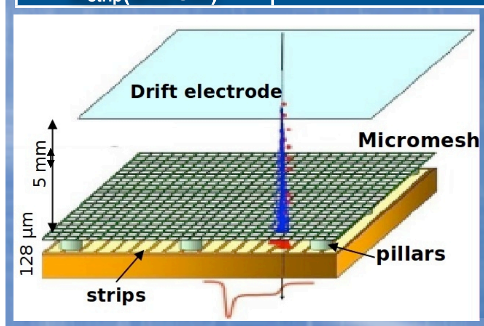
Development and Performance of Spark-Resistant Micromegas Detectors

George Iakovidis [a], Konstantinos Karakostas [a], Matthias Schott [b]
On behalf of MAMMA Collaboration
[a] National Technical University of Athens, [b] CERN

The Muon ATLAS MicroMegas Activity (MAMMA) focuses on the development and testing of large-area muon detectors based on the bulk-Micromegas technology. These detectors are candidates for the upgrade of the ATLAS Muon System in view of the luminosity upgrade of Large Hadron Collider at CERN (sLHC). They will combine trigger and precision measurement capability in a single device. A novel protection scheme using resistive strips above the readout electrode has been developed. The response and sparking properties of resistive Micromegas detectors were successfully tested in a mixed (neutron and gamma) high radiation field, in a X-ray test facility, in hadron beams, and in the ATLAS cavern. Finally, we introduced a 2-dimensional readout structure in the resistive Micromegas and studied the detector response with X-rays.

Resistive Chambers

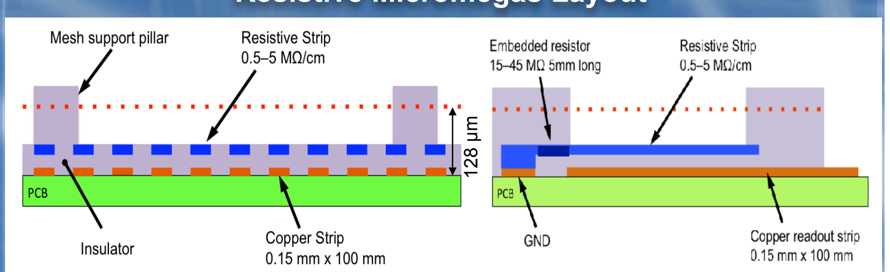
Resistivity/Chamber	Micromegas R11	Micromegas R12	Micromegas R13	Micromegas R16
R_{GND}(MΩ)	15	45	20	55
R_{strip}(MΩ/cm)	2	5	0.5	35

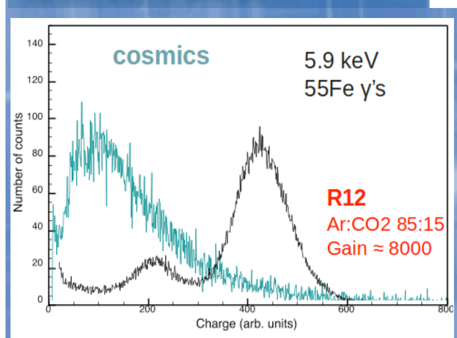


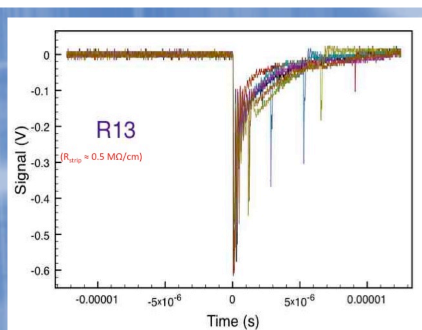
The resistive Micromegas developed by MAMMA group has separate resistive strips rather than a continuous resistive layer to avoid charge spreading across several readout strips and to keep the area affected by a discharge as small as possible. The resistive strips are separated by an insulating layer from the readout strips and individually grounded through a large resistance. The Micromegas structure is built on top of the resistive strips. It employs a woven stainless steel mesh which is kept at a distance of 128 µm from the resistive strips by means of small pillars.

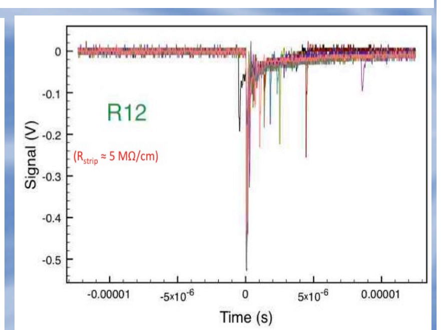
Above the amplification mesh, at a distance of 4 or 5 mm, another stainless steel mesh serves as drift electrode. Its lateral dimensions are the same as for the amplification mesh.The detectors have been operated with three Ar:CO_2 gas mixtures, with 80:20, 85:15 and 93:7.

Resistive Micromegas Layout



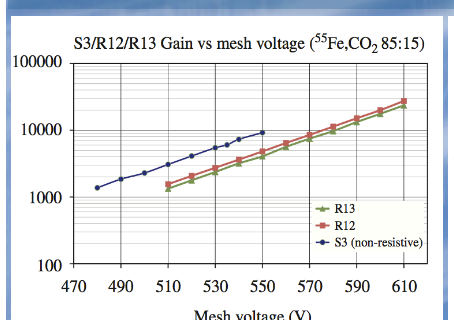


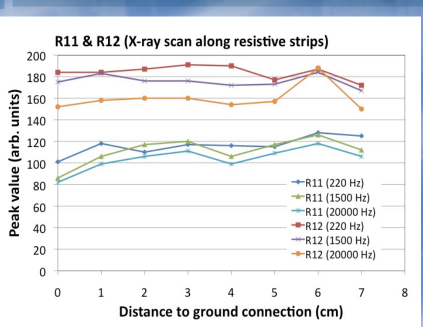


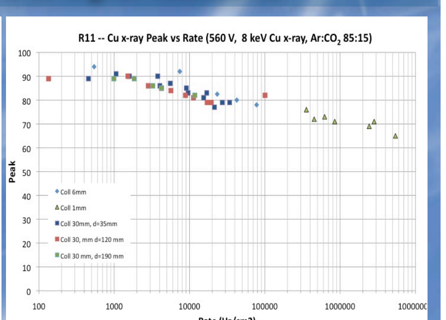


Cosmic and Fe(55) source spectra from the resistive Micromegas Chamber R12.

Typical spark signals in a Micromegas with resistive strips. The spark signal is reduced by a factor of 1000 compared to a standard Micromegas. Spark signals are fast (<100 ns), recovery time is a few µs, slightly shorter for Micromegas chamber R12 which has strips with higher resistance.







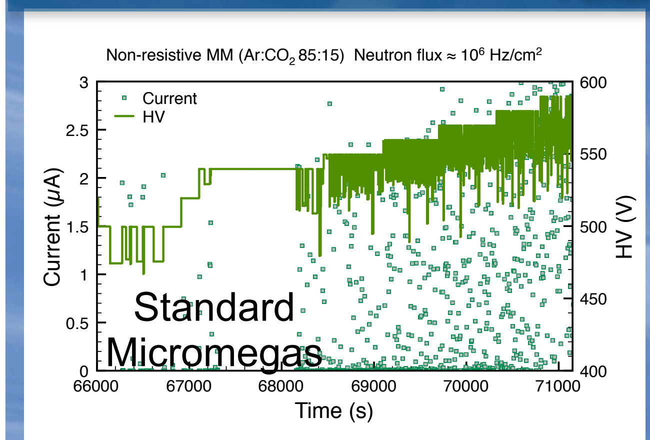
Gain of the resistive R12 and R13 Micromegas chambers compared to the non-resistive S3 chamber for a gas mixture Ar:CO_2 (85:15).

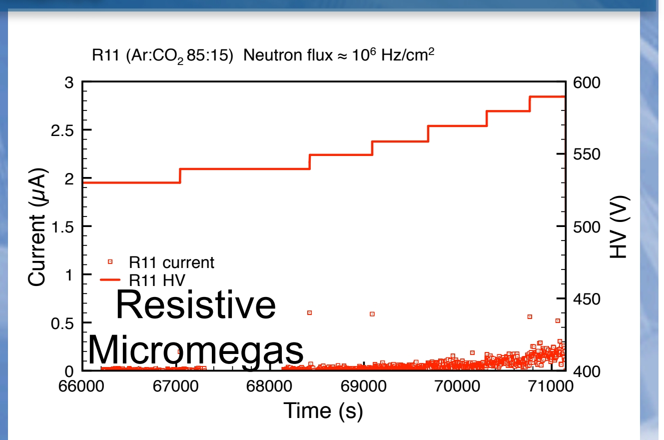
Uniformity along the strips of the resistive R11 and R12 Micromegas chambers for different X-Ray rates.

Response of the resistive R11 Micromegas chamber as a function of rate.
Rate capability > 5 MHz/cm^2.

Micromegas in Neutron beam

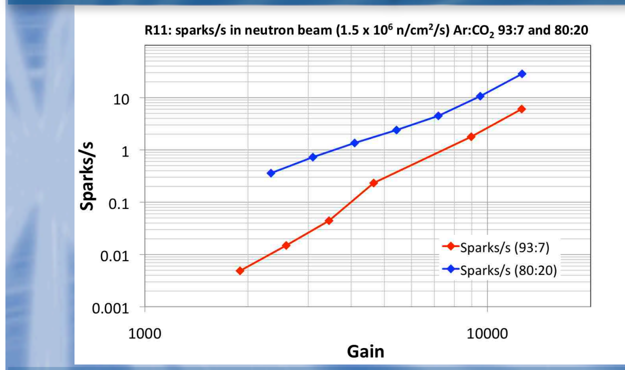
Performance

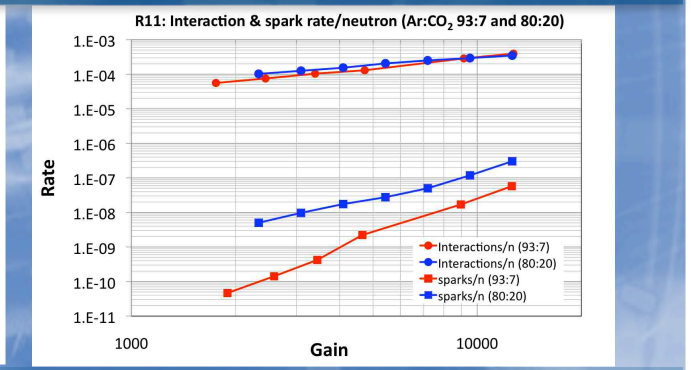




Performance of a standard Micromegas chamber versus a resistive one. On the standard Micromegas the HV break-downs and currents exceeding several µA occur already for gains of order 1000–2000. The resistive Micromegas showed no HV drops and small spark currents up to gas gains of 2 x 10^4.

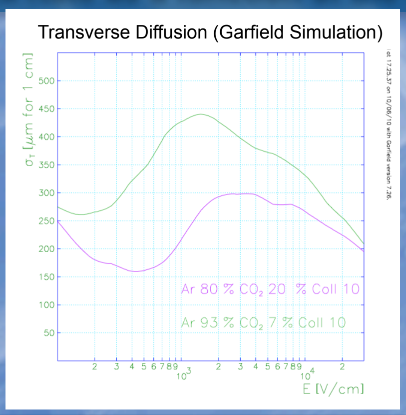
Spark Rates in 5.5 MeV Neutron Beam

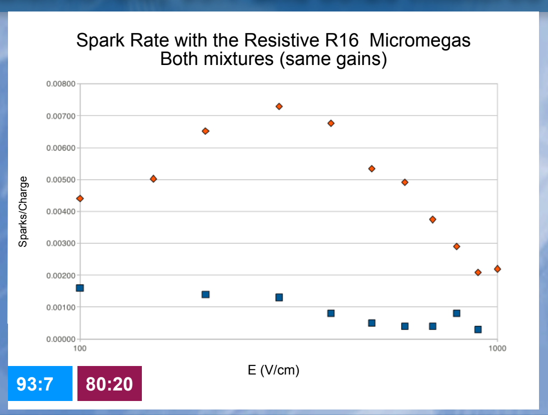




Only a few sparks per second were observed in a beam with 1.5x10^6 neutrons/cm^2/s. The spark rate was found four times higher with the 80:20 compared to the 93:7 Ar:CO_2 gas mixture. The neutron interaction rate was found independent of the gas. The spark rate/n was a few 10^{-8} for gain 10^4.

Spark Rate as a function of the drift field with Ar:CO_2 93:7 and 80:20 mixtures



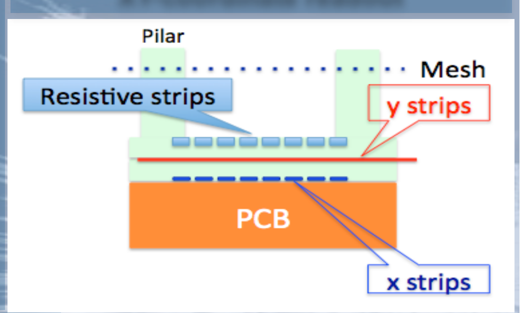


By changing the drift field the transverse diffusion changes as shown in the Garfield simulation above. The observed spark rate follows nicely the change in transverse diffusion, larger diffusion results in lower spark rate. This explains the four times higher spark rate observed with the Ar:CO_2 80:20 gas mixture for the same drift field (shown on the Spark Rate plot above).

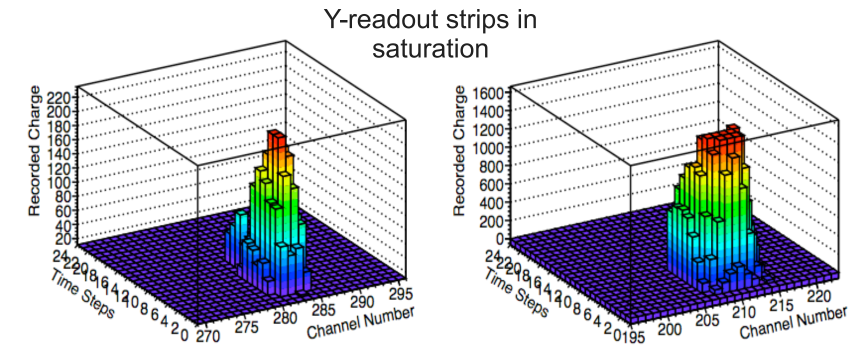
Performance of resistive-strip Micromegas detectors with two-dimensional readout

The readout strips in x-direction are placed in parallel to the resistive strips, while the readout-strips in y-direction are placed perpendicular. All strips are separated by isolation material. The signal on the readout strips is capacitively coupled to resistive strips. Hence it is expected that the induced signal on the x-strips is smaller compared to the signal on the y-readout strips due to the larger distance to the resistive strips and screening effects.

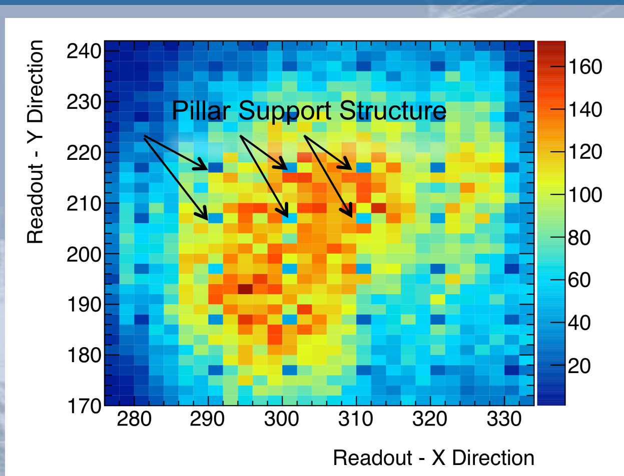
Sketch of Micromegas layout with XY-coordinate readout



Typical Event Display

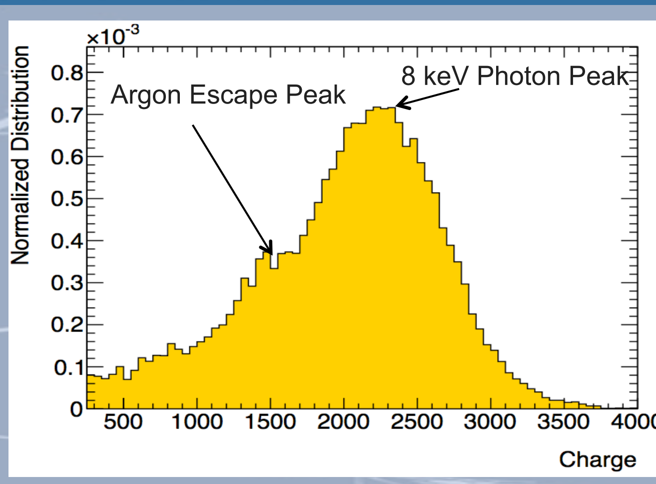


Event taken at X-Ray test facility (8 keV):The maximal recorded charge per channel is significantly larger on the y-readout strips than on the x-direction. In the chamber measured here the x and y strips had the same width and pitch. Future Micromegas layouts will equalise the signal strength by adjusting the pitch and the strip-width of the second strip layer.



Hit Distribution of X-ray test run

The photon interactions produce very localised signals and therefore we expect a reduced rate of reconstructed events, if the interaction happens close to a support pillar. The plot above shows the recorded hit-distribution for one of the test-chambers with two-dimensional readout. The pillar support structures are clearly seen as regions with lower recorded rates.



Distribution of the sum of all charges. The 8 keV photon peak and the argon escape peak (5 keV), can be seen and are indicated.

ATLAS EXPERIMENT