Figure 19 shows which effect Dilu as over the η distribution. We observe that as Dilu increases, the value $|\eta|$ decreases (the plot in black “squeeze”). This can be explain as follow. As Dilu increases, the proportion of light that cross the aluminum plate increases which implies that the difference between the E_{up} and E_{down} decreases. In other words, higher is Dilu, the worst is our measurement of the energy asymmetry between the two calorimeters.

We are now in measure to explain the behavior of the graphs of figure 15. As Dilu increases, $|\eta|$ decreases, which mean by equation 5 that the AP decreases. Similarly, as Dilu increases, $|\eta|$ decreases, implies that RMS of η decreases, which mean by equation 6 that the focus decreases[16].

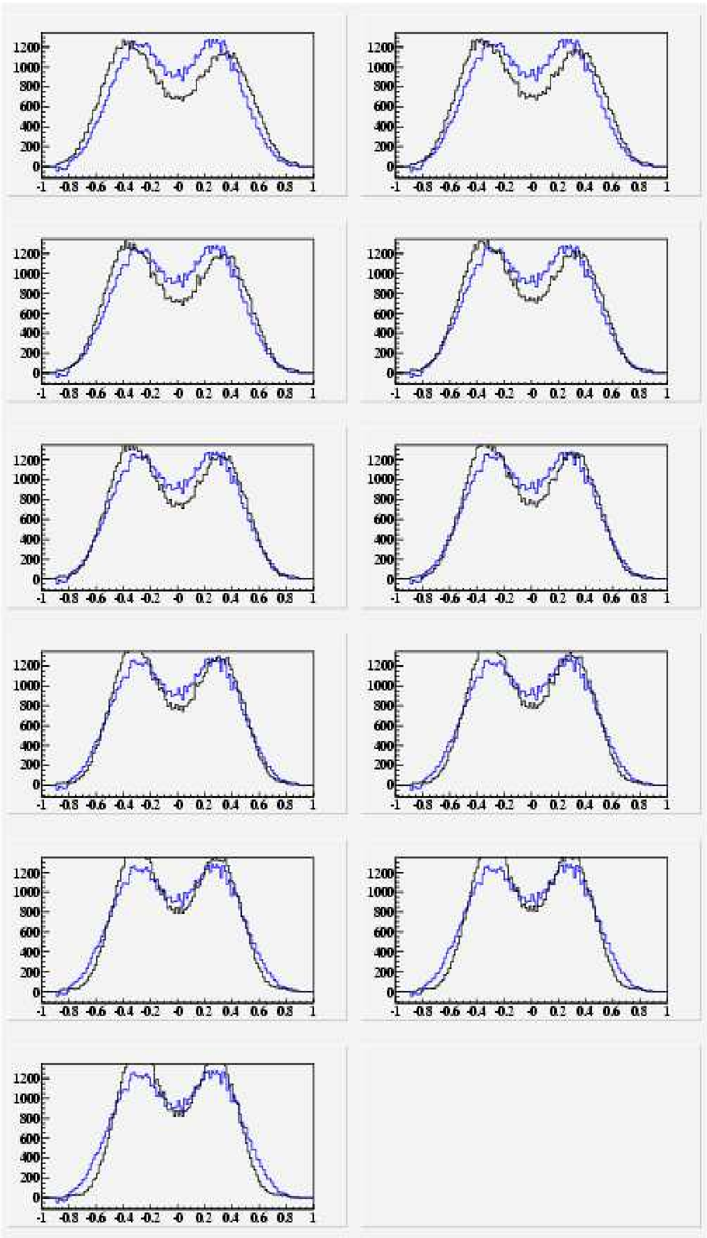

Figure 19: Plots of the η distribution (# of events vs η) for different values of Dilu. In black are the MC data and in blue are the data taken from the real TPOL polarimeter. The upper-left graph shows MC data for Dilu = 0. From left to right the value of Dilu increases of 0.01. For all the plot Difu = 0.6 and Phot = 15000 photons/GeV. Notice also that the MC histogram are normalized to have the same amount of events than the real distribution (blue).

16 This last observation means that the physical representation of the focus in mm (figure 6) should not be taken too seriously. The way it is defined, there is not only the size of the Compton beam that affect it.

6.3.2-Difu parameter

The figure 20 shows the energy distribution (eud = $E_{up} + E_{down}$) for different values of Difu [0, 0.9] and fixed Dilu and Phot. We observe that the value of eud increases as Difu increases. This phenomena can be explain as follow. Most of the photons/showers[17] hit the calorimeter around y=0. It implies that a fair amount of the created photons in the scintillators plates are simulated to go in the aluminum plate. On the other hand, as Difu increases, we simulate a larger proportion of hits as if they come from the center of the up or down calorimeter (figure 7). This has for consequence to reduce the proportion of photons that are simulated to end up in the aluminum plate. Since the photons that end in the aluminum plate are consider to be lost (with small fraction that cross); the energy lost decreases as Difu increases. That is, as Difu increases, eud increases.

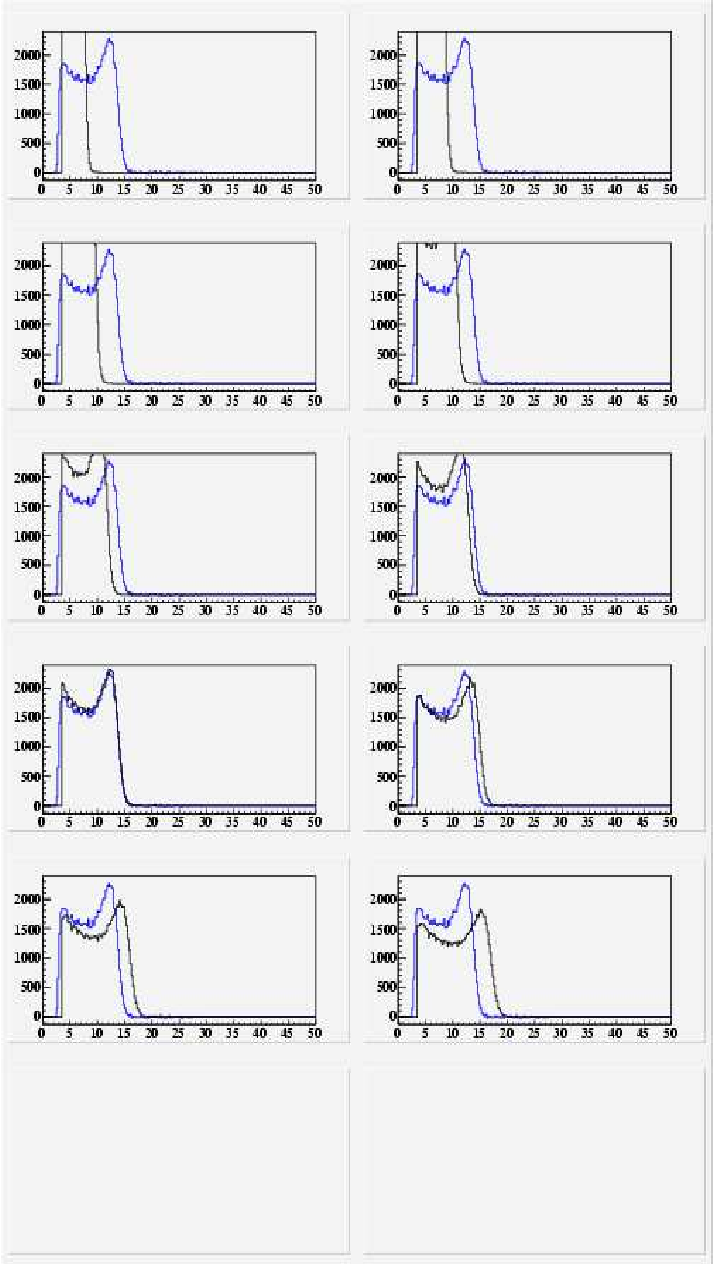

Figure 20: Plots of the energy distribution (# of events vs eud) for different values of Difu. In black are the MC data and in blue are the data taken from the real TPOL polarimeter. The upper-left graph show MC data for Difu = 0. From left to right the value of Difu increases of 0.1. For all the plot Dilu = 0.04 and Phot = 15000 photons/GeV. Notice also that the MC histogram are normalized to have the same amount of events than the real distribution (blue).

17 We refers to “photons/showers” since it depends whether the photon converted or not in the converter.

Figure 21 shows which effect Difu has over the η distribution. We observe that as Difu increases, $|\eta|$ increases. This could be understood as follow. If Difu increases, there is less photons that goes in the aluminum plate, which implies that there is less photons that cross between the two calorimeters. As explained for Dilu, less dilution make $|\eta|$ increases. That is, as Difu increases; $|\eta|$ increases. However, the dilution trough the aluminum plate is not the principal explanation for the behavior of $|\eta|$. We will elaborate on the subject later.

We can now try to explain the graphs of figure 16. As Difu increases, $|\eta|$ increases which implies that AP increases and the focus increases. This unfortunately doesn't explain why AP starts to decreases after Difu = 0.7. The retained explanation is that as Difu increases, eud increases. Since the cut eud is fixed; we accept “different” events. In the next section we will see how it impact the AP and focus.

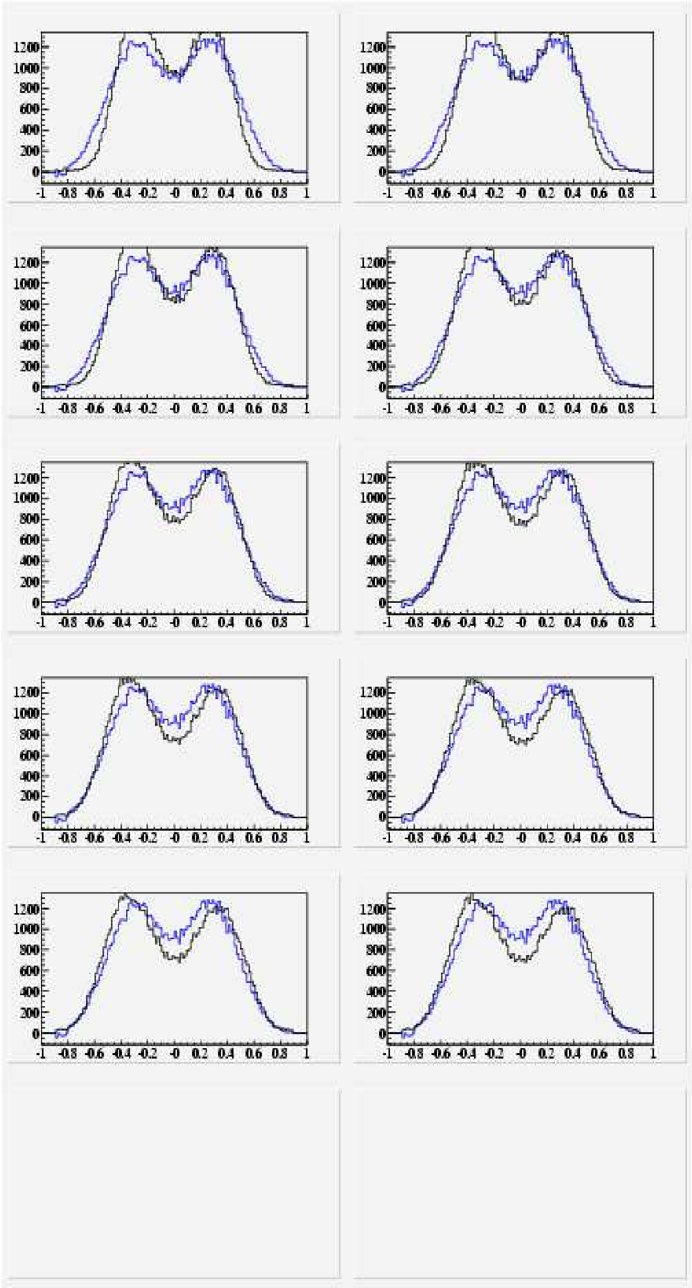

Figure 21: Plots of the η distribution (# of events vs η) for different values of Difu. In black are the MC data and in blue are the data taken from the real TPOL polarimeter. The upper-left graph show MC data for Difu = 0. From left to right the value of Difu increases of 0.1. For all the plot Dilu = 0.04 and Phot = 15000 photons/GeV. Notice also that the MC histograms are normalized to have the same amount of events than the real distribution (blue).

6.3.3-Phot parameter

The figure 22 shows the energy distribution (eud = $E_{up} + E_{down}$) for different values of Phot. As expected, when Phot increases; eud increases. This is obviously a consequence that the gain on each channels (side) is fixed. Thus, if we simulate more photons created by GeV, we of course increase the total energy detected by event.

The figure 23 shows the effect of the parameter Phot over the η distribution. We observe that $|\eta|$ increases as Phot increases. To understand this fact, we need figure 24 which shows the 2-D histogram of eud vs η[18]. We observe that when we increases Phot, we have a similar histogram, but spread over larger value of eud. We observe also that for low eud, η has a large spread ($|\eta|$ is large). On the other hand, when eud is high, the spread of eta “squeeze” ($|\eta|$ is small). Since we used the fixed energy cut

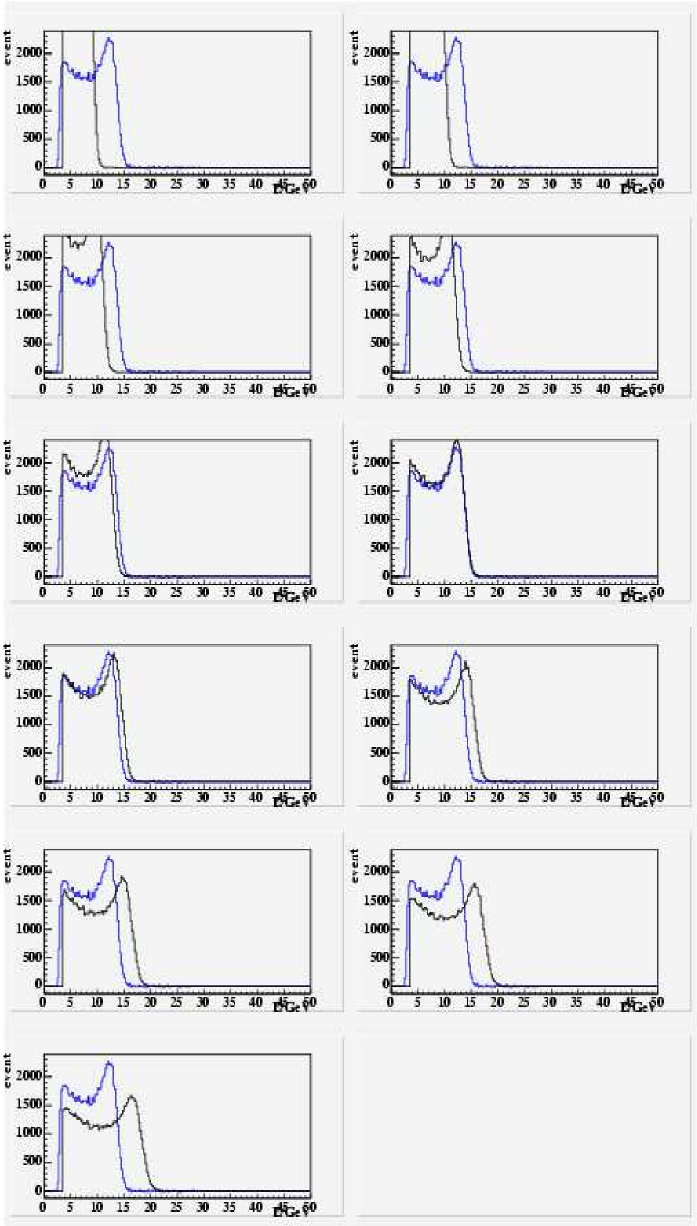

Figure 22: Plots of the energy distribution (# of events vs eud) for different values of Phot. In black are the MC data and in blue are the data taken from the real TPOL polarimeter. The upper-left graph show MC data for Phot = 10 000 photons/GeV. From left to right the value of Phot increases of 1 000 photons/GeV. For all the plot Dilu = 0.04 and Difu = 0.6. Notice also that the MC histogram are normalized to have the same amount of events than the real distribution (blue).

18 This is the same histogram used for the fitting of the off-line analysis.

eud > 3.5 GeV, we lose more events with $|\eta|$ large when Phot is low. That is, as Phot increases, $|\eta|$ increases. It must be understood, that this is only a consequence of the method used, and Phot has no real influence over η.

The behavior of the graph of AP vs Phot (figure 17) is also a consequence of the energy cut: equation 5 [5.225 GeV< eud < 11.4 GeV]. Clearly, the section we use in the 2-D histogram of eud vs η to calculate AP is not the same when eud spreads which implies that the η distribution is also not the same. We can thus explain the behavior of the AP vs Phot as followed. When we start to increase Phot, we accept more events with large $|\eta|$, which implies that the AP increases. However, if we keep increasing Phot, the upper bound of the energy cut starts to have an impact and we start to lose events with high energy. It will be explain later that has for consequence to lose sensibility between the left and right helicity of the photons. AP thus start to decreases. Finally,

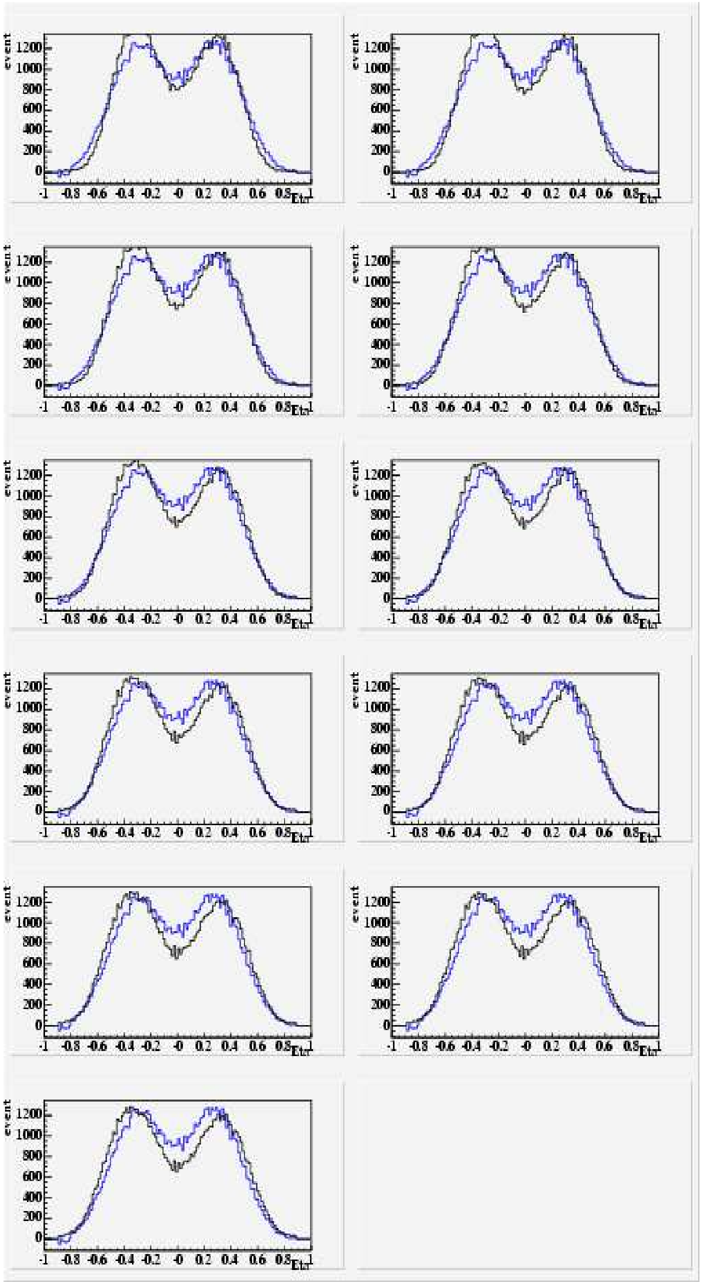

Figure 23: Plot of the η distribution (# of events vs η) for different values of Phot. In black are the MC data and in blue are the data taken from the real TPOL polarimeter. The upper-left graph show MC data for Phot = 10 000 photons/GeV. From left to right the value of Phot increases of 1 000 photons/GeV. For all the plot Dilu = 0.04 and Difu = 0.6. Notice also that the MC histogram are normalized to have the same amount of events than the real distribution (blue).

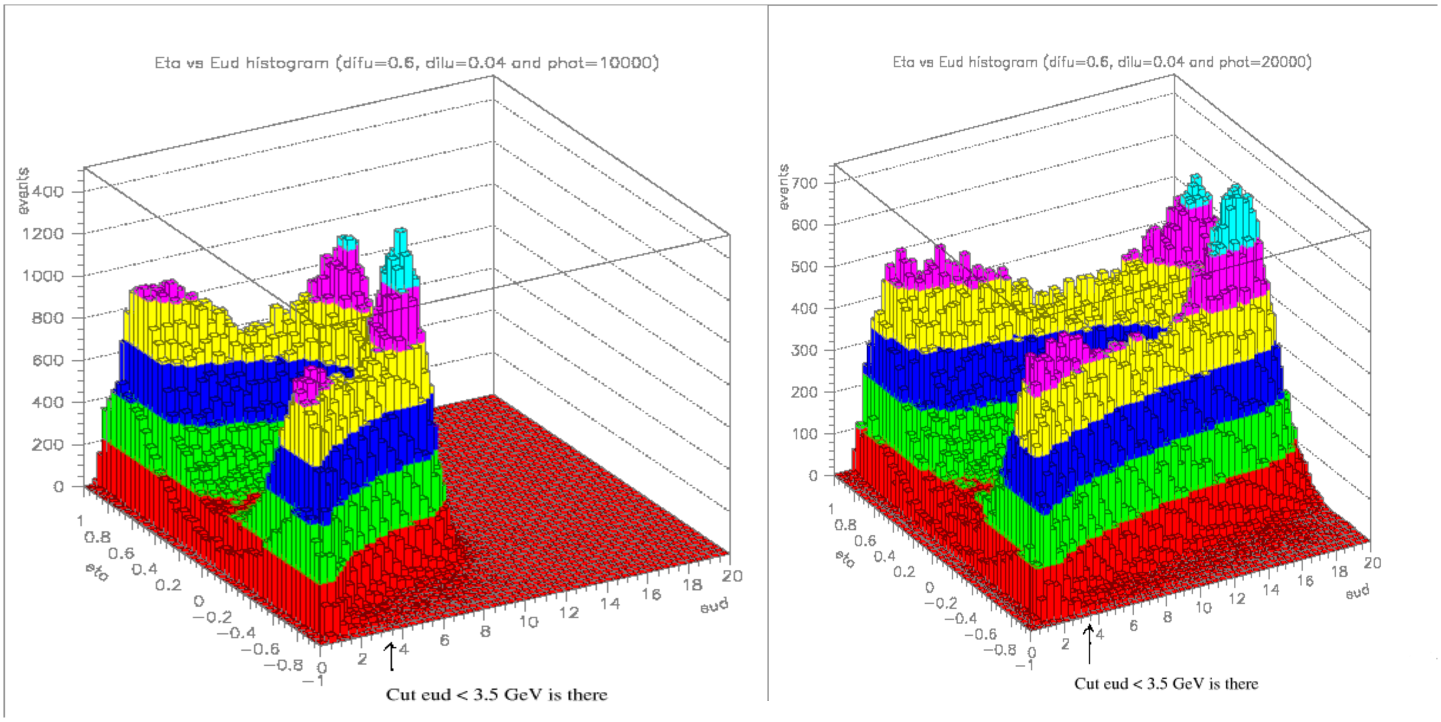

Figure 24: Simulation of the eud vs η histogram for Phot = 10 000 photons/GeV (left graph) and for phot = 20 000 photons/GeV (right graph). Difu and Dilu are fixed at 0.6 and 0.04 respectively. Both simulations have the same amount of events simulated.

the focus should always increases, since $|\eta|$ increases as Phot increases[19]. However, we see on figure 17 that the focus decreases as Phot increases, for low values of Phot (first part of the right graph). On the other hand, the error on these values is huge. If we look at the eud vs η histogram for Phot = 10 000 photons/GeV, we observe that there is extremely few events in the energy cut range of the equation 6: [11.4 GeV < E < 13.775 GeV]. That explain, firstly the large error, and secondly, why we should not trust these values at all. We conclude that there is a linear correlation between the focus and the parameter Phot with slope = (2.45 $\pm$ 0.04) E-5 mm/photons/GeV.

Since Difu also has a strong influence on eud, we should expect the see the same influence on the histograms of eud vs η than Phot has. This is confirmed by figure 25.

19 Notice by equation 6 that the focus is not really influenced by the difference between the η distribution of the photons with left helicity and the photons with right helicity, since we don't take the difference, but the sum of the root means squares. Ex: if the η distributions for the left and right helicity are the exact same: AP = 0 and the focus is not 0.

This is the most probable explanation for the strong similitude of the AP and focus dependence from the Difu and Phot parameters (figure 16 and 17): the behavior of the AP and focus is due to the strong influence that Difu and Phot have on eud. We thus specify, that there is most probably a linear correlation between the focus and the Difu parameter with slope = (0.297 ± 0.005) mm.

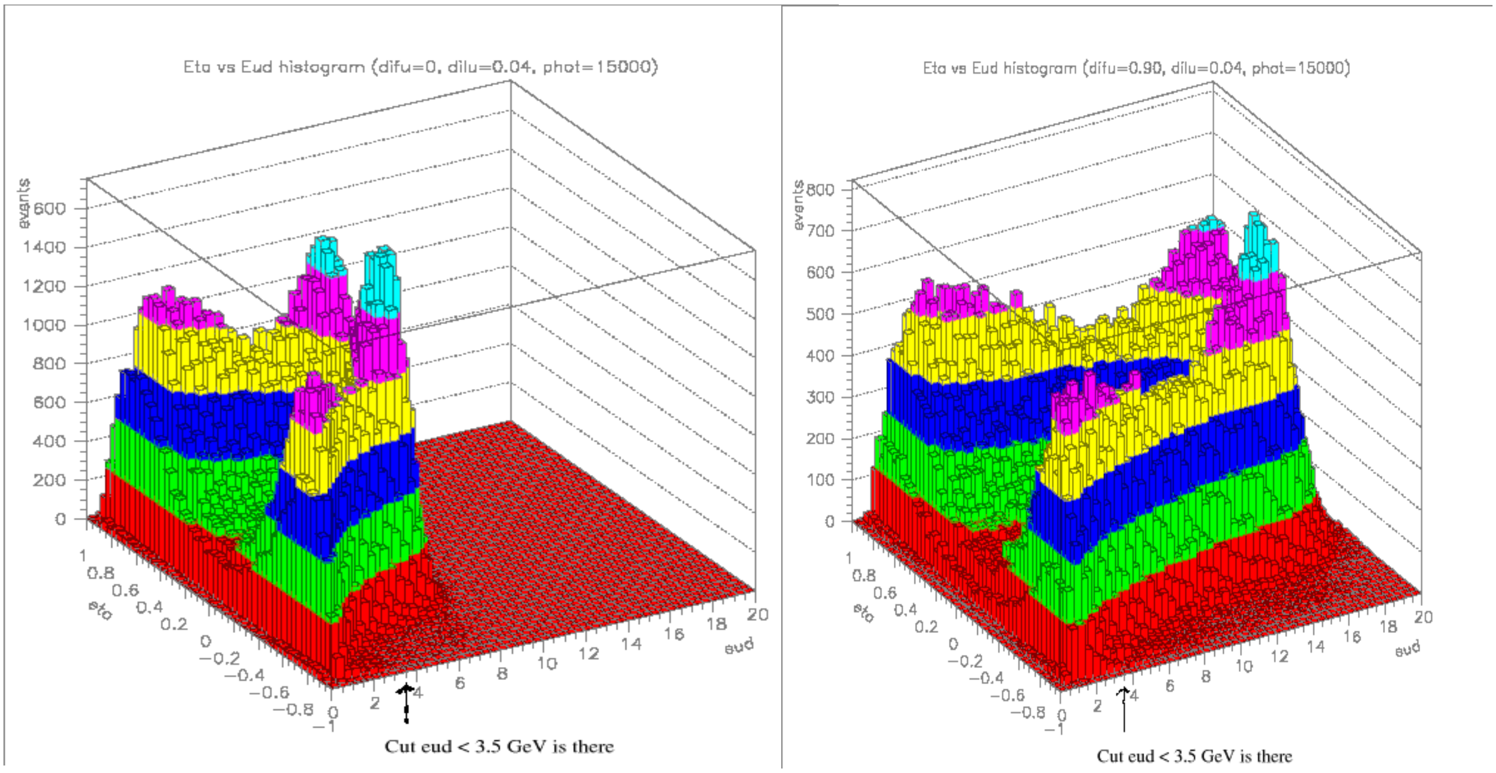

Figure 25: Simulation of the eud vs η histogram for Difu = 0.0 (left graph) and for Difu = 0.9 (right graph). Phot and Dilu are fixed at 15 000 photons/GeV and 0.04 respectively. Both simulations have the same amount of events simulated.

Moreover, figure 26 demonstrate clearly that the parameters Difu and Phot have no significant “direct”[20] influence over η. We observe that the histogram for the combination (0, 4, 10 000)[21] has the exact same shape than the histogram for the combination (90, 4, 20 000) when we don't use energy cut and after we have rescale the energy. This would not be the case if either Difu or Phot would have a direct influence over η. Notice that we checked the possibility that Difu and

20 By direct, we mean that their influence is not a direct consequence of their influence on eud.

21 For now on, we will use this notation to refer to a given combination of the parameters Difu, Dilu and Phot: (Difu in %, Dilu in %, Phot in photons/GeV).

Phot affect η in such a way that the effect canceled and we found that this was not the case.

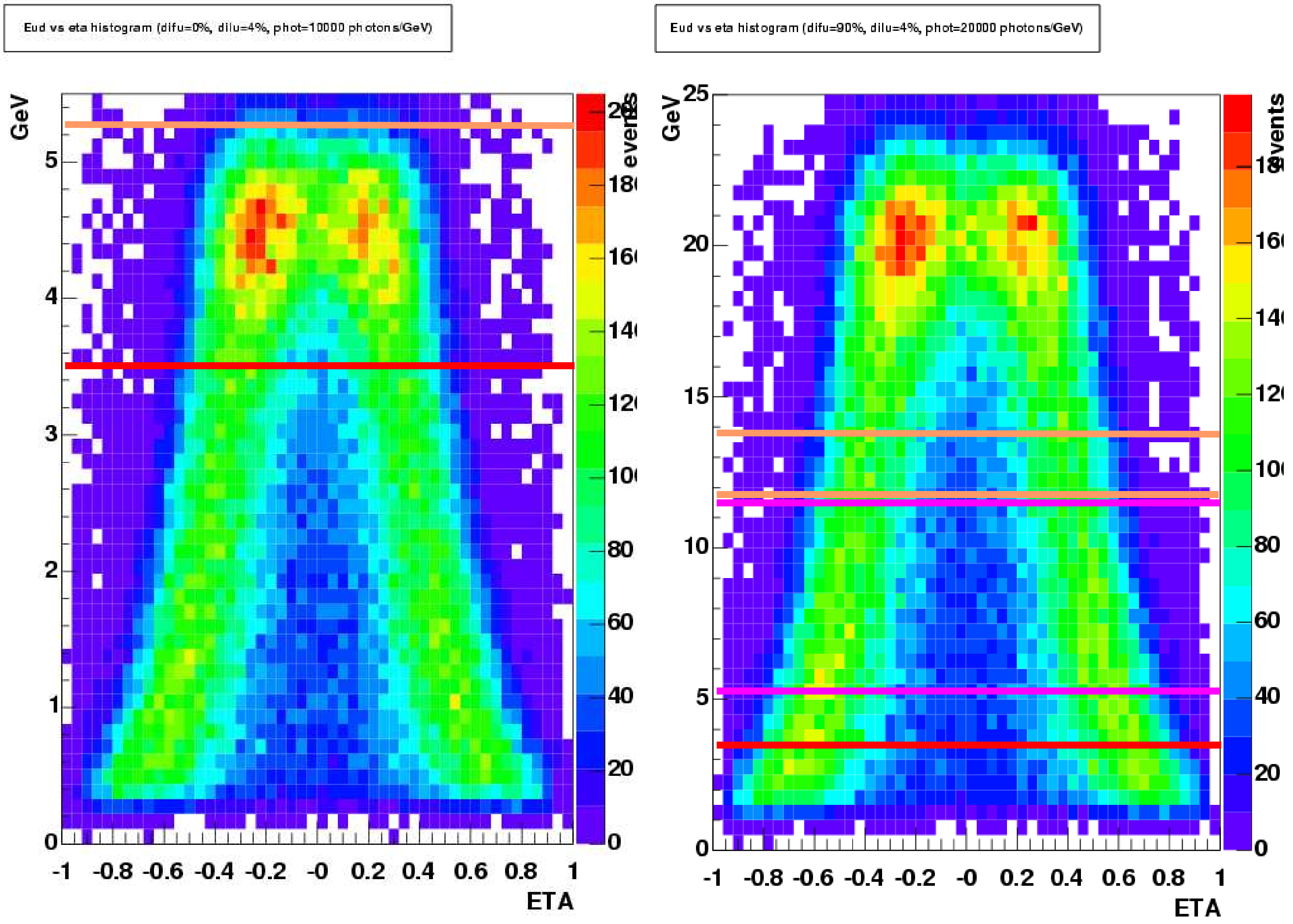

Figure 26: The eud vs η histogram for the combination (0, 4, 10 000) is shown on the left and the combination (90, 4, 20 000) is shown on the right. Notice that there is no cut applied and that the scaling of the energy is not the same for both histograms. The red line shows the energy cut (eud > 3.5 GeV), the purples lines show the energy cut for the AP (equation 5) and the orange lines show the energy cut for the focus (equation 6). Notice that the second purple line and the first orange line should be one over the other at 11.4 GeV, but they are not for clarity. Moreover, some of the AP and focus cuts don't appear on the left graph since the graph ends at 5.5 GeV.

However, figure 27 shows that Dilu, as expected, has a significant impact on η. We observe that the shape of the histogram is not the same over the η-axis for different Dilu which clearly indicate that Dilu influence directly η (η "squeeze" as Dilu increase). Moreover, we would like to point out that the energy scaling for both histograms of figure 27 is not the same which confirm the influence of Dilu over eud.

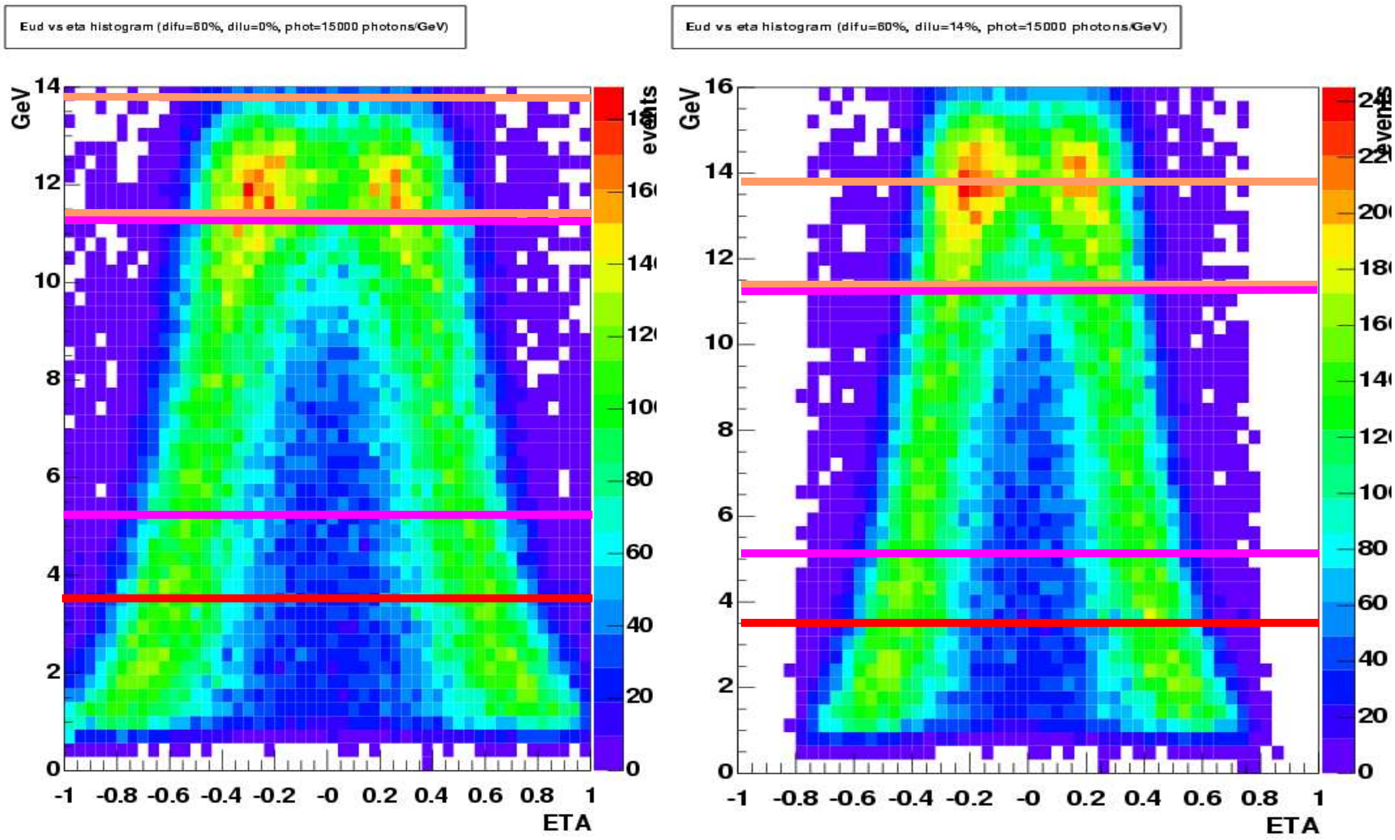

Figure 27: The eud vs η histogram for the combination (60, 0, 15 000) is shown on the left and the same histogram for the combination (60, 14, 15 000) is shown on the right. Notice that the scaling of the energy is not the same. Again, the red line shows the energy cut (eud > 3.5 GeV), the purples lines show the energy cut for the AP (equation 5) and the orange lines show the energy cut for the focus (equation 6).

We now use figure 28 to prove what we state before: at a certain point, when eud spreads because Difu or Phot increase, we start to lose sensibility over the helicity of the polarized left or right photons. The absolute values of the mean start to reduce when Difu (or Phot) get too high because we lose events with high energy trough the energy cuts and start to accept more events with low energy. That as for consequence to reduce the AP as Difu (or Phot) increases, even if the $|\eta|$ continue to increases.

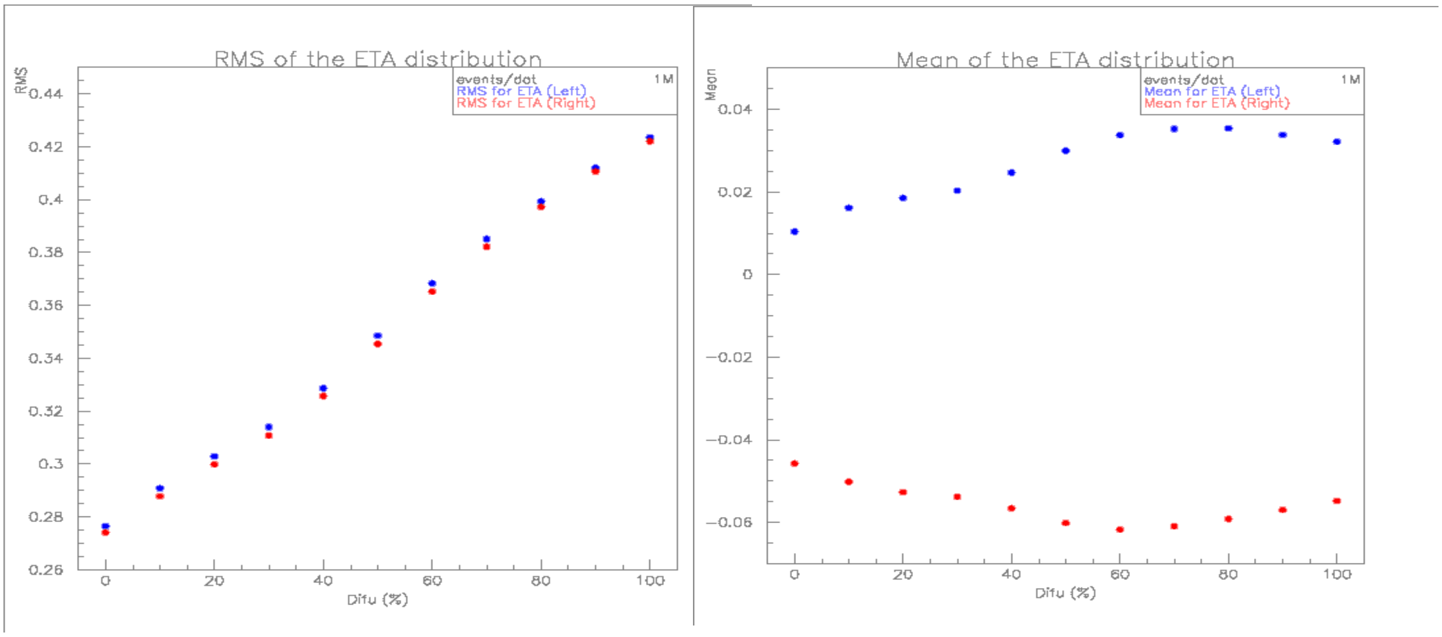

Figure 28: The left graph shows the root mean square of the η distribution (cut of equation 5) in function of the parameter Difu, while the right graph shows the mean of the η distribution (cut of equation 5) in function of the parameter Difu. The blue dot are for photons with left helicity and the red dot are for photons with right helicity. We would like to point out that RMS of the η distribution can be interpret as $|\eta|$ (if RMS increases, implies $|\eta|$ increases) and that eud is directly related to Difu. That is, $|\eta|$ increases linearly as eud increases (spreads). However, the right graph shows that even if $|\eta|$ increases at high Difu, the difference between the left and right photons start to decreases. That is, our data lose “quality”. We would get the exact same behavior for the parameter Phot.

The conclusion from this analysis are the following one. The parameters Difu and Phot have a big influence over the calibration of eud and they have no significant influence over η. On the other hand, Dilu has a significant influence over η and a small influence over eud. Equation 5 and 6 suggest that only Dilu should have an influence over the AP and the focus, since they are both calculated from the η distribution. However, figures 16 and 17 demonstrate that this is clearly not the case. This is a consequence of the fixed energy cut used. That is, the spread of eud has a strong influence over the η distribution since it affects which events we select to do our distribution. It must be understood that the energy cut has been fixed to select specific events from the real TPOL data (figure 29). This means that if our “wanted” events change their energy due to the new calibration, we should change our energy cut to keep only these events. In other words, Difu and Phot have no real influence on AP or the focus. They are just two parameters we can use the do the energy calibration.

6.4-Optimization of the Dilu, Difu and Phot parameters

Since Dilu, Difu and Phot parameters has been identified to have a strong influence over the AP and the focus[22], we would like to find the best set of the parameters Dilu, Difu and Phot such that the MC eud distribution and η distribution represent the most accurately the real TPOL data. However, it seems clear from the previous analysis, that we can't compare them individually since eud influence η trough the fixed energy cuts. We thus need to compare the MC histogram of eud vs η with the histogram of the real TPOL data. Figure 29 shows the real TPOL data for the eud vs η histogram.

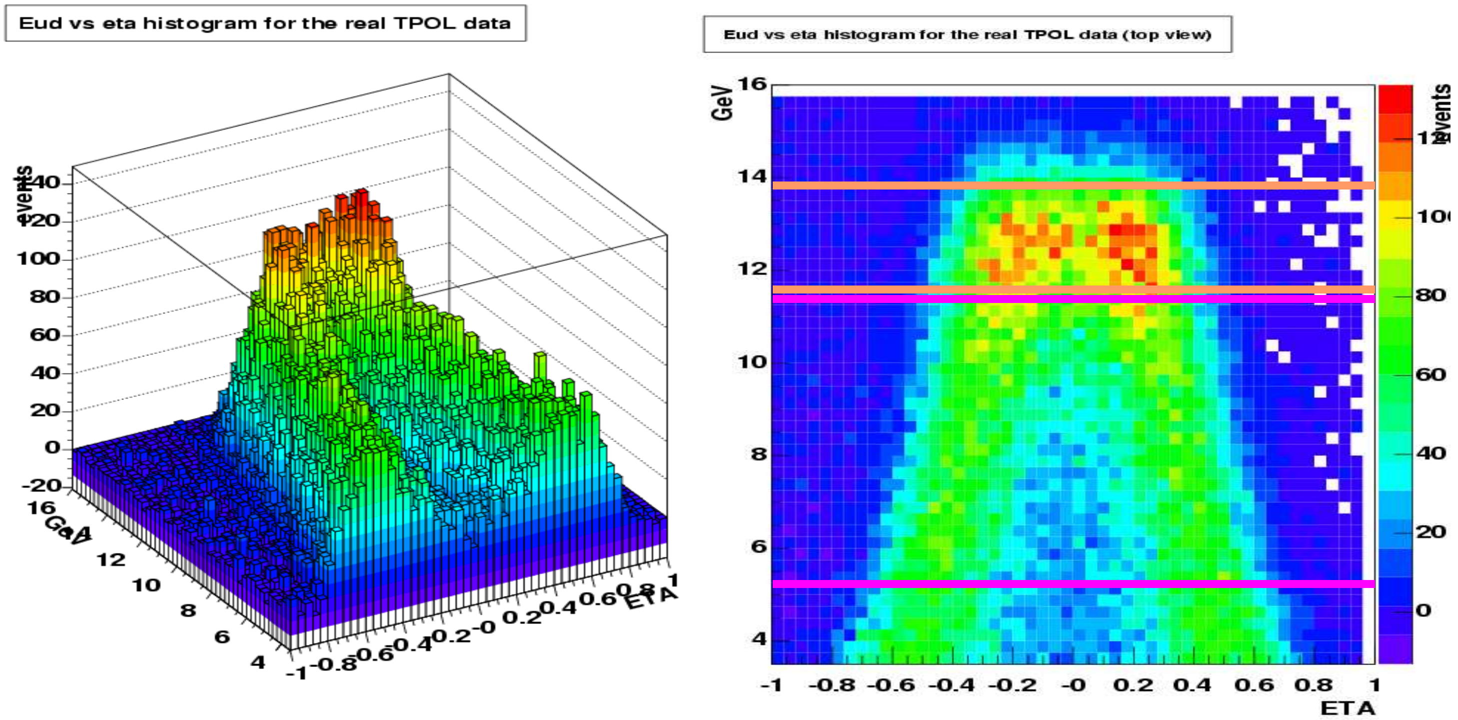

Figure 29: Eud vs η histograms of the real TPOL data (month of June with average polarization of 31%). The left graph shows the side view and the right graph shows the top view. Notice that this histogram is after back ground subtraction; method that we won't discuss in this report but details of the procedure can be found in reference [12]. The purples lines show the energy cut for the AP (equation 5) and the orange lines show the energy cut for the focus (equation 6).

22 Even if it is not always a direct influence.

In order to be able to compare the real data to the MC data we define a new quantity Δ (delta) which is similar to the standard deviation. We will take the Δ to be the square root of the sum of the squares of the difference of each histogram bin divided by the total number of bins in the histogram[23], equation (10):

$$\Delta = \sqrt{\frac{\Sigma_{bin} (MC_{bin} - Real_{bin})^2}{number\ of\ bin}} \tag{10}$$

Notice that we have to normalize the MC data with the real TPOL data such that both histogram have the same amount of events to use equation 10. Again, we specify that we used a polarization of 31% in the MC simulation in other to compare the same thing. Our goal is to find which combination of Difu, Dilu and Phot give the smallest Δ. The best method would be to do a 3D "grid" varying Difu = [0.0, 0.9], Dilu = [0.00, 0.14] and Phot [10000,20000] and then find which MC simulation give the smallest Δ. However, this would first implies a 4-D plot which is not obvious to analyze, and second, that would implies 1760 simulations, which is not realistic. We thus decided to do two 2D grids: one with Difu and Phot and one with Difu and Dilu. We also decided to do 500 000 events simulations instead of 1 000 000 events simulation.

6.4.1-Difu-Phot grid

Let's first analyze figure 30 which shows the Δ for the grid of Difu and Phot parameters.

23 The histogram used for the comparison has 50 bins on the eta axis and 50 bins on the eud axis for a total of 2500 bins. The range are [-1, 1] for eta and [3.5, 25] GeV for eud.

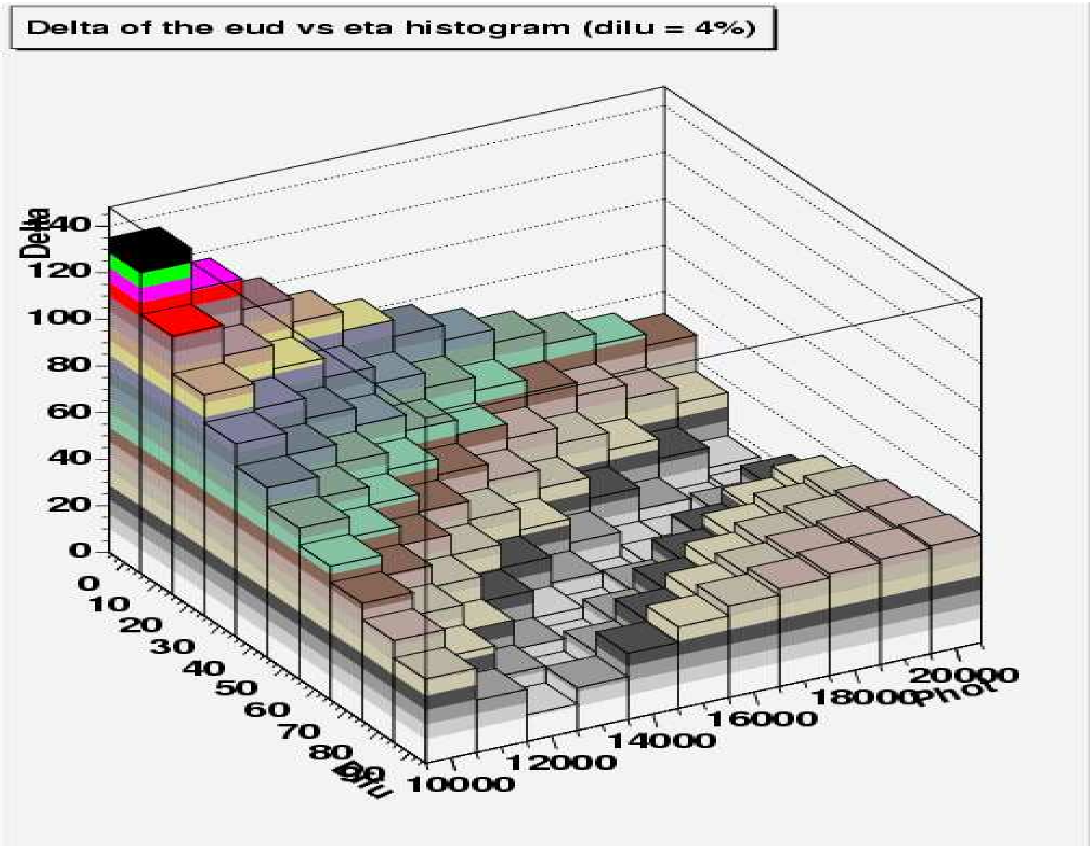

Figure 30: Graph of the Δ, define by equation 10, as function of the parameters Difu and Phot. Notice that Difu is in percentage and Phot is in photons/GeV. For all the simulations, Dilu = 4%. The best minimum for Δ is 10.37 and is given by the combination (30, 4, 19 000).

We observe that there is a lot of possible minimums all concentrated around the line starting from (90, 4, 12 000) to (20, 4, 20 000). This can be easily explained by the fact that both, Difu and Phot, parameters influence strongly eud. If we look at figure 29, we see that we are looking for simulations with a maximum eud ~15 GeV. Lot of combinations of Difu and Phot parameters fulfill this requirement. We thus can't determine with certitude the optimal combination of Difu and Phot when Dilu = 4%. We would like to point out that the best combination for fixed Dilu = 4% is (30, 4, 19 000) and gives Δ = 10.37. On the other hand, our original default parameters (60, 4, 15 000) gives use the third smallest Δ, with Δ = 11.35. The difference between both is not significant enough to suggest a change.