ATLAS New Small Wheel (NSW) Upgrade Status and Progress

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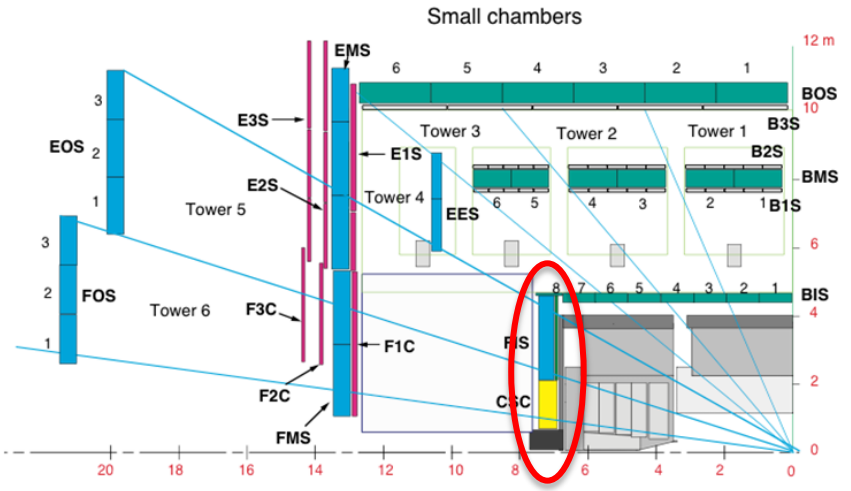
for the NSW project

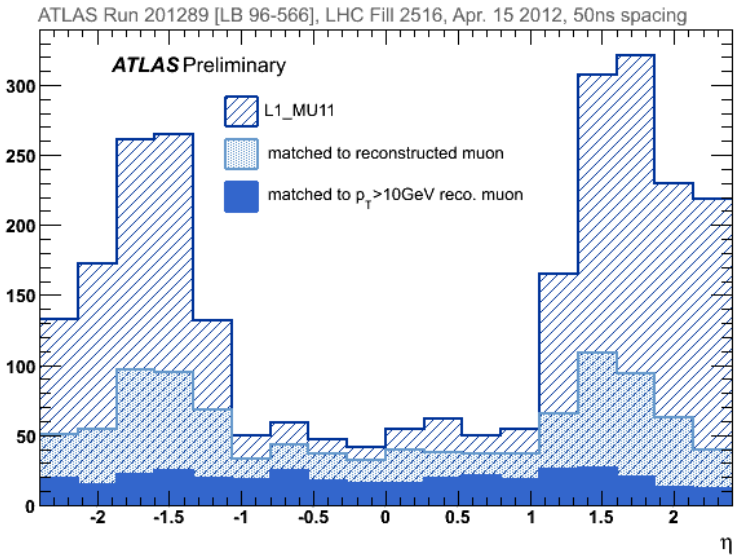
1. Introduction
2. Layout, Mechanics, New Small Engineering Aspects
3. Alignment
4. MicroMegas and sTGC Chambers and Chamber Construction
5. Electronics
6. Outlook and Conclusions

Introduction – NSW Motivation

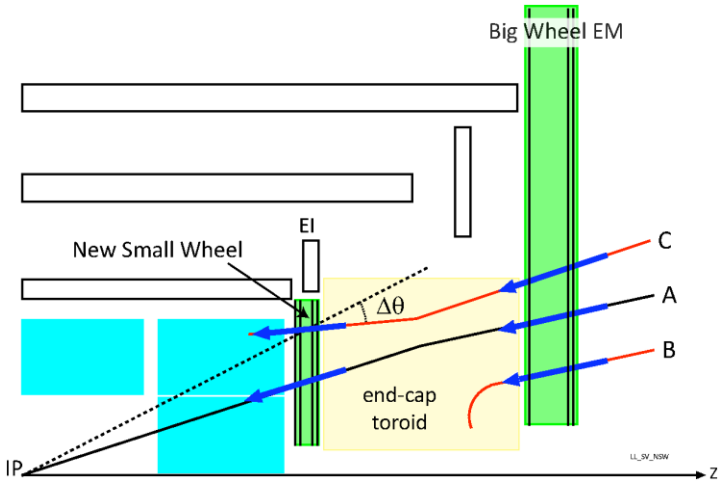
- The ATLAS New Small Wheel Upgrade's target is to replace the present Innermost station of the Muon Endcaps in LS2 (2018/19)
- The NSW addresses
  - high fake L1 trigger rate for high-pt muons
  - loss in tracking efficiency

  at luminosity beyond 10^{34} s^{-1} cm^{-2} with the present Small Wheels.
- NSW detectors -- MicroMegas + sTGC -- both provide triggering and tracking capability





NSW principle:
Rejection of tracks not from the IP (B: creation within the toroid, C: multiple scattering)



New Small Wheel Specifications & Requirements

Layout

- Compatibility with the existing tracking detectors and endcap alignment system
  - → precision coordinate of all chambers parallel to drift tubes of EM and EO stations to within 2 mrad
  - → coverage: $|\eta| > 1.3$ (minimum size of chambers)
  - → same segmentation into 16 pie-shaped sectors as the present Small Wheel

Performance

• Momentum resolution:	better than 15 % up to p_t = 1 TeV
• Single plane resolution:	100µm, independent from track angle
• Track segment reconstruction:	50 µm
• Track segment efficiency:	>= 97% @ p_t > 10 GeV
• Online angular resolution (trig):	<= 1 mrad
• Spatial resolution 2nd coordinate:	~cm, from stereo strips or wires
• Hit rate capability:	15 kHz/cm^2 (meeting perform. requ.)
• Accumulated charge without ageing:	1 C/cm^2 (3000 fb^{-1} w/o degradation)

- Redundancy of tracking and triggering
  - → provision against failure in a detector plane or element, limited accessibility

NSW Geometry

Present ATLAS Small Wheels

8 Large sectors (pie-shaped)

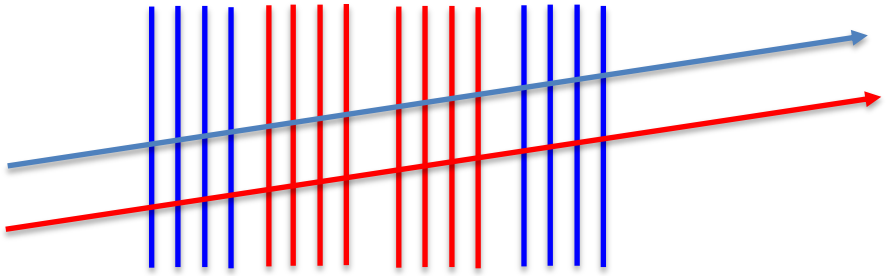
8 Small sectors (pie-shaped)

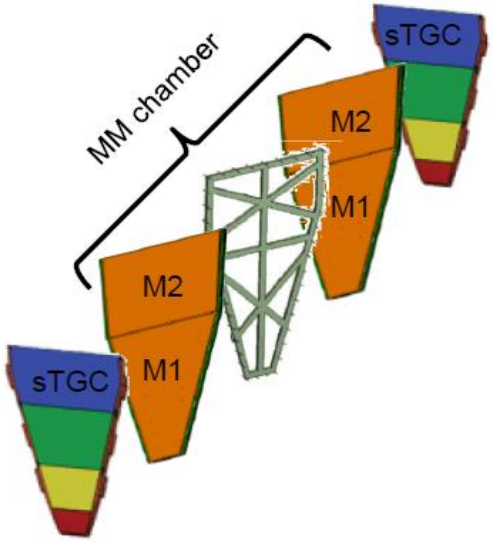
Large and Small Sectors overlapping in phi to avoid holes in coverage

Once installed in ATLAS, the (New) Small Wheel is sandwiched between the calorimeter and endcap toroid magnet and no longer accessible → criticality of redundancy !

Detector Technologies

- 2 detector technologies for NSW chambers: small strip Thin Gap Chambers (sTGC) and resistive MicroMegas (MM)
- 4 + 4 + 4 + 4 detection planes

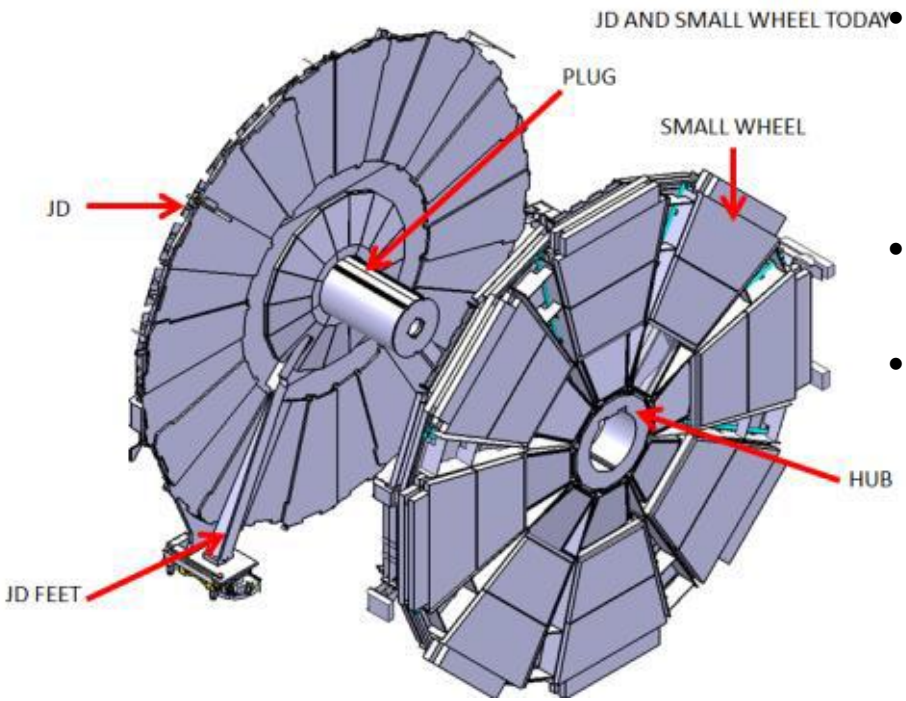




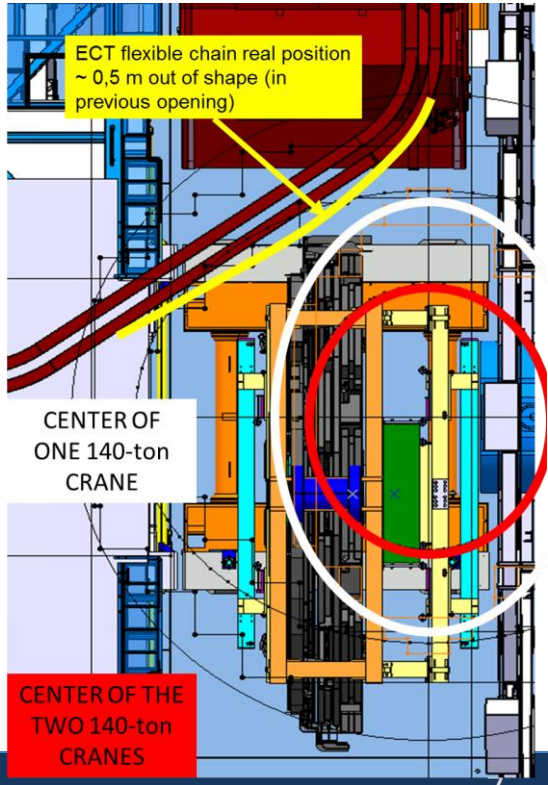
- sTGC – Primary trigger detector
  - Outside → longer lever arm
  - Track vector with angular resolution < 1 mrad
  - Good space resolution --- contribute to resolution offline track reconstruction, redundant tracking
- MM – Primary tracking detector
  - 500 µm strip pitch – very good position resolution of 100 µm independent of track angle, excellent track separation capabilities
  - Provide independent track vector – redundant triggering

Status & Progress

Mechancial Engineering I



- In the present ATLAS Small wheel, chambers (Monitored Drift Tubes + Cathode Strip chambers) for a disk like structure around a central hub
- A second disk (“JD”) provides shielding and the support
- The chamber “wheel slides on the plug of the JD

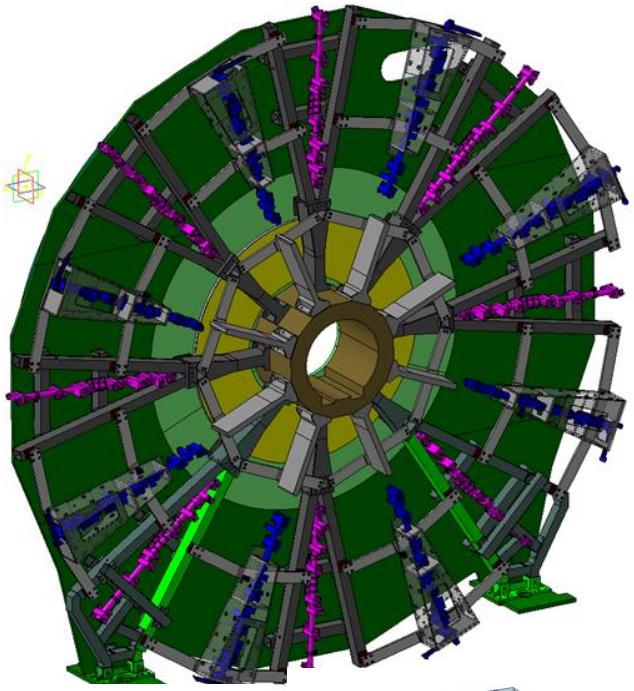


But …
With more layers (8 MM + 8 sTGC) the New Small Wheel is heavier ….
→ New concept needed to remain within the range of the 140 t crane in the ATLAS cavern and allow installation ….

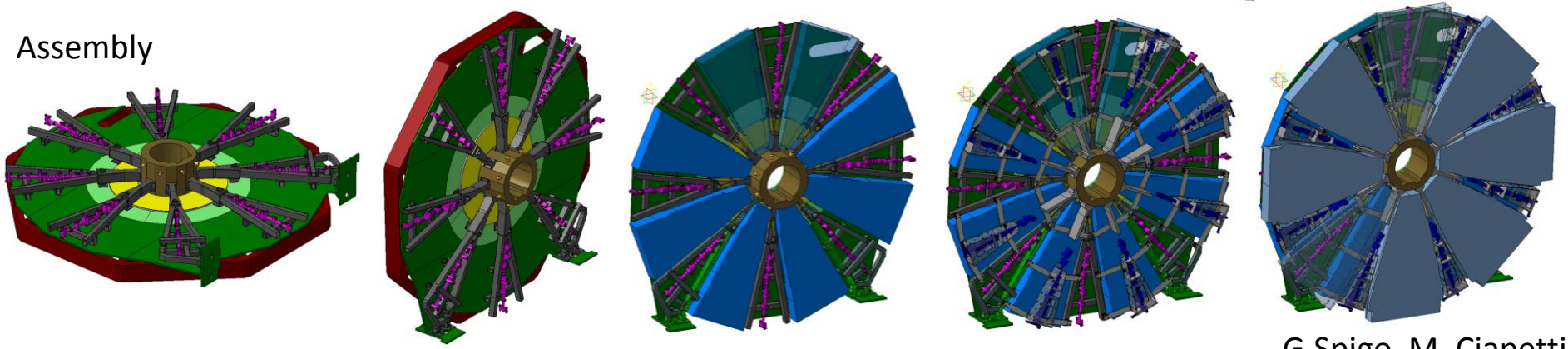
Mechanical Engineering II

New Small Wheel ---- New JD

- Shielding disk and “Spoke-like” structure are bolted fixedly together
- Increased rigidity allows reduction in disk thickness … back in the weight limit
- NSW assembly can start independent and before the retrieval of the present Small Wheel from the ATLAS cavern at the start of LS2



Assembly

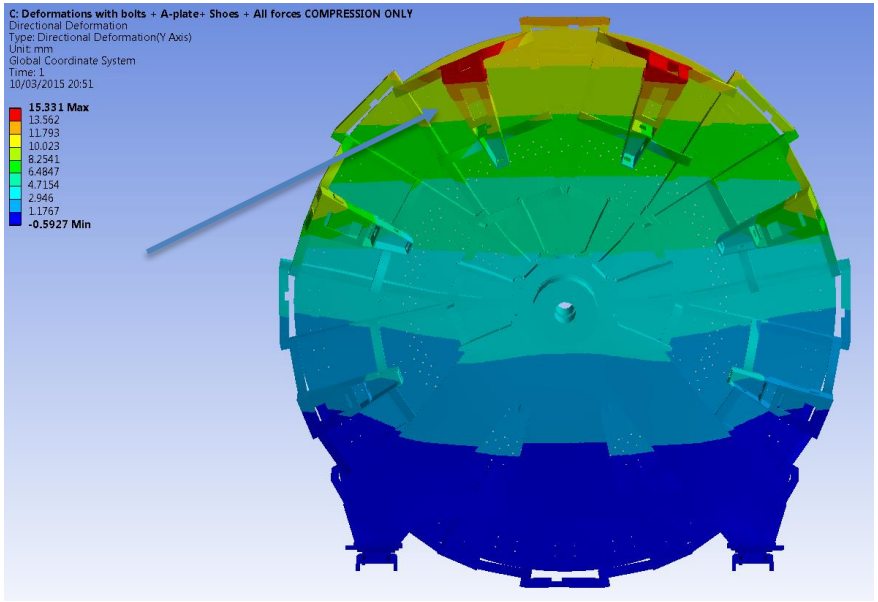


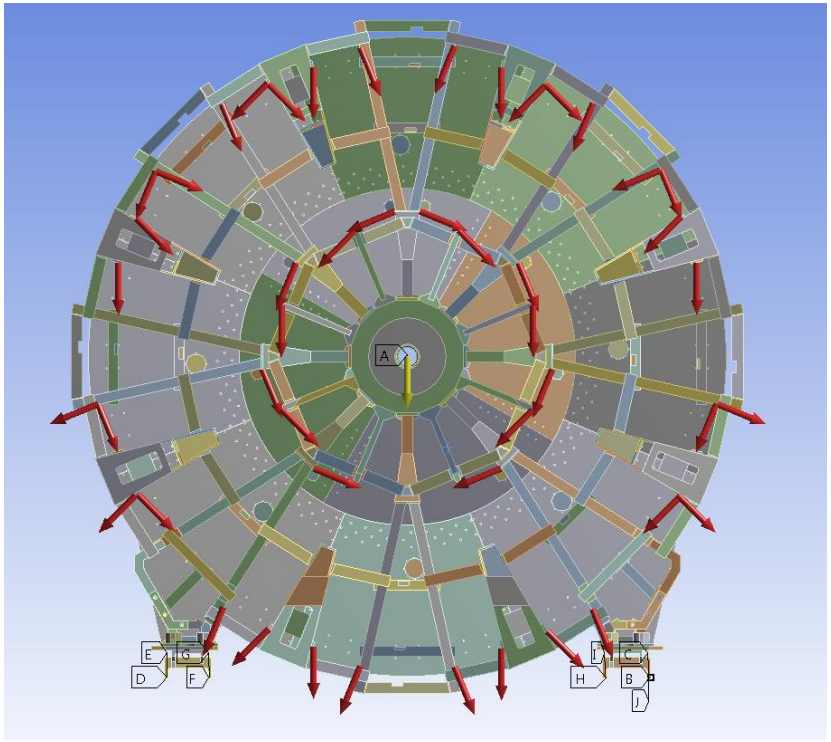
G.Spigo, M. Ciapetti

Mechanical Engineering III

- Structure + New JD + shielding design essentially complete, full 3D model exists
- Focusing next on Finite Element analysis and further optimization of deformation

Forces: ANSYS calculations

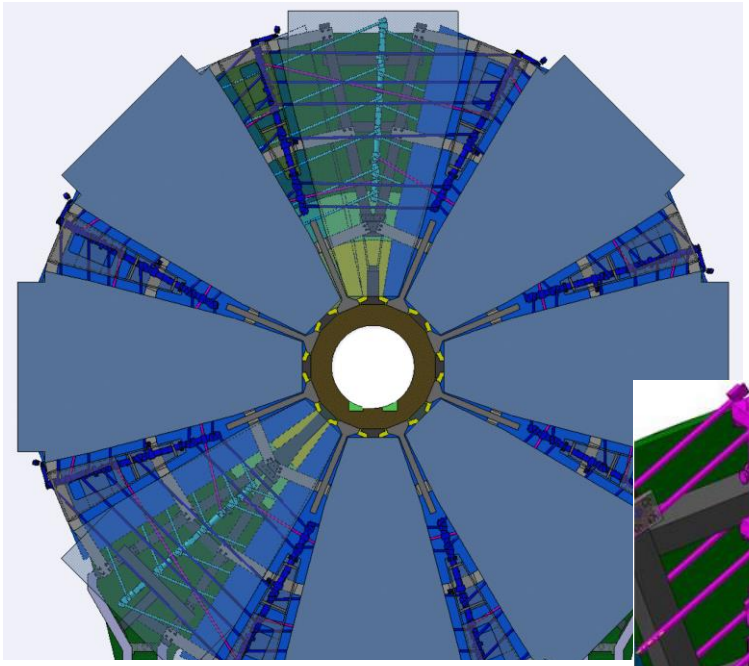


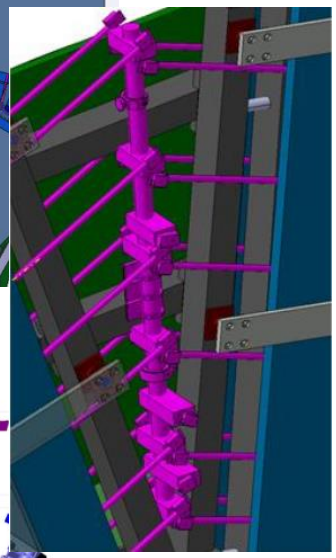


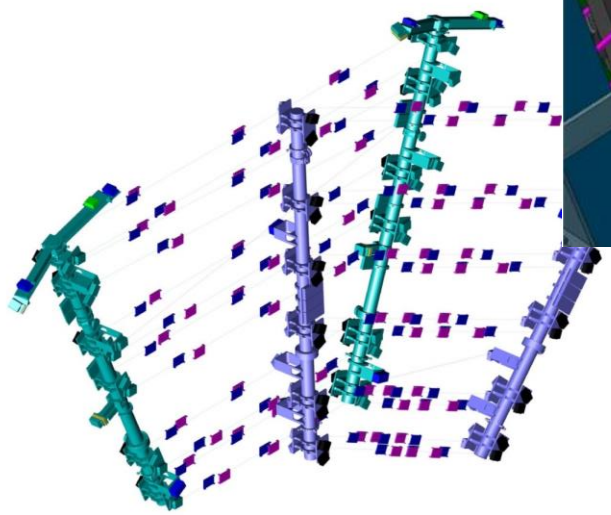
Presently max bending out of plane is 15 mm

- Mechanical Engineering proceeding well,
- Disk (JD), Spoke structure and new hub all scheduled to go for Tendering later in 2015
- Already working on detailed assembly planning: estimate 3 months (JD) + 5 months (sectors)

NSW Alignment System I







- Needed position resolution of the NSW requires knowing the position of all chambers very precisely, same for their deformations
- Monitor in situ by a system of “optical alignment lines” consisting of

  - 16 alignment bars per side, instrumented with CCD cameras “looking” at chambers and bars in the Middle and Outer endcap Muon station
  - Light sources mounted on quadru-plets/chambers

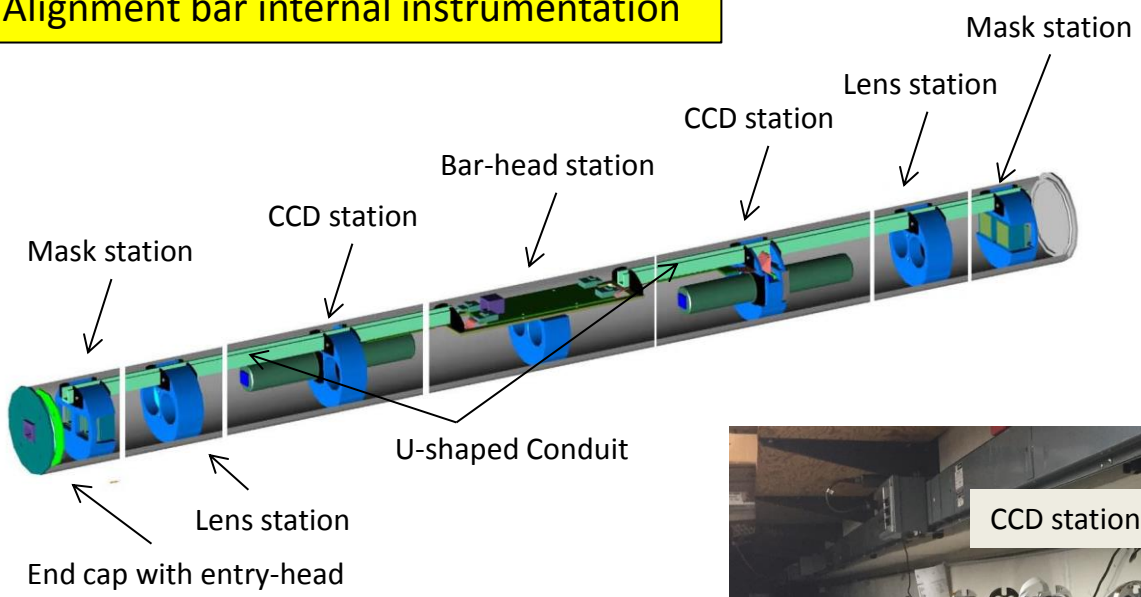
- Bars are a part of the New Small Wheel spokes --- complex and very complicated layout

NSW Alignment System II

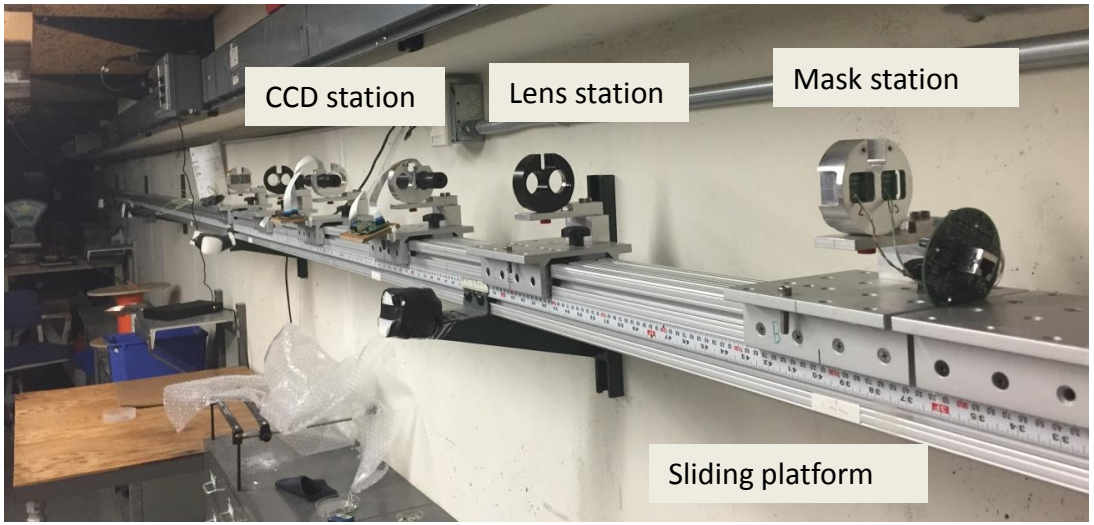
Just completed the Design Review for the Alignment System last week

→ Production of alignment bars and components to start

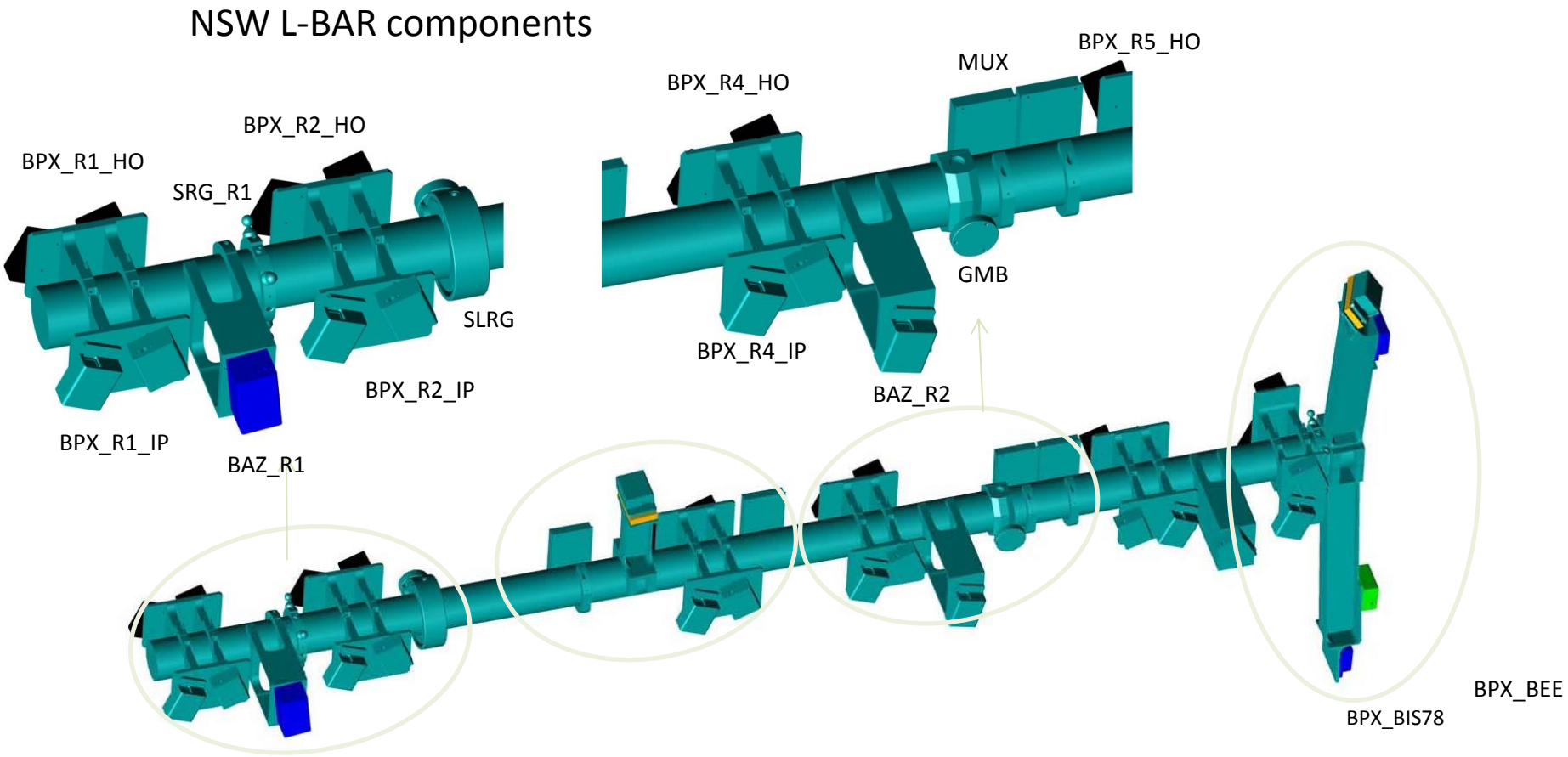
Alignment bar internal instrumentation



Calibration setup @ Brandeis University (US)



NSW Alignment System III

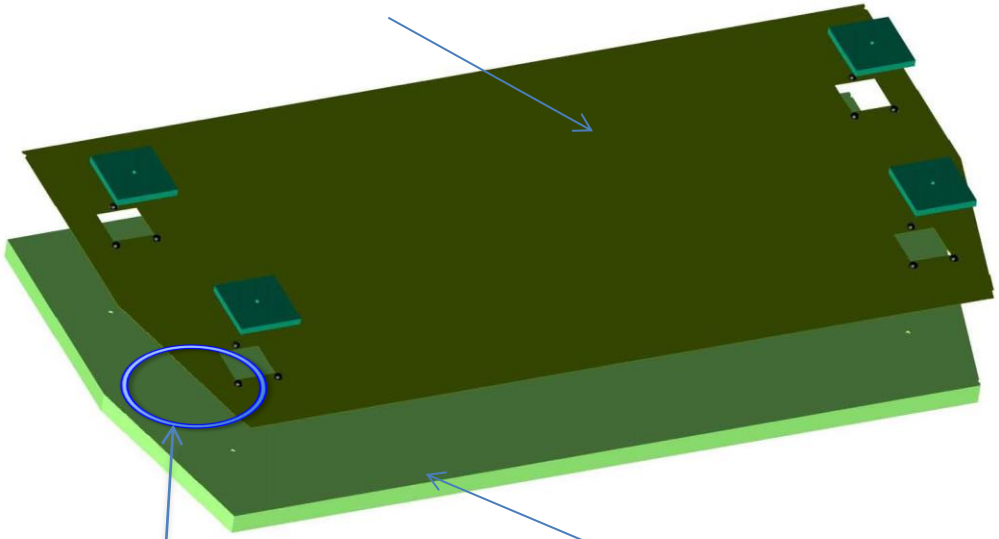


- Alignment Platforms will be machined @ Freiburg University (Germany)
- Alignment Bars will be assembled and calibrated on a 6m CMM in Freiburg

NSW Alignment System IV

Installation procedure/jig for alignment/source platforms on sTGC and MM chambers

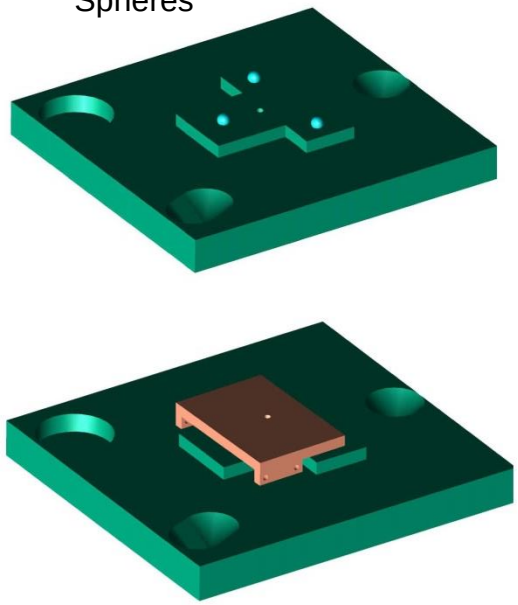
Jig base. Reference points aligned with reference points used to construct chambers.



Kinematic Mount

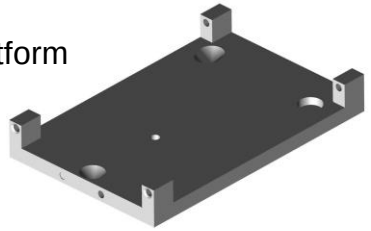
Quadruplet

Spheres



Kinematic platform with source platform attached

Source Platform

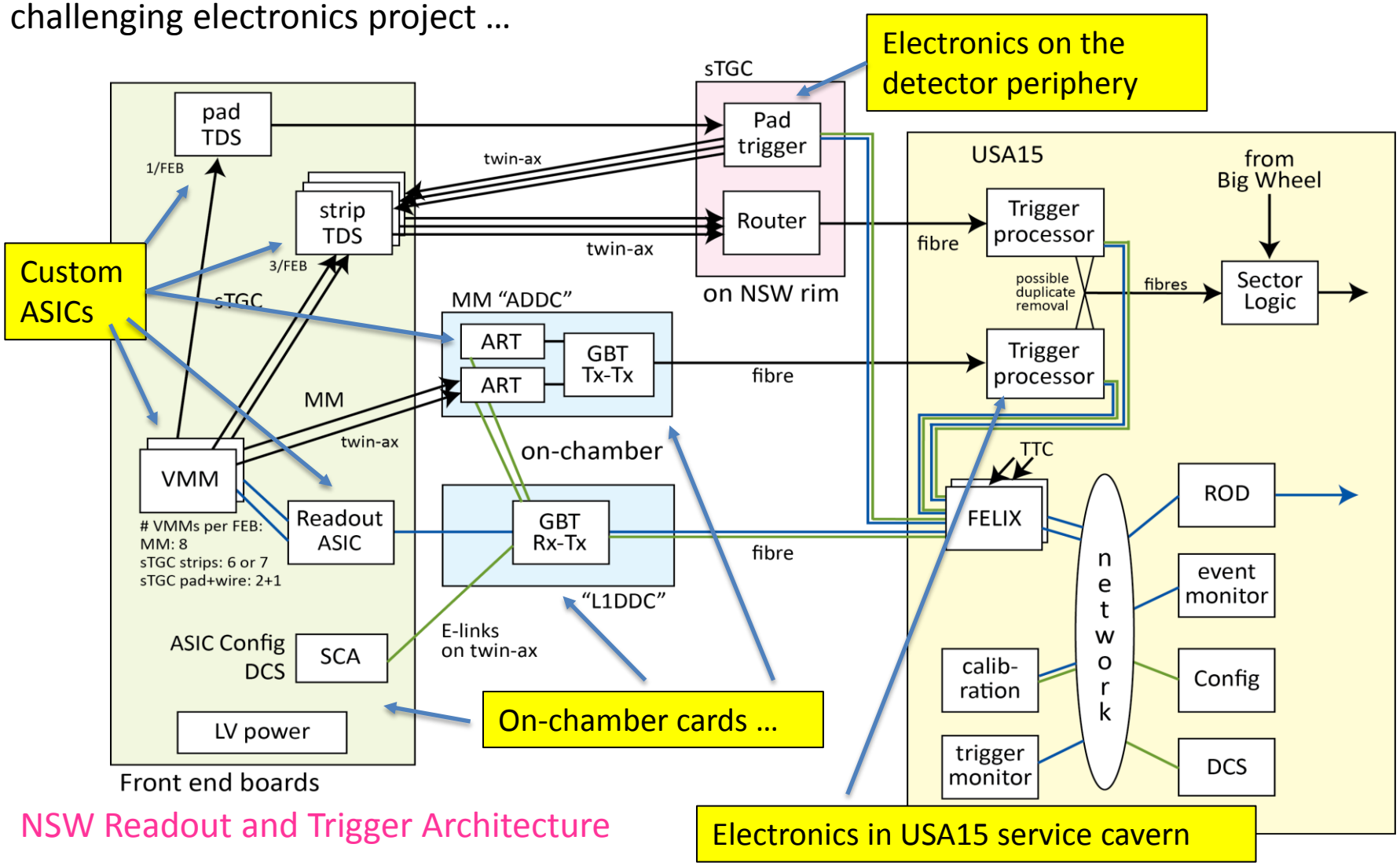


Source platform jig base set on top of a quadruplet positioned by two quadruplet alignment pins.

Jim Bensinger

NSW Electronics I

NSW project is not only a detector and mechanical engineering project, but also a very challenging electronics project …



NSW Readout and Trigger Architecture

NSW Electronics II

VMM	Readout companion ROC	TDS companion	ART companion
Frontend chip for both sTGC and MM, amplifier, shaper, fast ADC, address encoding, timing information	TTC interface, buffering of hits until L1 accept	Trigger Data Serializer (sTGC), send fired strip/pad information to pad trigger logic	MM trigger interface, collects address in real time info on fired strips and transmits to off-detector trigger processor
130 nm CMOS IBM process, co-produced on the same wafer for mass production			
Lat summer adaption to 1 MHz L0 and 400 kHz L1 rate (from 500 kHz/200 kHz)			

Status:

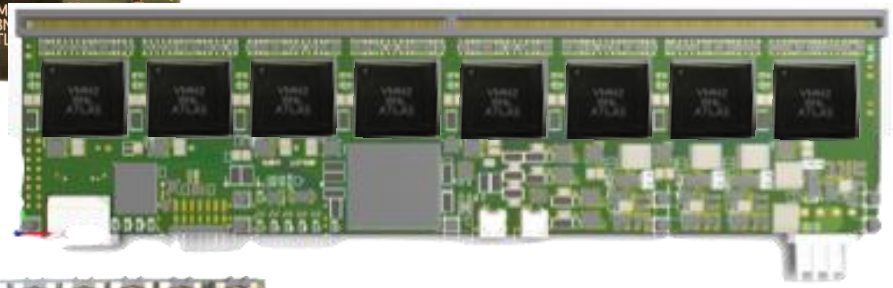
- Had the Preliminary Design Review for the NSW Electronics in mid February (project milestone)
- Had the Preliminary Design Review for the NSW Trigger Processor in mid February (project milestone)

- Prototypes for TDS and ART ASICs submitted in spring 2014 (ART, TDS) and august 2014 (TDS)
- VMM2 version of the frontend chip under intense testing at the moment
- Next submission (for ROC first version, ART2, TDS2, VMM3) planned mid to end summer 2015 --- (project milestone)

NSW Electronics III

Frontend Boards:

- Few mini-2 cards containing 2 VMM ASICs assembled with the help of Hans Muller (RD51), used to test VMM2 incl. with small MicroMegas



- MMFE-8 demonstrator/prototype v0 design finished, first card assembled and tests started, so far successful (FPGA providing the role of the readout companion ASIC)

L1 Data Driver Card (LDDC):

- First prototype exists, currently under test @ NTUA Athens
- Contains GBTx, FPGA for validation
- Multiple interfaces for testing

ART Data Driver Card (ADDC):

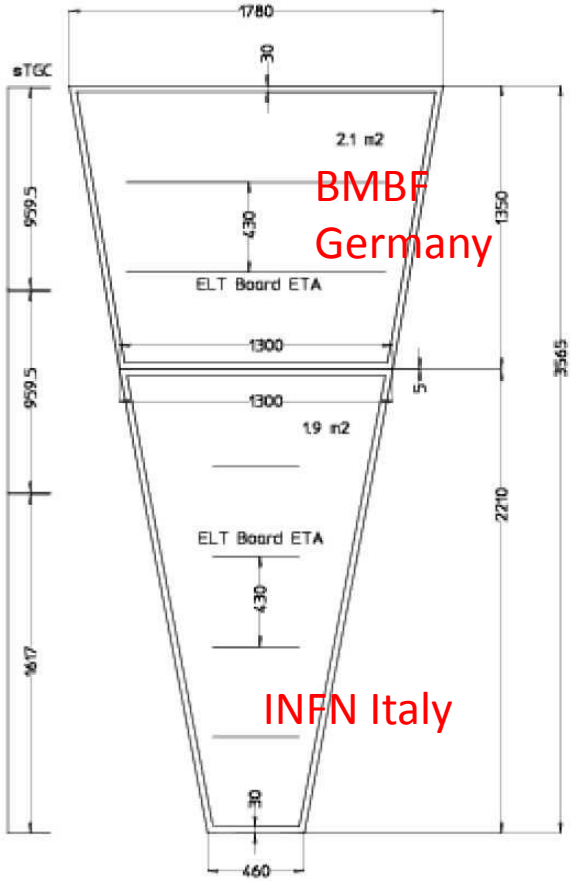
- First prototype excsts, currently under test @ BNL (US)
- Contains GBTx, FPGA for validation
- Multiple interfaces for testing

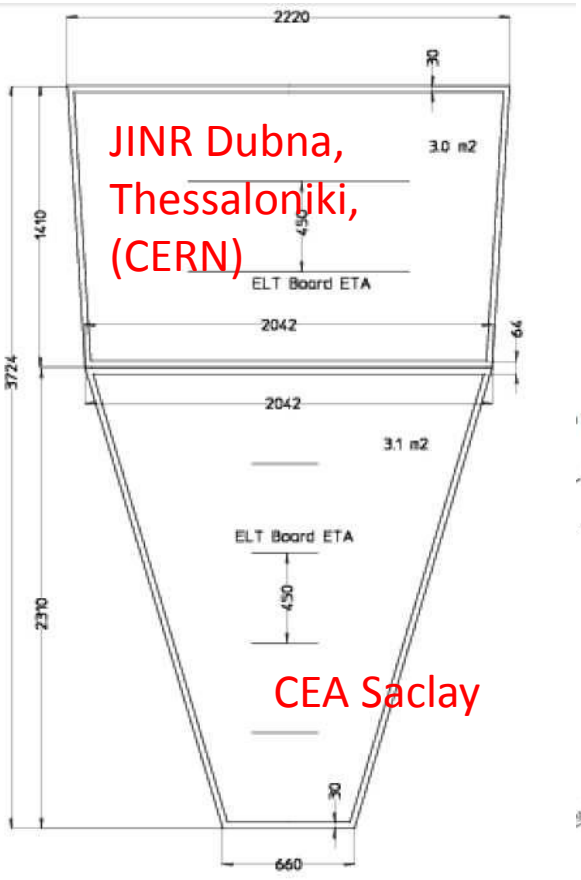
Vertical slice “test stand” being prepared at CERN, will with time reflect the full electronics chain of the NSW

Detector Construction

Construction sites

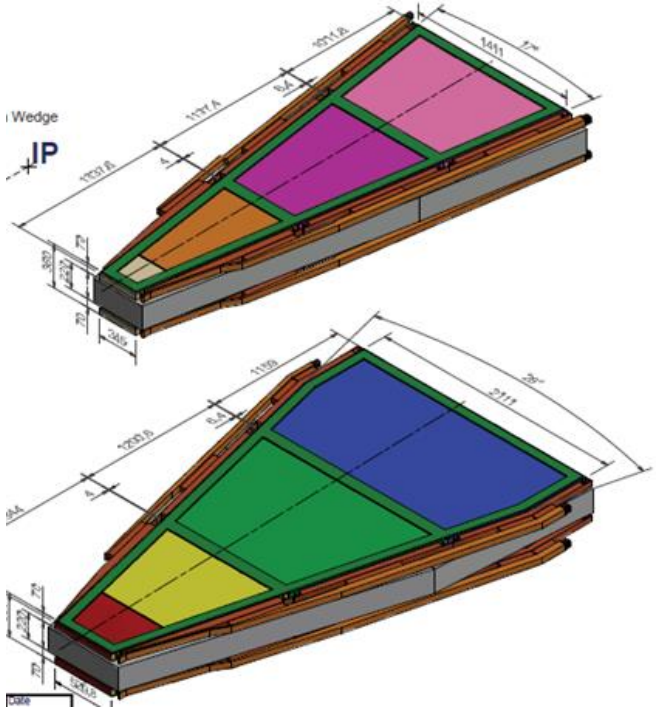
NSW has 4 different MicroMegas chamber types and 6 different sTGC types (sTGC types each come in addition as pivot and confirm sub-types with different pad arrangements)





sTGC:

- 3 quadruplets per wedge
- Construction in China (Shandong), Israel, Canada, Chile, (St. Petersburg)



MicroMegas:

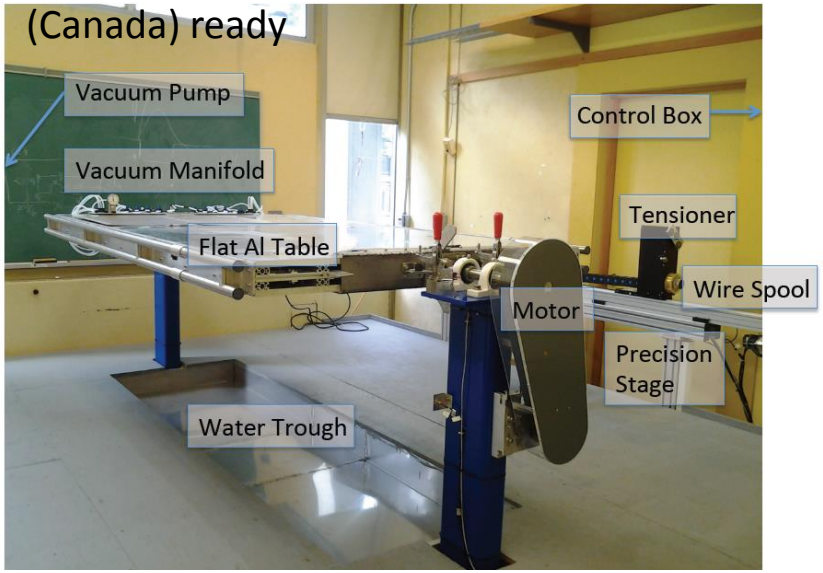
- 2 quadruplets per wedge

sTGC: Gearing up for producing module-0

- sTGC Module-0s (Canada, Israel) should be completed in ~May, China and Chile a little later
- Components and materials ordered
- Site infrastructure ready, gaining experience with smaller chambers
- Quadruplet equivalent to China module-0 already built as module -1 at Weizmann and extensively tested at FNAL and CERN test beams
- FDR in summer (project milestone)
- Mass production from after the summer on, Production readiness review in ~September (project milestone)

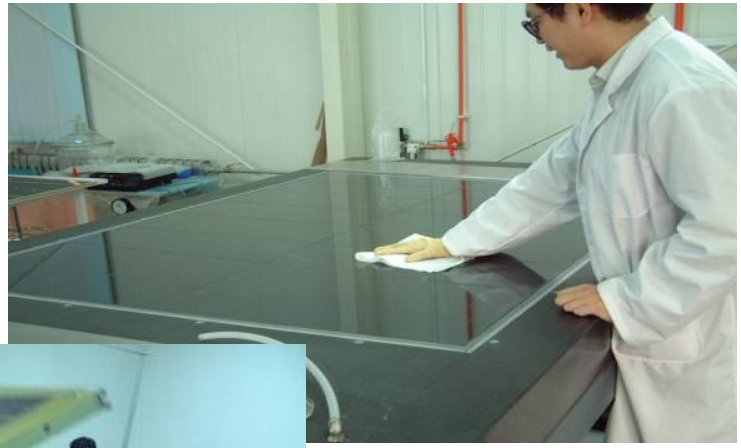
1. Cathode spraying machine at TRIUMF (Canada) ready

1. Wire winding machine at Carleton (Canada) ready



sTGC: Gearing up for producing module-0

2. Chile: Granite tables ready



3. Shandong (China): Granite tables ready, wire winding machine ready

4. Weizmann (Israel): Site ready and operational since last summer (module -1 construction !)

2. Chile: KUKA robot will be used for graphite spraying for module-0, can also used for X-ray testing completed chambers (gain uniformity)

MicroMegas: On the way to module-0

Module-0 construction is major project milestone for 2015, together with start of series production

- on the critical path
- A little behind the sTGC

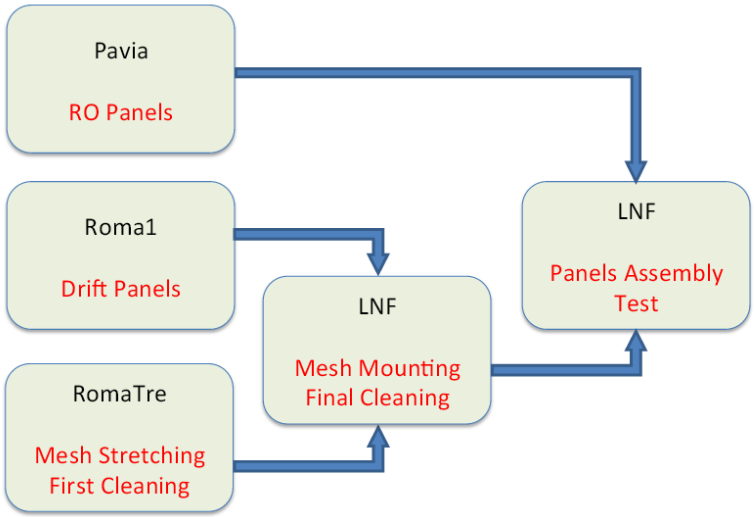
Module-0 Materials and Components:

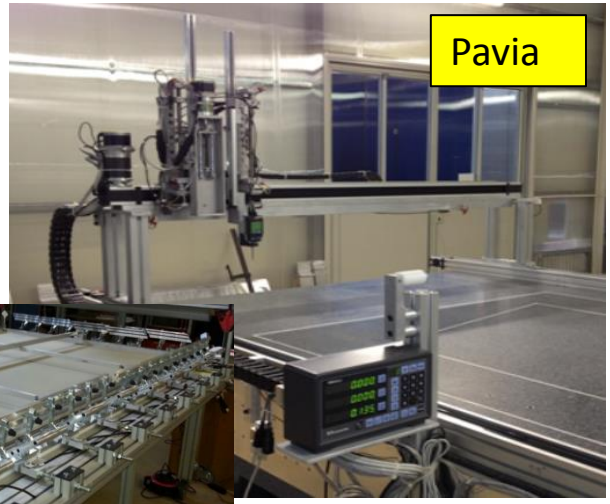
- Components all ordered, mostly before Xmas, few things just after Xmas
- About 2/3 received, last will be the readout PCBs in May

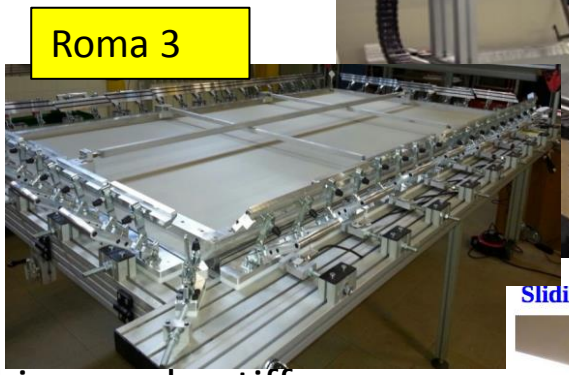
- Resistive foils
  - For SM1 module produced in Japan by Matsuda Screen Inc., successfully passed QA/QC tests at Kobe (→ talk by Atsuhiko this morning), shipped to CERN
  - For SM2 module produced in Japan by Raytech and Be-Sputter Ltd. By carbon sputtering technique, successfully passed QA/QC tests at Kobe (→ talk by Atsuhiko this morning), shipped to CERN
  - LM2 foils supposed to be produced in-house at CERN but some unexpected delays with the building → just now ordered in Japan
  - LM1 foild will be produced at CERN

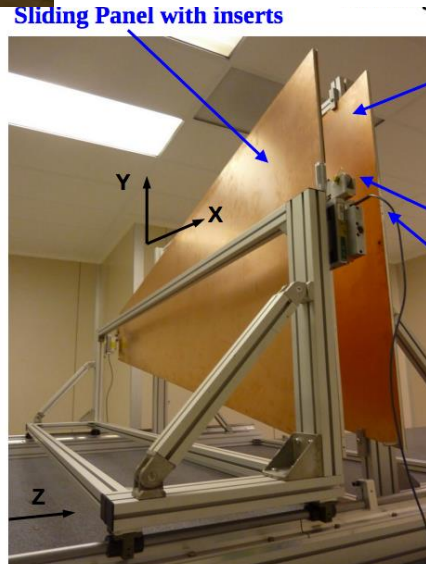
MicroMegas: Construction Sites

- Most advanced overall INFN Italy – expect module-0 completion by end July









Frascati

- Pavia: Granite table recertified, gluing machine ready, stiff backs and reference plates for precise placement of readout PCBs ready midMarch/end April
- Rome 3: Mesh stretching setup ready and operational
- Rome 1: use same glue dispenser as Pavia, ready end March
- Frascati: Lead in design of assembly tool for all construction sites, will be ready in June

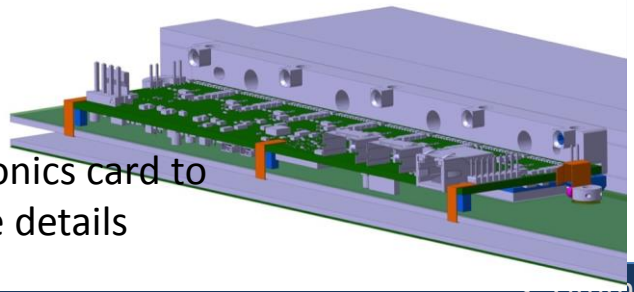
MicroMegas: Construction Sites

CERN

Vacuum table production ongoing

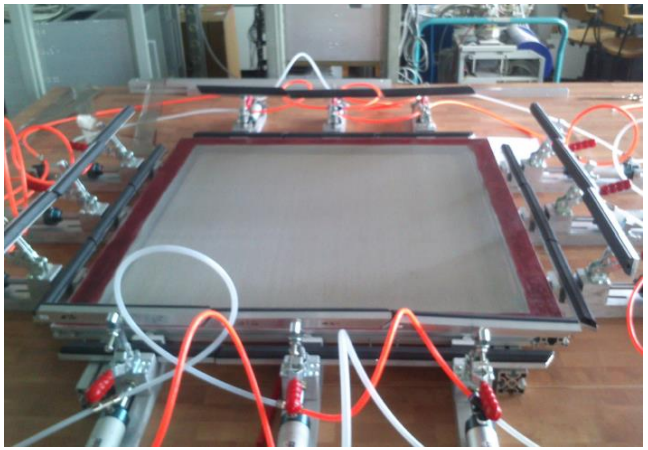
Mesh stretching setup ready

Studies for electronics card to detector interface details

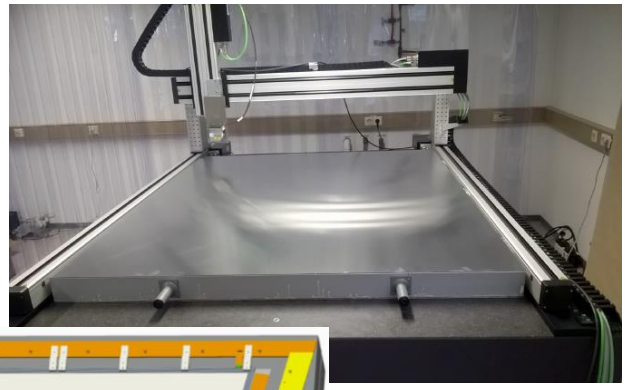


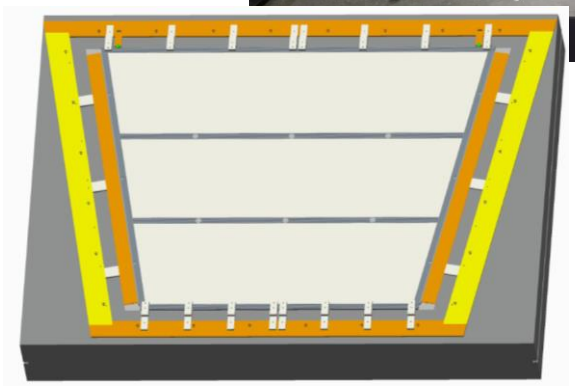
Germany

Mesh stretching procedure established, full complement of clamps ordered



Full size stiffbacks glued





Positioning method for the readout boards established

Saclay: start mod. 0 only in autumn

Conclusions & Outlook

- 2014 and first 2 months of 2015 saw enormous progress in all areas of the NSW project
  - Successfully passed the Preliminary Design Reviews for sTGC and MM chamber construction (July 2014)
  - Successfully passed the Preliminary Design Review for the NSW JD and Mechanics (Sept 2014)
  - Went through the Preliminary Design Review for the NSW Electronics ad Trigger Processor (Feb 2015)
  - Went through the Design Review for the NSW Alignment and Production Readiness Review for Alignment Bars (March 2015)

- 2015 remains a critical year
  - Module-0s
  - Start of mass production for sTGC and MM chambers
  - VMM3 ASIC and next submission/iteration of other custom ASICs