DEVELOPMENT OF RPC DETECTOR COMPONENTS WITH LOW-COST ALTERNATIVE MATERIALS

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INTRODUCTION

Resistive Plate Chambers (RPCs) are gas-based particle detectors widely used in High Energy Physics experiments such as CMS and ATLAS. Their main advantages are the relatively low cost of covering large areas, compared with non-gas-based detectors, and the very good timing resolution compared with other gas-based detectors. However, despite their popularity, conventional construction materials like glass and Bakelite impose manufacturing and operational limitations(SAMALAN, 2024). In this initial exploratory work, we search for alternative techniques and materials to produce RPC components in local laboratories. By developing 3D-printed frames, graphite-infused commercial ink for the graphite coating, painting techniques, and additive manufacturing for the electrodes, we can open new configuration possibilities due to their controlled resistivity and the ease of producing layers with controlled thickness.

MATERIALS AND METHODS

- **Paint Mixture for Centrifugal Coating Process**

A conductive coating was made by mixing acrylic paint with graphite powder (<140 µm) and acetone, followed by 30 minutes of magnetic stirring. 5 mL of the mixture were *spin-coated* into a 10x10 cm PVC substrate at 10,500 rpm for an even distribution. After a three-day curing period, a micrometer has been used to take thickness values of the coated PVC plates to compare thickness to graphite percentage relation. Then, the surface resistivity was measured using a *DESCO Concentric Ring Probe*.



Fig. 1: 3D-Printed Spin Coating Centrifuge;

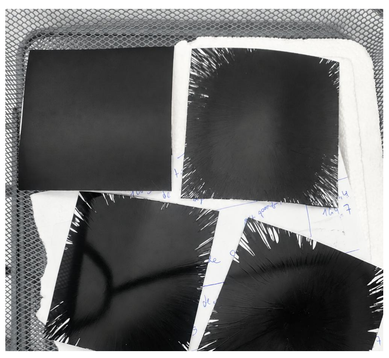


Fig. 2: Spin Coating Samples Curing;



Fig. 3: Ring Probe and Multimeter;

- **3D-printed PLA RPC frames**

A CAD design of the RPC main body was developed to study the unexplored geometric advantages from FDM 3D Printing, which has shown potential on previews studies of gas detectors manufacturing(COLAFRANCESCHI *et al*., 2021). The resulting physical prototype was printed on an Ender 3 V3 printer in PLA.

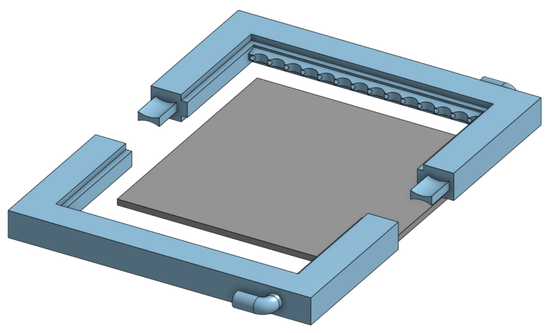


Fig. 4: 3D model of the RPC in CAD;

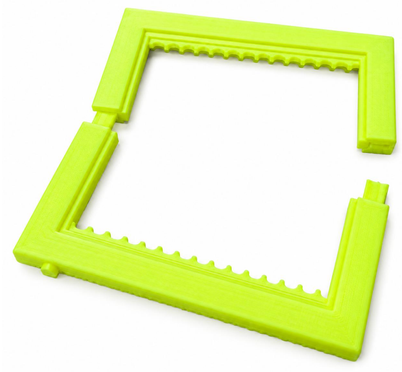


Fig. 5: 3D-Printed prototype;

- **Carbon Black-infused ABS Mixtures**

Carbon black (CB) doped ABS samples, ranging from 0.0 to 10.5 wt% in 1.5% increments, were prepared using a solvent casting technique. The ABS matrix was fully dissolved in P.A. acetone for 24 hours in an airtight glass container. Meanwhile, the CB filler was suspended in acetone and let on ultrasonic bath for 10 minutes to deagglomerate the particles. This dispersion was then incorporated into the ABS solution and submitted to another bath for 5 minutes to ensure a homogeneous blend. Finally, the mixture was cast into 4.5 x 4.5 cm square molds and left to rest until complete solvent evaporation prior to demolding, the samples were prepared to achieve a thickness of 2mm. For electrical characterization, the demolded samples were placed between 3 cm x 3 cm copper electrodes connected to a *CAEN A1526N* high-voltage(HV) module.



Fig. 6:Carbon Black-infused ABS Samples;

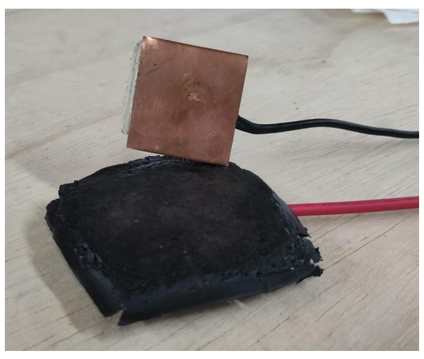


Fig. 7: Copper Electrodes Connected to a *CAEN A1526N*

RESULTS E DISCUSSION

The spin-coating technique proved highly effective, producing uniform films with minimal spatial variation in thickness. As anticipated, the film thickness exhibited a consistent and predictable increase proportional to the graphite concentration.

Table 1: Micrometer Measurements of PVC Plates (0,001 mm)

	A		B		C		Control	
Side	1st measr	2nd measr	1st measr	2nd measr	1st measr	2nd measr	1st measr	2nd measr
1	0.530	0.534	0.518	0.508	0.507	0.512	0.472	0.473
2	0.527	0.518	0.535	0.517	0.510	0.510	0.472	0.472
3	0.530	0.512	0.528	0.525	0.509	0.505	0.472	0.477
4	0.524	0.528	0.525	0.517	0.502	0.503	0.478	0.472
Averg	0.526 mm		0.522 mm		0.508 mm		0.472 mm	
SD	0.007 mm		0.008 mm		0.004 mm		0.003 mm	

Using a concentric ring probe to determine the order of magnitude for each graphite increment, the primary objective was to reach a target surface resistivity of approximately 10^5 to $10^6\ \Omega/\square$, matching the standard properties of traditional RPC materials such as Bakelite and glass.

Table 2: Graphite Doping Values and Measured Surface Resistivity (Ω/□)

Mixtures	Acrylic Paint (g)	Graphite(g)	Surface Resistivity (Ω/□)
A	**15,4**	**2,2**	**~10^4**
B	**15,0**	**1,9**	**~10^5**
C	**15,0**	**1,8**	**>10^9**

The electrical properties of the 2 mm thick solvent-cast ABS samples were recorded 60 points per step in voltage. The samples, between 0.0% and 6.0%, exhibited a highly linear, ohmic behavior across the tested voltage range. Linear regression analysis of these measurements yielded strong correlation coefficients ($R^2 > 0.93$ for all samples), allowing for accurate resistance extraction. Resistivity values (ρ) were derived from the V-I angular coefficients. A critical transition was observed in samples exceeding 6.0 wt% CB concentration. Above this threshold, the resistivity dropped sharply and the current increased significantly, exceeding the operational limits of the HV scan.

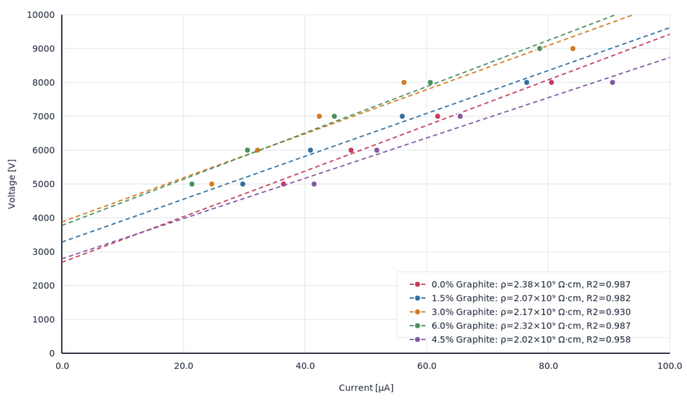


Fig. 8: Voltage x Current Measurements and Linear Aproximation

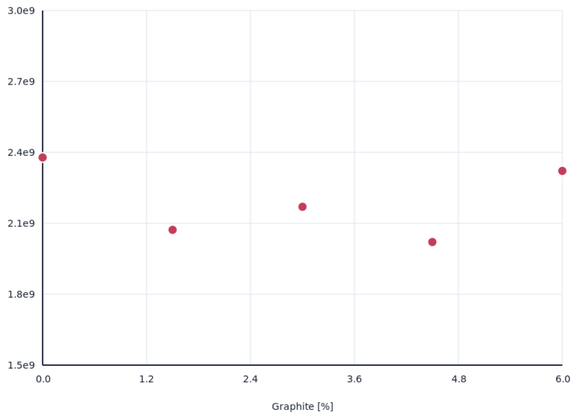


Fig. 9: Resistivity x Graphite Perecentage

CONCLUSION

This exploratory work successfully launched various initiatives to develop alternative, locally manufacturable components for Resistive Plate Chambers (RPCs). By exploring new materials and methods, the preliminary results have proven highly promising across multiple approaches. Building upon these successful initial trials, we intend to further refine these production techniques to achieve even greater control over the resistive and physical properties of the layers. Moving forward, we also plan to optimize our measurement methodologies for these physical quantities to ensure the components can meet the rigorous operational standards required for High Energy Physics applications.

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