Fabrication and testing of Resistive Plate Chambers

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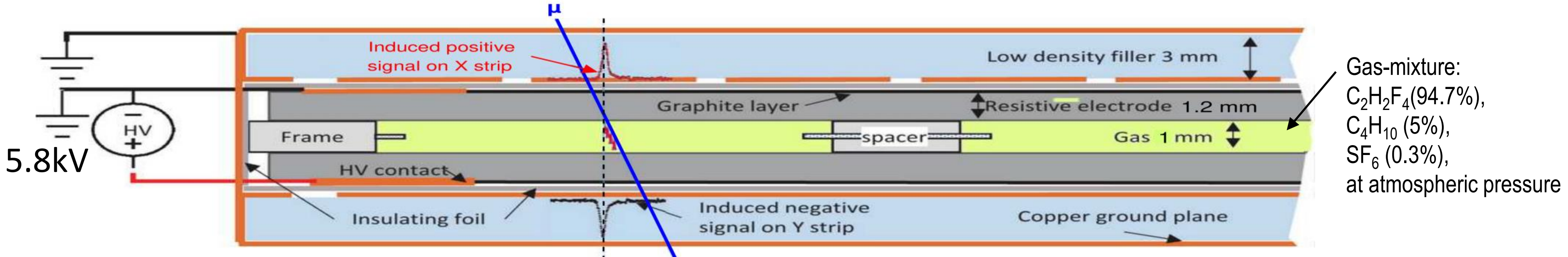
Upgrade of ATLAS muon spectrometer for HL-LHC

- Installation of 272 thin-gap RPC triplets **(i.e. 1 mm gas gap between the RPC electrodes)** in inner layer of barrel to maximize muon trigger acceptance and efficiency.
- **Challenges:**
  - High γ-radiation background: 10 kHz/cm^2 required rate capability
  - Required longevity: > 10 years of operation at HL-LHC
  - Very tight space constraints; only 4 cm in height available for triplet of RPC gas gaps



- Parallel plate gaseous ionization detector without wires and a small gas gap
- Use of highly resistive electrodes to limit avalanche development and graphite layer on outsides the electrodes for high voltage contact
- Inner surface coated with linseed oil varnish to obtain a smooth surface
- Position measurement with pick-up strip
- **Thin-gap RPCs:**
  - Gas gap thickness (High Pressure Laminate (HPL) electrodes distance) and operating voltage reduced to minimize the signal in order to meet the required longevity and high-rate capability; 400 ps time resolution
  - Highly sensitive, low noise electronics necessary to detect the small RPC signals

Production

- To produce required number of RPCs additional production capabilities necessary
- Creation of a new production site in Munich → Max-Planck-Institute developed production procedures and materials that are transferred to commercial companies
- For initial evaluation of the companies and production procedures each company produced several small test samples
- Size of a sample: 40x50 cm^2
- **Production procedures:**

  Production step 1: Graphite coating

  Production step 2: Application of electrical contact and gluing of Polyethylenterephthalat (PET) foil on HPL plate

  Production step 3: Positioning of spacers and lateral profiles

  Production step 4: Gluing HPL plate onto spacers and profiles

  Production step 5: Closing the gas gap with second HPL plate

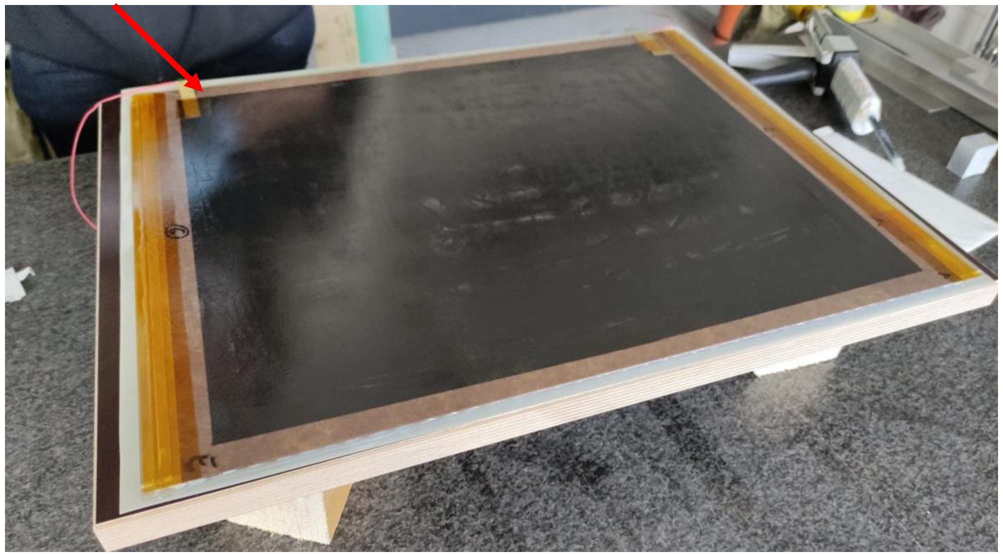
  Production step 6: Sealing

  Production step 7: Leak test

  Production step 8: Oil coating

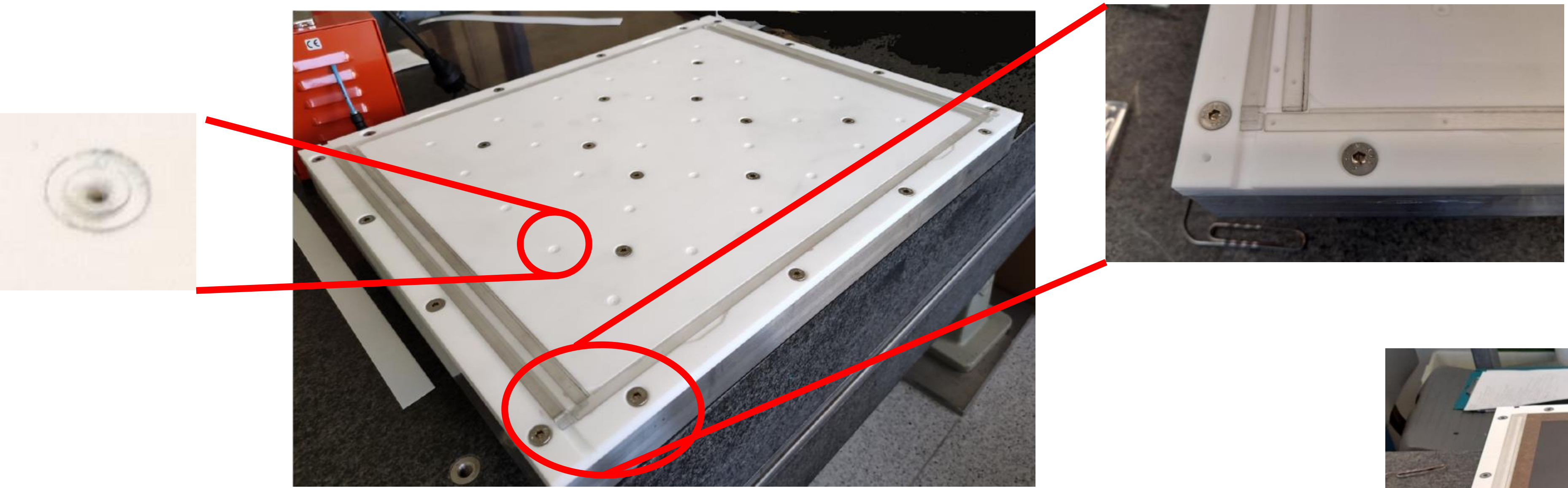
Preparing the electrodes

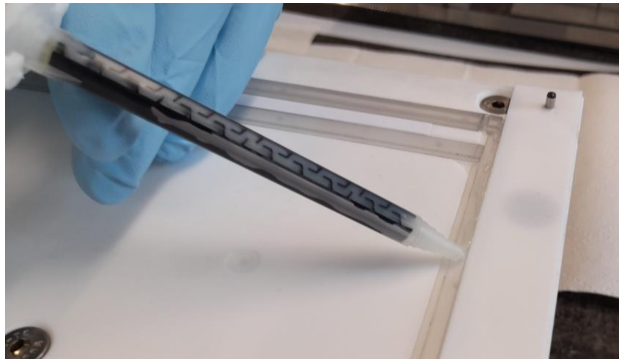
Electrical contact: Copper pad is glued to graphite layer using conducting silver glue



Insulating: The PET foil with pre-applied Ethylen-Vinylacetat (EVA) is placed on outside of electrodes and heated up with heating mats

Positioning spacers and lateral profiles

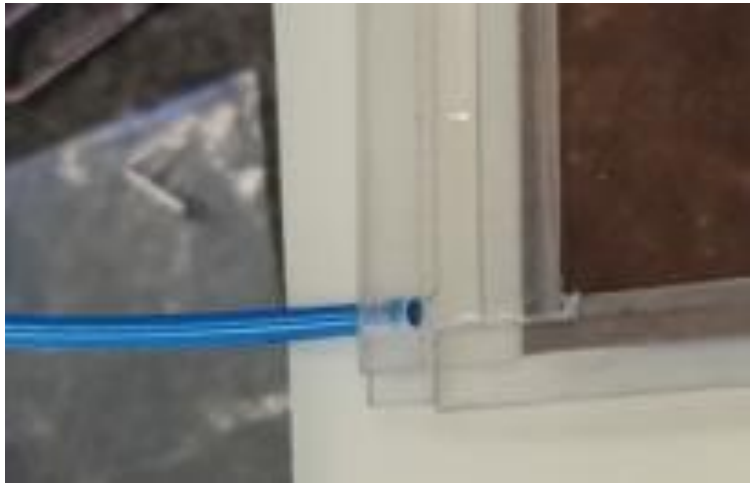


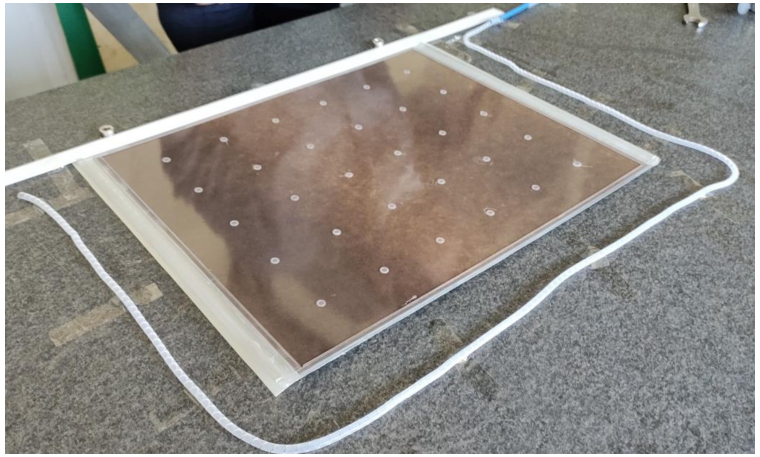


Template designed and built for this step:

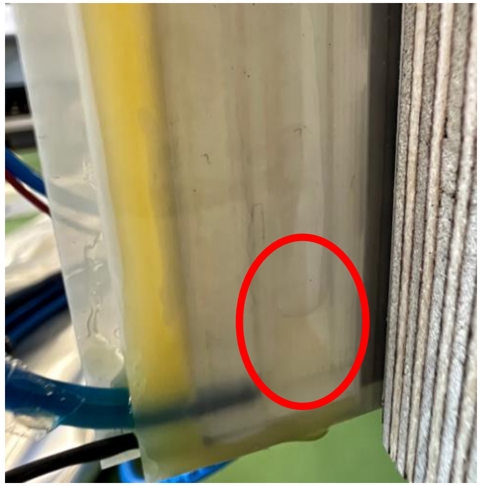
- Made from Teflon to prevent glue sticking to template
- Dimples and notches help place spacers and lateral profiles
- Allows for the use of a vacuum pump to suck down the profiles and spacers, fixing them in place
- HPL plate pressed on top of spacers and profiles
- Glue must cure for 6h

Closing, sealing and linseed oil coating the gap

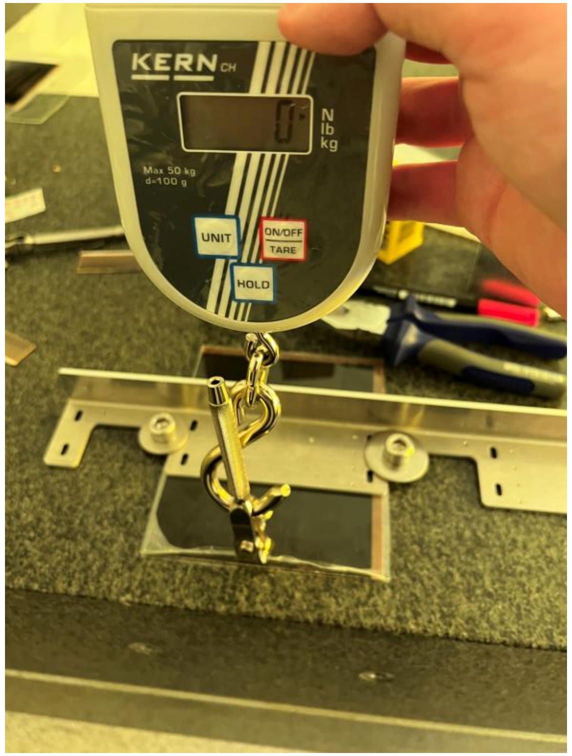


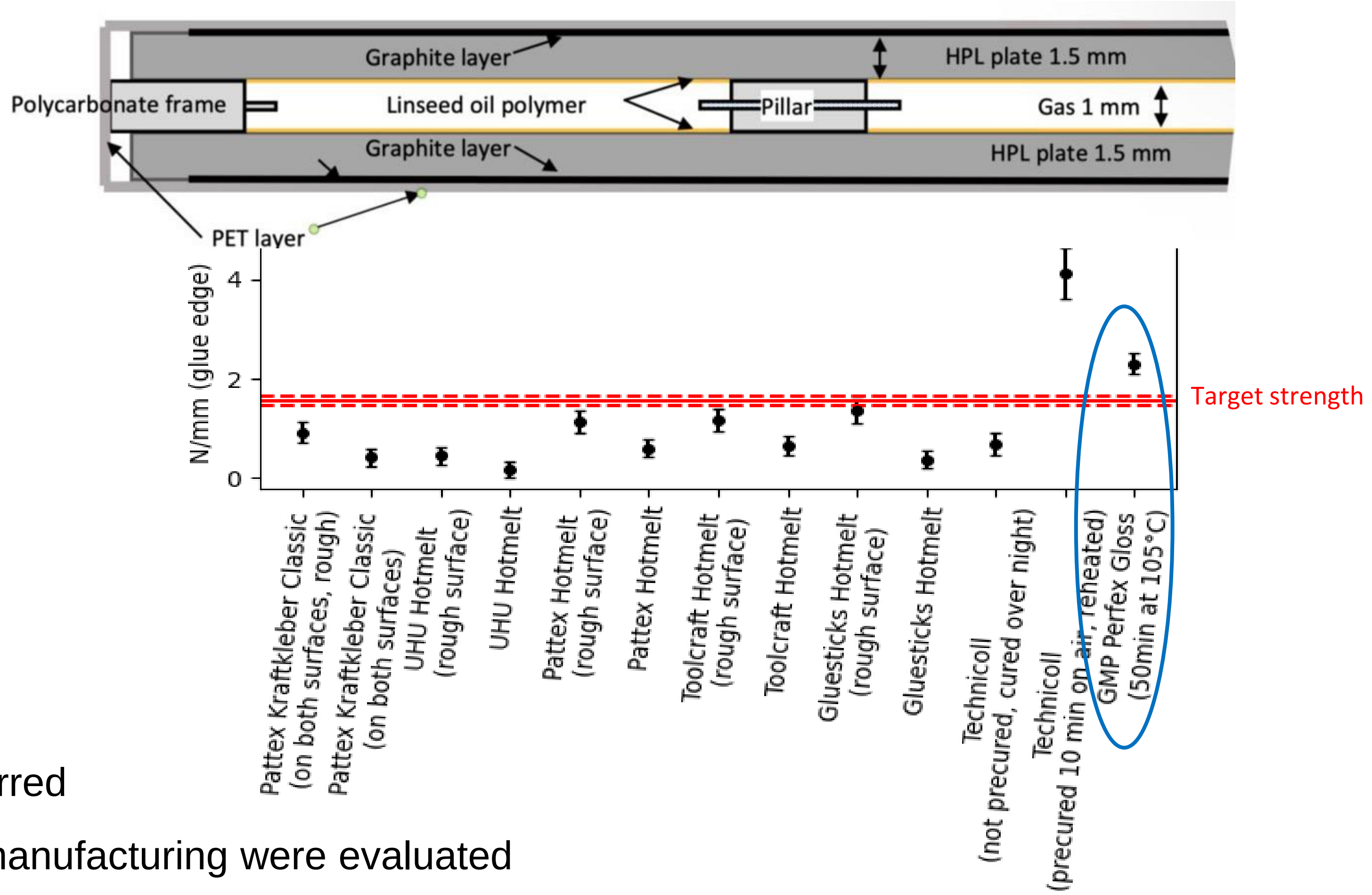


- Gas pipe inserted into lateral profiles
- Gap closed by gluing second electrode on top of first one, wich has spacers and profiles already applied
- Then sealed gas gap is filled with linseed oil and slowly drained to create an even and protective coating
- Linseed oil has to dry for a week with constant airflow pumped through gap



Testing of different glues

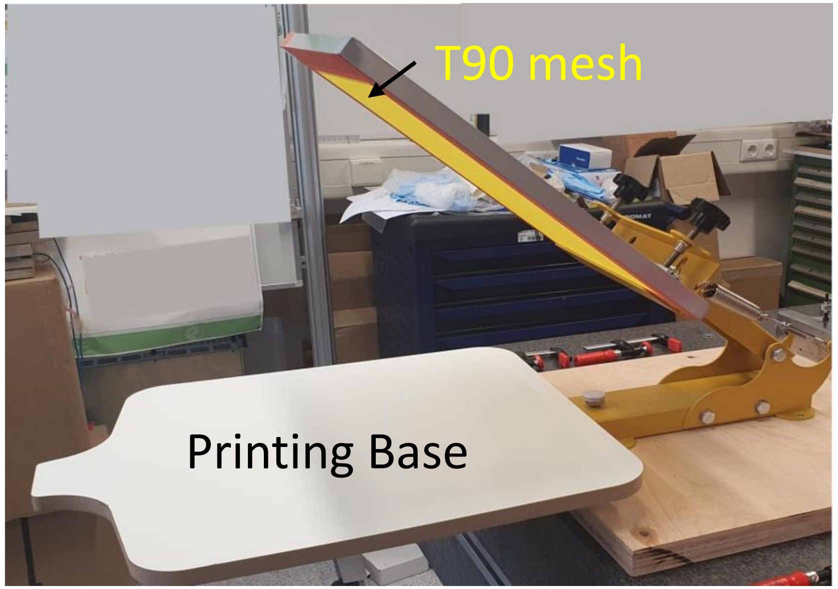


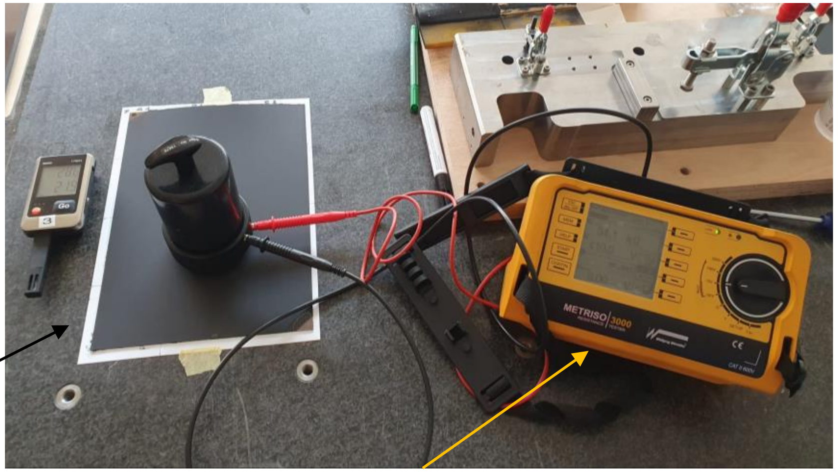


- Glue still flexible after curing preferred
- Strength and ease of use during manufacturing were evaluated
- Tested by pulling off pieces of PET with newton meter for measuring of strength
- Tested glues compared to example provided by current CERN supplier
- Best material: **GMP Perfex Gloss** (commercially available PET foil with pre-applied EVA hot-melt addhesive)

Graphite coating

- Goal: determine best procedure for silk-screen printing and drying
- Test setup: standard T90 silk-screen (polyester with 90 threads per cm)
- Carbon Paste WCP-3200HL (15) from Heysung Trade Company
- Measuring surface resistivity using METRISO 3000 Resistance Tester (IEC 61340-4-1)



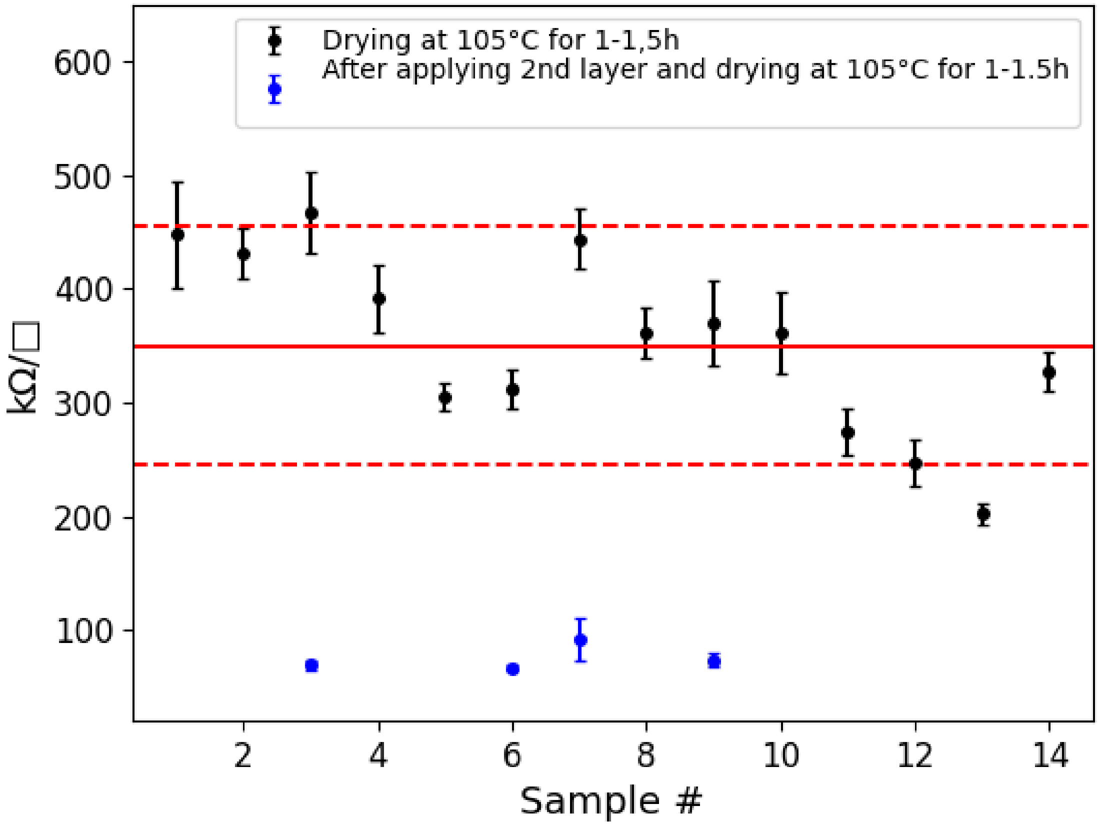


Sample

METRISO 3000

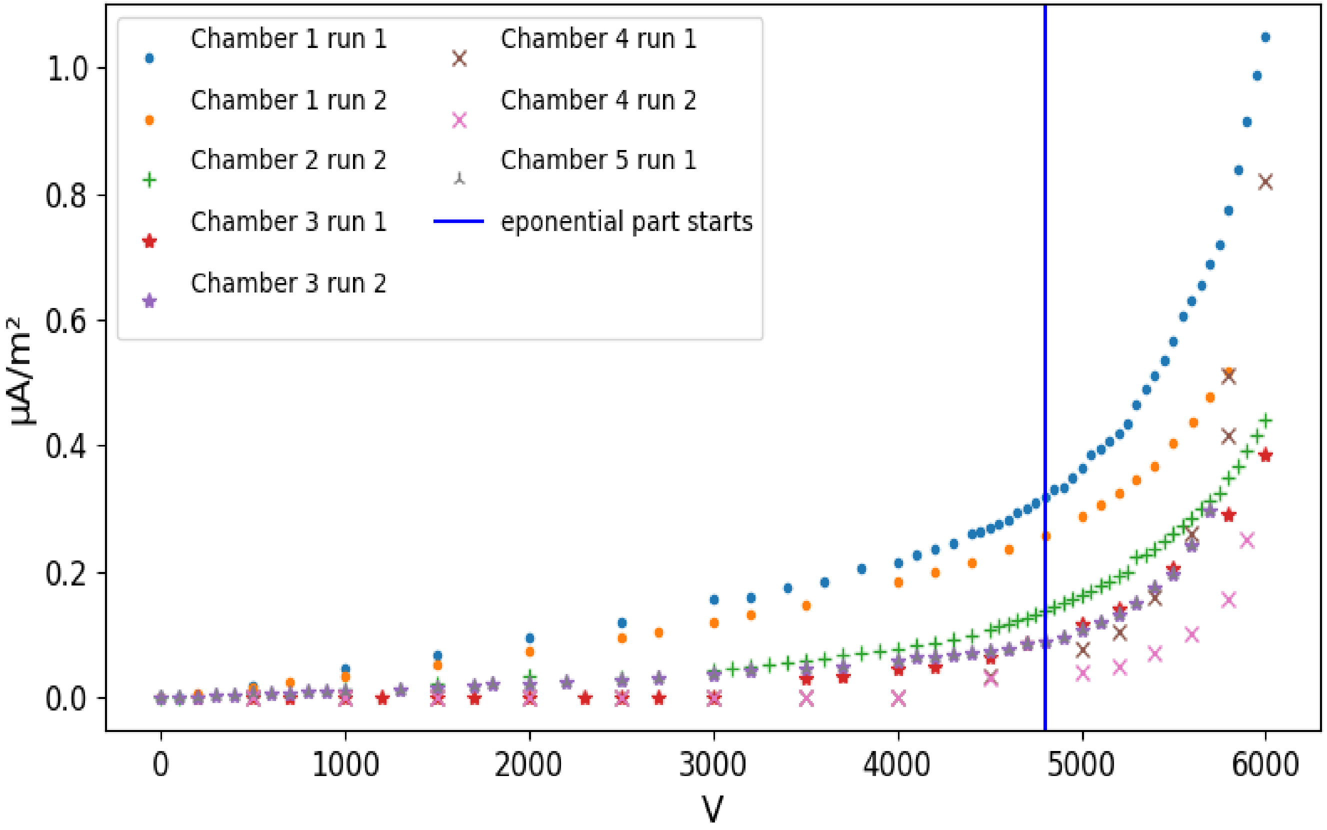
Graphite coating results

- Heat up to 105°C for drying 1-1.5h
  - ➢ average resistivity of (296± 5.7) kΩ/□
- End values match tolerance for ATLAS RPC
- Double printing reduces the resistivity further
  - ➢ Double layered edge can be used for high voltage contact → lower resistivity on edge improves voltage distribution



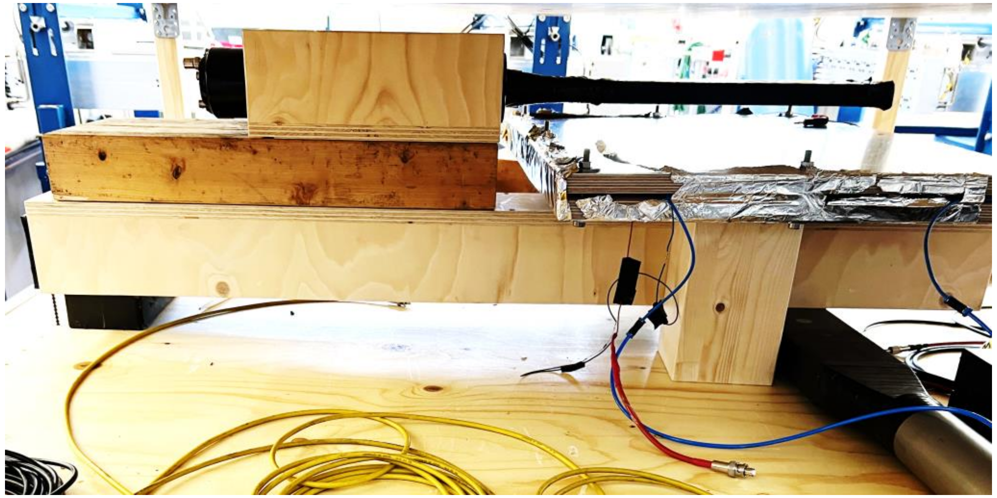
Voltage current curves

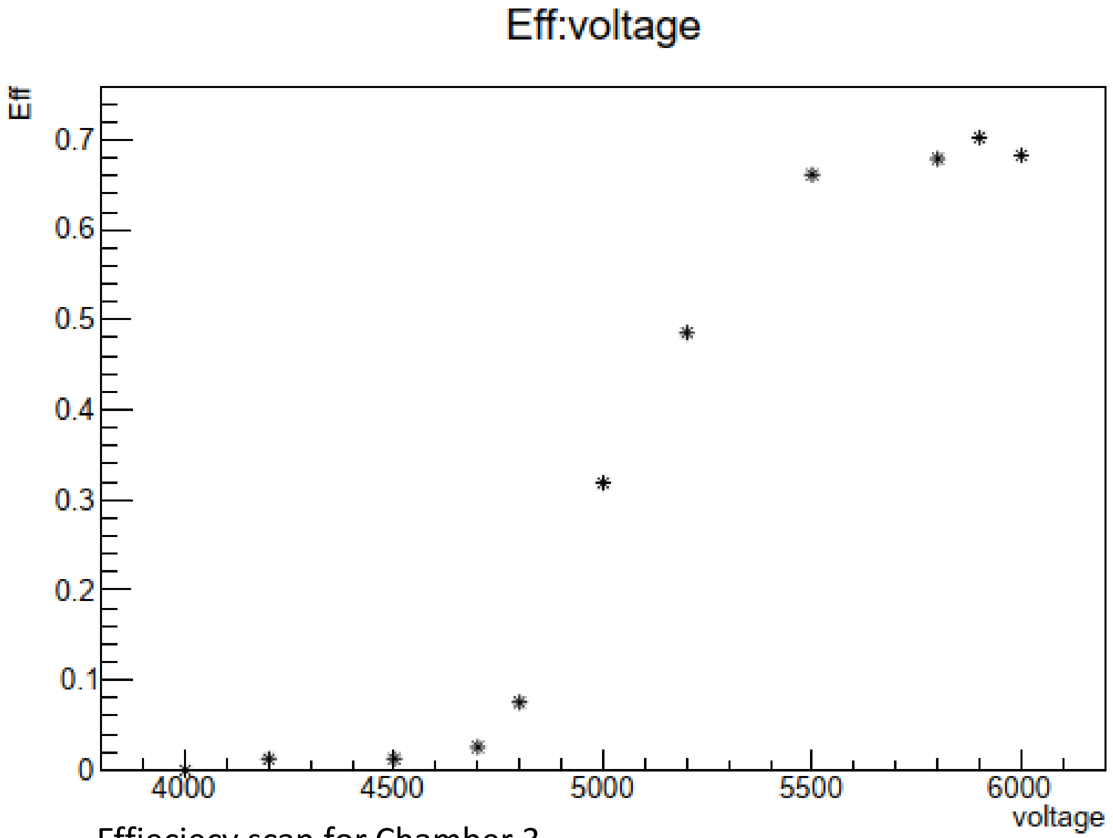
- Voltage-Current curves are a quality measure for RPCs
- First part of the curve linear: ohmic resistivity dominates the current behavior
  - Limit of 0.8 μA/m² at 3kV
- Second part exponential: gas amplification sets in → more and more of current generated in gas → dominates the curve
  - Limit of (total current – ohmic part) = 0.8 μA/m² at 6kV
- Beginning of the exponential regime indicates size of the gap



Efficiency curves

- Measurement with cosmic muons
- Two scintilators perpendicular to each other below the tested gas gap in hardware and configuration as hardware trigger
- One small scintilator above the chamber as software trigger
- Readout chain: Strip → Amplifier → discriminator → TDC (addapted sMDT prototype)
- Results show expected behaviour





Effieciecy scan for Chamber 3
No end resistor on strip -> curve shifted to lower voltage
No correction for geometry applied

Summary

- Production procedure compatible with industrial standards established
- Technology transfer to three companies.
- Successful production of small size prototype RPCs by these companies

Next steps:

- Production start for fullsize prototypes by the companies
- 1 year ageing study of the full-size prototypes at the GIF++ to certify the production