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Study of Primary Vertex Determination using the GEM Central Tracker in $H^0 \rightarrow \gamma\gamma$ events

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Abstract:

A study of vertex tagging in $H^0 \rightarrow \gamma\gamma$ events using the GEM central tracker is presented. The higher multiplicity and transverse momentum of the Higgs interaction is exploited to yield tagging efficiencies of at least 90% at nominal luminosity and better than 70% at high luminosity.

Introduction

One of the stated goals of the GEM central tracker is the determination of the primary vertex in an event of interest. A case in point is the decay of a Standard Model Higgs into two photons. In [1] it was reported that one must be able to determine the Z coordinate of the H^0 vertex to within 5 mm in order to obtain the mass resolution necessary to identify a Higgs.

To understand the capabilities of the GEM central tracker in addressing this goal, a study has been performed using the *gemgen* Monte Carlo interface package [2] and *gemfast*, the fast parameterization of the GEM detector's response. This study employed PYTHIA [3] as the interaction generator for both signal ($H^0 \rightarrow \gamma\gamma$) and underlying minimum bias events. A realistic distribution for interaction Z coordinates has been obtained through the generator package by smearing according to a Gaussian distribution with a width of 5 cm. The fast parameterization of the detector's response includes smearing of the momentum and impact parameter measured by the tracker.

H^0 Event Selection

A few simple 'trigger like' cuts have been applied to the sample of generated Higgs events in order to insure that the event can be observed in the detector:

- $|\eta| < 2.5$ and $P_t > 20$ GeV (both gamma's) or
- $|\eta| < 2.5$ and $P_t > 55$ GeV (one gamma).

These roughly match the two complementary triggers $2 \cdot E_{16}$ and E_{50} that have been foreseen for events of this type [4].

Figure 1a shows the transverse momentum spectrum for 120 GeV Higgs particles both before and after the above trigger requirements. It is interesting to note that the Higgs is produced with a substantial amount of transverse momentum. Figure 1b shows the mean P_t of the Higgs as a function of the H^0 mass.

Charged Track Selection

Conservation of momentum dictates that the large transverse momentum of the H^0 must be balanced by other particles recoiling against it (*i.e.* a jet). Since some of these particles will be charged, the tracker can be used to identify the vertex associated with recoil particles and thus determine (or tag) the Higgs production vertex.

In order to conservatively estimate the ability of the tracker to determine the Higgs vertex without a full detector simulation, only high-P_t isolated charged tracks are considered. Charged tracks that survive the following selection criteria should be detectable with near perfect efficiency:

- $|\eta| < 2.5$,
- $P_t > 0.5$ GeV, and
- track isolation.

The first cut matches the geometrical acceptance of the detector and the second cut is a somewhat arbitrary cutoff used to separate high-P_t tracks from low-P_t tracks. Isolation, the third, is obtained by requiring that no other charged tracks come within $\Delta\eta \leq 0.13$ and $\Delta\phi \leq 0.025$ of the charged track of interest.

The above isolation requirements are related to the average pad sizes $<\Delta\eta>= 0.13$ and $<\Delta\phi>= 0.0058$ by:

$$\Delta\eta = \sqrt{2} <\Delta\eta>,$$
$$\Delta\phi = 3\sqrt{2} <\Delta\phi>.$$

The factor of 3 in the second relation above is needed because the IPC's obtain highest precision by sharing charge over three pads in the phi direction. The $\sqrt{2}$ has been inserted to double the area of the isolation region in order to compensate for the memory time of the IPC's which corresponds to roughly two bunch crossings.

Figure 2a shows the P_t spectrum of charged tracks for 120 GeV Higgs events at nominal (10^{33} $cm^{-2}s^{-1}$) luminosity both before and after cuts. In Figure 2b, the percentage of tracks surviving these cuts is shown as a function of the H^0 mass and luminosity.

H^0 Vertex Determination

Determination of the Higgs vertex using the higher multiplicity of this interaction has been explored in [5] and found to be effective. This study differs from the former in that it considers only isolated tracks and it makes use of the large P_t boost of the Higgs to help identify its production vertex .

Figure 3a shows the P_t spectrum for tracks that have survived the above cuts separately for signal and minimum bias interactions. In Figure 3b the multiplicity for both signal and minimum bias interactions are shown. Here one can see that the Higgs interaction contains on average many more tracks with higher P_t than minimum bias interactions.

To determine the H^0 production vertex a hybrid histogram-cluster method is used. The Z impact parameters of tracks that survive the selection cuts are sorted and a sliding window[1] is used to find the cluster of tracks which contains the highest scalar ΣP_t. A P_t-weighted average of the Z impact parameters of the tracks in the cluster is used to locate the Higgs production vertex. Figure 4a shows the difference between the Z coordinate of the Higgs vertex as estimated above and the Z coordinate of the true Higgs vertex. The percentage of events in which the estimated vertex points to within 5 mm of the true Higgs vertex is shown in Figure 4b as a function of the H^0 mass and luminosity.

Conclusions

Given the kinematics of H^0 production, it is relatively simple to tag the Higgs vertex using high-P_t isolated charged tracks. Such tracks should be observable in the tracker with near perfect efficiency yielding a vertex tagging efficiency of at least 90% at

[1]The width of the window in this study was set to 10 mm in order to match the Z coordinate vertex determination requirements suggested in reference [1].

nominal luminosity and better than 70% at high luminosity. The observed tagging efficiency is independent of the H^0 mass.

References

[1] H.Yamamoto and R.Zhu, GEM TN-92-126.
[2] I.Sheer, GEM TN-93-379.
[3] T.Sjostrand, CERN-TH 6488/92.
[4] K.McFarlane and H.Uijterwaal, GEM TN 93-294.
[5] H.Yamamoto, GEM TN-92-127.

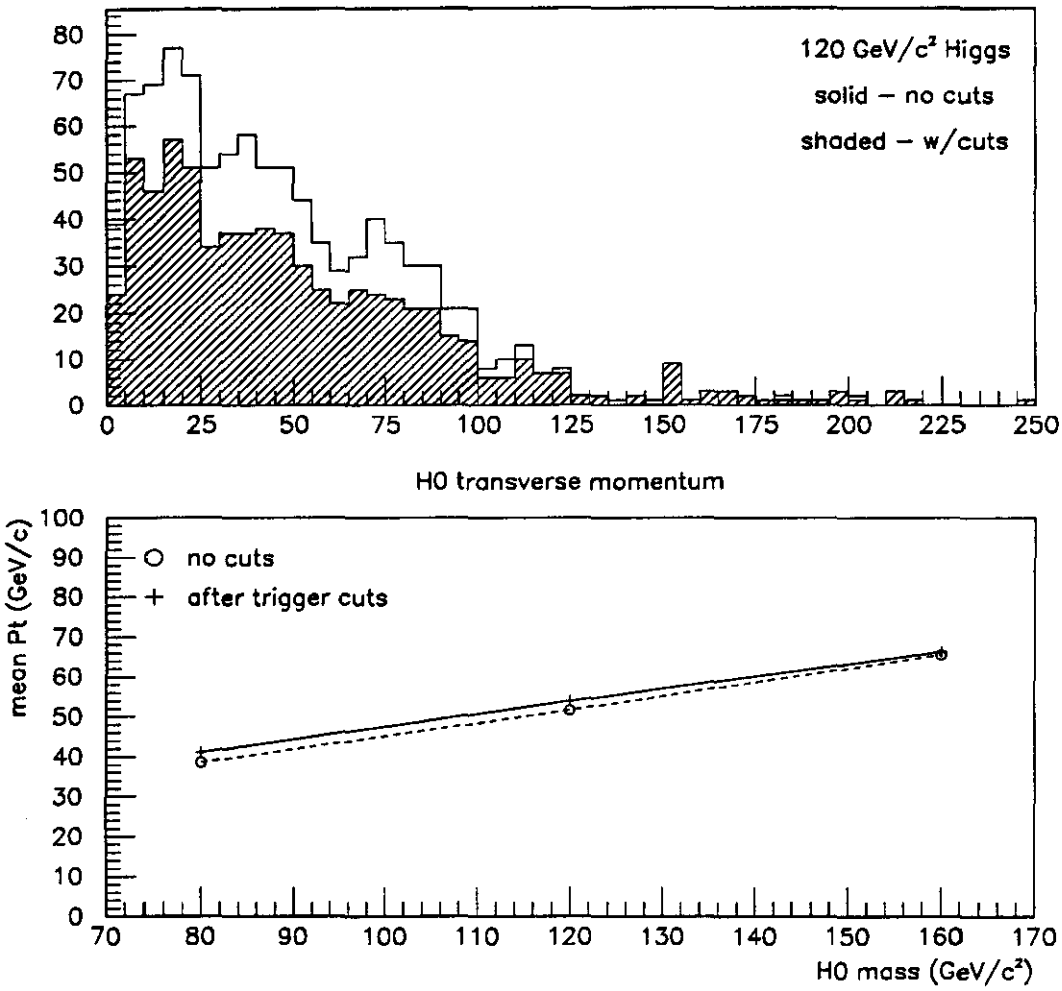
120 GeV/c² Higgs
solid – no cuts
shaded – w/cuts
H0 transverse momentum
mean Pt (GeV/c)
no cuts
after trigger cuts
H0 mass (GeV/c²)

Figure 1.

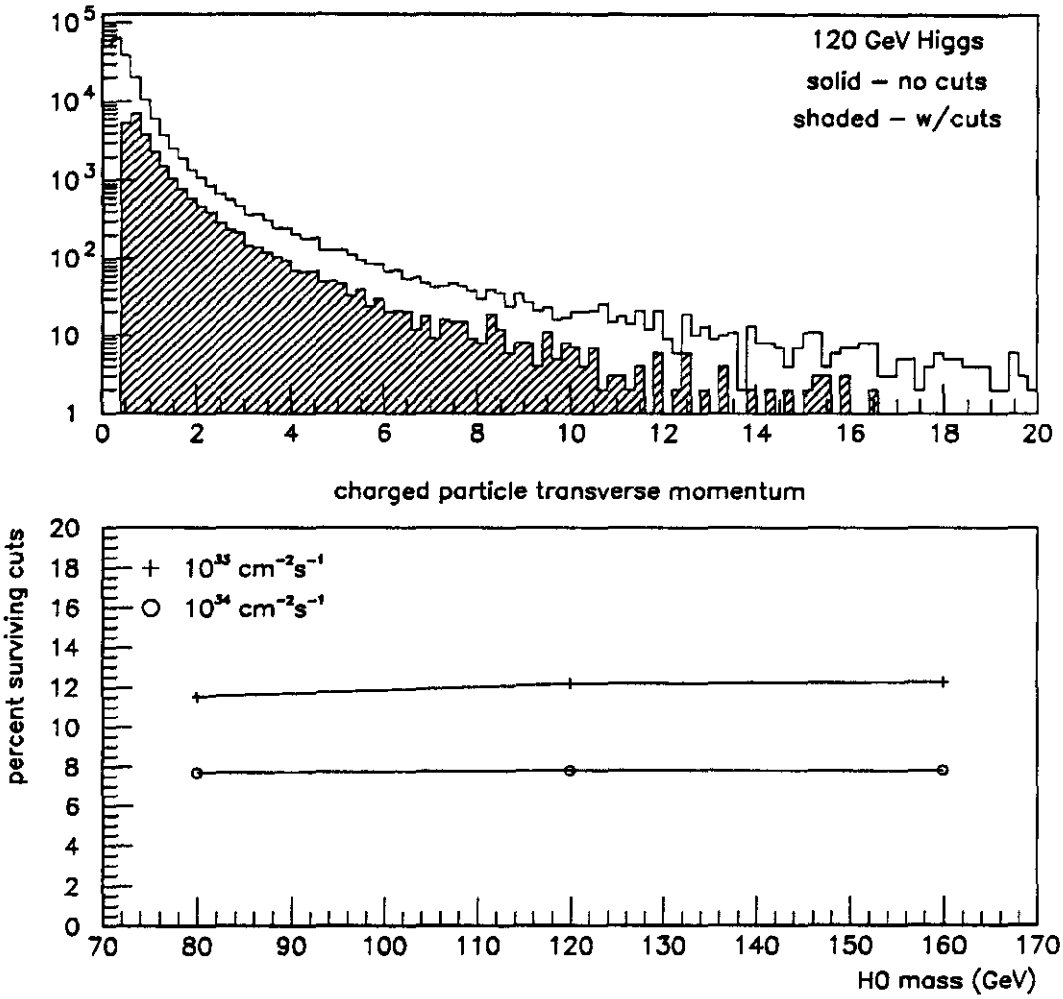
120 GeV Higgs
solid – no cuts
shaded – w/cuts
charged particle transverse momentum
percent surviving cuts
+ 10^33 cm^-2s^-1
O 10^34 cm^-2s^-1
H0 mass (GeV)

Figure 2.

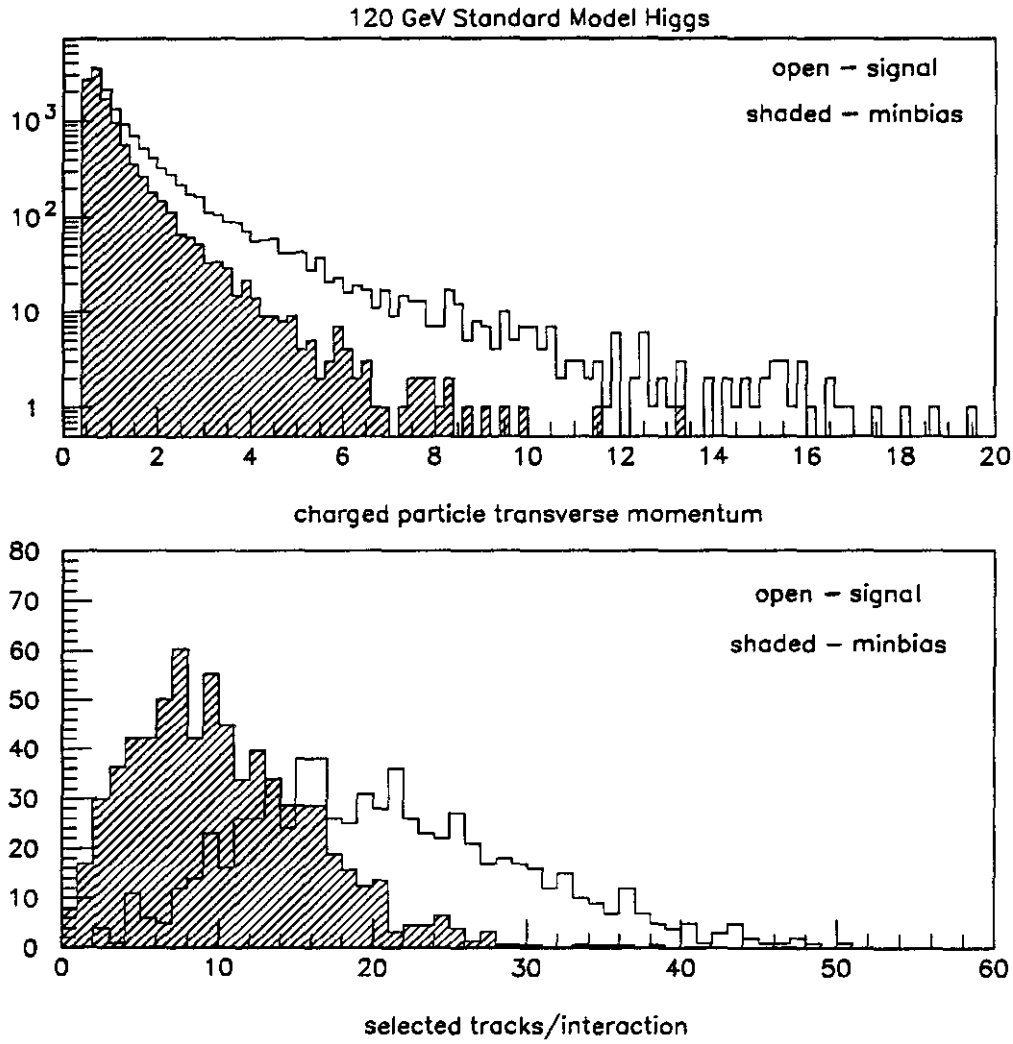
120 GeV Standard Model Higgs
open – signal
shaded – minbias
charged particle transverse momentum
open – signal
shaded – minbias
selected tracks/interaction

Figure 3.

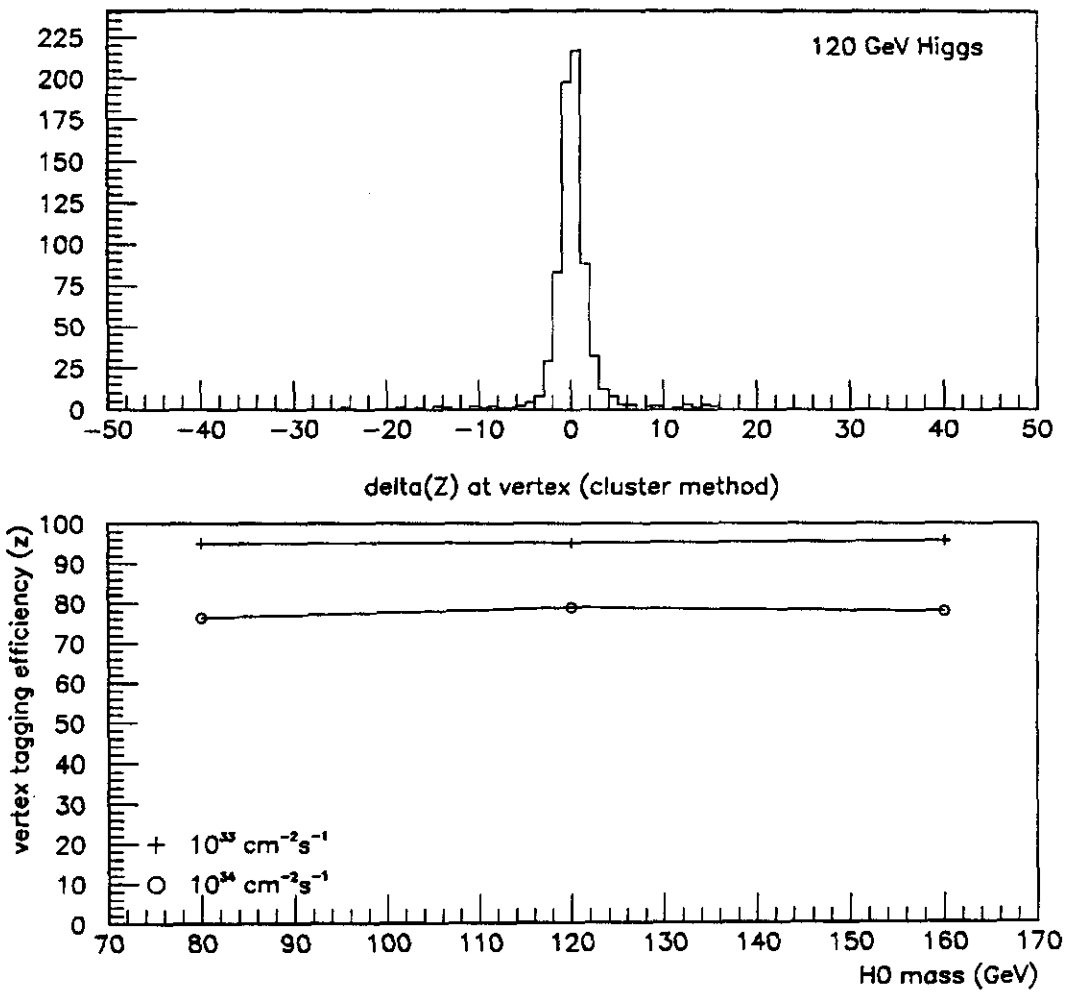
120 GeV Higgs
225
200
175
150
125
100
75
50
25
0
−50
−40
−30
−20
−10
0
10
20
30
40
50
delta(Z) at vertex (cluster method)
vertex tagging efficiency (z)
100
90
80
70
60
50
40
30
20
10
0
+ 10³³ cm⁻²s⁻¹
O 10³⁴ cm⁻²s⁻¹
70
80
90
100
110
120
130
140
150
160
170
H0 mass (GeV)

Figure 4.