Irradiation and longevity test of Resistive Micromegas detectors

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Introduction

- Resistive Micromegas[1] (resMM) have been developed for the upgrade of the Muon Spectrometer of the ATLAS Experiment at LHC leading to the successful construction of the largest MPGD based system ever (see L. Guan's talk on Saturday)
- Since then, many other MPGD exploiting the resistive protection schema have been developed

- Characterisation of aging behaviour and long-term performance of gaseous detectors is crucial for application in large experiments with a long operation lifetime and high radiation background
- For Muon detector at HL-LHC the expected integrated charge is ~20 mC/year in the hottest region

Revolutions The first of the ATLAS New Small Wheels (NSW-A) ready for transport to Point 1 of the LHC. On the right is NSW-C where, at the time of the photograph in July 2021, only a few sectors had been installed. Credit: F Lanni

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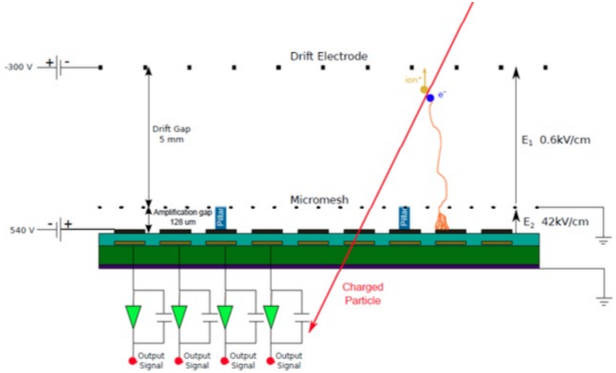
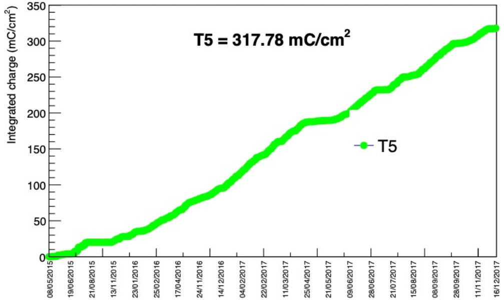
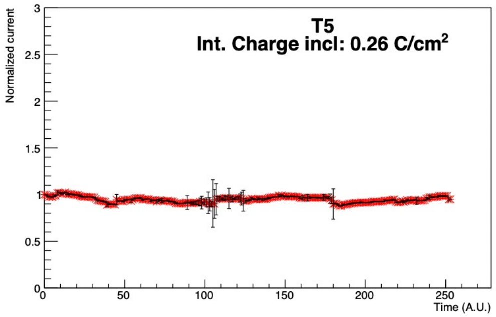


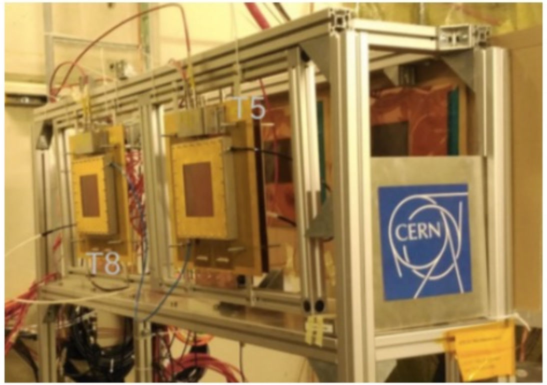
[1] *Nucl.Instrum.Meth.A* 640 (2011) 110-118
Nucl.Instrum.Meth.A 617 (2010) 161-165
Nucl.Instrum.Meth.A 937 (2019) 125-140

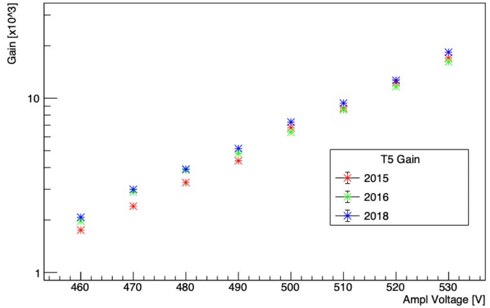
Introduction

- Long-term ageing test performed on two resistive bulk-MM at the CERN GIF++ (14 TBq Cs γ-source) with Ar:CO_2 93:7 gas mixture
- 0.3 C/cm^2 accumulated in 3 years, equivalent to >10 y at HL-LHC









Ageing and high rate studies on resistive Micromegas at the CERN Gamma Irradiation Facility

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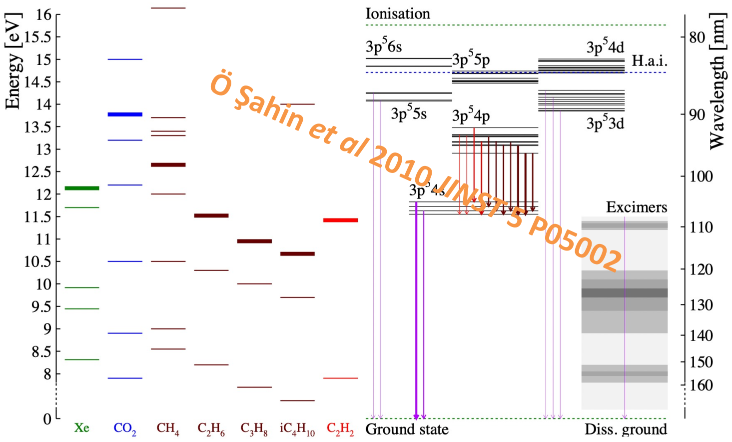
PoS ICHEP2018 (2019), 665

Final paper submitted for pubblication

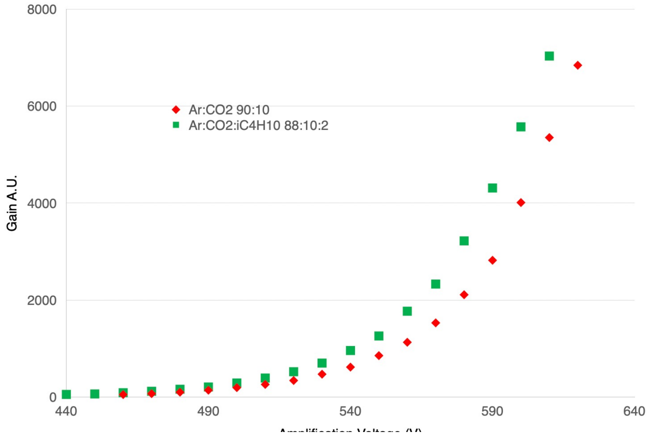
- No performance degradation observed in Ar:CO_2 93:7 for 0.3 C/cm^2 integrated charge
- No sign of aging
- Rad hardness studies of material components have been performed too

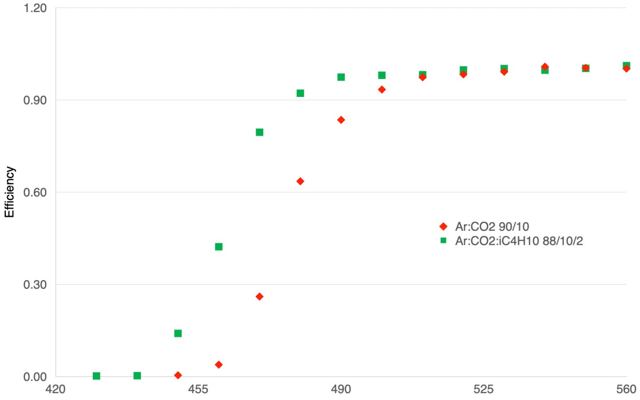
Introduction

- Ar:CO_2 mixtures are not the most suited for MPGD
- The addition of stronger quencher like hydrocarbons improves the quenching (discharge suppression) and allows better operating conditions
  - Higher gain at fixed voltage
  - Anticipated turn-on curve → lower operating voltage → lower electrical field → reduced spark probability
  - Larger stability plateau



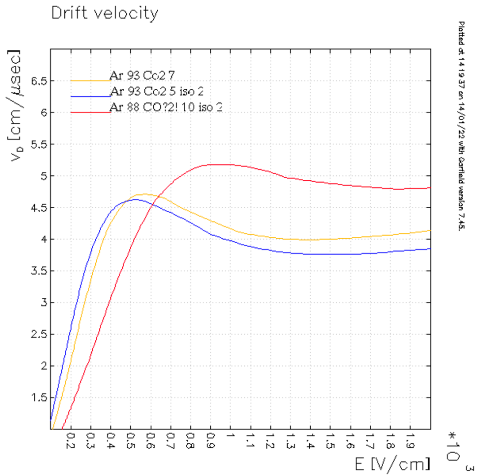
- Penning transfer is the effect at work





Ar:CO_2:iC_4H_{10}

- Ar:CO_2:iC_4H_{10} 93:5:2 has been identified as a good candidate for large detector operations
  - Ar-based → cheap
  - Availability of pre-mixed gas
  - Low GWP
  - Not flammable
- Transport properties very similar to Ar:CO2 93:7

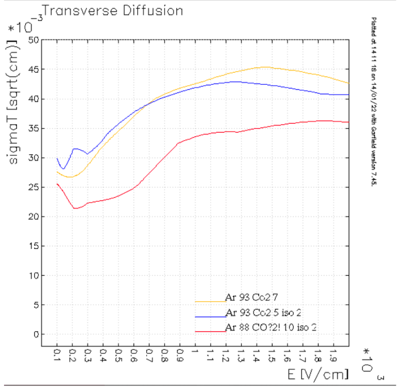


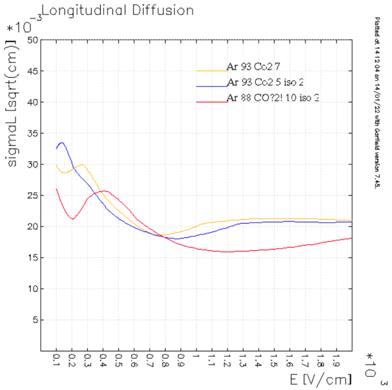
But …Is it the right thing to do?

8. Conclusions on Gases

A. If we obtain regular purity gases, a basic conclusion of the workshop is that *Noble gas + hydrocarbon* mixture should not be trusted for more than[11,18,21,46] 0.01–0.05 C/cm. The *Noble gas + CO_2* mixture appears to behave about ten times better.[11,21,46]

J.Va'Vra, Nucl.Instr.and Meth.A252 (1986) 547.



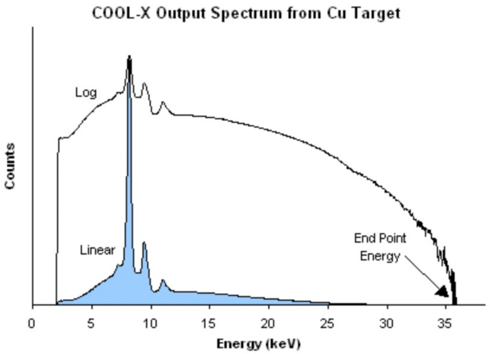


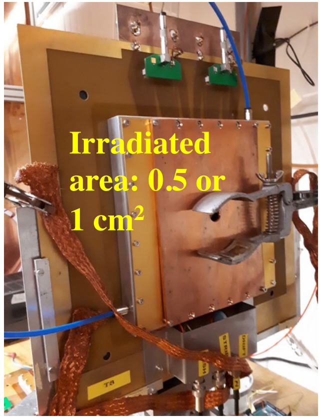
→ Need of thorough longevity and aging tests

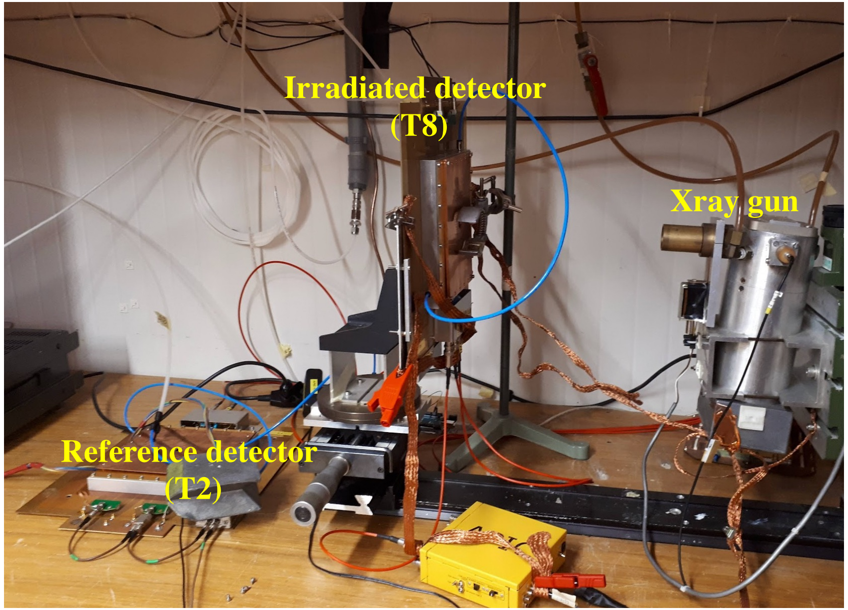
New results on accelerated test with X-rays with $Ar:CO_2:iC_4H_{10}$

Experimental setup

- Two bulk resistive Micromegas operated with Ar:CO_2:iC_4H_{10} 93:5:2
  - Detector under test: T8 (same detector used for the long-term aging test at GIF++ with Ar:CO_2): irradiated with X-rays from copper
  - Reference detector: T2 (same design, material and construction of T8): not irradiated
  - Amplification gap: 100 um; drift gap: 5 mm
- Active area 10x10 cm^2; irradiated area 0.5 & 1 cm^2
- Resistive protection layer: screen-printed strips (400 um pitch, 300 um width)
- Gas flow: 1l/h (2.5 renewal/hour)
- X-ray copper gun (8.04 keV K-α line)



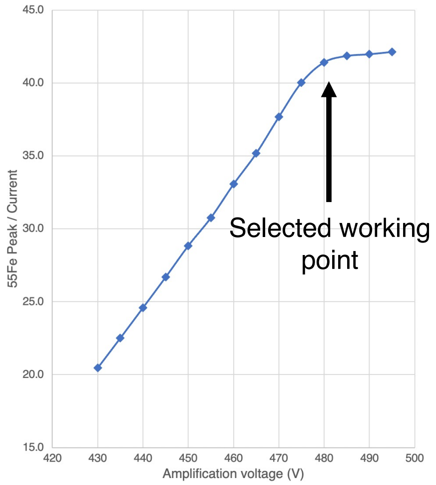




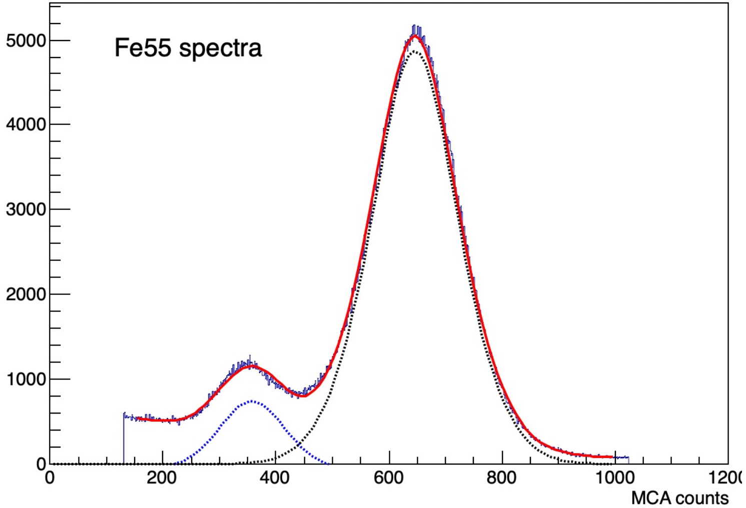
Measurements performed at the GDD/RD51 lab at CERN

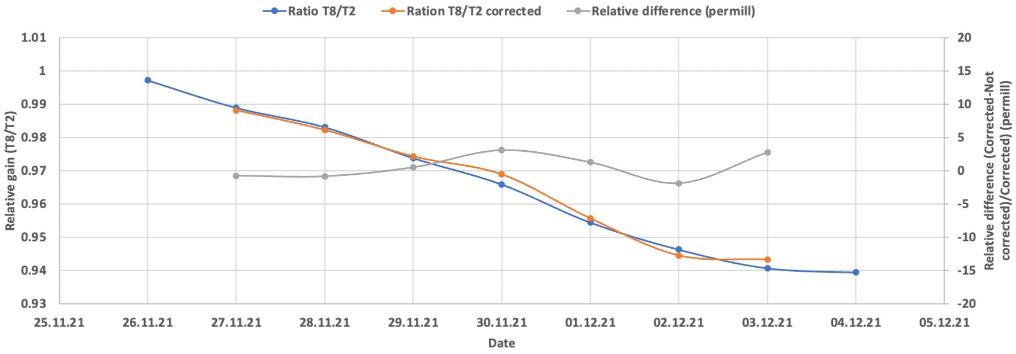
Procedure

- Test detector (T8) under continuous irradiation
- Working point: V^{amp} = 480 V; V^{drift} = 600 V/cm
- Measurement ~1/day of the energy spectra with ^{55}Fe source for both test (T8) and reference (T2) detectors → Gain and E_{res} from peak and FWHM/peak
- Monitoring (1Hz) of current during irradiation and of environmental parameters
- $T8^{peak}/T2^{peak}$ cancels out gain fluctuation for T,P variations (verified at per mill level)



Typical measured energy spectra

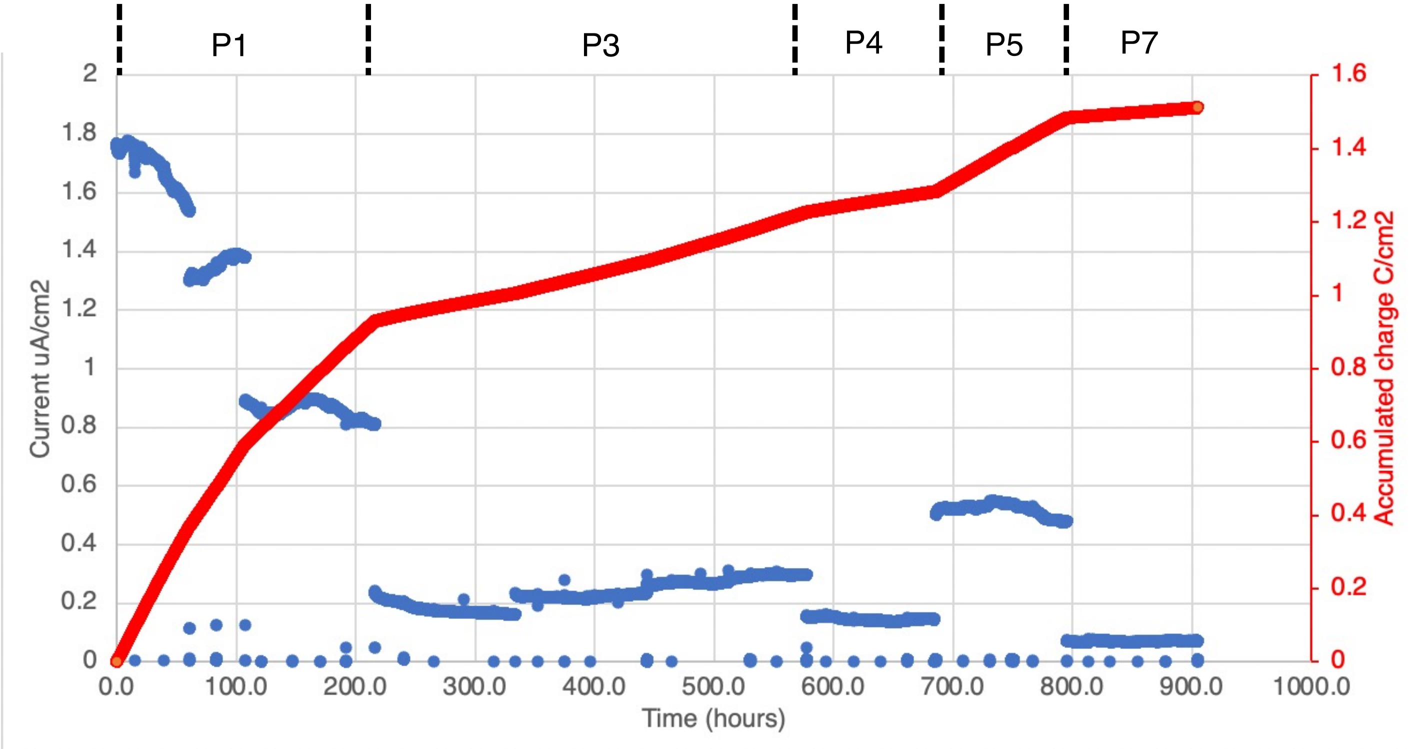




Accumulated charge

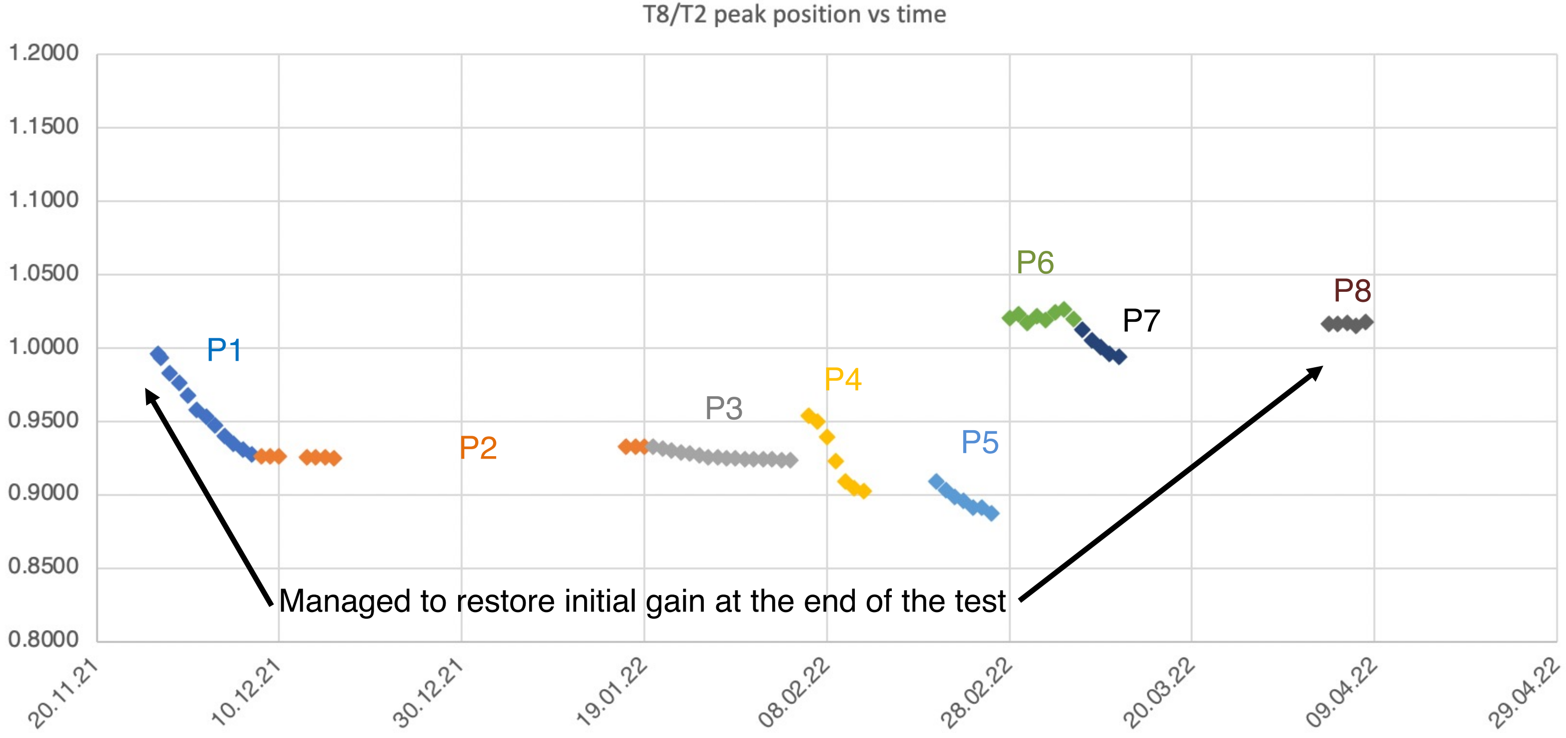
- Test from Nov. 2021 until March 2022
- Total irradiation time ~900 h
- Accumulated charge: 1.5 C/cm^2

- Several irradiation periods with different conditions



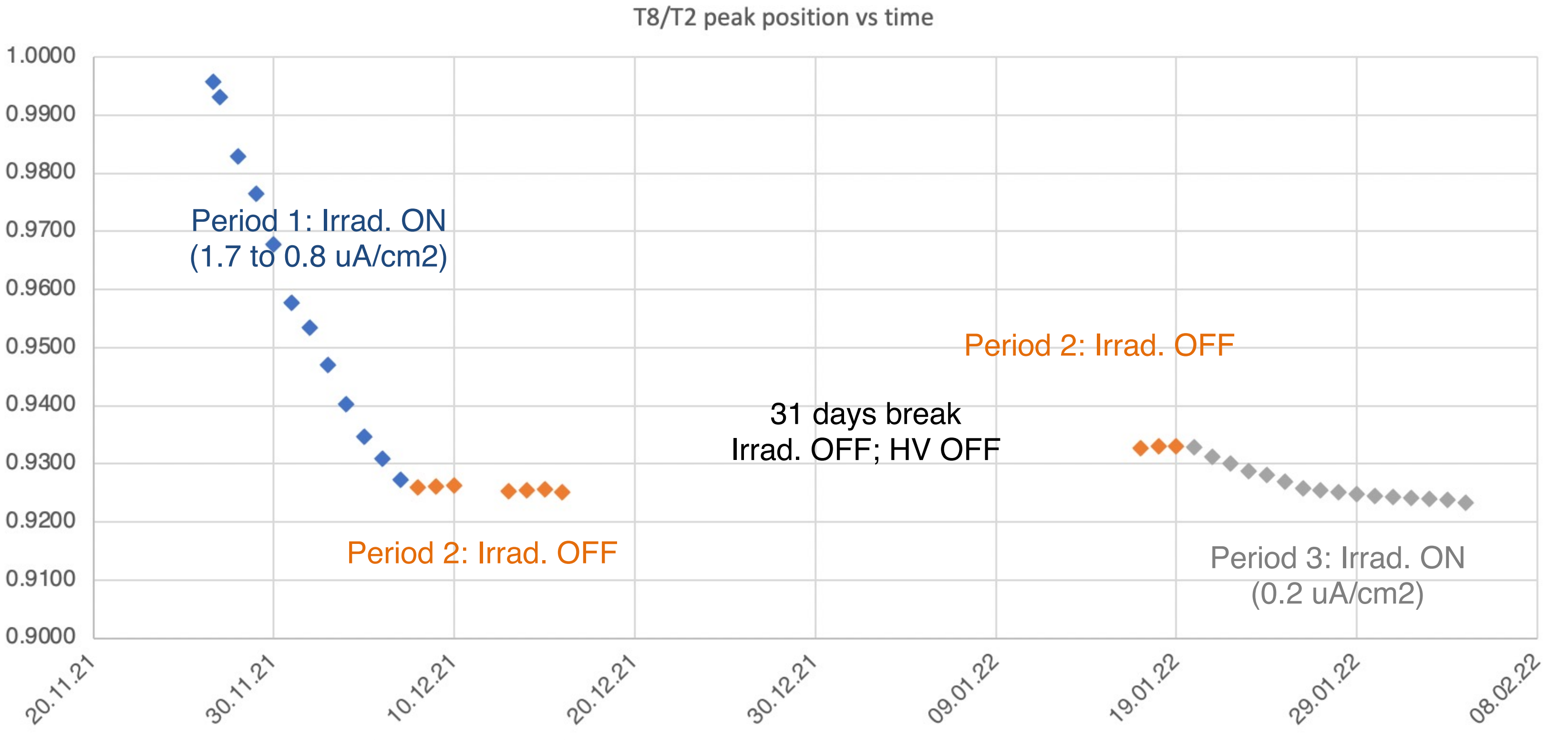
Gain variation

- Gain variation trend during the full duration of the test (900 h irradiation; 1.5 C)



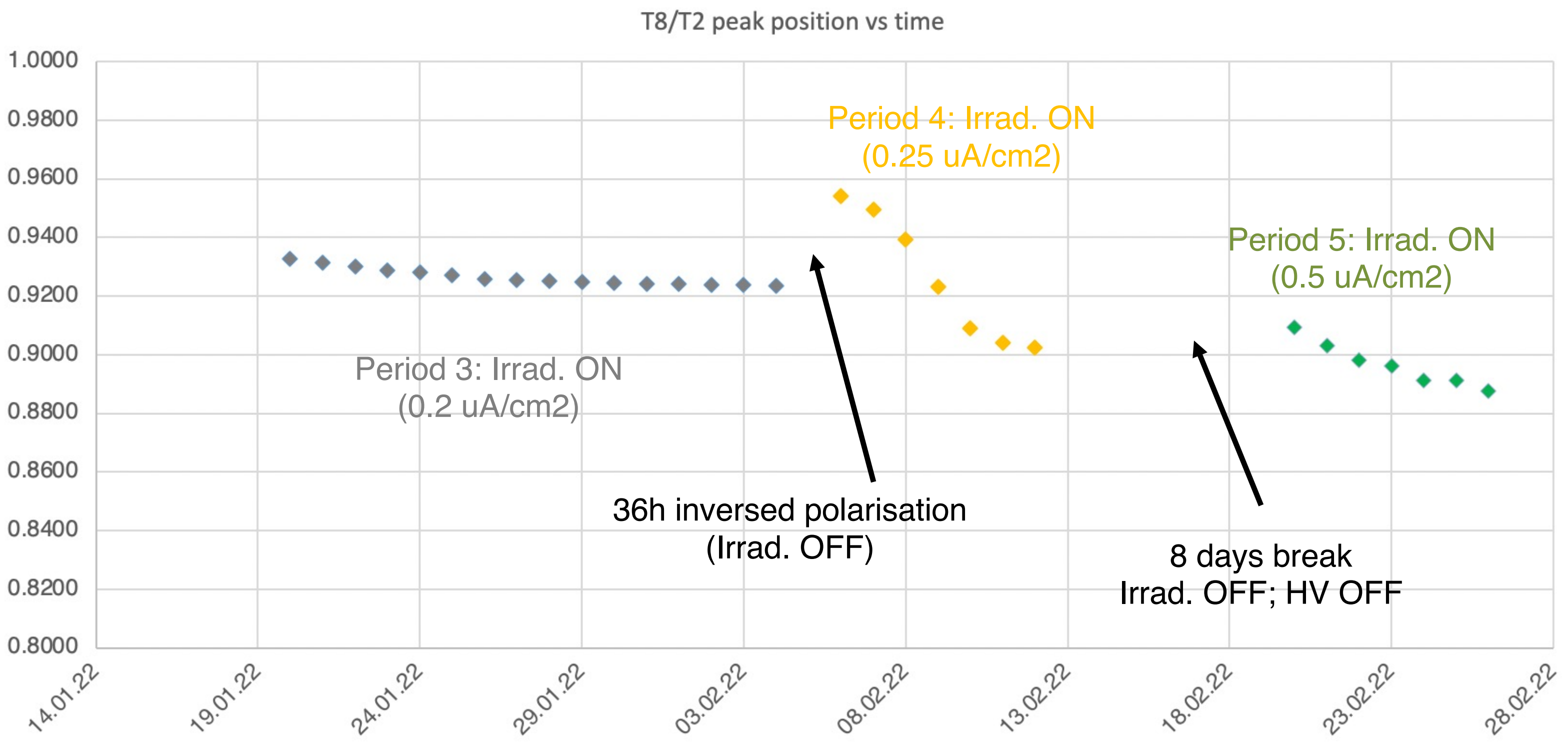
Gain variation P1-P3

- Gain variation trend during period P1 to P3 (570 h irradiation; 1.5 C)



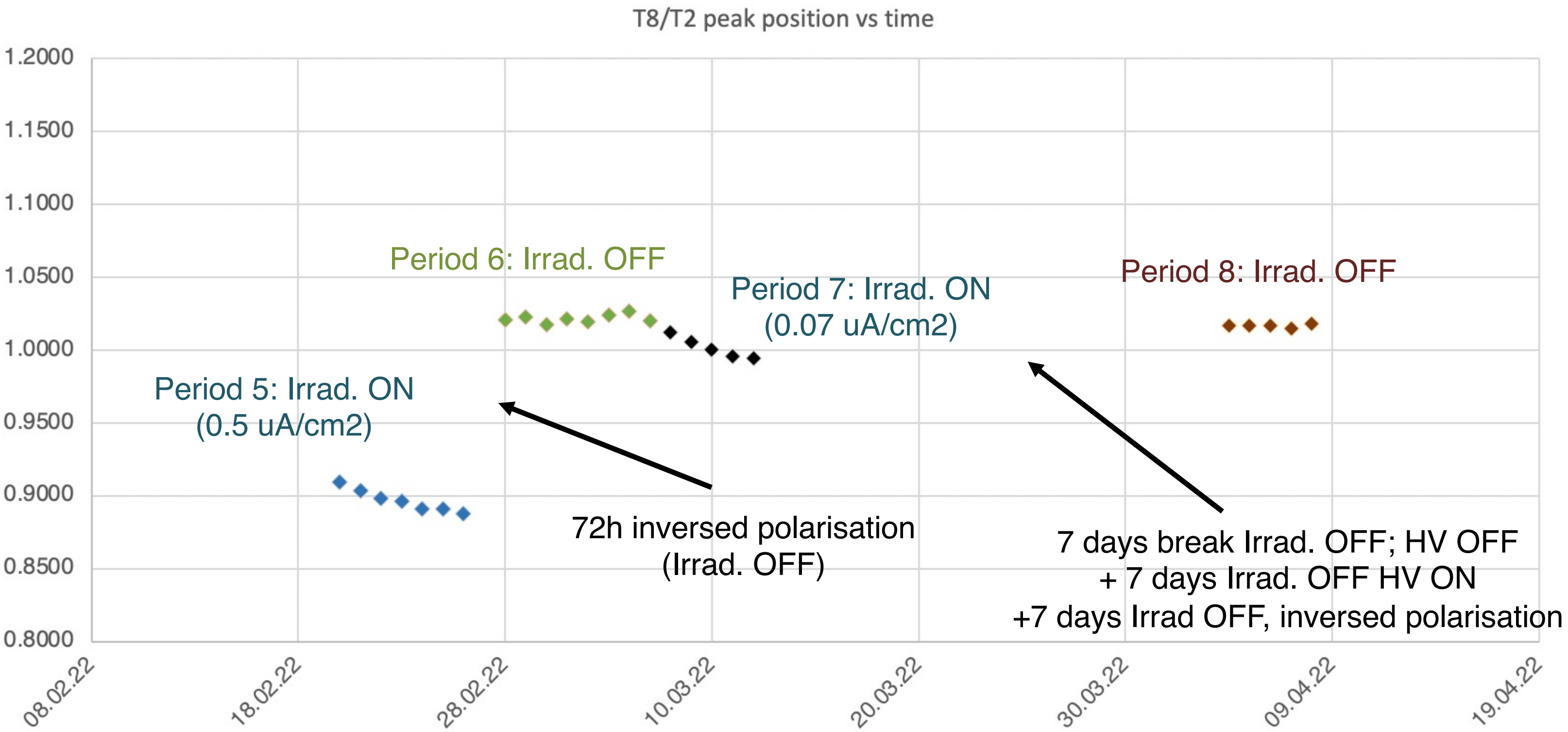
Gain variation P3-P5

- Gain variation trend during period P3 to P5 (540 h irradiation; 0.45 C)



Gain variation P5-P8

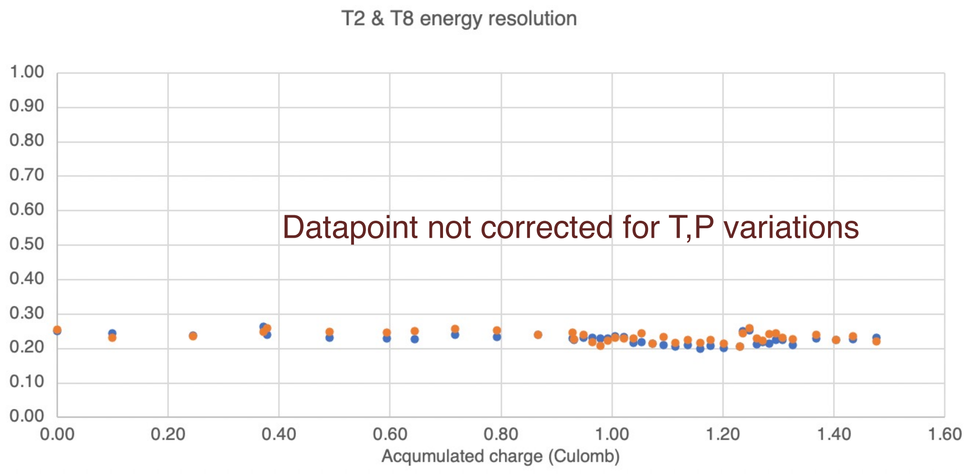
- Gain variation trend during period P5 to P8 (220 h irradiation; 0.25 C)



Energy resolution

- E_{res} ~22% did not significantly change during the test period
- No visible effect in different irradiation conditions

- Observation are consistent with gain variation due to charge-up effect

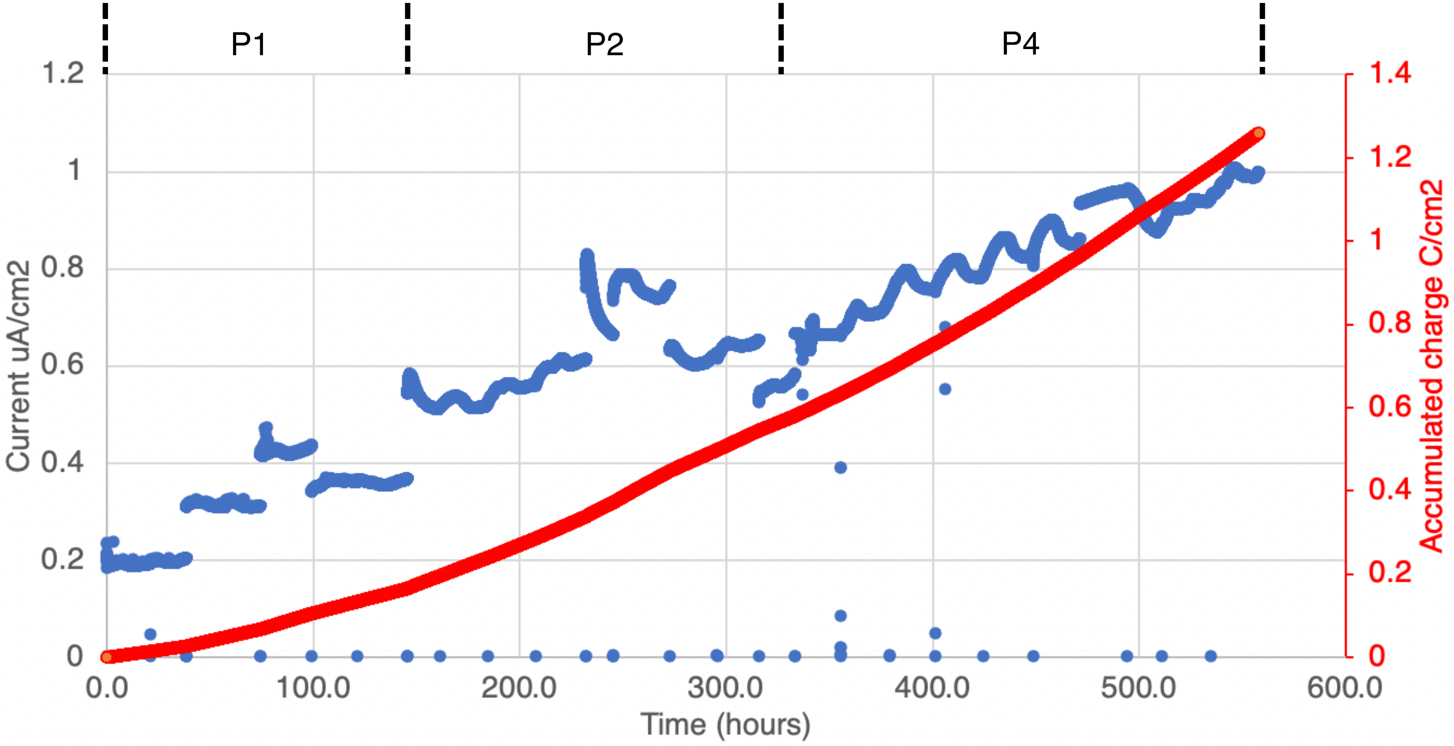


- Test repeated with Ar:CO2 mixture to verify charge-up hypothesis
  - Same conditions as test under Ar:CO_2:iC_4H_{10}
  - Charge-up behaviour (mostly) unaffected by gas composition
  - Working point: V^{amp} = 520 V (same gain as 480 V with isobutane); V^{drift} = 600 V/cm

Accumulated charge in Ar:CO_2

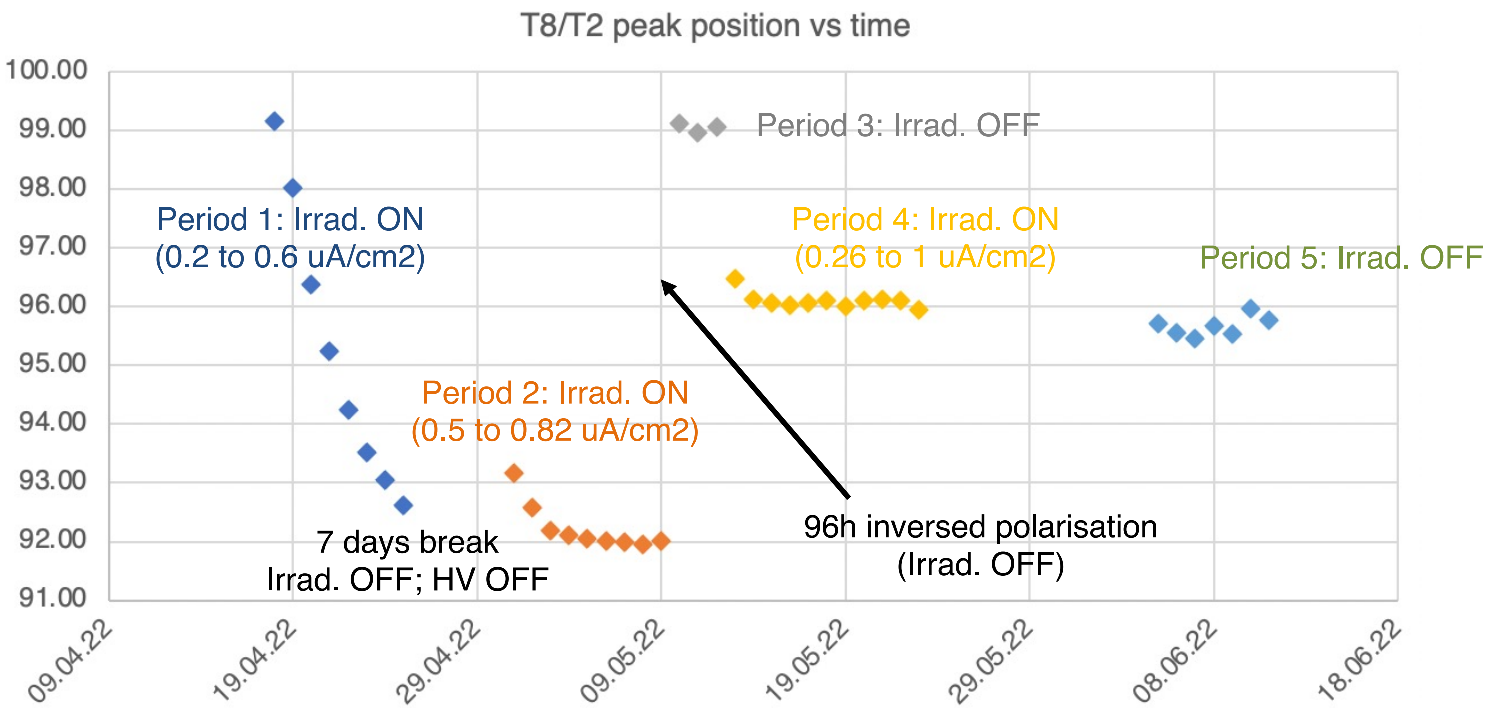
- Total irradiation time ~570 h
- Accumulated charge: 1.26 C/cm^2

- Several irradiation periods with different conditions



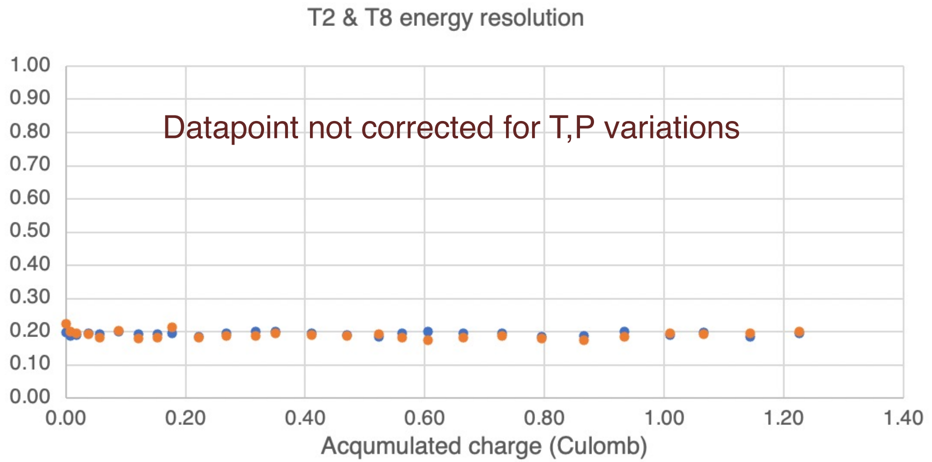
Gain variation in $Ar:CO_2$

- Gain variation trend during the full duration of the test in Ar:CO2 (570 h irradiation; 1.26 C)



Energy resolution in Ar:CO2

- E_{res} constant during the test period
- Acquisition chain improved after the first set of measurement → slightly better than what has been measured for $Ar{:}CO_2{:}iC_4H_{10}$



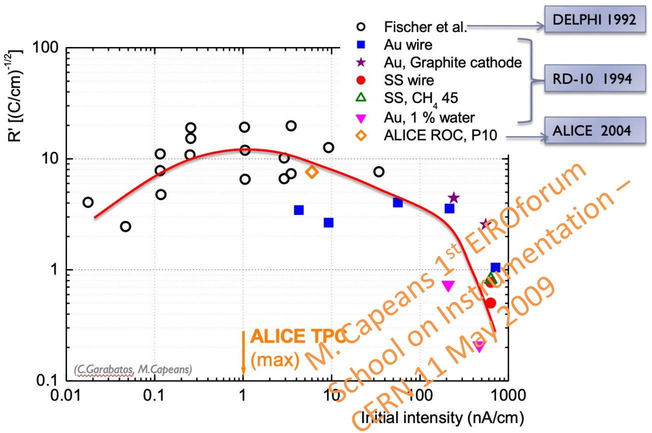
- Agreement between observation with $Ar{:}CO_2{:}iC_4H_{10}$ and $Ar{:}CO_2$ mixtures

Summary and outlook

- The accelerated longevity test performed on resistive Micromegas detector did not show sign of aging using both Ar:CO_2 93:7 and Ar:CO_2:iC_4H_{10} 93:5:2
- Observed gain reduction explained as local charge-up effect
  - Similar with both gas mixtures
  - Reversible
- Can we conclude that resMM operated with 2% isobutane are immune by aging?

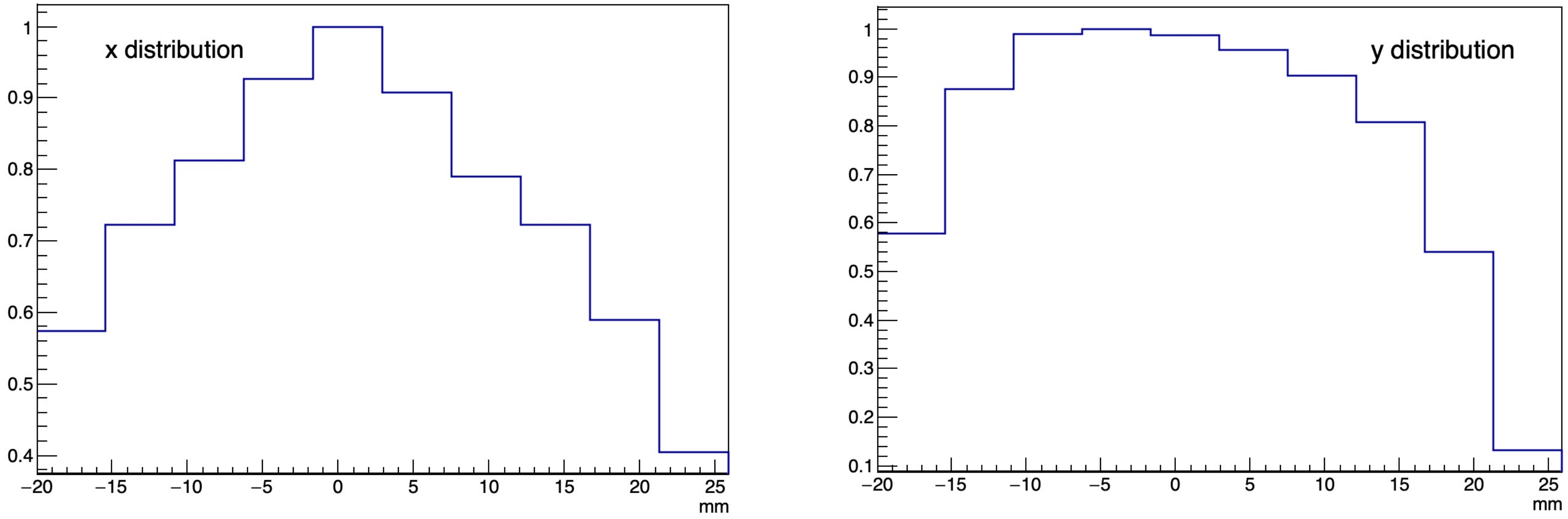
- From wire chambers it is know that accelerated test can induce less aging when compared with test integrating the same charge with less instantaneous radiation

- The conclusion of this study in that aging phenomena of iC_4H_{10} on resMM are (if any) much less evident than what one could expect from experience of wire chambers
- Long-term tests are needed to give a final answer but the use of small fraction of isobutane is not terrific!

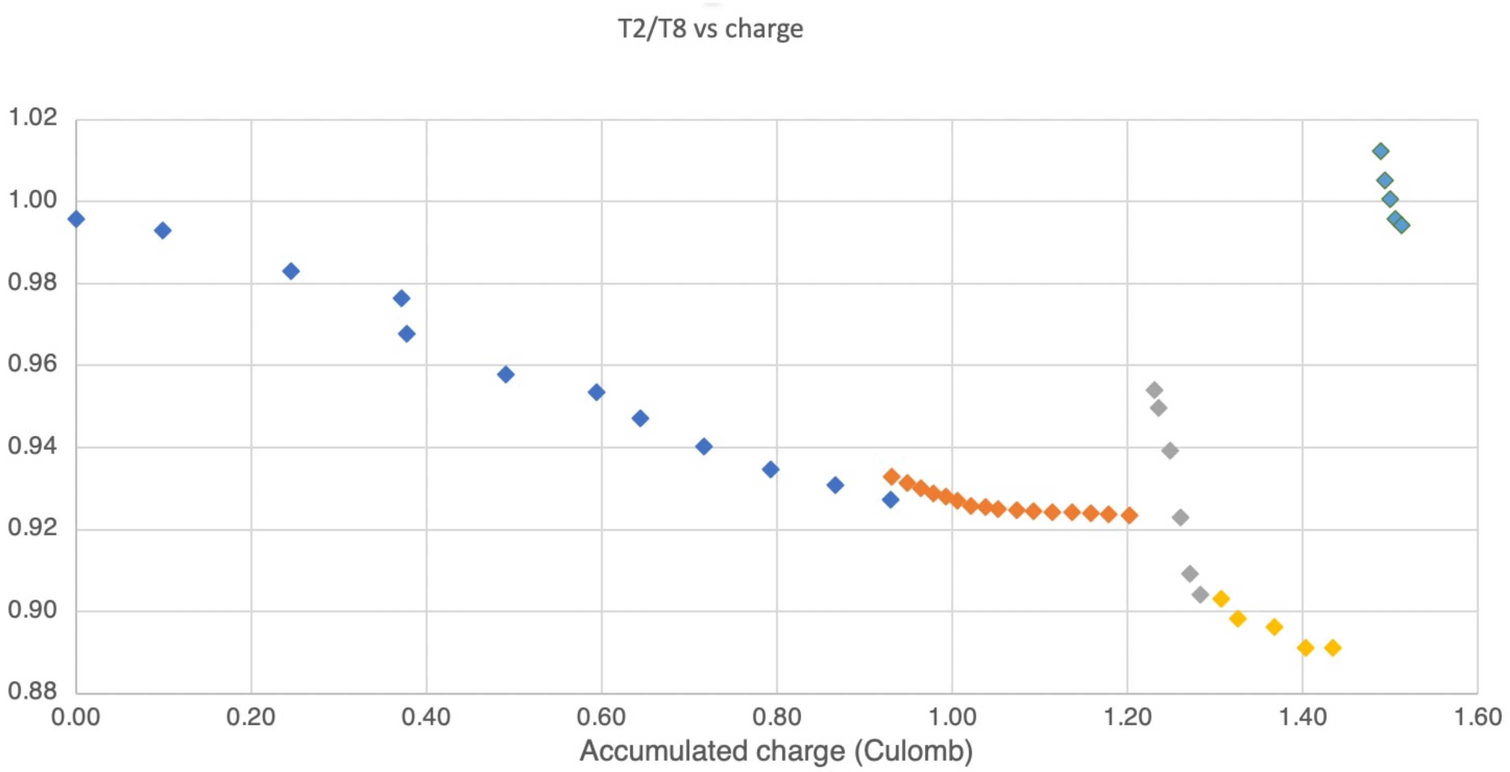


Additional Material

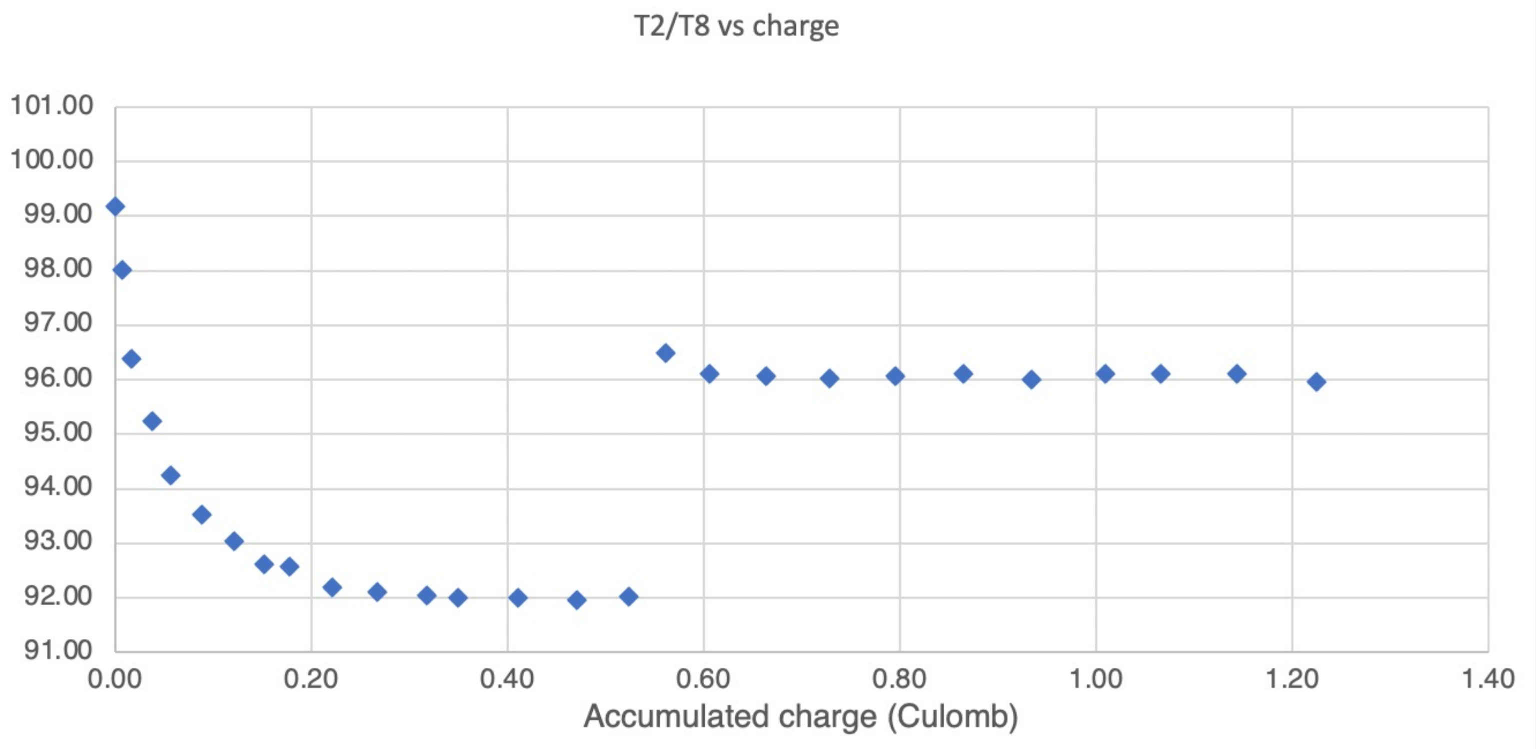
X-ray beam profile

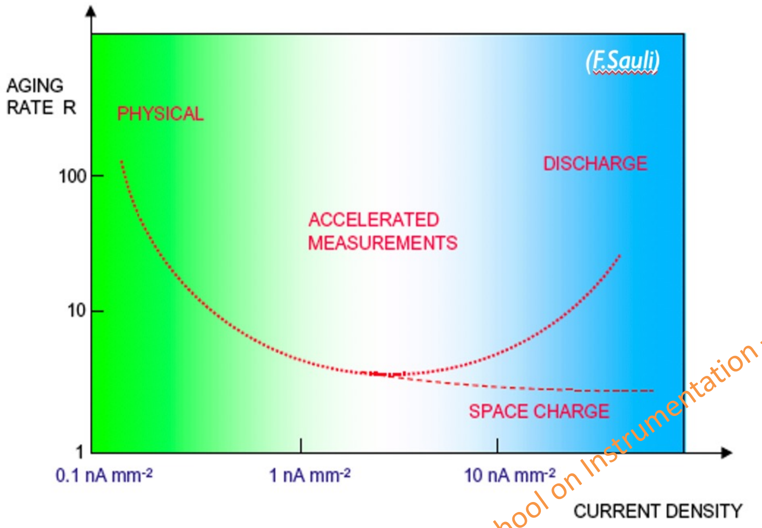


Gain variation vs charge – Ar:CO2:iC4H10



Gain variation vs charge – Ar:CO2





Examples:

- Space charge gain saturation can decrease the polymerization efficiency
- Gas flow insufficient to remove reaction products created at high rate