Construction of an RPC using additive manufacturing technology

Stefano Colafranceschi, Ethan Beiler, Jacob Horsley, Levi Peachey-Stoner, Reuben Peachey-Stoner

Motivation

We are exploring additive manufacturing as a breakthrough technology for the field of particle detection

- Detector manufacturing totally automatic
- Standardized materials and well-controlled procedure
- High integration of components/parts
- Cost-effective (future) large scale production
- High customization for various applications

Background work

Existing LHC experiments adopt Bakelite-based RPC, although it's a material superseded in industrial production

- Limited Bakelite stiffness requires the presence of internal spacers
- Bakelite cannot be produced in small batches controlling the resistivity
- The general properties of the material are not fully characterized
- Due to its hygroscopy, water vapor has to be added into the gas mixture balancing the outside humidity
- Chemical Stability limited in presence of chemical radicals possibly created during detector operation

Detector Design

The proposed detector is being designed following a simple, effective and flexible design methodology

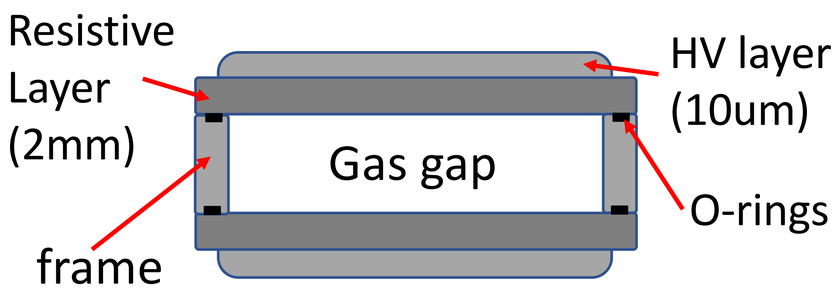
The detector features:

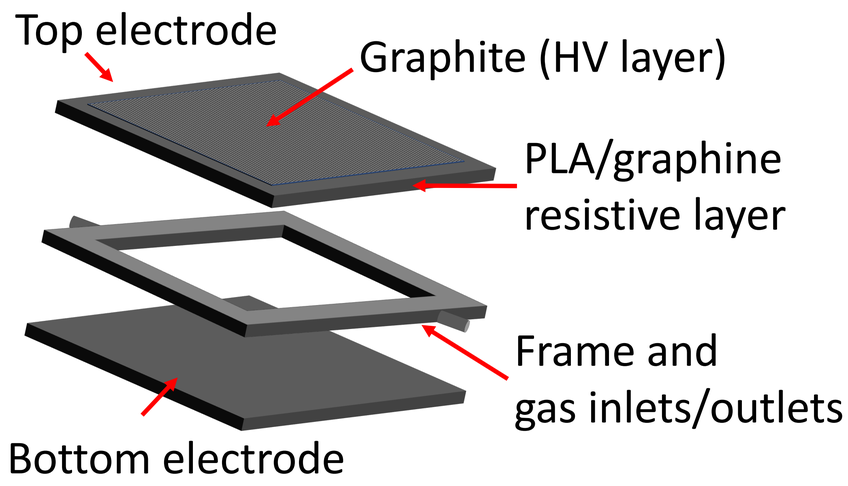
1) Top/Bottom 2mm electrodes designed with graphene doped PLA
- Varying the amount of graphene allows to achieve any value of bulk resistivity

2) Graphite layers that applies the HV
- 5μm graphite layer enables HV to be applied uniformly over the detector active area

3) Frame with o-rings that seals the chamber volume
- The detector is sealed and the electrodes are kept 2mm distant

Design features
- All parts are manufactured via 3D printing
- No glue, quick assembly and disassembly
- Readout pad can be designed and customized independently from the detector working cell
- The resistivity of the electrode can be easily adjusted decreasing or augmenting the graphene content in the PLA-based filament





Fabrication of the detector parts and preliminary tests

The detector printing requires a customized yet simple hardware and software printer configuration

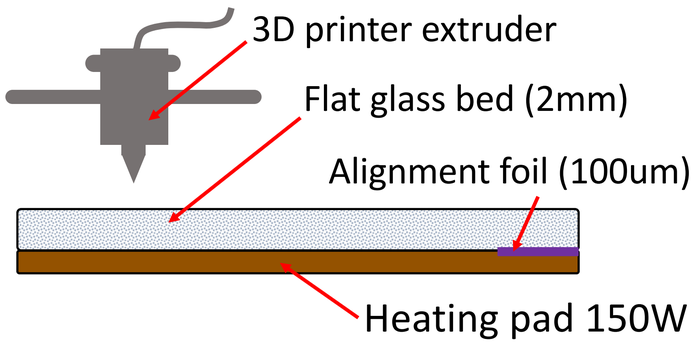
Construction phase 1: filament preparation:
- Pellet PLA and graphene are drying for 12 h in a dedicated oven at 80^0 C
- Pellet PLA + graphene are loaded into the extruder to be melted at 190^0 C
- The filament is produced and the spool is ready to be used

Construction phase 2: 3D printing:
- 150W heated flat (glass) bed
- Micrometric measurement/alignment of the bed
- Loading third-party filament spool
- Extruder that produces custom made filament with graphene dopant

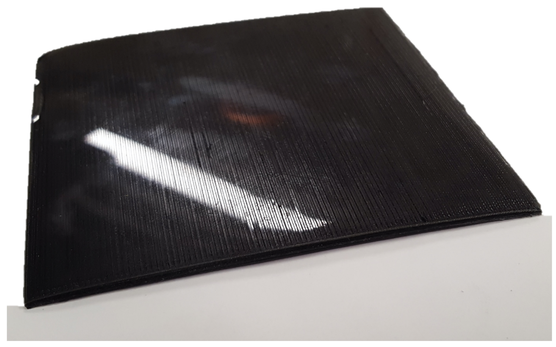
Construction phase 3: assembly:
- Two electrodes + one frame are built
- Mounting is quick and easy via screws and lateral o-ring

PLA + graphene

Extruder and filament machine



Customized setup for 3D printing the detector



Detector first electrode sample printed

Conclusions: promising R&D for a cost-effective detector design for general purpose uses

- Aiming at a broader impact, delivering affordable detectors for educational purposes, potential small experiments that with low budgets, etc.
- Additive manufacturing dramatically reduces prototyping costs and the need for an industrial partner
- In-house design and fabrication allows complete control of the costs, timeline and design optimization
- Prototyping and testing is a formative learning educational tool that shapes young students

Future plans & Outlook
- We will continue to explore RPC prototypes and test them with cosmic ray and/or radiation sources.
- Upon success, we would explore all various detector concepts with additive manufacturing, such as THGEM, Micro dot detectors.
- We aim at delivering affordable and innovative particle detectors for educational purposes as well as future particle physics experiments.

For more info:
Stefano.colafranceschi@emu.edu