Signal Formation in THGEM-like Detectors

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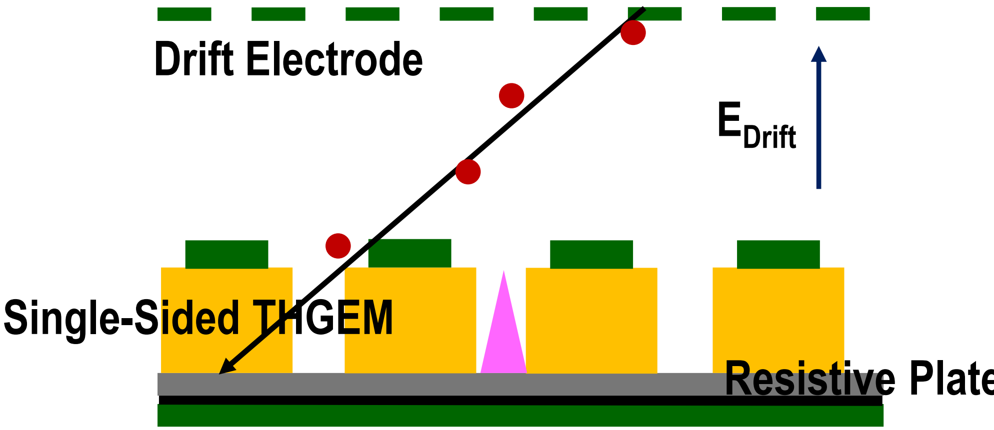
Resistive Plate WELL Detector (RPWELL)

- Robust, single-stage gaseous detector
- Single-sided THGEM electrode coupled to a readout electrode through a resistive-plate
- anode of high bulk resistivity ($\sim 10^8 - 10^{12}\ \Omega$-cm)
- The resistive plate quenches the charge created due to occasional discharges
- Discharge-free operation at high gain ($>10^4$).



Performance of resistive detector is characterized in terms of

- Gain stability over time
- Rate capabilities
- Uniformity of gain and energy resolution
- Effect of edges
- Spatial resolution
- Detection efficiency
- Pad multiplicity

} Current Group Activities

- Discharge probability
- Ageing effect

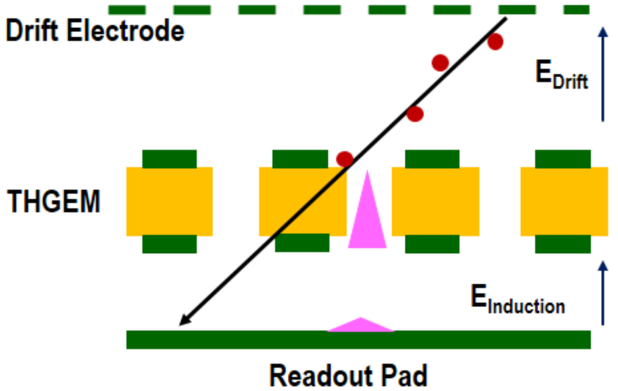
} Need to be studied

This work:

- **Goals:**
  - Develop a simulation tool to study signal formation in various Thick Gaseous Electron Multipliers
  - Incorporate the response of various pre-amplifier with different transfer functions

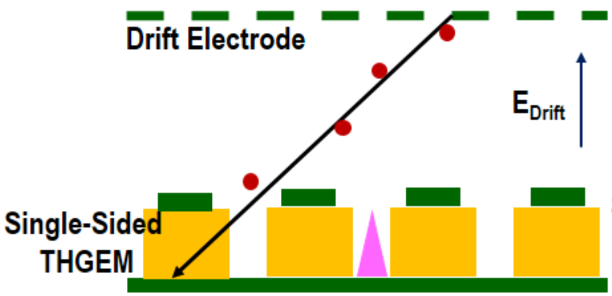
- **Validation:**
  - Detailed comparison of data with numerical simulation
  - Focus on signal shape

- **Configurations**
  - THGEM, THWELL, RPWELL
  - 0.8 mm and 0.6 mm thick
  - Argon and Neon gas mixtures
  - X-Ray, UV and muons sources

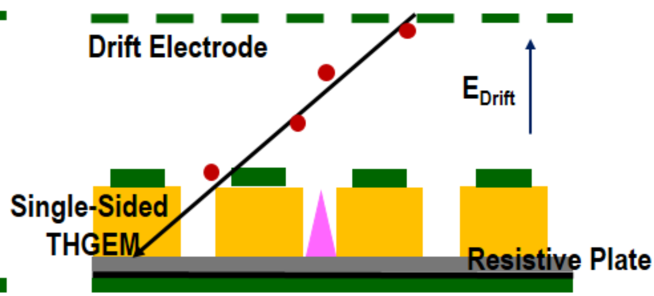


(a) THGEM

- ❑ Drift Gap: 5 mm,
- ❑ Drift Field: 0.5 kV/cm
- ❑ Induction Gap: 2 mm
- ❑ Induction Field: 2 kV/cm
- ❑ Hole Pitch: 0.96 mm,
- ❑ Hole Diameter: 0.5 mm, Rim: 0.1 mm
- ❑ Resistive layer thickness: 0.4 mm

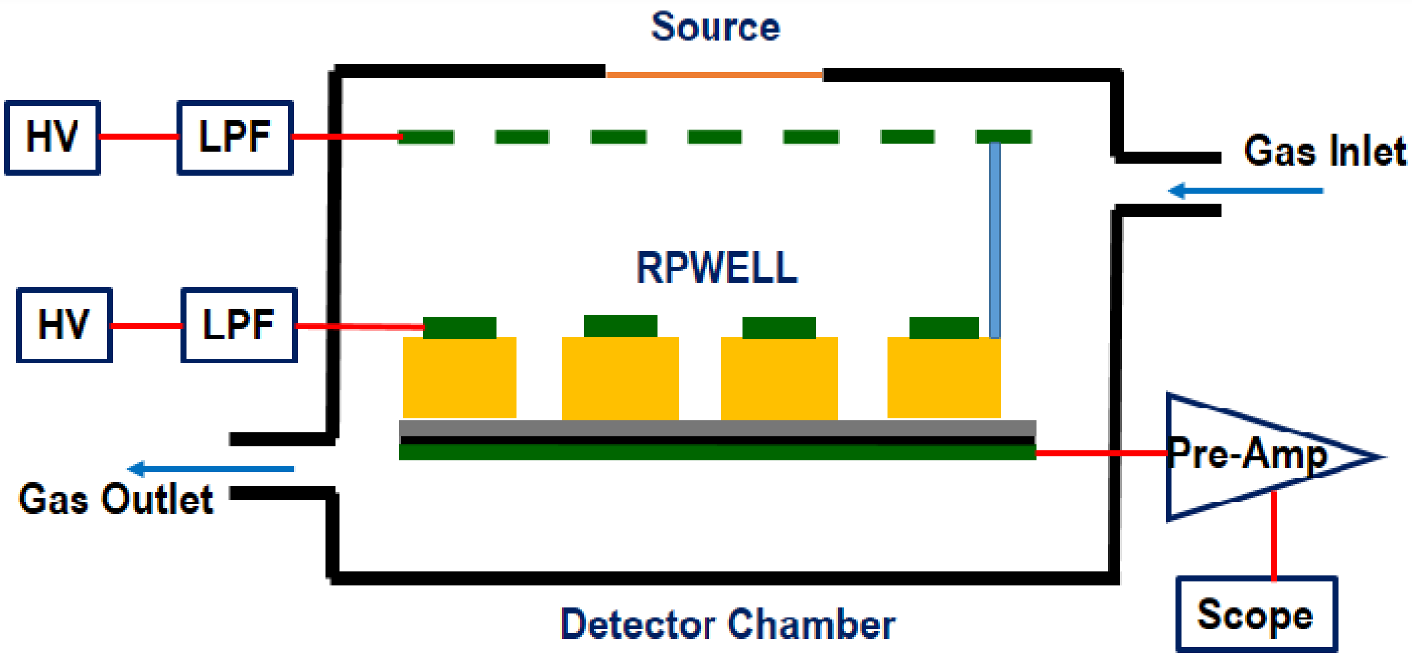


(b) THWELL

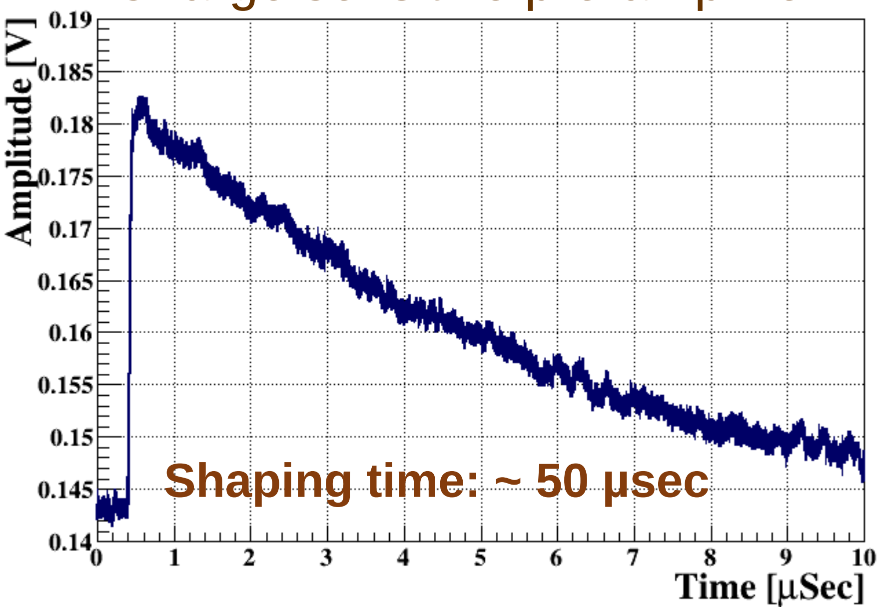


(c) RPWELL

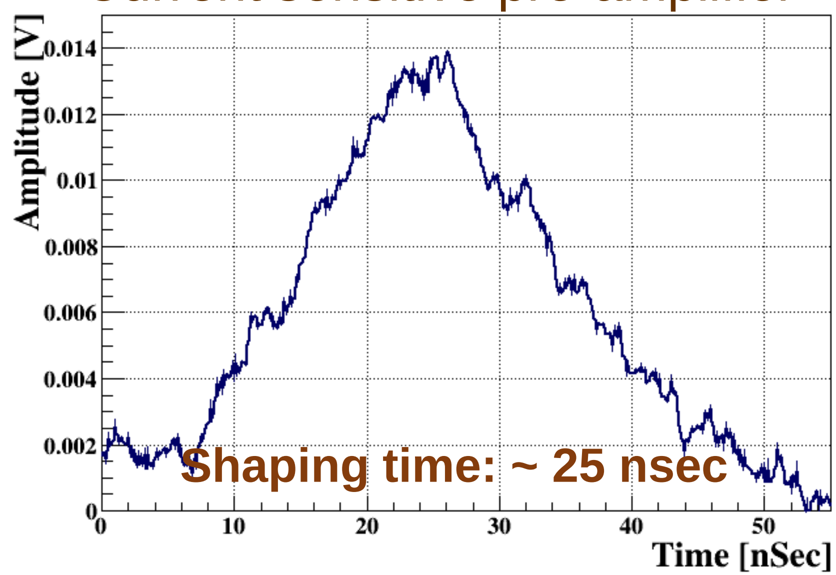
Experimental Setup



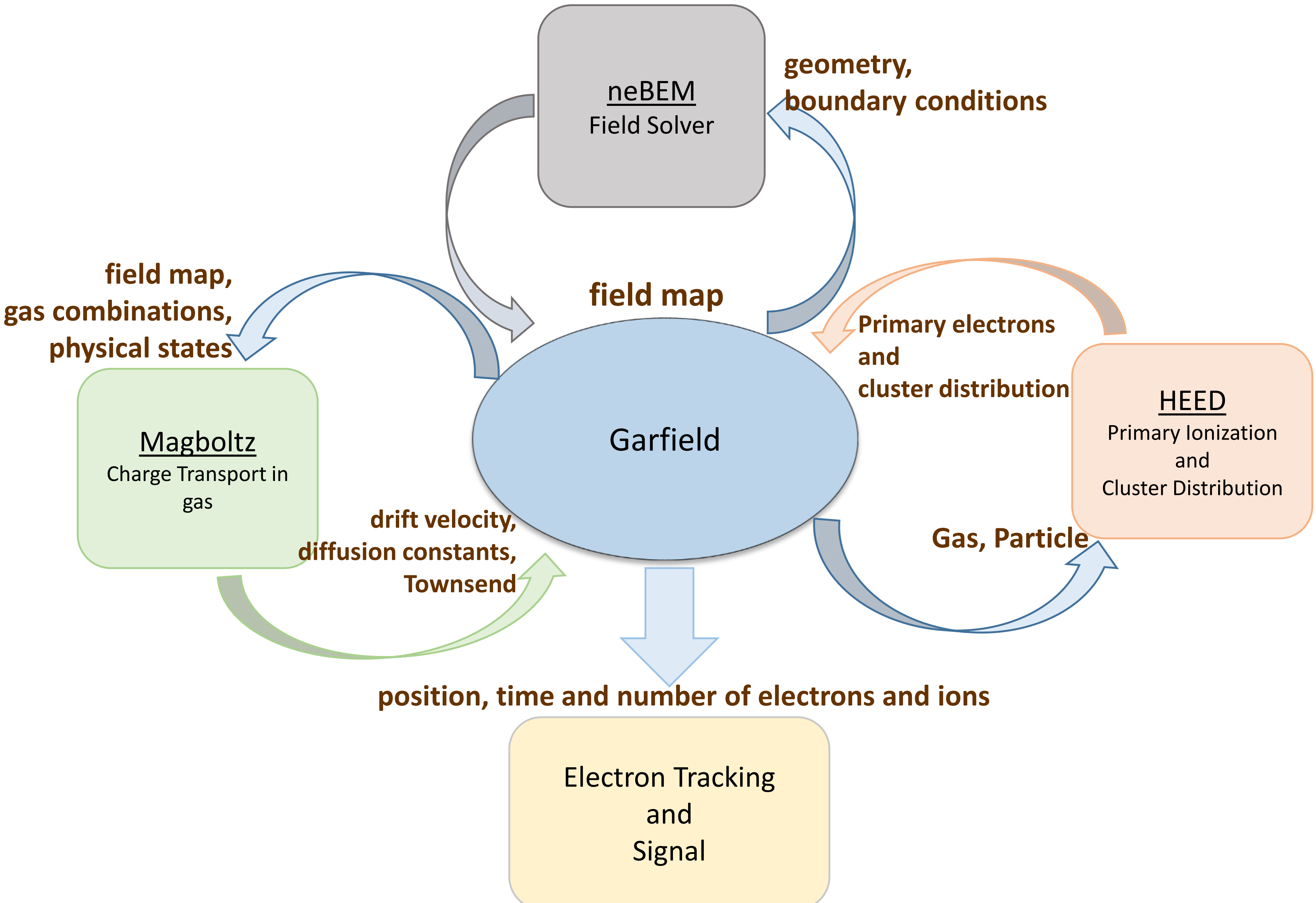
Charge sensitive pre-amplifier



Current sensitive pre-amplifier



Simulation Framework

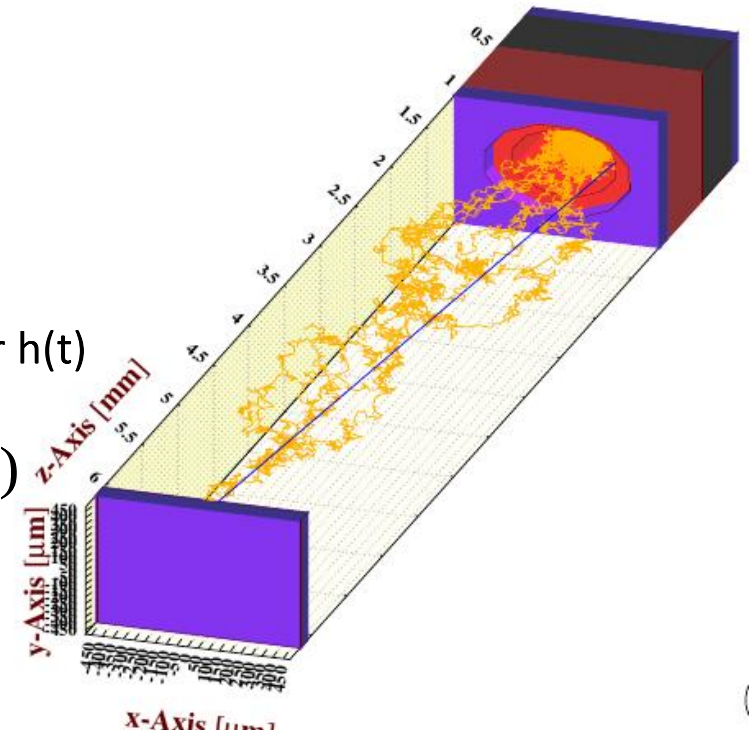


Approach:

- Model of basic CELL using Garfield, repeat this geometry along both X an Y axes to represent actual geometry
- Generation of primary electron-ion pair using different radioactive source; ^{55}Fe, Cosmic Muon
- Drift of primary electrons and production of secondary electrons in the amplification zone, Microscopic tracking routine of Garfield
- Consider also the drift of primary and secondary ions
- Calculation of raw signal using Shockley-Ramo theorem

$$I = -q \frac{\vec{v} \times \vec{E}_w}{V}$$

- Convolution with the response function of pre-amplifier h(t)
- Output voltage of the pre-amplifier $V(t) = i(t) \otimes h(t)$



Note:

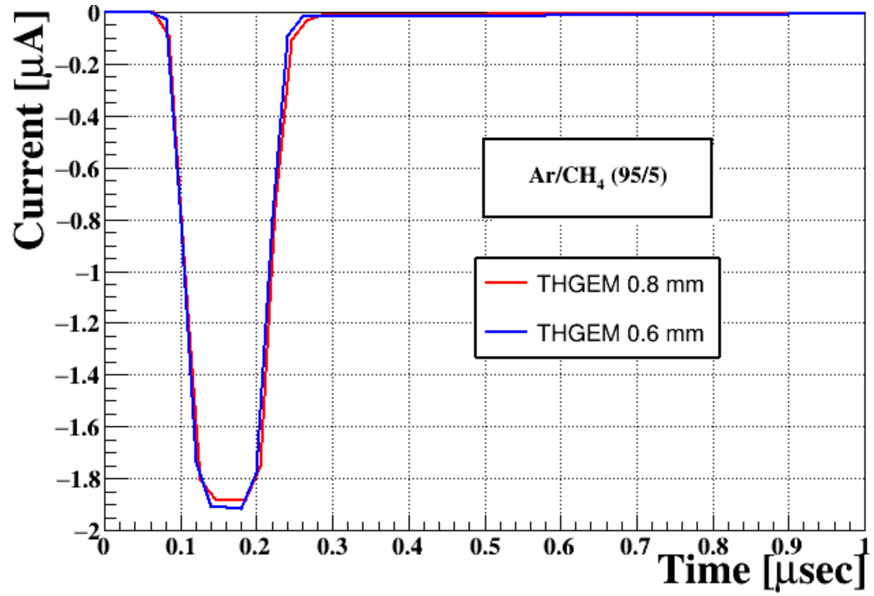
Resistive material has been considered as an insulator

W. Riegler, NIMA 491 (2002) 258

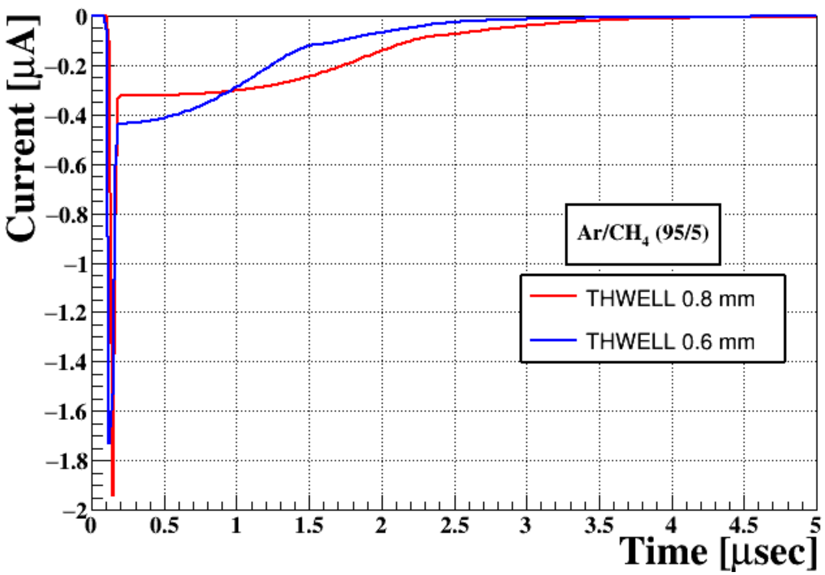
Raw Signal in Ar/CH_4 (95/5)

Source: ^{55}Fe

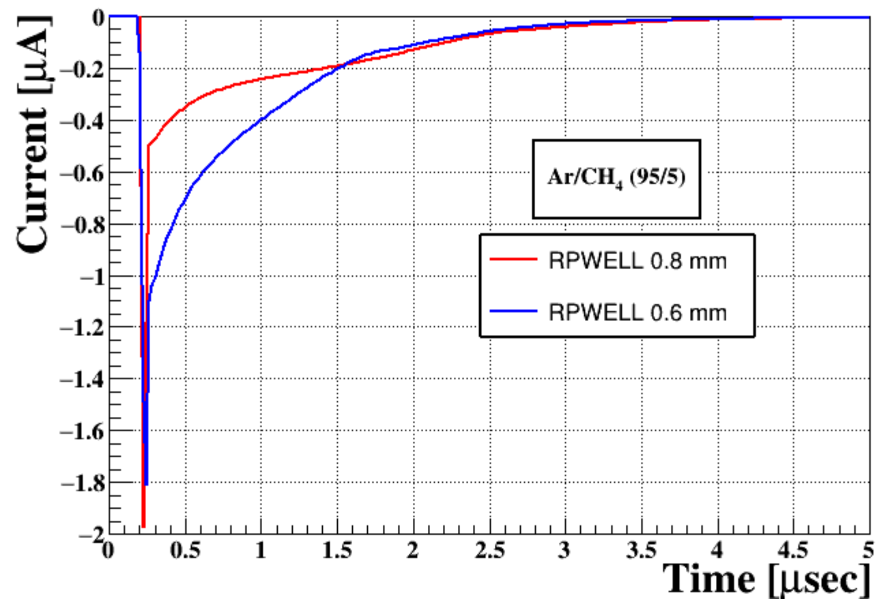
- Long ion tail absent in THGEM
- 2.5 – 3 μsec long ion tail in case of THWELL and RPWELL
- Raw signal shape is different between THWELL and RPWELL – work going on to understand the possible cause
- Variation of detector thickness by 0.2 mm (33%) affects the ion decay time by ~ few tenth to few hundred nsec depending on detector



(a) THGEM

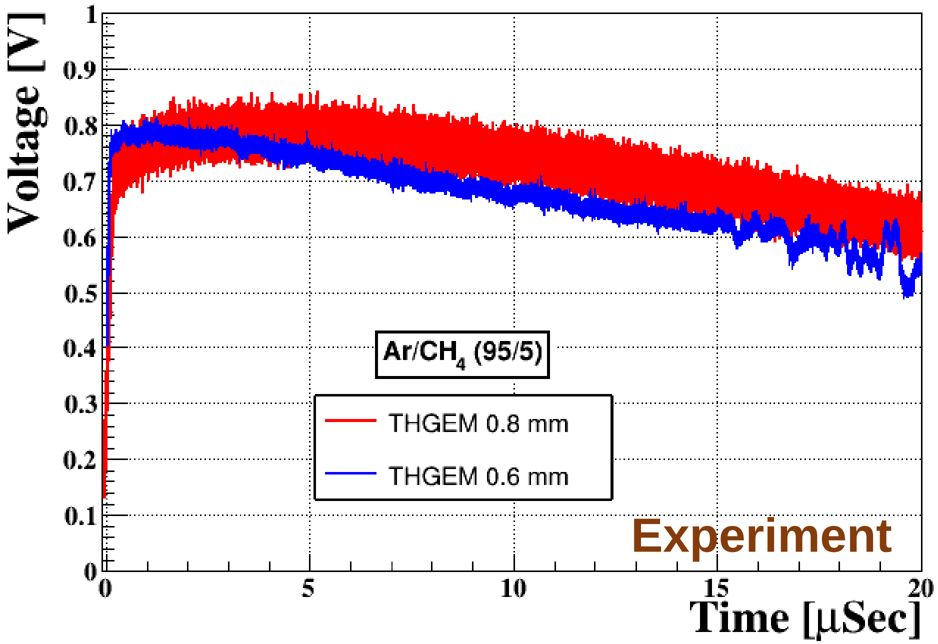


(b) THWELL



(c) RPWELL

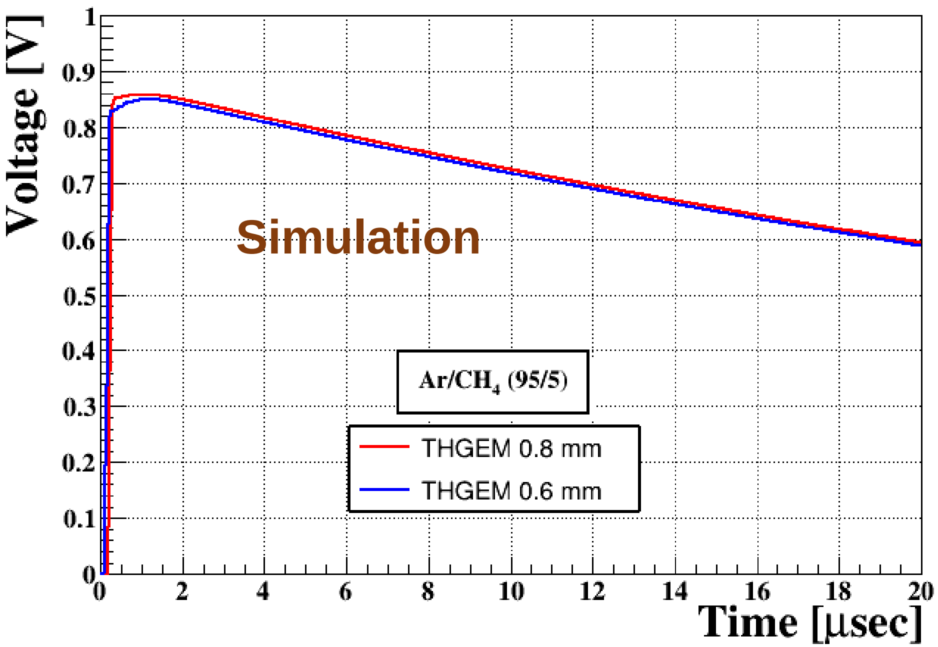
Signal Shape with Charge Sensitive Pre-amplifier (shaping time ~ 50 μsec)



THGEM

Source: ^{55}Fe

- Rise time is ~100 nsec
- No significant effect due to the change of detector thickness



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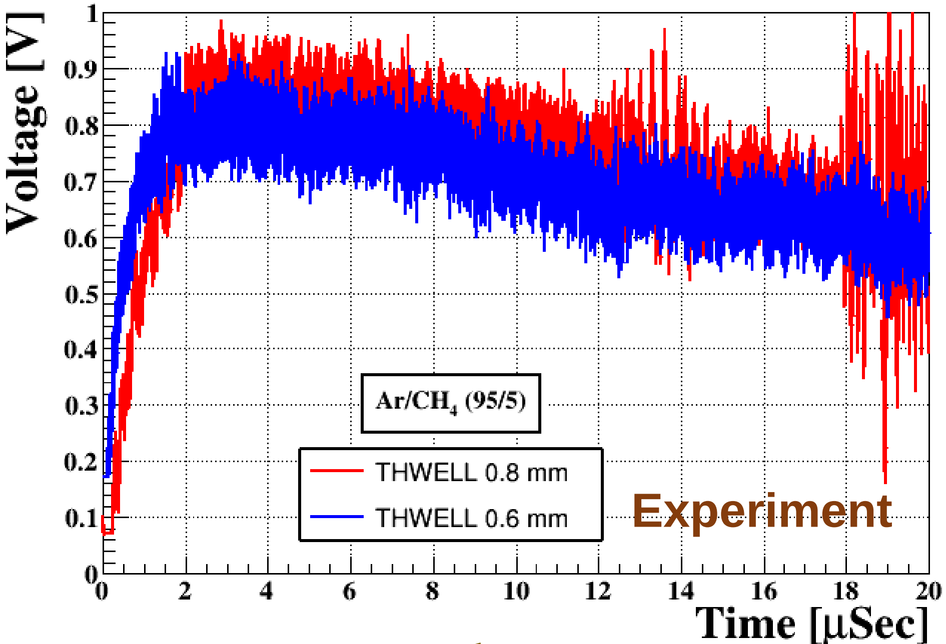
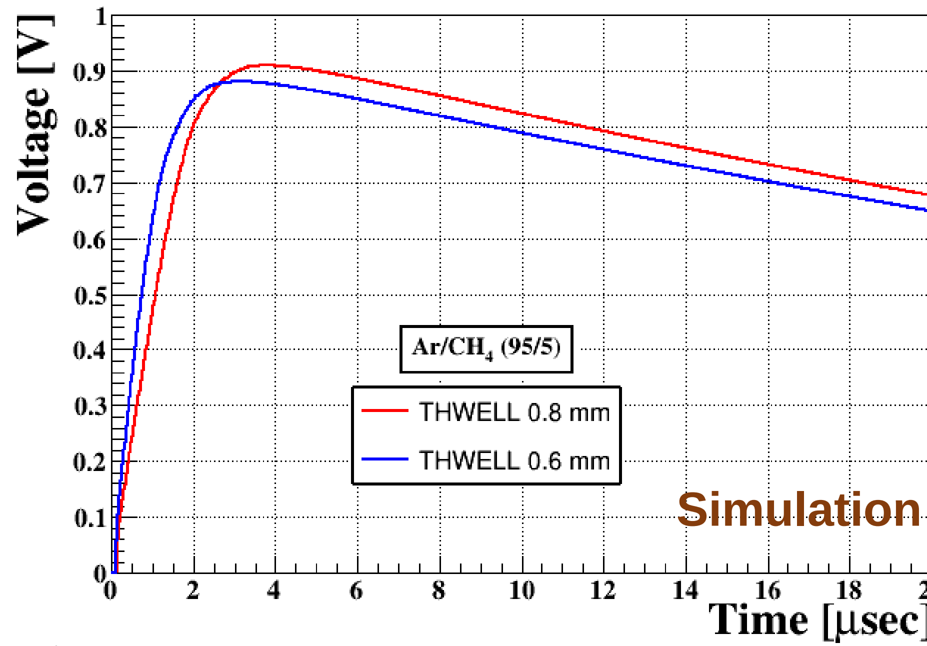
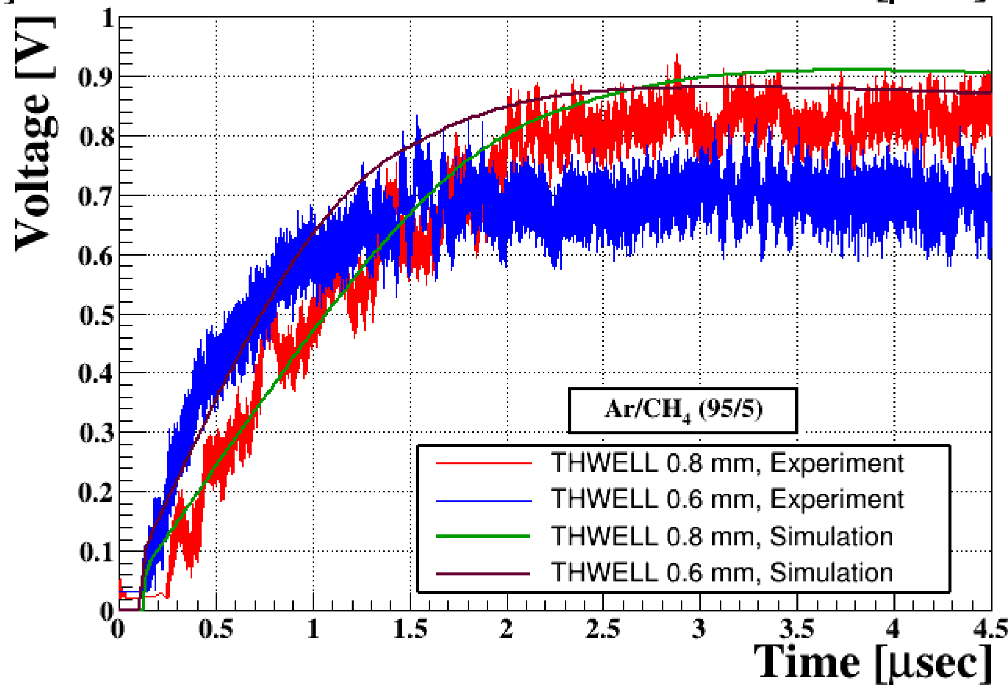




THWELL

Source: ^{55}Fe



- Rise time: ~ 2.5 μsec for 0.8 mm thickness,
  : ~ 2 μsec for 0.6 mm thickness
- Consistent with drift time in Ar/CH_4

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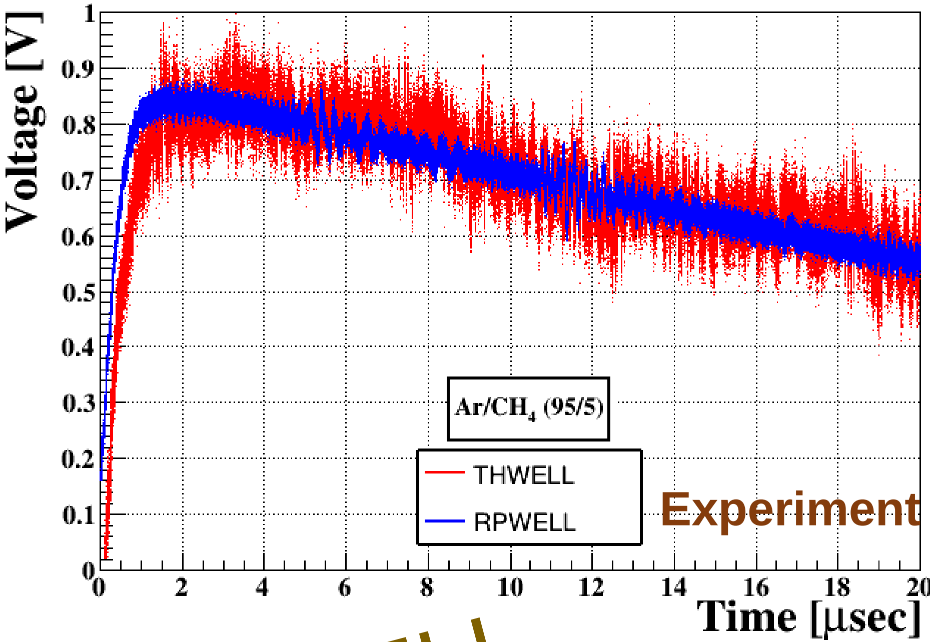
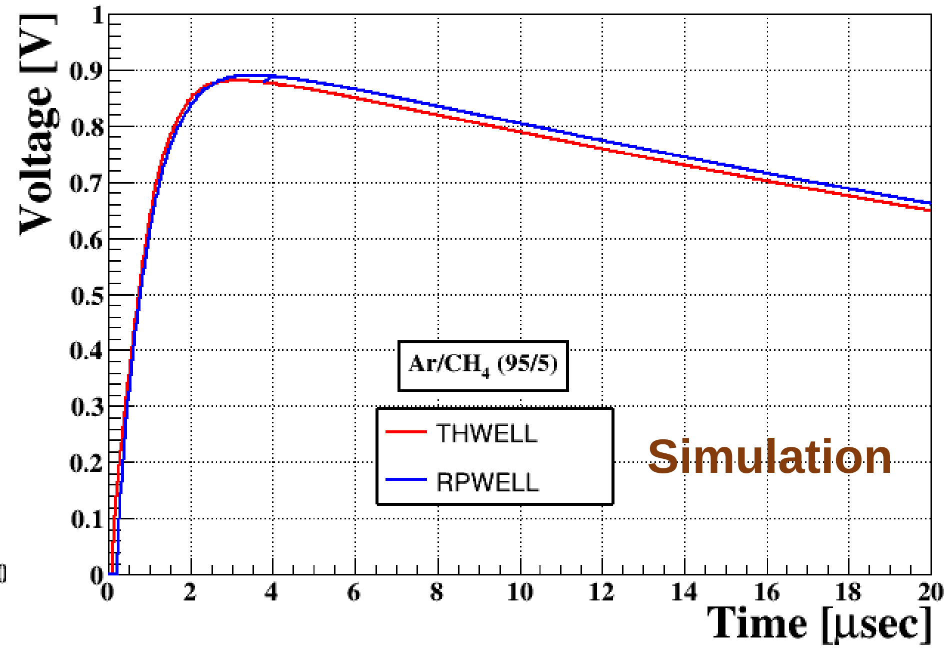
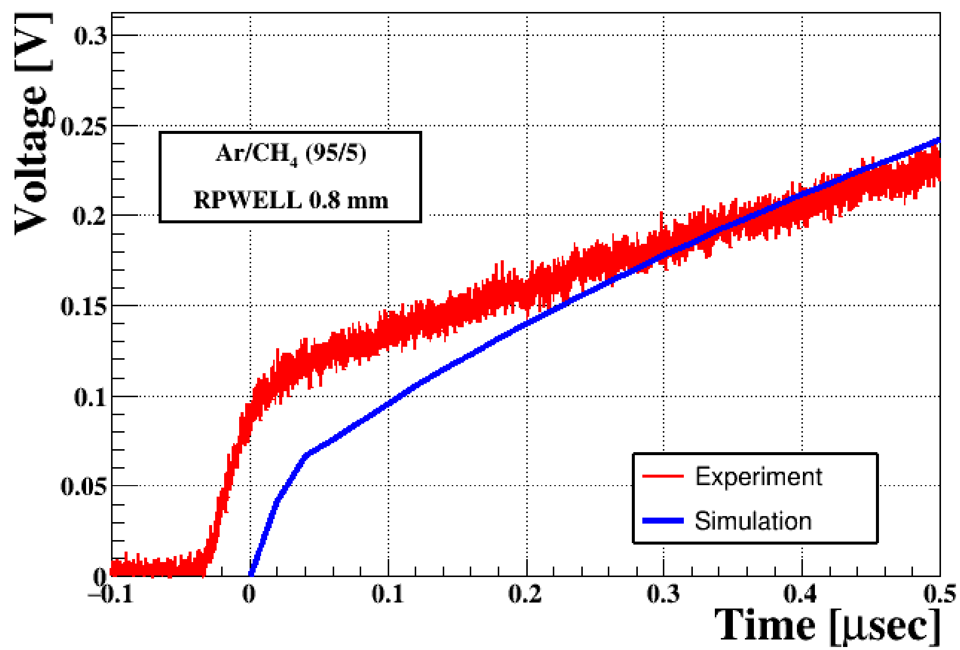




THWELL

&

RPWELL



- Similar signal shape for both the detectors
- A fast rise time followed by a slow rise time
- Resistive layer seems to have no effect on the signal shape, rise time for a continuous anode

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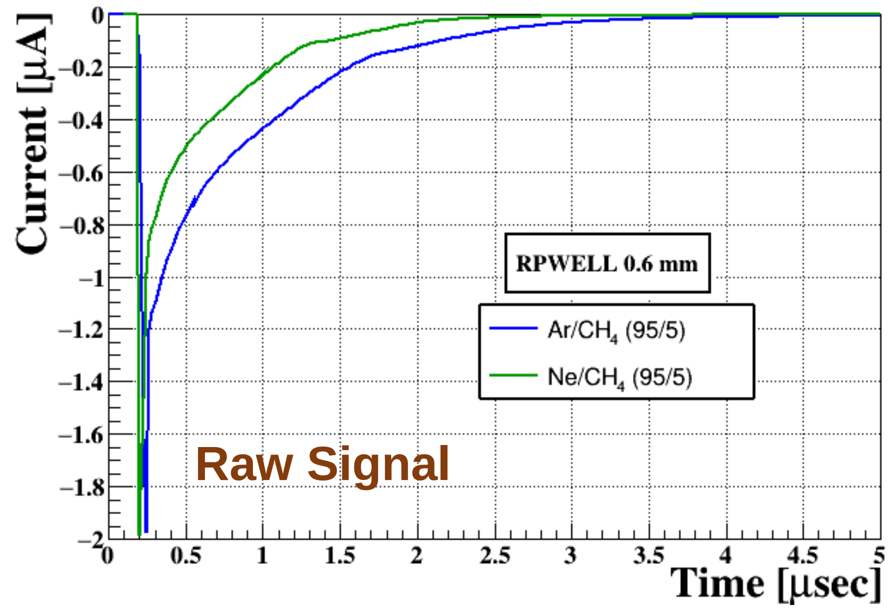
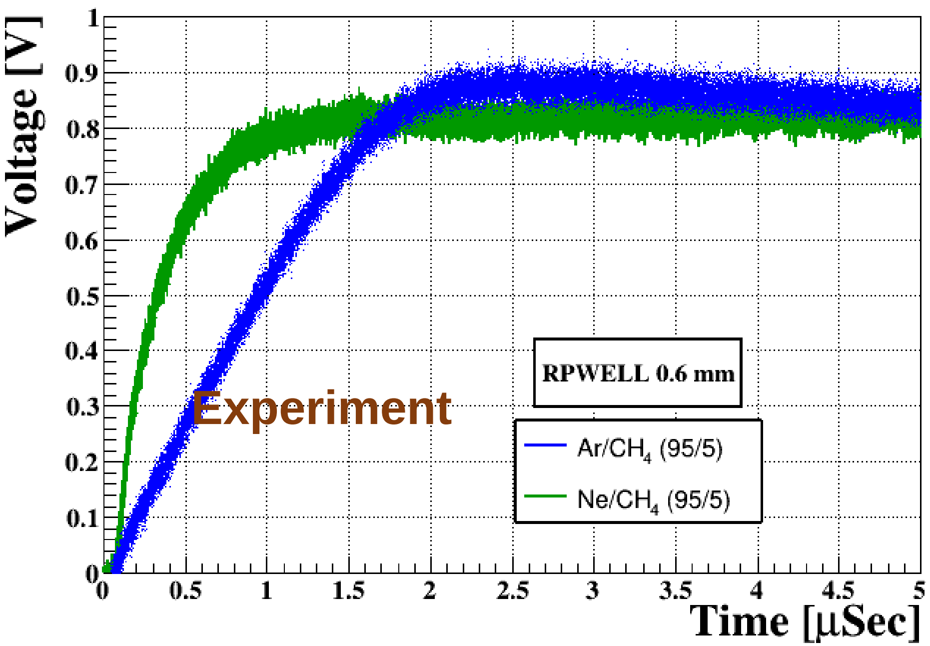
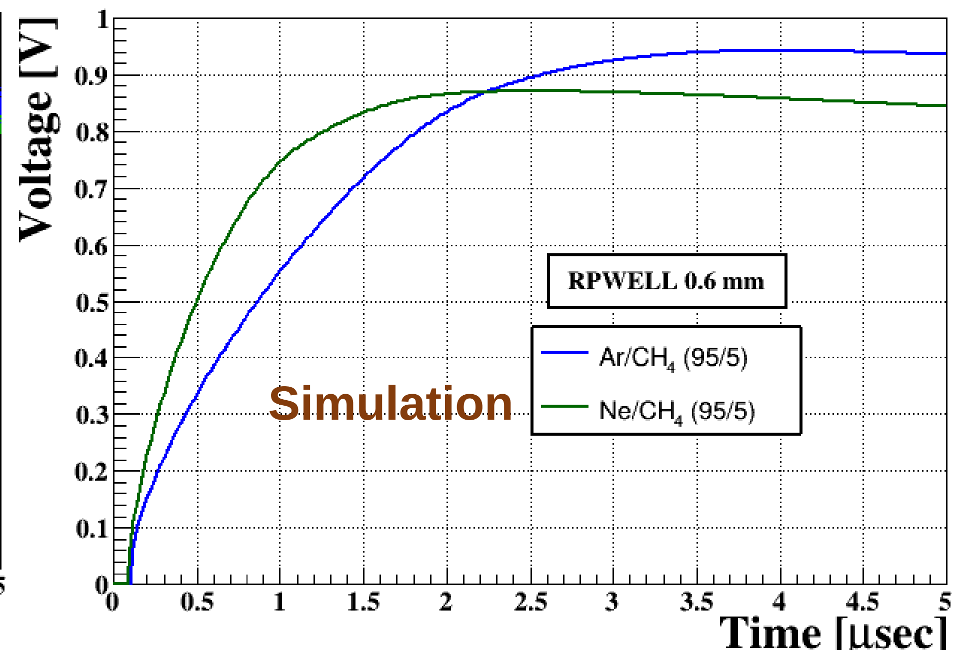
RPWELL

Comparison between Ar/CH_4 (95/5) and Ne/CH_4 (95/5)

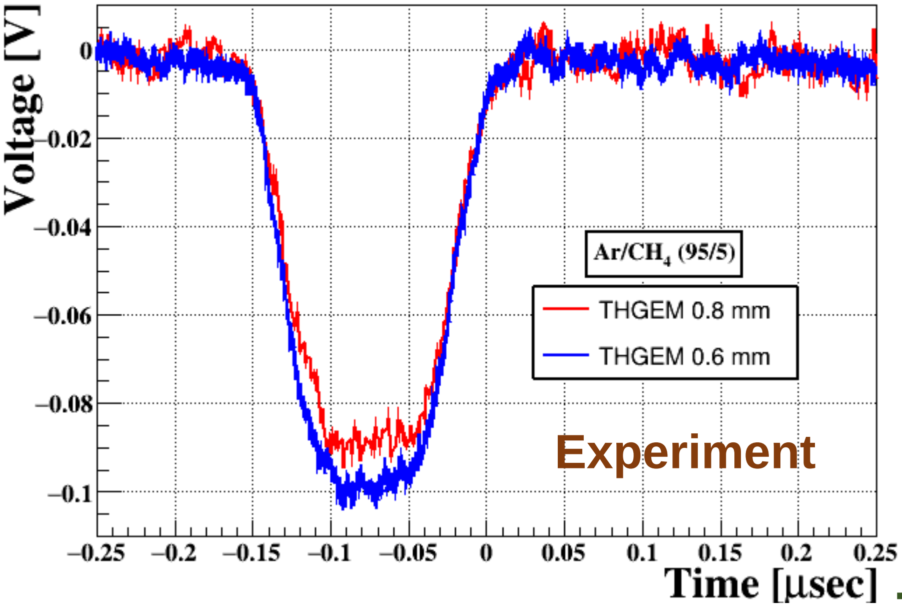
- Ion tail in Ne/5%(CH_4) mixture decays faster than that of Ar/5%(CH_4) mixture, consistent with drift time
- Rise time in Ne-mixture is faster, ~ 1 μsec

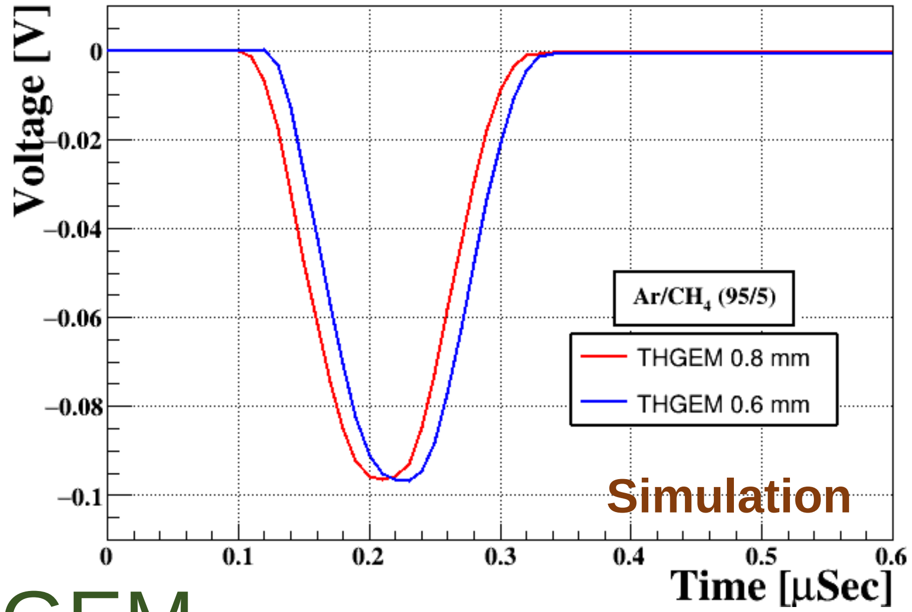




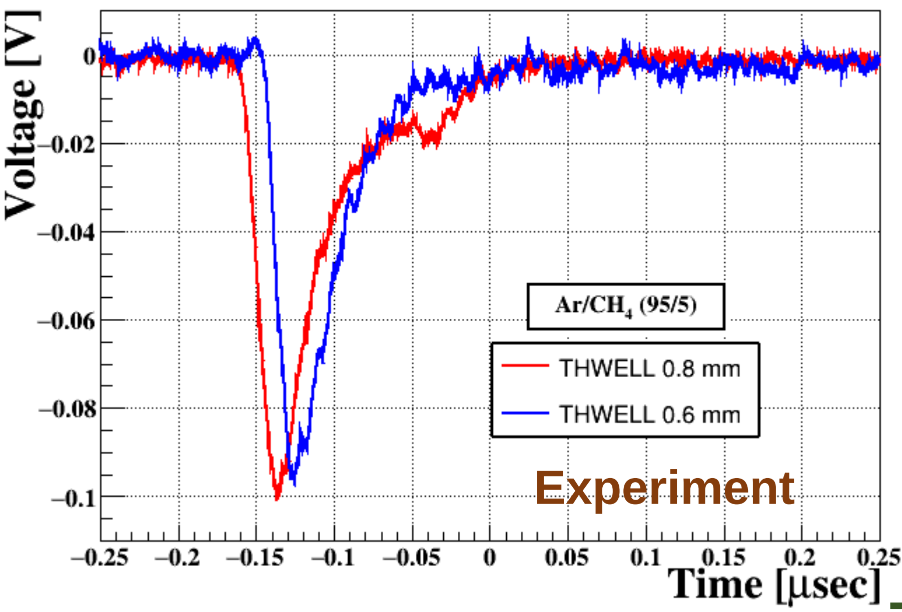


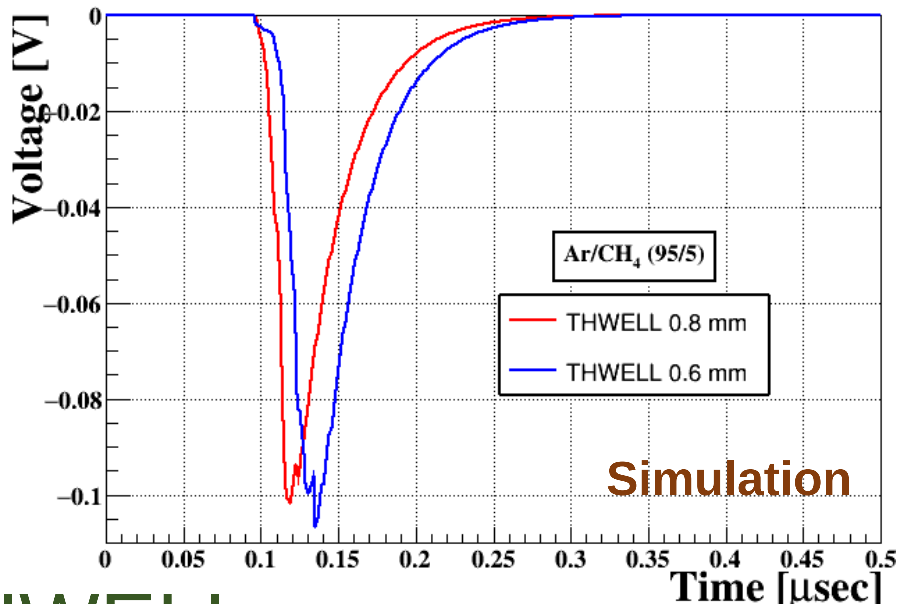
Signal Shape with Current Sensitive pre-amplifier (shaping time ~ 25 nsec)





THGEM





THWELL

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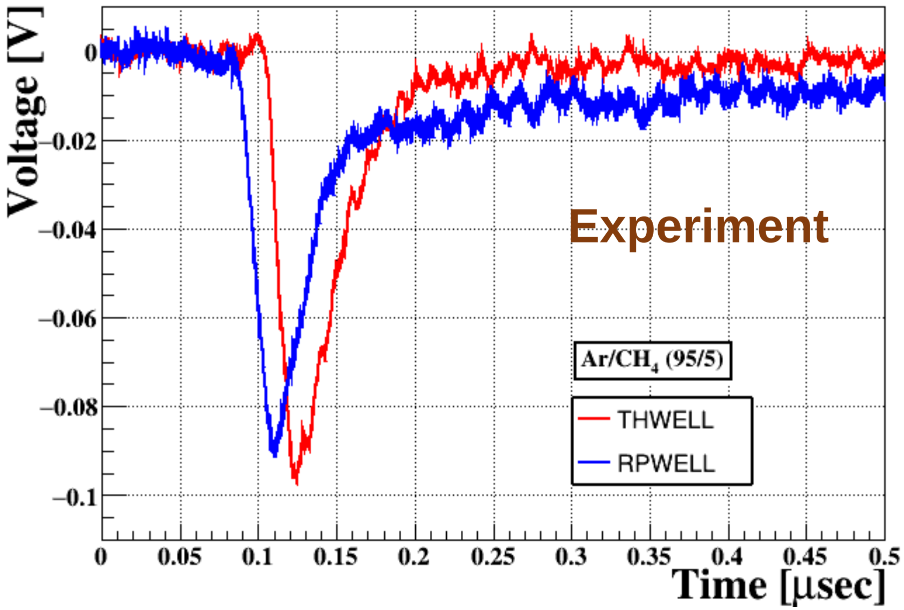
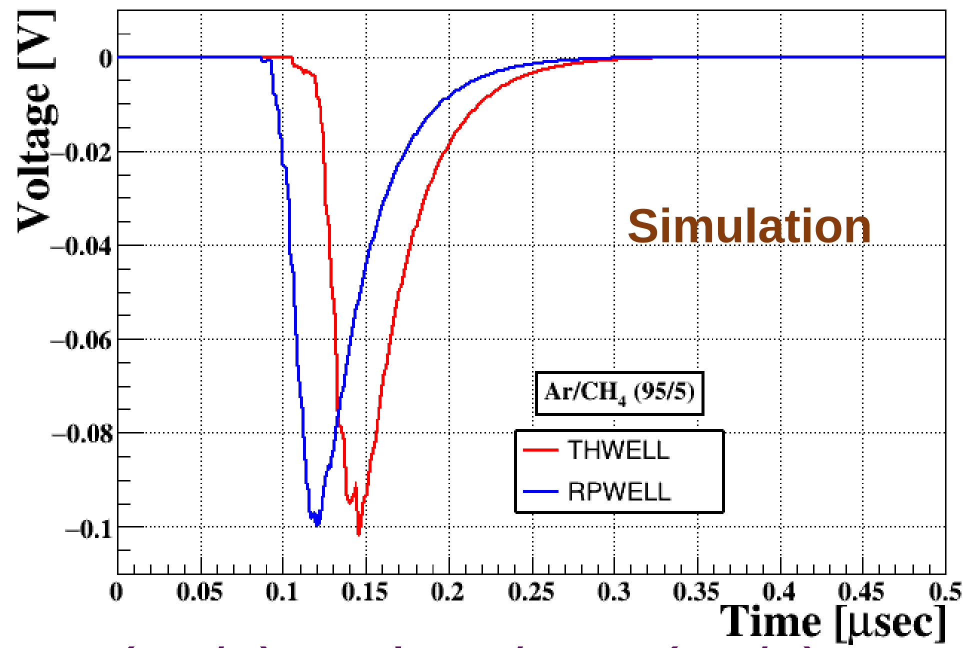
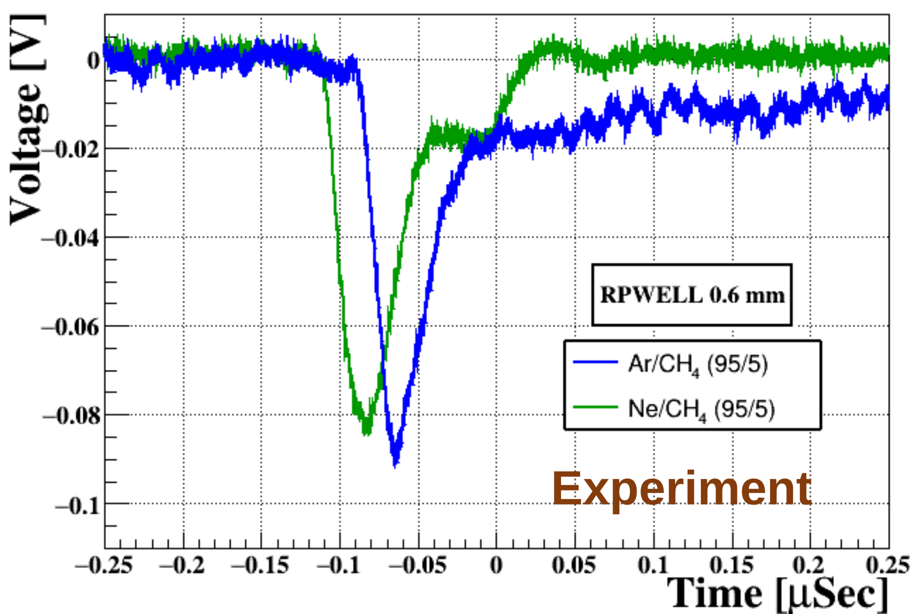
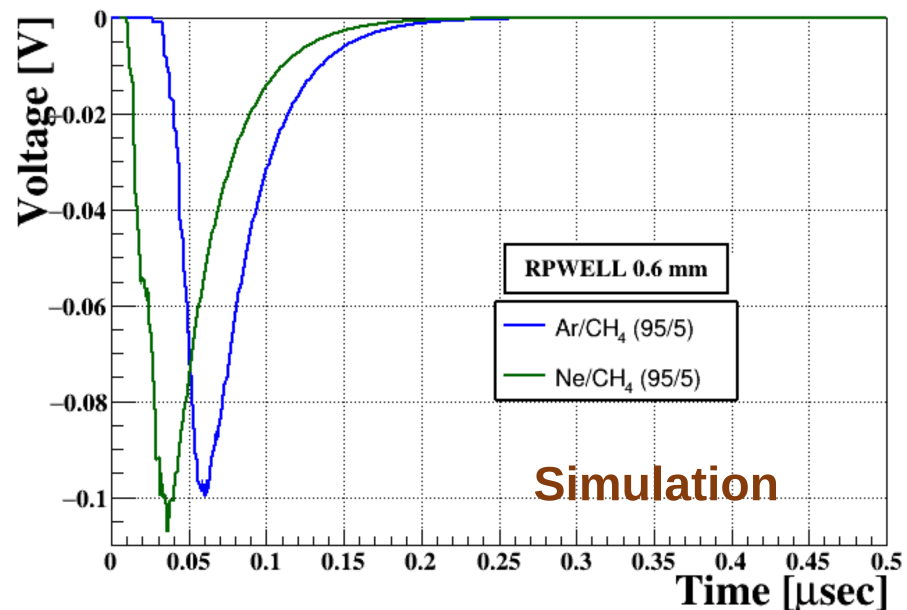
Comparison between THWELL & RPWELL





Comparison between Ar/CH$_4$ (95/5) and Ne/CH$_4$ (95/5)





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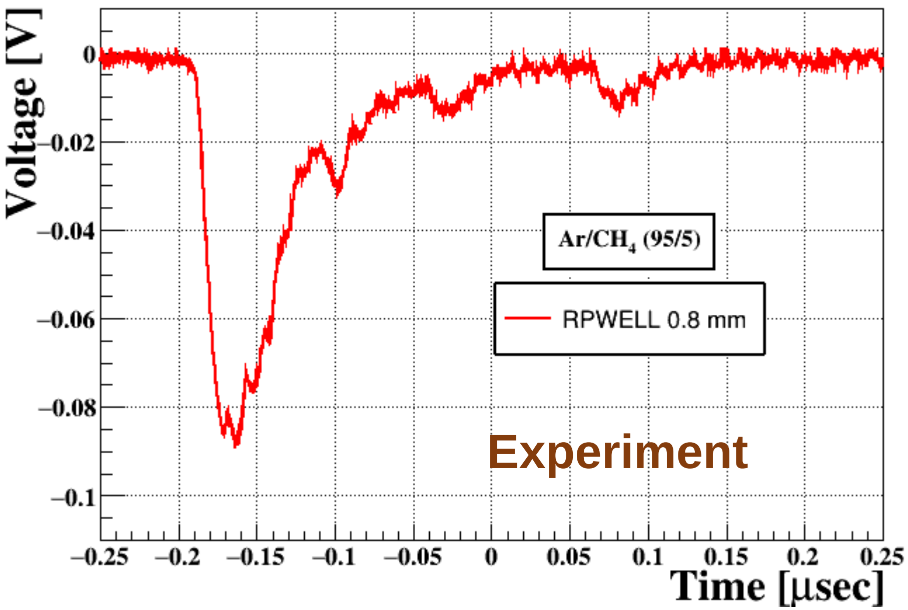
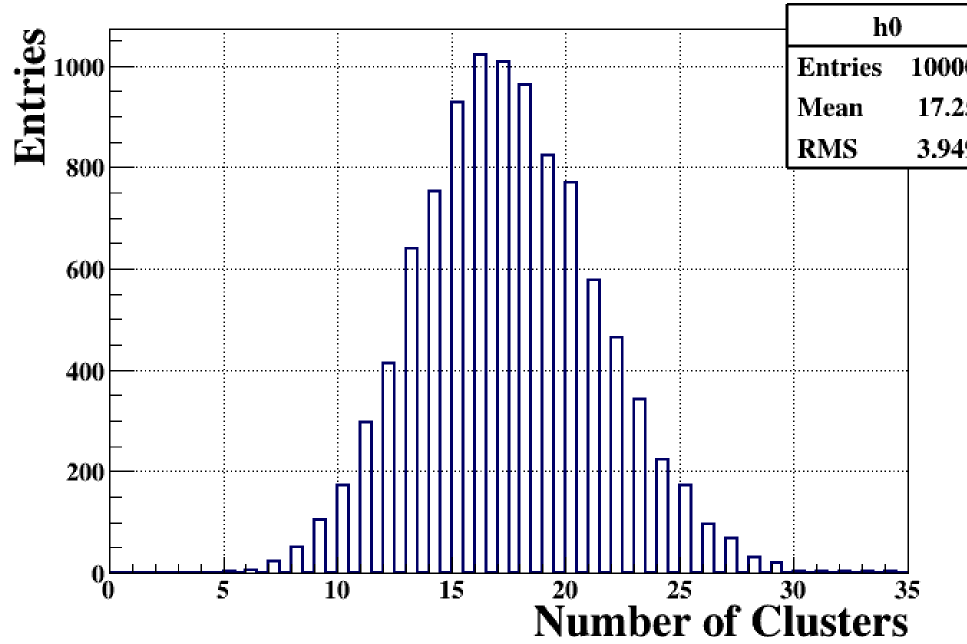
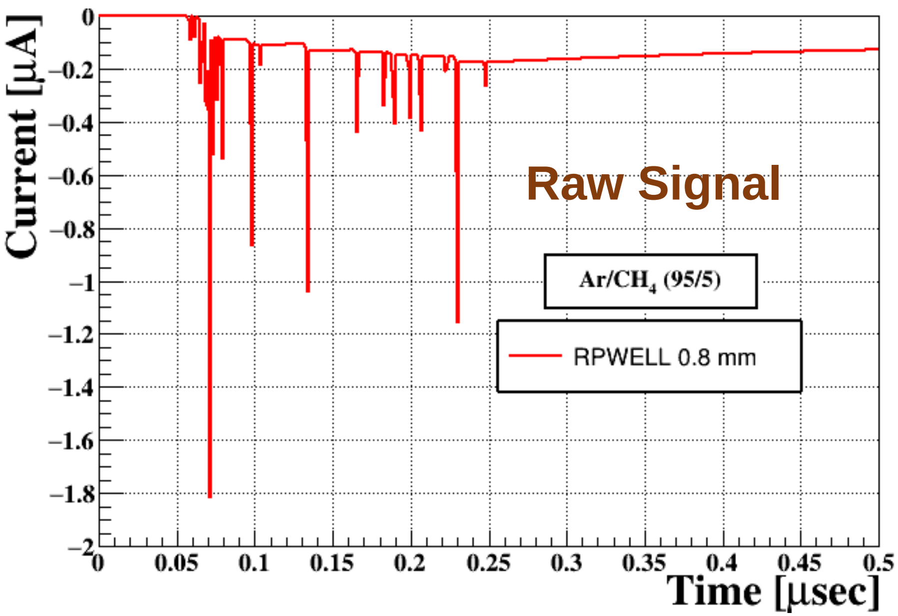
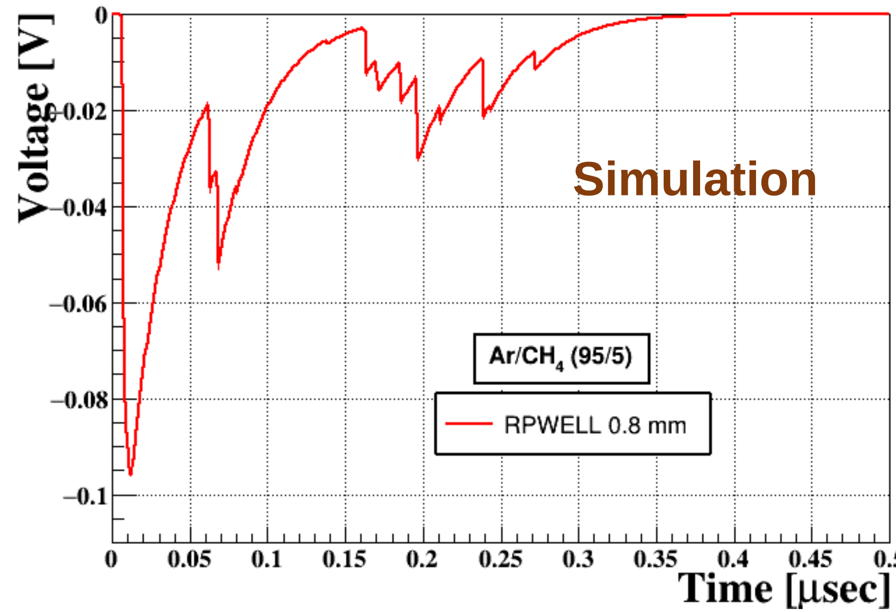
Source: Cosmic Muon

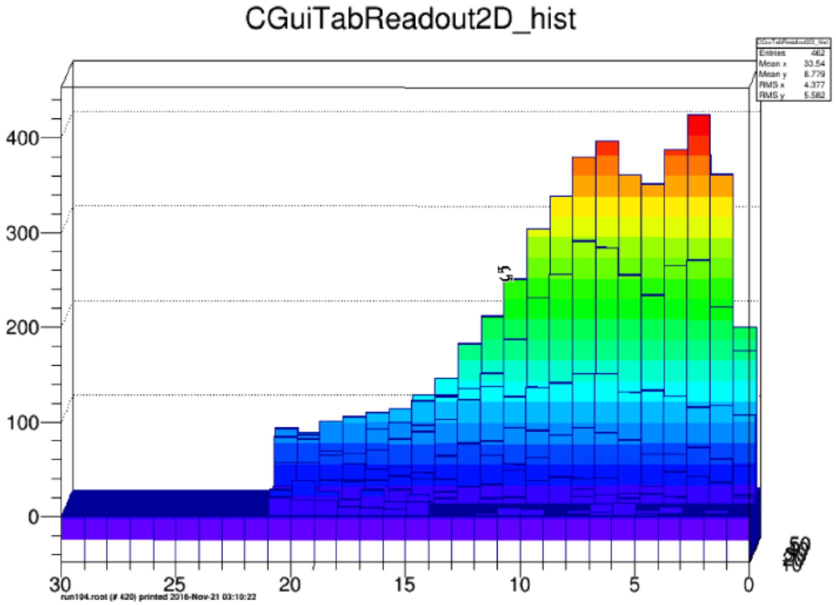


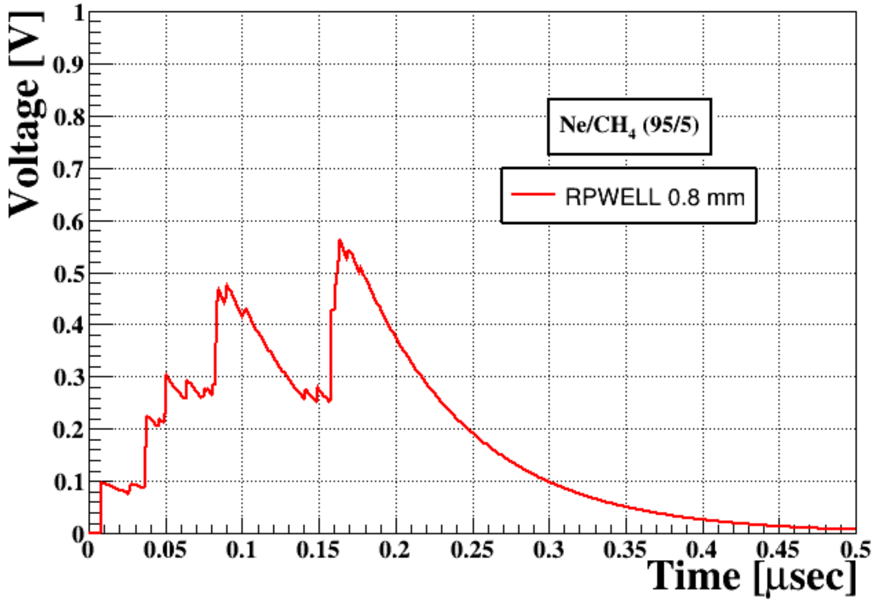






- ✓ Similar signal shape observed in Test Beam with 150 GeV muon
- ✓ Response of the APV25 with a shaping time of ~75 nsec





Monte Carlo simulations, incorporating all physics phenomena involved, were carried out for predicting the position resolution of RPWELL detector.

L. Moleri, et al. "On the localization properties of an RPWELL gas-avalanche detector." arXiv preprint arXiv:1707.00125 (2017), Accepted in JINST

Summary:

- We have developed a tool kit to simulate signal formation in THGEM-like detectors
  - Garfield and neBEM are combined to simulate the signal
  - The raw signal is convoluted with the response function of the preamplifier
- The tool kit was validated
  - By comparing the final signal shape form to experimental measurements
  - With THGEM, THWELL and RPWELL
  - With detectors of different thickness (0.6 and 0.8 mm)
  - In different gas mixtures
- Good agreement is found between the simulation and the data in terms of
  - Signal shape
  - Rise time

Future Plan:

- ✓ Ultimate goal is understanding from first principles and reproduce in simulations
  - ✓ The pad multiplicity
  - ✓ Spatial resolution
  - ✓ Edge effects
- ✓ Incorporate the effect of resistive layer --- it may affect the charge spreading between the pads
- ✓ The effect of electronic cross talk, noise will be considered

Work going on

Thank You