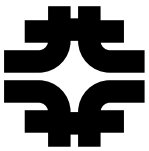

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The Effect of ECAL Resolution on Higgs Mass Resolution

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The Effect of ECAL Resolution on Higgs Mass Resolution

Jim Freeman, Weimin Wu
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Introduction

This note studies the effect of degraded ECAL resolution in different η intervals on the mass resolution of the Higgs particle. The Higgs mass was chosen to be 125 GeV. Sets of events were generated using ISAJET, with control commands as shown in **Appendix A**. There were no additional underlying events (low luminosity scenario). 5000 events were generated for each case.

Only energy deposition in the ECAL was used for the mass reconstruction. The energies were clustered using a fixed cone algorithm with R = 0.4. A detailed study of this process was performed for SDC [1] – [3].

Program description

The program we used to do this study is SSCSIM [4] which provides an interface between the event generators, detector simulation and the analysis code. It enables one to propagate particles generated by Monte Carlo generators through a detector, simulate various detector specific effects. The detector is assumed to be a solenoid of half-length HALFLE and radius RADCYL with a uniform magnetic field BFIE. The central detector is surrounded by endcap that extend to ETAMAX. Detector response is assumed to have a form of energy deposition in projective cells with dimension DETA * DPHI. Energy of the particle is distributed in space around the initial direction. For electromagnetic showers a Gaussian distribution, with 1 cm width is assumed. For hadron induced showers a convolution of two Gaussian is used, with parameters taken from F.Binon et al, NIM206(1983),373. Energy of the incoming hadrons, electrons and photons could be smeared using the formula E' = E inc * (1 + dE/E), where dE/E is a random number with a Gaussian distribution with a sigma ** 2 = (a/sqrt(E))**2 + b ** 2. Stochastic and constant terms in the resolution function are different for hadrons and electromagnetic particles in all above six cases. The cell size for EM section can be chosen, for HCAL, 0.086 * 0.086, and for ECAL (0.086/6.) * (0.086/6.) were used. The clustering package is divided into three parts. The first part is to setup the calling condition. The second part is to find the jet/gamma candidates. The third part provides user a reconstruction program to get the reconstructed invariant mass of the di-jets which has been found, or the highly boosted jet mass. The Higgs mass resolution is taken from the Gaussian fit. The influence of clustering cone size was studied by varying it from R = 0.3 to 1.7. The optimum, R = 0.4, was used for the final results. Note that this optimum (for low luminosity) will not be optimal at higher luminosities. The final results are summarized in the table 1.

Conclusion

1) For the CMS ECAL baseline, Case II below, we predict a Higgs mass resolution of 0.69% at low luminosity. We note that this resolution is consistent with that in the ECAL TDR [5], figure 1.16, which shows 650 MeV sigma for a 100 GeV Higgs mass. Our acceptance is 82%. Our acceptance is higher than in the ECAL TDR because, among other things, we ignore losses in the EB/EE transition region, and losses due to photon conversions in the tracker.

2) The acceptance will be reduced from 82 % down to 38 % if no ECAL is present in the endcap, although the Higgs mass resolution will be affected very little, from 0.69 % to 0.65 %, because gammas outside the barrel region are rejected.

3) If Shashlik ECAL, with a energy resolution of 10%/sqrt(E) $\oplus$ 1%, is used instead of crystal in the endcap region, the Higgs mass resolution will be degraded from 0.65 % to 0.93 %

4) If the constant term in energy resolution for the crystals is 1% rather than 0.5%, there is very little difference in performance between Shashlik and crystals. If we double the constant term both for crystal and Shashlik, the Higgs mass resolution only degraded from 0.91 % (crystals) to 1.08 % (Shashlik).

5) Consider the potential discovery significance, $\mathbf{S = N_{Signal} / Sqrt(N_{Background})}$. $\mathbf{N_{Signal}}$ is proportional to the signal acceptance (**Acc**). If the background has similar topology as the signal (as it will in this case, after appropriate cuts), then the $\mathbf{N_{Background}}$ is proportional to the signal acceptance. If we assume a flat background distribution, $\mathbf{N_{Background}}$ is proportional to the Higgs mass resolution, σ, as well. Thus, **S** is proportional to $\mathbf{Acc /sqrt(Acc*\sigma) = sqrt(Acc/\sigma)}$.

The Table shows a row of the ratio of **S** for each case divided by that for Case II, the CMS Baseline. We note that the different cases (aside from Case III) have within 20% the same sensitivity as the baseline. It is interesting to note Case V, where the constant term in the resolution of the baseline design is allowed to degrade. This case is only ~10% worse than the baseline.

Let us consider the ratio of significances for Case IV and Case III below. Then $\mathbf{S_{CaseIV} / S_{CaseIII}}$ = 1.2, so that for a given luminosity, the Higgs signal is 1.2 times more significant in Case IV than in Case III. It is to our advantage to instrument the Endcap with poorer resolution, rather that suffering the efficiency cut of no ECAL there at all.

Higgs Reconstruction Summary Table

Case I	Case II	Case III	Case IV	Case V	Case VI
Ideal detector (segmentation, size only)	ECAL Crystals up to $\eta = 3.0$	ECAL to η = 1.5, no ECAL in endcap.	Crystals in Barrel, Shashlik in Endcap	Case II but with const term = 1%	Case IV, but with const term 1% for Crystal, 2% for shashlik
Higgs Mass Resolution 0.46%	0.69%	0.65%	0.93%	0.91%	1.08%
Higgs Acceptance 100%	82%	38%	82%	82%	82%
Significance / Case II 1.35	1.0	0.70	0.86	0.87	0.80

Case I: Perfect detector, with only transverse segmentation to degrade the resolution.
Case II: CMS baseline design: Crystals with 2%/sqrt(E) $\oplus$ 0.5%.
Case III: CMS baseline with descope of no ECAL in Endcap region
Case IV: Crystal ECAL in barrel, operation at baseline parameters (as in Case II); Shashlik in Endcap, with 10%/sqrt(E) $\oplus$ 1%.
Case V: CMS baseline ECAL with 1% constant term (rather than 0.5%).
Case IV: Crystals in barrel (1% const term), Shashlik in Endcap (2% const term).

Bibliography

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[2]. Weimin Wu Investigation on the problem of H---> 2 gamma (II) June 28, 1992 SSC-SDC-F-115

[3] Detection of Higgs 0 --> gamma gamma by the SDC detector, W.Wu, A.Beretvas, D.Green, J.Maffaffin. Fermilab April 1993 Fermilab-FN-603

[4] A.Beretvas et. SSCSIM: development and use by the Fermi lab SDC group MC 93 International conference on Monte Carlo Simulation in High Energy Physics and Nuclear Physics. World Scientific

[5] CMS ECAL TDR, CERN/LHCC 97-33

Appendix A

These are the Isajet commands used to generate the data set.

```
HIGGS TO GAMMA GAMMA
14000,100,1,0/
HIGGS
BEAMS
'P','P'/
HMASS
125./
JETTYPE1
'GM'/
JETTYPE2
'GM'/
SEED
2525562/
END
STOP
```