$\overline{\mathrm{P}}$anda-MVD - note 002

Setup of a Mechanical Mock-up for the Micro-Vertex-Detector

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Abstract

A realistic and feasible model of the PANDA Micro-Vertex-Detector (MVD) must convert the general detector layout into a practical solution. Therefore, a full size model of the MVD was built which fully implements the strip part of the detector [1]. The pixel part is included schematically for reason of completeness. Moreover, the set-up of the mechanical model required a CAD development in parallel.

The construction of the mechanical detector model is based on a definition of sensor dimensions, the geometry of sensor arrangements and a first concept for the detector support structure. The main objective of this detector note is a detailed description of all individual detector parts and their implementation within the model. The basic and modular structure applied in the set-up can be generalized for future developments. A summary of these aspects can be found in a dedicated chapter. Finally, general design criteria are discussed and a modified layout for the outer barrel layer is deduced.

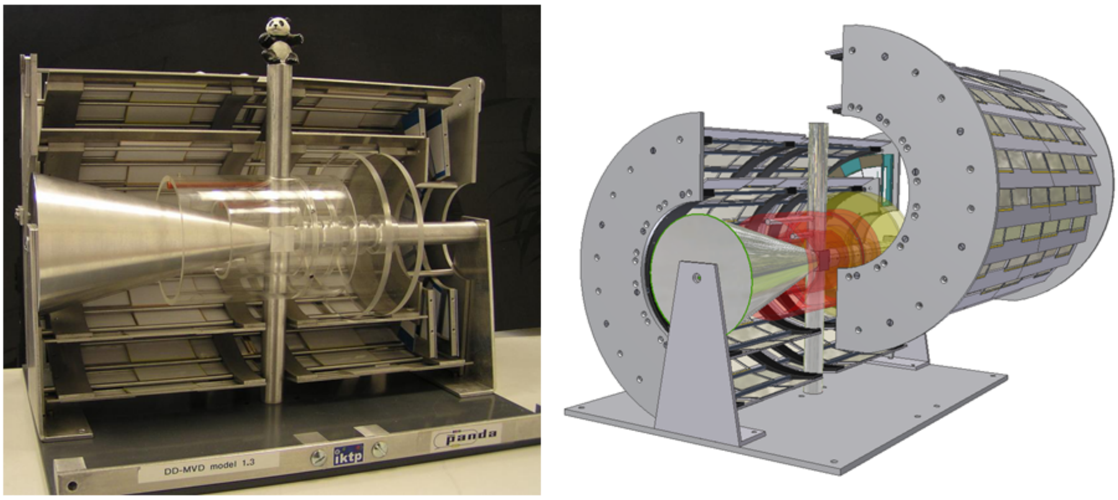

Figure 1: Photograph (left) and CAD drawing (right) of the MVD model. As shown in the drawing a half-detector concept is realized for the model allowing the crossing of the target pipe.

1 Introduction

The main objective of this work was the development of a more realistic detector model, in particular for the strip part of the MVD. The set-up is focused on the following aspects:

- The definition of a basic design for the Silicon microstrip sensors.
- An implementation of the main geometry into a feasible mechanical solution.
- The layout of a global support structure as an approach for future engineering solutions.
- The illustration of possible connections to the surrounding support structure and the integration of the pixel part as well as the beam-target cross into the MVD volume.

This detector note starts with a general description of the model including its main geometry. In the following, the implementation of the strip part is presented and all components are described in detail. Afterwards, the central points are summarized. From these facts general design criteria are derived. Finally, a short outlook concerning the model and its impact for further detector development is given.

2 General description and main geometry

In order to obtain realistic conditions, the mock-up model is built on a full size scale. The whole detector model fits into the maximum volume for the MVD in the specifications given by the PANDA design [2], i.e. a maximum radius of 150 mm and a length of 420 mm centred with respect to the vertex.
There are two inner pixel barrel and two outer strip barrel layers. All of them have different lengths. In the forward region there are six disks. The inner four disks are pixel disks. The two outer disks are foreseen to be equipped with both, pixel and

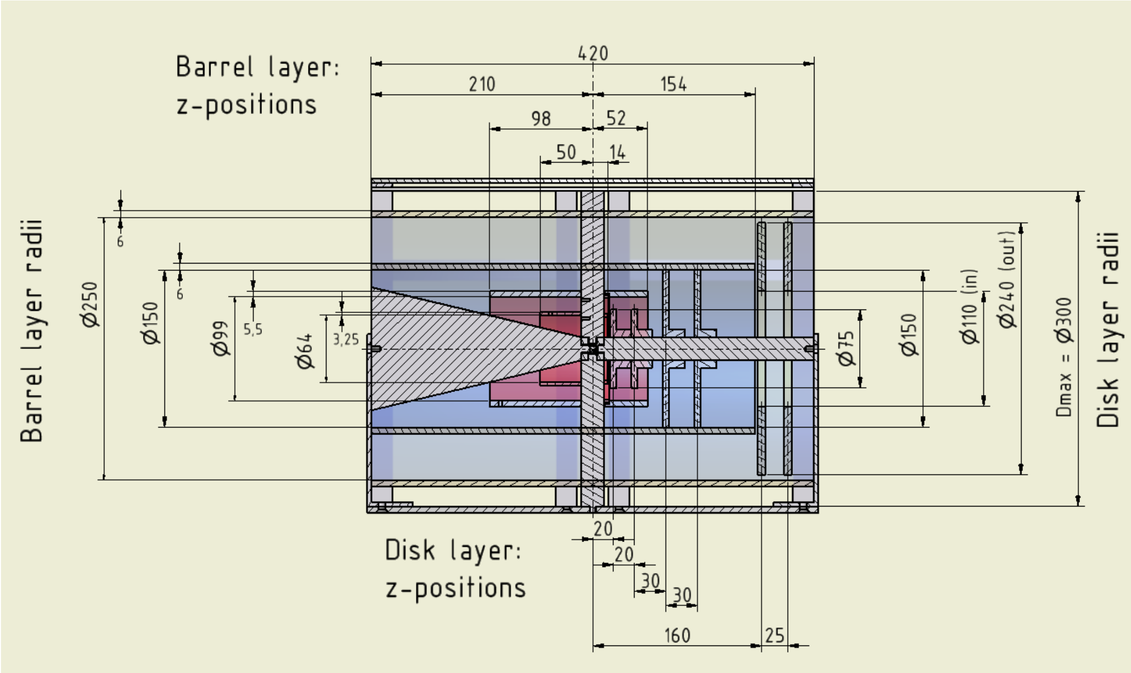

Figure 2: Overall geometry of the detector model: schematic view along the beam axis

strip sensors. The two innermost disks are embedded in the second barrel layer, the outer pixel disks into the third barrel layer and the mixed disks into the outermost barrel layer.
The overall geometry of the mechanical mock-up is summarized in figure 2. It is consistent with the general MVD layout described in the previous paragraph. The two outermost disk layers consist of the outer strip part only. While the strip layers are made of individual modules using aluminium sheets, the pixel layers are made of transparent acrylic glass.
The implementation of the strip part is described in the next chapter (chapter 3). The pixel layers only suit the purpose of schematic illustration. Hence, they do

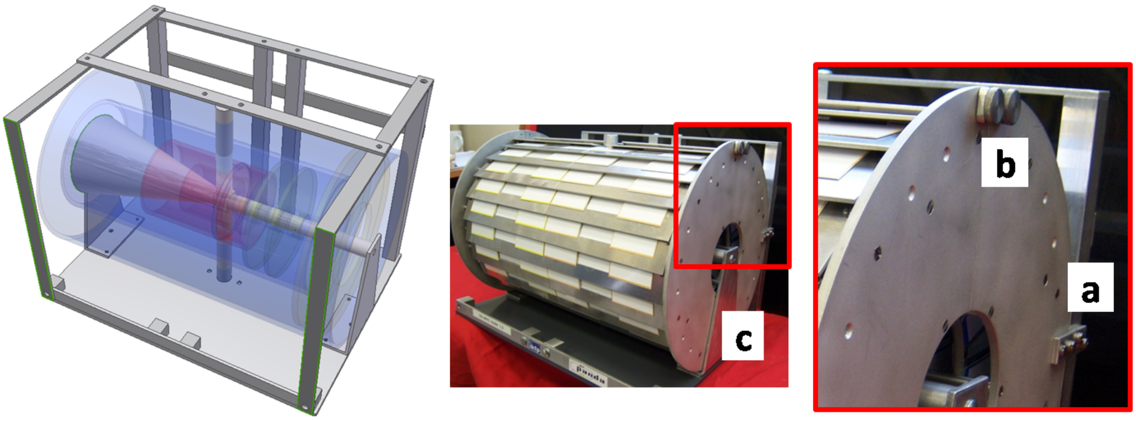

Figure 3: Illustration of the model support concept (left) and photographs of its implementation within the real model (middle): The left half-detector is fixed to the model support structure (a), the right halve is fixed to it afterwards (b). The supports for the beam pipe (c) give additional stabilization. All other parts of the model support act as a frame to protect the model during a transport.

not show any detailed solution nor do they suggest a feasible support structure for the pixel part. They are fixed directly to the beam and target pipe. The solid beam and target pipes as well as the beam-target cube are made of aluminium. The beam-target system is mounted on a PVC base plate. Additionally cross-ties fixed onto this plate provide the global support of the model. Due to the beam-target geometry the whole MVD consists of two halves. The left half is fixed to the model support structure and holds the second part.

3 Implementation of the strip part

3.1 Sensor design

There are two different sensor types used in the model; rectangular ones for the barrel part and trapezoidal sensors in the strip part. The sensor dummies are made from thin aluminium blanks (thickness: 0.4 mm). The size accounts for the active sensor volume and the sensor edge. In case of the trapezoidal sensor it includes additional space for mounting and the readout structure at the outer radius. For all details see figure 4. To distinguish visually between the active and passive volume white stickers with coloured edges indicating the passive volume are affixed on both sides of the sensor pieces.

3.2 Modules

The rectangular sensor dummies are glued on a stave which serves as local support. The ladder-like structure of the staves is formed by rectangular cut-outs for the active sensor areas. Hence, only the sensor edges are in contact with the support structure (see figure 5). Due to the different barrel lengths there are different stave types holding two or three sensors. To ensure the lead-through of the target pipe, modifications of some modules are necessary.
The sensors are arranged edge-to-edge in case of two-sensor modules or otherwise with an overlap accounting for the sensor edge. Therefore they are glued on one side or on both sides of the stave respectively. The broadening of the staves at two sides respects the space needed for sensor readout. Assuming a stereo angle of 90° and

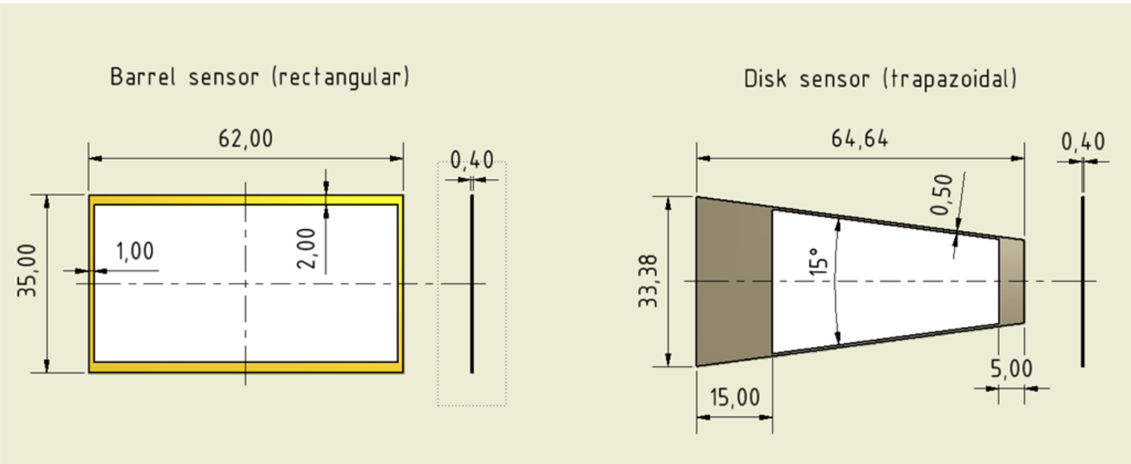

Figure 4: Sensor design

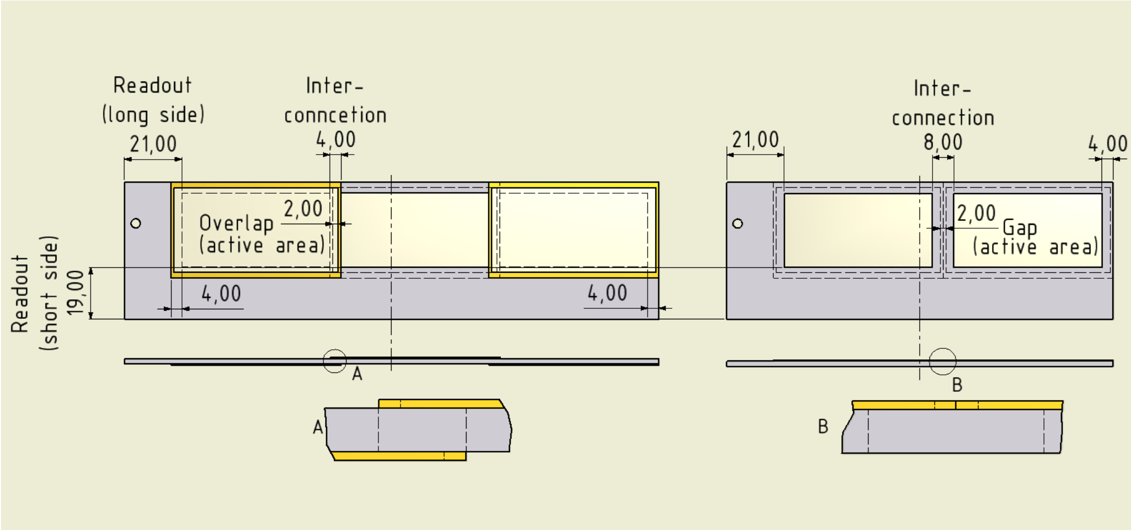

Figure 5: Sketch of a three-sensor module (left) and a two-sensor module (right)

a coupling of the long strips by wire bonding it allows positioning of the frontend electronics at the short and the long side.
For the disk part a support structure of strutted half-rings is used. This allows a gluing of the trapezoidal sensors to the support at the edges of their parallel sides. There are six sensors fixed on each side, such that a radial overlap of the active sensor volume of one millimetre is achieved.
Due to the choice of the manufacturing process (jet cutting) the support half-rings are 6 mm thick. Certainly it does not represent the thickness of a carbon like support structure. However, the stave thickness of 2 mm approaches more realistic conditions already.

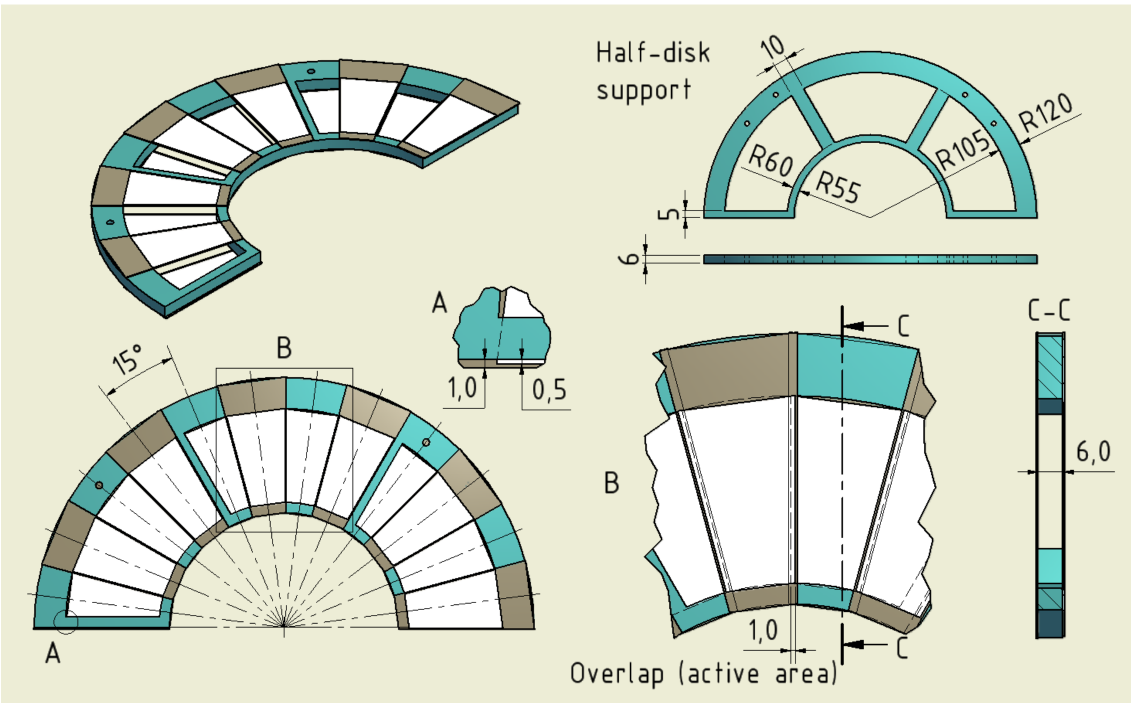

Figure 6: Assembly of an equipped half-disk

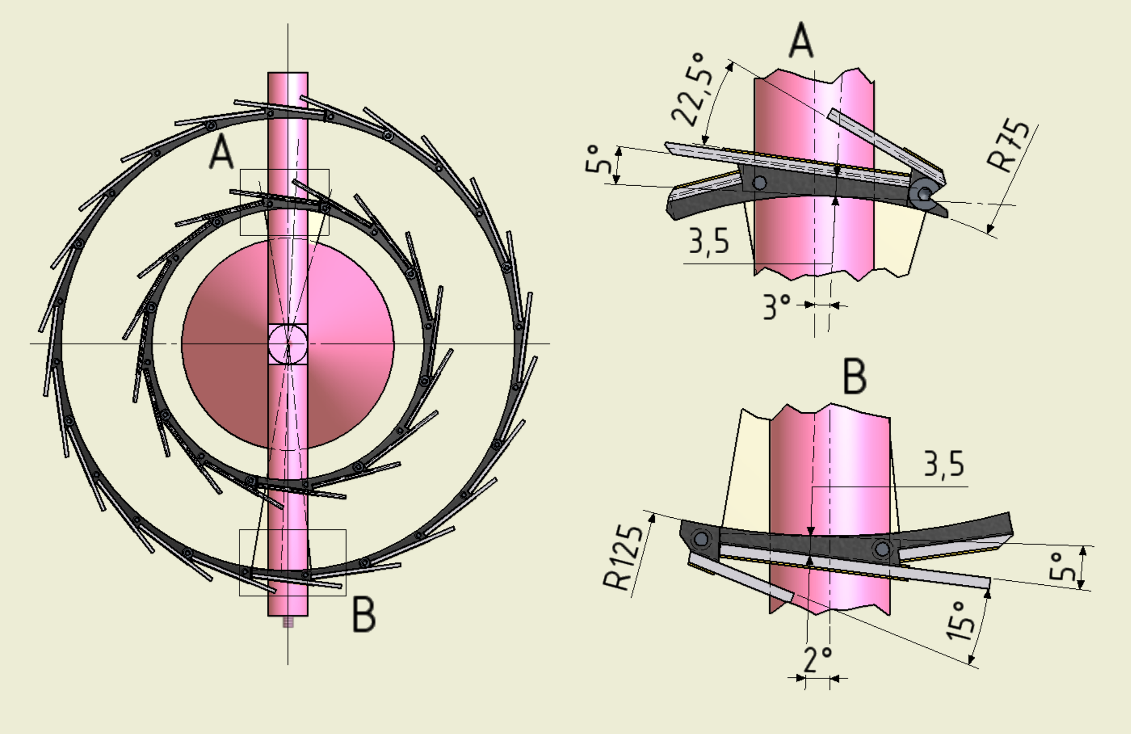

Figure 7: Radial symmetry of the barrel part
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3.3 Detector layer

The barrel part is realized in a fan-like geometry forming a 16 and a 24-fold radial symmetry for the inner strip barrel (barrel 3) and the outer strip barrel (barrel 4) respectively. Due to the half-detector concept the barrel layers have to be separated into half-barrels as well. These are not mirror-symmetric. In order to realize the target pipe crossing, the half-barrels are tilted by 3° and 2° for barrel layer three and four, respectively (see figure 7).

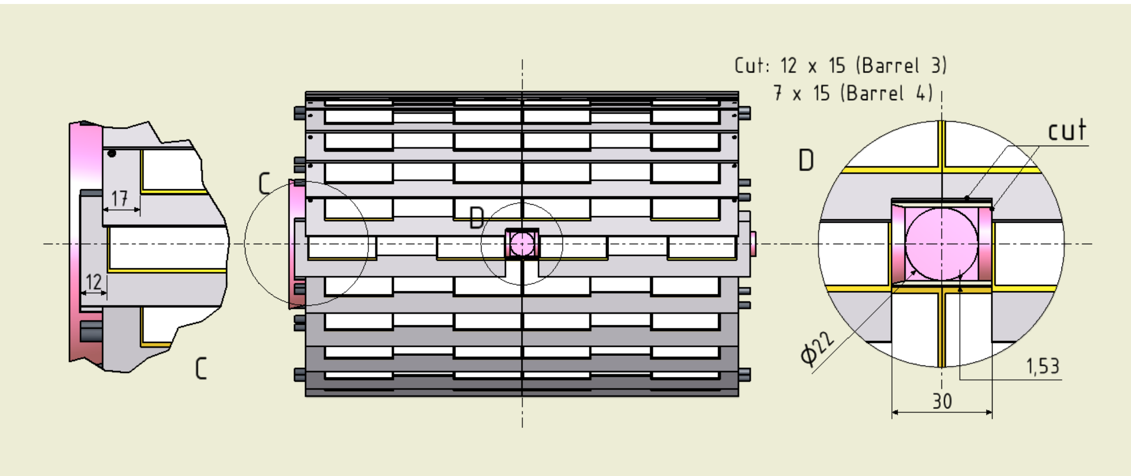

Figure 8: Axial symmetry of the barrel part. To achieve the target pipe crossing,staves are displaced by 15 mm and shortened at the end. Furthermore a cutout is necessary for the staves on top.

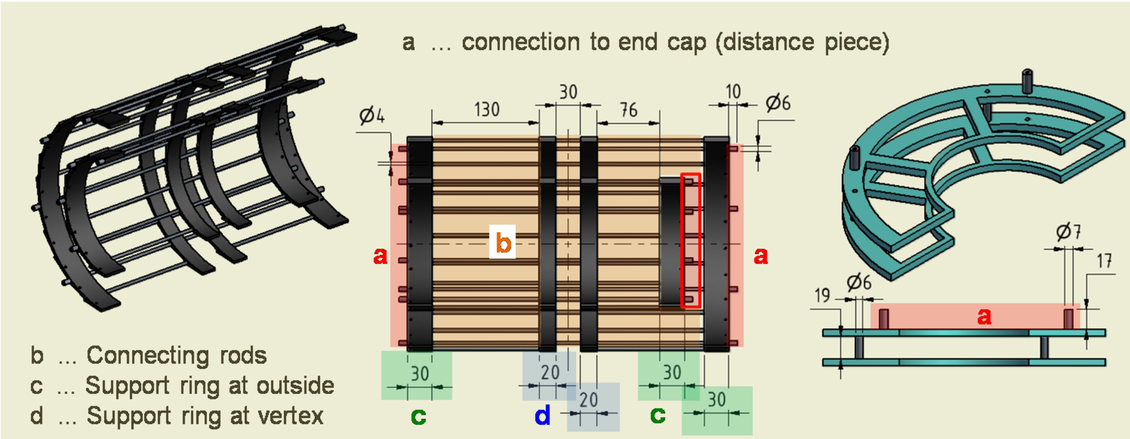

Figure 9: Different component of the support structure and its implementation in the barrel and the disk part.

Along the beam axis two modules are arranged back-to-back. One module is positioned upstream and the other downstream with respect to the vertex. The two modules at top and bottom are shifted by 15 mm each to the outside leaving a hole for the crossing of the target pipe which has a diameter of 22 mm.
A disk layer is simply formed by two of the equipped half-disks. This results in a 24-fold radial symmetry for the sensor arrangement.

3.4 Detector support structure

The detector support structure of the model carries the fully assembled half disks and the equipped staves which form the barrel layers. The staves are fixed at their ends onto segmented half rings. At one side they are aligned with each other while on the other there is an axial offset due to the staggered arrangement of the staves along the beam axis. Hence, there are four support half-rings for each barrel layer. The inner support half-rings close to the vertex have their position on both sides of the interaction point. They are aligned with the shifted stave modules at the top and bottom. The outer support half-rings are aligned with all stave modules that are mounted back-to-back.
In order to obtain a stiff structure the support half-rings are connected to each other by several rods. The full load of the barrel layers is carried to the end caps via an axial connection realized by distance pieces. Due to the different lengths of the barrel elements an additional end cap in the downstream region for the inner strip barrel layer is needed. It is connected to the outer end cap with distance pieces as well. Figure 9 and 10 illustrate the implementation of the global MVD support in the model.
The half disks located in between the two end caps in the downstream region are integrated in the same manner. The individual disk layers themselves are fixed to each other by distance pieces. Then the assembled disk layer part is fixed to the outer end cap. All end-caps are solid half-disks made from aluminium. The outer end-caps have a thickness of 6 mm while the inner one is 3 mm thick. Again, this thickness is due to the higher load of the mechanical model using pieces all made from aluminium and does not necessarily apply for the material budget of the real detector using carbon fibre structures.

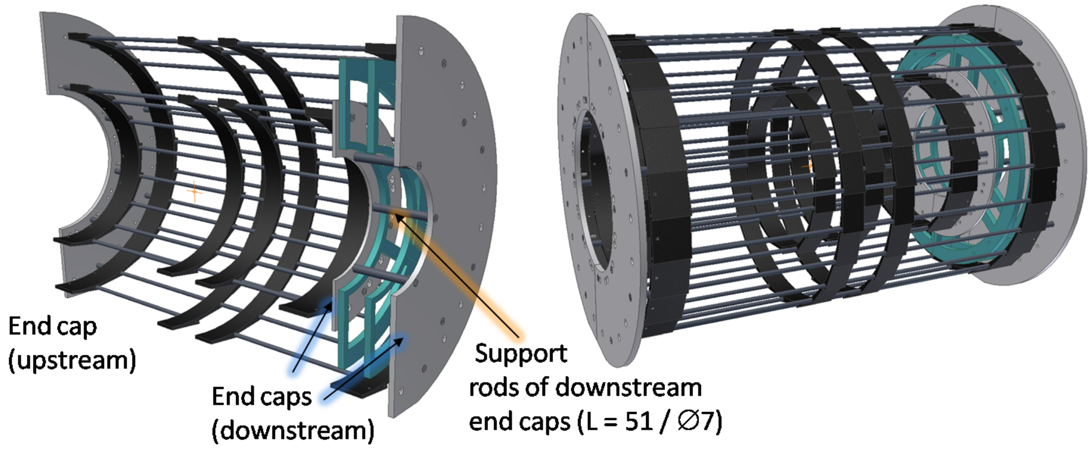

Figure 10: Integration of the endcaps (left) and sketch of the full support structure

4 Summary

The set-up of the mechanical detector model is based on a modular structure starting at the sensor level. Several sensors are mounted onto a local support structure forming individual modules. The different layers consist of a radial arrangement of such modules whereas in the barrel layer an arrangement of different modules along the beam axis is needed in addition. The modules are fixed to the detector support structure. The support is done by axial connections of different support components which carry the full load to the end caps.
There are two different sensor types used: rectangular for the barrel part and trapezoidal for the disk part. The sensor readout is foreseen at two edges and at the outer edge for both sensor sides, respectively. Therefore, a stereo angle of 90° for the rectangular and 15° for the trapezoidal sensors is required. Furthermore, it is assumed that there is a connection between the long strips for all sensors used in a barrel module. The full model follows a half-detector concept which is necessary due to the target pipe crossing the entire MVD volume.

5 Conclusions

In this chapter, the main results that emerge from the presented detector model as well as the conclusions for the future detector development are subsequently discussed.

5.1 Modular Design

The modular design used in this model can be generalized to a structure which is then valid for the whole MVD, namely the strip and the pixel part. Furthermore, it allows an adaptation to the CAD modelling. In doing so, the sensor describes the lowest level followed by the module on the next level of complexity. Such a module results from an assembly including sensors, local support and frontend electronic.
The detector consists of different sensor layers which are connected to a detector support structure. The layers consist of a circular arrangement of structural units

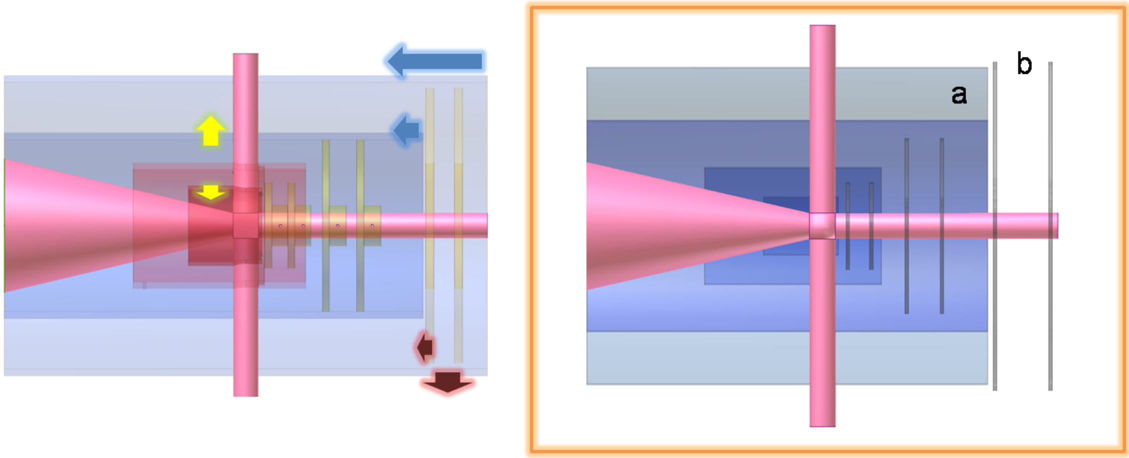

Figure 11: Illustration of the modifications for the updated MVD design (right) deduced from the evaluation of the design for the finalized mechanical mock up (left). The most significant change is the shortening of barrel layer four to the same length than barrel layer three (a). In consequence, the two outermost disks are shifted completely out of the barrel part (b).

which are formed by one or more modules. For example, in the presented model two modules assembled back-to-back are arranged circularly in the barrel part. Therefore, these structural units define an additional level between the module level and the detector layer.

5.2 Sensor design

In order to reach an optimized coverage of the solid angle, strip sensors with a trapezoidal shape are used for the disk part while in the barrel part a rectangular shape is favoured. For practical reasons one should take care to minimize the number of different strip sensor types. In the presented model there are two different sensor types. However, the number of designs may increase if using rectangular sensors of different length. Within the disk part only one sensor type should be used.

5.3 Detector layout

The implementation of four barrel layers within the restricted MVD volume is feasible. Considering the space needed for cooling and cabling, an adequate distance between the different barrel layers is guaranteed.
However, the insertion of disks into the barrel layers presents a more severe challenge. Notably this applies to the mixed disks because they demand even more sophisticated solutions. Moreover, the readout concept foreseen at the outer parallel side of the trapezoidal sensors aggravates the problems.
As a consequence, the mixed disks should be shifted from the barrel part (see figure 11). Besides giving more space to the readout this also provides the advantage of mechanical decoupling of the outer disks from the rest of the detector. In order to retain comparable solid angle coverage, the barrel layers must then be shortened while the mixed disk layers can be extended in their radius.

Additionally, it arises the opportunity of using the same arrangement of modules along the beam axis by giving the same length to both strip barrel layers.

5.4 MVD support structure

The basic concept for the MVD support adhere an axial stiffening. The load is taken by additional support frames or caps at both ends of the MVD. Depending on the total weight of the detector it may suffice to use such structure only in the upstream region where the cable routing out of the MVD is foreseen anyway. This would reduce the material budget significantly in the forward region of the detector. However, the integration of the disk layers is still a critical point.
Generally, it seems reasonable to separate the strip and the pixel part mechanically as much as possible, especially when taking into account that the cooling systems for both will probably be quite different. As an approach for the mechanical integration of the MVD into the entire detector the end caps may provide some connection points like they do in this model.
Furthermore, the assembling of the MVD from two detector halves may support the concept of fixing only one half to the global support structure while the second half is fixed to the first part.

6 Outlook

As an outcome of the realized mechanical model it is possible to work out a general structure for the MVD that can be applied for the CAD modelling. Furthermore, applying all design criteria summarized in the previous chapter in updated MVD models ensures a gradual improvement of the models towards a final and feasible solution.
Due to the full size model an estimation of the real proportions within the MVD is possible. This is a very important point when thinking about integration and dimensioning of all MVD components including the cooling system. Eventually this model can be used to practice the cable routing within the MVD.

7 References

[1] PANDA wiki: MVD web, developer pages
http://panda-wiki.gsi.de/cgi-bin/view/Mvd/DdMvdMod

[2] Technical Progress Report, PANDA collaboration, 2005