

IL PROGETTO **NEW SMALL WHEEL**
NEL QUADRO DELL'UPGRADE DI
ATLAS A LHC

NAPOLI - 7 NOVEMBRE 2016

SOMMARIO

1. Programma a lungo termine di ATLAS a LHC

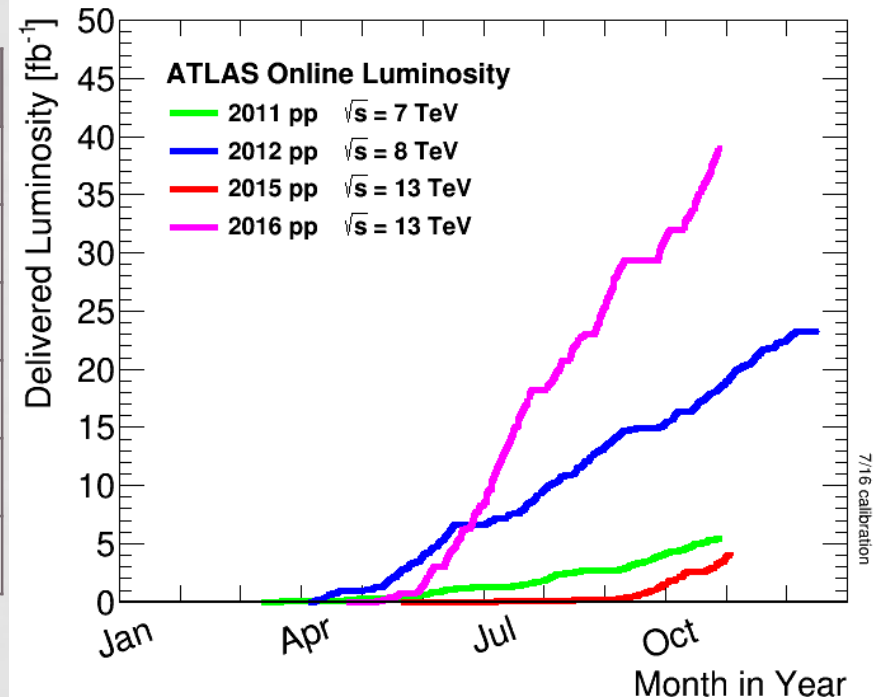
- L'esperimento ATLAS a LHC: run1 e run2 e prospettive di upgrade
- Il caso della fisica del bosone di Higgs
- Lo spettrometro a muoni dell'esperimento ATLAS: stato attuale e prospettive di upgrade

2. Il progetto New Small Wheel (NSW) e le camere MicroMegas

- Motivazioni e Layout
- Principio di funzionamento delle camere MM per la NSW
- Il Modulo0 SM1
- Stato del progetto e contributo INFN

L'ESPERIMENTO ATLAS AD LHC: RUN1/2

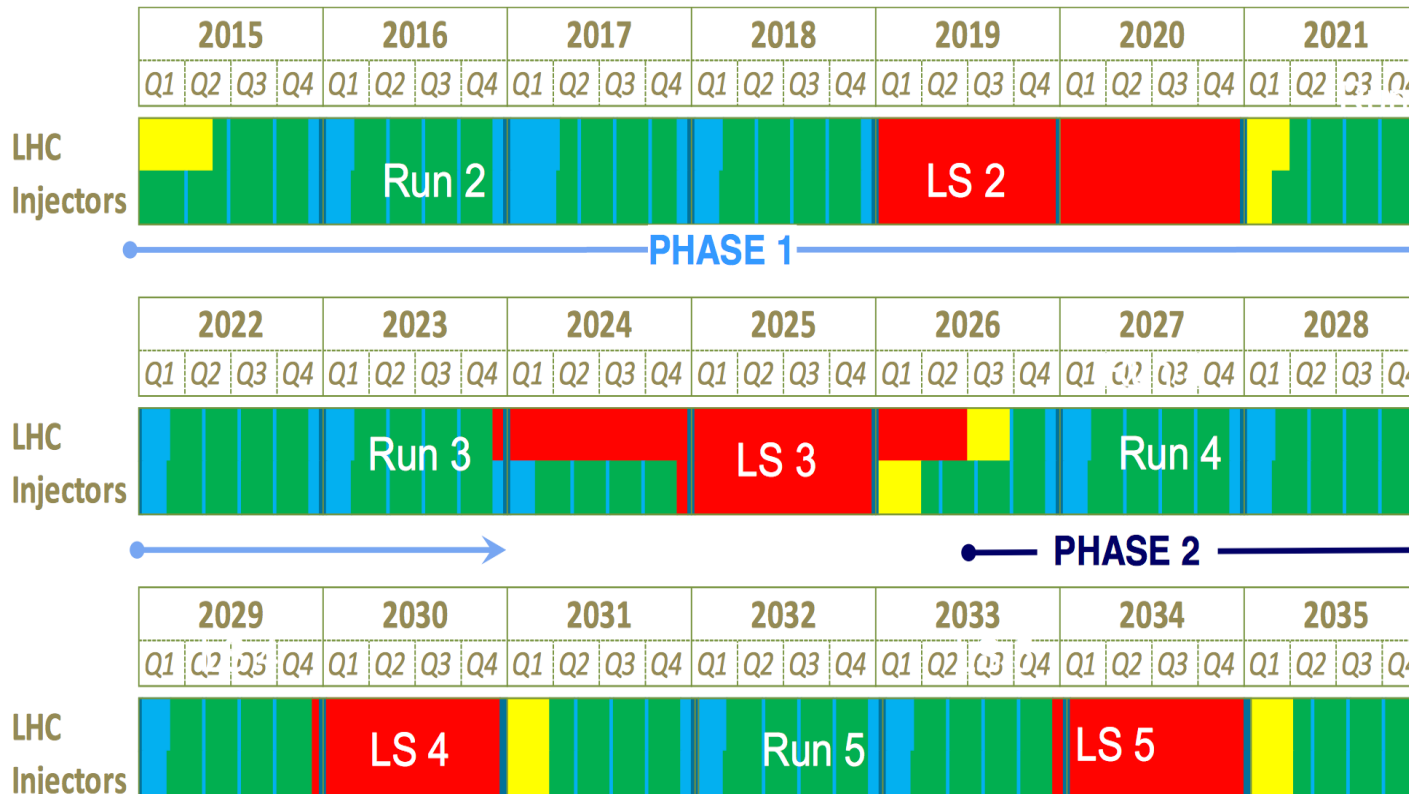
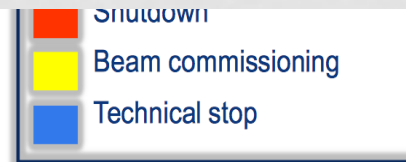
	Run1	Run2
Years	11-12	15-...
c.o.m. energy (TeV)	7 → 8	13
Peak luminosity (cm ⁻² s ⁻¹)	7×10 ³³	1.37×10 ³⁴
Int. Luminosity (fb ⁻¹)	25	40
Interbunch (ns)	50	25
<#collisions/crossing>	21	25



- *Run1*:
 - Osservazione del bosone di Higgs a $m_H = 125$ GeV e misura delle sue proprietà (massa, spin-parità, couplings)
 - Ricerche di fisica oltre il modello standard fino al TeV
 - Misure di precisione di Modello Standard.
- *Run2* in corso (fino a tutto il 2018)

PROGRAMMA LHC (A LUNGO TERMINE)

LS2 starting in 2019 => 24 months + 3 months BC
 LS3 LHC: starting in 2024 => 30 months + 3 months BC
 Injectors: in 2025 => 13 months + 3 months BC



- 2015-2018 $\sqrt{s} = 13-14 \text{ TeV} - L=1 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1} \rightarrow 100 \text{ fb}^{-1}$
- 2021-2023 $\sqrt{s} = 14 \text{ TeV} - L=2 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1} \rightarrow 300 \text{ fb}^{-1}$
- 2026-2033 $\sqrt{s} = 14 \text{ TeV} - L=5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1} \rightarrow 3000 \text{ fb}^{-1}$

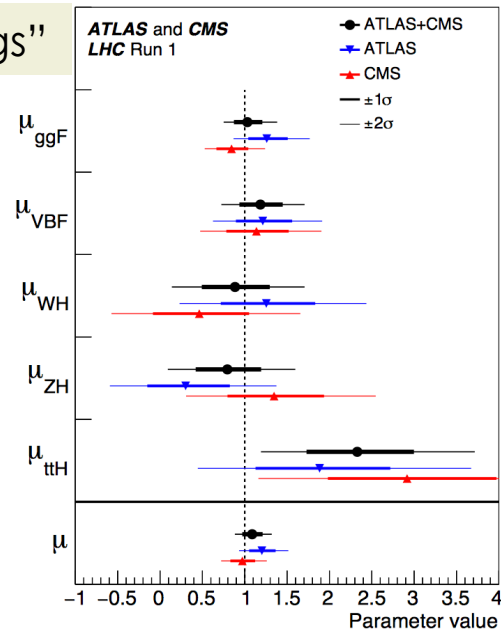
HIGGS: RISULTATI RUN1 (ATLAS+CMS)

1. Misura della massa: (*Phys.Rev.Lett.* 114, 191803)

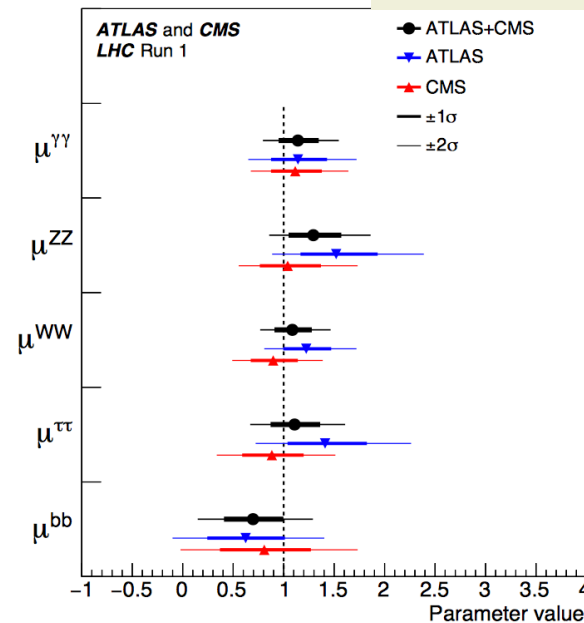
	ATLAS	CMS
$H \rightarrow 4l$	$124.51 \pm 0.52 \pm 0.06$	$125.6 \pm 0.4 \pm 0.2$
$H \rightarrow \gamma\gamma$	$125.98 \pm 0.42 \pm 0.28$	$124.70 \pm 0.31 \pm 0.15$
Combination	$125.36 \pm 0.37 \pm 0.18$	$125.02^{+0.26}_{-0.27} \quad ^{+0.14}_{-0.15}$
ATLAS + CMS	125.09 ± 0.21 (stat) ± 0.11 (scale) ± 0.02 (other) ± 0.01 (theory)	

2. Fit degli accoppiamenti: (*JHEP* 08 (2016) 045)

“Production couplings”



“Decay couplings”



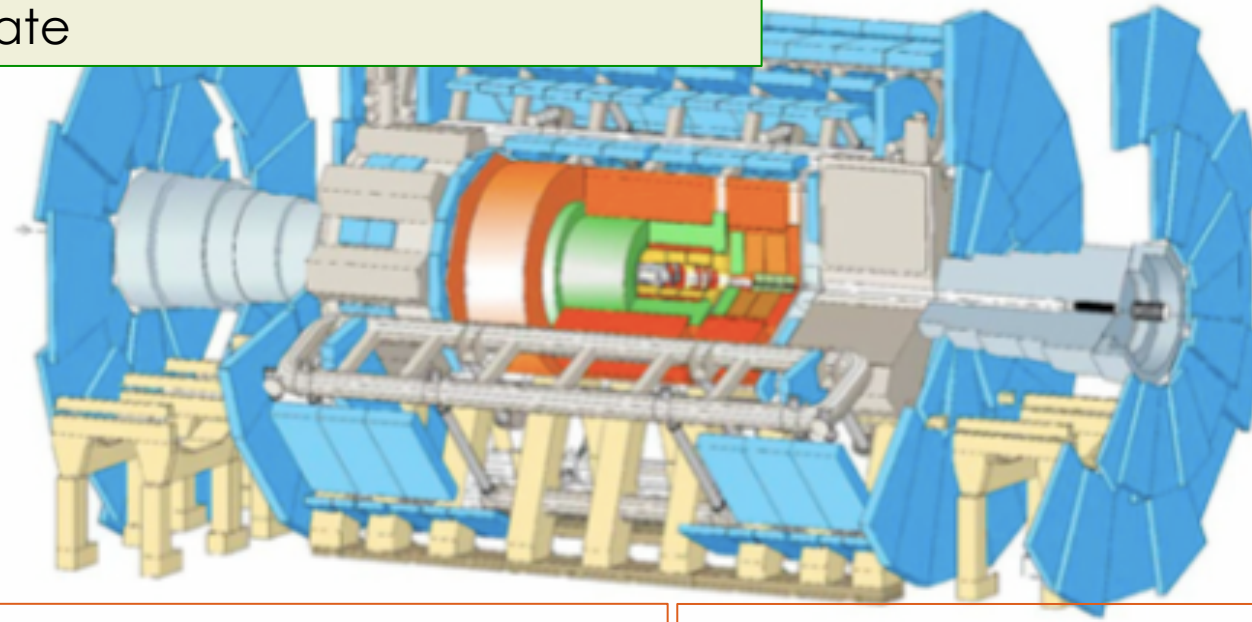
PROSPETTIVE DI FISICA DELL'HIGGS AD LHC

- **LHC Run2:** 13 – 14 TeV - 100 fb⁻¹: fine 2018
 - Osservazione di $H \rightarrow \tau \tau$, bb – ATLAS e CMS indipendentemente;
 - Osservazione di VBF and VH – ATLAS e CMS indipendentemente;
 - Evidenza di ttH
- **LHC Run3:** 14 TeV - 300 fb⁻¹: fine 2023
 - Probabile osservazione di ttH
 - Evidenza di $H \rightarrow \mu \mu$
 - Misura dei singoli coupling al livello del $\approx 10\%$
- **HL-LHC:** 14 TeV - 3000 fb⁻¹: >2030...
 - Osservazione di ttH
 - Osservazione di $H \rightarrow \mu \mu$ e $H \rightarrow Z \gamma$
 - Misura dei couplings a livello di pochi %
 - Probabile evidenza di produzione HH
 - Probabile sensibilità per SM Γ_H con metodo indiretto

L'ESPERIMENTO ATLAS - UPGRADE

In generale:

- "invecchiamento" rivelatori ed elettronica
- aumento rate



Principali upgrade previsti ATLAS

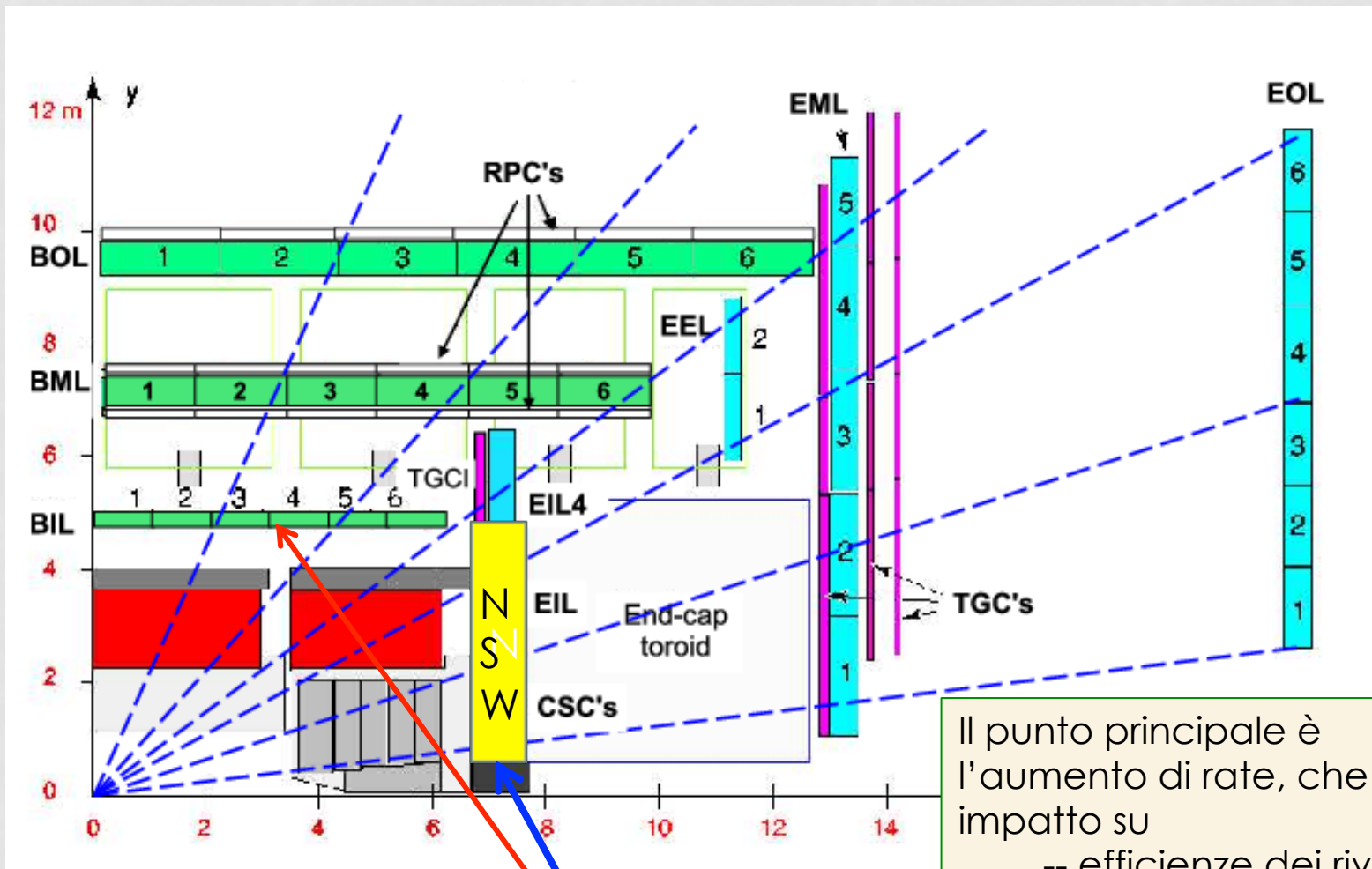
LS2:

- New Small Wheel
- Integrazione NSW nella logica di trigger
- Upgrade elettronica calorimetro LAr
- Completamento Fast Tracker

LS3

- New Silicon Tracker
- Upgrade foto-rivelatori calorimetro adronico
- Nuova architettura del trigger
- Upgrade elettronica MDT/RPC
- Nuove stazioni spettrometro μ

UPGRADE SPETTROMETRO A MUONI



Il punto principale è l'aumento di rate, che ha impatto su

- efficienze dei rivelatori
- proprietà di trigger

New Small Wheel $1.3 < |\eta| < 2.7$

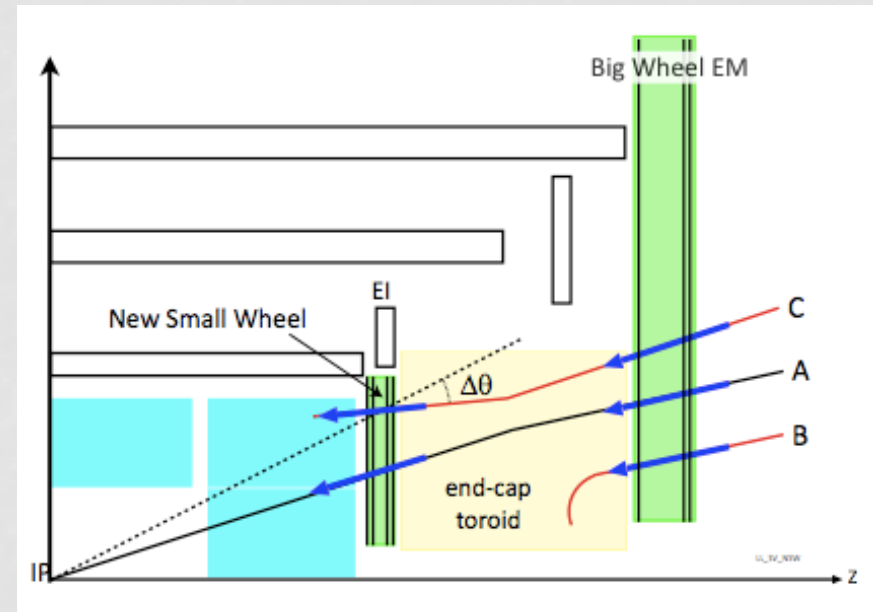
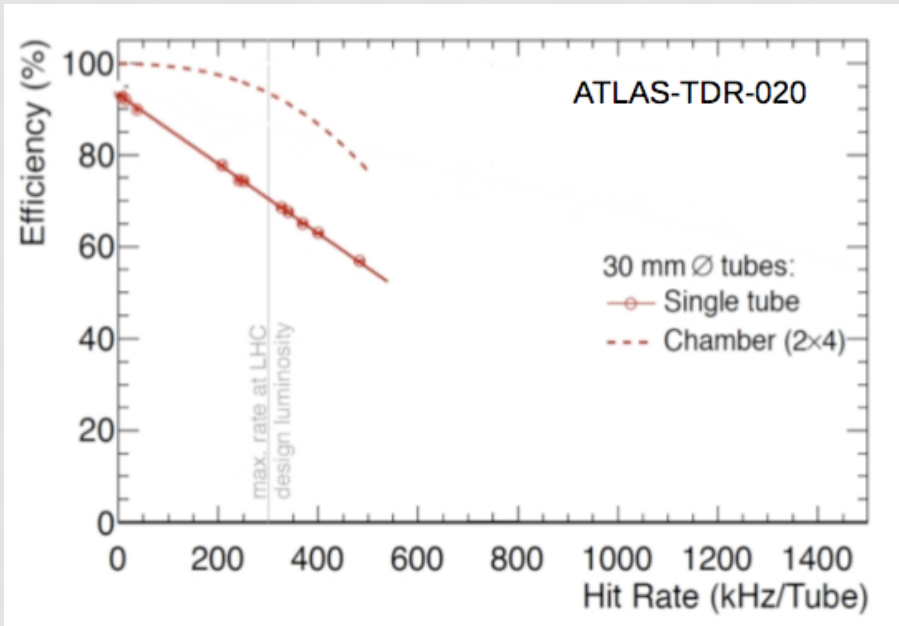
Trigger sulla stazione interna del barrel

Aggiornamento elettronica + altro (Small Angle Tagger...)

NEW SMALL WHEEL: MOTIVAZIONI

Attesa diminuzione di **efficienza e**
 aumento di risoluzione **MDT**
 oltre la luminosità di progetto
 → "Tube size" $\approx 3 \text{ cm} \times 1 \text{ m} \times 750 \text{ ns}$;
 → @ 7×10^{34} , 14 TeV → $\approx 4 \text{ kHz/cm}^2$
 $> 1 \text{ MHz/Tubo} \approx 1 / 750 \text{ ns}$
 $> 50\%$ drop in chamber efficiency

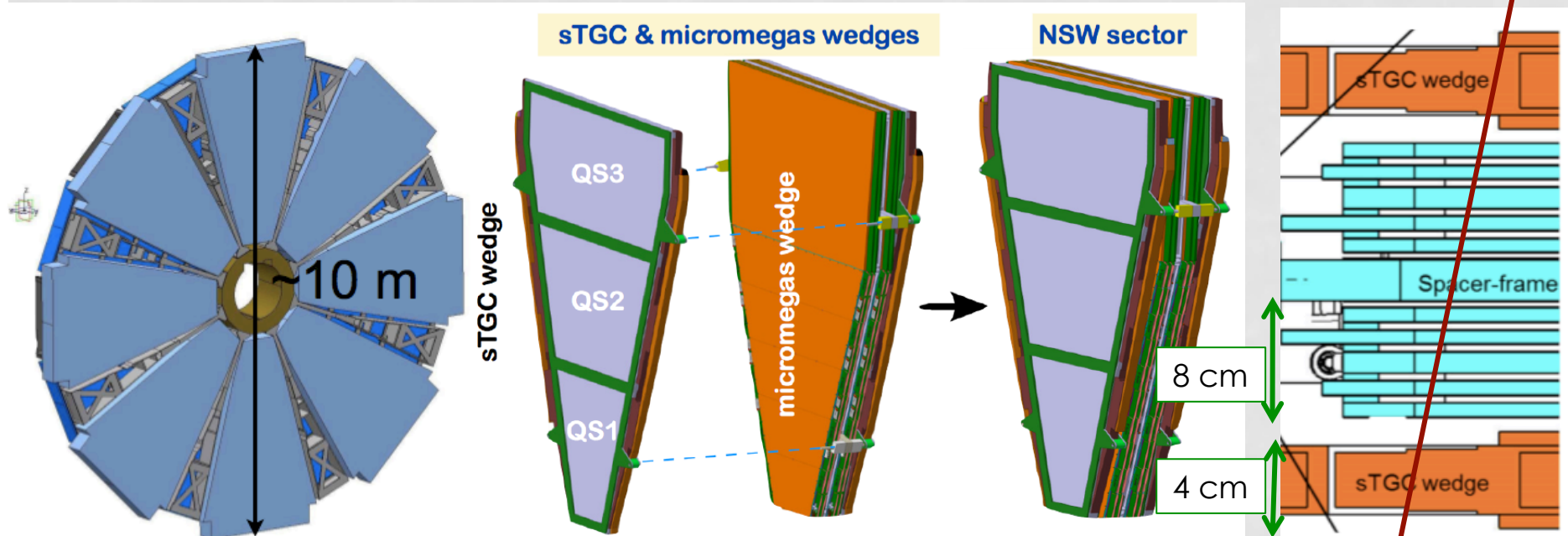
Trigger μ endcap dominato **da fake muons**
 → $R(p_T > 20 \text{ GeV}) = 60 \text{ kHz}$ (@ 3×10^{34} , 14 TeV)
 Necessaria una riduzione di un fattore 3
 → $R(p_T > 20 \text{ GeV}) = 21 \text{ kHz}$ (@ 3×10^{34} , 14 TeV)
 (10% fakes) compatibile con bandwidth
"trigger di puntamento"



→ Accept **topologies A** reject **B / C**

NEW SMALL WHEEL: LAYOUT

- 16 settori per wheel (8 large e 8 small): diametro totale ≈ 10 m;
- 2 tecnologie: **sTGC** (small Thin Gap Chambers) e **MM** (MicroMegas)
- 8 piani MM e 8 piani sTGC: trigger e tracking forniti da ambedue



Risoluzione spaziale per piano: $100 \mu\text{m}$ (η) 2-3 mm (ϕ)
Risoluzione sull'angolo di puntamento a L1 trigger: 1 mrad
Per entrambi i rivelatori: posizione degli hit conosciuti con precisione:
 $\sigma(\eta) < 30 \mu\text{m}$ $\sigma(Z) < 80 \mu\text{m}$

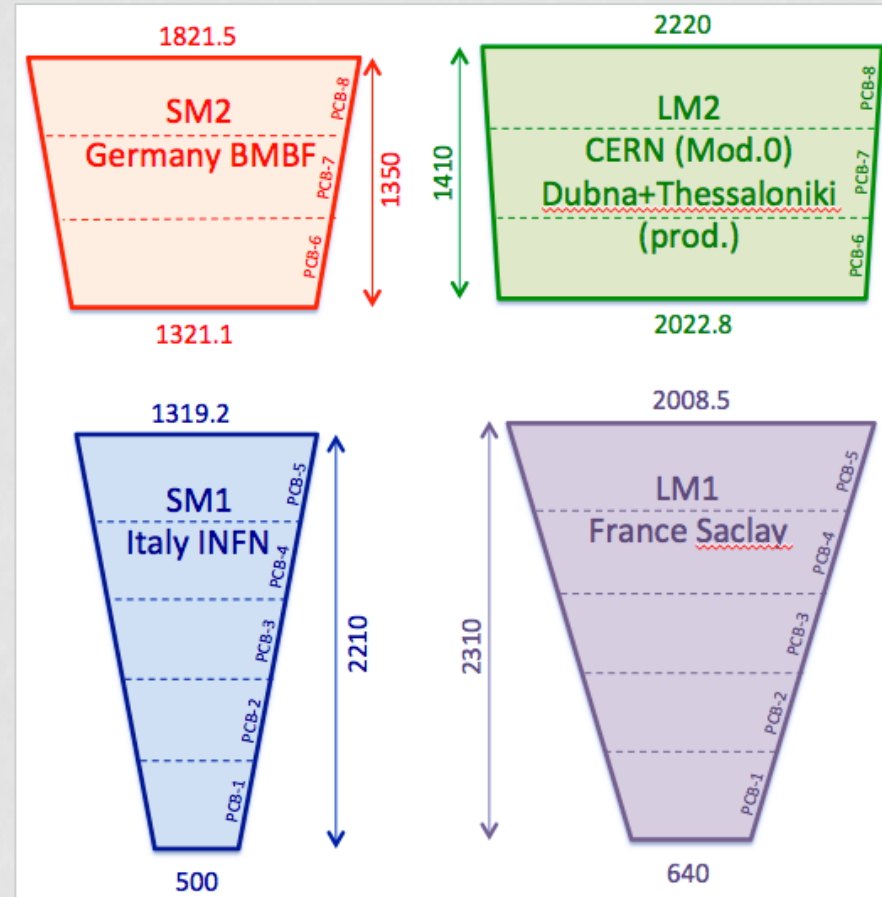
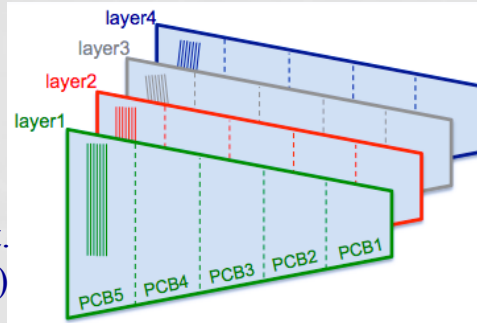
MICROMEAS - ORGANIZZAZIONE E IMPEGNO INFN

Ogni settore diviso in 2

- ➔ 4 tipi di camere (32 ciascuno)
- ➔ Suddivisione tra 4 siti di costruzione
- ➔ Una camera = un quadrupletto (2 piani eta + 2 piani stereo)

SM1 quadruplet:

- 425 μm strip pitch
- L1 & L2 vertical strips (eta),
- L3 & L4 $\pm 1.5^\circ$ w.r.t. vertical axis (stereo)

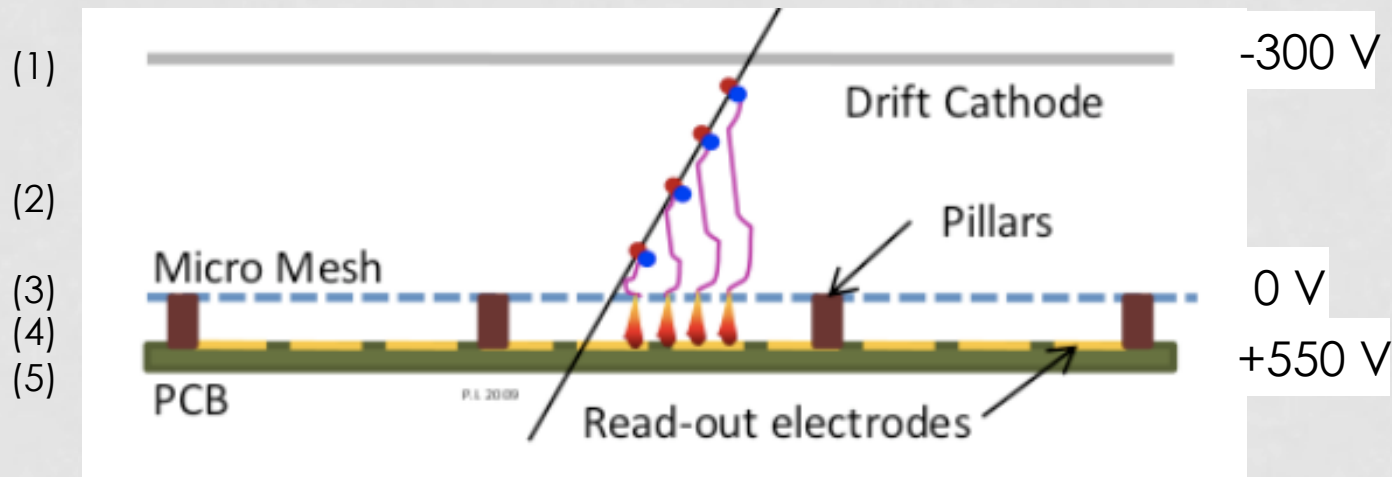


Sito di costruzione INFN:

Collaborazione di 7 gruppi: CS, LE, LNF, NA, PV, RM1, RM3

MICROMEAS: PRINCIPIO DI FUNZIONAMENTO - I

Inventate da Y.Giomataris, NIMA 376 1 (1996) 25



Componenti del rivelatore (i numeri si riferiscono al caso ATLAS):

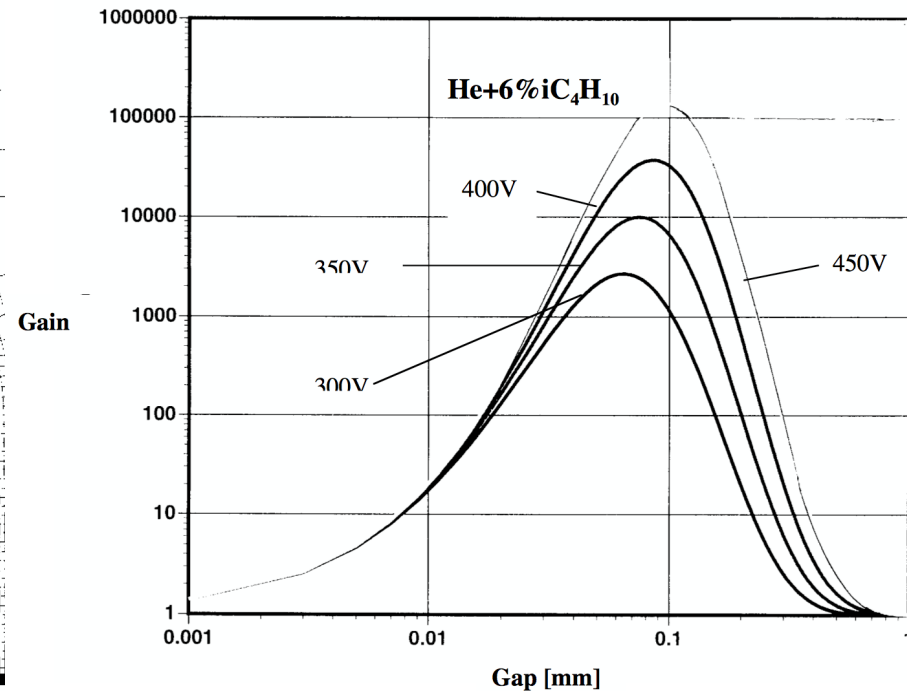
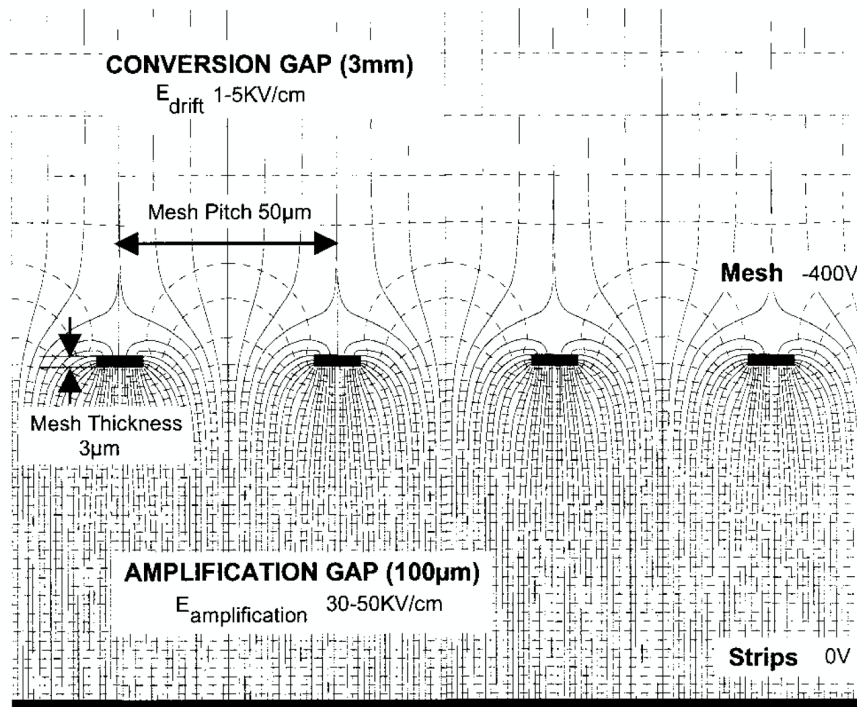
- (1) Catodo metallico piano
- (2) Gas gap (5 mm) con basso campo elettrico (0.6 kV/cm): conversione e drift e⁻;
- (3) Mesh metallica sottile appoggiata su "pillars" (alti 128 μm);
- (4) Gap di 128 μm con alto campo elettrico (40÷50 kV/cm): avalanche;
- (5) Anodo segmentato con strip di lettura (400 μm pitch) su un piano PCB.

Tempo massimo di deriva = gap size / v(drift) = 5 mm / 50 μm/ns = 100 ns

MICROMEAS: PRINCIPIO DI FUNZIONAMENTO - II

Linee di forza del campo elettrico nella zona della mesh

Andamento del guadagno in funzione della gap di lettura



Elevato electric field ratio:

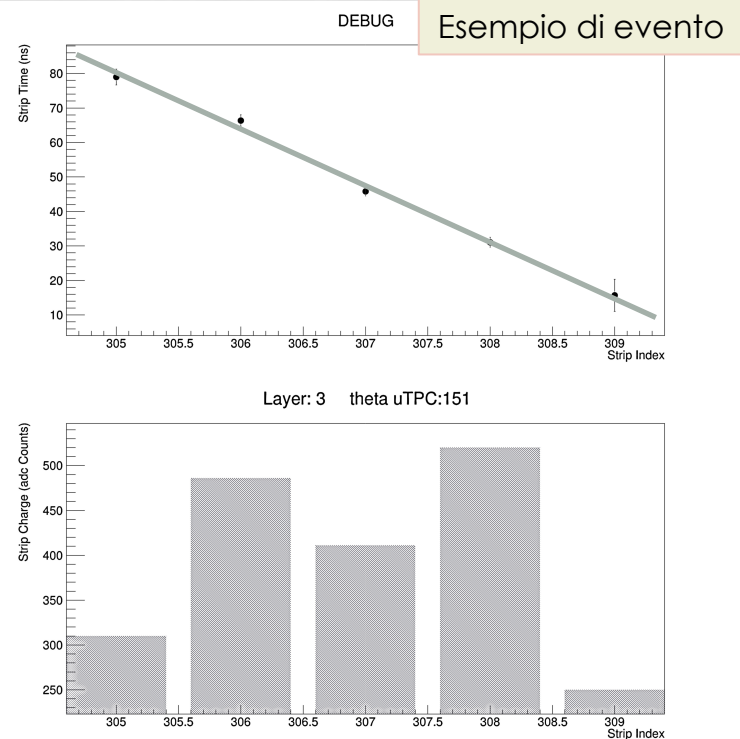
→ La mesh è "trasparente" agli elettroni

→ Gli ioni creati nella avalanche sono raccolti nella mesh (entro ≈ 100 ns)

"Plateau" di guadagno ($10^4 \div 10^5$) intorno a $d = 100 \mu m$

RISULTATI SU PROTOTIPI 10X10 CM2

Prototipi 10x10 cm² costruiti e testati al CERN (coll. MAMMA)

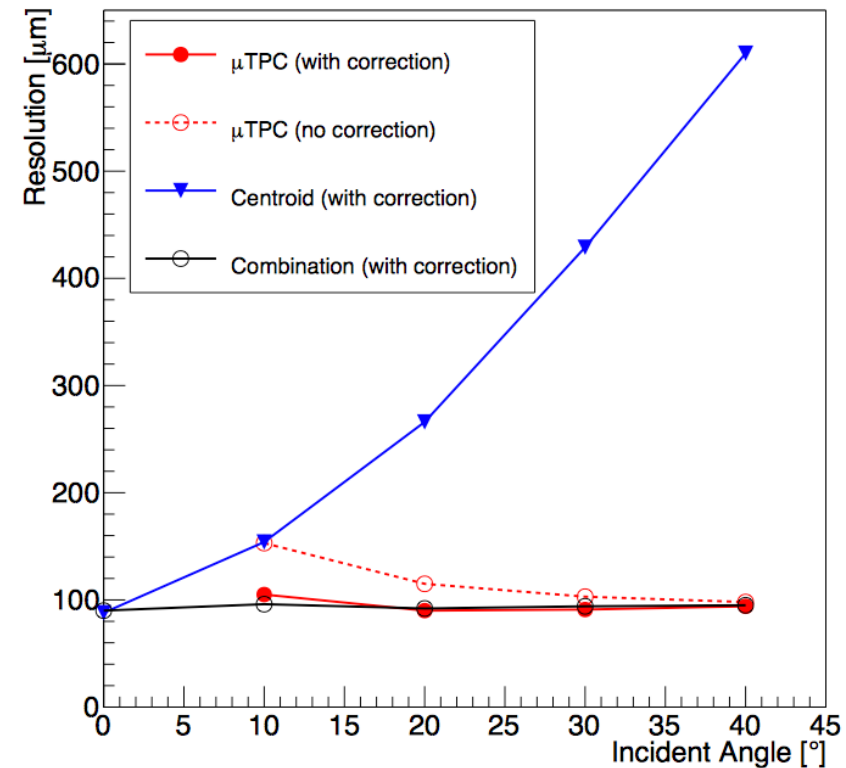


Per ogni strip accesa misura di:
carica
tempo
→ Centroide di carica
→ μ TPC (posizione e angolo)

15/11/16

Misure di risoluzione spaziale su TB

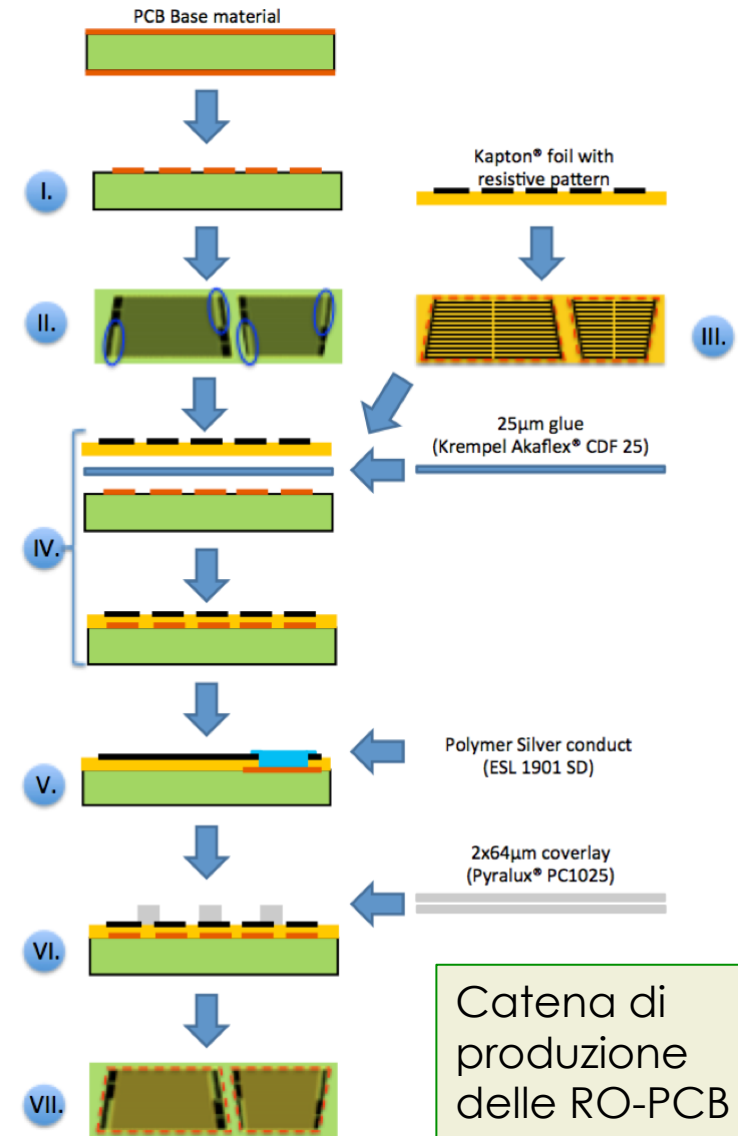
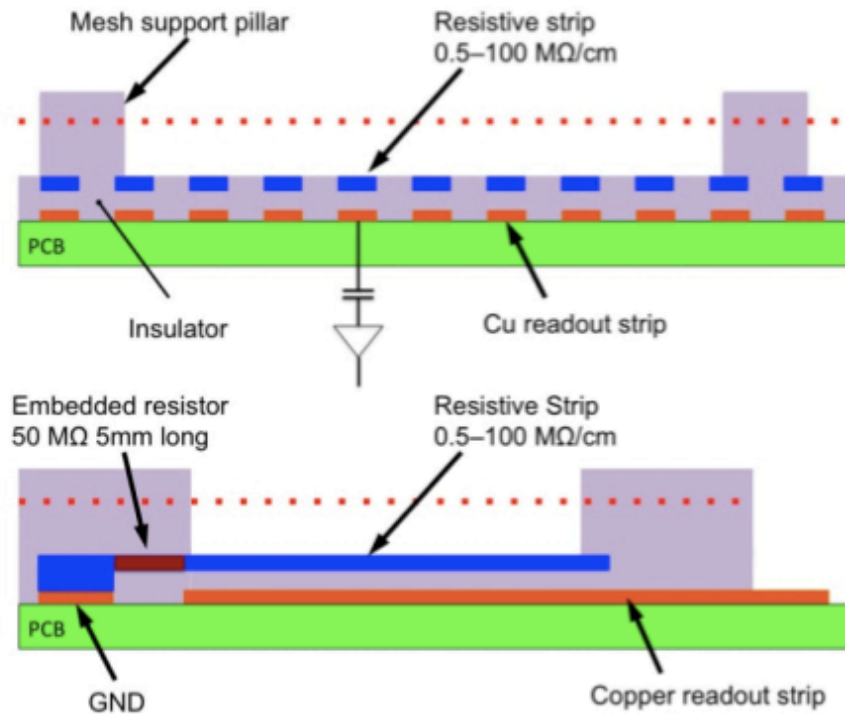
Single Plane Spatial Resolution



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MICROMEKAS PER LA NSW - I

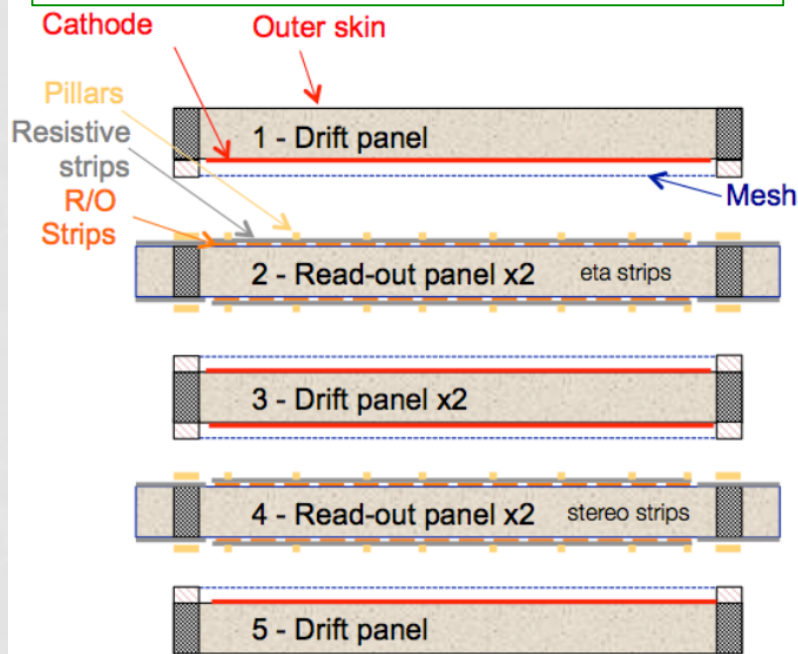
Alto rate aspettato: necessità di ridurre la probabilità di scariche mantenendo un guadagno $\approx 10^4$
→ **anodo con strip resistive**
($\approx 20 \text{ M}\Omega/\text{cm}$; $\approx 1 \text{ M}\Omega/\square$)



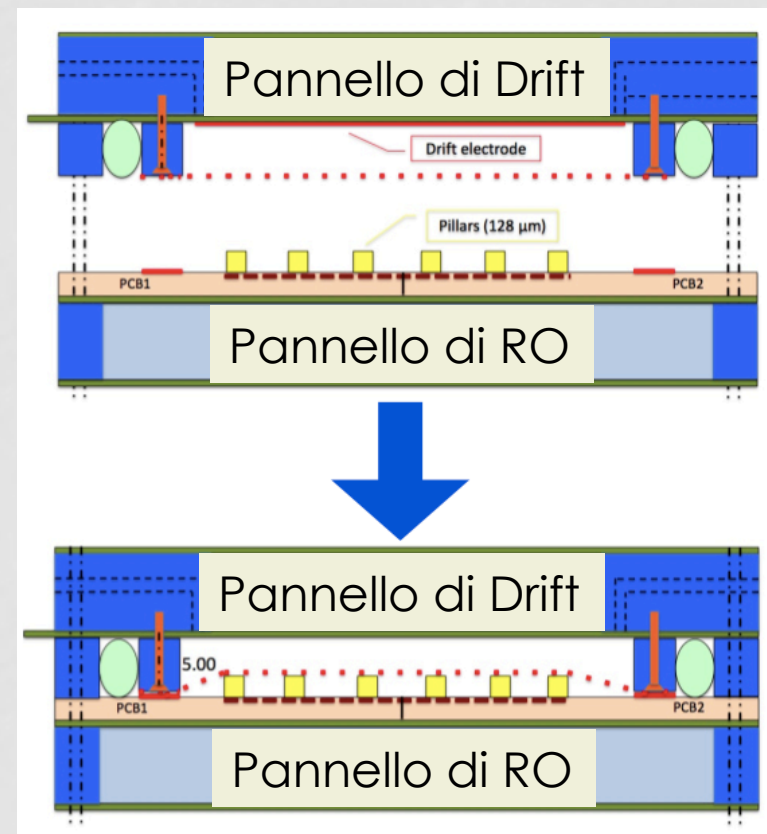
MICROMEAS PER LA NSW - II

Estendere la tecnologia a camere di **grandi dimensioni** ($2 \div 3\text{m}^2$) mantenendo **la precisione meccanica richiesta** ($30 \div 80 \mu\text{m}$) → **nuova tecnica di costruzione**

5 pannelli planari ($\text{RMS} < 40\mu\text{m}$)
spessore 1 cm; superficie 2 m^2 :
2 RO panels (con RO PCB)
3 Drift panels + mesh tesa



Tecnica di assemblaggio: **floating mesh**



IL MODULO0 SM1 - LA COSTRUZIONE

Primavera 2016: i siti INFN costruiscono la prima camera full-size: il Modulo0

Read-out panel assembled in Pavia



Drift panel assembled with vacuum bag in Roma1

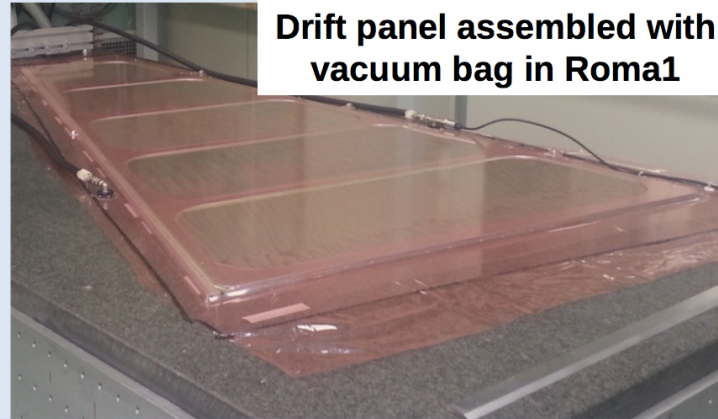


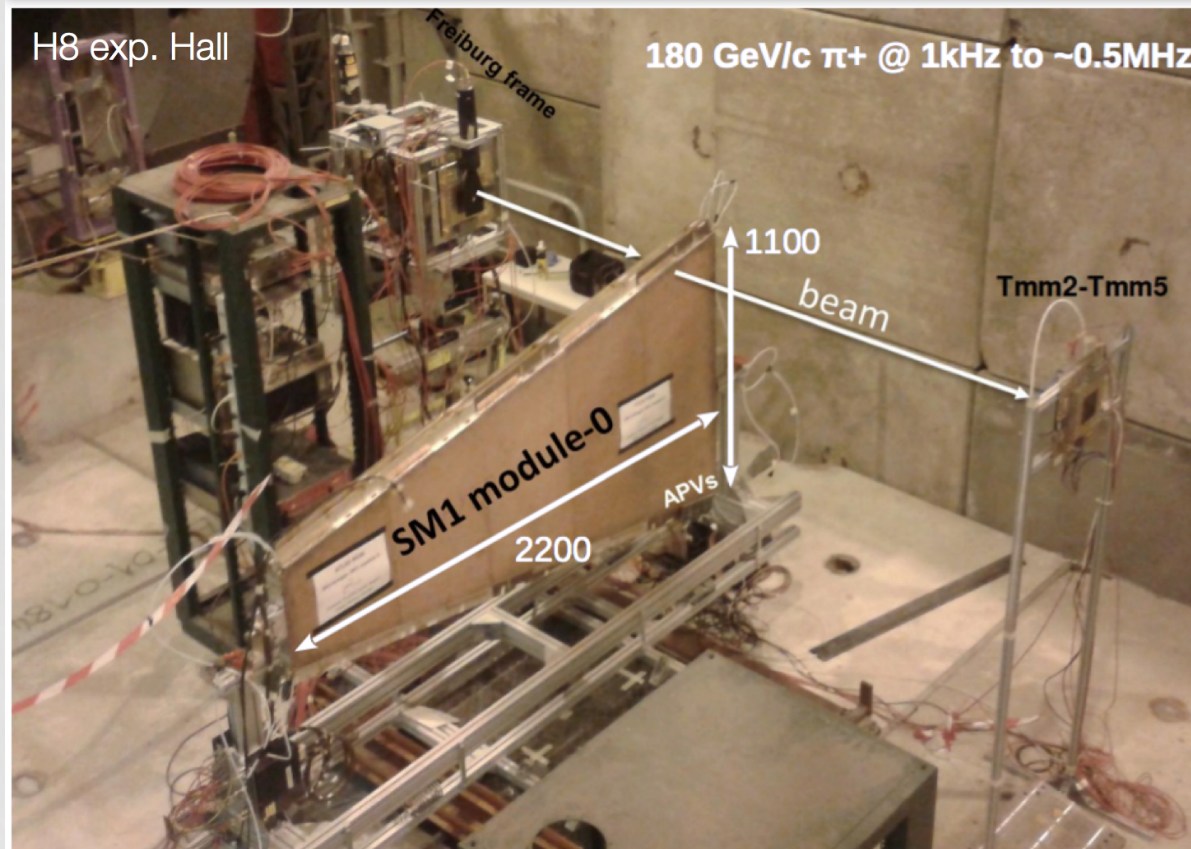
Table for mesh stretching and transfer frame in Roma3



Vertical assembly in Frascati



IL MODULO0 SM1 - IL TEST-BEAM - I



Misure su fascio di pioni da 180 GeV nelle condizioni "standard"

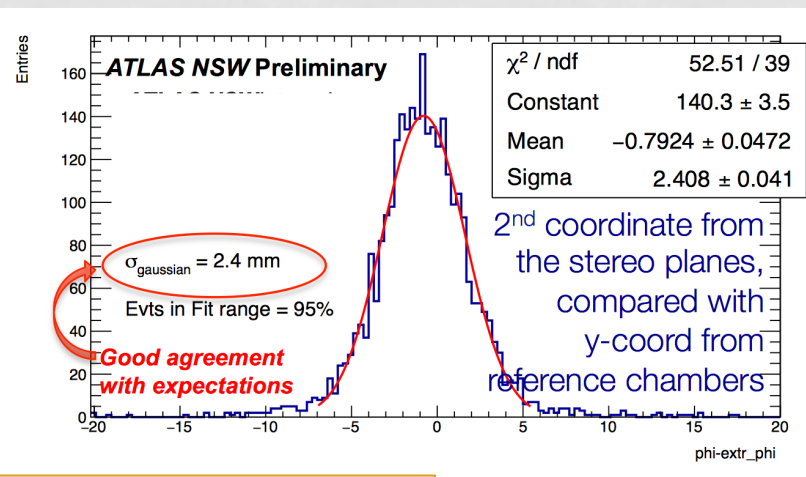
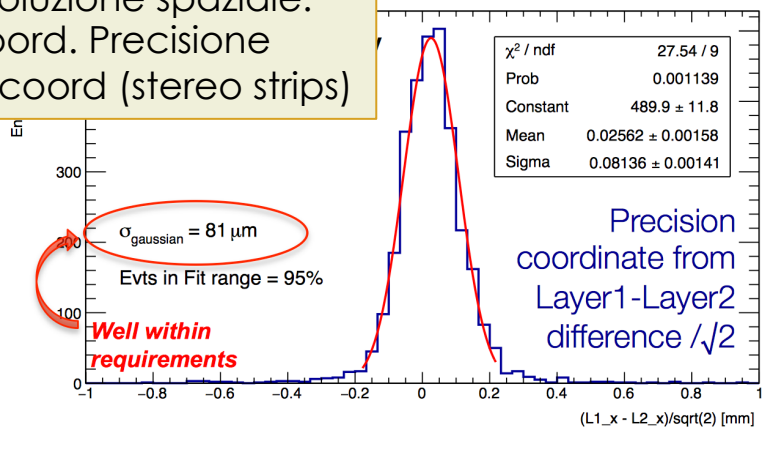
- Miscela Ar/CO₂ (93%-7%) @ 20 l/hr
- HV(ampl) = 580 V, HV(drift) = 300 V
- Elettronica APV25 (non la finale)

Obiettivo: validare il funzionamento del primo Q-pletto MM di 2m²

IL MODULO0 SM1 - IL TEST-BEAM - II

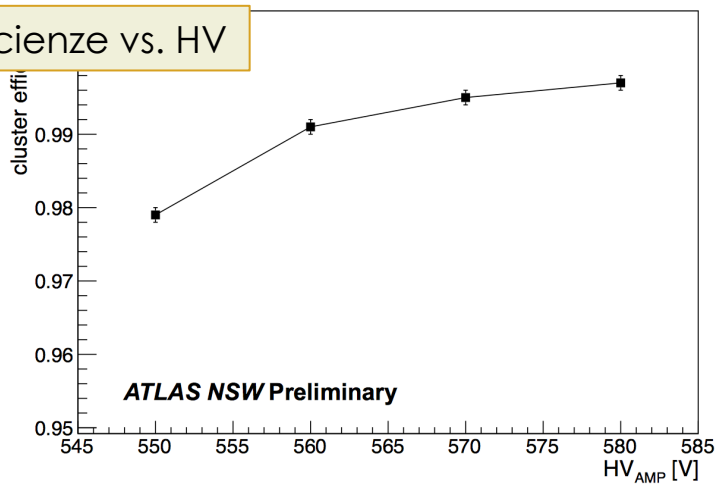
Risultati preliminari solo per tracce perpendicolari (centroide di carica)

Risoluzione spaziale:
Coord. Precisione
2° coord (stereo strips)

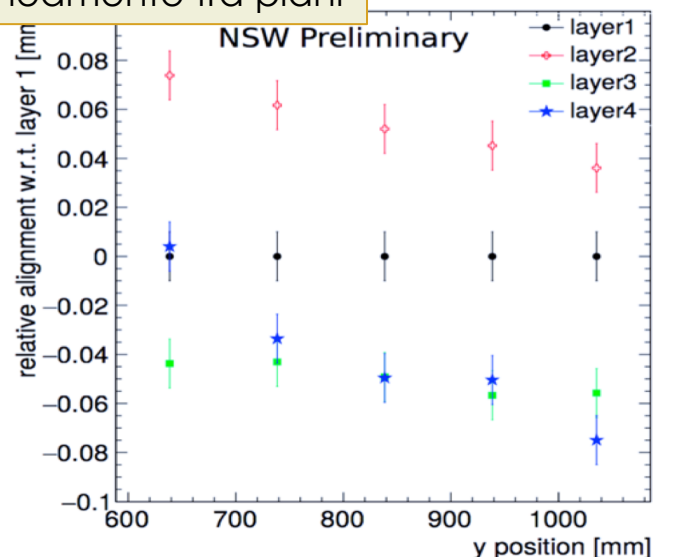


Cluster efficiency Vs Amplification HV for Layer1

Efficienze vs. HV



Allineamento tra piani



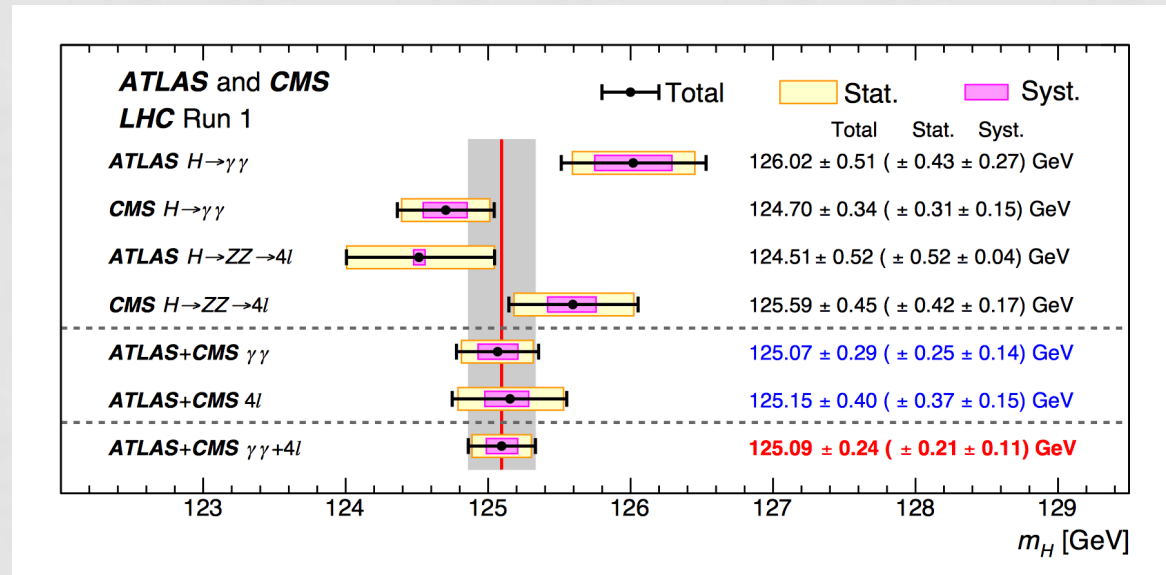
CONCLUSIONI E PROSPETTIVE

- Nei prossimi decenni LHC costituirà ancora e a lungo la “frontiera dell’energia” della Fisica delle Particelle Elementari
- L’esperimento ATLAS si sta organizzando per rinnovarsi al fine di raccogliere la sfida dell’alta luminosità.
- In questo contesto lo spettrometro a muoni di ATLAS verrà aggiornato con un ampio contributo INFN in particolare con la costruzione delle nuove camere in avanti (NSW) che costituiscono anch’esse una vera sfida tecnologica.

BACKUP

HIGGS: RISULTATI FINALI RUN1- I

Misura della massa: Combinazione ATLAS+CMS
(Phys.Rev.Lett. 114, 191803)

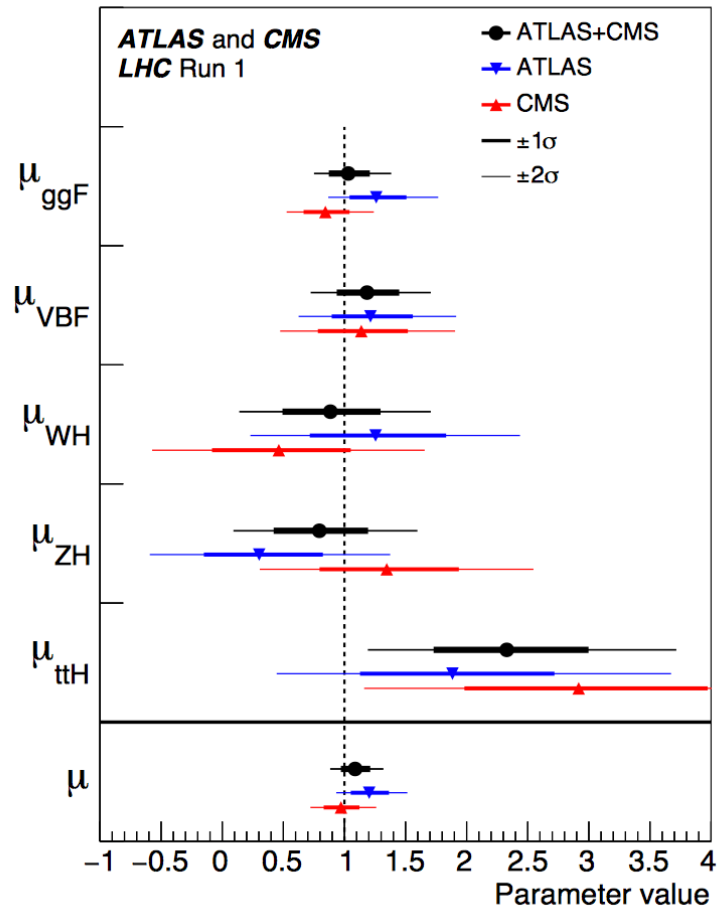


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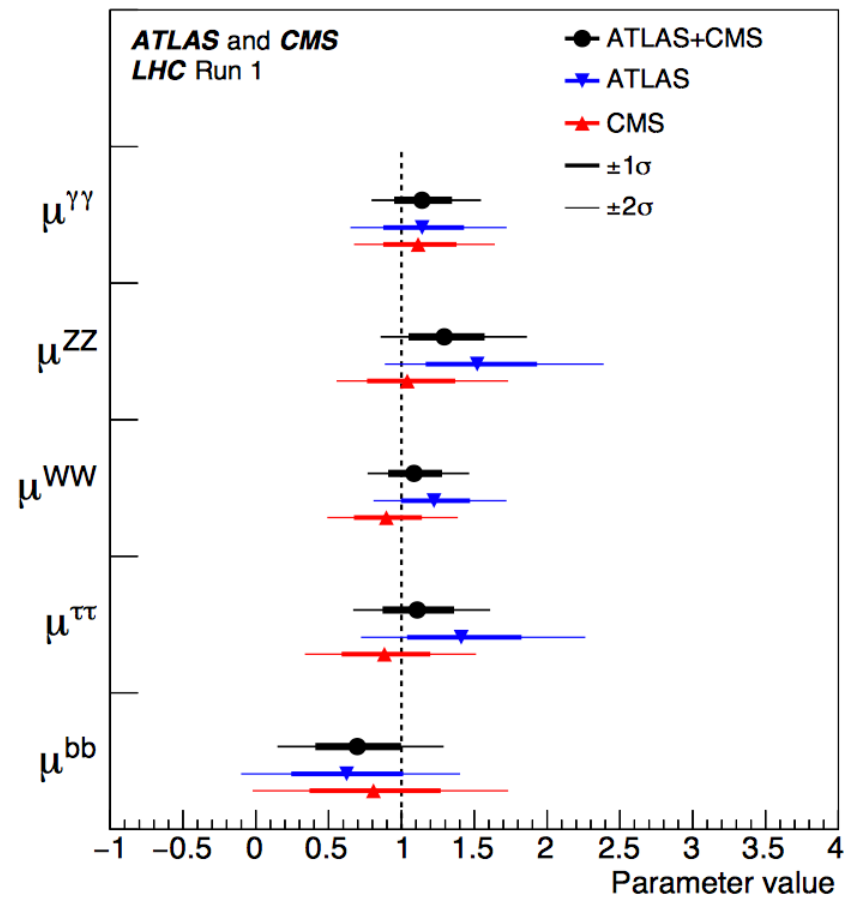
HIGGS: RISULTATI FINALI RUN1 - II

Fit degli accoppiamenti: Combinazione ATLAS+CMS
(JHEP 08 (2016) 045)

“Production couplings”

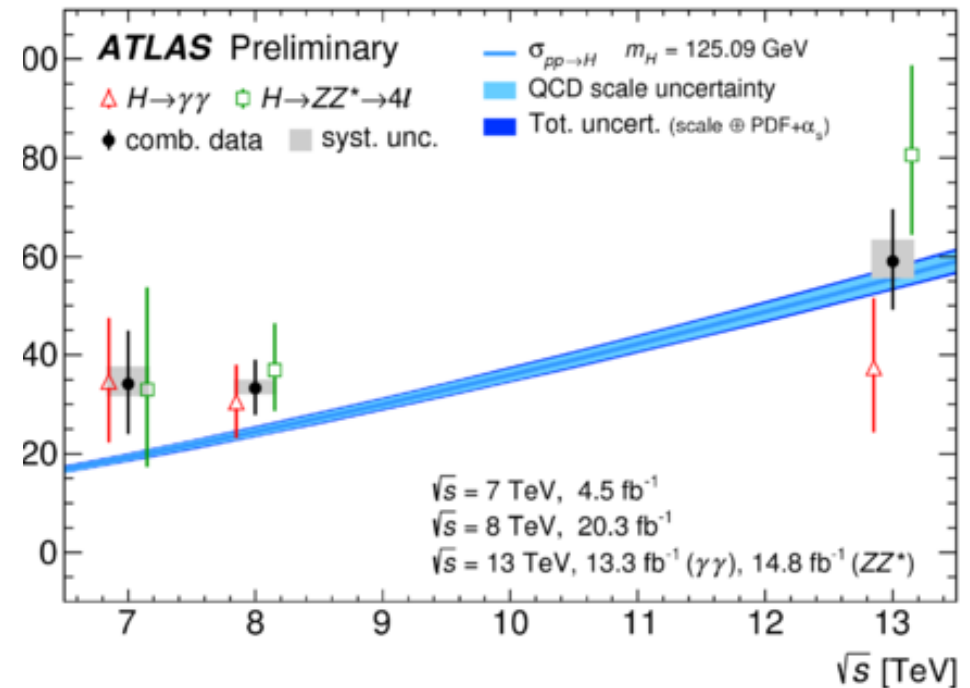
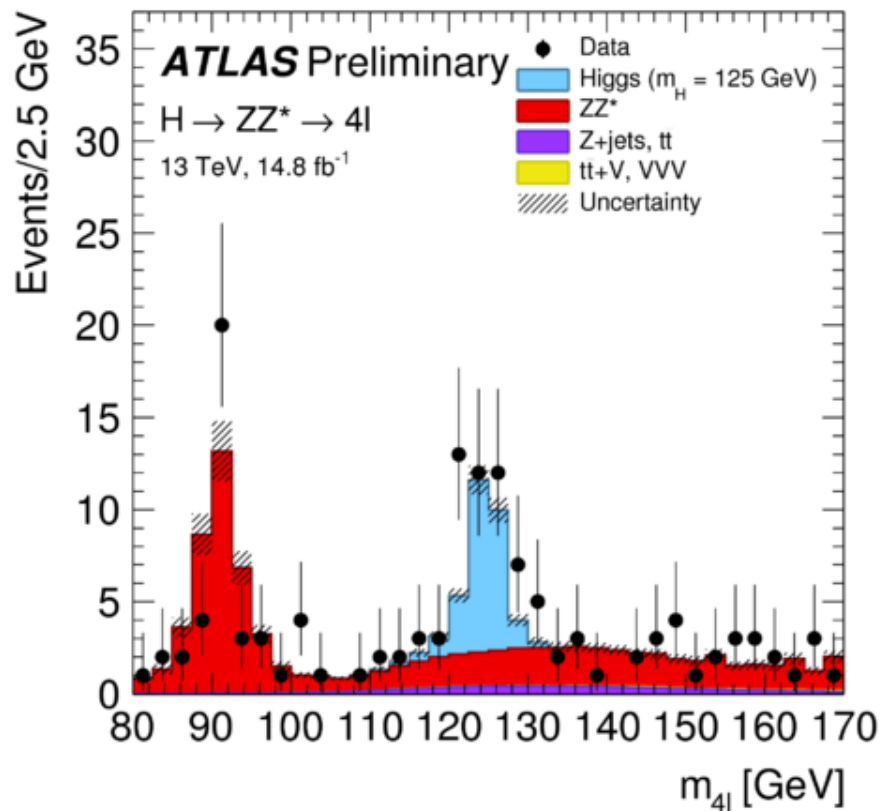


“Decay couplings”

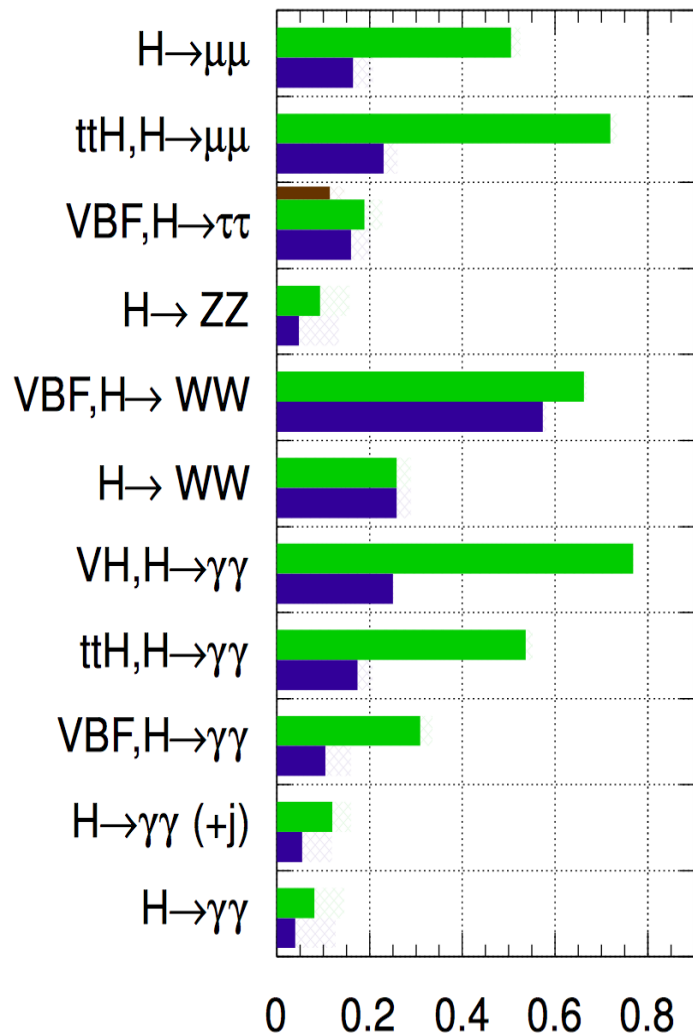


HIGGS: "RISCOPERTA" A 13 TEV

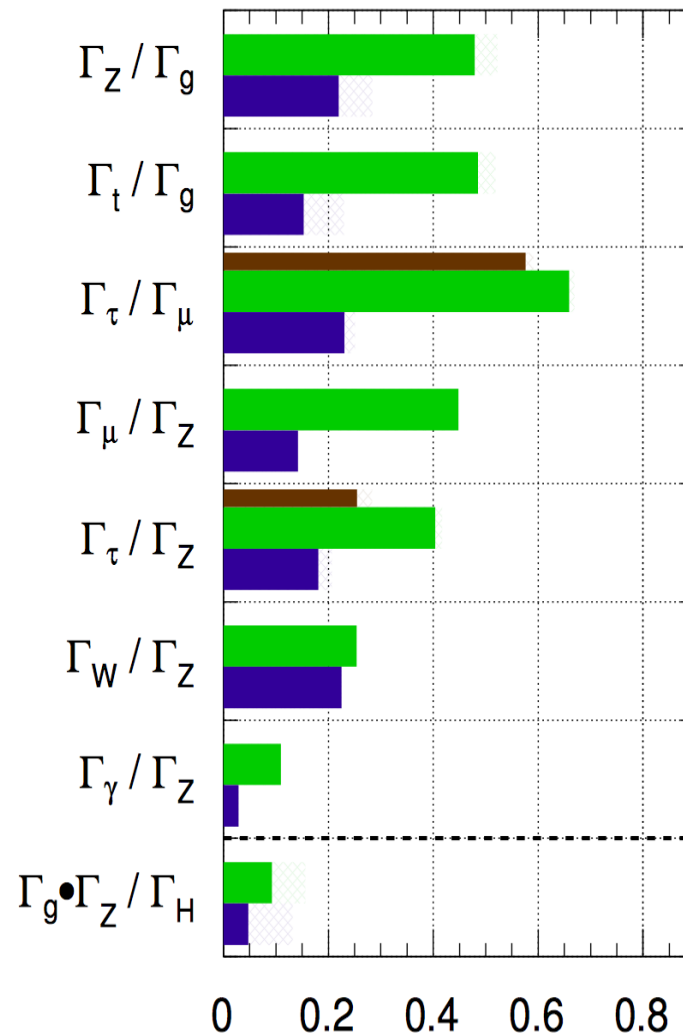
Osservazione del bosone di Higgs nel canale $H \rightarrow ZZ^* \rightarrow 4l$ a 13 TeV (ATLAS-CONF-2016-081) + Scaling della Sezione d'urto di produzione



$\int \text{Ldt}=300 \text{ fb}^{-1}$ extrapolated from 7+8 TeV



$\int \text{Ldt}=300 \text{ fb}^{-1}$ extrapolated from 7+8 TeV



PRECISIONE ASPETTATA: SIGNAL STRENGTH

canale	Prec. (%) 100 fb ⁻¹	Prec. (%) 300 fb ⁻¹		Prec. (%) 3000 fb ⁻¹	
		38	36	17	12
ttH H→γγ	~65	38	36	17	12
ttH H→ZZ*→4l	~85	49	48	20	16
VBF H→γγ	~80	47	43	22	15
VBF H→ZZ*→4l	~60	36	33	21	16
H→μμ	~70	39	38	16	12
H→ττ	~18	14	8	8	5
H→bb	~20	14	11	7	5
H→γγ	~15	12	6	8	4
H→4l	~15	11	7	9	4
H→4l	~15	11	7	7	4

ATLAS: incertezze sperimentali e teoriche; solo incertezze sperimentali
CMS: incertezze sperimentali e teoriche; inc. sper. ∝ 1/√L e ½ inc. teor.

- @ $7 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1} \rightarrow 3.6 \text{ kHz/cm}^2 \text{ su MDT} \rightarrow 1.5 \text{ MHz/tubo}$
- $\Delta t \text{ (tubo)} = 750 \text{ ns} \rightarrow r_{\text{max}} = 1/\Delta t = 1.3 \text{ MHz/tubo}$

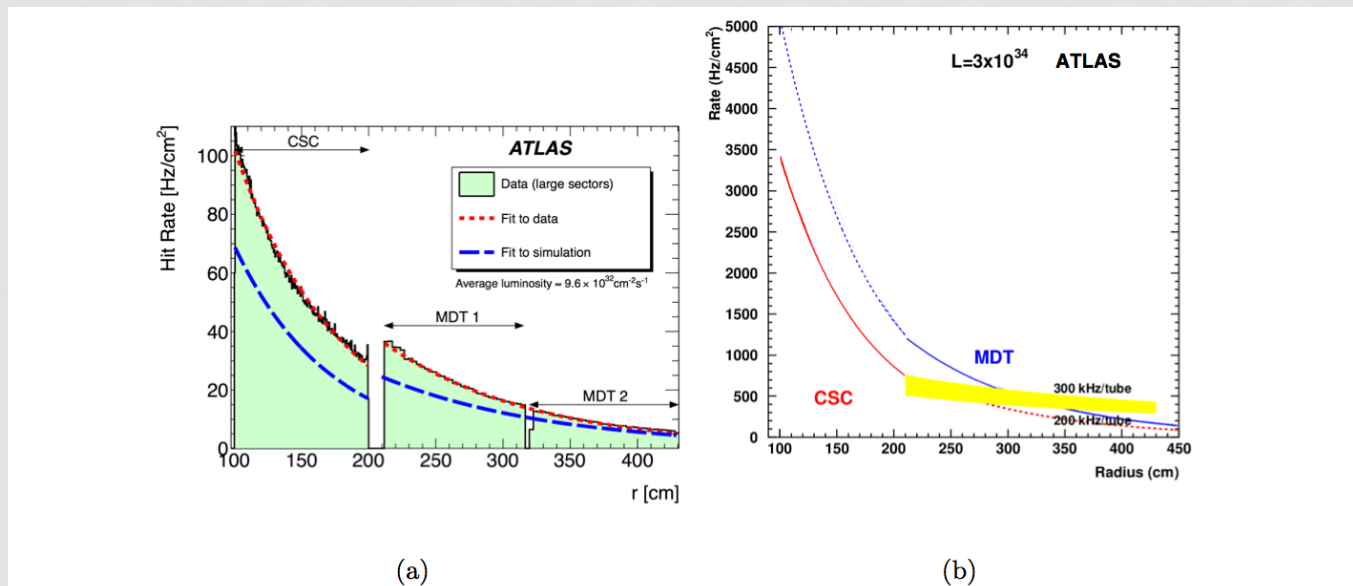
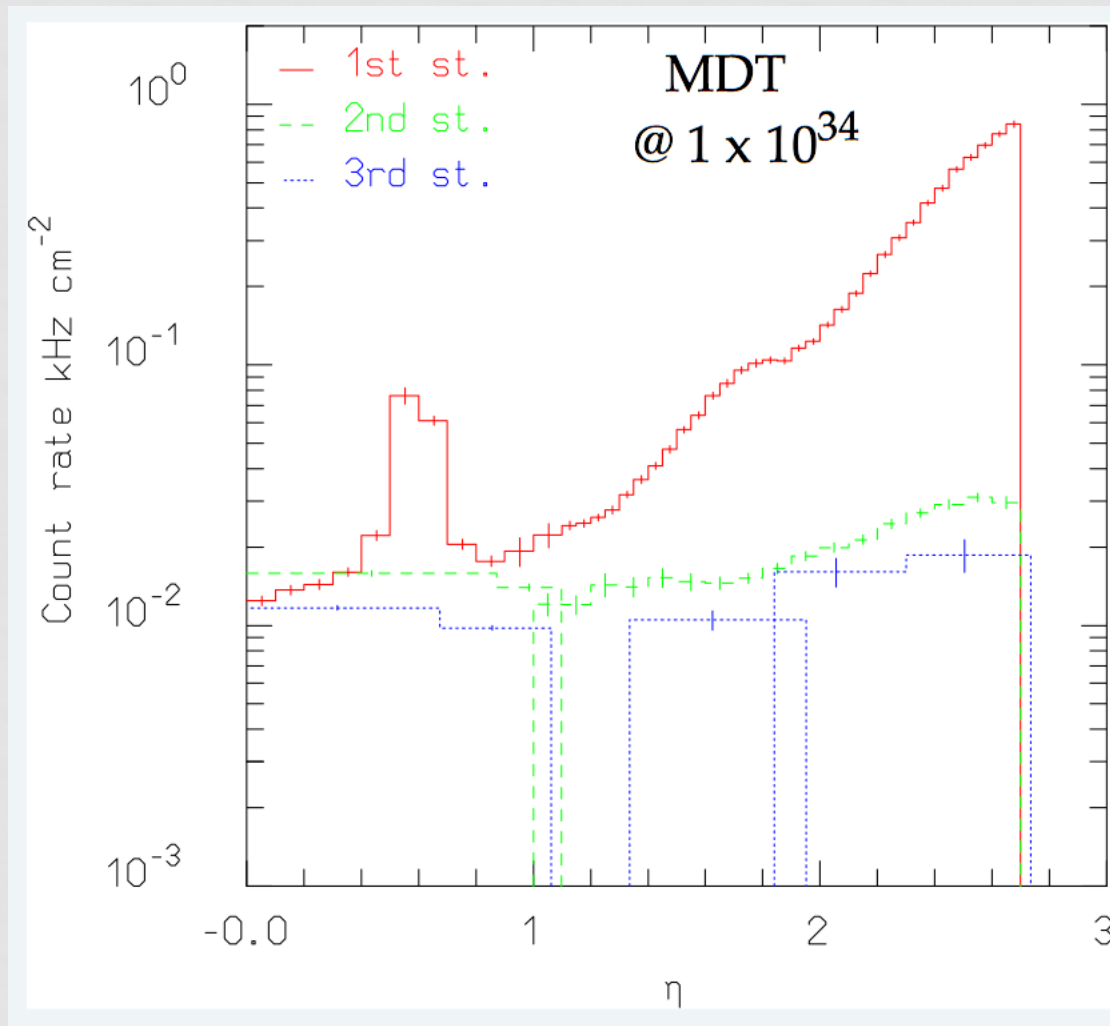


Figure 2.2: a) Measured hit rate in the region of the Small Wheel for $\mathcal{L} = 9.6 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ at $\sqrt{s} = 7 \text{ TeV}$ in the CSC and MDT chambers as function of the radial distance from the beam line. b) Extrapolated hit rate in the CSC and MDT regions for a luminosity of $3 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ at $\sqrt{s} = 7 \text{ TeV}$ as a function of the radial distance from the beam line. Also indicated is the range of tube rates of 200-300 kHz.



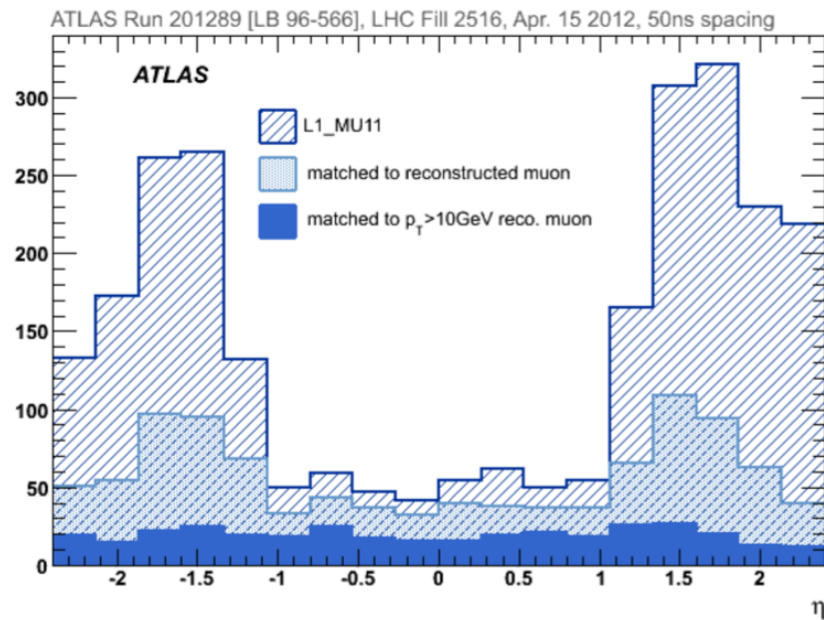


Figure 2.6: η distribution of Level-1 muon signal ($p_T > 10$ GeV) (L1_MU11) with the distribution of the subset with matched muon candidate (within $\Delta R < 0.2$) to an offline well reconstructed muon (combined inner detector and muon spectrometer track with $p_T > 3$ GeV), and offline reconstructed muons with $p_T > 10$ GeV.

RESISTIVE MICROMEAS

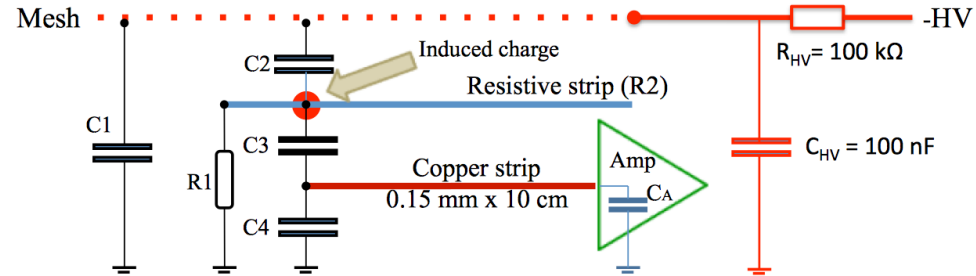
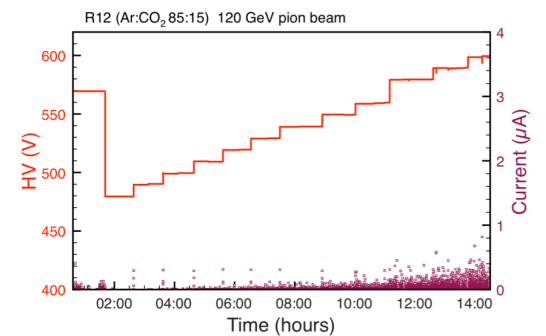
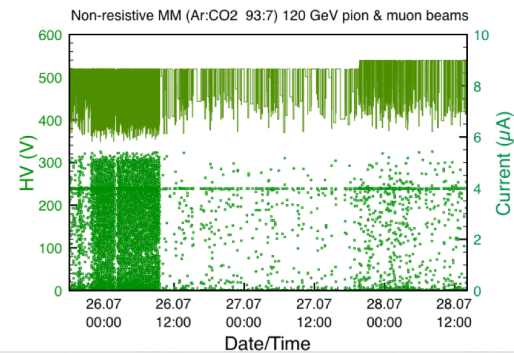
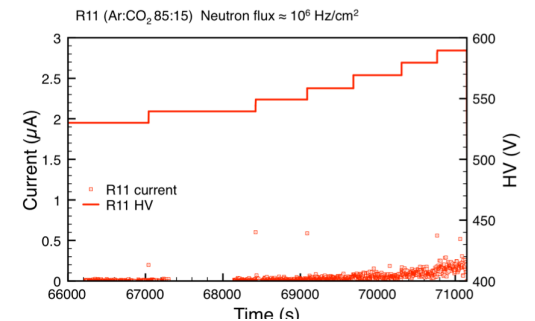
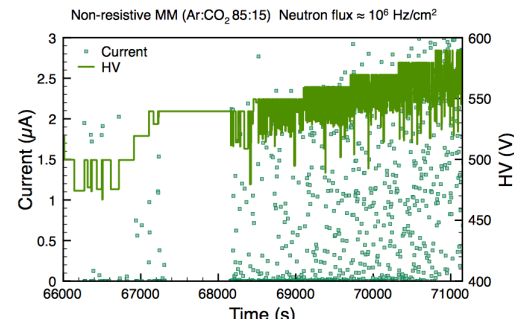
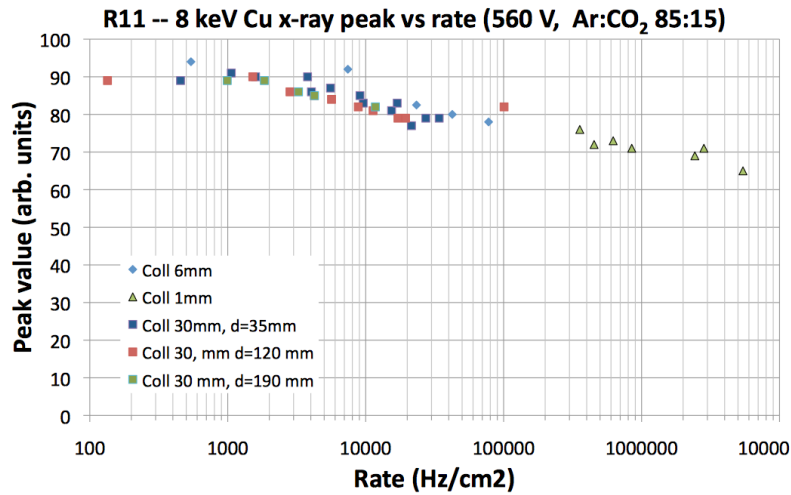
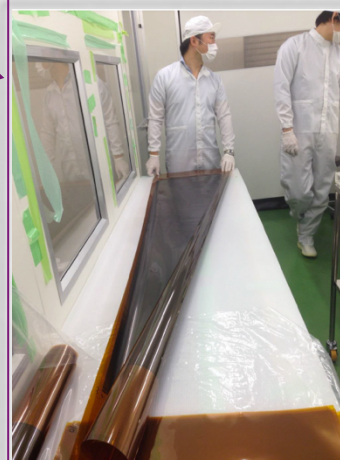
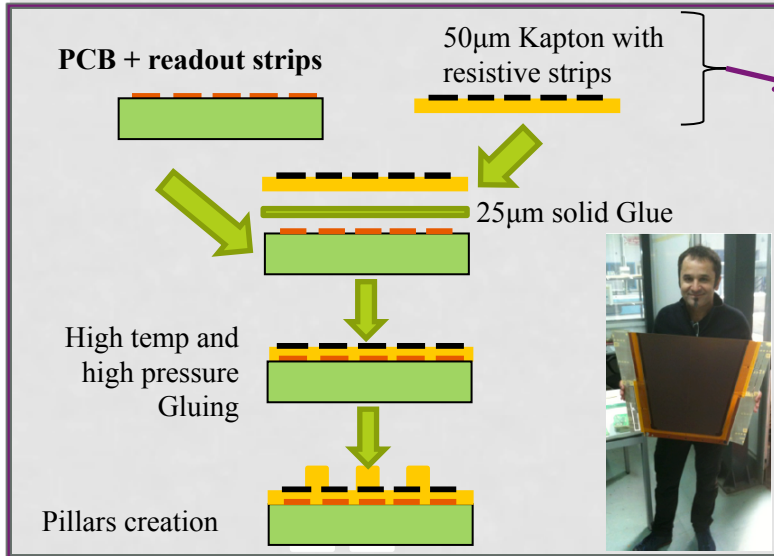


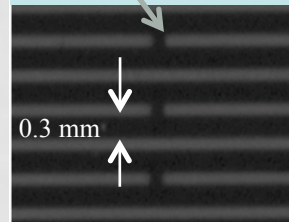
Fig. 2: Sketch of the equivalent electric circuit of the chambers with resistive strips



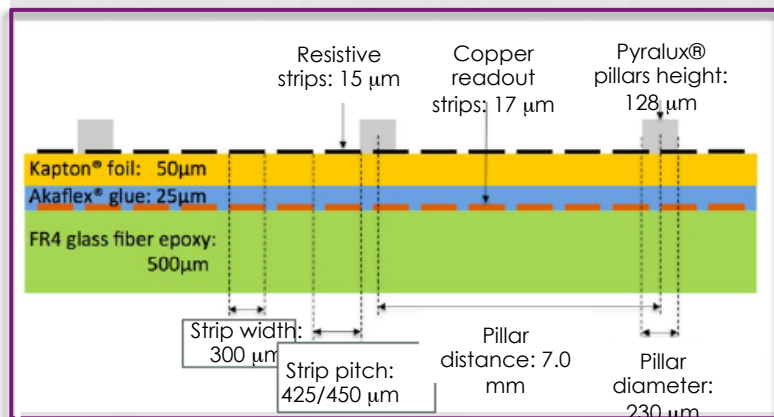
MicroMegas construction: Read-out boards and resistive strips



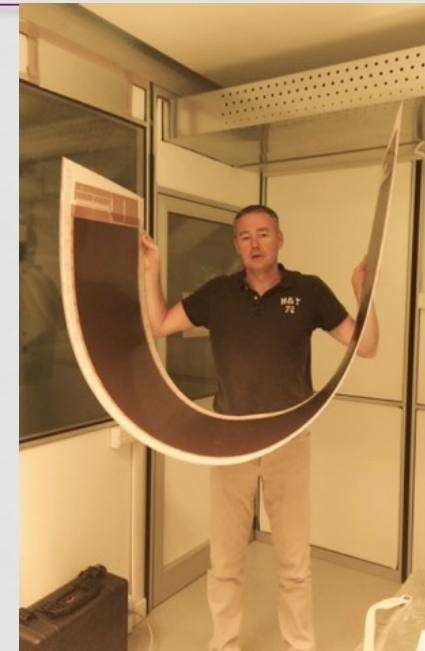
- Resistive strips on kapton by screen-printing
- “Ladder pattern” (connections every 20 mm):
 - Homogeneous resistivity (independent from distance)
 - Insensitivity to broken lines



Typical resistivity:
~ 10-20 MΩ/cm
(~800 kΩ/□)

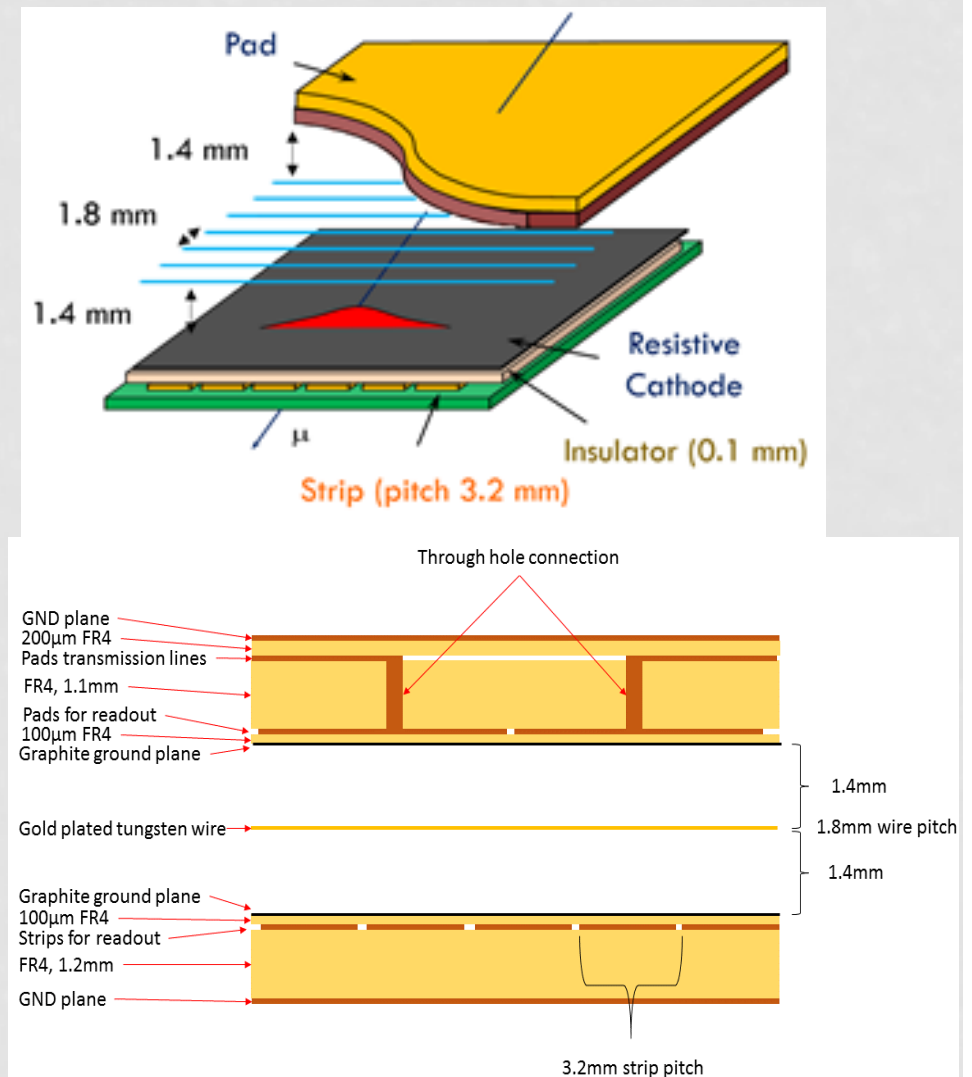
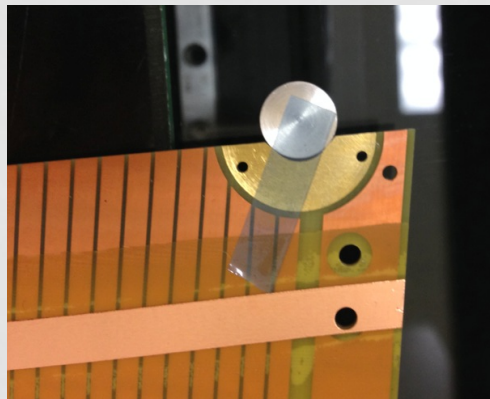


- Board dimensions: from 45x30 up to 45x220 cm²
- 1022 strips/boards
- Readout strips pitch: 425 or 450 mm
- Pillars height: 128 µm
- Several types of alignment masks



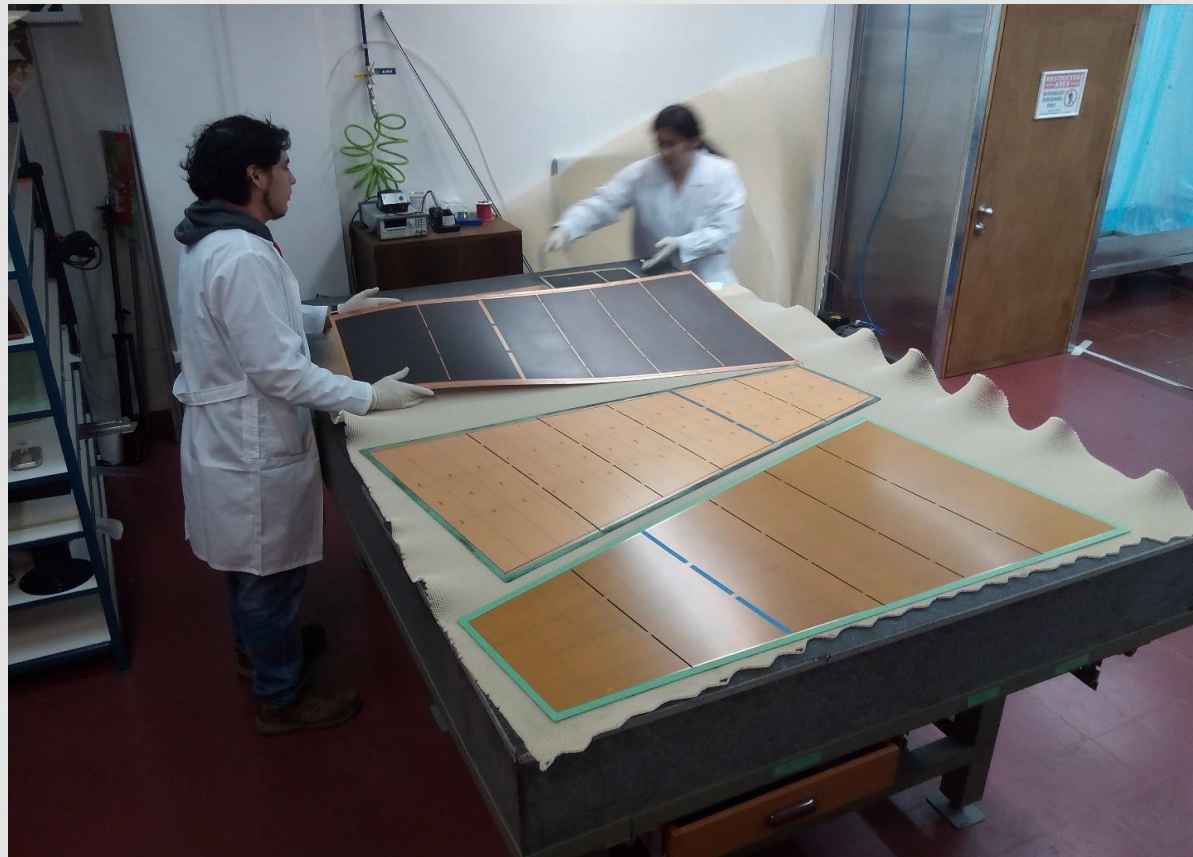
STGC STRUCTURE

- The basic sTGC structure consists of a grid of gold-plated tungsten wires sandwiched between two resistive cathode planes at a distance of 1.4mm from the wire plane
- The precision cathode plane has strips with a 3.2mm pitch for precision readout relative to a precision brass insert outside the chamber, and the cathode plane on the other side has the pads for triggering
- The gap is provided using $1.4\text{mm} \pm 20\mu\text{m}$ precision frames glued to the cathode boards



sTGC structure

- Pad readout provide fast pre-trigger to determine the strip to be read
- Precision strips for precision muon tracking reconstruction at level of $100\mu\text{m}$
- High efficiency at high background rate



sTGC working conditions

- sTGC chambers are working on n-Pentane/CO₂ (45% / 55%) gas mixture
- This mixture has three main properties:
 - High gain
 - Quenching of photons
 - Clean the chamber
- Nominal operational voltage – 2800V
- The cathode plane is made by the resistive layer of graphite with a surface resistivity of $\sim 100\text{k}\Omega/\square$ ($200\text{k}\Omega/\square$ for outer chambers)
- All quadruplets have trapezoidal shapes with surface area up to 2m^2