Cabling of EM calorimeters

Preliminary

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The following defines the cabling to be obeyed to for the EM LARG calorimeters of ATLAS. For module 0 people should try to be as close as possible to this cabling; however hardware pieces already built may impose some (hopefully small) departures from this scheme. The principle of the cabling scheme was defined in the TDR. This note completes and sometines corrects the information given there. This note supersedes the TDR.

To be checked:

Cables:	P. Imbert, D. Makowiecki
Feedthrough:	D. Rahm
Front-end crate:	H. Takai
Front-end board:	J. Parsons, E. Auge
Level 1 sums:	W. Cleland, J. Teiger
Calibration board:	I. Wingerter-Seez, L. Serin
Test beam software:	M. Seman

To be approved:

Electronics conveners:	V. Radeka, C. de la Taille, J. Colas
Technical coordinator:	V. Vuillemin
Project Leader:	D. Fournier

1.0 Constraints

- Channel mapping should obey to requirements imposed by the analog trigger summation: within a shaper chip, all channels belong to the same trigger tower. Trigger towers and detection cells are defined in figures 10-3 and 10-4 of the TDR and are repeated here for convenience in Figure 1 on page 11 and Figure 2 on page 12. In addition, in a front-end board, signals should be roughly in time.
- All barrel modules and associated feedthroughs have identical cabling. The same apply to the EMEC wedges. For a given rapidity interval and a given layer in depth, all motherboards are identical and are cabled in the same way.
- The channel mapping of EM barrel, PS barrel, EMEC should be as consistent as possible with one another.

2.0 Local coordinate system:

To enforce the identical cabling requirement, a coordinate system local to a module or a wedge and their associated feedthroughs is defined (see Figure 3 on page 13). In the following, η and ϕ refer to the rapidity and azimuth as defined in this local frame.

Both for barrel and end-cap, the local origin is the "pp collision point" as defined by the pattern drawn on the kapton. The z axis is along the LHC beam line. More specifically:

2.1 Barrel modules:

- **z axis:** pointing from the barrel centre to the "end" of the module i.e. toward the cut corner. This axis defines the pseudo-rapidity η and a positive rotation direction (right handed rotation) i.e. a positive direction for the local azimuthal angle ϕ.
- **x axis:** pointing from the inside toward the module in its centre. i.e. there will be one FT at negative ϕ and one at positive ϕ and the x axis goes in order through PS, strips, middle layer, back layer.
- **y axis:** defined such as to get a right handed system. Close to $\phi = 0$, increasing ϕ goes like increasing y.

2.2 End-Cap:

- **z axis:** pointing from the interaction point to the EMEC. i.e. the z axis points into the EMEC from strip layer to 2nd and then to 3rd layer. This axis defines the pseudo-rapidity η and a positive rotation direction (right handed rotation) i.e. a positive direction for the local azimuthal angle ϕ.
- **x axis:** points to large radius; aligned to the edge of the wedge so that the wedge is at positive ϕ.
- **y axis:** defined such as to get a right handed system.

3.0 From mother-boards to front-end boards

3.1 Cable harnesses

As shown in the TDR (p. 375 figure 10-9) the electrical connection from motherboards to the front-end boards is made by 4 successive harnesses with 64 signal lines each:

- harness A: between motherboards and patch-panel on the modules
- harness B: or pig tails; these are part of the feedthroughs
- harness C: vacuum cable in between the cold and warm flanges
- harness D: warm cable in the pedestal to connect the warm flange to the crate base-plane

The detail of the respective connectors and their pinout is given in figures 4 through 7, from P. Cornebise (LAL) and D. Mackowiecki (BNL).

Harness A has eight bundles numbered 1 to 8 of eight signal lines each. A “microD” connector is cabled on one end of the cable. On the other end, each bundle is connected to a low profile connector where pins are numbered 1 to 8. A mark on the low profile connector identify pin # 1. A signal line can be referred to either as 2.5 where the first digit is the low profile connector # and the second the pin # in the low profile connector or as 13, its position in the 64 signal lines in harness A. Note that connector and pin number start at 1.

The microD connector in between harnesses A and B is keyed and the pin numbering of harness A is transferred without ambiguity to the ATI connector which plugs onto the cold flange.

3.2 Connection to the feedthrough flanges

There are no keys on the feedthrough flanges (cold and warm). The connection of the harness B onto the cold flange is defined in Figure 8 on page 18. To minimize the risk for mistakes, a mark will be provided on the ATI connector of harness B close to signal line # 1.

The numbering of the feedthrough connectors is also defined on the same figure: by lines 1 to 15 and by rows A and B.

The warm flange is rotated by 90° respect to the cold flange, a positive rotation around an axis from the cold to the warm flange.

The vacuum cable (harness C) in between the two flanges is pin to pin and does not change the pin numbering. However, care should be taken during installation not to twist it.

3.3 Connection to the front-end crate

The warm cable in the pedestal (harness D) is connected to the base-plane of the front-end crate as sketched in Figure 9 on page 19. Custom made keys on the base plane allow to use the same warm cable to connect the two in-line connectors on the FT flange to a FEB (Figure 9 on page 19). The “left” cable (small z) is identical to the “right” one (larger z) but rotated by 180°.

Looking at a FEB board with the analog input connectors at the bottom and the power connector at right hand defines the top layer of the board. All connectors are mounted on this side. This is the side with the largest ϕ.

With the above conventions, the signal line 1.1 (pin #1 of first low profile connector) ends up into pin # C32 on the FEB as sketched in Figures 9 and 10.

Figure 18 on page 28 and Figure 19 on page 29 define the cabling between a row of connectors at the same ϕ on the warm flange and a slot in the front-end crate. Note however that for tests in beam, the EM end-cap and the HEC are in separate cryostats and, as only one eighth of a wheel will be tested, the cabling of the “special” feedthrough is slightly affected as shown in Figure 29 on page 39. The crate on top of this feedthrough is as in ATLAS.

4.0 Cell numbering

To more easily satisfy the constraint coming from the summation in trigger towers, the following cell numbering is proposed:

FT# . Trigger Tower # . Layer # . Cell # in TT

All cell numbers start at 0 and where appropriate, elements are ordered **first** by increasing ϕ_{local} **then** by increasing η_{local}.

For instance, in the barrel, a feedthrough serves 2x15 trigger towers in ϕxη. They are numbered 0-29 with the even numbers (0,2,...) at the lowest ϕ.

Layers are numbered from 0 to 3: 0 for PS, 1 for strips, 2 for middle, 3 for back.

Within a trigger tower and a layer, cells are numbered as sketched in Figure 11 on page 21.

5.0 Cabling of signal lines

Cells are cabled on the mother boards on low profile connectors in increasing order, keeping the pin ordering as defined above.

i.e. cells # 0, 8, 16, are connected to pin # 1.1, 2.1, 3.1,...

i.e. cells # 1, 9, 17, are connected to pin # 1.2, 2.2, 3.2,...

Thus on the FEB, cell #0 connected to pin #1 of the first low profile connector ends on row C, close to the Tile calorimeter and cell # increases with increasing z.

The logic is first to complete the 64 signal line harness with cells belonging to the same trigger tower (in a given layer in depth) with increasing ϕ first then increasing η as defined in Figure 11 on page 21. Figure 12 on page 22 and Figure 13 on page 23 define groups of trigger towers readout by the same microD connector. Within each group, trigger towers are ordered first increasing ϕ then η. These figures also define the assignment of the feedthrough connectors.

Figure 14 on page 24 and Figure 15 on page 25 sketch the cabling on the barrel mother-boards. Similarly Figure 16 on page 26 depicts the situation for the EM end-cap.

The connection of the cables to the cold flange is such that there is no cable twist for the back of the calorimeters (and presampler) and a twist for the front face of the calorimeters. This is shown in Figure 17 on page 27 in the case of the barrel calorimeter.

In the front-end crate, front-end boards are ordered by increasing ϕ and their position is given in Figure 18 on page 28 and Figure 19 on page 29 (note that this is the opposite of figure 10-15 in the TDR). This defines the cabling for the level 1 summation and the correspondence between a line of feedthrough connectors and a slot in the crate.

6.0 Cabling of the calibration

The cable harnesses for the calibration signal are similar to the one described above except for the number of signal lines on each low profile connectors: there are 4 (2) calibration lines on each low profile and 16 (32) low profile connectors per harness for the barrel (EM end-cap). As for the signal lines, calibration lines are identified by their low profile connector number and their pin # in the low profile.

The cabling between the low profile connector and the calibration board follows the same rules as for the signal lines i.e. the calibration line 1.1 (first low profile, pin # 1) is connected to pin #C32 on the calibration board.

The mapping between pulsers on the calibration board and the mother-boards obeys some simple rules:

- There are 128 pulsers per calibration boards. Pulser number starts at 0. Pulser # 0 is connected to calibration line #1 of calibration cable A; pulser # 64 is connected on calibration line #1 of calibration cable B.
- Calibration line #1 pulses cell #0;
- In the barrel and for most of the end-cap, calibration lines are arranged in group of 16 corresponding to 4 trigger towers:

lines #1-4	pulse the strip layer
lines #5-12	pulse the middle layer
lines #13-16	pulse the back layer.

The calibration pattern went through a small change respect to the TDR and is given in Figure 20 on page 30 and Figure 21 on page 31. This establishes the routing of the calibration lines on the mother boards.

For the barrel, one calibration board pulses a slice $\Delta\phi = 0.2$, $0 < \Delta\eta < 1.5$. The cabling of the corresponding calibration harnesses is sketched in Figure 22 on page 32 and in

Table 1 on page 6. They identify the harness A or B and the number of the low profile connector.

TABLE 1. Cabling of the calibration lines for a slice $\Delta\phi = .2$ of the EM barrel calorimeter. The table gives for each mother board the number of the low profile connector to connect. The letter A or B in front of the low profile connector # specifies the cable harness to use. For the middle layer, where there are two low profile connectors per mother boards, the first one is connected to the connector with the lowest ϕ as shown in Figure 22 on page 32.

	Presampler	Strips	Middle	Back
$0 < \eta < 0.2$		A 1	A 2, A 3	A 4
$0.2 < \eta < 0.4$		A 5	A 6, A 7	A 8
$0.4 < \eta < 0.6$	B 15	A 9	A 10, A 11	A 12
$0.6 < \eta < 0.8$		A 13	A 14, A 15	A 16
$0.8 < \eta < 1.0$		B 1	B 2, B 3	B 4
$1.0 < \eta < 1.2$		B 5	B 6, B 7	B 8
$1.2 < \eta < 1.4$	B 16	B 9	B 10, B 11	B 12
$1.4 < \eta < 1.5$			B 13--B 14	

For the "standard" region of the EM end-cap ($1.6 < \eta < 2.4$), a first calibration board pulses the slice $0 < \phi < 0.4$ and a second the slice $0.4 < \phi < 0.8$. For each board, harness A connect to the cells with the lowest azimuth and harness B to the remaining cells. The exact cabling valid for both harnesses is given in Table 2 on page 6 and is sketched in section a) of Figure 23 on page 33.

TABLE 2. Cabling of the calibration lines for a slice $\Delta\phi = .2$ of the "standard" region of the EM end-cap calorimeter. The table gives the number of the low profile connector to connect in each zone. When there are more than one connector per zone, the connector with the lowest number is connected to the cells with the smallest number as defined by the calibration pattern.

	Strips	Middle	Back
$1.6 < \eta < 1.7$	1--2	3--4	7
$1.7 < \eta < 1.8$		5--6	8
$1.8 < \eta < 1.9$	9--10	11--12	15
$1.9 < \eta < 2.0$		13--14	16
$2.0 < \eta < 2.1$		19--20	23
$2.1 < \eta < 2.2$	17--18	21--22	24
$2.2 < \eta < 2.3$		25--26	29
$2.3< \eta < 2.4$		27--28	30

One other calibration board is used to pulse each of the two wedges ($\Delta\phi = .8$) of the "special" region of the EM end-cap ($1.4 < \eta < 1.6$ and $2.4 < \eta < 3.2$). Its cabling is defined in Table 3 on page 7 and in Figure 23 on page 33 section b).

TABLE 3. Cabling of the calibration lines for a slice $\Delta\phi = .8$ of the "special" region of the EM end-cap calorimeter. The table gives the number of the low profile connector to connect in each zone. The letter A or B in front of the low profile connector # specifies the cable harness to use. When there are more than one connector per zone, the connector with the lowest number is connected to the cells with the smallest number as defined by the calibration pattern

	first layer	**second layer**	**third layer**
$1.4 < \eta < 1.5$			
$0.0 < \phi < 0.2$	A1	A2--3	
$0.2 < \phi < 0.4$	A4	A5--6	
$0.4 < \phi < 0.6$	A7	A8--9	
$0.6 < \phi < 0.8$	A10	A11--12	
$1.5 < \eta < 1.6$			
$0.0 < \phi < 0.2$	A17--18	A19--20	A13
$0.2 < \phi < 0.4$	A21--22	A23--24	A14
$0.4 < \phi < 0.6$	A25--26	A27--28	A15
$0.6 < \phi < 0.8$	A29--30	A31--32	A16
$2.4 < \eta < 2.5$			
$0.0 < \phi < 0.2$	B1--2	B3--4	B17
$0.2 < \phi < 0.4$	B5--6	B7--8	B18
$0.4 < \phi < 0.6$	B9--10	B11--12	B19
$0.6 < \phi < 0.8$	B13--14	B15--16	B20
$2.5 < \eta < 3.2$			
$0.0 < \phi < 0.4$	B25--26	B27--28	
$0.4 < \phi < 0.8$	B29--30	B31--32	

7.0 Cable impedance

Detector cells with small capacitance values (presampler, strips) are readout by 50 Ω impedance cable. 25 Ω cable is used for the larger capacitance values of middle and back samplings. This is precisely defined in Figure 1 on page 11 for the EM barrel and Figure 2 on page 12 for the EM end-cap.

Calibration signals are fed into the detector through 50 Ω cables. This impedance is also used to read-out the monitoring probes.

With all the above information, a map of the feedthrough flanges for each of the 5 types of feedthrough is shown in Figure 24 on page 34 and following. Note the slight differences in the cabling of the "special" feedthrough of the EM end-cap between ATLAS and test beam.

8.0 Cabling of the HV

8.1 EM Barrel and presampler

As described in the TDR, high voltage is provided by units of four trigger towers ($\Delta\eta$ x $\Delta\phi$ = .2 x .2) also called sectors. Two independent HV lines supply the two half-gaps of one sector. In the following the half-gaps are labelled according to their position in ϕ with respect to the kapton electrodes: $\phi > 0$ and $\phi < 0$ half-gaps. Half a module ($\Delta\phi = 2\pi / 32$) consists of 7 sectors. Thus they are 14 HV lines per half-module or feedthrough or 28 for one module.

The same principle holds for the presampler where there is one HV line per sector, so 8 HV lines per half-module and 16 for one module.

A 8 lines connector is being developed to fulfill the HV supply to the module. They are a total 28+16 HV lines per module so 6 HV connectors are needed. There are 4 left HV lines which will be used for the purity monitor when there is one on the module. These connectors can stand 5 kV. The connectors supplying the module are numbered by increasing ϕ: 1 to 4, and the two connectors for the presampler are numbered 5, 6 also by increasing ϕ. This number associated with the module number gives a clear identification of the connector on one half barrel.

There is a key on the connector and channels are labelled from 1 to 8.

Connectors 1, 2, 3 supply the 7 sectors of the half module with the lowest ϕ. Connectors 3, 4 and 6 supply the other half. For the calorimeter, it is suggested for reliability reasons to supply one sector by HV lines coming from separate connectors.

All the HV cables on each HV harnesses will have the maximum length (~ 3.5 m). The purity monitor can be located either at small or large η. Table 4 on page 8 summarizes how the HV lines supply the module.:

TABLE 4. Cabling of the HV lines on the EM barrel.

HV connector #	Line #	Part supplied	Sector	gap
1	1	half-module $\phi < 0$	1	$\phi < 0$
	2		2	
	3		3	
	4		4	
	5		5	
	6		6	
	7		7	
	8	purity monitor		

TABLE 4. Cabling of the HV lines on the EM barrel.

HV connector #	Line #	Part supplied	Sector	gap
2	1	half-module $\phi < 0$	1	$\phi > 0$
	2		2	
	3		3	
	4		4	
	5		5	
	6		6	
	7		7	
	8	purity monitor		
3	1	half-module $\phi > 0$	1	$\phi < 0$
	2		2	
	3		3	
	4		4	
	5		5	
	6		6	
	7		7	
	8	purity monitor		
4	1	half-module $\phi > 0$	1	$\phi > 0$
	2		2	
	3		3	
	4		4	
	5		5	
	6		6	
	7		7	
	8			
5	1	PS $\phi < 0$	1	
	2		2	
	3		3	
	4		4	
	5		5	
	6		6	
	7		7	
	8		8	
6	1	PS $\phi > 0$	1	
	2		2	
	3		3	
	4		4	
	5		5	
	6		6	
	7		7	
	8		8	

8.2 EM end-cap and presampler

...

9.0 Cabling of the monitoring probes

There are 4 types of probes on a barrel module: temperature gauges, strength and position gauges, and purity monitor.

9.1 Temperature probes

There are 6 temperatures probes located in the plane $\phi = 0$ of the module, 3 on the front face and 3 on the back. The numbering goes by increasing η then by increasing x (or R): 1,2,3 for the front and 4,5,6 for the back. Each temperature probe has 4 wires as two twisted pairs. It is forseen but not yet decided to patch them to a special connector holding 12 twisted pairs

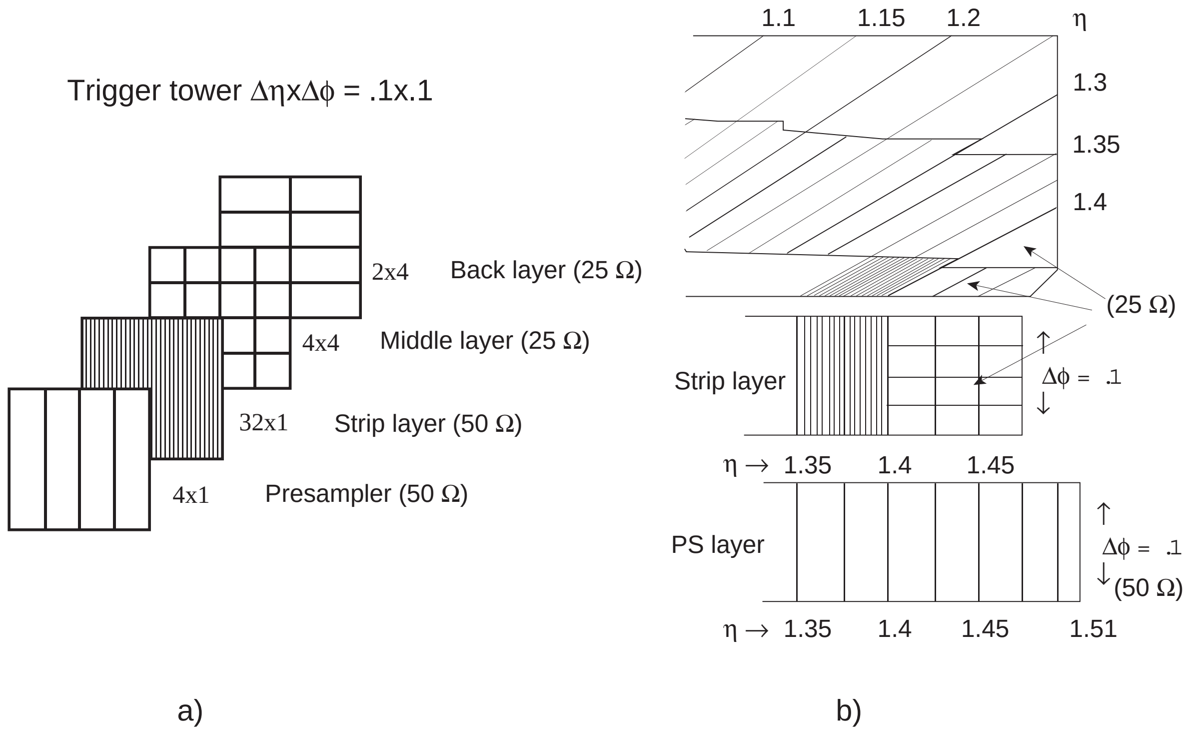

Figure 1 : a) Granularity of a trigger tower of the EM barrel ($|\eta| < 1.4$). There are 64 such trigger towers in azimuth and 2 x 14 in rapidity. b) Granularity at the end of the barrel (r-η and η-φ views).

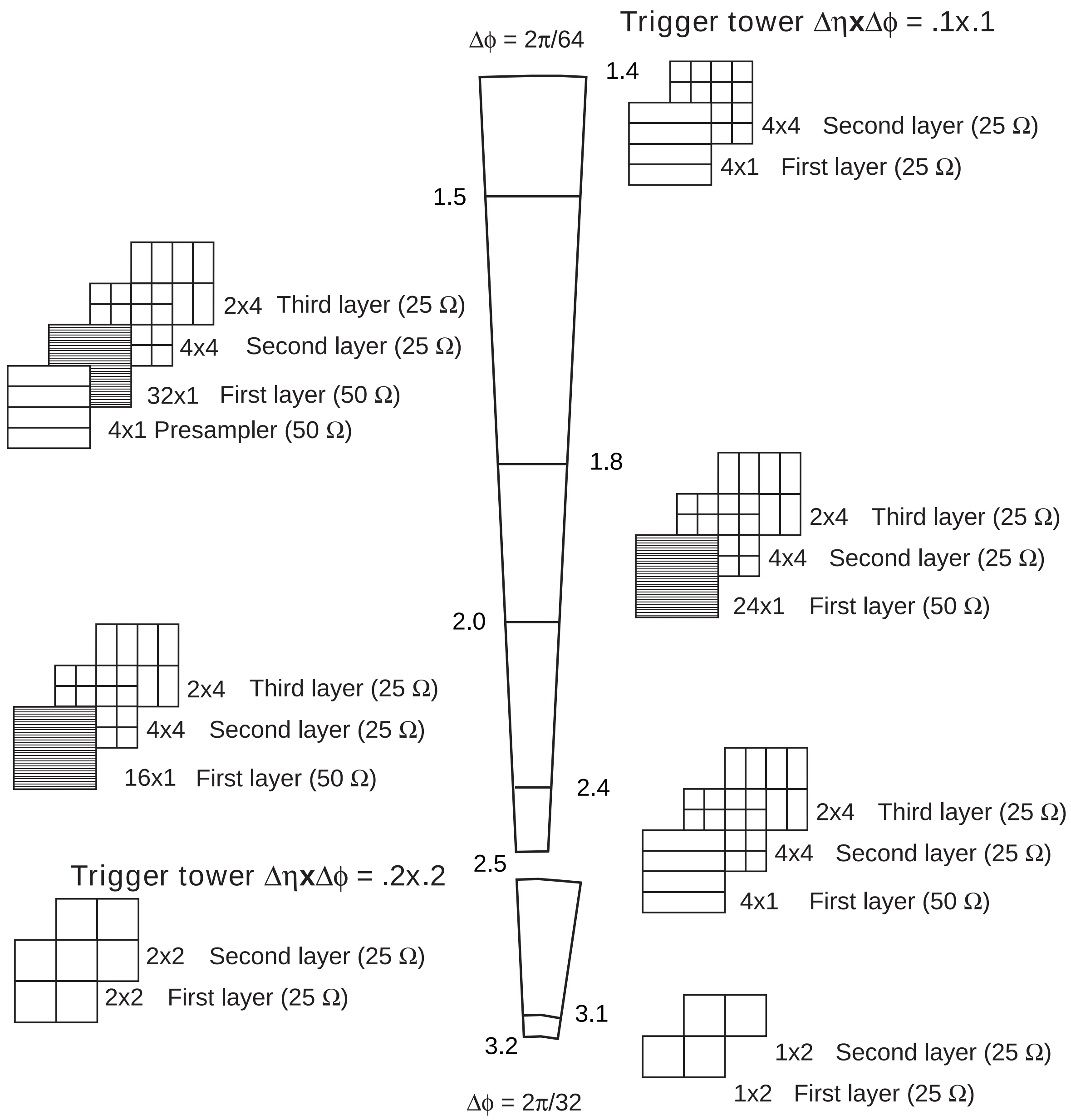

Figure 2 : Granularity of a trigger tower in the EM end-cap calorimeter. This pattern repeats itself in azimuth. Note the change of granularity above 2.5 in rapidity.

Local coordinate systems

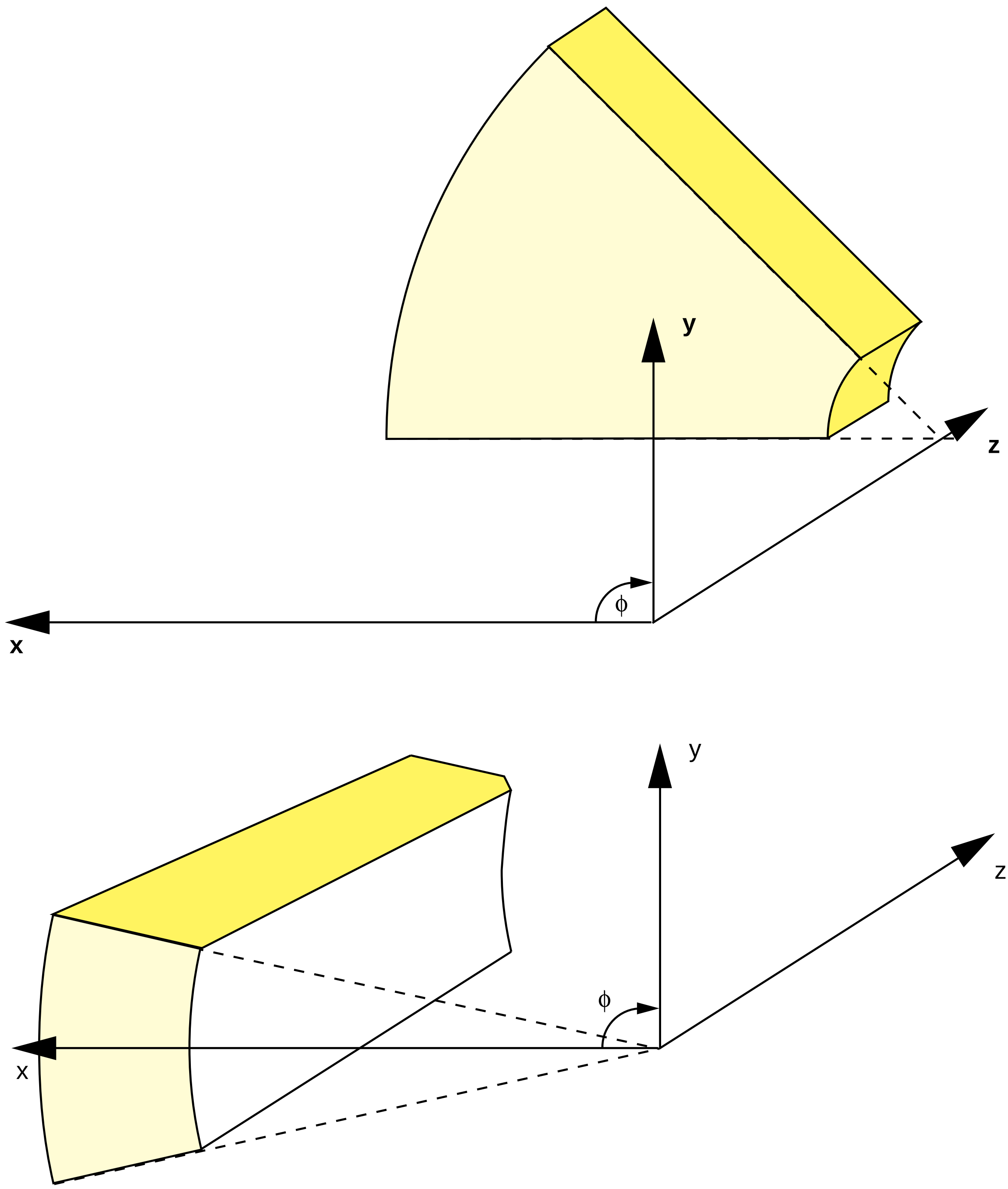

Figure 3 : Definition of local coordinate systems for a barrel or end-cap module.

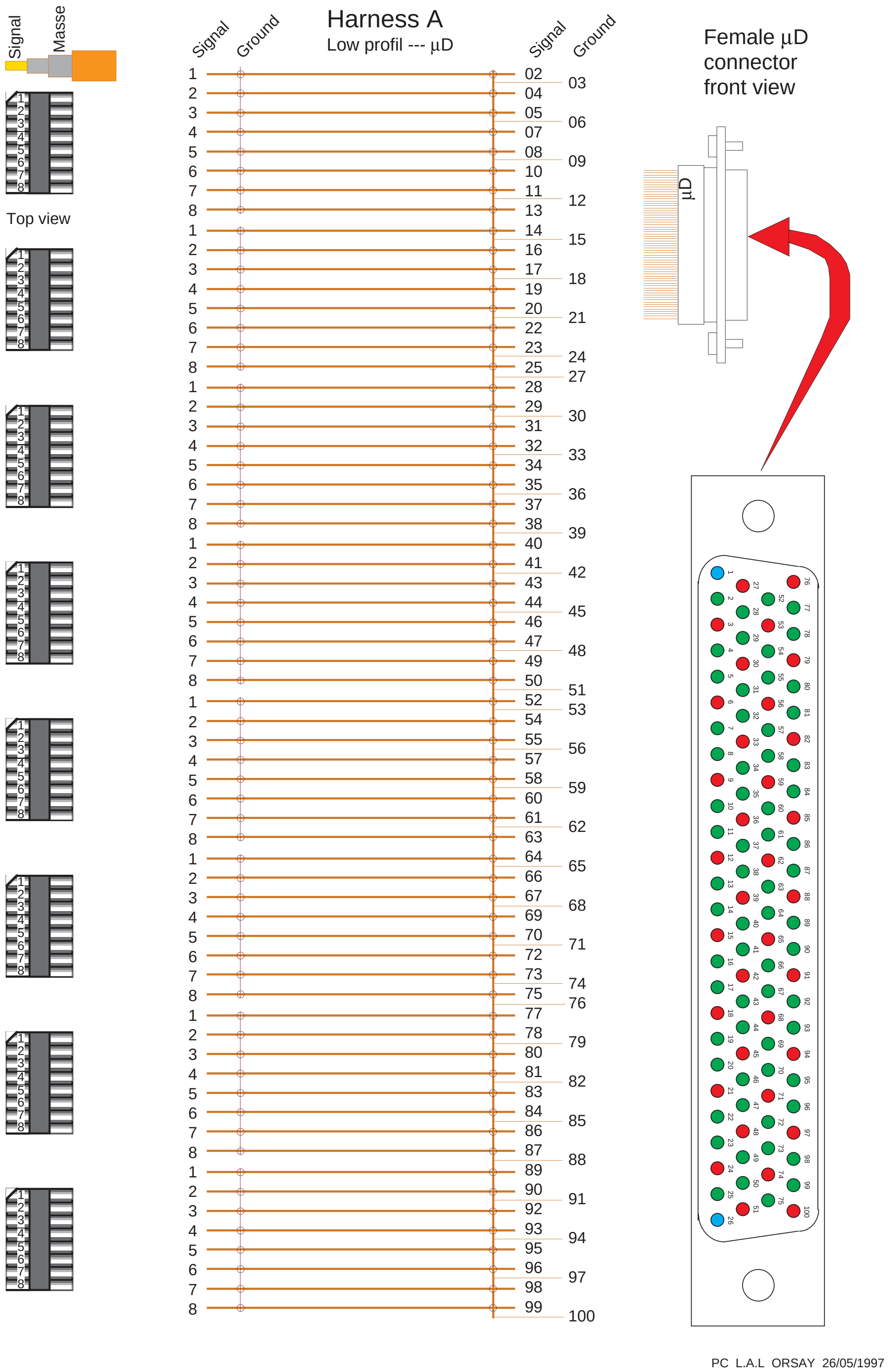

Figure 4 : Harness A: between mother-boards and patch panel.

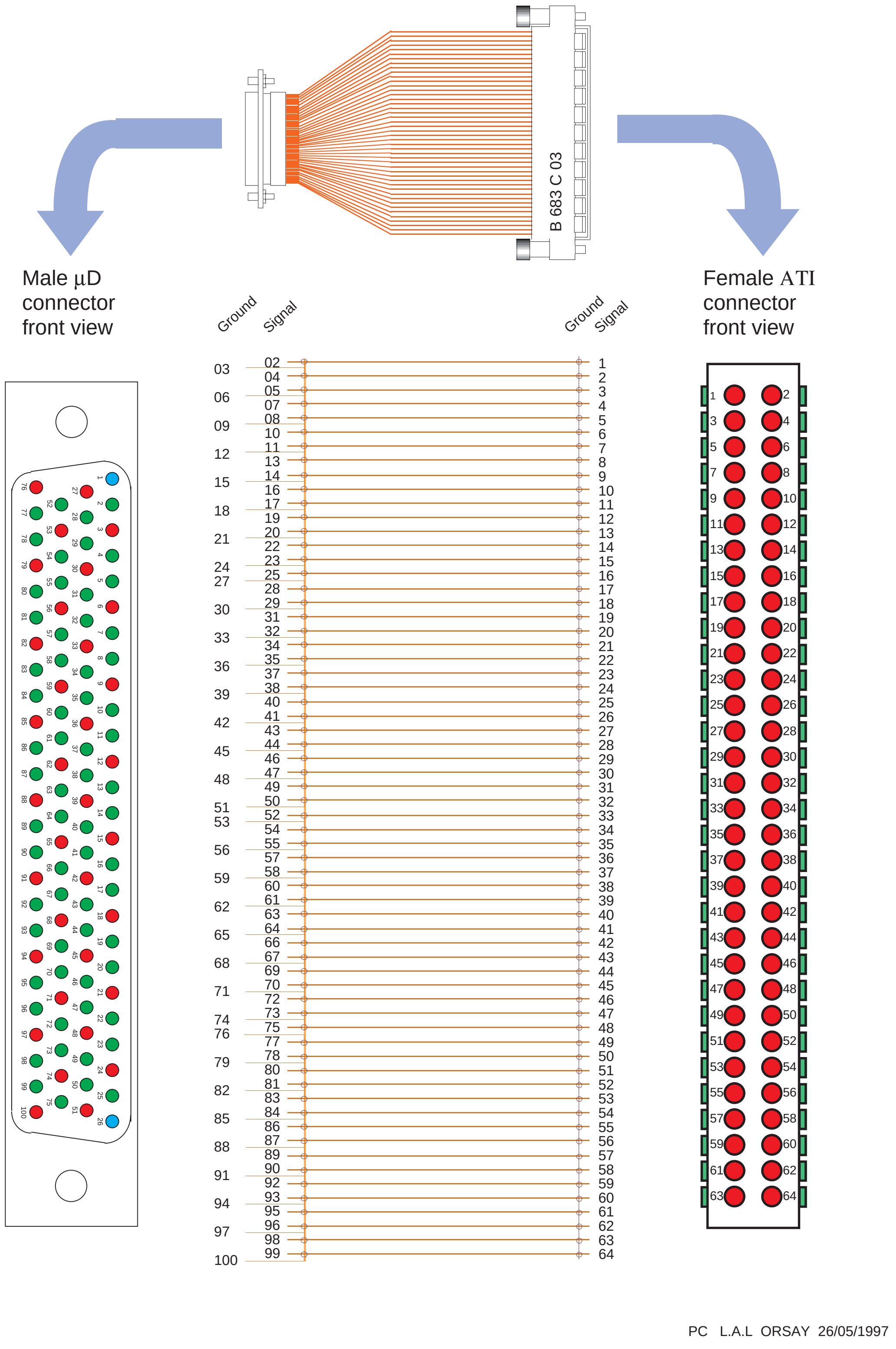

Figure 5 : Harness B or pig-tail between patch panel and the feedthrough cold flange.

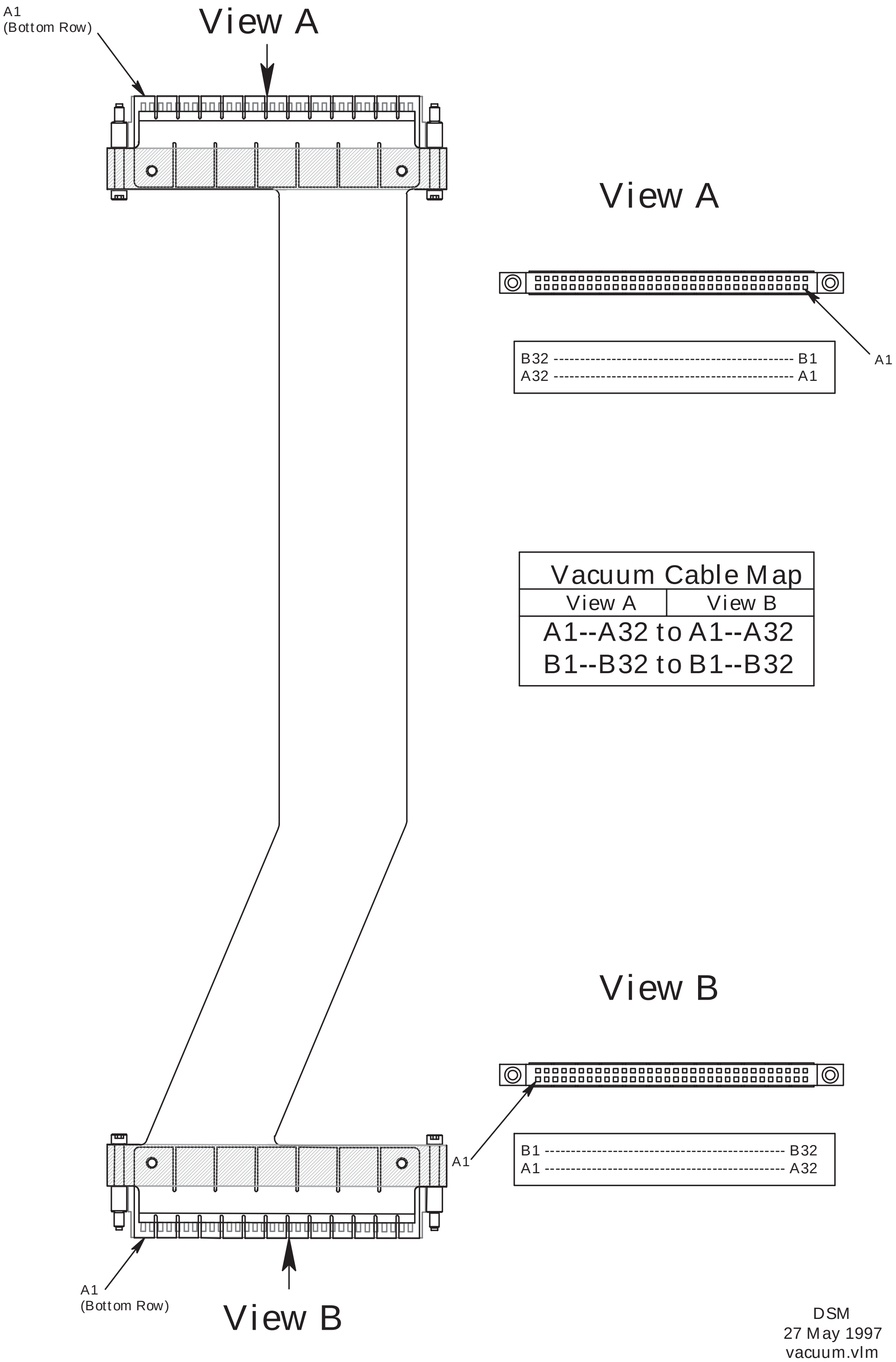

Figure 6 : Vacuum cable between the cold and warm flanges of the feedthroughs.

Warm Cable

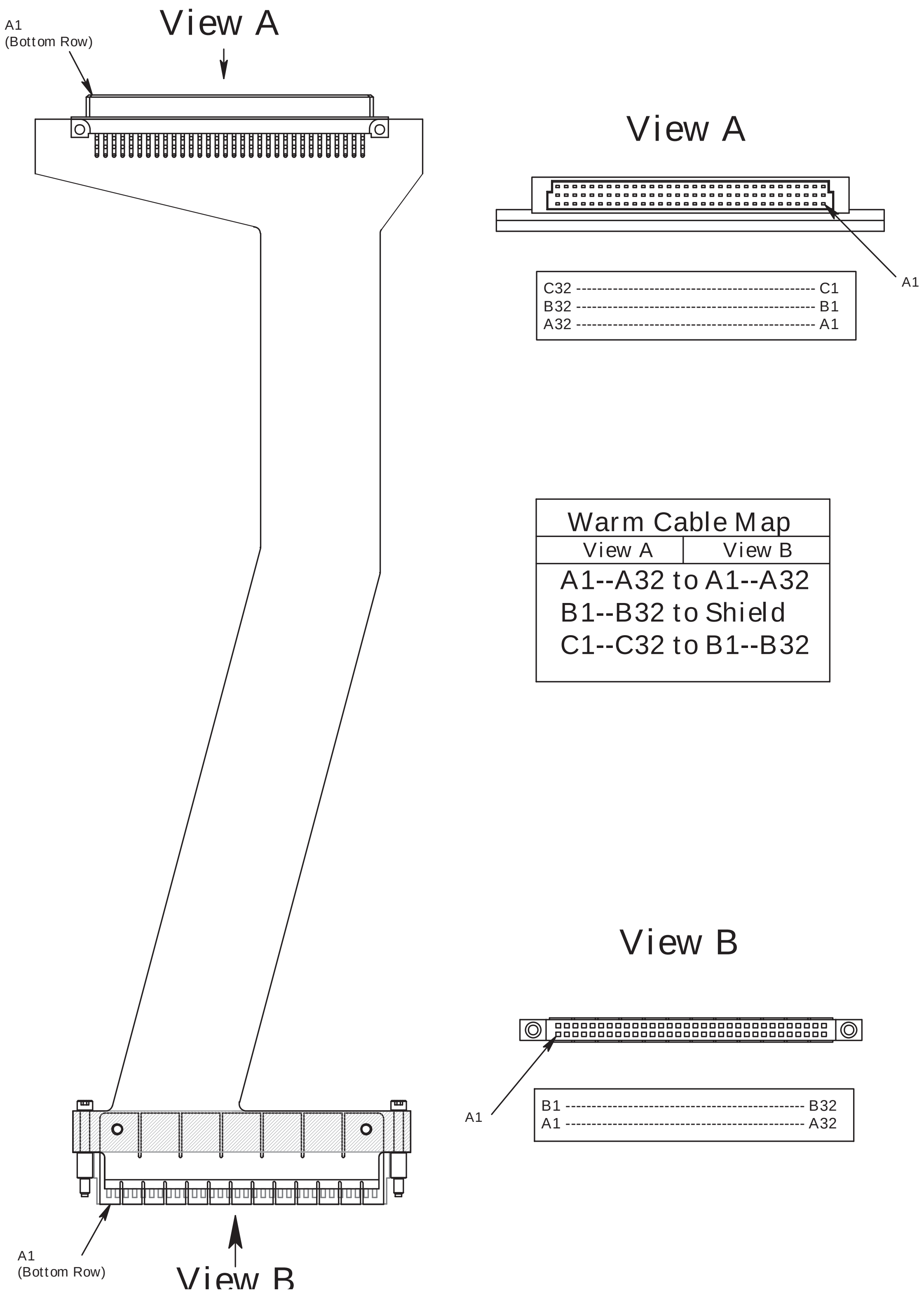

Figure 7 : Warm cable in the pedestal between the warm flange and the crate base-plane.

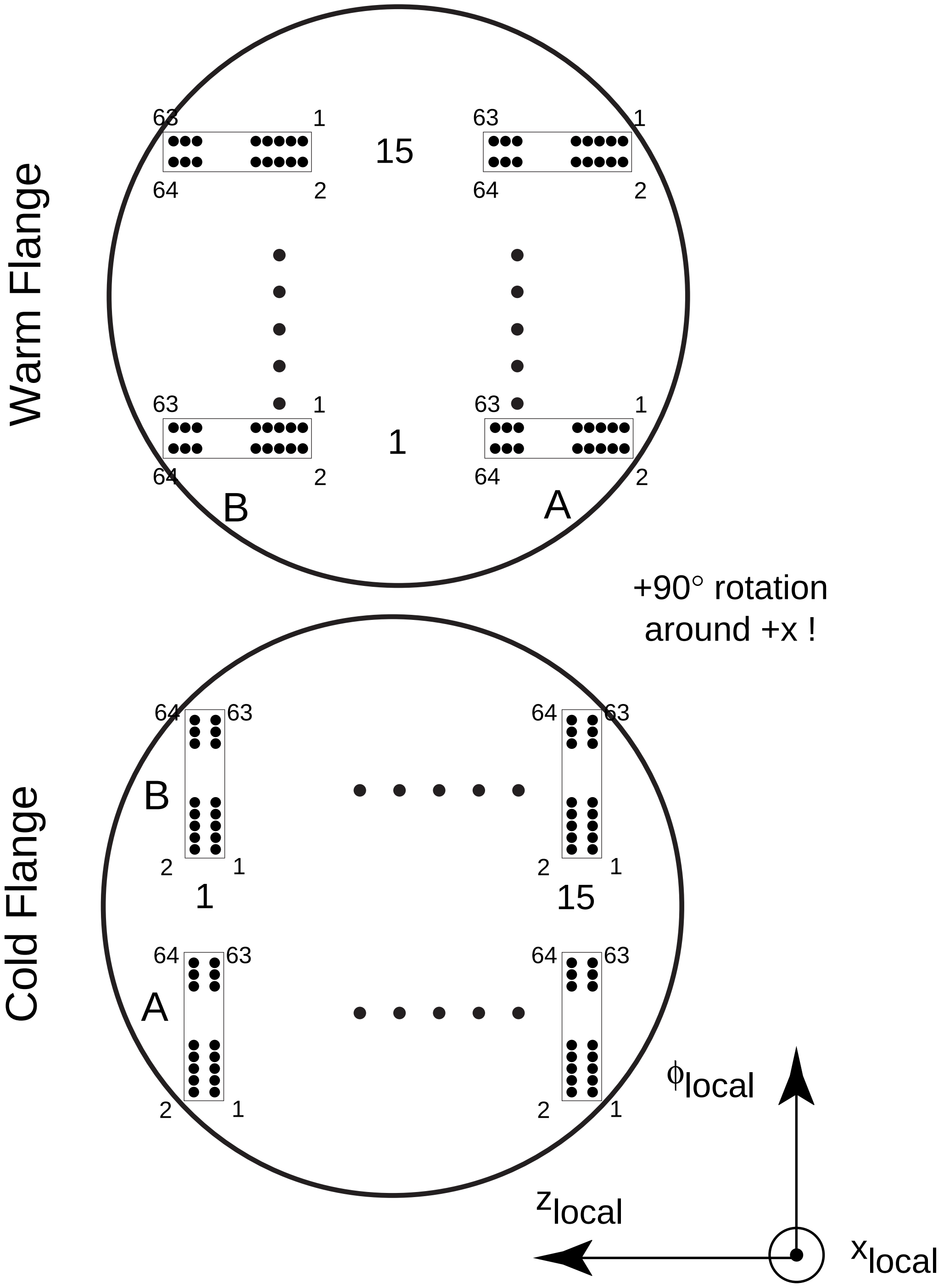

Figure 8 : Connection to the feedthrough flanges. Pin # refers to signal line # as defined in the text. Note the definition of the connector numbering on the flange from 1A to 15B. Note also the direction of the rotation between the cold and warm flanges.

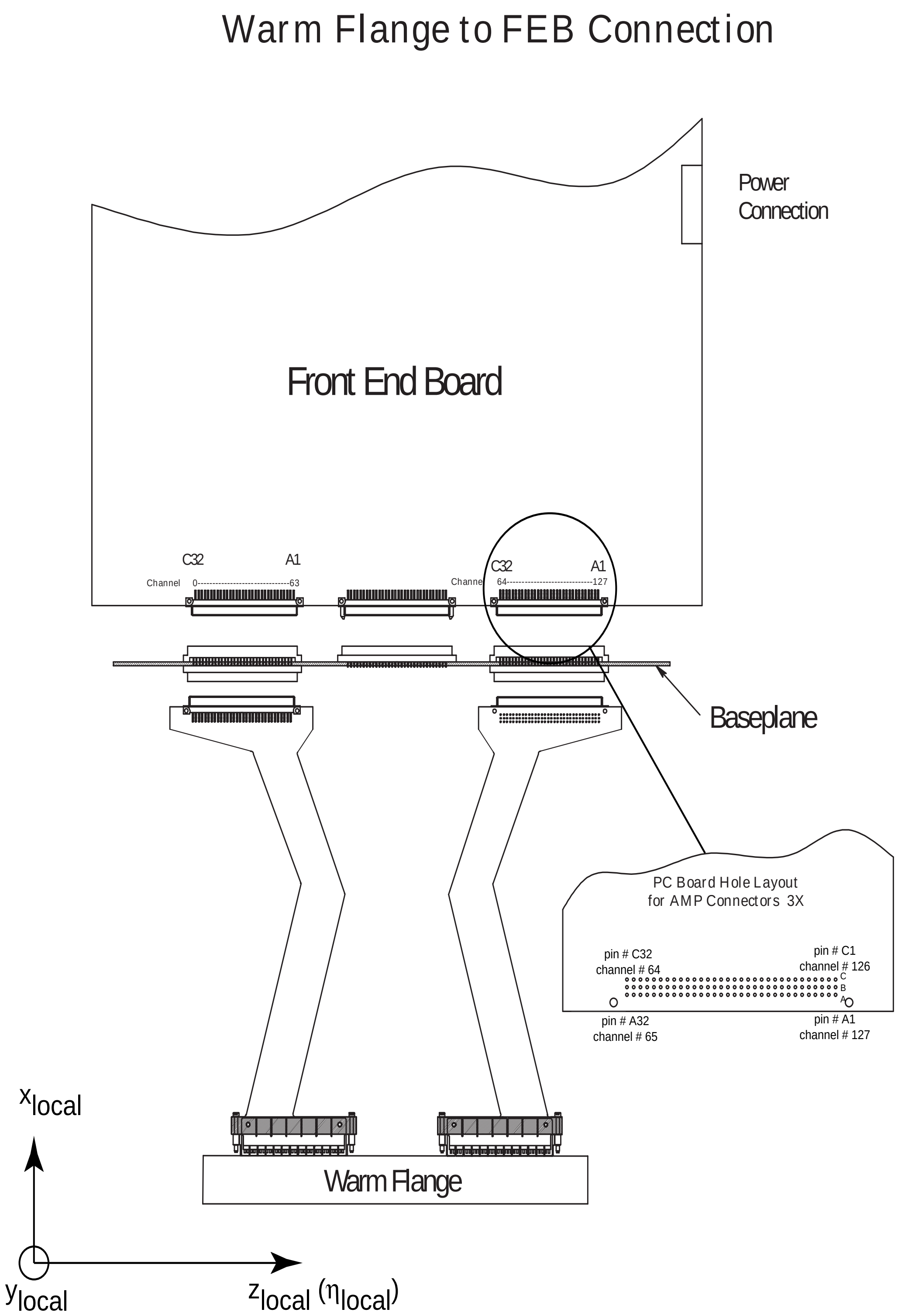

Figure 9 : Warm cable in the pedestal between the warm flange and the crate base-plane.

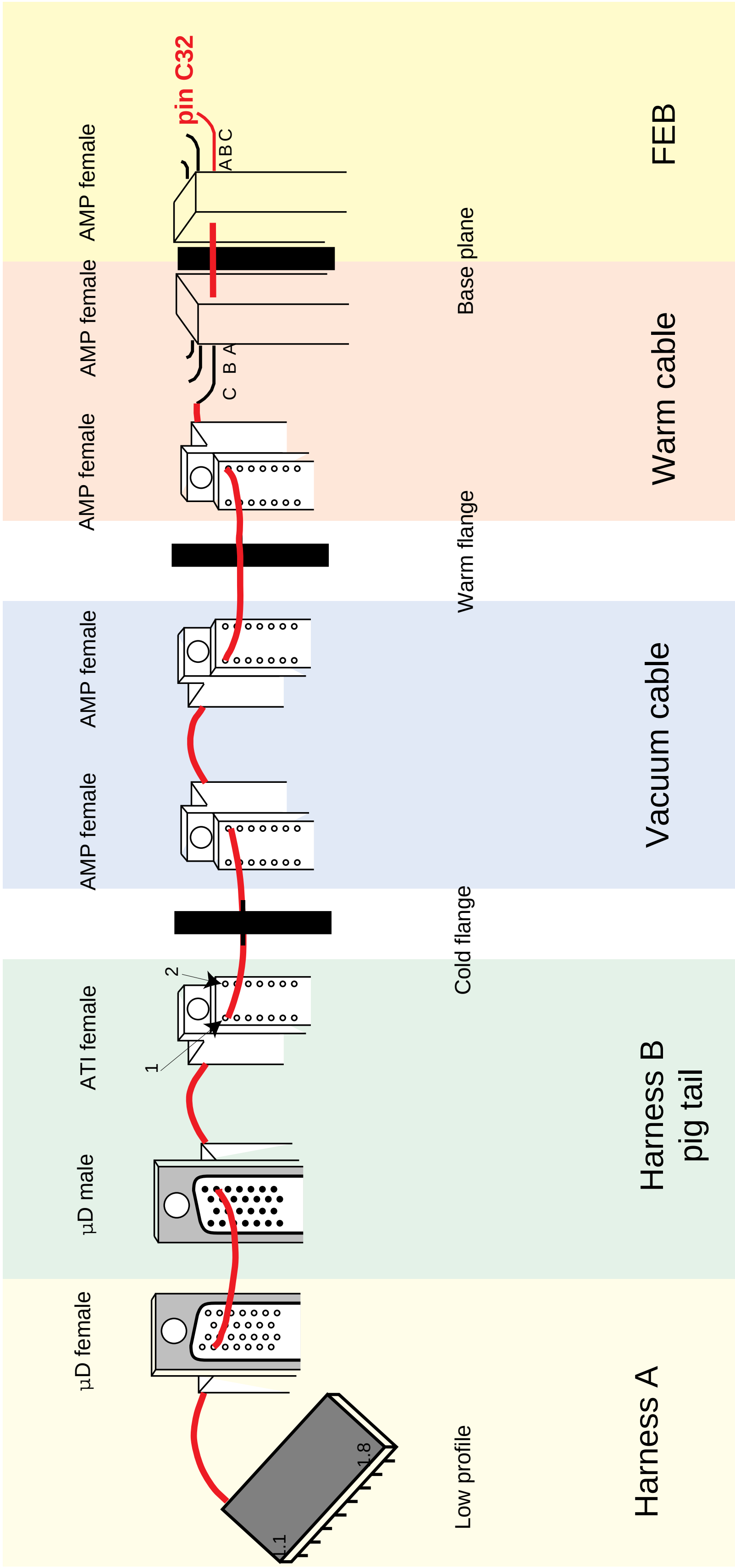

Figure 10 : Electrical connection from mother board to front-end board.

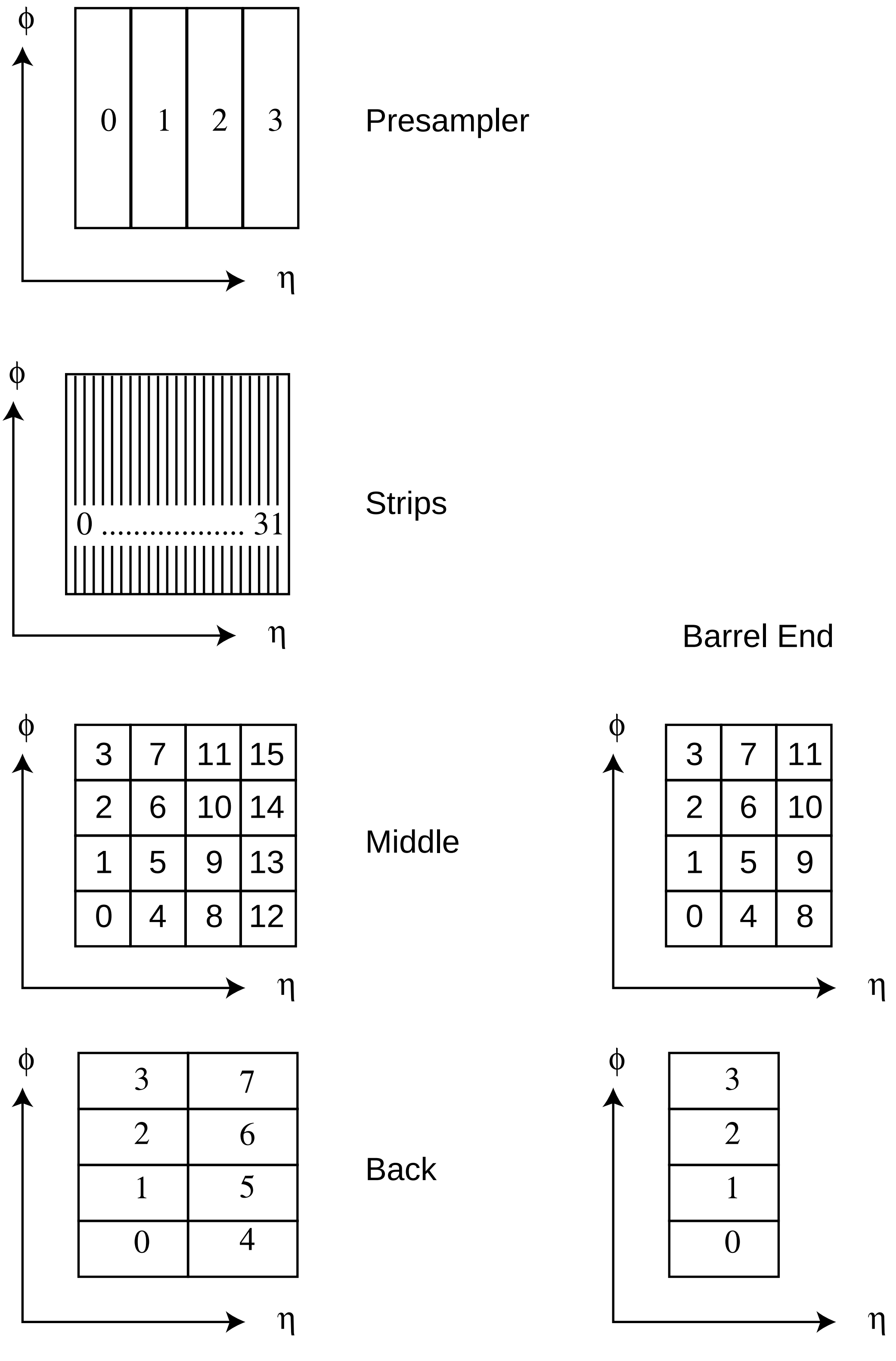

Figure 11 : Cell numbering inside of a trigger tower.

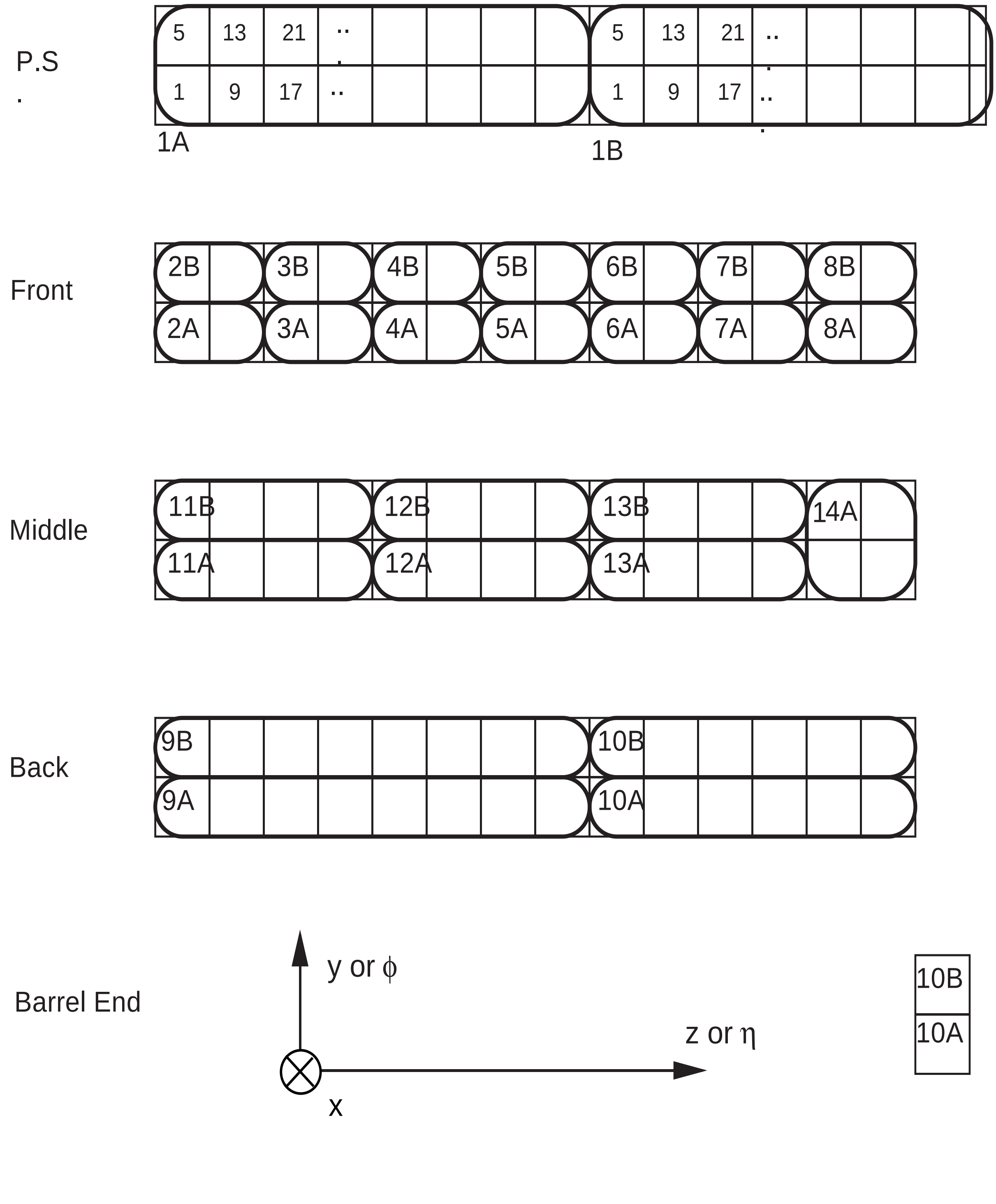

Figure 12 : Mapping of each layer of the barrel EM on feedthrough connectors. Each square represents a trigger tower. Groups of trigger towers sharing a common feedthrough connector (bold line) are labelled by the connector number. Within a connector, towers are cabled first by increasing ϕ then by increasing η.

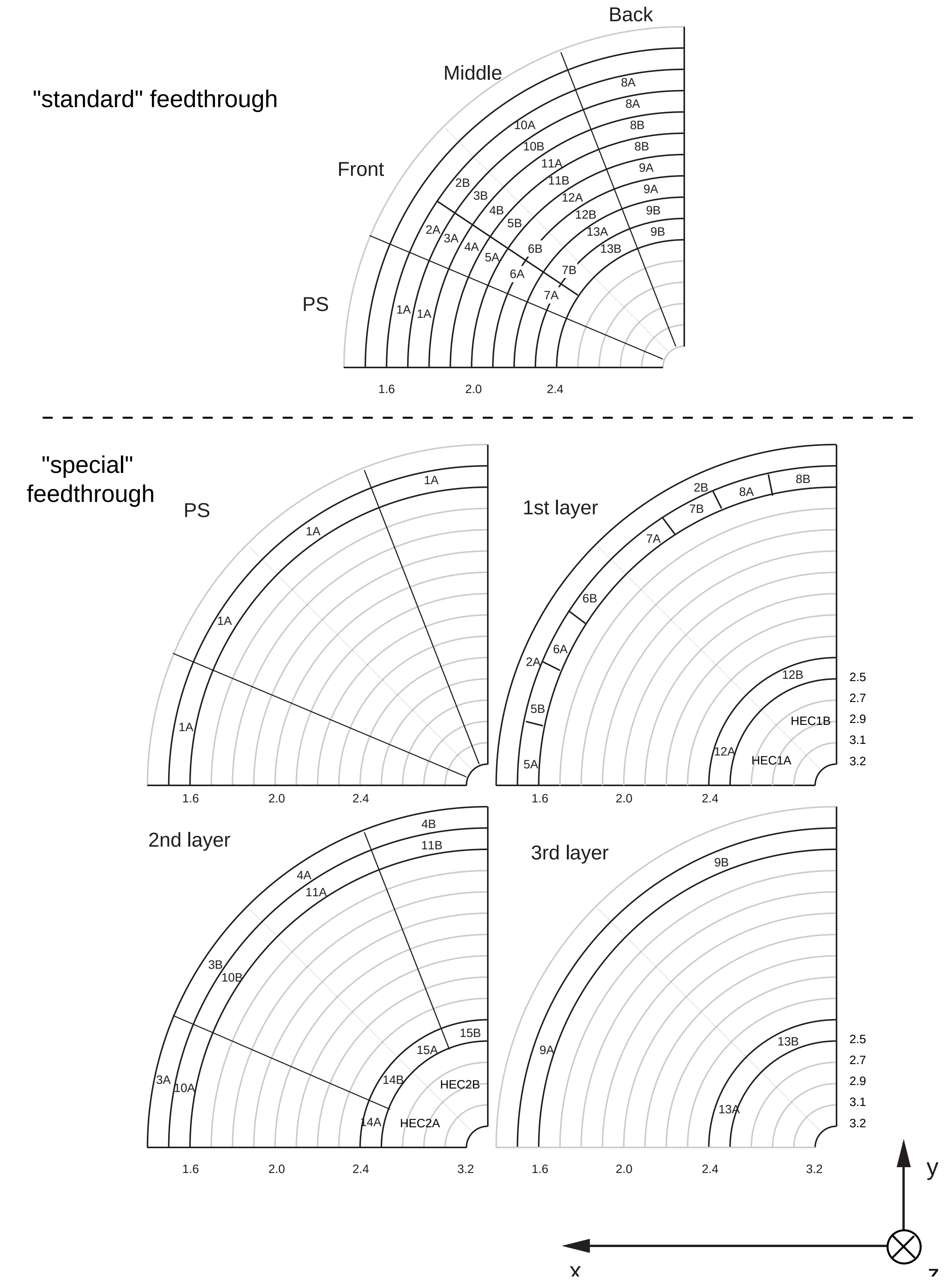

Figure 13 : Mapping of each layer of the end-cap EM on feedthrough connectors. Groups of trigger towers sharing a common feedthrough connector are labelled by the connector number. Within a connector, towers are cabled first by increasing ϕ then by increasing η. Note that the "distance" between lines is not constant in rapidity ($\Delta\eta = .1$ for $\eta < 2.5$ and .2 for $2.5 < \eta < 3.1$).

Barrel Front Mother Board

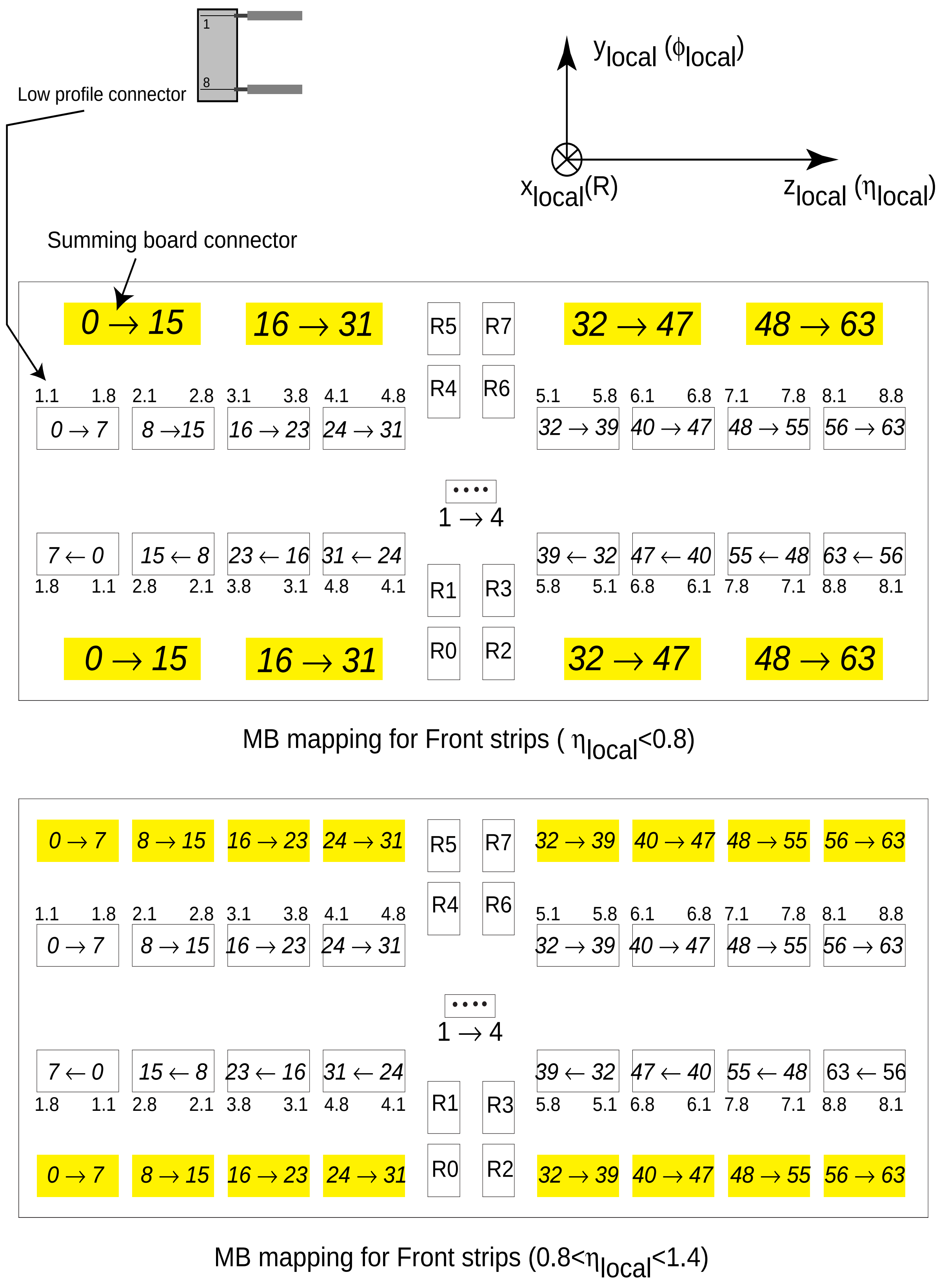

Figure 14 : Mapping of the barrel strip layer, looking from the interaction point towards the module. Numbers in italic refer to cell numbers. Numbers in roman refer to pin numbers.

Barrel Back Mother Board

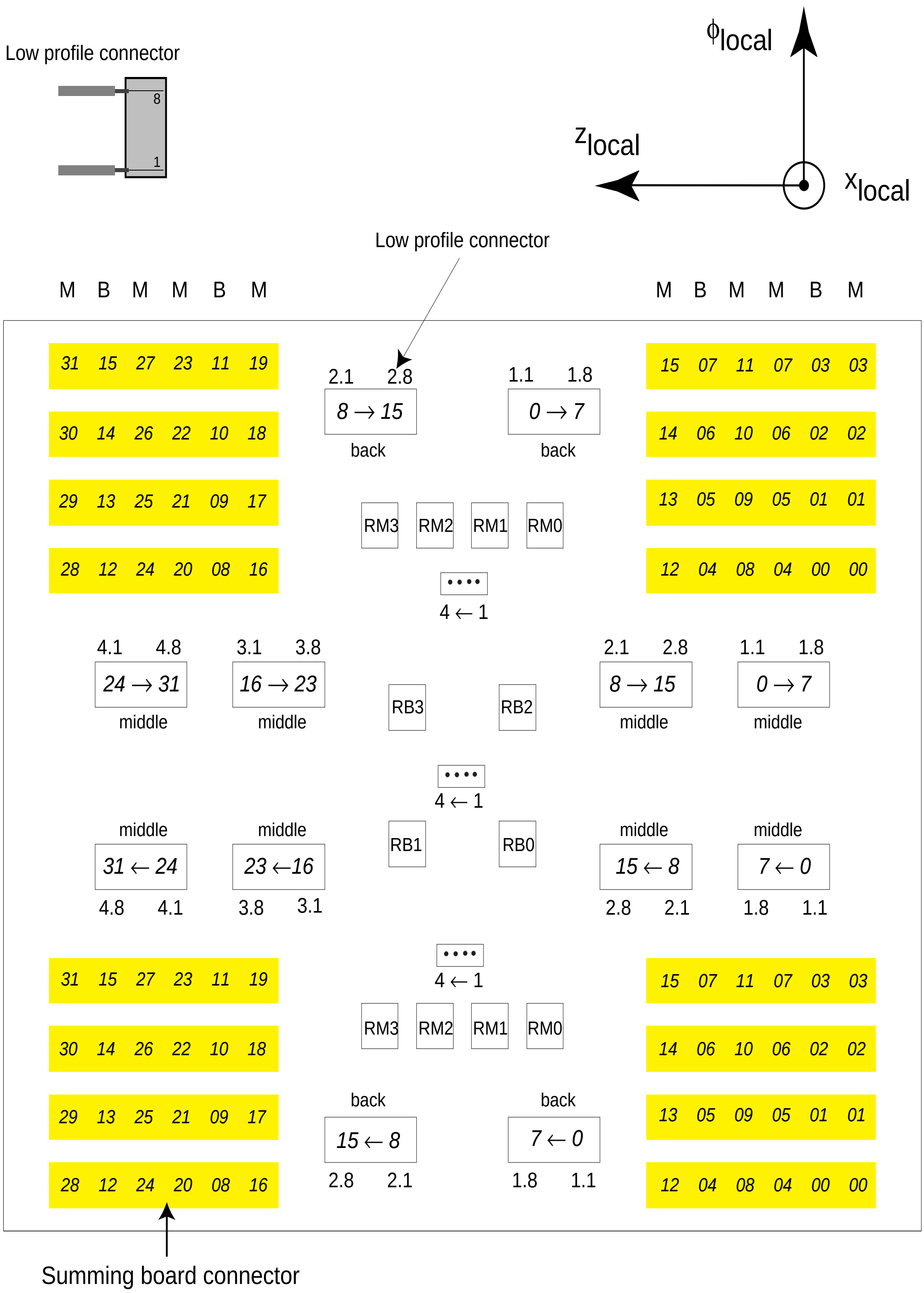

Figure 15 : Mapping of the barrel middle and back layers. Numbers in italic refer to cell numbers. Numbers in roman refer to pin numbers.

DUMMY

Figure 16 : Mapping of the EM end-cap. Numbers in italic refer to cell numbers. Numbers in roman refer to pin numbers.

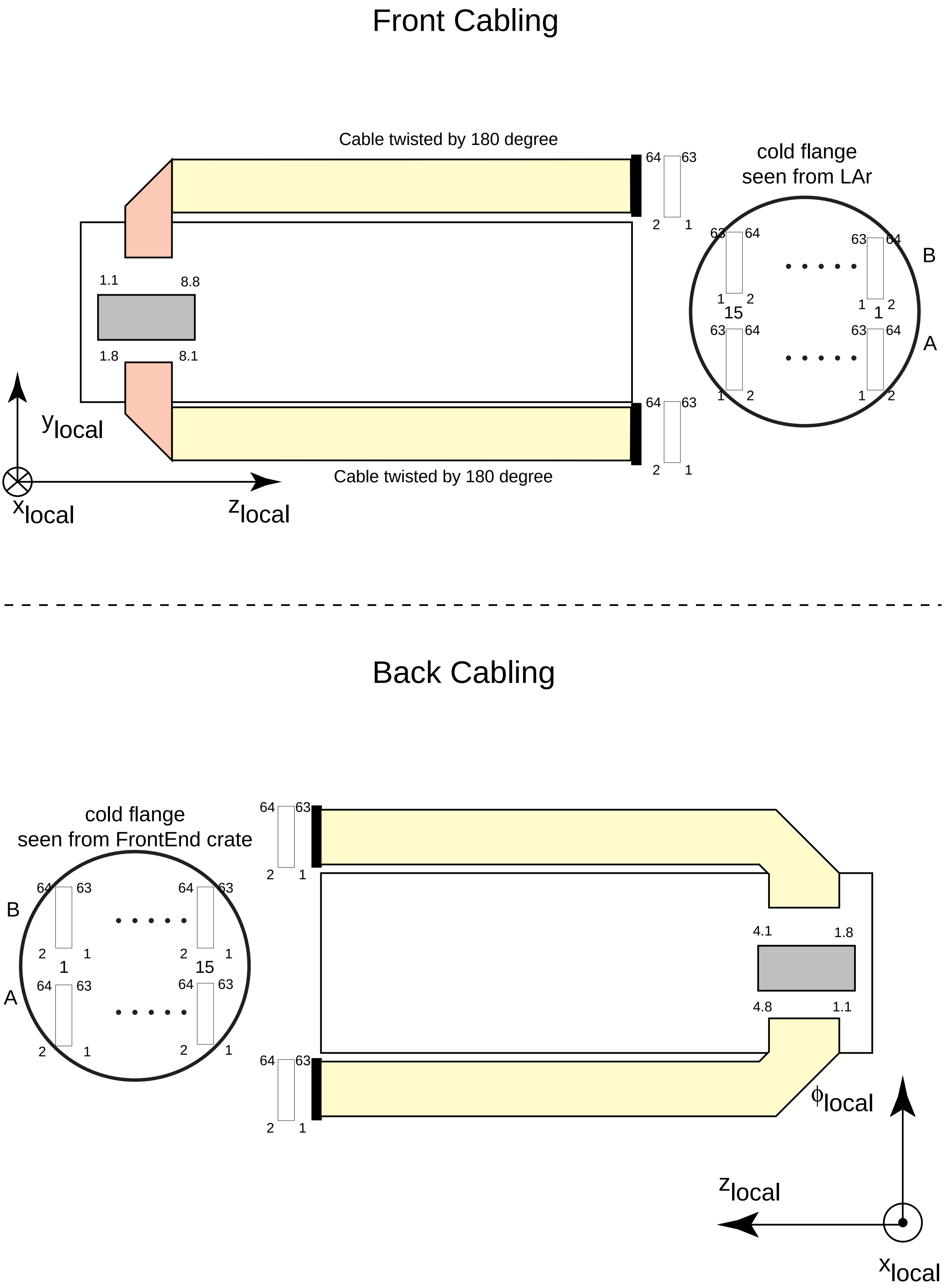

Figure 17 : Cabling of the EM barrel from the mother-boards to the feedthroughs.

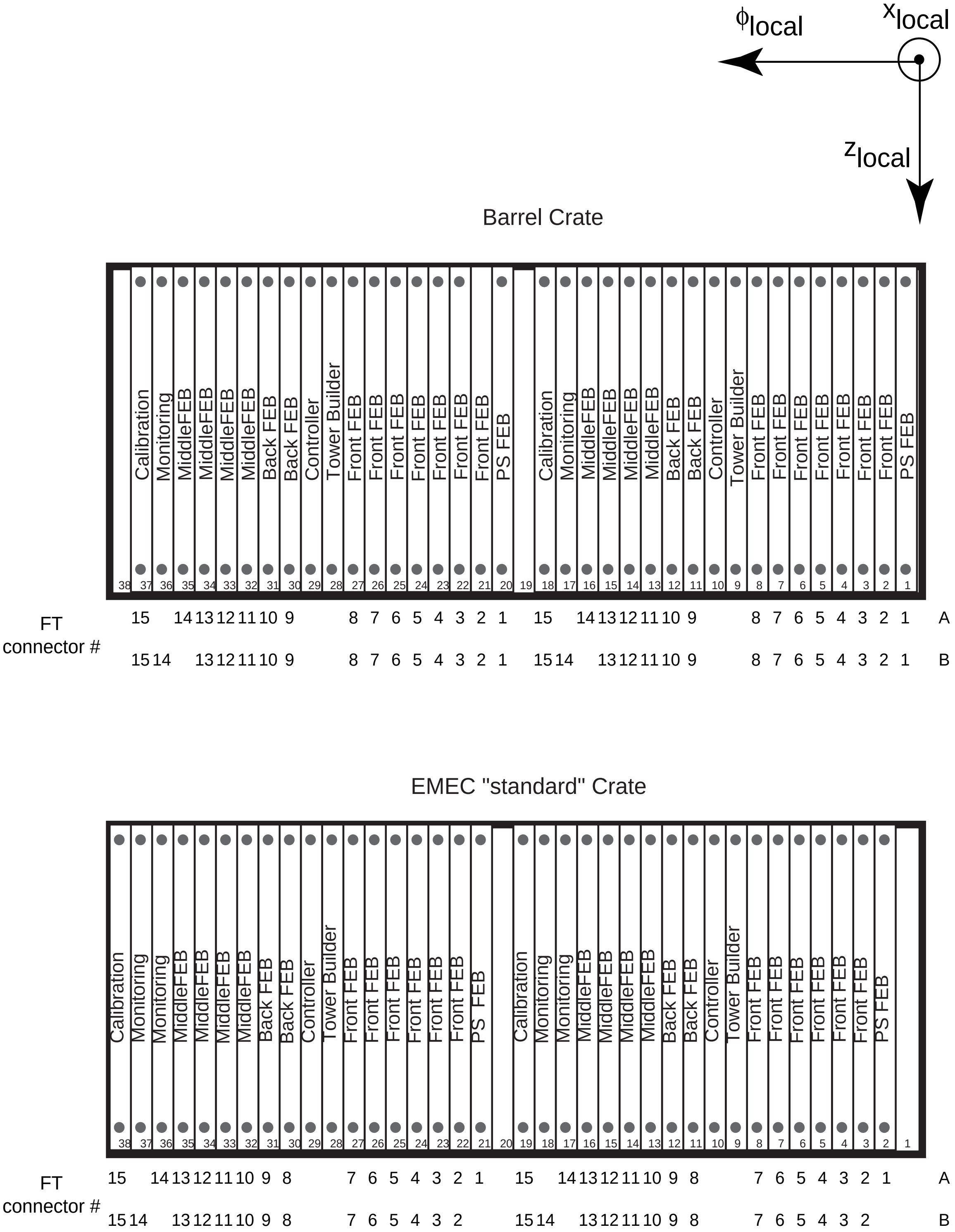

Figure 18 : Location of circuit boards by their function in the crates for the barrel and the EM end-cap (1.6<η<2.4).

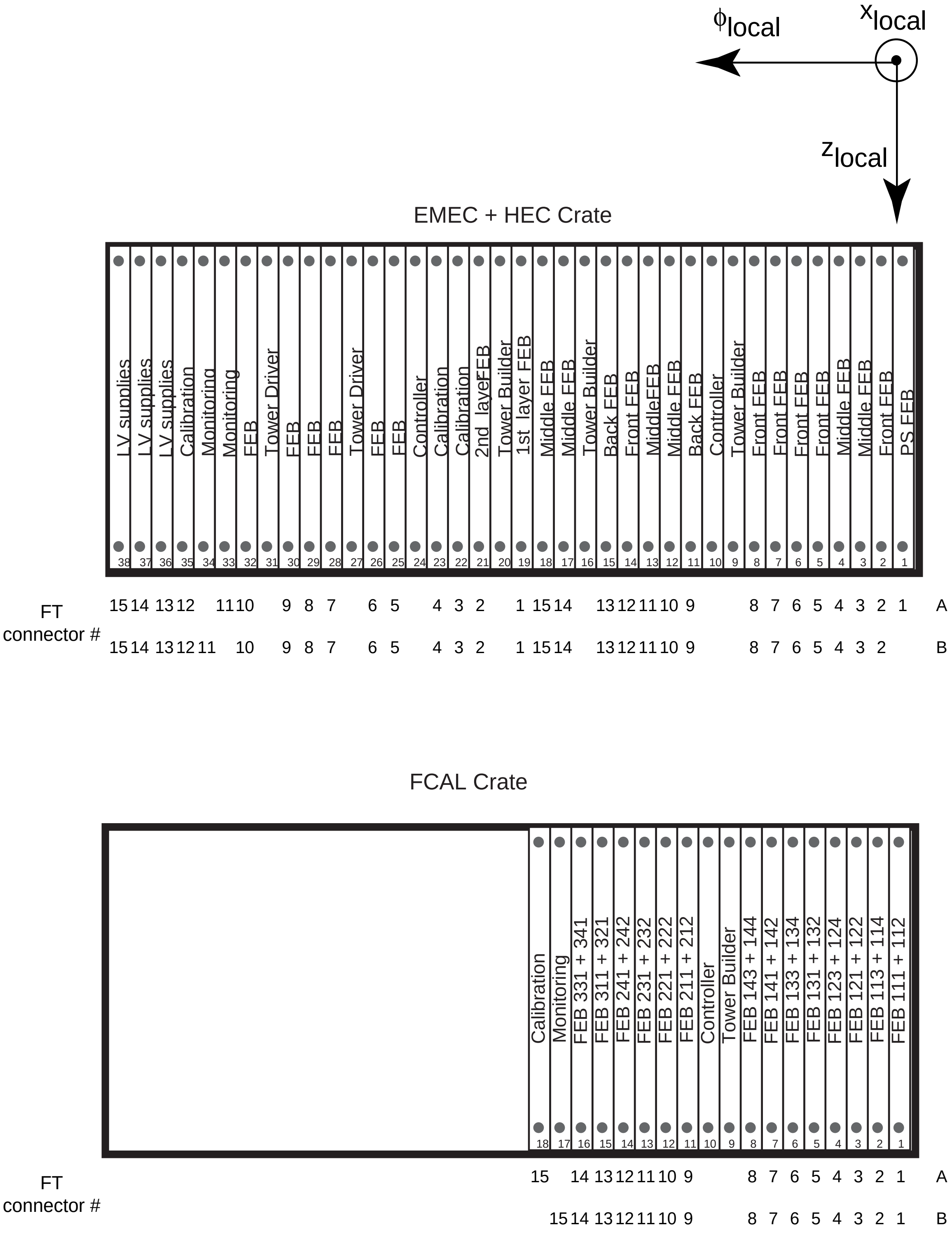

Figure 19 : Location of circuit boards by their function in the crates for the EM end-cap (1.5<η<1.6 and 2.4<η<3.2), for the HEC and the FCAL.

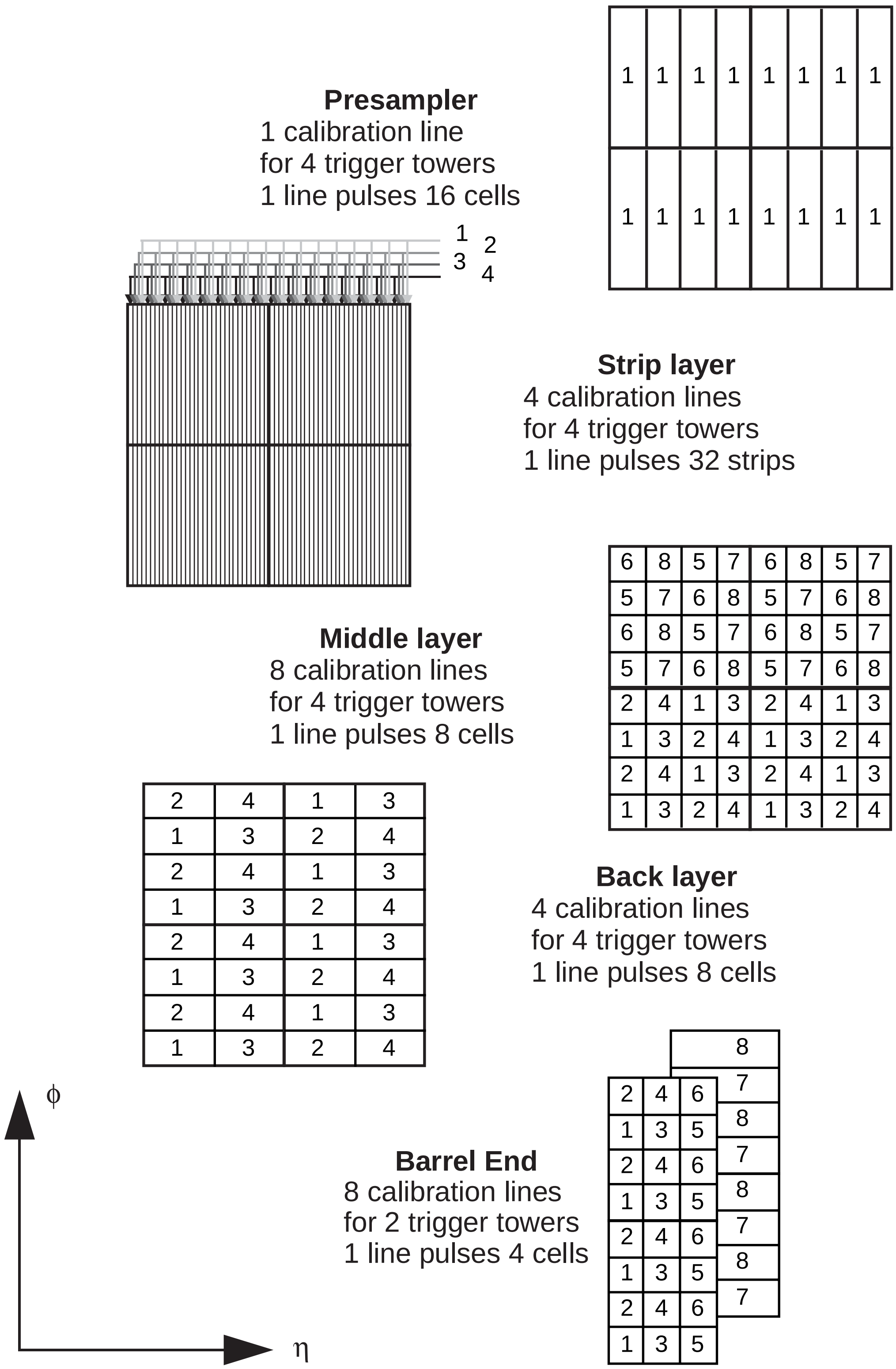

Figure 20 : Symbolic representation of the calibration pattern in the EM barrel. The number within a cell gives the calibration line number relative to this group of cells. Cells with identical calibration line # are pulsed simultaneously.

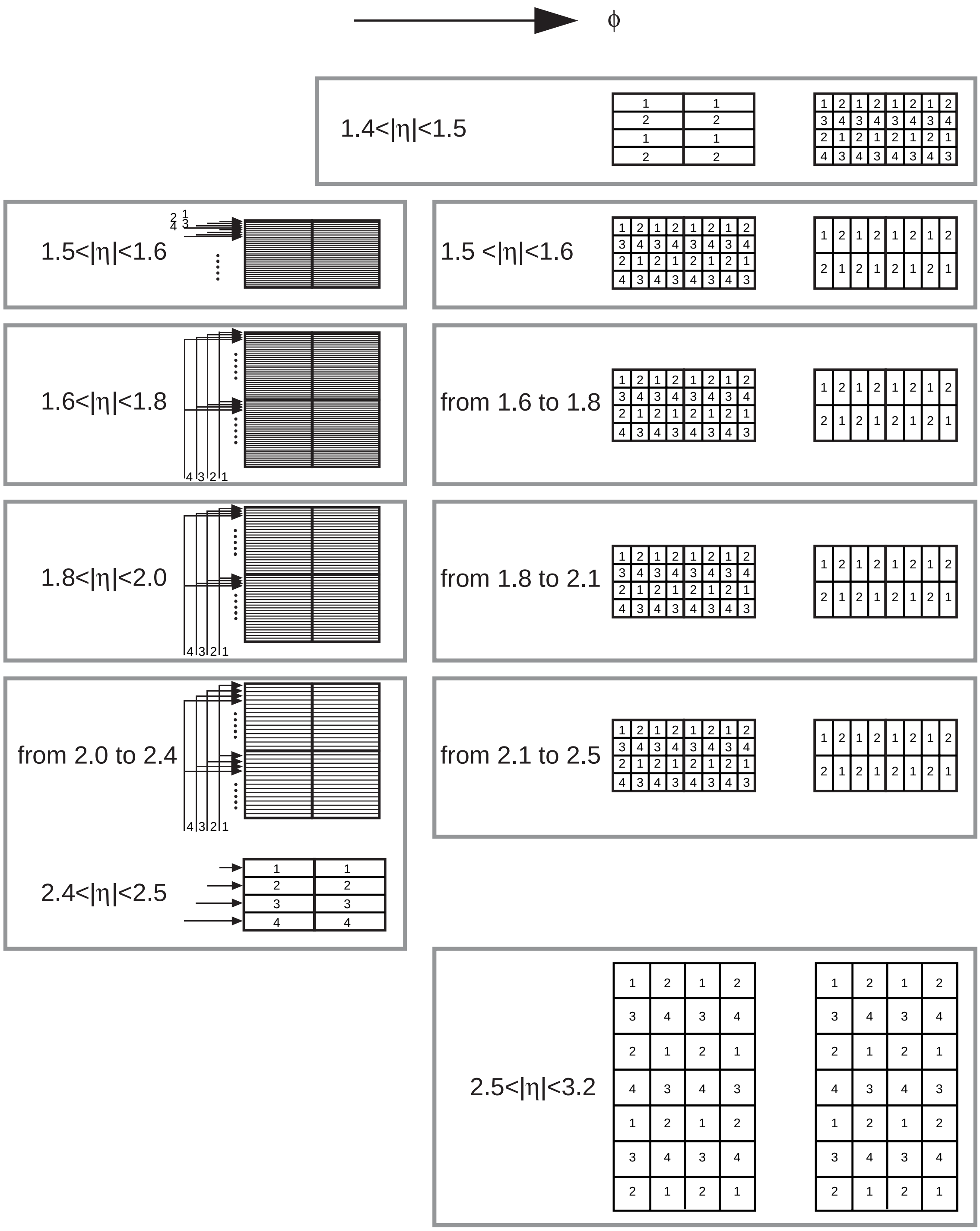

Figure 21 : Symbolic representation of the calibration pattern in the EM end-cap. The number within a cell gives the calibration line number relative to this group of cells. Within a layer, cells with identical calibration line # are pulsed simultaneously. Each cross-hatched box represents a mother board.

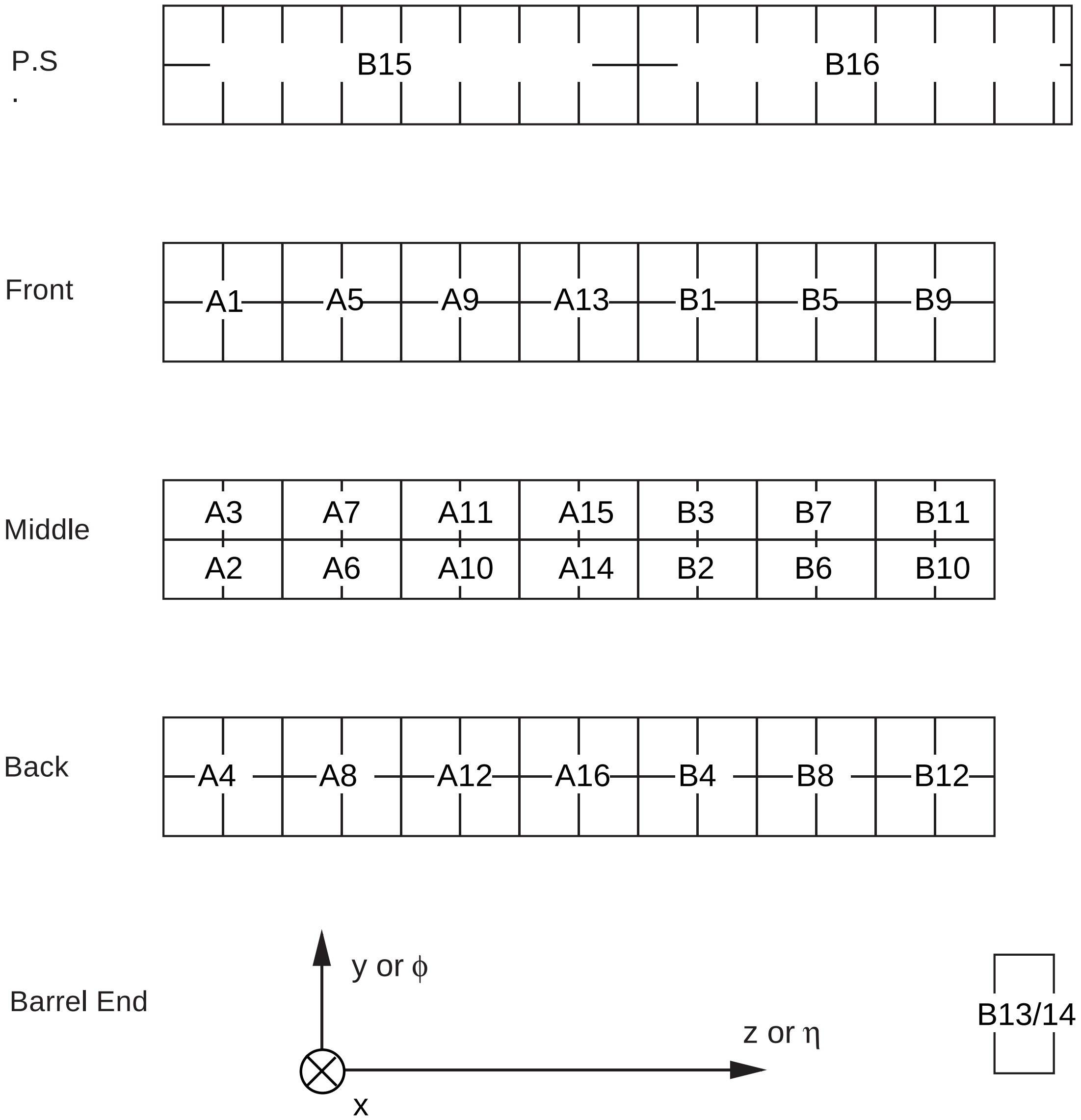

Figure 22 : One calibration board with two 64 lines harnesses (A and B) pulses an half barrel azimuthal slice of $\Delta\phi = 0.2$. Each harness ends in 16 low profile connectors numbered 1 to 16. This figure where each little square represents a trigger tower, sketches the cabling of these connectors on the barrel calorimeter.

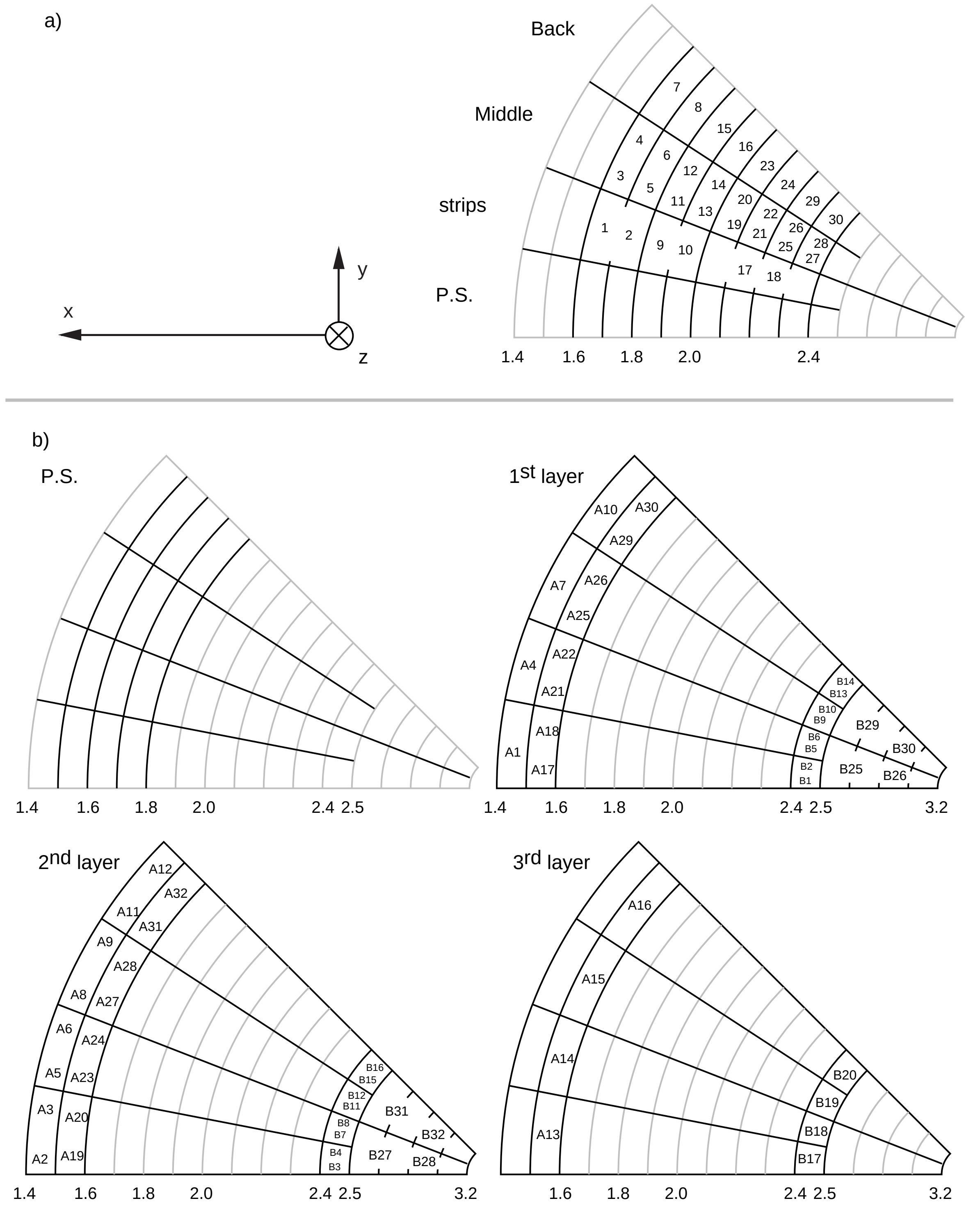

Figure 23 : Schematic representation of an EM end-cap wedge ($\Delta\phi = 0.8$). Concentric lines are drawn at trigger tower boundaries. Calibration harnesses end in 32 low profile connectors numbered 1 to 32.
a) Two calibration boards (i.e. 4 calibration harnesses) pulse the “standard” region. The first harness is cabled to the region $0<\phi<0.2$, the second to $0.2<\phi<.4$ and so on. Otherwise their cabling is identical and defined by a).
b) One calibration board pulse the “special” region of an EM end-cap wedge: $\Delta\phi = 0.8$. The cabling to the detector is defined by b).

Cold Flange seen from LAr

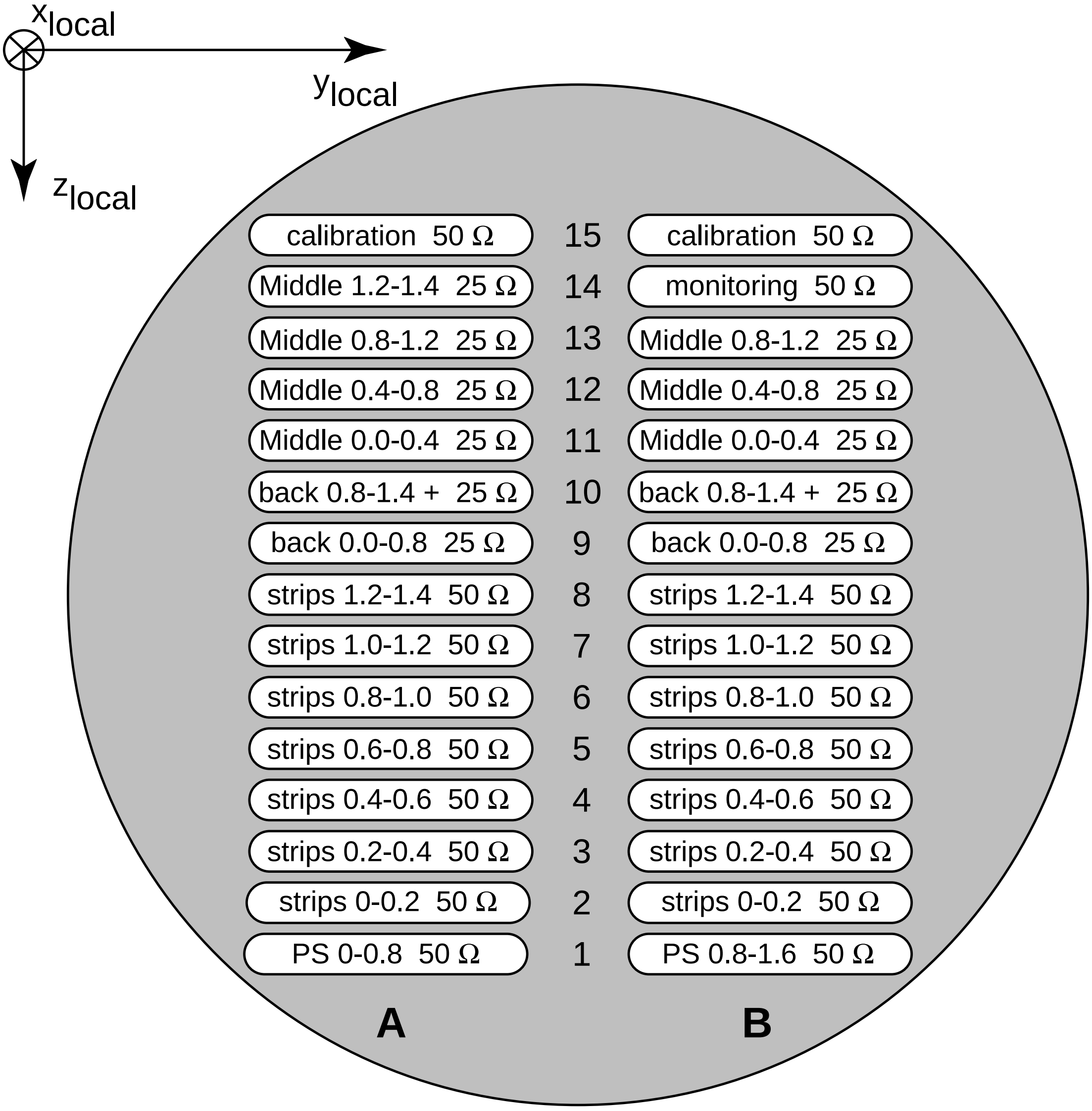

Figure 24 : Map of the cold flange seen from liquid argon for the **EM barrel** calorimeter. The cable impedance (50 or 25 Ω) together with a calorimeter zone or a function is indicated for each connector.

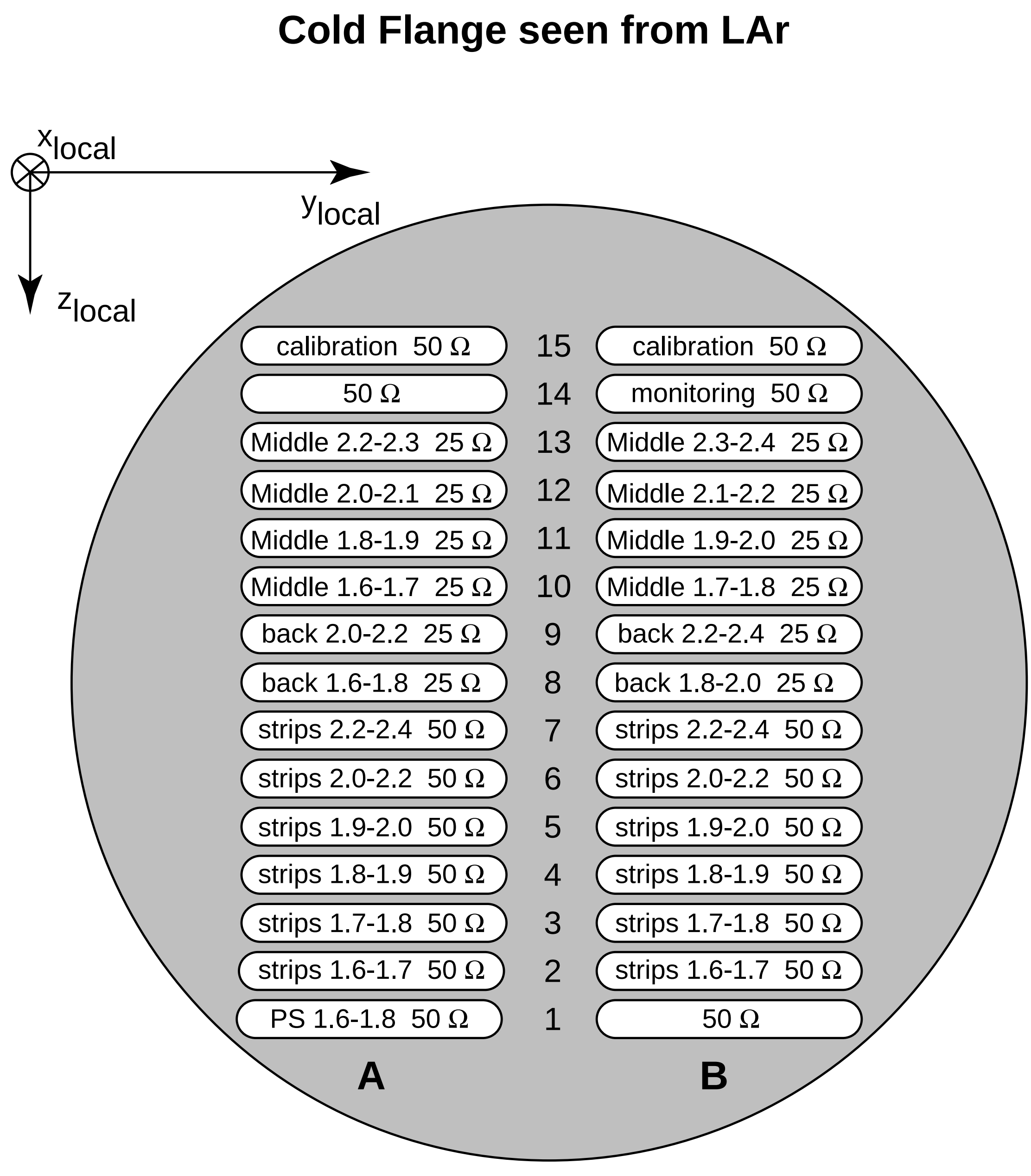

Figure 25 : Map of the cold flange seen from liquid argon for the **"standard" feedthrough** of the **EM end-cap** calorimeter. The cable impedance (50 or 25 Ω) together with a calorimeter zone or a function is indicated for each connector.

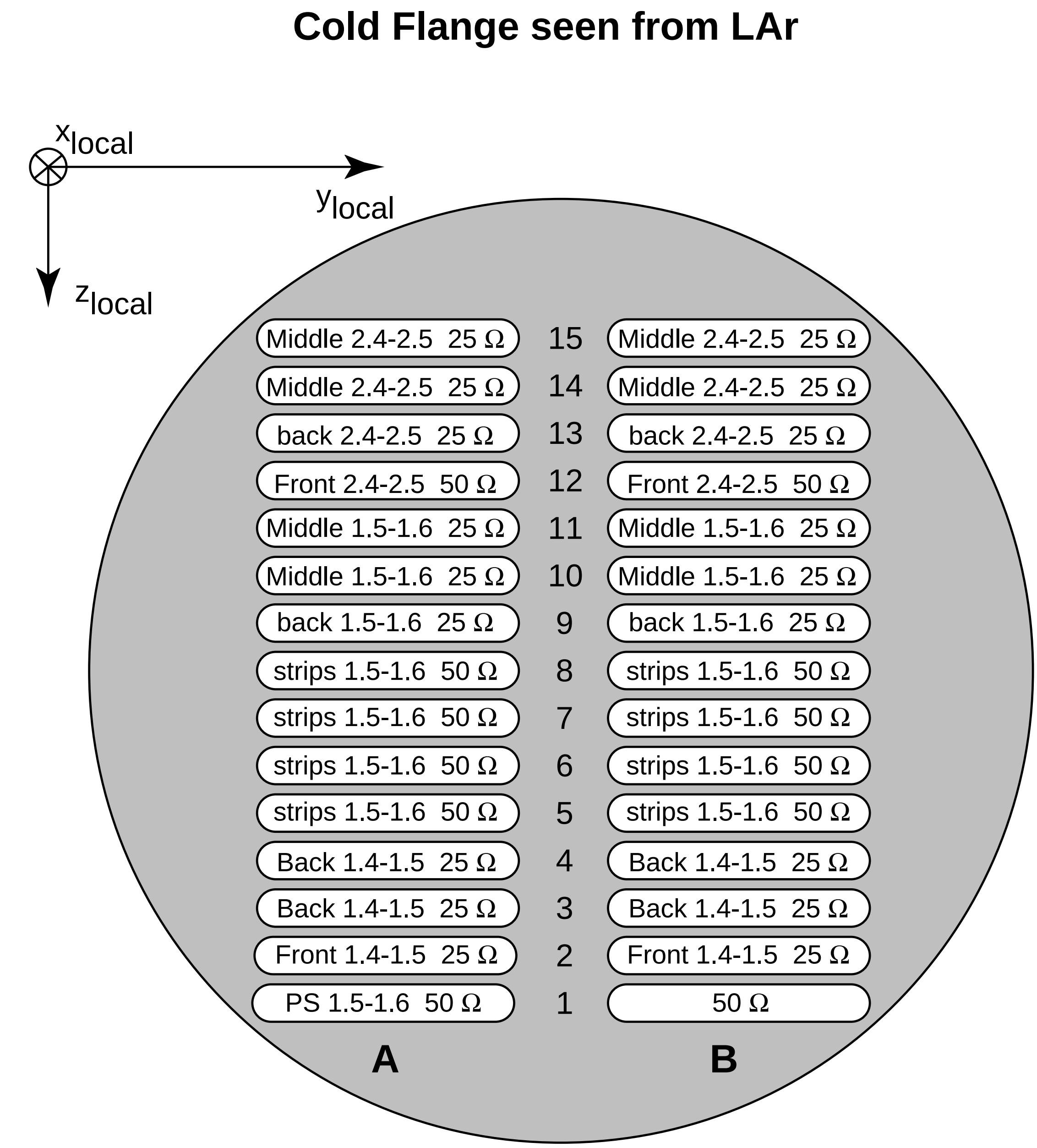

Figure 26 : Map of the cold flange seen from liquid argon for the **”special” feedthrough** of the **EM end-cap** calorimeter. The cable impedance (50 or 25 Ω) together with a calorimeter zone or a function is indicated for each connector.

Cold Flange seen from LAr

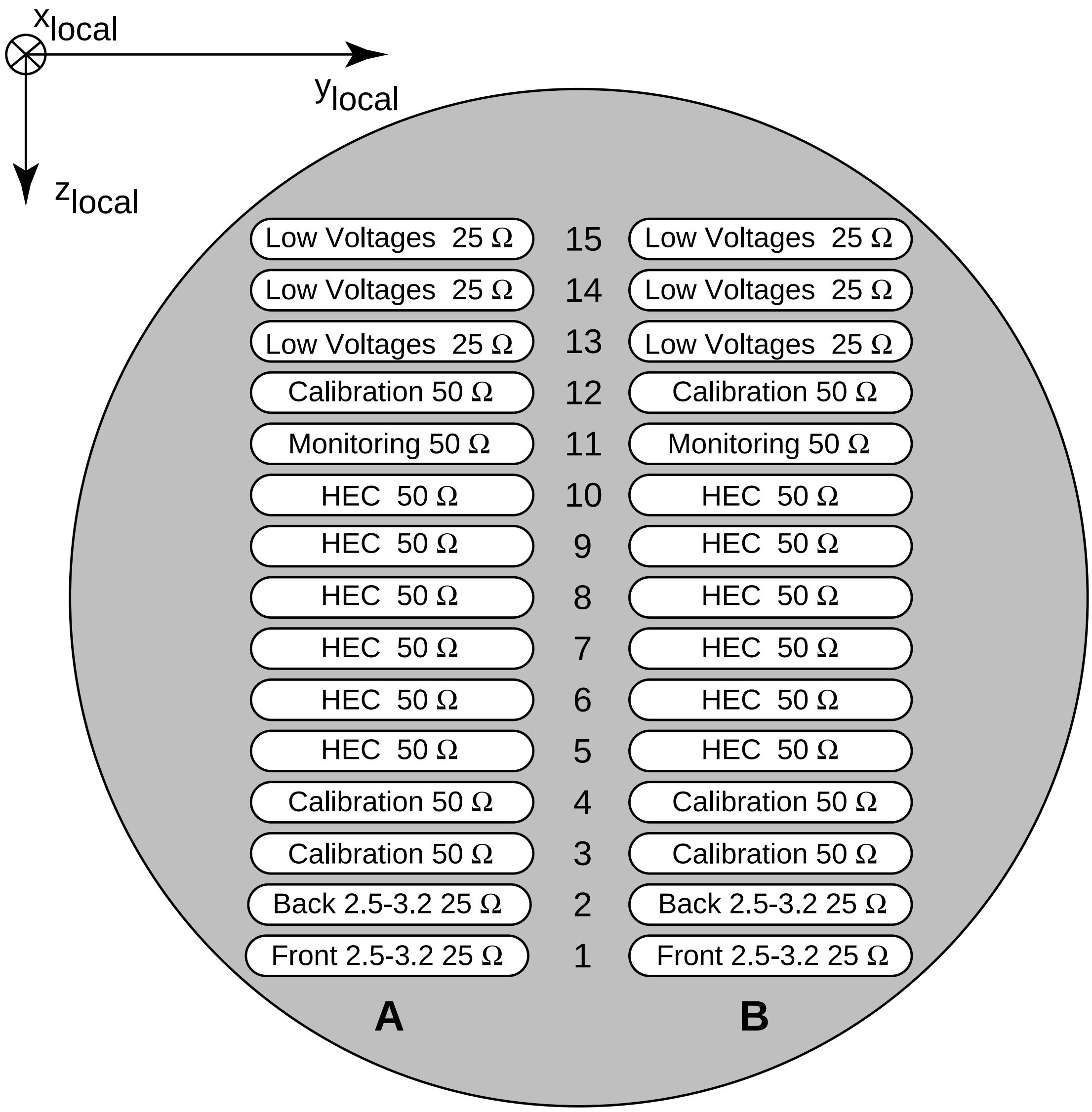

Figure 27 : Map of the cold flange seen from liquid argon for the **"HEC" feedthrough** servicing both the **EM end-cap** and the HEC calorimeters. The cable impedance (50 or 25 Ω) together with a calorimeter zone or a function is indicated for each connector.

Cold Flange seen from LAr

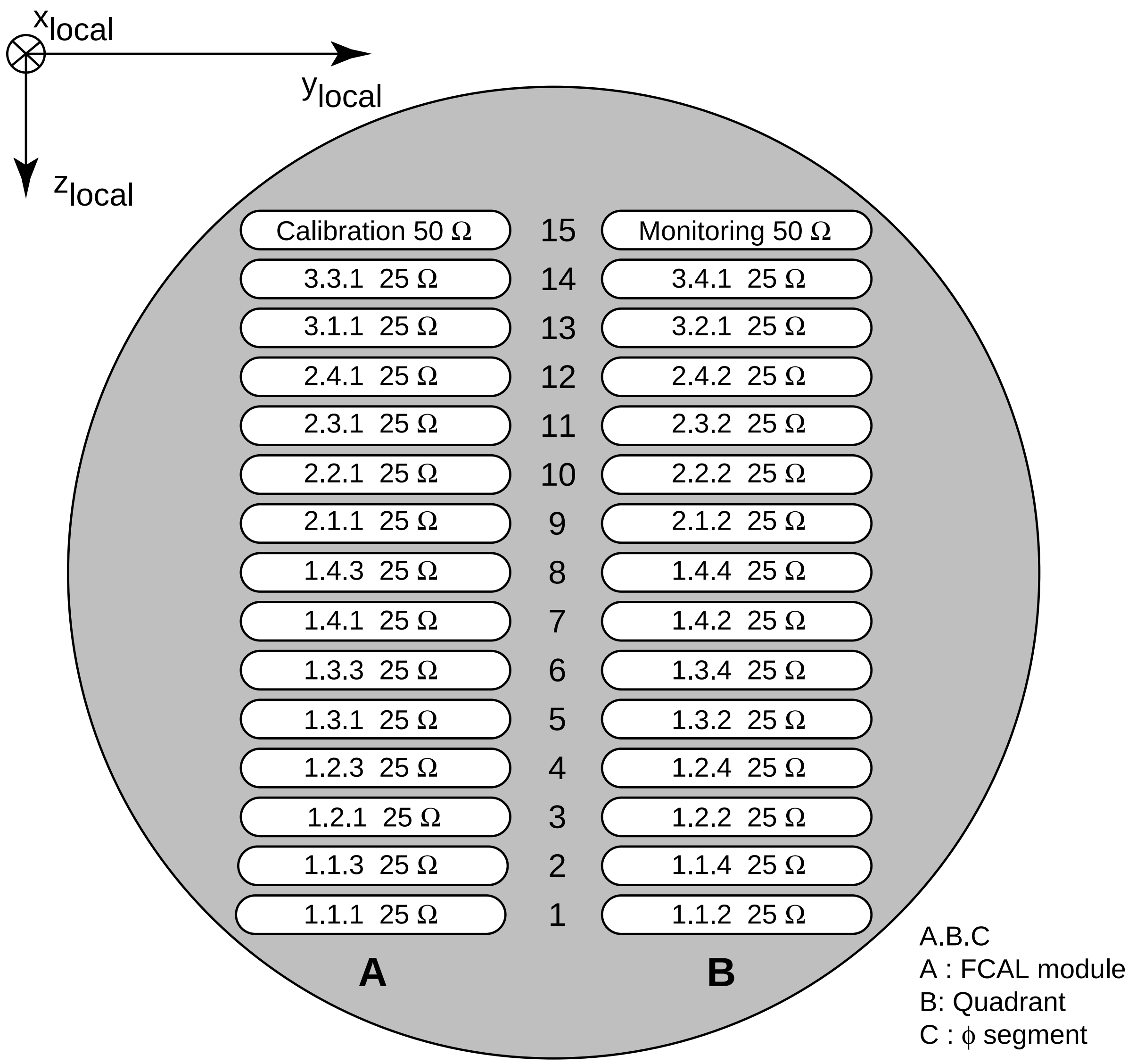

Figure 28 : Map of the cold flange seen from liquid argon for the **"FCAL" feedthrough**. The cable impedance (50 or 25 Ω) together with a calorimeter zone or a function is indicated for each connector.

Flange seen from LAr

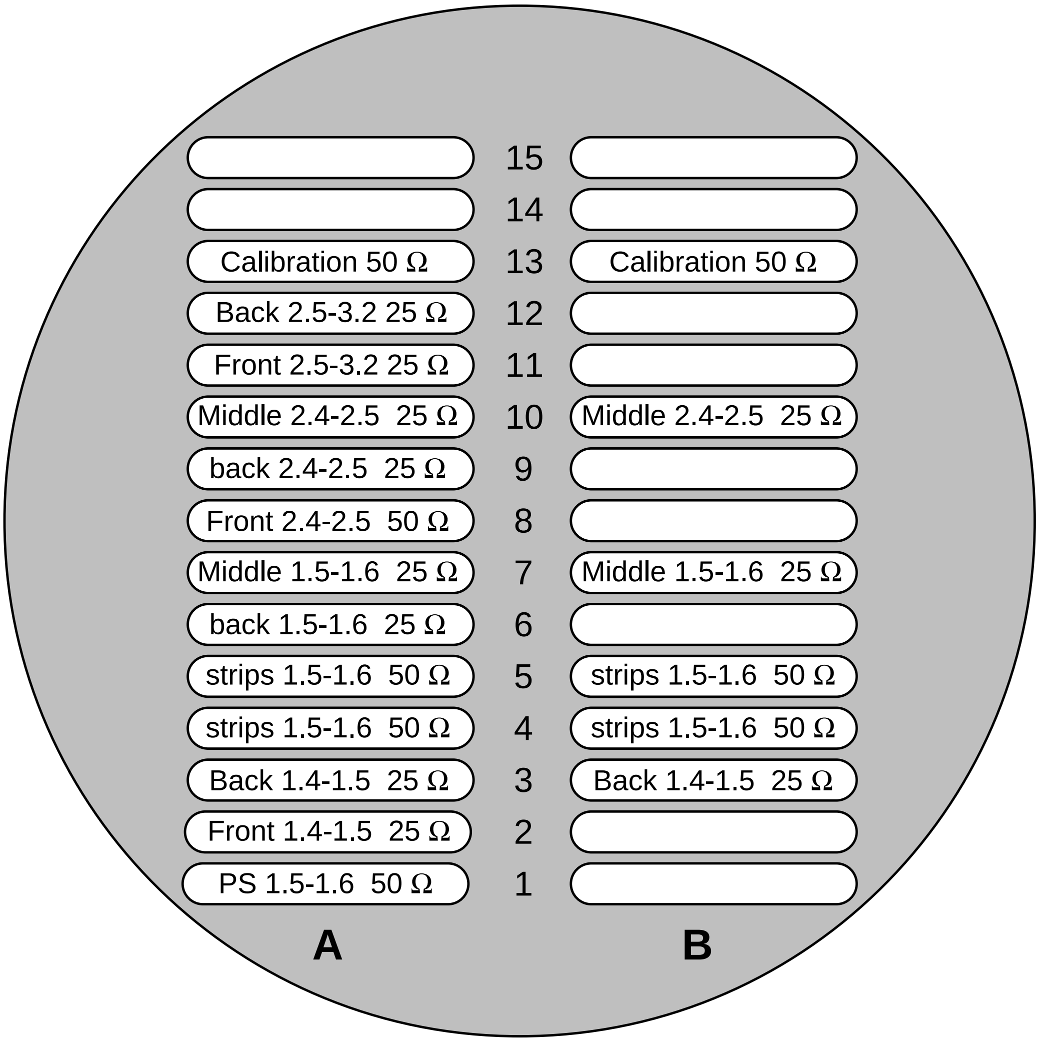

Figure 29 : Map of the flange seen from liquid argon for the **”special” feedthrough** of the **NA31 cryostat**. The cable impedance (50 or 25 Ω) together with a calorimeter zone or a function is indicated for each connector. The crate on top of this feedthrough is, as in ATLAS, sketched in Figure 19 on page 29.