ILD, a detector for PFA

Eight versus twelve, and in between?

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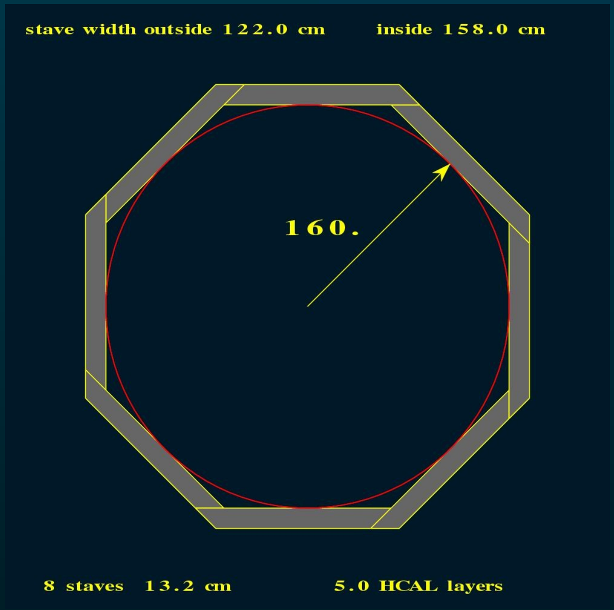
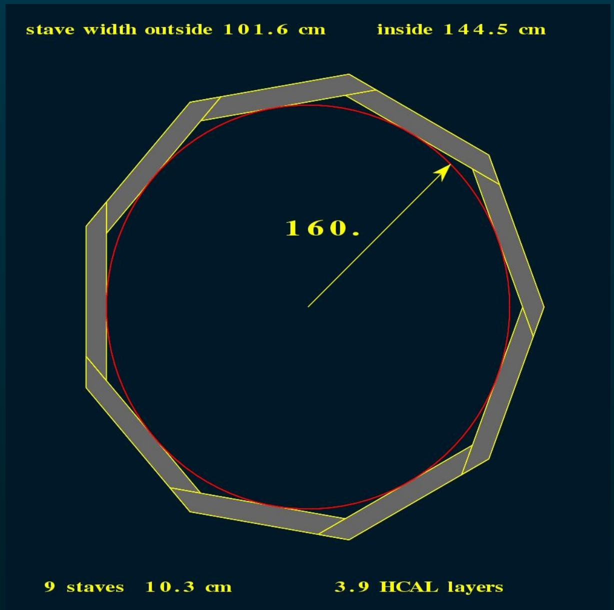
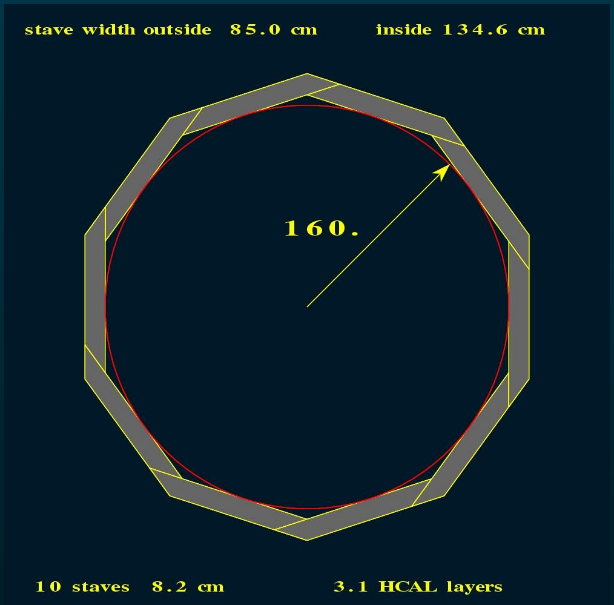
A certain number of issues distinguish 8 and 12

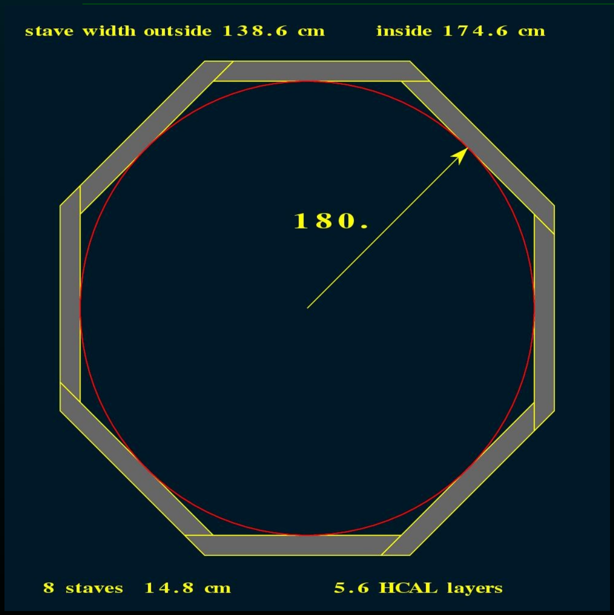
as pointed out by Tohru

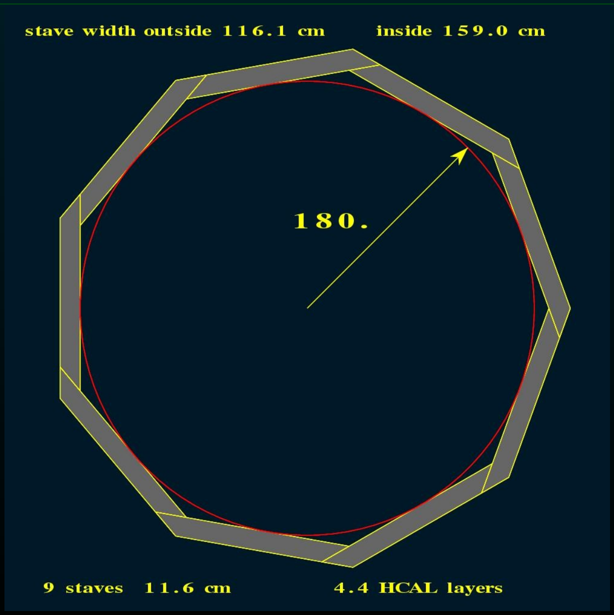
The HCAL depth
The interface TPC - ECAL
The overlap between adjacent barrel module
The space for front-end
The homogeneity of the ECAL depth
The engineering

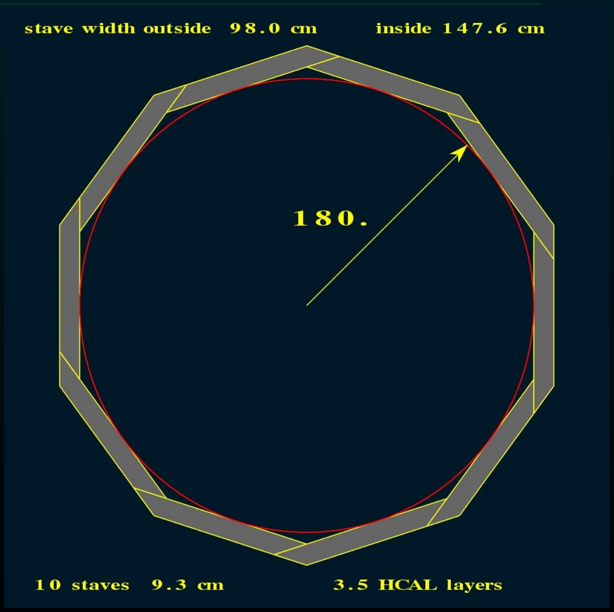

stave width outside 122.0 cm inside 158.0 cm
160.
8 staves 13.2 cm 5.0 HCAL layers

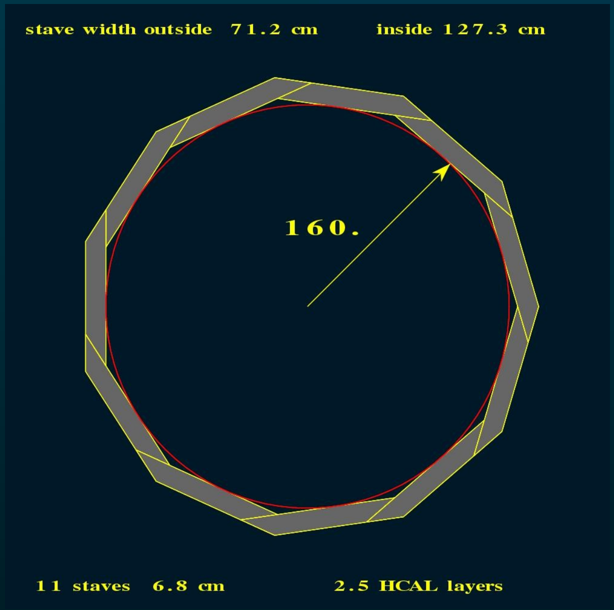

stave width outside 101.6 cm inside 144.5 cm
160.
9 staves 10.3 cm 3.9 HCAL layers

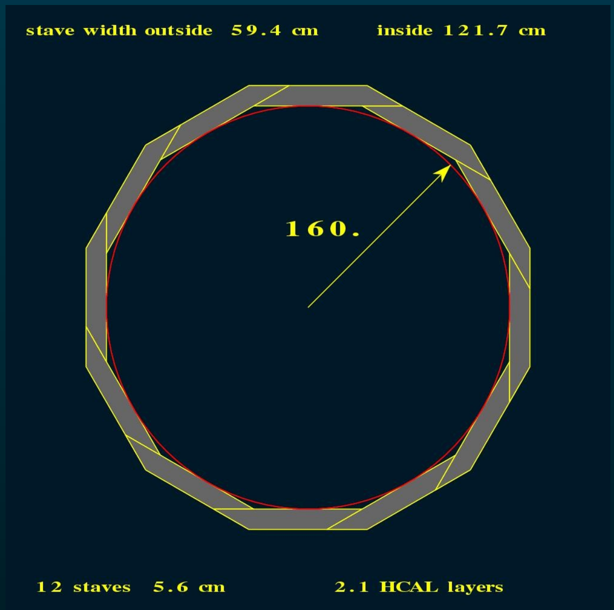

stave width outside 85.0 cm inside 134.6 cm
160.
10 staves 8.2 cm 3.1 HCAL layers

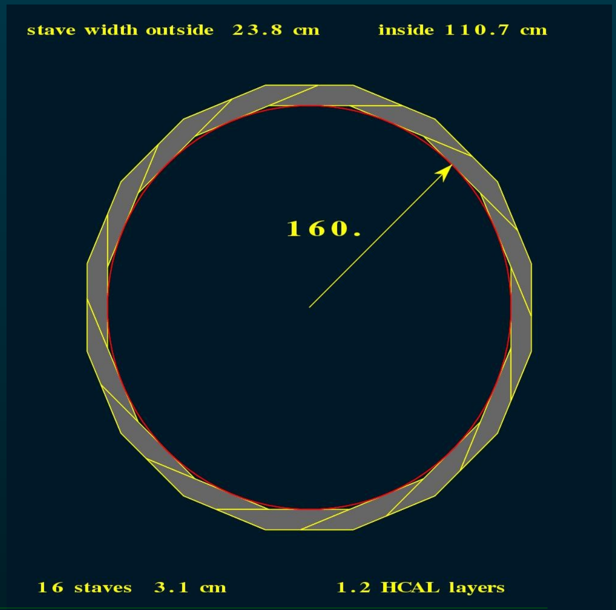

stave width outside 138.6 cm inside 174.6 cm
180.
8 staves 14.8 cm 5.6 HCAL layers

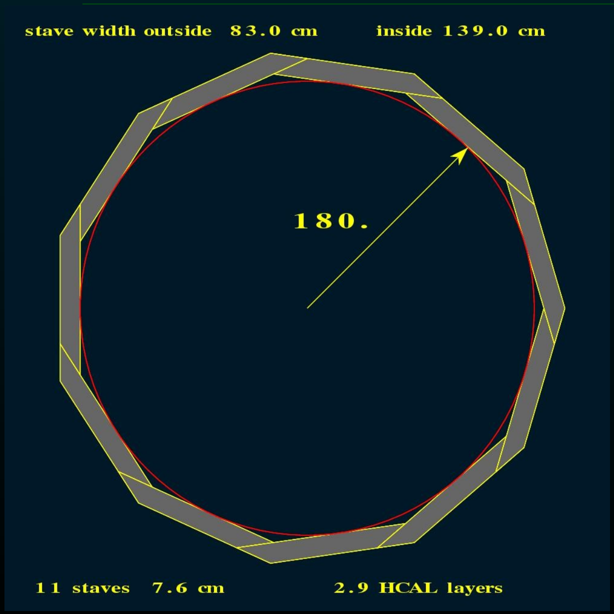

stave width outside 116.1 cm inside 159.0 cm
180.
9 staves 11.6 cm 4.4 HCAL layers

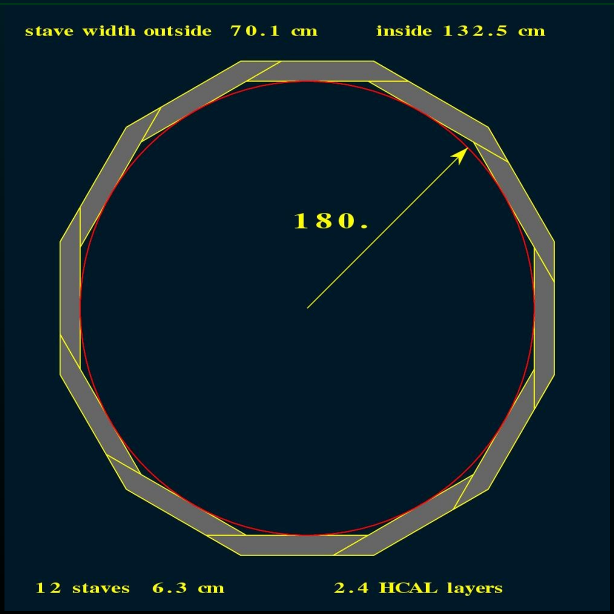

stave width outside 98.0 cm inside 147.6 cm
180.
10 staves 9.3 cm 3.5 HCAL layers

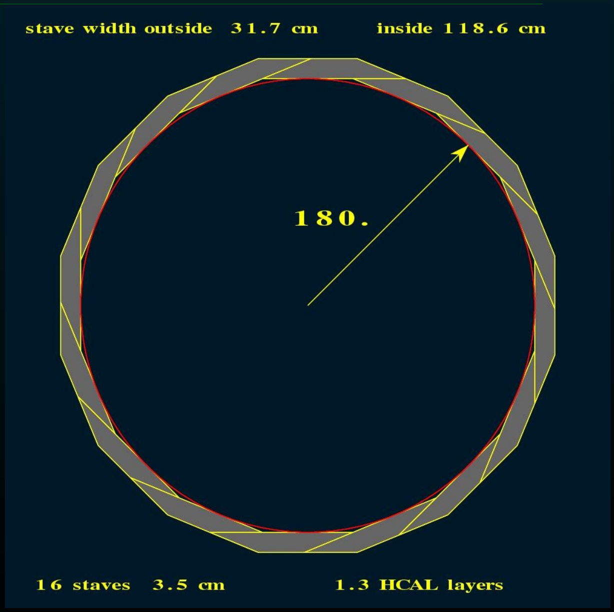

stave width outside 71.2 cm
inside 127.3 cm
160.
11 staves 6.8 cm
2.5 HCAL layers


stave width outside 59.4 cm
inside 121.7 cm
160.
12 staves 5.6 cm
2.1 HCAL layers


stave width outside 23.8 cm
inside 110.7 cm
160.
16 staves 3.1 cm
1.2 HCAL layers


stave width outside 83.0 cm
inside 139.0 cm
180.
11 staves 7.6 cm
2.9 HCAL layers


stave width outside 70.1 cm
inside 132.5 cm
180.
12 staves 6.3 cm
2.4 HCAL layers


stave width outside 31.7 cm
inside 118.6 cm
180.
16 staves 3.5 cm
1.3 HCAL layers

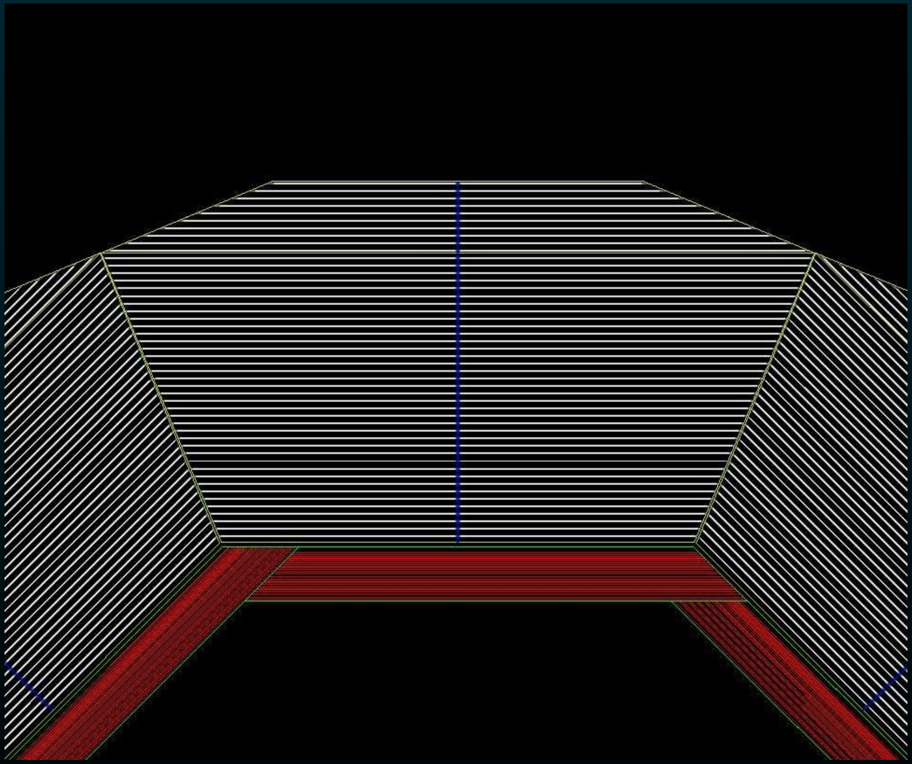
It is trivially clear that the circle is better approached by a dodecagon than by an octagon.

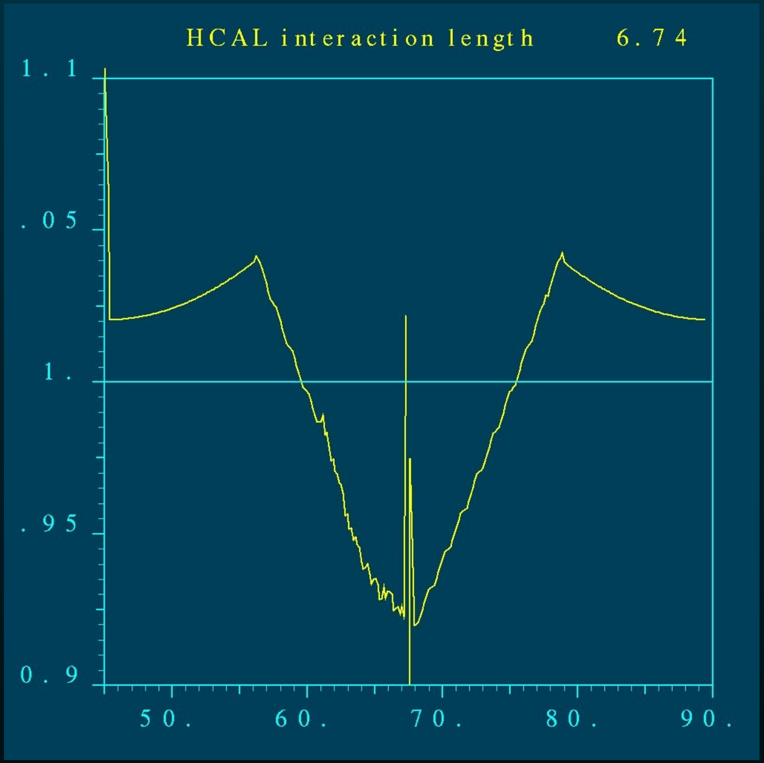
The coil cryostat imposes a circular form for the outer part of the Hcal, easily adjustable.

If cylindrical, the TPC could favour a dodecagon.

From the current MOKKA version for the analogue HCAL

Number of interaction lengths, normalised to the mean (6.75), in the calorimeter (Ecal+Hcal) as a function of φ



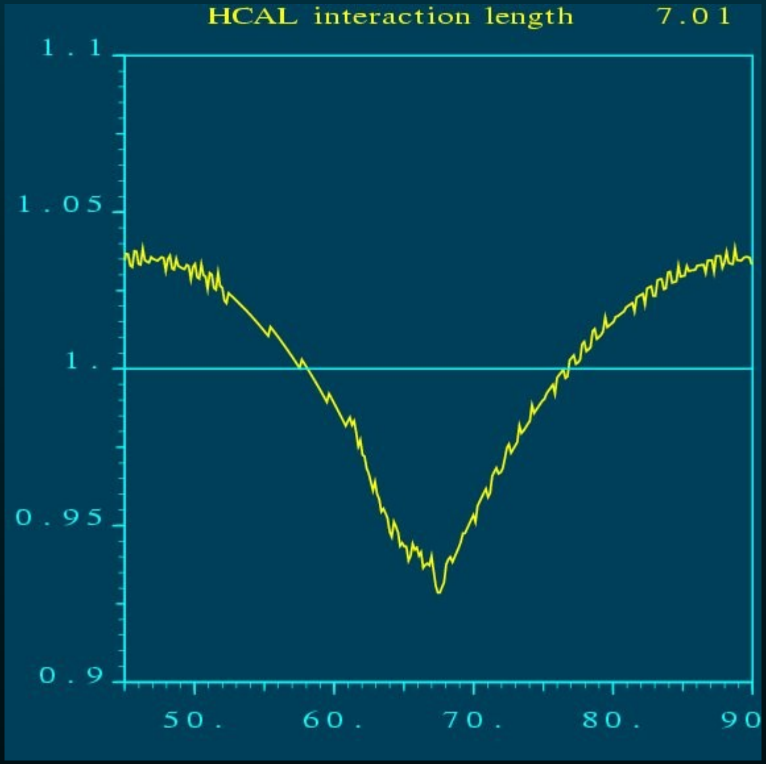


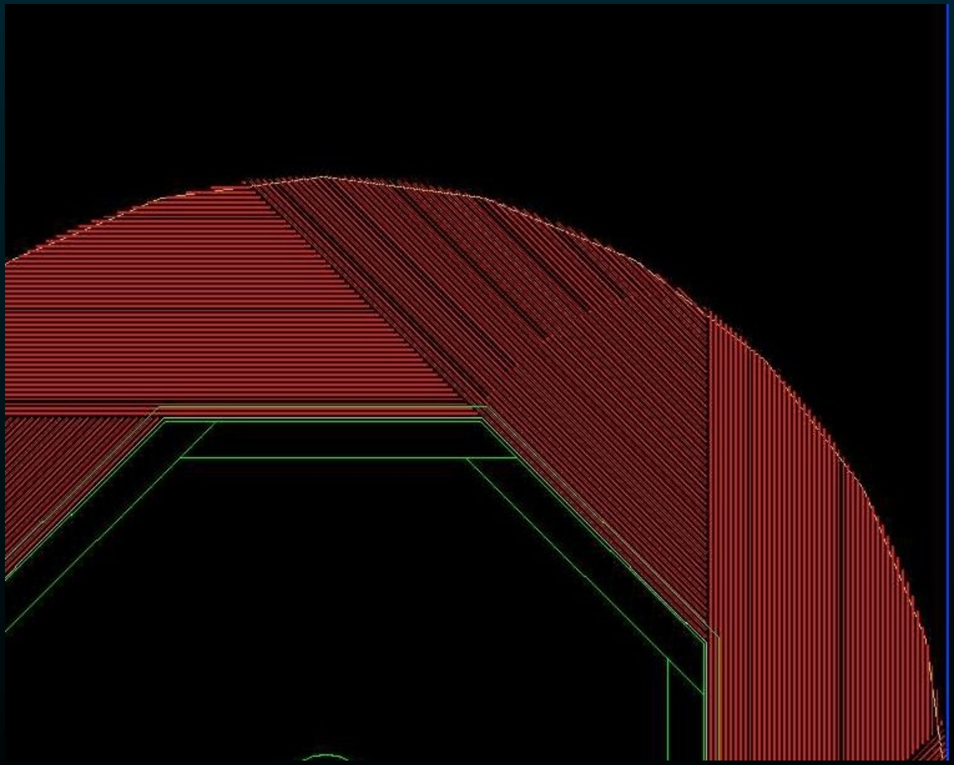
We loose about 10% in the corner of the octagon, only 5 for a dodecagon

correction factor for integration over the barrel: 1.14
which gives a mean number of interaction lengths of 7.7

From the current MOKKA version for the “digital” HCAL

Number of interaction lengths, normalised to the mean (6.75), in the calorimeter (Ecal+Hcal) as a function of φ





The space between calorimeter and coil is too small in Mokka, the mean interaction length is similar to the analogue case

The main advantage of the “digital” structure is that the electronics is at the periphery in R and does not interfere with the gap between barrel and end-caps.
This permits to reduce to a minimum the space in the overlap.
See my presentation in Valencia 2006
“Few considerations on the design of the electromagnetic calorimeter”

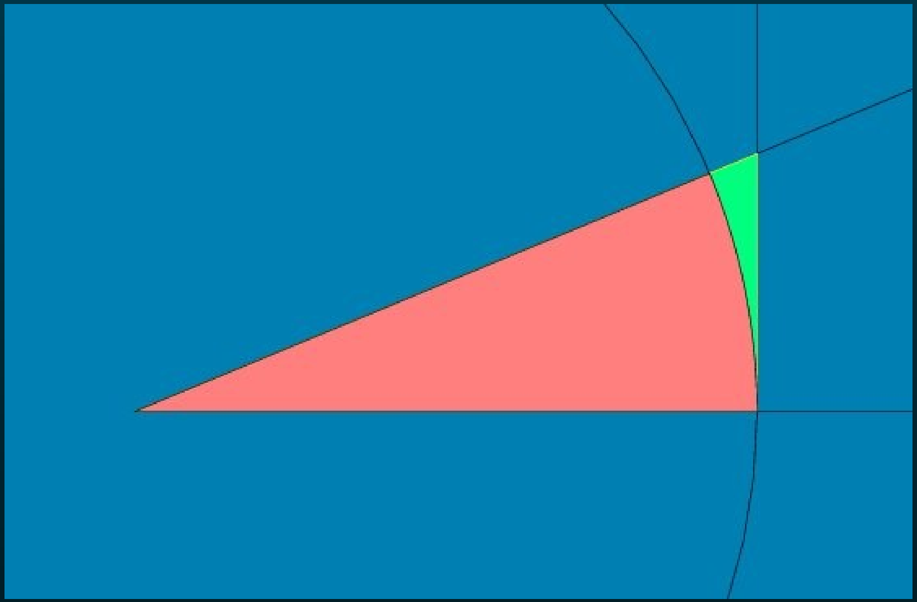
Under the assumption that the TPC field cage
is just in front of the Ecal,
does the shape of the Ecal hamper the measurement
of the tracks?

For a circular TPC the precision willl depend only on R.

For a given radius, an octagonal TPC may improve.

In fact you trade part of the momentum accuracy
for the depth of the Hcal !

On the "dead zone".



The relative importance of the dead zone
is the ratio of the green area on the pink one

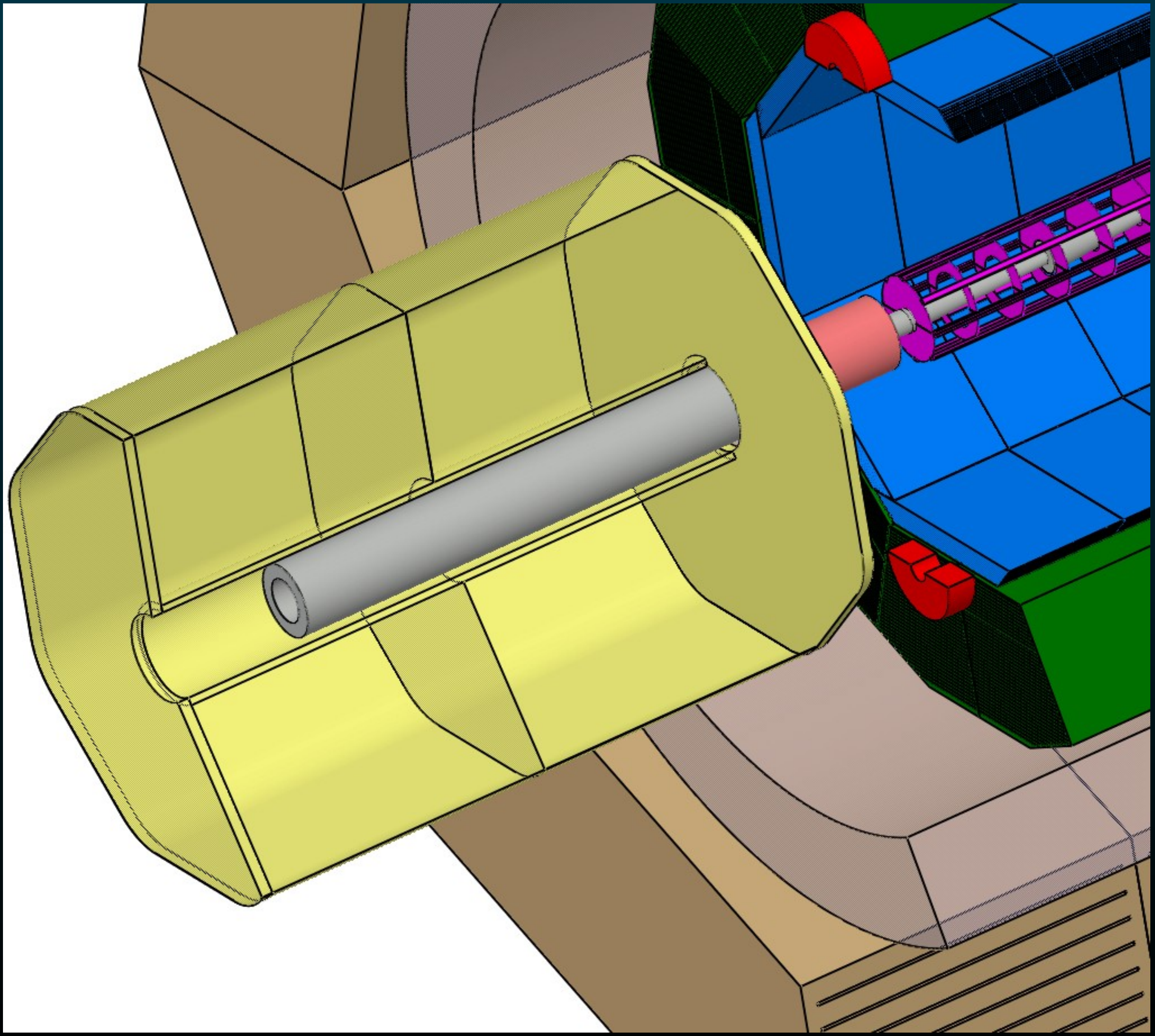
the expression is $\frac{\tan\alpha}{\alpha} - 1$

for the eight-fold solution $\alpha = \pi/8$ 5.5%
for the twelve-fold solution $\alpha = \pi/12$ 2.3%

But the dead zone is also linked to the TPC outer wall and the clearance;
taking optimistically 3cm this dead zone corresponds to 3.2% for a radius of 185.

Note that the TPC in our drawings is octagonal

with a rounding
by 50 cm
the dead zone
is reduced
by a factor > 10



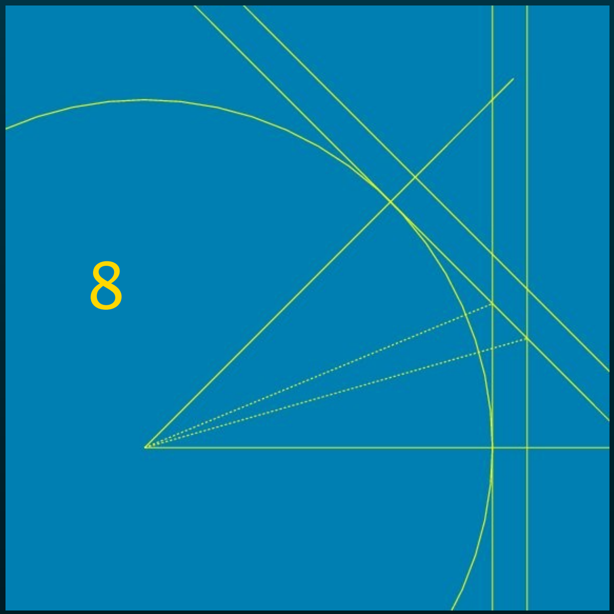
For a radius of 185. and
an ECAL thickness of 18.5
the overlap region amounts to

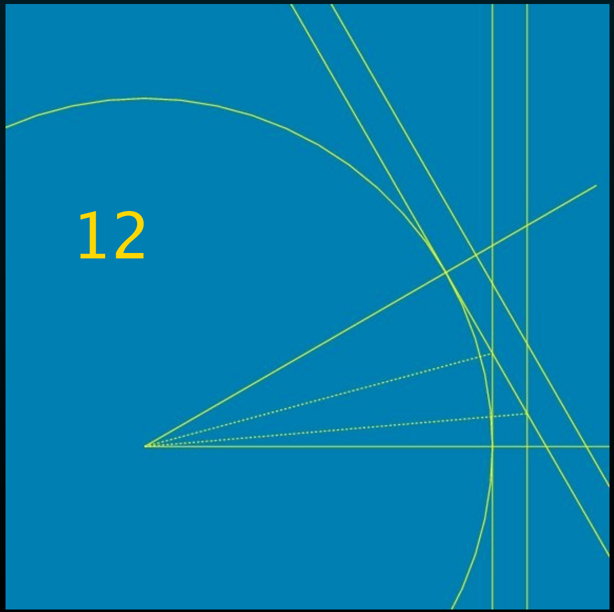
14.6% 8-fold
33.6% 12-fold

how harmful is it?

dead material in overlap
in 1/tanα
1.7 times more in 12

but aluminium?





Overlap between adjacent barrel modules

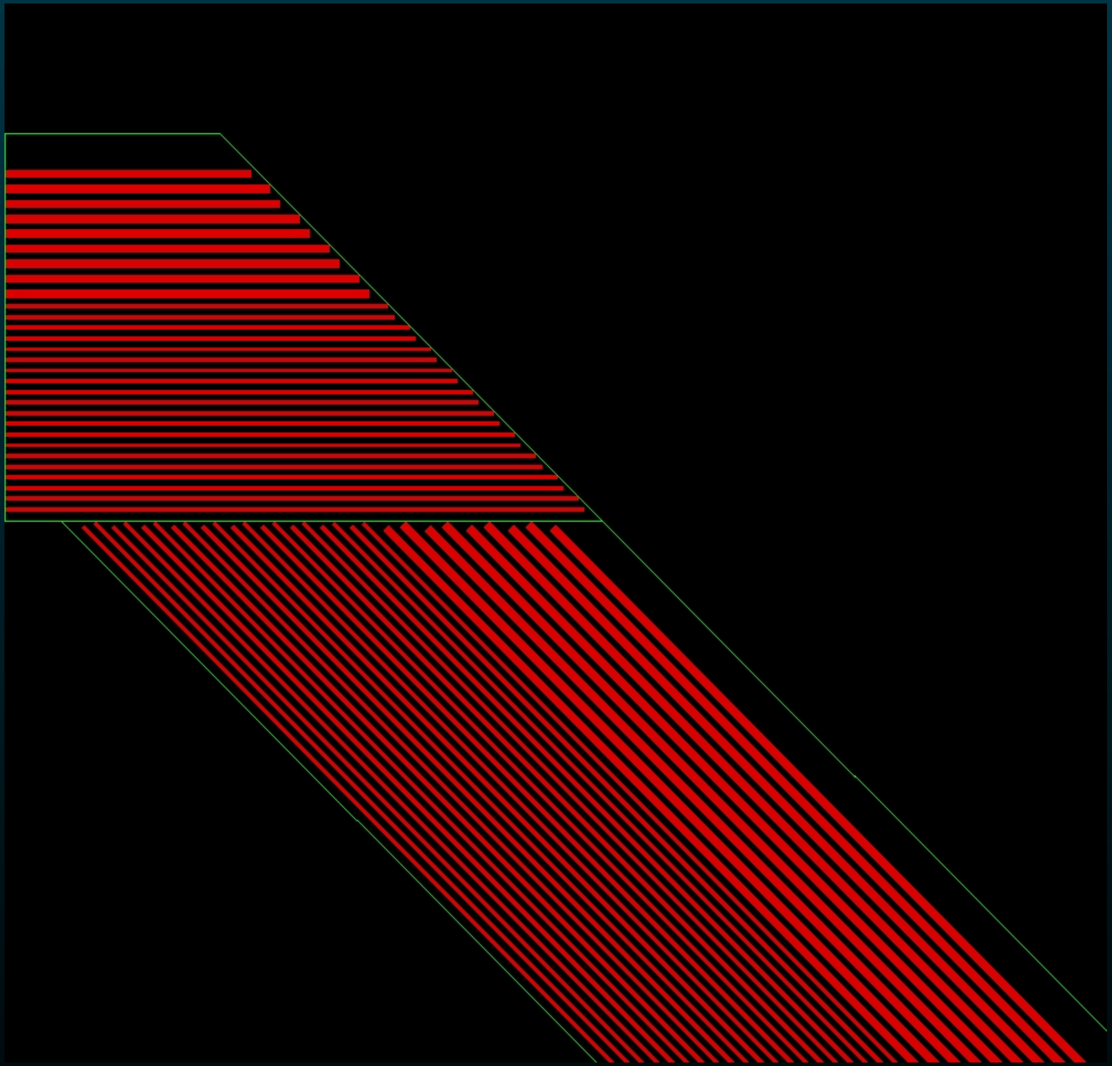
Using two different thicknesses makes it more awkward

see drawing

but better resolution at low energy, better for counting

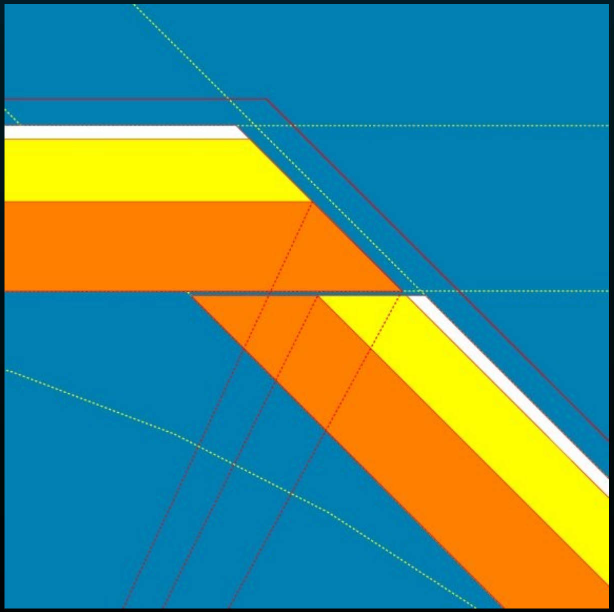
worse at high?   NO

Did anyone observe an effect in the simulation?



The ECAL corner
as seen in MOKKA.

There is a tiny angular region
where photons cross only
the thin sampling



By going from 2.8 to 2.1 in the first half
we expect to improve at most by 15%.
we do

From Monte-Carlo (Valencia)

Energies (GeV)	0.2	0.5	2.	5.	10.
ΔE/E 30x2.8 mm	0.365 0.009	0.230 0.004	0.130 0.003	0.084 0.002	0.057 0.002
ΔE/E 20x2.1+10x4.2 mm	0.295 0.008	0.212 0.004	0.112 0.003	0.074 0.002	0.053 0.001
improvement	24 ± 6%	8 ± 4%	16 ± 6%	14 ± 6%	8 ± 6 %

For the same total thickness, the same number of X0
the resolution is systematically better with a finer sampling in front.
The efficiency also!

It is clearly valuable to keep two thicknesses

but the overlap is more awkward

Remark

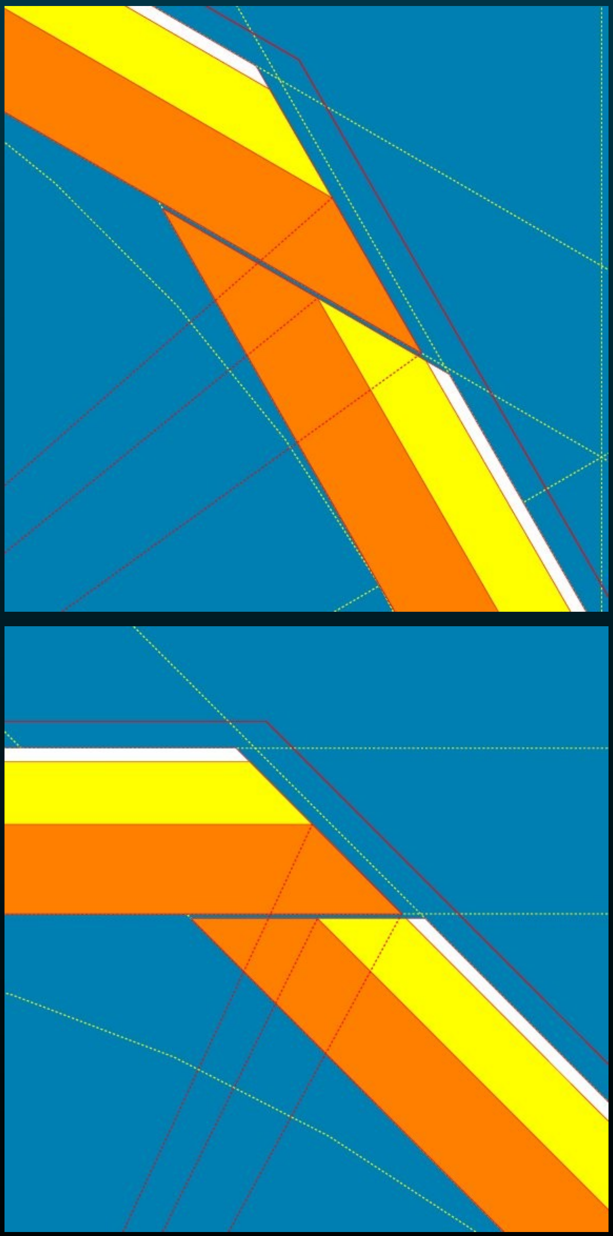
If we want to keep the same number of X0
and the same envelope (17cm)
taking 2mm of Sc + 2mm read-out + 0.6mm carbon = 4.6

n being the number of W layers and x the thickness of one

nx = 24 * 3.5mm = 84 mm
nx + (n+1)4.6 = 170mm

n = 18 and x = 4.7mm = 1.3 X0

The space for front-end



The total thickness of Ecal is 185 mm
including today a back plate of 15mm
We consider leaving 30mm
between Ecal and Hcal for
rails and support, cooling, power, signal

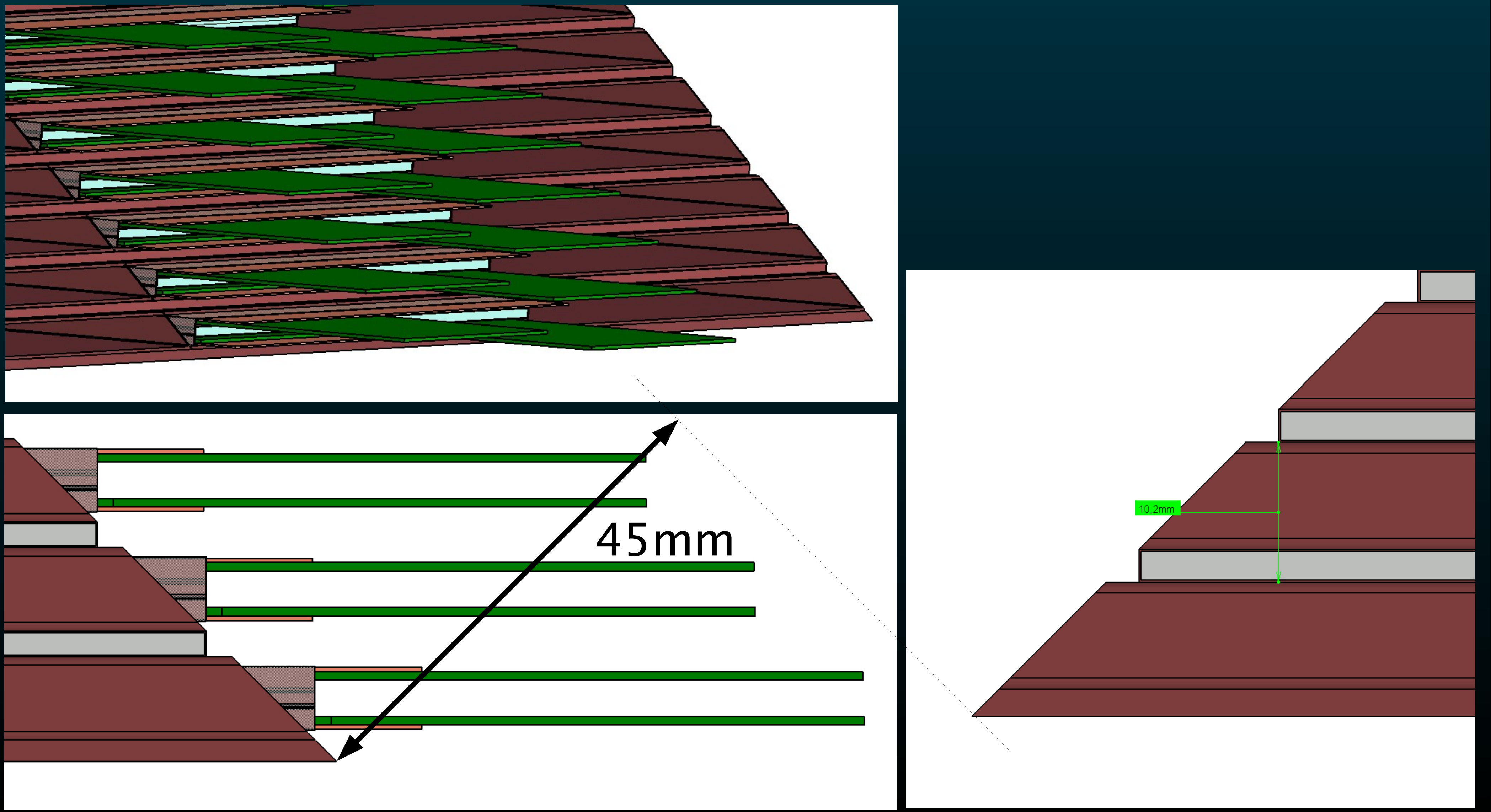
The volume usable for front-end
is 45 mm thick and the cards being
at 45° can extend up to 60mm

It seems reasonable and the EUDET module
is made accordingly

But the 30mm, or the 15mm plate, may
end up thinner!

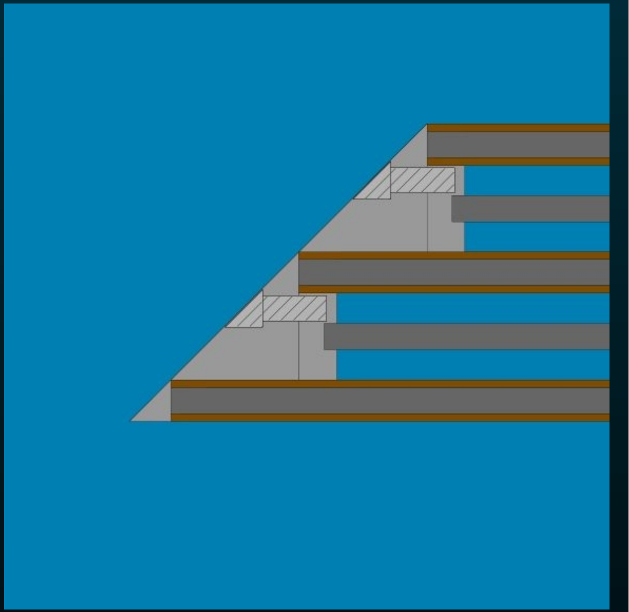
The space for front-end

From the current drawings of he EUDET module



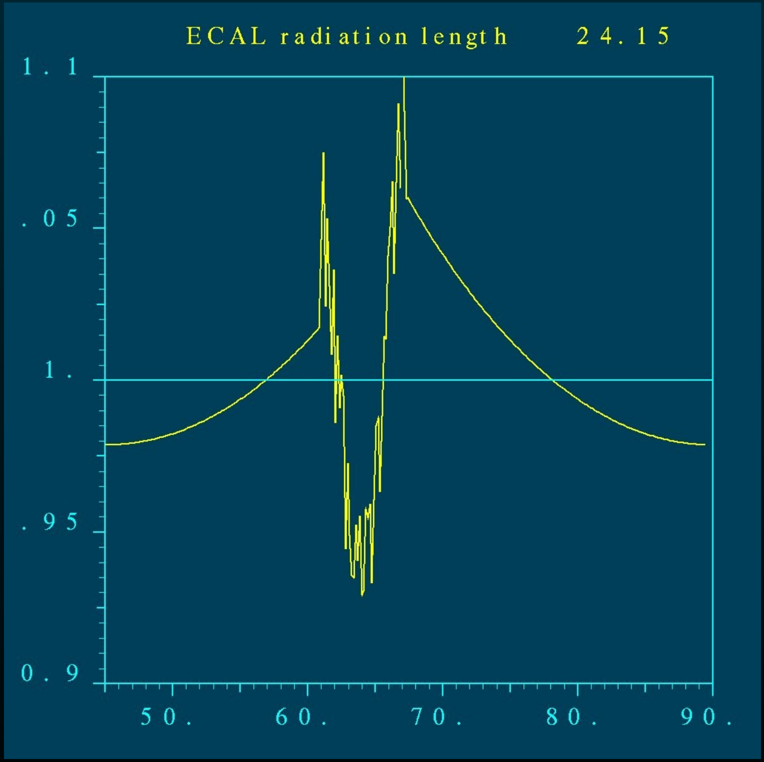
Beware! the devil is in the details

On the side opposite to the front-end
there may be caps to held the slabs



On the front-end side the slabs contain
an integer number of cells (5mm)

It is clear that, out of the overlap, the homogeneity is entirely due to the angle between the incident particle and the normal to the calorimeter.
The apparent thickness of the calorimeter varies like $1/\cos\alpha$. At $\theta=90°$ the azimuthal variation is from d to $d/\cos\alpha$.
Solution 8 : 8.2% max
Solution 12: 3.5% max



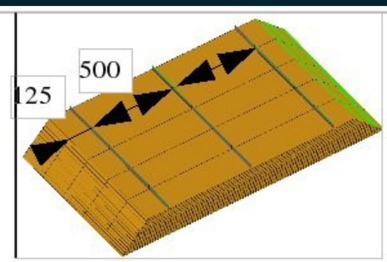
This effect is dominated by the overlap effect, see plot ±7%

But, does it harm?
anyway it is totally negligible compared to the effect in θ: 63%

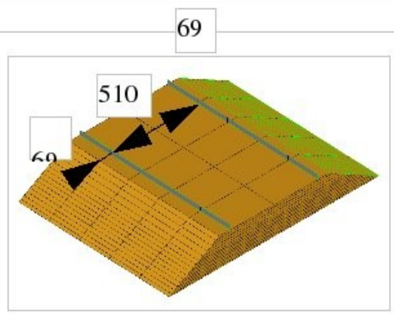
The engineering

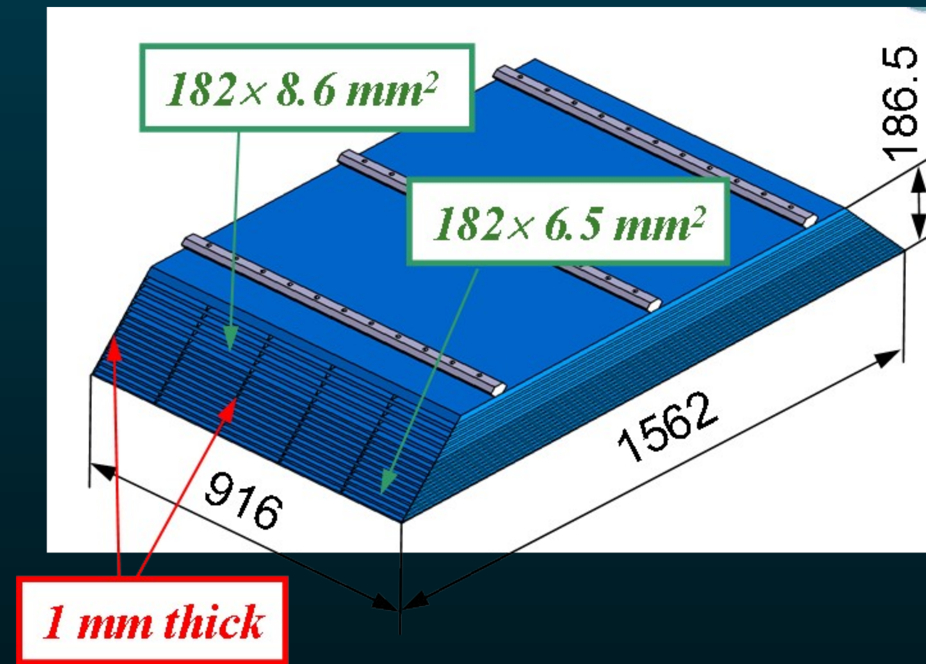
Both types of modules have been looked at by M. Anduze he is writing a LC note.

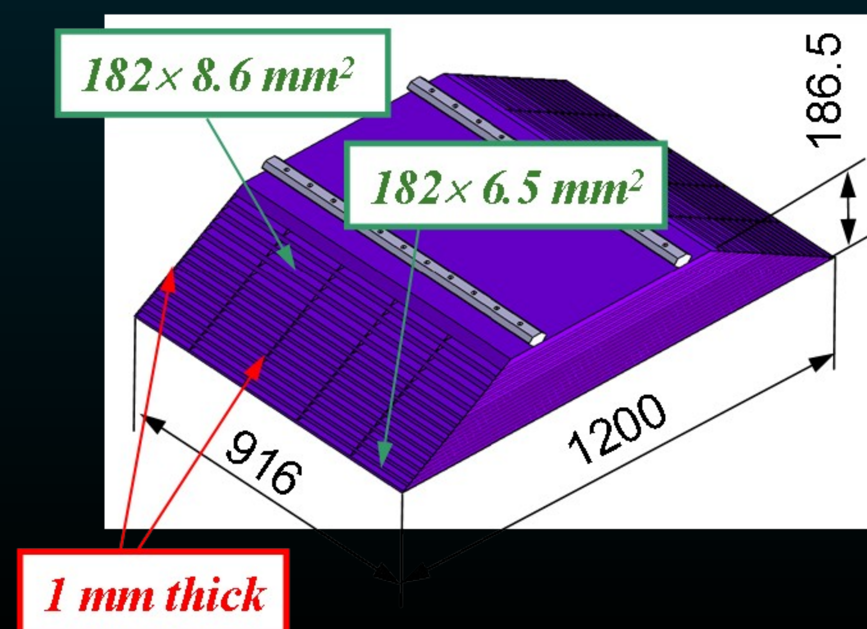
ECAL8-3r	0°	45°	90°
déformation (mm)	0,076	0,119	0,125
Tsai hill	4,10E-03	2,07E-03	7,14E-04
MoS (mini)	4,34	6,51	11,79
Mises (Mpa)	2,7	7,8	2,3



ECAL12-2r	0°	30°	60°	90°
déformation (mm)	0,126	0,176	0,189	0,185
Tsai hill	8,35E-03	8,22E-03	4,29E-03	4,89E-03
MoS (mini)	2,74	2,77	4,22	3,89
Mises (Mpa)	3,7	5,3	7,8	8,3

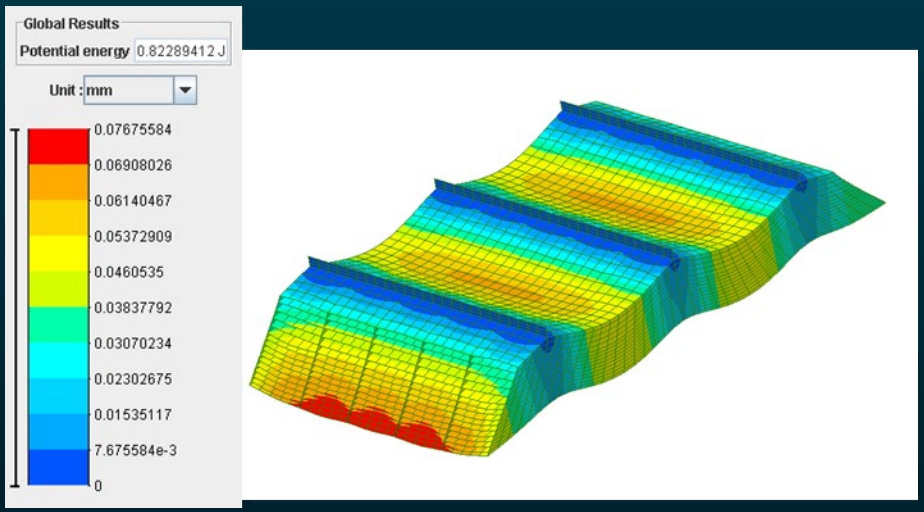


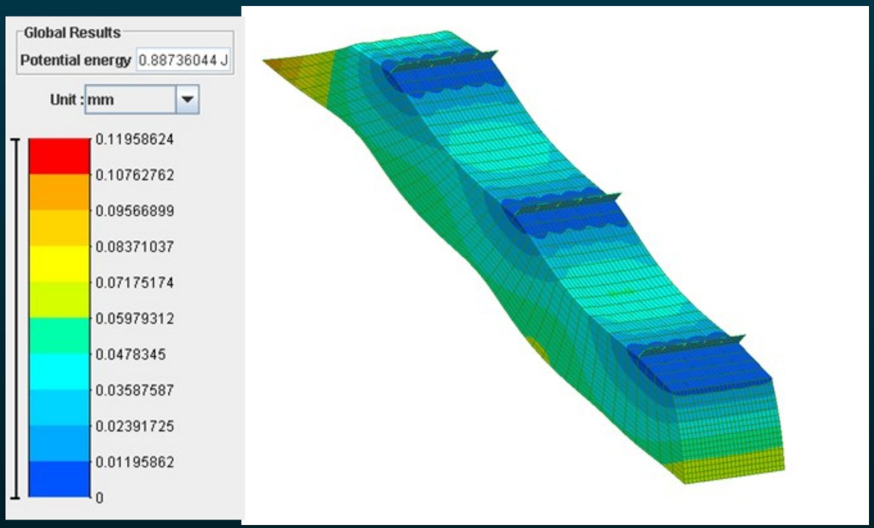


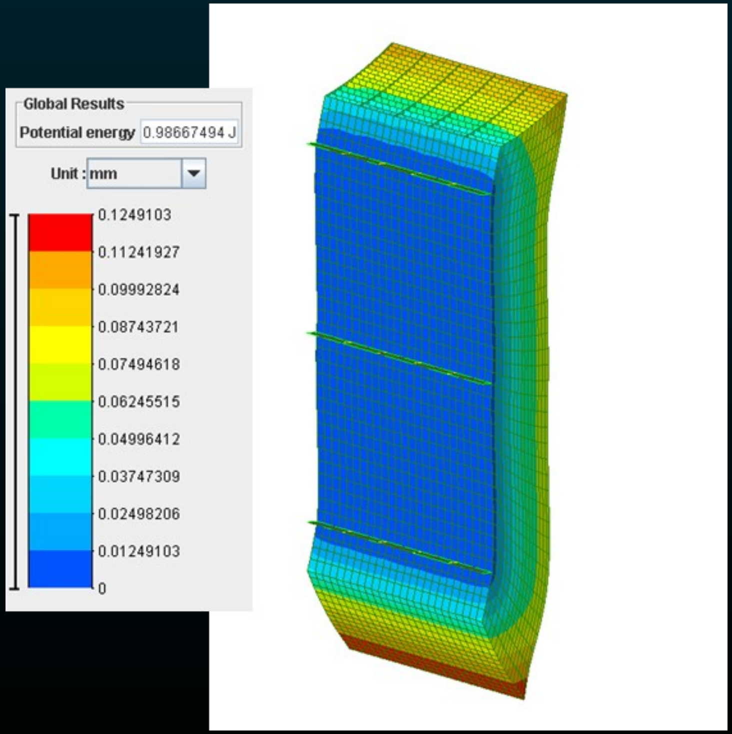


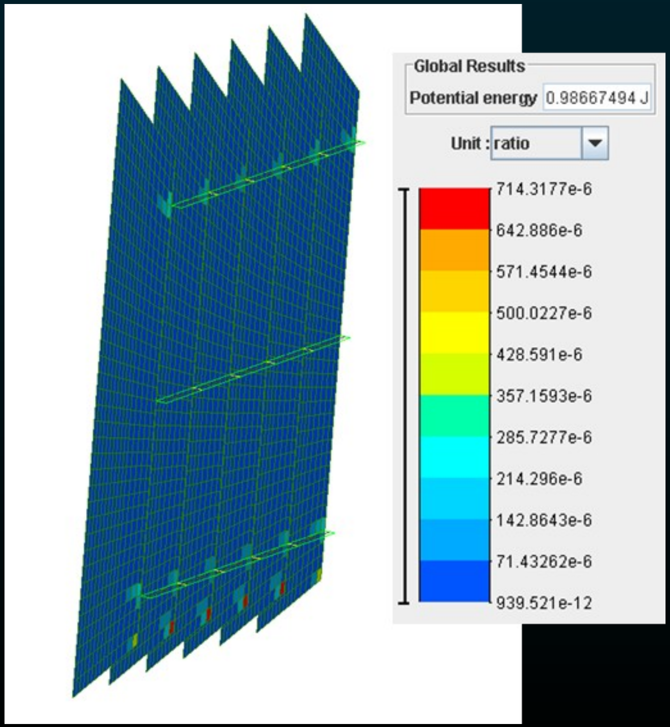
8 is stiffer but both acceptable

The engineering









Remarks:
for 8   a module weighs 2.1 T
for 12 a module weighs 1.4 T
does not make it really easier

You may prefer to build and insert
40 modules rather than 60

The case for the “digital” HCAL

With a 12 symmetry the design is much more awkward

The denomination “digital” is improper, the mechanical solution being fine also for the analogue HCAL
it is a historical point.

Both solutions seem feasible
with quite marginal advantages in one or the other.

Some personal preference for eight
in view of the overlap

The best argument for 12 being probably the HCAL depth

In view of the engineering and prototyping investment
our preference would be to use 8 as a baseline for the LoI
with the symmetry 12 as an option?