Improved analysis on $\gamma\gamma \rightarrow \text{higgs} \rightarrow b\bar{b}$

including overlaid events,
vertex smearing and crab crossing
for SM and MSSM

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Our analysis of precision $\sigma(\gamma\gamma \rightarrow higgs \rightarrow b\bar{b})$ measurement includes:

- realistic $\gamma\gamma$-spectra
- $b$-tagging
- overlaying events $\gamma\gamma \rightarrow hadrons$ (OE)

results for SM at $M_h = 120, 130, 140, 150, 160$ GeV

results for MSSM at $M_A = 200, 250, 300, 350$ GeV
with $\tan \beta = 7, M_2 = \mu = 200$ GeV (following M. Mühlleitner et al.)

Recent development:

- crossing angle
- primary vertex distribution
Photon-photon spectrum: CompAZ

Signal: HDECAY, PYTHIA
Background: NLO $Q\bar{Q}(g)$ (G. Jikia)

Pile-up events $\gamma\gamma \rightarrow$ hadrons with realistic $\gamma\gamma$-luminosity spectrum (V. Telnov)
Parton Shower (signal only): PYTHIA
Fragmentation: PYTHIA (Lund)

Detector performance: SIMDET 4.01
Jets: Durham algorithm with $y_{cut} = 0.02$,
      (clusters & tracks below $\theta_{det} = 555$ mrad are ignored)

Selection of $b\bar{b}$ events for $M_{higgs} = 120$ (300) GeV:

- ZVTOP-B-Hadron-Tagger by T. Kuhl
- consider only jets with $p_T^{jet}/E_T > 0.1$ (OE-jets suppression)
- $N_{jets} = 2, 3$
- $|P_z|/E < 0.12$ (0.07) where $P_z = \sum p_z^{jet}$ and $E = \sum E^{jet}$
- $|\cos \theta_{jet}| < 0.71$ (0.65) for each jet
Angles

2 or 3 jets above
\[ \theta_{\text{jet}} = 45^\circ \quad (\cos \theta_{\text{jet}} = 0.71) \]

Tracks/clusters ignored below
\[ \theta_{\text{det}} = 32^\circ \quad (\cos \theta_{\text{det}} = 0.85) \]

Remove particles on Pythia level below \( \theta_{\text{mask}} = 7.5^\circ \)
\( (\cos \theta_{\text{mask}} = 0.99) \)
Crab-wise crossing of beams

\[ \sigma'_x = \sqrt{\frac{1}{2}(\sigma_x^2 + \sigma_z^2 \tan^2(\alpha_c/2))} \quad \sigma'_y = \sigma_y / \sqrt{2} \quad \sigma'_z = \sigma_z / \sqrt{2} \]

Bunch: \quad \sigma_x = 140 \ nm \quad \sigma_y = 7 \ nm \quad \sigma_z = 0.3 \ mm

Primary vertex: \quad \sigma'_x = 3.6 \ \mu m \quad \sigma'_y = 5 \ nm \quad \sigma'_z = 0.2 \ mm

\alpha_c = 34 \ mrad
Corrected reconstructed mass:

\[ W_{\text{corr}} \equiv \sqrt{W_{\text{rec}}^2 + 2P_T(E + P_T)} \]

(using only accepted jets)

Correction for crossing angle:

\[ p_x \rightarrow p_x - \sin(\alpha_c/2)E \]

\[ E \rightarrow E - \sin(\alpha_c/2)p_x \]
**higgs-tagging at** $M_h = 120$ GeV

Using *higgs*-tagging:
- a cut on the ratio of $\gamma \gamma \rightarrow h \rightarrow b \bar{b}$
- to $\gamma \gamma \rightarrow b \bar{b}(g)$, $c \bar{c}(g)$ events

Earlier we used *b*-tagging:
- a cut on the ratio of $\gamma \gamma \rightarrow b \bar{b}(g)$
- to $\gamma \gamma \rightarrow c \bar{c}(g)$ events
SM summary, $M_h = 120-160$ GeV

\[ \Delta \sigma/\sigma \text{ for } \gamma\gamma \to h \to bb \] with OE, primary vtx distrib.

- with OE
- without OE
Number of overlaying events: \( \sim 2 \) per bc

**MSSM, \( M_A = 300 \) GeV**

- e\(^-\)e\(^-\) beams with \( \sqrt{s_{ee}} = 419 \) GeV
- Number of events / 5 GeV
- \( M_A = 300 \) GeV
- \( t\beta = 7 \)
- \( M_2 = \mu = 200 \) GeV
- NLO Background:
  - bb\((g)\)
  - cc\((g)\)
- Total \( L_{\gamma\gamma} = 808 \) fb\(^{-1}\)

\[ \Delta \sigma/\sigma = 9.2\% \]

Optimal *higgs*-tagging

- \#\(\gamma\gamma \rightarrow h \rightarrow b\bar{b} \)
- \#\(\gamma\gamma \rightarrow bb(g), cc(g) \)
MSSM, $M_A = 200-350$ GeV

$\Delta \sigma / \sigma$ for $\gamma\gamma \rightarrow A, H \rightarrow bb$ [%] with OE, primary vtx distrib.

- with OE, primary vtx distrib.
- with OE
- without OE

$\tan \beta = 7$  $M_2 = \mu = 200$ GeV

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Conclusions

High precision for SM & MSSM higgses can be achieved despite $\gamma\gamma \rightarrow \text{hadrons}$ pile-up events and primary vertex distribution.

Cut on $p_T^{\text{jet}}/E_T$ discriminates OE jets, remaining after $\theta_{\text{det}}$ cut.

Optimal cuts per mass point: $|P_z|/E$, $\cos \theta_{\text{jet}}$.

higgs-tagging: cut on the ratio of $\gamma\gamma \rightarrow h \rightarrow b\bar{b}$ to $\gamma\gamma \rightarrow b\bar{b}(g)$, $c\bar{c}(g)$ events (region in the plane $\text{btag}_1 \otimes \text{btag}_2$)

Precision of 2% for $\Gamma(h \rightarrow \gamma\gamma)\text{Br}(h \rightarrow b\bar{b})$ at $M_h = 120$ GeV.

Plans:

- Background $\gamma\gamma \rightarrow WW$
- MSSM: parameters space scan