Performance and aging studies for the ALICE muon RPCs

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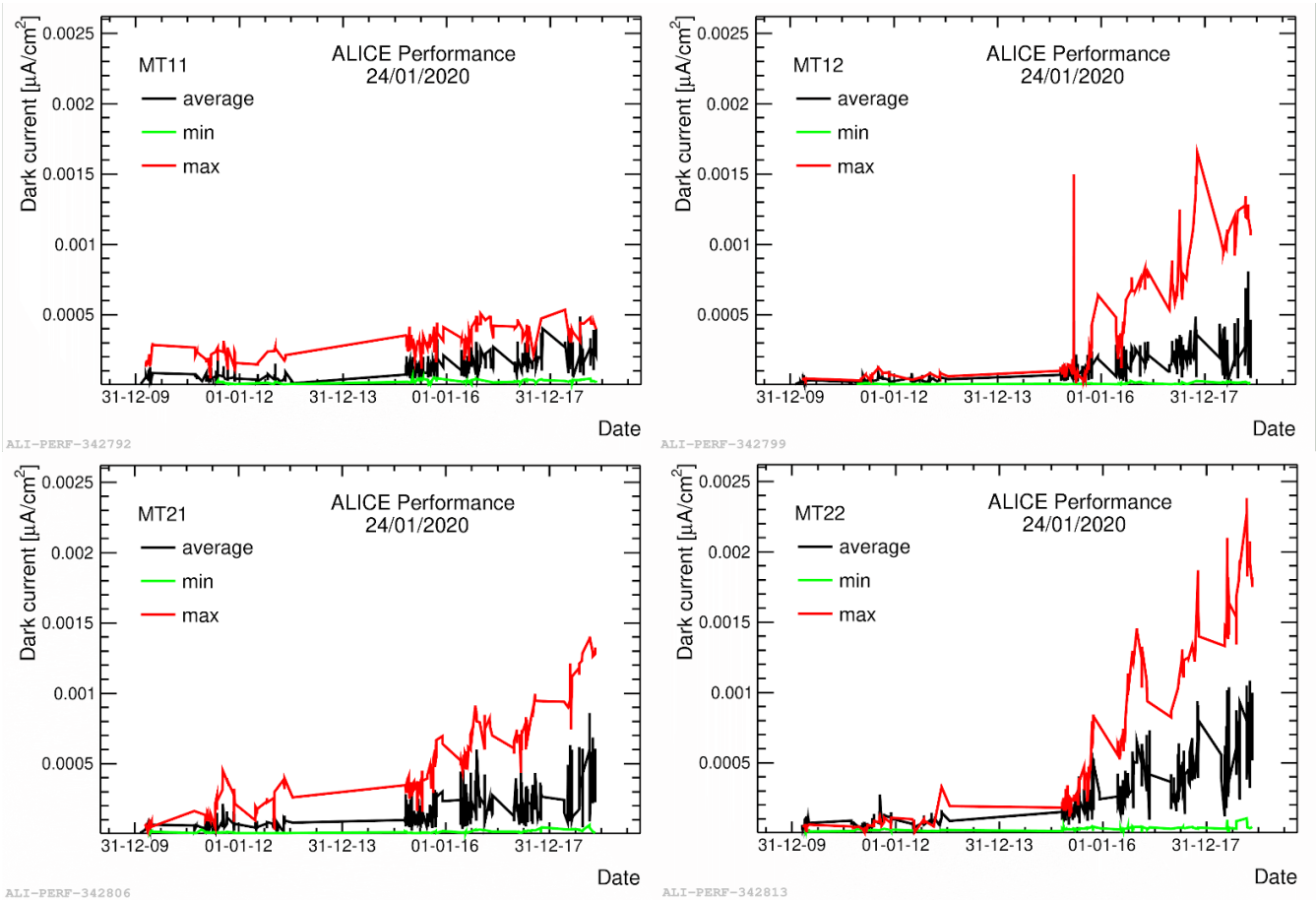
Outline

Motivation for the argon-plasma test

- An increase in the dark current absorbed by the ALICE muon RPC was observed during run 2
- No decrease in detection efficiency
  $\rightarrow$ No obvious aging effect is observed. Interesting to better understand the causes of the dark current increase
- Possible explanation: deposition of fluorinated compounds (e.g. HF) on the inner surfaces of the detectors
- Attempt to study this effect by creating an Ar plasma inside the detectors
  - Study of compounds produced by the interaction of the plasma with the inner surfaces of the detector using a Gas Chromatograph/Mass Spectrometer (GC/MS) and Ion Selective Electrode (ISE) by analyzing the exhaust gas
  - Effect on currents (?)

Status of the MID RPCs at the end of Run2 (1)

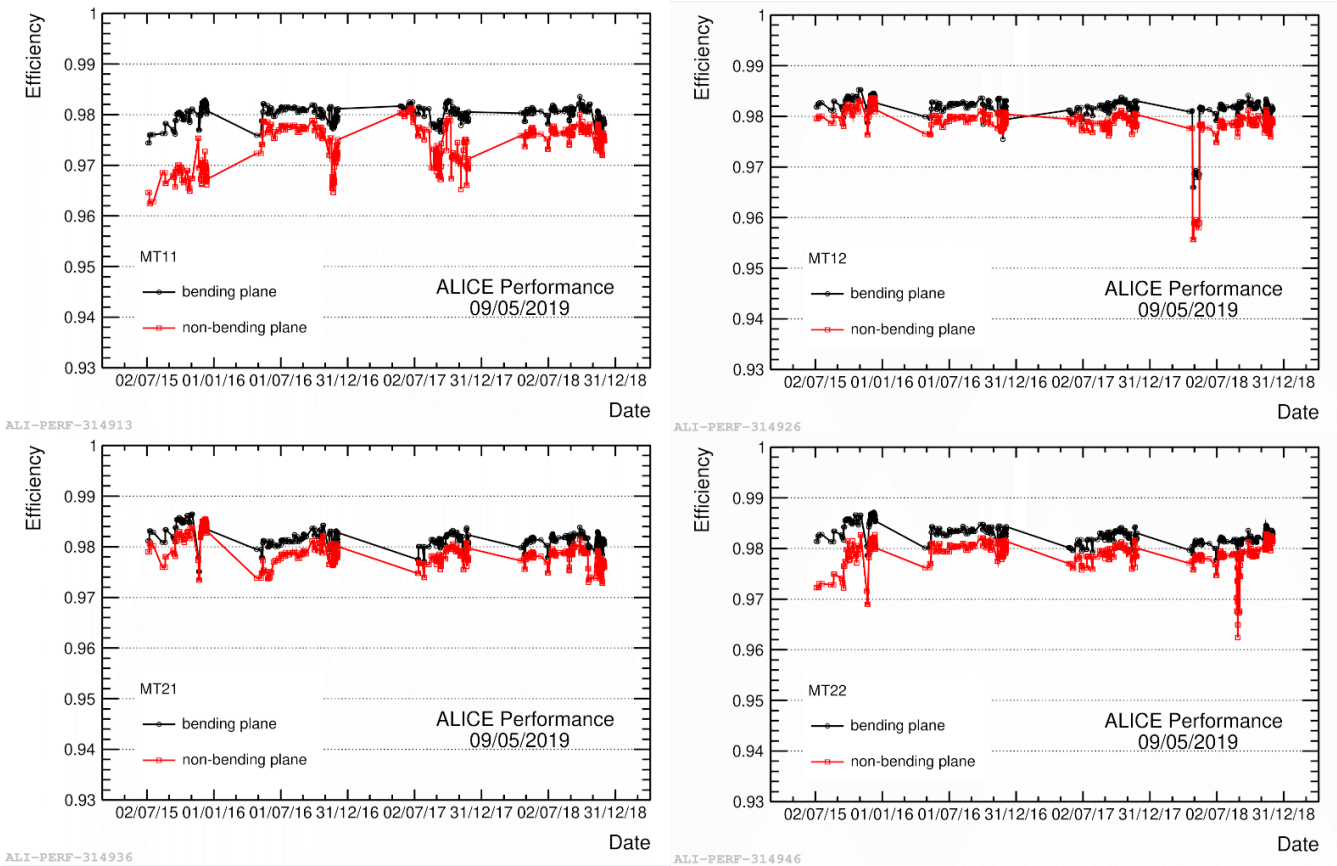
- Dark current measured when no collisions were present
- Average trend for all the 72 RPCs of the MID
- Increase in the absorbed dark current over time
- Not accompanied by a loss of efficiency → interesting to investigate



Average dark current trend for each MID plane

Status of the MID RPCs at the end of Run2 (2)

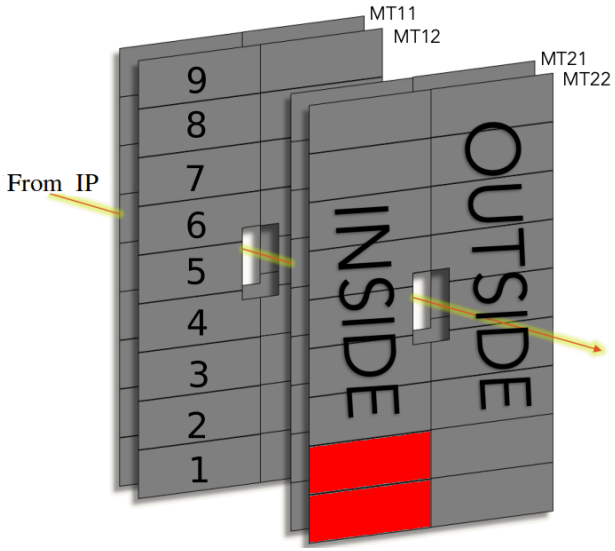
- Average trend of the efficiency measured with the beam
- Constant over time



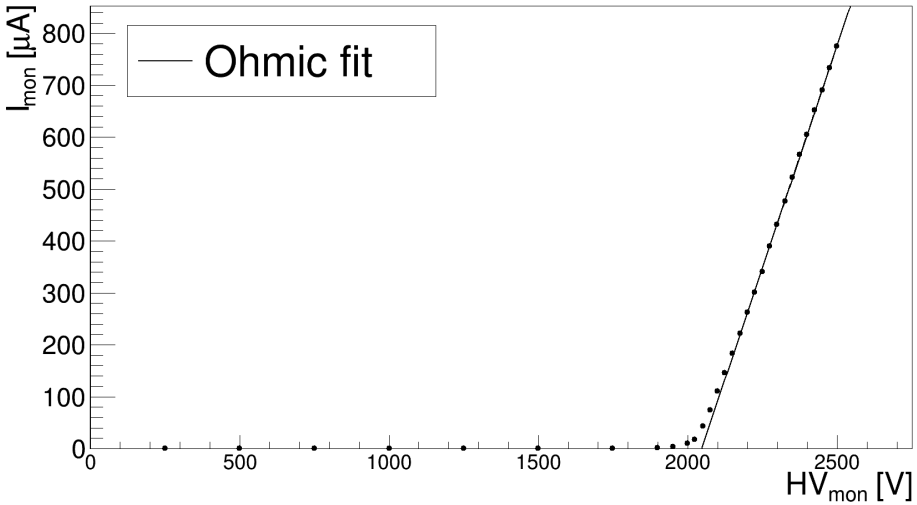
Average efficiency for each MID plane

Experimental technique

- Two chambers were selected for the Ar plasma treatment: MT 22 IN 1 and MT 22 IN 2
- The plasma was created and maintained at different currents
- GC/MS analyses performed to study the presence (and concentration) of new compounds, ISE to measure the F^- ion production
- Periodic resistivity measurements

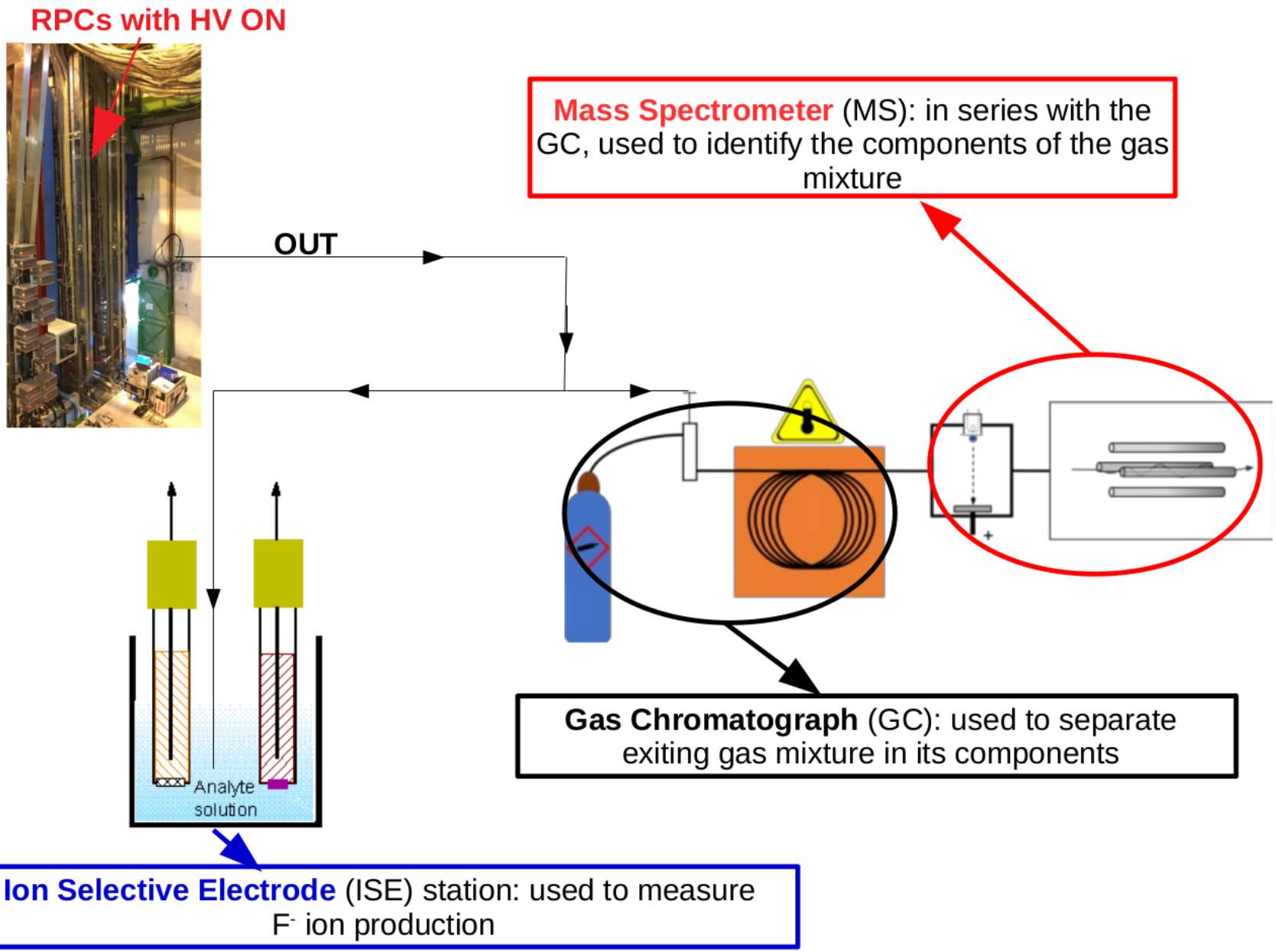


- ☐ At $\sim$ 2000 V Ar ionization begins
- ☐ When it is fully ionized
  $\rightarrow$ Plasma is created
  $\rightarrow$ I(HV) curve follows Ohm's law



I(V) curve for an RPC flushed with pure Ar

Experimental setup



Scheme of the experimental apparatus employed during the Ar plasma tests

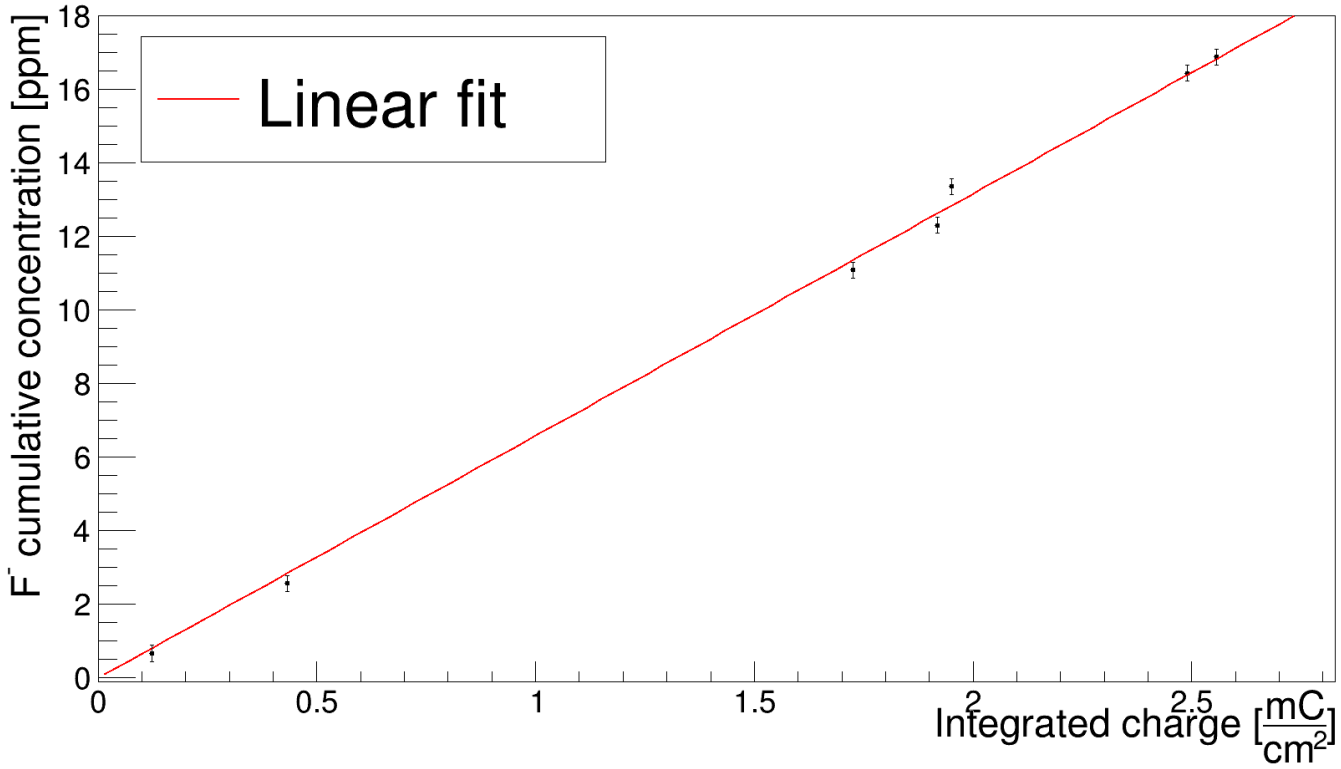
F^- ion production

- Free charges and photons formed by ion-electron recombinations in the plasma might be sufficiently energetic to detach the fluorinated compounds that have deposited during operation
- An ISE is used to identify the presence of F^- ions in the exiting gas mixture
- It provides a voltage value (mV) converted to concentration (ppm) via a calibration curve
- Integrated measurements were performed
  $\rightarrow$ Gas is bubbled through 33 ml of distilled water and the pH of the solution is buffered with the $TISAB^1$ II solution
  $\rightarrow$ The concentration of accumulated F^- ions is measured after a few hours of integration
- **No compound containing fluorine is present at the input $\rightarrow$ Whatever F^- is measured is coming from inside the detector**

[1] TISAB = Total Ionic Strength Adjustment Buffer, used to improve the F^- ions concentration measurements

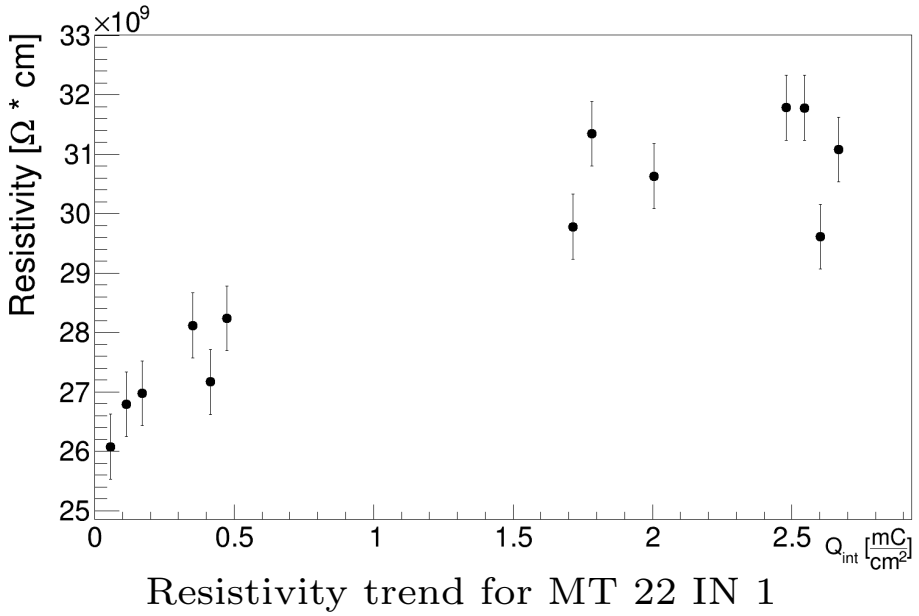
Correlation between cumulative F^- ion production and integrated charge

- Visible correlation between accumulated F^- ions and integrated charge

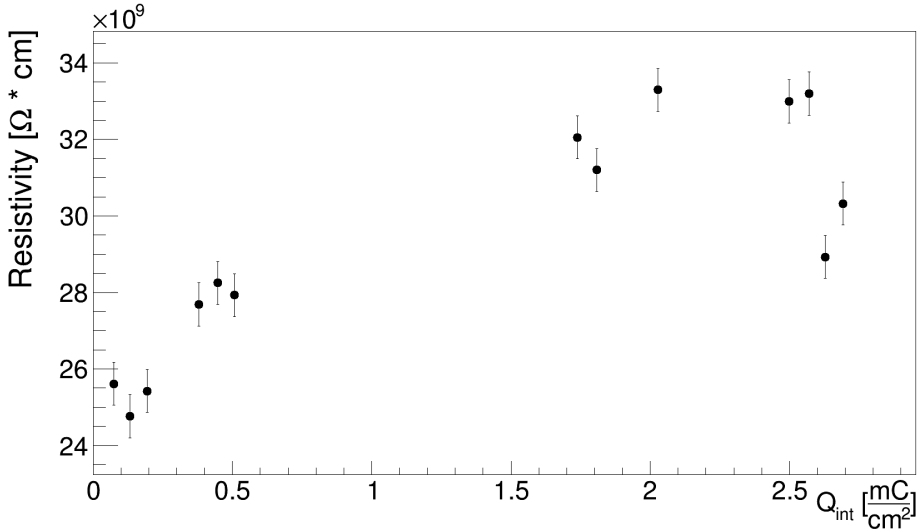


- F^- ions might be produced by the "cleaning" action of the Ar plasma
- Accumulation rate does not seem to slow down up to $\sim 2.5\ \frac{mC}{cm^2}$ of integrated charge
  $\rightarrow$ Possible presence of residual fluorinated impurities inside the chambers (?)

Bulk resistivity trend



Resistivity trend for MT 22 IN 1

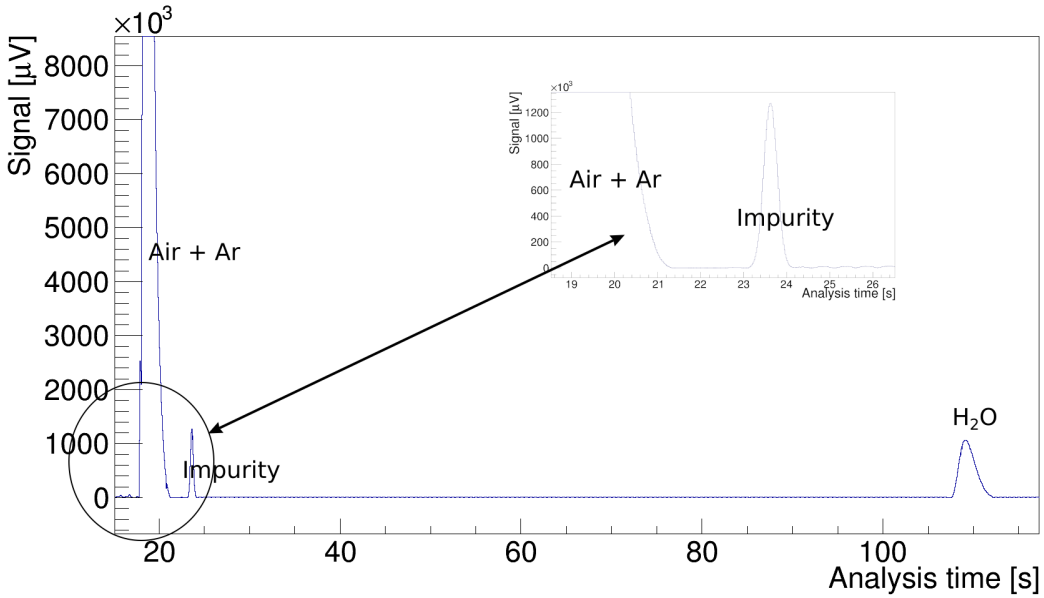


Resistivity trend for MT 22 IN 2

- Bulk resistivity is measured throughout the cleaning process and trend is plotted as a function of the integrated charge during the test
- Bulk resistivity increases as the integrated charge increases → Probably due to a drying effect of the plasma on the bakelite

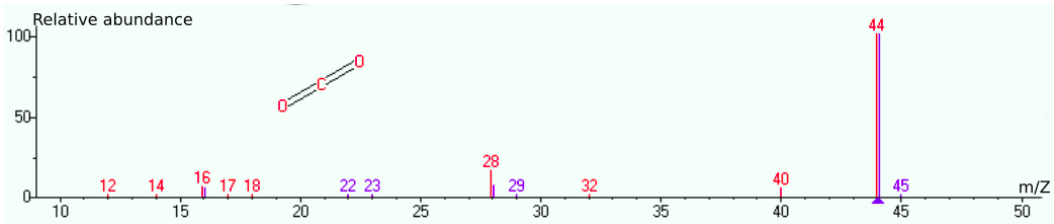
CO_2 production

- GC/MS analyses showed the presence of an impurity when the plasma is created (HV ON)



Chromatogram taken during Ar plasma tests

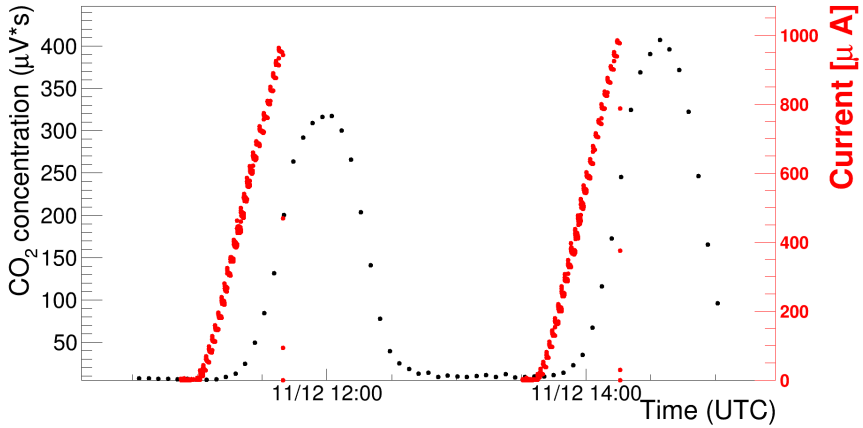
- Impurity identified as CO_2 thanks to the mass spectrometer (MS)



Identification of impurity as CO_2

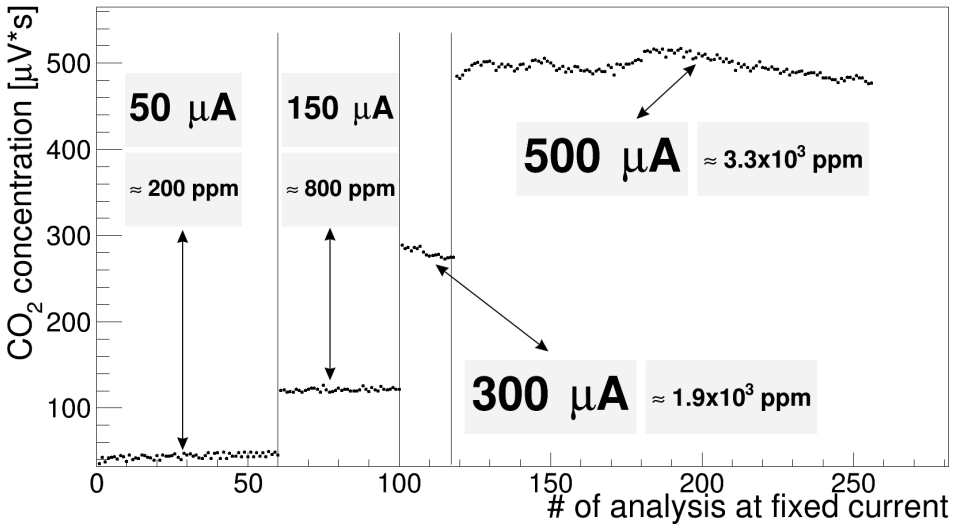
Correlation between applied current and CO_2

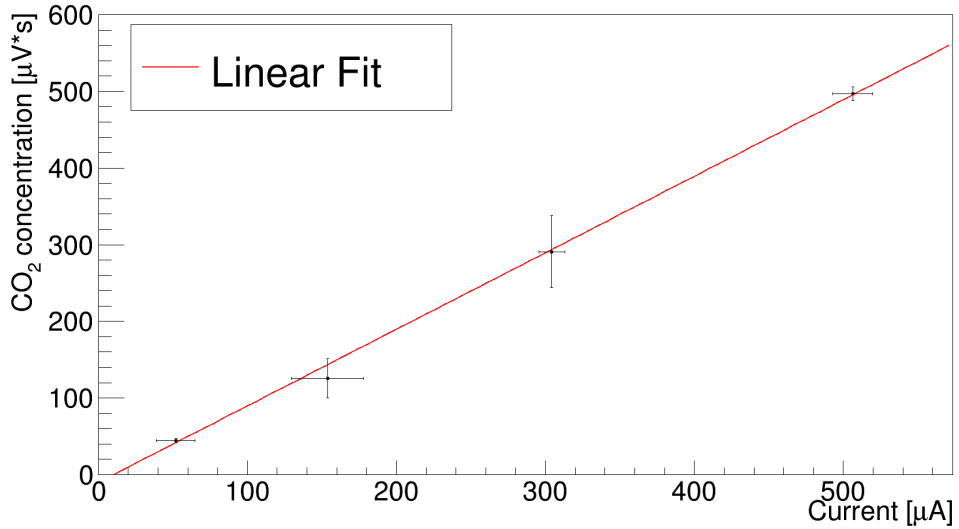
- If the current is increased → the CO_2 concentration increases
- Time lag between current increase and CO_2 observation ∼ 30 min



Time lag observed during two resistivity scans

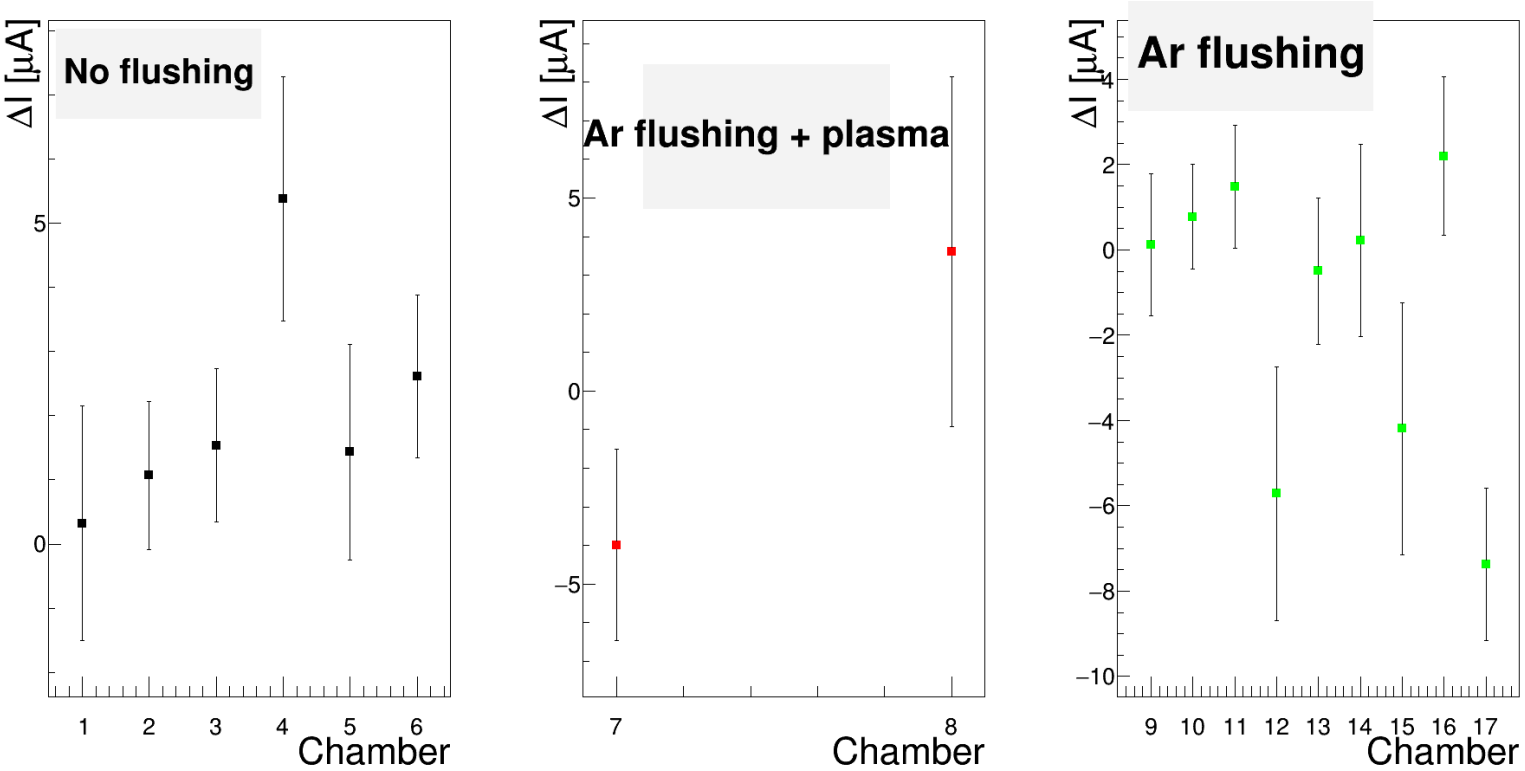
- A strong correlation between the applied current and the CO_2 concentration (given by the area under the peak in the chromatogram, measured in μV*s) is observed





Dark current comparison

- Some RPCs were flushed with Ar but the HV was kept OFF (no plasma was created) and some were kept as a reference (not flushed with argon at all)
- Plot of the quantity ΔI = current after the test - current before the test, with the ALICE standard gas mixture for all the chambers flushed with Ar



- No significant effect on the absorbed current is observed, either in the chambers treated with Ar plasma or the ones left untouched

Outline

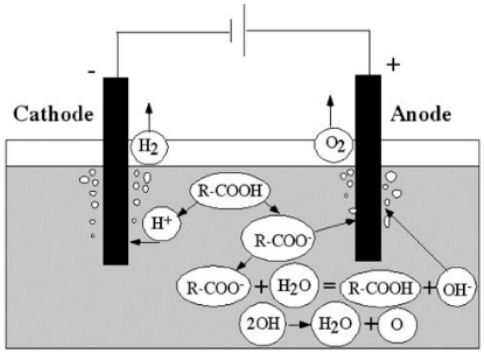
Conclusions

- The ALICE muon RPCs have shown satisfactory results during run 2:
- Efficiency was stable over time and was typically $> 96\%$
- Some of the chambers have collected a significant amount of charge wrt to the certified lifetime and may have to be replaced[2] before run 3
- An increase in the absorbed dark current was observed
- An Ar plasma test was carried out on the ALICE muon RPCs in order to gain more insights into such an increase:
  1. The production of F^- ions was observed in the exiting gas mixture
  2. An increase in the bulk resistivity was observed during these tests
  3. The production of CO_2 correlated with the circulating current was observed
  4. No significant effect on the dark current at the working point is observed
- Investigation ongoing to find possible explanations for the observed effects

[2] See Livia Terlizzi's talk today @ 14:20

Possible explanation for the CO_2 production (1)

- Va'vra proposed a conduction model in linseed oil[3] based on ionic current



Conduction in linseed oil

- Linseed oil is a very complicated substance, composed of various fatty acids
- When polymerized, the fatty acids can be described as R-COOH where R is a complicated carbon-based chain and "-COOH" is a carboxyl group

- The mechanism works as follows: R-COOH molecules break into $R\text{-}COO^-$ and H^+:

$$R\text{-}COOH + \Delta V \longrightarrow R\text{-}COO^- + H^+$$

- The $R\text{-}COO^-$ might react with water to recreate R-COOH and OH^-:

$$R\text{-}COO^- + H_2O \longrightarrow R\text{-}COOH + OH^-$$

- R-COOH returns the fatty acid and OH^- delivers the charge to the anode and H^+ delivers the charge to the cathode, forming H_2 and escaping near the cathode

$$2OH \longrightarrow H_2O + 2O$$

- Lastly, $2O \rightarrow O_2$ and it delivers oxygen near the anode

[3] J. Va'vra, "Physics and chemistry of aging–early developments" in Nuclear Instruments and Methods in Physics Research A 515 (2003) 1–14

Possible explanation for the CO_2 production (2)

- The key element in the previous reaction is water
- The conduction of current "consumes" the water in the linseed oil
  $\rightarrow$ This could explain the observed resistivity increase
- Note that, due to the high circulating current, many R-COO^- molecules are formed. In this situation, the Kolbe electrolysis[4] could also be taking place:

$$2RCOO^- \xrightarrow[-2CO_2]{-2e^-} R\text{-}R$$

- Va'vra observed the presence of gas bubbles in his tests
  $\rightarrow$ Might be oxygen and hydrogen
- If this model was correct, it could explain both the resistivity increase and the CO_2 production

[4] https://www.organic-chemistry.org/namedreactions/kolbe-electrolysis.shtm