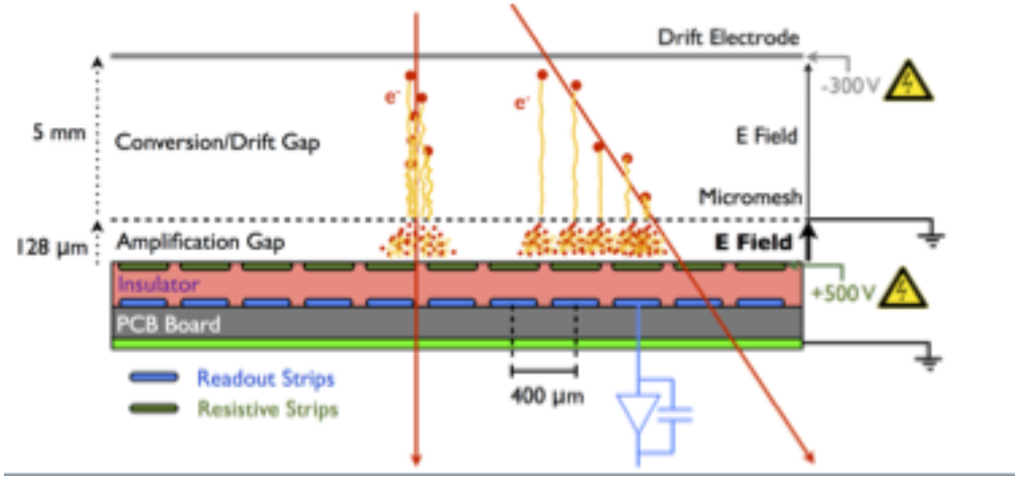
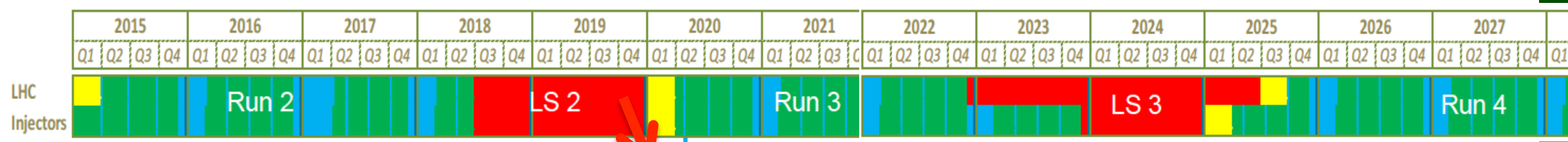
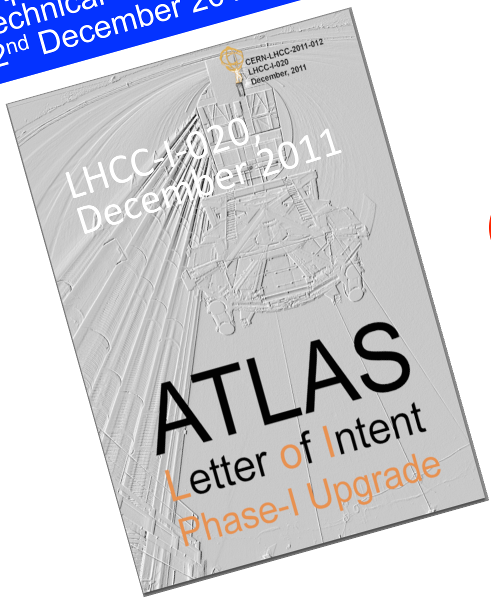
ATLAS MicroMegas



The New Small Wheel upgrade for LHC Phase 1



LHC schedule approved by CERN management and LHC experiments spokespersons and technical coordinators Monday 2nd December 2013



The New Small Wheel is one of the ATLAS upgrade project proposed in the LoI for Phase1 LHC

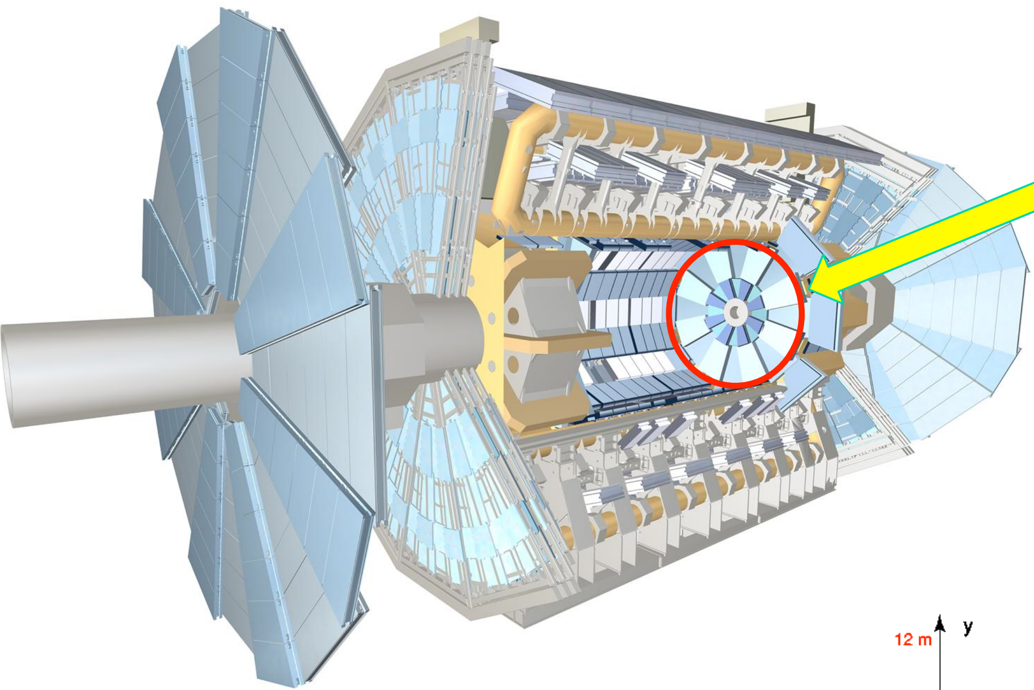
"Phase-I" upgrades:
ultimate luminosity
$\mathcal{L}_{inst} \approx 2\text{-}3 \times 10^{34}\ cm^{-2}s^{-1}$ ($\mu \approx 55\text{-}81$)
$\int \mathcal{L}_{inst} \gtrsim 350\ fb^{-1}$

- New Small Wheel (nSW) for the forward muon Spectrometer
- High Precision Calorimeter Trigger at Level-1
- Fast TracKing (FTK) for the Level-2 trigger
- Topological Level-1 trigger processors
- New forward diffractive physics detectors (AFP)

The NSW must cope with LHC Phase-2 running conditions

- In operation from 2017 to >2032
- Instantaneous luminosity up to 5-7 $10^{34}\ cm^{-2}s^{-1}$
- Average number of interactions per bunch-crossing ~140
- Background hit rate up to 14 kHz/cm^2
- Total dose expected in the hottest regions in 15 years ~1$Coulomb/cm^2$
- Total Ionizing Dose (TID) in 10 years at large η: about 0.5 Mrad

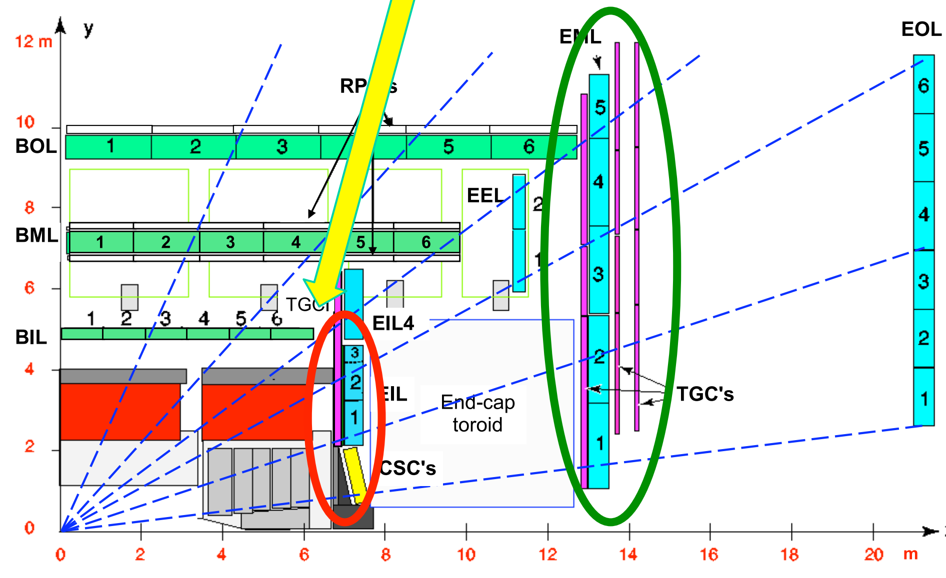
The ATLAS Muon Spectrometer – present layout



The small wheels

Pseudorapidity coverage: $1.3 < |\eta|$

BigWheel L1 trigger chambers

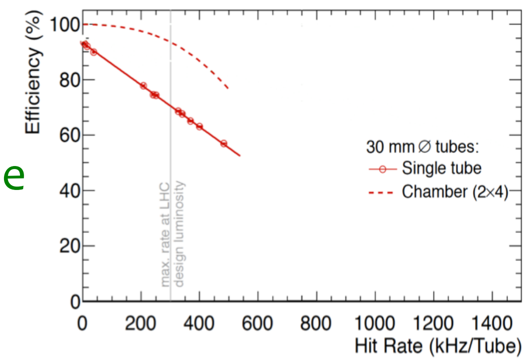


- The Small Wheel: region with highest background rates in the present ATLAS Muon Spectrometer
- Cathode Strip Chambers (***CSCs***) and Monitored Drift Tubes (***MDTs***) for particle tracking
- Thin Gap Chambers (***TGCs***) for trigger

New Small Whell - Motivations

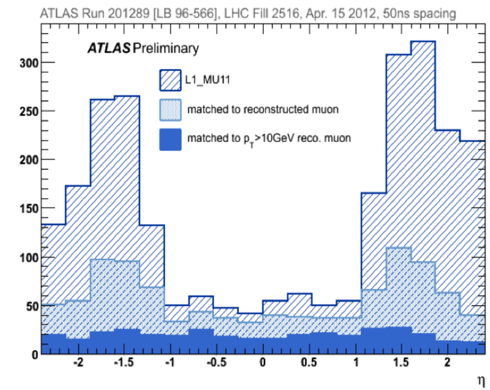
1) ***Cavern Background***

The MDT efficiency drops for tube-hit rates > 300 kHz/tube (tube hit and segment tracking inefficiency)



2) ***TRIGGER***

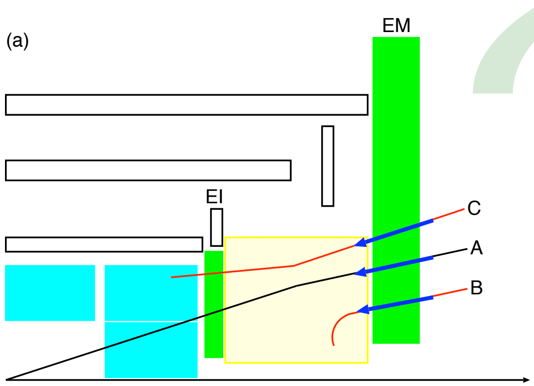
L1 muon trigger rate in the end-cap (based on Big Wheel) dominated by fake triggers.

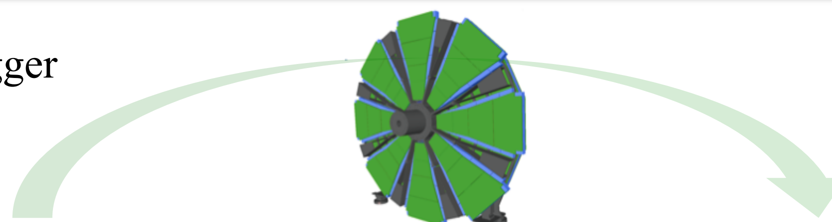


At 7x10^{34} (luminosity of phase2) the rate estimate is (safety factor 1.5) 14 kHz/cm^2 (>5 MHz/MDTtube)

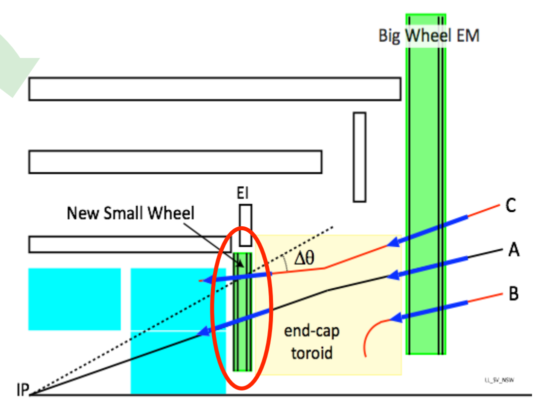
At $3 \cdot 10^{34}$ cm^{-2}s^{-1} rate L1MU20 (p_T>20 GeV) ~60 kHz exceed the available bandwidth for L1Mu (~15kHz)

Present Level1 muon trigger





Upgrade L1 with NSW



"New Small Wheels"

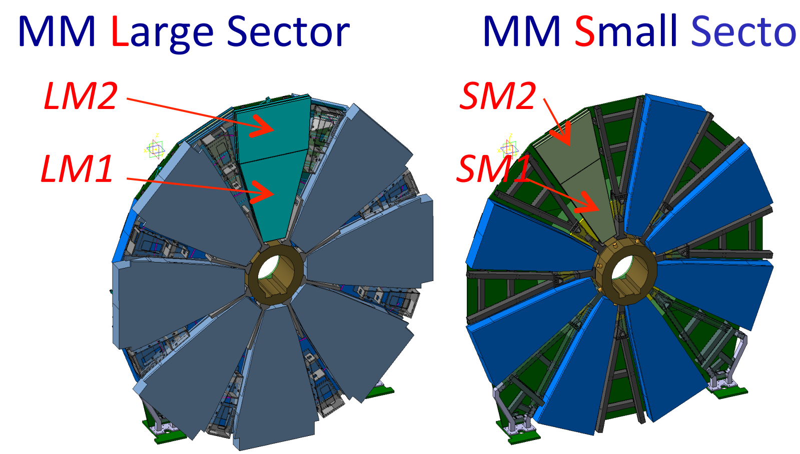
Reduce fake muon triggers requiring:

- Segments with High preciosn IP pointing (σ_θ~ 1mrad)
- Matching BigWheel segments

New Small Wheel – Layout

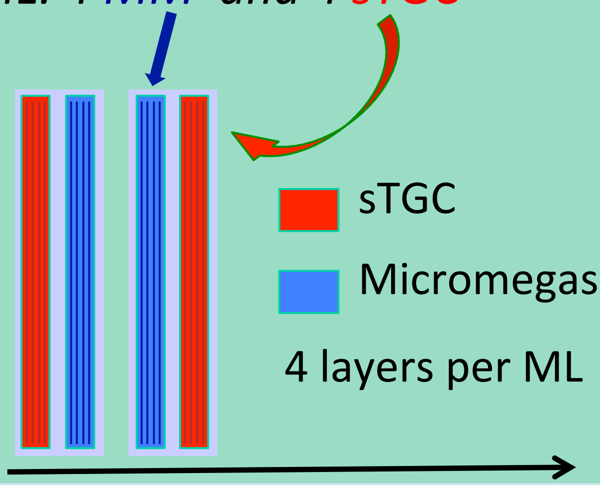
The present Small Wheel defines the basic layout and envelopes

- *16 sectors per wheel (8 Large – 8 Small)*
- *2 detector technologies: MicroMegas and sTGC*



16 detector layers per wheel :

- *2 Multilayers per sector*
- *Each ML: 4 MM and 4 sTGC planes*



sTGC *(small strip TGC)* *primary trigger detector*

- Bunch iD with good timing resolution
- Good online space resolution for NSW track vector with <1 mrad angle resolution

MicroMegas (MM) primary precision tracker

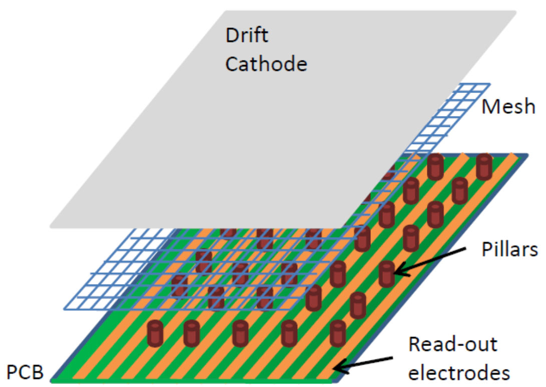
- Good Space resolution ~100 μm, independent of angle
- Good track separation (0.5 mm readout granularity)
- Provide also online segments for trigger

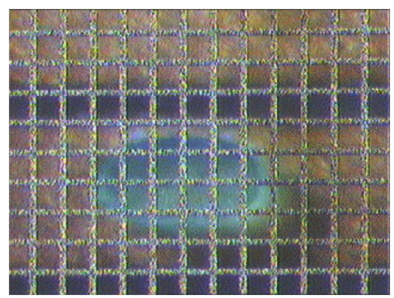
- Work together to make a robust detector for the high rate region of very limited access
- The NSW will operate from <u>2017 until 2032</u> → ROBUSTNESS and REDUNDANCY

Micromegas Tecnology

- MM belongs to the family of Micro Pattern Gaseous Detectors (MPGDs)

- Space resolution < 100 µm independent of track incidence angle
- Good track separation due to small 0.4 mm readout granularity (strips)
- Excellent high rate capability due to small gas amplification region and small space charge effects



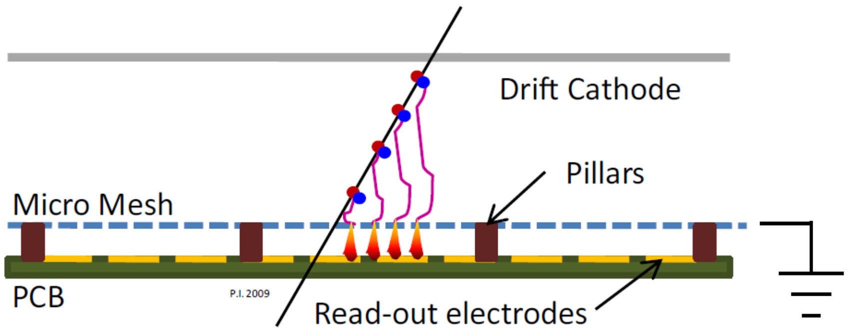


Gas mixture: Ar:CO_2 (93:7)
V drift = 47 µm/ns

Drift Gap = 5 mm
Amplification Gap: 128 µm

E=600 V/cm

E=50 kV/cm

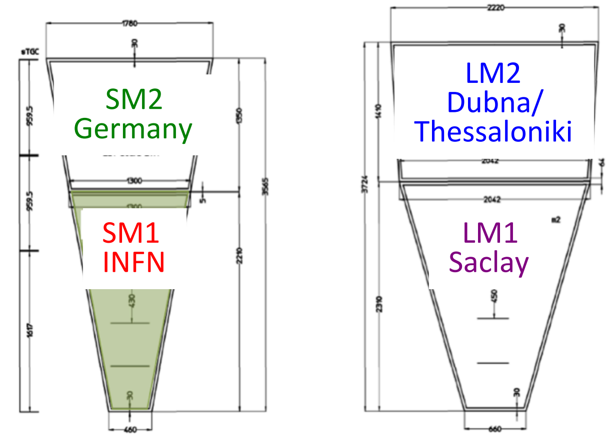


Micromegas Chambers

MM module segmentation scheme and work sharing

2 (small sector) + 2 (large sector) module types module production will be done in several production sites according to type:

- SM1: **Italy INFN** (Cosenza, Frascati, Lecce, Napoli, Pavia, Roma1, **Roma3**)
- SM2: Germany (Freiburg, Mainz, LMU Munich, Würzburg)
- LM1: Saclay
- LM2: Dubna, Thessaloniki

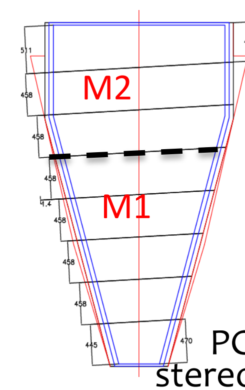


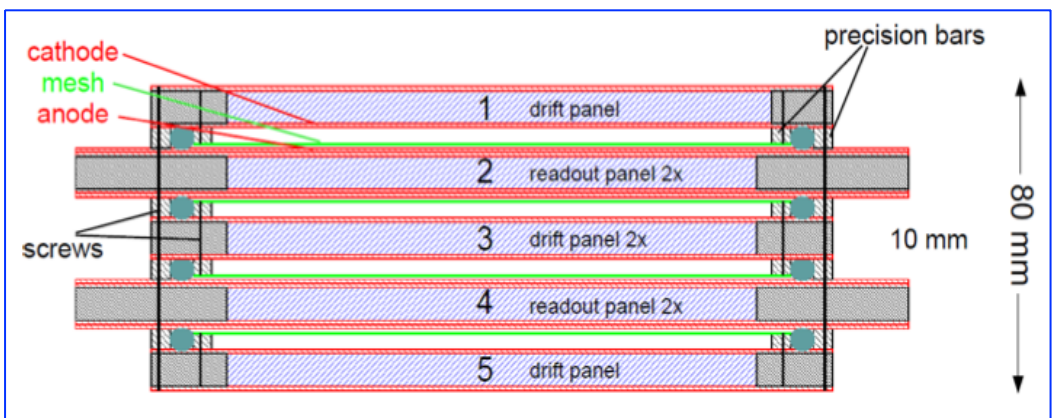
MM Configuration Scheme (decided in January 2014)

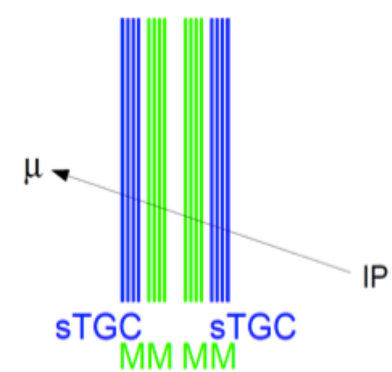
Two Quadruplet per module with read-out panels back-to-back

Each module composed by 5 panels and 4 read-out planes:

- 2 planes with "eta" strips (precision coordinate ~ 100μm resolution)
- 2 planes with stereo strips (+/- 1.5°) (second coord. ~2mm resolution)







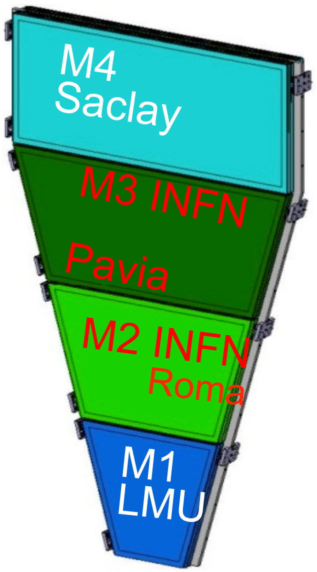
Micromegas Construction - Mechanical prototypes

Mechanical Prototypes - Recent activity

- Construction of 4 modules Mechanical Prototypes is CONCLUDED (according to old segmentation): INFN PV, INFN RM, Saclay, LMU-Germany
- Construction of single wedge full size mech. Protototype CONCLUDED: CERN

Ongoing measurements:

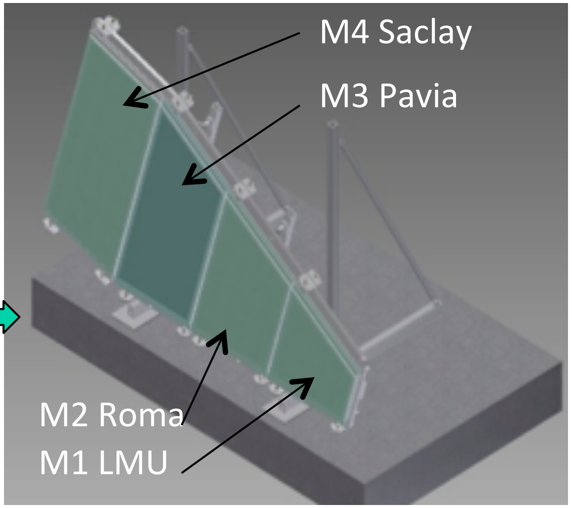
- Thermo-mechanical deformations
- Mesh tension and gas overpressure induced deformations



Mechanical prototypes
(based on old segmentation)

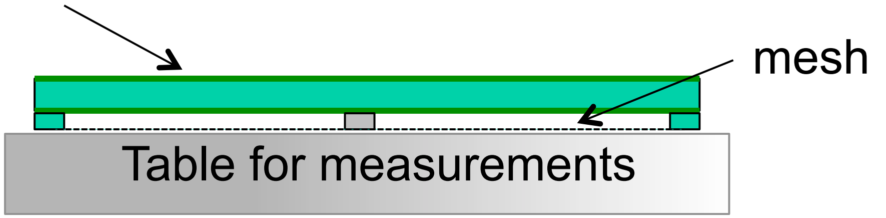
Current measurements being carried on in Freiburg

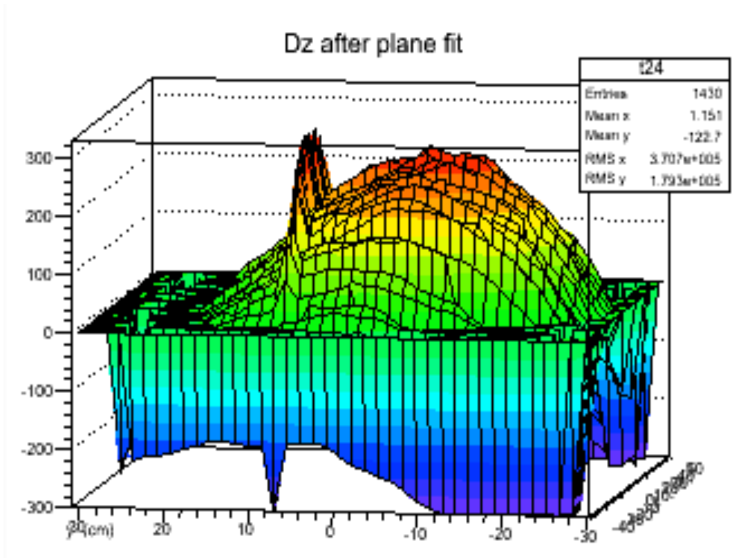
- Assembly prototypes into 2 dummy sectors, with dummy counter weights as 2nd wedge, to study mechanical deformation and stress
- Measurements to be done at Freiburg (4 modules) and at CERN (full wedge)
- Validation of simulation of Thermo-mechanical deformations
- Crucial input to settle In-plane alignment needs
- Assess and define method to attach modules to sector structure – glueing, kinematic mounting, ...



Mesh Tension Induced Deformation (example: test on 100x60cm2 in Roma)

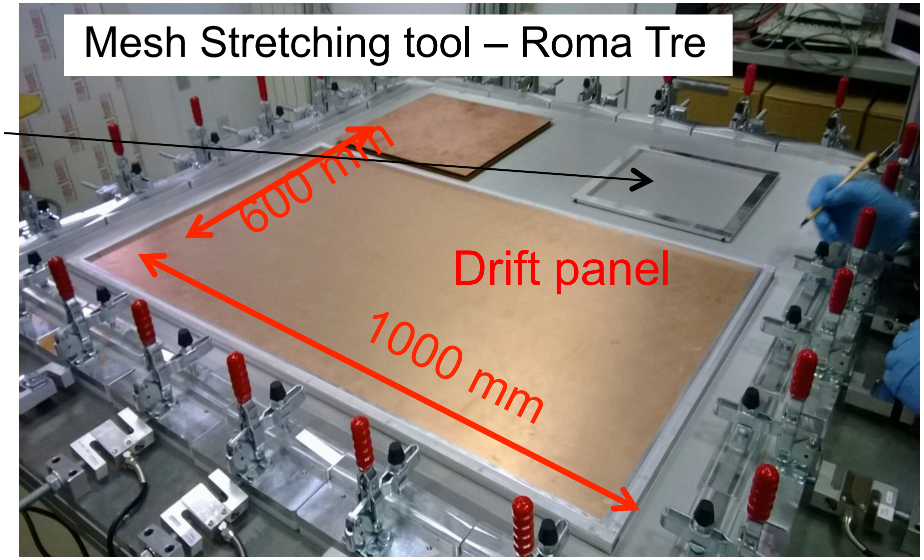
Surface measured for deformations



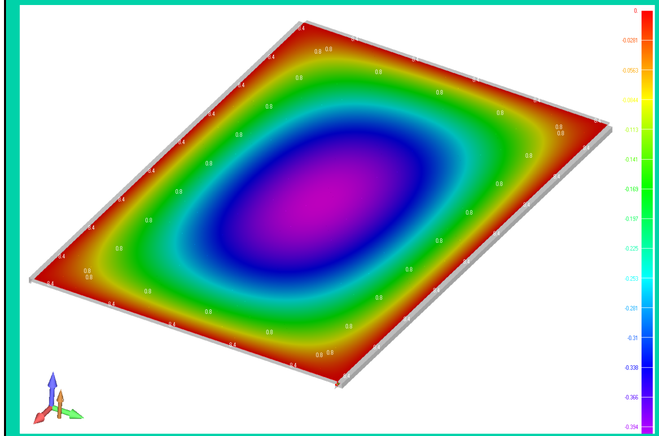


(The spike is a fake measurement)

z scale +-300 μm
Max deformation ~ 550 μm

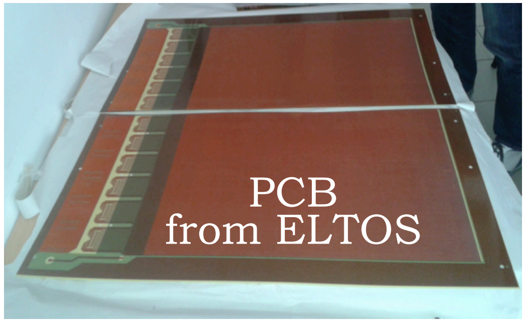


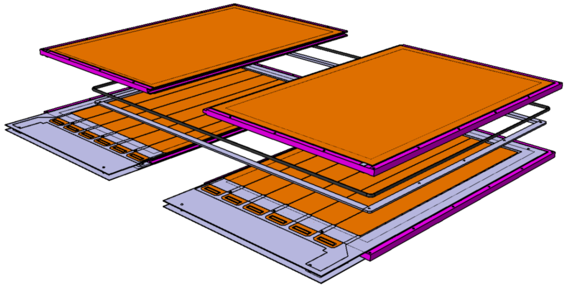
Simulation (A.Zullo)
Mesh tension: 10 N/cm → max 520 μm
Mesh tension: 8 N/cm → max 440 μm



Functional prototypes

Ongoing construction of functional Multiplets in Frascati (780x730 mm²) and Saclay (600x1000 mm²)

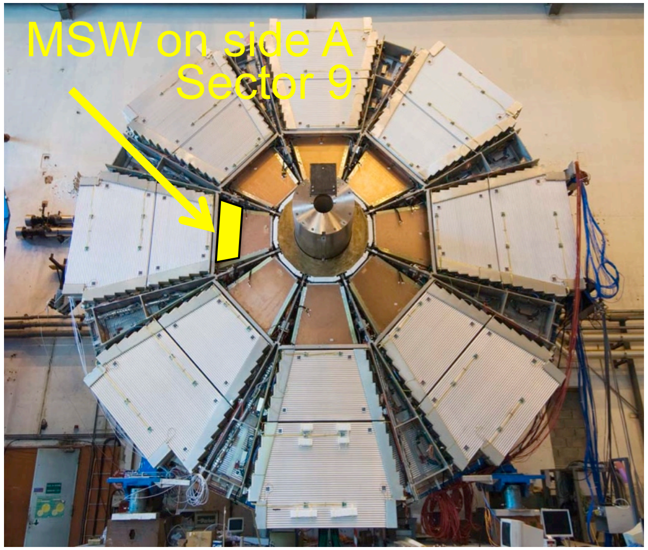




The MSW Project

- One CERN/Mainz prototype (Micromegas Small Whell module – MSW) will be installed in ATLAS on the Small Wheel to operate during Run2 in real conditions in (*Installation July 2014*)
  - -- Dimensions 1.2 x 0.5 m² (to fit upper half of CSC)
  - -- Four layers (quadruplet) 2 eta 2 stereo
  - -- strip pitch 0.425 mm, 1024 strips/layer
  - -- PCB Production as close as possible to final production

  Goal is to integrate the data into the ATLAS data stream.



Major Milestones

- The schedule is determined by the **installation in ATLAS in mid-2018**.
- Before the installation, it is planned that the completed wheels are fully **tested on surface during 2017** for about one year.
- In order to match the above schedule, the production of the chamber multiplets, which is expected to take at maximum two years, should **start in 2015**.
- Year 2014 will be devoted to the production of **module-0** and its qualification. Finalization of the chamber construction procedure, preparation of the tooling and infrastructure for qualification should proceed in parallel during this period.

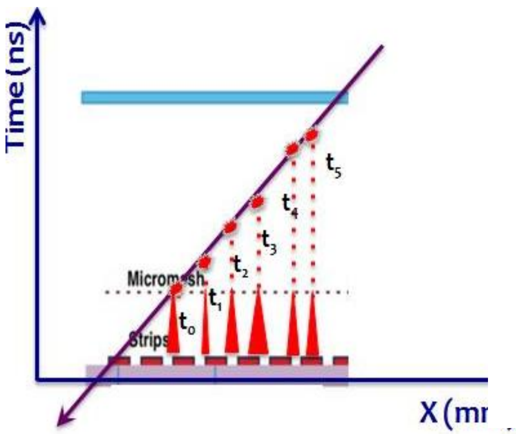
Milestone	Due
Submission of VMM ASIC prototype 1	Beginning 2012 (done)
Submission of VMM ASIC prototype 2	January 2014 (done)
Submission of final FE ASIC	2015
Construction of module-0	End of 2014
Start chambers production	March 2015
Start assembly of sectors	End 2015
NSW Assembly	Mid-End 2016
Installation	Mid 2018

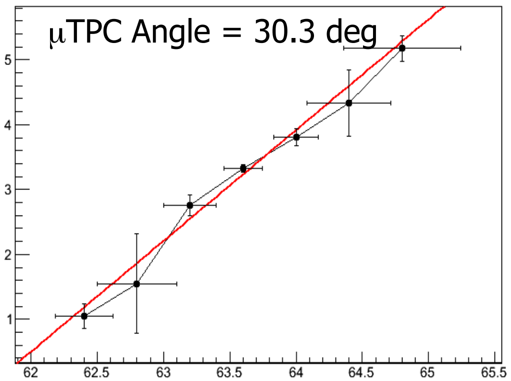
The MSW is a pre-series quadruplet for the NSW MMs

- It will be operational in 2015-2018 under realistic background conditions.
- Test for the integration of the MMs into the forward muon tracking system

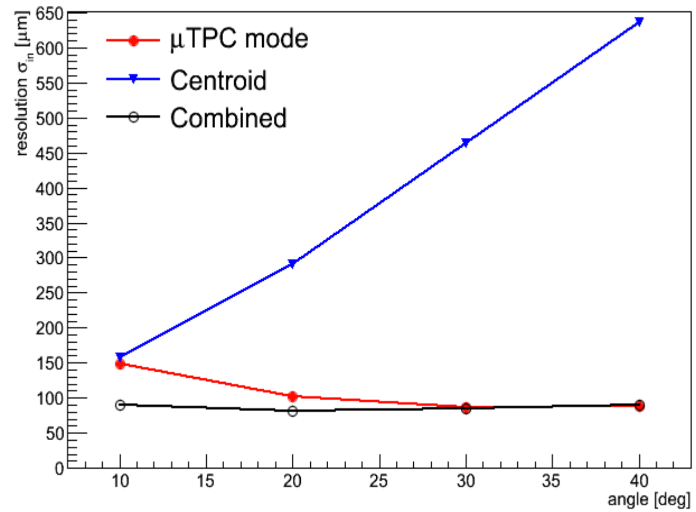
Performance studies

- Initiate a process of MM Performance Review, implying test-beam re-analysis, simulation, software development, algorithms improvements





Exploit time information for μTPC reconstruction



- Spatial resolution<100 μm in the whole angular range of the NSW
- Studies ongoing for possible improvements

<u>Test-Beam Plans:</u>

- 6-12 August (1 week) at PS T9 line: test of VMM2 chip on small or large MM prototypes
- 1-7 October (1 week) at PS T10 line: test of VMM2 chip on small or large MM prototypes
- 20 Oct. 2 Nov. (2 week) at SPS H6 line (to share with pixels): test of VMM2 on small or large MM prototypes
- 1 week (minimum) between 26 Nov. And 14 Dec. At SPS H4 line: test in Goliath magnet

RM3 contribution

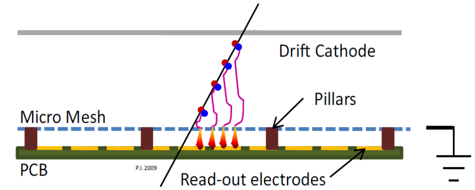
We are involved in different aspects of the ATLAS NSW MM project since the beginning:

- Active in preliminary studies, performance measurements, layout definition → ***TDR***
- Mauro is the deputy NSW project leader (MicroMegas Detector Working Group)
- We are contributing to the **analysis of the performance** and to the coming **test beam activities**

- We are involved in the definition of the construction procedures:
  - **mesh stretching**, gluing, …
  - assemply tools

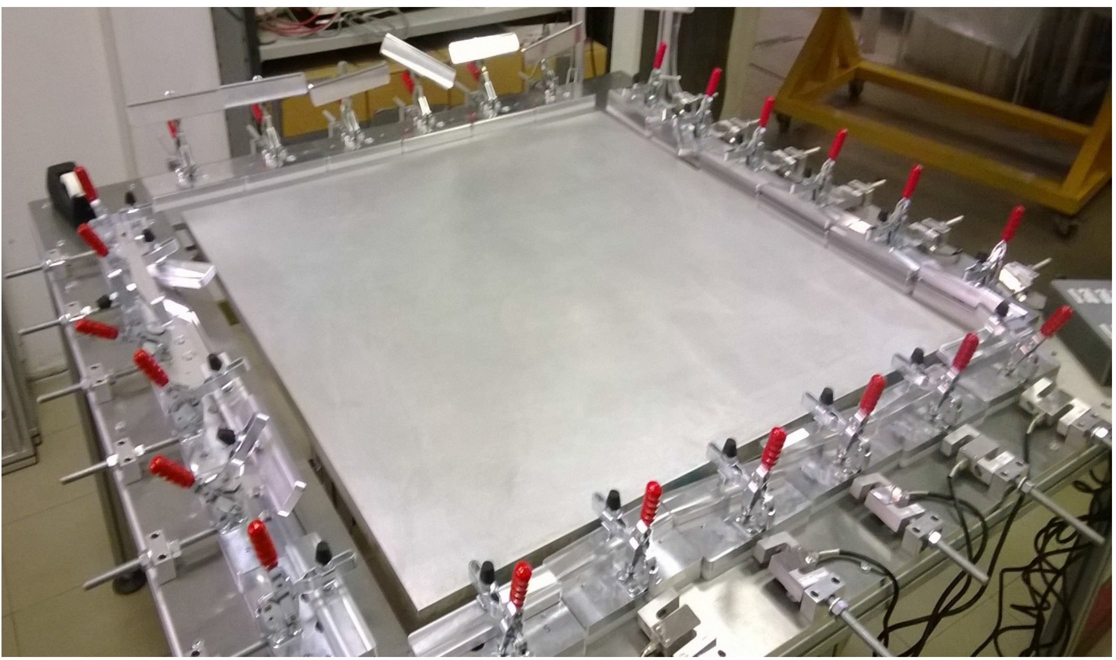
- We will contribute to the detector construction and test:
  - **all the meshes will be stretched in Roma Tre** and then transported to the assembly site (Frascati)
  - we will **participate in the assembly and in the test** at the production site

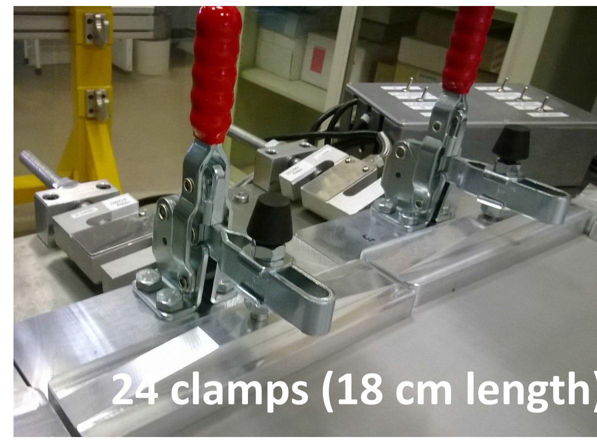
Set-up at Roma Tre

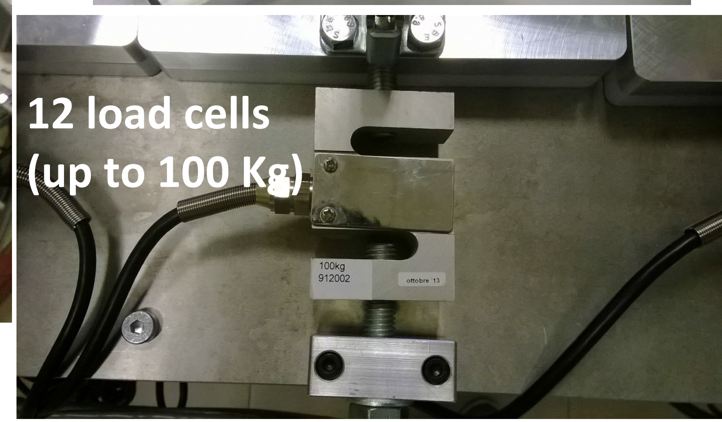


- **The mesh is a crucial element of Micromegas chambers.**
- **It divides drift gap from amplification gap. The distance of 128 µm between mesh and readout plane has to be more accurate as possibile, for a uniform amplification .**
- **It is necessary to stretch the mesh and glue it on the drift pannel in way that tension will be costant during all life of ATLAS.**

- **A mesh stretching tooling is being designed and built in Roma Tre.**
- **A 1m x 1m prototype is already operative.**

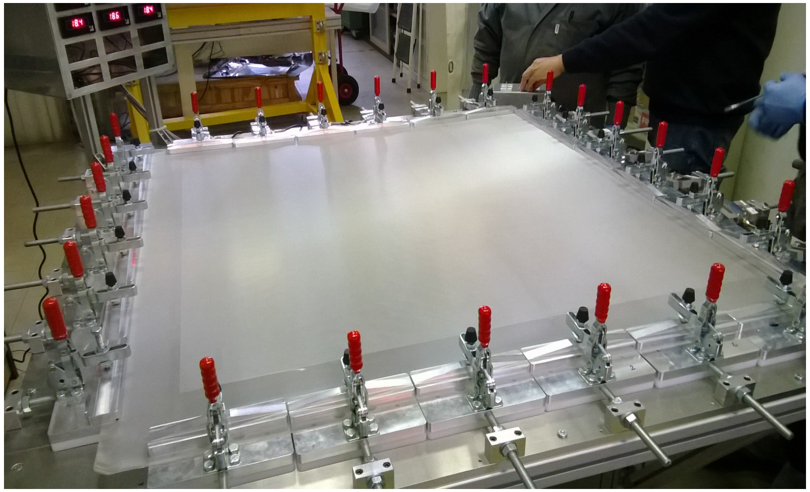


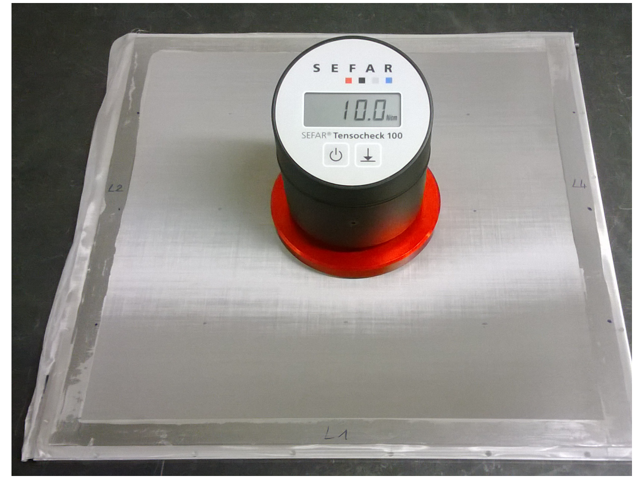




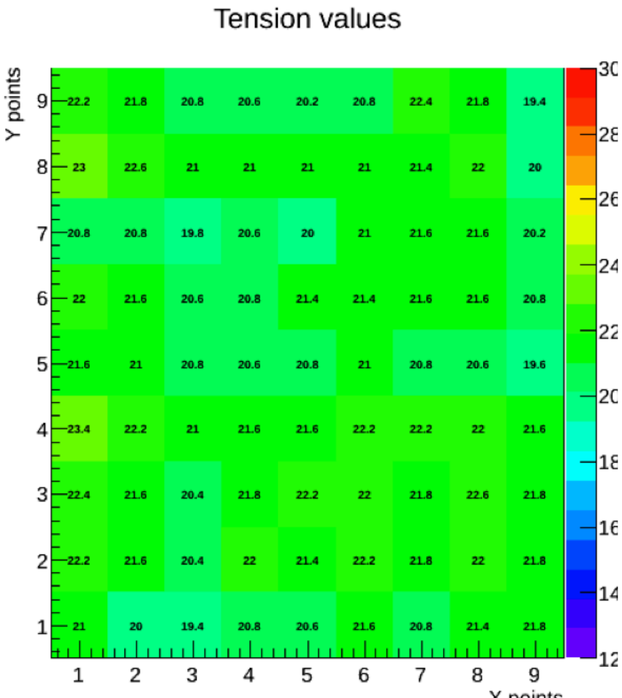
Thanks to Alfredo and Massimo…

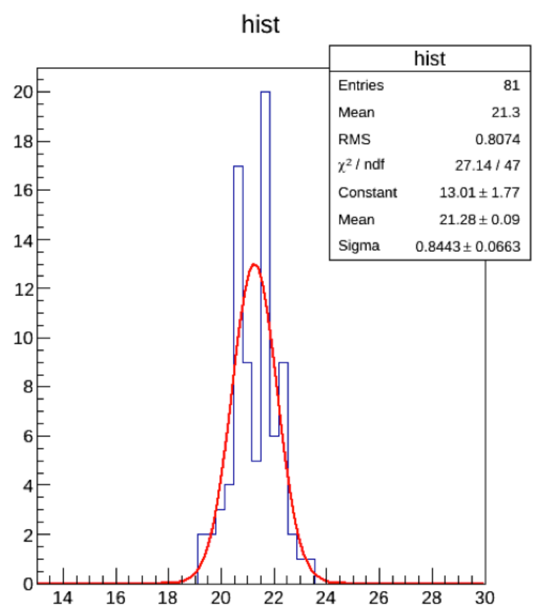
Mesh tensioning and tests





SEFAR Tensocheck 100



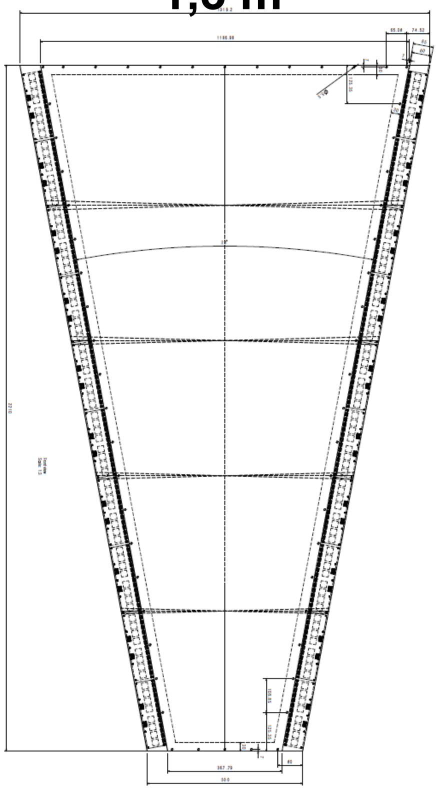


Map of tensions of the stretched mesh

Final mesh stretching tool and transport

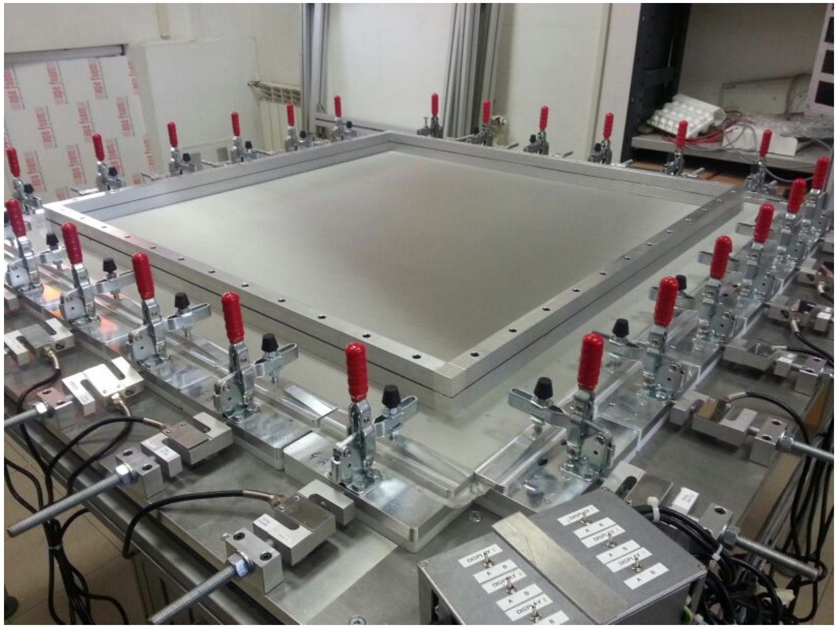
1,3 m

2,2 m



Sizes of the MM module that will be realized in Italy

A new stretching tool 2.5 m x 1.5 m is currently being designed



Prototype 1m x 1m transfer frame: two frames screwed together, the same principle of the clamps is used

Advantage: reusable several times

- More than 10 years ago we started contributing to the construction and test of the MDT precision chambers for the Barrel Muon Spectrometer; now we are in the new NSW phase…

- Overall, the construction of the MicroMegas for the NSW is less demanding (32 4-layer chambers will be built in Italy)

- The amount of work to be done in our lab is limited: we should stretch the mesh for all of them (128 meshes).
  - **Spaces:**
  - the stretching tool will be 2.5 m x 1.5 m. We need room for that (plus some temporary storage area + other service desks).
  - Although the meshes will be cleaned before assembly, our lab should be clean ***enough*** (a clean room?)
  - **Manpower:**
  - in 2015-2016 we need the help of the technicians (one more person is needed!)

Backup slides

Micromegas Mechanical Requirements

Aim: $\sigma(p_T)/p_T < 15\%$ @ 1 TeV

Exercise:

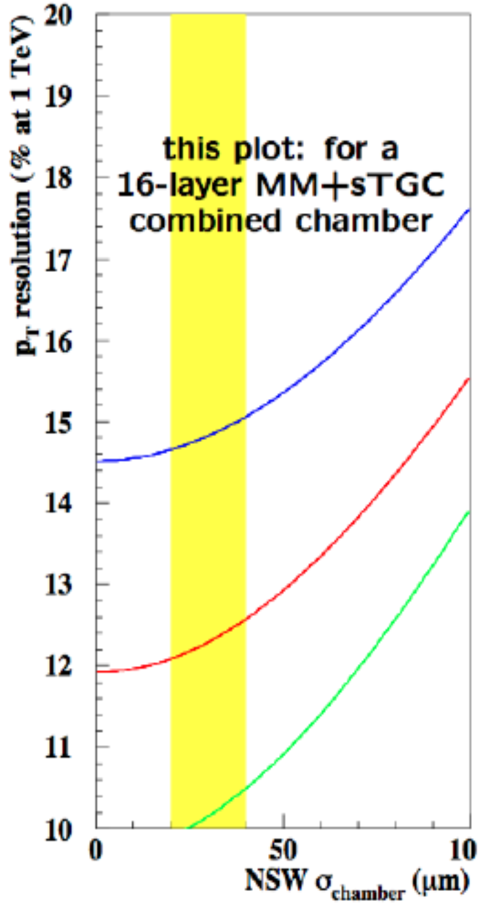
- p_T from "sagitta"$=(x_1+x_3)/2-x_2$

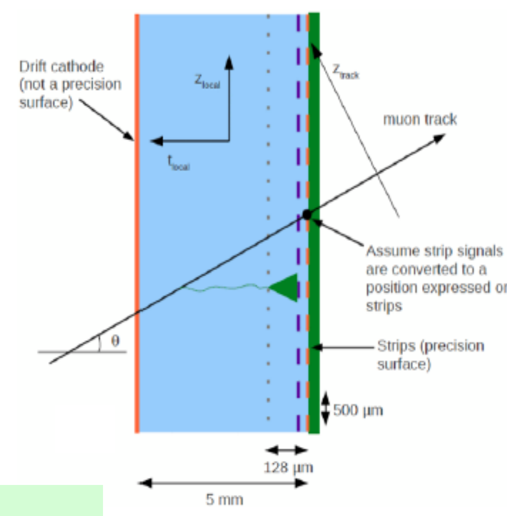
$$\sigma(x_1) = \frac{\sigma_{hit}}{\sqrt{N}} \oplus \sigma_{chamber} \oplus \sigma_{align}$$

- $\sigma_{chamber}$ = "granite table" accuracy
- Assume (blue line):
  - σ_{hit} = 100 μm; N = 16
  - σ_{align} = 50 μm

Up to which $\sigma_{chamber}$ can we tolerate ?

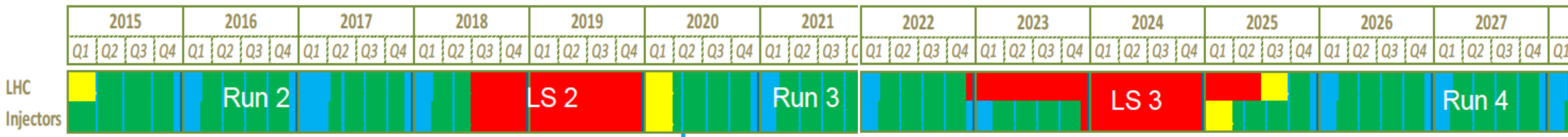
$\sigma_{chamber}$ **= 40 μm** is ok





Strip Position Accuracy:
In plane: σ(z) < 30 μm RMS ; MaxDev <100μm
Out-Plane: σ(t) < 80 μm RMS ; MaxDev <200μm

ATLAS UPGRADES



"Phase-0" upgrade: consolidation
$\sqrt{s}$ = 13~14 TeV, 25ns bunch spacing
$\mathcal{L}_{inst} \simeq 1 \times 10^{34}\ cm^{-2}s^{-1}$ ($\mu \simeq 27.5$)
$\int \mathcal{L}_{inst} \simeq 50\ fb^{-1}$

"Phase-I" upgrades:
ultimate luminosity
$\mathcal{L}_{inst} \simeq 2\text{-}3 \times 10^{34}\ cm^{-2}s^{-1}$ ($\mu \simeq 55\text{-}81$)
$\int \mathcal{L}_{inst} \gtrsim 350\ fb^{-1}$

"Phase-II" upgrades:
$\mathcal{L}_{inst} \simeq 5 \times 10^{34}\ cm^{-2}s^{-1}$ ($\mu \simeq 140$) w. leveling
$\simeq 6\text{-}7 \times 10^{34}\ cm^{-2}s^{-1}$ ($\mu \simeq 192$) no level.
$\int \mathcal{L}_{inst} \simeq 3000\ fb^{-1}$

ATLAS has devised a 3 stage upgrade program to optimize the physics reach at each Phase

- New Insertable pixel b-layer (IBL)
- New Al beam pipe
- New pixel services
- New evaporative cooling plant
- Consolidation of detector elements (e.g. calorimeter power supplies)
- Add specific neutron shielding
- Finish installation of EE muon chambers staged in 2003
- Upgrade magnet cryogenics

- New Small Wheel (nSW) for the forward muon Spectrometer
- High Precision Calorimeter Trigger at Level-1
- Fast TracKing (FTK) for the Level-2 trigger
- Topological Level-1 trigger processors
- New forward diffractive physics detectors (AFP)

- All new Tracking Detector
- Calorimeter electronics upgrades
- Upgrade part of the muon system
- Possible Level-1 track trigger
- Possible changes to the forward calorimeters

Cost of the Project

TDR
CERN-LHCC-2013-006

Item	CORE (kCHF)	Possible addition	Common item	2013	2014	CORE 2015	2016	2017	2018
sTGC detector	2,419			385	962	874	173	25	
MM detector	2,804			15	430	2,070	289		
Alignment system	610	132				59	474	77	
Mechanics, integration	150		1,558			60	60	30	
FE ASIC	1,049					682	367		
FE electronics	2,206				149	829	1,227		
DAQ(*), configuration	267						19	248	
DCS system	87				32		55		
HV, LV	1,600					500	500	600	
On-detector services	181					60	100	21	
Total	11,373	132	1,558	400	1,573	5,134	3,265	1,001	

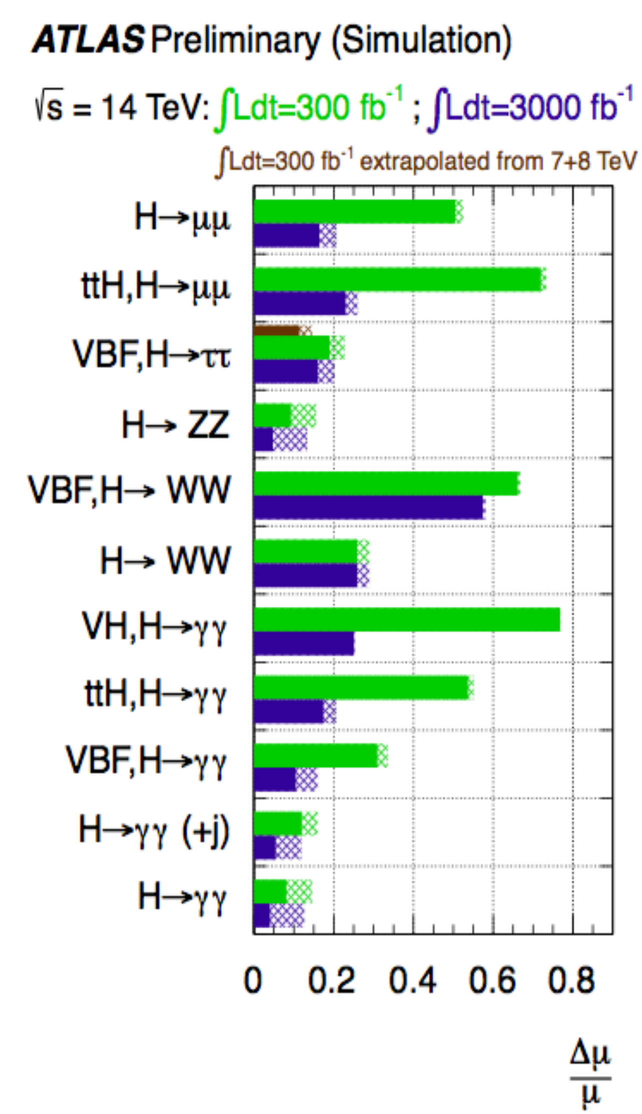
The cost of the project is planned to be covered by all institutions participating the NSW project

The commitments of each funding agencies will be formulated in the MoU of NSW construction (currently being finalized)

-
  - Branching ratios (molti canali di decadimento possibili…) in particolare per il settore fermionico (e quindi per i fermioni piu' pesanti accessibili: τ e b)
  - Higgs self-coupling (e.g. HH→bbγγ)
  - ttH; H→μμ per misure di coupling a t e μ

- Inoltre potremmo estendere ricerche BSM (in particolare SUSY) grazie ai ~3000 fb^{-1} previsti, raddoppiando i limiti di massa attuali

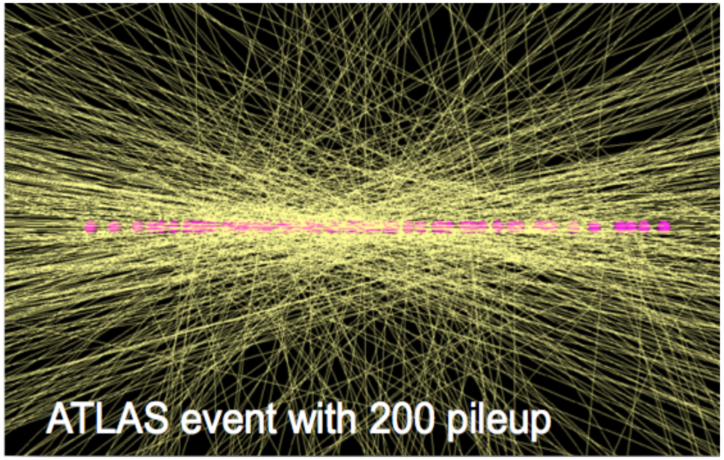
- Per poter far questo (in particolare per m_{Higgs} = 125 GeV) bisogna mantenere (o migliorare) le performance di ATLAS per tutte le osservabili importanti (p, E, $E_{T\text{-}miss}$, identificazioni e vertexing) e per le soglie di triger nelle condizioni di maggior luminosita' e pile-up



F.Petrucci – ATLAS MicroMegas – 5 June 2014

MOTIVAZIONI PRINCIPALI PER GLI UPGRADE DEI RIVELATORI

- Gli upgrade dei rivelatori sono motivati dal mantenimento e/o miglioramento delle performance con l'aumento della luminosita' istantanea:
  da 1×10^{34} a $> 5 \times 10^{34}$ $cm^{-2}s^{-1}$
- Il numero elevato di interazioni per bunch-crossing, pile-up fino a $<\mu> \sim 200$ rappresenta la sfida principale per la ridefinizione del trigger (hardware – Level1 – e software – High Level Trigger) ai fini di mantenere la sensitivita' ai pochi eventi interessanti



- L'alto pile-up puo' saturare read-out links (alta occupancy)
- Alcuni rivelatori (specialmente quelli vicino alla beam-pipe) sono danneggiati dall'accumulo di dosi elevate. Fluence fino a 10^{16} n_{eq}/cm^2

GLI UPGRADE DI FASE 0 (2013-2014)

2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	...	2030
				LS1					LS2				LS3			

"Phase-0" upgrade: consolidation
$\sqrt{s}$ = 13~14 TeV, 25ns bunch spacing
$\mathcal{L}_{inst} \approx 1 \times 10^{34}$ cm^{-2}s^{-1} ($\mu \approx 27.5$)
$\int \mathcal{L}_{inst} \simeq 50$ fb^{-1}

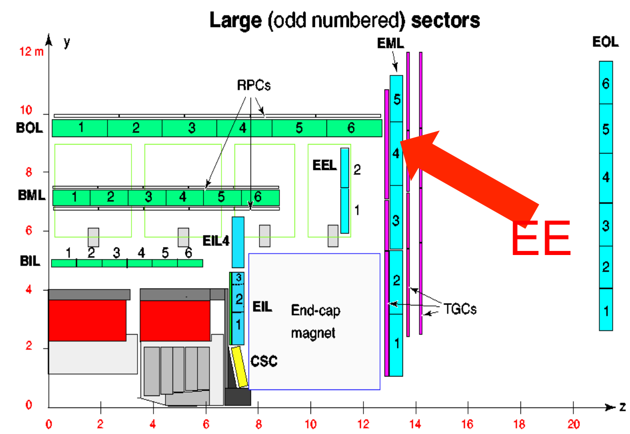
- New Insertable pixel b-layer (IBL)
- New Al beam pipe
- New pixel services
- New evaporative cooling plant
- Consolidation of detector elements (e.g. calorimeter power supplies)
- Add specific neutron shielding
- Finish installation of EE muon chambers staged in 2003
- Upgrade magnet cryogenics

UPGRADE di Fase 0

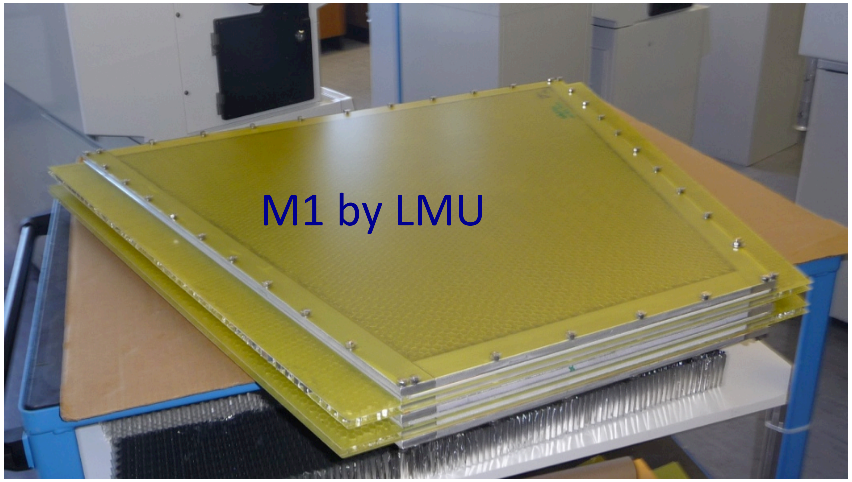
- Oltre alle attivita' di "consolidamento" del rivelatore, due "upgrade" principali:

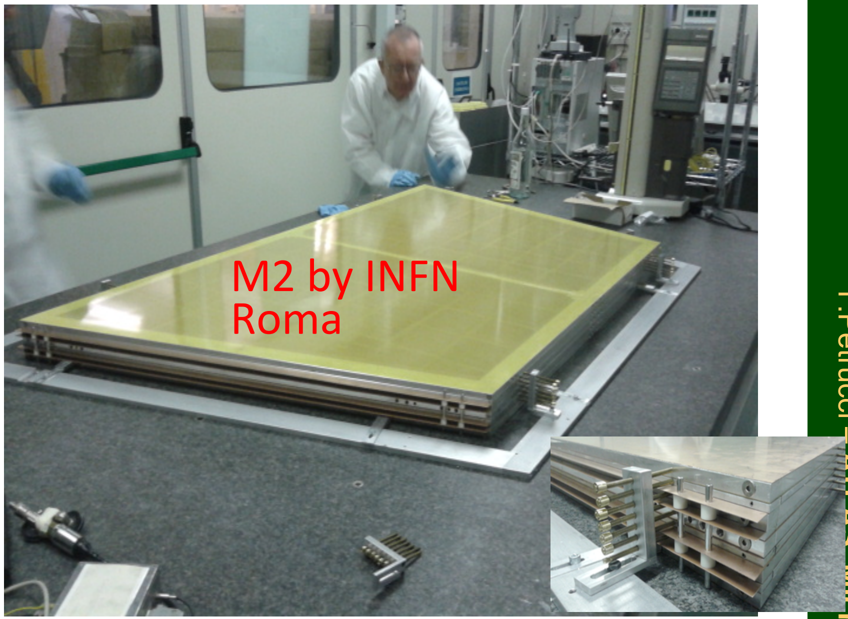
  → PIXEL: Insertable B-Layer (prossima slide)

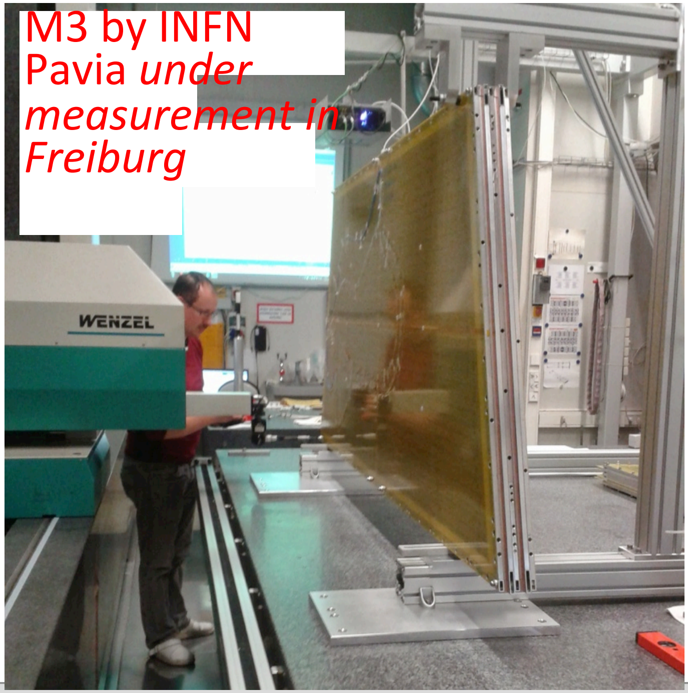
  → Completamento Installazione delle camere MDT EE (Endcap-Extension) nella regione $1.0<\eta<1.3$

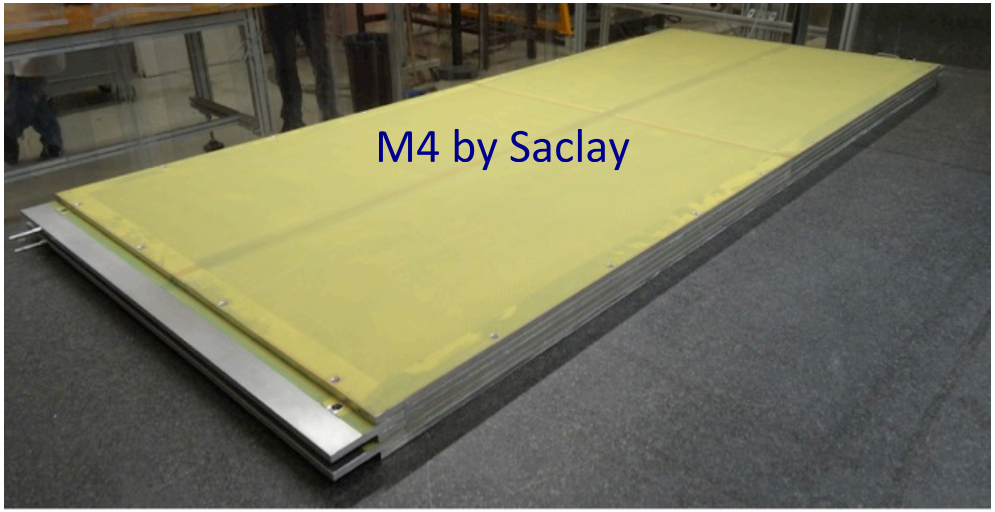


MECHANICAL PROTOTYPES – READY FOR MEASUREMENTS IN FREIBURG


M1 by LMU

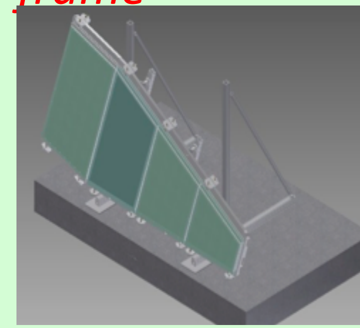

M2 by INFN Roma


M3 by INFN Pavia *under measurement in Freiburg*


M4 by Saclay

Mechanical Measurements in Freiburg

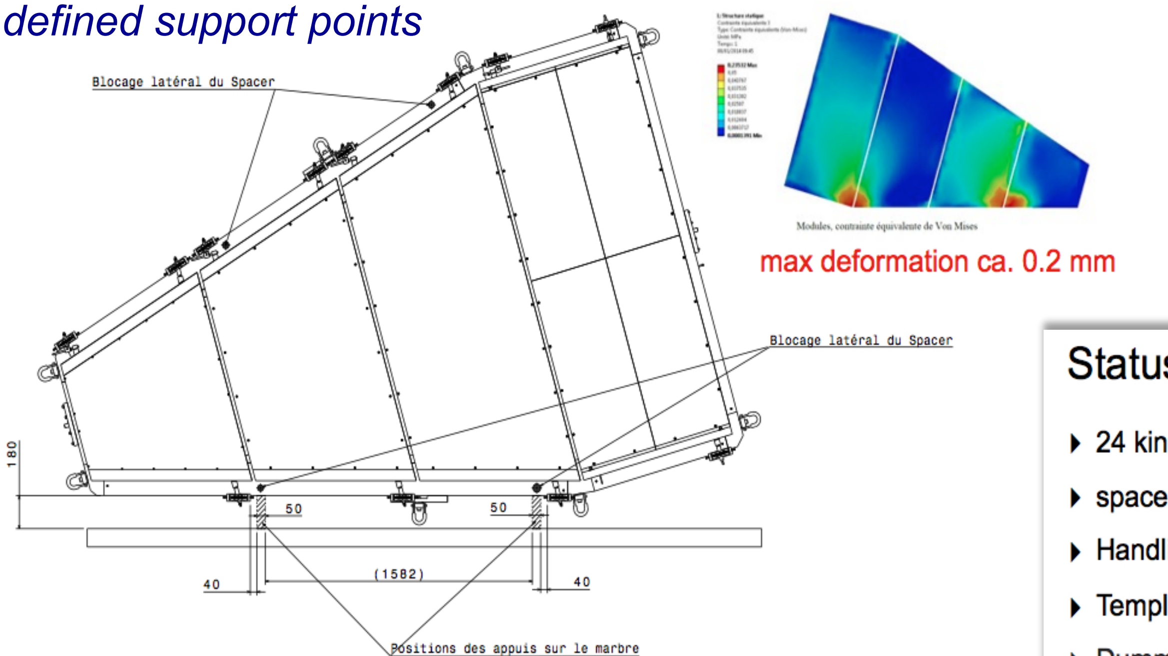
Mechanical prototypes are currently being assembled on a spacer frame and measured with the Freiburg CMM machine



Main purpose of the measurements

- Individual module measurements in vertical position
- Assembly/Fixation on spacer and deformation studies
- Induce thermal gradients and studty thermo–mechanical deformations

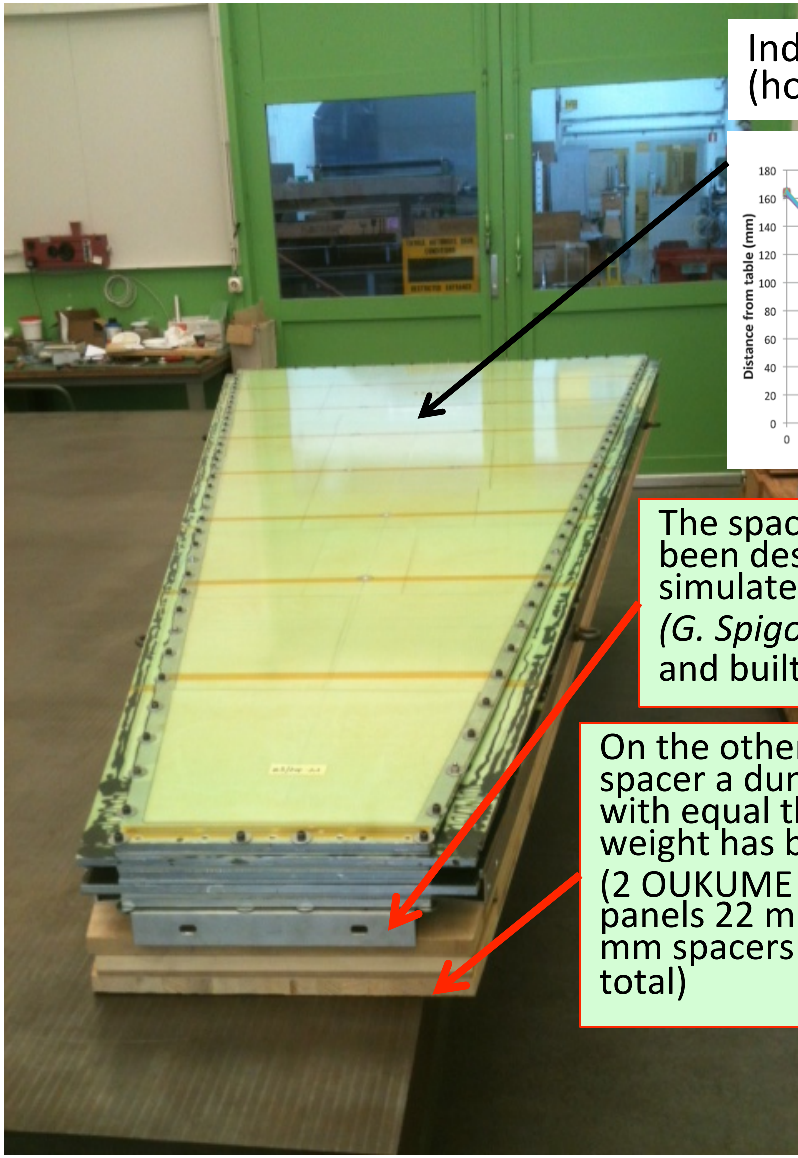
defined support points



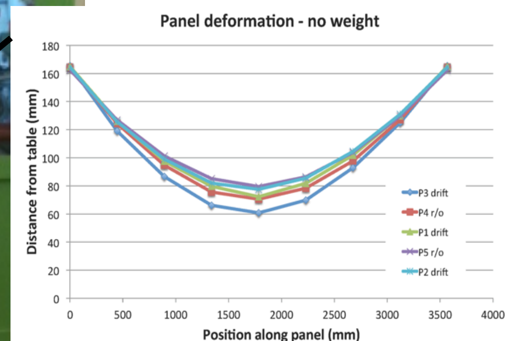
Status of preparations in Freiburg:

- 24 kinematical mounts (with ca. 10 parts each) ✔
- spacer frame , ready and glued ✔
- Handling tool: designed; ready ✔
- Templates for spacer and dummy modules glueing: ready ✔
- Dummy modules: designed, parts in workshop,

FULL WEDGE MECHANICAL PROTOTYPES BY CERN



Individual Panels sagitta (horizontal position)

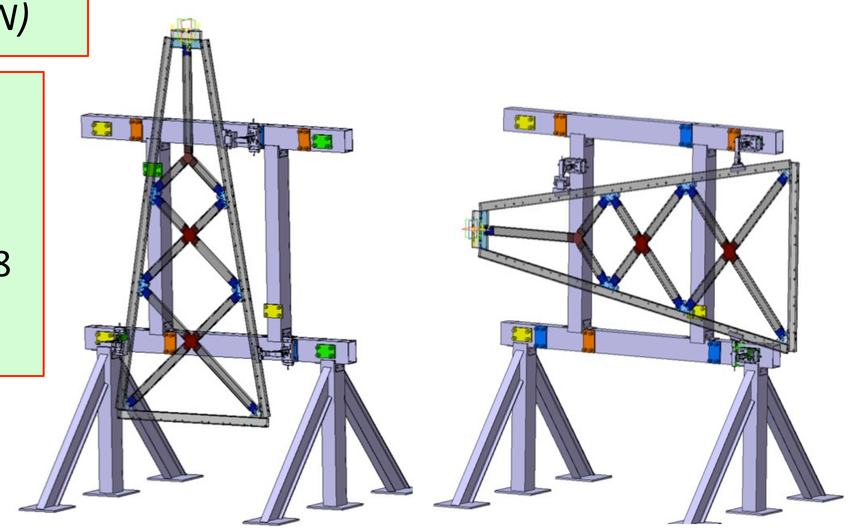


Support structure designed and under realization for vertical mounting

- Mechanical deformation at different angles (simulating different sector orientation)
- Deformation under thermal gradient

The spacer frame has been designed and simulated *(G. Spigo & M. Ciapetti)* and built *(Naples, CERN)*

On the other side of the spacer a dummy wedge with equal thickness and weight has been added (2 OUKUME block board panels 22 mm thick and 28 mm spacers – 80 mm in total)



Mechanical Prototypes – Some Examples

M2 INFN trapezoidal shape 1628x916mm^2 – "Vacuum bag technique"

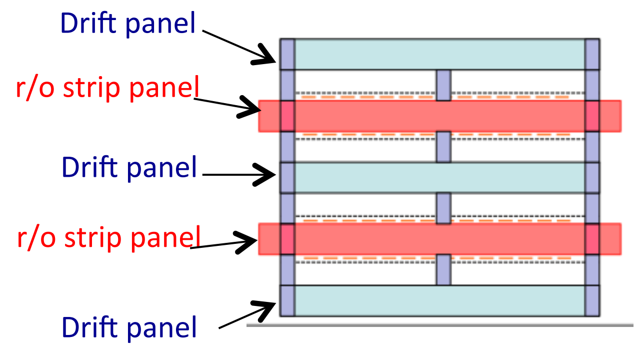
- All 5 panels built
- Quadruplet is completed

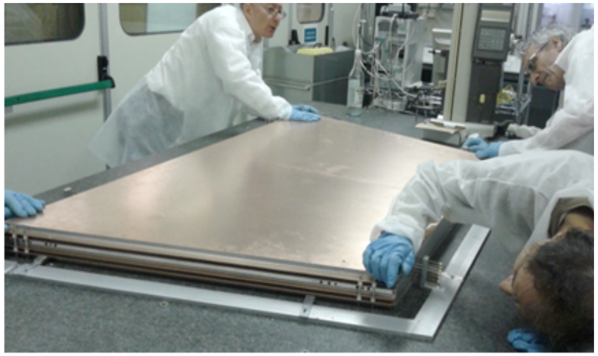
PANELS PLANARITY : Average σ_{fit} ~ 30 μm

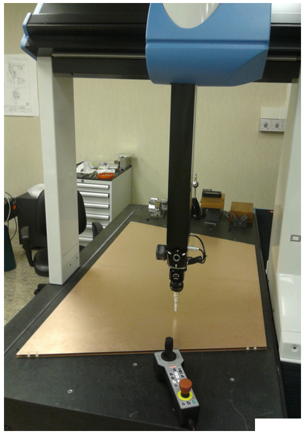
PANELS THICKNESS: average -15 μm; RMS 17 μm

Measurements compared with two different techniques

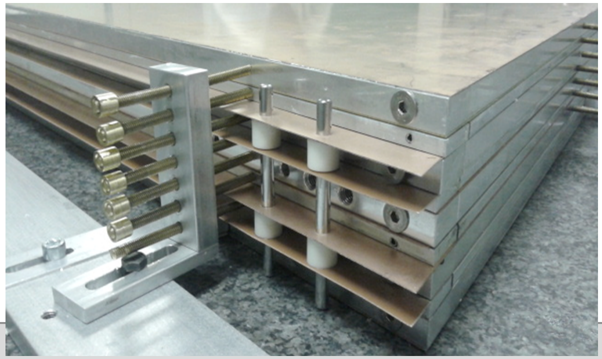
Measurements on QUADRUPLETS will follow

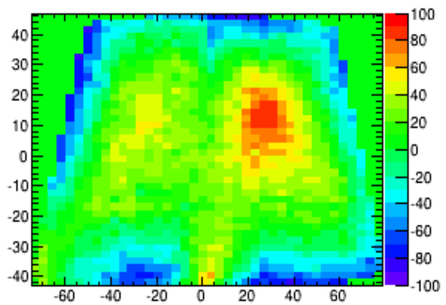


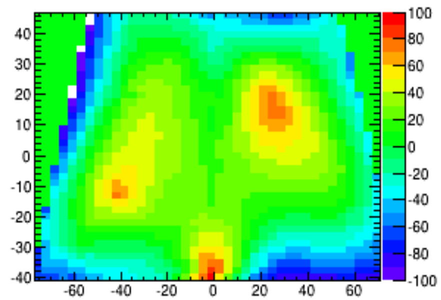




Compare results obtained with a Coordinate Measuring Machine (CMM) and with a Laser Tracker: Consistent !







MicroMegas Chamber Construction

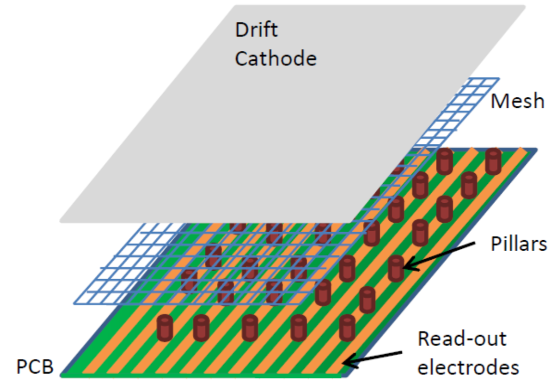
Read-out Boards

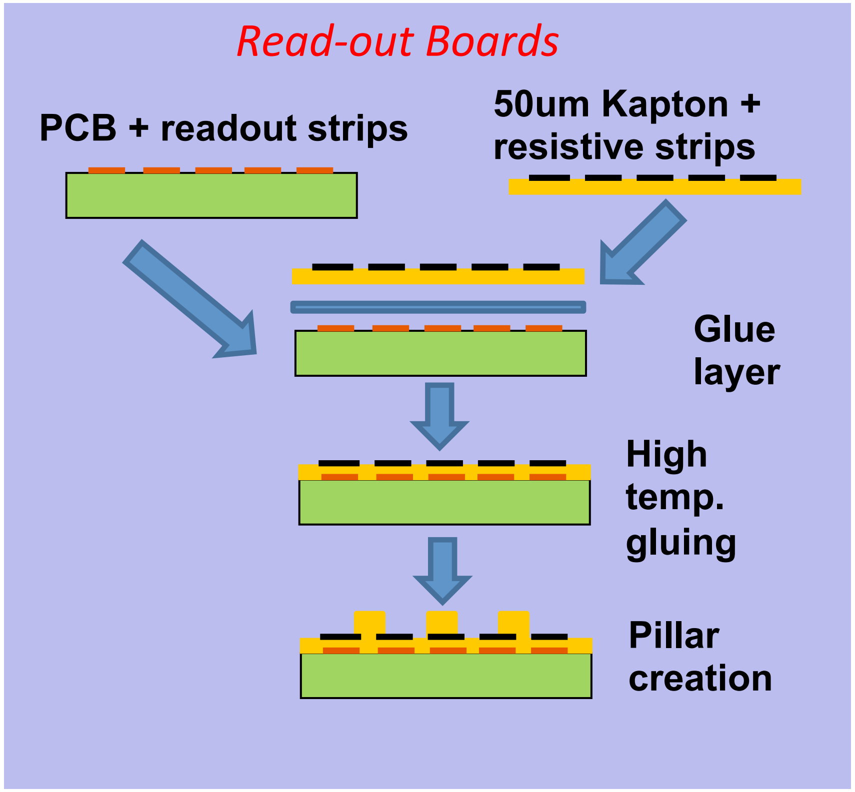
Currently finalizing requirements – Evaluating companies (ELTOS, ELVIA, Triangle Lab)

– Procurement and QA/QC by CERN

Resistive foils:

- 2 options: sputtering or screen printing
- Promising results from Japan (sputtering)

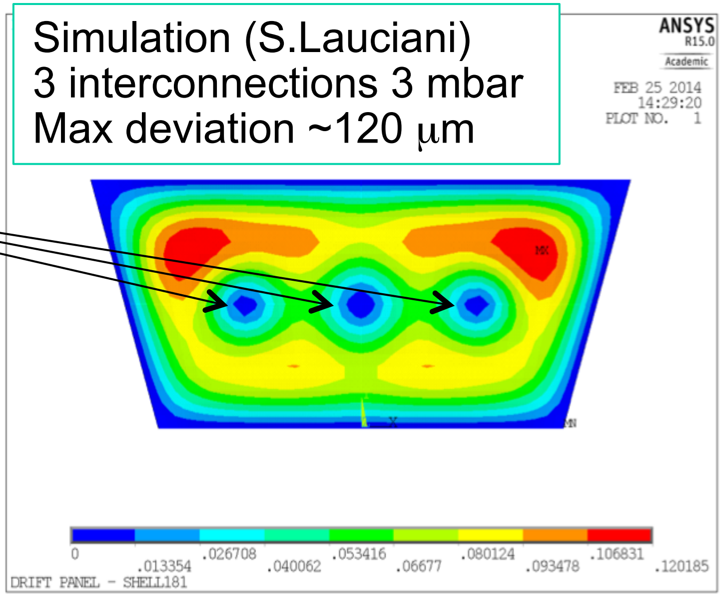


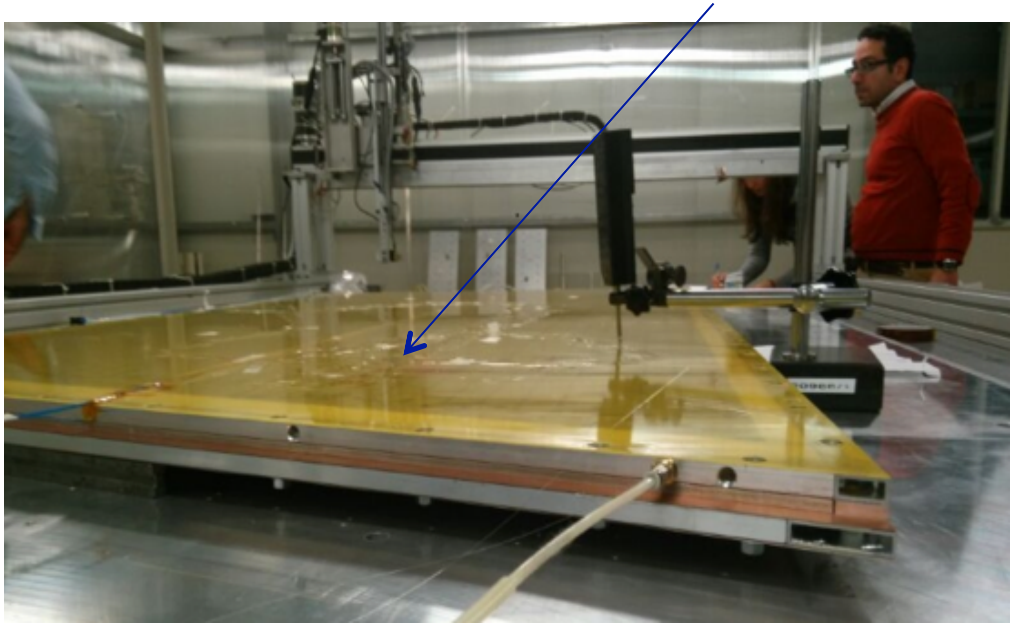


Gas overpressure induced deformations

- The effect of Gas over pressure has been tested using a Single Gap with Mesh.
- Deformation mitigation with INTERCONNECTION SCREWS (3 screws used)
- Mechanical deformations due to Gas over pressure (3 mbar) have been studied using, Laser and Optical Fibers (Fiber Bragg Grating)

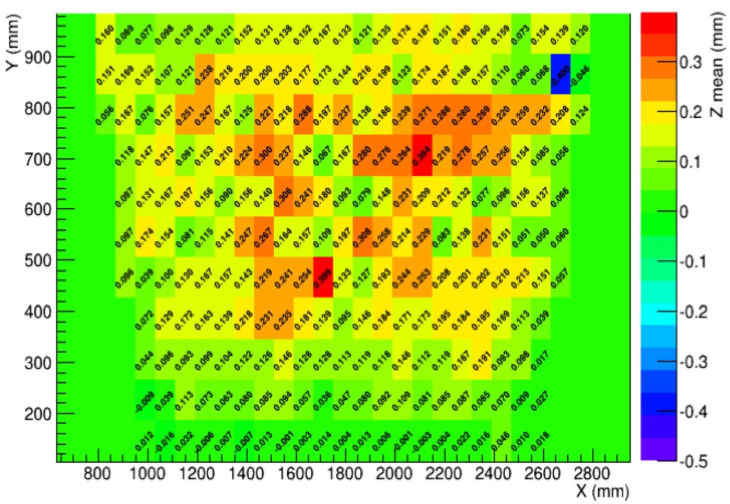
Simulation (S.Lauciani)
3 interconnections 3 mbar
Max deviation ~120 μm





Observed deformations due to Gas over pressure *AverageDeformation = 140 μm ; MaxDef <300 μm*

Deformation map (3mbar – 0 mbar)



ELECTRONICS

Challenge:

- Find track segments within 1000ns, incl 500ns fiber propagation time, to confirm segments found in downstream "Big Wheels".
- Micromegas: 2M 0.5mm strips
- sTGC: 300K chan: strips (3.2mm), wires, pads

Micromegas – sTGC commonalities

- Same FE ASIC, on-chamber and off-chamber readout
- Separate segment formation for trigger, but same final FPGA-based trigger processor (one ATCA crate per Endcap)
  - sTGC uses pads to select strips to read out for centroid finder
  - MM uses first strip hit in group of 64 to give track position

ELECTRONICS

VMM ASICS

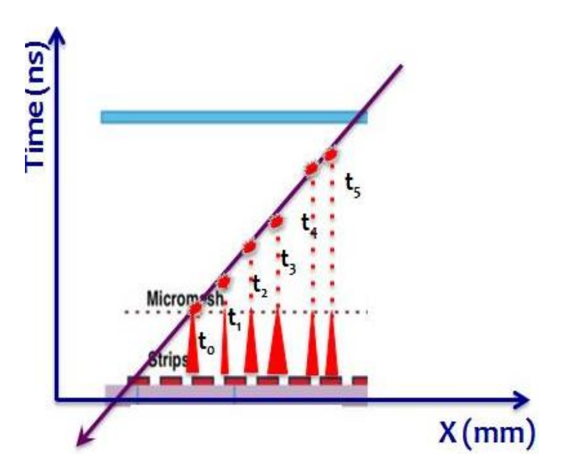
- Highly programmable ASIC provides both precision measurement and trigger primitives for both Detectors
- First version, fully functional, 64-channel analog front ends successfully fabricated in 2012
- Second version including ADC, simultaneous read/write was submitted in a custom MOSIS run last week
- About 450 samples expected in 10-12 weeks
- Nearly final version, missing SEU mitigation of config. register and ATLAS specific readout handshake

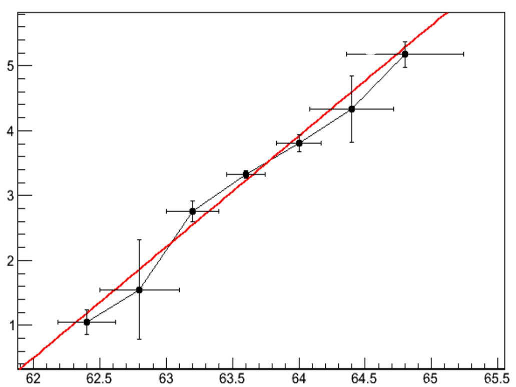
Companion ASICs for TTC distrib, clk gen, pgmable delays, etc.

- sTGC trigger data serializer for pads and strips
- MM address of 1st hit encoder for trigger
- Readout: VMM to E-link inputs to GBT

ANALYSIS DEVELOPMENTS – AN EXAMPLE: THE μTPC METHOD

Exploit time information for μTPC reconstruction

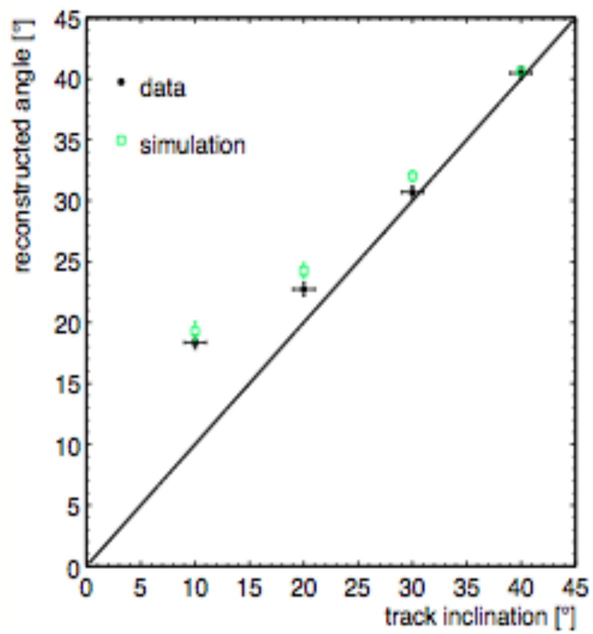




The observed bias in the reconstructed track angle, stronger for smaller chamber plane inclination is due to:

- tracklet edge effects (first/last strip and finite strip pitch
- induced charge from the neighbouring strips.

This has been studied with a circuit simulation and results are in good agreement with data (good understanding of the effect)



Ongoing studies:

- Characterization of hits affected by induced charge
- Re-weight affected hit and/or shift position

Preliminary studies are promising → can improve μTPC resolution at small angles