(D R A F T 3.1)

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

Geoff Taylor, Gareth Moorhead

University of Melbourne

Y. Unno

Physics, KEK

1. Introduction

The use of a centre-tap module similar to the barrel module in the forward geometry is appealing because of the expected better noise performance as well as the probable better cooling performance with 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 ideas for the module layout and cooling loop are discussed.

2. A centre-tap forward module

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

3. Alternating module layout

Since the cooling contact of the module, which is also the mechanical fixation point, is extended sideways out from under 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 adjacent modules alternate between the front and back of the overall supporting disk structure.

3.1 Requirement for overlapping the adjacent modules

In order to overlap the modules correctly, two cases must be considered: 1) overlap of the inner and the outer modules along the axial direction, "axial overlap", and 2) overlap of the modules around a ring, "circumferential overlap". Both requirements are driven by the separation, d, of the modules sandwiching the disk structure.

1) Axial overlap: This overlap is required when the outer of the two modules is the closer to the vertex, a condition to be minimised or avoided where possible. The worst case is in the first disk. The required overlap for stiff tracks is given by the formula

$$\zeta_a = d \cdot r_{mid} / z \tag{1}$$

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

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

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 $r\times\phi$ plane, and the longitudinal momentum, p_l, in the $r\times z$ plane. The former component is given by

$$p_t \cdot \sin\xi, \tag{3}$$

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

$$\zeta_b = d \cdot p_t \sin\xi / p_l. \tag{4}$$

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

$$p_t / p_l = r_{\max} / z, \tag{5}$$

and the dispersion angle at the radius is

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

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

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

Taking the values of H = 2 T, r_{max} = 0.56 m, z = 0.83 m, p_t = 1 GeV/c, and d = 20 mm, the overlap is required to be

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

A module requires overlap, plus the edge insensitive area, on two sides. Assuming the edge insensitive area is 1 mm, 6.4 mm space is required to overlap two detectors.

Figure 2a shows a plot of the required overlap of the active area as a function of p_t for various values of pseudorapidity, in the range covered by the forward wheels. The plot corresponds to the z = 0.83m forward wheel. It can be seen that the above estimate of the worst case coverage described above is quite generous for most of the phase space required. The necessary overlap falls quickly with p_t and with pseudorapidity, the overlap being less than 2mm for η>1.5 and p_t>1GeV.

Figure 2a. Required “Circumferential” overlap as a function of pt, for various values of pseudorapidity

3.2 Layouts

We consider two possible arrangements of modules in the alternating geometry. One has an unequal number of modules in the inner and the outer rings, as shown in Fig. 3. The other has an equal number of modules, as shown in Fig. 4. Since the disk geometry forces a fan (or wedge) shaped module, an unequal number of modules in each ring allows maximisation of the detector area from one wafer. In this case, however, the "axial overlap" requirement is large because the inner and the outer modules are not aligned at one edge. The alternative layout with equal numbers of aligned inner and outer modules, the "sector module" layout, does not involve a large "axial overlap" requirement, although the innermost detectors become very narrow and the outermost detectors very wide. Both layouts require the same amount of "circumferential overlap" because of their alternating geometry.

3.2.1 Unequal number of modules in the inner and outer rings

Taking the number of modules in the inner and the outer rings to be 40 and 52 respectively, the maximum detector sizes (Fig. 5) are calculated so as to fit within a 90 mm diameter, the maximum useable area of a 4 inch wafer. The inner- and outermost radii are 26.1 cm and 56.0 cm respectively. If more (side-) overlap is required, these radii would be smaller. The detector lengths are tabulated within Fig. 5. The total number of silicon wafers per disk is 184×2 for the case of back-to-back single-sided detectors, plus the 40×2 GaAs wafers for the innermost 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 sets of modules, i.e., 6 modules (counting separately the innermost 7.5 cm module), can be serviced with one cooling loop. Some cooling loops may have to service one extra module in the outer ring because of the unequal numbers of modules per ring. Electrical cables use the same route. The cooling loop concept presented here has the 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 - the “sector module” layout

In this layout (Fig. 4), minimising the number of wafers (and hence maximising the detector area) results in the choice of 46 sectors. The cooling loop and electrical cable route is relatively straight-forward and “clean”. The equivalent required number of silicon wafers is 184×2, which is the same as in the "unequal number" case, with an increase to 46x2 of wafers for the innermost modules, a total increase of only 2.7% in the number of wafers required (ignoring the difference between silicon and GaAs). The dimensions of the detectors are shown in Fig. 7. The outermost module, incorporating detector numbers 3 and 4, has a width of 7.7 cm at its centre, a width which might increase the difficulty of wire-bonding to the hybrid. Reduction of the detector width by 10 %, should it be necessary, would increase the number of wafers by 10 %.

One interesting idea applicable in the case of an all-silicon forward solution is to reduce the number of electrically distinct modules from three to two per sector side as shown in Fig. 8. This would reduce the amount of electronics by 36 % per disk at the expense of increasing the strip length from 12 cm to 15 cm. The noise penalty of increasing the strip length would be only 10 to 12 %, equivalent to that gained by choice of a centre-tap geometry over an end-tap geometry.

4. Summary

A concept for centre-tap modules for the forward geometry has been presented, together with module, support, and cooling loop layouts. Since the module dimensions are similar to those in the barrel centre-tap module design, one can expect the similar thermal and electrical performances. The proposed “alternating module” layout has adjacent modules alternating between the front and back of the disk structure. The circumferential overlap requirement is small (2.2 mm per side) even though the front and back modules are separated by 20 mm. A simple and mechanically “clean”, “sector module” layout has been proposed which uses a slightly greater number of detector wafers than an alternative “unequal module number” also considered. In both options, the cooling loop enters directly from outside without the requirement of a manifold within the disk structure.

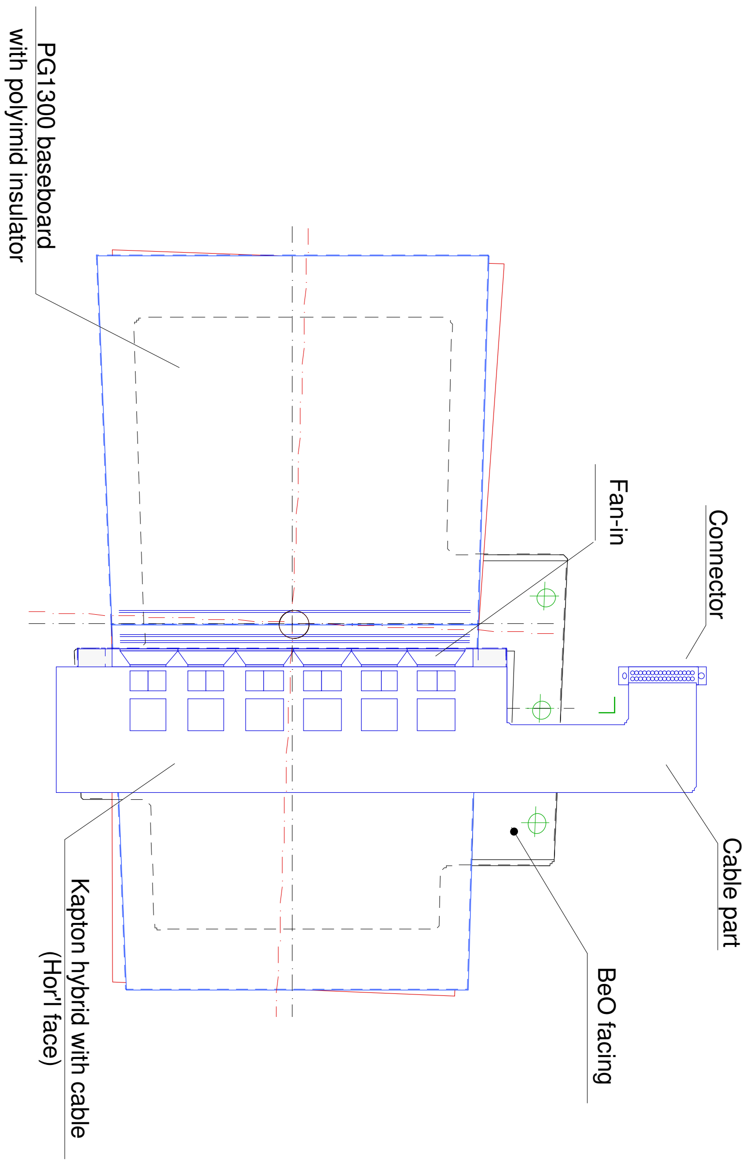
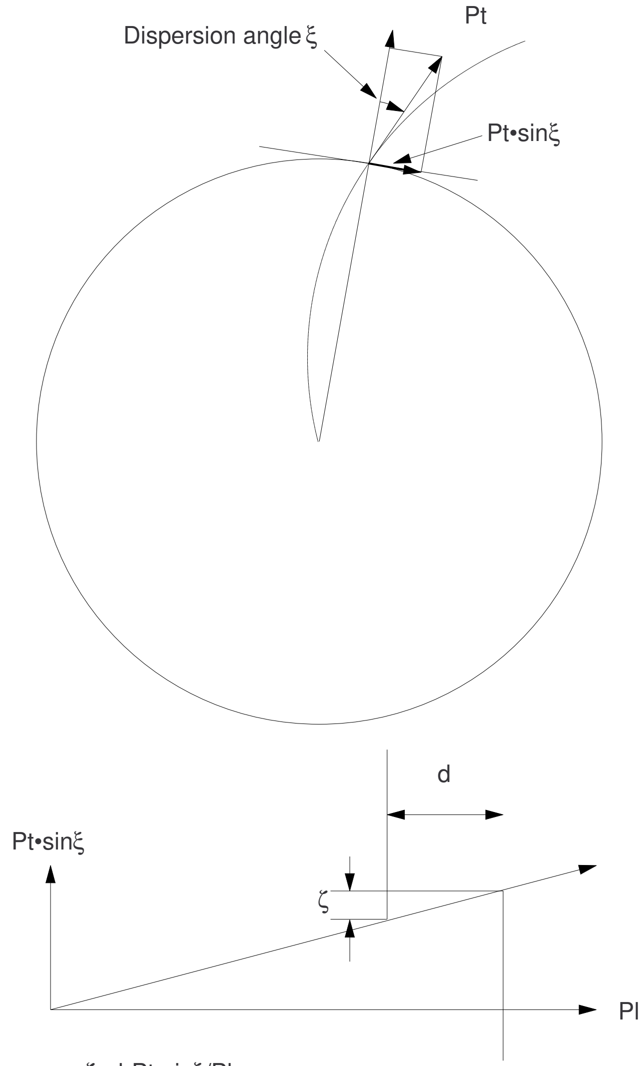


Fig. 1 A forward centre-tap module concept (= Wedged barrel PG-based centre-tap module)



ζ=d•Pt•sinξ/Pl
≤d•rmax/zmin•sinξ
=d•rmax/zmin•0.3H•rmax/(2•pt)
=0.15•H•d•rmax^2/(zmin•pt)

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

Fig. 2 Circumferential overlap requirement

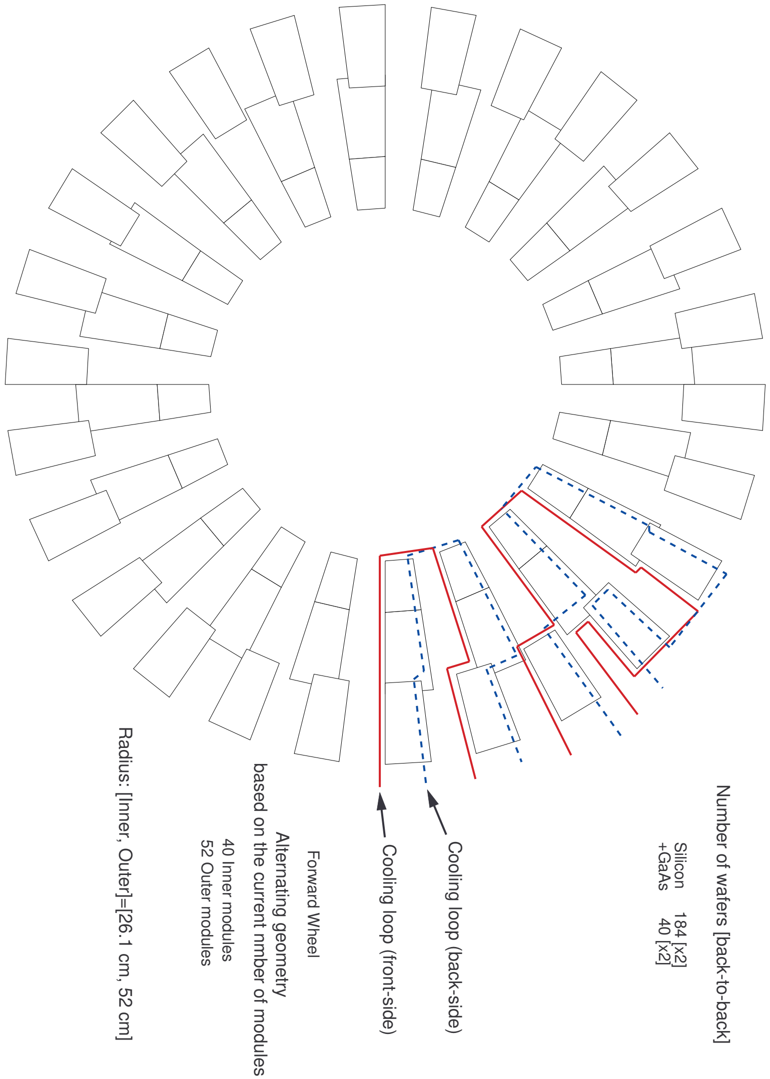


Fig. 3 A forward layout with unequal number of modules in the inner and the outer rings. The number of GaAs modules in the innermost ring equals the number of modules in the silicon inner ring. This layout minimises the number of wafers used.

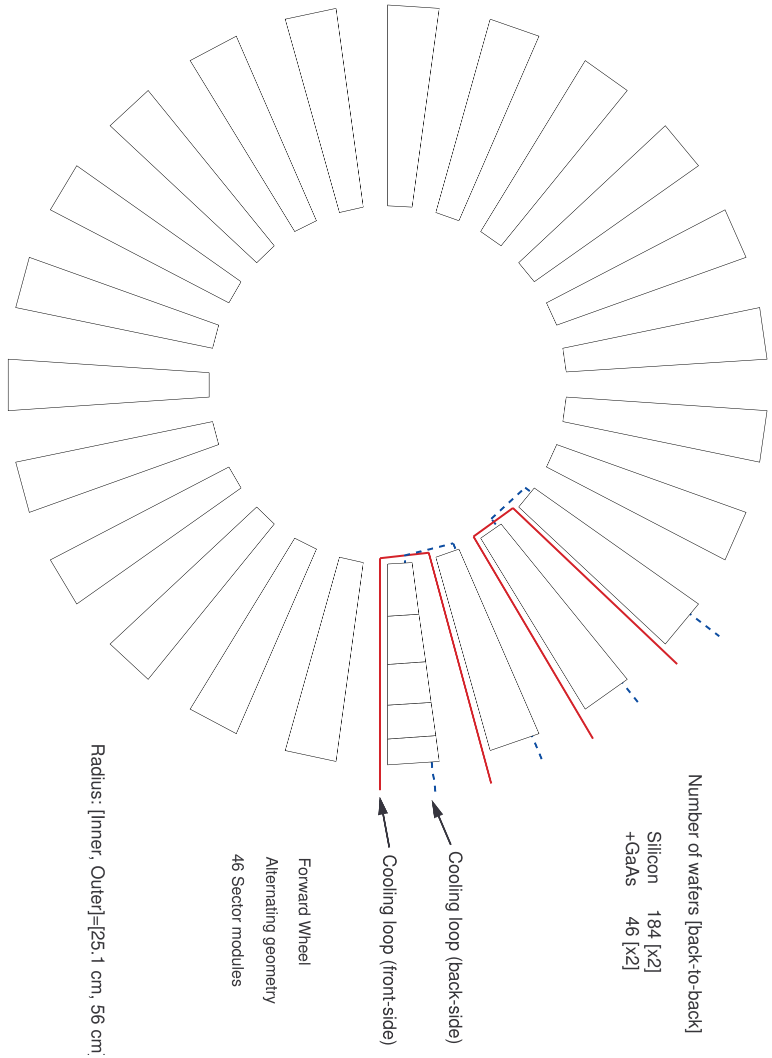
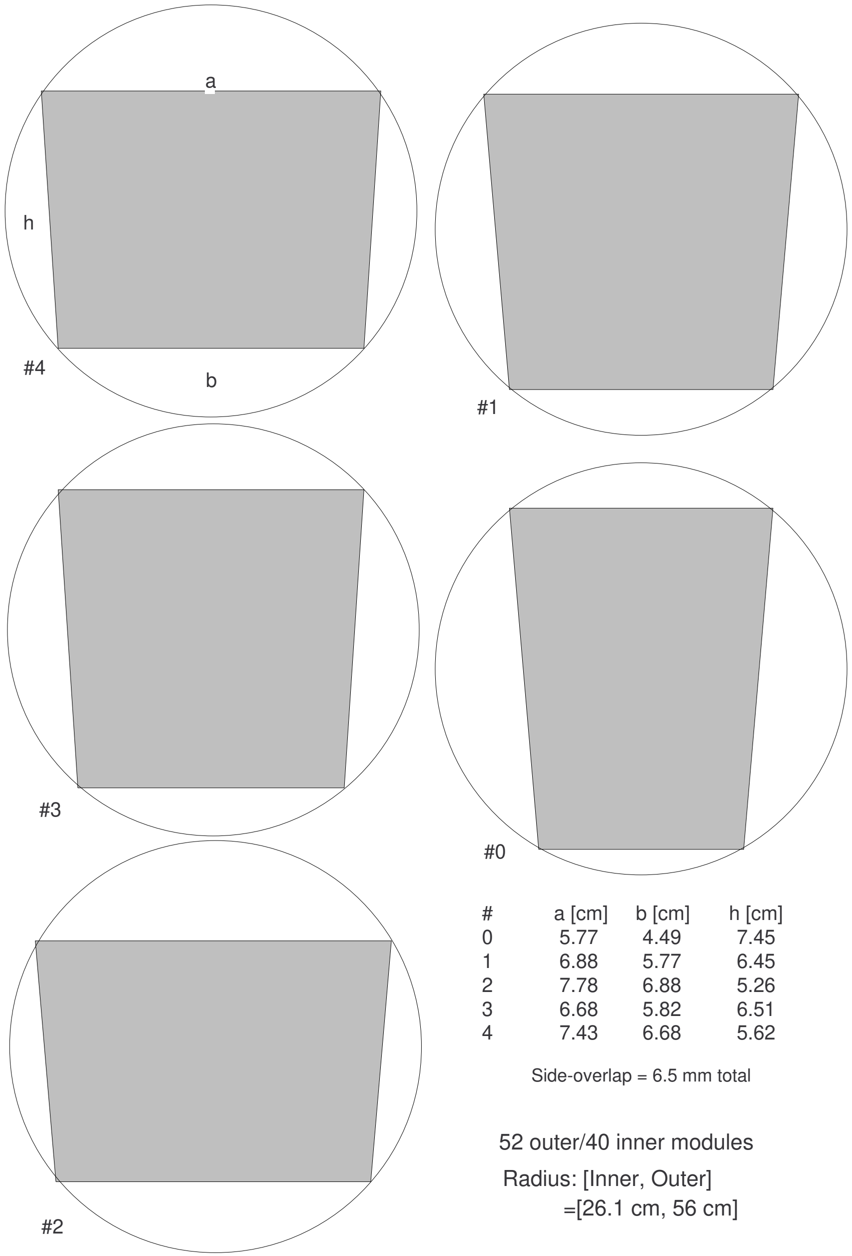


Fig. 4 A forward layout with equal numbers of modules in the inner and the outer rings - the “sector module” layout.



#	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

Side-overlap = 6.5 mm total

52 outer/40 inner modules

Radius: [Inner, Outer]
=[26.1 cm, 56 cm]

Fig. 5 Dimensions of the forward detectors for the layout shown in Fig. 3 with unequal numbers of modules in the inner and outer rings

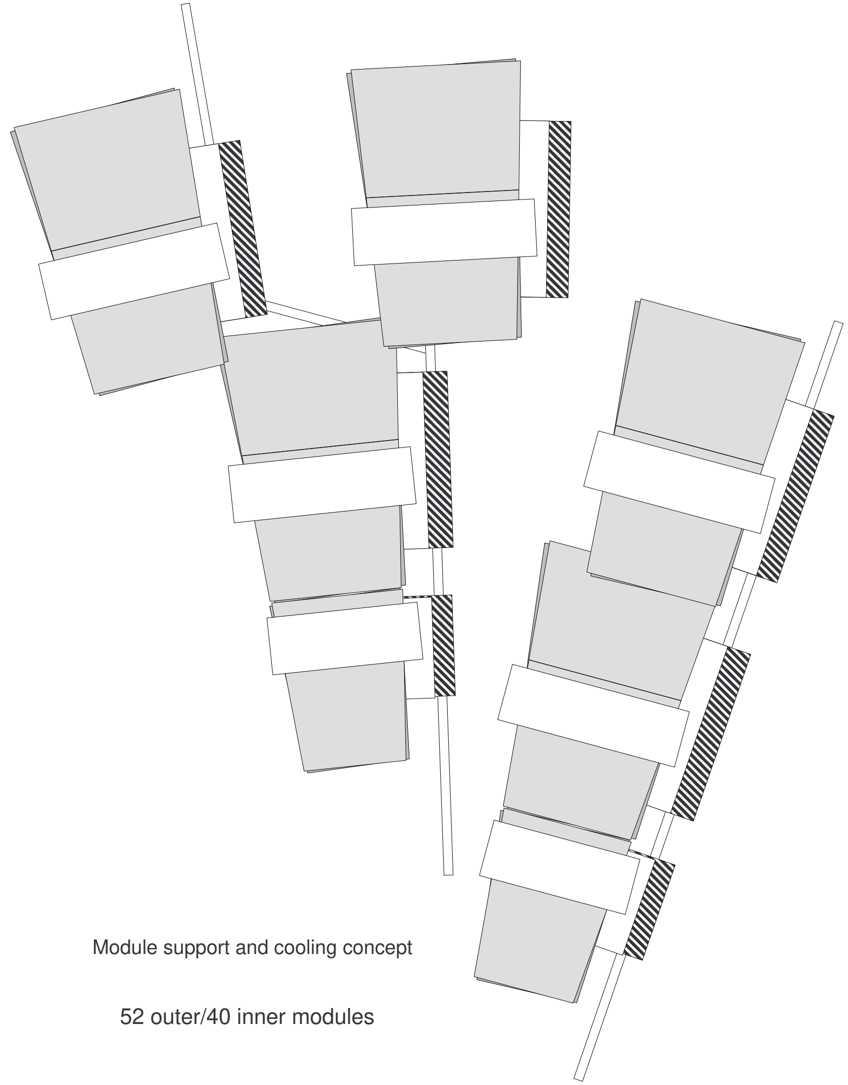
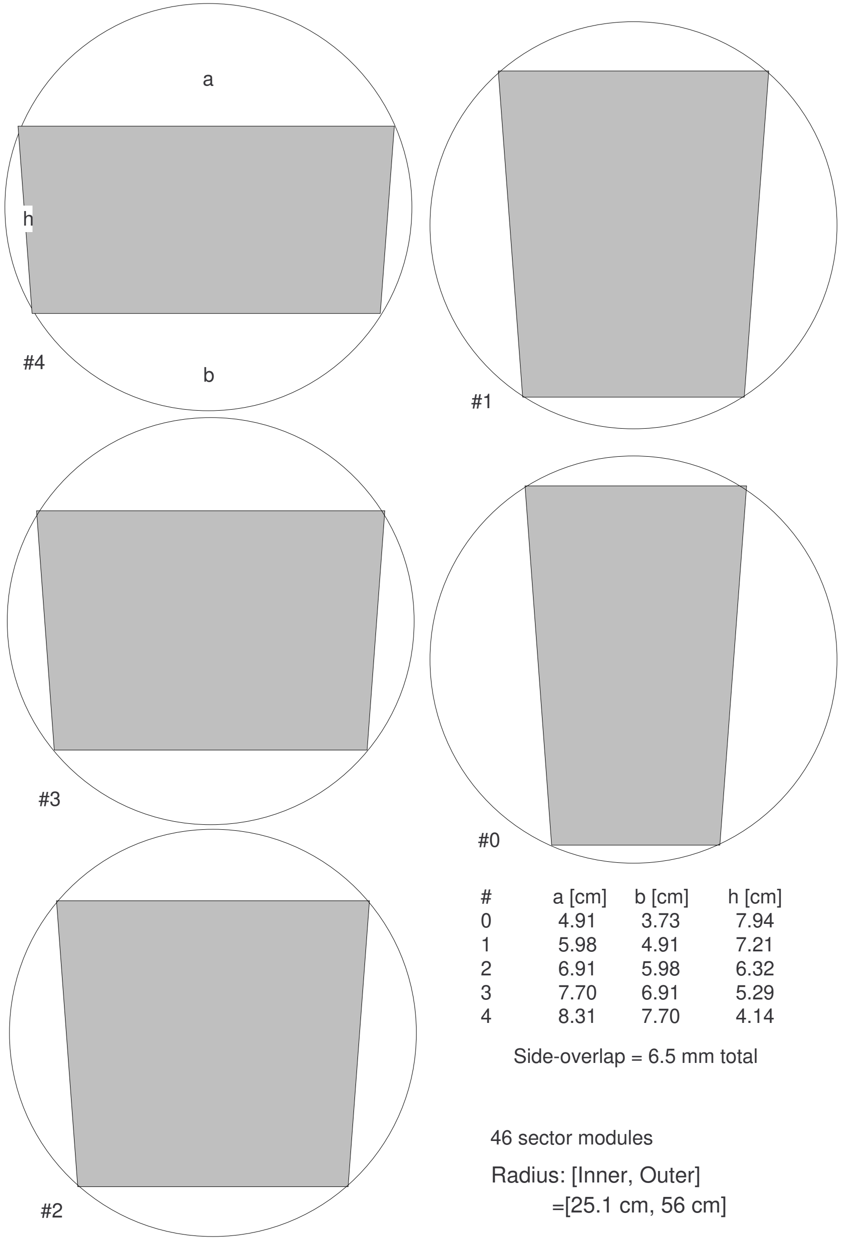


Fig. 6 Module support and cooling concept for the layout of Fig. 3 with unequal numbers of modules in the inner and outer rings.



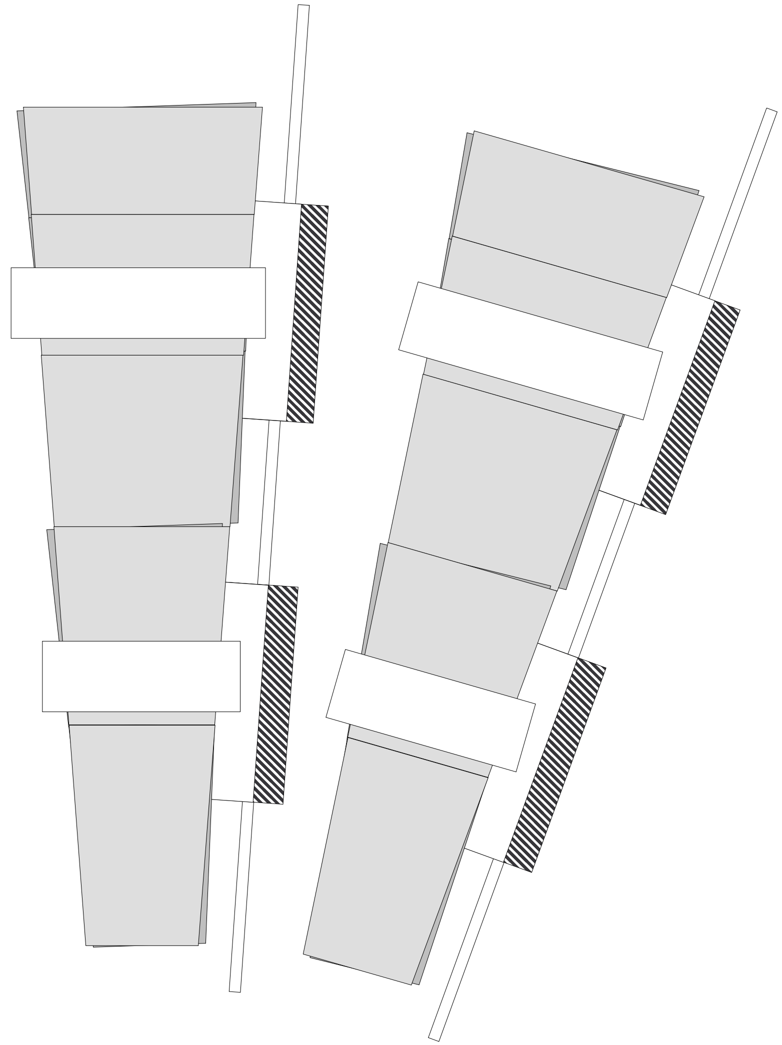
#	a [cm]	b [cm]	h [cm]
0	4.91	3.73	7.94
1	5.98	4.91	7.21
2	6.91	5.98	6.32
3	7.70	6.91	5.29
4	8.31	7.70	4.14

Side-overlap = 6.5 mm total

46 sector modules

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

Fig. 7 Dimensions of the forward detectors for the layout of Fig. 4 with equal numbers of modules in the inner and outer rings - the “sector module” layout.



Module support and cooling concept

Fig. 8 Module support and cooling concept for the layout of Fig. 4 with equal numbers of modules in the inner and outer rings - the “sector module” layout.