GEM TN-93-276

Pointing Accuracy and Light Higgs Mass Reconstruction in a Gamma Gamma Channel

Yu. Efremenko
Oak Ridge National Laboratory

January 18, 1993

Abstract:

For light Higgs mass reconstruction in the $\gamma\gamma$ channel, the precise determination of the angle between the photons as well as their energy measurement, is important. In this note, the analysis of pointing accuracy for light Higgs mass reconstruction is presented. All calculations were done for the GEM electromagnetic calorimeter with parameters from Baseline 2.

Pointing Accuracy and Light Higgs

Mass Reconstruction in a Gamma Gamma Channel

Yu. Efremenko

O R N L

Abstract.

For light Higgs mass reconstruction in the $\gamma\gamma$ channel, the precise determination of the angle between the photons as well as their energy measurement, is important. In this note, the analysis of pointing accuracy for light Higgs mass reconstruction is presented. All calculations were done for the GEM electromagnetic calorimeter with parameters from Baseline 2.

1. Introduction.

For light Higgs mass reconstruction in the $\gamma\gamma$ channel, the precise determination of the angle between the photons as well as their energy measurement, is important. The shower position in the E-M calorimeter can be determined with the high accuracy, better then 1 mm. However, the bunch crossing adds to the Higgs event, 1.6 minimum bias events on average (at a luminosity of 10^{33} $cm^{-2}s^{-1}$). They are distributed along the beam line according to a Gaussian Distribution with a RMS. width of 4.2 cm. To reconstruct the Higgs mass with good accuracy, the correct vertex must be determined.

2. Overview.

There are several different approaches to selecting the correct vertex.

1. The first was investigated by Ren-yuan Zhu and Hiro Yamamoto [1]. They used difference in charged particle multiplicities for the Higgs and minimum bias events. Their procedure selected the correct vertex, but at the same time looses about 10-15 % of the good events. This correspond to an increase in the discovery time factor by 1.2 - 1.3 The method essentially relies on information from the central tracker.

2. Another approach has been proposed by K.Shmakov [2]. Random vertex selection has a 50% probability of being correct at a luminosity 10^{33} $cm^{-2}s^{-1}$. The measured Higgs width increases by 20% compared with the perfect vertex selection. Also, about 25% of the events go to the nongaussian tail, or just sink in the background. Both this factors increase the discovery time in 2.1 times. At the high luminosity with the large numbers of interactions per bunch crossing this method doesn't work at all.

The above approaches essentially require information from the central tracker. If the luminosity is high or tracker information is absent (for some reason), one can assume the vertex position to be in the center of the colliding bunches. This corresponds to an increase on the measured Higgs width by a factor of 2.5.

3. The E-M calorimeter itself, if longitudinal segmentation exists, can produce some information about the photon direction or so called "pointing". For this, at least two independently measured separated points along the electromagnetic shower inside the

EM calorimeter are required. To achieve this, the most simple method is to divide, the calorimeter towers in the longitudinal directions in two or more sections. Shortly, this technology could be called Tower-Tower geometry (or TT). The narrow strips placed inside the calorimeter provide more precise measurement of the shower position and, as a result, better pointing accuracy. If only one strips layer is present, one can call it Strips-Tower (or ST), and if two layers - Strips-Strips (or SS) geometries.

There are a number of papers, analyzing the angular accuracy achievable in these three techniques. See ref. [2,3,4,5]. In these papers the different designs of an LKr E-M calorimeter were under study, but only ref. [5] considered the GEM Baseline 2 design. The results are shown on Fig. 1. Unfortunately, the authors did not analyze the Strips Strips geometry. It was done by us using code for accordion calorimetry geometry developed at ORNL [6]. The open circle In Fig 1 is our result for the Strip-Tower geometry ana photon energy 100 GeV. The result is in a good agreement with data from [5]. It is show the adequate of using procedures and codes. Our calculation of the angular resolution for the strip-strip geometry is indicated by the triangles.

Based on the simulation above we can parametrize the pointing accuracy as:

Tower-Tower, pointing is 55/sqrt(E)+1.8 mrad.

Strips-Tower, pointing is 39/sqrt(E)+0.5 mrad.

Strips-Strips, pointing is 32/sqrt(E)+0.1 mrad.

3. Results.

The detection of a light Higgs with the mass of 80 GeV is the most difficult experimentally, due to the small signal to background ratio. We choose this most complicated case to study the pointing accuracy for Higgs mass reconstruction. The Monte Carlo program PYTHIA 5.6 was used for the Higgs signal simulation.

The Higgs width was calculated under the following assumptions: Energy resolution $\sigma E/E$=0.06/sqrt(E)+0.004 for the Barrel and $\sigma E/E$= 0.075/sqrt(E)+0.004 for the Endcap. Rapidity regions are 0.0 - 1.02 for the Barrel and 1.16 - 2.7 for the Endcap. For each photon the transverse momentum was required to be greater than 20

GeV.

The 80 GeV Higgs produces two photons in the following regions: for 32% of events both photons go to the Barrel; for 36% one goes to the Barrel and one goes to the Endcap; and in 32% both photons go to the Endcap part of the E-M calorimeter.

Two different luminosities were considered. For the low luminosity (10^{33} $cm^{-2}s^{-1}$), pile up and thermal noise were assumed to be 180 MeV in a 5*5 tower. In addition to the Higgs vertex, extra minimum bias vertices were generated according to a Poisson distribution with mean value of 1.6. Higgs width only due the energy resolution and noise was 560 MeV. For the high luminosity (10^{34} $cm^{-2}s^{-1}$), the total noise increases up to 430 MeV in the 5*5 tower,and 16.0 additional vertices on average were generated. For the perfect pointing, the measured Higgs width becomes 690 MeV.

In Tables (1-4), the Higgs width variation for different pointing schemes is shown. All data are normalized on the Higgs width measured with the ideal pointing. Different technology for the Barrel and Endcap E-M calorimeter are shown on vertical and horizontal columns. The statistical and systematical errors are estimated to be 1.5-2%

In the tables, independent results with and without central tracker information are present. It means that if we have vertex position from the central tracker pointing from calorimeter helps us just to choose the right one. If no vertex coordinate from tracker, we reconstruct vertex using E-M calorimeter information only.

4. Discussion and Conclusions.

From the simulation presented above one can conclude that:

1. The most complicated and expensive Strips-Strips technology does not bring a large advantages for Higgs mass reconstruction accuracy compared with the Strips-Tower.

2. Vertex information from the central tracker is very important at low luminosity. Together with pointing from the electromagnetic calorimeter even for the simplest Tower-Tower technology, it can produce excellent Higgs measurement.

3. Without vertex information from the central tracker Strips-Tower pointing technol-

ogy can produce robust capability for Light Higgs detection in the $\gamma\gamma$ channel.

4. Pointing in the Endcaps is more important that in the Barrel. This fact is most clearly illustrated in Fig 2.

5. At high luminosity, the vertex information from the central tracker improves the discovery time by no more than a few percent.

4. Acknowledgements.

Author gratefully acknowledges Yuri Kamyshkov for his helpful comments and interest for this work, Shirly Ball and Ken Read, for their assistance during preparation for publication.

REFERENCES

- [1] GEM TN-92-126, "Intermediate Mass Higgs Searches with GEM Detector", Ren-yuan Zhu and Hiro Yamamoto.
- [2] GEM TN-92-139, "Higgs to Gamma Gamma Task Force Meeting - SSCL", K Shmakov.
- [3] GEM TN-92-220, "Calorimeter Group Meeting - SSCL", Yu. Efremenko.
- [4] A. Onuchin, private communications.
- [5] GEM TN-92-257, "Optimization of Accordion EM Calorimeter in GEM", Hong Ma, Mikhail Leltchouk.
- [6] K. Shmakov, private communications.

Table 1. Low luminosity, with vertex information from central tracker.

Barrel \ Endcap	TT	ST	SS
TT	1.09	1.05	1.04
ST	1.07	1.03	1.03
SS	1.03	1.04	1.02

Table 2. Low luminosity, no vertex information from central tracker.

Barrel \ Endcap	TT	ST	SS
TT	1.43	1.24	1.18
ST	1.34	1.20	1.20
SS	1.33	1.21	1.16

Table 3. High luminosity, with vertex information from central tracker.

Barrel \ Endcap	TT	ST	SS
TT	1.27	1.16	1.11
ST	1.22	1.12	1.13
SS	1.17	1.12	1.09

Table 4. High luminosity, no vertex information from central tracker.

Barrel \ Endcap	TT	ST	SS
TT	1.32	1.19	1.13
ST	1.27	1.15	1.14
SS	1.22	1.14	1.11

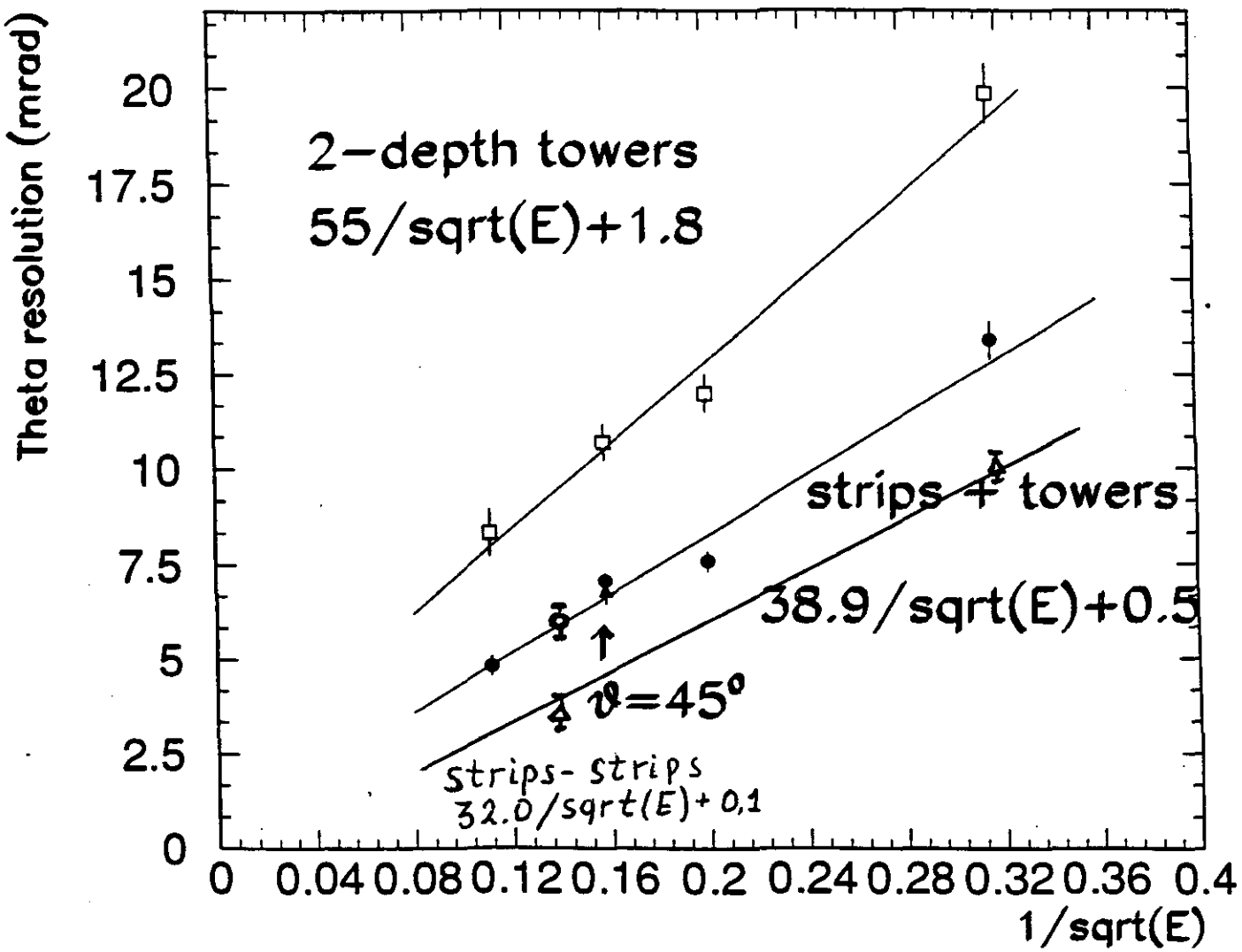
Theta resolution (mrad)
20
17.5
15
12.5
10
7.5
5
2.5
0
0
0.04
0.08
0.12
0.16
0.2
0.24
0.28
0.32
0.36
0.4
1/sqrt(E)
2-depth towers
55/sqrt(E)+1.8
strips + towers
38.9/sqrt(E)+0.5
ϑ=45°
strips- strips
32.0/sqrt(E)+0.1

Fig 1.

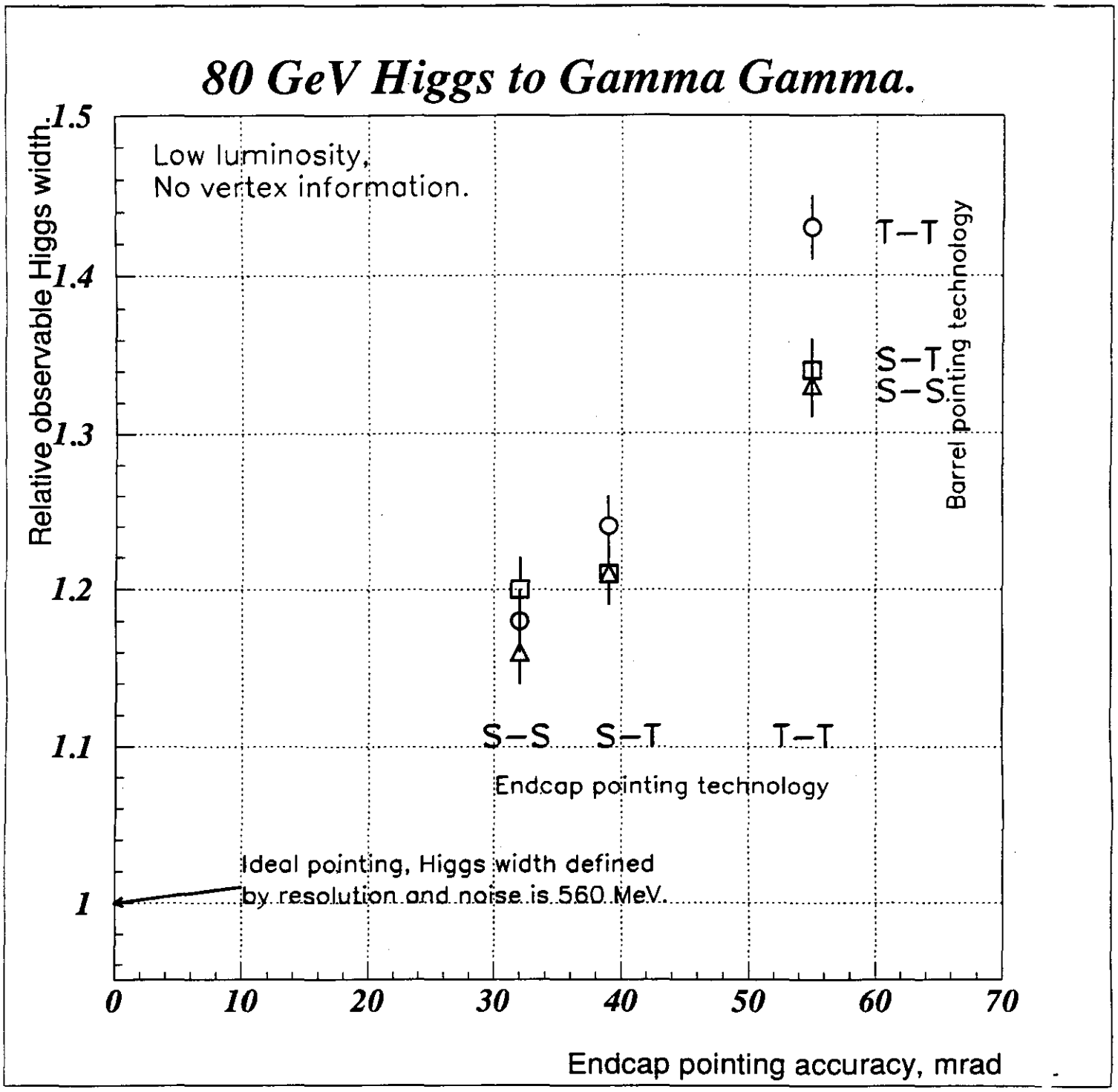
80 GeV Higgs to Gamma Gamma.
Low luminosity,
No vertex information.
Relative observable Higgs width
1.5
1.4
1.3
1.2
1.1
1
0
10
20
30
40
50
60
70
T−T
S−T
S−S
Barrel pointing technology
S−S
S−T
T−T
Endcap pointing technology
Ideal pointing, Higgs width defined
by resolution and noise is 560 MeV.
Endcap pointing accuracy, mrad

Fig 2.