Enabling Technologies for Silicon Microstrip Tracking Detectors at the HL-LHC
WP1 "Exchange of Experience"

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The current silicon strip detector systems of the two general-purpose LHC experiments ATLAS and CMS differ in many design aspects. The aim of this work package is to exchange the experience that was collected during the different stages of design, construction and running of the detector in order to identify weak and strong points.

This report describes the key findings from the initial half-day session on the first WP ("Exchange of Experience"). This session was held in the framework of a HHA detector workshop in Mainz, with participation from a large number of international experts from both experiments.

The topics covered in the presentations included a detailed and comparative discussion of the module designs realized in the present detectors, integration reports from barrel and end-cap, and overviews of the running experience from the silicon strip systems in both experiments. A full list of the material presented is available from the event indico page:
https://indico.desy.de/conferenceDisplay.py?confId=7063

Below is a brief summary of main recommendations from the speakers, summarized by topic.

General Design Issues.

- Do not make your production chains any more complicated than necessary. It is already hard enough to deal with the logistics necessary for production in an extended collaboration with different skill sets and equipment.
- Reduce number of part types to a minimum. It is really easy to "just" add another hybrid/module/cable type to make something else easier- you will pay for this.
- Most mechanical problems could have been found earlier. It is essential to stress all components to and beyond their limits prior to the start of mass production.
- It is necessary to increase amount of parts available for prototyping, and handle them in same way as production. Put parts into final environment ASAP.
- "Babying" rare prototypes puts off finding serious issues.
- Production times always get squeezed. Need to design for peak rates that are 2-3 times higher than original plans.

- Design to allow for scalability. Some CMS facilities had to increase production rates by a factor of ~3.
- Proper failure management is important. It requires a plan to deal with any potential (critical) fault in the system. Plan the services and how they tie into the system.
- The foundations of any good design are well-defined sets of requirements and specifications, which are consistent throughout your project. These are also essential to develop meaningful QA.
- Use realistic prototyping (adequate scale, using realistic conditions and equipment.
- Aim for a coherent system development, rather than driven by components. Tim Jones: "*Choose "Integration by design" rather than "Integration by Assembly*".
- If your readout system has a bottleneck in it, it is much better if it is OFF detector rather than ON detector.
- If at all possible go with COTS solutions.

Hybrid Design.

- Keep the hybrids as simple as possible. Use novel materials only when absolutely necessary. This avoids the risk of getting stuck with single vendors which make logistics harder than necessary.
- Hybrids must be part of system level design from the start. It is too late to design them once ASIC and/or mechanics are frozen.
- Design hybrids with industry from the beginning. Use standard design rules, i.e. ask industry what would be comfortable for production of several ten thousands of parts over 2-4 years.
- Plan for volume manufacturability from the start. Don not push the technology to the limit unless really necessary. Don not use custom technology from one vendor. It makes finding alternate venders very difficult. Tony Affolder: "*If you think custom technology is necessary, think again*. "
- Include material where needed, especially ground and power. Over-constraining radiation length makes hybrid production very difficult, or even impossible. Include panel level test structures to reduce QA turn-around times.
- Be aware of reduced lifetime of smaller feature size technologies. Each new generation of ASICs is wearing out faster than previous one.

General Components (e.g. Sensors), Testing.

- Testing and operation should work under standard conditions. If non-understood conditions are needed for good operations take this as a strong sign that something is not understood, or not under control.
- Most significant issues from industry arise during the change from pre-production to production. Leave enough time in production planning for hiccups in the transitional period.
- A system test of relevant size with all the final hardware should be done as early as possible.

Module Design.

- Keep the modules as simple as possible. As for hybrids, only use novel materials when necessary, the single vendor risk should be avoided.
- Tight tolerances need to be justified strongly. Do not pick tolerances just because they are achievable somewhere. The may be difficult to maintain or propagate onto different sites. In the end, they will be relaxed if not achievable and well motivated.
- When there are many module types, make sure to test carefully all flavors. The simplest case may hide problematic issues or traps. Avoid having many flavors if possible.

Logistics.

- Shipments should be avoided (where possible). However, due to the sheer number of modules and the diverse locations of participating institutes it seems inevitable to ship assembled parts. The alternative would be to have the whole production based at CERN, with all manpower and infrastructure located there. This seems unfeasible.
- Transport is an important part of integration, requiring thorough preparation. For large units, transporting is a high-risk enterprise. The risks might be so complex that the effort to understand and control them might be unmanageable.
- Involve professional shipping companies. They usually know their part of the task well, for them it is just another job.

Mounting, Services & Components.

- Keep it simple. Solutions which might look practical on the bench can become very complex, when scaled to the real thing. Think through ahead what you are going to do with the services throughout the assembly. Do optimize your service break points. Prototyping all components needs to be done in a realistic environment (incl. handling).
- Plan your services carefully, including planning for their installation. Avoid complex activities with limited access.
- Full-scale service mock-ups are essential – go through the effort to make them real.
- Avoid safety factor creep – safety factors should be defined as part of the specifications and then not be added arbitrarily
- Keep module mounting (design, tooling, etc.) simple. Manual work by trained operators is often quite adequate. Assembly of modular components which are well tested at previous levels makes the assembly simpler. In this way one can focus on the job itself.
- Climbing the production curve requires focused activity and the wider project gets forgotten. (People turn into module builders and stave/petal/disk assemblers. The risk is leaving a hole in the 'brain-power' devoted to final assembly & sub-system integration).

Quality Assurance.

- QA automation is mandatory with large through-puts . A database back-end is recommended.
- Re-check quality at each step (even after a shipment) and track the history of parts.
- Consider visual inspections, destructive tests on samples and the quality of signals.
- Pay attention to trivial/cheap/low-tech elements.

Activation Issues.

- For Phase-II the activation on contact and at 40cm will be very significant. Taking longer to install the tracker will be a luxury we will just not have.
- After just a few years access for simple repairs will not be possible - we need to think very hard ahead of time.
- Plan for rapid installation and removal of detectors, including remote handling.
- It is important to qualify models of activation between t=0 and Phase II. Risk analysis: have we thought through the consequences of all failures? (Minimizing the risk of parts failing by extensive qualification/reliability assurance and system tests)