Développement de détecteurs Micromegas pixellisés pour l'expérience COMPASS

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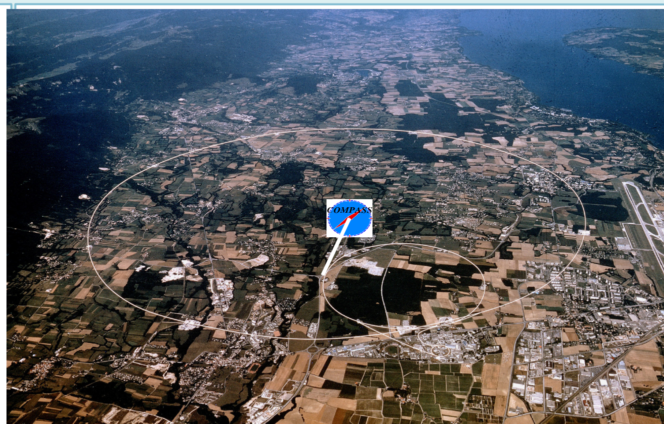
COMPASS et les détecteurs Micromegas

Le projet

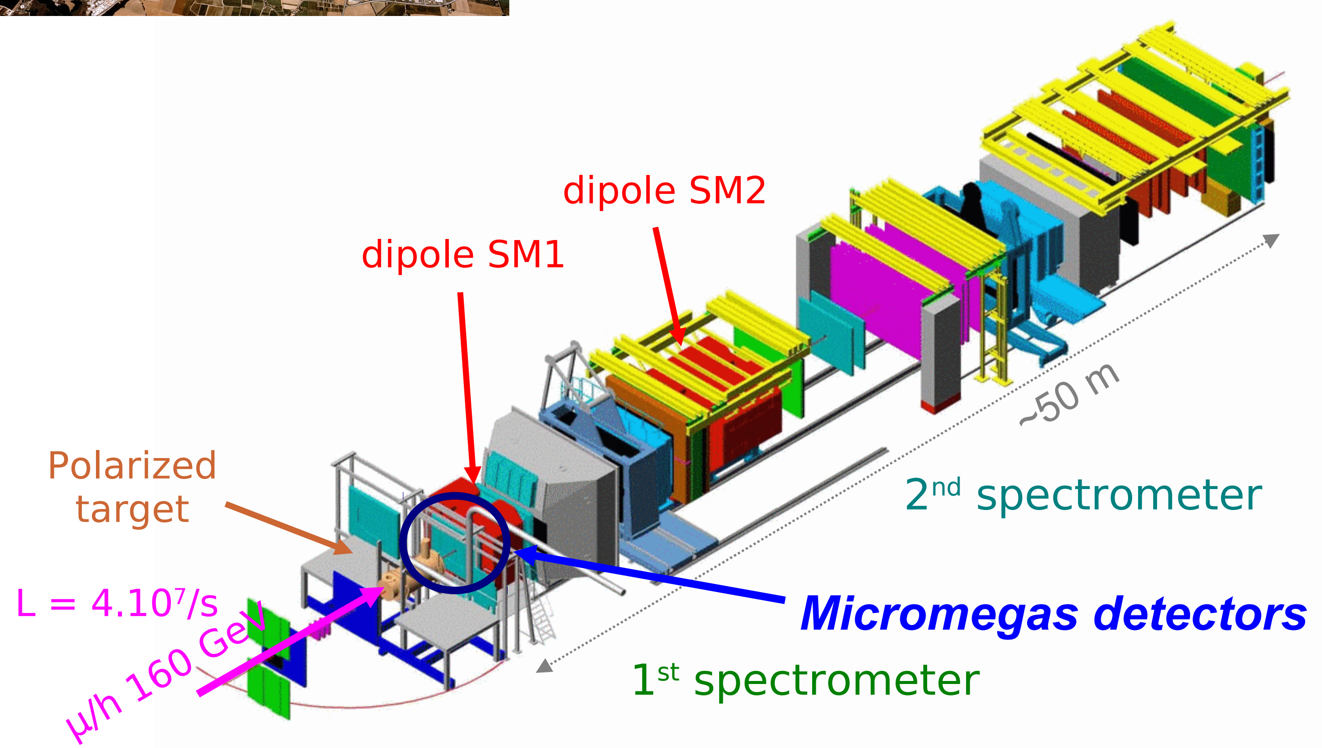
Les prototypes pixellisés

La réduction de l'impact des décharges

The COMPASS experiment at CERN



Dedicated to nucleon structure and spectroscopy studies
2 spectrometers for small and large angles
High statistic experiment (30kHz trigger rate)
Very good spatial resolution (<100µm) required for kinematics and particle identification



Present COMPASS Micromegas detectors

Interest of Micromegas

Ions neutralized by mesh

Short signals → high flux

Main characteristics

Large size 40x40 cm² with deported electronics

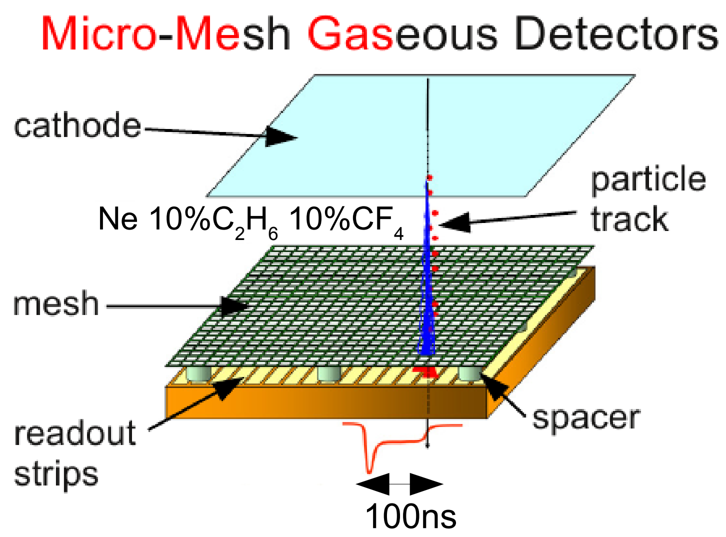
Reduced discharge rate with light gas and low noise electronics

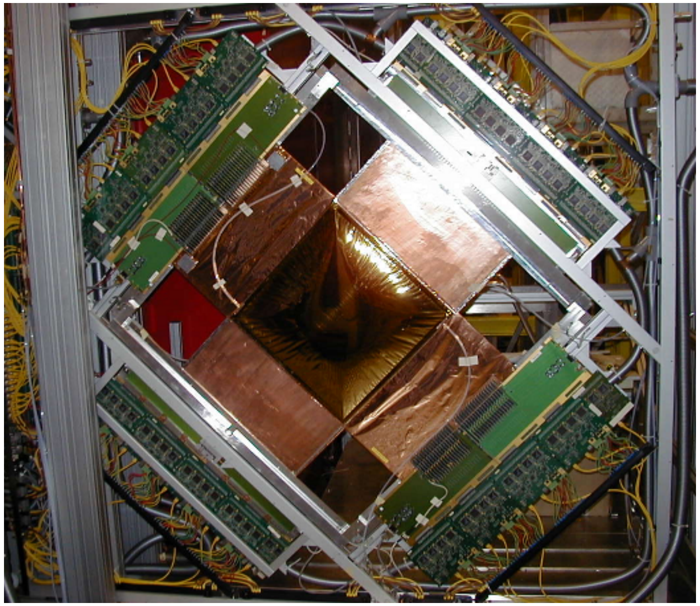
Very good performances (70-100µm, 10ns resolution)

Room for improvements

Blind center (5cm diameter disk in amplification gap, beam area)

Discharge rate in amplification gap is limiting factor with hadron beam





New MM R&D project

New proposal discussed in COMPASS collaboration for several years

→ Opportunity for the evolution of the MM detectors

Main objectives of the project

Detectors active in beam area

Less discharge → stand 5 times higher flux hadron beams

New MM detector to design with:

10 to 100 times less discharges

Read-out with pixels in the detector center (beam area)

Integrated electronics (APV25 chips)

Robustness improved (bulk technology)

Pixels read-out in the detector center

Too high flux for strips

Expected particle flux > 100kHz/mm²

→ > 500kHz/channel if strip read-out

→ > 10% inefficiency !

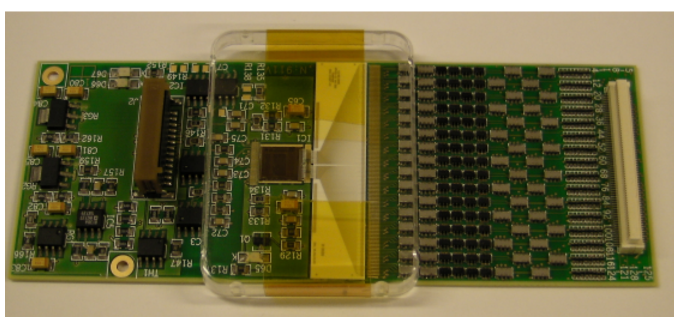
Read-out with rectangular pixels

5cm diameter, cover present inactive area

Keep spatial resolution in perpendicular dimension (400µm pitch as strips)

1280 pixels + 1280 strips to read !

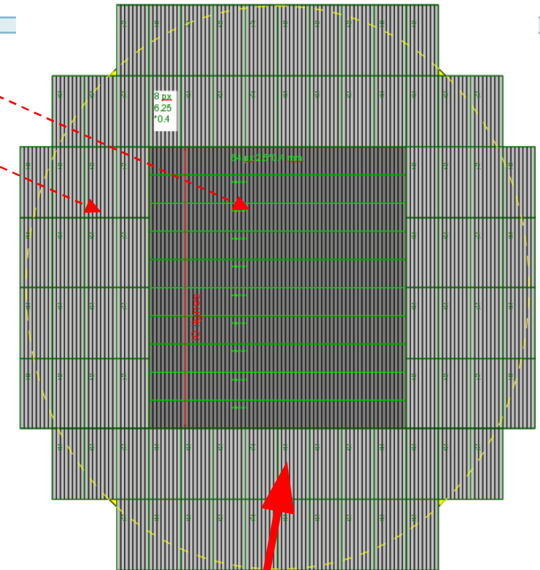
Read-out electronics: 128-channels APV25 chips
(from CMS silicon detectors, card design derived from TUM Munich)



2.5x0.4 *mm²*

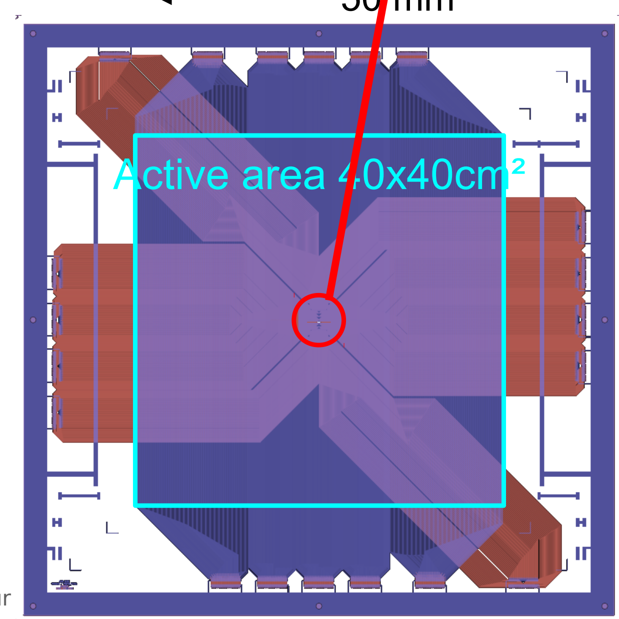
6.25x0.4 *mm²*

1280 pixels

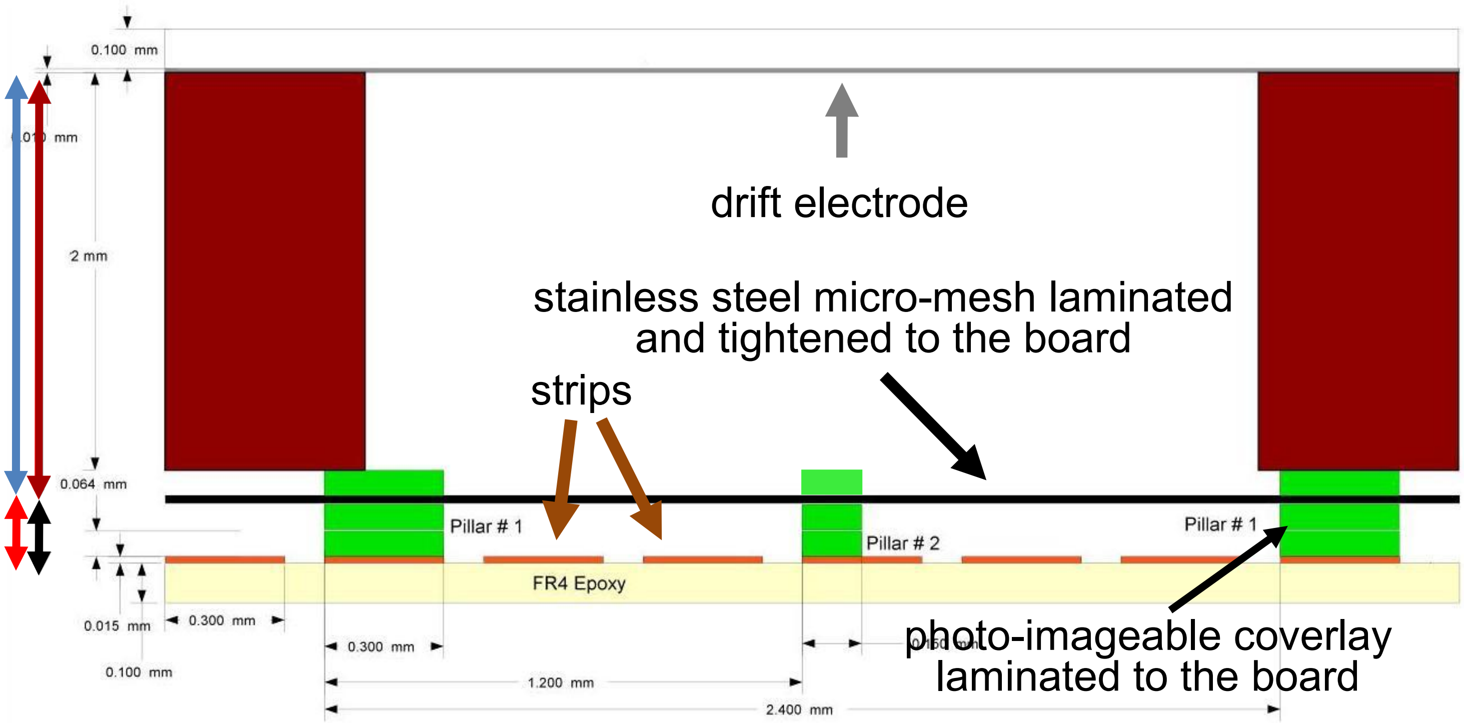


25 mm

50 mm



Improved robustness with bulk technology



Developed at Saclay and Cern, can be produced at Cern lab

Advantages:

- monolithic detector → no dust beneath the mesh
- less mechanical constraint (no more frame to tight the mesh)
- R&D done to produce bulk MM on honeycomb sandwich

Works on 2009 prototypes

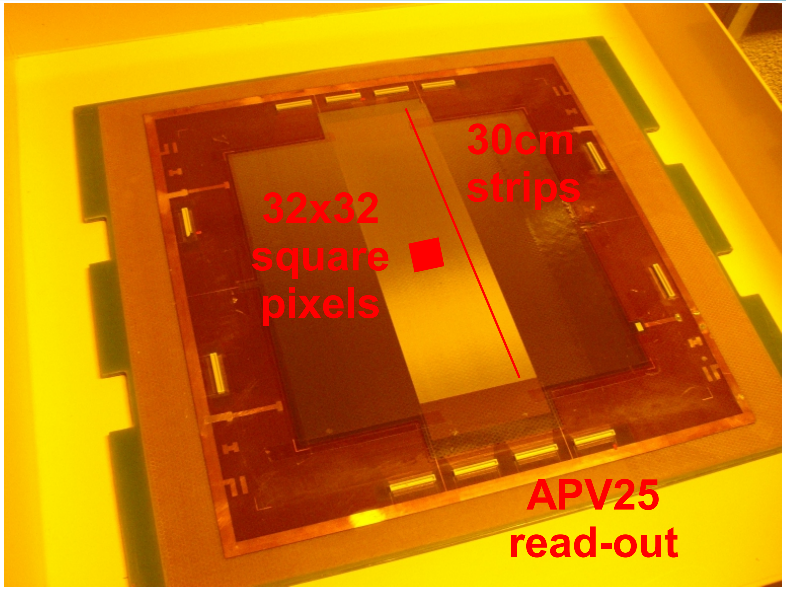
2009 prototypes

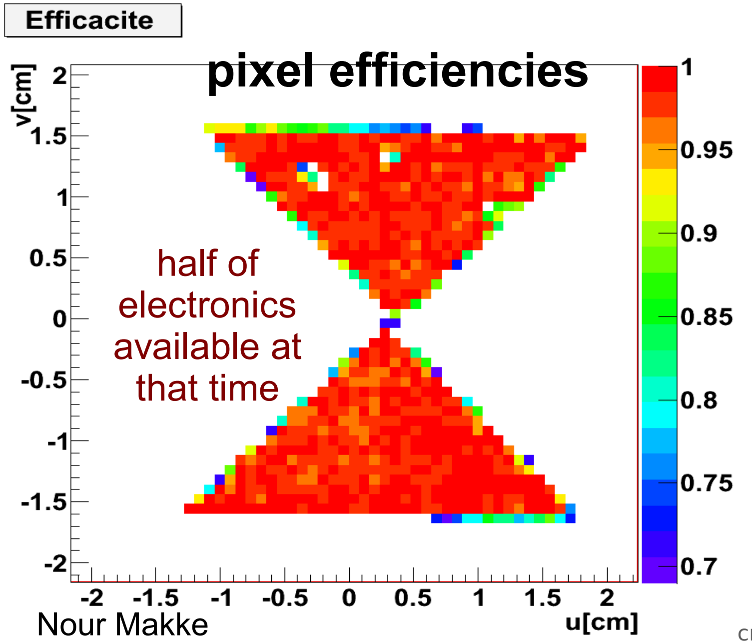
32x32 1mm² square pixels and 30cm strips (design from TUM Munich)

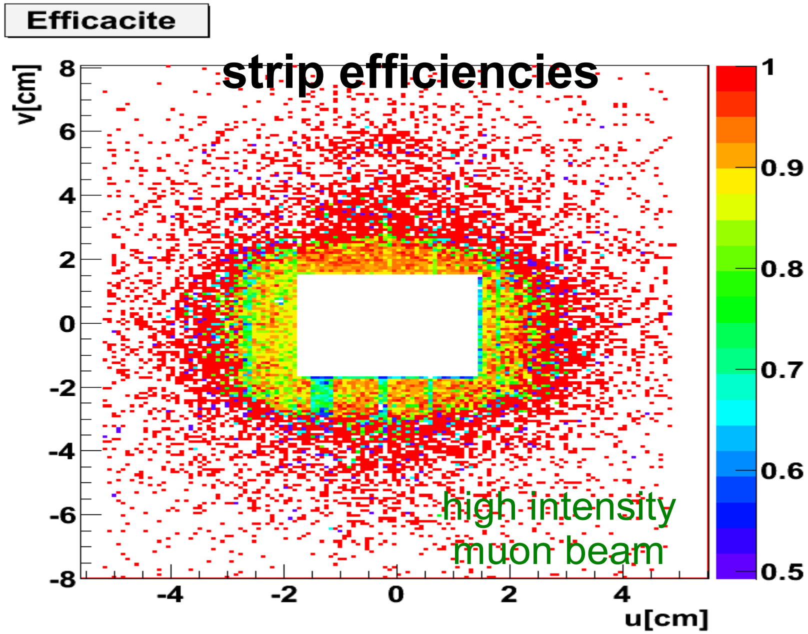
Comparison bulk/non-bulk technologies, no difference in discharge rate

Validation of APV25 read-out on Micromegas

Installed in COMPASS muon and hadron beam







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Works on 2010 prototype

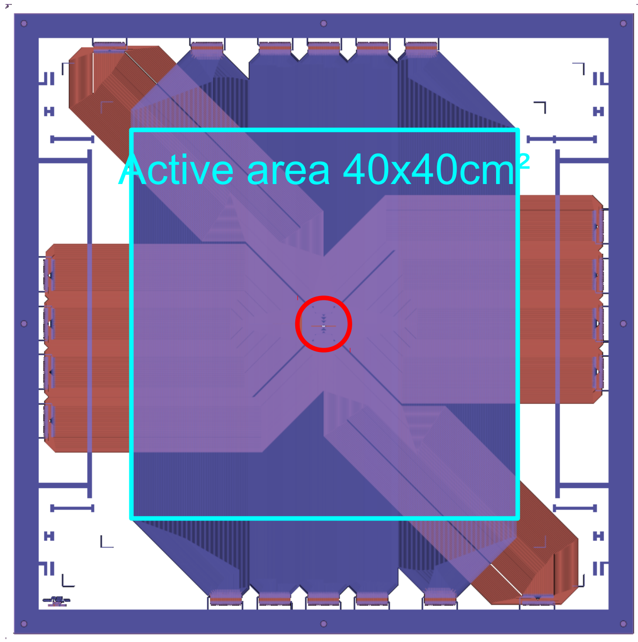
2010 prototype

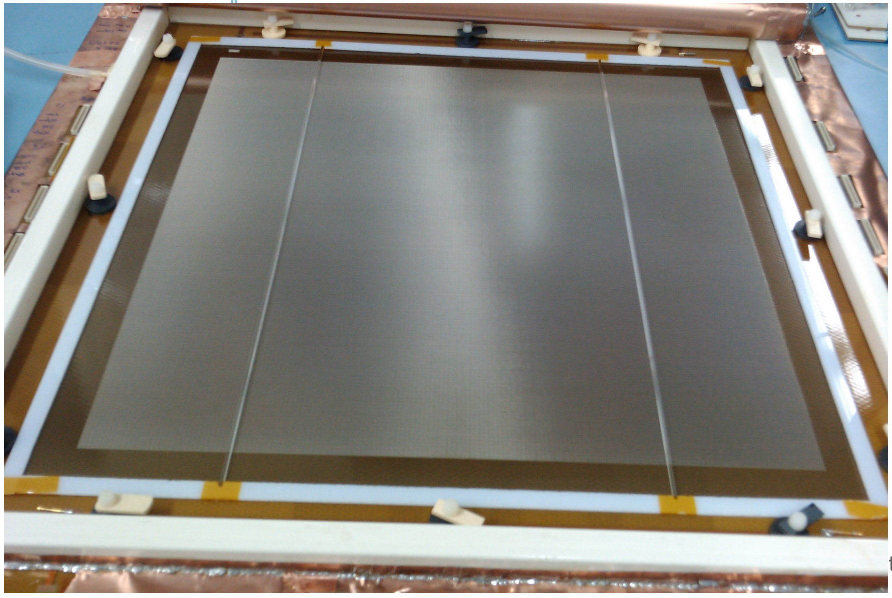
Almost final design

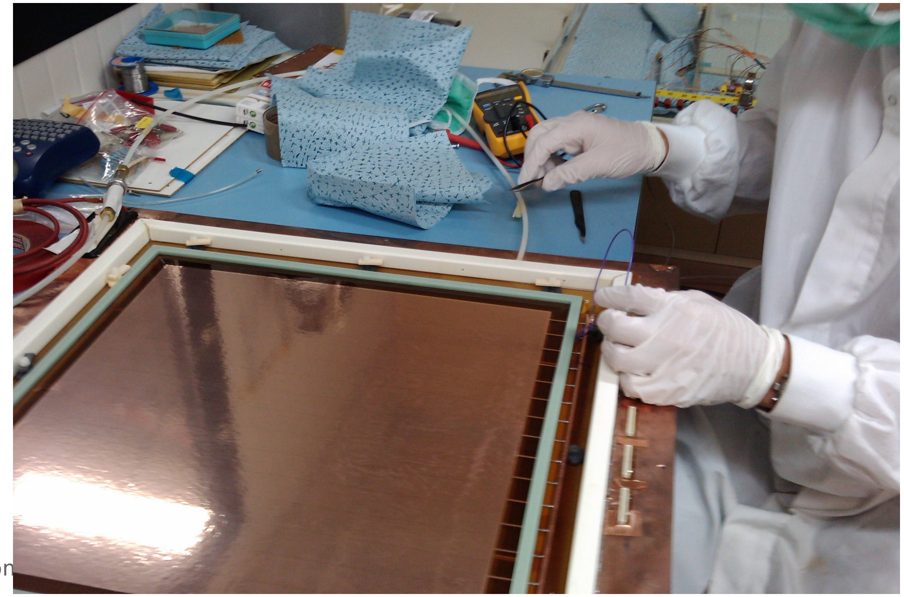
40x40cm² active area with 1280 rectangular pixels

Installed in COMPASS muon beam

GEM foil added for last days of COMPASS run







Résultats préliminaires sur le prototype 2010

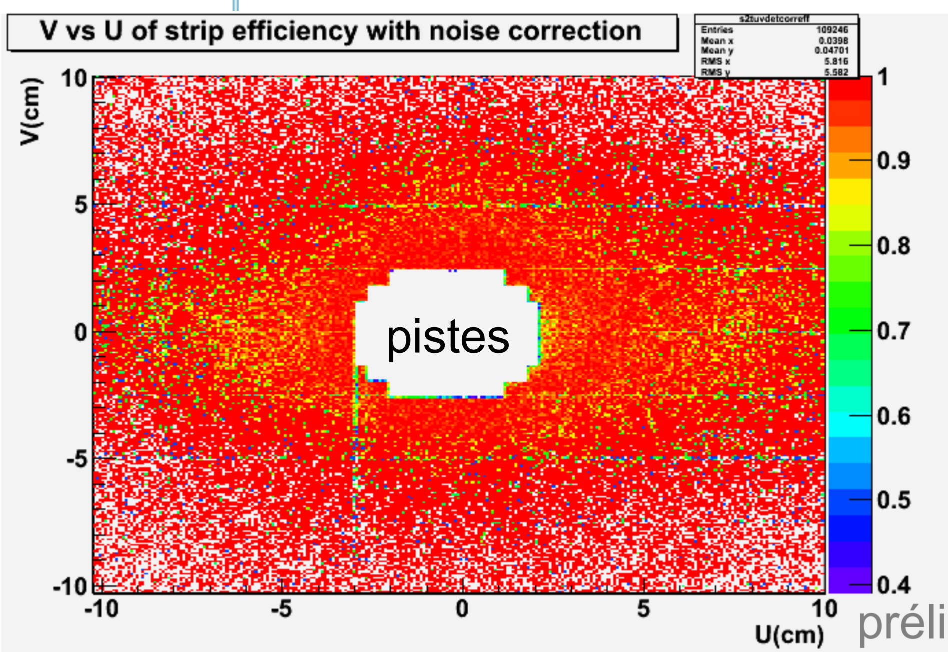
Zone pistes

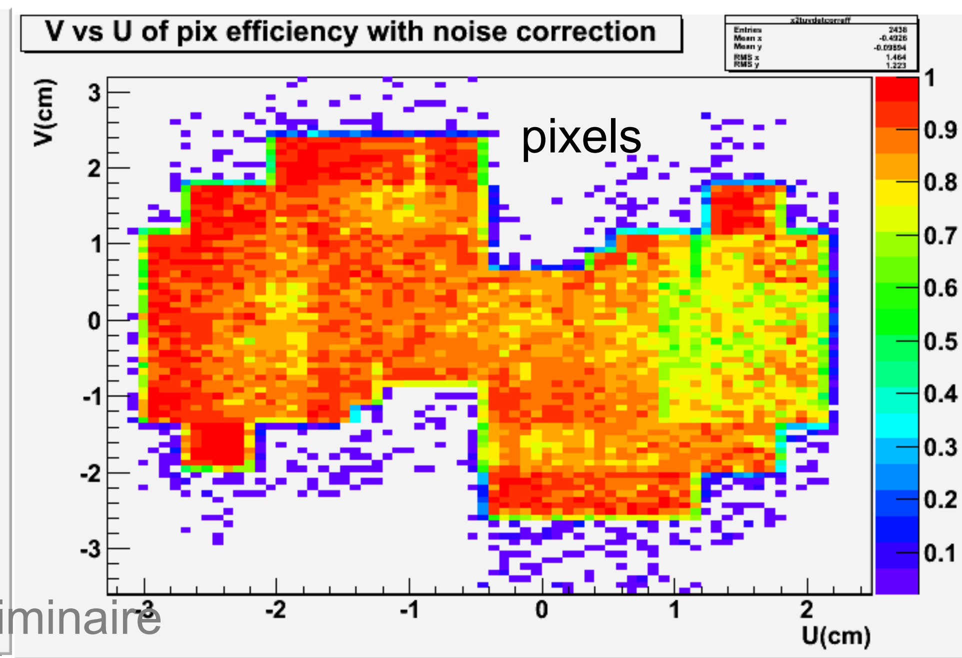
Bonne efficacité à grand flux de muons

Zone pixels

Efficacité dégradée par canaux manquants (>5%) et occupation de l'électronique (signal mis en forme >500ns)

Paramétrage de l'électronique APV (registres) à optimiser





préliminaire

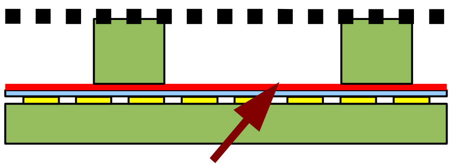
Discharge rate reduction: 2 possible ways

Resistive Micromegas

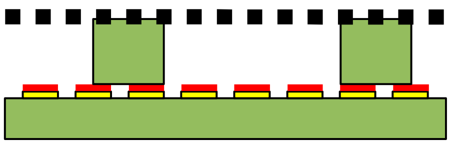
Resistive layer on top of anode to reduce discharge amplitudes

With or without isolator layer

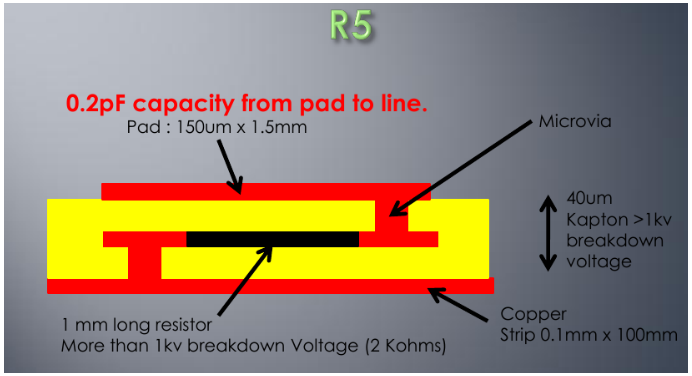
Several evolutions ongoing in the domain



resistive layer on isolator



resistive paste on strips

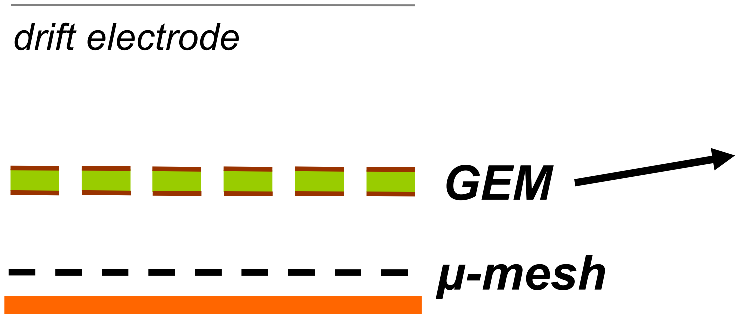


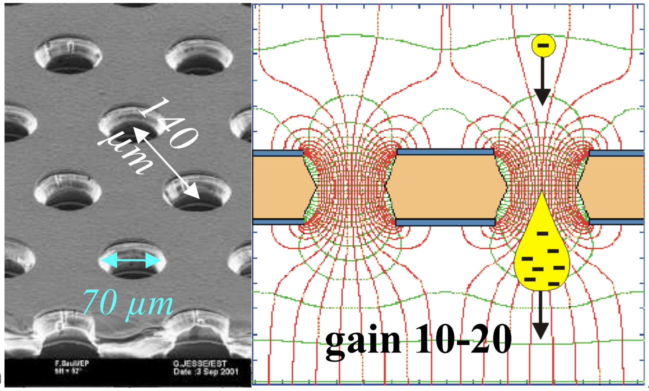
Buried resistors design of R. de Oliveira et al.

Micromegas + 1 GEM foil

Preamplification with a GEM foil (gain 10-20)

Micromegas stage at lower gain → less discharge





Beam tests on small prototypes for discharge and performances studies

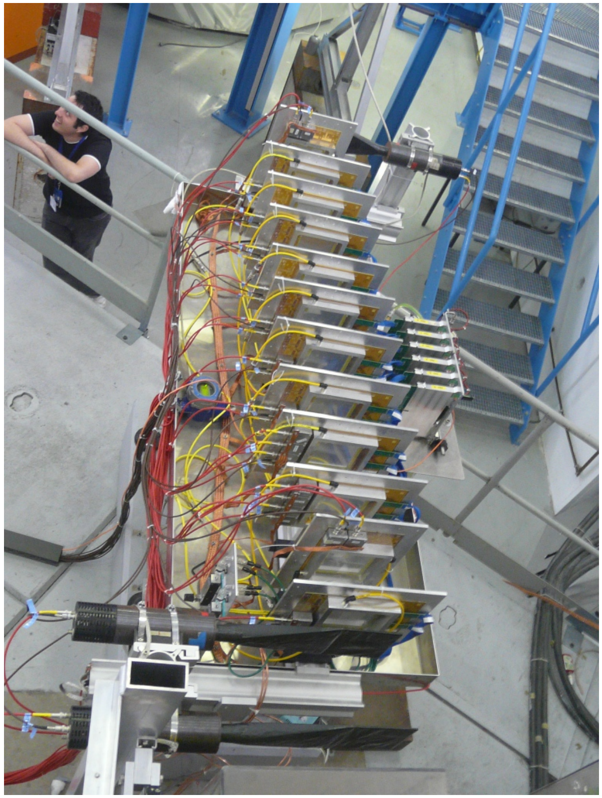
Common studies with Saclay Jefferson lab CLAS12 group

Both solutions studied

10x10cm² MM boards with 400µm pitch strips

Several types of resistive detectors (including last design with buried resistors from R. de Oliveira et al.)

Prototypes featuring a GEM foil



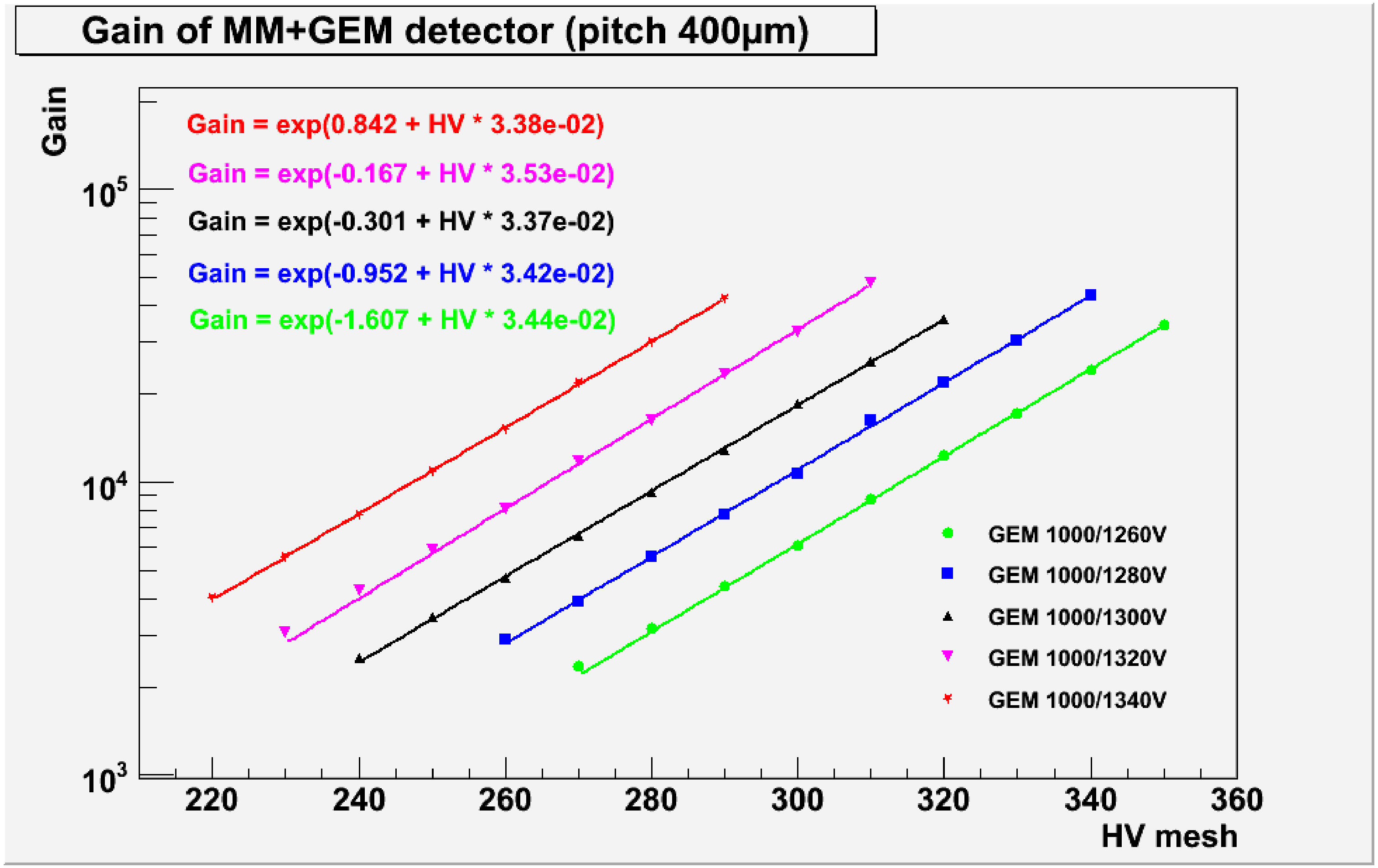
Tests with different conditions

High flux 150 GeV hadron beam at CERN SPS (2009, 2010) in framework of RD51 collaboration

High flux 150 GeV muon beam (2009, 2010) for performance measurements

Low energy (0.3-3 GeV) hadron beam at PS (2010)

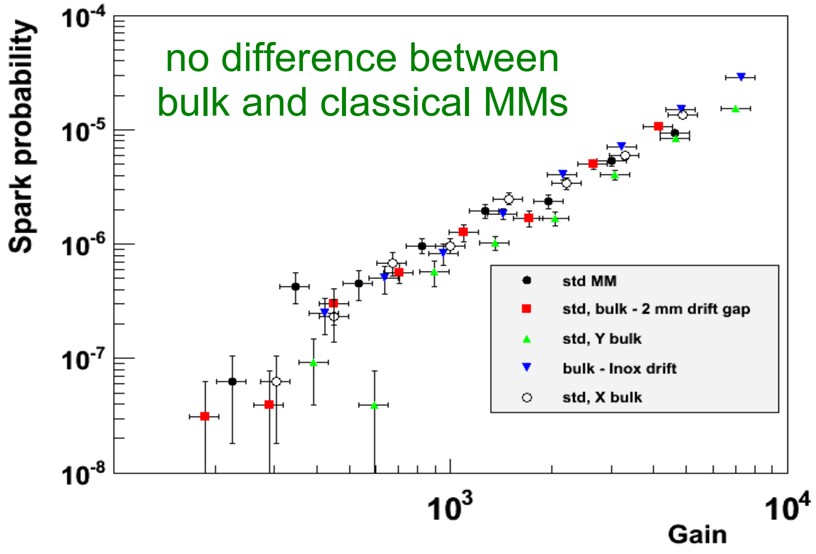
Gain of “MM+GEM” detector

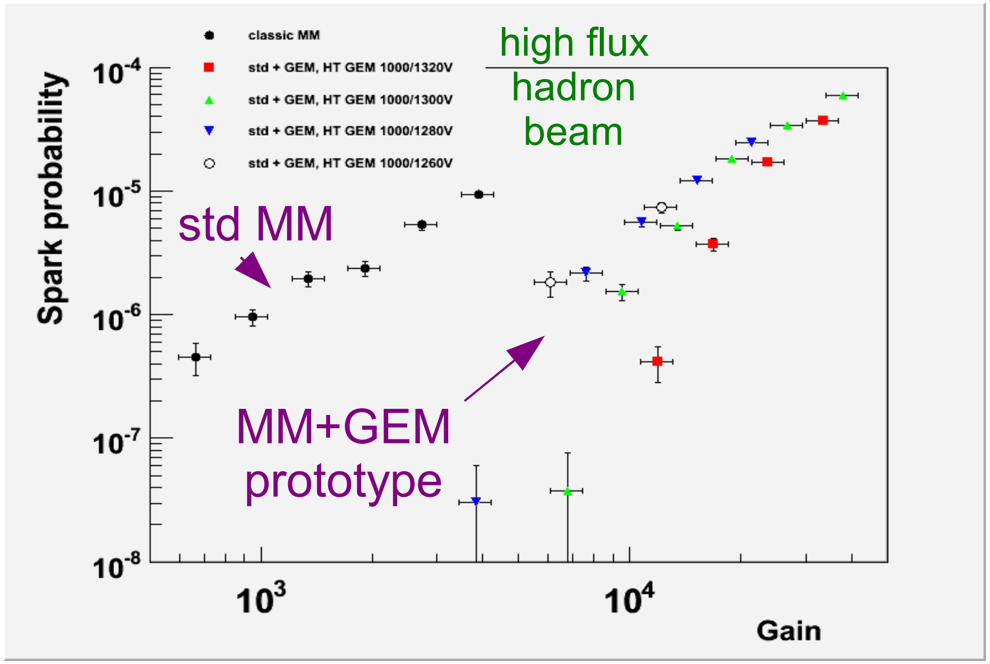


2 parameters only: HT mesh and HT top GEM

Gain detector = gain MM * gain GEM

Spark probability of MM+GEM (2009 tests)



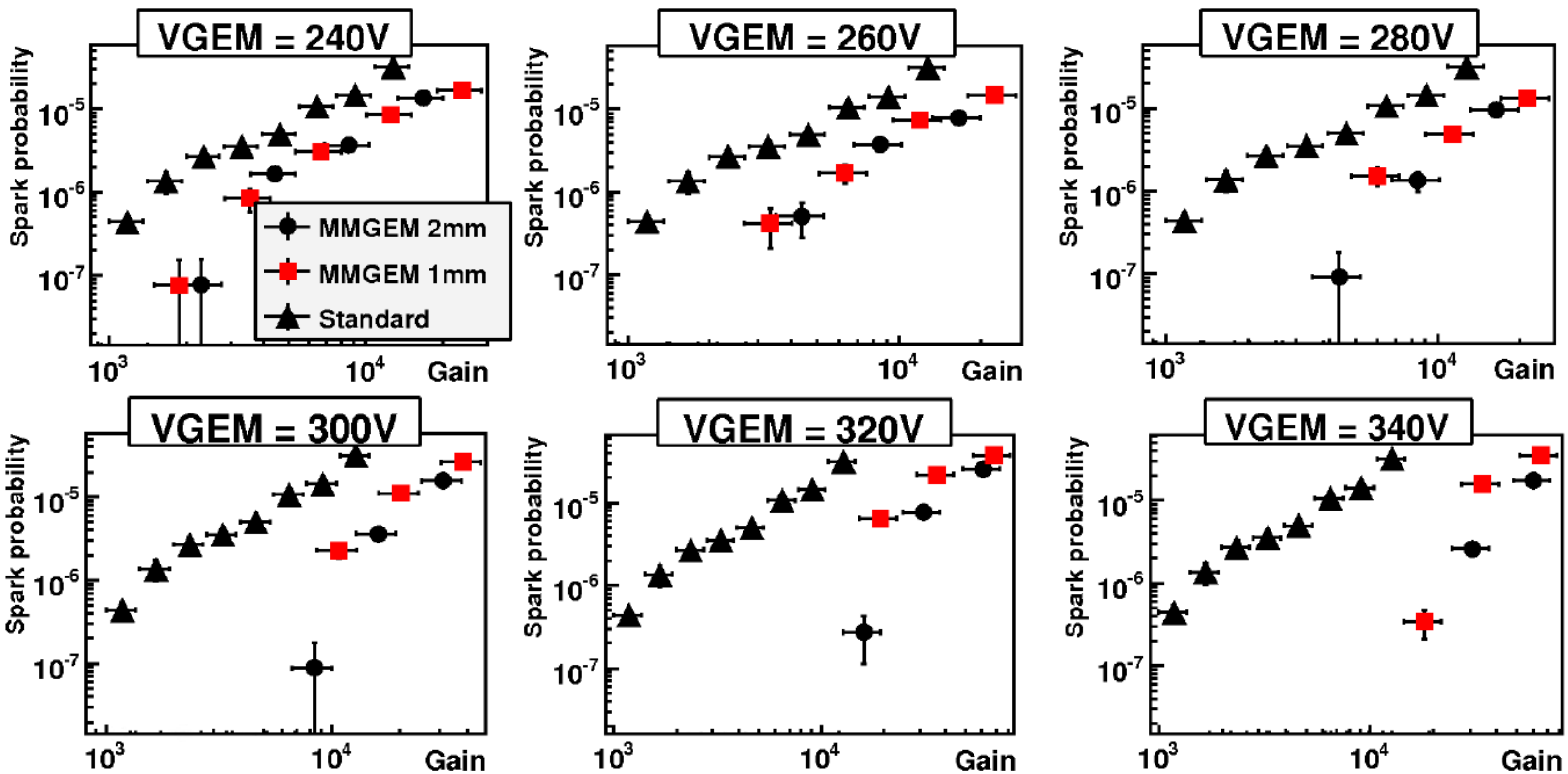


Rate reduced by 10 to 100 with MM+GEM prototype compared to standard Micromegas

Spark probability of MM+GEM (2010 PS tests)

2 MM+GEM prototypes

1 and 2mm distance between mesh and GEM foil



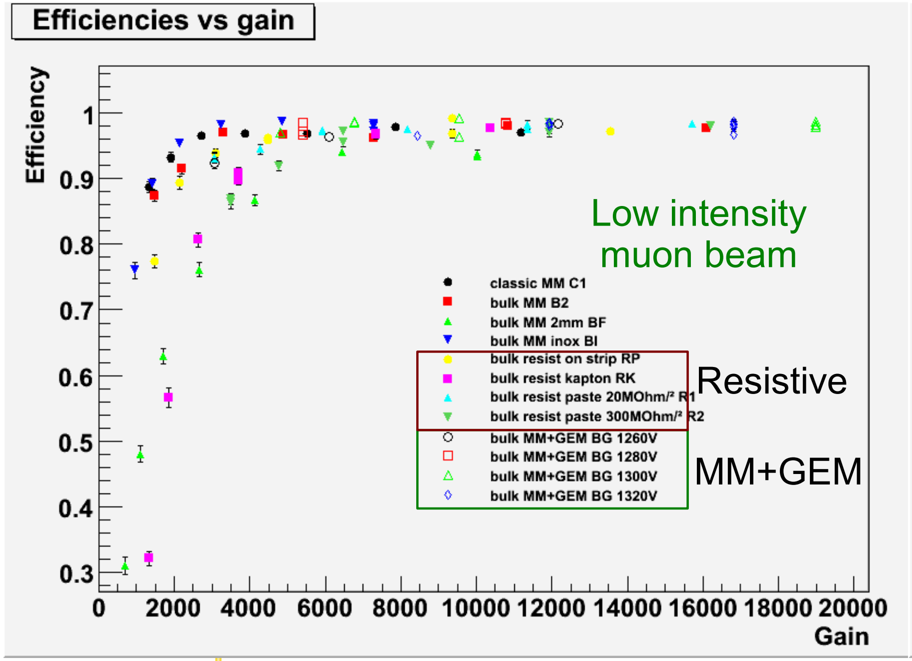
S. Procureur

2 effects which explain discharge rate reduction:

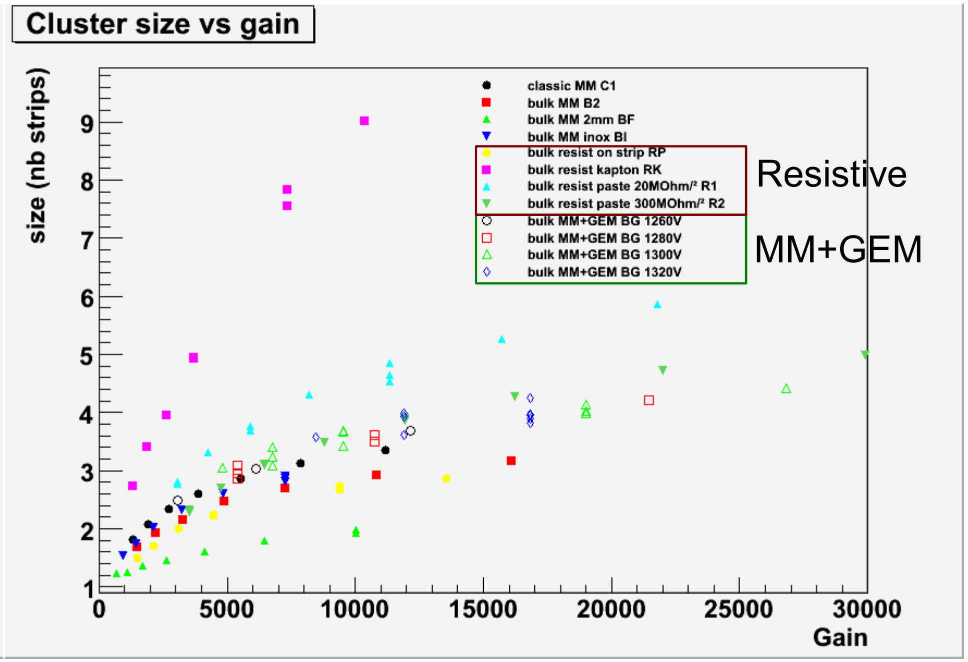
- lower gain on mesh stage (charges deposited between GEM and mesh)
- charge dispersion between GEM and mesh (charges before GEM)

Efficencies and cluster sizes vs gain (2009 tests)

Prototypes efficiencies

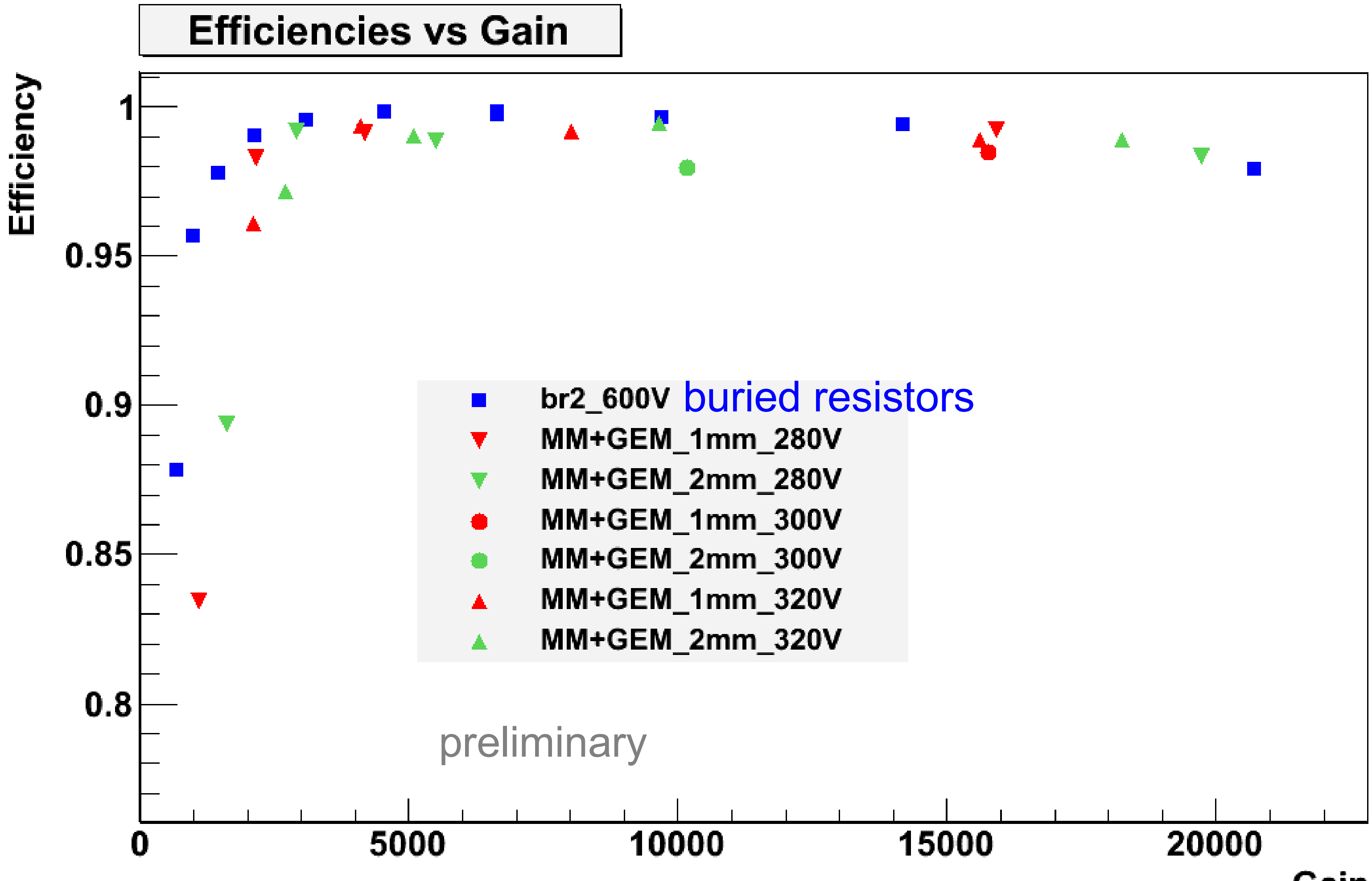


Cluster sizes



Efficiencies (2010 SPS tests)

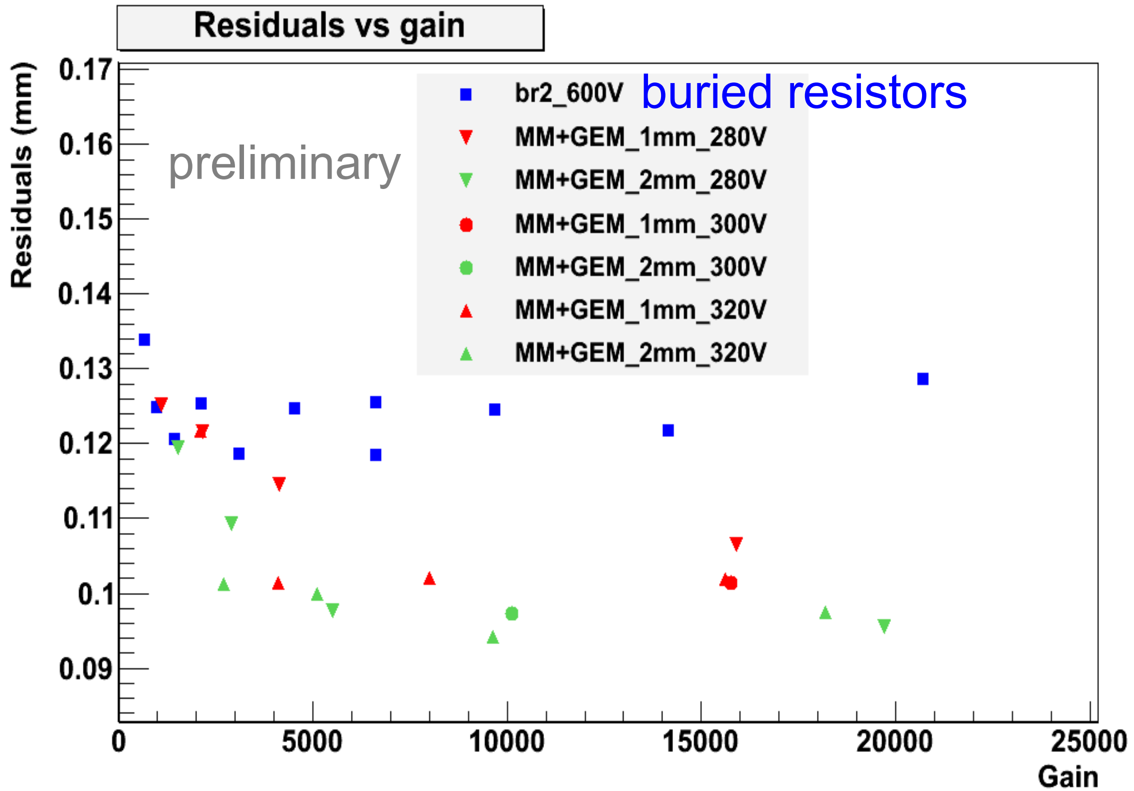
Tests with muon+hadron beam (RD51 tests)



M. Vandenbroucke

Residuals (2010 SPS tests)

Tests with muon+hadron beam (RD51 tests)



M. Vandenbroucke

MM+GEM is a solution

- discharge rate decreased by factor >>10
- efficiencies and spatial resolution ok

Buried resistor promising solution, further studies needed

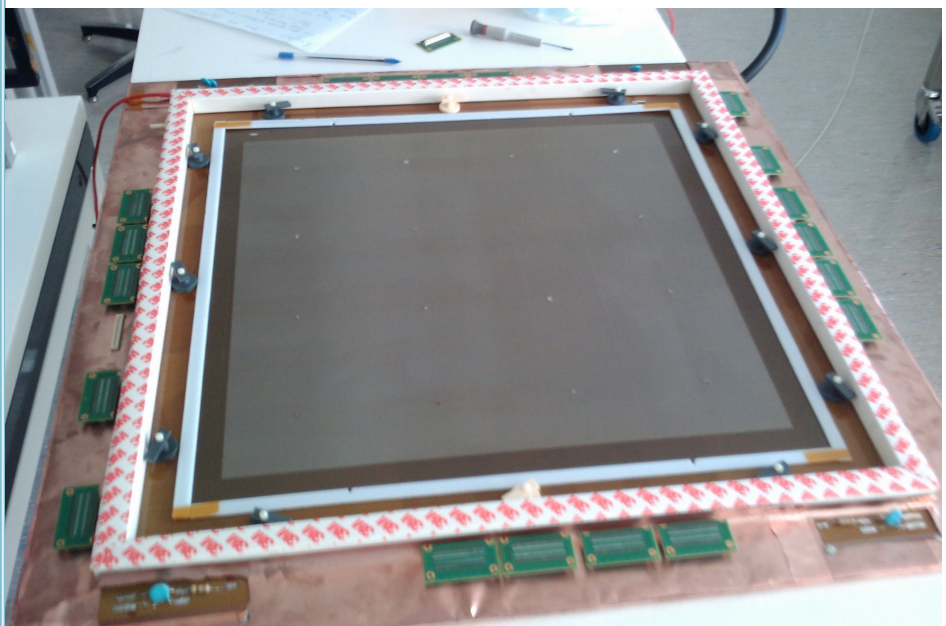
- spatial resolution
- gain at high flux
- production of large size detectors

Activités prévues en 2011

2 détecteurs MM+GEM pixel de grande taille

1 prototype installé à COMPASS

But: optimisation fonctionnement détecteur (HT) et électronique



1 prototype « résistances enterrées » pixel grande taille

En cours de développement au CERN, prévu pour l'automne 2011

Conclusions

Design de détecteurs MM de grande taille pixellisés en cours de validation

Dessin incluant 1280 pixels au centre du détecteur

Lecture par circuits APV25 validés, performances similaire à l'électronique utilisée sur les détecteurs actuels

Performances en faisceau en cours d'analyse

Réduction de l'impact des décharges

Excellents résultats de la solution avec feuille GEM additionnelle, à valider sur des détecteurs de grande taille

Pas de solution validée avec couche résistive

Mais résultats intéressants des prototypes « résistances enterrées », études à compléter

Prochaines étapes

2011: prototypes avec feuille GEM et avec résistances enterrées en test

2012: début de la production des nouveaux détecteurs