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Technical Support Finding: Crosstalk Issue Due to Shorted PD Cables in NP04

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Summary

In the NP04 ProtoDUNE demonstrators at CERN, the PD system utilizes Cu differential cables to connect the PD modules installed on the APAs to the warm side. One year after installation, we've found two modules suffering from critical connectivity problems. These short circuits cause electrical signals to bleed into neighboring circuitry, resulting in crosstalk to other PD channels within the same APA and even the charge readout system.

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1 Introduction

In 2022, the Photon Detection (PD) system was installed at NP04, the ProtoDUNE demonstrator. During this period, the installation of PD modules and extensive testing of their connections took place. The procedure had several critical steps, including the assembly and warm-temperature testing of PD modules within a controlled environment, data acquisition, installation onto the Anode Plane Assembly (APA), a preliminary assessment of connectivity, APA insertion into the cold box, extensive testing at low temperatures with additional data acquisition, warming procedures, cold box extraction, and eventual installation onto the cryostat.

At present, the ongoing tests involve data collection from the PD detector on the horizontal drift (HD) side, with issues in signal quality identified in Modules 7 (M7) and 8 (M8) on APA2.

A review of the logbook and previous PD presentations has revealed that these modules have been experiencing connection problems since their initial installation. To gain insight into this issue, a mock-up module with a cable connection was constructed at that time with the aim of understanding the nature of the problem.

The present document seeks to consolidate all available information related to these modules. Its primary objectives are to pinpoint the root cause of the issue and provide valuable feedback to the production chain. The ultimate goal is to implement measures to prevent the recurrence of similar problems in the far detector, thereby ensuring the robustness of the Cu connections of the PDS.

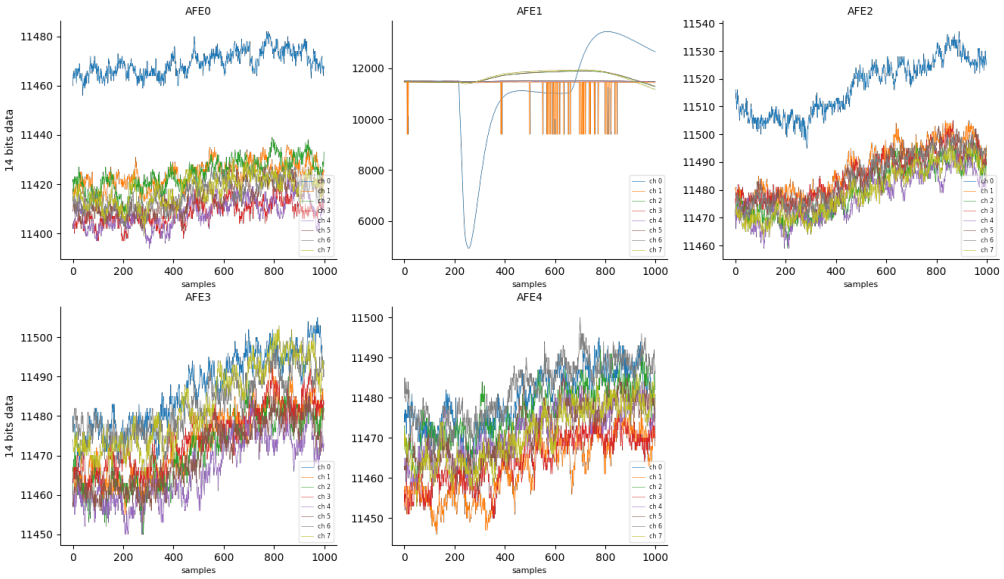


Figure 1: One waveform from each channel of APA 2. PD modules M7 and M8 are connected to AFE 1. Noticeable crosstalk in all channels of the APA 2

2 Issue identified during detector commissioning

Detailed data acquisition was done with DAPHNE V2 in coordination with the DAQ. By the second week of October 2023, PD modules had been seamlessly integrated. Yet, during the early stages of data collection, irregularities were observed in modules 7 and 8. Importantly, these discrepancies were only apparent when analyzing the data and couldn't be identified using standard multimeter measurements. The problem is apparent when taking data in all 40 modules from APA2, Figure 1.

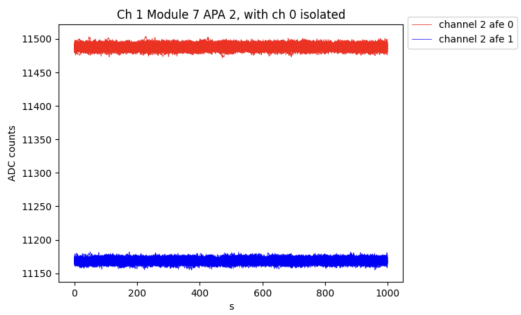
A series of tests were executed to trace the source of the issue. Components such as the FEB, warm cables, and flange were systematically ruled out.

2.1 Module M7 find outs:

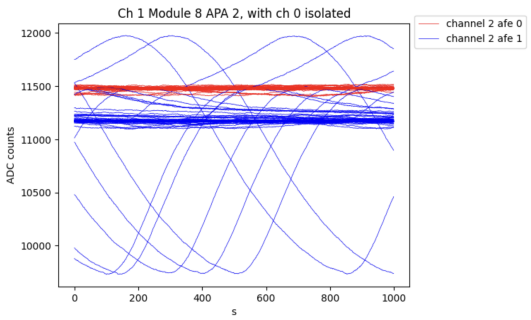
- When focusing on the most concerning channels, we discovered that quality data from three channels of M7 was achievable upon disconnecting the differential pairs related to the first channel of this module, specifically the orange wires. Under such conditions, no evident cross-talk was observed in other AFEs, and the RMS values remained consistent with PD modules found in other APAs. See figures 2a, 4a, and 3a

2.2 Module M8:

- Challenges with M8 persisted even after isolating the more problematic channels.
- Alarmingly, with only a single differential pair linked to the FEB, the RMS of the other 32 channels in APA2 saw a substantial rise. See figures 2b, 4b, and 3b

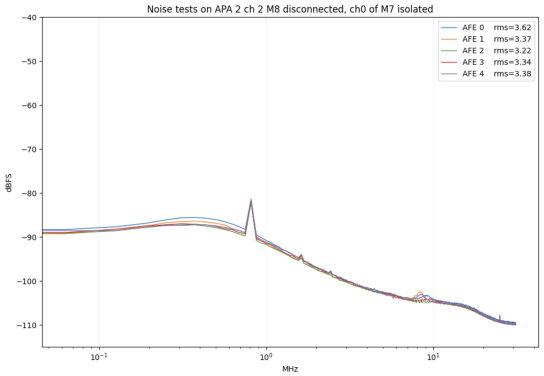


(a) 100 waveforms from a functioning channel (red) and 100 waveforms from Module 7's second channel (blue) after disconnecting the orange differential pairs on the DB15 connector (DAPHNE side). Both channels are connected to a PD, with no bias applied.

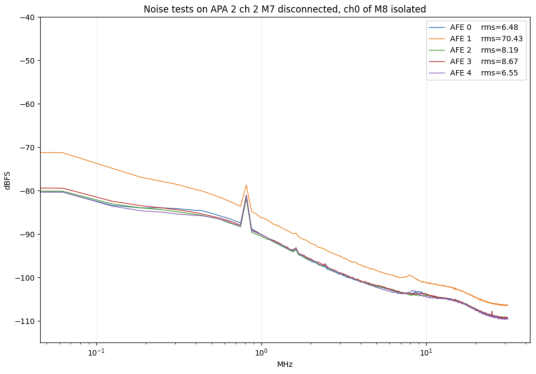


(b) 100 waveforms from a functioning channel (red) and 100 waveforms from Module 8's second channel (blue) after disconnecting the orange differential pairs on the DB15 connector (DAPHNE side). Both channels are connected to a PD, with no bias applied.

Figure 2: Comparison between M7 and M8 when isolating problematic channels

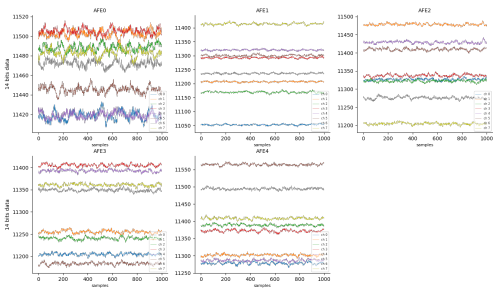


(a) FFT from one channel of each AFE in the DAPHNE FEB. M8 disconnected. The first channel of M7, orange differential pairs, was disconnected and isolated on the warm cable, DAPHNE side. Notice RMS values are similar to other PD modules installed in the system.

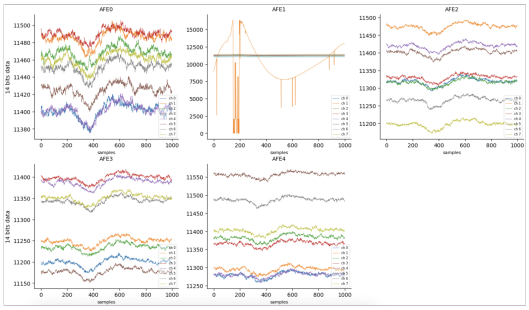


(b) FFT from one channel of each AFE in the DAPHNE FEB. M7 disconnected. The first channel of M8, orange differential pairs, was disconnected and isolated on the warm cable, DAPHNE side. Notice RMS values are similar to other PD modules installed in the system.

Figure 3: FFT comparison on the induced noise by each module.



(a) One waveform from each channel of APA2. M8 disconnected. The first channel of M7, orange differential pairs, was disconnected and isolated on the warm cable, DAPHNE side.



(b) One waveform from each channel of APA2. M7 disconnected. The first channel of M8, orange differential pairs, was disconnected and isolated on the warm cable, DAPHNE side.

Figure 4: Data from all the channels within APA2 after removing problematic channels.

3 Description of the electrical system

Specification of Electrical Cabling and Wiring Connections is on EDMS:
Photon Detector Cabling Document

The general scheme is in Figure 5

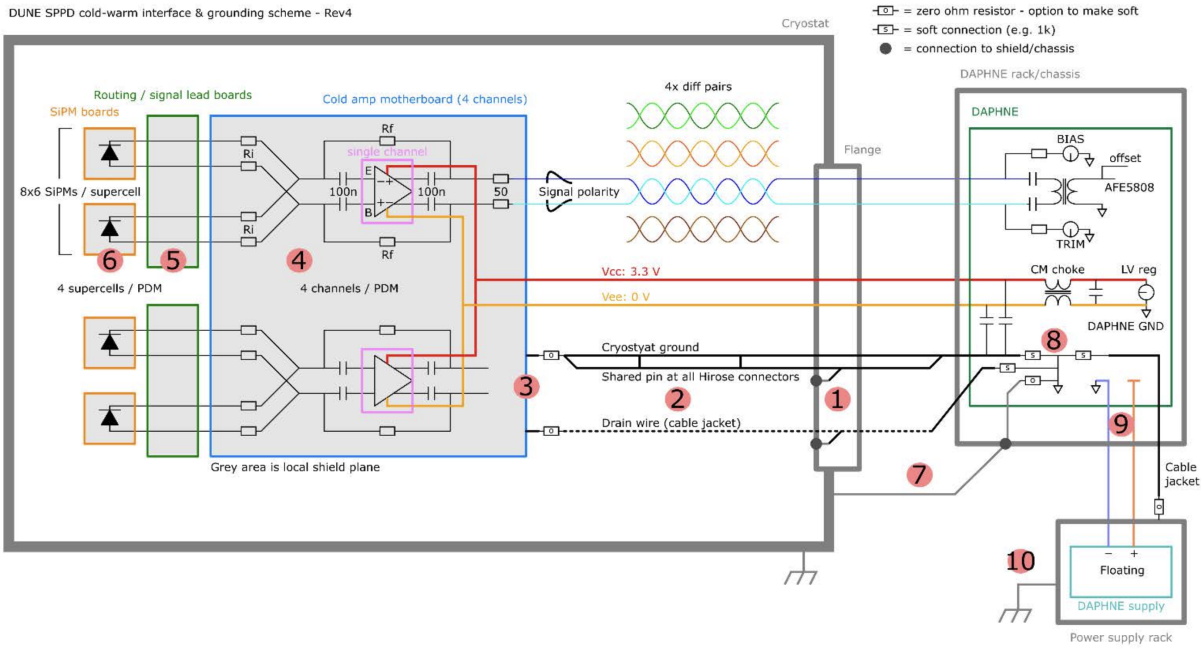


Figure 5: Electrical and ground scheme of PDS HD

4 First report of failure on M7 and M8 and historical

4.1 June 14th of 2022: electrical connection lost and recovered

The first report on issues with the connection of these modules was in the preparation for the HD cold box of APA2. Presentation from Niccolo Gallice on the PDS group, 14th of June of 2022. The issue was also documented in the Logbook, page 17, red higlight.

A mockup module was designed to test the connection. After removing and installing the modules again, a voltage different from zero was measured between the differential pairs of all the channels of M7. On the other hand, one channel from M8 was missing (orange cables). The lost connections were reported between the Sasebo board and the APA frame. The Sasebo connection can be found in figure 6

4.2 June 28th of 2022: data taking

The team managed to take data with DAPHNE using those modules in the ColdBox: Update on the PDS installation June 28th. Gain results from M8 were anomalous.

5 Afectation of the charge readout

The impact on the charge readout was studied using data before and after connecting module 8 to DAPHNE. Unplugging the module from the end board solves the noise induction in the charge readout system. The FFTs are in figure 7a and 7b

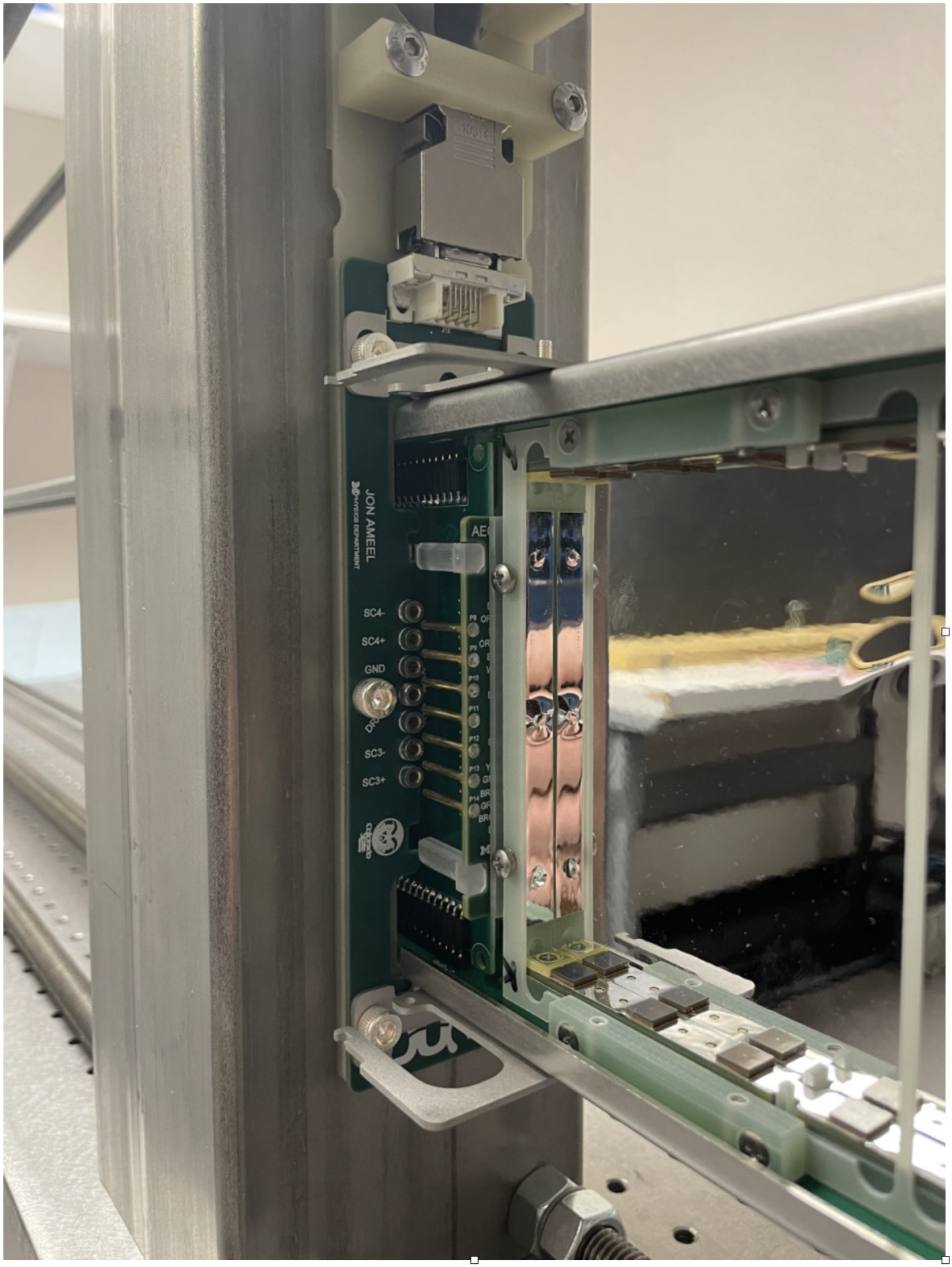
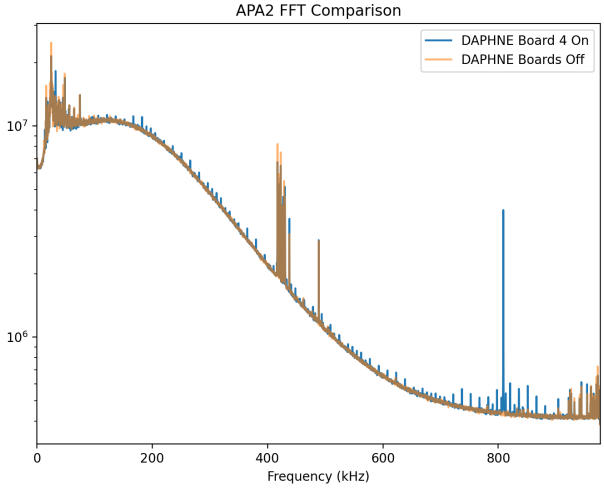
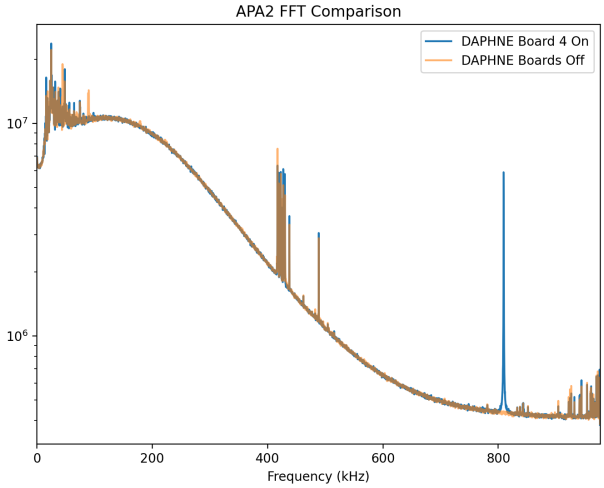


Figure 6: Sasebo connection



(a) nominal FFT from the charge readout with M7 and M8 connected.



(b) nominal FFT from the charge readout with M7 connected, problematic channel disconnected from the warm cable, and M8 NOT connected to the DAPHNE FEB.

Figure 7: The forest of peaks disappears when removing the M8 connection from the FEB (DAPHNE) side.

6 Conclusions

- Module 8 from APA2 cannot be connected to the FEB to prevent any noise in the PDS or the charge readout.
- Channel 0 from module 7 has to be disconnected from the warm cable on the DAPHNE side.