(D R A F T)

A concept of the support and cooling of the centre-tap design forward modules

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1. Introduction

A concept of using a centre-tap module similar to the barrel module in the forward geometry is appealing because the module is said to have a better noise performance and possibly a better performance in cooling because of the shorter cooling path to the cooling block, compared with the end-tap geometry. In this note, a brief description of a centre-tap forward module is presented and concepts of the module layout and cooling loop are discussed.

2. Concept of the centre-tap forward module

The concept of the centre-tap forward module is very similar to the barrel centre-tap module being proposed by KEK. A schematic drawing is shown in Fig. 1. The module cooling is provided via the heat conductor (PG: 1300 W/m/K) between the two single-sided detectors. The bridged hybrid's pedestal touches the heat conductor at the extended ears. One side of heat conductor has a wide area extension to have a good thermal contact area to a cooling block.

3. Alternating module layout

Since the cooling contact, which is also the mechanical fixation point, of the module is extended sideways outside the silicon detector area, no adjacent modules can be put in the circumferential direction. A solution to place and support the modules is to have an "alternating layout" in which the adjacent modules are put in the front and the back of the overall supporting disk structure.

3.1 Requirement for overlapping the adjacent modules

In order to make overlap of the modules, one has to take care of the two cases: 1) overlap of the inner and the outer modules, "axial overlap", and 2) overlap of the modules within a ring, "circumferential overlap". Both overlap requirement is driven by the separation, d, of the modules sandwiching the disk structure.

1) Axial overlap: The worst case is in the first disk. The required overlap is given by the formula

$$\zeta_a = d \cdot r_{mid} / z_{\min} \qquad (1)$$

In the current geometry, taking d = 20 mm, r_{mid} = 44 cm, and z_{min} = 83 cm, the required overlap is

$$\zeta_a = 11 \text{ (d/20 [mm]) [mm].} \qquad (2)$$

2) Circumferential overlap: In the circumferential direction, the required overlap is driven by two factors: the circumferential component of the transverse momentum, p_t, in the r×ϕ plane, and the longitudinal momentum, p_l, in the r×z plane. The former component is given as

$$p_t \cdot \sin\xi, \qquad (3)$$

as shown in Fig. 2, where ξ is the particle dispersion angle to the normal line from the interaction point. When the separation of the two modules in z direction is d, the required overlap, ζ_b, is given as

$$\zeta_b = d \cdot p_t \sin\xi / p_l. \qquad (4)$$

Since the worst case can be given at the outer edge of the first disk, the factor p_t/p_l is

$$p_t / p_l = r_{\max} / z_{\min}, \qquad (5)$$

and the dispersion angle at the radius is

$$\sin\xi = 0.3H \cdot r_{\max} / (2 p_t). \qquad (6)$$

Inserting the eqs. (5) and (6), the required overlap is obtained as

$$\zeta_b = 0.15H \cdot d \cdot r_{\max}^2 / (z_{\min} \cdot p_t). \qquad (7)$$

Taking the values of H = 2 T, rmax = 0.56 m, zmin = 0.83 m, pt = 1 GeV/c, and d = 20 mm, the overlap is required to be

$$\zeta_b = 2.2 \text{ (d/20 [mm]) [mm].} \qquad (8)$$

A module requires the overlaps, in addition to the edge insensitive area, in two sides. Assuming the edge insensitive area is 1 mm, one requires 6.4 mm space for the overlap of two detectors.

3.2 Layouts

There are two possible layouts in arranging the modules in the alternating geometry. One is having un-equal number of modules in the inner and the outer rings, as shown in Fig. 3. The other is having the equal number of modules, as shown in Fig. 4. Since the disk arrangement forces us to have a fan (or wedge) shaped modules, the un-equal number of modules in each ring provides a possibility to maximize the detector area out of one wafer. In this case, however, the "axial overlap" requirement is large because the inner and the outer modules are not aligned in one side. The latter layout, which may be called as "sector module", has aligned modules in the inner and the outer rings. This does not involve a large "axial overlap" requirement, but the inner (-most) detectors become very narrow and the outer(-most) detectors very wide. Both layouts requires the same amount of "circumferential overlap" requirement because of the alternating geometry.

3.2.1 Unequal number of modules in the inner and the outer rings

Taking the number of modules in the inner and the outer rings to be 40 and 52, respectively, the maximum detector are calculated to fit in a 90 mm diameter, which is the maximum usable area out of 4 inch wafer, as shown in Fig. 5. The outer-most and the inner-most radius are 26.1 cm and 56.0 cm, respectively. If more (side-) overlap is required, these radii would be smaller. The detector lengths are summarized in a table in Fig. 5. In one disk, the required total number of silicon wafers is 184×2 for the case of back-to-back single-sided detectors, in addition to 40×2 GaAs wafers for the inner-most modules.

A concept of the module support and cooling pipe is shown in Fig. 6. A concept of cooling loop is shown in Fig. 3. Two rows of modules, i.e., 6 modules (counting the inner-most 7.5 cm module as one module), can be serviced with one cooling loop. The cooling loop may have to service one more module in the outer ring because there are more modules. Electrical cables are also serviced passing through the same route. The cooling loop concept presented here has an advantage that each loop can be serviced without a manifold in the disk structure.

3.2.2 Equal number of modules in the inner and the outer rings - Sector module

Minimizing the number of wafers and, at the same time, maximizing the detector area, one can choose the number of sectors to be 46. The sector layout is shown in Fig. 4. In this case, the cooling and cable route is straight-forward and clean. The required number of silicon wafers is 184×2, which is the same as the "unequal number" case, and 46×2 for the GaAs wafers. The increase of number of wafers, ignoring the difference of silicon or GaAs, is 2.7 %. The dimension of the detectors are shown in Fig. 7. The outer-most module, i.e., the combination of the detector number of 3 and 4 has a width of 77 mm near the middle. The width might be too wide to do wire-bonding to the "bridged hybrid". The cost of reducing the width by 10 % is increasing the number of wafers by 10 %.

One interesting idea of making module is to arrange two electrical modules, instead of three (i.e., two full and one half modules), which is shown in Fig. 8. This will reduce the number of electronics by 36 % (in one full disk) with a price tag of increasing the strip length from 12 cm to 15 cm. The noise penalty by increasing the strip length would be 10 to 12 % which cancels the noise-saving by going from the end-tap modules to the centre-tap ones.

4. Summary

A concept of the centre-tap module for the forward geometry is presented, together with the module, support, and cooling loop layouts. Since the module dimensions are very much similar to the barrel centre-tap module design, one can expect the similar thermal and electrical performances. A proposed module layout is called "alternating module" layout where adjacent modules are placed in the front and the back of the disk structure. The circumferential overlap requirement is small (2.2 mm per side) even though the front and the back modules are separated by 20 mm. Although the "sector module" arrangement is clean, the "un-equal number of module" layout would be preferred in order to make the required number of wafers minimum, paying a little bit of complexity in the cooling loop arrangement. The cooling loop can be serviced directly from outside, without manifold in the disk structure.

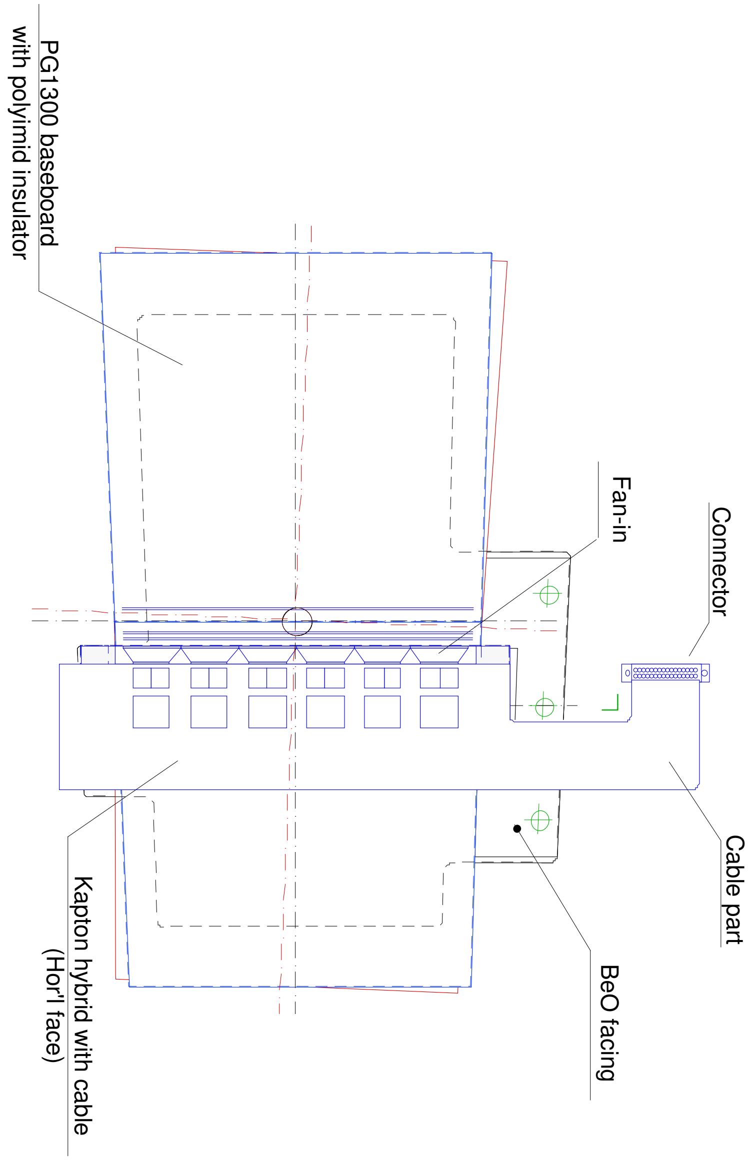
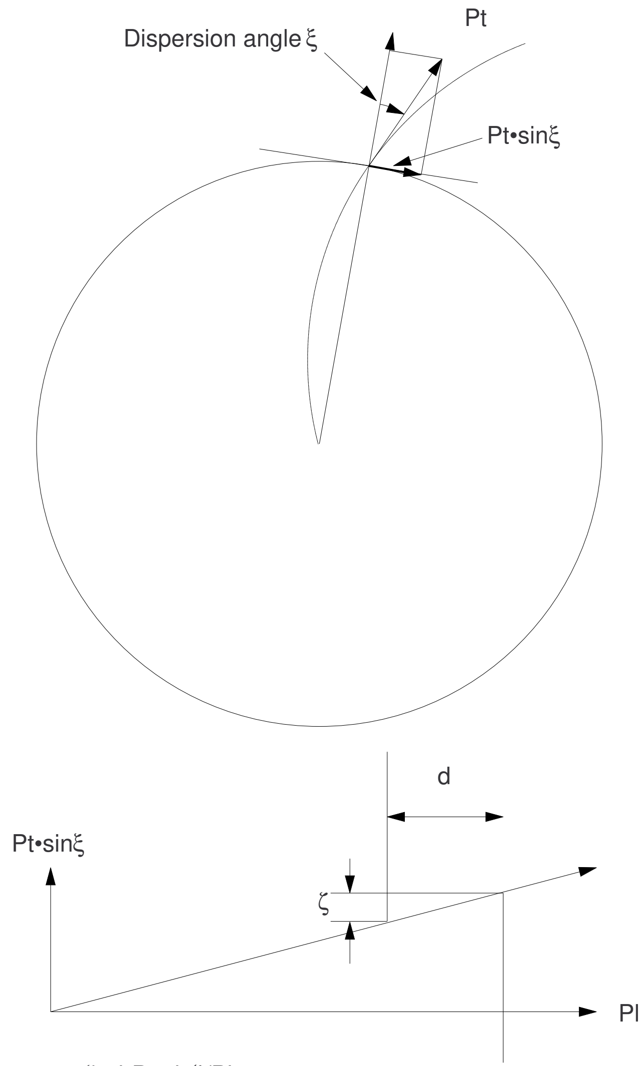


Fig. 1 A concept of forward centre-tap module



$\zeta = d \cdot Pt \cdot \sin\xi / Pl$
$\leq d \cdot rmax/zmin \cdot \sin\xi$
$= d \cdot rmax/zmin \cdot 0.3H \cdot rmax/(2 \cdot pt)$
$= 0.15 \cdot H \cdot d \cdot rmax^2/(zmin \cdot pt)$

rmax=0.56 m, zmin=0.86 m, H=2 T, pt=1 GeV/c
$\zeta = 0.11 \cdot d$
e.g., d=20 mm, then ζ=2.2 mm

Fig. 2 Circumferential overlap requirement

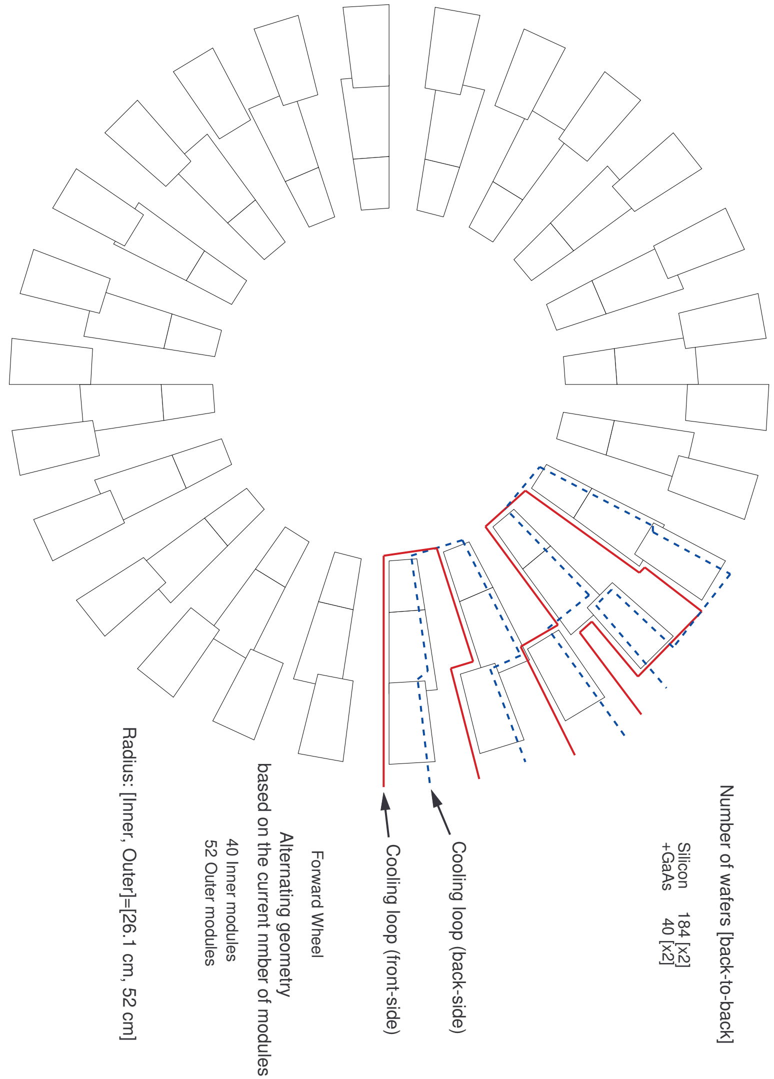


Fig. 3 A forward layout with unequal number of modules in the inner and the outer rings. The GaAs inner-most ring has the equal number of modules with the silicon inner ring.

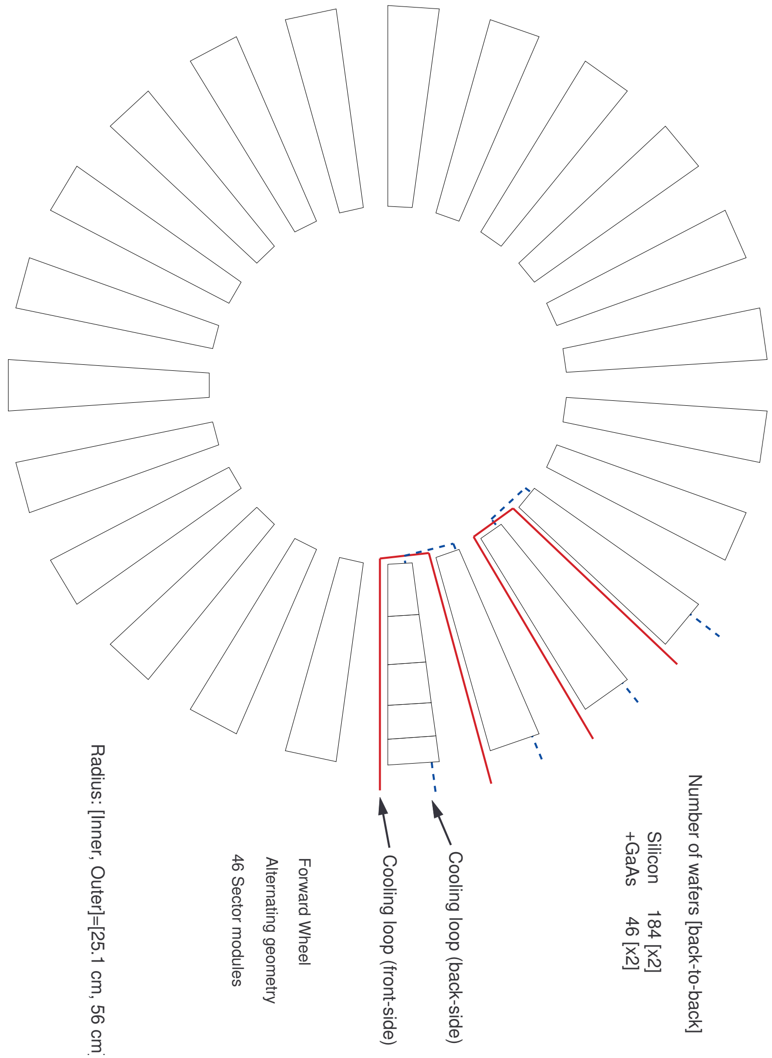
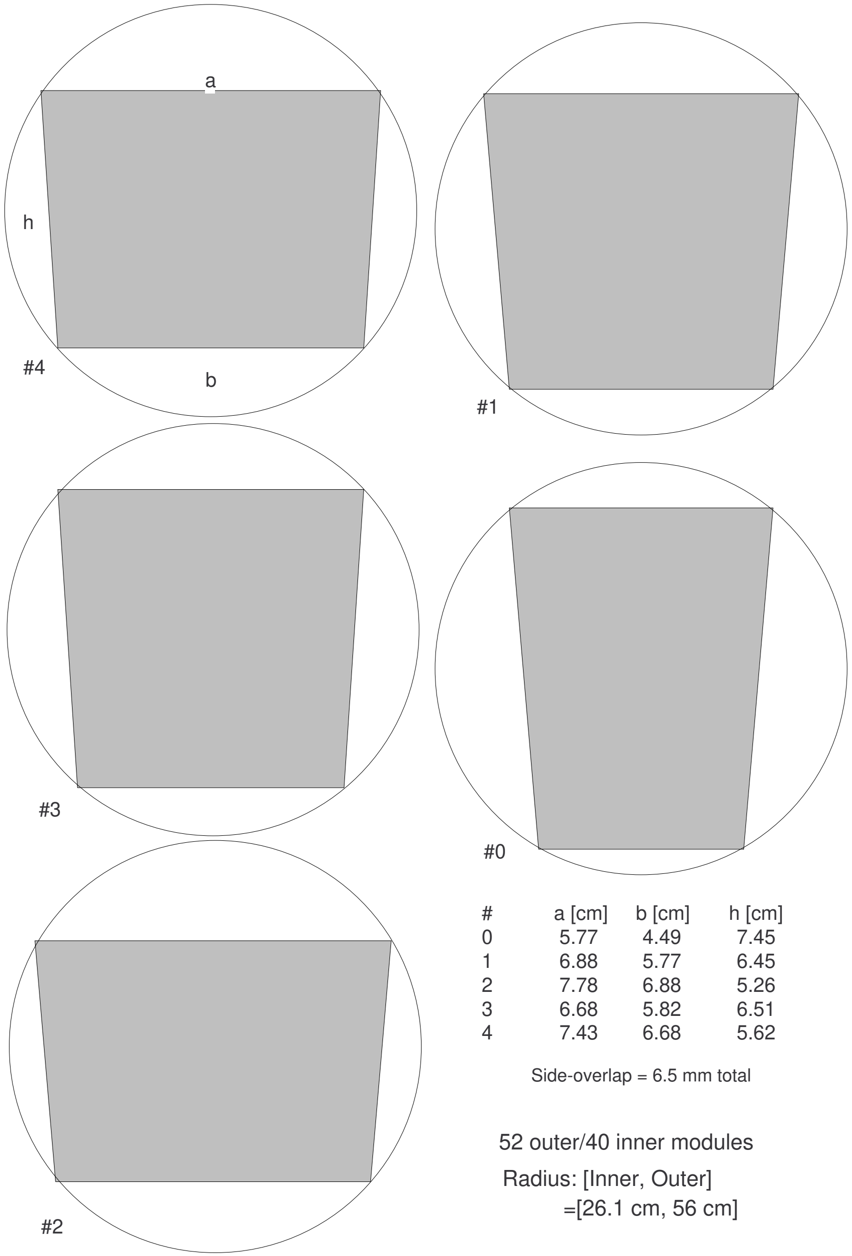


Fig. 4 A forward layout with equal number of modules in the inner and the outer rings.



#	a [cm]	b [cm]	h [cm]
0	5.77	4.49	7.45
1	6.88	5.77	6.45
2	7.78	6.88	5.26
3	6.68	5.82	6.51
4	7.43	6.68	5.62

Fig. 5 Dimension of the forward detectors for the layout with unequal number of modules in the inner and the outer rings

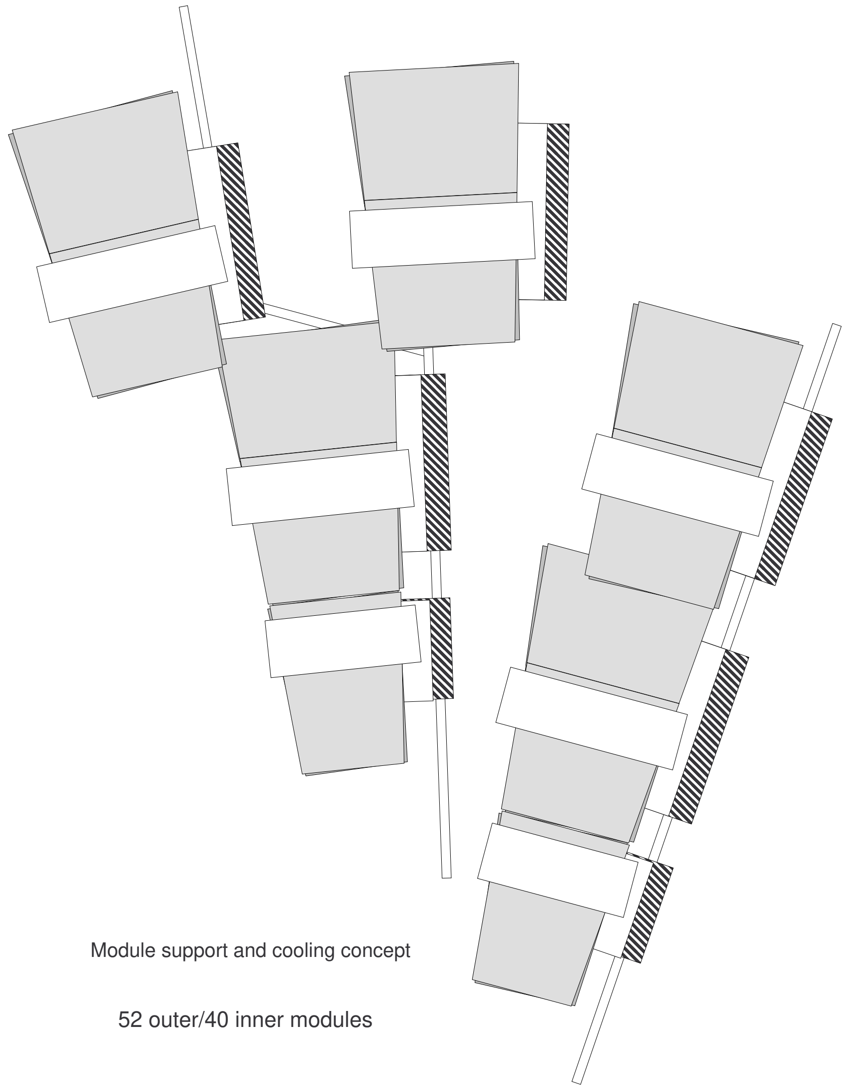
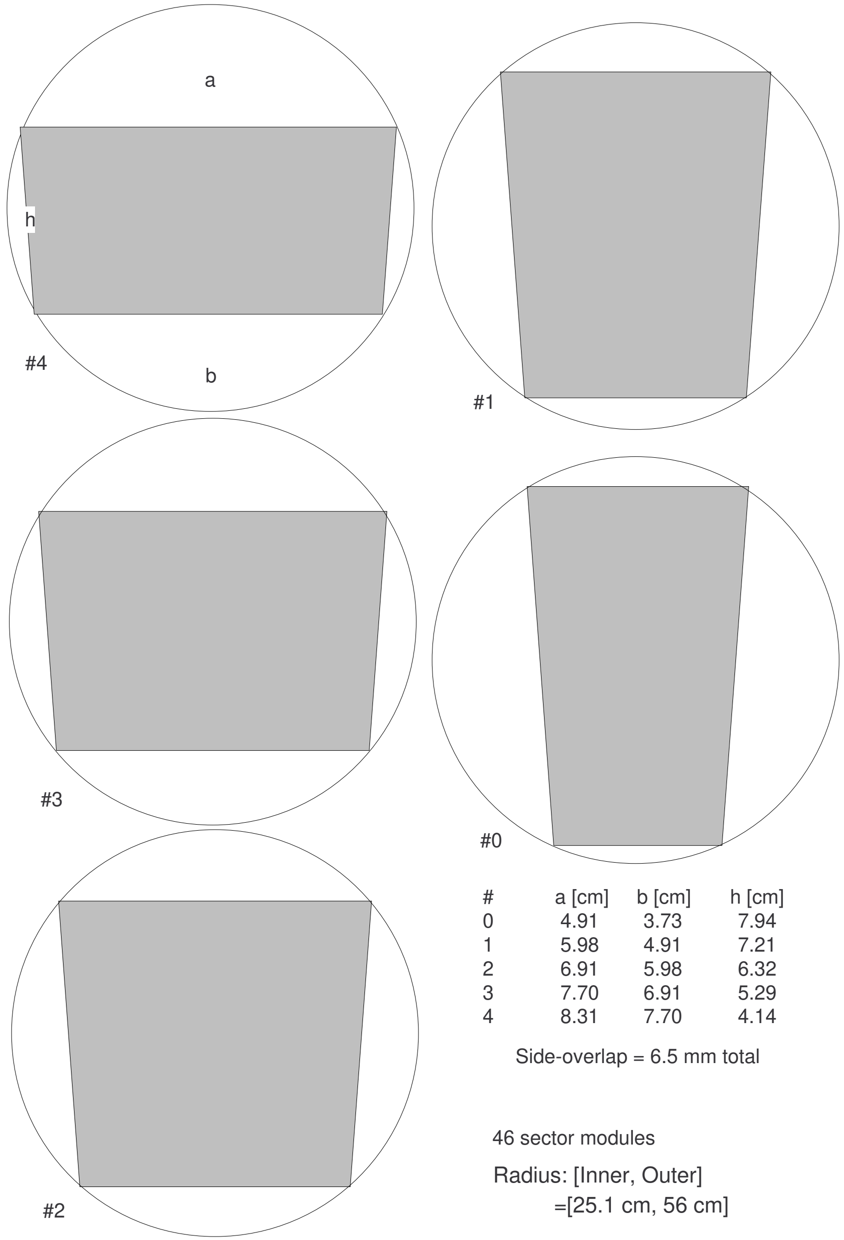


Fig. 6 Module support and cooling concept for the layout with unequal number of modules in the inner and the outer rings.



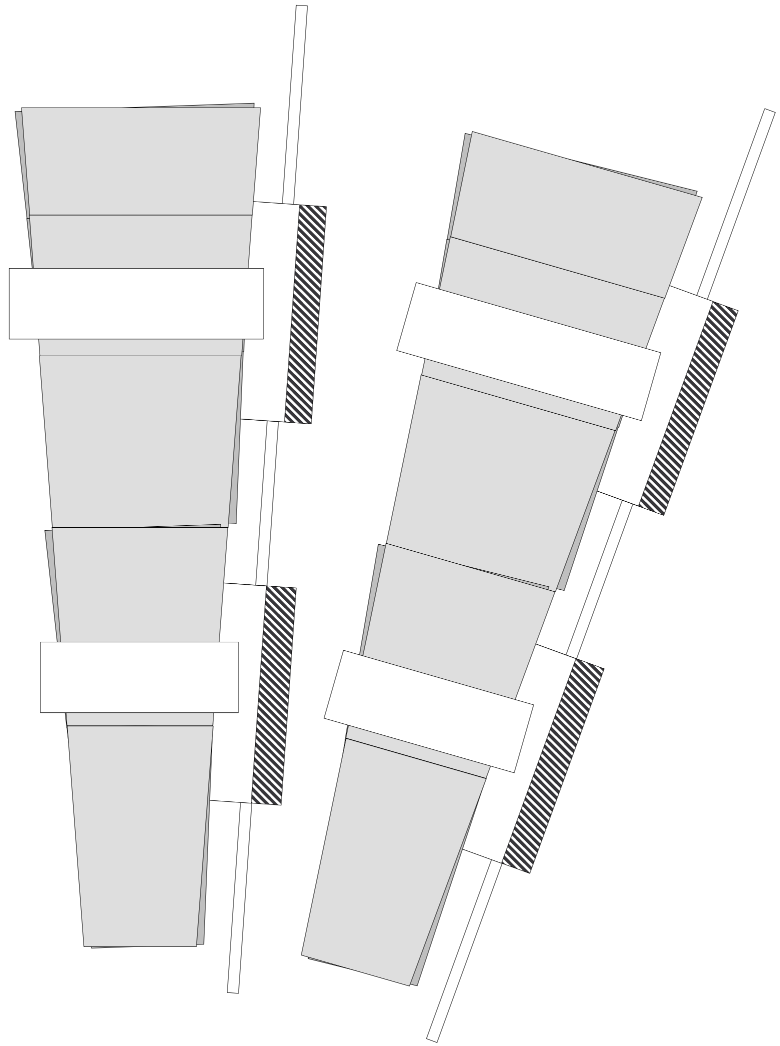
#	a [cm]	b [cm]	h [cm]
0	4.91	3.73	7.94
1	5.98	4.91	7.21
2	6.91	5.98	6.32
3	7.70	6.91	5.29
4	8.31	7.70	4.14

Side-overlap = 6.5 mm total

46 sector modules

Radius: [Inner, Outer]
=[25.1 cm, 56 cm]

Fig. 7 Dimension of the forward detectors for the layout with equal number of modules in the inner and the outer rings



Module support and cooling concept

Fig. 8 Module support and cooling concept for the layout with equal number of modules in the inner and the outer rings - Sector module.