Industrialization of the Production of Thin-Gap Resistive Plate Chambers

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Introduction

Goal

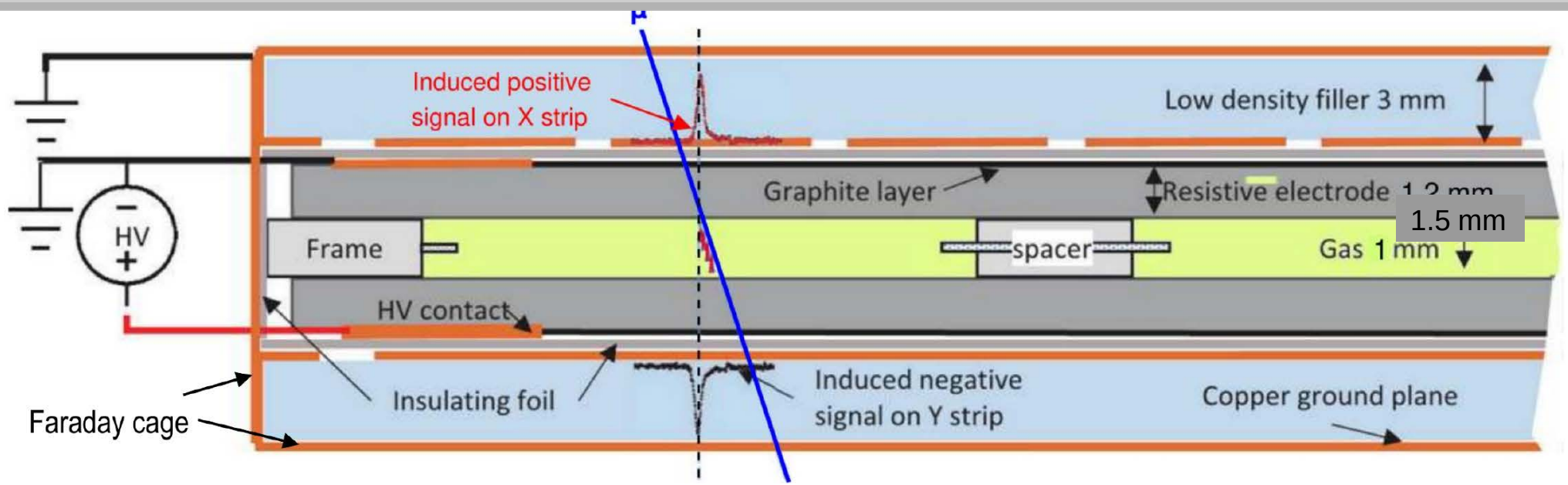
Alternative fabrication of thin-gap bakelite RPC gas gaps in industry.

First application: Thin gap RPCs for ATLAS barrel muon detector upgrade for HL-LHC

Strategy

- Specifications by Univ. Rome 2
- Detailed instructions from Rome 2 group and Kodel facility in South Korea
- Production setup of thin-gap RPCs at the Max-Planck Institute for Physics
- Optimization of the production steps in interaction with companies
- Qualification of companies with prototypes
- Qualification of companies for ATLAS production

ATLAS thin-gap RPCs



Operating voltage 5.8 kV

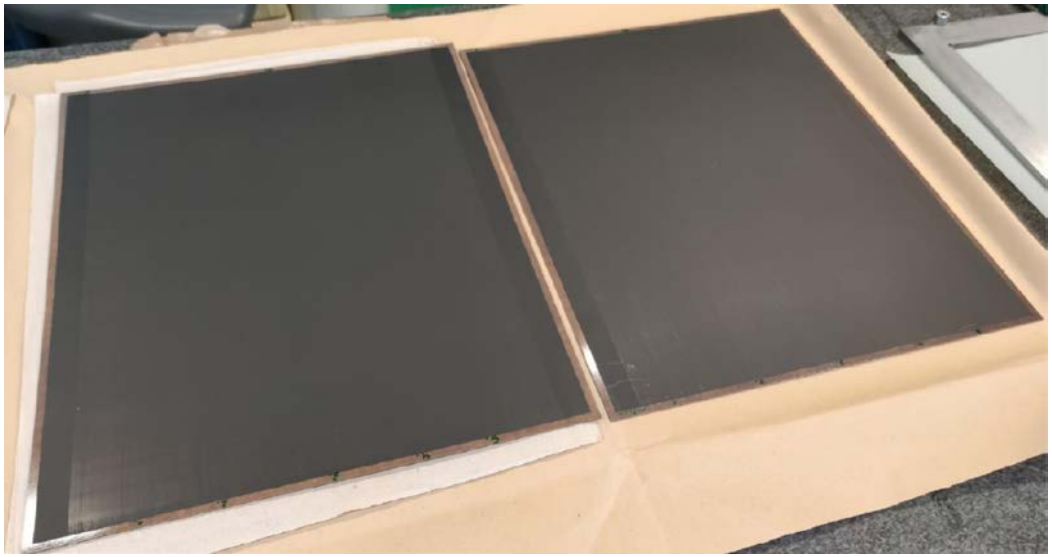
Gas gap components

- Resistive electrodes of phenolic high-pressure laminate (HPL):
  - Typical dimensions for ATLAS: (1634±0.5) mm x (1064±0.5) mm x (1.5±0.09) mm.
  - Resisitivity: $1.5\text{-}6 \cdot 10^{10}$ Ωcm.
  - Graphite layer resistivity: (350±100) kΩ/sq.
- Polycarbonate spacers of (1.000±0.015) mm thickness („thin gap“)
- Polycarbonate frame parts of (1.000±0.015) mm thickness.
- 200 µm electrically insulating PET foil with ethylen vinyl acetate (EVA) hotmelt glue.
- Standard gas mixture so far: $C_2H_2F_4$/iso-C_4H_{10}/SF_6 (94.7/5/0.3).

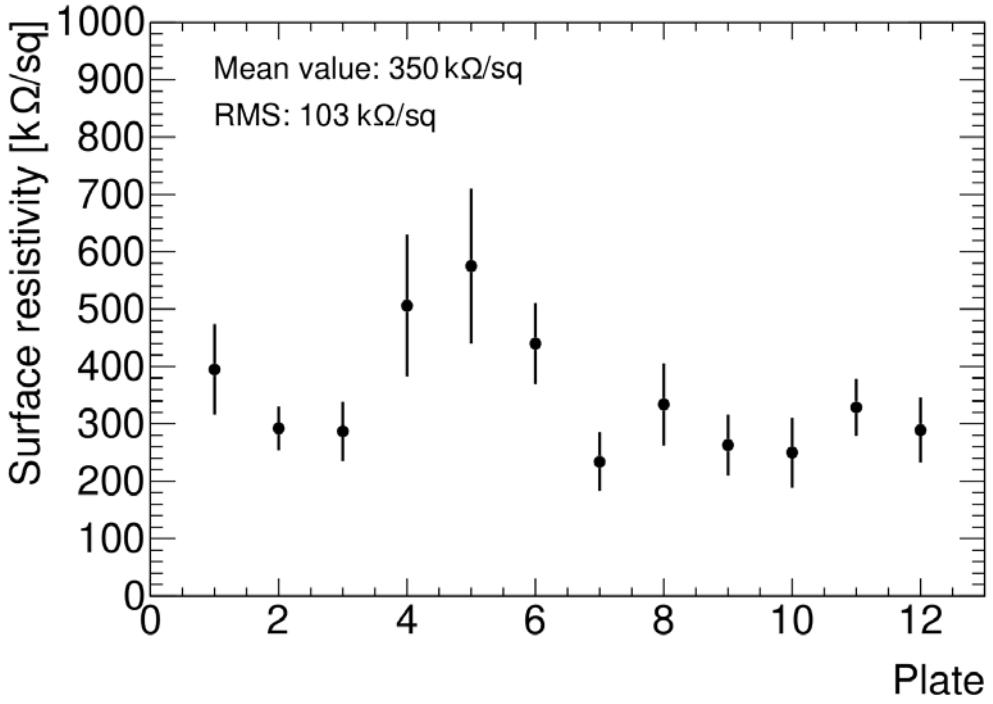
HPL electrodes

- The only supplier for the moment: Teknemika.

Graphite coating of the HPL electrodes

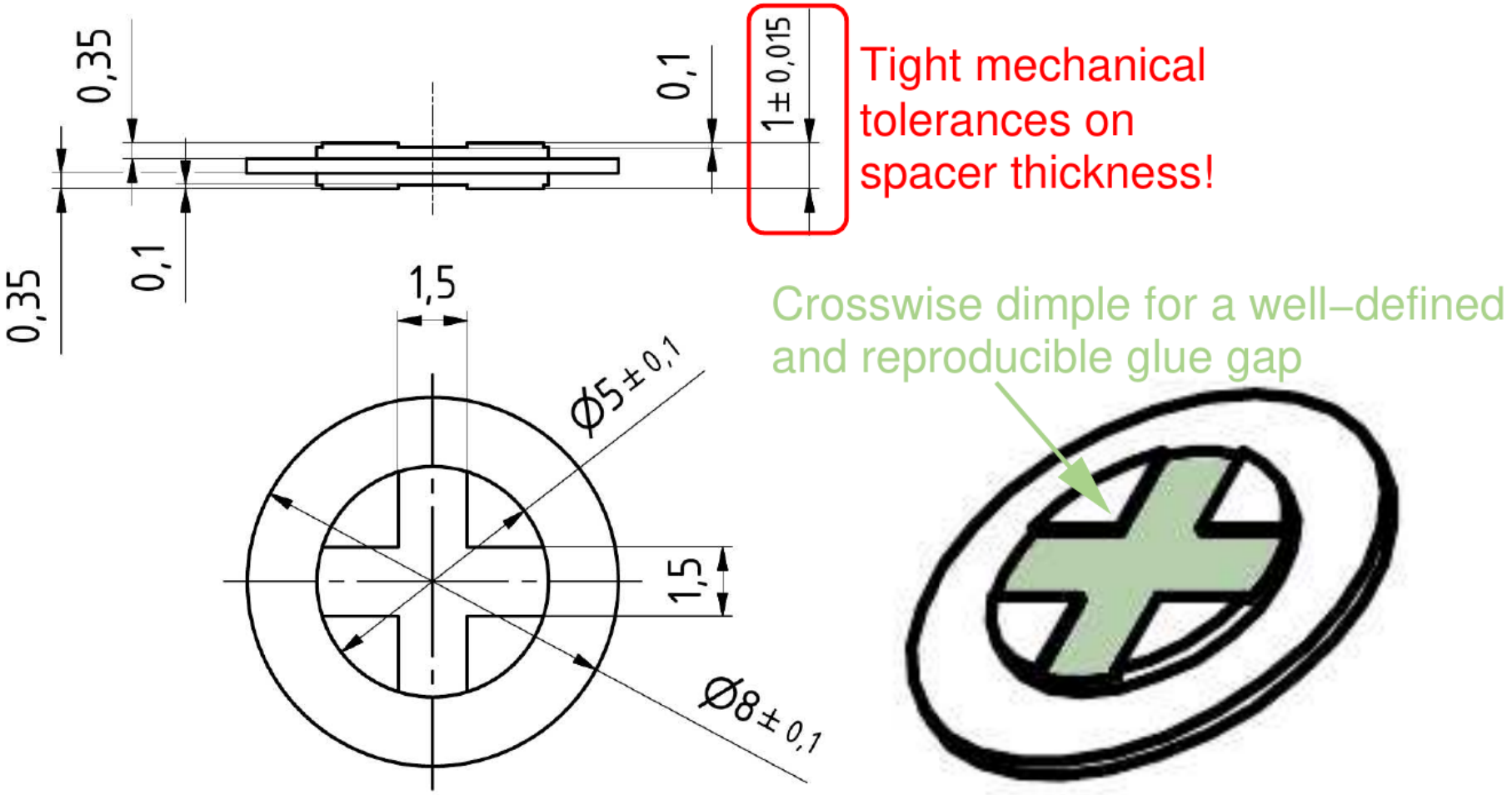


Surface resistivity of the coating



- Supplier of the graphite varnish: Heysung trade company (South Korea)
- Graphite coating by silk-screen printing in industry:
  - Mesh size: 80 threads/cm.
  - Drying in air for 5 days.
- Achieved surface resistivity: 350 kΩ/sq within 30%, compliant with specifications

Spacers



Spacers produced with required precision by injection moulding,

with cross-shaped imprint on both sides to absorb excess glue to ensure defined gap height.

Insulating PET foil

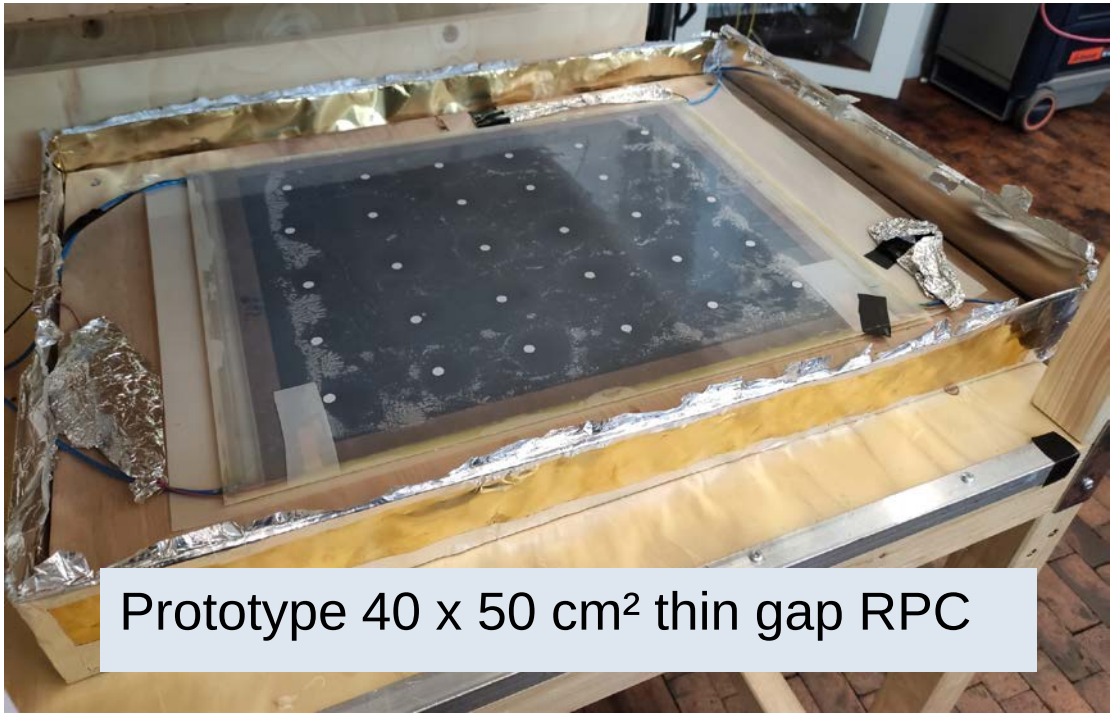
- Suitable glue needed to reliably attach the insulating PET foil to the graphite coated electrode without bubbles at not too high temperatures.
- A variety of EVA based glues and PET-EVA compound s were tested

  (see poster by T. Turkovic).
- Best behaviour: Perfex gloss PET-EVA compound foil (190 µm PET, 80 µm EVA).
- Lamination of the foil on the electrode under pressure at 105°C for 1 h in a press.

Fabrication of thin-gap RPCs at MPI

- Development of industrializable production procedures with high reliability and reproducibility
- First step with 40x50 cm² prototypes successful using procedures scalable to typical dimensions of 1 x 2 m².
- Transfer to three companies.
- Next step under preparation for this year:

  production of 10 full-size ATLAS RPCs at each of the new companies for qualification.



Prototype 40 x 50 cm² thin gap RPC

Critical production steps

Production steps

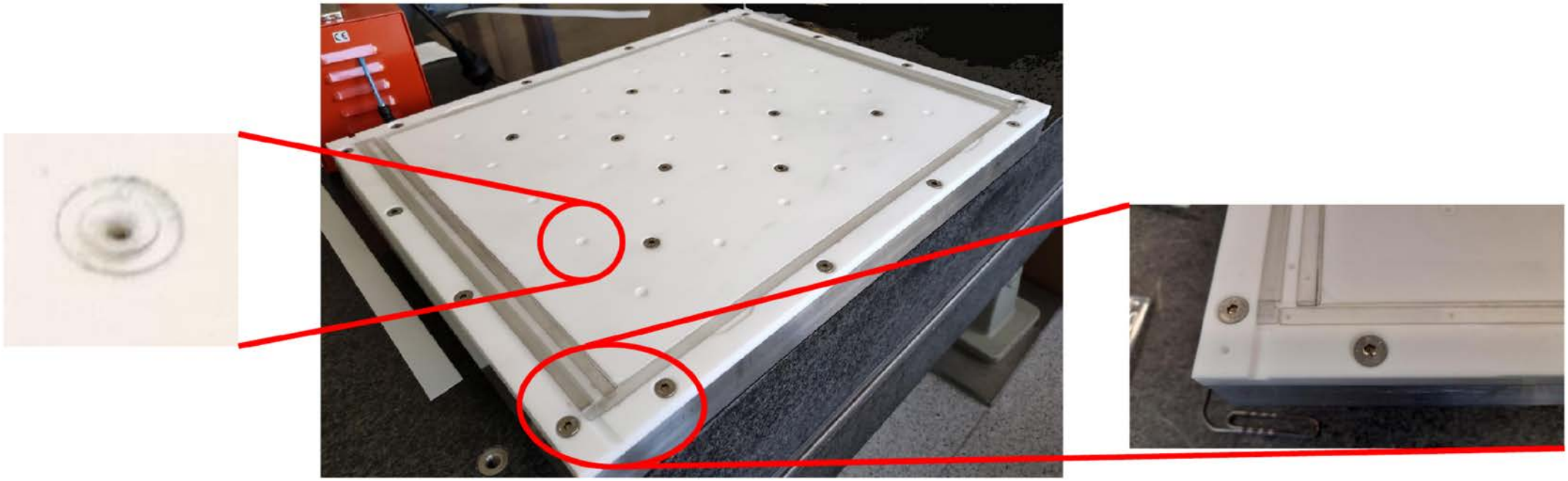
1. Graphite coating of the HPL electrodes
2. Adding electrical contacts
3. Laminating the insulating PET foil onto the HPL electrodes.
4. Positioning of spacers and frame profiles and gluing of those onto the electrode.
5. Closing of the gas gap with the second HPL electrode
6. Adding gas pipes
7. Linseed oil coating

Most critical steps

- Positioning and gluing of the frame profiles and ~300 spacers within the 1 h worklife of the 3M DP460 glue.
- Linseed oil coating.

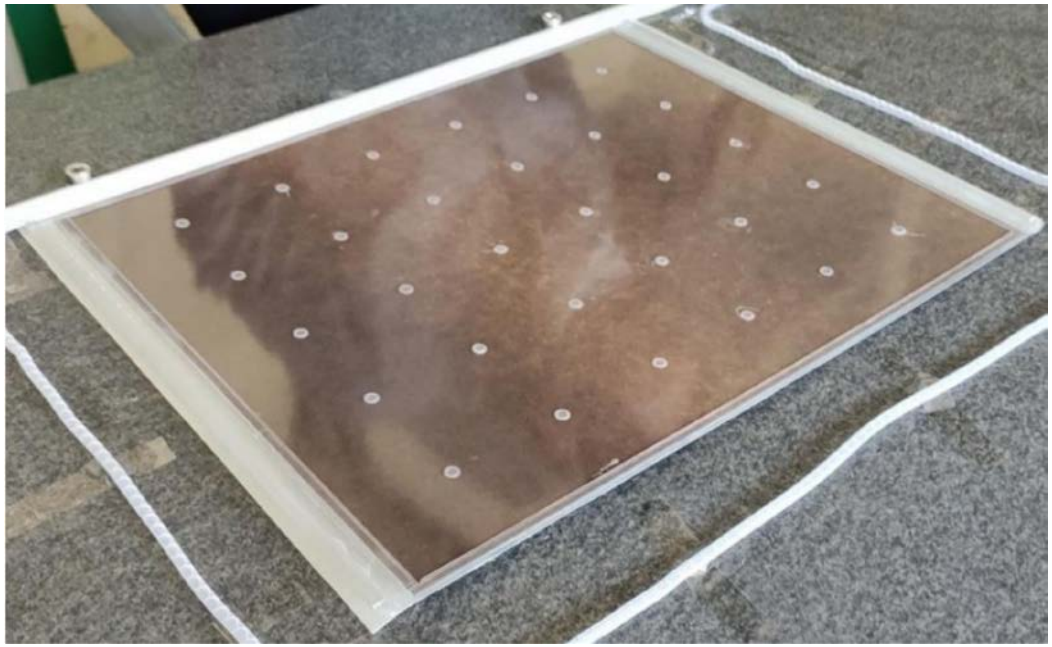
Gas gap gluing

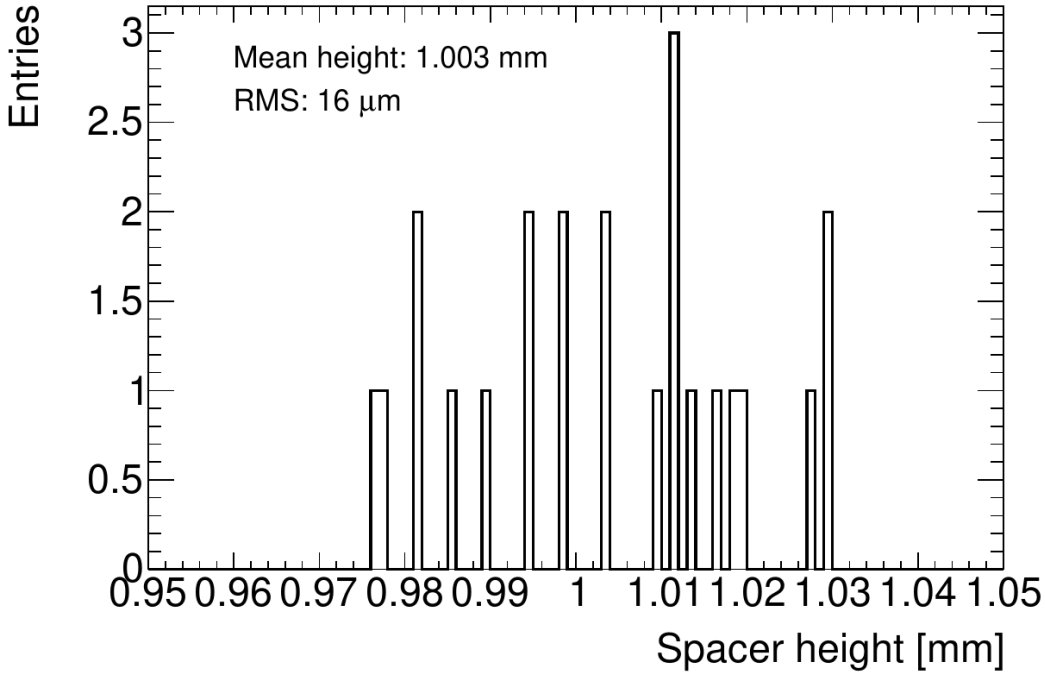
- Teflon template designed for fast positioning of the spacers and the side profiles which are held down by vacuum.
- Gluing of spacers and side profiles with Araldite 2011 expoxy applied with and automated gluing machine (spacers) and hand held glue dispenser (side profiles).



Gas pipe inserted into a hole in the frame profile and fixed with glue.

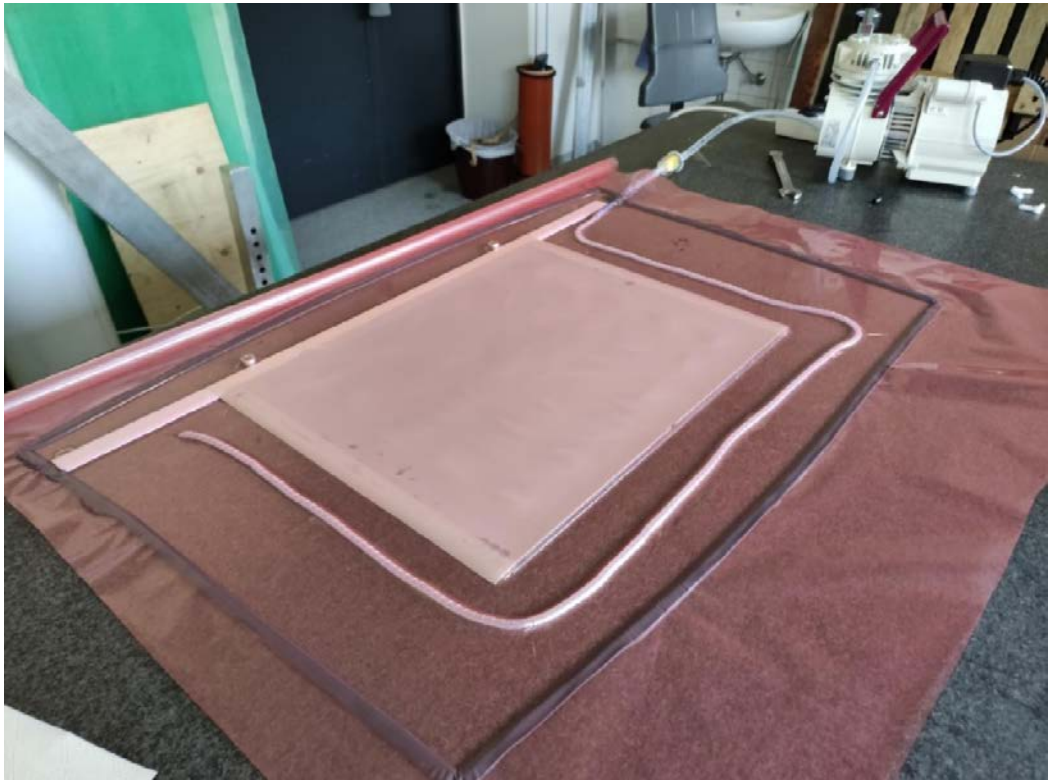
Verification of the spacer heights





- Measured spacer heights within specifications:
  Mean height: 1.003 mm. RMS: 16 µm.

Closing the gas gap with the top electrode plate



- Application of glue to the spacers and frame profiles like for the bottom plate
- The top plate is pressed down using a vacuum bag.

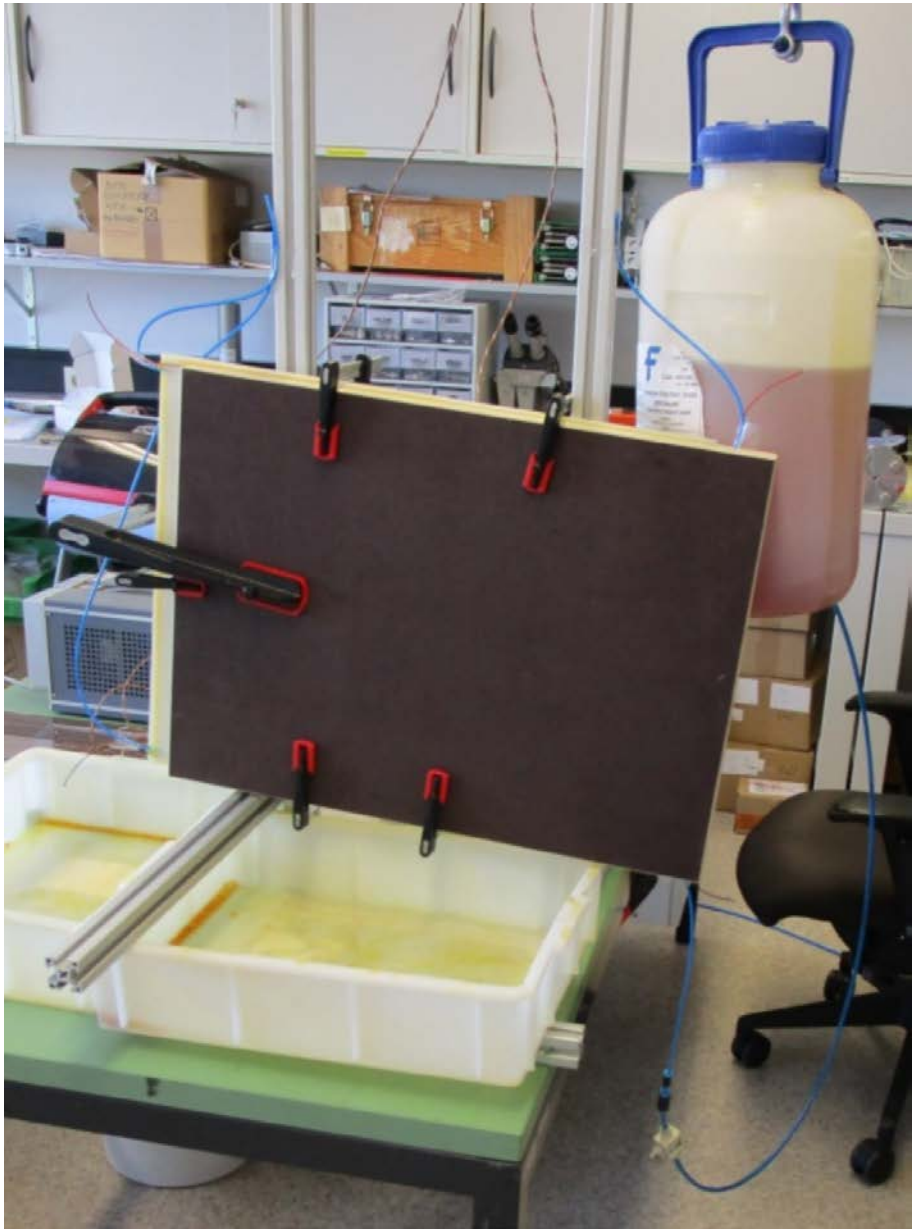
Quality control before linseed oil coating of the electrodes

Gas leak test

Gas leak test:

- Gas gap filled with argon at 3 mbar overpressure.
- Leak search with argon sniffer.
- Leaks sealed with epoxy.
- Prevention of linseed oil leakage during the coating procedure.

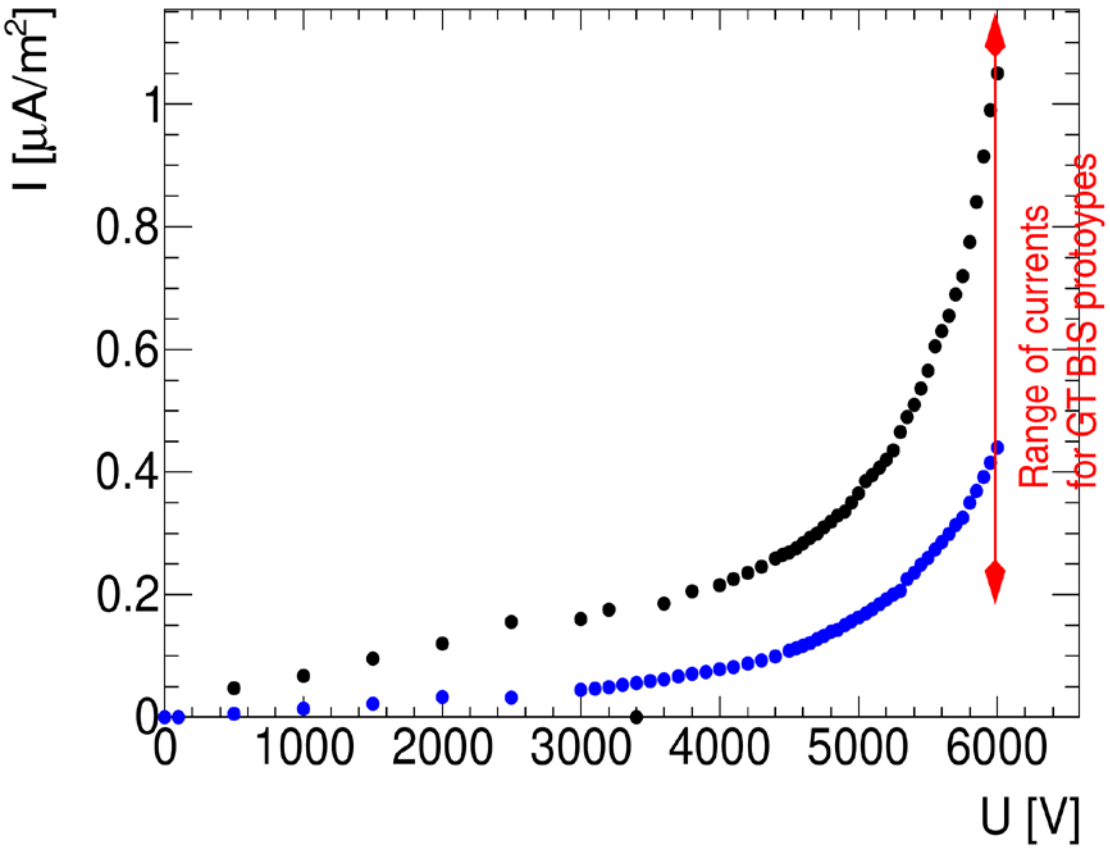
Linseed oil coating



- Gas gap filled with a mixture of 30% linseed oil and 70% heptane inserted through the gas connections from a supply bottle.
- Gas gap pressed together with two plates to prevent bursting under the oil pressure.
- Oil drained slowly (<1 m/h) after lowering of the linseed oil bottle.
- Pumping of air through the gap for one week to achieve full polymerization of the oil.

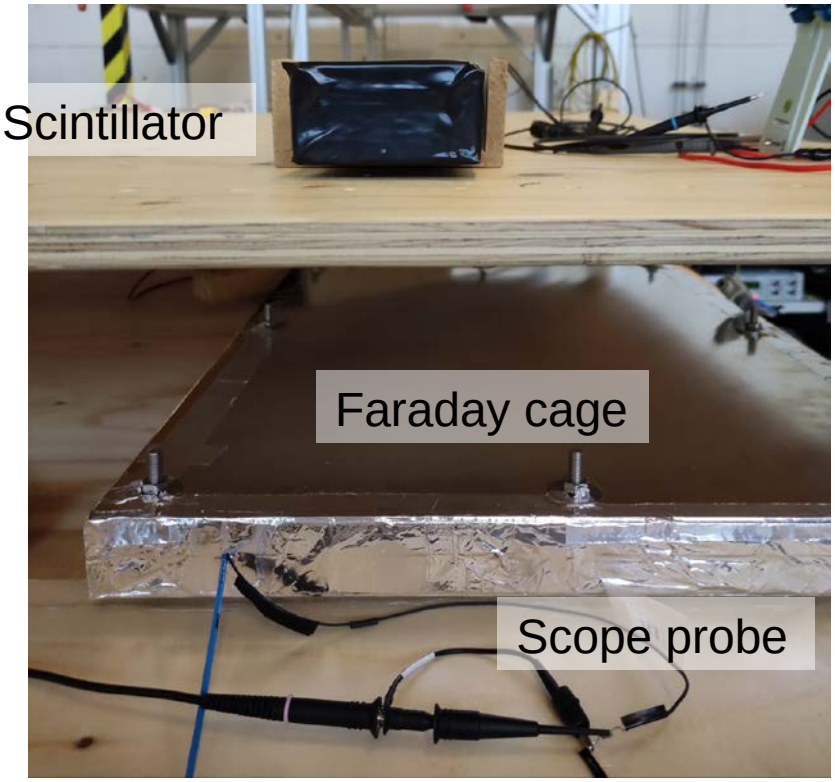
Gas gap tests

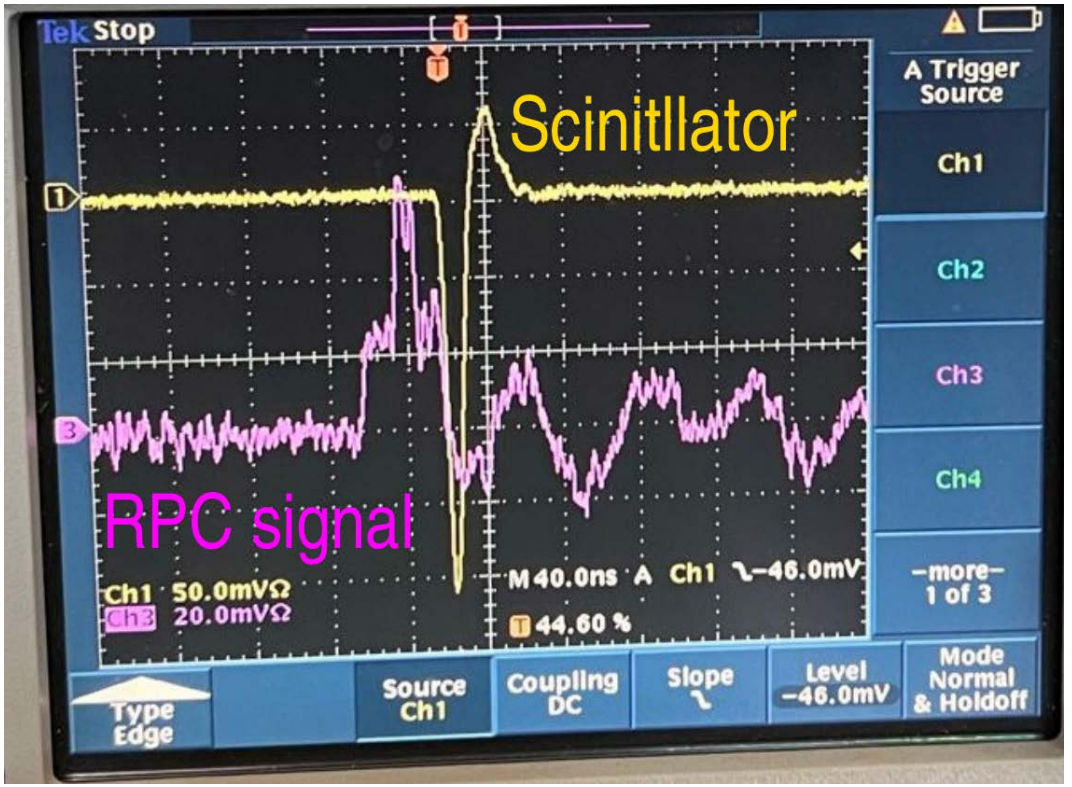
- Check for broken spacers by applying overpressures of 1, 2, 4, 8 mbar and measuring if the surface of the gas gap is lifted.
- Measurement of the current-voltage curve.



Measured I-V curves of prototype gas gaps compatible with the I-V curves of the thin-gap prototype chambers already installed in ATLAS.

Signals from cosmic muons





RPC signal: voltage drop on 1 MΩ resistor in the ground line measured with an oscilloscope probe in coincidence with the trigger scintillator.

Evolution to large-size gas gaps

Goal

Production of 300 thin gas gaps for the ATLAS HL-LHC upgrade within one year.

Production time budget

- Visual inspection of the electrodes :10 min/electrode
- Silk-screen printing of the graphite: 16 plates/week
- Adding the HV contacts to the graphite layers: 10 min/electrode
- Lamination of the PET foil onto the electrode: 2 hours/electrode
- 1st gluing step (spacers+profiles onto the electrode): 30 min preparation/30 min gluing
- Curing of the glue: 6 hours
- 2nd gluing step (closing of the gap): 30 min
- Soldering of HV cable, insertion of gas pipes: 20 min
- Sealing of the edges with hotmelt glue: 4 x 30 min
- Check for broken glue bonds and leak test: 3 hours
- Linseed oil coating : 1.5 hours
- Polymerization of the coating: 7 days

Production workflow for two gas gaps per day with one setup

Morning:

- Closing of the second gas gap from the previous day one a separate table.
- Gluing of spacers and profiles to the bottom electrode of the next gas gap on the table with template and gluing machine.
- 6 hours glue curing time.

Afternoon:

- Bottom electrode moved to the table for the gluing of the top electrode (closing).
- Start of next gas gap by gluing of spacers and profiles to the bottom electrode.
- Curing of the glue over night.

$\Rightarrow$ Production of 2 gas gaps per day from Monday to Friday.

$\Rightarrow$ Weekly production of 10 gas gaps filled with linseed oil in parallel and left for polymerisation for one week.

Summary

Fabrication of several prototype gas gaps was successfully perfromed at three companies

These companies are preparing their setups for the production of 10 full-size prototypes each in November 2022.

After a one-year aging test of the prototypes in the CERN Gamma Ray Facility GIF++ for the certification the companies, the production for the ATLAS upgrade can start to be completed in 2024.