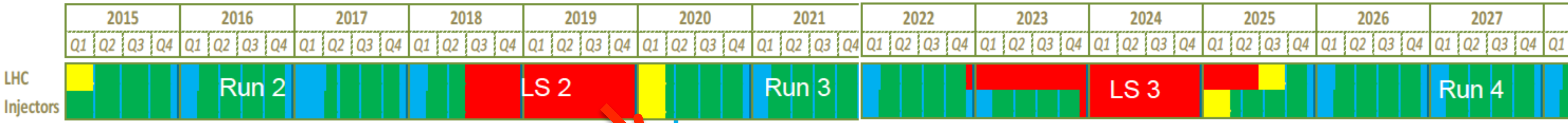
13th RD51 Collaboration Meeting

CERN February 6th 2014

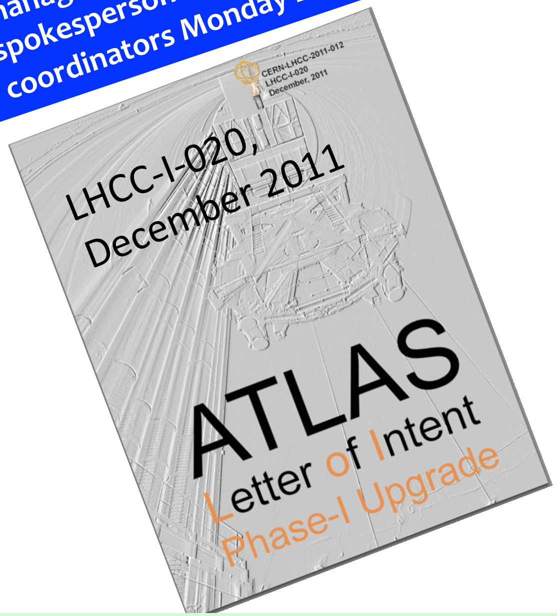
Technical and Political Status for the ATLAS' NSW project

Mauro Iodice – INFN Sezione di Roma Tre

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

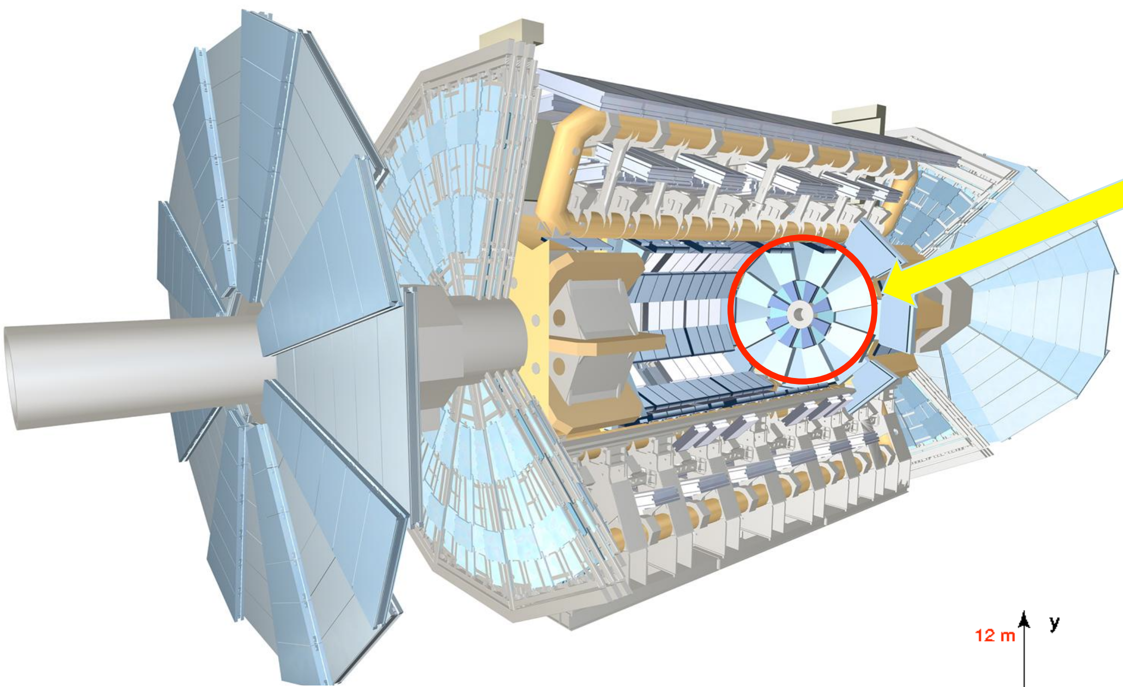
"Phase-I" upgrades:
ultimate luminosity
$\mathcal{L}_{inst} \approx 2\text{-}3 \times 10^{34}\ cm^{-2}s^{-1}$ ($\mu \approx 55\text{-}81$)
$\int \mathcal{L}_{inst} \gtrsim 350\ fb^{-1}$ **FASE-1**

- 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 $5\text{-}7\ 10^{34}\ cm^{-2}s^{-1}$
- 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 ~1Coulomb/cm^2
- Total Ionizing Dose (TID) in 10 years at large η: about 0.5 Mrad

THE ATLAS MUON SPECTROMETER – PRESENT LAYOUT

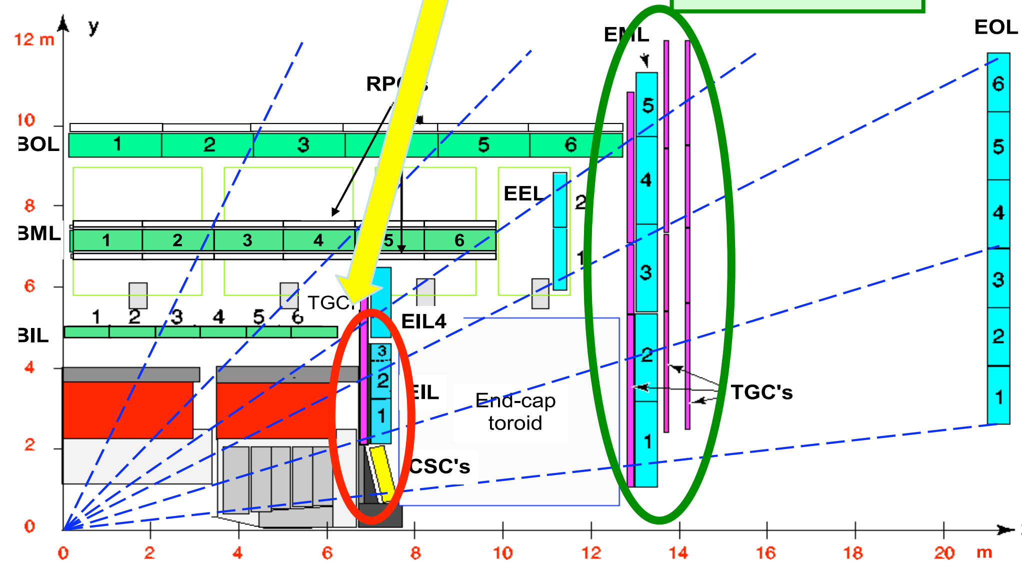


The small wheels

Pseudorapidity coverage:
$1.3 < |\eta| < 2.7$

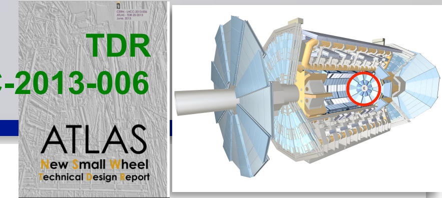
BigWheel L1 trigger chambers

- The Small Wheel Region (Innermost Endcap Muon Station) is the region with highest background rates in the present ATLAS Muon Spectrometer
- Present system is based on Cathode Strip Chambers (CSCs) and Monitored Drift Tubes (MDTs) for particle tracking
- Located between endcap calo and toroid



New Small Wheel - Overview

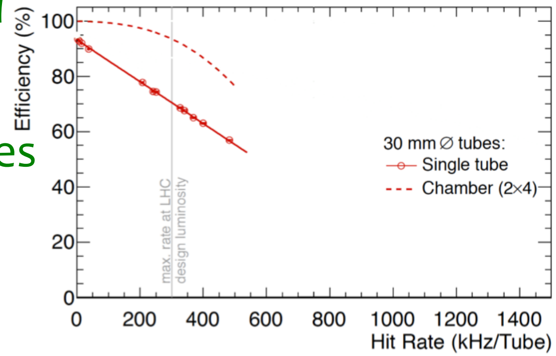
TDR
CERN-LHCC-2013-006



Two main motivations for the NSW

1) *Cavern Background*

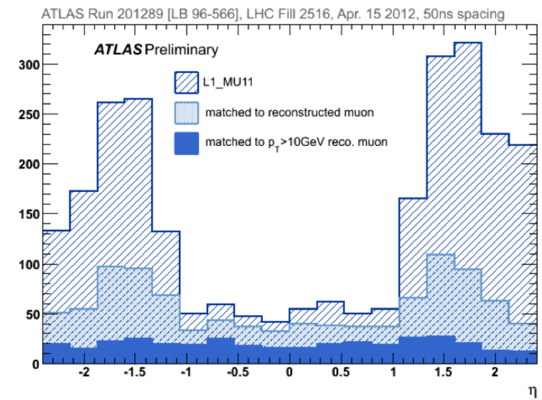
The MDT efficiency drops for tube-hit rates > 300 kHz/tube (tube hit and segment tracking inefficiency)



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

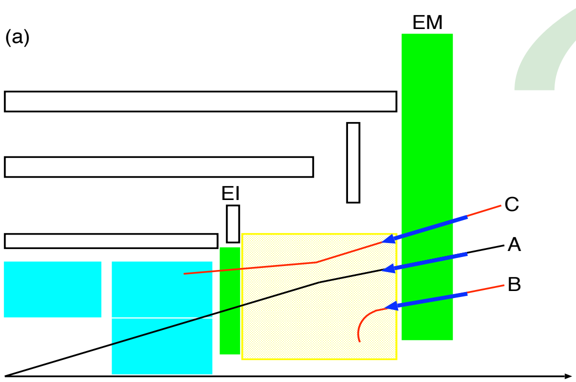
2) *TRIGGER*

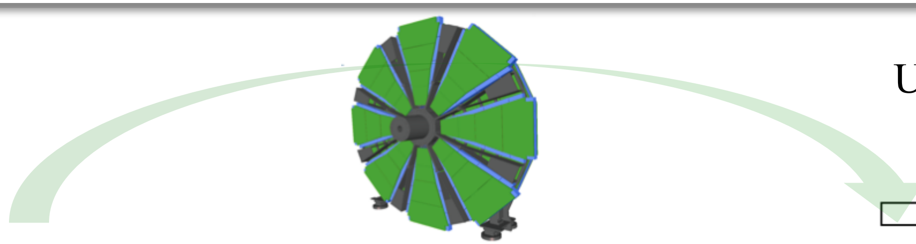
L1 muon trigger rate in the end-cap (based on Big Wheel) dominated by fake triggers.



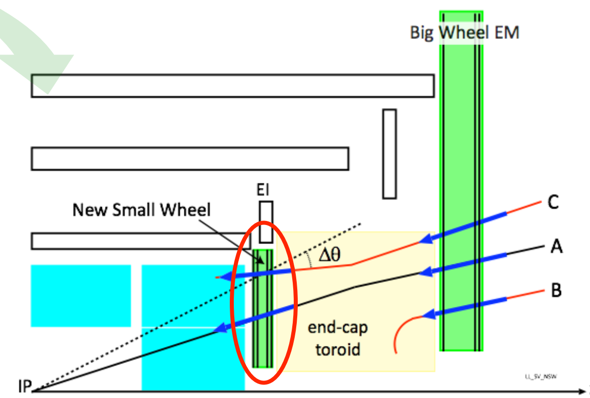
At 3·10^{34} cm^{-2}s^{-1} rate L1MU20 (p_T>20 GeV) ~60 kHz exceed the available bandwidth for L1Mu (~15kHz)

Present Level1 muon trigger





Upgrade L1 with NSW



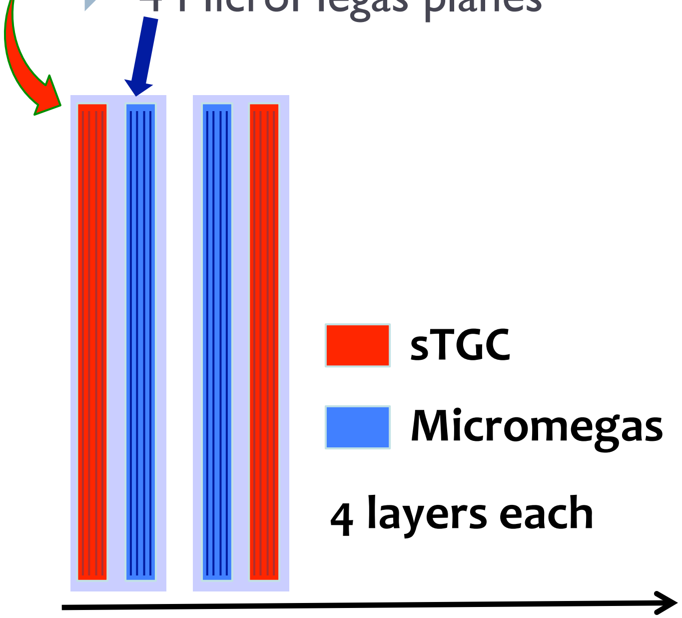
"New Small Wheels"

Reduce fake muon triggers requiring:

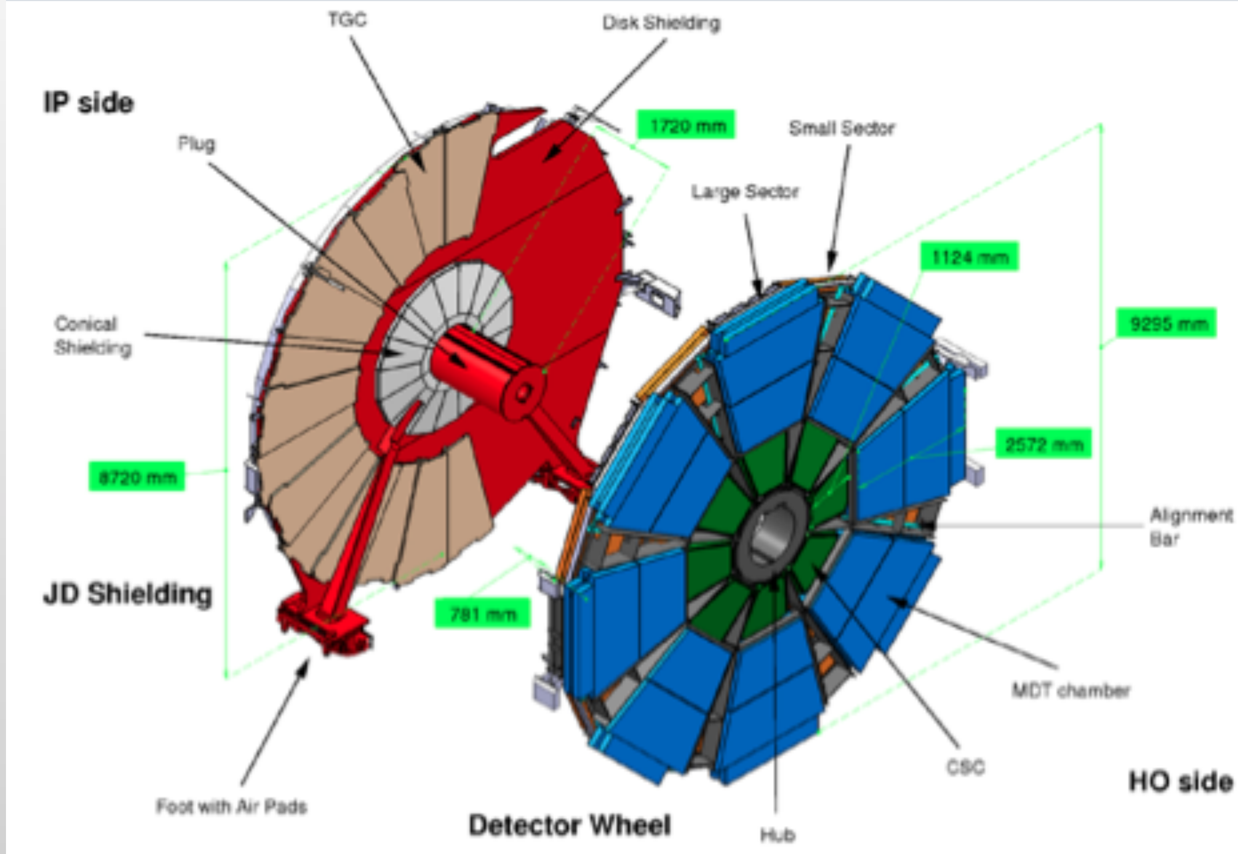
- Segments with High preciosn IP pointing (σ_θ~ 1mrad)
- Matching BigWheel segments

New Small Wheel – Layout

- 16 Sectors per wheel
  - 8 large
  - 8 small
- 2 multilayers per sector
- Each multilayer:
  - 4 sTGC planes
  - 4 MicroMegas planes



Present Small Wheel –
defines basic layout and envelopes



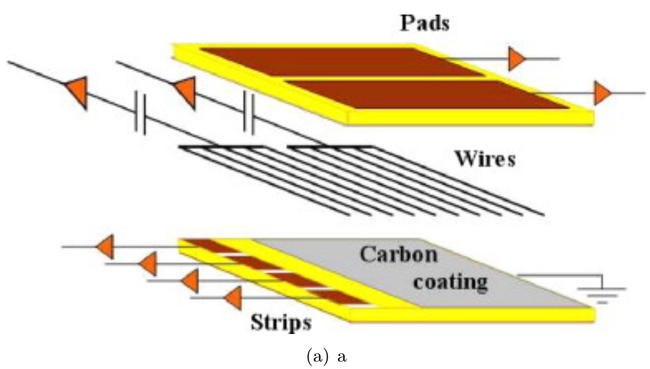
- *16 detector layers per wheel*
- *2 detector technologies: MicroMegas and sTGC*

THE DETECTORS

Combination of **sTGC** and **MicroMegas (MM)** multiplets: 4+4+4+4 detector planes

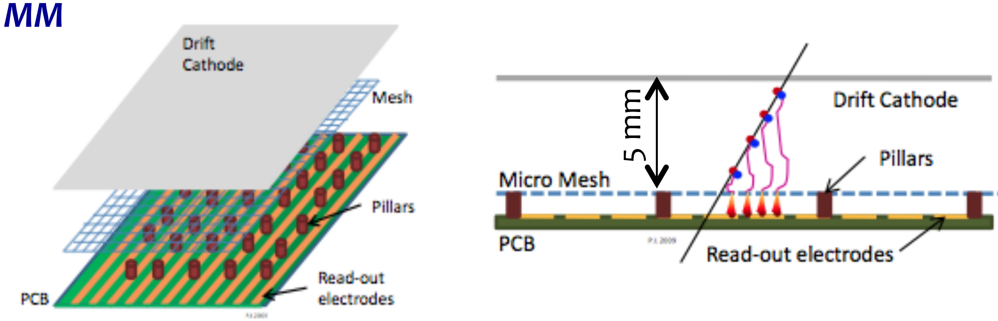
sTGC *(small strip TGC) primary trigger detector*
- Bunch iD with good timing resolution
- Good online space resolution for NSW track vector with <1 mrad angle resolution

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



sTGC
(strip pitch 3.2 mm)

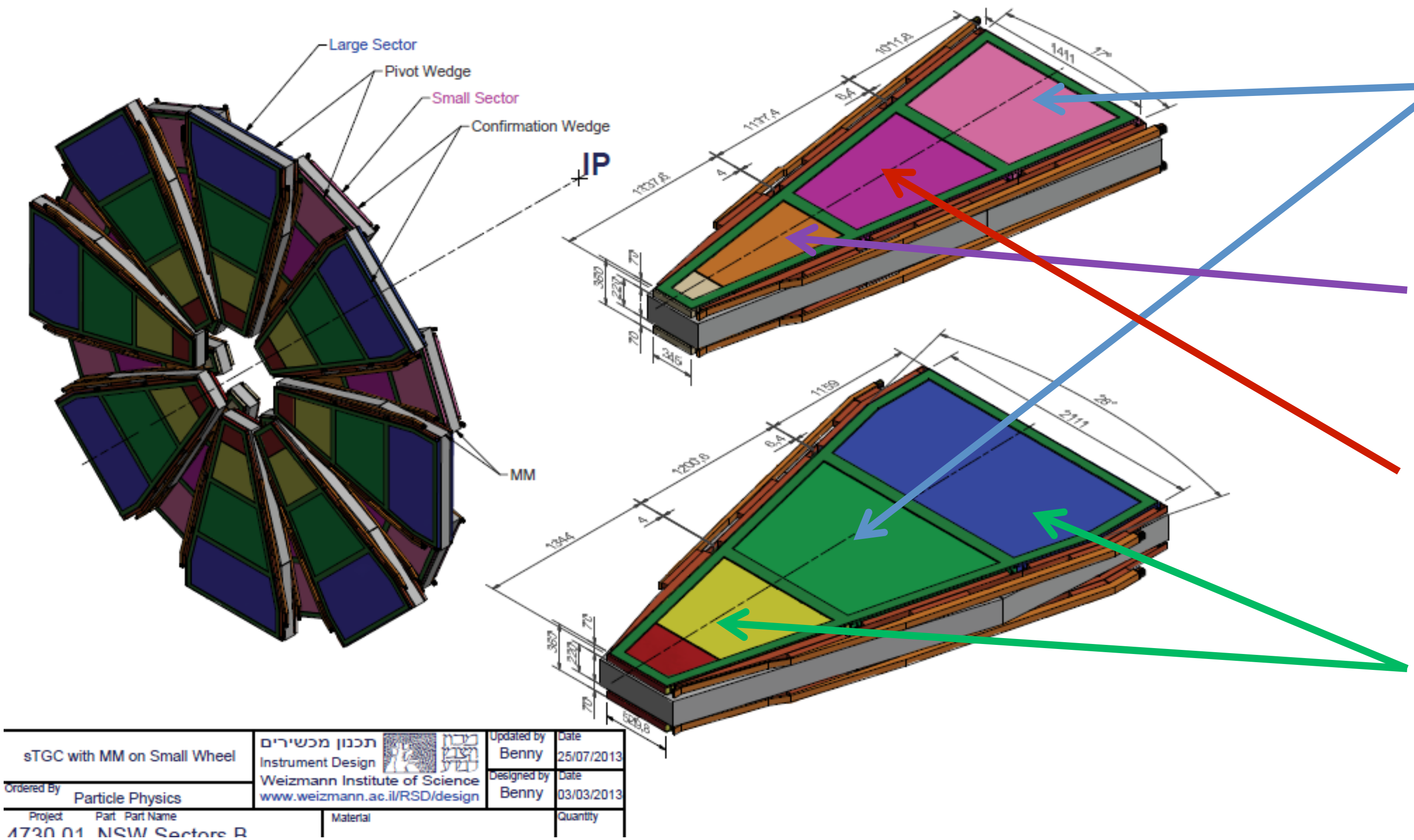
MM



- Common front-end ASIC: VMM under development at BNL. First prototype tested on detector at beam test in 2012; new version submitted for production in January 2014
- Work together to make a robust detector for the high rate region of very limited access
- **The NSW will operate from 2017 until 2032 → ROBUSTNESS and REDUNDANCY**

sTGC chamber – Planned sharing of constructions

There will be 6 different type of sTGC modules (quadruplets), produced in 4 major and 1 auxiliary production sites: Israel, Canada, Chile, China (Shandong) + St. Petersburg.
Note: IL and CN produced TGC for the current muon spectrometer.

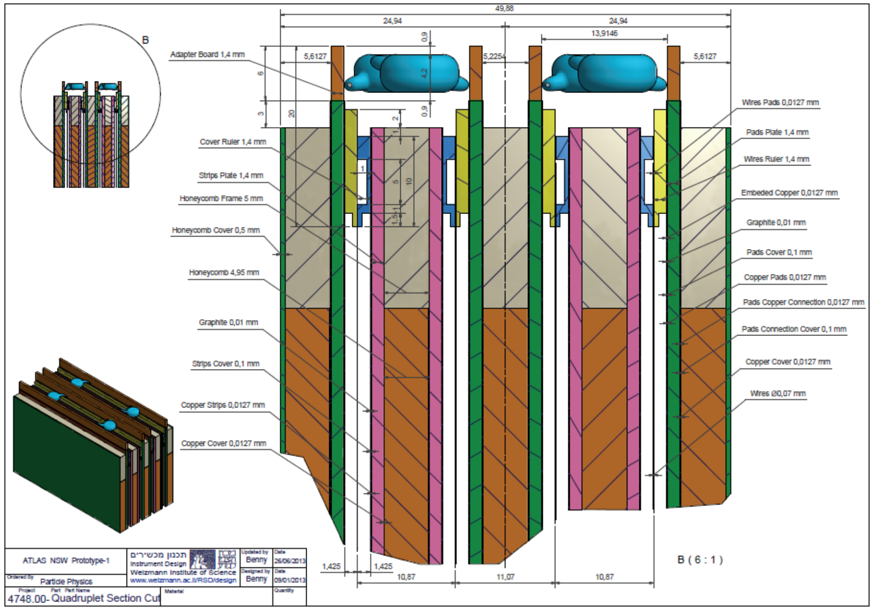


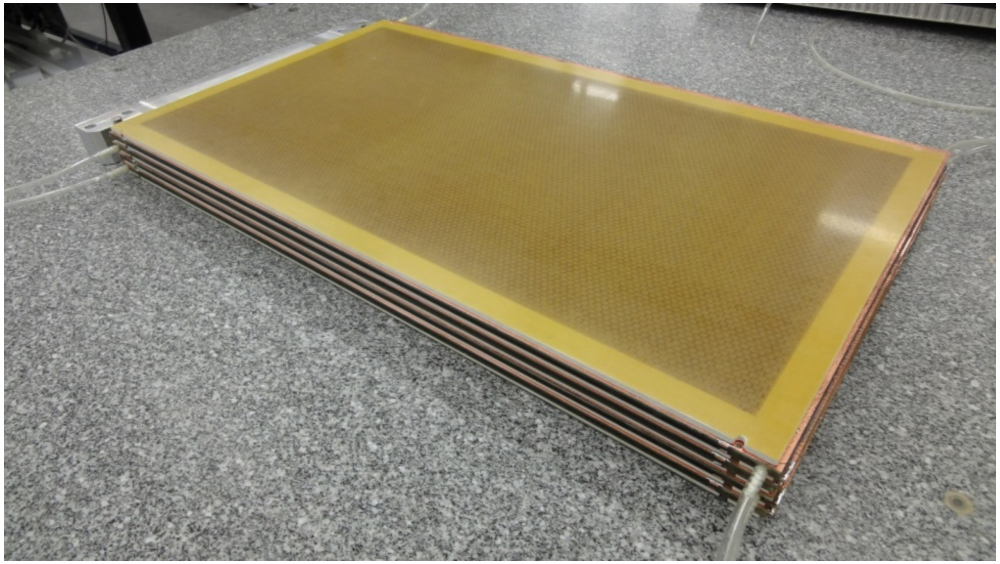
- Canada
  64 quadruplets +
  6 spares
- Chile
  32 quadruplets +
  3 spares
- China
  32 quadruplets +
  3 spares
- Israel
  64 quadruplets +
  6 spares

sTGC CHAMBER CONSTRUCTIONS

Israel

- New 60x40cm^2 module produced using quasi final tooling, results meet specs for flatness and uniformity: Flatness to within 50μm and uniformity of thickness around the edges with σ=48μm with largest deviation ~100μm.
- 2nd module being built to complete qualification of procedure and involved company





- Currently on-going activity: Preparations for Module-1. Quotes asked from 2 companies for production of the cathode plane

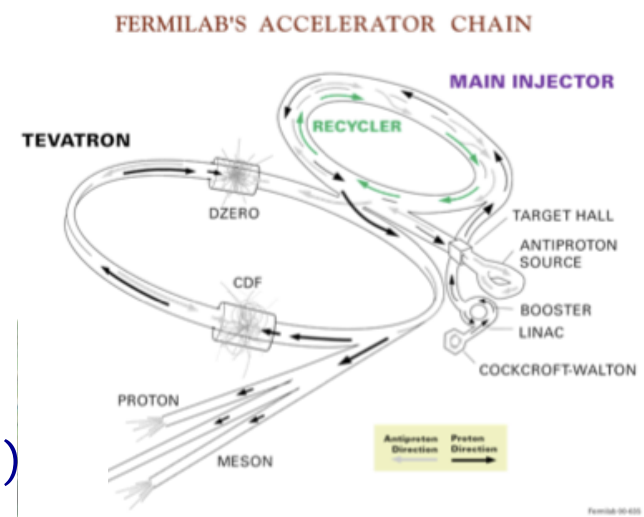
sTGC short term plans towards Module 0

sTGC Production Milestones

- Production of sTGC Module -1 (Weizmann - April 2014) for test-beam at FermiLab
- Construct 3 quadruplets 40x60 cm^2 by the Canadian groups, using the existing tooling at Weizmann, so it can be used in the Fermilab test beam
- Expect to have the first series of Module-0 (not all) towards the end of 2014 to test at GIF++

sTGC Test Beam Plans and Goals

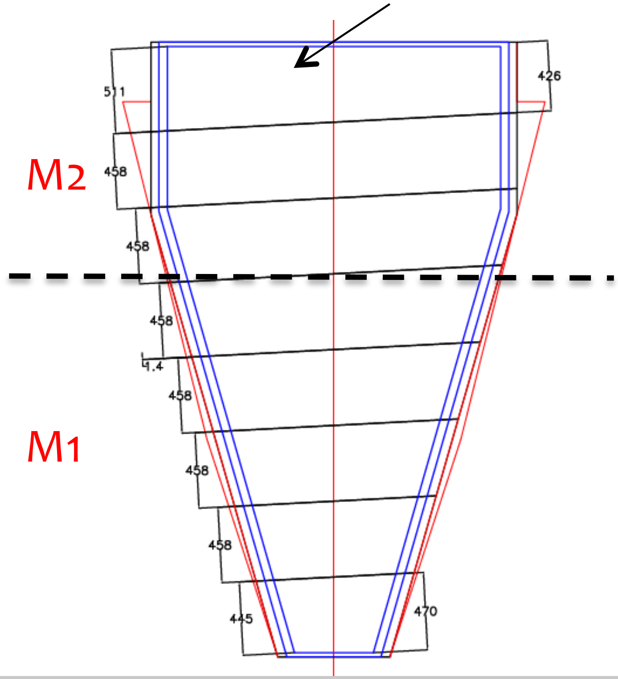
- **sTGC test beam scheduled in May at the Fermilab Test Beam Facility**
- Uniformity of large scale sTGC detectors and resolution
- Use external pixel telescope to determine resolution and make absolute position measurements.
- Fully test VMM1 capabilities (VMM2 not available until later 2014)
- Timing performance (also vs beam angle)
- Opportunity for broader sTGC community to collaborate in a common test beam.
- Depending on the results at the Fermilab test, **get the green light to start with Module-0 construction** of the various sites

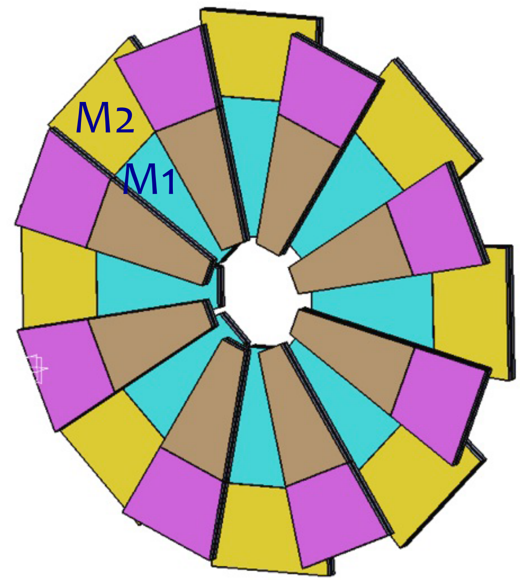


Beam is extracted from Main Injector (120 GeV protons) with spills over 4.2s

MICROMEGAS CHAMBER CONSTRUCTION

- In July 2013 (MM Mechanical Meeting in Rome) the module segmentation scheme has been decided : 2 (small sector) + 2 (large sector) module types
  – criteria: dead areas, alignment, support, services and production facilities
- Modules of 4 different types composed by 3 (M1) and 5(M2) pcb strip planes
  -- each module composed by 4 planes:
  - 2 planes with "eta" strips (precision coordinate ~ 100μm resolution)
  - 2 planes with stereo strips (+/- 1.5°) (second coordinate ~2mm resolution)

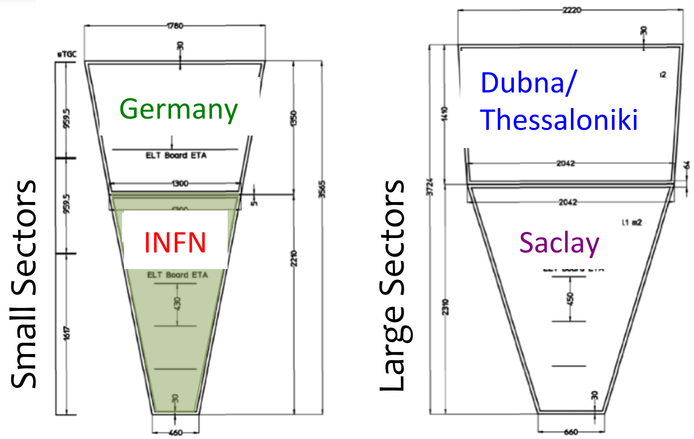




MicroMegas Chamber Construction

As for the sTGC case, Micromega **module production** will be done in several production sites according to type:

- SM1: Italy, INFN consortium
  Pavia, Rome1, Rome3, Frascati, Lecce, Cosenza, Napoli
- SM2: Germany (Wurzburg, LMU Munich, Freiburg, Mainz)
- LM1: Saclay
- LM2: Thessaloniki (drift panels, assembly) +
  Dubna (readout panels, assembly)

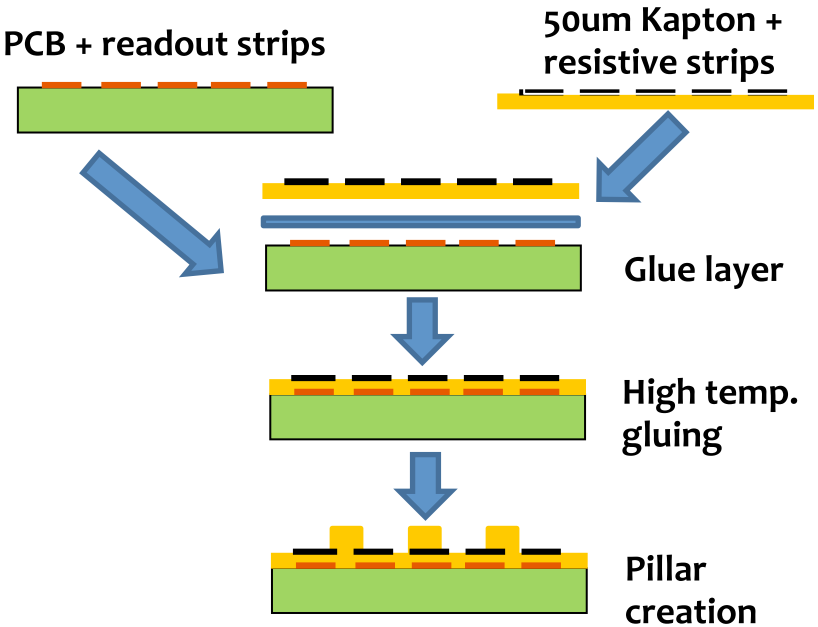


Readout PCB production in industry:

- Evaluating several companies
  - 2m x 0.5m boards have been already produced
  - Quote requested for 1200 m2 large quantity
- Defining QA/QC procedures and development of methods has started, QA/QC to be done at the company

Resisitive Foil:

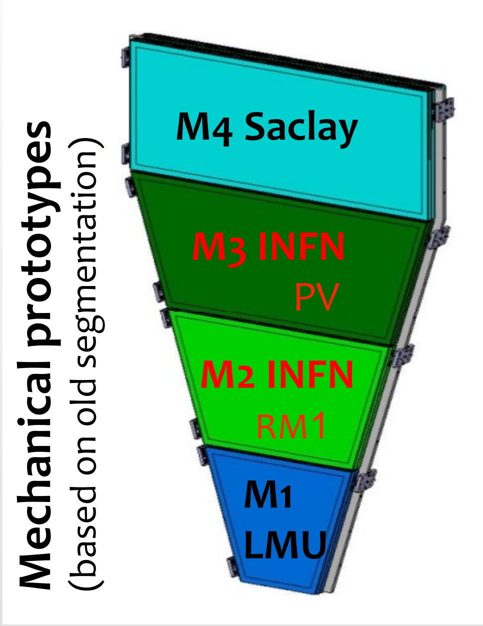
- 2 options: sputtering or screen printing
- Promising results from Japan (sputtering)



Mechanical prototypes

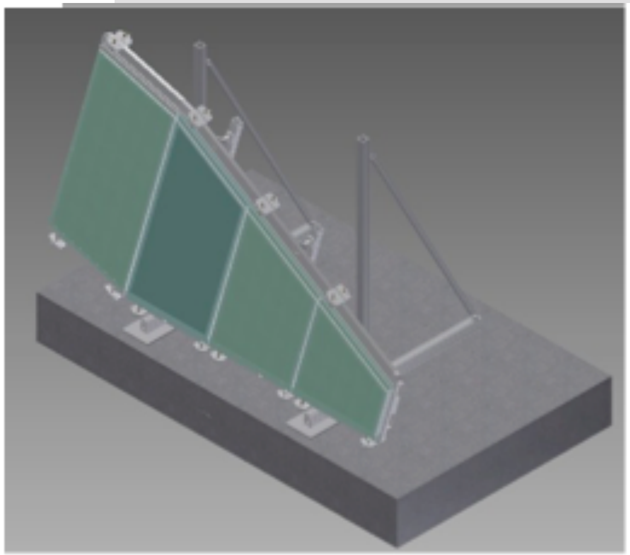
Recent activity

- Construction of Mechanical Prototypes in **4 modules** (according to old segmentation: INFN PV, INFN RM, Saclay, LMU-Germany
- Construction of **single wedge full size** mech. protot.: CERN
  - Demonstrate feasibility: Strip pos. in plane ≈ 50 μm, Parallelism ≤100 μm
  - Test of different gluing procedures with the aim to define a common procedure
  - Test of different material, e.g. type of glue
  - Setup of basic infrastructures
  - Gain experience



Short term plans

- Assembly prototypes into 2 dummy sectors, with dummy counter weights as 2nd wedge, **to study mechanical deformation and stress**
- Crucial input to settle In-plane alignment needs
- Assess and define method to attach modules to sector structure – glueing, kinematic mounting, ...



MECHANICAL PROTOTYPES – SOME EXAMPLES

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

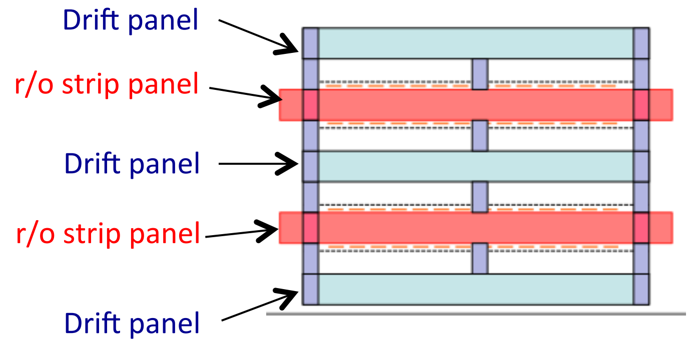
- All 5 panels built
- Quadruplet is completed

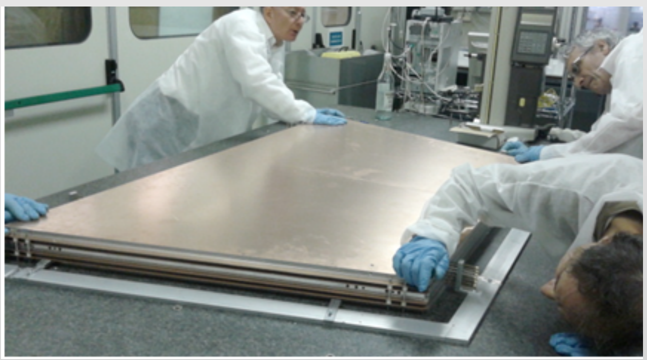
PANELS PLANARITY : Average σ_{fit} ~ 30 μm

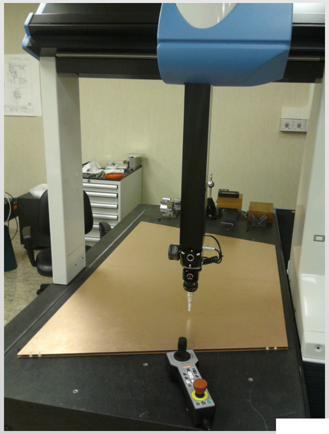
PANELS THICKNESS: average -15 μm; RMS 17 μm

Measurements compared with two different techniques

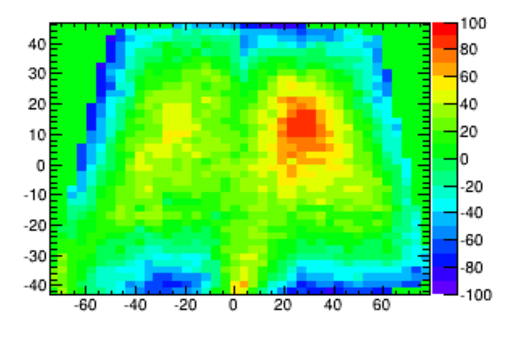
Measurements on QUADRUPLETS will follow

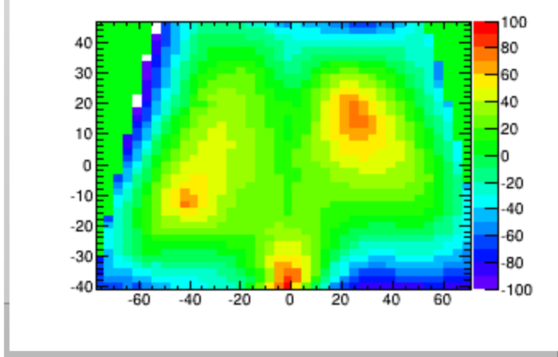


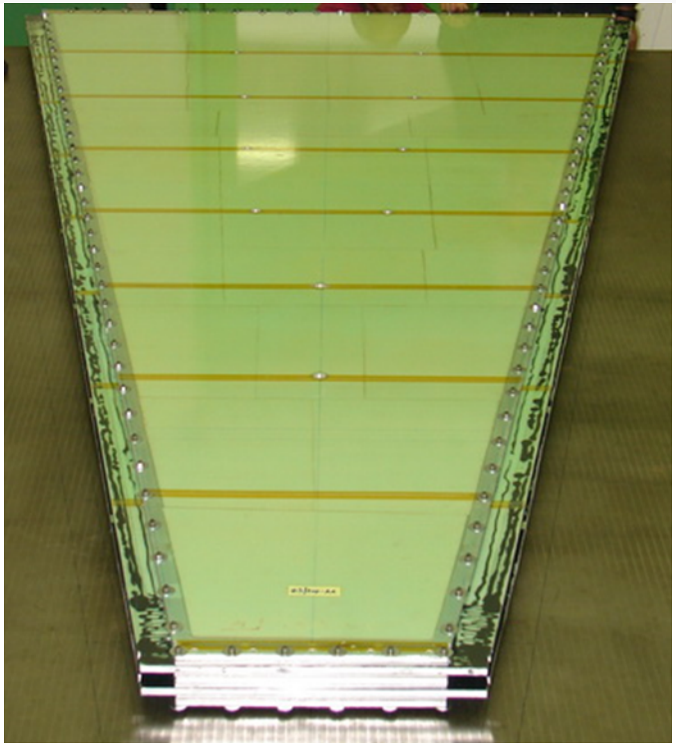




Compare results obtained with a Coordinate Measuring Machine (CMM) and with a Laser Tracker: Consistent !

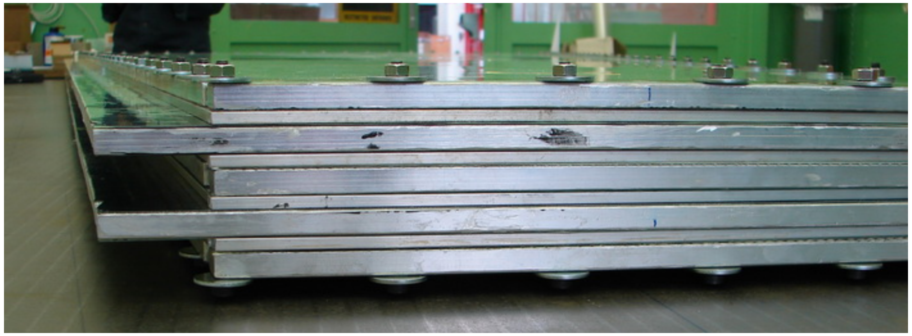


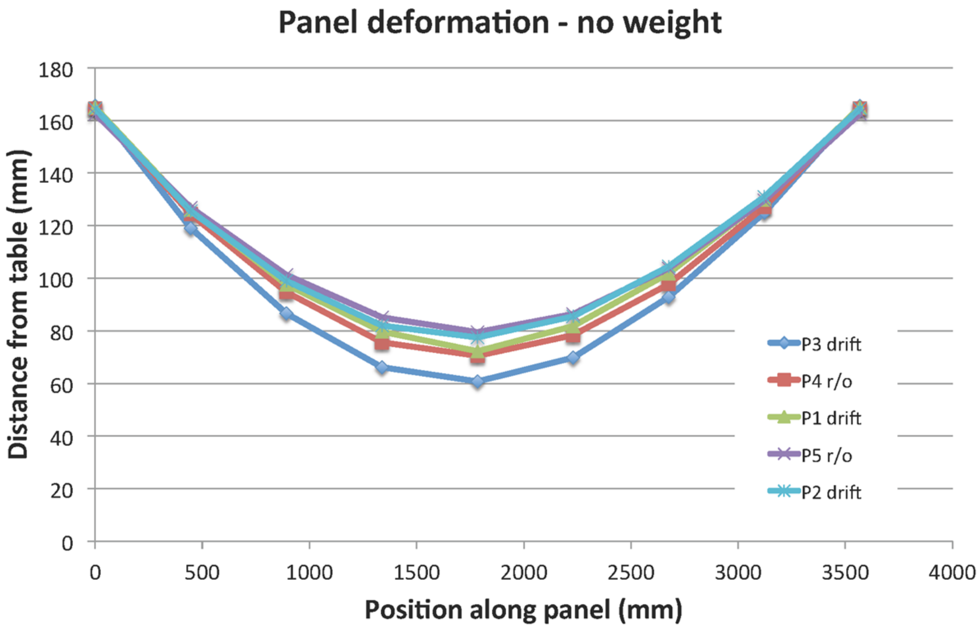


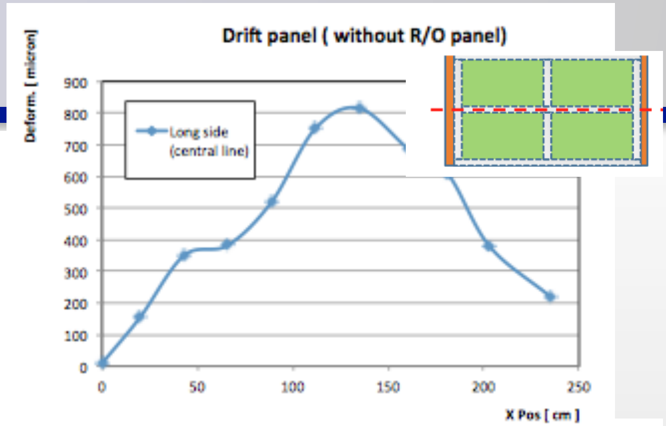


CERN: Small Sector - sized prototype, fully assembled.

- Study panel deformation and sag
- Measure elastic and mechanical properties (Young Module) of the PCB and other material

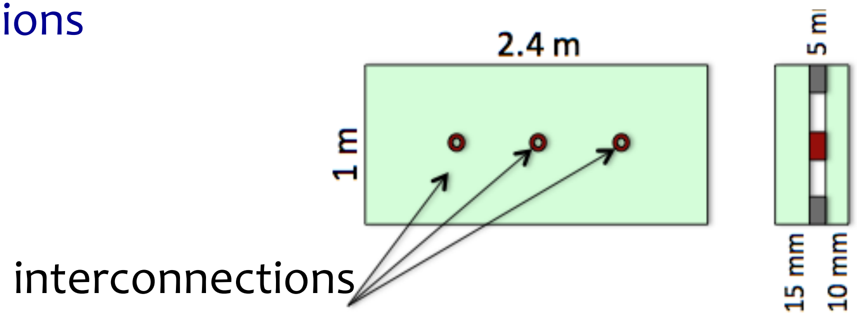






Recent activity

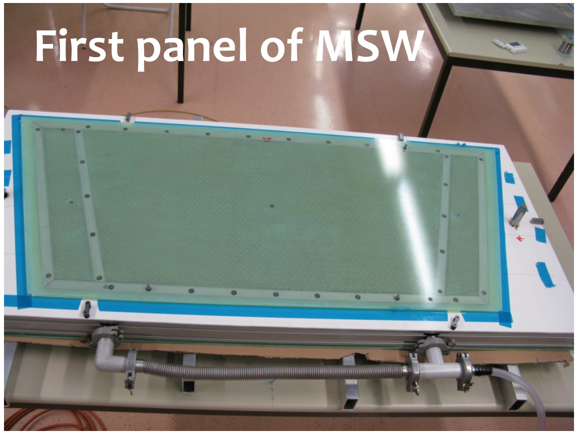
- Large area functional prototypes built at **CERN.**
  - -- Last L3 chamber single gas gap 2.4x1 m^2
  - -- tests of mesh stretching induced deformations
  - -- gas overpressure induced deformations
  - -- concept of interconnections



*Ongoing construction of functional Multiplets **in Frascati, Saclay, CERN/Mainz***

The MSW Project

- In particular the CERN/Mainz prototype (Micromegas Small Whell module – **MSW**) will be installed in ATLAS on the Small Wheel to operate during Run2 in real conditions
  - -- Dimensions 1.2 x 0.5 m^2 (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

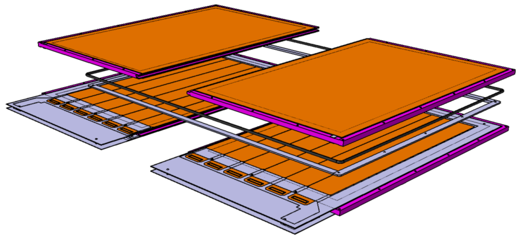


Top side flatness: 160μm (max-min)
Bottom side flatness: 90μm (max-min)
Improvements expected with new stiffback

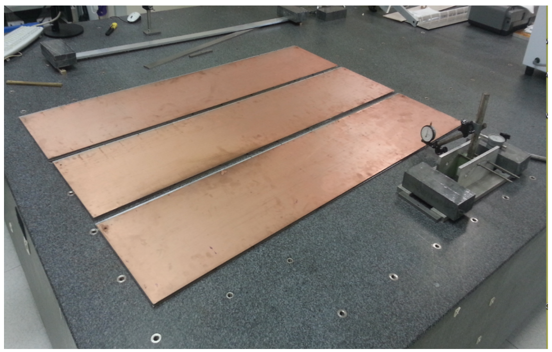
FUNCTIONAL PROTOTYPES

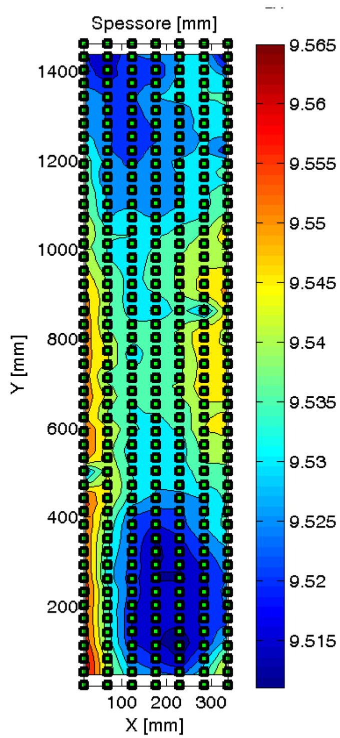
Prototype in Frascati

- ***Functional prototype***
  Dimensions
  780x730 mm^2

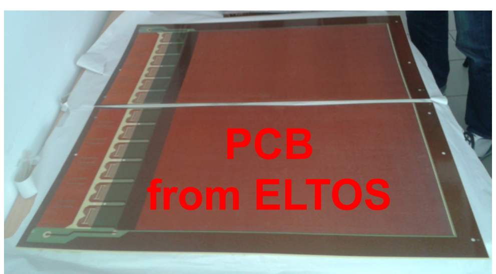


- Panel construction with stiffback technique with molds used by LHCB



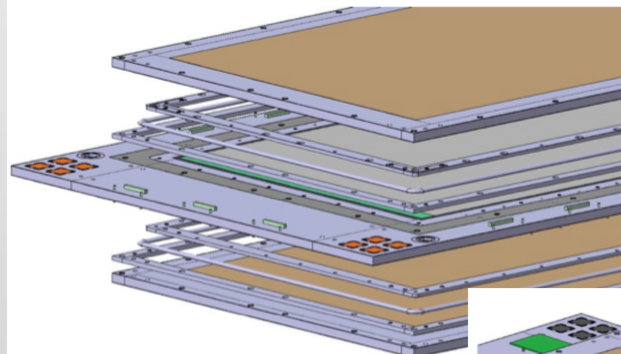


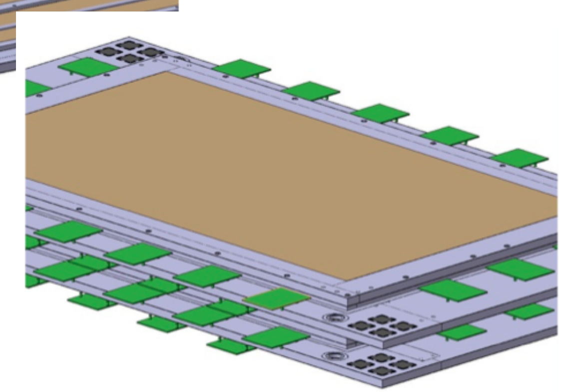
- Thickness measurements with max deviation <50 μm

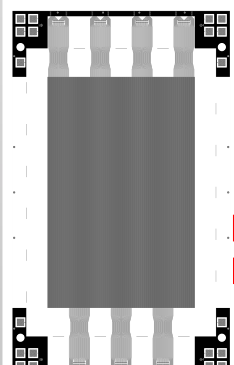


SACLAY functional Prototype

- 2 independent doublets
- X/Y resistive readout
- Test of mechanical and optical alignment
- Dimensions: 600 x 1000 mm2
- Mesh stretched on independent frame screwed on the readout plane
- Electronic readout APV/SRS
- Symmetrical design
- Layout finished







PCB Layout

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

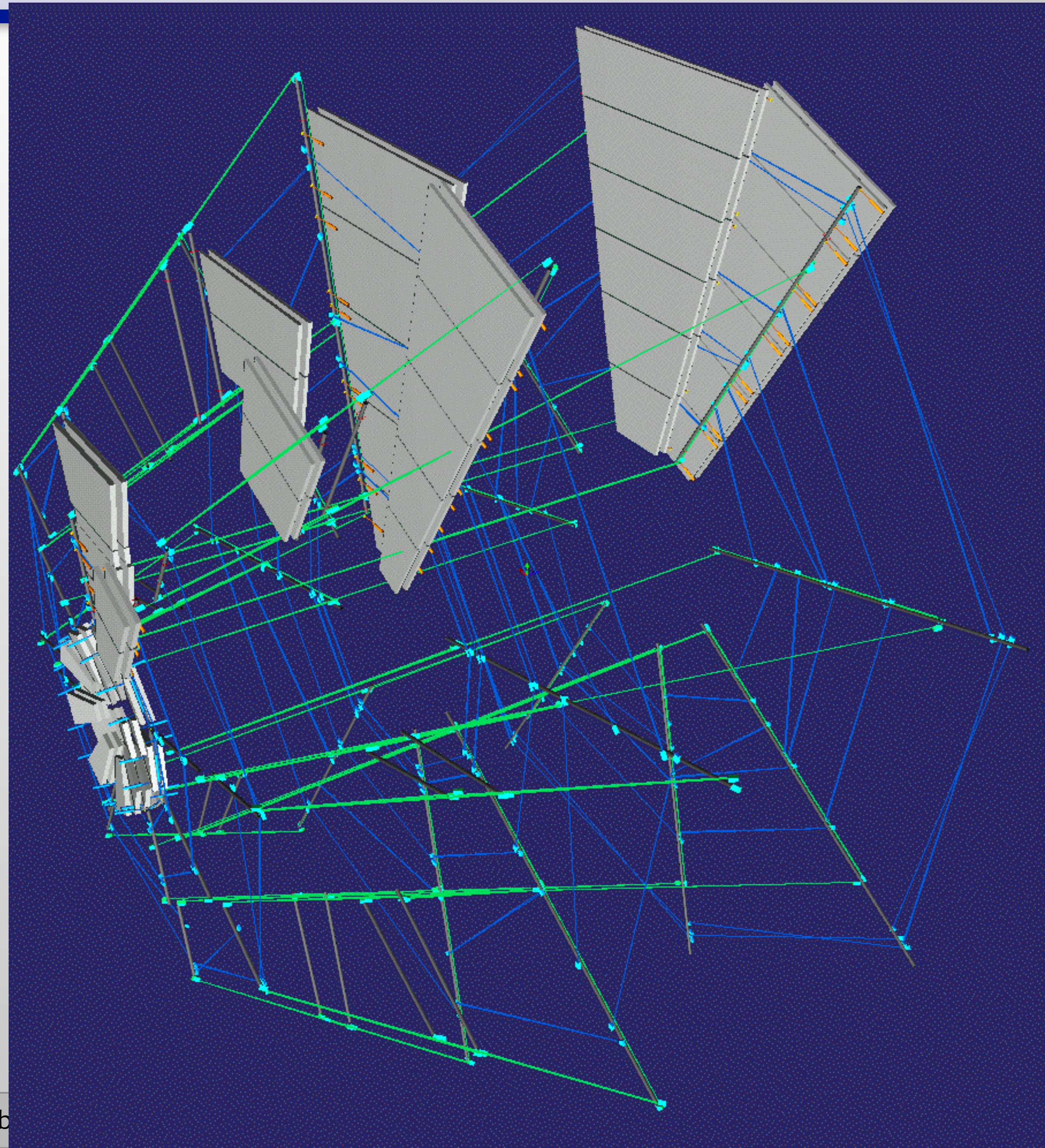
- Highly programmable ASIC provides both precision measurement and trigger primitives for both Detectors
- First version, fully functional, 64-channel analog front ends successfully fabricated in 2012
- **Second version** including ADC, simultaneous read/write was submitted in a custom MOSIS run **last 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

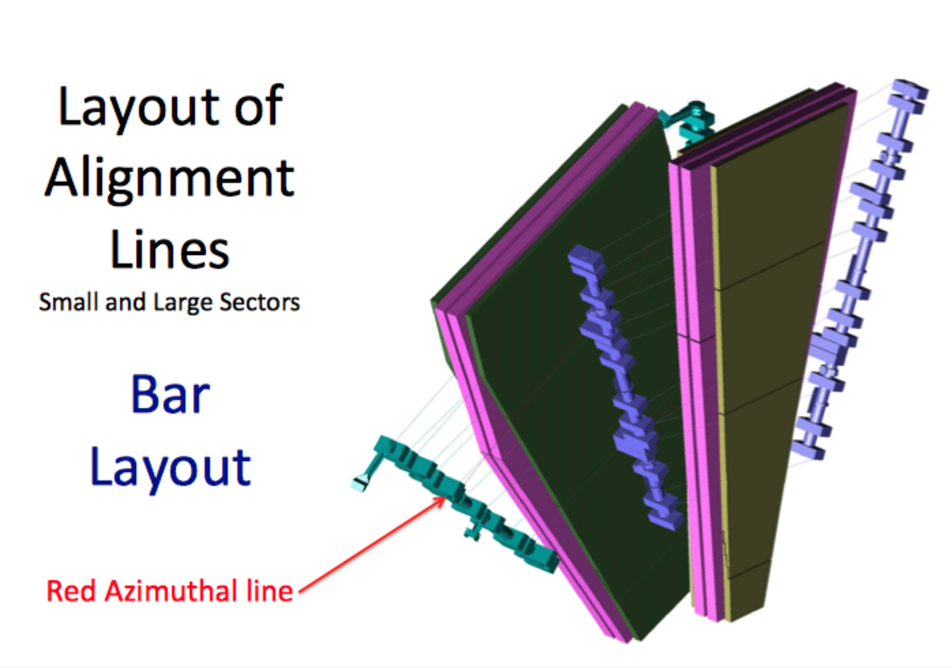
The Muon Endcap Alignment System

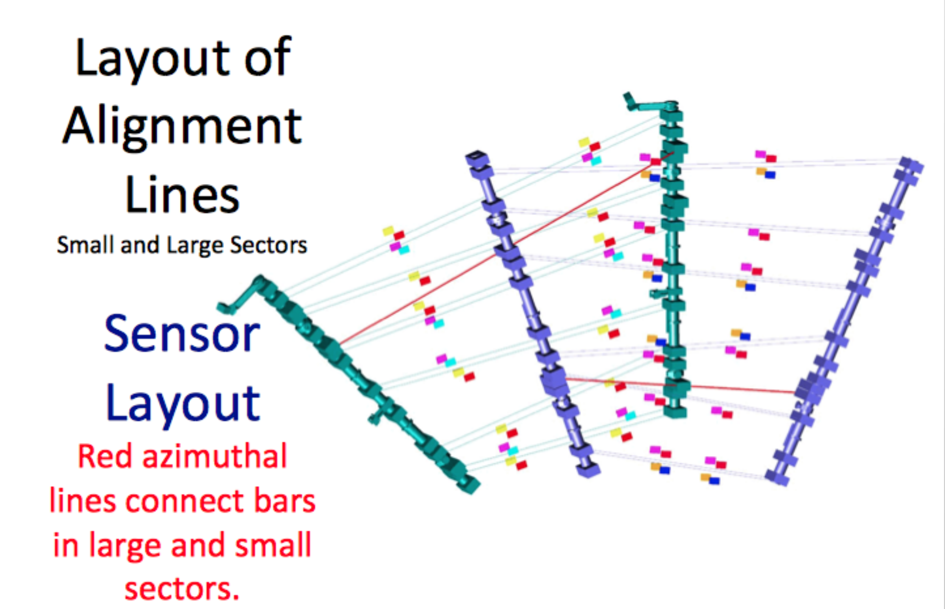
- Chambers are instrumented to detect their own shape. The "In-Plane" system.
- A grid is set up with alignment bars using a quasi-projective alignment system.
- The chambers are referenced to this grid.
- The system factorizes into bars, grid, and chambers relative to the grid.
- Two basic sensors are used for this system. CCD cameras (BCAM and Proximity) and a straight line monitor called RASNIK.



NSW Alignment System Design

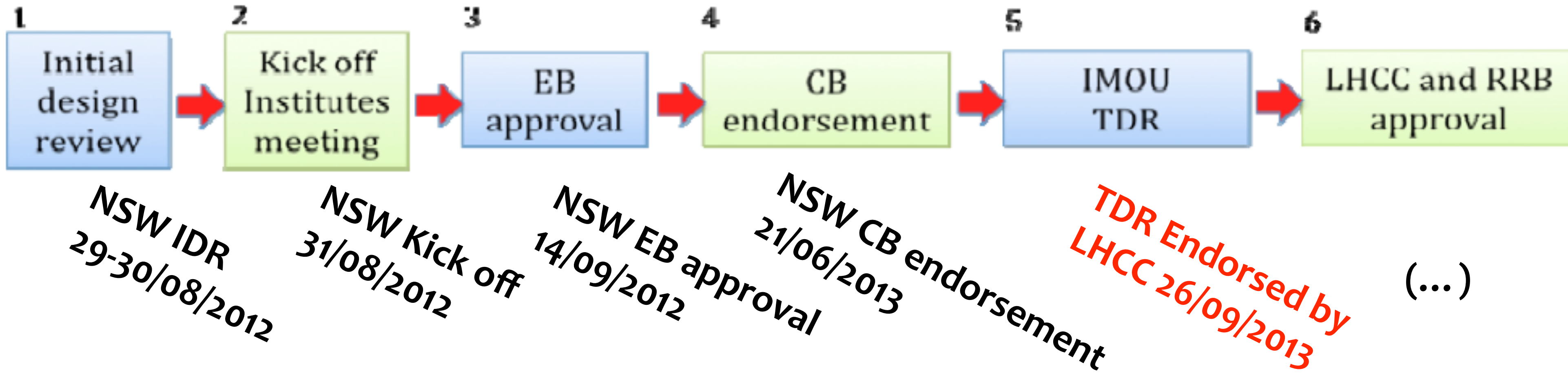
- The alignment bars in the NSW attach to the endcap alignment grid in the same way that the current wheels attach to the grid.
- The proximity system locates the chambers w.r.t. the grid. This is done with (light) sources on the chambers that are viewed by BCAMs on the alignment bars.
- Sources on the chambers are driven by light injectors that are positioned on the outer edge of the NSWs.
- **16 bars will be positioned to locate the chambers in the large sectors (8 bars) and in the small sectors (8 bars).** These two sets of bars are connected by azimuthal BCAM lines.
- The in-plane system measures the distortion of the chambers (B-lines). At the present time there is no design for this system.





STAGES IN ATLAS UPGRADE PROJECTS APPROVAL PROCESS

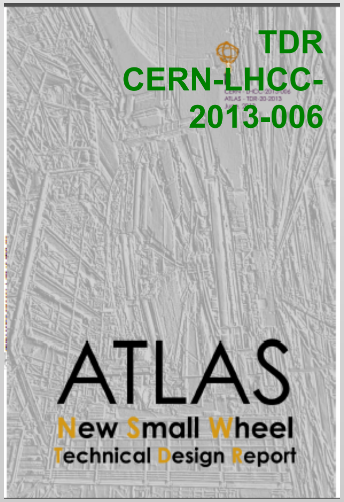
See: http://edms.cern.ch/file/1093133/5/ATLAS-Upgrade-Organization.pdf



- NSW TDR was submitted to the LHCC in June 2013, after ATLAS EB and CB approval → Approved by the LHCC on September 26 2013
- Memorandum of Understanding (MoU) document prepared for the Marrakech Atlas Week in October → Funding for all components defined
- Upgrade Cost Group (UCG) Scrutiny Review: **yesterday** (Feb. 5th)

Documents required by the UCG include information on the cost sharing, project work break down, schedule, manpower requirements and coverage including a manpower survey on institute level, and risk analysis

- Next step: finalize the MoU
- FINAL APPROVAL: Research Board **MARCH 2014**



Cost of the Project

TDR
CERN-LHCC-2013-006

Item	CORE (kCHF)	Possible addition	Common item	CORE 2013	2014	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)**

WORK SHARING - WBS

>50 Institutions in the NSW project

Micromegas Construction

Work responsibility:	
CERN	Readout boards: procurement, QA/QC, logistics. Central spacer frames (design, procurement, production)
Kobe, Tokyo	Readout boards: Resistive foil (development, procurement)
INFN (Frascati, Pavia, Rome1, Rome3, Lecce, Cosenza, Napoli) [1]	Small sector inner (SM1) modules
BMBF (Freiburg, LMU Munich, Wurzburg, Mainz)	Small sector outer (SM2) modules
CEA Saclay	Large sector inner (LM1) modules
Dubna, Thessaloniki [2]	Large sector outer (LM2) modules
Moscow cluster	QA/QC instrumentation: Contribution

sTGC Construction

Work responsibility:	
Canadian clusters (Carlton, Alberta, Toronto, McGill, Montreal, TRIUMF, Victoria, SFU)[1]	Large sector middle modules; small sector outer modules
Shandong	Small sector middle modules
Chilean cluster (UTFSM/CCTVAL, PUC)[1]	Small sector inner modules
Weizmann, Technion, Tel Aviv	Large sector inner and outer modules
Moscow cluster	X-ray scanner
St Petersburg	Module production: Contribution

Alignment System
- Freiburg
- Brandeis
- Saclay

Front-end ASICs and On-chamber FE elx
- BNL
- Bucharest
- Arizona
- NTUA (Greece)

sTGC Rim Elx (Pad and Router)
- INFN (Italy)
- Michigan
- Taiwan

List of other WP:

- DAQ and Off-Detector Readout Chain, Configuration

- SERVICES:
- *HV/LV Power Supply Chain & Controls*
- *Environmental and Magnetic Field Monitoring & DCS*
- *Optical Transmission and Fibres*
- *Gas System, Cooling System, Racks, Supports*
- *Integration, Testing & Commissioning*

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 from 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

Slightly tuned wrt TDR

THANK YOU FOR YOUR ATTENTION

Backup Slides

VMM Design parameters and Signal Processing Concept

Design Parameters/Features

- Dual Polarity
- Adjustable Gain (0.5 – 9.0 mV/fC)
- Adjustable peaking Time (25-200 ns)
- Address in Real Time (Fast OR in effect - Mmegas Trigger)
- Prompt digitized (6-bit) Amplitude, Time-over-threshold, time-to--peak (TGC Trigger)
- Peak Detector, Time Detector (<1 ns)
- Discriminators with sub-hysteresis
- Neighbor enable logic (channel to channel and across Ics)
- Sparse readout w/smart token passing,
- Threshold trim, built-in calibration, channel mask, analog monit temp. sensor, 600 BGR, 600 mV LVDS

presented 15/10/2013 at RD51
by V. Polychronakos

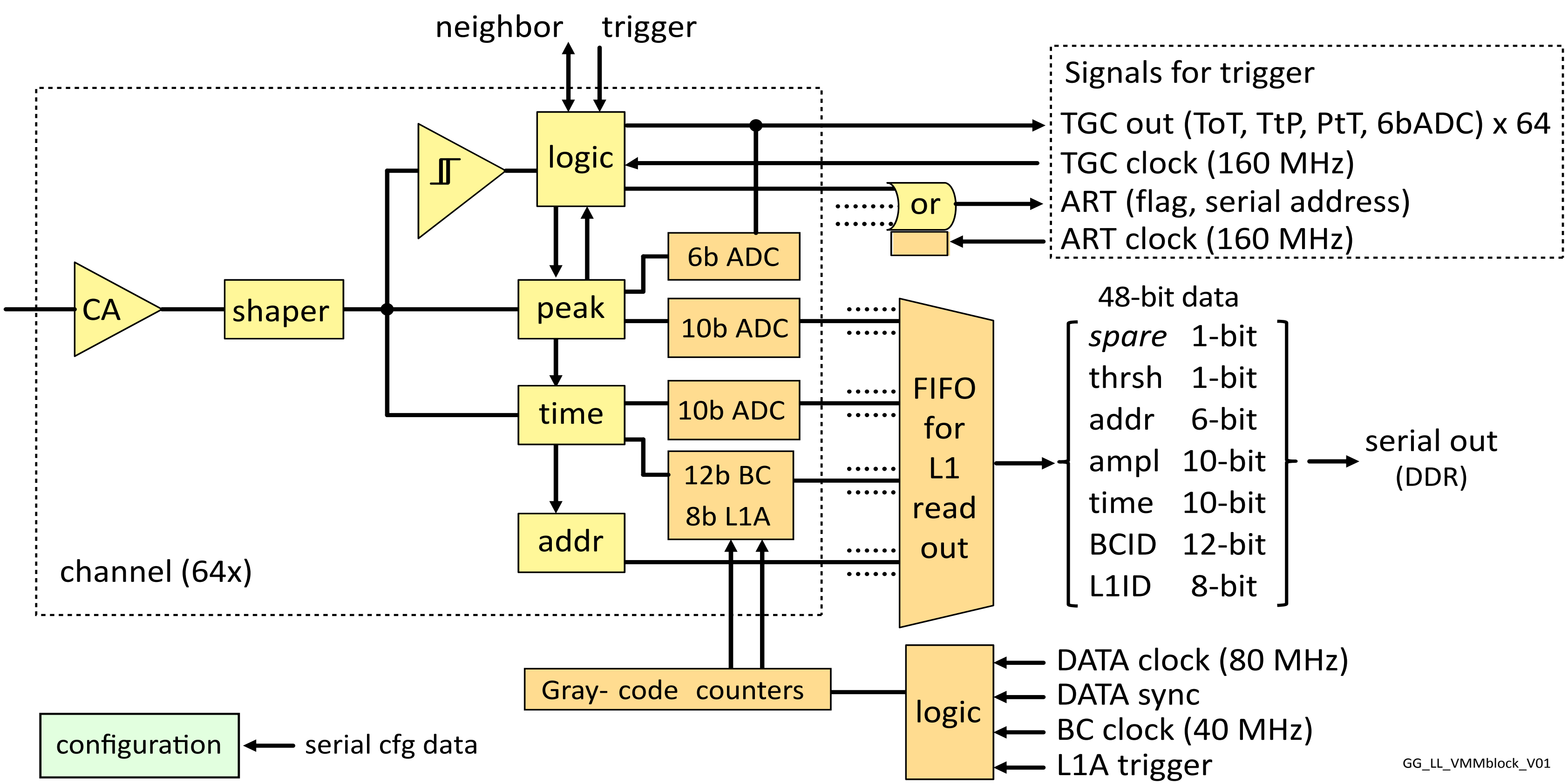
Signal Processing Concept

- Discriminators → Data driven front end
  - Zero suppression
- Neighbor Logic (channel to channel and across chips) allows processing below threshold signals
- Peak Detector provides signal amplitude
- Peak timing with negligible time walk and excellent resolution
- Discriminators with sub-hysteresis feature allow trigger at a few mV above baseline

THE FRONT END VMM ASIC

- Fixes issues (mostly minor) of the first version
- Includes 10-bit digitizers for amplitude and timing (200 ns)
- Includes a 6-bit Amplitude digitizer at ~40 ns conversion time
- Includes 4 word buffer, simultaneous read/write, effective 800 Mbps readout

VMM Architecture



ATLAS UPGRADE PROJECT APPROVAL PROCESS

6.1. **Approval process:** organized in 6 steps

Upgrade Projects are approved in several stages, as illustrated in Fig. 2. When an R&D project has reached the level of maturity agreed with the USC, the proponents submit the documents that constitute the Upgrade Project proposal to the USC. This initiates the start of the approval process and provides a basis for the initial design review.

Fig. 2: Stages in Upgrade Project approval process

6.1.1. **Initial Design Review:** The review should verify that the overall performance and technical requirements on the Upgrade Project are clearly defined and that the initial design, as described in the documents that constitute the Upgrade Project proposal, is technically sound and corresponds to the requirements. It shall also examine the initial cost estimate, preliminary schedule and milestones up to and including the writing of a Technical Design Report (TDR).

6.1.2. **Initial kick-off meeting:** A meeting of all institutes that have announced an interest in participating in the Upgrade Project. It is organized in the framework of the parent system's Institute Board (IB) and it shall be chaired by that system's IB Chairperson. The meeting shall be announced to the entire ATLAS Collaboration allowing institutes that have not been directly involved and/or are outside the parent system to participate. The meeting shall endorse the organisation of the Upgrade Project within the parent system and the interim UPR-leader. The term of office of the interim project leader will last until the full approval (step 6, see 6.1.6) of the Upgrade Project. All minutes of such meetings will be made available to the Collaboration for consultation. A meeting dedicated to a presentation and discussion of the physics driving the Upgrade Project precedes this meeting and is organised by the Upgrade Coordinator.

6.1.3. The Upgrade Coordinator, after consultation with the ATLAS management, will present to the **ATLAS Executive Board** the outcome of steps one and two (i.e. 6.1.1 and 6.1.2) and ask **for an approval** of the Upgrade Project by the Executive Board, such that it can move to the next step of the approval process, see below. Note, the commencement of the approval process shall have been brought to the attention of the ATLAS Executive Board prior to implementation of step 1 (see section 6.1.1)

6.1.4. The ATLAS management presents the Upgrade Project, as well as the management structures, the agreed milestones and the selected interim Project Leader to the **CB for endorsement**.

6.1.5. As part of the agreed milestones a TDR is prepared. In parallel an **MOU** (or if necessary an interim MOU) is also prepared. The two documents shall be submitted to the USC. Subsequently the Upgrade Coordinator shall inform the Executive Board of the completion of the TDR and MOU (or interim MOU) and request that the documents be submitted to the CB for approval and in due course be submitted to the LHCC.

6.1.6. The TDR is presented for **approval to the LHCC**. The **RRB is informed** of the outcome of the Collaboration approval process and of the approval by the LHCC. A plan for submitting to the RRB a financial proposal based on the MOU (or interim MOU) is presented. Thereafter the status of the Upgrade Project (technical and financial) is presented in each meeting of the RRB.