Higgs mass measurement and $\gamma(\ast)\gamma(\ast)$ backgrounds

Toshinori Abe

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Introduction

- Want to study $\gamma(*)\gamma(*) \rightarrow \text{hadrons}$ effect on Higgs mass measurement
- How severe the backgrounds are for Warm?
- How much difference do we see between Cold and Warm?
- Compare the results with European study
Contents of this talk

- We are doing the followings
  1. Analysis overflow and 5C kinematical fit
  2. Lesson from Higgs mass measurements with no $\gamma^(*)\gamma^(*)$ suppression
  3. $\gamma^(*)\gamma^(*) \rightarrow$ hadrons suppression and European results
  4. Our results
Analysis assumption

- Use $e^+e^- \rightarrow ZH \rightarrow q\bar{q}bb$ at $E_{cm}=500\text{GeV}$.
- Use $\gamma^*(\gamma^*) \rightarrow $ hadrons provided by Tim to overlay on signal and background events.
- Only $e^+e^- \rightarrow ZH \rightarrow qqqq$ process is taken into account as backgrounds.
- Use fast detector simulation (SDMar01).
Event selection

- Force into four jets using Durham algorithm.
- Jets to form Higgs mass satisfy b-jet tagging.
- We require four-momentum conservation and constrain one of the two dijet masses to be $m_Z=91.2\text{GeV}$ (5C-fit). One of the six possible jet pairings, the one minimizing $\chi^2$ of the fit is chosen.
- Etc....
5C Kinematical fit

The code is provided by courtesy of European colleagues.
Reconstructed Higgs mass

$m_{\text{Higgs}}$ (GeV) $N_{\gamma\gamma}=0.00$

width=2.7GeV

$m_{\text{Higgs}}$ (GeV) $N_{\gamma\gamma}=5.82$

width=7.0GeV

100fb$^{-1}$
m_{Higgs} without γ(*)γ(*) suppression

Higgs mass measurements with various BX (100fb⁻¹)

N_{γγ} = 0.000
120.46 ± 0.13 GeV

N_{γγ} = 0.291 (1BX)
120.48 ± 0.13 GeV

N_{γγ} = 0.808 (TESLA)
121.22 ± 0.15 GeV

N_{γγ} = 1.164 (4BX)
121.01 ± 0.15 GeV

N_{γγ} = 1.455 (5BX)
121.69 ± 0.16 GeV

N_{γγ} = 2.910 (10BX)
123.17 ± 0.19 GeV

N_{γγ} = 5.820 (20BX)
127.64 ± 0.27 GeV

N_{γγ} vs. \delta m_{Higgs} (100fb⁻¹)

T   E   S   L   A

N   L   C

χ² / ndf = 0.0001135 / 5
p0 = 0.1254 ± 0.00279
p1 = 0.02426 ± 0.001078

100fb⁻¹
\( \gamma(\ast)\gamma(\ast) \) effect on Higgs mass

- \( \gamma(\ast)\gamma(\ast) \rightarrow \text{hadrons} \) results in widening reconstructed Higgs mass distribution.
  
  1. 5\textasciitilde8\,\text{ns} time separation is needed to be equivalent to TESLA.
  
  2. About 2X worse measurement error for 20BX compared to no \( \gamma(\ast)\gamma(\ast) \rightarrow \text{hadrons} \).

- We need to suppress \( \gamma(\ast)\gamma(\ast) \rightarrow \text{hadrons} \).
Possible cut to suppress $\gamma(\ast)\gamma(\ast)$ backgrounds

- European colleague already studied to suppress $\gamma(\ast)\gamma(\ast)$ backgrounds and they found $P_T$ cut is very useful.
- After $P_T > 1.0\text{GeV}$ requirement, most of $\gamma(\ast)\gamma(\ast)$ backgrounds are gone.
**γ(∗)γ(∗) background suppression**

Angle between jet-axis and particles

Before (red γ(∗)γ(∗) backgrounds)

After (red γ(∗)γ(∗) backgrounds)

Not same number of events…

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### European results (500fb⁻¹)

<table>
<thead>
<tr>
<th>$N_{\gamma\gamma} \rightarrow$ hadrons</th>
<th>$\delta m_{\text{Higgs}}$ (MeV)</th>
<th>$\frac{\delta m_{\text{Higgs}}}{\delta m_{\text{Higgs}}(0)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>68</td>
<td>-</td>
</tr>
<tr>
<td>TESLA</td>
<td>75</td>
<td>1.10</td>
</tr>
<tr>
<td>4BX</td>
<td>78</td>
<td>1.15</td>
</tr>
<tr>
<td>18BX</td>
<td>92</td>
<td>1.35</td>
</tr>
</tbody>
</table>

~2.0 for no $\gamma\gamma$ suppression

![Graph showing $N_{\gamma\gamma}$ vs. $\delta m_{\text{Higgs}}$ (500fb⁻¹)]

- TESLA
- NLC

Summary:
- $\Delta m_{\text{Higgs}}$: Variations in Higgs boson mass
- $N_{\gamma\gamma}$: Number of gamma-gamma hadrons produced
- Values show slight to moderate shifts in Higgs boson mass relative to baseline.
Higgs mass (European method)

- $P_T > 1.0\, \text{GeV}$ requirement helps to suppress the $\gamma(\gamma^*)$ effect on Higgs mass measurement.
- But we still need 5~8ns time separation to match up Cold (TESLA) environment.
- The larger error with $P_T > 1.0\, \text{GeV}$ can be understood due to information loss of reconstructed jet energy.
Our approach

- We want to recover jet energy resolution to improve reconstructed Higgs mass resolution with $P_T > 1.0\text{GeV}$.
- Since we use Linear Collider environment with which we know total four momentum of the reaction, we could recover the jet energy resolution.
- We already use this information (5C fit), but European colleague uses resolution function which is determined with “NO” $P_T > 1.0\text{GeV}$ requirement. ➞ re-determine the function with the requirement.
Higgs mass distribution

0BX

TESLA

4BX

20BX
Our results (500fb⁻¹)

<table>
<thead>
<tr>
<th>N_{\gamma\gamma} \rightarrow hadrons</th>
<th>\delta m_{\text{Higgs}} (MeV)</th>
<th>\delta m_{\text{Higgs}} / \delta m_{\text{Higgs}}(0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>1BX</td>
<td>74</td>
<td>1.04</td>
</tr>
<tr>
<td>TESLA</td>
<td>77</td>
<td>1.08</td>
</tr>
<tr>
<td>4BX</td>
<td>79</td>
<td>1.11</td>
</tr>
<tr>
<td>5BX</td>
<td>79</td>
<td>1.11</td>
</tr>
<tr>
<td>10BX</td>
<td>82</td>
<td>1.15</td>
</tr>
<tr>
<td>20BX</td>
<td>81</td>
<td>1.14</td>
</tr>
</tbody>
</table>

\[ \delta \text{m_{Higgs}} \text{ vs. } N_{\gamma\gamma} \text{ (500fb}^{-1}) \]

- TESLA: \chi^2 / n df = 1.43e-096 / 4
- p0: 0.98159 ± 0.0005871
- p1: -0.01059 ± 0.0007758
- p2: -1.111 ± 0.1978
Compared to European results

<table>
<thead>
<tr>
<th>$N_{\gamma\gamma}$ hadrons</th>
<th>$\delta m_{\text{Higgs}}$ (MeV) (European’s)</th>
<th>$\delta m_{\text{Higgs}}$ (MeV) (Ours)</th>
</tr>
</thead>
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<tr>
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<td>81</td>
</tr>
</tbody>
</table>
Summary

- Larger $\gamma\gamma$ backgrounds results in increasing error of Higgs mass measurement, so we need good time separation for warm environment.
- European colleague establishes efficient $\gamma\gamma$ backgrounds suppression, but it looks we still need good time separation.
- 5C-fit recovers the measurement accuracy with reasonable level compared to Cold environment even 20BX case.
- Our and European results are consistent ($<10$BX).