New pixellized Micromegas detectors for the COMPASS experiment

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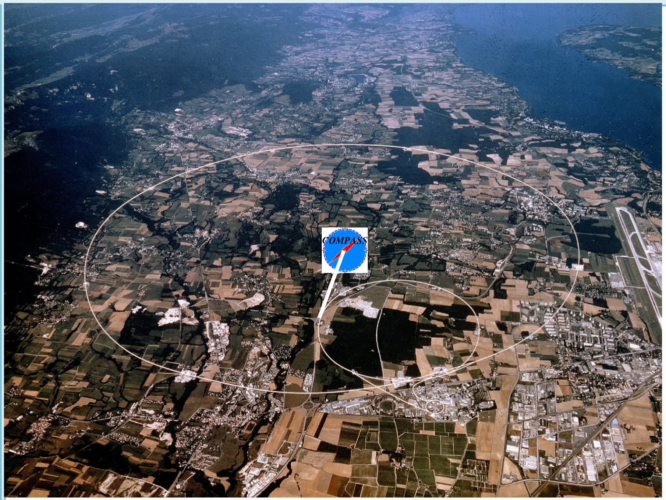
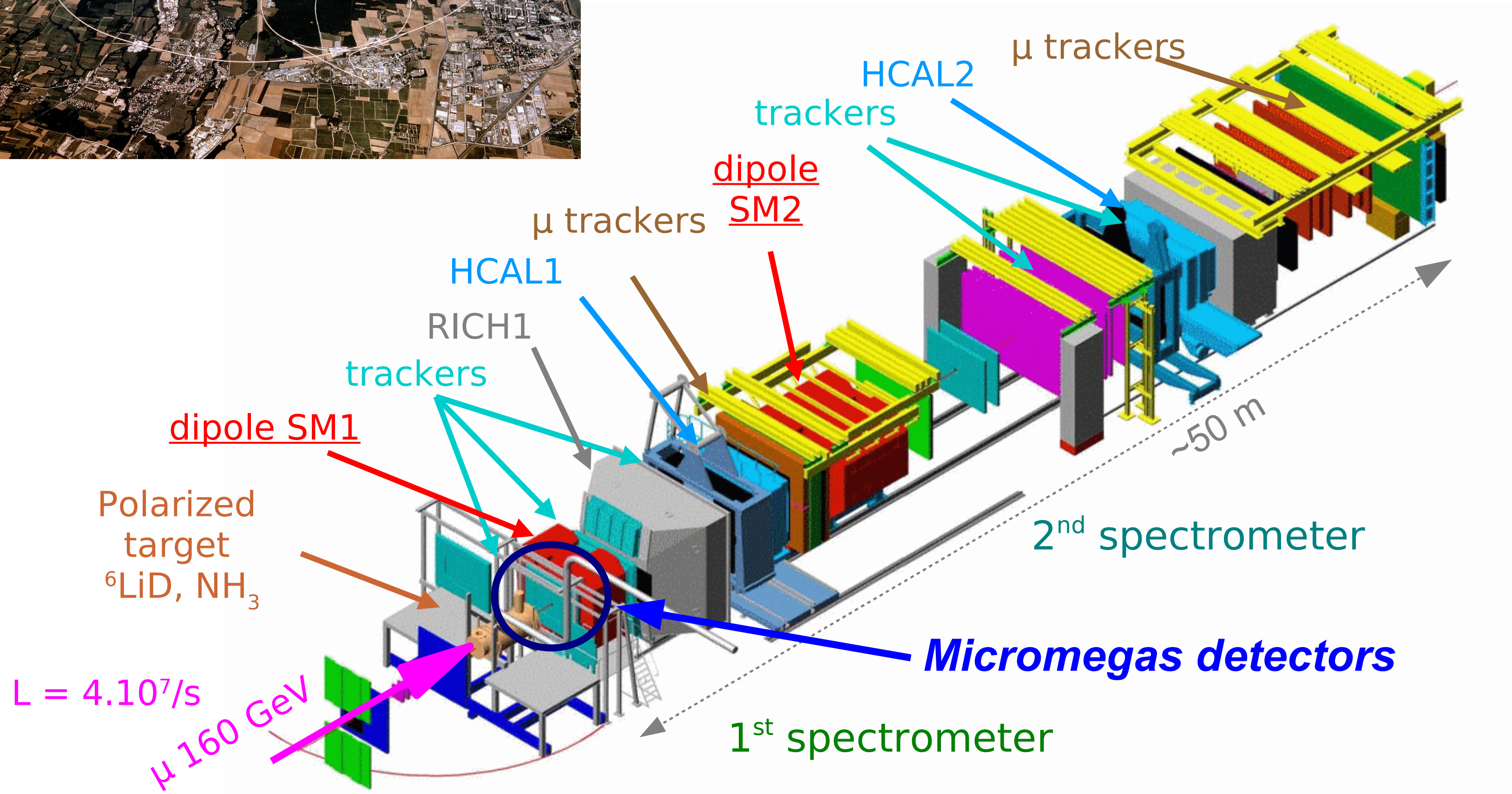
- The present MM detectors of the COMPASS experiment
- Future requirements and the projected Micromegas

The COMPASS experiment at CERN



- *muon or hadron beams*
- *2 spectrometers for small and large angles*
- *taking data since 2002*
- *High statistic experiment (30kHz trigger rate)*



The present Micromegas detectors

1st use in a part. physics exp.

Prototypes 1999-2000

Final detectors in 2001

R&D for COMPASS needs

Large size 40x40 cm² with deported electronics

Reduction of discharge rate

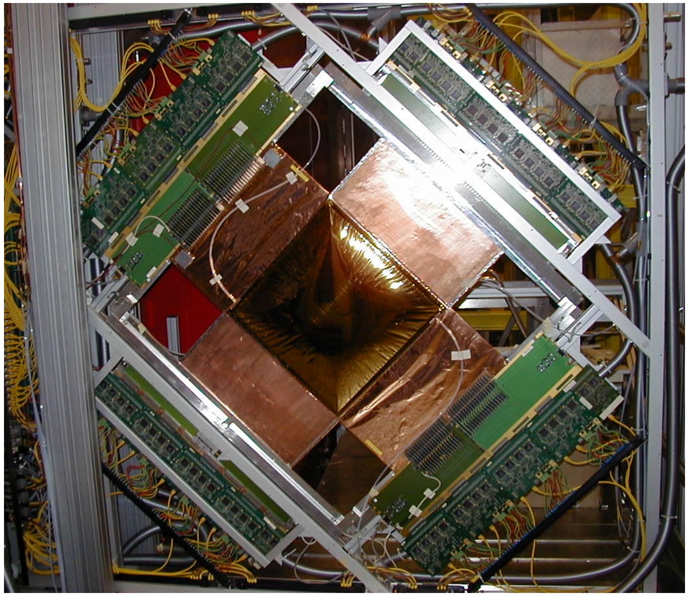
Light gas Ne + 10% C_2H_6 (+ 10% CF_4)

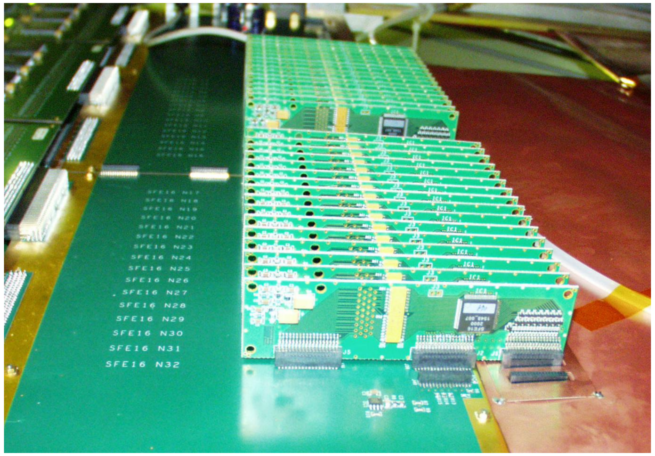
Read-out electronics

Low noise electronics SFE16 (threshold ~ 4000 e^-)

TDC digitization leading + trailing edges

> 12000 channels





Performances of the Micromegas detectors

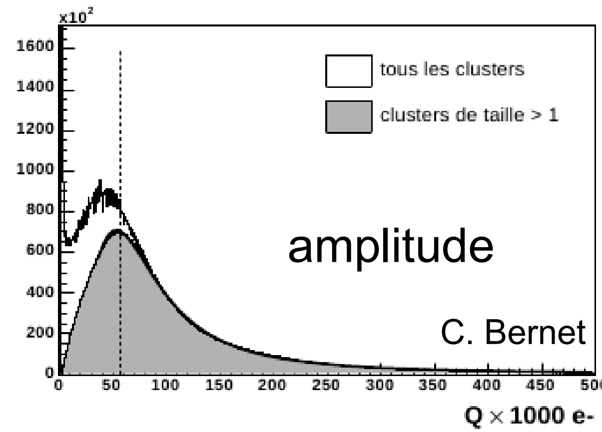
Main characteristics

3.2 → 5.5mm / 100μm gaps

5μm Ni meshes → copper (2006)

HV 800V / 390-420V

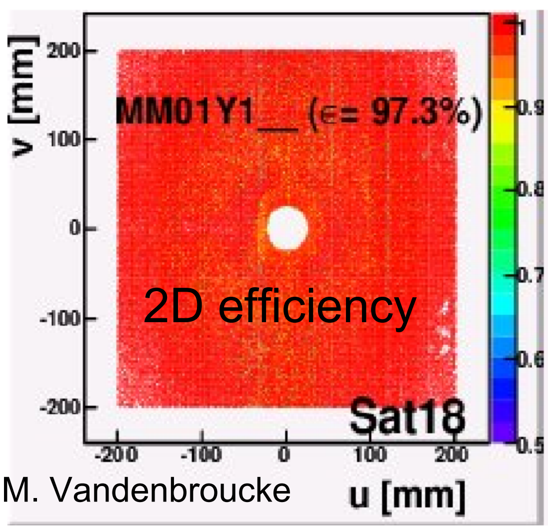
Gain 3000 to 6000

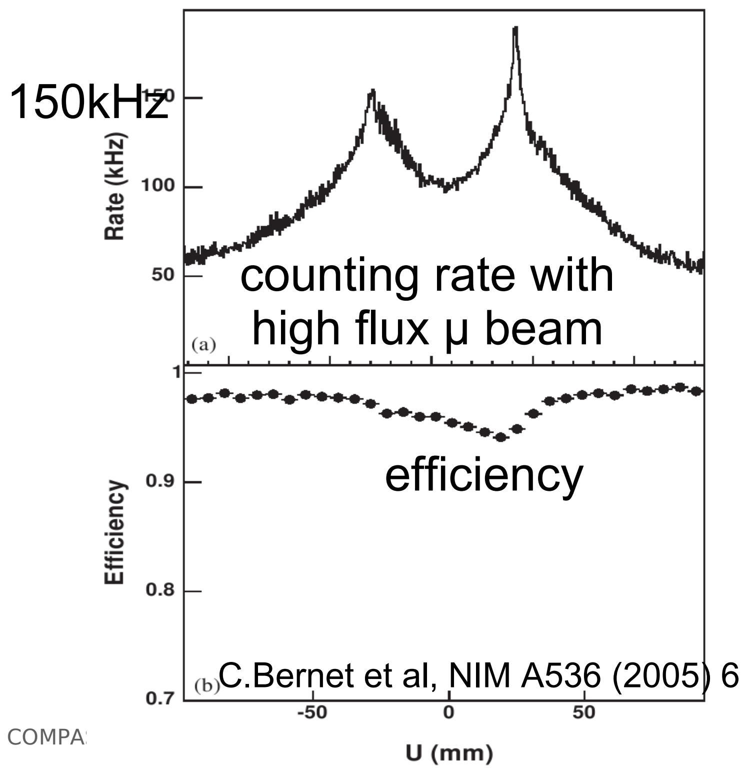


Detection efficiencies

~ 98-99% low particle flux

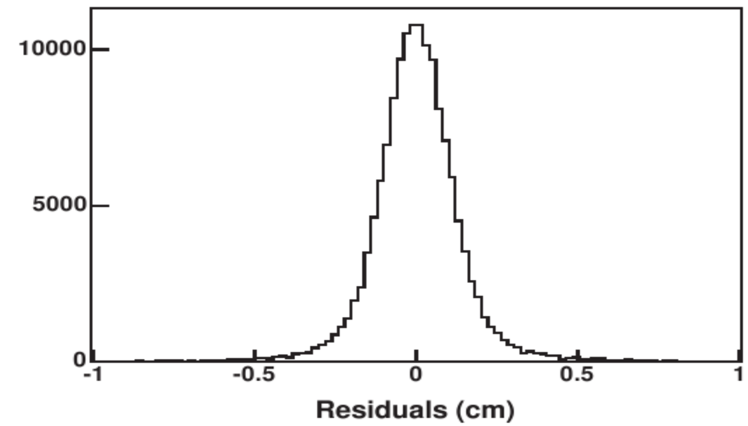
~ 96% high flux, up to 150kHz / channel





Performances of the Micromegas detectors

Irfu
cea
saclay

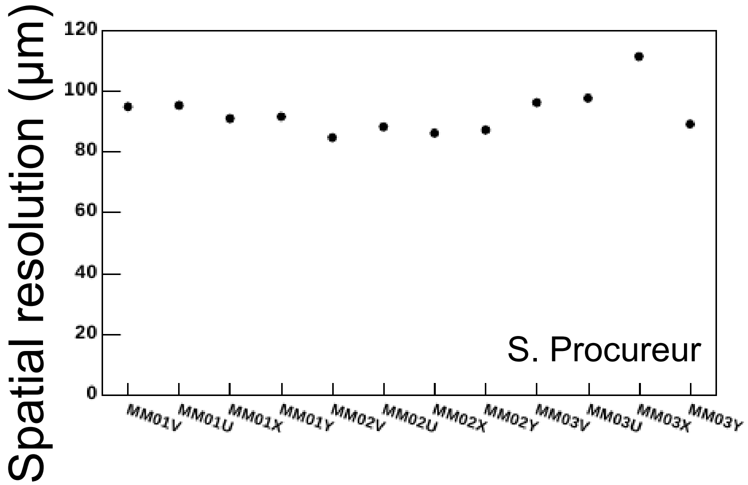


Resolutions

Time resolution ~10ns

Spatial resolution ~90-100µm

Spatial resolution affected by magnetic field



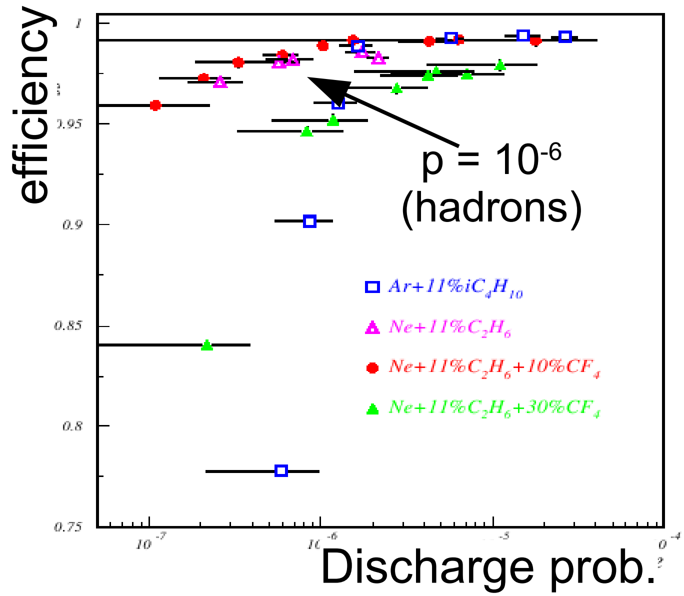
Discharges in COMPASS MM detectors

Discharges rate and effect optimized

- *Light gas Ne-C_2H_6(-CF_4) selected*
- *Moderate gain with low noise electronics*
- *Each strip decoupled → small recovery time*

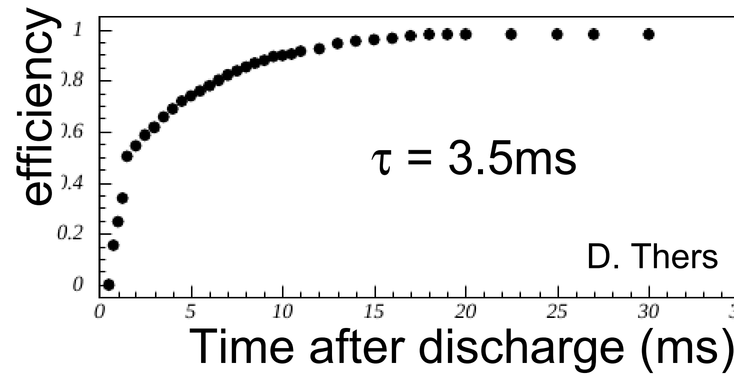
→ Ok with muon beam

- *<0.1 disch./spill at high μ flux*



But close to the limits with hadron beam

- *Drift gap already increased in 2006-2007 (3.2 → 5.5mm)*
- *0.5 to 1 disch./spill with 4.10^7h/spill*



Larger rate may reduce efficiency and damage the detector

Motivations and objectives for a new Micromegas R&D project

New proposal discussed in COMPASS collaboration

- *Several physics programs (GPDs, Drell-Yann, hadron spectroscopy, hadron spin structure)*
- *Muon and hadron beams with higher flux + various targets*
- *COMPASS detectors will continue to run for many years*

→ **Opportunity for the evolution of the MM detectors**

Objectives for a new detector

- *Stand 5 times higher flux hadron beams*
- *Detectors active in beam area in order to replace thick scintillating fibers*
- *Lighter electronics with 2 times more channels*
- *Improve the reliability of the detectors and the environment*

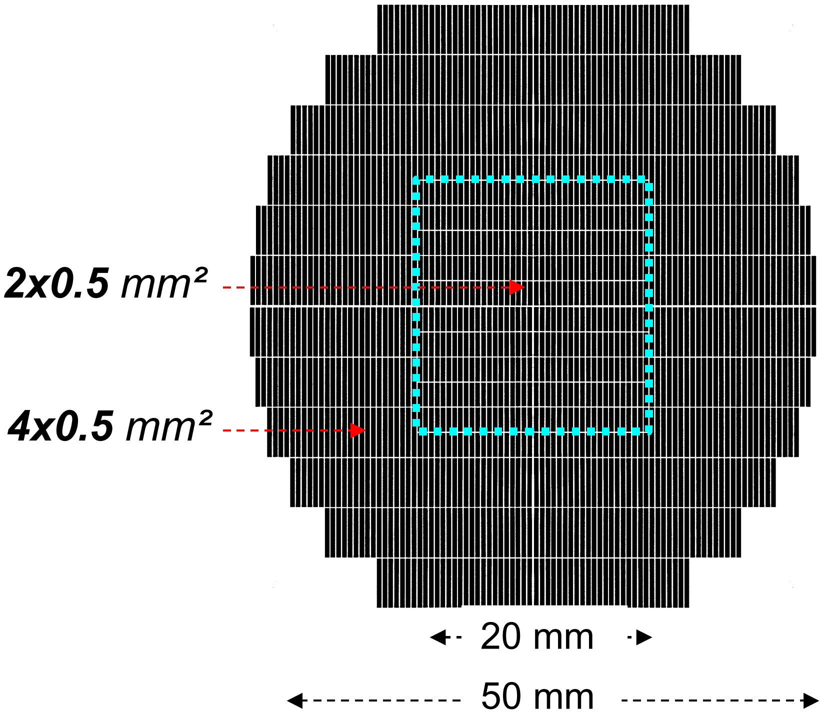
Goals of the R&D project: *to design a new Micromégas detector with*

- Read-out with pixels in the detector center (beam area)
- 10 to 100 times less discharges
- Integrated electronics (APV25 chips)
- Robustness improved (bulk technology)

Pixels read-out in the detector center

What if only strips ?

- *Expected particle flux > 100kHz/mm²*
- → *> 500kHz/channel*
- → *> 10-20% inefficiency !*



Rectangular pixels

- *5cm diameter, cover present inactive area*
- *2x0.5 and 4x0.5mm² pixels*
- *Keep spatial resolution in perpendicular dimension*
- *~1300 pixels + ~1000 strips to read*

How to reduce discharges rate ?

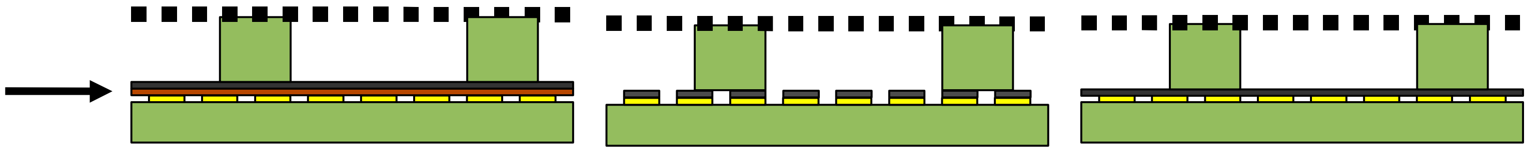
Resistive layer on top of the strip

Reduce effect and amplitude of the discharges

Several solutions (resistive foil on isolating layer, resistive coating on strip, etc..)

Studies launched in particular by Saclay sLHC group, common studies to be done also with other groups (Clas12, ILC,...)

Tests foreseen during October RD51 beam



Additional GEM foil above the mesh

Charge spread + lower gain of the MM layer → less discharges

Also to be tested in October

Segmentation of the mesh

Lower mesh capacitance → smaller discharge and faster recovery

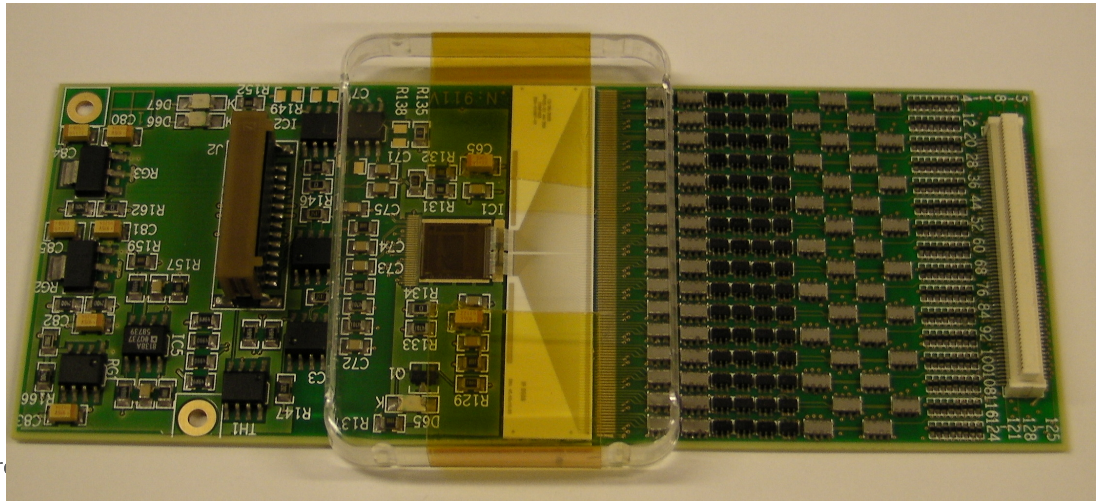
Read-out with APV25 chips

SFE16 + TDC electronics not convenient enough

- *1024 channels/detector → 64 SFE16 cards, 16 F1 cards*
- *No more space available*
- *~400W per detector → high power cooling required*

Integrated electronics based on APV25 chips

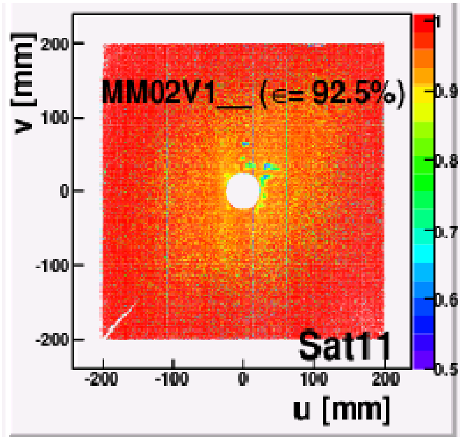
- *128 channels amplifier and multi-sample analog multiplexer*
- *Digitization by flash ADC with noise common mode correction and zero suppression*
- *Already used at Compass: Silicon, GEM, Rich MWPC*
- *TUM Munich card for pGEM adapted to MM (protection circuit with strips decoupling) + tuning of APV configuration*
- *Low cost, < 5€/ch.*

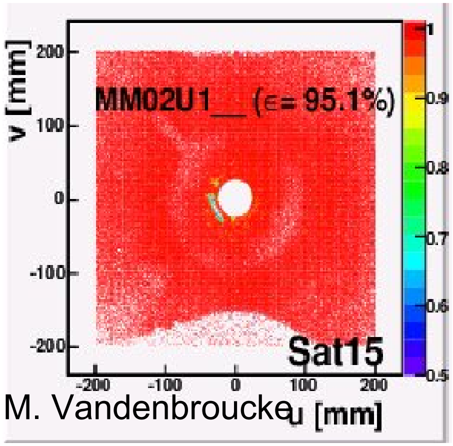


Improved robustness with bulk technology

A few issues with the old MM detectors

- *Low material budget: thin epoxy layers (100µm) on honeycomb, sometimes gluing defaults of the epoxy layer*
- *Difficulties to tight thin mesh → sometimes slightly folded or not flat*
- *Shorts or current leaks between mesh and strips (dust, impurities)*





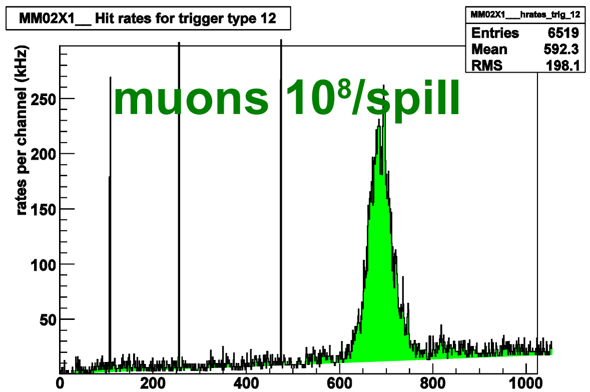
Monolithic detector with the bulk technology

- *Techno. developed at Saclay, can be produced by CERN lab.*
- *Inox mesh laminated on detector, with photosensitive coverlay*
- *Mesh fixed on board, dust tight, less sensitive to gluing defaults*
- *Bulk process on honeycomb board ?*
- *How about high hadron flux ? (gain, discharge rate)*

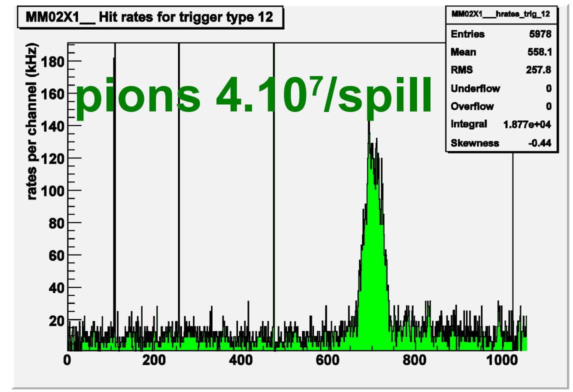
2008 tests with COMPASS detectors

2 MM detectors shifted to have beam in active area

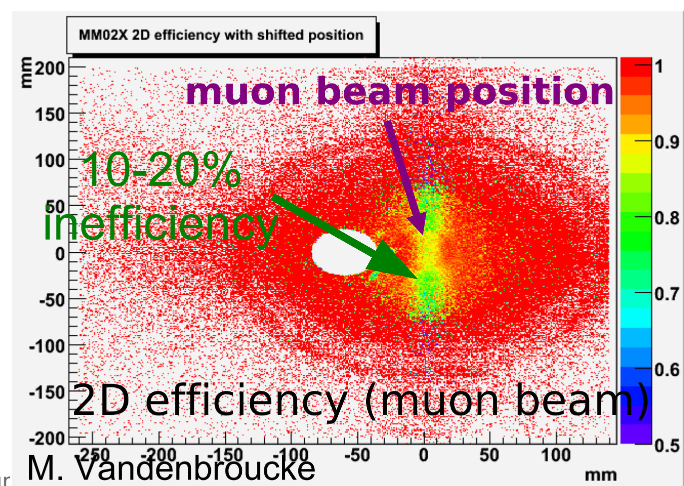
To study behavior of MM at high muon and hadron beams flux

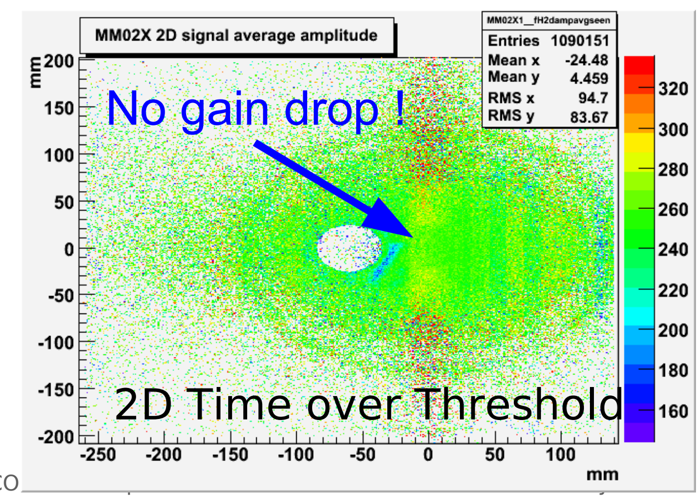


230 kHz/ch, no discharge



130 kHz/ch, 2-3 disch./spill

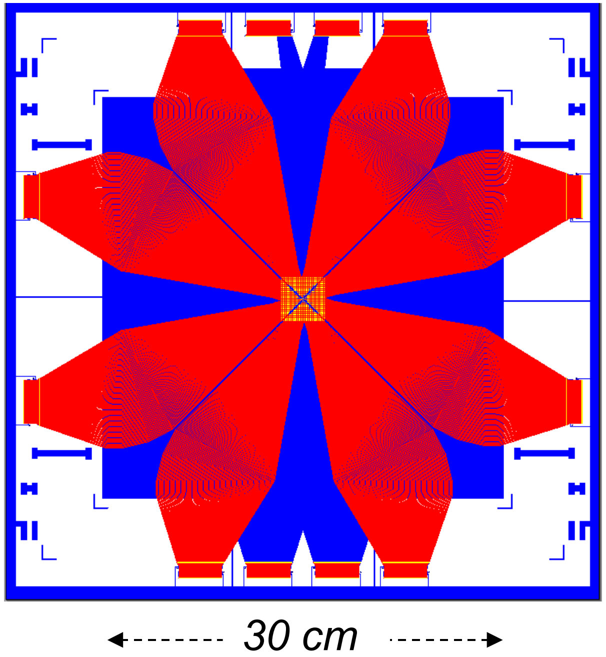




Present activities

Prototypes of pixellized Micromégas

- *32x32 1mm² pixels in the center, 30cm strips*
- *Original design from TUM Munich, adapted by CEA Saclay + CERN*
- *Kapton board, 2 faces used, built by CERN lab*
- *Read-out by APV electronics, pGEM cards + new cards with MM protection circuit under production*



Two prototypes: bulk and non-bulk

- *Non-bulk using standard 5µm copper mesh, 100µm amplification gap*
- *Bulk with 30µm inox mesh, 125µm gap*
- *No other difference*
- *Goal: study performances and impact of thick mesh (discharge rate)*

Ongoing work with prototypes

Non-bulk prototype

Tested with source: same gain as present Micromegas detectors, similar gain between pixels and strips

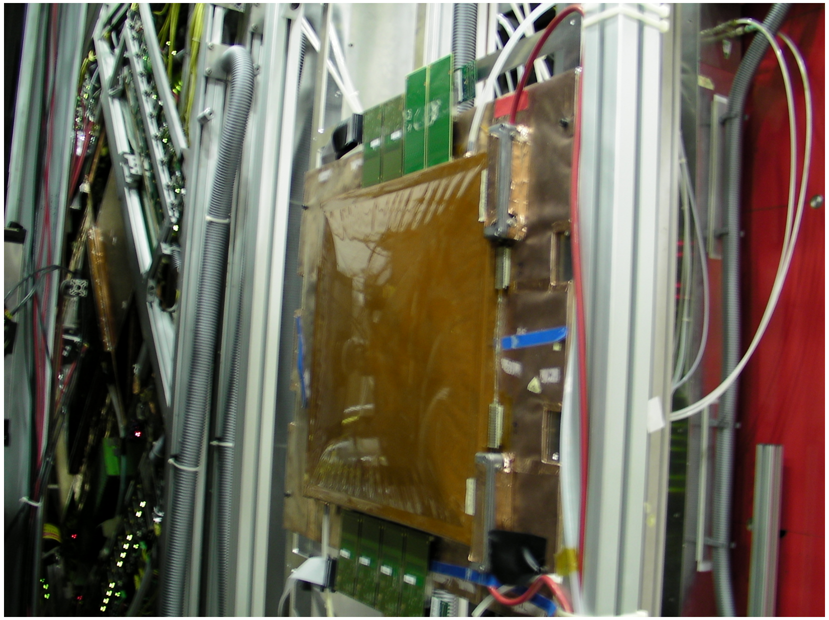
Installed at Compass end of May

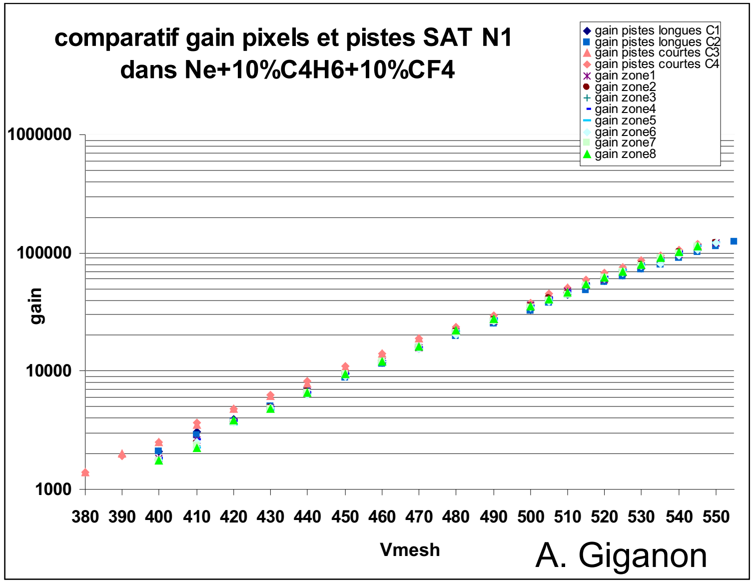
Discharge rate with hadron beam similar to 2008 shifted MM detectors

Electronics noise figure as expected

No results on resolution and efficiency yet

Tests with new APV card prototypes ongoing





Ongoing work with prototypes

Bulk prototype

Difficulties to apply bulking process on large size honeycomb

A lot of R&D in CERN lab to overcome them

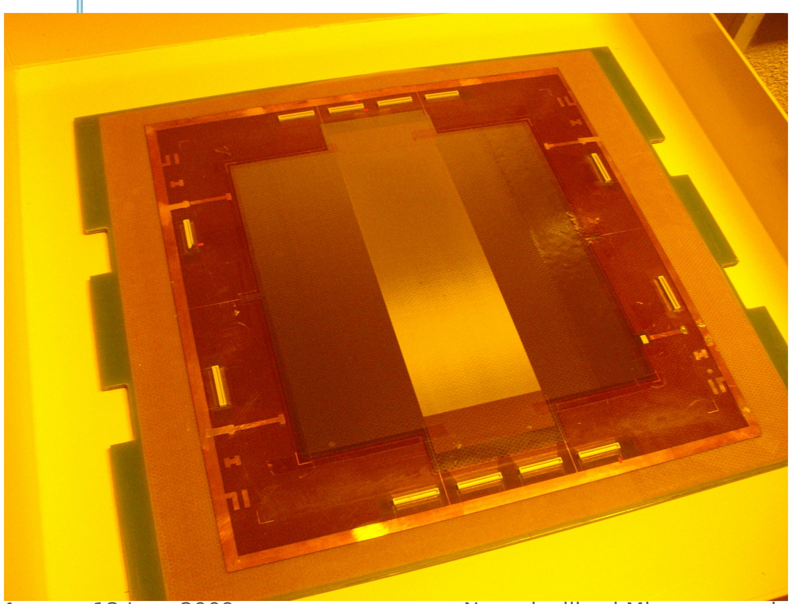
Delivered end of February

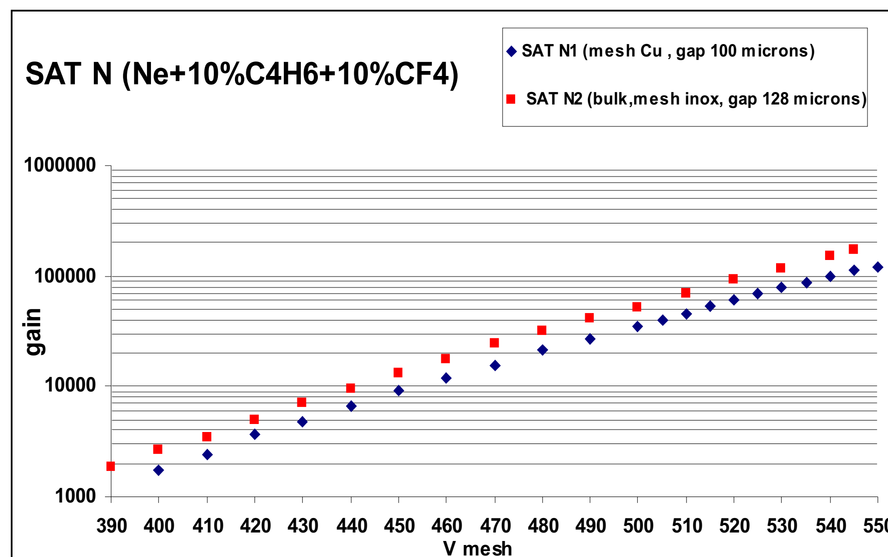
A few issues: bad gluing, impurities in amplification gap, current leak, discharges

Finally working: up to 540V in Ne-C_2H_6-CH_4 gas

Gain slightly larger than the non-bulk prototype

To be tested at Compass end of June





Time line

2009

Studies with the 2 llarge prototypes in hadron flux

R&D on resistive layers on small (10x10cm) prototypes, in collaboration with other Saclay groups (RD51 beam period in October)

Design of large (30x30 or 40x40cm) prototype with rectangular pixels

2010

Production and characterization of large prototype in beam

Continuation of R&D on resistive layers and decision

2011

Validation of the final prototype with discharge reduction

Proposition to the collaboration

- **Spares**

Le circuit APV25-S1

•APV25-S1 chips amplifies, shapes, samples and multiplexes analog signals, which are then read by flash ADCs

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•Main characteristics of the APV25-S1:

- designed for CMS silicon microstrip tracker
- CMOS 25 µm
- fast analog signal pre-amplifier, shaper and multiplexer, adjustable time constants
- 128 channels / chip, low cost
- 40 MHz sampling on 192 cells analog pipeline
- already used on other COMPASS detectors (GEM, Silicon tracking detectors)

Joint project between TUM Munich and CEA Saclay COMPASS groups

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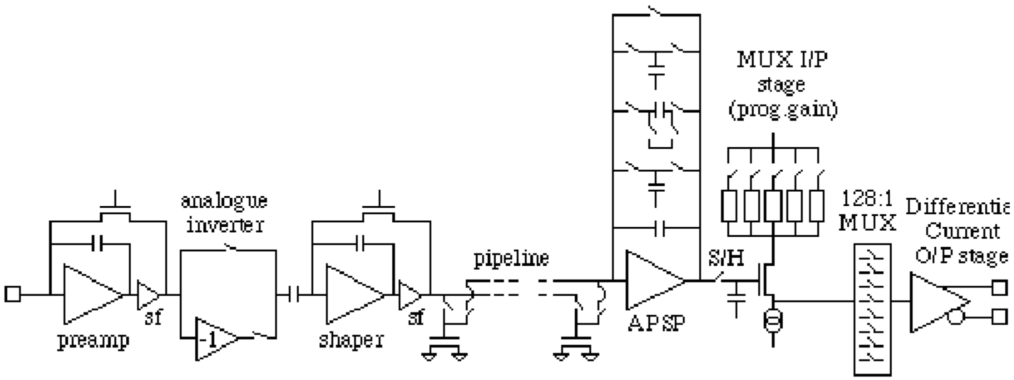
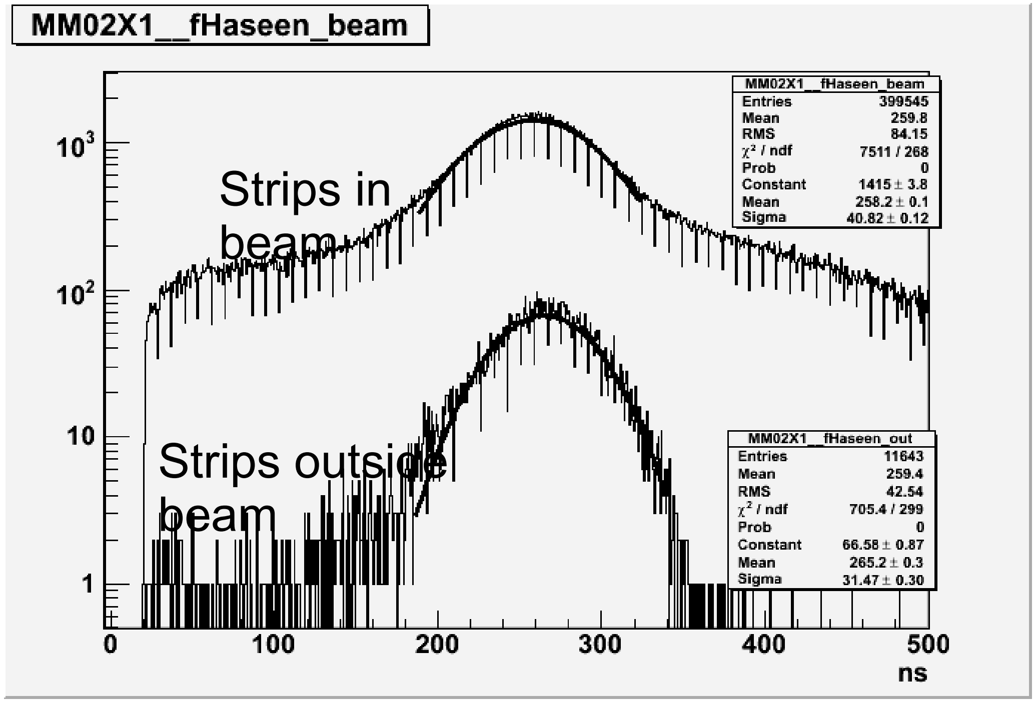
APV25 functional schematic



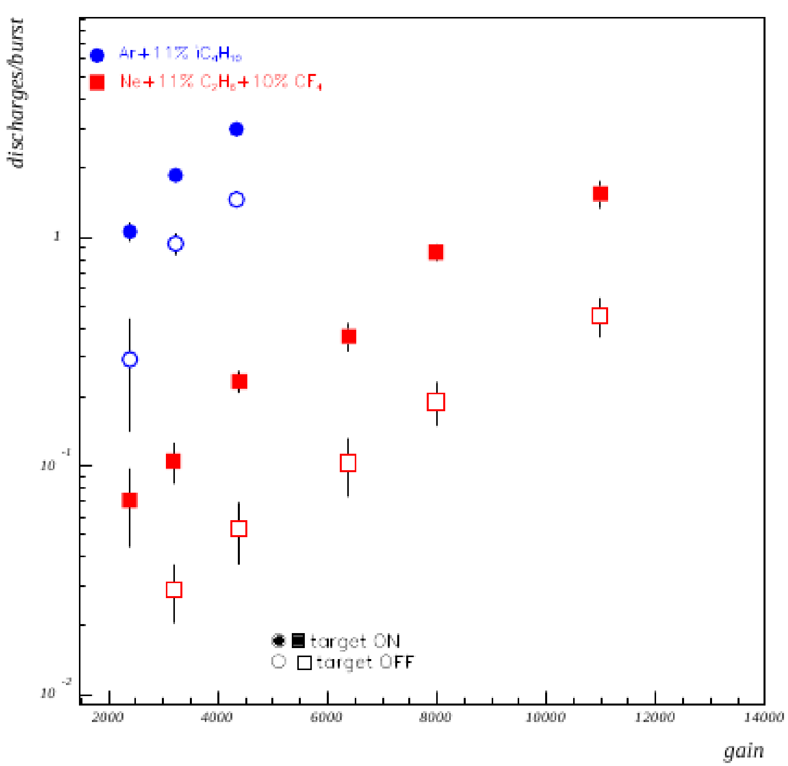
Gain comparison, strips in or outside beam

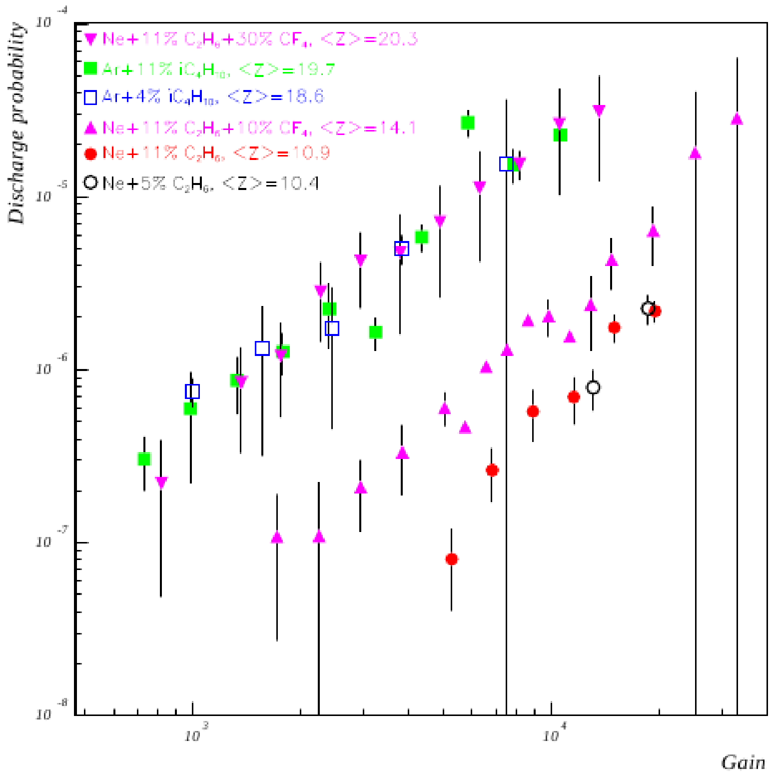


Time over threshold distribution (ToT)

- No gain loss ToT peak centered at same value
- Pile-up : tail with larger ToT when beam IN

  efficiency loss: 10-20%


discharges/burst
Ar+11% iC_4H_{10}
Ne+11% C_2H_6+10% CF_4
1
10^{-1}
10^{-2}
2000
4000
6000
8000
10000
12000
14000
gain
target ON
target OFF


Discharge probability
Ne+11% C_2H_6+30% CF_4, <Z>=20.3
Ar+11% iC_4H_{10}, <Z>=19.7
Ar+4% iC_4H_{10}, <Z>=18.6
Ne+11% C_2H_6+10% CF_4, <Z>=14.1
Ne+11% C_2H_6, <Z>=10.9
Ne+5% C_2H_6, <Z>=10.4
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{3}
10^{4}
Gain