New developments in spark-protected micropattern detectors

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In the last couple of years several groups, in the framework of RD51collaboration, tried to develop spark protective micropattern gaseous detectors

This activity, probably, was triggered by the article of *R. Oliveira, NIM A576, 2007, 362*, who developed first spark protective micropattern detector-GEM with resistive electrodes instead of metallic one

Nowadays, beside **GEM** several other resistive micropattern detectors were successfully developed by our and other groups:

WELL/CAT detector (*A. Di Mauro, et al., 2006 IEEE Nucl. Sci. Conf. Record 6, 2006, 3852.V. Peskov, arXiv:0906.5215, 2010, Hugo Natal da Luzet et al., : report on the R5iMini-week, CERN,Jan 18, 2011)*,

resistive mesh detectors (*R. Oliveira et al.,, IEEE Trans. Nucl. Sci., 57,2010, 3744)*

and, of course, **Micromegas** (*R. Oliveira et al.,, IEEE Trans. Nucl. Sci., 57,2010, 3744, T. Alexopoulos J.Burnens, et al.,. NIM. A 640, 2011, 110)*

***See also recent reports** at the 2nd Intern. Conf. on Micro Pattern Gaseous Detectors,*

August 2011, Kobe, Japan (to be published in JINST)

(http://ppwww.phys.sci.kobeu.ac.jp/%7Eupic/mpgd2011/abstracts.pdf)

Today we will present the latest progress of our group in development spark-protected MPGDs, namely:

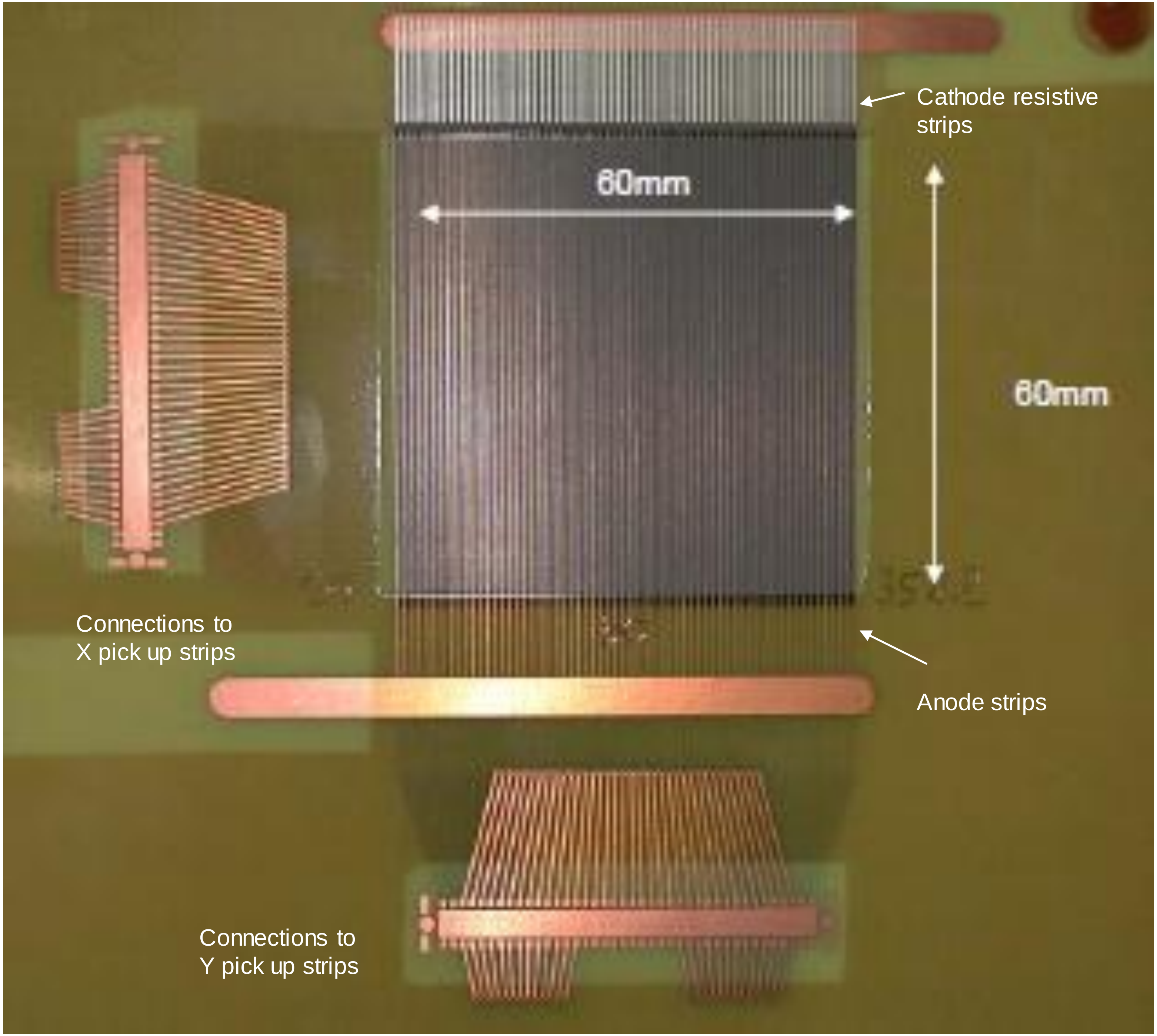
1) 2D sens. R-MSGC,
2) Hybrid detectors: R-MSHD,R-COBRA, and
3) R-Microdot

As will be shown these detector have several advantages and can be **optimal** for some specific applications, for example:

cryogenic detectors and photodetectors

1) 2-D sensitive R-MSGC

At the 7th RD-51 collaboration meeting, CERN, April 13-15, 2011 we showed a photograph of a just developed by Rui 2D sensitive R-MSGC, but no tests of this detector were done at this moment



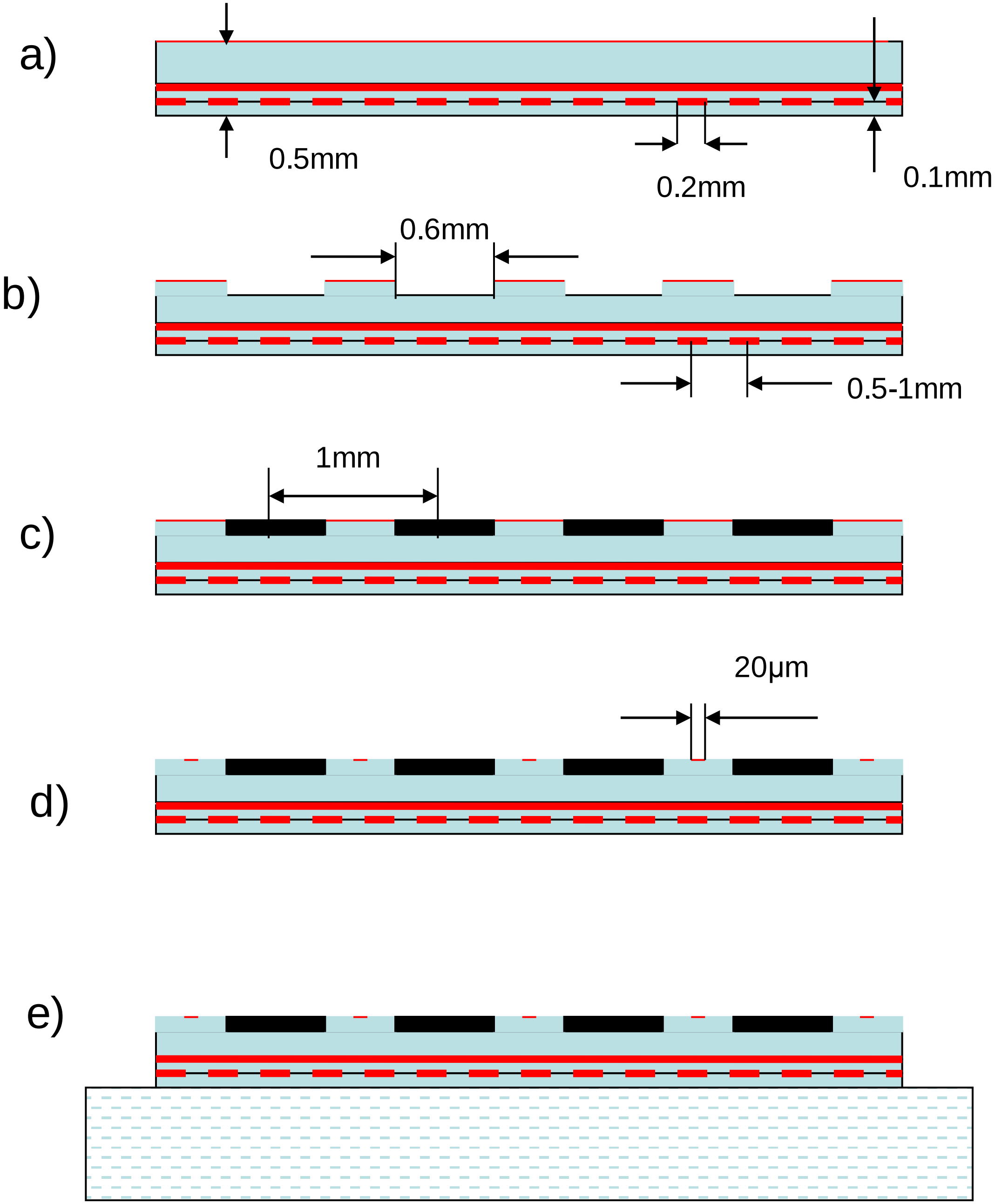
Cathode resistive strips

Connections to X pick up strips

Anode strips

Connections to Y pick up strips

Manufacturing of 2-D sensitive R-MSGC



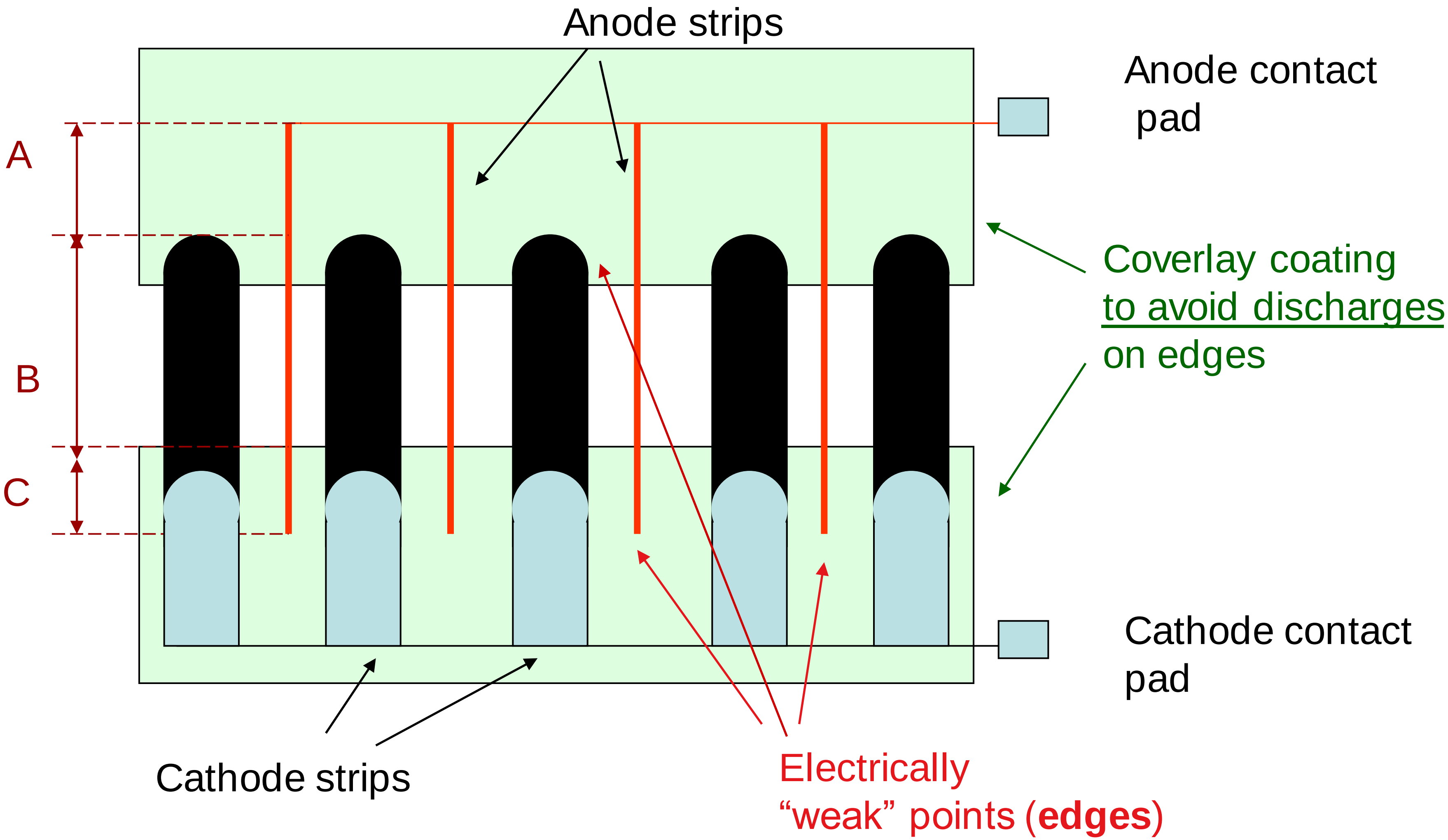
PCB with 5µm thick Cu layer on the top and two layers of readout strips (oriented perpendicularly) on the bottom

Milled grooved 100 µm deep and 0.6 µm wide, pitch 1mm.

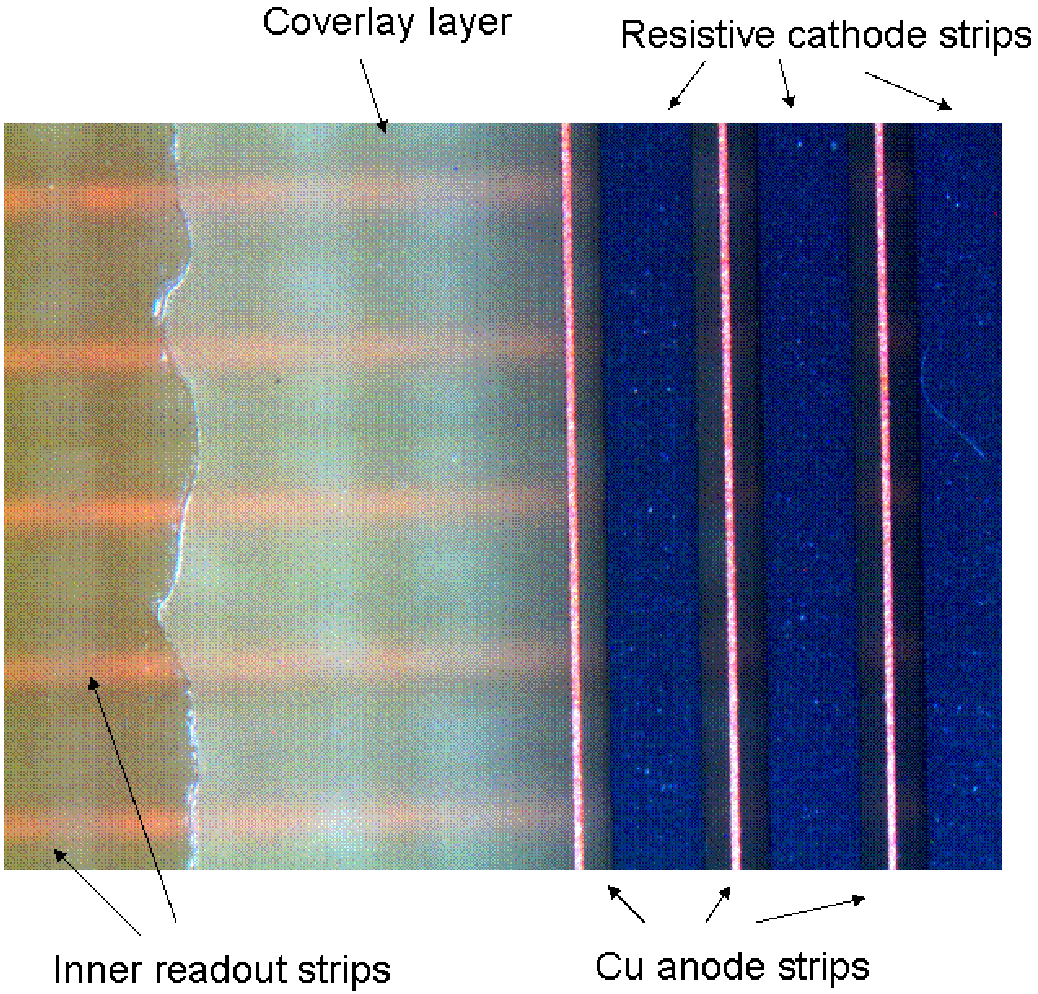
The grooves were then filled with resistive paste (ELECTRA Polymers

By a photolithographic technology Cu 20 µm wide strips were created between the grooves

Finally the entire detector was glued on a supporting FR-4 plate



The new R-MSGC thus has the following three features:
1) very this metallic anode strips, 2) resistive cathode strips manufactured by filling grooves with a resistive paste, 3) a Coverlay layer to protect the edges against surface discharges. These three features allow the detector to operate at gas gains as high as it was achieved in the past with metallic MSGC manufactured on a glass substrate



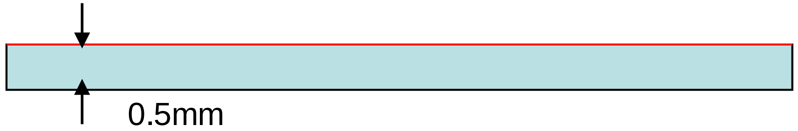
A magnified photograph of the R-MSGC showing the left side (see figure 3) of its active area near its edge. Cu anode strips, resistive cathode strips and the readout strips manufactured in the inner layer of the PCB (under the anode and the cathode strip) are clearly seen as well as the Coverlay layer.

2)Hybrid detectors

(R-MHSP and R-COBRA)

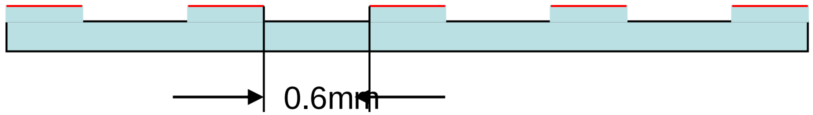
Manufacturing procedures of the R-MHSP

a)



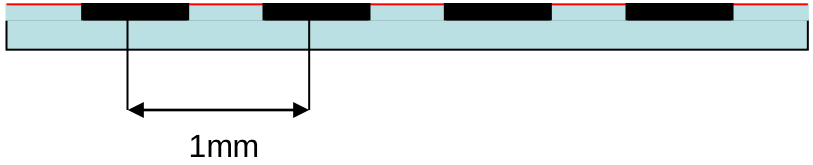
PCB with 5µm thick Cu layer

b)



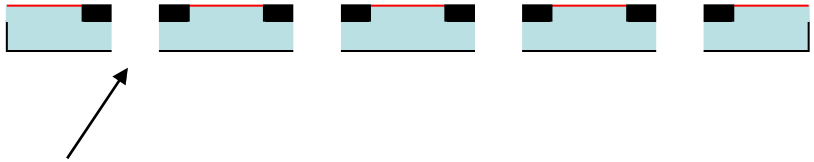
Milled grooved 100 µm deep and
0.6 µm wide, pitch 1mm.

c)



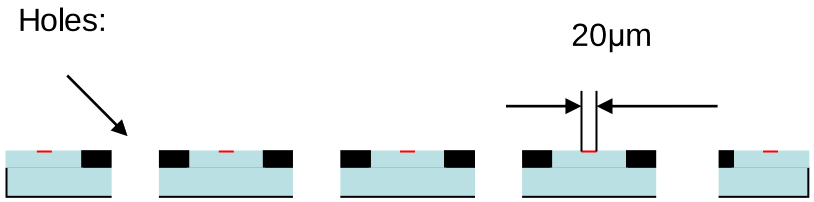
The grooves were then filled with
resistive paste

d)

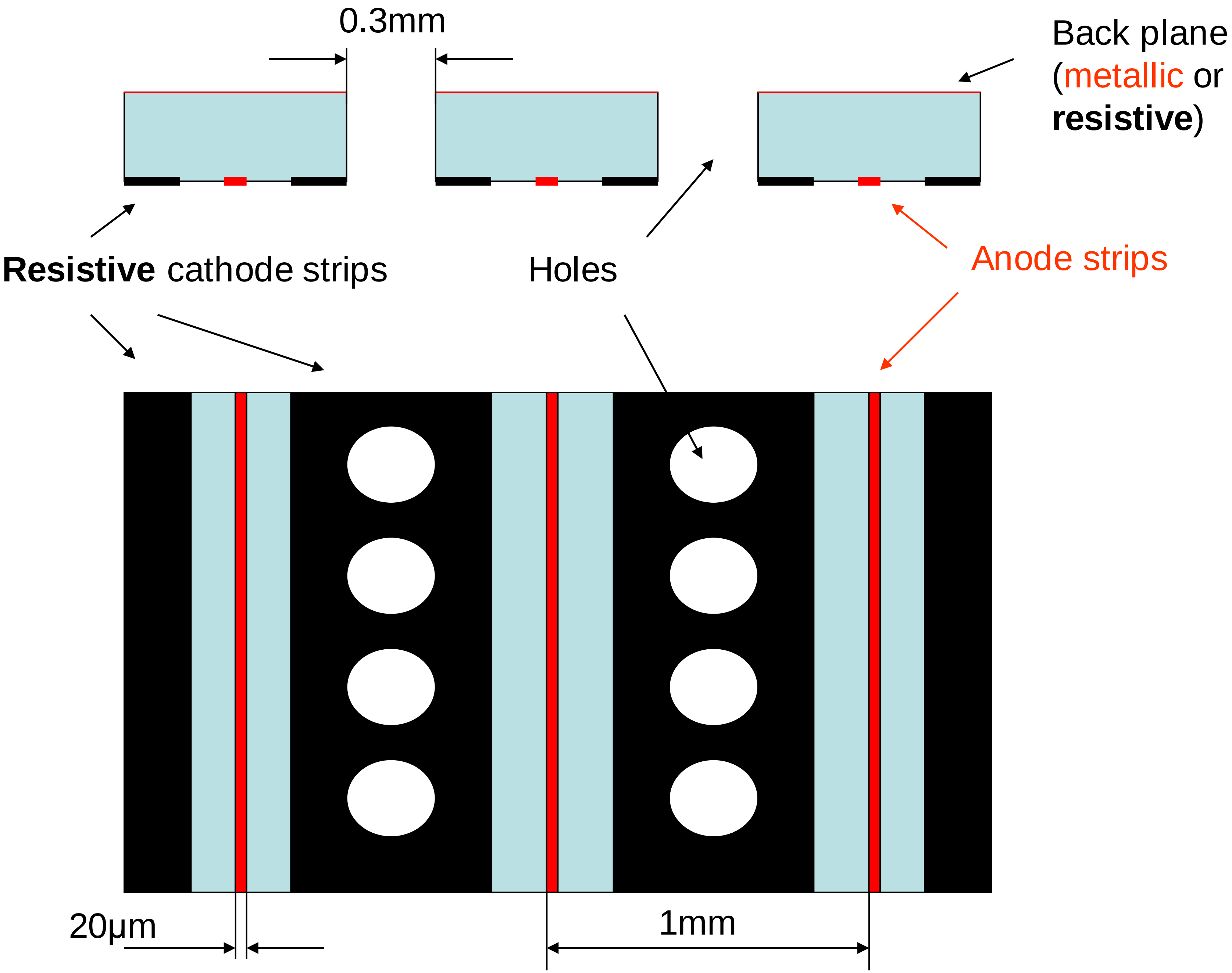


The holes were drilled by the CNC
machine

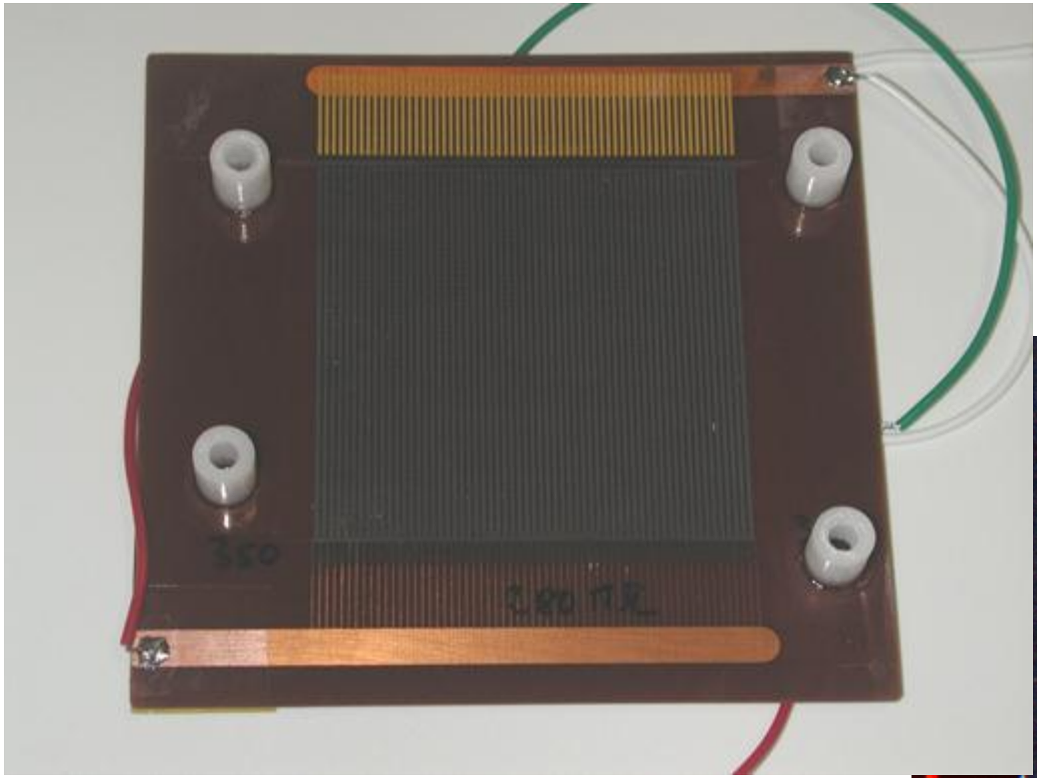
e)

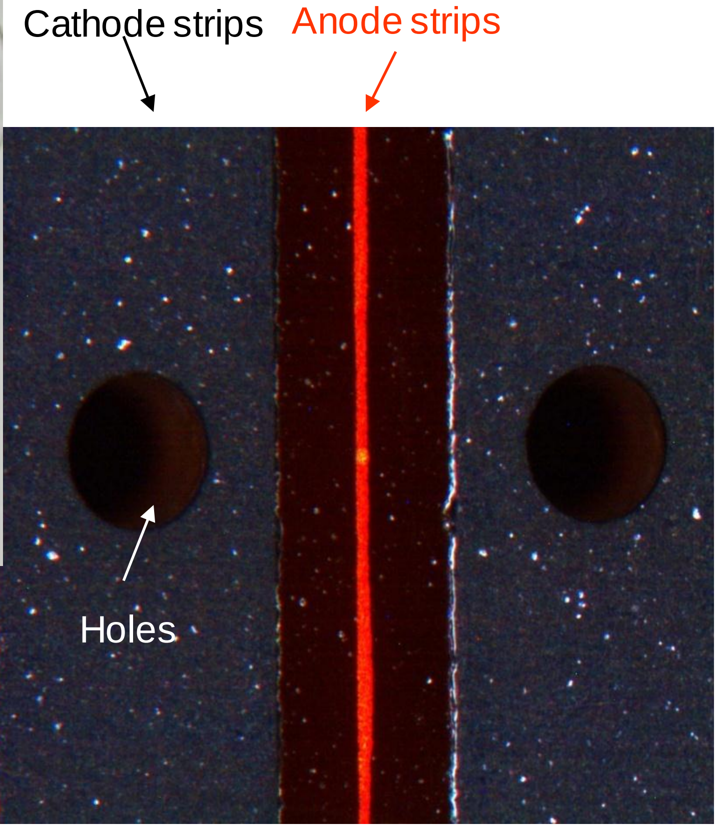


By a photolithographic technology
Cu 20 µm wide strips were created
between the grooves


0.3mm
Back plane
(metallic or
resistive)
Resistive cathode strips
Holes
Anode strips
20µm
1mm

Photos of R-MHSP



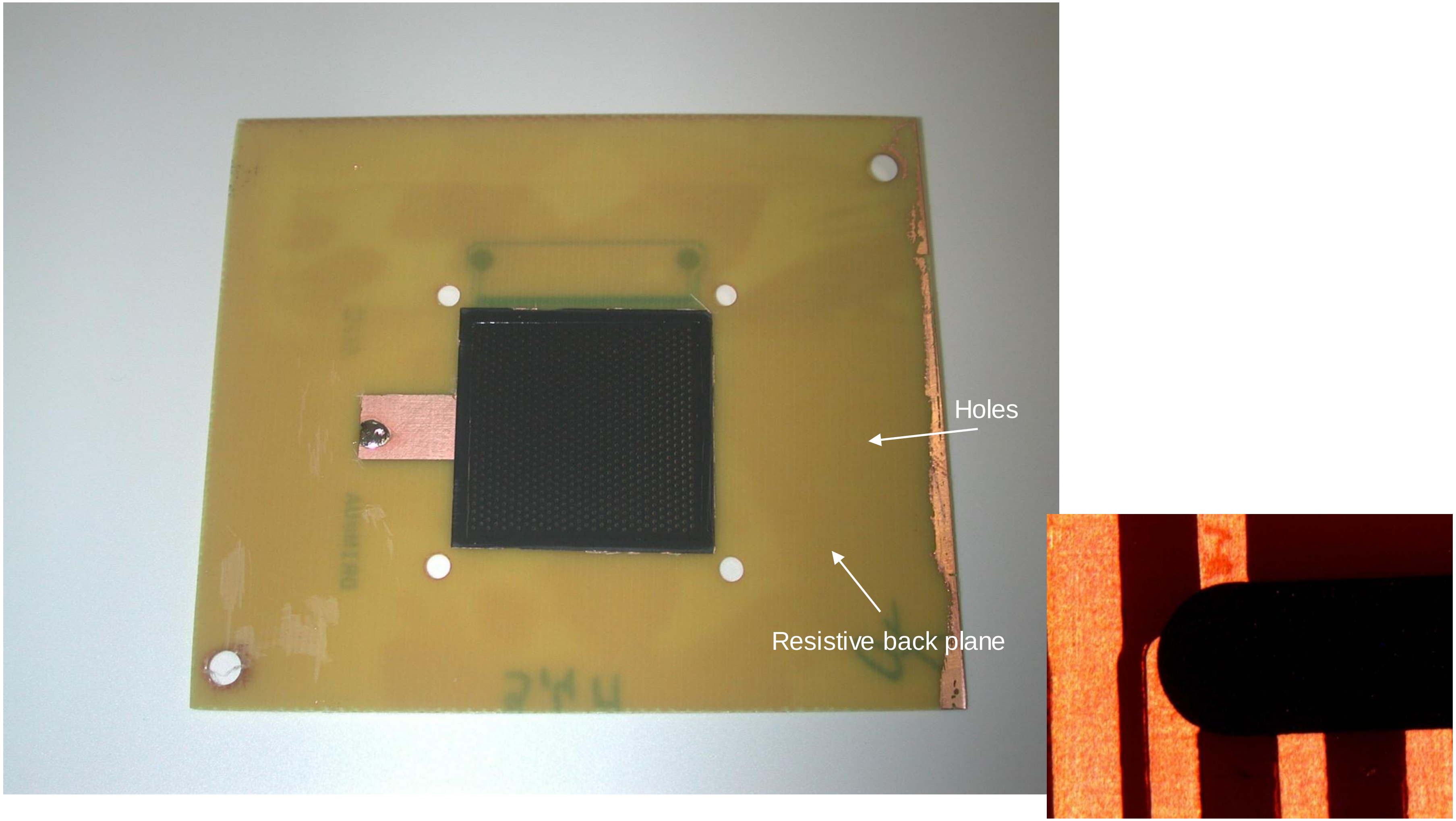


The concept of this detector is similar the so called "MHCP detector"* , however the important <u>differences</u> were that it was manufactured from a printed circuit plate 0.4 mm and had resistive cathode strips making it <u>spark-protective</u>.

**J.M. Maia et al., NIM A504,2003, 364*

Manufacturing of the R-COBRA

Photos of R-COBRA



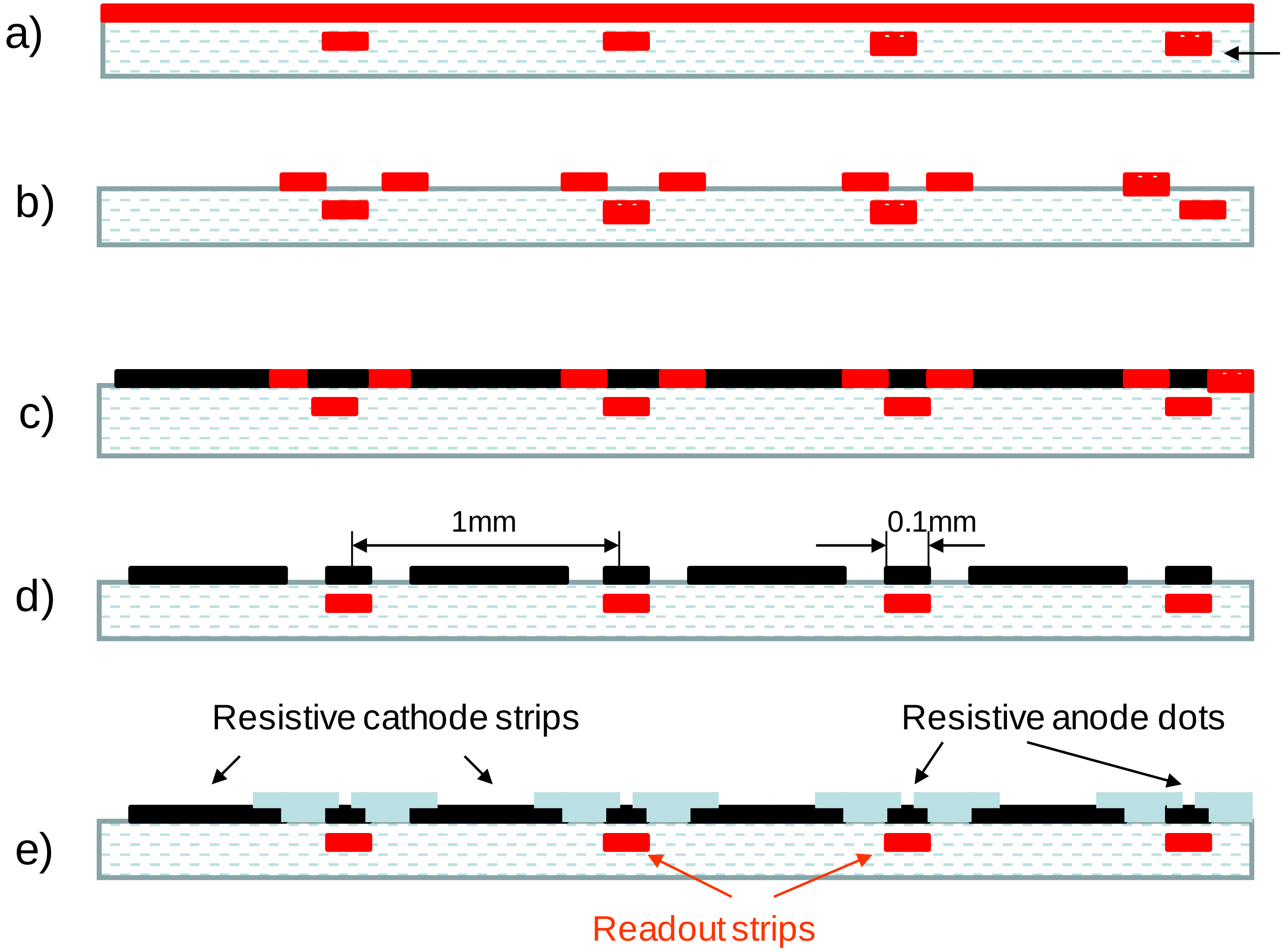
The second detector was quiet similar to the Thick -COBRA design*, but featuring a resistive back plane instead of a metallic one. In addition, anode strips ate terminated on film resistors

**J.F.C.A. Veloso et al., , NIM, A639,2011,134-136*

3) R-Microdot

Manufacturing technique of a Microdot detector

Microdot detector manufacturing steps



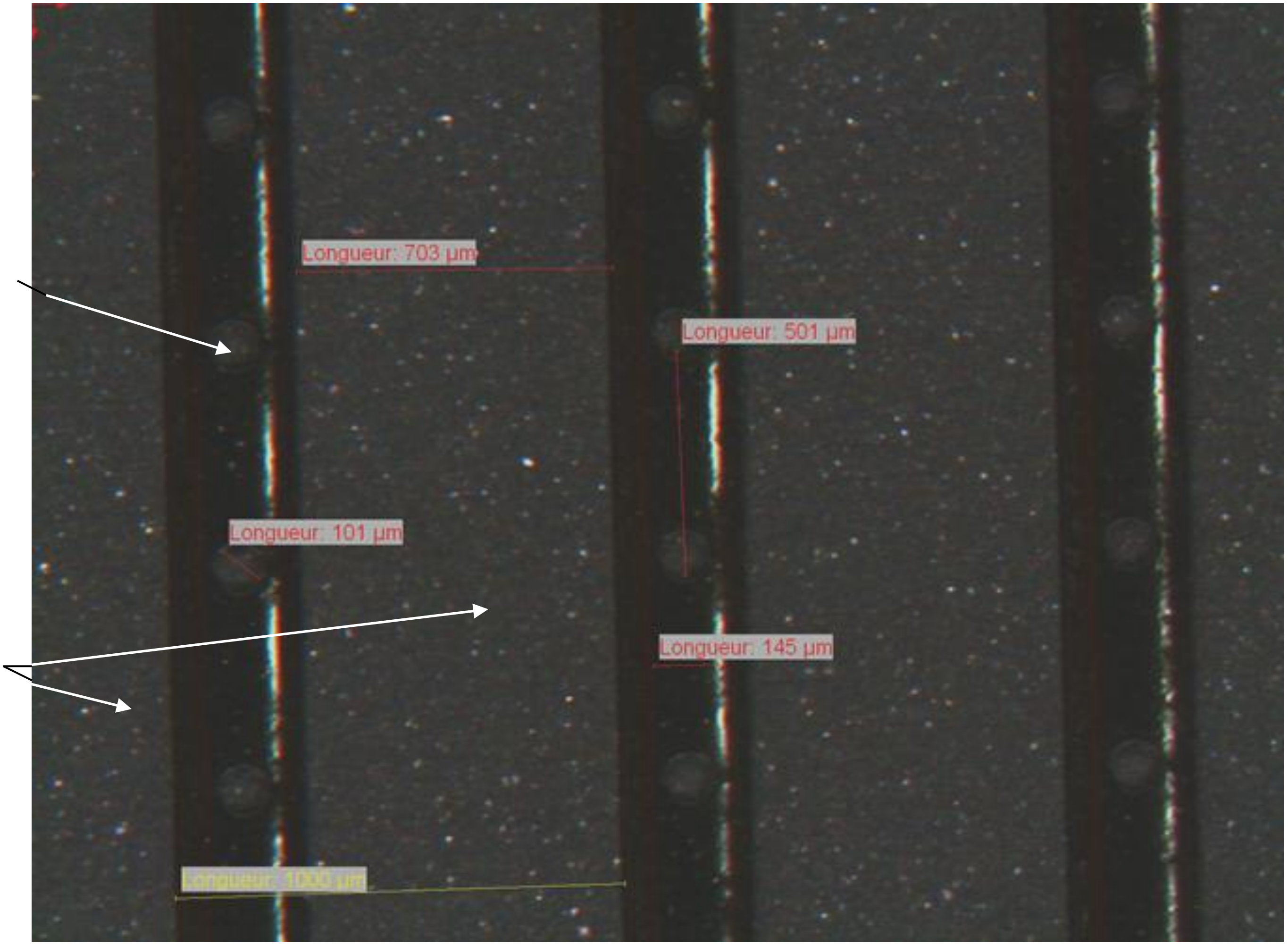
a) Multilayer PCB with a Cu layer on the top and one layer of readout strips on the bottom, 1mm pitch

b) Upper Cu layer etching

c) The grooves were then filled with resistive paste (ELECTRA Polymers

d) Removal of the Cu

e) Filling with Coverlay

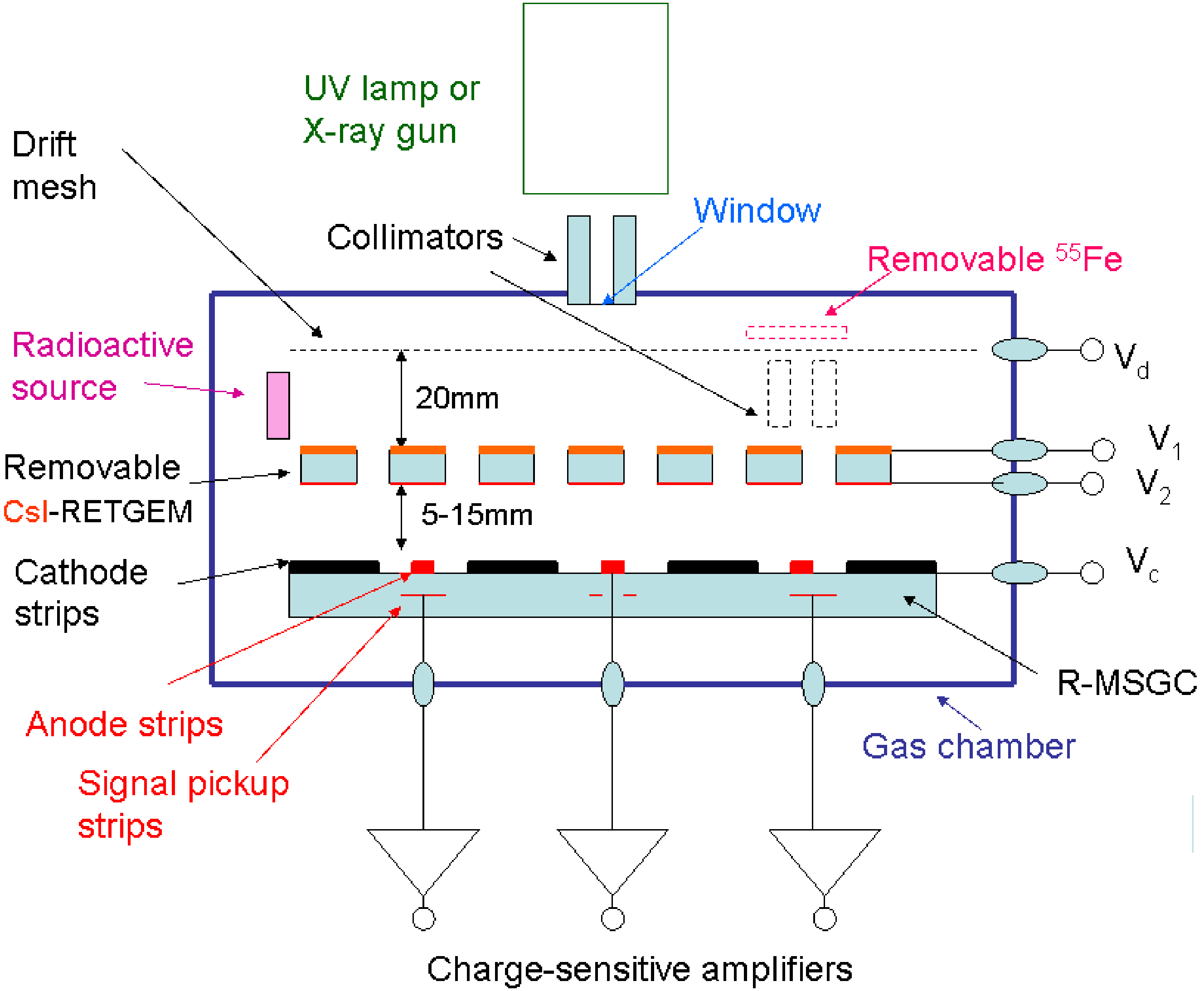


Anode
dots

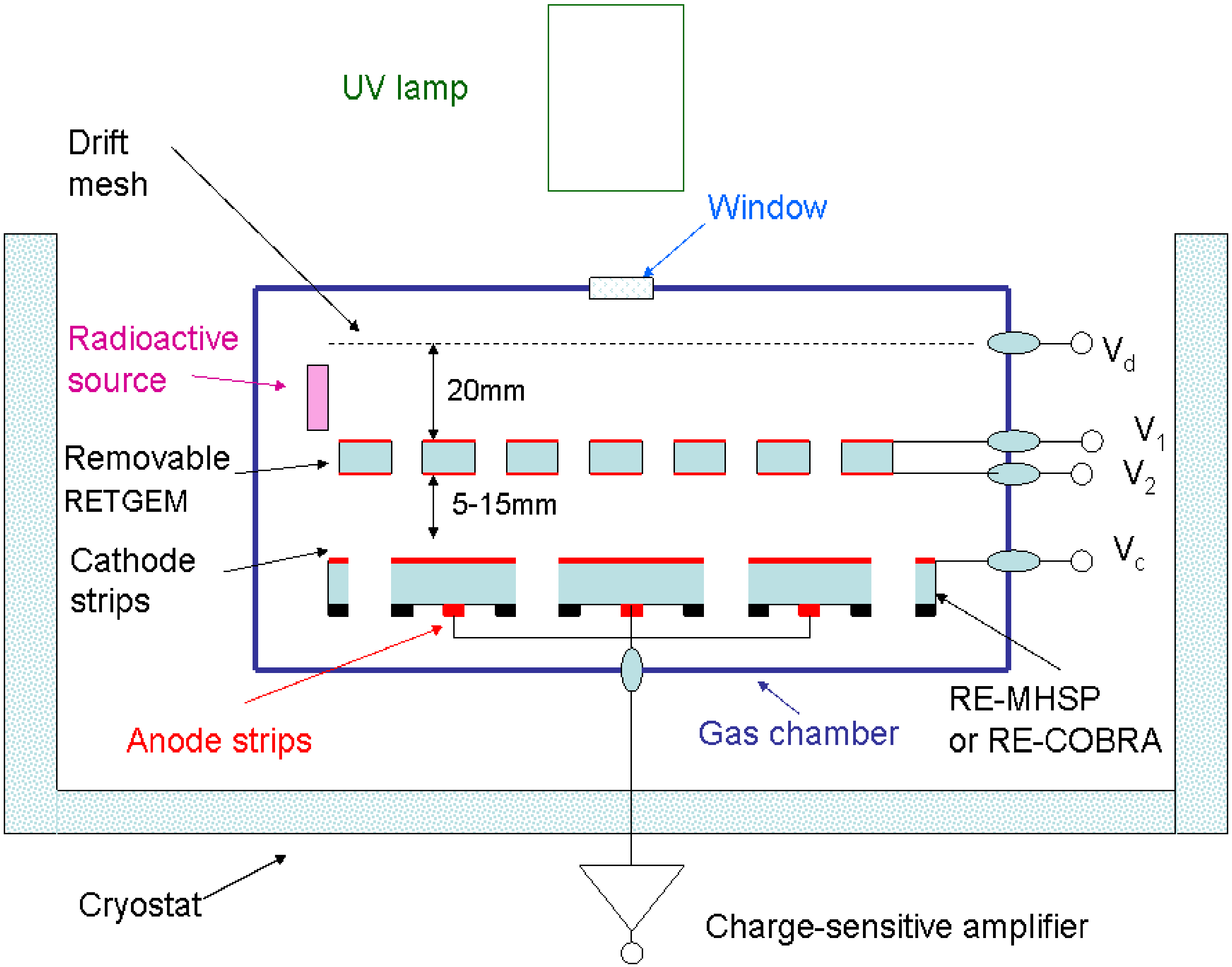
Resistive
cathode
strips

A magnified photo of Microdot detector

Experimental setup



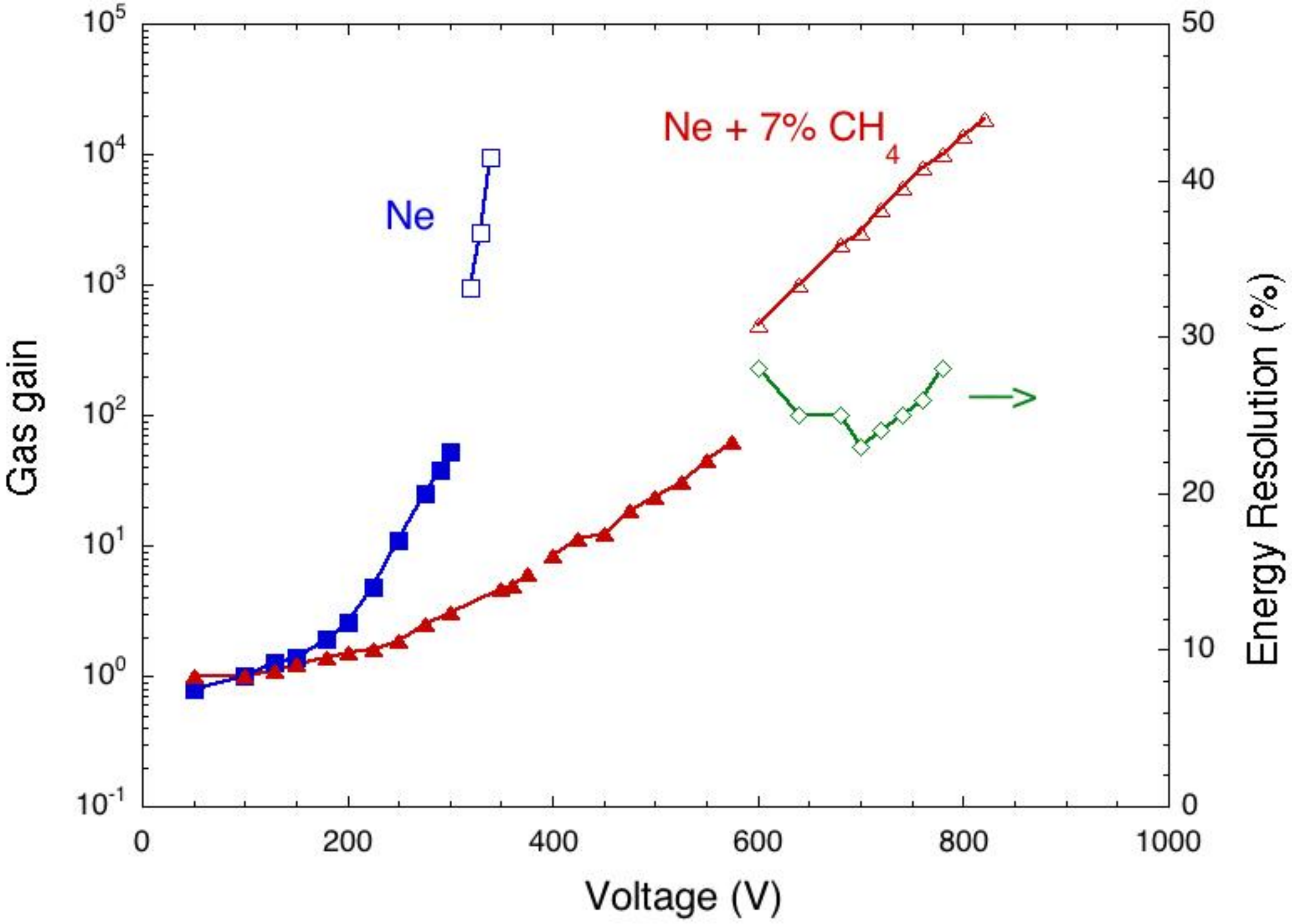
A schematic drawing of the experimental set up used for tests of R-MSGC



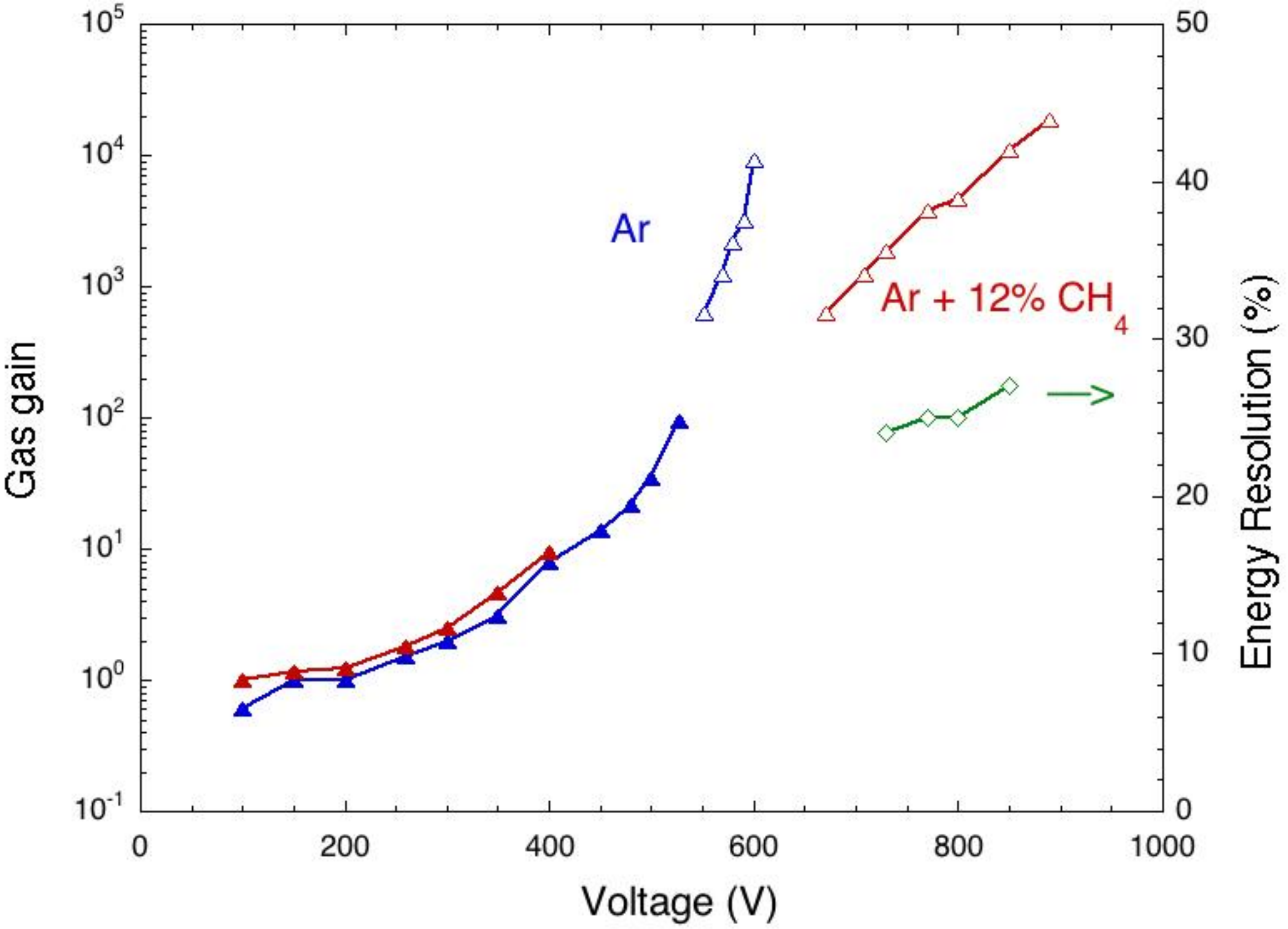
A schematic drawing of the experimental setup used for tests of R-MHSP and R-COBRA at room and cryogenic temperatures

Results

1) 2-D R-MSGC



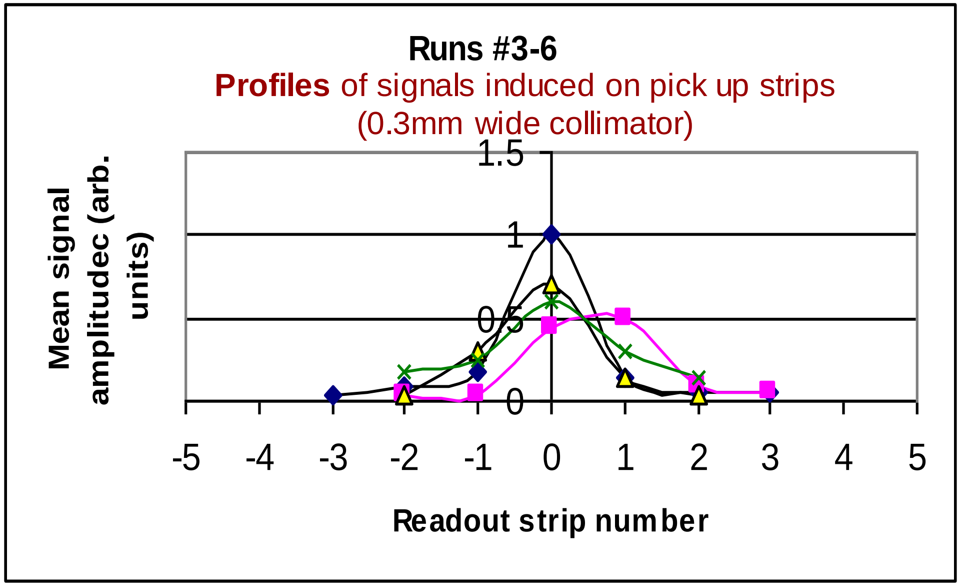
Gas gain vs. the voltage applied between the anode and the cathode strips of an R-MSGC measured in Ne (squares) and Ne+7%CH4 (triangles) with alpha particles (filled symbols) and with 55Fe (empty symbols). The curves with rhombuses represent the energy resolution (FWHM at 6 keV) measured in Ne+7%CH4



Gain dependence on voltage applied to R-MSGC (between its anodes and the cathode strips) measured in Ar (blue triangles) and Ar+12%CH4 (red triangles). In all curves filled triangles-measurements performed with alpha particles, open triangles - 55Fe. Open rhombuses-energy resolution measured in Ar+12%CH4.

In all gases tested the maximum gains achieved with the R-MSGCs ~10^4 are as high as obtained with the best quality "classical" MSGCs manufactured on glass substrates

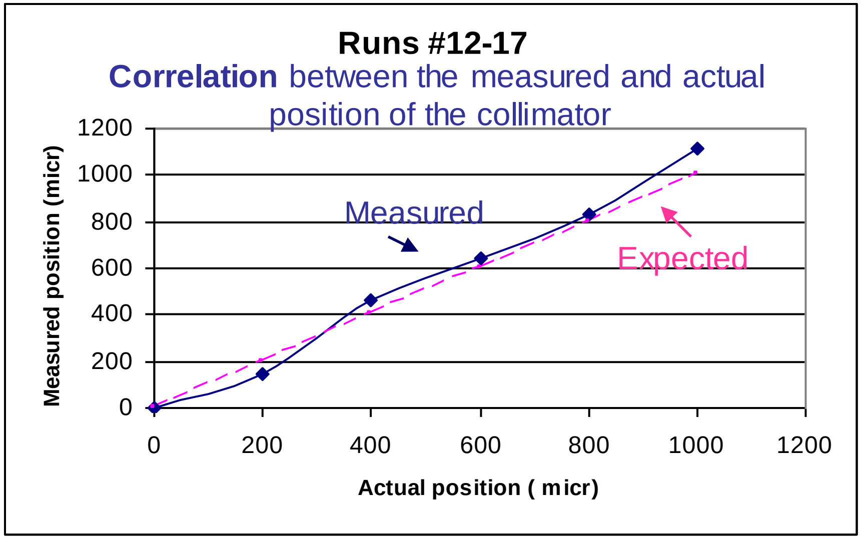
Preliminary results of the induced charge profile measuremenst



Runs #3-6

Profiles of signals induced on pick up strips (0.3mm wide collimator)

Results of measurements **induced signals profile** from the readout strip oriented along (green curve with crosses) and perpendicular to the anode strips of R-MSGCs (rhombuses, triangles and squares). Rhombus- the collimator is aligned along the strip #0. Triangles -the collimator was moved on 200µm towards the strip#1. Squares- the collimator was aligned between the strip#0 and # 1. Measurements were performed in Ar+10%CO_2 at a gas gain of 5x10^3.

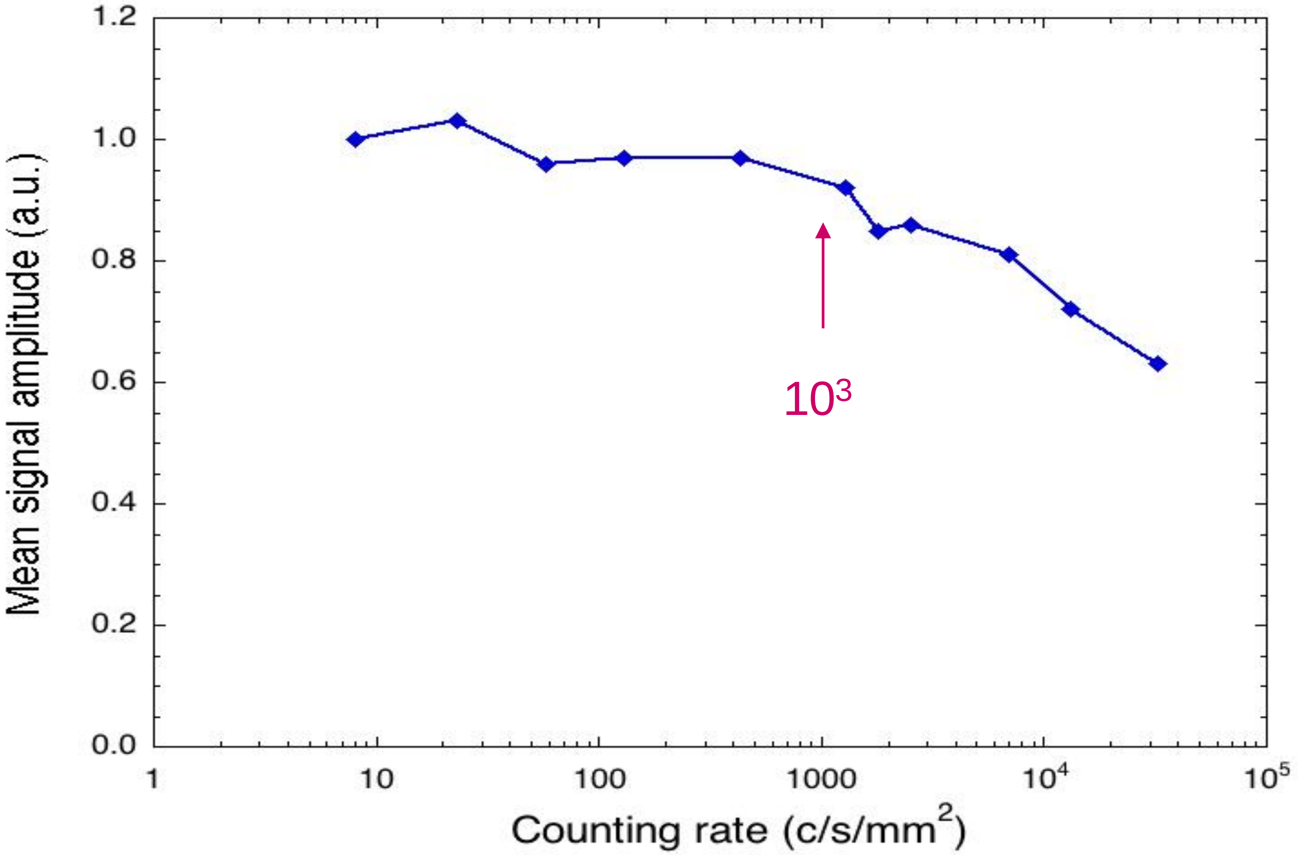


Runs #12-17

Correlation between the measured and actual position of the collimator

The position resolution will be determined during the oncoming beam test

Rate response:

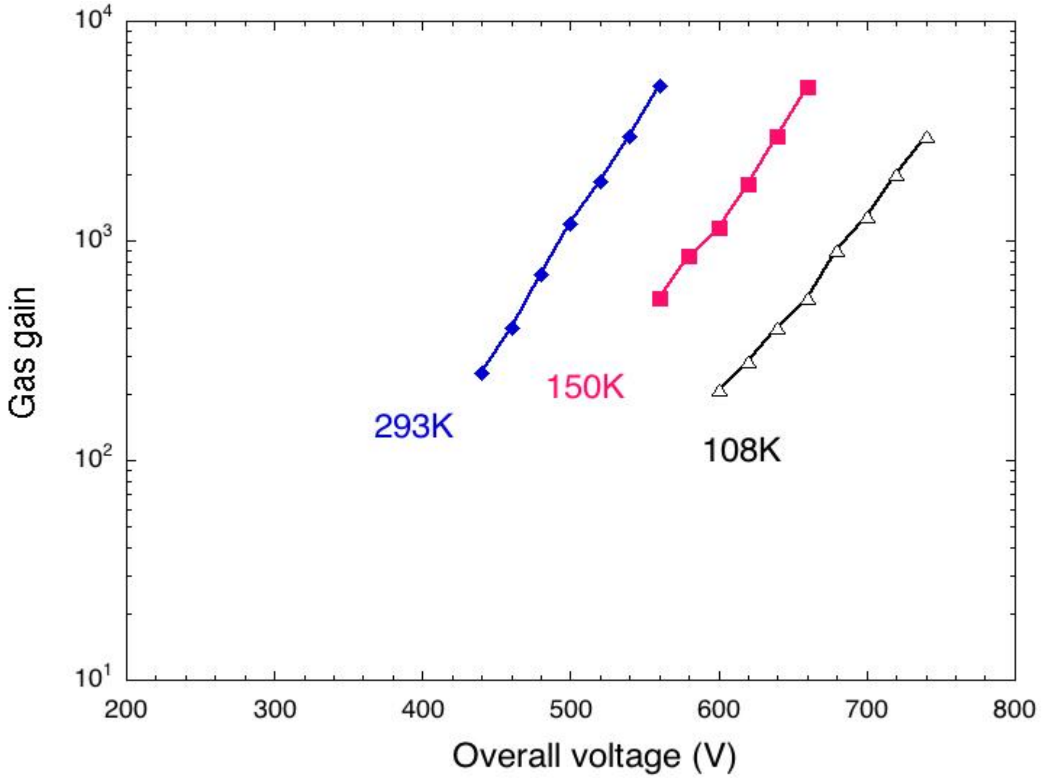


The gas gain variations with counting rate.
Measurements were performed in Ne+10%CO_2 at gas gain of 5$10^3$

(signal drop at counting rate >10^3Hz/mm^2 is due to the PCB board surface charging up, but not due to the voltage drop on resistive strips)

2) Some results obtained with hybrid detectors

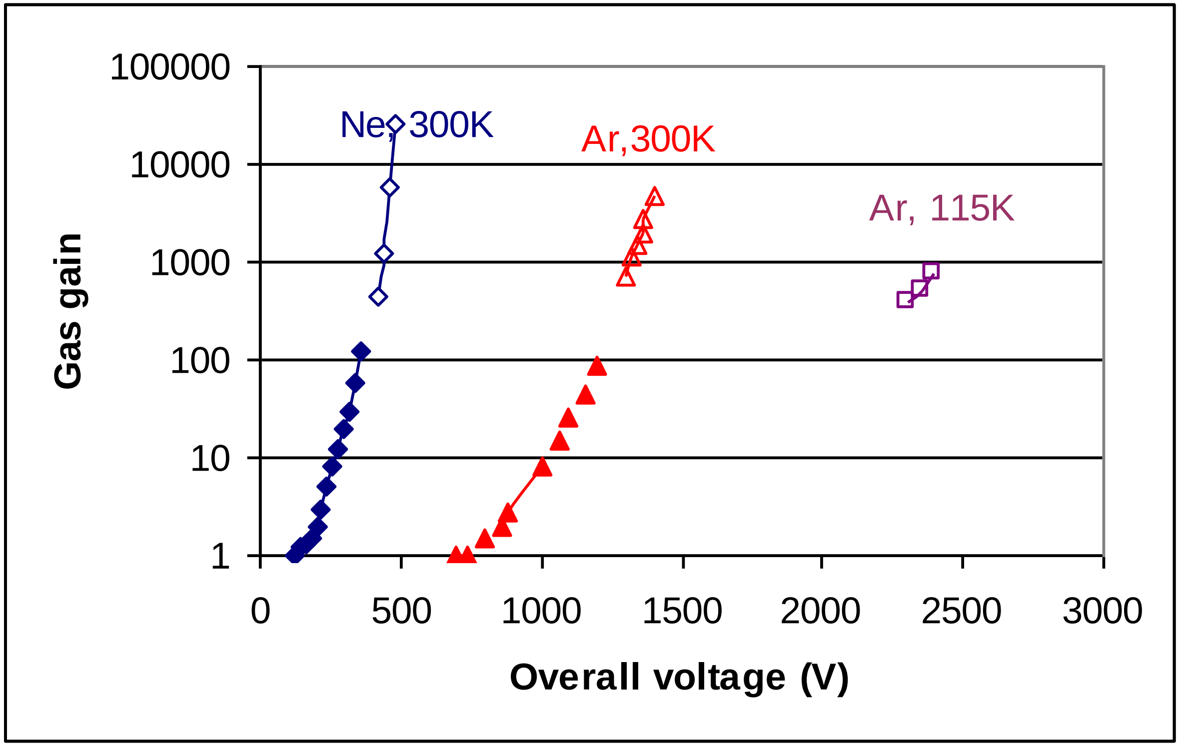
R-MHSP



Gains approaching 10^4 were achieved

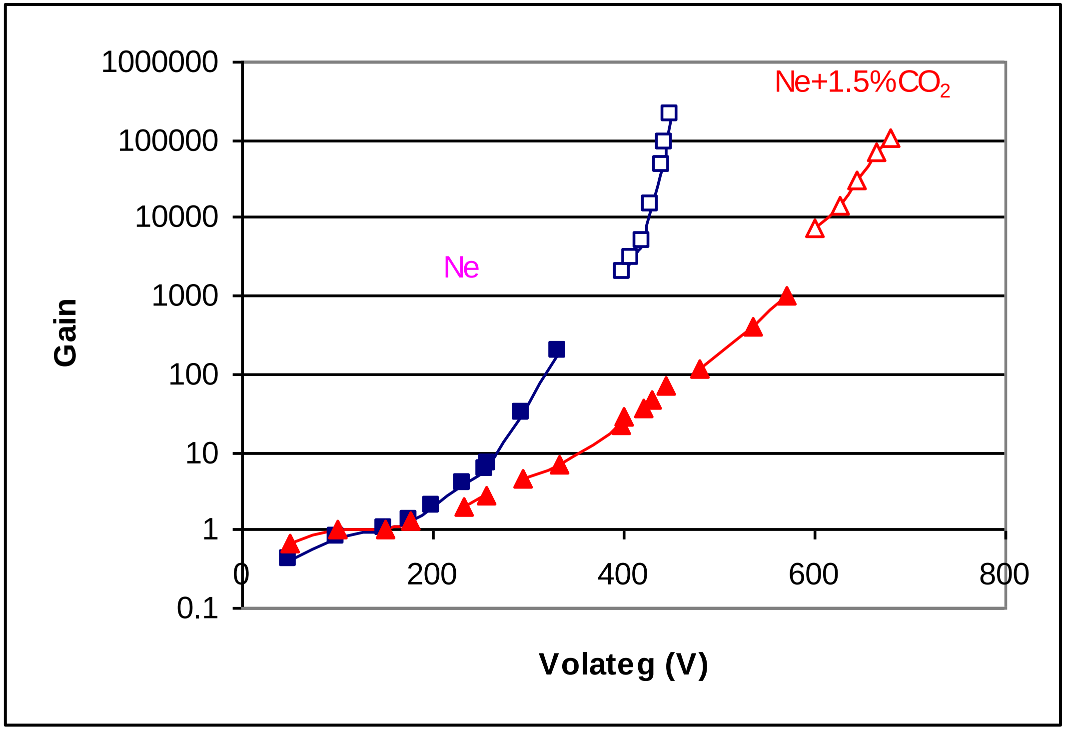
Gas gain vs. the overall voltage (the voltage applied across the holes and between the anode and cathode strips) for **hybrid R-MSGC** measures in **pure Ar** at various temperatures: 293K, 150K and 108K

R-COBRA

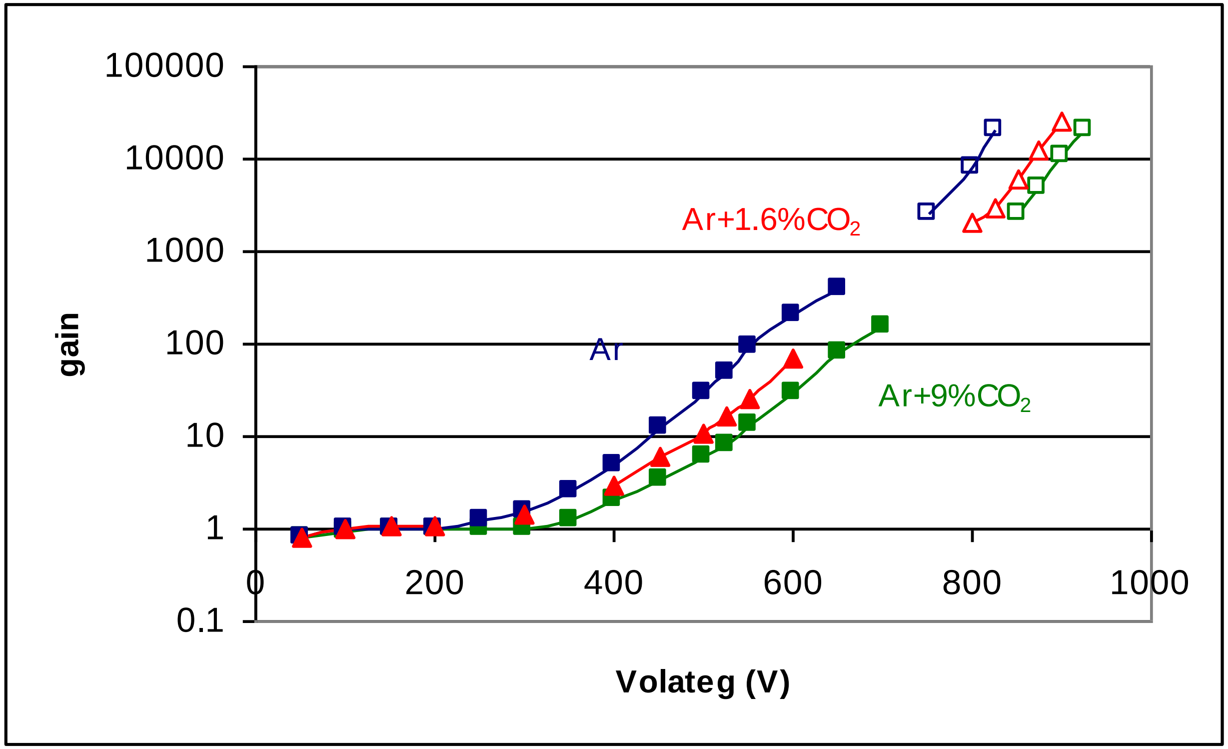


As can be seen, with this detector operating in Ar at 115 K the maximum achievable gas gain was ~10^3- a little less than in the case of the RE-MHSP . Presumably this is because the width of the anode strip in the RE-COBRA design is larger that in the RE-MHSP.

3) Microdot detector



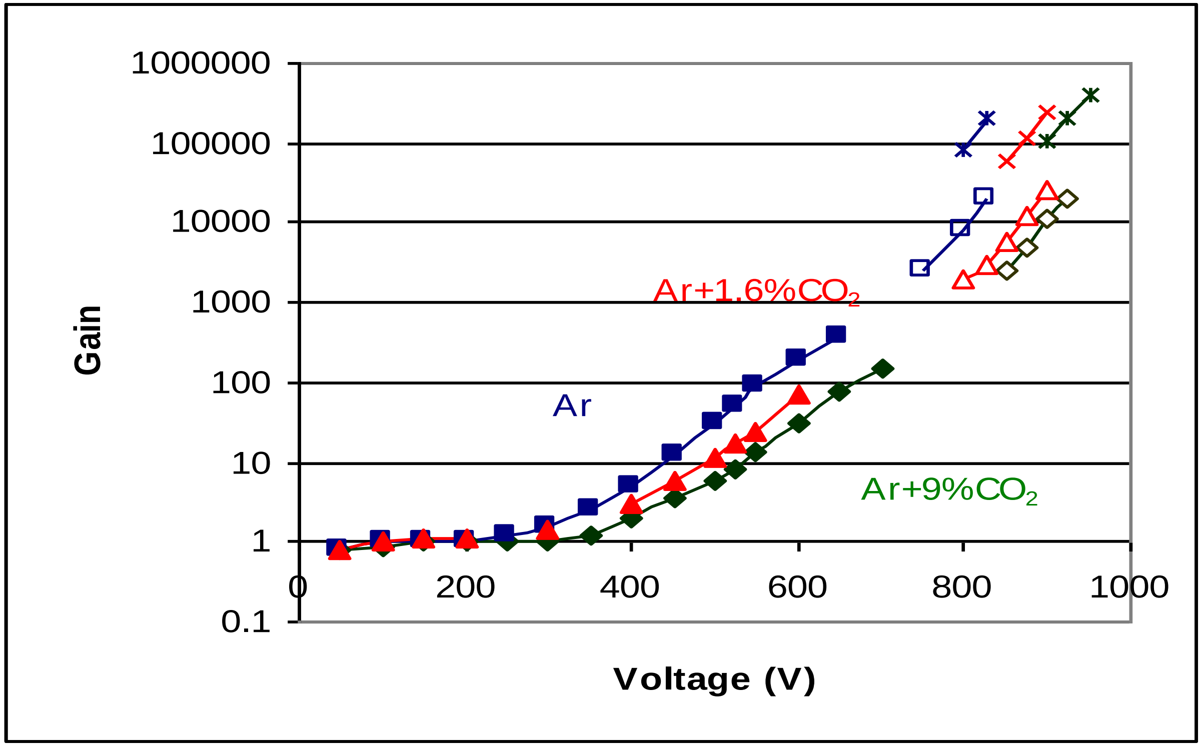
Gas gain vs. the voltage of R-Microdot measured in Ne and Ne+1.5%CH_4 with alpha particles (filled triangles and squares) and with ^{55}Fe (empty triangles and squares).



Gains higher than with R-MSGC were acieved

In all gases tested the maximum gains achieved with the R-Microdot detectors were 3-10 time higher than with R-MSGCs

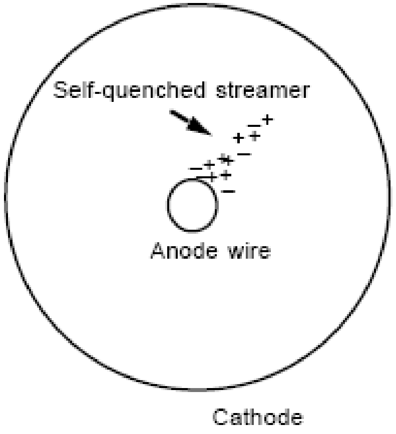
SQ streamers

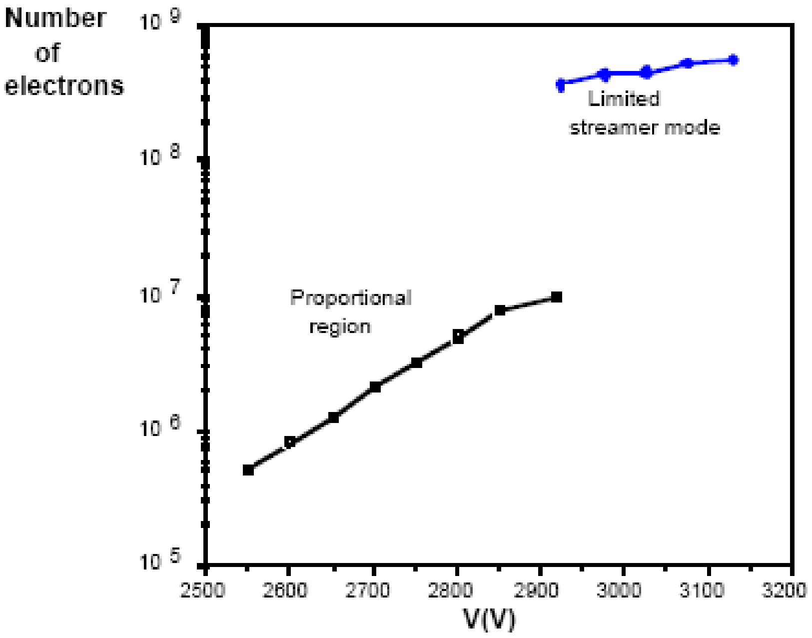


Gain (triangles) dependence on voltage applied to R-Microdot measured in Ar (blue symbols) and Ar+1.6%CH$_4$ (red symbols) and in Ar+9%CO$_2$.

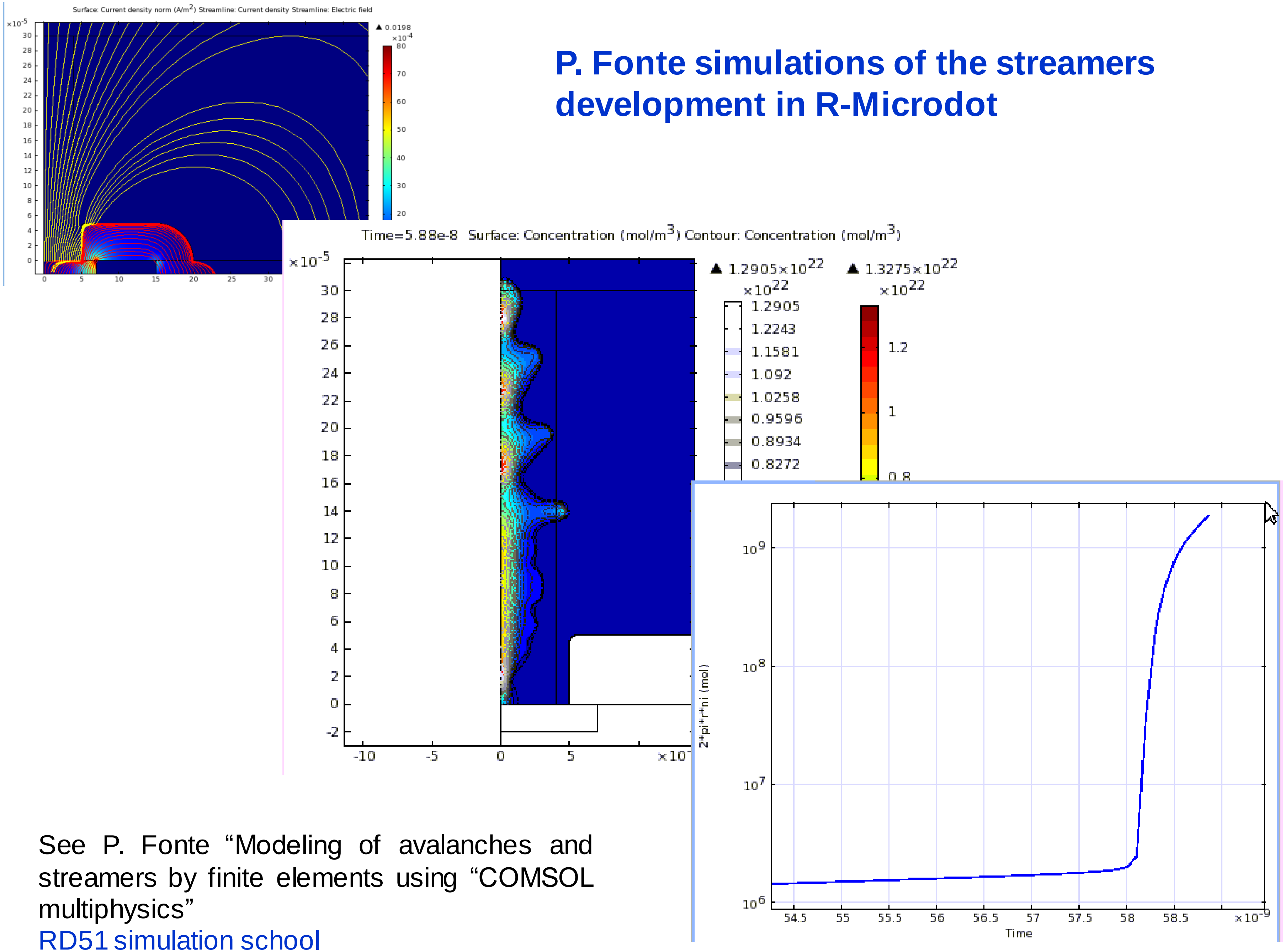
Filled triangles and squares -measurements performed with alpha particles, open symbols - ^{55}Fe.

SQ streamers





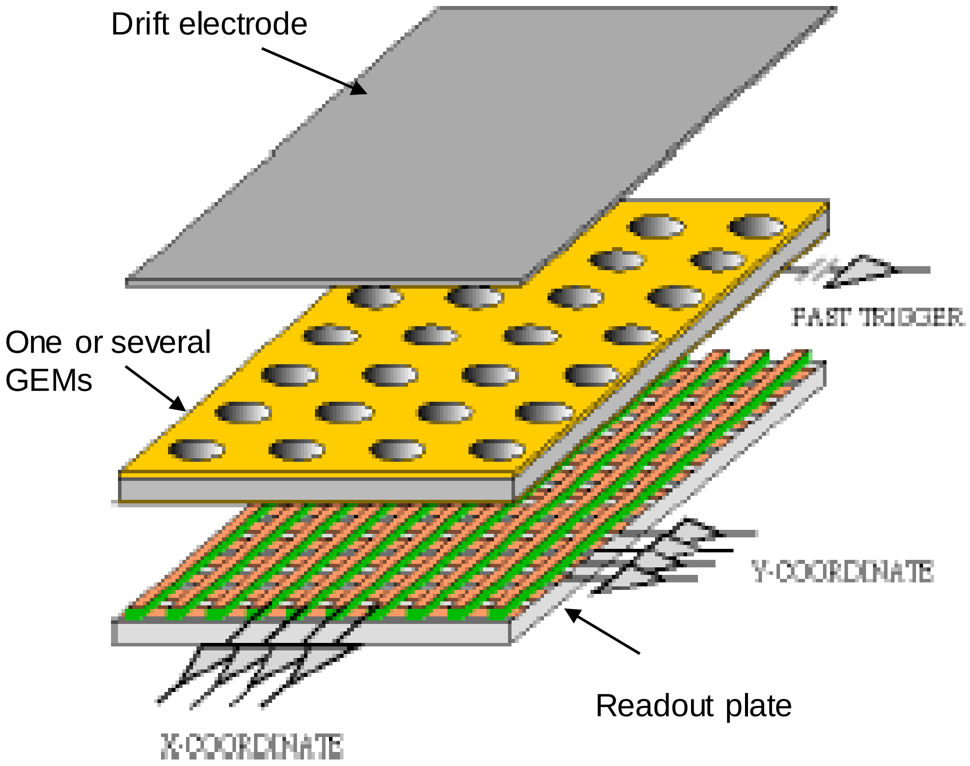
P. Fonte simulations of the streamers development in R-Microdot



See P. Fonte "Modeling of avalanches and streamers by finite elements using "COMSOL multiphysics"
RD51 simulation school

Comparison to other micropattern detectors

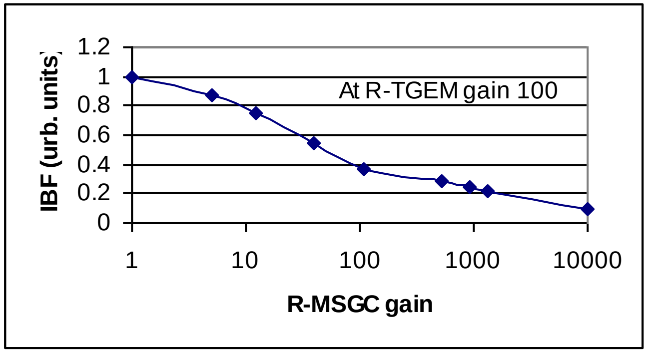
a) Comparison to GEM



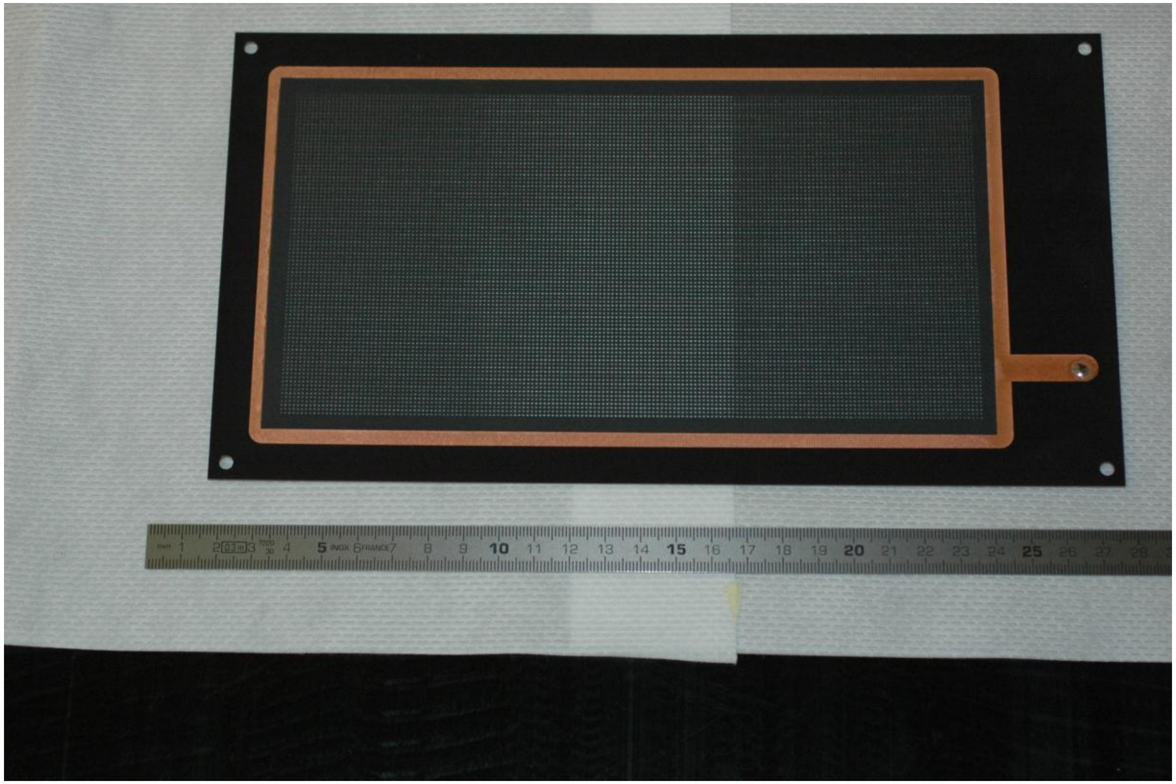
Standard GEM detector layout

Advantages of R-MSGC compared to GEM:

1) Less elements
2) Ion back flow suppression (which is essential for photodetectors, TPC and so on)



b) Comparison to TGEM/RETGEM



Similar gain, however fewer parts,
potential for better position resolution

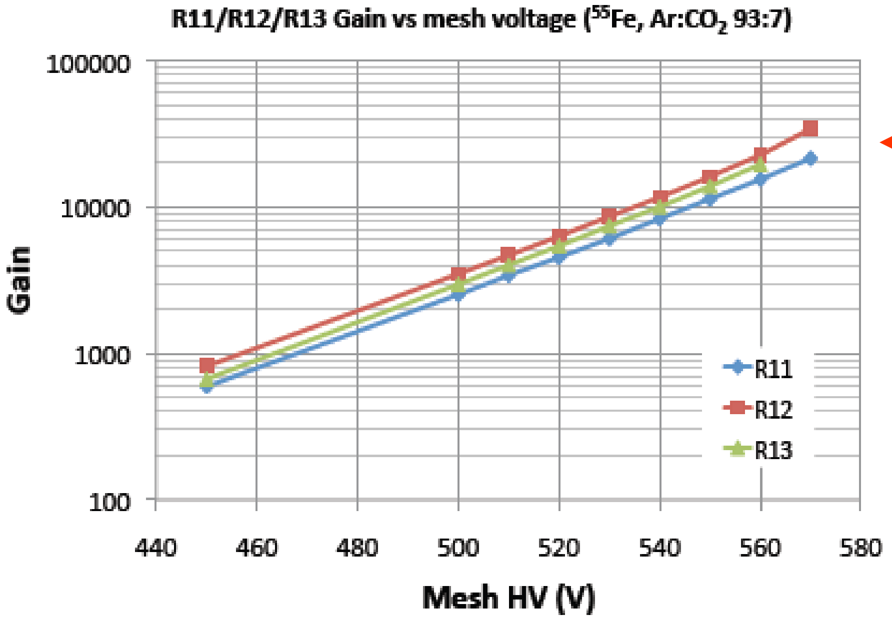
c) Comparison to ATLAS R-MICROMEGAS

Note that gains achieved with R-MSGCs (~10^4) are comparable to those obtained with spark-protected MICROMEGAS having resistive anode strips (R-MICROMEGAS). The rate characteristics of R-MSGCs are also as good as those of R- MICROMEGAS.
However, R-MSGCs have several **advantages** over R-MICROMEGAS:

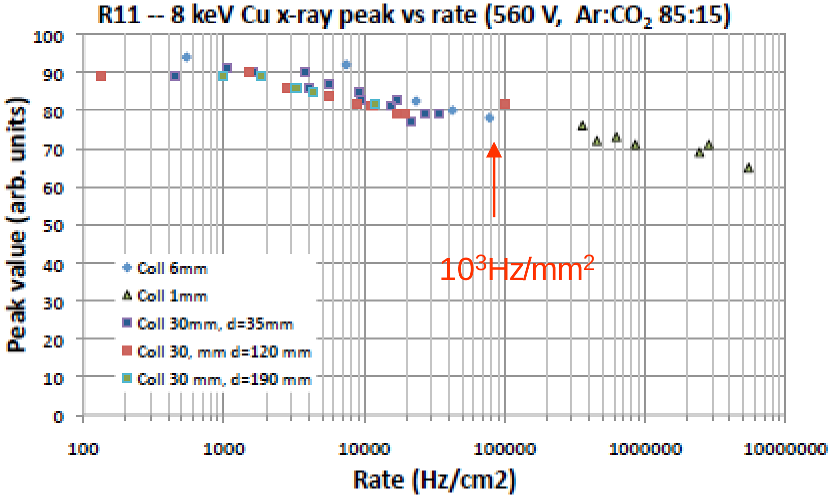
1) R-MSGCs are easier to manufacture than MICROMEGAS,
2) It is easier to clean the formed dust particles (since there is no cathode mesh which blocks these microparticles)
3) There are fewer parts in R-MSGCs than in R-MICROMEGAS
4) Large area R-MSGCs can be assembled from patches with minimum dead spaces (in contrast to R-MICROMEGAS)

Thus R-MSGCs appear to be a very attractive and competitive detector of photons and charged particles.

ATLAS R-MICROMEGAS characteristics



$(2\text{-}3)10^4$



10^3Hz/mm^2

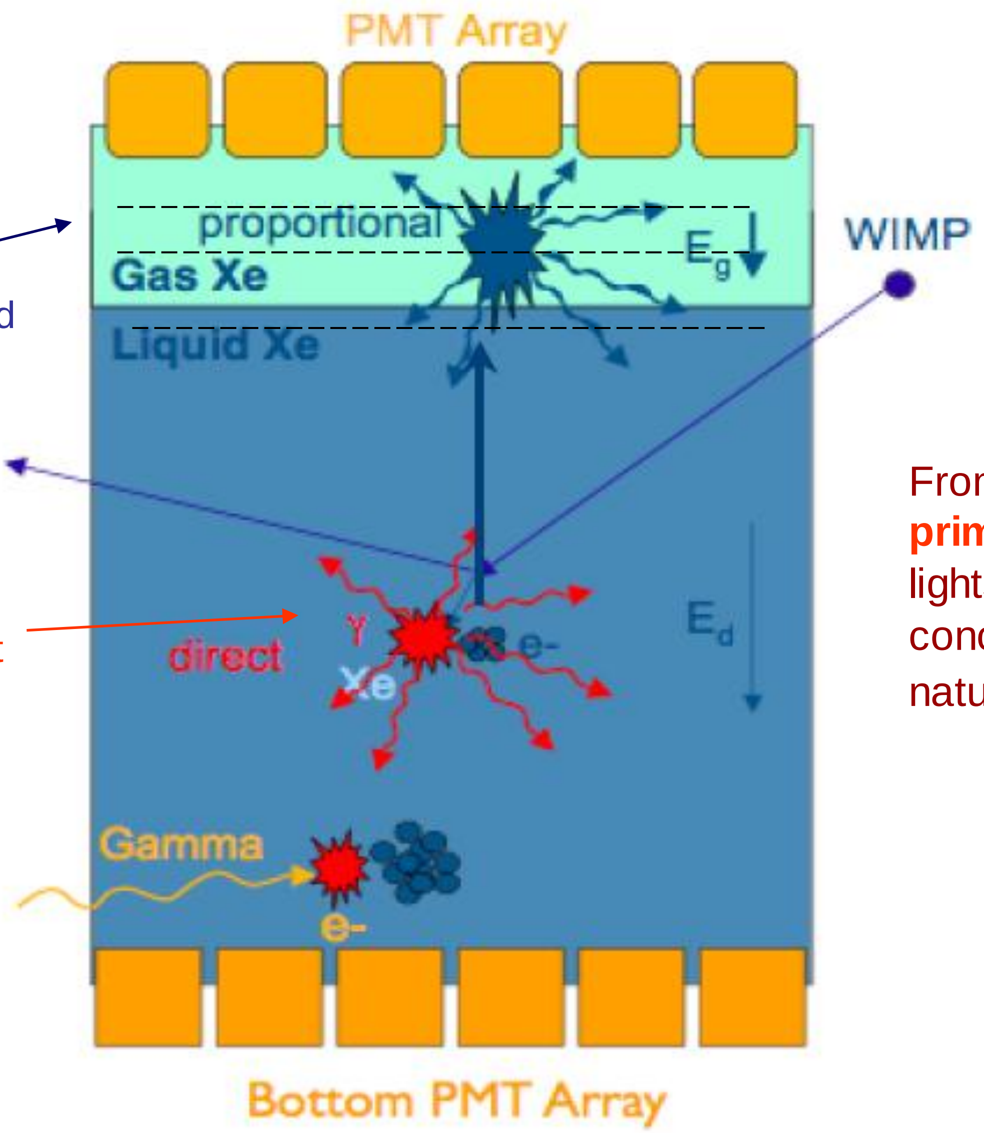
T. Alexopoulos et al., NIM A640, 2011,110

Applications

R-MSGCs can be used in many applications especially in those which requires ion or photon feedback suppression.

Below examples of two applications are given on which our group is involved

1. Double phase noble liquid dark matter detectors



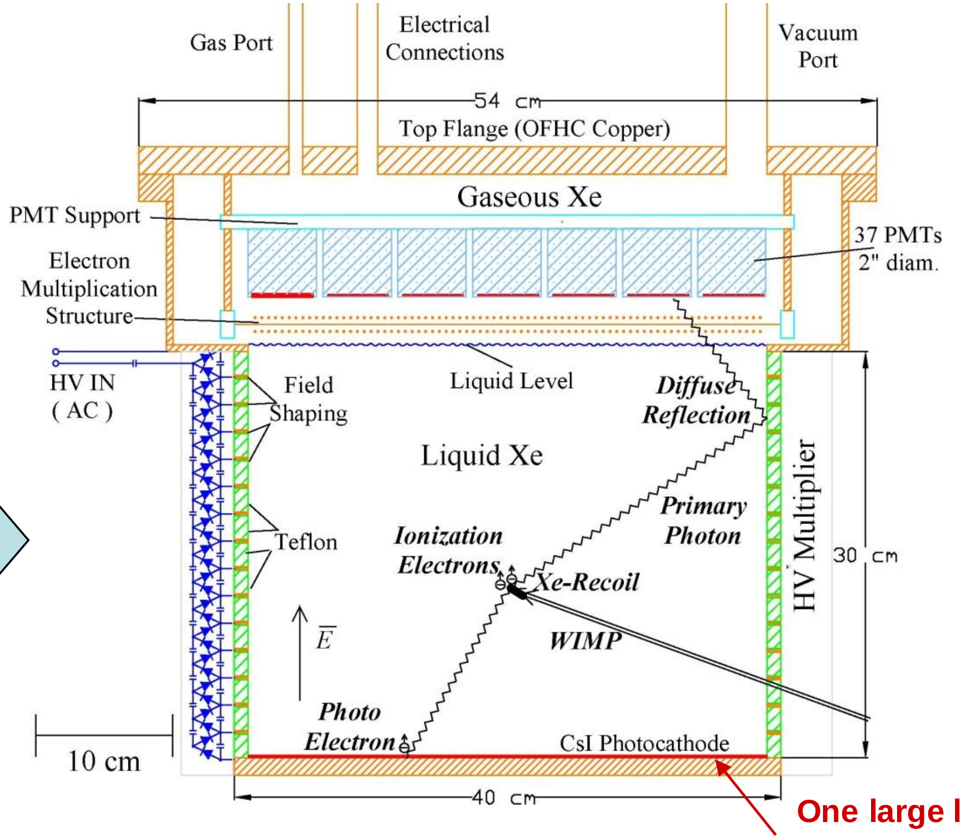
Two parallel meshes where the **secondary** scintillation light is produced

Primary scintillation light

From the ratio of **primary/secondary** lights one can conclude about the nature of the interaction

Several groups are trying to develop designs with reduced number of PMs

Large amount of PMs in the case of the large-volume detector **significantly increase its cost**

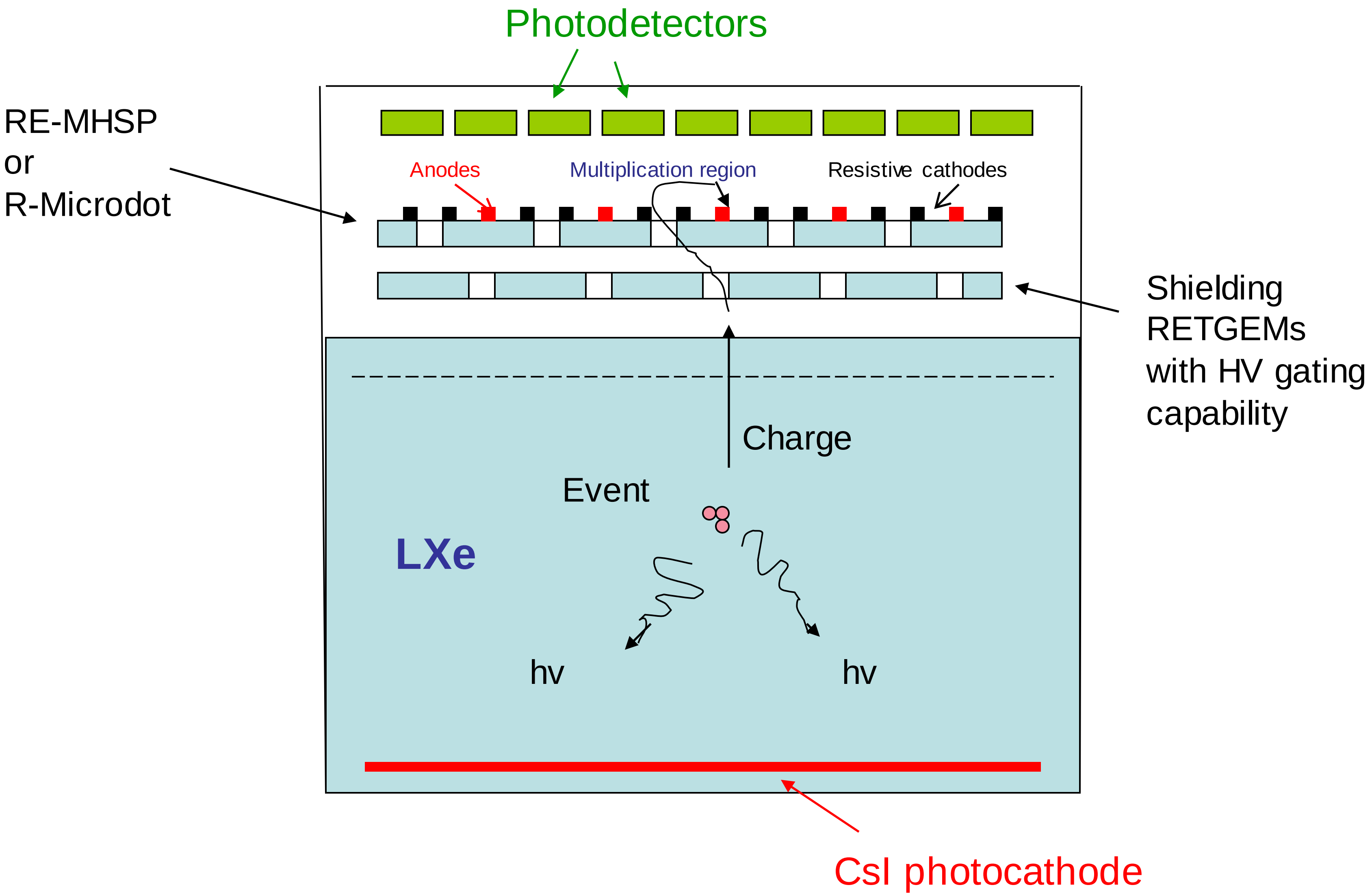


One large low cost "PM"

See: E. Aprile [XENON: a 1-ton Liquid Xenon Experiment for Dark Matter](http://xenon.astro.columbia.edu/presentations.html)
http://xenon.astro.columbia.edu/presentations.html
and A. Aprile et al., NIM A338,1994,328; NIM A343,1994,129

Another option for the LXe TPC, which is currently under the study in our group, is to use LXe doped with low ionization potential substances (TMPD and cetera**).**

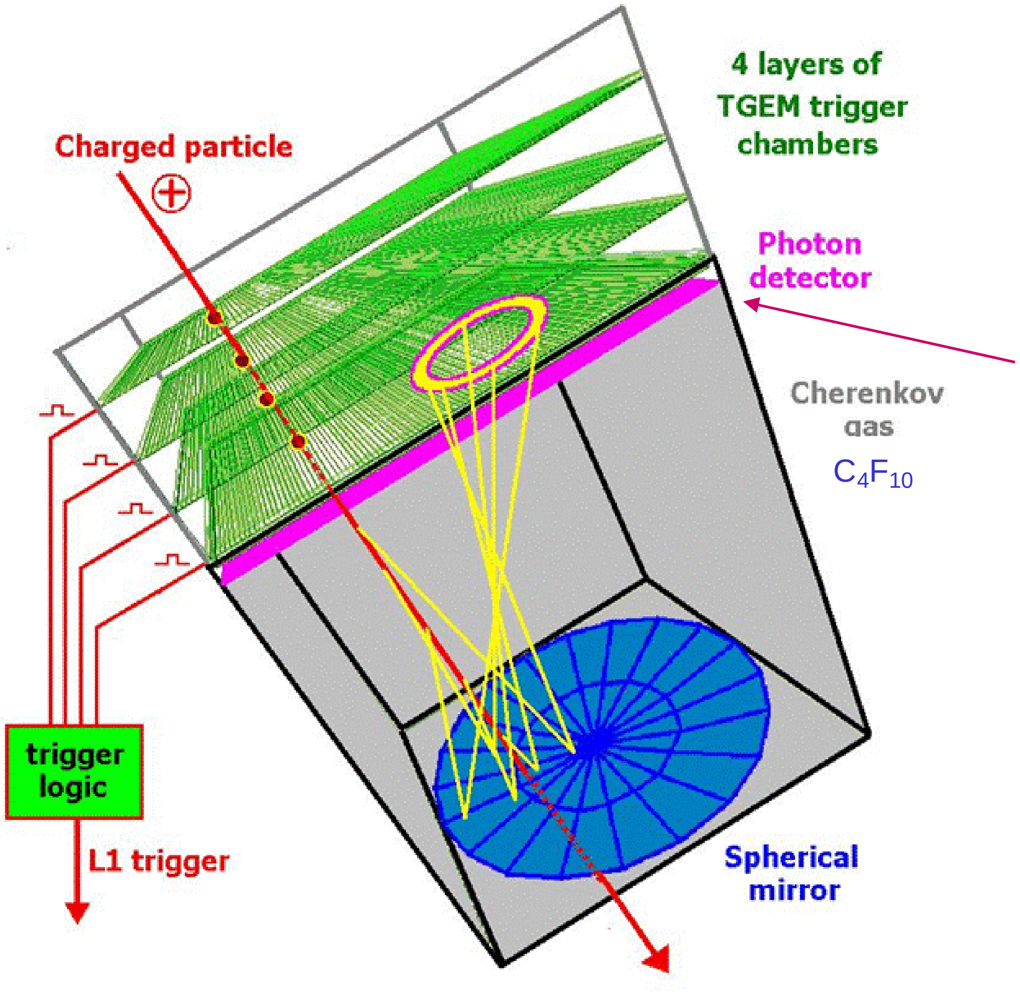
Implementation of hybrid R-MSGC



In hybrid R-MSGC, the amplification region will be <u>geometrically shielded</u> from the CsI photocathode (**or from the doped LXe**) and accordingly the feedback will be reduced

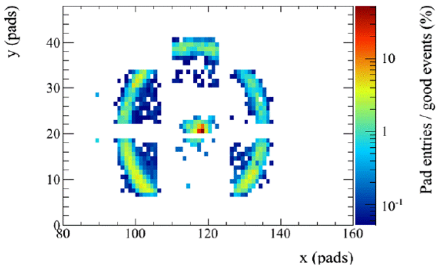
2. Photodetectors

The suggested detector will consist of a gaseous radiator (for example, CF_4 or C_4F_{10}) and a planar gaseous photodetector

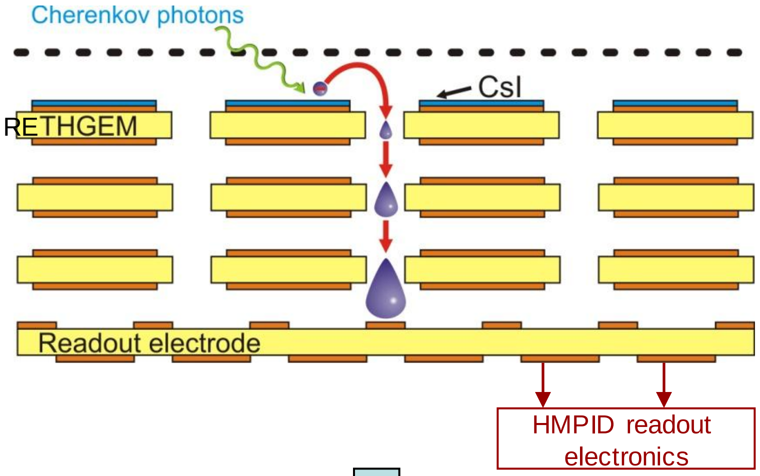


The key element of the VHMPID is a planar photodetector

Our previous prototype (very successful!)

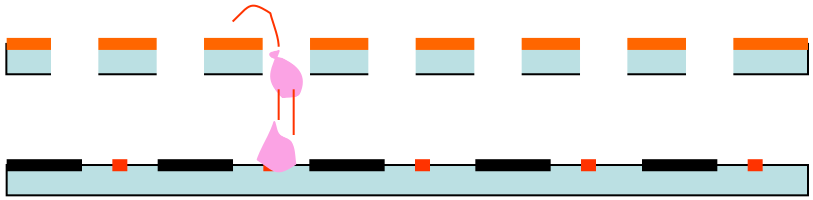


Cherenkov light was detected



P. Martinengo, V. Peskov, et al., NIM, 639,2011,126
V. Peskov et all., arXiv:1107.4314 (2011) 1-7

New prototype (recently tested)



RETGEM

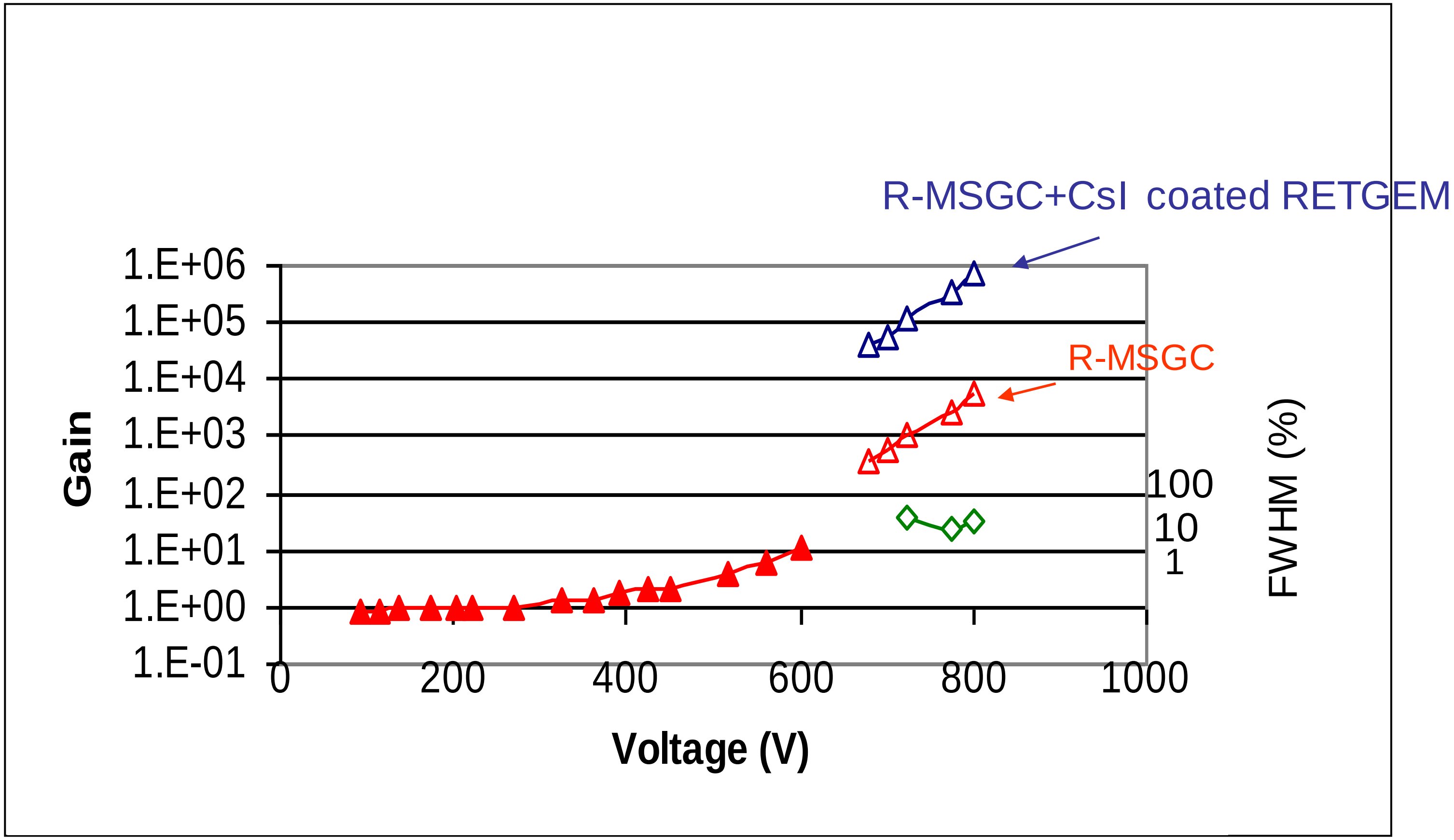
R-MSGC
(or
R-MICRODOT)

Advantages:
Less elements, better ion back flow suppression

Concerns:
Aging (to be studied)

Gas gain of R-MSHC combined with CsI coated RETGEM

(it is as high as was achieved with three RETGEMs operating in cascade mode)



Gas gain curves measured in Ne+10%CO_2: filled triangles –alpha particles, open symbols- ^{55}Fe. Open rhombuses-energy resolution. Blue triangles represent gas gain measures with a CsI-coated RETGEM preamplification structure.

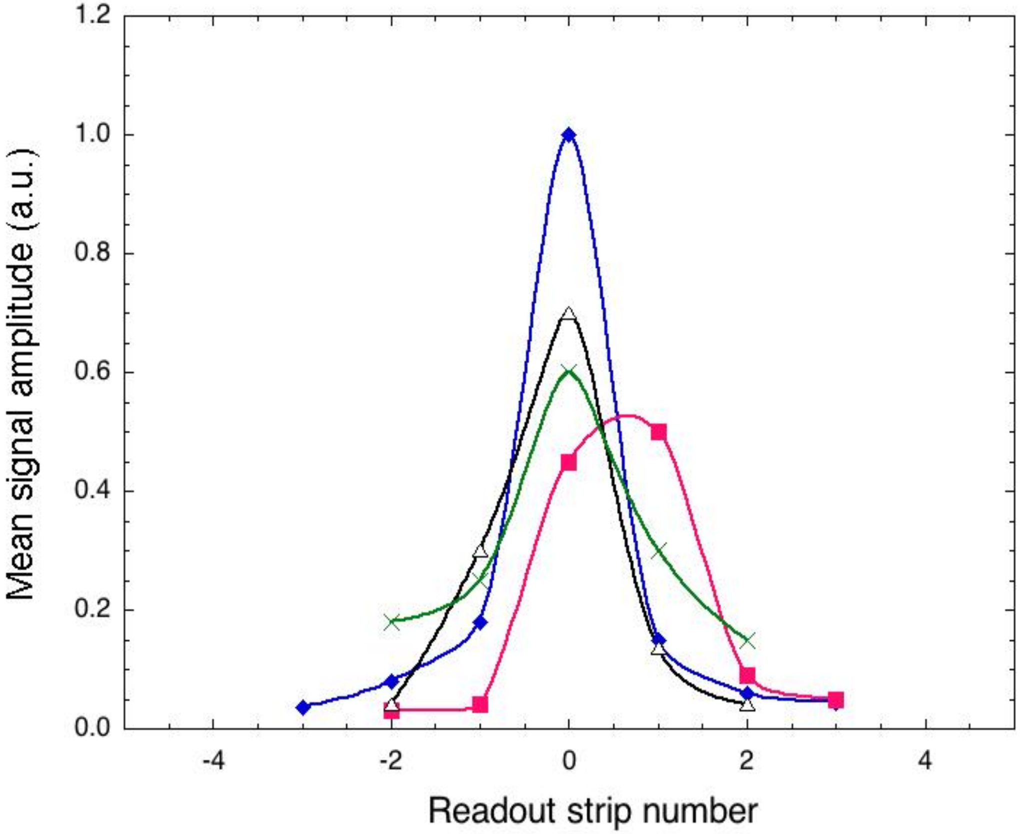
VI. Conclusions

- Recently developed micropttern detectors with resistive electrodes **show a great success**
- We enlarge this family of these detectors by introducing an **R-MSGCs, R-MSGC –based hybrid detectors and aR-Microdot detector**
- The maximum gains achieved in the present designs of R-MSGCs are as high as obtained with the best quality "classical" MSGCs manufactured on glass substrates
- R-MSGC have several important advantages over other designs of resistive micropattern detectors, for example: **fewer parts, simpler design, easier to assemble large area R-MSGCs from patches with practically no dead spaces and so on.**

In mass production an automatic procedure can be applied which will dramatically reduce the cost compared to other micropttern detectors

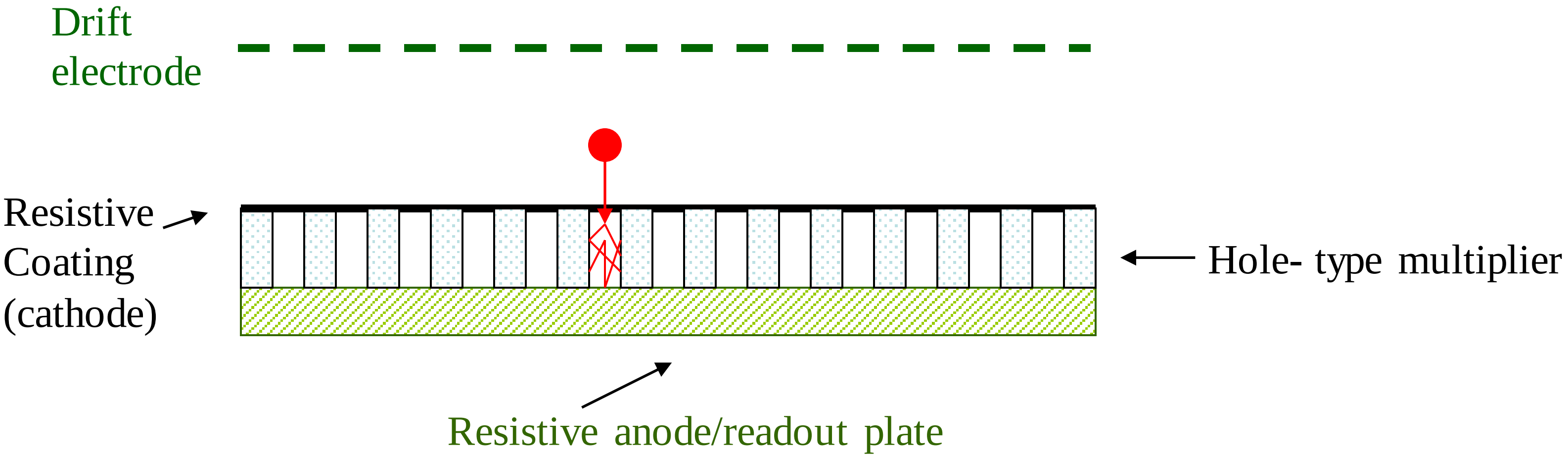
- They can be a very attractive option for applications requiring ion back flow or photon feedback suppression: photodetectors, TPCs and cetera
- We already tested R-MSGC combined with a CsI–RETGEM as a candidate for the ALICE VHMPID, and preliminary results are very encouraging
- The spark-protected hybrid R-MSGC will be an attractive option for the detection of charge and light from the LXe TPC with a CsI photocathode immerses inside the liquid.
- Another option for the LXe TPC, which is currently under the study in our group, is to use LXe doped with low ionization potential substances. In this detector the feedback will be also a problem and thus hybrid R-MSGC or R-Microdot will be also an attractive option.

Back up slides



Results of measurements induced signals from the Y- and X-readout strips oriented along and perpendicular to the anode strips of R-MSGCs respectively (see figure 3). Green curve with crosses-the collimator is aligned along the Y readout strip #0. Rhombus - the collimator is aligned along the X-strip #0. Triangles -the collimator was moved 200µm towards the X strip #1. Squares - the collimator was aligned between the X strips #0 and # 1. Measurements were performed in Ar+10%CO_2 at a gas gain of $5x10^3$. The voltage was applied to the cathode strips. For a better comparison of the induced signal profiles, the amplitudes of the signals measured on the Y- readout strips were reduced by a factor of four.

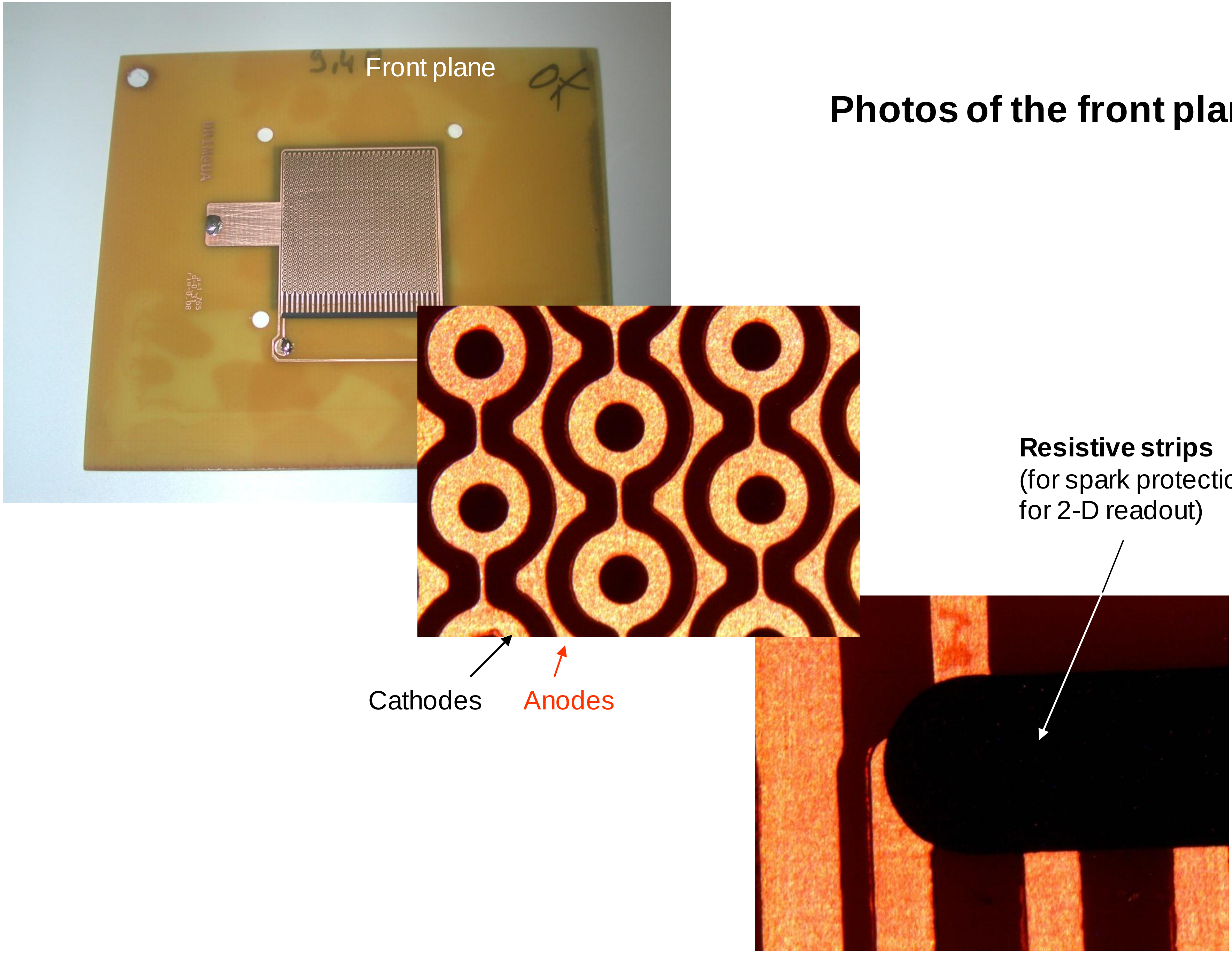
Resistive CAT/WELL



A hole type structures made of FR-4 pate 1 –2 mm thick with drilled holes (0,3 – 1 mm in diameter, depending on a design). One or both surfaces were covered with resistive layers.

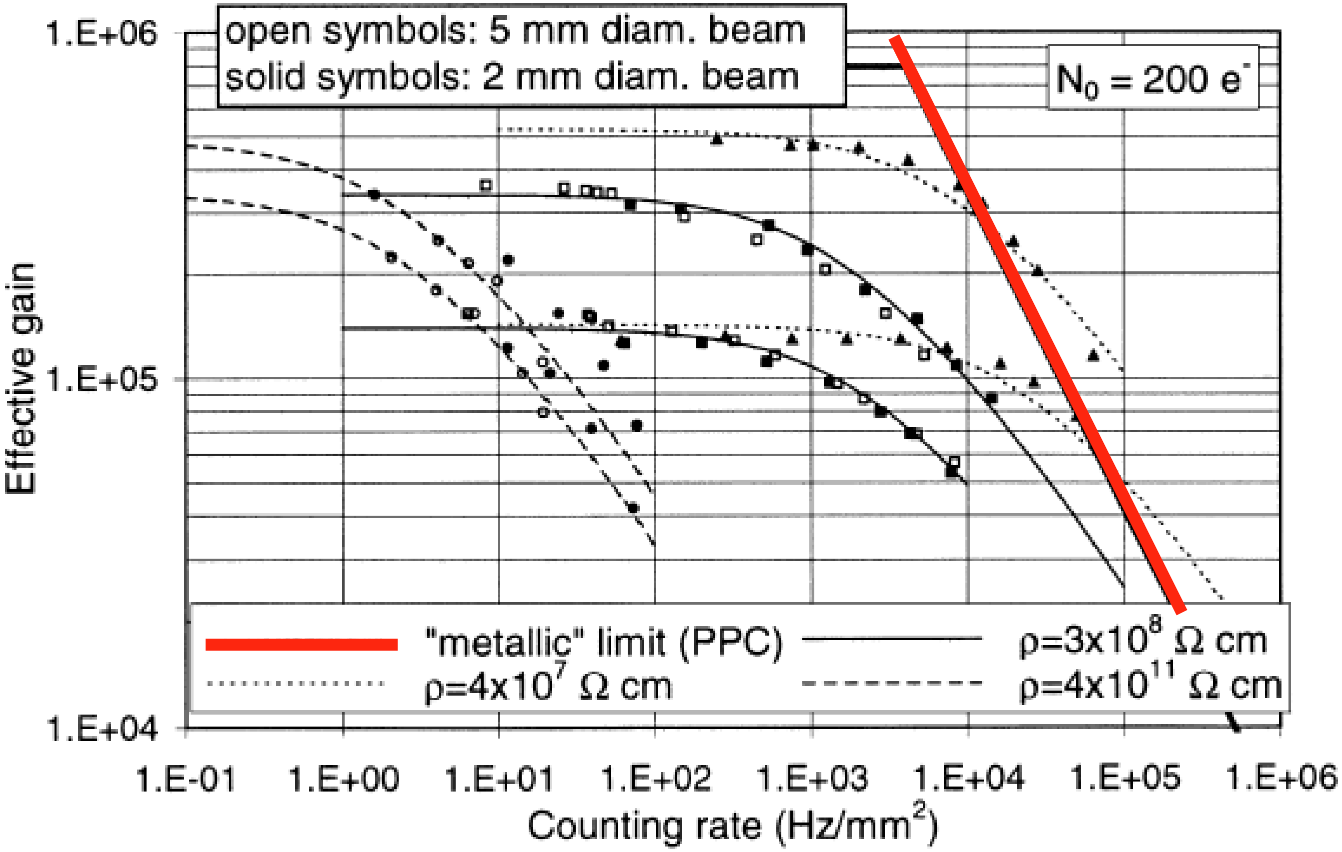
A. Di Mauro, et al., 2006 IEEE Nucl. Sci. Conf. Record 6, 2006, 3852.
V. Peskov, arXiv:0906.5215, 2010
Hugo Natal da Luz et al., : report on the RD-51 Mini-week, CERN, Jan 18, 2011

Photos of the front plane



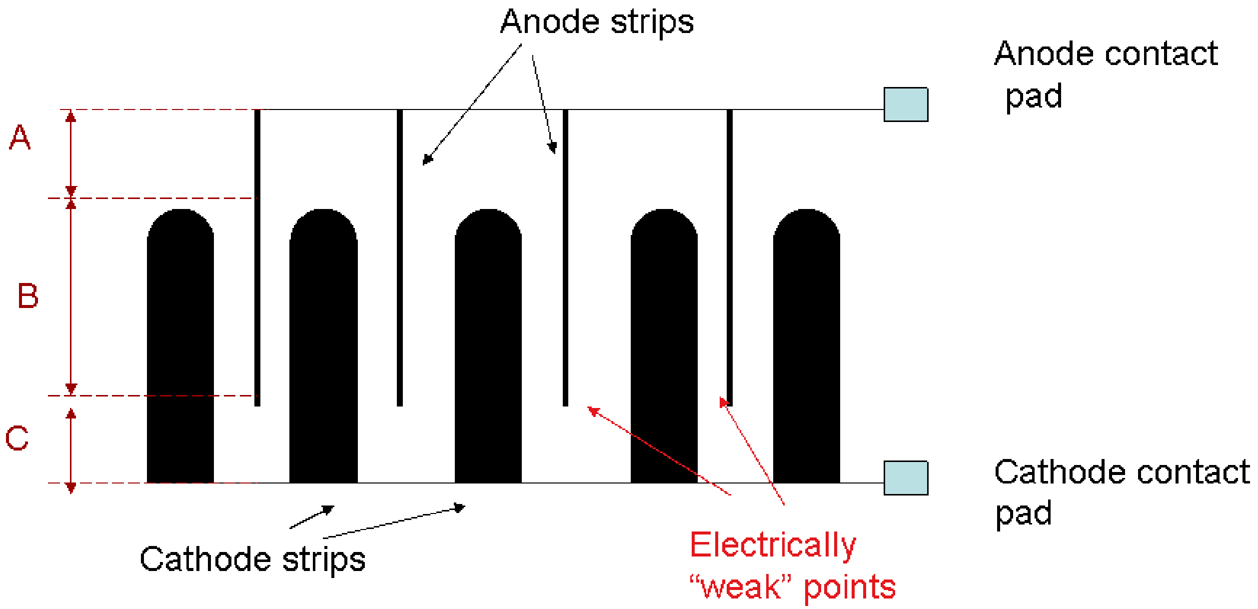
Resistive strips
(for spark protection or
for 2-D readout)

Optimization of the RPC electrodes resistivity for high rate applications

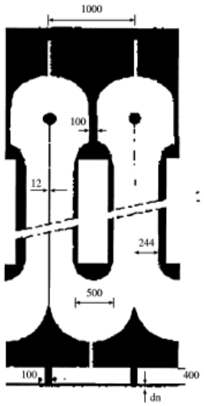


P. Fonte et al., NIM A413,1999,154

For the sake of simplicity <u>no special</u> care was done about edges of the strips

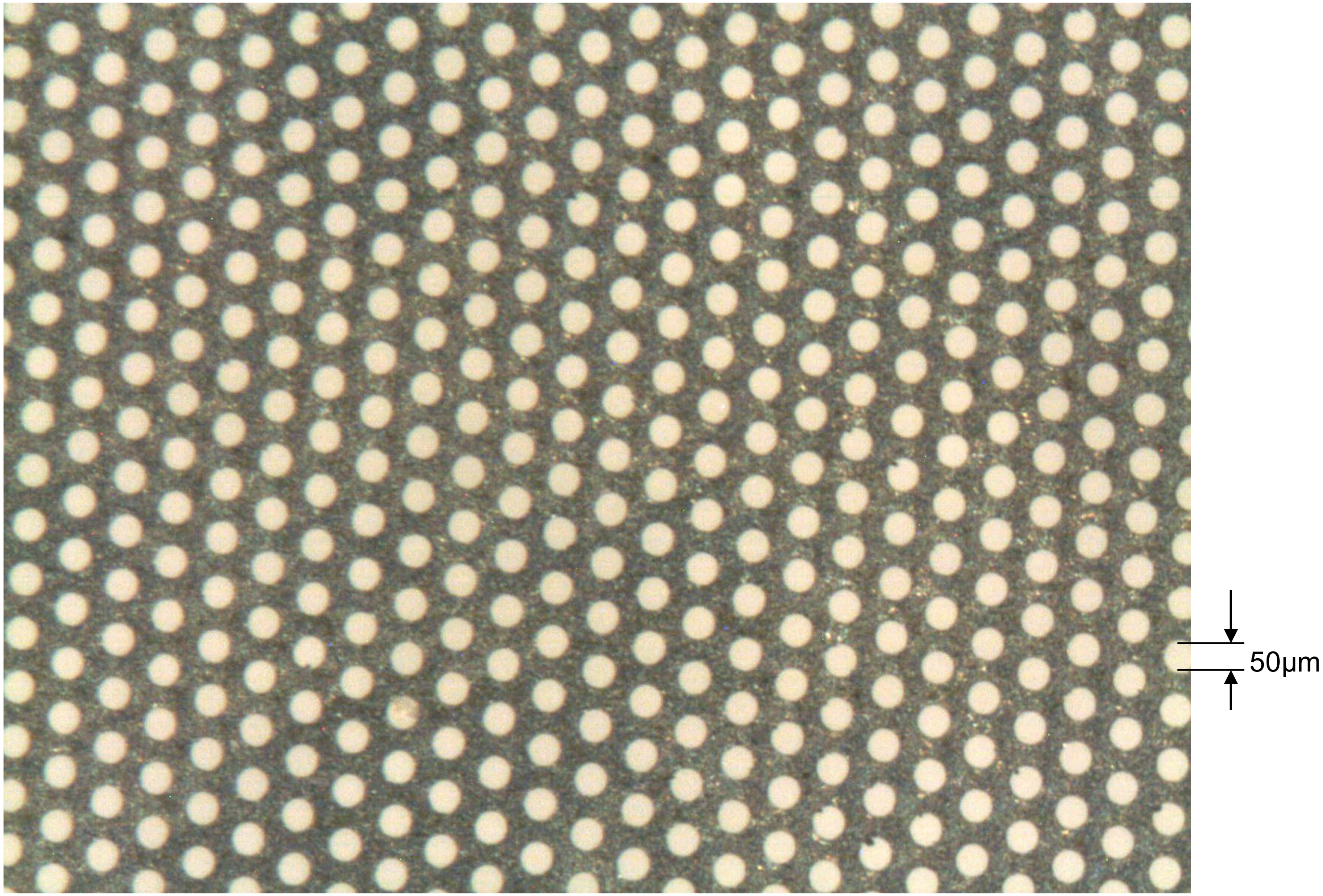


However these parts was “enforced” by resistivity



MSGC edges

MICROMEGAS with a resistive mesh cathode



Resistive Kapton 100XC10E5, resistivity 2.8-3 MΩ/□, a thickness of 20µm,
a hole diameter d=50 µm and hole spacing a=100 µm. Manufactured by laser drilling technique

*R. Oliveira, V. Peskov, et al.,, IEEE Trans. Nucl. Sci.**,** 57**,** 2010, 3744*

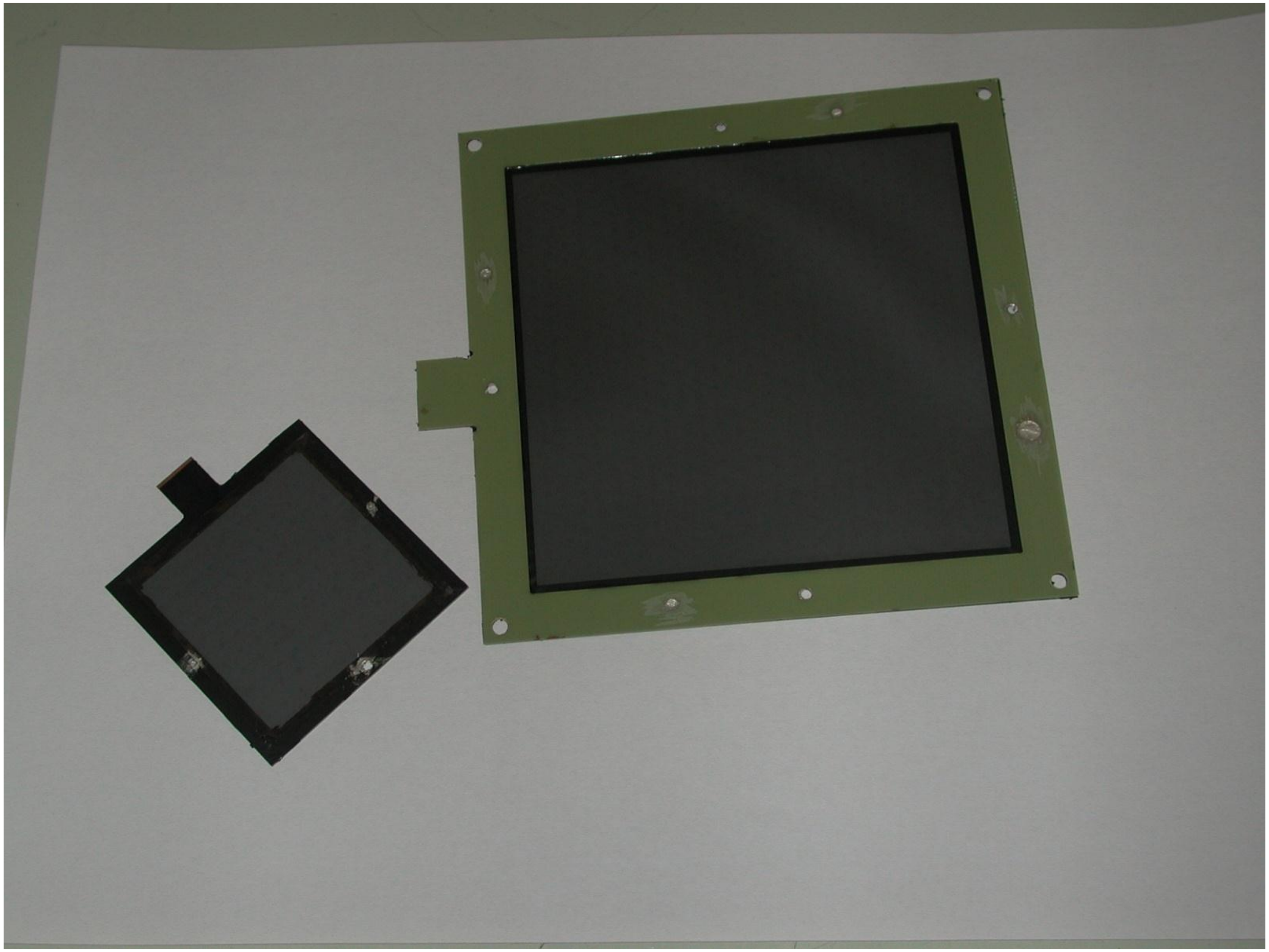
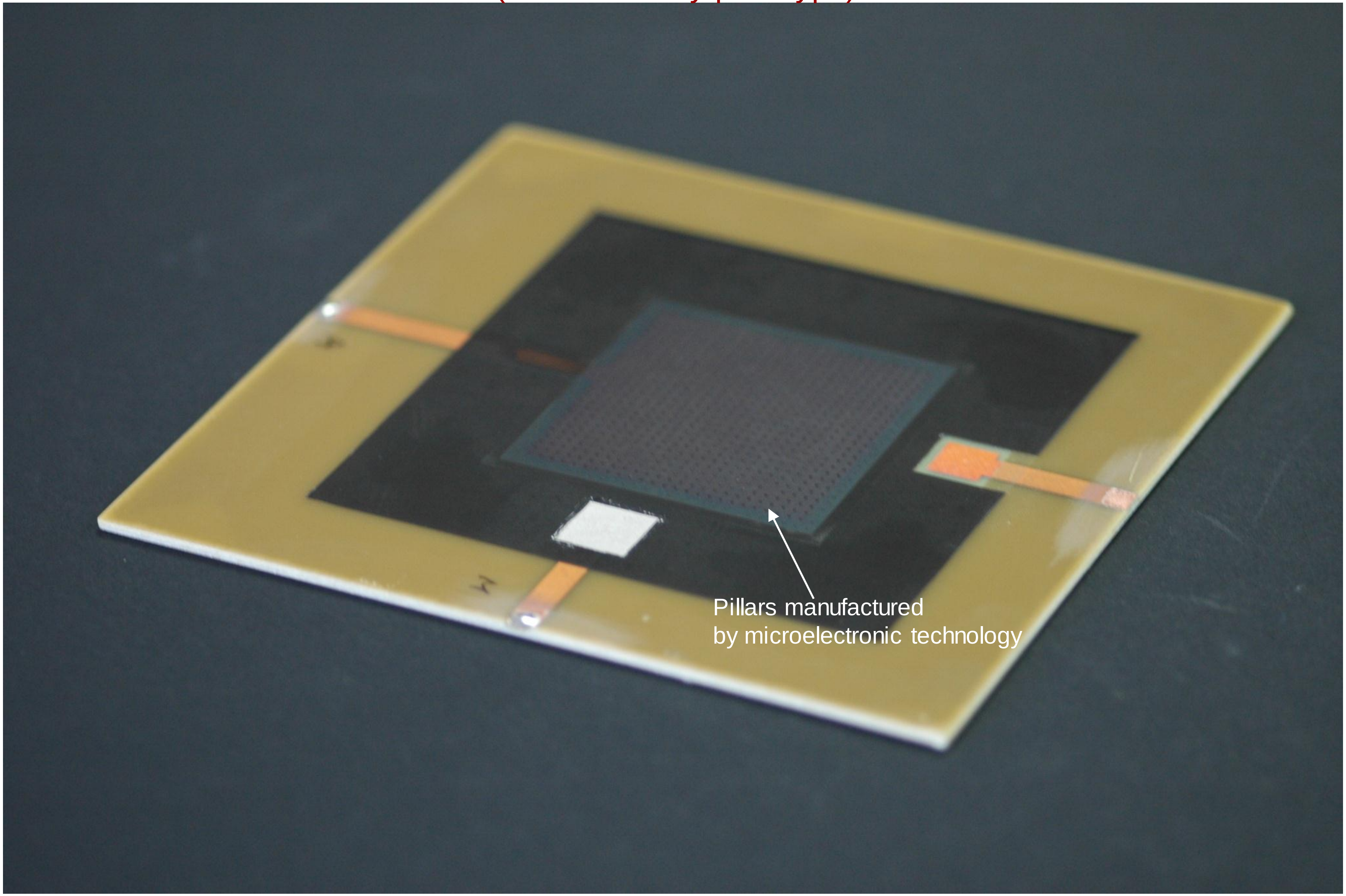


Photo of resistive meshes stretched on G-10 frames of size 5x5 cm^2 and 10x10cm^2 (these meshes could be building blocks for other types of detectors)

R. Oliveira, V. Peskov, et al.,, IEEE Trans. Nucl. Sci., ***57***, *2010, 3744*

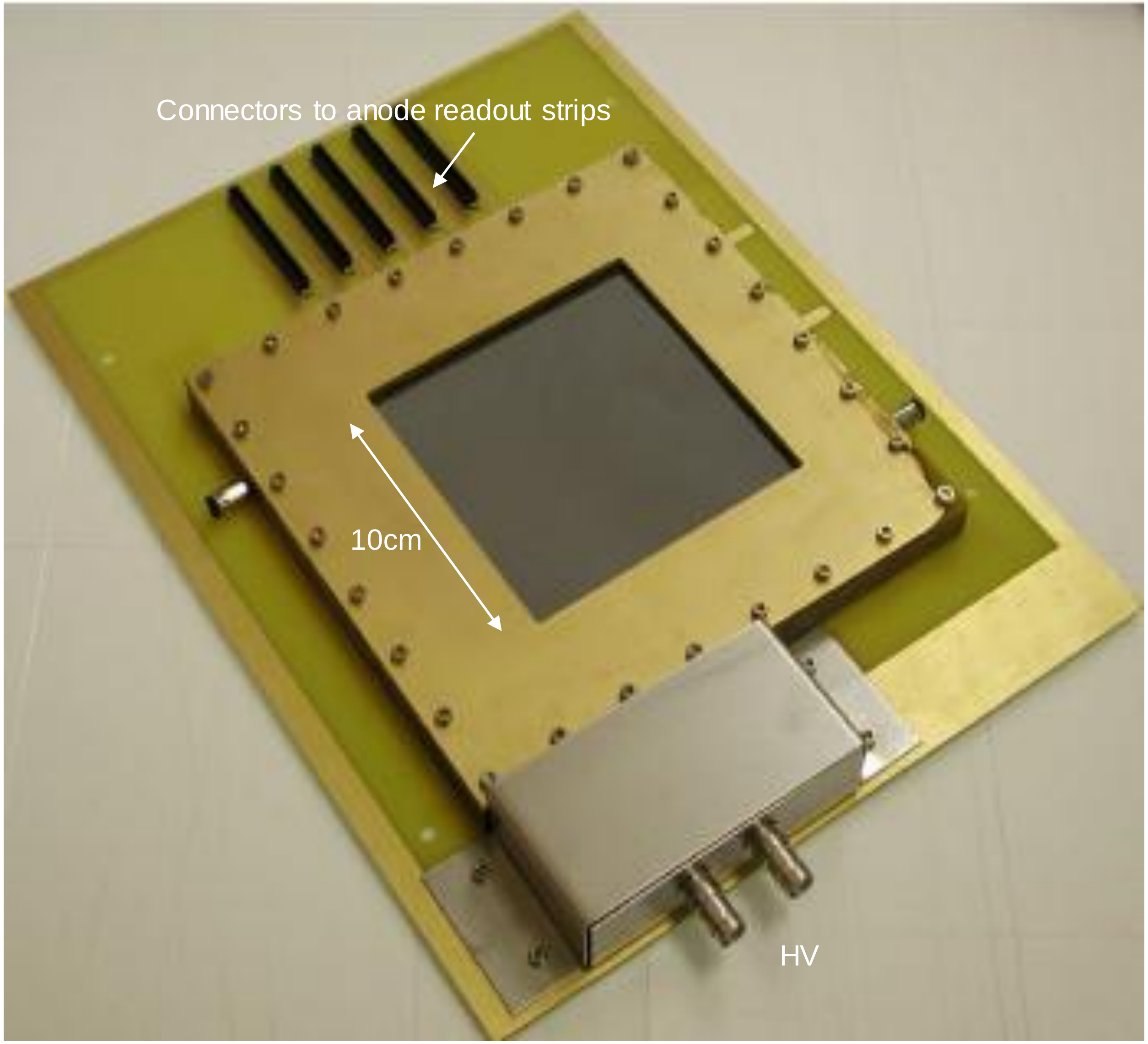
"Bulk" MICROMEGAS (with incorporated pillars) with a resistive mesh cathode

(first laboratory prototype)



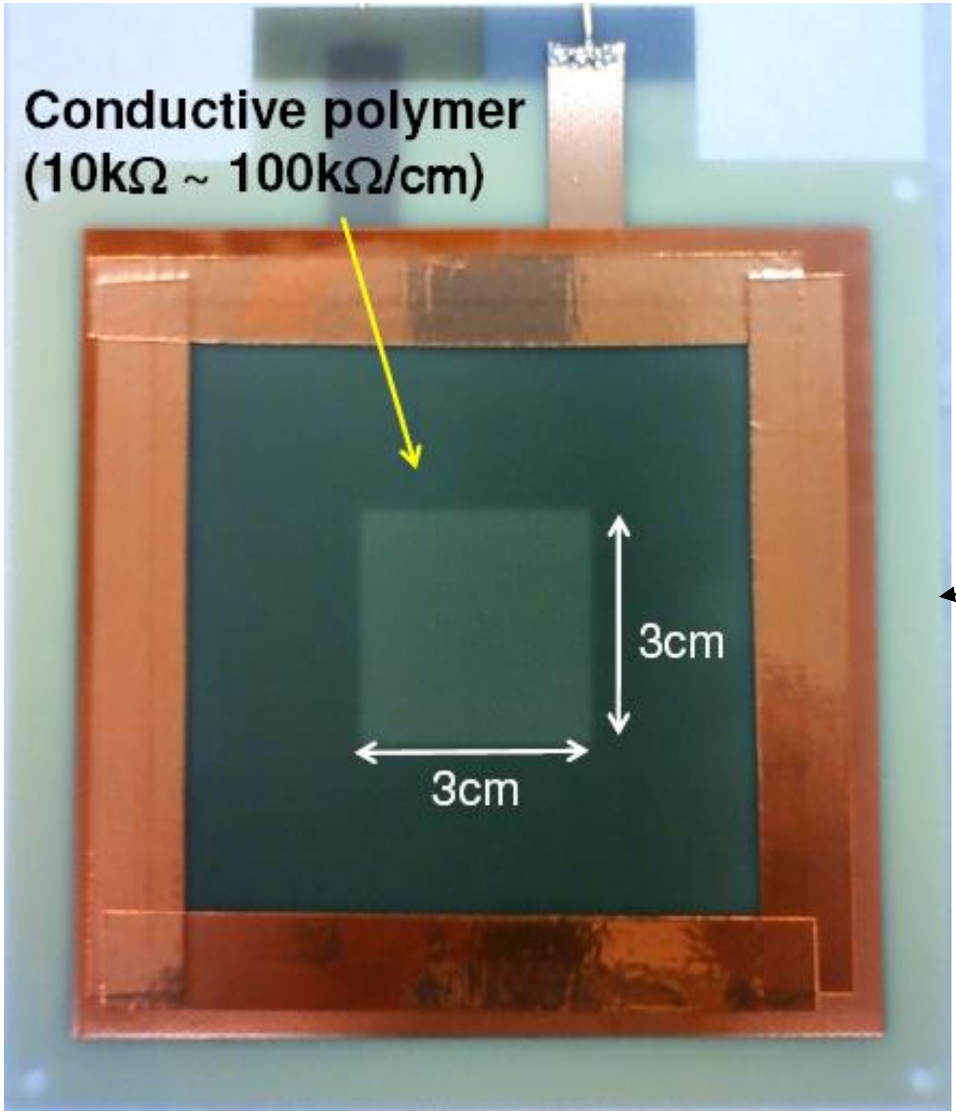
Pillars manufactured
by microelectronic technology

R. Oliveira et al, arXiv:1007.0211 and IEEE 57, 2010, 3744



<u>Latest</u> design of “bulk”-MICROMEGAS with resistive mesh cathode and position-sensitive anode

RETGEMs developed by other groups:

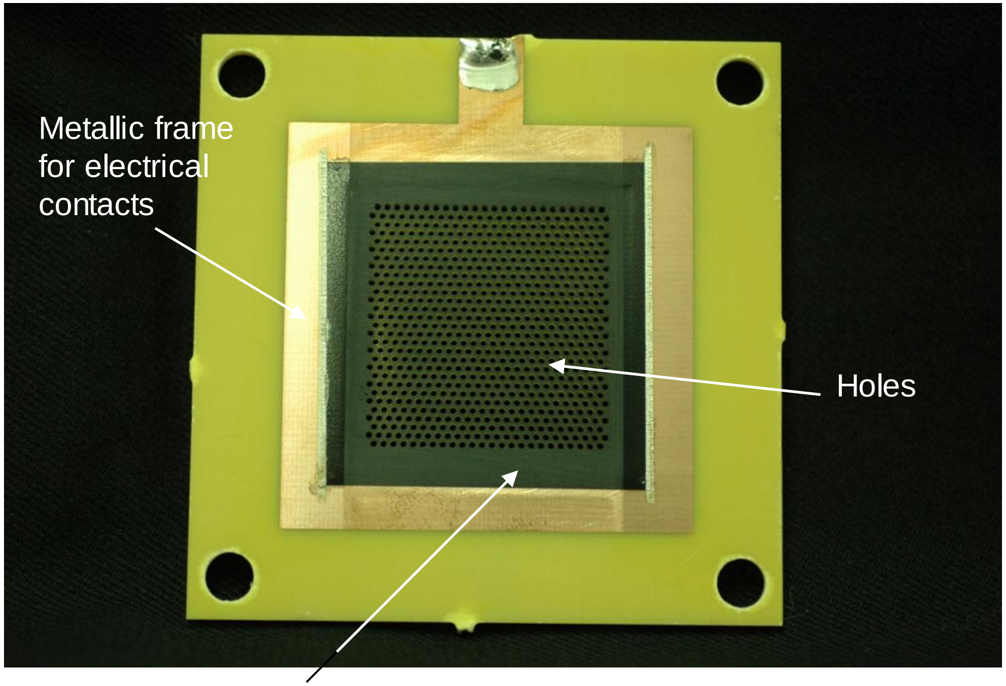


Several groups (mostly Japanese) are now successfully developing various designs of **RETGEMs**

See for example:
a photo of RETGEM
from: *R. Akimoto et al, presentation at 1st MPGDs conference in Crete,2009*

First design of Resistive GEM (RETGEM)

It was a GEM-type detector featuring resistive electrodes instead of metallic ones. The resistive electrodes limit the current during the sparks and make them "mild".

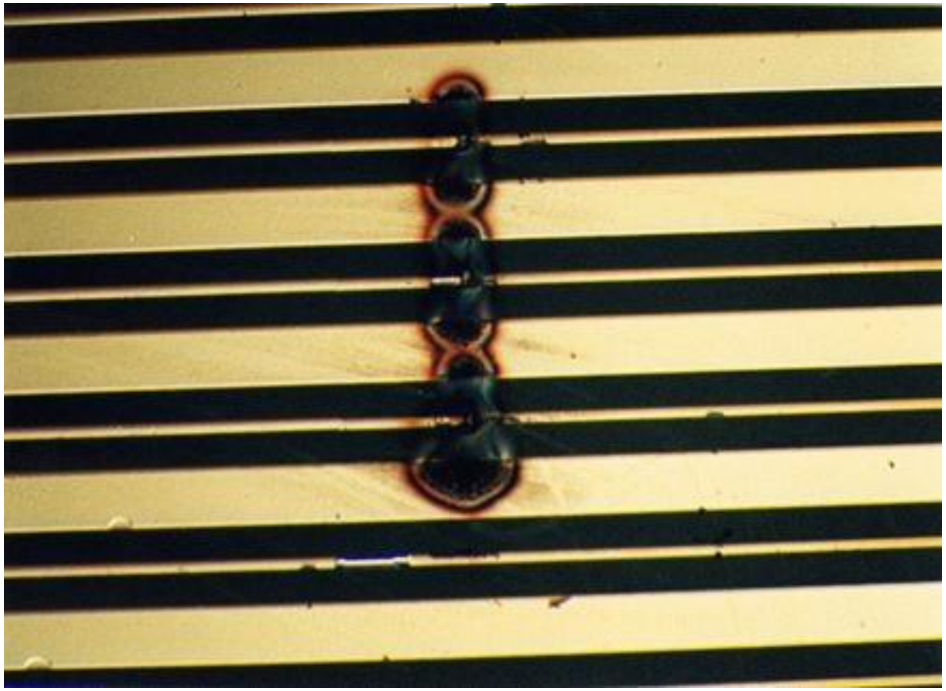


R. Oliveira, NIM A576, 2007, 362

Example of robustness:
10 minutes of continuous discharge did not destroy the detector (a photo made by a mobile phone)!

MSGC is the firs micropattern detector (*A. Oed, NIM A263, 1988, 351)* which is completely abundant these days

The main reasons: complicated production technique and it can be easily damaged by sparks



In addition we investigate if microdot detectors can be made spark protective

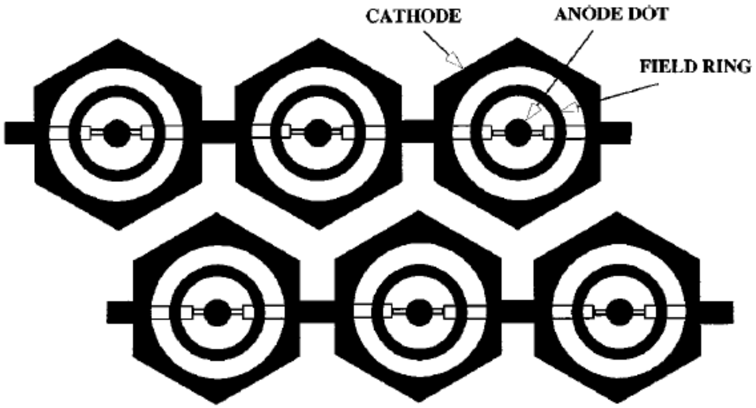


Figure 26 Schematics of the microdot chamber. A pattern of metallic anode dots surrounded by field and cathode electrodes is implemented on an insulating substrate, using microelectronics technology. Anodes are interconnected for readout.

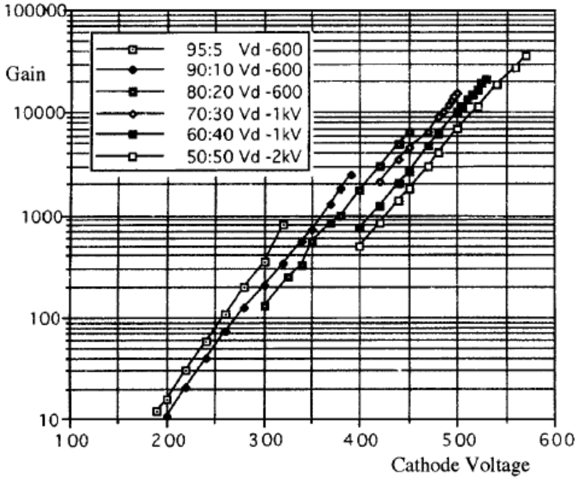


Figure 27 Examples of the very high gains attained with the microdot detector in various argon–dimethyl ether mixtures.

(S.F. Biagi, NIM A421, 1999, 234)

In the past the Microdot detector offered the highest maximum achievable gain among all micropattern detectors