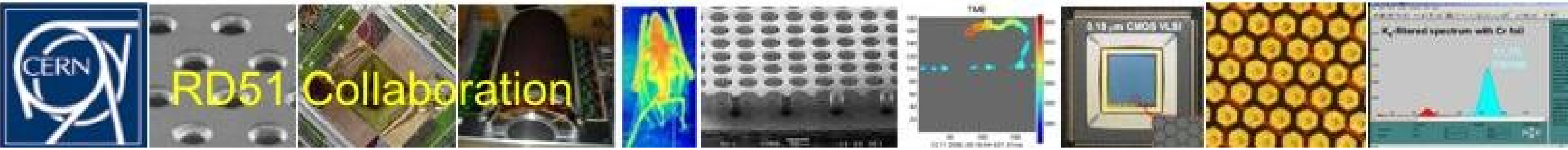
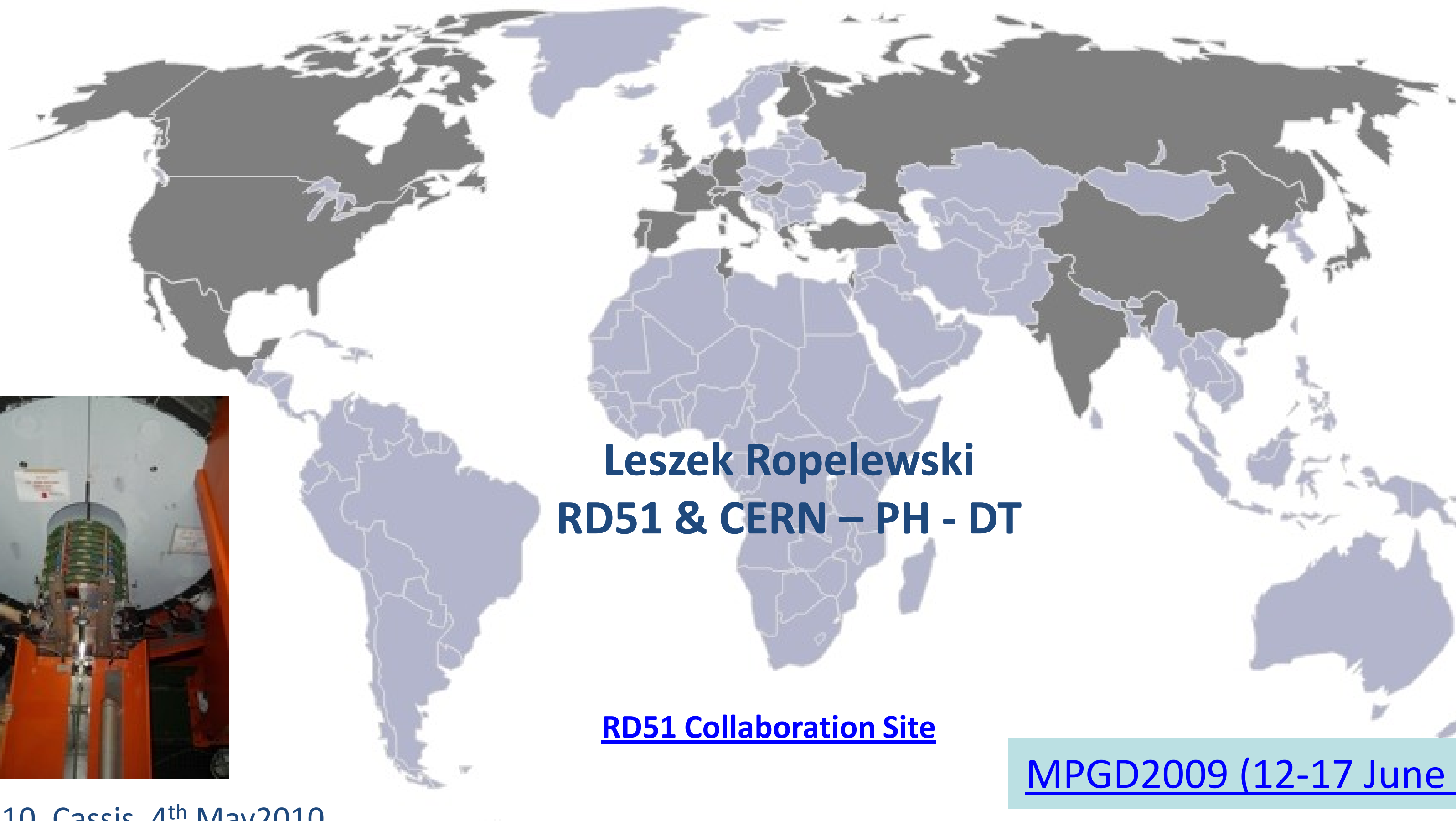


Recent Developments of Gaseous Detectors and MPGDs

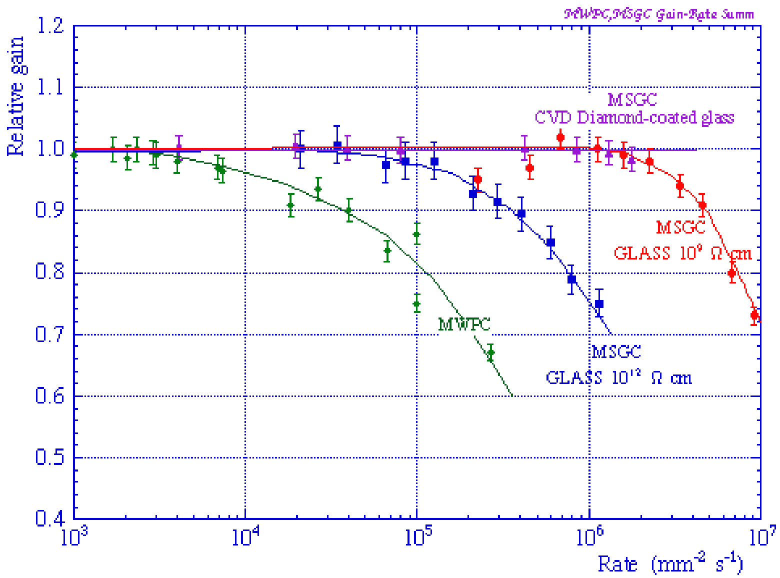


Leszek Ropelewski
RD51 & CERN – PH - DT

[RD51 Collaboration Site]

[MPGD2009 (12-17 June 2009)]

Gaseous Detectors

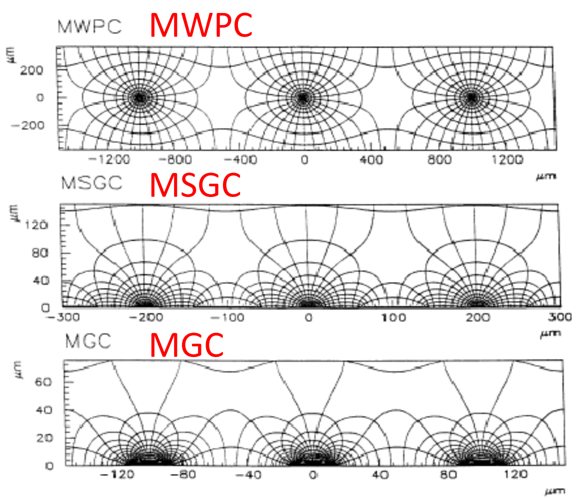


scale factor

1

5

10



R. Bellazzini et al.

Advantages of gas detectors:

- low radiation length
- large areas at low price
- flexible geometry
- spatial, energy resolution …

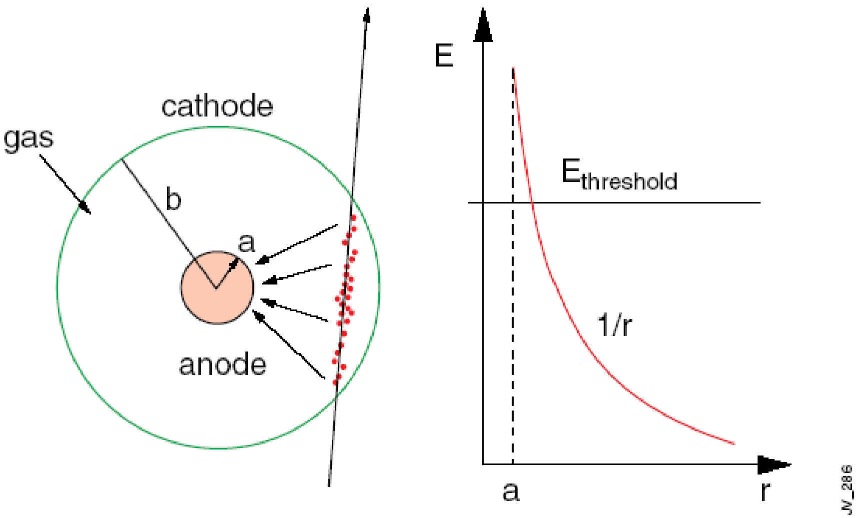
Limitation:

- rate capability limited by space charge defined by the time of evacuation of positive ions

Solution:

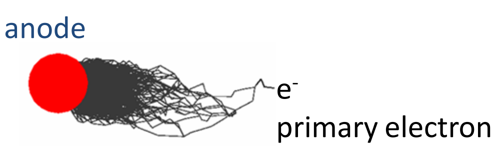
- reduction of the size of the detecting cell (limitation of the length of the ion path) using chemical etching techniques developed for microelectronics and keeping at the same time similar field shape.

Single Wire Proportional Chamber



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.

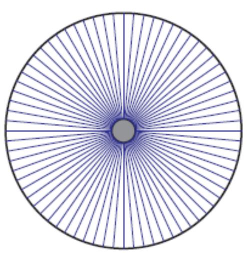


$$E(r) = \frac{CV_0}{2\pi\varepsilon_0} \cdot \frac{1}{r}$$

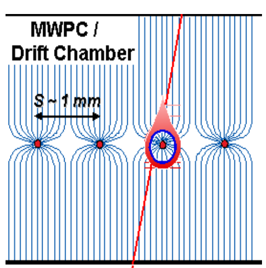
$$V(r) = \frac{CV_0}{2\pi\varepsilon_0} \cdot \ln\frac{r}{a}$$

C – capacitance/unit length

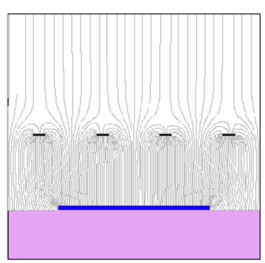
Cylindrical geometry is not the only one able to generate strong electric field:



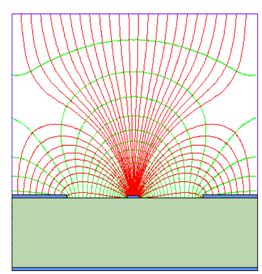
wire



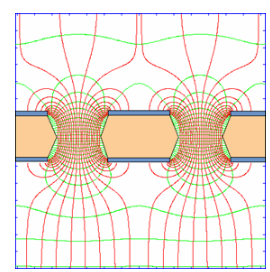
mwpc



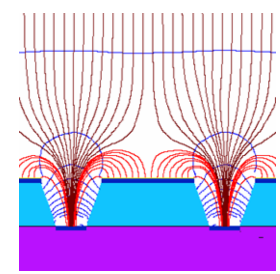
parallel plate



strip



hole

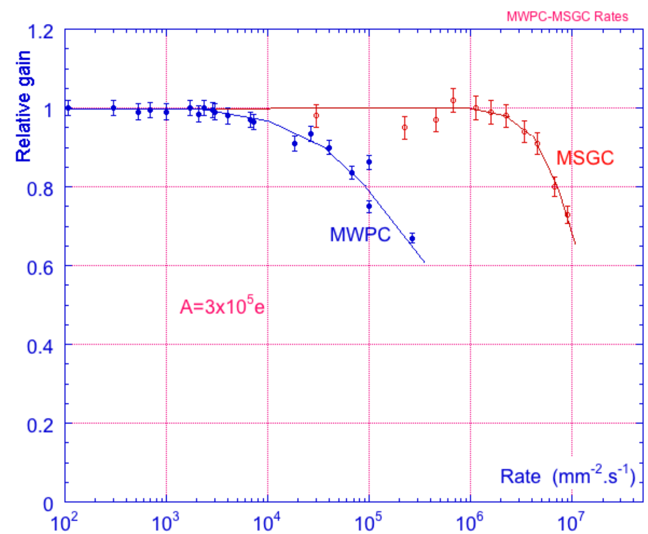


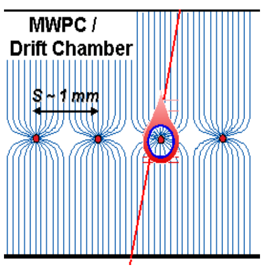
groove/well

Current Trends in Micro-Pattern Gas Detectors (Technologies)

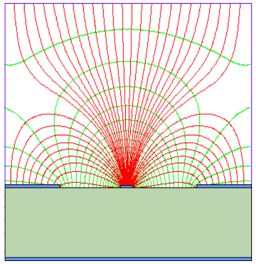
Semiconductor Industry technology:

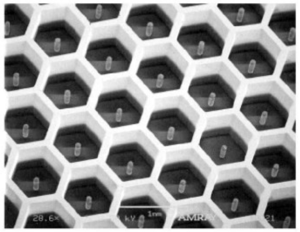
- Photolithography
- Etching
- Coating
- Doping
- Wafer postprocessing

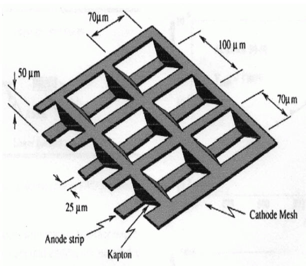




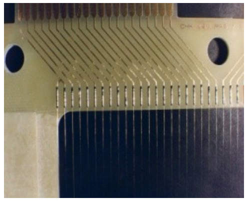
Amplifying cell reduction by factor of 10



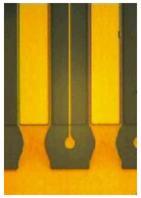




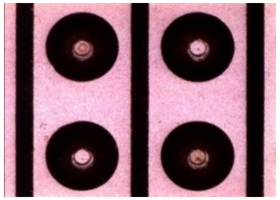
Operational instabilities:

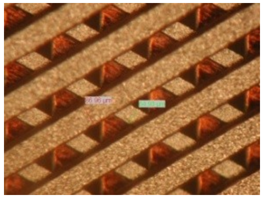


Rate Capability>10^6/mm^2
Position Resolution ~40µm
2-track Resolution ~400µm



Substrate charging-up
Discharges
Polymer deposition (ageing)



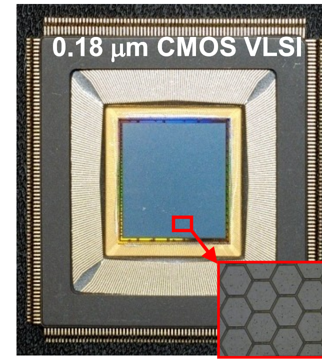


MWPC

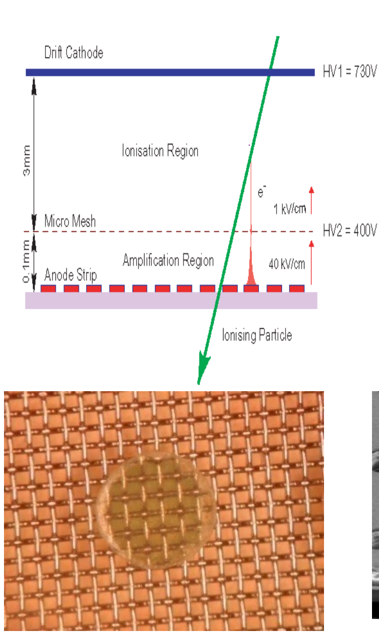
MSGC

Current Trends in Micro-Pattern Gas Detectors (Technologies)

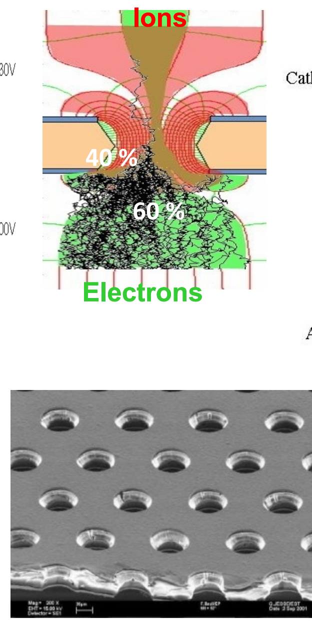
- MSGC
- Micromegas
- GEM
- Thick-GEM, Hole-Type Detectors and RETGEM
- MPDG with CMOS pixel ASICs
- Ingrid Technology



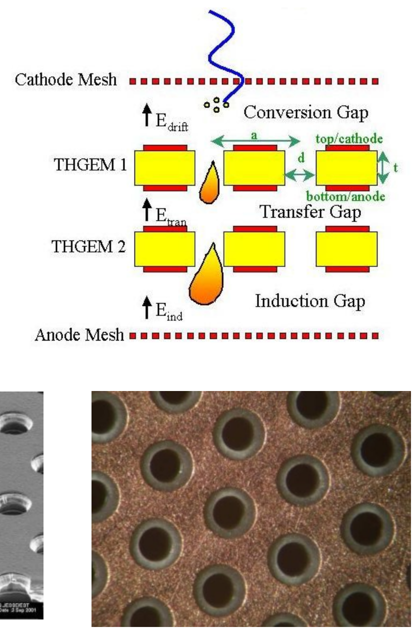
CMOS high density readout electronics



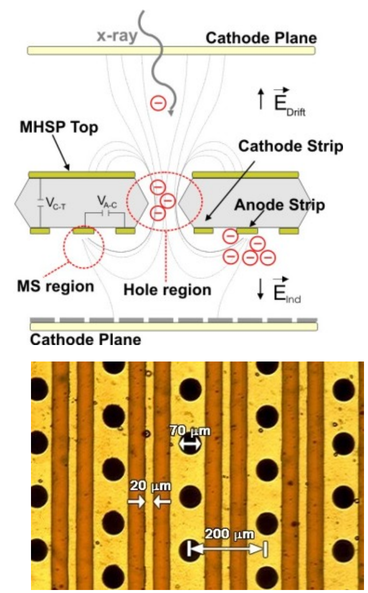
Micromegas



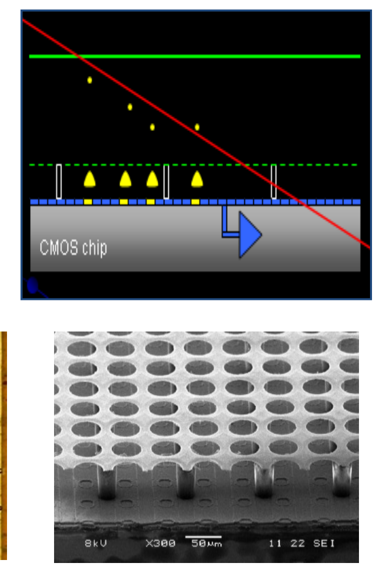
GEM



THGEM



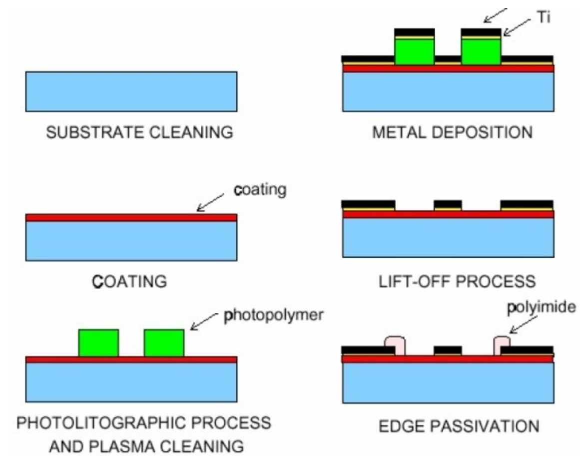
MHSP



Ingrid

MSGC – MicroStrip Gas Chamber

Anton Oed

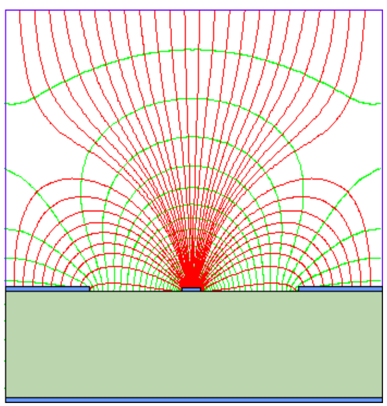


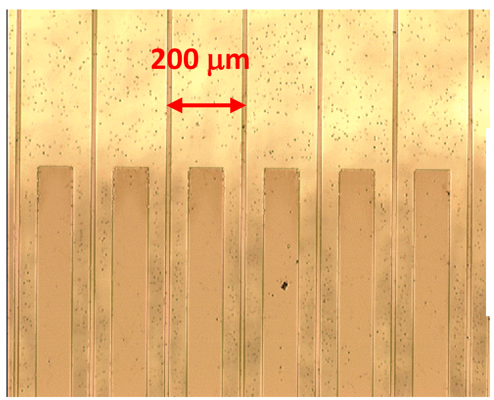
Thin metal anodes and cathodes on insulating support (glass, flexible polyimide ..)

Problems:

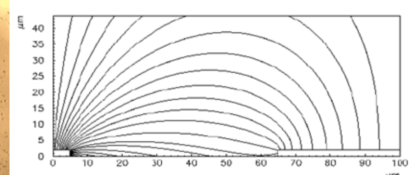
High discharge probability under exposure to highly ionizing particles caused by the regions of very high E field on the border between conductor and insulator.

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

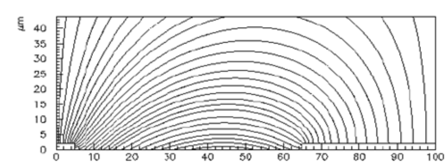




insulating support



slightly conductive support



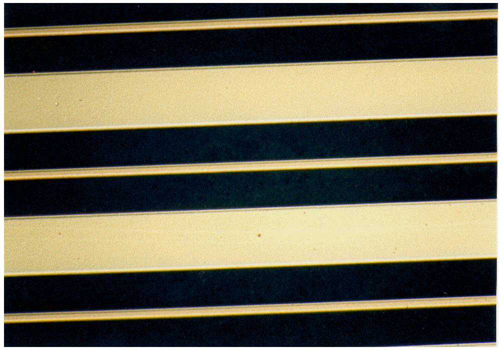
R. Bellazzini et al.

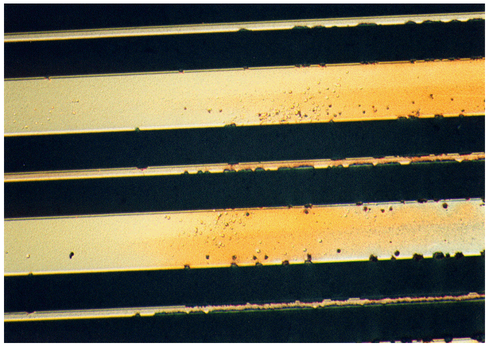
Solutions:

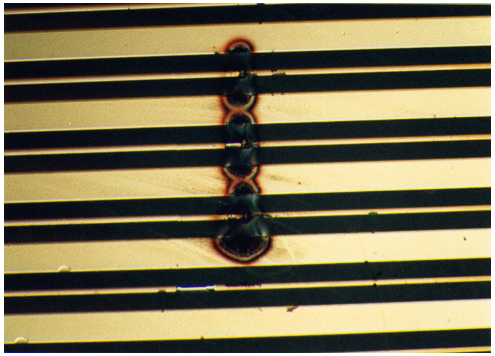
slightly conductive support

multistage amplification

MSGC – MicroStrip Gas Chamber







Surface charging

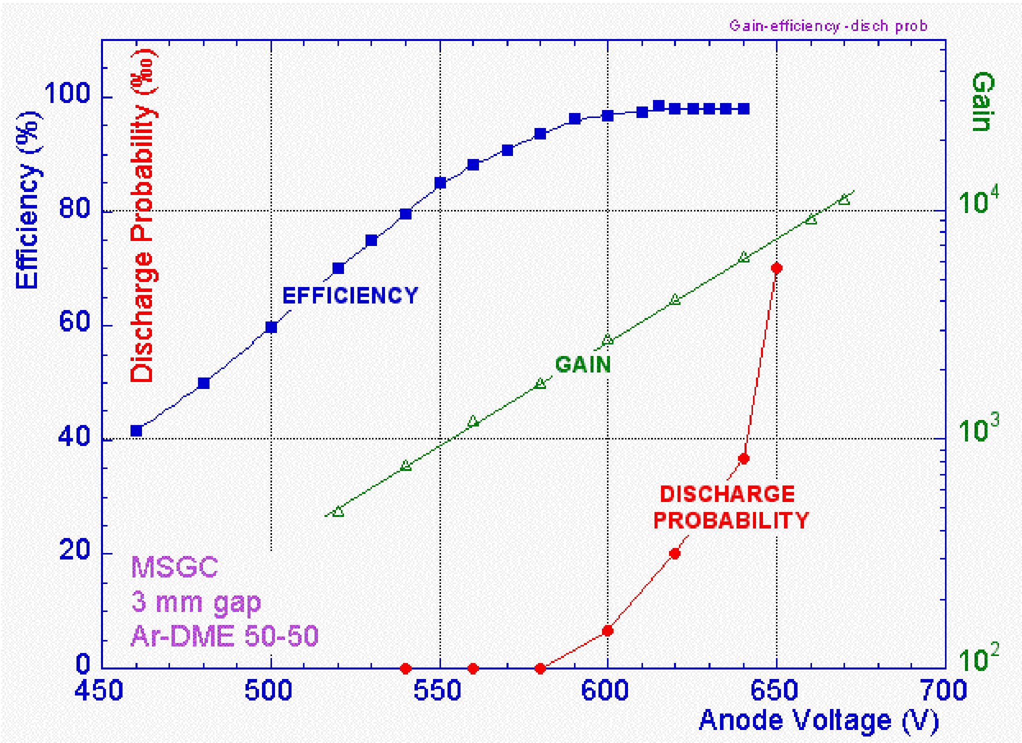
Bulk resistivity of the support material

Surface modification by doping or deposition

Ageing

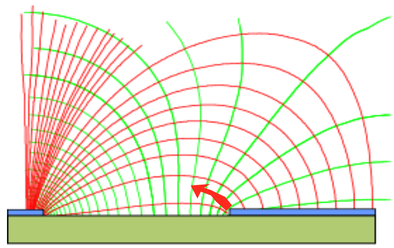
Gas, Gas system, MSGC support, Construction material

Discharges

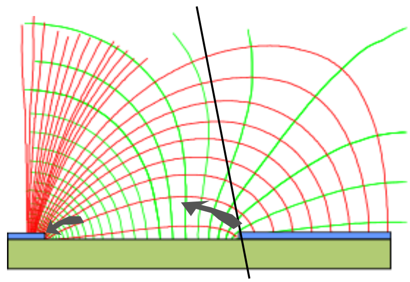


MSGC – MicroStrip Gas Chamber

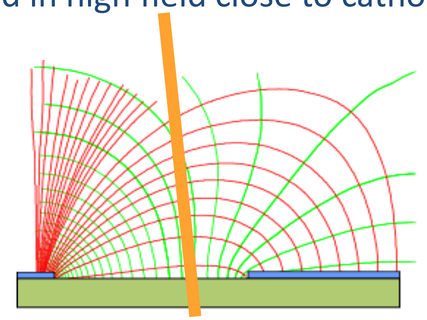
MSGC: Discharge mechanisms



Field emission from the cathode edge

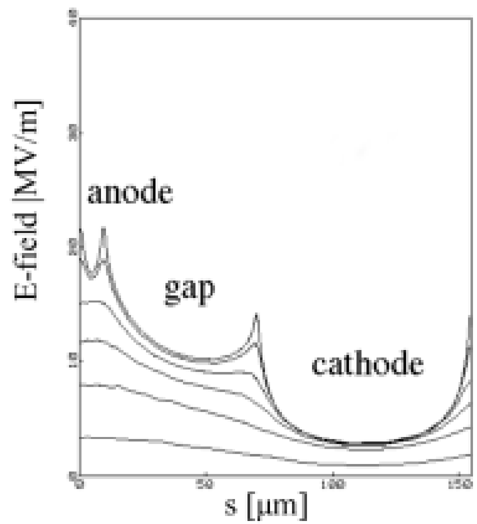


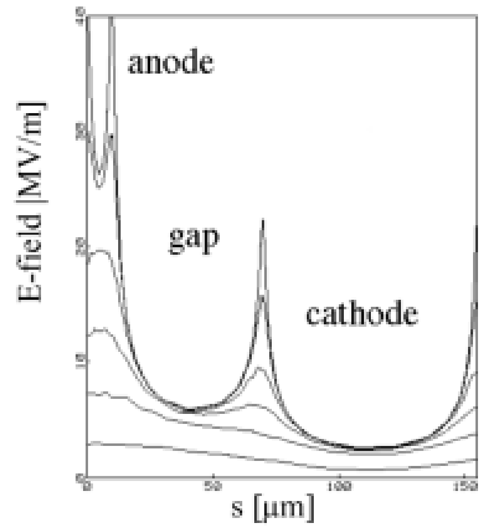
Charge pre-amplification for ionization released in high field close to cathode



Very high ionization release:
avalanche size exceeds Reather's limit: $Q \sim 10^7$

Electric field strength close to support plane in MSGC

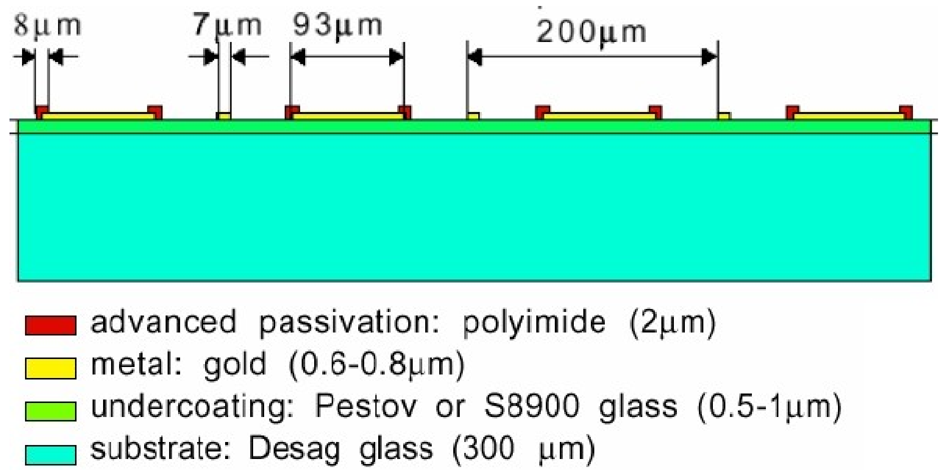


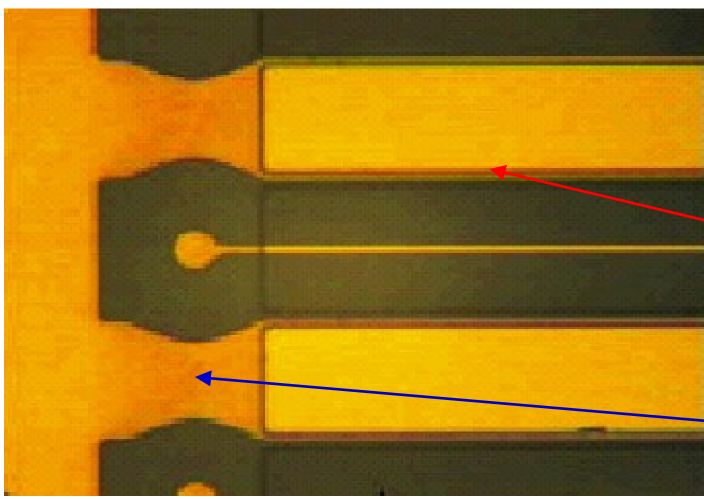


Coated MSGC **Uncoated MSGC**

Surface resistivity modification

Cathode edge passivation



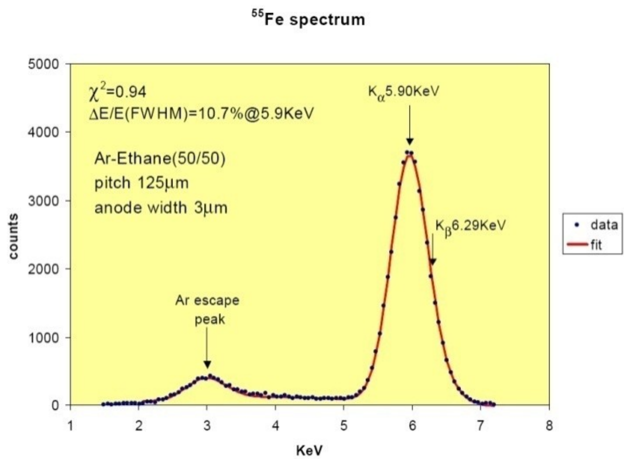


Advanced passivation

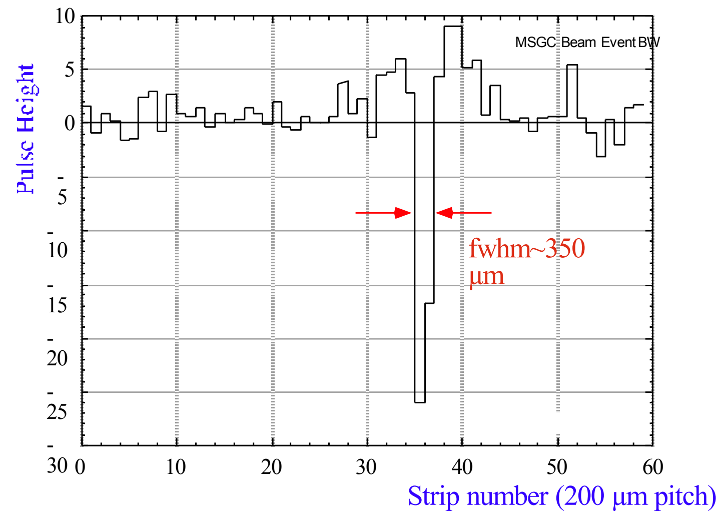
Standard passivation

Bellazzini et al.

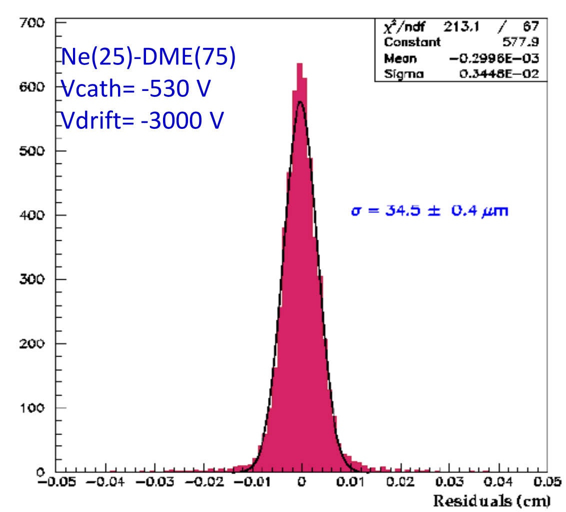
MSGC – MicroStrip Gas Chamber



Energy resolution ~11% for 5.9 keV

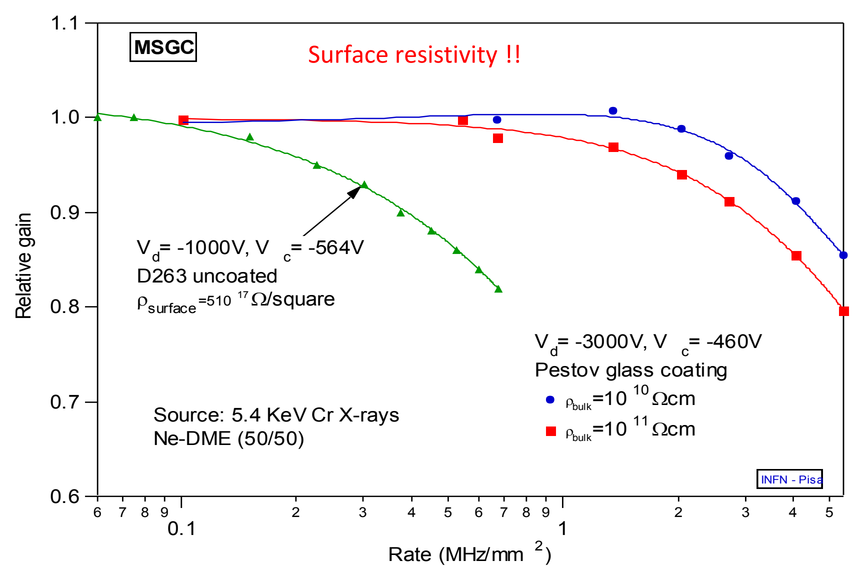


Single event wire map



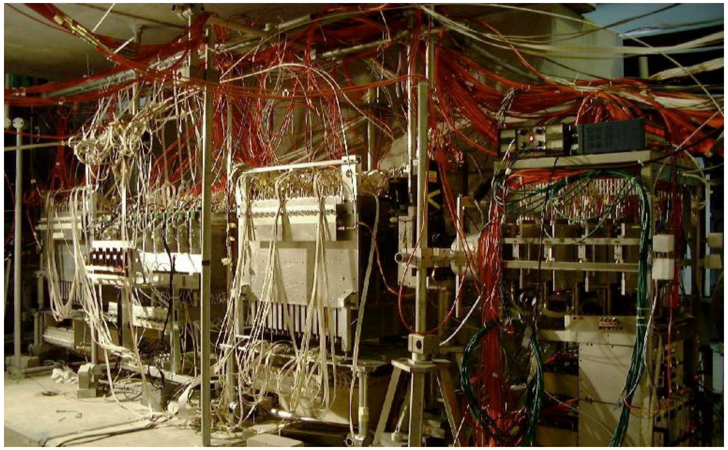
Spatial resolution = 34.5 ± 0.4 μm

2-track resolution ~400 μm

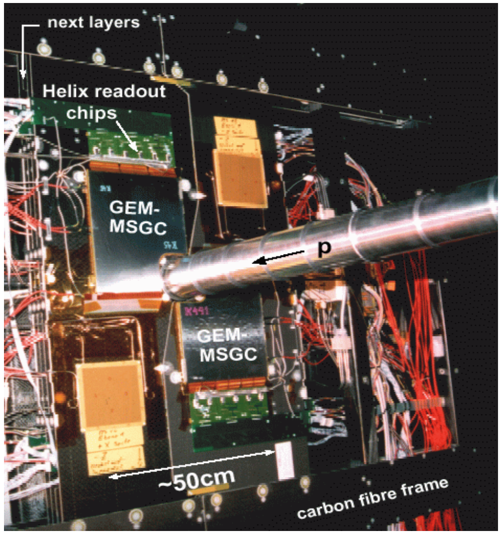


Rate capability > 1 MHz/mm²

MSGC – MicroStrip Gas Chamber

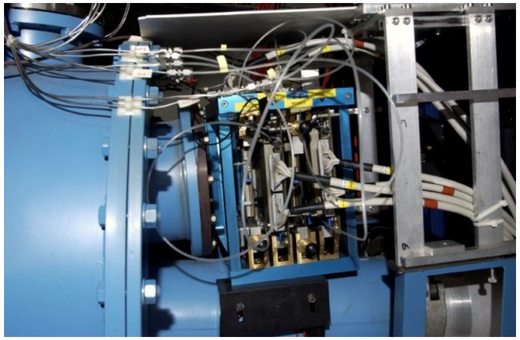


Telescope of 32 MSGCs tested at PSI in Nov99 (CMS Milestone)



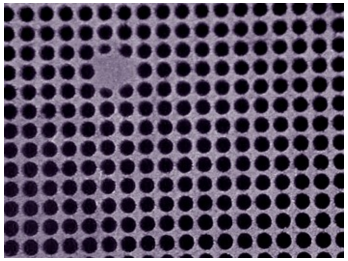
HERA-B Inner Tracker
MSGC-GEM detectors
R_{min} ~ 6 cm
$\Rightarrow 10^6$ particles/cm^2•sec
300 μm pitch
184 chambers: max 25x25 cm^2
~ 10 m^2; 140.000 channels

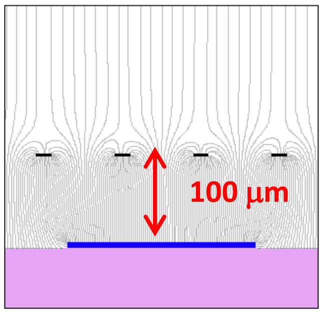
The D20 diffractometer MSGC is working since Sept 2000
1D localisation
48 MSGC plates (8 cm x 15 cm)
Substrate: Schott S8900
Angular coverage : 160° x 5,8°
Position resolution : 2.57 mm (0,1°)
5 cm gap; 1.2 bar CF4 + 2.8 bars 3He
Efficiency 60% @ 0.8 Å

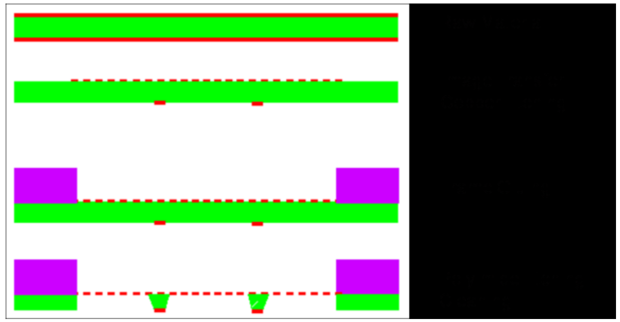


DIRAC
4 planes MSGC-GEM
Planes 10x10 cm^2

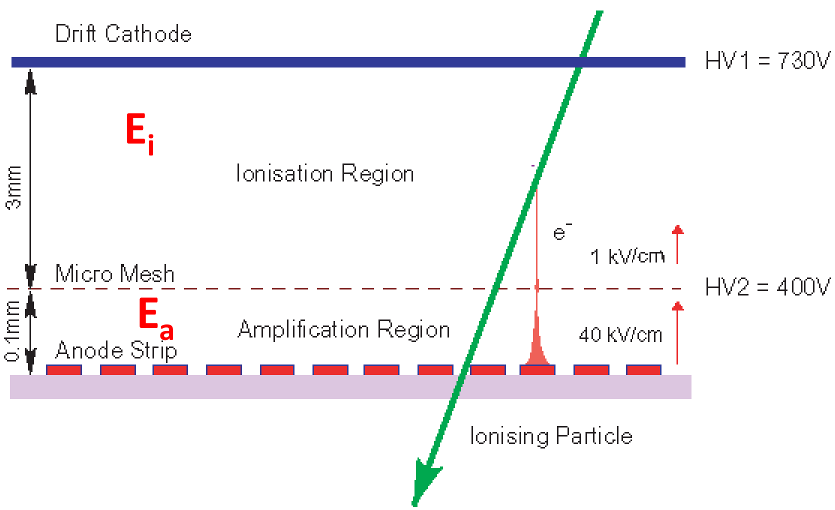
Micromegas – Micromesh Gaseous Structure

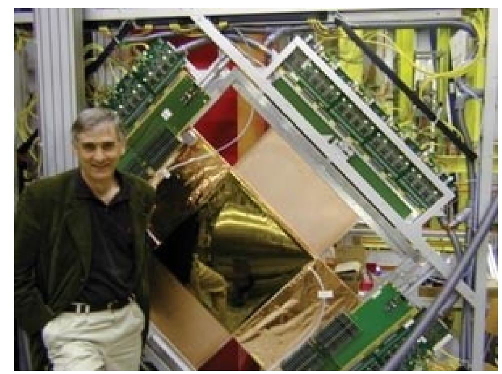






Micromesh mounted above readout structure (typically strips).
E field similar to parallel plate detector.
E_a/E_i ~ 50 to secure electron transparency and positive ion flow back suppression.



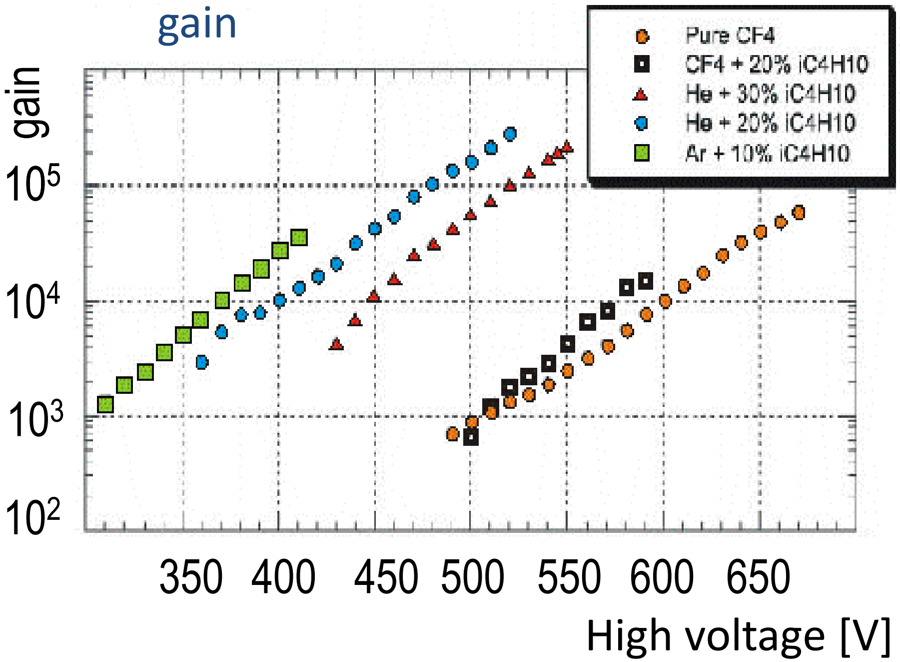


Ioannis Giomataris

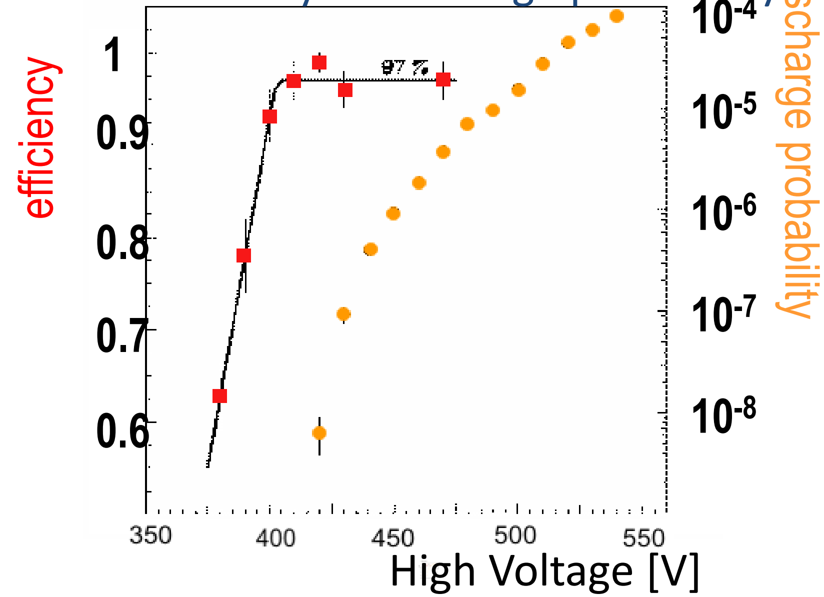
Y.Giomataris et al, NIM A 376 (1996) 29

Micromegas – Micromesh Gaseous Structure

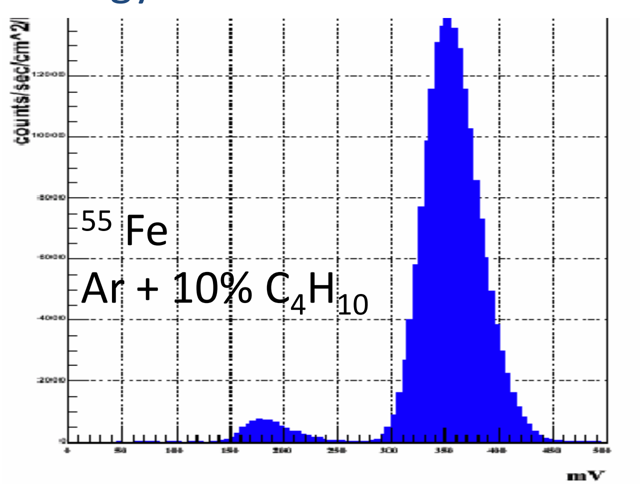
gain



efficiency & discharge probability

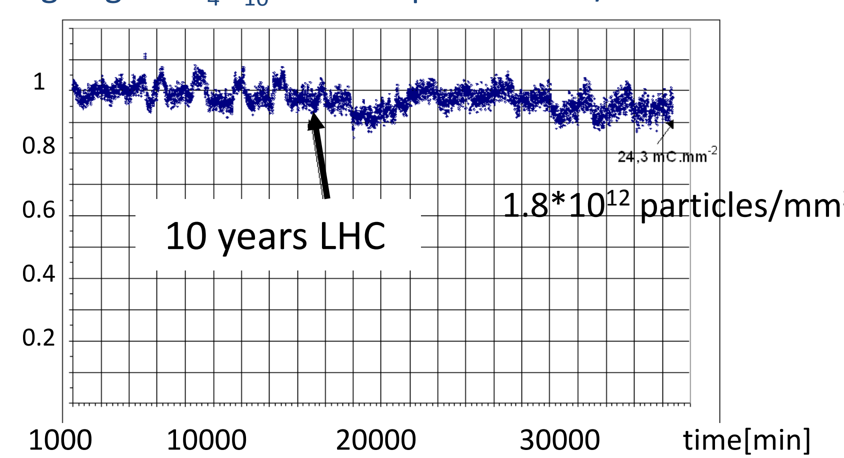


energy resolution ~ 10%

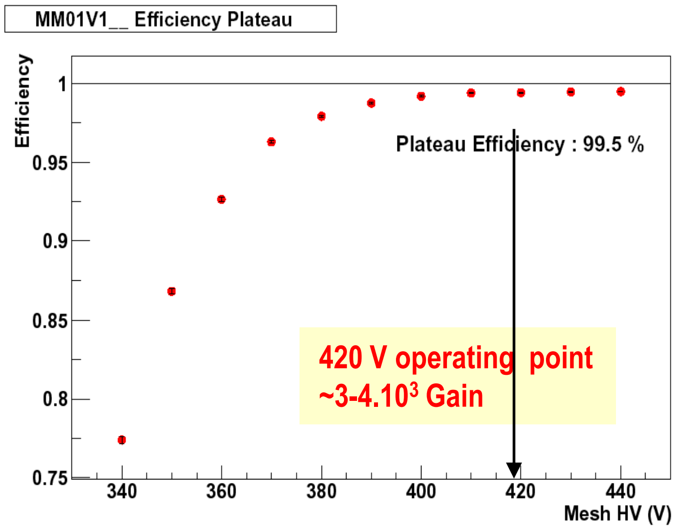


D.Thers et al NIM A 469 (2001) 133

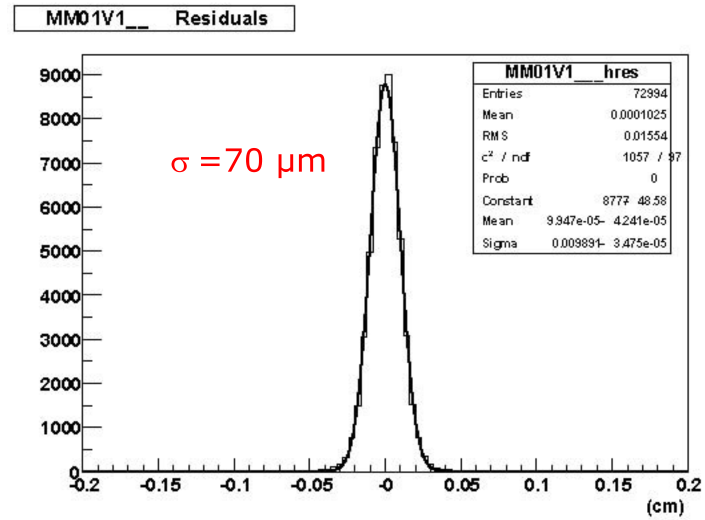
ageing:Ar-iC_4H_{10} 94-6% up to 24.3mC/mm^2



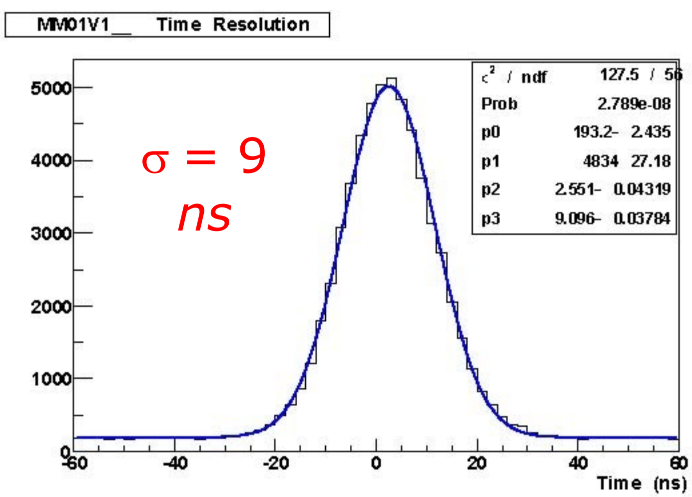
Micromegas – Micromesh Gaseous Structure



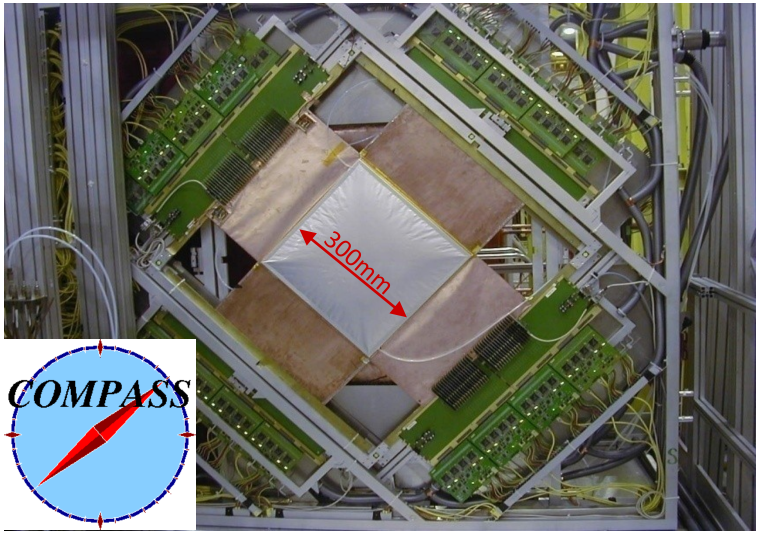
Large efficiency plateau > 40 V



Spatial resolution < 70 µm



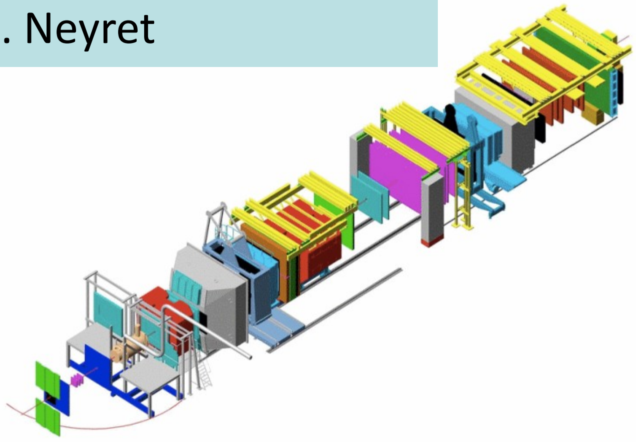
Time resolution : 9 ns

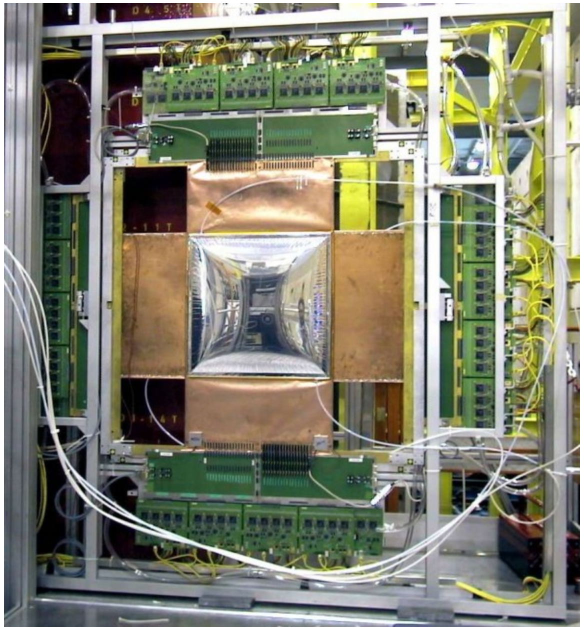


D.Thers et al NIM A 469 (2001) 133

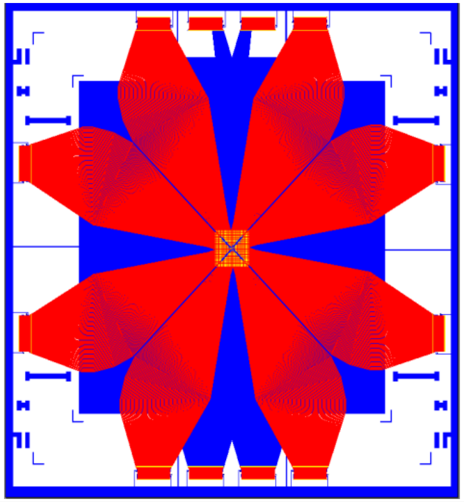
Micromegas – Micromesh Gaseous Structure

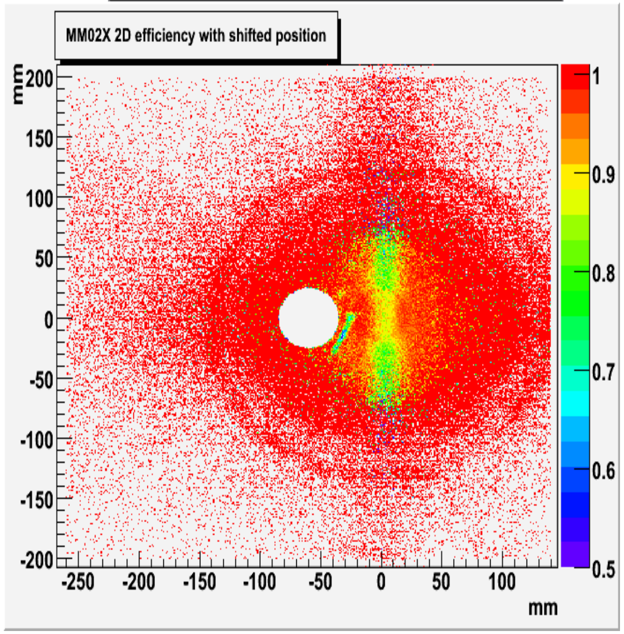
COMPASS Micromegas
D. Neyret





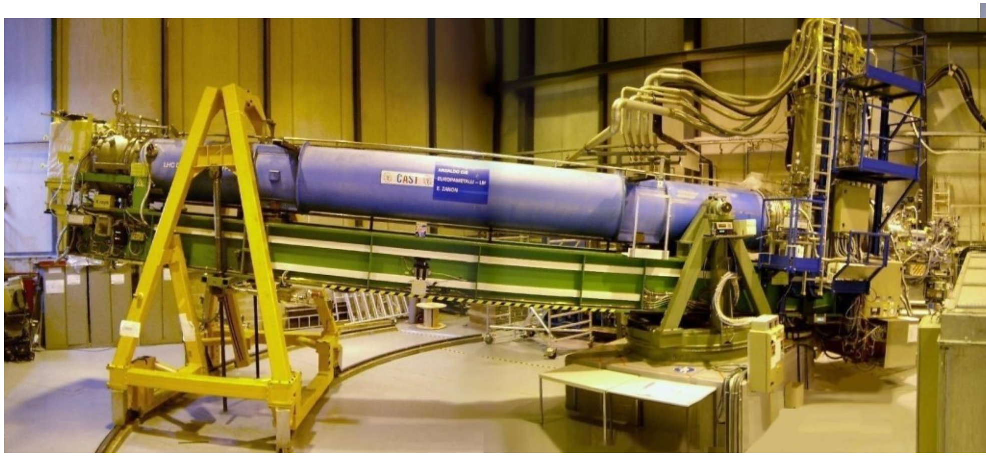
Pixelized Micromegas

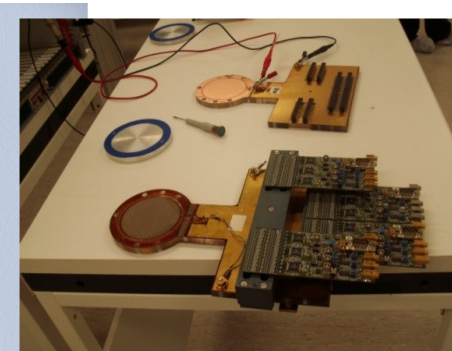




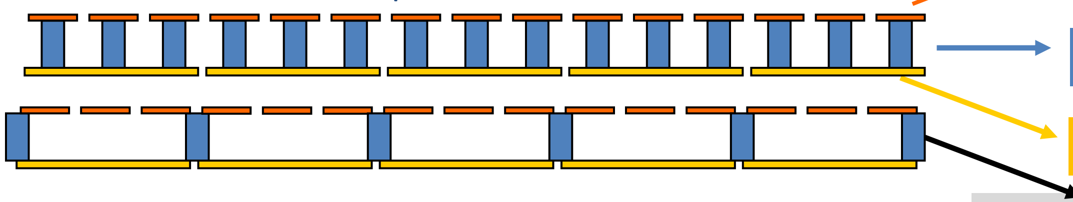
Low background Micromegas,
J. Galan, E. Ferrer, A. Tomas

Micro-Bulk Micromegas
Th. Papaevangelou





Readout plane + mesh all in one



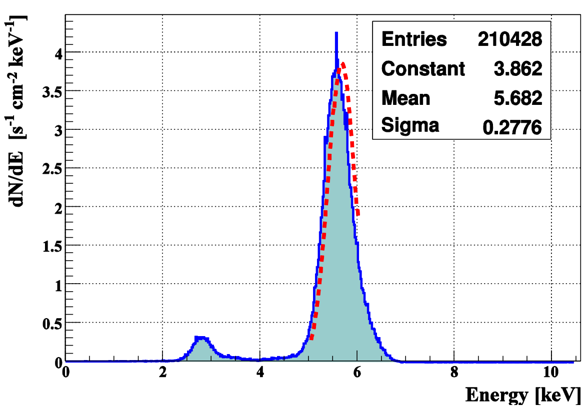
Micromesh
5µm copper

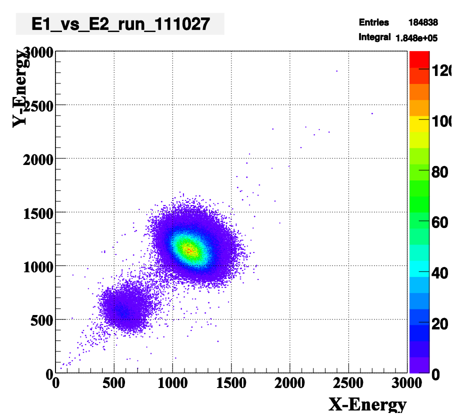
Kapton 50 µm

Readout pads

Lower capacitance
Under development

An I. Giomataris and R. De Oliveira idea

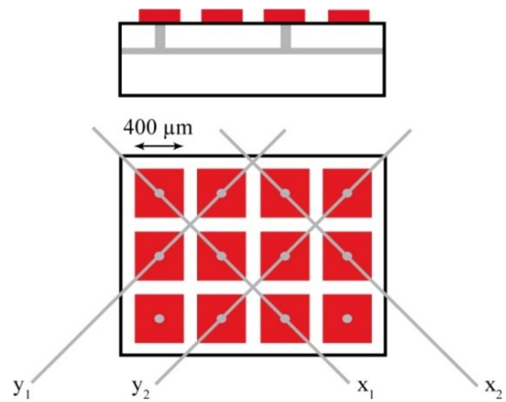


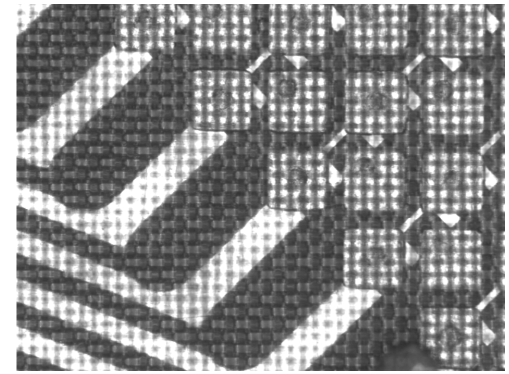


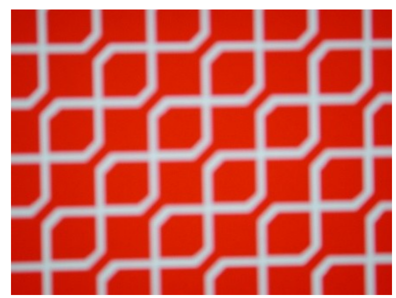
^{55}Fe Calibration with Ar – 5% isobutane @ 1 bar
Collimated source to avoid border effects
FWHM @ 6 keV = 11.5 %

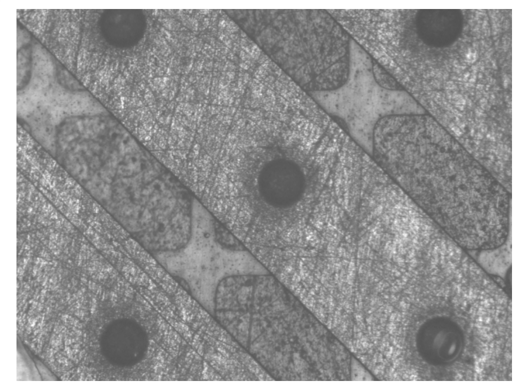
2D MM Readout schemes

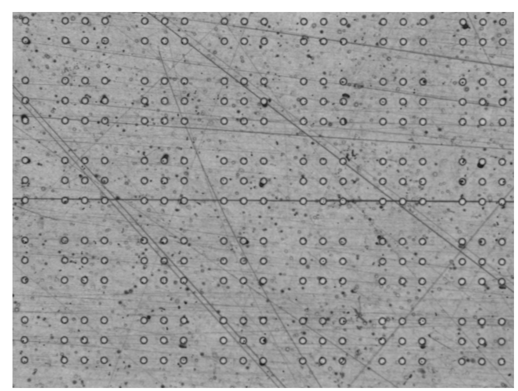
- Square pads connected through 2 extra layers
- Combination of "strips" and pads connected through one extra layer:
  - Detector thickness ~80 µm
  - Simpler process
  - Charge distribution in x-y is determined by the hole geometry
- Possibility of more etching around holes











Low background Micromegas,
J. Galan, E. Ferrer, A. Tomas

ATLAS Micromegas R&D (MAMMA)

Purpose: Development of large-area muon chambers based on bulk Micromegas technology

Collaboration: 19 institutes (most) in ATLAS, but also active in RD51

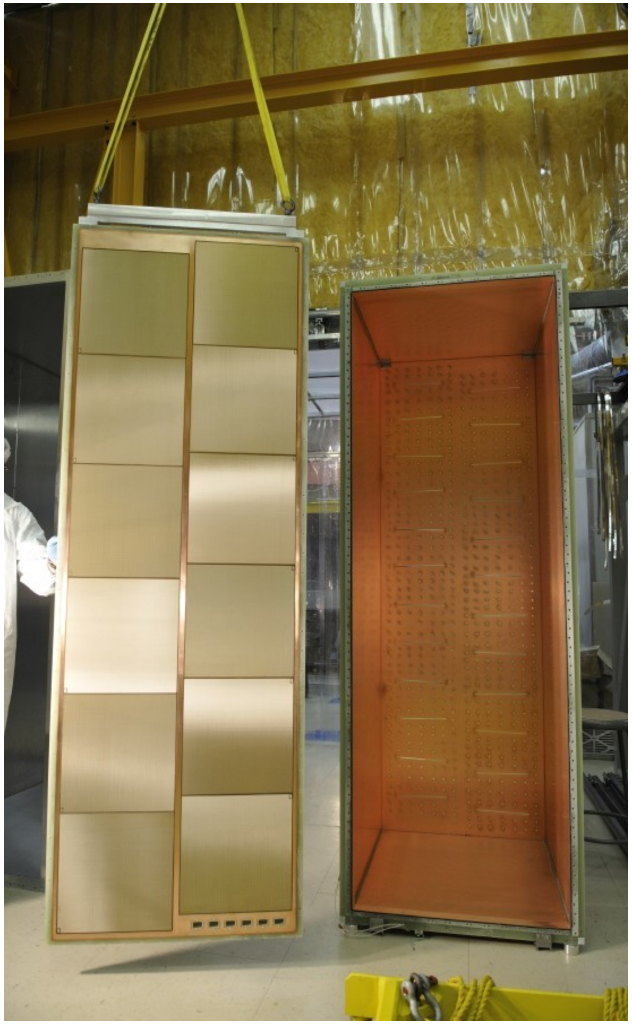
Main lines of R&D activities:

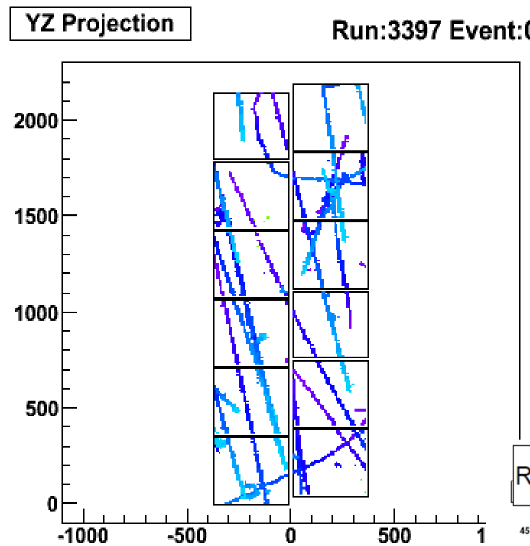
1. Spark neutralization and/or suppression
   - Resistive coating on readout strips
   - Multi-stage amplification schemes
2. Large-area chambers
   - P3 (1.5 x 0.5 m^2) successfully tested in H6; strips of 400 and 1000 mm length, strip pitches 250 and 500 µm
   - Full-size chamber (1.2 x 1.2 m^2) under construction; with front-end electronics (demonstrator project with APV25) and services integration.
     To be tested in 2010 test beam (October)
3. Front-end end readout electronics
   - Scalable Readout System (RD51, H. Muller)
   - Readout chip specs and design (BNL, LAPP, CEA, CERN)

Micromegas – Micromesh Gaseous Structure

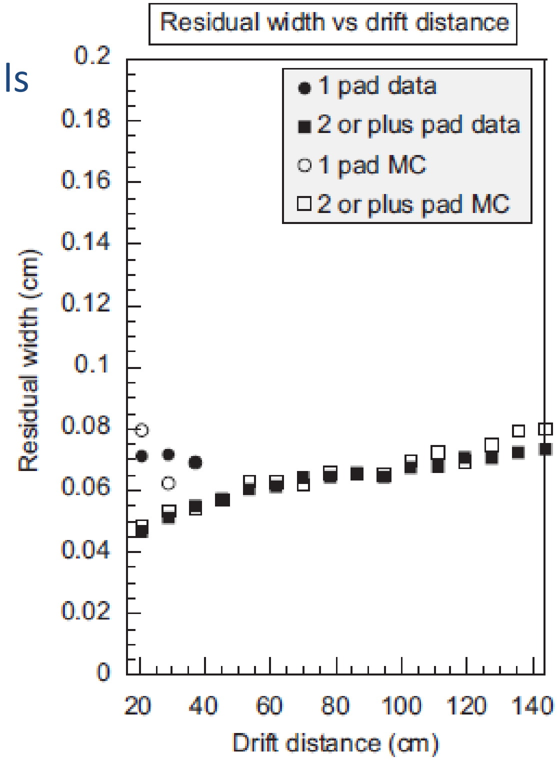
T2K TPC, J. Beucher

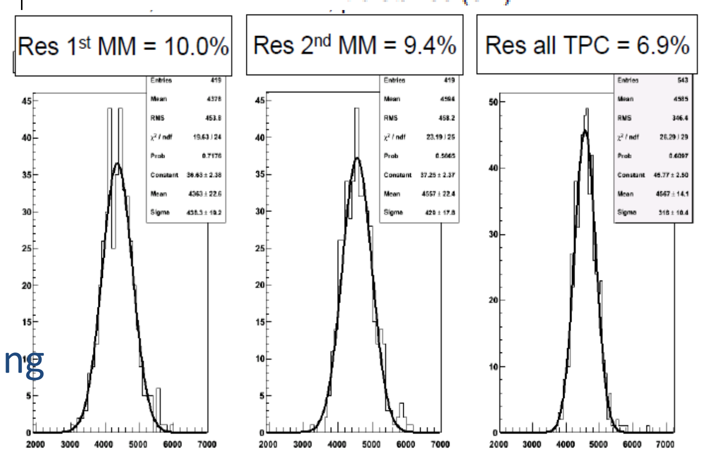
24 bulk-Micromegas + FEE + mechanicals
3 m^2 of bulk Micromegas
41472 FEE channels





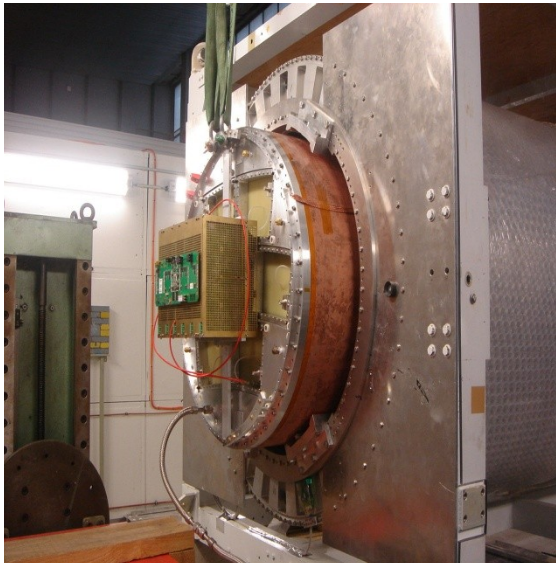
Reconstructed cosmics
by a readout plane
(beam tests @ TRIUMF on-going

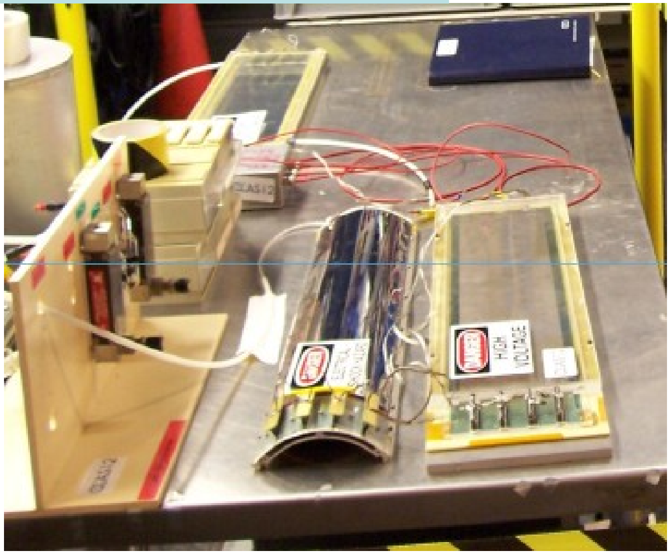




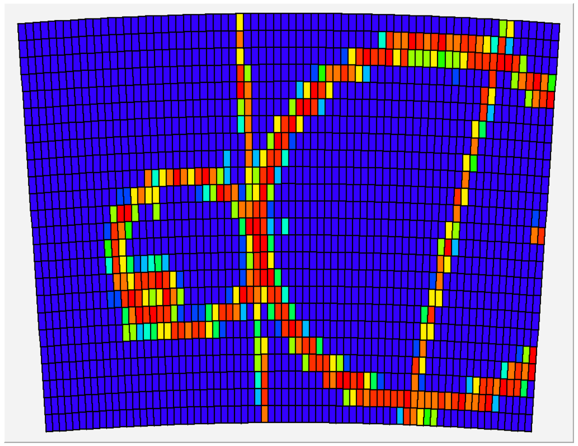
Micromegas – Micromesh Gaseous Structure

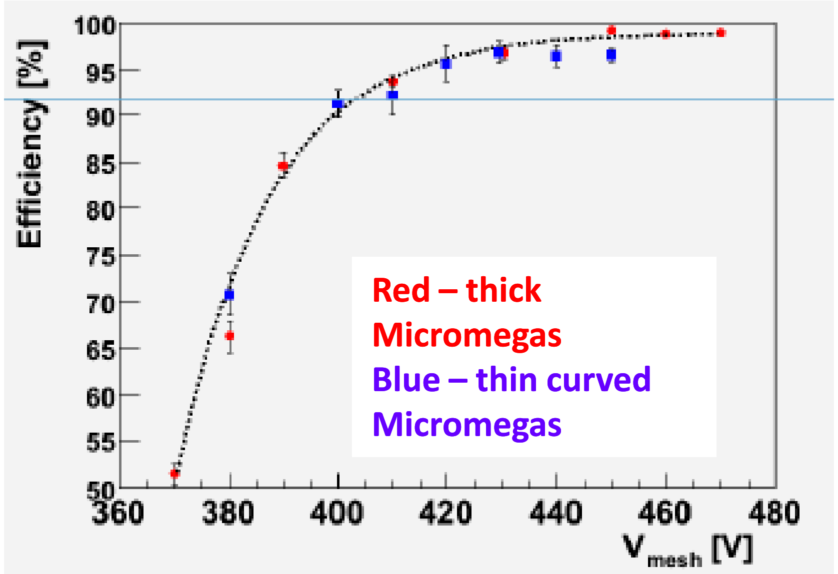
Micromegas ILC-TPC,
D. Attie



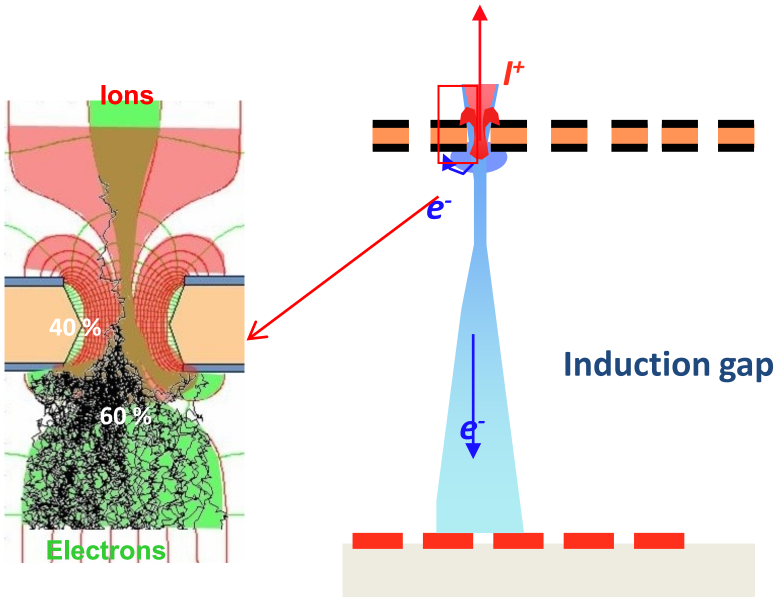


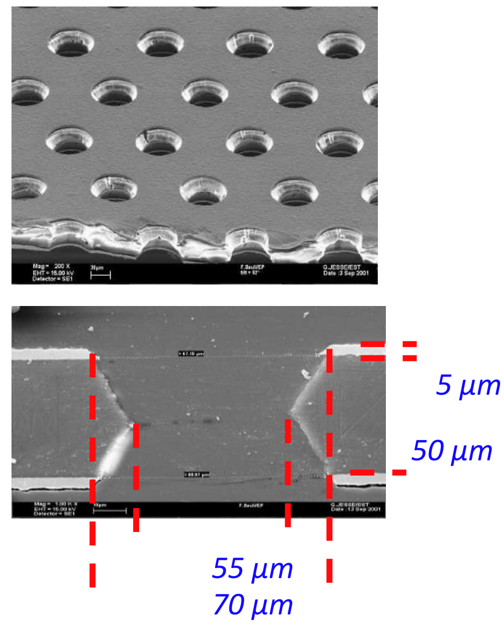
Curved Micromegas CAS12,
S. Aune

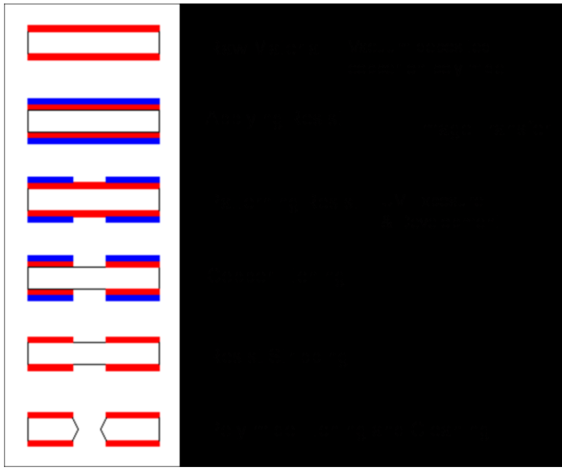


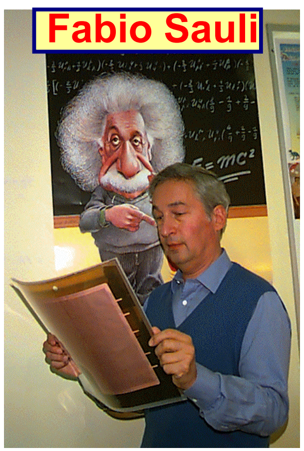


GEM – Gas Electron Multiplier





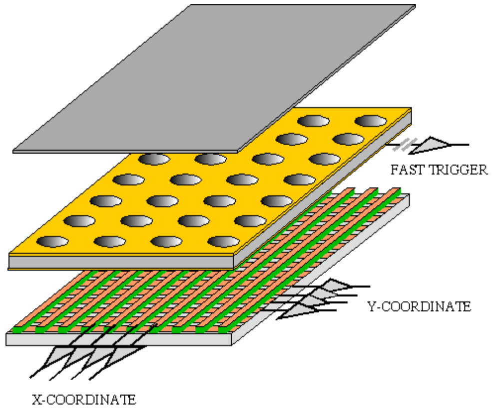




Thin, metal coated polyimide foil perforated with high density holes.

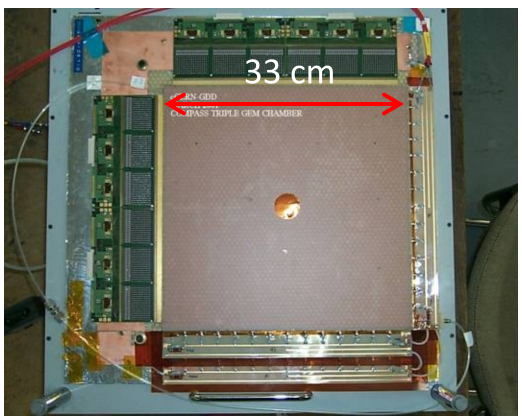
Electrons are collected on patterned readout board.
A fast signal can be detected on the lower GEM electrode for triggering or energy discrimination.
All readout electrodes are at ground potential.
Positive ions partially collected on the GEM electrodes.

GEM – Gas Electron Multiplier



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

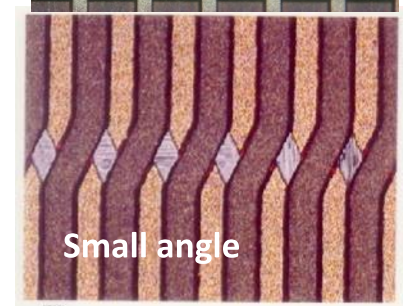
A. Bressan et al, Nucl. Instr. and Meth. A425(1999)254



Compass

Totem

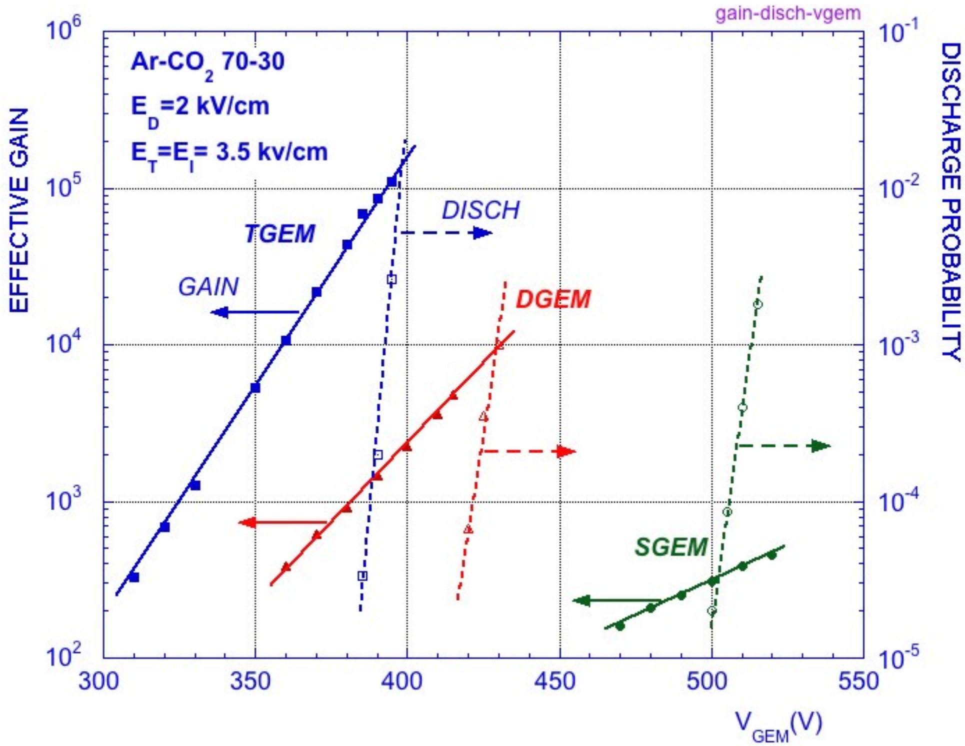
Both detectors use three GEM foils in cascade for amplification to reduce discharge probability by reducing field strength.

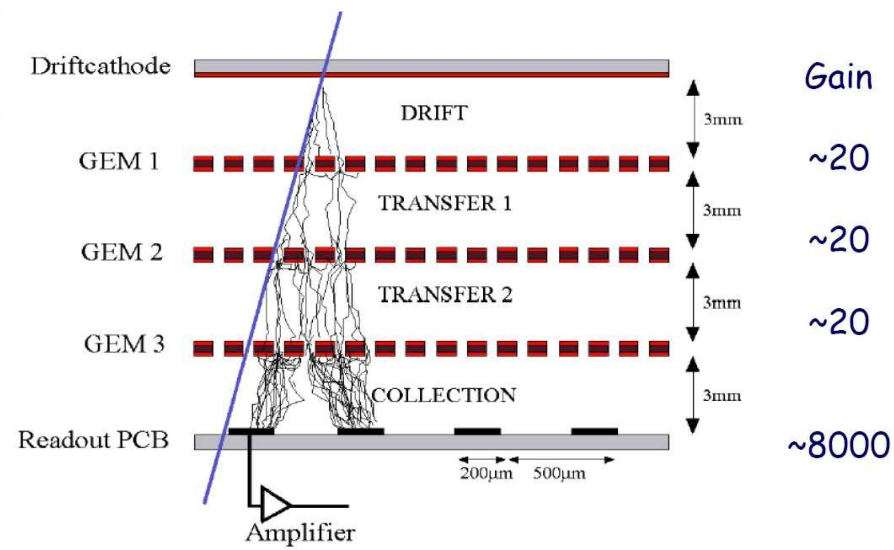


Multi-GEM Detectors

Discharge Probability on Exposure to 5 MeV Alphas

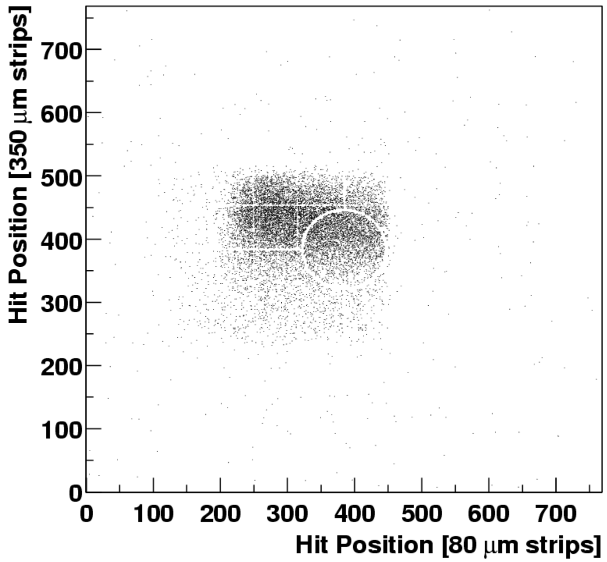
Multiple structures provide equal gain at lower voltage.
Discharge probability on exposure to a particles is strongly reduced.

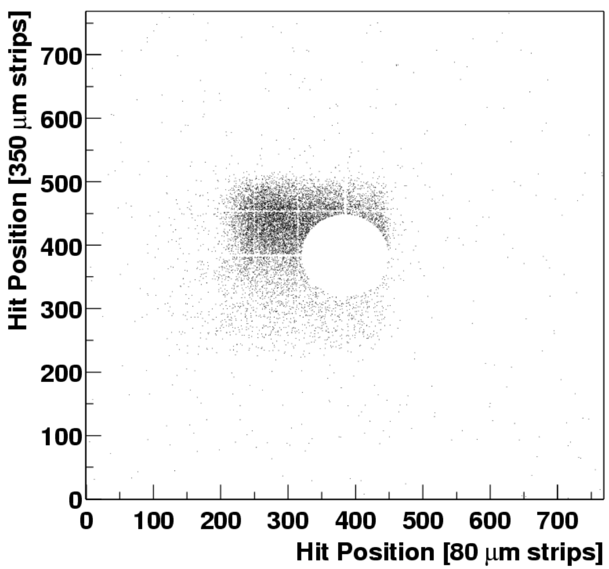


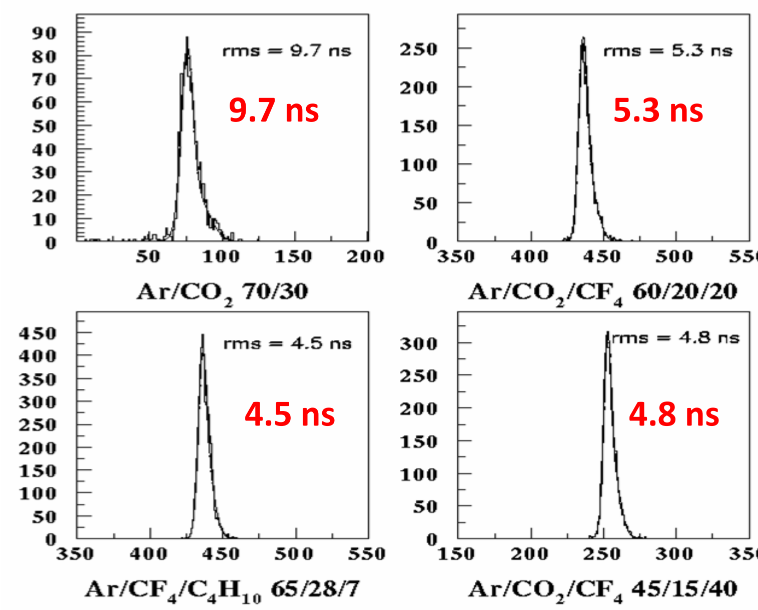


S. Bachmann et al Nucl. Instr. and Meth. A479(2002)294

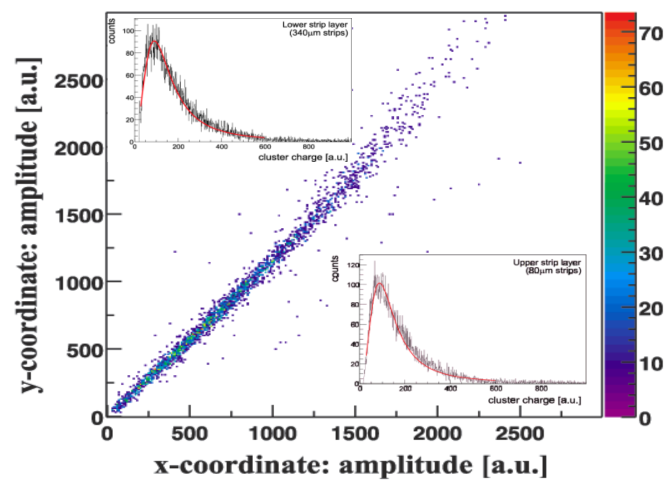
GEM – Gas Electron Multiplier







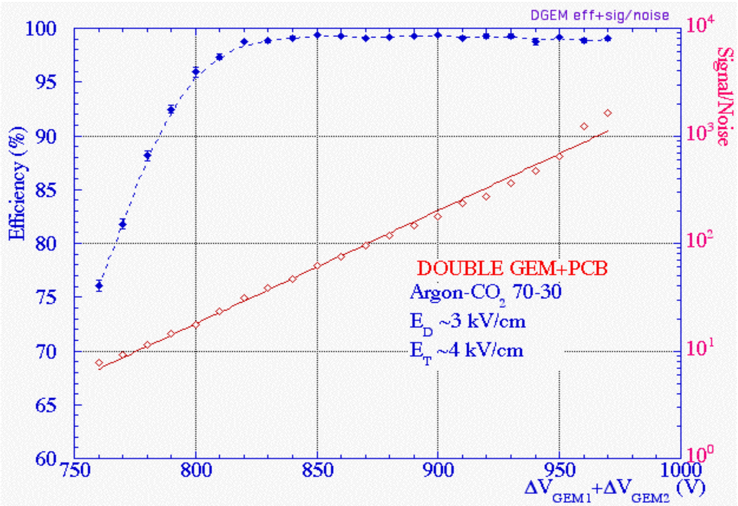
Time resolution



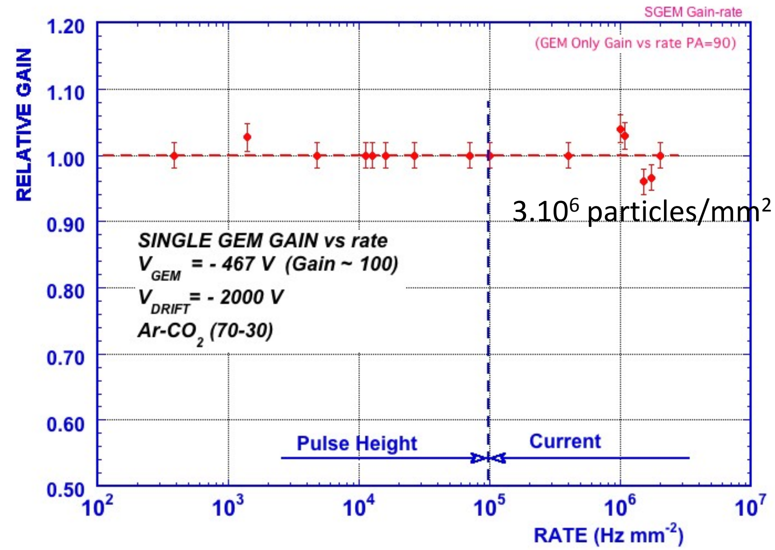
Charge correlation (Cartesian readout)

GEM – Gas Electron Multiplier

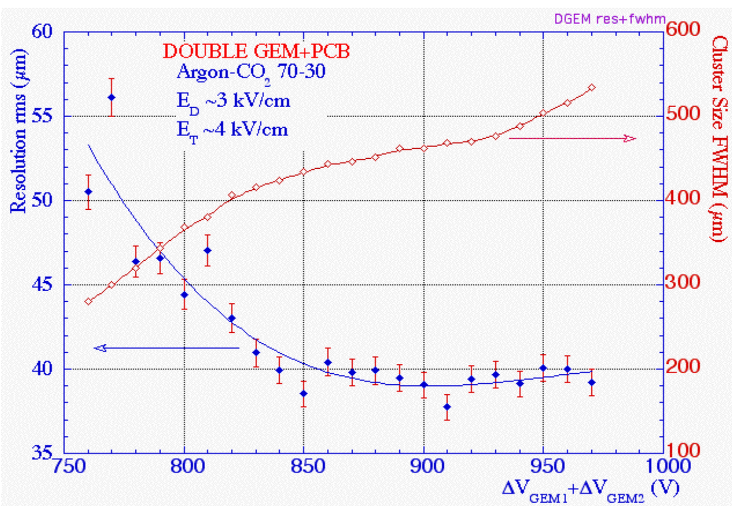
A. Bressan et al, Nucl. Instr. And Meth. A425(1999)262



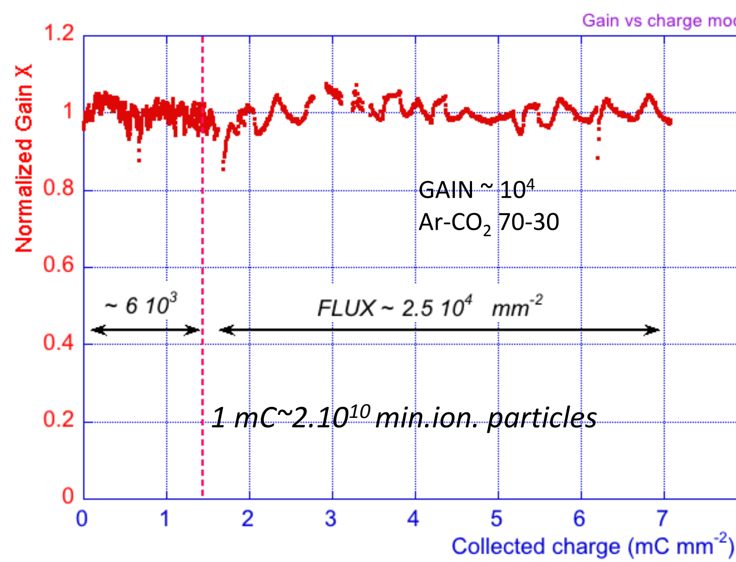
Efficiency for minimum ionizing particles with 3 mm gap



Rate capability > 10^6 Hz mm^{-2}



Space resolution ~ 40 μm rms
Cluster size ~ 500 μm FWHM

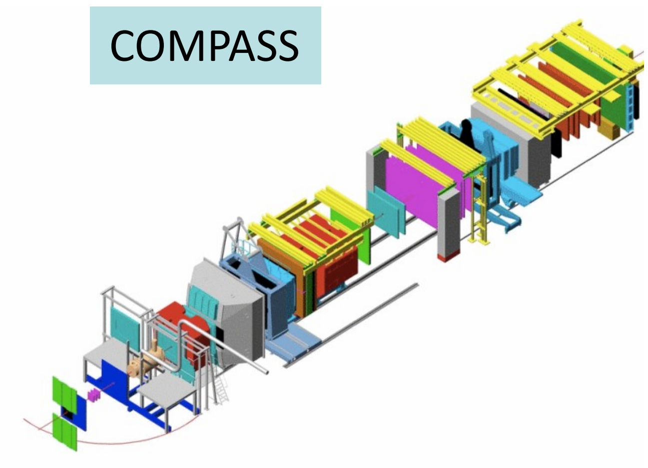


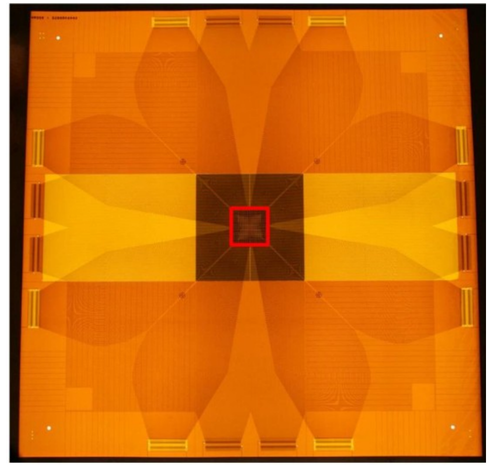
C. Altunbas et al, DESY Aging Workshop (Nov. 2001) Nucl. Instr. and Meth. A
J. Benlloch et al, IEEE NS-45(1998)234

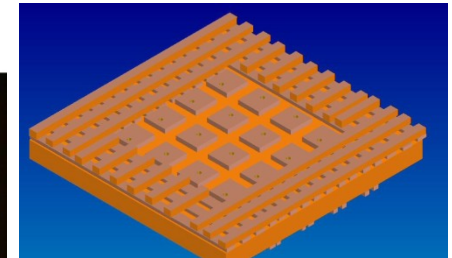
GEM – Gas Electron Multiplier

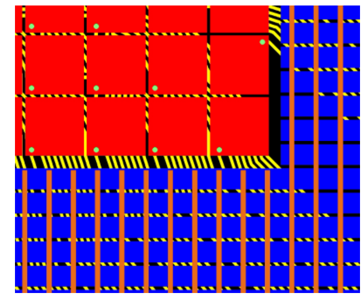
Pixel GEM

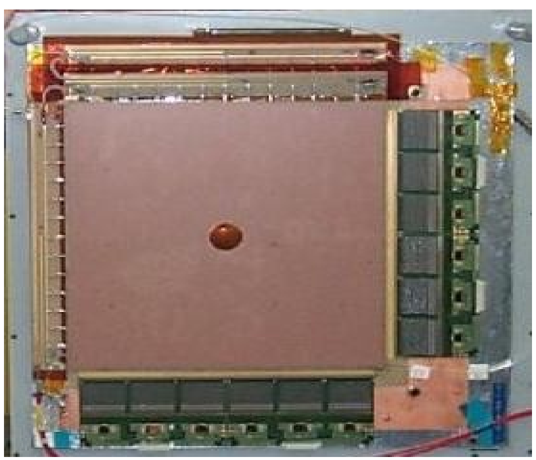
COMPASS

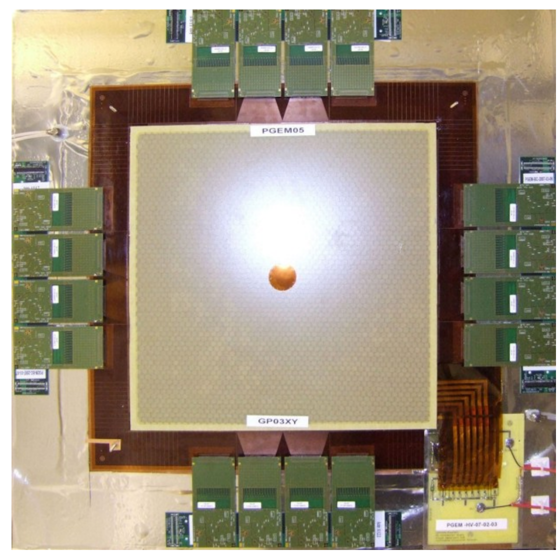






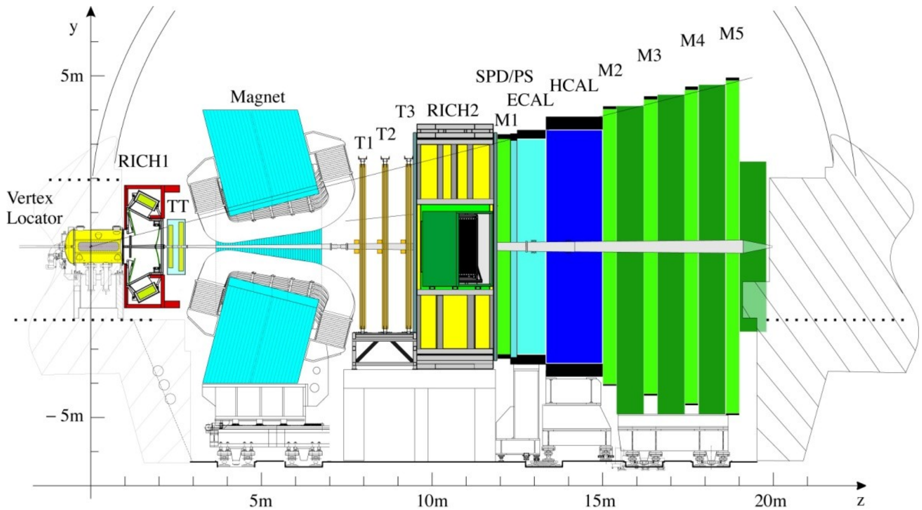






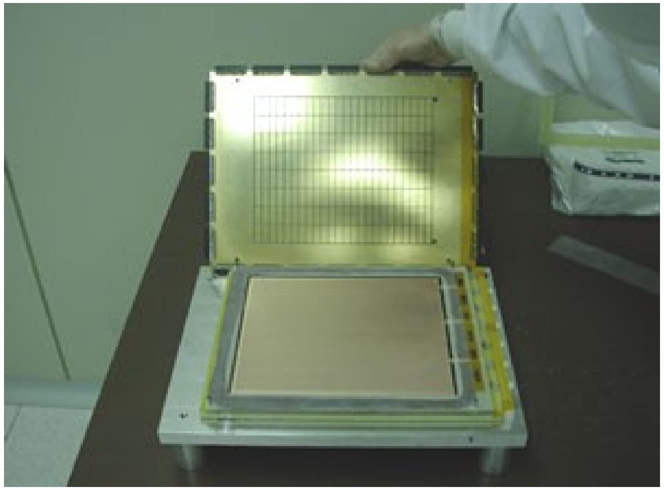
LHCb Muon Trigger

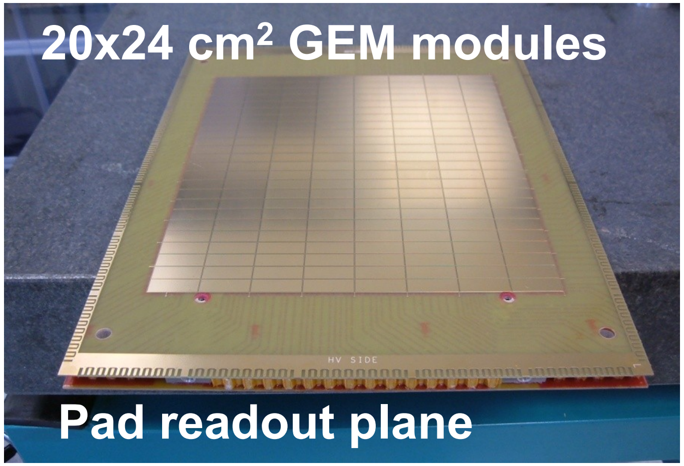
Fast TripleGEM Detectors for LHCb Muon Trigger



12 double TGEM detectors operated with fast gas mixture (Ar-CO_2-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)

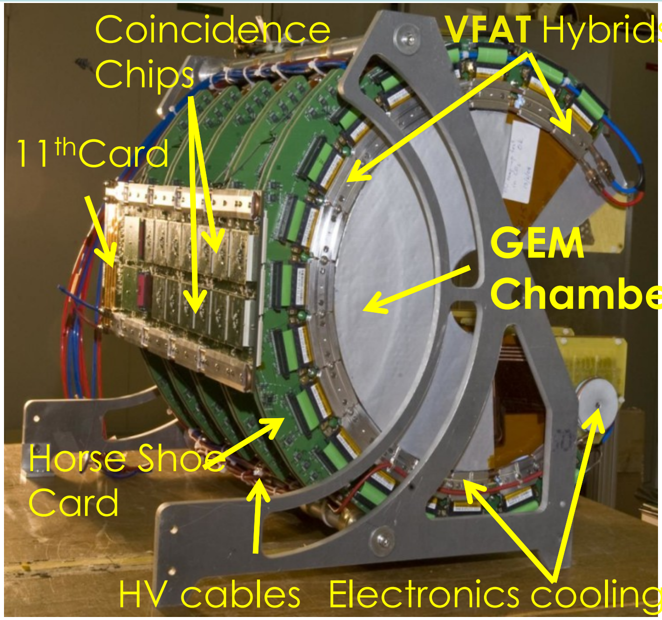


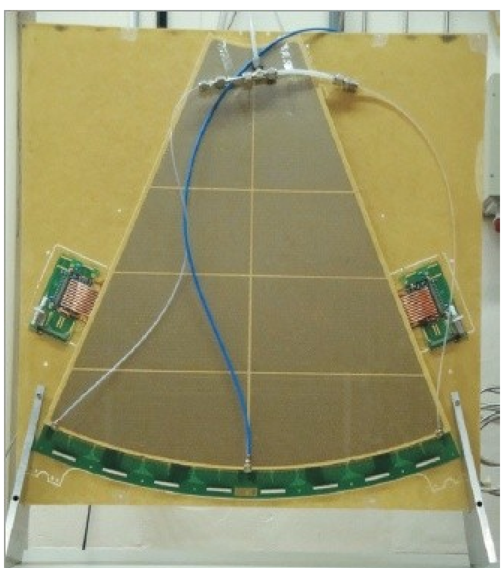


M. Alfonsi et al, Nucl. Instr. and Meth. A535(2004)319

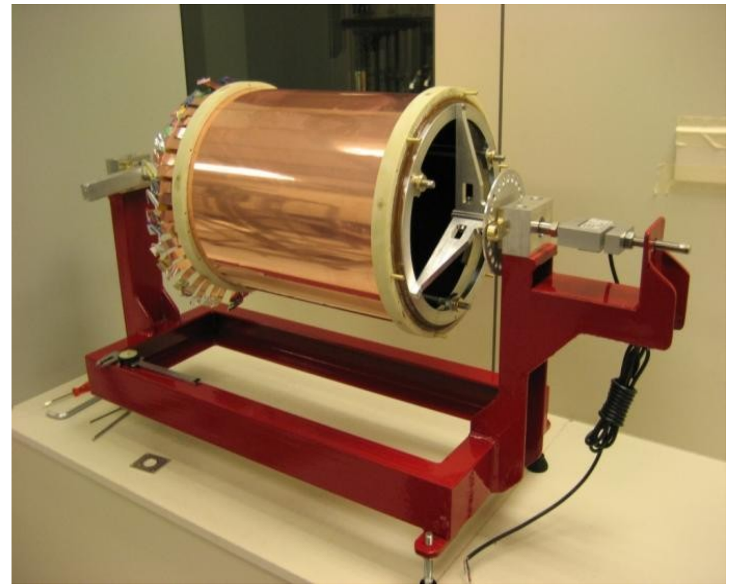
GEM – Gas Electron Multiplier

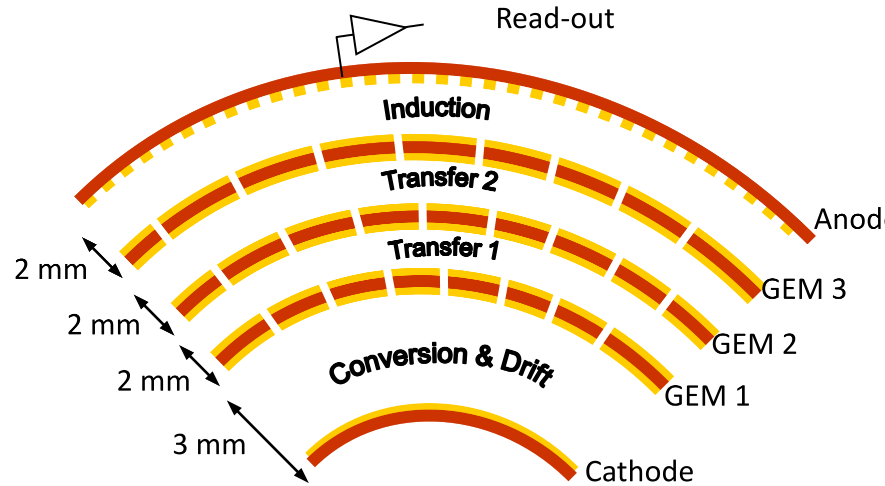
TOTEM GEMs, T. Hilden,V. Greco…



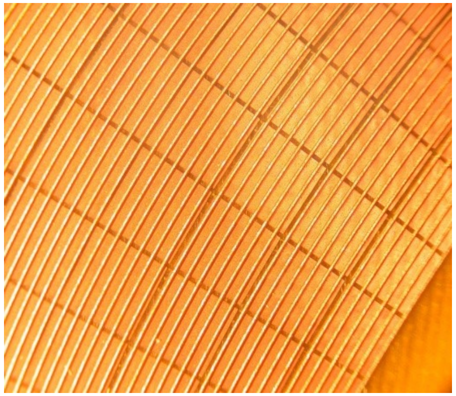


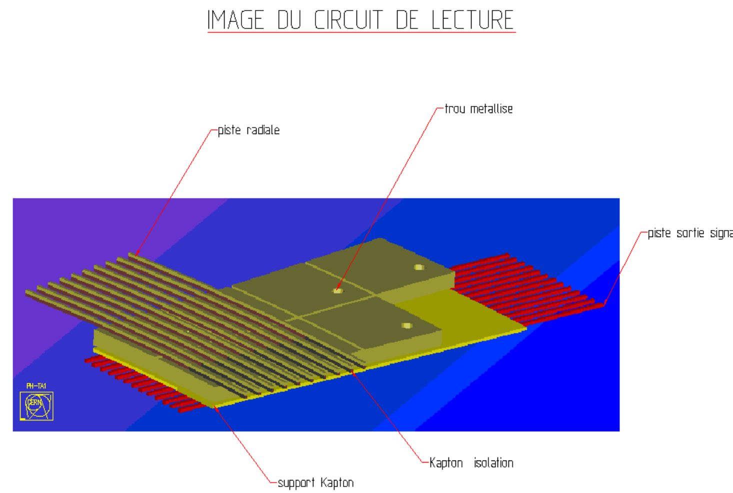
KLOE2 - Cylindrical Triple GEM

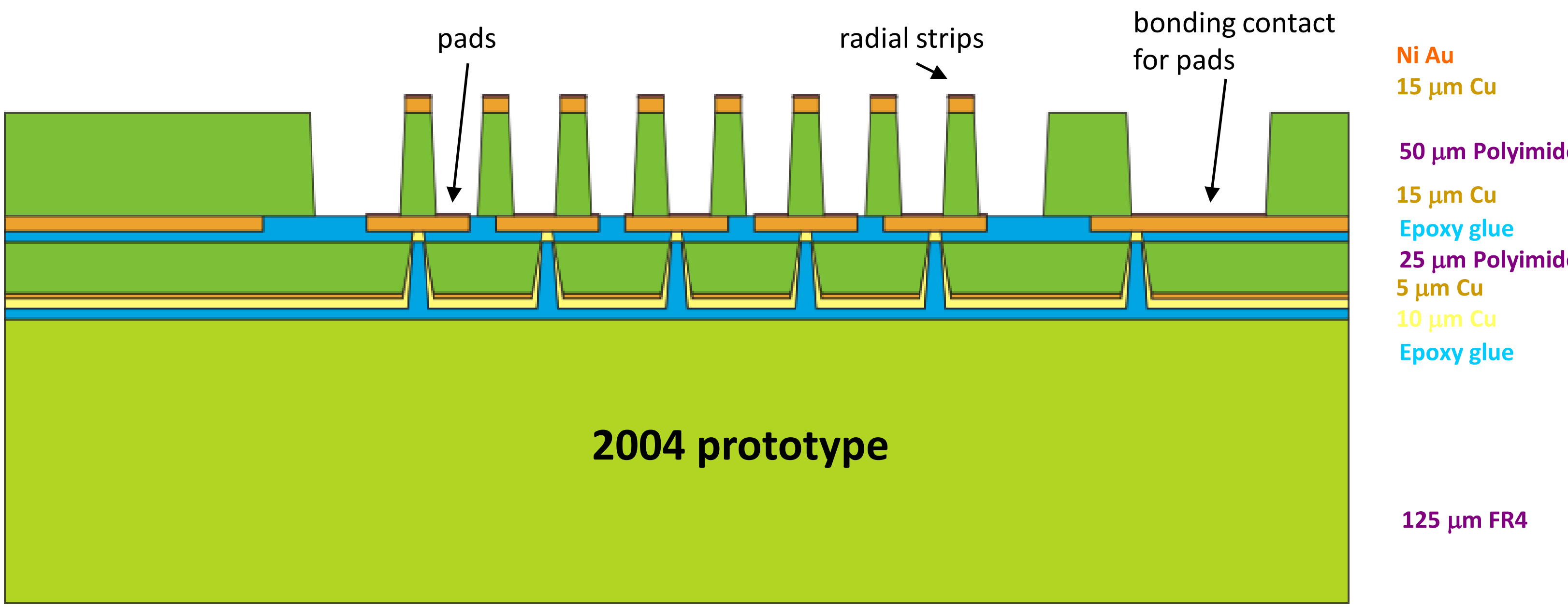




TOTEM GEM - Readout Board

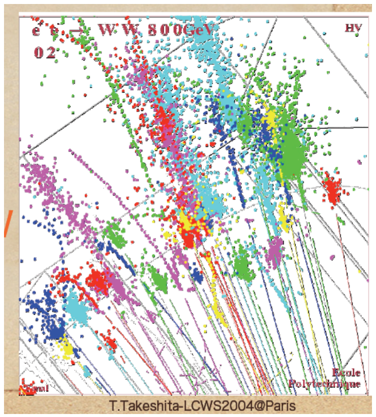


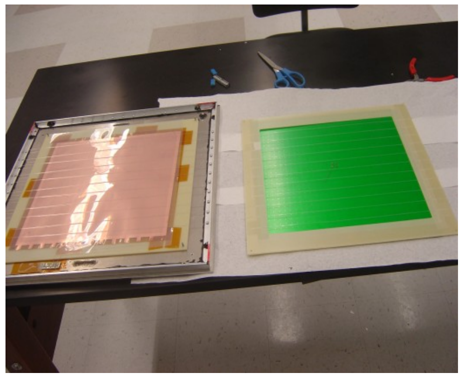


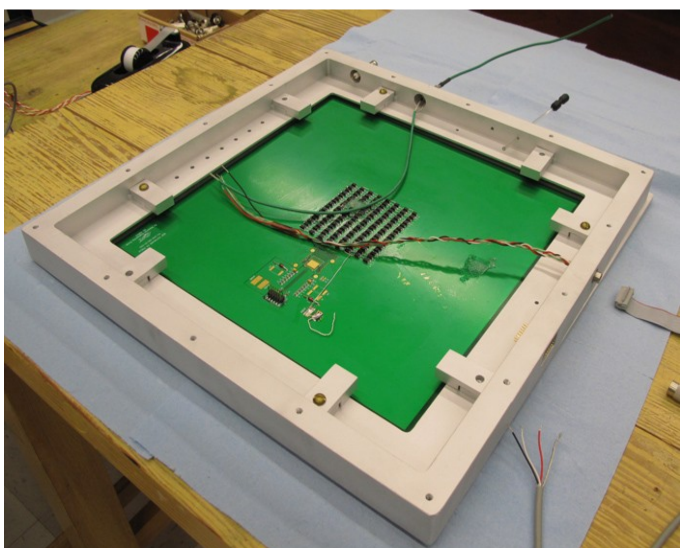


GEM – Gas Electron Multiplier

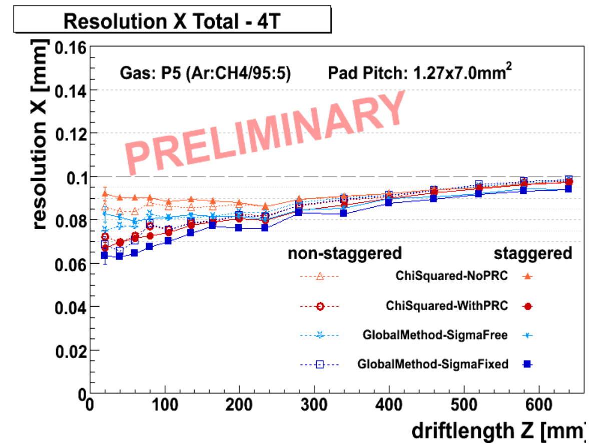
GEM HCAL, A. White



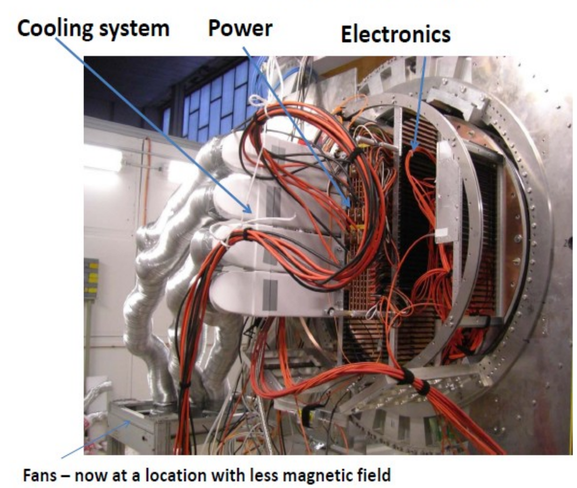




GEM ILC TPC,
T. Matsuda

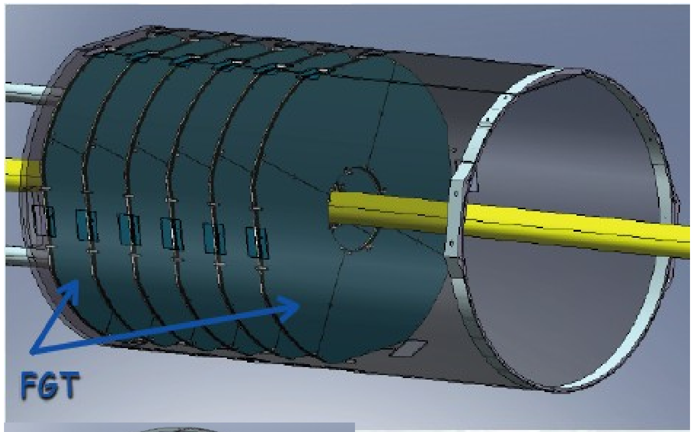


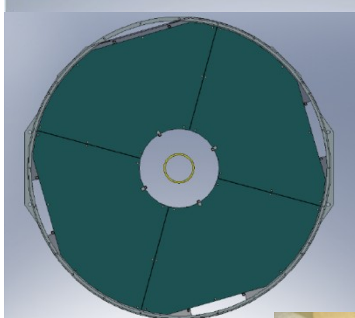
Rotatated for cosmics



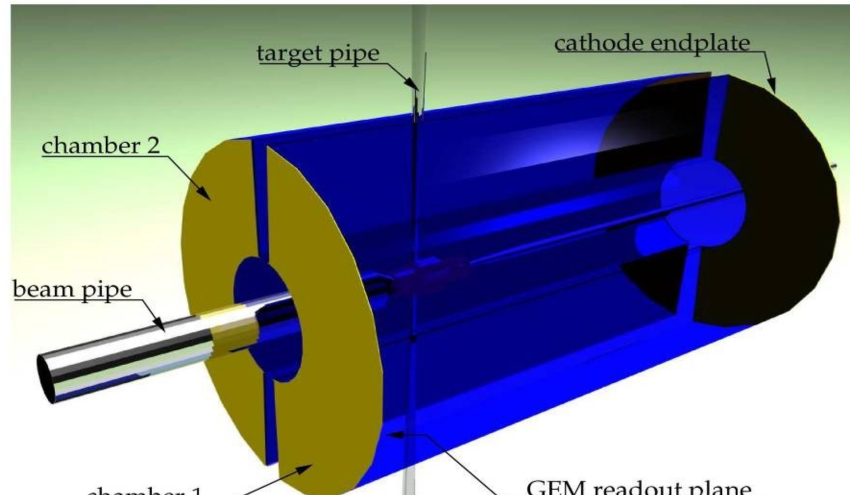
GEM – Gas Electron Multiplier

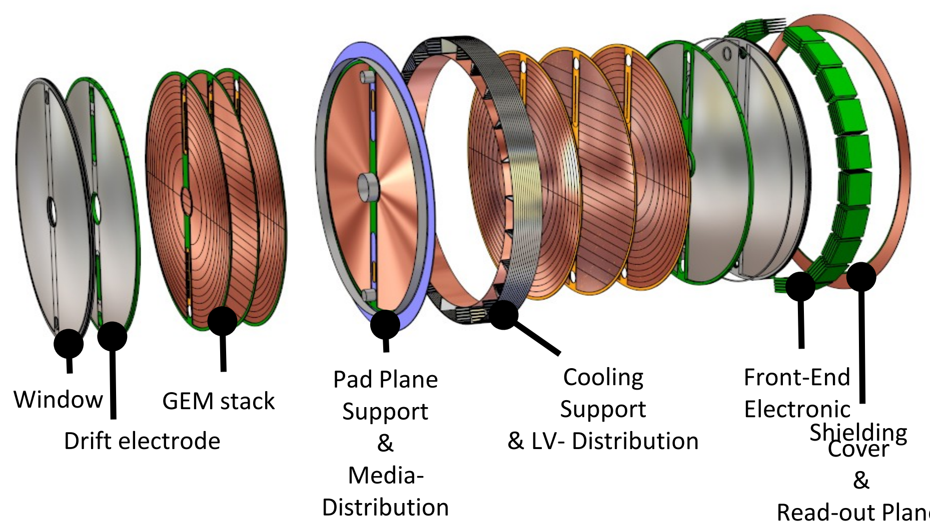
B. Surrow, STAR GEM





PANDA TPC and Planar Trackers , X. Zhang



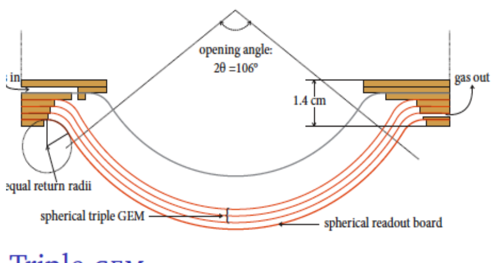


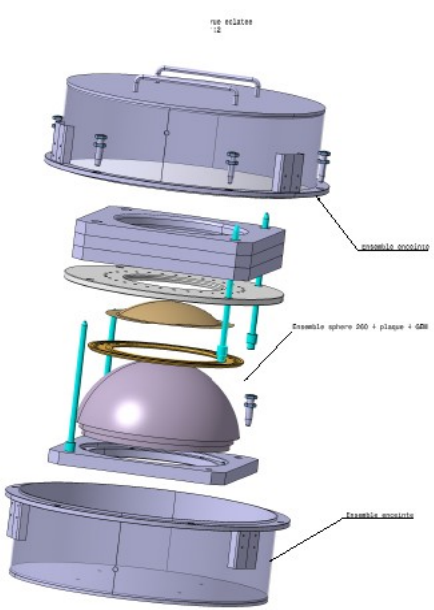
GEM – Gas Electron Multiplier

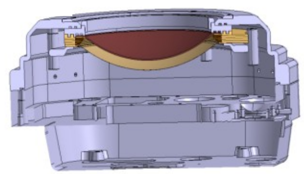
Spherical GEM, S. D. Pinto

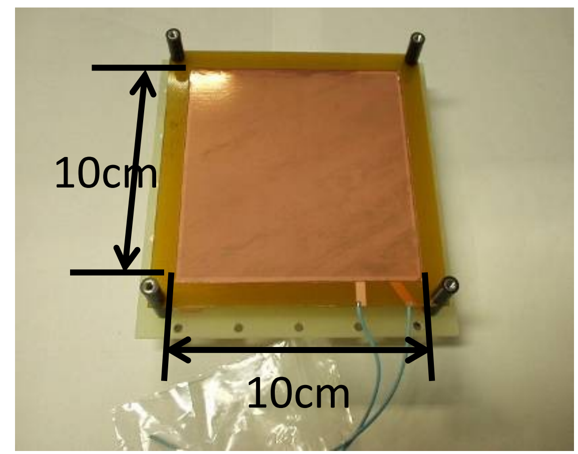
Spherical GEM
for X-Ray diffraction application

Japanese GEMs
S. Uno



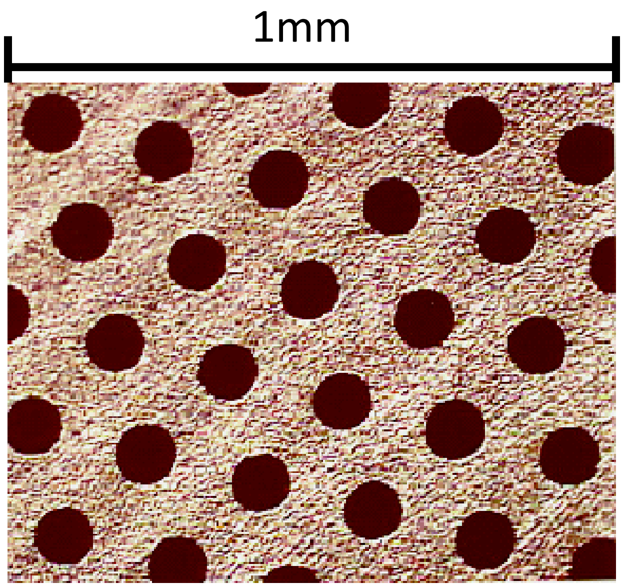






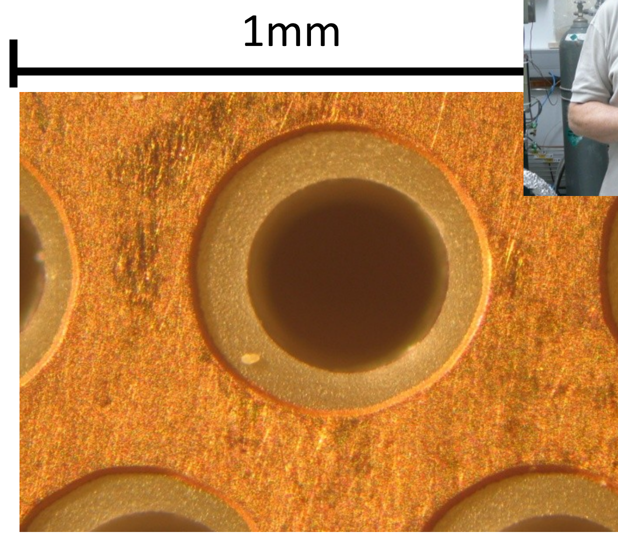
THGEM – Thick GEM / RetGEM Resistive Thick GEM

Standard GEM



- Microlithography + etching
- High Spatial resolution (tens of microns); V_{GEM}~400V
- >10^3 gain in single GEM
- 10^6 gain in cascaded GEMs
- Fast (ns)
- Low pressure – gain~30

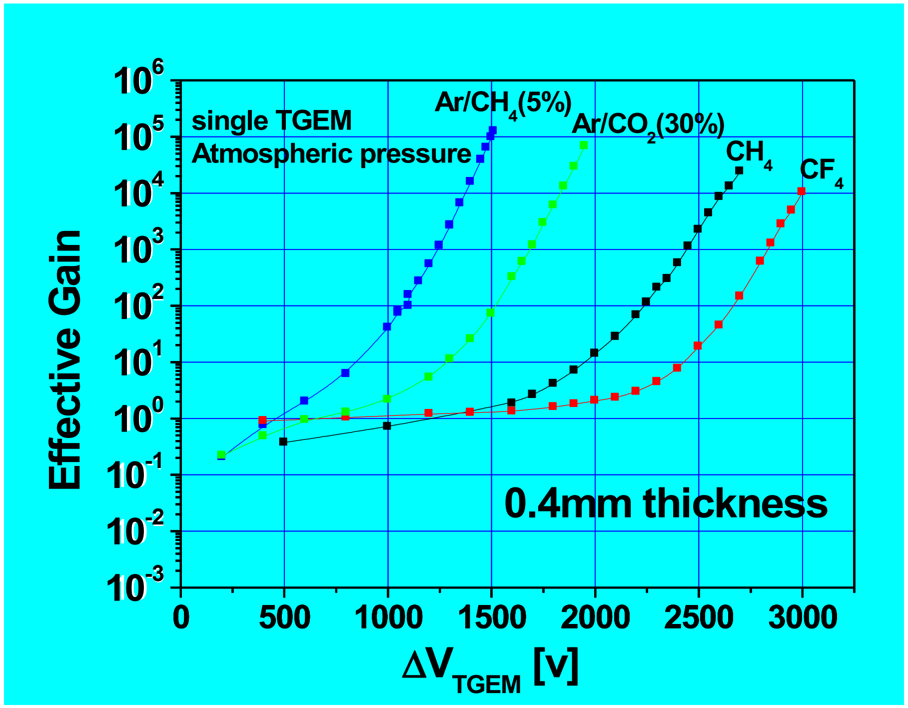
THGEM

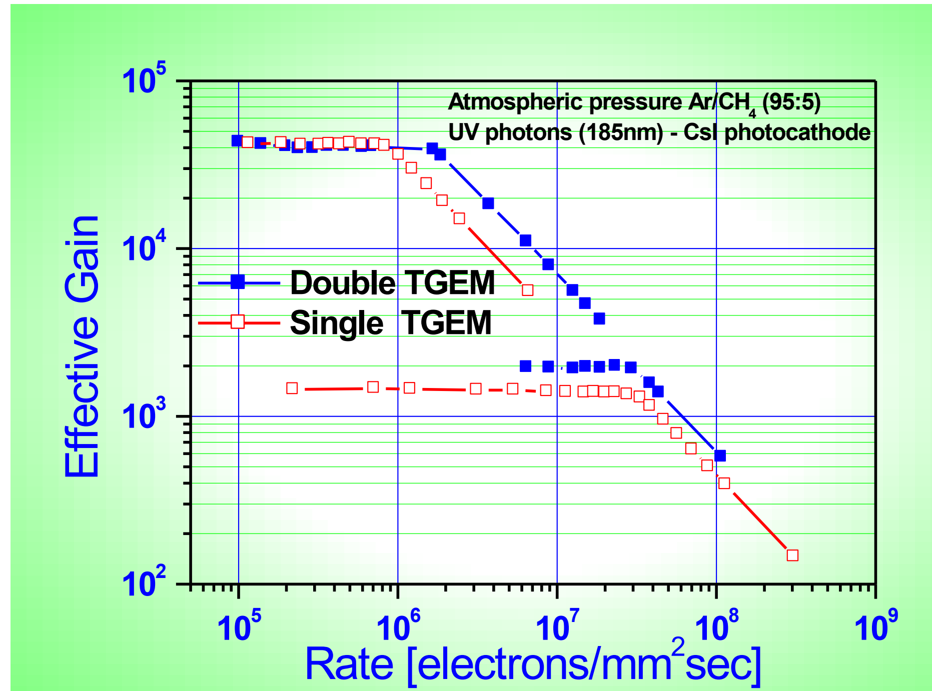


- PCB tech - etching + drilling
- Simple and robust
- V_{TGEM}~2KV (at atmospheric pressure)
- 10^5 gain in single- & 10^7 double-TGEM
- Sub-mm to mm special resolution
- Fast (ns)
- Low pressure (<1Torr) gain 10^4

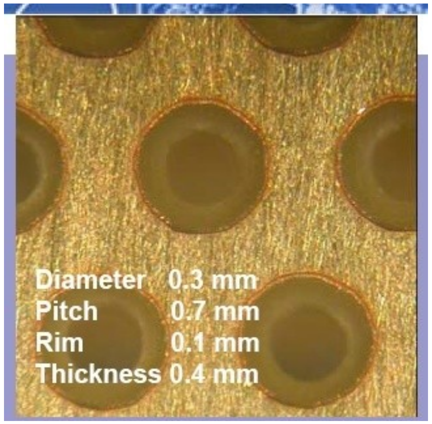
V. Peskov, A. Breskin …

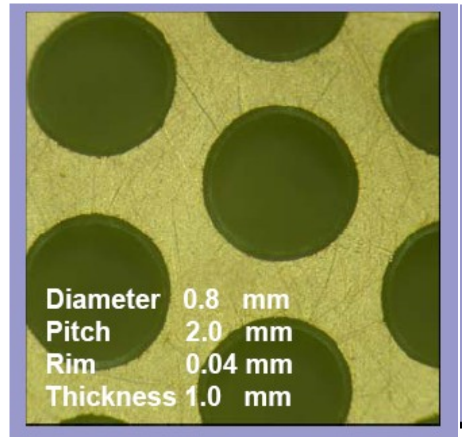
THGEM – Thick GEM / RetGEM Resistive Thick GEM

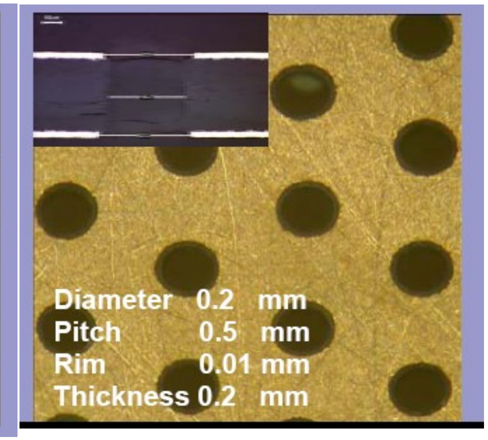




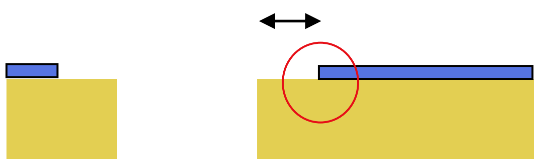
THGEM – Thick GEM / RetGEM Resistive Thick GEM

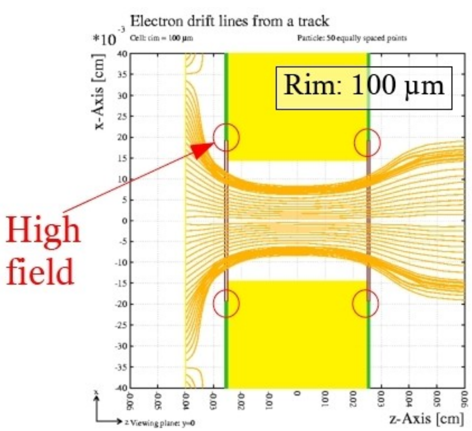


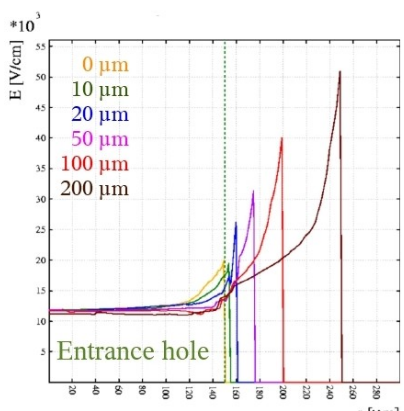




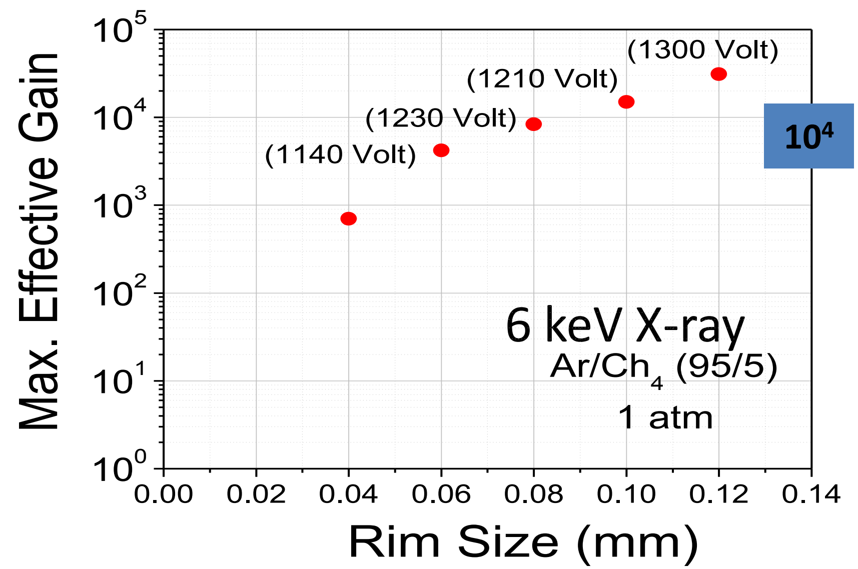
Mask etching + drilling; rim = 0.1mm





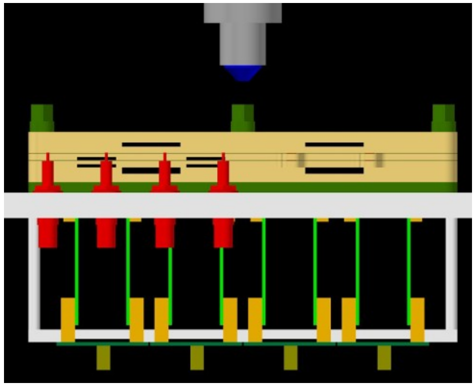


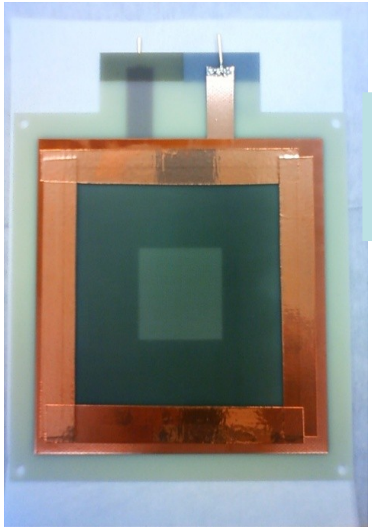
Drilling + chemical rim etching without mask



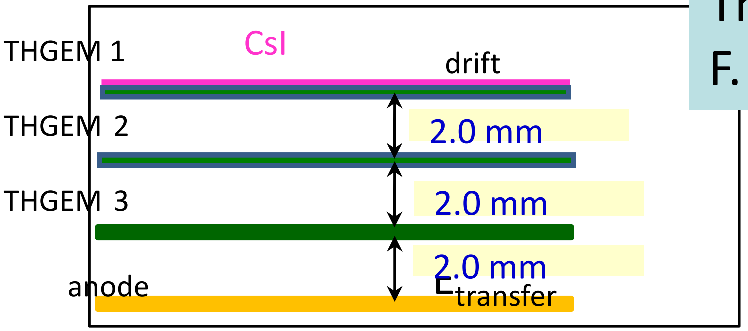
pitch = 1 mm; **diameter** = 0.5 mm;
rim=40; 60; 80; 100; 120 µm

THGEM – Thick GEM / RetGEM Resistive Thick GEM



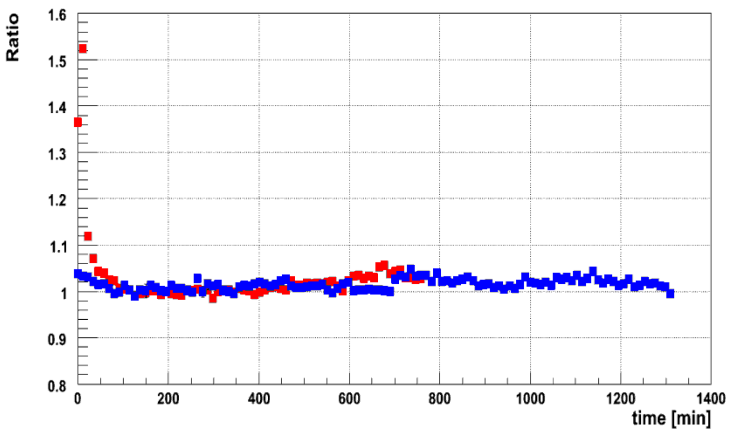


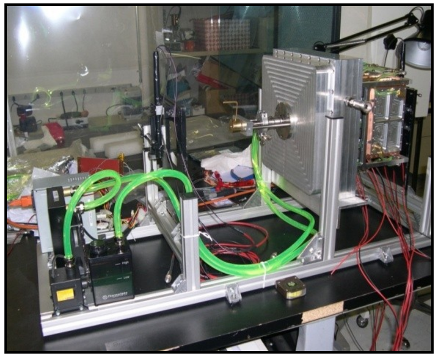
RET-thick GEM
R. Akimoto

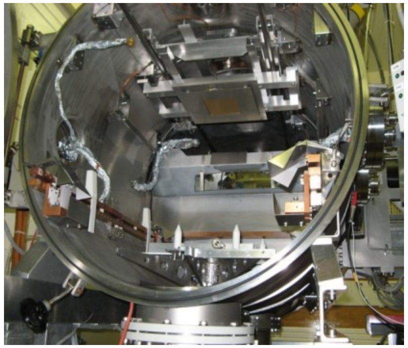


Thick GEM
F. Tessaroto

- Gain increase → stability gets worsen.
- At first few hours, gain drops down.
- After that, the fluctuation of gain is within ±4%.



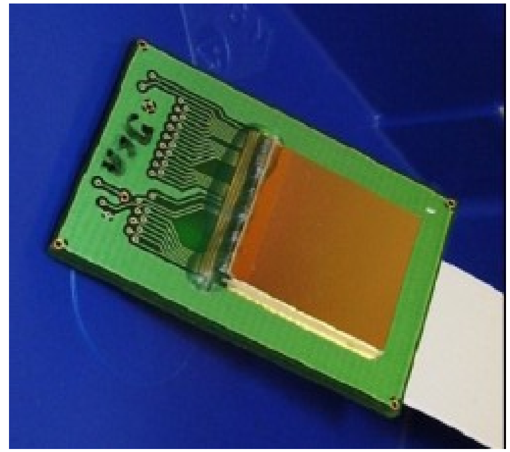




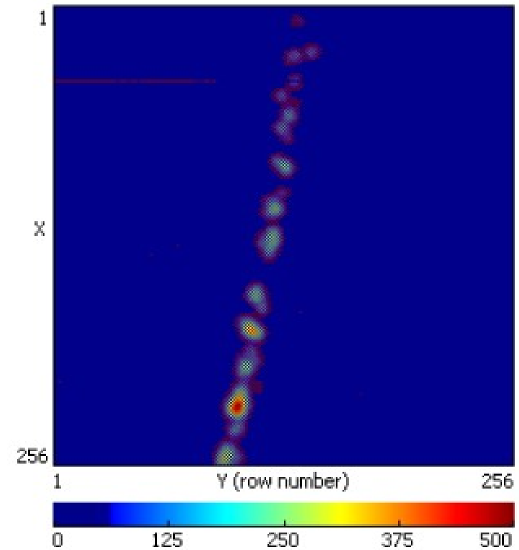
Pixel MPGDs

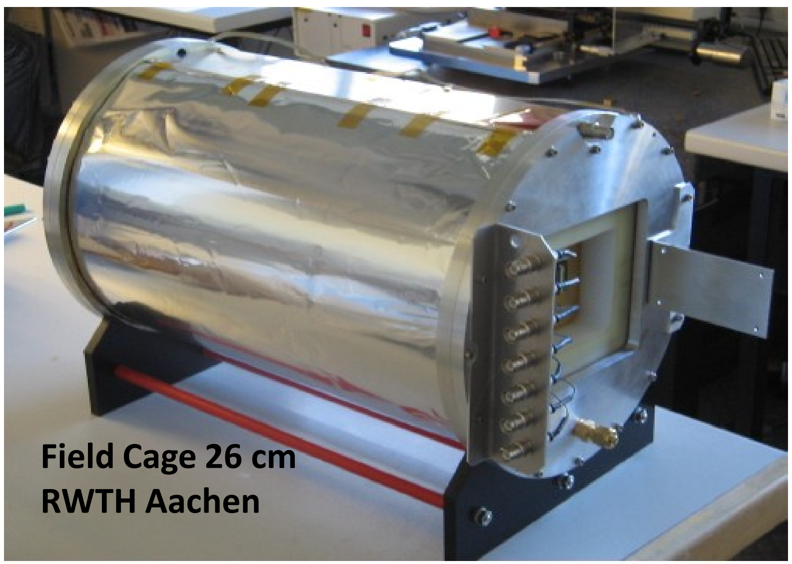
Triple GEM TPC with Solid State Pixel Readout

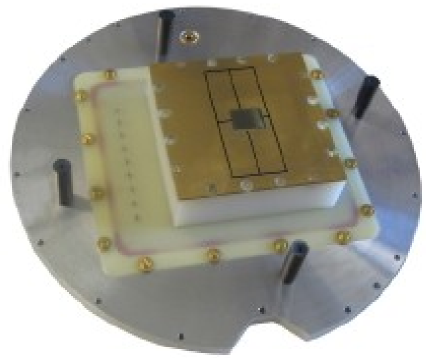
TIMEPIX
256x256 pixels, 55x55µm^2
14x14 mm^2 active area

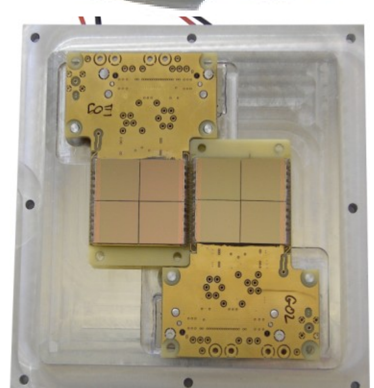


Cosmic track: short Drift

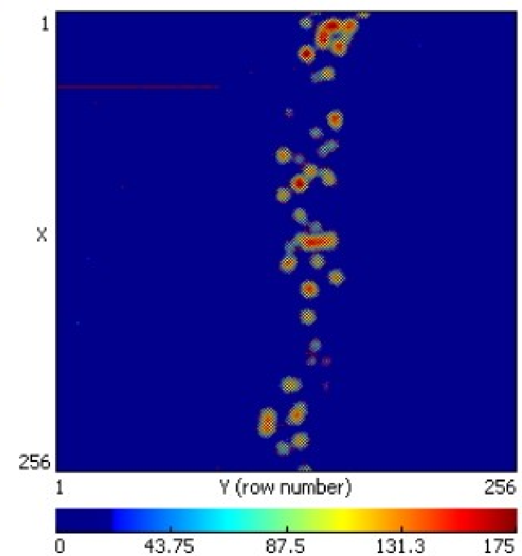








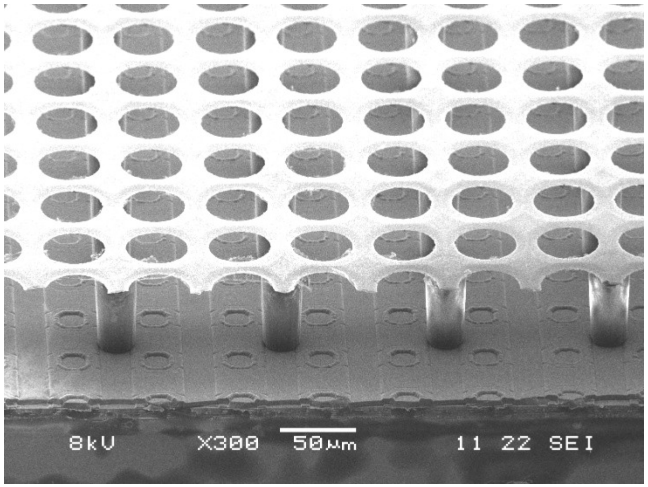
Long Drift:

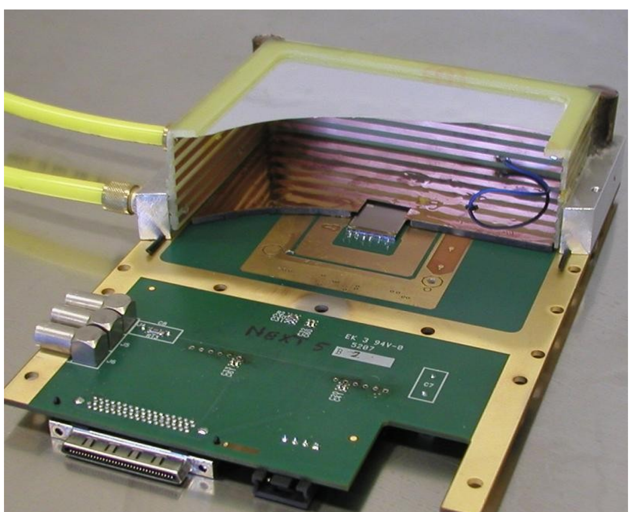


J. Kaminski, RD51 Workshop, Paris (October 2008)
Bonn University ILC-TPC

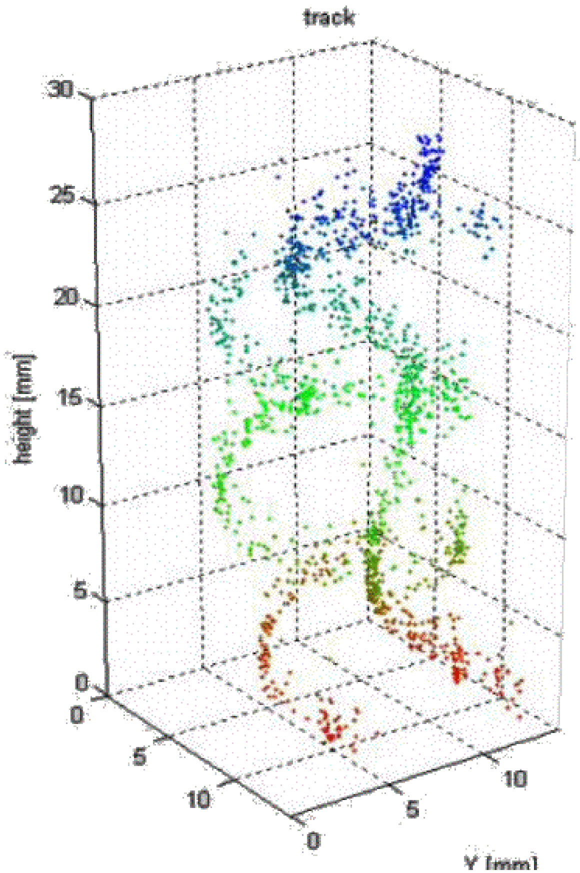
INGRID

Integrated Micromegas and Pixel Sensor
Postprocessing of the TIMEPIX chip to build a metal mesh on insulating pillars





Electron tracks from ^{90}Sr in magnetic field (0.2 T):

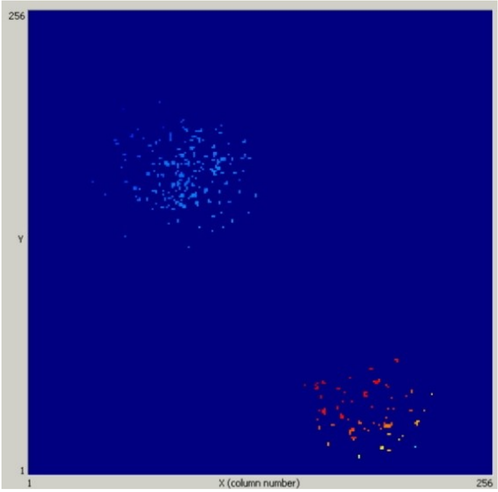


H. Van der Graaf ,
IEEE Nucl. Sci. Symp. Conf. Rec. (Dresden, October 2008)

Singe Electron Count

Intrinsic Energy Resolution
Due to low pixel capacitance and noise, the device can detect individual electrons released in the gas by an X-ray source.The pixel count provides the best energy resolution (statistical limit):

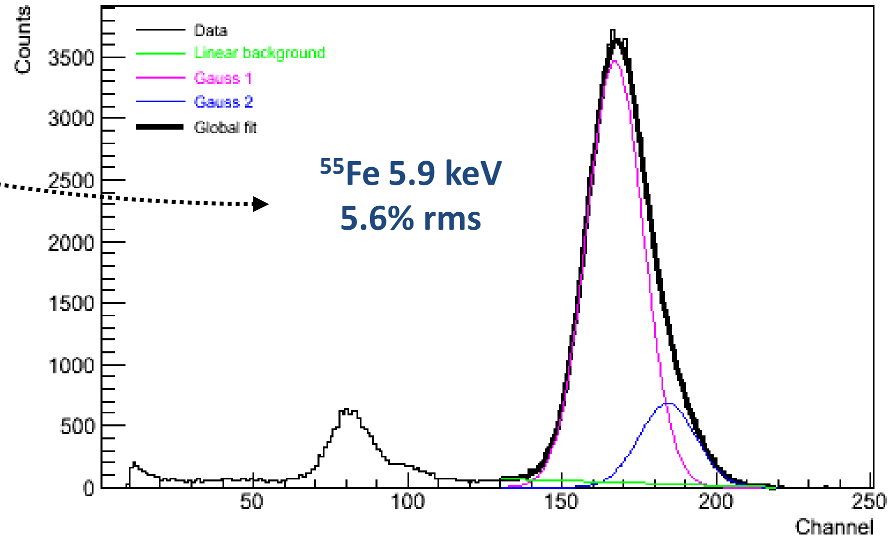
$$\frac{\sigma_E}{E} = \frac{1}{\sqrt{N}}$$



For 5.9 keV in Argon (N≈220):

$$\frac{\sigma_E}{E} \approx 6\%$$

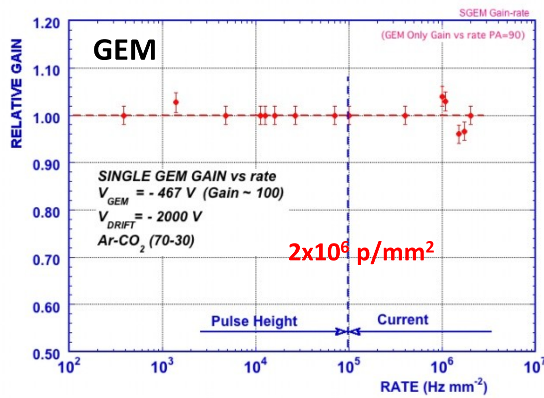
^{55}Fe rays conversions in Argon

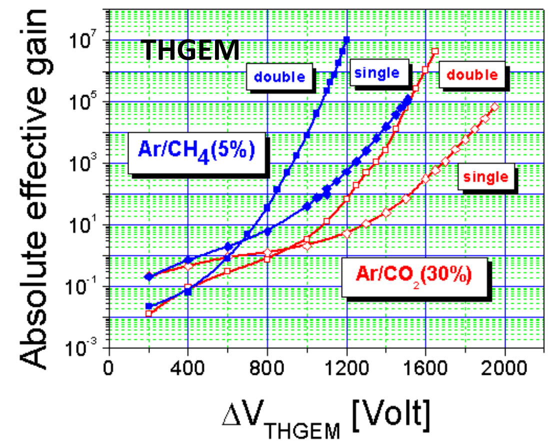


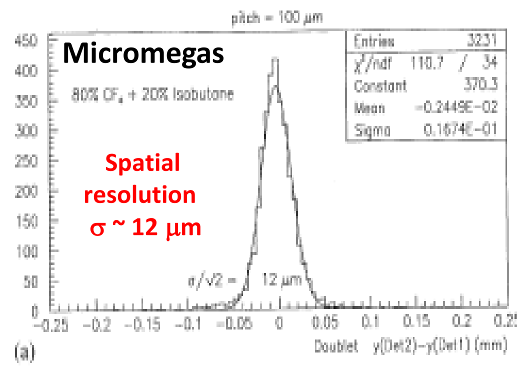
P. Colas, IEEE Nucl. Sci. Symp. Conf. Rec. (Dresden, Oct. 2008)

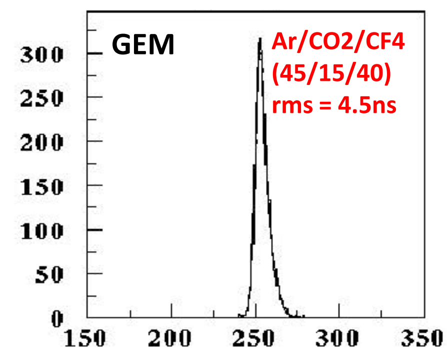
Micro-Pattern Gas Detectors Performance Summary

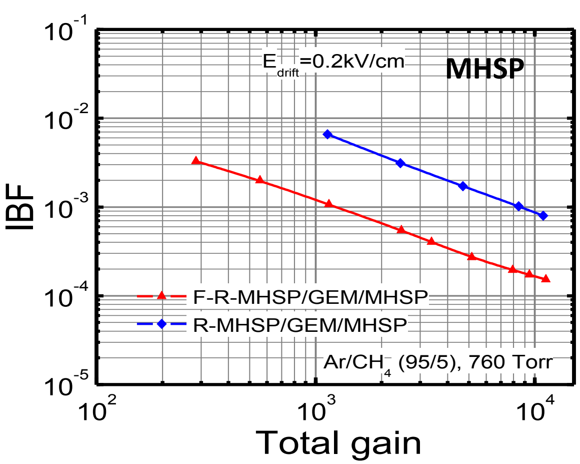
- Rate Capability
- High Gain
- Space Resolution
- Time Resolution
- Energy Resolution
- Ageing Properties
- Ion Backflow Reduction
- Photon Feedback Reduction

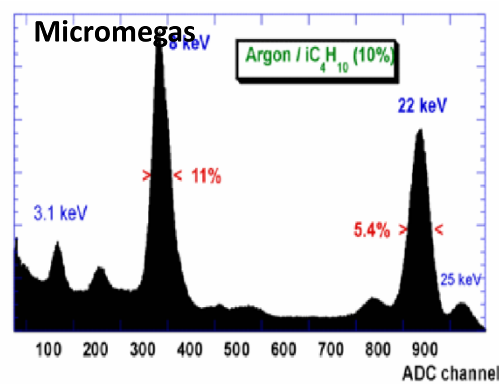


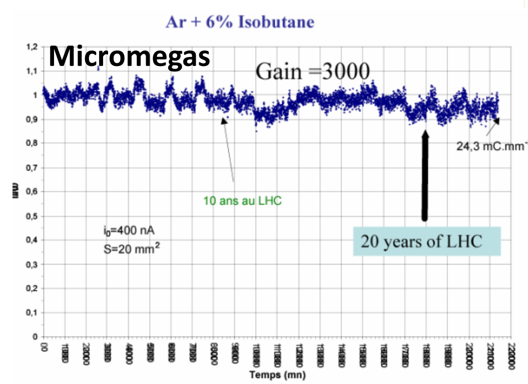








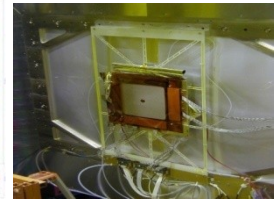


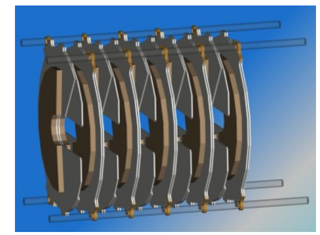


Spare Slides

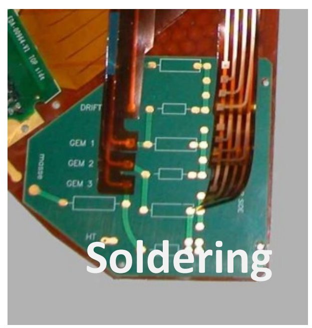
Production Aspects

Detector Design

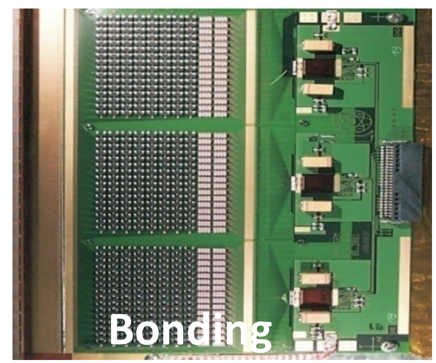



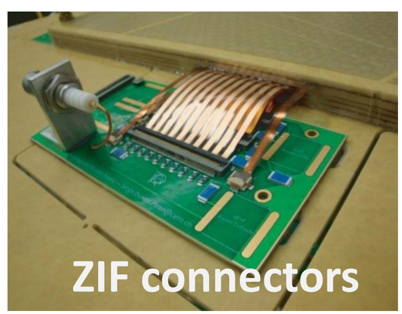



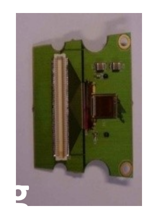

Services and Connectivity



Soldering

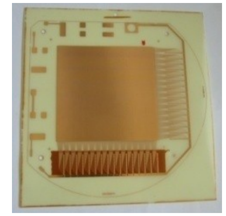
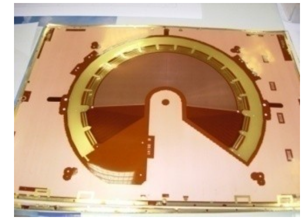
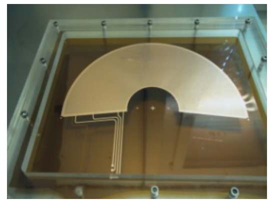

Bonding

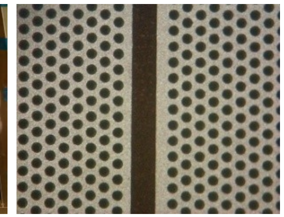
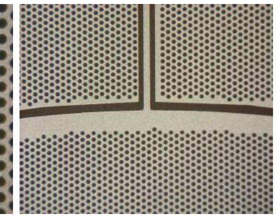
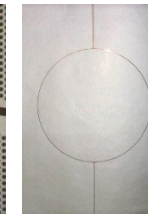

ZIF connectors



Soldering

Production Aspects

Component Production

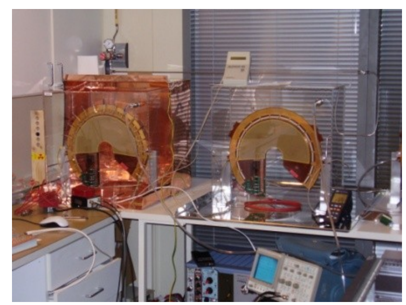
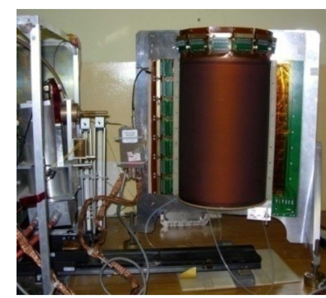





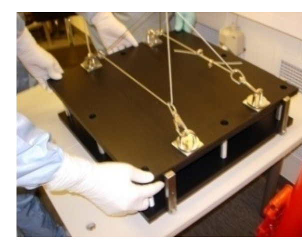


Infrastructure and Assembly Tools



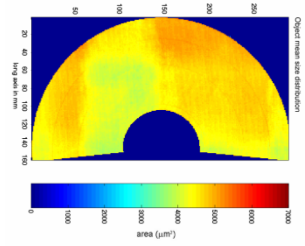



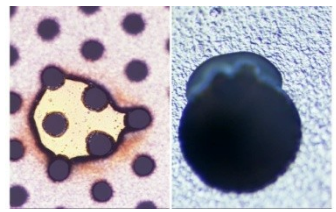


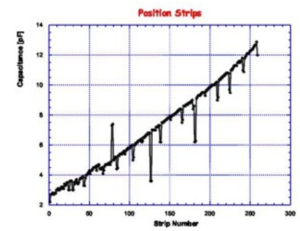


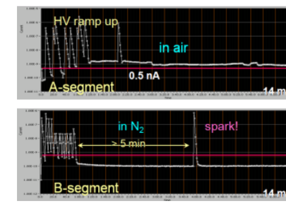
Production Aspects

Component Quality Control

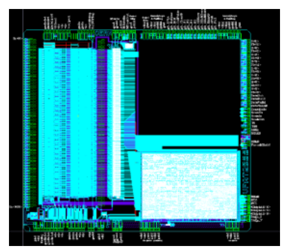


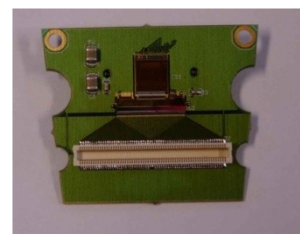


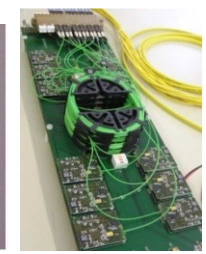




Electronics

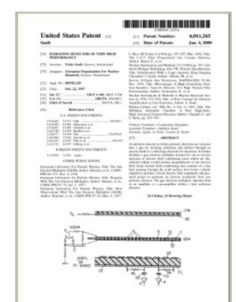






APV
VFAT
GP5
ALTRO
MEDIPIX

Industrialization



PANalytical
3M
TechEtch
Techtra
Centronic
G&A

RD51 Collaboration: Motivation and Main Objectives

The main objective of the R&D programme is to advance technological development of Micropattern Gas Detectors

Estimated time scale – 5 years

1. Optimize detectors design, develop new multiplier geometries and techniques
2. Develop common test and quality standards
3. Share common infrastructure (e.g. test beam and radiation hardness facilities, detectors and electronics production and test facilities)
4. Share investment of common projects (e.g. technology development, electronics development, submissions/production)
5. Setup a common maintainable software package for gas detectors simulations
6. Common production facility
7. Optimize communication and sharing of knowledge/experience/results
8. Collaboration with industrial partners
9. The existence of the RD51 collaboration, endorsed by the LHCC, will support and facilitate the acquisition of funding from national and other agencies.

RD51 Collaboration

Alessandria, Italy, Dipartimento di Scienze e Technologie Avanzate, Universita del Piemonte Orientale and INFN sezione Torino
Amsterdam, Netherlands,Nikhef
Annecy-le-Vieux, France, Laboratoire d'Annecy-le-Vieux de Physique des Particules (LAPP)
Argonne, USA, High Energy Physics Division, Argonne National Laboratory
Arlington, USA, Department of Physics, University of Texas
Athens, Greece, Department of Nuclear and Elementary Particle Physics, University of Athens
Athens, Greece, Institute of Nuclear Physics, National Centre for Science Research "Demokritos"
Athens, Greece, Physics Department, National Technical University of Athens
Aveiro, Portugal, Departamento de Física, Universidade de Aveiro
Barcelona, Spain, Institut de Fisica d'Altes Energies (IFAE), Universtitat Autònoma de Barcelona
Bari, Italy, Dipartimento Interateneo di Fisica del'Universtà and sezione INFN
Bonn, Germany, Physikalisches Institut, Rheinische Friedrich-Wilhelms Universität
Braunschweig, Germany, Physikalisch Technische Bundesanstalt
Budapest, Hungary, Institute of Physics, Eötvös Loránd University
Budapest, Hungary, KFKI Research Institute for Particle and Nuclear Physics, Hungarian Academy of Sciences
Bursa, Turkey, Institute for Natural and Applied Sciences, Uludag University
Cagliari, Italy, Dipartimento di Fisica dell'Universtà and sezione INFN
Coimbra, Portugal, Departemento de Fisica, Universidade de Coimbra
Coimbra, Portugal, Laboratorio de Instrumentacao e Fisica Experimental de Particulas
Columbia, USA, Department of Physics and Astronomy, University of South Carolina
Frascati, Italy, Laboratori Nazionale di Frascati, INFN
Freiburg, Germany, Physikalisches Institut, Albert-Ludwigs Universität
Geneva, Switzerland, CERN
Geneva, Switzerland, Département de Physique Nucléaire et Corpusculaire, Universite de Genève
Grenoble, France, Laboratoire de Physique Subatomique et de Cosmologie (LPSC)
Hefei, China, University of Science and Technology of China
Helsinki, Finland, Hesinki Institute of Physics
Kolkata, India, Saha Institute of Nuclear Physics
Lanzhou, China, School of Nuclear Science and Technology, Lanzhou University
Melbourne, USA, Department of Physics and Space Science, Florida Institute of Technology
Mexico City, Mexico, Instituto de Ciencias Nucleares, Universidad Nacional Autonoma de Mexico
Montreal, Canada, Département de physique, Université de Montréal
Mumbai, India, Tata Institute of Fundamental Research, Department of Astronomy & Astrophysics
Műnchen, Germany, Physik Department, Technische Universität
Műnchen, Germany, Max Planck Institut fűr Physik
Naples, Italy, Dipartimento di Scienze Fisiche dell'Università and sezione INFN
New Haven, USA, Department of Physics, Yale University
Novara, Italy, TERA Foundation
Novosibirsk, Russia, Budker Institute of Nuclear Physics
Ottawa, Canada, Department of Physics, Carleton University
Rehevot, Israel, Radiation Detection Physics Laboratory, The Weizmann Institute of Sciences
Rome, Italy, INFN Sezione di Roma, gruppo Sanità and Istituto Superiore di Sanità
Saclay, France, Institut de recherche sur les lois fondamentales de l'Univers, CEA
Sheffield, Great Britain, Physics Department, University of Sheffield
Siena, Italy, Dipartimento di Fisica dell'Università and INFN Sezione di Pisa
St Etienne, France, Ecole Nationale Superieure des Mines
St Petersburg, Russia, St Petersburg Nuclear Physics Institute
Thessaloniki, Greece, Physics Department Aristotle University of Thessaloniki
Trieste, Italy, Dipartimento di Fisica dell'Università and Sezione INFN
Tucson, USA, Department of Physics, University of Arizona
Tunis, Tunisia, Centre Nationale des Sciences et Technologies Nucléaire
Upton, USA, Brookhaven National Laboratory
Valencia, Spain, Instituto de Fisica Corpuscular
Valencia, Spain, Universidad Politécnica
Zaragoza, Spain, Laboratorio de Física Nuclear y Astropartículas, Universidad de Zaragoza

350 authors from 64 Institutes
from 23 countries and 4 continents

RD51 Collaboration

400 authors from 70 Institutes
from 23 countries and 4 continents

- CERN MPGD workshop (10-11 September 2007)

  Micro Pattern Gas Detectors. Towards an R&D Collaboration. (10-11 September 2007)
- 1st draft of the proposal presentation during Nikhef meeting (17 April 2008)

  Micro-Pattern Gas Detectors (RD-51) Workshop, Nikhef, April 16-18, 2008
  Gas detectors advance into a second century - CERN Courier
- Collaboration and Management Board meetings in Amsterdam (17-18 April 2008)
- Conveners and Management Board meetings (10+15) RD51 MB meeting (2 October2009)
- Proposal sent to CB members (23 June 2008)
- Proposal presentation in LHCC open session (2 July 2008)

  94th LHCC Meeting Agenda (02-03 July 2008)
  CERN-LHCC-2008-011 (LHCC-P-011)
- Meeting with LHCC referees (23 September 2008)

  Meeting with LHCC referees (23 September 2008)
- LHCC meeting closed session (24 September 2008) LHCC-095 minutes
- 2nd RD51 Collaboration meeting (Paris 13-15 October 2008)

  2nd RD51 Collaboration Meeting (13-15 October 2008) ~100 participants; parallel session; ~60 presentations.

- **Research Board approval(5 December 2008)** 186th Research Board meeting minutes
- Memorandum of Understanding (37 signed; Common fund)
- Consolidation around common projects; DEM workshop upgrade, beam tests, electronics, software tools

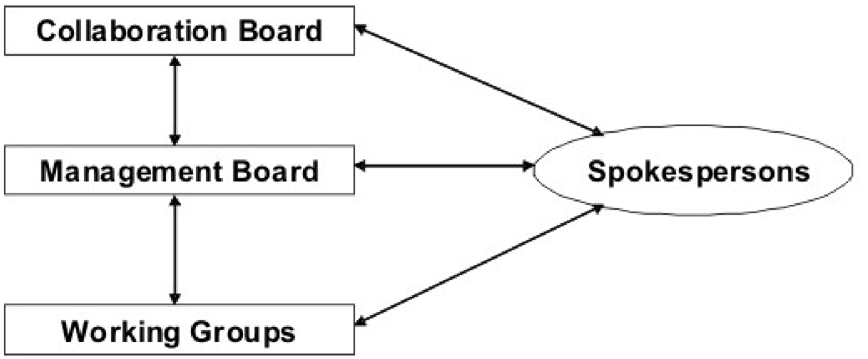
WG2 meeting (10 December 2008)
WG1-Task 1 meeting: large area MPGDs (21 January 2009)
GEM & Micromegas detector design & assembly training: Lecture Session (16 February 2009)
RD51 week (27-29 April 2009)
3rd RD51 Collaboration Meeting (Kolympari, Crete, June 16-17, 2009) and MPGD2009 Conference
RD51 Week (CERN, September 23-25, 2009)
4th RD51 Collaboration Meeting (CERN, November 23-25, 2009)

RD51 Collaboration – Working Groups

RD51 – Micropattern Gas Detectors

	WG1 MPGD Technology & New Structures	WG2 Characterization	WG3 Applications	WG4 Software & Simulation	WG5 Electronics	WG6 Production	WG7 Common Test Facilities
Objectives	Design optimization Development of new geometries and techniques	Common test standards Characterization and understanding of physical phenomena in MPGD	Evaluation and optimization for specific applications	Development of common software and documentation for MPGD simulations	Readout electronics optimization and integration with MPGD detectors	Development of cost-effective technologies and industrialization	Sharing of common infrastructure for detector characterization
Tasks	Large Area MPGDs Design Optimization New Geometries Fabrication Development of Rad-Hard Detectors Development of Portable Detectors	Common Test Standards Discharge Protection Ageing & Radiation Hardness Charging up and Rate Capability Study of Avalanche Statistics	Tracking and Triggering Photon Detection Calorimetry Cryogenic Detectors X-Ray and Neutron Imaging Astroparticle Physics Appl. Medical Applications Synchrotron Rad. Plasma Diagn. Homeland Sec.	Algorithms Simulation Improvements Common Platform (Root, Geant4) Electronics Modeling	FE electronics requirements definition General Purpose Pixel Chip Large Area Systems with Pixel Readout Portable Multi-Channel System Discharge Protection Strategies	Common Production Facility Industrialization Collaboration with Industrial Partners	Testbeam Facility Irradiation Facility

RD51 Scientific Organization:



Home - RD51 Collaboration
Collaboration Web Page

Members of the RD51 Collaboration Management Board (MB):

the two Co-Spokespersons: L.Ropelewski, M.Titov
the CB Chairperson and its deputy: S.Dalla Torre, A. White
MB members: A.Breskin, I.Giomataris, F.Sauli, H. van der Graaf, P. Colas, H. Taureg

Working Groups Conveners:

WG1 MPGD Technology & New Structures	P.Colas, S. Duarte Pinto
WG2 Common Characterization & Physics	H. van der Graaf , M. Chefdeville
WG3 Applications	F.Simon, A.White
WG4 Software & Simulations	A.Bellerive, R.Veenhof
WG5 Electronics	H. Muller, J. Kaminski
WG6 Production	R. de Oliveira, I.Giomataris, H.Taureg
WG7 Common Test Facilities	M.Alfonsi, Y. Tsipolitis

RD51 Collaboration status and organization

Consolidation around common projects: large area MPGD R&D, CERN/MPGD Production Facility, electronics developments, software tools, beam tests

WG1: large area Micromegas, GEM; THGEM R&D; MM resistive anode readout (discharge protection); design and detector assembly optimization; large area readout electrodes and electronics interface

WG2: radiation tolerance, discharge protection, rate effects, single-electron response, avalanche fluctuations, photo detection with THGEM, TPC (IBF) readout optimization

WG3: applications beyond HEP, industrial applications (X-ray diffraction, homeland security)

WG4: microtracking; neBEM field solver, electroluminescence simulation tool, Penning transfers, GEM charging up; MM transparency and signal, MM discharges

WG5: scalable readout system; Timepix multi-chip MPGD readout

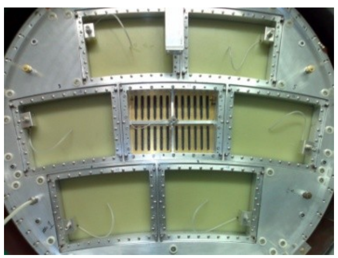
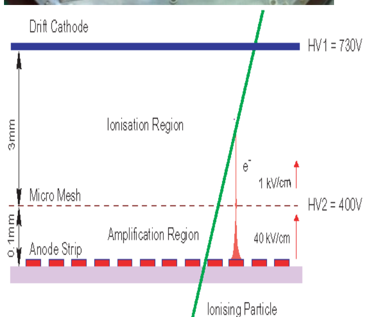
WG6: CERN MPGD Production Facility; TT Network

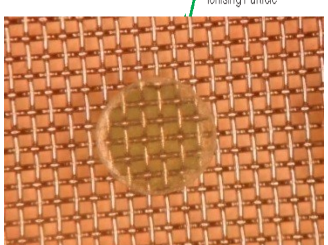
WG7: RD51 test beam facility (November 2009 - 8 groups/5 setups)

Development of large-area MPGDs

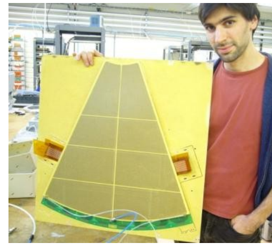
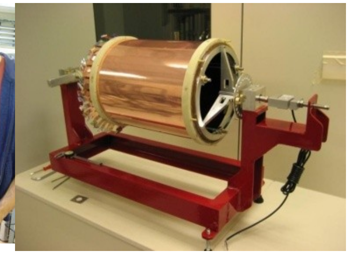
Bulk Micromegas

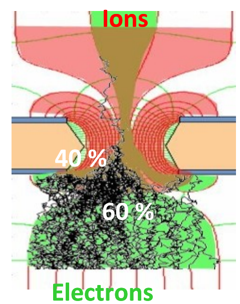


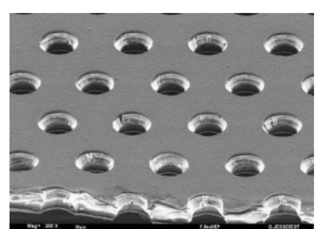





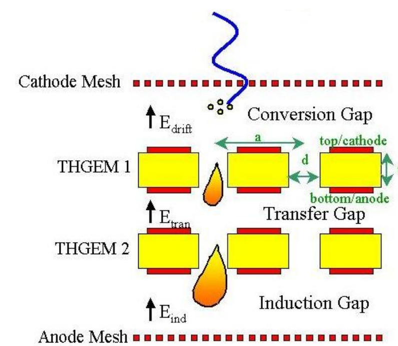
Single mask GEM

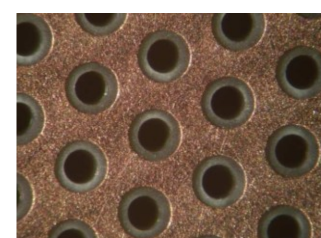





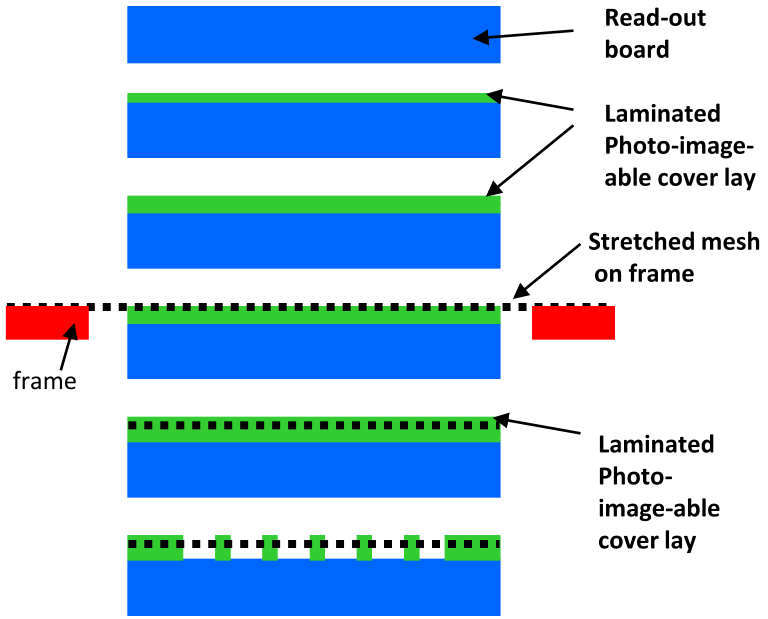
THGEM

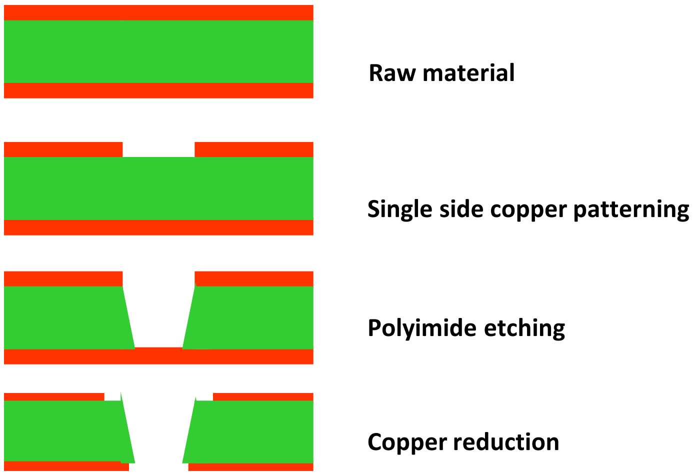


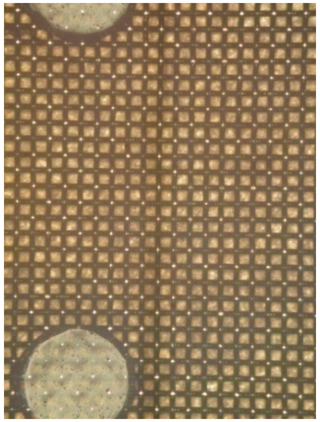
Development of large-area MPGDs

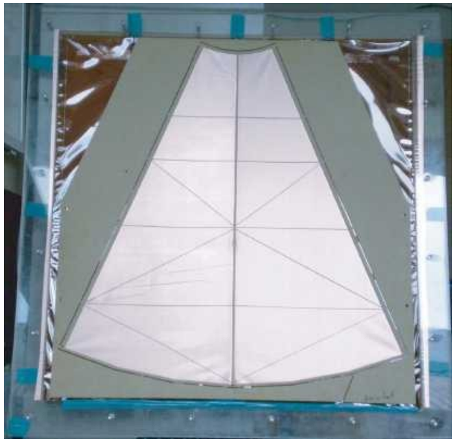
Bulk Micromegas

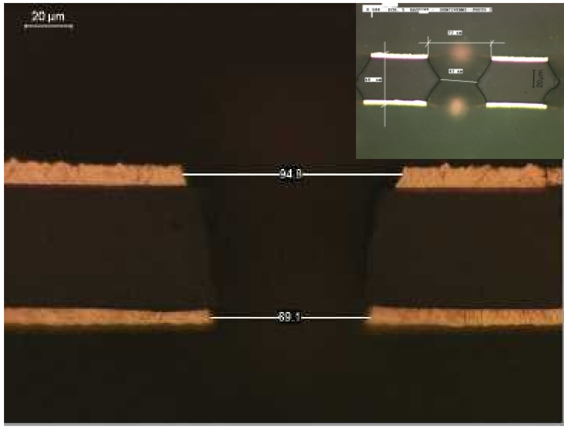


Single mask GEM









RD51 WG6 – MPGD Production

Objective: Development of cost-effective technologies and industrialization

1) Current: CERN-MPGD workshop is the UNIQUE MPGD production facility (generic R&D, detector components production, quality control)

Detector Technology	Currently produced	Future Requirements
	cm * cm	cm * cm
GEM	40 * 40	50 * 50
GEM, single mask	70 * 40	200 * 50
THGEM	70 * 50	200 * 100
RTHGEM, serial graphics	20 * 10	100 * 50
RTHGEM, Kapton	50 * 50	200 * 100
Micromegas, bulk	150 * 50	200 * 100
Micromegas, microbulk	10 * 10	30 * 30

RD51 Collaboration Survey:

2) Future MPGD R&D: Reinforcement of CERN-MPGD workshop infrastructure to produce 2x1m Bulk Micromegas and 2x0.5 m GEMs has been approved by CERN Management (Nov. 2009)
Participation the AIDA proposal

3) Technology Industrialization → transfer "know-how" from CERN workshop to industrial partners for MASS PRODUCTION

MPGD in the sLHC upgrades – requests from experiments

Atlas - Nigel Hessey
CMS - Jordan Nash
LHCb - Sheldon Stone
ALICE - Paolo Giubellino
TOTEM - Angelo Scribano

PANDA - Bernd Voss

Potential Interest of the ATLAS Collaboration in the MPGD Technology:

MPGD Technology / **Detector upgrade**	**Total detector size**	**Timescale**
Gridpix (Micromegas/Ingrid + CMOS pixel ASIC) B-layer Pixel detector ATLAS TRT	~ 0.2 m^2 ~ 5 m^2 ~ 100 m^2	2018-2019
Micromegas ATLAS Muon System (add chambers to inner ring of a small wheel) ATLAS Muon System (replacement of a small wheel and inner ring of a large wheel)	~100 m^2 (single module size ~ 1-2 m^2) ~ 1000 m^2	2013-2014 (demonstrator prototypes ready in 2010-2011) 2018-2019

Complementary Developments:

Development	**Function Required**	**Timescale**
Timepix2 /Gossip CMOS pixel chip	Time information & resolution ~ few ns, external triggering capability, radiation hardness	2011-2013
General purpose electronics chip for ATLAS Muon/Micromegas	Time information, external triggering capability, radiation hardness, integration to long strips (~ 1 m)	2011-2012
Software / MC simulation	Integration of gas detector packages (Garfield, Magboltz) into GEANT4 framework	2010-2011

MPGD in the sLHC upgrades – requests from experiments

Potential Interest of the ALICE Collaboration in the MPGD Technology:

MPGD Technology / **Detector upgrade**	**Total detector size**	**Timescale**
ThickGEM (THGEMs) and RETGEMs Technology – CsI-based Photodetectors (including triggering capability) Very high momentum particle identification detector (VHMPID) Upgrade	Total size ~ 10 m^2 (6 - 12 detectors of 1.4 * 1 m^2 single module size)	2013 - 2014 (demonstrator prototypes ready in 2011 – 2012)

- **ATLAS – Micromegas (muon)**
- **CMS – GEM (muon)**
- **LHCb – GEM (muon)**
- **ALICE – THGEM (photon detector)**
- **TOTEM – GEM (tracker & trigger)**

- **Panda & GSI – GEM (tracker)**
- **LC Time Projection Chamber – Micromegas & GEM**
- **LC Hadronic Calorimeter (DHCAL) - Micromegas & GEM**
- **STAR & RHIC – GEM (tracker)**
- **KLOE2 – GEM (tracker)**
- **JLAB – GEM & Micromegas**
- **Potential clients from neutrino community**

Technology Industrialization (potential partners)

THGEM Technology – ELTOS S.p.A. (Italy)

GEM Technology

- New Flex (Korea, Seoul)
- Tech-ETCH (USA, Boston)
- Scienergy (Japan, Tokyo)

Micromegas Technology

- TRIANGLE LABS (USA, Nevada)
- SOMACIS (Italy, Castelfidarco)
- CIRE (France, Paris)

Technology Transfer - Contract summary 12/9/2008

SUMMARY

CERN has developed, and owns all rights to a technology concerning Radiation Detectors of Very High Performance and Planispherical Parallax-Free X-Ray Imager using Gas Electron Multipliers (GEM foil technology). GEM technology is a proven concept of gas amplification that was introduced in 1996 by Fabio Sauli and GEM foils are currently being manufactured at a small workshop on CERN premises by the TS/DEM group. Furthermore, the use of GEM foils as gas detectors is also covered by a patent owned by CNRS (the CAT patent) to which CERN has a sub-licensable license.
SciEnergy is a Japanese company developing, manufacturing and selling X-Ray detectors systems. This company works closely with Hamagaki Laboratory (U. Tokyo) in Japan, and it is through the latter's involvement in the RD51 Collaboration that SciEnergy's interest in GEM foils grew. After initial contacts with participants to the RD51 Collaboration, SciEnergy approached CERN to request a license from CERN to manufacture and sell GEM foils and GEM based detector systems both to the R&D community and commercial end-users.

Scienergy, Japan signed license contract for GEMs

Partnership agreement for the development and implementation of spherical GEMs for X-Ray diffraction detectors

RD51 WG6 – MPGD Electronics Development

Objective: Readout electronics optimization and integration with detectors.

Definition of front-end electronics requirements for MPGDs

Survey of existing conventional readout systems:
GASSIPLEX, ASDQ, CARIOCA, ALTRO, SUPER ALTRO; APV, VFAT

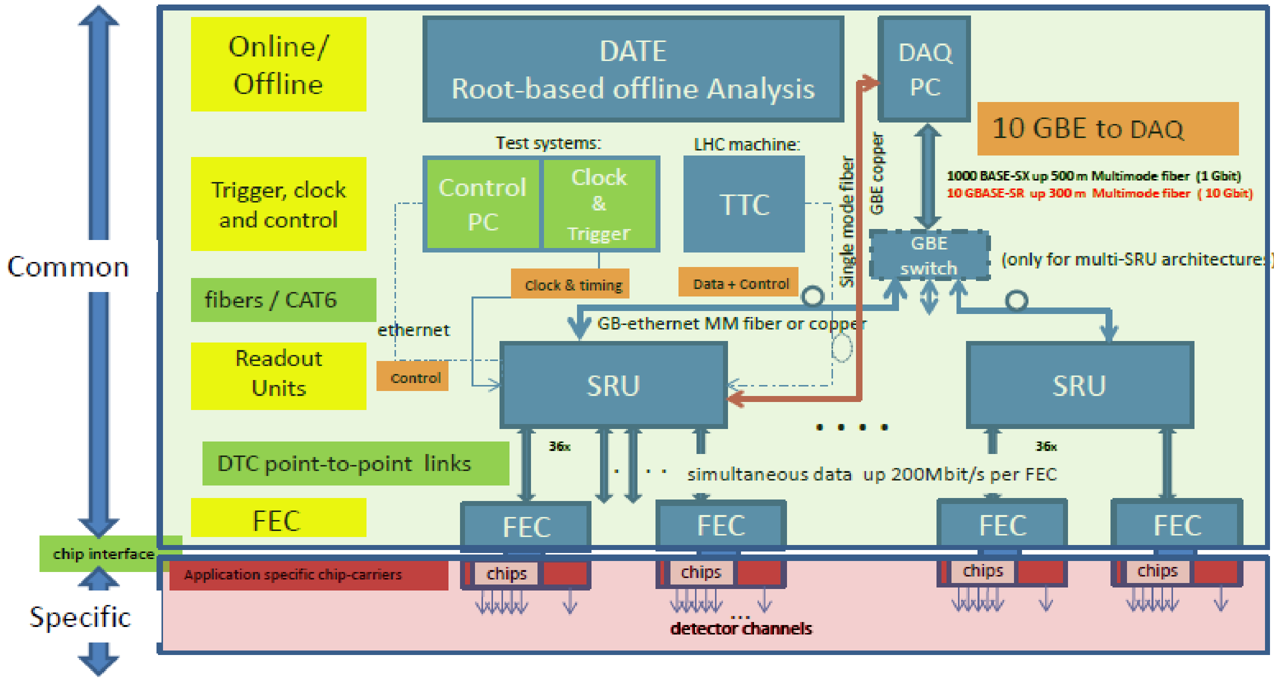
Name	Exp	Det	#ch	Shaper (ns)	Noise	Range (fC)	Pol.	ADC	f (MHz)	P/ch. (mW)	Feat.	Tech	Rad hard
APV25	CMS	Si strip	128	50	270+38e/pF	20	both	A	40	2.7	PD, PR	0.25 CMOS	10
AFTER	T2K	TPC	72	100-2000 s-gauss	(350-1800)+(22-1.8)e/pF	19	both	A	1-50 (100)	7.5	VG,VS	0.35 CMOS	no
MSGCROC	DETNI	Gas strip	32	T: 25 E: 85	2000e @ 40pF	800	both	A,1	2ns TDC		VG, ZS	0.35 CMOS	no
Beetle	LHCb		128	25	500+50e/pF	17.5	both	A/1	40	5.2	F-OR	0.25 CMOS	40
VFAT	TOTEM		128	22	650+50e/pF	18.5 (cal)	both	1	40	4.47	F-OR	0.25 CMOS	50
NINO	ALICE	TPC	8	1	1900+165/pF	2000 th<100	both	1	async	30	BR	0.25 CMOS	no
CARIOCA	LHCb	MWPC	8	<15 @ 220pF	2000+40e/pF	250	both	1	async	46	BR	0.25 CMOS	20
PASA+ ALTRO	ALICE TPC	TPC	16	190_{fwhm} s-gauss	570e @20 pF	160	both	10	20	< 40	BC, TC, ZS	0.35,0.25 CMOS	
SVX4	CDF, D0	Si strip	128	100-360	410+45e/pF	60fC	neg	8	106 (212)	2	ZS	0.25 CMOS	20
SPIROC	ILC, T2K	SIPM	36	A:25-175 T: 10	A: 1/11pe; T:1/24pe	2000 pe	neg	8-12	100ps TDC	0.025 *pulse*	dual-gain	0.35 SiGe	no
Legend:	PD = peak detection, PR = pile-up rejection, VG = variable gain, VS = variable shaping, F-OR = fast-OR, BR = baseline restorer, BC = baseline correction, TC = tail correction, DC = data compression, ZS = zero suppression												

- shaping time: 5ns .. 1us
- dynamic range: <100fC
- power: < 10 mW/ch (?)
- ADC accuracy: 10 bits (?)
- TDC accuracy: 1ns

… **From Chip Matrix to the "Ideal MPGD Chip" → develop 2-3 chip concepts for the MPGDs**

We need an ***APV25*** *chip with* *variable gain and shaping time* *like the* ***AFTER*** *chip,* *dynamic range* *like* ***MSGCROC,*** *integrated* *fast-OR* *like* ***Beetle****,* *integrated ADC* *like* ***SVX4,*** *digital signal processor* *like* ***ALTRO***

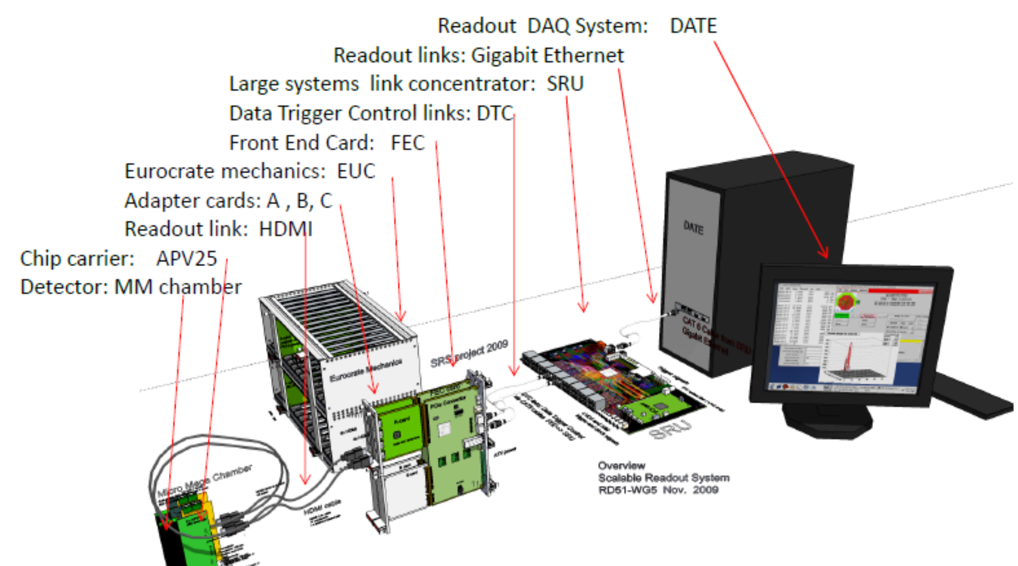
Electronics: Scalable Readout System



"RD51 Common Project"
(financed by the RD51)→

First prototype system
to be ready in June 2010

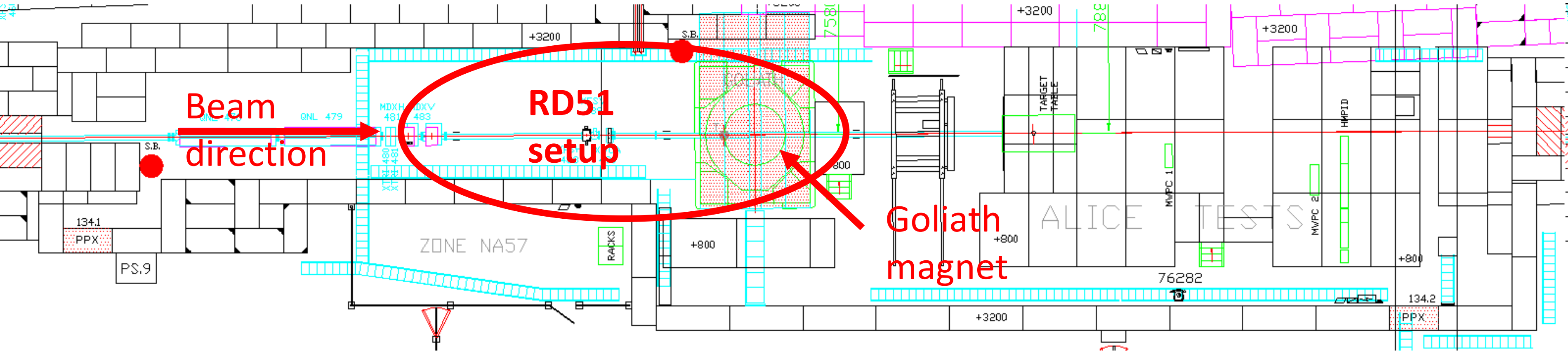
- Scalability from small to large system
- Common interface for replacing the chip frontend
- Integration of proven and commercial solutions for a minimum of development
- Default availability of a very robust and supported DAQ software package.



→ **Scalable Readout System**

H. Muller, RD51 Collab. Meet., Nov.23-25, 2009, WG5 Meeting

Beam facility for RD51 in H4@SPS

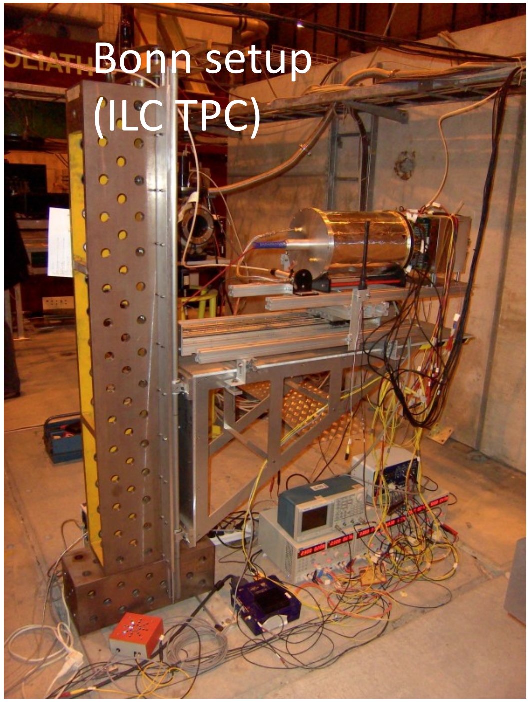


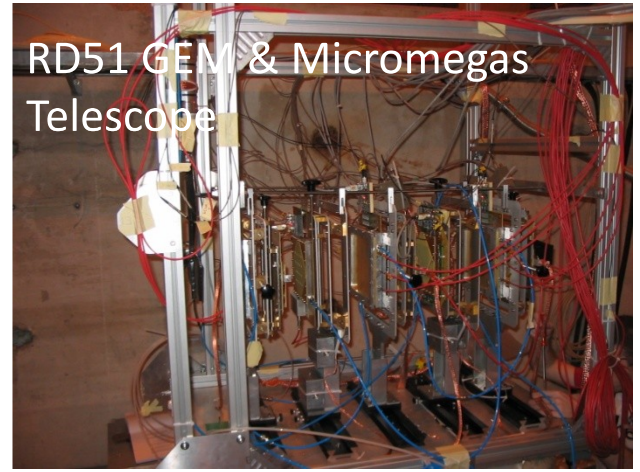
Initial Safety Discussion: RD51 (21 April 2009)

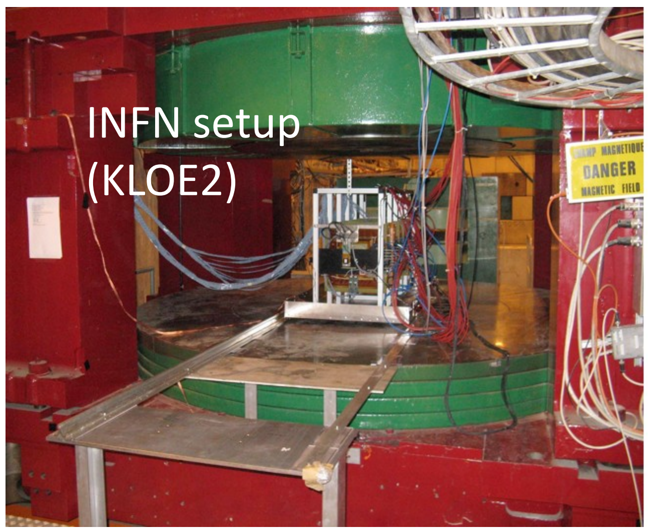
RD51 test beam periods: 21.06-6.07 - 4 groups/2 setups; 22.10-1.11 8 groups/4 setups

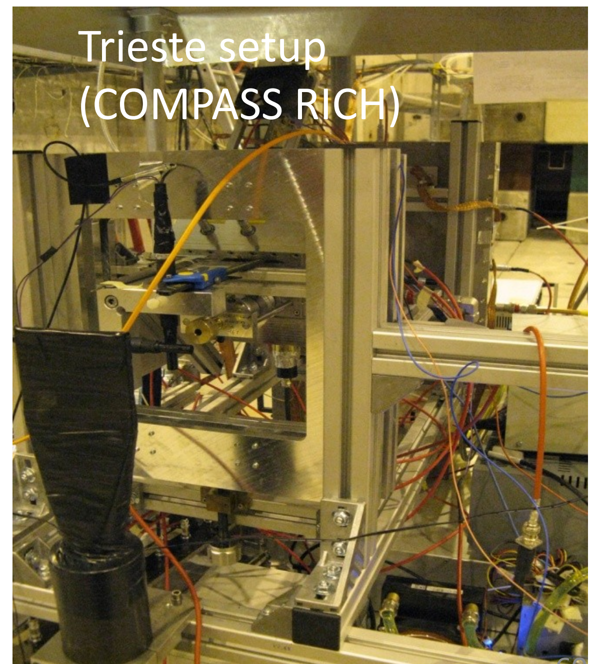
Beam facility for RD51 in H4@SPS

Objective: Design and maintenance of common infrastructure for detector characterization ("semi-permanent" test-beam infrastructure at CERN SPS@H4 beam)







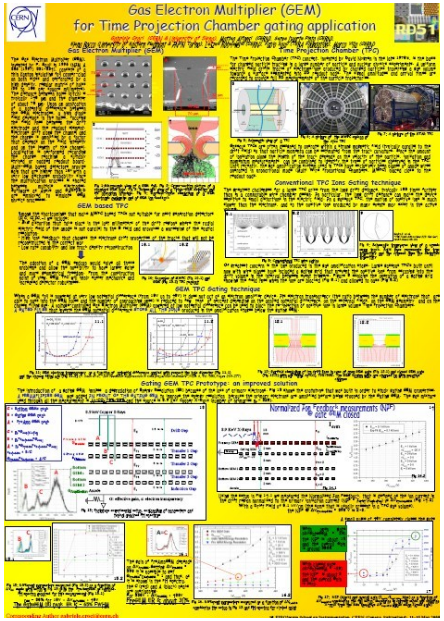


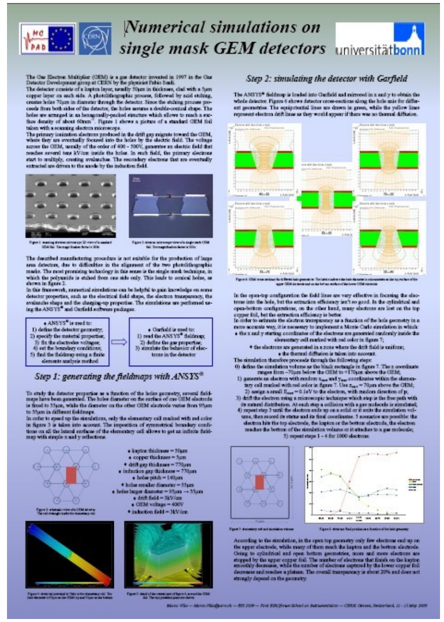
Common infrastructure:
Services, trigger, tracking
Telescope, DAQ, Slow control

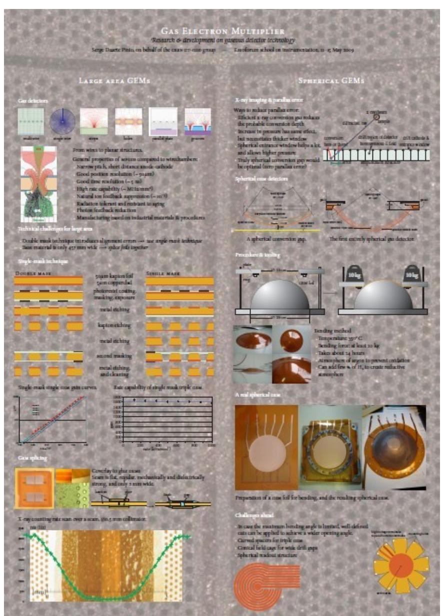
- **8 RD51 groups have been taking data in parallel during the last test beam campaign (Oct. 22 – Nov. 2, 2009)**

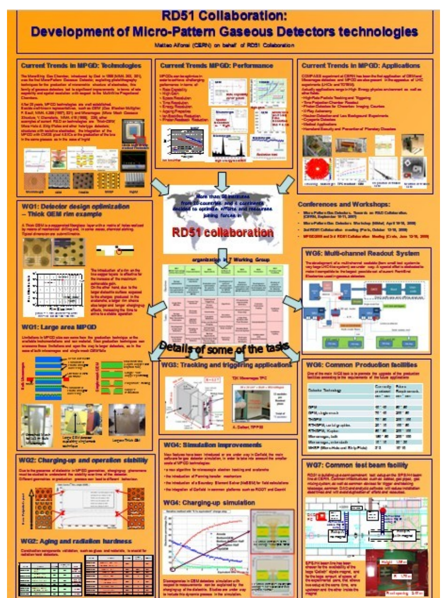
RD51 Collaboration : WG meetings and Training session

Education & Training









Dear Colleagues,

It is my pleasure to inform you that the talk "Activity of CERN and LNF Groups on Large Area GEM Detectors", presented by Danilo Domenici (LNF-Frascati) on behalf of the RD51 Collaboration at the "Frontier Detectors for Frontier Physics - 11th Pisa Meeting on Advanced Detectors", held in Isola d'Elba, Italy, has won the "Young Scientist Award" for the "contribution to the development and test of large area planar and cylindrical Gas Electron Multiplier detectors (GEM) **in view of their use for various detector upgrades at SLHC and KLOE at LNF-Frascati**". I hope that this Award will motivate even stronger our younger collaborators to devote their efforts to the MPGD developments.

Congratulations !

Leszek Ropelewski

Summary:

• consolidation of the Collaboration and MPGD community integration

• considerable progress in MPGD technologies in particular large area GEM ,THGEM, Micromegas; some picked up by experiments (including sLHC upgrades) for feasibility studies and prototyping

• secured future of the MPGD technologies development through the TS DEM workshop upgrade and eventually FP7 AIDA contribution

• improved MPGD simulation software framework allows for the first applications

• Infrastructure for common RD51 test beam facility

• Development of common, scalable electronics (financed by RD51)

• TT, IP issues and contacts with industry

• Education and training