Irfu - CEA Saclay
Institut de recherche
sur les lois fondamentales
de l'Univers

Pixelized Micromegas detector with low discharge rate for the COMPASS experiment

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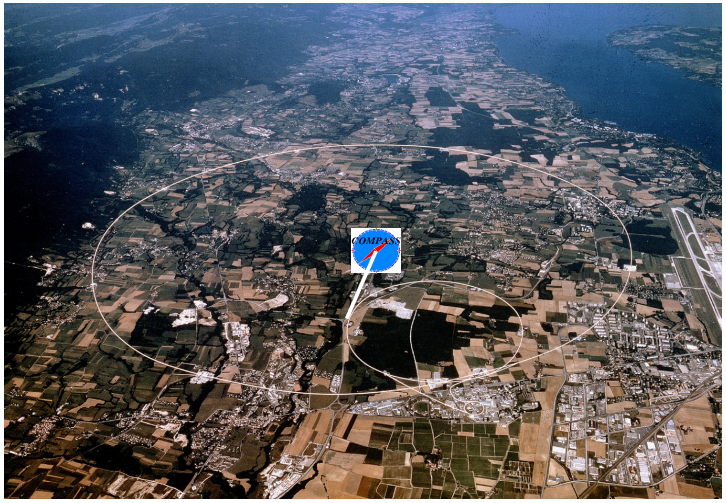
Outline

- The COMPASS experiment at CERN
- The Pixel Micromegas Project
- R&D on discharge rate reduction technologies
- Large size prototypes in the COMPASS setup
- Conclusion
- Outlook
- Plans for 2012

The COMPASS experiment at CERN

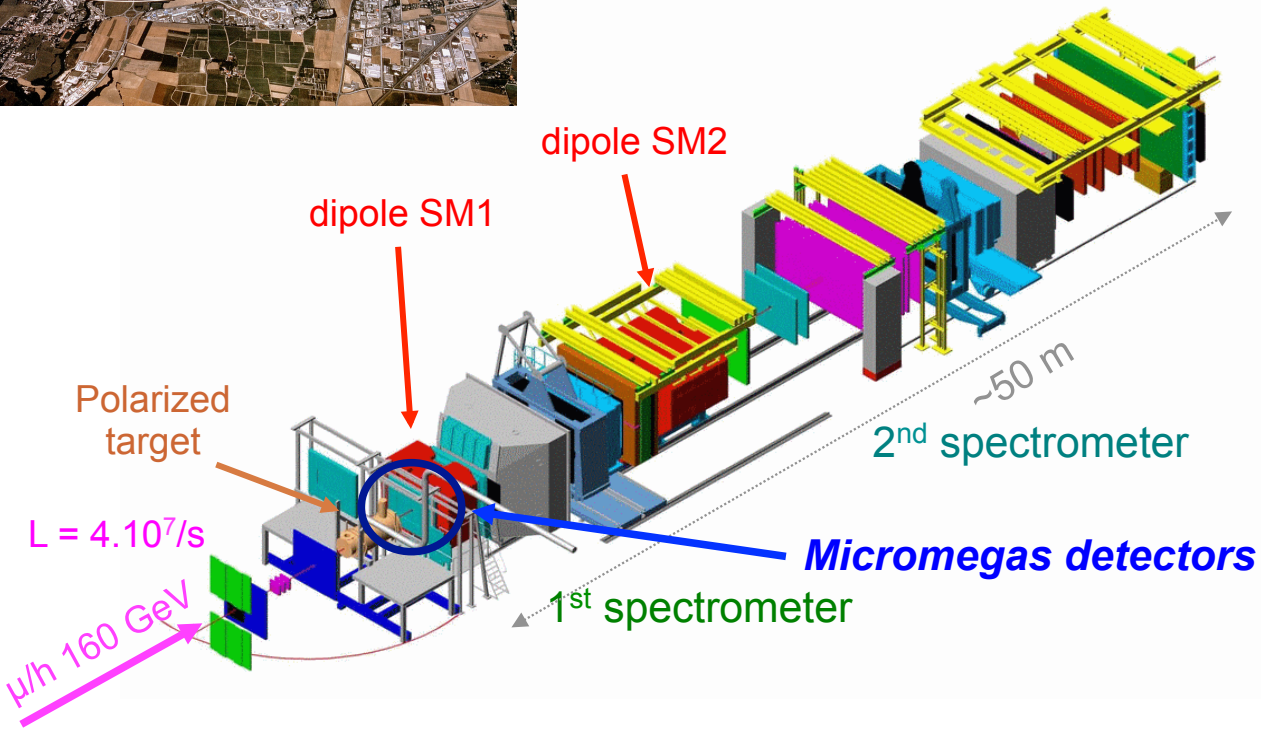


Dedicated to nucleon structure and spectroscopy studies

High resolution spectrometer at small and large angles

High statistic experiment (30kHz trigger rate)

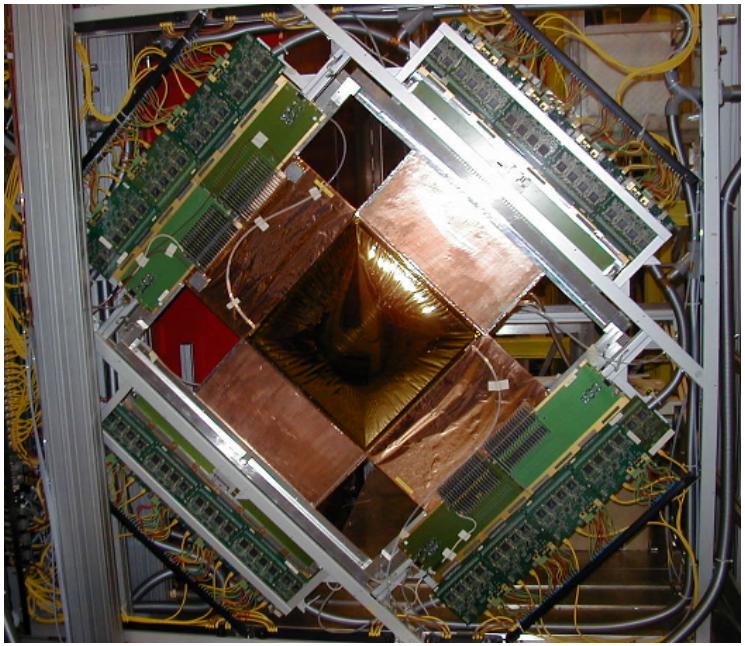
Very good spatial resolution (<100µm) required at small angle for kinematics and particle identification



Present COMPASS Micromegas detectors

- 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, beam area)*
  - *Discharge rate in amplification gap is limiting factor with hadron beam*



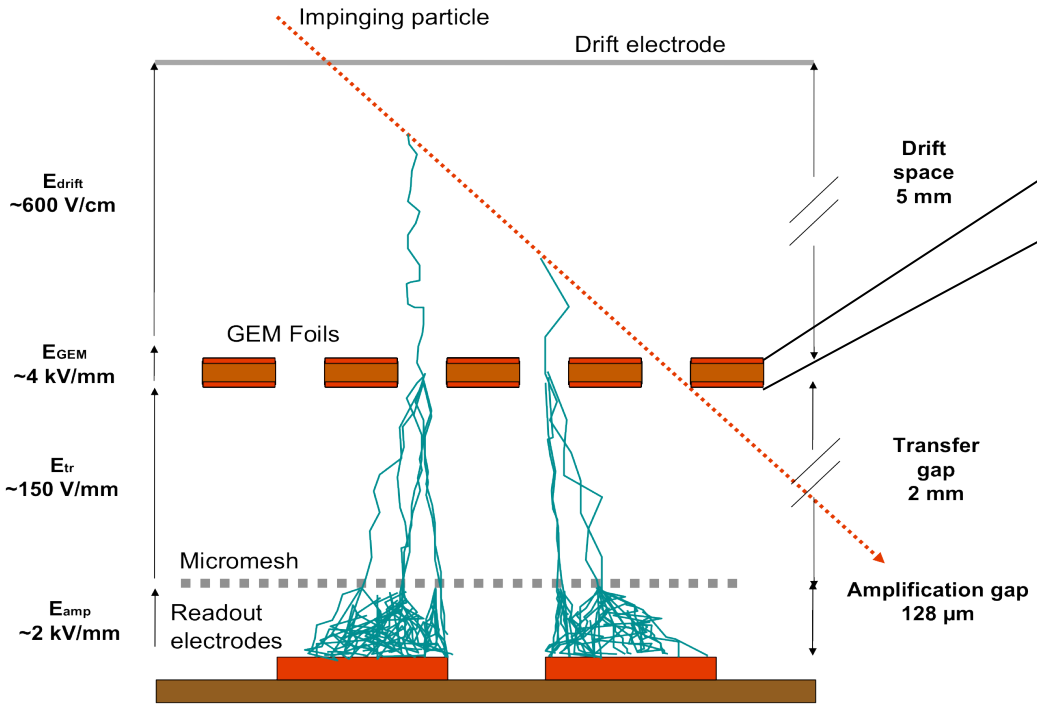
The Pixel Micromegas Project

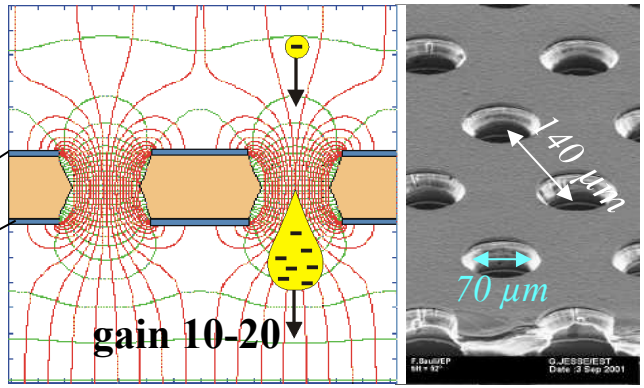
- Main Objectives
  - *Fewer Discharges -> Stand five time higher flux hadron beams*
  - *Detector active in beam area*

- New MM detector to design with :
  - *10 to 100 times fewer discharges compared to present MM*
  - *Read-out with pixels in the detector center (beam area)*
  - *Integrated electronics (APV25 chips)*
  - *Improved robustness (bulk technology)*

The Pixel Micromegas Project

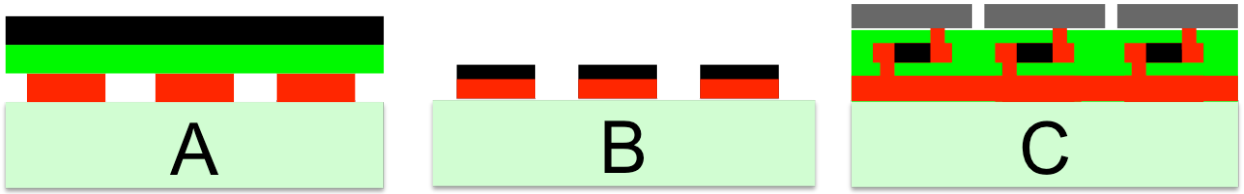
- 2 solutions investigated to reduce the discharge rate :
  - *Preamplification stage with a GEM foil*
    - Gain shared between amplification gap and GEM foil
    - Diffusion of the primary electron cloud





The Pixel Micromegas Project

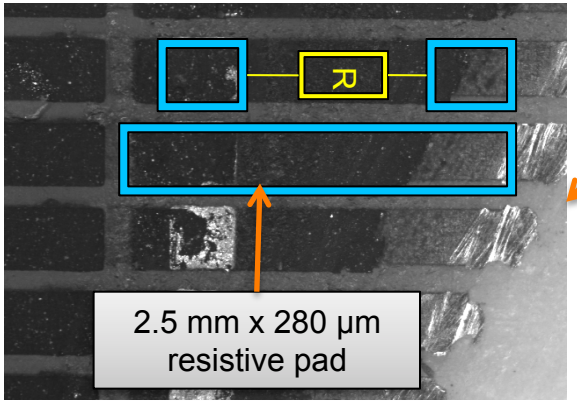
- 2 solutions investigated to reduce the discharge rate :
  - *Resistive layer on readout electrodes*
    - Quick rise of the electrode's potential
    - Limitation of the discharge intensity

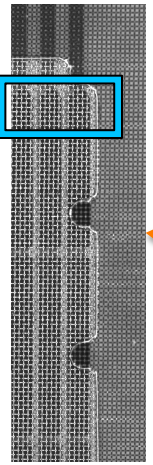


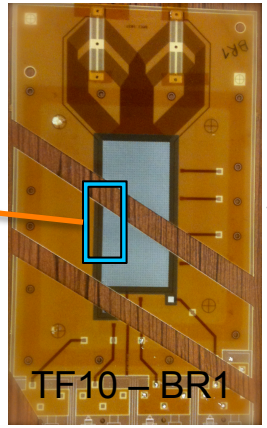
A) Resistive layer +insulator layer on top of strips

B) Resistive paste on top of strips

C) Buried resistors "BR" connecting strips to resistive pads





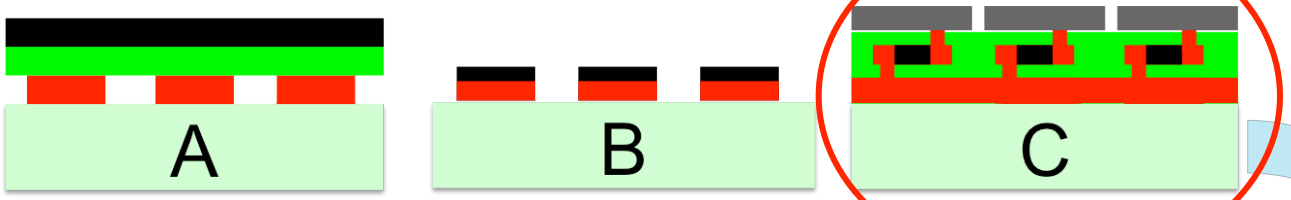


From M.Vandenbroucke

The Pixel Micromegas Project

- 2 solutions investigated to reduce the discharge rate :
  - *Resistive layer on readout electrodes*
    - Quick rise of the electrode's potential
    - Limitation of the discharge intensity

Selected technology for PMM project



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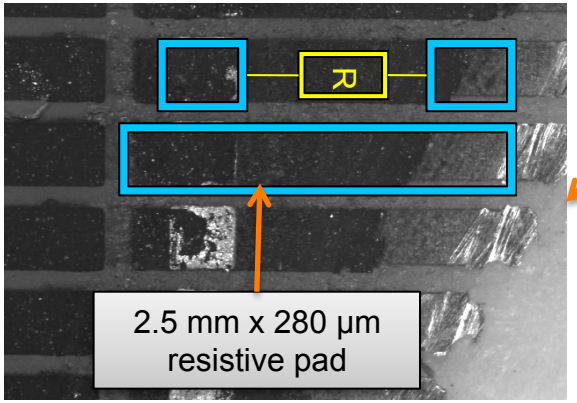

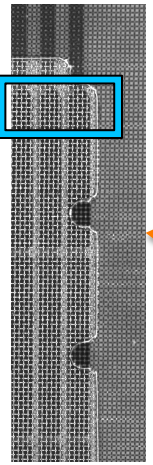

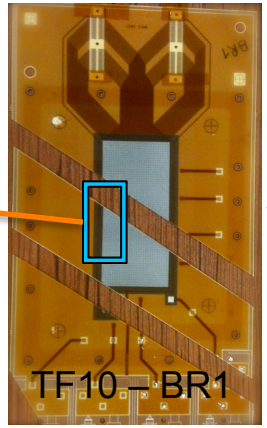

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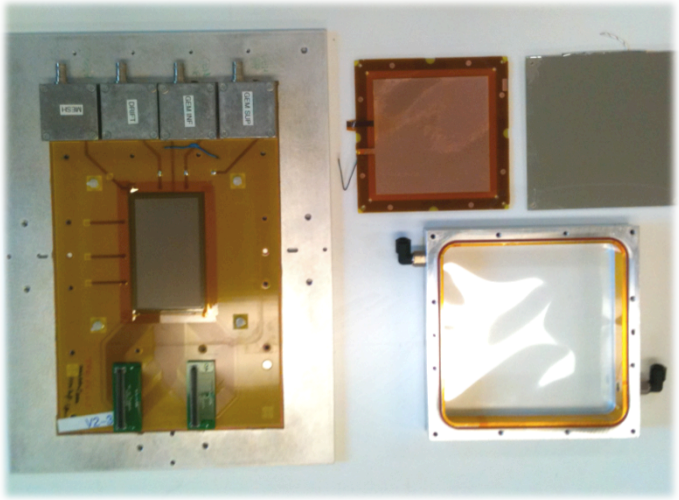
R & D on discharge rate reduction technologies

TF 10 Prototypes :



- 144 strips with 400µm pitch read by AFTER/T2K FEE
- 5mm drift gap
- 128 µm amplification gap
- 56.7×100mm^2 active area
- Gas 5% iC_4H_{10} / 95% Ar
- Different detectors :
  - *Bulk MM made at CERN and CEA,*
  - *Different meshes*
  - *2 MM with GEM pre-amplification with 1 and 2 mm transfer gap*
  - *2 MM with a resistive layer + isolation on strip (kapton of 1MΩ/□ and resistive paste of 10MΩ/□) and 2 MM with resistive paste on strip*

- *Performance studies at SPS in 170 GeV muon beam*
- *Discharge rate reduction studies at PS in 0.2 to 3 GeV hadron beam*
- Common R&D with CLAS 12 Saclay group

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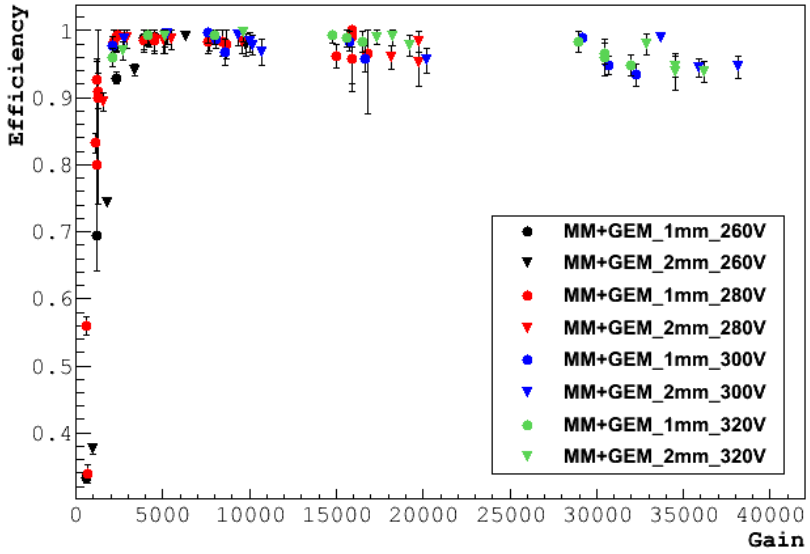
R & D on discharge rate reduction technologies

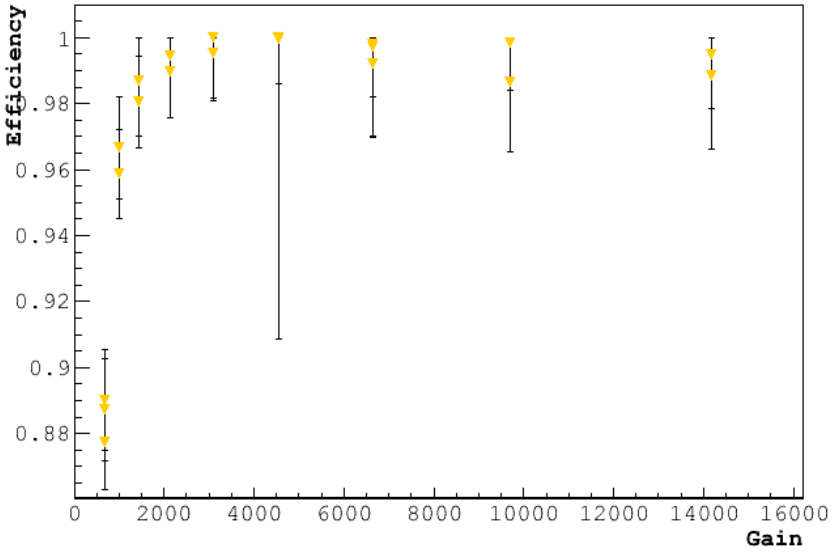
- 170 GeV/c muon beam at SPS (RD51 Beam time) :
  - ➢ *Efficiency plots*

MM + GEM



➢ *MM + GEM detectors : up to 98%*

MM with Buried Resistors



➢ *Above 99% for BR2 detector*

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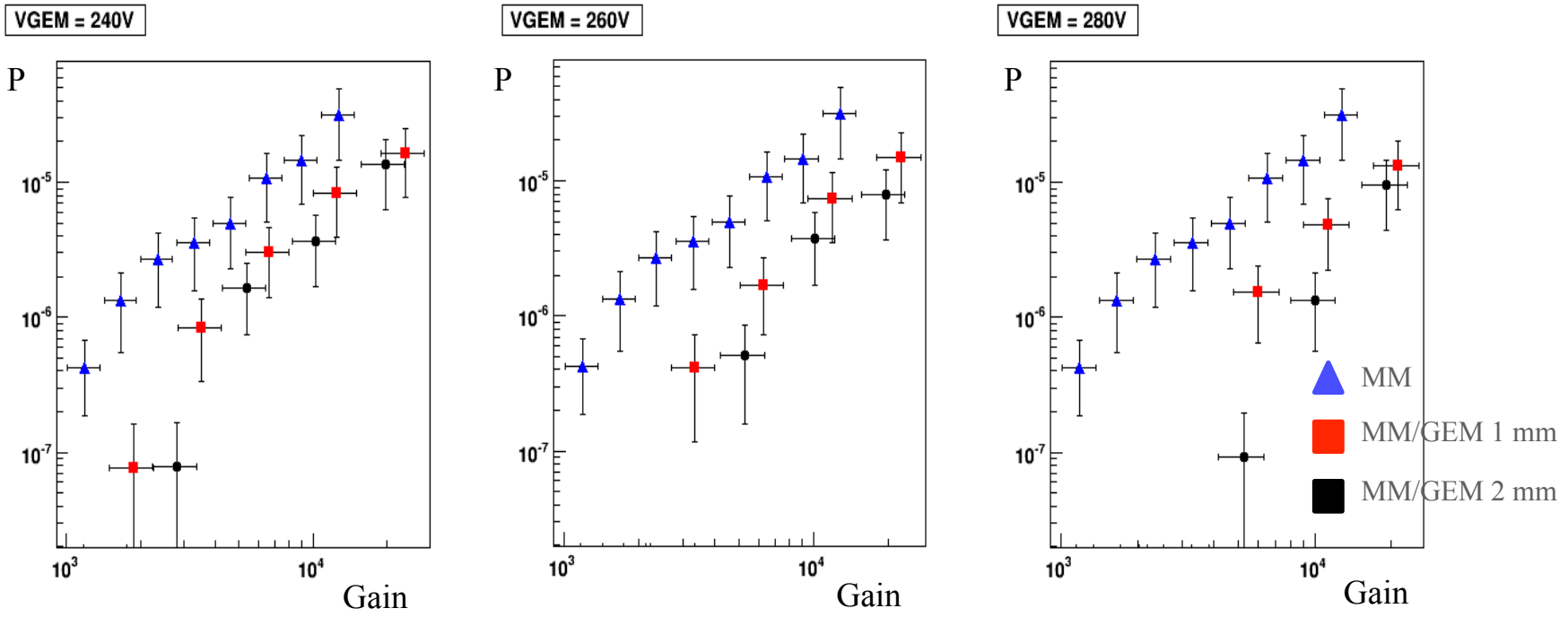
R & D on discharge rate reduction technologies

- [MM+GEM] discharge rate in 0.2 to 3 GeV/c hadron beam (CERN PS)



  - *A GEM pre-amplification reduces the discharge rate by at least a factor 10*

- Resistive detector discharge rate:
  - *No discharge has been detected on resistive detectors with the experimental setup*

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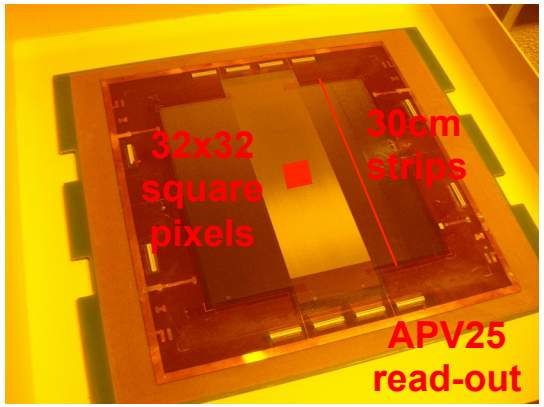
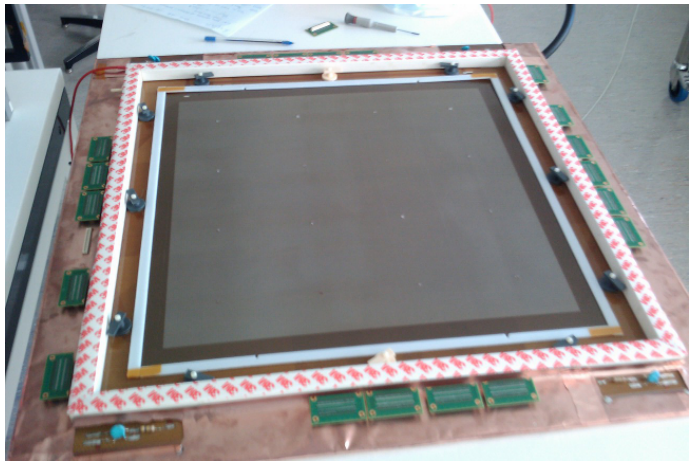
Large size prototypes

- 2009 : First prototypes
  - *Square pixels in the center, APV read-out with MM detectors*
  - *Comparisons bulk / non-bulk*



- 2010 : 40 x 40 cm^2 prototype
  - *Validation of geometry*

- 2011 : 3 40 x 40 cm^2 prototypes
  - *2 large size MM+GEM detectors*
  - *1 large size Buried Resistors prototype*

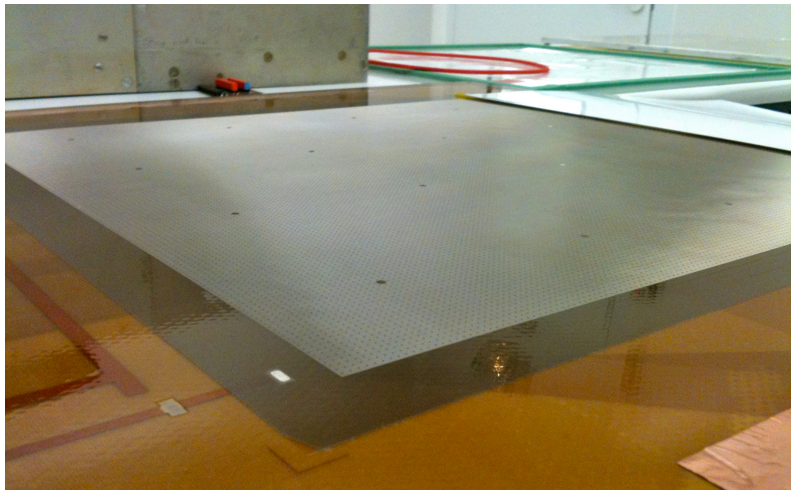


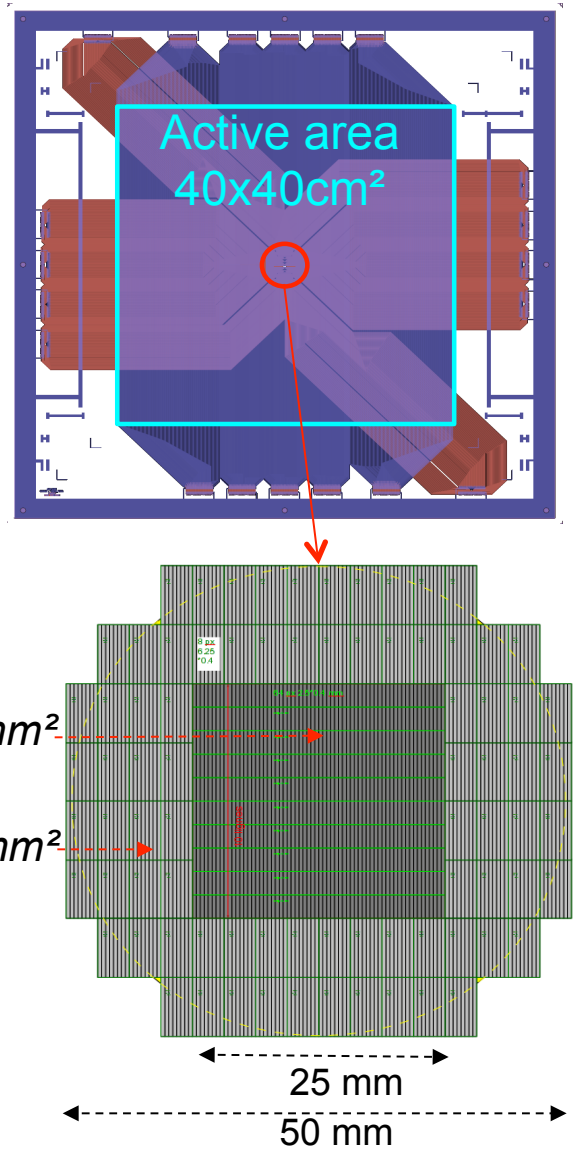
- PCB+Bulk & GEM foils produced at CERN
- Detectors built in Saclay

Large size prototypes

Design of 2010 & 2011 prototypes close to final one

- 40 x 40 cm^2 active area
- 2560 readout channels
  - *1280 strips*
    - *768 of 400 µm x 20 cm (center)*
    - *512 of 480 µm x 40 cm (edges)*
  - *1280 rectangular pixels*
    - *640 of 400 µm x 2.5 mm*
    - *640 of 400 µm x 6.25 mm*



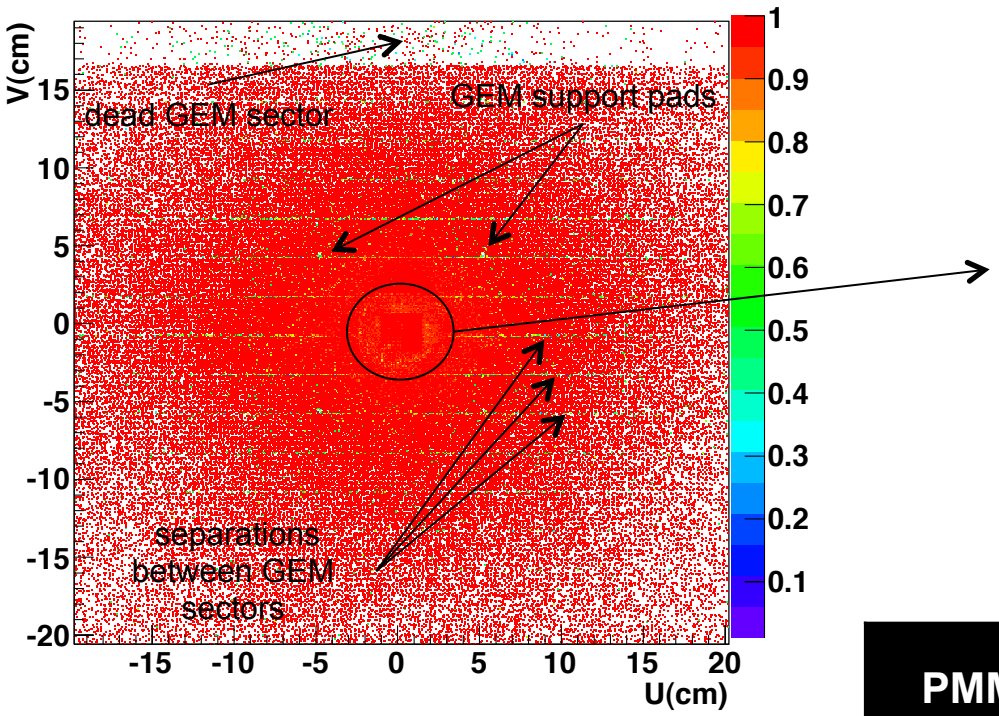


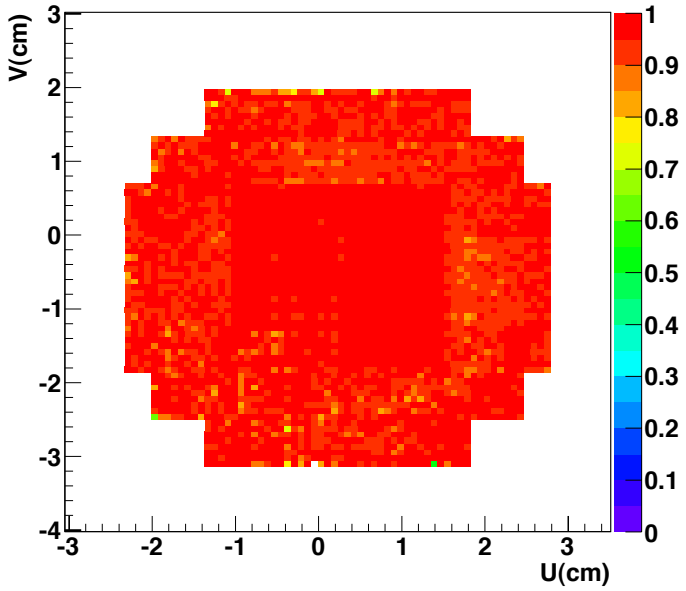
Large size prototypes

- All prototypes tested in COMPASS conditions :
  - *200 GeV muon beam*
  - *flux around 10^7 μ/s*
  - *fringe fields from target and first dipole*
  - *integrated in the DAQ system*
  - *reconstruction and analysis with COMPASS softwares*

Large size prototypes

- PMM + GEM : Efficiency
  - *2011_1 prototype – voltages 300 V / 320 V - Gain ~ 6000*

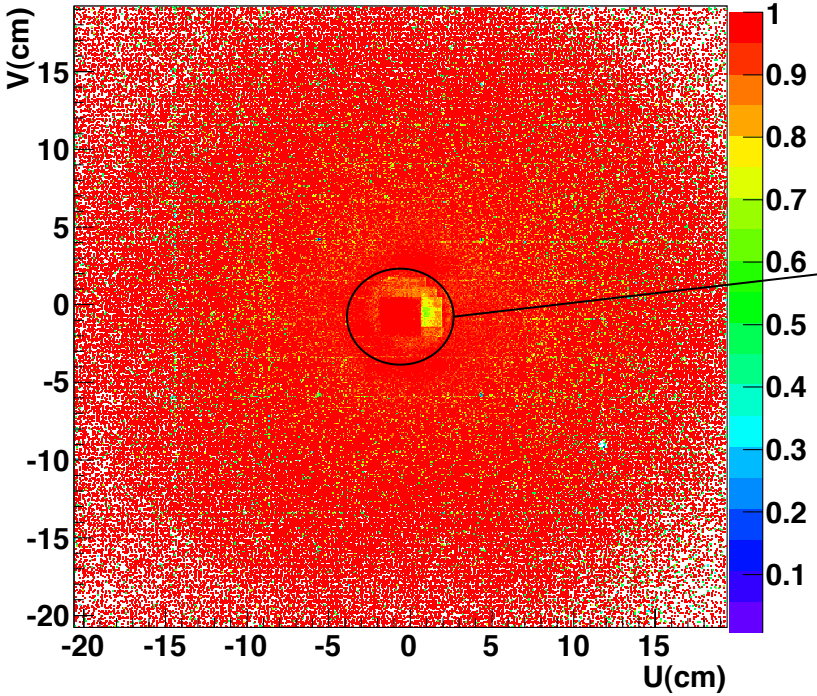


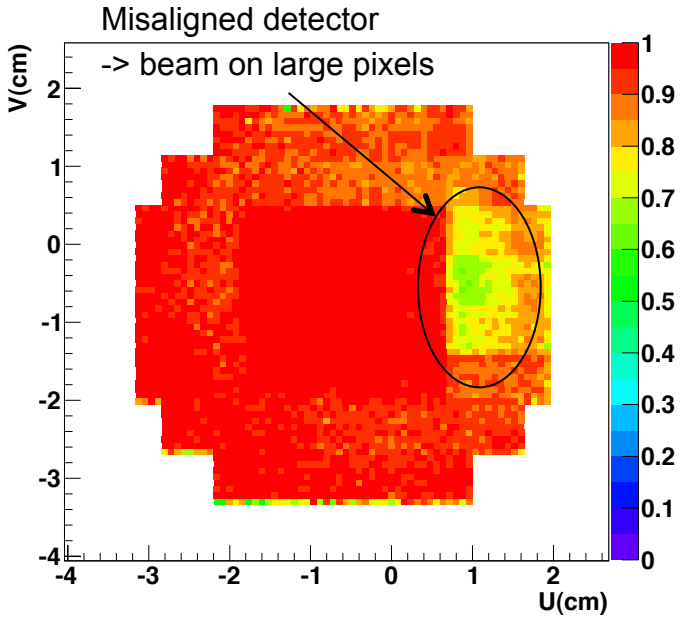


PMM_2011_1	Efficiency (dead sector excluded)
Pixels	96.6%
Strips	97.9%
Global	97.2%

Large size prototypes

- PMM + GEM : Efficiency
  - *2011_2 prototype – voltages 300 V / 320 V - Gain ~ 6000*



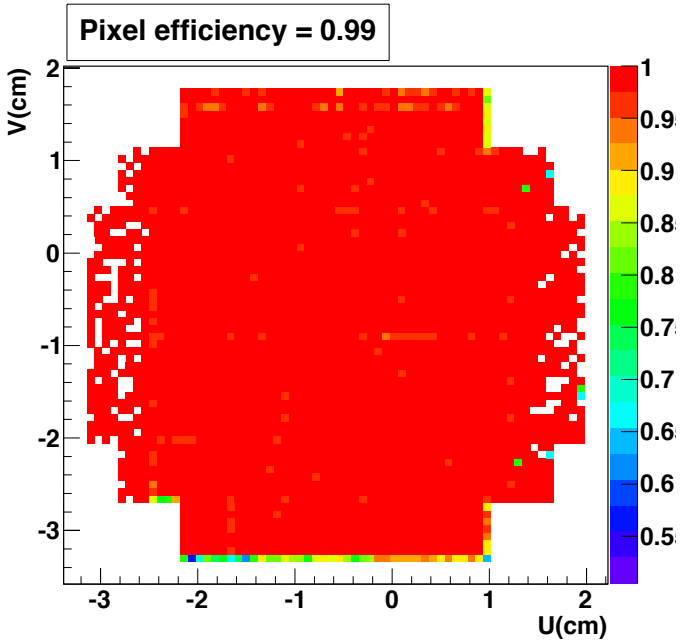


PMM_2011_2	Efficiency
Pixels	93.7%
Strips	98.1%
Global	96.5%

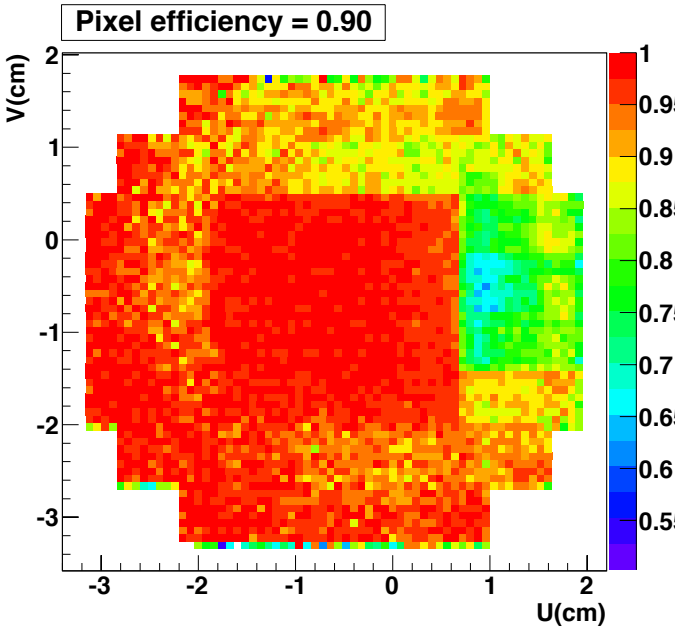
Large size prototypes

- Efficiency drops on large pixels at high beam intensity

Low beam intensity (~10^6 μ/s)



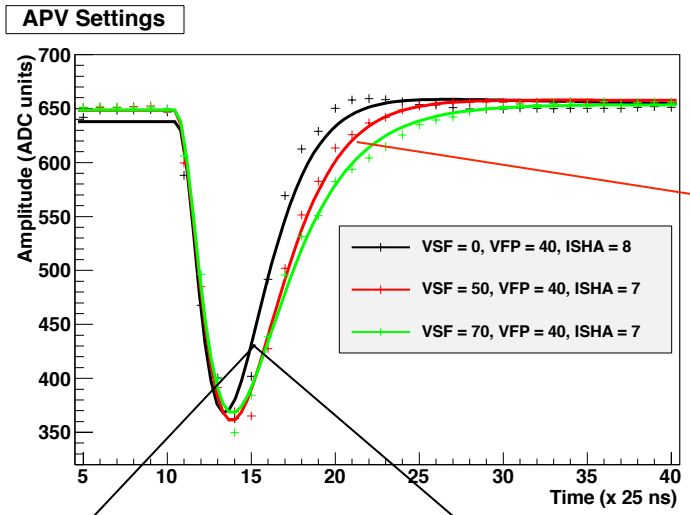
High beam intensity (~10^8 μ/s)



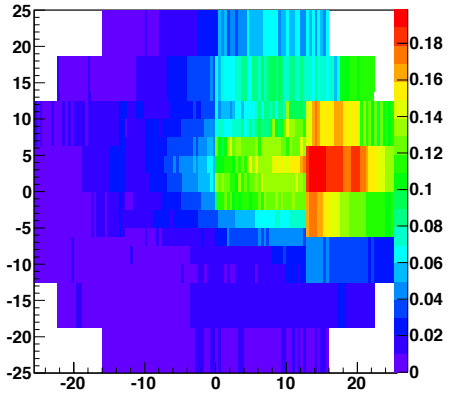
- 2 possible sources :
  - *electronics occupancy*
  - *clustering in the pixel area*

Large size prototypes

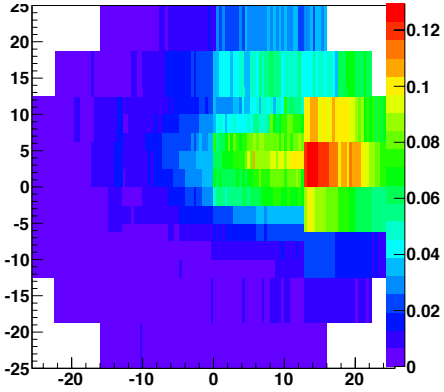
- Efficiency drops on large pixels at high beam intensity
  - *Reduction of the electronics occupancy (-> shorter APV shaping)*

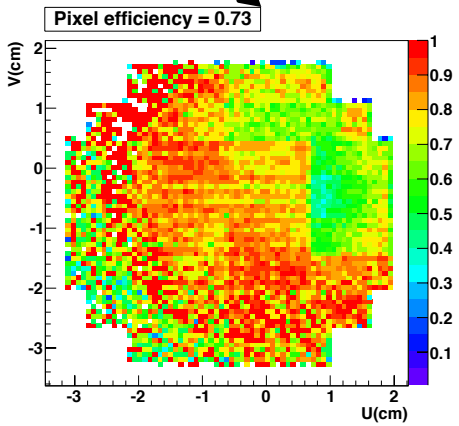


occupancy



occupancy



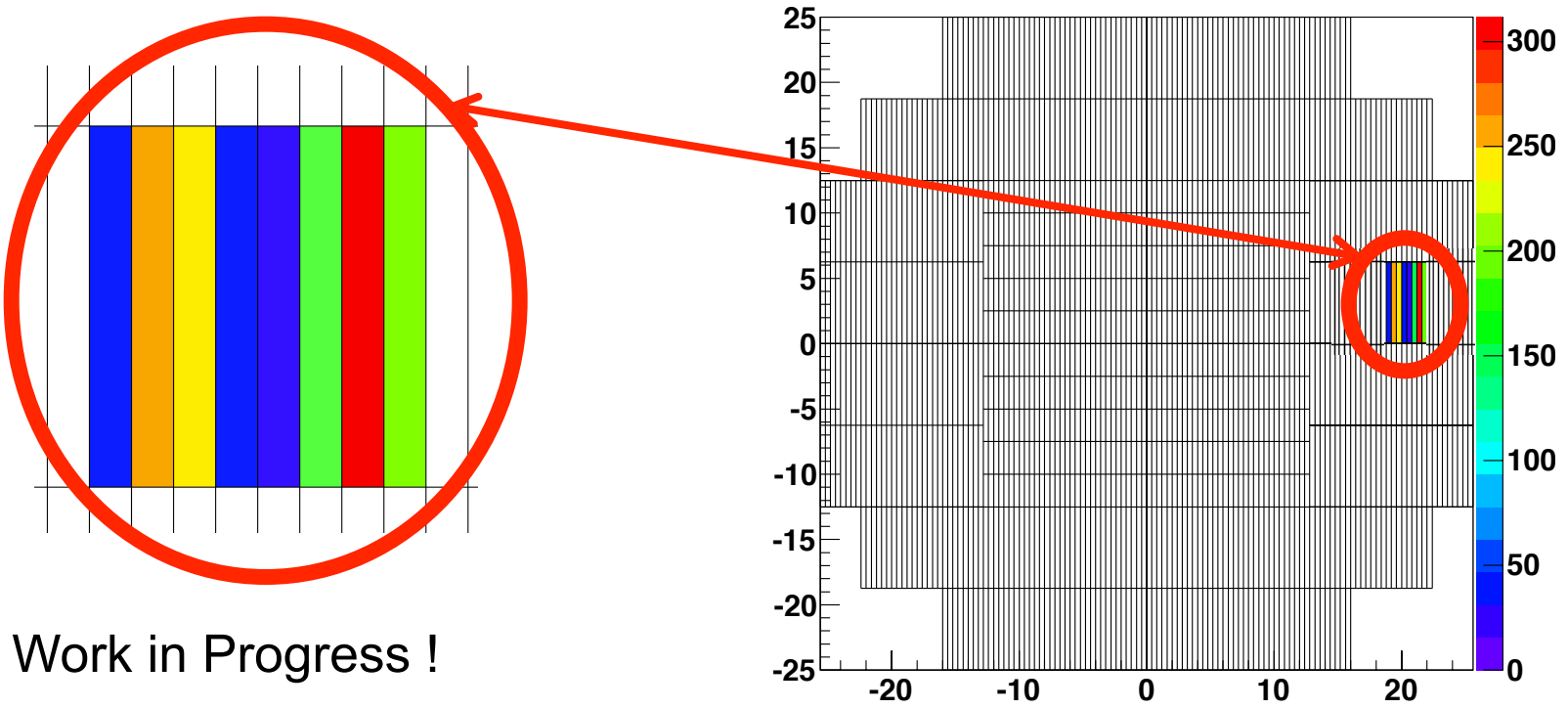


Occupancy decreases but efficiency drops globally,

probably due to undershoot or ballistic deficit

Large size prototypes

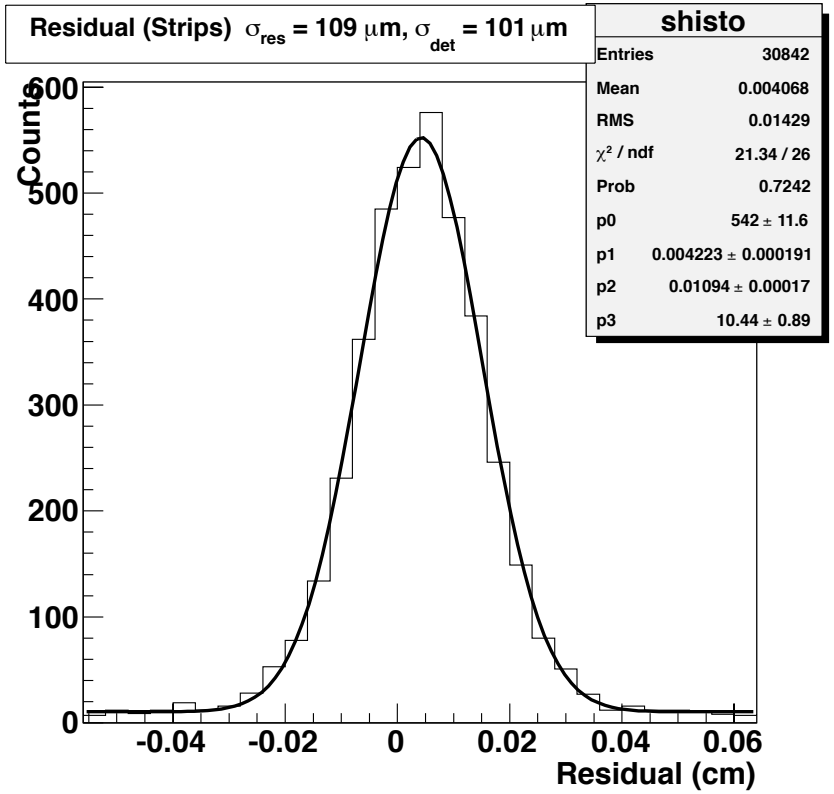
- Correction of the clustering in the pixel area :
  - Current clustering is pretty basic (and maybe bugged)
  - At high flux, several clusters can « pile up » and be interpreted as one unique cluster
    - Wrong position determination

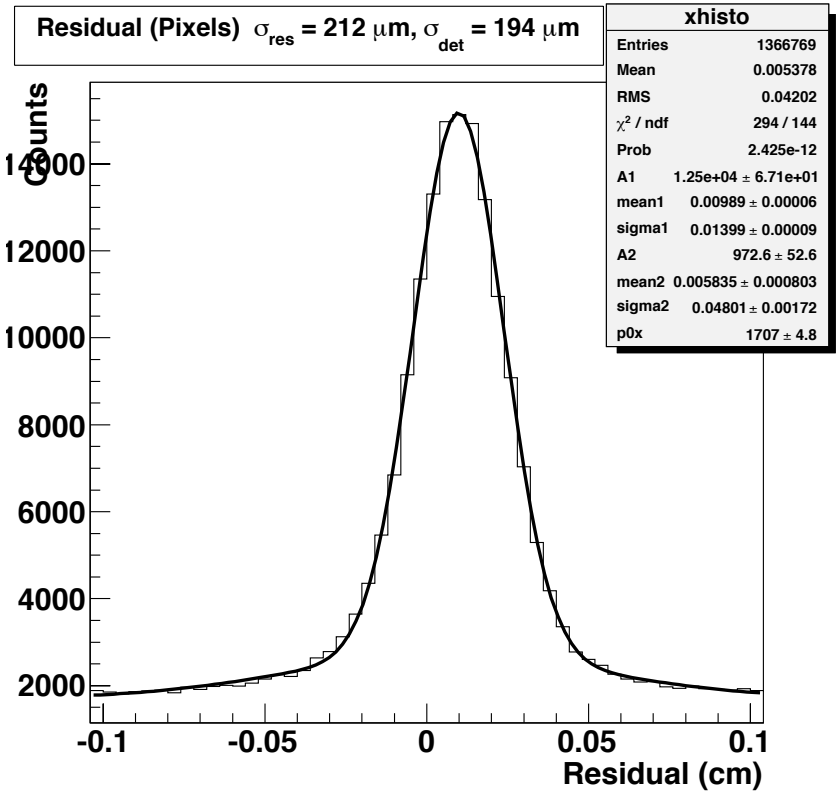


- Work in Progress !

Large size prototypes

- PMM + GEM : Residuals
  - *2011_1 prototype – voltages 300 V / 320 V - Gain ~ 6000*

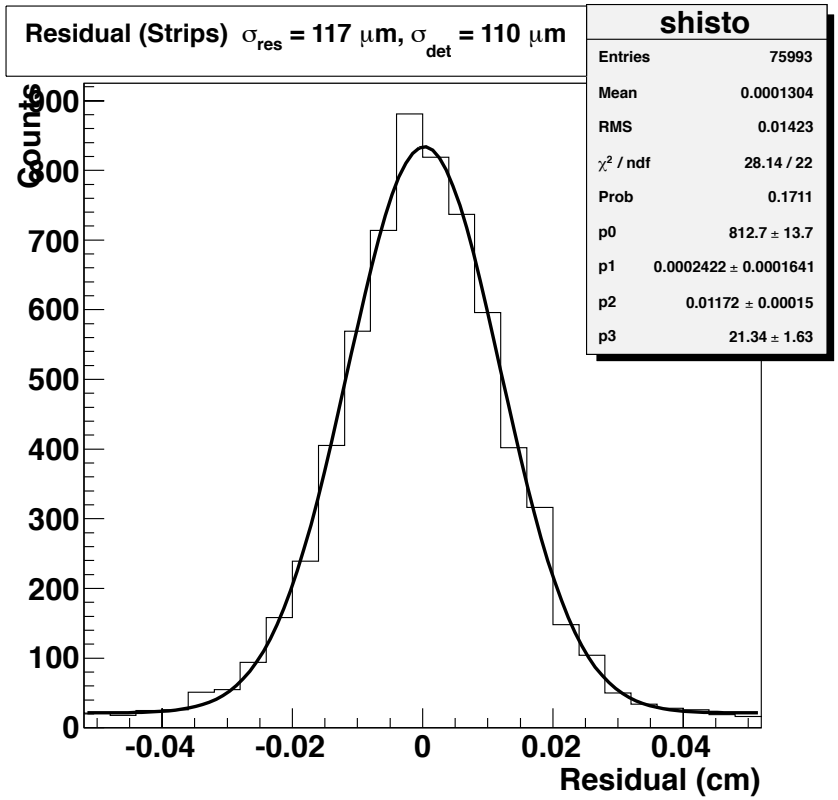


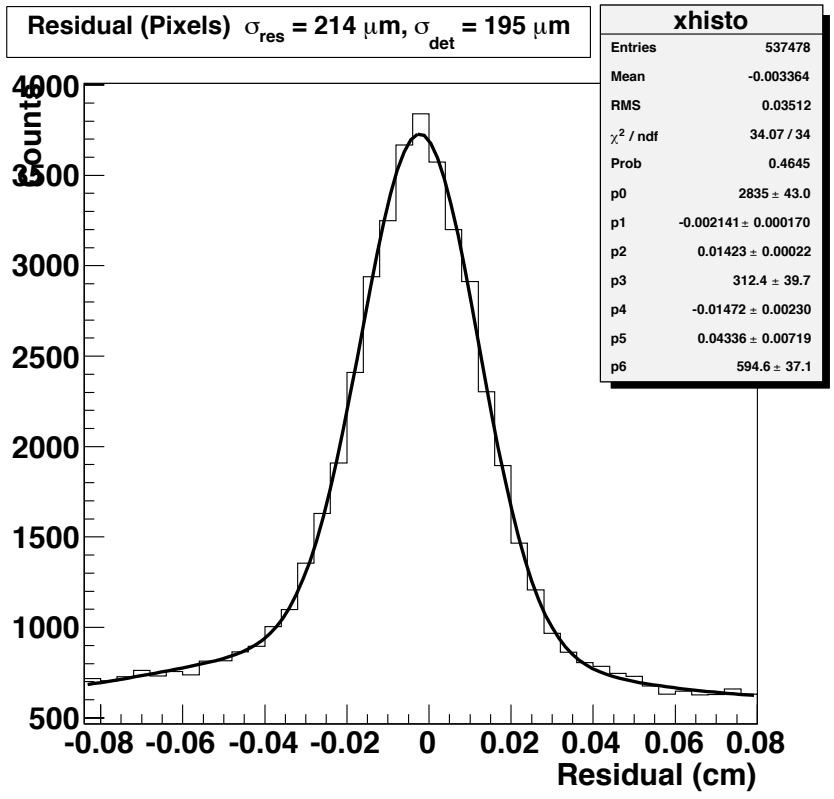


- *Good results on strips (comparable to present COMPASS MM)*
- *Higher values on pixels : clustering algorithm to be corrected*

Large size prototypes

- PMM + GEM : Residuals
  - *2011_2 prototype – voltages 300 V / 320 V - Gain ~ 6000*

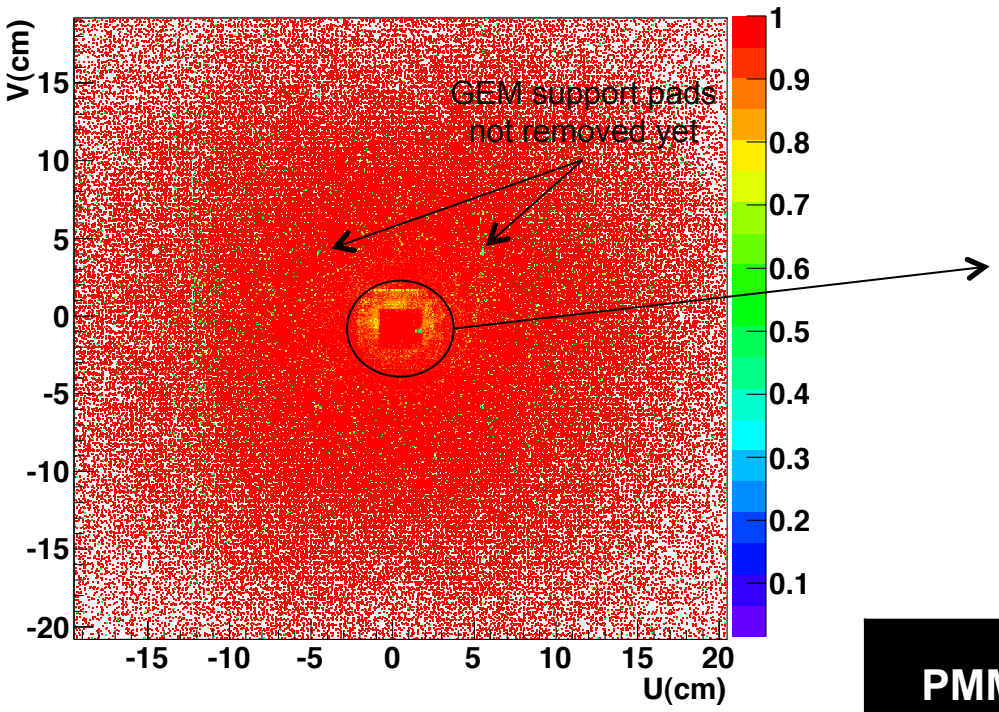


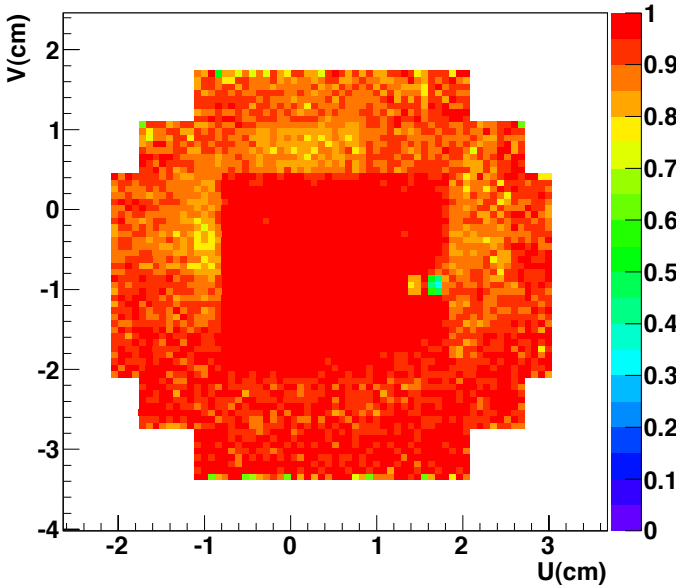


- *Good results on strips (comparable to present COMPASS MM)*
- *Higher values on pixels : clustering algorithm to be corrected*

Large size prototypes

- PMM with Buried Resistors : Efficiency (PRELIMINARY)
  - *mesh voltage 470 V - Gain ~ 8000*





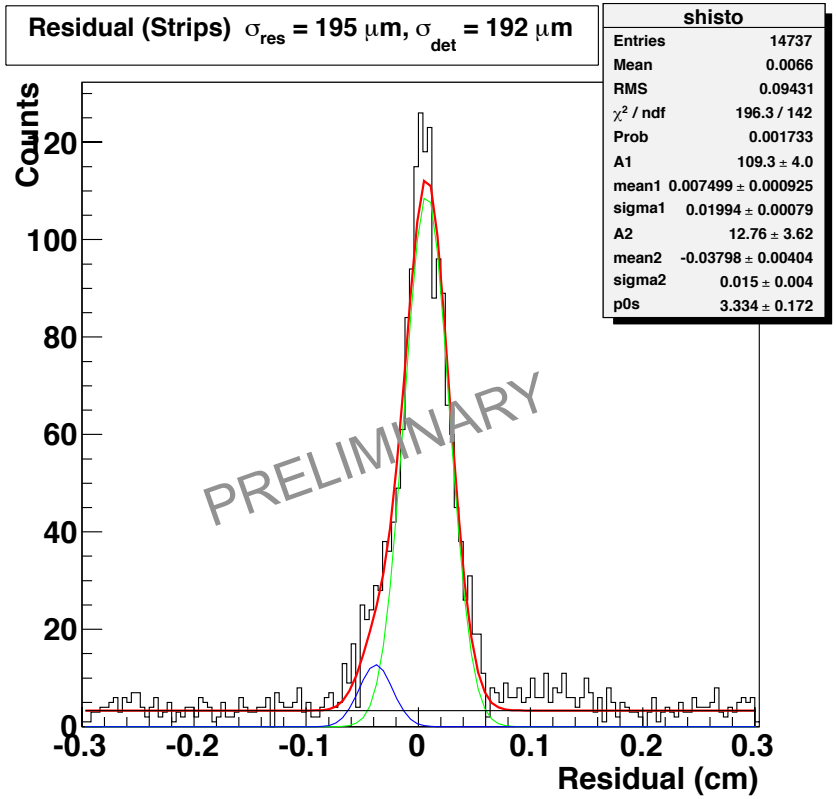
Quickly built in Saclay before Installation

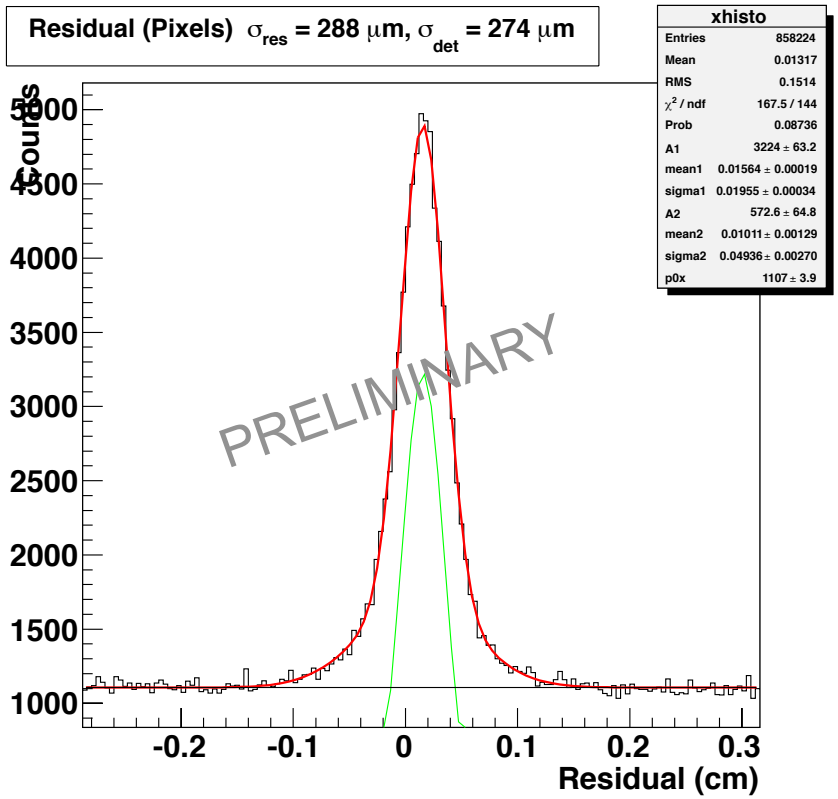
- several cut channels

PMM_2011_3	Efficiency
Pixels	95.7%
Strips	97.8%
Global	96.8%

Large size prototypes

- PMM with Buried Resistors : Residuals (PRELIMINARY)
  - *mesh voltage 470 V - Gain ~ 8000*





- *Results not satisfying yet, reconstruction must probably be adapted*

Conclusion

- 3 Prototypes working in real COMPASS conditions
- No spark observed in 2011 (muons), even at high gain
- Bulk technology proved to be robust and feasible for large detectors

Preliminary results	Efficiency	Res. Strip (μm)	Res. Pixels(μm)
PMM_2011_1	97.2%	101	194
PMM_2011_2	96.5%	110	195
PMM_2011_3 (BR)	96.8%	192	274

Outlook

- Analysis
  - Pixels clustering
  - APV shaping tuning tests
  - Time resolution studies

- Tests on BR prototypes:
  - Charging effect test on with X-ray generator at Saclay
  - Electronic simulation of the resistive circuit
  - Reconstruction to be optimized

Activities in 2012

- Plans for 2012 COMPASS run :
  - one MM doublet replaced by 2 PMM + GEM
  - PMM 2011_BR in prototype position during commissioning period, for performance measurement in hadron beam
- R&D on detector production :

➢ Objective : going to industrial production of large size PMM

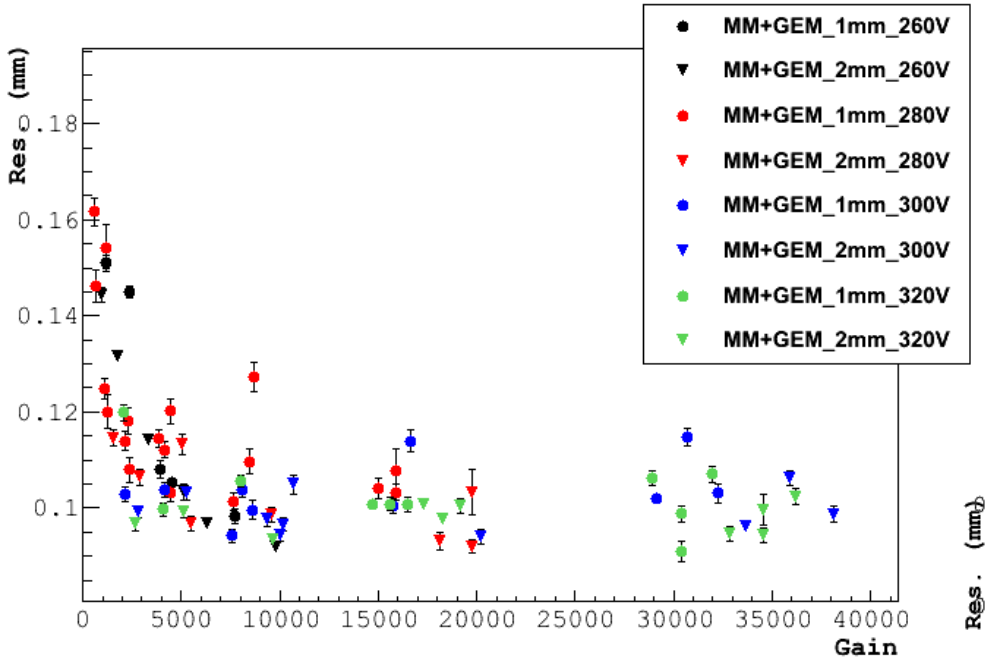
- R&D initiated with Cirea to produce bulk MM
  - PMM prototype produced at Cirea in 2012
- R&D with Cirea on buried component board production
  - Small buried resistor MM prototype in 2012

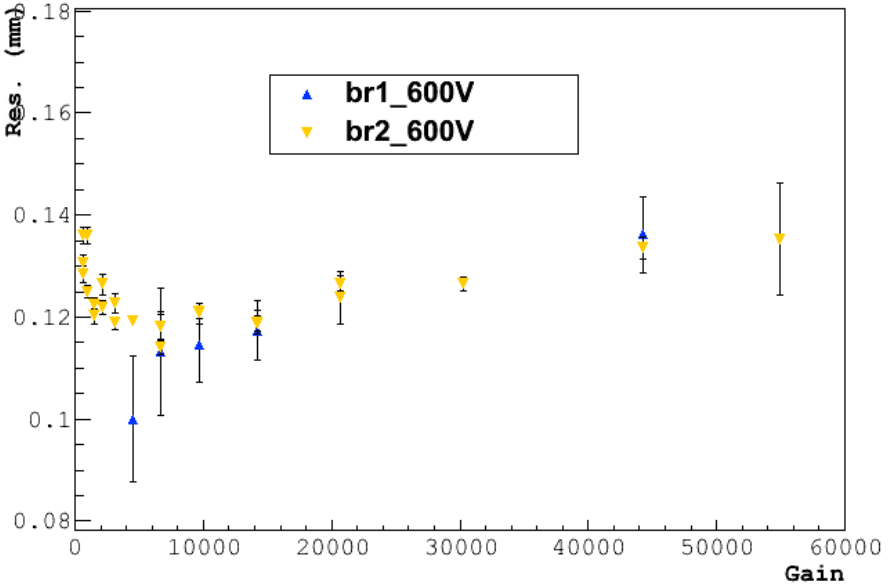
Grant obtained from ANR for this R&D

- Final objective : all COMPASS Micromegas replaced by new detectors in 2014

Spares

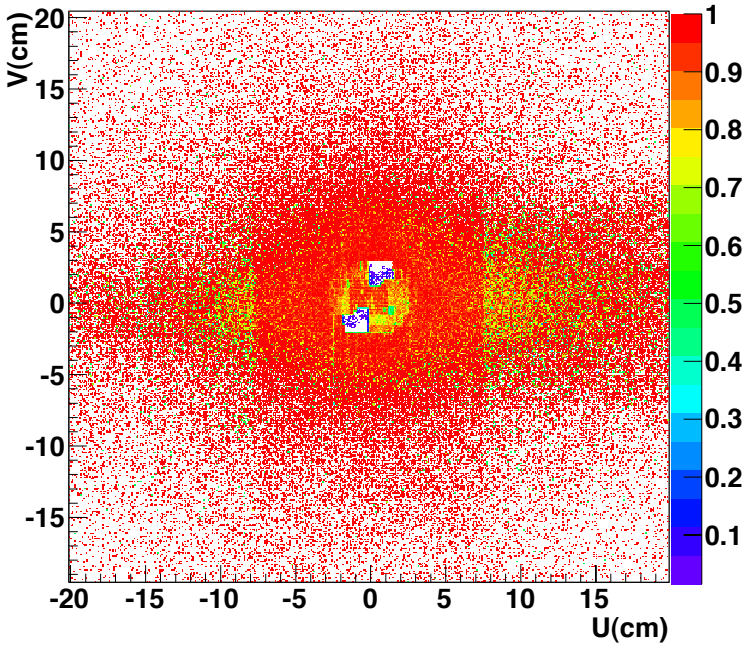
R & D on discharge rate reduction technologies



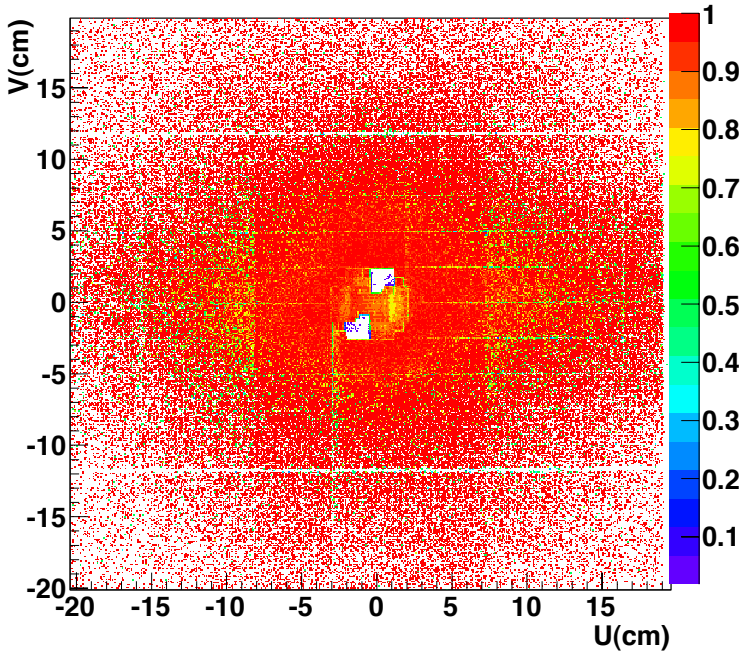


Large size prototypes : PMM 2010 - Efficiency

PMM 2010



PMM 2010 + GEM

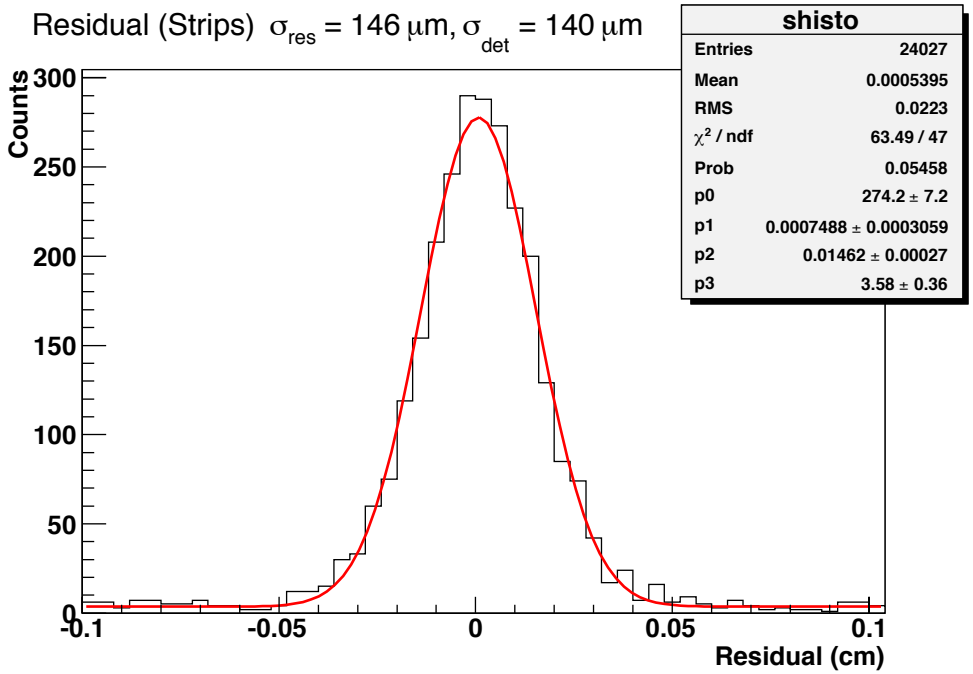


- Transverse muon beam
- 4 Missing APVs
- Several inactive channels

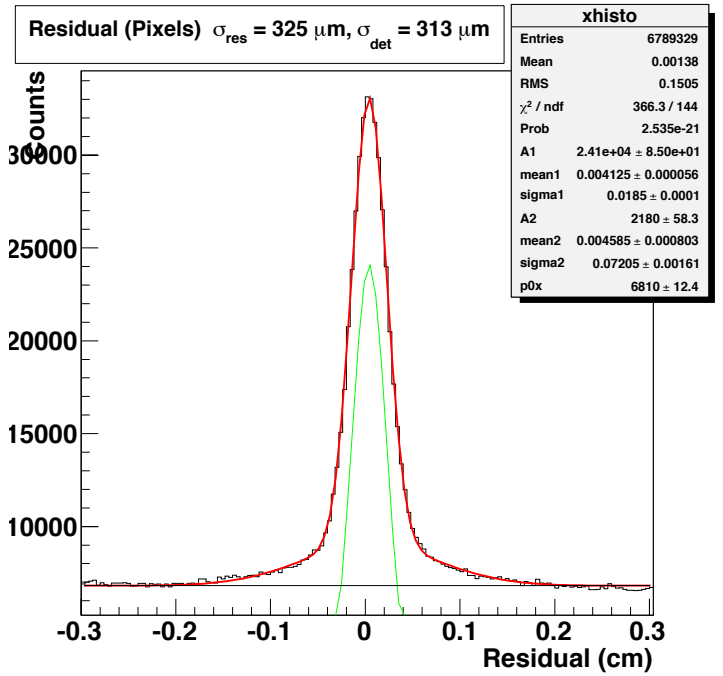
PMM_2010	Raw efficiency	Inactive areas excluded	+GEM (higher gain)
Pixels	60.1%	86.2%	89.7%
Strips	92.4%	94.8%	96.2%
Global	75.8%	90.5%	92.4%

Large size prototypes : PMM 2010 - Residuals

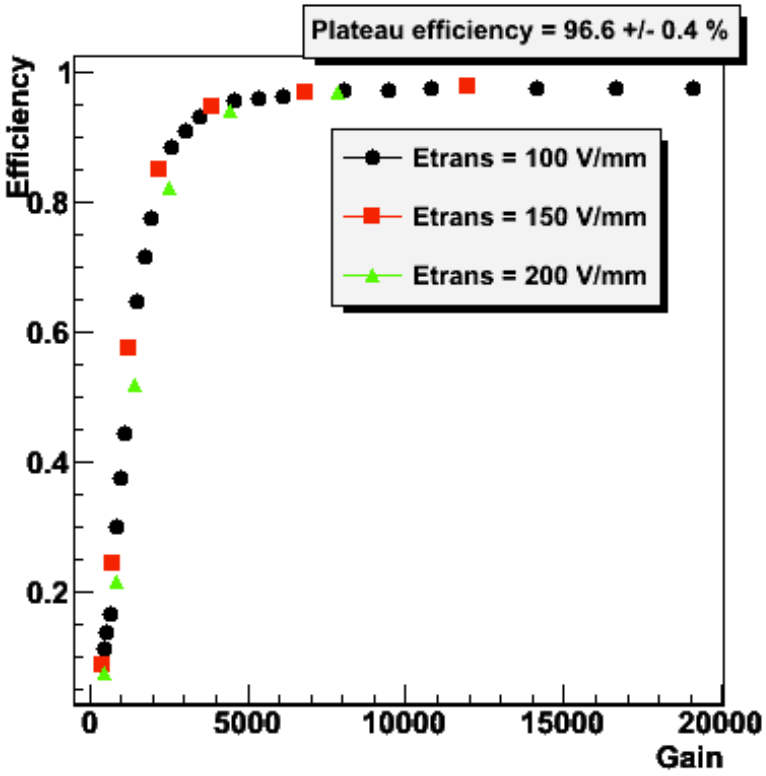
Strips

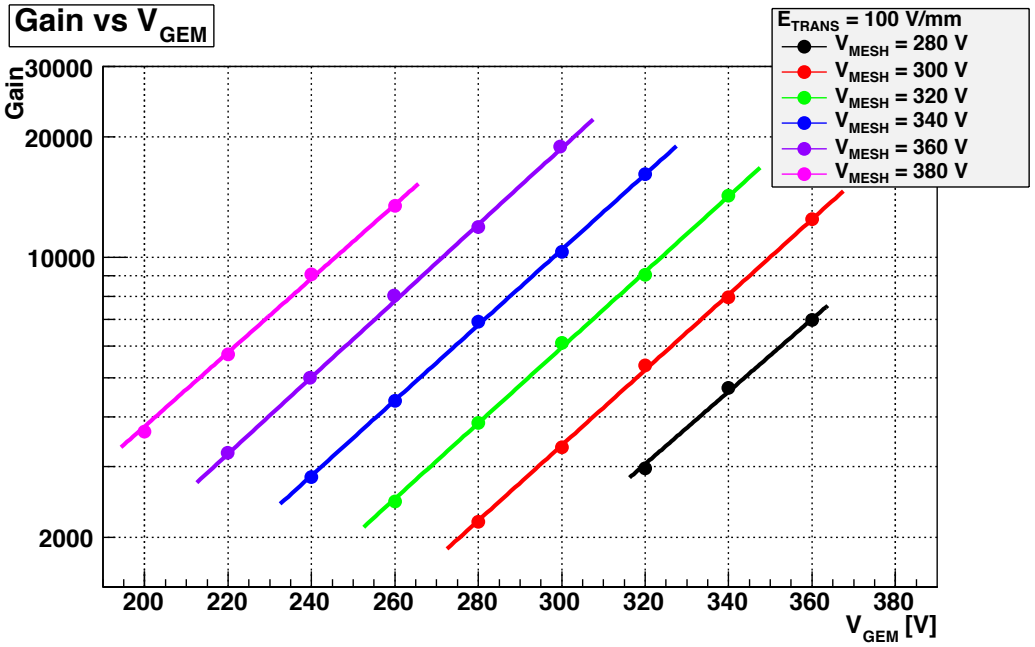


Pixels



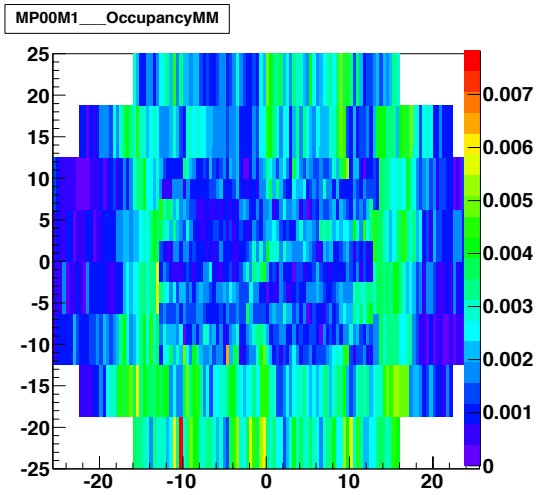
Large size prototypes : PMM 2011_1 – Plateau scan

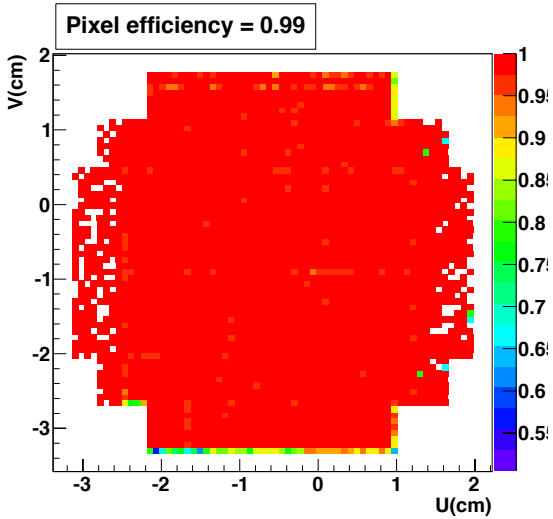




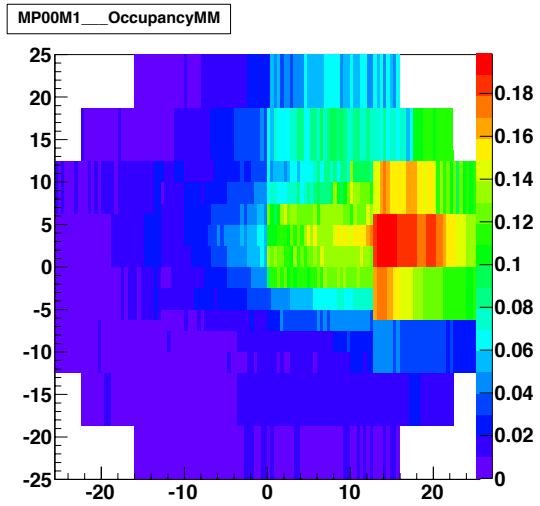
Improvements : Efficiency drop on large pixels

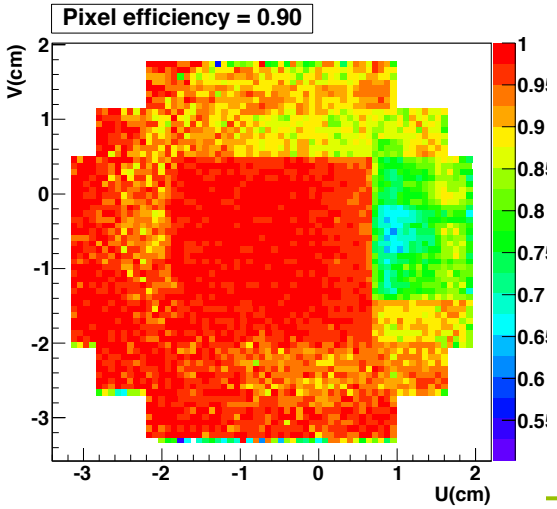
Occupancy and efficiency for low beam intensity (alignment run)





Occupancy and efficiency for nominal beam intensity (physics run)





Improvements : Residuals

- Pixels : clustering issues (cf previous slide)
  - ➢ Resolution spoiled by high size clusters