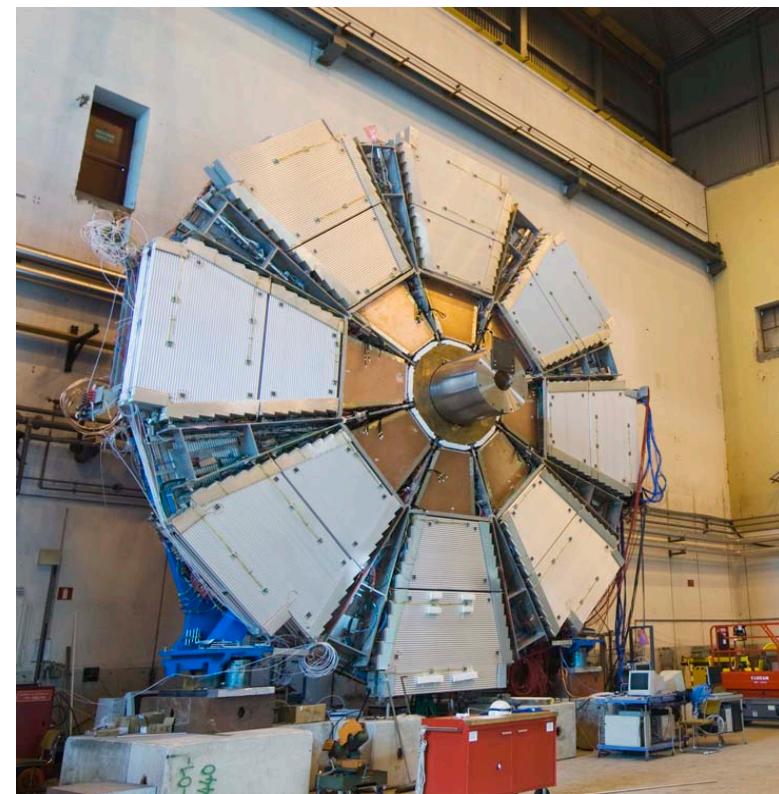


# New Small Wheel per lo Spettrometro a muoni di ATLAS

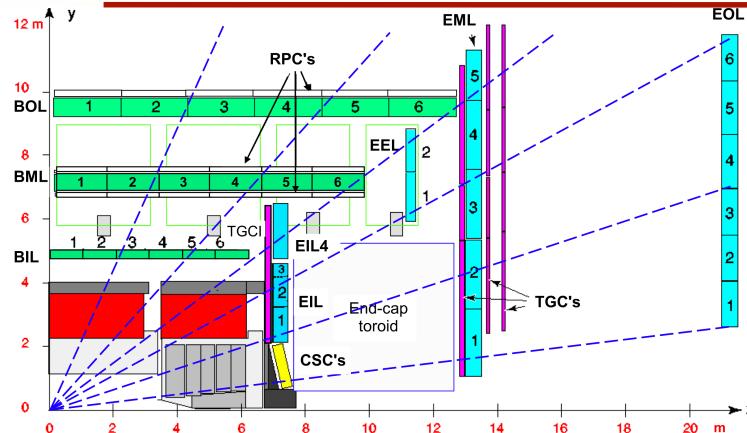
Paolo Iengo (INFN Napoli)

Cosenza  
Lecce  
LNF  
Napoli  
Roma1  
Roma3  
Pavia

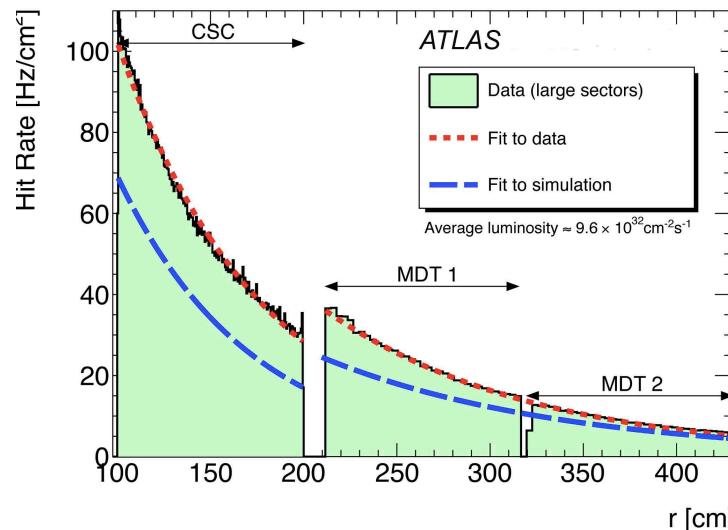


- Necessita' della NSW
- Proposte per la NSW e processo di selezione
- Soluzione omogenea e milestone
- Stato attuale delle Micromegas
- Piani per il 2012-2013
- Richieste 2012 e stima costi

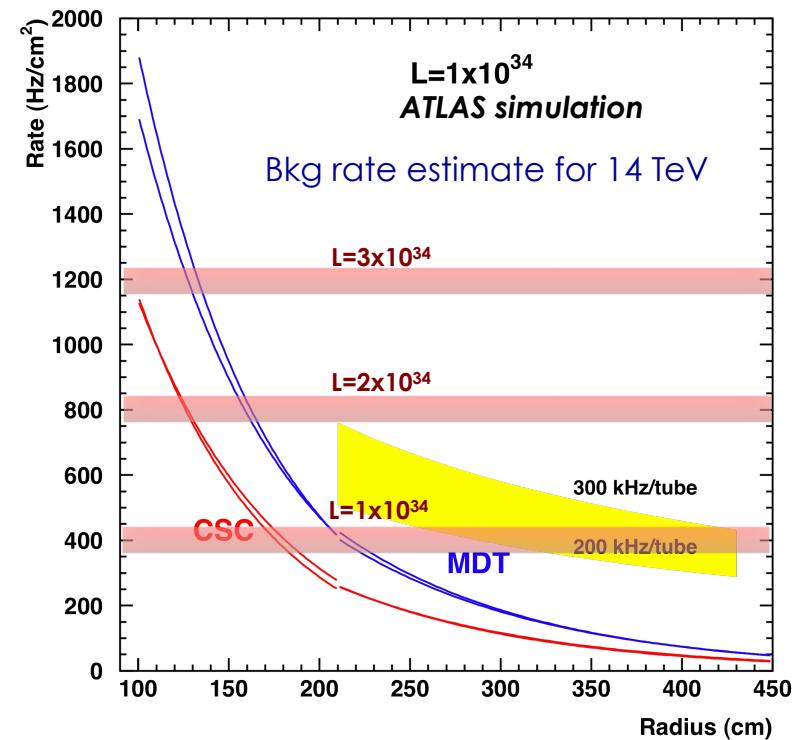
# Necessita' delle NSW



- MS progettato per rate attesi a  $1 \times 10^{34}$  con margine di sicurezza ~5
- Rate misurato nelle SW superiore a quello atteso dalle simulazioni originarie (in accordo con le attuali)
- $1 \times 10^{34}$  e' il limite dei rivelatori attuali (MDT), non c'e' margine per luminosita' piu' alta

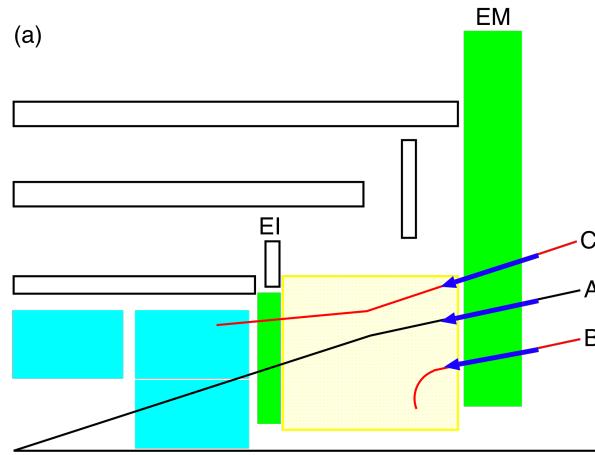


**Necessario upgrade di phase1 delle SW con rivelatori a piu' alta rate capability**

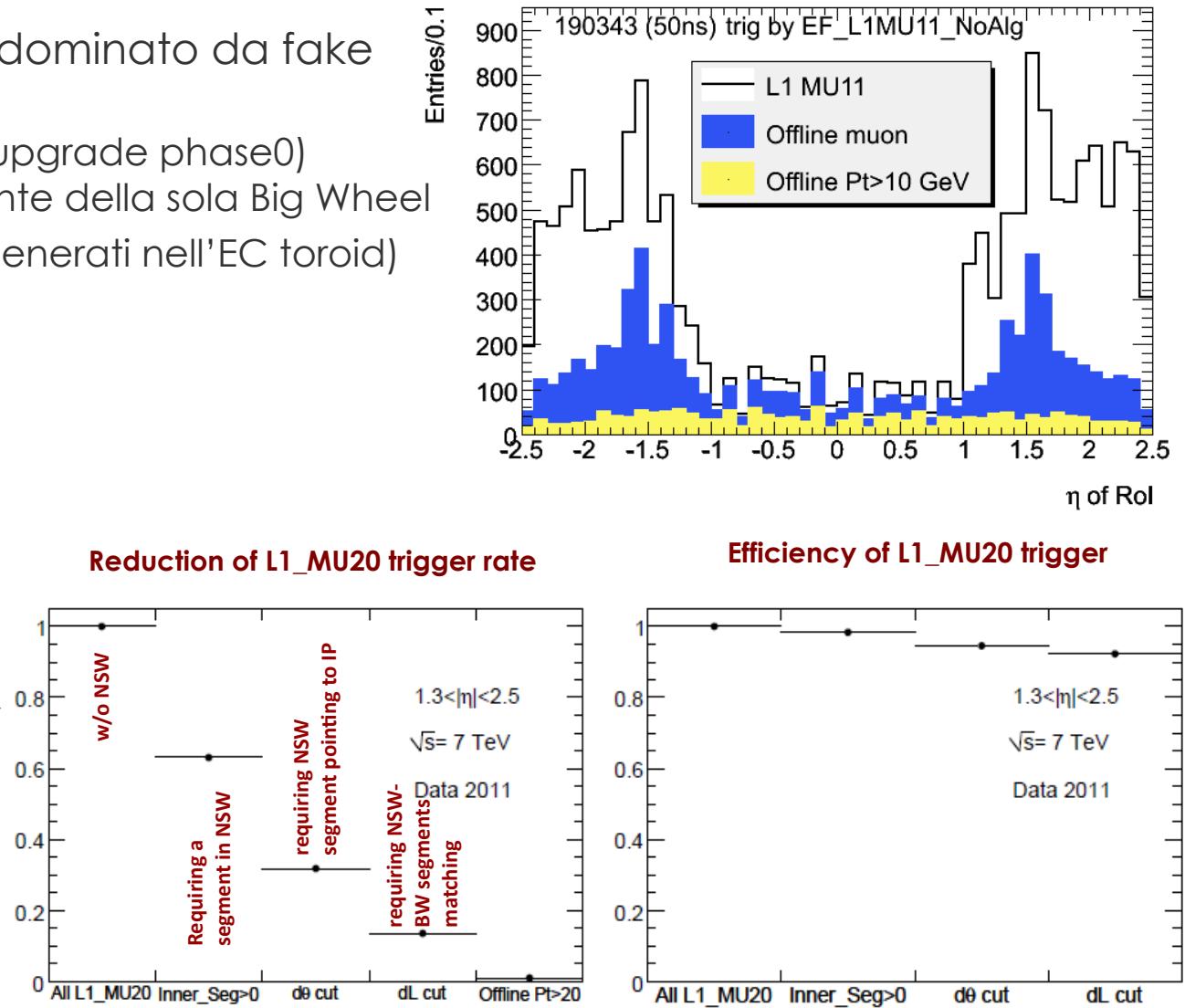


# Necessita' delle NSW

- Trigger di muoni attuale dominato da fake rate nelle endcap
  - SW non incluse nel L1 ( $\rightarrow$ upgrade phase0) scarso potere discriminante della sola Big Wheel
  - Particelle lente (protoni generati nell'EC toroid)

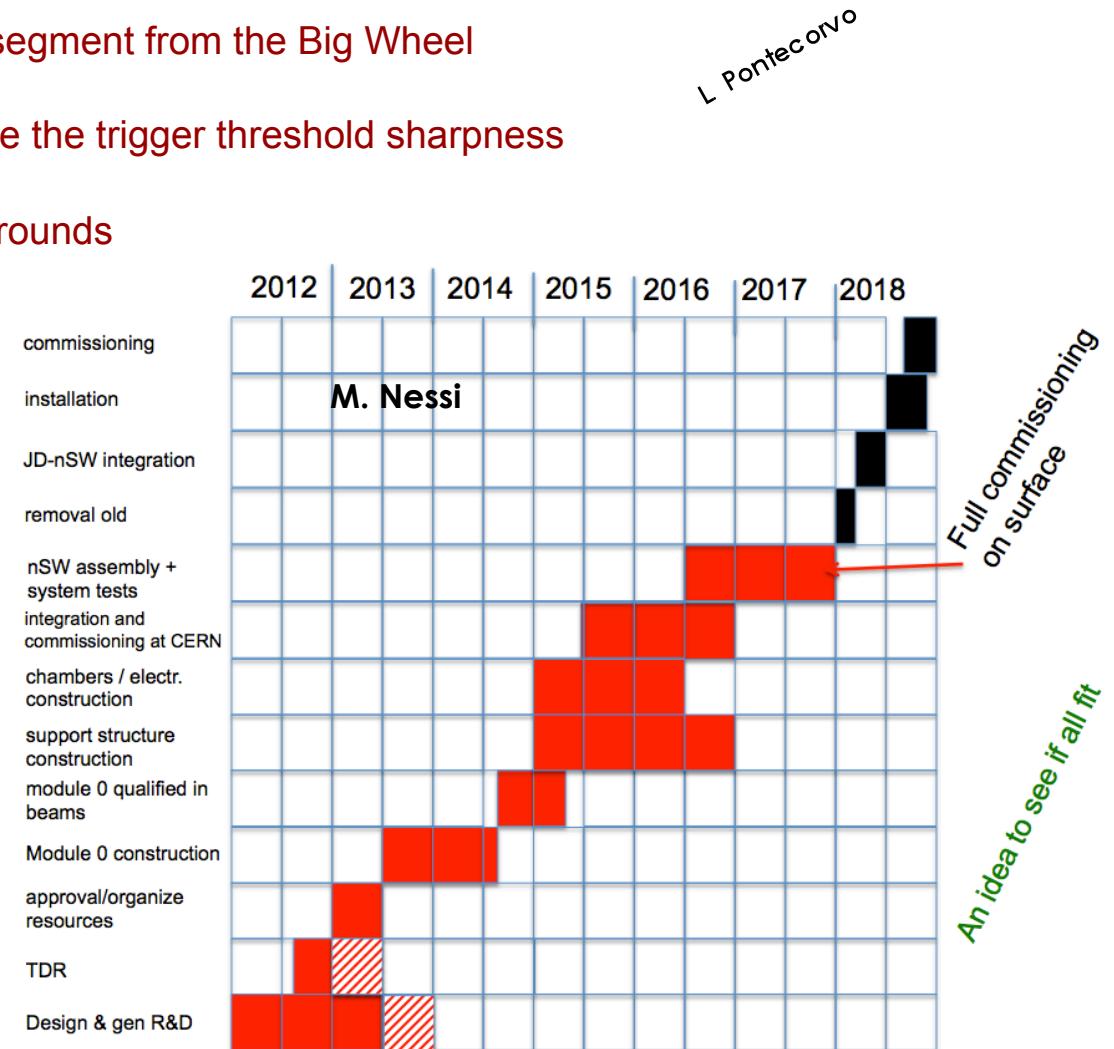


**Necessario upgrade di phase1  
delle SW con risoluzione  
angolare  $\sim 1\text{mrad}$**



# NSW requirements e timeline

- Provide on line reconstruction of track segments with 1 mrad accuracy.
  - Trigger formed with coincidence of track segment from the Big Wheel
  - High angular resolution needed to improve the trigger threshold sharpness
  - Robust trigger against unexpected backgrounds
  - BC Identification (fast detectors)
- Precision tracking to preserve position and angular resolution as good even at ultimate high luminosity, including phase-2
- Cavern background foreseen in the hottest region up to 14 KHz/cm<sup>2</sup>
  - Large number of high resolution space points (100 µm )
  - High rate capability and High efficiency





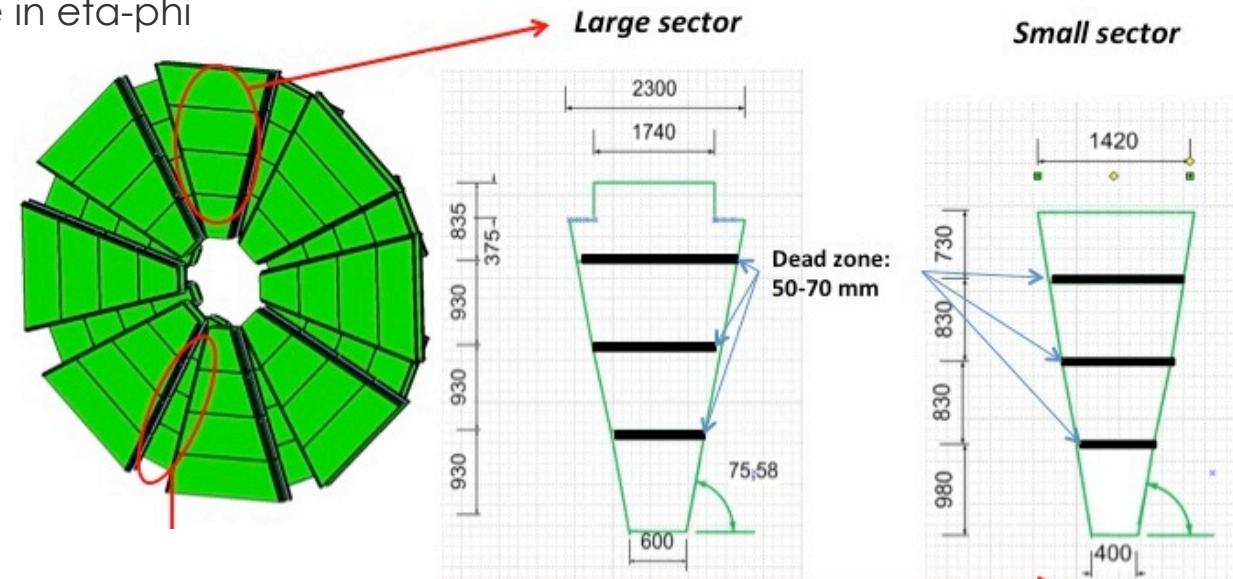
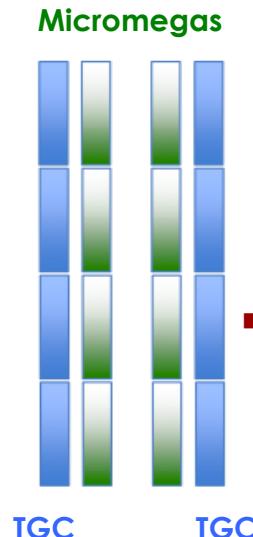
# Selezione delle proposte per NSW

6

- Tre proposte distinte avanzate per la costruzione della NSW e contenute nella LOI di phase1
    - sTGC+sMDT
    - mRPC+sMDT
    - Micromegas
  - Nominato un ‘panel’ di valutazione nell'estate 2011
    - A. Romanik, F. Lanni, P. Farthuat, N. Kostantinidis, M. Nessi
  - Workshop dedicato a Les Brassus a fine gennaio 2012
  - Esaminate due soluzioni ‘miste’:
    - TGC+Micromegas
    - TGC+MDT(alto R)+Micromegas(bassoR)
  - NSW workshop al CERN fine marzo
  - Management (L. Pontecorvo, S. Vlacos, T. Kawamoto, J. Dubbert) ha proposto la soluzione omogenea (TGC+Micromegas)
  - Soluzione omogenea votata dal Muon IB a fine aprile 2012 assieme ad una lista di milestone da verificare entro il 2012

# La soluzione omogenea

- sTGC (main trigger) + Micromegas (main tracking)
- Doppia ridondanza
  - Entrambe le tecnologie in grado di fornire trigger e tracciamento entro le richieste
  - Entrambe segmentate in eta-phi
- FE Elx comune

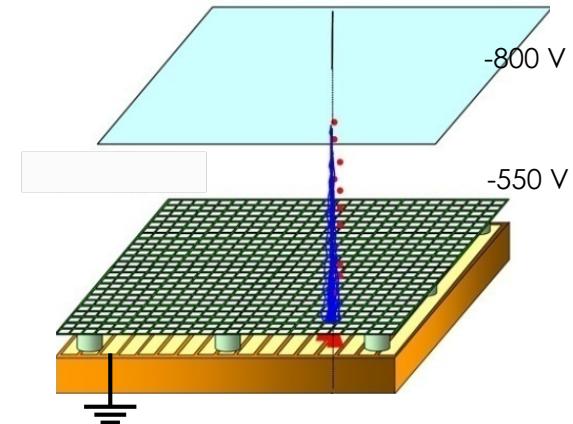


- Ogni camera composta da:
  - 2 quadrupletti TGC (esterni)
  - 2 quadrupletti Micromegas (interni)
- **Micromegas: 128 camere (0.5-2.5 m<sup>2</sup>)  
- 1028 volumi - 1200m<sup>2</sup> - 2M canali r/o  
(500 μ m-2mm pitch)**

# Milestone da dimostrare entro il 2012

8

- Micromegas:
  - Risoluzione  $<100 \mu\text{m}$  nel modo  $\mu\text{TPC}$
  - Possibilita' di costruire camere di grandi dimensioni ( $\sim 1\text{m} \times 1\text{m}$ )
  - Immunita' alle scariche per camere grandi
- Comuni (Micromegas+sTGC)
  - Allineamento interno (strip, layer e multilayer)
  - Progressi nell'industrializzazione
- sTGC:
  - Dimostrazione del 'trigger concept' su test-beam



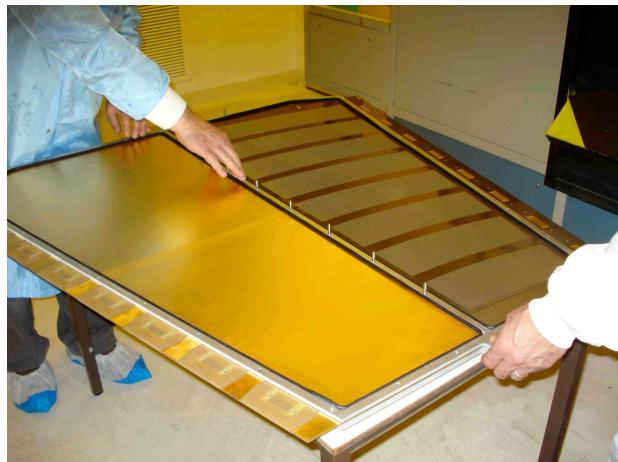
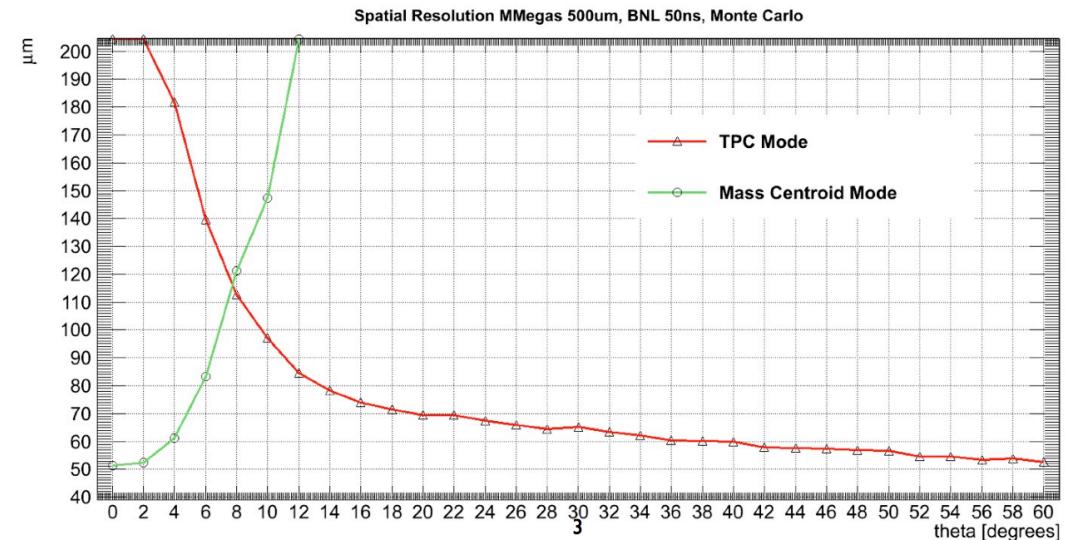
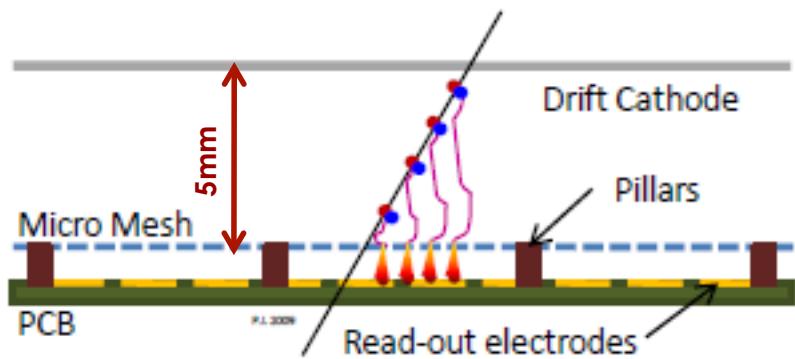
## Micromegas in ATLAS

- 'Proto' Collaborazione MAMMA (Muon Atlas MicroMegas Activity) nata nel 2007
- Oggi 21 gruppi partecipanti:
  - Arizona, Athens (U, NTU, Demokritos), Brandeis, Brookhaven, CERN, Carleton, Frascati, Istanbul (Bogaziçi, Doğuş), JINR Dubna, MEPhI Moscow, LMU Munich, Naples, Rome1, Rome3, CEA Saclay, USTC Hefei, South Carolina, Thessaloniki
  - Altri gruppi interessati; confluira' nella NSW collaboration

## Interesse italiano su Micromegas e trigger

# Micromegas: stato attuale (1/3)

- MM come  $\mu$  TPC: simulazioni e primi risultati incoraggianti, manca ancora dimostrazione su fascio della risoluzione spaziale  $<100 \mu\text{m}$

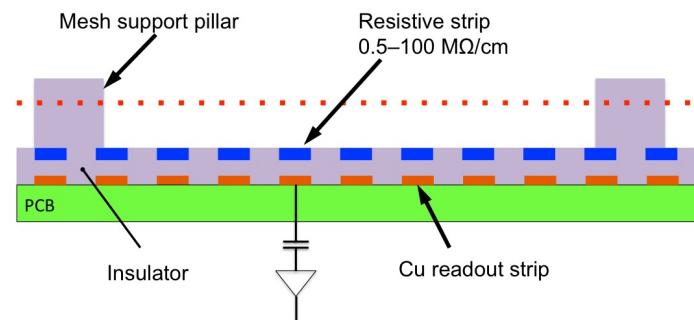


- MM di grandi dimensioni: ad oggi realizzata camera 60cmx120cm. 60cm e' il limite della macchina per lavorare PCB del CERN.
- Il CERN si e' dotato di macchine di dimensione maggiore (1m). Edificio che dovrà ospitarle in costruzione, pronto nel 2014

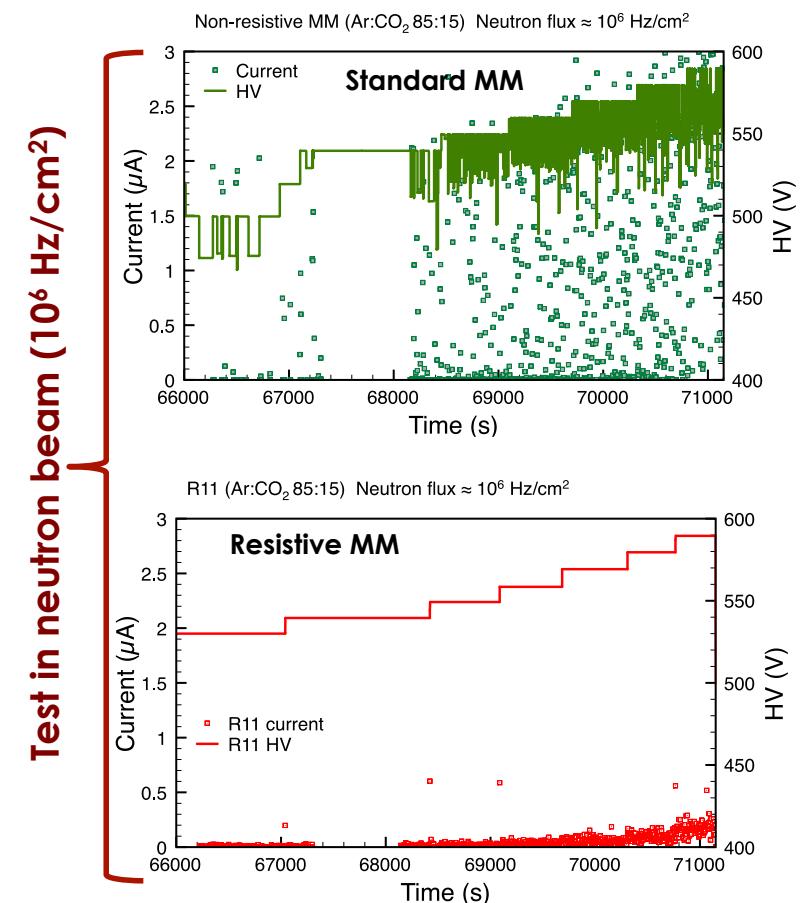
# Micromegas: stato attuale (2/3)

10

- Riduzione delle scariche: R&D di ATLAS per risolvere il problema con l'aggiunta di un layer resistivo sugli elettrodi di lettura.
- Ottimi risultati su rivelatori di piccole-medie dimensioni, ancora da realizzare detector discharge-proof  $\sim 1\text{m}^2$



- Allineamento:  
Richiesta precisione su posizione delle strip  
 $<20\mu\text{m}$   
Allo studio diverse opzioni (interferometria, fotogrammetria etc.) anche in collaborazione con ditte specializzate





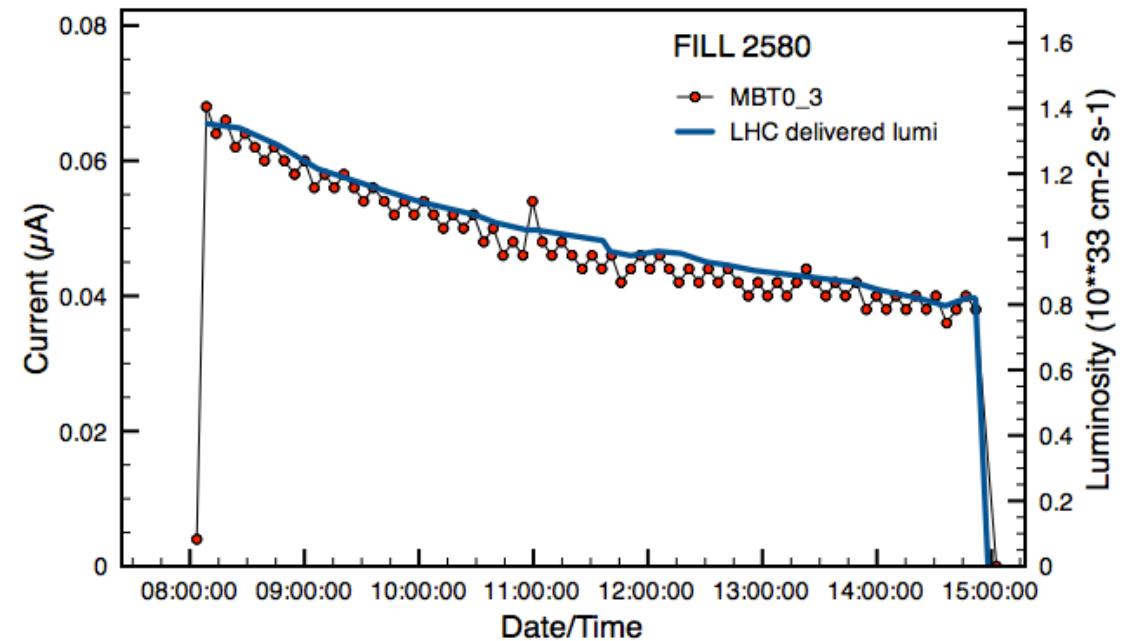
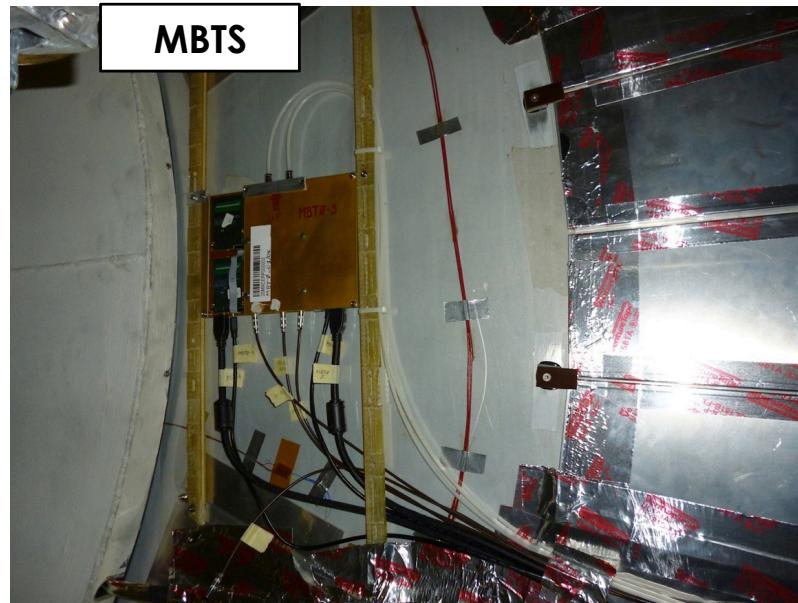
# Micromegas: stato attuale (3/3)

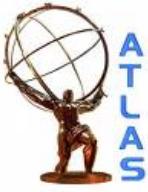
11

- Industrializzazione:
  - Tecnica 'industrializzabile' di produzione delle MM (bulk) sviluppata al CERN, trasferimento tecnologico verso le aziende in corso da parte del CERN (RD51 – sforzo comune per MPGDI)
  - Due le industrie allo stadio piu' avanzato: CIREA (Parigi) ELTOS (Arezzo). ELTOS gia' in contatto con INFN per la produzione di THGEM (Trieste)
  - Riteniamo possibile avere in Italia un centro di produzione (30-50% della produzione totale), in tal caso in Italia ci sarebbe anche un centro di assemblaggio delle camere (LNF?). Stiamo indagando la possibilita' di inserire questa attivita' nel contesto della convenzione per TT tra INFN e regioni.
  - Proposta di avere un 'responsabile produzione' in ambito INFN accolta sia nella collaborazione MAMMA che RD51. Francesi (Saclay) hanno gia' definito una figura analoga
- Elettronica di r/o:
  - Chip VMM1 sviluppato da BNL da utilizzare per MM e sTGC. Prima produzione appena terminata, test su fascio a Luglio
  - Misura di carica, tempo di drift ( $O(2\text{ns})$ ), uscita 'veloce' per il trigger, latenza  $O(100 \mu\text{s})$

# Micromegas in ATLAS

- Quattro prototipi MM installati nell'Aprile 2011 alle spalle della stazione esterna dello spettrometro ed operate con successo (background misurato  $\sim 3 \text{ Hz/cm}^2$  at  $L=10^{34} \text{ cm}^{-2}\text{s}^{-1}$ )
- Camere ora installate sulla SW
- Un nuovo prototipo installato sull' MBTS per valutare la possibilita' di usare MM per l'upgrade del MBT
- Integrazione nel DAQ di ATLAS in programma





# Piani per il 2012-2013

13

- Test beam 2012:
  - 3 al CERN, 1 in campo magnetico (Giugno-Luglio-Ottobre):  $\mu$  TPC, effetti del campo magnetico, primo test del chip di lettura finale
  - 1 a LNF (Luglio): test di elx veloce, cooperazione gruppi italiani, proposta per TB 2013 (nessuna disponibilita' al CERN)
- R&D: realizzazione di una MM resistiva 1mx1m al CERN e test di uniformita'
- Verifica dell'allineamento interno su singole schede e su un multipletto (4 piani MM)
- Prosecuzione del trasferimento della tecnologia alle aziende: MM resistive e di dimensioni 60x100 cm<sup>2</sup>
- Finalizzazione TDR (2013)
- Realizzazione Modulo-0 (2013)
- Organizzazione risorse tra istituti partecipanti (2013)



# Interessi italiani

14

	TB	Analisi Dati	R&D e test al CERN	MM in ATLAS	Test in sede	Modulo 0	Ageing- Irraggiame- nto	Meccanica	Simulazione	Servizi
Napoli	X	X	X	X	X	X	X			
LNF	X	X	X	X	X	X		X		X
Roma1	X	X		X	X	X	X	X		
Roma3	X	X			X	X	X	X		
Lecce	X	X				X			X	
Cosenza	X	X					X			X
Pavia						X		X	X	X

## Personale

Napoli	<b>Alvaggi, Canale, Givi, Iengo, De Asmundis, Della Pietra</b>
LNF	<b>Antonelli, Maccarrone, Laurelli, Gatti + supporto tecnico</b>
Roma1	<b>Bini, Lacava, Anulli</b>
Roma3	<b>Baroncelli, Iodice, Petrucci, Biglietti, Trovatelli (dott.) + supporto tecnico</b>
Lecce	<b>Gorini, Primavera + supporto tecnico</b>
Cosenza	<b>Tassi, Schioppa, Policicchio</b>
Pavia	<b>Lanza, Rimoldi + supporto tecnico</b>

Lista di nomi indicativa, FTE in alcuni casi ancora da definire



# Richieste 2013

15

	ME				TOT ME	TB LNF	MI		TOT MI	Consumo	Inv. (+Cons.)
	TB fuori CERN	MM in ATLAS	Riunioni e contatti tecnici	Ageing-Irraggiamento			Riunioni e contatti produzione				
Napoli	2 MU	2 MU	2 MU	2 MU	8 MU	2 MU	2 MU	4 MU	10 kE	Prototipi MM+Elx +test cosmici	8 kE HV+SRS
LNF	2 MU	2 MU	3 MU		7 MU		2 MU	2 MU	15 kE	TB LNF + test cosmici	20+15 kE HV+FE elx + attrezzatura meccanica
Roma1	2 MU	1 MU	2 MU	1 MU	6 MU	1 MU	1 MU	2 MU	10 kE	Prototipi MM + test cosmici + elx	
Roma3	2 MU	1 MU	2 MU	1 MU	6 MU	1 MU	1 MU	2 MU	10 kE	Prototipi MM + test cosmici + meccanica	5 kE Elx
Lecce	0.5 MU		1 MU		1.5 MU	0.5 MU	1 MU	1.5 MU	5 kE	Meccanica/TB	
Cosenza	0.5 MU			1 MU	1.5 MU	0.5 MU		0.5 MU	10 kE	Prototipi MM + RO Ing. Servizi + meccanica	1 kE Elx
Pavia			1 MU		1 MU		0.5 MU	0.5 MU	7 kE		
<b>TOT</b>	<b>9</b>	<b>6 MU</b>	<b>11</b>	<b>5 MU</b>	<b>31 MU</b>	<b>5 MU</b>	<b>0.5 MU</b>	<b>12.5 MU</b>	<b>67 kE</b>		<b>49 kE</b>

MI: 1MU~4000 Euro

Richieste razionalizzate secondo uno spirito 'collaborativo': materiale distribuito su alcuni gruppi da mettere in comune per i test (TB a LNF etc.)



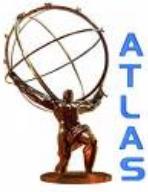
# Costi CORE

16

- Contributo stimato in base ai possibili deliverables
- Costo totale NSW soluzione omogenea:

- TGC: 2300 kCHF
- MM: 6000 kCHF
- Common: 2300 CHF

<b>Micromegas</b>	<b>MM detector</b>	<b>1024</b>	<b>2500</b>	<b>2560</b>
	<b>Detector mechanics</b>	<b>128</b>	<b>2500</b>	<b>320</b>
				<b>2880</b>
	<b>Alignment</b>			<b>600</b>
	<b>Chip development and production</b>	<b>2000000</b>	<b>0.7</b>	<b>1400</b>
	<b>front-end cards</b>	<b>4096</b>		<b>600</b>
	<b>GBTx and fibres</b>	<b>1024</b>		<b>400</b>
	<b>CAM</b>			<b>800</b>
	<b>Readout system</b>			<b>500</b>
				<b>3700</b>
	<b>HV PS , cables, LV ps</b>	<b>1280</b>	<b>400</b>	<b>512</b>
	<b>Gas distribution</b>			<b>100</b>
				<b>612</b>
				<b>7792</b>



# Previsione costi INFN

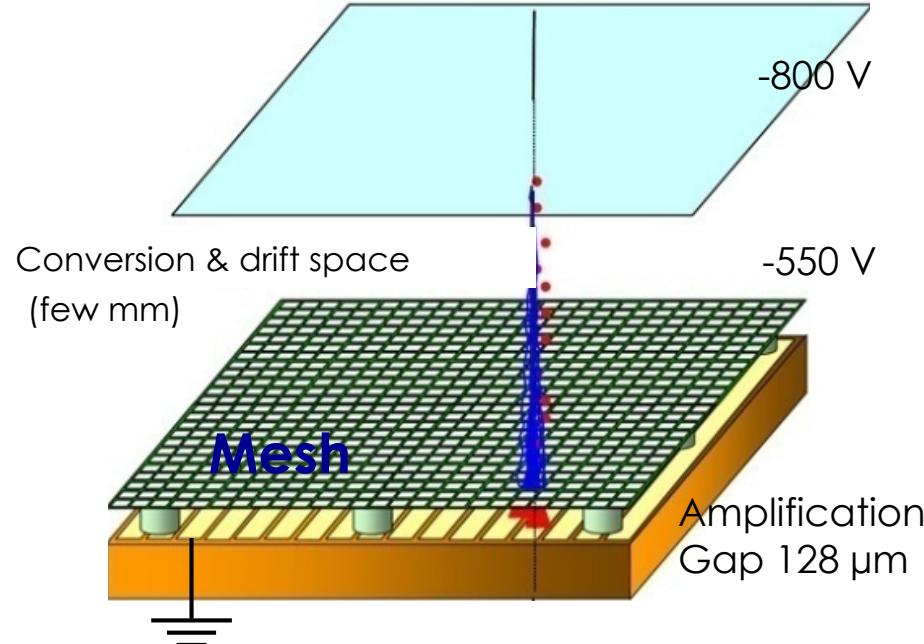
17

Contributo Italiano		2012	2013	2014	2015	2016	2017	2018	TOT
MM detector	<b>33%</b>			<b>281.6</b>	<b>281.6</b>	<b>281.6</b>			
Detector mechanics	<b>33%</b>			<b>35.2</b>	<b>35.2</b>	<b>35.2</b>			
Alignment									
Chip development and production									
front-end cards									
GBTx and fibres									
CAM									
Readout system	<b>20%</b>				<b>50</b>	<b>50</b>			
HV PS , cables, LV ps	<b>20%</b>				<b>51.2</b>	<b>51.2</b>			
Gas distribution	<b>10%</b>				<b>5</b>	<b>5</b>			
		<b>0</b>	<b>0</b>	<b>316.8</b>	<b>316.8</b>	<b>423</b>	<b>106.2</b>	<b>1162.8</b>	

Costi (in kCHF) stimati in base agli interessi italiani e in previsione di produrre O(1/3) dei rivelatori in Italia

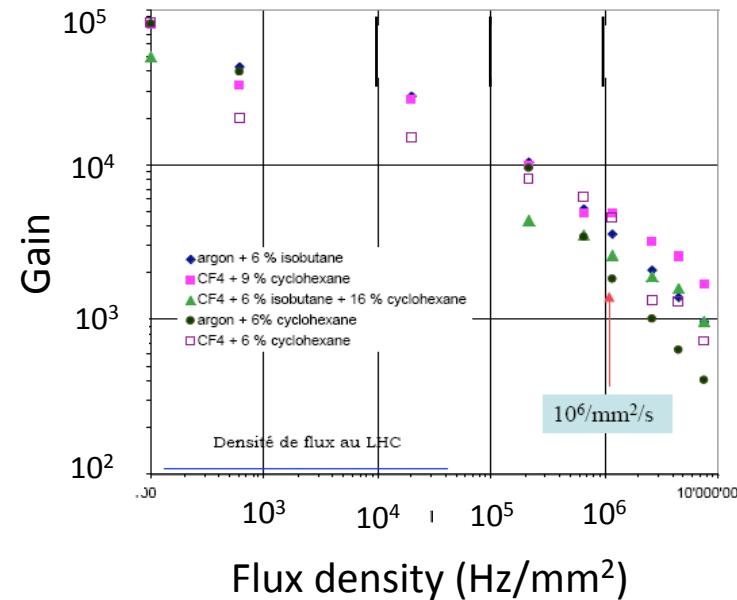
# Backup Slides

# Micromegas operating principle



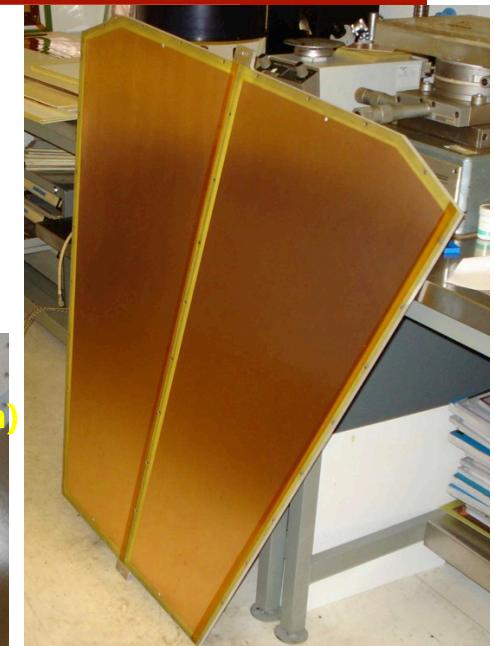
No space charge effect  
 Reduced ballistic deficit (only for fast electronics <20 ns)  
 Intrinsic rate limit  $\sim 200 \text{ MHz/cm}^2$

- 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

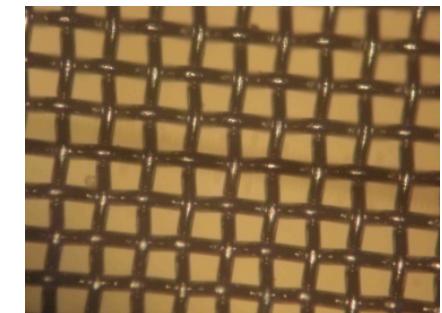


# The bulk-Micromegas

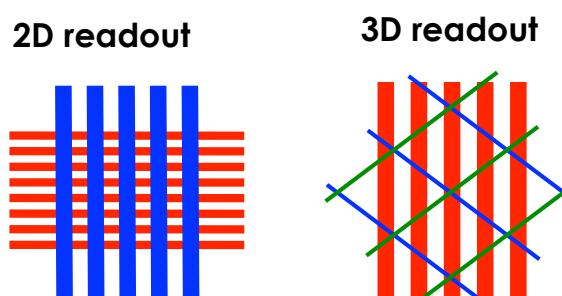
- A production technique developed in 2006 (bulk-micromegas) opened the door to industrial fabrication
- Big effort for going to large dimensions
- In 2007 production of the first large MM prototype for ATLAS (50x60 cm<sup>2</sup>, the largest MM at the time)
- In 2010 production of a CSC-size Micromegas
- 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



# Required performance

## Performance requirements for the Small Wheel chambers

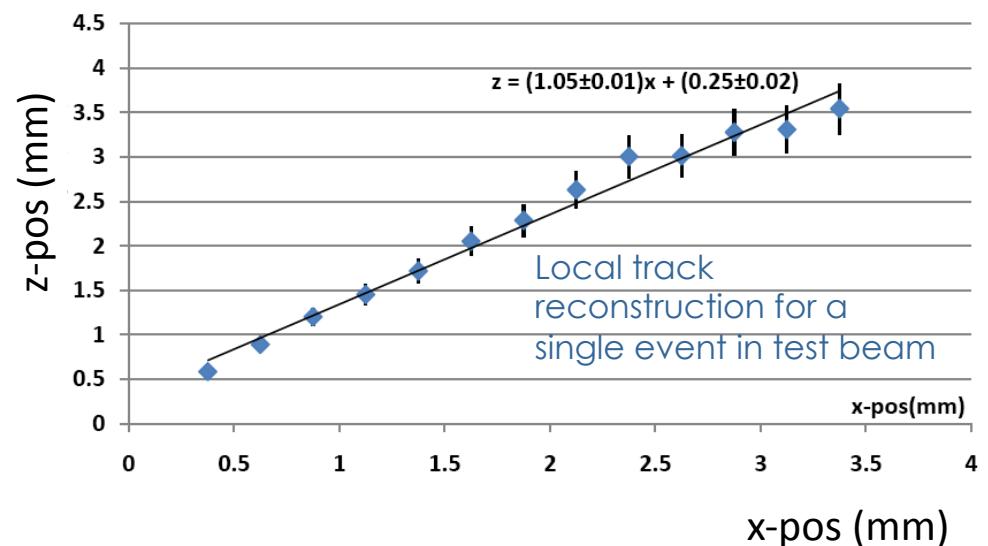
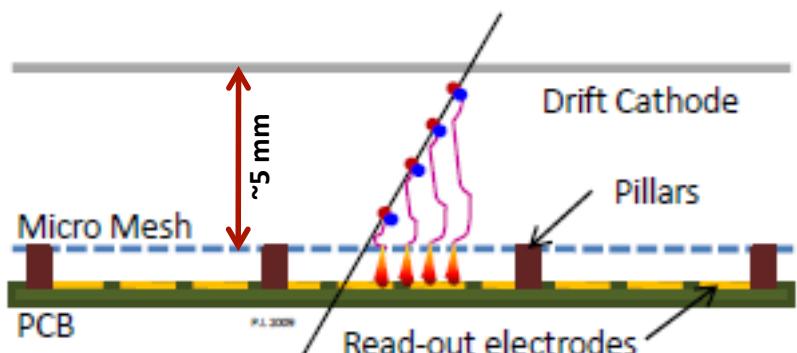
- Rate capability  $15 \text{ kHz/cm}^2$  ( $L \approx 5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ )
- Efficiency  $> 98\%$
- Spatial resolution  $\approx 100 \mu\text{m}$  ( $\Theta_{\text{track}} < 30^\circ$ )
- Good double track resolution
- Trigger capability (BCID, time resolution  $\leq 5\text{--}10 \text{ ns}$ )
- Radiation resistance
- Good ageing properties

Micromegas can satisfy all of them

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

### ■ Micromegas as $\mu\text{TPC}$

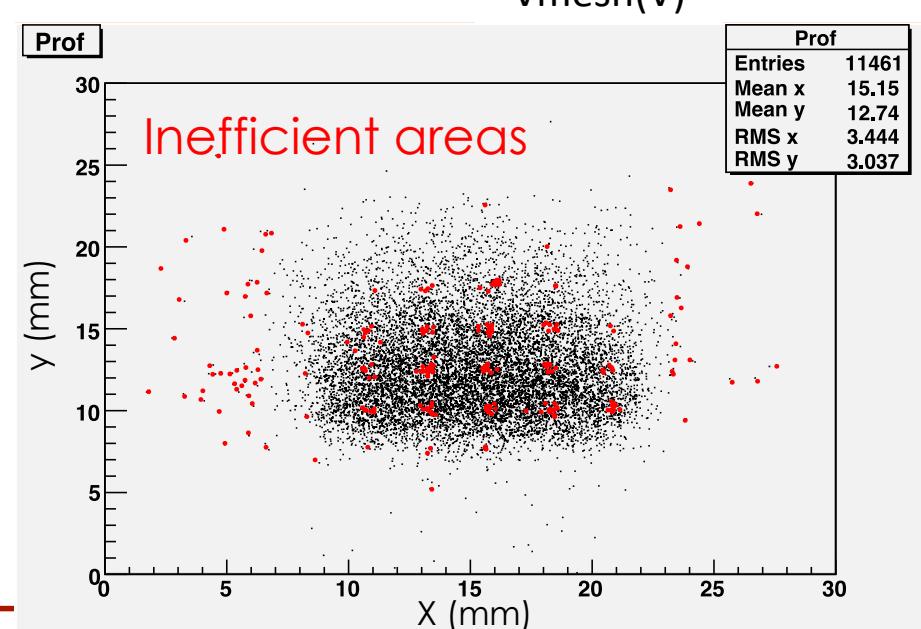
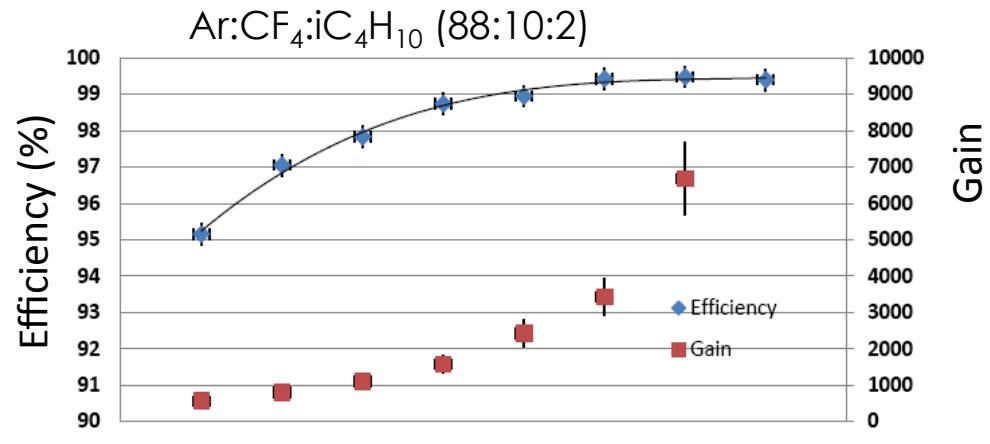
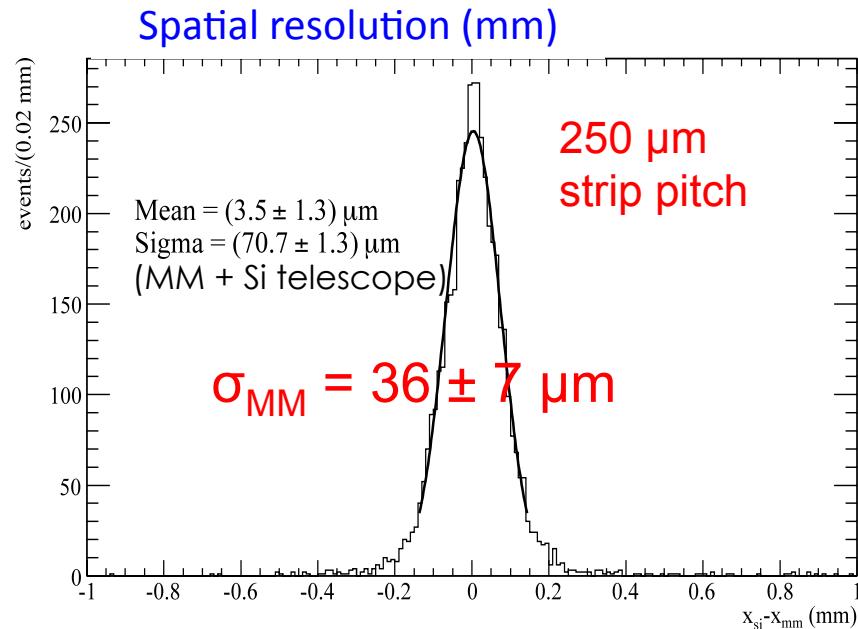
- Can deliver track vector in single plane for track reconstruction at LVL1 trigger



# Demonstrated performance

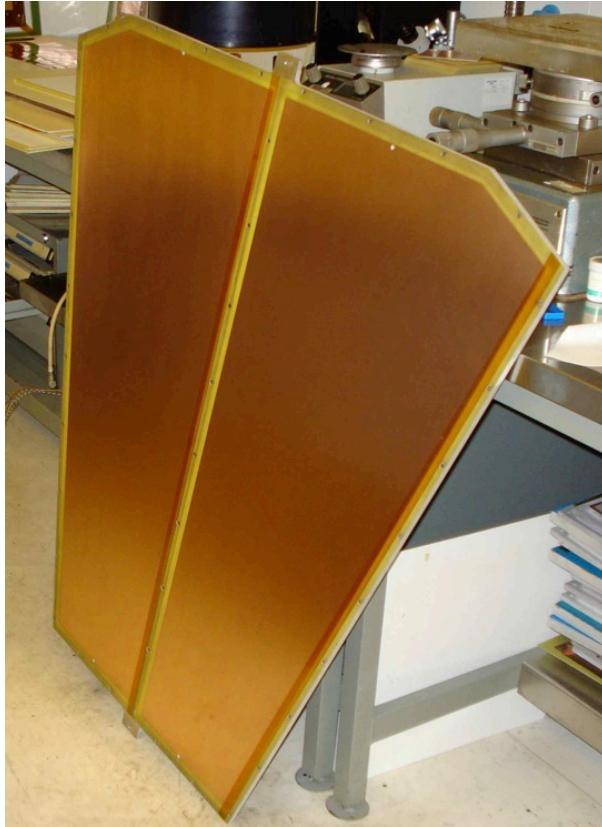
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- Standard micromegas
- Safe operating point with efficiency  $\geq 99\%$
- Gas gain:  $3-5 \times 10^3$
- Very good spatial resolution

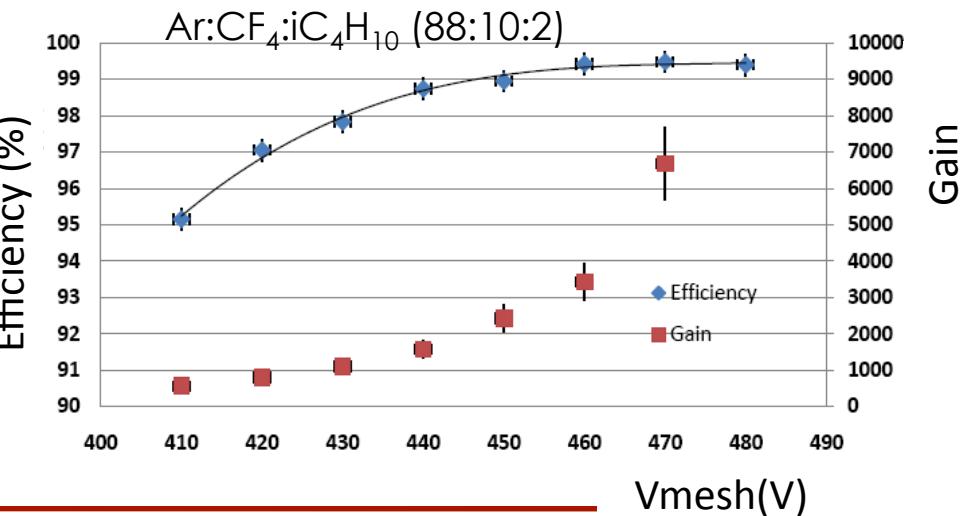
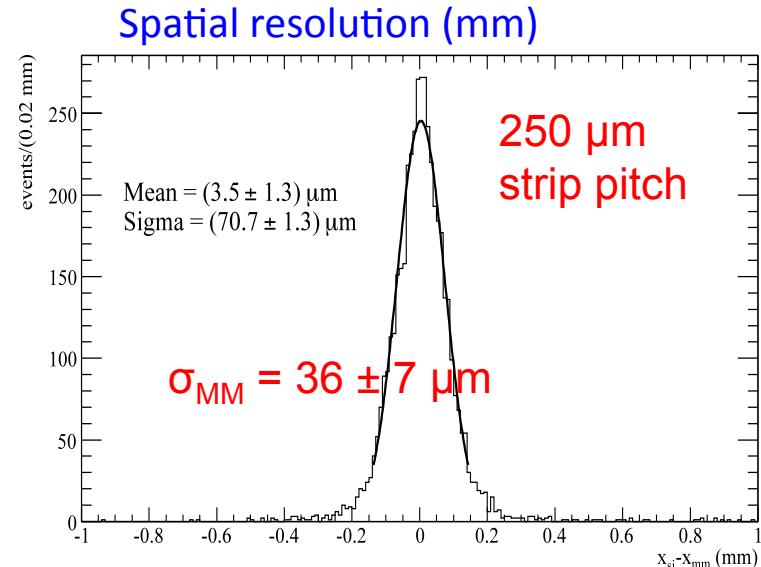


# Large-size Micromegas

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

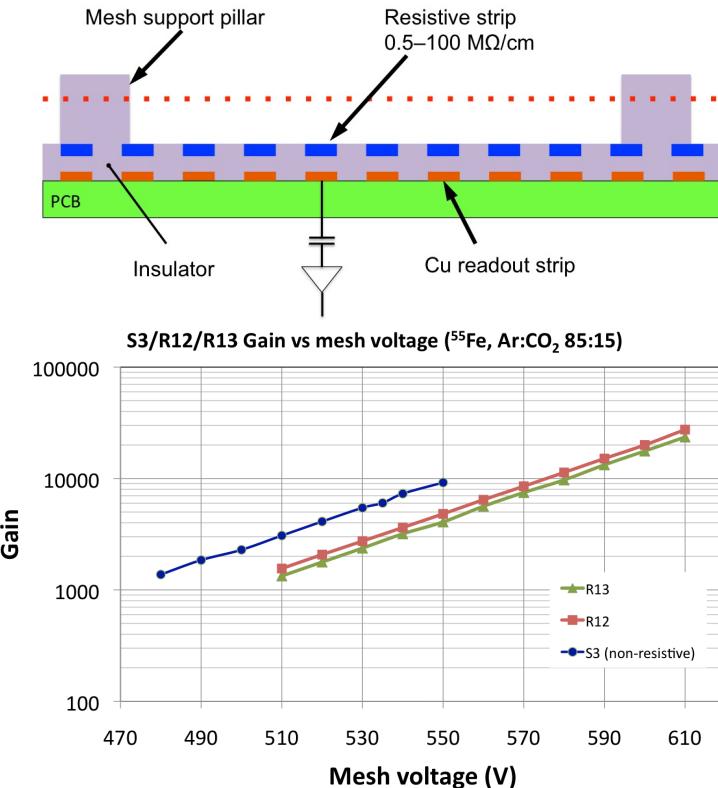


The largest MM ever built

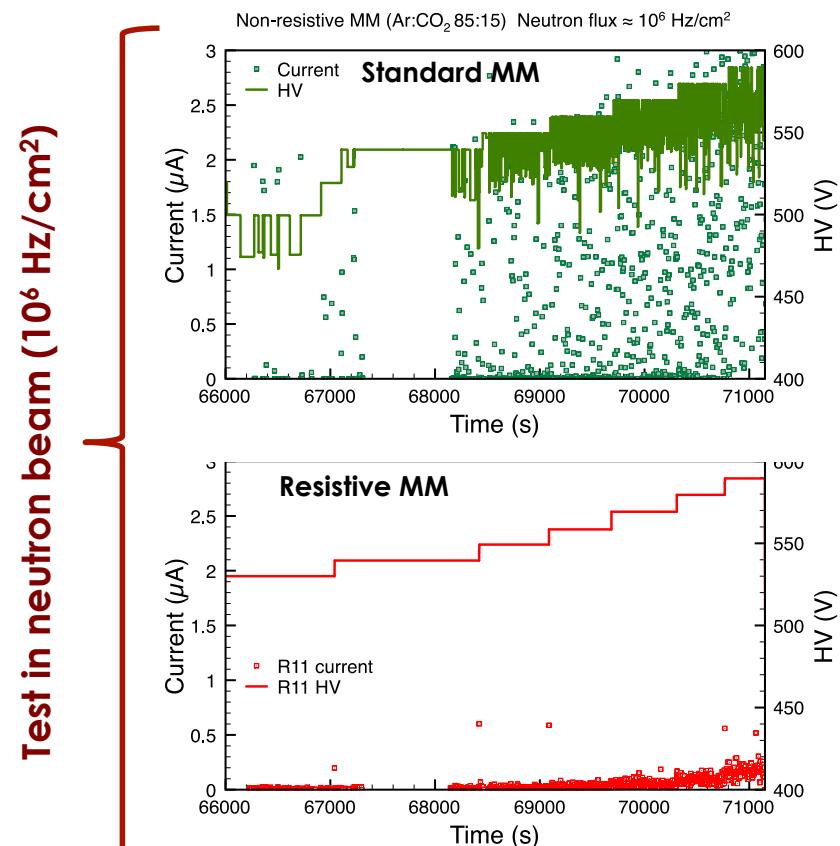


# Sparks: problem and solution

- 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

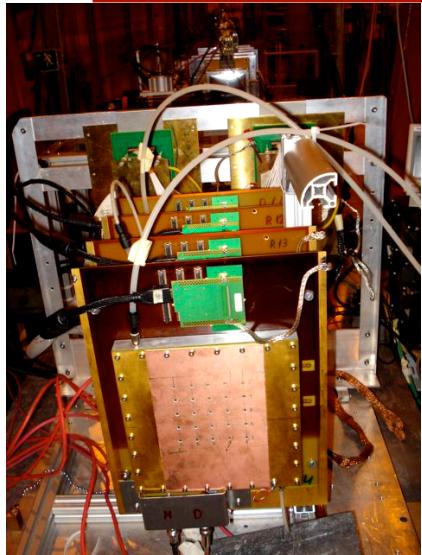


- Sparks can be drastically reduced by adding a resistive layer on the r/o strips
- Specific R&D to optimize the resistive protection
- Excellent results

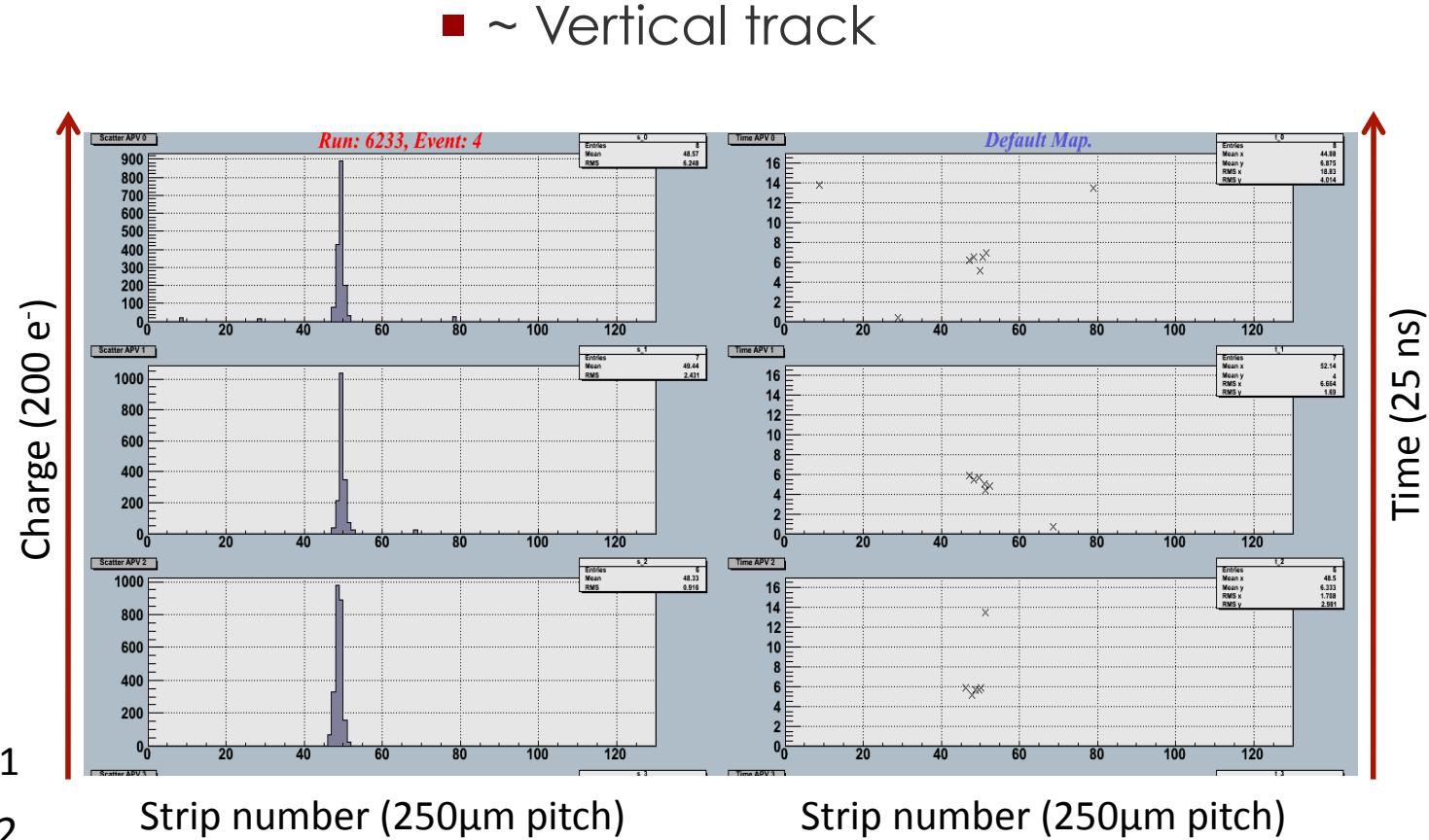
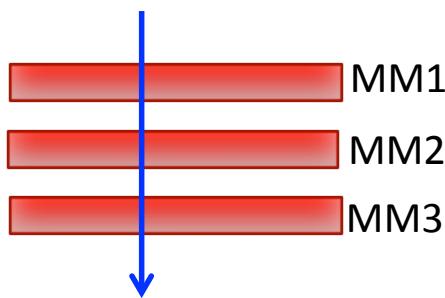


# Event display from TB

25

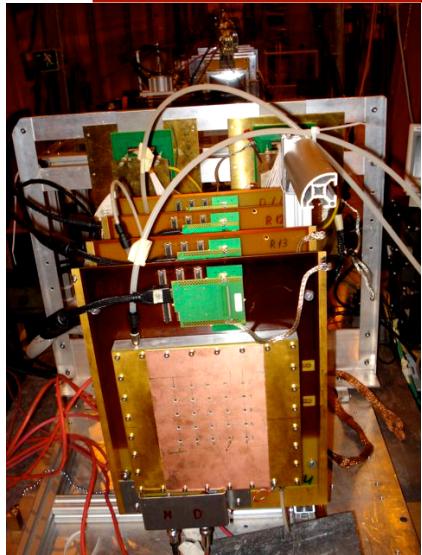


Three chambers in stack

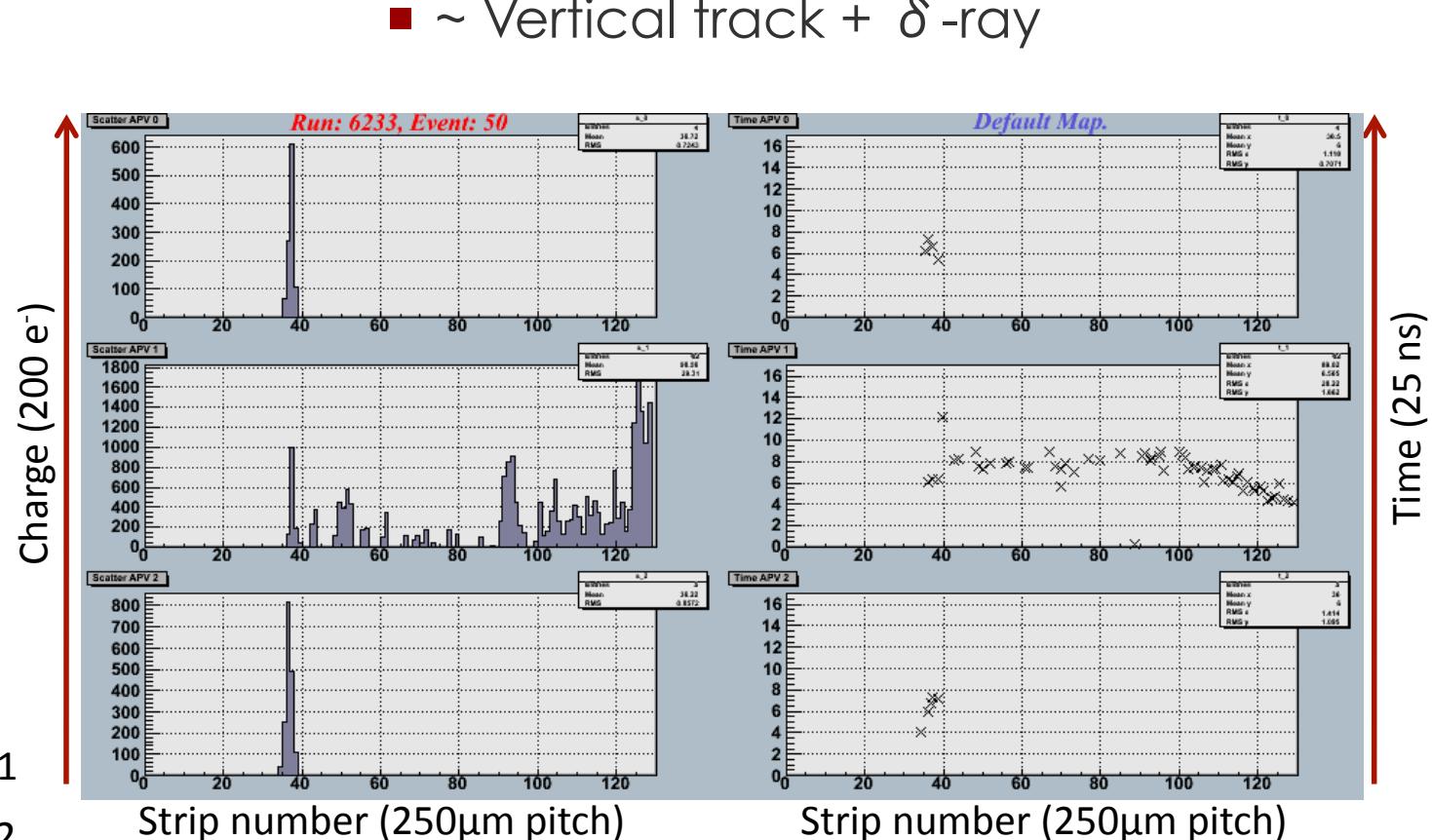
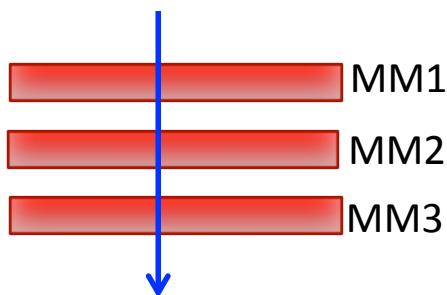


# Event display from TB

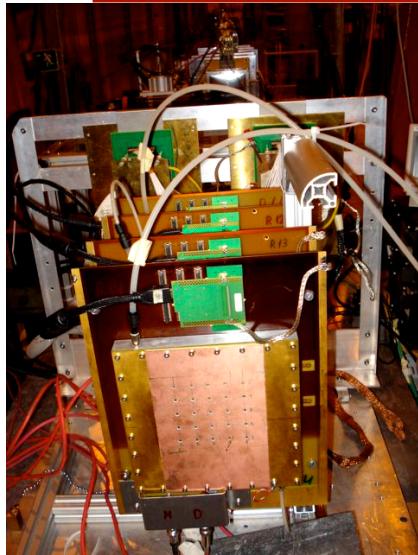
8



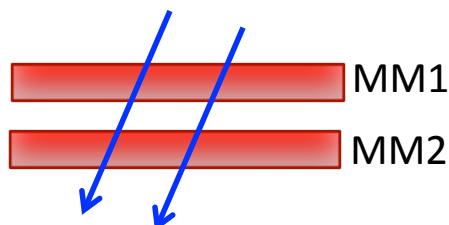
Three chambers in stack



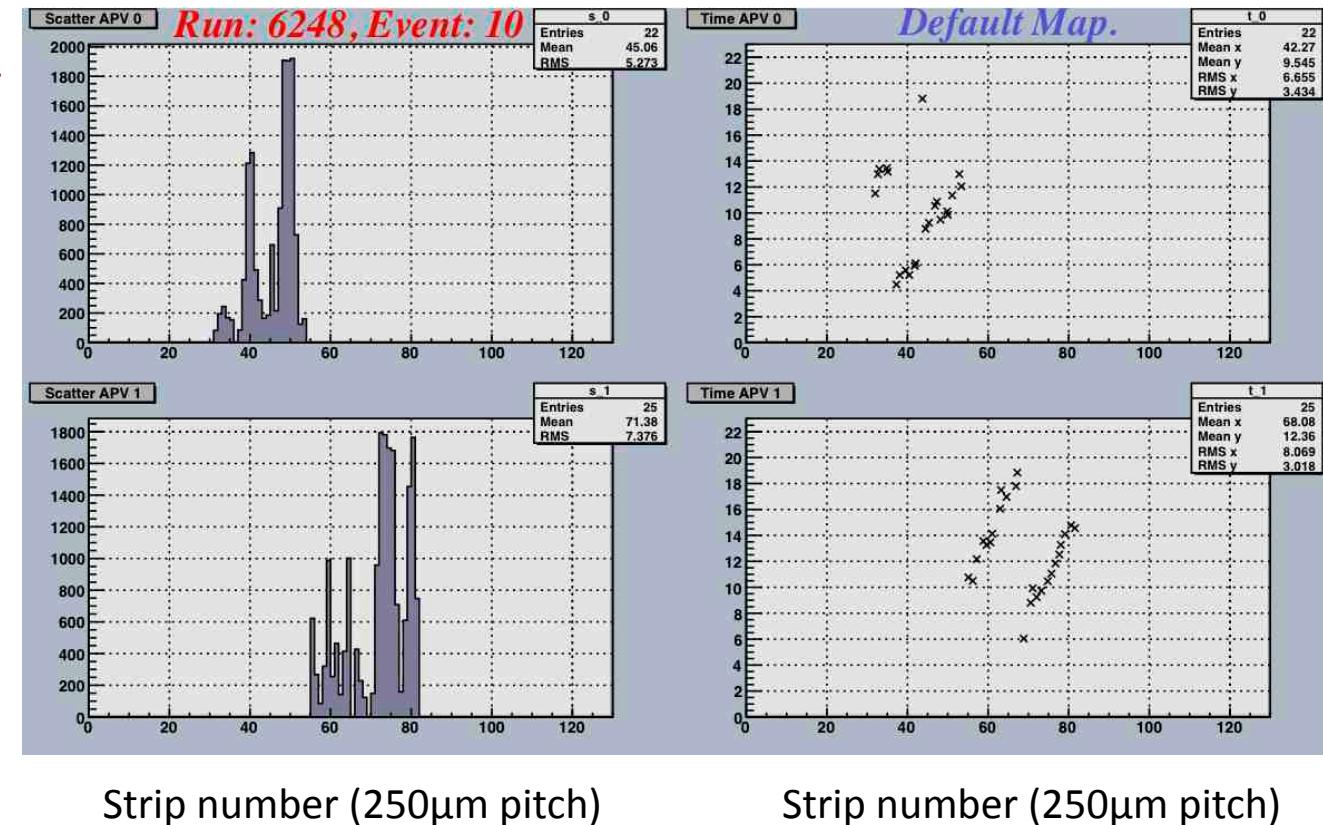
# Event display from TB



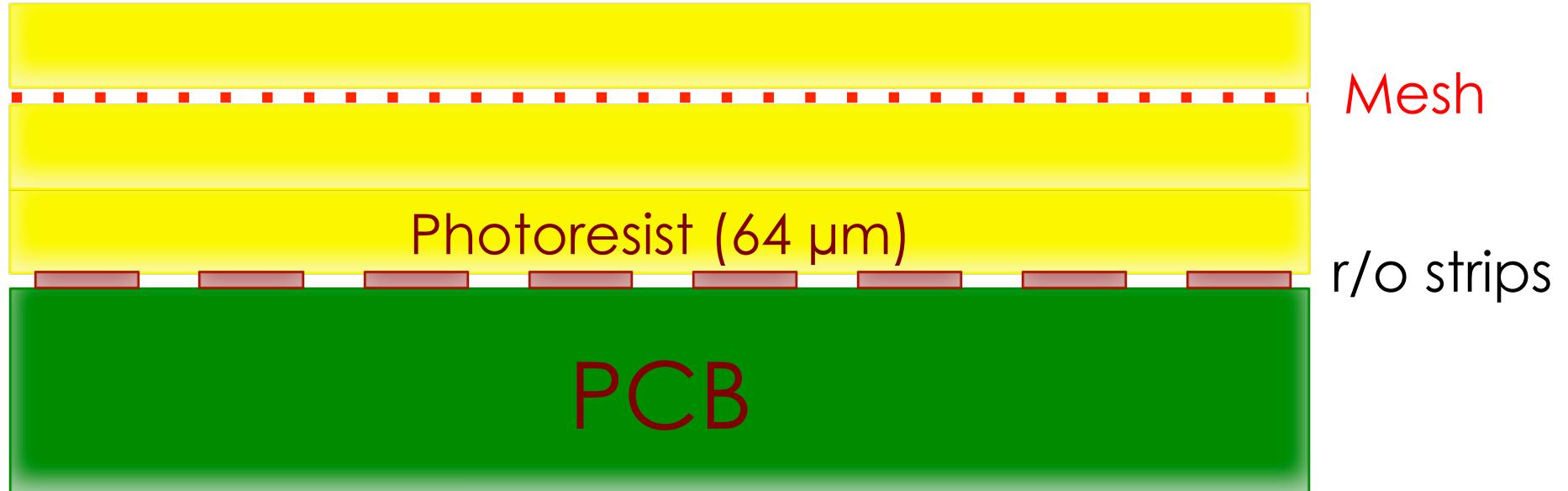
Two chambers in stack



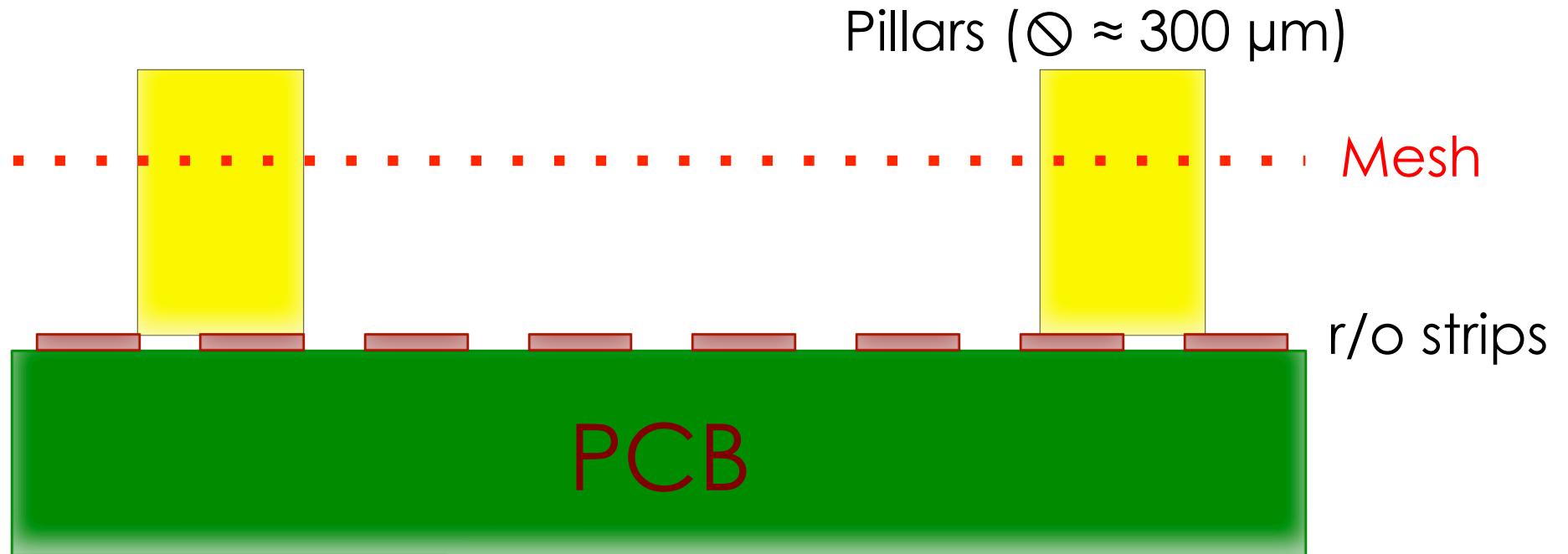
Charge (200 e<sup>-</sup>)



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

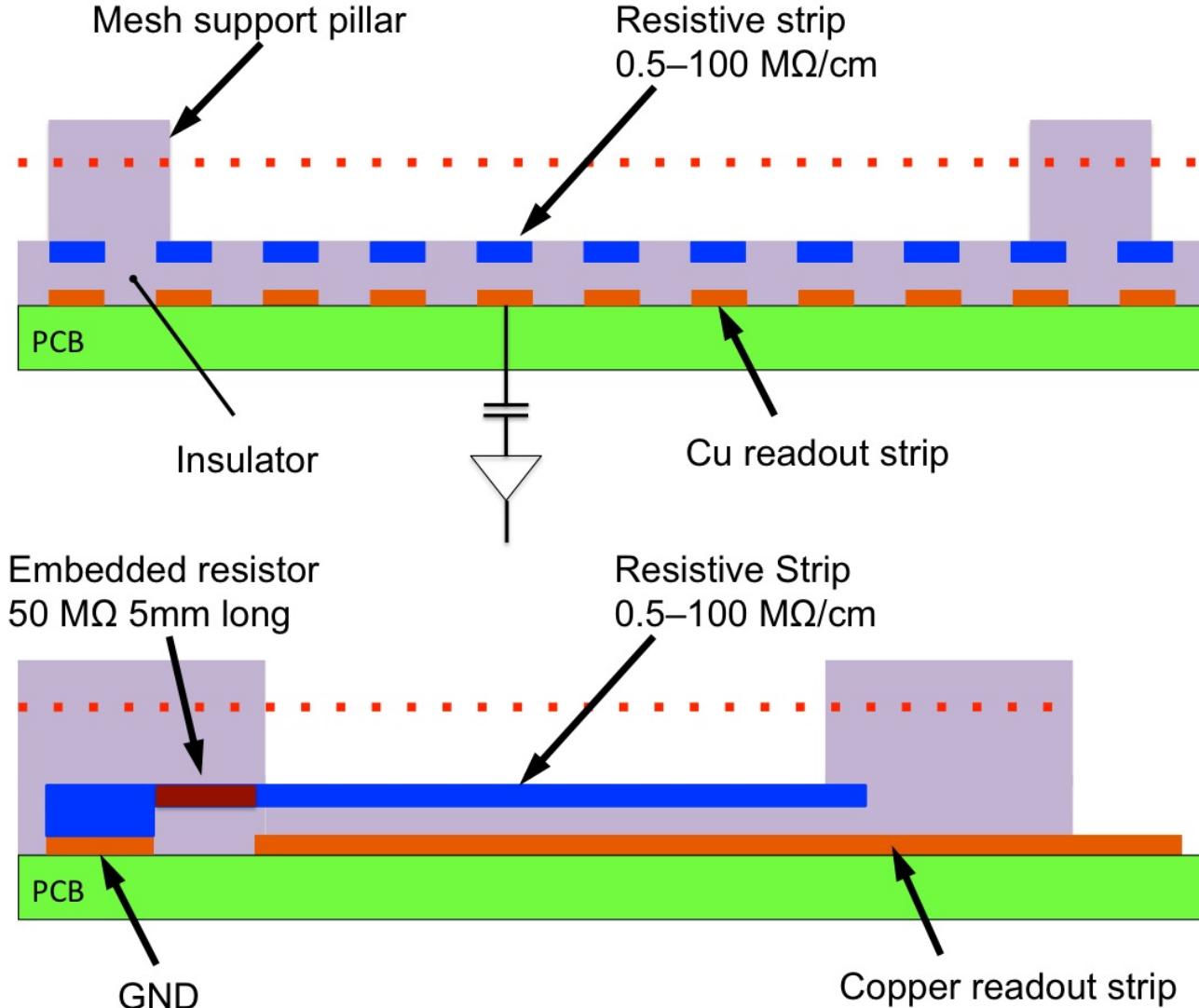


- The bulk-micromegas technique opens the door to industrial fabrication



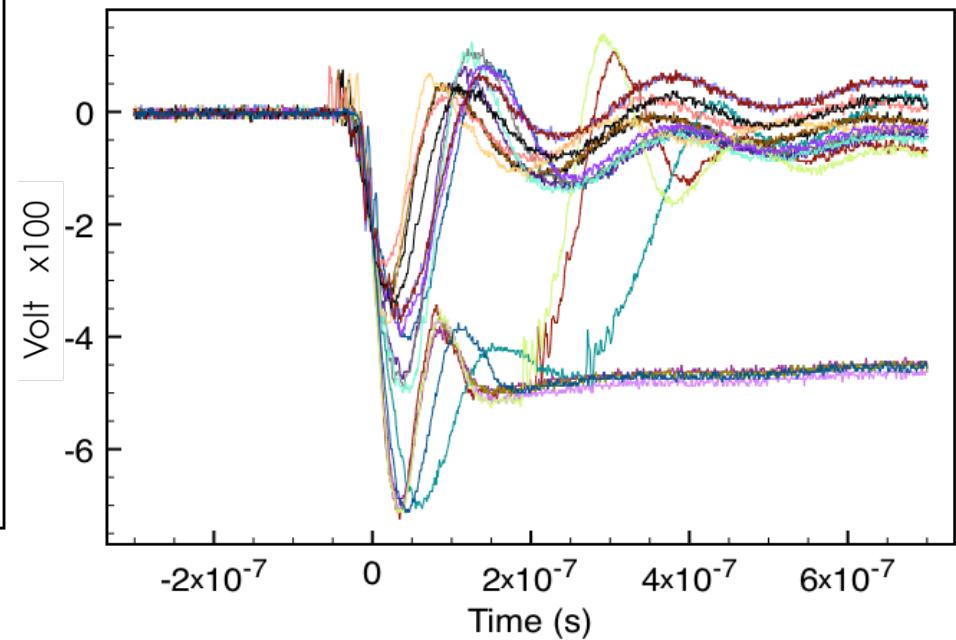
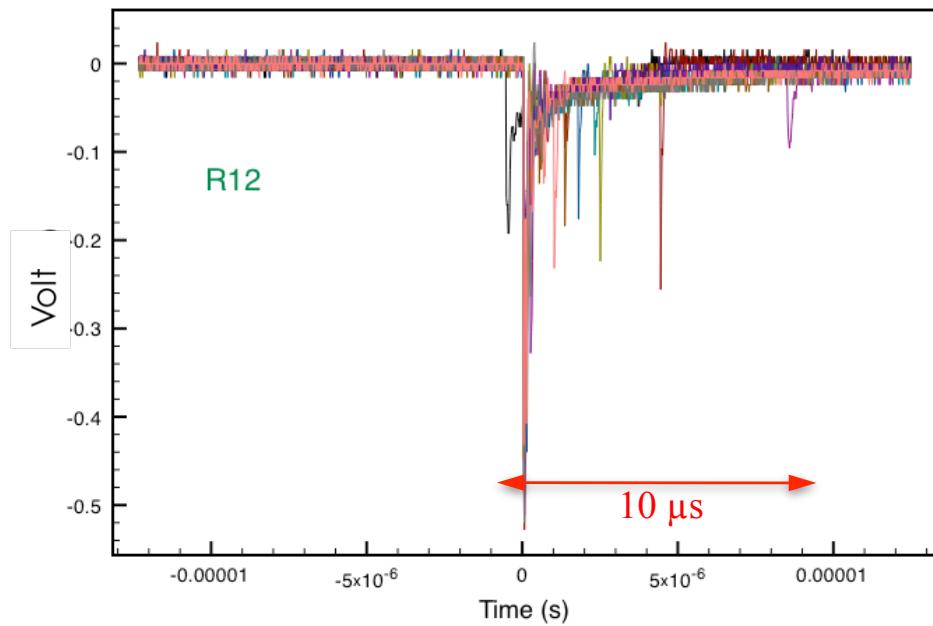
# Resistive-strip protection concept

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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



## VMM1 IC SPICE Simulation performance

Analog section:  
transistor-level simulations  
power  $\approx 4$  mW

