Defining the size of the TPC services.

A TPC endplate micromegas style has about 80 modules (between 78 and 84). Each of them makes use of 2 fibres, 1 HV (400V) cable and 125W under 5V. This last service is the most cumbersome, it also imposes cooling of the cables if we extend them to the outside of the detector.

The cables to be used are either for 25A with a copper section of 4mm² of for 32A with a section of 6 mm².

Loss of voltage along a copper cable of section S and length L:

Be ρ the copper resistivity 1.7 10^{-8} Ω m, the resistance of a cable of length L and section S is $R = \rho\, L\, /\, S$. For a 4mm² section on 1m length, R = 1.7 10^{-8} / 4 10^{-6} Ω = 0.425 10^{-2} Ω. The loss of voltage along 1m of such cable is ΔV= RI. The power we need is 125W at 5V, which makes 10kW per endplate. The intensity is then I = 125/5 A = 25 A. Then ΔV= RI = 0.425 10^{-2} 25 V = 0.1 V and the dissipated power is P = 2.5W. If we consider the factor 100 linked to the power pulsing we dissipate 25mW per module.

For a complete end plate the dissipation in the cables is 80x25mW = 2W per meter.

Path of the cables: consider the assumption that the cables run from the middle of the TPC to the outside of the yoke that makes about 10m. The drop in voltage is then 1V and the power dissipated per cable is 25W without power pulsing and 250mW with it, per end plate it makes 2W. How to cool it? Do we need to use converters to avoid these losses? Here we take the assumption that there are no converters which anyway may have trouble in 4T.

Consider the 80 cables, can they be bundled? What would be the size of the bundle? What is the size of the insulation? Do we need insulation? Consider the size of the square containing the 4mm² copper it uses about 5mm² and we double for insulation to 10mm². As we have 80 cables the cross section of the bundle is about 800 mm² or 4 layers of 20 cables 64 x 13 mm². There is no problem to get that through the gaps. For the cooling it may be easy to run CO2 pipes in the bundle and add some thermal insulation around. On the other side there is no reason to have the 80 cables running the same way, we could consider to create 6 bundles of 13 cables 4x40mm².

Concerning the high voltage (400V) cables with an adequate insulation have a diameter smaller than 5mm. We can route them in 6 bundles of 13 cables 5x65mm² more or less at the same place as the low voltage cables.

Then the fibres are 2 per module with a diameter of say 1mm, dividing again in 6 bundles of 26 fibres it is quite negligible except by the constraints on the curvature (R=5mm?). If we have to provide a connection with a patch panel it could be adequate that the fibres start at the patch panel only, the signals being brought to the patch panels by copper cables. But the space needed to convert the signal may be larger than the space needed for an optical connection.

Globally at the level of the calorimeters we need about 6 times 10x70mm².

Possible layout of an endplate:

The end plate is divided in 4 concentric rings with the same size in R. It is attempted to cut these rings in modules of about the same size in R-phi. A solution is to divide the first in 12, the second in 18, the third and the fourth in 24. This makes 78 modules. In the drawing from Saclay this shape is shown but also with 84 modules, the second ring being split in 24 modules. This is shown on the figure ??. It appears that in each ring the number of modules can be divided by 6. A way to cable would be then to use six exits corresponding to ECal modules the up and down ECal modules being reserved to leave place for the TPC support. Such a sketch is shown on figure ??. The width of the tree stem is 65mm and it has4 layers: low voltage, cooling, high voltage, fibres. This looks fine but does not allow the mounting and dismounting. If that is required a place for connections has to be found and the services have to disappear from the interface ECal-TPC at the time of opening.

As the "à la Videau" HCal structure does not impose any constraint on the path of the services it is used in this study.

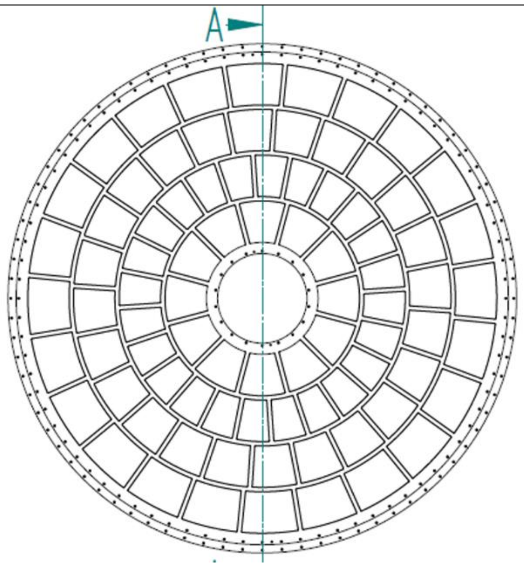


Figure 1. . Sketch of a TPC end plate presented in ?? by Paul Colas

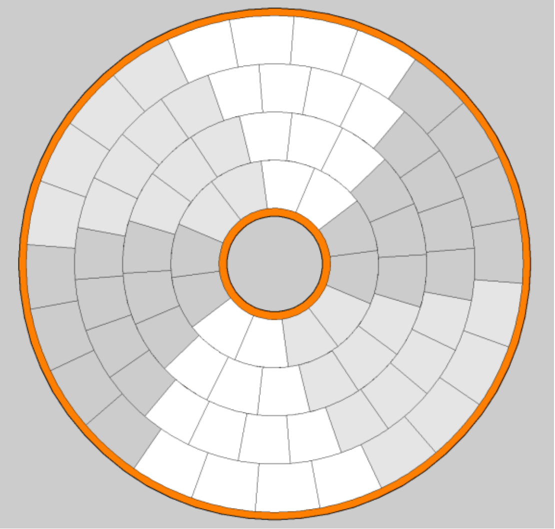


Figure 2. Sketch of the TPC sectors divided in 6 groups

Structure of the end plate modules in this model: The modules start at a radius of 385 and end at 1717.8. The start is the inner radius of the TPC + a field cage of 25 and an insensitive zone of 30. The end is the TPC outer radius minus a field cage of 52. The area is divided into 4 equal radial zones with DR=333.2. In phi the first crown is divided in 12, the second in 18, the last ones in 24, which makes 78 total. The module area is 96233mm² in the first crown, 102909 in the second, 106247 in the third, 135312 in the fourth.

This structure has 4 parameters: an overall rotation and a rotation of any crown against the preceding one. The last three parameters have to be optimised for the track momentum measurement. The first one can be adjusted against the position of the ECal for extracting as easily as possible the services. In the drawings of this note the relative rotations have been chosen to be pi/60, pi/30 and pi/20.

It can noticed that in every crown the number is a multiple of 6. Then we can build 6 sectors of 13 for example as drawn in figure 2.

Some remarks about how to suspend the TPC are presented in the baseline dimensions note. For this study we use the simplest and may be best solution with two carbon fibres plates attached on the HCal. The estimate of the endplate distortion under its weight, the ISS weight and the gas pressure has to be redone but is probably dominated by the bulging under the inner pressure. The exact shape of the plate has to be computed the question here being to know if there is a global solution to have the services grossing the overlap gap.

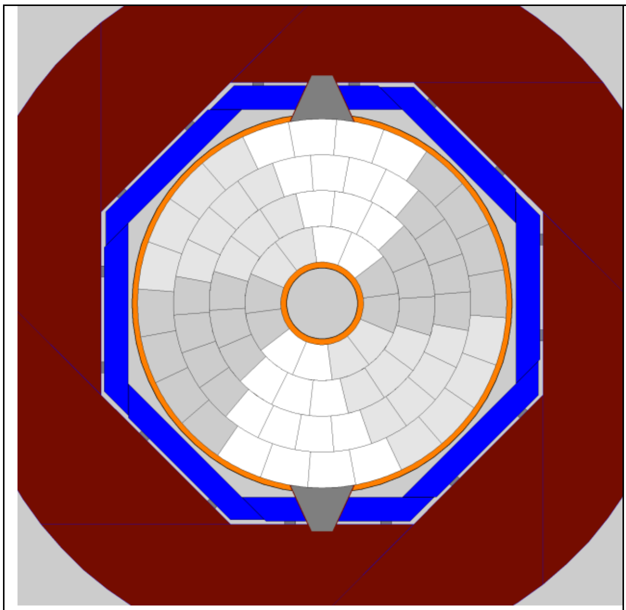


Figure 3. The TPC is shown hanging from the HCal. The ECal barrel is also represented with its rails.

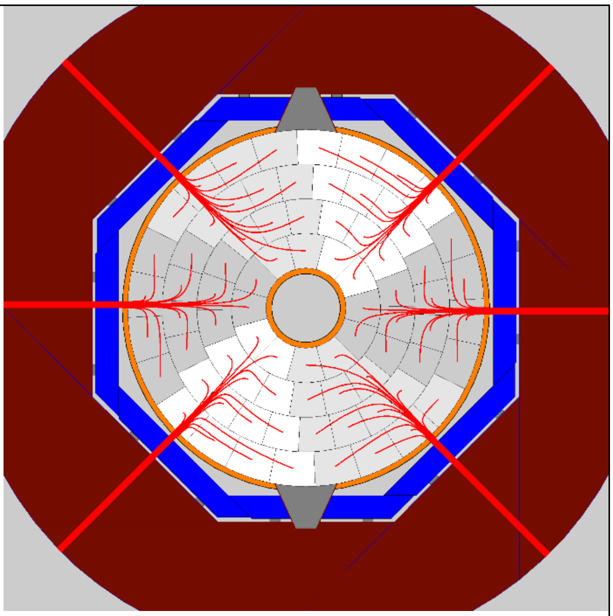


Figure 4. Getting the services out of the TPC. An example.

To go further we need an idea about how the TPC services run. As described above we have 4 networks connecting the modules to the outside, low voltage, high voltage, signals, cooling. We can figure out how to have one, the other coming on top or aside. As we have designed 6 sectors we can consider that on two ECal staves are the suspensions and the services for the 6 sectors run over the 6 other staves. Such a design is sketched in figure 4. And the detail is shown in figure 5. The services are drawn from the centre of the module to the outlet chosen here in the middle of the staves, where they come all parallel. The lines do not cross and are drawn (using Bézier curves) not too exhibit too strong a curvature. They figure services like a cable 4x4mm². At the level of the ECal they make a ribbon 4x50mm² about.

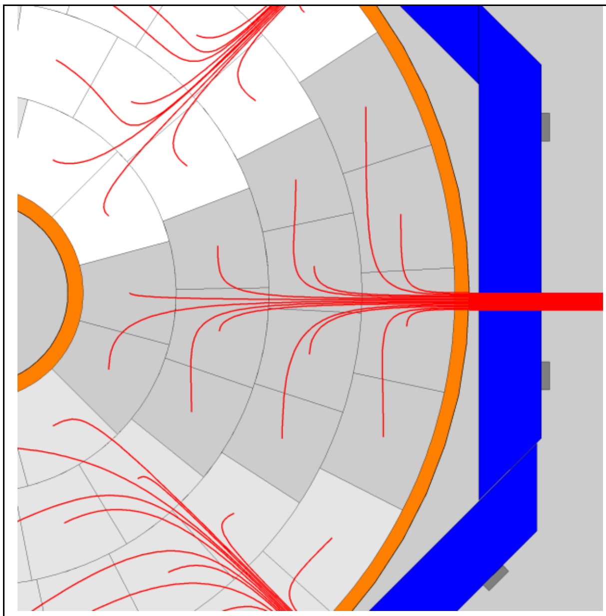


Figure 5. Detail of the running of the cables in a TPC sector.

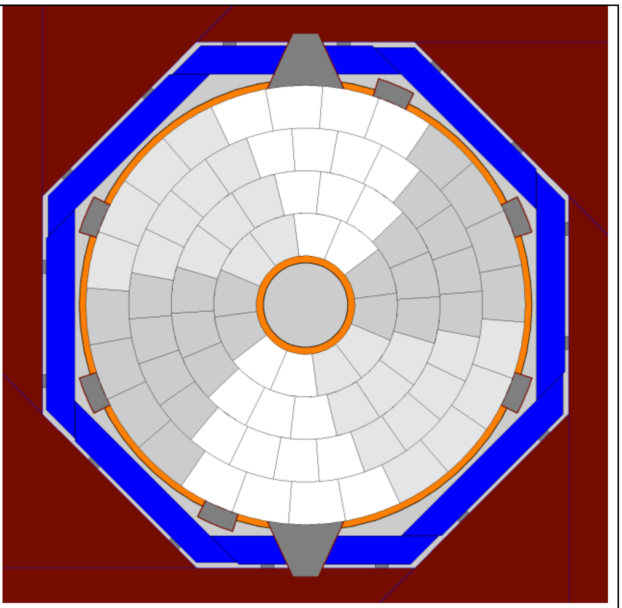


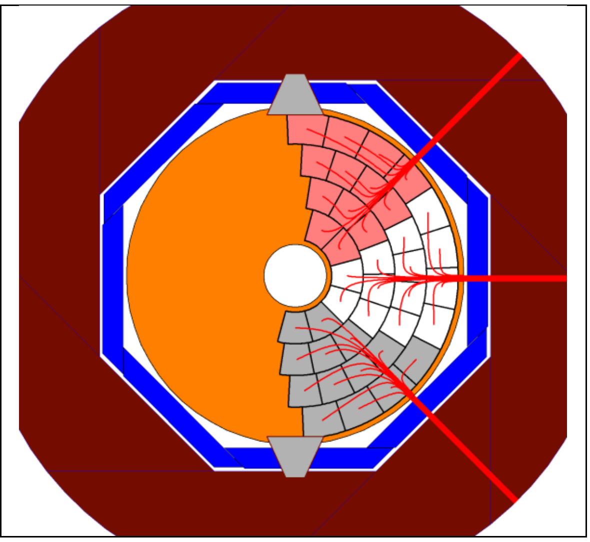
Figure 6. Possible position of patch panels.

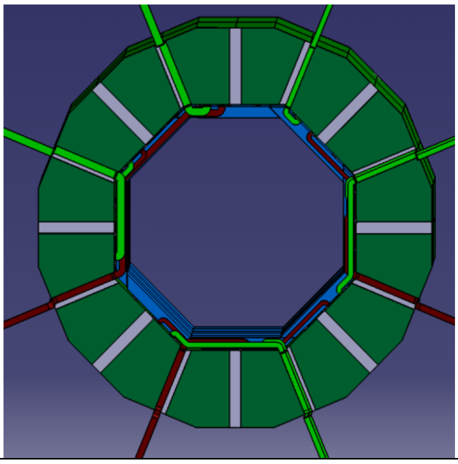
Connexions and patch panels:

This looks perfect if we do not need to disconnect the TPC for taking it out for example. It would also be very interesting to be able to connect the TPC in the same way when in test by itself or when mounted in ILD. We need then a connexion place, a patch panel at the border of the TPC and not interfering with the SET or ECal. It is difficult to find this in figure 5. We have at our disposal the field cage and we can probably overlap a little with the last TPC module.

But the fact that the TPC is round when the ECal is octagonal may provide some space to insert the patch panels. This does not interfere with the SET except for its services which are not known better than the rest of SET. The figure 6 shows possible patch panels about 150 by 300 mm, the TPC sectors have been rotated by pi/8. This should be enough for connecting side by side 2 layers of services using 15mm. The 2 others are then on top, the total thickness reaching about 30mm.

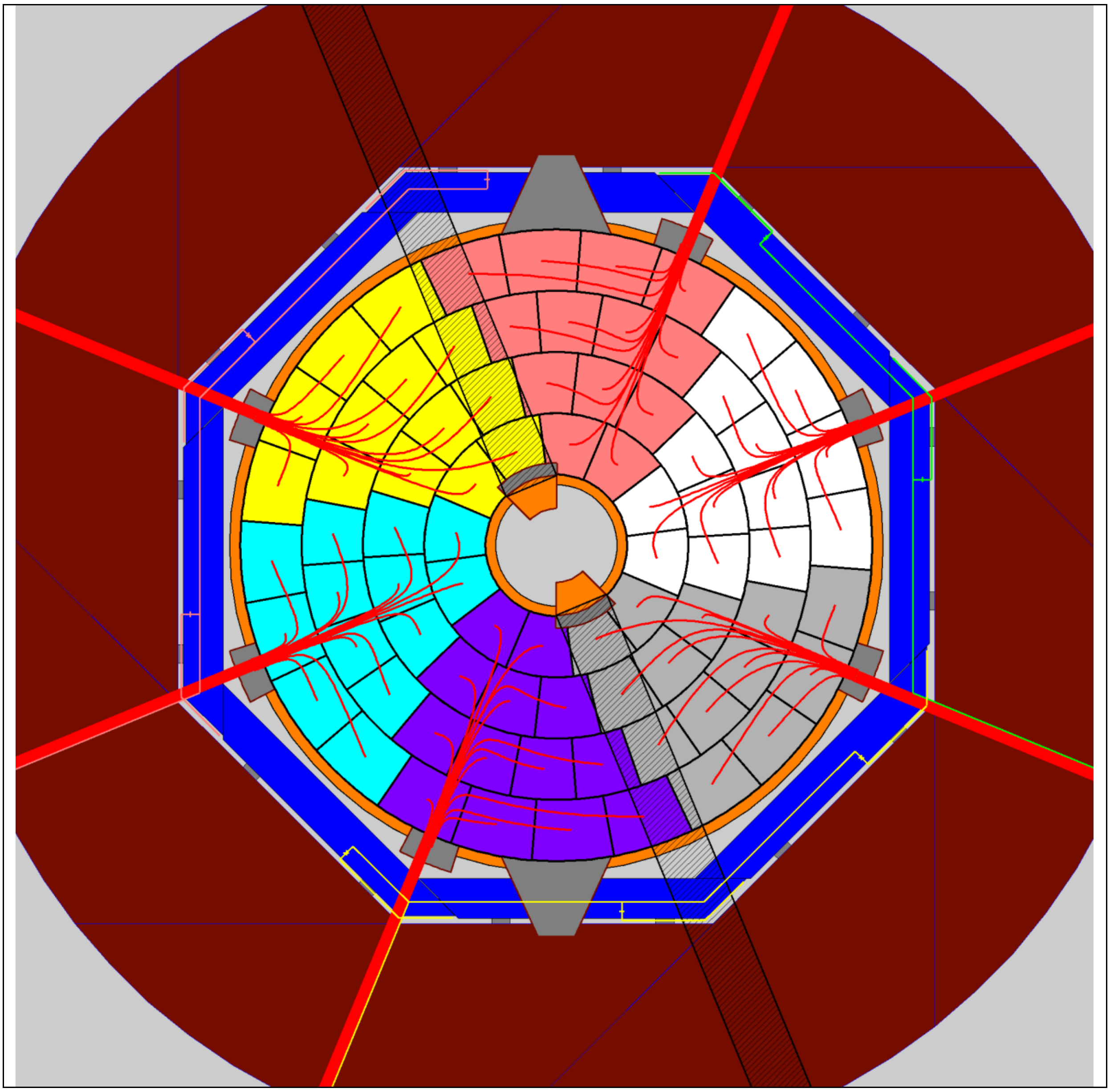
In the same figure are shown patch panels and services routes for the inner detector. They are considered as coming out at the outer radius of the beam tube which is largely smaller than the TPC inner tube. The patch panels are fastened to the inner ring of the TPC wheel. The services run radially from there, getting out at the corners left free by the TPC.





With these cooling paths we observe interferences with the bottom TPC support but that may be cured with an additional cooling line. We remark that a certain number of cooling lines go down. Some crossing with the TPC lines can be avoided like at 4h30 or at 1h30.

Where should we have the connections?



The crossings with the cooling remains to be understood.