Study of $\gamma\gamma \to higgs \to b\bar{b}$ in SM & MSSM at the Photon Collider

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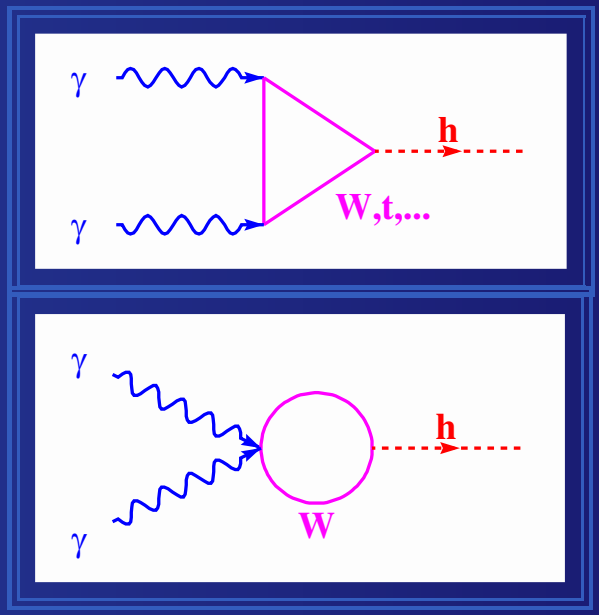
Loop coupling $h\gamma\gamma$:

- Higgs-bosons can be produced as s-channel resonances
- Non-decoupling $\Rightarrow$ tests of models
- The best machine for this measurement: Photon Collider



Beyond SM: $H^{\pm}$, $\chi^{\pm}$, $\tilde{q}$, $\tilde{l}$ ...

hep-ph/0208234, hep-ph/0307180, hep-ph/0307183, hep-ph/0503295

presented ar LCWS05 (hep-ph/0507004, hep-ph/0507006)

Introduction

Our analysis of $\sigma(\gamma\gamma \to h \to b\bar{b})$ and $\sigma(\gamma\gamma \to A, H \to b\bar{b})$ measurement:

- Realistic $\gamma\gamma$-spectra (TESLA-like)
- Beams crossing angle, primary vertex distribution
- NLO QCD background $\gamma\gamma \to Q\bar{Q}(g) \quad (Q = c, b)$
- Other backgrounds: $\gamma\gamma \to W^+W^-$, $\gamma\gamma \to q\bar{q}$ $(q = u, d, s)$, $\gamma\gamma \to \tau^+\tau^-$
- Overlaying events $\gamma\gamma \to hadrons$: about 1–2 OE per bunch crossing
- b-tagging (*e.g.* for $M_A = 300$ GeV: $\varepsilon_h = 53\%$, $\varepsilon_{bb} = 47\%$, $\varepsilon_{cc} = 2.9\%$, $\varepsilon_{uds} = 0.5\%$)
- Realistic detector simulation (SIMDET)
- Full optimization of cuts

$\Rightarrow$ results for SM with $M_h = 120$, 130, 140, 150, 160 GeV

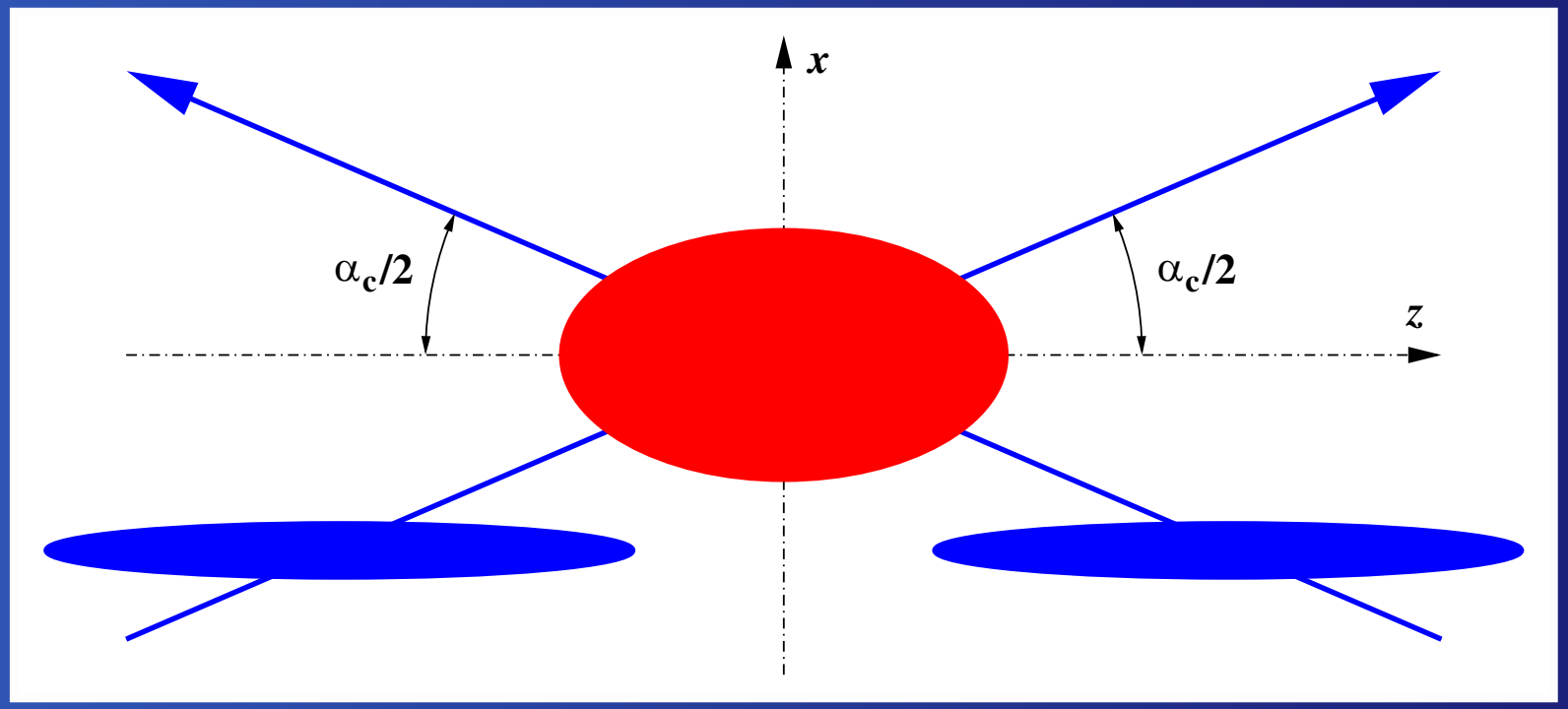
$\Rightarrow$ results for MSSM with $M_A = 200$, 250, 300, 350 GeV
four MSSM scenarios for $\tan\beta = 3$–20.

Crab-wise crossing of beams

$$\sigma'_x = \sqrt{\tfrac{1}{2}(\sigma_x^2 + \sigma_z^2 \tan^2(\alpha_c/2))} \qquad \sigma'_y = \sigma_y/\sqrt{2} \qquad \sigma'_z = \sigma_z/\sqrt{2}$$

Bunch: $\sigma_x = 140$ nm $\sigma_y = 15$ nm $\sigma_z = 0.3$ mm

Primary vertex: $\sigma'_x = 3.6\ \mu$m $\sigma'_y = 11$ nm $\sigma'_z = 0.2$ mm

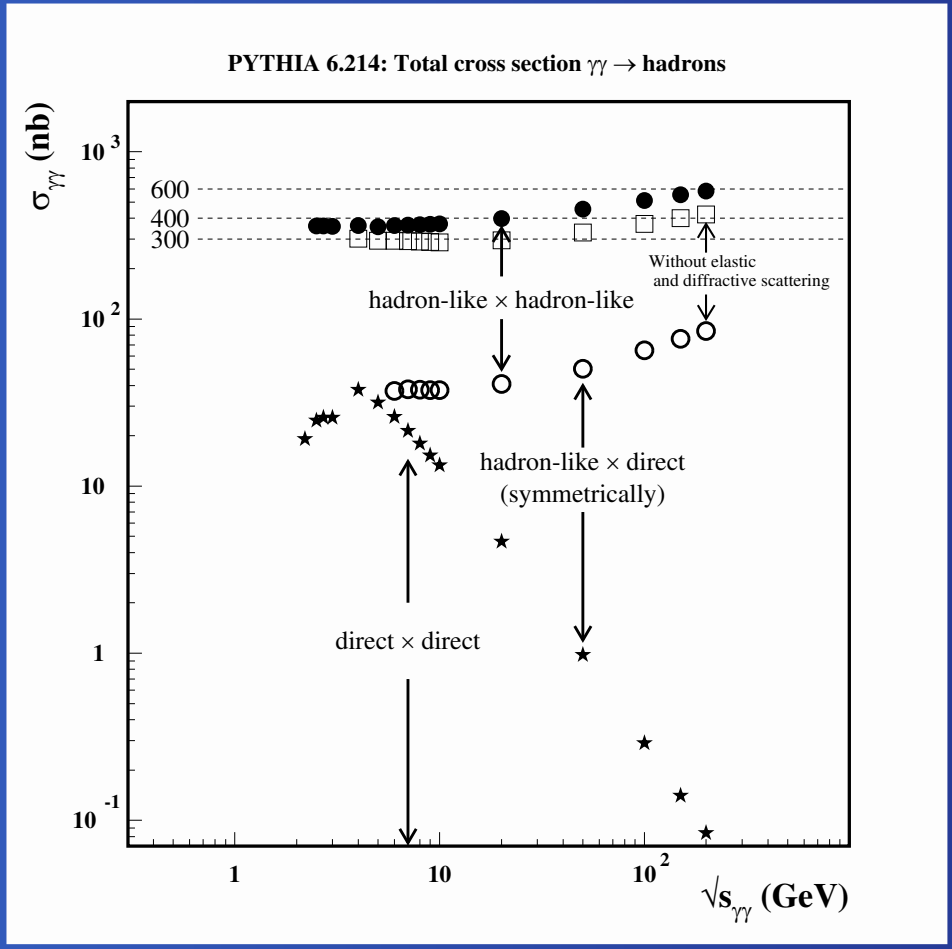


$\alpha_c = 34$ mrad

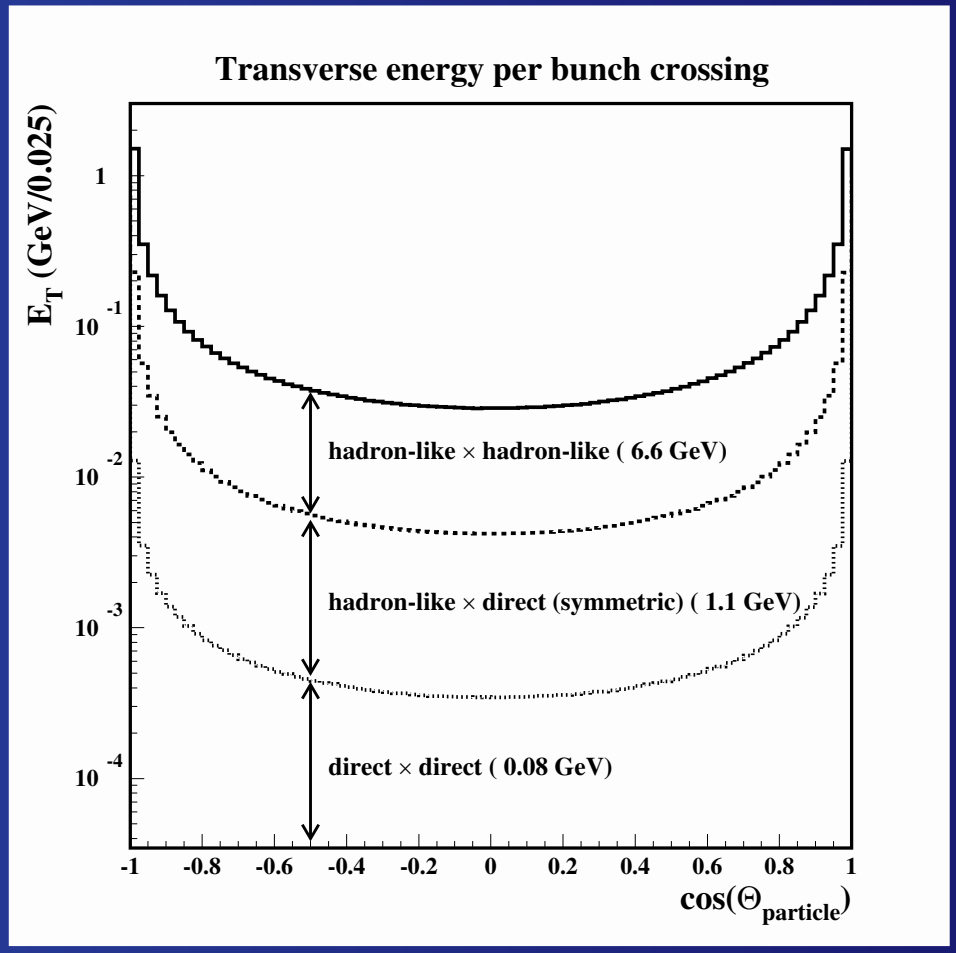
Primary vertex distribution + $\gamma\gamma \to hadrons$ OE = possible flavour mistagging

$\gamma\gamma \to hadrons$ events

Cross sections



Angular E_T-flow per bunch crossing.



Generation for $\sqrt{s_{ee}} = 210.5$ GeV.

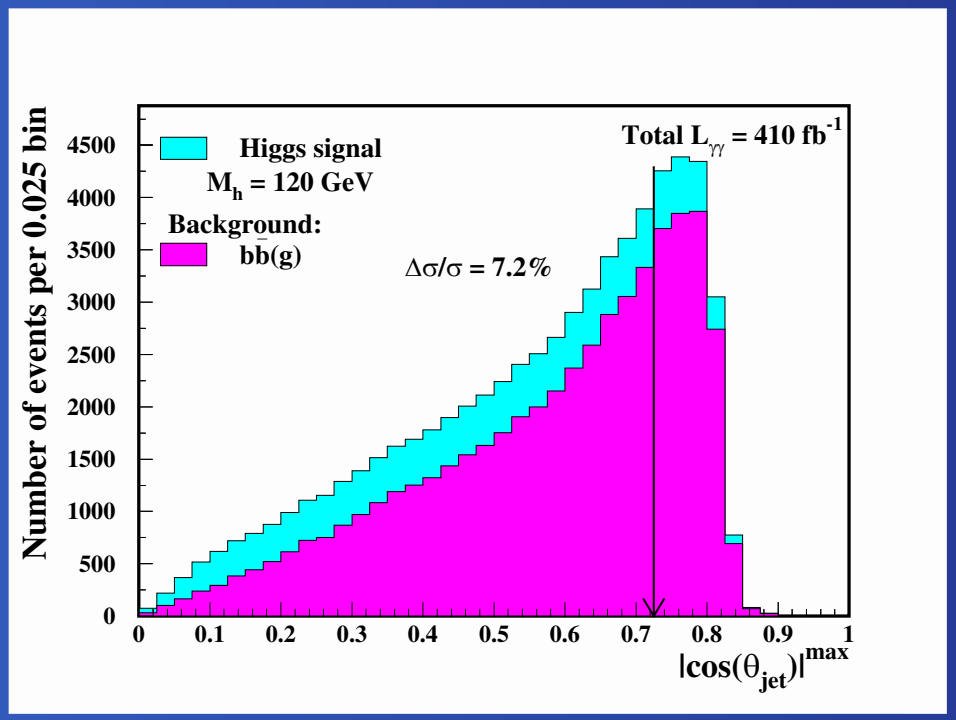
$\Rightarrow$ Reject tracks and clusters below θ_{TC}

Cuts

Cuts optimized by minimizing:

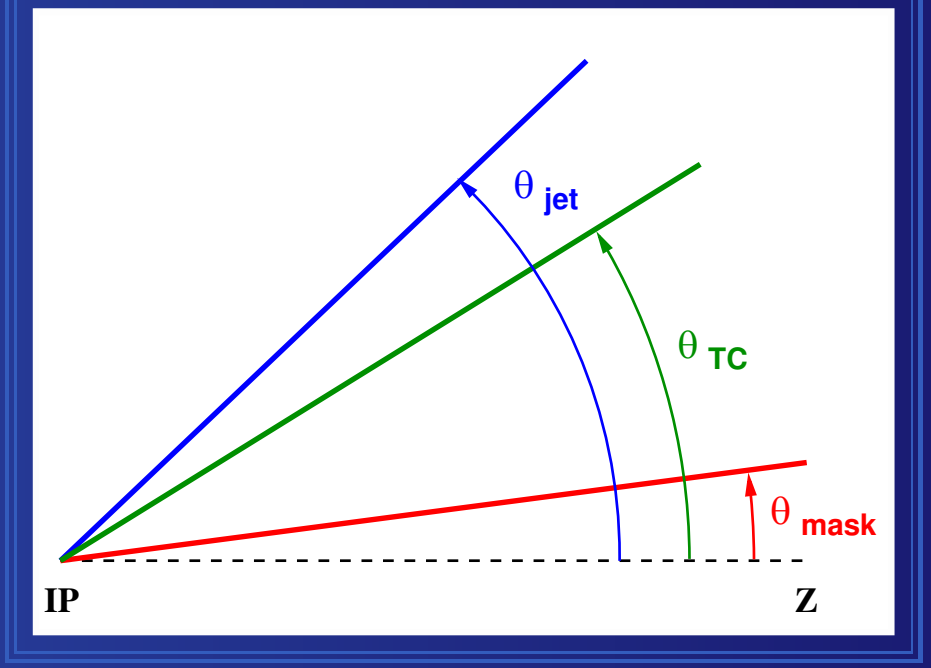
$$\frac{\Delta\sigma(\gamma\gamma \to h \to b\bar{b})}{\sigma(\gamma\gamma \to h \to b\bar{b})} = \frac{\sqrt{\mu_S + \mu_B}}{\mu_S},$$

For example, for $M_h = 120$ GeV:



Maximal value of $|\cos\theta_{jet}|$ over all jets in the event

All angular cuts



Detector mask
Particles on Pythia level: $\cos\theta_{mask} \approx 0.99$

OE suppression
Tracks & clusters: $\cos\theta_{TC} = 0.85$

$\gamma\gamma \to Q\bar{Q}(g)$ suppression
Jets: $|\cos\theta_{jet}|^{\max} = 0.725$

Reconstruction & Selection

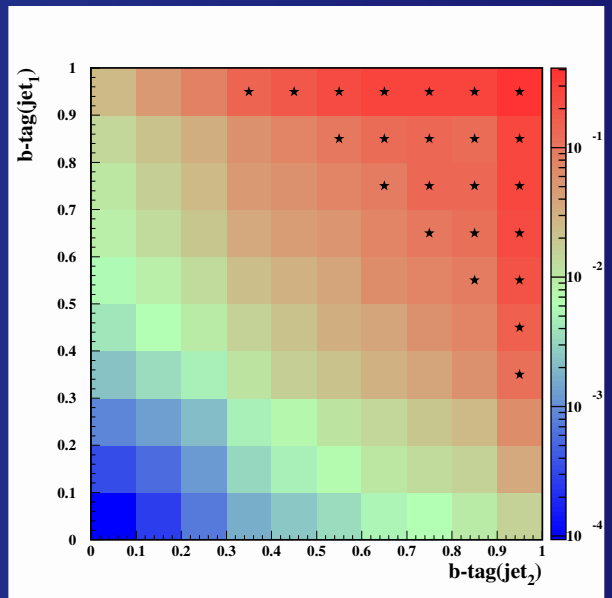
Selection of $b\bar{b}$ events for $M_h = 120$ GeV:

- OE suppression: clusters & tracks with $|\cos\theta_i| > \cos\theta_{TC} = 0.85$ ignored
- $W_{rec} > 1.2\, W_{\gamma\gamma}^{\min}$

  Jets: Durham algorithm, $y_{cut} = 0.02$
- $N_{jets} = 2, 3$
- for each jet: $|\cos\theta_{jet}| < 0.725$
- $|P_z|/E < 0.1$

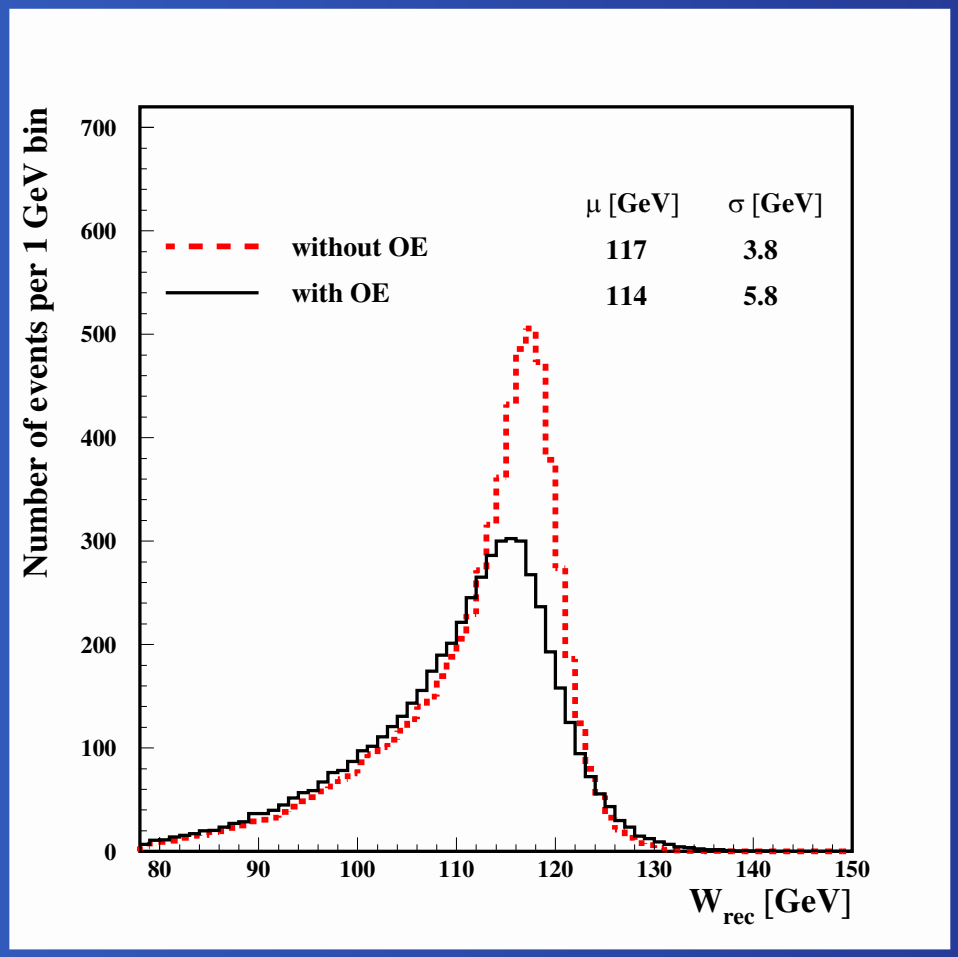
Rejection of W^+W^- events for masses ≥ 150 GeV, for example for $M_A = 300$ GeV:

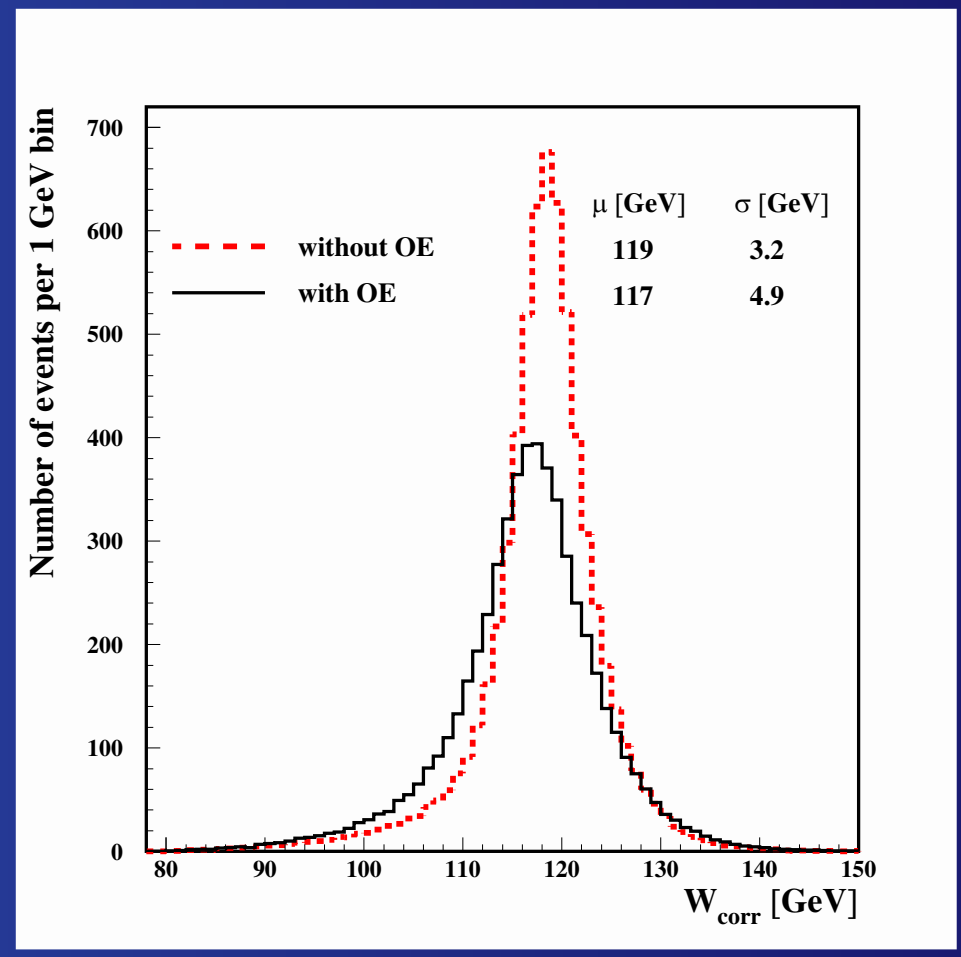
- for each jet: $M_{jet} < 65$ GeV
- energy below θ_{TC}: $E_{TC} < 80$ GeV
- for each jet: $N_{trk} \geq 4$
- b-tagging



Correction for crossing angle: jets boosted with $\beta = -\sin(\alpha_c/2)$

SM, $M_h = 120$ GeV





Without OE: 6450 events
With OE : 5530 events

$W_{\rm corr} \equiv \sqrt{W_{rec}^2 + 2P_T(E + P_T)}$

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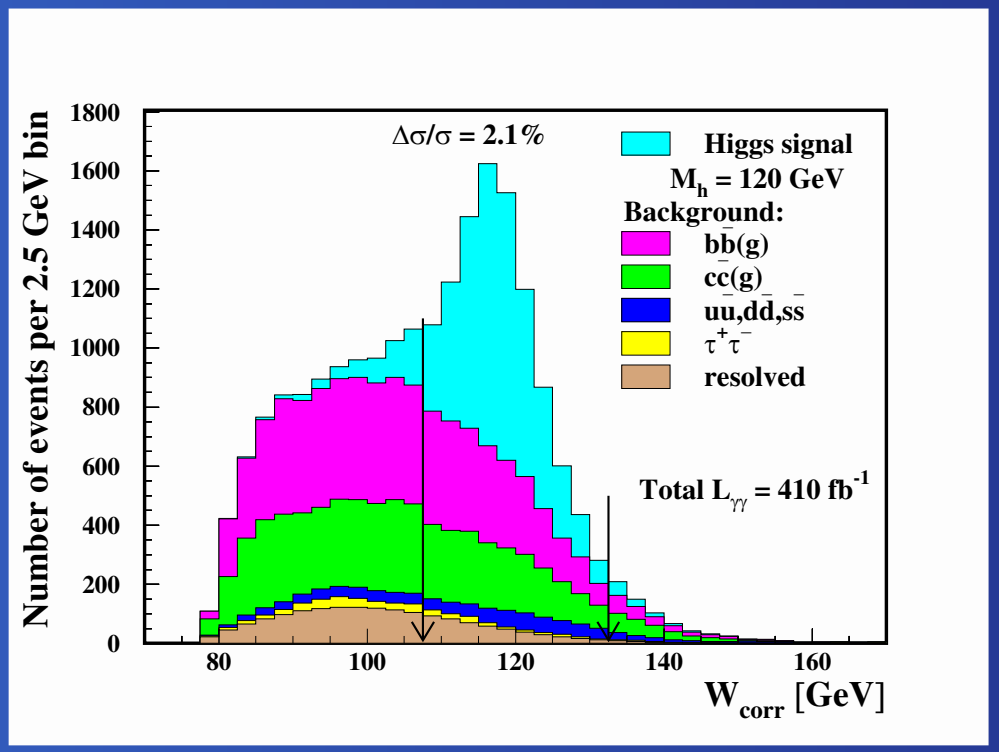
Gaussian fit from $\mu - 1.3\sigma$ to $\mu + 1.3\sigma$.

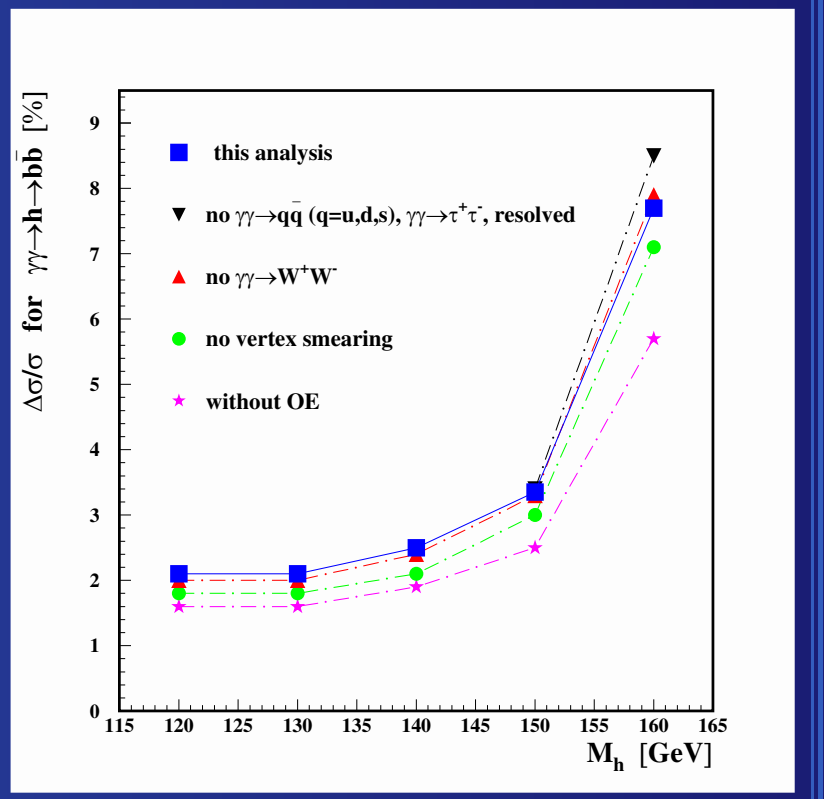
SM summary

Results for $M_h = 120$ GeV



Corrected invariant mass distributions for signal and background events

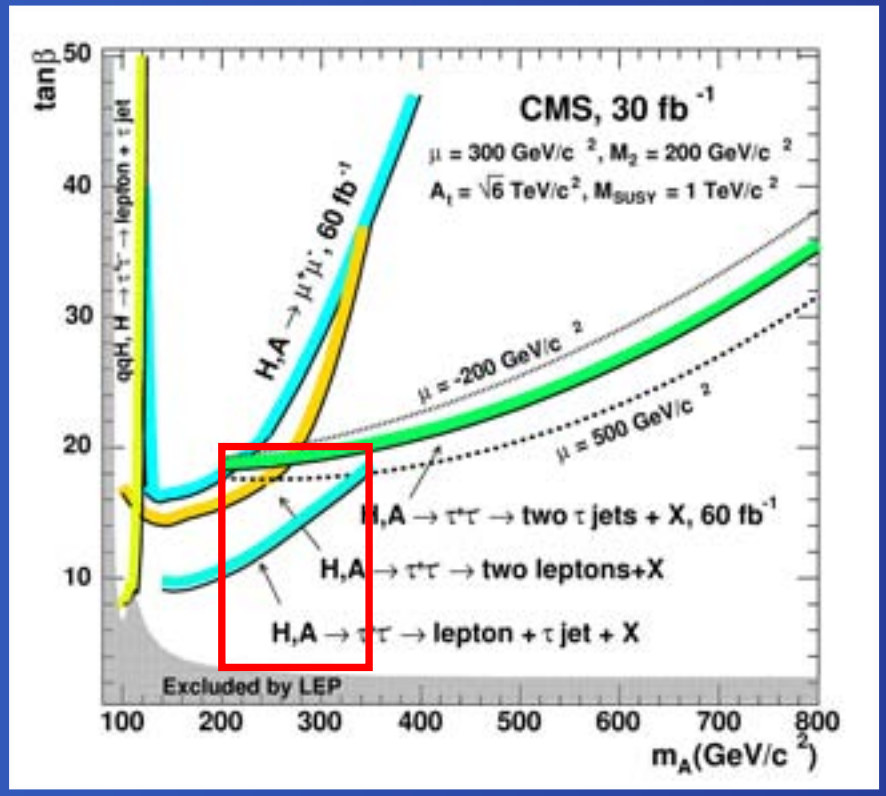
Results for $M_h = 120$-160 GeV



For $M_h = 150$, 160 GeV additional cuts to reduce $\gamma\gamma \to W^+W^-$

MSSM: LHC wedge at PLC

LHC wedge



From: CMS NOTE 2003/033
(the same results as in newer CMS CR 2004/058)

We consider four MSSM parameter sets:

Symbol	μ [GeV]	M_2 [GeV]	$A_{\tilde{f}}$ [GeV]
I	200	200	1500
II	-150	200	1500
III	-200	200	1500
IV	300	200	2450

I and III – as in M. Mühlleitner *et al.* with higher $A_{\tilde{f}}$ to have M_h above 114 GeV

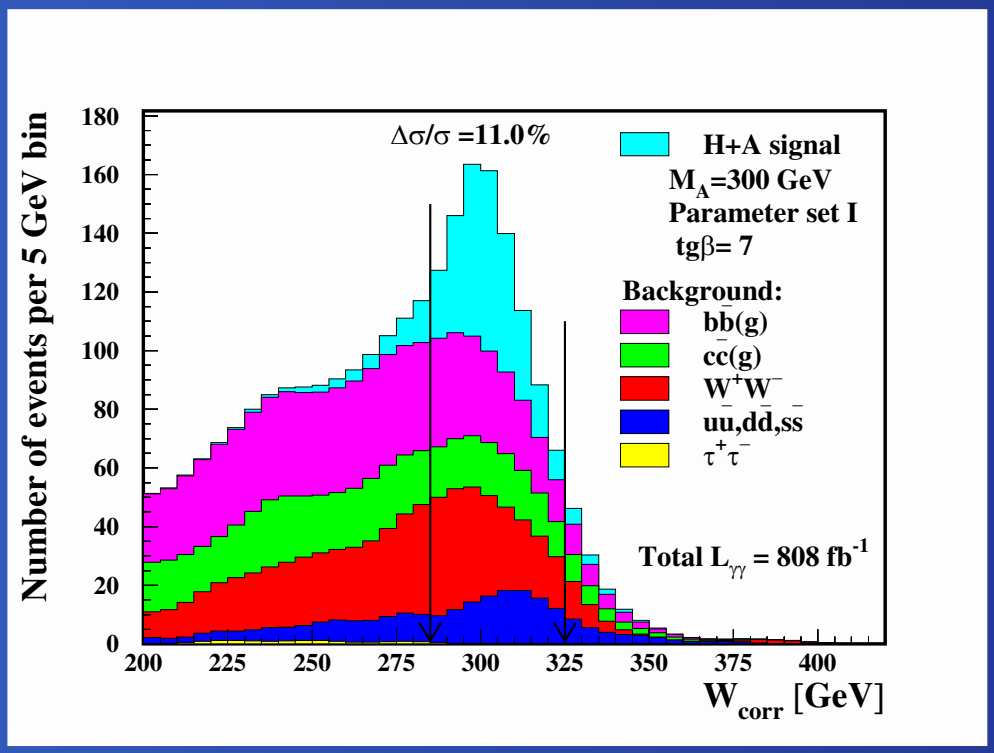
II – an intermediate scenario

IV – as in CMS NOTE 2003/033

MSSM: Precision at PLC

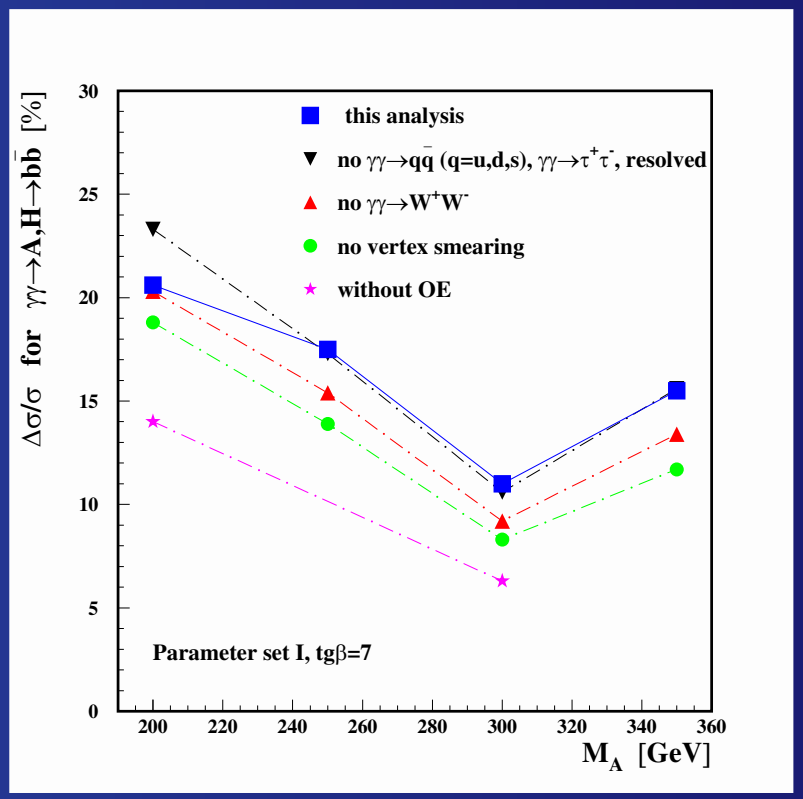
Precision of $\sigma(\gamma\gamma \to A, H \to b\bar{b})$ mesurement

Results for $M_A = 300$ GeV



Corrected invariant mass distributions

Results for $M_A = 200$-350 GeV

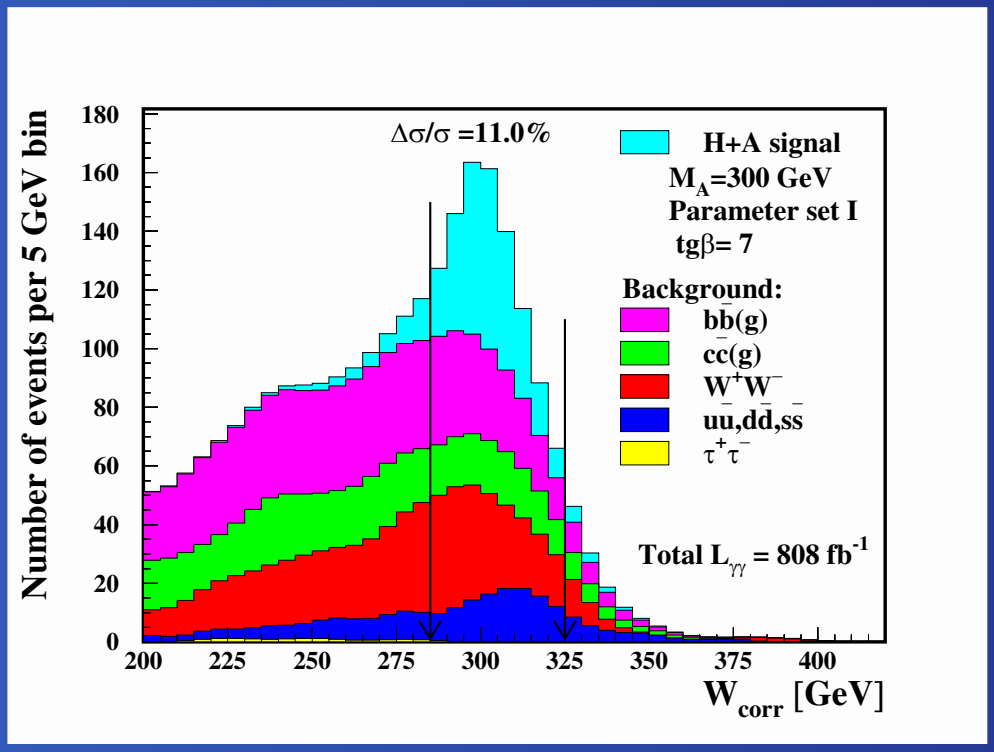


our previous results compared

MSSM: Precision at PLC

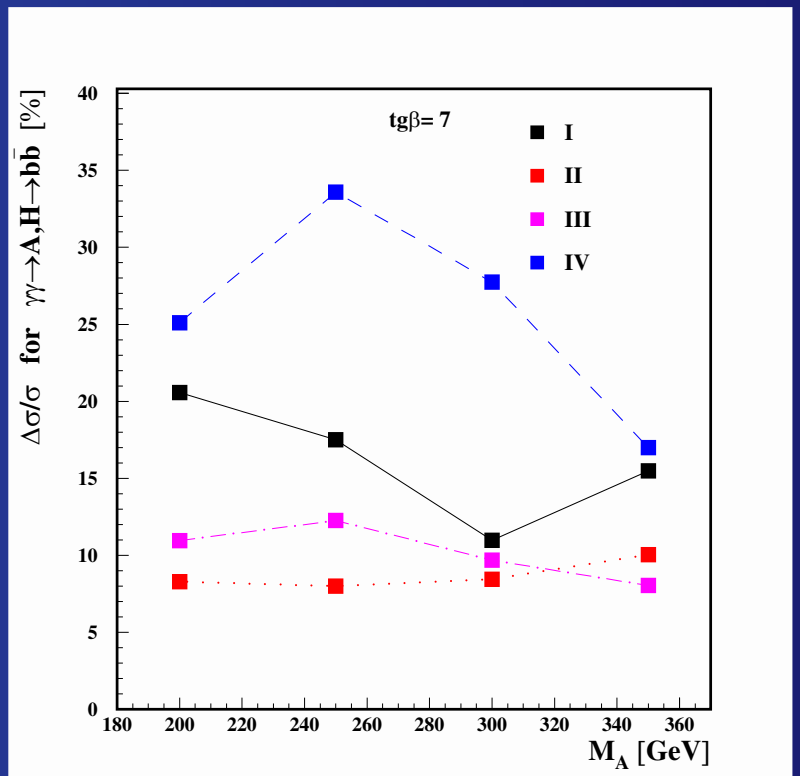
Precision of $\sigma(\gamma\gamma \to A, H \to b\bar{b})$ mesurement

Results for $M_A = 300$ GeV



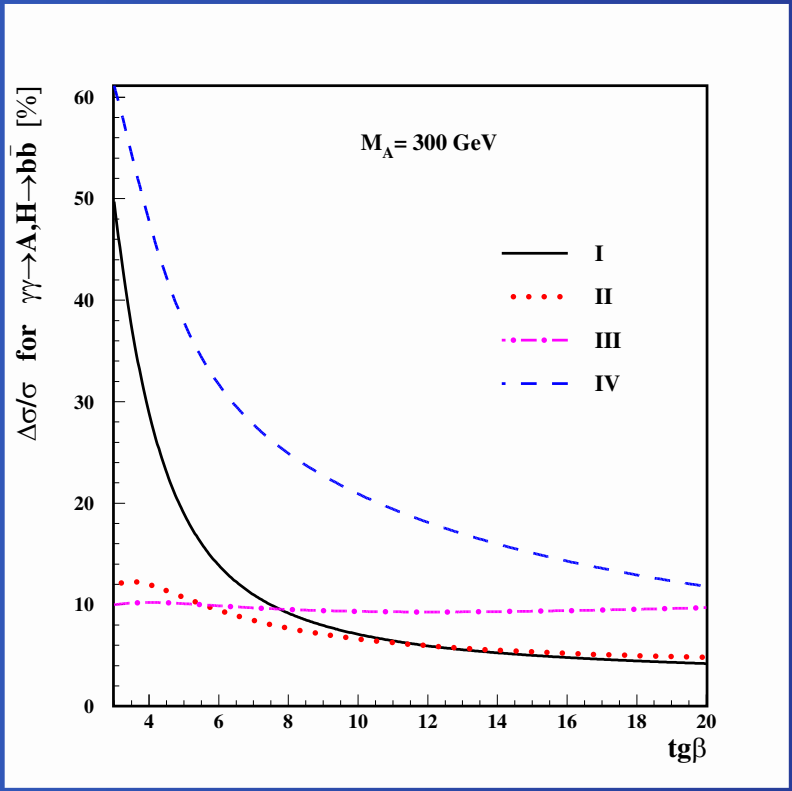
Corrected invariant mass distributions

Results for $M_A = 200$-350 GeV

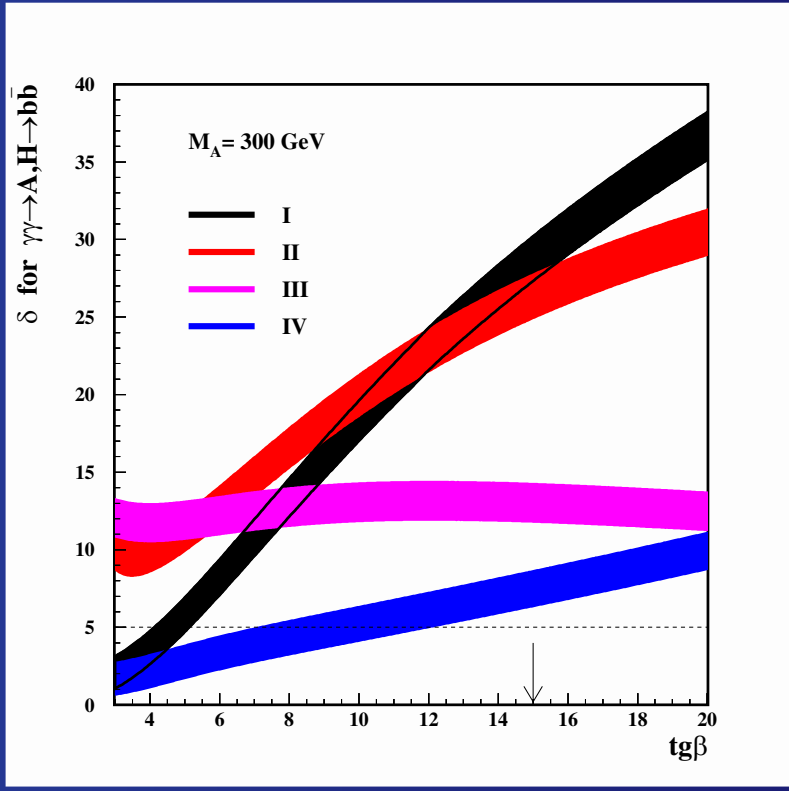


Precision & Significance

$\Delta\sigma(\gamma\gamma \to A, H \to b\bar{b})/\sigma(\gamma\gamma \to A, H \to b\bar{b})$



Significance for $\gamma\gamma \to A, H \to b\bar{b}$



$$\frac{\Delta\sigma}{\sigma} = \frac{\sqrt{\mu_S + \mu_B}}{\mu_S}$$

$$\delta = \frac{\mu_S}{\sqrt{\mu_B}} \pm \sqrt{1 + \frac{\mu_S}{\mu_B}}$$

Arrow – lower limit at LHC

Conclusions

- All relevant theoretical and experimental aspects taken into account.
- SM

  High precision for measurement of the SM Higgs boson despite large effects due to $\gamma\gamma \to hadrons$ overlaying events.

  Statistical precision of 2% for $\Gamma(h \to \gamma\gamma)\mathrm{BR}(h \to b\bar{b})$ at $M_h = 120$ GeV.
  Systematic uncertainty about 2%.

- MSSM

  LHC wedge $\Rightarrow$ four MSSM parameter sets, $\tan\beta = 3$–20 considered

  Precision 11–21% for $M_A = 200$–350 GeV, $\tan\beta = 7$ (set I, after one year)

  For $M_A \gtrsim 300$ GeV the Photon Collider can discover heavy MSSM Higgs bosons below $\tan\beta = 15$ (LHC limit)

$\Rightarrow$ The Photon Collider is a very promising machine

Detailed description of the analysis: hep-ph/0503295