Electromagnetic endcap calorimeter:number of channels, layout for cables,FE and mother boards.

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1. Inputs are the following :

   - We started that study looking only to the e.m. calorimeter itself, including an η strip preshower over the η coverage of the outer wheel.The endcap e.m calorimeter,divided in 8 wedges, will cover the range in rapidity from 1.4 to 3.2 with two independant wheels:the outer one covers the range from 1.4 to 2.4 and the inner one from 2.4 to 3.2 (see figures 1 and 2). We did the hypothesis of the following η and ϕ coverage per trigger tower size and per cell :

Inner wheel : $\delta\eta.\delta\phi$	.1 x .1
Outer wheel : $\delta\eta.\delta\phi$	.1 x .1
Elementary η cell (inner)	.05
Elementary η cell (outer)	.025

   The total number of absorbers we consider is 384 and 768 for the inner, respectively the outer wheel.

   All the numbers quoted in the following document are given for one wedge and for the sum of both end-caps.

   Finally we decided to equip one wedge in a complete independent way - no cables nor electronics will be shared by different wedges.

2. Number of trigger towers.

   - Inner wheel :

     Considering a ϕ coverage of .1 per trigger tower,ie approx. $2\pi/64$, leads to 64 trigger towers in ϕ.

     The inner wheel is supposed to cover a range of 0.8 in η.Assuming a tower size of $\delta\eta$=.1 gives 8 trigger towers in η .

     The wheel being divided into 8 wedges,the total number of trigger towers per wedge will be : 64. Finally the total number of trigger towers for both end-caps is :

     $$16(\#\text{endcaps}.\#\text{wedges}) \text{ x } 64 = 1024.$$

     Each individual trigger tower will have 4(2) signal channels for sampling 1 and 2 (respec. 3)-(see figure 3).

   - Outer wheel :

     Considering a ϕ coverage of .1 per trigger tower,ie approx. $2\pi/64$, leads to 64 trigger towers in ϕ.

     The outer wheel is supposed to cover a range of 1.0 in η.Assuming a tower size of $\delta\eta$=.1 gives 10 trigger towers in η .

     The wheel being divided in 8 wedges,the total number of trigger towers per wedge will be : 80. Finally the total number of trigger towers for both end-caps is :

     $$16(\#\text{endcaps}.\#\text{wedges}) \text{ x } 80 = 1280.$$

     Each individual trigger tower of the outer wheel will consist of 32 signal channels for sampling 1 (integrated preshower with a granularity $\delta\eta$=.025/8 and $\delta\phi$=.1), 16 channels for sampling 2 and 8 for sampling 3 (see figure 4).

3. Number of channels.

   - Inner wheel :

     The 384 kaptons are grouped by 3 in the ϕ direction for sampling 1 and 2 and by 6 for sampling 3. One wedge will then consist in $(384/3)/8 = 16$ signal channels in ϕ for S1 and S2 and 8 for S3.

     The total number of channels/wedge will be :

256(16 in η x 16 in ϕ) and 128(16 in η x 8 in ϕ),respectivelly for S1,2 and S3 .

The total amount of channels for both end-caps is :

16(# endcaps.# wedges) x (256(S1)+256(S2)+128(S3))= 10240

- Outer wheel :

  Because the first sampling of the outer wheel will consist of η strips with a granularity in η of .025/8=.003125 , The 768 kaptons are grouped by 12 in the ϕ direction for the first sampling.

  S2 and S3 are standard cells with an η coverage per elementary cell taken to be .025 for both S2 and S3 samplings.As for the inner wheel the kaptons will be grouped by 3 for the second sampling and by 6 for the third sampling. For the η strips of S1,the number of signal channels becomes (768/12)/8 = 8 per wedge in the ϕ direction. One wedge will also consist in (768/3)/8 = 32 signal channels in ϕ for S2 and 16 for S3.

  The total number of channels/wedge is :

  2560(8*40 in η x 8 in ϕ) for S1,

  1280(40 in η x 32 in ϕ) for S2 and

  640(40 in η x 16 in ϕ) for S3 .

  The total amount of channels for both end-caps is :

  16(#endcaps.#wedges)x(2560(S1)+1280(S2)+640(S3))=71680.

- Total number of read-out channels :

  The total number of read-out channels for both end-caps is 10240+71680=81920 ,corresponding to 2304 trigger towers.

4. Printed circuit boards and calibration (see figure 5 and 6)

   - Inner wheel.

     One PC board could cover the following range: $\delta\eta$ x $\delta\phi$=.4 x .4

     The dimensions of such PC's as well as the number of trigger towers,channels and pins are listed in the following tables :

	Trigger towers	Pins	S1	S2	S3
Inner front	16	192	64	-	-
Inner back	16	384	-	64	32

	R ext (cm)	R int (cm)	L (cm)
Inner front	52.	23.	37.
Inner back	60.	27.	42.

For front and back region only 4 different boards are needed.Per wedge we will need to have 2x2 PCB's.A total amount of 32 boards of each type,ie 4x32=128 in total, will be used to equip both end-caps.

Concerning the calibration (each calib. channel will go to 16 cells) we suggest the following scheme : 2 raws in η of 8 cells each with a 4-raw pich (to allow cross-talk studies) for sampling 1 and 2. For sampling 3 the scheme becomes :4 raws in η of 4 cells each with a 2-raw pich.

- Outer wheel.

  One PC board could cover the following range: $\delta\eta$ x $\delta\phi$=.2 x .2

  The dimensions of such PC's as well as the number of trigger towers,channels and pins are listed in the following tables :

	Trigger towers	Pins	S1	S2	S3
Outer front	4	1536	128	-	-
Outer back	4	384	-	64	32

	R ext (cm)	R int (cm)	L (cm)
Outer front	150.	52.	125.
Outer back	157.	60.	124.

  For front and back region 10 different boards are needed.Per wedge we will need to have 5x4 PCB's.A total amount of 64 boards of each type,ie 10x64=640 in total, will be used to equip both end-caps.

  Concerning the calibration of sampling 1 (η strips) we suggest the following scheme (fig. 6) : 8 raws in η of 2 cells each with a 4-raw pich. For sampling 2 and 3 the calibration scheme will be the same as for the inner wheel.

- Summary

  In summary 768 PCB's are needed to equip both end-caps.But only 14 different mother boards will be designed.

	types	ex/type	channels/PC	pins
Inner front	2	32	64	192
Inner back	2	32	96	384
Outer front	5	64	128	1536
Outer back	5	64	96	384

5. Connexion to FE boards (figure 7 and 8)

   Hypothesis:each FE board consists in 64 channels (according E.Auge pre-design).

   The goal is to try to group on a same front-end board channels with the same timing ie with almost the same capacitance values. In order to fulfil that requirement,we propose to group preferably the channels in the ϕ direction.

   - Inner wheel.

     For both samplings S1 and S2 we suggest to take 4 consecutive lines in η from two adjacent PCB's in ϕ of one wedge. This corresponds to 64 channels (figure 7). Each FE board covers .2 x .8 in $\delta\eta$ x $\delta\phi$.

     For sampling S3,the coverage per FE board becomes twice larger in η. The 32 channels of each PCB go the the same FE board.

     The amount of FE boards per wedge would then be : 4+4+2 = 10 for all three samplings.That number becomes 16 x 10 = 160 for both endcaps.

   - Outer wheel.

     For samplings S1 (η strips) the 128 channels of one PCB are read-out by 2 FE cards,grouping the 2 sets of 32 channels of two adjacent values in ϕ into one FE (figure 8).

     For sampling S2 and S3,the read-out scheme will be the one proposed for the inner wheel.Two adjacent PCB's in ϕ are read-out by two FE cards for S2 and by one for S3.

     The amount of FE boards per wedge would then be : 40+20+10 = 70 for all three samplings.That number becomes 16 x 70 = 1120 for both endcaps.

6. Cables to feedtroughs and to FE crates

Assuming 16 channels per cable,we expect per wedge:

(256(S1)+256(S2)+128(S3))/16=40 for the inner wheel and

(2560(S1)+1280(S2)+640(S3))/16=280 for the outer wheel.

They will be uniformelly distributed in ϕ,escaping the calorimeter via holes in the supporting structure.

- Layout

  The 320 cables per wedge are uniformely distributed in ϕ. This solution would be the simplest for both the PCB design and probably also for the insertion of the calorimeter inside the cryostat,as well as for the design of the supporting structure.The 320 cables would correspond to a maximum thickness in radius of 10mm (assuming a section of 30 x 1 mm^2 per cable - Fileca coaxial cables for ex.).

  According the actual design of the endcap cryostat we expect to have 38 feedtroughs per endcap.In case of the proposed cable distribution with 320 cables uniformely distributed ,corresponding to 5120 channels.Those numbers should fit with 4 feedtroughs/wedge.In total,to bring out all the signal cables we need 32 feedtroughs per endcap, ie 64 for both.

- "en résumé"

  1 wedge = 5120 channels = 4 feedtr.= 80 FE boards = 4 FE crates

7. HV and calibration cables

   - HV

     Assuming a $\delta\eta$=.05 modularity for the high voltage distribution with a longitudinal splitting in two compartments,we need : (3.2-1.4)/.05=36 HV cables per compartment.The total number of cables will be of 72 per wedge and 16 x 72=1152 for both endcaps.This could correspond to 18 crates of 4 boards with 16 channels.

   - Calibration

     As described before, we forsee to pulse 16 calorimeter channels with one calibration channel. Using 16 channels cables gives :

(5120) / (16 x 16) = 20 pulser cables per wedge.For both end-caps we will need : 16x20=320 of those cables.

8. Conclusion

   As a summary,we expect the following amount of cables per wedge : 72 HV cables, 320 signal cables and 20 pulser cables. All those cables should fit into 4 mixed (HV and Signal) feedtroughs.

   More precisely,the summary per wedge and for both end-caps looks like:

	In. wheel	Out. wheel	Wedge	Both EC
Signal channels	640	4480	5120	81920
Trigger towers	64	80	144	2304
HV cables	32	40	72	1152
FE boards	10	70	80	1280
FE crates			4	64
Calibration ch.	40	280	320	5120
Total number of ch.			5512	
Number of feedt.			4 (signal&HV?)	

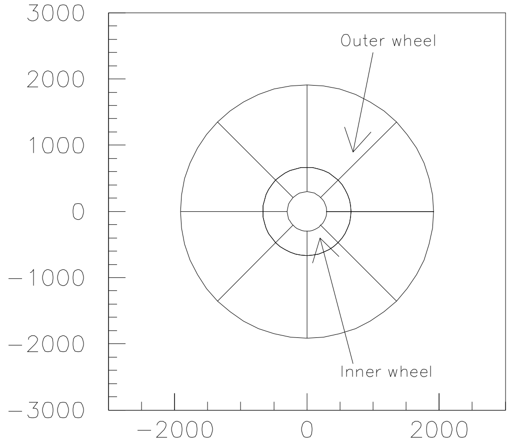

Figure 1 : Endcap wedges 1 to 8

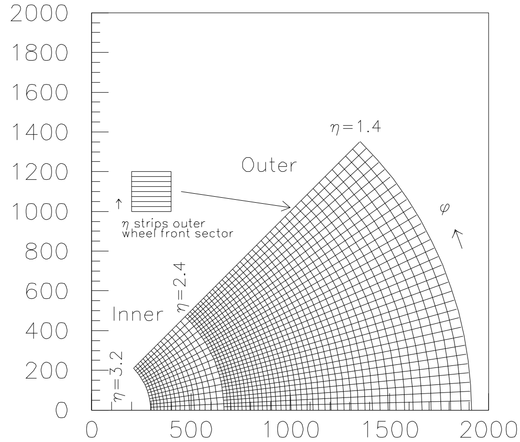

Figure 2 : Elementary cells per wedge

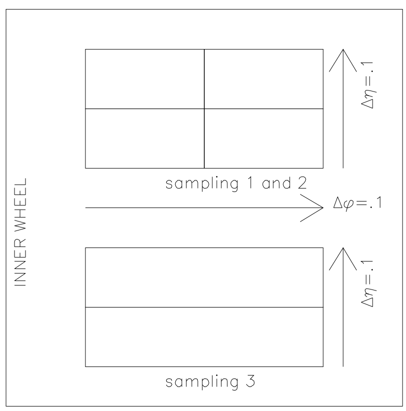

Figure 3 : Number of cells/trigger tower

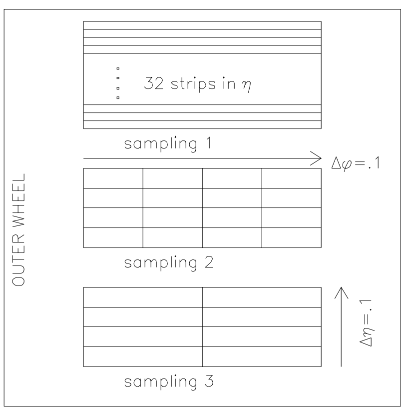

Figure 4 : Number of cells/trigger tower

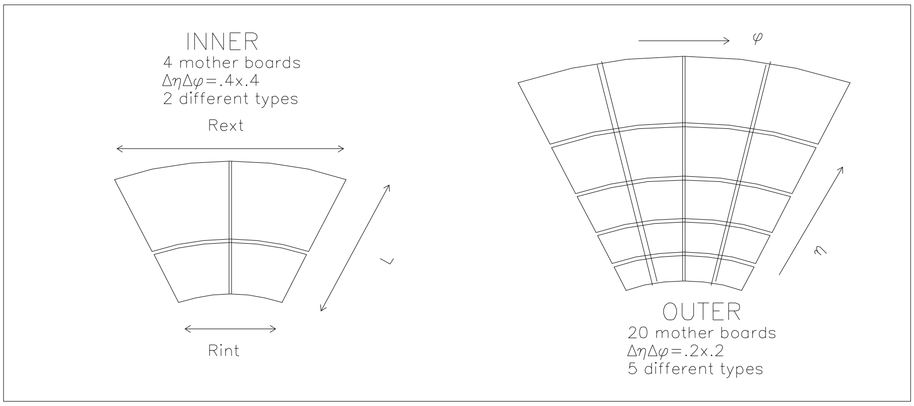

Figure 5 : Endcap mother board distribution for both inner and outer wheels

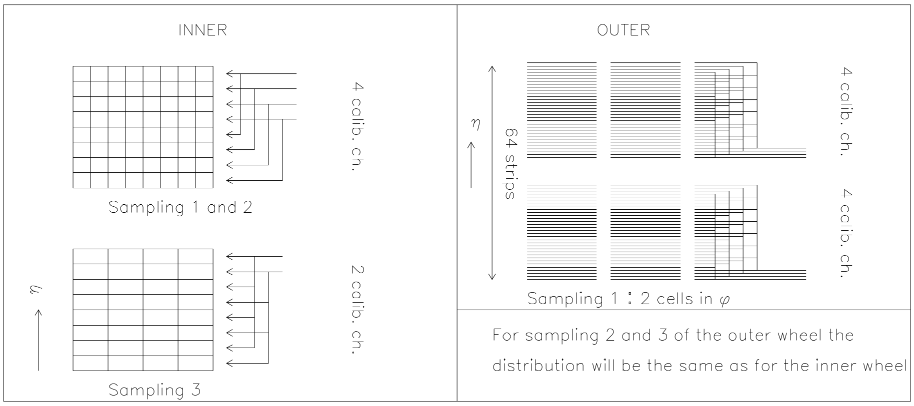

Figure 6 : Endcap calibration distribution per MB for both wheels

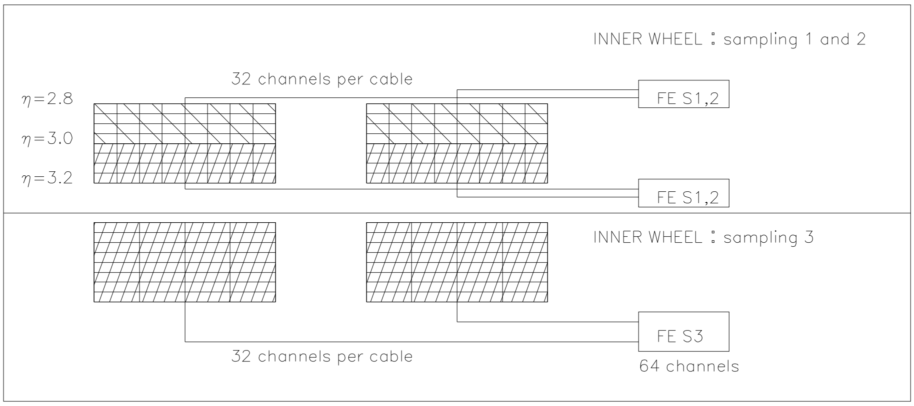

Fig 7 : Front end distribution on 1/2 a wedge (2 PCBs) of the inner wheel

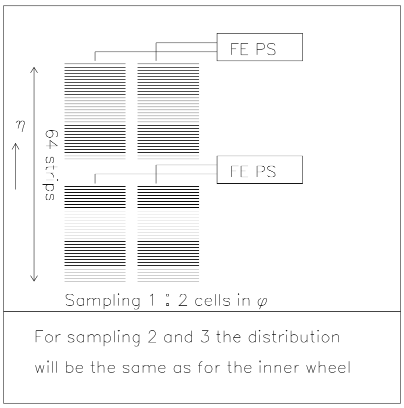

Figure 8 : Front end distr. of outer wheel