Research and development of very long and dense data bus for sPHENIX INTT detector

T. Hachiya,*[1,*2] Y. Akiba,*[1] Y. Kawashima,*[1,*3] T. Kondo,*[4] E. Mannel,*[5] H. Masuda,*[1,*3] G. Mitsuka,*[1] I. Nakagawa,*[1] R. Nouicer,*[5] K. Shiina,*[1,*3] M. Tsuruta,*[1,*3] and Y. Yamaguchi*[1]

sPHENIX is a major upgrade project of the PHENIX experiment at RHIC.[1)] The aim of sPHENIX is to explore the properties of the quark-gluon medium created in high energy heavy ion collisions by using the jets and bottom quarkonia as probes. sPHENIX consists of a tracking detector system followed by electromagnetic and hadron calorimeters with a superconducting solenoid magnet. INTT is an intermediate tracker, which is a silicon detector sandwiched between the MAPS silicon detector and the time projection chamber, as shown in Fig. 1.[2,3)] The space available for INTT is small, and the readout electronics (ROC) needs to be placed at least 105 cm away from the detector. INTT is also designed to have a good timing resolution to resolve the collision timing in some beam crossings. In addition, we reuse the ROC of the PHENIX forward silicon vertex detector for INTT. Thus, the interface for the electronics is also pre-defined. This indicates that the data bus for INTT must satisfy the following requirements:

- at least 120-cm long,
- flexible form to fit the tight space,
- a data rate of 200 mega bits per second,
- 100-ohm differential impedance, Z_{diff}, of LVDS data transfer,
- 62 (124) differential pairs (signal lines) for one ladder.

It is challenging to meet all the requirements for the data bus because a long data bus and high-speed transfer of the signal are contradictory. There is no commercial data bus in the market. We carried out research and development of the data bus through an electromagnetic field simulation and by making prototypes.

First, we designed a data bus made from a flexible printed circuit board (FPC) because FPC is capable of establishing a high-density data line with impedance control. We studied the signal integrity by simulation with the realistic layer structure of the FPC, which has a line width (l) and space (s) between lines of 150 μm as shown in Fig. 2. Here, Z_{diff} is calculated based on the intrinsic impedance Z_0 and the space between the pair.[4)] From the result, we found that the thickness (w) of FPC should be 400 μm to make Z_{diff} 100 ohm. A thick FPC is usually made by gluing some thin sheets of FPC to each other. However the adhesive to glue the FPC causes a significant loss of signal for the long data bus because of a large dielectric tangent of the adhesive. To solve this problem, we need a thick FPC material with a small dielectric tangent. A liquid crystal polymer (LCP) is a material. Thick LCP sheets (100 μm) with a small dielectric tangent are available in the market.

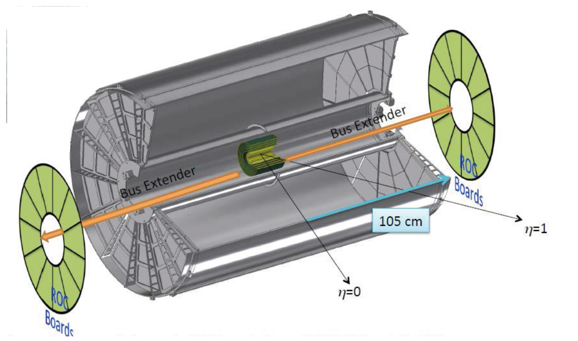

Fig. 1. INTT detector in the sPHENIX tracking system.

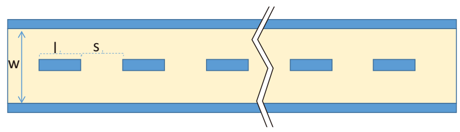

Fig. 2. Cross-sectional view of the FPC.

Second, we studied the uniformity of line and space which is key to keep the impedance for the long data bus. The widths of the signal lines and spaces between the signal lines for the 120-cm-long FPC are measured to examine how accurately the manufacturer produces the FPC.[4)] We found that the line width changed periodically depending on the position of the FPC. After further investigation, we pinned down the cause of the problem as the printed circuit on the mask film for the FPC production.

Third, we produced the first version of the prototype FPC to verify our solutions. The prototype FPC has a strip-line structure with 72 signal lines. We are now measuring the line and spaces of the prototype and studying the electrical properties such as impedance, signal loss, and signal distortion.

We plan to make the second and third versions of the prototype in 2018 to ensure that the data bus for INTT meets all the requirements, and mass production will be performed in 2019.

References

1) A. Adare *et al.*, arXiv:1207.6378 [nucl-ex].
2) I. Nakagawa *et al.*, in this report.
3) Y. Yamaguchi *et al.*, in this report.
4) M. Tsuruta *et al.*, in this report.

*1 RIKEN Nishina Center
*2 Division of Natural Sciences, Nara Womens University
*3 Department of Physics, Rikkyo University
*4 Tokyo Metropolitan Industrial Technology Research Institute
*5 Brookhaven National Laboratory