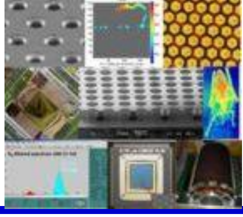
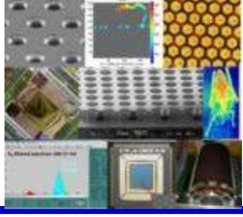
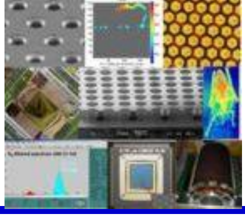


MPGDs developments & MPGD2013

S. Dalla Torre

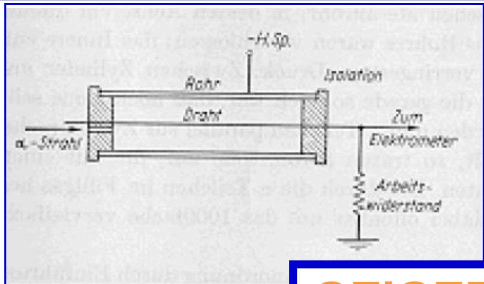


INTRODUCTION

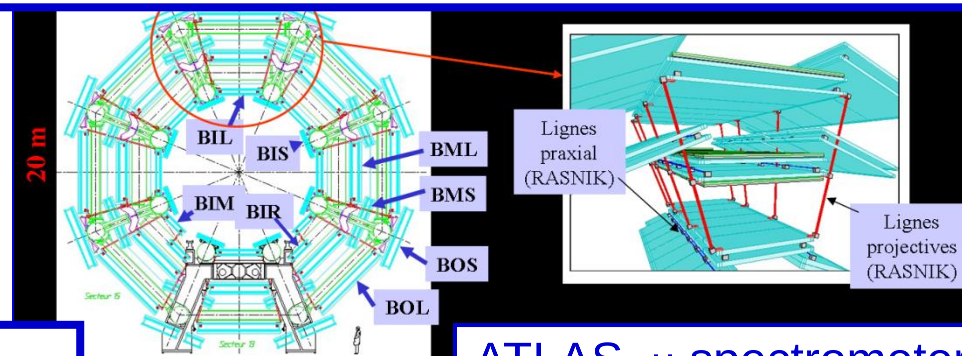


GAS DETECTORS & FUNDAMENTAL RESEARCH

Still today <u>the only way</u> to equip <u>large volumes</u> at a <u>reasonable cost</u>, with good <u>space resolution</u> and <u>limited material</u> budget

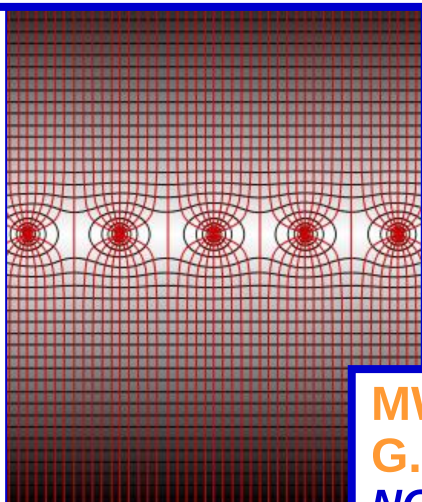


GEIGER counter
Rutherford, Geiger 1908



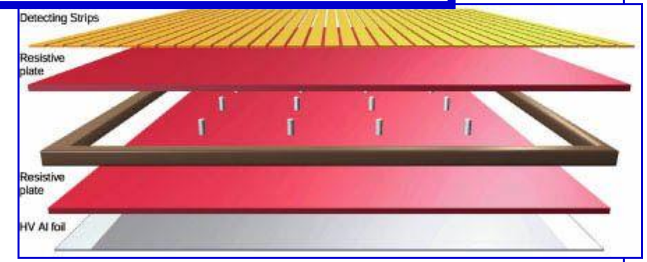
ATLAS, μ spectrometer

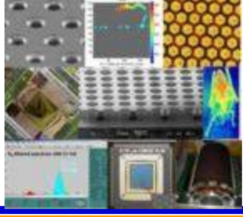
the only approach to achieve good space resolution before introducing the Si trackers



MWPC,
G. Charpak, 1968
NOBEL prize in 1992

Time resolution record in extended counters
RPC: σ_t ≤1 ns
trigger in ALICE, ATLAS, CMS

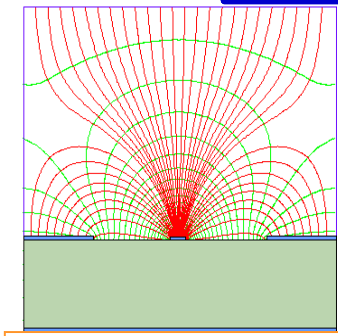


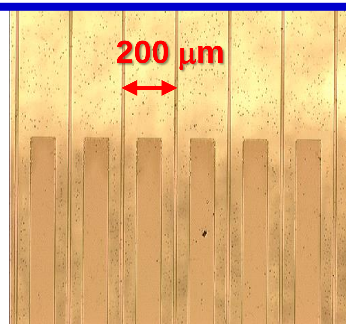


MPGDs: THE EARLY DAYS

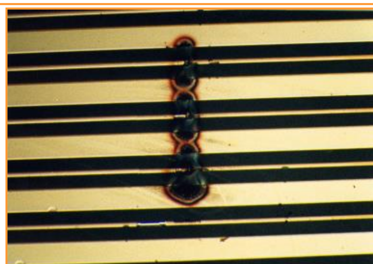
MSGC - MicroStrip Gas Chamber

A. Oed, NIMA 263(**1988**) 351

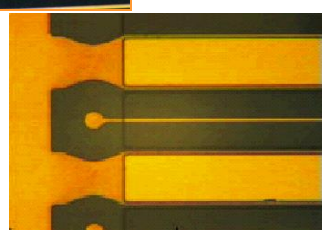




- **High E-values at the edge between insulator and strips → damages**
- **Charge accumulation at the insulator → gain evolution vs time**

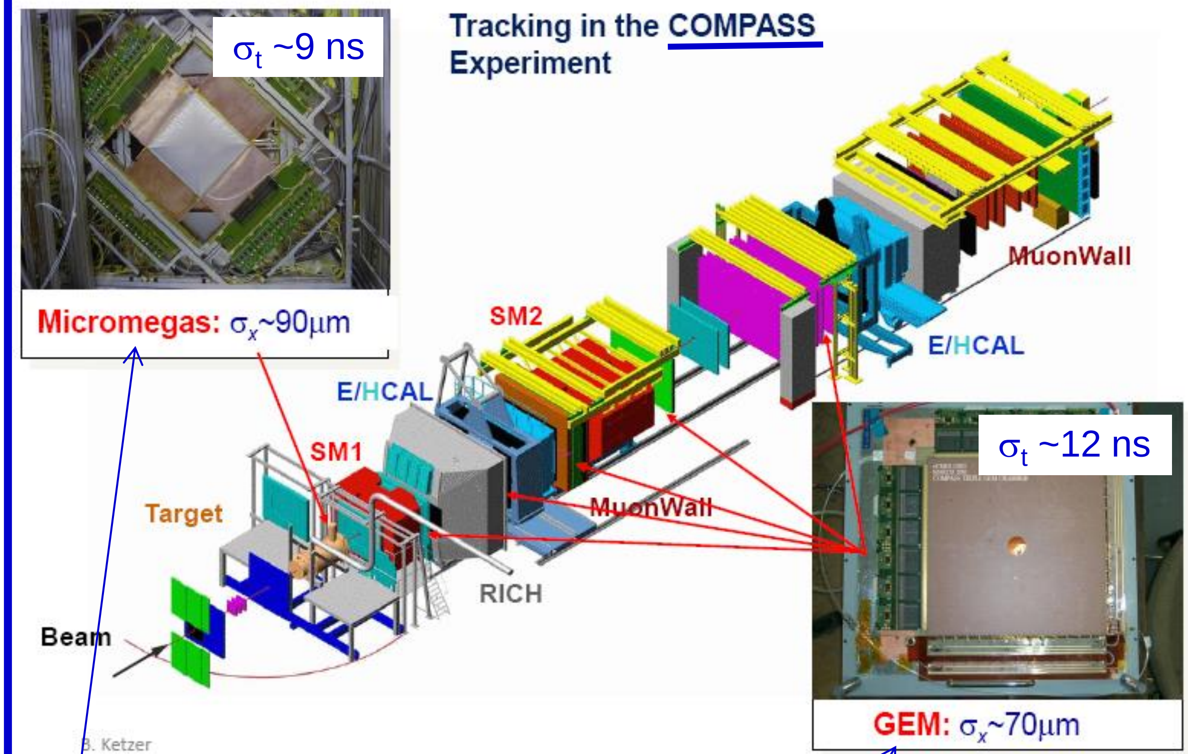


Later (~ 1999-2000): Passivation of the cathode edges → MSGD operational !



slide by W. Riegler, CERN Academic Traning, April 2008

First Large Scale Use of GEMs and MICROMEGAs

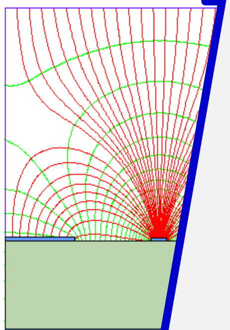


MICROMEGAS (MM) :
Y. Giomataris et al,
NIMA A376 (**1996**) 29

GEM:
F.Sauli, NIMA A386 (**1997**) 531

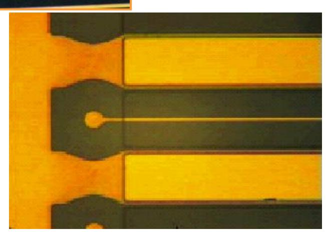
MPGDs: THE EARLY DAYS

MSGC - MicroStrip Gas Chamber



•High E...
insulat...
•Charg...
insula...

Later (~ 1999-2000):
Passivation of the cathode edges
→ MSGD operational !



slide by **W. Riegler, CERN Academic Traning, April 2008**

First Large Scale Use of GEMs and MICROMEGAs

Tracking in the COMPASS ...

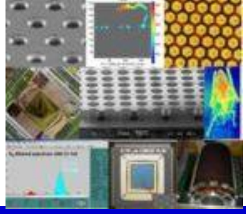
ALREADY SOME LESSONS:

1. **Why MPGDs?**
   - High rates (granularity & occupancy, signal formation time)
   - Fine space resolution

   → Moving towards high luminosity / high precision experiments, i.e. towards the future
2. **Technological maturity and accurate engineering FUNDAMENTAL for successful MPGDs**

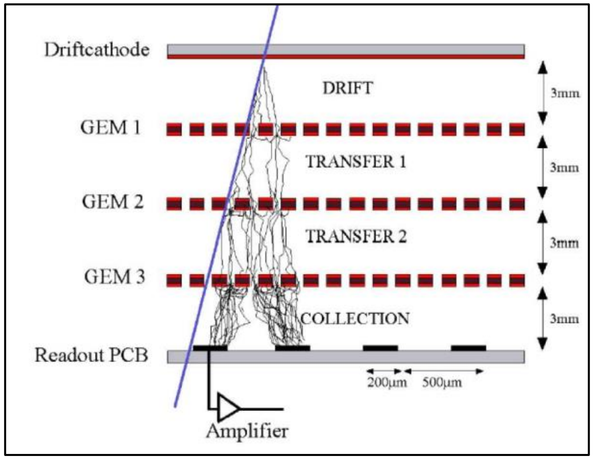
MICROMEGAS:
Y. Giomataris et al, NIMA A376 (**1996**) 29

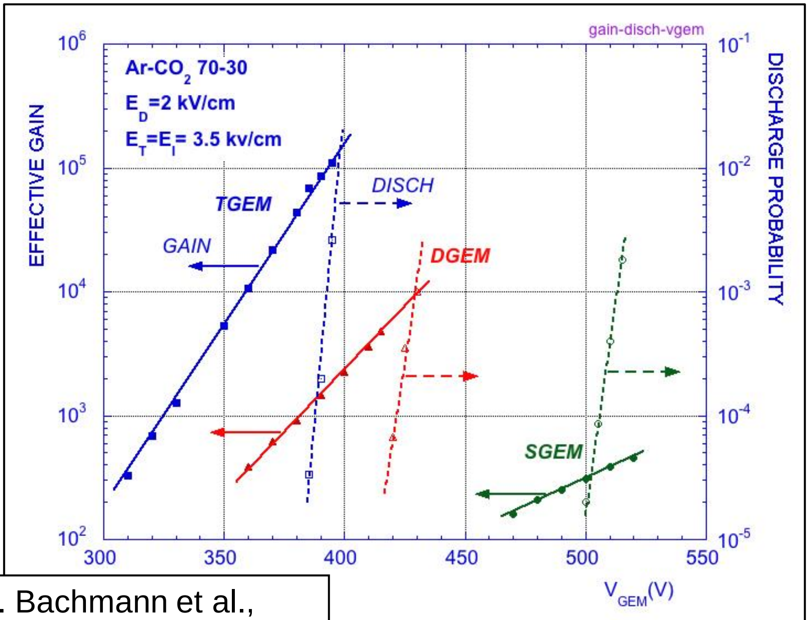
GEM:
F.Sauli, NIMA A386 (**1997**) 531



THE ENEMY: THE DISCHARGE RATE

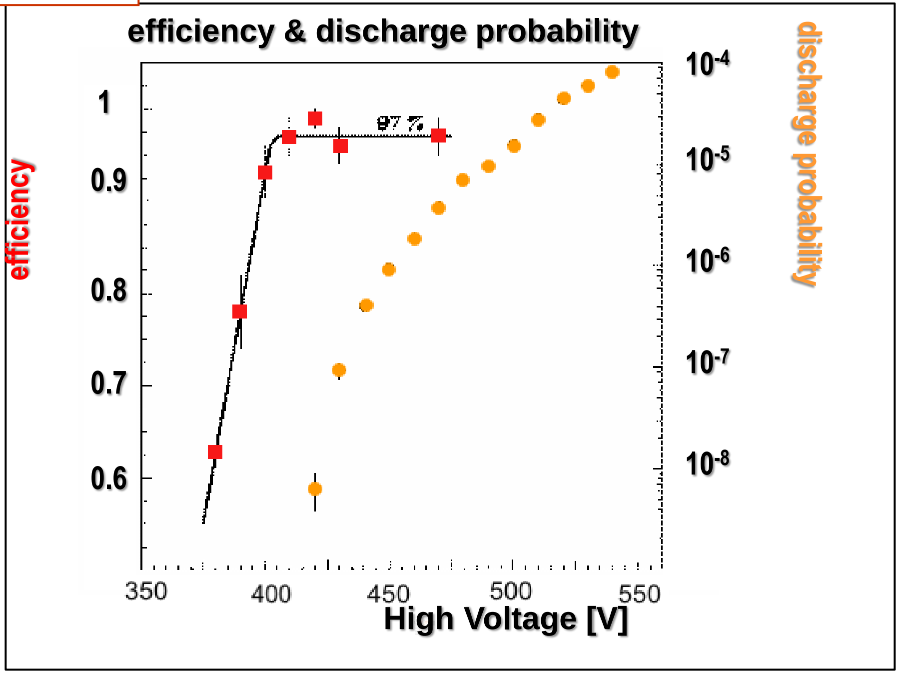
GEM





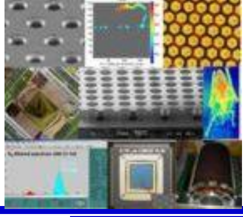
S. Bachmann et al.,
NIMA A479(2002) 294

MM



Discharges:

- Detector damages
- F-E damages
- Dead-time



MPGD: THE PROGRESS

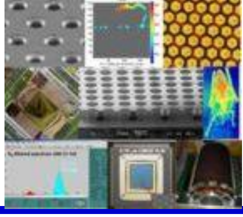
from early days towards the present and the *future*,

4 main directions:

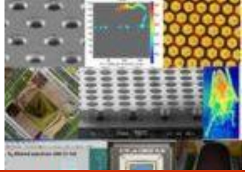
- **Novel architectures**
- **Consolidation of the establish architectures**
- **Wide application portfolio**
- **Tools**

A large variety of ideas, activities and approaches: the matter can be cover only by examples, but the richness of the global picture is due to the whole activity →

All what I will not be able to mention is as relevant as the mentioned examples !



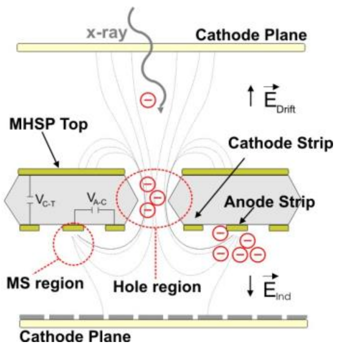
NOVEL ARCHITECTURES

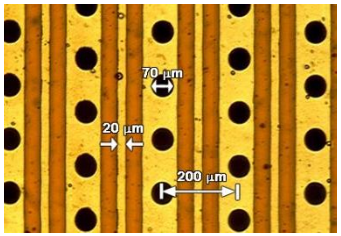


NOVEL ARCHITECTURES BY IMAGES

(1) GEM-derived

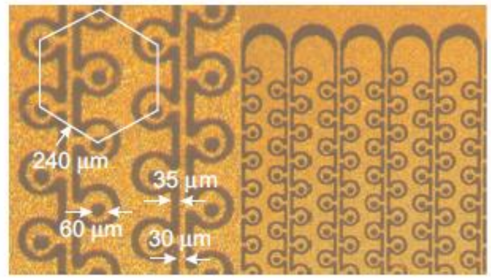
Towards gas PMTs by
- **Extremely reduced (~10^{-4}) IBF to PC**
- **Non outgassing materials**



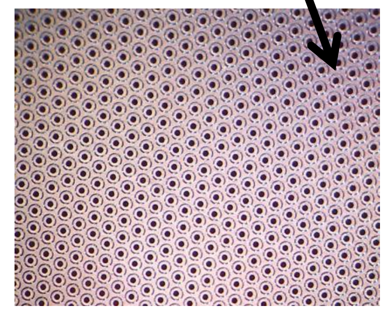


MHSP

&



COBRA

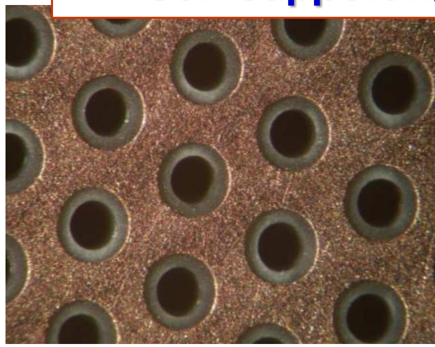


Glass GEM

Limit the discharge damages

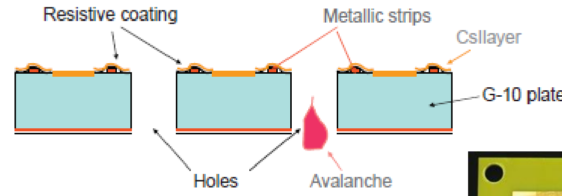
Re-GEM: electrodes by resistive kapton

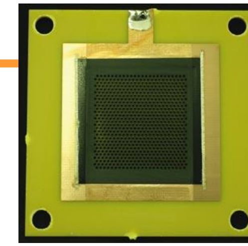
A different technology
- **PCB industry**
- **Robust**
- **Self-supporting plates**

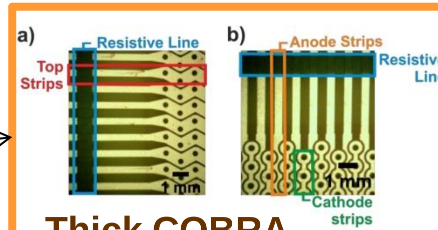


THGEM

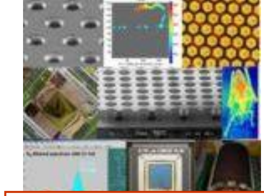
RTGEM







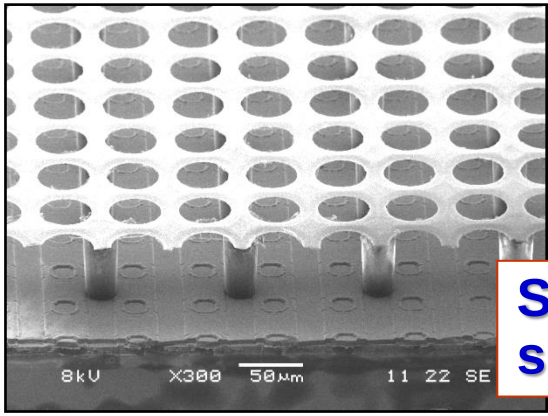
Thick COBRA

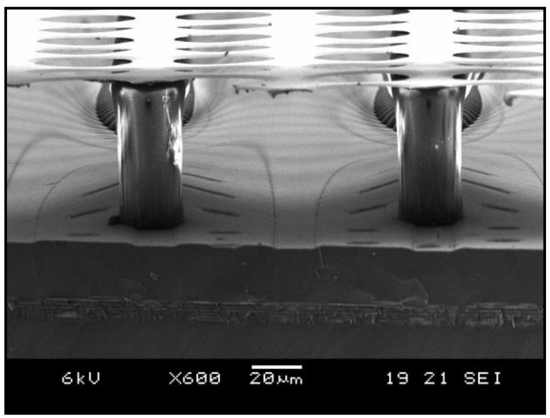


NOVEL ARCHITECTURES BY IMAGES

(2) MM-derived

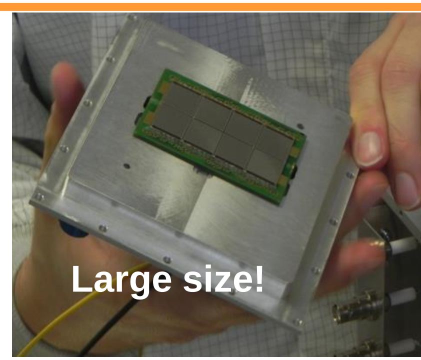
Timepix chip + SiProt + Ingrid

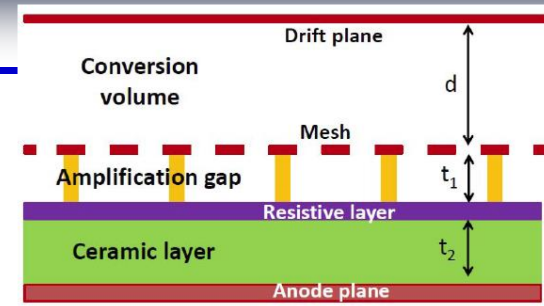




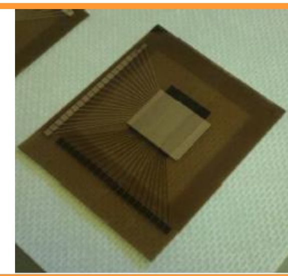
GRIDPIX

Single electron sensitivy



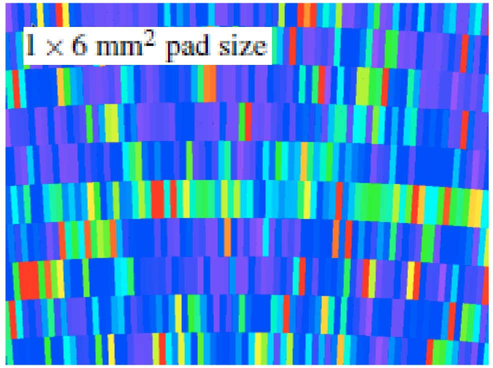


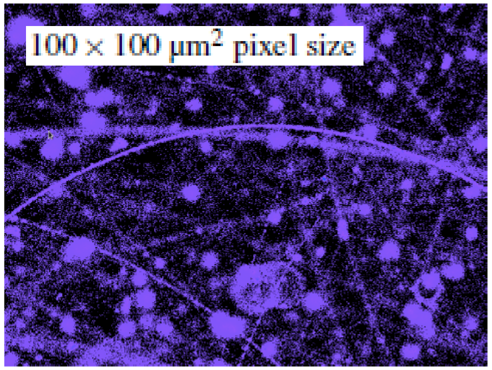
Piggy Back: read-out separated from the active volume

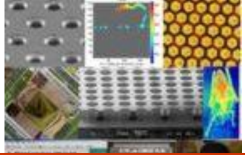


Microbulk:
Low mateiail budget,
radioactive pure

Simulations for CLIC, M. Killenberg, LCD-Note-2013-005



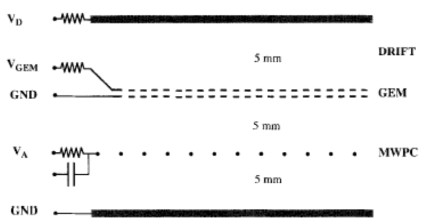




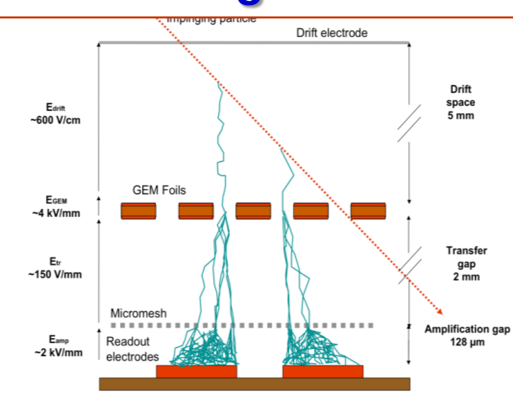
NOVEL ARCHITECTURES BY IMAGES

(3) hybrids

Since the beginning (Sauli et al.):
- **GEM + MWPC, GEM + MSGD** (NIMA 396 (1997) 50)



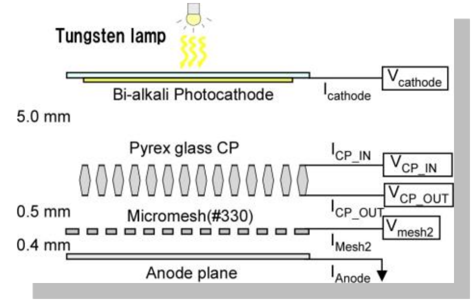
GEM pre-amplification: control the discharge rate in tracking



MM w GEM pre-amplification

Towards gas PMTs: IBF control

GAS PMT



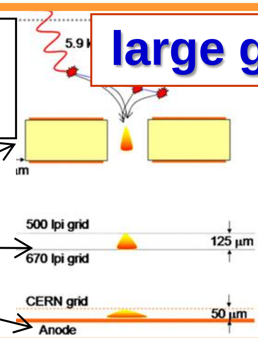
S. Duval et al., NIMA 695 (2012) 163

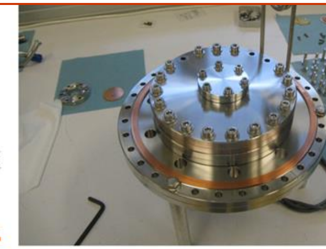
large gain / low IBF

THGEM

PIM

MM

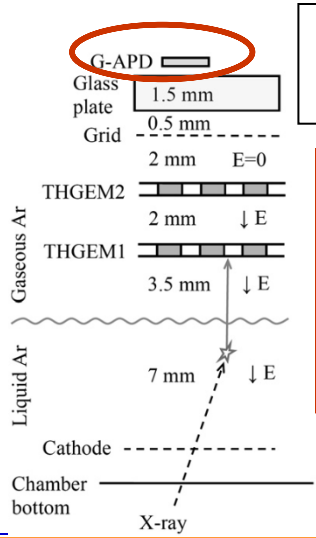




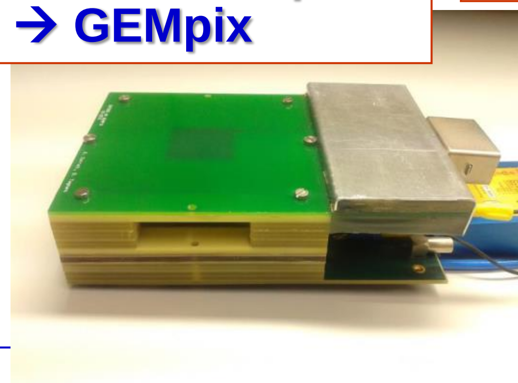
A. Bondaret al., NIMA 628 (2011) 364

THGEM + G-APD

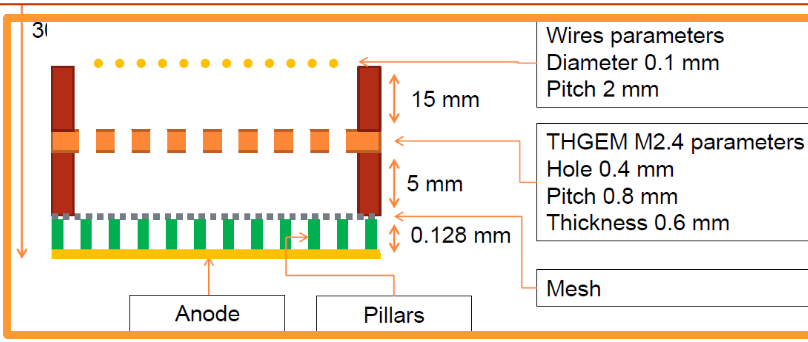
Detect scintillation light



GEM + medipix → GEMpix

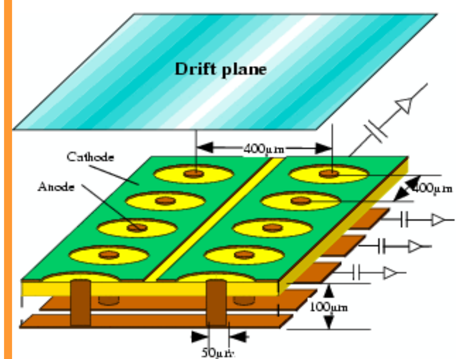


THGEM + MM for single photodetection: IBF control



(4) novel geometries

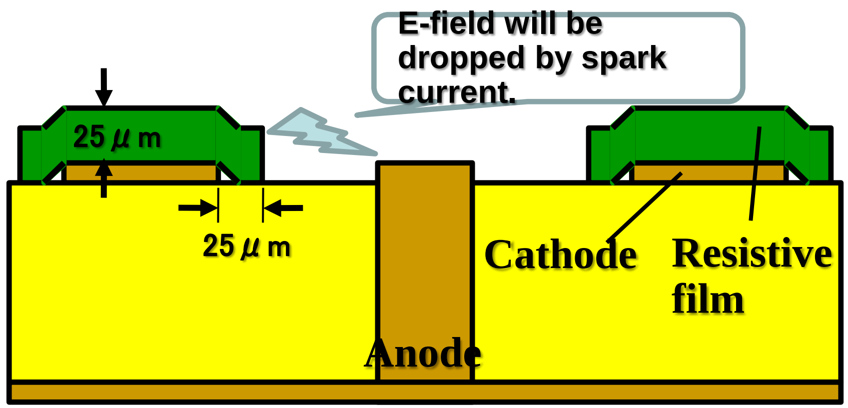
General purpose tracking: fundamental research & applications
Motivation:
- **use PCB technology for mass production,**
- **no floating structure**



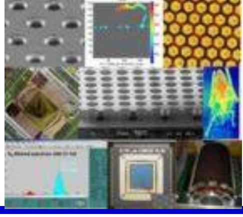
μPIC

A.Ochi and T.Tanimori,
NIMA 471 (2001) 264

Spark-tolerant structure

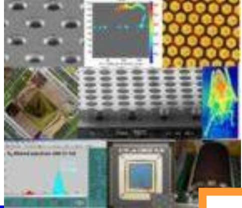


Resistive μPIC



CONSOLIDATION OF ESTABLISHED ARCHITECTURES

(new ideas & tecnological progress)



MICROMEGAS, construction 1/2

the challenge: keep uniform the thin gap by insulating spacers

1) electroformed **Ni mesh** + quartz fibres (75 μm)

Y Giomataris et al., NIMA 376 (1996) 29

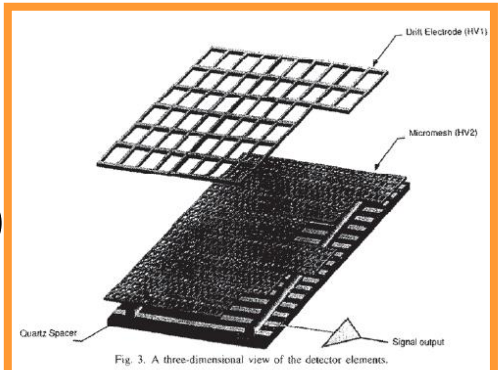
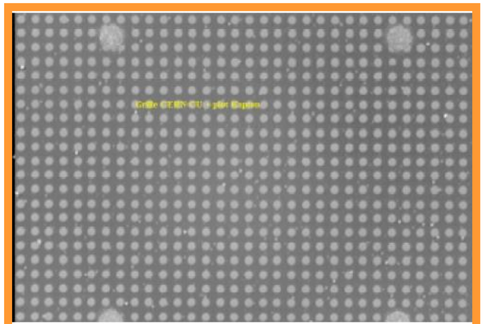
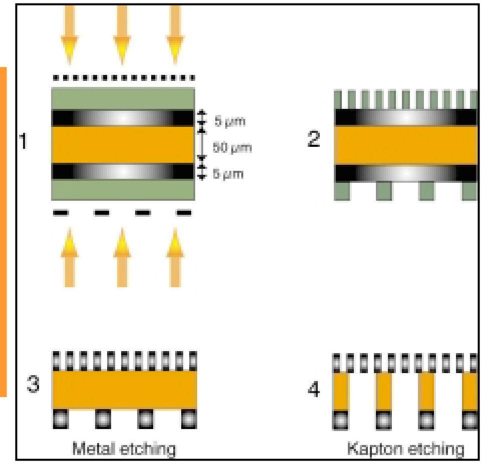


Fig. 3. A three-dimensional view of the detector elements.

2) Etched metalized **polyimide foil;** pillars (spacers) produced during etching

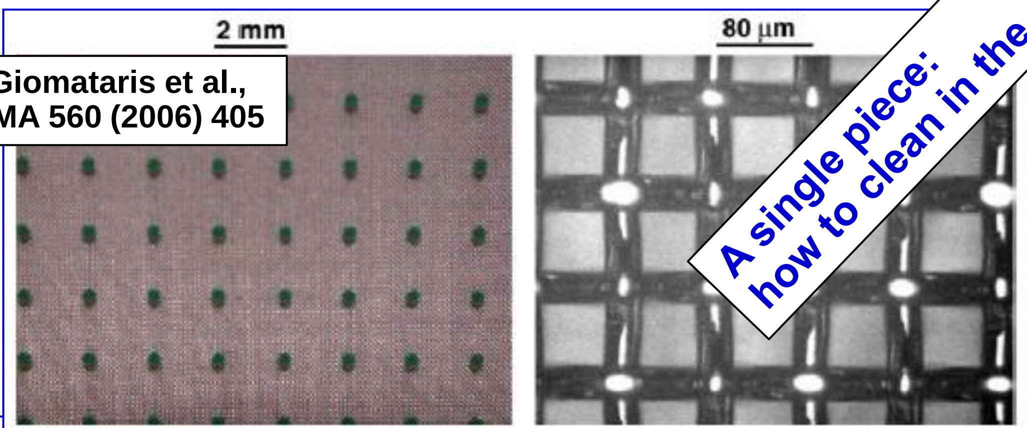
A. Delbart et al., NIMA 461 (2001) 84



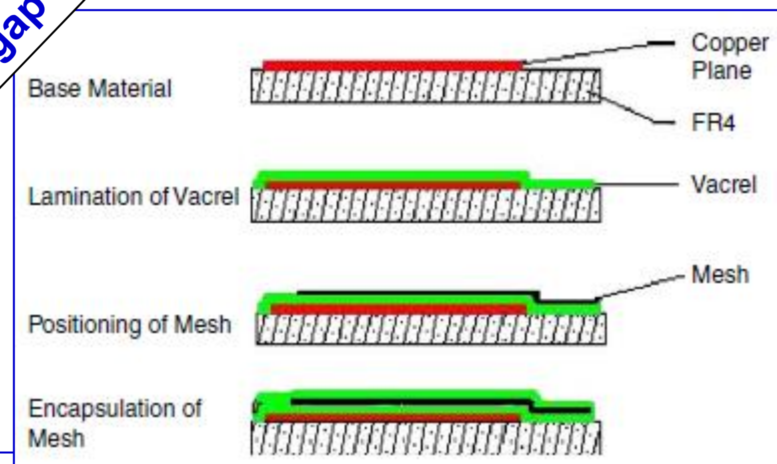


3) **Bulk micromegas** : pre-stretched steel mesh laminated together with a PCB support and a photoresistive layer, later removed apart where pillars are formed

Y Giomataris et al., NIMA 560 (2006) 405

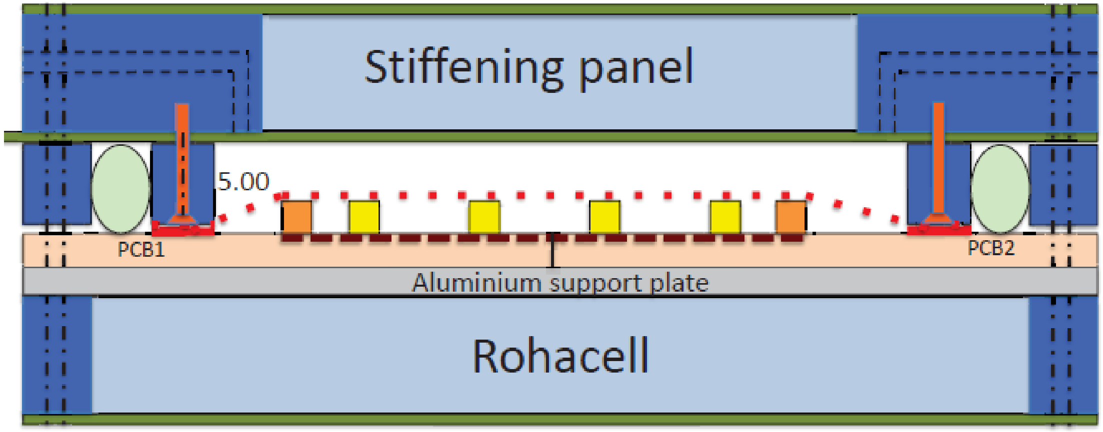


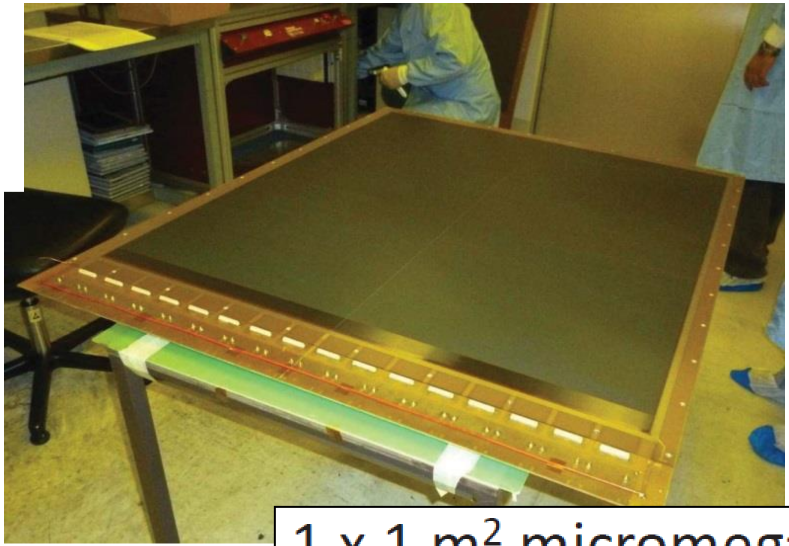
A single piece: how to clean in the gap ?



MICROMEGAS, construction 2/2

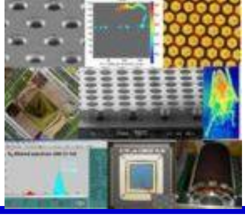
4) Grow **pillars at the anode** surface, keep the **mesh in place by mechanical tension (ATLAS-MAMMA)**





1 x 1 m^2 micromegas

J.Wotschack, RD51 coll. meeting, 1/10/2012

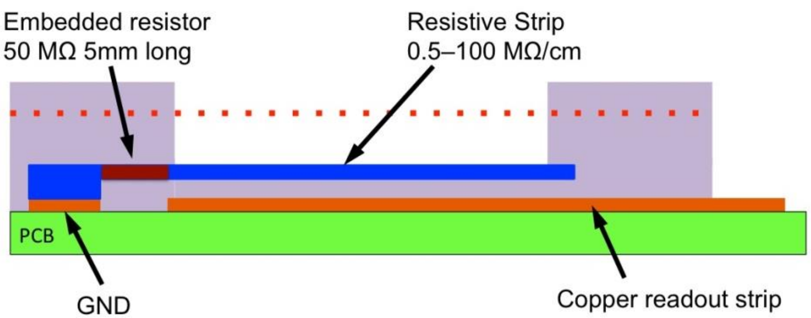


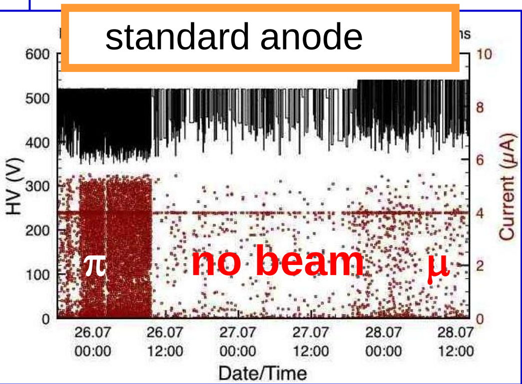
MICROMEGAS, overcoming discharges

living with / overcoming **the high discharge rate**

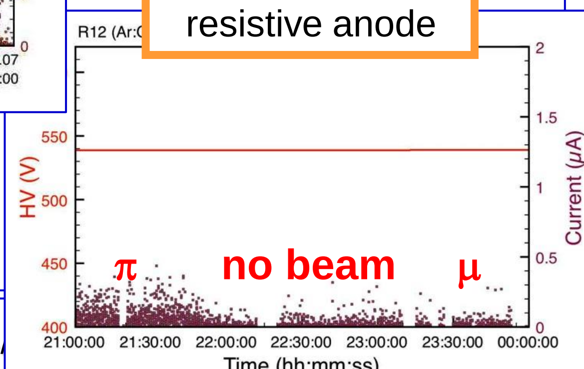
Resistive Anodes

Developed within the ATLAS-MAMMA project





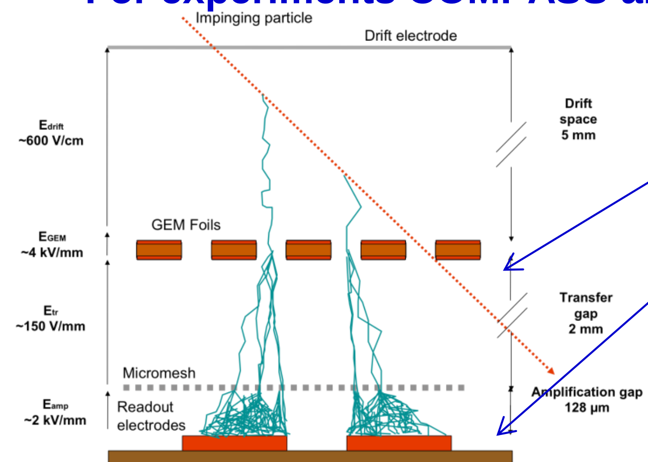
beam: π, μ
120 GeV/c



J. Wotschack
CERN Det. seminar,
18/11/2011

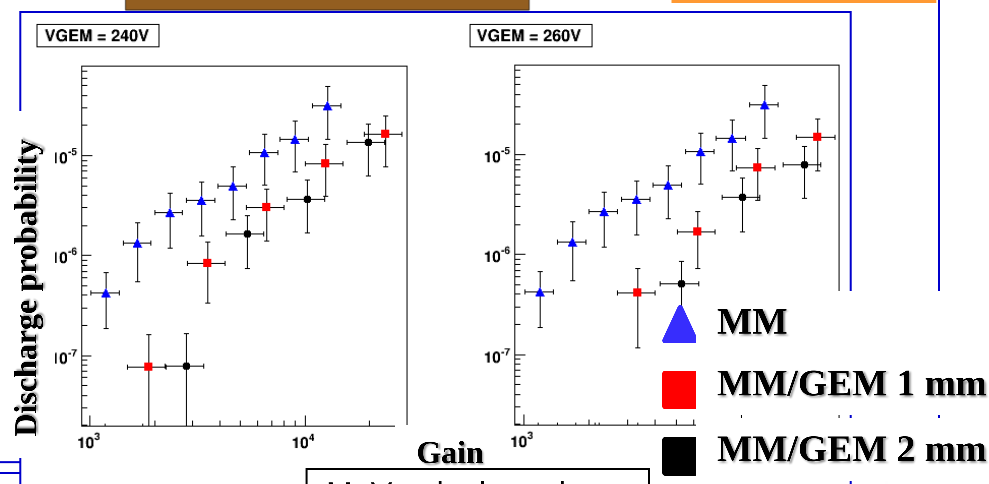
Hybrid Structures

- For experiments COMPASS and CLAS12

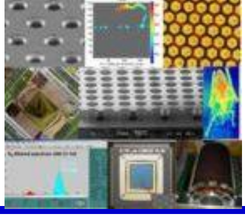


GEM
+
MM

beam: h
~3 GeV/c

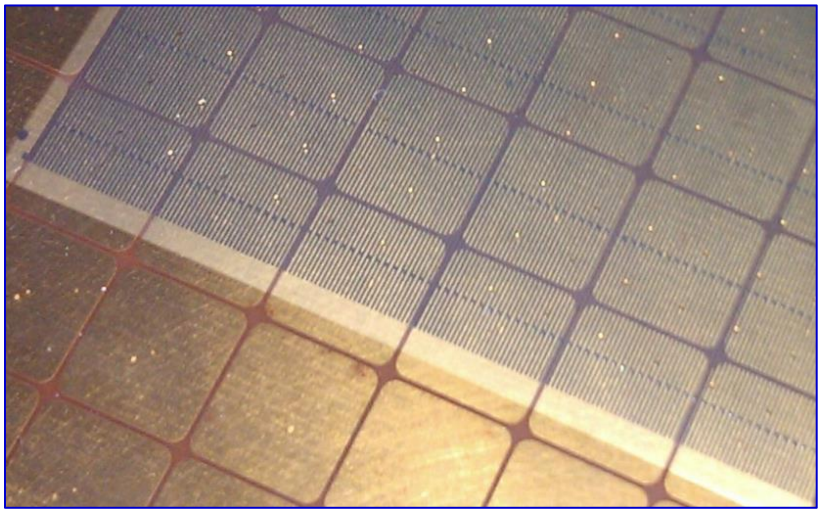


M. Vandenbroucke,
MPGD 2011



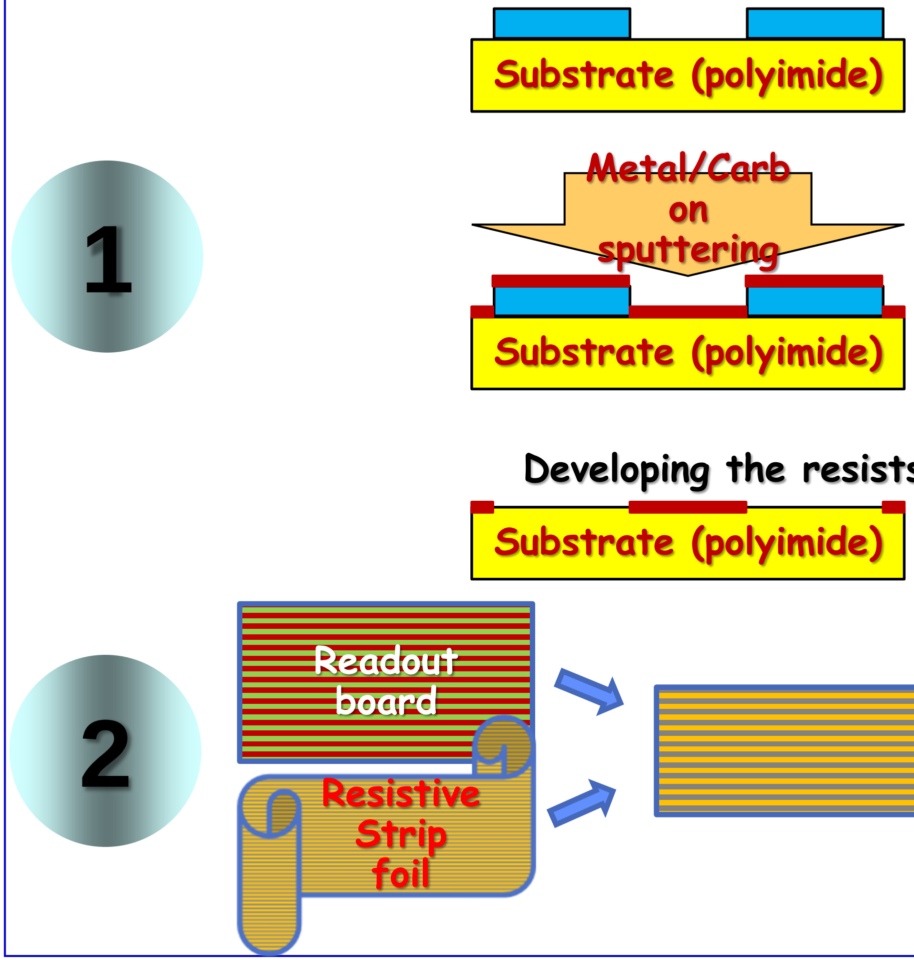
MM, resistive anode implementation

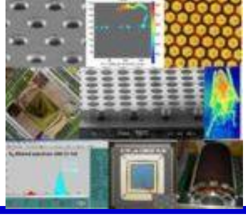
- Photolithography



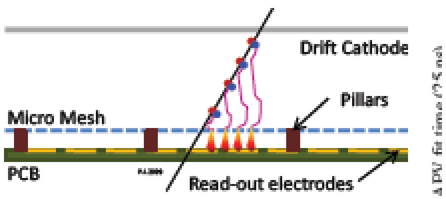
- Screen printing

- New: by sputtering

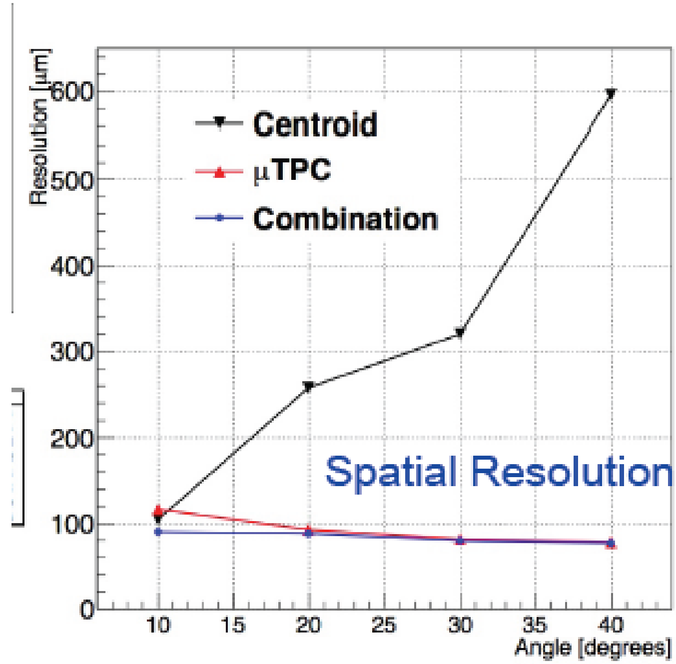




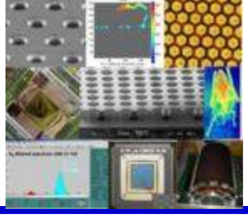
MM, TRACKING ALGORITMS



Single Segment Reconstruction in a Micromegas



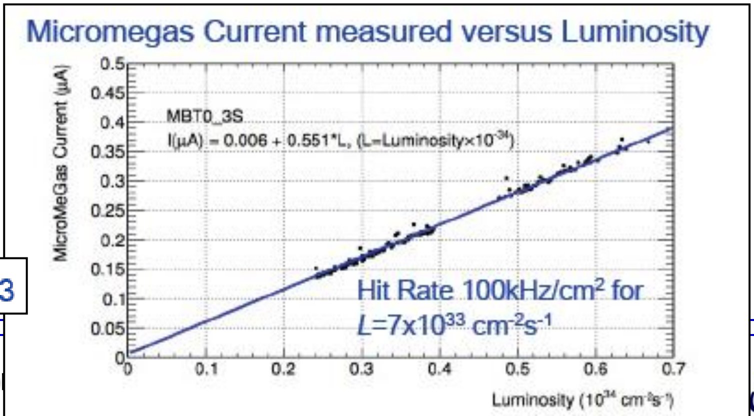
George Iakovidis - MPGD 2013



MICROMEGAS in experiments

- **Space resolution**
  - **COMPASS small area trackers, ~90µm** (P. Abbon et al., NIMA 577 (2007) 455.)
- **Time resolution**
  - **COMPASS small area trackers, ~ 9 ns** (P. Abbon et al., NIMA 577 (2007) 455.)
- **Gain**
  - **At COMPASS: G ~ 6400** (D Thers et al., NIMA 469 (2001) 133)
  - **T2K TPC: G ~ 1500** (N. Abgrall et al., NIMA 637 (2011) 25)
- **Material budget**
  - **COMPASS small area trackers: 0.3 % X0** (P. Abbon et al., NIMA 577 (2007) 455.)
- **Rate capability**

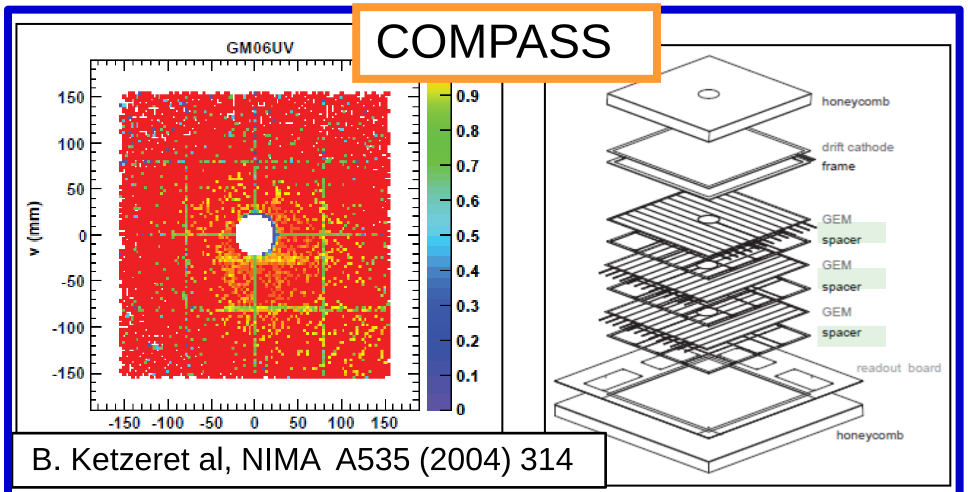
George Iakovidis - MPGD 2013



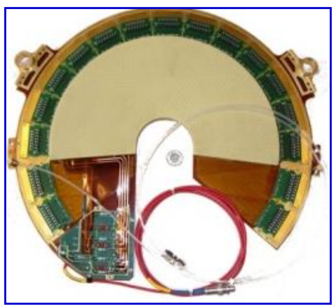
GEMs, spacers & stretching

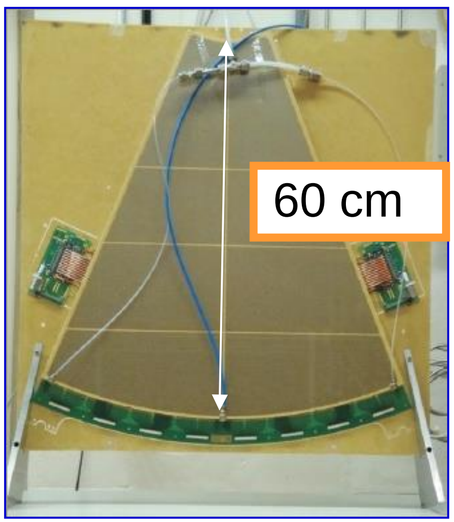
GEM detectors w/ spacers

COMPASS



B. Ketzeret al, NIMA A535 (2004) 314



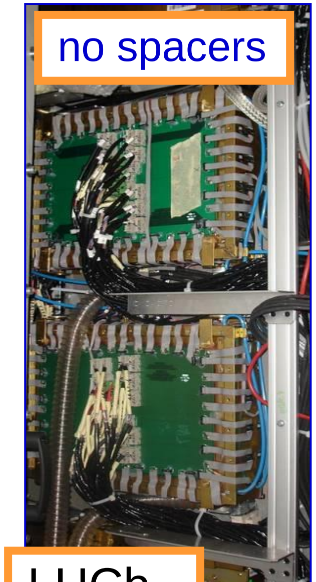


60 cm

TOTEM

Emphasis on GEM foils stretching

no spacers

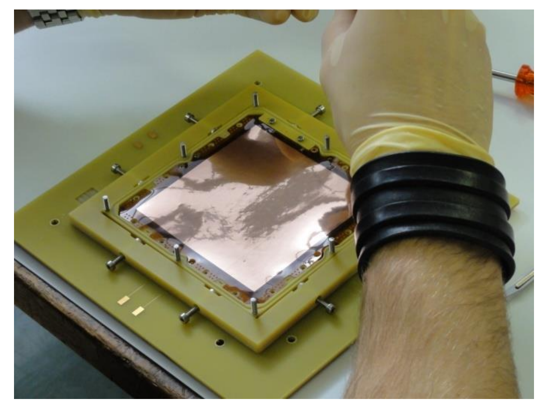


LHCb

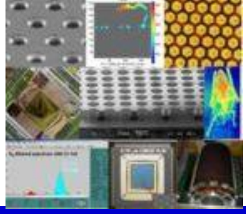
KLOE2: Triple cylindrical GEM
assembly completed 14/3/2013

no spacers

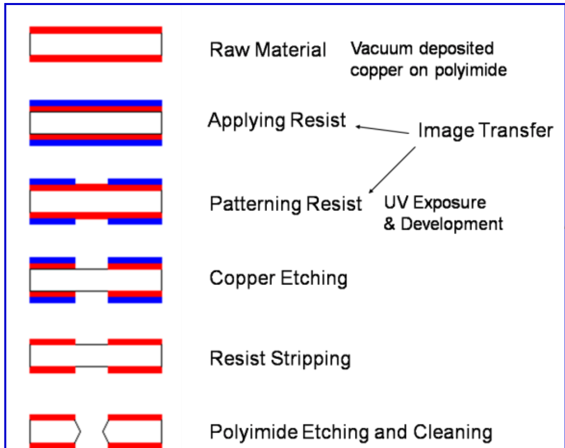
CMS upgrade: mechanical stretching for mass production



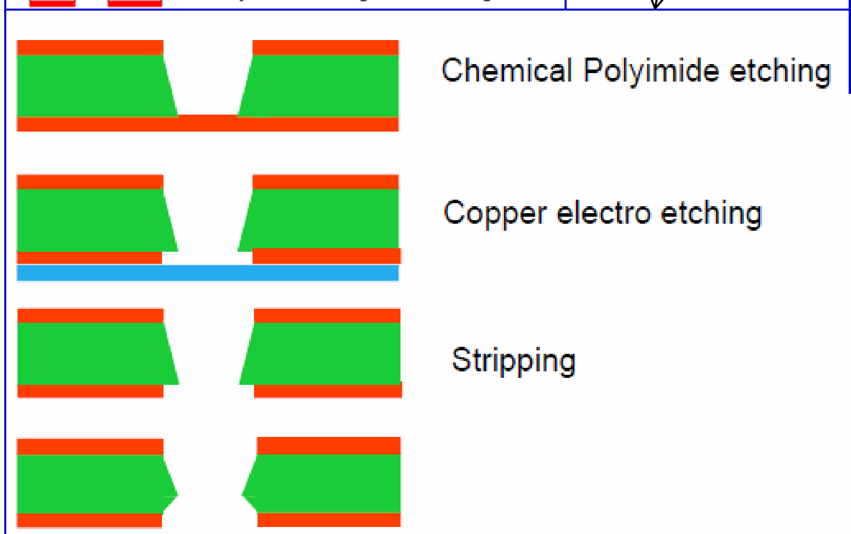
GEMs, *large* foils



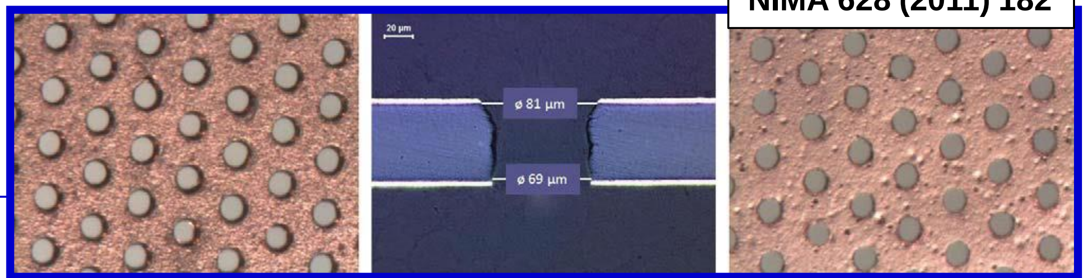
Single mask: the way towards large size



- standard (double mask)
- single mask



M. Villa et al., NIMA 628 (2011) 182

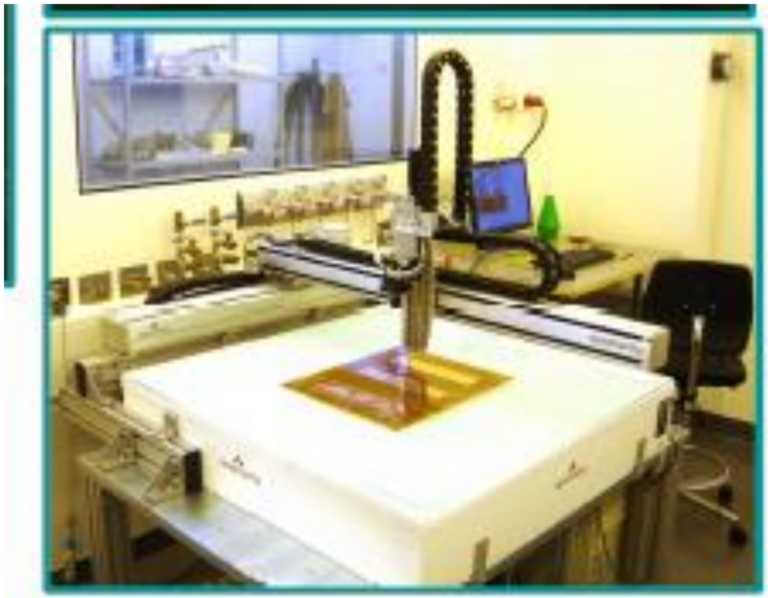


The path:

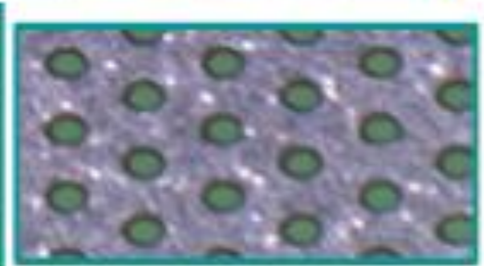
- TOTEM upgrade
- KLOE2
- CMS
- CBM

GEM FOIL QC

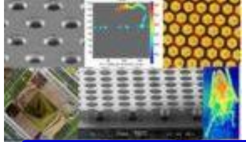
- **By optical inspection @ Helsinki**
  - **TOTEM**
  - **superFRS**



Based on 9 Mpix camera with integrated telecentric optics for this setup one pixel corresponds to 1.7 x 1.7 microns

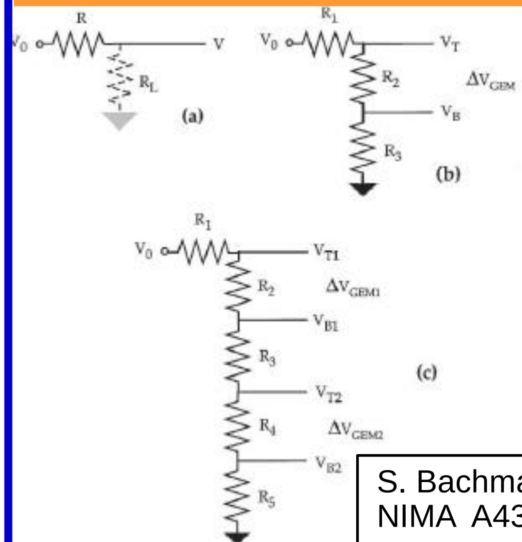


F.Garcia et al., This workshop



GEM & HV

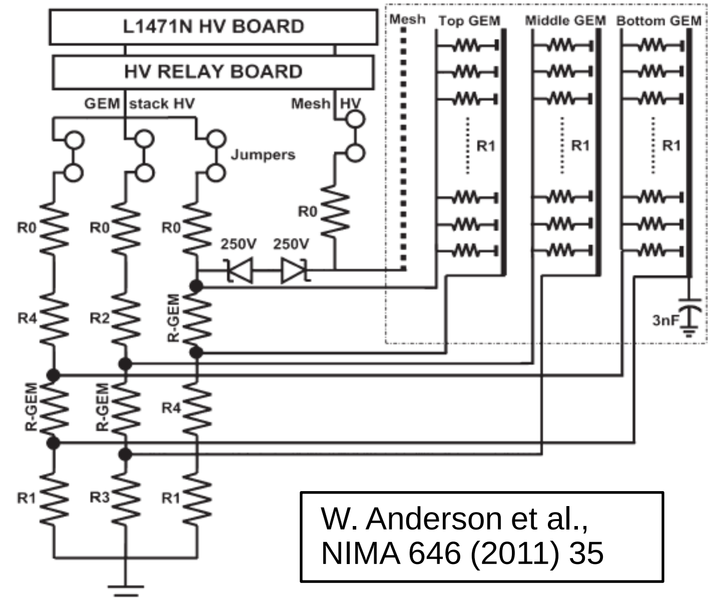
Attention paid since the beginning



S. Bachmann et al,
NIMA A438 (1999) 376

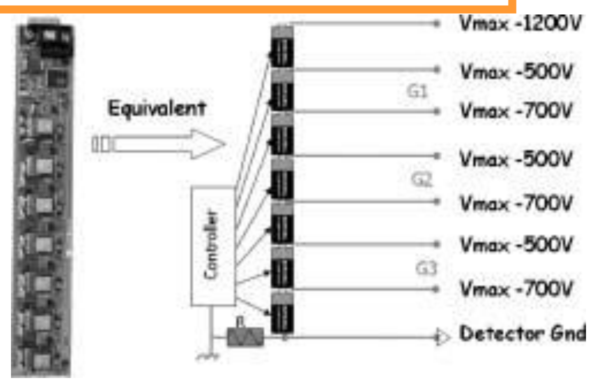
The PHENIX HBD experience:

- Fast trip protection
- HV scaling with P/T



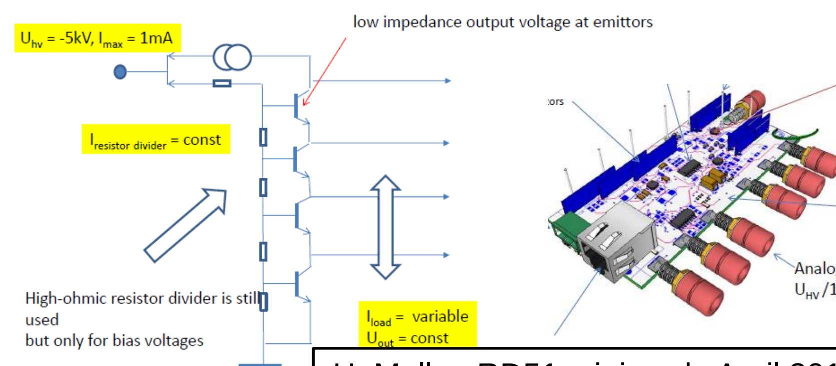
W. Anderson et al.,
NIMA 646 (2011) 35

Active HV Divider (LHCb)

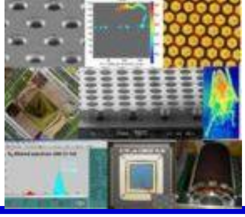


G. Corradi et al, NIMA A572 (2007) 96

Active voltage divider & HV monitoring

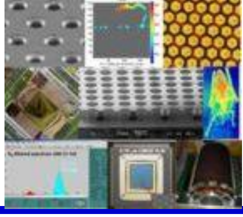


H. Muller, RD51 miniweek, April 2013



GEMs in experiments

- **Space resolution**
  - **COMPASS small area trackers, ~70 μm** (P. Abbon et al., NIMA 577 (2007) 455.)
- **Time resolution**
  - **COMPASS small area trackers, ~12 ns** (P. Abbon et al., NIMA 577 (2007) 455.)
  - **LHCb, 4.5 ns - dedicated effort** (M. Alfonsi NIMA 535 (2004) 319)
- **Gain**
  - **At COMPASS: G ~ 8000** (B. Ketzer, private comm.)
  - **At LHCb: G ~ 4000** (M.Alfonsi NIMA 581 (2007) 283)
  - **At TOTEM: G ~ 8000** (G. Catanesi, private comm.)
  - **Phenix HBD: G ~ 4000** (W. Anderson et al., NIMA 646 (2011) 35)
- **Material budget**
  - **COMPASS small area trackers: 0.4 % X0** (P. Abbon et al., NIMA 577 (2007) 455.)
  - **COMPASS pixelated GEMs: 0.2 % X0** (A. Austregesilo et al., NP B PS 197 (2009) 113



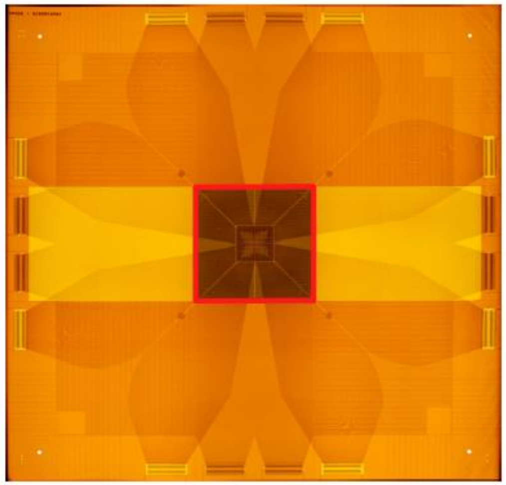
PIXELIZED R-O for HIGH RATE

Pixelised GEMs (used in COMPASS)

Foil: 450 × 450 mm²
- 3 conducting layers 5 μm Cu
- 2 intermediate layers 50 μm Polyimide

Centre: 32 × 32 mm²
- 32 × 32 quadratic pixels

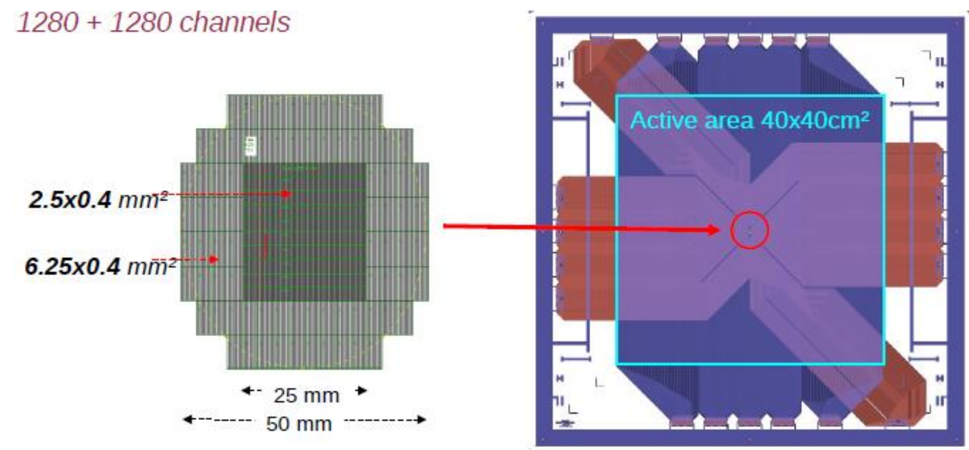
Periphery: 100 × 100 mm²
- 2 layers, 512 strips each
- equal charge sharing
- pitch: 400 μm



- **stable operation in particle flux up to $1.2{\cdot}10^5$/s/mm²**
- **extremely thin: 0.2% X_0**
- **spatial resolution: 90 μm**

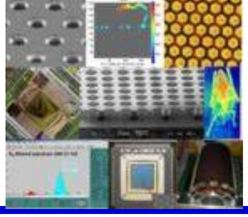
A. Austregesilo et al., NP B PS 197 (2009) 113

Pixelised MICROMEGAS (to be used in COMPASS)



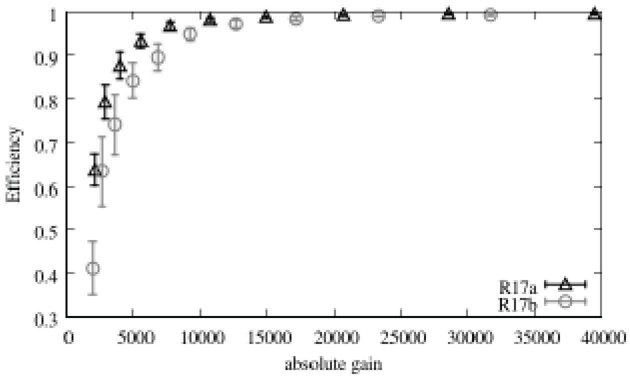
D.Neyret, RD51 Coll. Meeting, Oct 2012

ABOUT AGEING



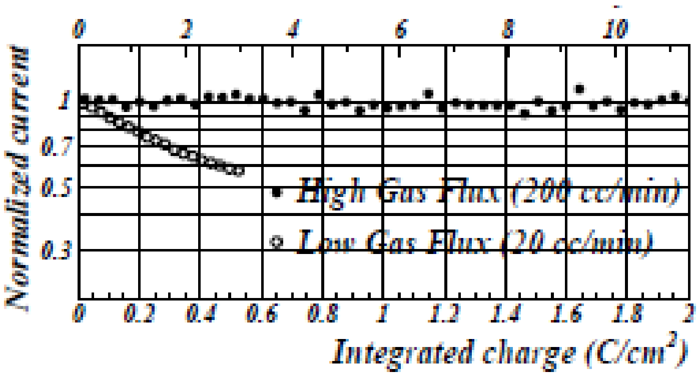
MM, MAMMA studies

Irradiation with	Charge Deposit (mC/cm^2)
X-Ray	225
Neutron	0.5
Gamma	14.84
Alpha	2.4



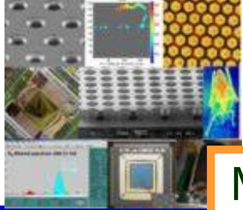
VCI2013 Conference Proceedings arXiv:1304.2053v1, J.Galan et al.

GEM studies for LHCb



M. Alfonsi et al, NPB PS 150 (2006) 159

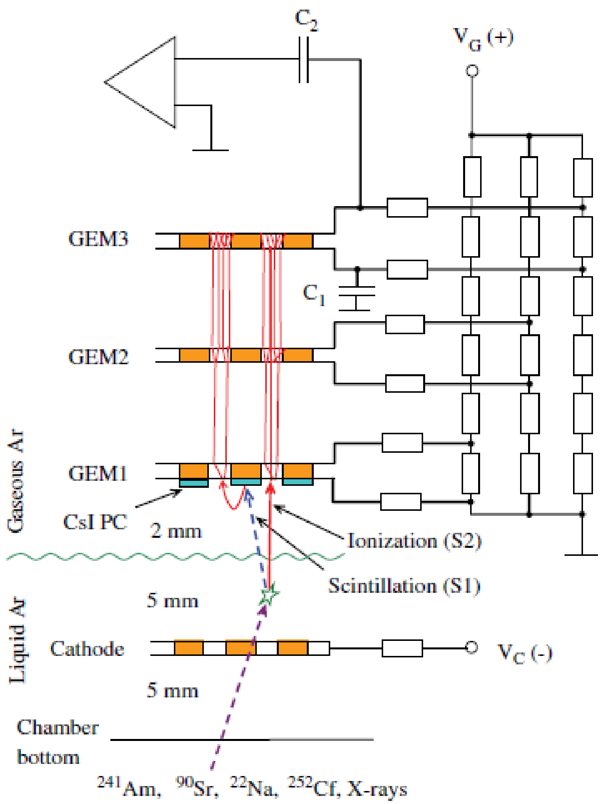
COMPASS Pixelised GEMs



THE CRYOGENIC FRONTIER

Main physics goals:
- **Neutrino detectors**
- **Dark matter**

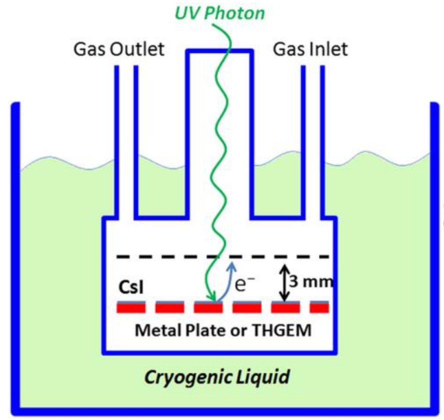
GEM

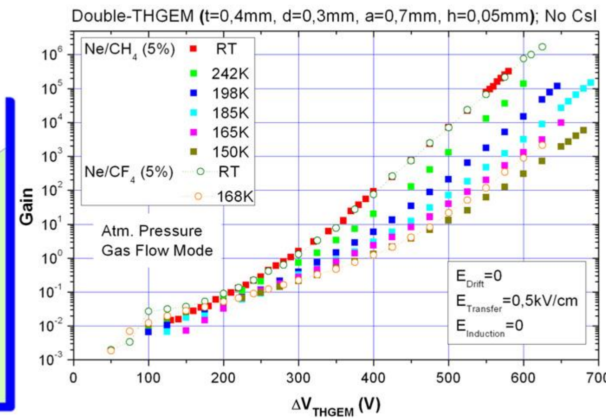


A. Bondar et al., NIMA 581 (2007) 241

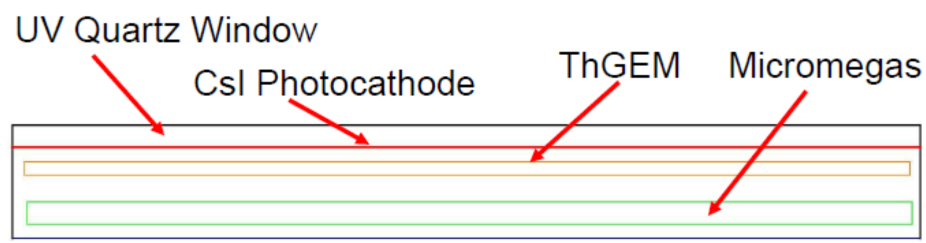
THGEM

A. Breskin et al., NIMA 639 (2011) 117

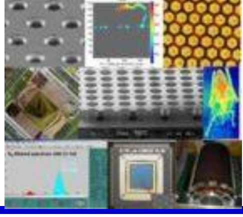




Hybrid: THGEM + MM



K. L. Giboni, seminar at KEK, Nov 2011



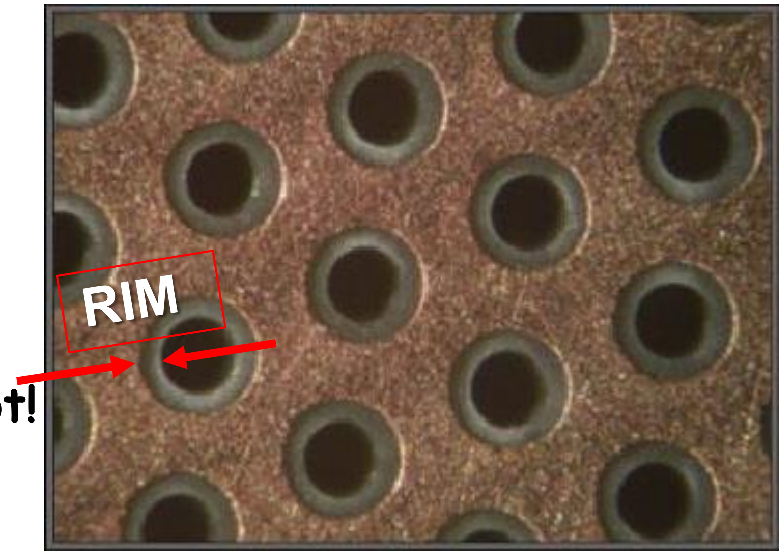
ESTABLISHING THGEMs 1/3

PCB technology, thus:

- robust
- mechanically self supporting
- industrial production of large size boards
- economic

About PCB geometrical dimensions:

Hole diameter :	0.2 - 1 mm
Pitch :	0.5 - 5 mm
Thickness :	0.4 - 3 mm



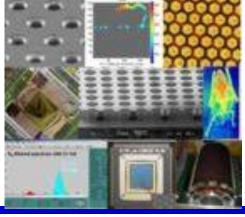
Comparing to GEMs

- Geometrical dimensions X ~10
  - But e^- motion/multiplic. properties do not!
  - Larger holes: dipole fields and external fields are strongly coupled

introduced in // by different groups:
L. Periale et al., NIM A478 (2002) 377.
P. Jeanneret, PhD thesis, Neuchatel U., 2001.
P.S. Barbeau et al, IEEE NS50 (2003) 1285
R. Chechik et al., NIMA 535 (2004) 303

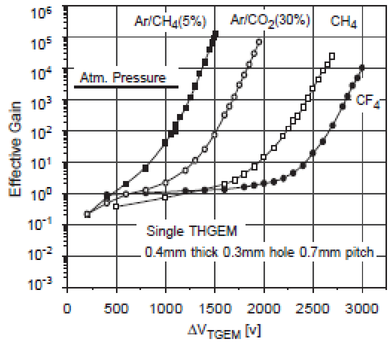
About gain:

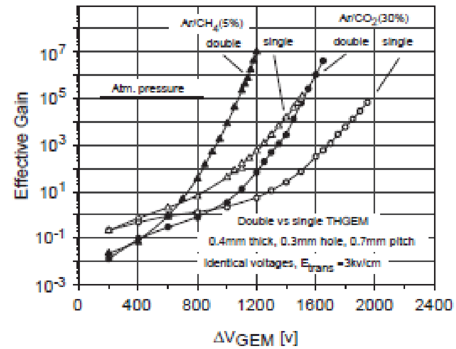
- Large gains are easily obtained (rim !)

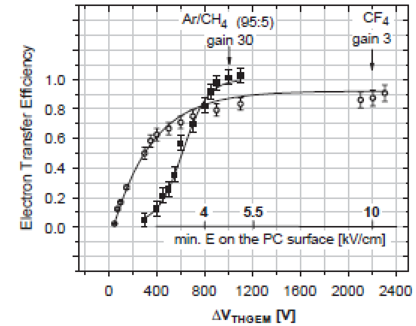


ESTABLISHING THGEMs 2/3

The first phase of the systematic studies is entirely due to the **Weizmann group**



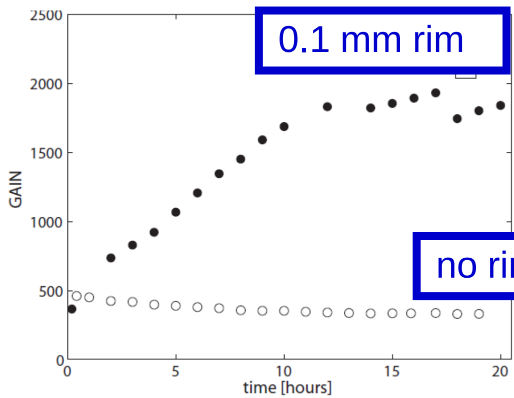




R. Chechik et al., NIMA 553 (2005) 35

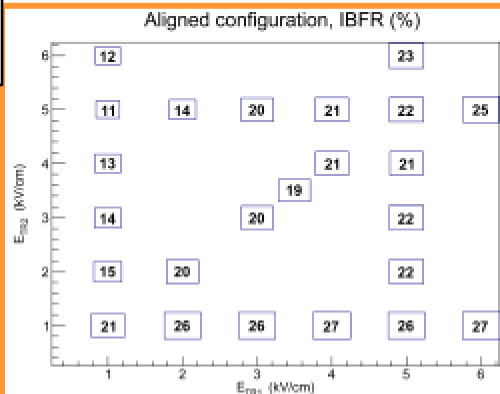
Gain vs time

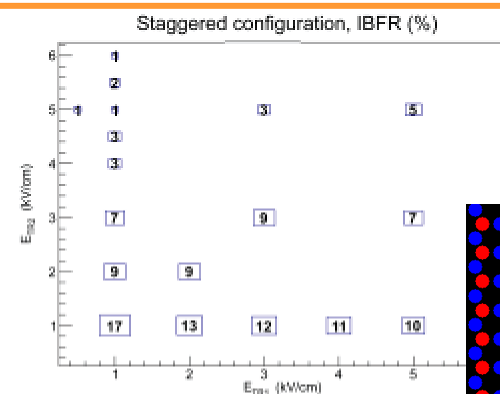
M. Alexeev et al., NIMA 617 (2010) 396

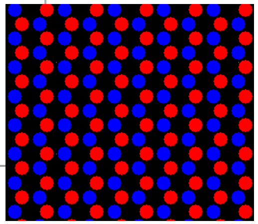


0.1 mm rim

no rim

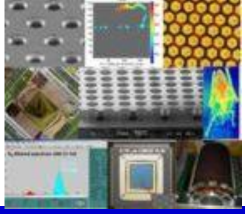






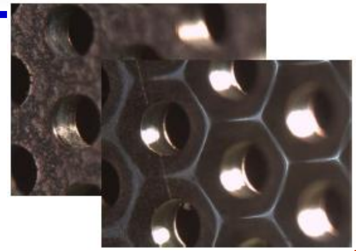
Tripple THGEM: Ion Back Flow by staggering plates

M. Alexeev et al., JINST 7 (2012) C002014

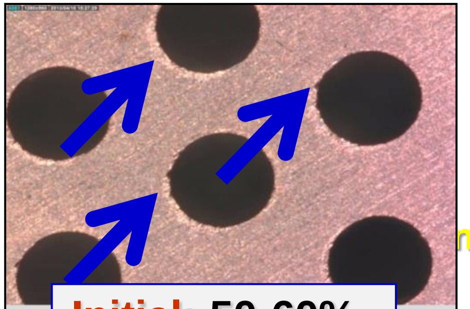


ESTABLISHING THGEMs 3/3

Engineering aspects

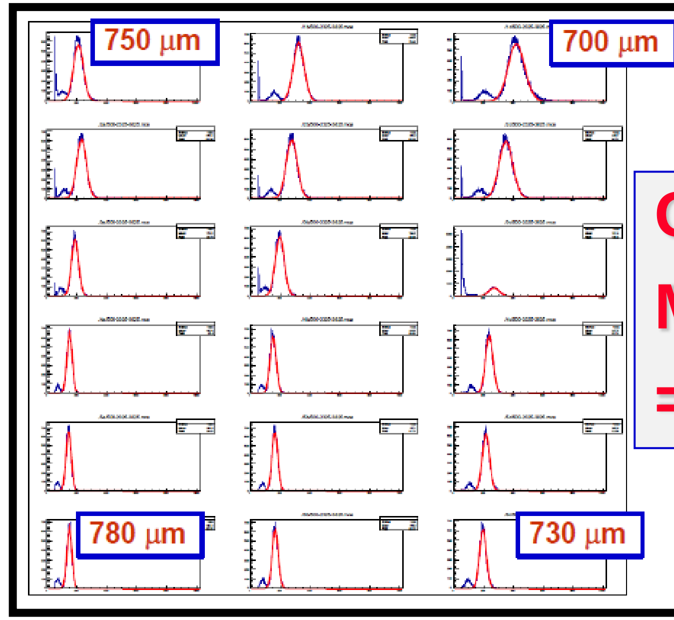


polishing (Pumice Powder)
ultrasonic bath (~1 h) @ 50-60 ºC in Sonica

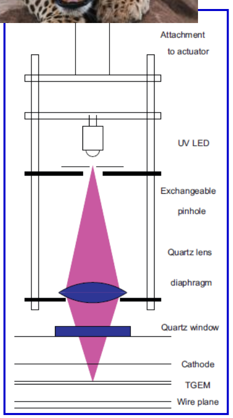


Initial: 50-60% Paschen curve

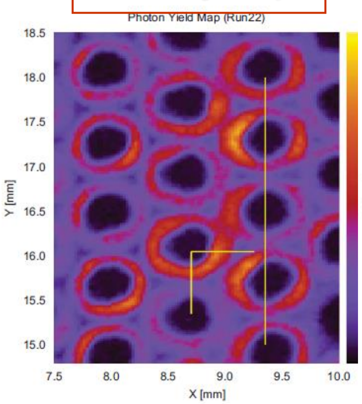
Final: > 90% Paschen curve



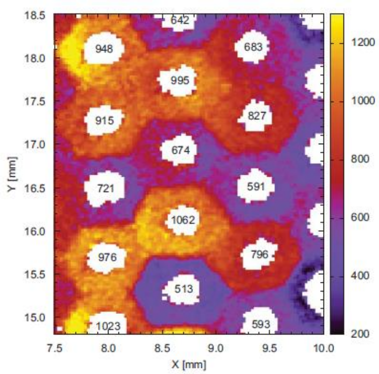
GAIN Max/Min = 2.9



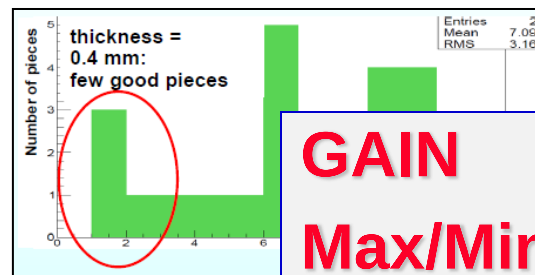
Effiency map



Gain map

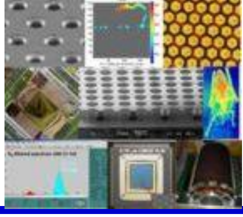


G.Hamar and D. Varga, NIMA 694(2012)16



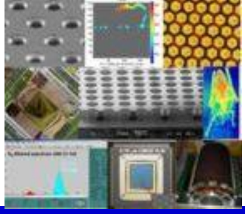
GAIN Max/Min = 1.6

Selecting uniform fiberglass plates



WHAT ABOUT TPCs ?

- Gas & noble liquids → very different ionization !
- TPCs with MPGD r-o widely aimed
  - Accelerator physics, ν, double β-decays, dark matter, X-ray polarimetry, n-induced reaction, active targets in nuclear reaction, geological exploration …
- Nevertheless, only very few operated in experimental conditions:
  - T2K (MM r-o)
  - FOPI (GEM r-o)
  - NIFFTE (MM at very low gain)
- The performance issue related to IBF still requires deeper studies
  - The gated vs no-gate dilemma is open



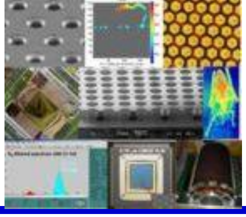
Intermediate summary

- **A rich and diversified panorama:**
  a number of novel architectures !

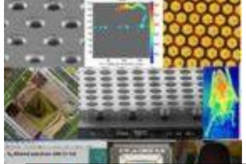
- **Only the future evolution will let the fruitful ideas emerge**

- **Moreover, a great idea is not the only ingredient:**
  to establish a technique
  - **dedication**
  - **technical progress**
  - **engineering**

  are as important as a good starting point



APPLICATIONS



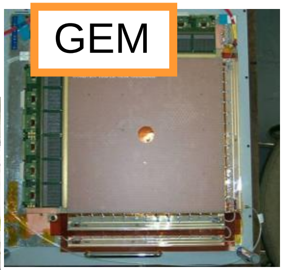
HEP & PARTICLES

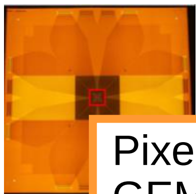
Completed / Running Experiments

COMPASS

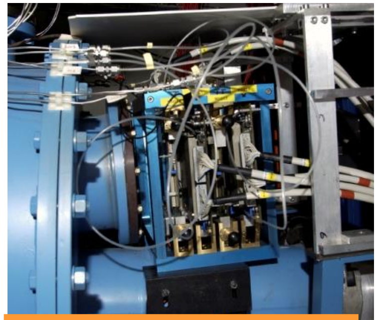
MM

GEM

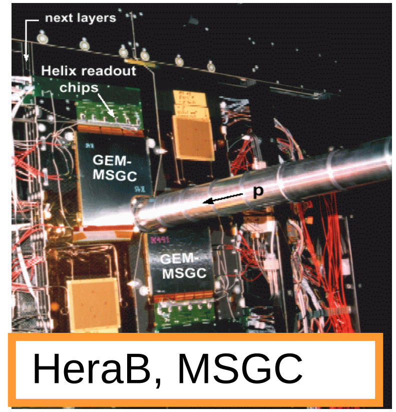




Pixel GEM

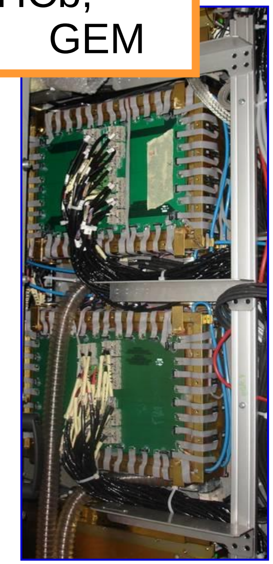


DIRAC, MSGC

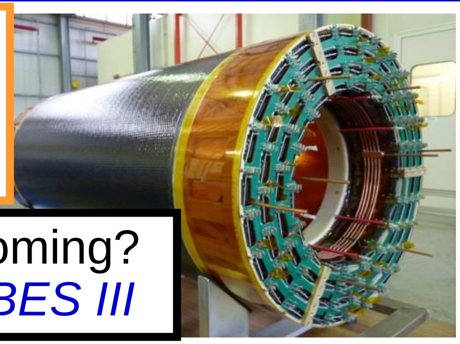


HeraB, MSGC

LHCb, GEM

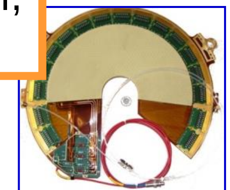


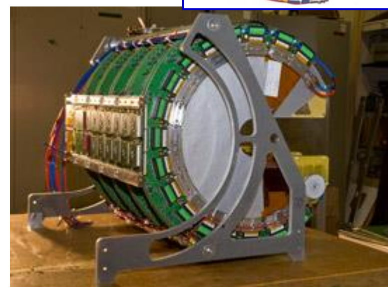
KLOE2:
triple cylindrical GEM
assembled: 14/3/2013



Other cylinders coming?
CMD-3 detector, BES III

TOTEM, GEM

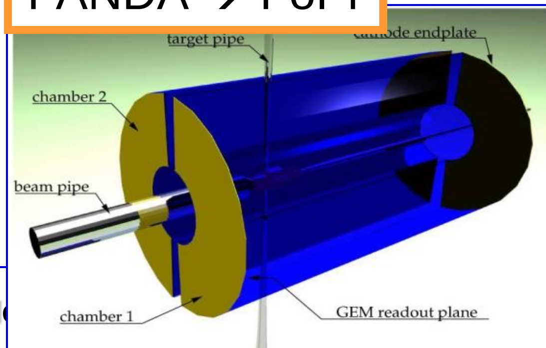


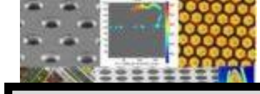


MM, T2K
TPC read-out

CAST, MM

PANDA → FoPi





HEP & PARTICLE

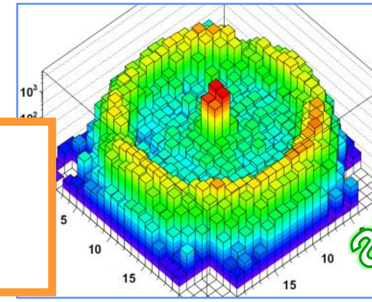
Future @ CERN LHC & more

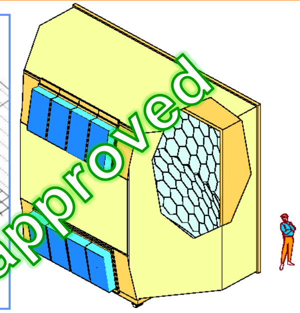
ATLAS – MAMMA project (MM)
Goal: ~1 x 2.5 m^2

New Small Wheel, ATLAS muon system,
1200 m^2, tracking & trigger

more GEM for LHCb (LS3) ?

Goal: ~.6 x 0.3 m^2
~50-60 m^2 of GEM foils





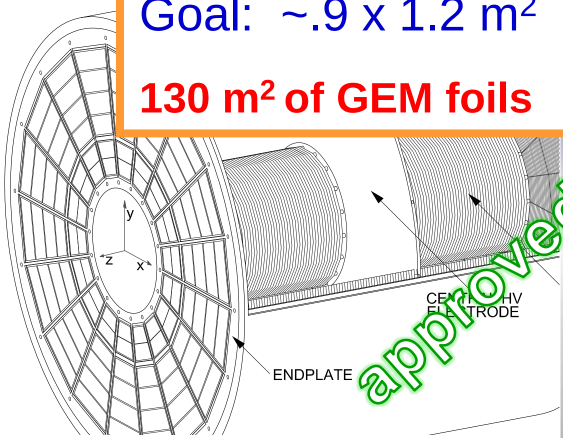
COMPASS RICH-1 upgrade

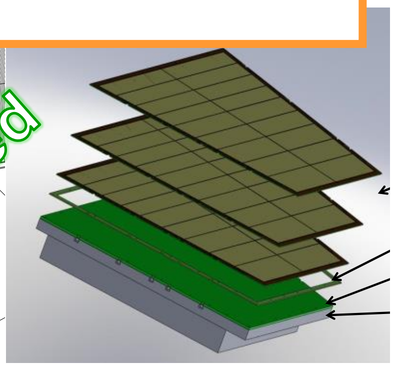
12 m^2 of THGEM plates

A NEW FRONTIER: THE MASS PRODUCTION
→ INDUSTRIALISATION IS AN ABSOLUTE MUST

ALICE – TPC r-O, upgrade (GEM)
Goal: ~.9 x 1.2 m^2

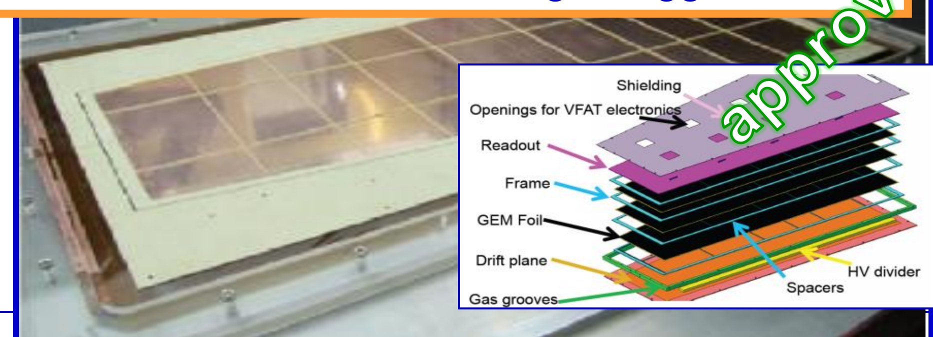
130 m^2 of GEM foils

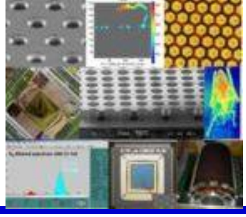




CMS – forward muon spectrometer (GEM)
Goal: ~1.2 x 2 m^2

1000 m^2 of GEM foils, tracking & trigger





INDUSTRIAL PRODUCTION

GEM

- Techtra
  - Polish company
  - Making GEM since 10 years
  - Licensed by CERN
  - Setting up equipment for large GEM production since 1 year
  - 30cm x 10cm GEMs already produced
  - First delivery of 30 GEMs last week
- UPLUS/Mecharonics
  - Korean company
  - Making GEM since a few months
  - Licensed By CERN
  - 30cm x 30cm GEMs already produced (characterization in progress)
  - Willing to ramp up to large size
- Tech-etch
  - US company
  - Making GEM since 15 years
  - Many small and medium sizes GEM have been produced
  - Recently involved in STAR experiment (80 GEMs 40cmx40cm)
  - Willing to ramp up to large size
  - Licensed by CERN
- Scienergy
  - Japanese company
  - Making GEM since 6 years
  - Top quality laser drilled GEM up to 30cm x 30cm
  - Licensed by CERN

MICROMEGAS

- ELTOS
  - Resistive 10cm x10cm BULK Micromegas → OK
  - Large single side read-out boards and drift (2mx0.5m) → OK
  - Screen printing of large area → in progress
  - Pillars on large area → OK
- ELVIA (see Fabien talk in WG6)
  - Resistive 40cm x 40cm BULK Micromegas → OK
  - Embedded resistor BULK detectors → in progress (see Damien talk WG6)
  - Large single side read-out boards and drift (2mx0.5m) → OK
  - Screen printing of large area → in progress
  - Pillars on large area → OK

THGEM

- ELTOS
  - 10 holes/ sec drilling machine
  - They have produced 60cm x 60cm just for mechanical purpose
  - They have produced 80cm x 40cm working THGEM
  - They are able to produce RIMs.
  - The final cleaning should still be performed by the user or CERN
  - Long polishing or PU coating are not yet available in industry

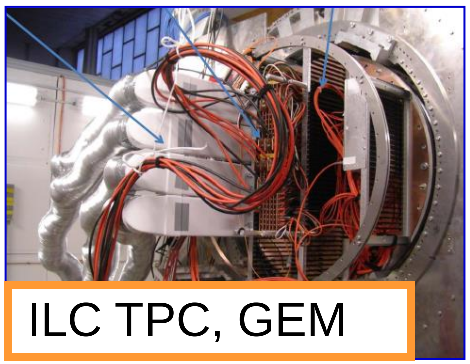
  - Mass production costs are still difficult to predict (cleaning technology transfer should be organized)
- Print Electronics
  - Israel
  - Many pieces made for Weismann institute
  - Little information on the capabilities

R. De Olivera, this workshop

HEP & PARTICLES

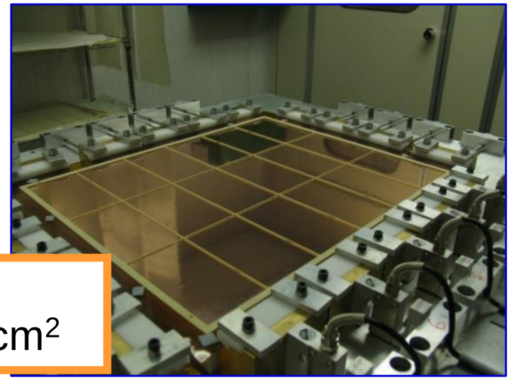
More about Future

ILC TPC, MM

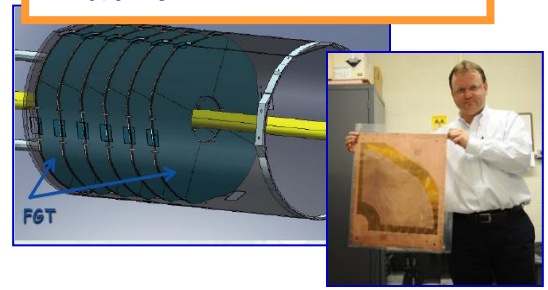


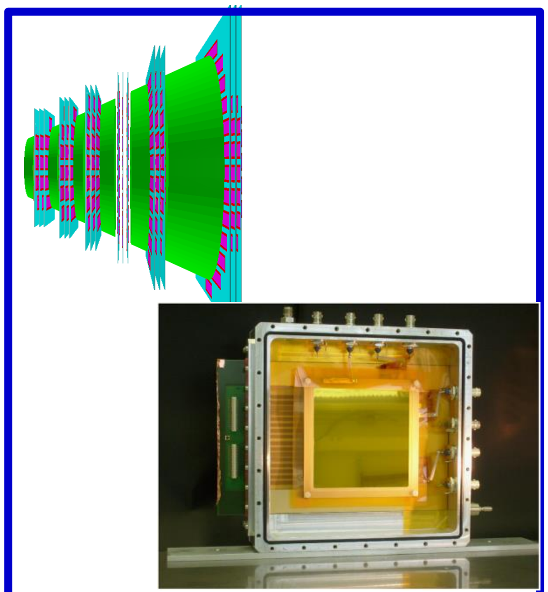
ILC TPC, GEM

JLab Hall A
GEM 40 x 50 cm^2



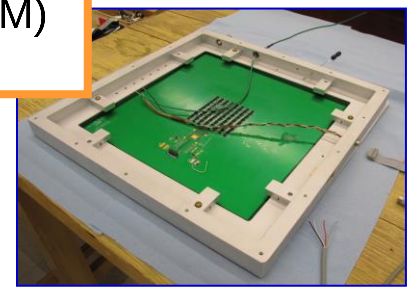
STAR - Forward GEM Tracker



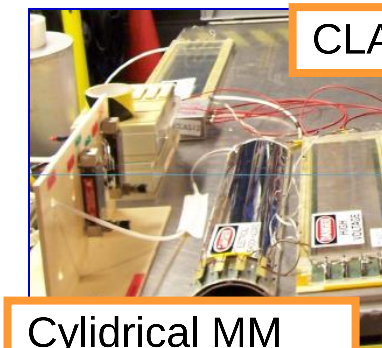


CBM: GEMs for tracking

H calorimetry(GEM) (ATLAS, ILC)



CLAS12



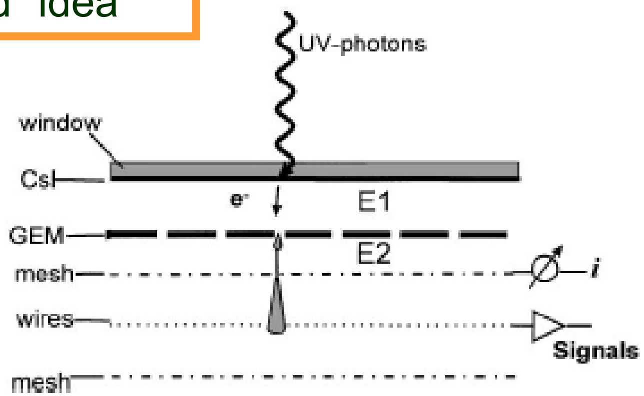
Cylidrical MM

MM forward tracking

HEP & PARTICLES

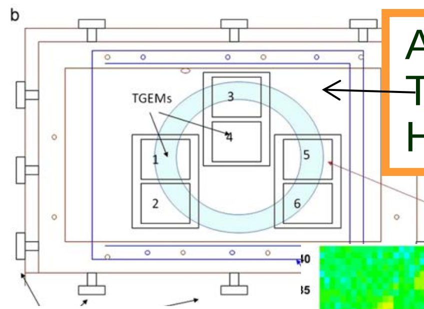
PHOTON detection

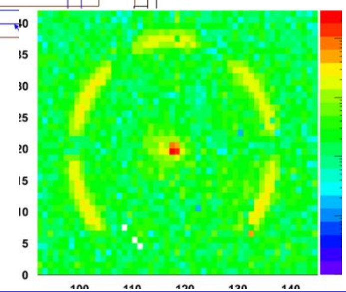
An “old” idea

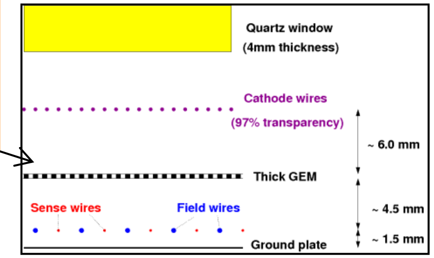


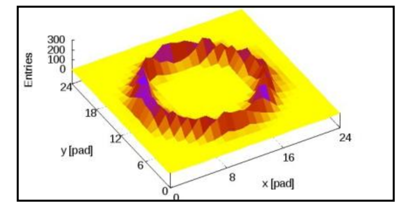
R. Chechwik et al., NIM A 419 (1998) 423

ALICE VHPID THGEM & HYBRID

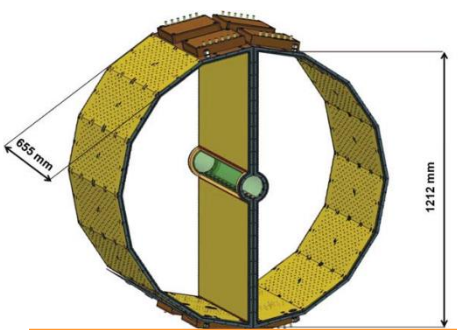


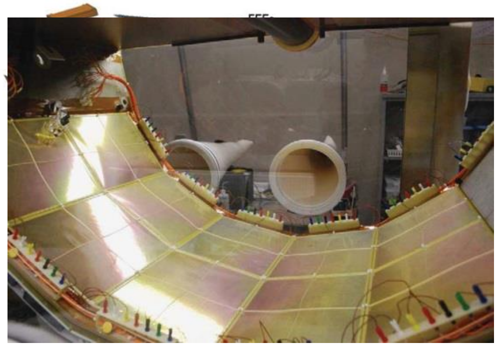




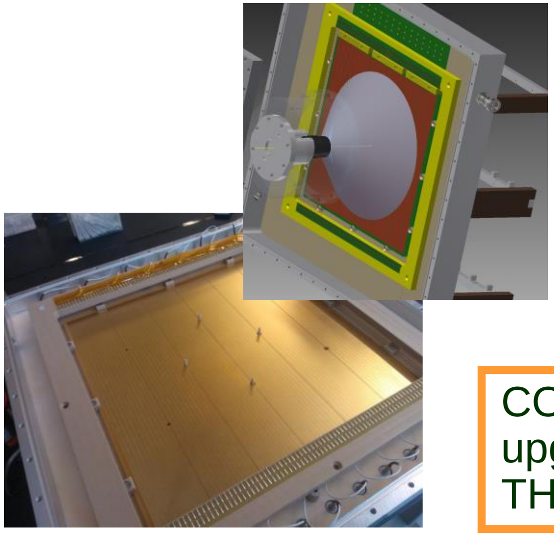


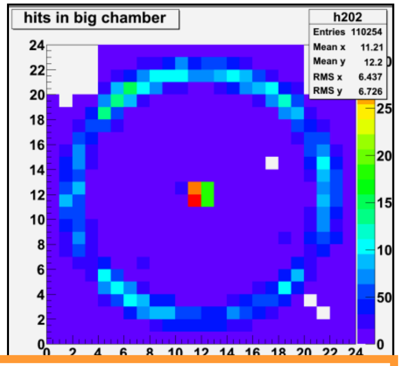
PHENIX HBD, GEM

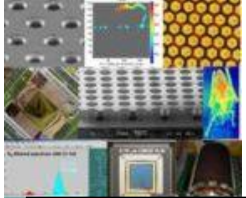




COMPASS, RICH-1 upgrade by THGEM detectors

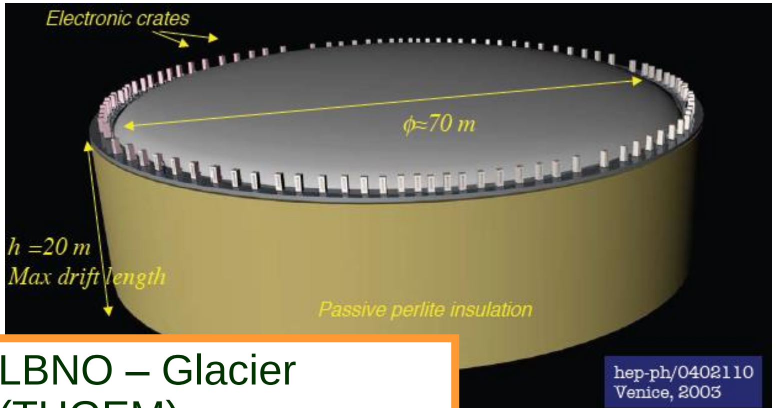




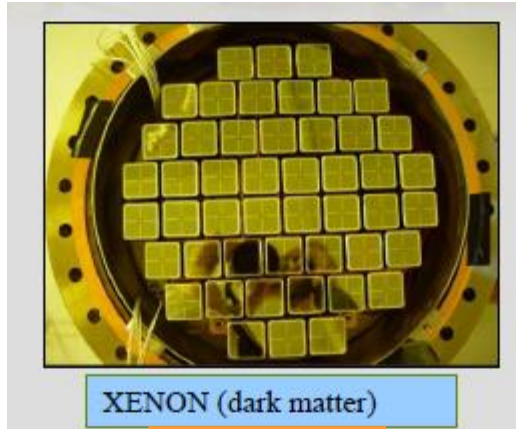


HEP & PARTICLES

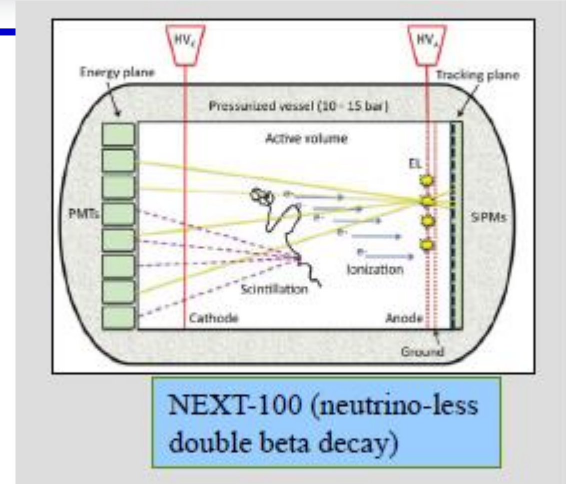
Very rare events



LBNO – Glacier
(THGEM)

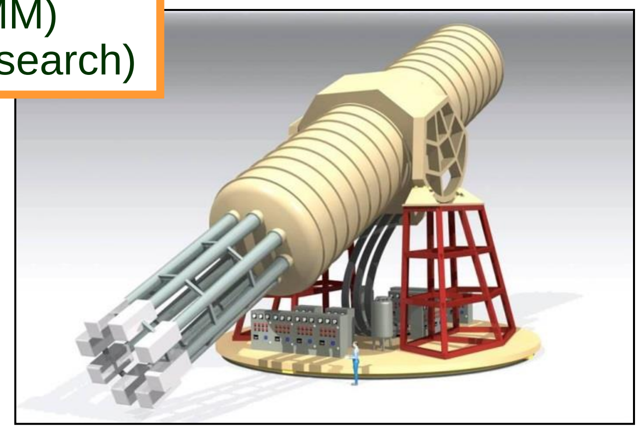


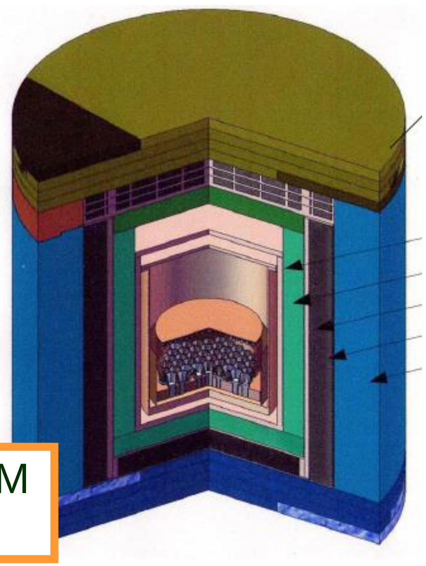
(THGEM)



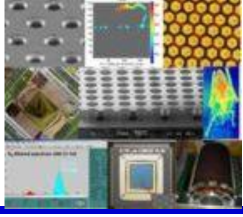
(baseline:EL+PMT+SiPM
1ton upgrade: all options open,
microbulkMM?)

IAXO (MM)
(assion search)





Panda-X, THGEM + MM
(dark matter)



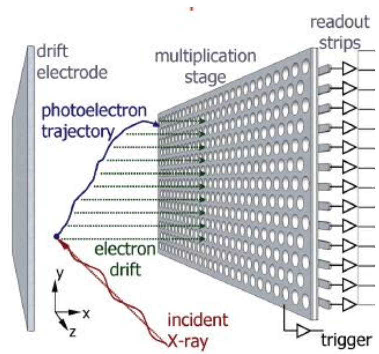
LOWER ENERGIES & EXOTIC APPLICATIONS 1/4

- The amount of *projects and information* in these fields is certainly <u>one of the workshop highlights</u> !
    - Only considering talks:
    - 15 contributed over 37 + 1 review talk

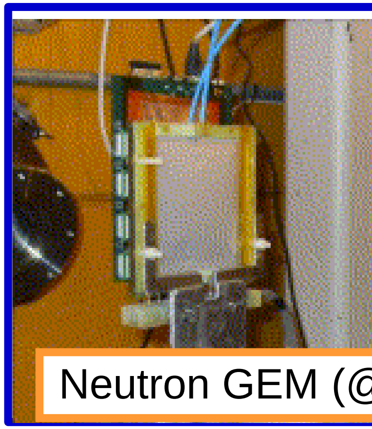
- **MPGD-based X-ray detectors**
  - Sealed triple GEM for X-ray detection
  - Bragg crystal X-ray spectrometry by GEM detectors
  - GEM-TPC X-ray Polarimeter (GEMS, XACT)
  - diagnostic of Magnetic fusion plasmas
- **MPGD-based neutron detectors**
  - GEMs coupled to n-converters for
    - ITER
    - n-beam diagnostic

Super FRS @ FAIR (GEM)

D20 difractometer @ILL, MSGD



GEMS-GEM TPC, NASA mission

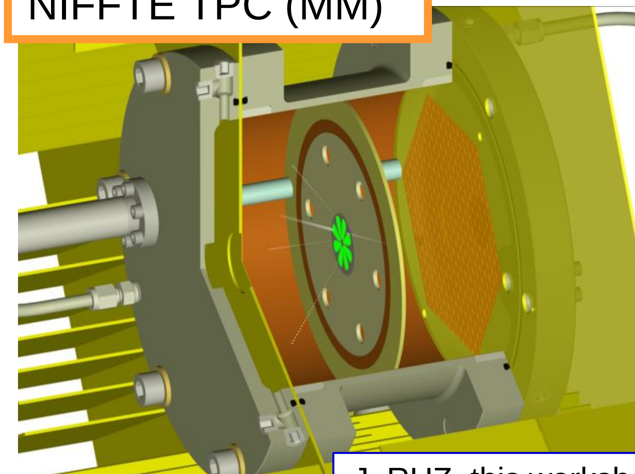


Neutron GEM (@ ISIS)

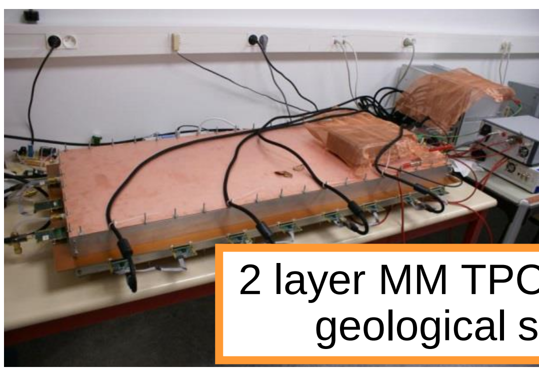
LOWER ENERGIES & EXOTIC APPLICATIONS 3/4

- **Nuclei studies**
  - Tracking of low energy nuclei by secondary electron detection (Spiral2, GANIL)
  - PID of exotic nuclei fragments (NIFFTE)
  - AstroBox
- **Double β-decay**
- **Muon radiography with MPGDs**
  - Homeland security (THGEM)
  - Geological studies (MM TPC)

NIFFTE TPC (MM)



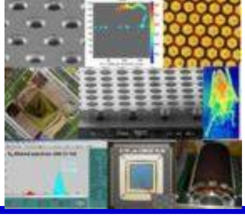
J. RUZ, this workshop



2 layer MM TPC for geological studies

NSC active Target (THGEM)

C.S.Lee, this workshop



LOWER ENERGIES & EXOTIC APPLICATIONS 4/4

Fast and Thermal Neutron
Non destructive diagnostic
Biology
Nuclear Energy Plant
Tokamak Diagnostics
Chip Irradiation

Xray Low energy

Tokamak diagnostics
Radioactive waste

Pixelated GEM

Microdosimetry
Tissue Equivalent chamber
Direct measurements with real tissue
Radon Monitor

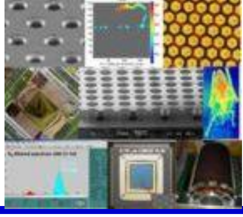
High Intensity Beam Monitors

Hadrotherapy
Ions Beam Monitor

Gamma High fluxes

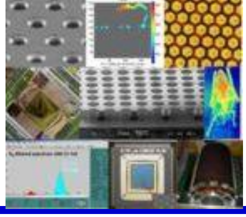
Radiotherapy

F. Mutas,
this workshop



TOOLS

(all what boosts MPGD R&D)



RD51

- **MPGDs exist thanks to a few genial inventors (very end of 20th century)**
- **Later, some progress due to engineering for the use in experiments**

- **Then, fundamental boost thanks to RD51:**

"The proposed R&D collaboration, RD51, aims at facilitating the development of advanced gas-avalanche detector technologies and associated electronic-readout systems, for applications in basic and applied research." (RD51 proposal, 28/7/ 2008)

RD51 serves as an access point to MPGD "know-how" for the world-wide community

L. Ropelewski, M. Titov
114th LHCC Meeting, CERN, 12-13 June 2013

Unique in providing:

- **Space and resources for non – project related R&D**
- **tools for the word-wide MPGD community AND BEYOND**

- **~ 80 Institutes from 4 continents: Europe, Nord and South America, Asia, Africa**
- **~ 450 physicists**

SIMULATION TOOLS

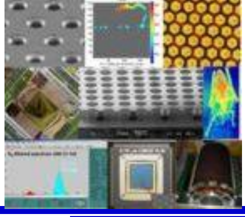
- **The progress of gas detectors is largely indebted to GARFIELD**

  (R. Veenhof, Nucl. Instr. and Meth. A419 (1998) 726; http://garfield.web.cern.ch/garfield/)

- **MPGDs have been designed / studied using GARDFIELD(++)**

  → needs (*and answers within RD51 effort*):

  - **Maintenance (a service to the whole gas detector community !)**
  - **Interface to software packages, generic & specific**
    - **electron and photon transport using cross sections provided by Magboltz**
    - **ionization processes in gases, provided by Heed, MIP**
    - **ionization and electron transport in semi-conductors**
  - **Answers to MPGD specific requirements**
    - **Dramatic E variations within microscopic distances ~ e^- mean free path**
      - **FEM and analytic methods with high granularity**
      - **Dedicated approaches: NEBEM**
    - **The role of the open dielectric surfaces**
      - **Simulation of the charging-up phenomena, material properties**
  - **description of the physical phenomena, continuos improvements**
    - **Ion mobility, diffusion, recombination, e^- cross sections**
    - **Photons (UV emission, IR production, trapping, absorption, photocathodes)**



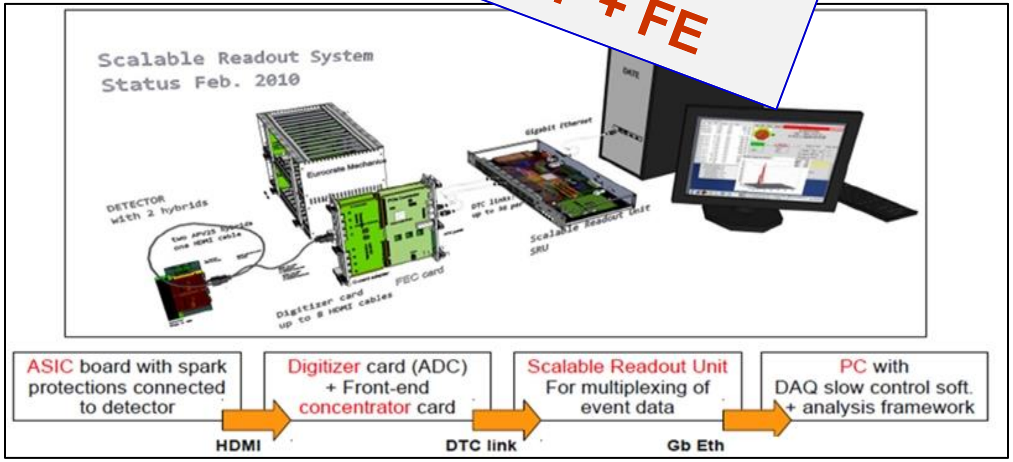
Scalable Readout System

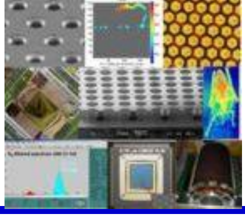
- **Once upon a time**
  - **Complete non experiment-specific read-out systems; for example:**
    - **RMH, MWPC read-out developed at CERN; PCOS III by Le Croy**
- **Then, experiment dedicated systems**
- **Still, up-to-date read-out systems available off-the-shelf needed**
  - **A must for detector developers, wider use according to needs**

Scalable Readout System (SRS) for MPGDs (developed with RD51)

- **A variety of FE chips: APV25, VFAT, Beetle, VMMx, Timepix**
- **Common acquisition hardware & software**
- **Scalable readout architecture: ~100 ch.s → ~100 k ch. (ATLAS MAMMA project)**
- **So successful, to be used outside MPGDs (SiPM, ALICE Ecal, …)**

Cheap!
~ 2 € / ch + FE





TECHNOLOGICAL REFERENCE

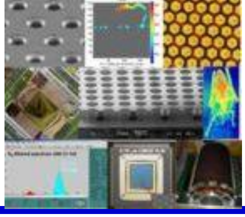
- **@ CERN, since always, a reference workshop**

'96: GEM 50 x 50mm with a gain of 10.
'97: GEM 100 x 100mm with gain of 1000.
'98: GEM 400 x 400mm; 1D and 2D readouts; micro-groove and micro-well detectors.
'00: 3D GEM readout; 1D readout for Micromegas in COMPASS.
'01: PIXEL GEM readout; 2D Micromegas readout.
'03: PIXEL Micromegas readout.
'04: Bulk Micromegas detector 100mm x 100mm. Micro BULK detectors
'06: Half cylindrical GEM detector.
'08: first large GEM 1.2m x 0.4m. First spherical GEM
'09: first large BULK Micromegas 1.5m x 0.5m
'11: First resistive Bulk Micromegas 100mm x 100mm
'12: First 30cm x 30cm NS2 GEM detector
'12: First 1m2 Resistive Micromegas
'12: First 2m2 Resistive Micromegas
'12: First NS2 GEM detector 1.2m x 0.5m
'12: Full cylindrical GEM detector
'13: GEM 2m x 0.5m ?? Micromegas 3.4m x 2.2m ??

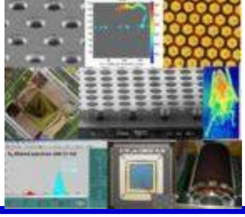
R. De Olivera, this workshop

- **More powerful with the new CERN-MPGD workshop (thanks to RD51), being completed**

CERN Building 107
Basis of Design



CONCLUSIONS



MPGDs:

Impressive progress and
enormous potentiality!

… and a marvelous professional adventure

Thank you for our common effort !