Further optimization studies of Resistive Plate WELL detector

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The Resistive Plate WELL (RPWELL), shown in Figure 1, is a single-sided THGEM electrode (THWELL) coupled to the readout anode through a material of high bulk resistivity (10^9 – 10^{10} Ω). Radiation induced primary charge drifts along the field lines into the THGEM holes where it undergoes charge-avalanche multiplication. The avalanche charges induce signal on the readout anode. Typical RPWELL detectors have the following properties:

- Gains up to 10^4 [1]
- Energy resolution ~20% (FWHM) [1]
- Irradiation rate up to 10^4 Hz/cm^2 [1]
- Position resolution ~200 um [1]

Studies were carried out aiming at improving the RPWELL performance in terms of:

- Electrical stability at the maximum achievable gain
- Energy resolution
- Gain stability over time

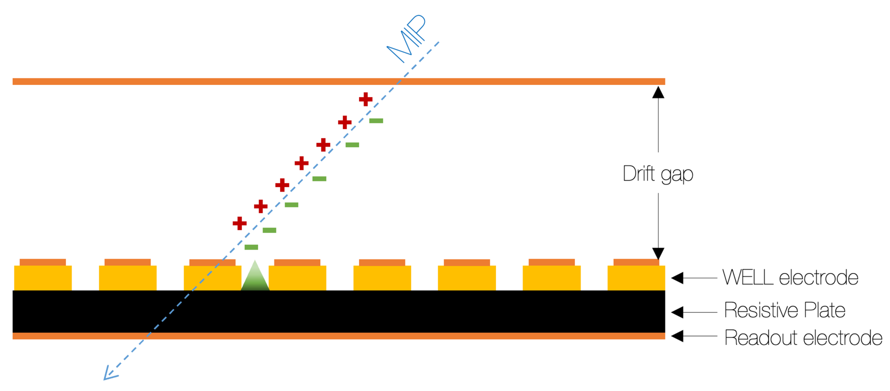

Figure 1. Schematics of the RPWELL detector.

We present recent studies of RPWELL detectors operated with ArCO2-isobutane mixture. This was shown in [2] to improve the gain and HV stability of MM detectors. In addition, the effect of DLC coating on mitigating charging up effect and the corresponding gain stabilization processes are discussed.

The experimental setup used for the measurements is shown in Figure 2.

Figure 2. Schematics of the experimental setup.

RPWELL parameters:

- 0.8/1 mm thick, 500um holes, 50/100um rim
- Active area: 20x20 mm^2
- Constant drift field: 1kV/cm

Irradiation source:

- 8.05 keV Cu X-Ray collimated in 1 mm hole
- Rate: 700 Hz/mm^2

Readout:

- Single-pad anode → ORTEC 109A preamp → linear amp → MCA/oscilloscope

Use of ternary gas mixture

Figure 3 summarizes the gain measurements in various Ar-based gas mixtures. In ArCO2-isobutane mixture, gain at the level of 10^4 is achieved at lower operation voltages. This results in lower discharge rate (Figure 4) when the detector is operated close to its limit – thus more stable behavior.

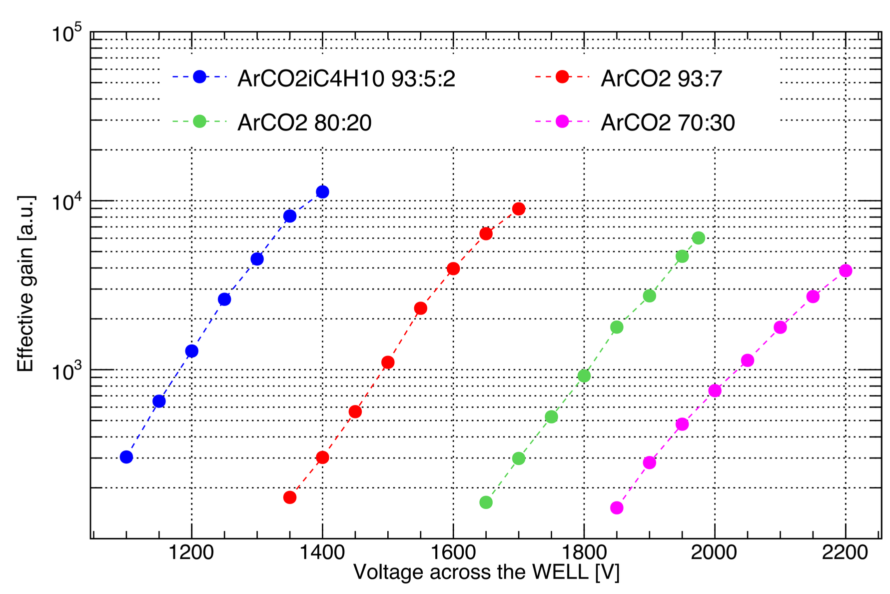

Figure 3. RPWELL gain measured in Ar-based mixtures.

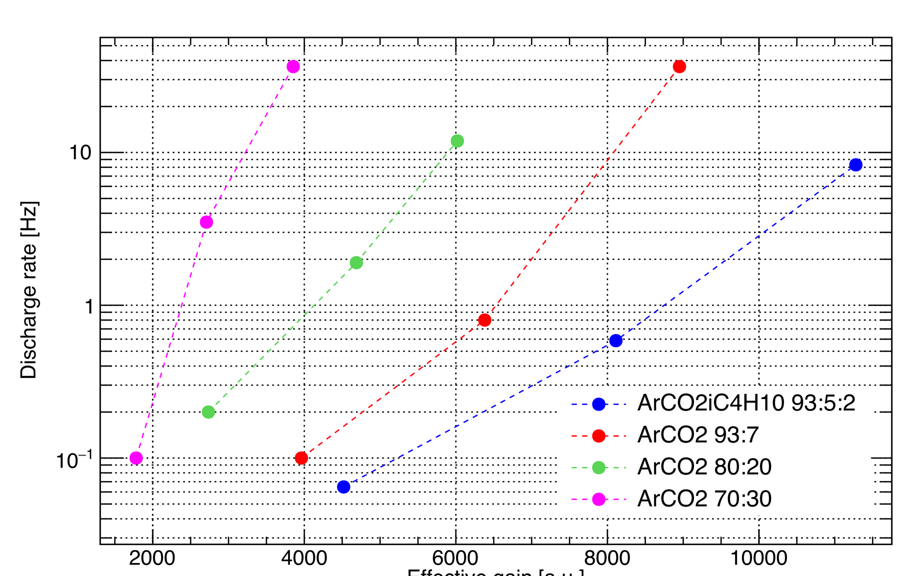

Figure 4. Discharge rate as a function of gain measured in Ar-based mixtures.

Better energy resolution was measured with ArCO2iC4H10 and ArCO2 93:7 (Figure 5), albeit at ~300 V lower voltage with the former. In all the tested mixtures, the energy resolution shows optimal value when measured relative to the gain. Poor resolution is measured at low and high gains due to large statistical fluctuations at the low gains and occasional discharges at the high gains.

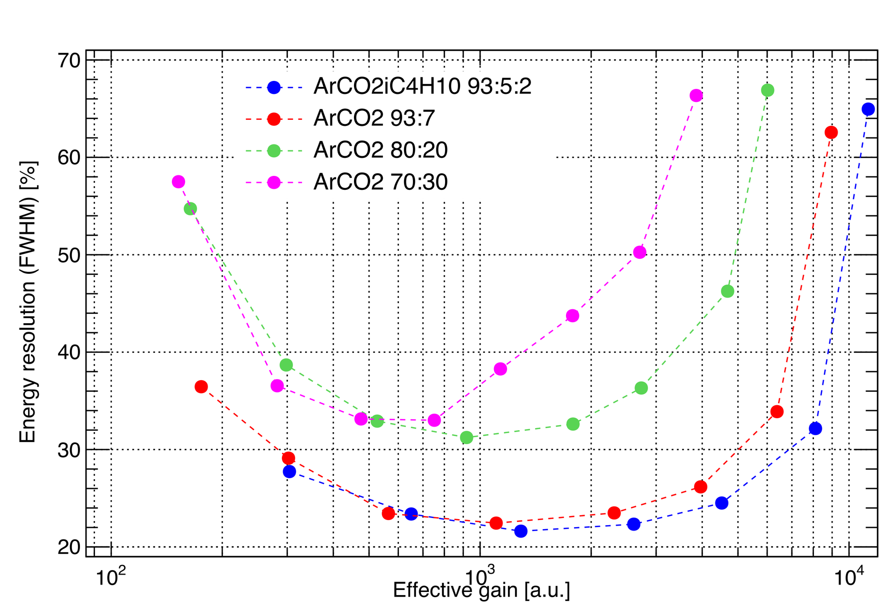

Figure 5. Energy resolution as a function of gain measured in Ar-based mixtures.

Charging-up processes

In THGEM detectors, gain stabilization processes are characterized by fast drop followed by a slow rise. This is attributed to charge accumulation on the walls of the holes and their rim, respectively [3]. The gain stabilization over 2.5 hours is shown in Figure 6. Two observation are made: a) large diffusion coefficient increases the rim charging up, and b) large amplification field is effective in focusing the primary electrons into the holes reducing rim charging up effects.

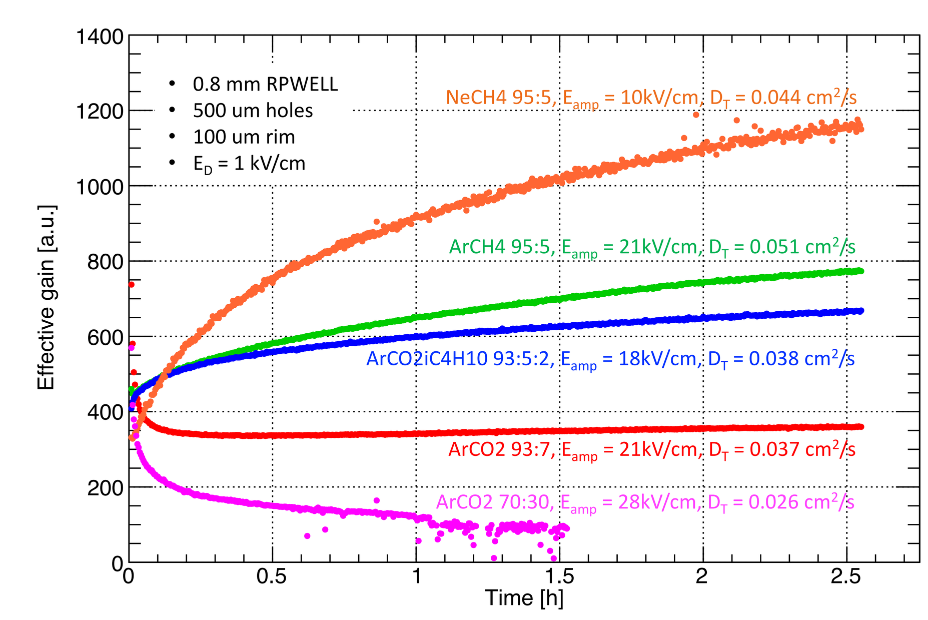

Figure 6. Gain evolution of RPWELL detector in various gas mixtures.

These effects are further demonstrated with two dedicated gain vs. time measurements: a) for two mixtures with different diffusion coefficients operated at the same amplification field (Figure 7). b) a single gas operated at different amplification fields (Figure 8).

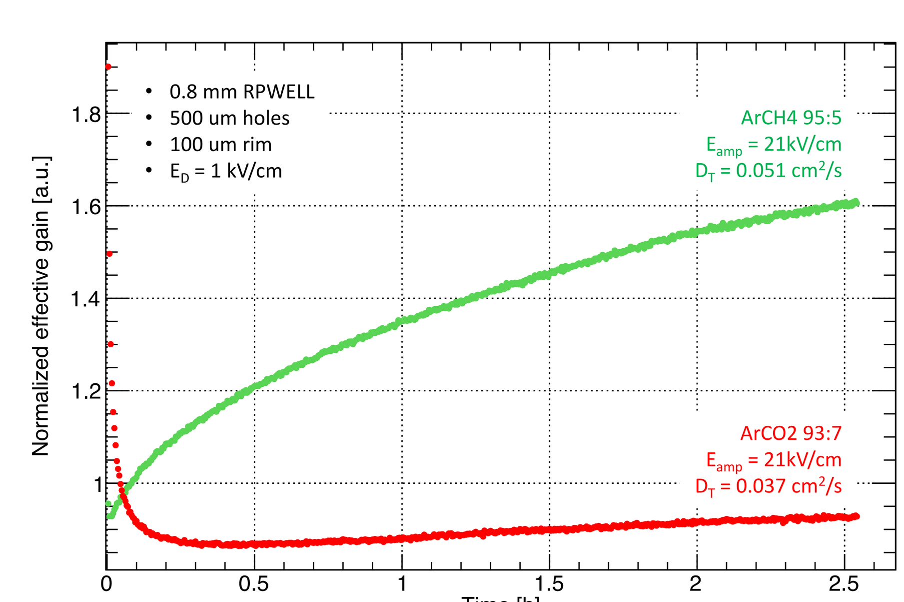

Figure 7. Gain evolution of RPWELL detector measured with the same amplification field, but with different diffusion coefficients in the drift field.

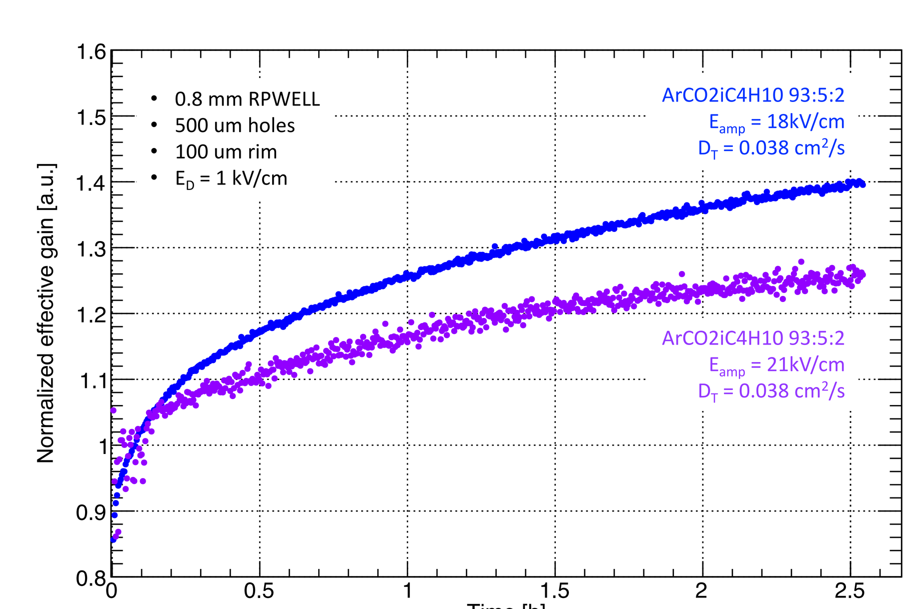

Figure 8. Gain evolution of RPWELL detector measured in the same gas with the different amplification field.

DLC-coated RPWELL

Charging-up effects in the RPWELL detector can be mitigated using Diamond Like Carbon (DLC) coating of the insulating walls and rims [4,5].

The effect of DLC coating on charging up effects of RPWELL detectors is studied using two WELL electrodes (Figure 9); a reference standard electrode and and electrode coated with DLC layer (2 – 3 TΩ).

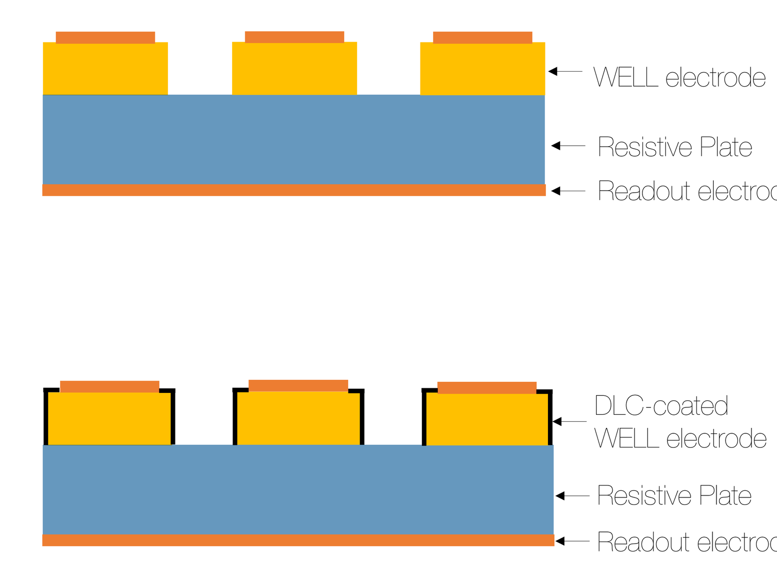

Figure 9. Schematics of the tested electrodes: top – reference WELL; bottom – DLC-coated WELL.

The measurements were carried out after a preparation run (operation of the detector at 800V for 2.5 hours) which was found useful in initializing the detector and assure the same irradiation history as well as environmental conditions.

The gain as a function of time is shown for the reference and DLC coated electrodes in Figure 10. The gain is normalized to its average value measured in the first 10 minutes. The nominal gain measured with the DLC-coated RPWELL was roughly a factor of 2 higher than that measured with the reference electrode at the same operation voltage. The rim charging up is shown to be strongly mitigated with the DLC coating.

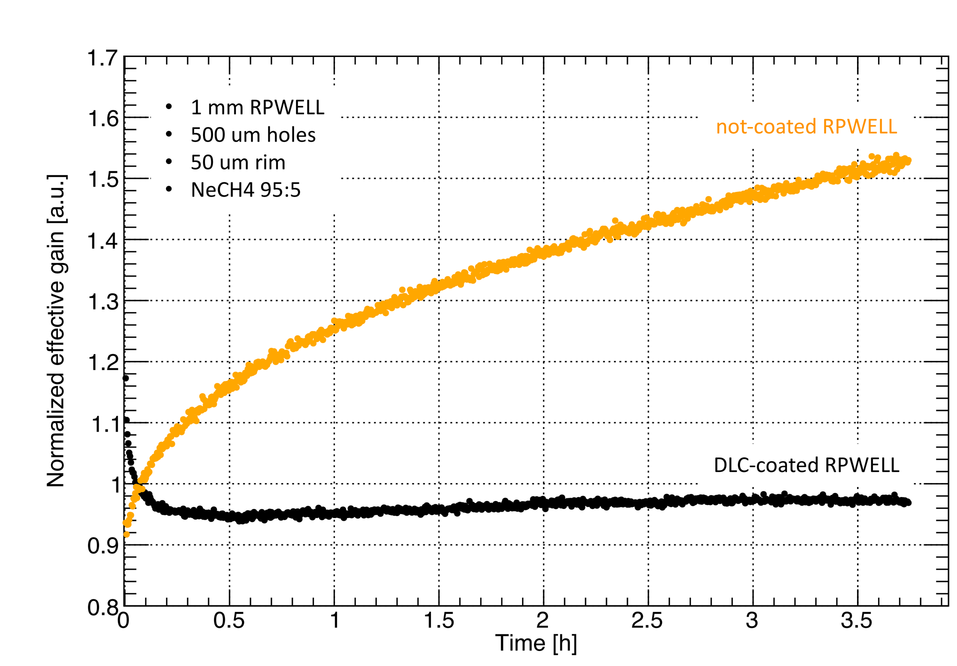

Figure 10. Gain evolution measured for two identical WELL electrodes: one coated with DLC layer, the other is not coated.

Conclusion

We focused on optimizing the RPWELL detector performance in two fronts. The first aimed to achieve higher gains with better energy resolution and electrical stability. For this purpose, ternary gas mixture, ArCO2iC4H10 93:5:2, was used. Relative to other Ar-based mixtures, it allowed reaching higher maximum gain (10^4) at lower applied voltages and reduce the discharge frequency. Optimal energy resolution of ~20% was measured at the gain of 1500.

In the second front, we investigated charging-up processes in RPWELL detector and aimed to reduce their effect on gain stabilization over time. It was shown that charging-up of the holes rim depends on a combination of two factors: electron diffusion in the drift field and the amplification field strength. It was observed that charging-up is reduced with lower electron diffusion and higher amplification field. The effect of rim charging up was further mitigated by coating the holes and rims with highly resistive DLC layer.

The usage of ArCO2iC4H10 gas mixture and DLC-coating should be considered for operating the RPWELL detectors in future applications.

References:
[1] S. Bressler et al, The Thick Gas Electron Multiplier and its derivatives: physics, technologies and applications, review, 2022
[2] https://doi.org/10.22323/1.398.0757
[3] P.M.M. Correia et al 2018 JINST 13 P01015
[4] doi:10.1088/1748-0221/15/11/P11013
[5] https://doi.org/10.1016/j.nima.2020.163868

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