ITk Pixel Electronics Interface Control Documents: Optosystem Interfaces

Project Document No.:	*Institute Document No.:*	*Created:* 28th May 2020	*Page: 1 of 29*
AT2-IP-MG-0010		*Modified:* 15th November 2022	*Rev. No.: 2.7*

ITk Pixel Electronics Interface Control Documents: Optosystem Interfaces

Abstract

This document presents the electronics interfaces of the Optosystem of the ITk Pixel Detector. The Optosystem is the part of the data transmission chain that performs the optical-electrical conversion. This system will be connected to the detector modules via about 17800 uplink and 8400 downlink electrical Type-1 cables, and will be linked to the readout cards in the electronics cavern by about 4100 optical fibres, grouped in bundles.

Prepared by	*Checked by*	*Approved by*
L. Franconi and A. P. O'Neill, University of Bern, laura.franconi@cern.ch, aaron.paul.o'neill@cern.ch	**A. Fehr, L. Halser, R. Müller, C. Tognina, M. Weber**	

Distribution List

History of Changes

Rev. No.	*Date*	*Pages*	*Description of changes*
1.0	28th May 2020	All	First Draft.
1.0	9th June 2020	All	Implementation comments by L. Halser and C. Tognina.
1.1	15th June 2020	All	Inclusion pinout of the optical connectors.
2.0	30th June 2020	All	Changes determined by the new baseline of 1 MHz over the whole ITk Pixel Detector.
2.1	30th October 2020	All	Inclusion Pixel Lumi Ring and correction optical fan-out pinout.
2.2	27th January 2021	All	Inclusion of Termination board pinout, removal of the small Optopanels.
2.3	25th May 2021	All	Correction Figure 7 with correct channel dimensions and change of specification on metal hood for external power and CANbus cables.
2.4	24th February 2022	All	Implementation of updates.
2.5	25th May 2022	All	Use of Optoboard V3.0 and removal of super-slim and slim mirrored Termination boards.
2.6	7th October 2022	All	Restoring of Super-slim, introduction of CERN Termination board, other minor changes.
2.7	15th November 2022	All	Implementation of some minor comments, update of figures and declaration that Optoboard V3 is the final version.

Contents

1 Introduction

This document describes the interfaces to the Optosystem. The Optosystem is the part of the ITk Pixel data transmission chain that hosts the ASICs for electrical link aggregation and the conversion to optical signals. Its interfaces consist of the connections to the Type-1 data cables towards the detector, and fibres, power and CAN connections towards the electronics caverns.

2 Related Documents

Connectivity map	EDMS Document No. 2423241
Optical link (VTRx+)	EDMS Document No. 1719329
lpGBT chip manual	`https://lpgbt.web.cern.ch/lpgbt/`

Table 1: Related documents.

3 The Optosystem

A block diagram showing an overview of the ITk Pixel Detector services is presented in Figure 1. The Optosystem (labelled in the figure as "Optobox") is the central part of the data transmission chain, between the detector modules and the electronics caverns. From the data transmission point of view, the Optosystem is connected to the ITk Pixel Detector via Type-1 data cables, called twinax cables, while it is connected to the USA15 electronics cavern via optical fibres. It is reached, from the two ATLAS electronics caverns, by power and CAN bus cables. In the following subsections, the main components of the Optosystem, whose scheme is shown in Figure 2, are briefly described.

3.1 Optoboards

The Optoboard is the heart of the Optosystem: this Printed Circuit Board (PCB) hosts the ASICs that perform the (de-)multiplexing and the electrical-optical (optical-electrical) conversion. There are 1564 Optoboards reading out the entire ITk Pixel Detector and 16 more Optoboards to read the Pixel Luminosity Ring (PLR) detector and the new Beam and Control Monitor detector (BCM'). From the PP0 region, Type-1 cables (twinax cables, which have AWG34) leave the detector and transmit the data signal to the Optosystem (and vice versa, downlink twinax cables bring clock and commands to the detector). For each Optoboard there is an interface board, called Termination board, where

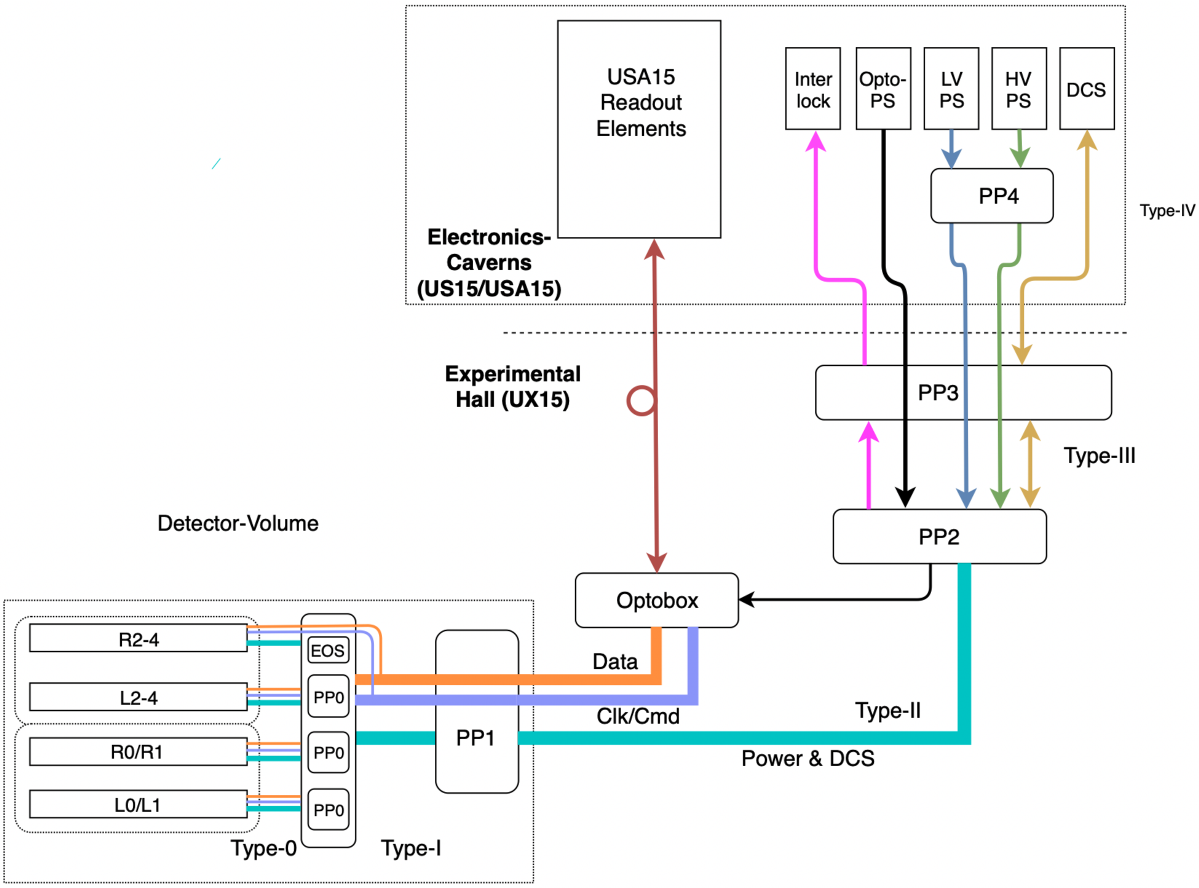

Figure 1: Diagram of the ITk Pixel Detector services.

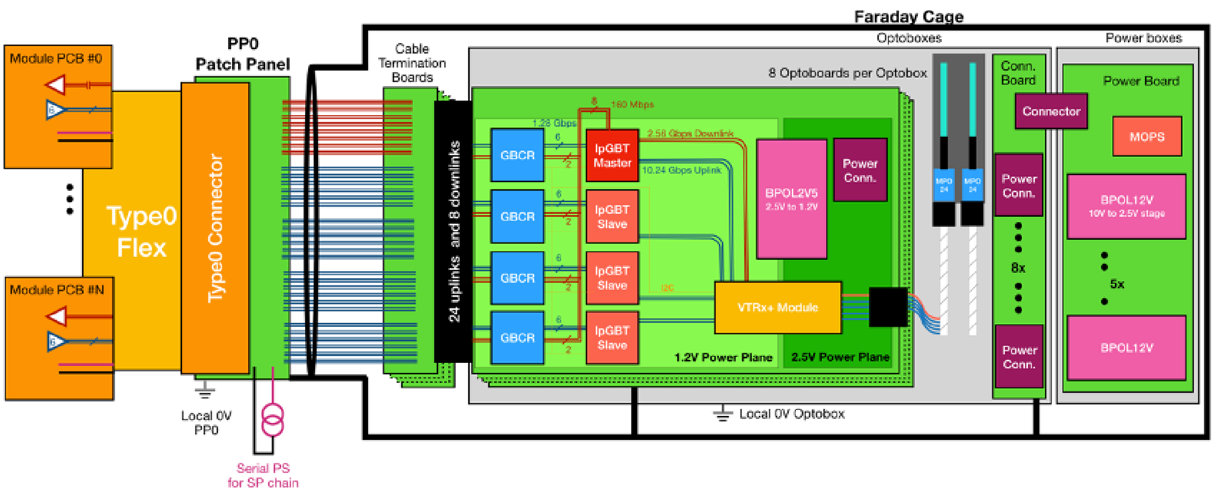

Figure 2: Data transmission scheme, with emphasis on the Optosystem.

up to 32 twinax cables are soldered. There are 26184 Type-1 cables in total for the ITk Pixel. The Optoboard version 3.0 (V3.0) is the final design. Its CAD drawing is shown in Figure 3 and it is populated with:

- Up to four lpGBT chips, which multiplex the uplink data signals (running from the detector to the electronics cavern). One of the lpGBT chips, called lpGBT master, receives and demultiplexes the downlink clock and commands (running from the readout cards to the modules) and distributes, via I2C, the configurations and commands to the other chips on the Optoboard.

- A VTRx+ module, which converts the electrical uplink signal into an optical signal (Laser Driver), and vice versa for the downlink signal (VCSEL).

- Up to four GBCR chips, which are used to recover the uplink signal after the transmission over the twinax cables.

- A bPOL2V5 DCDC converter, mounted on a carrier board, that dispatches the power to the active components on the Optoboard.

- An ERM8 connector, where the Termination board is plugged.

- A TFM power connector, from the Connector board (see Section 3.2), which brings power to the board.

- Passive components.

The uplink signals from the detector (up to 24 signals per Optoboard) are received by the GBCR (up to six signals per chip), recovered, transmitted to the lpGBT where they are serialised and transmitted to the VTRx+ module. Here, the electrical signal is converted into optical and sent, through the optical cable plant, to the FELIX readout cards in the USA15 electronics cavern. The downlink signals (up to eight electrical signals per Optoboard) follow the opposite path: from the FELIX cards, they are sent via optical fibres (a single fibre per Optoboard) to the VTRx+ module, converted into electrical signals, parallelised and pre-emphasised in the lpGBT master chip and sent to the modules, bypassing the GBCR.

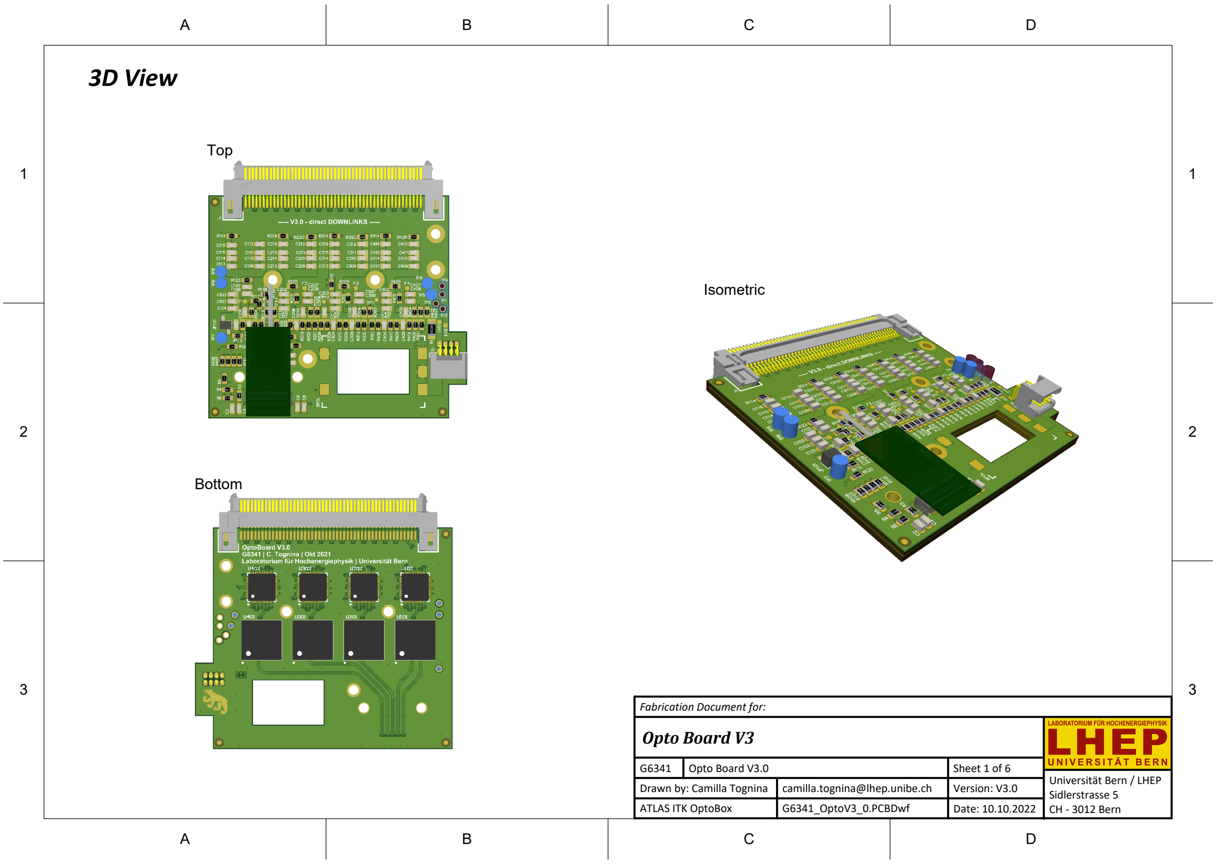

Figure 3: CAD drawing of the Optoboard V3.0. Top left: front side, hosting the VTRx+ and the bPOL2V5, with its carrier board (which would be mounted at the five pads at the hole). Bottom left: back side, hosting the four GBCR and the four lpGBT chips. The rectangular hole, visible on the right-hand side, allows for direct contact between the cooling profile and the bPOL2V5 carrier board. The ERM8 connector to the termination board is mounted on the top. Right: An isometric view of the front side.

3.2 Powering

The power distribution of the Optoboxes uses a two-stage DC/DC converter system, composed of bPOL12V and bPOL2V5 converters. The main supply is provided at 9 V and is adapted to 2.5 V by the bPOL12V converter. The 2.5 V supply powers the VCSEL driver of the VTRx+ module and the bPOL2V5. This second converter provides the 1.2 V voltage used by the ASICs on the Optoboard. The bPOL12V chips are mounted, in groups of five, on a PCB called Powerboard (shown in Figure 4). Their power is distributed to up to eight Optoboards by the Connector board, see Figure 5. This intermediate PCB features a configurable distribution of the power channels.

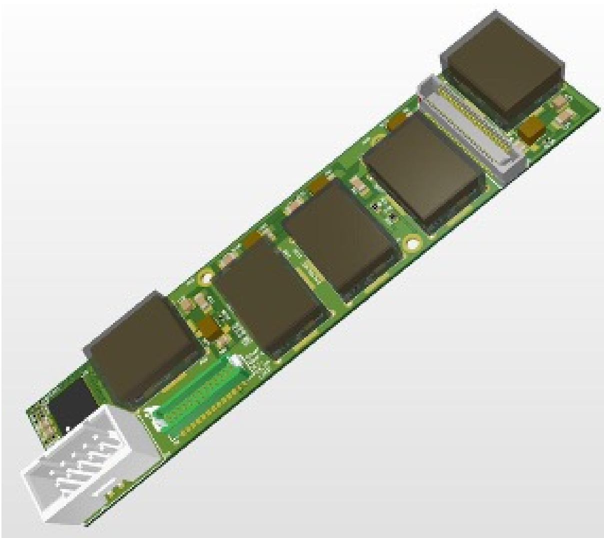

Figure 4: CAD drawing of the Powerboard. The five bPOL12V converters with shields, the MOPS chip and the connectors are mounted.

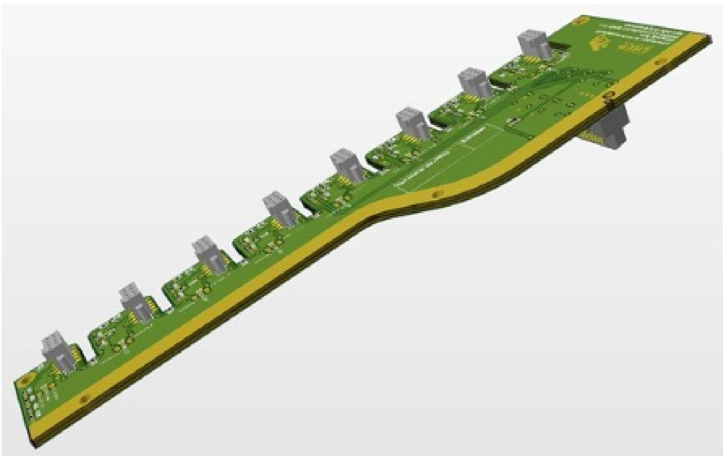

Figure 5: CAD drawing of the Connector board. The connectors to the Optoboards (top) and to the Powerboard (bottom) are shown.

The Powerboard, in summary, hosts:

- Five bPOL12V converters.
- A Monitor of Pixel System (MOPS) chip (see Section 3.3).
- A connector to the Connector board (produced by Samtec, serial number ERF8-025-05.0-L-DV).
- A power connector (Harwin, serial number G125-MS12605L3P), connected to the power cable (which is routed only internally in the Optosystem, see Section 3.4).

- An SMD CAN bus connector, connected to the Optosystem-only CAN bus cable (see Section 3.3).

3.3 Monitoring

The Optosystem is monitored by the MOPS chip mounted on the Powerboard. It monitors all bPOL output voltages (5 x 2.5 V and 8 x 1.2 V), the output currents of the bPOL2V5 chips (8 signals), the temperature on the Optoboards and Powerboard (8+1 signals) and the temperatures of the PTAT (positive-to-ambient temperature) output of two bPOL12V chips. The MOPS is read out via a CAN bus. Up to four MOPS chips are connected to one CAN bus. A cable, integrating two CAN buses, will be routed to multiple Powerboards. The MOPS is independently supplied with 1.6 V, via a line integrated into the same cable.

3.4 Optoboxes and Optopanels

Up to eight Optoboards are installed into a mechanical structure called Optobox (see Figure 6), which also hosts the first part of the optical cable plant (described in Section 3.5), and the Connector board. The Powerboard is contained in a separate box, called Powerbox. For servicing the ITk Pixel Detector, there are 220 Optoboxes and, correspondingly, 220 Powerboxes. The PLR and the BCM' detectors are serviced by one Optobox and one Powerbox each per ATLAS side.
In the ATLAS experiment, the Optoboxes will be installed inside mechanical structures called Optopanels, which also provide shielding against electromagnetic interference (EMI) and cooling to the system. The 4-mm thick walls and lid ensure the EMI shield, while the cooling is provided by the bottom cooling plate, where cooling pipes guide coolant below the Optoboxes.

The Optopanel structure is sketched in Figure 7. There are 4 Optopanels on each ATLAS side, located at R = $[1450, 2400]$ mm, z $\sim$ 3500 mm, that host 28 Optoboxes each.

Each Optopanel has an opening at low radius (left-hand side of Figure 7) that allows the Twinax cables to reach the Termination boards, and an Opto Patch Panel at high radius (right-hand side of the Figure 7), which hosts connectors for the power and the CAN bus cables, and openings for the fibres. Fibres do not break at the Opto Patch Panel but go straight through its three openings. To keep the integrity of the Faraday cage, a U-shaped nose, with a thickness of 30 mm, is added around these openings.

The Optoboxes create, inside the Optopanels, channels dedicated either to the Twinax

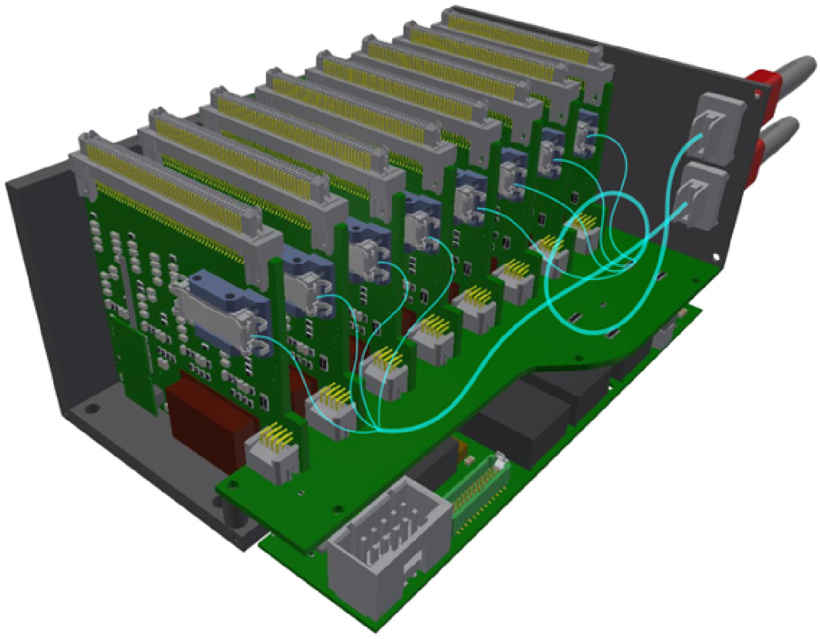

Figure 6: CAD drawing of an open Optobox. Visible are the eight Optoboards, the Connector board, the Powerboard, and, on the wall of the box, the MT-MTP adapters and MPO24 connectors. The optical fan-outs are drawn from the VTRx+ pigtail position to the MT-MTP adapters.

cables (represented in Figure 7 as yellow channels), or to the fibres and power&interlock and CAN bus channels (represented as light-blue channels in Figure 7). This structure requires two versions of Optoboxes, one "normal" type and one "mirrored". As a consequence, there are mirrored versions of the Powerboard, of the Connector board and of the Termination board designs. Given the complexity of the Optoboard design, it was decided to have a single version of the Optoboard, with opposite orientations inside the Optoboxes with respect to the coordinate system.

3.5 Optical Fibre Plant

The optical section of the ITk Pixel data transmission chain has been optimised for minimisation of the number of the readout FELIX cards and the minimisation of the unused (dark) uplink fibres. The specific structure of the system is described in the EDMS Document No. AT2-IP-EN-0030 [1], here the general description will be provided. The conceptual scheme of the optical section is shown in Figure 8, consists of:

- The VTRx+ module pigtail [2], composed of five fibres (4 uplinks + 1 downlink), terminated with an MT12 connector. The MT12 connector has 12 fibres, but only up to[1] five will be used.

[1]Not all Optoboards utilise all four uplinks.

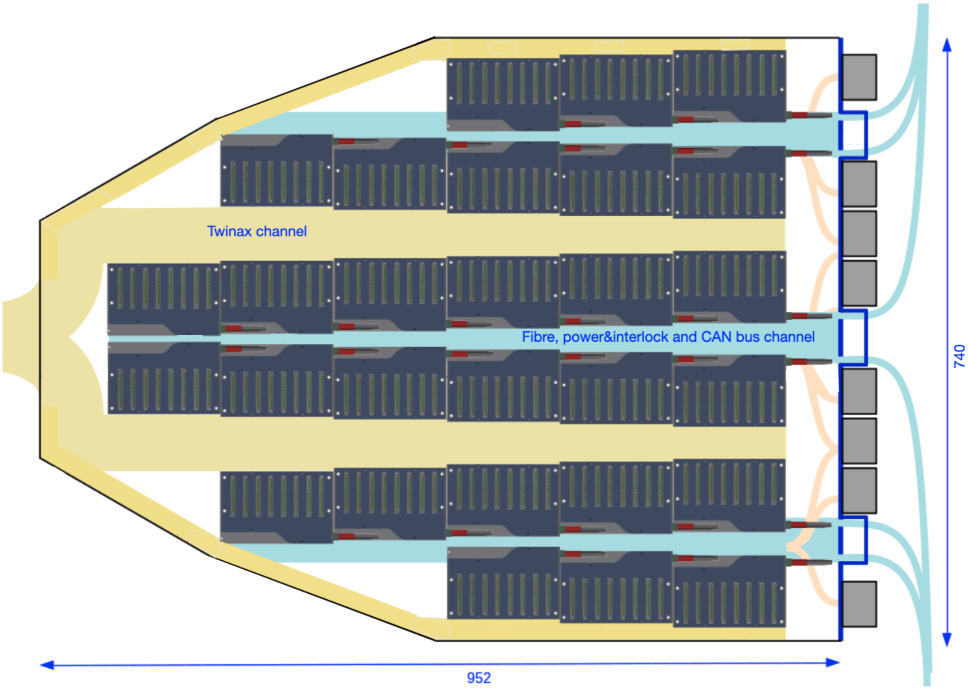

Figure 7: Sketch of the Optopanel.

- An optical fan-out, collecting the signals several VTRx+ modules. There are 3 flavours of optical fan-out, which connect to different numbers of Optoboards (4 or 8) and gather different numbers of uplink and downlink fibres. On the Optoboard side, the connectors are MT12 ferrules, and the multiple (four to eight) branches are staggered by 1.5 cm, corresponding to the pitch between Optoboards inside the Optobox. The fan-out is terminated at the other extremity with an MT24 connector, which has up to 24 active fibres (16 uplinks and 8 downlinks). There are one or two optical fan-outs in each Optobox.
- One or two MT-MTP adapters, one per optical fan-out, on the wall of each Optobox.
- Optical trunk cables, connecting the Optosystem to the USA15 electronics cavern. They have six MPO24 connectors at each extremity, connecting to up to six Optoboxes. The length of the branches is of about 2.5 m on both side, to ensure connections to the Optoboxes with some take-up length, and to the shuffle boxes.
- Shuffle boxes, required because of the different number and arrangement of uplinks and downlinks in the MPO24 connectors of the trunk cables and of the FELIX readout cards. In fact, the trunk cables have up to 16 uplinks + 8 downlinks per MPO24 connector, while the MPO24 connectors at the FELIX side accommodate 12 uplinks + 12 downlinks. The shuffle boxes, therefore, allow the re-routing of the uplink and downlink fibres. There are 4 flavours of shuffle box.

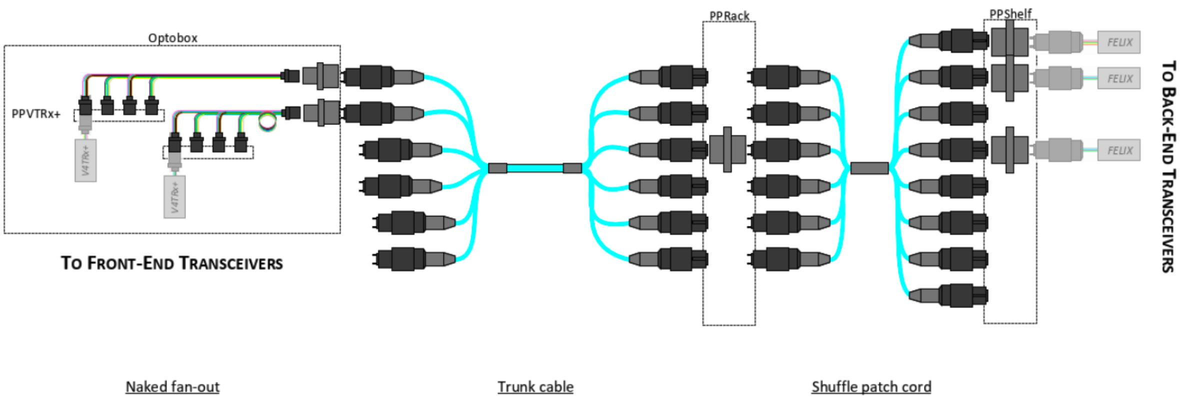

Figure 8: Scheme of the ITk Pixel fibre cable plant.

4 The Optosystem Interfaces

Table 2 lists the interfaces to the other detector parts and their basic properties.

Interface to	Name	Properties	Description
Modules	Command (CMD)/ Clock (CLK)	CERN Low Powering Signal DC-balanced signals at 160 Mbps	Electrical downlink (twinax cable)
	Data	Current Mode Logic DC-balanced signals at 1.28 Gbps	Electrical uplink (twinax cable)
FELIX	CMD/CLK	Optical link at 2.56 Gbps	Optical downlink
	Data	Optical link at 10.24 Gbps	Optical uplink
Power	V_{in}	9 V / 3 A supply line	Power supply
DCS	Tilock	NTC signal lines	Temperature interlock signals
	V_{CAN}	2 V / 0.5 A supply line	MOPS power supply lines
	CAN	1.2 V differential at 125 kbps	CAN signal lines

Table 2: Description of the interfaces to the Optosystem.

4.1 Interface to the Modules: The Termination Boards

Each Optoboard communicates with the modules through a Termination board, where the Type-1 cables are soldered. There are 7 flavours of Termination Boards (TBs), described in [1]. The need for such plethora of TBs is dictated by the number of uplinks and downlinks at the detector level, also striving to minimise the number of optical uplinks and of FELIX cards.

At the time of writing, two vendors have been identified to produce the twinax cables. One important difference between the two designs is the implementation of the grounding: in one, the ground is transmitted through a ground wire running parallel to the P and N wires inside the cable, while in the other it relies on the shielding around the differential wires. As a consequence of these different approaches, two corresponding sets of Termination boards are being designed, at SLAC and at CERN.

The 7 flavours, of both design styles, can be grouped in three main categories: the L-shaped, the Slim and the Super-slim TBs: the L-shaped TB, whose SLAC layout is shown in Figure 9, can connect up to 24 uplink and eight downlink signals, while the Slim (Super-slim) TB has 20 (12) soldering pads and can connect up to 12 (6) uplinks and 8 (6) downlinks.

Regardless the shape, the SLAC designs foresee the twinax cables to be soldered to a rigid PCB, while the connector to the Optoboard is at the end of the flex part, which features a stiffener. The central part allows for a 90° bending along the Optobox wall and top, while the stiffened extremity hosts the ERF8 connector that mates the ERM8 connector on the Optoboard.

The 3D envelopes of the ERF8 connector and its mating connector, the ERM8, are presented respectively in Figure 10 and Figure 11. The pinout of these connectors is shown in Figure 12.

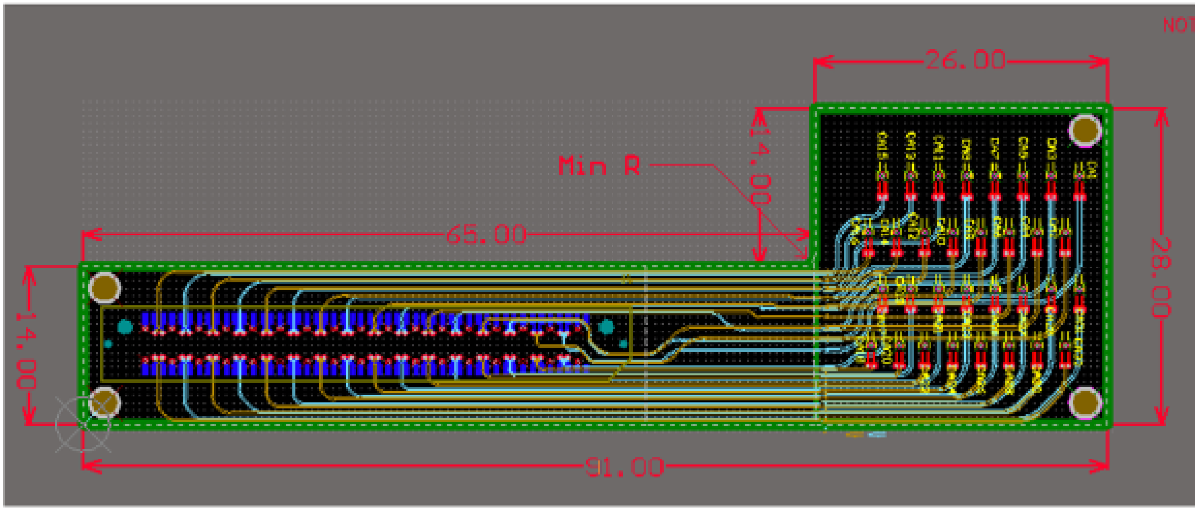

Figure 9: CAD drawing of the L-shaped Termination board designed at SLAC. The twinax cables will be soldered on the wide side of the board (rigid PCB); in the middle, the flex PCB allows for 90° bending along the Optobox (bending radius below 4 mm); at the other extremity, along the narrow side of the board, a stiffener is added to the flex PCB in correspondence of the ERF8 connector to the Optoboard.

Figure 10: CAD drawing of the ERF8 connector, mounted on the Termination board.

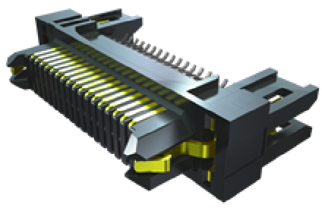

Figure 11: CAD drawing of the ERM8 connector, mounted on the Optoboard.

Figure 13: CAD drawing of the arrangement of the L-shaped Termination boards on the side walls of the Optoboxes for the "normal" Optobox (left) and the "mirrored" Optobox (right). The Twinax cables, represented as yellow arrows, come from the common Twinax channel inside the Optopanel. For each type, short and long L-shaped Termination boards will be alternated, to allow for optimised Twinax cables' space management.

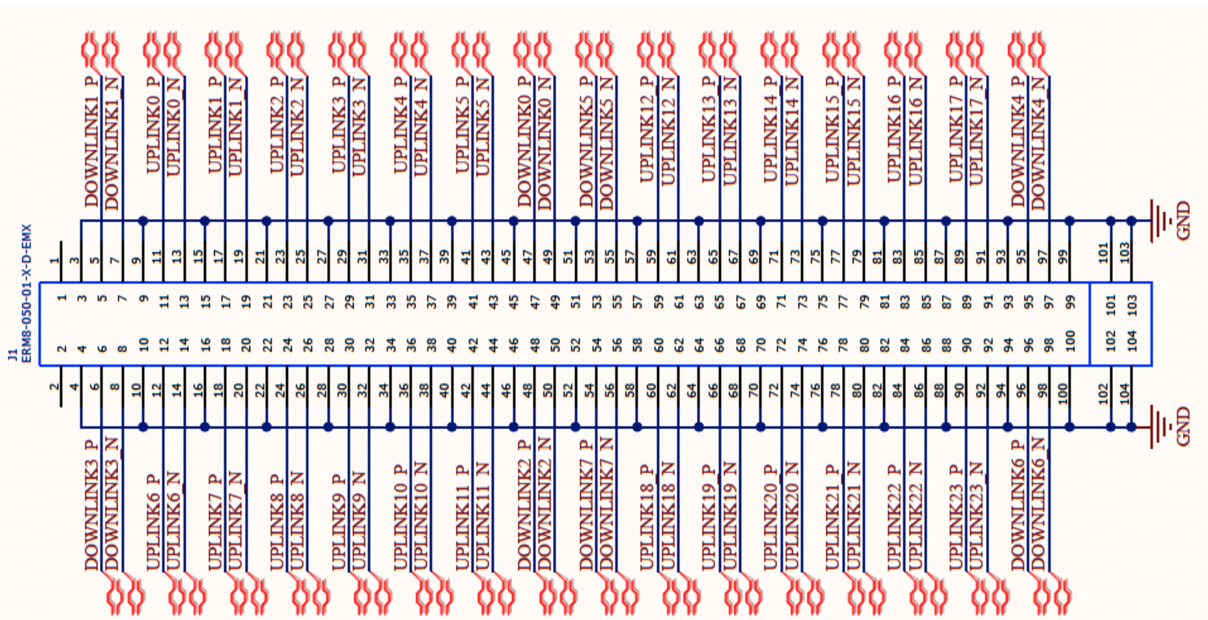

Figure 12: ERM8-050-01-X-D-EM connector pinout.

As mentioned in Section 3.4, there will be mirrored types of Termination board: the one shown in Figure 9 and its mirrored version. For the L-shaped TB, a sketch of the mirrored versions of Optoboxes and Termination boards is presented in Figure 13. In the case of the Slim TB, the addition of buried ground vias allows the same TB to be used for both normal and mirrored Optoboxes.

The mapping between the soldering pads of the "normal" version of the L-shaped Termination board with respect to the pins of the ERM8 connector on the Optoboard is presented in Figure 14. There will be 13 different "flavours" of Optoboard mappings, depending on the number of Twinax cables that will be link to the board. Table 3 indicates the number of uplinks and downlinks and the required number of board (for each side of the ATLAS experiment) for each flavour.

ERM8 pin no.	Signal	Polarity	Soldering pad	Pin soldering pad	ERM8 pin no.	Signal	Polarity	Soldering pad	Pin soldering pad
1	/				2	/			
3	gnd				4	gnd			
5		P		1	6		P		2
7	D1	N	17	2	8	D3	N	1	1
9	gnd				10	gnd			
11		P		2	12		P		2
13	U0	N	18	1	14	U6	N	2	1
15	gnd				16	gnd			
17		P		2	18		P		1
19	U1	N	19	1	20	U7	N	3	2
21	gnd				22	gnd			
23		P		2	24		P		1
25	U2	N	20	1	26	U8	N	4	2
27	gnd				28	gnd			
29		P		2	30		P		1
31	U3	N	21	1	32	U9	N	5	2
33	gnd				34	gnd			
35		P		2	36		P		1
37	U4	N	22	1	38	U10	N	6	2
39	gnd				40	gnd			
41		P		2	42		P		1
43	U5	N	23	1	44	U11	N	7	2
45	gnd				46	gnd			
47		P		2	48		P		1
49	DO	N	24	1	50	D2	N	8	2
51	gnd				52	gnd			
53		P		2	54		P		1
55	D5	N	25	1	56	D7	N	9	2
57	gnd				58	gnd			
59		P			60		P		1
61	U12	N	26	1	62	U18	N	10	2
63	gnd				64	gnd			
65		P		2	66		P		1
67	U13	N	27	1	68	U19	N	11	2
69	gnd				70	gnd			
71		P		2	72		P		1
73	U14	N	28	1	74	U20	N	12	2
75	gnd				76	gnd			
77		P		2	78		P		1
79	U15	N	29	1	80	U21	N	13	2
81	gnd				82	gnd			
83		P		2	84		P		1
85	U16	N	30	1	86	U22	N	14	2
87	gnd				88	gnd			
89		P		2	90		P		1
91	U17	N	31	1	92	U23	N	15	2
93	gnd				94	gnd			
95		P		2	96		P		1
97	D4	N	32	1	98	D6	N	16	2
99	gnd				100	gnd			

Figure 14: Mapping, in the "normal" version of the L-shaped Termination board, between the pins of the ERM8 connector on the Optoboard, the signal they transmit (and its polarity) and the Termination board's soldering pads. "D" stands for downlink, "U" stands for uplink; "P" and "N" are respectively positive and negative polarities. The polarity of the differential signals can be swapped in the lpGBT.

Number of Uplinks	**Number of Downlinks**	**Number of Termination Boards (in each ATLAS side)**
24	2	28
20	5	92
18	3	12
18	2	30
16	8	52
16	4	48
12	6	100
12	2	12
10	5	40
9	1	30
8	8	64
6	6	218
5	5	60

Table 3: The 13 "flavours" of the twinax cable bundles between PP0 and the Optoboards, which differ for the number of uplinks and downlinks. The last column indicate the number of Termination boards with such link combination on each side. Numbers include the PLR detector requirements.

4.2 Interface to FELIX: The Fibre Cable Plant

The fibre plant was discussed in Section 3.5. It is a complex network with four breaking points. In the following, the detailed description of a single flavour of fan-out and of shuffle box (both labelled as type or flavour "A"). **The others are described in [1].**

4.2.1 Key-up-to-key-down adapters

All connectors, as well as the trunk cable, use the type-A convention, with key-up-to-key-down adapters. These adapters maintain the same pin mapping for 12-pin connectors (e.g. pin No. 1 is connected to pin No. 1). However, at each interface between two 24-fibre connectors and inside the trunk cable itself, there is a swap between the top and the bottom row of fibre pins, as shown in Figure 15. There are 4 of such swaps: at the interface between the Optobox and the trunk cable, internal in the trunk cable, at the patch panel in USA15 between the trunk cable and the shuffle box and at the front panel of the FELIX cards between the shuffle box connectors and the FELIX card ones.

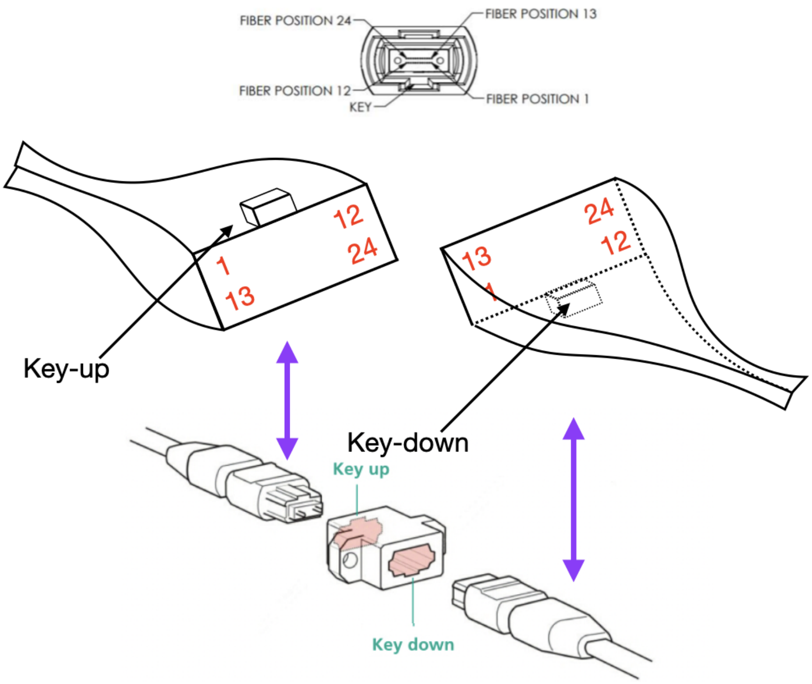

Figure 15: Fibre adapter. Top: the pin labels for a 24-fibre connector. Bottom: the fibre key-up-to-key-down adapter to connect two 24-pin connectors. Bottom: the correspondence between pins of the two connectors. For example, pin 1 of the connectors on the left pairs with pin 13 of the connector on the right.

4.2.2 MT-MTP Adapter at the Optobox Wall

Up to two optical fan-outs inside an Optobox, like the one presented in Figure 16, are connected with the outside environment by an MT-MTP adapter, also shown in the figure, directly placed on the Optobox wall.

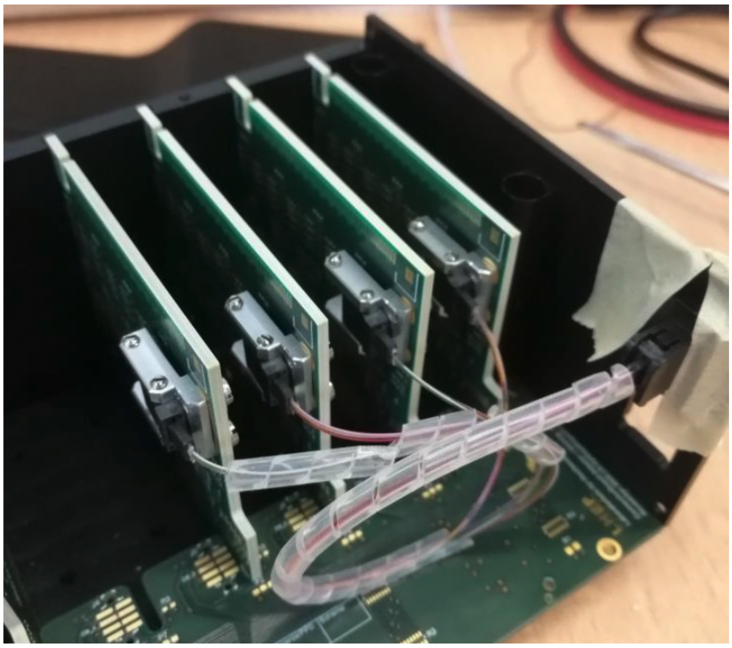

Figure 16: Prototype of the optical fan-out, connected in the mechanical mock-up of an Optobox. Also present in the photo, the mechanical support for the connection between the VTRx+ pigtail and the optical fan-out connector on the Optoboard, and the MT-MTP fibre adapter at the Optobox's wall.

The pinout of the output of the optical fan-out of flavour "A" is shown, as an example, in Figure 17 and in Table 4.

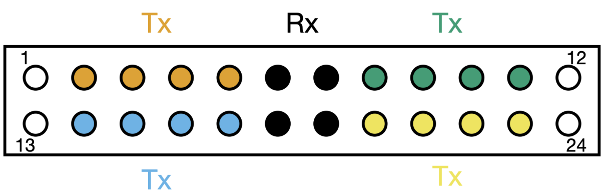

Figure 17: Pinout of the output of the optical fan-out flavour "" at the Optobox wall. The different Tx colour indicate the different Optoboards from which the signals are transmitted.

4.2.3 MPO24 Connectors of the Trunk Cable

The MPO24 connectors of the trunk cable towards the shuffle boxes (at the patch panel in USA15) have the same pinout of the MPO24 connectors at the Optoboxes' wall (there are

MPO24 Pins	MT12 #1	MT12 #2	MPO24 Pins	MT12 #3	MT12 #4
1			13		
2	3		14	3	
3	4		15	4	
4	5		16	5	
5	6		17	6	
6	7		18	7	
7		7	19		7
8		6	20		6
9		5	21		5
10		4	22		4
11		3	23		3
12			24		

Table 4: Connection table of the optical fan-out output (flavour "A") at the Optobox wall. Pin No. 7 of the MT12 connectors (underlined) is the Rx, pins No. 3-6 are the Tx's.

two swaps, at the Optobox's wall and internally inside the trunk cable). The trunk cables will connect preferably fan-outs from Optoboxes reading the same sub-system (Inner System/Outer Barrel/End Caps) and the same flavour of fan-out. To limit the number of trunk cables, however, this division is not always strictly observed. The separation between subsystems will happen at the shuffle boxes in the USA15 cavern.

4.2.4 Shuffle Box

The shuffle boxes will be located in the USA15 cavern. The exact location is still to be decided by Technical Coordination. Shuffle boxes are meant to redistribute the fibres, to accommodate the different number of uplinks and downlinks in each connector from the Optosystem and from the FELIX readout card: in fact, while the MPO24 connectors on the trunk cable have up to 16 uplinks and 8 downlinks each (depending on the fan-out flavours), the FELIX readout cards have two MPO24 connectors, each of which can receive 12 uplinks and 12 downlinks. For the case of the A-type fan-out, its corresponding shuffle box, A-type, will receive up to 12 uplinks and 3 downlinks.

The shuffle boxes feature MPO24 connectors on both sides. The pinout of the connectors on the Optosystem side has swapped rows with respect to the output of the trunk cable, and it is shown, for the A-type, in Figure 18. On the FELIX side, the pinout it shown in Figure 19, while Figure 20 shows the specific pinout.

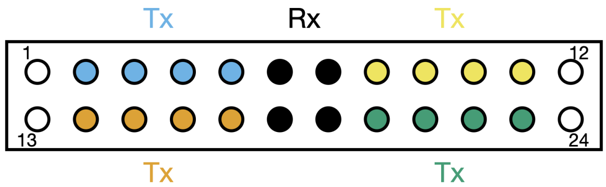

Figure 18: Pinout of the MPO24 connector at the input of a shuffle box of flavour “A”. The same colour-code has been used as in Figure 17. It can be easily seen that the top and the bottom rows are swapped, as a consequence of the presence of multiple key-up-to-key-down adapters along the optical chain.

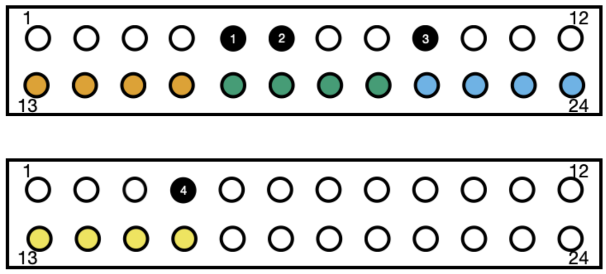

Figure 19: Pinout of the MPO24 connectors at the FELIX side, to read one fan-out of type “A”, with 4 Optoboards using 4 uplink fibres. The two FELIX connectors correspond, for example, to the connector B1 and part of B4 of Figure 20.

4.3 Interface for Power, Interlock and MOPS: the Opto Patch Panel

The interface to the power supplies and to the Detector Control System (DCS) is the Opto Patch Panel. There is one Opto Patch Panel per Optopanel, for a total of eight Opto Patch Panels. A preliminary version of the CAD drawing of this interface is presented in Figure 21.

Each Powerboard requires a power connector (for a total of 28 in the Opto Patch Panels), while there are up to six CAN bus connectors in each Opto Patch Panel.

Shuffle box type A (for fan-outs types A, B)															
B1 or B5	A1 or A4	A2 or A5	A3 or A6	B2 or B6	A1 or A4	A2 or A5	A3 or A6	B3 or B7	A1 or A4	A2 or A5	A3 or A6	B4 or B8	A1 or A4	A2 or A5	A3 or A6
1				1				1				1			
2				2				2				2			
3				3				3				3			
4	13			4		13		4			13	4	7		
5	18			5		18		5			18	5	12		
6	19			6		19		6			19	6		7	
7	24			7		24		7			24	7		12	
8	1			8		1		8			1	8			7
9	6			9		6		9			6	9			12
10				10				10				10			
11				11				11				11			
12				12				12				12			
13	14			13		14		13			14	13	8		
14	15			14		15		14			15	14	9		
15	16			15		16		15			16	15	10		
16	17			16		17		16			17	16	11		
17	20			17		20		17			20	17		8	
18	21			18		21		18			21	18		9	
19	22			19		22		19			22	19		10	
20	23			20		23		20			23	20		11	
21	2			21		2		21			2	21			8
22	3			22		3		22			3	22			9
23	4			23		4		23			4	23			10
24	5			24		5		24			5	24			11

Figure 20: Connection table of the MPO24 connector at the FELIX side (B1 to B8), with respect to the input MPO24 of the shuffle box side (A1 to A6). For the A-type, the Rx pins are pins 6, 7, 18 and 19. Here also pins 1, 12, 13 and 24 are included because this shuffle box scheme is also used for reshuffling fibres from B-type fan-outs, not discussed in this document. For more information, see [1].

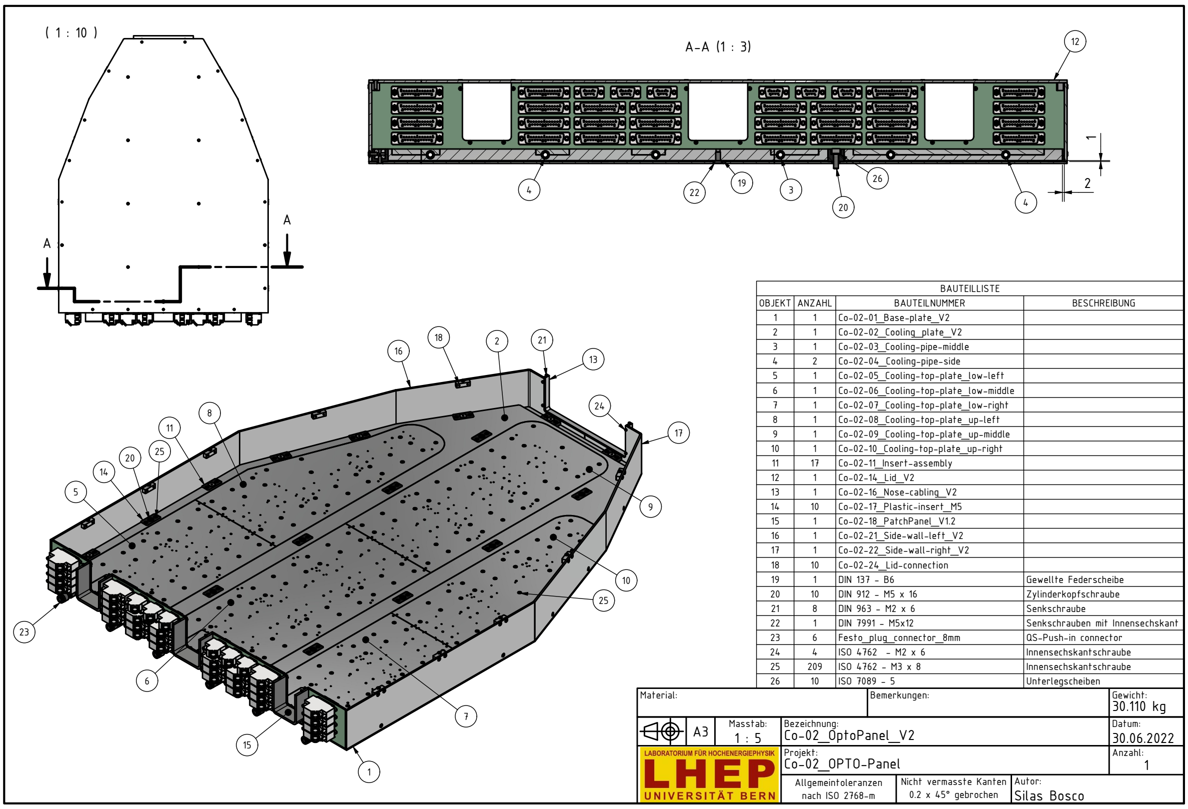

Figure 21: Final version of the CAD of the Patch Panel for the Optopanel. In the new design, the CAN bus connectors will be placed on top, while the power&interlock ones will be lower. Not all connectors are shown in the drawing. The red markings are the fibre outlets of the Optoboxes behind the Opto Patch Panel.

4.3.1 Interlock and Power Connector

The interface of the interlock and power at the Opto Patch Panel consists of:

- At the internal face of the Opto Patch Panel, there is a D-Sub 25 connector (serial number D25PZ/2FP682 [3]). This connector has an integrated 6.8-nF filter. Its CAD drawing is shown in Figure 22 and its pinout is shown in Figure 23.
- Its mating connector is a 25-pin crimp connector (Deltron, serial number DTS 25 PX), shown in Figure 24 [4].
- The external connector is protected from electromagnetic and radio-frequency interferences (EMI and RFI) by a metal hood (serial number DVM 25 UN4-OS, produced by Deltron [5]), which is shown in Figure 25. This hood has an integrated EMI filter.

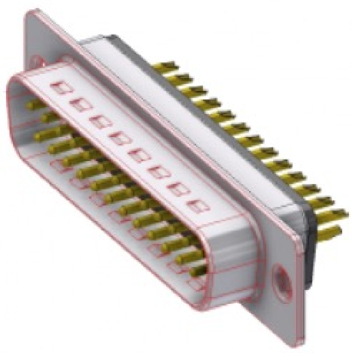

Figure 22: D-Sub 25 interlock and power connector, located on the inner side of the Opto Patch Panel [3].

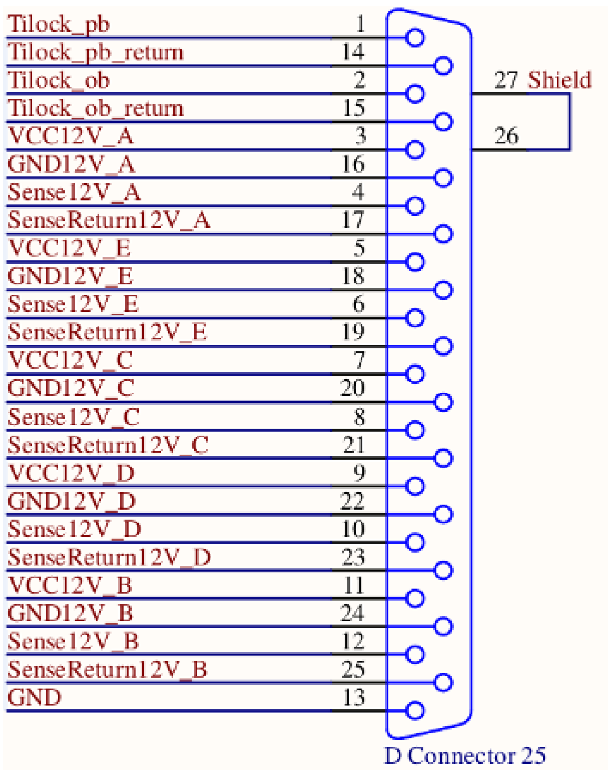

Figure 23: D-Sub 25 Power and Interlock connector pinout.

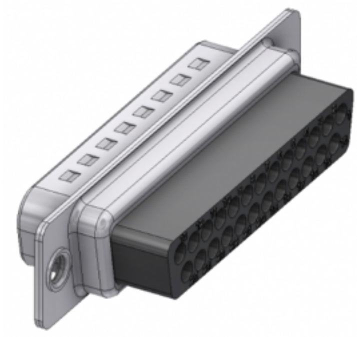

Figure 24: Crimp connector for the interlock and power cable, located on the outer side of the Opto Patch Panel [4].

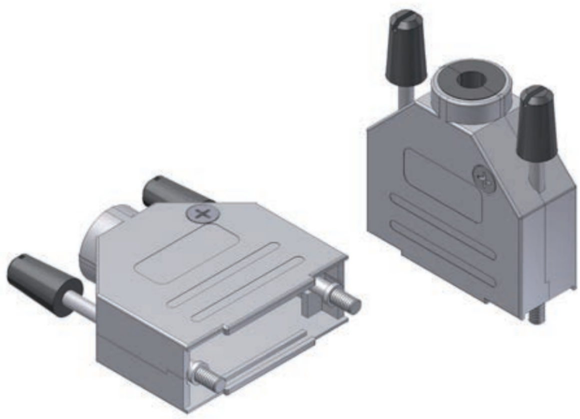

Figure 25: Metal hood EMI/RFI shielding with 90° cable exit [5].

4.3.2 CAN Bus Connector

The interface of the CAN bus at the Opto Patch Panel consists of:

- At the internal face of the Opto Patch Panel, there is a D-Sub 9 connector (serial number D09PZ/2FP331 [6]). This connector has an integrated 330-pF filter. Its CAD drawing is shown in Figure 26, while its pinout is presented in Figure27.
- Its mating connector is a 9-pin crimp connector (Deltron, serial number DTS 09 PX), shown in Figure 28 [7].
- The external connector, similarly to the interlock and power connector, is protected by radiofrequency interferences by a metal hood (serial number DVM 09 UN4-OS) [5].

Figure 26: D-Sub 9 CAN bus connector inside the Optopanel [6].

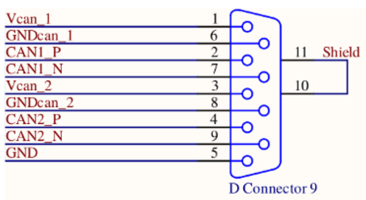

Figure 27: D-Sub 9 CAN bus connector pinout.

Figure 28: Crimp connector for the CAN bus cable outside the Optopanel [7].

4.3.3 Summary of the Interlock & Power and of the CAN Interfaces

Table 5 summarises the power & interlock and CAN interfaces. Numbers only consider ITk Pixel needs, they do not include PLR or BCM'.

Function	Component	Serial number	Quantity	Comment
Interlock and power connectors	Crimp connector D-sub 25 Metal hood	DTS 25 PX D25PZ/2FP682 DVMA 25 M3-OS	220	1x per Optobox
CAN bus connectors	Crimp connector D-sub 9 Metal hood	DTS 09 PX D09PZ/2FP331 DVMA 09 M3-OS	34	4x per Optobox

Table 5: Summary of the Power&Interlock and CAN interfaces for the ITk Pixel only.

Bibliography

[1] L. Franconi and A. O'Neill. Pin-to-pin mapping between PP0 and the FELIX connectors in ITk Pixel. EDMS Document No. AT2-IP-EN-0030. Technical report, 2021.

[2] J. Troska, A. Brandon-Bravo, S. Detraz, A. Kraxner, L. Olanterä, C. Scarcella, C. Sigaud, C. Soos, and F. Vasey. The VTRx+, an optical link module for data transmission at HL-LHC. *PoS*, TWEPP-17:048, 2017.

[3] Deltron AG. D-Sub 25 connector, D25PZ/2FP682.

[4] Deltron AG. Crimp connector Deltron DTS 25 PX.

[5] Deltron AG. Metal hood EMI/RFI shielding, DVM 25 UN4-OS and DVM 09 UN4-OS.

[6] Deltron AG. D-Sub 9 connector, D09PZ/2FP331.

[7] Deltron AG. Crimp connector Deltron DTS09PX.