Calorimeter hit signal and clustering parameters

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1 Lateral spread

Lateral spread of signals in Elemag and Hadron calorimeter is generated assuming the following formula.

$$F(x) = a_1 \exp^{-|x|/b_1} + a_2 \exp^{-|x|/b_2} \quad (1)$$

where, a1, a2, b1, b2 are parameters which characterize the lateral spread of signals in calorimeters. In the Quick Simulator, they are defined in the subroutine smrshw. They are show in the table below.

2 New formula for hadron shower

According to Dr. Yoshiaki Fujii, following formula is as a lateral distribution of hadron shower.

$$G(r) = p_1 \exp^{-r/p_2} + p_3 \exp^{-(r/p_4)^2} \quad (2)$$

where r is radius from the particle entrance and typical value for parameters are $(p_1, p_2, p_3, p_4) = (3.6, 13.4, 6.4, 2.47)$.

Fig. 1 shows the function, $G(r)$, for $y = 0, 3, 5$, and 10 cm, as a function of X.

In the Fig. 2, the lateral distribution of hadron shower used in the current quick simulator and the one given by Eq. 2 are compared. The function $G(r)$ is a function of

Table 1: Standard parameter for shower shape generation.

	Elemag Calorimeter	Hadron Calorimeter
a_1	0.07/1.263	1.0/11.40
b_1	0.45	2.20
a_2	0.50/1.263	0.50/11.40
b_2	1.20	7.00

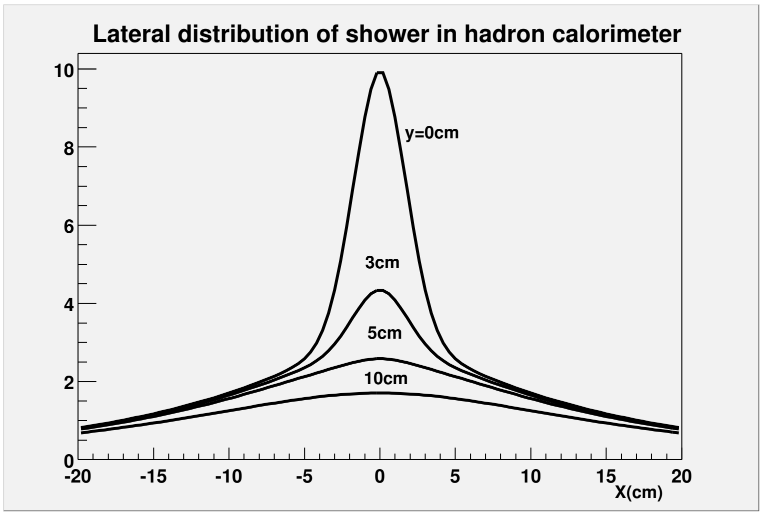

Figure 1: A function of hadron shower distribution, $G(r)$. Plotted for $y = 0, 3, 5$, and 10 cm, as a function of x coordinate.

radius, while the function $F(x)$ defined in Eq. 1 is the distribution projected on x axis, we integrated $G(r)$ with respect to y when they are compared in the Fig. 2. $G(r)$ is the signal density in small area $rdrd\phi$. By change of the variable, $rdrd\phi = dxdy$. Therefore,

$$P(x) \equiv \int G(r)dy \tag{3}$$

where $r = \sqrt{x^2 + y^2}$.

From the Fig. 2, it is found that the lateral distribution of current quick simulator is about five times narrower than those given by the function, $G(r)$. However, shape seems to be equal. Therefore, we fit the projected distribution provided by Eq. 2 by the function $F(x)$ given by Eq. 1. The fit result are shown in the Fig. 3.

In the JLC weekly meeting in 14 January, 2000, it was pointed out that the integration of Eq. 2 as described above is not correct. Correct treatment needs further study. For a time beeing, continue study using old method and old parameters.

3 Clustering algorithm

3.1 Clustering Effeciency

In the quick simulator, following algorithm is used to clusterize hit cell information of elemag calorimeter. Note that for hadron calorimeter, another algorithm for track-cluster matching developed by Keisuke Fujii is used without clustering of calorimeter's hit cell..

1. Find highest energy counter BL1 whose energy larger than ETH.
2. Find neighbor counter BL2 and include in the cluster.
3. Find BL3 that is neighbour counter of BL2, include in the cluster if one of the following two conditions is satisfied.

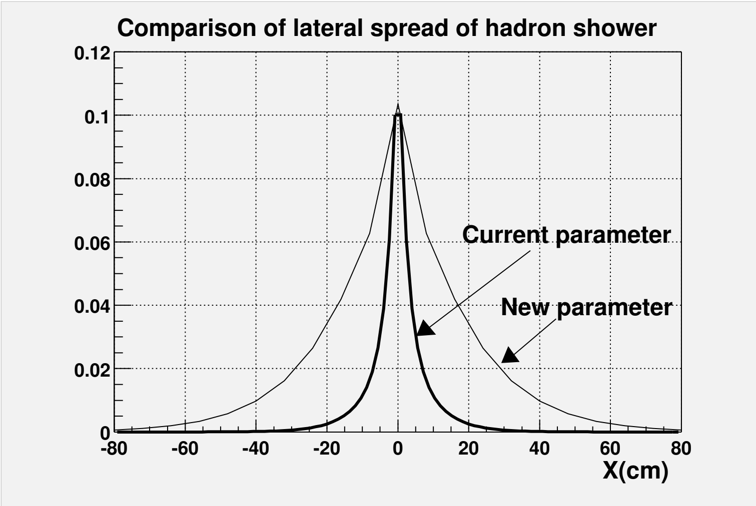

Figure 2: Lateral distribution of hadron shower used in the current quick simulator compared with the distribution given by $G(r)$.

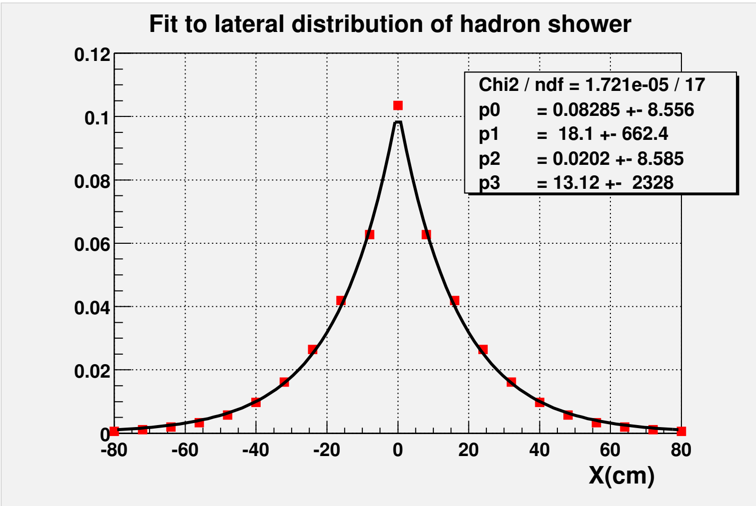

Figure 3: The fit to the shower shape. The data points are those calculated from Eq. 2.

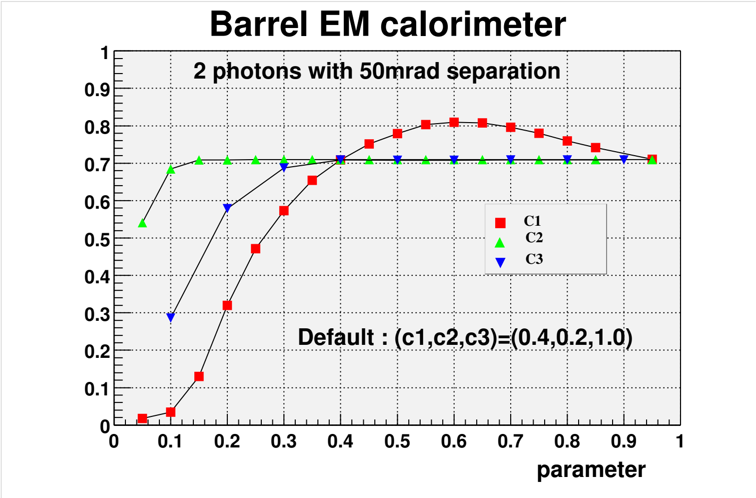

Figure 4: The efficiency to cluster into two cluster when two photons are generated. The opening angle between two photons is fixed at 50 mrad. The energy of two photons are same, but changes event by event between 1 to 50 GeV.

(a) $E(BL2) > c_1 \times E(BL1)$

(b) $E(BL3) < c_2 \times E(BL1).and.E(BL3) < c_3 \times E(BL2)$

(ETH, c_1, c_2, c_3) are parameters to be optimized for each detector geometry.

To find out optimum value of clustering parameters, we generated two photons whose opening angle is some fixed value and study the efficiency to be clustered to two clusters. The energy of photon is generated randomly in betwen 1 GeV to 50 GeV and $\cos\theta$ range is from -0.7 to 0.7 so as to cover barrel Elemag calorimeter region. The azimuthal angle is from 0 to 360°. The obtained figure is shown in Fig. 4. In this figure, the opening angle of two photon is 50mrad.

3.2 Conclusions from parameter study

For 1 photon reconstruction in Barrel EM calorimeter(Fig. 6), $c_1 \leq 0.4$, $c_2 \geq 0.2$, $c_3 \geq 0.3$ for high efficient clustering. For two photons with 100 mrad separation in Barrel EM calorimeter (Fig. 5), requirement to the clustering parameters for efficient clustering is, $0.3 < c_1 < 0.5$, $c_2 > 0.2$, $c_3 > 0.5$.

Parameters of EM calorimeters are summarized in the Fig. 10. As seen in the figure, phi segmentation is about 25 mrad. Therefore, if opening angle between two photon is 50 mrad, EM hit cell is quite over lap and it is hard to separate them with high efficiency. It requires about 100 mrad separation to high efficient cluster separation.

As a conclusion, current default value of clustering is good for both barrel and end cap EMC calorimeter.

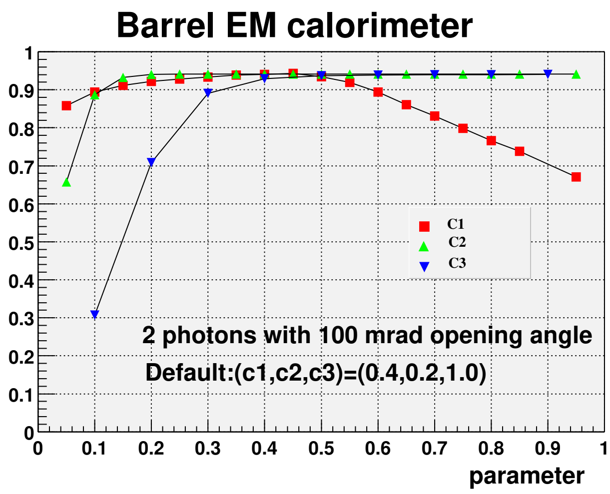

Figure 5: Same as Fig. 4, but with 100 mrad opening angle between photons.

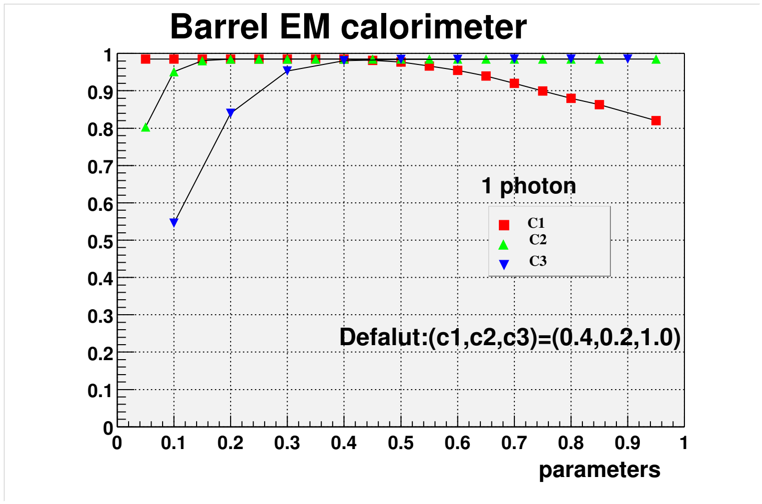

Figure 6: The efficiency to cluster to one when one photon is generated. The energy of photon is same, but changes event by event between 1 to 50 GeV.

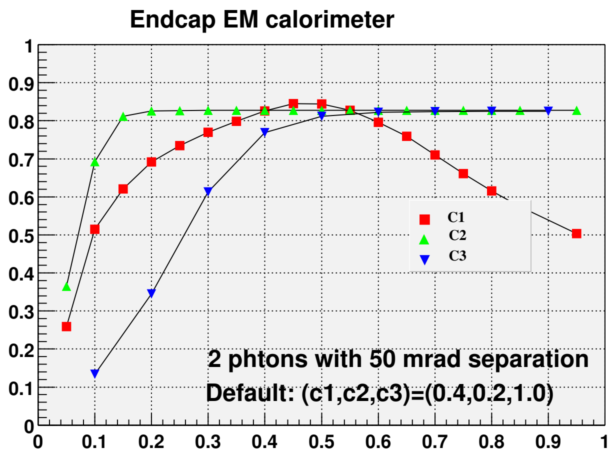

Figure 7: Same as Fig. 4 for the case of Endcap Elemeg Calorimeter. First photon is generated with the $\cos\theta$ range from 0.79 to 0.96. Second photon is generated with the opening angle of 50 mrad and same energy.

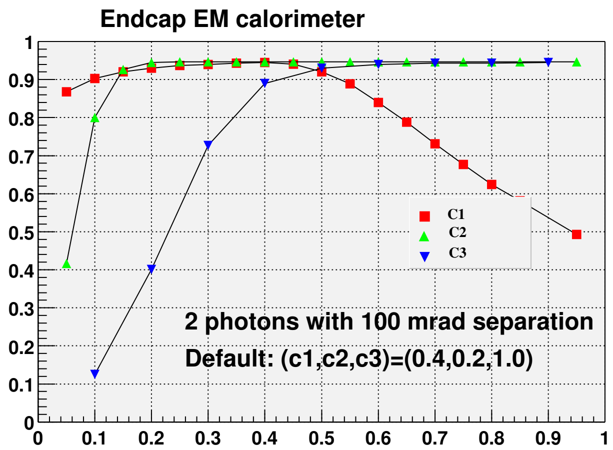

Figure 8: Same as Fig. 7, but with 100 mrad opening angle between photons.

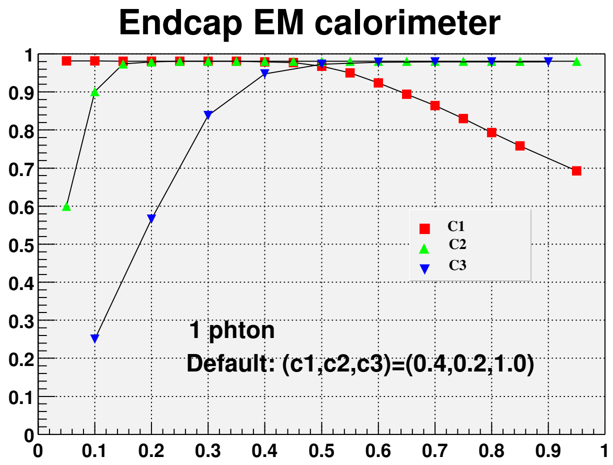

Figure 9: The efficiency to cluster to one when one photon is generated. The energy and the angular range is same as Fig. 7.

EMC		
	Number of Phi segment	252
	Number of theta segment	90
	number of radial segment	29
	Inner radius (cm)	45
	Outer radius (cm)	160
	Z max (cm)	190
	Pi	3.141592654

Maximum cos(theta)	0.765
Barrel Phi segment size (cm)	3.989
Barrel Phi segment size (m radian)	24.933
costh segmentation in barrel	0.017
Z segmentation size@90 degree (cm)	2.720
Theta max	0.700
Theta max - 1 bin	0.683
Z segmentation size@max	6.691
Z segmentation size (m rad)@z max	16.998
Z segmentation size (mrad)@90	16.999

Figure 10: parameters of EM calorimeter.

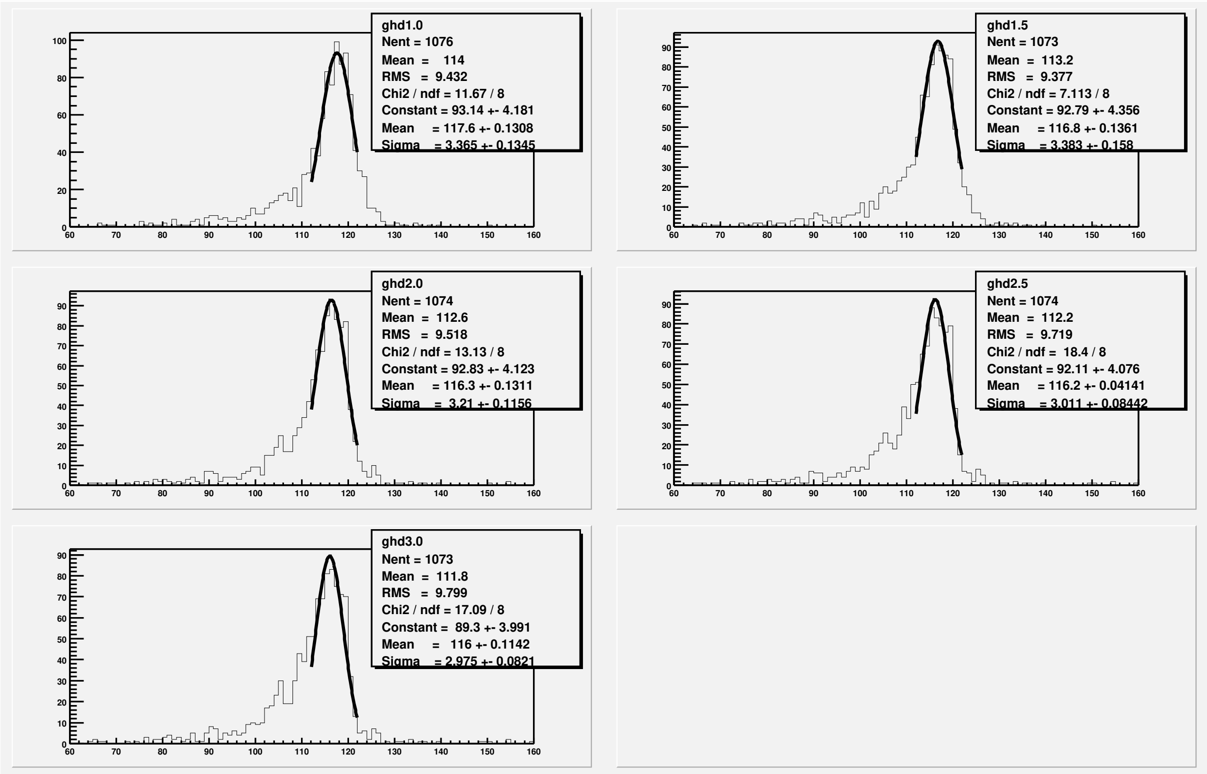

Figure 11: Reconstructed invariant mass of Higgs. The parameter of cluster track matching, `ENSGHD`, is changed from 1.0 (left-top figure) to 3.0 (left-bottom) figure by 0.5 step. The solid curves in the figure are gaussian fit in the mass region from 112 GeV to 122 GeV.

4 Tuning for cluster-track matching parameter and Higgs mass

It is recommended to tune parameters for Cluster-Track matching process dependantly(ref: http://www-jlc.kek.jp/http://www-jlc.kek.jp/subg/offl/lib/docs/cmbtrk/main.html). To this end, I generated 20k events of $e^+e^- \to ZH$ and study the invariant mass resolution using the decay mode of $Z- > \nu\bar{\nu}$ and $H \to hadron$. In the study, the center of mass is 300 GeV, and the mass of higgs was 120 GeV. Event was generated using Phythia5.7. The parameter of cluster track matching, `ENSGHD`, is changed from 1.0 to 3.0 by 0.5 step. Standard parameter for the case of 2 Tesla magnetic field was 2.0 for both `ENSGHD` and `ENSGHD`. The Higgs mass distributions for each parameter set are shown in Fig. 11. For the comparison, similar distribution for the case of 2 Tesla solenoid field and for the case of the scan of the parameter, `EMSGEM`, of the Elemag Calorimeter are shown in Fig. 12 and Fig. 13, respectively.

First of all, the histograms in Fig. 13 shows no difference despite the change of the parameter, `ENSGEM`. This confirms that EMC cluster is not used in Cluster-Track matching algorithm as was told by K.Fujii.

Comparing the Fig. 11 and Fig. 12, we see that

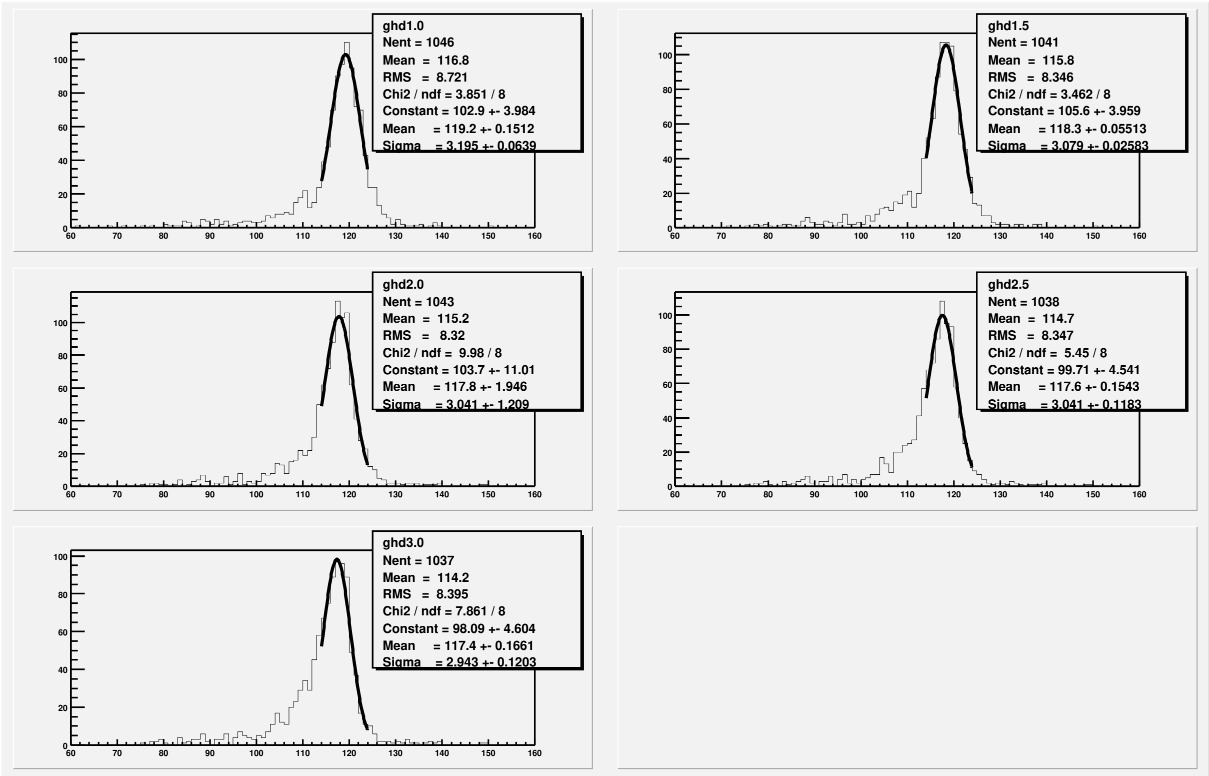

Figure 12: Same as Fig.13, but the solenoid field is 2 Tesla. Fitted mass region is from 114 to 124 GeV.

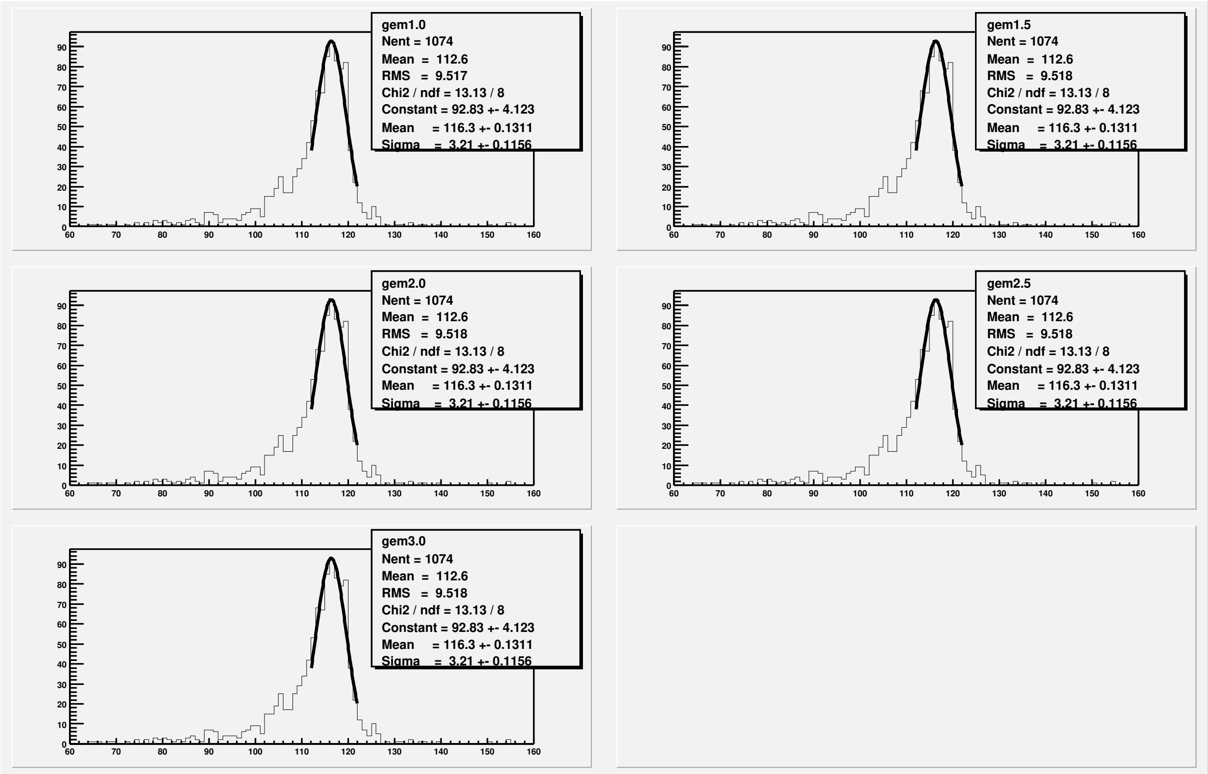

Figure 13: Same as Fig.13, but the parameter `EMSGEM` for Elemag calorimeter are changed for comparison with the case of Fig.13

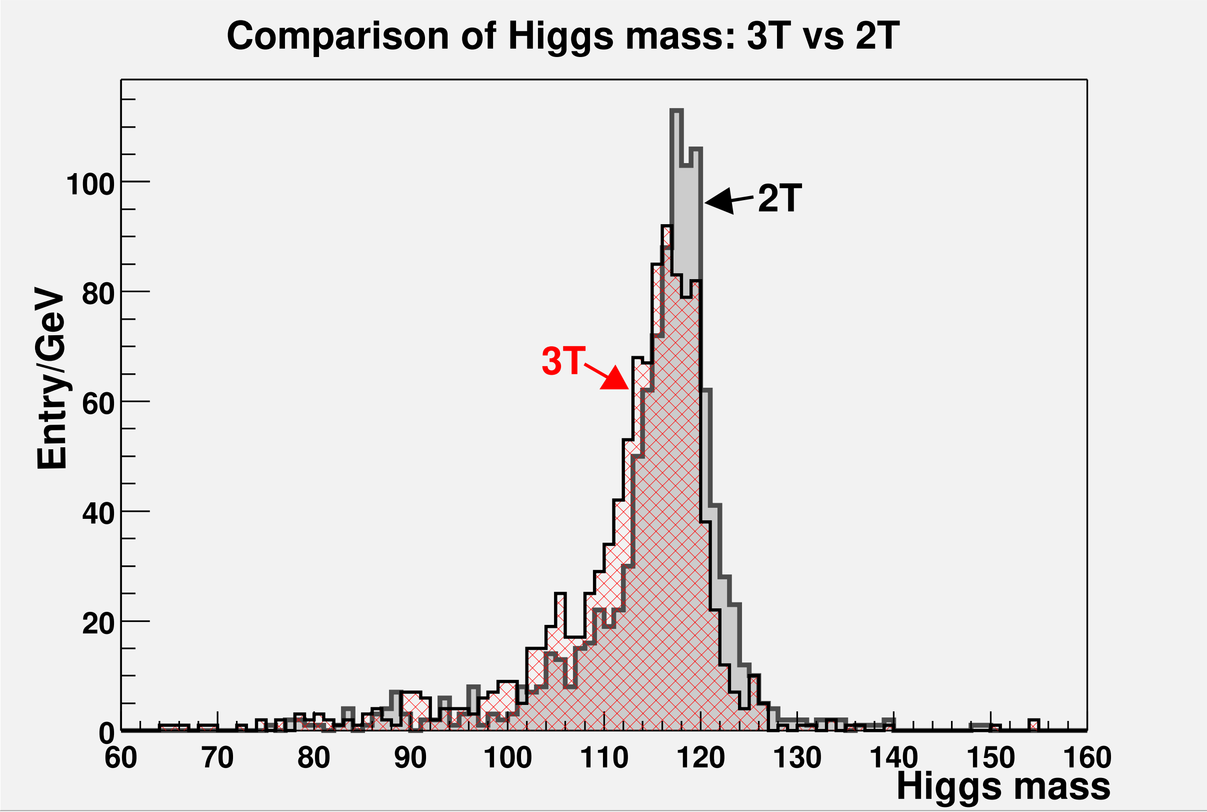

Figure 14: Comparison of Higgs mass distribution between 2 Tesla and 3 Tesla.ENSGHD is 2.0 in both cases.

- Number of selected event in the case of 2 Tesla and 3 Tesla are same within 1σ of statistical error.
- Fitted mean vale of Higgs mass for 3 Tesla case is about 1.5 GeV less than that of 2 Tesla.
- In the 2 Tesla case, the sigma of gauss fit changes from 3.37 to 2.98 GeV when EMSGHD changes from 1.0 to 3.0. On the other hand, the changes in the 3 Tesla case is from 3.20 to 2.94 GeV and slightly smaller than the case of 2 Tesla case.

In the Fig. 14, we compare the invariant mass distribution of Higgs for the case of 3 Tesla detector and 2 Tesla detector. We see, in addition to the shift of peak position, that tail part in the 3 Tesla case is larger than 2 Tesla case. We are loosing particles which cases the shift of peak and increase of tail in the mass distribution. This would be due to the inproper us of ENSGHD parameter.

In the Fig. 15, we compare 3 Tesla case and ENSGHD = 1.0 with 2 Tesla and ENSGHD=2.0. We see both distribution is consisten within statistical error. Since ENSGHD=2.0 is used as a standard value so far, ENSGHD=1.0 should be used as a standard calue for 3 Tesla case, to get similar results as 2 Tesla case.

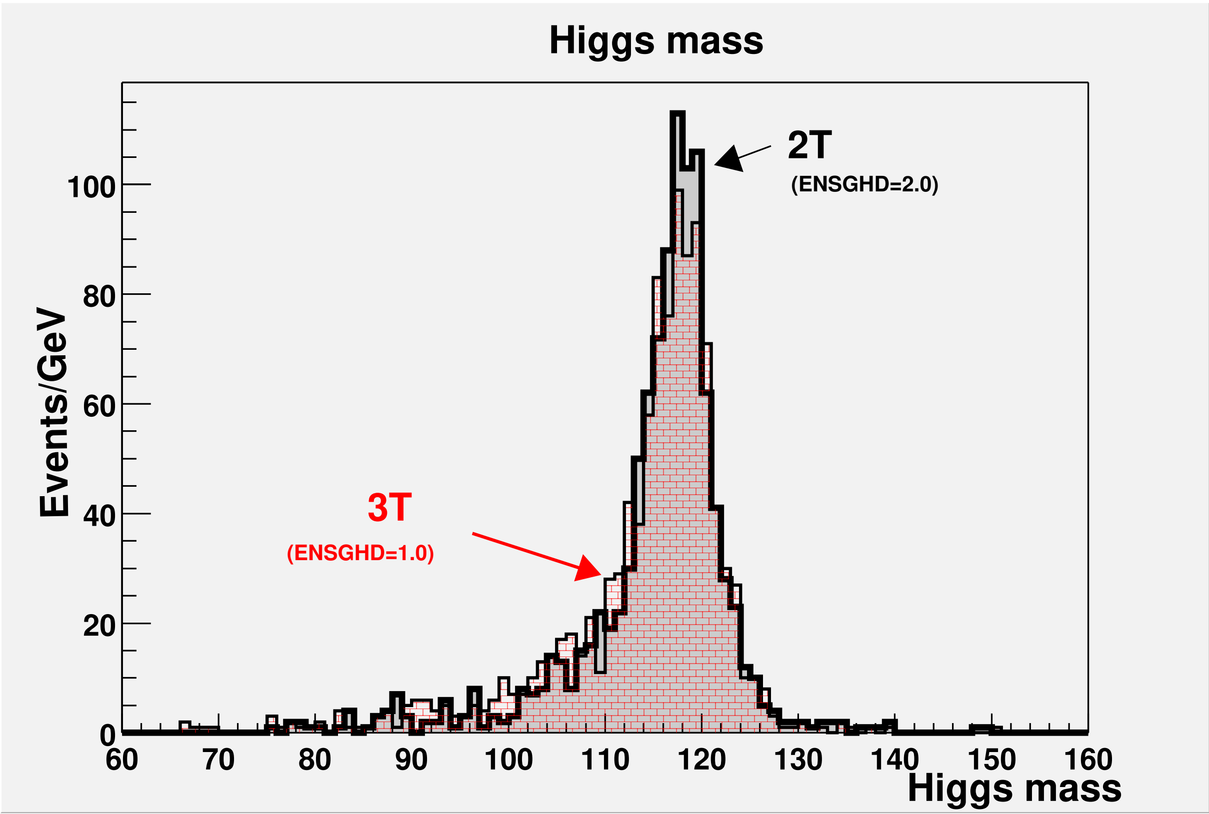

Figure 15: Comparison of Higgs mass distribution between 2 Tesla and 3 Tesla.`ENSGHD` for 2 Tesla case is 2.0, while the one for 3 Tesla case is 1.0.