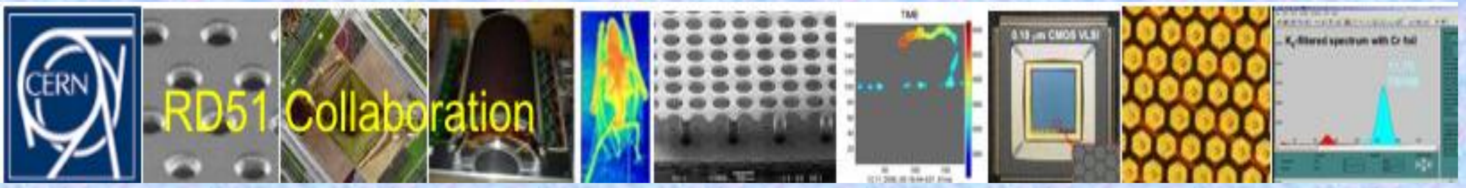
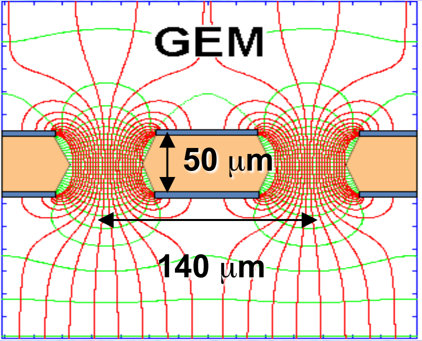
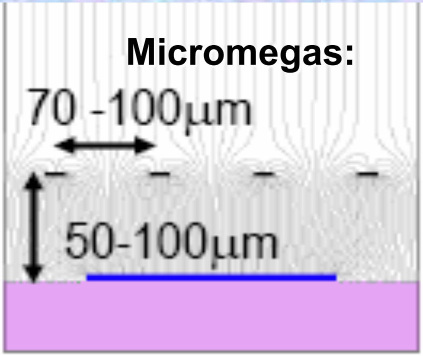
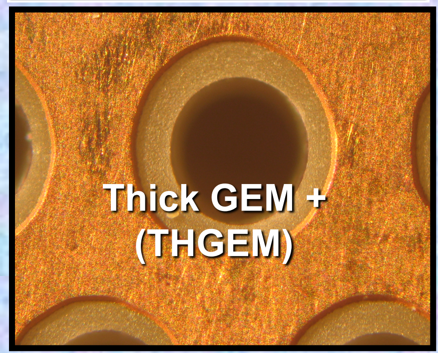
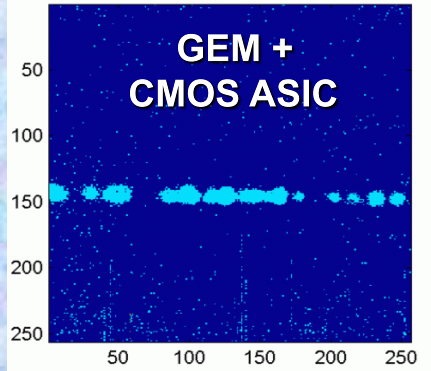










The RD51 Collaboration, Development of Micro-Pattern Gas Detector Technologies

Maxim Titov, CEA Saclay, France

SEMINAR OUTLINE:

- RD51 Motivation and Main Objectives
- Micro-Pattern Gas Detectors (GEM, Micromegas, Thick GEM)
- RD51 Collaboration Activities and Results
- Summary and Outlook

Research Technique Seminar, Fermilab, December 1, 2009

RD51 Collaboration: Motivation and Main Objectives

World-wide coordination of the research in the field to advance technological development of Micropattern Gas Detectors

- **Foster collaboration between different R&D groups; optimize communication and sharing of knowledge/experience/results concerning MPGD technology within and beyond the particle physics community**

- **Investigate world-wide needs of different scientific communities in the MPGD technology**

- **Optimize finances by creation of common projects (e.g. technology and electronics development) and common infrastructure (e.g. test beam and radiation hardness facilities, detectors and electronics production facilities)**

- **The RD51 collaboration will steer ongoing R&D activities but will not direct the effort and direction of individual R&D projects**

- **Applications area will benefit from the technological developments developed by the collaborative effort; however the responsibility for the completion of the application projects lies with the institutes themselves.**

RD51 Collaboration Milestones

- **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
- **Proposal presentation in CERN/LHCC open session (2 July 2008)**

  94th LHCC Meeting Agenda (02-03 July 2008);

  CERN-LHCC-2008-011 (LHCC-P-011)
- **CERN/LHCC committee close session (24 September 2008)**

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

  2nd RD51 Collaboration Meeting (13-15 October 2008)
- **CERN Research Board approval(5 December 2008)**

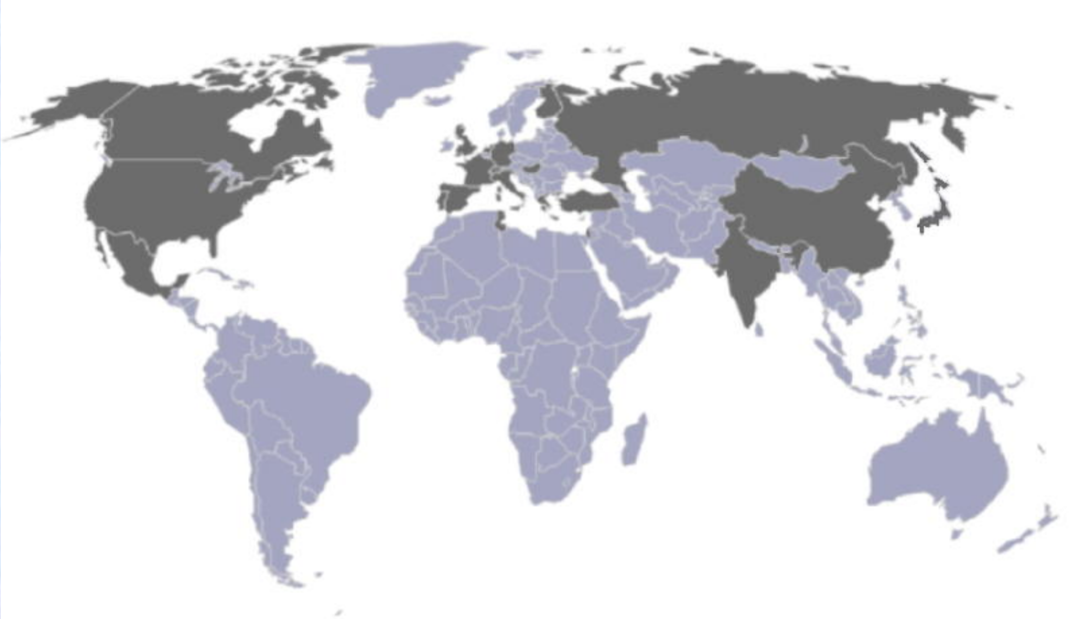
  186th Research Board meeting minutes

- WG2 meeting (10 December 2008)
- WG1 meeting: large area MPGDs (21 January 2009)
- GEM & Micromegas detector assembly training session (16 February 2009)
- RD51 Mini-Week (27-29 April 2009)

- 3rd RD51 Collaboration Meeting (Kolympari, Crete, June 16-17, 2009) and MPGD2009 Conference
- RD51 Mini-Week (CERN, September 23-25, 2009)

- 4th RD51 Collaboration Meeting (CERN, Nov. 23-25, 2009)

RD 51 : Development of Micro-Pattern Gas Detector Technologies



Collaboration of ~70 institutes worldwide, ~ 400 authors

"RD51 aims at facilitating the development of advanced gas-avalanche detector technologies and associated electronic-readout systems, for applications in basic and applied research."

Co-Spokespersons: L.Ropelewski, M.Titov
CB Chair and Deputy: S.Dalla Torre, A. White
Management Board members: A.Breskin, I.Giomataris, F.Sauli, H. Taureg, H. van der Graaf, A.White

Collaboration Meetings:
1st - Amsterdam April 16-18, 2008 : http://indico.cern.ch/conferenceDisplay.py?confId=25069
2nd - Paris, October 13-15, 2008 : http://indico.cern.ch/conferenceDisplay.py?confId=35172
3rd - Crete (Greece), June 12-16, 2009 : http://candia.inp.demokritos.gr/mpgd2009/
4th – CERN, November 23-25, 2009 : http://indicobeta.cern.ch/conferenceDisplay.py?confId=72610

Public Web Site: http://rd51-public.web.cern.ch/RD51-Public

RD 51 Collaboration - Working Groups

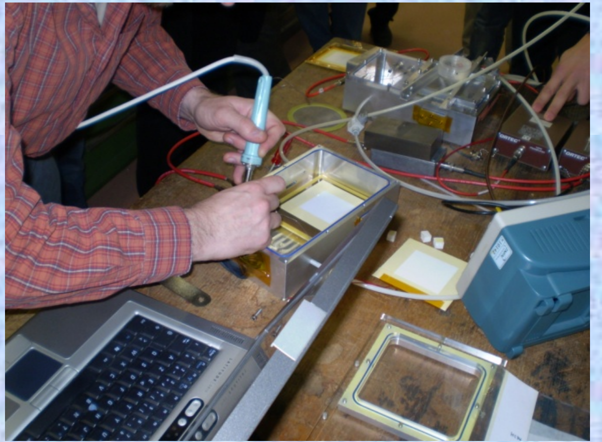
“Transverse organization” of MPGD activities in 7 Working Groups

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

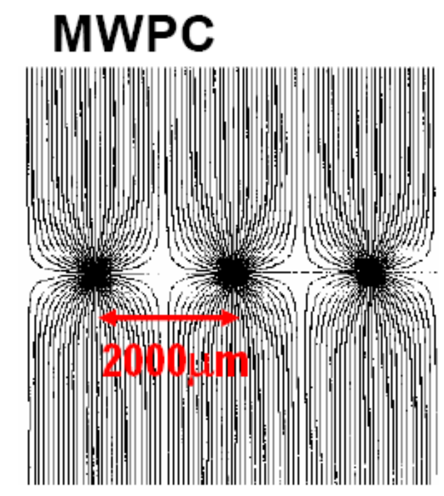
RD51 / MPGD Training Session

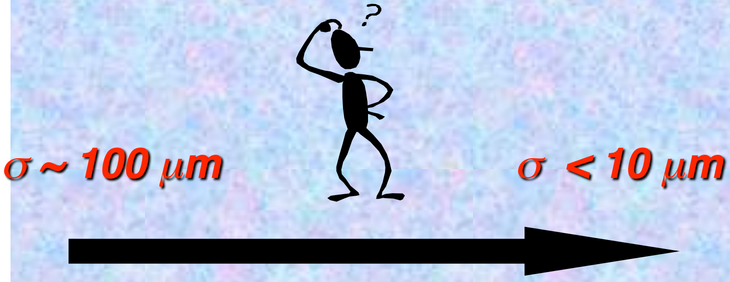
February 16-20, 2009 @ CERN: GEM and Micromegas detector design and assembly training - lecture session



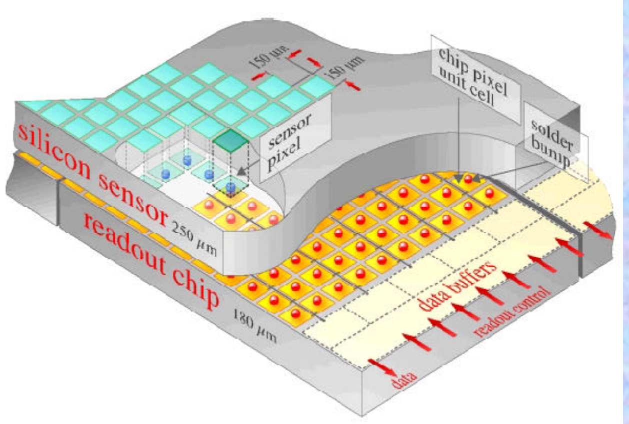
http://rd51-public.web.cern.ch/RD51-Public/Meetings/TrainingSessions.html

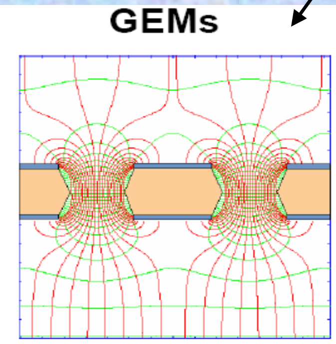
Closing the Gap between Wire Chambers and Silicon Detectors

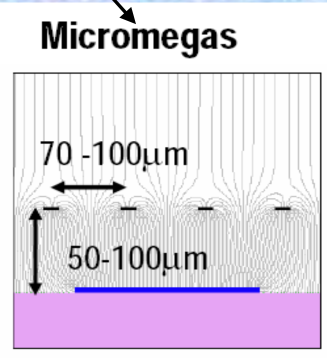




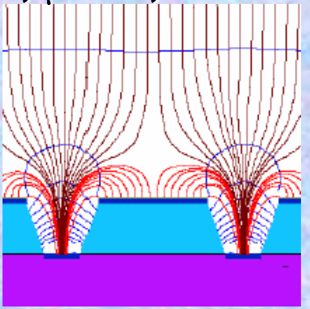
Novel Pixel System:







CAT, µCAT, mGROOVE, …



Evolution is always driven by the physics requirements and experimental conditions

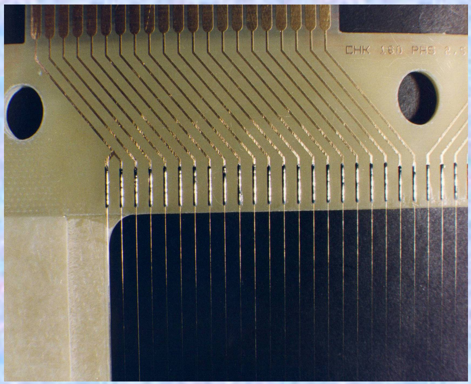
→ Trade-offs between read-out, S/N, power, and segmentation
(Often defined by state-of-the-art in microelectronics or etching technology):

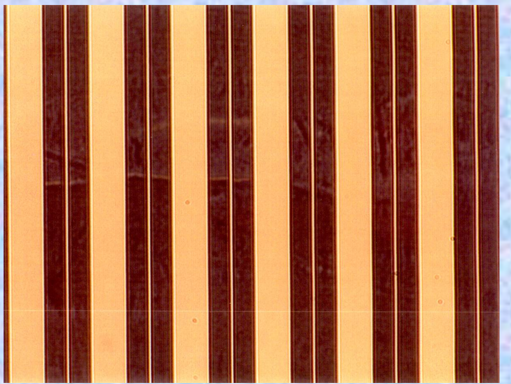
- Microelectronics – eg. Silicon pixels
- Bump bonding technology – low capacitance connections
- Modern etching technology – eg. Micro pattern Gaseous Detectors

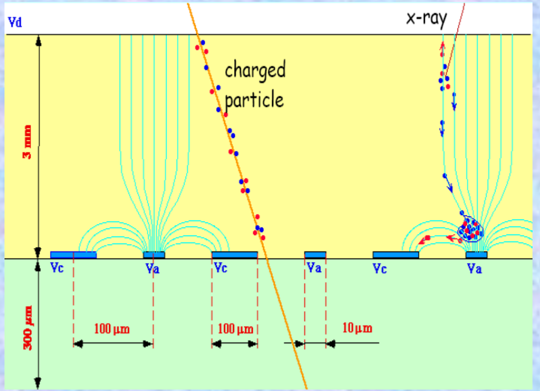
Micro-Strip Gas Chamber (MSGC)

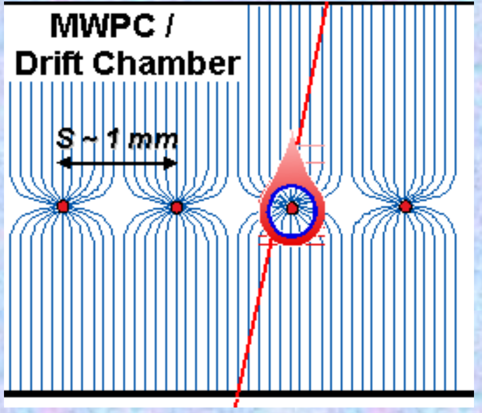
MWPC

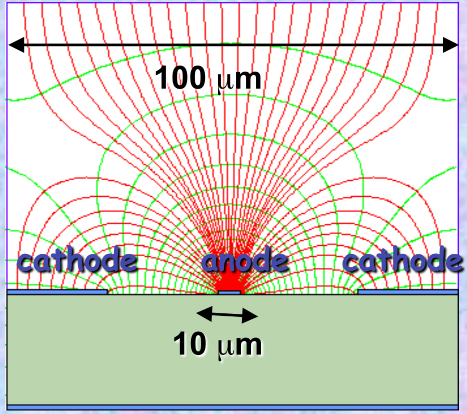
MSGC









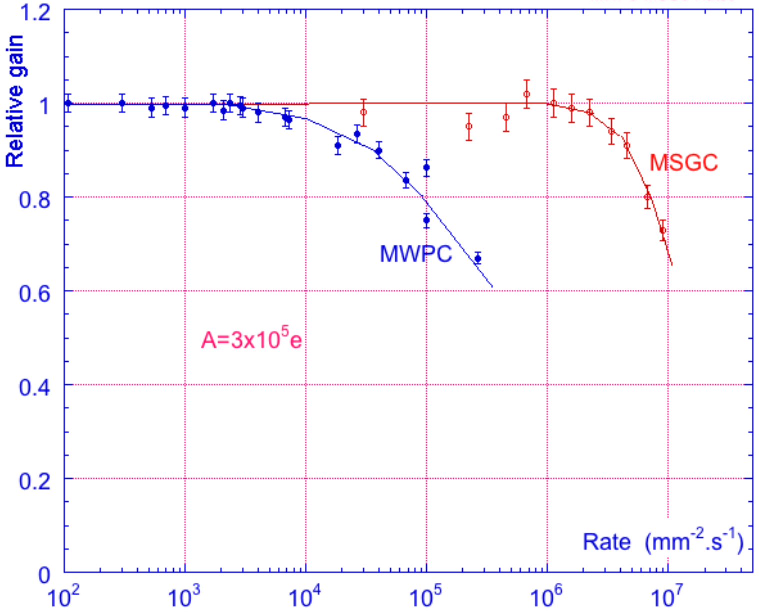


Typical distance between wires limited to 1 mm due to mechanical and electrostatic forces

Typical distance between anodes 200 µm thanks to semiconductor etching technology

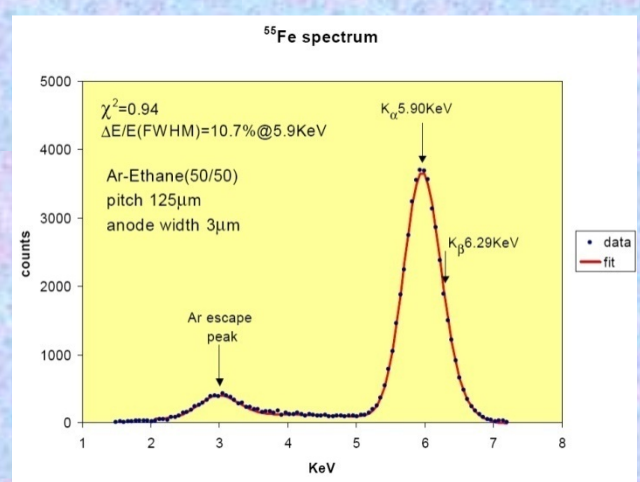
A. Oed, Nucl. Instr. and Meth. A263 (1988) 351.

Rate capability limit due to space charge overcome by increased amplifying cell granularity



MSGC Performance

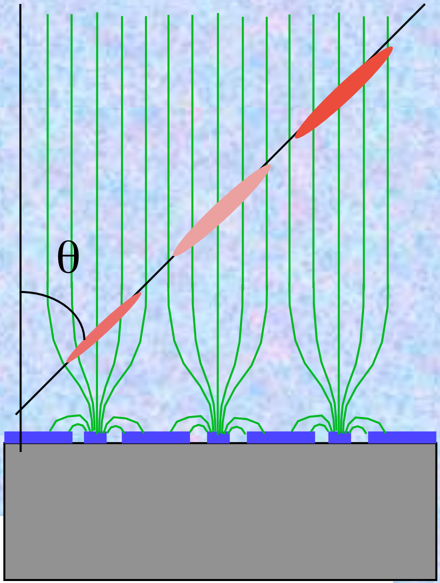
EXCELLENT RATE CAPABILITY, SPATIAL AND MULTI-TRACK RESOLUTION



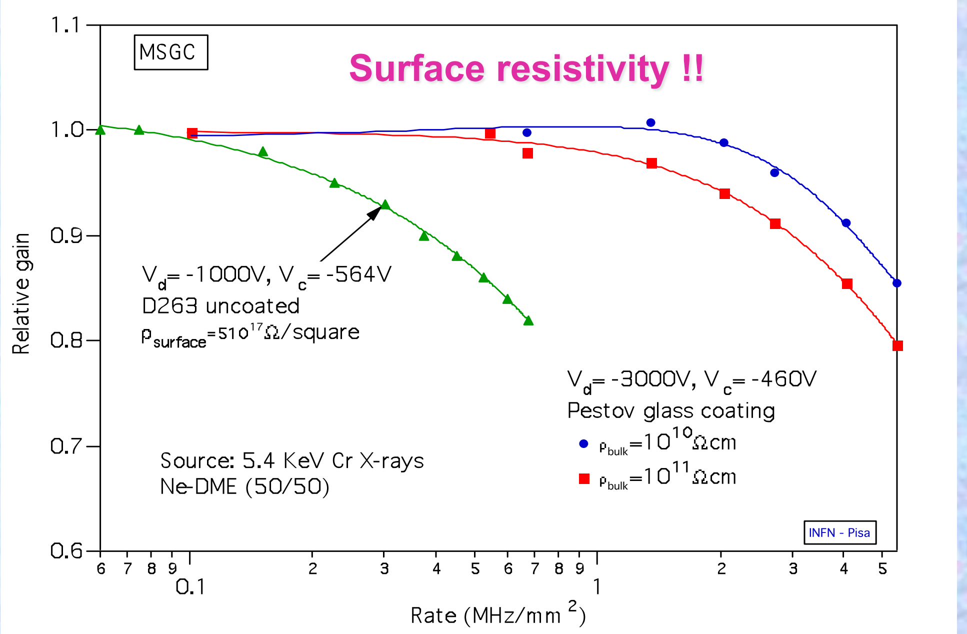
RATE CAPABILITY > 10^6/mm^2 s

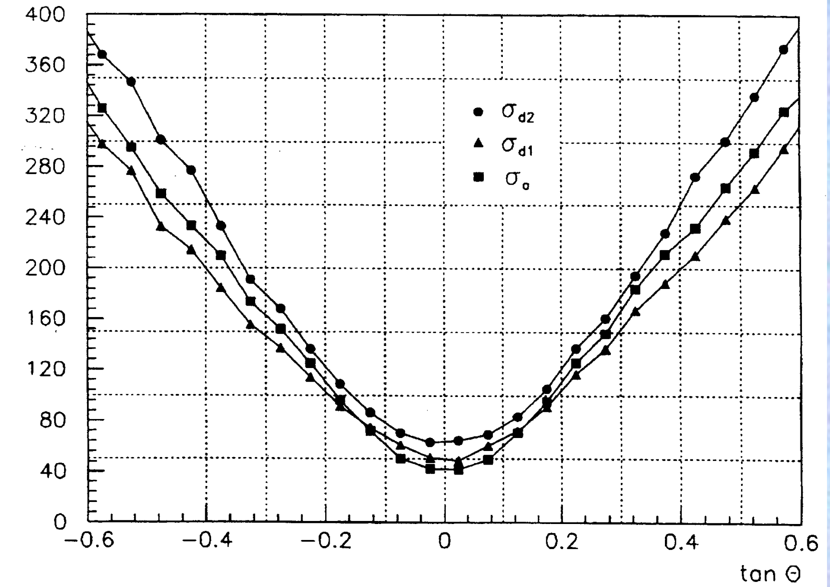
SPACE ACCURACY ~ 40 μm rms

2-TRACK RESOLUTION ~ 400 μm



ENERGY RESOLUTION ~11% for 5.9 keV

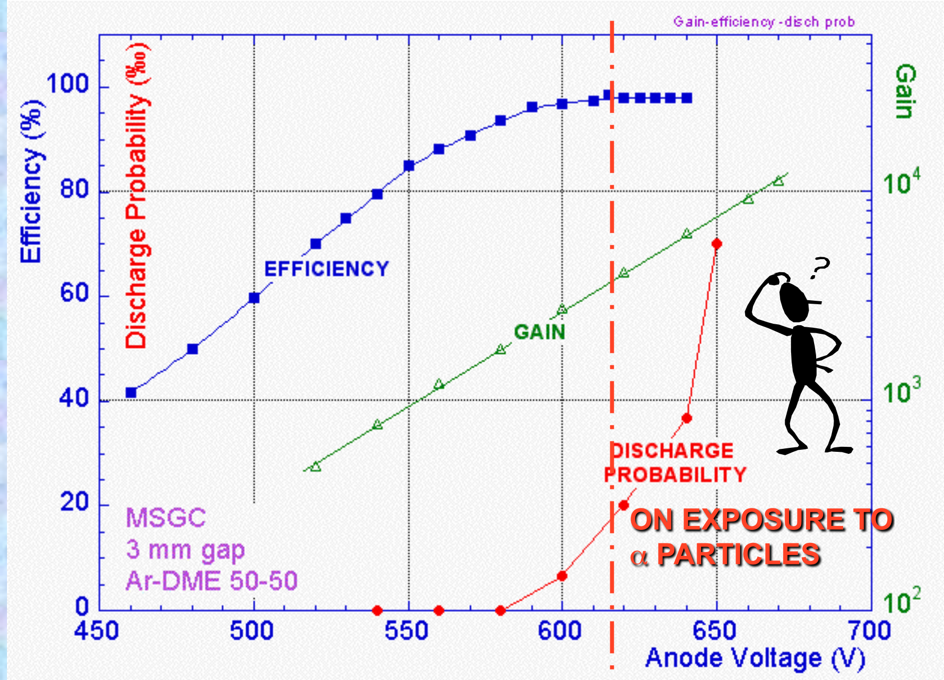




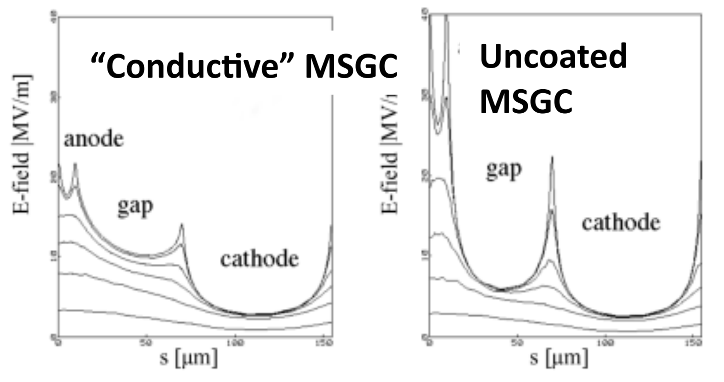
F. Van den Berg et al, NIMA A349 (1994) 438

Micro-Strip Gas Chambers: Discharge Problems

Major processes leading at high rates to MSGC operating instabilities:



- **Substrate charging-up and time-dependent modification of the E field**
  → **slightly conductive support**



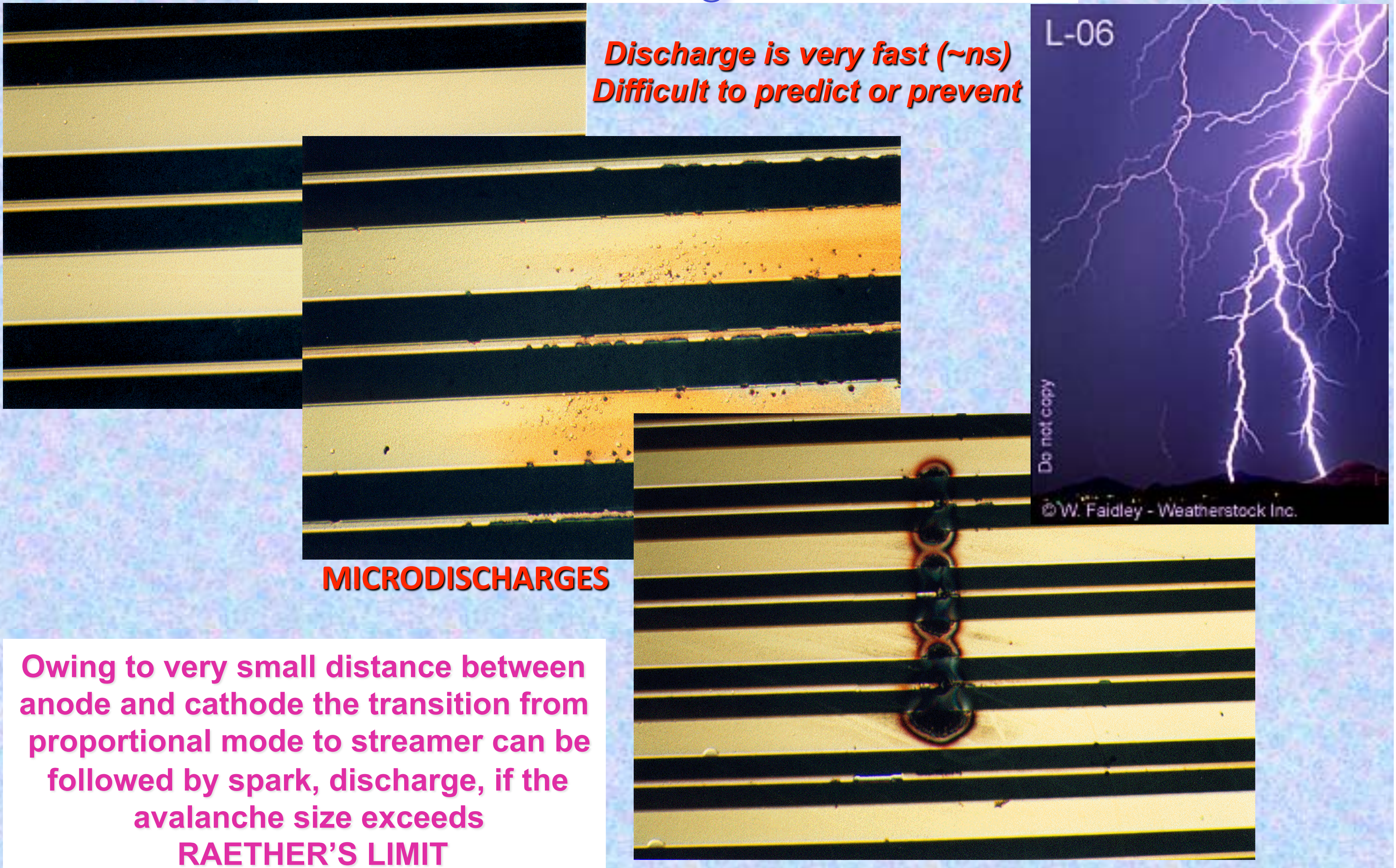
- **Deposition of polymers (aging)**
  → **validation of gases, materials, gas systems**

- **Discharges under exposure to highly ionizing particles**
  → **multistage amplification, resistive anodes**

Induced discharges are intrinsic property of all single stage micropattern detectors in hadronic beams (MSGC turned out to be prone to irreversible damages)

MSGC Discharge Problems

Discharge is very fast (~ns)
Difficult to predict or prevent



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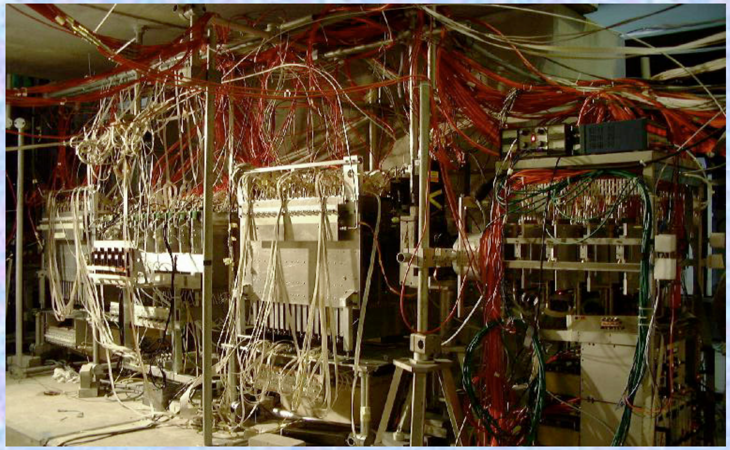
MICRODISCHARGES

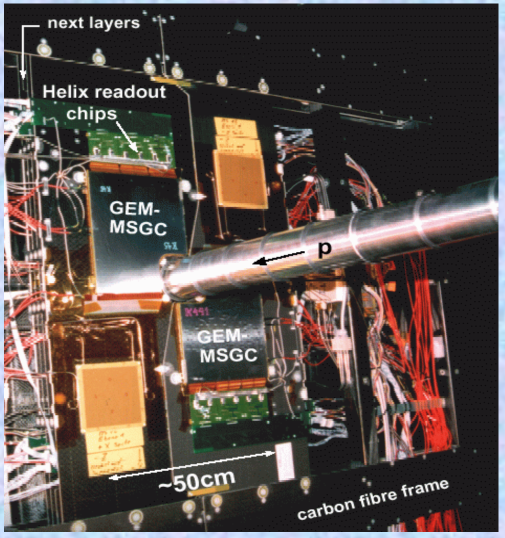
FULL BREAKDOWN

Owing to very small distance between anode and cathode the transition from proportional mode to streamer can be followed by spark, discharge, if the avalanche size exceeds
RAETHER'S LIMIT
$Q \sim 10^7 - 10^8$ electrons

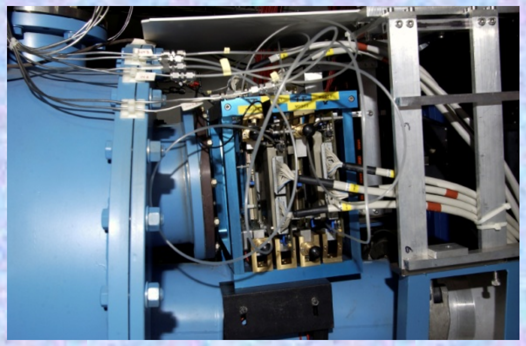
Micro-Strip Gas Chamber (MSGC)



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



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

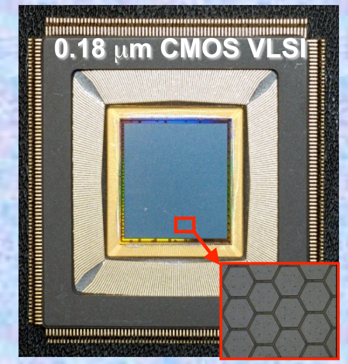


DIRAC
4 planes MSGC-GEM
Planes 10x10 cm^2

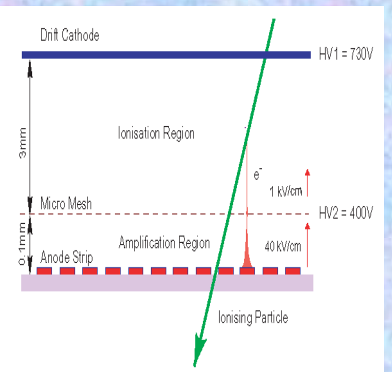
The D20 diffractometer MSGC
is working since Sept 2000
1D localisation
48 MSGC plates (8 cm x 15 cm)
Substrate: Schott S8900
Angular coverage : 160° x 5,8°
Position resolution : 2.57 mm (0,1°)
5 cm gap; 1.2 bar CF4 + 2.8 bars 3He

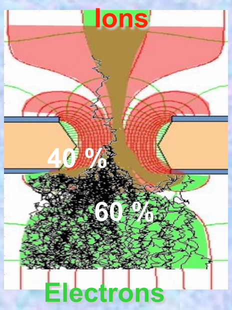
Current Trends in Micro-Pattern Gas Detectors (Technologies)

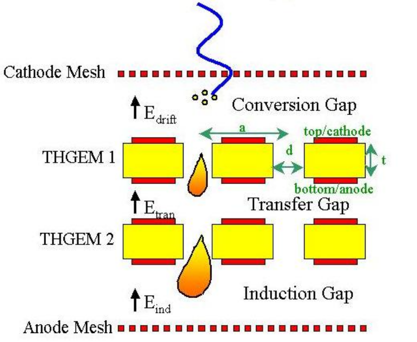
- **Micromegas**
- **GEM**
- **Thick-GEM, Hole-Type Detectors and RETGEM**
- **MPDG with CMOS pixel ASICs**
- **Ingrid Technology**

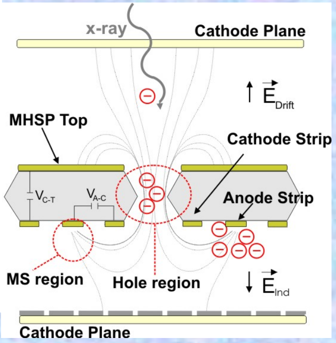


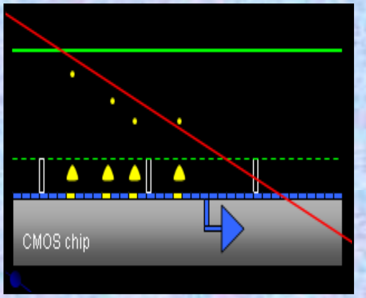
CMOS high density readout electronics

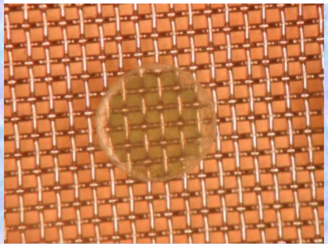




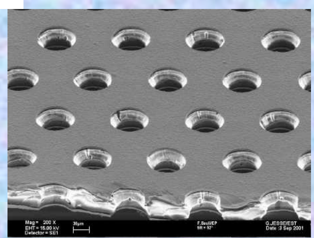




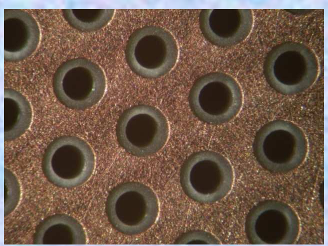




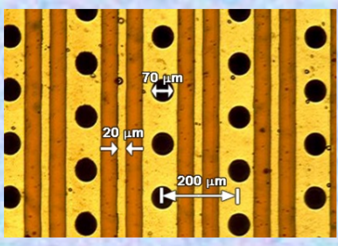
Micromegas



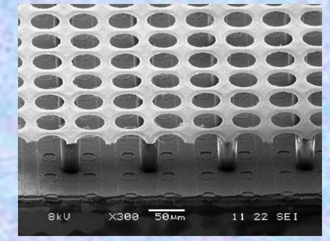
GEM



THGEM



MHSP

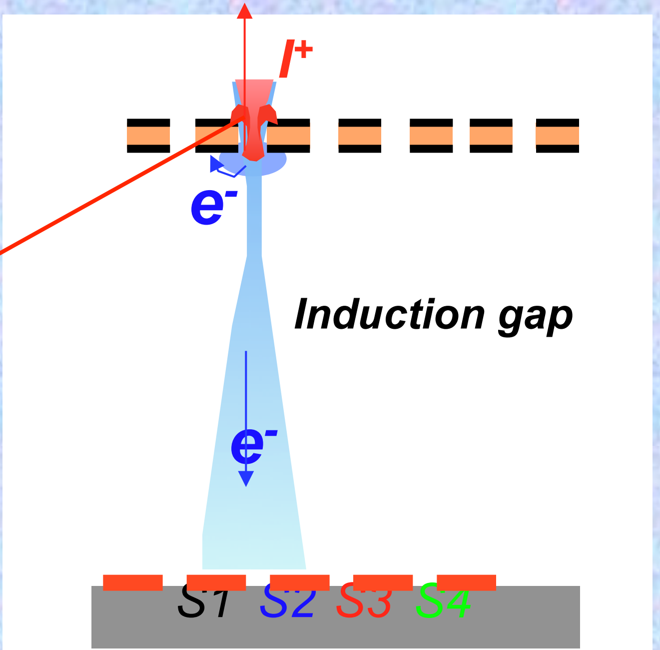


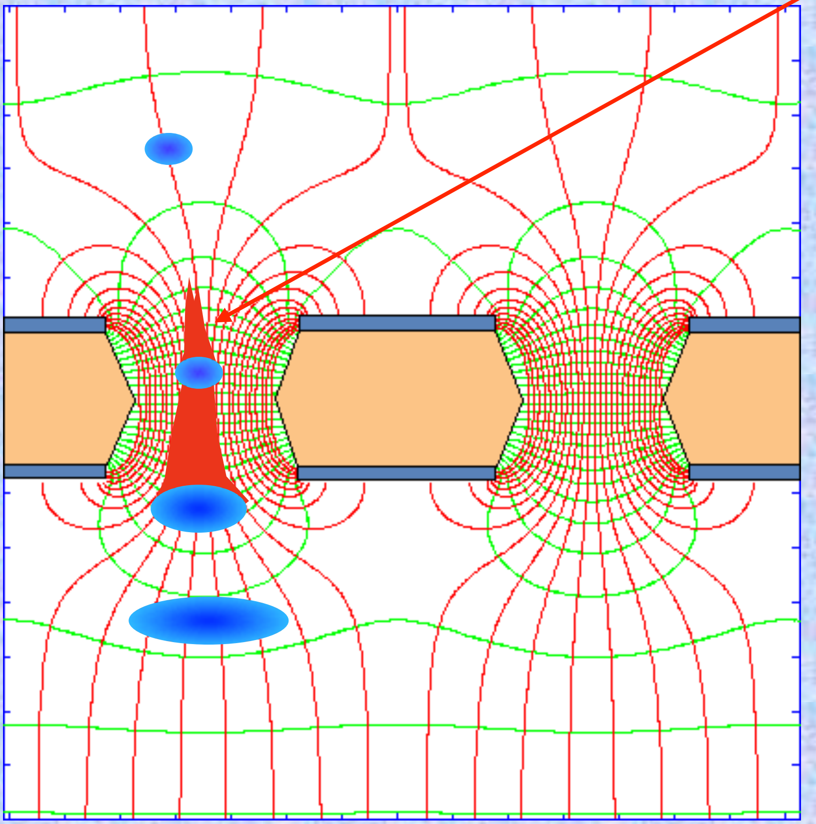
Ingrid

GEM (Gas Electron Multiplier)

Thin metal-coated polymer foil chemically pierced by a high density of holes

A difference of potentials of ~ 500V is applied between the two GEM electrodes. The primary electrons released by the ionizing particle, drift towards the holes where the high electric field triggers the electron multiplication process.





Electrons are collected on patterned readout board.

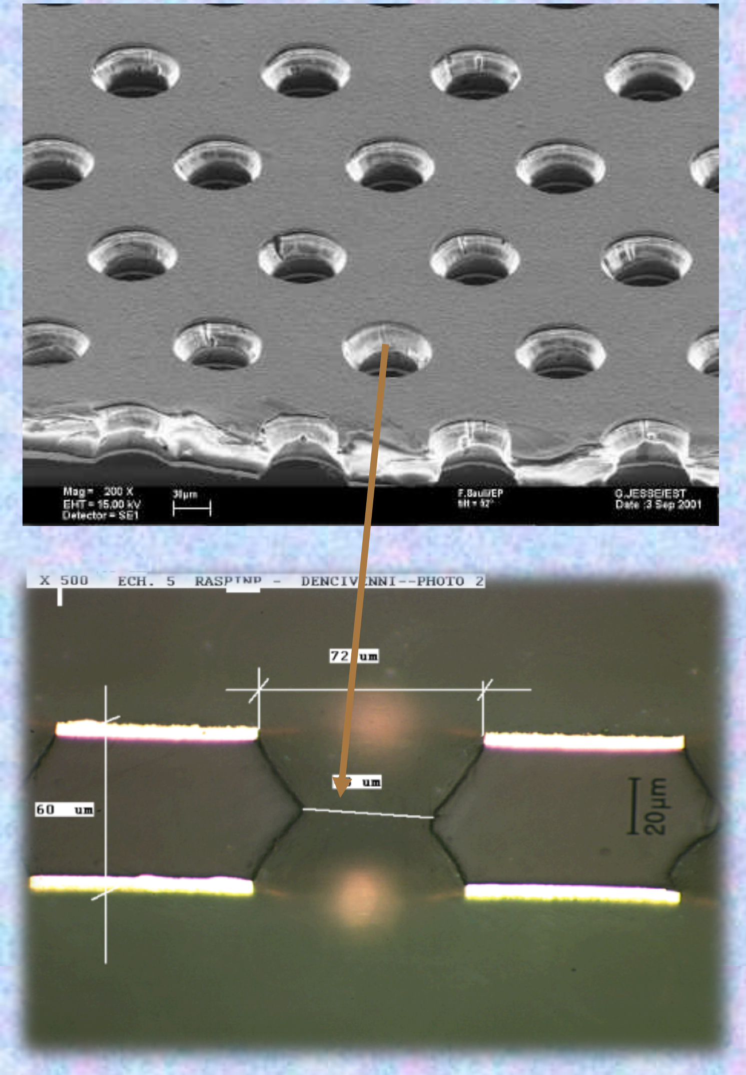
A fast signal can be detected on the lower GEM electrode for triggering or energy discrimination.

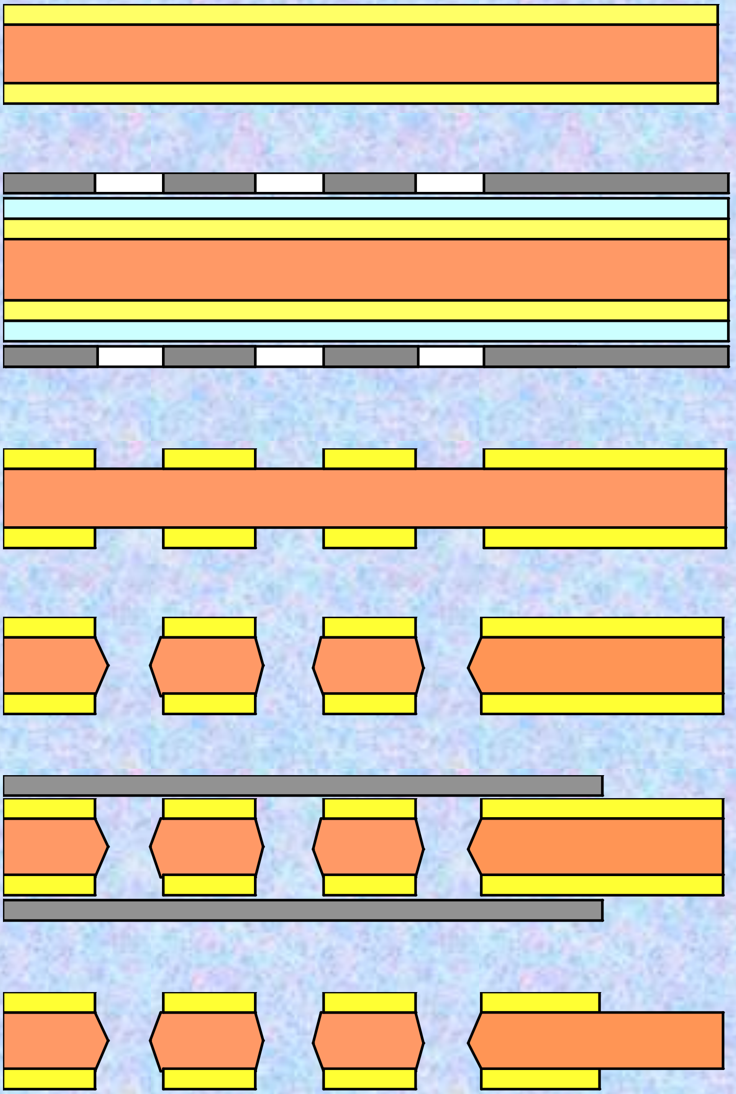
All readout electrodes are at ground potential.

F. Sauli, Nucl. Instrum. Methods A386(1997)531
F. Sauli, http://www.cern.ch/GDD

GEM Manufacturing

Typical geometry:
5 µm Cu on 50 µm Kapton
70 µm holes at 140 mm pitch





50 µm Kapton
5 µm Cu both sides

Photoresist coating, masking and exposure to UV light

Metal chemical etching

Kapton chemical etching

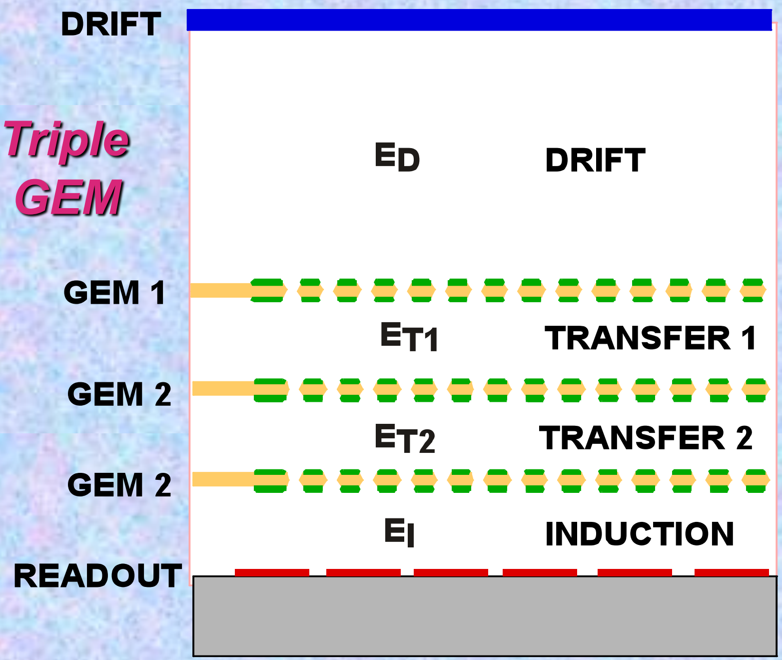
Second masking

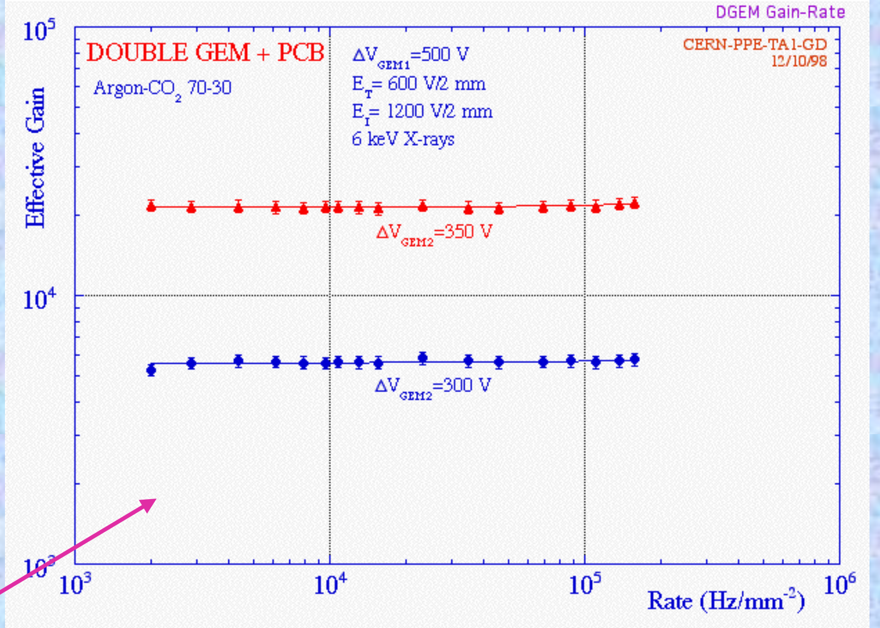
Metal etching and cleaning

Multiple GEM Structures

Cascaded GEMs achieve larger gains and safer operation in harsh environments

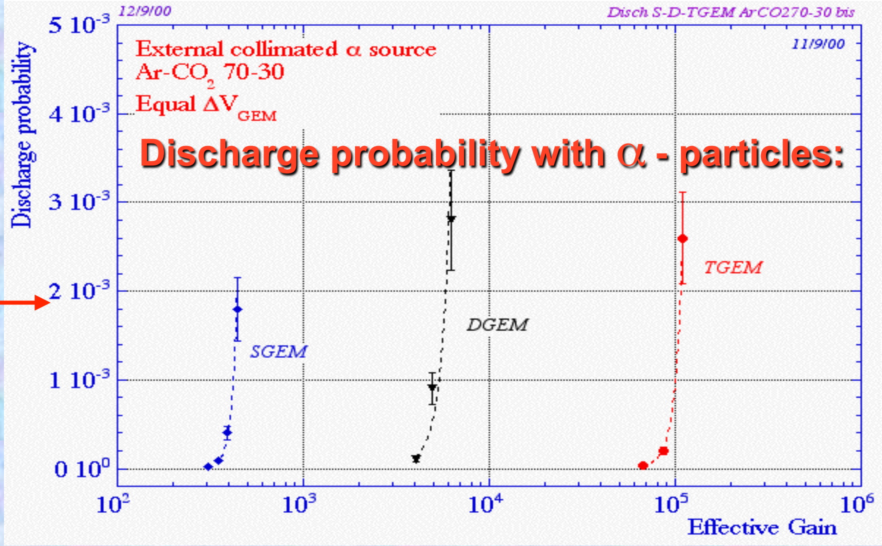
Triple GEM





High-rate capability > 10^5 Hz/mm^2;
No space-charge phenomena

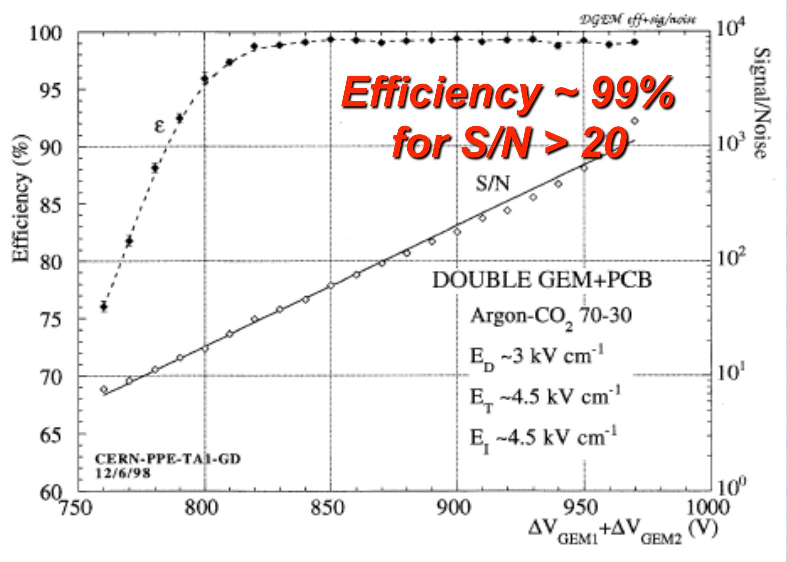
Discharge probability with α - particles:



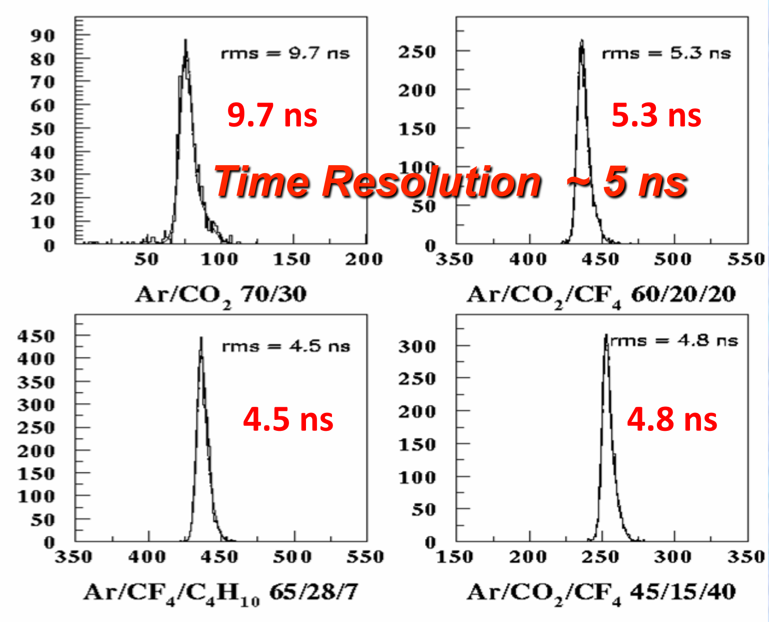
Multiple GEM structure strongly reduces probability of discharges

C. Buttner et al, NIM A 409(1998)79
S. Bachmann et al, NIM A A 443(1999)464

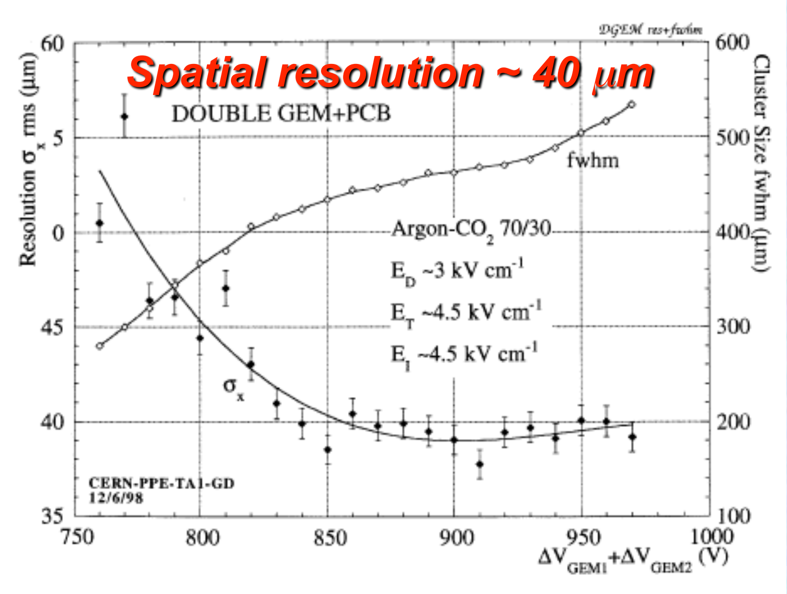
Multiple GEM Performance



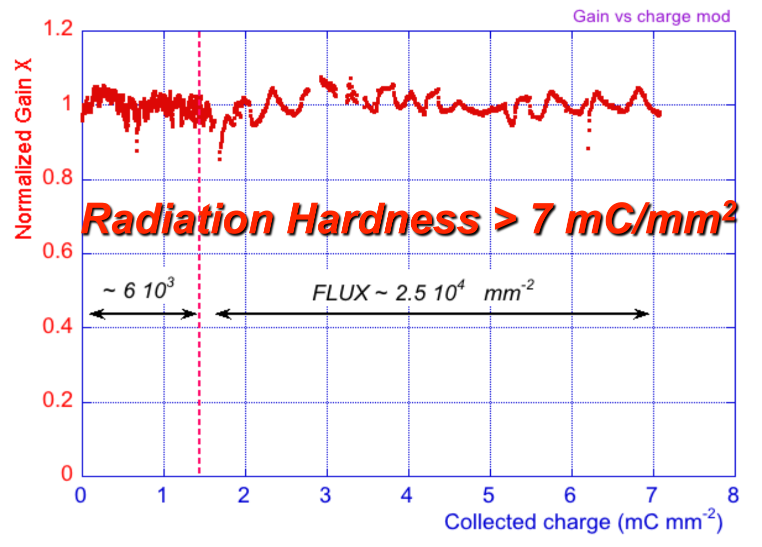
Efficiency ~ 99% for S/N > 20



Time Resolution ~ 5 ns



Spatial resolution ~ 40 μm



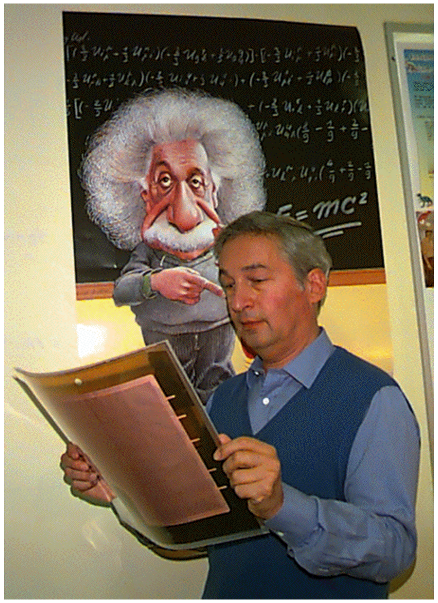
Radiation Hardness > 7 mC/mm²

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

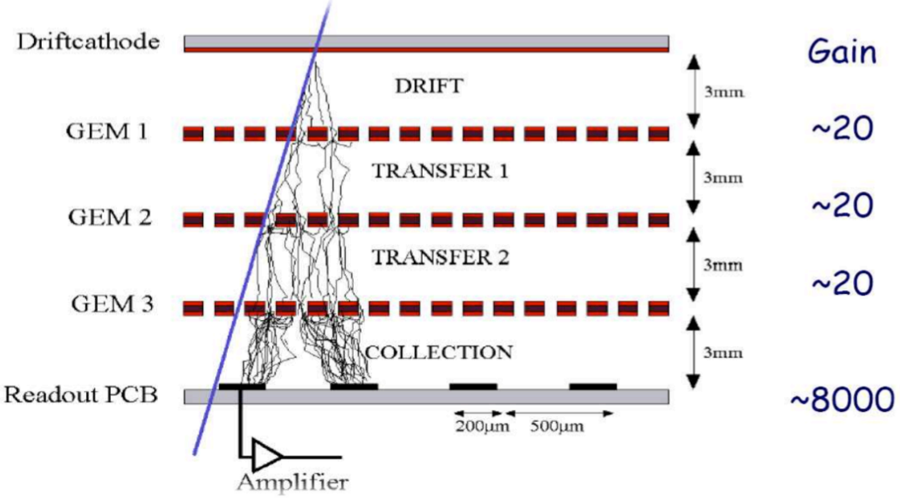
J. Benlloch et al, IEEE NS-45(1998)234; C. Altunbas et al, Nucl. Instr. and Meth. A515

Gas Electron Multiplier (GEM)

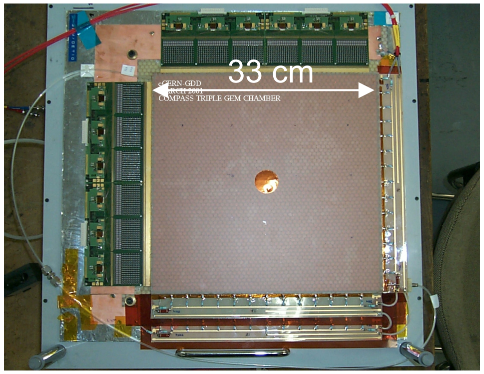
F. Sauli, NIM A386(1997) 531;
F. Sauli, http://www.cern.ch/GDD



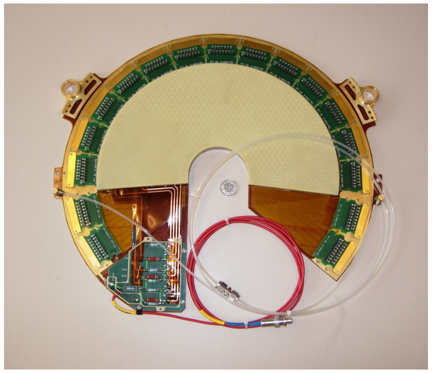
Full decoupling of amplification stage (GEM) and readout stage (PCB, anode)



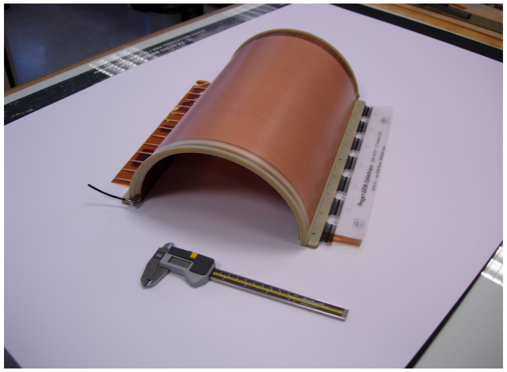
Amplification and readout structures can be optimized independently !



Compass

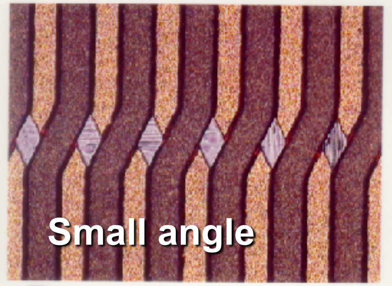


Totem

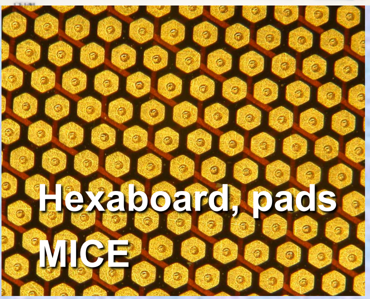


NA49-future

Cartesian
Compass, LHCb



Small angle

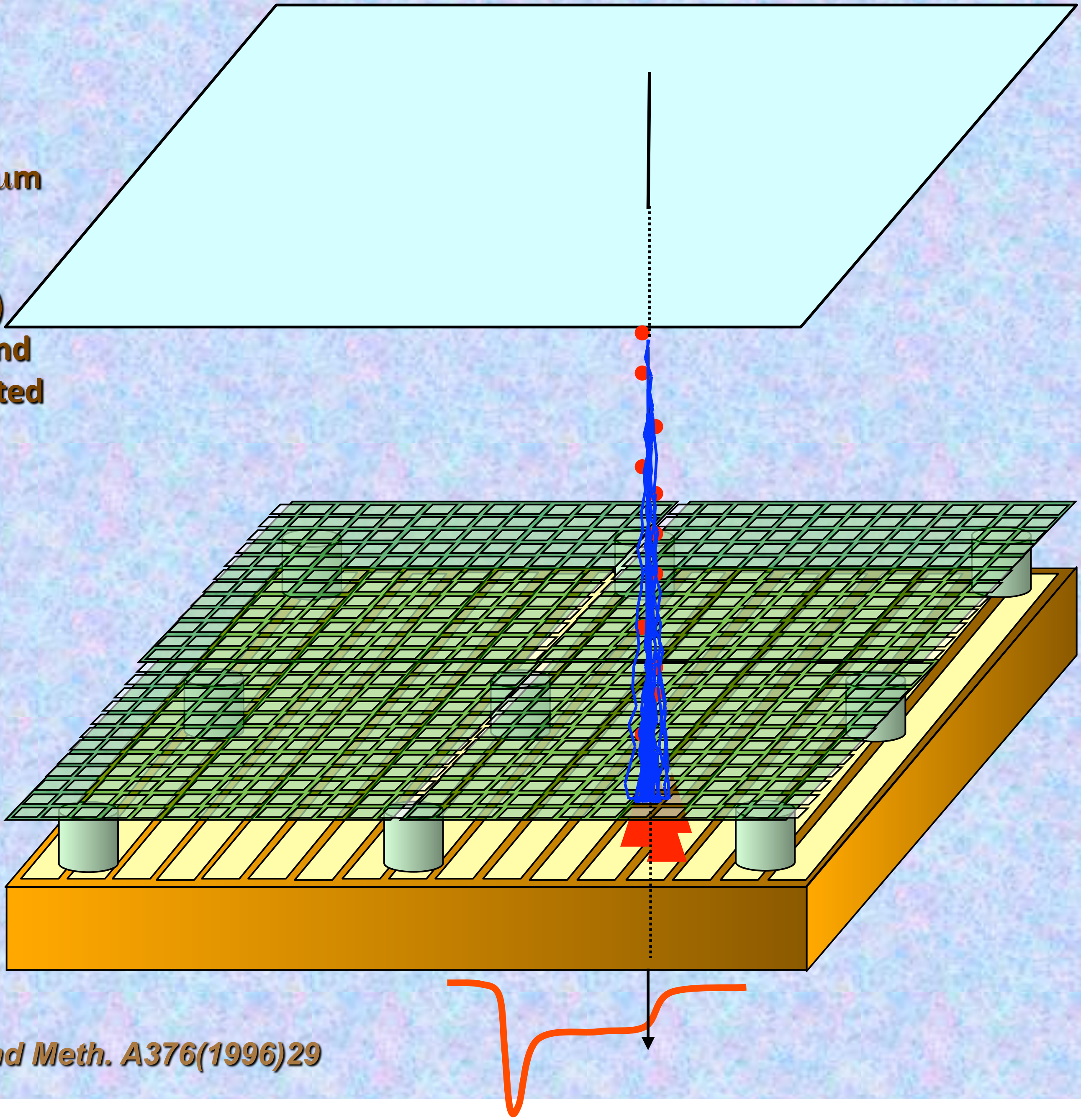


Hexaboard, pads
MICE

Mixed
Totem

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

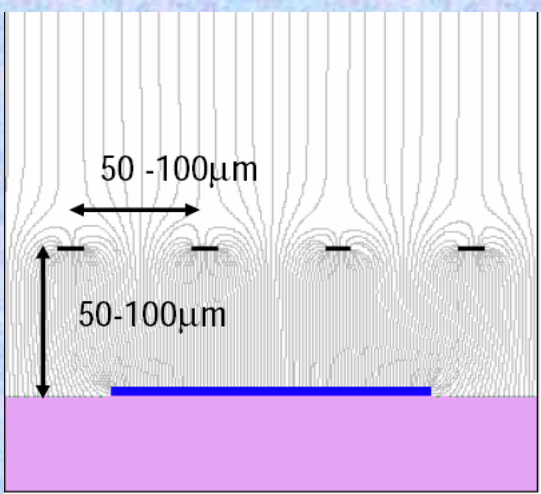
MICro MEsh GAseous Structure (MICROMEGAS)



Micromesh Gaseous Chamber: a micromesh supported by 50-100 μm insulating pillars

Multiplication (up to 10^5 or more) takes place between the anode and the mesh and the charge is collected on the anode (one stage)

Small gap: fast collection of ions



Y. Giomataris et al, Nucl. Instr. and Meth. A376(1996)29

Manufacturing Bulk Micromegas

The micro mesh consist of 18um µm thick stainless steel 400 Lpi woven microstrings. This micro mesh is embedded between two photoimageable coverlay layers with a micron precision (to define the amplification region)

Read-out board
4 layers PCB

Laminated
photoimageable
coverlay

Stainless steel
mesh on frame

Laminated
photoimageable
coverlay

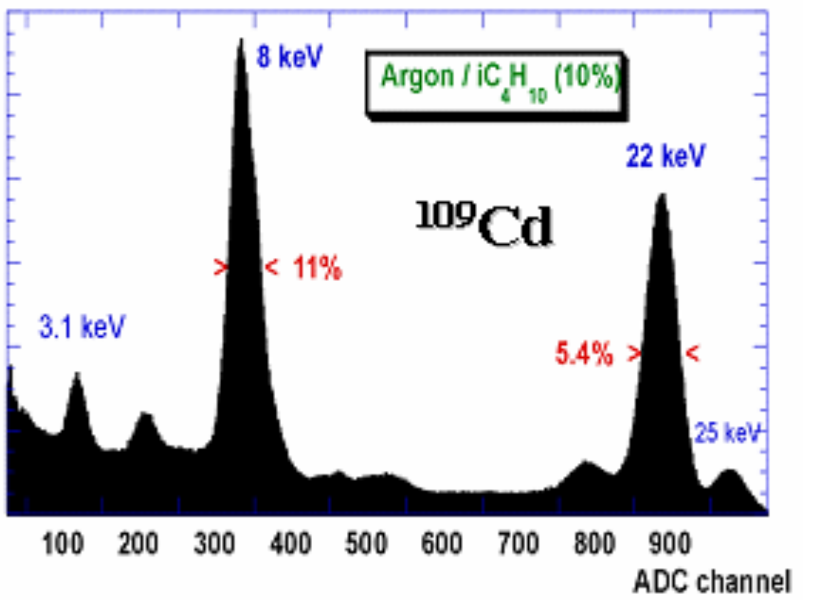
Exposure +
development
+ cure + cut

Easy manufacturing - Large size compatible - Low cost

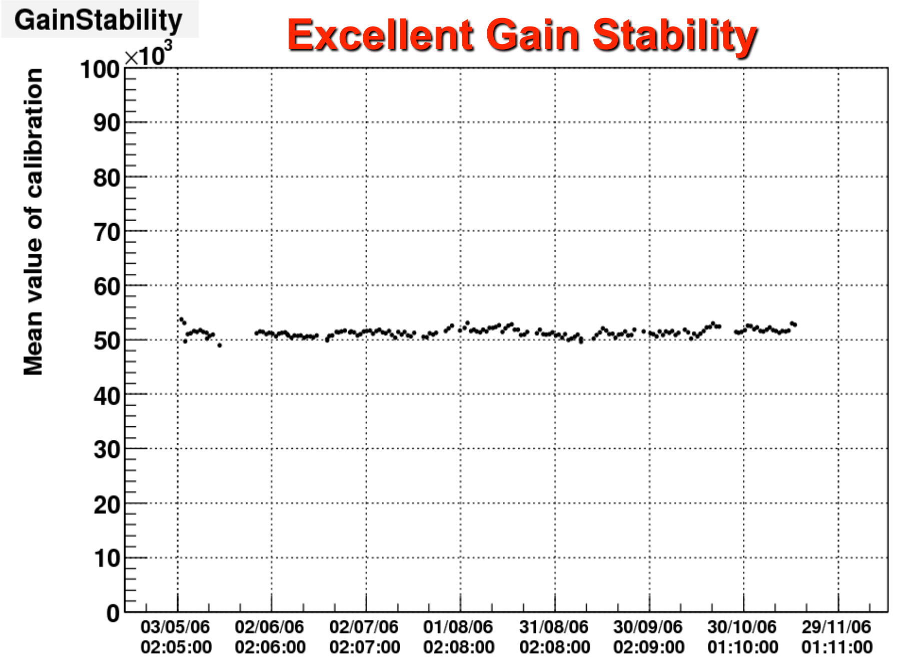
Robust and electrically testable at the production time

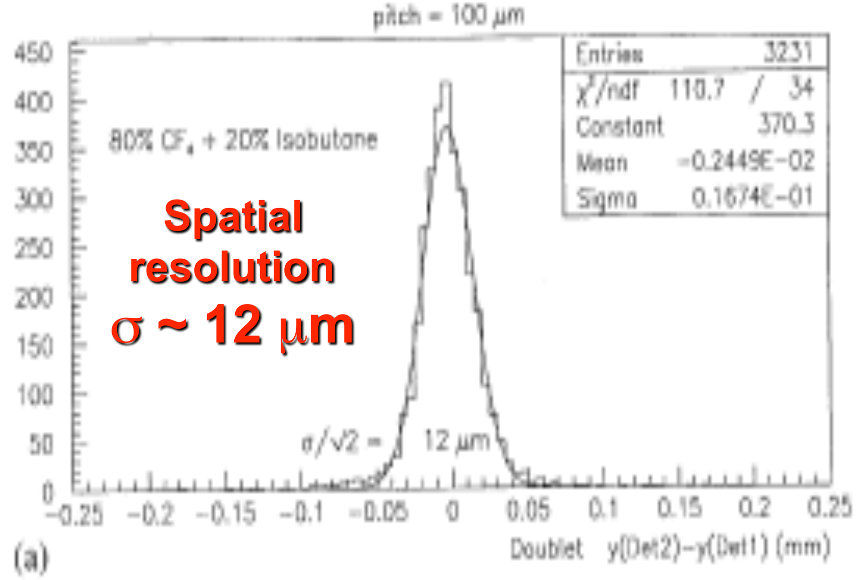
Micromegas Performance

Small gap→ good energy resolution



Excellent Gain Stability

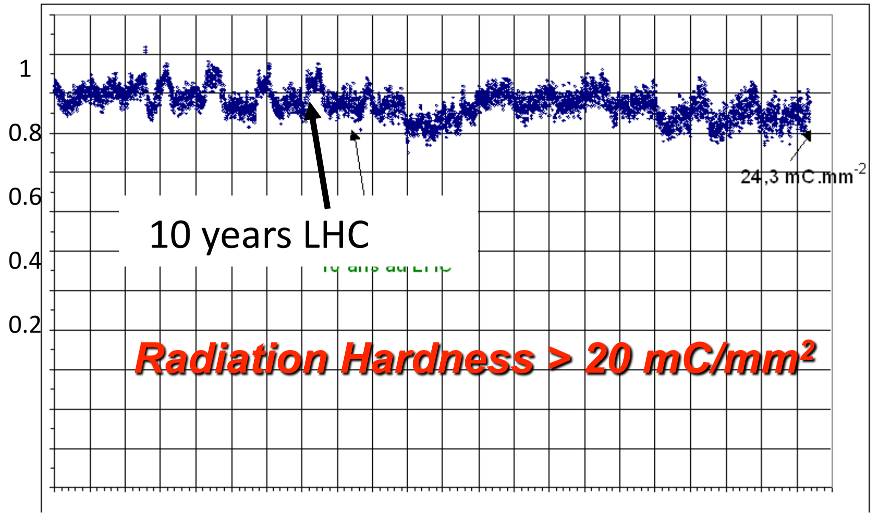




Spatial resolution

σ ~ 12 μm

ageing:Ar-iC$_4$H$_{10}$ 94-6% up to 24.3mC/mm^2

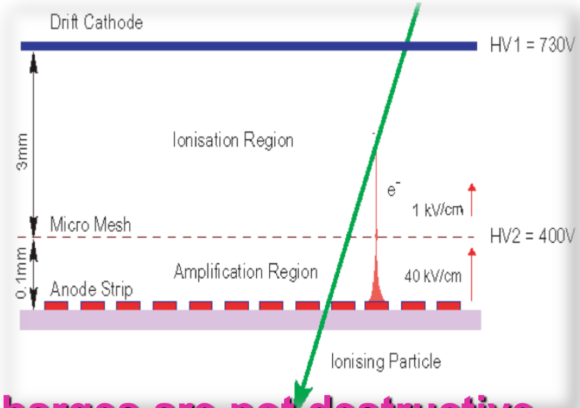


10 years LHC

Radiation Hardness > 20 mC/mm²

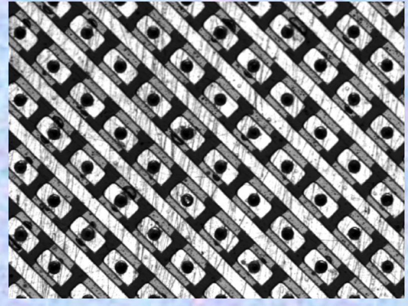
MICROMEGAS

Parallel plate multiplication in thin gaps between a fine mesh and anode plate

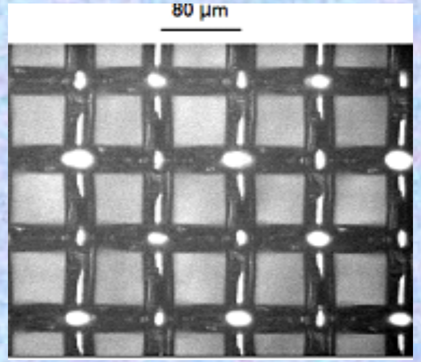


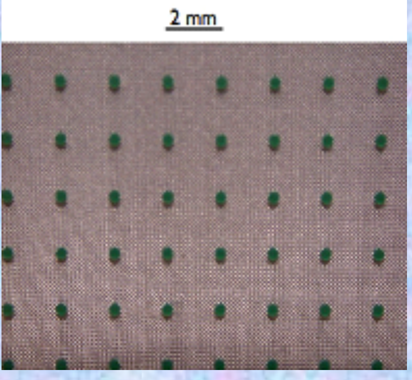
- **Discharges are not destructive,**
- **Further studies to mitigate discharges (minimize dead time) by resistive coating, GEM preamplification**

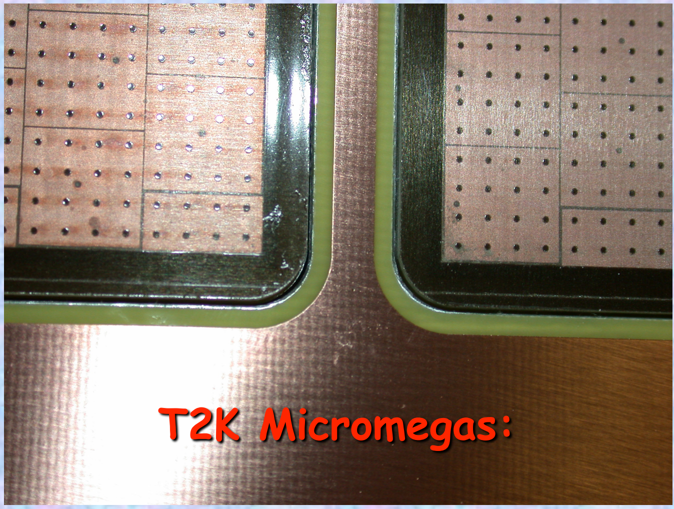
CAST readout:



"Bulk" Micromegas:



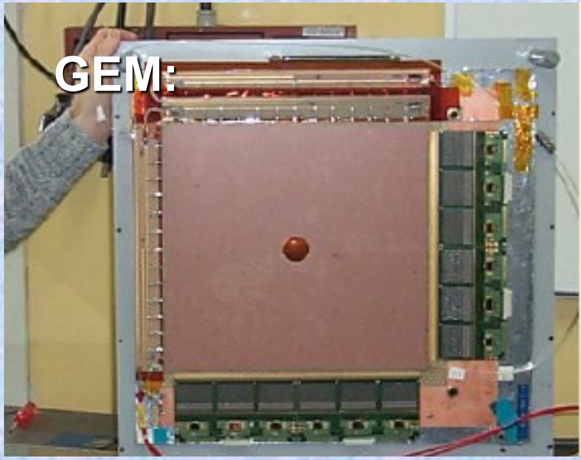


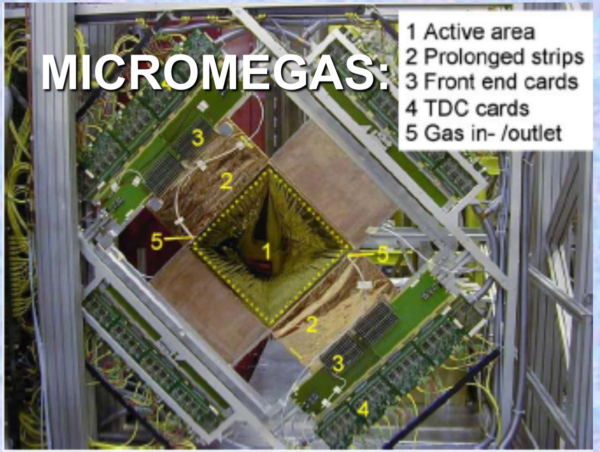


GEM / Micromegas in COMPASS - Textbook of Modern Detectors

High Rate Forward spectrometer:

COMPASS beam ~ 5* 10^7 muons/s on ^{6}LiD target

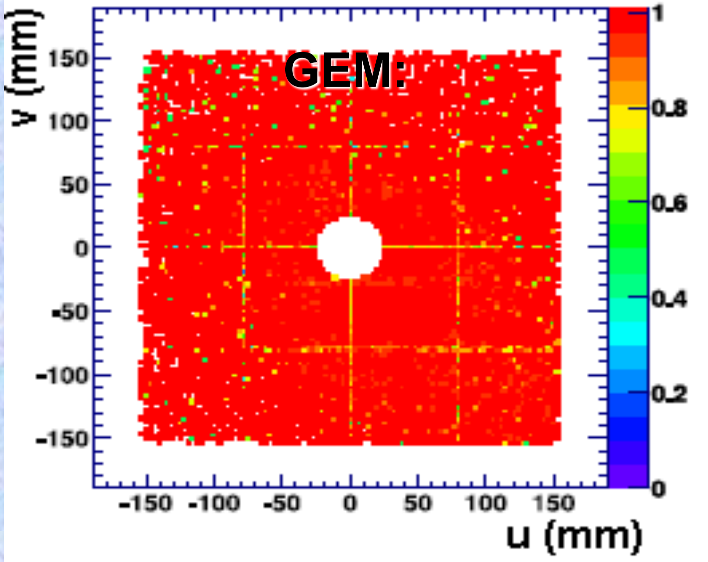




22 TRIPLE GEM DETECTORS
(31*31 cm^2)
& 12 MICROMEGAS PLANES
(40*40 cm^2)

High Rate /
High Precision /
Low Mass Detectors:

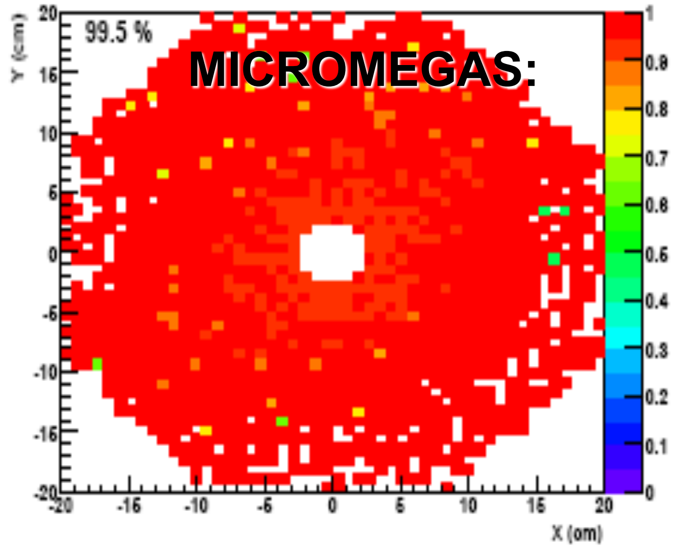
25 kHz/mm^2



UNIFORMITY
OF
TRACKING
EFFICIENCY:
(ε > 95 %)

RELIABLE
OPERATION
in 2002 – 2006

NO SIGN
OF AGING

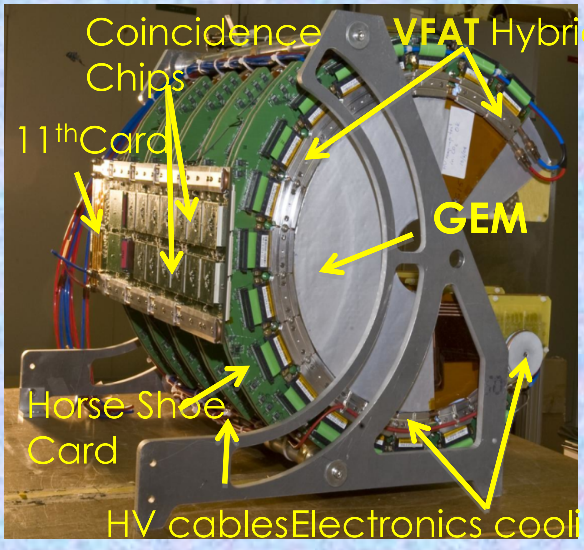


B. Ketzer et al, NIM A535 (2004) 314
F. Kunne, 2006 IEEE NSS/MIC Proceedings

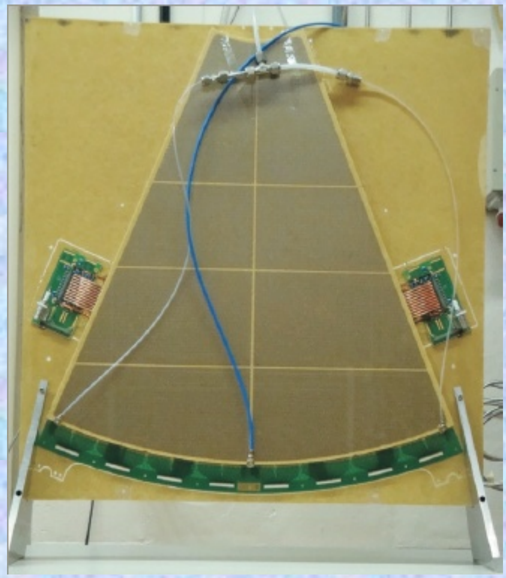
GEM in the LHC Experiments

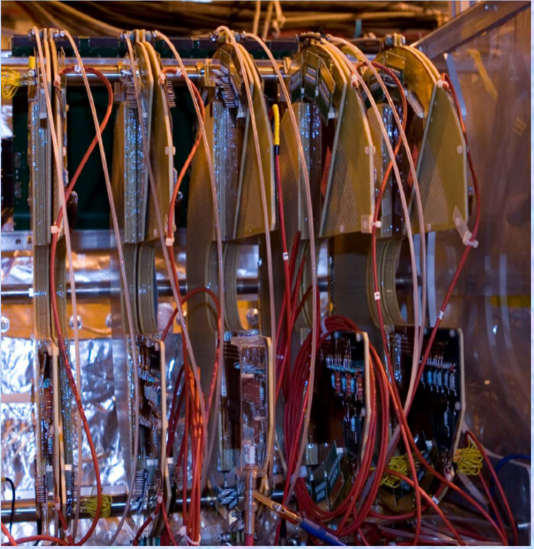
GEMs are used in the TOTEM (tracking and triggering) and LHCb Muon (triggering)

TOTEM GEMs:



2D readout (strips & pads)

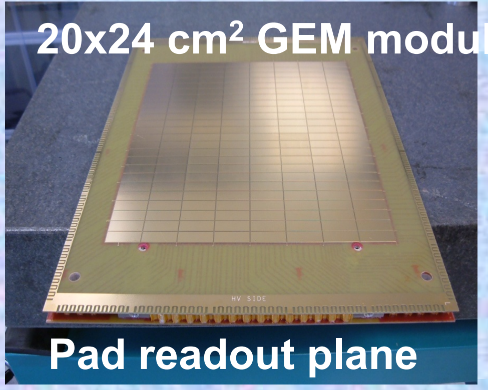




LHCb Muon Trigger:

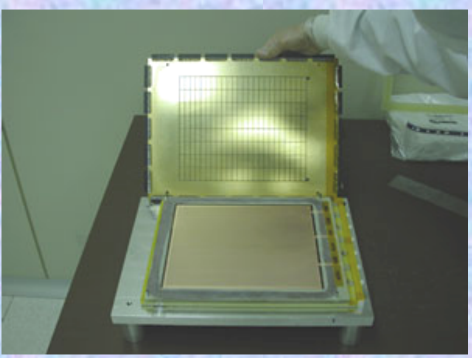
(12 double TGEM detectors)

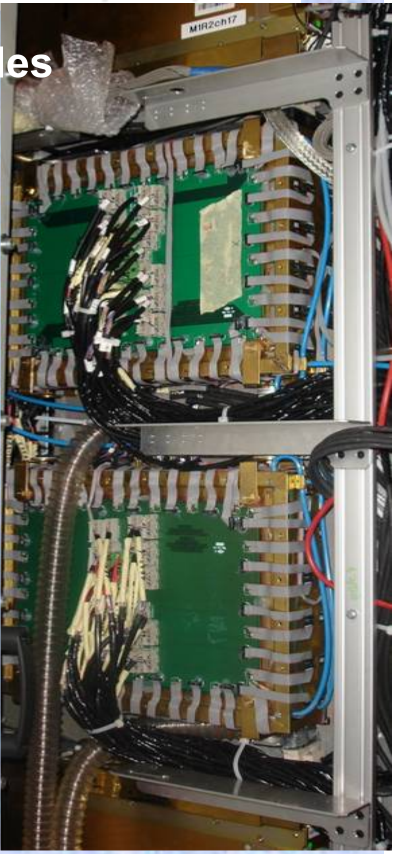
Rate - 5 kHz mm-2
Time resolution 4.5 ns rms
Radiation hard up to integrated charge of 20 mC mm-2 (15 LHCb years)



20x24 cm^2 GEM modules

Pad readout plane

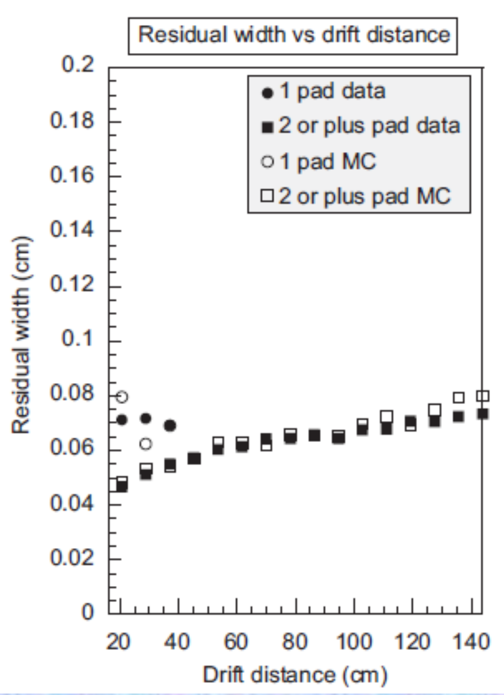




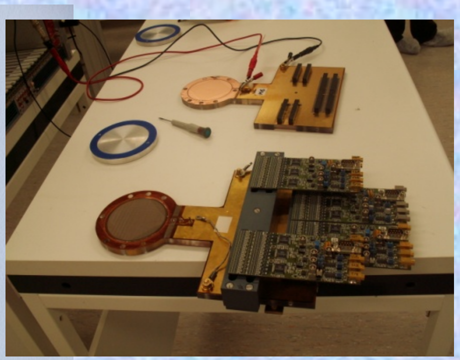
Micromegas in the Neutrino & Astrophysics Experiments

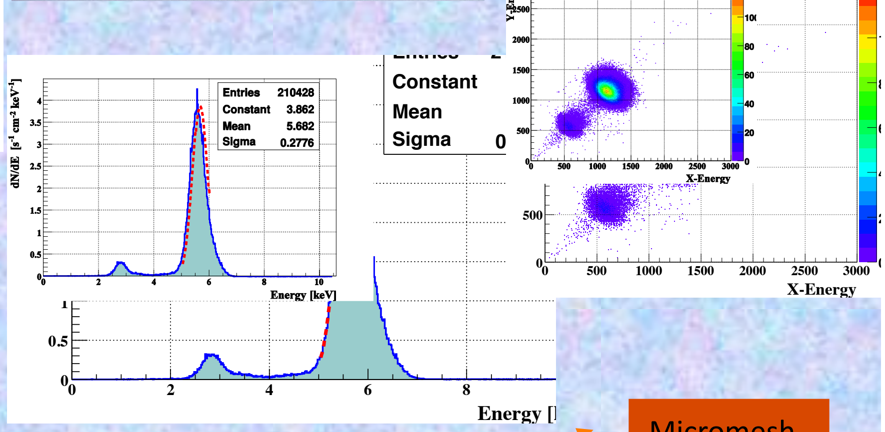
T2K TPC:

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



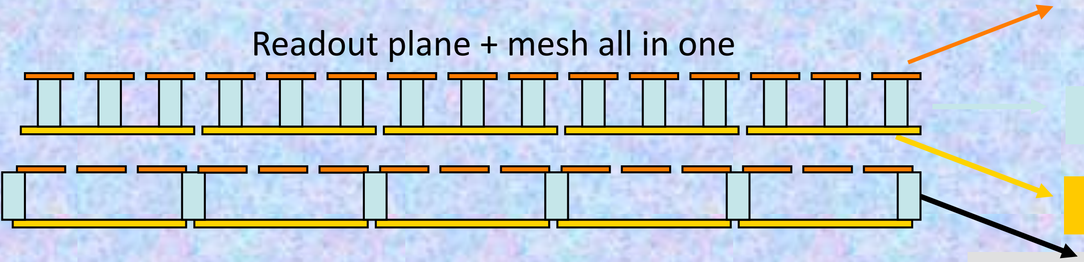
CAST (Micro-Bulk Technology):





Micro-Bulk Technology:

^{55}Fe with Ar – 5%
iC4H10 @ 1 bar
FWHM @ 6 keV = 11.5 %



Readout plane + mesh all in one

Micromesh
5µm copper

Kapton 50 µm

Readout pads

Lower capacitance
Under development

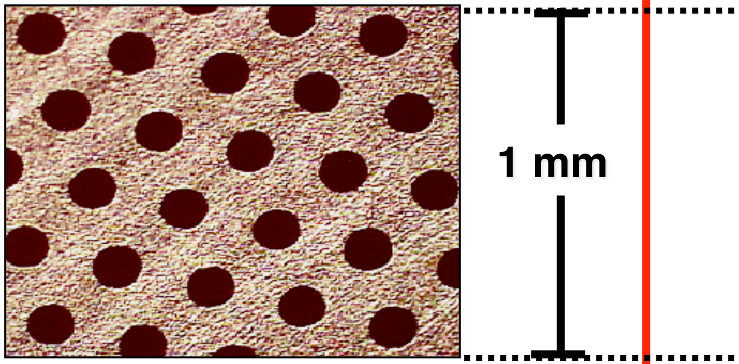
An I. Giomataris and R. De Oliveira idea

Thick-GEM Multipliers (TGEM)

Simple & Robust → Manufactured by standard PCB techniques of precise drilling in G-10 (and other materials) and Cu etching

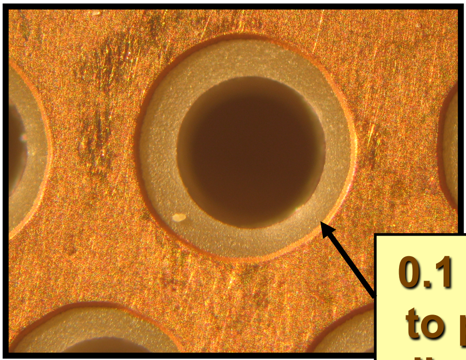
STANDARD GEM

10^3 GAIN IN SINGLE GEM



THGEM

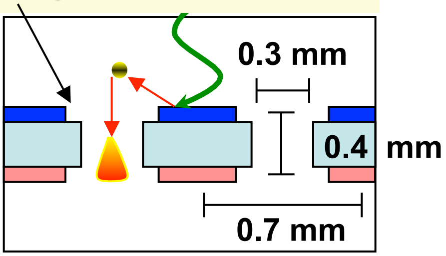
10^5 gain in single-THGEM



0.1 mm rim to prevent discharges

Similar to V. Peskov "Optimized GEM"

Reflective CsI PC

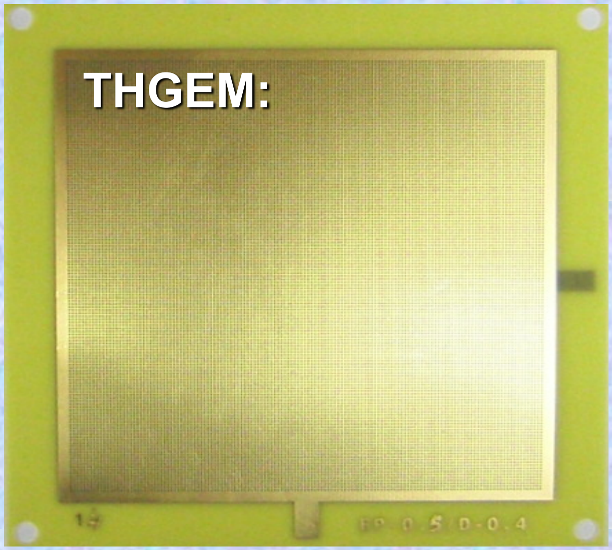


- Microlithography + etching
- High Spatial resolution (~ 30 μm)
- $>10^3$ gain in single GEM, 10^6 gain in cascaded GEMs
- Fast (ns)
- Low pressure – gain~30

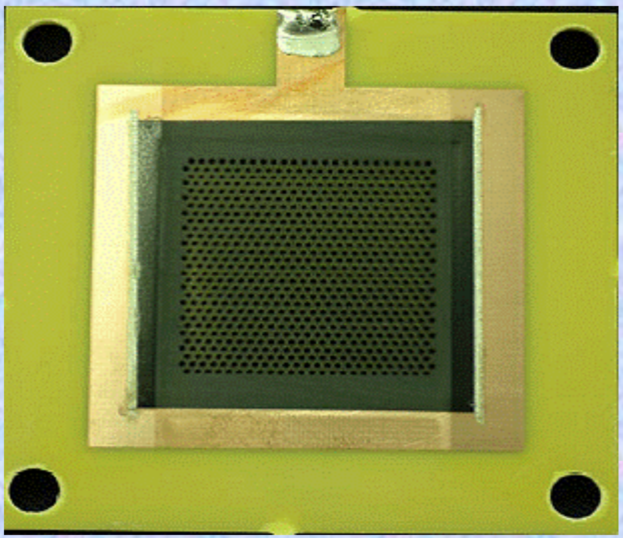
- PCB tech - etching + drilling, Simple & robust
- Sub-mm to mm spatial resolution
- 10^5 gain in single- & 10^7 double-TGEM
- Fast (ns)
- Low pressure (<1Torr) gain 10^4

THGEM- Thick GEM / RETGEM Resistive Thick GEM

THGEM:



Resistive Electrode Thick GEM (RETGEM):

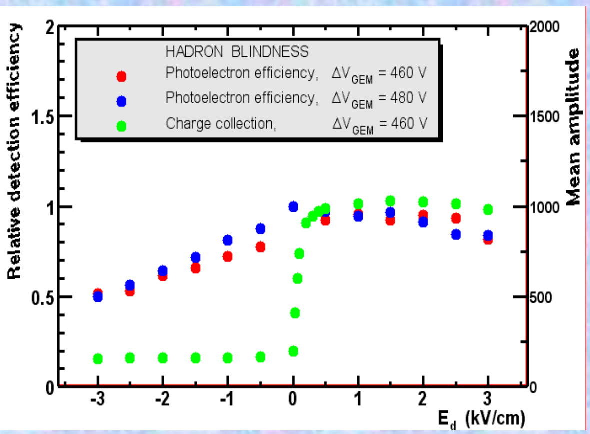


3 Advantages of THGEM/ RETGEM for RICH:

- **Very high gains** (>10^5) can achieved with TGEMs in some gases, especially in mixtures of Ne with a small concentration of quenchers

- TGEM can operate in badly quenched gases as well as in gases in which are strong UV emitters . This may open a possibility of using **windowless detectors** for some RICH designs

- If necessary TGEMs can operate in "**hadron blind mode**" with zero and even reversed electric field in the drift region which allows strongly suppress the ionization signal from charged particles



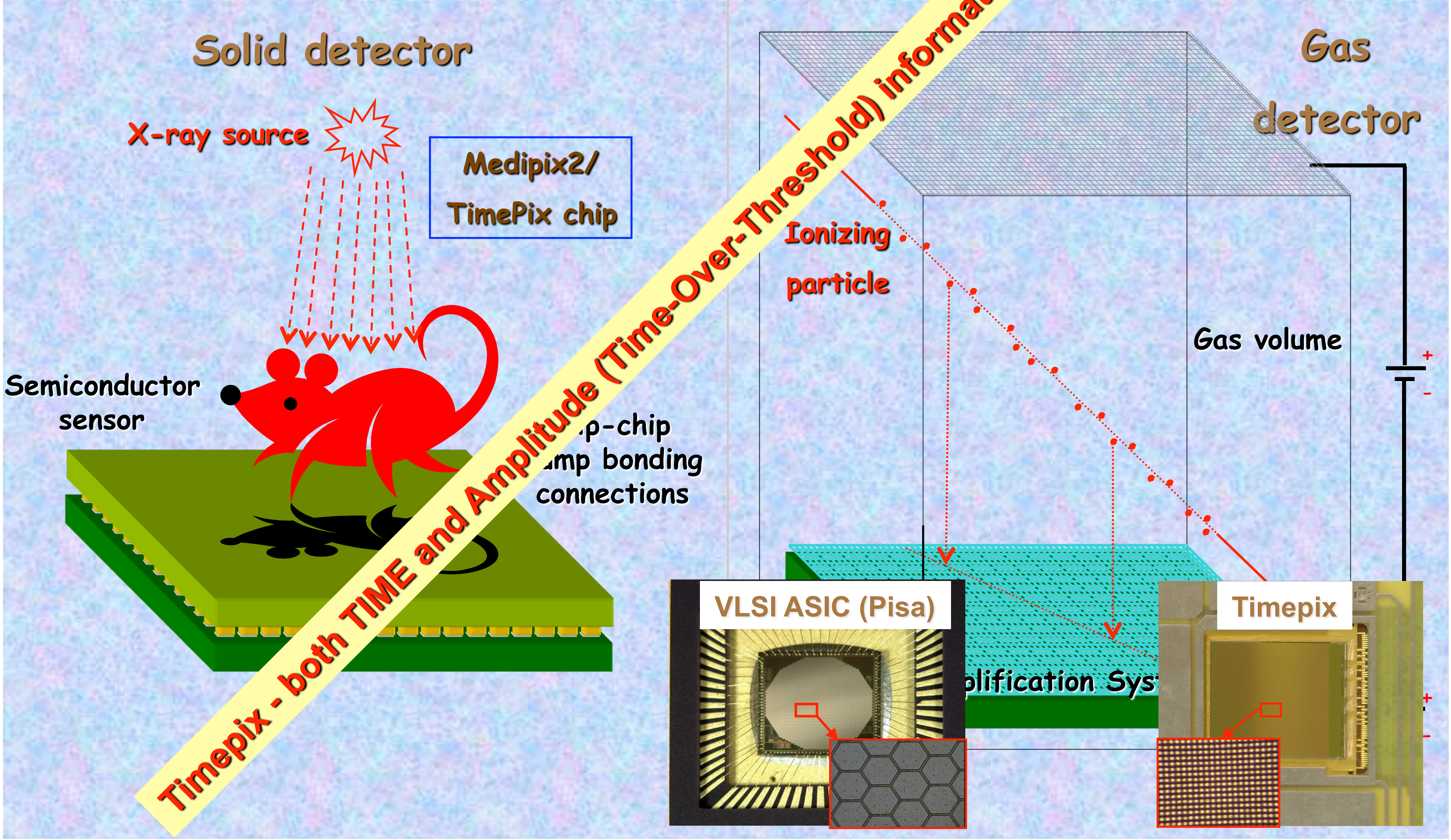
Measurements with 3-GEM for Hadron Blind Detector for Phenix @ RHIC

Pixel Readout of Micro-Pattern Gas Detect

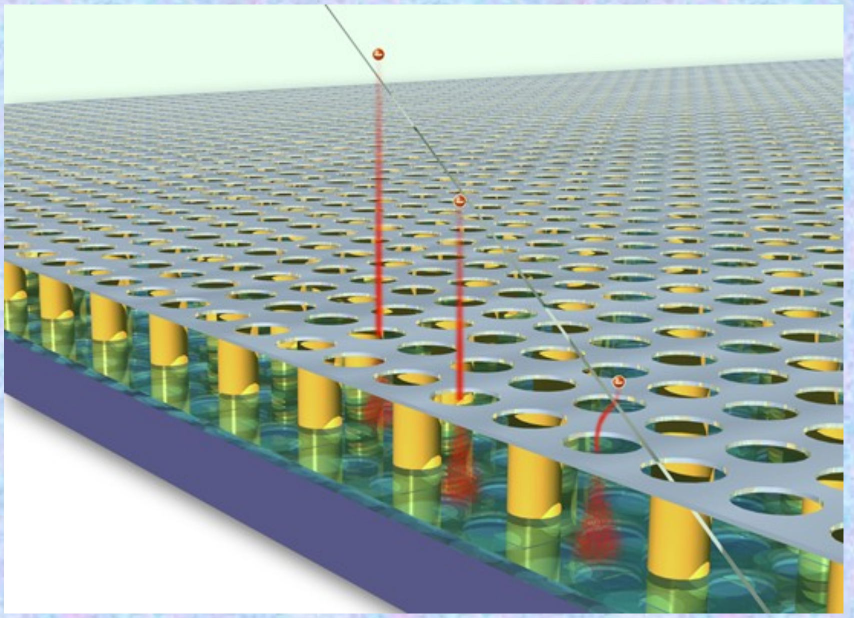
Gas Detector Readout by multi-pixel CMOS array (used as c ge collecting anode)

CMOS readout concept → Analog VLSI ASIC (Pisa), ME X2 / TIMEPIX Chips

Timepix - both TIME and Amplitude (Time-Over-Threshold) information are available

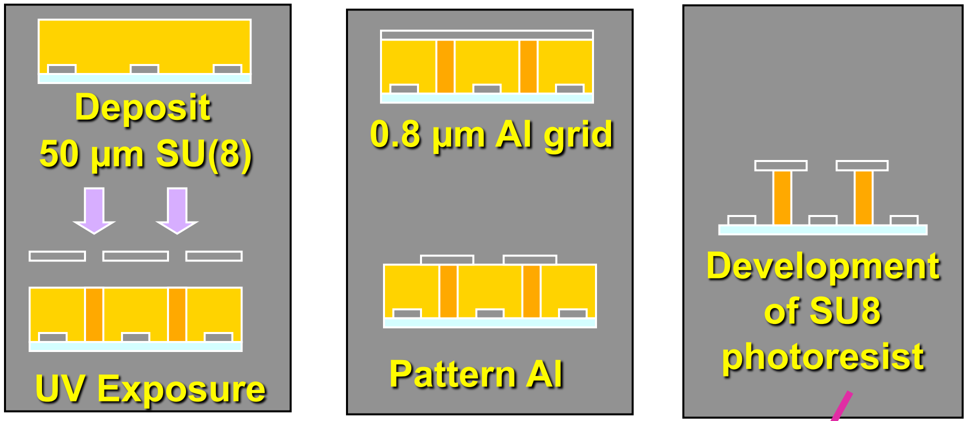


Micromegas/Ingrid + Timepix Detector



InGrid: integrate Micromegas & pixel chip by Si-wafer post-processing technology

- Grid robustness & Gap/Hole accuracy

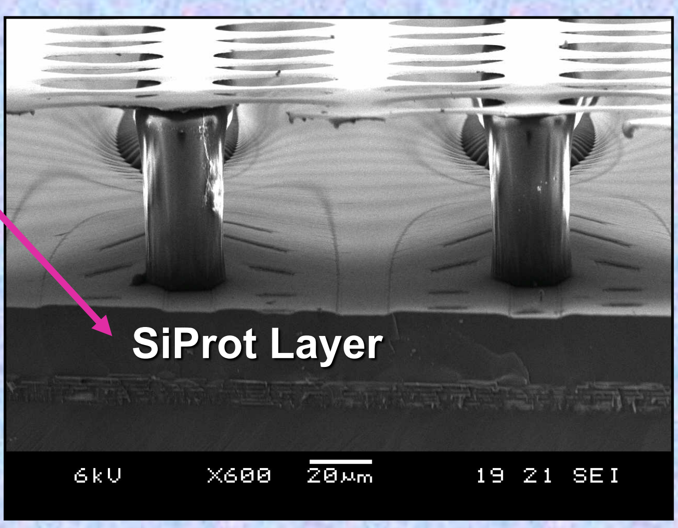


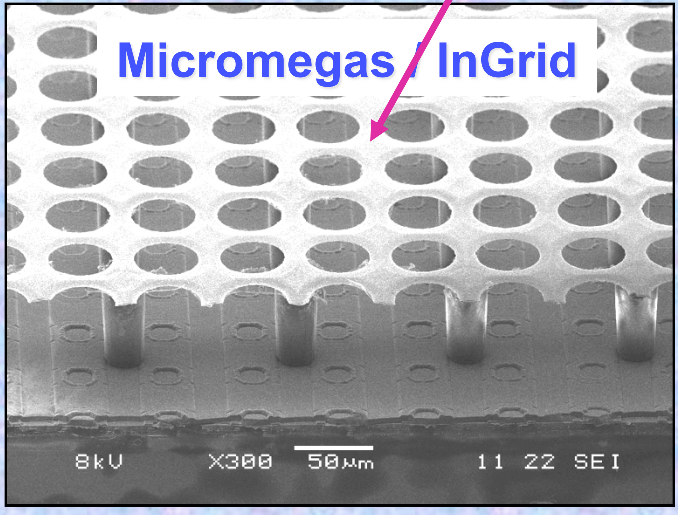
Micromegas/Ingrid + SiProt + Timepix Detector:

Apply Si3N4 (high resistivity layer 3-20 µm)

for discharge quench & SPARK PROTECTION

before InGrid production

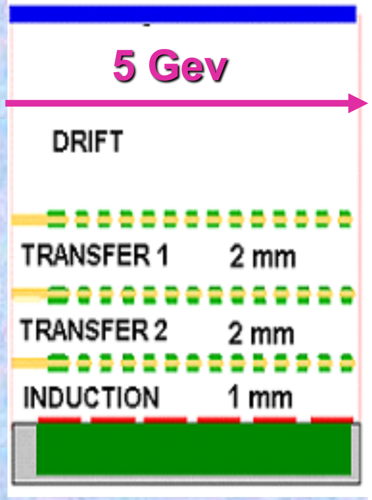


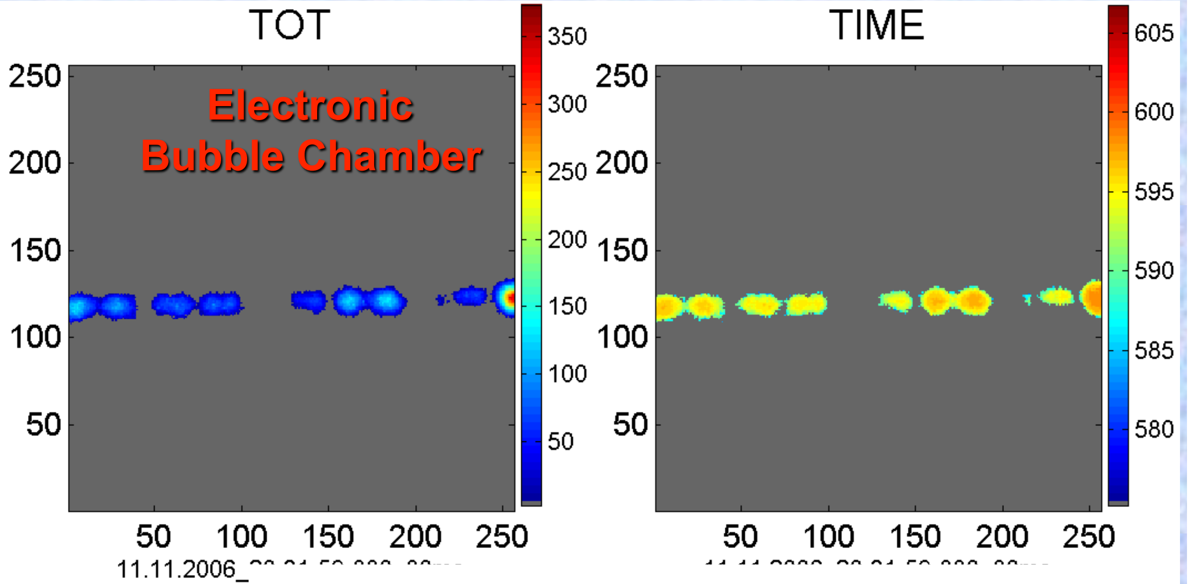


GEM/Micromegas + Timepix Readout @ 5 GeV Electron Beam

Triple GEM + Timepix:

Operated in checker-board pattern of TOT (charge) and TIME (time)

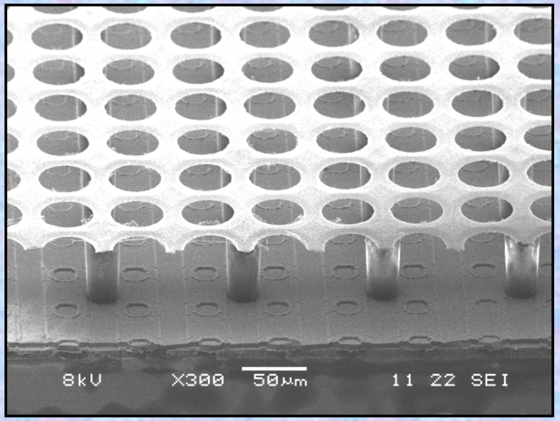


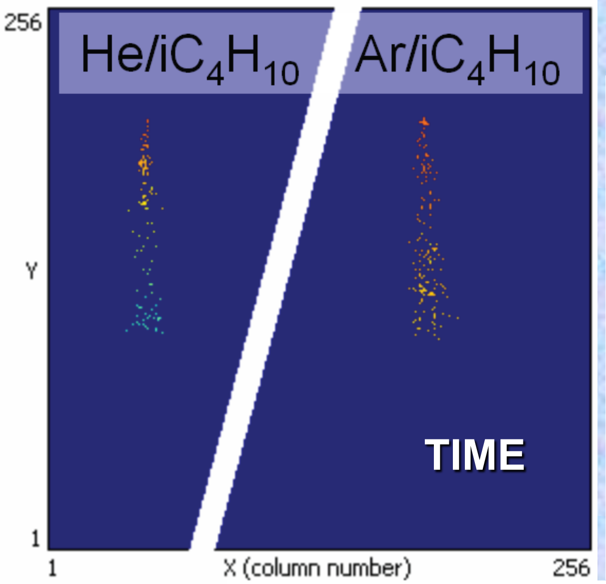


M. Titov, Nucl. Instr. and Meth. A581 (2007) 25.

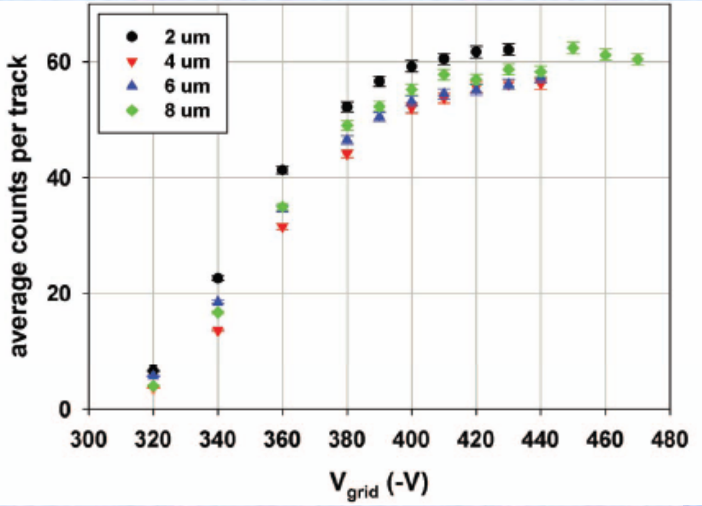
Micromegas/ Ingrid + Timepix:

Studies of SiProt layer thickness (efficiency & discharges):





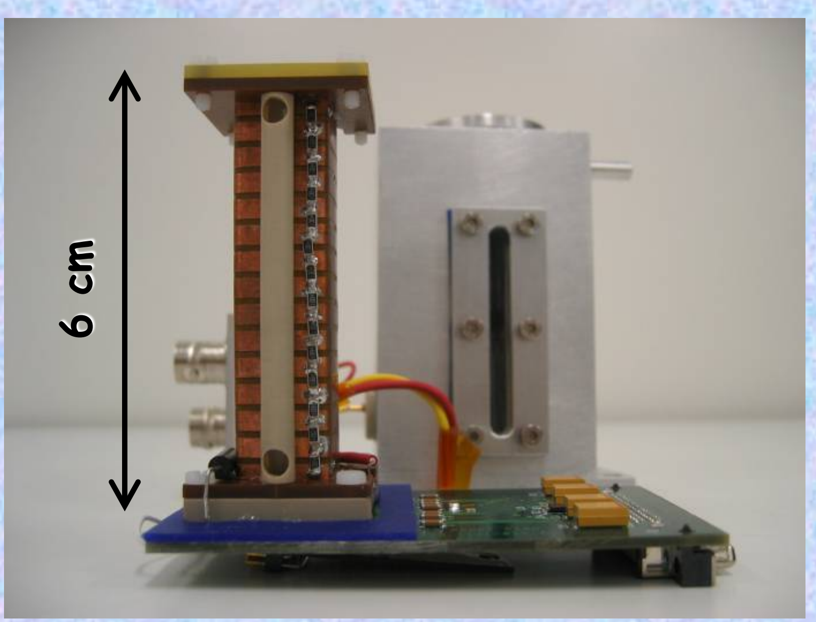
<Nhits> per track vs Si3N4 layer thickness:

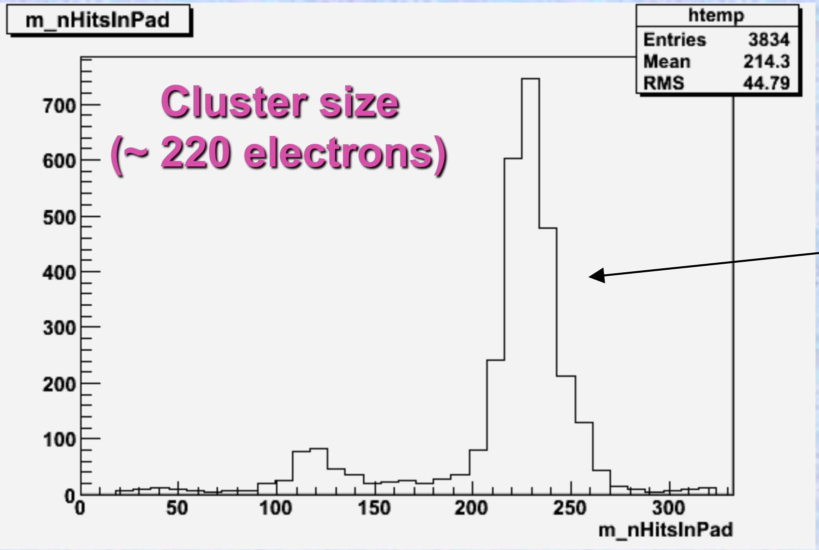


Y. Bilevych et al., 2009 IEEE NSS/MIC Conference Record.

Micromegas/Ingrid + Timepix & microTPC

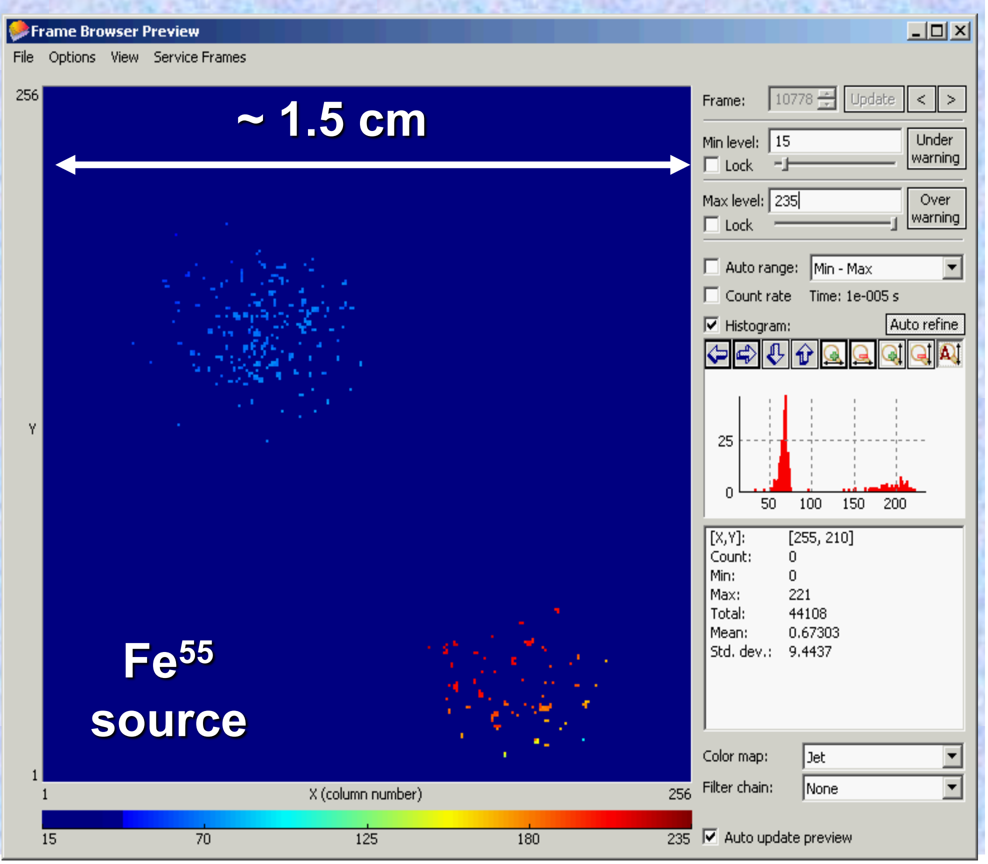
μTPC with a 6 cm height field cage
Size: 4 cm x 5 cm x 8 cm





Observe electrons (~220) from an X-ray (5.9 keV) conversion one by one and count them

→ Study single electron response



Frame: 10778
Min level: 15
☐ Lock
Max level: 235
☐ Lock
☐ Auto range: Min - Max
☐ Count rate Time: 1e-005 s
☑ Histogram:

[X,Y]: [255, 210]
Count: 0
Min: 0
Max: 221
Total: 44108
Mean: 0.67303
Std. dev.: 9.4437

Color map: Jet
Filter chain: None
☑ Auto update preview

Micromegas/Ingrid + Timepix & Discharges

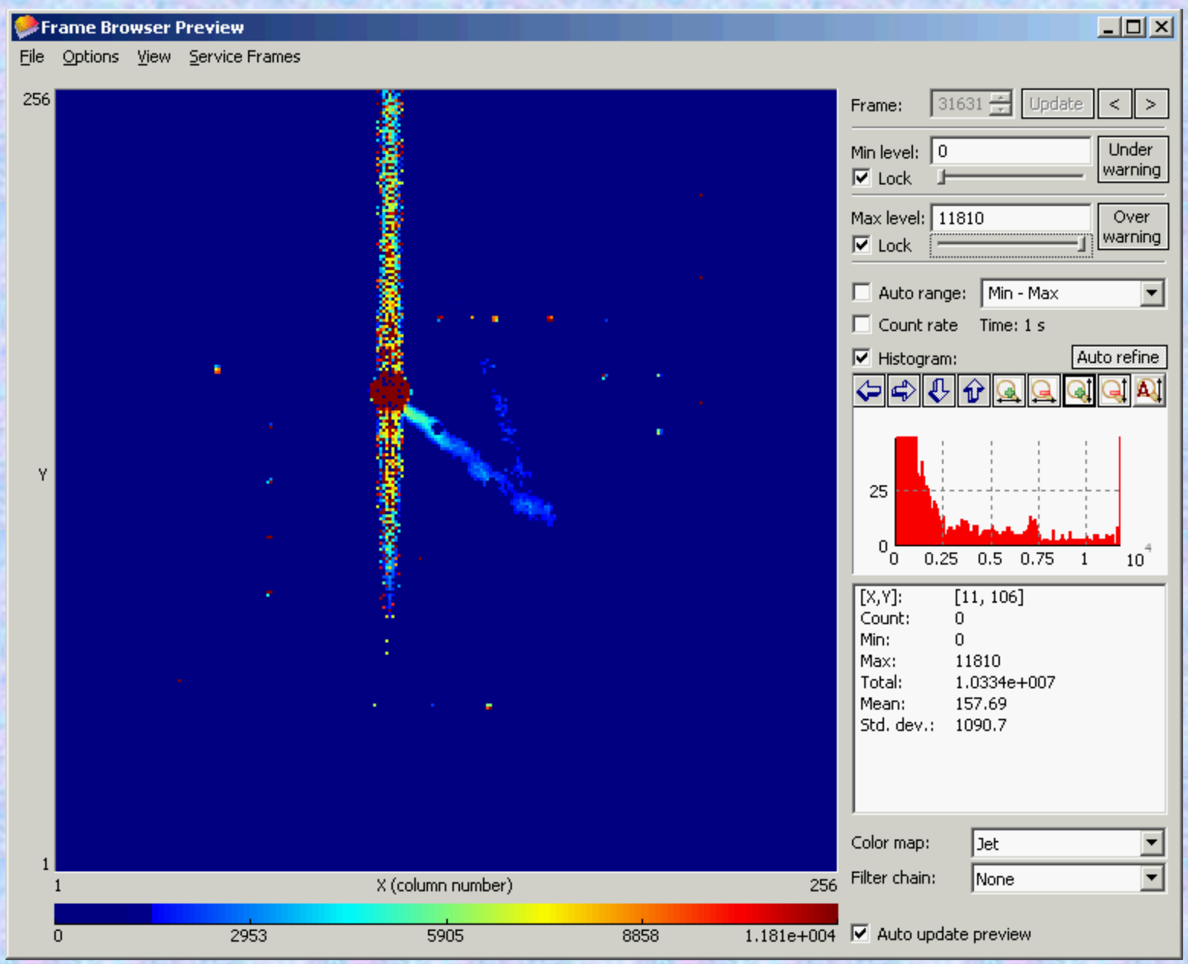
- **Strong electric field (70 – 100 kV/cm) over the Si-pixel chip**
- **Provoke discharges by introducing small amount of Thorium in the Ar gas**
  - **Thorium decays to Radon 222 which emits 2 alphas of 6.3 & 6.8 MeV (~ 10^5 e)**

- **Round-shape images of discharges are being recorded**

- **Perturbations in the concerned columns**

  - **Threshold ?**
  - **Power ?**

Chip keeps working !



Frame: 31631

Min level: 0

☑ Lock

Max level: 11810

☑ Lock

☐ Auto range: Min - Max

☐ Count rate Time: 1 s

☑ Histogram:

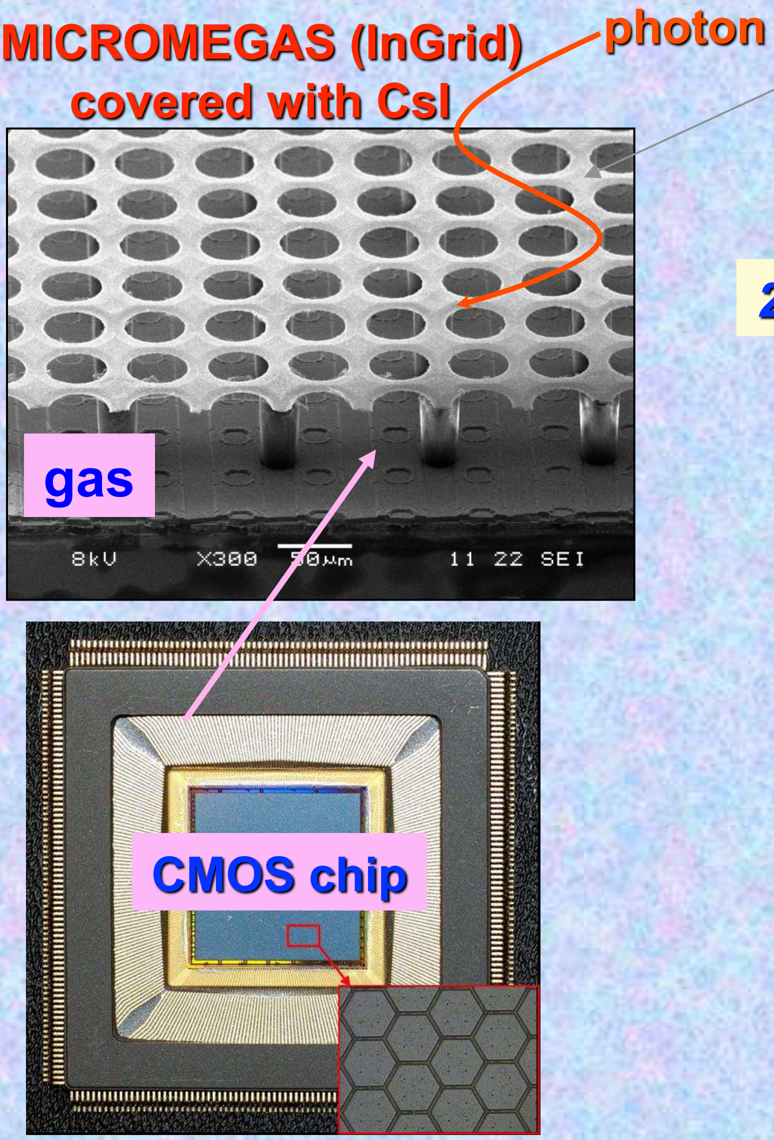
[X,Y]: [11, 106]
Count: 0
Min: 0
Max: 11810
Total: 1.0334e+007
Mean: 157.69
Std. dev.: 1090.7

Color map: Jet

Filter chain: None

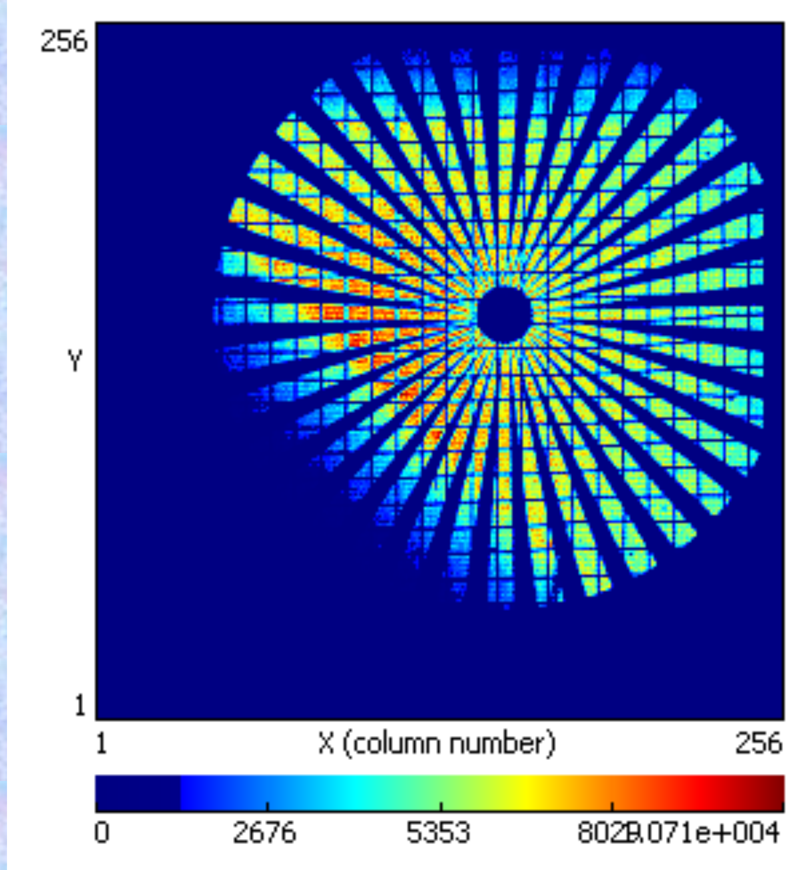
☑ Auto update preview

Integrating Photon Detectors and Electronics



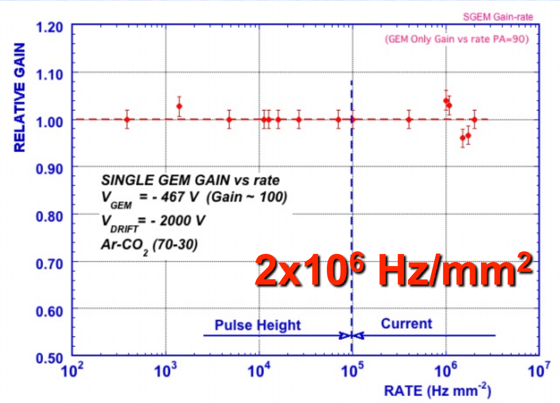
Chip area: 14x14mm².
(256×256 pixels of 55×55 µm²)

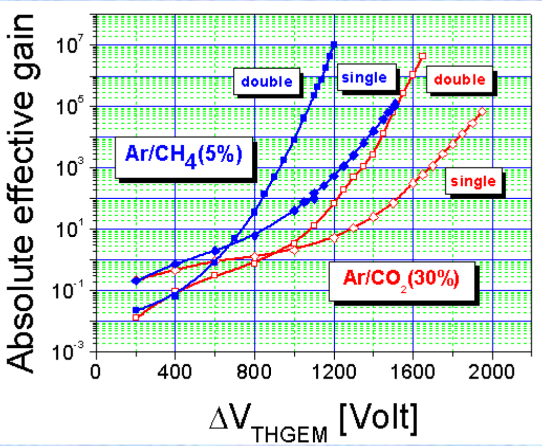
2D UV Image of a 10mm diameter mask

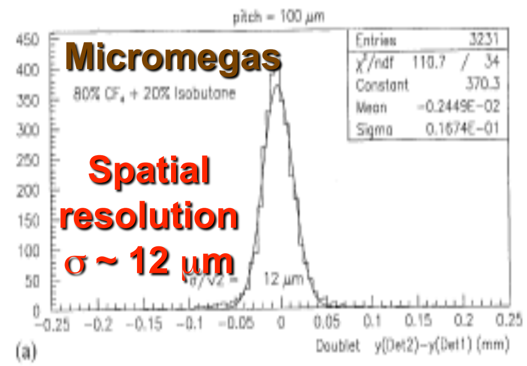


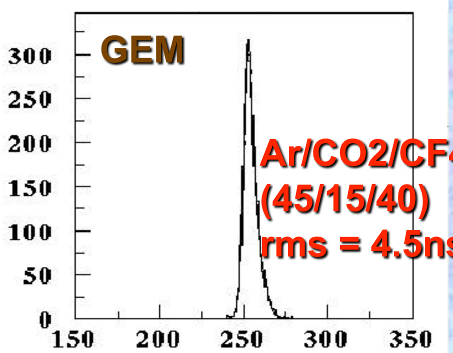
Micro-Pattern Gas Detectors Performance Summary

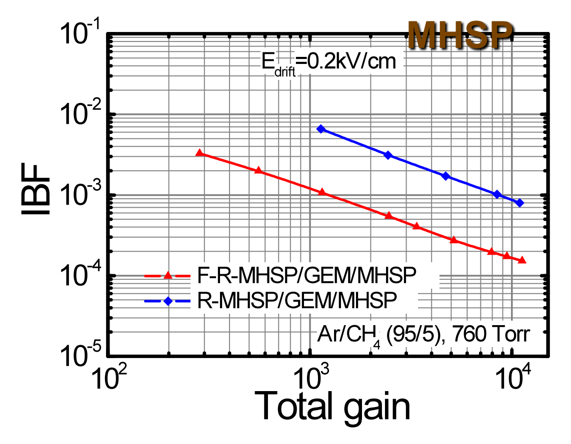
- **Rate Capability**
- **High Gain**
- **Space Resolution**
- **Time Resolution**
- **Energy Resolution**
- **Ageing Properties**
- **Ion Backflow Reduction**
- **Photon Feedback Reduction**

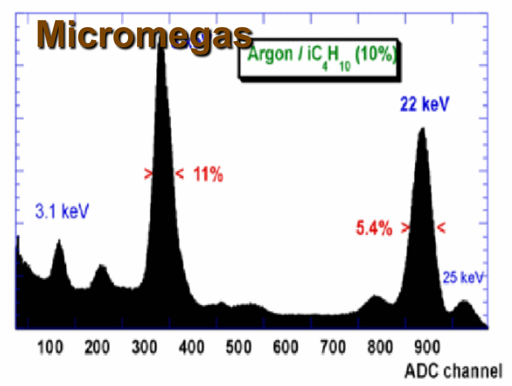


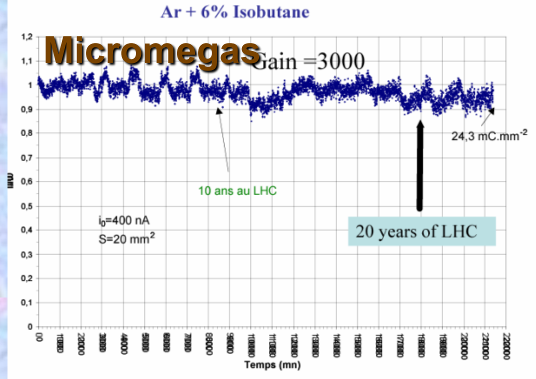












RD 51 Collaboration - Working Groups

Advance Technological Developments of Micro-Pattern Gas Detectors

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

RD 51 Collaboration 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; resistive anode readout; design optimization (discharge protection)

WG2: single-electron response, avalanche fluctuations, photo detection with THGEM, GOSSIP/Ingrid (radiation tolerance, discharge protection, rate effects)

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

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

WG6: CERN MPGD Production Facility; TT Network

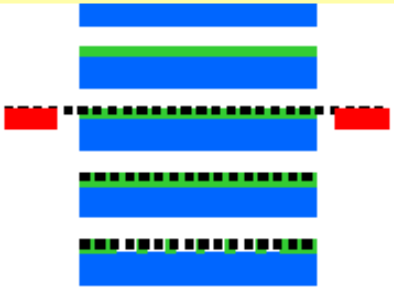
WG7: RD51 test beam facility (November 2009 - 8 groups/5 setups)

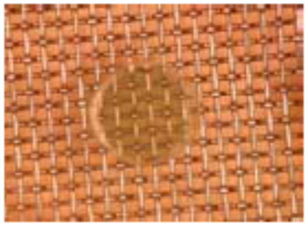
RD 51 WG1- MPGD Technology and New Structures

Objective: Detector design optimization, development of new multiplier geometries and techniques.

- **Development of Large Area MPGD (production of demonstrators)**

Bulk Micromegas



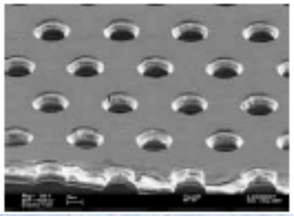


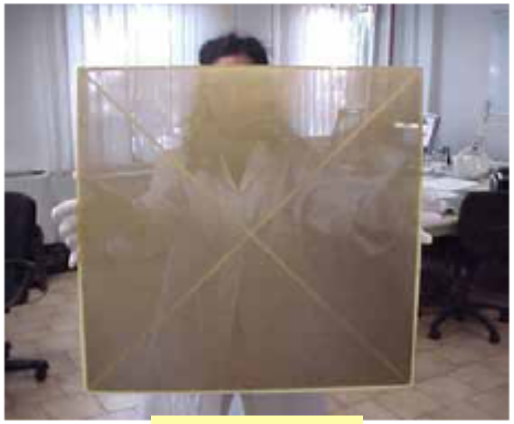
NEW - Single mask GEM technique

Single side copper patterning

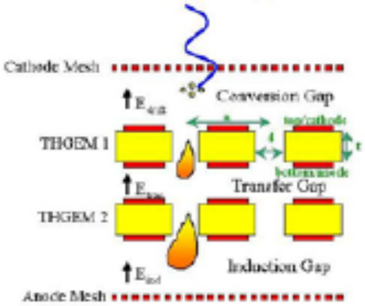
Polyimide etching

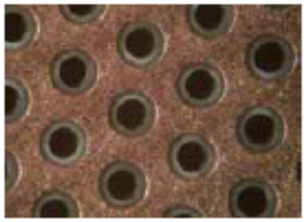
Copper reduction





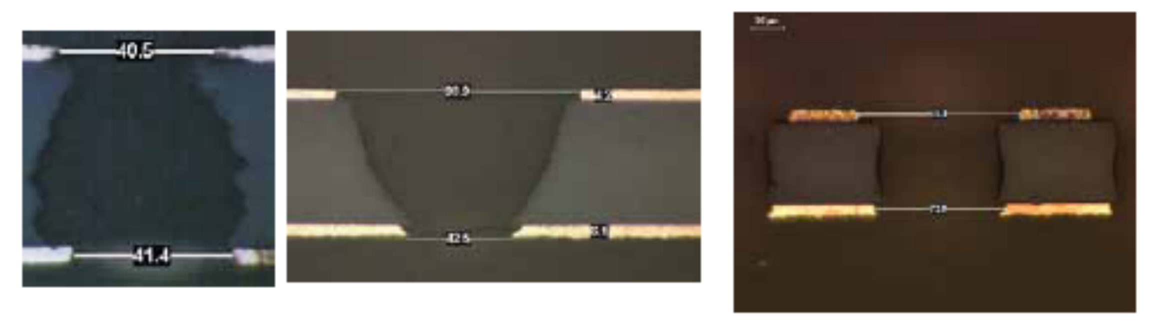
THGEM



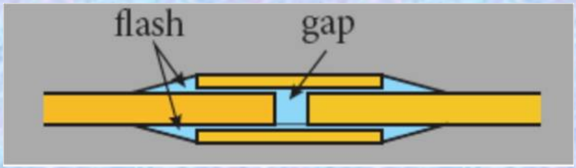


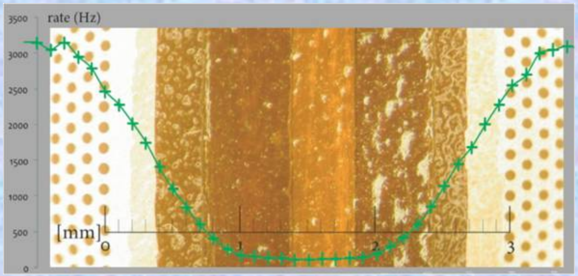
Large Area GEM Detector Development

New single mask technology:
Development and evaluation
With small prototypes

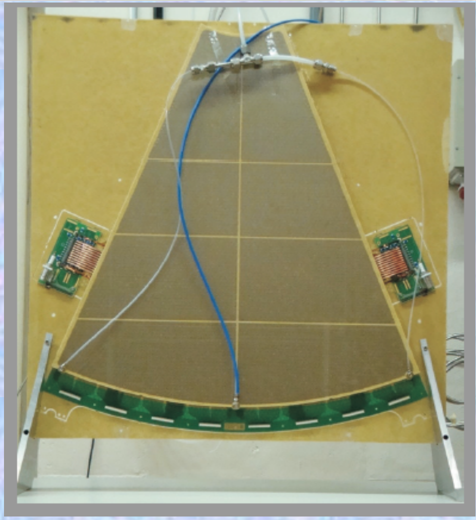


GEM foils splicing
Technology development
and tools





TWO-SECTORS TRIPLE-GEM
PROTOTYPE FOR
TOTEM T1 UPGRADE
(60x60 cm^2)



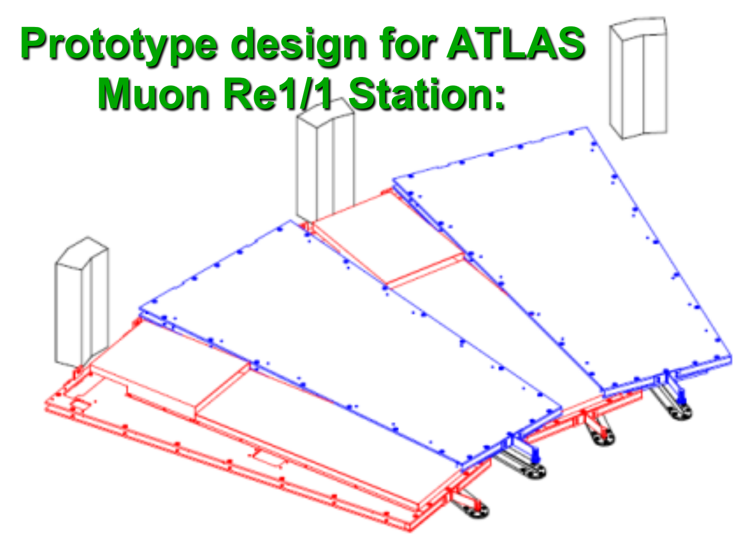
Large Area Micromegas Detector Development

ATLAS MAMMA Collaboration:

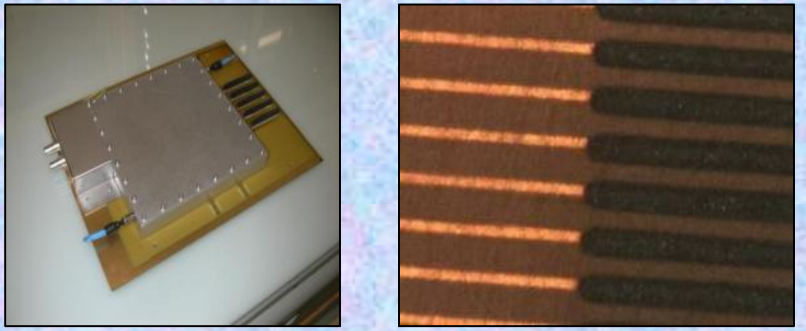
On the road to large area detectors:
($1.5 * 0.5$ m^2) - Half the final size

Segmented mesh,
250 and 500 µm strip pitches,
Longer strips (350 & 850 µm)

Prototype design for ATLAS
Muon Re1/1 Station:



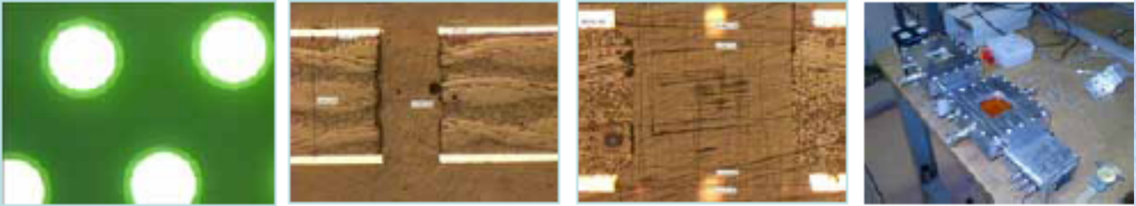
Study of resistive coatings for
spark protection (smaller prototypes)



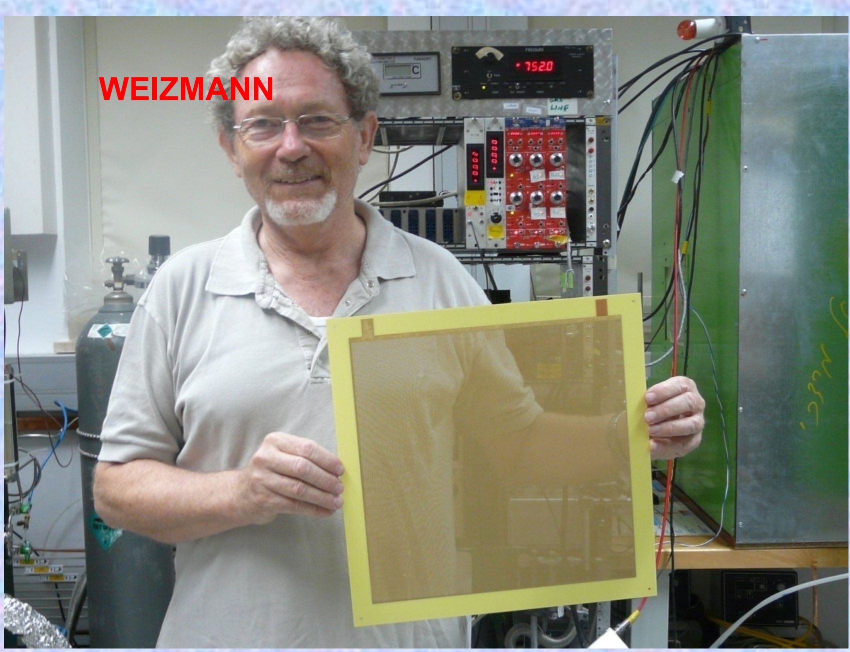
Uniformity, robustness, easy fabrication.
no support frames, small dead regions
& <u>"Full path of industrial production"</u>

Development of UV Large Photon Detectors based on THGEM

Technology Development & Prototype Construction



$300 \times 300 mm^2$ THGEM
90,000 0.5mm diameter holes
(Print Electronics, IL)



$600 \times 600 mm^2$ THGEM
600,000 0.4mm diameter holes
(Eltos, IT)

Industry: square-meters possible

Status: so far only "mechanical" electrodes

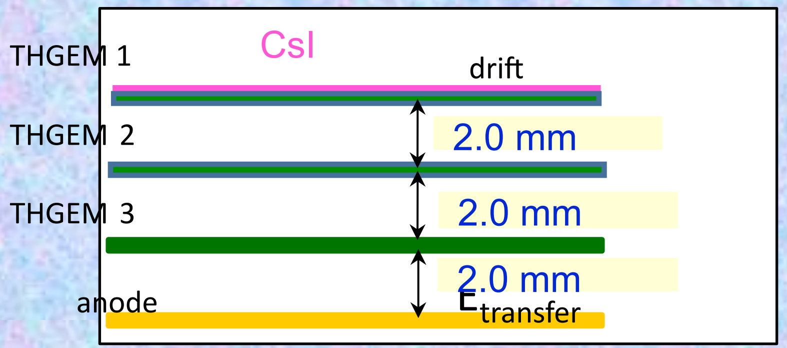
RD 51 WG2 - Common Characterization and Physics Issues

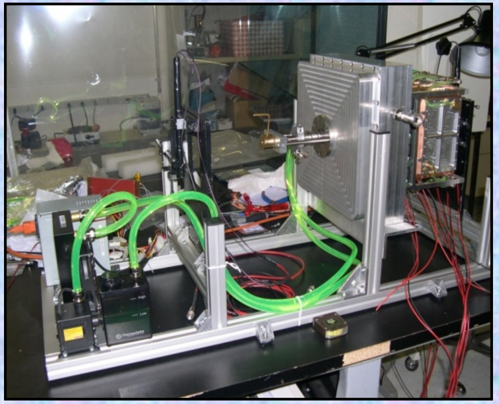
Objective 1: Development of common standards and comparison of different technologies, performance evaluation of different MPGD detectors.

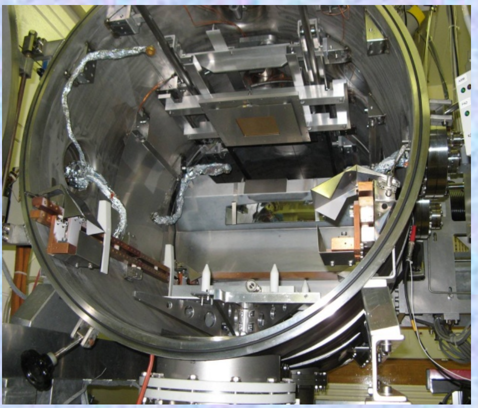
Objective 2: Development of radiation-hard gaseous detectors operating beyond the limits of present devices.

- **Single electron response, charging up (gain stability) and rate capability issues**

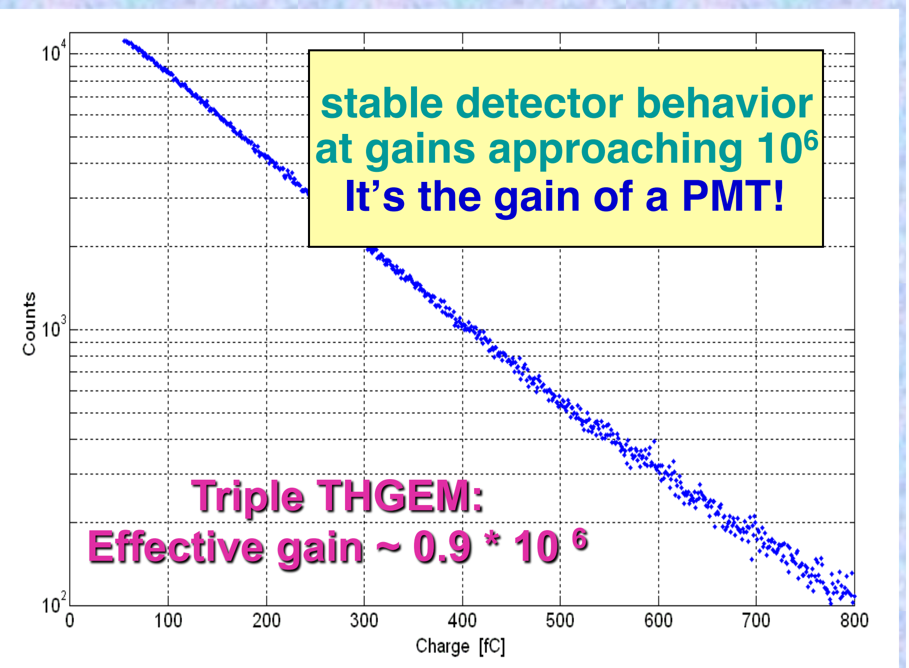
3 THGEM Structure:







Amplitude distribution for single photons:



stable detector behavior at gains approaching 10^6

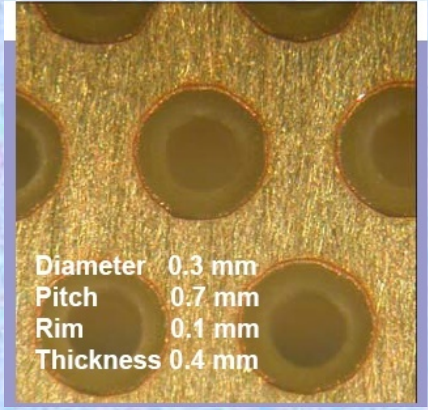
It's the gain of a PMT!

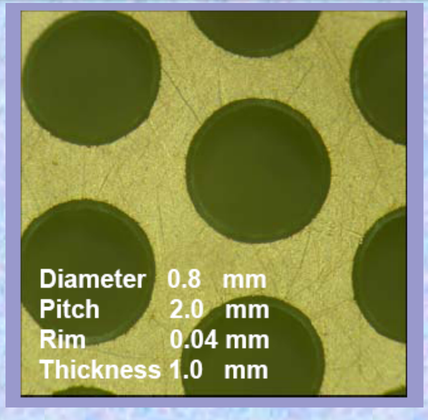
Triple THGEM:

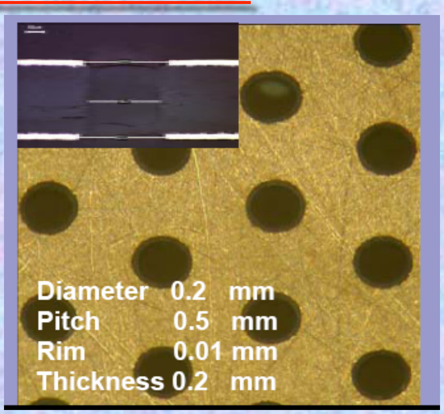
Effective gain ~ 0.9 * 10^6

Detector Desing Optimization and New Geometries

Choice of geometry (max. gain, stability) of THGEM Detectors:





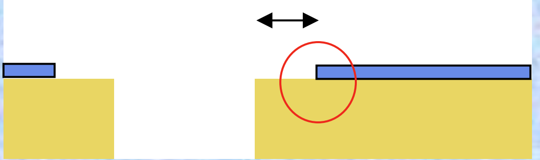


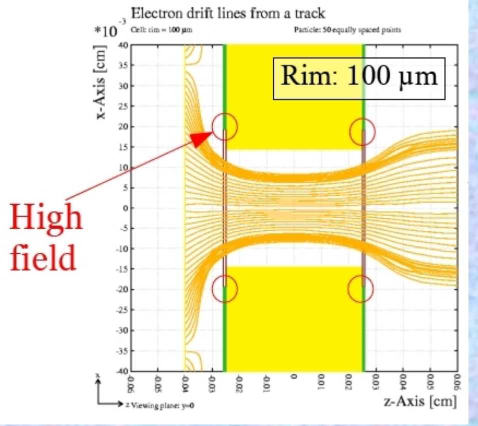
Mask etching + drilling; rim = 0.1mm

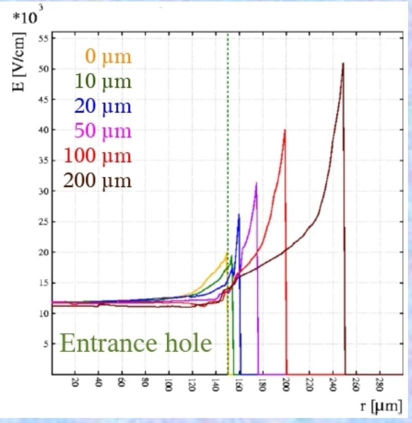
Drilling + chemical rim etching without mask

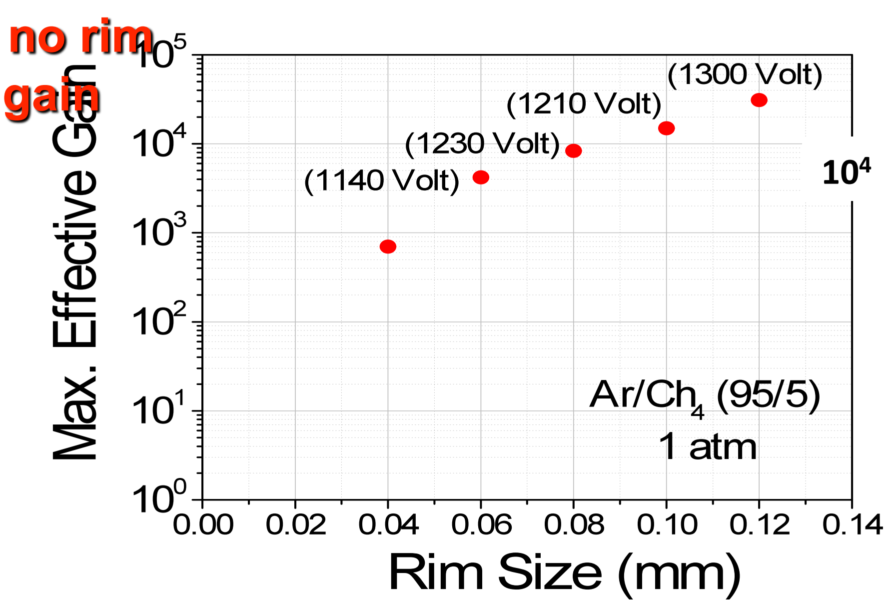
Best stability (no charging up): Holes with no rim

But: no-rim resulted in 10-100 times lower gain





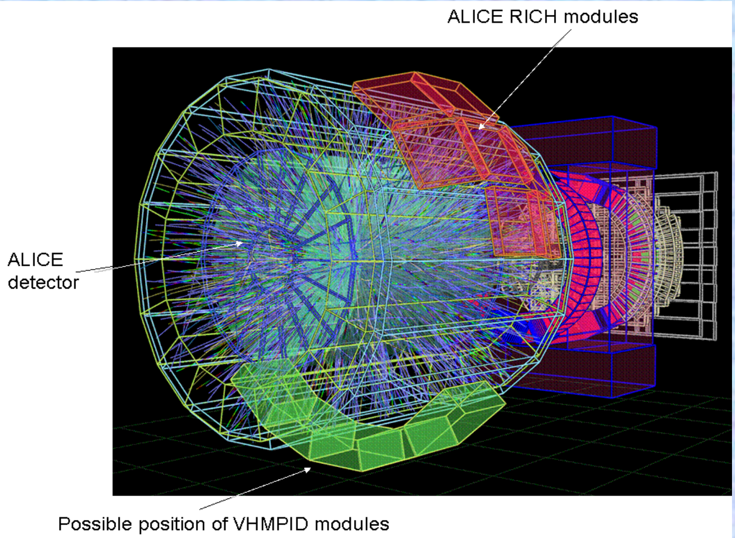


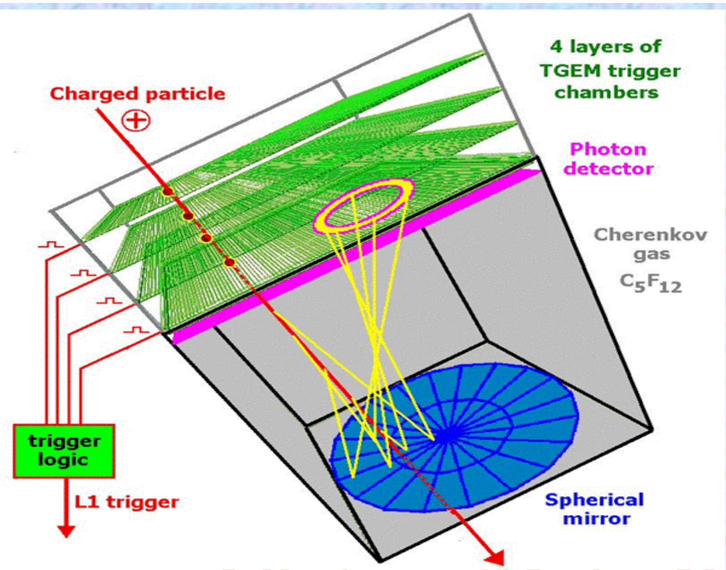


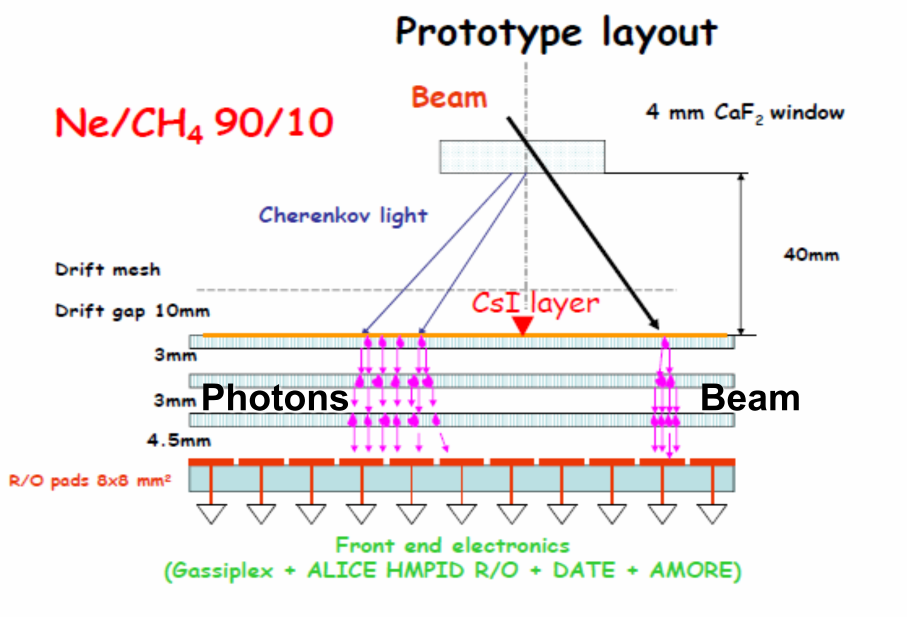
pitch = 1 mm; diameter = 0.5 mm;
rim=40; 60; 80; 100; 120 μm

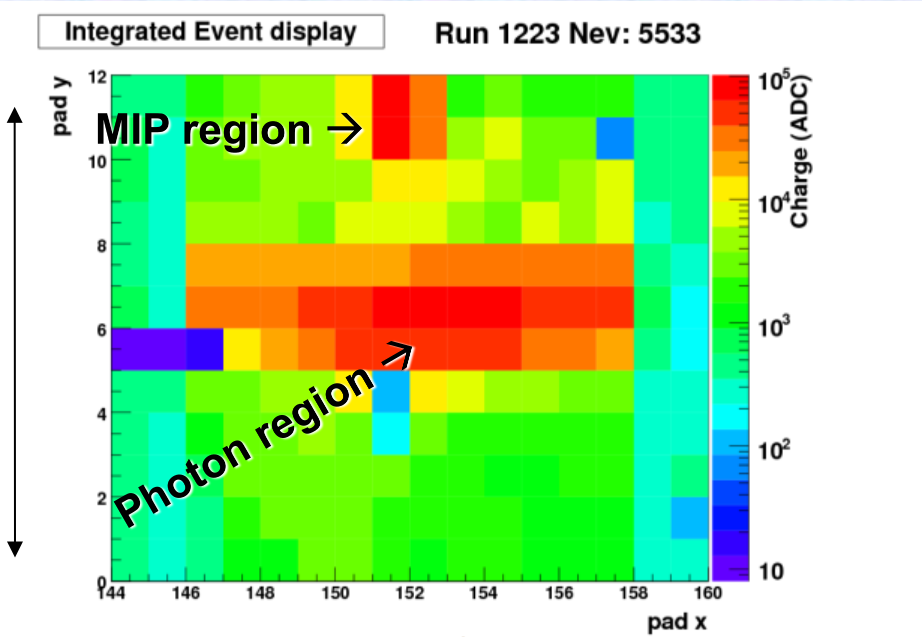
Detection of Cherenkov Light with CsI coated triple THGEM

3THGEM Detector is proposed for Very High Momentum Particle Identification Detector (VHMPID) for ALICE









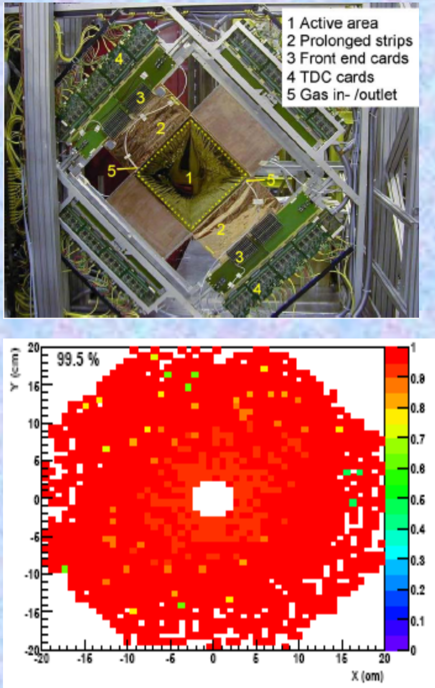
P. Martinengo, V. Peskov, RD51 Collab. Meet., Nov.24, 2009, WG2 Meeting

RD 51 WG3 - Applications

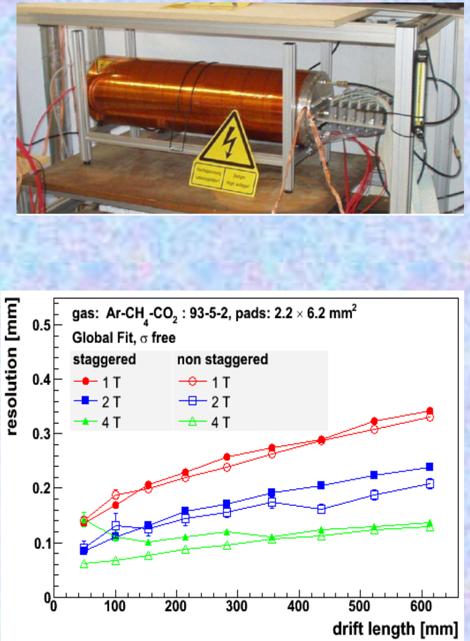
Objective: Evaluation and optimization of MPGD technologies for specific applications.

- MPGD based detectors for tracking and triggering (including Muon Systems).
- MPGD based Photon Detectors (e.g. for RICH).
- Applications of MPGD b
- Cryogenic Detectors for
- X-ray and neutron imagi
- Astroparticle physics ap
- Medical applications.
- Synchrotron Radiation, Plasma Diagnostics and Homeland Security applications.

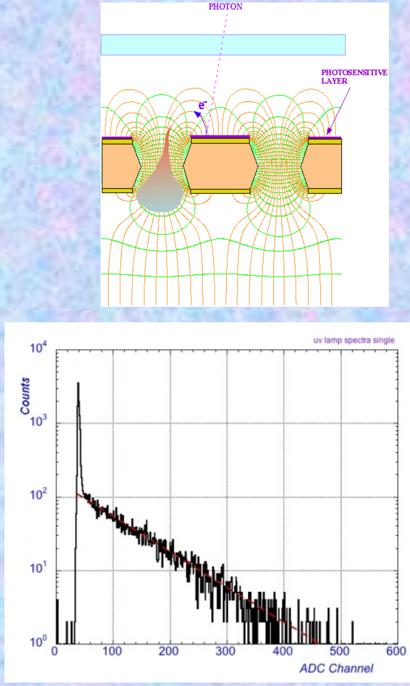
Applications area will benefit from the technological developments proposed by the Collaboration; however the responsibility for the completion of the application projects lies with the institutes themselves.



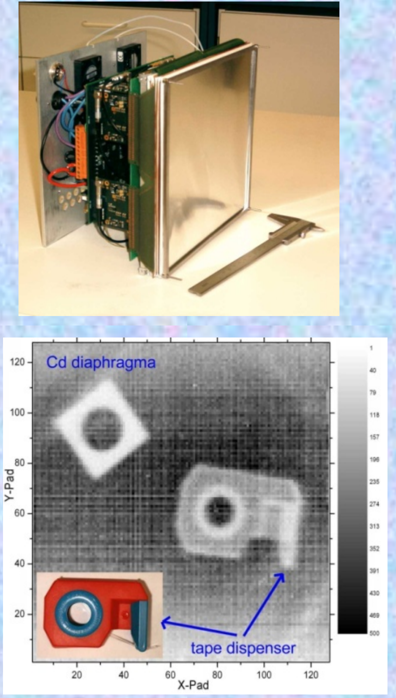
Tracking



TPC readout



UV photon detection

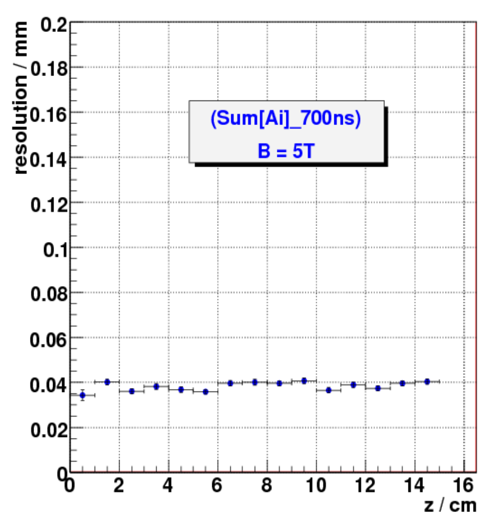


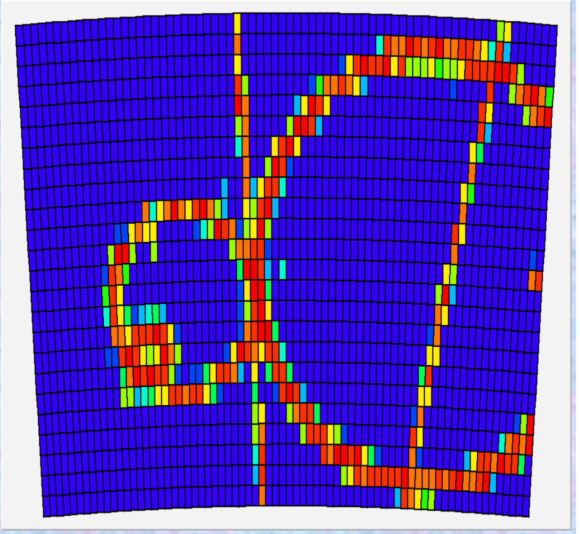
Neutron detection

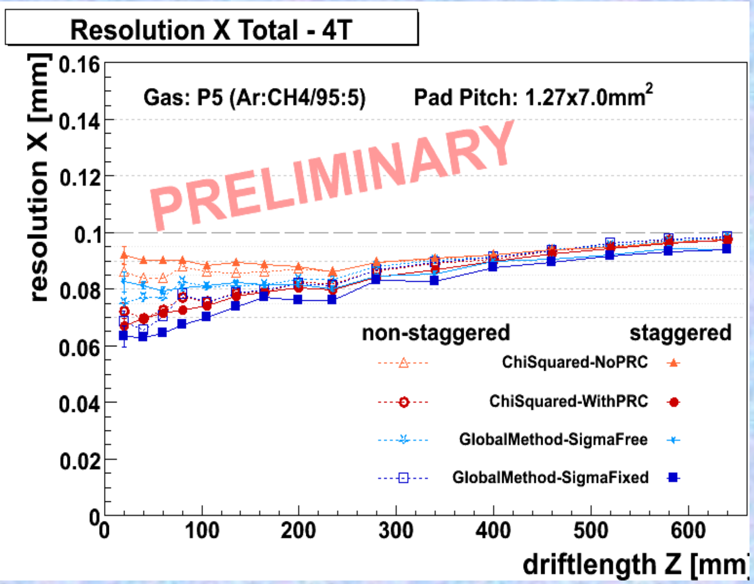
Micromegas/GEM for the ILC TPC

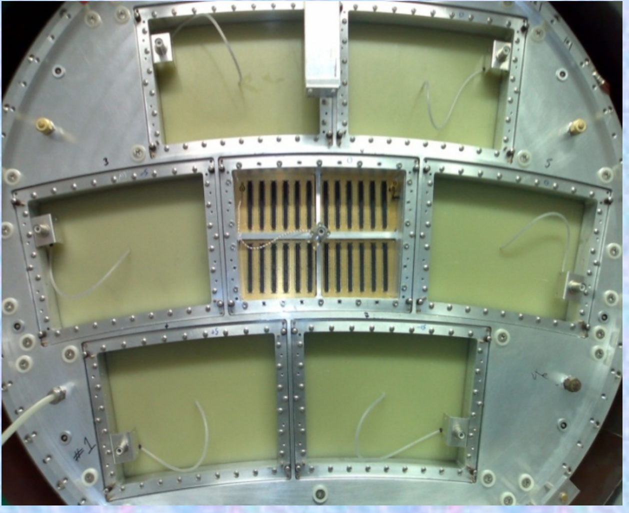
Micromegas TPC

GEM TPC







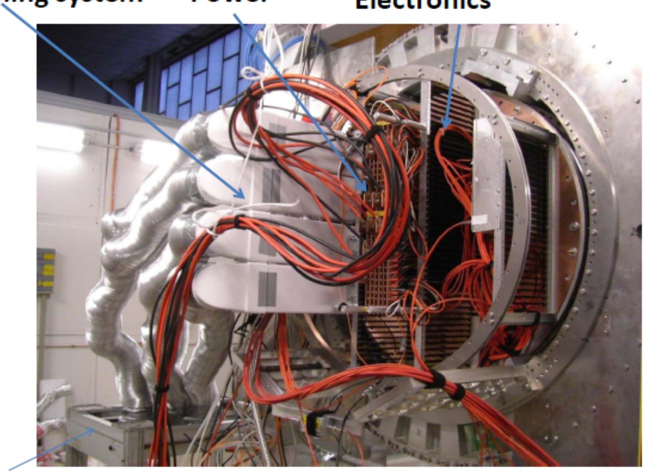


Rotatated for cosmics

Cooling system

Power

Electronics

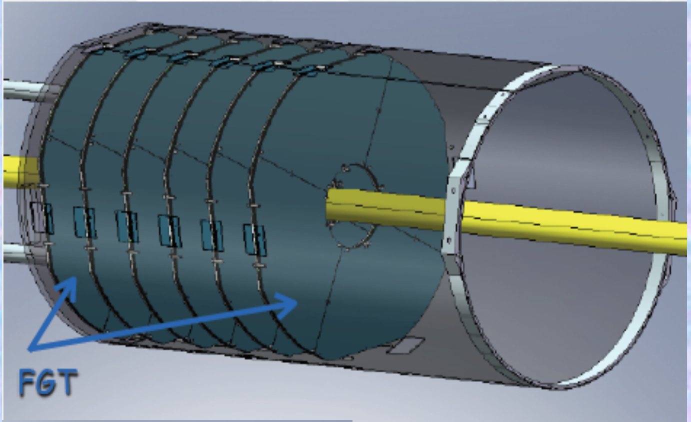


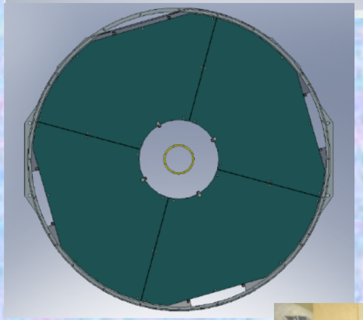
Fans – now at a location with less magnetic field

Large Prototype tests in 2009

GEM - Gas Electron Multiplier

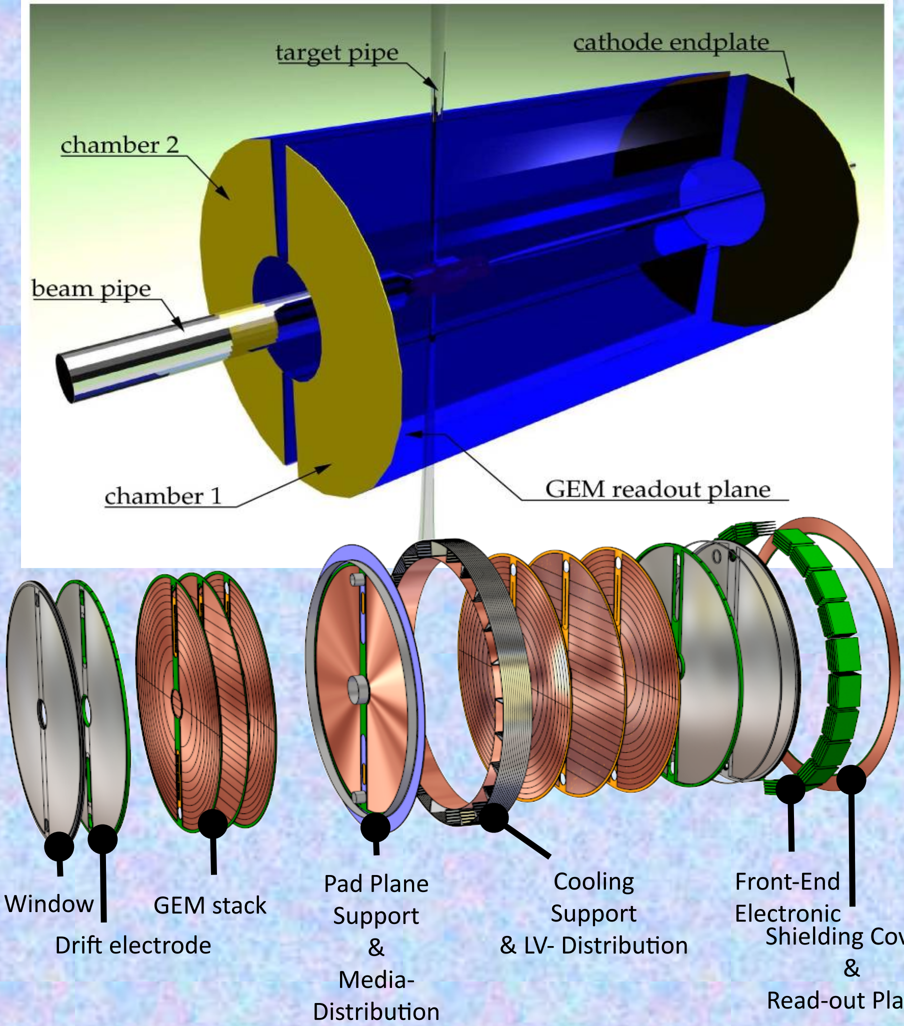
STAR GEM





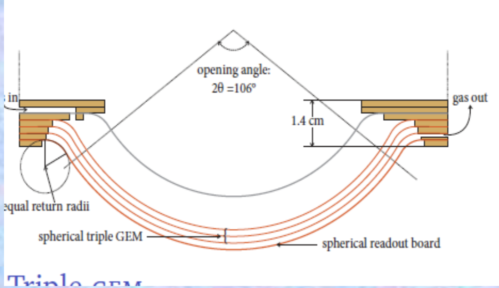
Foils production and Q&A by the Tech-Etch company

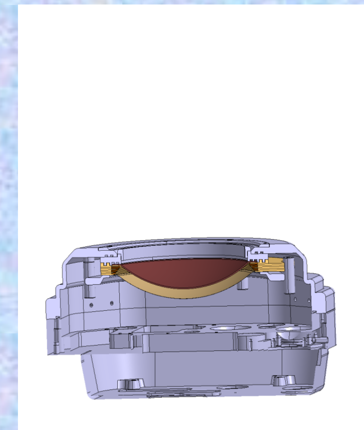
PANDA TPC and Planar Trackers

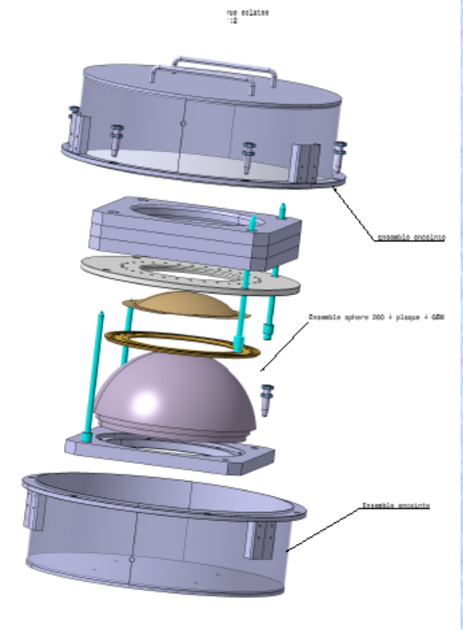


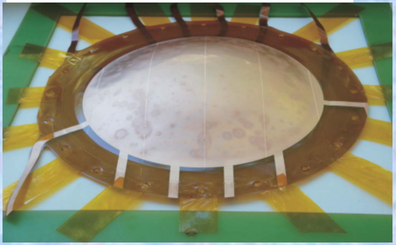
GEM - Gas Electron Multiplier

Spherical GEM for X-Ray diffraction application

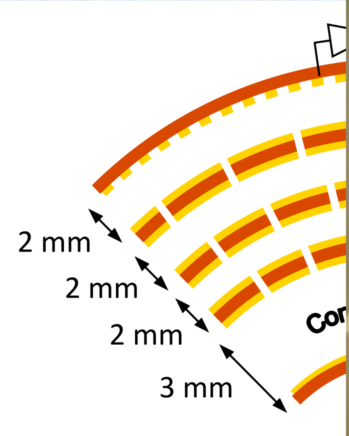


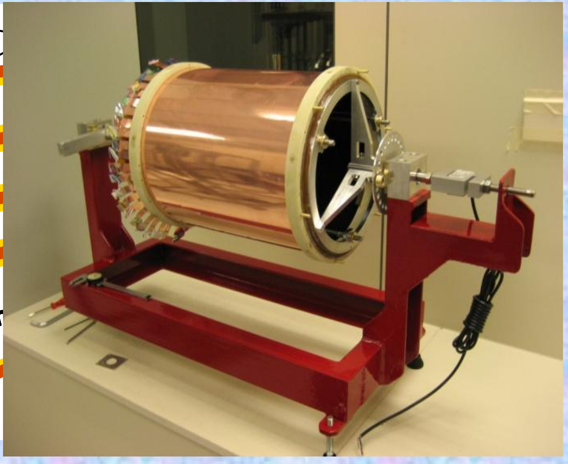


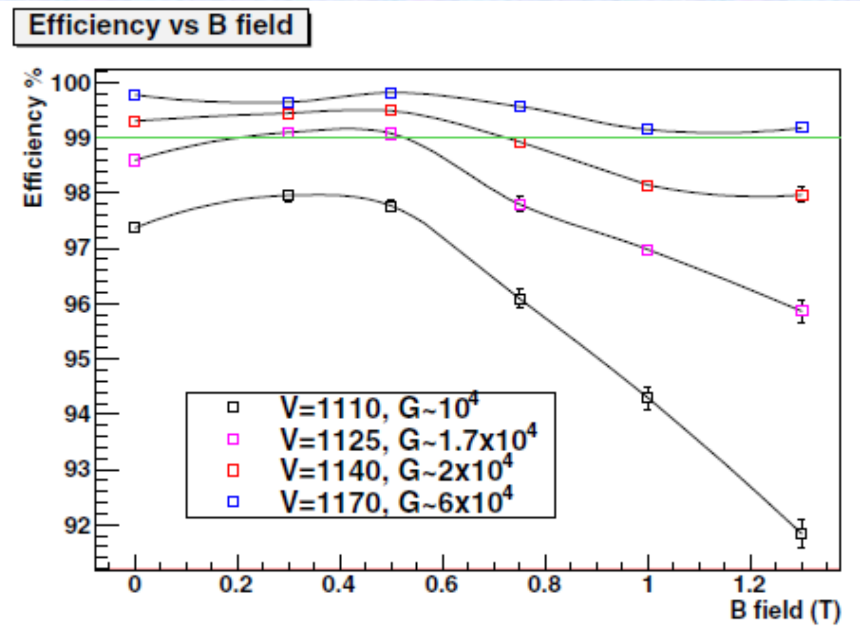




KLOE - Cylindrical Triple GEM



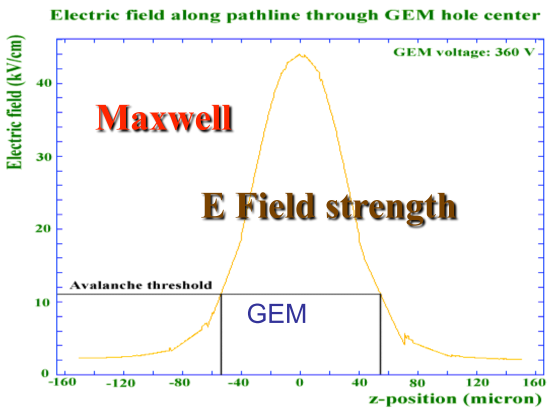


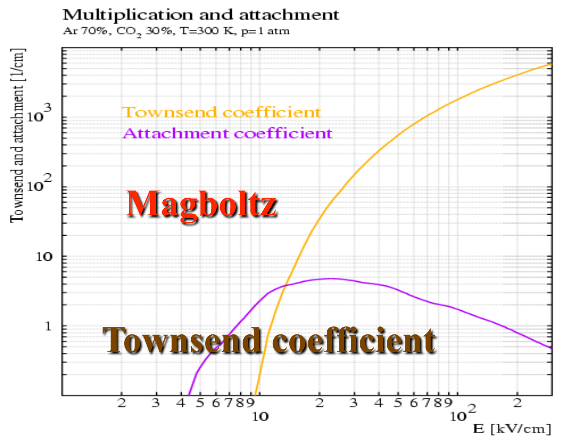


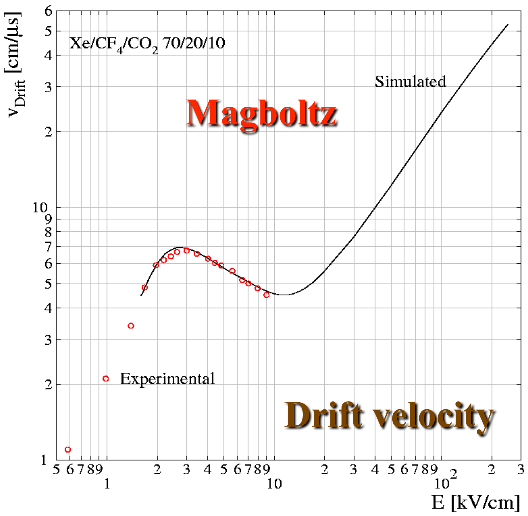
RD51 WG4 - Simulation and Software Tools

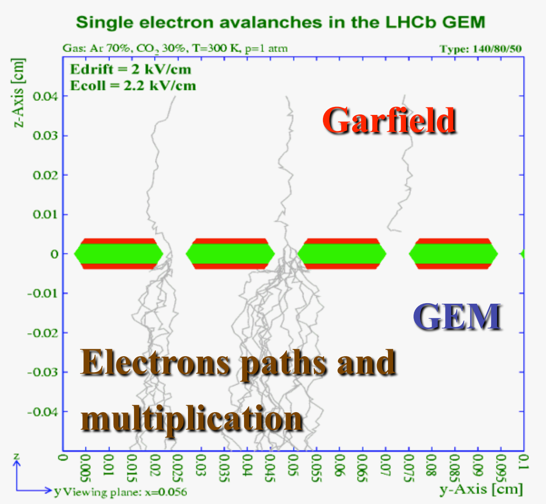
Objective: Development of common, open access software and documentation for MPGD simulations

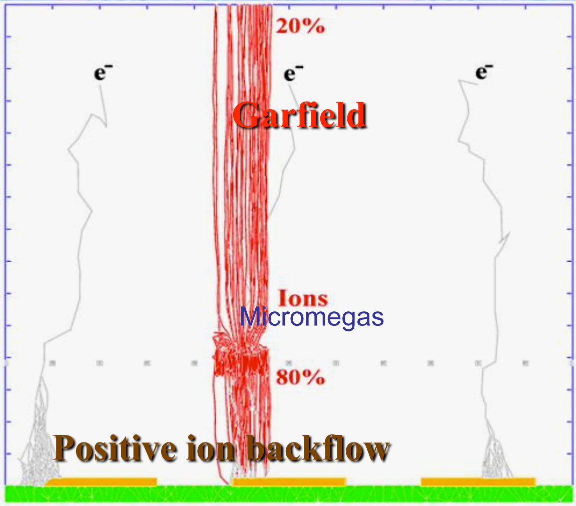
- Development of common platform for detector simulations (gas detector simulation in Geant4, interface to ROOT).
- Development of algorithms (in particular in the domain of very small scale structures - <u>implementation of nearly exact boundary element method interfaced to Garfield</u>).
- Simulation improvements (penning transfer studies, photon excitation via excimers)





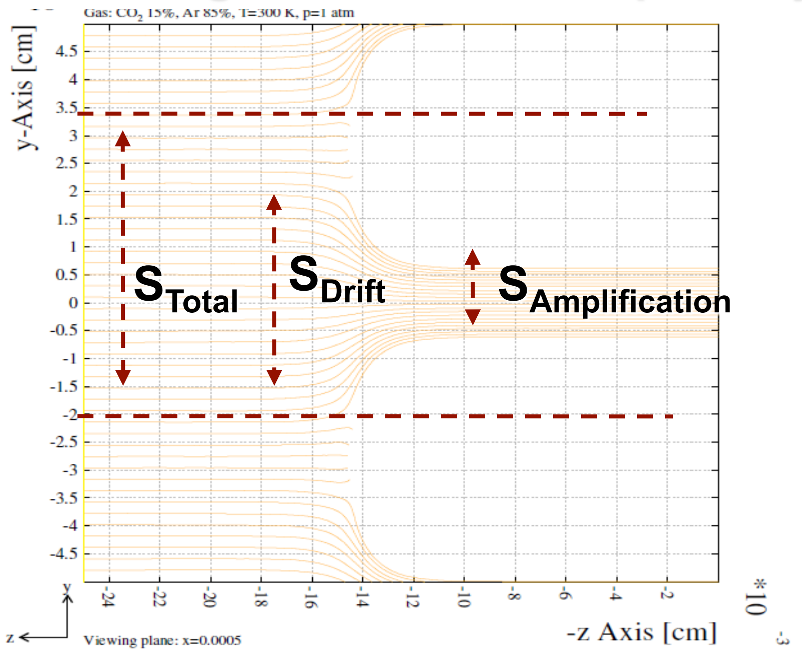


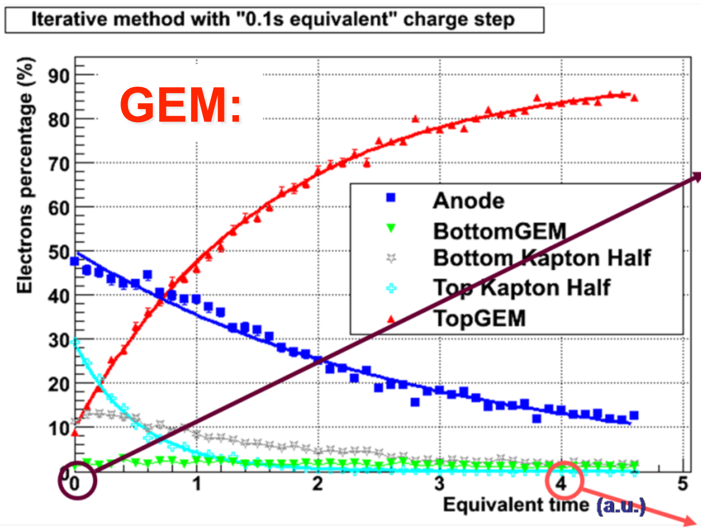


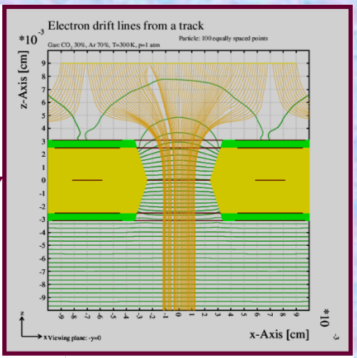


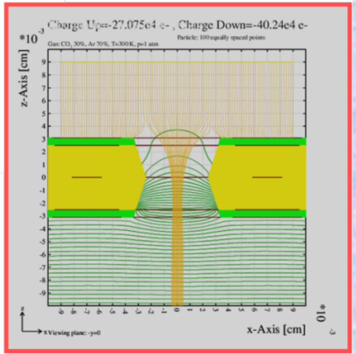
GEM and Micromegas: Charging-Up and Transparancy Simulation

Micromegas Electron Transparency

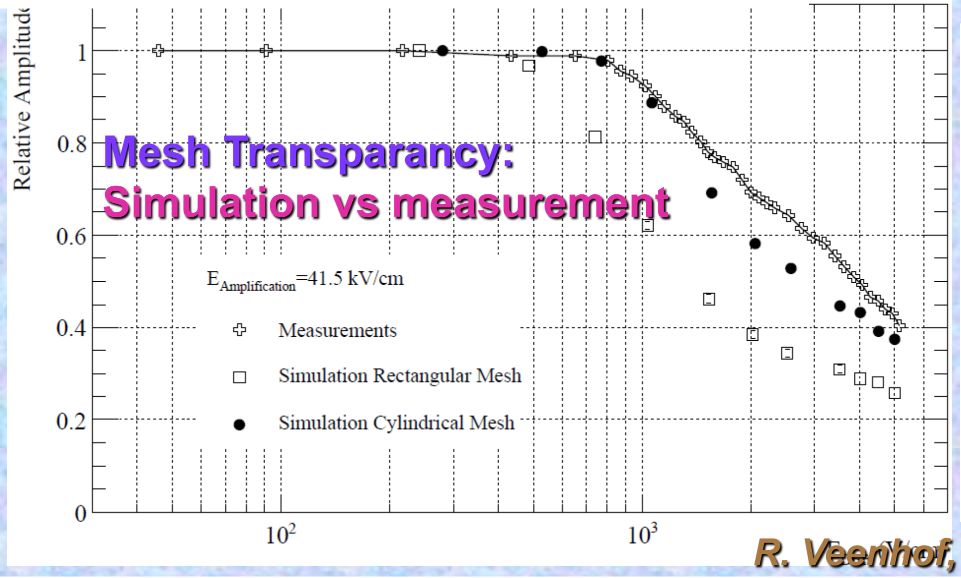








First "manual" iterative method GEM simulation with "0.1s equivalent charge step



Mesh Transparancy: Simulation vs measurement

Micromegas Electron Transparancy:

$$P(\text{e-collection}) = S_{Drift} / S_{Total}$$

$$= S_{Amplification} \times \text{Field-Ratio} / S_{Total}$$

~ (hole diameter)^2 ~ (wires pitch)^2

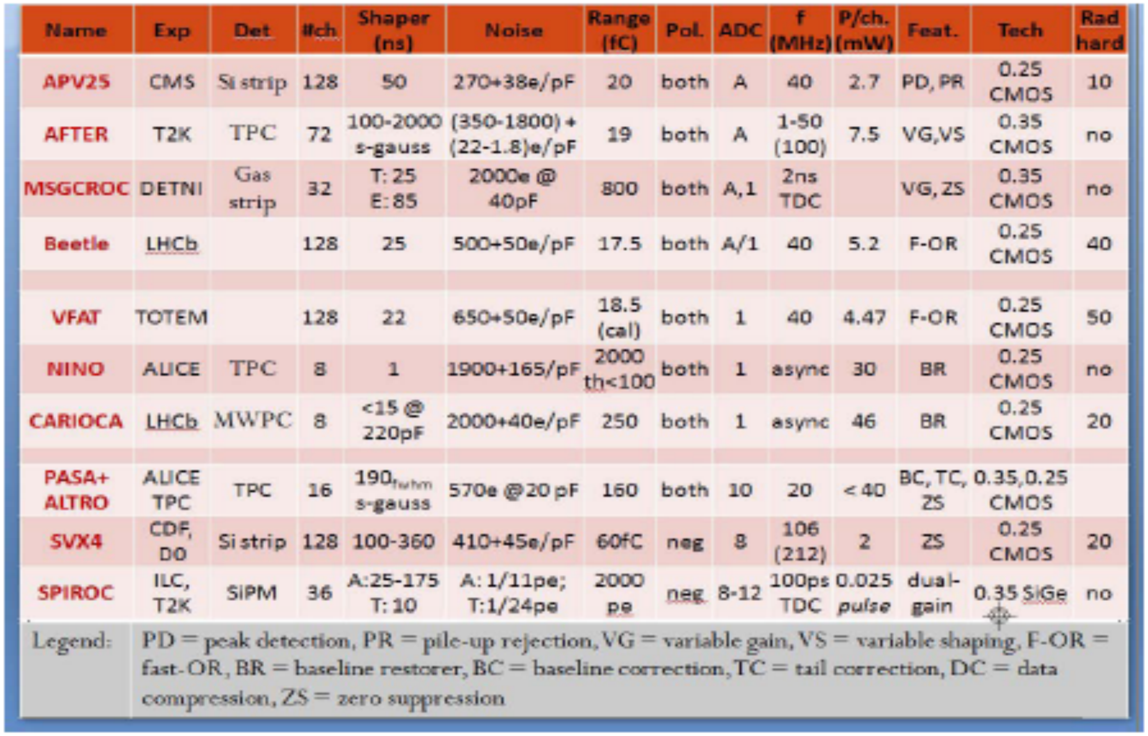
R. Veenhof, RD51 Collab. Meet., June 16-17, 2009, WG4 Summary

RD51 WG5: MPGD Electronics Developments

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

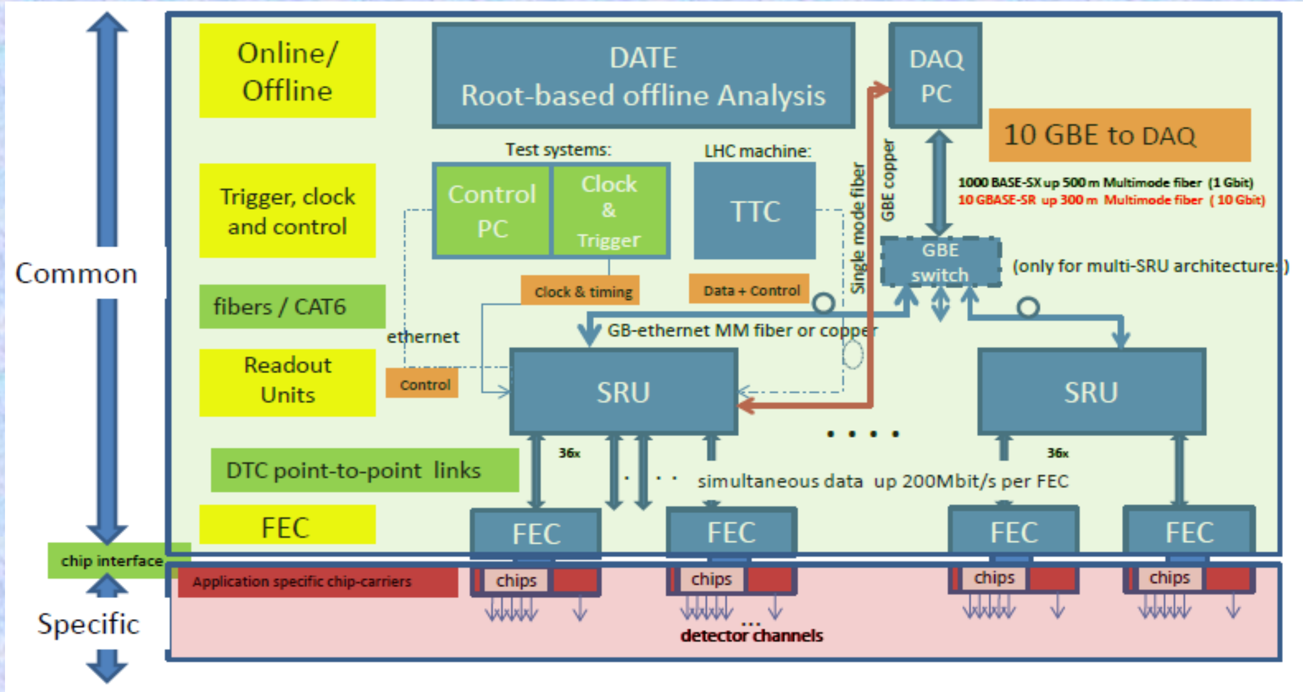
Legend: PD = peak detection, PR = pile-up rejection, VG = variable gain, VS = variable shaping, F-OR = fast-OR, BR = baseline restorer, BC = baseline correction, TC = tail correction, DC = data compression, ZS = zero suppression

- 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***

Development of Portable Multi-Channel DAQ Systems for MPGD

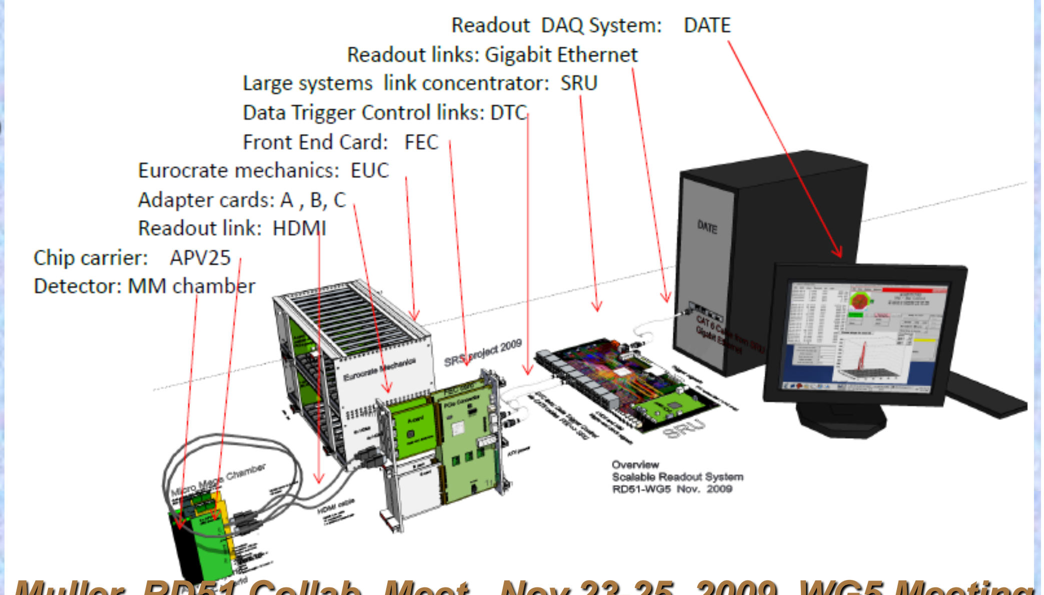


"RD51 Common Project" (financed by the RD51)→

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.**

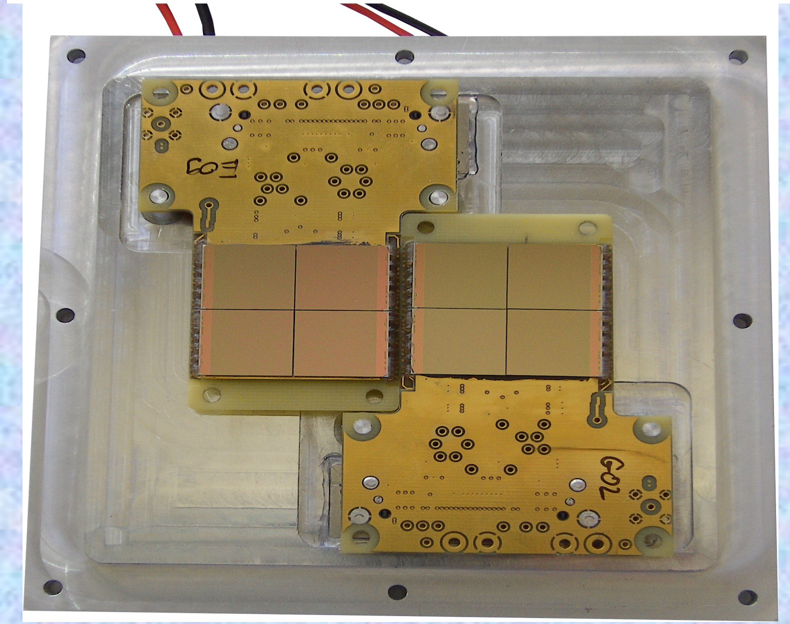
→ Scalable Readout System



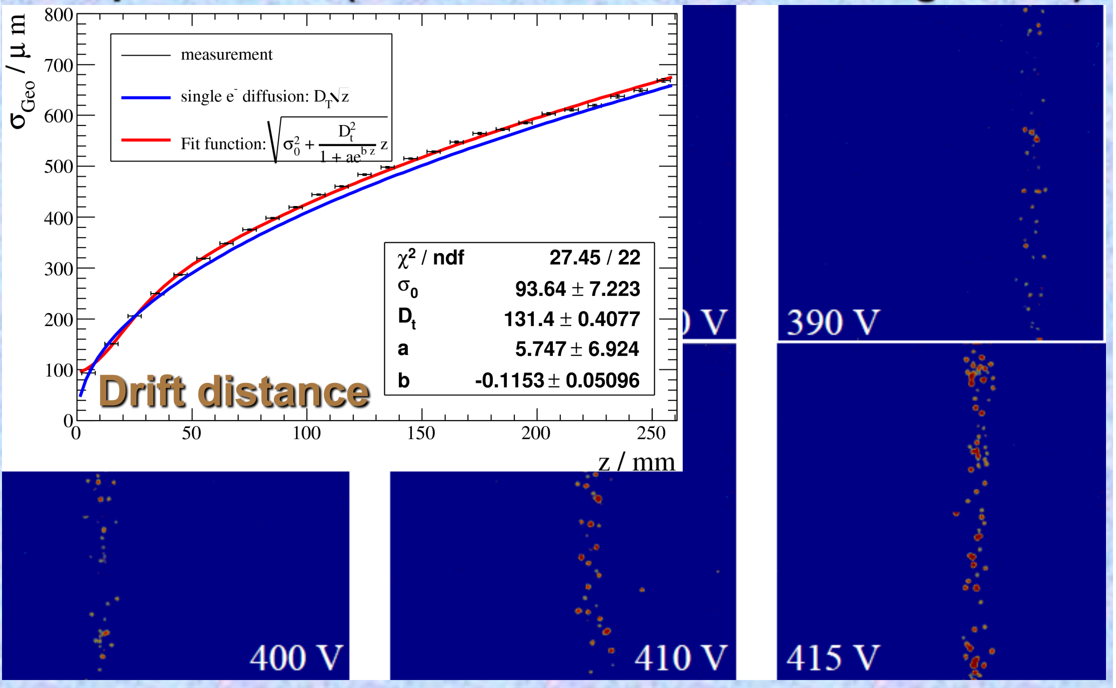
H. Muller, RD51 Collab. Meet., Nov.23-25, 2009, WG5 Meeting

Development of Large Area Detectors with Pixel Readout

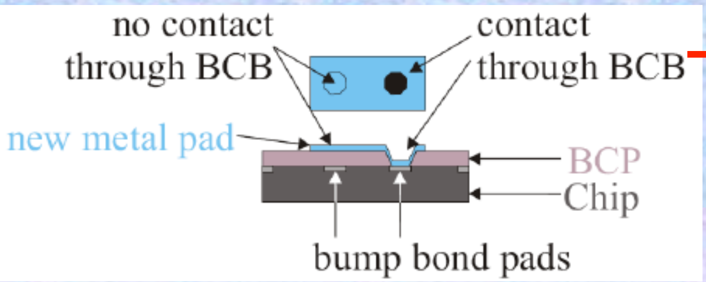
8 Timepix Readout Matrix (~ 3* 6 cm^2)
55*55 μm^2 pixel size

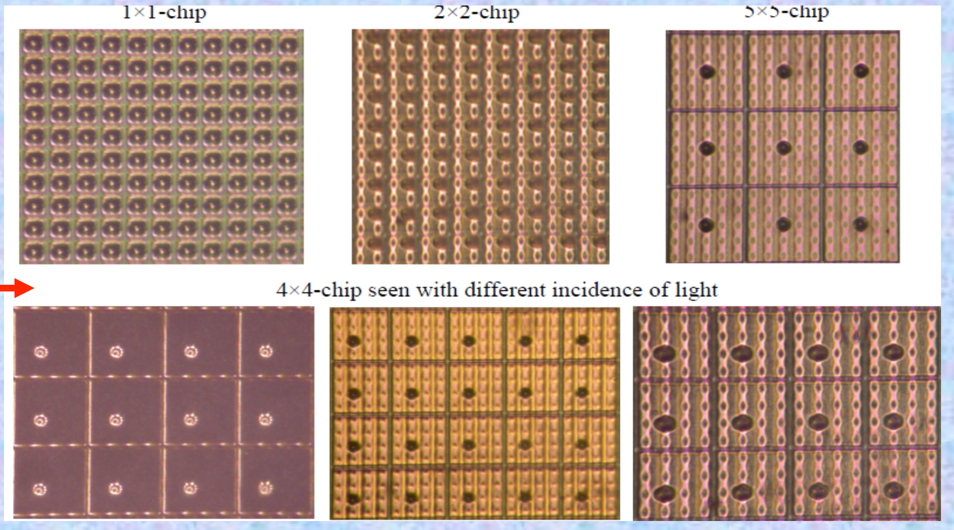


4 Chips + 3GEM (150 GeV muons after drifting 25 cm)



Test chips with larger pixels:
expensive to design new chips, easier to combine pixels by post-processing
(55*55, 110*110, 220*220, 275*275 μm^2)





J. Kaminski et al, RD51 Collab. Meet., Nov.23-25, 2009, WG7 Report

RD 51 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)

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

Technology Industrialization (potential partners)

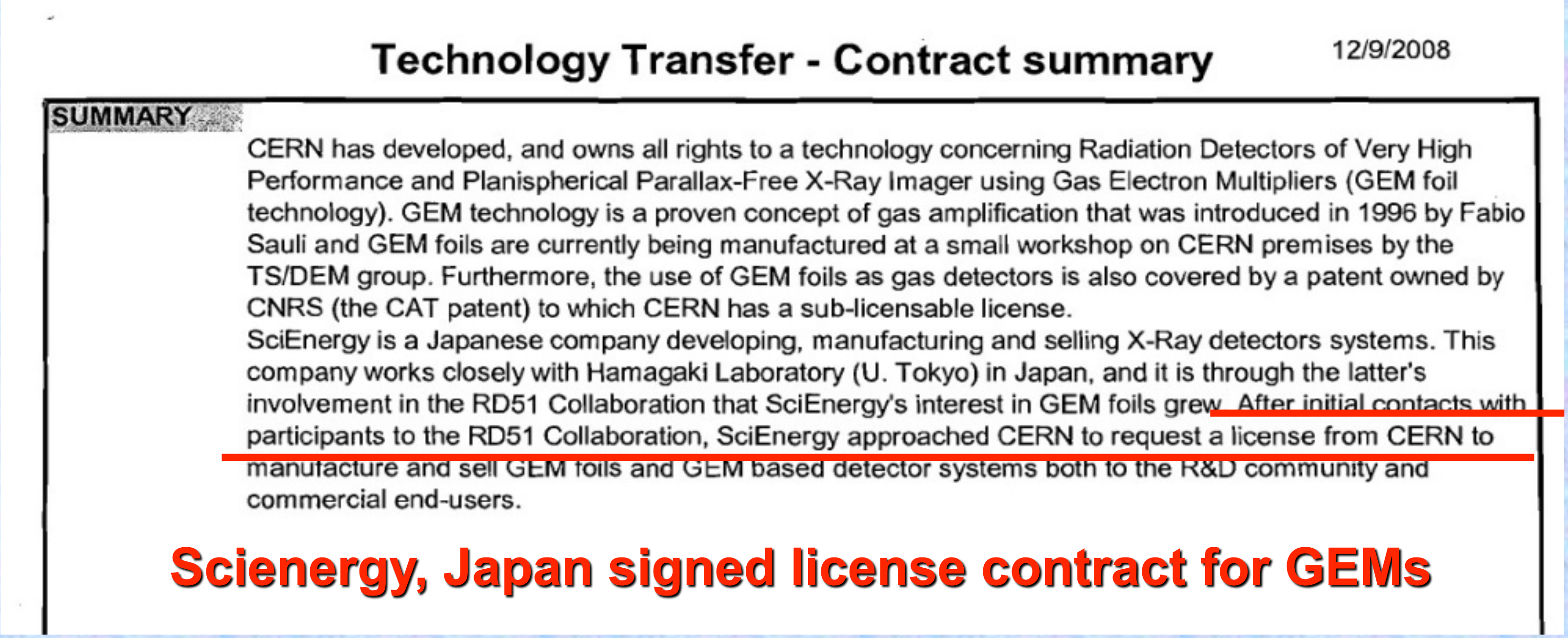
THGEM Technology – ELTOS S.p.A. (Italy)

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.

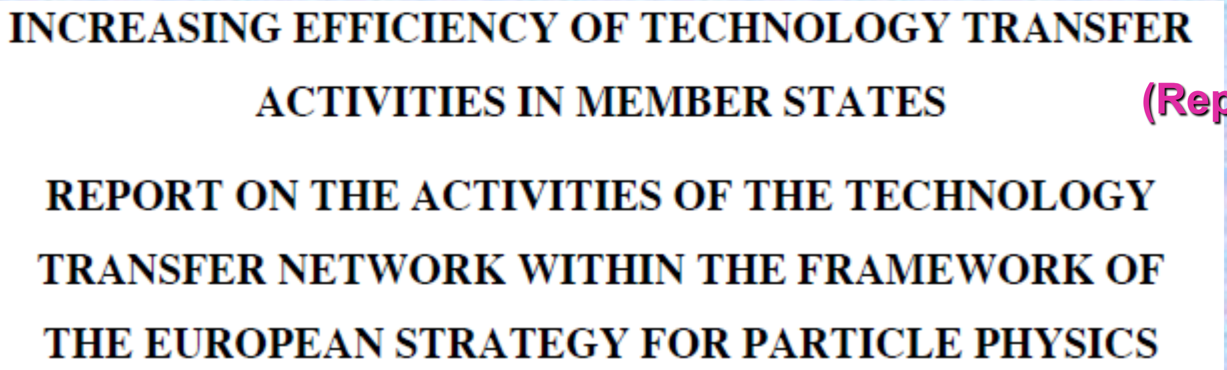
SciEnergy is a Japanese company developing, manufacturing and selling X-Ray detectors systems. This company works closely with Hamagaki Laboratory (U. Tokyo) in Japan, and it is through the latter's involvement in the RD51 Collaboration that SciEnergy's interest in GEM foils grew. After initial contacts 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

Technology Transfer Network

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

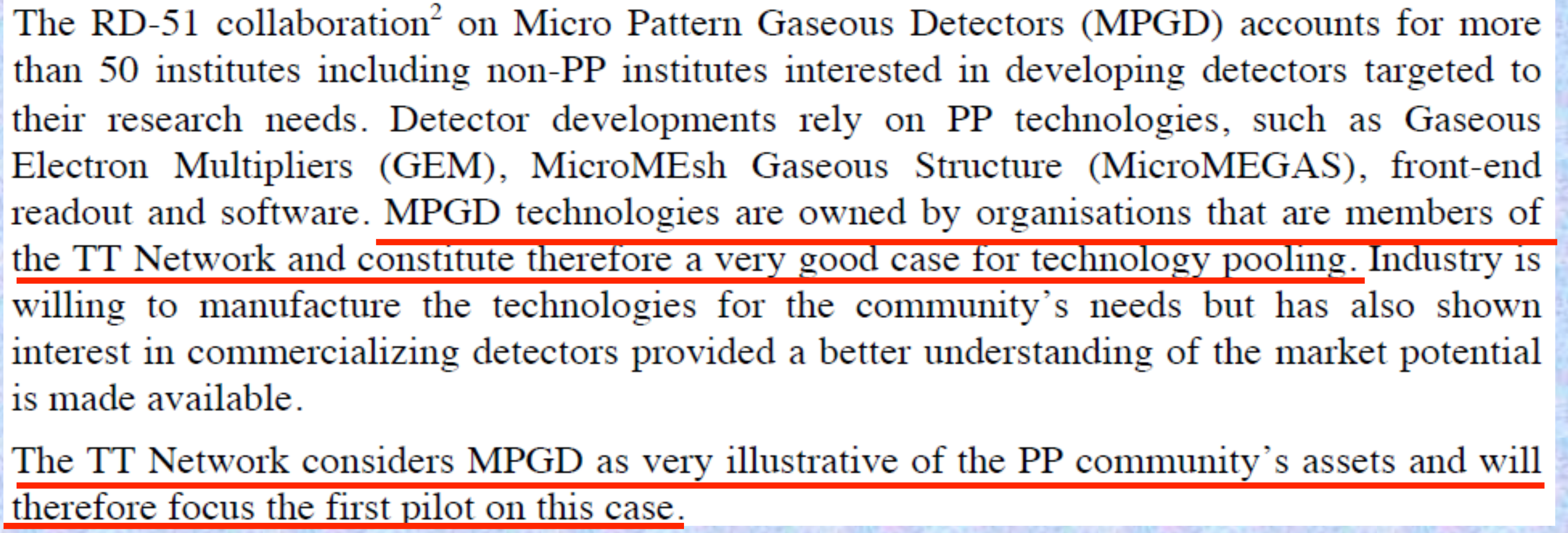


INCREASING EFFICIENCY OF TECHNOLOGY TRANSFER
ACTIVITIES IN MEMBER STATES

REPORT ON THE ACTIVITIES OF THE TECHNOLOGY
TRANSFER NETWORK WITHIN THE FRAMEWORK OF
THE EUROPEAN STRATEGY FOR PARTICLE PHYSICS

(Reported in CERN-Council-S/049, September 7, 2009)

- **"One-stop licensing for industry" (bridging the gap between institutes and industry)**
- **The IP coming from the HEP research community is better identified and more visible**

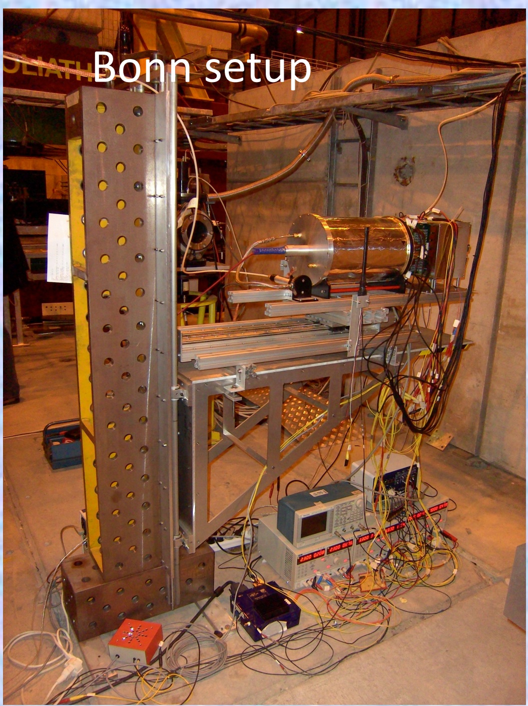


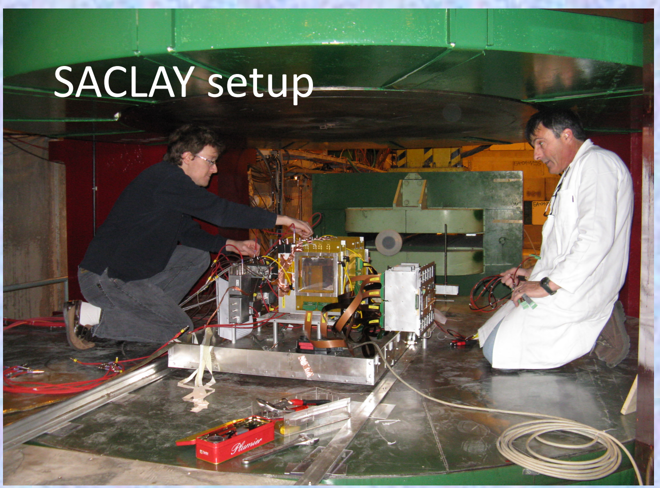
The RD-51 collaboration[2] on Micro Pattern Gaseous Detectors (MPGD) accounts for more than 50 institutes including non-PP institutes interested in developing detectors targeted to their research needs. Detector developments rely on PP technologies, such as Gaseous Electron Multipliers (GEM), MicroMEsh Gaseous Structure (MicroMEGAS), front-end readout and software. MPGD technologies are owned by organisations that are members of the TT Network and constitute therefore a very good case for technology pooling. Industry is willing to manufacture the technologies for the community's needs but has also shown interest in commercializing detectors provided a better understanding of the market potential is made available.

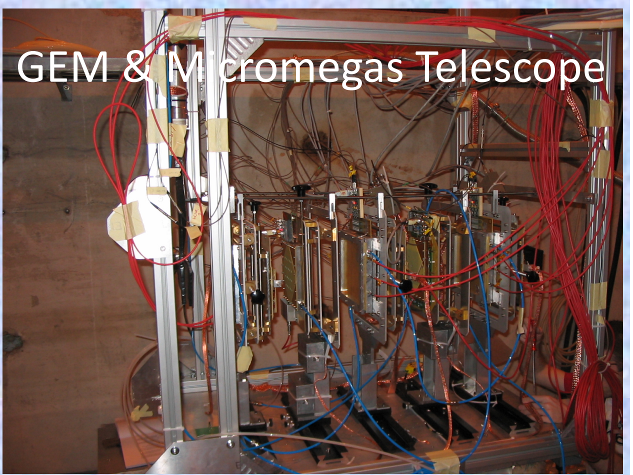
The TT Network considers MPGD as very illustrative of the PP community's assets and will therefore focus the first pilot on this case.

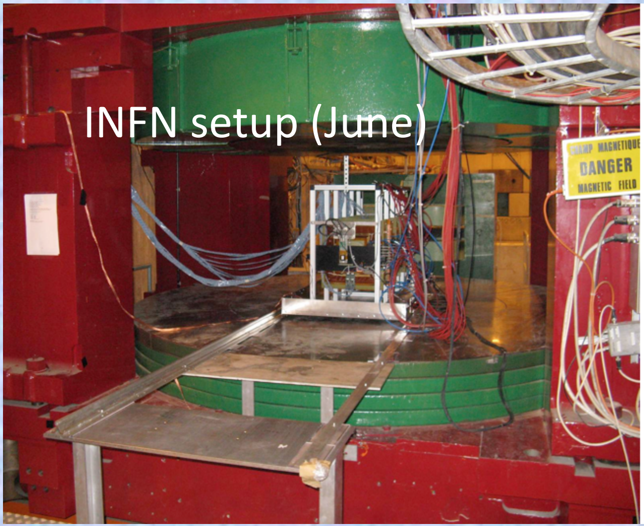
RD 51 WG7 - Common Test Facility

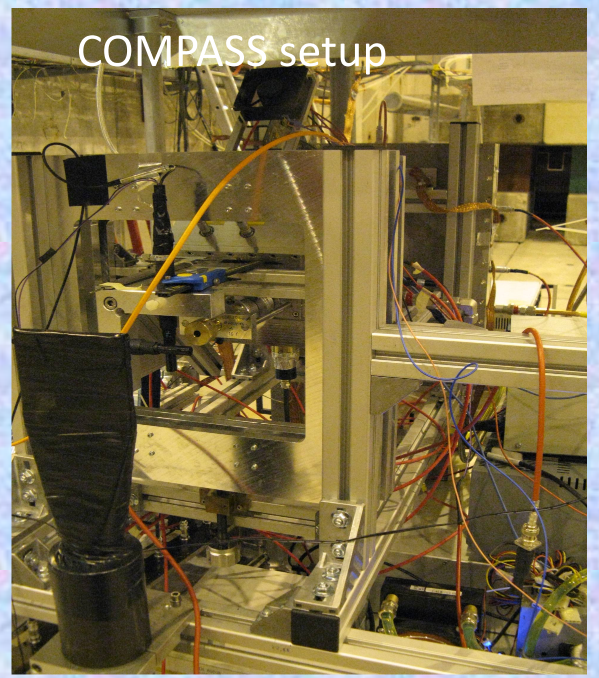
Objective: Design and maintenance of common infrastructure for detector characterization ("semi-permanent" test-beam infrastructure at CERN SPS@H4 beam)


Bonn setup


SACLAY setup


GEM & Micromegas Telescope


INFN setup (June)


COMPASS setup

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

Summary and Outlook

- **RD51 aims at facilitating the development of advanced gas-avalanche detector technologies and associated electronic-readout systems → Many successful common projects were initiated during the first year of collaboration**

- **Industrial methods of MPGD production allows to extend technology to ~ m^2 areas → many potential MPGD applications within the HEP and beyond;**

- ***Collaboration with industrial partners is ongoing;***

- ***Progress in micro-pattern detector developments promises to extent the applicability of gaseous detectors to the*** **precision tracking at high counting rates (large area coverage, low material budget, spatial resolution~*30-50 μm)***

- ***Modern, sensitive & low noise electronics will enlarge the range of applications***