LHCb Mighty Tracker MP - Road from Prototypes to Production

Meeting Minutes

Date / Time	9 November 2026; 12:32–14:16
Venue	Online - https://indico.cern.ch/event/1750621/
Attendees	Sebastian, Klaas, Atanu, Alex, Oscar, Mike, Ksenia
Apologies	Stefano, Marco

Purpose

Informal brainstorming, led by Sebastian, on how to get from the current prototypes to a design and production organisation ready for production. It responded to an email from Stefano asking how the collaboration gets from today's prototypes to a fully working stave that is as close as possible to the production staves.

Summary of Discussion

1. Ongoing projects

- **Carbon-foam bare stave (Manchester, with Liverpool):** Metrology and thermal properties, with electrical heaters in place of modules and a simplified loading procedure.
- **Honeycomb stave (Freiburg and RAL):** Mechanical properties, stave loading procedures and handling tools. Atanu clarified that RAL's prototype is also honeycomb because it is cheaper, with the aim of learning precision module loading, and that foam would follow later. Tooling adjustments for different thicknesses are expected to be small, and peripheral items such as edge closure will be added over time. Ksenia confirmed that Freiburg also plans to populate its honeycomb stave. A true full prototype with real sensors was regarded as a future project.
- **Module assembly centres (Liverpool, Bonn, RAL, Manchester):** Process development and precision sensor placement.
- **Glue studies:** Properties and radiation hardness of the candidate adhesives.
- **ATLASPix3 mini-stave (Edinburgh, Liverpool):** A PCB carrier with a five-sensor module and up to three modules, for early experience in multi-chip operation, serial powering and readout before Mighty Pix2 is available. Operating a larger HV-MAPS system has little precedent, so surprises are expected. Atanu noted that RAL has the real flex for Mighty Pix2 and will start with one chip on a carbon-fibre stave, but multi-chip readout (Mars, Gecko, MiniDAQ) needs parallel DAQ development. Klaas reported that Mars readout with four data links per chip

works from firmware to Python, that more links are being added (up to about 20 in total, possibly at reduced rate), and that extra manpower has joined in Bonn. Details were deferred to the workshop next week.

2. Items still missing

- Stave grounding is largely ignored so far; a copper mesh in targeted places of the co-cured stave and a Kapton layer for HV insulation were mentioned. Kapton insulation is easier on the bare stave than on the chip back, so it may belong to bare-stave production (co-curing was suggested).
- Funding and test procedures for the cooling.
- The production procedures themselves, which must be defined by the R&D projects. The Freiburg/RAL and Manchester stave-making approaches are similar but not identical.
- A common specifications document (Sebastian's Overleaf draft) needs input from everyone.
- The list of tasks and a rough roadmap (for example a project-planning chart) should be kept in parallel.

3. Harmonising production across sites

- Sebastian wants production as uniform as possible between sites, ideally with identical tools developed at one institute and distributed (as done for SciFi), and uniform QA. Atanu and Klaas disagreed for module production: sites already own different pick-and-place machines and procuring identical ones is impractical. Agreeing on specifications and QA/QC criteria for the output (stave and module grades) is enough, and Mighty Tracker precision requirements differ from SciFi (sensors are aligned in the beam). Sebastian accepted this for pick-and-place but keeps his view for stave tooling and notes that manual steps such as gluing will vary anyway. Alex said he changed his mind towards Sebastian's view during the meeting; the discussion on tool production and number of sites continues by email.

4. Milestone project and tests

- A proposed milestone is a full stave with one quarter populated with sensors (the basic electrical unit) and the rest with heaters. Atanu said a MiniDAQ offers 48 + 48 fibres, of which about 40 are usable, and a full stave could need up to 12×4 links. The HDI count is the real limit at the moment, so read-out would first cover roughly one column.
- Electrical scaling should be staged from one module to three in a column and then to nine, a full serial-power chain, with fewer chips per module at first. A full stave dissipates about 180–200 W, with 35 modules, so powering, slow control, monitoring and cooling are demanding. It is still to be defined what is mandatory and what is nice to have.
- Atanu proposed a pre-production test of two or three staves side by side for grounding and coupling, and a permanent slice-test facility at CERN (cooling, powering, DAQ, space in the surface hall or clean room) for the layer test and later re-commissioning.

Sebastian noted that space is restricted and that UP needs similar space.
- Open handling questions: transfer and installation frames, and features on the stave needed only for handling, which couples the stave design to the tooling.

5. Tasks of the production centres

- **Sensor and wafer testing:** Wafer-level testing, plus picking of thinned and diced wafers. This is manpower intensive, and nobody has yet taken it into account. Tape-off is needed within about two weeks, so an intermediate step before pick-and-place is likely, followed by a post-picking test. Klaas will try integrating a tape-stretching machine in Bonn with a pick-and-place machine.
- **Module centres:** Assembly, metrology, electrical and thermal tests, and removal of test wire bonds. Klaas and Atanu stated that removing a bad sensor from a module must be possible, otherwise yield is lost (all five sensors); with Loctite the glue releases from the Kapton side and stays on the silicon, and a tool is needed to push the chip sideways and peel it off.
- **Bare-stave centres:** Cooling pipes, grounding, support structures and inserts, and edge sealing with glue to avoid carbon dust (a time-consuming manual task that should be done by the bare-stave site before the stave leaves). Quality control with metrology, thermal tests and gas tightness. Alex noted that a test site needs a cooling plant (blow-off or recirculating), manifolds and a thermal enclosure; two plants and several boxes exist. Sebastian considers this production step ("sparse" in the captions, presumably bare-stave production) critical, as only one institute can currently do it.
- **Full-stave centres:** Whether to re-test incoming modules after transport (and so remove test wire bonds again), loading and stave QC. Ksenia argued that wire-bond removal is manageable at a site with bonding experts. Sebastian and Oscar stressed the added work and handling risk for 35 modules per stave, and the extra experts (wire bonder, test operator) in the manpower estimate. Ksenia suggested deciding on the basis of shipping tests with a few modules; Sebastian is more concerned about packaging and unpacking than shock.
- **Planning logic:** First define the number of centres needed (for example for 20 000–30 000 sensors), then the manpower and infrastructure per centre, and only then assign work to institutes. Atanu cautioned that the UK funding situation is uncertain and needs project-management discussion. Oscar suggested adding synergies with UP, such as sharing chip testing.
- **Formal steps:** An engineering design review of the final design, then a production readiness review for each site before the green light.

6. Updates and any other business

- **Bare stave status (Freiburg):** Ksenia has not yet managed to finish it, owing to repeated equipment problems and the large amount of manual work. Atanu is using an off-the-shelf carbon-fibre/Nomex honeycomb panel as a placeholder, sliced to 620 mm; this is fine for the 30-sensor column but excludes the PP0 height, so the frame pins were adjusted.
- **New glue (Oscar):** Loctite 9497, from the same family as the Hysol used for the

bare stave, is a two-component glue doped with aluminium and titanium oxides, with thermal conductivity 1.4 W/(m K) (about seven times higher than usual epoxy at about 0.2) and electrically insulating. It can be cured in a few hours at about 40 °C and is a candidate for attaching sensors to the stave; samples will be tested. For the flex-to-chip layer, Loctite 5145 (single component, gummy after curing) is a strong candidate for module assembly. Wire bonding on Loctite was successful in Manchester, although a recent mini-stave test with weak hold-down gave lower-quality bonds. A PhD chapter and student reports on glue tests exist and will be shared.

- **Honeycomb insulation (Oscar):** A stack of one Nomex honeycomb layer between two carbon-fibre sheets measured 0.036 W/(m K), comparable to AIREX, and so is a promising low-material insulation-box option, with humidity trapping and edge sealing to be solved. Ksenia's student working on double honeycomb sandwiches will be put in contact. Sebastian warned that the Nomex used in SciFi was a special flame-retardant grade (to be checked, including the epoxy or resin), so flammability must be considered early.
- **Workshop talks:** Atanu will give a general module update (Bonn and RAL). Ksenia plans to present the Freiburg bachelor student's edge-definition work and may add a short stave-loading overview. Sebastian asked for general overviews that mention other groups' work.
- **Future meetings:** This is not a regular meeting. Sebastian asked for requests whenever there is something to discuss. The workshop at CERN follows next week (Atanu will join remotely).

Agreements

1. No formal decisions were taken; the discussion was exploratory and meant as input for Stefano's workshop talk.
2. Start from the production-planning sequence: define the number of production centres, then estimate manpower and infrastructure, then assign institutes. Add UP synergies.
3. Write a specifications document with input from all groups, and keep a task roadmap in parallel.
4. Send short status updates to Stefano (copying Sebastian) for the workshop.

Action	Owner
Update the slides (add the wafer-testing centres correction, number-of-sites step, UP synergies, Kapton/HV insulation) and upload them to Indico.	Sebastian
Circulate the minutes.	Alex
Contribute to the specifications document (Overleaf).	All
Share glue-test reports (PhD chapter, student reports) and the Loctite 9497 datasheet.	Oscar
Check the SciFi Nomex specification and non-flammability requirements.	Sebastian
Send MiniDAQ and HDI numbers needed for a full-stave read-out.	Atanu
Report on the integration of tape stretching with pick-and-place in Bonn.	Klaas

Open Risks and Follow-up Questions

- How to ensure uniform results across production sites with different equipment, and who develops and distributes the tooling.
- Who performs wafer picking and post-picking tests, and whether it can be automated.
- Whether incoming modules are re-tested at stave centres, and the extra manpower and handling risk this brings.
- Whether sites can run stave tests at -20 to $-40\,^{\circ}\mathrm{C}$ with about 200 W of power; this needs cooling, powering, monitoring and many experts.
- Number of production centres needed, with the UK funding situation uncertain.
- Facility for pre-production multi-stave and layer tests, and clean-room space at CERN.
- Stave grounding, HV insulation by Kapton and its production site, the gluing process and wire-bond quality on 'gummy' adhesives.