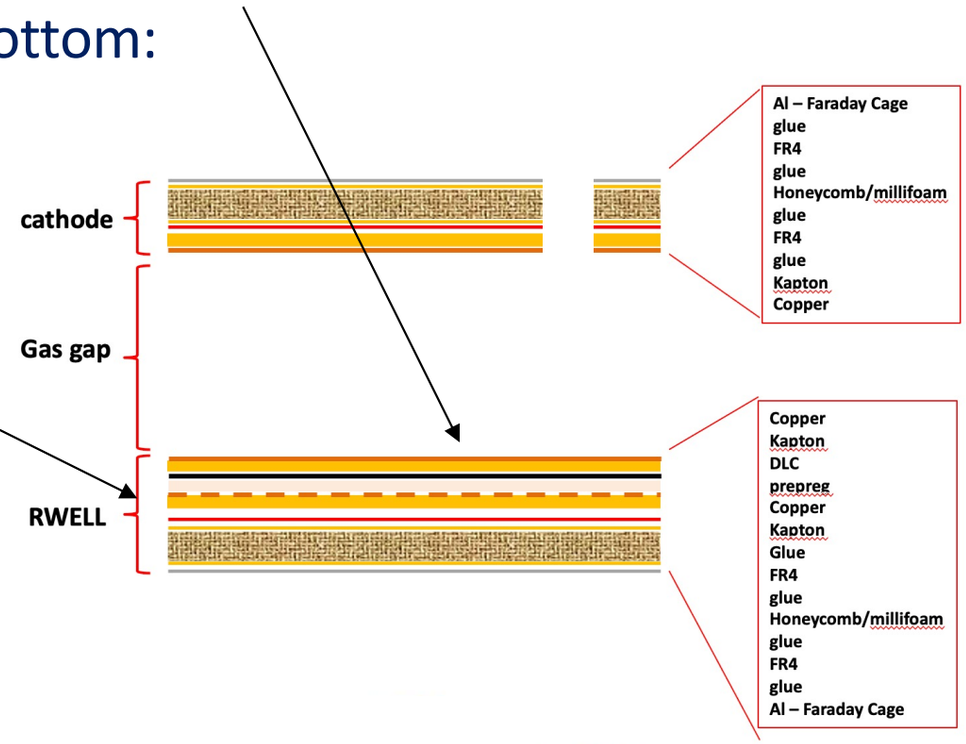
2D – readout: step by step approach

1. One prototype reads the 2-nd coordinate on the “top” copper layer

Same readout geometry on the top and the bottom:

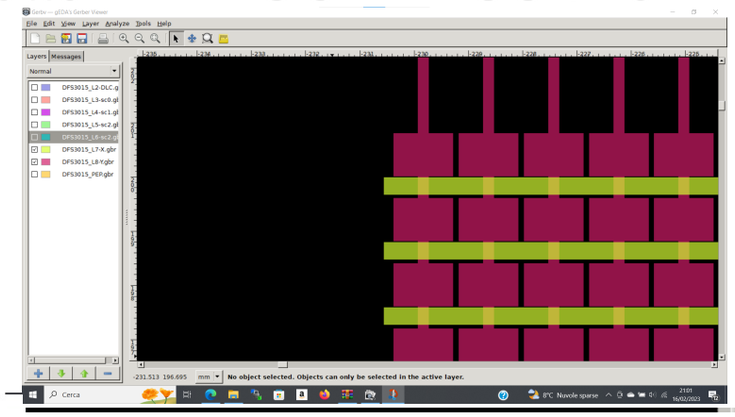
- 780 mm pitch
- 300 mm width
- 10 x 10 cm^2 active surface
- 128 channels

The effect charge collection on the «top» layer is the object of investigation.



2. A second prototype reads both coordinates on the bottom in “COMPASS-like” strips configuration with capacity sharing read-out:

- 1200 μm pitch
- 300 μm vs 1000 μm strips width
- 10 x 10 cm^2 active surface
- 83 channels

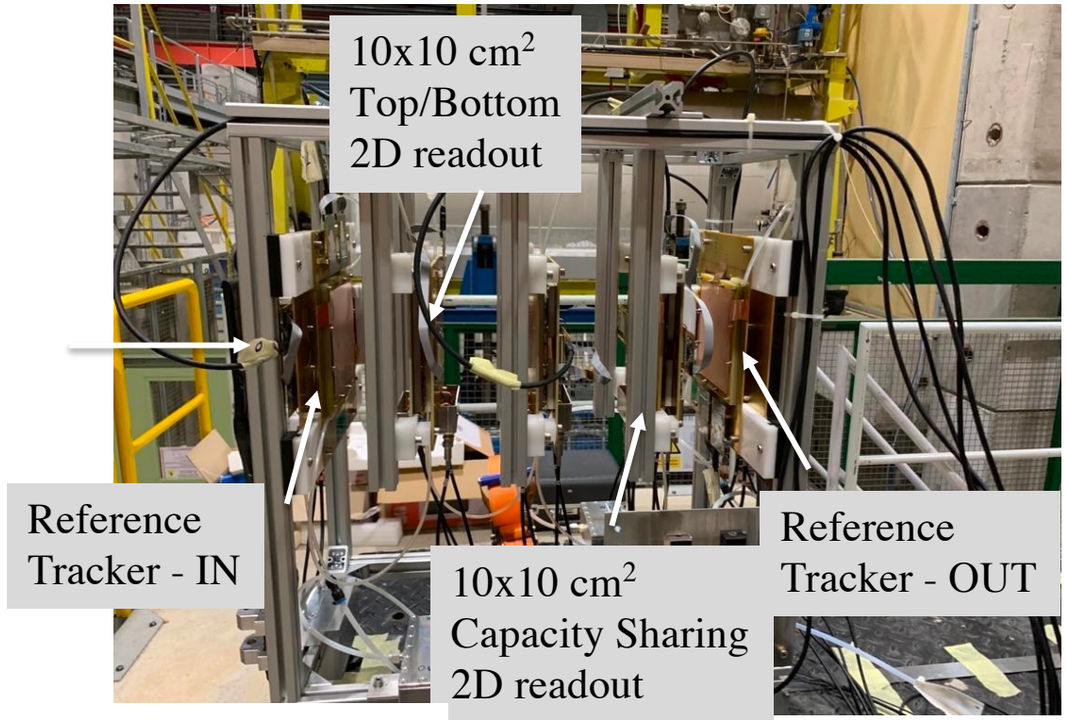


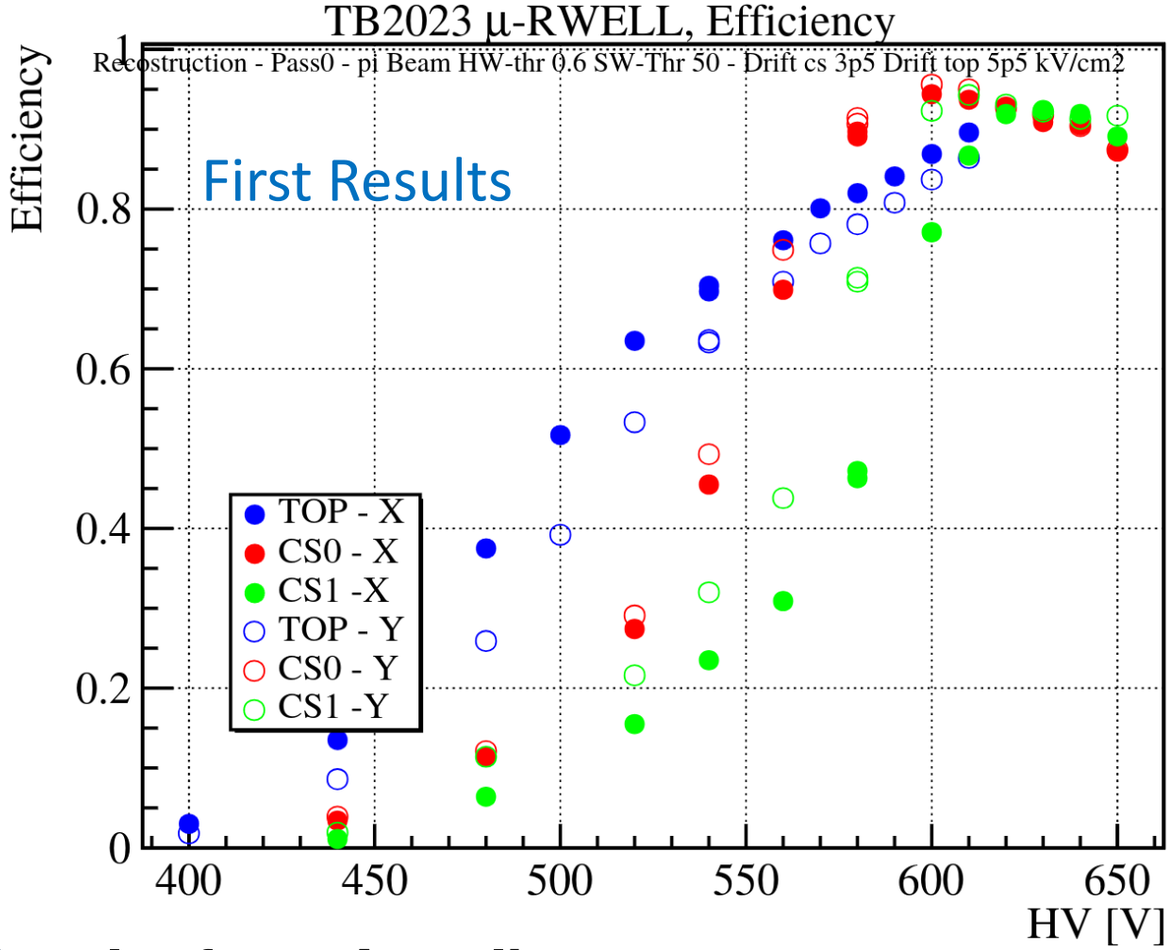
Slide by Annalisa

μRWELL Prototype Tests at INFN

Test Beam at CERN SPS North Area H8 in June

π/μ





Efficiency

- CS readout reaches a plateau at higher HV values than standard readout scheme.
- TOP readout is not yet at plateau at 600 V

(HV was chosen to to be raised to higher values)

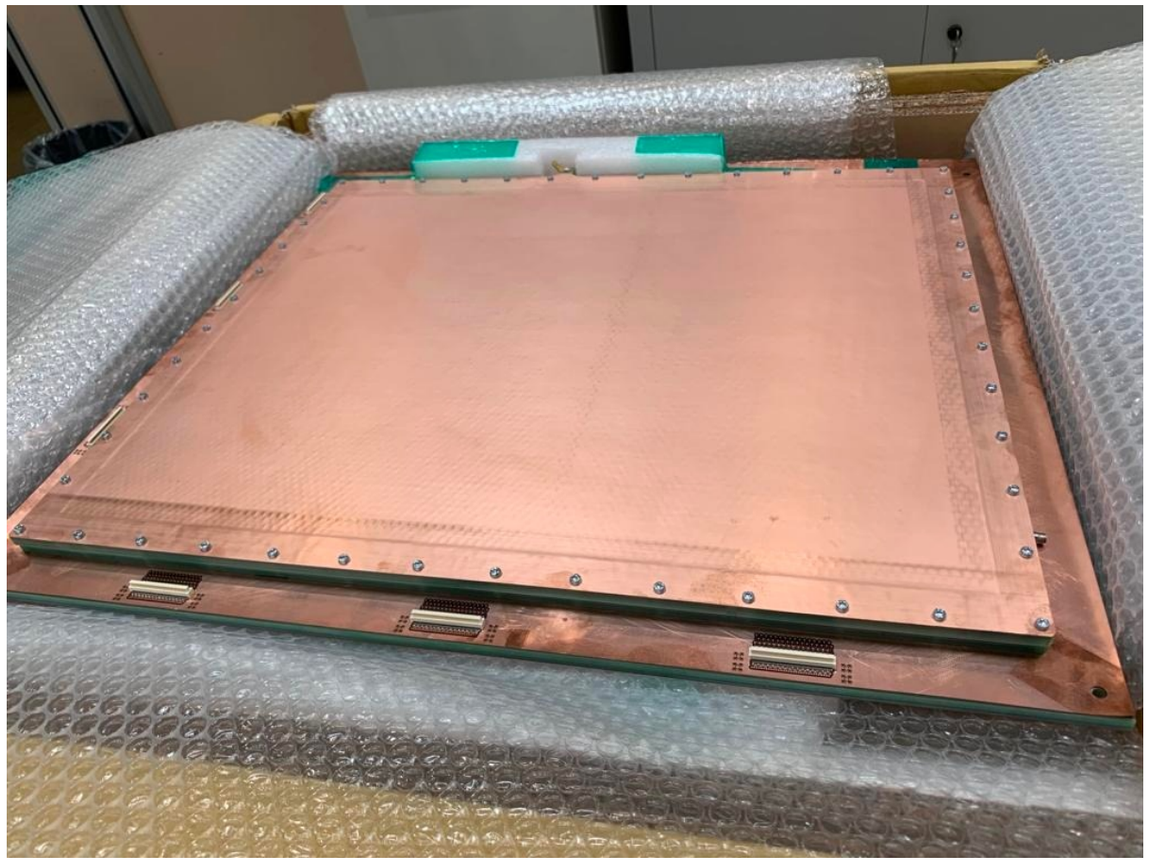
Results from Annalisa

μRWELL Prototype Tests at INFN

NEXT STEP

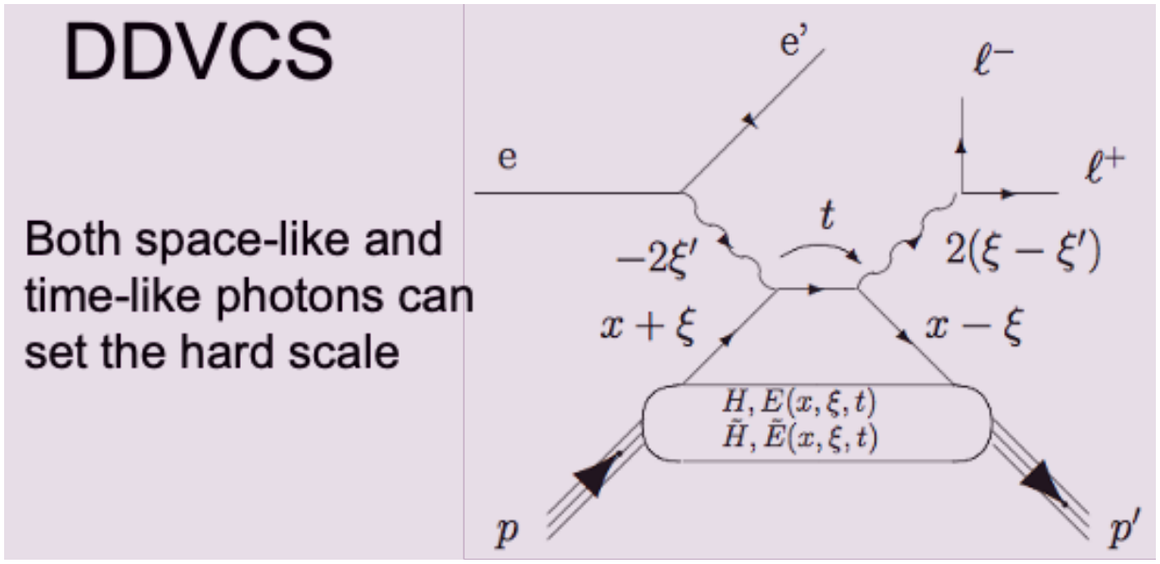
- Test the 50x50 cm2 prototype!

with X-RAYS and cosmics

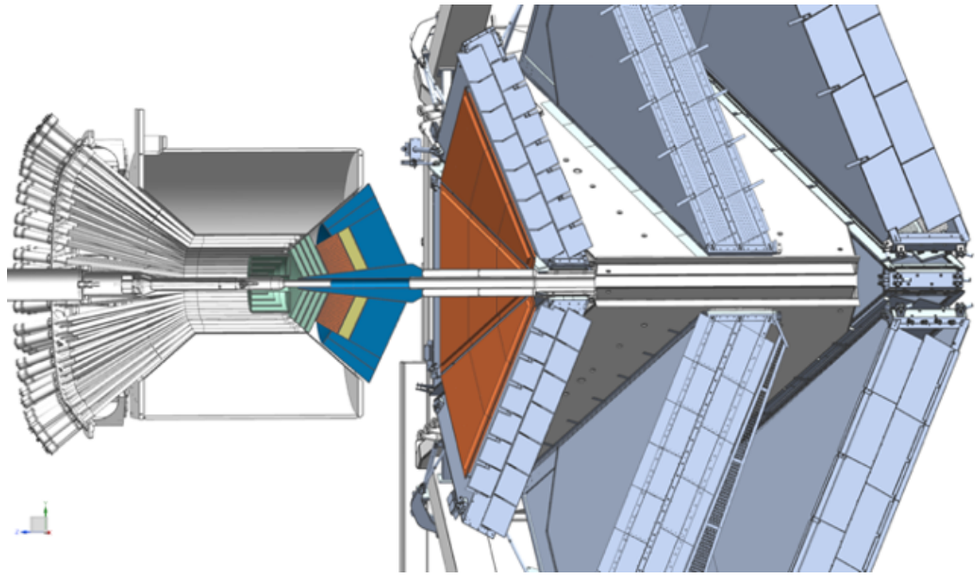


Future Phase-2 Luminosity Upgrade

- **CEBAF can deliver $10^{37}cm^{-2}s^{-1}$ luminosity**
- **High luminosity needed to study new and low cross section reaction like DDVCS**



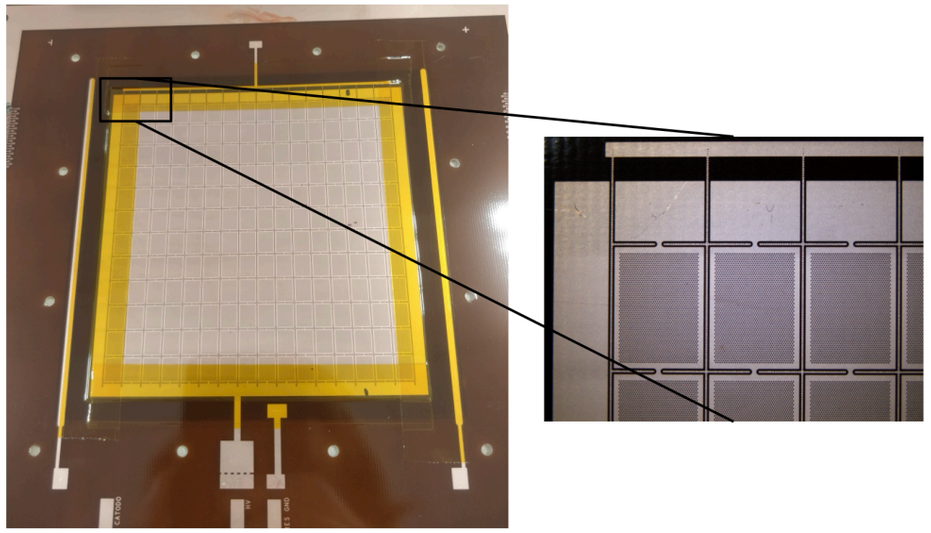
- **Phase-2 update converts CLAS to μCLAS**
  - **new Moller cone**
  - **μ-pairs in FD after shielding**
  - **calorimeter and tracker instead of HTCC**
  - **tracker inside solenoid for recoils**
  - **timeframe 7-10y**

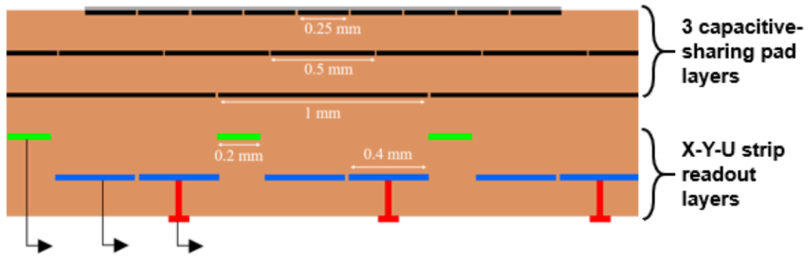


Tracker — High-rate capable μRWELL

- **LDRD project**

- **Prototype testing**
  - Various resistive layer layouts
  - Capacitive sharing X-Y-U strip readout
  - Thin gap





Cross section view of 3-coordinates X-Y-U strips capacitive-sharing readout

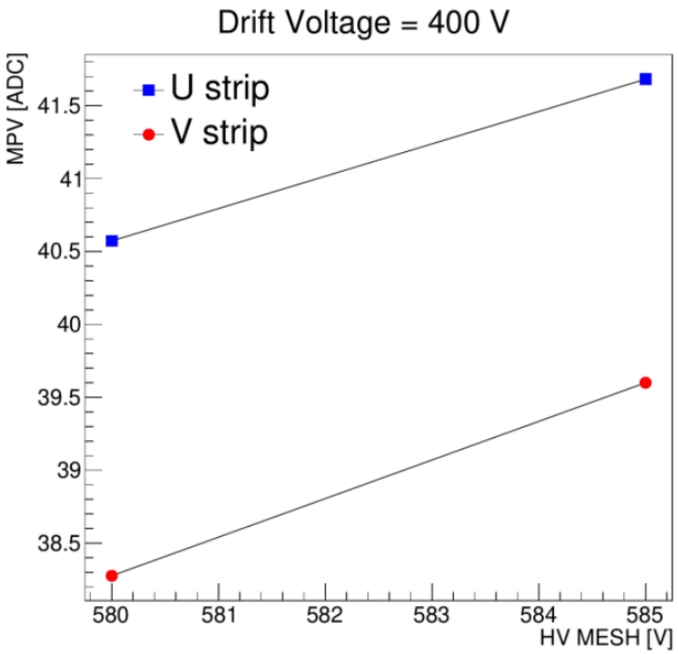
- **Software development**
  - Implementation in GEMC
  - Hit and track reconstruction algorithm in a high-rate environment
  - Validation with test measurements

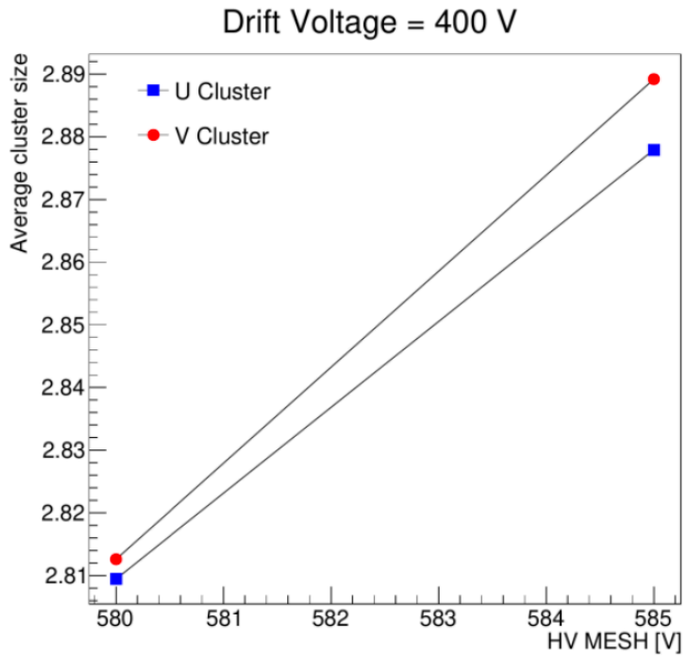
- **Personnel:**
  - 1 Postdocs (80% FTE)
  - Florian Hauenstein, Rafayel Paremuzyan, Kondo Gnanvo

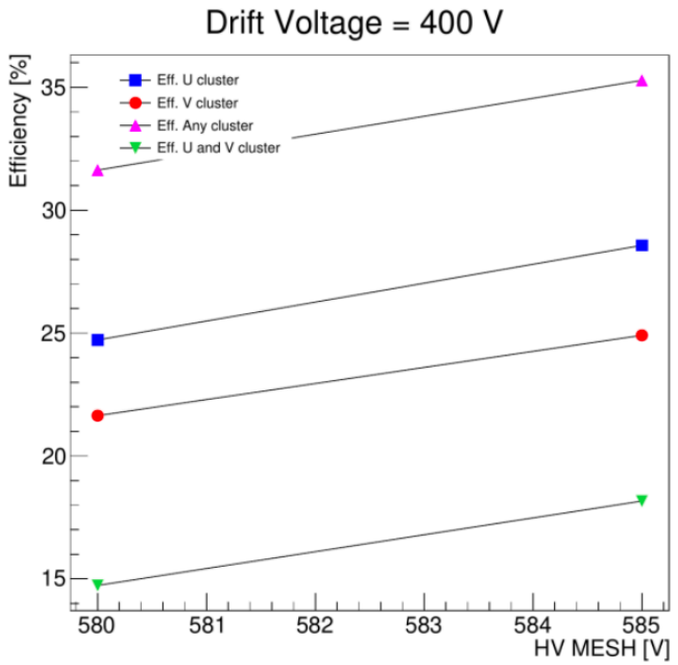
Questions?

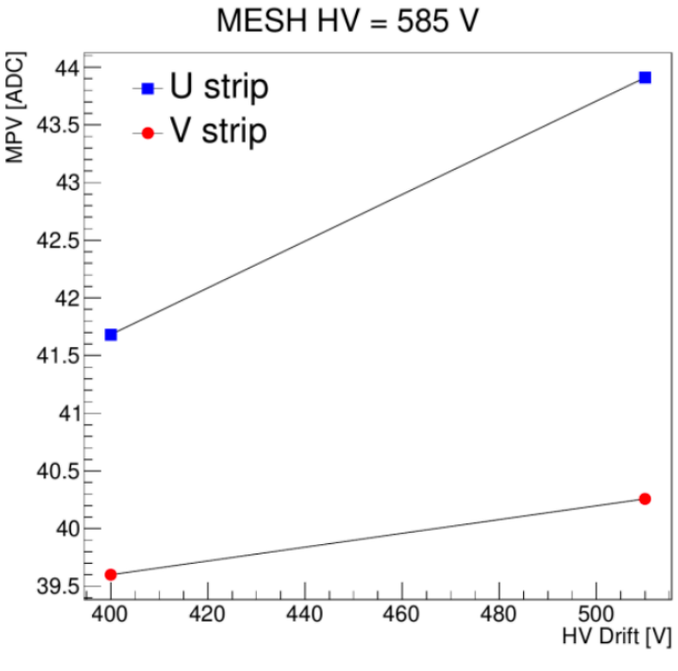
Backup

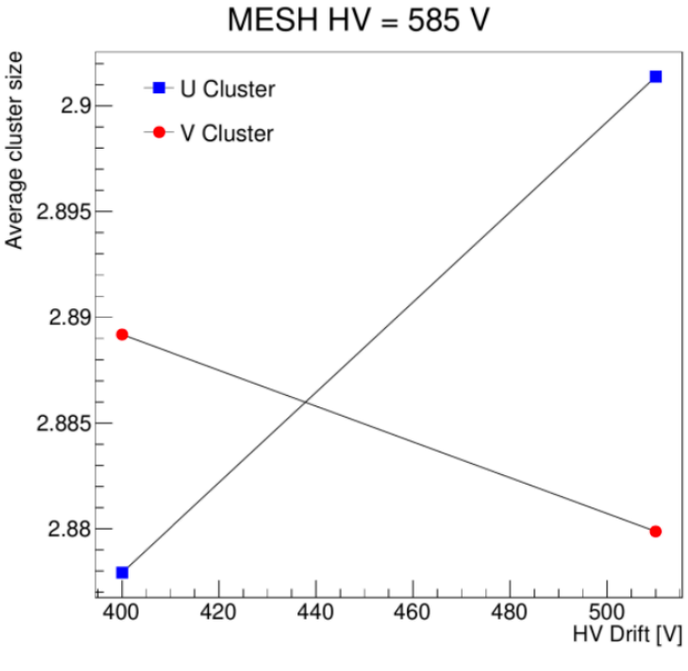
Results Ar/CO2 75:25

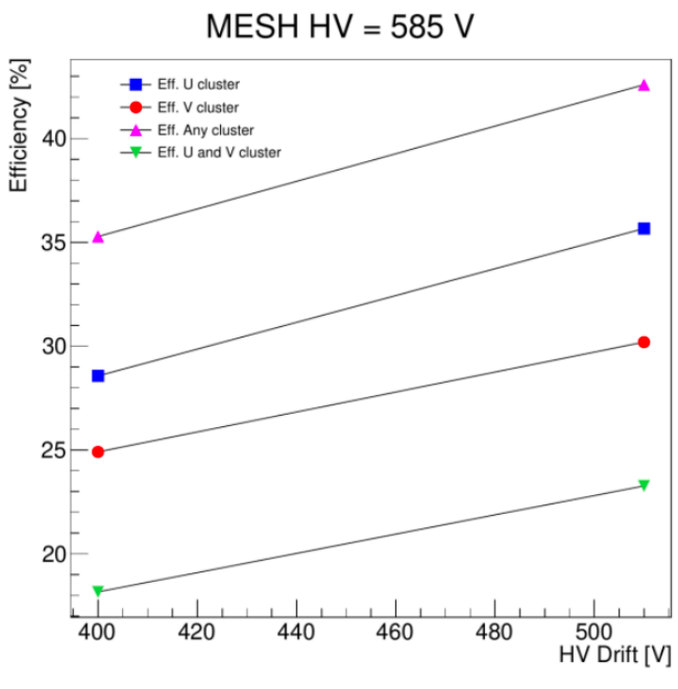




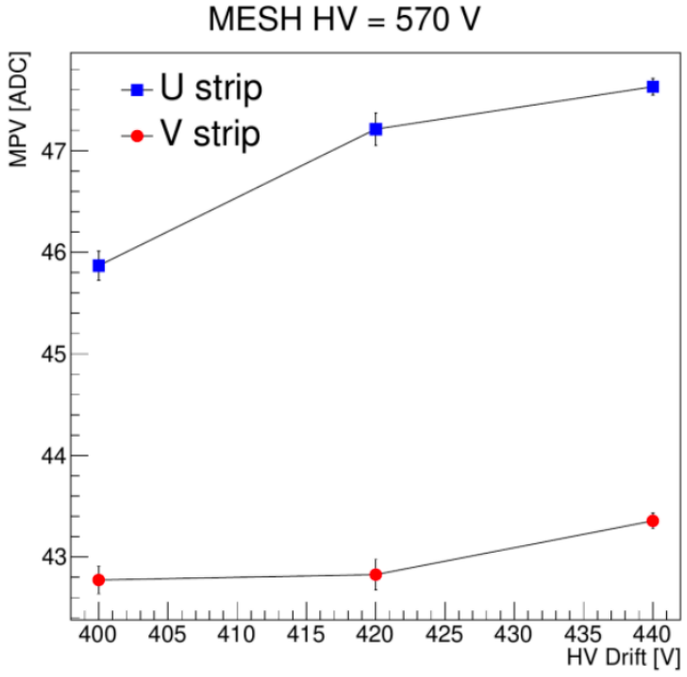


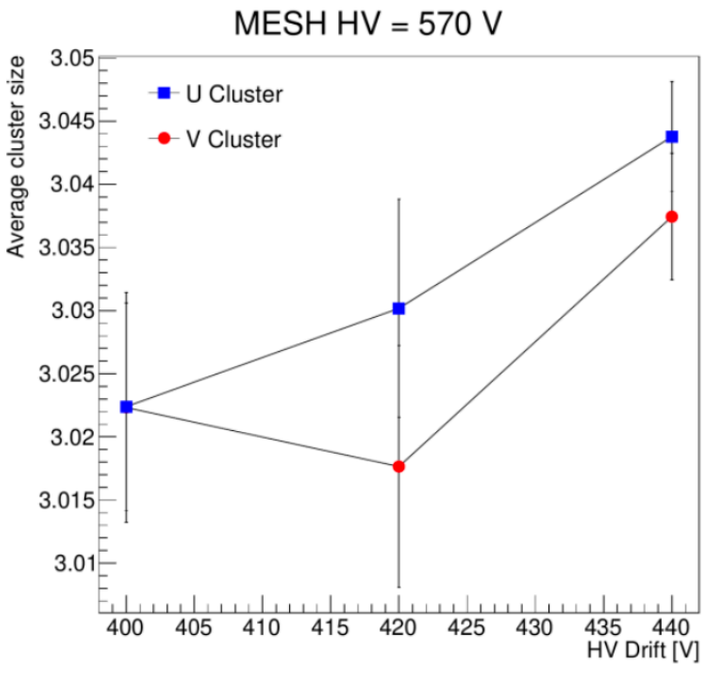


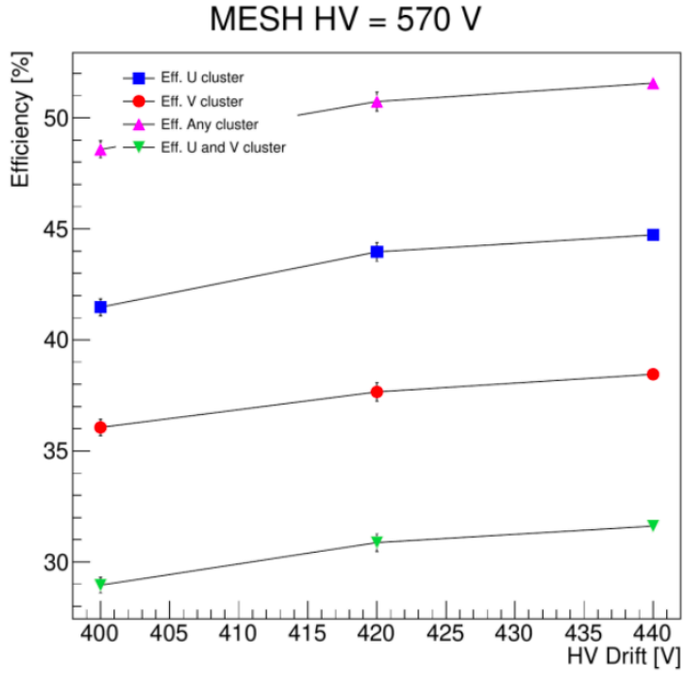


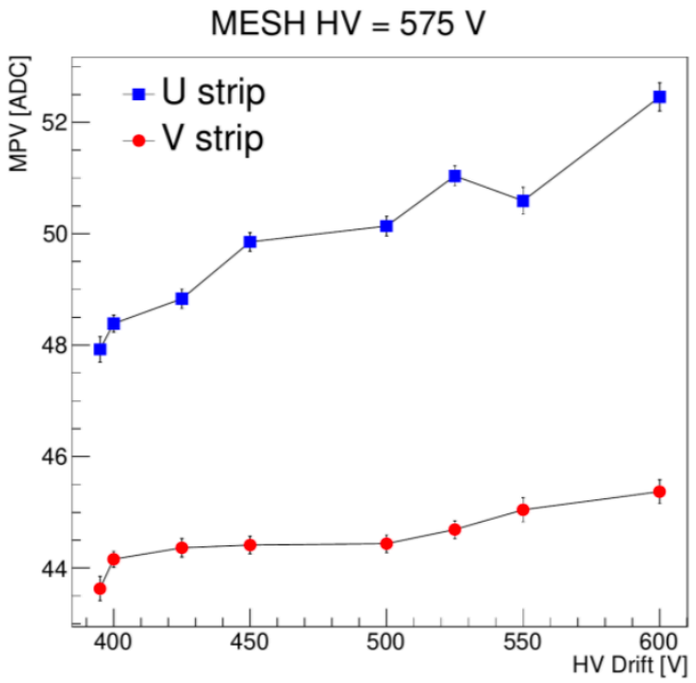


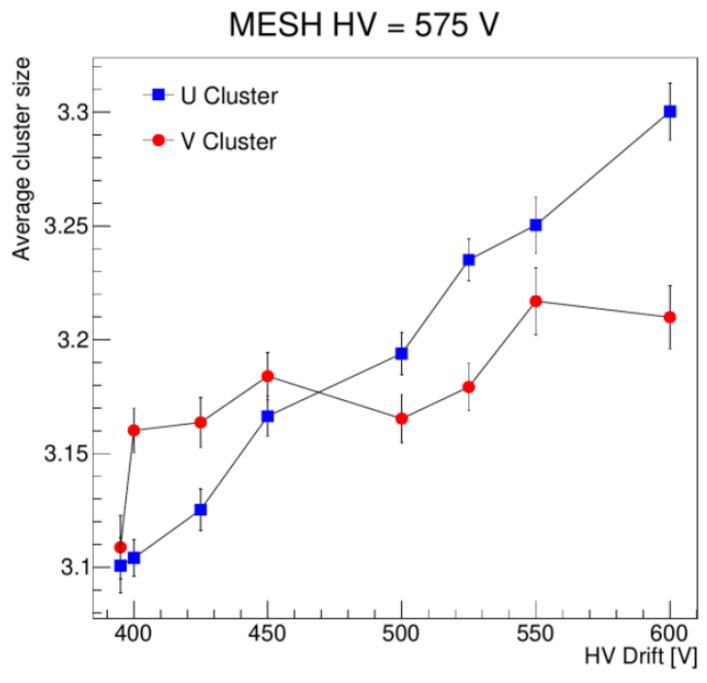
Results Ar/CO2 80:20

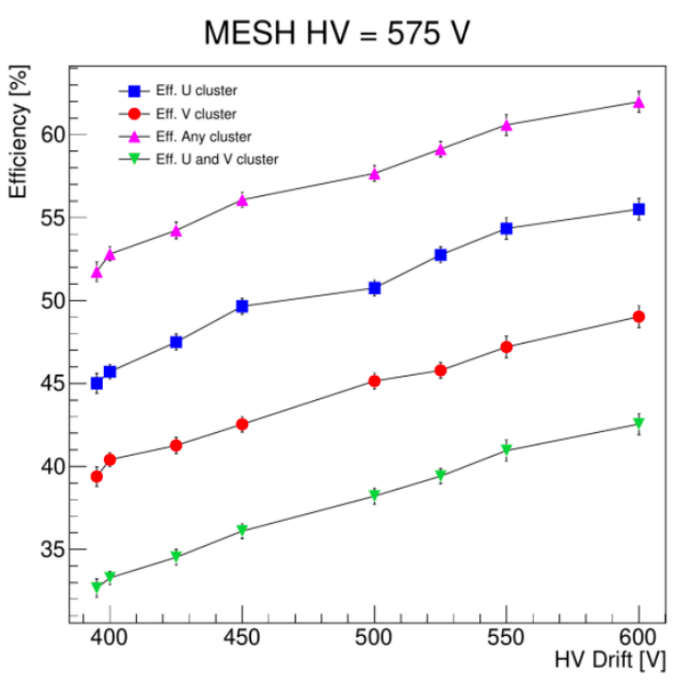




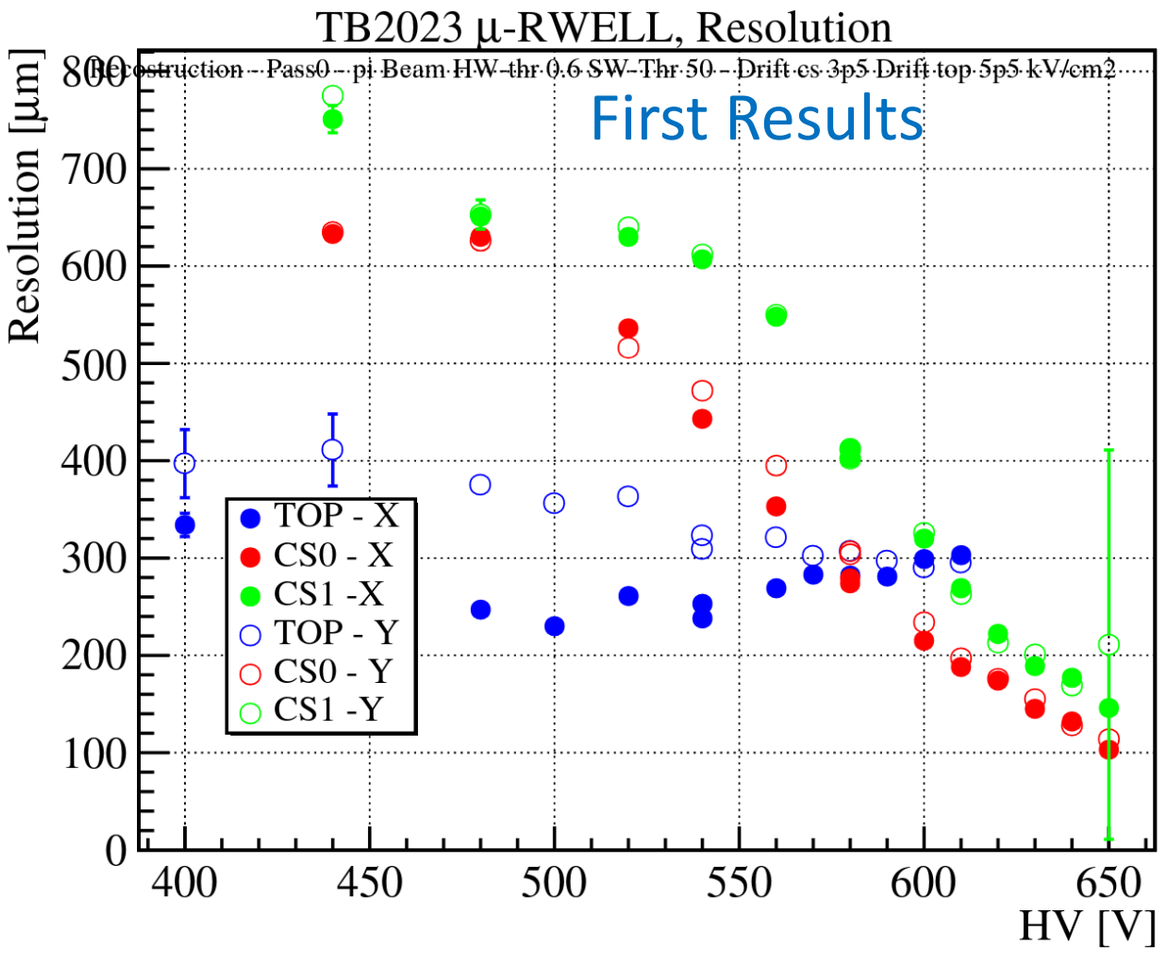








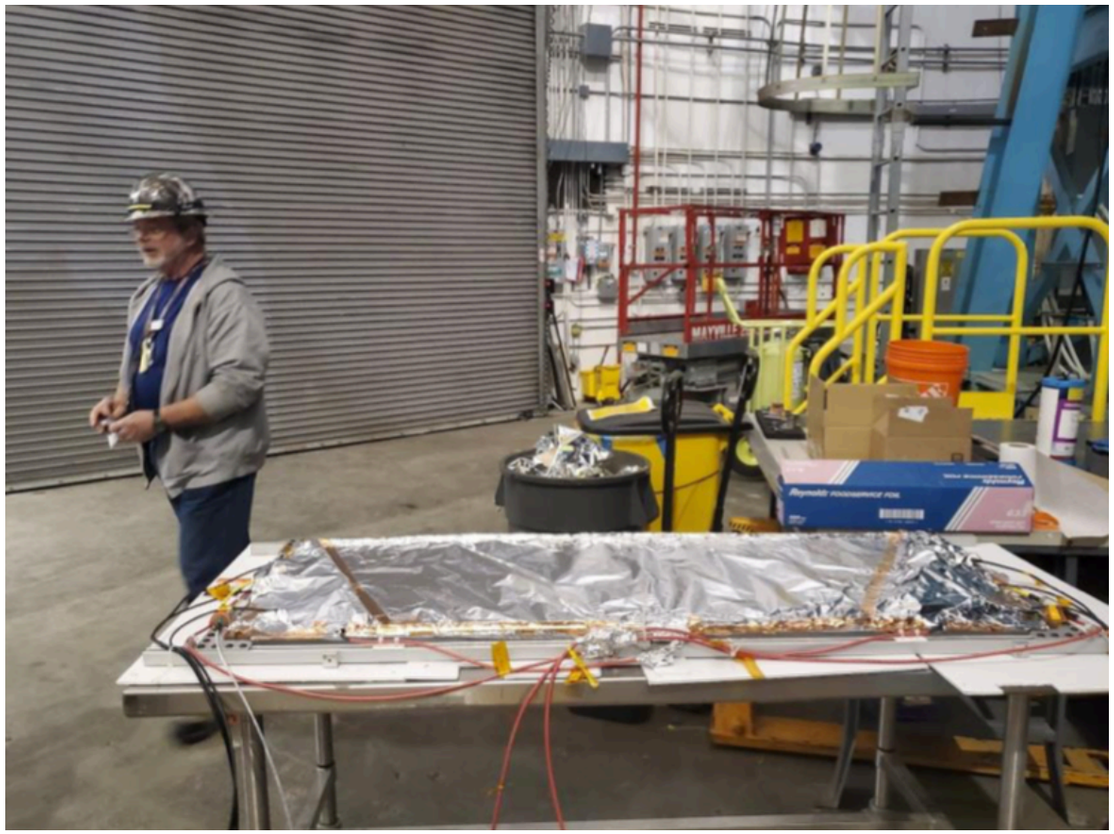
μRWELL Prototype Tests at INFN



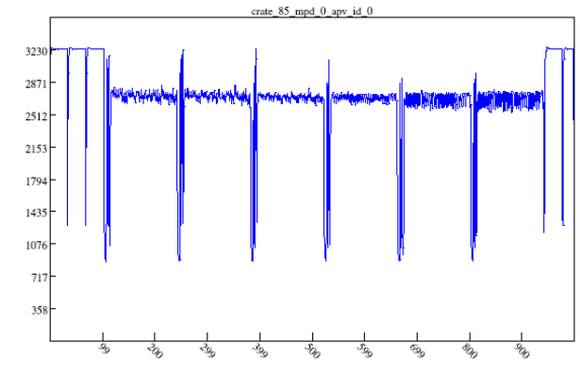
Resolution

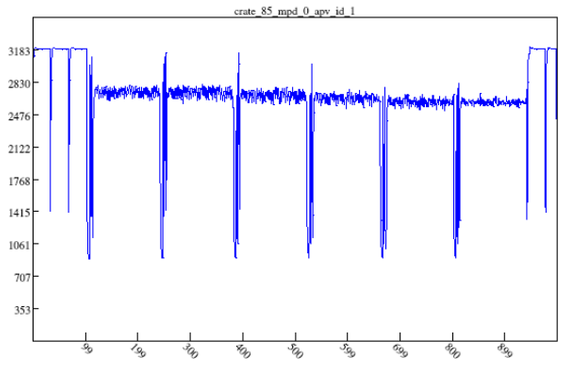
- CS readout reaches 100 μm resolution at highest HV values (starting from 1200 μm pitch)
- TOP readout resolution is fixed at 250-300 μm (pitch is 780 μm)

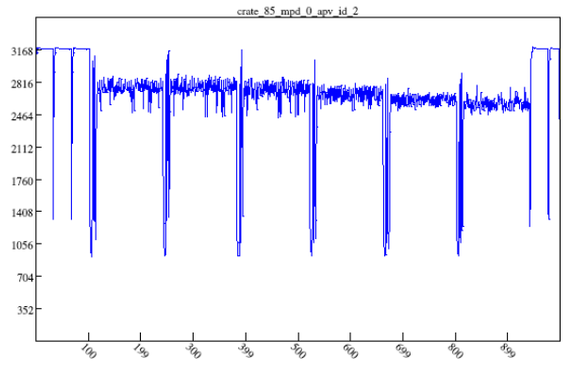
Urwell in HallB

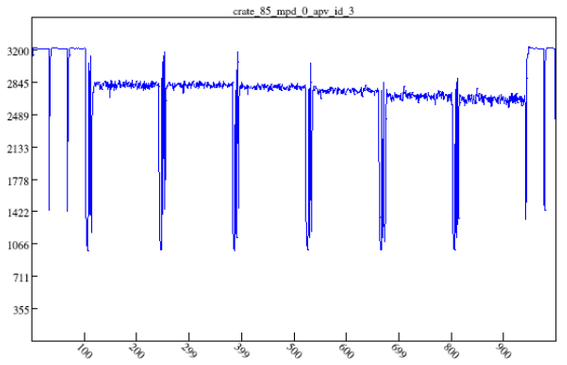


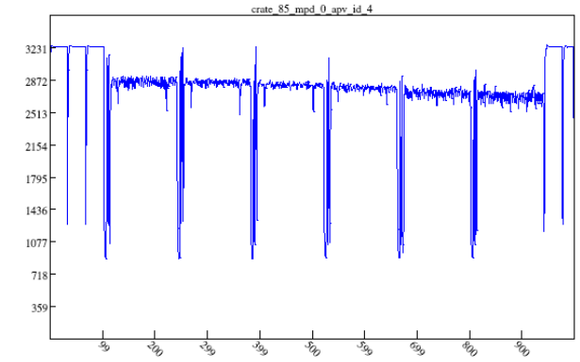
Noise Issue fixed

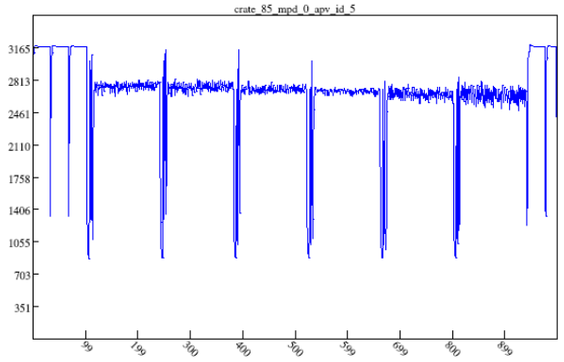


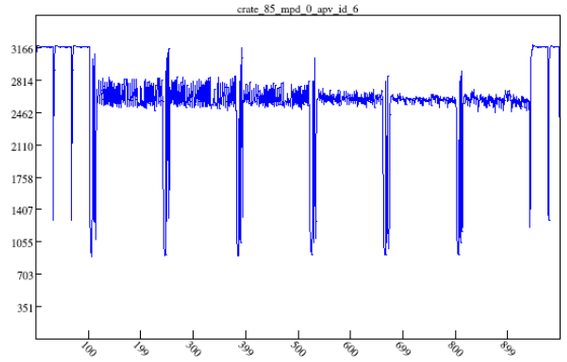


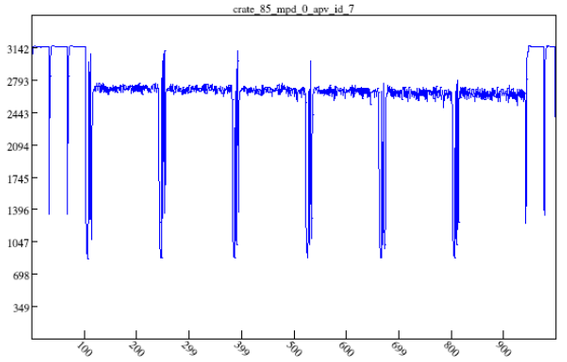


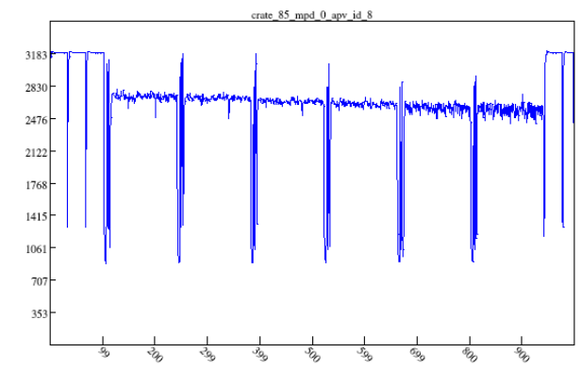


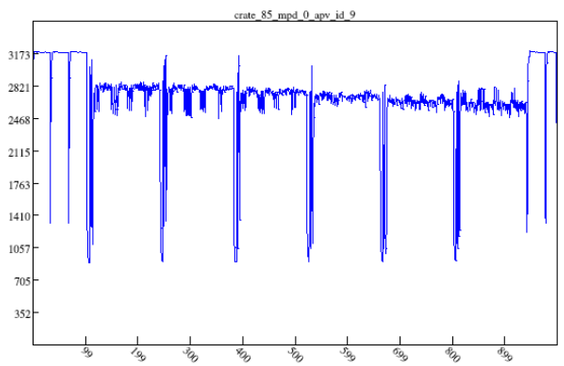


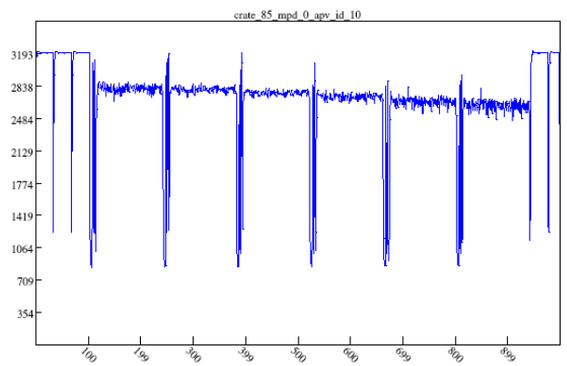


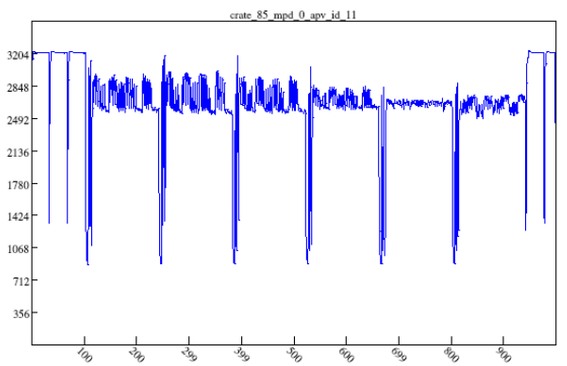






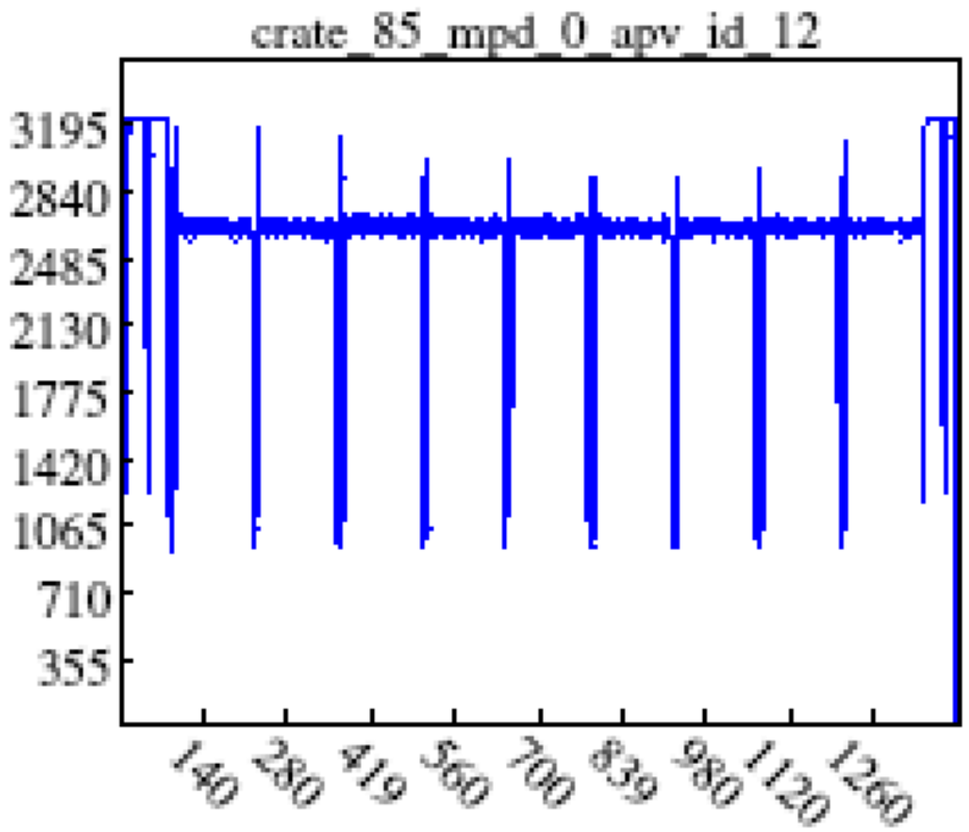


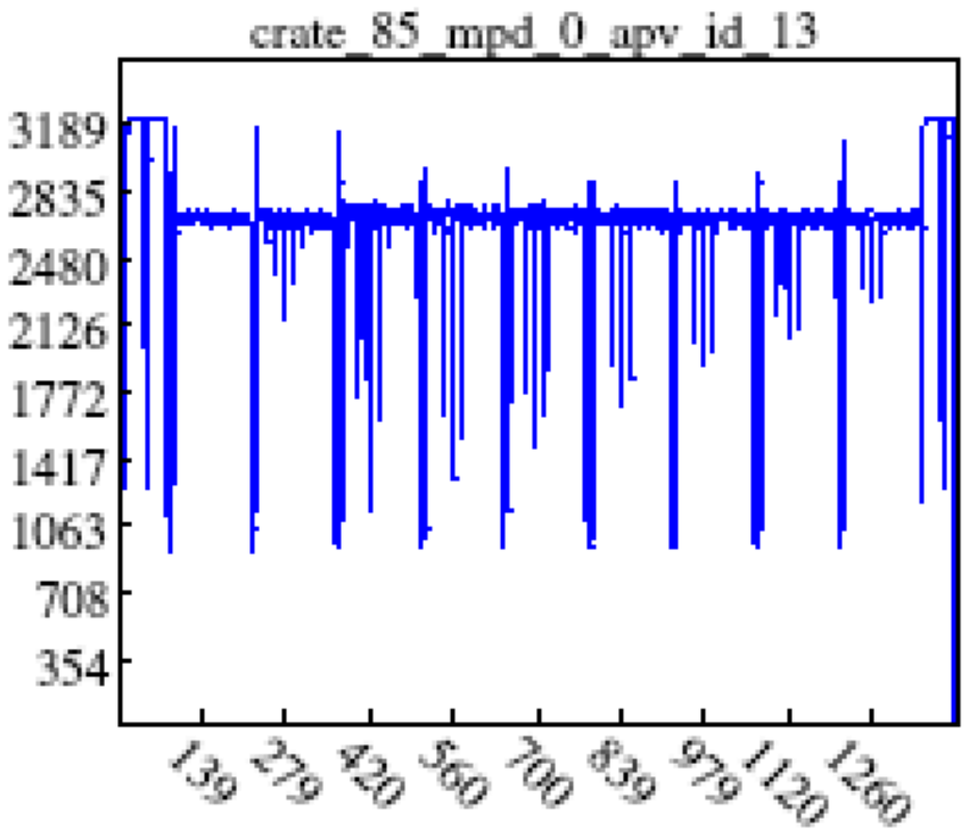




- **However, still no clear signal observed :(- latency issues?**
- **Installed GEM behind the trigger bar in FTOF panel 2, cover about 1/90 of FTOF bar**

Signals from GEM in HallB

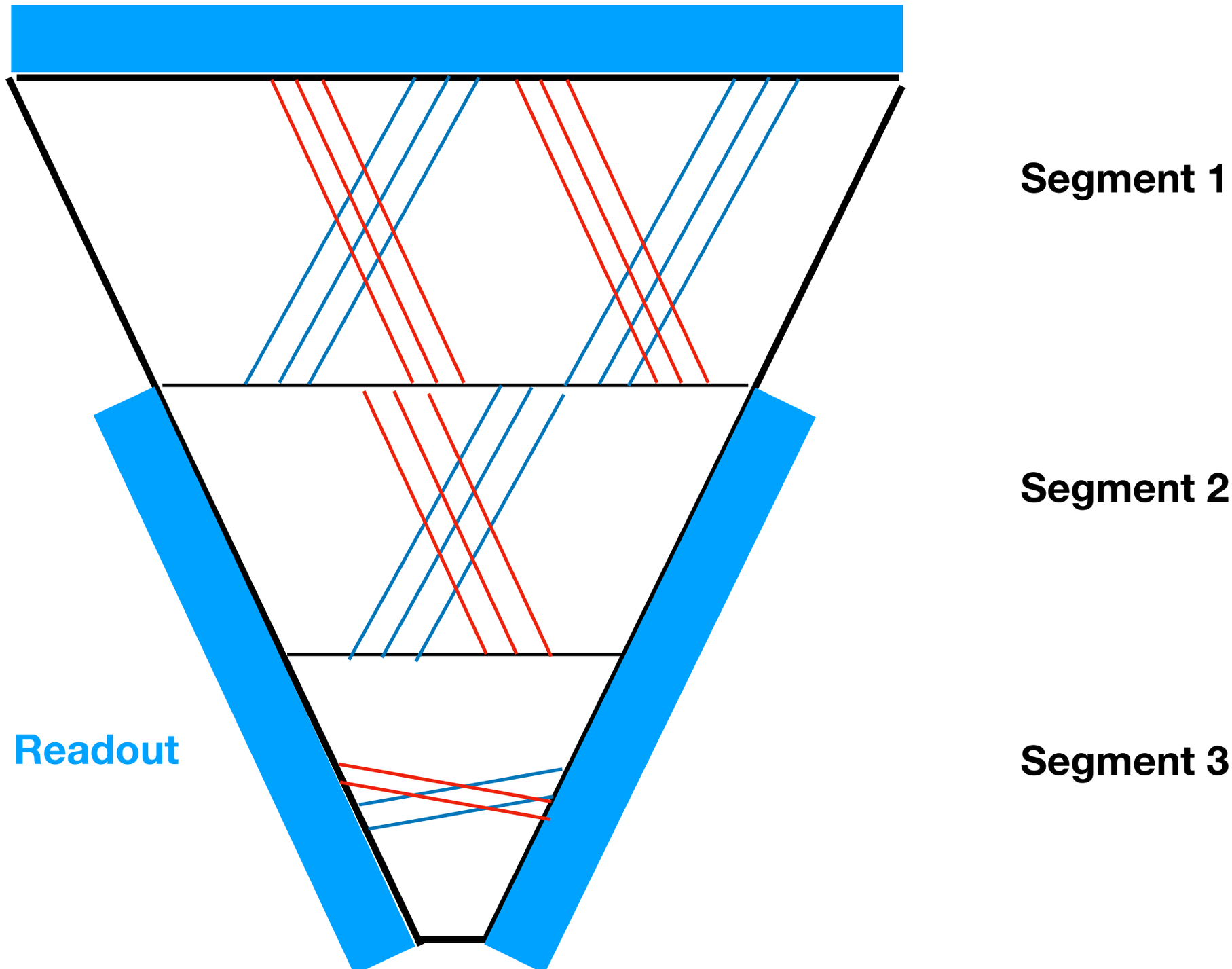




- **GEM showed signal but still nothing seen in uRWELL**

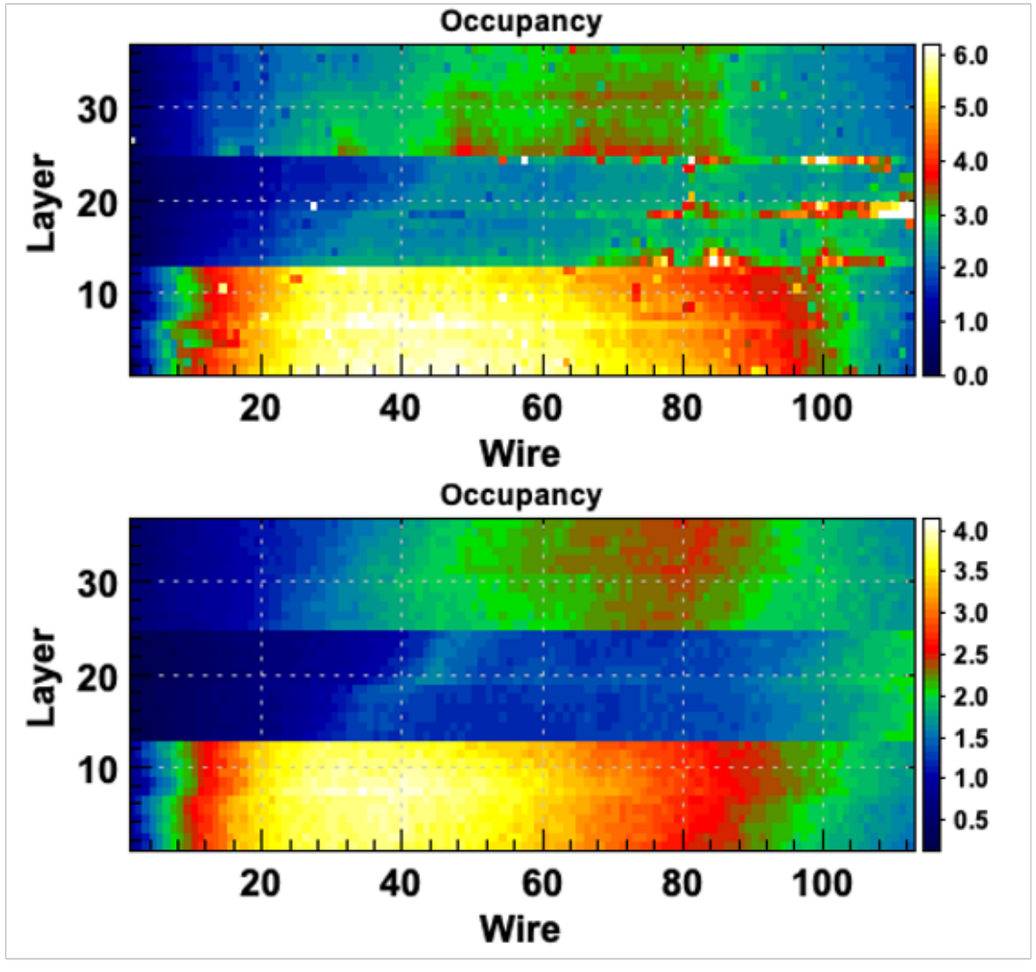
Alternative Design

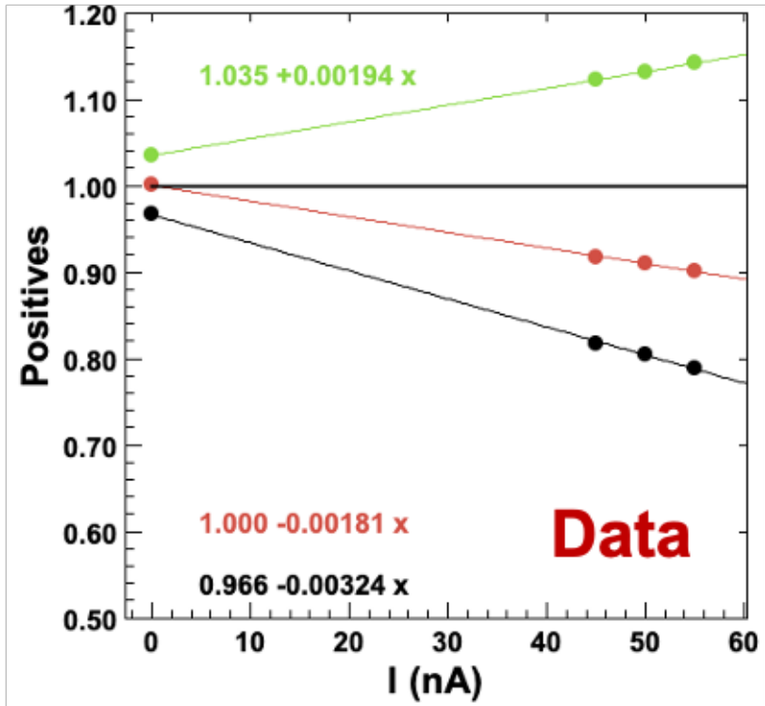
strips parallel to sides for segment 1, readout from top, pitch could be larger than 1mm
strips parallel for segment 2 with vias to readout on side
strips at +/-10deg for Segment 3

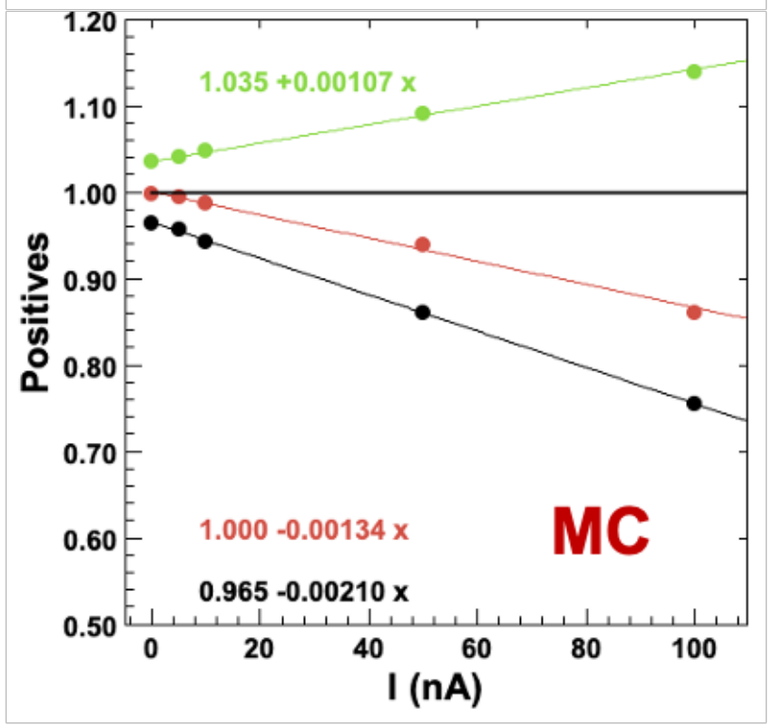


Generation of Beam Background

- Using GEMC to generate URWell beam background
- Assessing the accuracy comparing DC GEMC background to data
  - Currently both occupancy and tracking efficiency from luminosity-scan analysis indicate simulated BG is 30% lower than data
  - Investigation of possible sources in progress







Slide by Raffaella