Overview of Micromegas technologies and applications

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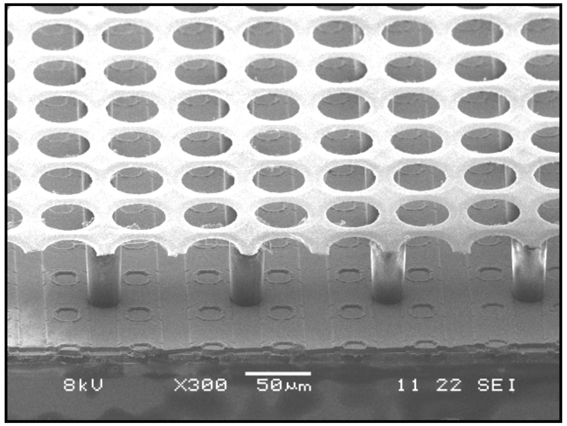

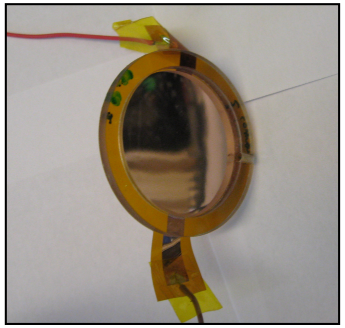

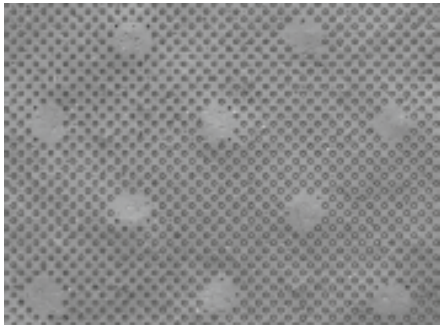

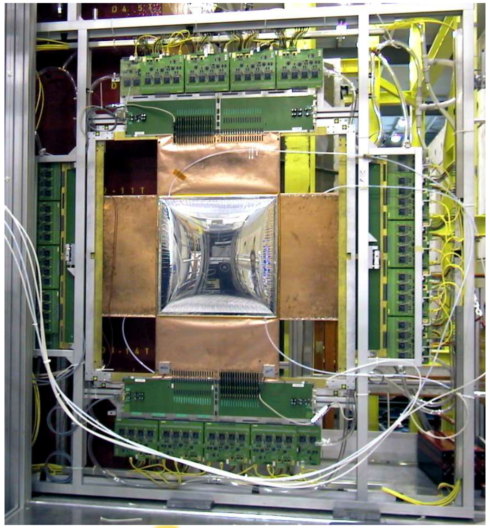

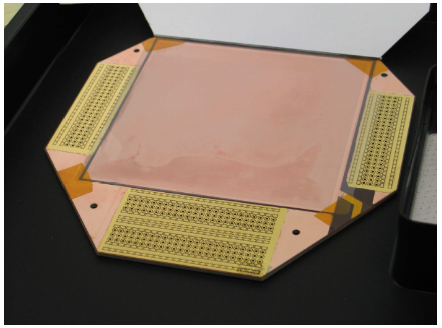

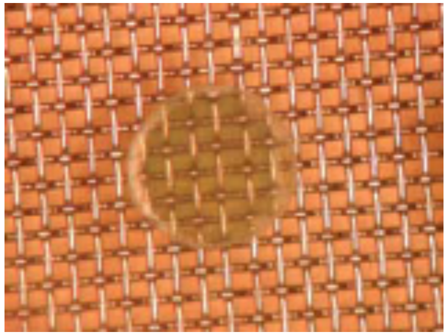

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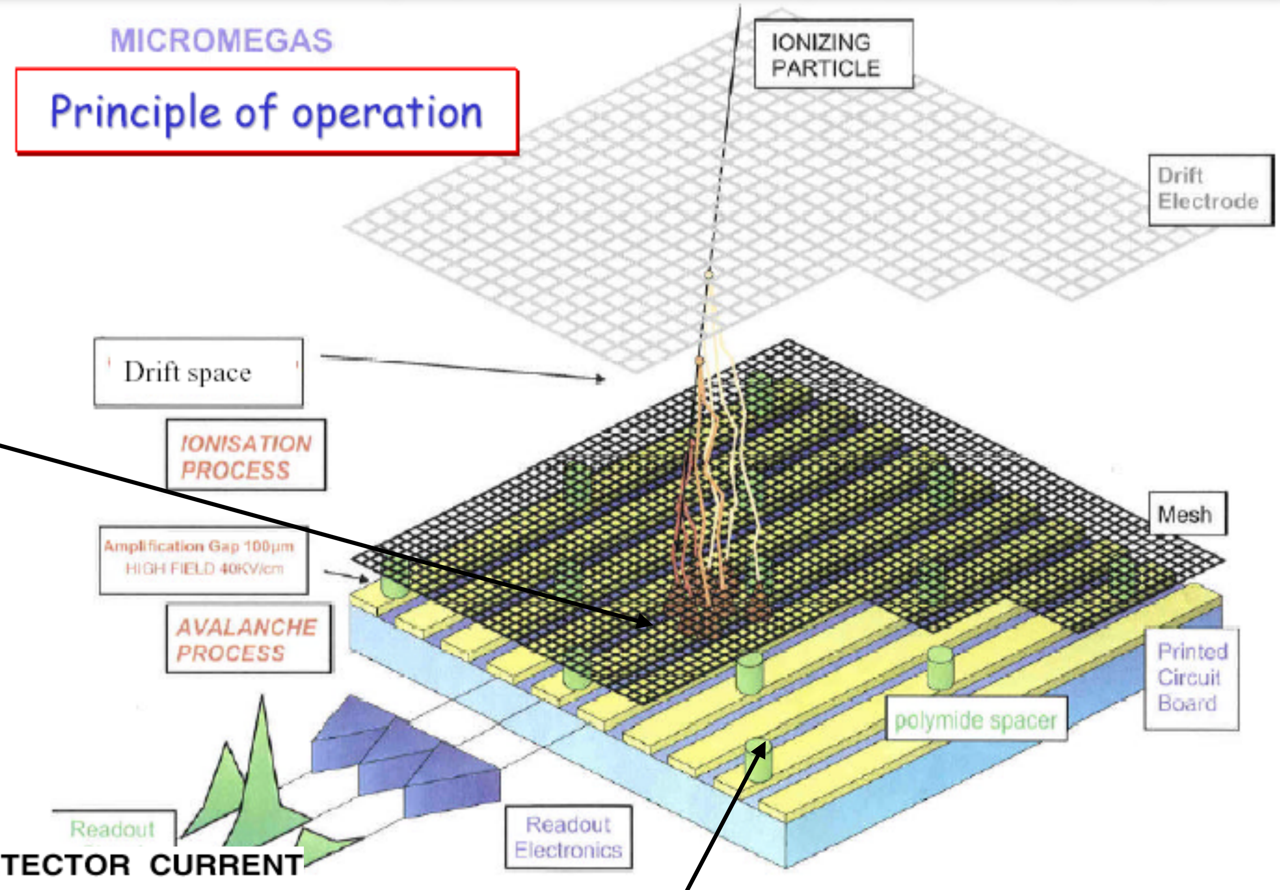
Outline

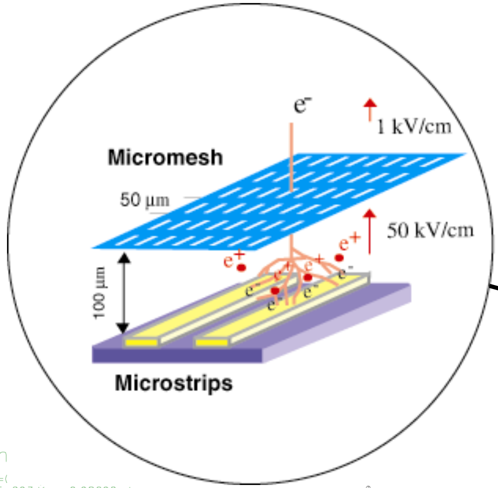
- IRFU MPGD activities & Micromegas principle
- Early years technologies → COMPASS / NA48-KABES
- Bulk-micromegas
  - Large scale production of the T2K/TPC readout modules
  - ILC/TPC large prototype
  - n-TOF X-Y neutron beam profiler
  - SLHC/ATLAS muon chambers upgrade : high flux applications
  - TOF Low-pressure detectors for beam tracking (BTD)
- Micro-bulk micromegas
  - n-TOF transparent neutron beam flux monitor
  - High-pressure and/or cryogenic temperature applications : micromegas as a charge readout of a double phase Argon TPC
- Micromegas on chip R&D : InGrid +TimePix

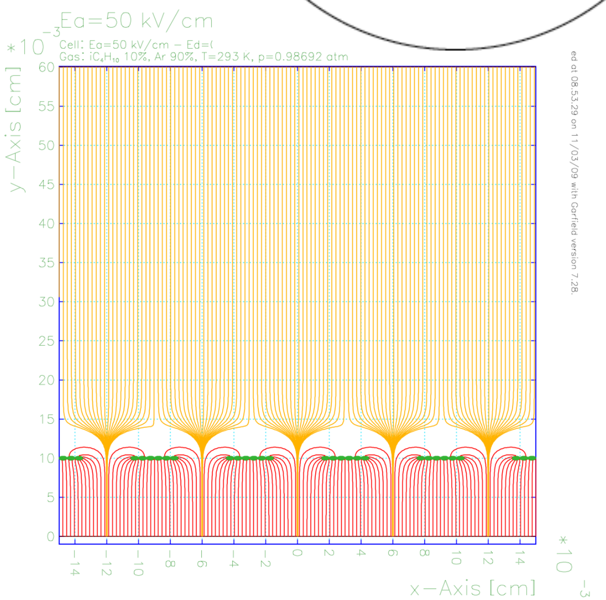
- Conclusion & perspectives

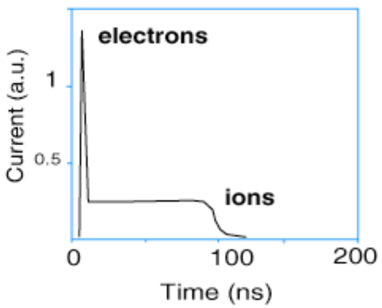
Micromegas

Micro Mesh Gaseous Structure, Y. Giomataris, Ph. Rebourgeard, J-P Robert and G. Charpak, NIM A376, 1996, p29 (CEA-biospace patent)



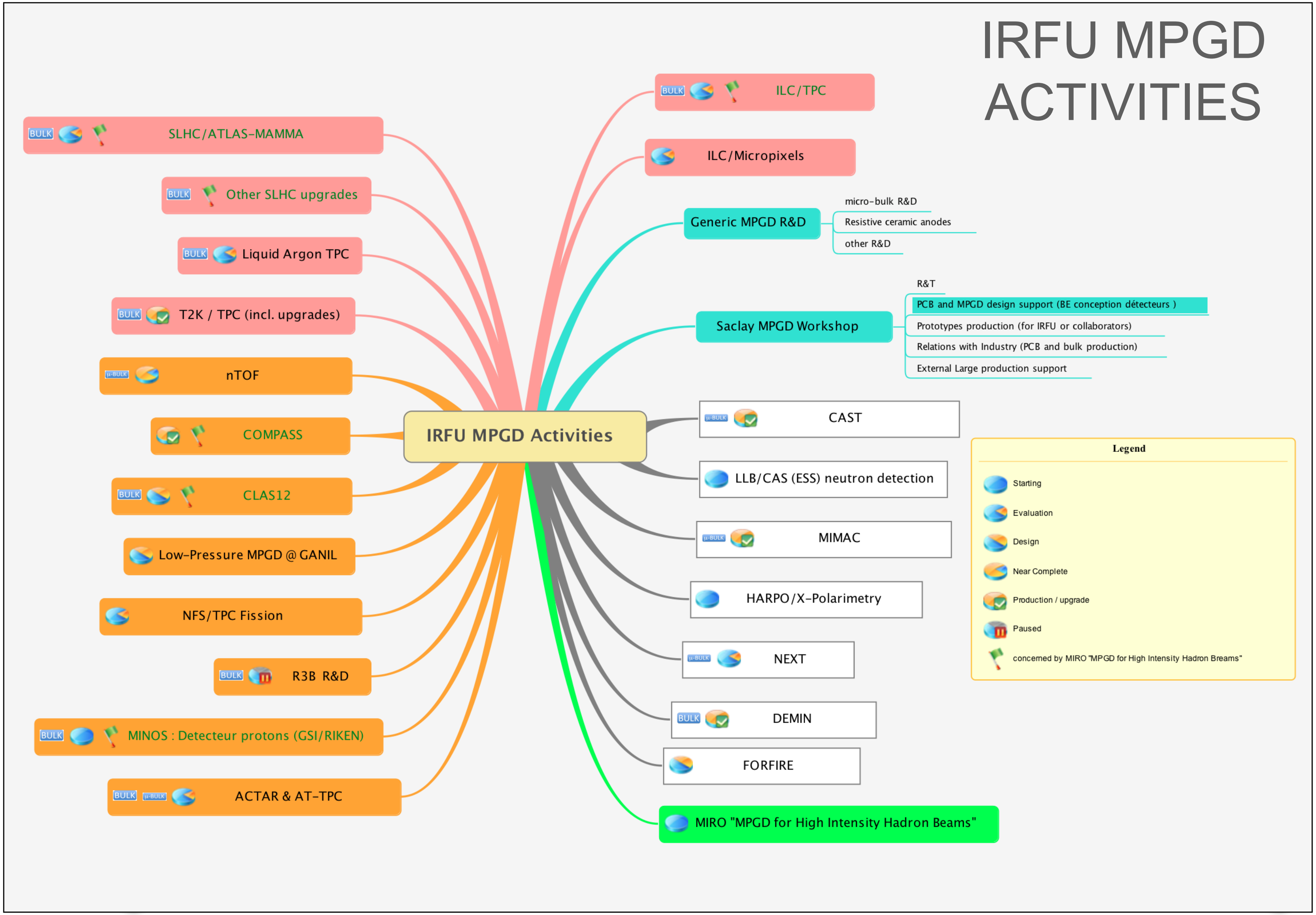






keeping the gap constant ~100 µm gap

- **Ni or Cu micromesh + pillars on PCB**
- **Self-supported copper micromesh**
- **« bulk » and « micro-bulk » technologies**
- **Recent InGrid techniques** : mesh over Si pixel chip



IRFU MPGD ACTIVITIES
IRFU MPGD Activities
BULK SLHC/ATLAS-MAMMA
BULK Other SLHC upgrades
BULK Liquid Argon TPC
BULK T2K / TPC (incl. upgrades)
μ-BULK nTOF
COMPASS
BULK CLAS12
Low-Pressure MPGD @ GANIL
NFS/TPC Fission
BULK R3B R&D
BULK MINOS : Detecteur protons (GSI/RIKEN)
BULK μ-BULK ACTAR & AT-TPC
BULK ILC/TPC
ILC/Micropixels
Generic MPGD R&D
micro-bulk R&D
Resistive ceramic anodes
other R&D
Saclay MPGD Workshop
R&T
PCB and MPGD design support (BE conception détecteurs)
Prototypes production (for IRFU or collaborators)
Relations with Industry (PCB and bulk production)
External Large production support
μ-BULK CAST
LLB/CAS (ESS) neutron detection
μ-BULK MIMAC
HARPO/X-Polarimetry
μ-BULK NEXT
BULK DEMIN
FORFIRE
MIRO "MPGD for High Intensity Hadron Beams"
Legend
Starting
Evaluation
Design
Near Complete
Production / upgrade
Paused
concerned by MIRO "MPGD for High Intensity Hadron Breams"

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The RD51 collaboration : Development of MPGD technologies

Collaboration of ~70 institutes worldwide. Approved by CERN's Research Board (dec 5, 2008)

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

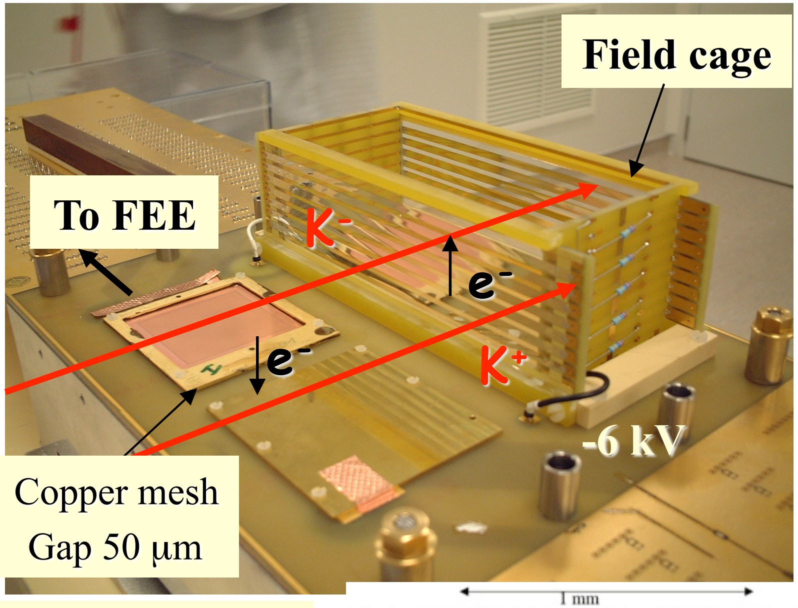
	WG1 MPGD Technology & New Structures	WG2 Characterization	WG3 Applications	WG4 Software & Simulation	WG5 Electronics	WG6 Production	WG7 Common Test Facilitites
Objectives	Design optimization Development of new geometries and techniques	Common test standards Characterization and understanding of physical 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	Common Test Standards Discharge Protection Ageing & Radiation Hardness Charging up and Rate Capability Study of Avalanche	Tracking and Triggering Photon Detection Calorimetry Cryogenic Detectors X-Ray and Neutron Imaging Astroparticle Physics Appl. Medical Applications Synchrotron Rad.	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	Common Production Facility Industrialization Collaboration with Industrial Partners	Testbeam Facility Irradiation Facility

CEA DSM Irfu

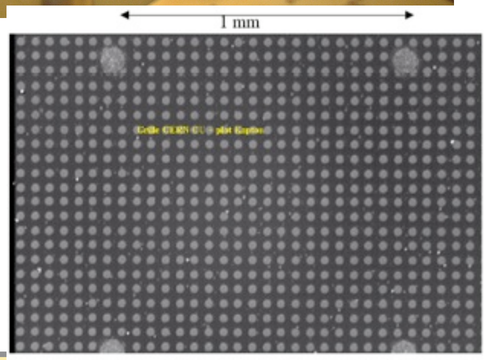
2nd International Conference on MPGDs, Maiko, Kobe, Japan, from 29 August to 1 September 2011

Past Micromegas technologies used in physics experiments

NA48/KABES station

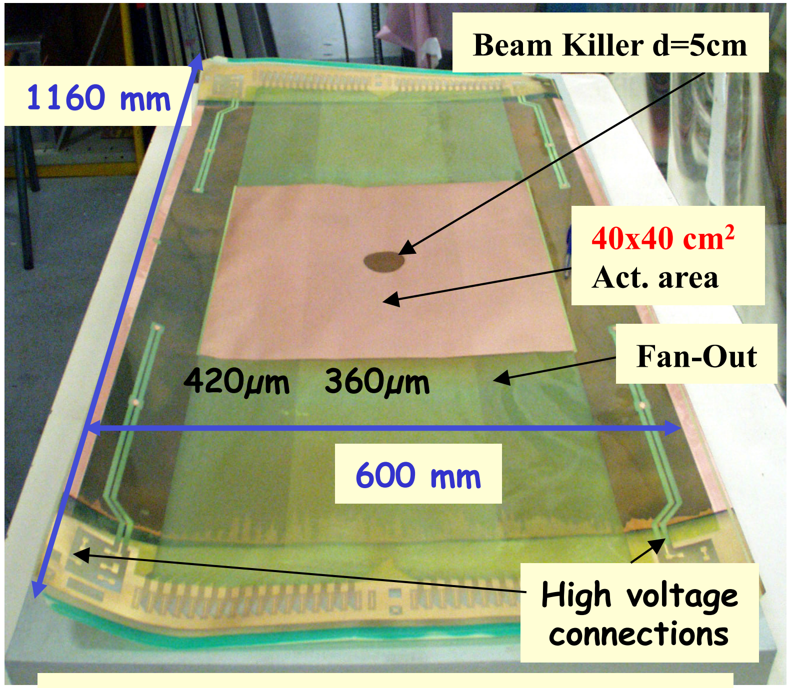


Kapton pillars on 5 µm thick Cu mesh



- ✓ spatial resolution σ =70 µm
- ✓ time resolution of 0,7 ns
- ✓ 3.10^{8} Hz Kaon beam (in 8 cm^2)

COMPASS Micromegas PCB



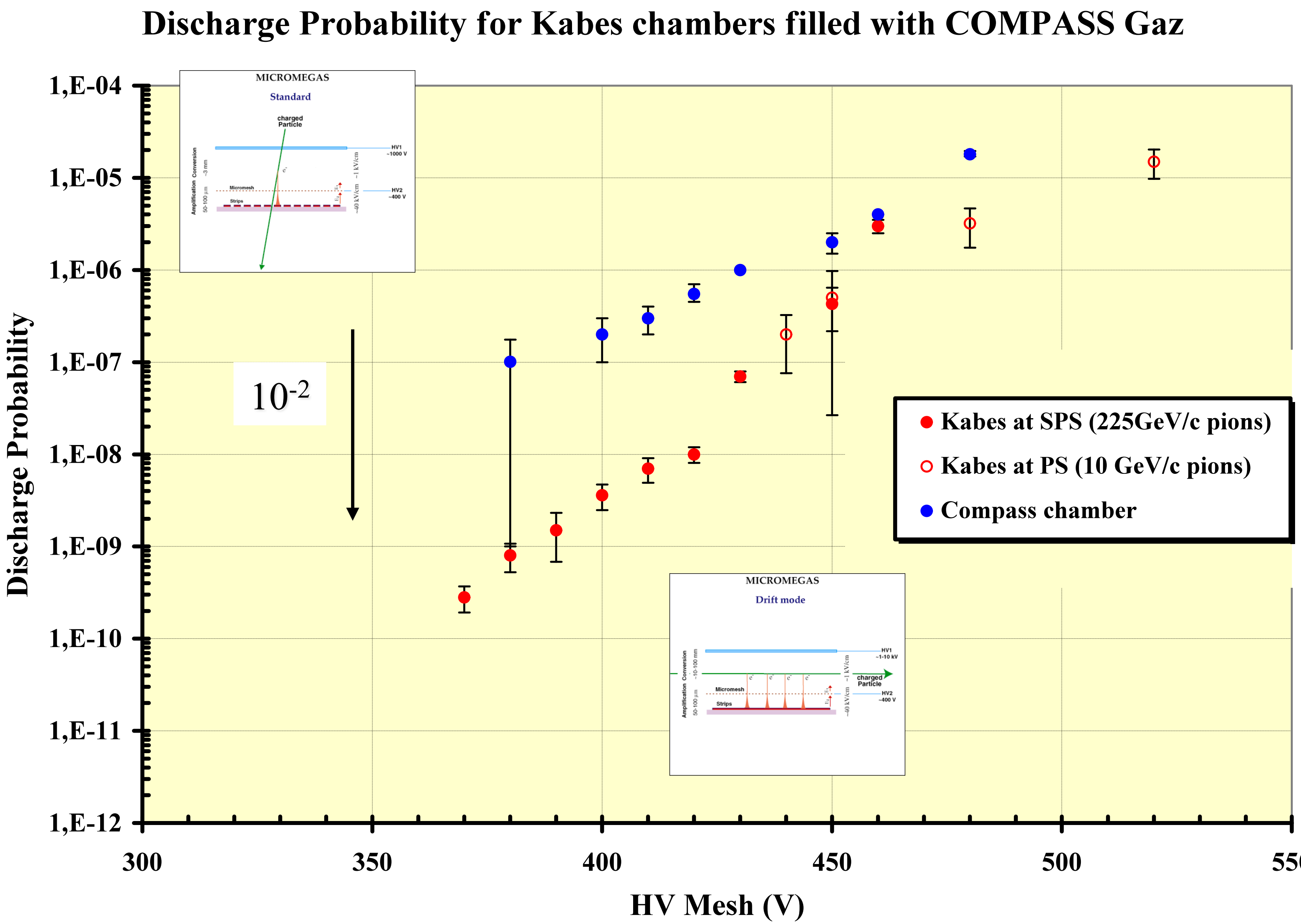
Solder mask pillars on PCB + 3 µm thick Ni mesh

- ✓ spatial resolution σ =70 µm
- ✓ time resolution of 9 ns
- ✓ 0.15 discharges/spill, local dead time < 3 ms

Drawback of these technologies :

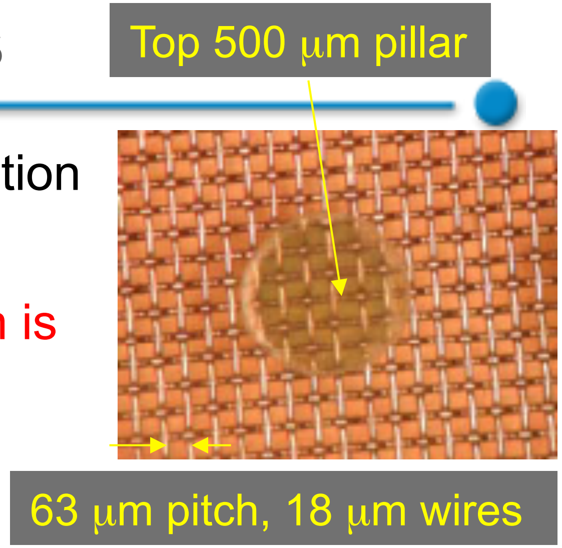
- "large" dead zones around active area + delicate assembly due to the mesh frame
- gap irregularities in corners : amplification gap is obtained only when mesh HV is applied (Elec. Force)

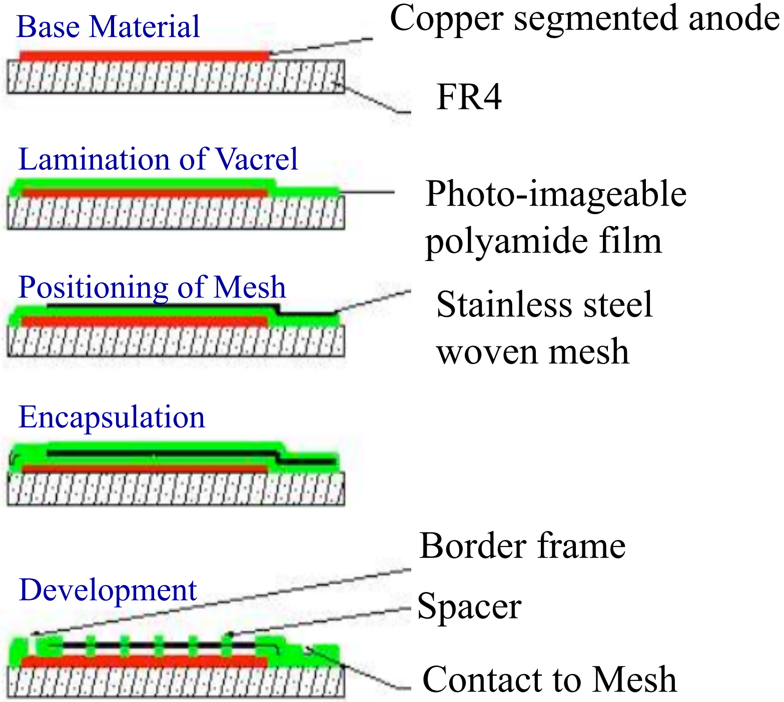
Discharges in TPC mode Vs tracker mode

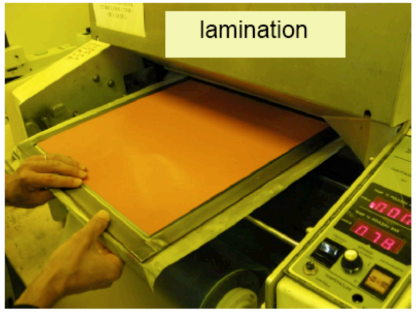


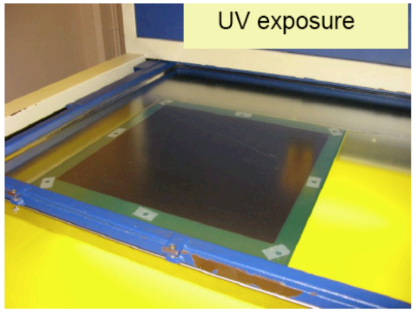
The bulk-micromegas

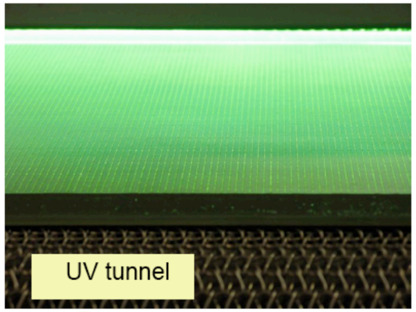
- First prototypes in 2004. CERN-TS-DEM/Irfu collaboration
- A woven micro-mesh is embeded between 2 layers of photo-imageable material. Amplification gap of 128 μm is standard, 104 μm should be ok, 64 μm is tricky
- No farme, no mechanics → % level dead zones
- Up to 50x50 cm^2 is standard
- Robust, Industrial process

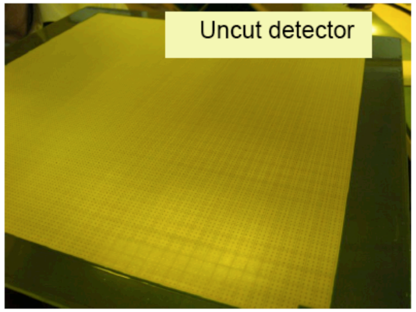






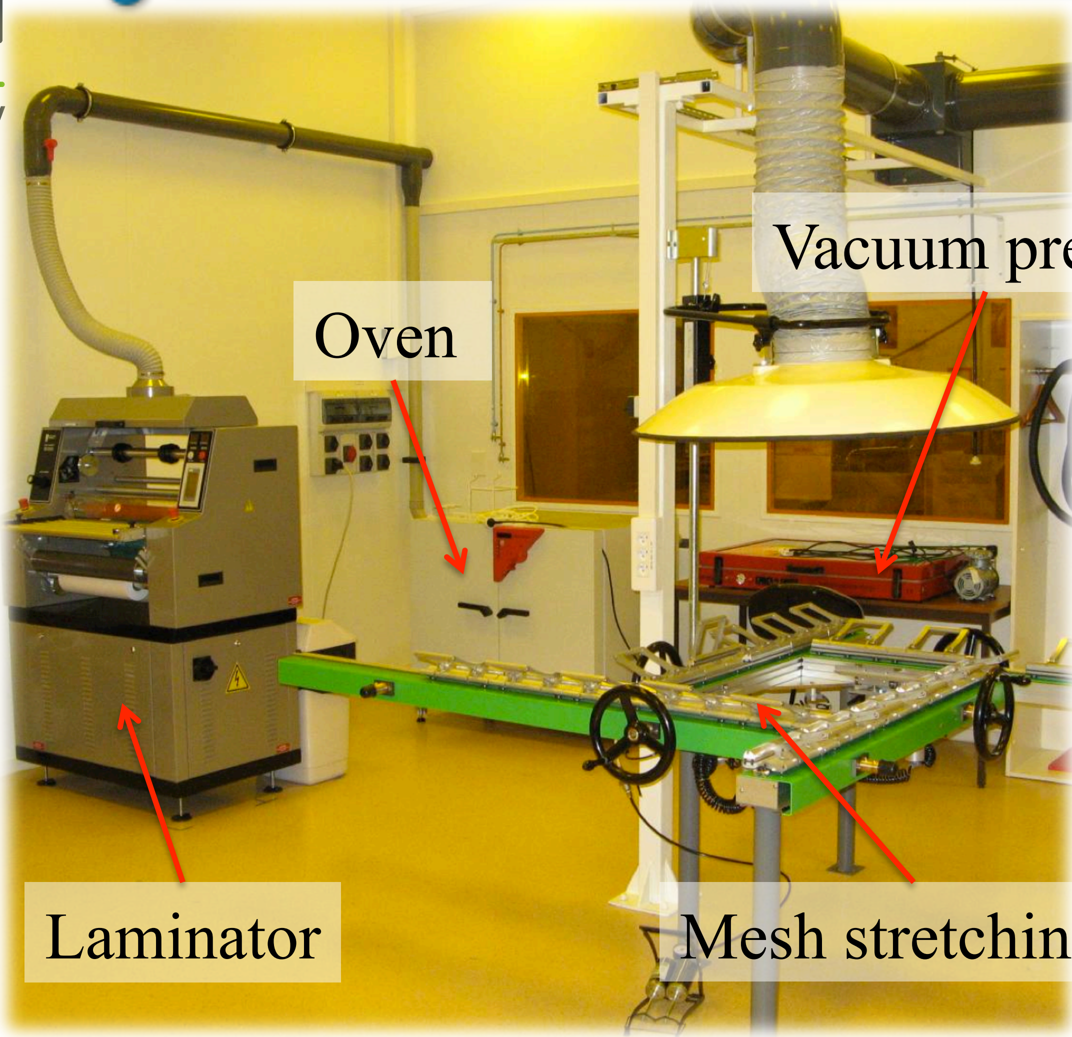






Ref: I. Giomataris *et.al.*, NIM A560 (2006) 405

Bulk Micromegas Workshop @ CEA-IRFU



→ on-going Bulk-micromegas transfer to industry (CIRE-CIREA company, RD51)

→Future upgrade of the CERN/EN-ICE-DEM workshop is on-going

→New equipment to fabricate larger area MPGDs (GEM & MM) expected for mid 2011

Current Bulk-Micromegas developments

✓ Class12 @Jefferson lab (central & forward tracker), USA, prototype tests (in B=4,5T (sept08) : low material budget detector (X/X0~5.10^{-4}) cylindrical shape (ϕ 200−600 mm)

✓ ILC/DHCAL, prototype tests @ CERN (oct08) : on-detector ASICs, 1cm^2 pads, 35.10^4 channels

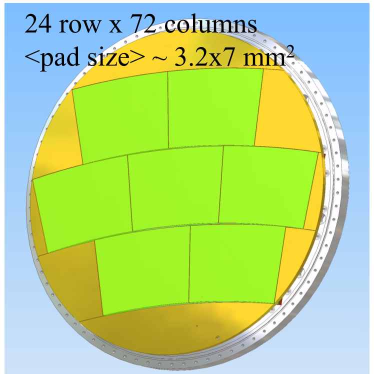
✓ Super LHC/ATLAS Muon chambers upgrade (MAMMA): 5 kHz/cm^2 flux, ~2 m^2 ch., 100 μm/5 ns resol.

✓ ILC/TPC, prototype tests @ DESY (oct08) : 3,5T magnetic field, high flux, <10^{-3} ion backflow, <50 μm resolution @ short drift distance (resistive bulk-micromegas), high readout electronics density (>10^6 ch.)

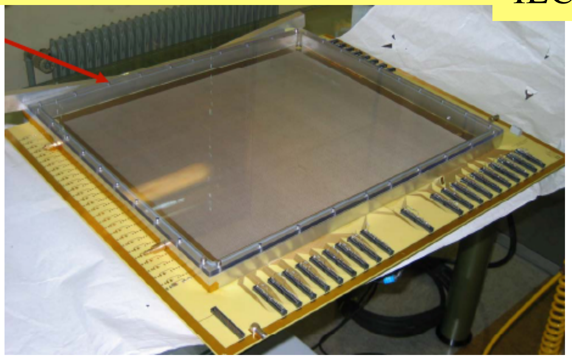
& T2K/TPC !!!

SLHC/ATLAS μ ch. (MAMMA) 2009 prototype (largest bulk-MM)

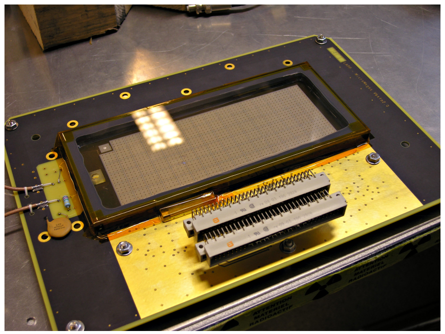
ILC/TPC (Carlton,CEA/Irfu)



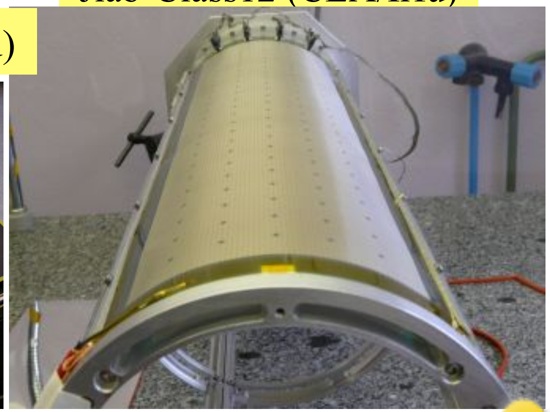
SLHC/ATLAS μ ch. (MAMMA) 2008 prototype



ILC/DHCAL (LAPP&CEA/Irfu)



Jlab-Class12 (CEA/Irfu)



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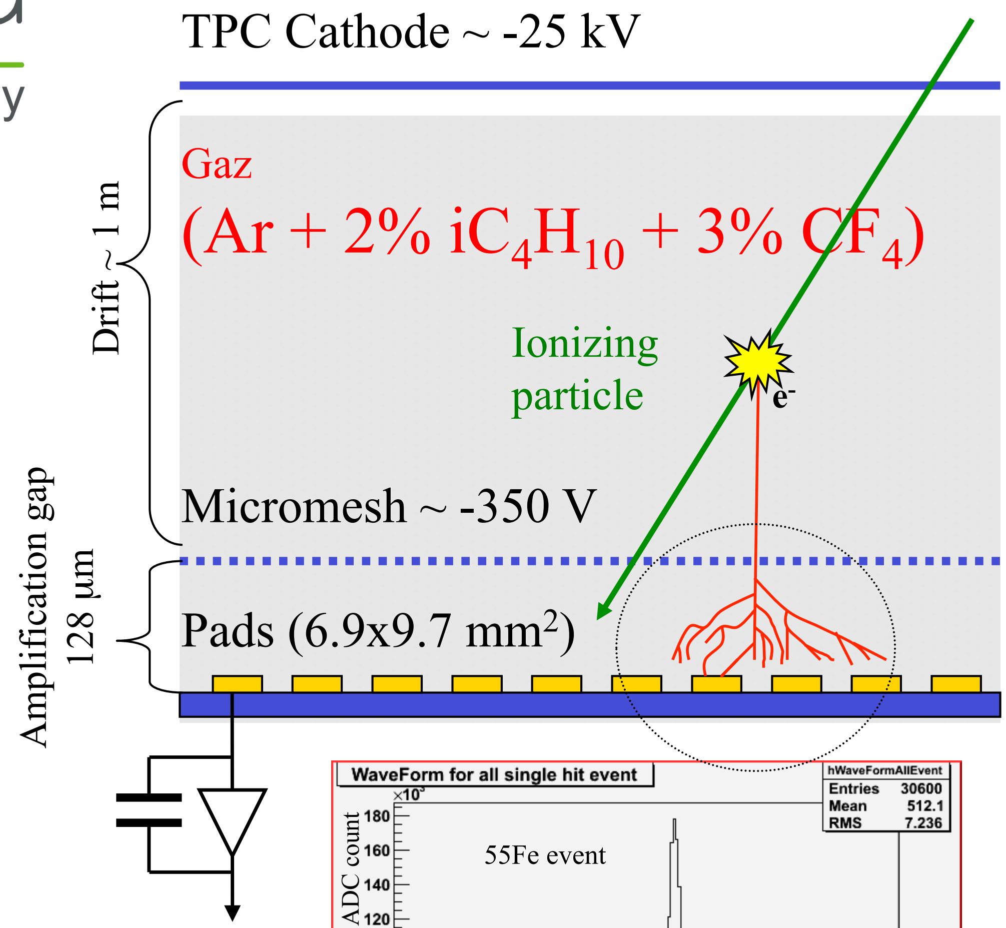
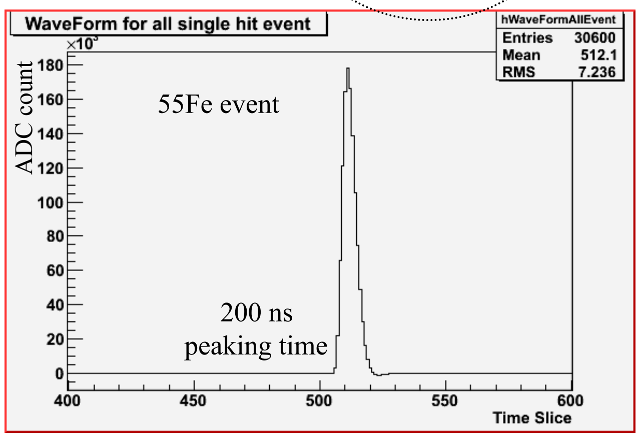
The T2K/TPC micromegas



Pads readout
(AFTER ASIC)



1 time bin = 50 ns (20 MHz sampling freq.)

a new gas mixture

- ✓ Non-flammable
- ✓ low tr. Dif. for small B (250 µm/cm$^{1/2}$)
- ✓ operation close to the maximum drift velocity (7,5 cm/µs @ 200 V/cm)
- ✓ minimization of the effect of impurities (mainly O_2) : > 30m att. Length

Drawbacks of micromegas technologies with seperate mesh & anode PCB :

- "large" dead zones around active area + delicate assembly due to the mesh frame
- gap irregularities in corners

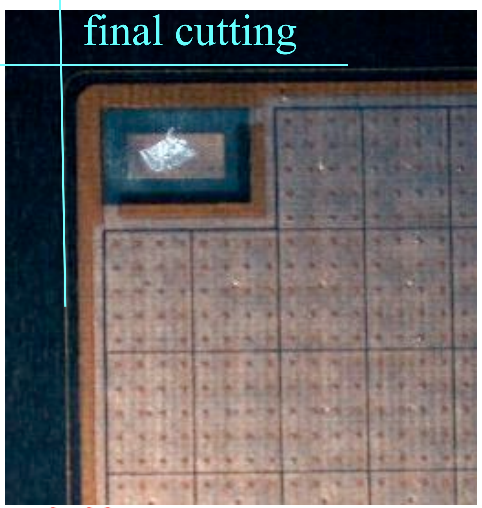
NIM A560 (2006) 405

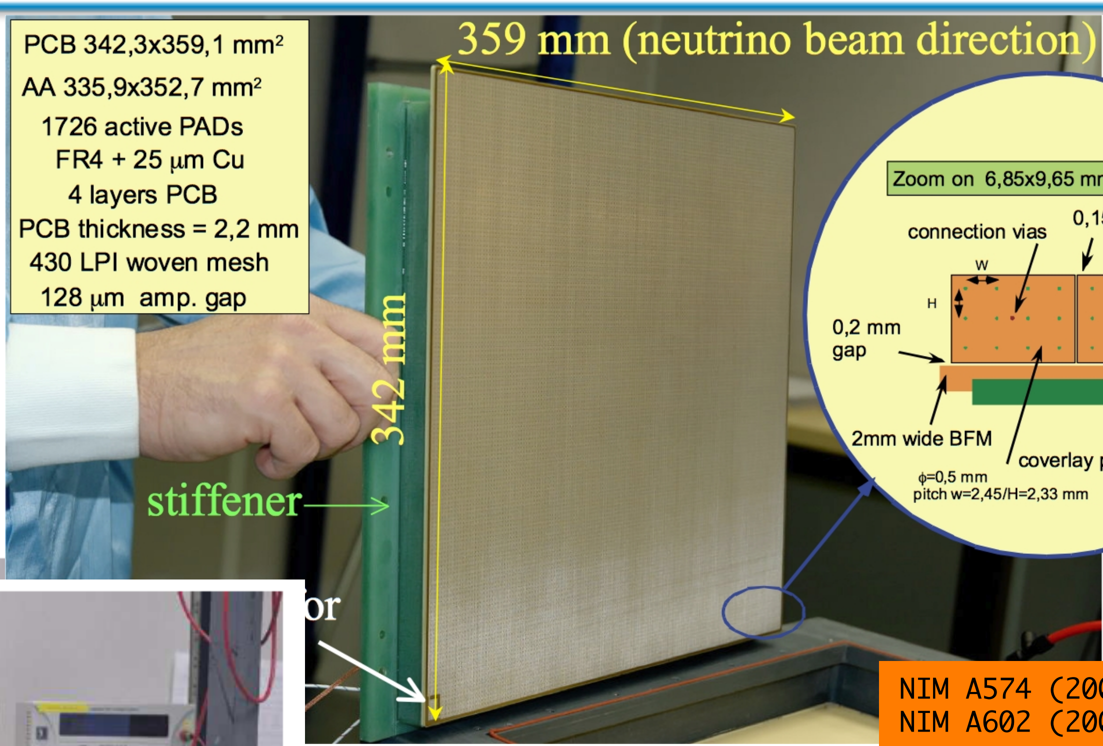
Use of bulk-micromegas technology

- ✓ all-in-one detector : minimized blind areas, including edges and corners
- ✓ simple design, cheap & robust
- ✓ good uniformity of performances
- ✓ Production by CERN/TS-DEM-PMT

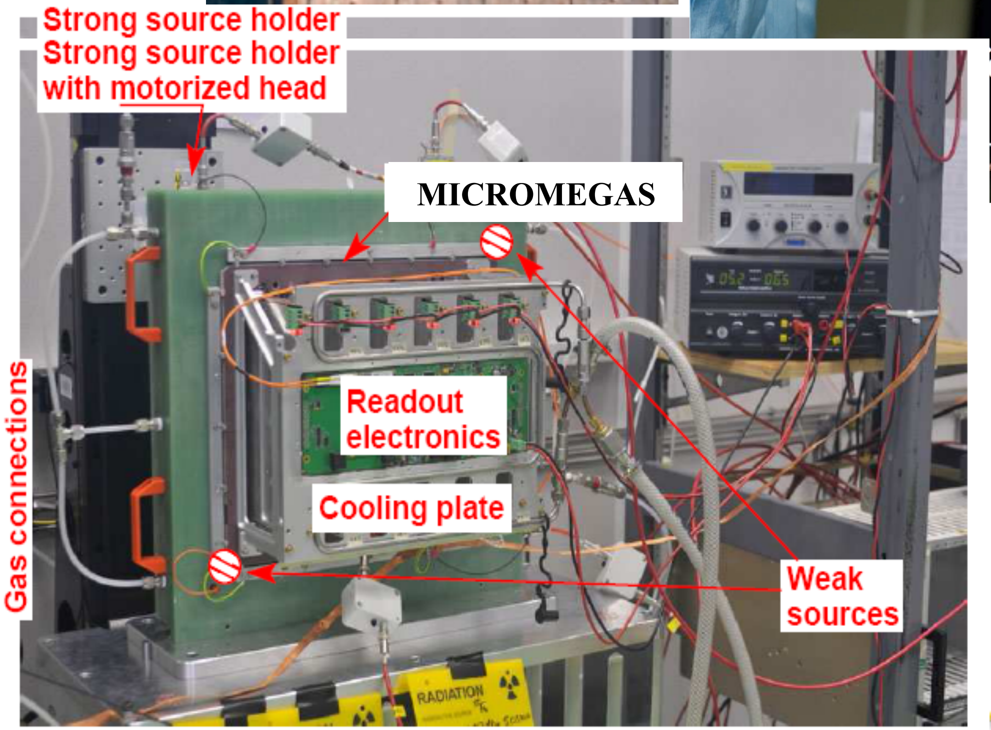
2005 HARP tests., NIM A574, p425 (2007)
2007 HARP tests., NIM A602, p415 (2009)
T2K/TPC paper submitted to NIM A

The T2K/TPC bulk-micromegas





NIM A574 (2007) 425-432
NIM A602 (2009) 415-420



1 year production of 10 m²

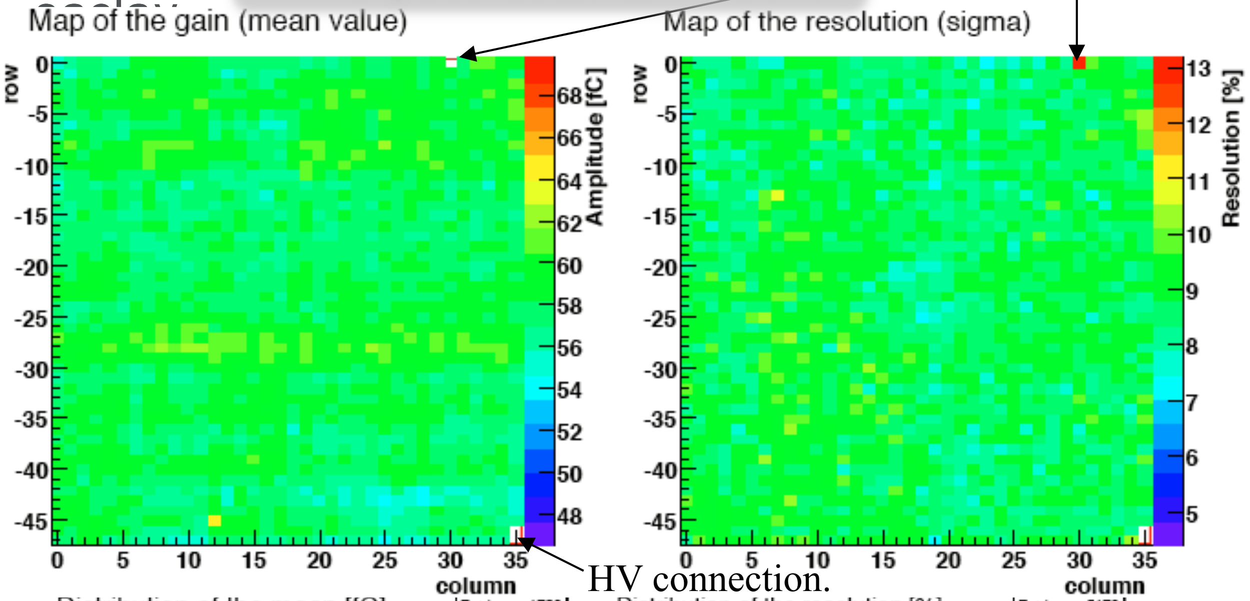
- Bulk-MM produced @ CERN/EN-ICE-DEM
- 86 modules produced (6 rejected)
-10 faulty pads / 124000 !
- Electronic readout designed at SEDI :
AFTER 72ch. ASIC + digital (124000 ch. !)

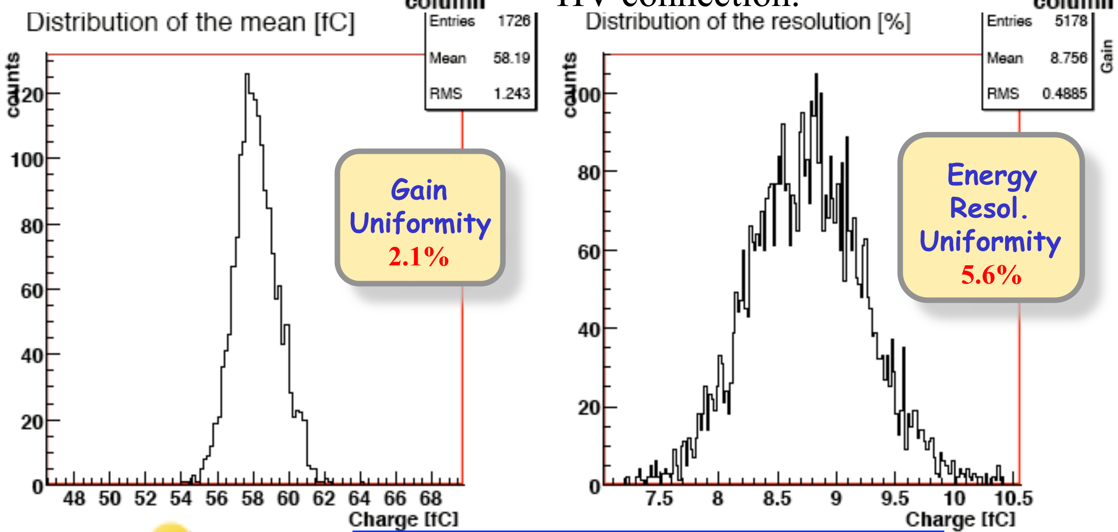
Ref: A. Delbart *et.al.*, NIM A623, p105 (2010)

T2K/TPC Module calibration : a uniform production

1726 pads scan @ -350 V

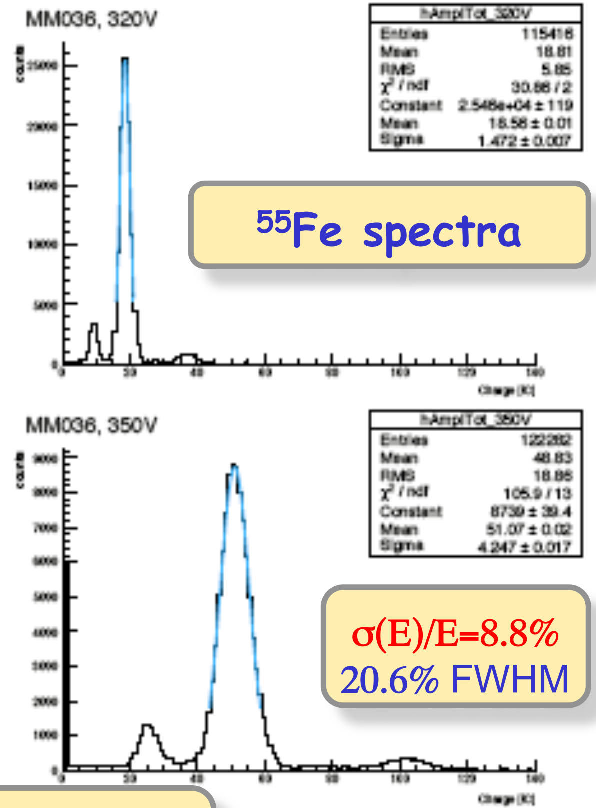
1 FEC dead ch.





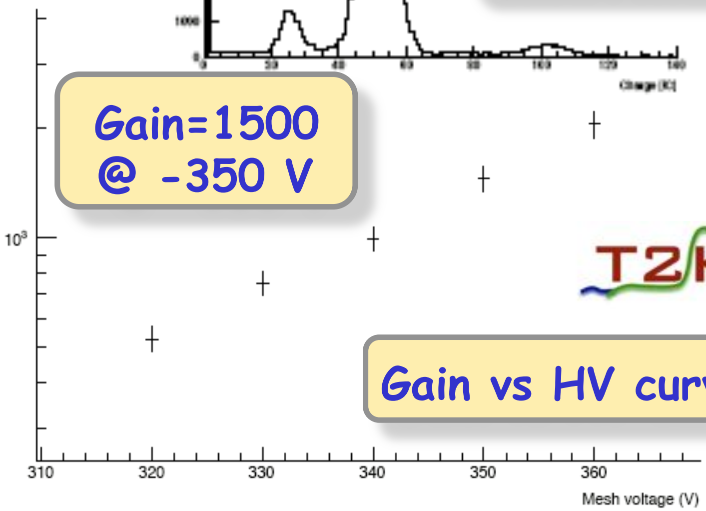
Gain Uniformity 2.1%

Energy Resol. Uniformity 5.6%



^{55}Fe spectra

σ(E)/E=8.8%
20.6% FWHM



Gain=1500 @ -350 V

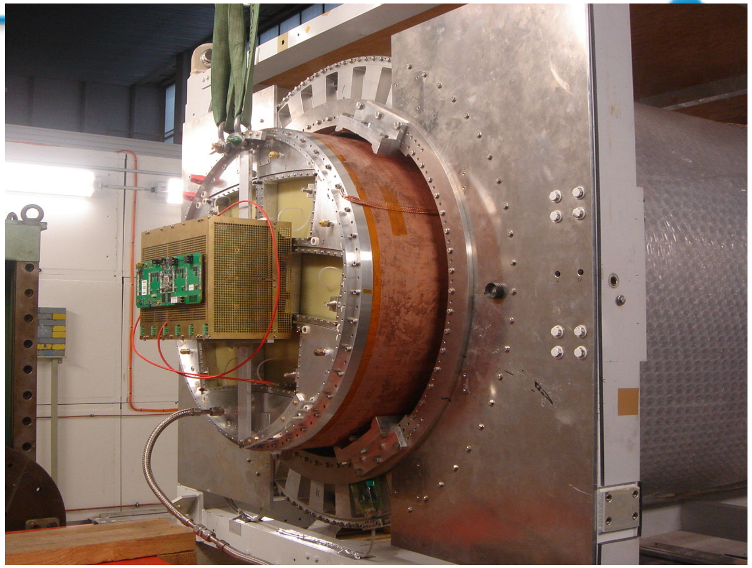
Gain vs HV curve

Ref: A. Delbart *et.al.*, NIM A623, p105 (2010)

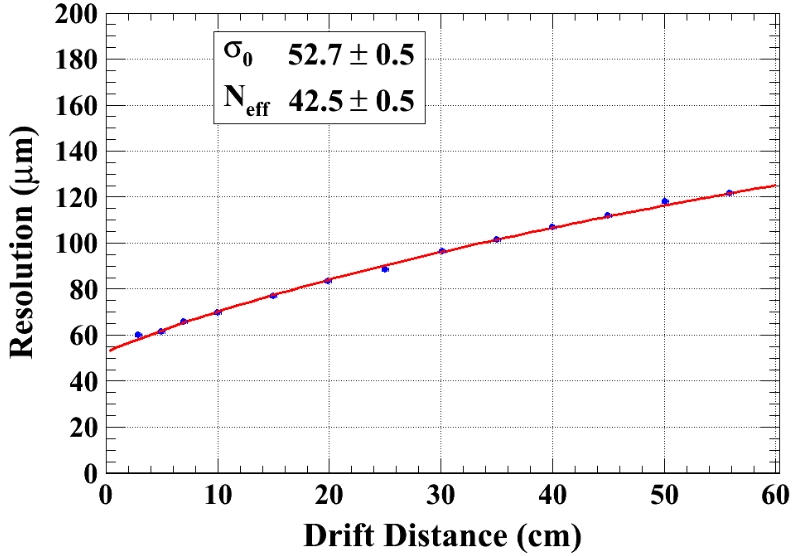
8% performance uniformity over the 86 modules

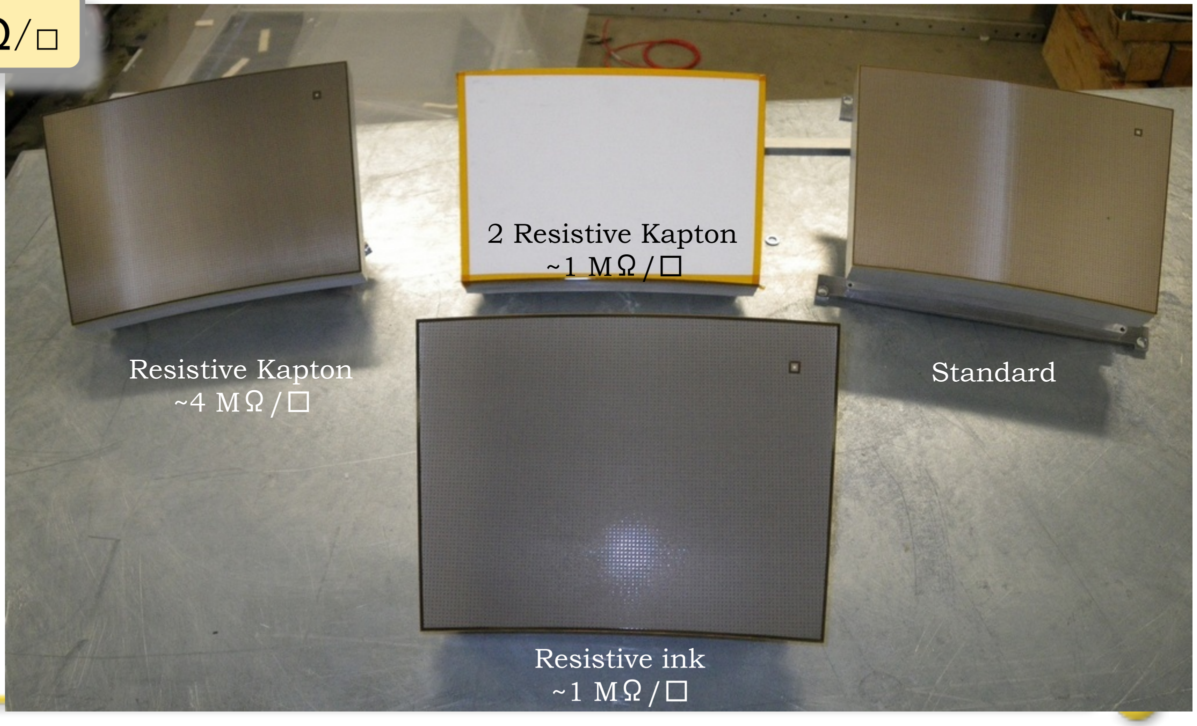
ILC/TPC large prototype R&D

- **Goal** : ~ 100 μm space point resolution on 200 track points, as constant as possible Vs drift distance
- Use of a resistive foil to spread the charge over several pads to improve resolution for short drift ditance
- bulk-micromegas with 1726, 3×6.8 mm² pads
- First step with 1 module and use of T2K electronics
- Second step with a new, more compact, design of Electronic readout for 7 module integration



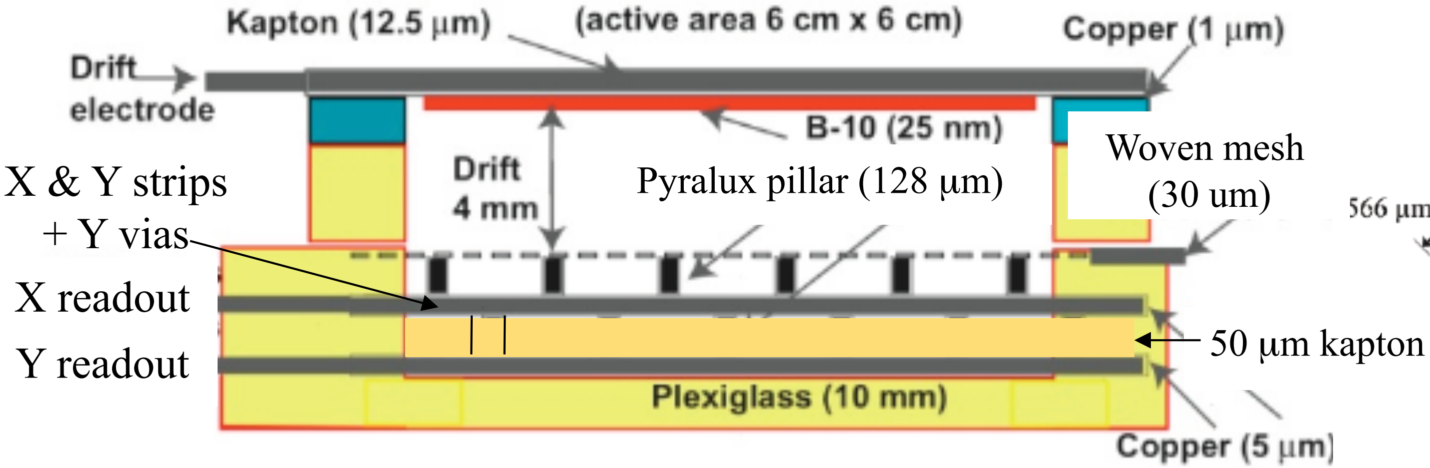
Best $\sigma_0 \approx 50\ \mu m$ for resistive Kapton 1 MΩ/□

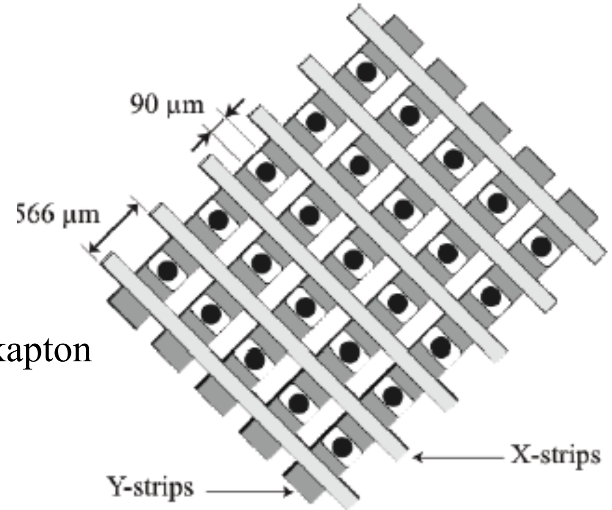


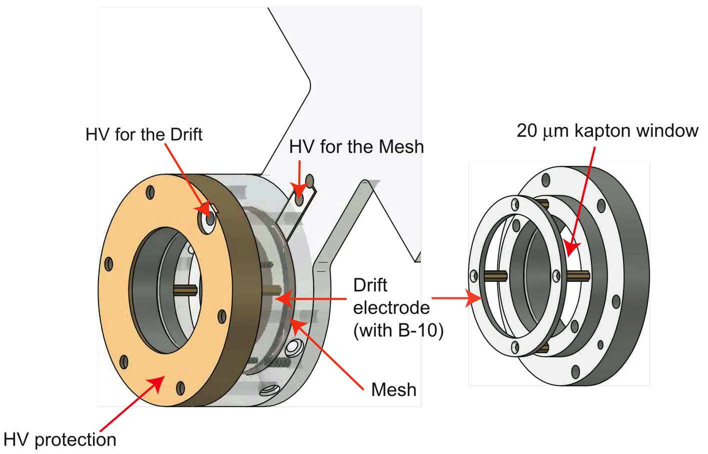


CERN/n-TOF 2D X-Y neutron beam profiler

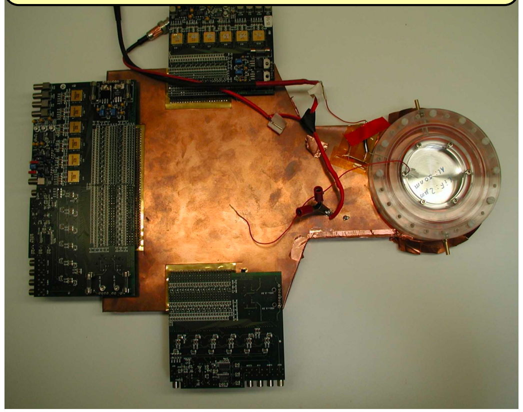
128 µm Bulk-micromegas technology with 2D X-Y readout (CAST-like)
Use of $^{10}B(n,a)^{7}Li$ for up to 1 MeV neutron conversion







Modified CAST chamber



Specifications

- ✓ $Ar+2\%iC_4H_{10}+10\%CF_4$
- ✓ 6x6 cm² active area
- ✓ Φ 60 mm, 24 nm ^{10}B layer on a 1 µm copper coated 12,5 µm Kapton foil
- ✓ 212 channels : readout with 2 x 96 ch. Gassiplex cards

Ref: S. Andriamonge *et.al.*, proceedings of ND2010, International Conference on Nuclear Data for Science and Technology

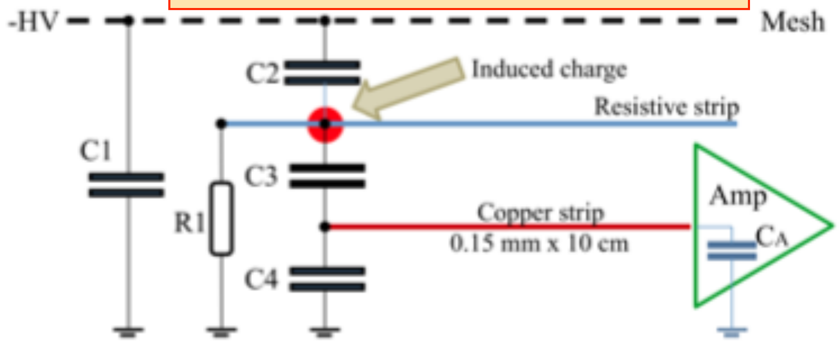
SLHC-ATLAS Muon chambers upgrade

Most advanced spark reduction technique : resistive strips connected to ground

Equivalent circuit (R. de Oliveira)

CERN/EN-ICE-DEM

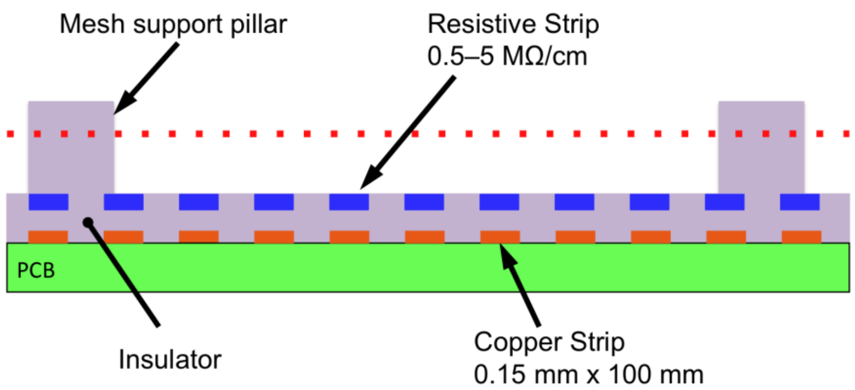
Sparks neutralized through the resistive strips to the ground

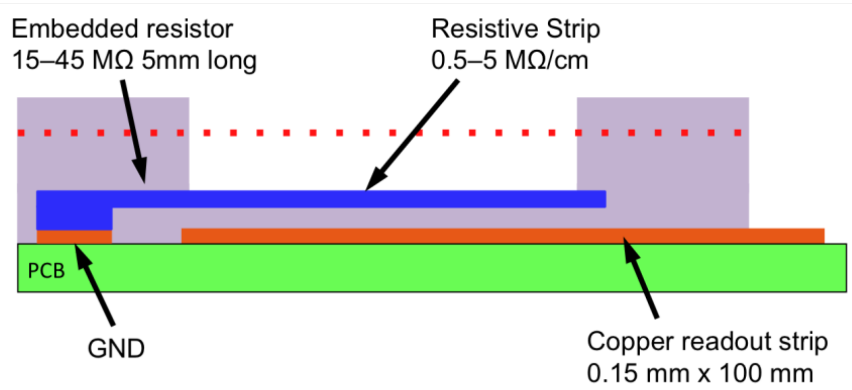


C1 – capacitance Mesh to ground
C2 – capacitance R-strip to ground
C3 – capacitance R-strip to readout strip
C4 – capacitance readout strip to ground
CA – input capacitance of preamplifier

Requirements

High rate capability (≤ 10 kHz.cm-2)
Spatial resolution ~100 µm (θ ≤ 45 °)
Radiation hardness and good ageing properties
Time resolution ~few ns
Level1 triggering capability
Large m^2 surface chambers for hundreds of m^2 !





CEA DSM Irfu

Ref: V. Polychronakos (on behalf of the MAMMA collaboration), *Micromegas progress report*, RD51 collaboration meeting, Bari, oct 8-11 2010)

Resistive anode micromegas tests in neutron beam

"Joerg" like prototypes: R11,R12,R13

100 x 100 mm^2 with 100 mm long strips, 250 µm pitch

CHAMBER	R11	R12	R13
Resistance to Ground (MΩ)	15	45	20
Resistance along strip (MΩ/cm)	2	5	0.5

Gas: Ar:CO_2 (85:15) Neutron flux: ≈ 1.5x10^6 n/cm^{2}s

Standard MM:

Large currents

Large HV drops, recovery time O(1s)

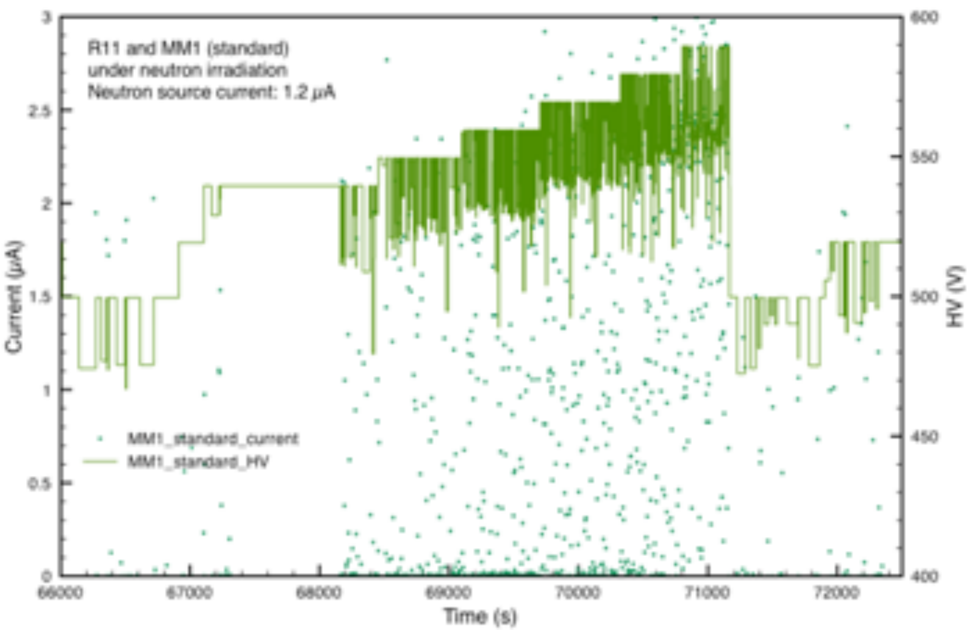
Chamber could not be operated stably

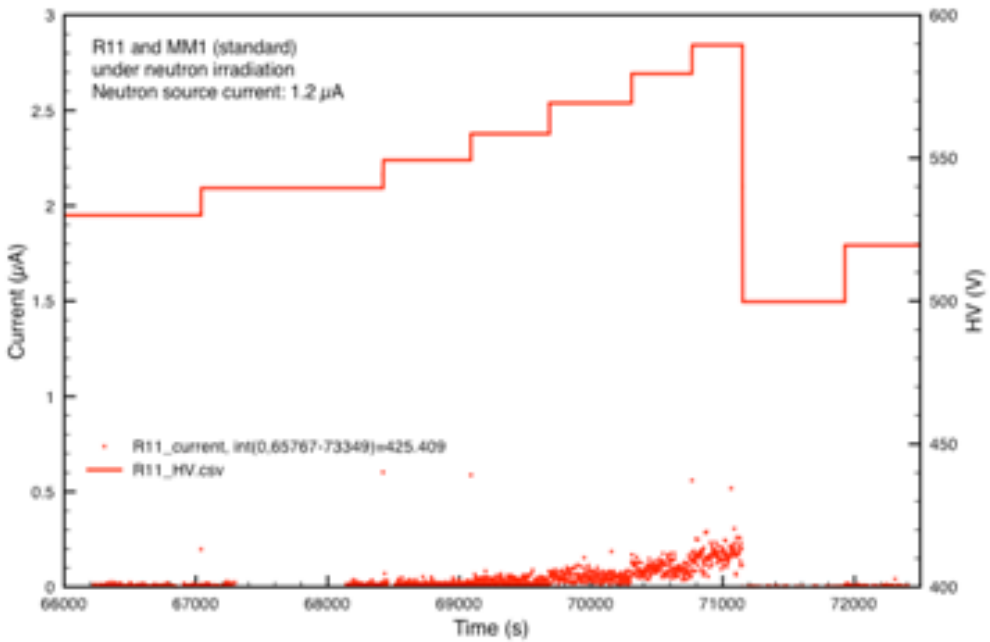
R11:

Low currents

Despite discharges, but no HV drop

Chamber operated stably up to max HV



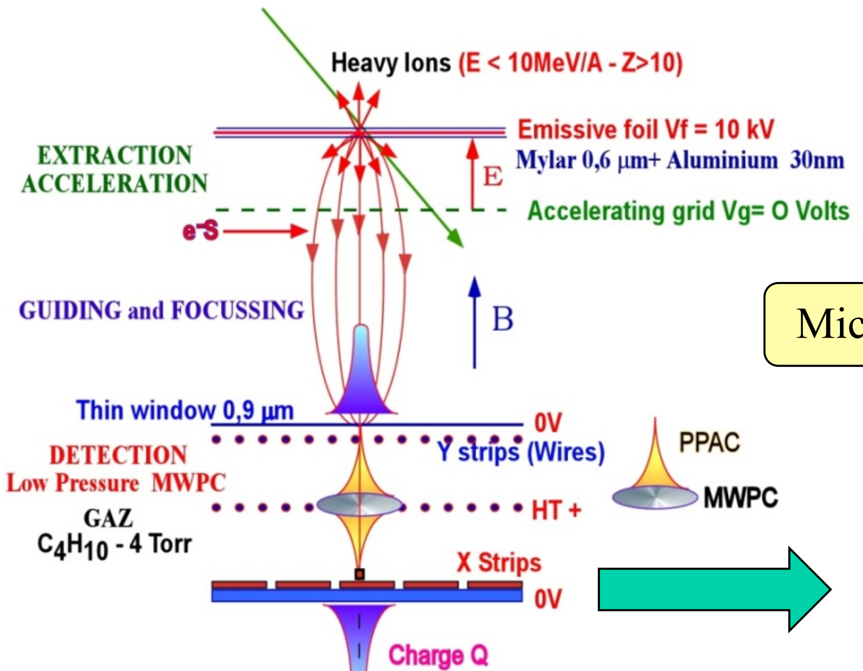


Ref: V. Polychronakos (on behalf of the MAMMA collaboration), *Micromegas progress report*, RD51 collaboration meeting, Bari, oct 8-11 2010)

Micromegas-SED at GANIL (GANIL-IRFU-CNA-Sevilla coll.)

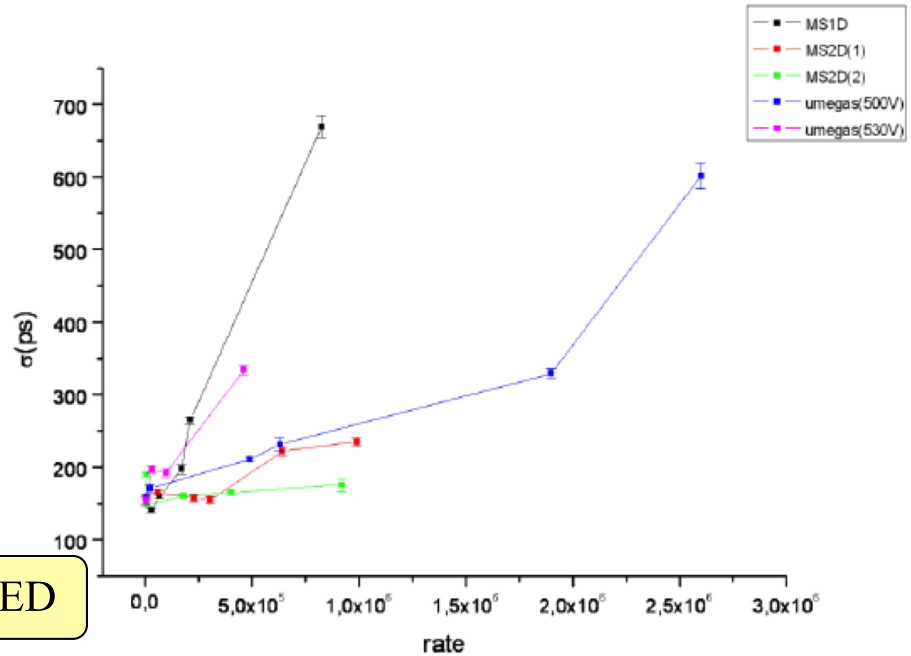
Use of Bulk-micromegas technology to detect secondary electrons in a SED for its good spatial resolution and robustness. Time resolution $\sigma_t \approx 200\text{-}350$ ps & better spatial resolution than SED

- Kr from CIME at 1.7 MeV/n from 10^3 to 10^6 p/s.cm^2
- very thin emissive foil : mylar + Al 130 μg/cm^2
- No magnetic field

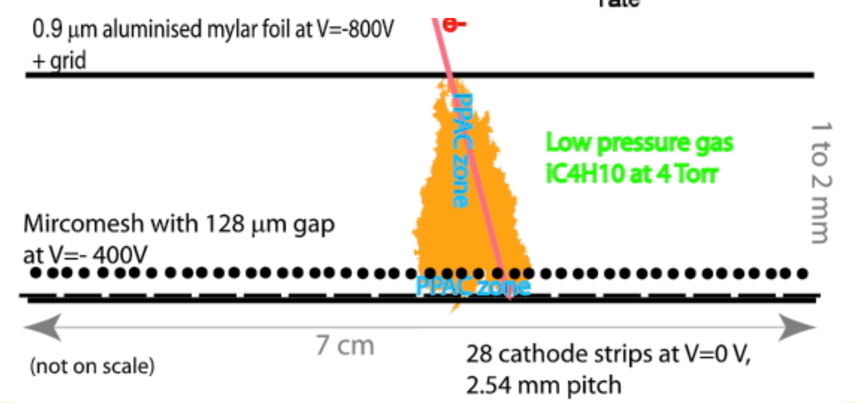


A. Drouart et al., NIMA579(2007)

J. Pancin et al., JINST4:P12012(2009)



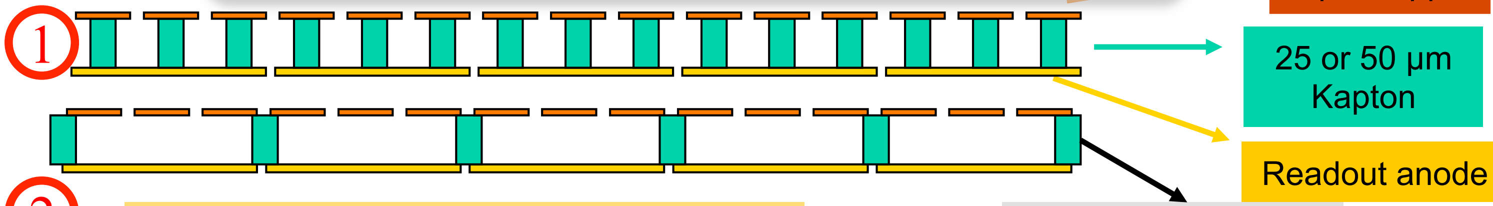
Micromegas-SED

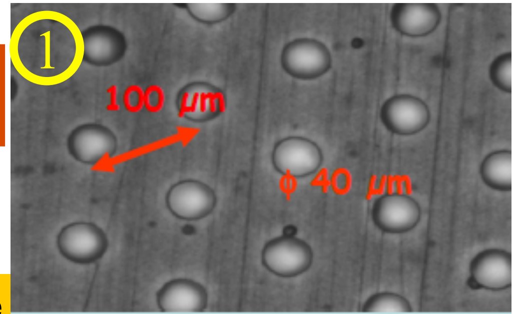


From T. Papaevangelou (CEA-IRFU) & J. Pancin (GANIL)

The micro-bulk micromegas

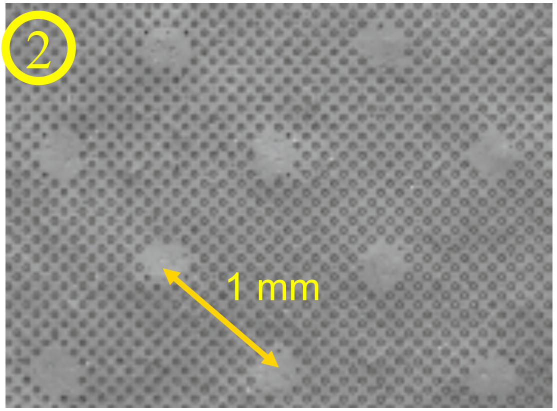
Same manufacturing techniques as GEM :
Copper & Kapton etching of a copper cladded Kapton





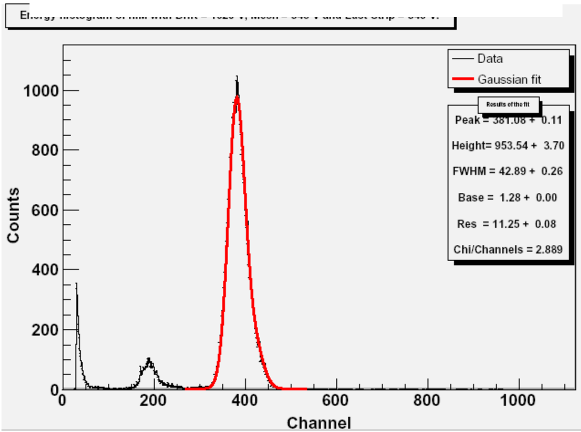
CEA-CERN Patent 09 290 285.0 (2009)

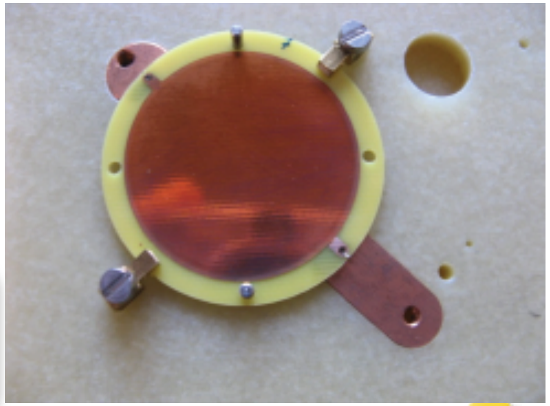
Lower capacitance
Under development



- "All-in one" structure mesh+anode
- Excellent Energy resolution
  11% FWHM @ 5,9 keV, 6 % @ 22 keV, 1,5 % @ 5 MeV)
- Good uniformity
- Low materiel budget detector
- Flexible structure
- Low intrinsic radioactivity
- Fabrication process still improving
- Fragile
- Limited sizes (<100 cm^2)

11% FWHM at 5.9 keV
Ar + 5% Iso at **1 bar**





Better mesh transparency &
12 µm gap under development

Ref: S. Aune et al. NIM A 604, 15-19, 2009
S. Andriamonje et al. JINST 4, MPGD2009 conf. proceedings

Current Micro-bulk developments

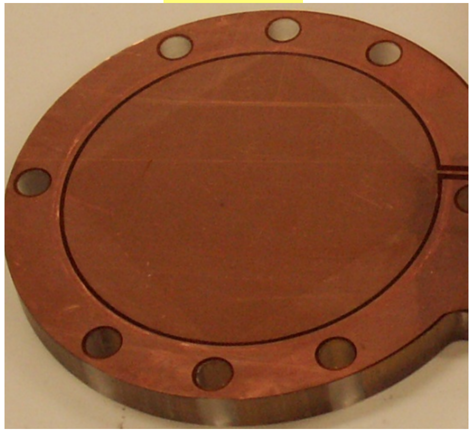
✓ CAST @ CERN (Axion search), on CAST telescope, rare 1-10 keV event search, low radioactivity materials,

✓ NEXT @ Zaragoza (Search for the ββ0ν decay, High pressure Xe gas TPC): 30x30 cm^2 under development

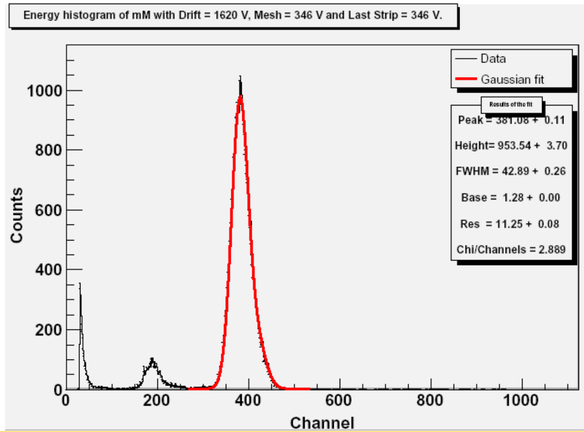
✓ n-TOF, in n-TOF beam @ CERN (2009) : neutron beam flux monitor, 25 μm amplification gap, pillars with 500 μm pitch

✓ Double phase Liquid Argon TPC, ETZH 3l TPC @ CERN (2011) : 70x70 mm^2 , 25 μm amp. gap under development

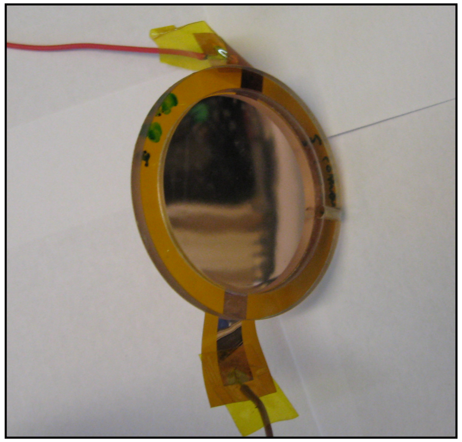
CAST



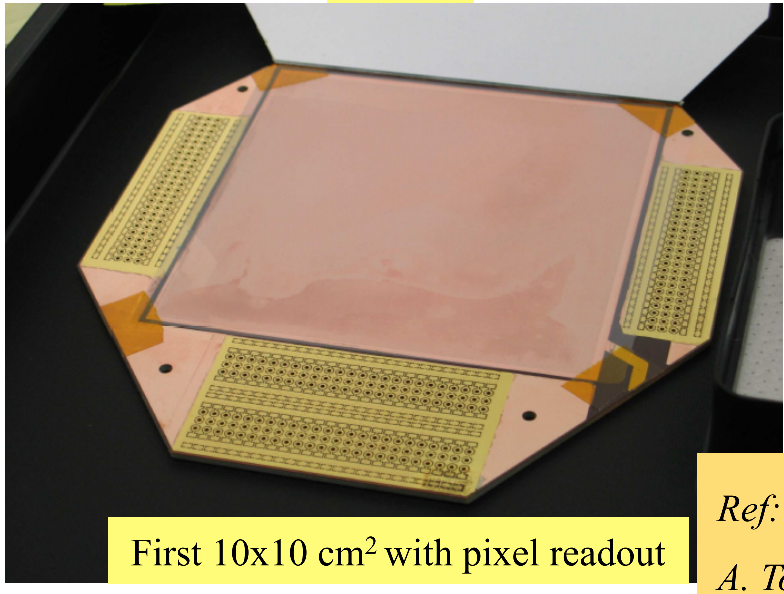
^{241}Am alpha source (1 bar)
0.7% FWHM @ 5.5 MeV



N-TOF (CERN)



NEXT



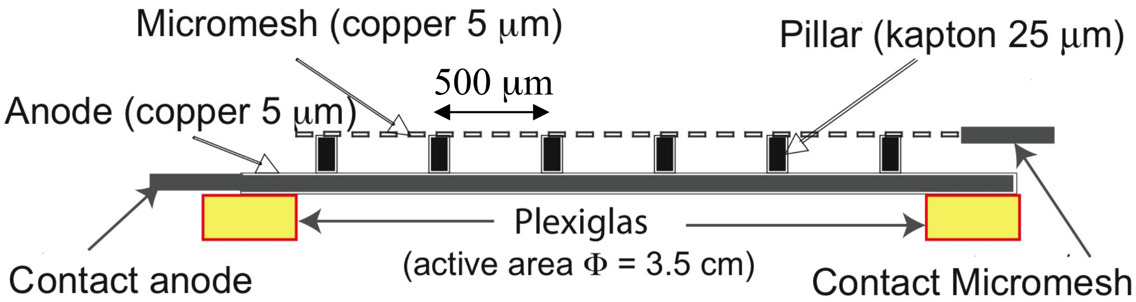
First 10x10 cm^2 with pixel readout

Ref: T. Dafni et al. NIM A 608 259-266, 2009

A. Tomas et al JINST 4: P11016, 2009

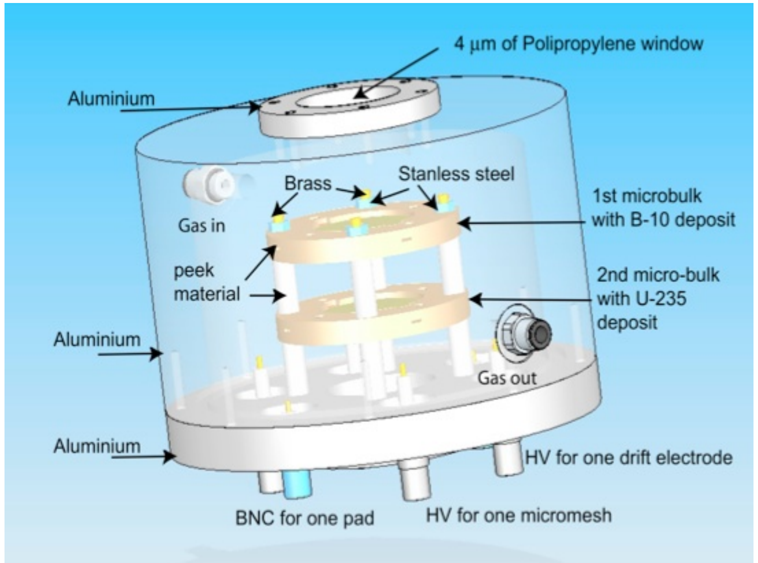
n-TOF transparent neutron beam flux monitor

Micro-bulk technology for very low budget material detector
Use of 2 converters : $^{10}B(n,a)^{7}Li$ for up to 100 eV neutrons and $^{235}U(n,f)$ for 100 eV-1 MeV



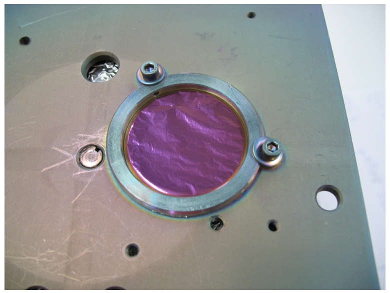
Specifications

- ✓ $Ar+2\%iC_4H_{10}+10\%CF_4$
- ✓ 35 mm diameter active area
- ✓ 1 plane Anode
- ✓ 1 channel : on-shelf fast current preamp. + 1GHz flash ADC



^{10}B Converter

- ✓ Sputtering from B_4C at CERN
- ✓ on 1 μm copper coated 12,5 μm Kapton foil
- ✓ ~1 μm on a Φ 35 mm



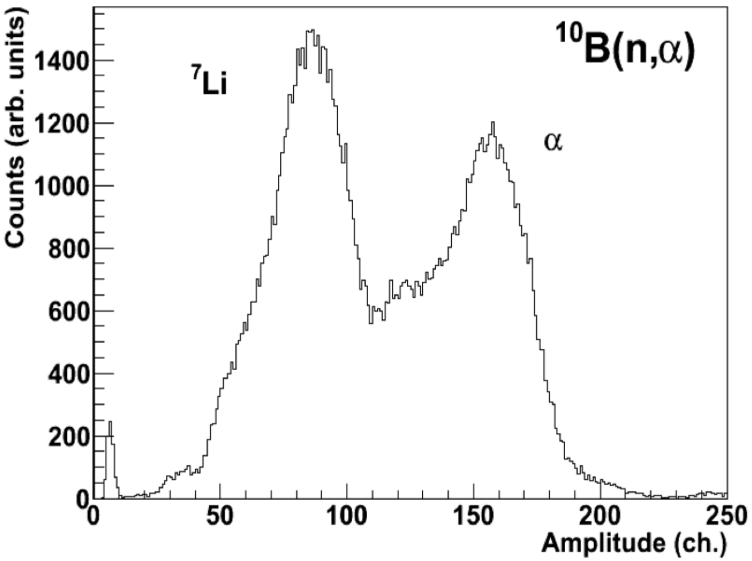
^{235}U Converter

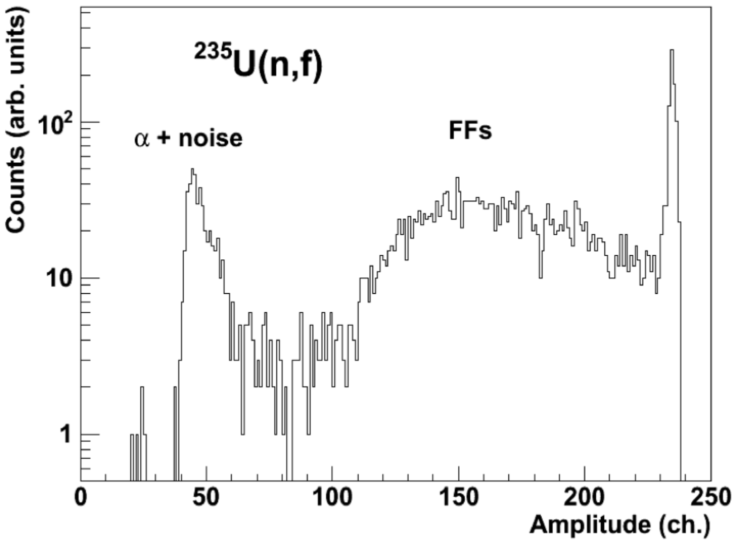
- ✓ Vaccuum Evaporation (1 mg ^{235}U @ 99,94%) at JRC-IRMM (Geel)
- ✓ on 1,5 μm aluminized mylar foil
- ✓ 1 mg on a Φ 20 mm

Ref: S. Andriamonge *et.al.*, proceedings of ND2010, International Conference on Nuclear Data for Science and Technology

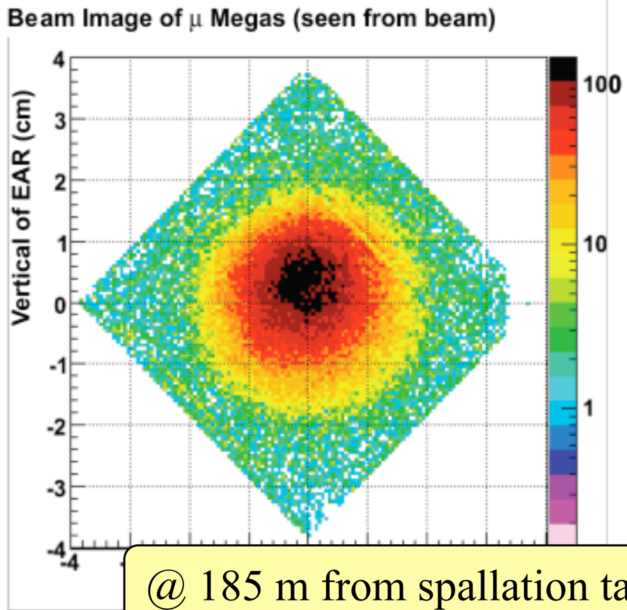
n-TOF beam profile and flux monitor

n-TOF beam flux monitoring (2008)

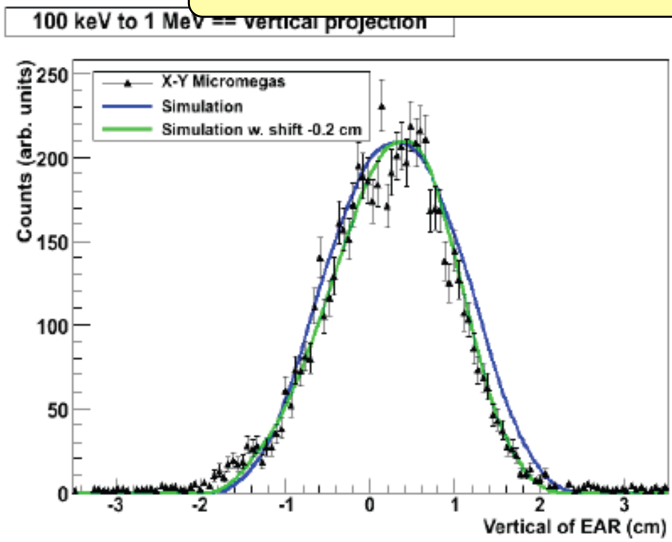




n-TOF beam profile (2009)



@ 185 m from spallation target

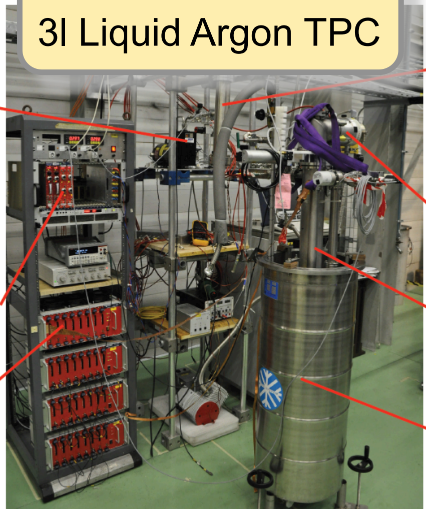


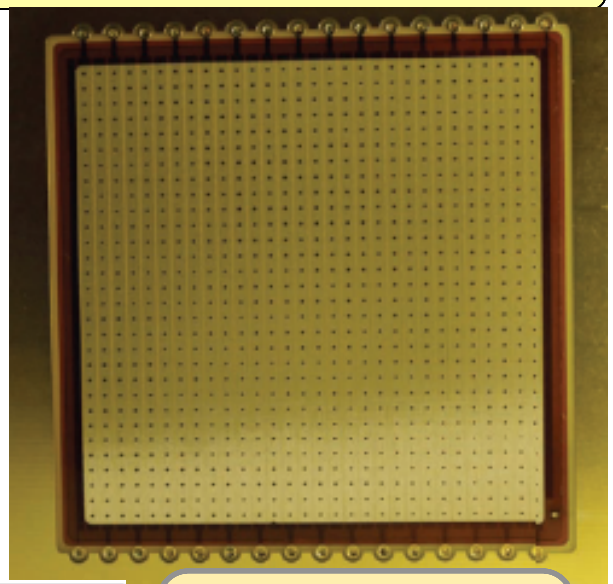
Ref: S. Andriamonge *et.al.*, proceedings of ND2010, International Conference on Nuclear Data for Science and Technology

Micromegas for double phase Liquid Argon TPC readout

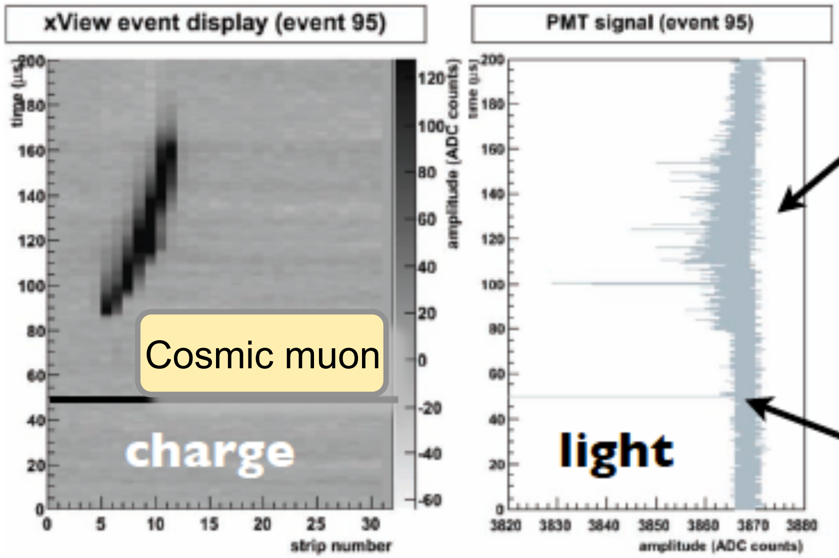
First tests of a micromegas as charge readout of a double Argon TPC (1 bar / 87 K pure Argon)

ETH Zurich
3l Liquid Argon TPC





100 μm gap
32 strips, 3mm pitch
bulk-micromegas



secondary scintillation light produced in GAr (field between extr. grids and micromegas)
➡ proportional to charge

prompt scintillation light produced in LAr
➡ used as trigger

E_{Amp}= 46 kV/cm ~25fC/strip
Gain~3

Max Gain of 5
→ 12 μm micro-bulk

Ref: A. Delbart, RD51 collaboration meeting, Bari, 7-10 october 2010

Comparison of bulk & micro-bulk technologies

Table 1. Comparison of some bulk and micro-bulk specifications and performances. Gaps of 64 μm for bulk and 12.5 μm for micro-bulk need to be tested.

	bulk	micro-bulk
Standard amplification gap	128 μm	50 μm
Other possible amplification gaps	(64)-100-150-194 μm	(12.5)-25 μm
Standard Mesh pitch	63 μm	100 μm
Standard Mesh openings	45 μm	40 μm
Standard maximum size	50x150 cm^2	10x10 cm^2
R&D maximum size	100x200 cm^2	30x30 cm^2
Best FWHM 5.9 keV resolution	19%	11%
Currently in use in experiments	T2K/TPC	Axion CAST experiment, nTOF
Current R&D programs	ILC/TPC, ILC/DHCAL, SLHC/Muon chambers upgrade, CLAS12 spectrometer, ...	NEXT, MIMAC, ...

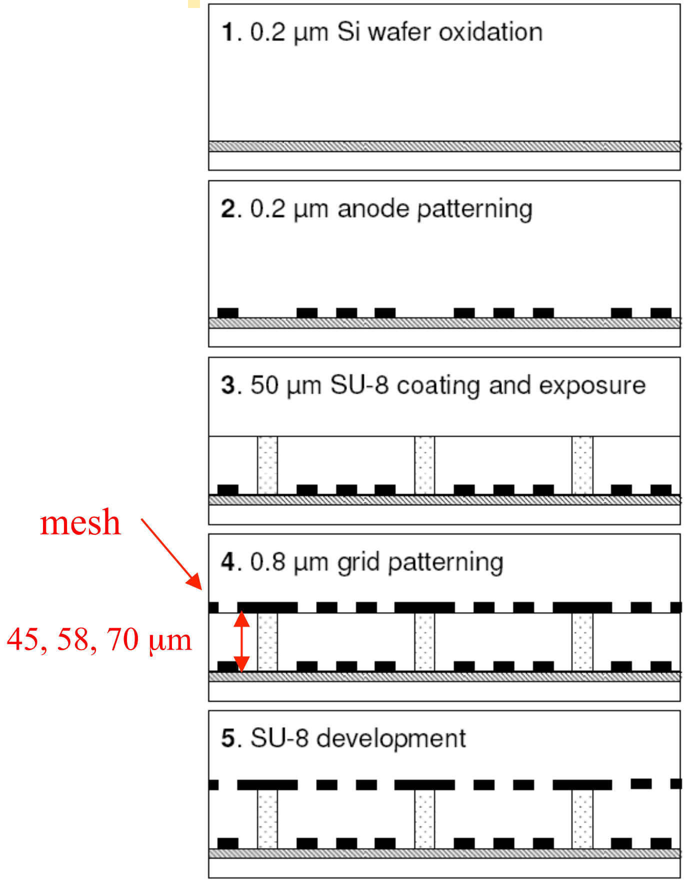
- Large size
- Large scale production
- Robustness (incl. sparks)

- Low-budget material
- Excellent energy resolution
- Thin gap / High pressure app.

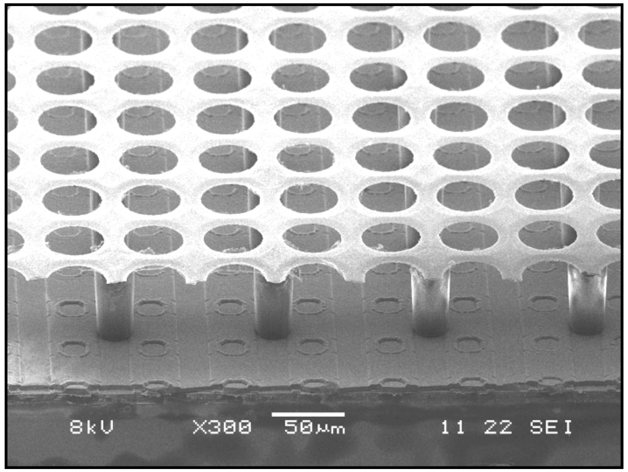
InGrid + Timepix (within the european R&D program EUDET/AIDA)

Micromegas integration within the pixels sensor by post-processing of the Si wafers Al grid, 0.8 μm thick, accurately positionned with respect to the pilars and pixels

Si wafer Post-processing



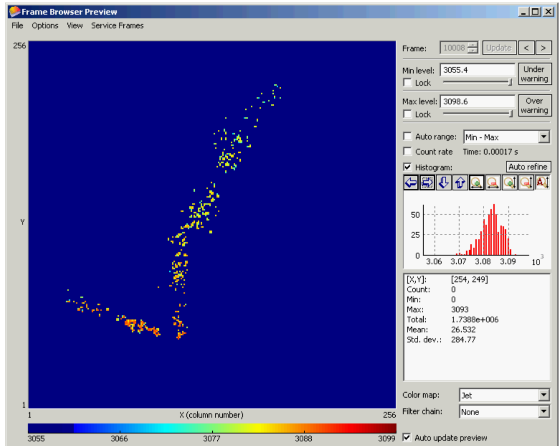
Timepix chip + SiProt + InGrid



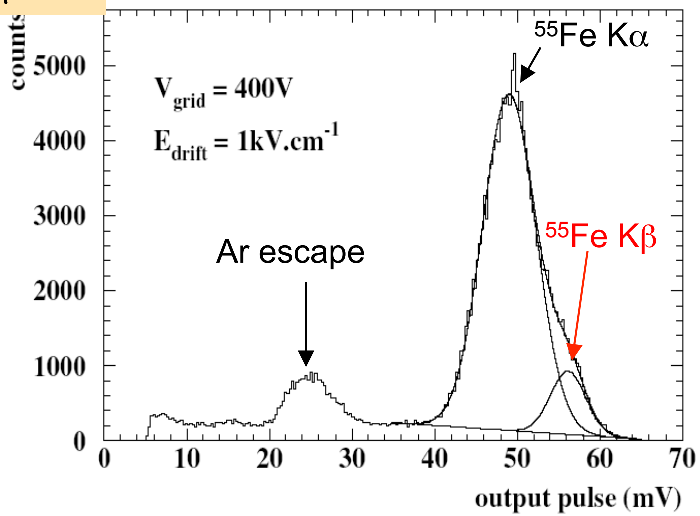
φ40 μm pilars No dead zones

Hole pitch : 20, 32,45, 58 μm

- Single electron detection
- Ion feedback down to 1 ‰



^{55}Fe spectrum in Argon + 20% iC_4H_{10}



Excellent Energy resolution : $s_E/E = 6.5\%$

Gain variations: < ±5%

Gas gains: $5 \cdot 10^2$ - $6 \cdot 10^3$

Collaboration NIKHEF-Saclay-CERN-univ. Of Twente

... towards digital mini-TPCs

Conclusion

- Micromegas is a mature Micro-Pattern Gaseous Detector
  - The main involved physical processes are understood
  - Rich R&D and R&T programs since 1996 (→ bulk) and 2004 (→micro-bulk)
  - Prooved performances in several experiments (COMPASS, T2K/TPC, …)
  - Active worldwilde RD51 collaboration on MPGDs

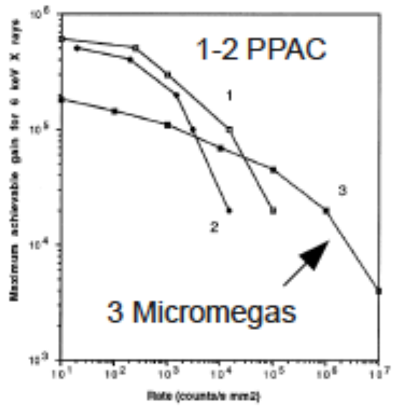
- Main advantages and performances of Micromegas
  - Easy & cheap to build & operate (compared to MWPCs & other MPGDs)
  - Robustness (to ageing, to sparks, …)
  - Large surface paving capabilities (few % level dead zones)
  - Low radiation length budget capabilities (micro-bulk)
  - Good spatial and time resolution (↓12 μm and 0.7 ns)
  - High flux capabilities (3.10^8 ples/s/cm^2 in NA48/KABES) in TPC mode
  - Good γ rejection (at least 10^{-3}) for neutron applications

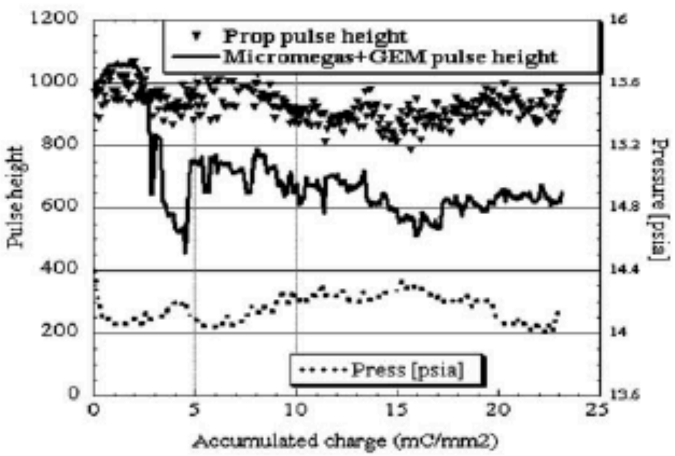
  - On-going R&D : spark reduction and protection, 2D readout micro-bulk, micro-bulk manufacturing, $2m^2$ bulk-micromegas, multi stage micro-bulk for high efficience neutron detection (alternative for ^3He), …

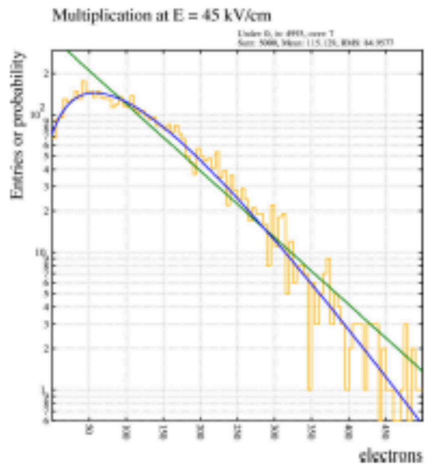
Backup

RD51 WG2 characterization studies

Gas discharges	Aging	Charging-up	Gain fluctuations
Micro-defects **Rather limit** Max. gain VS radiation **Feedback phenomena** Ion impact in noble gas Photo-effect in avalanche **High rate mechanisms** Avalanche overlap Ion space charge at the cathode	**Material outgasing** **Radiation hardness** Database of bad/good materials **Gas flow/mixture** ppm Impurities **Rate effects** Polymer deposits Malter effects Photo-cathode QE loss	**Dielectric charging-up** Diffusion of avalanche charge **Geometry** Influence of dielectric Shielding against avalanche charge **Gain stability** Time constants Discharges	**Single electron response** Polya VS exponential **Photon feedback** Second Townsend coef. **Penning transfers** Gain enhancement **Electric field** Low VS High Hole edges

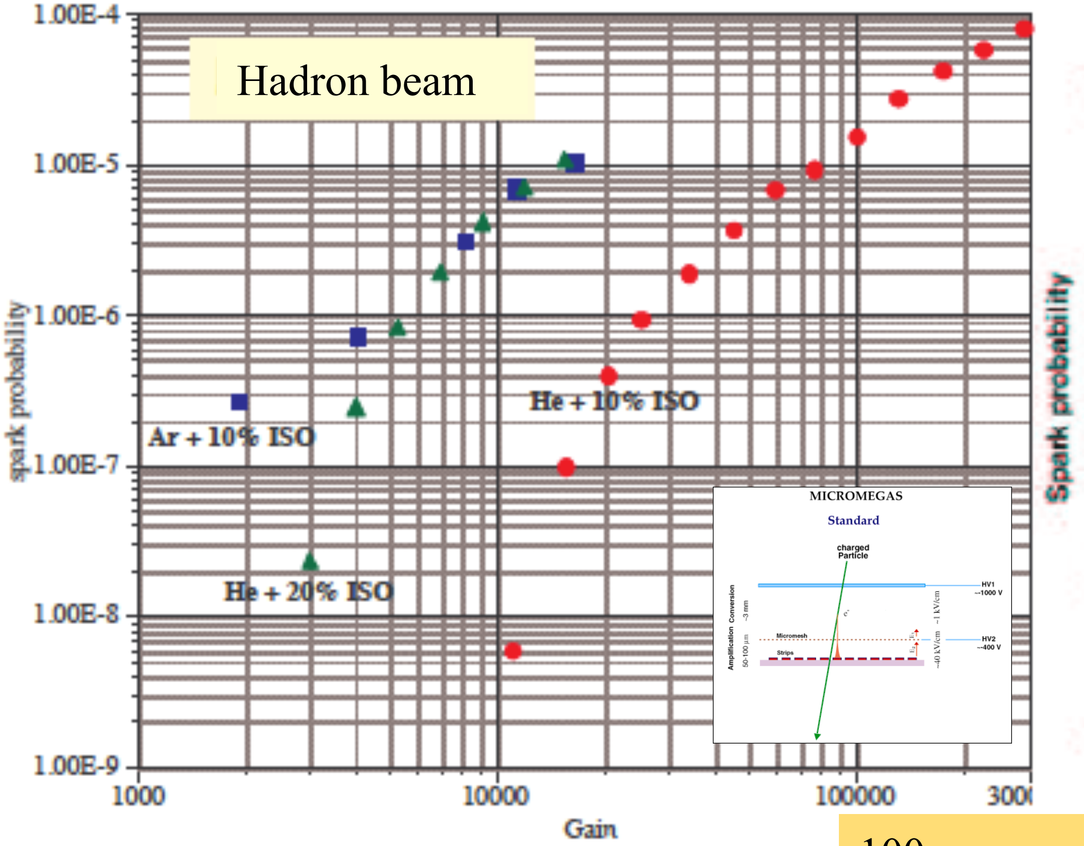




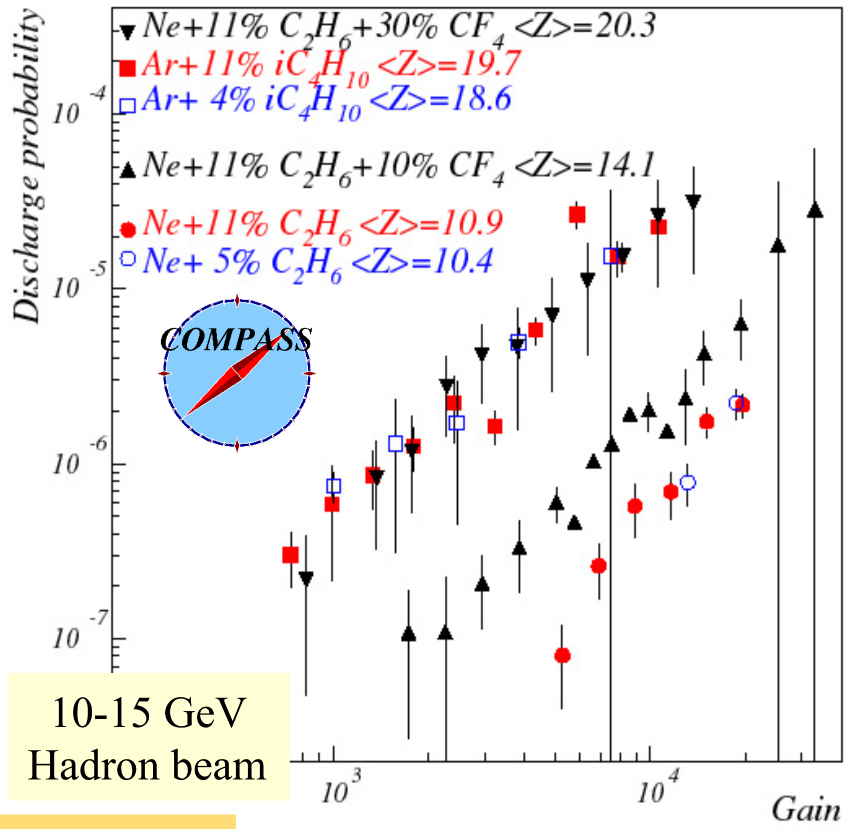


Discharges probabilities with standard metallic anode plane

⇒ A spark provoques a dead time (loss of efficiency) which depends on the Front End and mesh AC coulping. Readout Front-End Electronics must be protected !



Ref: A. Delbart et al., NIM A478, p205 (2002)



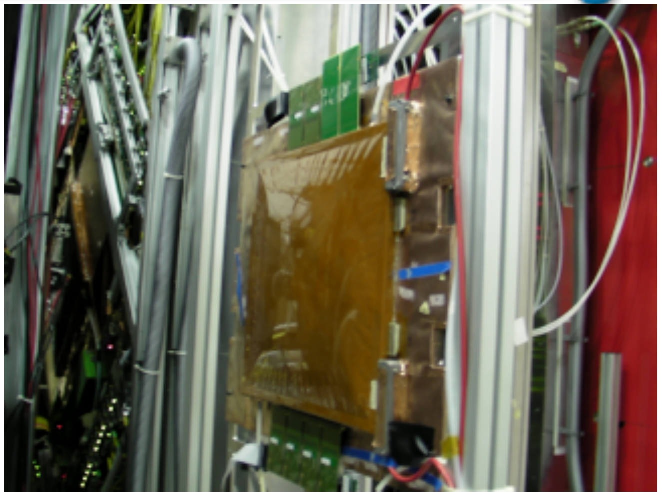
100 mm gap, Nickel mesh

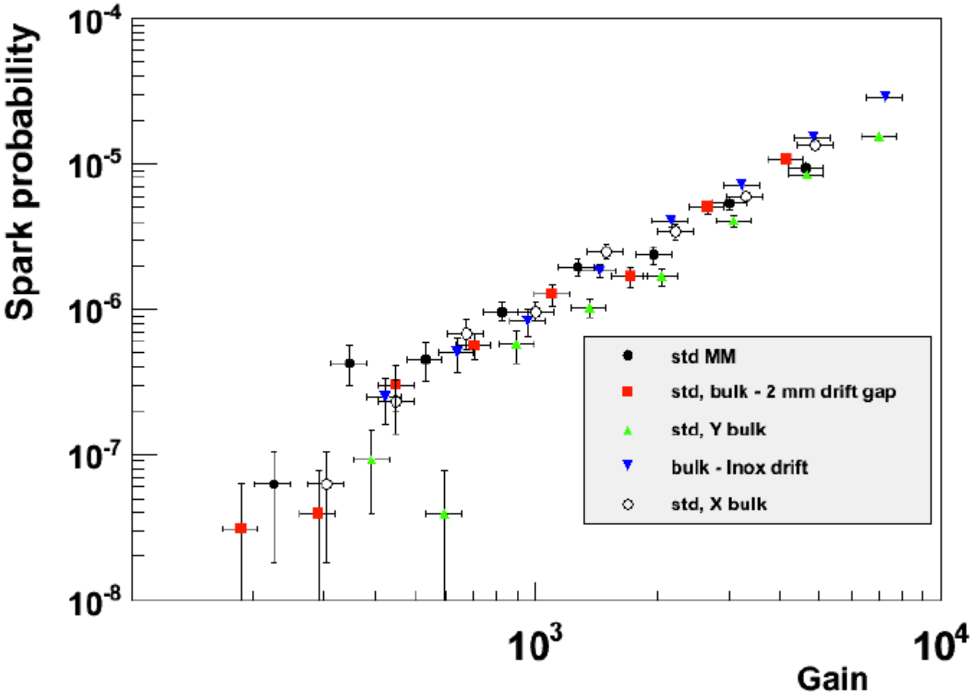
Ref: Ph. Abbon et al, NIM A461, p29 (2001)

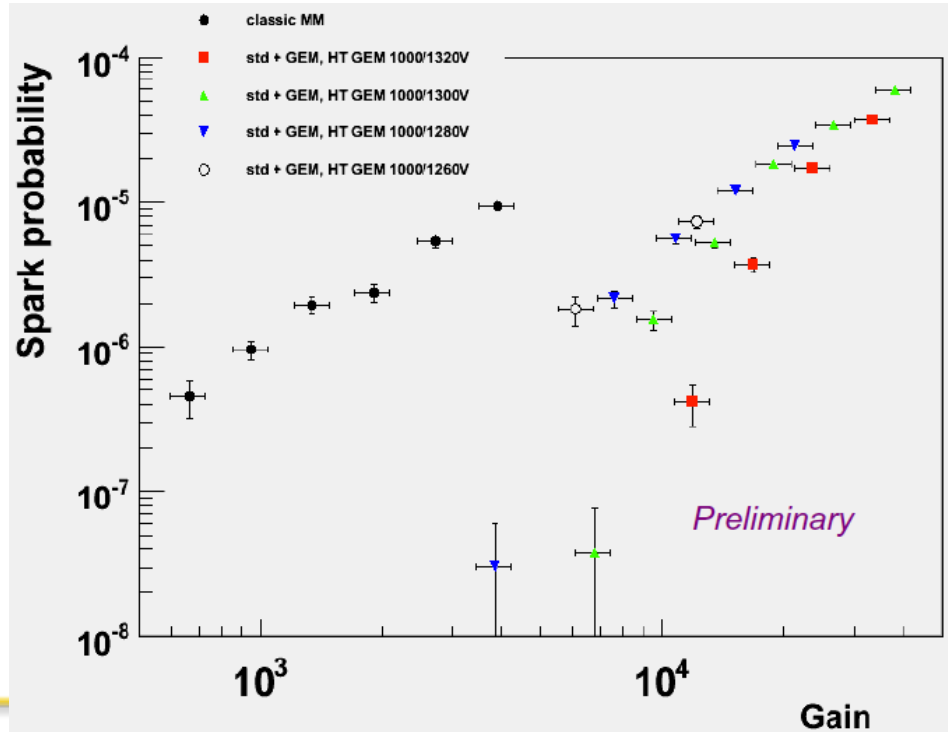
- sparking rate depends on the type of incident particles and the nature of the gas mixture
  - ↳ Spark probability increases with Gain and Z number of the Gas (first order)

COMPASS bulk-micromegas upgrade chambers

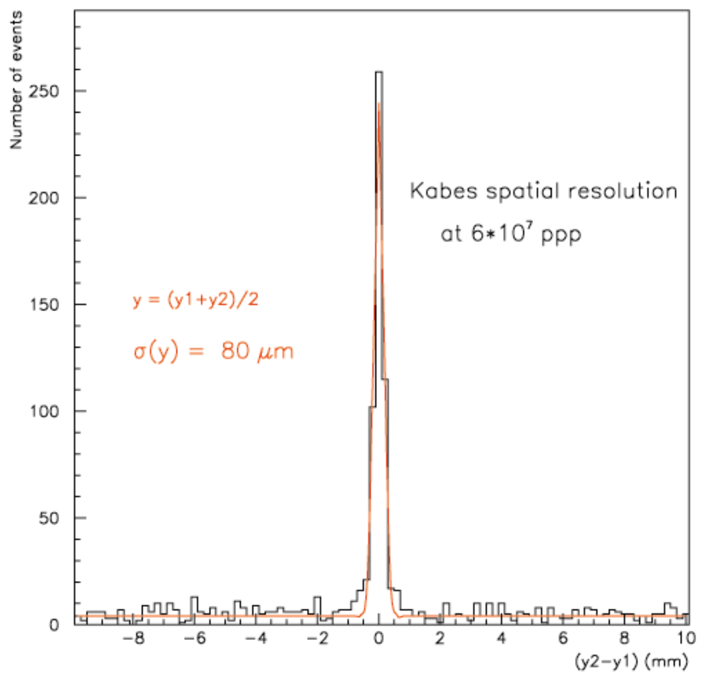
- Pixel readout in beam central area
- Reduce the discharge rate by factor 10 to 100 for higher intensity hadron beam
→ studies on resistive Micromegas and MM+GEM
-Improvement of robustness → use of bulk technology





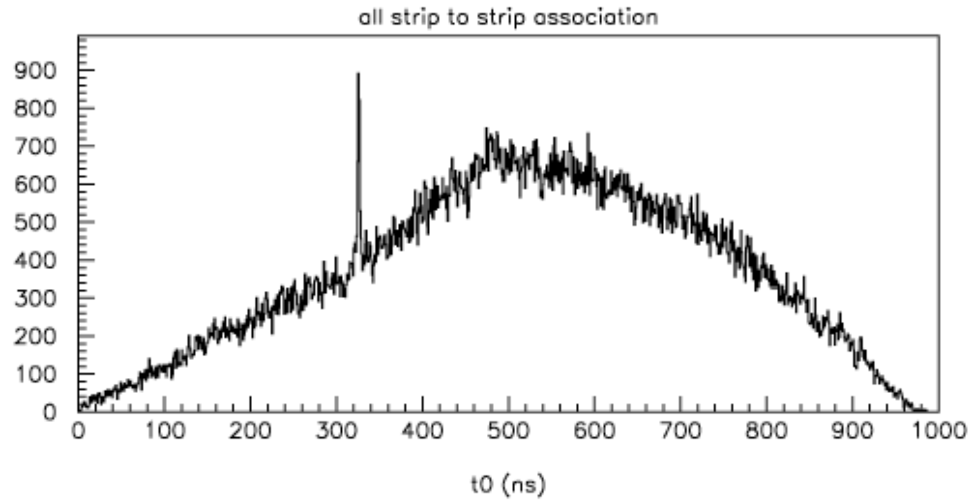


KABES SPS Beam test results (2002)



80 μm spatial resolution

No space charge effect
at 20 MHz beam rate



KABES Station performances
at 20 MHz beam rate (July 2002)

highest strip rate = 2 MHz

efficiency > 0.95

time resolution = 0.7 ns
➔ ~60 μm resolution in drift direction
space resolution = 80 μm

↳ Excellent 2D high rate beam profiler

NA48/KABES : KAon BEam Spectrometer

KABES Spectrometer

- 2 Kabes stations on the NA48 60 GeV/c charged kaon beam
- 30 Mhz beam in ~8 cm²

➢ Measure of the momentum of individual tracks with $\Delta p/p < 1\%$

➢ nanosecond time resolution required

➢ 250 µm spatial resolution needed in y direction

➢ $X/X_0 < 10^{-3}$ per station (dominated by gas)

⇒ Fast and low sparking gas mixture

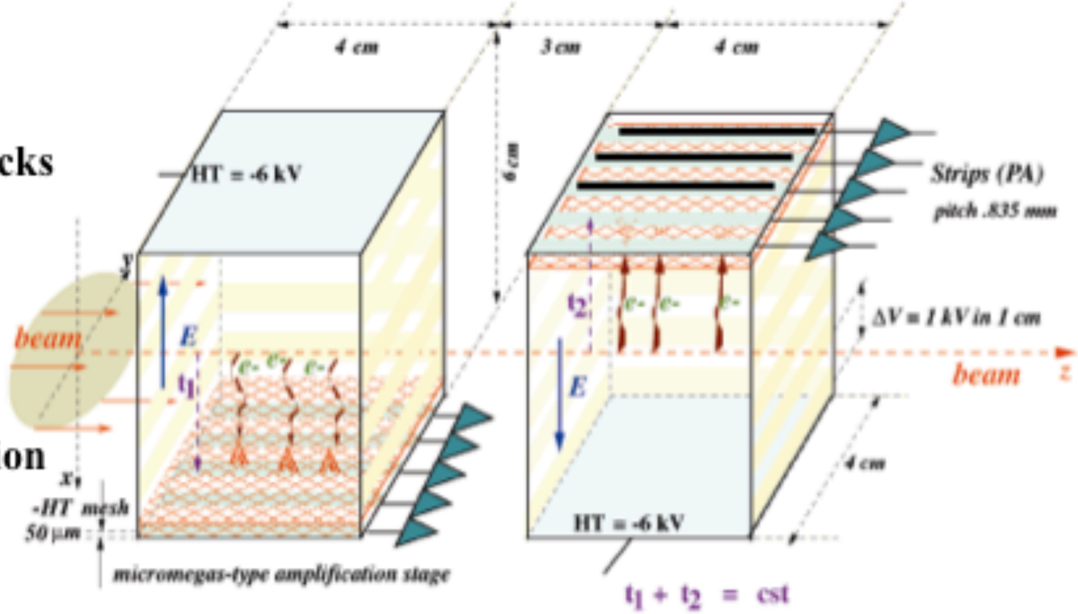
⇒ Field cage to minimize time jitter (E field distorsions)

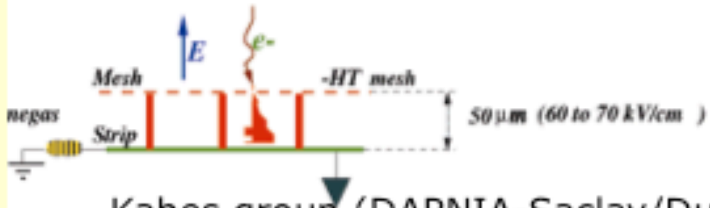
⇒ Fast and low noise current preamplification

Kabes Station

Gas : 79%Ne/11%C2H6/10%CF4

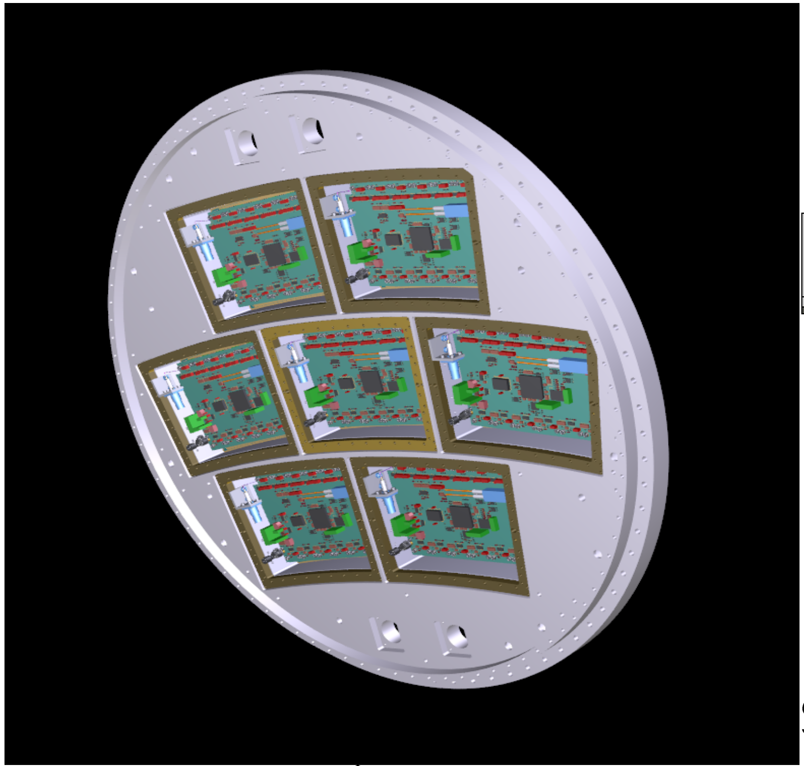
2 Micromegas-type projection chambers

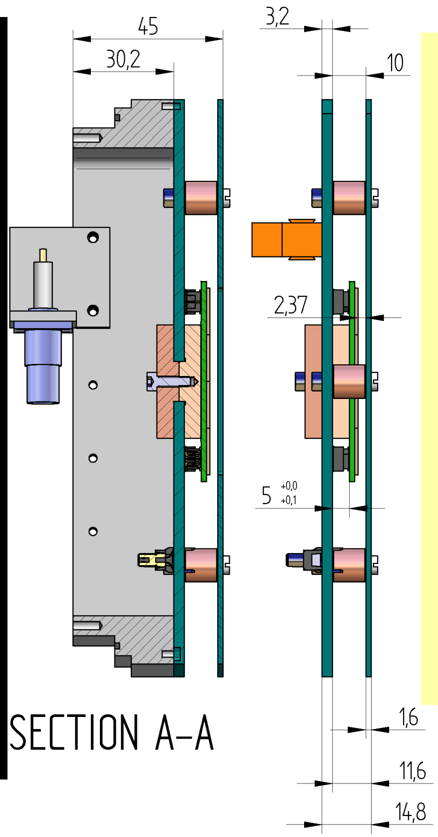


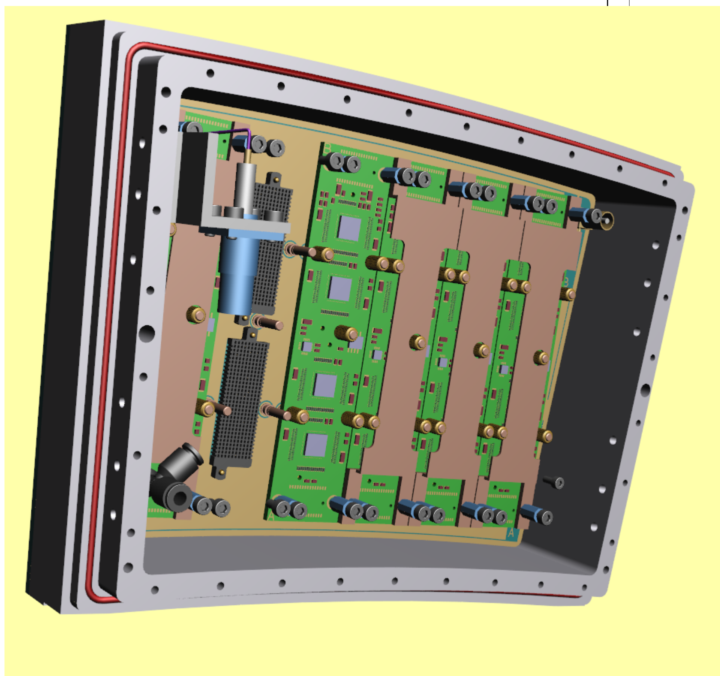


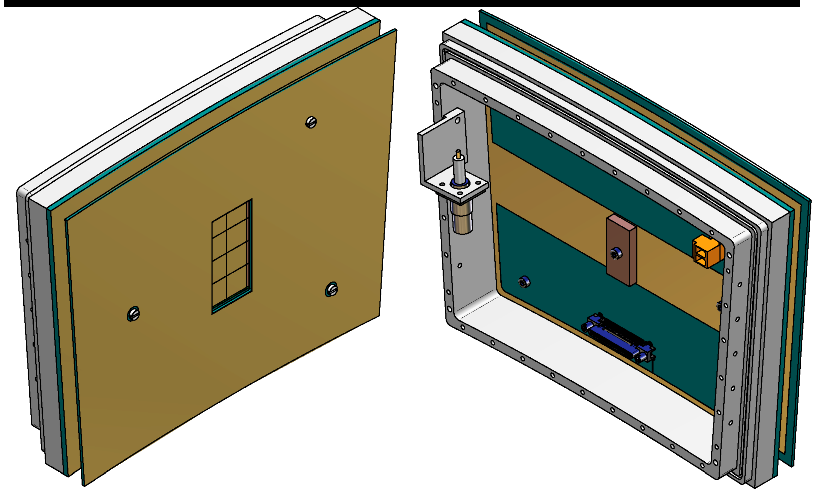
Kabes group (DAPNIA-Saclay/Dubna)

7 modules integration with new AFTER based FEE



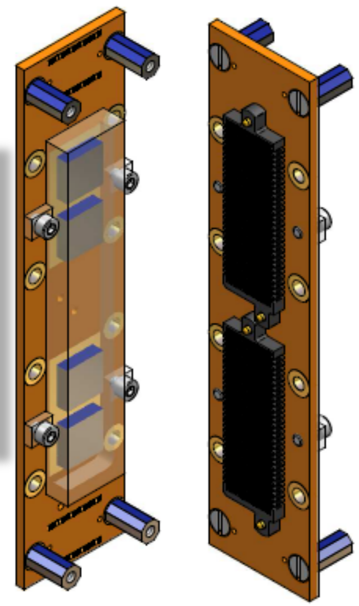






Compact 288 ch. FEC

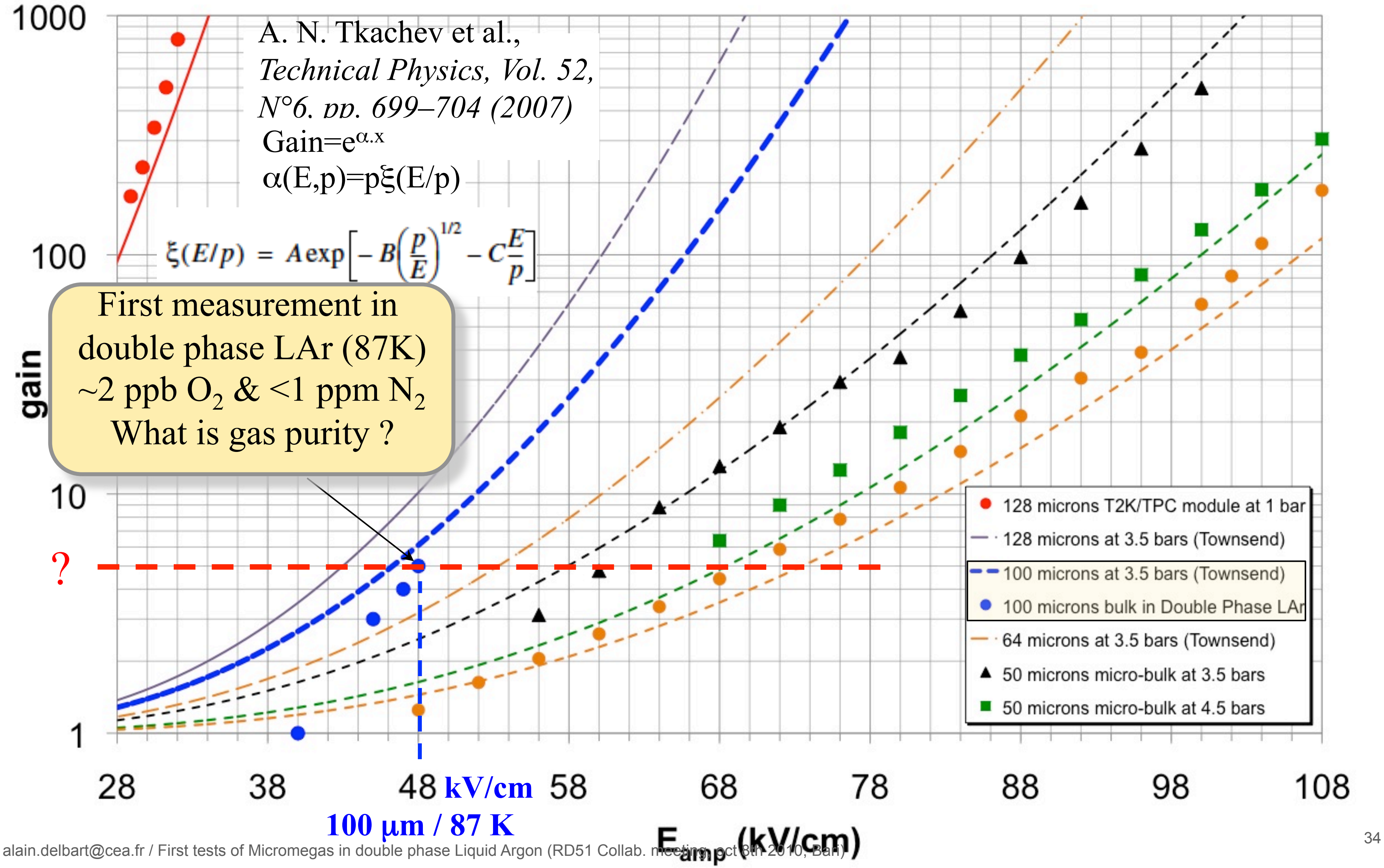
- ✓ wire-bonded unpacked AFTER chip
- ✓ diode protection removed
- ✓ LV regulation and quad ADC removed and displaced to the digital FEM



Summary of Gain measurements in Argon

→ On-going R&D to test thinner gaps (25 μm micro-bulk)

For Argon: A = 43 (cm Torr)$^{-1}$, B = 27.5 [V/(cm Torr)]$^{1/2}$, C = 2.5 10^{-4} (cm Torr)/V



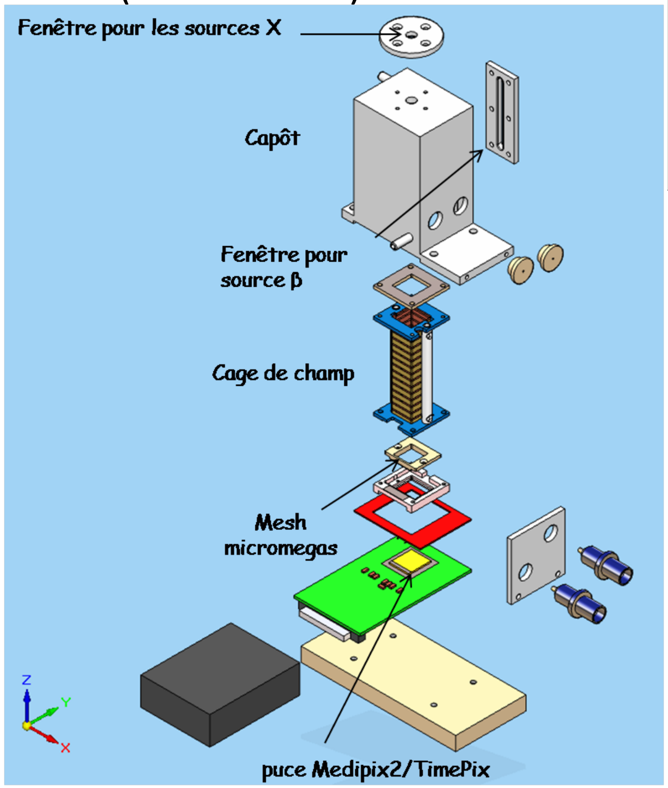
A Timepix + InGrid micromegas readout μTPC

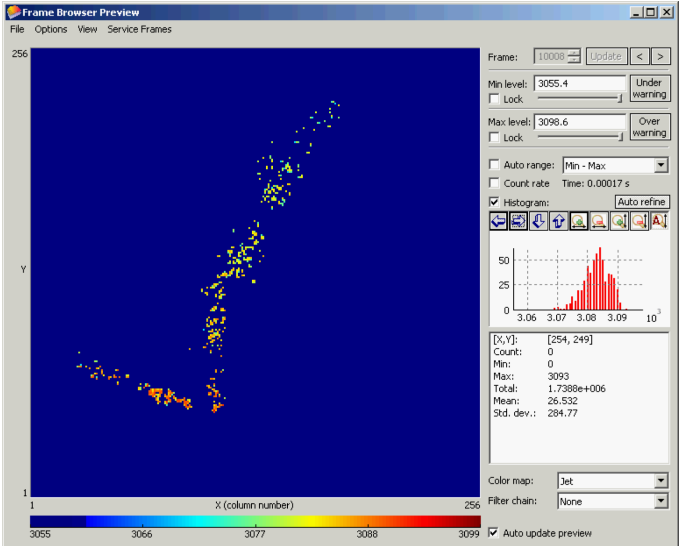
Current R&D @ IRFU

- Single electron detection

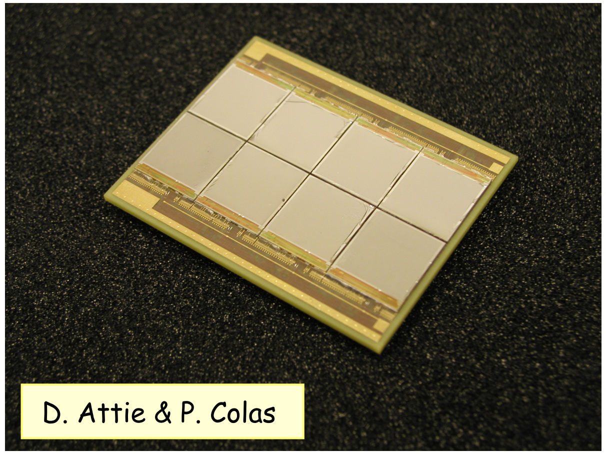
  → Unique tool to study Gas properties

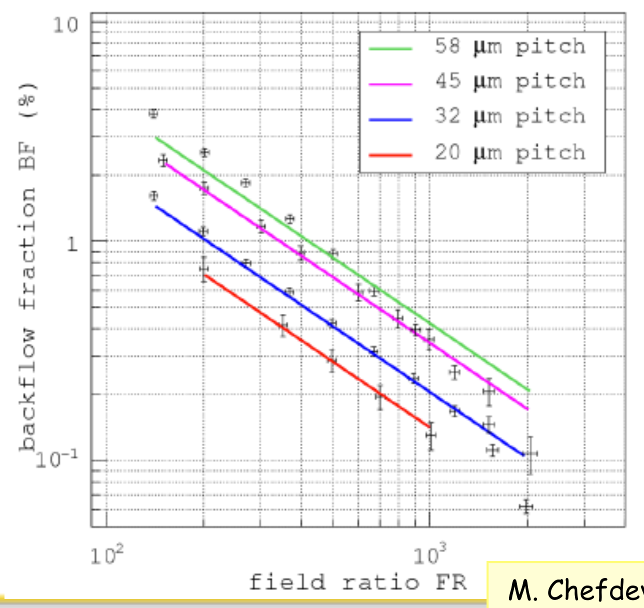
- Ion feedback down to 1 ‰ (for FR=1000)

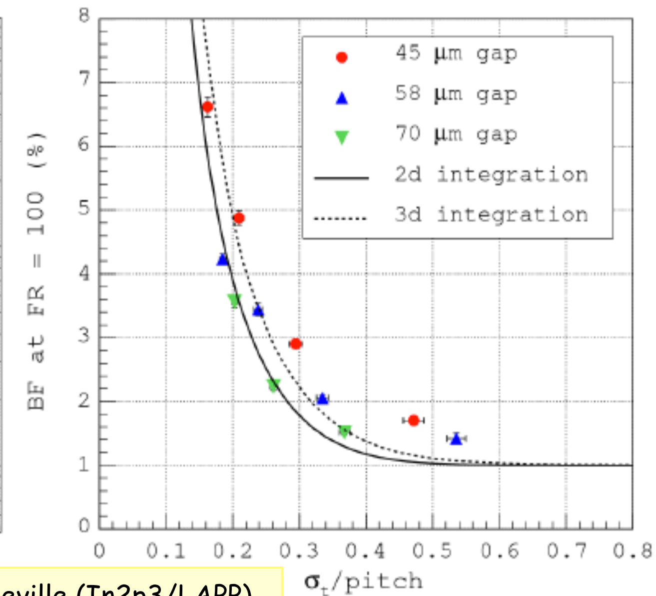




Octopuce : 8 Timepix array







M. Chefdeville (In2p3/LAPP)