Discharge behaviour of resistive Micromegas

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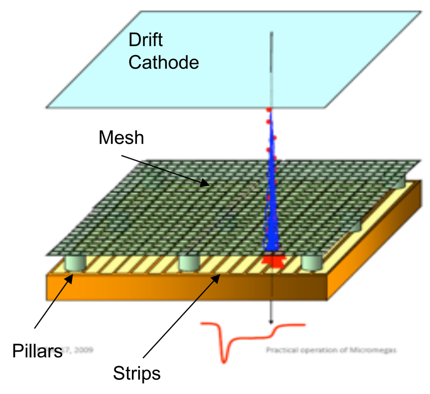
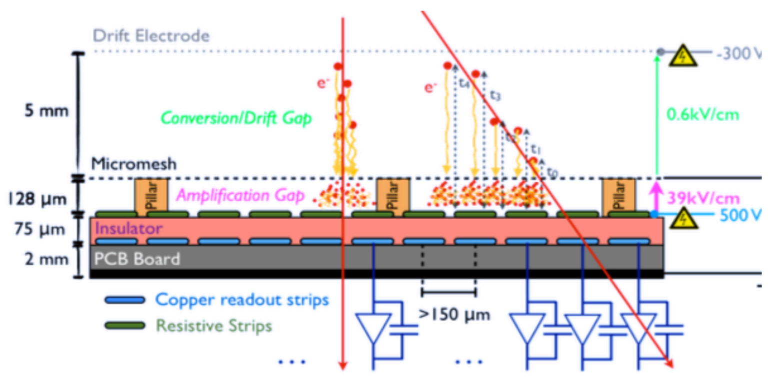
Introduction

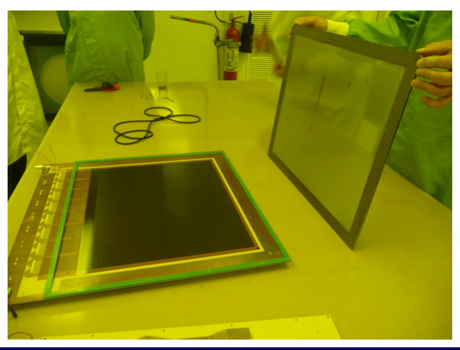
The Micromegas detector bases its operation on the large charge amplification that occurs in a very thin region, 100 μm thick, between the mesh and the readout electrodes. The thinness of this region, however, makes the detector particularly sensitive to discharges, especially in presence of high particles rate, a problem that has been greatly mitigated in the last years, during the development phase of the Micromegas for the ATLAS experiment, introducing a resistive protection on the readout electrodes. These resistive strips in fact acts reducing locally the electric field and then quenching discharges. An excessive increase in the amplification field, however, may anyway cause sparks thus limiting the maximum operating voltage of the detector. This voltage also depends on the geometry of the electrodes and in particular from that one of the mesh plane. We present the measurements made with meshes of different wire diameter, weft opening and constructive method in order to find the one that ensures the highest stability to the detector.

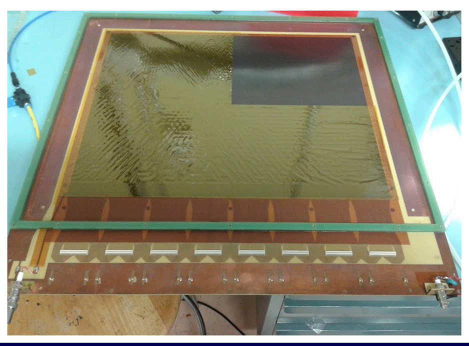




The test detector: Exchangeable Mesh (ExMe)

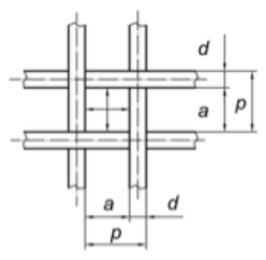
- The detector we used for these measurements has been designed and built at CERN in 2014 (J.Wotschack, P. Iengo, R. De Oliveira, G. Sekhniaidze) to help selection of mesh type and pillar spacing for the ATLAS NSW project
- The mesh plane is stretched on an iron frame → easy to replace
- 4 sectors with different pillar spacing (5/7/8.5/10 mm) but only the one with 7mm pillar spacing is active; other sectors have been passivated with 12.5 μm kapton film on top of the pillars (circular, 300μm diameter)
- Otherwise similar to ATLAS MM (screen-printed resistive lines on Kapton, same width/pitch as ATLAS)

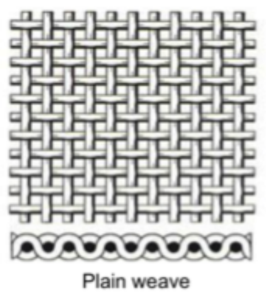




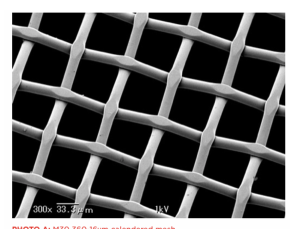
Tested meshes

Type (d-a μm)	Comment
30-71 C	Calendered
18-45 C	Calendered
18-45 N	Non calendered
30-71 P	Non calendered, Hand polished
28-50 N	Non calendered
30-80 C	Calendered

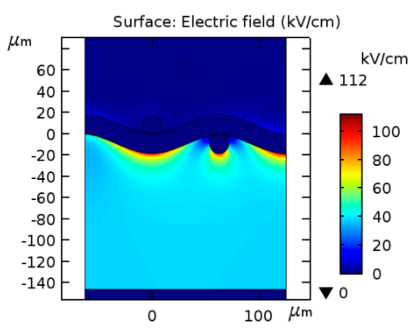




Calendered mesh



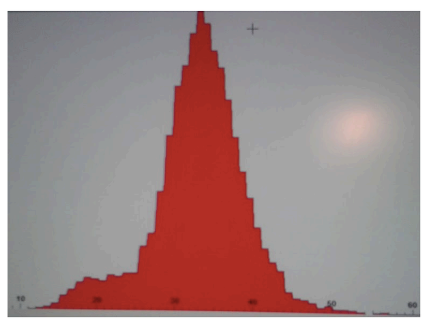
Mesh wires shape influences the field shape: there will be small regions with very high electric field, presumably responsible for the HV stability of the detector, while the average voltage will mostly affect the gain



Courtesy of D. Sankar Bhattacharya [1]

Test procedure

- HV_{ampl} scan in Ar:CO2 (93:7), with/out ^{55}Fe source measuring voltage and current in the amplification region, I_{ampl};
- Gain measurement, from the ^{55}Fe Auger peak position (Amptek MCA);
- Rate measurements, from the OR of 128 channels (51.2 mm)
- Irradiated region ~ 2 mm diameter → rate ~ 3 kHz/cm²
- HV_{drift} = 300V (corresponding to maximum of transparency)



Peak position (ADC counts)

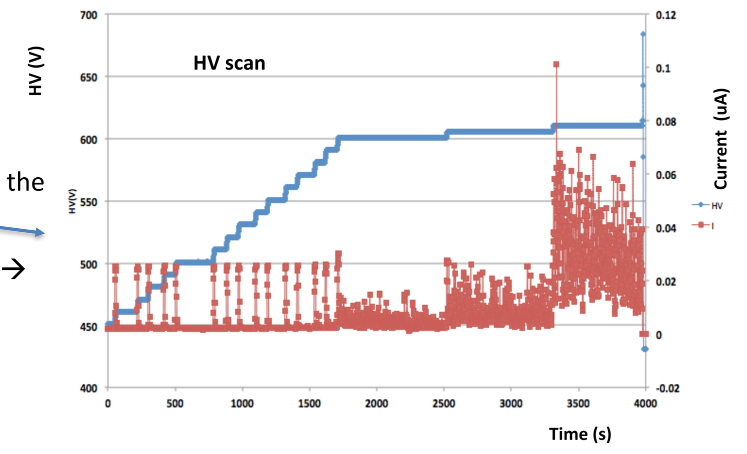
Discharges at breakdown point are triggered by defects/geometry or external dust → crucial to ensure the same level of cleanliness as the detector is opened/closed to replace the mesh

Current values affected by T/P and RH → measurements done trying to keep constant overpressure (few mb) and RH (~3%); RH, P, T measured at the gas output of the detector

HV scan performed w/ and w/o ^{55}Fe source: from 450 V up to the max achievable (600 to 620 V with 5-10 V steps)

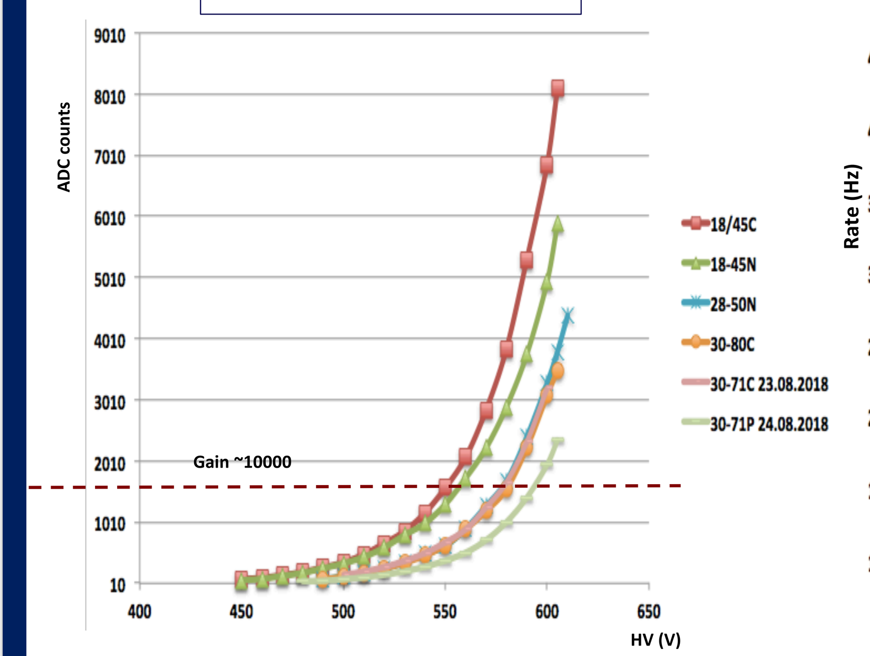
No significant difference in currents measured w/ and w/o source → currents mostly from discharges, not from 'signals'

Current value measured every sec



Results with different mesh planes

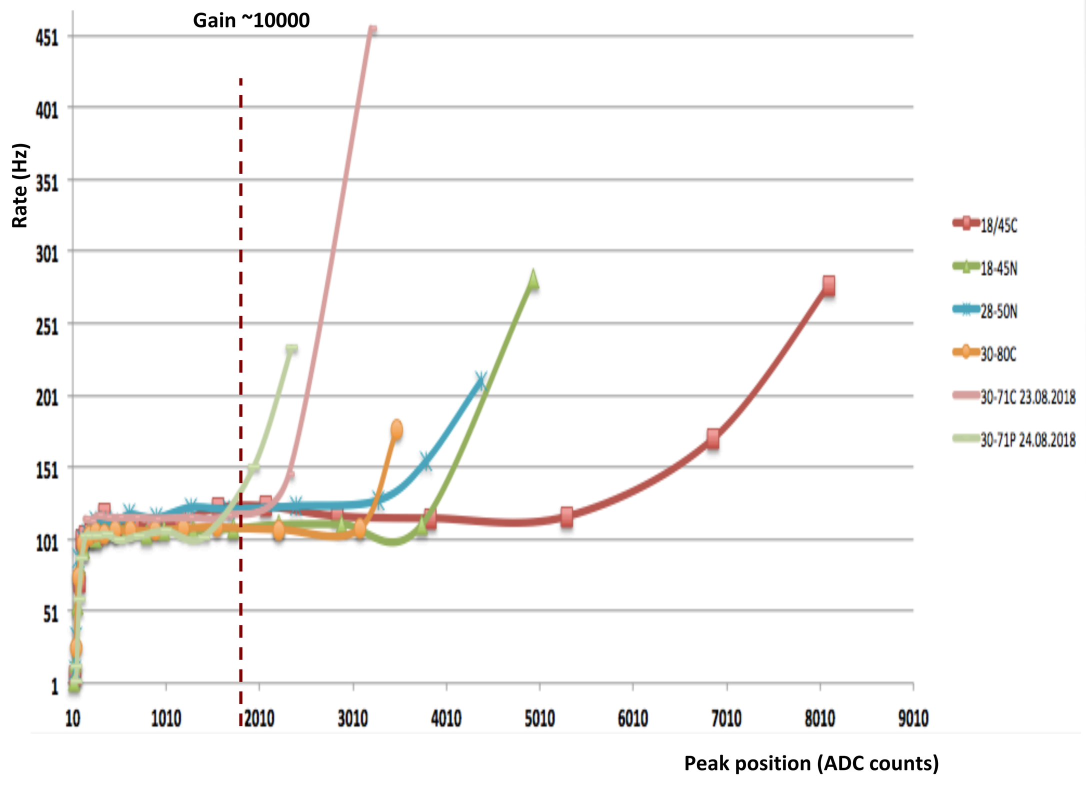
Gain in A.U. (MCA channel)



Gain shows an increase at smaller wires diameter and improved flatness quality (calendering)

Less clear the behaviour inside the mesh group having 30 μm wire diameter (30-80C, 30-71C, 30-71P)

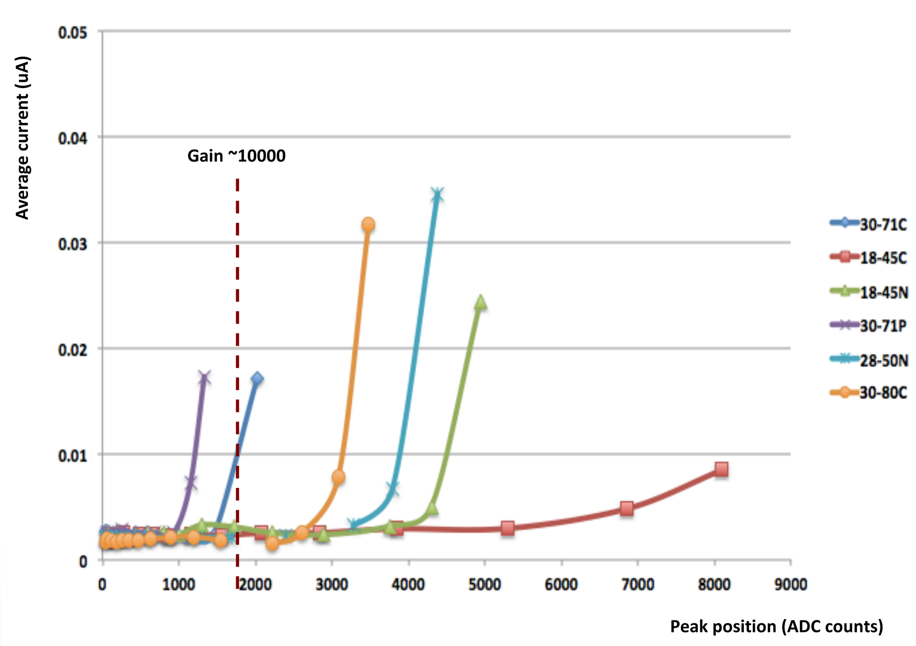
Rate measurements



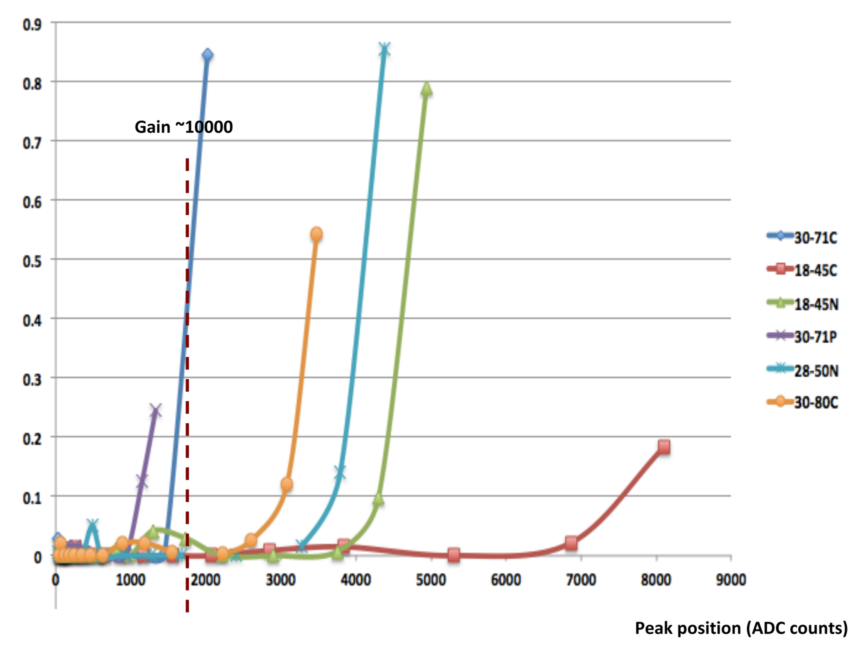
The 'singles rate' of ^{55}Fe seems to jump (due to spikes) later at smaller wires diameter/openings and improved flatness quality

As for Gain, less clear the behaviour inside the mesh group of 30 μm wire diameter

Current measurements, averaged over the period at constant voltage (removing points during transient)



Number of spikes (arbitrarly defined when the current exceeds by more then 10nA the average value at constant voltage)



The relation between Peak position and average current should be linear, so deviation (increasing) of the current from linearity should be due to spikes/discharges.

Average current and number of spikes, shown in the plots, seems to jump later at smaller wires diameter/openings and improved flatness quality

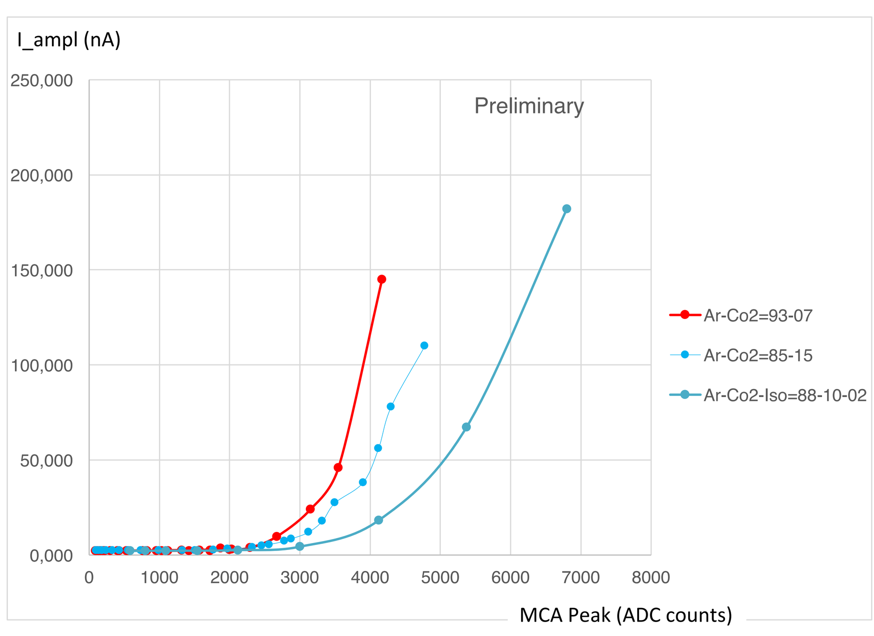
Less clear the behaviour inside the mesh group having 30 μm wire diameter (30-80C, 30-71C, 30-71P)

Results with different gas mixtures

We also started to test different gas mixture, fixing the mesh to the best we have (18-45C)

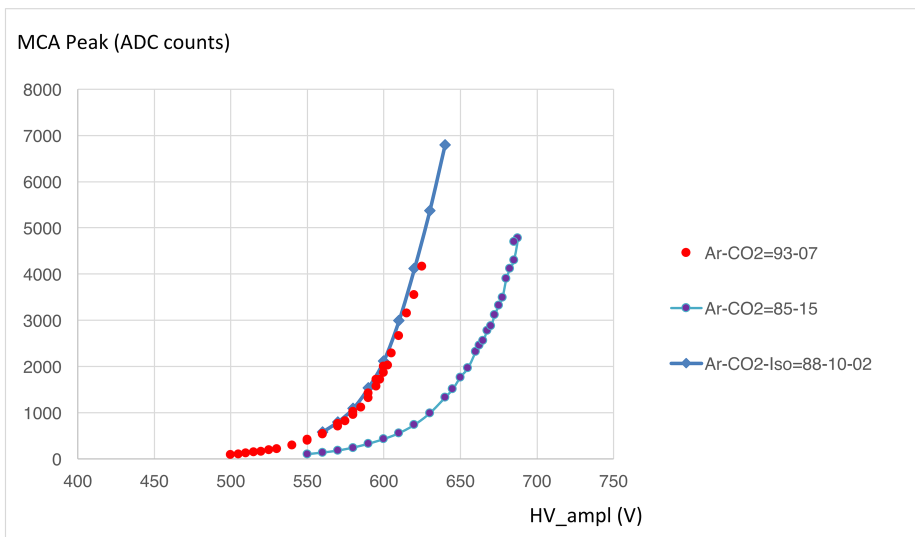
Stability increases with the CO2 percentage, in the Ar-CO2 mixtures

Also adding a bit of Isobutane to Ar-CO2, improves the discharge behaviour

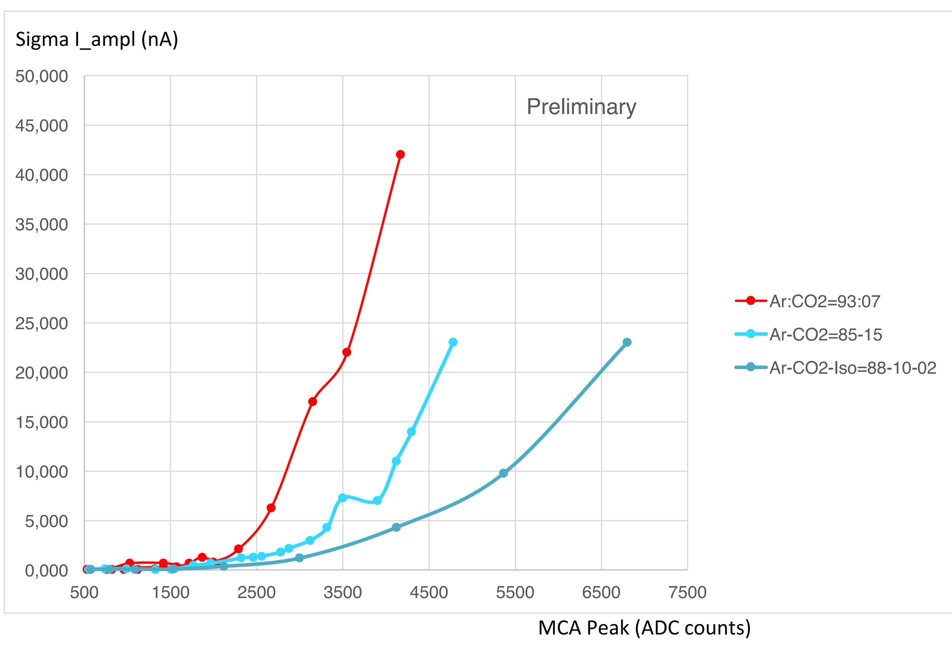


Going from Ar-CO2=93-07 to Ar-CO2-Iso=88-10-02 and fixing, for ex., a threshold at 25nA, we gain ≈10 V on the maximum reachable HV_{ampl}

Together with the average current (I_ampl, top-left plot) also the sigma of its distribution (Sigma I_ampl, bottom-right plot) increases with voltage due to spikes/discharges



Gain of Ar-CO2=93-07 and Ar-CO2-Iso=88-10-02 are very similar (the number of primary electron produced in the two different mixtures vary within 1%)



Conclusions and outlooks

We have studied the impact of mesh geometries and (few) gas mixtures on the HV stability of MM resistive detectors finding:

1. Clear dependence of stability on mesh geometry:
   - Smaller openings between wires produce a more uniform electric field and therefore greater stability;
   - Thinner wires are less bent in the mesh structure, thus allowing to reach a higher gain when compared to thicker wires;
   - Calendered meshes perform better;
2. Experimental results in (qualitative) agreement with expectations:
   - 18-45 C found to be the best tested mesh
   - Less clear the behaviour among the meshes with 30 μm wire diameter (30-71C worst than 30-80C, defects?)
3. More CO2, in Ar-CO2 mixtures, improves stability
4. Adding small quantities (non flammable mixture) of Isobutane, does even better
5. Other mesh planes and gas mixtures are in preparation to continue tests

Acknowledgments and References

We would like to thank:

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- E. Oliveri and the whole RD51 Collaboration for support with the tests at the Gas Detector Development (GDD) Laboratory at CERN,
- R.Hertenberger for the many usefull discussions.

References:

[1] https://indico.cern.ch/event/756297/contributions/3143807/attachments/1722095/2780629/Study_MicroMesh_deb_RD51.pdf