Summary of Discussion on Inner Tracker Readout Link

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1 Patch Panel and "5 m"-Cable

The Service Box contains a number of digitizer boards, each of which carries all electronics that are required to read out the data from one detector ladder. The patch panel on the detector box, and the 5 m cable that connects the detector box to the Service Box, have to provide a one-to-one connection between the front-end readout hybrid on the ladder and this digitizer board.

Those temperature and humidity sensors inside the detector box that are not associated to a detector ladder will be read out via DCUs implemented on the SPECs slave in the Service Box. A separate cable for these sensors will be used between detector box and Service Box.

The following criteria were discussed concerning the choice of cables and connectors for the 5 m cable:

- The copper cross section should be as small as possible in order to minimise material in front of the Outer Tracker. For signal lines, Achim's tests have demonstrated that AWG30 is sufficient for cable lengths of up to 10 m. For LV, a single pair of AWG30 lines should be sufficient for cable lengths of up to 5 m (the resulting voltage drop being less than xx mV for the expected current per Beetle of xx mA). If necessary, LV currents can be distributed over several pairs.
- Cross talk from fast control lines to HV/LV lines and signal lines has to be small enough not to compromise data integrity.
- Cables have to withstand bias voltages of up to 500 V in between pairs. Standard off-the-shelf twisted-pair cables are qualified only up to 100 V between adjacent pairs. Cables with Teflon or Kapton insulation should withstand more than 1 kV between pairs.
- Cables should not be too stiff, the bending radius not too large.

The following options were discussed:

1. One twisted pair cable per ladder:
   Flat twisted-pair cable with 64 lines (same number of lines as hybrid tail) and a common shielding is the simplest and cheapest option. HV qualification and cross talk from control lines to signal lines could be a concern. Simple 3M flat cable connectors could be used, but connecting the shielding could be cumbersome. A survey of existing solutions for the connector should be performed.

2. One AVX-type hybrid cable per ladder:
   AVX cables consist of a core containing lines for power, which is shielded against the signal lines surrounding this core. In addition, a common shield surrounds the signal lines. AVX cables can be bought off the shelf but are more expensive than simple twisted pair cable. Material budget of connectors could be a concern, as well as the stiffness and bending radius of the cables.

3. Two separate cables per ladder:
   To completely suppress cross talk, separate cables could be used for control lines on the one hand and low voltage, bias voltage and signal lines on the other hand. A clear disadvantage is the fact that the number of connectors is doubled. Material budget should not be much higher than for a single cable since it is mainly dominated by the total cross section of the copper lines, which can be chosen the same as for the single-cable option.

It was decided to first test option 1). Only if these tests do not give satisfactory results, will options 2) and 3) be investigated. The Lausanne group will look into possibilities of organising these tests.

2 Grounding Scheme

The grounding scheme as shown in the Inner Tracker TDR foresees to use the cooling plate (now replaced by cooling rods) as common ground for all silicon ladders in a detector box. The design of the silicon ladders has to ensure an excellent ground connection between hybrid, carbon frame, and cooling rod. It was suggested that, in addition to the cooling rods, also the patch panel PCB should contain a common ground plane for all ladders. This ground plane and the cooling rod must then be very well connected electrically.

In the current grounding scheme, ground loops will be introduced if the LV power for several ladders is derived from the same LV power supply channel. Another ground loop will be introduced by common control signals that are generated in the Service Box and distributed to all ladders in a detector box. The grounding scheme should be re-evaluated with respect to these issues. Pickup between silicon ladders in the second detection layer and ladders in the third detection layer within a detector box could be a problem, since these are installed face-to-face and at a short distance from each other. These issues will have to be investigated as part of a full system test.

3 Location of Service Box

In the Inner Tracker TDR design, Service Boxes are installed on the IT support frame, directly underneath the detector boxes. The Service Boxes move together with detector boxes when the detectors are moved away from the beam pipe during installation or for maintenance. This gives the shortest possible cable length for the "5 m cables" between detector boxes and Service Boxes.

Space constraints in the region below the detectors limit the dimension of the Service Box to $\Delta z = 190\,\text{mm}$, 220 mm and 190 mm in T1, T2 and T3, respectively, and to $\Delta y = 600\,\text{mm}$ (our estimate, to be confirmed) in all three stations. Achim sees no problem to adhere to these constraints in the design of the Service Boxes.

At the time of the TDR, it was assumed that the region below the detectors would be accessible for maintenance work on the Service Boxes. This seems now not to be the case, any maintenance work on the Service Boxes would thus require to roll out the detectors.

Alternative locations for the Service Boxes were discussed. Most of them require cables between detector boxes and Service Boxes to be longer than in the originally foreseen design. Achim expects no problem for signal integrity, as long as the cables are shorter than 10 m.

- On the IT support frames, directly above the detectors:
  Service Boxes would move with the detector boxes and cables could be as short as in the originally foreseen location below the boxes. However, accessibility and safety concerns for maintenance work at this location have to be checked as well as the radiation load (radiation load is not up/down symmetric because of support structures and hall floor).

- On top of the gallery above the detectors:
  The expected radiation load is similar to the previous case, access to the Service Boxes would be significantly easier. However, the Service Boxes could not more with the detector boxes when these are rolled out, since the cables would have to pass through a hole at a fixed position in the floor of the gallery. A quantitative estimate for the necessary cable lengths between detector boxes and Service Boxes was not yet available but it was clear that cables would need to be significantly longer than originally foreseen, since compensating cable loops will be needed. In order to minimize the additional cable length, Service Boxes would best be installed at a y-position approximately half-way in between the beam pipe and the outer edge of the station frames (i.e. half-way in between the data-taking and maintenance positions of the detector boxes).

- On the sides of the OT frames, at the height of the beam pipe:
  Cable lengths would be only slightly longer than in the originally foreseen location, if cables can be routed horizontally across the OT. However, this location is excluded by the expected radiation load, which is significantly higher than at the originally foreseen location.

- On the lower (left and right) corners of the station frames:
  Here, expected radiation loads are lower than at the originally foreseen location, but cables between detector boxes and Service Boxes would need to be longer. Several scenarios were discussed, but quantitative estimates for the necessary cable lengths were not yet available for any of these scenarios. Cables can be shorter if they can be installed running diagonally across the OT, than if they have to run vertically down to the OT detector frames and then along these frames to the corners of the detector. However, all Monte-Carlo studies performed so far included material for vertical cables and OT occupancies for diagonally installed cables would need to be checked. If the Service Boxes are installed on the OT frames, they will not move together with the IT detector boxes when these are rolled out. Additional cable length will then be needed for compensating cable loops. These can be avoided if the IT support frames are extended horizontally all the way to the corners of the station. The Service Boxes can then be mounted on these extended support frames such that they move together with the detector boxes, as in the originally foreseen design. A serious disadvantage of this scheme is, however, that with extended IT frames it will be impossible to roll out the IT far enough to gain access to all detector boxes (this is due to an interference with LHC cryogenics installations on one side of the detector). The only way to gain access for maintenance work on the IT detector boxes is then to roll out the OT stations and to enter the space opened up in the region around the beam pipe.

- Inside the concrete "tunnel" underneath the detector:
  During the discussion, it was not clear wether it would be allowed to install electronics

inside the tunnel and wether space will be available for the Service Boxes. Helge pursued the issue after the meeting and found out that there is no space available in the tunnel.

No agreement was reached on the prefered location of the Service Box. In order to proceed, quantitative estimates of the required cable lengths have to be provided for the different locations. This will be done by the Lausanne group. Furthermore, it is important to get a better picture of the foreseen access scenarios for detector maintenance (frequency and duration of access periods). The location of Service Boxes will be discussed again in the common IT/OT infrastructure meeting end of March.