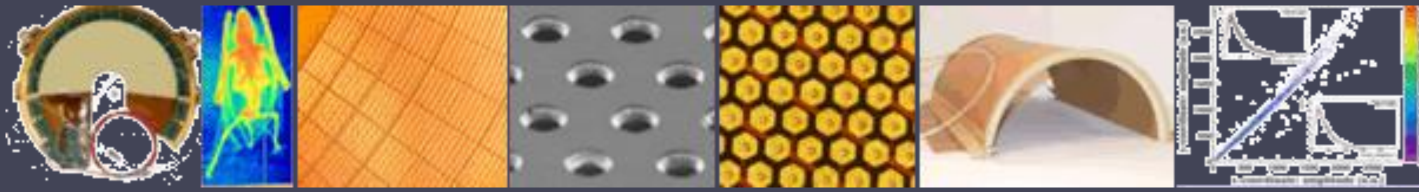


MC-PAD final activity report

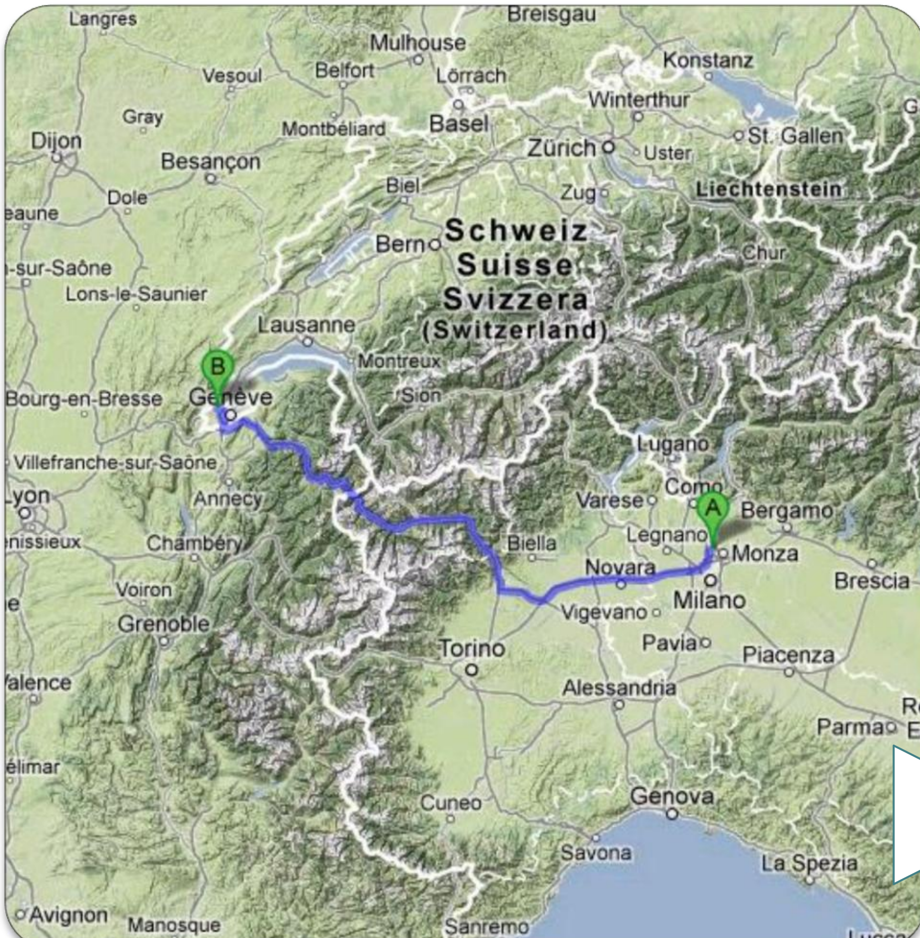
Marco Villa

MC–PAD end of network event

19–22 September 2012

LNF, Frascati, Italy

A 3-years-long journey…



Dec 2008 – Nov 2011

ESR @ CERN

PhD @ Bonn Uni

Project supervisors:

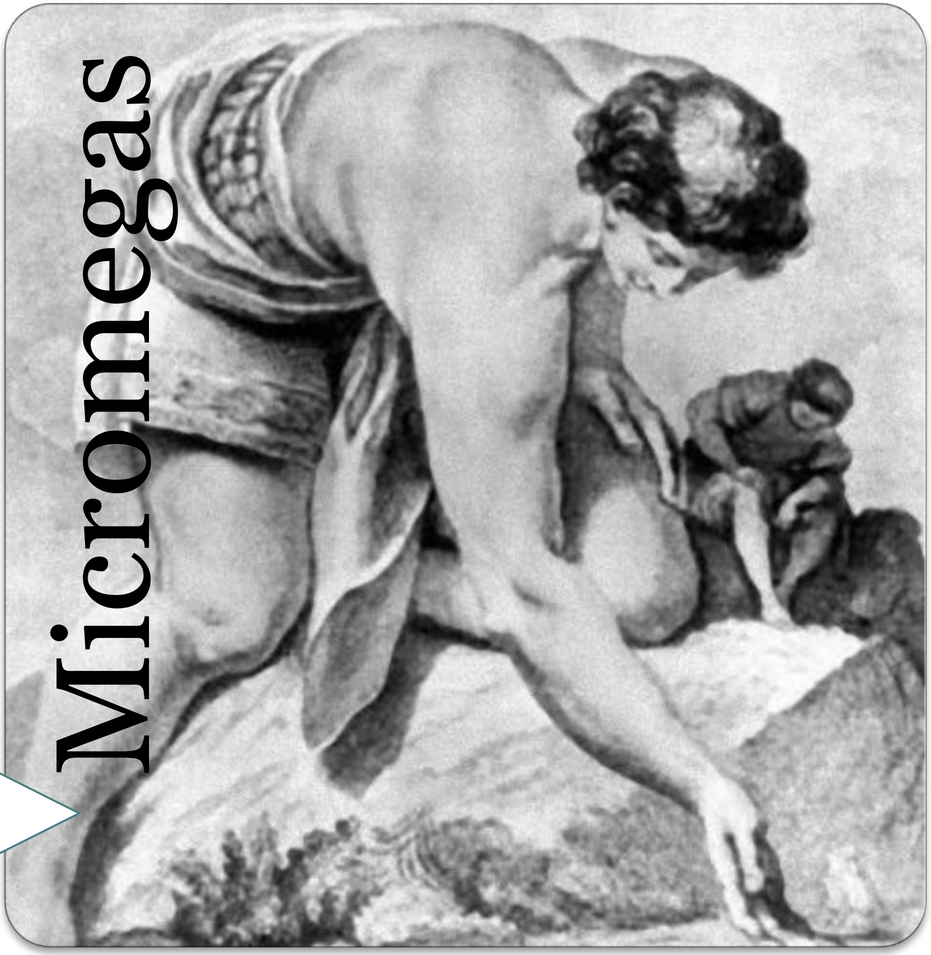
Leszek Ropelewski

Joerg Wotschack

PhD advisor:

Ian Brock

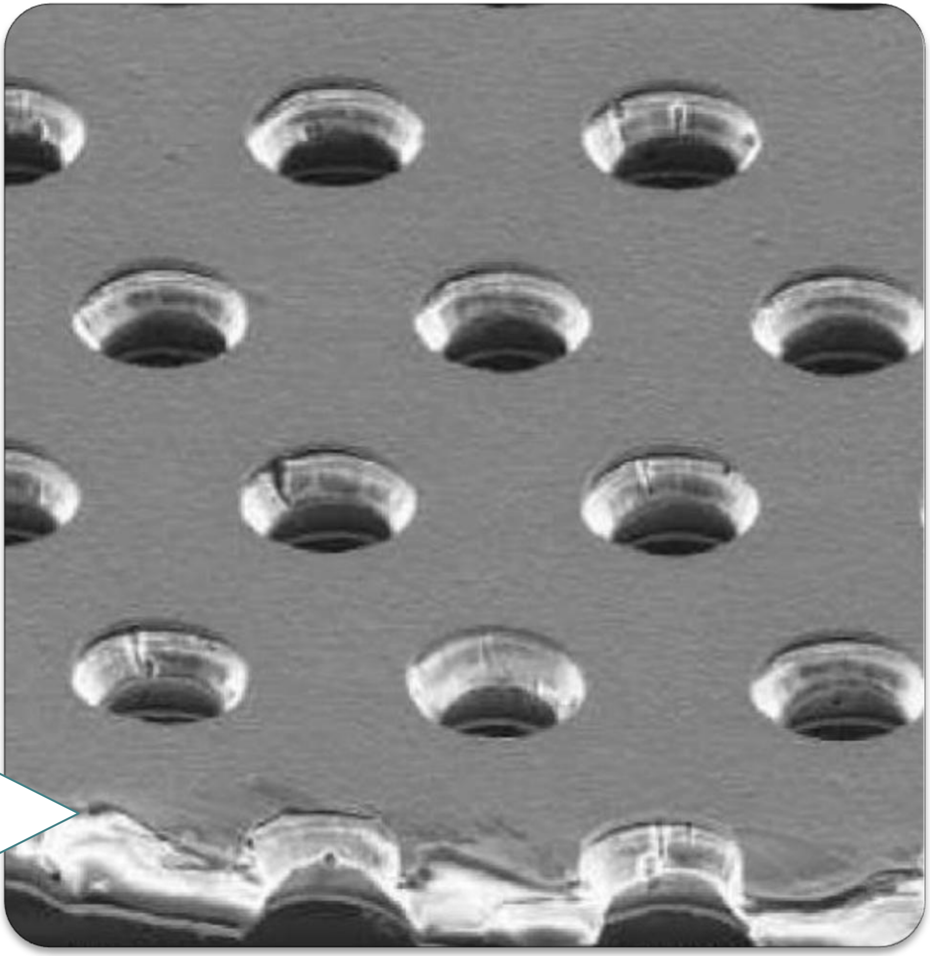
…a journey in Wonderland



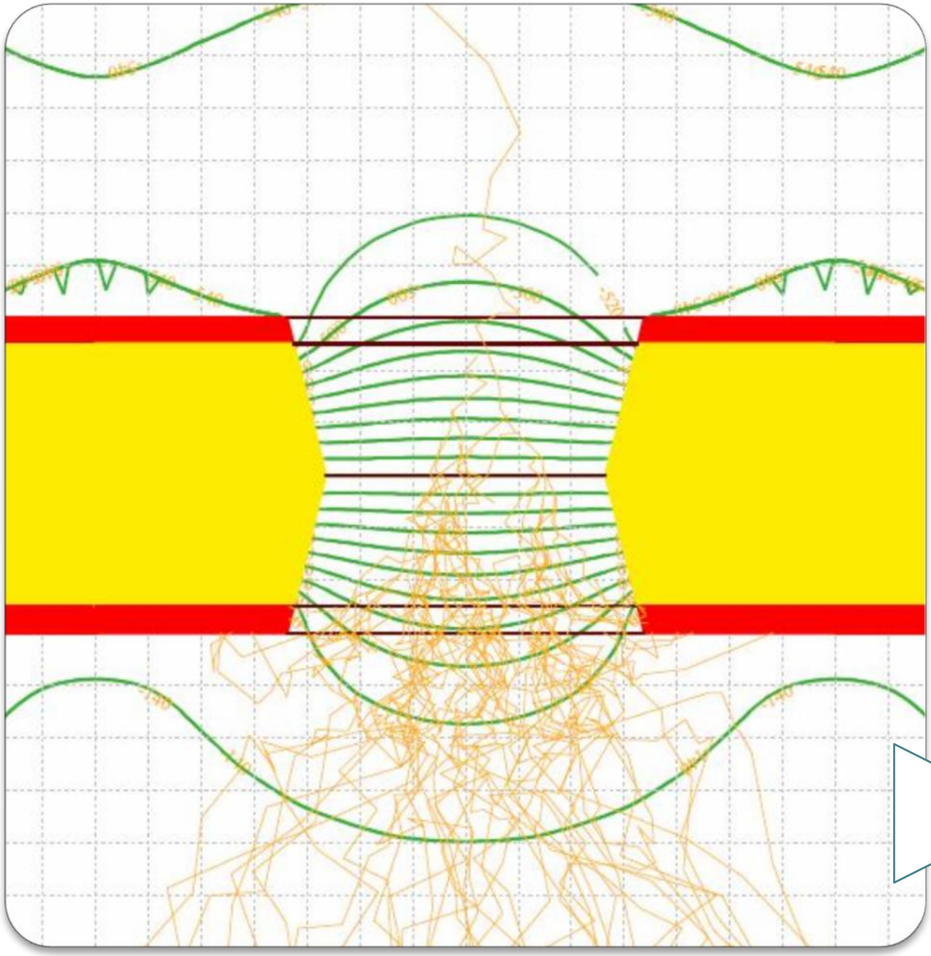
What is a GEM?

Gas Electron Multiplier

- Charge amplification structure
- Fabio Sauli (1997)
- 50μm Kapton clad on both faces with 5μm copper
- Double photolithography and wet chemical etching
- Bi–conical holes: 140μm pitch and 70–55–70μm diameter



How does a GEM work?



Ionization charges drift under ~kV/cm cathode field

~400V across GEM

Field gradient focuses electrons into holes

~100kV/cm field initiates avalanche multiplication

Electrons induce a signal on the independent readout

Towards large area GEMs

The challenge…

- Increasing demand for large area (~m²) GEMs
- Photolithographic masks positioned manually
- ~10μm required pattern alignment precision
- Not feasible for linear dimensions >30cm

…and the strategy

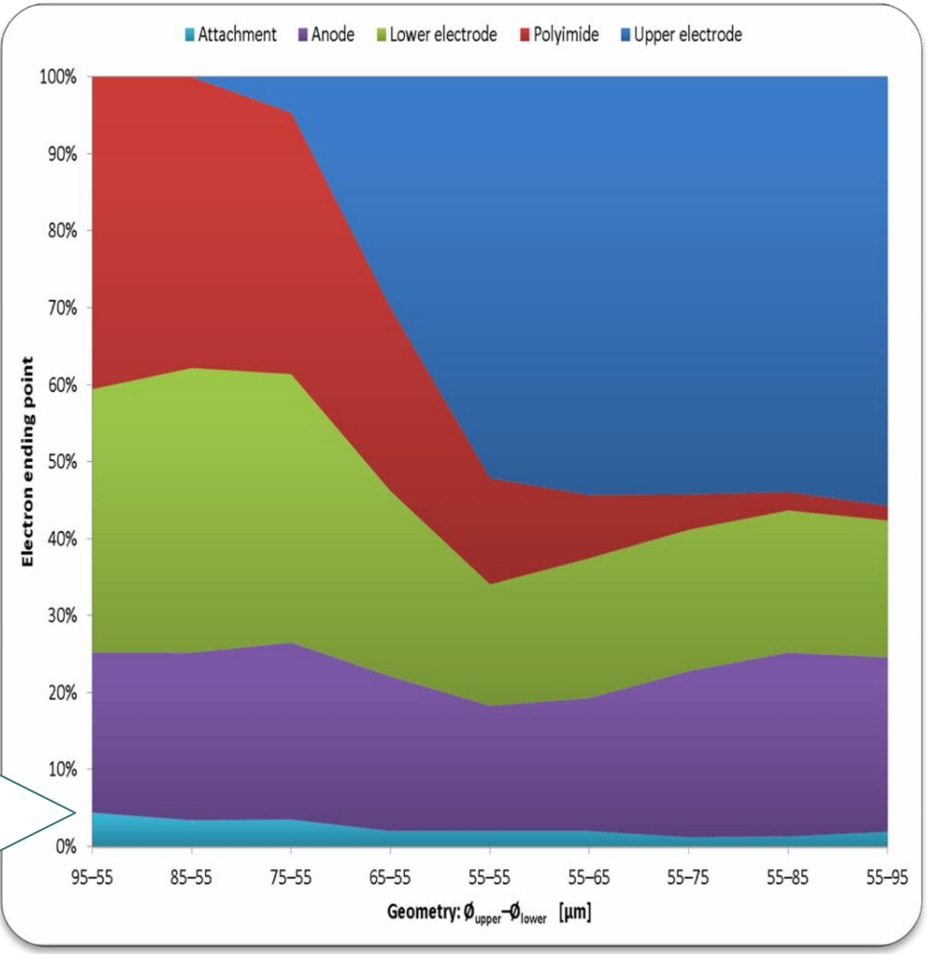
- Use single mask photolithography
- 2007: start to enhance etching chemistry
- 2008: ~0.2m² prototype triple GEM completed
- Conical holes, rim of exposed polyimide

Marco Villa 19-22 Sep 2012
MC-PAD closing event LNF, Italy

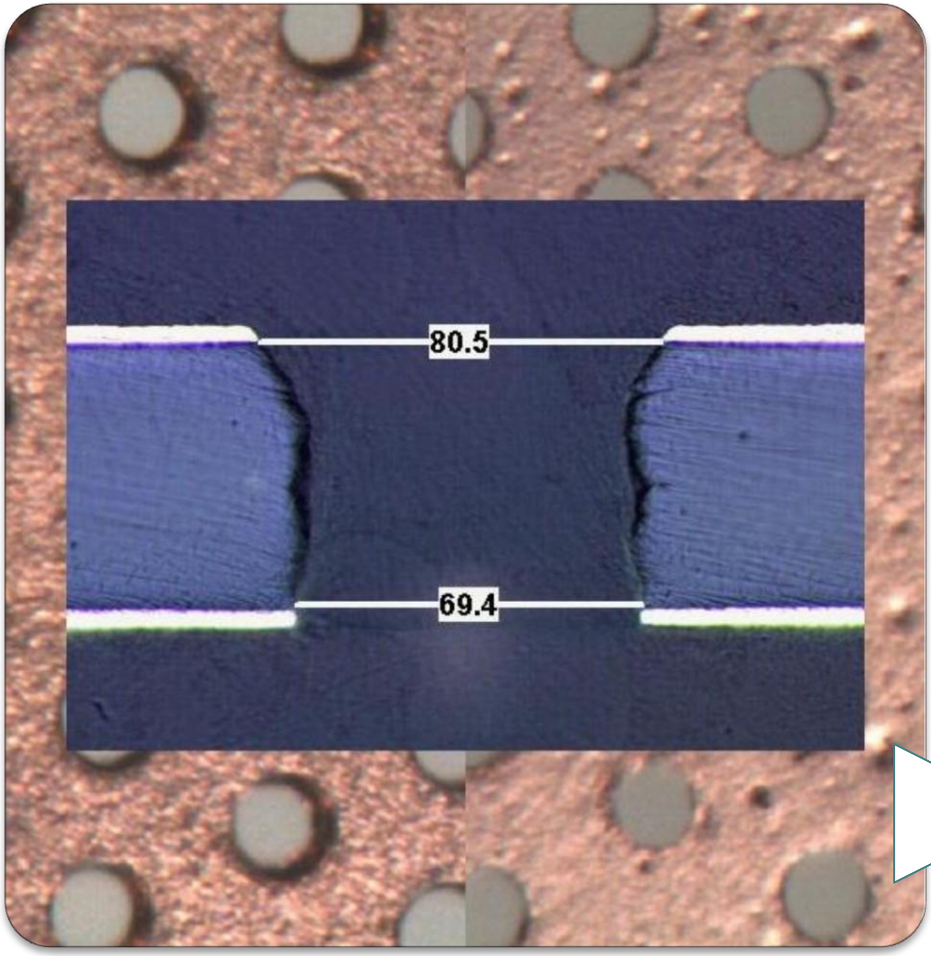
Choosing the holes geometry

Simulating the GEM

- Holes diameter and steepness tunable at will
- What's the best geometry?
- ANSYS: field
- Garfield: charge drift and multiplication
- Transparency studied as a function of the hole shape



Improving the time stability



Removing the rim

- Charge buildup on dielectric worsens time stability
- Rim from top copper etching while piercing bottom copper
- Need to shield upper electrode
- Electrochemical active corrosion protection
- Minimal rim (~μm) needed to prevent damage from sparks

Boosting the gain

Remolding the holes

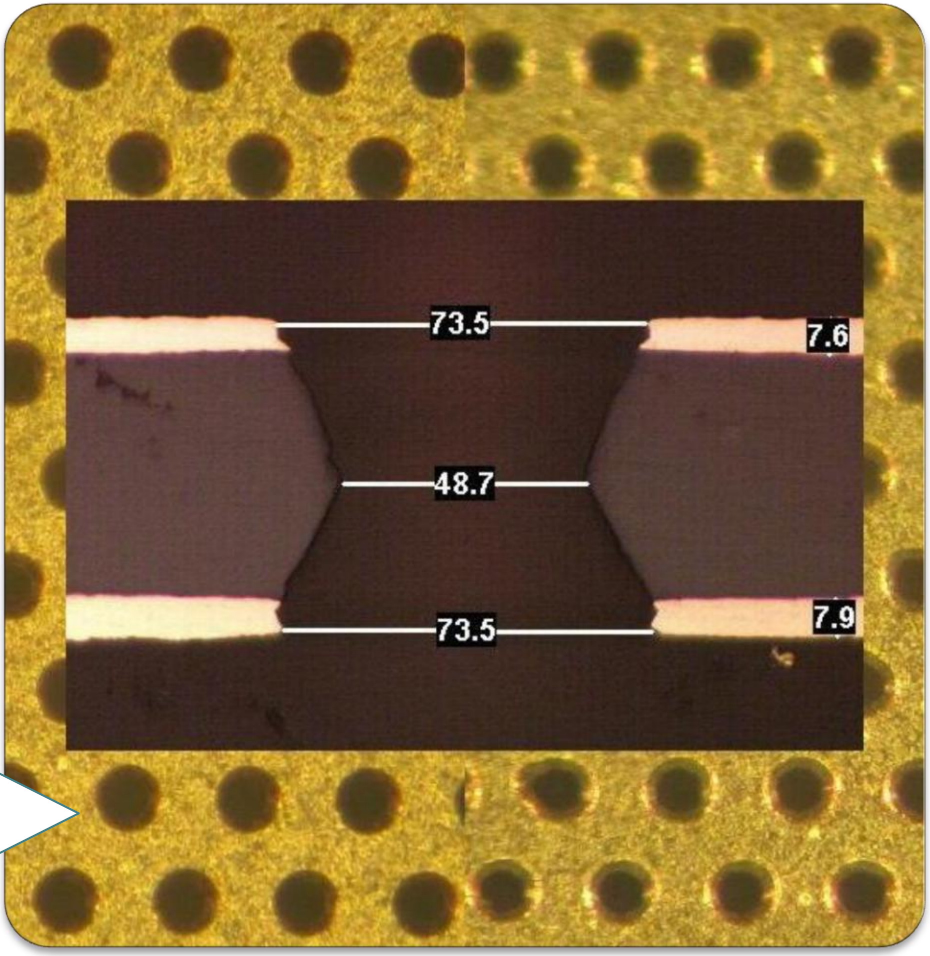
Homogeneous and perfectly defined holes of tunable shape

Procedure is reproducible, electrodes clean and polished

Still, gain and time stability are not satisfying

Need for field focusing elements inside the holes

Post processing restores traditional bi–conical shape



Large area GEMs

Concluding…

Single mask bi–conical GEMs with electrochemical active corrosion protection

Complete control over all the geometrical parameters

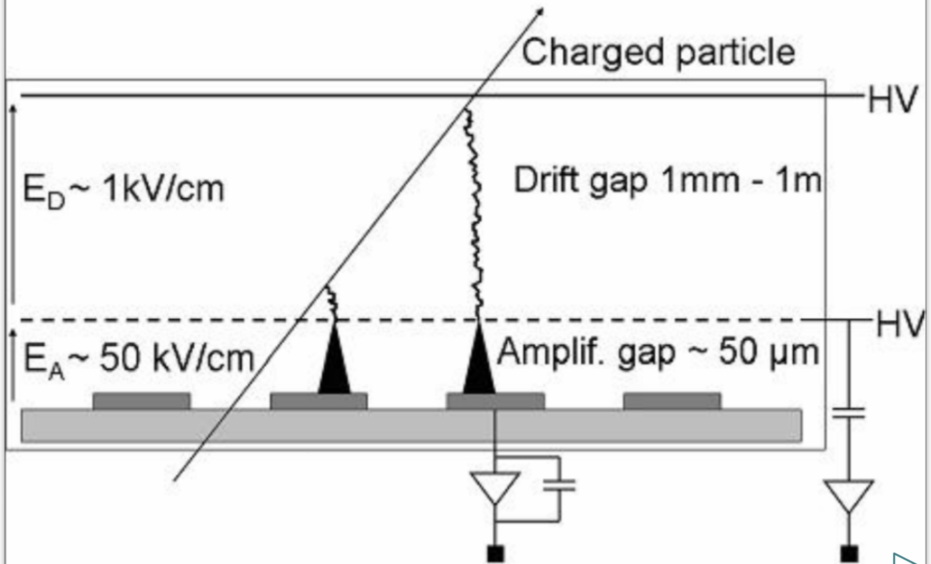
Performance is compatible with traditional GEMs; outgassing, aging and radiation hardness are expected to be as good

Process is reproducible with high production yield

Scalable up to square metre size, in principle limited only by the dimensions of the base material ($100 \times 0.61 m^2$)

Compatible with PCB standards, price drop of 1–2 orders of magnitude in case of large volume production in industry

What is a Micromegas?



Micro Mesh Gaseous Structure

- Micropattern gaseous detector
- Ioannis Giomataris (1996)
- Asymmetrical parallel plate chamber
- Amplification gap ~100μm thick defined by metallic mesh
- Bulk process: woven mesh is stretched on pillars created by photolithography

How does a Micromegas work?

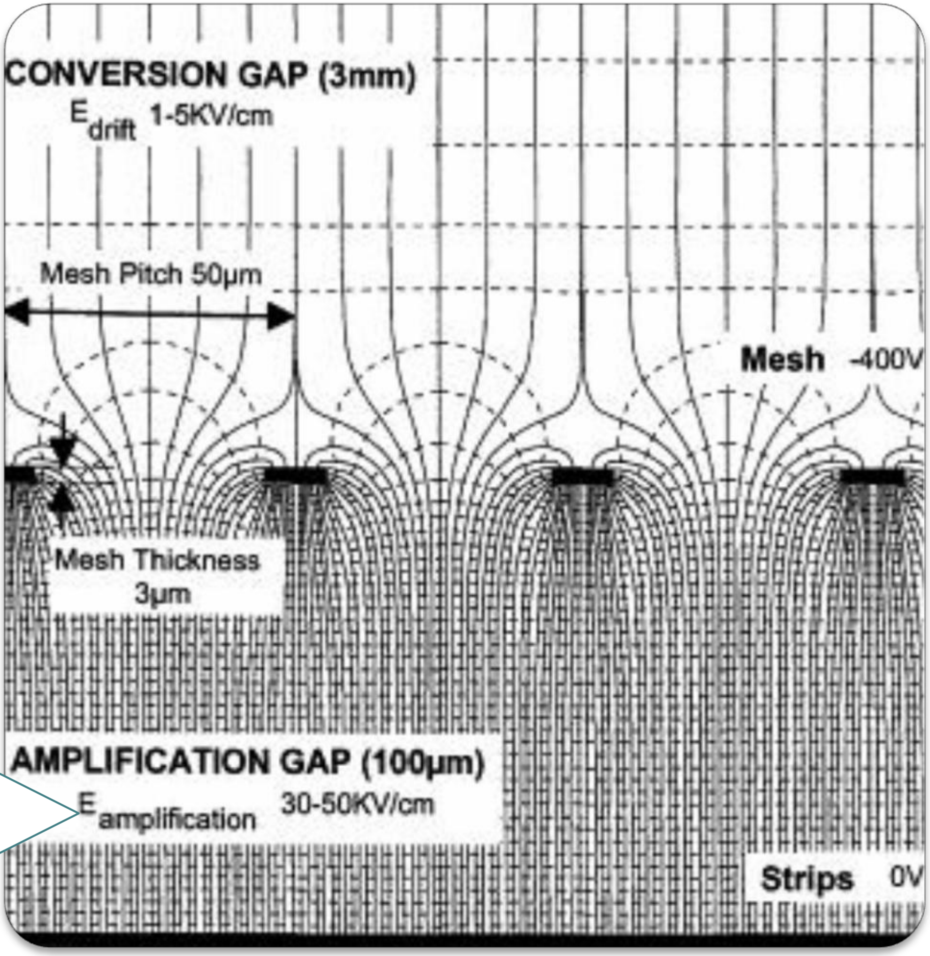
Ionization charges drift under ~kV/cm cathode field

~600V on Micromegas

Field gradient focuses electrons into mesh openings

~100kV/cm field initiates avalanche multiplication

~ns electron signal followed by ~100ns ion tail



Reinventing the (ATLAS) wheels

New small wheels…

Present small wheels: MDTs, CSCs and TGCs

LHC luminosity up to $2\text{x}10^{34}\text{cm}^{-2}\text{s}^{-1}$ after 2018

Expected rate on small wheels: 6.3kHz/cm^2

MDTs limit: 150Hz/cm^2
CSCs limit: 1kHz/cm^2

Need for new small wheels

…novel Micromegas

Micromegas are one of the candidate technologies

MAMMA: Muon ATLAS Micromegas Activity

Gain $\sim 10^4$ needed for high MIP detection efficiency

Raether's limit $\sim 10^7$; $\sim 10^3$ electrons may cause sparks

Need for novel Micromegas

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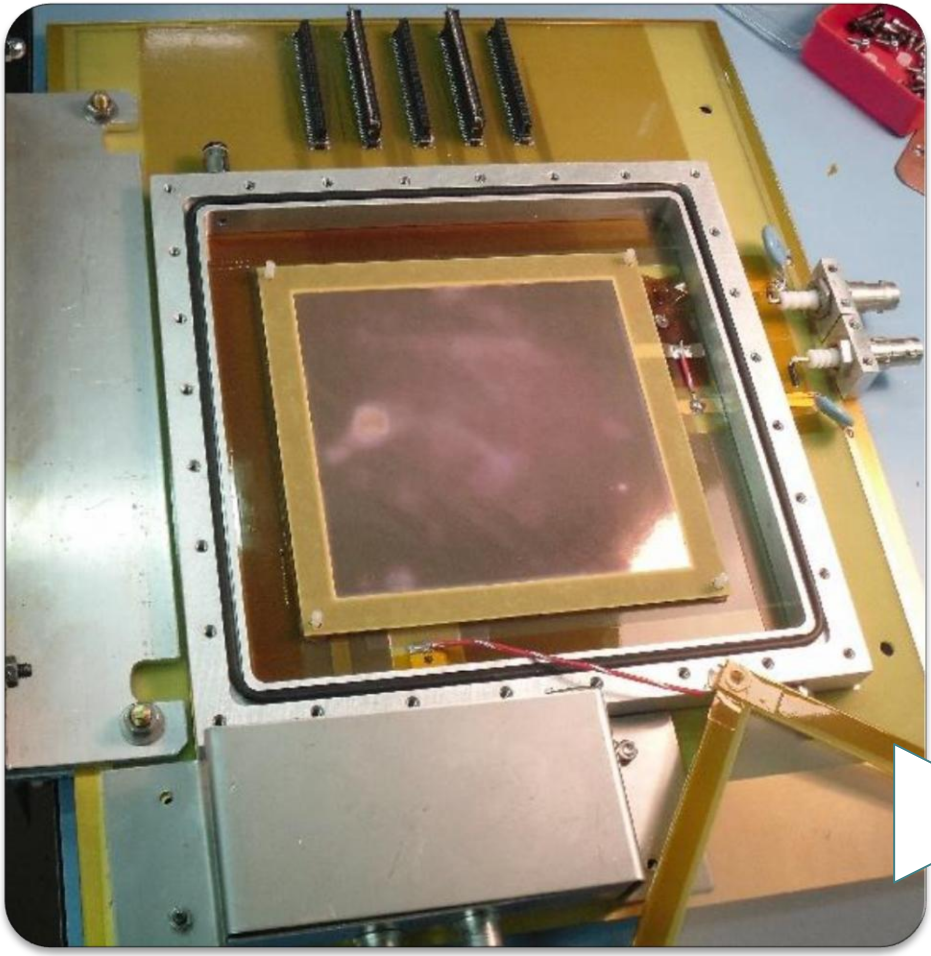
Lowering the discharge probability



Splitting the gain

- Multi stage amplification structure
- Sparks suppressed thanks to charge diffusion
- Preamplification GEM above the Micromegas mesh
- Gain measured with X–rays
- Discharge probability estimated with α–particles

Don’t invite sparks to the party!

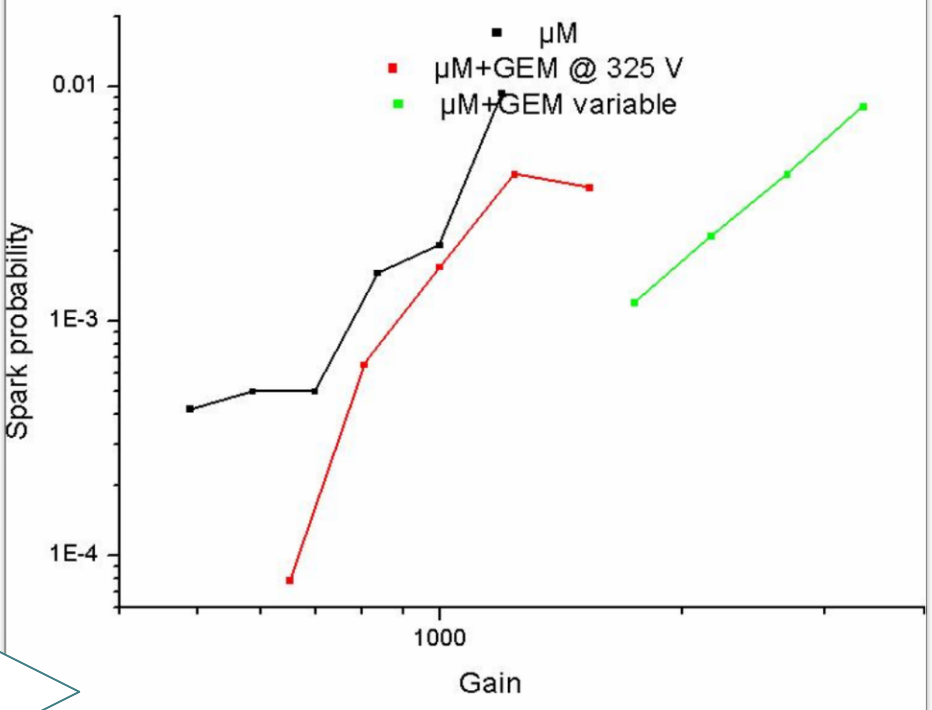
A high price to pay

Discharges reduced by one order of magnitude

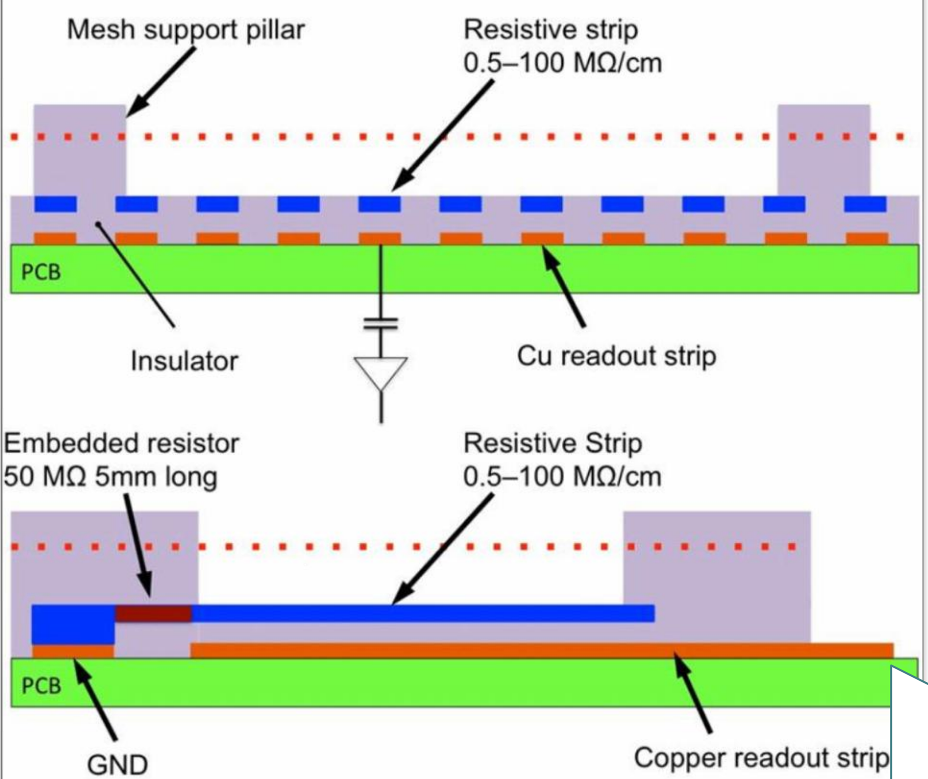
Scalable to m² area

Outgassing, aging and radiation hardness expected to be good

Considerable increase of detector complexity



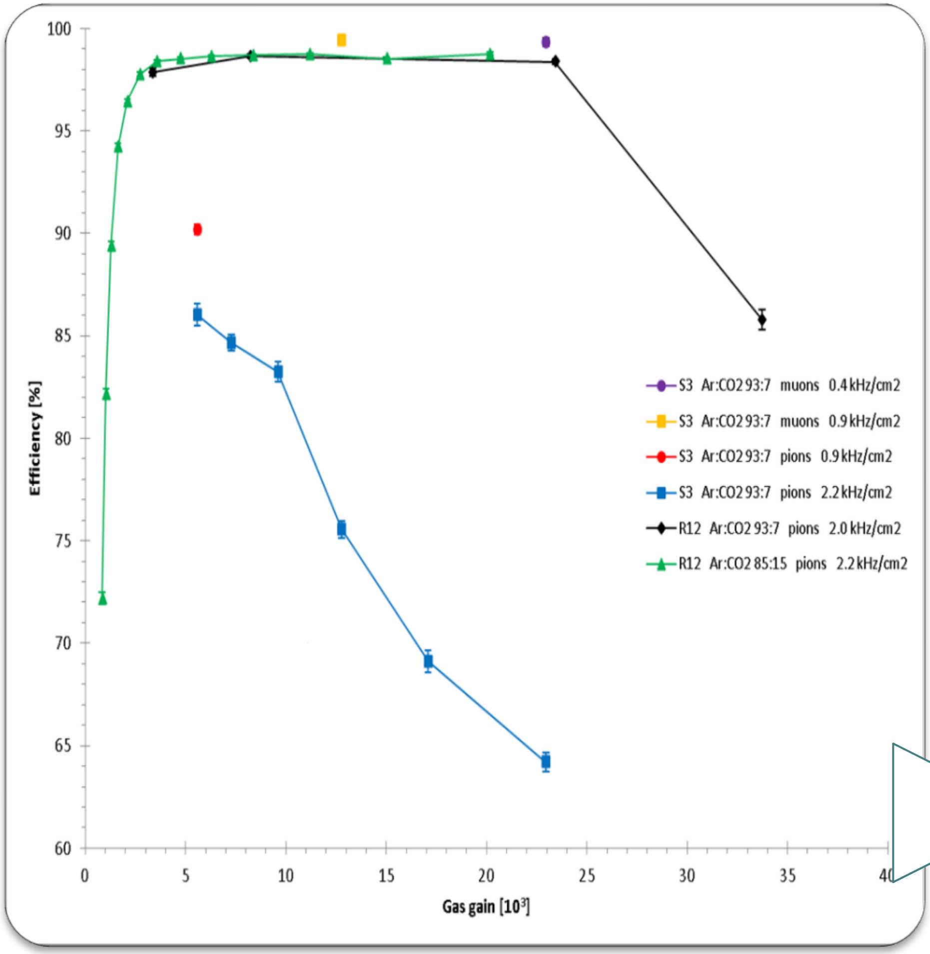
Neutralizing the discharge effects

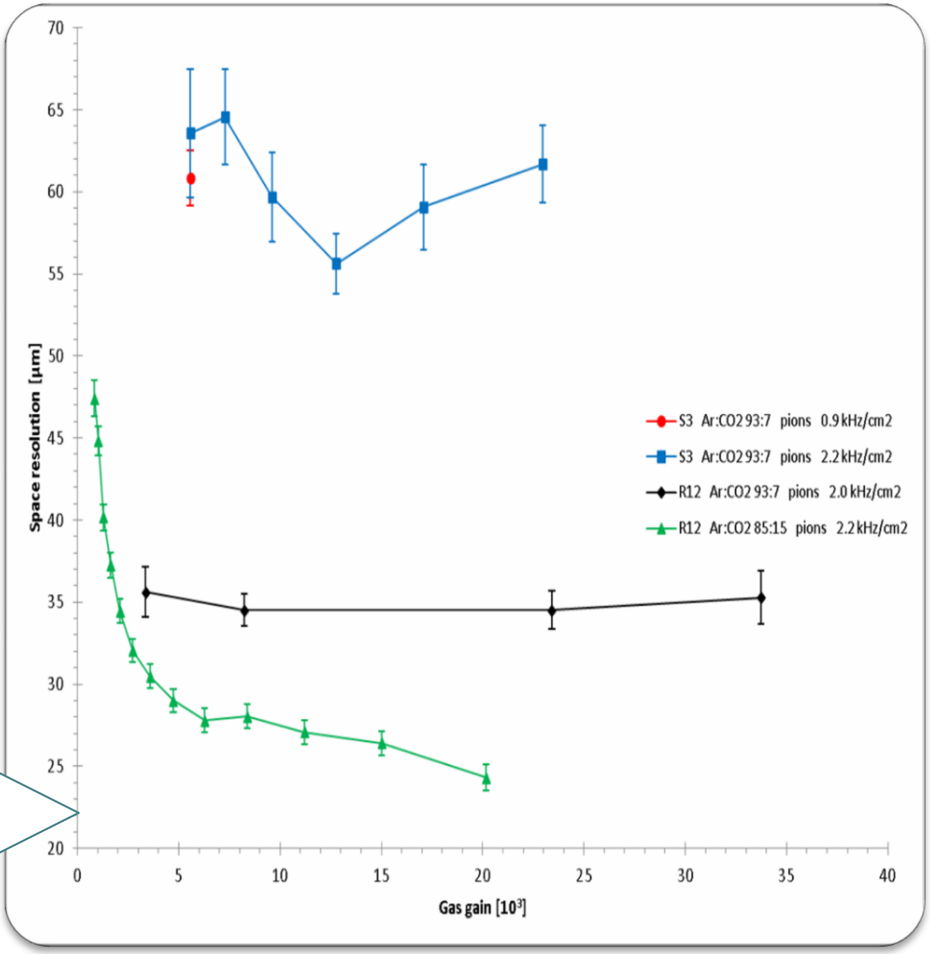


Dumping the sparks

- Dead time due to mesh recharging after sparks
- Avoid shorts with grounded anode
- Readout covered with FR4 layer topped with grounded resistive strips
- Based on standard PCB photolithography

Come on sparks, I don’t fear you!





Discharge tolerant Micromegas

Concluding…

- Bulk Micromegas with resistive grounded strips
- Great MIP efficiency improvement thanks to reduced dead time (sparks dumping)
- Better space resolution thanks to charge spreading
- Compatible with bulk processing and PCB industrial standards; scalable up to square metre size
- All the requirements for the new ATLAS small wheels are met – moving to implementation studies

Much more than a job…

…an enriching experience

English & French

C++, ROOT, Origin, ANSYS & Garfield

Propose, organize, manage, supervise & tutor

Take responsibilities & make decisions

After MC–PAD: what's next?

Me: present…

Working on my PhD thesis: "*Developing and evaluating new Micropattern gaseous detectors*"

PhD advisor:
Dr. prof. Ian Brock
Bonn University

Thesis defense expected in November

…and future

Continue in academia or research

Looking for post–doc in Applied Physics

Detector simulation, R&D, DAQ and data analysis

The Good, the Bad and the Ugly

Hardly any defect

- ☑ Superb training, generous resources, access to a huge intellectual pool
- ☑ Unus pro omnibus, omnes pro uno
- ☑ Trust: freedom and responsibility
- ☒ Industrial partners

Acknowledgements

A big thanks to:

Ian Brock

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Veronique Wedlake

Joerg Wotschack

Thank you! Any questions?