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| | **ALICE LS2 optical fibers** | | |
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# ALICE LS2 optical fibers

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*Distribution List*

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# 1 Introduction

The ALICE read-out performance will increase substantially for the run period after LS2. More than 20'000 optical fibers will be needed for this upgrade. Given the amount of fibers, the best technical solution consists of using pre-connectorized multi-fiber optical cables (called trunk cables). This solution is preferable to blowing individual fibers (i.e. what is in place at the moment), because of the complication of making the splices in situ. Trunk cables with different number of fibers are available on the market, ranging from 4 to 144 fibers. 144 fibers trunk cables are preferred for their compactness, and – in only few cases – 48 fibers cables will be used.

In Chapter 2 the O2 fiber architecture is described. Chapter 3 reports the timeline and the strategy for the purchase and installation of fibers. Chapter 4 lists the number of O2 and trigger fibers needed per detector, along with their routing and the position of the terminal plates inside the ALICE cavern. The Trigger distribution through CRU fibers is described in Chapter 5. Chapter 6 defines the responsibilities for the installation of fibers and patch cords. Finally, Chapter 7 provides the criteria for the repartition of cost across the different projects.

As complement to this document, an Excel file reports the detailed schemes of all sub-racks as well as the CR1 layout.

# 2 O2 fiber architecture

The O2 fiber architecture is shown in Figure 1. The CRU, located in CR1, is fitted with 12-channel MPO connectors. The trunk cables are terminated in the sub-racks inside the CR1 racks. From there, individual MPO-MPO patch cords are used towards the CRUs. The detector front-end electronics in the cavern is fitted with LC/PC connectors; therefore, MPO-12LC patch cords (1 MPO in 12 LC) are used. By doing so, the FEE signals inside the trunk cables are mapped in a way to reflect the CRU allocation. The MPO connectors are plugged in the 4U or 1U sub-racks where the trunk cables are terminated. In some cases (e.g. TPC A-side and MCH), these sub-racks are housed in 8U or 12U mini-racks (for extra mechanical protection). In other cases (e.g. TOF, MFT, and ITS) where the available space is reduced, the bare terminal plates are installed (with or without the sub-racks). The 144 fiber trunk cables have 12 MPO connectors on each side. One cable fills one terminal plate, and up to 12 terminal plates can be fitted inside a sub-rack. So, in principle, we could have up to 144 x 12 = 1'728 fibers in a 4U sub-rack. This solution, although feasible, is considered too 'dense' by the fiber experts (EN-EL-CF section). It is therefore preferable to limit the number of terminal plates inside a sub-rack to 10 (1'440 fibers). All the O2 fibers will be multi-mode fibers, with the exception of fibers from CTP via LTU to CRU and ITS/MFT trigger fibers from CTP to ITS/MFT read-out boards where single mode fibers are needed.

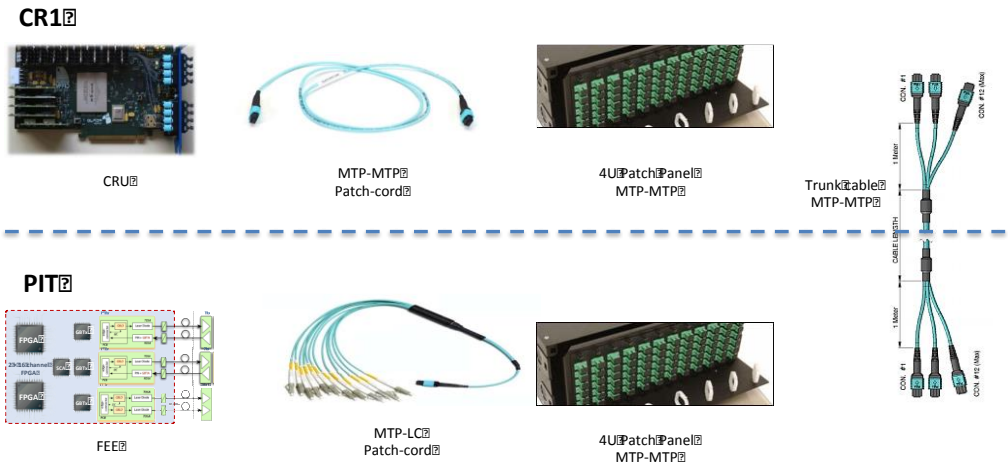


Figure 1 – O2 fiber architecture

# 3 Fibers procurement and installation planning

The installation of the optical fibers is planned in the first year of LS2, precisely from March to December 2019, in parallel to the TPC upgrade in the cleanroom. As it is not foreseen to install a patch panel for fibers in PP0 (e.g. on the side of the Mini-Frame opposite to the TPC/ITS), the ITS and TPC-A fibers have to be bundled next to the present PP0 until the Mini-Frame installation, in March 2020. For all the other detectors the complete test of the fibers is foreseen in 2019 (right after the installation).

The prices quoted in this document are from the present CERN frame contract, managed by EN-EL-CF. This contract has been re-negotiated at present and updated prices are available as of November 2017.

As for the patch cords, a competitive tender (together with LHCb) has been initiated in November 2017. In this document, the pricing of the patch cords is done considering the updated offer from EN-EL-CF (Nov 2017).

# 4 O2 and trigger fibers

## 4.1 TPC

The TPC O2 fibers are summarized in Table 1. The A-side trunk cables will be terminated in 4 mini-racks in the Mini-frame (Figure 2). On the C-side, the existing sub-racks located in the Back-Frame will be reused. The distribution of terminal plates inside the TPC sub-racks is reported in the Excel file.

| | Trunk cables (144x) | Length [m] | Patch cords (pit) MPO-12LC | Length [m] | Patch cords (CR1) MPO-MPO | Length [m] |
|---|---|---|---|---|---|---|
| **TPC-A** | 52 (4) | 105 | 580 (40) | 8 (30cm fan-out) | 580 (40) | 5 |
| **TPC-C** | 52 (4) | 125[1] | 580 (40) | 7 (30cm fan-out) | 580 (40) | 5 |
| **TPC TOT** | 104 (8) | | 1160 (80) | | 1160 (80) | |

Table 1 – TPC trunk cables and patch cords. The spares are in brackets.

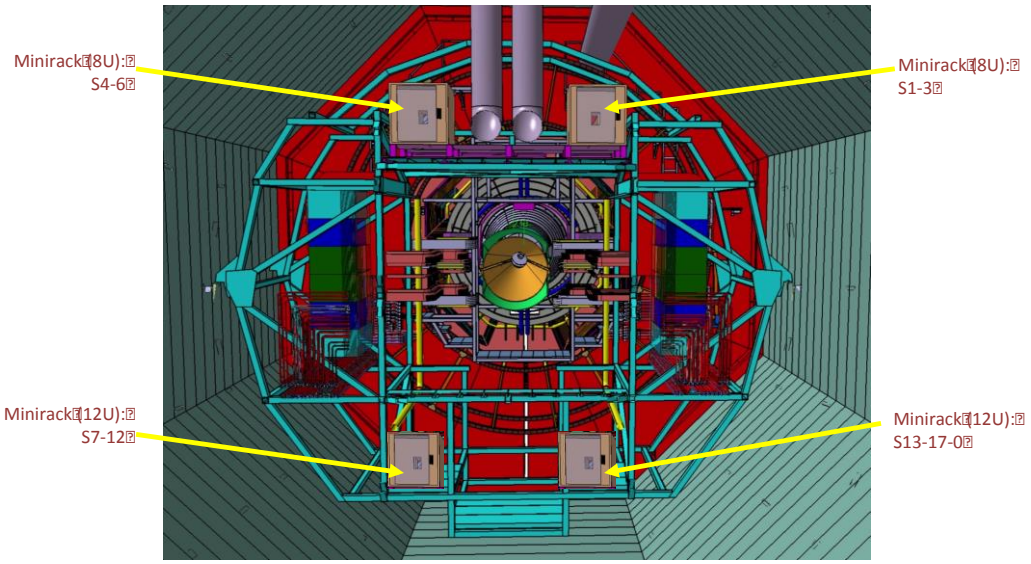


Figure 2 – Position of TPC mini-racks in the Miniframe.

The TPC trunk cables will be routed according to the routing in Figure 3. The A-side trunk cables will follow the O-side cable-trays from CR1, which were installed by EN-EA during the EYETS 2016-17. The distance inside the Mini-Frame is 25 m (the fibers must be bundled in the place indicated by the arrow in Figure 3).

[1] 120m in case the cables are routed in the gap between L3 and Dipole (instead of using the C-side chicanes).

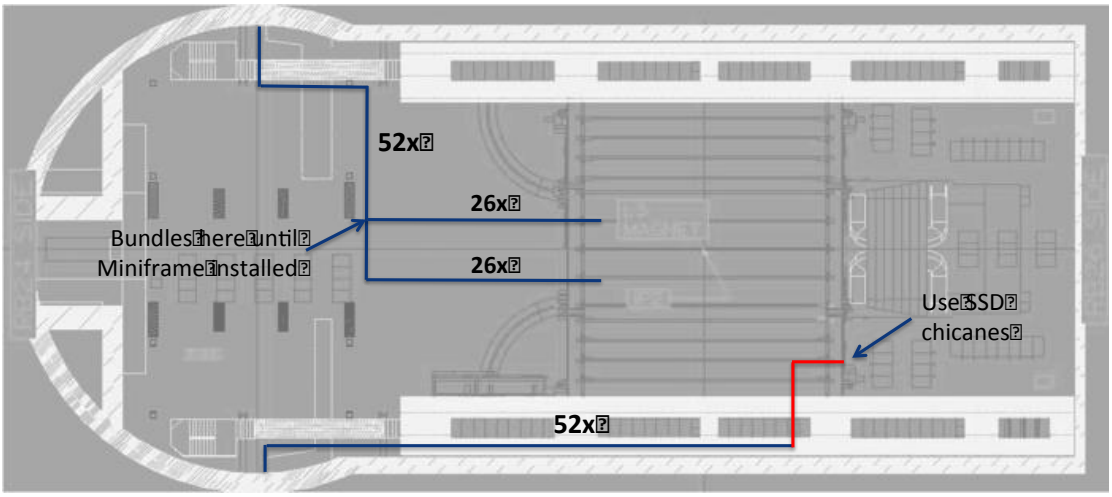


Figure 3 – Routing of TPC trunk cables in the pit.

The C-side trunk cables will be routed on the I-side cable-trays, installed during the EYETS 2016-17. The SSD LV cables (marked in red in Figure 3) must be removed in order to free the space in the L3 chicanes for the TPC-C trunk cables (see Figure 4). Up to 10 chicanes can be freed in this way. As alternative path to access the L3 magnet, the trunk cables can be routed in the gap between the L3 and Dipole magnet, enter the FASS and then be routed towards the back-frame (see Figure 5). In this way, the TPC-C cables are 5 meters shorter than what is reported in Table 1. The advantage of this solution is that there is more space (therefore also fan-out cables would fit the installation).
The termination of the TPC-C trunk cables inside the L3 magnet are the, already existing, fiber sub-racks installed all around the Back-Frame. In order to leave the space for the TPC terminal plates, the existing TPC and TOF DAQ terminal plates must be removed. The distribution of terminal plates inside the TPC sub-racks is reported in the annexed Excel file.

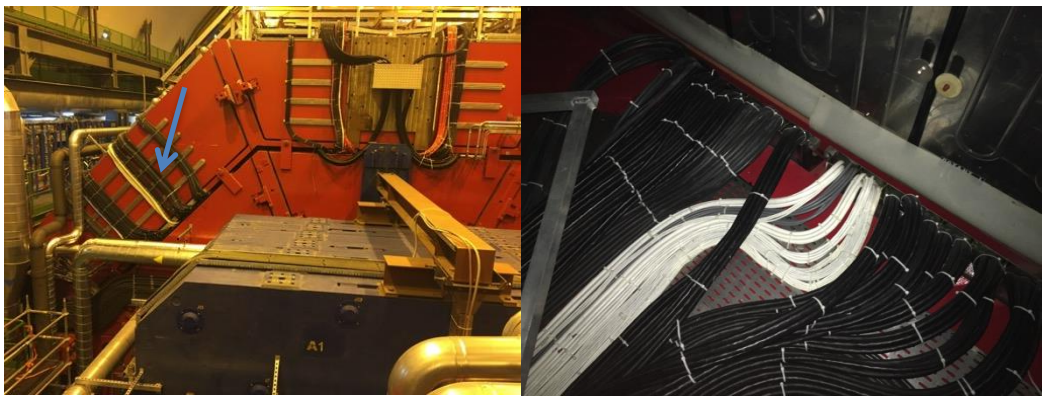

Figure 4 – Chicanes on the C-side of L3. The SSD LV cables (right photo) must be removed to install the TPC trunk cables.

**Figure 5 – Possible passage of TPC-C cables through the gap between the Dipole and L3 magnets. The left photo shows the gap from outside, and the right photo is taken from inside the Dipole. The inox pipes (ITS) must be removed.**

## 4.2 ITS

The ITS O2 fibers are summarized in Table 2.

| | Trunk cables (144x) | Length [m] | Patch cords (pit) MPO-12LC | Length [m] | Patch cords (CR1) MPO-MPO | Length [m] |
|---|---|---|---|---|---|---|
| **ITS** | 8 (2) | 100 | 80 (8) | 1.5 (30cm fan-out) | 80 (8) | 5 |

**Table 2 – ITS trunk cables and patch cords. The spares are in brackets.**

All the ITS services will be routed on the A-side, and the optical fibers will therefore follow the same routing of the TPC-A fibers (see Figure 3). The cables will be bundled next to PP0, as the TPC ones. Inside the Mini-Frame, they will be split in two identical bundles (4 trunk cables each), going to the 12 ITS RU crates (6 per side) shown in Figure 6. MPO-12LC patch cords will be connected to the electronic cards.

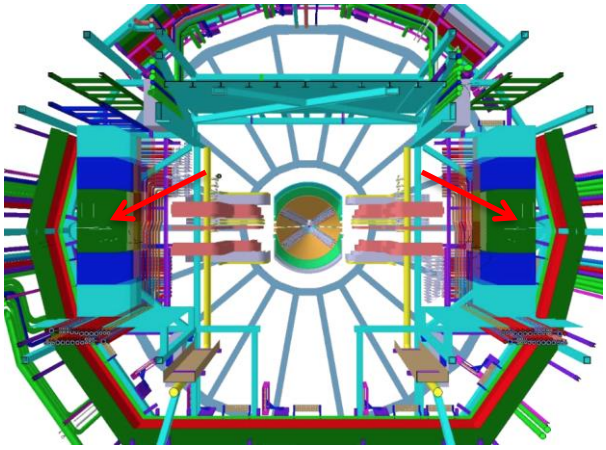

Figure 6 – Position of the ITS RU crates in the Mini-frame (red arrows). The optical fibers will be connected to terminal plates installed in the crates.

Concerning the ITS direct trigger, 12 Single Mode (SM) fibers plus 12 spares, the setup is the following. Single LC/PC-LC/PC SM patch cords will connect the GBTx standard LTU plugs to terminal module of 24xLC/PC connectors, from there conventional cables of 12 fibers will be routed to the ITS RU crates in the Mini-frame and spliced in 6U VME size terminal plates with 12xLC/PC connectors. From there, 12 LC/PC-LC/PC patch cords will connect each 1→16 splitter boxes which will distribute the trigger to the 192 ITS RUs by means of the LC Single Mode patch cords exiting from the splitter boxes (Table 3).

| | Conventional cables (12 fibers) | Length [m] | Patch cords (CTP-C24) LC/PC-LC/PC | Length [m] | Patch cords (Mini-Frame) LC/PC-LC/PC | Length [m] |
|---|---|---|---|---|---|---|
| **ITS (GBTx)** | 2 | 50 | 15 (3) | 3 | 15 (3) | 2 |

Table 3 – ITS conventional cables for direct trigger with GBTx standard and patch cords. The spares are in brackets.

## 4.3 TRD

The TRD O2 fibers are summarized in Table 4. The existing TRD fiber infrastructure from the Supermodules (SMs) to the C17 rack will stay in place, and the new trunk cables will be terminated inside C17.

| | Trunk cables (144x) | Length [m] | Patch cords (pit) MPO-12LC | Length [m] | Patch cords (CR1) MPO-MPO | Length [m] |
|---|---|---|---|---|---|---|
| **TRD (C17)** | 10 (1) | 135 | 120 (12) | 3 (30cm fan-out) | 120 (12) | 5 |

Table 4 – TRD trunk cables and patch cords. The spares are in brackets.

## 4.4 MFT

The MFT O2 fibers are summarized in Table 5.

| | Trunk cables (144x) | Length [m] | Patch cords (pit) MPO-12LC | Length [m] | Patch cords (CR1) MPO-MPO | Patch cords (CR1) MPO-12LC | Length [m] (fan-out) |
|---|---|---|---|---|---|---|---|
| **MFT** | 4 (1) | 125[2] | 35 (5) | 5 (30cm fan-out) | 23 (3) | 12 (2) | 5<br>5 (30cm fan-out) |

Table 5 – MFT trunk cables and patch cords. The spares are in brackets.

The MFT trunk cables will be terminated in 2x 1U sub-racks, located on the top of the Front Absorber (Figure 7). The cables will be routed along with the TPC-C fibers, and the same considerations concerning the chicane apply to the MFT cables (see 4.1). MPO-12LC patch cords will be connected to the electronic cards in 4 RU crates located on the feet of the Front Absorber (Figure 7 and Figure 8). The trunk cable used to carry on the control signal will be connected in a second sub-rack of the same rack in CR1 to 6x 2xMPO→24xLC terminal plates, to better distribute the controls from the CRUs by means of MPO-12LC patch cords.

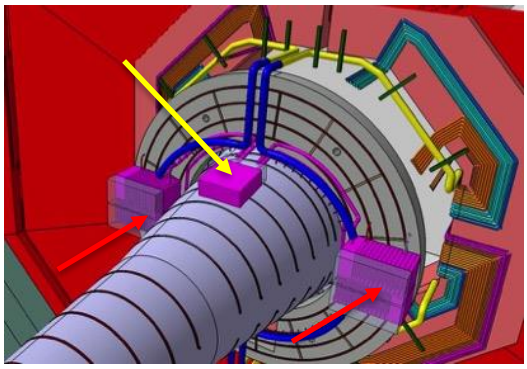

Figure 7 – Location of 2x 1U sub-racks (yellow arrow) for the MFT trunk cables, and RU crates (red arrows).

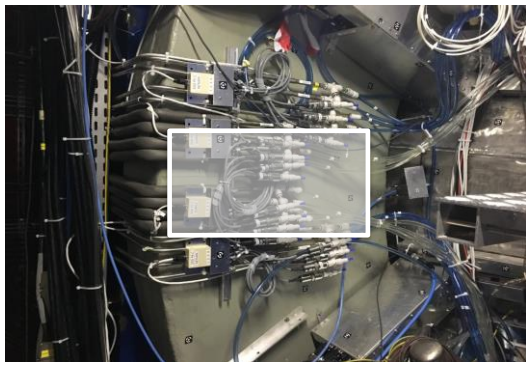

Figure 8 – Location of the MFT crates (O-side) on the feet of the Front Absorber. The I-side is symmetric.

Concerning the MFT direct trigger (8 Single Mode fibers plus 4 spares), the setup is the following. Single LC/PC-LC/PC SM patch cords will connect the GBTx standard LTU plugs to terminal module of 24xLC/PC connectors, from there a conventional cable of 12 fibers will be routed to the MFT 1U sub-racks on the Front Absorber and spliced in a terminal plate with 12xLC/PC connectors. From there, 8 LC/PC-LC/PC patch cords will connect each 1→16 splitter boxes which will distribute the trigger to the 80 MFT RUs by means of the LC Single Mode patch cords exiting from the splitter boxes (Table 6).

[2] 120m in case the cables are routed in the gap between L3 and Dipole (instead of using the C-side chicanes).

| | Conventional cables (12 fibers) | Length [m] | Patch cords (CTP-C24) LC/PC-LC/PC | Length [m] | Patch cords (Absorber) LC/PC-LC/PC | Length [m] |
|---|---|---|---|---|---|---|
| **MFT (GBTx)** | 1 | 30 | 8 (2) | 3 | 8 (2) | 5 |

Table 6 – MFT conventional cables for direct trigger with GBTx standard and patch cords. The spares are in brackets.

## 4.5 TOF

The TOF O2 fibers are summarized in Table 7.

| | Trunk cables (48x) | Length [m] |
|---|---|---|
| **TOF-A-O** | 2 (1) | 90 |
| **TOF-A-I** | 1 | 110 |
| **TOF-C** | 3 (1) | 130[3] |
| **TOF TOT** | 6 (2) | |

Table 7 – TOF trunk cables. The spares are in brackets.

The TOF trunk cables will be routed according to the scheme in Figure 9. The C-side trunk-cables will come from the I-side, on cable trays installed during the EYETS 2016-17. The cables will be routed along with the TPC-C fibers (see 4.1 for the considerations about the L3 chicanes). The termination of the TOF-C trunk cables inside the L3 magnet are the, already existing, fiber sub-racks installed all around the Back-Frame. In order to free the space for the TOF terminal plates, the existing TPC and TOF DAQ terminal plates must be removed. The existing TOF DCS and TTC and TRD DAQ terminal plates (and patch cords) will stay in place. The two TOF-C trunk cables will be terminated in SR8 and 17 (2xMPO-24xLC terminal plate), which are opposite sectors (and the spare in SR10). Individual patch cords LC-LC (4 per TOF SM) will be routed (inside corrugated ducts) from those sectors to each TOF SM.

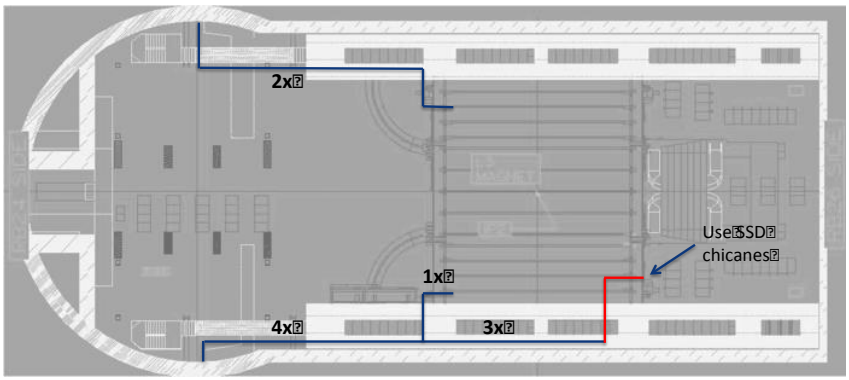


Figure 9 – Routing of TOF trunk cables in the pit.

[3] 120m in case the cables are routed in the gap between L3 and Dipole (instead of using the C-side chicanes)

Two of the A-side trunk cables (1 plus 1 spare) will be routed into the O-side cable-trays from CR1. This cable will be used for TOF SM4 to SM12. For the last part, including the passage through the O-side L3 door, the existing cable tray for the TOF DAQ fibers will be reused (see Figure 10). Inside the L3 magnet, there will be 2x 1U sub-rack. This sub-rack will be located under the Baby-Frame beam (see Figure 12). The sub-rack will split the connectors from MPO to LC (2xMPO-24xLC terminal plates). From there, individual LC-LC patch cords (4 per TOF SM) will be routed (inside corrugated ducts), across the Baby-Frame, to reach the TOF SMs.
The third A-side trunk cable will be routed in the I-side cable trays from CR1. This cable will enter inside the L3 magnet via an empty chicane located on the vertical part of the I-side door (see Figure 11). This cable will be used for TOF SM13 to SM17 and SM0 to SM3. The sub rack will be located under the Baby-Frame beam, in a similar place as for the O-side (Figure 12). The sub-rack will split the connectors from MPO to LC (2xMPO-24xLC terminal plates). From there, individual LC-LC patch cords (4 per TOF SM) will be routed (inside corrugated ducts), across the Baby-Frame, to reach the TOF SMs.

The total lengths of the TOF patch cords are reported in Table 8.

| | Patch cords LC-LC (pit) | Length [m] | TOF sector | Patch cords MPO-MPO (CR1) | Length [m] |
|---|---|---|---|---|---|
| **TOF-A** | 44(4) | 5 | 0,8-12,14-17 | 12(4) | 5 |
| | 32(4) | 8 | 1-3,5-7,13 | | |
| | 8(4) | 10 | 4 | | |
| | 8 | 15 | spares | | |
| **TOF-C** | 44(4) | 5 | 0,1,6-10,15-17 | 12(4) | 5 |
| | 36(4) | 8 | 2-5,11-14 | | |
| | 8 | 15 | spares | | |

**Table 8 – TOF patch cords, number and lengths.**

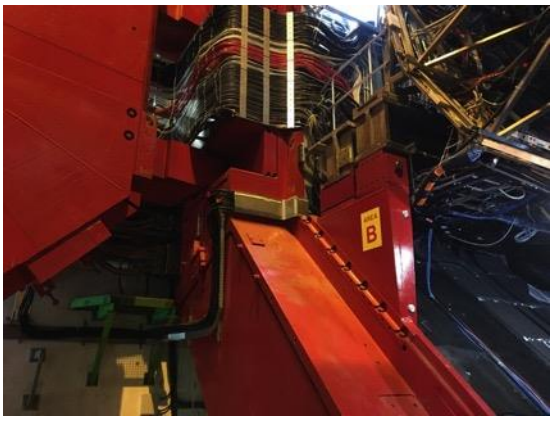

**Figure 10 - Existing TOF DAQ fibers on the A-side.**

**Figure 11 – Existing empty chicane on the vertical part of A-I side door.**

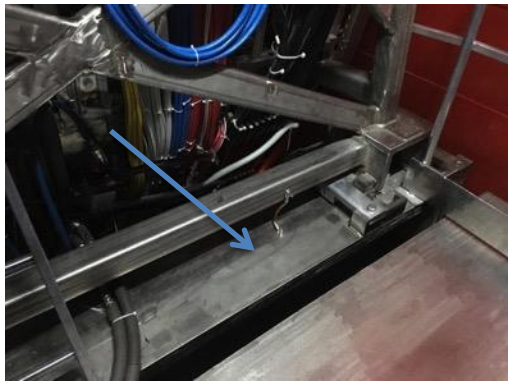

Figure 12 – Location of the TOF fiber patch panel on the A-O side (symmetric on the A-I side).

## 4.6 FIT

The FIT O2 fibers are summarized in Table 9. All the FIT fibers will be terminated inside the FIT rack C33.

| | Trunk cables (48x) | Length [m] | Patch cords (pit) MPO-12LC | Length [m] | Patch cords (CR1) MPO-MPO | Length [m] |
|---|---|---|---|---|---|---|
| **FIT (C38)** | 3 (1) | 140 | 8 (2) | 5 (30cm fan-out) | 8 (2) | 5 |

Table 9 – FIT trunk cables and patch cords. The spares are in brackets.

For the FIT calibration laser system, the following fibers are needed: from T0A+ to C33 (34m): 1 fiber (type FVP100110125) plus 1 spare; 2 fibers (type 50/125 OM3 dispersion compensated fiber) plus 2 spares; from T0C+ to C33 (33m): 2 fibers (type FVP100110125) plus 1 spare; 2 fibers (type 50/125 OM3 dispersion compensated fiber) plus 2 spares. From V0A+ to C33 (38m): 4 fibers (type 50/125 OM3) plus 2 spare (type 50/125 OM3).

## 4.7 MCH

The MCH O2 fibers are summarized in Table 10.

| | Trunk cables (144x) | Length [m] |
|---|---|---|
| **MCH-I** | 6 (1) | 135 |
| **MCH-O** | 6 (1) | 135 |
| **MCH TOT** | 12 (2) | |

Table 10 – MCH trunk cables. The spares are in brackets.

The trunk cables will be terminated into two 12U mini-racks (one per each side), which will be attached to the cast-shielding wall as shown in Figure 13. ST4-5, which have movable half-planes, will have a patch-panel for the fibers. The position of these patch panels is shown in Figure 13. MPO-MPO fibers will connect the MCH mini-rack to these patch-panels (these fibers will be routed under the

floor, in order to clear the way for opening the half-planes). These patch-panels will also split the MPO connectors into a series of LC connectors. From there, individual LC-LC fibers will be routed (along the service structure) to reach the SOLAR boards. ST1-2-3 will not use these intermediate patch-panels: individual MPO-12LC patch cords will be routed from the MCH mini-rack to the stations.

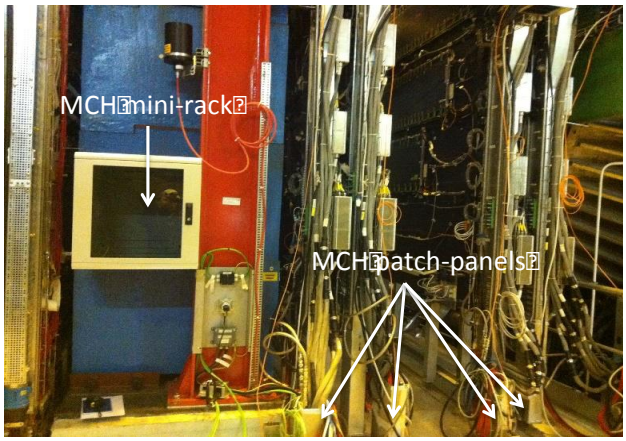


**Figure 13 – Location of the MCH mini-rack and ST-4&5 patch panels on the O side (symmetric on the I side). The ST1-3 do not have intermediate patch panels.**

The quantities and total lengths of the MCH ST1-3 and ST4-5 patch cords are reported in Table 11 and Table 12 respectively.

| MCH ST | Patch cords MPO-12LC (pit) | Length [m] (fan-out length included [m]) | Patch cords MPO-MPO (CR1) | Length [m] |
|---|---|---|---|---|
| **1-O** | 8 | 25 (2) | 8 | 5 |
| **2-O** | 8 | 25 (2) | 8 | 5 |
| **3-O** | 12 | 25 (2) | 12 | 5 |
| **1-I** | 8 | 25 (2) | 8 | 5 |
| **2-I** | 8 | 25 (2) | 8 | 5 |
| **3-I** | 12 | 25 (2) | 12 | 5 |
| Spares | 6 | 25 (2) | 6 | |
| **MCH TOT** | 62 (6) | | 62 (6) | |

**Table 11 – MCH ST1-3 patch cords, number and lengths.**

| MCH ST | Patch cords MPO-MPO (pit) | Length [m] | Patch cords LC-LC (pit) | Length [m] | Patch cords MPO-MPO (CR1) | Length [m] |
|---|---|---|---|---|---|---|
| **4-O** | 16 | 15 | 152 | 10 | 16 | 5 |
| **5-O** | 16 | 15 | 176 | 10 | 16 | 5 |
| **4-I** | 16 | 15 | 152 | 10 | 16 | 5 |
| **5-I** | 16 | 15 | 176 | 10 | 16 | 5 |
| Spares | 6 | | 24 | | 6 | |
| **MCH TOT** | 70 (6) | | 680 (24) | | 70 (6) | |

**Table 12 – MCH ST4-5 patch cords, number and lengths.**

### 4.8 MID

The needed MID O2 fibers are summarized in Table 13. All the MID fibers will be terminated inside the MID racks I36 and O36.

| | Trunk cables (48x) | Length [m] | Patch cords (pit) MPO-12LC | Length [m] | Patch cords (CR1) MPO-MPO | Length [m] |
|---|---|---|---|---|---|---|
| **MID-I (I36)** | 2 (1) | 110 | 6 (2) | 4 (1.5 m fan-out) | 6 (2) | 5 |
| **MID-O (O36)** | 2 (1) | 110 | 6 (2) | 4 (1.5 m fan-out) | 6 (2) | 5 |
| **MID TOT** | 4 (2) | | 12 (4) | | 12 (4) | |

Table 13 – MID trunk cables and patch cords. The spares are in brackets.

### 4.9 ZDC

The MCH O2 fibers are summarized in Table 14. The trunk cables will be terminated in CR4, where the ZDC rack X08 is located.

| | Trunk cables (48x) | Length | Patch cords (CR4-X08) MPO-12LC | Length [m] | Patch cords (CR1) MPO-MPO | Length [m] |
|---|---|---|---|---|---|---|
| **ZDC (CR4-X08)** | 2 (1) | 50 | 6 (2) | 3 (50cm fan-out) | 6 (2) | 5 |

Table 14 – ZDC trunk cables and patch cords. The spares are in brackets.

### 4.10 CTP

The CTP O2 fibers are summarized in Table 15.

| | Trunk cables (48x) | Length [m] | Patch cords (pit) MPO-12LC | Length [m] | Patch cords (CR1) MPO-MPO | Length [m] |
|---|---|---|---|---|---|---|
| **CTP (C24)** | 3 (1) | 140 | 12 (4) | 5 (30cm fan-out) | 12 (4) | 5 |

Table 15 – CTP trunk cables and patch cords. The spares are in brackets.

## 5 Trigger through CRUs for TPC, MCH, MID, FIT, ACO, TOF, TRD, ZDC, CTP

These detectors will receive trigger through the CRUs with the following routing. MPO-12xSC/UPC Single Mode (SM) fan-out will connect the LTU XGPON standard plugs to 12xMPO-MPO terminal plate and from there a trunk cable of 48 fibers will be routed up to CR1 in terminal plates 2xMPO-24xLC/APC, through I-side path. Single LC/APC-SC/APC patch-cords will connect each splitter box and from there single SC/APC-SC/UPC patch-cords will connect the splitter outputs to each CRU (Table 16).

The needed fibers are the following: TPC (6), MCH (1), MID (1), FIT (1), ACO (1), TOF (1), TRD (2), ZDC (1) and CTP (1) and spares (34).

| | **Trunk cables (48x) SM** | **Length [m]** | **Patch cords (pit) SM MPO-12SC/UPC** | **Length [m]** |
|---|---|---|---|---|
| **CTP (C24)** | 1 | 140 | 6 (2) | 3 (30cm fan-out) |
| | **Patch cords (CR1) SM LC/APC-SC/APC** | **Length [m]** | **Patch cords (CR1) SM SC/APC-SC/UPC** | **Length [m]** |
| | 20 (7) | 10 | 465 (27) | 5 |
| | **Patch cords (CR1) SM LC/APC-SC/UPC** | **Length [m]** | **Patch cords (CR1) SM LC/APC-SC/UPC** | **Length [m]** |
| | 3(2) | 10 | 3(2) | 5 |

**Table 16 – CTP trunk cable and patch cords for XGPON standard. The spares are in brackets.**

# 6 Responsibilities

The installation and test of the trunk cables (including spares), mini-racks and sub-racks and of the terminal plates (both sides) will be done centrally, under the coordination of the ALICE TC. The O2 team will do the installation of the patch cords and splitter modules in CR1. The installation of the patch cords in the pit (including the corrugated ducts, where needed) will be done by the projects (with the only exception of the MCH MPO-LC patch cords for ST1-2-3 and the MCH MPO-MPO patch cords for ST4-5).

# 7 Budget

The supply of trunk cables and patch cords will be paid by the projects, depending on the effective number of items purchased (according to the quantities reported in Ch. 4). The cost for the installation and test of the trunk cables will be paid by the common fund (the cost quoted by EN-EL-CF in 2017 corresponds to 260kE). Table 17 and Table 18 report respectively the total number of trunk cables to be purchased (and installed) and the number of patch cords.

| | Trunk cables O2 (incl. spares) | |
|---|---|---|
| | 144 | 48 |
| TPC | 104 | |
| ITS | 8 | |
| TRD | 10 | |
| MFT | 4 | |
| TOF | | 6 |
| FIT | | 3 |
| MCH | 12 | |
| MID | | 4 |
| ZDC | | 2 |
| CTP | | 3 |
| TOTAL | 138 | 18 |

Table 17 – Total number of trunk cables to be purchased.

| | MPO-12LC | MPO-MPO | LC-LC |
|---|---|---|---|
| TPC | 1160 | 1160 | |
| ITS | 80 | 80 | |
| TRD | 120 | 120 | |
| MFT | 47 | 23 | |
| TOF | | 10 | 180 |
| FIT | 8 | 8 | |
| MCH | 62 | 202 | 680 |
| MID | 12 | 12 | |
| ZDC | 6 | 6 | |
| CTP | 12 | 12 | |
| TOTAL | 1507 | 1633 | 860 |

Table 18 – Total number of patch cords to be purchased.

In order to provide indicative numbers about the cost for each project, the offers for supply of trunk cables and patch cords received in 2016 from CERN are compared with the discounted ones received in Nov 2017 (see Table 19).
Table 20 reports the cost per project according to the CERN offers of Nov 2017. The length of patch cords and trunk cables is assumed everywhere to be 5m and 120m respectively.

| | CERN cost (2017) [Euros] | CERN cost (2016) [Euros] |
|---|---|---|
| **1x 144 trunk cable (120m)** | 3'219 | 4'789 |
| **1x 48 trunk cable (120m)** | 1'520 | 1'626 |
| **1x MPO-12LC patch cord (5m)** | 119 | 186 |
| **1x MPO-MPO patch cord (5m)** | 94 | 150 |
| **1x LC-LC (5m)** | 12 | Not quoted |

**Table 19 – Cost of trunk cables and patch cords according to quotations from CERN frame contracts.**

In addition to the fibers, materials related to the installation (terminal plates, fixing clamp, subracks, etc.) will be paid by the projects, depending on the effective number of needed items (the total cost of these additional materials quoted by CERN in 2017 corresponds to 46kE).

| | Cost trunk cables (2017) | Cost patch cords (2017) | Tot (2017) | Tot (2016) |
|---|---|---|---|---|
| **TPC** | 325 | 245 | 570 | 888 |
| **ITS**[4] | 23 | 17 | 40 | 65 |
| **TRD** | 34 | 25 | 59 | 88 |
| **MFT**[5] | 14 | 7 | 20 | 31 |
| **TOF**[6] | 9 | 4 | 13 | 12 |
| **FIT**[7] | 5 | 3 | 8 | 8 |
| **MCH**[8] | 42 | 34 | 76 | 99 |
| **MID** | 6 | 3 | 9 | 10 |
| **ZDC** | 2 | 1 | 3 | 5 |
| **CTP**[9] | 5 | 3 | 8 | 9 |
| **TOTAL** | 689 | 526 | **806** | **1'215** |

**Table 20 – Cost per project, using CERN frame contracts. All numbers in k-Euros.**

[4] ITS trigger fibers not included
[5] MFT trigger fibers not included
[6] TOF single LC-LC patch cords included in the quote of 2017
[7] FIT laser calibration fibers not included
[8] MCH single LC-LC patch cords included in the quote of 2017
[9] CTP trigger fibers to CRU not included