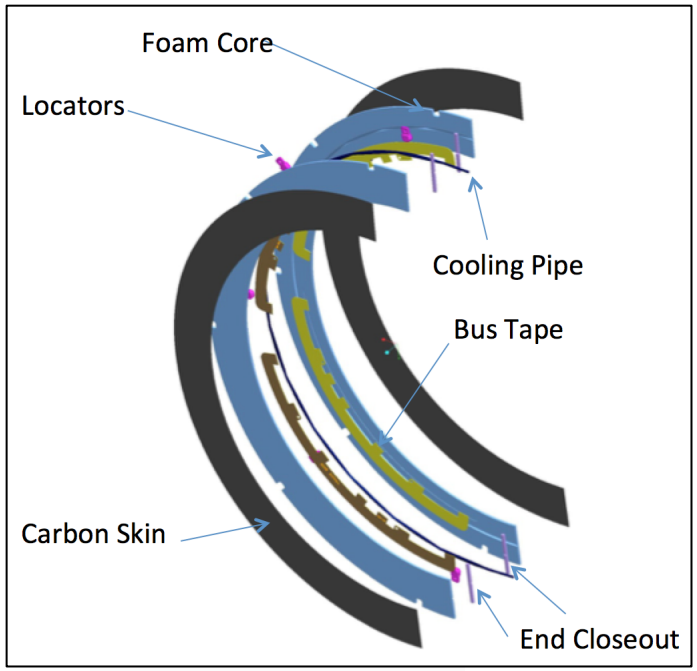
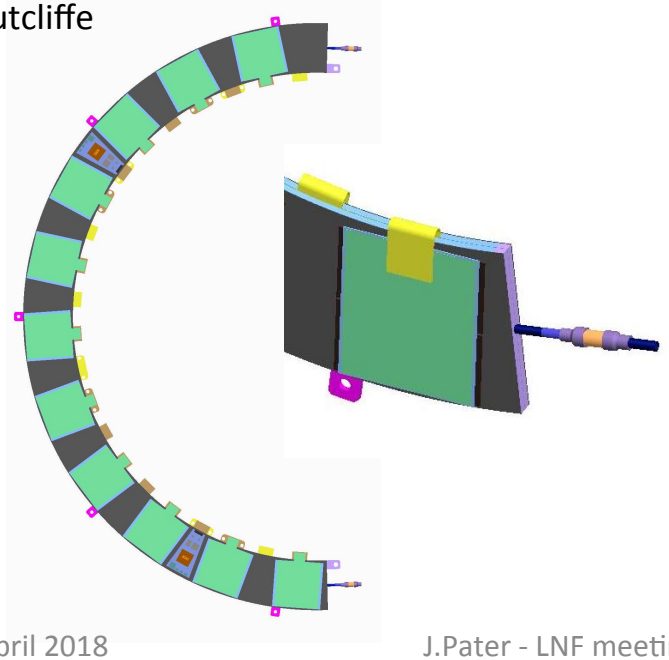
Outline

- Ring design
- Ring production procedures, tooling, quality control
- Handling frame design and functionality
- prototypes and testing



P.Sutcliffe



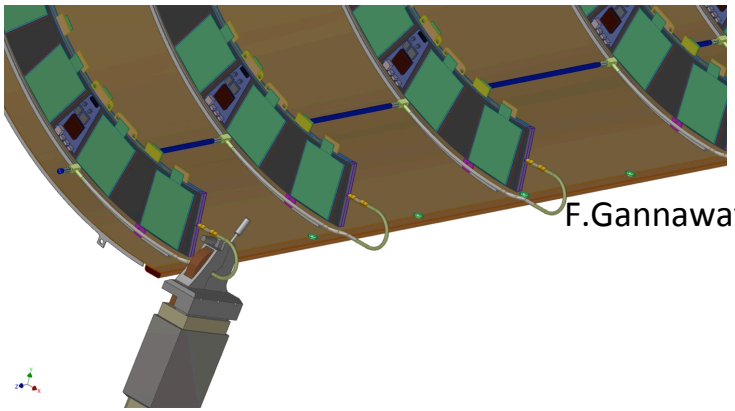
Half-Ring Design

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

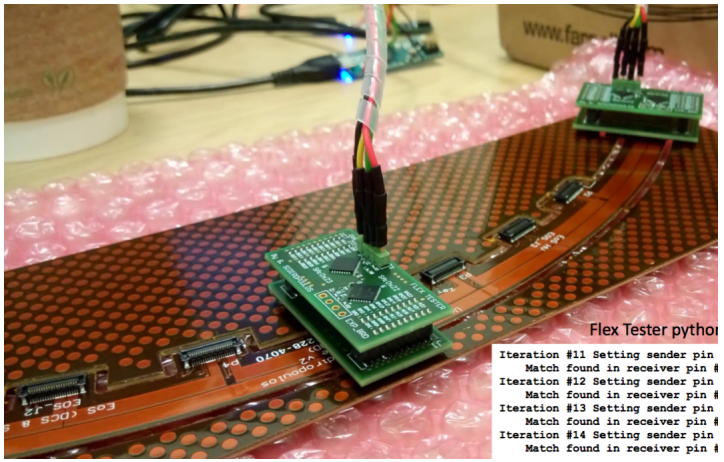
- One row of modules per ring
  - Phi overlap achieved by alternating modules front/back
- Embedded bus tape as baseline
  - alternate suface-mounted tape under consideration
- embedded cooling pipe; electrical isolators on ends
  - Pipes are Titanium OD 2.275mm (possibly moving to OD 2.5mm)
- Electrical patch cards ("EoS cards") on surface to transfer power, slow controls and clock/commands to modules via bus tape
  - Shown conceptually at left in blue
  - No data on bus tape, data cables will connect directly to modules

On-Ring Services

- Cooling pipes:
  - Once cut, bent and welded (including electrical breaks and fittings) the pipes will be pressure and leak tested:
    - test pressure 186 bar
    - helium leak test 10^{-6} mbar l/s
- Bus tapes:
  - produce in industry
  - thoroughly test in ITk institute(s)
  - automatic test kit under development (see photo)
    - continuity
    - shorts
    - leakage
    - mating cycles (QA)
    - …
- EoS cards
  - produce in industry
  - full functionaltiy tests in ITk institute(s)
  - test kit in early stages of development



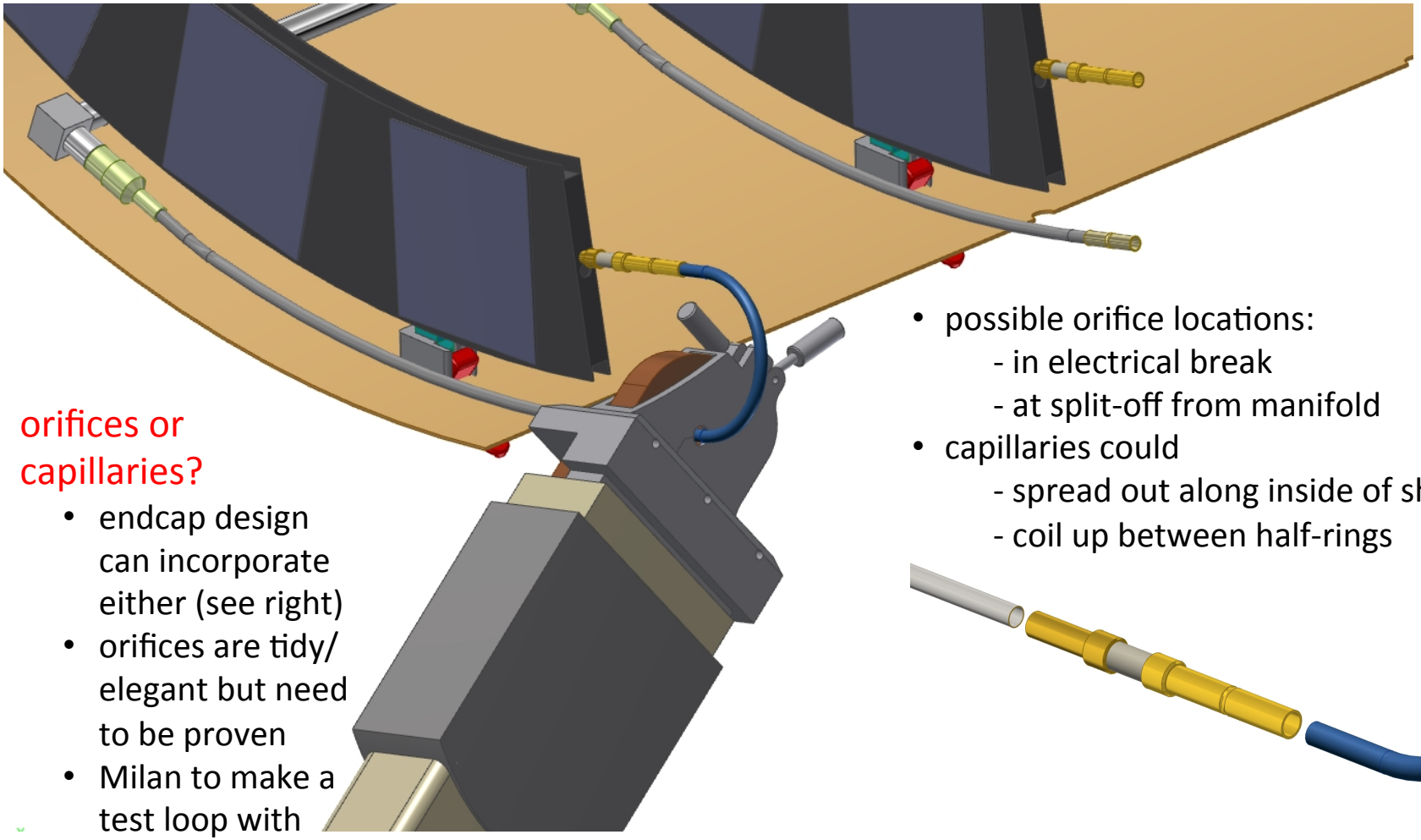
F.Gannaway



J.Stuart, B.Masic

Return Loop Orbital Welding
(F.Gannaway, S.Edwards, R.French)

Queen Mary University of London



orifices or capillaries?

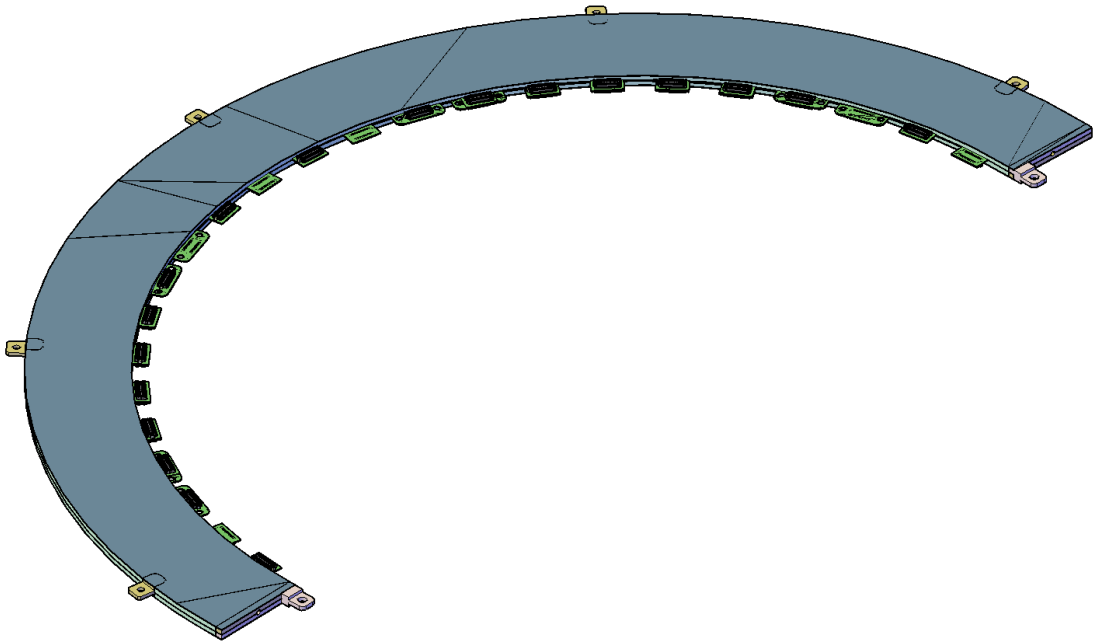
- endcap design can incorporate either (see right)
- orifices are tidy/ elegant but need to be proven
- Milan to make a test loop with orifice for study at cern

- possible orifice locations:
  - in electrical break
  - at split-off from manifold
- capillaries could
  - spread out along inside of shell
  - coil up between half-rings

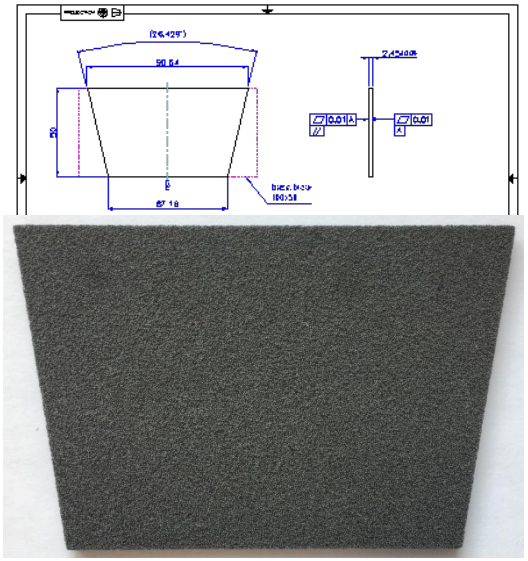
Welding of Ring and Manifold – see backup slides

Middle Half-Ring Construction in UK

(Julian Freestone, Manchester)



Parts:



Allcomp Foam

12” square x 1” slab. [0.19g/cm^3] machined into 4.5mm thick wedges in Manchester University physics department workshop.

Need 18 trapezoid tiles per half-ring.

Tiles sent to Liverpool for pre-assembly onto face-sheets.

Face sheets: 3 layers of K13C2U/EX-1515 pre-preg. 45 g/m2

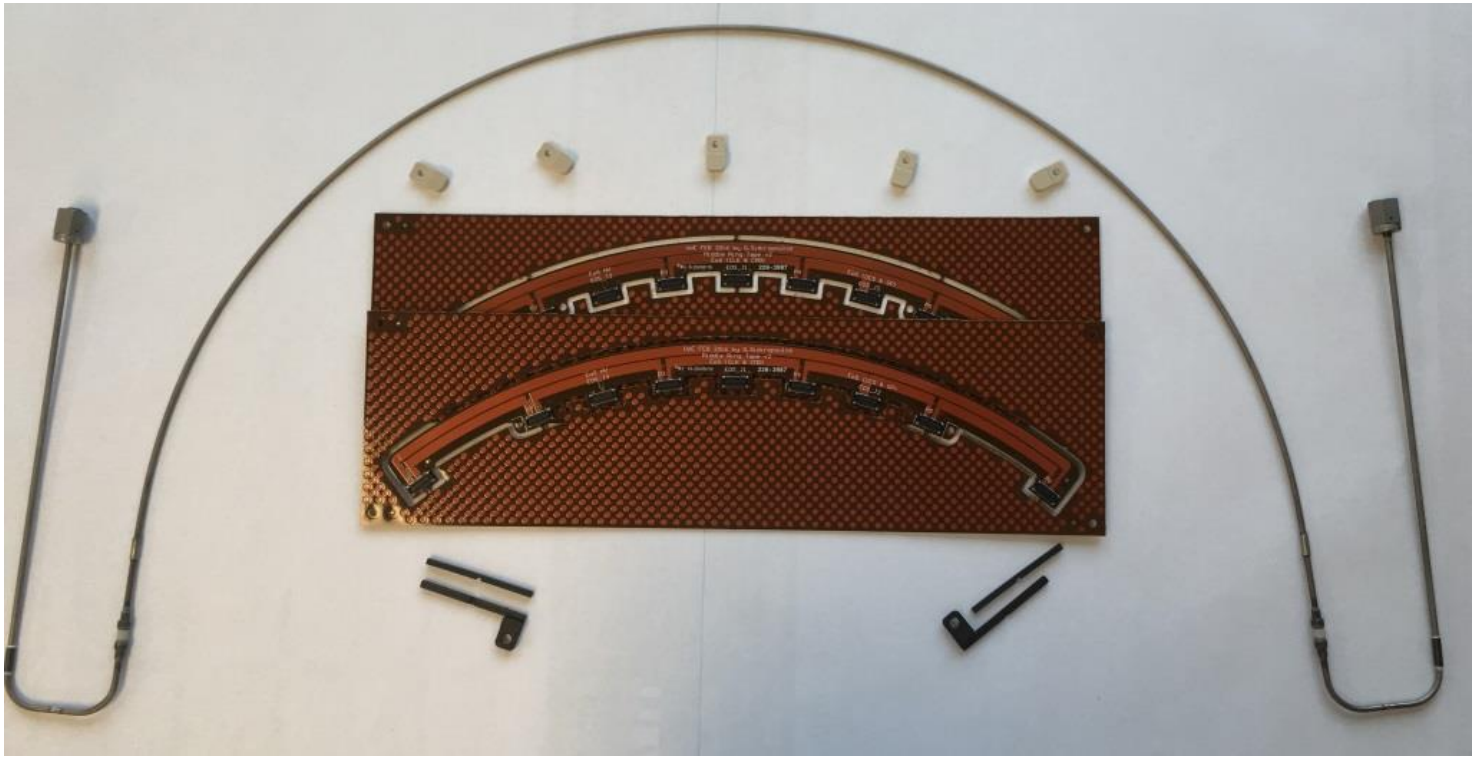
Layup: 0-90-0

resulting facesheet is ~0.15mm thick

9 foam tiles per arc are temporarily taped onto cut pre-preg sheet.

Co-cured on flat plate.

Assemblies returned to Manchester for machining.



Cooling Tube (Lancaster, Sheffield)

2.275mm O/D fitted with connectors and electrical breaks (Lancaster, Sheffield).

(odd shape pictured is due to having recycled electrical breaks. To be replaced with correct shape.)

Power Tapes (Edinburgh)

Connectorised, in production plates. Need some trimming.

EoS cards: LV, HV, NTC (Manchester, Edinburgh)

Simple pass-through designs for connection to bench supplies and NTC readout

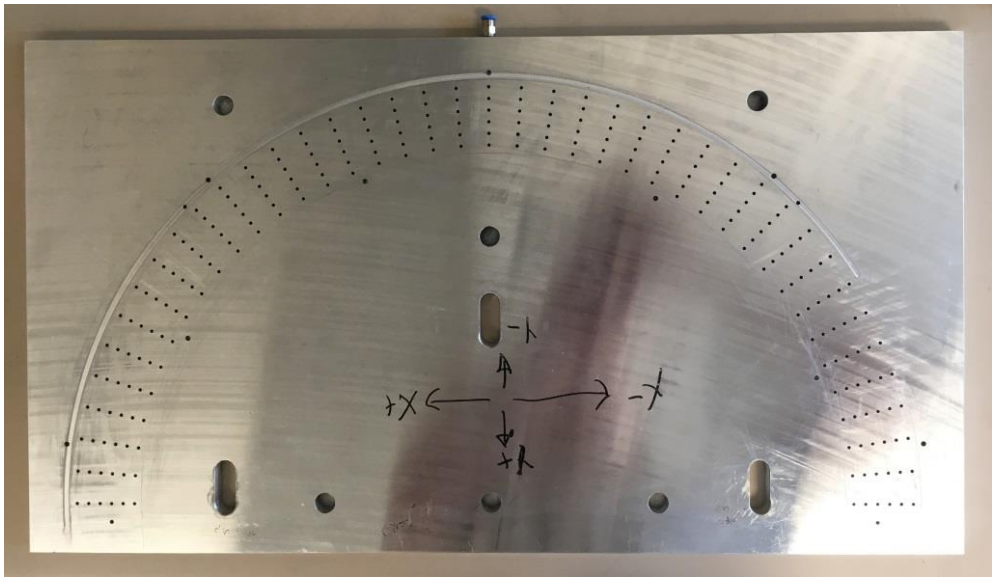
Closeouts and Mounting Tabs (Liverpool)

Batch production

Tooling:

Vacuum Machining/Assembly Plate

Flat plate with vacuum channels for machining disk profiles.
For precision assembly has holes for dowels to locate mounting lugs and power tapes.



Vacuum ‘Bag’ Press

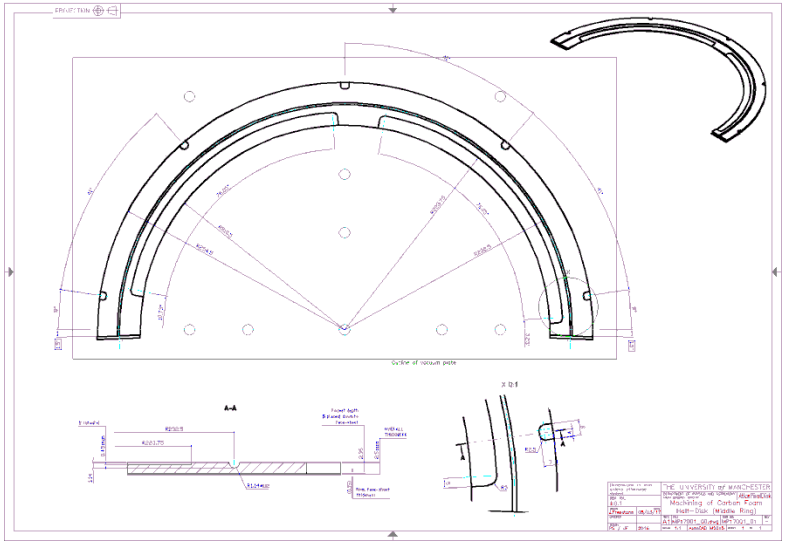
To press parts together whilst glue cures.

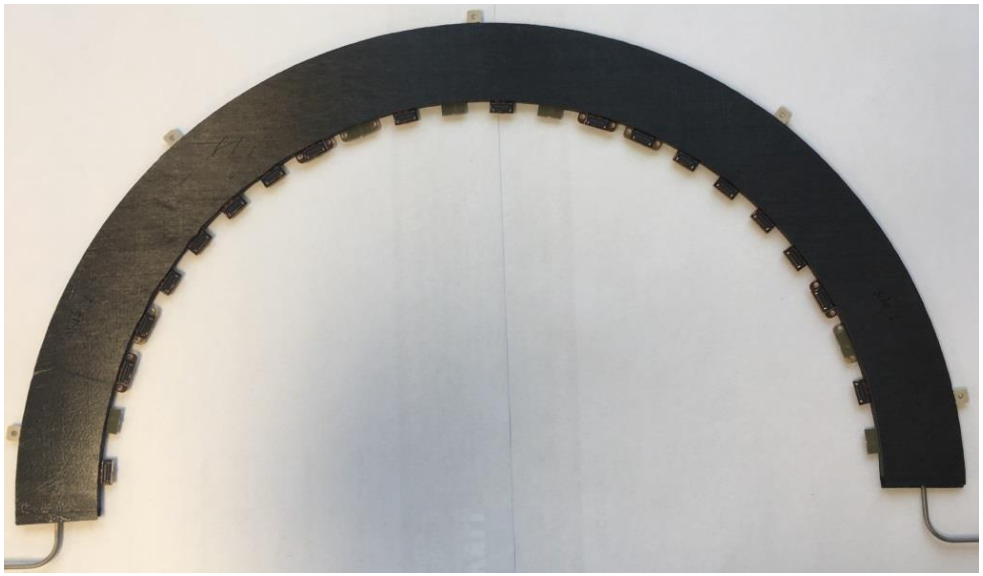
Construction:

1. Machine both half-ring faces flat and to uniform thickness. Machine recesses for tapes, pipes, mounting tabs, edge closeouts.
   2 days, Manchester workshop

2. Glue tapes into both faces, allow to cure
   1 day, Manchester engineer/technician

3. Final assembly: apply glue to foam side of both faces, locators, closeouts and pipe. Align and press together. Allow to cure.
   1 day, Manchester engineer/technician





Total Elapsed Time
About 1 week including preparation, cleaning, etc..

Half-Ring Handling and Transport

half-ring assembly site → module loading site → endcap assembly site

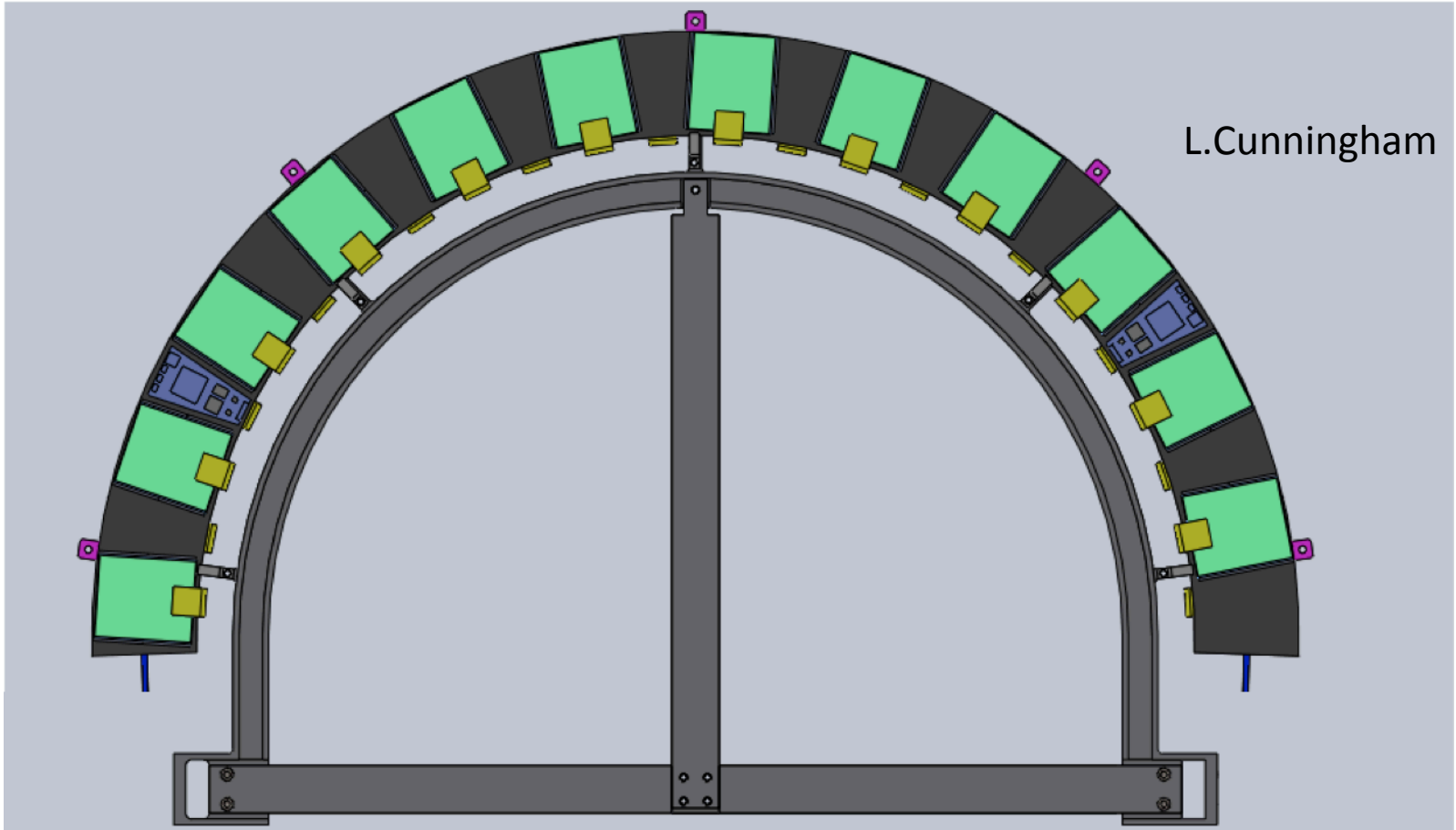
- Completed half-rings will travel in bespoke frame and box
  - To include shock logger and indicator dessicant
- Frame/box is multi-functional:
  - will include electrical-test patch cards + cooling and gas-flush capability
    - (pipe shape shown is not to baseline design)
  - frame is part of endcap assembly tooling – see next slide

Half-Ring Handling and Transport

half-ring assembly site → module loading site → endcap assembly site

- Completed half-rings will travel in bespoke frame and box
  - To include shock logger and indicator dessicant
- Frame/box is multi-functional:
  - will include electrical-test patch cards + cooling and gas-flush capability
    - (pipe shape shown is not to baseline design)
  - frame is part of endcap assembly tooling – see next slide

Half-Ring Handling and Transport



Outer ring removed and stiffening supports inserted. This has straight edge to be used as part of the insertion tooling.

Assembled Half-Ring QC

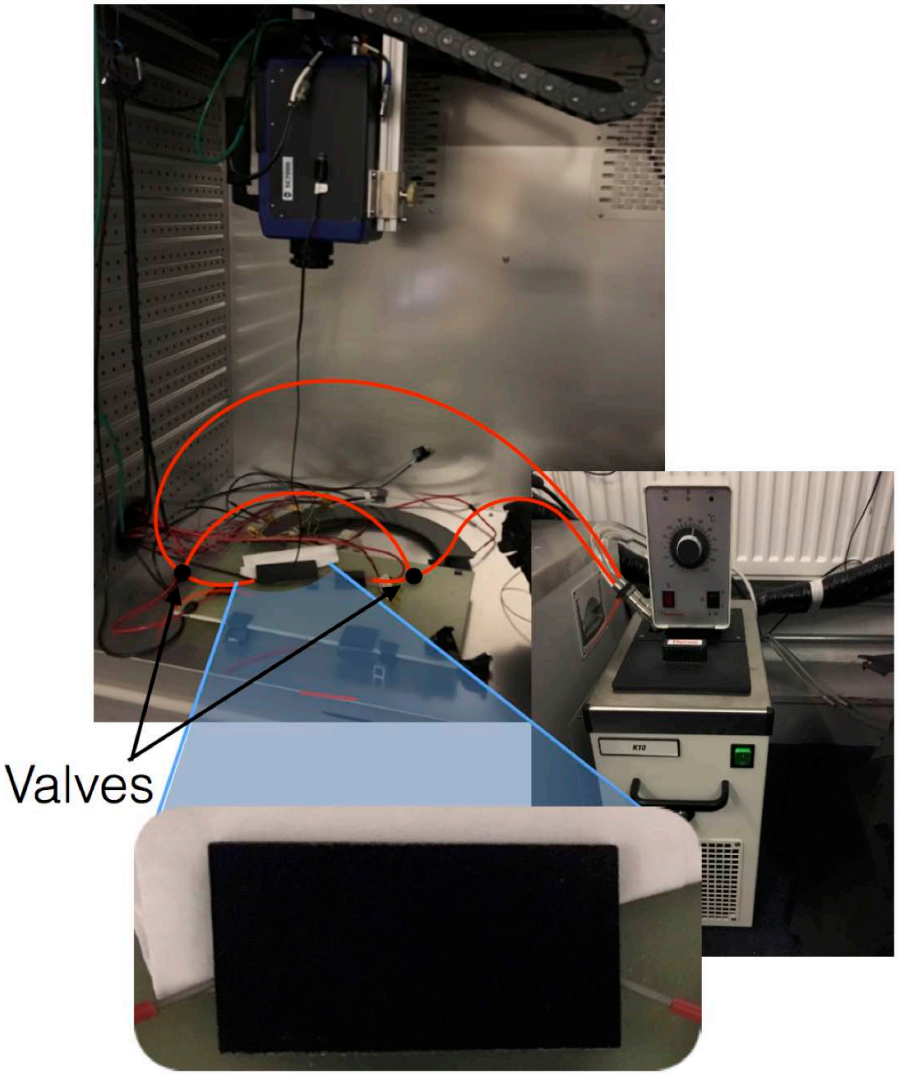
1. Thermal defect search with infrared video camera
   - see following slides
2. Pressure cycle. Suggested:
   - once to 186bar then many to 100bar
   - motivation: expansion of pipe may degrade foam-pipe interface
     - NB this should be better understood at prototyping/QA level
3. Repeat thermal defect search
4. Temperature cycle over specified operational temperature range (currently -55^{o}C→+60^{o}C)
5. Repeat thermal defect search

NB full-half-ring defect scan may be labour- and time-intensive making three repetitions impractical. May be scope here to streamline based on experience.

Bare Endcap Rings Thermal QC

F. Munoz-Sanchez, N.Scharmberg

- **A method to identify defective rings before being populated with modules is under development showing promising results with half ring prototypes**
- **Setup:**
  - **Climate Chamber (T,RH monitoring)**
  - **FLIR camera (fast video)**
  - **Chiller —>CO2 (production)**
  - **Test structures and prototypes**
  - **Pt sensors inlet and outlet**
  - **Valves for instant cooling**

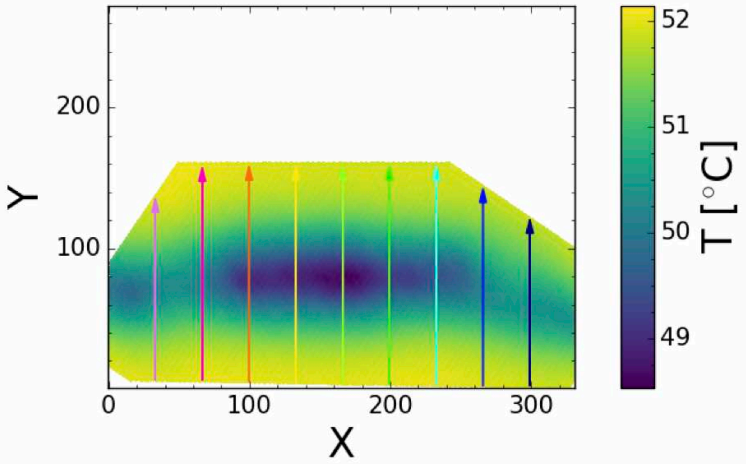


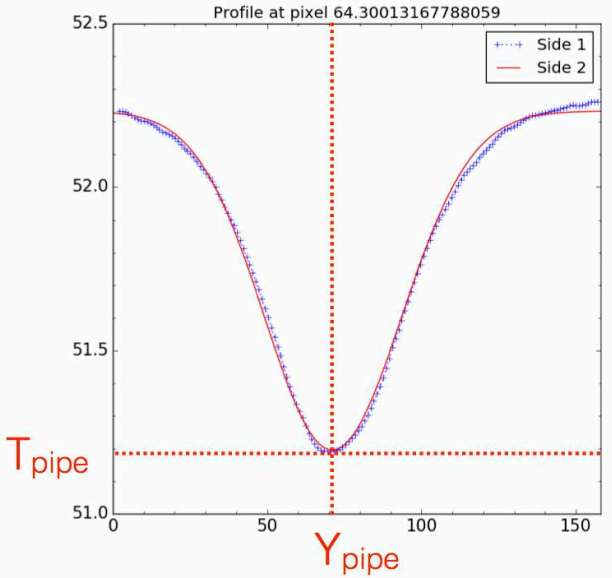
Software development

- Extract temperature profiles along line perpendicular to the pipe
- Profiles have “gaussian” distribution:

$$f(x) = \begin{cases} a \cdot \exp\left(\frac{-(x-\mu)^2}{2\cdot\sigma^2_{\text{left}}}\right) + b & \text{for } x<\mu \\ a \cdot \exp\left(\frac{-(x-\mu)^2}{2\cdot\sigma^2_{\text{right}}}\right) + b & \text{for } x>\mu \end{cases}$$

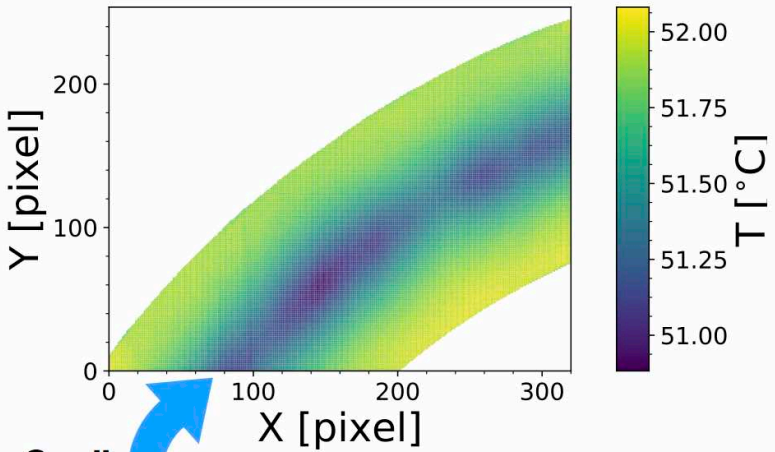
- Parameters are sensitive to different defects:
  - **Minimal value (a+b):** Temperature on top of the pipe.
    - Defects on top of pipe
  - **Mean (*μ*):** Pipe position
    - Misalignment of the pipe
  - **Standard deviation (σ):** Cooling capacity perpendicular to pipe
    - Defects misaligned with the pipe



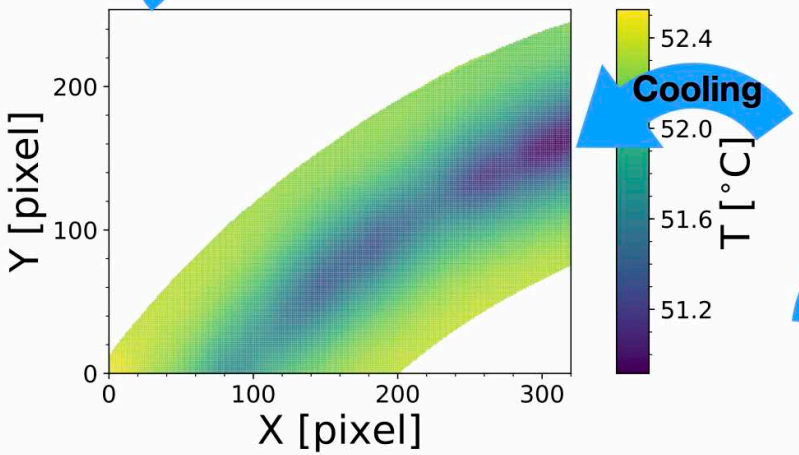


Application to Prototype with known poor thermal performance

Work on going



Cooling

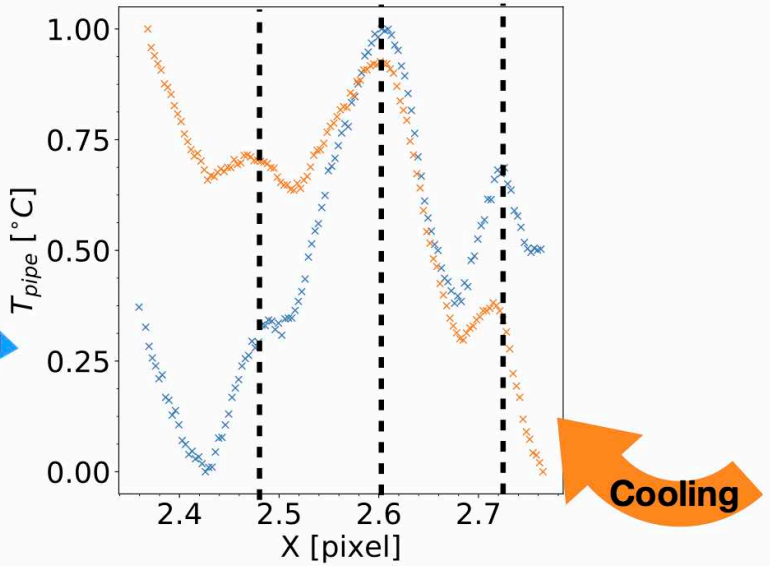


Cooling

Cooling

- Pattern recognition works
- Cooling direction gives slope to temperature
- Multiple defects: visible in either cooling direction

  ➡ Combine multiple measurements at different positions

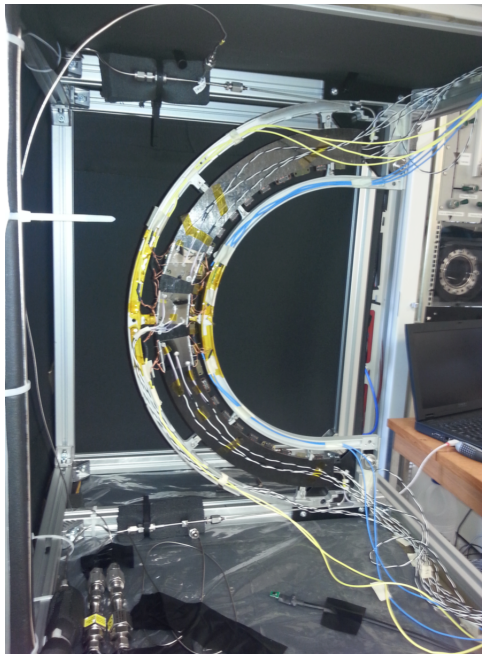


Cooling

A bump in the Tpipe distribution along X show defects

Prototypes - made

- three inner (R2) rings
  - two with bus tapes (old design)
  - used for preliminary deformation measurements, TFM
  - facesheets were cured separately and glued to foam → poor thermal performance
- so far two middle (R3) rings
  - first was used for TFM measurements (results were near spec), now going to Milan for thermal deformation work
  - second was thermally cycled but glued pipe fell apart
  - third is in production (see next slide), intended for electrical tests with modules



Prototypes - planned

- "Ring-0" currently being produced (cf earlier slides this talk, from Julian Freestone)
  - for electrical tests with up to 12 FEI4 quads
  - middle layer (R3)
  - 2.275mmOD Ti pipes, electrical breaks, removable CO2 fittings
  - embedded FEI4-style bus tapes (4 tapes each serving 6 modules), pass-through versions of EoS cards (to connect to bench power supplies)
- near future:
  - three more R3s planned for April-May-June
  - 3-4 inners (R2) planned from July
  - all will be used for TFM measurement, QC development
  - some to go to Liverpool for assembly tooling/procedures preparation

Key Dates

- 06/04/2018: Specifications Reviews
  - Local Supports, Services
- 23/08/2018: Preliminary Design Review
  - include results from preliminary prototypes
  - start producing final prototypes. how many of what type is not clear, JP to discuss with DG. Should share the work Italy/UK.
- 30/05/2019: Final Design Review
  - check performance of final prototypes
  - start pre-production (6 rings i.e. 2 of each type?)
- 13/11/2019: Production readiness Review
  - check pre-production rings
  - start production: 20/16/18 R2/R3/R3
- 16/03/22: production complete