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A proposal for a supporting structure for the Hybrid Pixel Detectors of RICH2

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Abstract

This document is a proposal for the supporting structure of the Hybrid Pixel Detectors (HPD) that the Collaboration Board has accepted as a baseline solution for the RICH detectors.
Layout, structural, thermal, electronic, magnetic and optical considerations have been taken into account in order to produce a design that could satisfy all the requirements.
As the HPD is not an industrial large-series product, but a new type of detector whose development hasn't been completed yet, the outline of its interfaces as well as its shape had to be considered a preliminary one, making assumptions where precise information was missing.

1. CONSTRAINTS AND REQUIREMENTS

In the following paragraphs the main design specifications for the supporting structure of the HPDs[(1)], are described. They provide the input to the current study.

1.1. Layout

The HPDs have to cover a minimum sensitive area of 640x1200 mm^2, i.e. the active detector surface that the experiment requires (see figure 1). A descriptive drawing of the HPDs can be found in figure 2 (courtesy of T. Gys).
The clearance between neighbouring HPDs needs to be reduced to the minimum technically achievable, in order to minimise the blind area on the detector surface.
The gas radiator volume has to be separated from the volume where the HPDs and the related electronic boards are located, for easy and quick maintenance operation and saving of gas.
The HPDs and the related electronic boards must be arranged in such a way to allow easy and quick maintenance operation.
The overall dimensions of the assembly have to fit inside the vessel volume.
The accuracy and stability of the structure should not compromise the spatial resolution of the detector.
The HPDs have to be tilted towards the average direction of the incoming photons by an angle of about 15° from the normal to the average plane of the HPDs, to increase the efficiency in collecting photons.

1.2. Thermal exchanges

Every HPD is expected to dissipate about 0.5 W, drained from the inside electronics by means of some additional pins on its base connection socket.
The electronic boards, the HPDs are connected to, will dissipate about 0.5 kW on each side.

1.3. Magnetic shielding

As the HPDs response is sensitive to transverse and longitudinal magnetic field, a magnetic shielding is necessary. Each HPD must have its own shield, made of 0.9 mm thick μ-metal, extending beyond the HPD window of about 20 mm. For more details, see T. Gys's home page at http://tilde-gys.home.cern.ch/~gys/LHCb/PixelHPDs.htm.

1.4. Electronics

An electronic board is foreseen for every two HPDs, located as close as possible to them. Enough space has to be foreseen for the routing of the connecting cables. Three high voltage insulated cables plus the ground line, with a diameter of 3.2 mm, will feed the detector, while about 200 pins (for signals and thermal dissipation) will come out from the base connection socket. The HPD pins will have to be inserted into a handle-operated Zero Insertion Force (ZIF) socket (see figure 3), for easy installation and dismantling.

2. CONSIDERATIONS AND ASSUMPTIONS

The statements listed in the previous paragraph were critically analysed, discussed with the responsible people and their feasibility assessed. In general we tried to apply, where possible and sensible, the same concepts of the solution already proposed for the backup solution with MAPMTs[(2)]. Then we agreed on some assumptions as guidelines of the design.

2.1. Layout

General considerations on the dimensions and mechanical requirements of the supporting structure lead to the choice of commercial aluminium alloys for the main structure components. These fit both from the point of view of the resistance and of the workability. The accuracy technically achievable after manufacturing and assembling will lie within ± 0.1 mm. As the active area of each HPD is made of 1024 0.5x0.5 mm^2 square pixels, with a demagnification of a factor 5, an accuracy of ± 0.1 mm should be an acceptable value, being quite below the 2.5 mm granularity of the photon detector. Aluminium alloys have a coefficient of thermal expansion that would hardly allow complying with the above requirements of stability in case of big temperature changes. As the alternative of employing special alloys, stainless steel or composite materials is not appealing due to higher cost, limited advantages and/or poor workability, the simplest solution is to keep the system at roughly constant temperature (see paragraph 2.3).
The dimensional accuracy of the HPD, that means of the integral magnetic shielding that is located around it, is rather poor: ± 0.5 mm over a nominal diameter of 83 mm. This aspect has to be considered in the definition of the minimum achievable clearance between neighbouring HPDs. We have assumed that 1.0 mm is the minimum clearance technically and reasonably allowable, in the present structure, between surfaces that have to move without touching each other during assembling and dismantling operations. In the pitch estimation we also considered that a corner of the required ZIF socket would protrude outside the shape of the magnetic shield. Such a protrusion will reduce the clearance between neighbouring HPDs.
Therefore, taking into account the thickness of the magnetic shield (0.9 mm minimum required) and the tolerance on the distance between the centres of two neighbouring HPDs (the general accuracy, as stated above, is ± 0.1 mm), we assumed the following layout parameters:

- pitch of the HPDs: 88± 0.1 mm;
- gap between HPDs: 1.0÷2.2 mm;

The HPDs are arranged in groups of 2 on a common board. To cover the 640 x 1200 mm^2 of active area, 135 HPDs per side are required arranged in 9 columns of 16.

2.2. Thermal exchanges

The power dissipation of the HPD is individually low (see paragraph 1.3) and, considered the total number of HPDs, the total value is not too big (about 68 W per panel). The natural convection alone would probably be sufficient, provided that the extra pins foreseen on the HPD could efficiently convey the heat from the chip inside the tube through the backplate.
Assuming that the heat dissipated by the electronic boards is 0.5 kW per panel, it clearly appears that this is the contribution to be considered for cooling. Anyway the electronic boards layout is not too dense and this helps the heat transmission, so that forced, or perhaps even natural, gas circulation inside the vessel compartment where the HPDs are housed should be sufficient.

2.3. Magnetic shielding

As the magnetic shield is integrated with the HPD, it does not affect at all the supporting structure. But their poor manufacturing accuracy forces to increase the pitch, to ensure a gap large enough between neighbouring HPDs even in the worse situation

2.4. ZIF socket and support board

As the expected number of pins coming out from the HPD (between 150 and 200) is very high, their introduction into a socket is problematic, if simply done by hand. Therefore a ZIF socket was foreseen. Very preliminary considerations clearly pointed out that a custom designed ZIF socket is required in this application because, due to the dimensions of the HPD itself, there’s no room to operate the standard lever foreseen by the manufacturer. Furthermore, the orientation of the ZIF

socket will have to be specified, in order to have free access from the sides to the disengaging device.
As a not negligible amount of lines is common for the HPDs, the solution that groups them in pairs on common boards allows to reduce the number of lines that connect them to the electronic on the rear side of the panel. Furthermore, those lines can be routed, by means of a multi-layer board, to a more convenient position, where linear connectors could be attached to ensure the connection to the rear electronics.

3. DESIGN OF THE STRUCTURE

The considerations previously summarised lead us to design and propose the following structure for the detector plane of RICH2.

3.1. Layout and supporting frame

The HPDs are arranged in groups of two, fixed by means of their own pins on a common multi-layer board (through a ZIF socket), making an elementary subassembly unit (see figure 4).
Each of these units is located, by means of two dowel pins, in an aluminium supporting frame that houses 8 sub-assemblies (15 HPDs, 7 groups of 2 plus 1 group of 1) arranged column-wise. These sub-assemblies are mechanically fixed by means of screws that hold the HPDs back-plate through spacers made of thermoplastic resin (see figure 5). Such a solution allows avoiding introducing stresses, but it does not allow to precisely locating the HPDs respect to the supporting structure. The accuracy of the pins with respect to the HPD body could be specified and achieve a satisfactory value, compared to the experiment alignment requirement. The accuracy of installation of the ZIF socket on the board could be specified and achieve satisfactory values as well. So, the real unknown from the point of view of the HPDs positioning in space is the misalignment due to the coupling of the pins with the ZIF socket. We don't expect a large error, but we recommended checking its compliance with the requirements. The above mentioned frame also houses one electronic board on the back of each unit, whose size, assumed to be 140x300 mm^2, should be large enough to house all the required components. These boards are arranged vertically, for good convective heat exchange, and can be individually pulled backward, for maintenance purposes, by sliding on their own guides without disturbing any of the other components of the system (figure 6). Their electrical contact with the board on the back of the HPDs (that is located on the other side of the supporting structure) is ensured by means of high-density linear connectors face-mounted on the rear of this last board (figure 7).
There are in total 9 supporting frames that can be individually pulled backward without disturbing the neighbouring ones, provided that the minimum clearance previously stated is respected. They are fixed by means of dowel pins and screws to a main supporting frame. In case of maintenance, after slackening the screws, the 9 supporting frames can be individually pulled backward, sliding on their own guides.
A FEA harmonic analysis of this supporting frame estimated that the first resonance frequency is at about 45 Hz, and that other resonances are at about 90 Hz and 125 Hz. Then the system looks to be stiff enough to withstand low frequency excitation without getting into resonance. Nevertheless, as a good practice, a dynamic insulation through the foundations of the system is recommended.
A main supporting frame made of aluminium houses the 9 supporting frames and their sliding guides, and has spring-backed screw devices that allow for small adjustments of the plane of the HPDs, and a jacking screws system for inclination adjustments.
The whole assembly is installed on high precision guide-rails that allow for the extraction of the full assembly out of the vessel structure, as well as its approaching to the fixed structure (figure 8).

3.2. Power connections

Every HPD features 3 high voltage round cables, plus the ground line, that means a total of four cables whose expected outer diameter, insulation included, is 3.2 mm. All these cable will get off the HPD through its backplate, close to the outer border, and will be routed by the side of the supporting frame (figure 5). This layout allows no interference while extracting the supporting frame. Local strain relief of the cables to the frame can be easily foreseen.

3.3. Cooling system

The stability constraints on the structure, as well as the electronics requirements, compelled us to consider the problem of the temperature control in the vessel compartment where the detector plane is located. As the power generated by the HPDs themselves is relatively low, we don't expect any problem in draining it away with natural, or eventually forced, gas flow. Anyway, an inert controlled atmosphere in the detector volume should be beneficial.
As their packaging is much less tight, the heat power loss of the electronic boards on the rear side of the detector plane probably will not require a conductive heat drain system, being the convection sufficient. We only arranged the boards with their faces vertically oriented, to help the adduction, and recommended forced ventilation of the whole volume where the HPDs assembly has to be installed.

4. CONCLUSIONS

A preliminary design has been proposed for the supporting structure of HPDs in the LHCb RICH-2 detector.
The different requirements and constraints have been taken into account and viable solutions have been proposed.
More detailed studies will be required while in the executive design phase, but we don't expect they will deeply change the current design.

5. REFERENCES

(1) T. Gys, LHCb 2000-064 RICH: *The use of Pixel Hybrid Photon Detectors in the RICH counters of LHCb.*

(2) S. Cuneo et al., LHCb 2000-005 RICH: *A Proposal for a Supporting Structure for the Multianode Photomultiplier of RICH2.*

6. LIST OF FIGURES

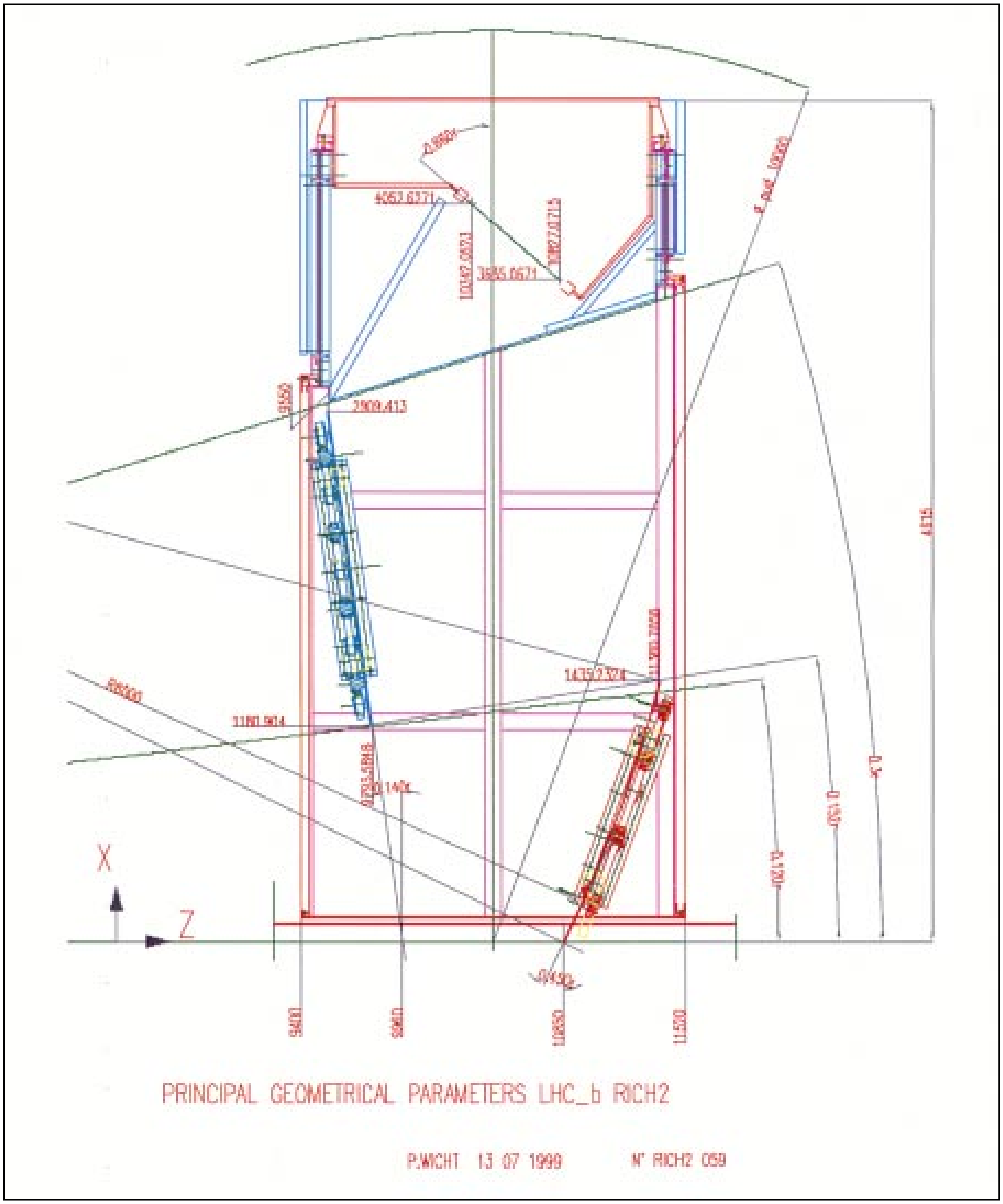

Fig. 1 : **RICH2 layout (courtesy of P. Wicht)**

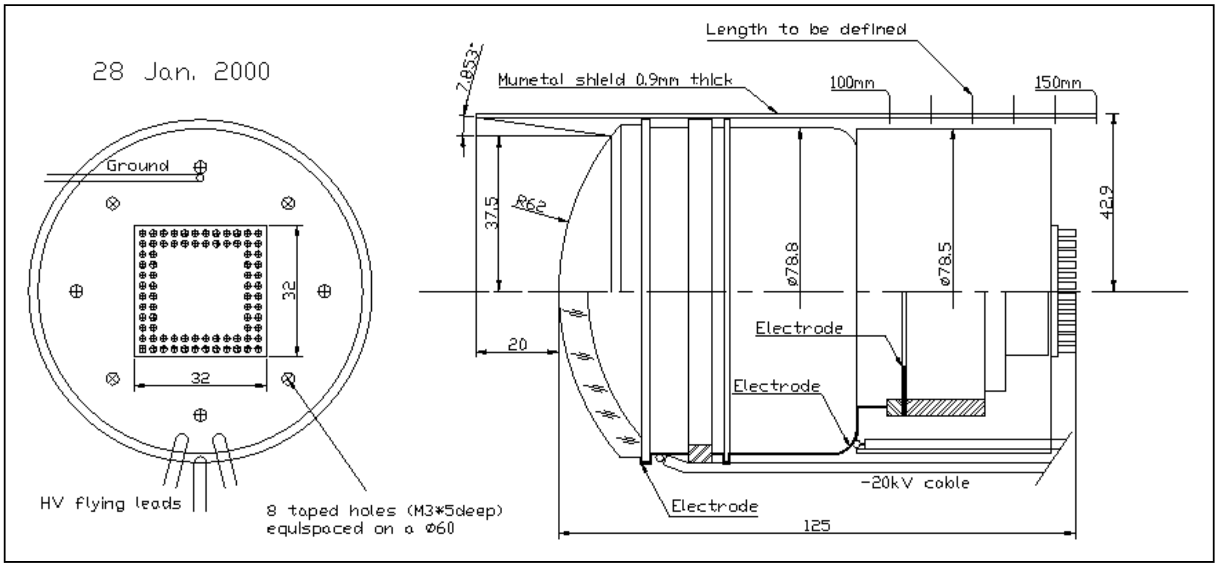

Fig. 2 : HPD mechanical outline (courtesy of T. Gys)

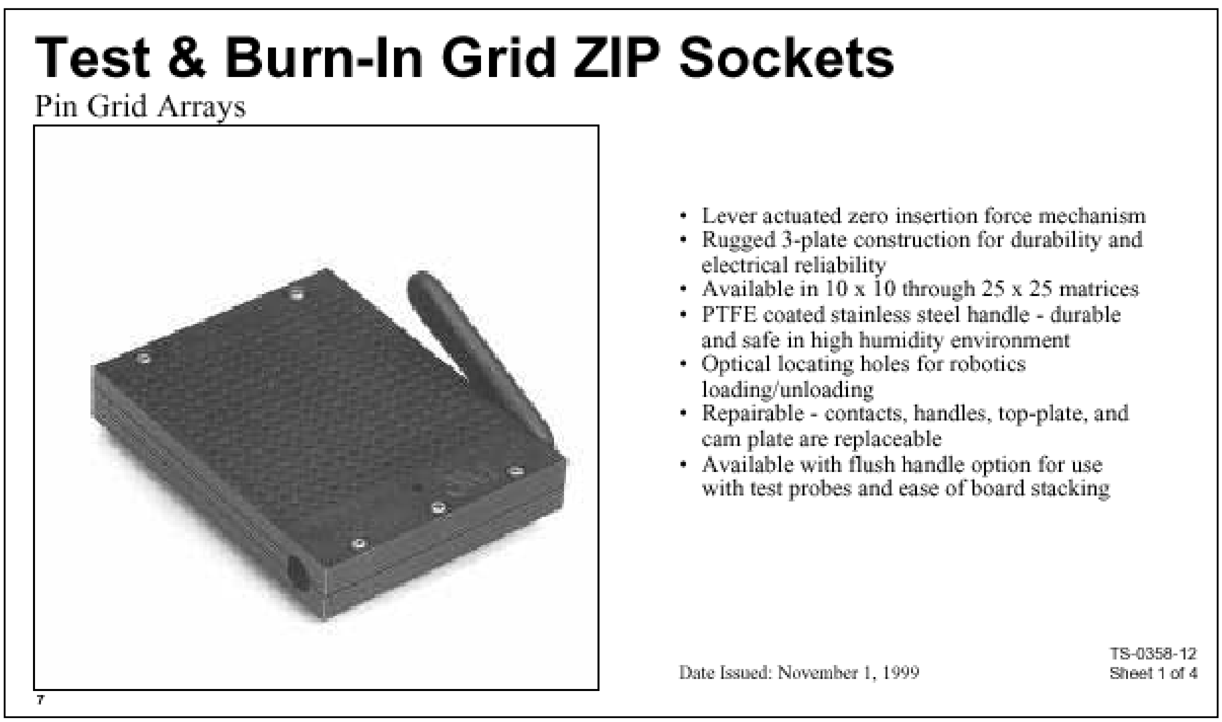

Fig. 3 : ZIF socket detail (courtesy of 3M)

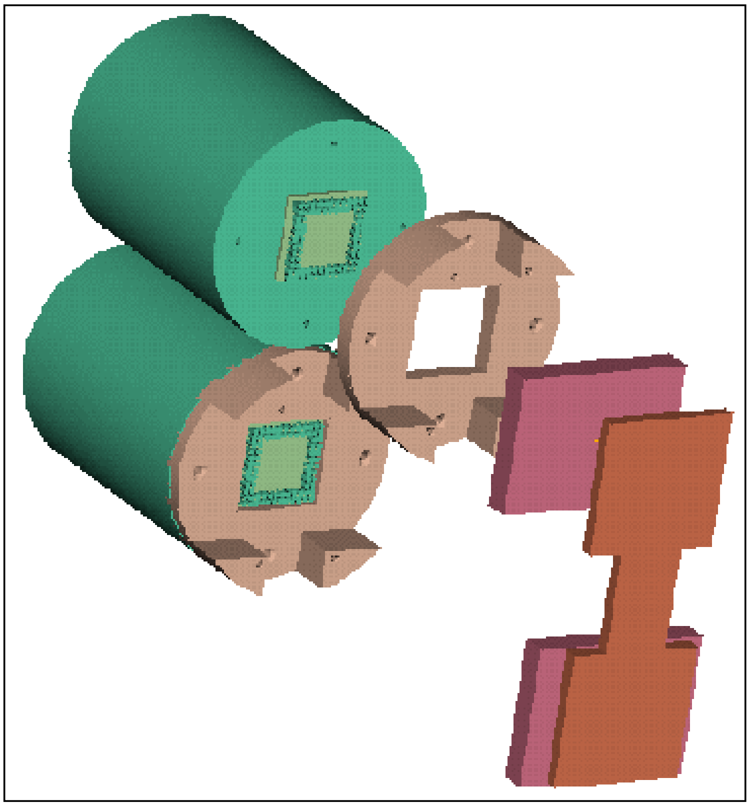

Fig. 4 : **HPD subassembly**

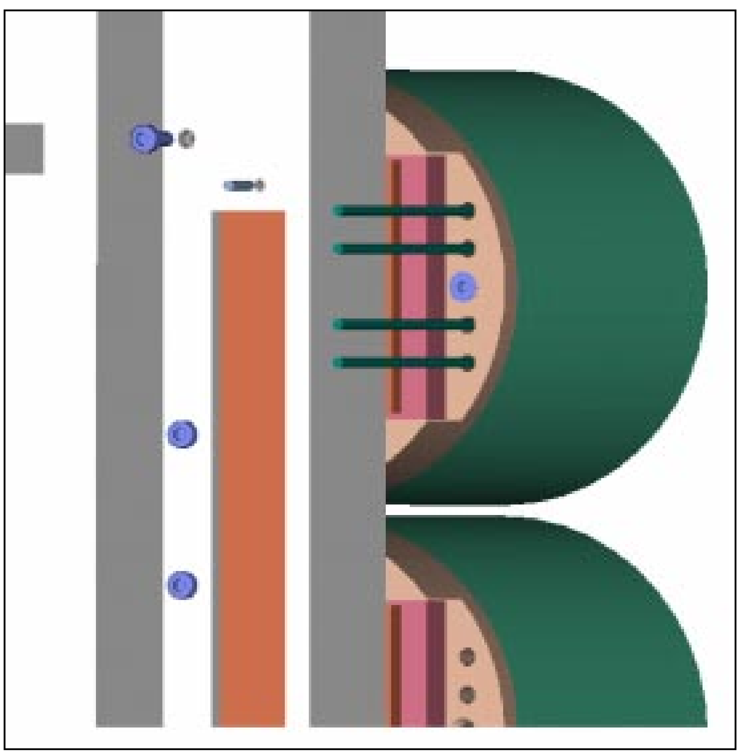

Fig. 5 : **HPD subassembly fixation details and routing of the HV cables**

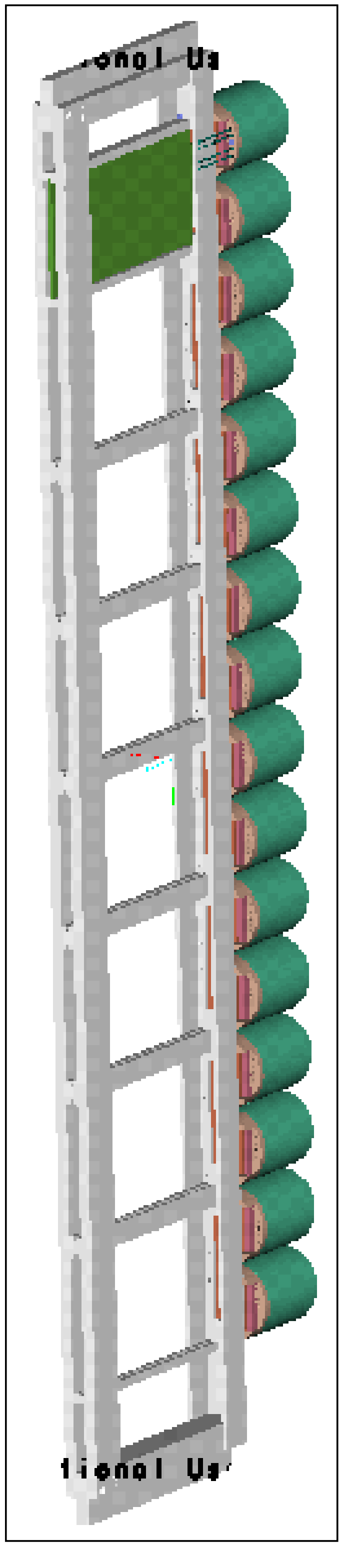

Fig. 6 : **HPD supporting frame layout**

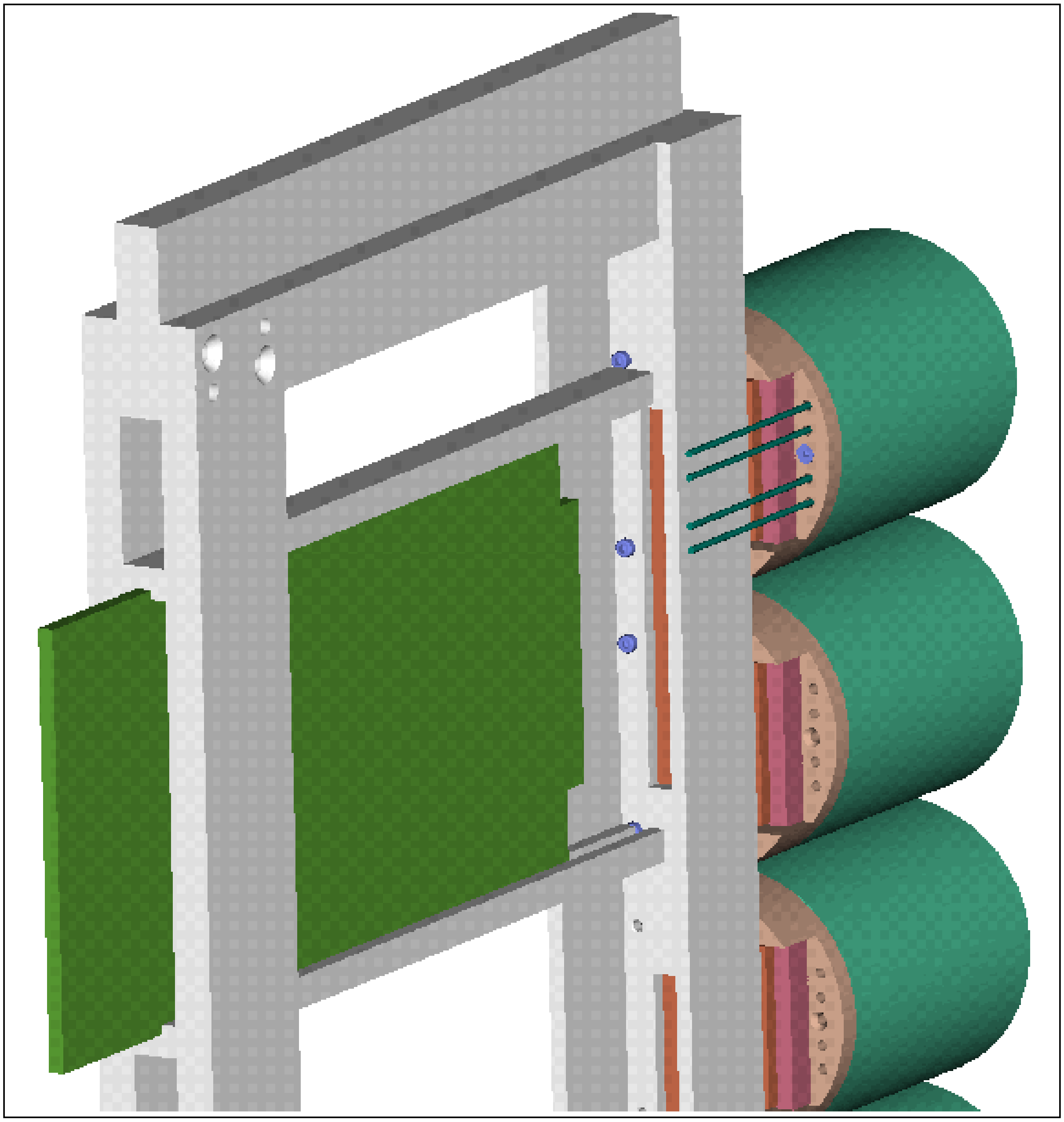

Fig. 7 : Electronics connections

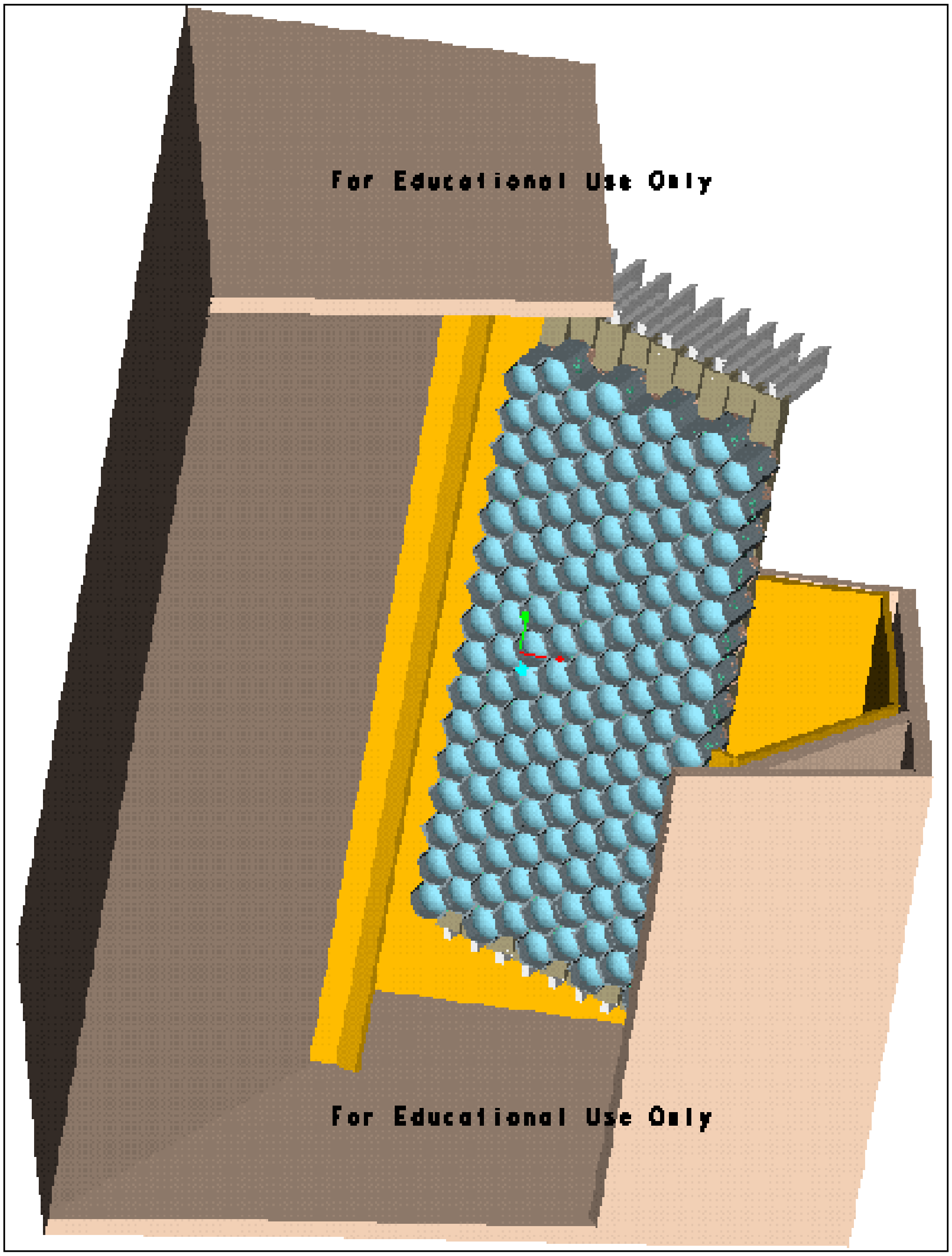

Fig. 8 : Detector plane assembly inside the vessel