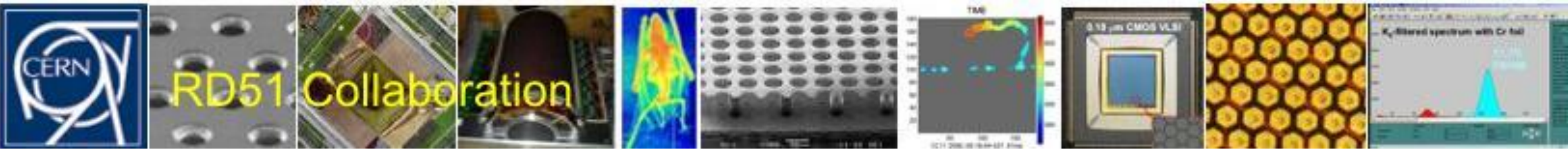
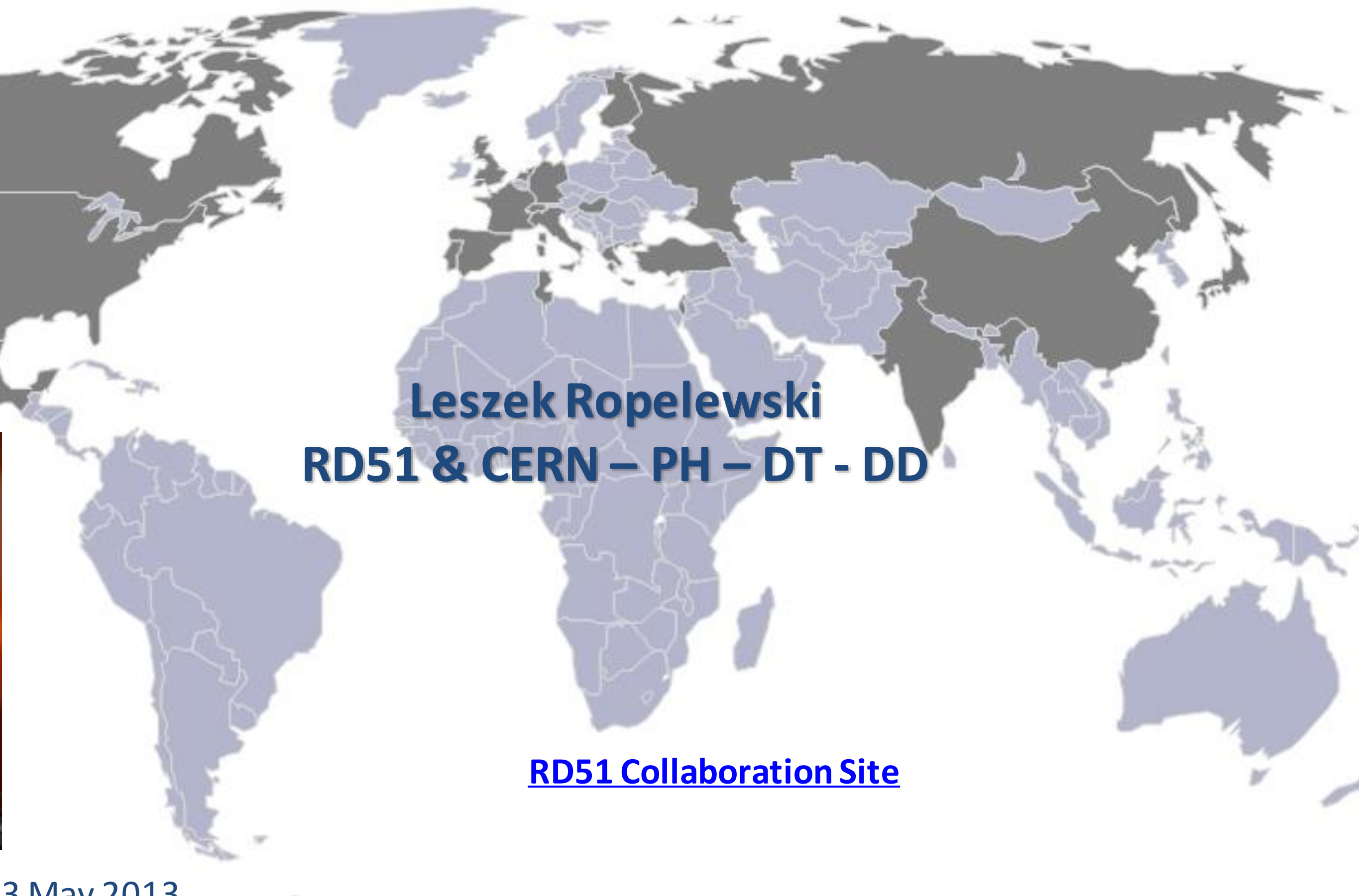


Introduction to the Micropattern Gaseous Detectors

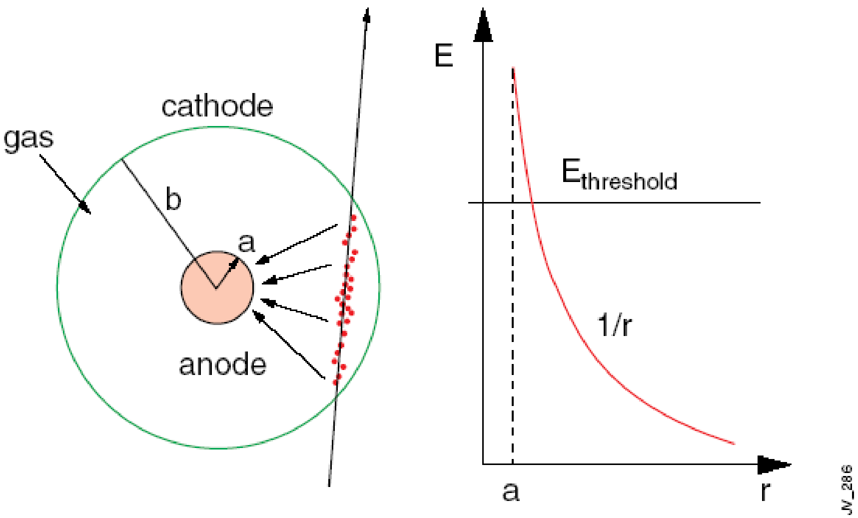


Leszek Ropelewski
RD51 & CERN – PH – DT - DD

[RD51 Collaboration Site]

CSEM-CERN meeting, 23 May 2013

Field Configurations



Electrons liberated by ionization drift towards the anode wire.

Electrical field close to the wire (typical wire Ø ~few tens of μm) is sufficiently high for electrons (above 10 kV/cm) to gain enough energy to ionize further → avalanche – exponential increase of number of electron ion pairs.

anode

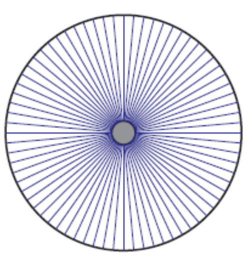
e^-
primary electron

$$E(r) = \frac{CV_0}{2\pi\varepsilon_0} \cdot \frac{1}{r}$$

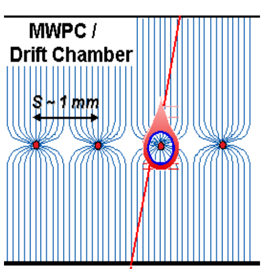
$$V(r) = \frac{CV_0}{2\pi\varepsilon_0} \cdot \ln\frac{r}{a}$$

C – capacitance/unit length

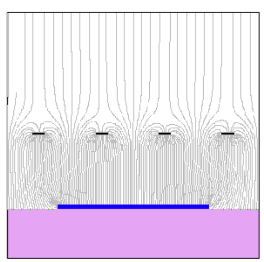
Cylindrical geometry is not the only one able to generate strong electric field:



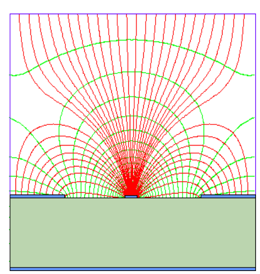
wire



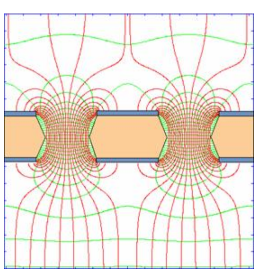
mwpc



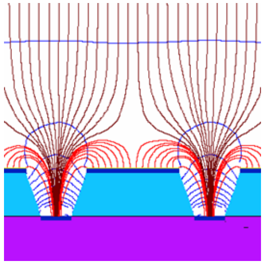
parallel plate



strip



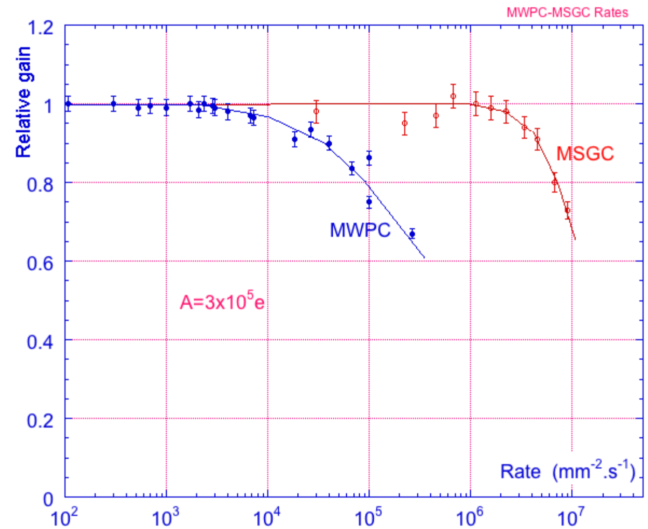
hole

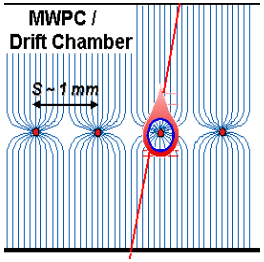


groove/well

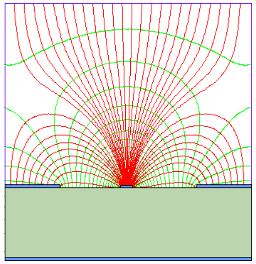
Current Trends in Micro-Pattern Gas Detectors (Technologies)

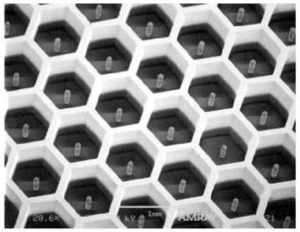
Semiconductor Industry technology:
- Photolithography
- Etching
- Coating
- Doping
- Wafer postprocessing

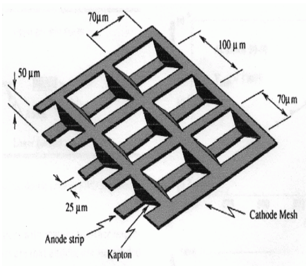




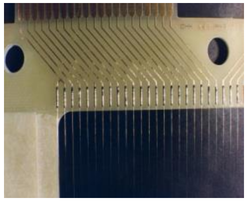
Amplifying cell size reduction by factor of 10



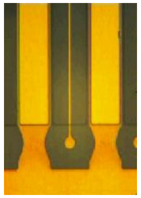




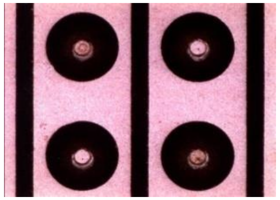
Operational instabilities:

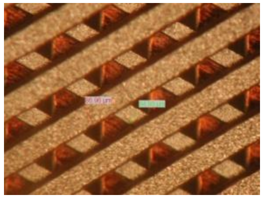


Rate Capability>10^6/mm^2
Position Resolution ~40µm
2-track Resolution ~400µm



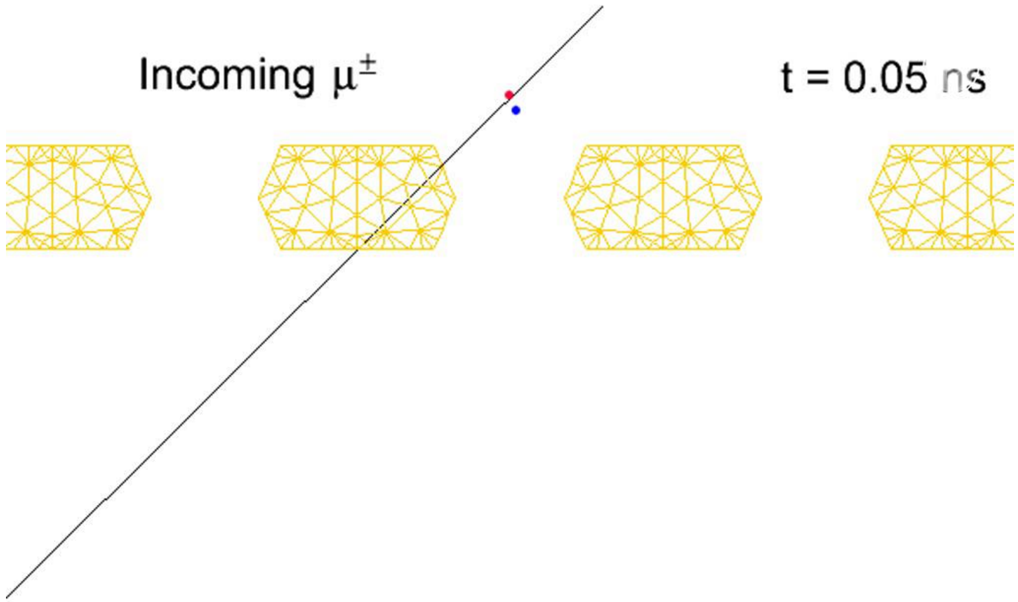
Substrate charging-up
Discharges
Polymer deposition (ageing)





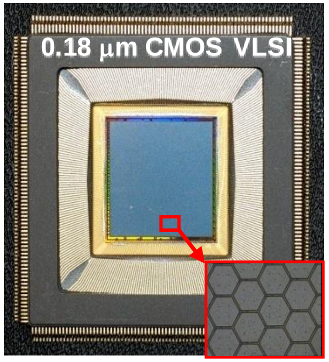
MWPC

MSGC

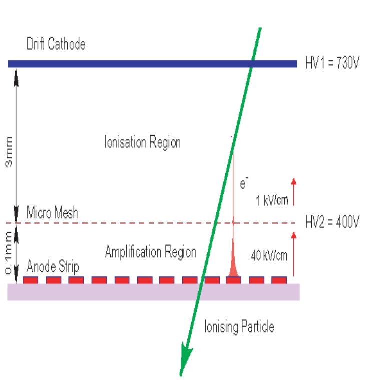

Incoming $\mu^{\pm}$
t = 0.05 ns

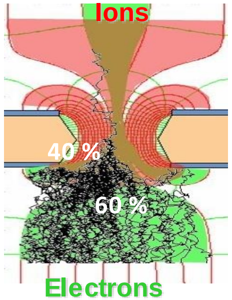
Current Trends in Micro-Pattern Gas Detectors (Technologies)

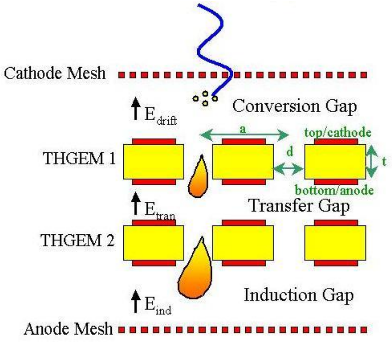
- MSGC
- Micromegas
- GEM
- Thick-GEM, Hole-Type Detectors and RETGEM
- MPDG with CMOS pixel ASICs
- Ingrid Technology

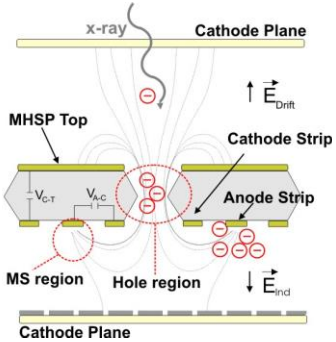


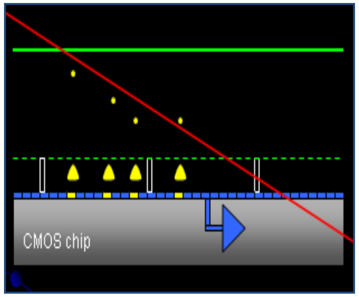
CMOS high density readout electronics

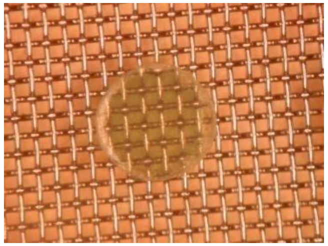




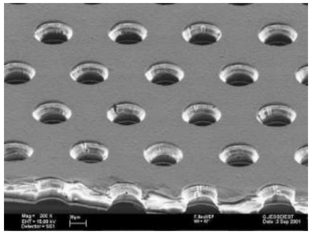




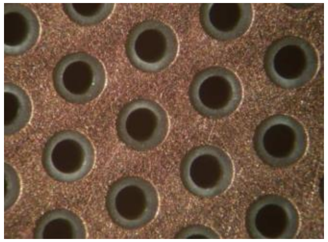




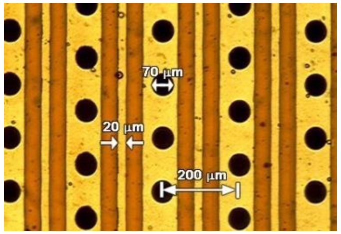
Micromegas



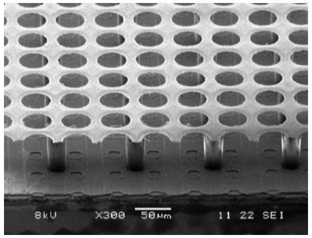
GEM



THGEM



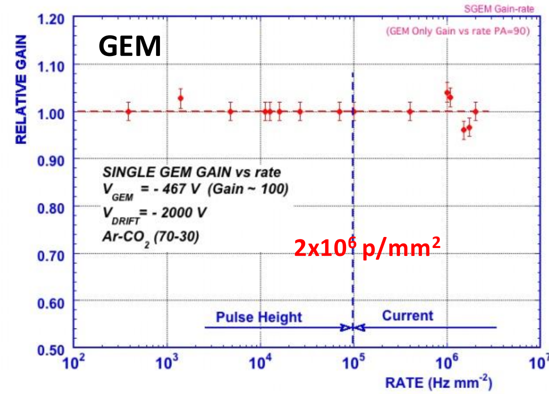
MHSP

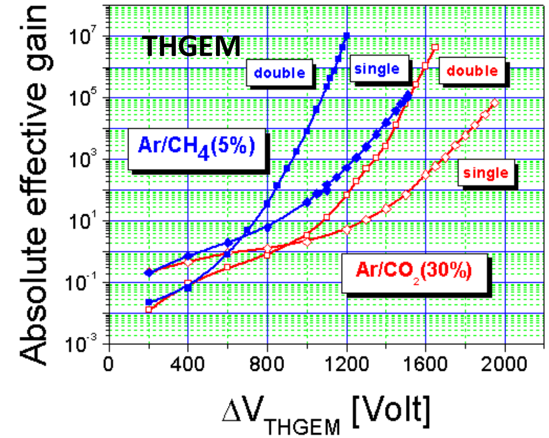


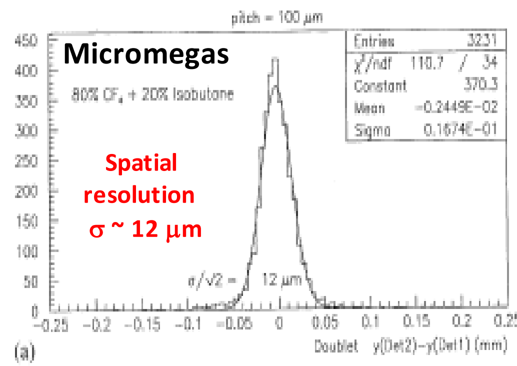
Ingrid

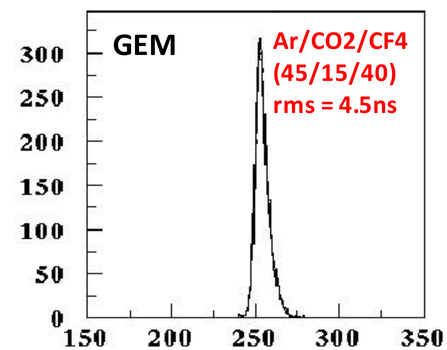
Micro-Pattern Gas Detectors Performance Summary

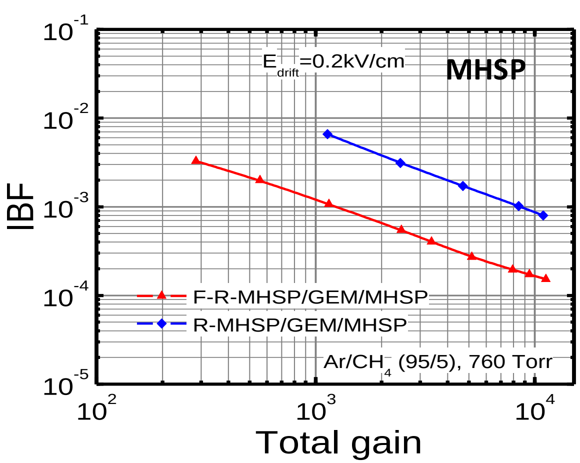
- Rate Capability
- High Gain
- Space Resolution
- Time Resolution
- Energy Resolution
- Ageing Properties
- Ion Backflow Reduction
- Photon Feedback Reduction

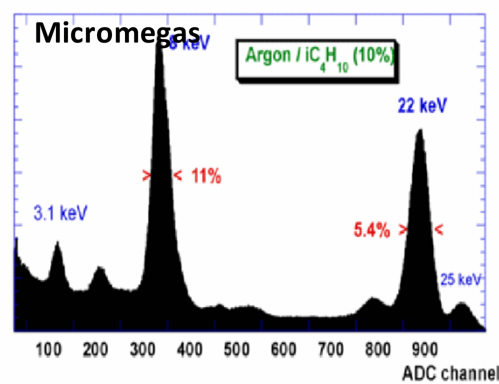


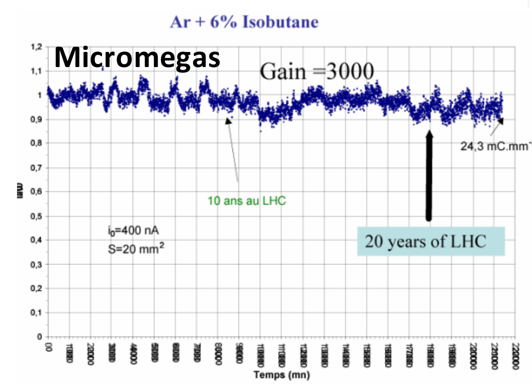




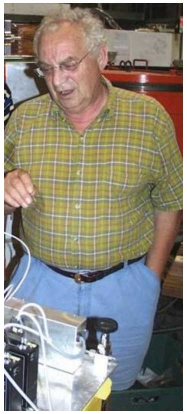




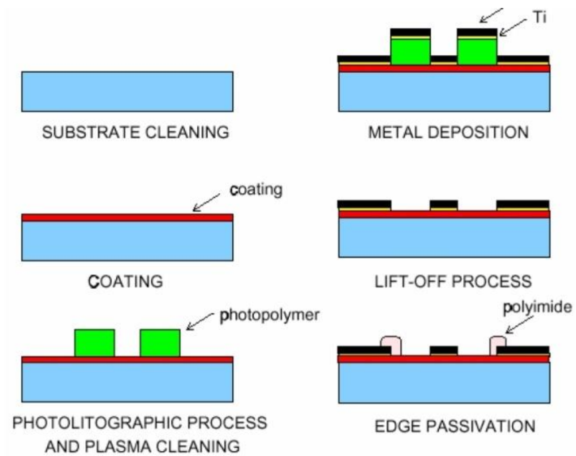




MSGC – MicroStrip Gas Chamber



Anton Oed

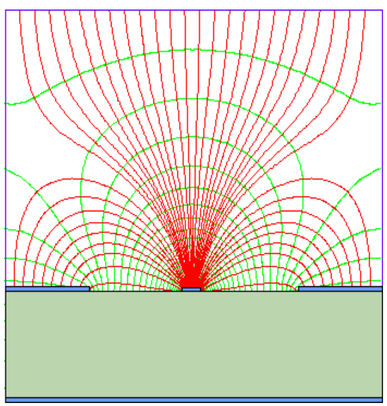


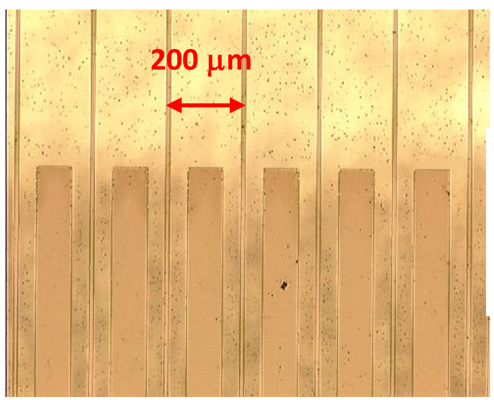
Thin metal anodes and cathodes on insulating support (glass, flexible polyimide ..)

Problems:

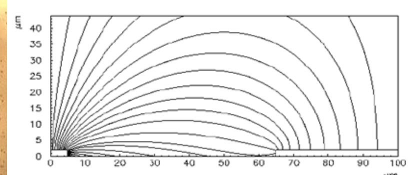
High discharge probability under exposure to highly ionizing particles caused by the regions of very high E field on the border between conductor and insulator.

Charging up of the insulator and modification of the E field → time evolution of the gain.

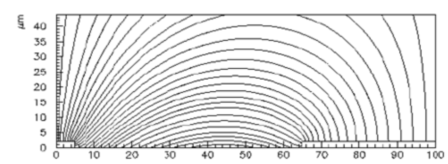




insulating support



slightly conductive support



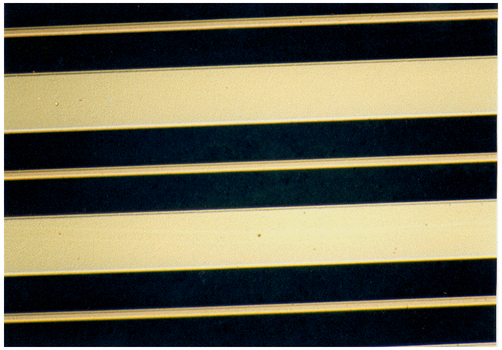
R. Bellazzini et al.

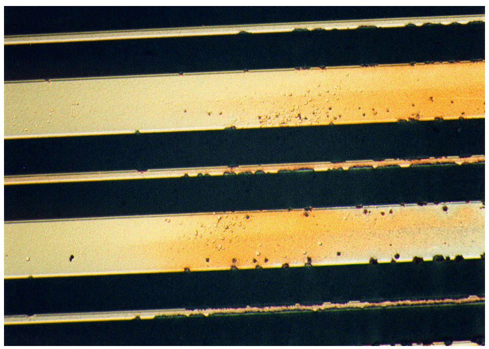
Solutions:

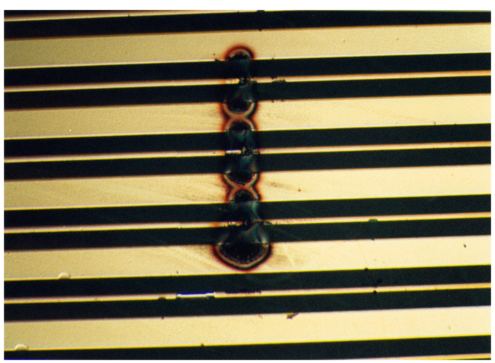
slightly conductive support

multistage amplification

MSGC – MicroStrip Gas Chamber







Surface charging

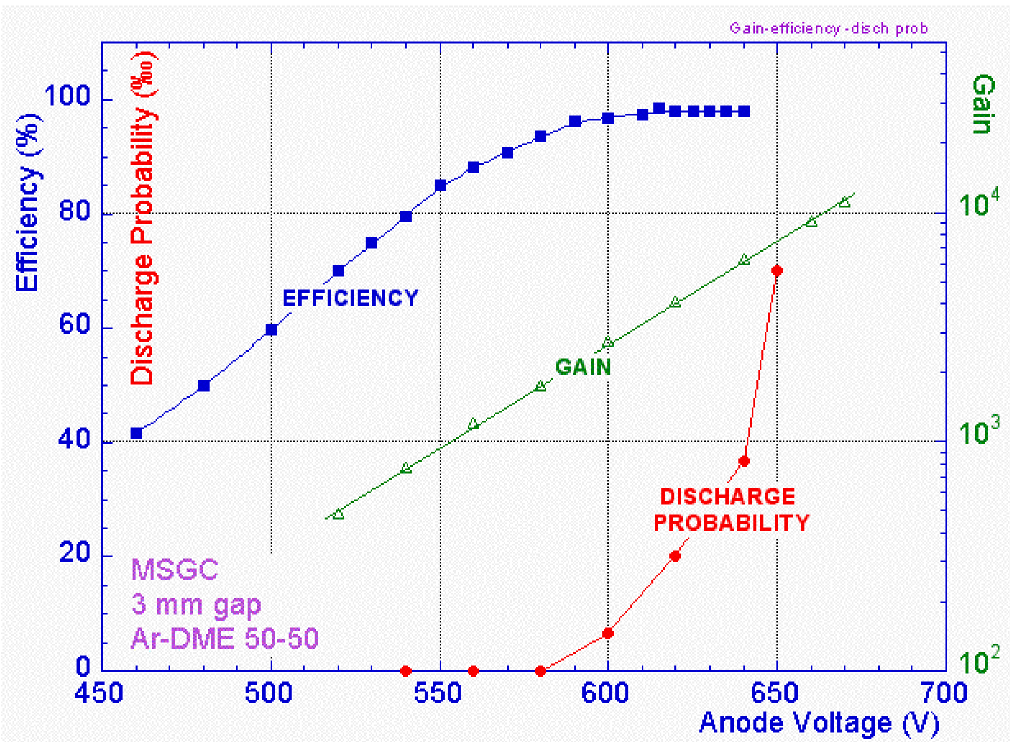
Bulk resistivity of the support material

Surface modification by doping or deposition

Ageing

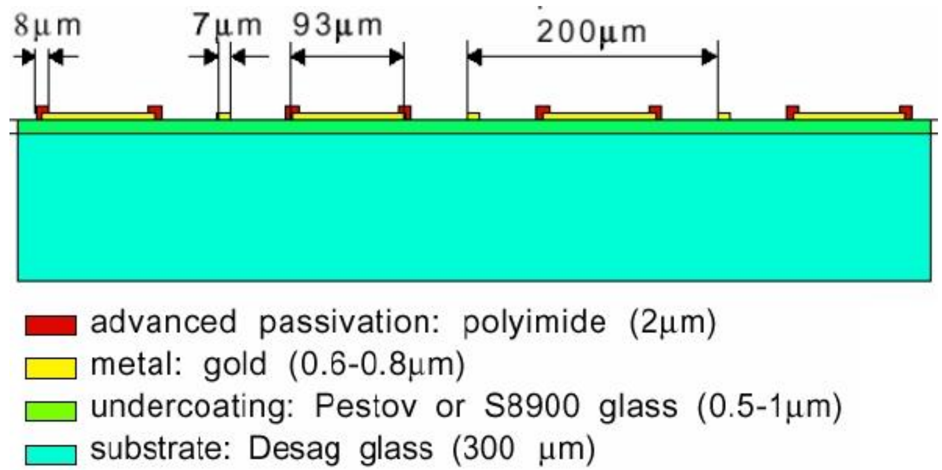
Gas, Gas system, MSGC support, Construction material

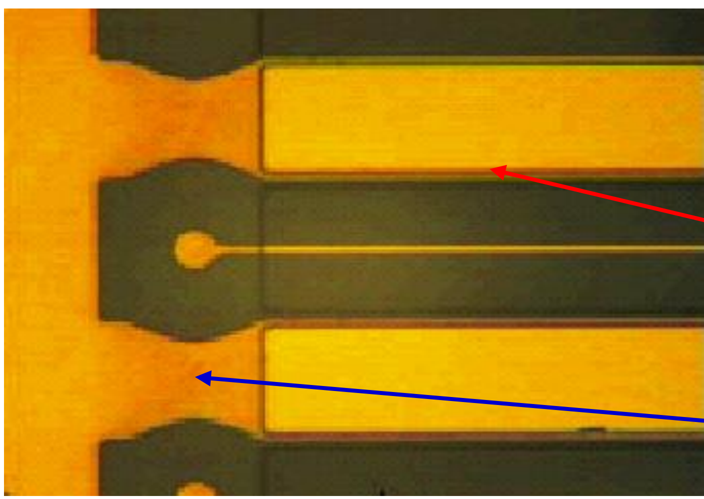
Discharges



MSGC – MicroStrip Gas Chamber

Cathode edge passivation



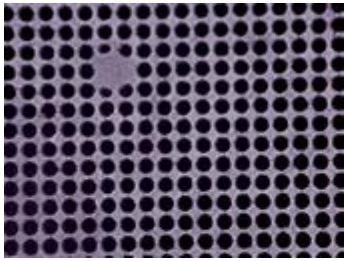


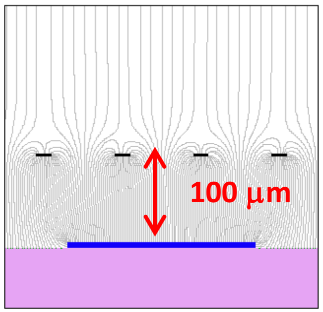
Advanced passivation

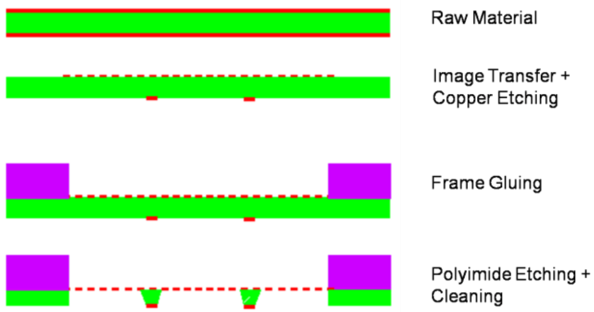
Standard passivation

Bellazzini et al.

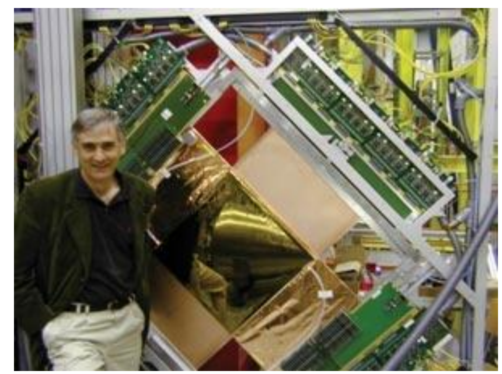
Micromegas – Micromesh Gaseous Structure



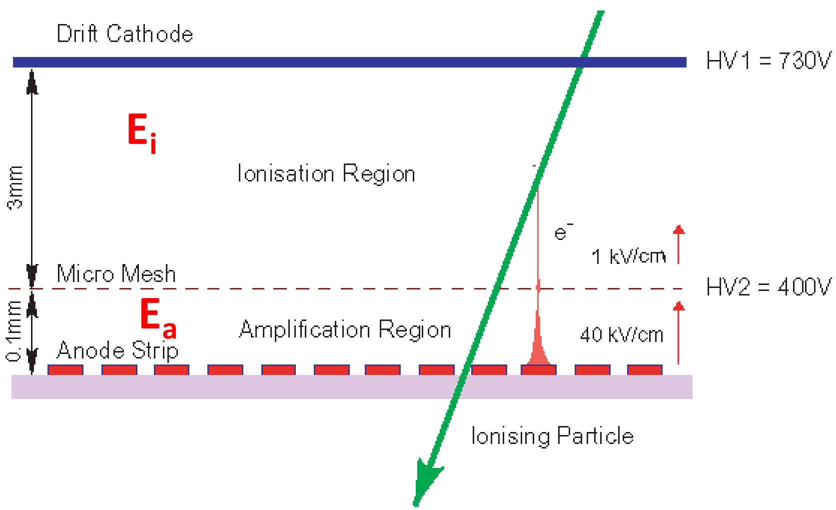




Micromesh mounted above readout structure (typically strips).
E field similar to parallel plate detector.
E_a/E_i ~ 50 to secure electron transparency and positive ion flow back suppression.



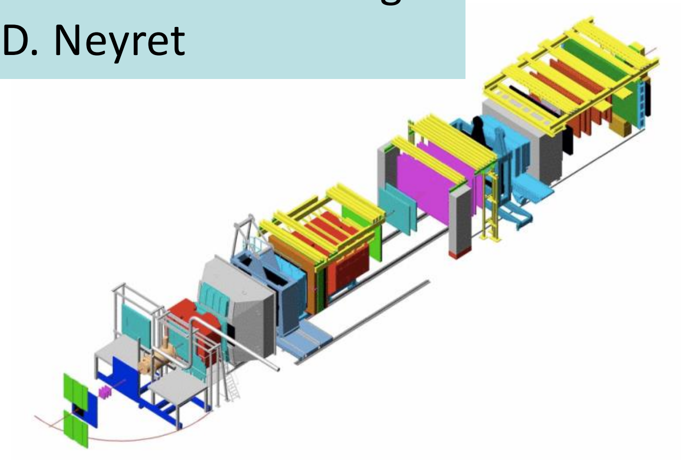
Ioannis Giomataris

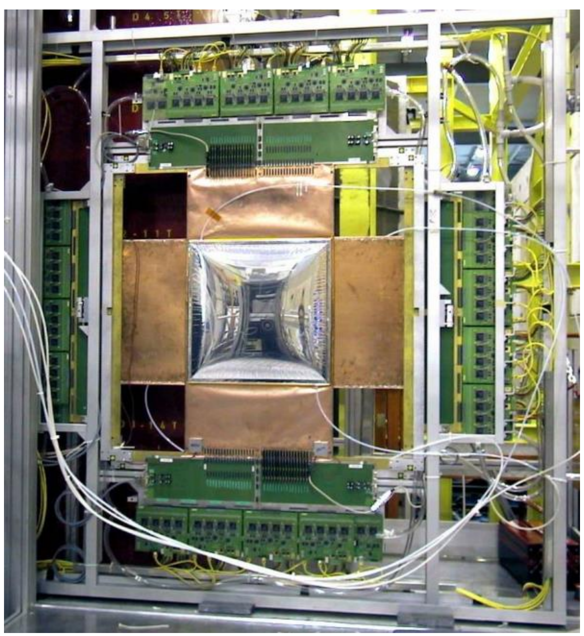


Y.Giomataris et al, NIM A 376 (1996) 29

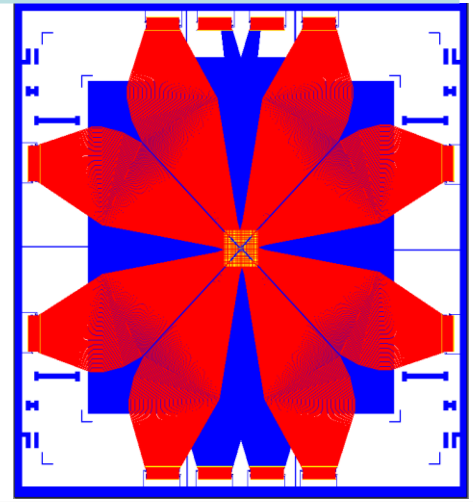
Micromegas – Micromesh Gaseous Structure

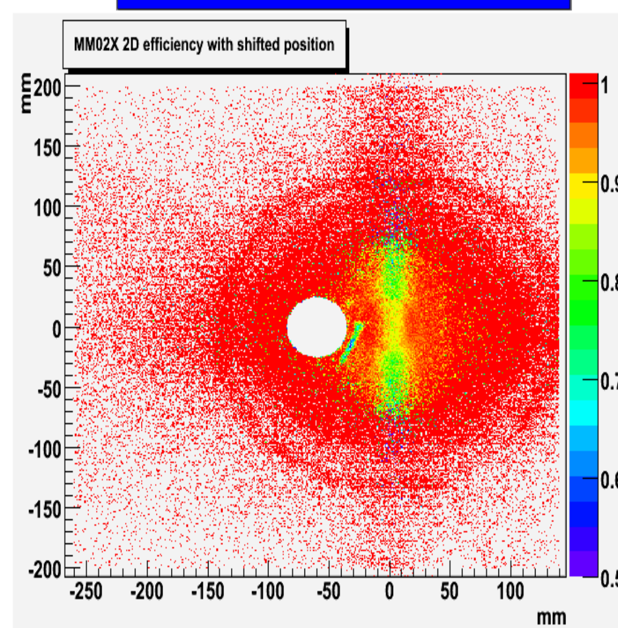
COMPASS Micromegas
D. Neyret





Pixelized Micromegas
D. Neyret

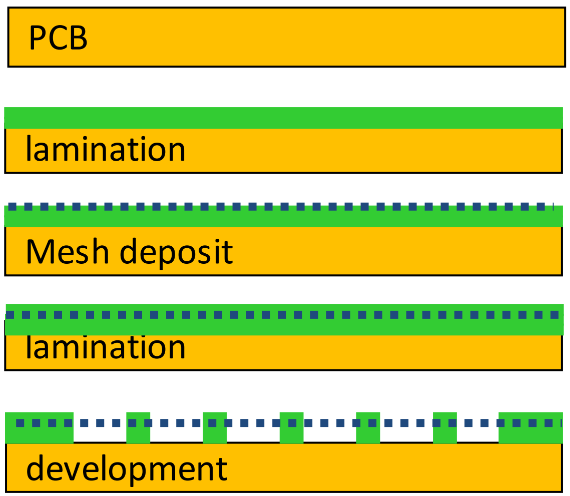


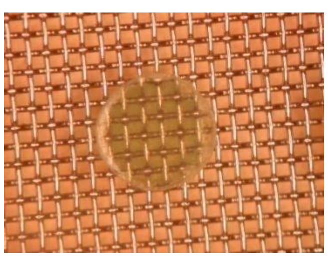


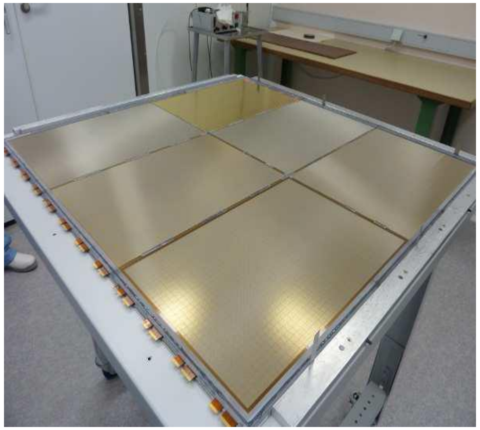
Bulk MicroMegas technology

Y. Giomataris
R. de Oliveira

M. Chefdeville





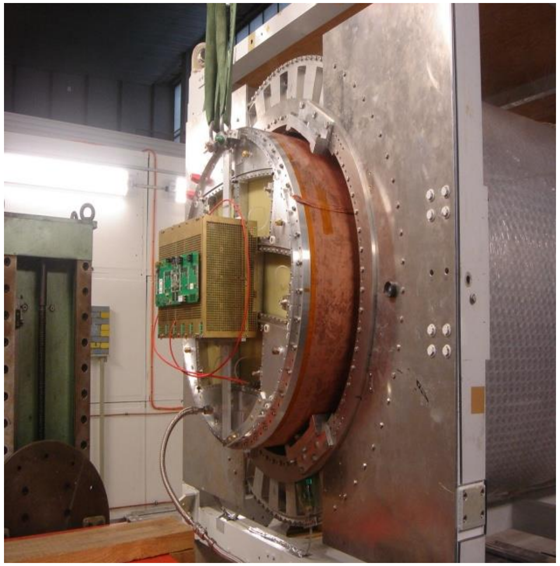


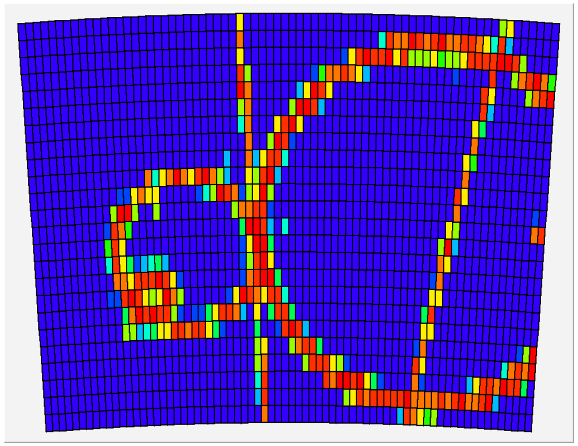
- Fine segmentation 1cm^2, thickness 8mm for ILC Hadronic calorimetry
- Tested in the RD51 1 kHz beam

Bulk Micromegas ILC DHCAL first m^2
LAPP Annecy

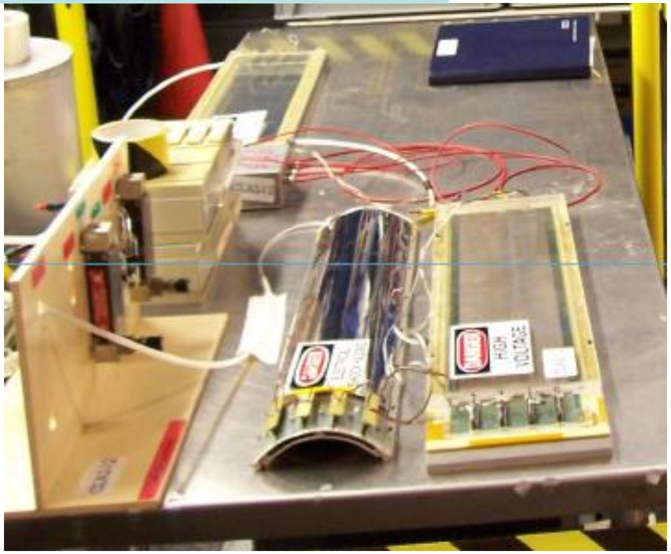
Micromegas – Micromesh Gaseous Structure

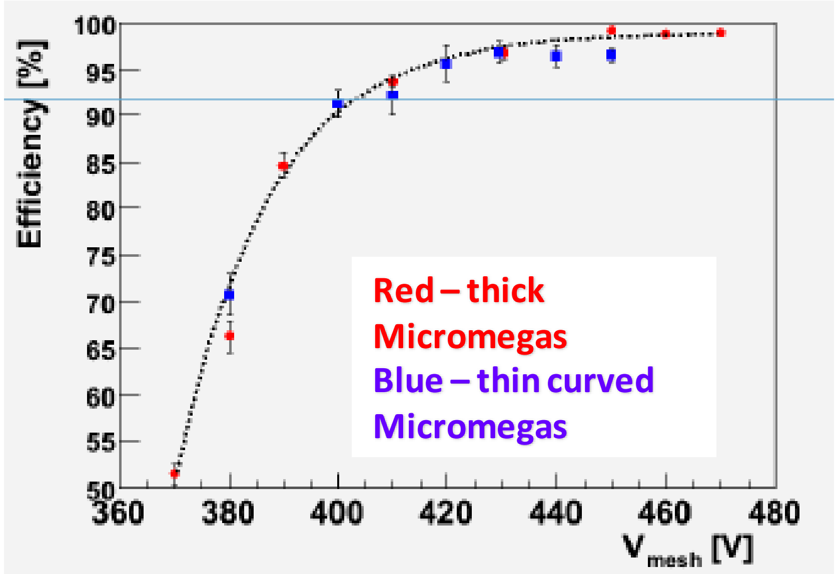
Micromegas ILC-TPC,
D. Attie



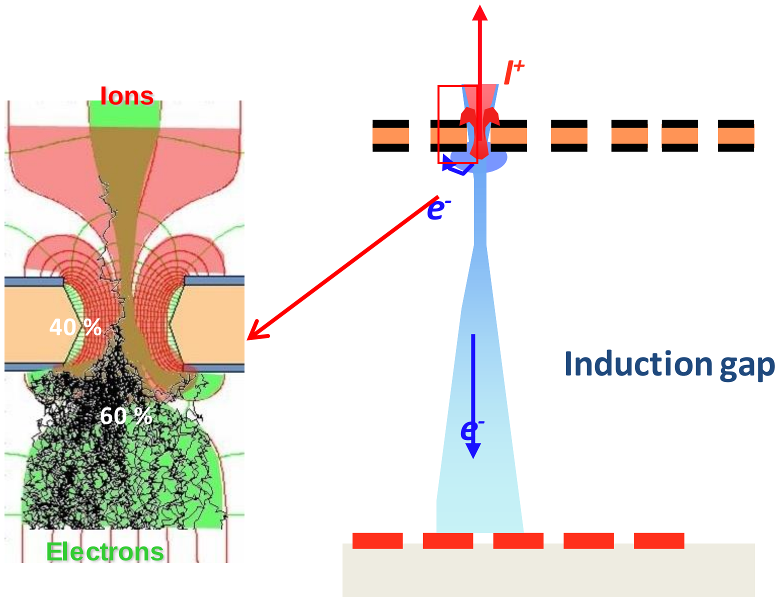


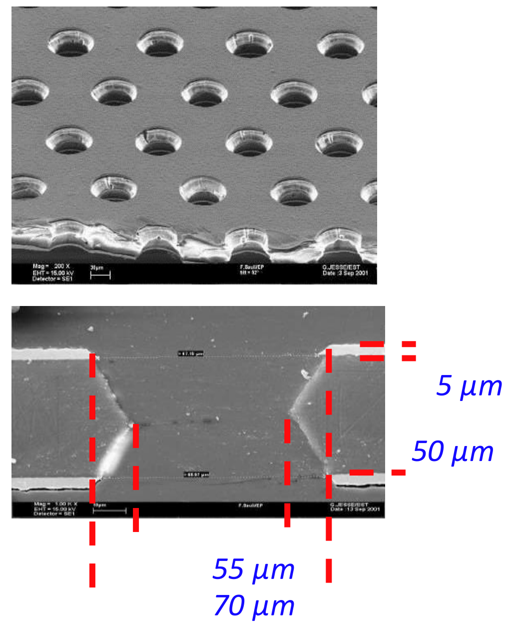
Curved Micromegas CAS12,
S. Aune

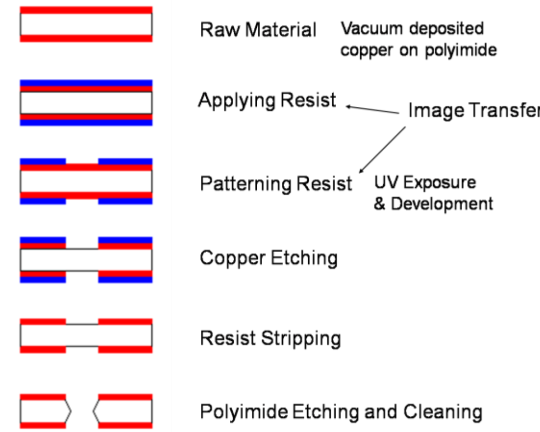


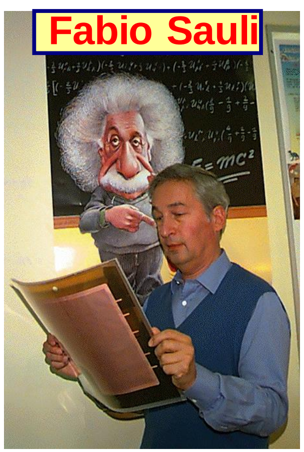


GEM – Gas Electron Multiplier





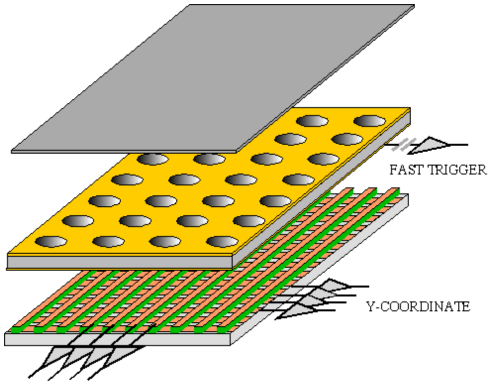




Thin, metal coated polyimide foil perforated with high density holes.

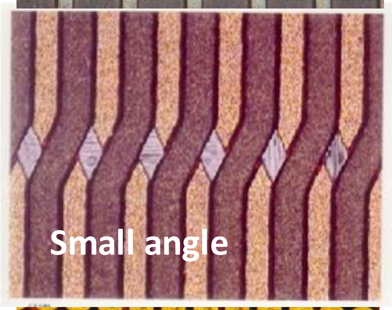
Electrons are collected on patterned readout board.
A fast signal can be detected on the lower GEM electrode for triggering or energy discrimination.
All readout electrodes are at ground potential.
Positive ions partially collected on the GEM electrodes.

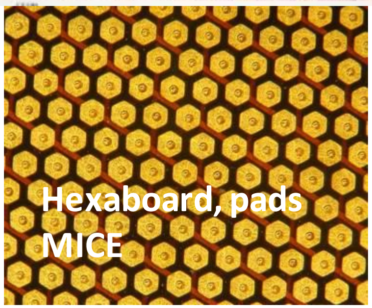
GEM – Gas Electron Multiplier

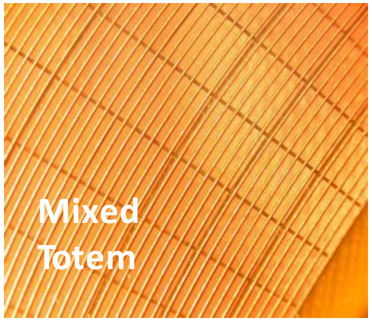


Full decoupling of the charge amplification structure from the charge collection and readout structure.
Both structures can be optimized independently !

A. Bressan et al, Nucl. Instr. and Meth. A425(1999)254

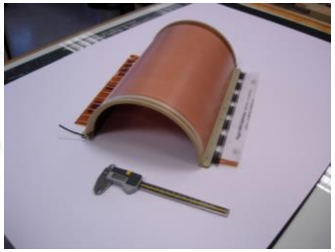






Compass

Totem

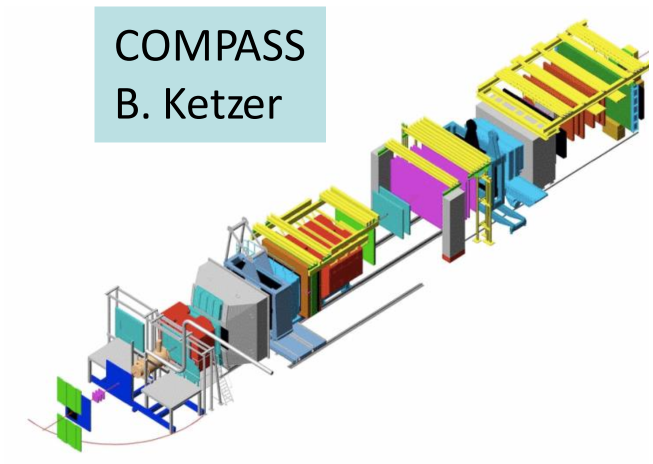


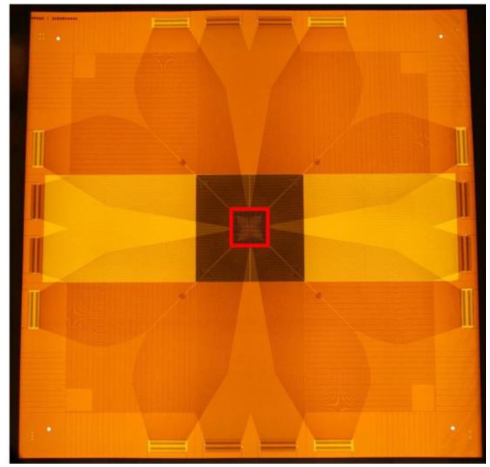
Most of the detectors use three GEM foils in cascade for amplification to reduce discharge probability by reducing field strength.

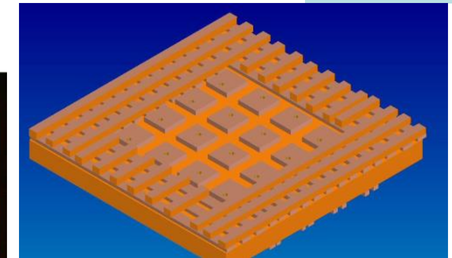
GEM – Gas Electron Multiplier

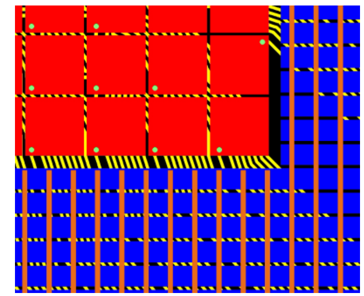
Pixel GEM
B. Ketzer

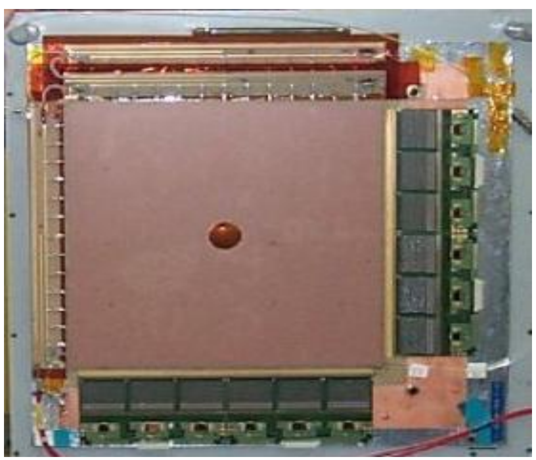
COMPASS
B. Ketzer

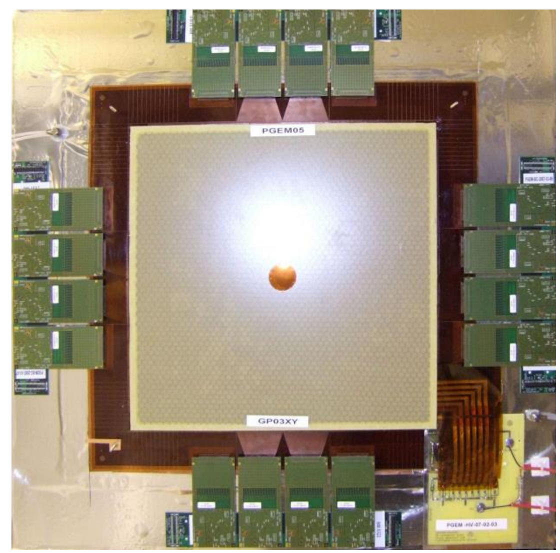






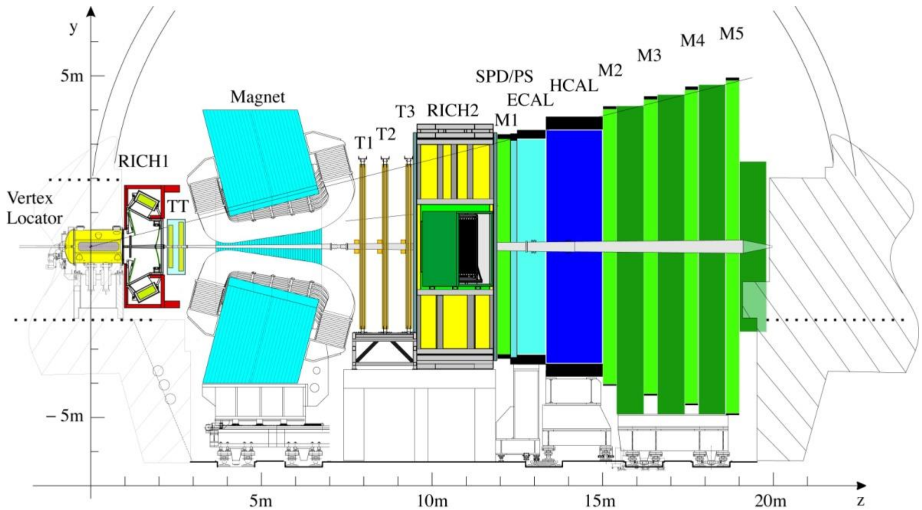






LHCb Muon Trigger

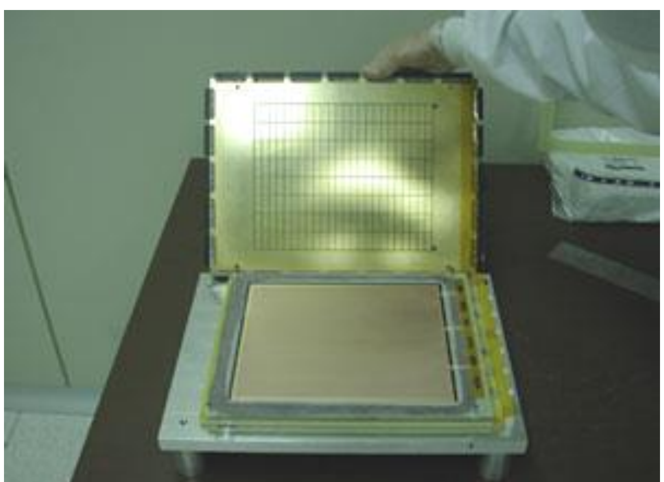
Fast TripleGEM Detectors for LHCb Muon Trigger

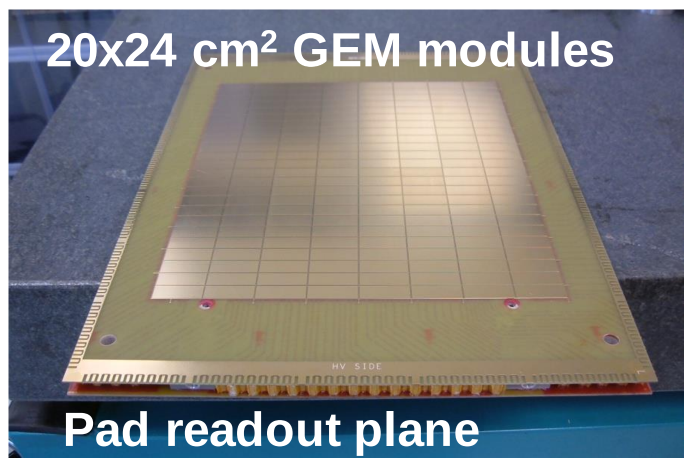


12 double TGEM detectors operated with fast gas mixture ($Ar\text{-}CO_2\text{-}CF_4$)

Rate - 5 kHz mm^{-2}
Time resolution 4.5 ns rms
Radiation hard up to integrated charge of 20 mC mm^{-2} (15 LHCb years)

G. Bencivenni

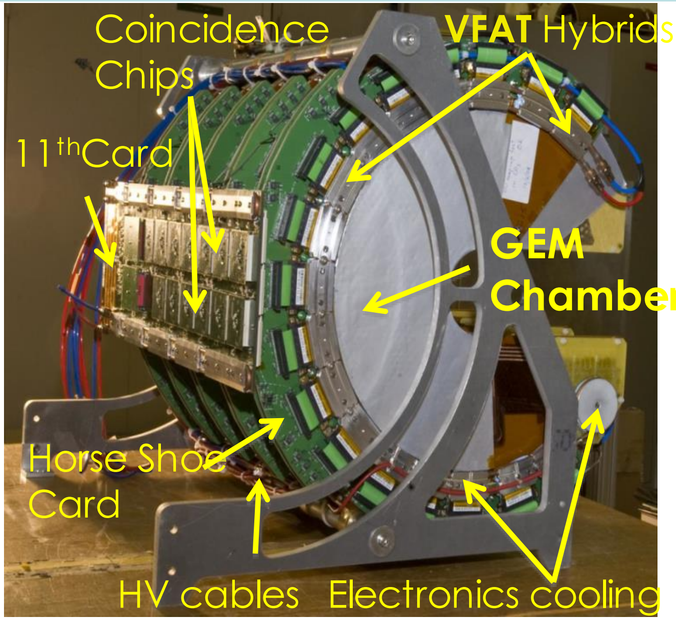




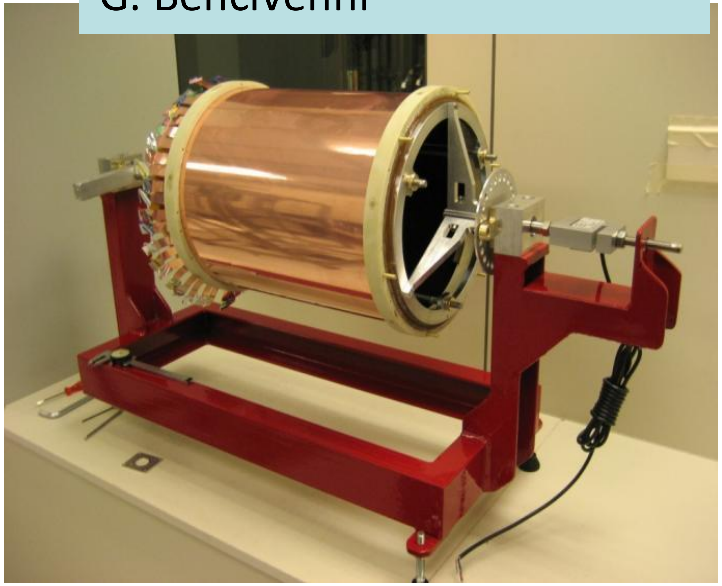
M. Alfonsi et al, Nucl. Instr. and Meth. A535(2004)319

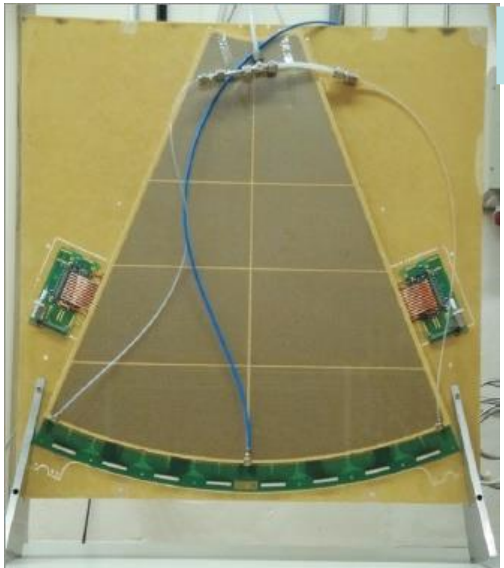
GEM – Gas Electron Multiplier

TOTEM GEMs, T. Hilden, V. Greco

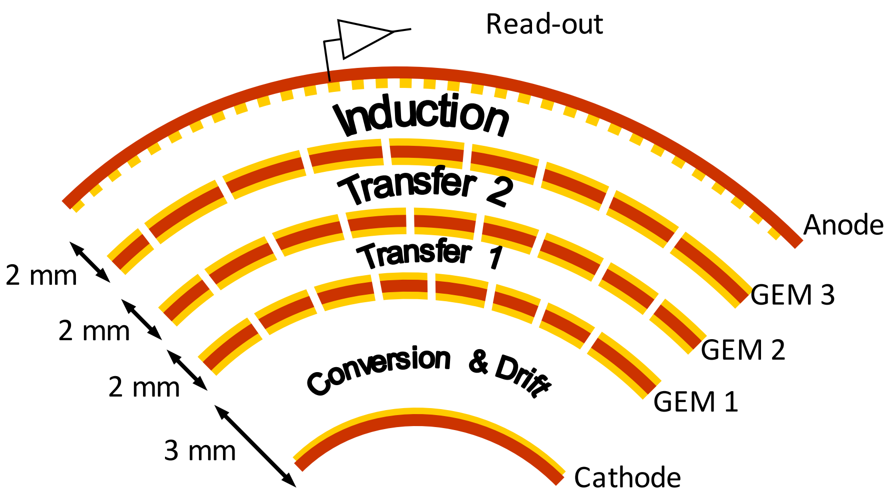


KLOE2 - Cylindrical Triple GEM
G. Bencivenni

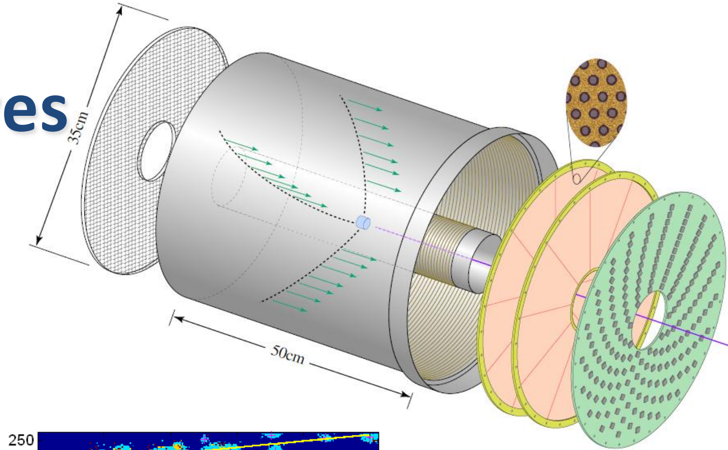




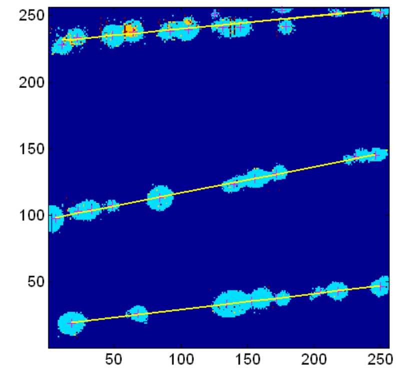
S. Duarte Pinto



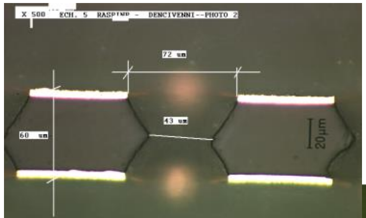
Field of Applications and Perspectives



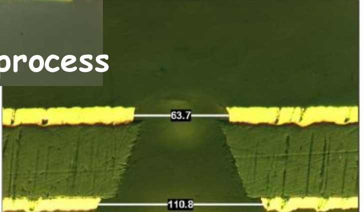
Large size detectors for tracking and triggering in HEP
TPC end cap readout
UV light detection
Hadron blind detectors
Cryogenic detectors
Two-phase detectors
High resolution detectors integrated with pixel CMOS chips
Non planar large acceptance detectors
Parallax error free detector
Neutron detection
X-ray radiography
Optical GEM detectors



Light detectors – mass reduction
Clean material components for sealed and light detectors
New readout structures adopted to experimental needs
Radiation hardness of assembly materials
Industrialization of the mass production

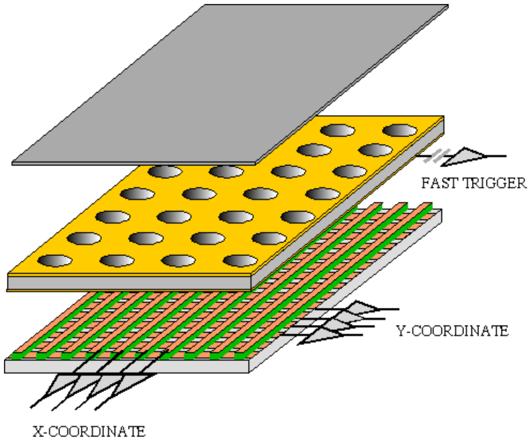


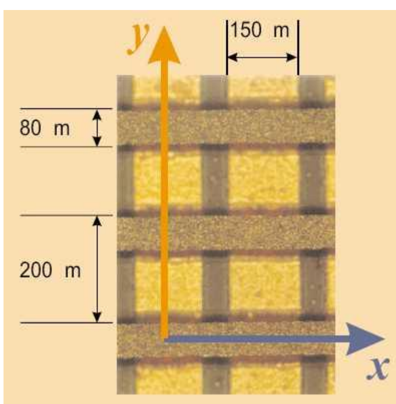
Double mask process

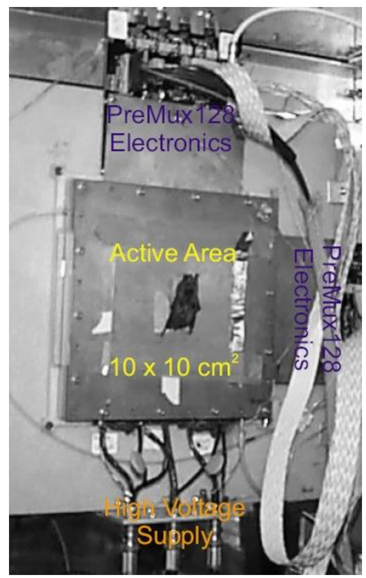


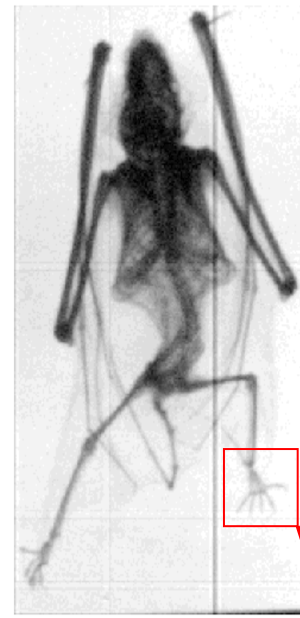
Single mask process

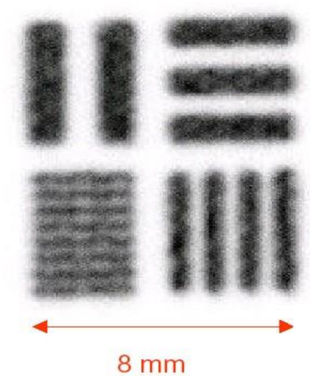
Absorption radiography with GEM (8 keV X-rays)

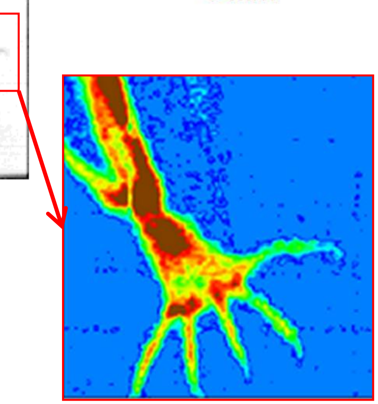








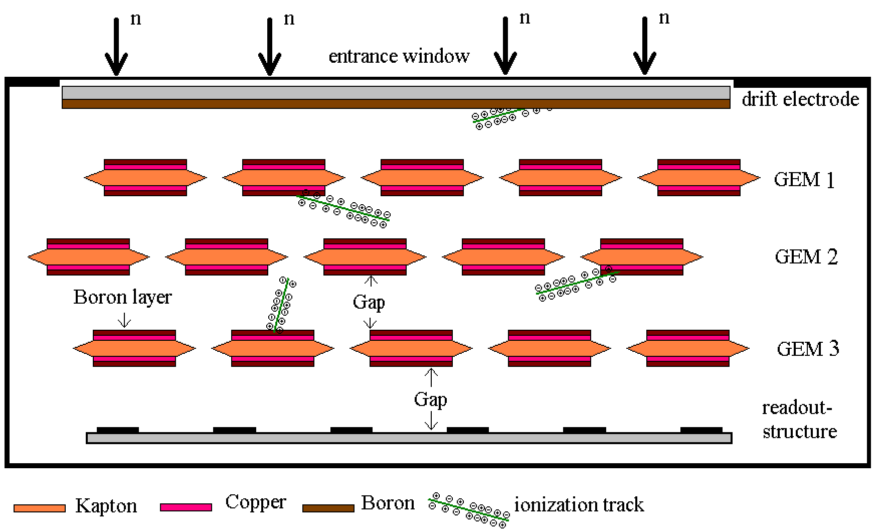




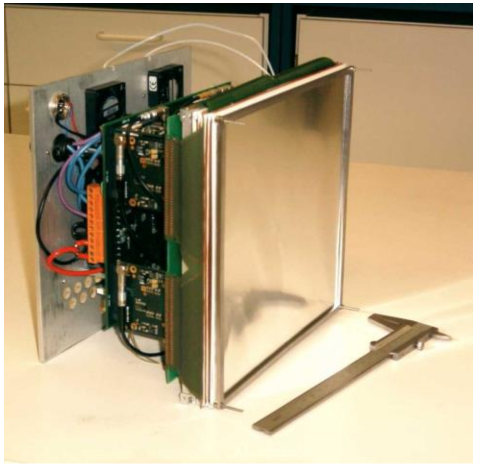
Trigger from the bottom electrode of GEM.

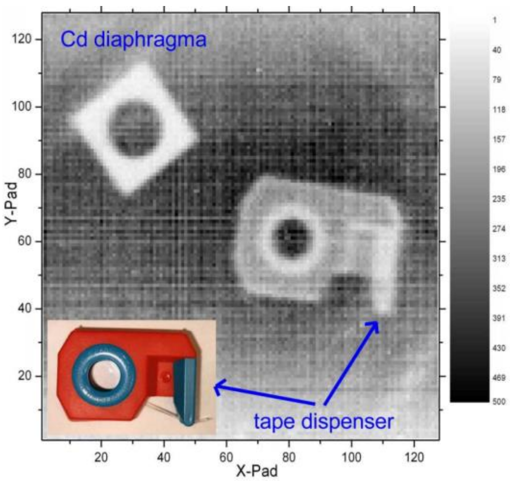
S. Bachmann et al, Nucl. Instr. and Meth. A471(2001)115

High-Rates Detector for Neutron Applications



CASCADE Heidelberg

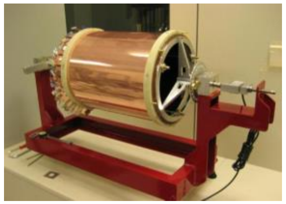




http://www.physi.uni-heidelberg.de/physi/cascade/index.html

RD51 Collaboration

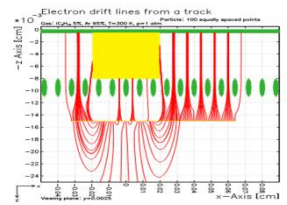
Large area (MM, GEM, THGEM)
Design optimization
(e.g. THGEM, Resistive MM)



WG1:

"RD51 Common Projects"
(Generic R&D)

WG2:



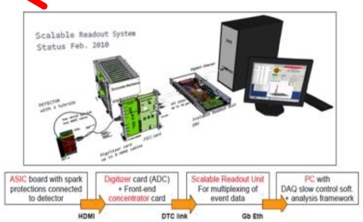
WG5:

MPGD SRS
Electronics

RD51

Software and
Simulation

WG4:



WG7:

WG6:

RD51 Common
Test Beam Facility


CERN MPGD Workshop
& Industrialization

WP5/RD51 Common Projects Highlights

- consolidation of the Collaboration and MPGD community integration (80 Institutes, 450 members)
- considerable progress in MPGD technologies in particular large area GEM, THGEM, Micromegas; some picked up by experiments (including LHC upgrades)
- secured future of the MPGD technologies development through the TE MPE workshop upgrade and FP7 AIDA contribution (upgrade in progress)
- improved MPGD simulation software framework allowing first applications
- infrastructure for common RD51 test beam and lab facilities (~20 user groups)
- development of common, scalable electronics (~20 development and user groups) (industrialization and availability through CERN store)
- contacts with industry for large volume production, first runs

RD51 Future – beyond 2013

- Continuation of the R&D support for the experiments and LHC upgrades (QC)
- MPGD Industrialization - GEM, MicroMegas, Thick GEM
- Generic R&D (new structures, ideas, detector physics) – RD51 Common Projects
- Development and Maintenance of the SRS Electronics
- Maintenance and extension of the RD51 Lab and Test-Beam Infrastructure
- Development and Maintenance of Software & Simulation Tools; basic studies & software support for the RD51 community
- Applications: organization (HEPTEC) of series of specialized workshops disseminating MPGD applications beyond fundamental physics – RD51, potential users and industry (e.g. dosimetry, neutron detection, medical physics, …)
- MPGD Education and Training : organization of schools for students and newcomers & academic training outside CERN, covering specific areas of the RD51/MPGD activities