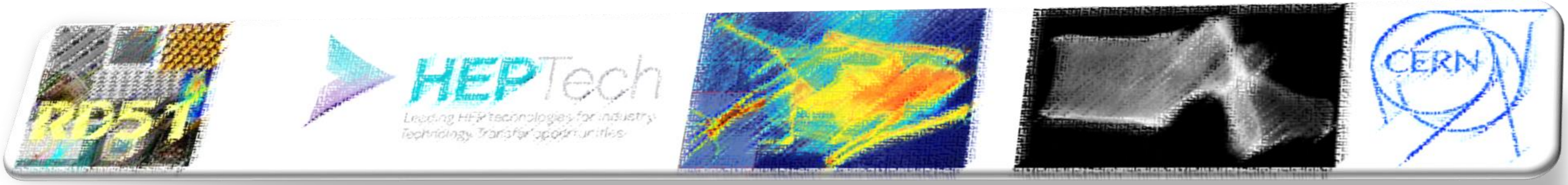
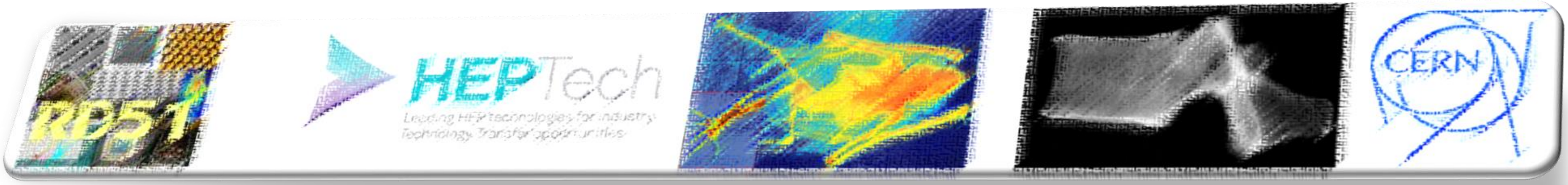


Introduction to MPGDs and RD51

Eraldo Oliveri, PH-DT-DD, CERN, Switzerland



Outline

- Micro Pattern Gas Detector
- An overview of the various technologies
- The Micro Pattern Technology Workshop at CERN
- A collaboration to facilitate MPGD technological developments: RD51

Not chronologically organized… sort of random… not exhaustive… overview

Before entering into the subject of the talk… let's talk about the logos

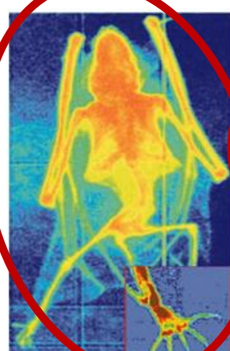
HEPTech
Leading HEP technologies for industry
Technology Transfer opportunities

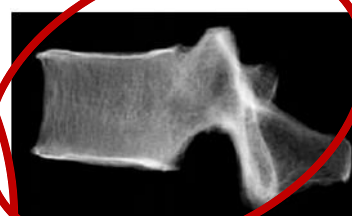
The specialized workshop "Photon Detection with Micro-Pattern Gaseous Detectors" organised by RD51 in collaboration with HEPTech, will take place at CERN on June 10-11, 2015.

The goal of the workshop is to help disseminating MPGD technologies beyond fundamental physics, where academic institutions, potential users and industry could meet together.

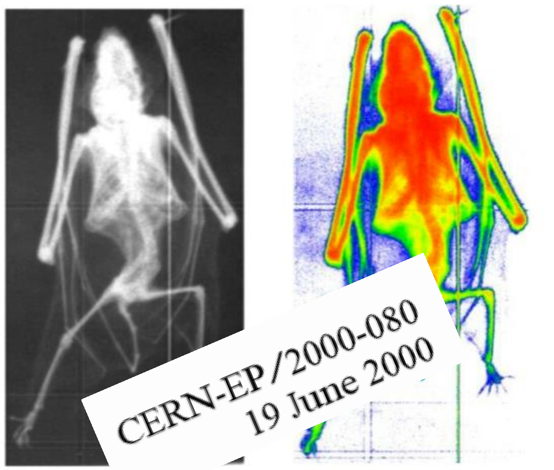
This workshop aims to foster collaboration between the particle physics community and the industry of photon detection, and to discuss the potential of the MPGD technologies for the field. This event is jointly organized by the RD51 collaboration, the HEPTech Network and CERN KT Group. It is open to all researchers and commercial partners interested or working in the field of photon detection.

Dates: 10th and 11th June 2015
Venue: The Council Chamber, CERN
Route de Meyrin 385, 1217 Meyrin





The famous bat….



The first imagin… demonstration with GEM, 17 years ago (X-ray, 8keV)

Still in the lab….

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-EP/2000-080
19 June 2000

GAS DETECTORS: ACHIEVEMENTS AND TRENDS

Fabio Sauli

CERN, CH-1211 Geneva, Switzerland

High rate X-ray imaging using multi-GEM detectors with a novel readout design

S. Bachmann[a], S. Kappler[ab*], B. Ketzer[a], Th. Müller[b], L. Ropelewski[a], F. Sauli[a], and E. Schulte[c]

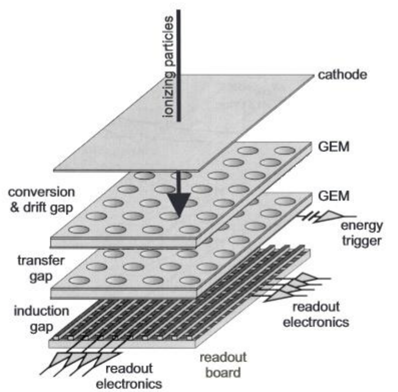


Figure 1. Schematic view of a multi-GEM detector.

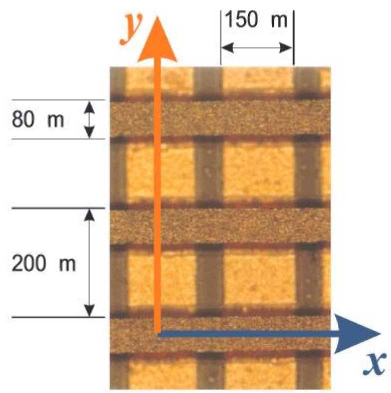
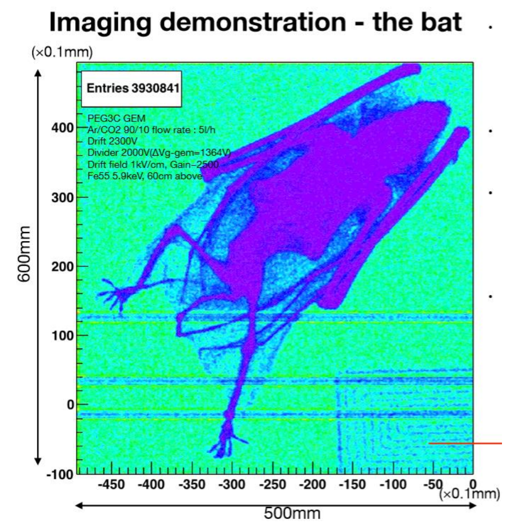


Figure 2. Microscope photograph of the two-dimensional projective microstrip readout.

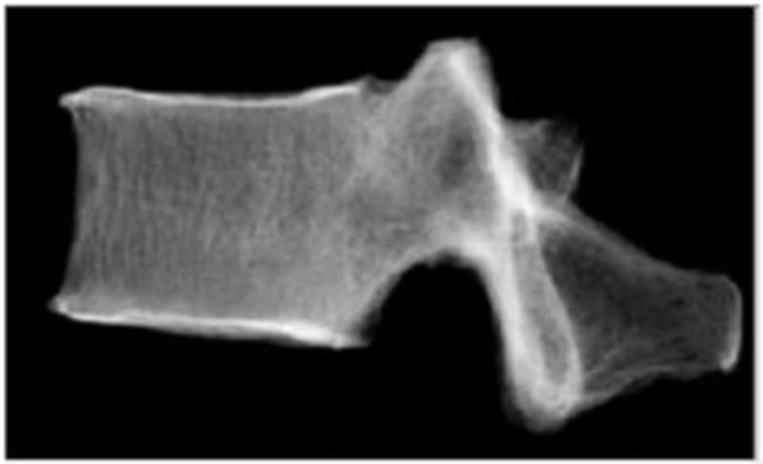
… and no peace for it, even after roughly twenty years…



The Latest Results of Crystalized Glass GEM 15th RD51 Collaboration Meeting, **20.FRI.2015**, Yuki Mitsuya

5.3.2.4. *The MICROMEGAS X-ray Gallery*

Operating in pure Xenon at atmospheric pressure, the MICROMEGAS detectors have been developed for X-ray imaging. Figure 5.33 [66] shows an example of a vertebra scanned by MICROMEGAS.



Operating in pure xenon at atmospheric pressure, MICROMEGAS detectors have been developed for X-ray imaging. This shows a human vertebra (70 ¥ 25 mm) scanned by a MICROMEGAS, giving a resolution of 250 µm. (G Charpak and M Meynadier, Biospace.)

[66] G. Charpak and M. Meynadier Priv. Com. Oct. 2000

G. Charpak and M. Meynadier

Annu. Rev. Nucl. Part. Sci. 1999. 49:341–88

MICROPATTERN GASEOUS DETECTORS

Fabio Sauli
CERN, European Laboratory for Particle ... 23, Switzerland; e-mail: fabio.sauli@cer...

Archana Sharma
GSI, Gesellschaft für Schwerionenforsch... e-mail: archana.sharma@cern.ch

Nuclear Instruments and Methods in Physics Research A 494 (2002) 128–141
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
ELSEVIER
www.elsevier.com/locate/nima

Micro-pattern gaseous detectors

L. Shekhtman*
...cs, Acad. Lavrentiev prospect 11, 630090 Novosibirsk, Russia

Modern Physics Letters A
Vol. 28, No. 13 (2013) 1340022 (25 pages)
© World Scientific Publishing Company
DOI: 10.1142/S0217732313400221
World Scientific
www.worldscientific.com

MICRO-PATTERN GASEOUS DETECTOR TECHNOLOGIES AND RD51 COLLABORATION

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LESZEK ROPELEWSKI
CERN PH, CH-1211, Geneva 23, Switzerland
leszek.ropelewski@cern.ch

Since the end of the millennium… many reviews

ELSEVIER
Nuclear Instruments and Methods in Physics Research A 478 (2002) 13–25
IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Progress with micro-pattern gas detectors

R. Bellazzini*, G. Spandre, N. Lumb
INFN-Pisa, V. Livornese 1291, 56010 Pisa, Italy

...and Interfaces, 2009. IWASI 2009. 3rd International Workshop on

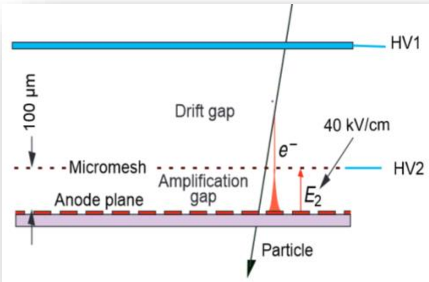
Progress in Micro-Pattern Gaseous Detectors and their Applications

V. Peskov[1,2]
[1]UNAM, Mexico
[2]CERN Geneva, Switzerland
e-mail:Vladimir.peskov@cern.ch

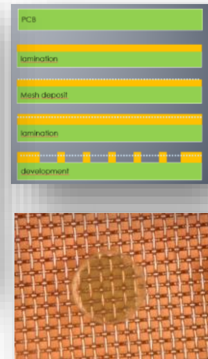
High Rate Capability	MHz/mm^2 (MIP - Minimum Ionizing Particles, 2MeV cm^2/g)
High Gain	Up to 10^5-10^6
High Space Resolution	<100μm
Good Time Resolution	In general few ns , sub-ns in specific configuration
Good Energy Resolution	10-20% FWHM @ soft X-Ray (6KeV)
Excellent Radiation Hardness	
Good Ageing Properties	
Ion Backflow Reduction	% level sort of easy, below % in particular configuration
Photon Feedback Reduction	
Large Size	m^2
Low Cost	

In this talk…. We will focus on the following amplification stages…

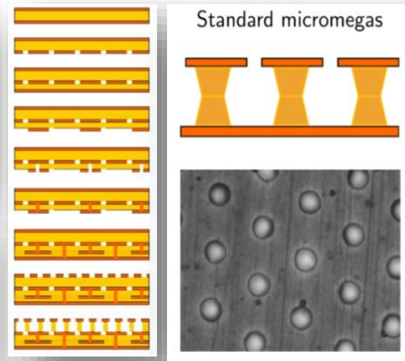
Micromegas



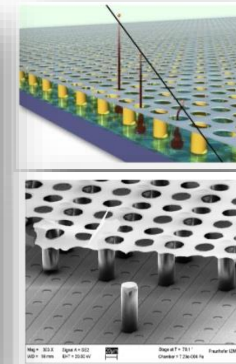
Bulk



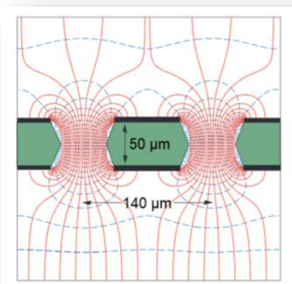
Micro bulk

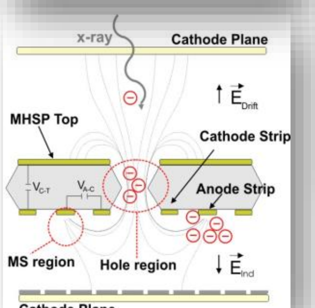


InGrid

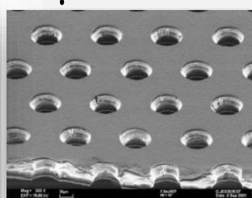


GEM

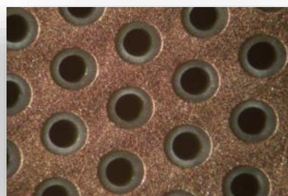




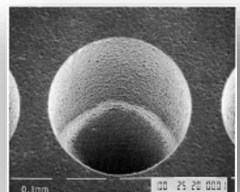
50µm GEM



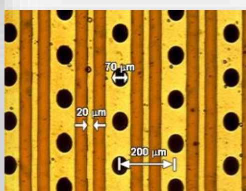
THGEM



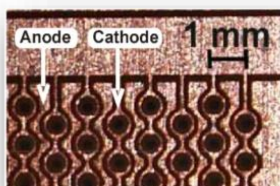
GLASS GEM



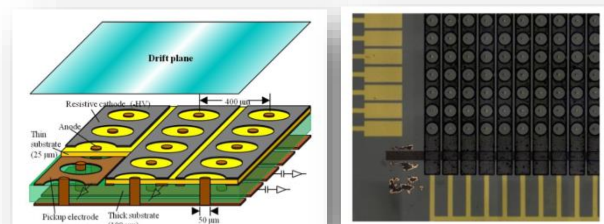
MHSP

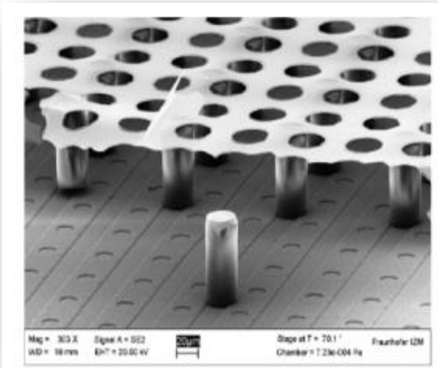


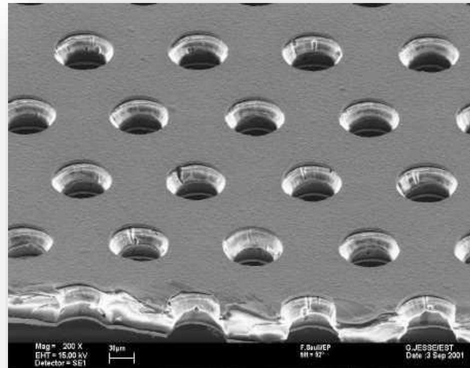
THCOBRA

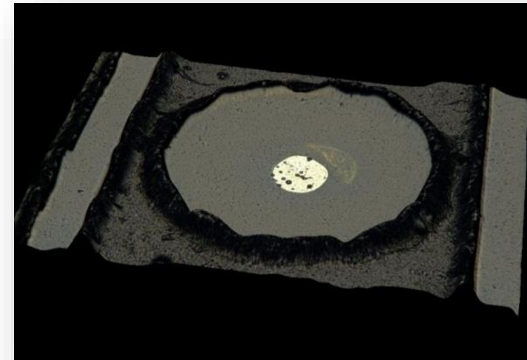


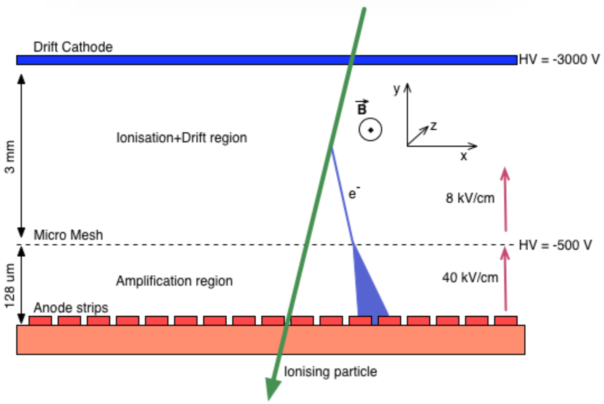
µPIC



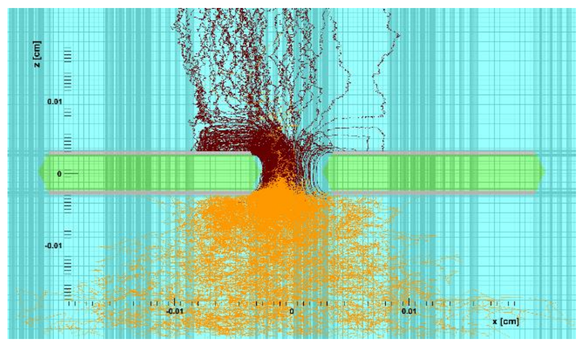




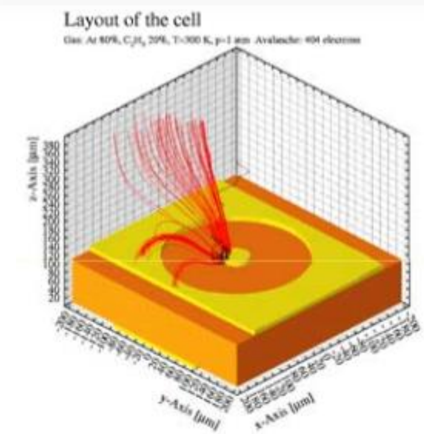




http://garfieldpp.web.cern.ch/garfieldpp/examples/mmlowenergypion/

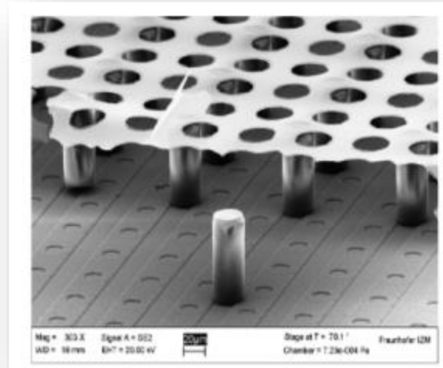


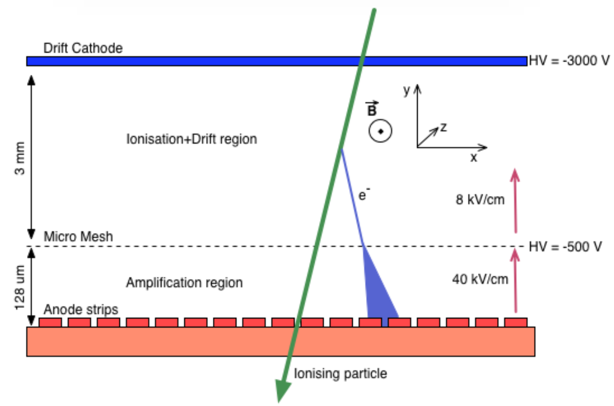
http://www-flc.desy.de/tpc/projects/GEM_simulation/



Development and tests of m-PIC Resistive Cathode, A. Ochi

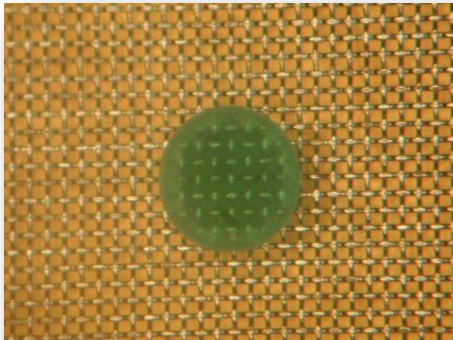
meshes

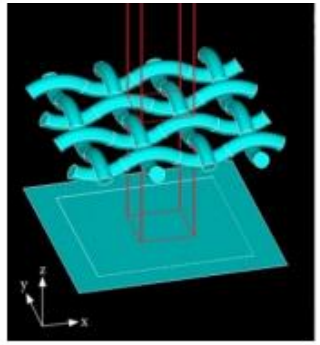


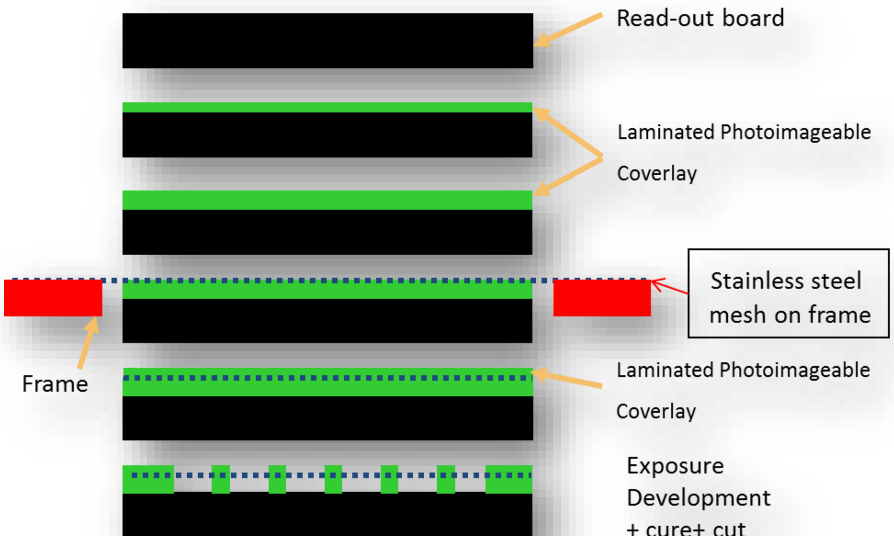

Drift Cathode
HV = -3000 V
Ionisation+Drift region
3 mm
B
y
z
x
e-
8 kV/cm
Micro Mesh
HV = -500 V
128 um
Amplification region
40 kV/cm
Anode strips
Ionising particle

Micromegas

Bulk (using woven meshes)



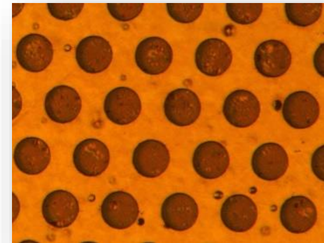




Spacers: 400µm diameter
128µm High

Micro-bulk (using kapton)

Copper Etching



Kapton Etching

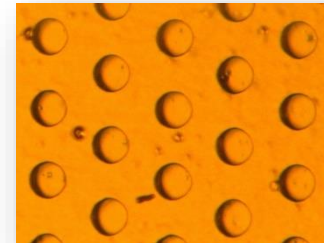


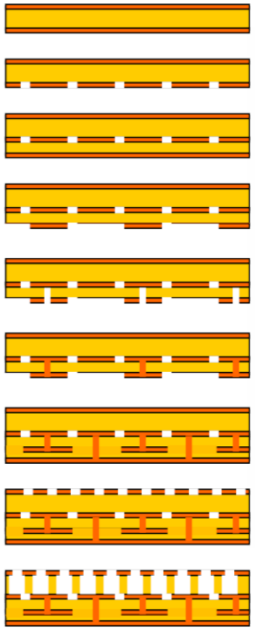
Figure 1. Kapton pillars are created below the copper in each mesh step.

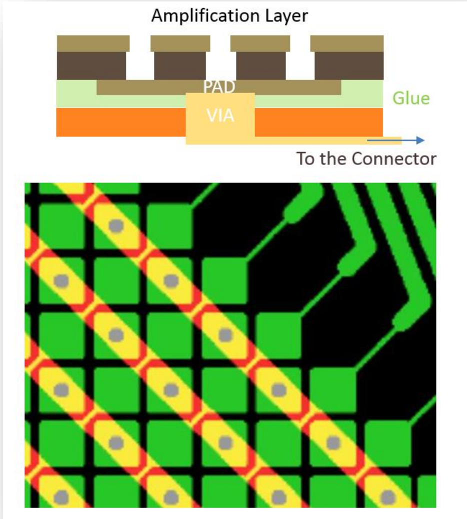
Figure 2. Left: Kapton pillars are created with a step of about 500 microns; Right: photo of a mesh with copper spots used to protect the polyimide bellow during etching in order to form the pillars.

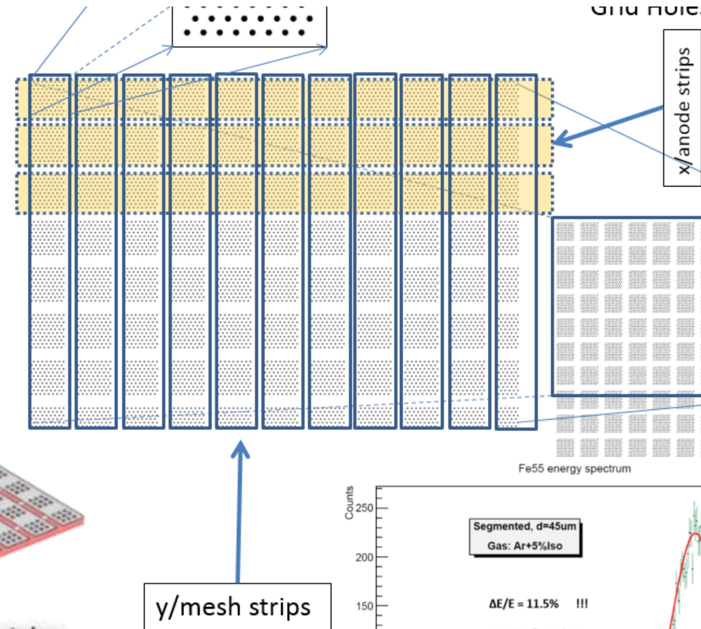
http://iopscience.iop.org/1748-0221/5/02/P02001/pdf/1748-0221_5_02_P02001.pdf

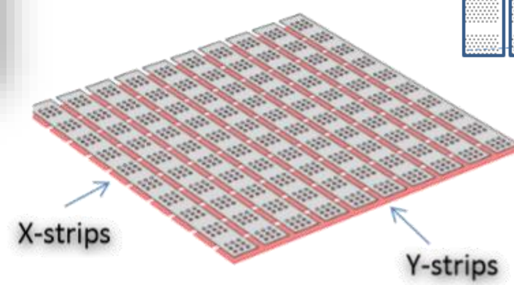
(...later built directly on CMOS pixels)

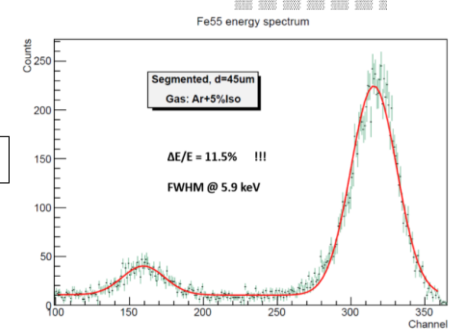
microbuk.. A sort of “ART” on working with Kapton…











A real x-y Microbulk Micromegas with Segmented mesh

Theo Geralis, NCSR Demokritos
TIPP 2014, 2 June 2014

TIPP '14

The collaboration

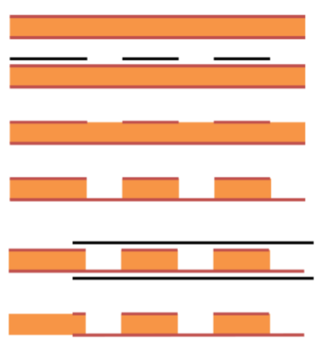
CERN
Martyn Davenport, Rui De Oliveira, Serge Ferry
NCSR Demokritos
Theodoros Geralis, Athanasios Kalamaris, Chryssa Vassou
IRFU Saclay
Esther Ferrer-Ribas, Mariam Kebbiri, Thomas Papaevangelou
University of Zaragoza
Fransisco Aznar, Theopisti Dafni, Fransisco J. Iguaz

OUTLINE
- **The Micromegas evolution**
- **The segmented mesh microbulk**
- **Manufacturing and tests**
- **Results**
- **Prospects and applications**

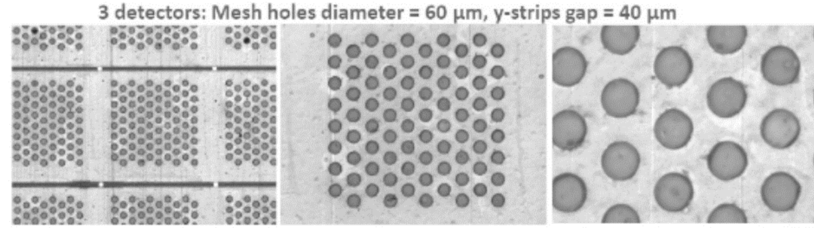
RD51 Common Fund Project

2/6/2014 1

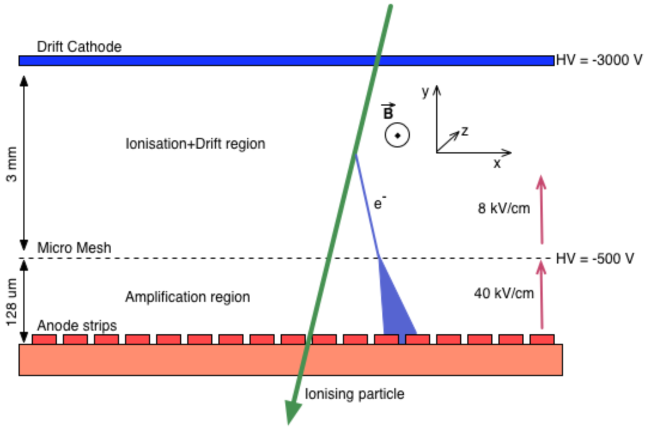
Serge FERRY-TE/MPE/EM
28/09/2012

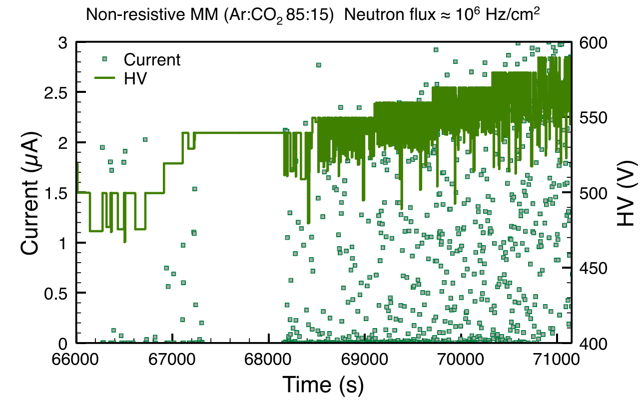


3 detectors: Mesh holes diameter = 60 μm, y-strips gap = 40 μm

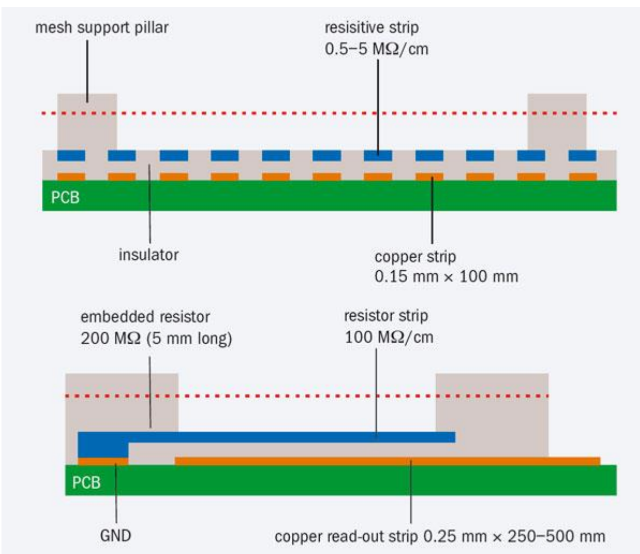


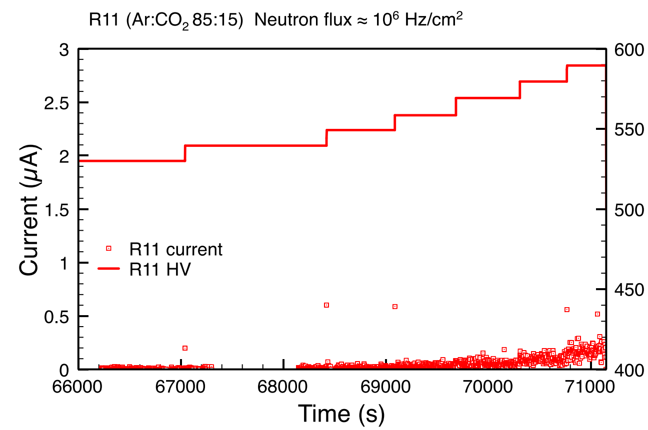
Bulk… spark protection (from now "resistive" a la mode… motivated)





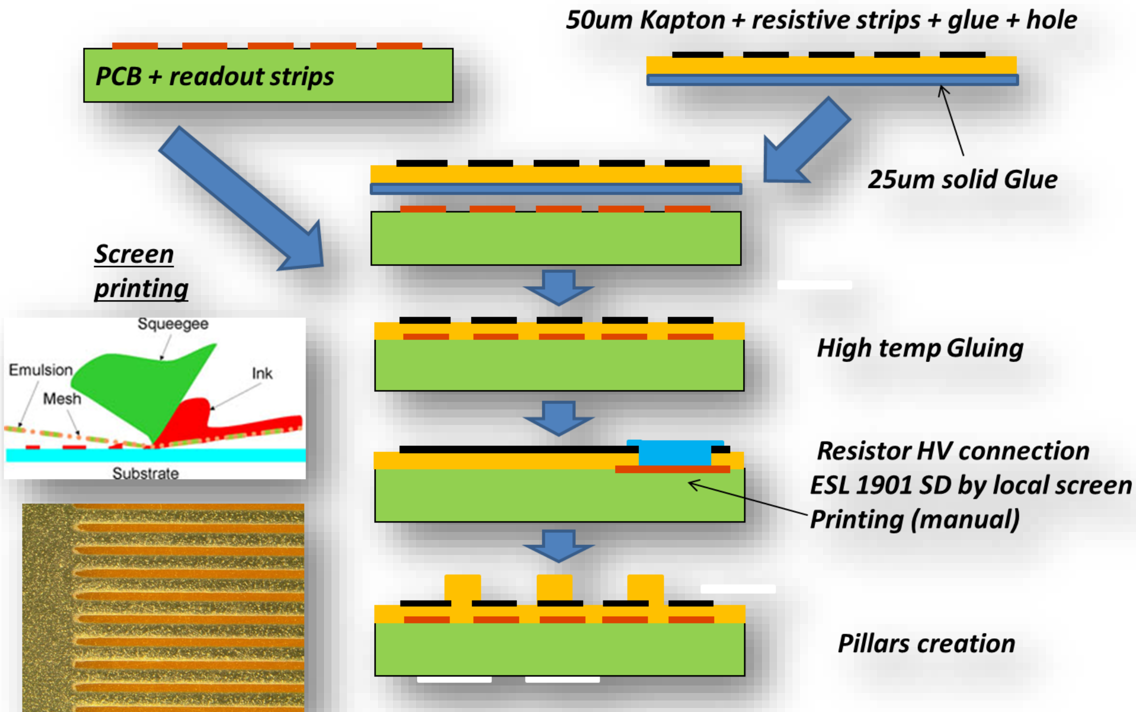
Resistive Micromegas (ATLAS NSW upgrade & MPT Workshop)





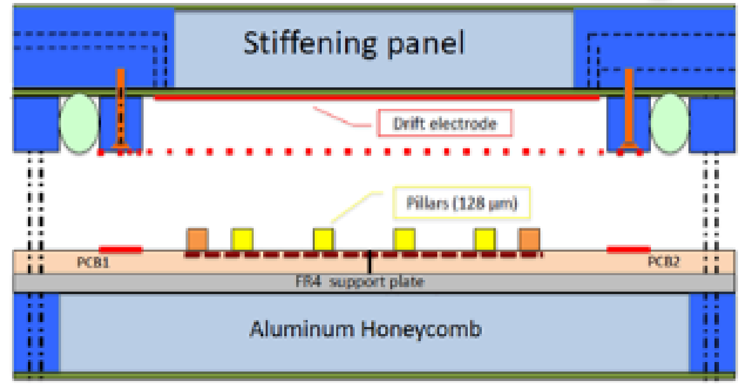
Nuclear Instruments and Methods in Physics Research A 640 (2011) 110–118

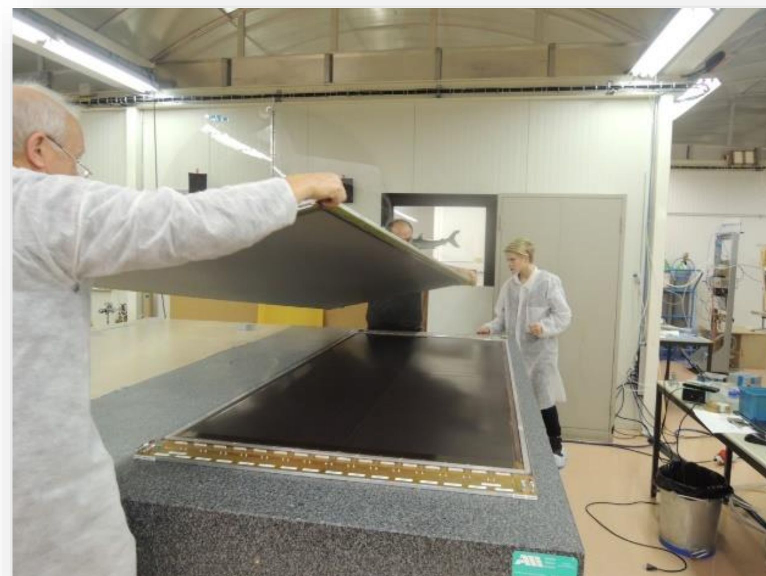
Screen Printed Resistive Layer for ATLAS



Resistive layer screen printed

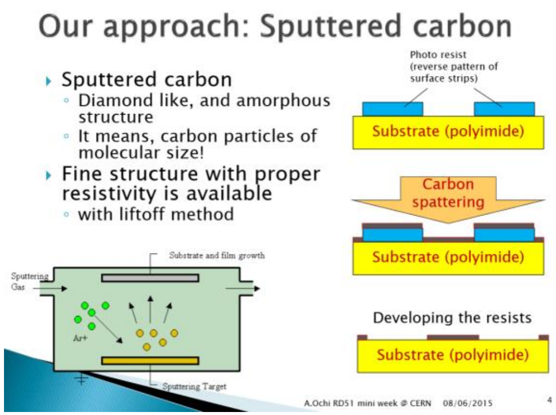
Large area… not bulk anymore

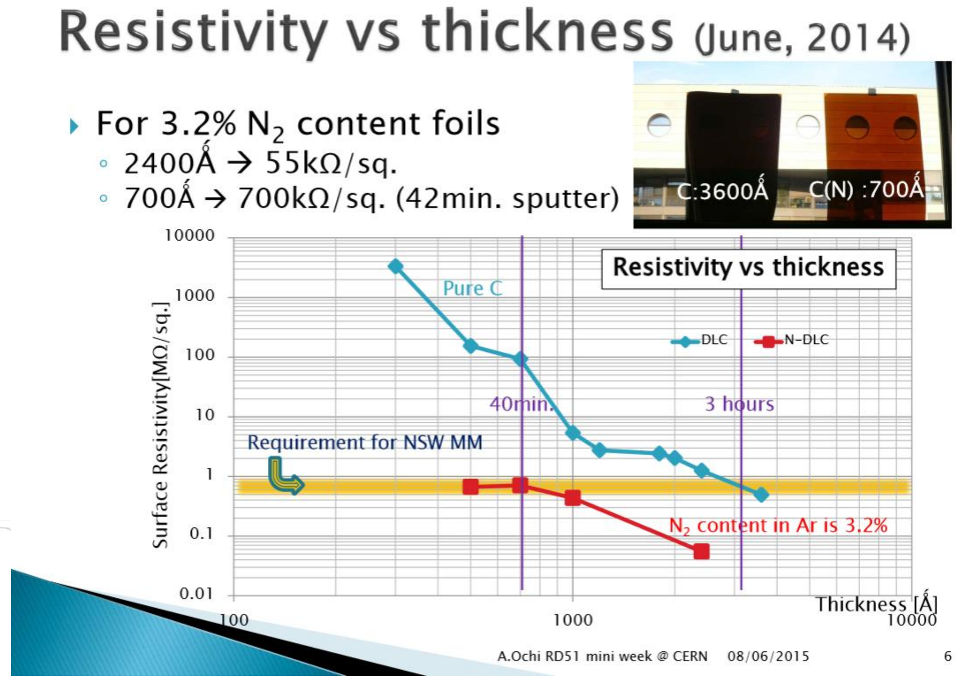


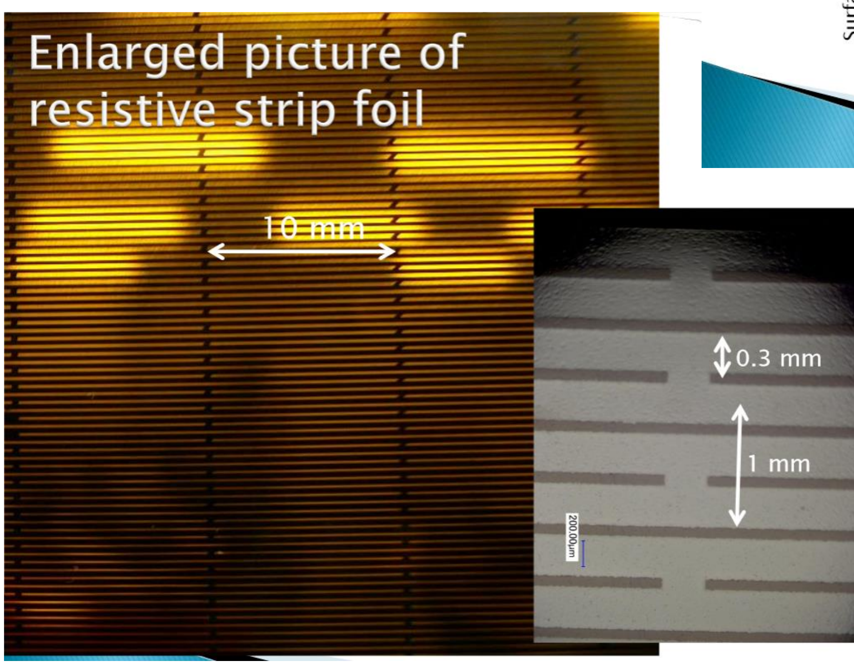


Assembly … as important as the micro structure ..
If you want to preserve the properties at large scales

Resistive Layers… not only screen printing
Vacuum Deposited Diamond Like Coating



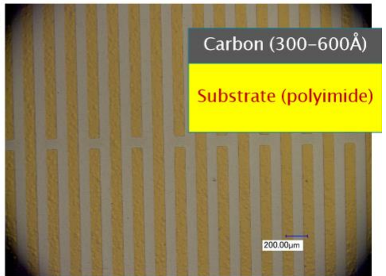


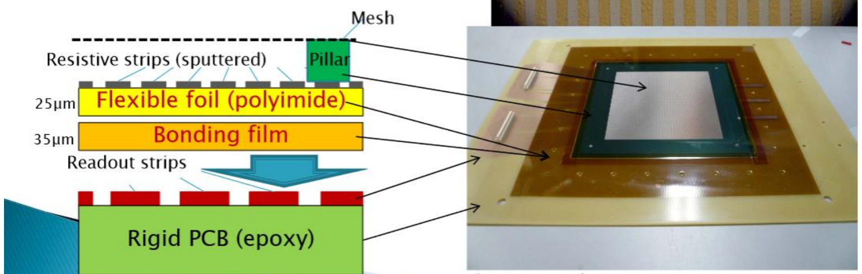


Resistive Layers… not only micromegas… (I start to mix technologies)

Resistive MicroMEGAS

- First attempt to make MPGDs using carbon sputtering (from June 2013)
  - This R&D is aimed for ATLAS NSW MM.
  - Fine strip pitch of 200 μm or 400 μm is formed on 50μm polyimide foil.

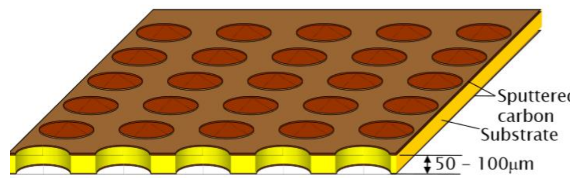


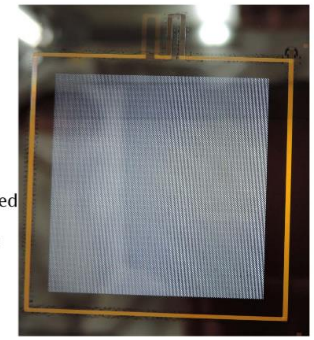


A.Ochi RD51 mini week @ CERN 08/06/2015 8

Resistive GEM

- Standard type GEM (holes with 140μm pitch, diameter with 70-85μm.) with resistive electrodes.
- The resistive electrodes are made by very thin (~100nm) sputtered carbon
  - It will improve the signal gain
  - Surface resistivity ~ 1MΩ/sq.
- Holes are made by laser drilling

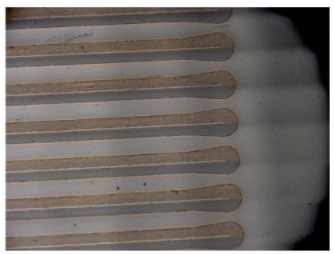


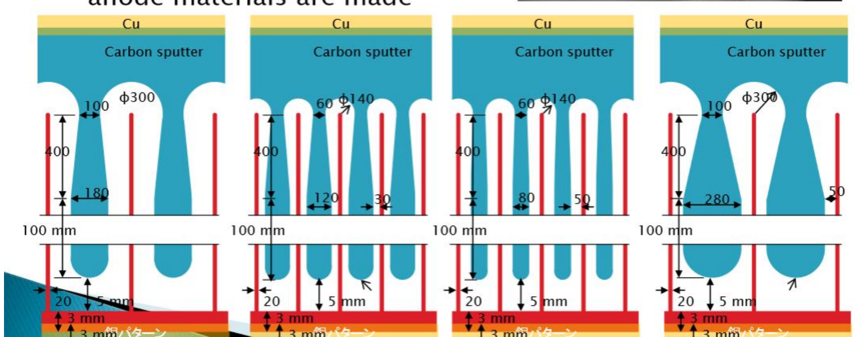


A.Ochi RD51 mini week @ CERN 08/06/2015 12

Resistive MSGC

- To study basic properties of fine structure MPGD, prototype of RE-MSGC using carbon sputter have been made.
- 4 geometry with 2 different anode materials are made





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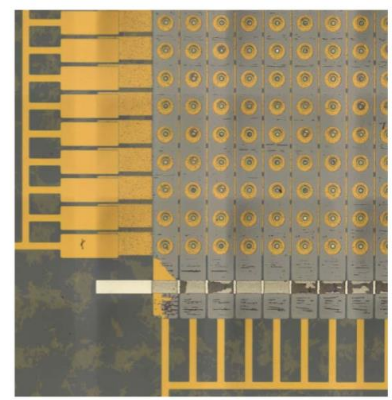
Carbon sputtered μ-PIC

- Cathode structure should be fine
- Sputtering with liftoff is very good method for those structures.
- Prototype was made, however, it has not operated yet.
  - Some problems for alignment of multi layer



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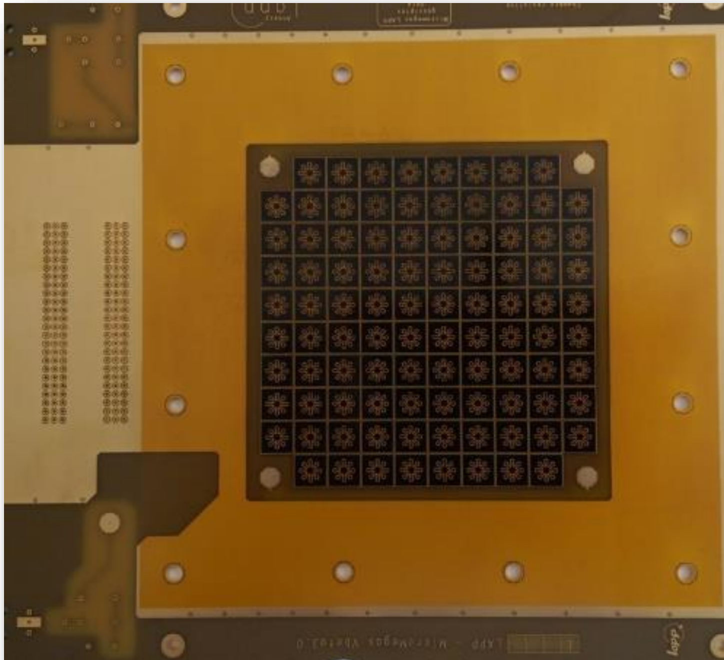
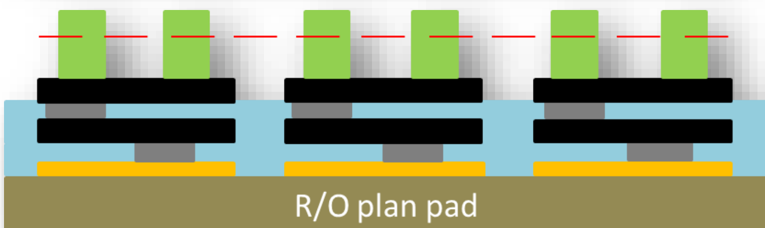
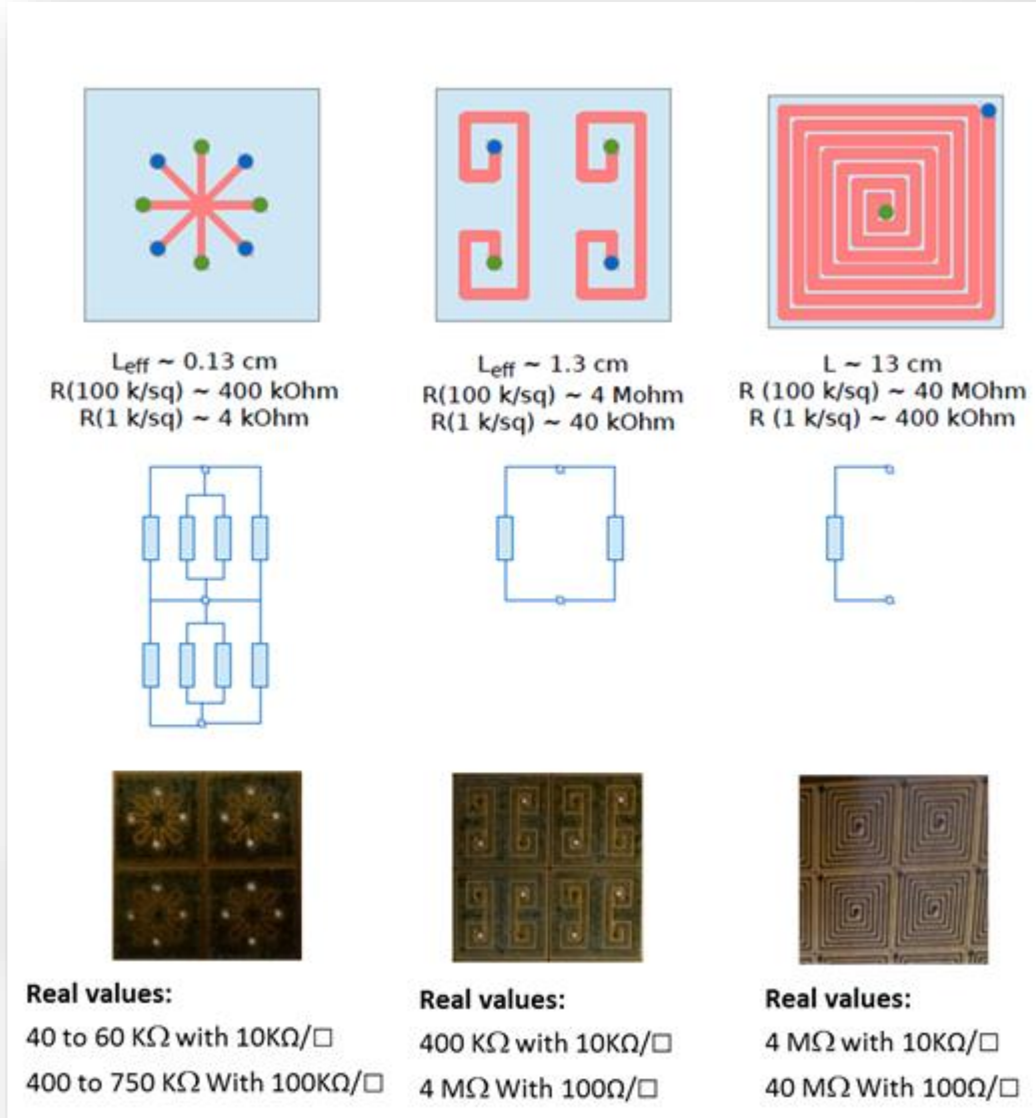
mm Resistive… not only strips…. Resistive pads



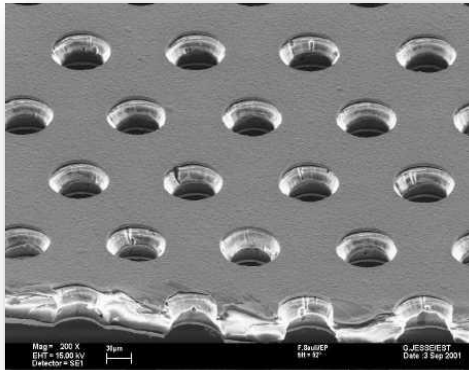


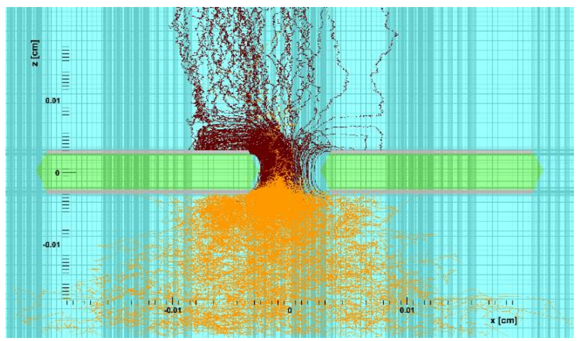
De Oliveira, Peskov, Chefdeville et al.



A possible solution for MPGD&Calorimetry… Chefdeville et al.

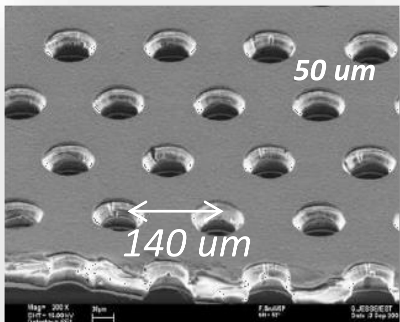
holes

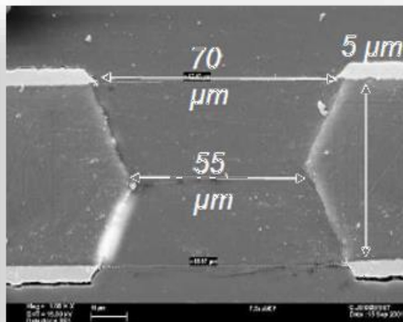




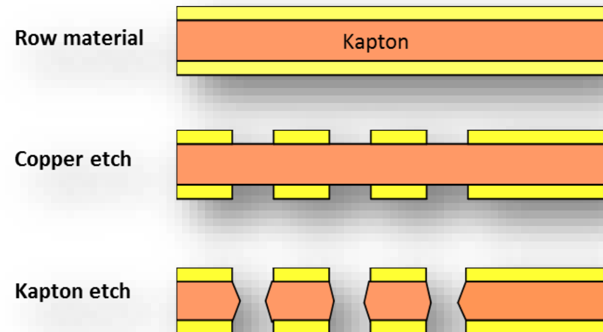
GEM… <100μm holes, <100μm tickness, Kapton (Apical)

Sort of standard dimensions…

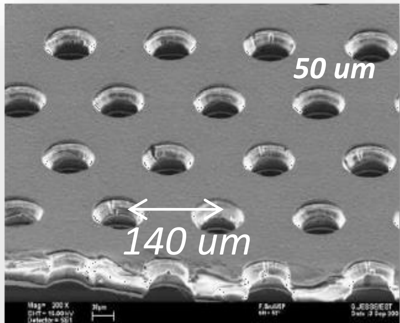


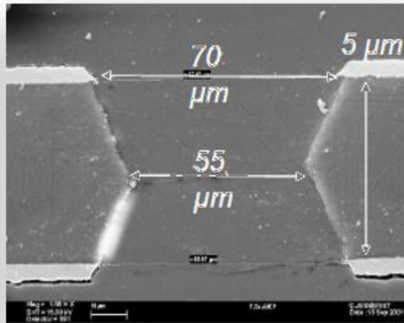


Double Mask

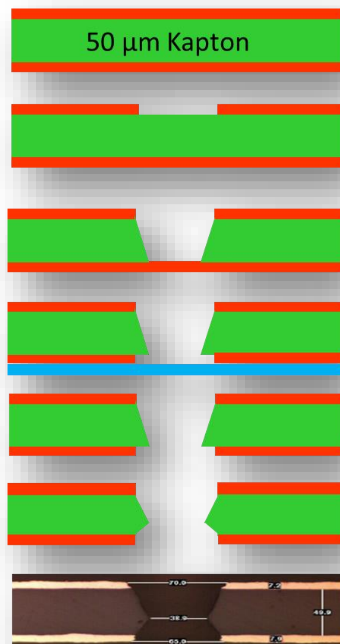


GEM on large area





Single Mask



Base material

Copper etch

Chemical Polyimide etching

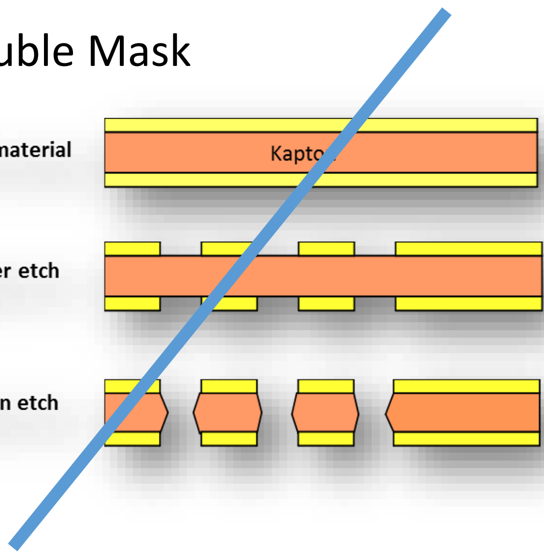
Copper electro etching

Stripping

Second Polyimide etching

Reality

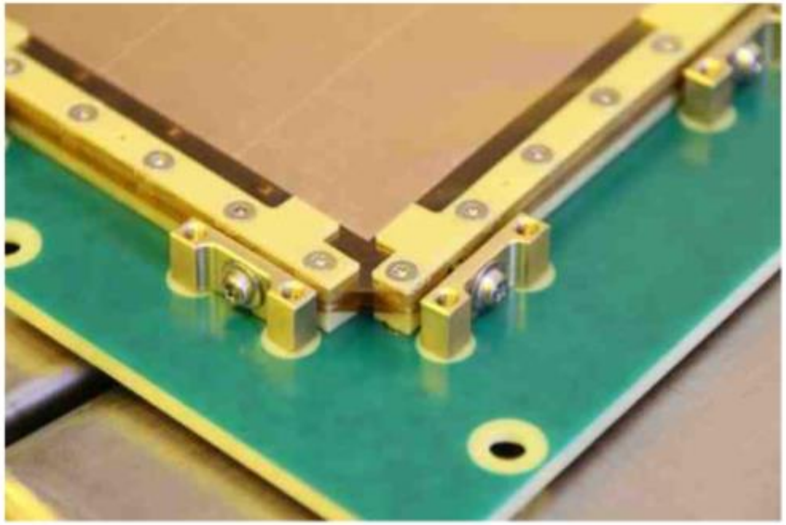
Double Mask

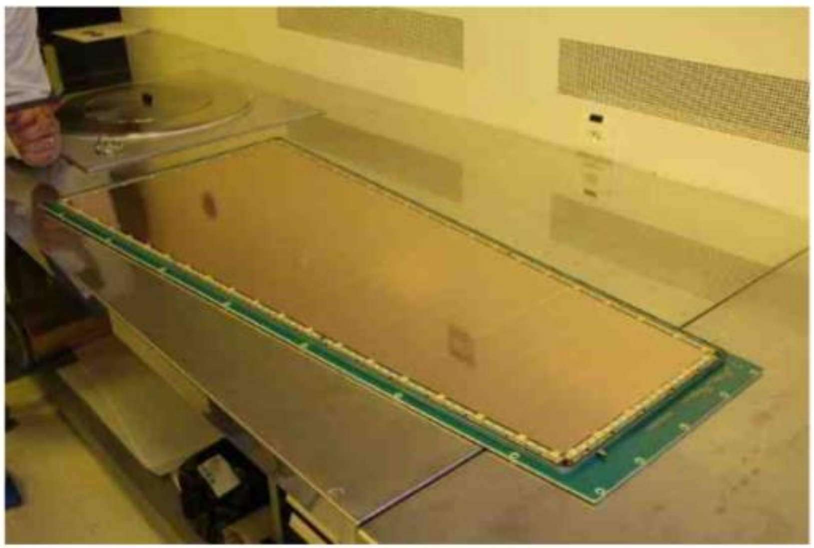


Row material

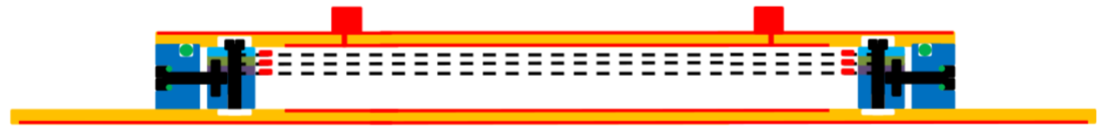
Copper etch

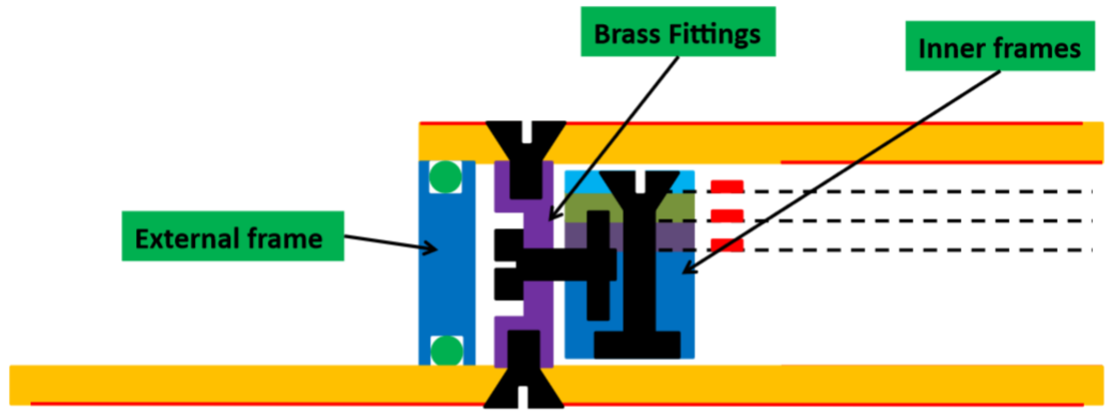
Kapton etch





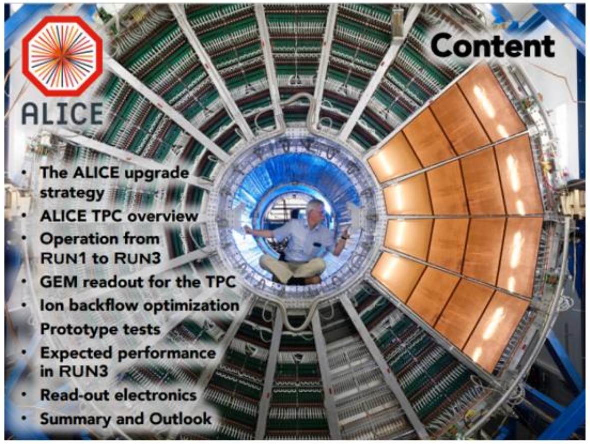
NS2..... New Stretching – No Spacers...





Assembly ... as important as the micro structure ..
If you want to preserve the properties at large scales

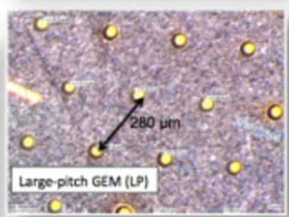
Another example of large GEM…. ALICE TPC Upgrade



Large GEMs….
Multiple stages…
From small prototypes.. To final size.. proved

IBF optimized configuration (2)

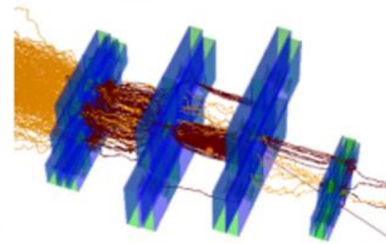
- Satisfactory performance could not be achieved with 3 GEM stack
- Best results in terms of IBF and energy resolution:
  - 4 GEM stack
  - S-LP-LP-S configuration
  - S: standard GEM foils
  - LP: large hole pitch foils
  - Optimized V settings: V_{GEM}, E_T (transfer fields)



13th Pisa Meeting on Advanced Detectors
La Biodola, Isola d'Elba (Italy)
May 24 - 30, 2015

IBF optimized configuration (7)

- Electron transport properties for IBF optimized voltage settings
- ε_{coll} = collection efficiency
- ε_{extr} = extraction efficiency
- M = gas multiplication factor
- $G = \varepsilon_{coll} \times M \times \varepsilon_{extr}$ = effective gain
- $n_{e\text{-}ion}$ = number of produced e-ions pairs
- $n_{ion,back}$ = number of ions drifting back into the drift volume



	ε_{coll}	$n_{e,in}$	M	n_{e-ion}	ε_{extr}	$n_{e,out}$	G	$n_{ion,back}$	fraction of total IBF (sim.)	fraction of total IBF (meas.)
GEM1 (S)	1	1	14	13	0.65	9.1	9.1	3.6 (28%)	40%	31%
GEM2 (LP)	0.2	1.8	8	12.7	0.55	8	0.88	3.3 (26%)	37%	34%
GEM3 (LP)	0.25	2	53	104	0.12	12.7	1.6	1.3 (1.3%)	14%	11%
GEM4 (S)	1	12.7	240	3053	0.6	1830	144	0.84 (0.03%)	9%	24%
Total				3183		1830	1830	9 (0.28%)		

13th Pisa Meeting on Advanced Detectors
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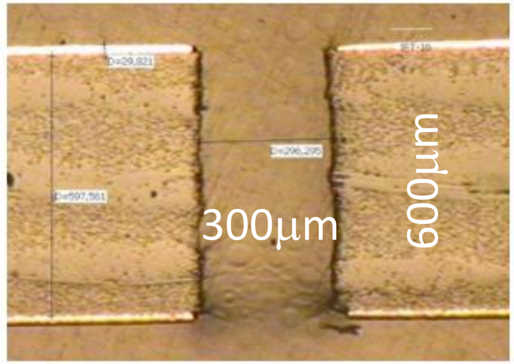
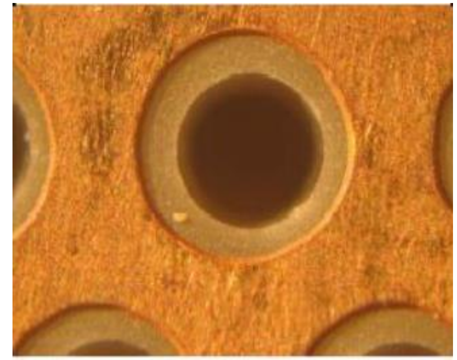
May 24 - 30, 2015

20

A continuous read-out TPC for the ALICE upgrade, C. Lippmann, Elba 2015

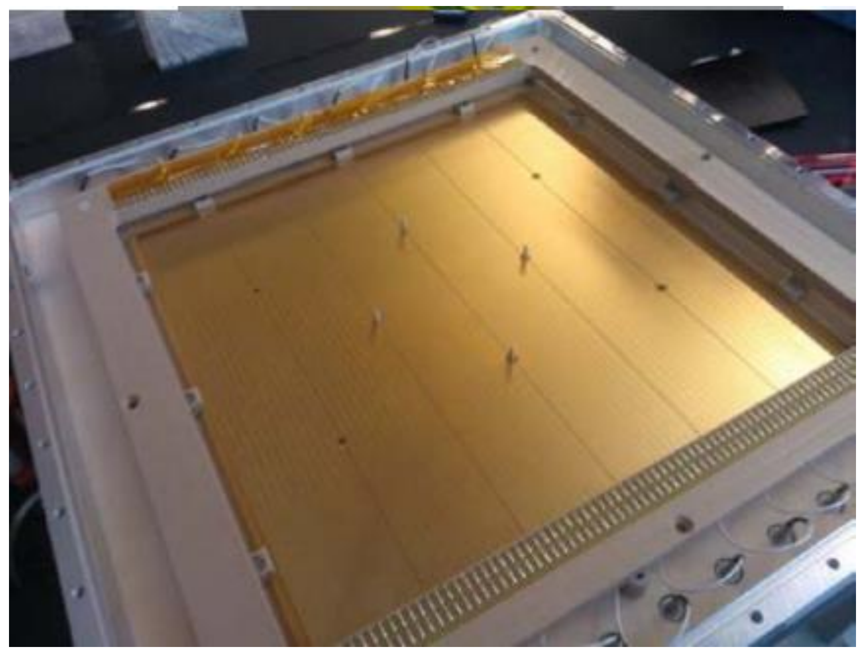
THICK GEM… Scale up by a factor of 10 (geometrically.. not the processes in gas)





1mm

Mechanically Drilled



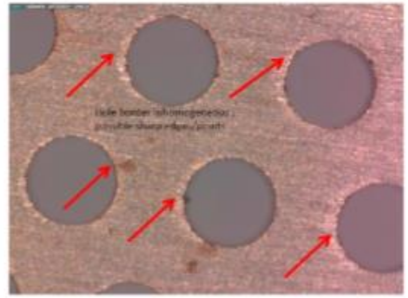
Compass RICH prototype

Thick GEM

THGEM: looking for the Pashen limit

300 X 300 Single Sector #1 (before treatment)	300 X 300 Single Sector #1 (After treatment)
1390	2180

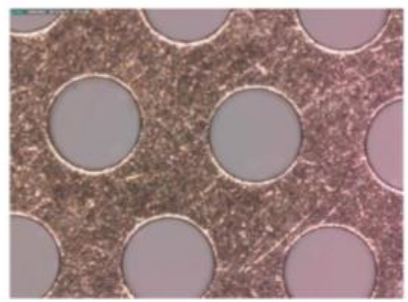
Paschen limit expected = 2190.76V



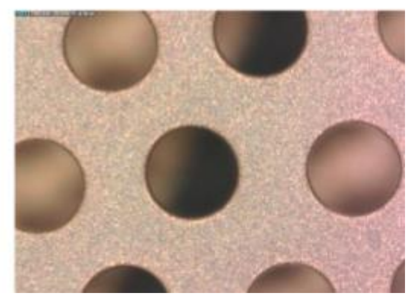
First step mechanical brushing using pumice stone plus water 3 types are used I 0-40 μm II 90-300 μm III (coarse) Hinrichs Pumice Powder, Coarse

Ultrasonic bath @ 50-60 C in Sonica pcb solution, long bath ~1h or more (check every 20 min) extremely mild chemical attack Sonica PCB is alkaline pH11 ultrasonic cleaning solution

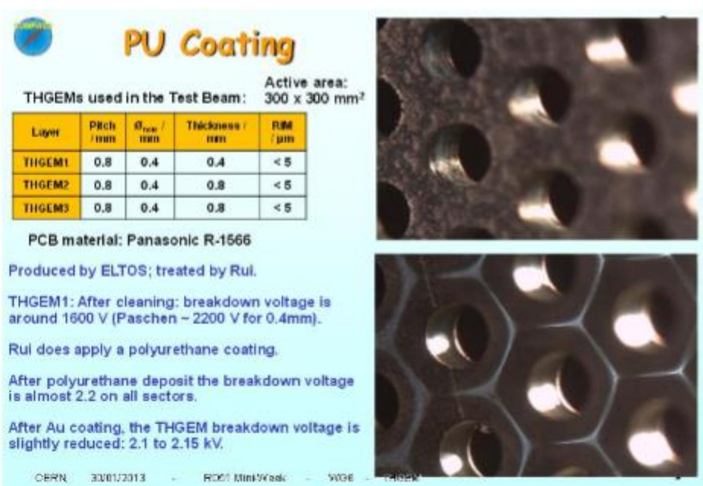
Cleaning with high pressure wate to remove all pumice residuals a/o other materials,
Result after first polishing, reduced irregularities, smoothened borders, still scratches



After washing with demineralized water plus oven at 180 C for 24 h



Polyurethane Coating (CERN workshop)



PU Coating

THGEMs used in the Test Beam: Active area: 300 x 300 mm²

Layer	Pitch / mm	$\varnothing_{hole}$ / mm	Thickness / mm	RIM / μm
THGEM1	0.8	0.4	0.4	< 5
THGEM2	0.8	0.4	0.8	< 5
THGEM3	0.8	0.4	0.8	< 5

PCB material: Panasonic R-1566

Produced by ELTOS; treated by Rui.

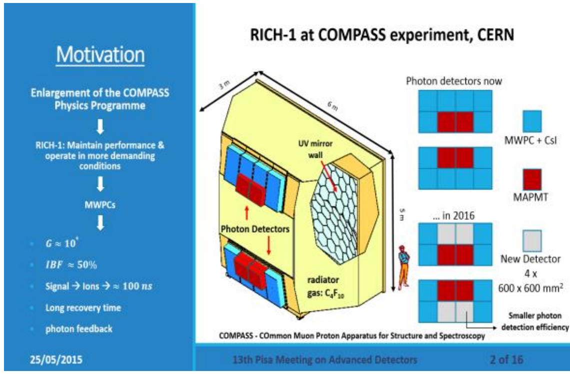
THGEM1: After cleaning: breakdown voltage is around 1600 V (Paschen ~ 2200 V for 0.4mm).

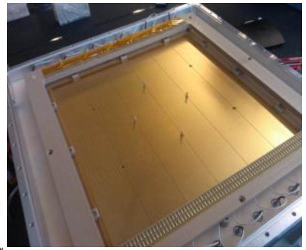
Rui does apply a polyurethane coating.

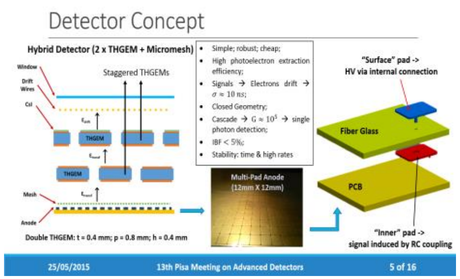
After polyurethane deposit the breakdown voltage is almost 2.2 on all sectors.

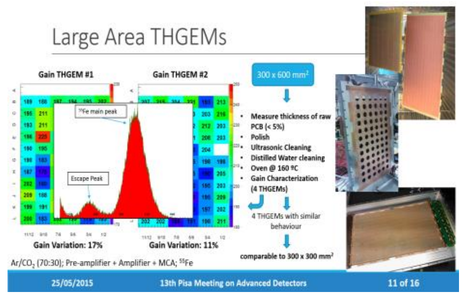
After Au coating, the THGEM breakdown voltage is slightly reduced: 2.1 to 2.15 kV.

Large area THGEM… the COMPASS RICH-1

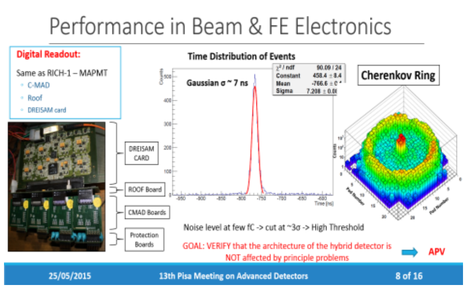


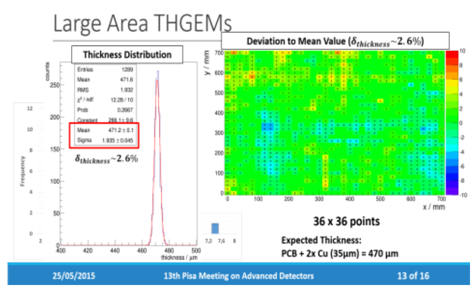






Status of the Development of Large Area Photon Detectors based on THGEMs and Hybrid MPGD architectures for Cherenkov Imaging Applications , C.A.Santos, Elba 2015



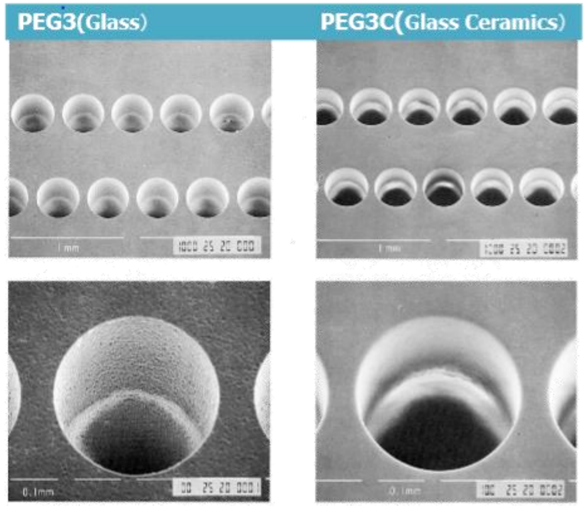


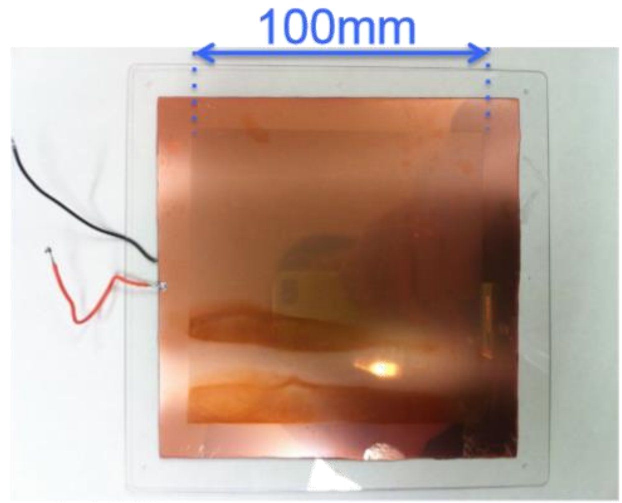
holes…. different materials

Mostly JAPAN…. Only JAPAN in my slides…

The Glass GEM **Univ. Tokyo, Fujiwara group**

THE UNIVERSITY OF TOKYO





HOYA

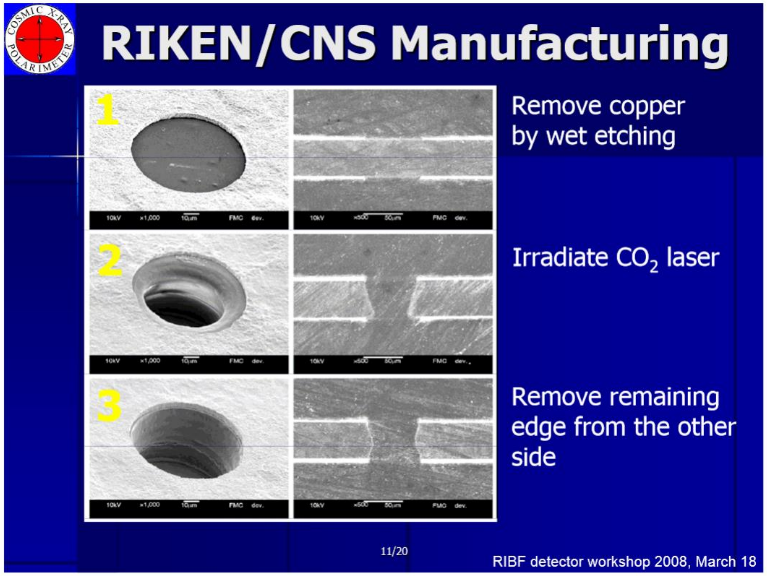
HOYA corporation
Innovative Glass Material Developer in Japan

Photo Etchable Glass 3 : PEG3

GEM fabricated with photo-etchable glass
- *No outgas*
- *Stable material*

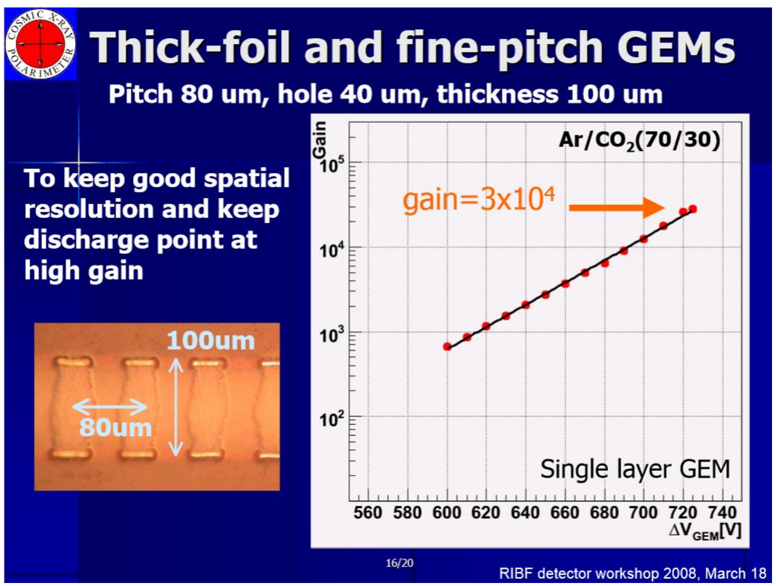
- Substrate:PEG3
- Thickness: 680μm
- Hole dia.: 170μm

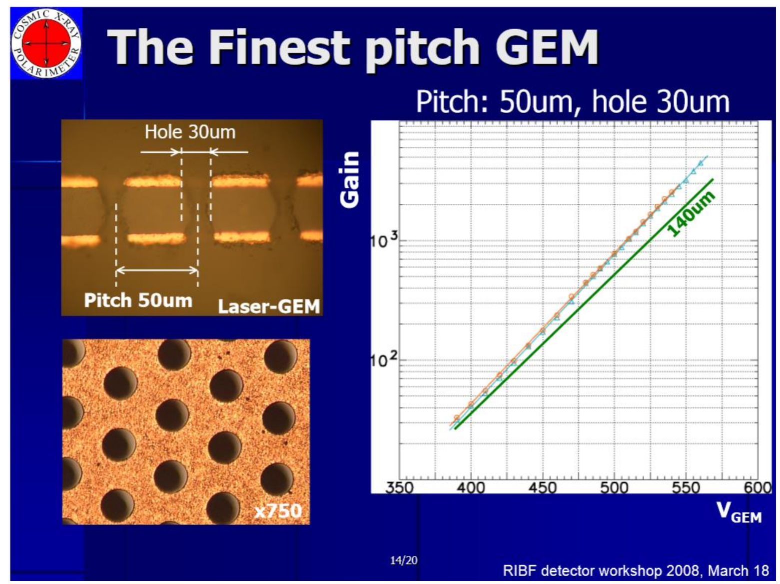
2013/6/10 *A. Ochi, Cygnus 2013 @ Toyama*



LCP

Different process.. Different geometrical characteristics

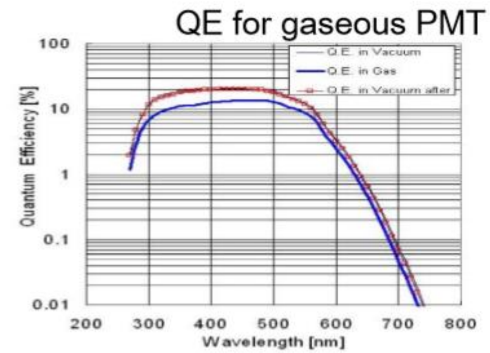


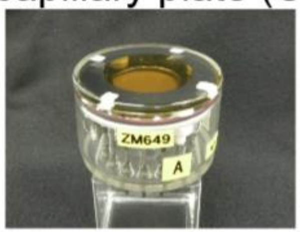


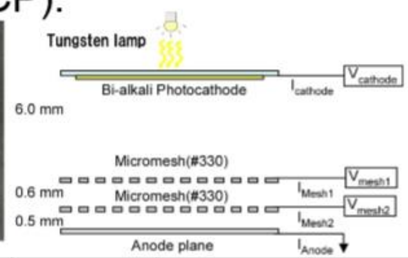
Gaseous PMT

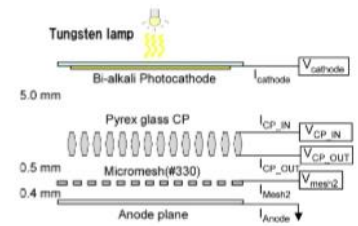
Yamagata U. TMU, HAMAMATSU

- To suppress the ion- and photon-feedback,we have been developing a gaseous PMT using MPGDs such as GEM, Micromegas and glass capillary plate (CP).









Sensor type	Sensitivity	Position Resolution	Timing Resolution	Uniformity	Price	Magnetic Field	Effective Area
Vacuum PMT	◎	△	◎	△	○	△	○
CCD / CMOS	△	◎	×	◎	△	◎	×
Gaseous PMT	○	○	○	○	◎	◎	◎

- The advantage of the **gaseous PMT**:
  - ✓It can achieve a **very large effective area** with moderate **position** and **timing** resolutions.
  - ✓It can be easily operated under a **very high magnetic field**.

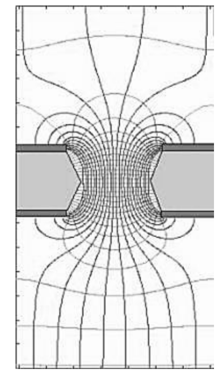
2013/6/10 A. Ochi, Cygnus 2013 @ Toyama 10

WELL... as in the past, WELL... not true... now resistive

HOLES.... NOT FLOATING ANYMORE

Nuclear Instruments and Methods in Physics Research A 423 (1999) 125–134

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A



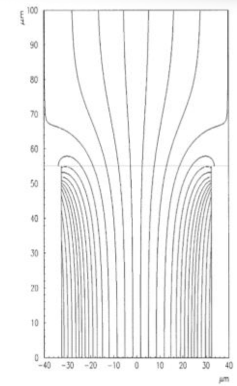


Fig. 2. Electric field map of one cell of a WELL detector.

The WELL detector

R. Bellazzini[a,b,*], M Bozzo[c], A. Brez[a], G. Gariano[a], L. Latronico[a], N. Lumb[a], A. Papanestis[a], G. Spandre[a], M.M. Massai[a], R. Raffo[a], M.A. Spezziga[a]

R. Bellazzini et al. / Nucl. Instr. and Meth. in Phys. Res. A 423 (1999) 125–134

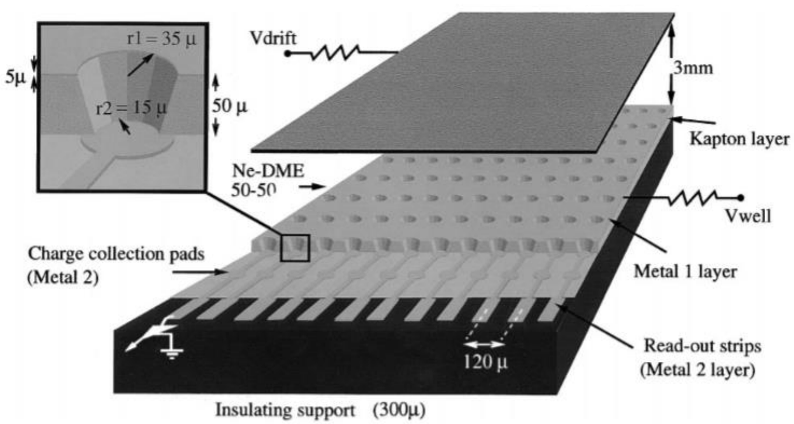
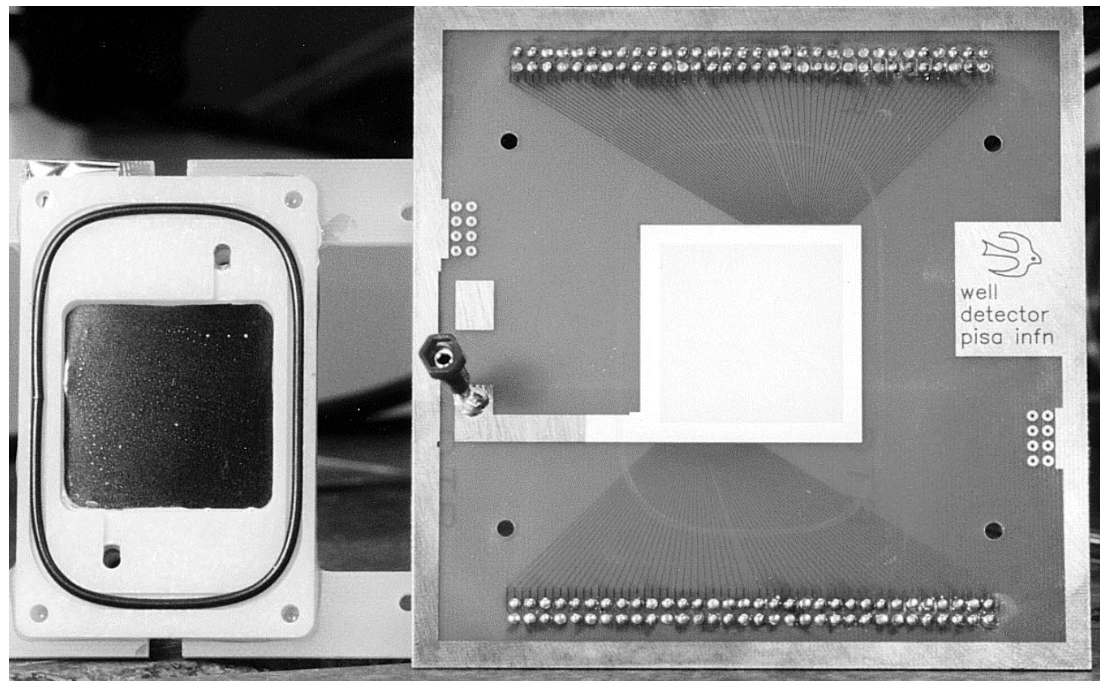


Fig. 1. Schematic diagram of a WELL detector.

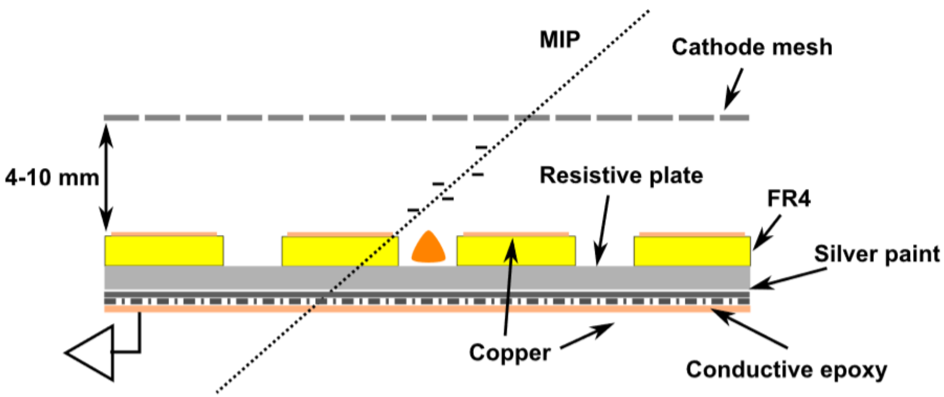


With THGEM….

First studies with the Resistive-Plate WELL gaseous multiplier

A. Rubin[1], L. Arazi, S. Bressler, L. Moleri, M. Pitt, and A. Breskin

Department of Particle Physics and Astrophysics,
Weizmann Institute of Science, 76100 Rehovot, Israel
E-mail: adam.rubin@weizmann.ac.il



Protection, signal integrity and charge evacuation

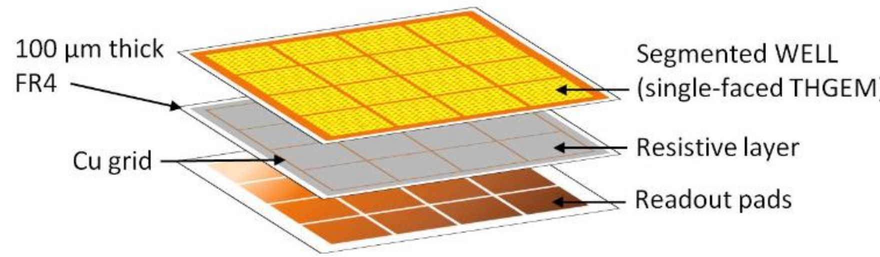


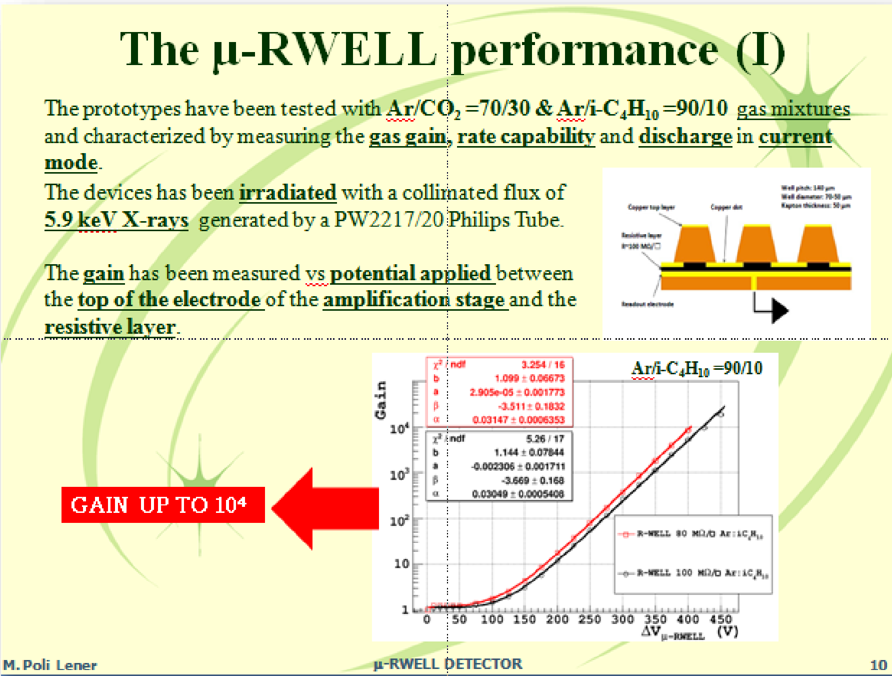
Figure 1: The three layers comprising the SRWELL. Bottom: readout pad array (here 4×4); middle: resistive layer on top of a copper grid (on FR4 sheet); top: segmented single-faced THGEM. The layers are assembled one on top of the other in direct contact (see Fig. 2).

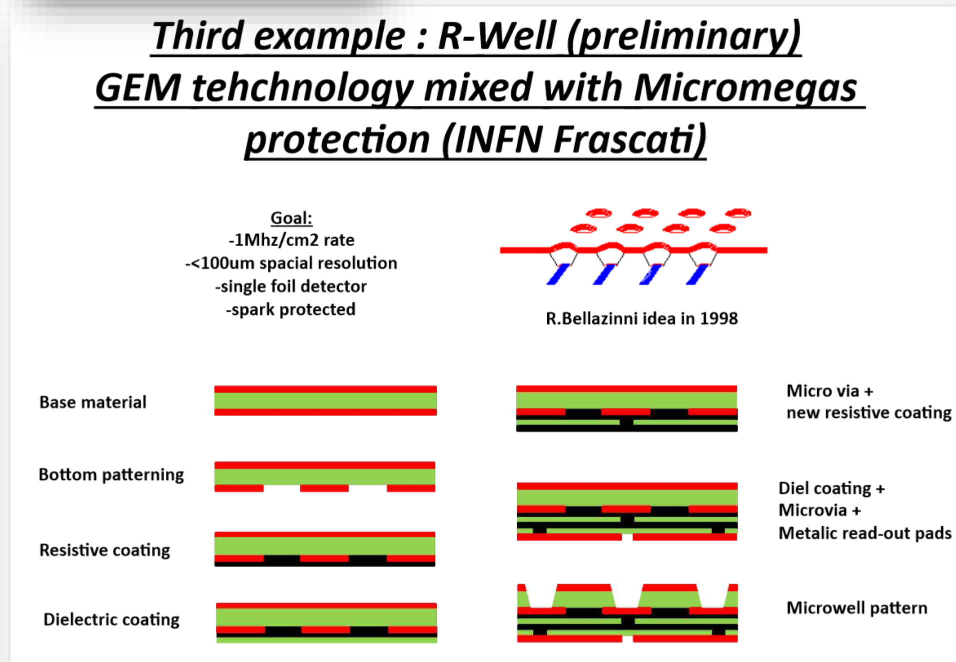
Beam Studies of the Segmented Resistive WELL: a Potential Thin Sampling Element for Digital Hadron Calorimetry

With GEM….

New designs

Previous designs





Protection, signal integrity and charge evacuation

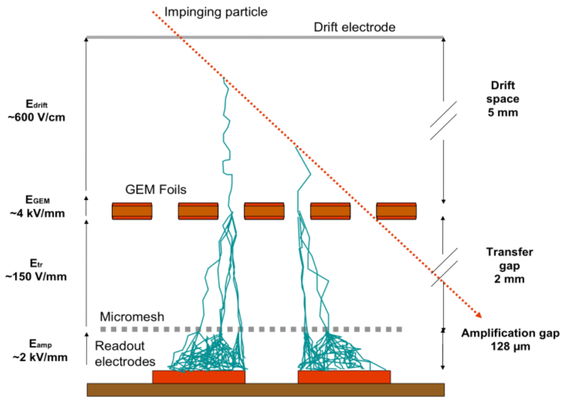
https://agenda.infn.it/getFile.py/access?contribId=20&sessionId=9&resId=0&materialId=slides&confId=7618

hybrids

A reciprocal support in between multiple amplification stages

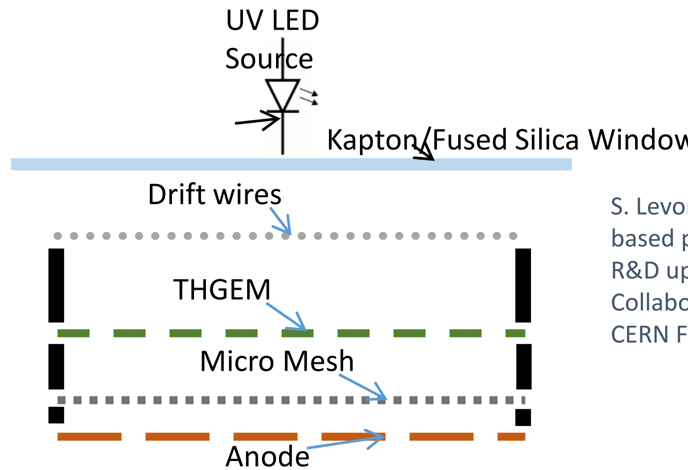
Hybrids…

GEMs+mm



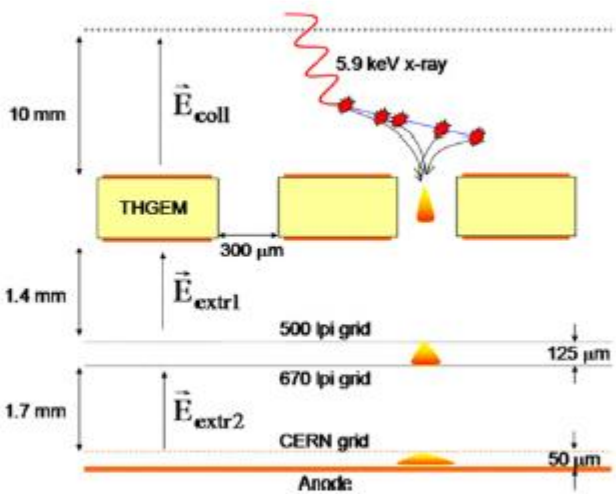
An aging study of MICROMEGAS+GEM S. Kane et al

THGEM+mm

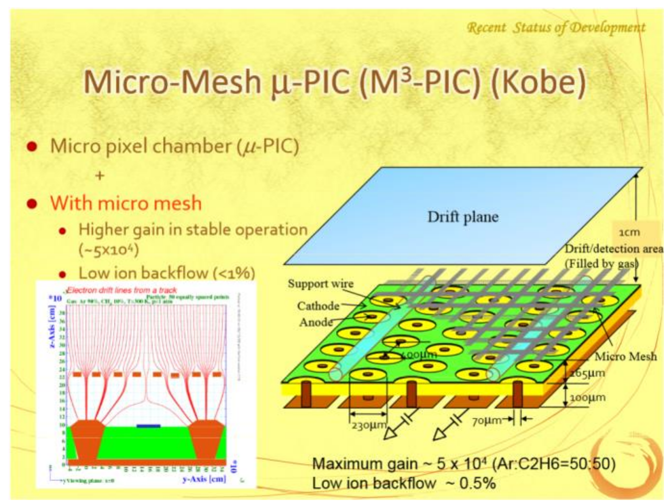


S. Levorato, Hybrid MPGD based photon Detector, R&D update, Rd51 Collaboration Meeting, CERN Feb-2014

THGEM+PIM+mm



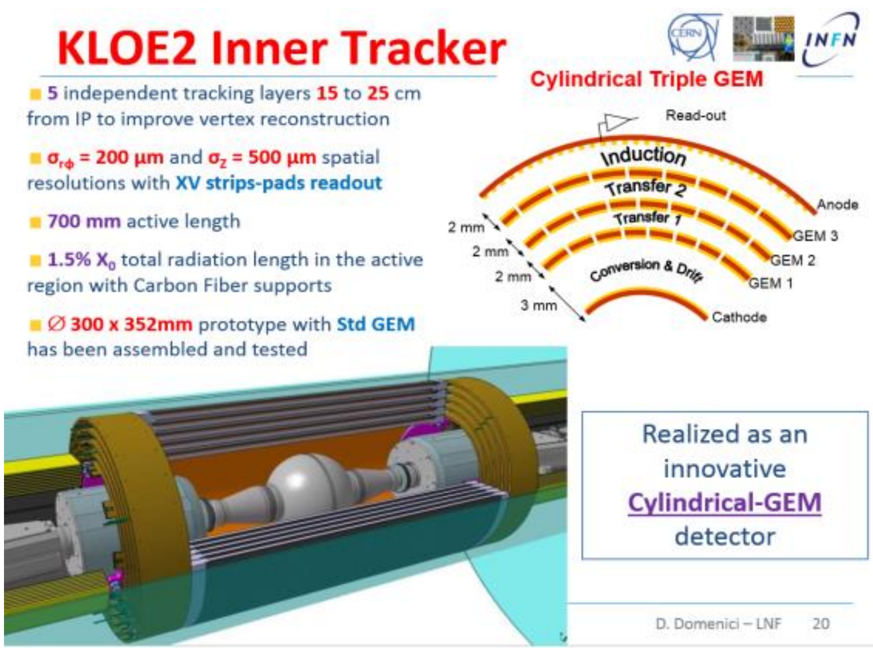
S. Duval et al., NIMA 695 (2012) 163



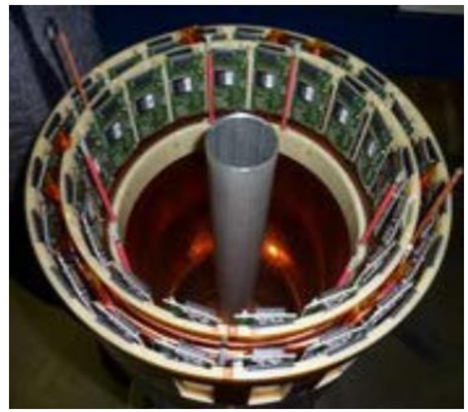
https://indico.cern.ch/event/35172/session/0/contribution/6/material/slides/1.pdf

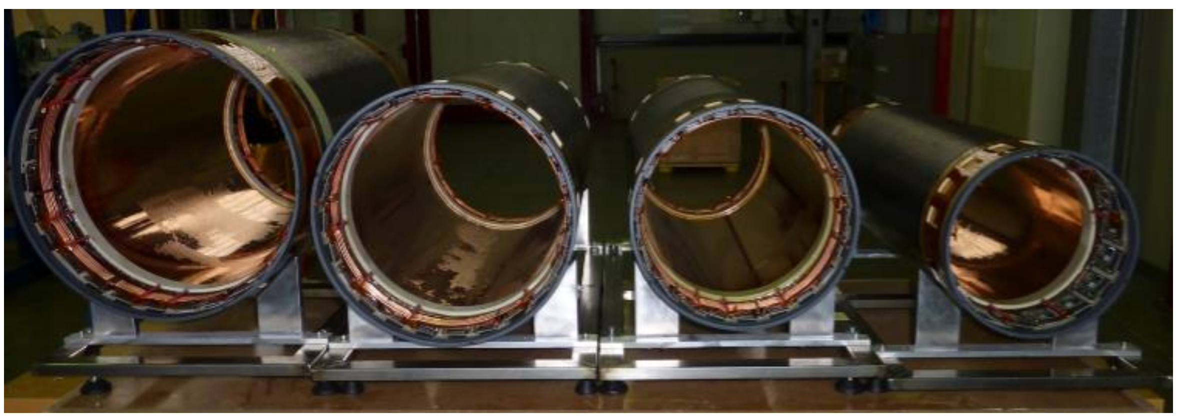
MPGD Shapes

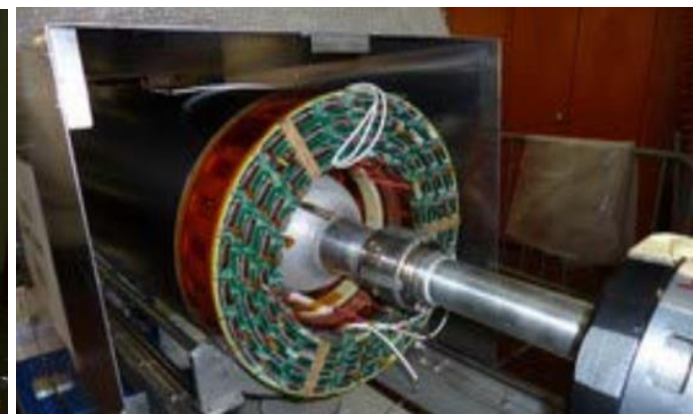
GDD team, PH-DT CERN


KLOE2 Inner Tracker
5 independent tracking layers 15 to 25 cm from IP to improve vertex reconstruction
$\sigma_{r\phi}$ = 200 μm and σ_z = 500 μm spatial resolutions with XV strips-pads readout
700 mm active length
1.5% X_0 total radiation length in the active region with Carbon Fiber supports
∅ 300 x 352mm prototype with Std GEM has been assembled and tested
Cylindrical Triple GEM
Read-out
Induction
Transfer 2
Transfer 1
Conversion & Drift
Anode
GEM 3
GEM 2
GEM 1
Cathode
2 mm
2 mm
2 mm
3 mm
Realized as an innovative Cylindrical-GEM detector
D. Domenici – LNF
20

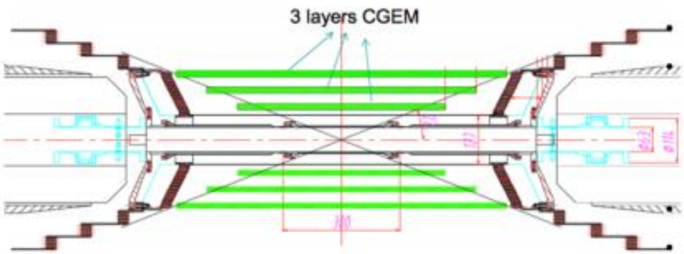

The Cylindrical GEM detector for the KLOE-2 Inner Tracker
G. Morello on behalf of the KLOE-2 IT group
Exploring Hadron Structure with Tagged Structure Functions,
January 18th, Newport News (VA)







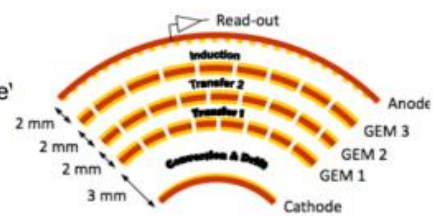
CGEM detector for BESIII



- Three active layers
- Active area
  - L1 length 532 mm
  - L2 length: 690 mm
  - L3 length: 847 mm
- Inner radius: 78 mm
- Outer radius: 178 mm

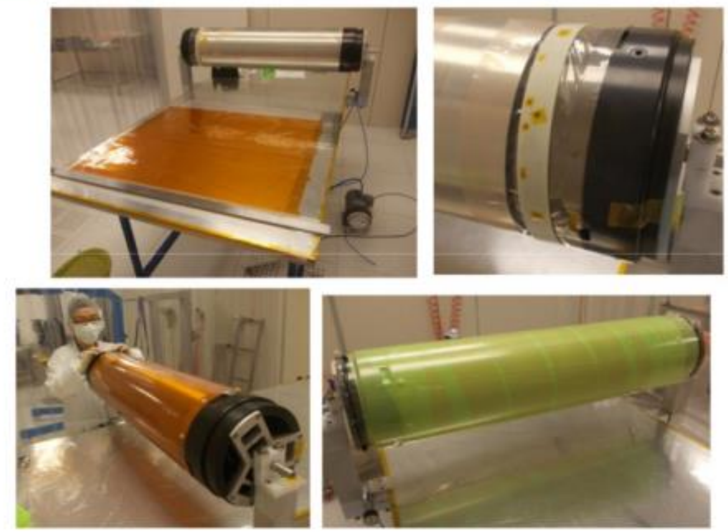
Requirements

- Rate capability: ~10^4 Hz/cm^2
- Spatial resolution: s_{xy} =~100µm : s_z=~1mm
- Momentum resolution:: s_{pt}/P_t =~0.5% @1Ge'
- Efficiency=~98%
- Material budget <= 1.5% all layers
- Coverage: 93% 4π
- Operation duration~ 5 years



A. Calcaterra, for BESIII-Italy BESIII Physics Workshop, IHEP 2013-09-22

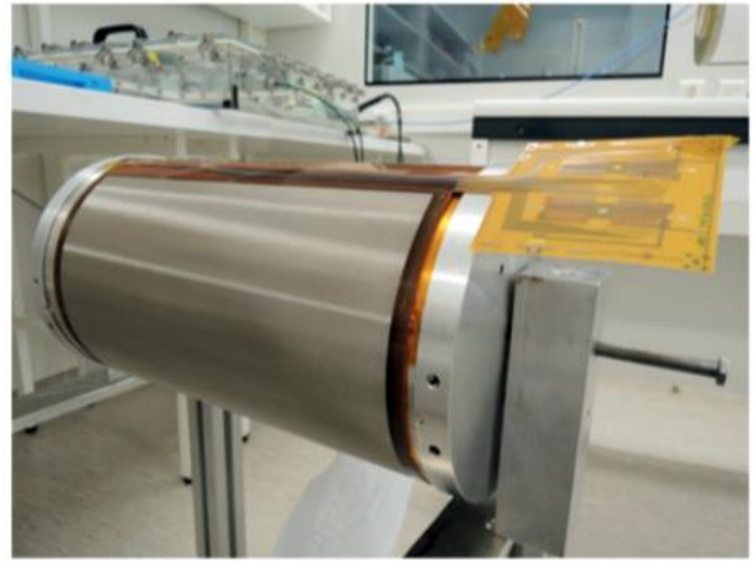
GEM foil assembly test

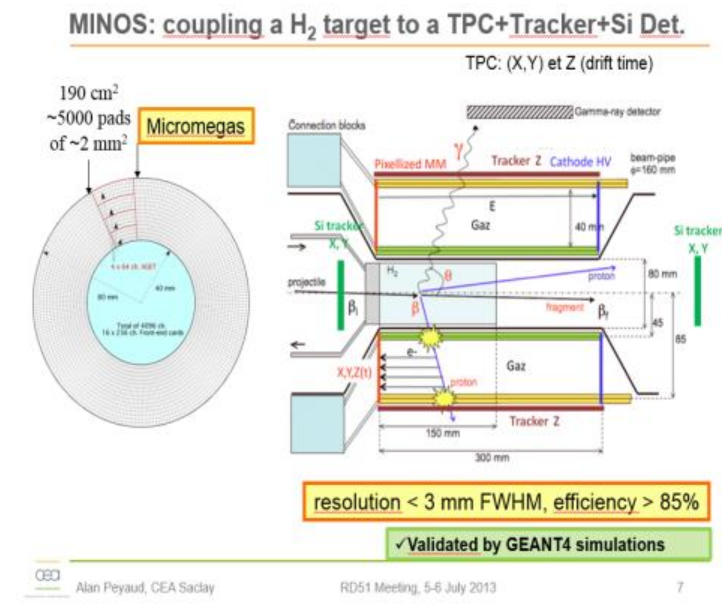


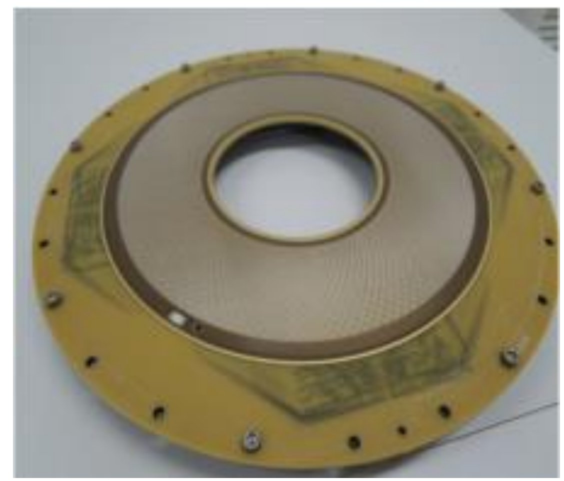
R.Farinelli CGEM-IT RD51 mini-week meeting - CERN - Dec 09, 2014

Irfu
Institute of Research
into the Fundamental Laws of the Universe

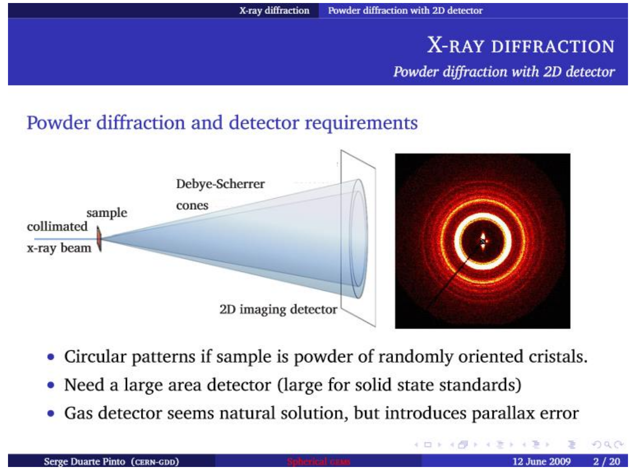
Ancillary cylindrical Micromegas This ancillary detector is to be place around the MINOS Time Projection Chamber and used for real-time drift velocity calibrations and, possibly, for its trigger capabilities. The first part of the MINOS cylindrical tracker detector has been built at the CERN/TE-MPE-EM. This anode is 200 µm thick to make easier the curvature of the detector (radius of 92 mm), to reduce the radiation length and its capacitance. It is composed of 2 tiles of 128 strips of 260 mm along. The 2 detectors' goals are realized by zones different pitch : the z-position is measured thanks to 2*21 strips of 1 mm pitch and the external trigger by 2*43 strips of 2.5 mm pitch. This anode has been integrated on a 90 mm radius cylinder and tested electrically. Before summer 2013, we will receive the cathode in polyimide and finish the integration and characterization of the detector.

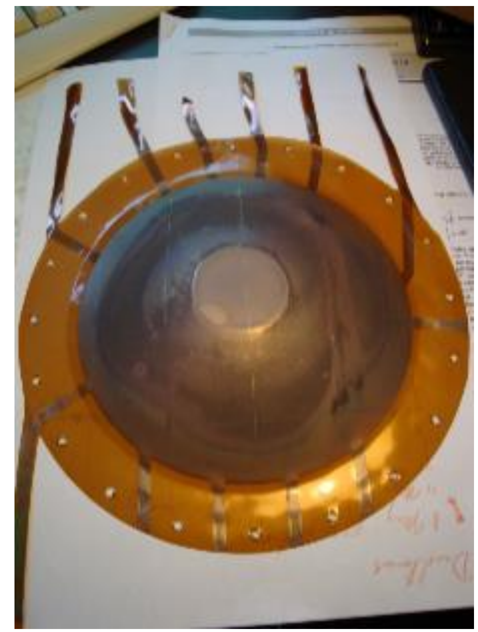


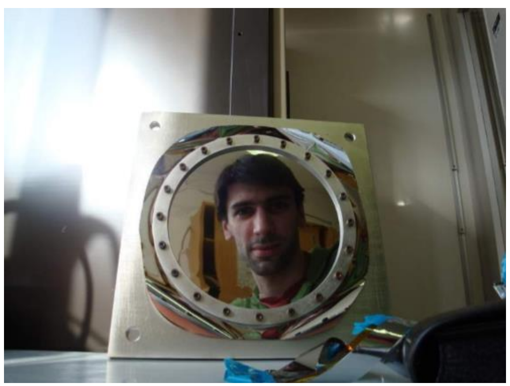


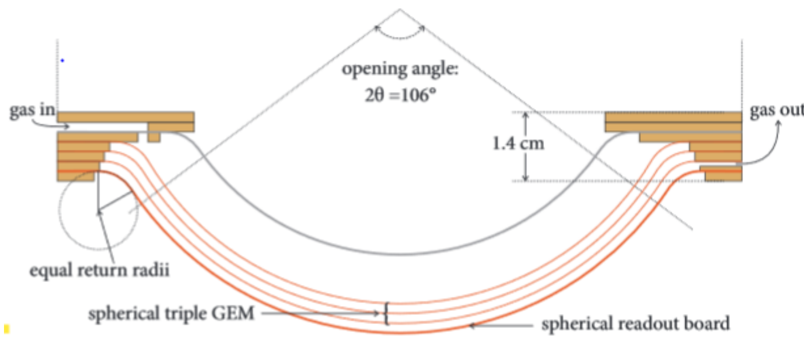



MPGD2009
Kolympary, Crete, Greece, 12–17 June 2009
Spherical GEMS
Development of spherical GEM detector for parallax-free XRD
Serge Duarte Pinto
CERN-GDD
12 June 2009
Serge Duarte Pinto (CERN-GDD)
12 June 2009 1 / 20


X-ray diffraction Powder diffraction with 2D detector
X-RAY DIFFRACTION
Powder diffraction with 2D detector
Powder diffraction and detector requirements
Debye-Scherrer cones
sample
collimated x-ray beam
2D imaging detector
Circular patterns if sample is powder of randomly oriented cristals.
Need a large area detector (large for solid state standards)
Gas detector seems natural solution, but introduces parallax error
Serge Duarte Pinto (CERN-GDD)
12 June 2009 2 / 20

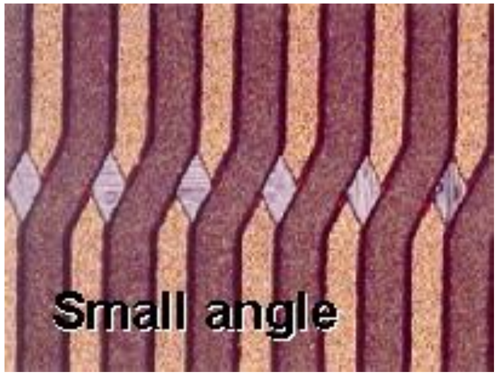


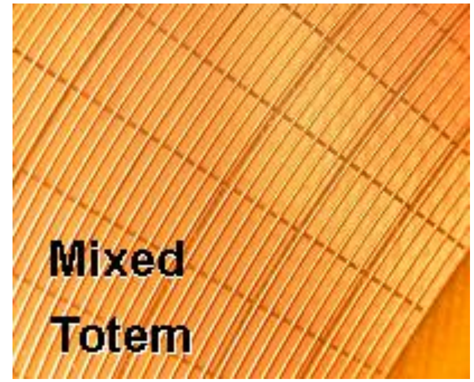



opening angle:
2θ =106°
gas in
gas out
1.4 cm
equal return radii
spherical triple GEM
spherical readout board

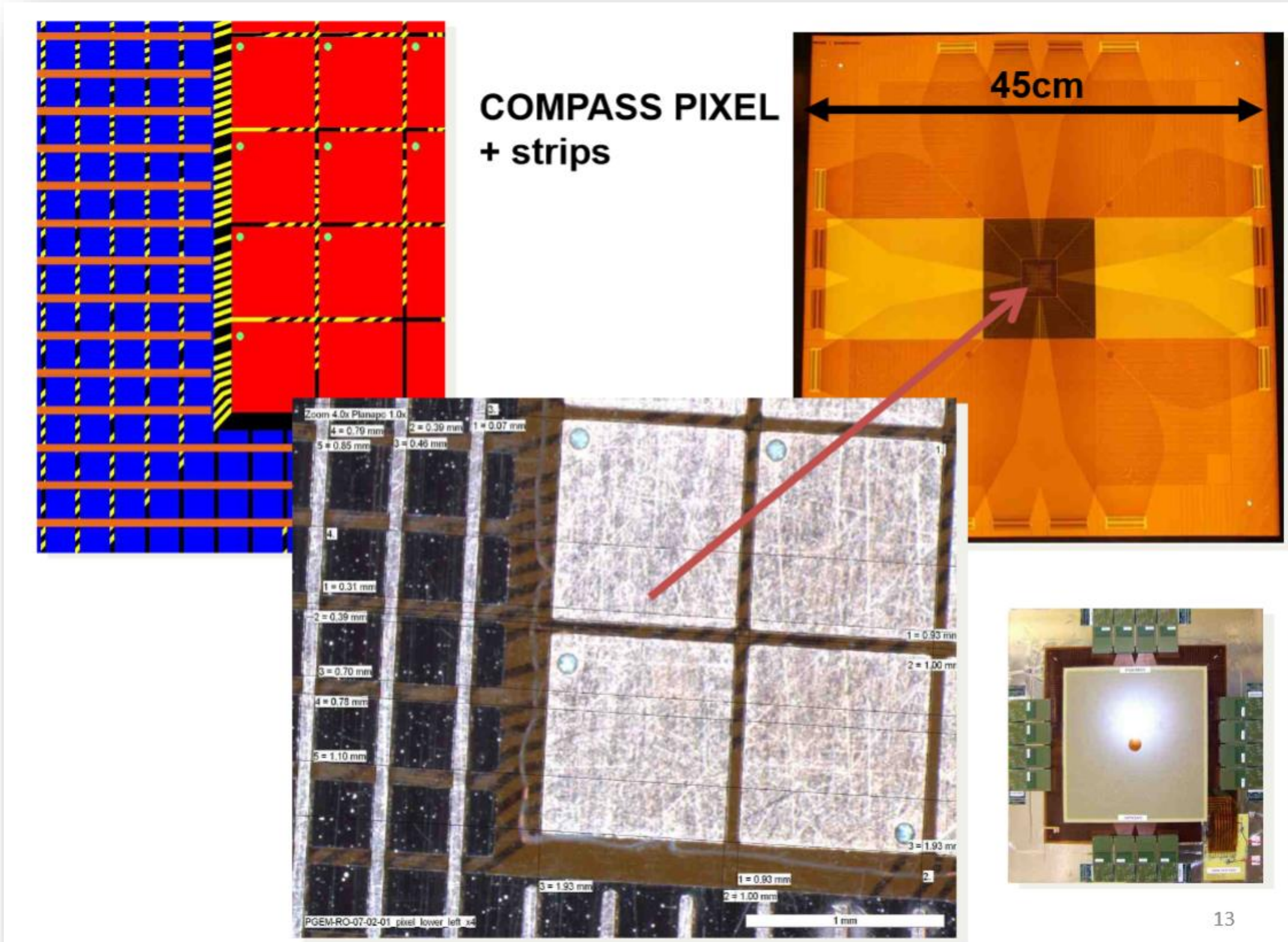
readout

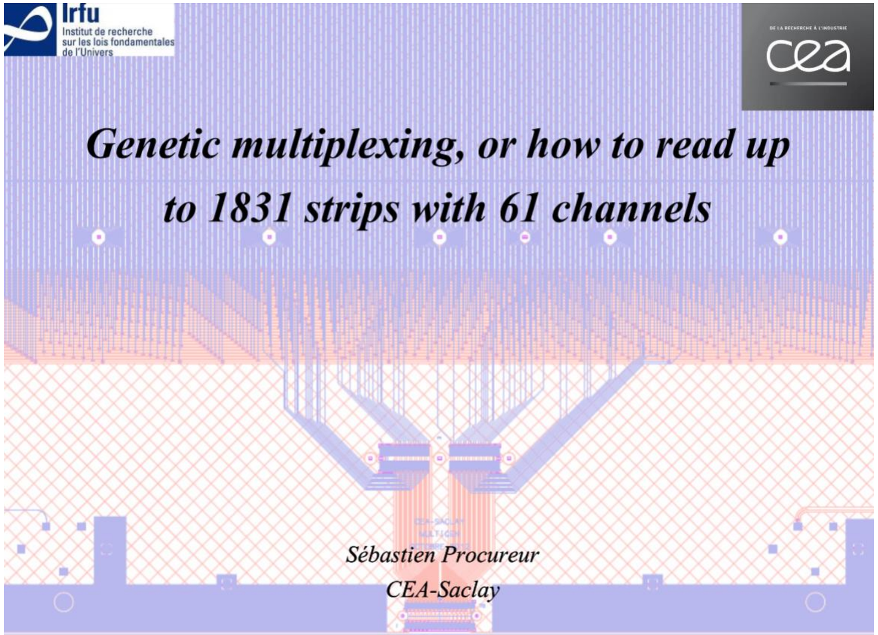
Readout Pattern… if the readout is not part of the amplifying stage there are no particular limitation..

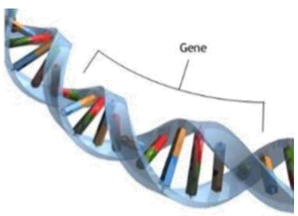


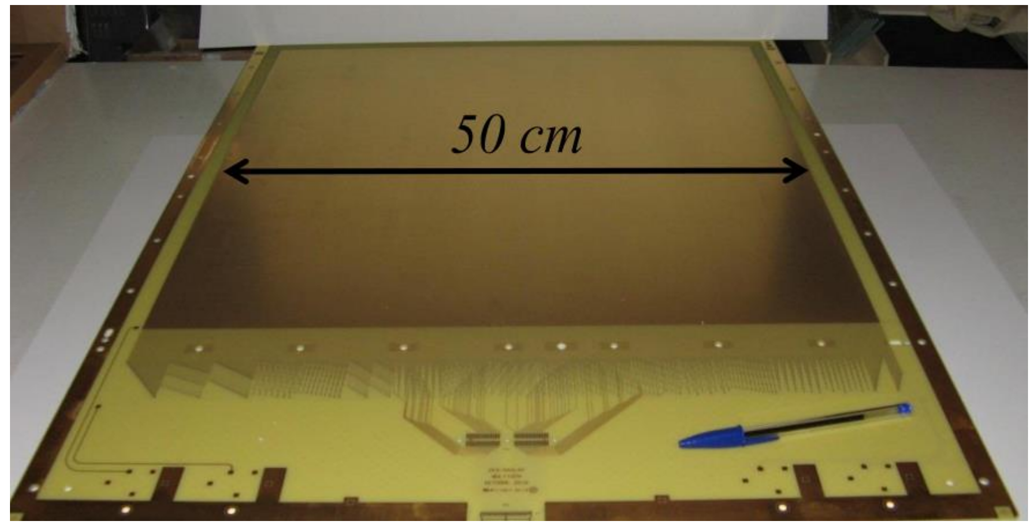


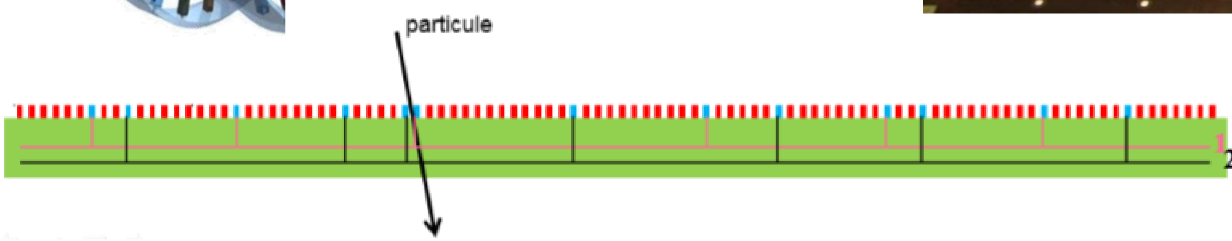
If it is part of the amplification stage (mm)… one has to avoid any effect on the gap..(flat.. or capacitive coupling)


COMPASS PIXEL
+ strips
45cm
13





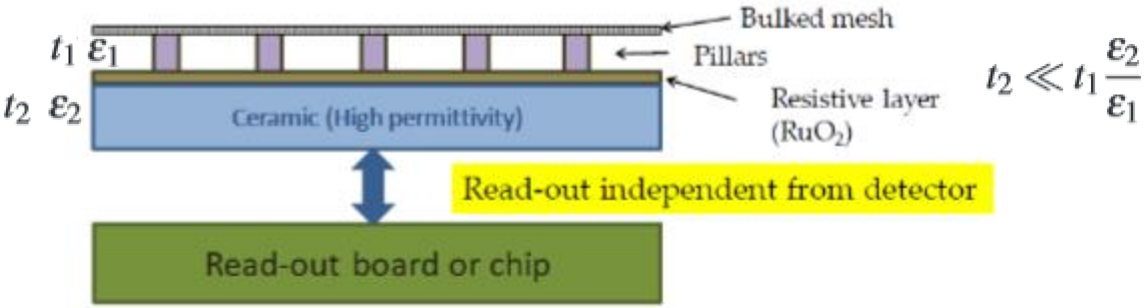


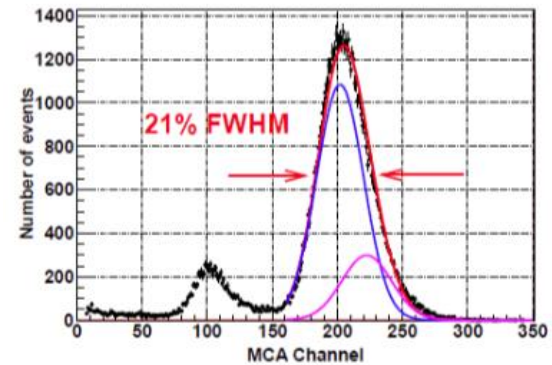


Two given channels are connected to neighboring strips only once in the detector

A Piggyback resistive Micromegas

D. Attié [a], A. Chaus [a], P. Colas[a], E. Ferrer Ribas [a], J. Galán [a], I. Giomataris[a] ;
F.J. Iguaz [a], A. Gongadze [a], R. De Oliveira [b], T. Papaevangelou [a], A. Peyaud [a]





Medipix2/Timepix
CMOS chip
256 × 256 square pixels of 55 µm side each

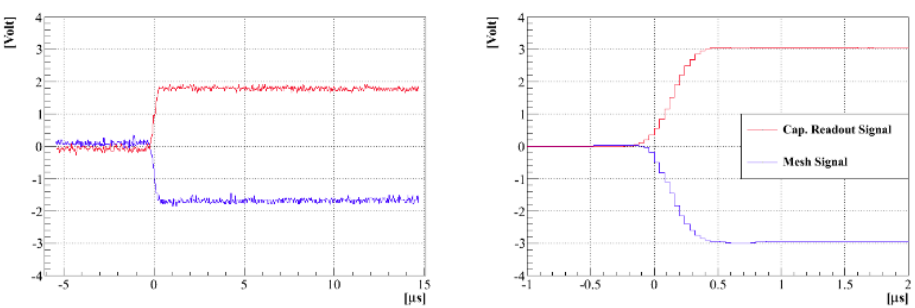
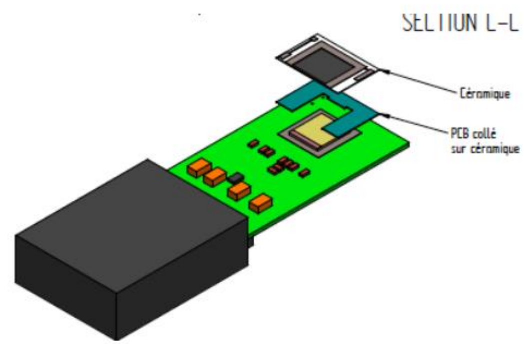
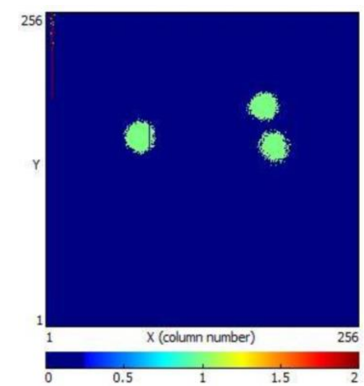
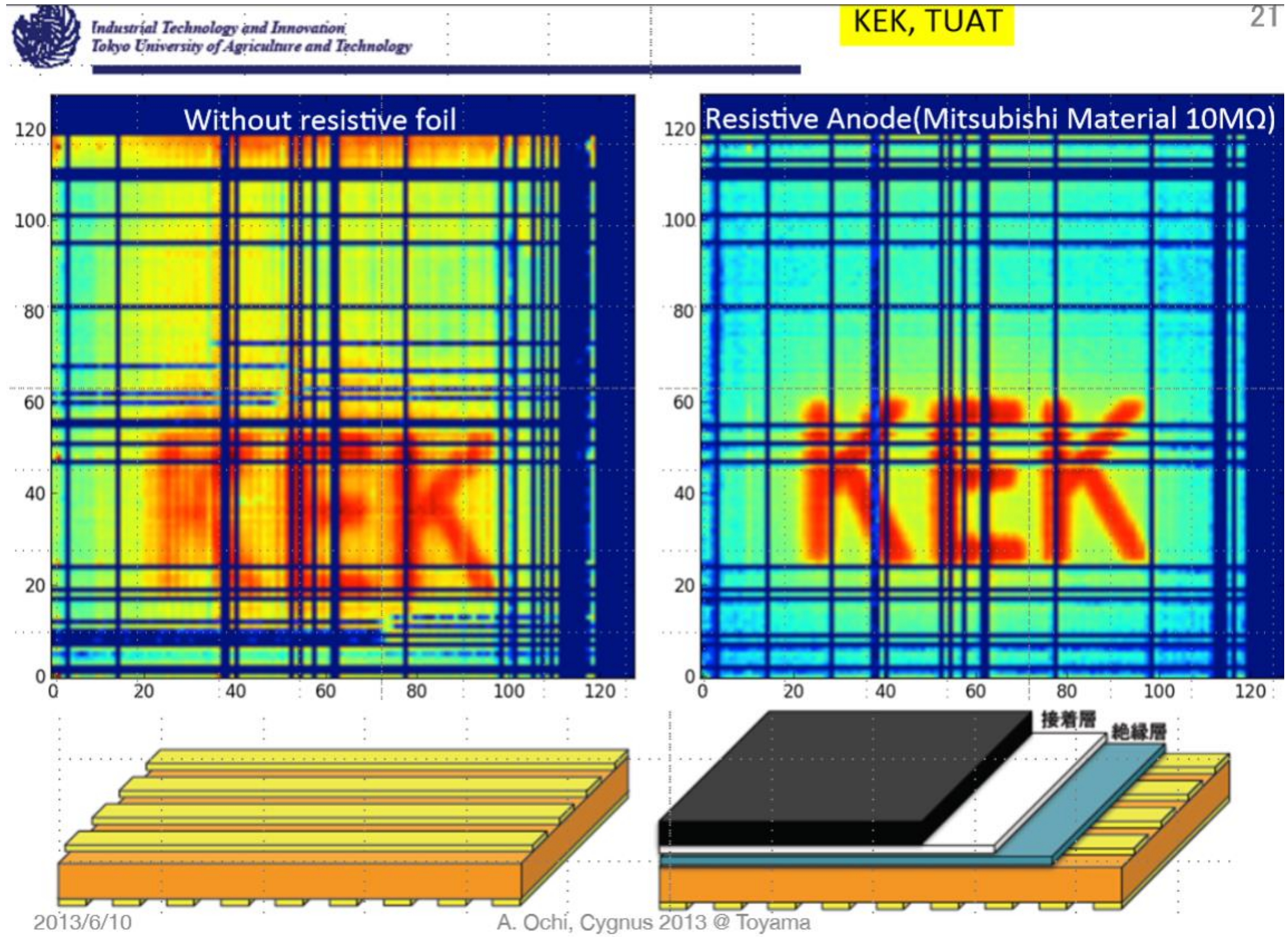


Figure 7. Signals from fission fragments as they are recorded by the mesh and the anode. On the left a single event is drawn, while on right is shown the accumulation of 5000 events.






MPGD R&D Activity in Japan
Kobe University
Atsuhiko Ochi
10 June. 2013 Cygnus 2013 workshop at Toyama


Industrial Technology and Innovation
Tokyo University of Agriculture and Technology
KEK, TUAT
21
Without resistive foil
Resistive Anode(Mitsubishi Material 10MΩ)
接着層
絶縁層
2013/6/10
A. Ochi, Cygnus 2013 @ Toyama

N·H
ELSEVIER
Nuclear Instruments and Methods in Physics Research A 392 (1997) 244–248
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

An interpolating 2D pixel readout structure for synchrotron X-ray diffraction in protein crystallography

H.J. Besch, M. Junk*, W. Meißner, A. Sarvestani, R. Stiehler, A.H. Walenta
ZESS, Center for Sensor Systems, University of Siegen, Adolf-Reichwein-Strasse 2, 57068 Siegen, Germany

resistive charge partition

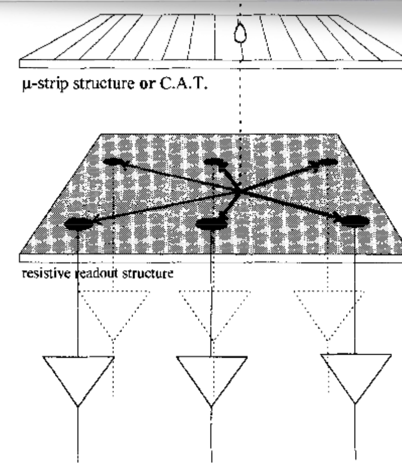
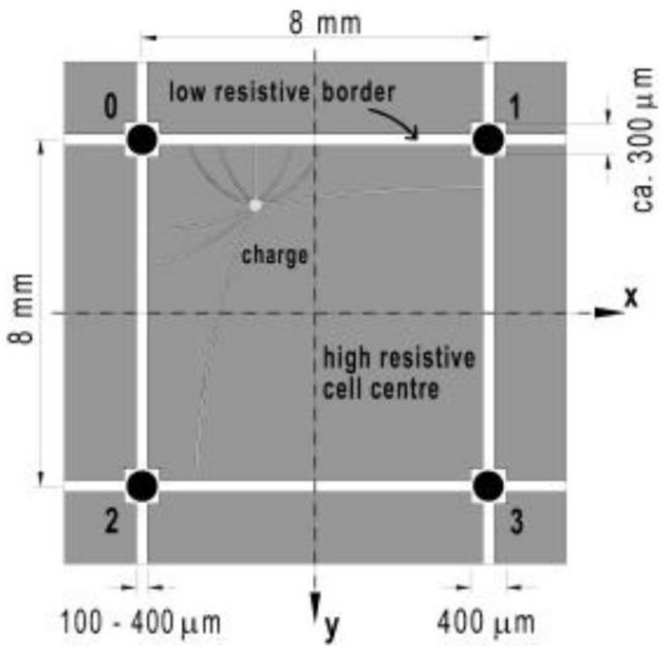
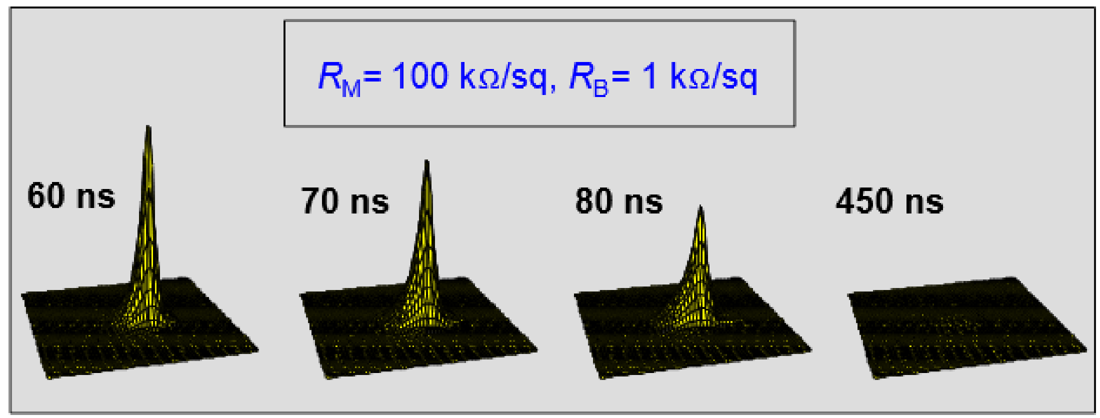


Fig. 1. 2D resistive charge division – schematic.



Besch et al. NIM A 392 (1997)

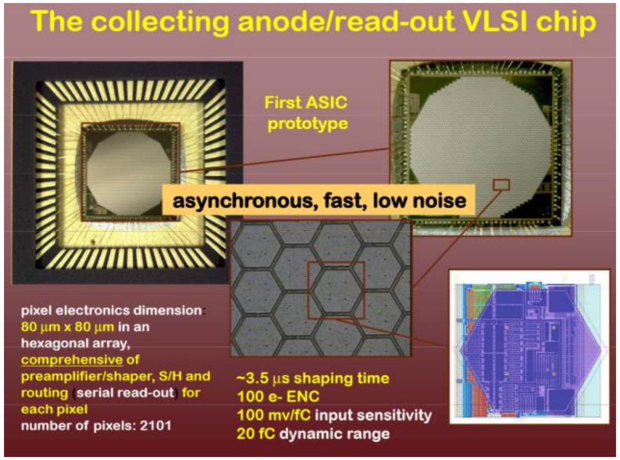
TIME DEVELOPMENT OF THE POTENTIAL SHAPE

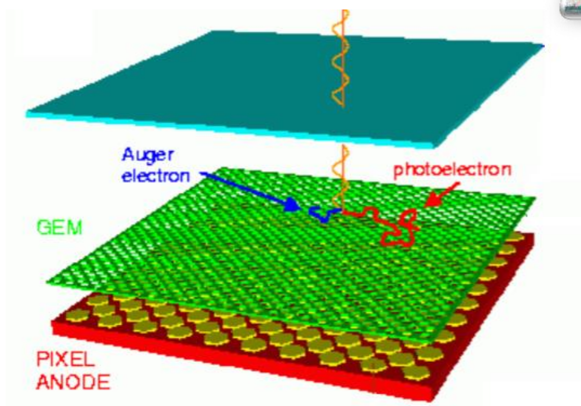


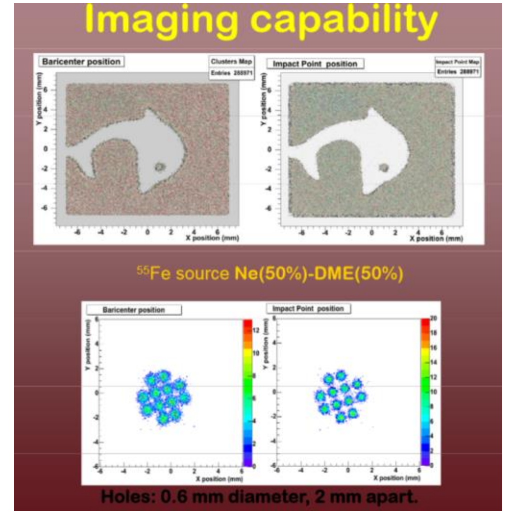
Recent progress with the MicroCAT Gaseous Imaging Detector

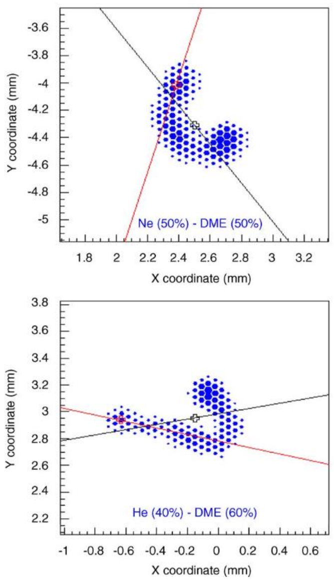
A. Orthen, H. Wagner
H.J. Besch, N. Pavel, A. Sarvestani, A.H. Walenta, H. Walliser
Department of Physics, University of Siegen, Germany
R.H. Menk
Sincrotrone Trieste, Italy

MPGD and CMOS pixels









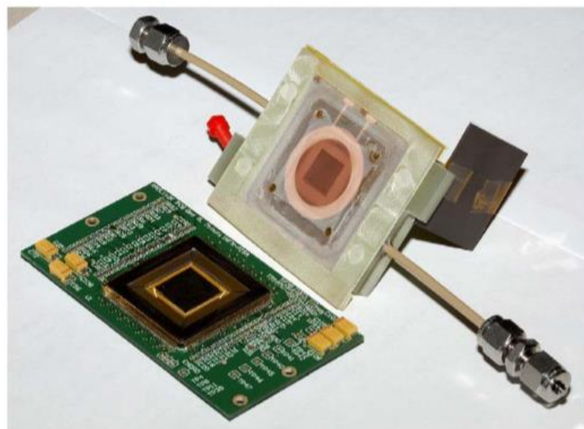
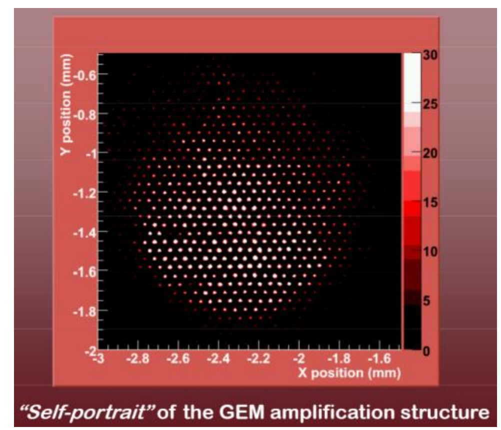


Fig. 4. Photo during the assembly phase of the detector. The GEM foil glued to bottom of the gas-tight enclosure and the large area ASIC mounted on the control motherboard are well visible.



ftp://ftp.iaps.inaf.it/polar/Weiqun/Bellazzini_NIM_2006_105k_NIM.pdf

https://indico.cern.ch/event/16213/session/0/contribution/16/material/slides/2.pdf

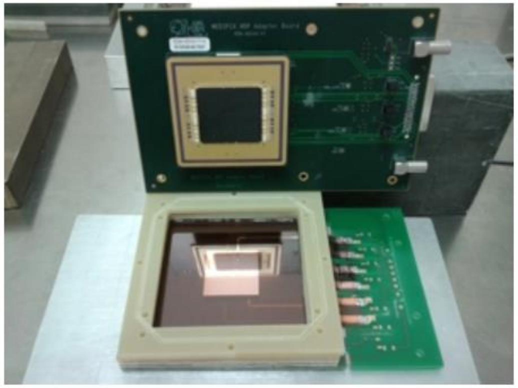
Welcome on triple GEM detectors R&D

Font size Bigger Reset Smaller

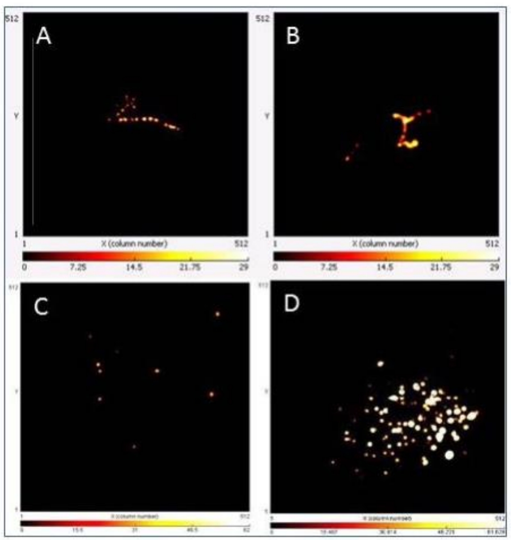
You are here: Home ▸ GEMPIX Detector

- Home

GEMPIX Detector



The other board, already designed for other purposes, called Quad-Medipix, consist of a socket for a ceramic board that houses a 2x2 matrix of Medipixes CMOS readout chip as shown in figure.



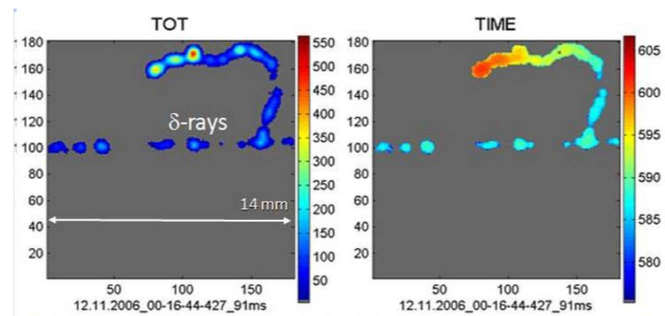
Some pictures taken for different particles (picture dimension 3x3 cm^2) :
A) Compton electron from Cesium 137 gamma
B) Compton electron from Cobalt 60 gamma
C) X-Rays from Iron 55
D) Alphas from Americium 241

Triple GEM

Quad Timepix ASIC

Triple GEM

Quad Timepix ASIC



https://web2.infn.it/GEMINI/index.php/gempix-detector

Micromachines **2014**, *5*, 594-606; doi:10.3390/mi5030594

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micromachines

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www.mdpi.com/journal/micromachines

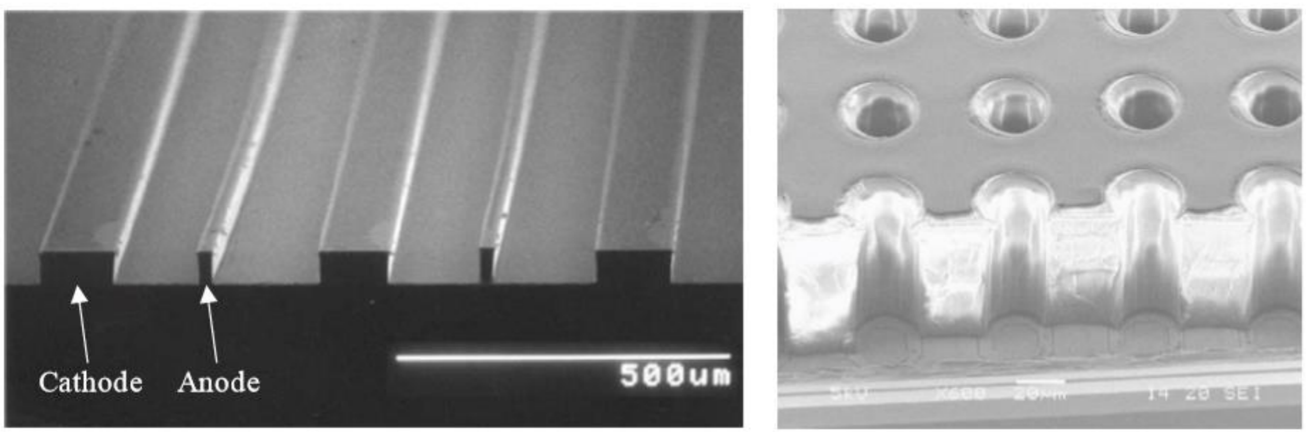
Review

SU-8 as a Material for Microfabricated Particle Physics Detectors

Pietro Maoddi [1,2,*], Alessandro Mapelli [1], Sebastien Jiguet [3] and Philippe Renaud [2]

Photosensitive epoxy SU-8

Figure 2. (**a**) Scanning electron microscope (SEM) image of basic non-planar microstrip gaseous detectors (MSGD) structure on a glass substrate, sectioned with a wafer saw. Alternated gold anode and cathode electrodes are patterned on top of 50 µm thick SU-8 strips. Adapted from [8], with permission. (**b**) SEM image of a microwell structure consisting in a 55 µm thick SU-8 layer defining the microwells, with an aluminium top cathode, patterned over a Timepix CMOS chip. Reprinted from [9], © 2004 Elsevier.



(**a**) (**b**)

Micromachines **2014**, *5*, 594-606; doi:10.3390/mi5030594

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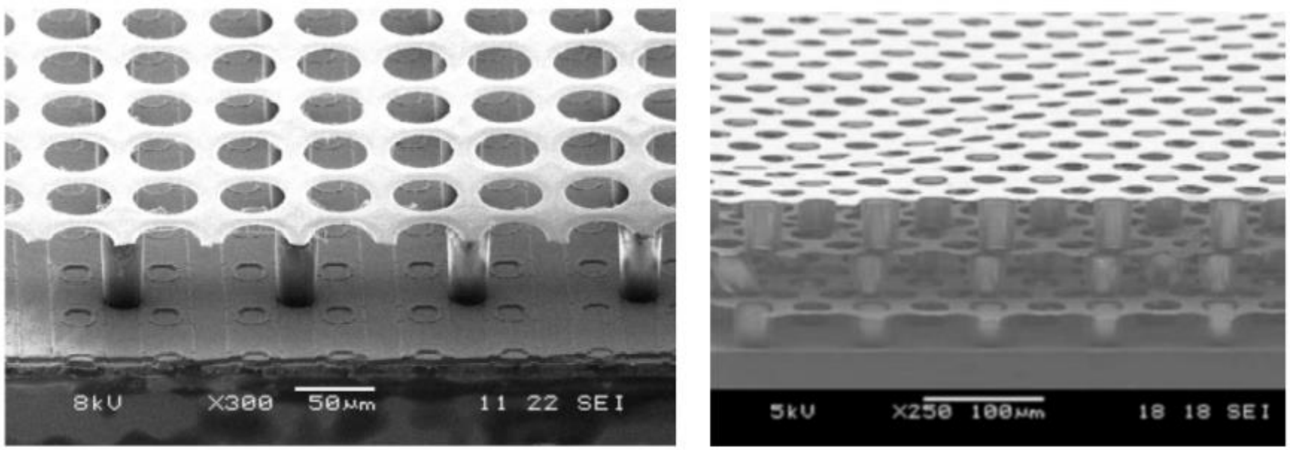
Review

SU-8 as a Material for Microfabricated Particle Physics Detectors

Pietro Maoddi [1,2,*], Alessandro Mapelli [1], Sebastien Jiguet [3] and Philippe Renaud [2]

Photosensitive epoxy SU-8

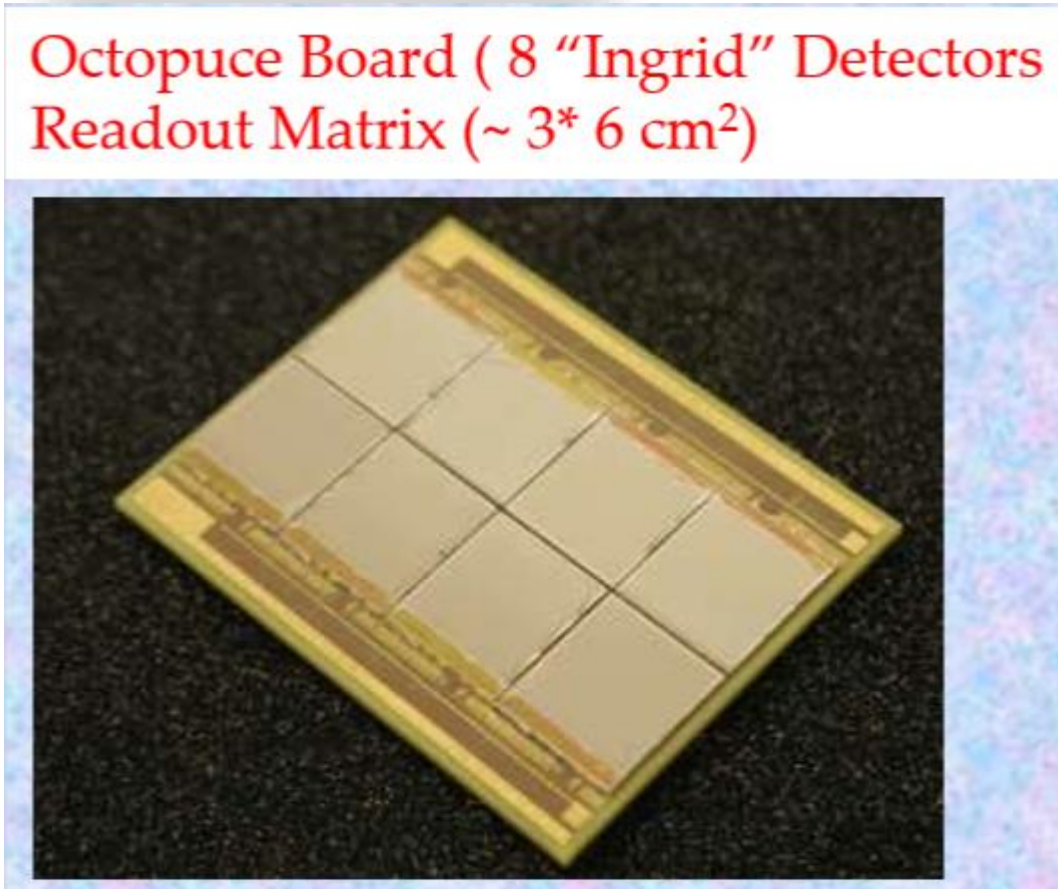
Figure 3. (**a**) SEM image of an aluminium micromesh grid suspended on top of SU-8 pillars structured in the middle of four pixels of a Medipix2 silicon pixel detector. Reprinted from [13], © 2008 IEEE. (**b**) SEM image of a triple grid structure. Reprinted from [12], © 2009 Elsevier.

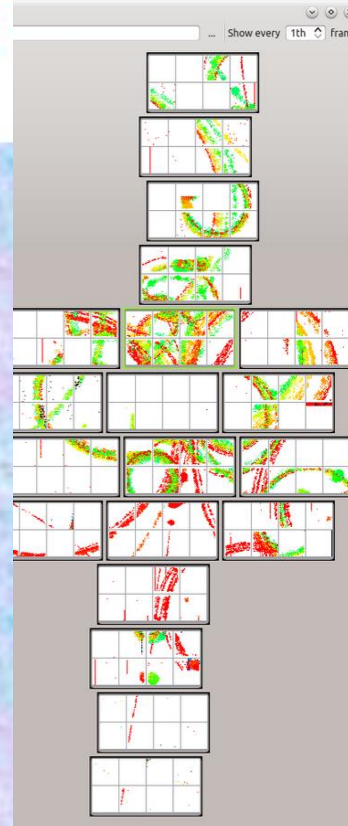


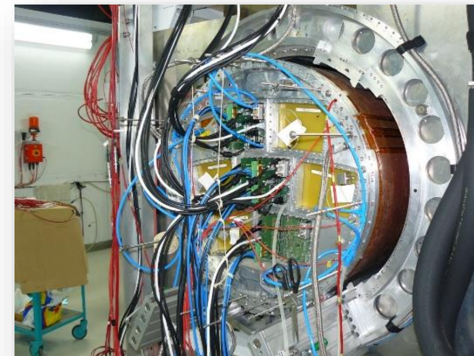
(**a**) (**b**)

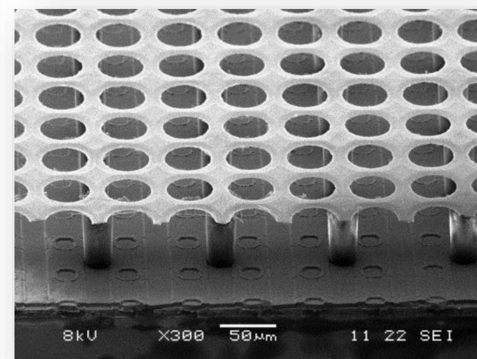
Octopuce Board

A Time Projection Chamber for a future Linear Collider









M. Lupberger, J. Kaminski, Bonn university

MPGD Technologies

MPT (micro pattern technology) workshop @ CERN

Antonio Teixeira

https://indico.cern.ch/event/352483/

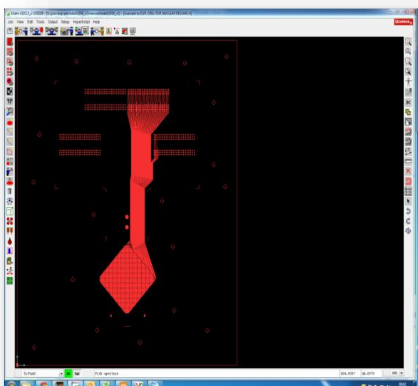
DT Training Seminars

Micro-Pattern Technologies (available at CERN)

by Antonio Teixeira (CERN)

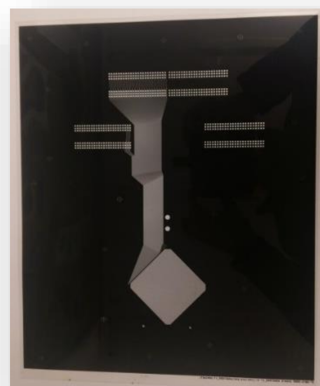
Thursday, 22 January 2015 from **11:00** to **12:00** (Europe/Zurich)
at CERN (32-1-A24)

Photolithography



Software UCAM

Photo Plotter



Film

Film Developer

Antonio Teixeira

https://indico.cern.ch/event/352483/

DT Training Seminars

Micro-Pattern Technologies (available at CERN)

by Antonio Teixeira (CERN)

Thursday, 22 January 2015 from **11:00** to **12:00** (Europe/Zurich)
at CERN (32-1-A24)

Lamination

Copper/Epoxy/Copper

Laminator (600mm max)

Solid photoresists
30 µm: standard
20 µm: Gem
15 µm: fine line

MPT Workshop @ CERN

Antonio Teixeira

https://indico.cern.ch/event/352483/

Development

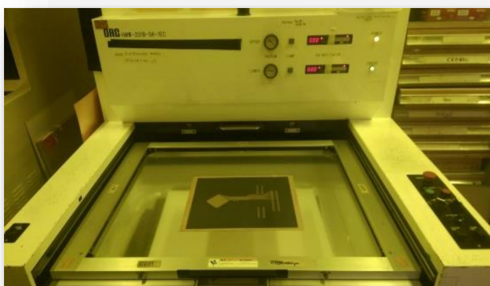
DT Training Seminars

Micro-Pattern Technologies (available at CERN)

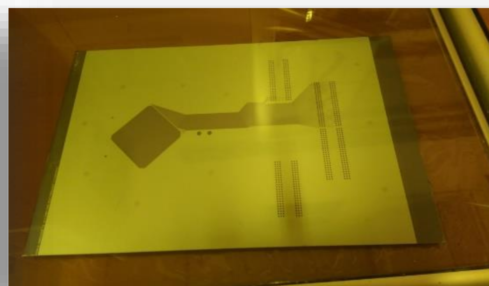
by Antonio Teixeira (CERN)

Thursday, 22 January 2015 from **11:00** to **12:00** (Europe/Zurich)
at CERN (32-1-A24)

UV exposure and development

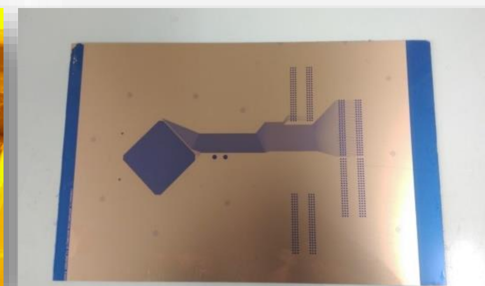


UV Exposure



After Exposure

UV development



After Development

MPT Workshop @ CERN

Antonio Teixeira

https://indico.cern.ch/event/352483/

DT Training Seminars

Development

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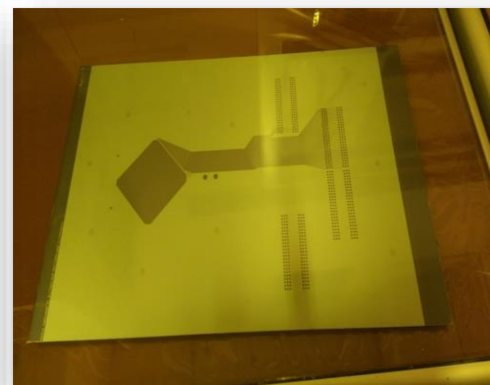
Laser Direct Imaging



Antonio Teixeira

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Development

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at CERN (32-1-A24)

Copper Etching

Before etching

Etching

After etching

After stripping

Antonio Teixeira

https://indico.cern.ch/event/352483/

Development

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Kapton Etching

Ethylene and soap Tank for large detectors

Ethylene Tank for Micro-bulks

Kapton Etching online

Antonio Teixeira

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DT Training Seminars

Micro-Pattern Technologies (available at CERN)

by Antonio Teixeira (CERN)

Thursday, 22 January 2015 from **11:00** to **12:00** (Europe/Zurich)
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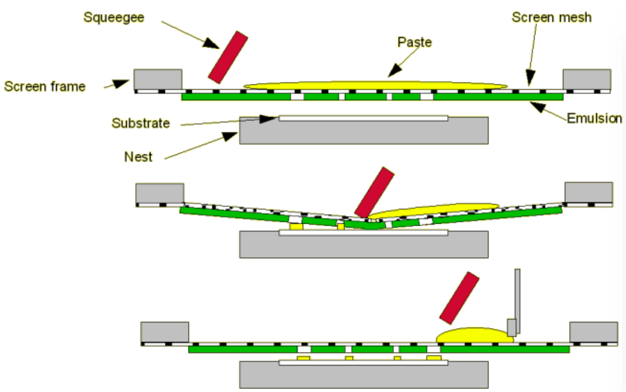
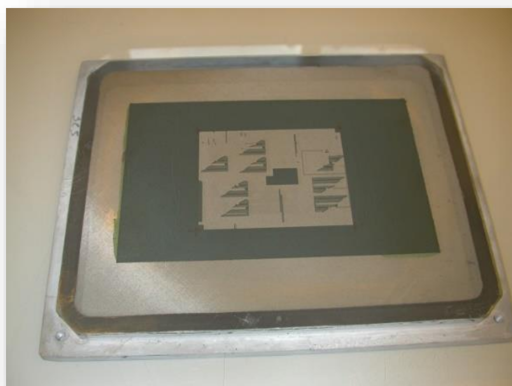
Screen Printing





Screen

Semi Automatic Screen Printer

Screen Printer (purchased)
Printing area 1.5m x 2m

Antonio Teixeira

https://indico.cern.ch/event/352483/

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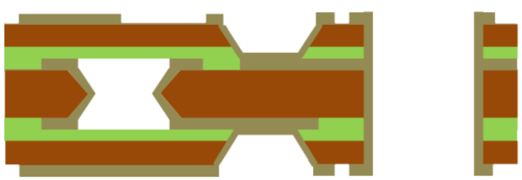
MCM-L Low Mass

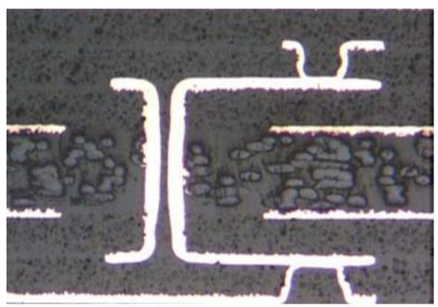
MCM-L – Multi-Chip Module - laminated MCM. The substrate is a multi-layer laminated PCB (Printed circuit board).

Mechanical Holes 200 µm
Chemical Vias 80 µm
Minimum Lines 50 µm

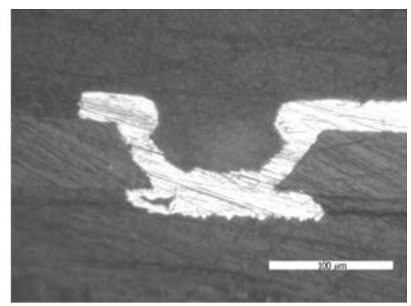
HDI High Density interconnection



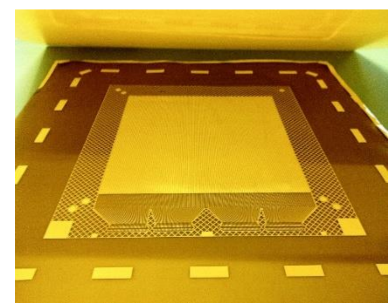
Multilayer 8 Layers
Kapton /Copper



Complete stack cross section



Micro Via Cross Section



Antonio Teixeira

https://indico.cern.ch/event/352483/

DT Training Seminars

Micro-Pattern Technologies (available at CERN)

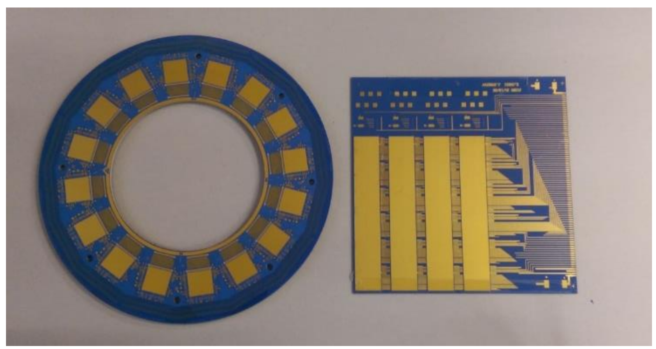
by Antonio Teixeira (CERN)

Thursday, 22 January 2015 from **11:00** to **12:00** (Europe/Zurich)
at CERN (32-1-A24)

MCM-C

MCM-C – ceramic substrate MCMs

Metal Layers: GOLD
Dielectrics : Glass
Via filled by GOLD
Paste Cured at 900 Degrees



Wire Bonding Sector
Pitch 100 µm
Lines 50 µm

Technology aspects in constructing the basic components of MPGDs

Rui de Oliveira

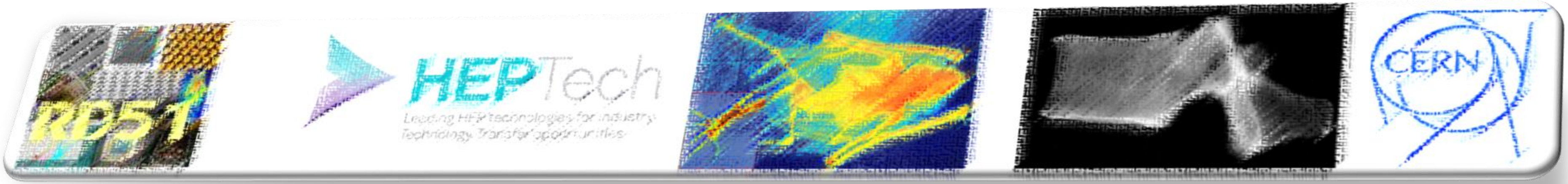
IV Seminario Nazionale Rivelatori Innovativi

10-14 November 2014 *INFN - LNS*

Conclusion

- Many techniques are existing to build MPGDs
  - Mechanical (1mm scale structures)
  - Chemical (100um scale structures)
  - Screen printing
  - Laser
  - Vacuum deposition
- Plasma and ink jet printing are good candidates to produce 3 D 10um to 1um scale structures in the future.
- Single board or foil detector are nearly ready

From Rui De Oliveira….
I guess we should trust his point of view



RD51

The **main objective** is to advance **MPGD technological development** and associated electronic-readout systems, for applications in basic and applied research".
http://rd51-public.web.cern.ch/rd51-public

- Large Scale R&D program to ***advance MPGD Technologies***
- Access to ***the MPGD "know- how"***
- Foster ***Industrial Production***

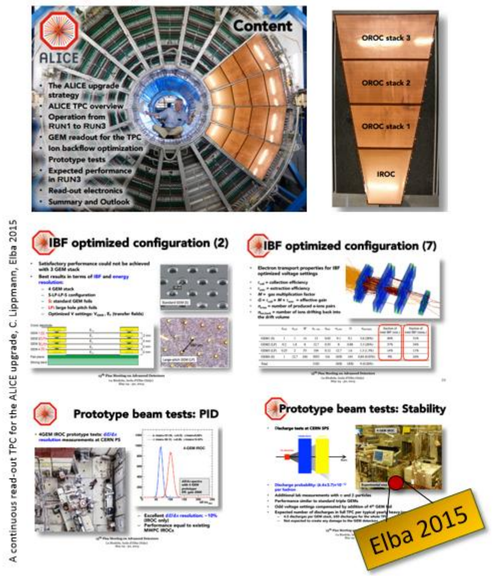
- More than 80 groups
- More than 400 people
- National and International Laboratories
- National Institutes and Universities


RD51 (well consolidated) Working Groups
Technological Aspects and Development of New Detector Structures
WG1:
Common Facilities : Test Beam and Laboratory
WG7:
Production, quality control, industrialization
RD51
WG2:
Common Characterization and Physics Issues
WG6:
WG4:
WG5:
MPGD Related Electronics
Academia-Industry Matching Events, Training, Education
WG3/NEW WG:
Simulations and Software Tools
GARFIELD & Co.
GOLIATH

WG1
Technological Aspects
and Development of
New Detector Structures

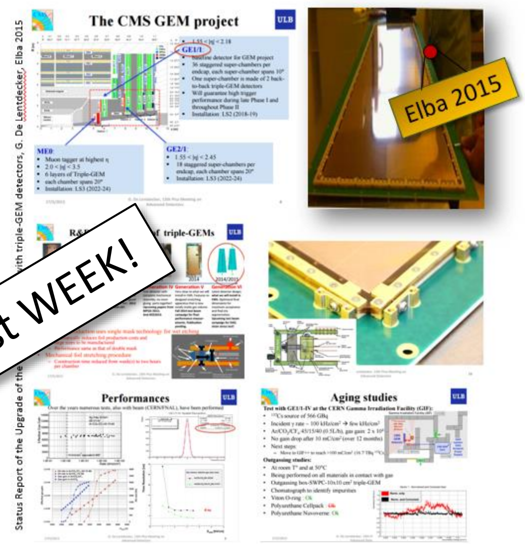
R&D support for
experiments and LHC
upgrades

ALICE (GEM)



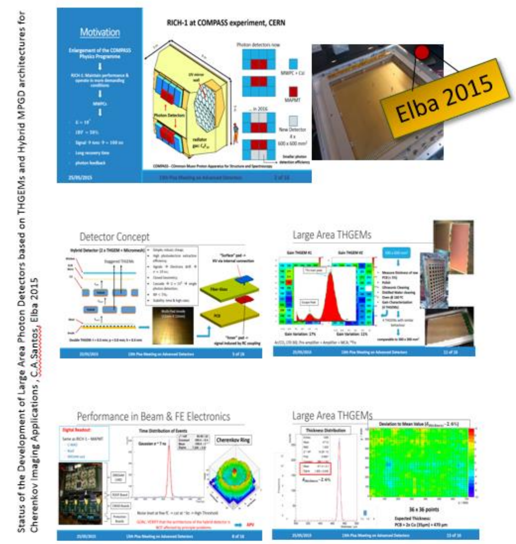
ATLAS NSW (mm)

CMS (GEM)



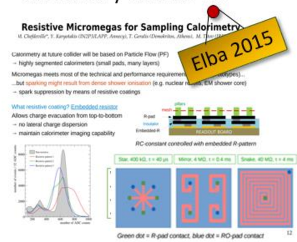
APPROVED Last WEEK!

COMPASS RICH-1 (THGEM+mm)



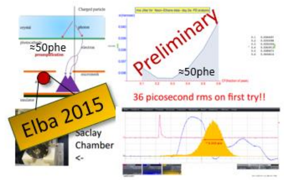
WG2
Common Characterization
and Physics Issues
Generic R&D
RD51 Common Projects

Calorimetry with MPGD

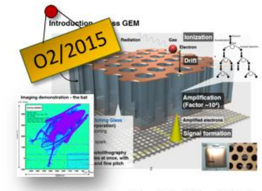


Fast Timing

MicroMegas based:
(initial tests March/April 2015)
Ne-Ethane(10%)-200 micron drift+50micron Micro Bulk



New Materials (Glass GEM)

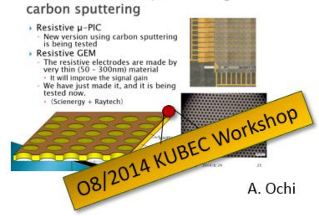


The Latest Results of Crystalized Glass GEM, Y. Mitsuia, RD51 miniweek (GDD/RD51 lab)

Resistive Material

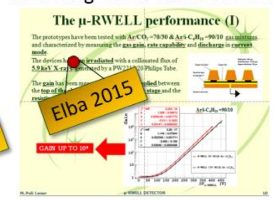
Other MPGD development using carbon sputtering

- Resistive μ-PIC
  - New version using carbon sputtering is being tested
- Resistive GEM
  - The resistive electrodes are made by very thin (50 – 300nm) material
  - It will improve the signal gain
  - We have just made it, and it is being tested now.
  - (Scienergy + Raytech)

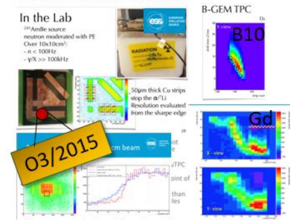


A. Ochi

New Large Area Thin Detectors



Neutrons Detection

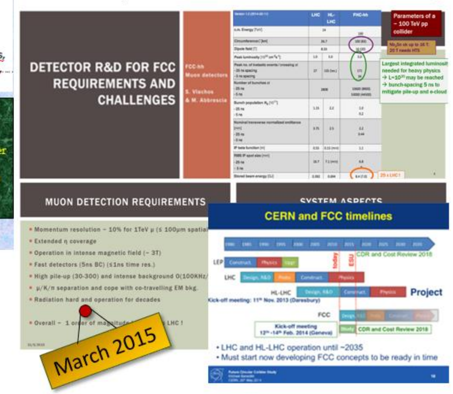


European Spallation Source (ESS)

..with "open eyes" to new requirements

RD51 invited at the *"Future Detector Technologies for FCC-hh"* workshop

..and FCC present in one of the RD51 meetings



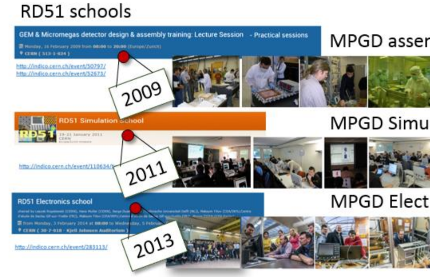
WG3
Applications - organization of series of specialized workshops disseminating MPGD applications beyond fundamental physics – RD51, potential users and industry

NWG
MPGD Education and Training : organization of schools for students and newcomers & academic training

Academia-Industry Matching Events (understanding requirements, applications, approaching new communities and technologies)

RD51 & International School

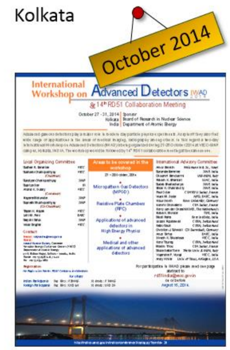
RD51 schools



XII ICFA School (Bogota, Colombia)

Danube School on Instrumentation in Elementary Particle & Nuclear Physics (Novi Sad Serbia)

RD51 MPGD Lectures:
MPGD students lectures (1 week) at the International Workshop on Advance Detectors & RD51 CM in Kolkata

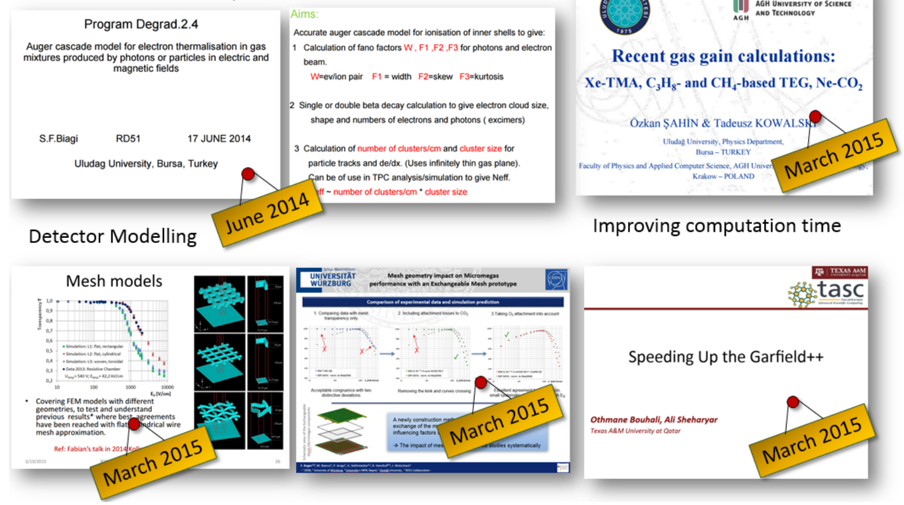


WG4
Detector physics
Development and
Maintenance of
Software & Simulation
Tools for the RD51
community.

Physics, Garfield & co… common developments …

Continuous implementation of the available tools and simulation capabilities

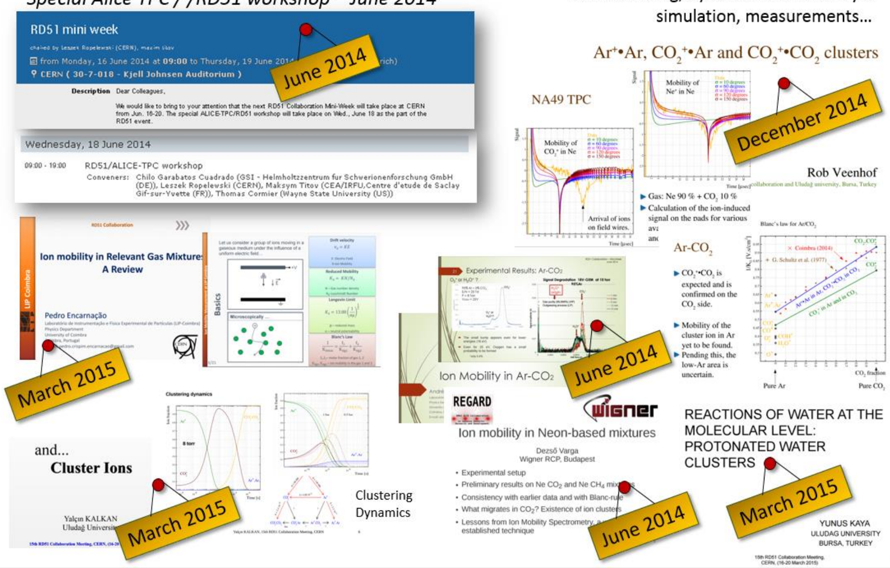
Simulation & data for the better understanding of the detectors physics



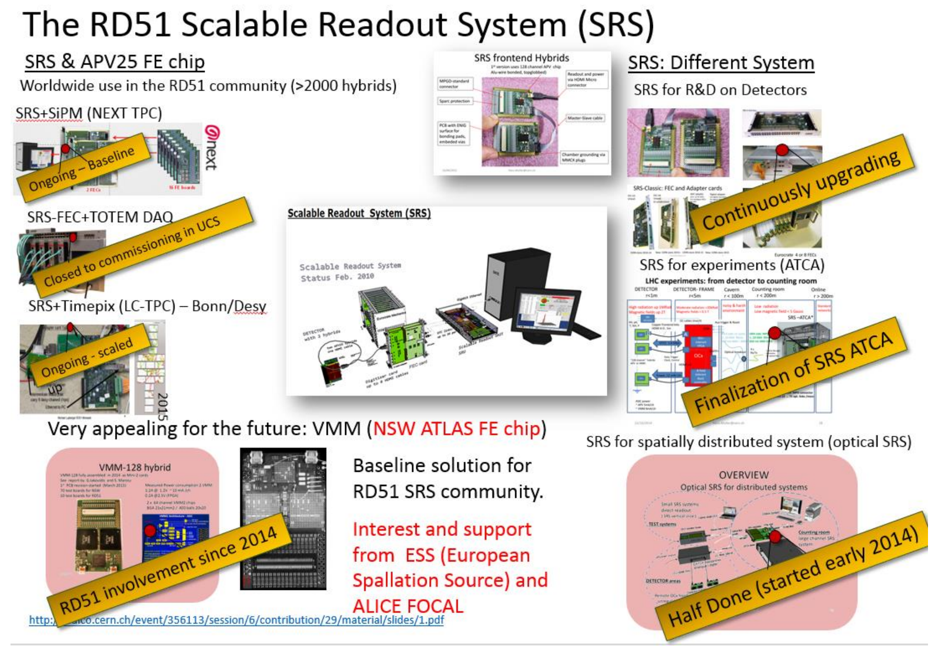
… strong efforts in very specific needs.. ALICE TPC

Special Alice TPC / /RD51 workshop – June 2014

Ions clustering, dynamics and mobility… simulation, measurements…



WG5
Development and Maintenance of the SRS Electronics; An extended support for the SRS including new developments and implementations of additional features



WG6
MPGD
Industrialization and QA Control - GEM, MicroMegas, Thick GEM; Completion of the industrialization of main technologies

Technology: MPGD Production @ CERN

Interesting Workshop Overview Capabilities

https://indico.cern.ch/event/352483/

MPGD Projects….

•SBS tracker	GEM 600mm x 500mm
•ALICE TPC upgrade	GEM 600mm x 400mm
•CMS muon	GEM 1.2m x 450mm
•ATLAS NSW muon	Micromegas 2m x 1m
•COMPASS pixel Micromegas	GEM & Micromegas 500mm x 500mm
•BESIII	GEM 600mm x 400mm
•KLOE	GEM 700mm x 400mm
•SOLID	GEM 1.1m x 400mm
•CLAS 12	Micromegas 500mm x 500mm
•LSBB (geoscience)	Micromegas 1m x 500mm
•Prad	GEM 1.5m x 55cm
•CBM	GEM 1m x 450mm
•ASACUSA	Micromegas

•Most of them are still at the R&D phase but some are already in production:

•ATLAS NSW	1300 m2
•SBS Tracker	100 GEMs
•ALICE TPC upgrade	350 GEMs
•COMPASS pixel Micromegas	20 GEM + Micromegas
•BESIII	15 GEM
•CLAS 12	30 Micromegas
•CMS	450 GEM

New Capabilities….

UV exposure unit limited to 2m x 0.6m → 2.2m x 1.4m (OK)
Resist developer limited to 0.6m width → 1.2m
Resist stripper "
Copper etcher (OK)
Dryer
GEM electro etch limited to 1m → 2m (OK)
GEM polyimide etch limited to 1m → 2m (OK)
Ovens limited to 1.5m x 0.6m → 2.2m x 1.4m (OK)
Laminator limited to 0.6m width → 1.2m (OK)

installation of the new infrastructure (to fabricate 2x1m² Bulk MM & 2x0.5m² GEM) COMPLETED

Construction of the new workshop's building:

Start : beginning 2012
End: end 2017

CERN Building 107
Basis of Design

Technology: Industrialization

Technology Industrialization → transfer "know-how" from CERN workshop to industrial partners

GEM Technology (contacts)
- Mecharonix (Korea, Seoul)
- Tech-ETCH (USA, Boston)
- Scienergy (Japan, Tokyo)
- TECHTRA (Poland, Wroclaw

THGEM Technology (contacts):
- ELTOS S.p.A. (Italy),
- PRINT ELECTRONICS

GEM Licenses signed by:
- Mecharonics, 21/05/2013
- TECH-Etch, 06/03/2013
- China IAE, 10/01/2012
- SciEnergy, 06/04/2009
- Techtra, 09/02/2009
- CDT, 25/08/2008
- PGE, 09/07/2007

MicroMegas Technology(contacts):
- ELTOS S.p.A. (Italy)
- TRIANGLE LABS(USA, Nevada)
- SOMACIS (Italy, Castelfidarco)
- ELVIA (France, CHOLET)

GEM Industrialization Status (today):

TECH-ETCH
• Single Mask process fully understood. Many 10cm x 10cm produced and characterized.
• 40cm x 40cm GEM successfully produced
• CMS GE1/1 size of 1m x 0.5m started

TECHTRA
• Production Line Operational
• Stable process for 10cm x 10cm
• Single Mask process completely understood – 10cm x 10cm produced
•30cm x30cm Single Mask Produced

MECHARONICS
• 10cm x 10cm double mask produced and tested
• 30cm x 30cm double mask under evaluation @ CERN
•CMS GE1/1 size of 1m x 0.5m started

Micromegas Industrialization Status (today):

ELVIA
• Bulk Micromegas detectors are routinely produced with sizes up to 50cm x 50 cm.
• Contract for ATLAS NSW module-0 signed
•Tendering process for full production ongoing

ELTOS
• Many small size bulk Micromegas detectors have been produced.
• Contract for ATLAS NSW module-0 signed
•Tendering process for full production ongoing

WG7
Maintenance and extension of the RD51 Lab and Test-Beam Infrastructure

PH-DT-DD GDD Laboratory … Laboratory available for the RD51 collaboration

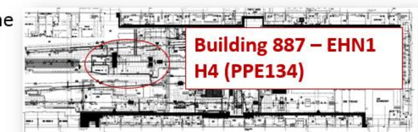
Permanent installations (Today): ALICE, ATLAS, ESS
CMS moved roughly two years ago to TIFF, access to the lab for specific measurements
More than 15/20 groups per year coming to perform measurements

Clean Rooms

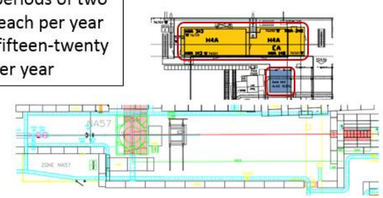
Mechanical and Electronic Workshop

Technical support
MPGD Detectors
Gas system and services
Readout electronics (std and custom
RD51 SRS&APV)
Radioactive Sources
Interface with CERN services (RP, gas,
metrology, irradiation facilities,…)

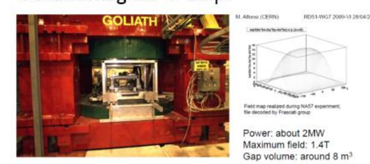
Semi permanent test beam in the SPS extraction Line



Three periods of two weeks each per year
About fifteen-twenty users per year

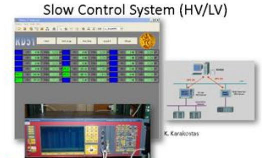


Goliath Magnet → Ship?



Rd51 trackers

Slow Control System (HV/LV)



A warm and special thanks to the SPS, the North Area Facility and to all the people that supports our installations

2014 test Beam

CMS (GEM) WIS/A/C(WELL, THGEM) ATLAS NSW (mm) BESS III & SHIP (GEM) LAPP/DEM/IRFU(mm) ALICE TPC (GEM and mm)

2015 test Beam: May-June **(now)**, July, October

IWAD conference & RD51CM

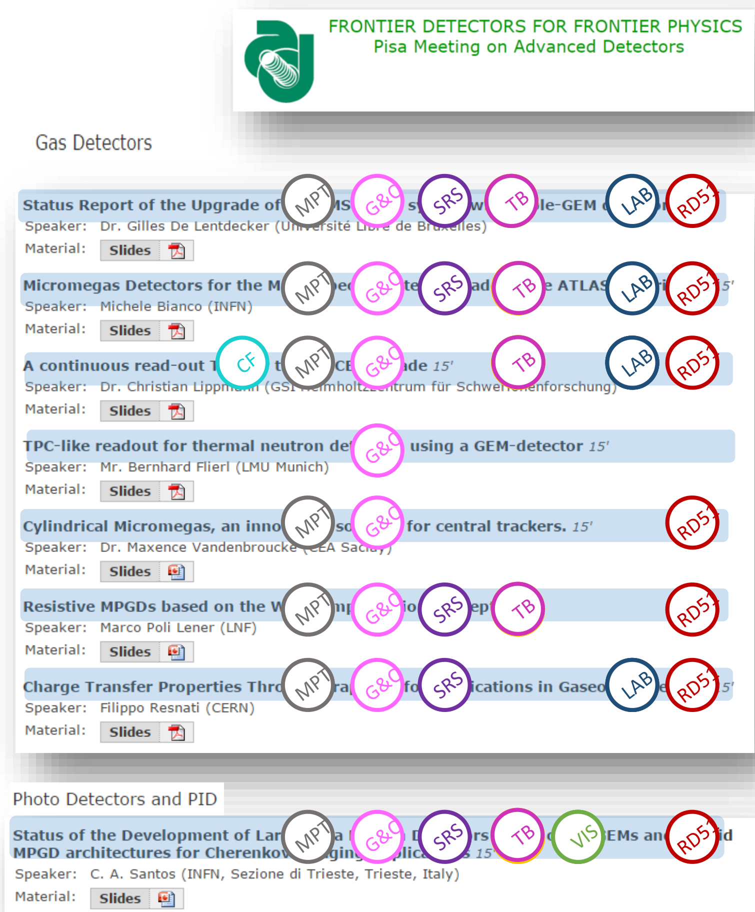
MPGD conferences & RD51CM

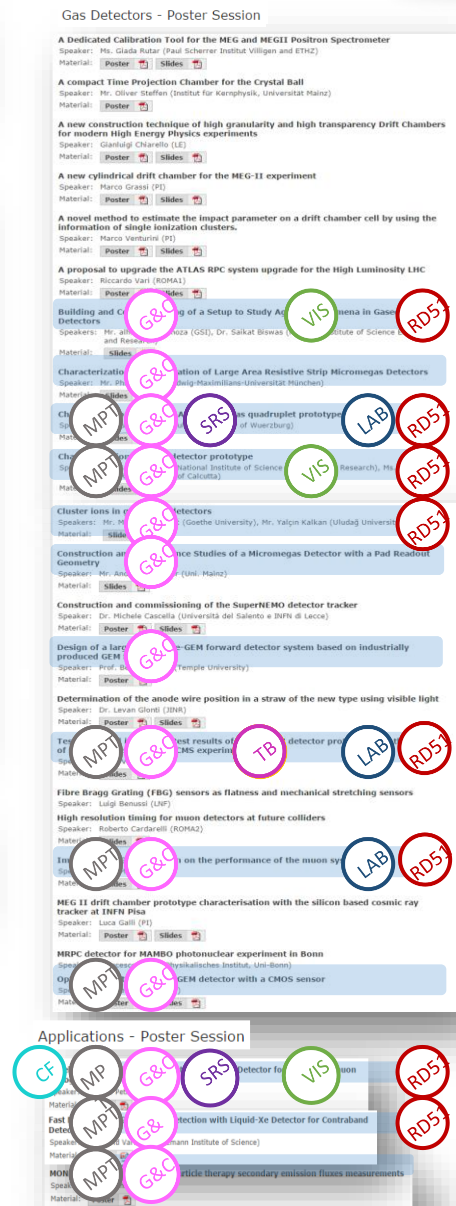
2009

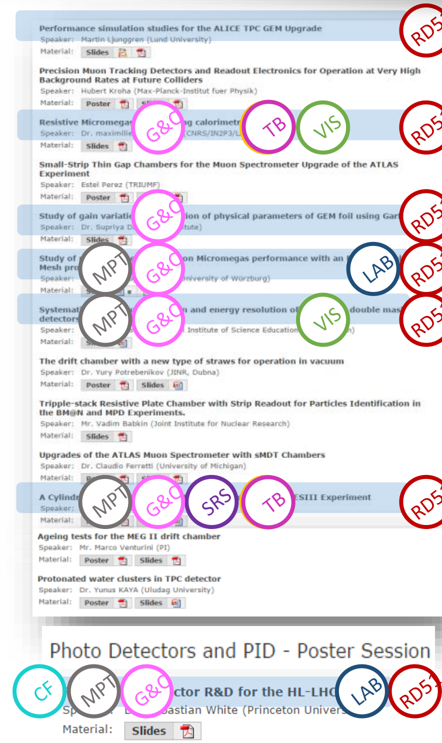
2011

2013

RD51 and the MPGD community







RD51 = project is in the list of RD51 member

LAB = as a project they have/had permanent installation in the RD51 lab

VIS = has used the RD51 lab for specific measurements

TB = has used the RD51 test beam facility

SRS = has used the RD51 Scalable Readout System (SRS)

G&G = has used simulation tool for MPGD (Garfield etc.)

MPT = MPGD from the MPT workshop

CF = RD51 Common Fund Projects

From 2009… maybe an interesting discussion for the workshop…

M. Chefdeville
4th RD51 collaboration meeting
Nov. 2009, CERN

SUMMARY OF WG2 SESSION

Conclusions

- Fabrication setup complicated and expensive
  - *e.g. setup in Weizmann Institute*
- Experience of several groups show that gaseous PMs based on MPGDs and sensitive to visible light can be done, although it is not an easy task
- Development PMs based on MPGD could be an excellent RD51 scientific and technological project
- A. Braem Lab has all know-how and all necessary equipment, so CERN could be the best place to implement this project
- What is needed to implement this project: some more funds and a few enthusiasts ready to work full time on this project

Outline

- Review on gaseous photo-multipliers

Conclusion

- Micro Pattern Gas Detector: a versatile technology… different option for different requirements… VERY IMPORTANT TO move to different APPLICATIONS
- The technology offer already well consolidated solutions…
- Resistive protection is strongly entering in the field…
- New materials can enlarge the “field of use”
- MPGD and CMOS pixel… the future MPGDs for future experiments…
- New processing techniques (plasma etching, ink jet printing) can open the scenario to new structures (or smaller)
- RD51 is present and it is an important support to all the previous items… because most of the MPGD developers are active members of RD51

Backup