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Material between the presampler and the EMB module 0

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Abstract

This note presents an evaluation of the amount of material located between the presampler and the ℓAr electromagnetic barrel module 0. After a study concerning the level of accuracy to which the material has to be described, the amount of material due to the mother boards and the cables is evaluated. The hardware used in the barrel module 0 in august 2000 test beam is in principle similar to the final setup. So the present computation should hold for the final calorimeter.

1 Introduction

In the detailed Monte Carlo, based on GEANT [1], describing the ℓAr electromagnetic barrel module 0, the material located after the presampler detector and the beginning of the accordion calorimeter, called PStoCALO material in the following, has been so far described as an homogeneous medium. This medium is shaped as a tube located between the radii 1447mm and 1470mm and made of a mixture of ℓAr and polyethylene. The distribution of the amount of material in the calorimeter [2] as a function of η can be found in Figure 1. In reality the PStoCALO space is filled with cables, front summing boards and mother boards, some G10-like pieces (plates and inner rings) and the rest completed with ℓAr.

Looking in more details, there are small metallic pieces at various places (e.g. pins in the summing boards). It is then interesting to know to what level of accuracy the description of the material needs to be pushed. This is done in section 2. Then the description of the geometry of the PStoCALO material is given in section 3, followed by an estimate of the motherboard material in section 4, and of the front cables (section 5). A summary describing how the material should be implemented in the Monte Carlo is can be found in section 7.

2 Detail of the description

The level of detail for the description of the amount of PStoCALO material is estimated in the following way. Let us consider one η value. The total energy accessible in the active parts of the calorimeter is $E_{\mathrm{tot}} = E_{\mathrm{presampler}} + E_{\mathrm{front}} + E_{\mathrm{middle}} + E_{\mathrm{back}}$. When the amount of PStoCALO material is varied by ΔX_0 the total energy E_{tot} varies by ΔE_{tot}. This non uniformity expressed as a relative variation $\Delta E_{\mathrm{tot}}/E_{\mathrm{tot}}$ has to be kept below a certain level, small compared to the expected response uniformity of 0.5%. A level of 0.2% is chosen as a reference (small in quadrature compared to 0.5%). The number of ΔX_0 determined in this way corresponds to the quantity of material along the incoming particle. But the material present in the calorimeter has a cylindrical geometry. It then is useful to define $X_0^{\perp} = X_0/\mathrm{ch}(\eta)$ which corresponds to the amount of material orthogonal to the wall of the cryostat.

The longitudinal energy profile is computed according to the formula found in [3]:

$$\frac{dE}{dt} = E_{\mathrm{beam}} b^{\alpha+1} \frac{t^{\alpha} e^{-bt}}{,\ (\alpha+1)}$$

with $b = 0.5$, $t = x/X_0$, $\alpha = b(ln(E_{\mathrm{beam}} Z_{Pb}/E_c) - 1)$ and $E_c = 0.55$ GeV.

At a given η the X_0 boundaries of the layers are taken from Figure 1. For a given E_{beam} the amount of PStoCALO material is varied and the energy accessible to measurement in the calorimeter, i.e. $E_{\mathrm{presampler}} + E_{\mathrm{front}} + E_{\mathrm{middle}} + E_{\mathrm{back}}$, is computed using the above longitudinal formula.

Figure 2 shows for $E_{\mathrm{beam}} = 50$ GeV and $\eta = 0.14$ what is the acceptable precision on X_0 or $X_0^{\perp}$ for a given relative precision on E_{tot}. For example, for a precision on E_{tot} of 0.2% the amount of PStoCALO material has to be precise up to 0.4 $X_0^{\perp}$.

Similarly the same computations are performed at $\eta = 1.2$ and shown in Figure 3. Now for the same precision on E_{tot} of 0.2% the maximum variation on PStoCALO material is $0.04 X_0^{\perp}$. For a precision on E_{tot} of 0.5% the maximum variation on PStoCALO material is $0.1 X_0^{\perp}$. The precision in the description at higher η has therefore to be higher, as more energy is lost in the material in front of the presampler (polar angle effect). An other way of saying it is that the higher the energy lost in front of the active part, the worse the resolution.

Figure 4 shows the maximum variation of X_0 and $X_0^{\perp}$ as function of η for $E_{\rm beam} = 50;$GeV and a precision on $E_{\rm tot}$ of 0.2%. This confirms that the description of the material has to be more accurate at larger rapidity. It also provides a guide about how precise should be our description of the material function of η.

Finally at $\eta = 1.2$ and for a precision of 0.2% on $E_{\rm tot}$ Figure 5 shows the dependency with $E_{\rm beam}$. As the showers are shorter at low energy, the description has to be more accurate, as more energy is lost in relative at the beginning of the shower.

In conclusion, we keep as a guideline that the description of the PStoCALO material has to be better that 0.04 $X_0^{\perp}$ in order to give a variation of the energy deposited in the active part of the calorimeter less than 0.2% (assuming $E_{\rm beam} = 50$ GeV and a large rapidity $\eta = 1.2$). Note that this is a strong limit (established at large η).

3 Geometry of the PStoCALO material

A cut view of the calorimeter in the (R-ϕ) plane is shown on figure 6. It shows half a module in ϕ. Just beyond the radius R=1470.8mm are the 32 inner G10 bars. The electrodes are between two absorbers. It results that the active cells are shifted by $2\pi/2048$ in ϕ relatively to the standard local frame attached to the module (this frame is described in [4]) and drawn in Figure 6). The boundaries in ϕ of a cell described by n_ϕ in the EMTB system is then:

$$\begin{aligned}\phi_{min} &= (n_\phi - 8)\frac{2\pi}{256} + \frac{2\pi}{2048} \\ \phi_{max} &= \phi_{min} + \frac{2\pi}{256}\end{aligned}$$

The range $\phi \in [0, 2\pi/32]$ can be divided into three successive zones in ϕ, filled with cables, motherboard and cables again.

The front motherboard have a half-width of 36.15mm in the ϕ direction [5]. Sitting at a radius of R= 1465.9mm to take into account the summing boards are various shrouds (plastic pieces around the pins), it covers an angle of $\arcsin(36.15/1465.9) = 0.0247$rad. Expressed in middle cell unit (m.c.u.) in ϕ it corresponds to $\arcsin(36.15/1465.9)/(2\pi/256) = 1.005$ m.c.u. as shown in Figure 6. To a good approximation the cells $n_\phi = 11$ and $n_\phi = 12$ are behind the motherboards, when the others are behind the front cables.

4 Material due to the motherboards

In order to evaluate the amount of material in a front motherboard the following method is used. The motherboard is assumed to be made of copper and G10. The volume and the weight of the board are measured. Knowing the densities of the copper and G10, one can estimate the effective thicknesses for copper and G10.

One motherboards sizes $0.43 \times 7.23 \times 25.65\text{cm}^3$ and weighs 220g according to [5]. This gives effective thicknesses

$$\begin{aligned}e_{\rm Cu} &= 0.63 \text{ mm} \\ e_{\rm G10} &= 3.67 \text{ mm}\end{aligned}$$

As a crosscheck an other motherboard is measured: it sizes $0.43 \times 7.23 \times 38.5\text{cm}^3$ and weighs 325g (again according to [5]). This gives effective thicknesses and amount of material:

		thickness	$X_0^\perp$
$e_{\rm Cu}$	=	0.6 mm	0.042
$e_{\rm G10}$	=	3.7 mm	0.019
total		4.3 mm	0.061

(It is taken here $1X_0(\mathrm{Cu}) \equiv 14.3$mm, $1X_0(\ell\mathrm{Ar}) \equiv 140$mm, $1X_0(\mathrm{G10}) \equiv 194$mm.)
The $0.061X_0^\perp$ total had to be compared to 0.031 $X_0^\perp$ corresponding to 0.43 cm of ℓAr (in places where there is no motherboard). The variation between the motherboard and the ℓAr is 0.03, lower than $0.04X_0^\perp$ quoted in section 2. Furthermore one can ignore the interval in η between the front motherboards in the description, especially at small rapidity and describe the presence of the motherboards as a continuous parallelepipedic volume.

5 Material due to the cables

In the space between the presampler and the calorimeter are running mainly strip readout cables plus some extra cables that can be neglected due to the huge number of strips. The strip readout cables are 50Ω kapton and copper cables with the following characteristics according to [6]:

object	material	geometry
conductor	Cu	section = 0.0324 mm^2
braid	Cu	section = 0.1496 mm^2
cable	Cu+kapton	diameter = 1.2 mm

At a given η in the plane (η, ϕ) two bunches of cables are running as drawn in Figure 6. These cables are those coming from all the strips located in $[0, \eta]$. Up to the detail of the connection on the motherboards it is assumed that the number of cables in each side on the motherboard is 320η. (Because this number varies linearly with η and there are 320 strips between $\eta = 0$ and $\eta = 1$.) These cables are spread in the $R - \phi$ dimension between the edge of the half-module and the motherboard. This space intercepts an azimuthal angle of $\Delta\phi = 2\pi/64 - \arcsin(36.15/1465.9)$ corresponding to a size of 10.8 cm.

Looking in more detail how the front cables run in this region (please have a look to pictures on the ℓAr WEB page about the cabling of the front face), it is clear that they don't cover the full 10.8 cm in $R - \phi$, especially at low rapidity. At higher rapidity the cables are quite squeezed, giving a more homogeneous repartition, but are very squeezed when they cross an inner ring region. Nevertheless it will be assumed in the following computation that all the cables spread regularly on a given $R - \phi$ width of $L = 7$ cm. As the position of the cable is not known better that 1 cm, a $10 - 20\%$ error can be applied to the final result.

According to Ref. 5 each cable is equivalent to 0.182 mm^2 of Cu. The cable section is $\pi 1.2^2/4 = 1.131$ mm^2, then the kapton section is 0.949 mm^2. Therefore on the width L the cables are equivalent to the thicknesses:

$$\begin{aligned} E_{\rm Cu} &= 320\ \eta \times 0.182\ \mathrm{mm}^2/\mathrm{L} \\ E_{\rm kapton} &= 320\ \eta \times 0.949\ \mathrm{mm}^2/\mathrm{L} \end{aligned}$$

replacing a ℓAr thickness of $E_{\rm lAr} = 320\eta \times \pi 1.2^2/4\ \mathrm{mm}^2/\mathrm{L}$.
This corresponds to amounts of material of

material	thickness	$X_0^\perp$
Cu	0.83η mm	0.058η
kapton	4.34η mm	0.015η
total	5.17η mm	0.073η

taking $1X_0$(kapton) $\equiv$ 286mm.
The 0.073η $X_0^\perp$ replaces 0.037η $X_0^\perp$ of ℓAr.

In Figure 7 are plotted the amount of material X_0 and $X_0^\perp$ due to the cables as explained above. $X_0^\perp$ variation is 0.1 over the η range. Therefore the description of the cable has to be put in the Monte Carlo in order to guarantee the level of precision quoted in section 2.

6 Going into more details

The effect due other materials, e.g. summing boards and pins in summing boards can also be investigated.

Let's take the case of the pins on the summing boards. Herafter $(x, y, z) \equiv (R, \phi, \eta)$ is the local frame from [4]. The copper pins in the summing boards size $10 \times 0.8 \times 0.8\text{mm}^3$. They are spaced by $\Delta z = 2.54$mm and $\Delta y = 2\pi 1470.8/1024 = 9$mm. Trying to describe the presence of these pins as an average medium, one can say that in the volume $v = 10 \times 9 \times 2.54\text{mm}^3$ there is on pin of volume $v_{\text{pin}} = 10 \times 0.8 \times 0.8\text{mm}^3$. This amount of copper has to be spread on the surface $9 \times 2.54\text{mm}^2$. This gives equivalent thicknesses of copper and ℓAr:

			thickness	$X_0^\perp$
With pins:	e_{Cu}	=	0.28 mm	0.02
	e_{lAr}	=	9.72 mm	0.07
	together		10 mm	0.09
without pins:	e_{lAr}	=	10 mm	0.07

The variation is $\Delta X_0^\perp = 0.02$ and is smaller than $0.04 X_0^\perp$. Nevertheless the spacial distribution of the pins is not random. They are organized along ligns parallel to the ATLAS beam line. This should contribute to a non uniformity in ϕ with a periocicity of $2\pi/1024$. According to our understanding of the ϕ unformity from the test beam we cannot yet say anything relevant. Therefore we can ignore at present this amount of material.

7 What's to be put in the Monte Carlo

Finally the description of the PStoCALO material in the Monte Carlo can be the following. The cylinder described in section 1 defined by $R \in [1447, 1470]$mm has to be filled with :

- In the zone $\{(\eta, \phi), \phi \in [2\pi/64 - 0.0247, 2\pi/64 + 0.0247]\}$ the amount of material can be described by 0.6 mm of Cu, 3.7 mm of G10 and 18.7 mm of ℓAr.
- In the zone $\{(\eta, \phi), \phi \in [0, 2\pi/32] \setminus [2\pi/64 - 0.0247, 2\pi/64 + 0.0247]\}$ the amount of material can be described by 0.83η mm of Cu, 4.34η mm of kapton and $23 - 5.17\eta$ mm of ℓAr.

This medium can of course be modelled by an average X_0 fictive material in the Monte Carlo.

References

[1] *GEANT: Detector description and simulation tool*, CERN program libray long write-up W5013, Application software group, IT division, CERN.

[2] From Gaston Parrour.

[3] Fabjan's review in *Experimental techniques in high energy physics*, ed. by T. Ferbel, Addison-Wesley 1987.

[4] J. Colas et al., *Cabling of EM calorimeters*
ftp lapphp.in2p3.fr
user anonymous
cd /pub/atlas/cabling
get EMMapping.ps

[5] My personnal measurements.

[6] P. Cornebise, private communication

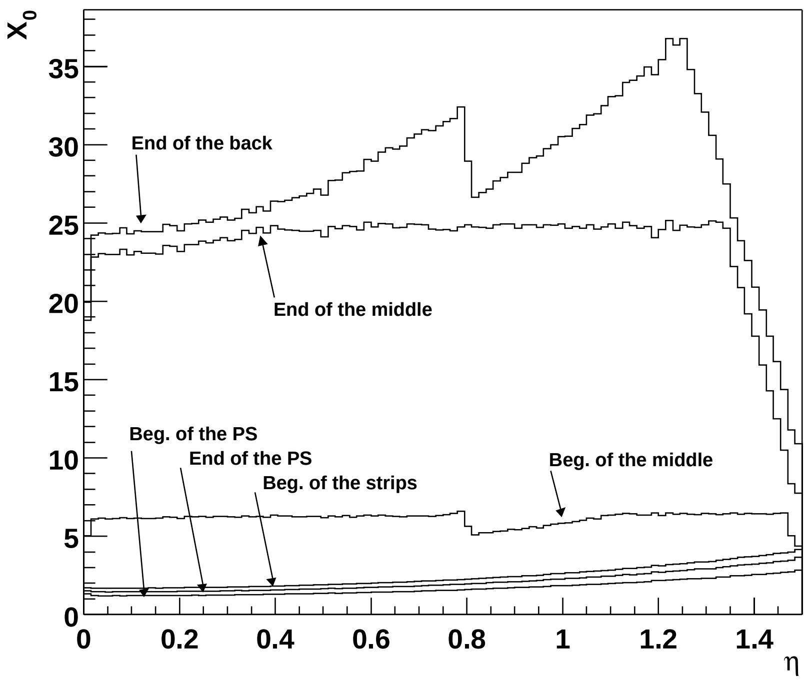

Figure 1: Limits of the various compartments of the EMB module function of η.

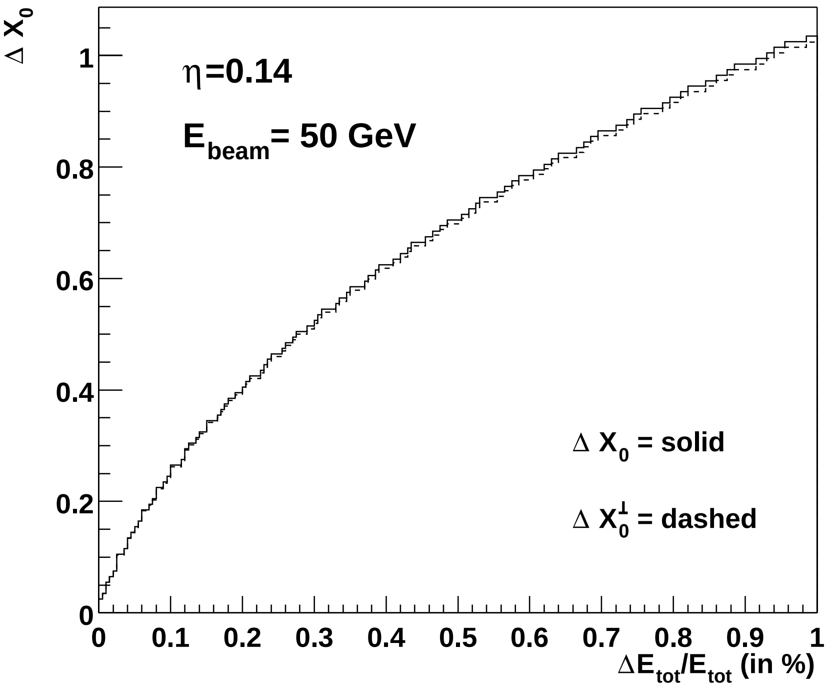

Figure 2: Maximum variation ΔX_0 between the presampler and the strips as function of the desired precision on $E_{\rm tot}$, for $E_{\rm beam} = 50{\rm GeV}$ and $\eta = 0.14$.

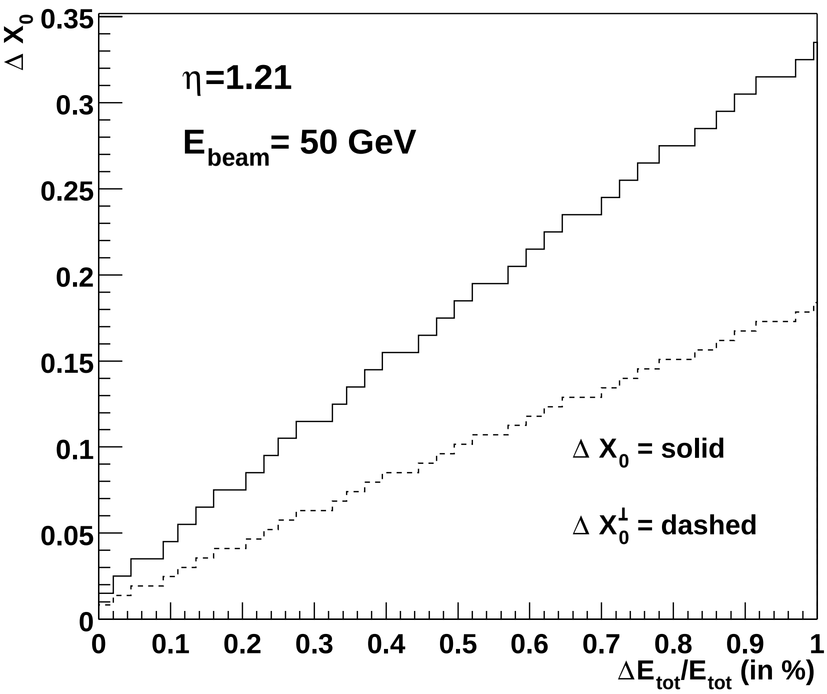

Figure 3: Maximum variation ΔX_0 between the presampler and the strips as function of the desired precision on $E_{\rm tot}$, for $E_{\rm beam} = 50{\rm GeV}$ and $\eta = 1.21$.

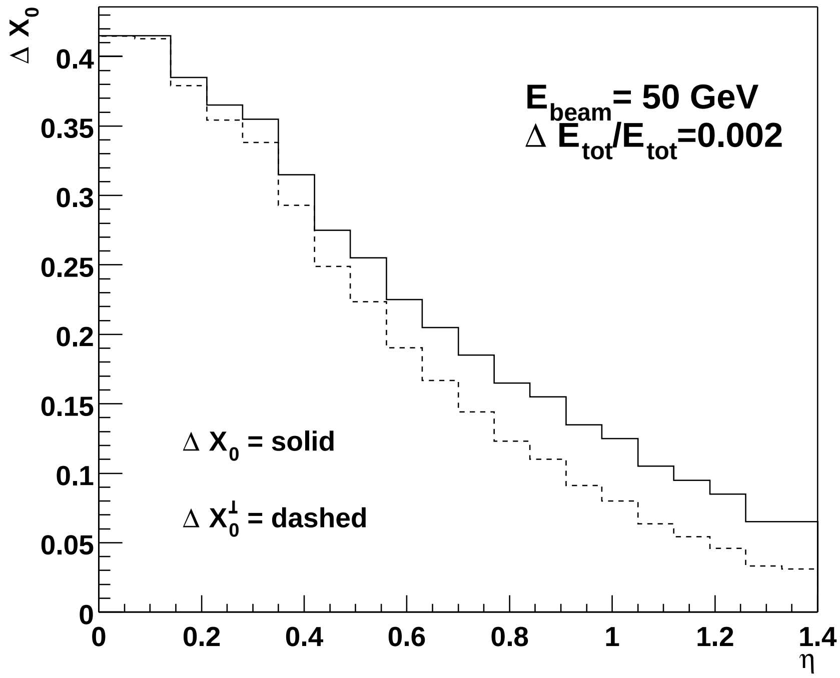

Figure 4: Maximum variation ΔX_0 between the presampler and the strips as function of η, for $E_{\rm beam} = 50{\rm GeV}$ and a precision on $E_{\rm tot}$ of 0.2%.

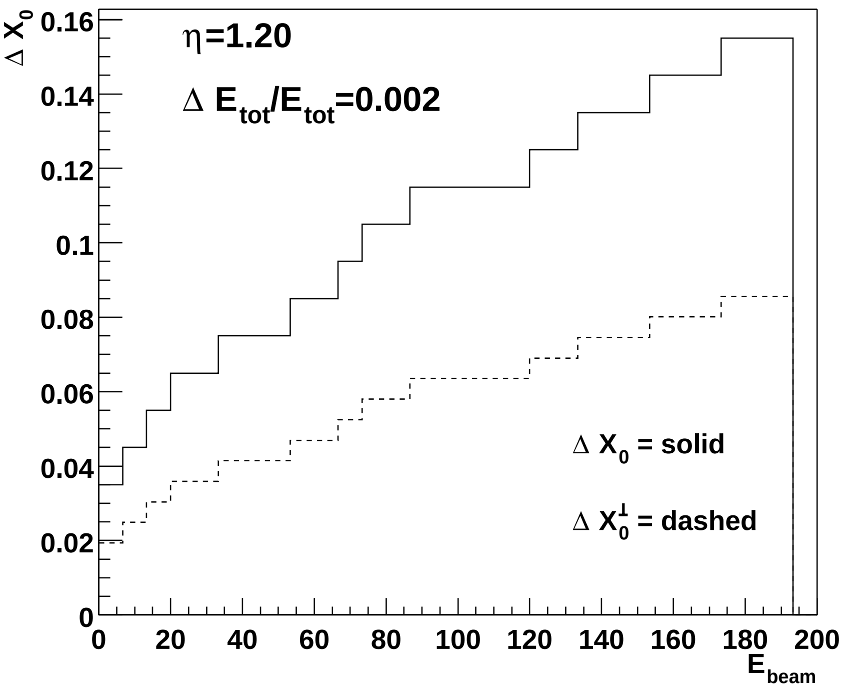

Figure 5: Maximum variation ΔX_0 between the presampler and the strips as function of $E_{\rm beam}$, for $\eta = 1.20$ and a precision $\Delta E_{\rm tot}/E_{\rm tot} = 0.2\%$.

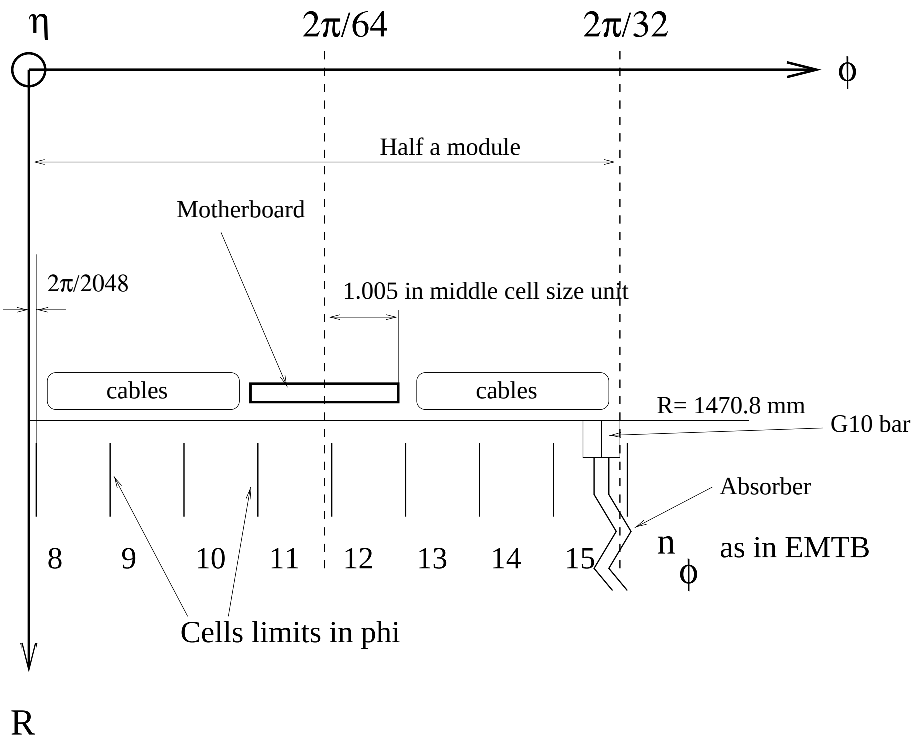

Figure 6: This Figure shows the distribution of material between the presampler and the strips in the ϕ dimension, for half a module.

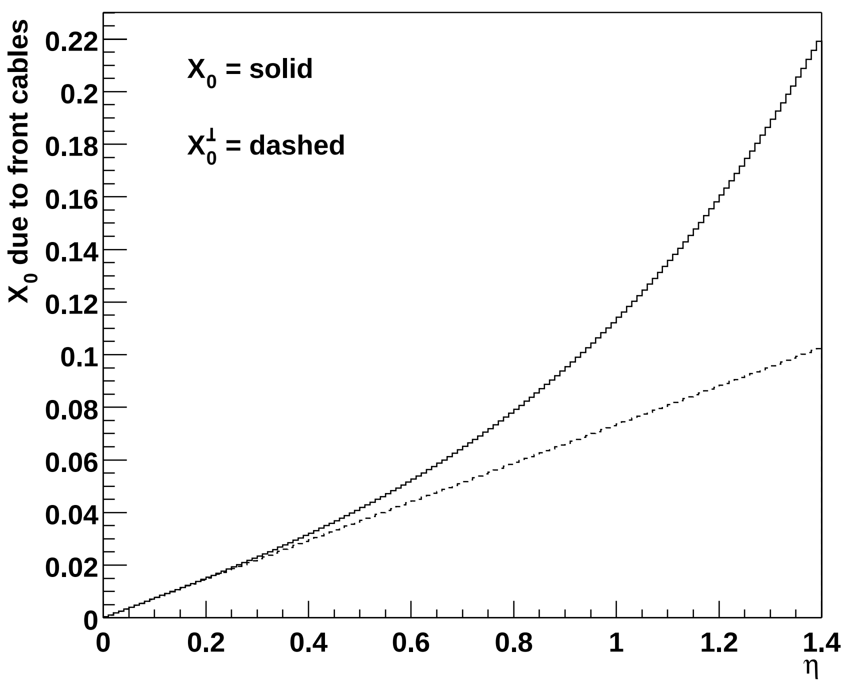

Figure 7: This Figure shows the amount of material to be added in the Monte Carlo as function of η (dashed line or $X_0^{\perp}$) and the effect taking into account $cos\theta$ (solid line).