• Forum on Tracking Detector Mechanics

ATLAS Pixel Endcap Structure

Peter Sutcliffe
On behalf of the UK/Italy ATLAS Pixel Groups
17th June 2019
• ATLAS up and running (LHC) since 2009
• LHC Phase-II shutdown (~2025): upgrade to higher luminosity
  → higher radiation, hit rates and occupancies. Further ~10 years running
  → Tracker must be replaced

Current ATLAS tracker: Si pixels, Si strips, straw tubes (TRT)
Inner Tracker (ITk) Envelope Model v1.7
https://edms.cern.ch/document/1905419/1.7
AT2-IC-EP-0001 v.1.7

For Discussion

Modifications:
- Strip Layout updated - NEEDS TO BE VERIFIED.
- Pixel Layout Version v143.
- Middle part of the Pixel Support Tube is now part of the Strip Barrel Detector.
- Length of the Strip Moderator is changed from 800mm to 1200mm.
- Max Z coordinate of the Outer Type II Services Volume is shortened by 5mm from 3510mm to 3505mm.
New Endcap Model

- 9 outer half rings R294.7
- 8 middle half rings R234.65
- 10 inner half rings R174.6

Outer Pixel Layers
3 Layers

Pixel Support Tube

Beam Pipe

Inner Support Tube

Lightweight Pixel Endcap Support Flanges

Half rings

Heavyweight Pixel Endcap support flanges

Last half rings Z=3000

1879mm
16-26 pixel detector modules (approx. 4x4 cm$^2$) per half-ring

16-20 half-rings per layer, assembled into half-shells, with services

half-shells are put together into a complete endcap

P. Sutcliffe

F. Gannaway
Ring Details

The half-rings are Carbon-fibre/carbon-foam sandwiches

- One row of modules per ring
  - Phi overlap achieved by alternating modules front/back
- Embedded bus tape and cooling pipe; electrical isolators on pipe
  - Pipes are Titanium OD 2.275mm, wall thickness 160μm
  - evaporative CO₂
- Electrical patch cards on surface to transfer power, slow controls and clock/commands to modules via bus tape
  - Shown conceptually in blue/red
  - No data on bus tape, assume data cables will connect directly to modules
- Each half-ring layer is fixed to a supporting half-cylinder

26 Modules outer
22 Modules Middle
16 modules Inner
• Core of the half ring is made from Allcomp carbon foam and made up of tiles
  • Minimise waste
  • Easy to machine flat

Julian Freestone, Manchester
Cecilia Rossi Genoa
Tiles sent to Liverpool to be co-cured onto 3 layers of K13C2U/EX1515 90,0,90
Vacuum plate fixed to CNC machine bed. Axes set to reference holes.

Machining order:
1. Skim to thickness
2. Mill outer profile
3. Mill cut-outs and ends
4. Mill groove

0.089” Carbide ball-nose end mill
• Mounting lugs (not glued yet) hold disk and aid with alignment of other half.
• Coated veil pieces laid onto one half of disk.
• Coated pipe aligned with groove and gently pressed in place.
Joining two halves

• Other half eased onto first half, pressing pipe into its groove.
• Perspex load spreader placed on top.
• Short PVC tubes protect pipe ends from damage.
• Bag press closed and vacuum applied until glue cured.
- End close-outs and mounting lugs glued into place.
- Aligned by dowel pins on machining/assembley plate.
Thermo/Mechanical FEA

• FEA shows the half ring deformation is within the accepted limits of 3µm/°C in Rφ
• Current work at Genoa is looking into actual deformations

Mauro Monti, Simone Coelli
I.N.F.N. MILANO
• Stresses are shown to be quite low, even for carbon foam
Half cylinders

- Half cylinders are manufactured as a co-cured item with the end flanges.
- Material M55J/LTM110 80gsm
  - Layup 90,45,-45,0,0,45,-45,90 0.62mm thick 90 gives the greatest axial stiffness
- Several test half cylinders with different layups were manufactured and this proved to be the most stiff.

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Manufacture of Half cylinders

- Prototype of the outer layer
- Manufacture a female ‘plug’ from tooling block.
- Manufacture a CFRP male tool from the female.
- Manufacture a 62cm long half cylinder.
- Use the same system for a full size half cylinder
Half cylinder cure technique

- Layup the half cylinders and end rings in one piece.
- Cure in one cycle
Male mold tool

- First tool (plug) manufactured from tooling block

Peter Cooke and the advanced composites lab, Liverpool
The next stage is to layup the carbon weave to make a male tool.

- Mould Tool Lay-up in Tencate HX42 Tooling Prepreg 205gsm
- Cutting pre-preg on the pattern cutter
- Laying up the pre-preg
- Vacuum bagging ready for the autoclave
Mould tool preparation

- Mould tool complete, manufacture end flanges
  - Cured Mould Tool ready for Post Cure, finishing, sealing and releasing
  - Cured end sections for Pre-forming end flanges
  - Lay-up of Outer Pressure Plate in Tencate HX42 directly onto Mould Tool
  - Parts on Pattern Cutter for Cylinder End Flanges – Tencate EX1515 M55J 80 gsm
  - End Flange Pre-forms removed from Formers
  - Cylinder End-flange pre-formed on Former prior to lay-up on Mould Tool
Mould tool preparation

- **Half Cylinder layup**
  - Half Cylinder Lay-up Tencate EX1515 M55J 80 gsm
  - Half Cylinder lay-up including End Flange pre-forms
  - Half Cylinder Lay-up ready for cure, complete with pressure plate
  - Following cure, Half Cylinder removed from Mould Tool
  - Complete Half Cylinder ready for deburring and cleaning
On Cylinder Components

- On cylinder components
  - Currently manufactured from ULTEM 1000
  - This maybe under review as it may suffer long term creep.
  - Carbon impregnated PEEK or ULTEM has shown to suffer creep less.
- These parts will be part machined, and finished when the radius of the half cylinder has been measured
• All the services run between the half cylinder and the half ring.
• The layout shows how tight everything is
Layer 2 Services

• The worst case is the inner services

Fred Gannaway QMUL
MAGENTA Twin Ex Cables = Rings 1,2,3
GREEN Twin Ex Cables = Rings 4,5,6,7
BLUE/GREEN Twin Ex Cables = Rings 8,9,10,11
BLUE LV Cables
RED HV Cables (very small inbetween LV cables)
Endcap cooling

- Endcap cooling is by CO\textsubscript{2} at around -35°C
- Manifolded inlet and exhaust and the inlet has a capillary
- We are considering 3d printing, Ti CP2, and welding the high Z manifold to the inlet/return tubes
  - Recent current prototyping is very encouraging and will be ongoing.
• The tubes are 2.275mm diameter x 0.16mm wall
• Each tube is ‘sleeve welded’ using an orbital welder, Swagelok or similar.
• This technique has been perfected at Sheffield.
• Sleeve weld concept allows a full spigot for the tube and provides an integral weld filler
  – This means the gas flow can be easily controlled and improves the weld quality and repeatability for
    the many 1000s of welds needed for the ATLAS upgrade
• Welds can be tested at any stage using the Sleeve Weld De-Mountable Test Fitting or ‘Fred Fitting’
• The tubes are 2.275mm diameter x 0.16 wall
• Each tube is ‘sleeve welded’ using an orbital welder, Swagelok or similar.
  – Ours is a VBC IP50
• This technique has been perfected at Sheffield.

Paul Kemp-Russel, Sheffield
There is a requirement in the ATLAS tracker to isolate the local supports (the ones that support the pixel detectors) and the global supports (half cylinders). This is for grounding and shielding.

The isolator comprises of two CP2 sleeves with an alumina ceramic break vac brazed in-between with silver/copper braze.

The latest samples have been passed by CERN.
FE Analysis - static deflections Oxford University K. Arndt, S. Yang

1. Full cylinders, total deflection: 0.029mm, gravitational sag: 0.025mm

2. Half shells connected at 3 positions along the seams, total (localized) deflection: 0.137mm

3. Half shells with no connection along the seams, total deflection: 0.57mm; gravitational sag is 0.47mm.
Components needed

- 3+3 shells populated with at least 3 half rings per shell.
- First generation of power harness and data harness in the shells.
- 1st generation of half-shell installation tooling

Dario Orecchini, Sandro Tomassini
Frascati
One **full scale** sector prototype @ LNF

**Goals:**

- Focus on routing of the cables along the cylinders, to the half rings, through the flange, to PP1 and through the PP1 feedthrough.
- Focus on piping, pipe welding and cooling manifold integration.
- Develop and test the assembly tooling.
- Train people to integrate the half rings in the cylinders.
- Train people to integrate the half shell in the Endcap.
- Focus on interfaces (PP1 vs Bulkhead, IST, IPT).

Dario Orecchini, Sandro Tomassini
Frascati
Summary

• Current mechanical design is getting final and is at the detail design stage
  – Local supports PDR is complete
  – Services are shown to fit in the tight space!
• Prototyping is well underway in all areas
• Endcap integration is at an advanced stage

Thank you for listening!