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High Speed Data Transmission on Small Gauge Cables for the ATLAS Pixel Upgrade

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Data transmission requirements for the upgrade of the ATLAS Pixel detector will be difficult to meet. The expected trigger rate and occupancy imply multi-gigabit per second transmission rates but radiation levels immediately at the detector preclude completely optical solutions. Electrical transmission for a short distance will be necessary to move optical components to a safer area. We have evaluated electrical transmission over short distances to determine the minimum size cable capable of 1-5 Gbps. Test results indicate multi-gigabit bandwidth is achievable with very small cables. Results for various low-mass cable configurations and bandwidths will be presented.

Summary

Simulations of the 1 MHz trigger rate and pile up on the order of 200 events per beam crossing expected for HL-LHC running indicate that the data transmission rates for the upgraded ATLAS Pixel detector will be extremely high. For the inner most Pixel layer, 10 Gbps per 2-IC module are expected, dropping off to 2.5 Gbps per 4-IC module at the outer layer. This would imply the need for high-speed optical transmission, but the expected radiation levels inside the Pixel detector (up to 10 MGray) indicate that this will not be possible because present-day optical components cannot tolerate that radiation dose. Electrical transmission will be required for a few meters before a transition to optical can be made in an area with lower radiation levels. While gigabit/second bandwidths on electrical cables have readily been achieved, those applications normally use comparatively large mass cables. Material in the tracking volume must be kept to a minimum in order to minimize multiple scattering and energy loss of the particles being measured. The challenge then is to achieve gigabit/second bandwidth with electrical transmission over as small a cable as possible.

Twisted pair cable or, even better, twin-axial shielded cable (twin-ax) represent the best options for a possible solution provided that the cable size can be sufficiently minimized. In the case of twin-ax cable, most of the mass is contained in the thin shield and not the actual signal conductors or the dielectric coverings. For this reason, unshielded twisted pair would be preferable if it can meet the transmission requirements. One compromise solution may be a hybrid cable made of unshielded twisted pair along the barrels and rings that hold the detector modules with a transition to shielded twisted pair (twin-ax) for the longer run away from the detectors themselves and to the safe area for optical components. This could minimize the material in the sensitive areas of the detector modules.

We have tested twisted pair cables in various configurations of wire gauges (down to 42 AWG) and dielectric coverings to determine their maximum bandwidth vs. distance. We have also spliced unshielded twisted pair to shielded twin-ax cables to test the hybrid solution described above. By matching impedances of the two cable types, a simple solder connection does not disrupt the transmission across the joint. While the unshielded solution has a limited range at gigabit frequencies, the two-cable type hybrid solution can meet the bandwidth and transmission length requirements with a minimum of material.

Test results of bandwidth vs. distance, including bit error rates and crosstalk, will be presented.

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