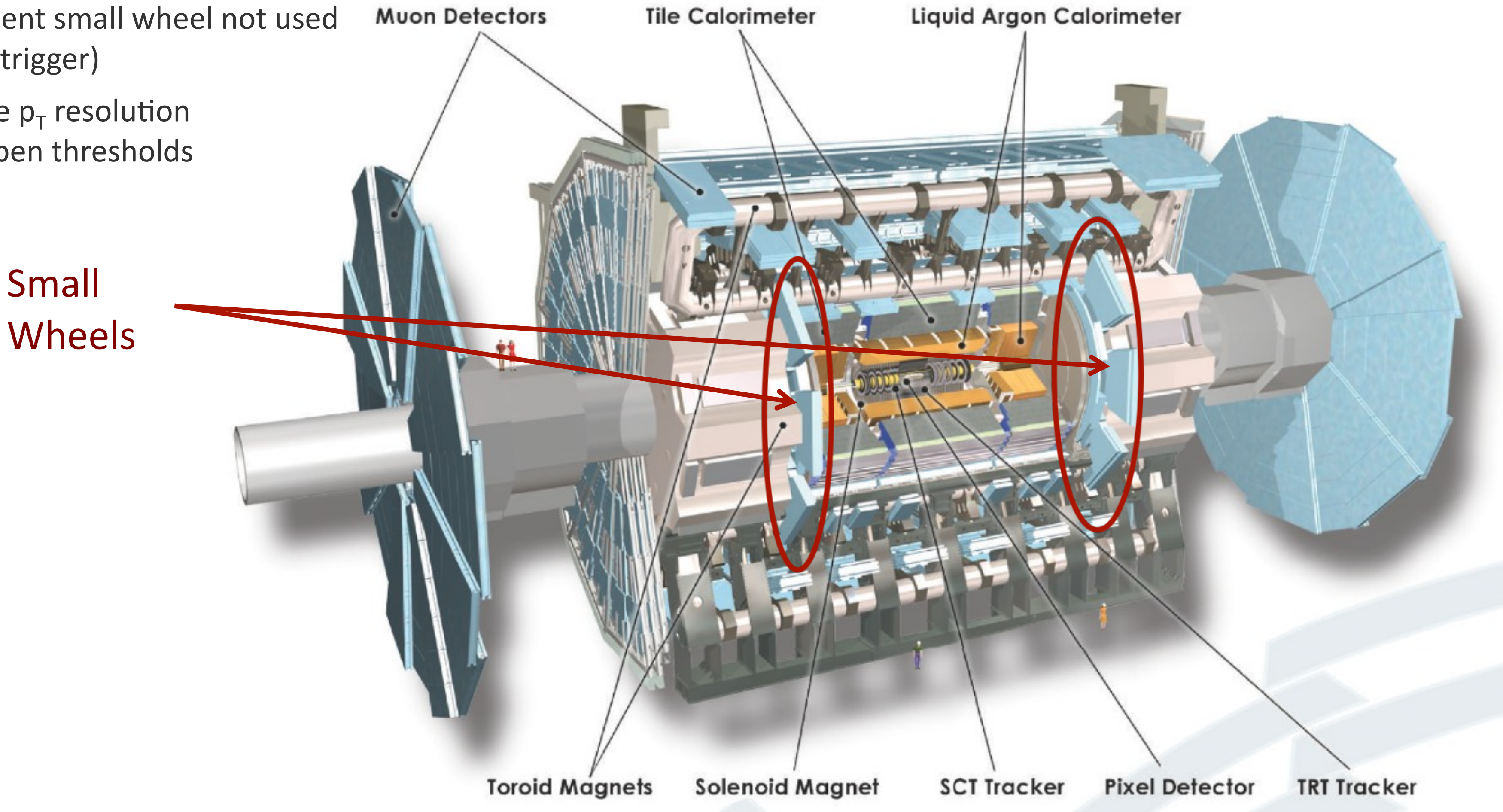
# Development of Micromegas detectors for the ATLAS Muon System upgrade

**M.Alviggi, M. Della Volpe, R. De Asmundis, R.Giordano, P.Iengo, V.Izzo, S. Perrella, G. Sekhniaidze**

# Introduction



- Small Wheel muon chambers need to be upgraded (in phase I)
  - Measured rate higher than estimate (rate limit at ~$5x10^{34}$ $cm^{-2}s^{-1}$)
  - Reduce the fake rate at $p_T$>20GeV (at present small wheel not used in LVL1 trigger)
  - Improve $p_T$ resolution to sharpen thresholds



# The MAMMA Project

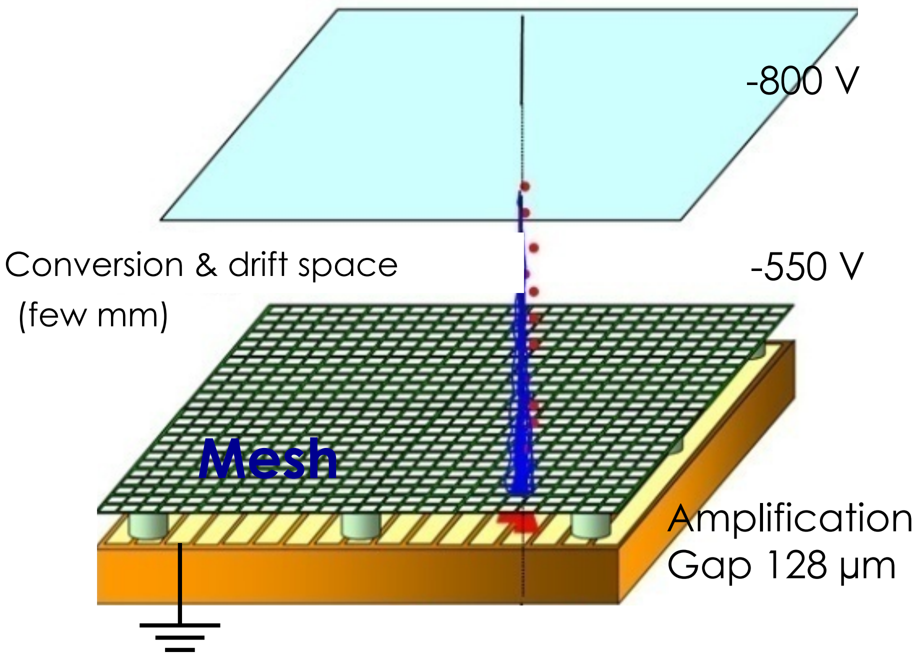

Replace the muon chambers of the Small Wheels with 128 micromegas chambers (0.5–2.5 $m^2$)

- Combine precision and 2nd coord. measurement as well as trigger functionality in a single device
- Each chamber comprises eight active layers, arranged in two multilayers
  - ⇒ a total of about 1200 $m^2$ of detection layers
  - ⇒ 2M readout channels
- Project (MAMMA, for Muon Atlas MicroMegas Activity) started in 2007
  - 15 groups involved
  - Napoli the only Italian one, but others interested

other candidates: combined systems: sMDT+TGC and sMDT+RPC

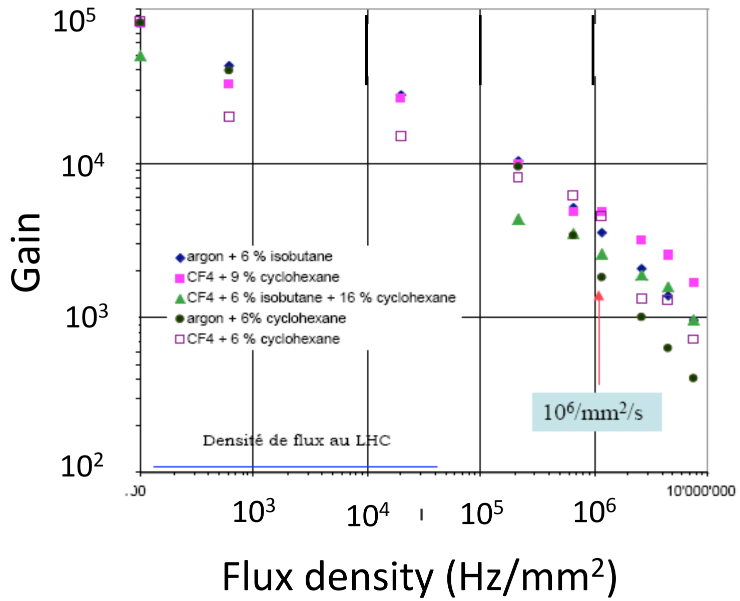
# Micromegas operating principle






- Micromegas (I. Giomataris, G. Charpak et al., NIM A 376 (1996) 29) are parallel-plate chambers where the amplification takes place in a thin gap, separated from the conversion region by a fine metallic mesh
- The thin amplification gap (short drift times and fast absorption of the positive ions) makes it particularly suited for high-rate applications

No space charge effect
Reduced ballistic deficit (only for fast electronics <20 ns)
Intrinsic rate limit ~200 MHz/cm$^2$



# Required performance



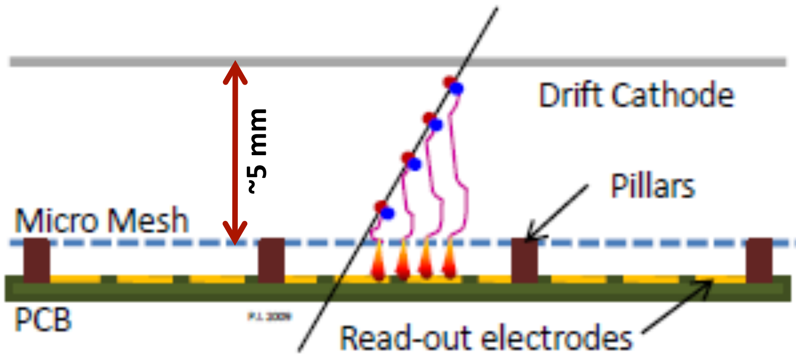
**Performace requirements for the Small Wheel chambers**

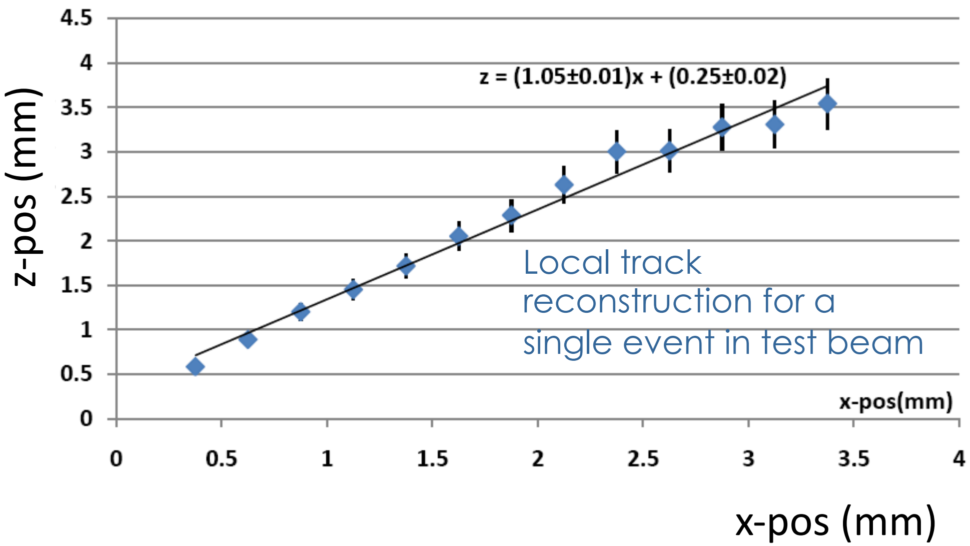
- Rate capability 15 kHz/cm$^2$ (L ≈ 5 x $10^{34}$ cm$^{-2}$s$^{-1}$)
- Efficiency > 98%
- Spatial resolution ≈100 μm ($\Theta_{track}$< 30°)
- Good double track resolution
- Trigger capability (BCID, time resolution ≤ 5–10 ns)
- Radiation resistance
- Good ageing properties

Micromegas can satisfy all of them

Two main problems:
1. Large-size detector
2. Sparks

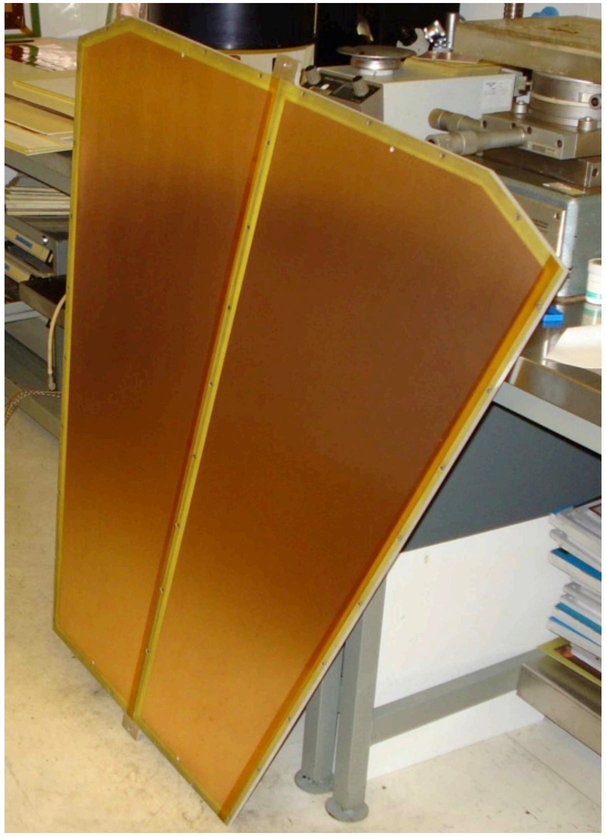
- Micromegas as μTPC
  - Can deliver track vector in single plane for track reconstruction at LVL1 trigger



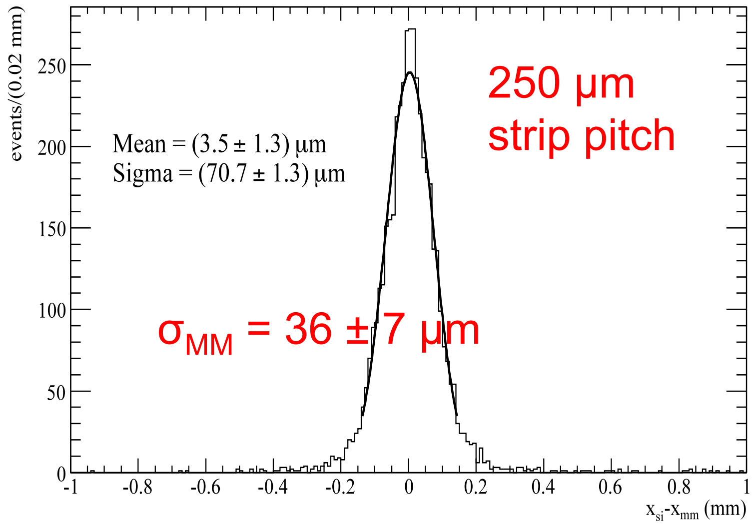
# Large-size Micromegas

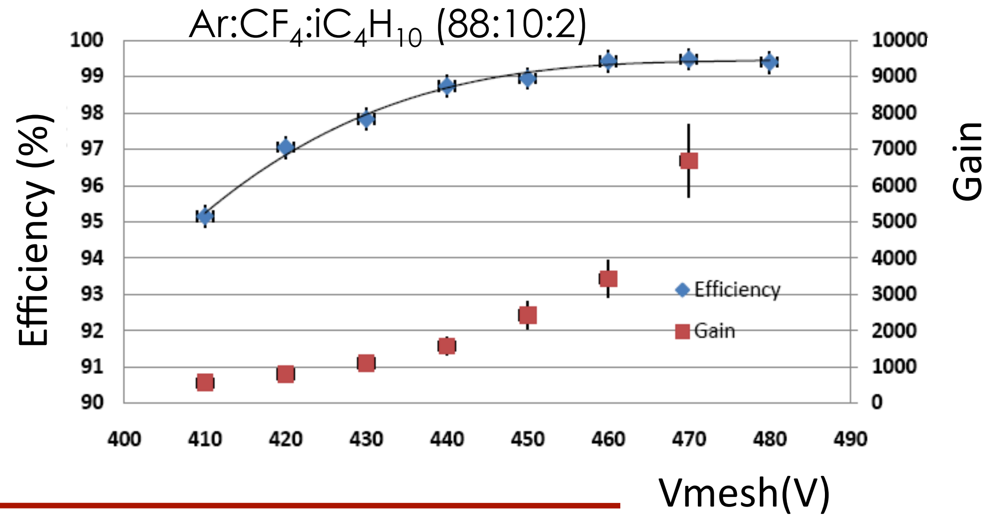
- A production technique developed in 2006 (bulk-micromegas) opened the door to industrial fabrication
- Reliable production of large size Micromegas is possible!



The largest MM ever built

Spatial resolution (mm)

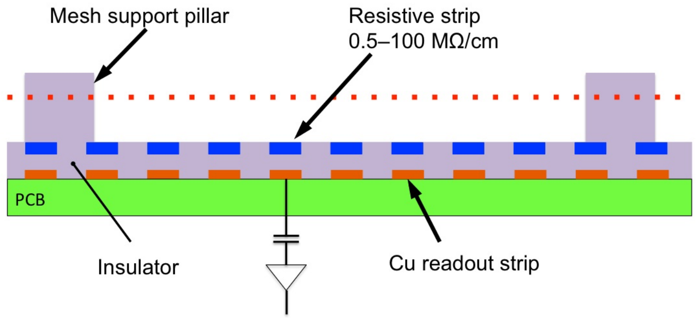


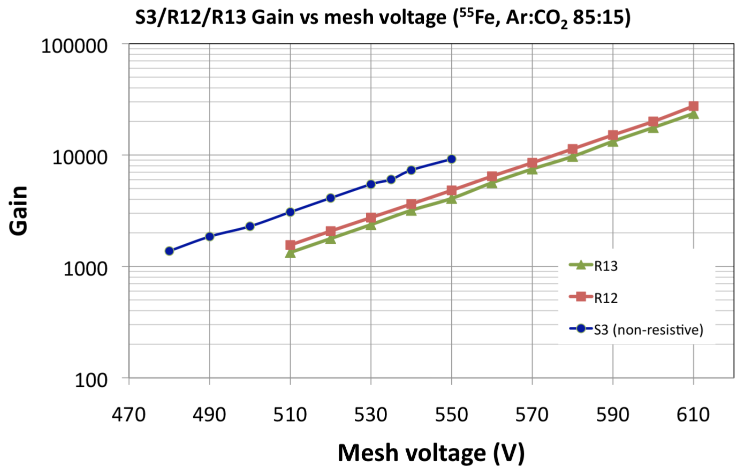



# Sparks: problem and solution

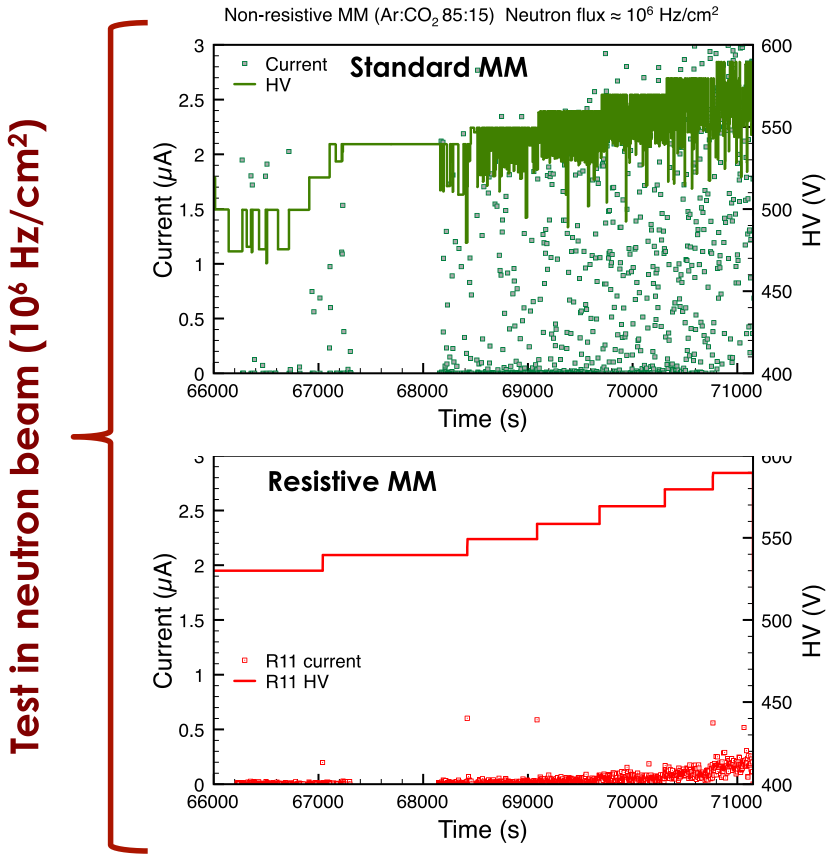


- Small defects or impurities on the detector surfaces trigger discharges (breakdowns). Even in device of good quality, when the avalanche reaches Raether limit ($10^6$-$10^7$ e-) a breakdown appears in the gas, often referred as ‘spark’
- Sparks lead to a partial discharge of the amplification mesh → HV drop & inefficiency during charge-up; not acceptable at LHC



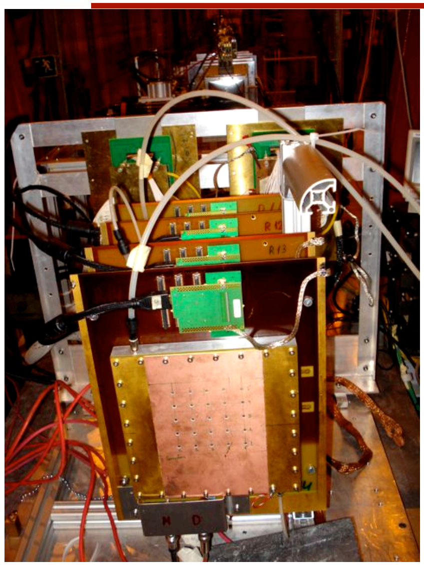




- Sparks can be drastically reduced by adding a resistive layer on the r/o strips
- Specific R&D to optimize the resistive protection
- Excellent results

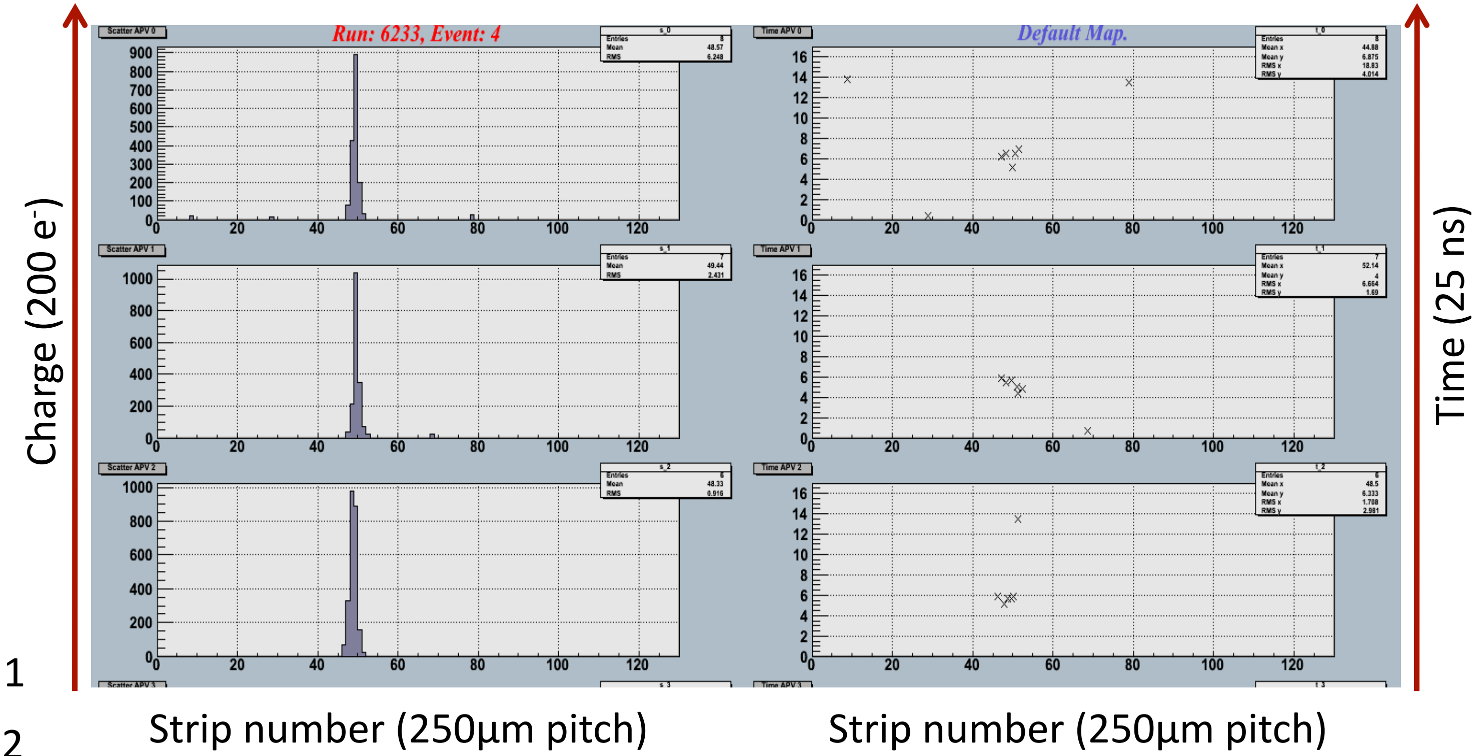


# Event display from TB

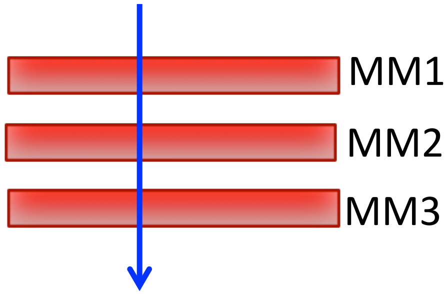




- ~ Vertical track




Three chambers in stack



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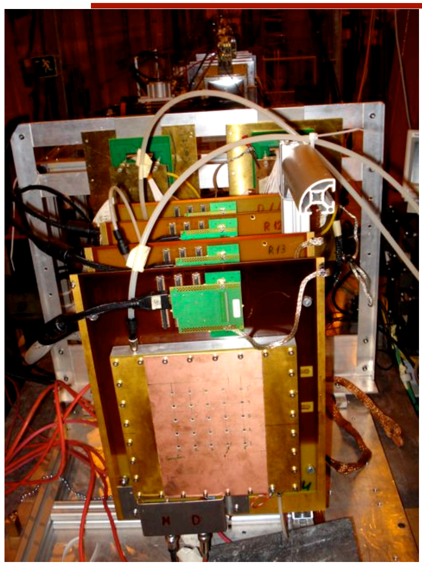
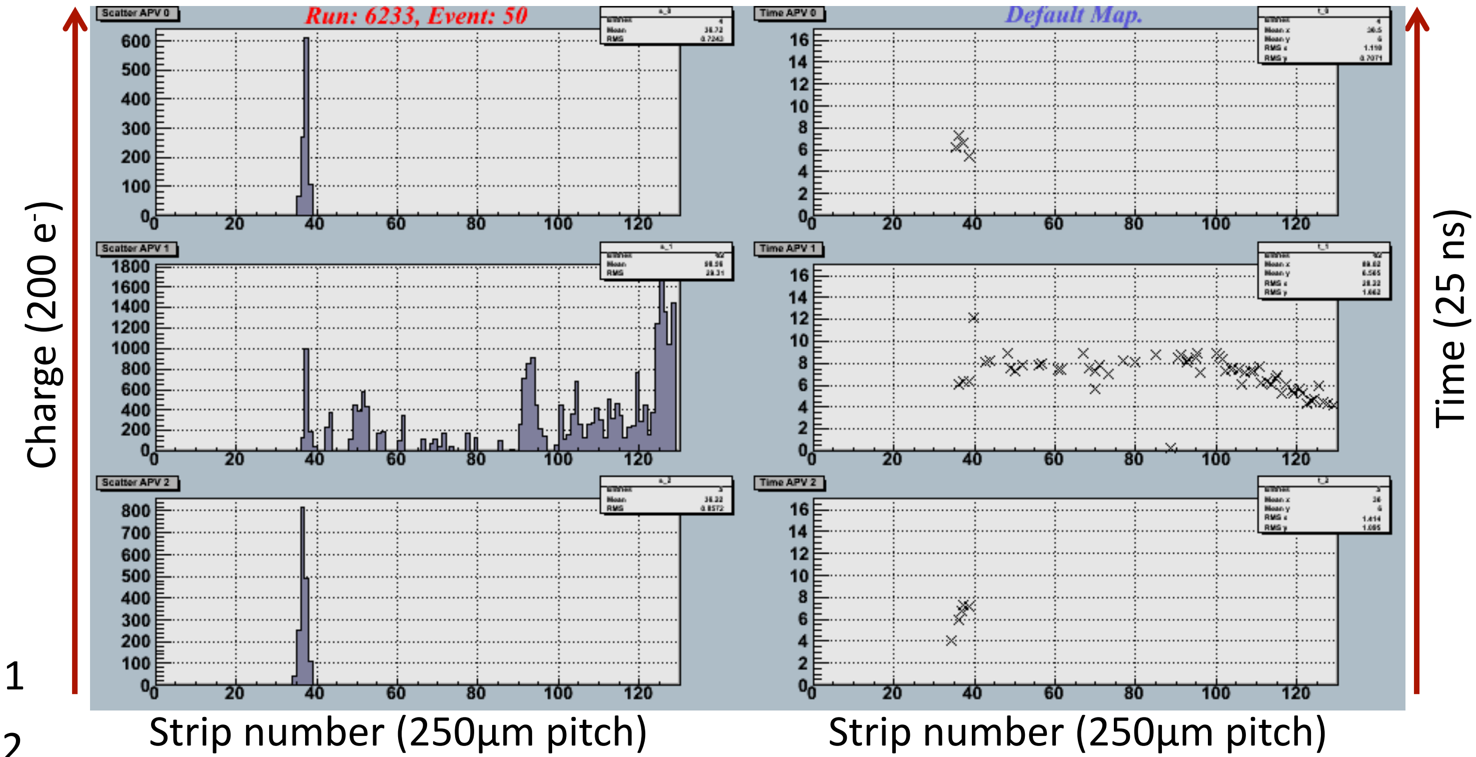


- ~ Vertical track + $\delta$ -ray

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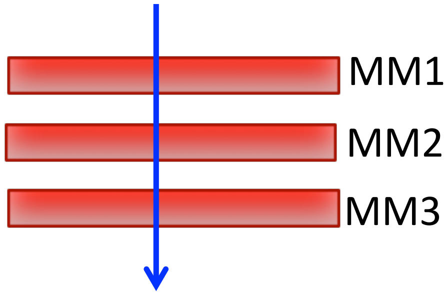

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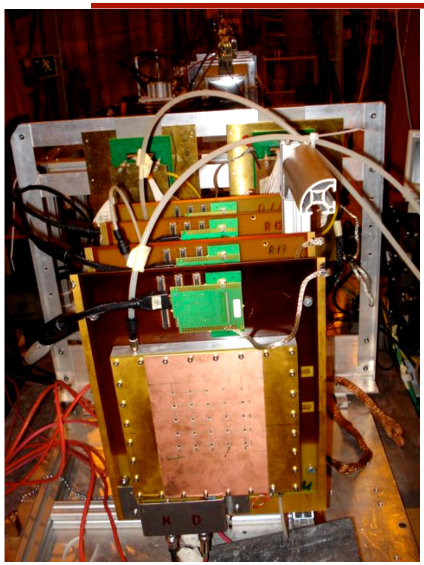
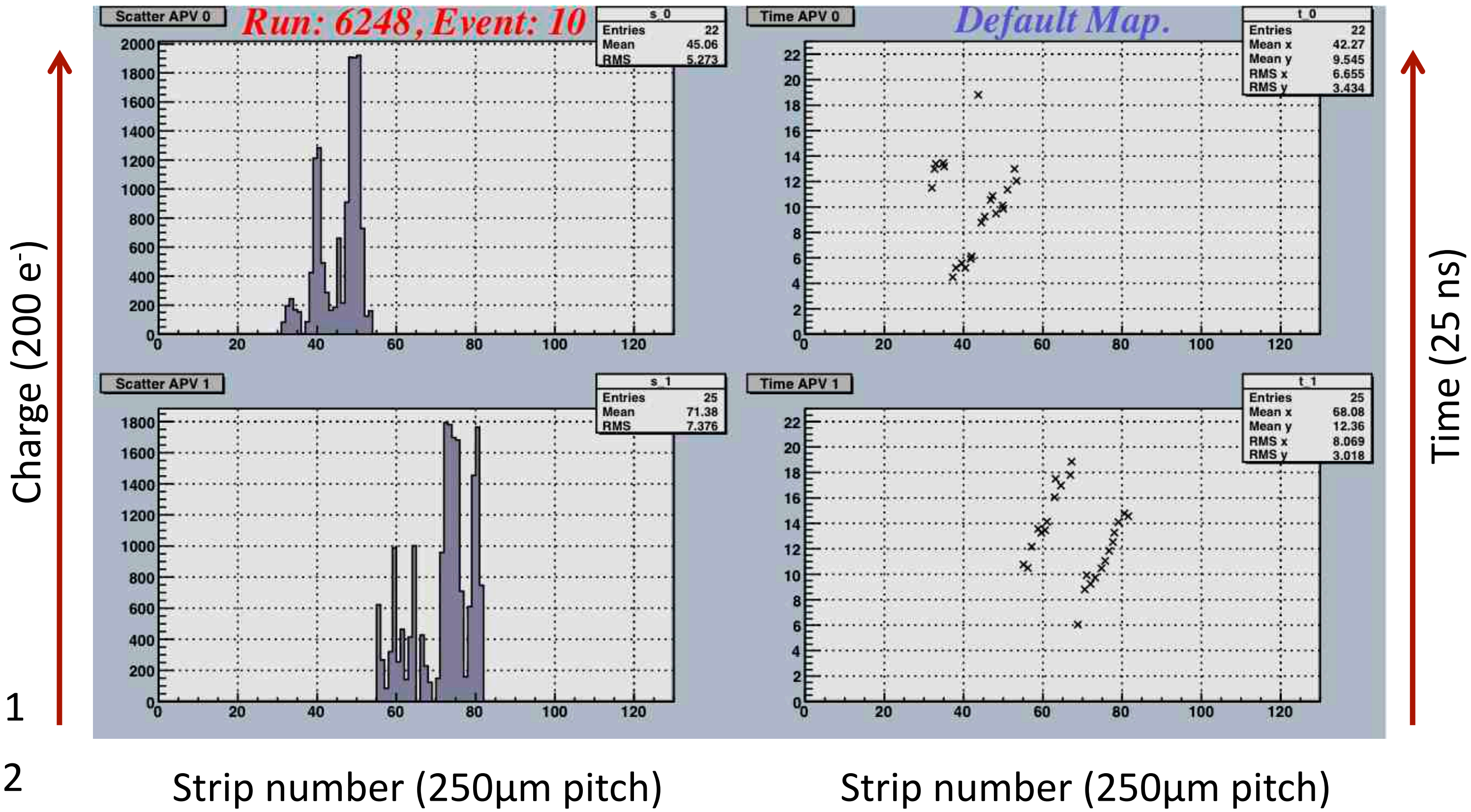


- Two Inclined tracks (~40°)

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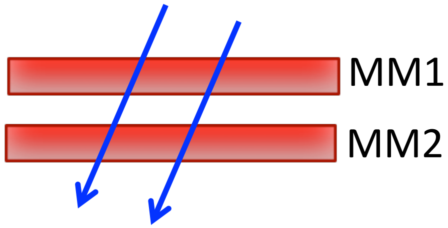
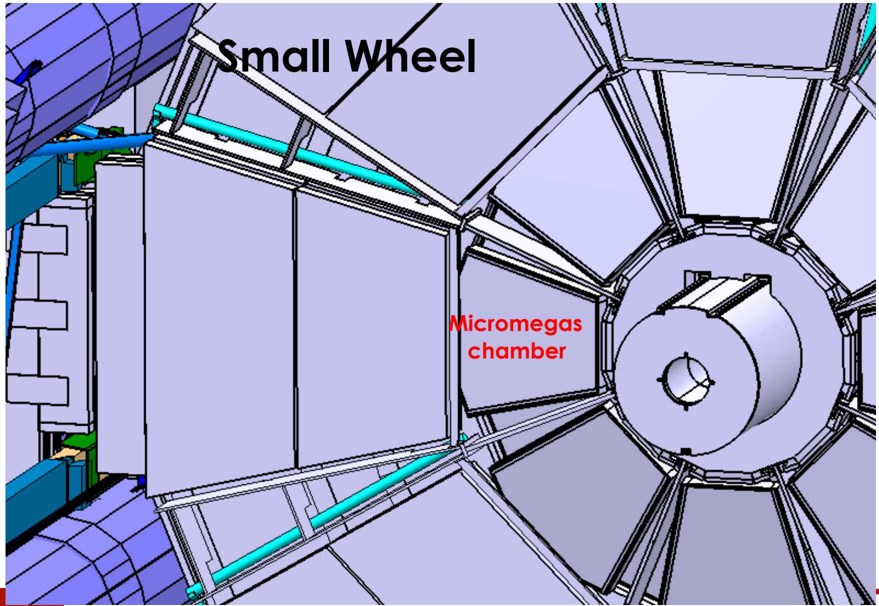
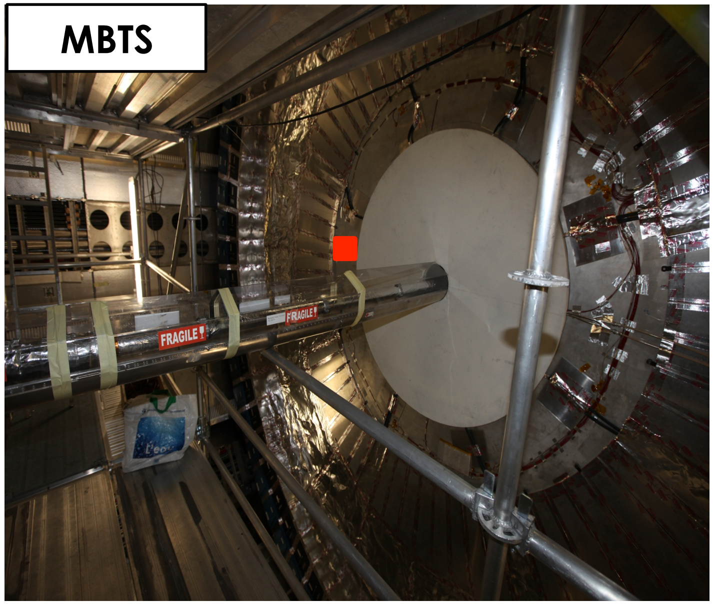


# Micromegas in ATLAS



- Four small MM chambers were installed in ATLAS behind the last muon station in April 2011 and smoothly operated all along the 2011 (background measured to be ~3 Hz/cm$^2$ at L=$10^{34}$ cm$^{-2}$s$^{-1}$)
- First large size resistive MM assembled and tested in muon beam in 2011
  - To be installed in the ATLAS cavern on the small wheel early 2012 for test
- A small prototype will be installed to evaluate the possibility to replace the Minimum Bias Trigger Scintillator of ATLAS with Micromegas
- Integration in the ATLAS acquisition system

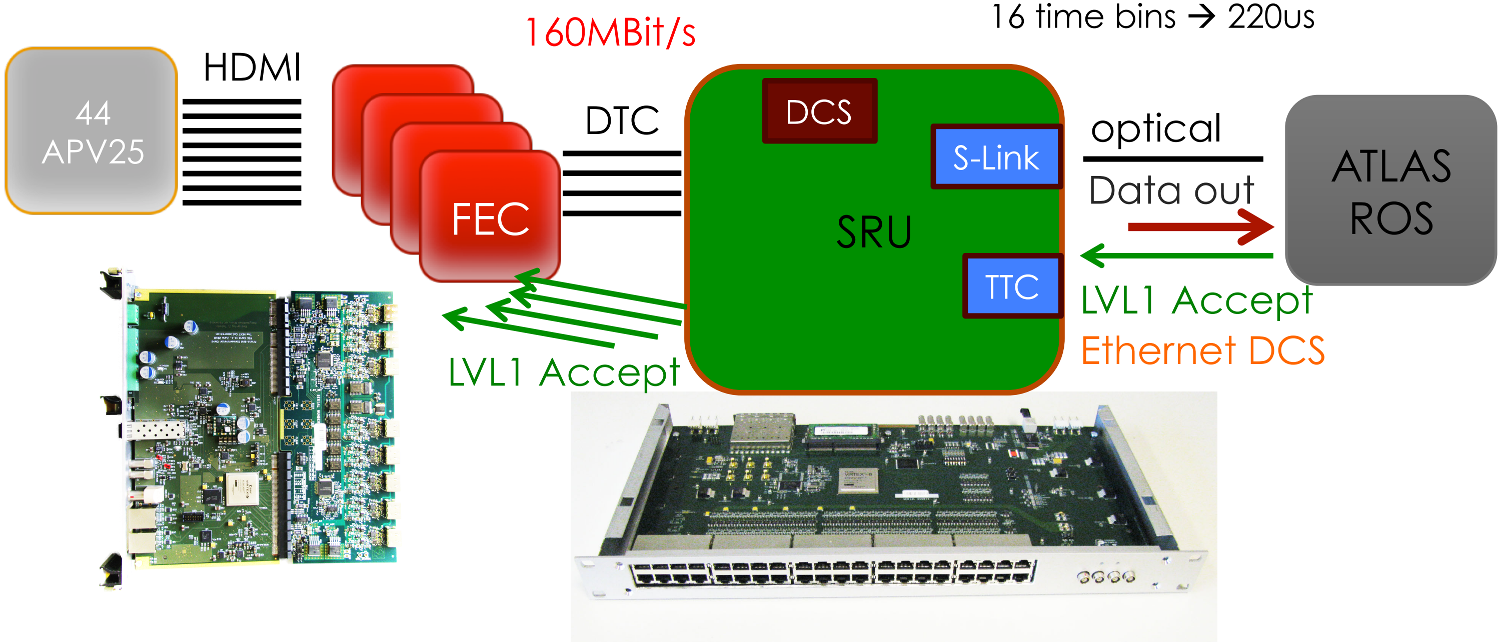


# Integration in ATLAS DAQ

Synchronous data flow at 75kHz

APV →FEC readout timing
APSP 4x70clocks = 7us / timebin
Output 140bits*clock = 3500 ns /timebin
16 time bins → 220us




- Dedicated project started in August, to be ready by February, very tight timescale
- Firmware for Front End data processing and zero suppression (R. Giordano)
- Firmware for high speed data transmission on serial link ≈ 2 Gbit/s (V. Izzo and S. Perrella)
- Integration within ATLAS software (M. Della Volpe and P. I.)

# Napoli group's contribition



Napoli is one of the most active groups in the Collaboration
In 2011 Givi has played a leading role in many activities

- Test in Naples on standard MM, gas mixture optimization
  - Mariagrazia, Givi, Riccardo
- Development of a LabView-based acquisition system
  - Riccardo
- Development and test at CERN of resistive chambers, mechanical assambling, high rate test in Munich, installation in ATLAS cavern
  - Givi
- Test beam activities at CERN
  - Givi, Mariagrazia, Paolo, Raffaele
- Integration in ATLAS DAQ
  - Raffaele, Sabrina, Vincenzo, Mimmo, Paolo
- Data Analysis
  - Mariagrazia, Givi, Paolo

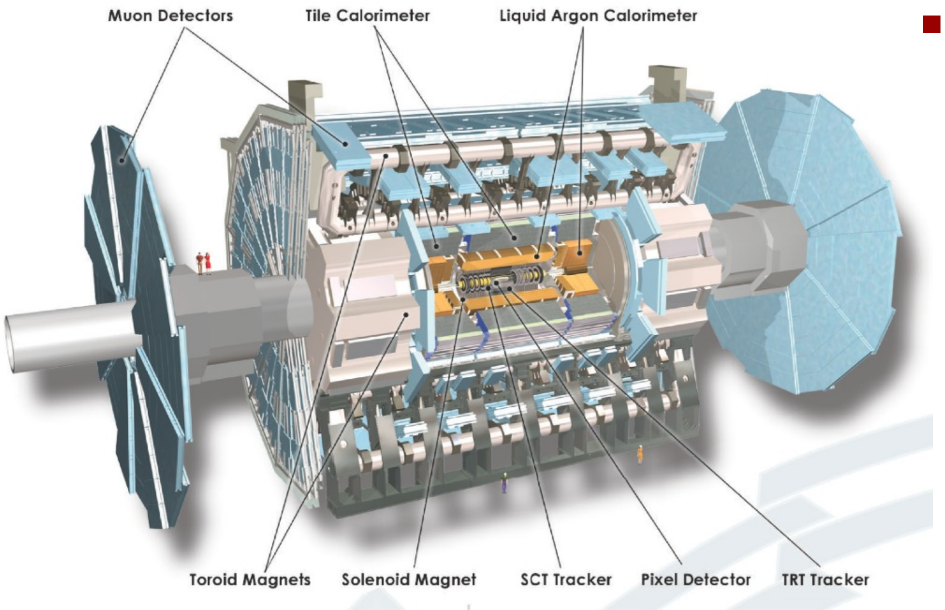
# Summary & Plans

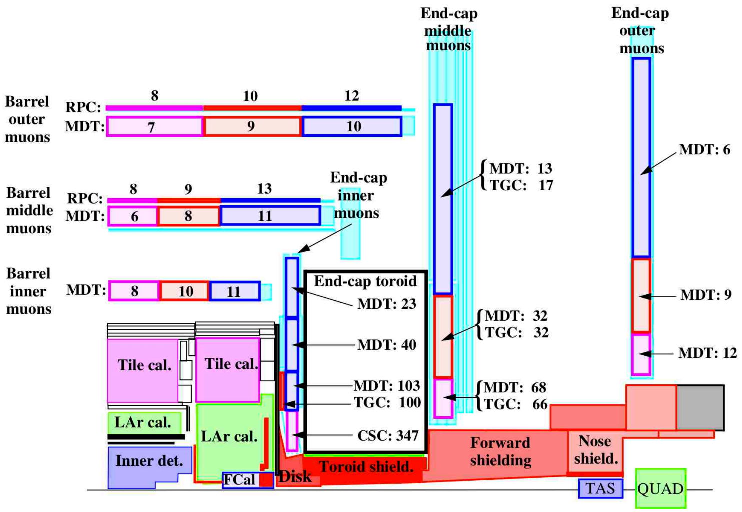


- Micromegas fulfil all of the Small Wheel requirements
- We found an efficient spark-protection system that is easy to implement; sparks are no longer a show-stopper
- MMs are very robust and (relatively) easy to construct
- Large-area resistive-strip chambers can be built and they work very well
- Micromegas are going to be installed in the ATLAS cavern for test early 2012, but the final decision on which technology will be used for the Small Wheel upgrade will be taken in February
- If Micromegas will be the selected option, we have to double our efforts to be ready for the installation during the long LHC shutdown (end of 2012 run, 16 months )
- Important contribution from Napoli's group in many activities

# Backup Slides

# Introduction

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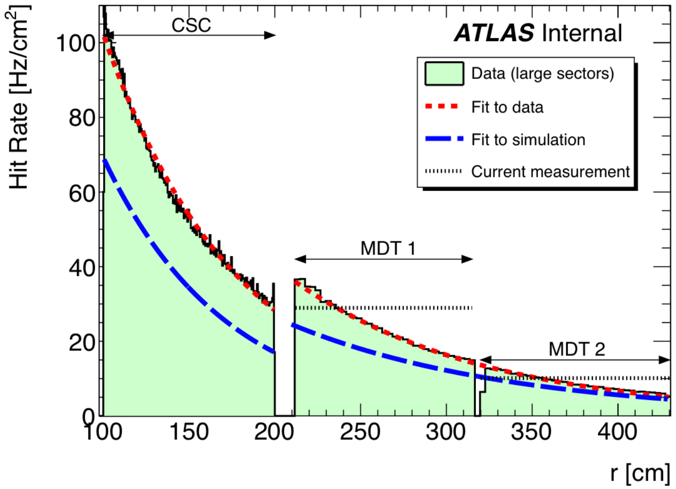
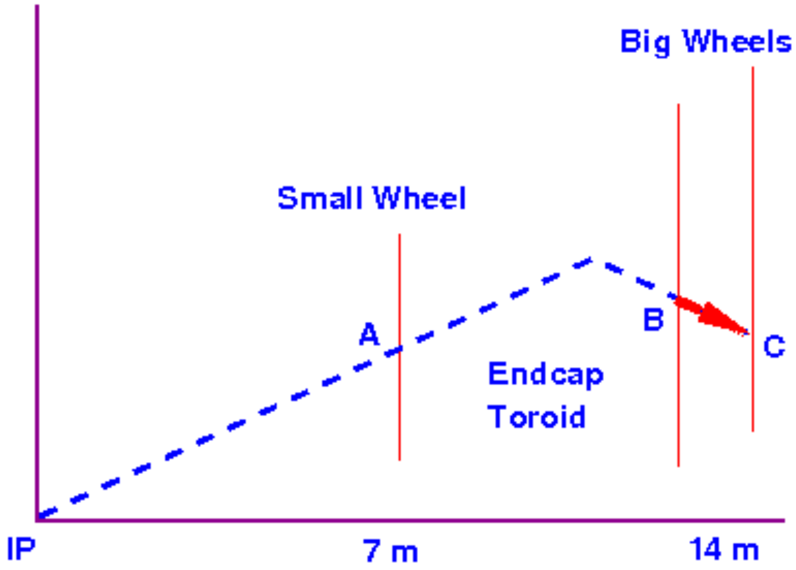



Measured and expected count rates and in the Small Wheel detectors

Data correspond to L = 0.9 x 10$^{33}$ cm$^{-2}$s$^{-1}$ at $\sqrt{s}$ = 7 TeV

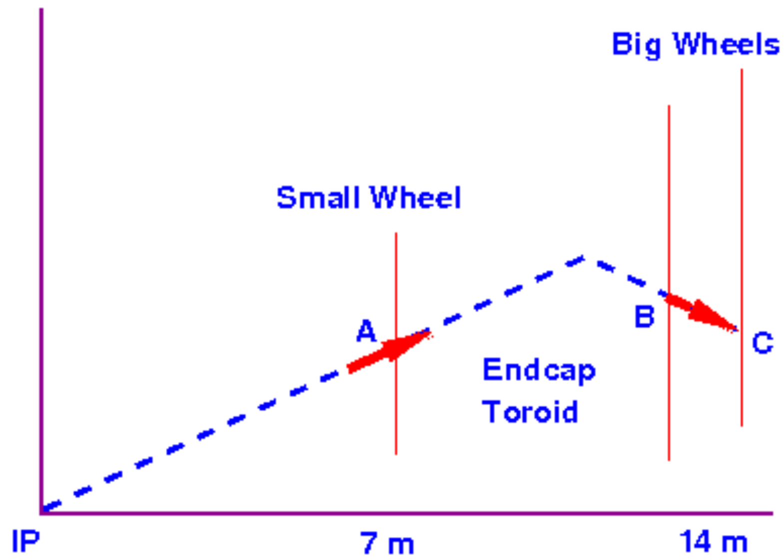
# The problem of the fake rate






**Current LVL1 end-cap trigger**

- Only the vector BC at the Big Wheels is measured
- Momentum defined by assumption that track originated at IP
- Random background tracks can easily fake this
- Currently 96% of forward high-$p_T$ triggers (at LVL1) have no track associated with them

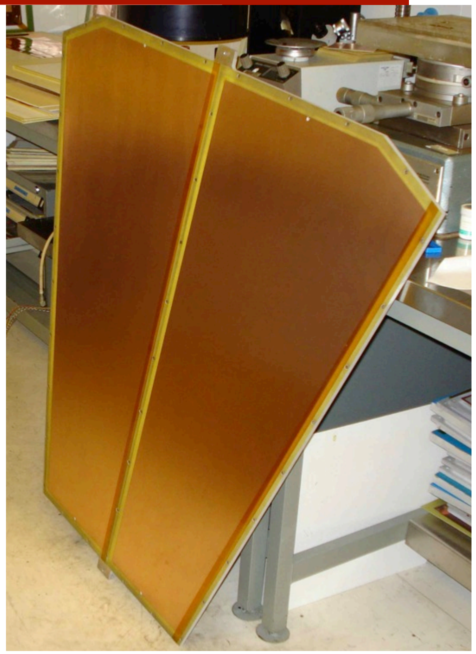


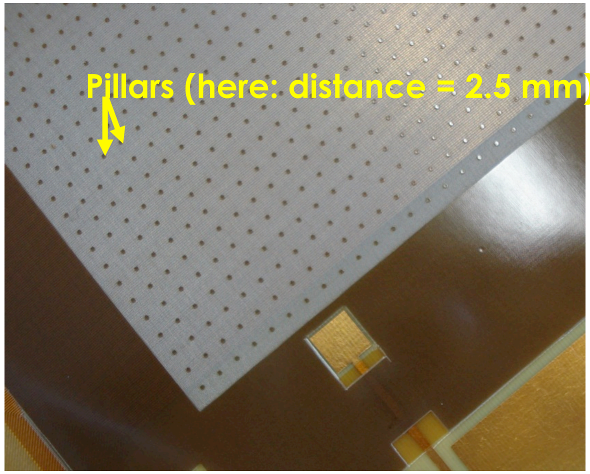

**Proposed LVL1 trigger**

- Add vector A at Small Wheel
- Powerful constraint for real tracks
- A pointing resolution of 1 mrad will also improve $p_T$ resolution

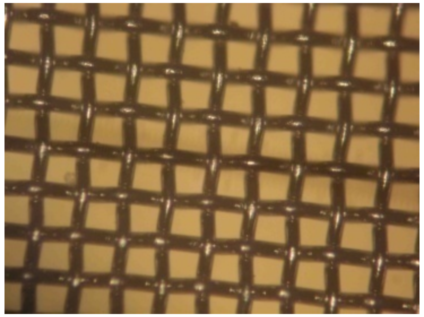
# The bulk-Micromegas

- A production technique developed in 2006 (bulk-micromegas) opened the door to industrial fabrication
- Big effort for going to large dimensions
- In 2007 production of the first large MM prototype for ATLAS (50x60 cm2, the largest MM at the time)
- In 2010 production of a CSC-size Micromegas
- **Reliable production of large size Micromegas is possible!**

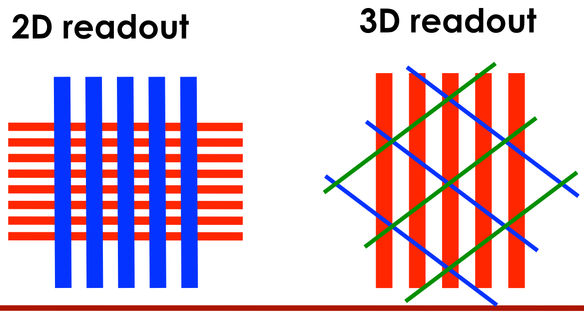





The mesh

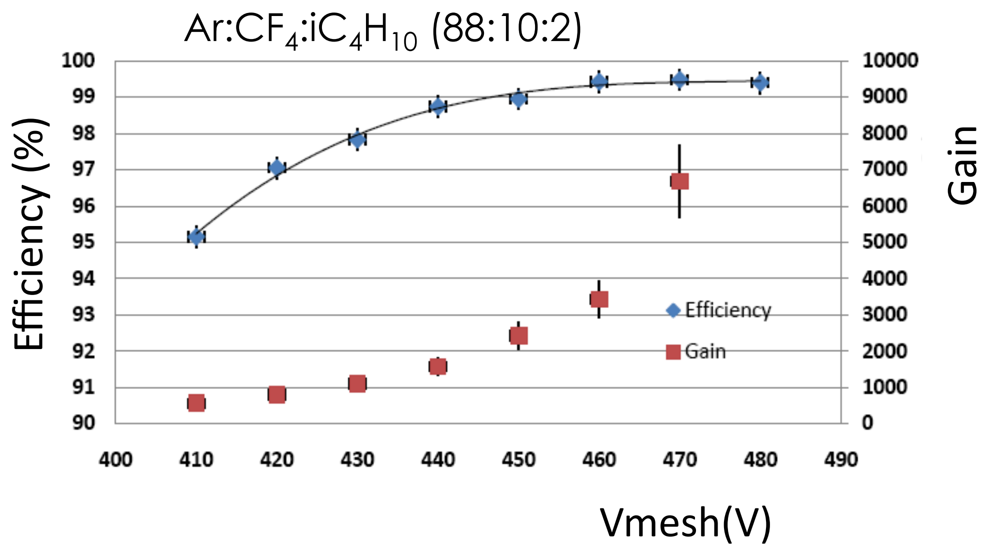


- Other improvements in the segmentation of the r/o electrodes
- 2D (xy) and 3D (xuv) r/o strips showed encouraging results

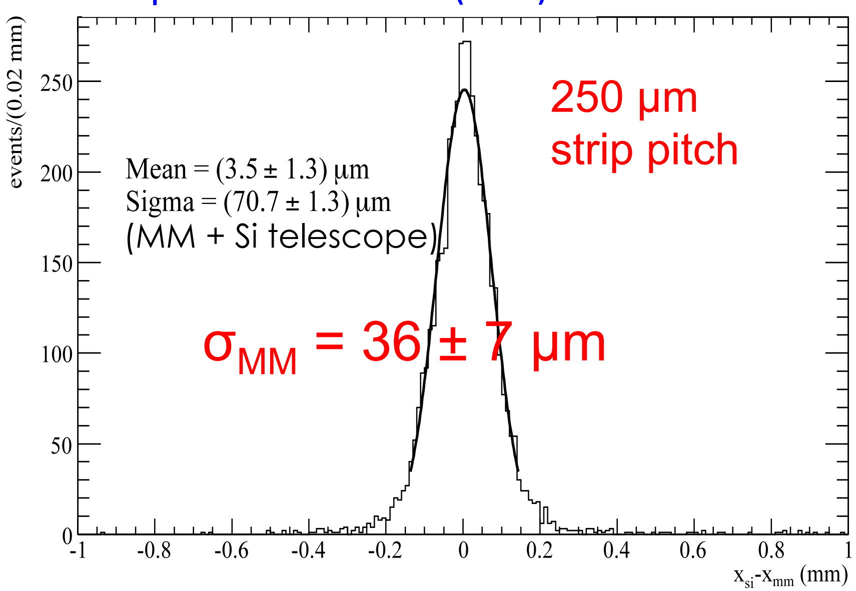


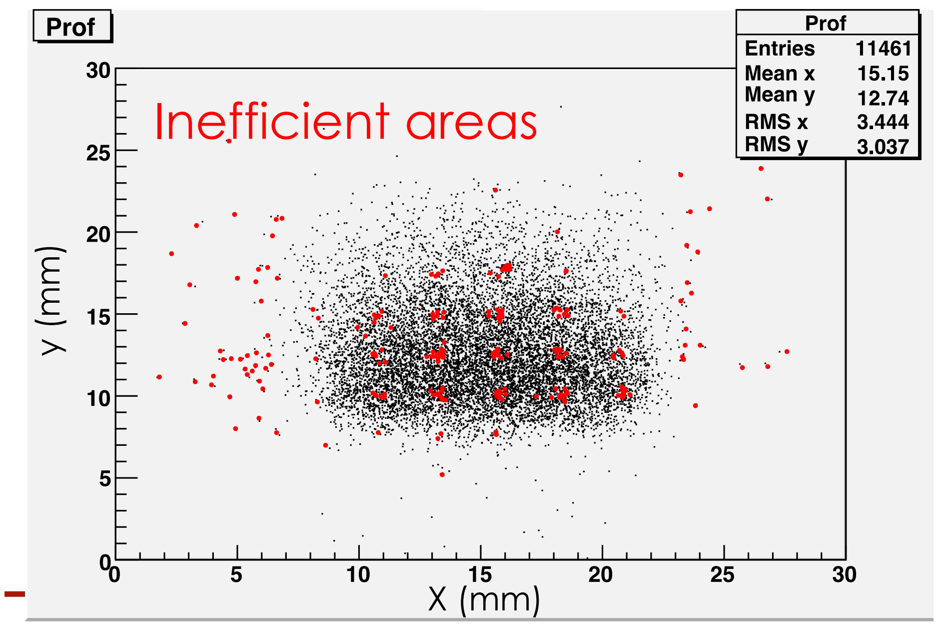
# Demonstrated performance

- Standard micromegas
- Safe operating point with efficiency ≥99%
- Gas gain: 3–5 x $10^3$
- Very good spatial resolution

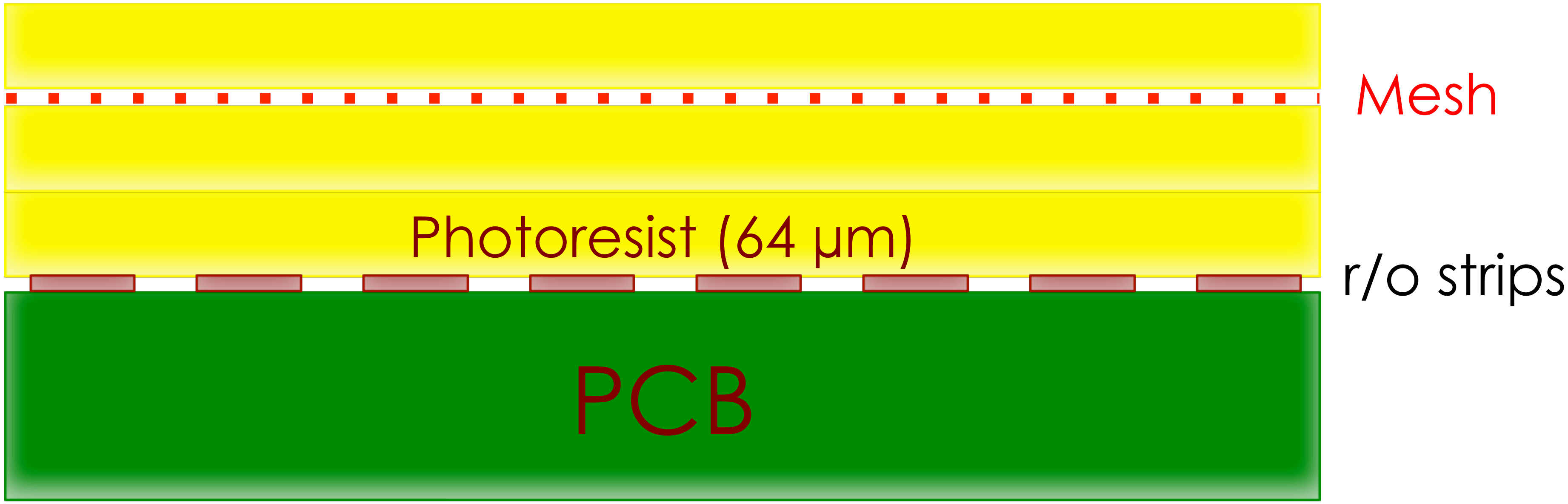



Spatial resolution (mm)



- The bulk-micromegas technique opens the door to industrial fabrication



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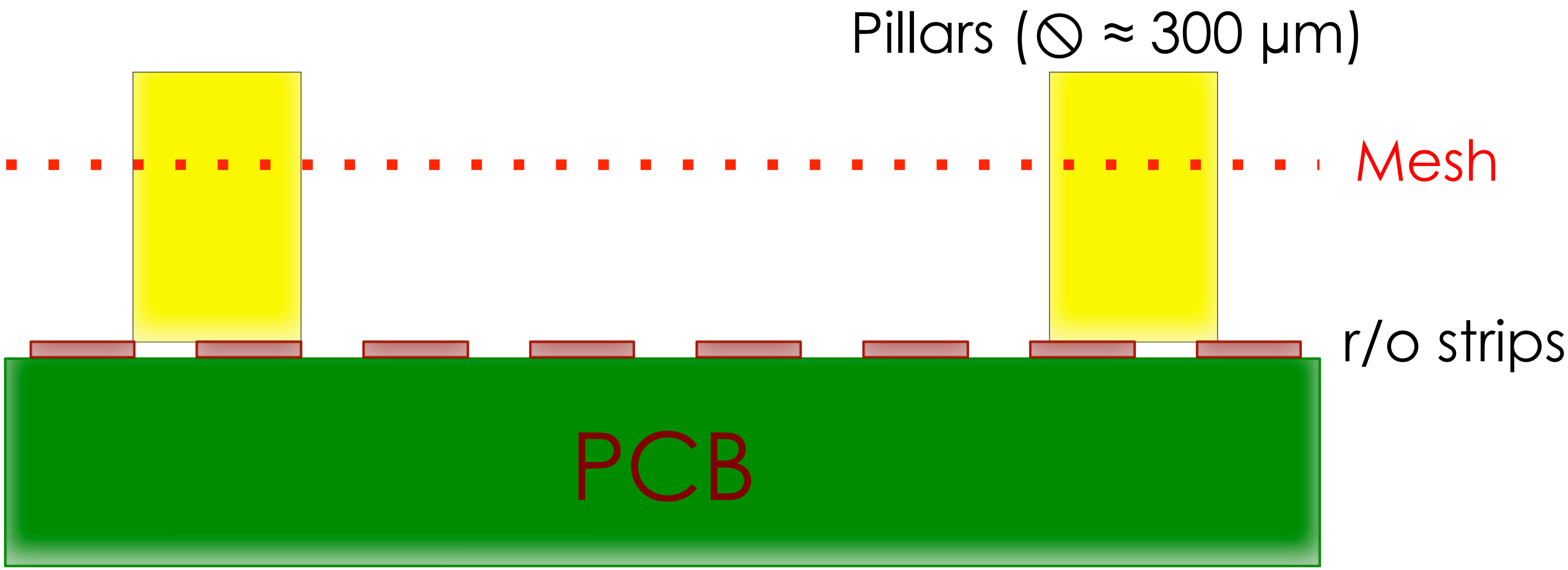
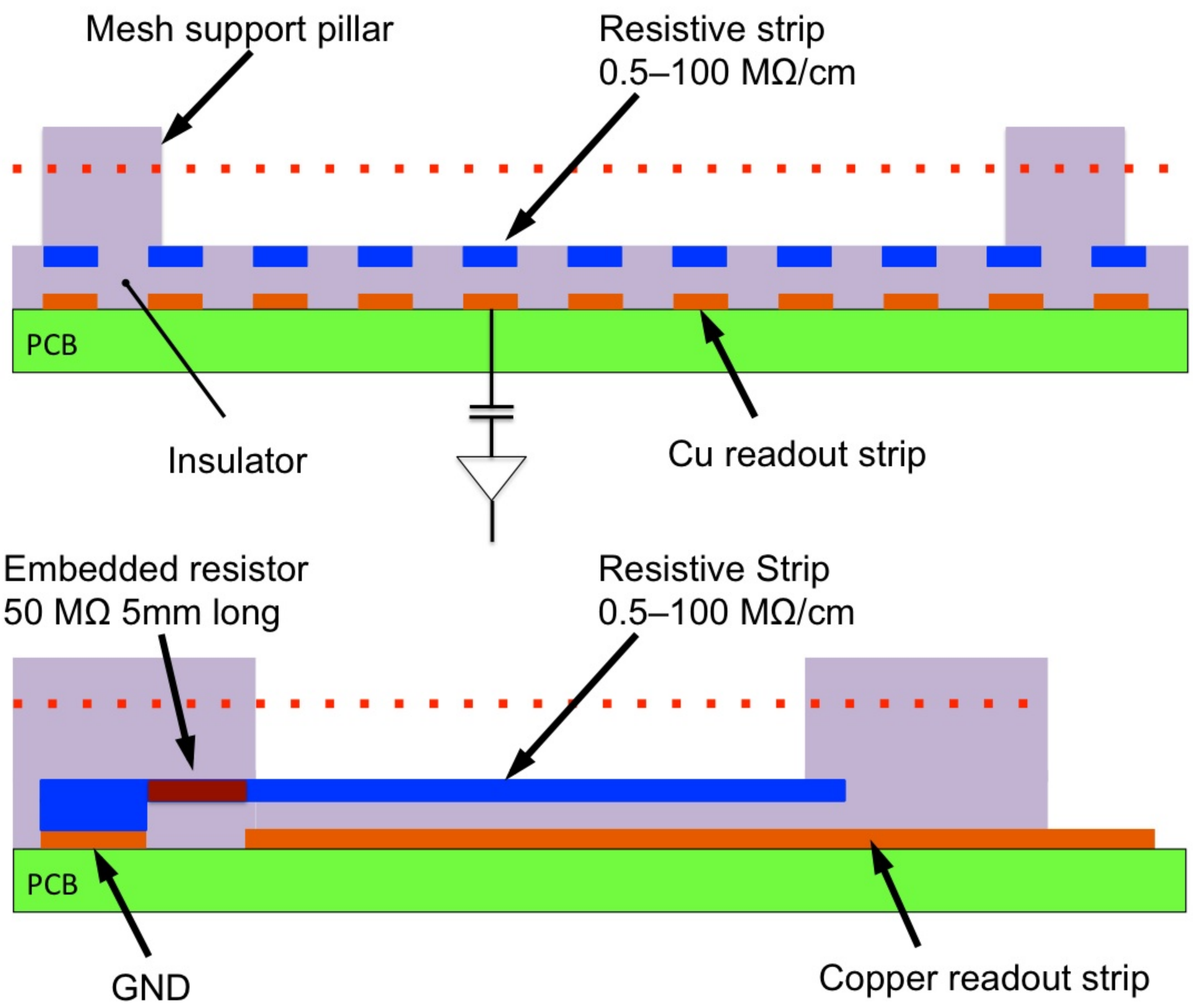


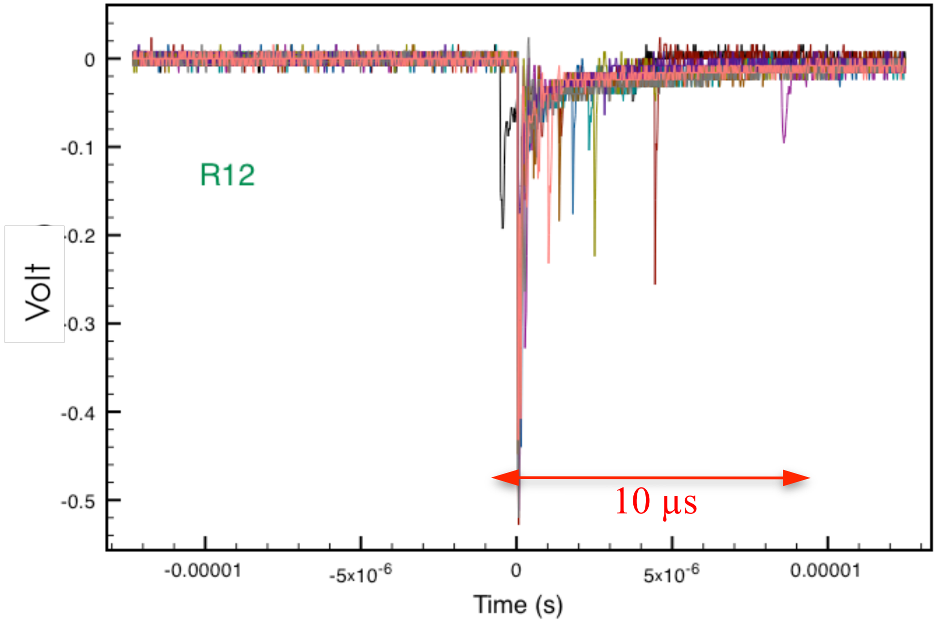
# Resistive-strip protection concept

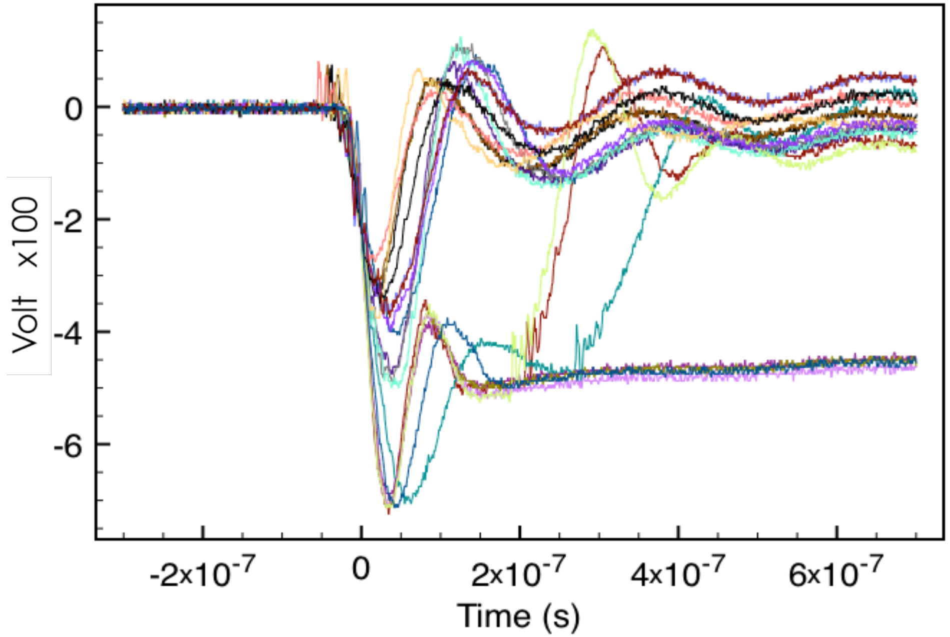


# Spark signals resistive vs standard

Sparks measured directly on readout strips through 50 Ohm
Several spark signals plotted on top of each other to enhance the overall characteristics

R12 shows ~100 times smaller signal and shorter recovery time than C1



# Micromegas integration in ATLAS

A partire da agosto, abbiamo avviato un progetto di R&D per integrare il sistema di readout delle Micromegas all'interno della architettura del DAQ di ATLAS

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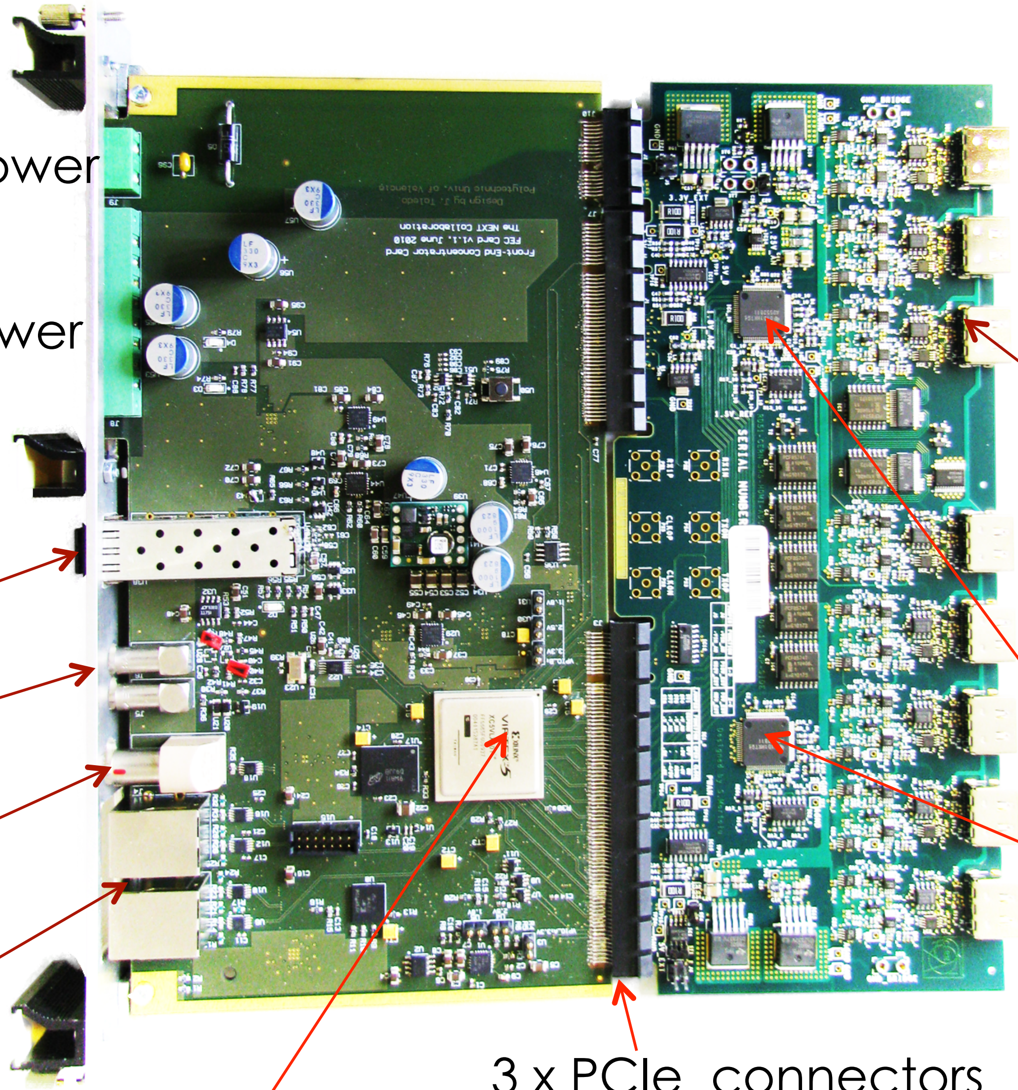
Ci stiamo occupando di diversi aspetti, a vari livelli di integrazione:

- Raffaele Giordano (firmware per Front End data processing e zero suppression)

# FEC and ADC adapter details



FEC card V1.2

HV power

LV power

GbEthernet
( New 2x )

NIM I/O (Trigger)

LVDS I/O ( BUSY)

2x RJ45
DTC link to SRU

ADC card V1.0

HDMI chip links
8x

Firmware:
Data processing
and buffering

Octal ADCs
12 bit 40 MHz
( 65 MHz in new version)

3 x PCIe connectors

Virtex 5 FPGA (Virtex 6 in new version)

# FEC card revision V6

- **New FPGA**: Virtex 6 (faster and significantly more resources for Online firmware)
- **Dual SFP+** on Front panel (separated Data and Control via GBe)
- **More I/Os** on PCIe ( more applications )
- **4 x GTX transceiver (5 GBps)** on interface connector A (fast applications)
- **Remote FPGA configuration** via Ethernet (reconfiguration from distance)
- **LDO's** replace switching regulators ( less noise, and operation in magnetic field)
- **DDR3** pluggable memory ( optional large data buffer )

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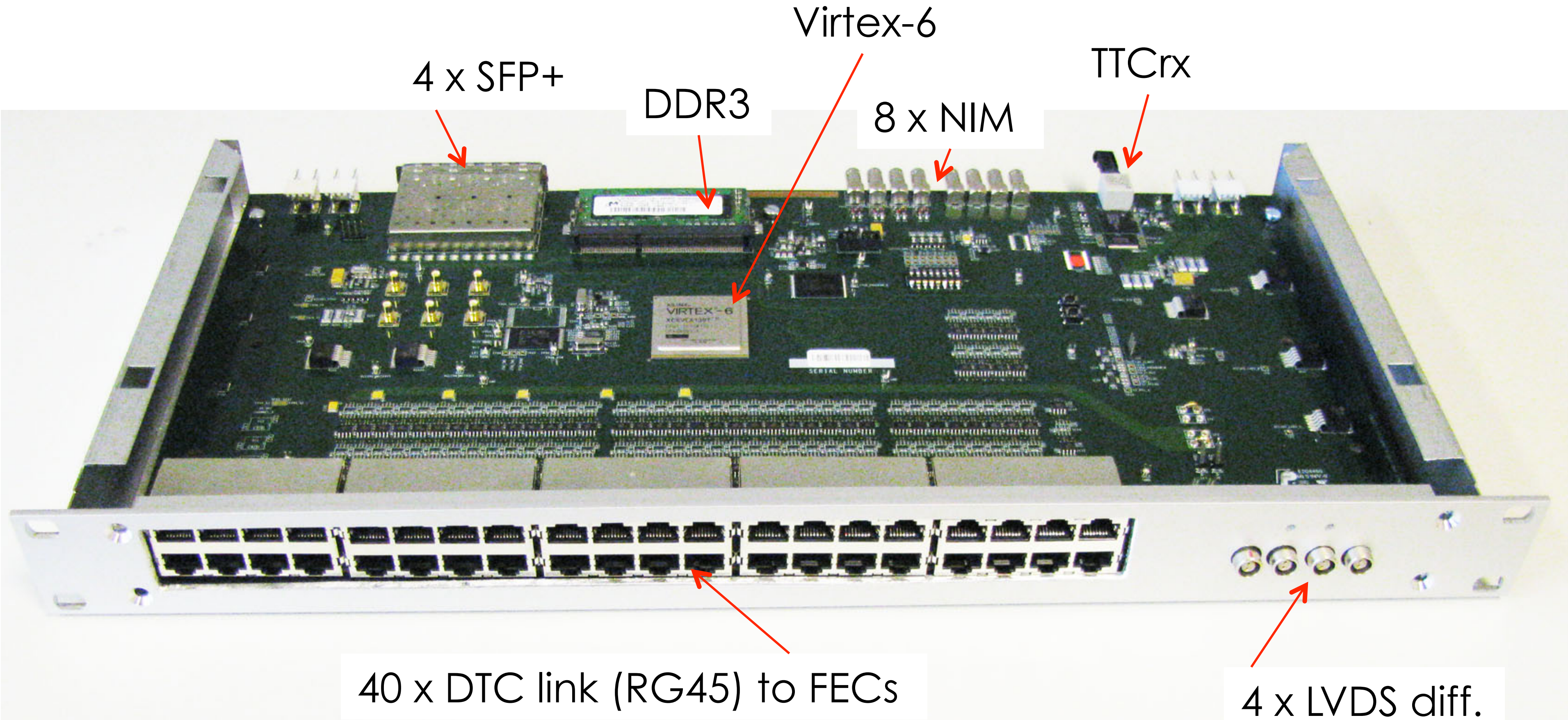
# 1st SRU box (status 15 Jan. 2011)




25 SRU's ready for production by Firstec
2 SRU's under power / test

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- Mimmo Della Volpe (integrazione col software di ATLAS)