

Impact of trace amounts of water on the stability of MPGDs measured in Ar-CO₂ (90-10)

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[NIM A 1082 \(2026\) 170912](#)



- H_2O in gas is usually regarded as an unwanted contaminant
- Humidity in the gas can be, however, favorable for the detector to, for example:
 - Mitigate aging effects¹
 - Prevent glue used for detector components from drying out (e.g. ALICE TPC)
- Previous studies regarding the effects of adding humidity to the gas composition are not comprehensive
 - Especially, no consensus has been reached concerning discharge stability

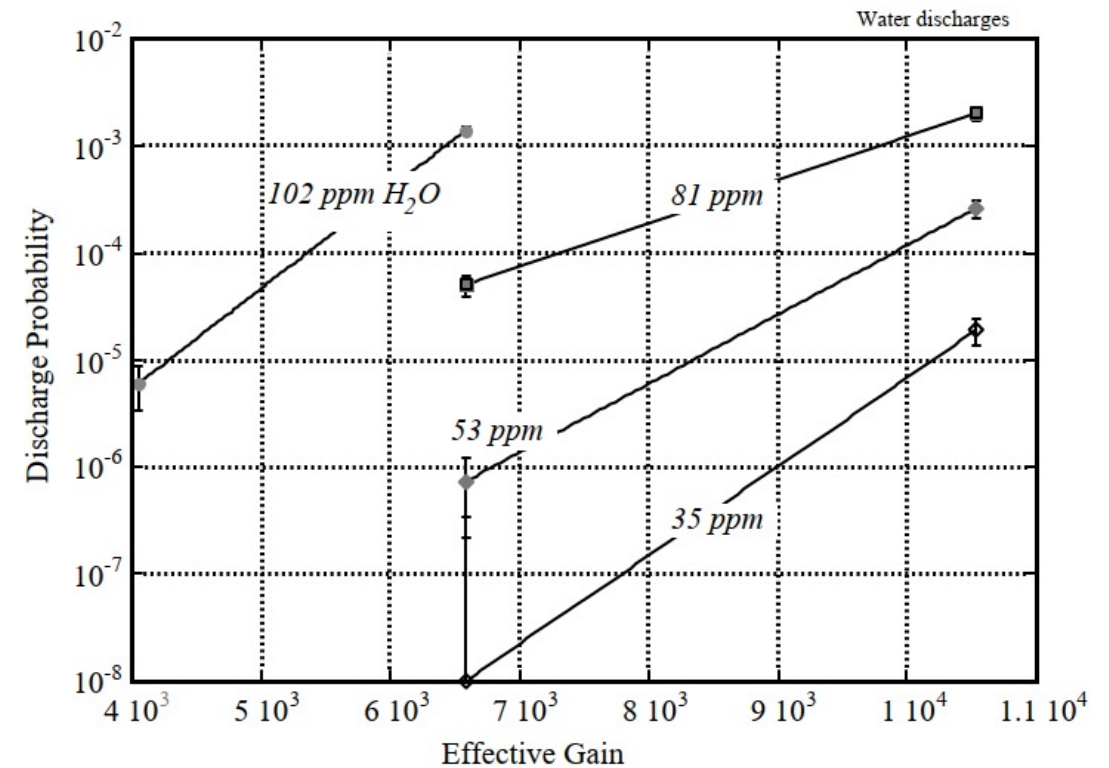
¹[M. Hohlmann et al. NIM-A 494 \(2002\) 179–193](#)

Humidity in MPGDs

- Apart from various presentations, the last (known to us) published study of humidity influence on GEM stability in

[F. Sauli et al. NIM-A 490 \(2002\) 177–203](#)

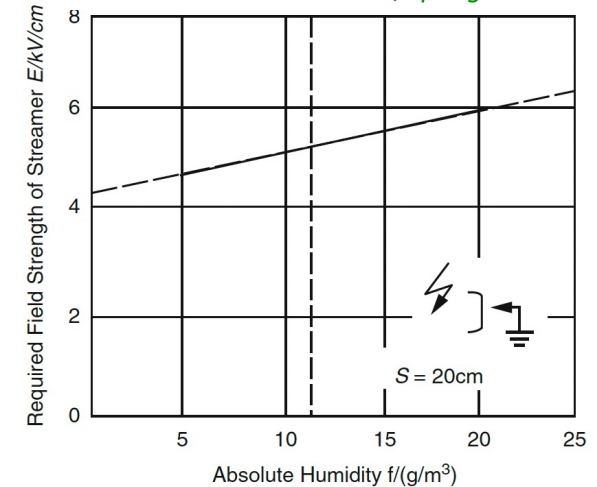
- Double GEM, Rn (gaseous) alpha source
- Detector in a nitrogen-filled plastic bag wrapper
- Water content varied by modifying the gas in the wrapper or by extending of plastic tubing
- Dependency on the humidity level observed
 - Origin of the effect unknown
 - Operational conditions should be strictly monitored



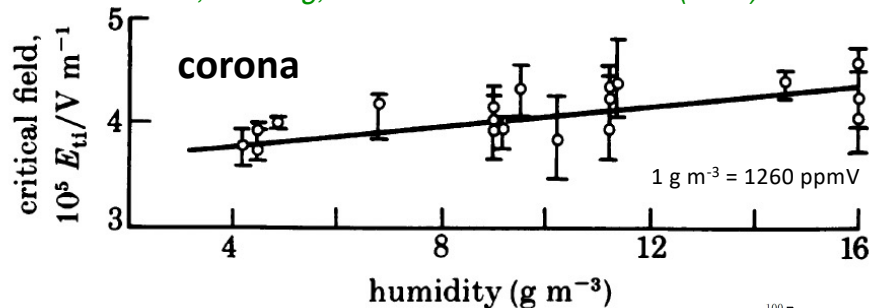
Humidity and discharges in literature

- Recent R&D related to the Ultra HV transmission lines, and insulation of those.
- Humidity R&D related mainly to corona and streamer development in rod-plane air gaps
- Following D. Xiao, “Gas discharge and gas insulation”, Springer:
 - With the increase of the water content in air, the photon free path is shortened
 - No. charged particles produced in an avalanche will be reduced and the E-field of a streamer head will be weakened
 - In addition electronegative water molecules increase attachment
- Similar effects reported in other works on streamer propagation/breakdown, corona dev., etc.

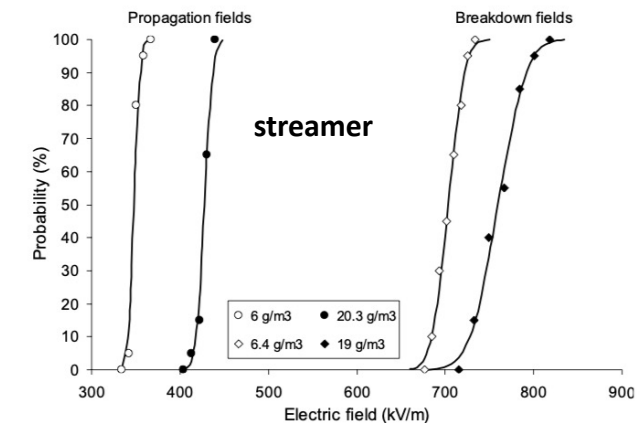
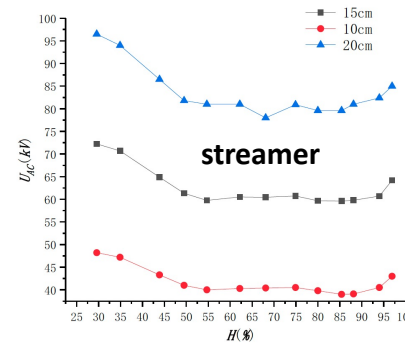
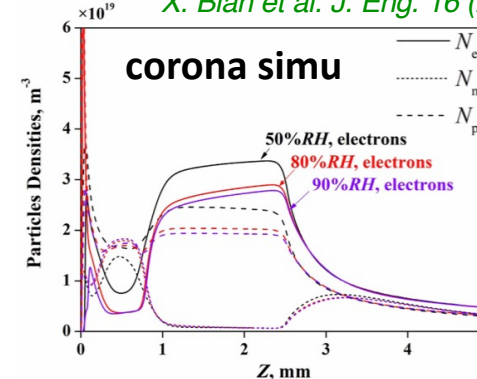
D. Xiao, Springer 2016



N. Allen, D. Dring, Proc. R. Soc. Lond. A 396 (1984) 281



X. Bian et al. J. Eng. 16 (2019) 2869



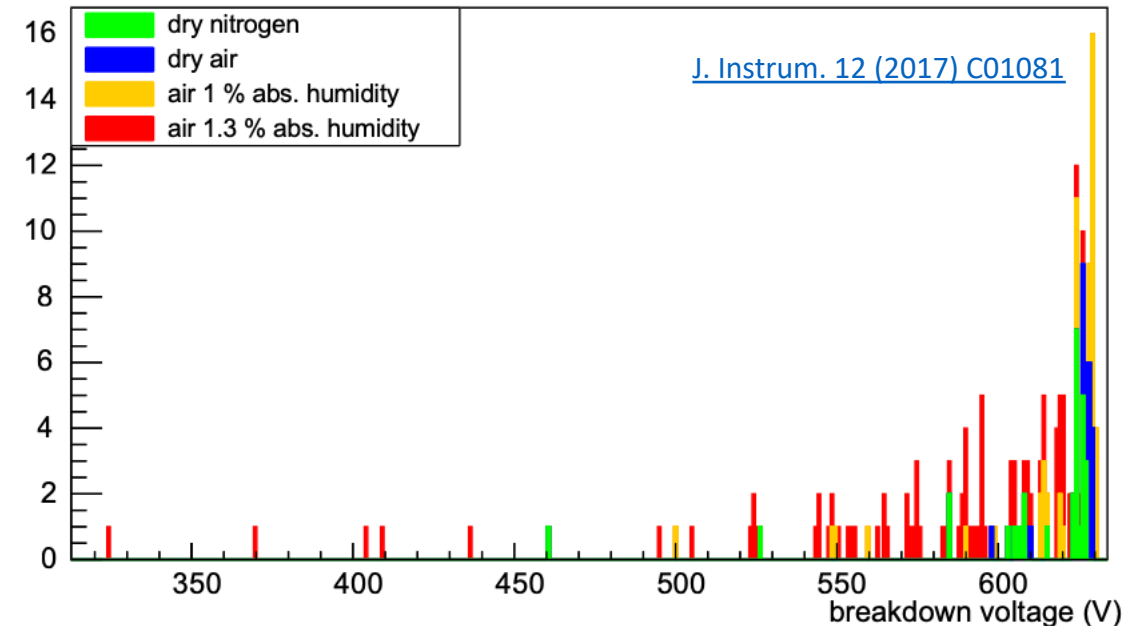
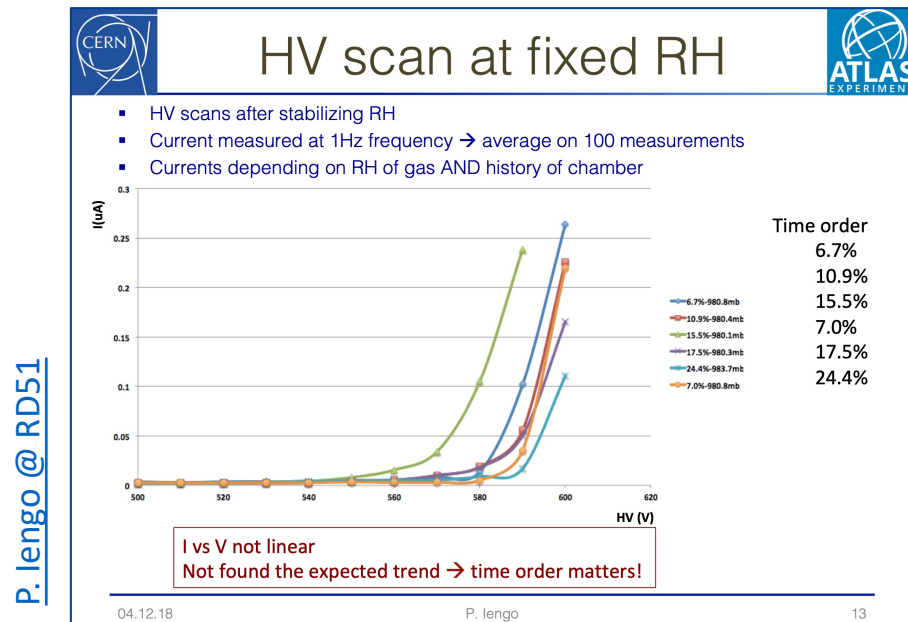
P. N. Mikropoulos et al.
IEEE Trans. Dielectr. Electr. Insul. 15 (2008) 416

- But also opposite effects discussed

X. Ren et al. Energies 15 (2022) 817

Experience from QC

- All LHC upgrades performed their HV tests at low-humidity levels, below RH = 50%, or even below 10%
- ALICE, GEMs: [J. Instrum. 12 \(2017\) C01081](#), [J. Instrum. 16 \(2021\) P03022](#)
- CMS, GEMs: [Instr. and Meth. A 1034 \(2022\) 166716](#)
- ATLAS, MMG: [Nucl. Instr. and Meth. A 1026 \(2022\) 166143](#)



ALICE GEM studies:

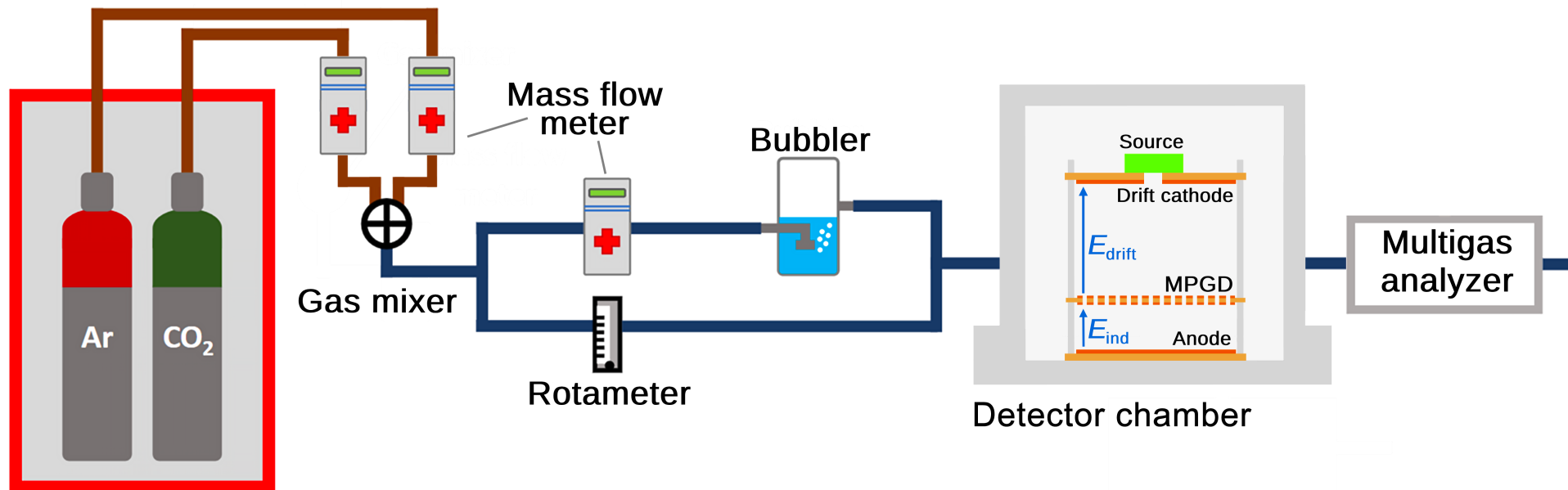
- Increased discharge rate and leakage current at high H
- GEM QC for ALICE at <6000 ppmV

ATLAS MMG studies:

- No clear relation between RH and leakage current at high voltages
- Flushing time (history of the chamber) plays an important role
- No gain variations with RH

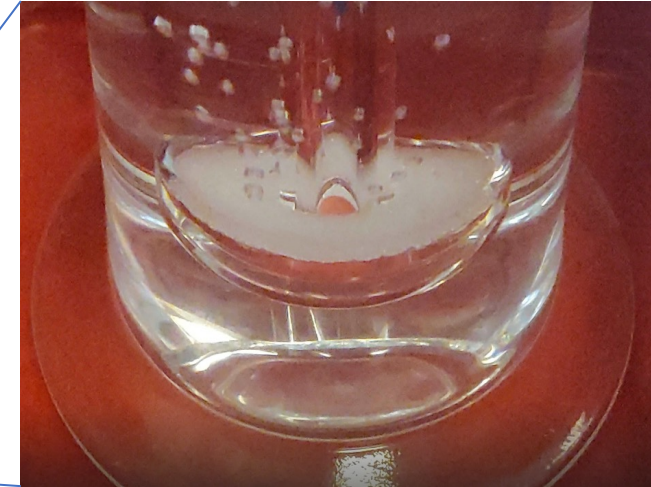
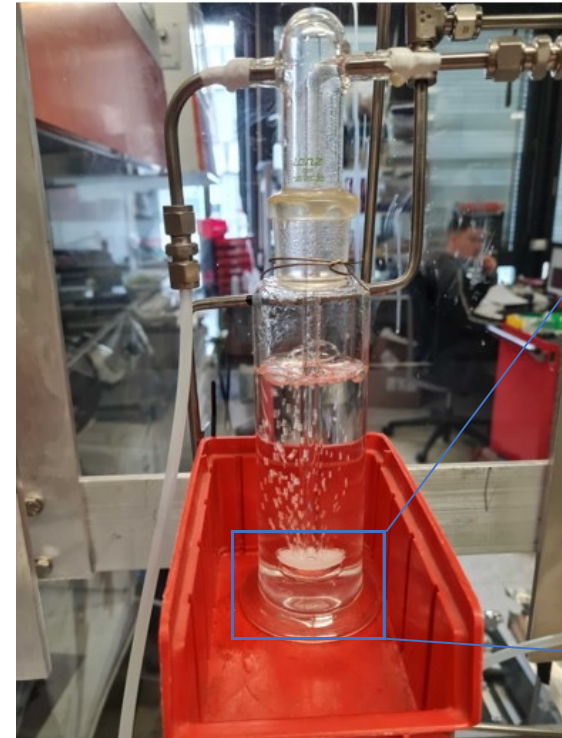
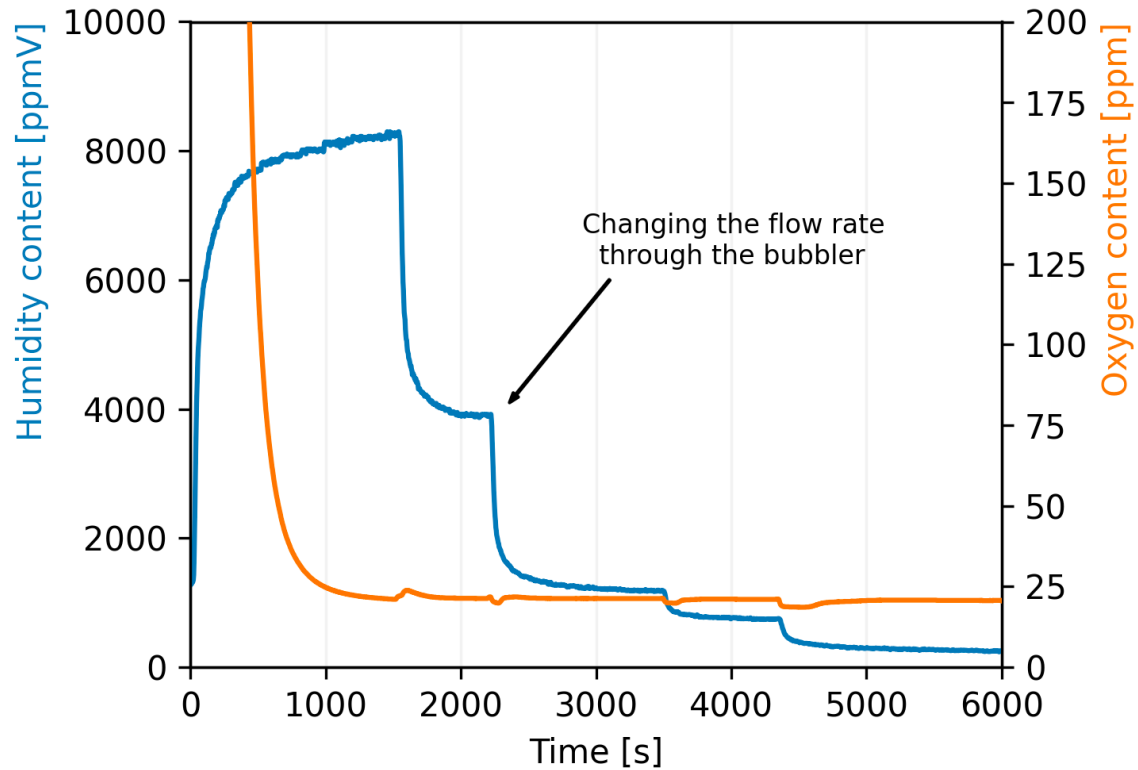
Experimental Setup

- A dedicated setup was implemented to introduce a controlled humidity level into the gas mixture, adjustable **in the range of 0–5000 ppmV (i.e., up to 20% RH at NTP)**
- This is achieved by integrating a water-filled bubbler* into the gas system, through which the carrier gas is flushed at variable flow rates.



*We warmly thank Chilo Garabatos for many fruitful discussions on the gas system configuration

Experimental Setup



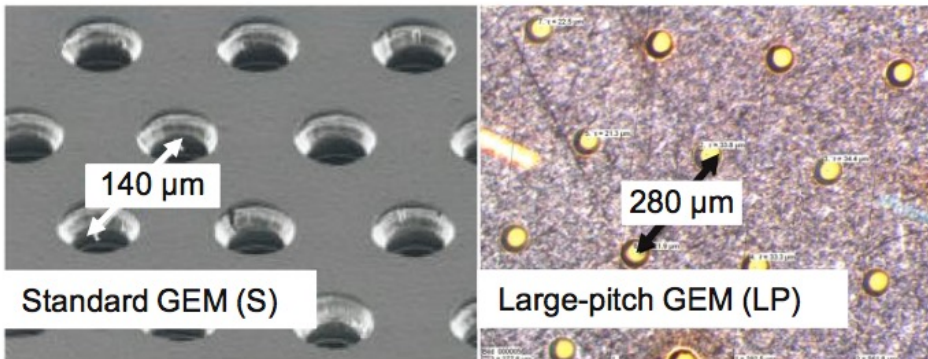
- Test series/scan: Set a constant humidity level while keeping the oxygen content at the minimum

- A close-up of the bubbler while flushing gas through it

Non-resistive MPGDs

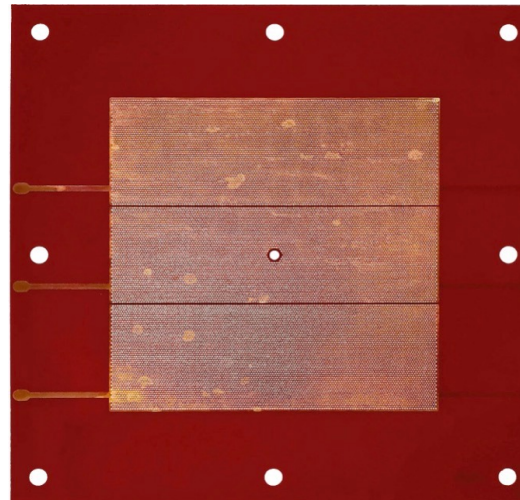
GEM

- Thickness: 60 μm
- Hole diameter: 50 μm (70 μm) inner (outer)
- Pitch: 140 μm (S), 280 μm (LP)
- CERN



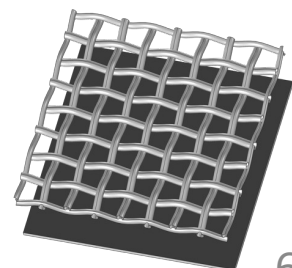
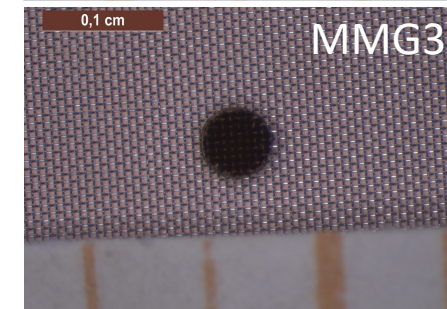
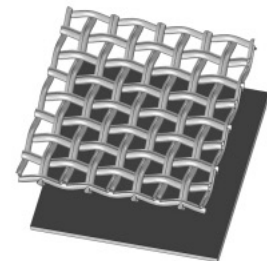
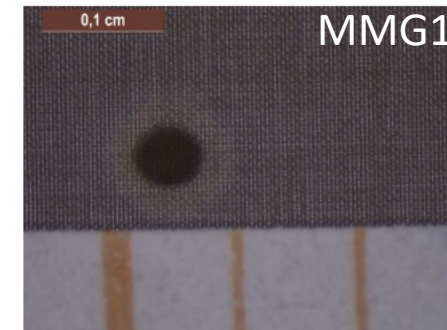
THGEM

- Thickness: 470 μm
- COMPASS-like
- Hole diameter: 400 μm (500 μm for edge holes)
- Pitch: 800 μm
- ELTOS



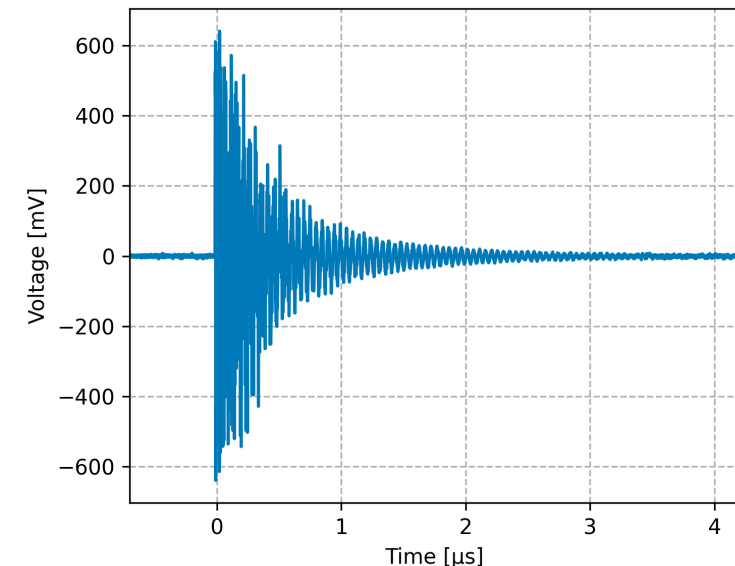
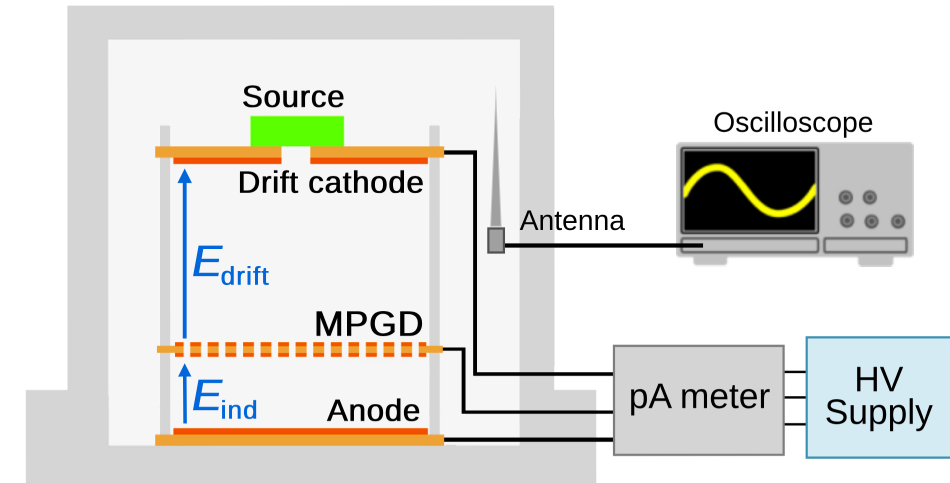
MMG1/MMG3

- Wire distance: 22/45 μm
- Wire thickness: 13/18 μm
- Gap: 128 μm
- LPI: 730/400
- CERN



Discharge measurements

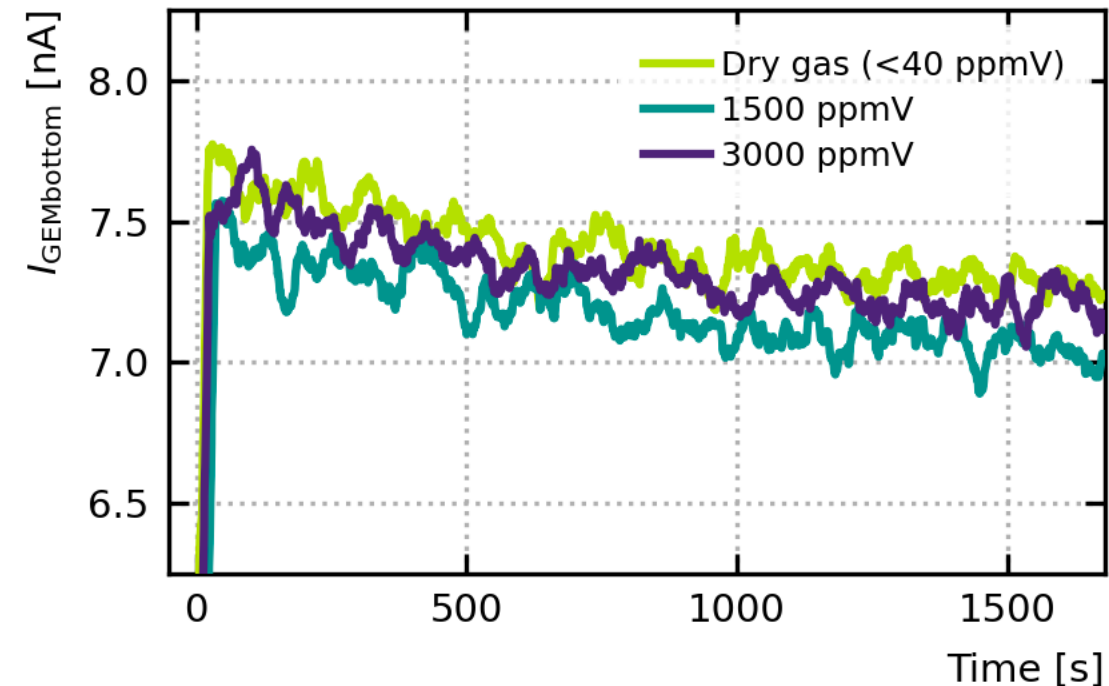
- Radioactive sources:
 - Alpha emitter ($^{239}\text{Pu} + ^{241}\text{Am} + ^{244}\text{Cm}$)
Drift distance chosen to have Bragg peak close to the MPGD
 - X-Ray source (Fe^{55})
- Electrode currents used for calculating the gain are measured with a picoamperemeter
- Discharges are visualized and counted with an high-speed acquisition oscilloscope



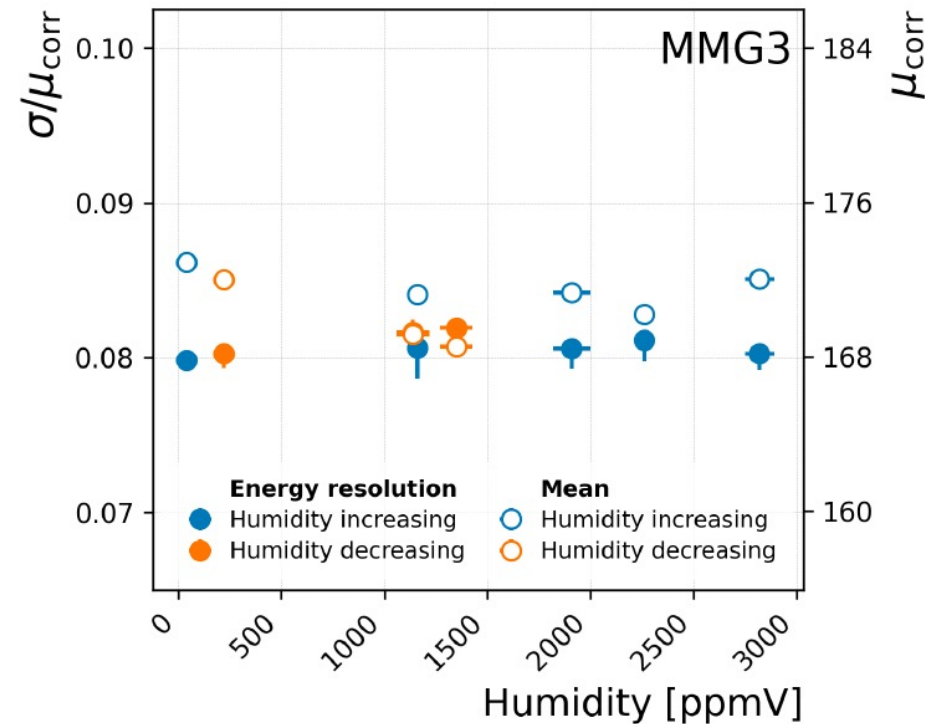
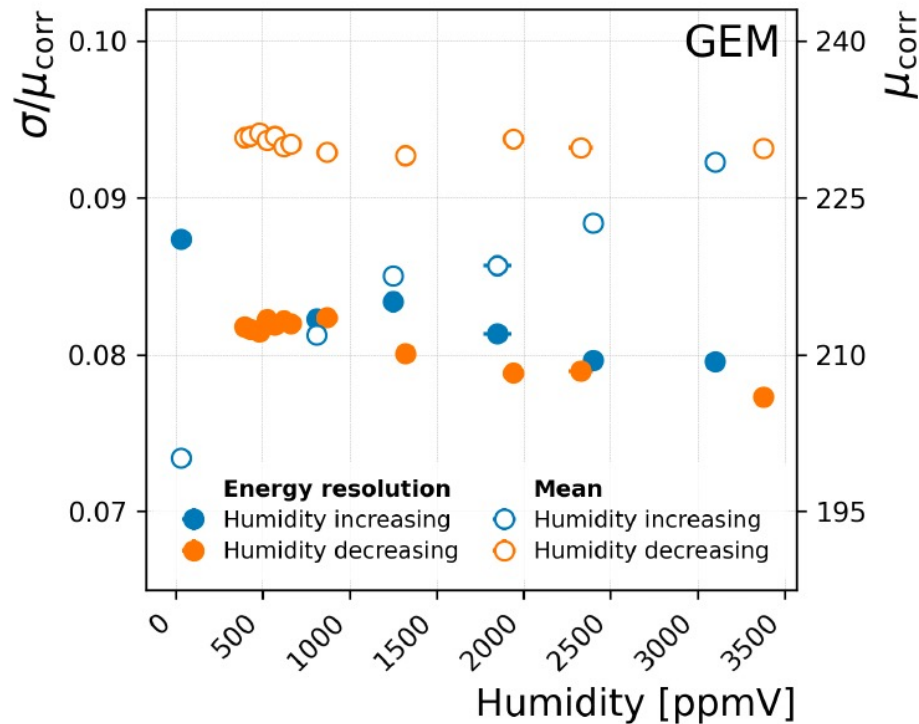
Unified measurement procedure

- Primary current I_{prim} measurement
 - 400 V/cm drift field on for 15 min.
 - Measure I_{prim} for 5' (and average)
- Increase voltage/gain gradually
 - Wait 5', measure 2'
- First discharges after $\sim 45'$ of operation
 - MPGD can be considered charged-up
- During discharge studies
 - Apply a voltage step 15'
 - Discharge/gain measurement starts
- Detailed charging-up studies not in the scope of this work

*Current development after a voltage step
Gain/discharge measurements starts after 900 s*

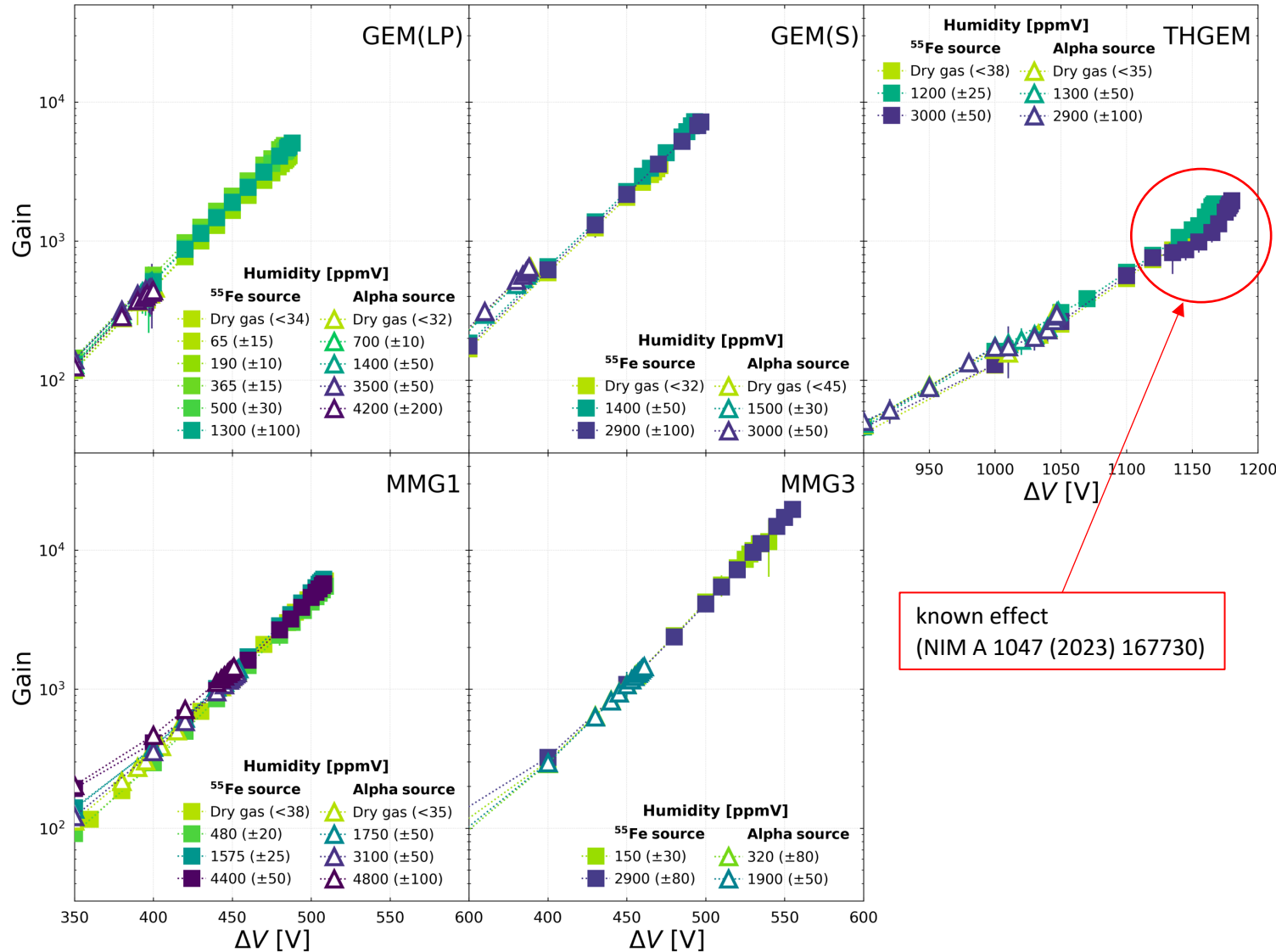


Amplitude spectra with ^{55}Fe



- GEM gain values (μ_{corr}) increase with humidity by $\sim 10\%$ (+slight improvement of σ/μ_{corr})
- MMG3 gain values are stable with humidity
- Influence of GEM/MMG insulating material (Apical/Pyralux), its area (75%/0.5%), and its hygroscopicity?
- TO avoid any influence on discharge curves: **gain measured for each discharge probability point**

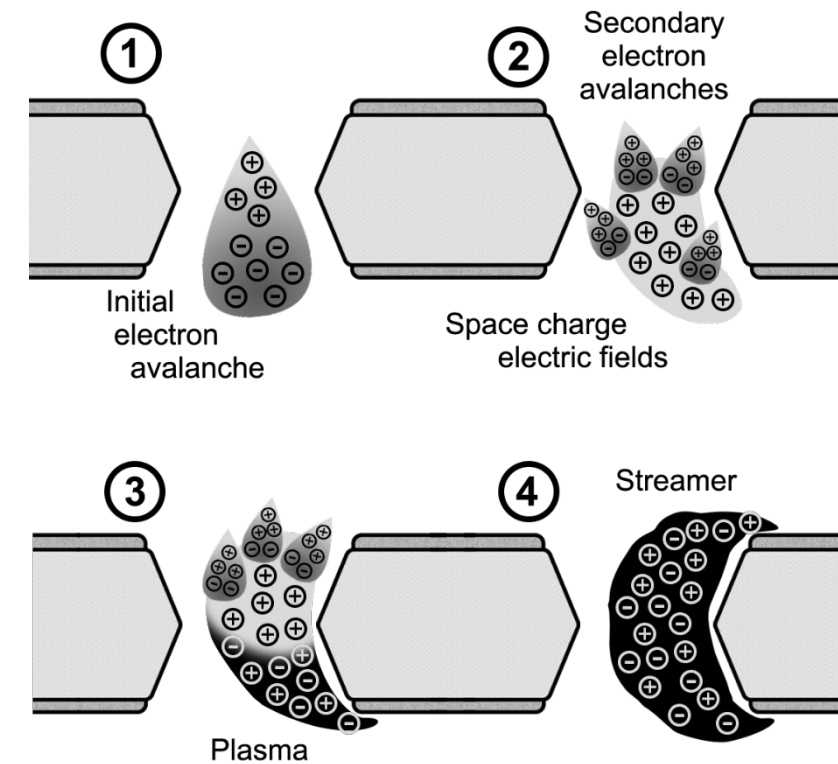
Gain curves



- We measure the absolute gain as a function of the amplification voltage
- Presented curves are not corrected for T/p variations
- Gain of MMG1 corrected for <100% collection efficiency at $E_{\text{drift}} = 400$ V/cm
- No major influence of humidity on the gain is observed $\rightarrow$ not expected in this humidity range as Townsend coefficient is not affected (see backup)

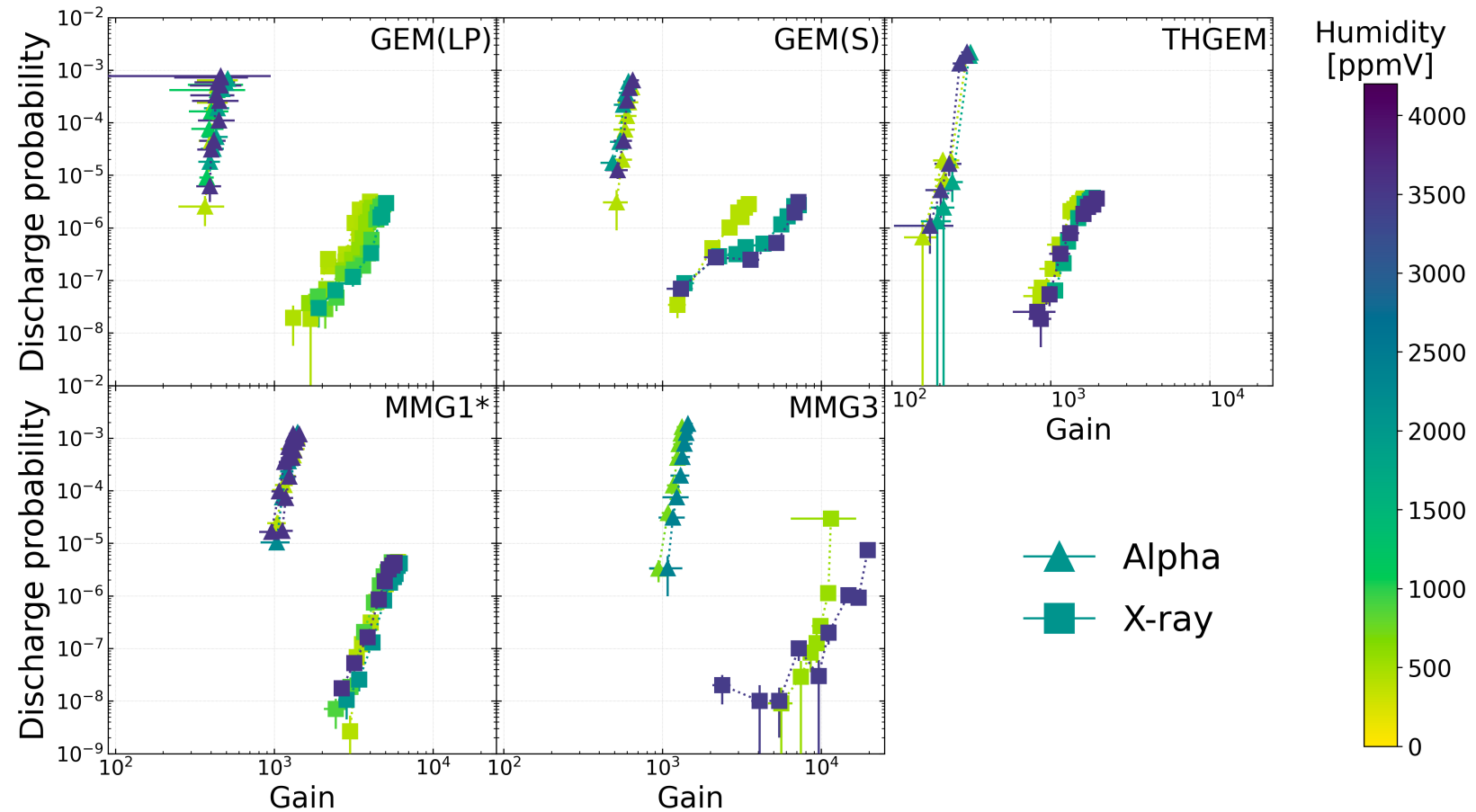
Discharges in MPGDs

- Main source of discharges:
 - Exceeding the critical charge limit (typically 10^6 - 10^7 e) in the amplification region
 - Development of a streamer
 - Resulting in a spark between the electrodes, harmful to the detector
- Spurious discharges:
 - Appears even without the radiation source
 - Due to local field enhancement around electrode defects, sharp edges, etc.
 - These studies: only (spurious) spark discharges considered
- Influence of geometry, source, gas composition studied
 - Effect of humidity contamination inconclusive^{1,2}



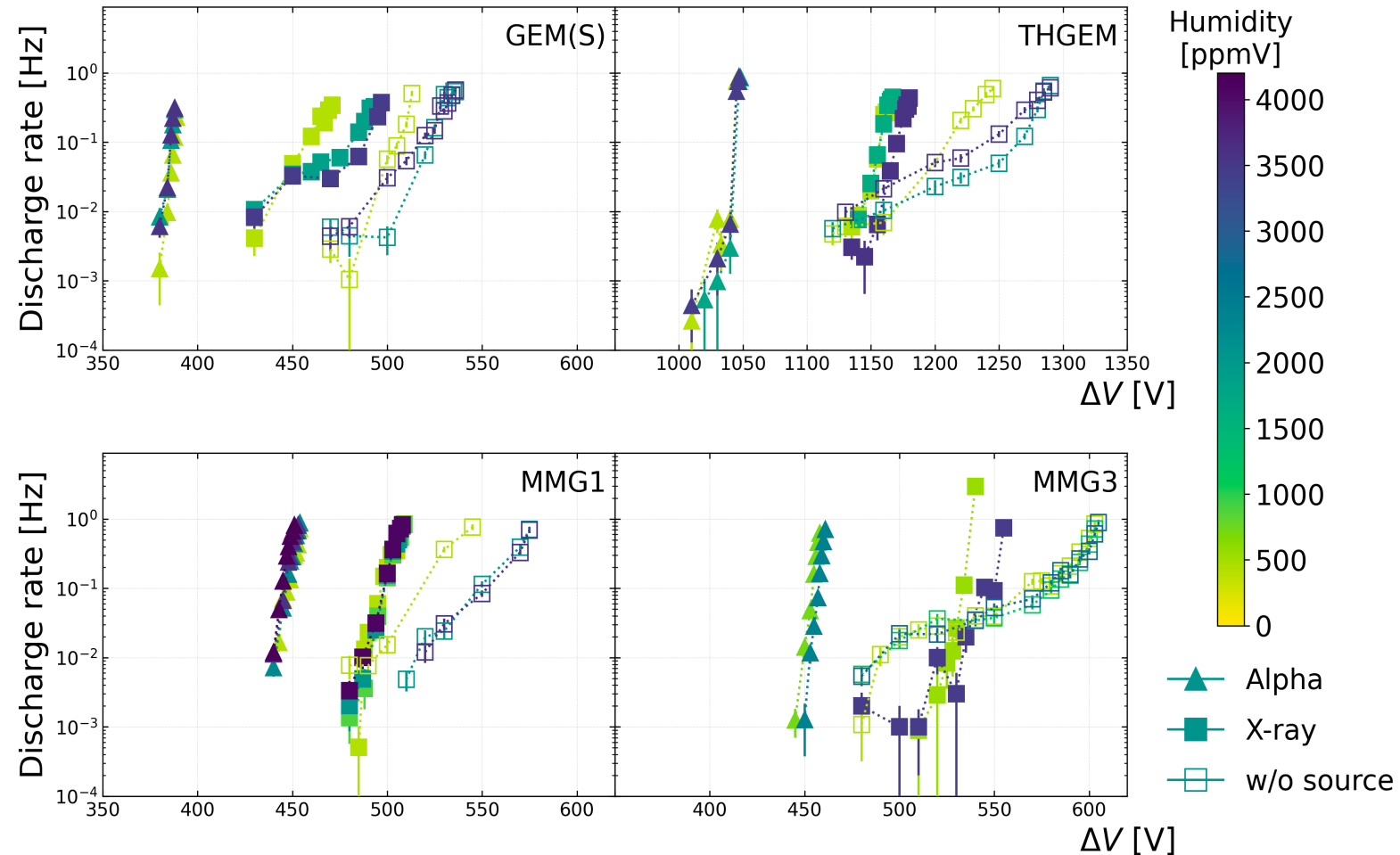
Discharge studies

- Discharge probability as a function of gain
- No hierarchy observed with the alpha source
- Discharge limits (Q_{crit}) not affected by the water content
- Slight influence of humidity on discharge stability is only observed for the GEM operated at higher gains with the iron source



Discharge studies

- Discharge rate without a radiation source
- When operating the detector w/o a source, the discharges appear at much higher voltages/gains, where other effects play a role (defects, field emission, charge-up of insulating layers, ...)
- **Improved discharge stability** at the highest voltages when adding water vapor to the gas
- **Humidity helps to reduce spurious discharges** related to electrode defects or charging up of the insulating layers

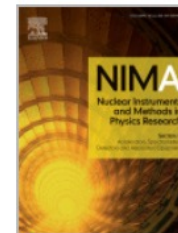


- **No deteriorating effects of humidity observed in the performance, in 0-5000 ppmV humidity range (up to 20% RH max!)**
 - Gain, energy resolution, charging up
- **Adding trace amount of water vapor to the gas mixture improves the discharge stability at the highest fields**
 - No influence of humidity on the critical charge limits is observed based on the alpha measurements
 - Reduction in the rate of spurious discharges related to electrode defects or charging-up of the insulating layers observed



Nuclear Instruments and Methods in Physics
Research Section A: Accelerators, Spectrometers,
Detectors and Associated Equipment

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Full Length Article

Impact of trace amounts of water on the stability of Micro-Pattern Gaseous Detectors measured in Ar-CO₂ (90-10)

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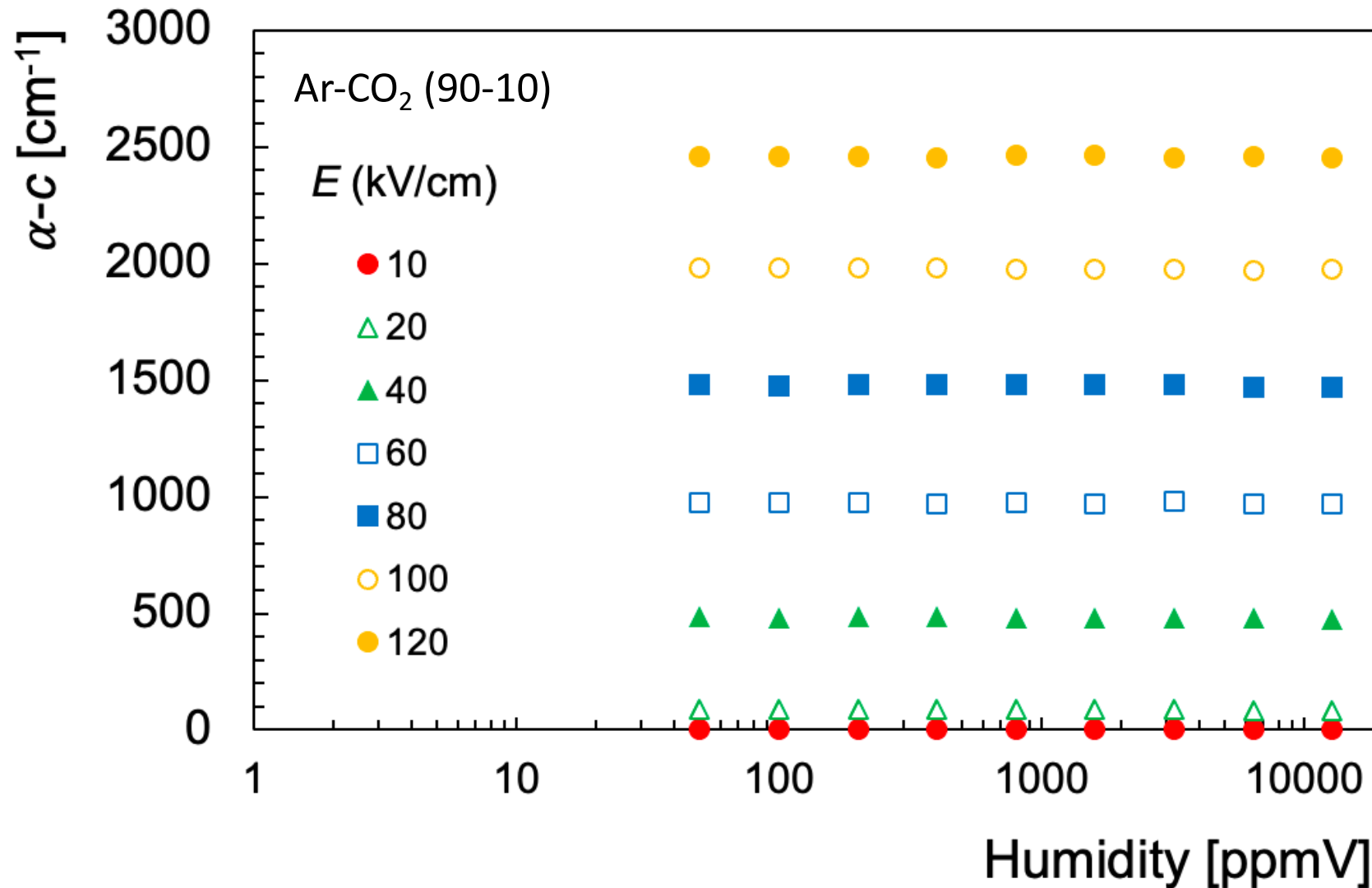
^a Technische Universität München, TUM School of Natural Sciences, Garching, Germany

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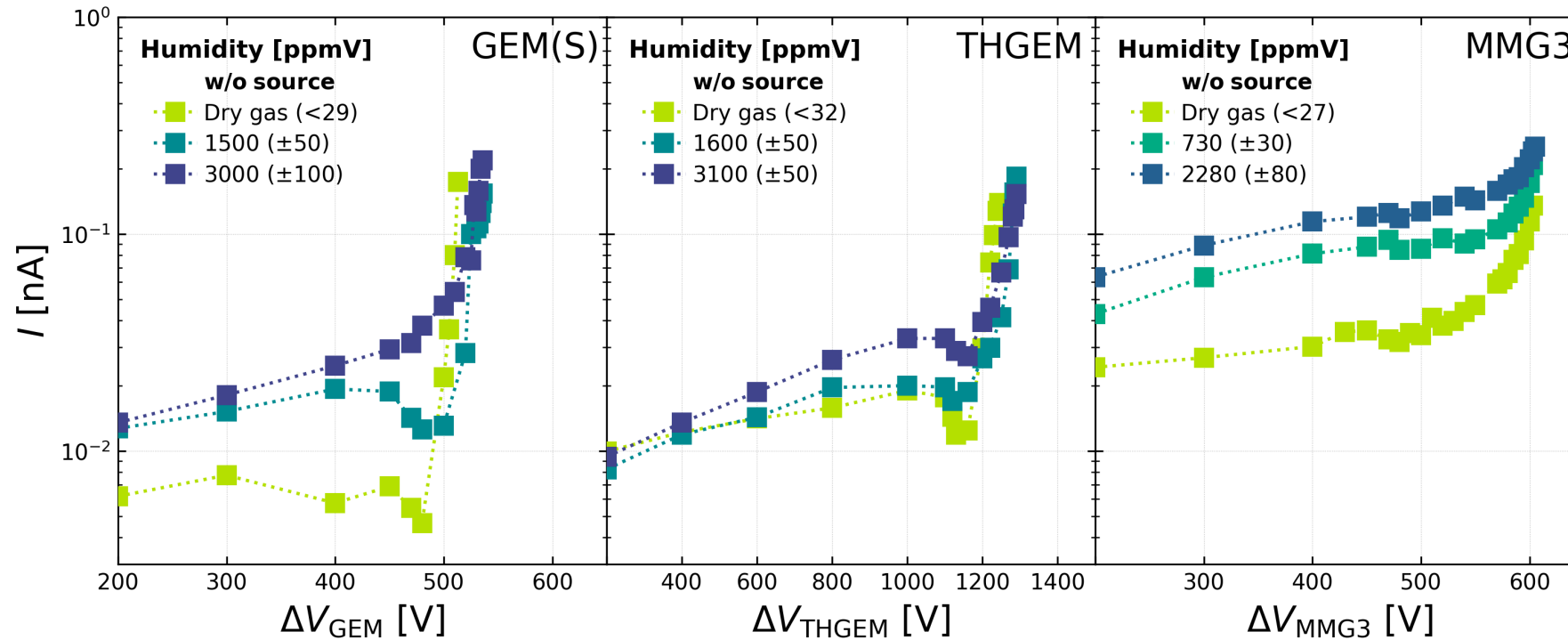
^c Facility for Antiproton and Ion Research in Europe GmbH (FAIR), Darmstadt, Germany

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Magboltz simulations



Leakage currents

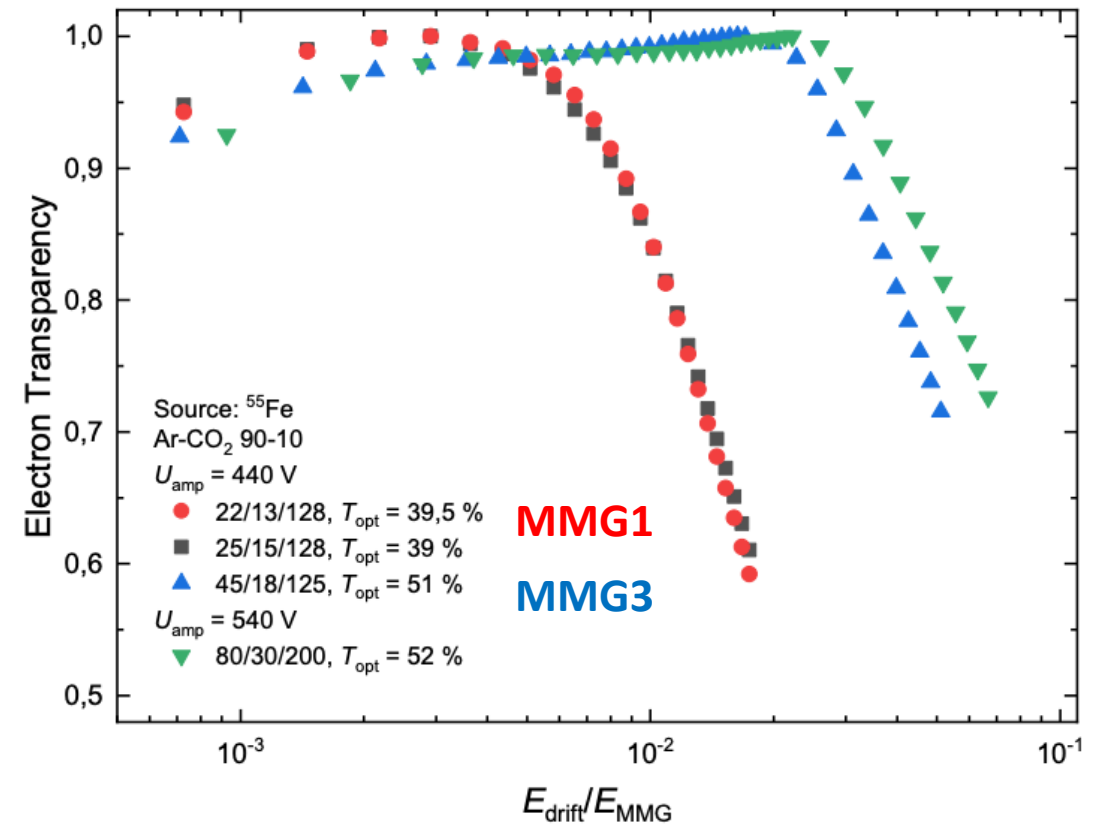
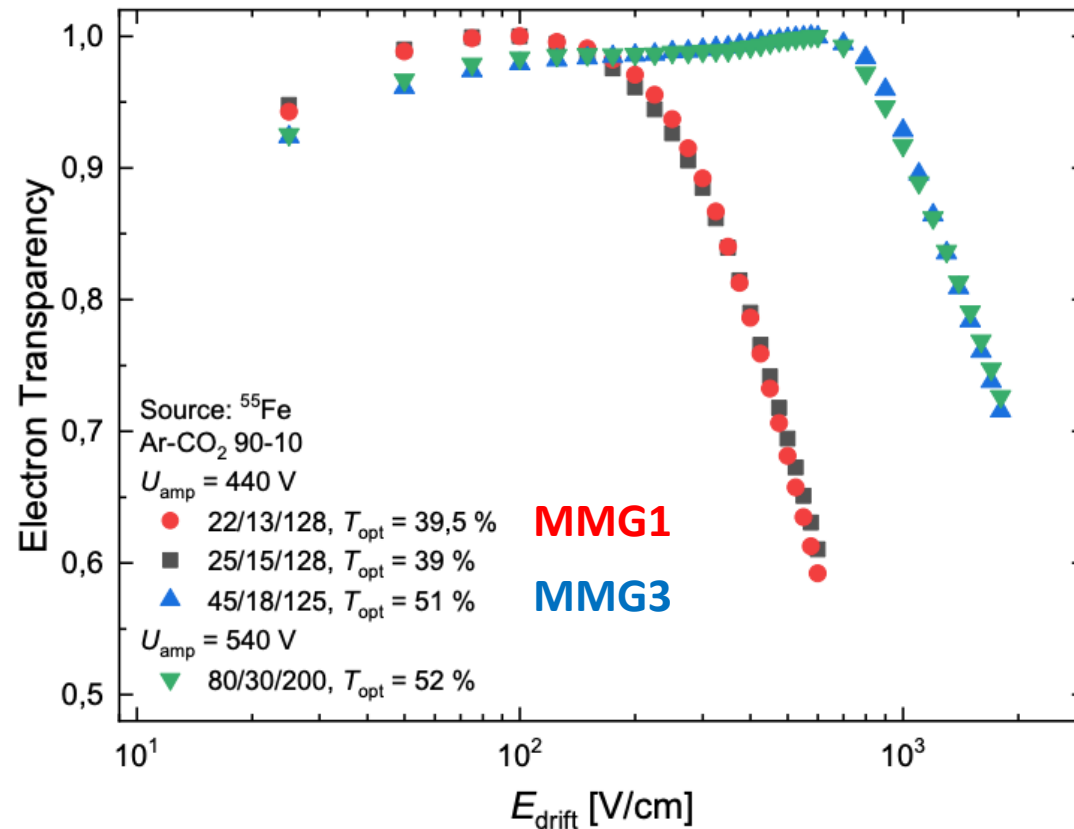


- Measurement w/o a radioactive source, clear dependency on gas humidity
- At very high voltages (exceeding operational range), the current-to-voltage relation deviates from linearity
- In this regime influence of humidity is significantly reduced or even inverted
- In the HV range of this work, I_{leak} at the level of tens of pA

MMG transparency

- Electron transparency scales with the optical transparency
- Dependence on wire thickness less relevant

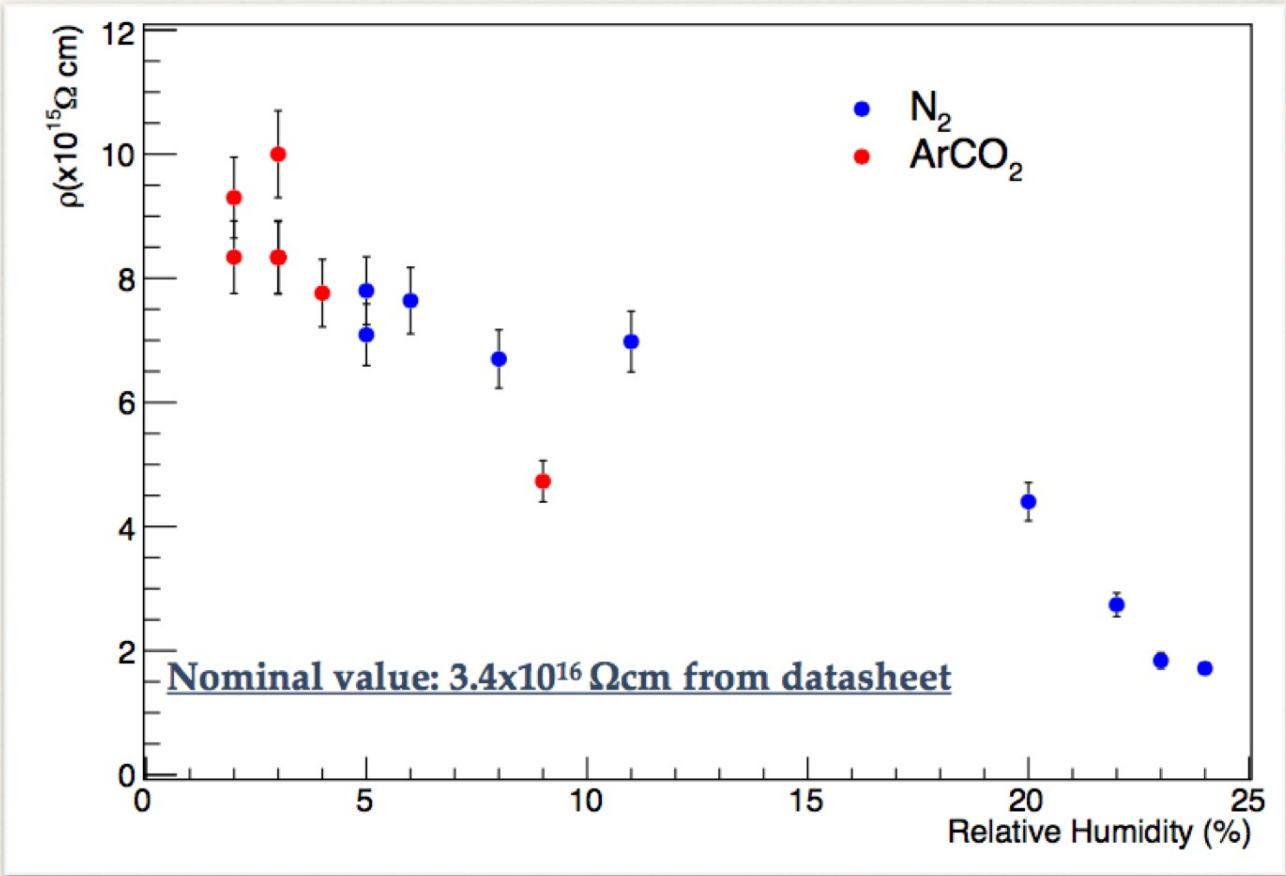
MPGD	(TH)GEM				Micromegas				Optical transparency [%]	Producer
	d_{ins} [μm]	d_{Cu} [μm]	$\varnothing$ [μm]	Pitch [μm]	z_{MMG} [μm]	d_{wire} [μm]	a_{wire} [μm]	Density [LPI]		
GEM (S)	50	5	50/70	140	–	–	–	–	24	CERN
GEM (LP)	50	5	50/70	280	–	–	–	–	6	CERN
THGEM	400	35	400	800	–	–	–	–	24	Eltos S.p.A.
MMG1	–	–	–	–	128	13	22	730	40	CERN
MMG3	–	–	–	–	128	18	45	400	51	CERN



Resistivity Vs Humidity

Drying the test board with ArCO_2 or with N_2 gives the possibility to gain **one/two order of magnitude in resistivity** with respect to the initial value

These results are coherent with what has been observed immediately after the cooking procedure



The measured lower resistivity can be explained with the absorption of humidity on part of the coverlay material