Large area GEMs

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The manufacturing procedure used to make standard bi-conical GEMs is not suitable for the production of large area detectors, due to difficulties in the alignment of the two photolithographic masks. The most promising technology in this sense is the single mask technique, in which the polyamide is etched from one side only, which leads to conical holes. Figure 1 shows a comparison between the two manufacturing techniques.

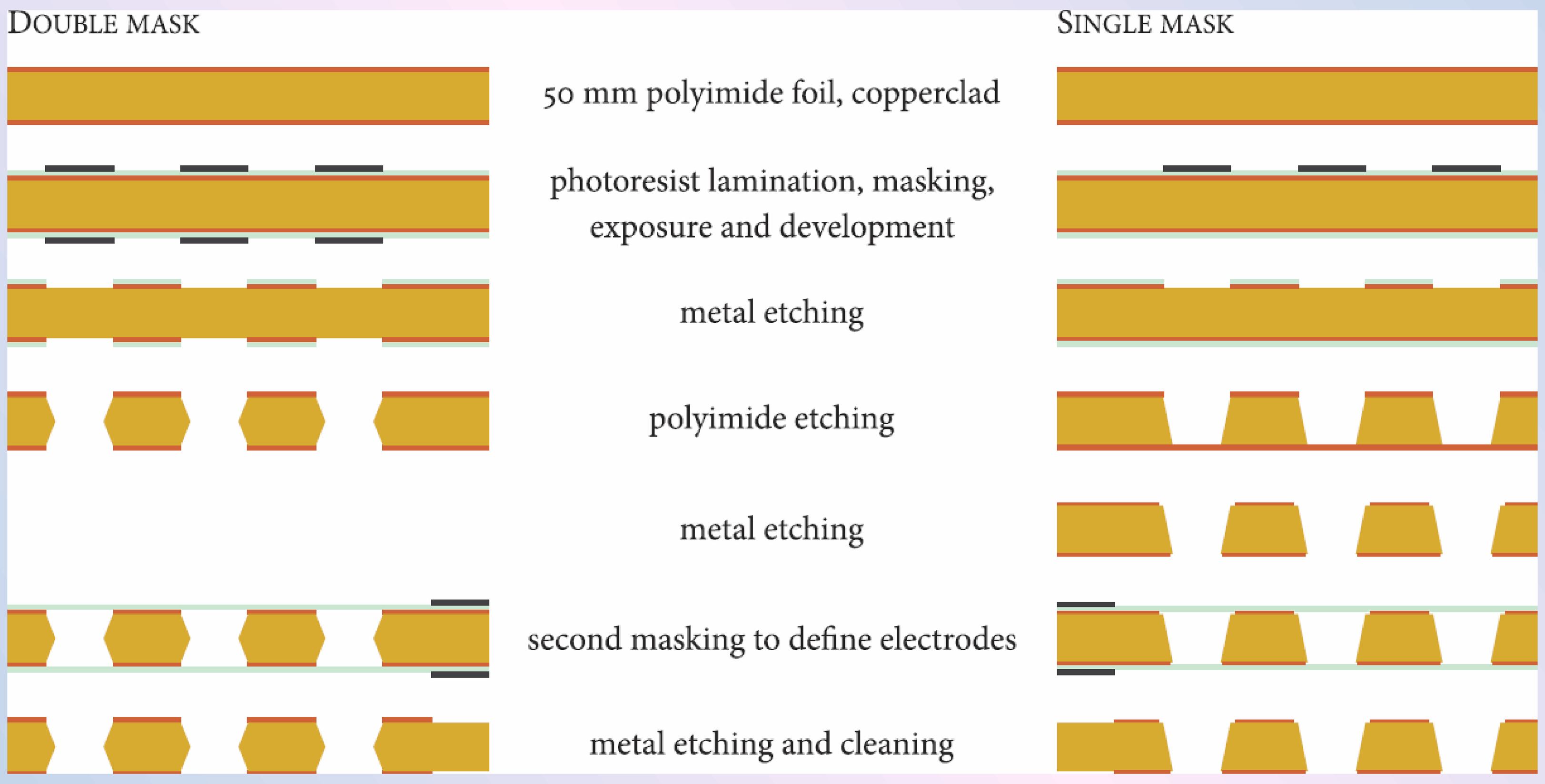


Figure 1: comparison between the standard double mask and the single mask photolithographic techniques for GEM production.

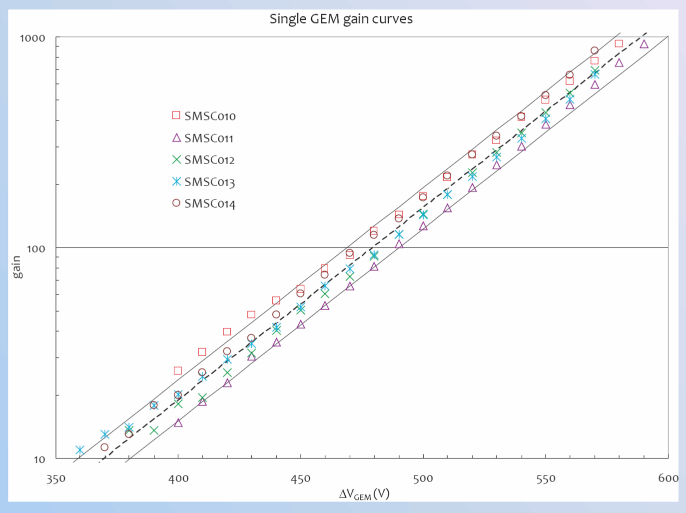


Figure 2: gain study for several 10 x 10 cm foils of single mask GEMs in $Ar:CO_2$ 70:30 (summer 2008).

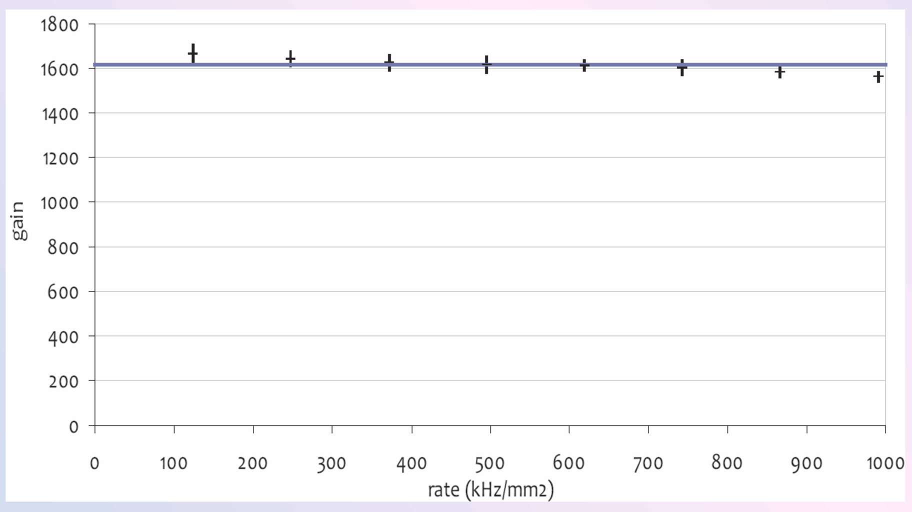


Figure 3: rate capability study for a single mask based triple GEM arrangement. The gas mixture is $Ar:CO_2$ 70:30 (summer 2008).

In summer 2008 a large area detector (~ 2000 cm^2) based on single mask foils was built at CERN (figure 4). Figure 5 shows a pulse height spectrum obtained with such detector in $Ar:CO_2$ 70:30 gas mixture. Using copper X-rays (8.9 keV) it is possible to achieve an energy resolution of 9.5 % (22.4 % FWHM).

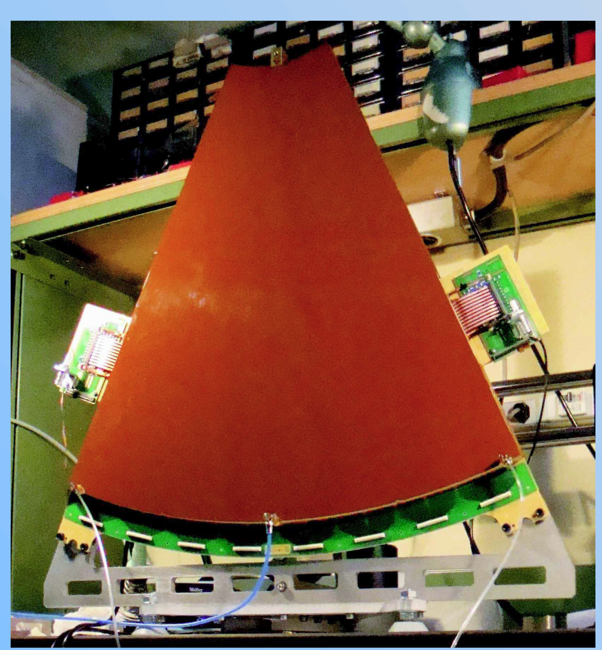


Figure 4: large area triple GEM detector mounted on its support.

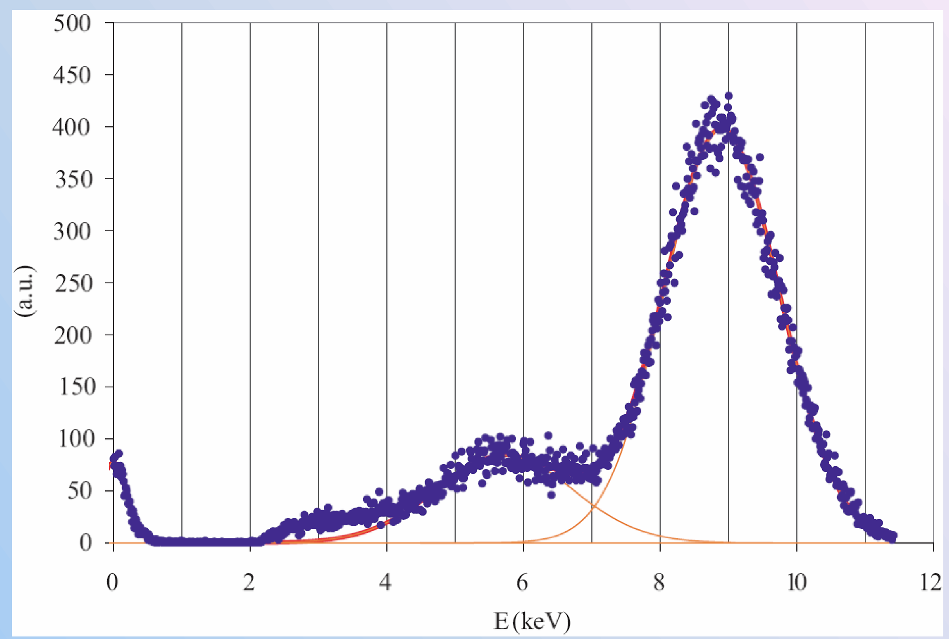


Figure 5: pulse height spectrum in $Ar:CO_2$ 70:30 obtained with the detector in figure 4.

The latest manufacturing techniques allow to finely tune the hole shape (diameter and conicality) by slightly changing the production process. Garfield-based numerical simulations were used to study the field lines inside the holes and the detector transparency as a function of the holes shape.

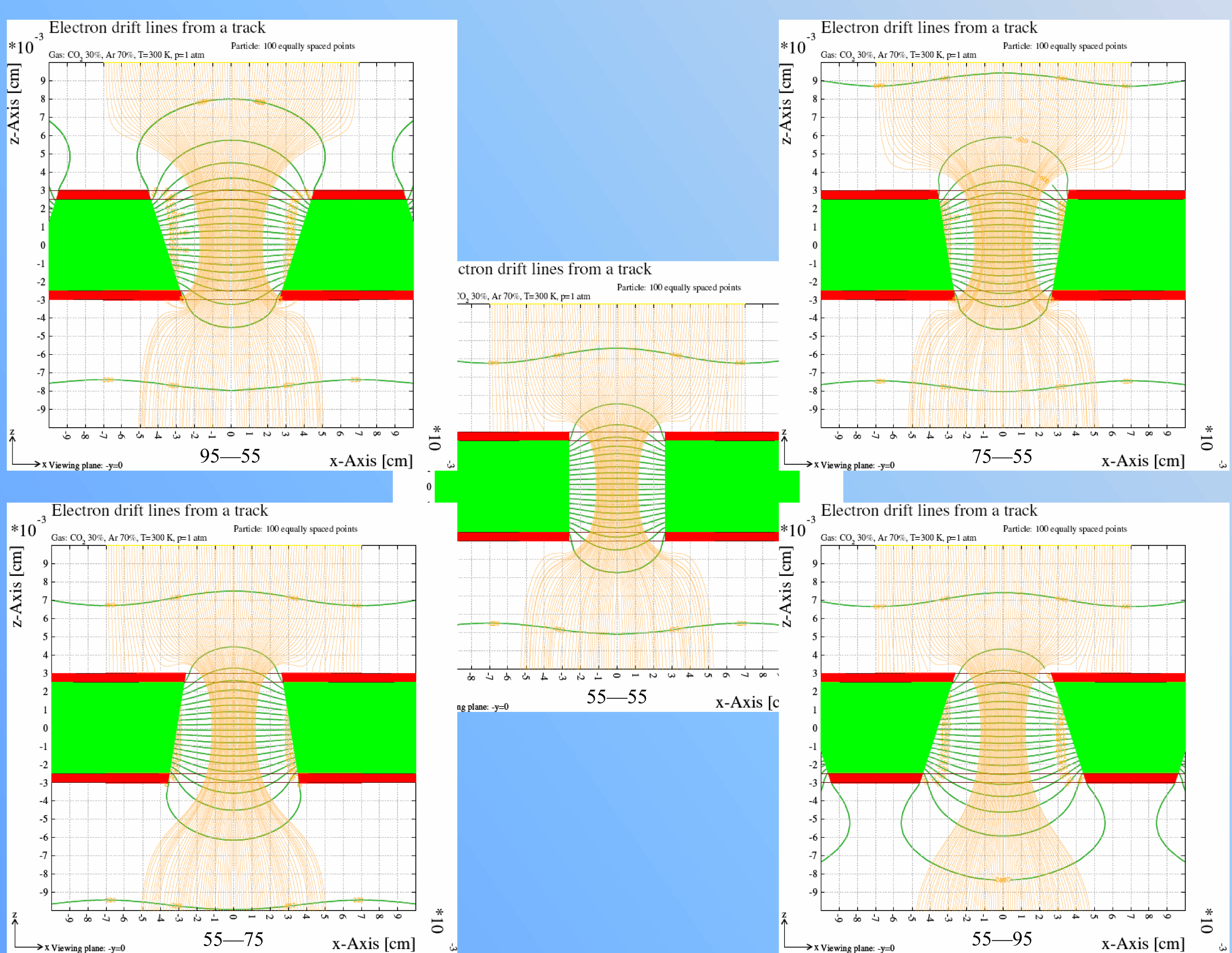


Figure 6: GEM cross-sections for different hole geometries. The labels indicate the hole diameter in micrometers on the top surface of the upper GEM electrode and on the bottom surface of the lower GEM electrode.

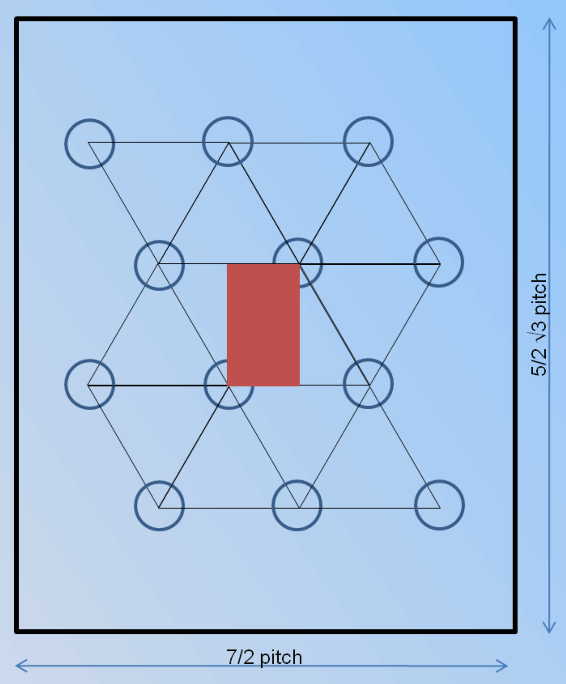


Figure 7: elementary cell and simulation volume.

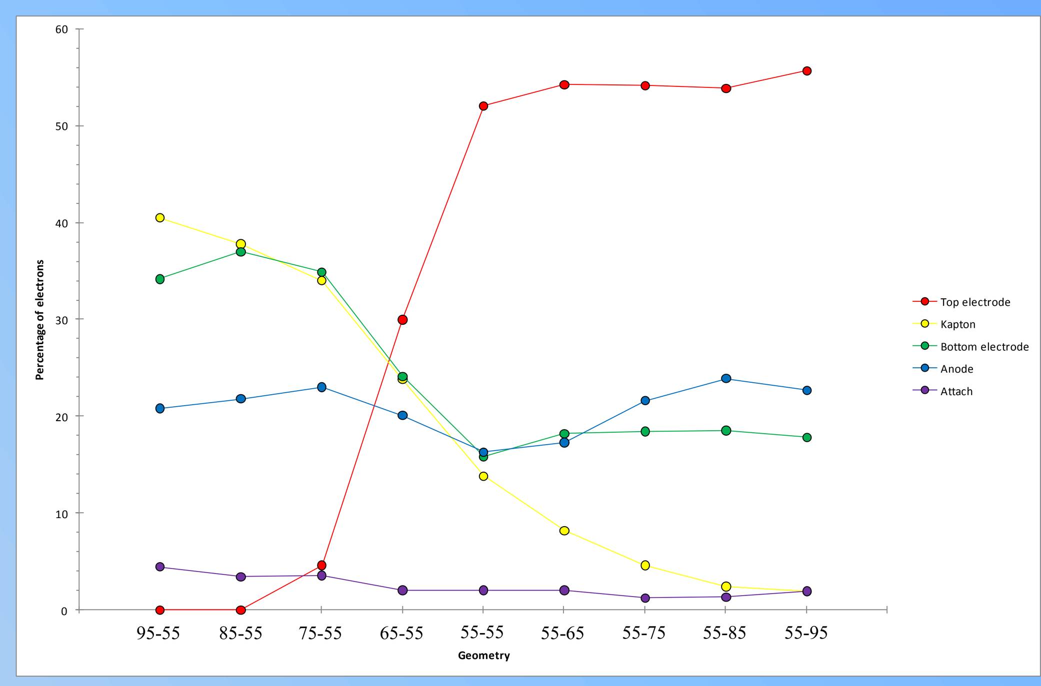


Figure 8: transparency study: electrons final position as a function of the hole geometry.

The newest manufacturing techniques allow to get almost cylindrical holes in the GEM foils. This is achieved using a strong isotropic conical chemical etching followed by an isotropic cylindrical chemical etching. Moreover, the hole conicality can be tuned by slightly changing the duration of the second process.

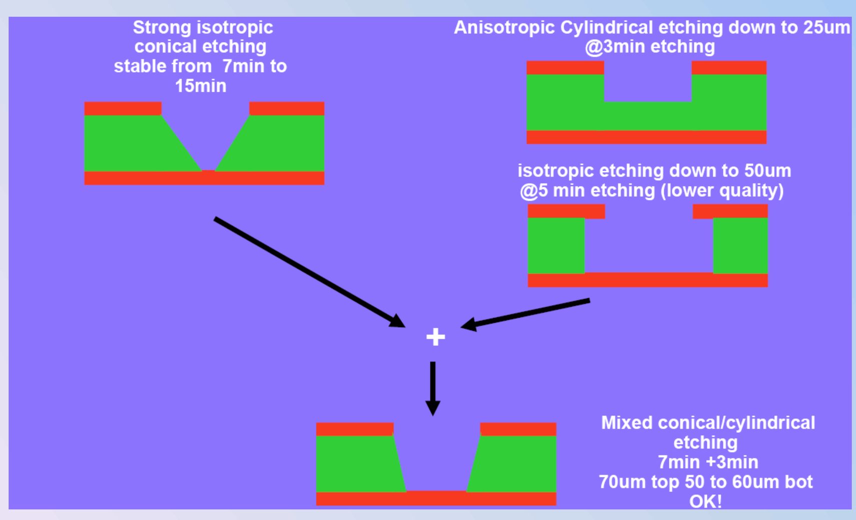


Figure 9: latest kapton etching technique (*Rui de Oliveira, Latest MPGD developments and readout board guidelines*).

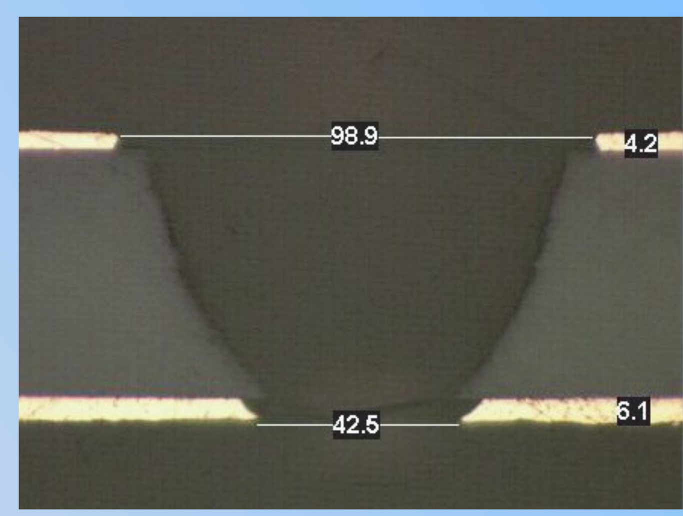


Figure 10: electron microscope picture of a single mask GEM (summer 2008).

It is also possible to get a "zero rim" around the holes using two different methods:

- ***the first possibility is to gold-plate the top electrode to protect it while the naked bottom electrode is spray-etched***

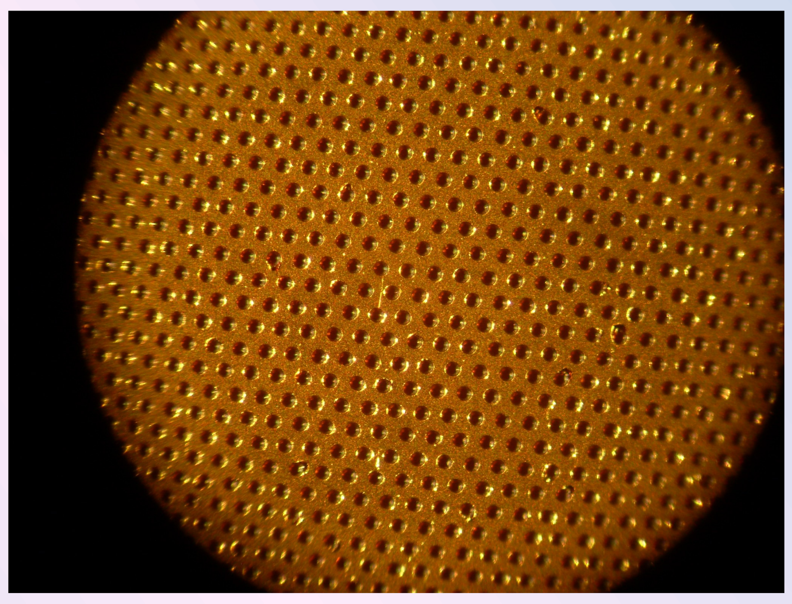


Figure 11: microscope picture of the top electrode of a gold-plated GEM (January 2009).

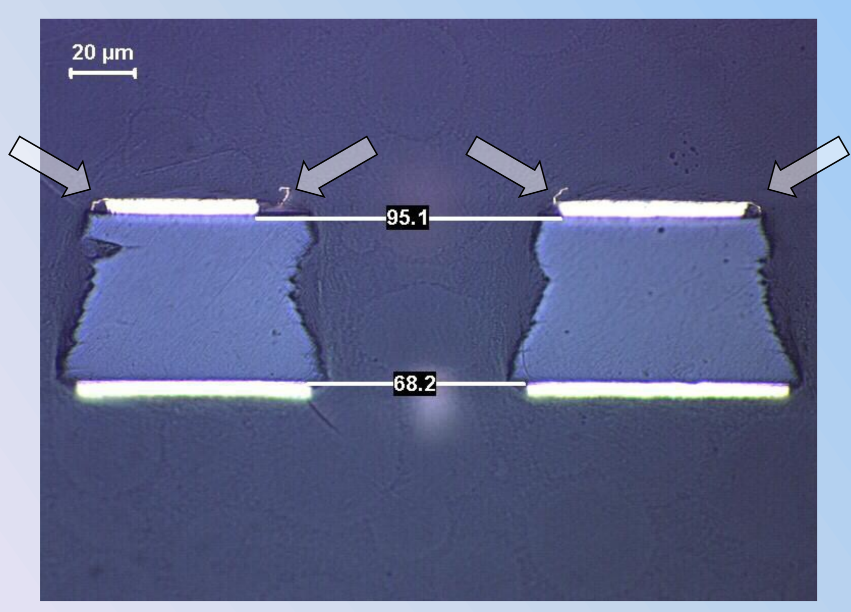


Figure 12: electron microscope picture of a gold-plated GEM (January 2009). The magnification factor is 500x.

- the gold layer increases the manufacturing cost;
- the most critical problem is the non-hermeticity of the gold protection at the boundary between the copper and the polyamide

→ copper underetching which leaves delaminated gold around the holes (Figure 12)
→ inverted sparking limit: ~ 580 V in air in open-top configuration and ~ 660 V in air in open-bottom configuration

- ***the second possibility is to use an electro-chemical active corrosion protection on the top electrode while the bottom one is chemically etched***

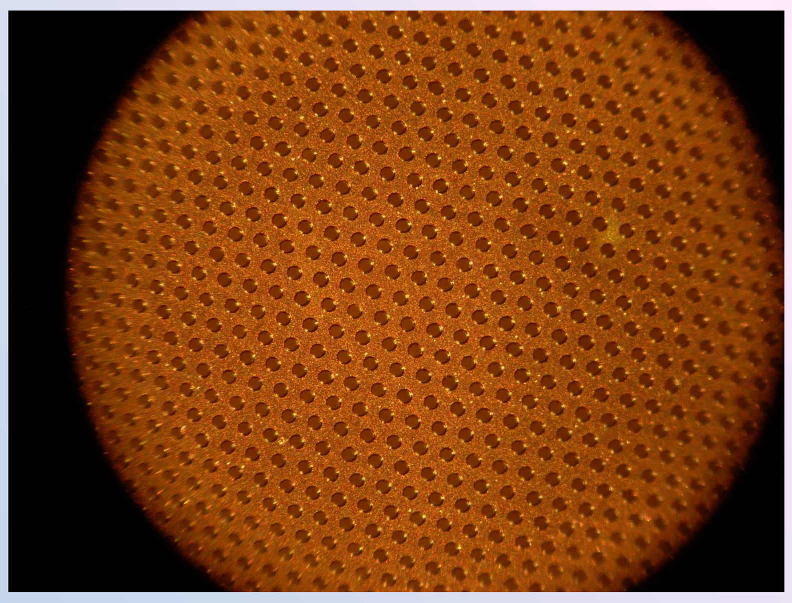


Figure 13: microscope picture of the top electrode of an electro-chemically protected GEM (April 2009).

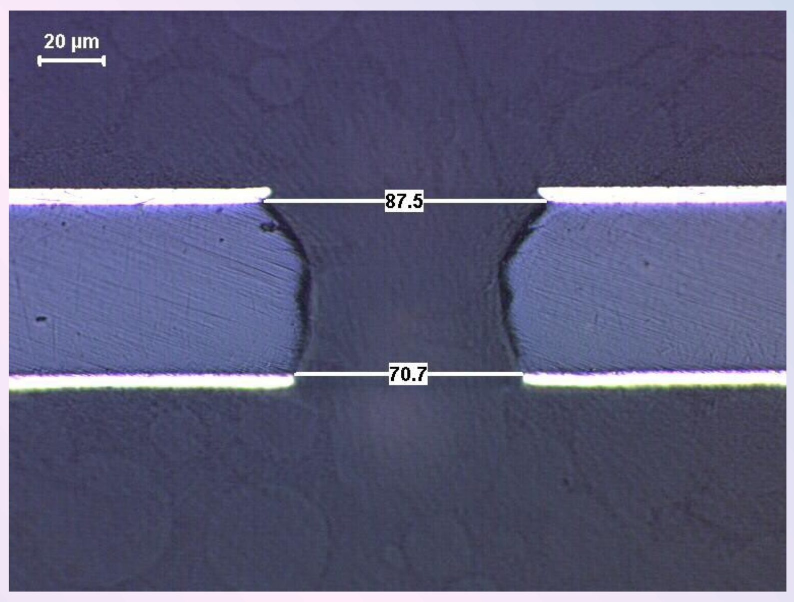
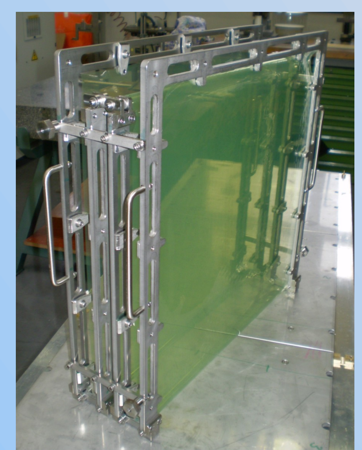


Figure 14: electron microscope picture of an electro-chemically protected GEM (April 2009). The magnification factor is 500x.

- the sparking limit is ~ 650 V in air in open-top configuration and ~ 630 V in air in open-bottom configuration;
- the energy resolution seems to be not very good;
- the tested foils seem to be fragile

→ a small rim around the holes is probably needed



The electro-chemical protection allows to obtain well shaped holes and the introduction of a small rim will probably cure the fragility of the foils. The group is now getting ready for the production of 2 x 0.5 m single mask GEMs. Figure 15 shows the mechanical support that allows to handle the foils during the manufacturing phase.

Figure 15: the mechanical support for the 2 x 0.5 m single mask GEMs.