OPTIMIZATION AND TEST OF NEW RESISTIVE PLATE CHAMBERS FOR THE ATLAS-DETECTOR UPGRADE AT THE LARGE HADRON COLLIDER

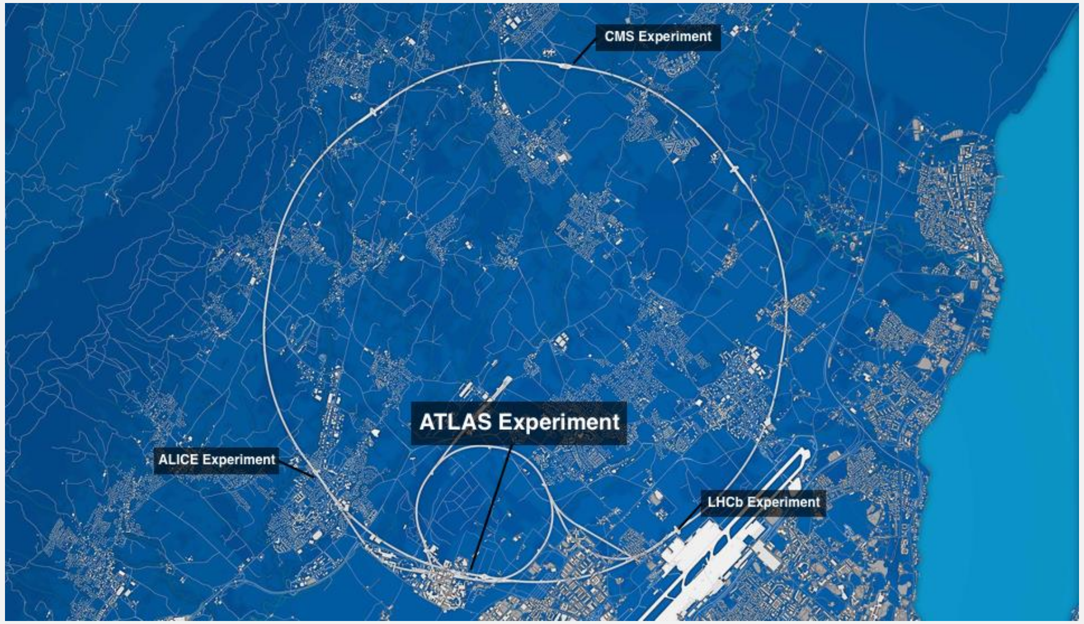
Jan Darsow, July 12th 2021

MAX-PLANCK-INSTITUT FÜR PHYSIK

CONTENTS

LARGE HADRON COLLIDER (LHC)

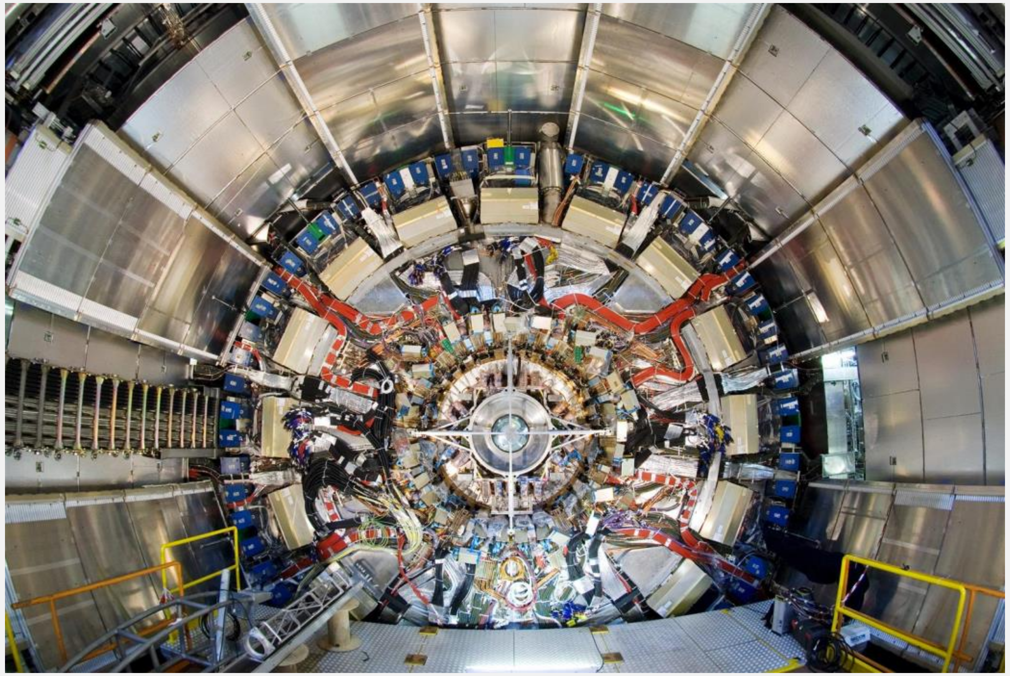
- Belongs to CERNs accelerator complex
- Largest and most powerful particle accelerator
- Centre-of-mass energy proton-proton collisions: $\sqrt{s}$ =13TeV
- Started up on 10 September 2008
- 27km ring of superconducting magnets and accelerating structures
- Four collision points: CMS, ALICE, LHCb and ATLAS



Reference 1

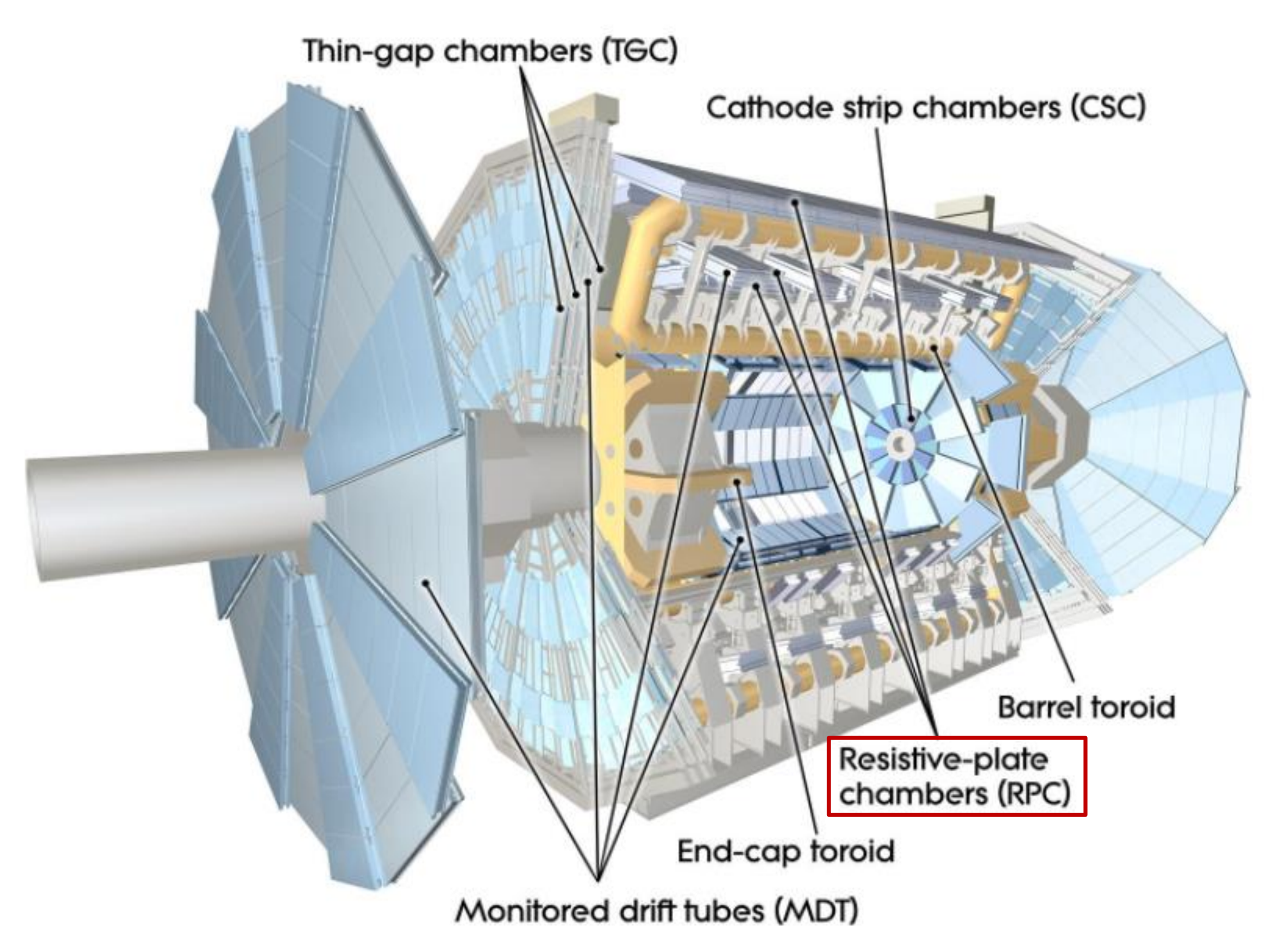
THE ATLAS DETECTOR

- **A T**oridal **L**HC **A**pparatu**S**
- Biggest particle detector ever constructed
- 46m meters long and 25m of diameter
- Weighs 7000 metric tons
- 100m below the ground
- 1 billion collisions/second



Reference 1

THE ATLAS DETECTOR



Reference 1

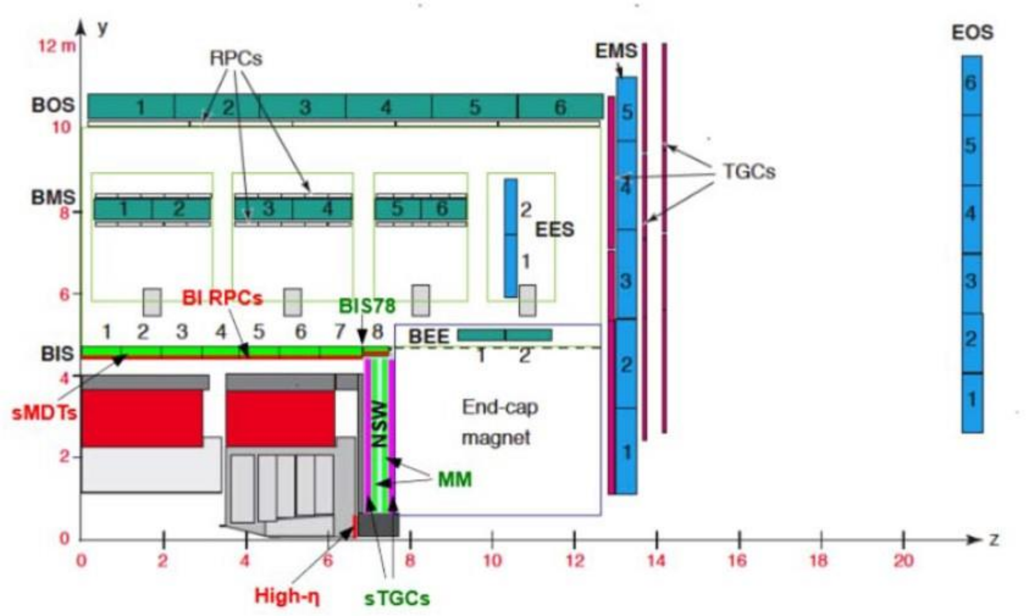
THE ATLAS DETECTOR PHASE II UPGRADE

- LHC: peak Luminosity will increase by factor ten in the next ten years
  - ➢ Higher particle rates, integrated radiation and pile up
- ATLAS will upgrade while long shutdown 2 in 2021

Reference 2

AIM OF THE PHASE II UPGRADE

- Preserve muon identification and tracking performance and momentum resolution
- More selective muon trigger while keeping a low muon transverse momenta threshold
- Ten times higher trigger rates
  - ➢Complete redesign of all trigger and readout systems required



Reference 2

PHASE II UPGRADE: OPPORTUNITIES

- Explore nature of physics beyond standard model
  - E.g. Measure rare B –> μμ (muon transverse momenta several TeV) in search for high mass resonances (e.g. Z`–>μμ)
- Study electroweak symmetry breaking
  - E.g. double- Higgs production H–>μμ

➢ Muon signatures play a crucial role

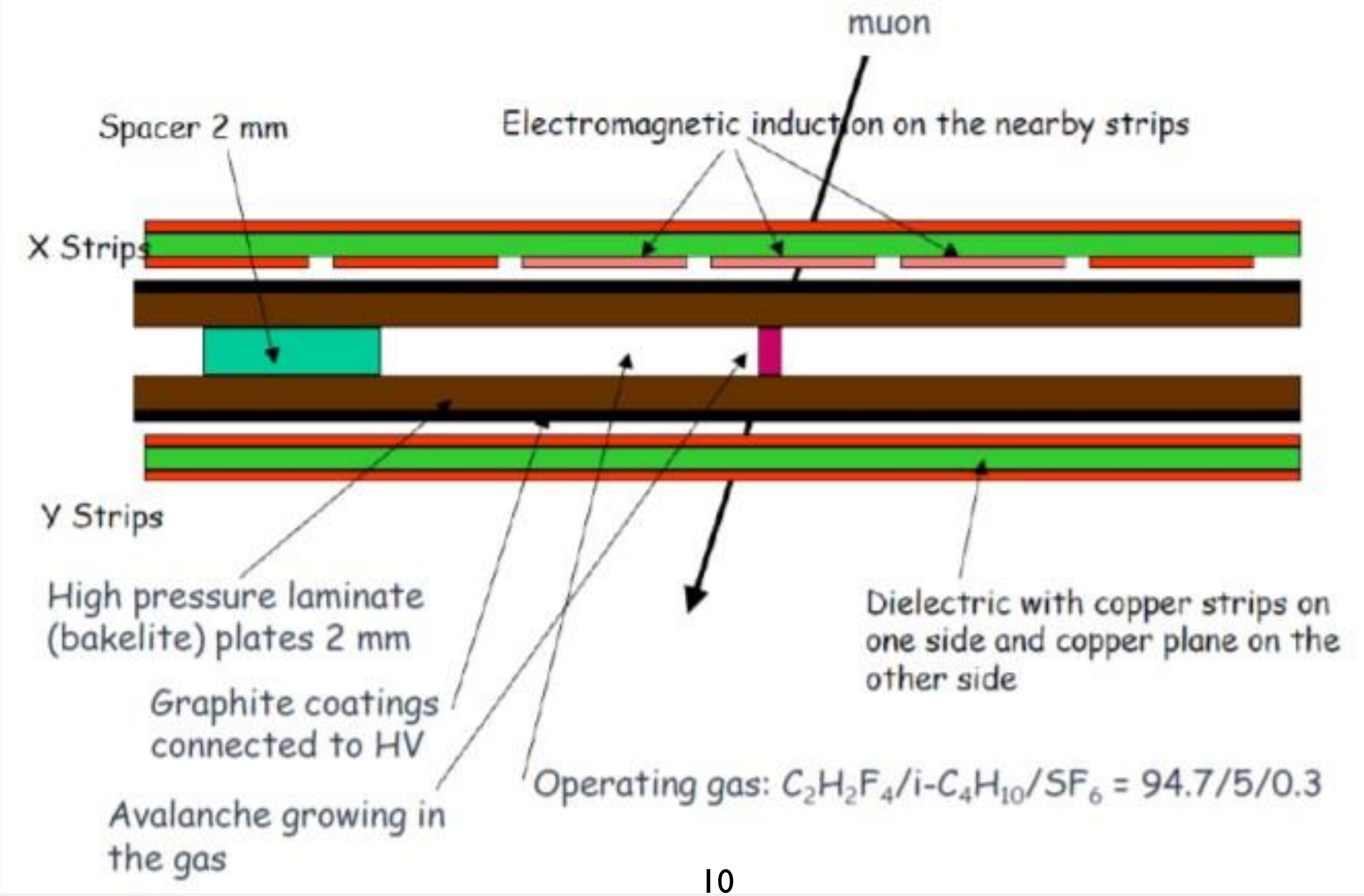
Reference 2

WORKING PRINCIPLE OF RPCS

- Originally developed for cosmic ray experiments: low-rate capability, good time resolution and low cost per unit of area
- Same features, but with increased rate capability, required in the muon spectrometers of collider experiments

Reference 3

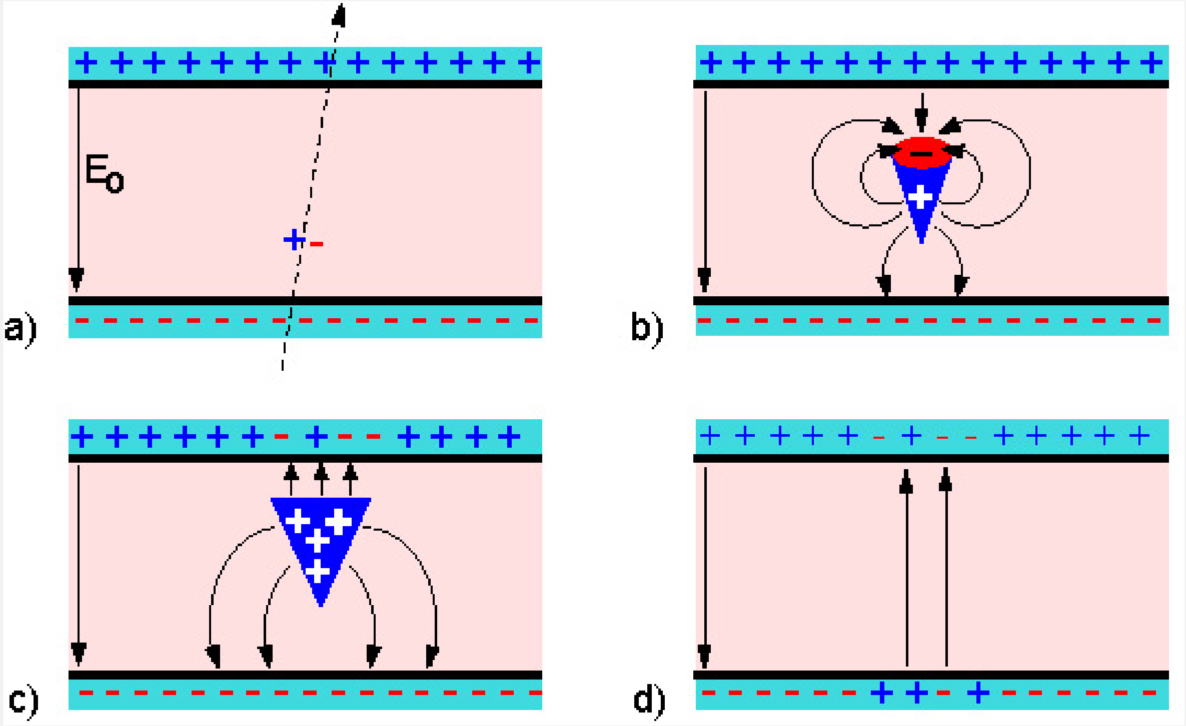
WORKING PRINCIPLE OF RPCS



Reference 6

WORKING PRINCIPLE OF RPCS

a) Gas ionization
b) Avalanche development, space charge effects
c) Ion drift speed slows down
d) Charges in the electrode plates change the electrical field

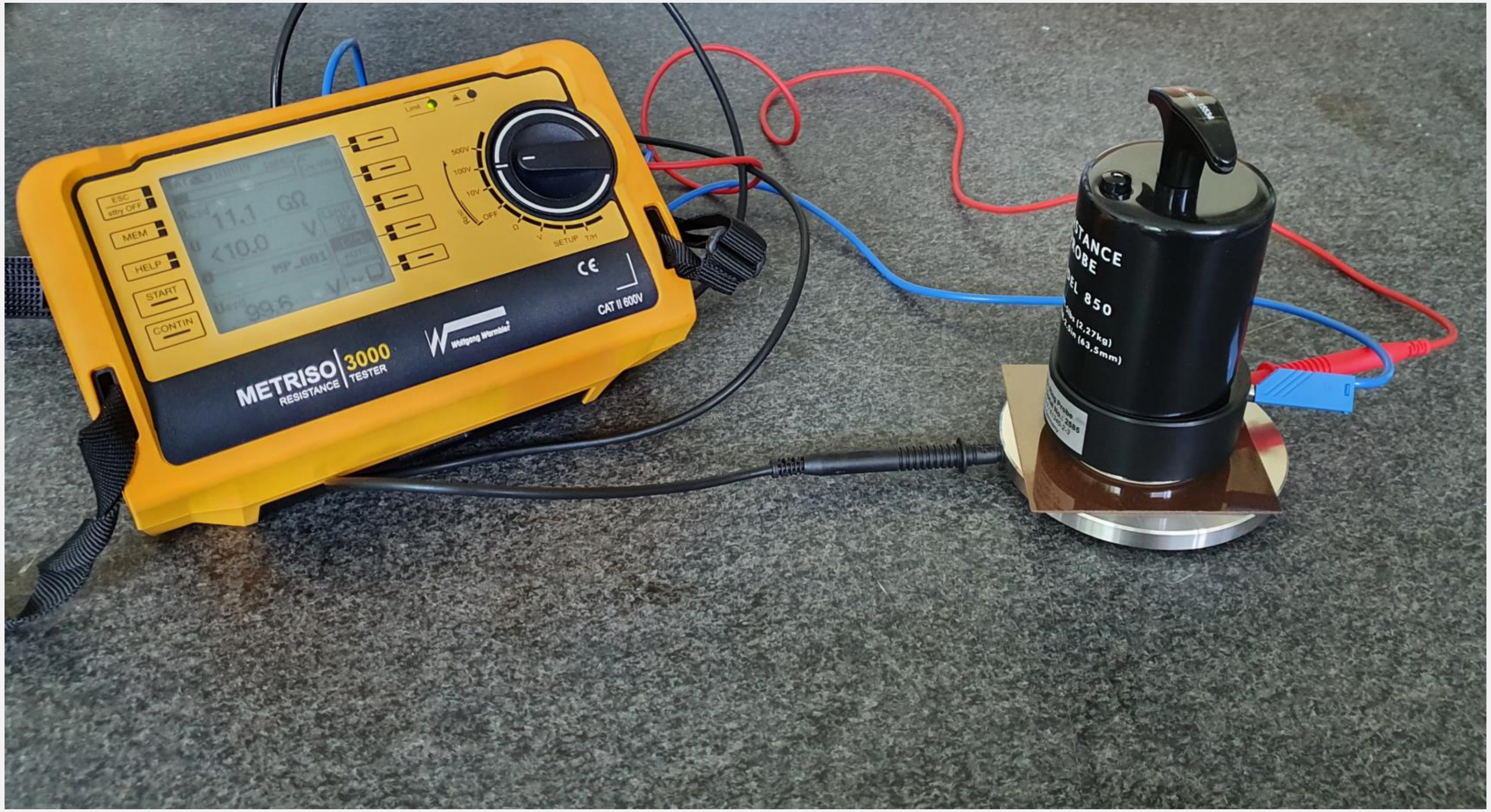


Reference 4

MOTIVATION

- Compare the volume resistance of different plate types
  - Important parameter for RPC plates
  - Lower costs, commercially available
- Build small RPCs
  - Discover the most efficient way of producing RPCs
  - Document the process for mass production in an external company
- Functional Test: U-I curve of RPCs
  - Test the plates under high voltages (6kV)
  - Test if the detector is working

MEASUREMENT OF THE VOLUME RESISTANCE OF THE PLATES



MEASUREMENT OF THE VOLUME RESISTANCE OF THE PLATES

- Clean the plate with isopropanol
- Keep the lower electrode moist with isopropanol
- Place the plate between the electrodes
- Place the weight on top (2,27kg)
- Measurement: High resistance measuring device (METRISO 3000)

MEASUREMENT OF THE VOLUME RESISTANCE OF THE PLATES

- Measurement according to the DIN IEC 93 standard
- Upper electrode: outer ring shields the surface current

$$R_V = \frac{A \cdot R}{d}$$

$$A = \frac{1}{4}\pi l^2$$

- Volume resistance R_V, thickness of the plate d, area A, diameter l (gap is half weighted)
- Six individual measurements per measuring point

MEASUREMENT OF THE VOLUME RESISTANCE OF THE PLATES

RIVA

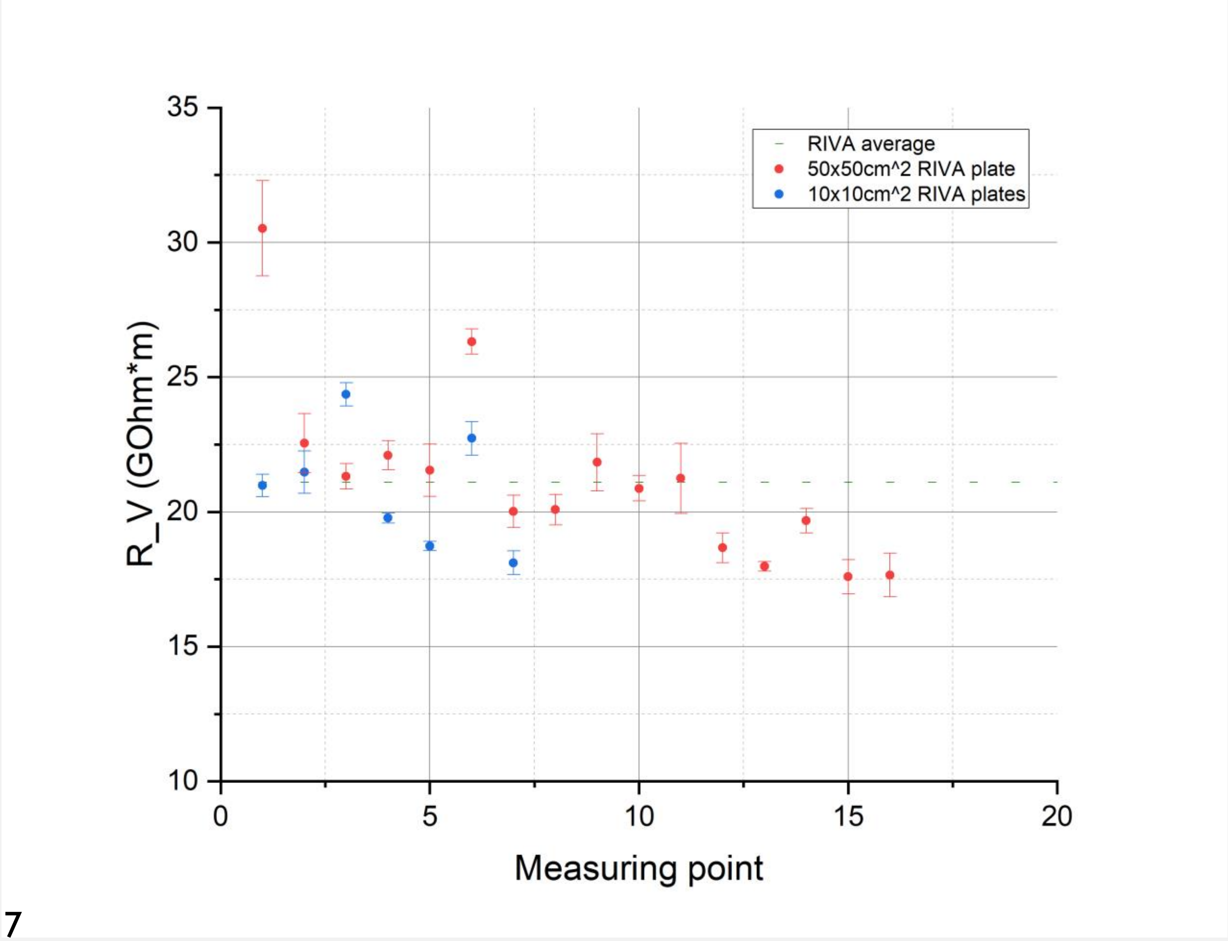
- Custom made: long delivery time
- Only company which produces plates with correct specifications for RPCs
- Material: laminate from phenolic resin and paper
- Layers get pressed at high temperatures

Pertinax (Dr Dietrich Müller GmbH)

- Commercially available
- Similar plates as RIVA (same materials)
- Volume resistance won't get controlled so precisely
- Much cheaper

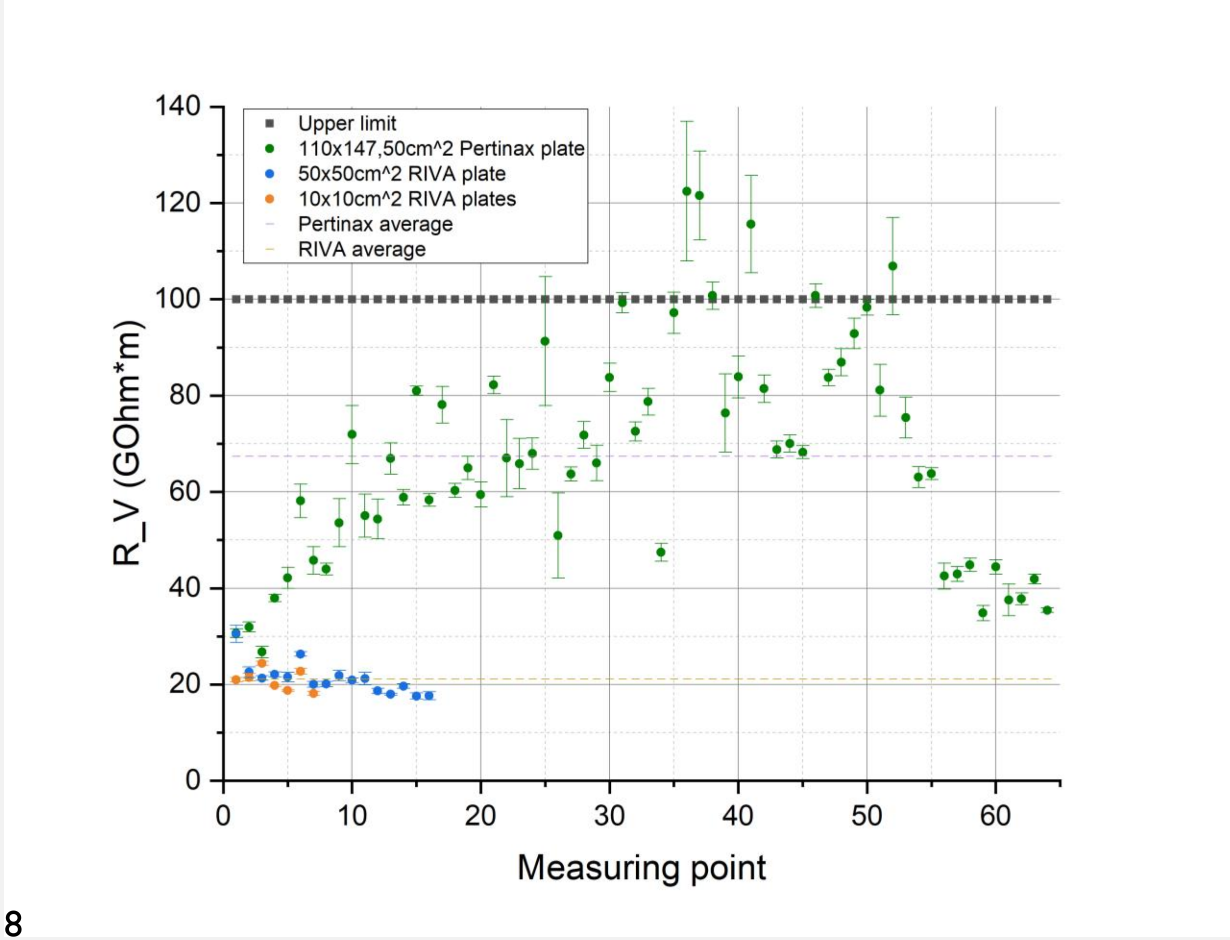
MEASUREMENT OF THE VOLUME RESISTANCE OF THE PLATES

- 10x10cm^2 RIVA plates
  - One measuring point in the middle each
  - 26,3°C, 24,7% humidity
- 50x50cm^2 RIVA plate
  - One measuring point every 10cm in a 4x4 grid
  - 26°C, 21,6% humidity



MEASUREMENT OF THE VOLUME RESISTANCE OF THE PLATES

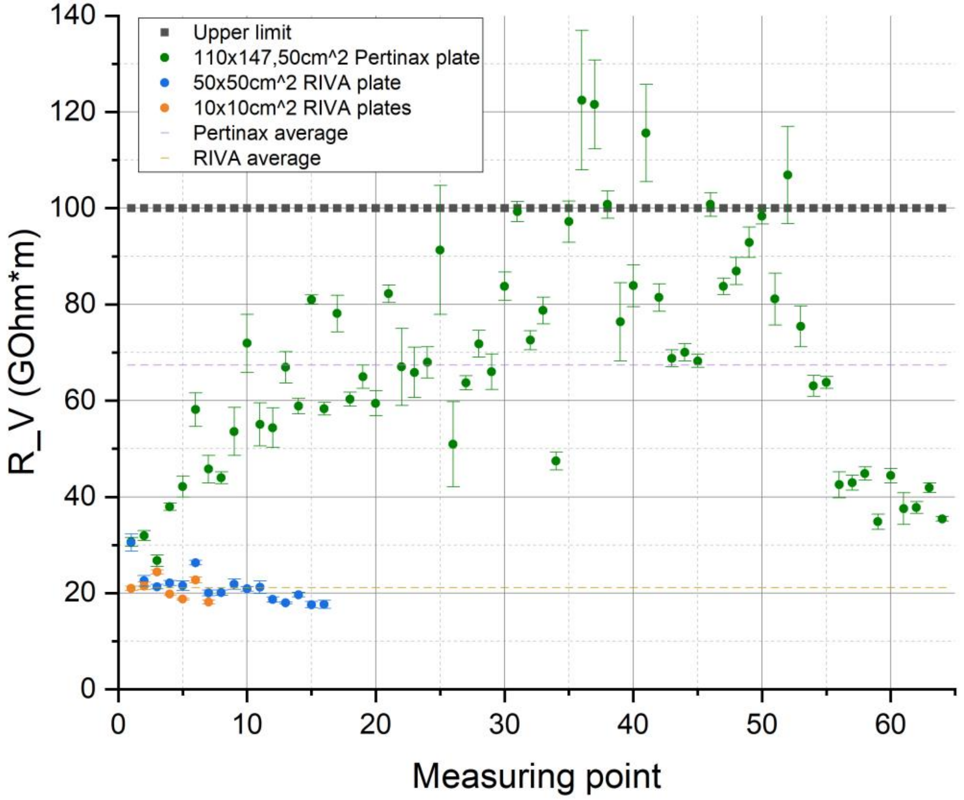
- 110x147.5cm^2 Pertinax plate
  - One measuring point every 8cm around the sides, 8cm from the edge
  - 23,9°C 23.5% humidity



MEASUREMENT OF THE VOLUME RESISTANCE OF THE PLATES

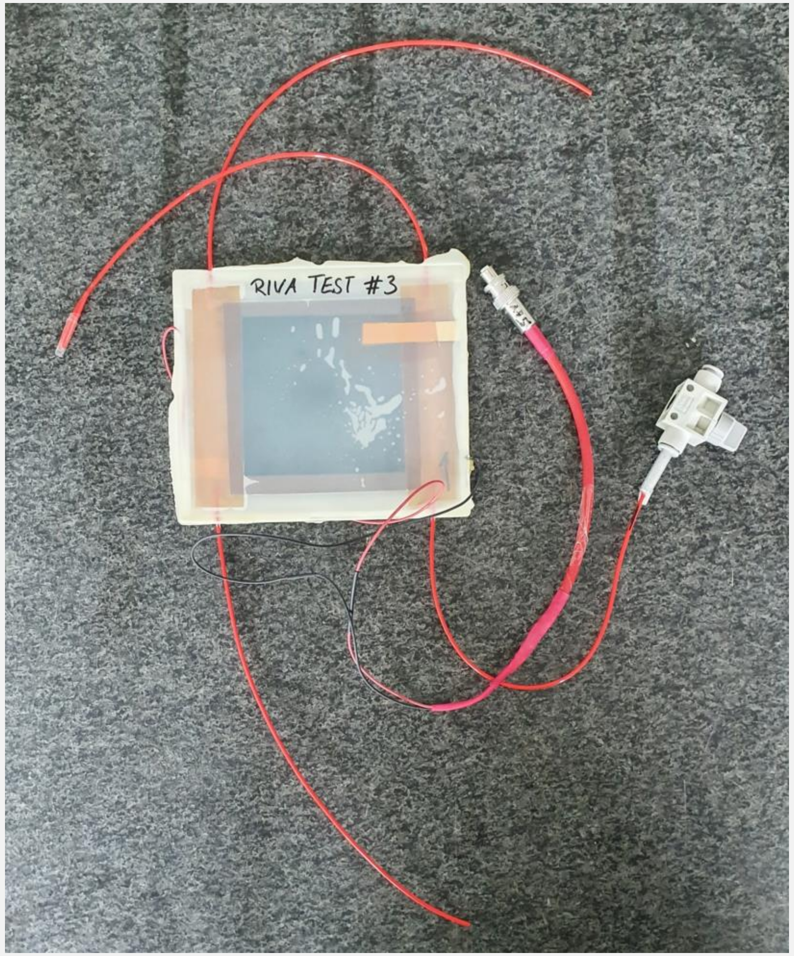
Results: Pertinax compared to RIVA plates

- Higher volume resistance (still correct magnitude)
- Larger variation of the volume resistance
- Bigger error (bending of the bigger plate: worse contact)



CONSTRUCTION OF PROTOTYPE RPCS

- Measurement of the volume resistance
- Graphite coating
- Bonding: Three stages
- Galloil coating
- Flushing and polymerisation



CONSTRUCTION OF PROTOTYPE RPCS

- Measurement of the volume resistance
  - As discussed in the last chapter
  - Two plates with similar volume resistance for each RPC
- Graphite coating
  - Edges were covered with removeable duct tape
  - Lacquer coating with Graphite 33 spray
  - It conducts the applied voltage and the output signal

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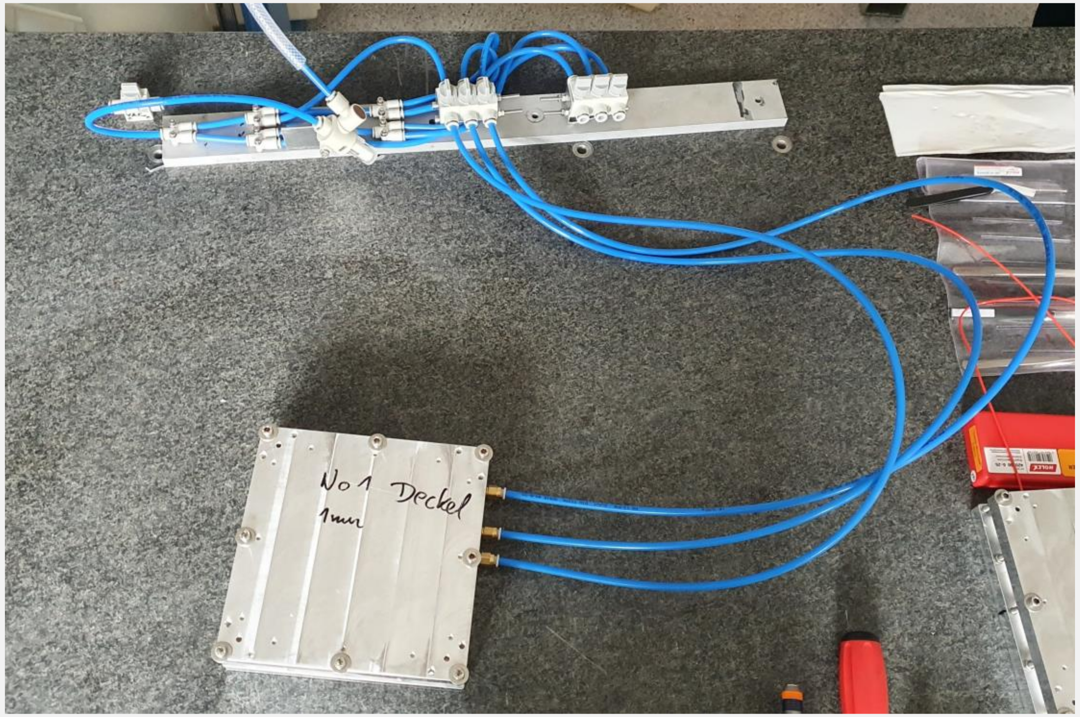
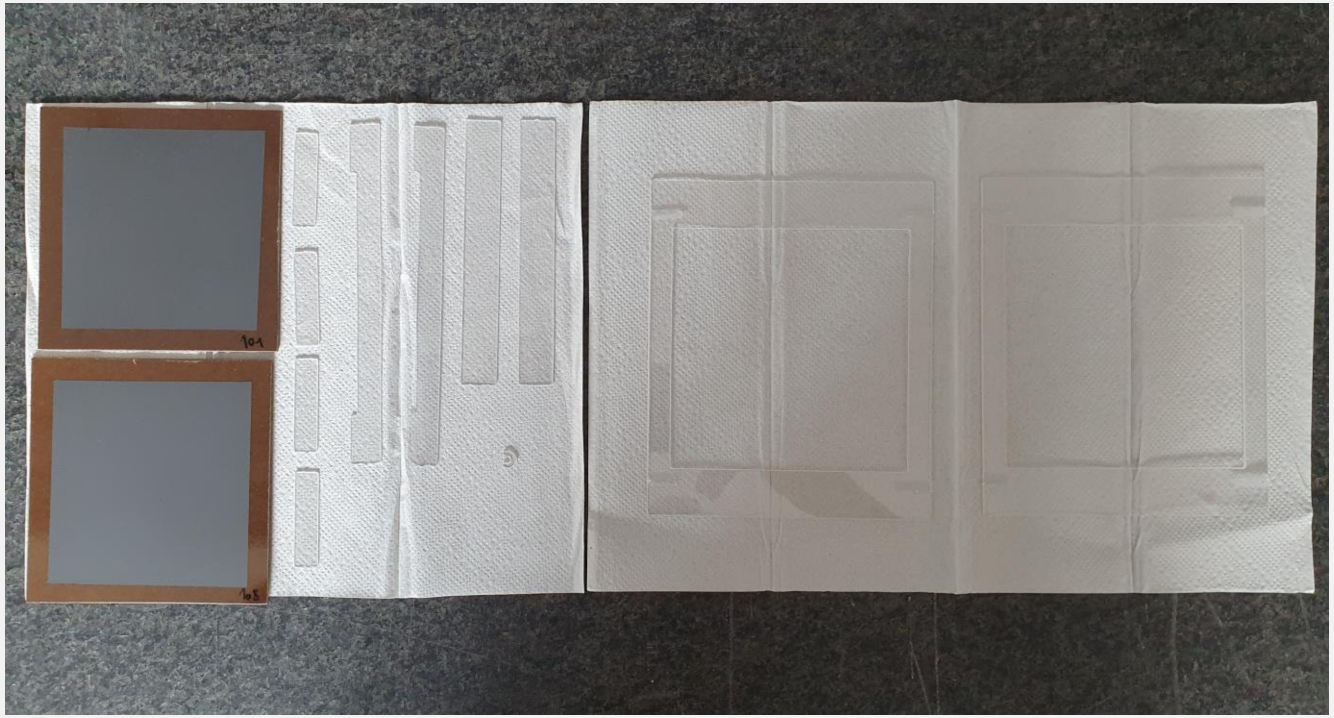
PROTOTYPE RPCS STAGE 1

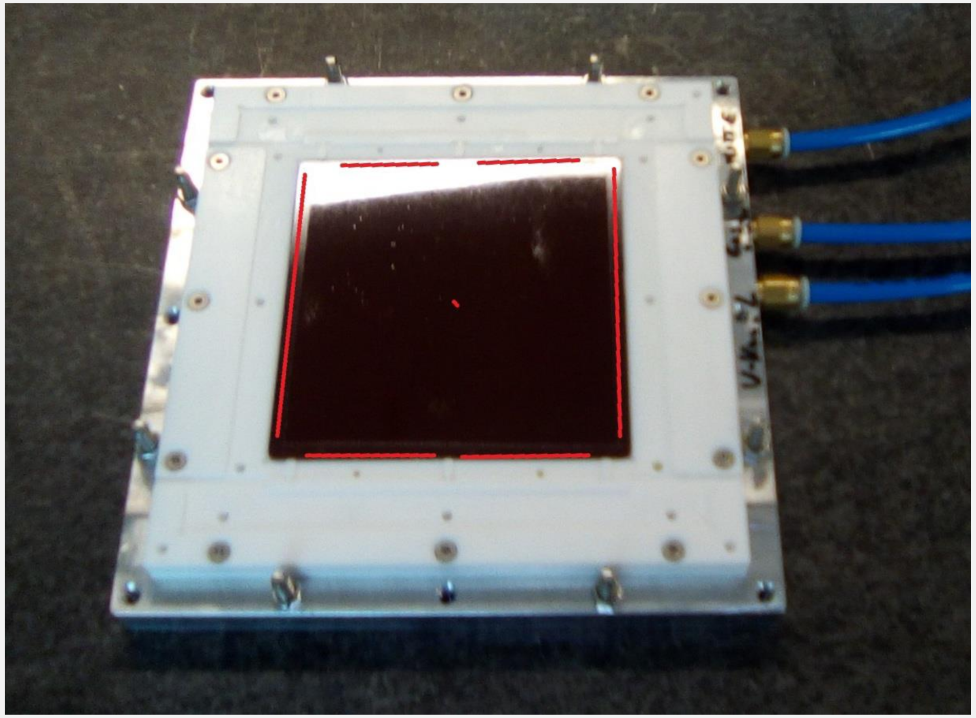


The first bonding stage connected to the vacuum pipe system.

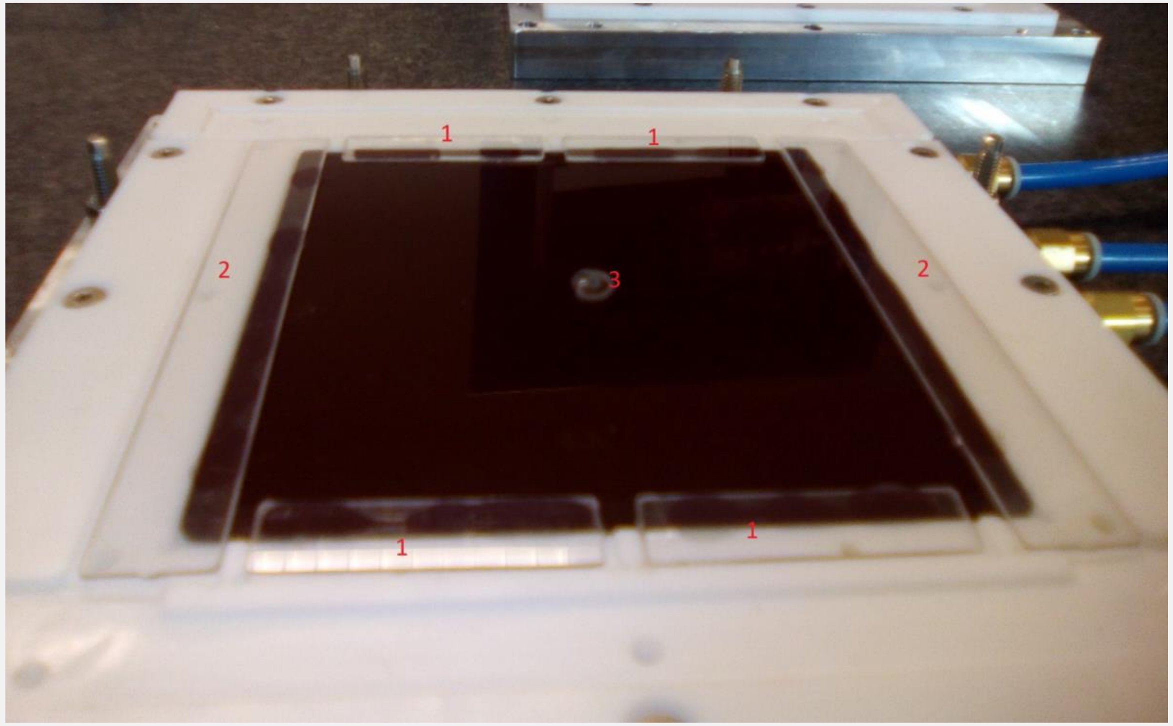


Plates and polycarbonate parts for the three bonding stages. From left to right: Graphite coated Pertinax plates, spacer and parts for the gas channels (nine), two outer frames.

PROTOTYPE RPCS STAGE 1



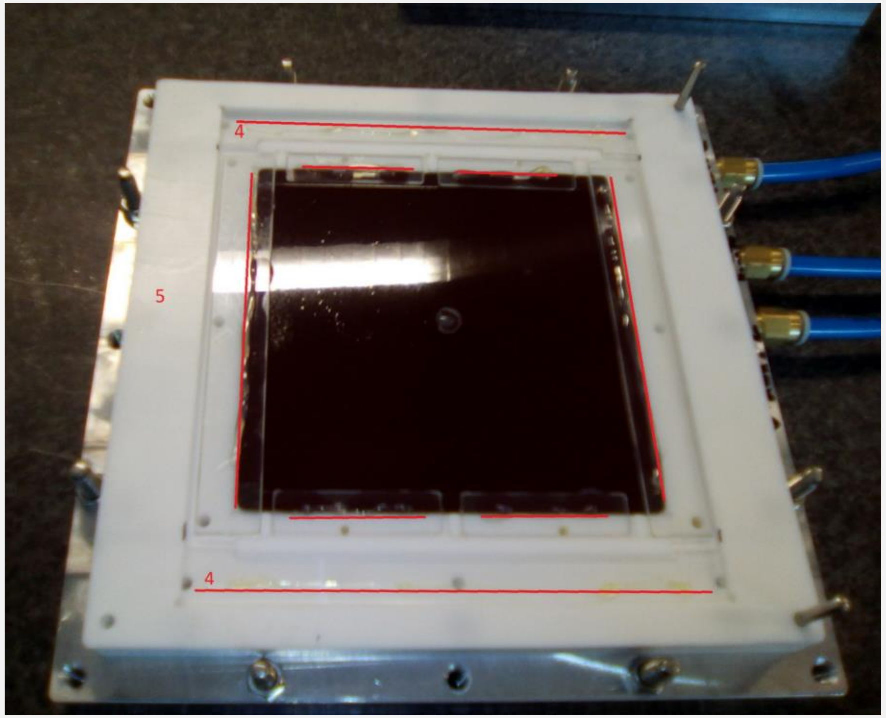
The first bonding stage. The red
lines mark the position of the glue traces.



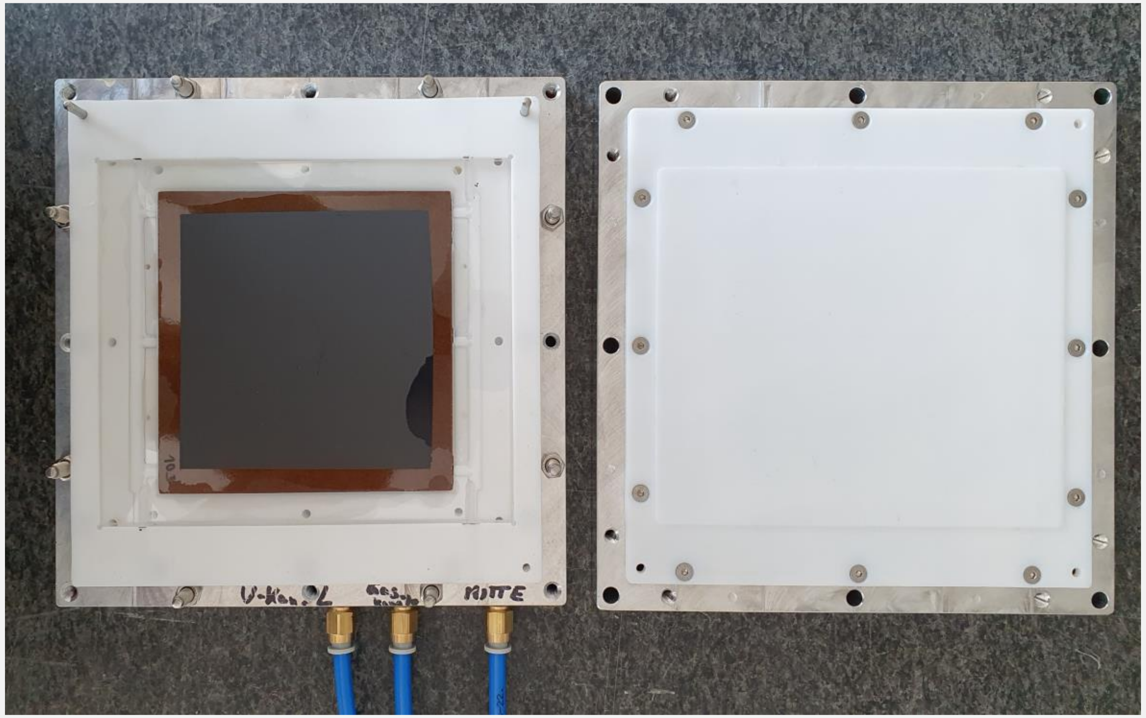
Four small spacers (1) leave space for six gas channels, two long spacers (2) seal the side and a c-shaped spacer (3) in the middle of the plate.

Reference 5

PROTOTYPE RPCS STAGE 1



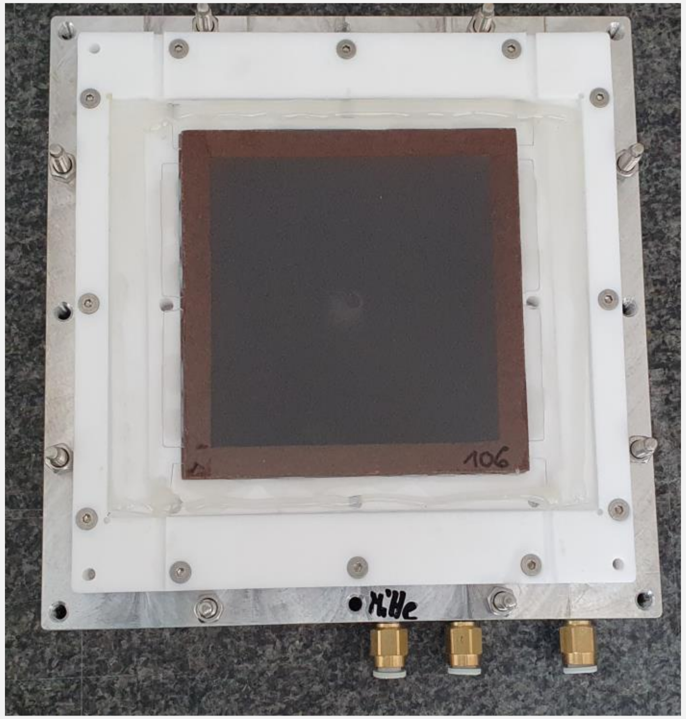
The first bonding stage. The red lines mark the position of the glue traces.



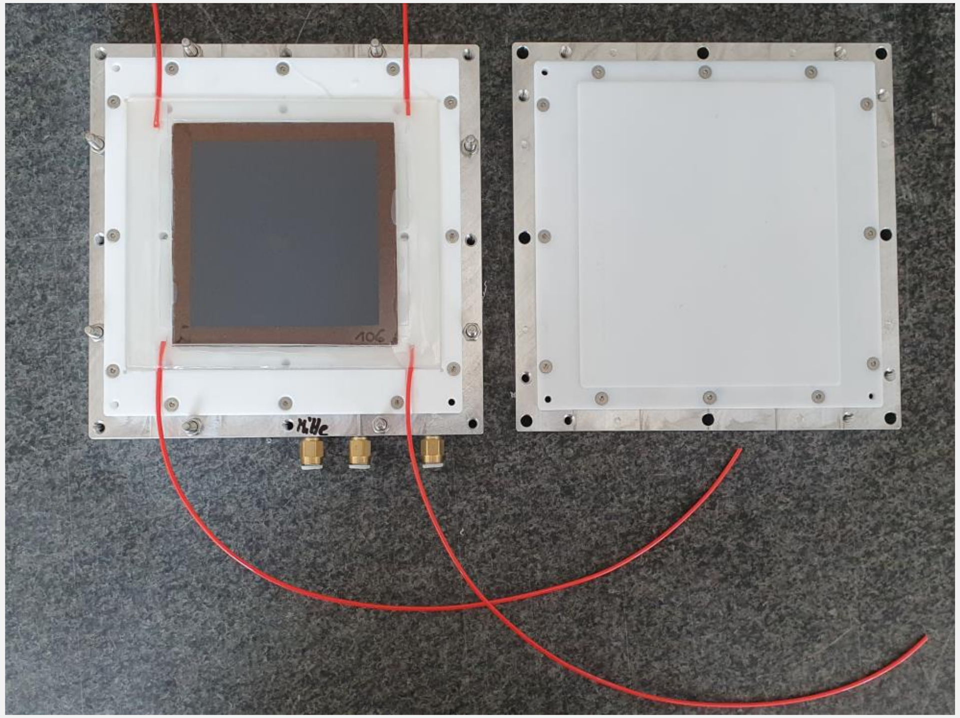
The first bonding stage with all parts in place.

Reference 5

PROTOTYPE RPCS STAGE 2

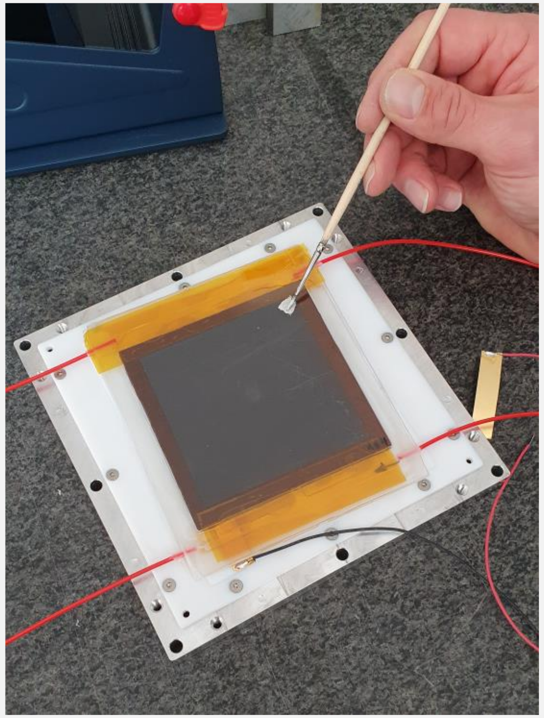


The second bonding stage prepared with the glue.

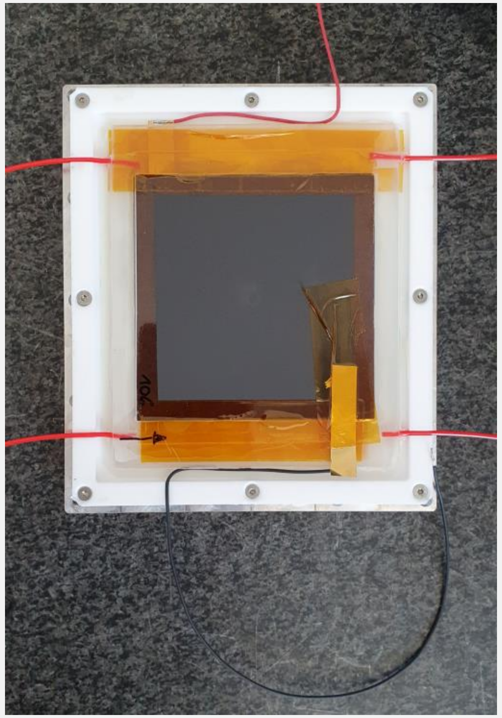


The second bonding stage with all parts in place.

PROTOTYPE RPCS STAGE 3

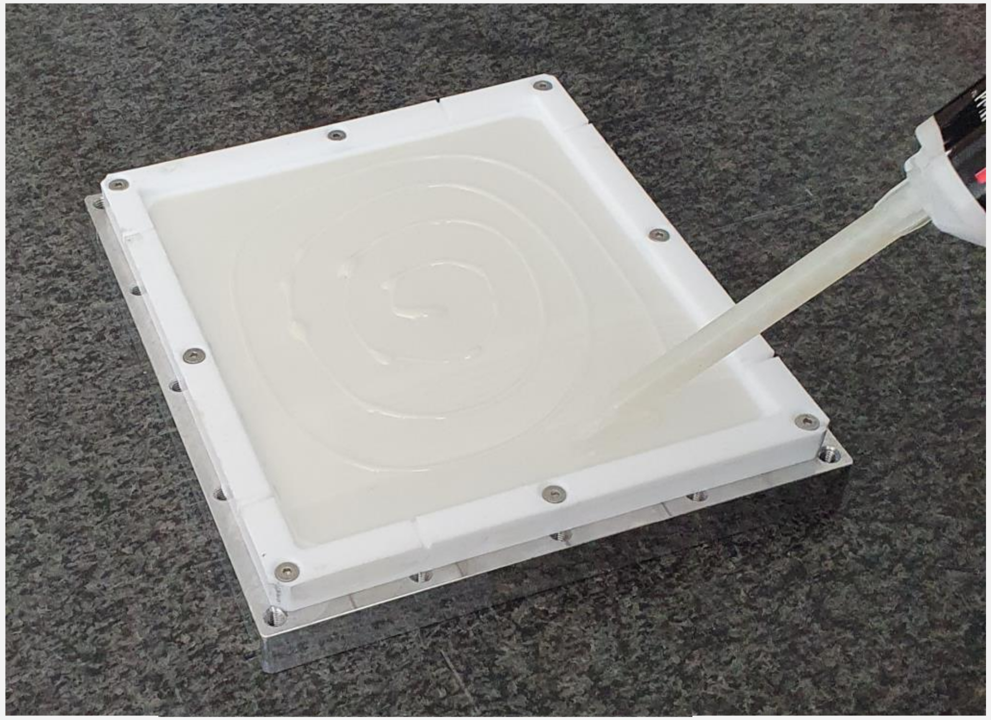


Application of the conductive silver adhesive to strengthen the contact of the electrode.

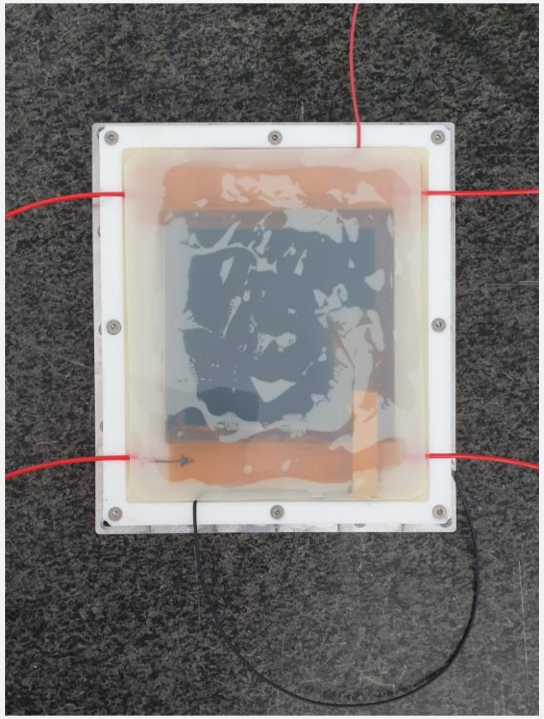


The electrodes fixed to the plates with Kapton tape

PROTOTYPE RPCS STAGE 3



The gluing of the lower mylar foil. The glue needs to get spread out evenly.



The third bonding stage before the the drying process.

PROTOTYPE RPCS: GALLOIL COATING

- Coating as last step to avoid pollution
- Detectors get filled with a mix of 30% Galloil and 70% Heptan
- Clamped between two metal blocks (protect the object from bursting by the hydrostatic pressure)
- The corner with the input tube is fixed on the lowest point to fill the volume evenly

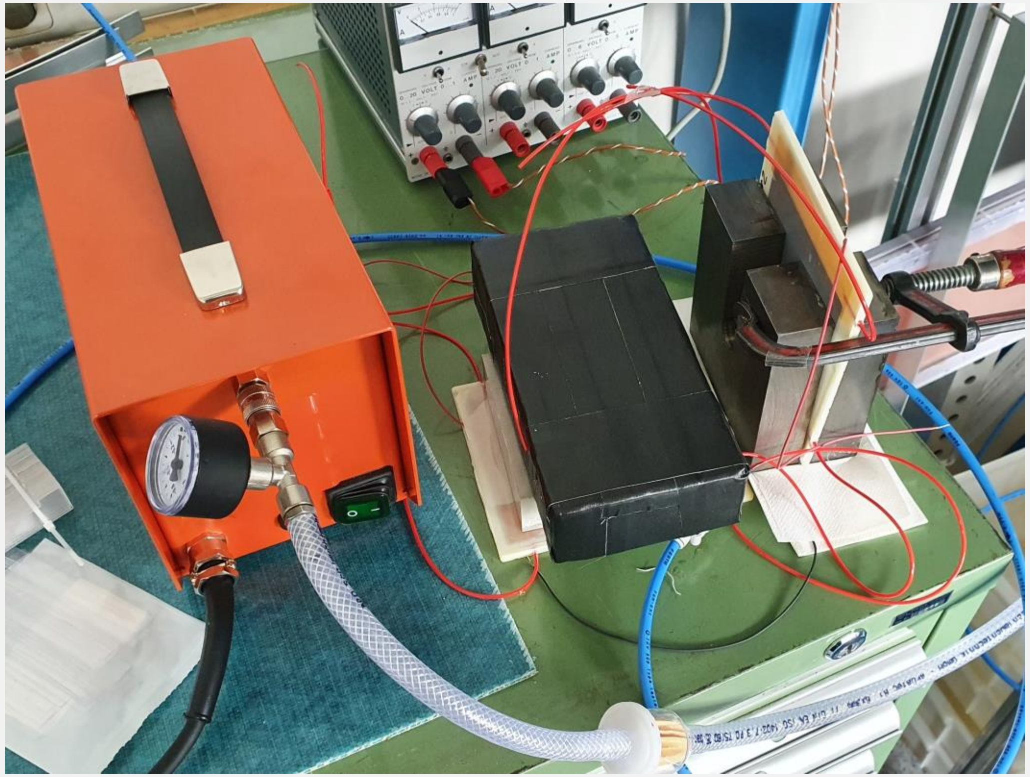
PROTOTYPE RPCS: GALLOIL COATING

- Two petrol filters, to clean the in-and out-coming liquid from contamination
- The Galloil tank hangs on an wire, which gets pulled up by a motor, so the height difference causes the pressure to fill the detector
- Reverse motor to remove excessive Galloil: maximum speed of about 0.5 m/h (avoid droplet formation)

PROTOTYPE RPCS

Flushing and Polymerisation

- Detectors were flushed with filtered air for about two weeks every 15 minutes
- Distribute fresh air into every part of the detector to enable the polymerisation of the Galloil



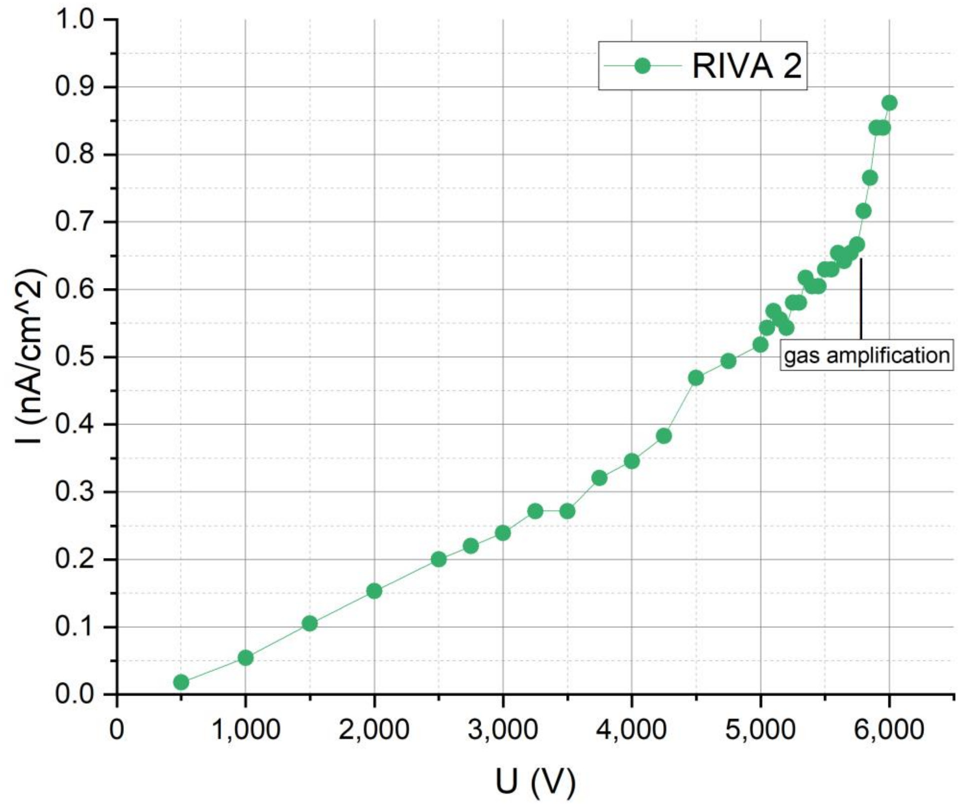
FUNCTIONAL TEST: UI-CURVE OF RPCS

- Detectors were flushed with argon for four hours: remove the air and moisture (speed 0.5l/h)
- Filled with a mix of butan, tetrafluoroethylene and sulfur hexafluoride (speed 0.5l/h)
- Current was applied with a high voltage device (EHS 8260p)

FUNCTIONAL TEST: UI-CURVE OF RPCS

RIVA Test 2

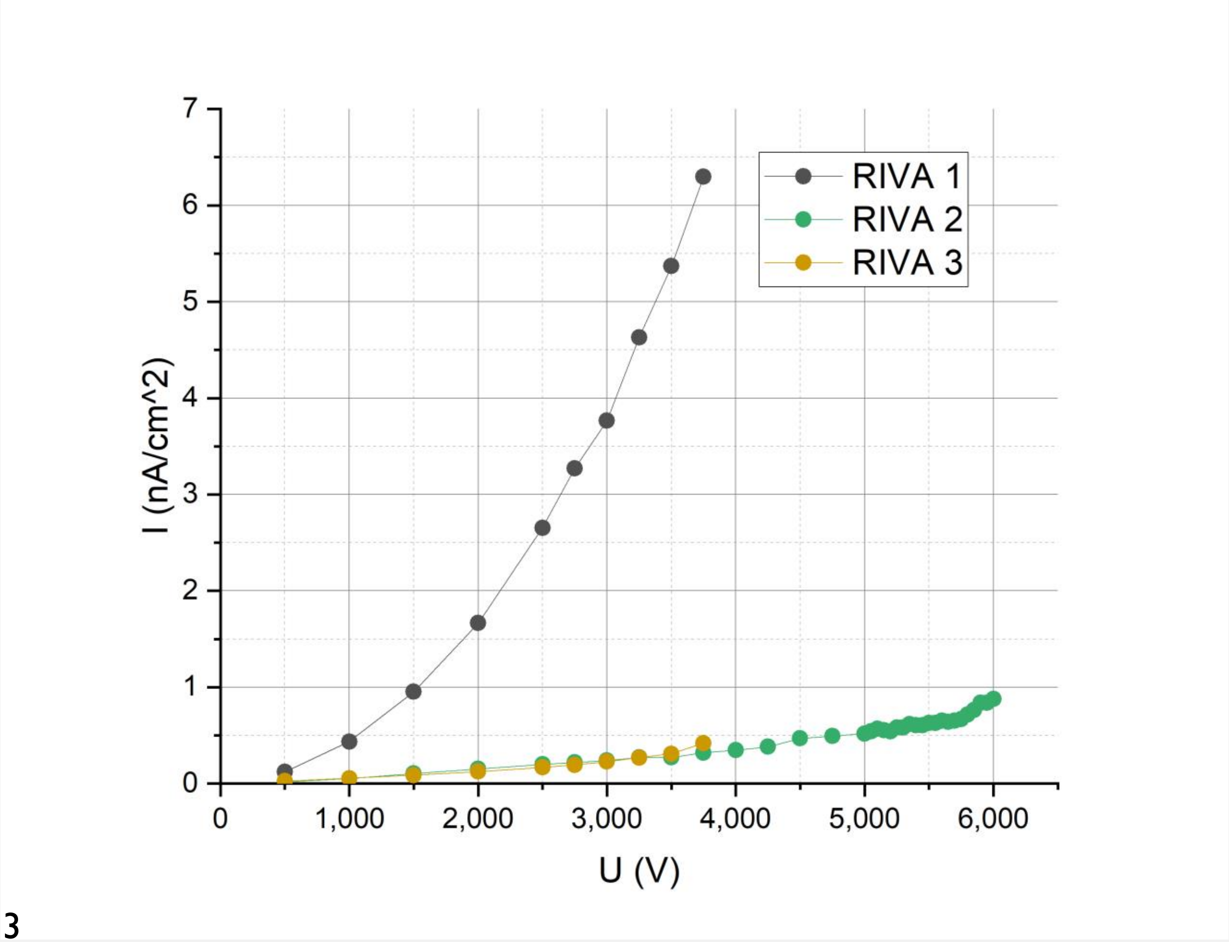
- Linear ohmic resistance
- Gas amplification starts at 5750V: exponential grow
- Repeated current drops (loose contact at the soldering?)



FUNCTIONAL TEST: UI-CURVE OF RPCS

RIVA Test 1

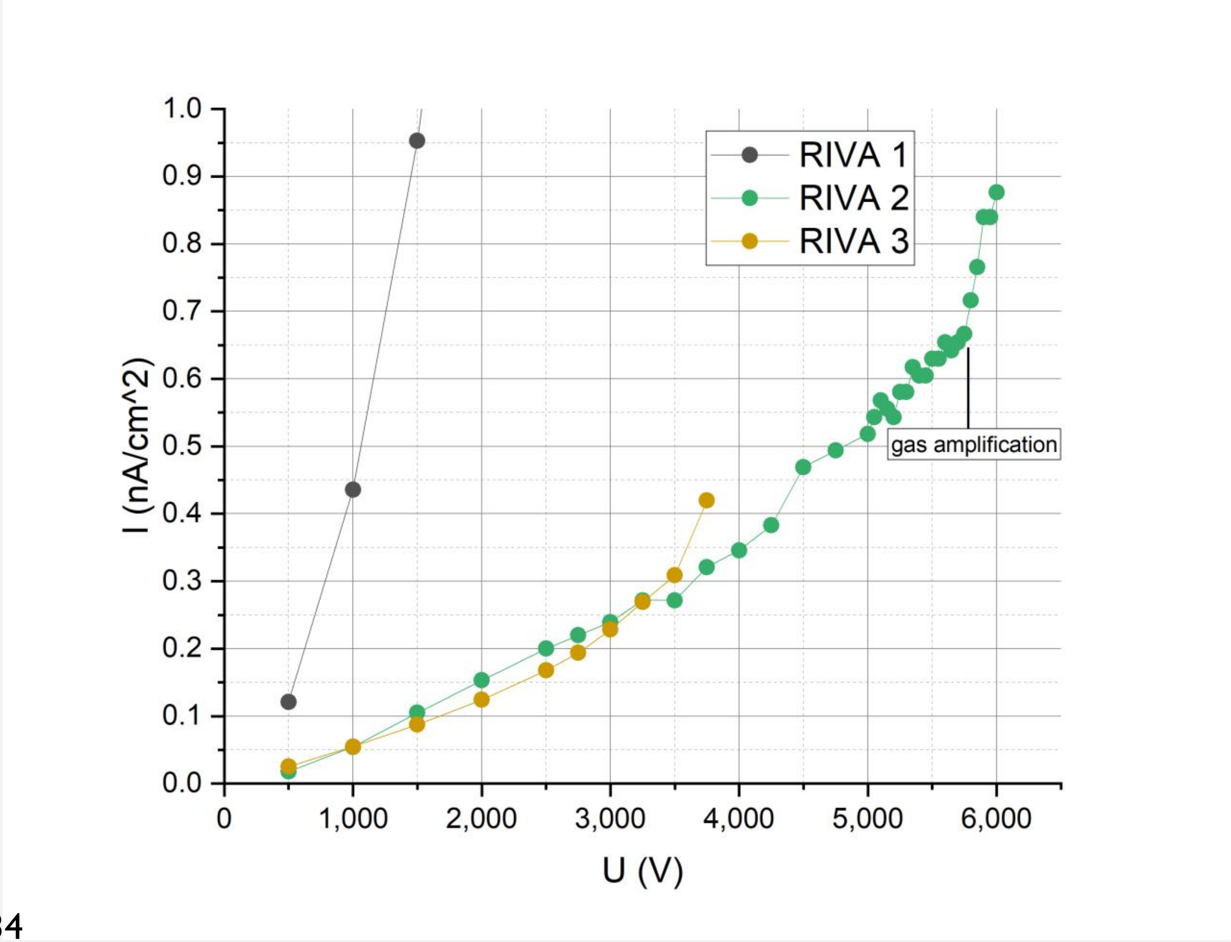
- Way too high current
- Acoustically audible flashover at 3750V
- Second flushing didn´t improve the measurement



FUNCTIONAL TEST: UI-CURVE OF RPCS

RIVA Test 3

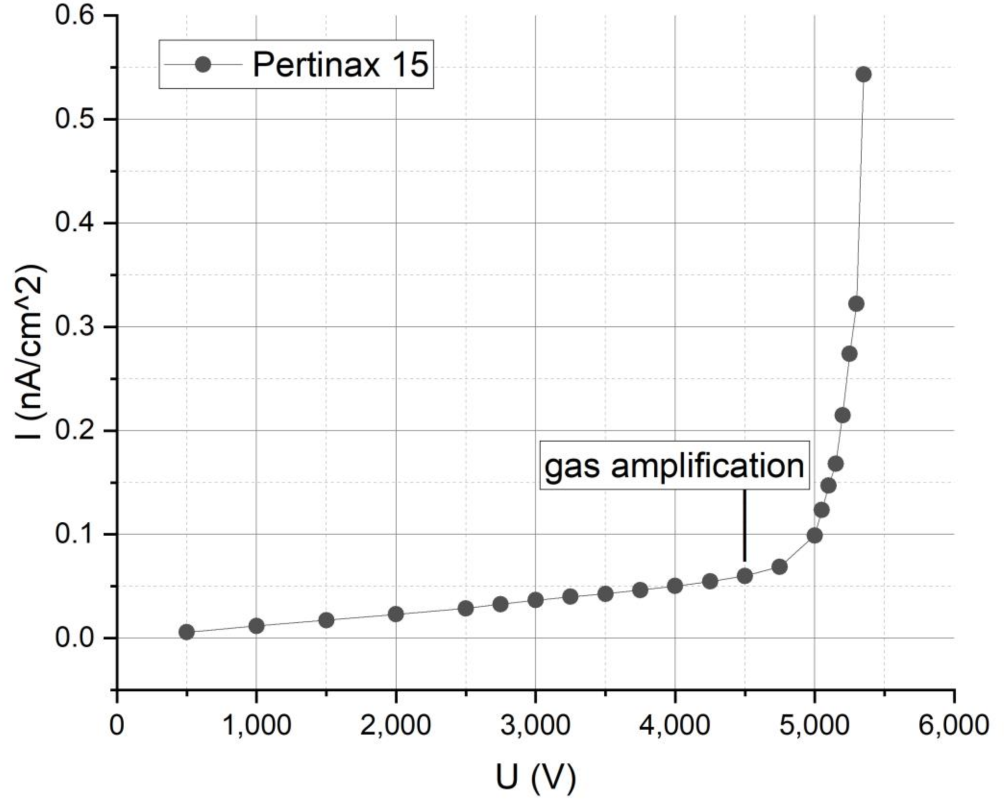
- Acoustically audible flashover at 4000V



FUNCTIONAL TEST: UI-CURVE OF RPCS

Pertinax Test 15

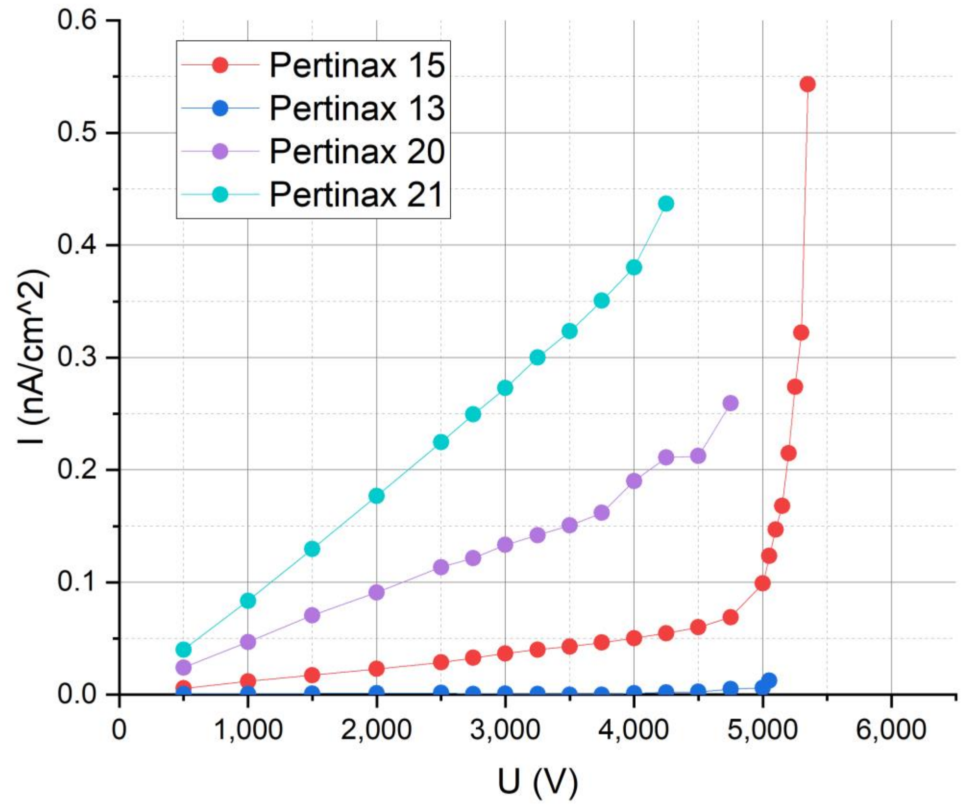
- Linear ohmic resistance up to 4500V
- Exponential grow: gas amplification
- One year old prototype
- But breaks later at 5350V



FUNCTIONAL TEST: UI-CURVE OF RPCS

Pertinax Test 13, 20, 21

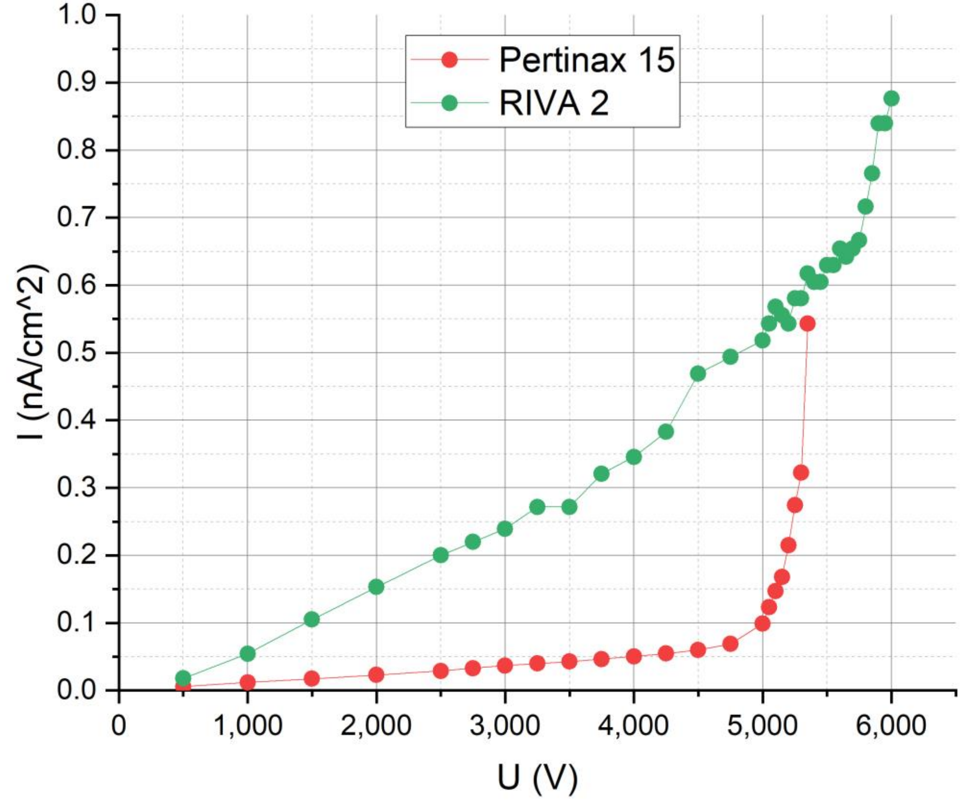
- Material of the plates gets damaged between 4300-5050V: current increases constantly at constant voltage
- After that: Same behavior at lower currents
- Breaking occurs before gas amplification
- Pertinax 13: 1 year old, extremely low current



FUNCTIONAL TEST: UI-CURVE OF RPCS

Results: Pertinax vs. RIVA plates

- Both plates show similar UI-curves
- Short circuits in the detectors need to be avoided (in both plate types)
- Pertinax curve is flatter in the linear region (higher R_V)
- The Pertinax plates break at about 4500V (possibly because of the surface texture)



SUMMARY AND FURTHER PLANS

- Commercially available Pertinax plates have a volume resistance in the correct magnitude
- In this composition the Pertinax plates break too fast for efficient use in the ATLAS detector
  - Other important parameters: e.g. surface texture
  - Sand down the surface
  - Ask the supplier for the details of the production process
  - Try other material/ company

SUMMARY AND FURTHER PLANS

- Understanding and documentation of the construction of RPCs
- Improve the structure of the prototypes: Open circuits need to be avoided in the further construction
- Test with copper plates
  - Measurement of the volume resistance of the Galloil coating
  - Detector prototype: Are resistive plates even needed?

THANK YOU FOR YOUR ATTENTION!

SPECIAL THANKS TO DR. OLIVER KORTNER AND DANIEL SOYK

Reference 1

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