Extended analysis of the MSSM Higgs-bosons production at the Photon Collider

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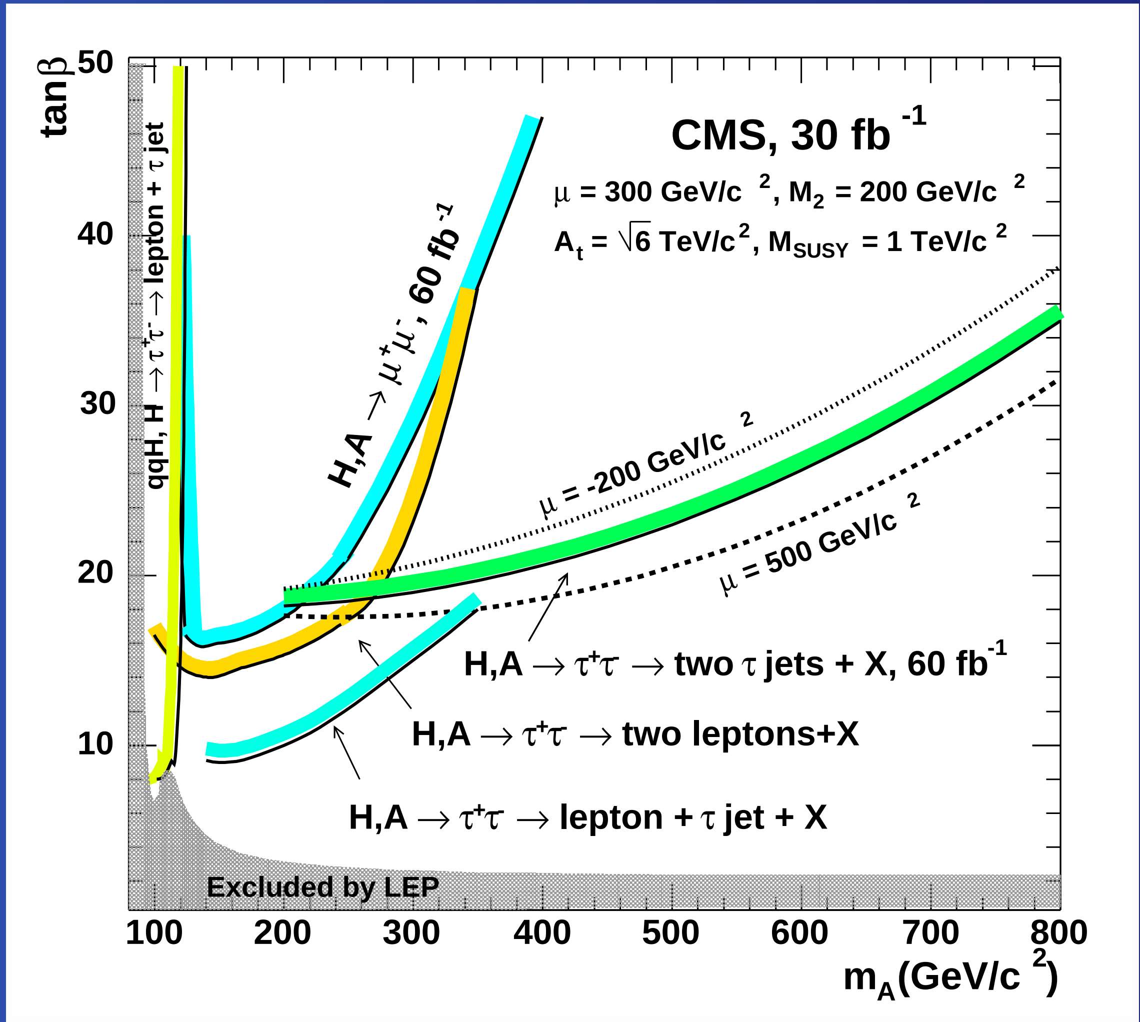
- Motivation: LHC wedge
- Overview of the analysis
- Short summary of SM higgs results
- New results for MSSM higgs bosons

Motivation: LHC wedge

LHC wedge: only one light SM-like higgs boson h can be seen



Photon Collider offers unique possibility for precise H/A studies

Overview

Analysis of $\sigma(\gamma\gamma \to$ *higgs* $\to b\bar{b})$ measurement

LCWS'04 Paris:

- NLO QCD background $\gamma\gamma \to Q\bar{Q}(g)$ $(Q = c, b)$
- realistic $\gamma\gamma$-spectra
- b-tagging
- overlaying events $\gamma\gamma \to hadrons$ (OE)
- crossing angle
- primary vertex distribution

⇒ 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.*)

Overview

Analysis of $\sigma(\gamma\gamma \rightarrow \textit{higgs} \rightarrow b\bar{b})$ measurement

NEW:

- $\gamma\gamma \rightarrow W^+W^-$ background contribution (polarized cross section)
- $\gamma\gamma \rightarrow q\bar{q}$ ($q = u, d, s$) background contribution (unpolarized cross section)
- $\gamma\gamma \rightarrow \tau^+\tau^-$ background contribution
- Full optimization of cuts

$\Rightarrow$ results for MSSM at $M_A = 200, 250, 300, 350$ GeV

with four MSSM scenarios and $\tan\beta = 3$–20.

Tools

Photon-photon spectrum: CompAZ

Signal: HDecay, Pythia

Background:

- NLO $\gamma\gamma \to Q\bar{Q}(g)$ for $Q = c, b$ (G. Jikia)
- $\gamma\gamma \to W^+W^-$ (Pythia + polarized cross section)
- $\gamma\gamma \to q\bar{q}$ for $q = u, d, s$ (Pythia, unpolarized cross section)
- $\gamma\gamma \to \tau^+\tau^-$ (Pythia).

Overlaying events $\gamma\gamma \to hadrons$ (Pythia) with realistic $\gamma\gamma$-luminosity spectrum (V. Telnov)

Parton Shower (not for $Q\bar{Q}(g)$): Pythia

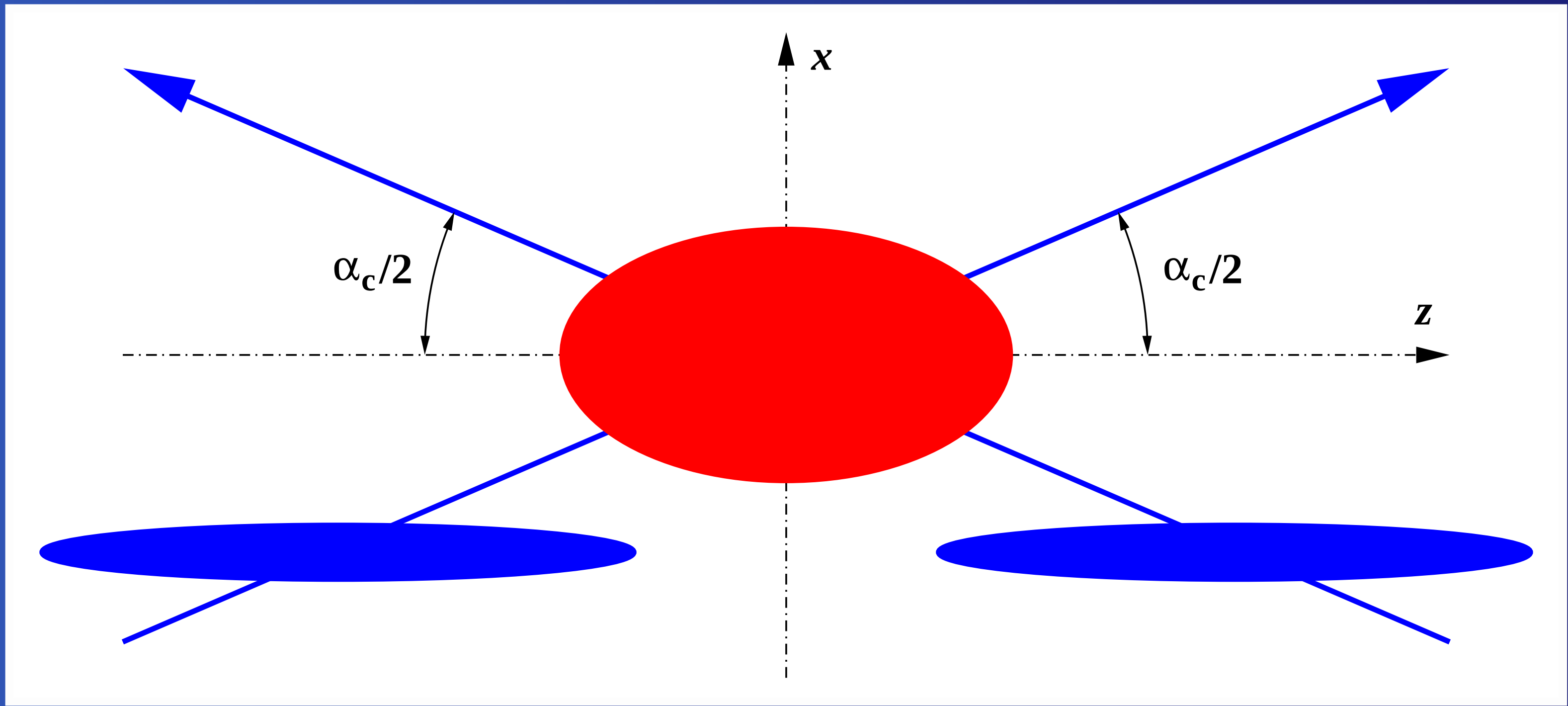
Fragmentation: Pythia (Lund)

Detector performance: Simdet 4.01

Crab-wise crossing of beams

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

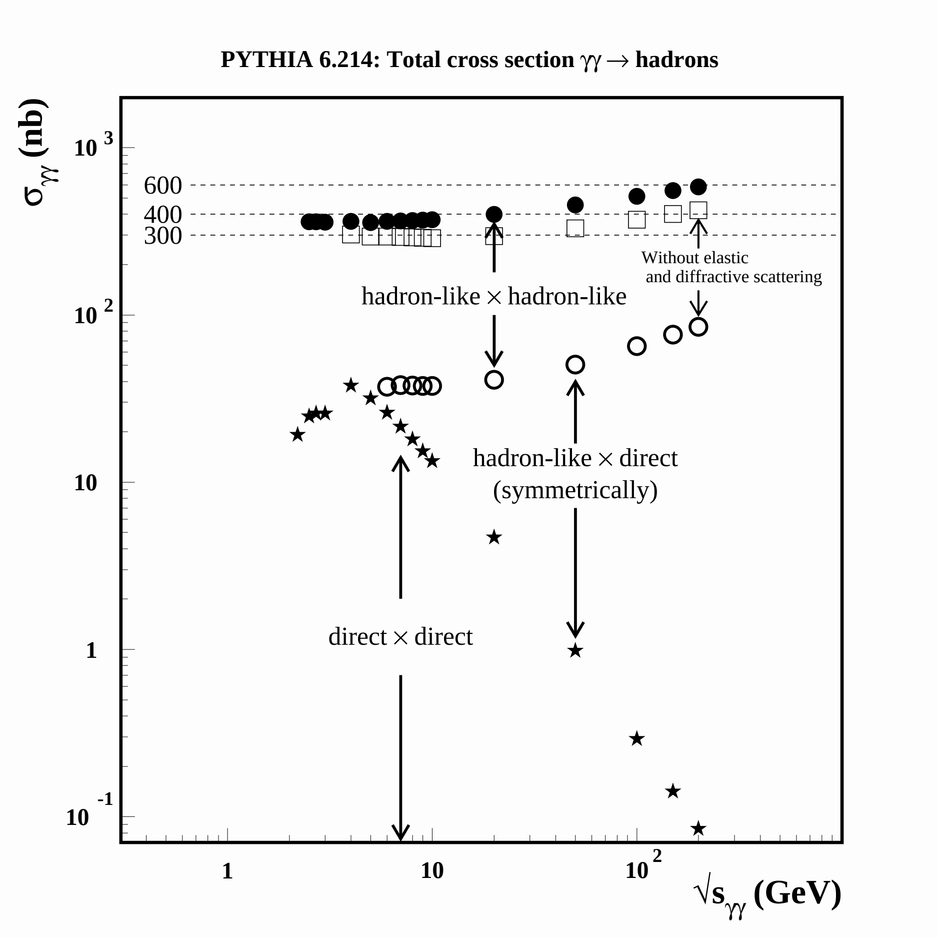
Bunch:	$\sigma_x = 140$ nm	$\sigma_y = 15$ nm	$\sigma_z = 0.3$ mm
Primary vertex:	$\sigma'_x = 3.6\ \mu$m	$\sigma'_y = 11$ nm	$\sigma'_z = 0.2$ mm



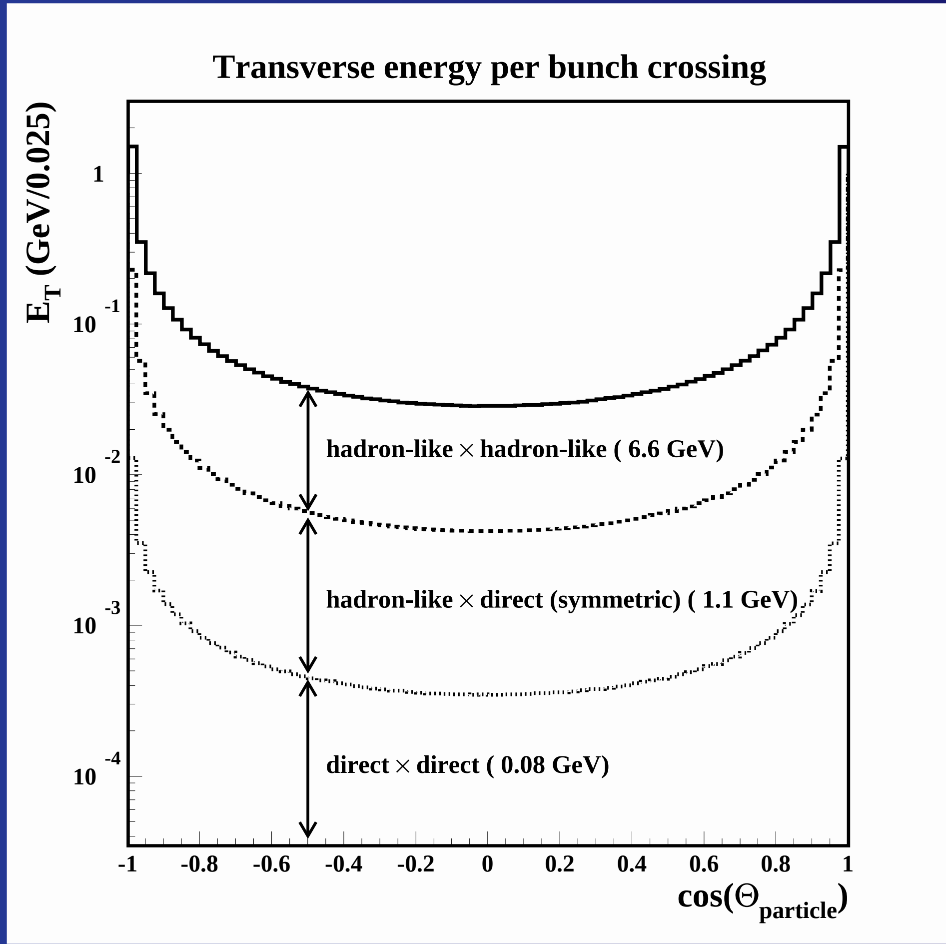
$\alpha_c = 34$ mrad

$\gamma\gamma \to hadrons$ events

Cross sections



Angular E_T-flow per bunch crossing.

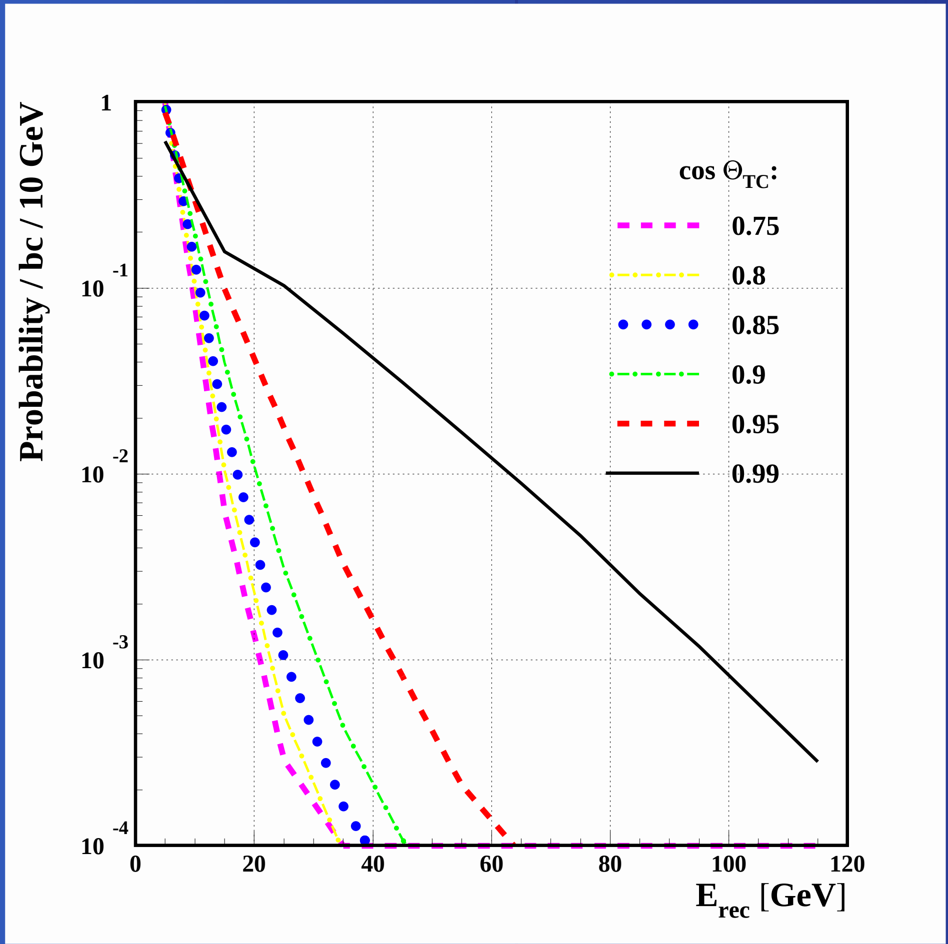


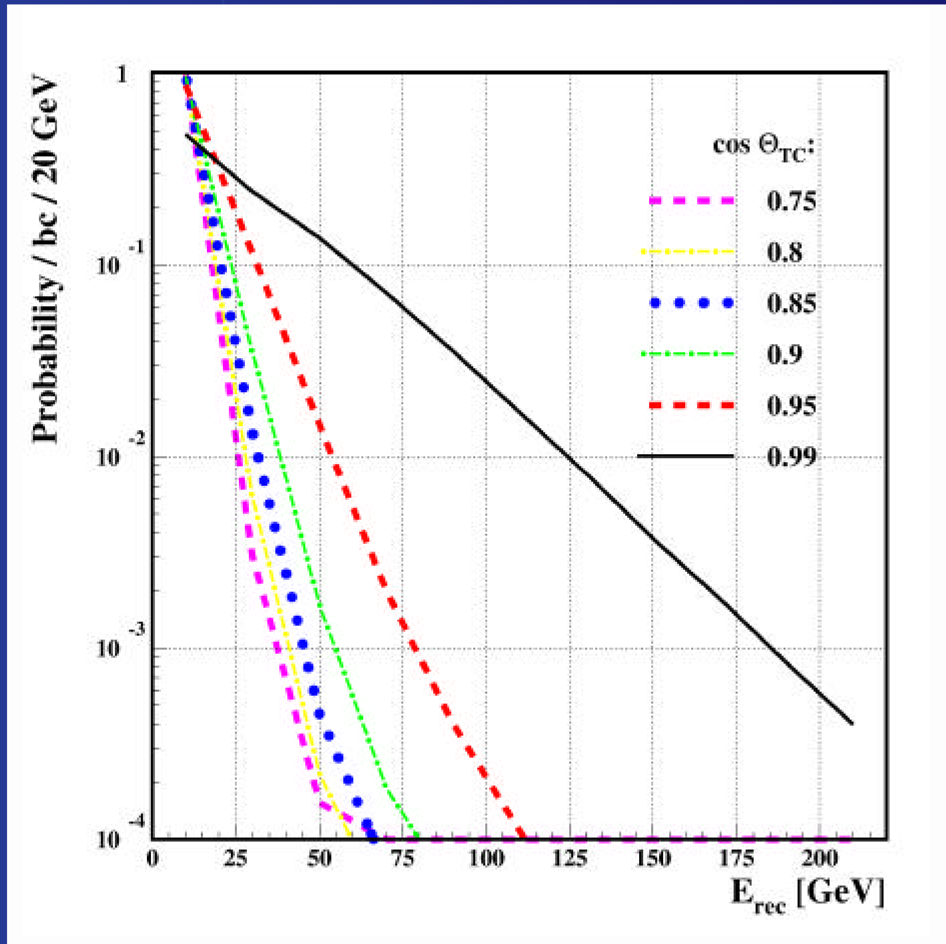
Generation for $\sqrt{s_{ee}} =$ 210.5 GeV.

θ_{TC}

Reconstructed energy per bc

$\gamma\gamma \rightarrow hadrons$



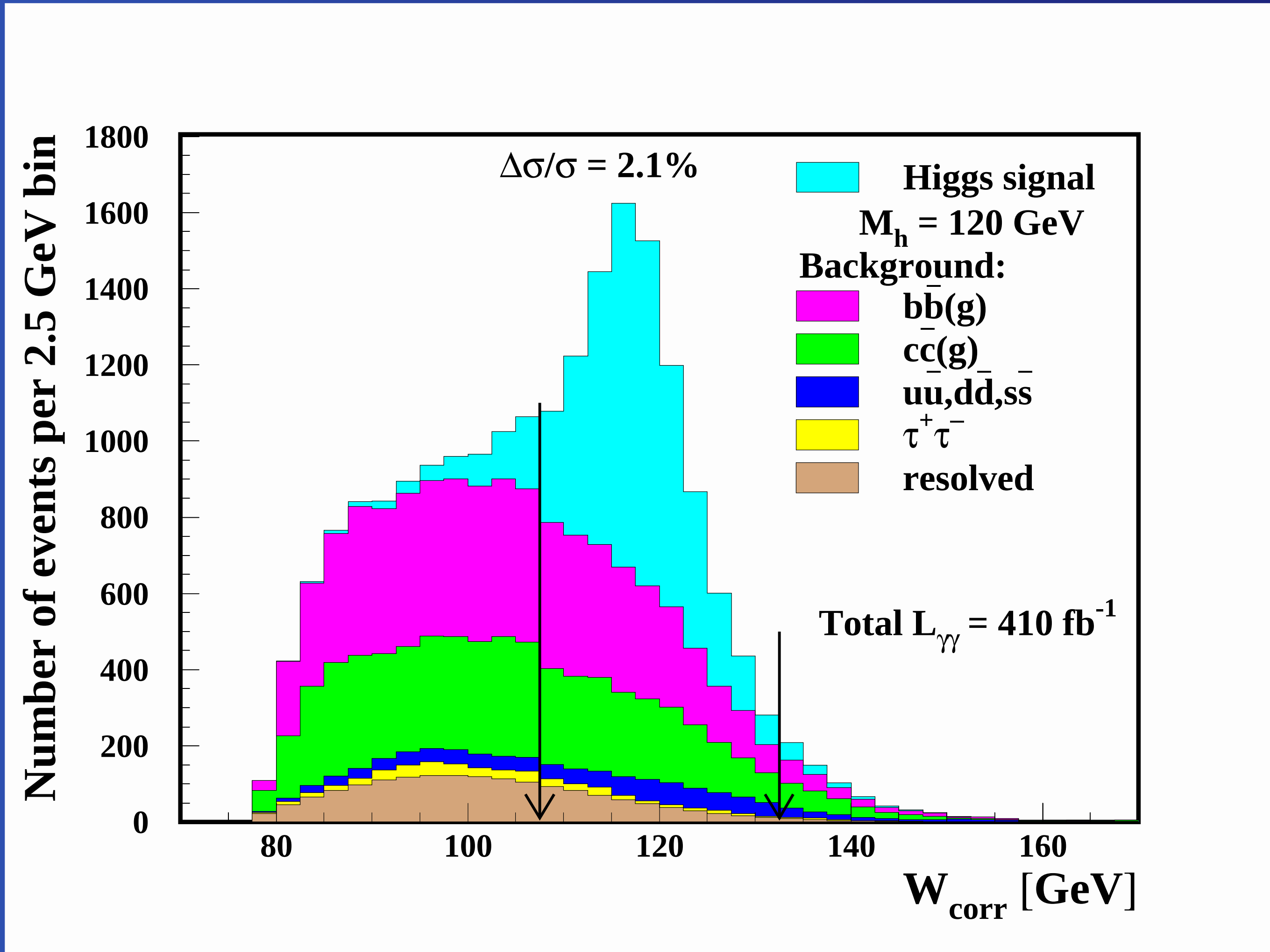


$\sqrt{s_{ee}} = 210.5$ GeV; N_{OE}/bc ≈ 1

$\sqrt{s_{ee}} = 419$ GeV; N_{OE}/bc ≈ 2

Summary of our SM analysis

Final results for the SM Higgs boson



For $M_h = 120$ GeV precision from constrained max. likelihood fit: 2.0% stat., 1.8% syst.

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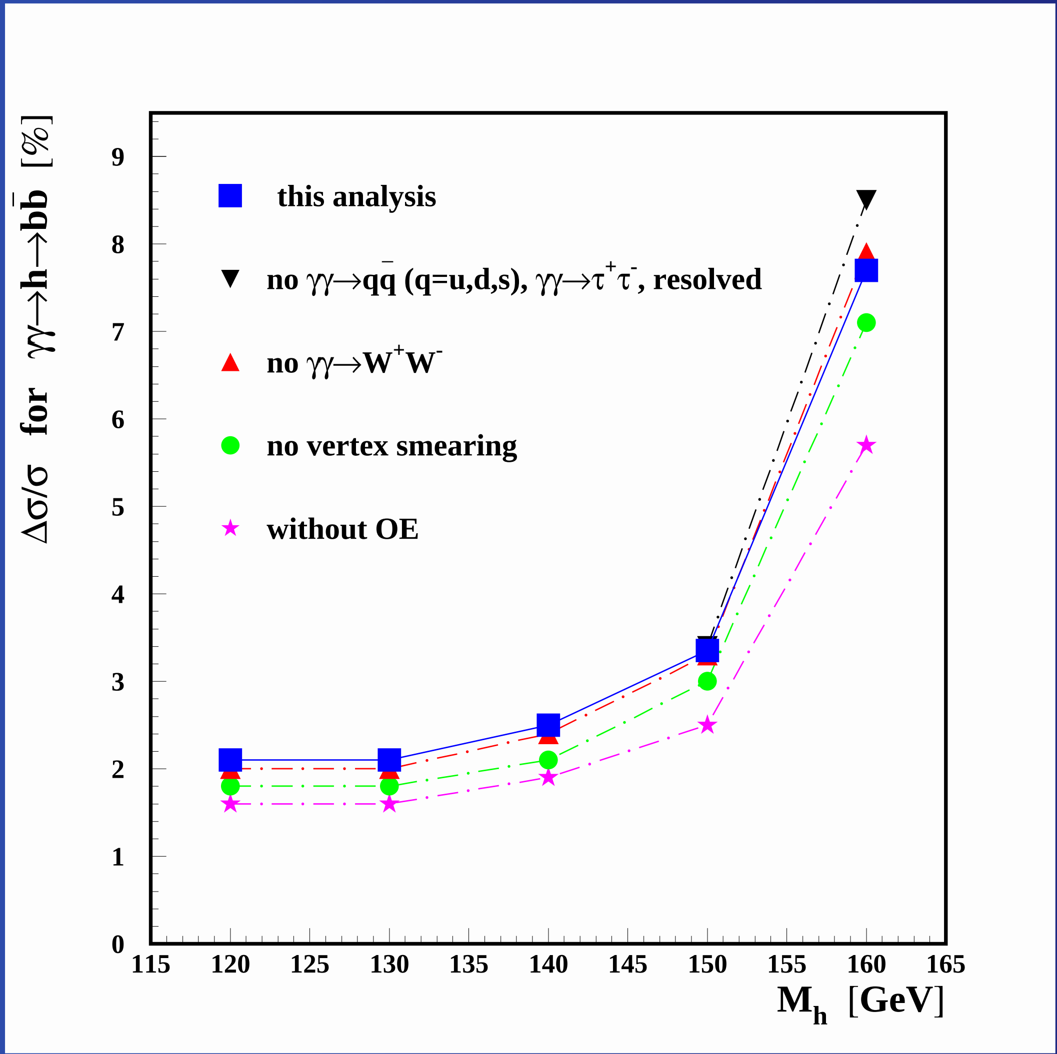
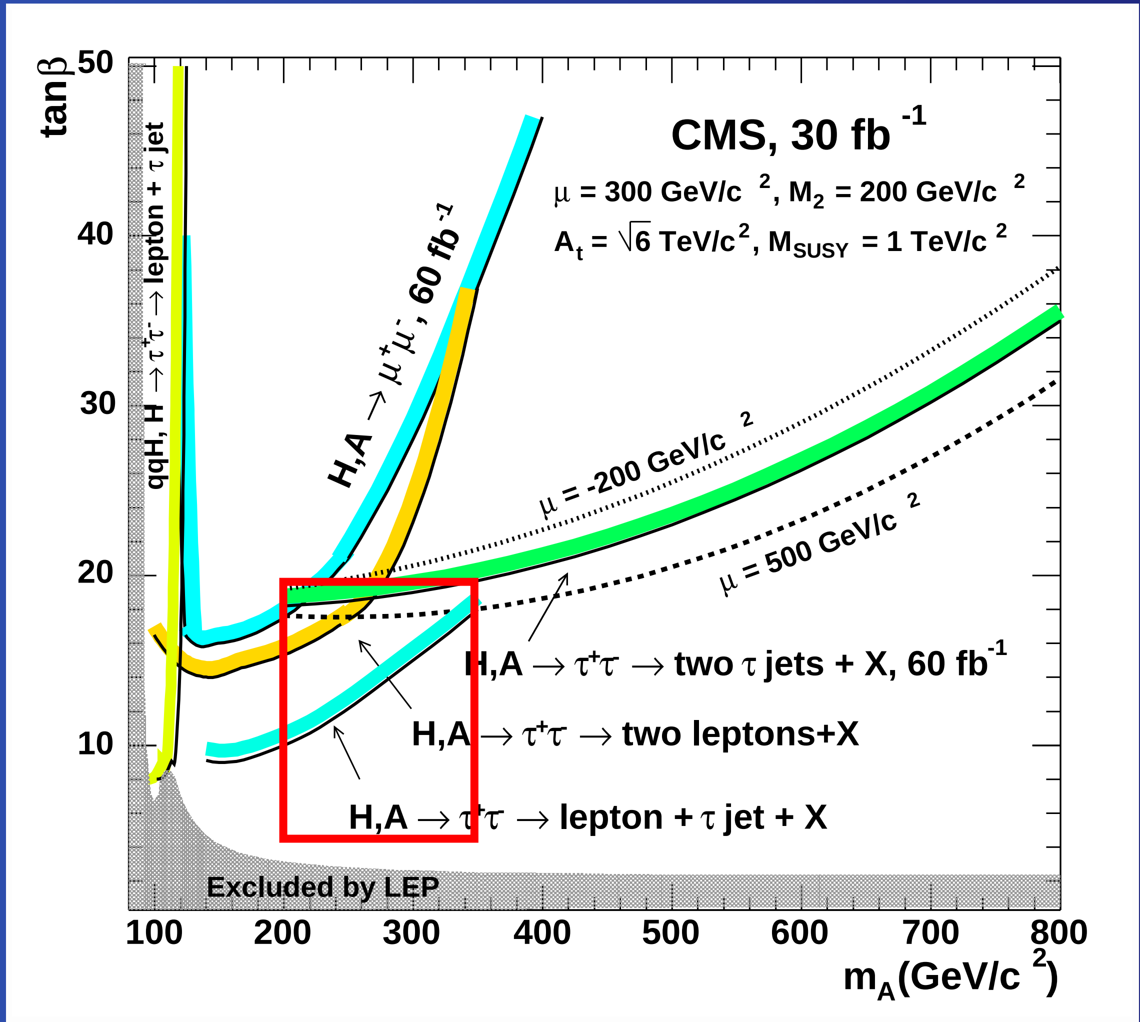
Final results for the SM Higgs boson



Choice of MSSM parameters

LHC wedge



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

Choice of MSSM parameters

We consider following MSSM parameter sets:

Symbol	μ [GeV]	M_2 [GeV]	$A_{\tilde{f}}$ [GeV]	$M_{\tilde{f}}$ [GeV]
I	200	200	1500	1000
II	-150	200	1500	1000
III	-200	200	1500	1000
IV	300	200	2450	1000

I and III – as in M. Mühlleitner *et al.* but we take higher $A_{\tilde{f}}$ to have M_h above limit

II – an intermediate scenario

IV – as in CMS NOTE 2003/033

Reconstruction & Selection

Selection of $b\bar{b}$ events for $M_A = 300$ 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: $|\cos\theta_{jet}| < 0.65$
- $|P_z|/E < 0.06$

Rejection of W^+W^- events:

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

b-tagging: ZVTOP-B-HADRON-TAGGER (T. Kuhl)

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

higgs-tagging at $M_A = 300$ GeV

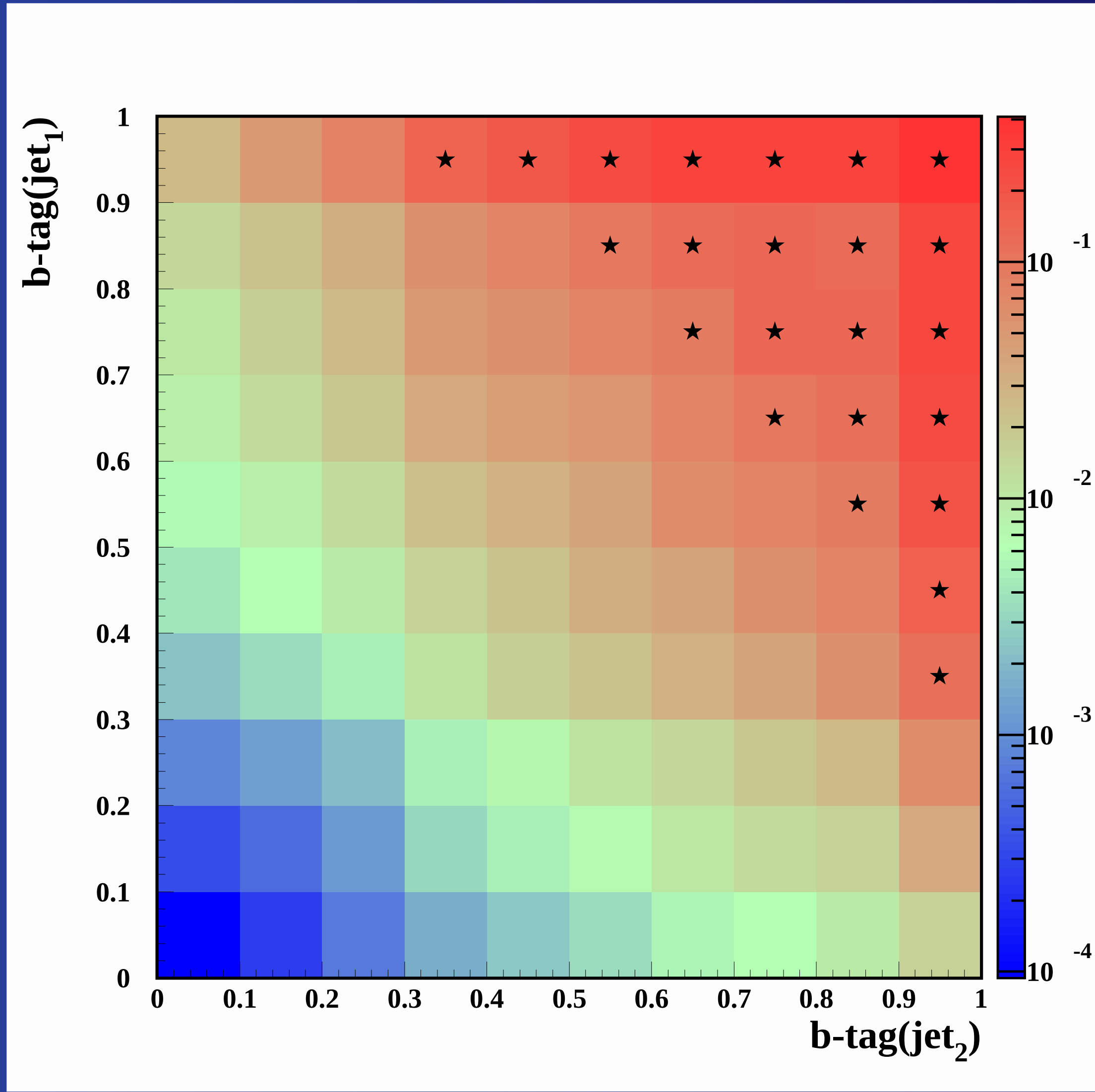
higgs-tagging: a cut on the ratio of $\gamma\gamma \to A, H \to b\bar{b}$ to $\gamma\gamma \to b\bar{b}(g), c\bar{c}(g), q\bar{q}$ ($q = u, d, s$) events

$\Rightarrow \varepsilon_h = 53\%$
$\varepsilon_{bb} = 47\%$
$\varepsilon_{cc} = 2.9\%$
$\varepsilon_{uds} = 0.5\%$

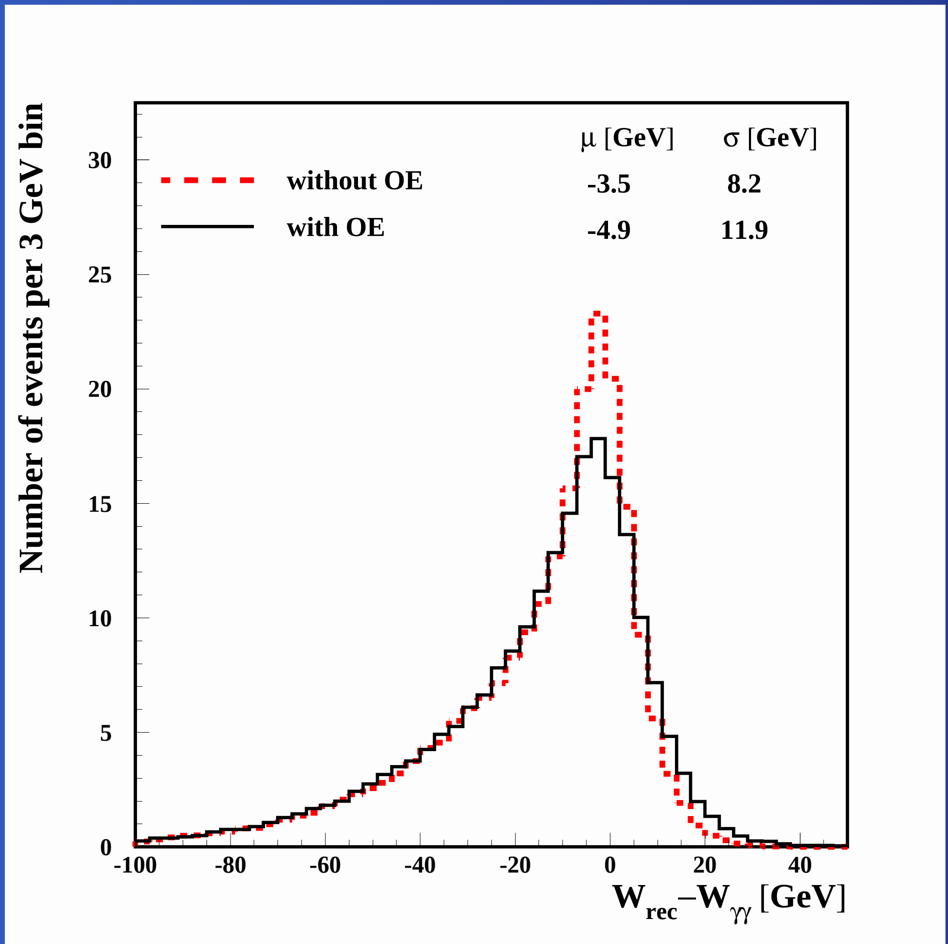
Without OE

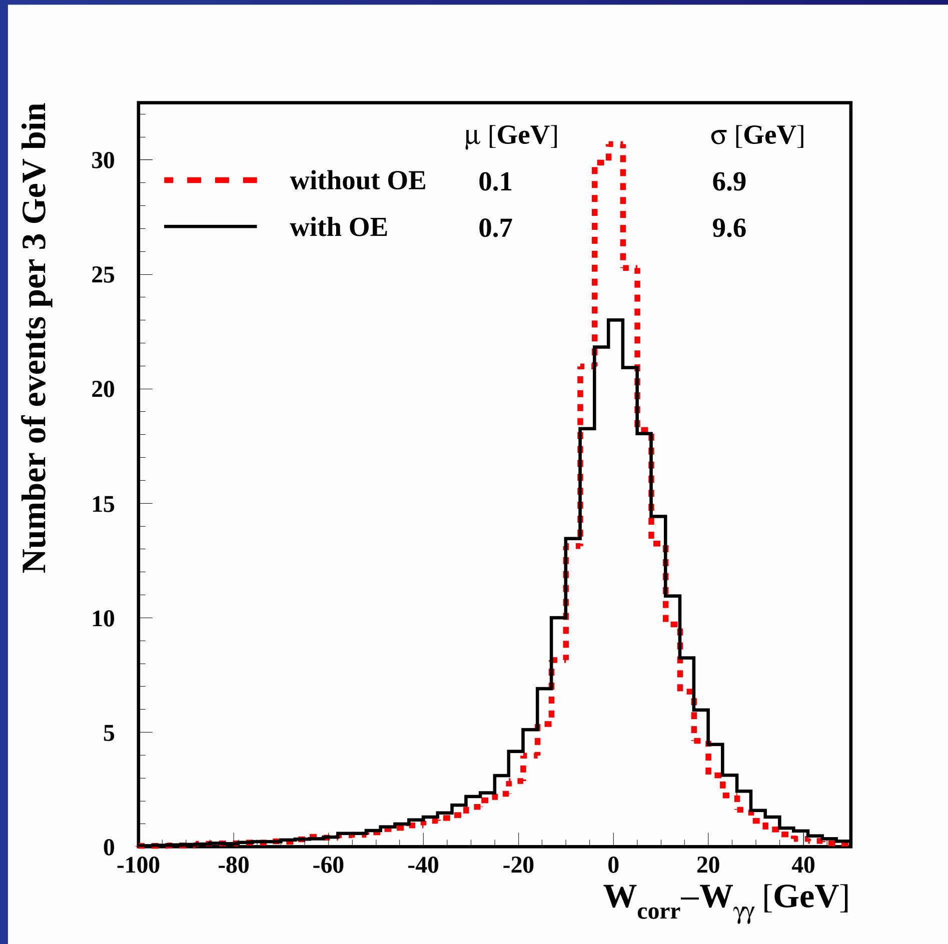
$\Rightarrow \varepsilon_h = 57\%$
$\varepsilon_{bb} = 52\%$
$\varepsilon_{cc} = 1.8\%$
$\varepsilon_{uds} = 0.1\%$

Tighter cuts are needed due to OE contribution



$\gamma\gamma \to A \to b\bar{b}$





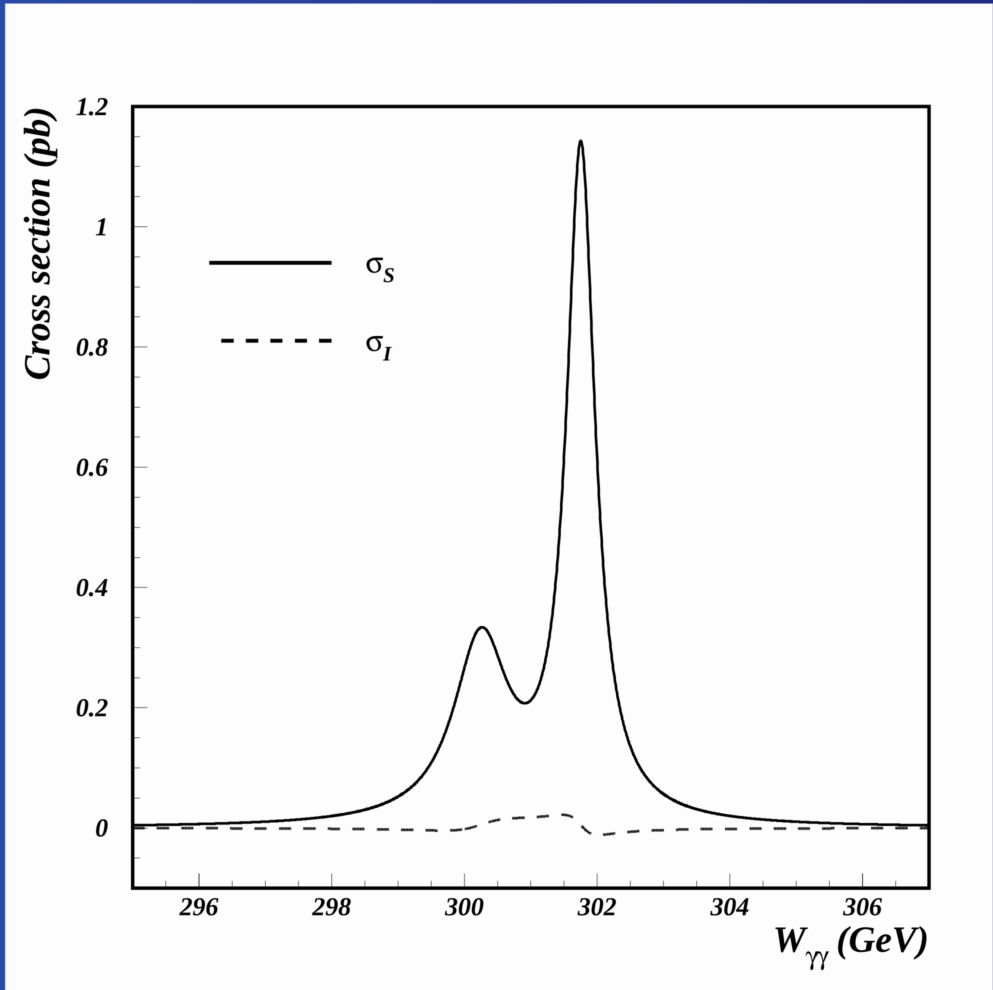
$W_{corr} \equiv \sqrt{W_{rec}^2 + 2P_T(E + P_T)}$

Acta Phys. Pol. B34 177 2003, hep-ph/0208234

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

$\gamma\gamma \rightarrow A, H \rightarrow b\bar{b}$

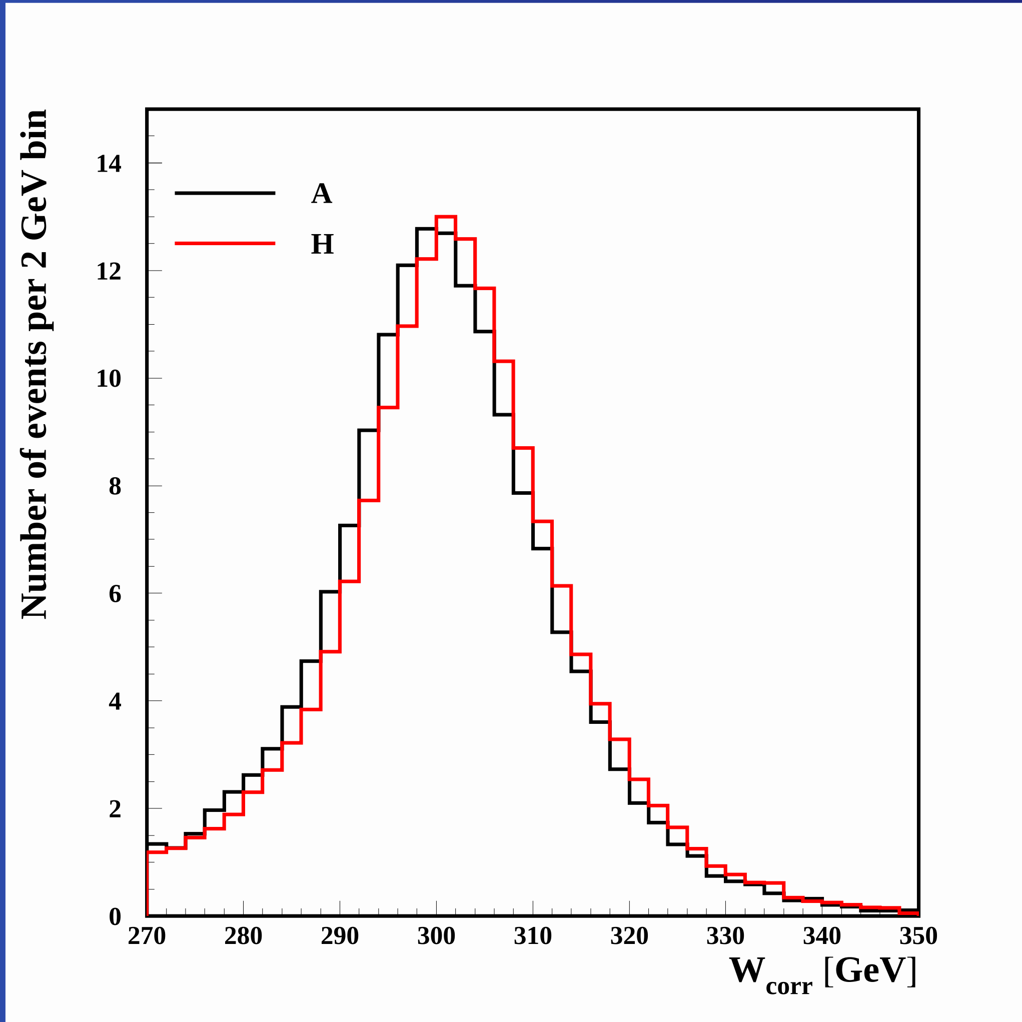
LO cross section for signal and interference term.



Interference with $\gamma\gamma \rightarrow b\bar{b}$ is less than 1% of the signal even after higher order corrections (M. M. Mühlleitner, hep-ph/0008127)

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

Reconstructed events

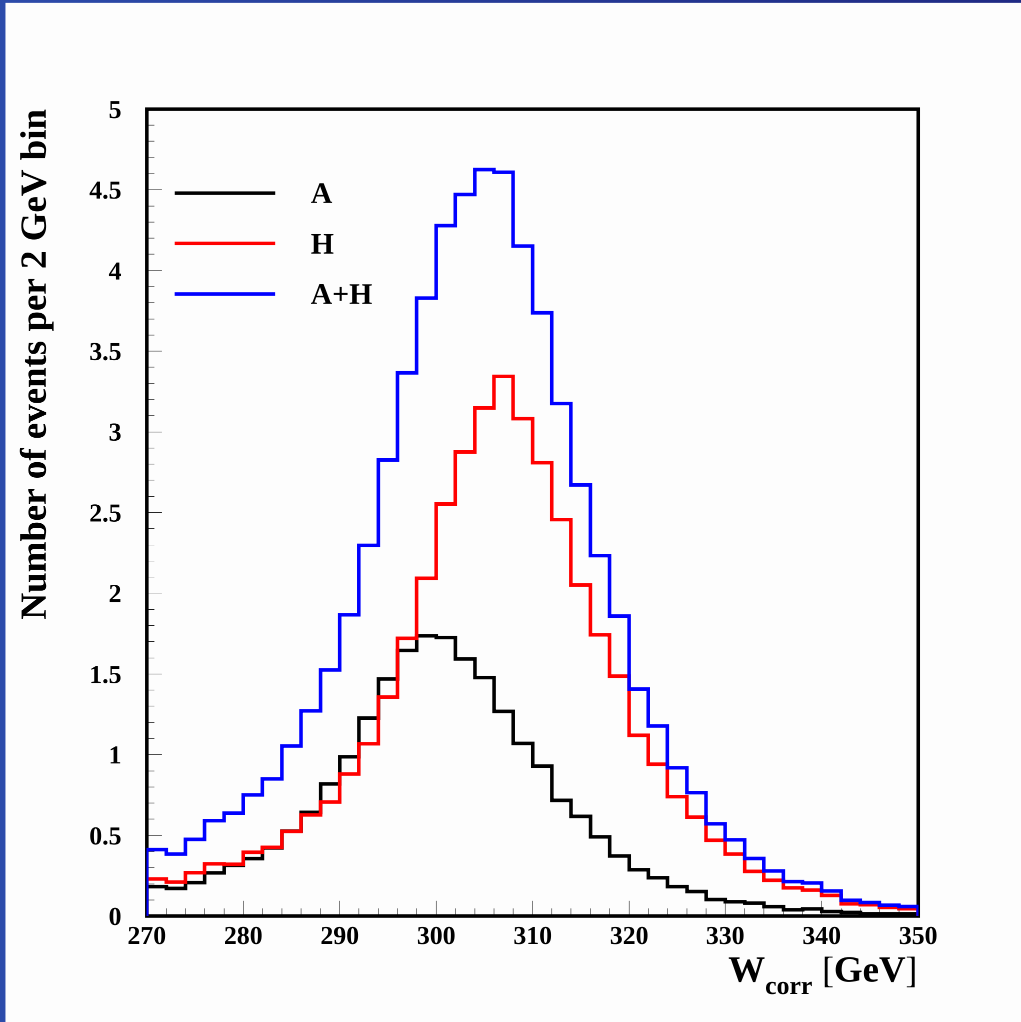


$\tan\beta = 7$

$M_H - M_A \approx 1.5$ GeV

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

Reconstructed events

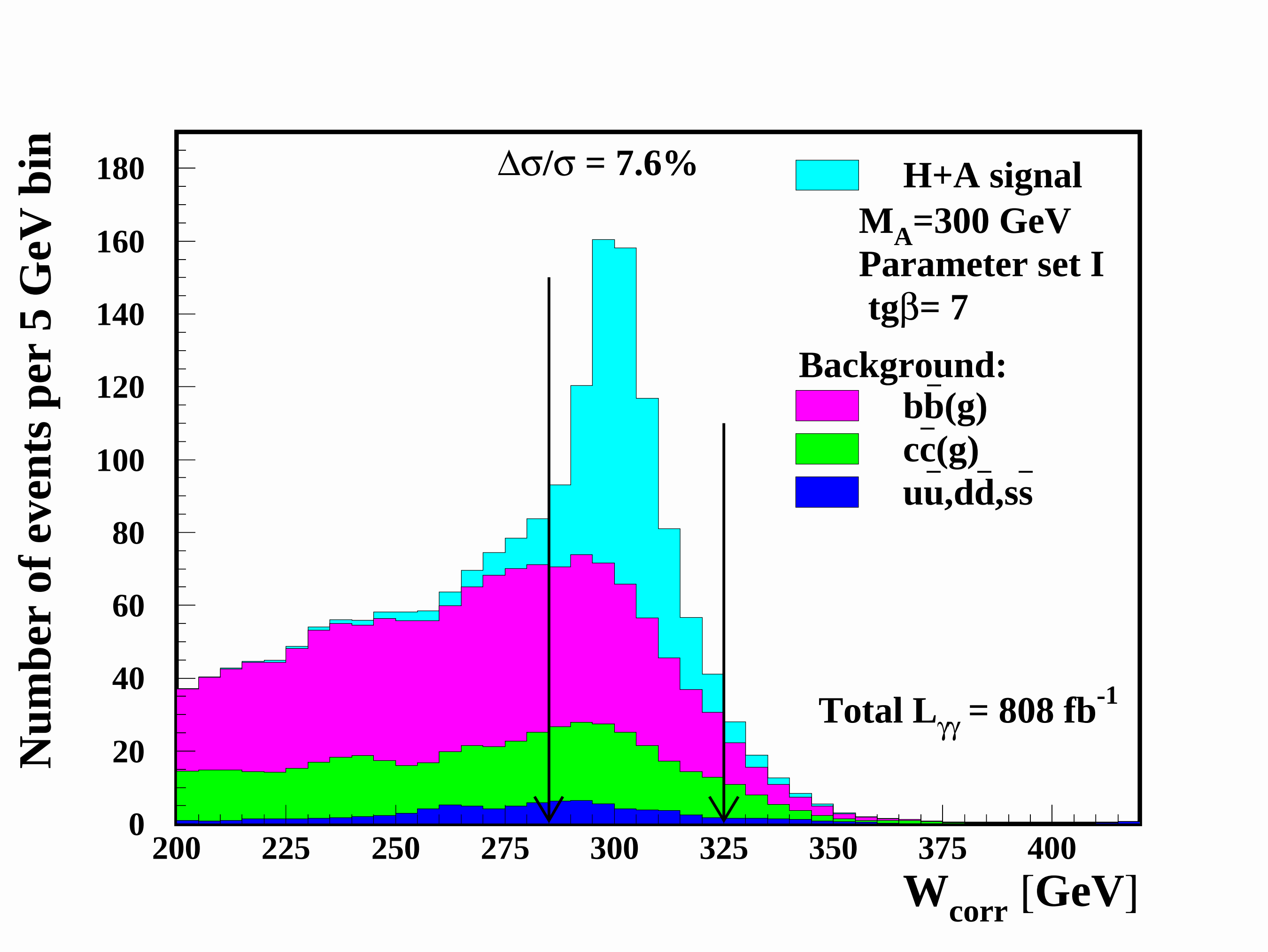


$\tan\beta = 3$

$M_H - M_A \approx 6.8$ GeV

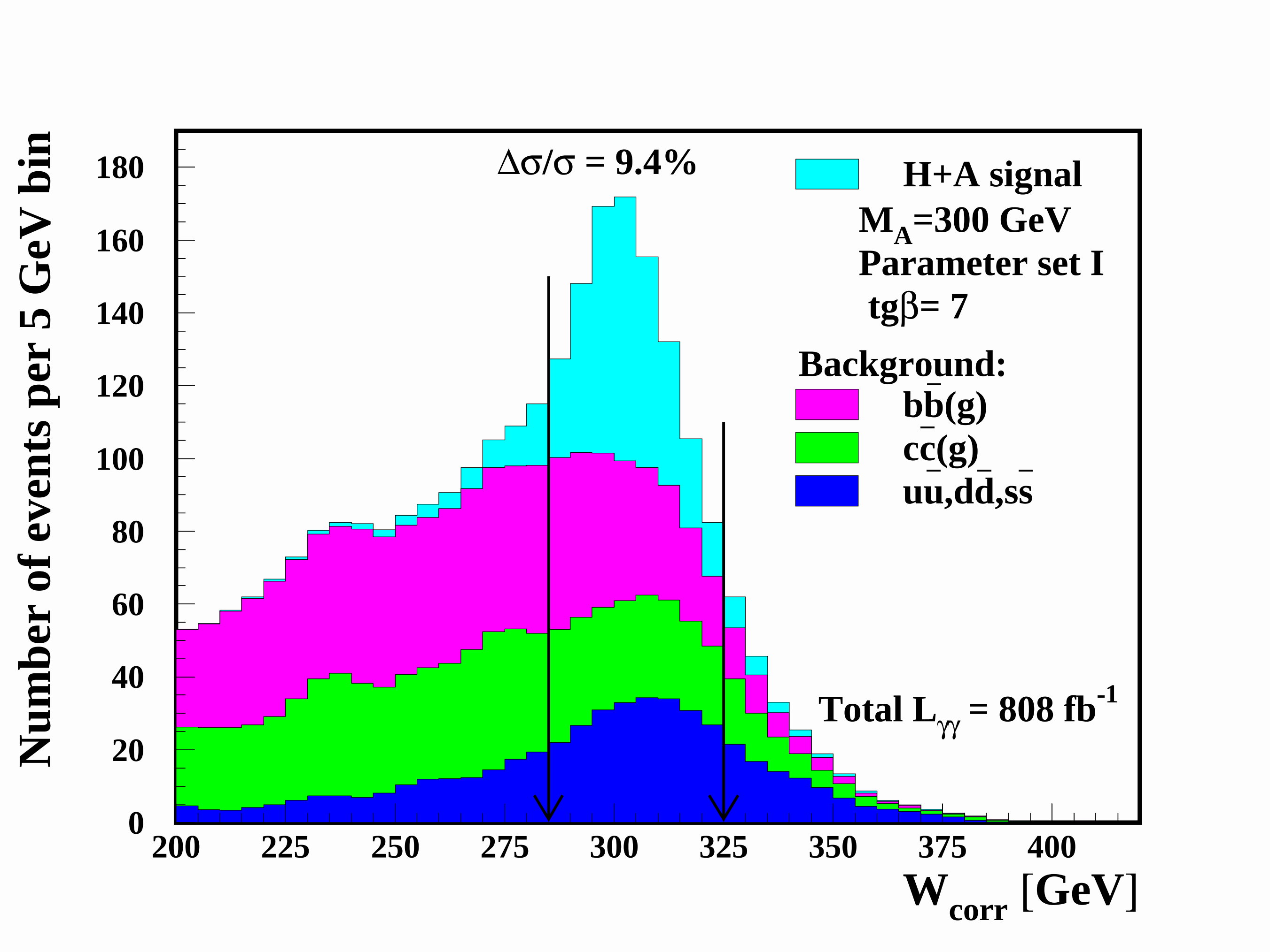
$M_A = 300$ GeV

Without OE, without $\gamma\gamma \rightarrow W^+W^-$



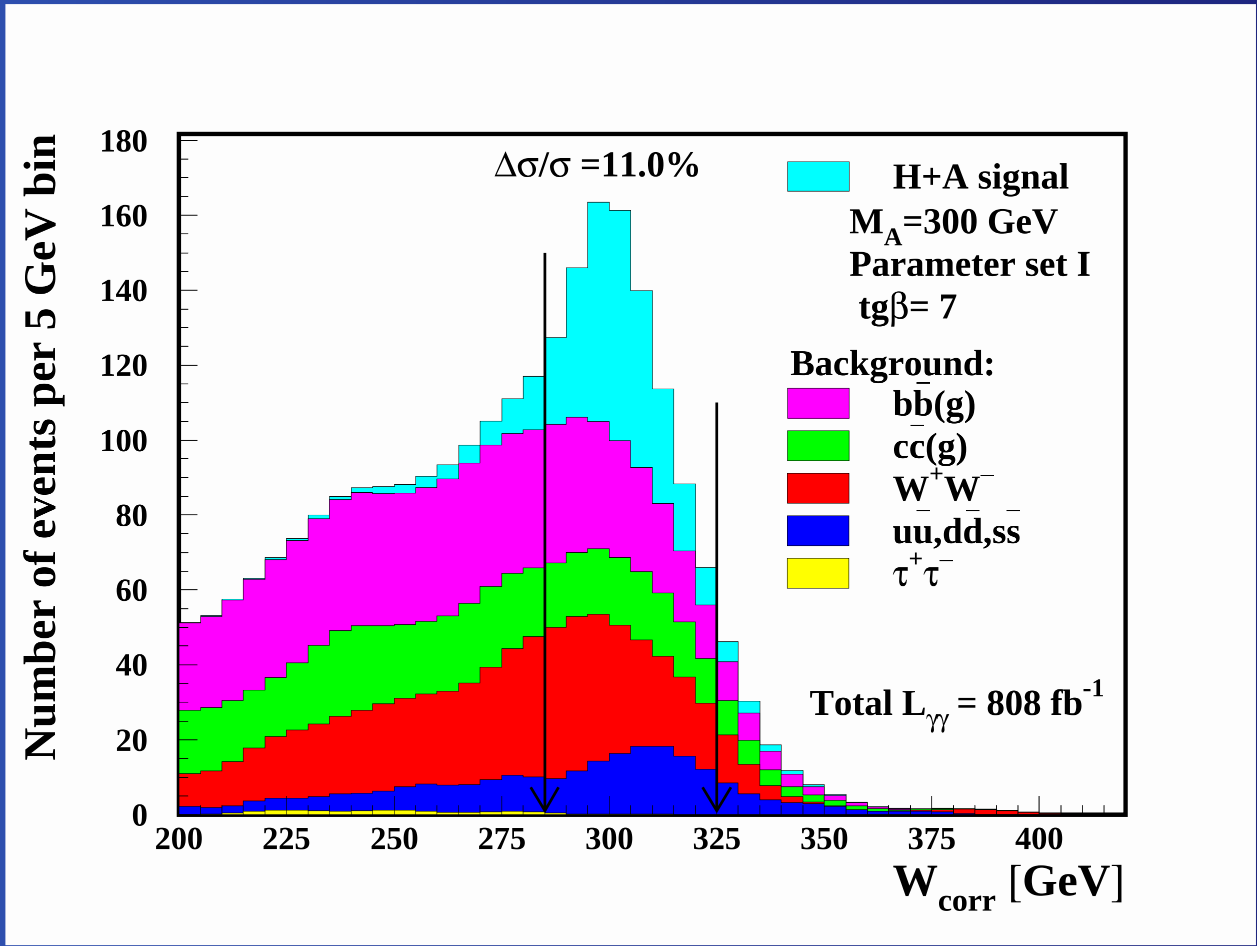
$M_A = 300$ GeV

With OE, without $\gamma\gamma \to W^+W^-$



$M_A = 300$ GeV

Final results

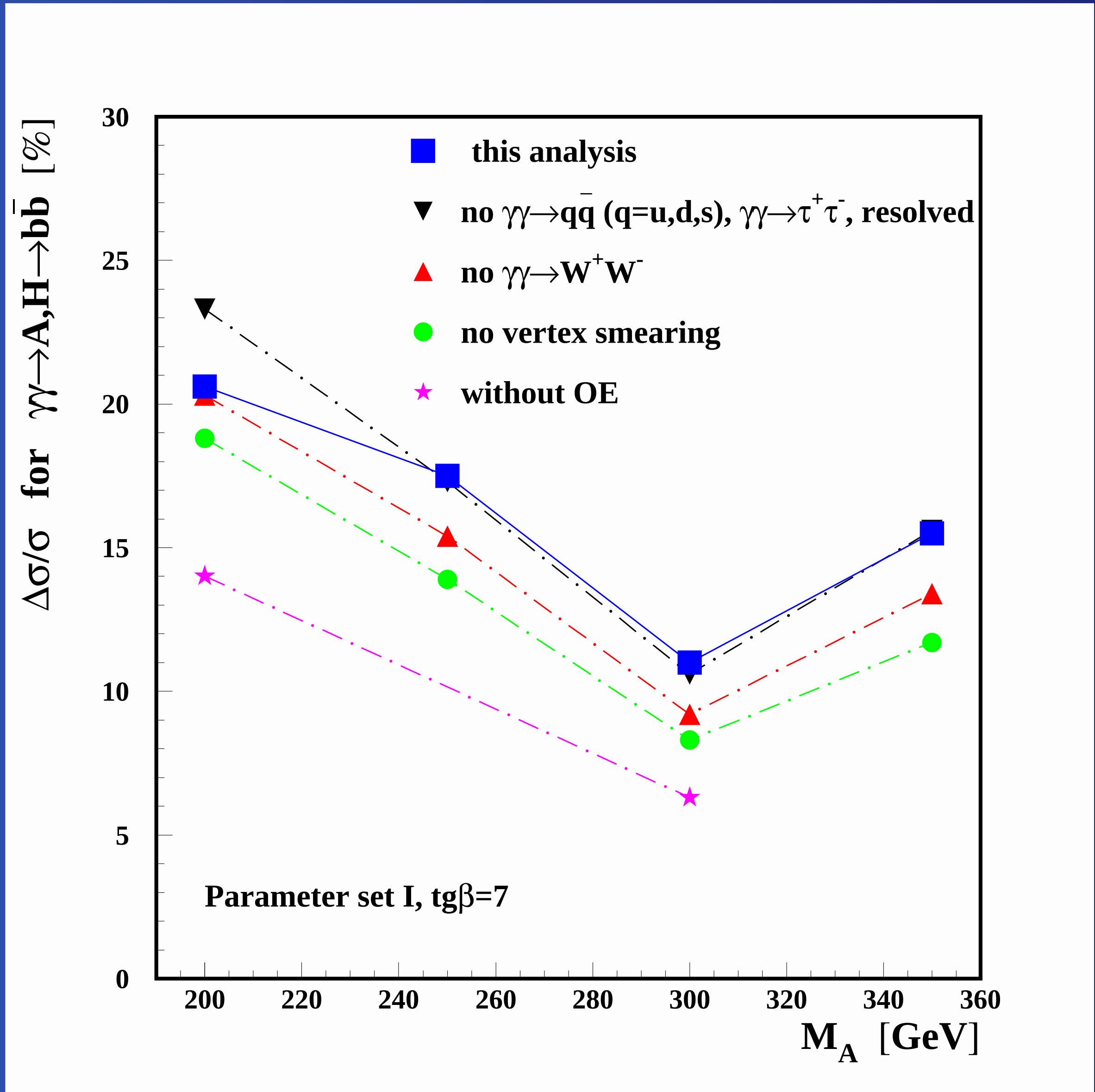


$\gamma\gamma \rightarrow hadrons$ (resolved) as a separate contribution – ineffi cient generation

$\Rightarrow$ we estimate number of events in the mass window

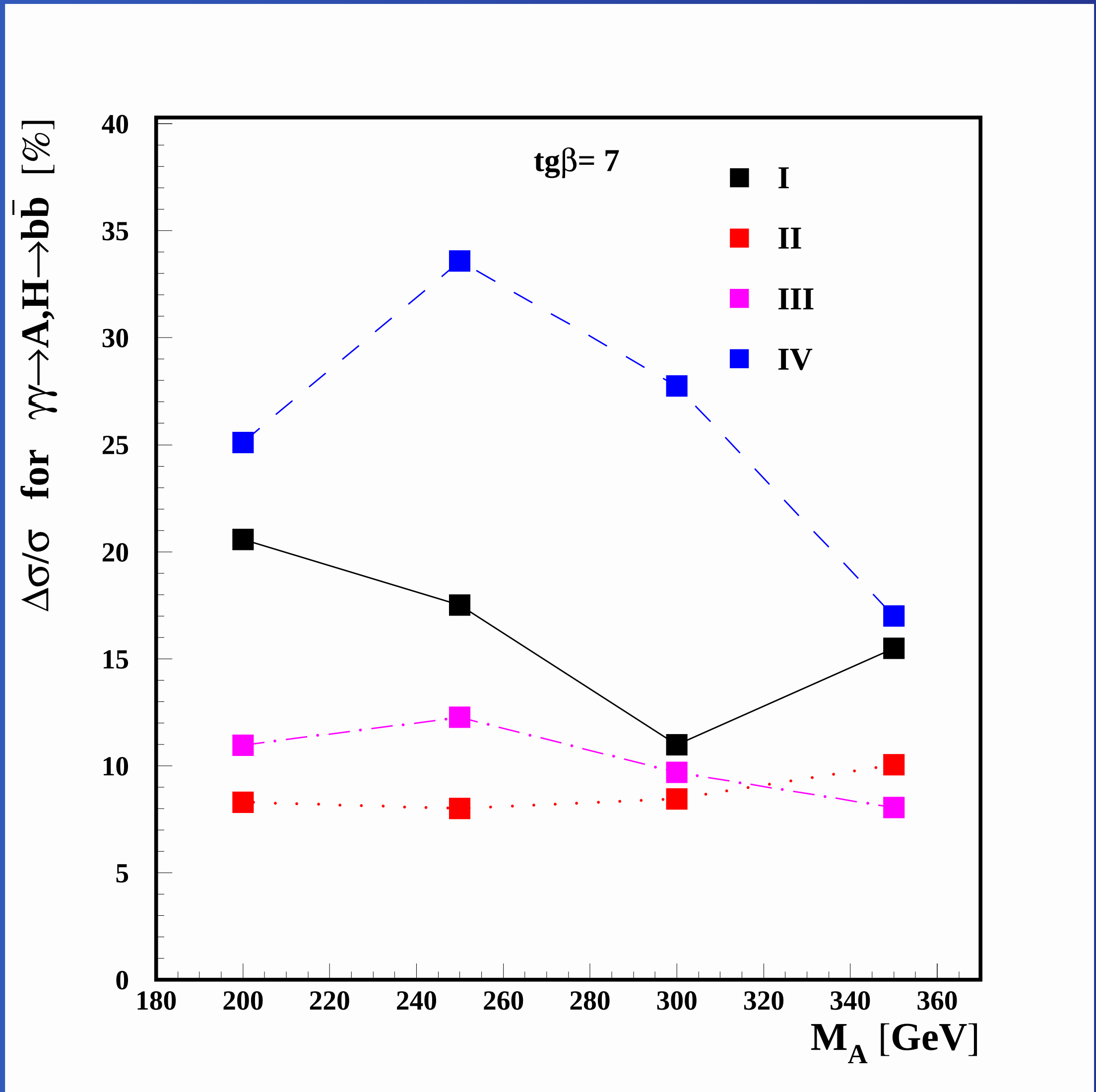
$\gamma\gamma \rightarrow q\bar{q}$ $(q = u, d, s)$ (unpolarized cross sec.) is overestimated but compensates the lack of *resolved* contribution

MSSM summary



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

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



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

Precision

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

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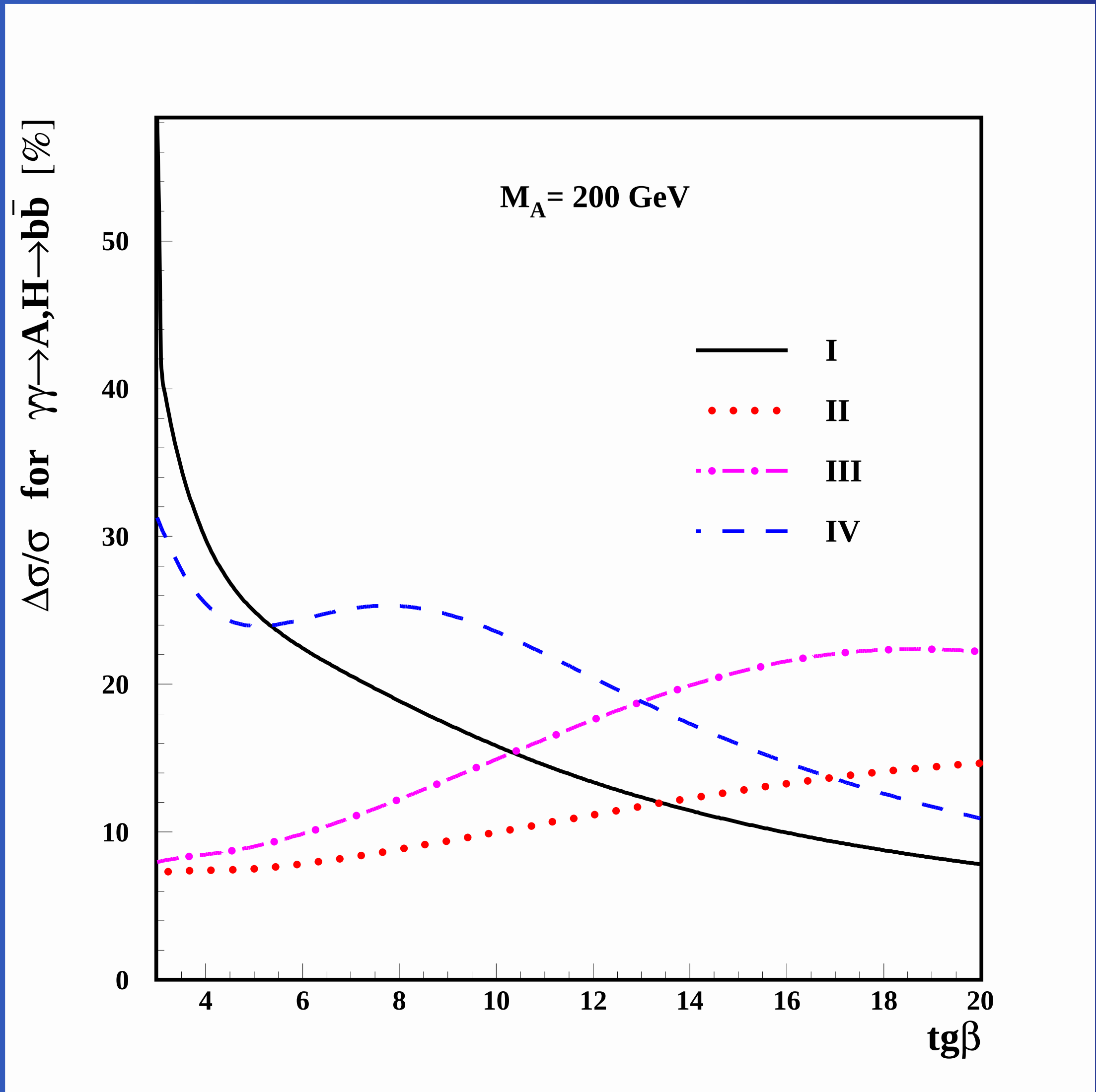

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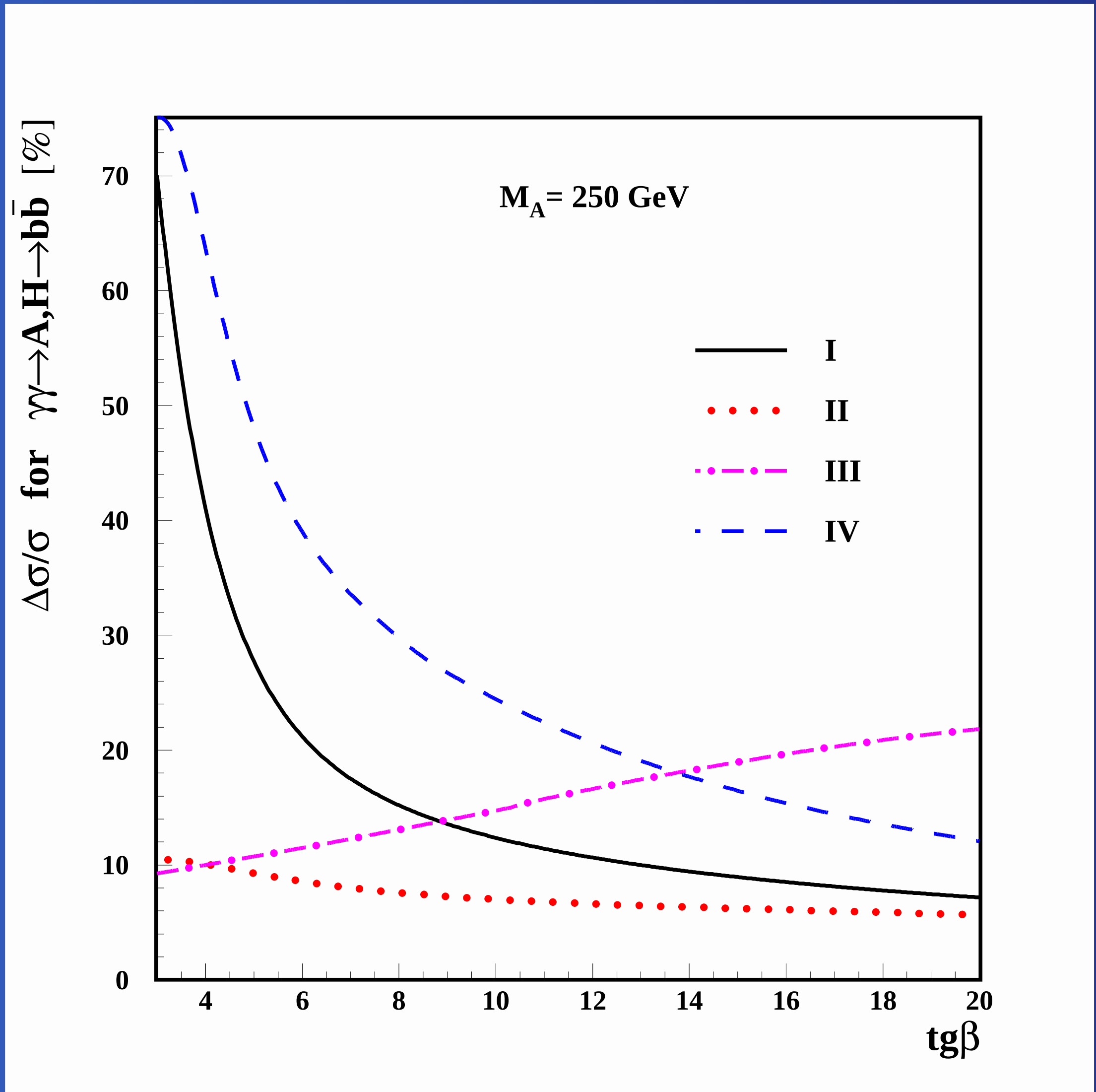

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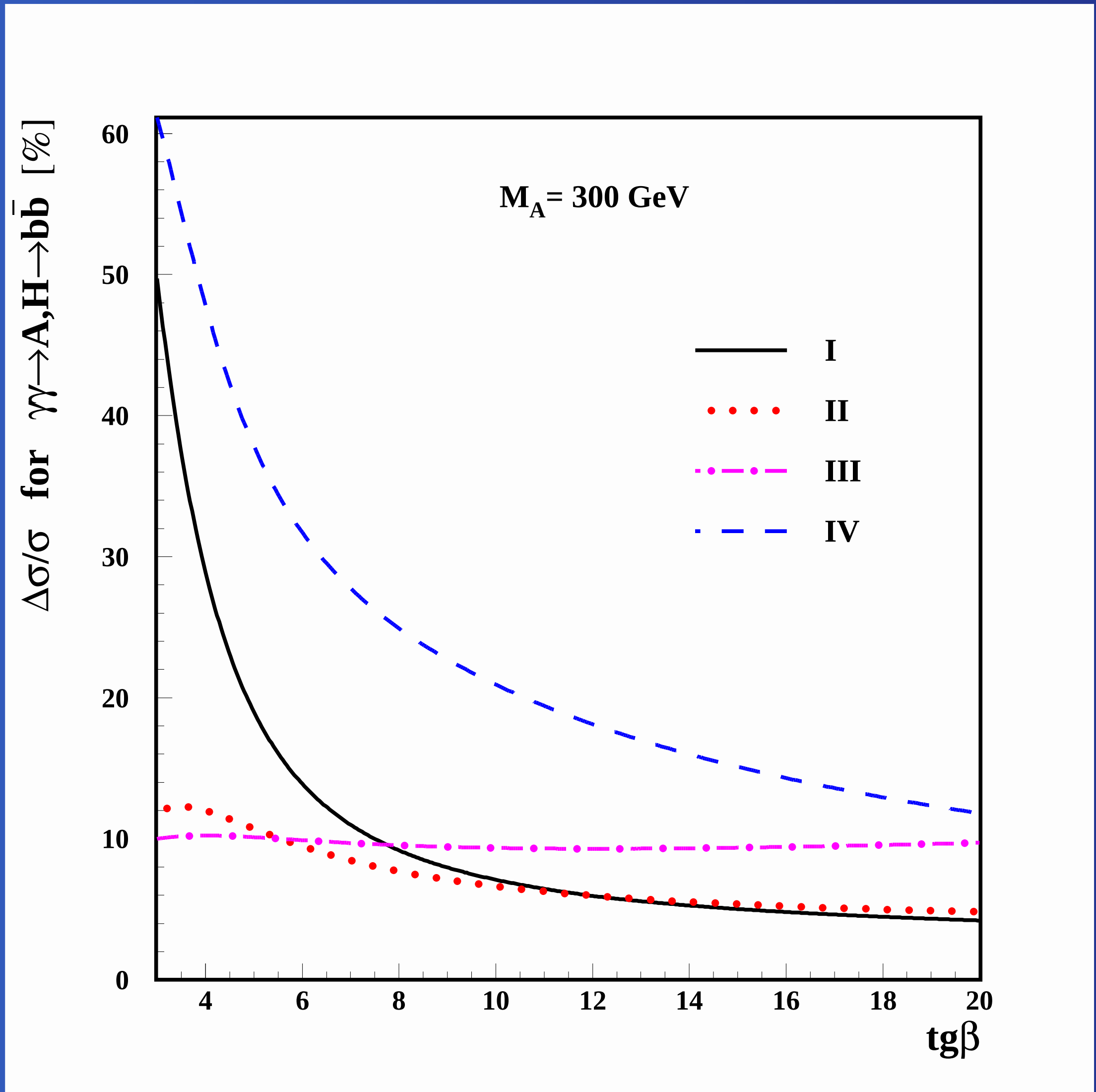

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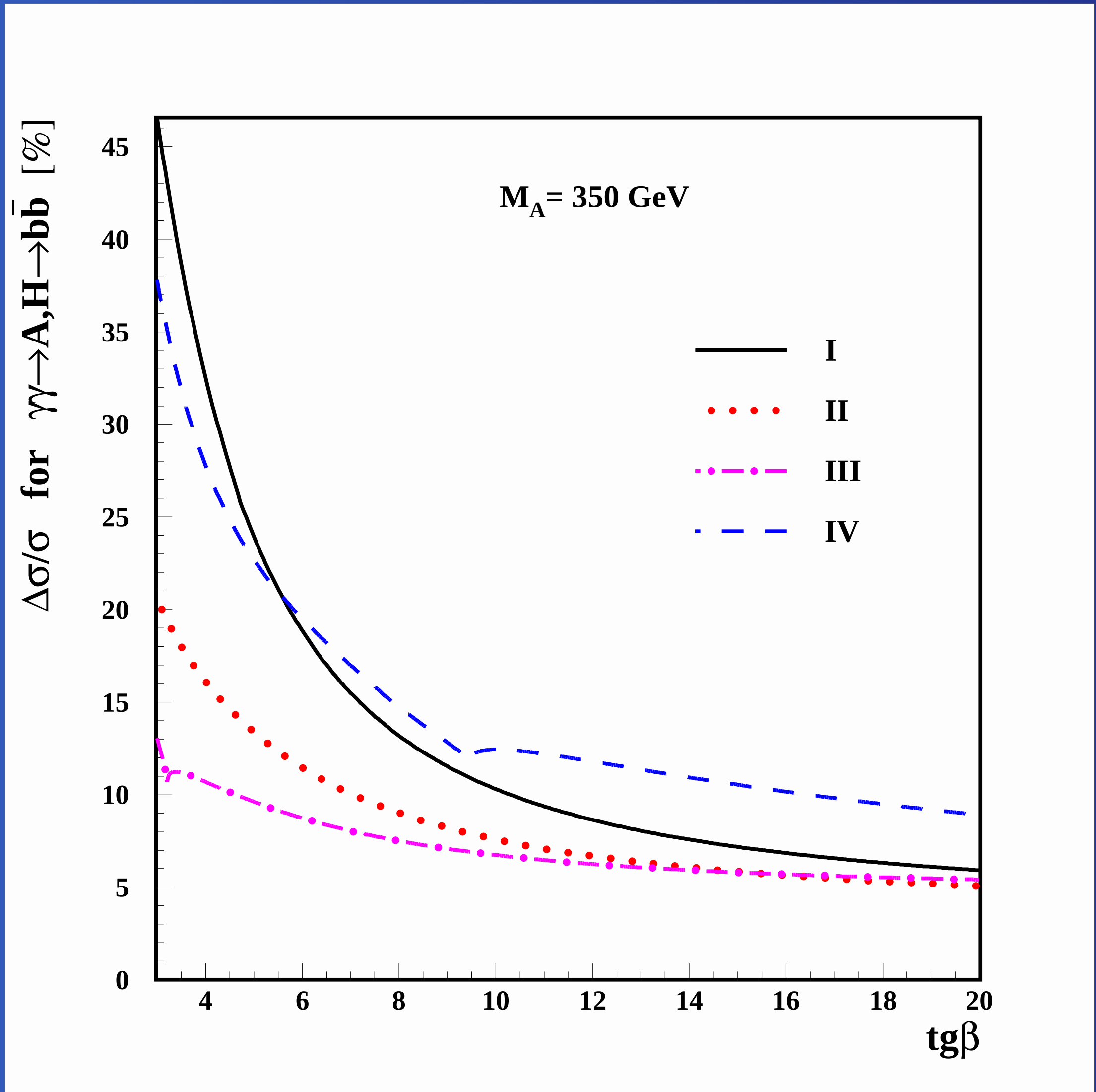

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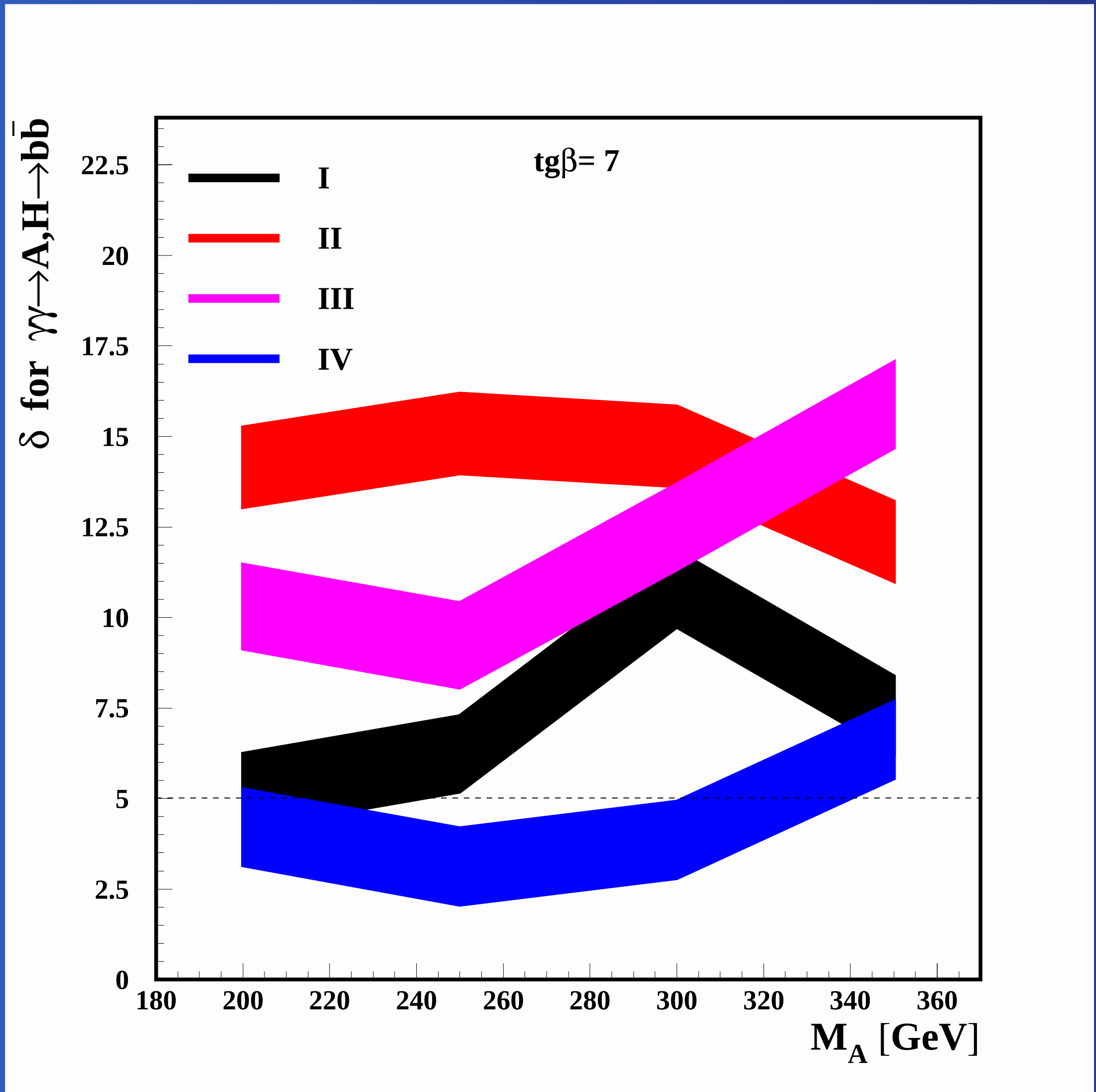
Photon Collider reach

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



Symbol	μ [GeV]	$A_{\tilde{f}}$ [GeV]
I	200	1500
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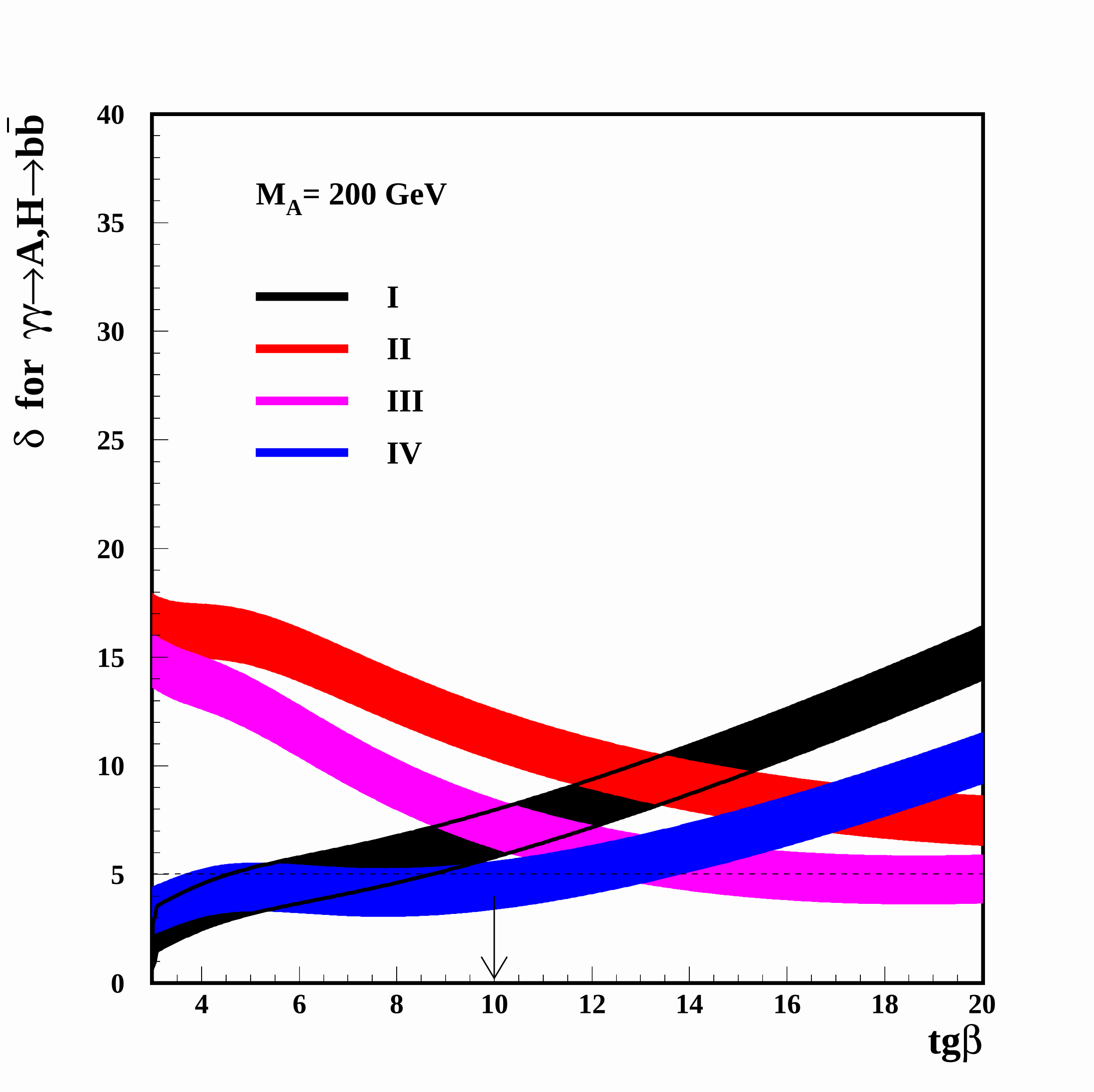
Significance

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

The band widths indicate the level of possible statistical fluctuations

Photon Collider reach

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



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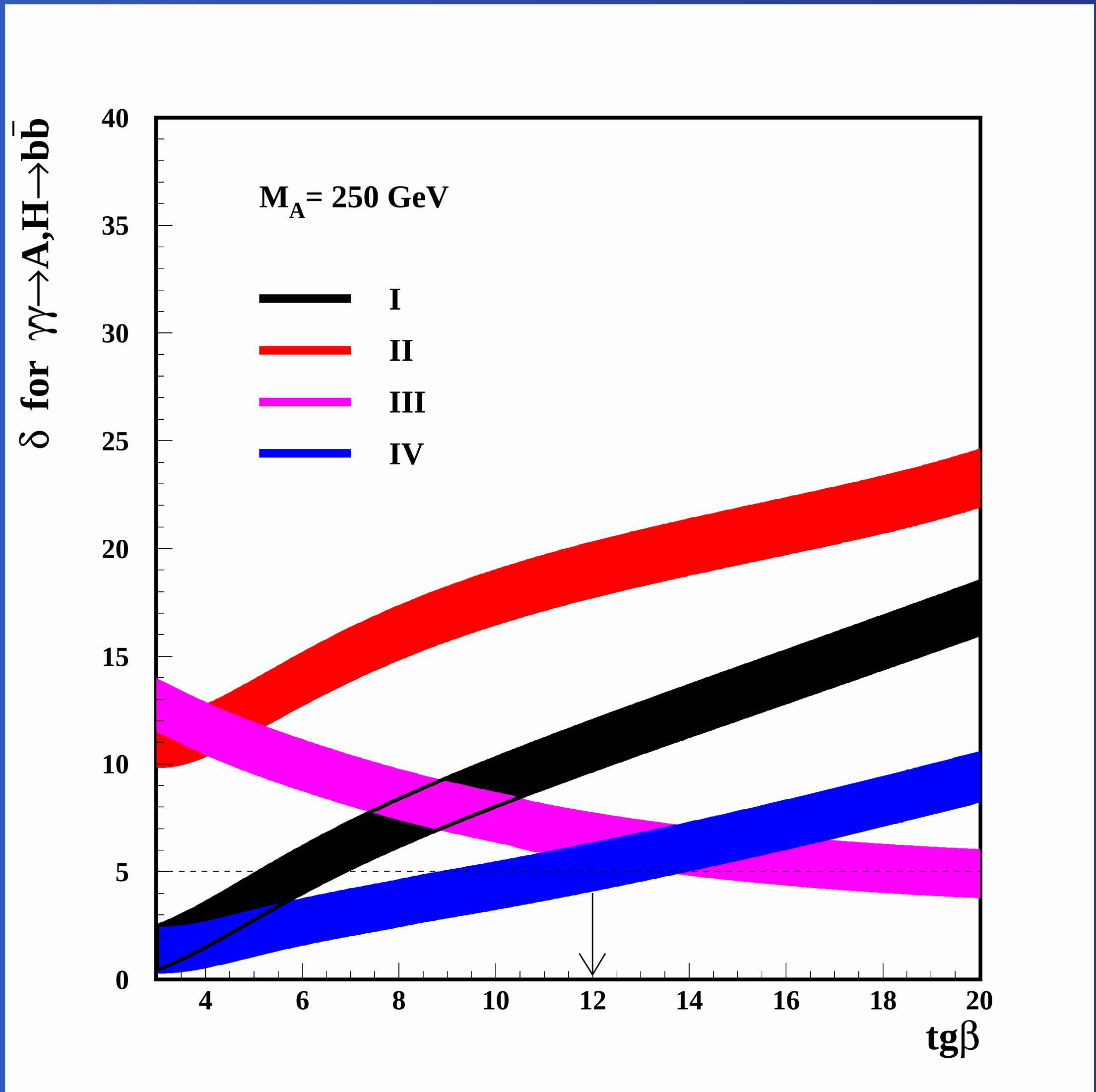
Arrow – lower limit of the LHC discovery region.

Photon Collider reach

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



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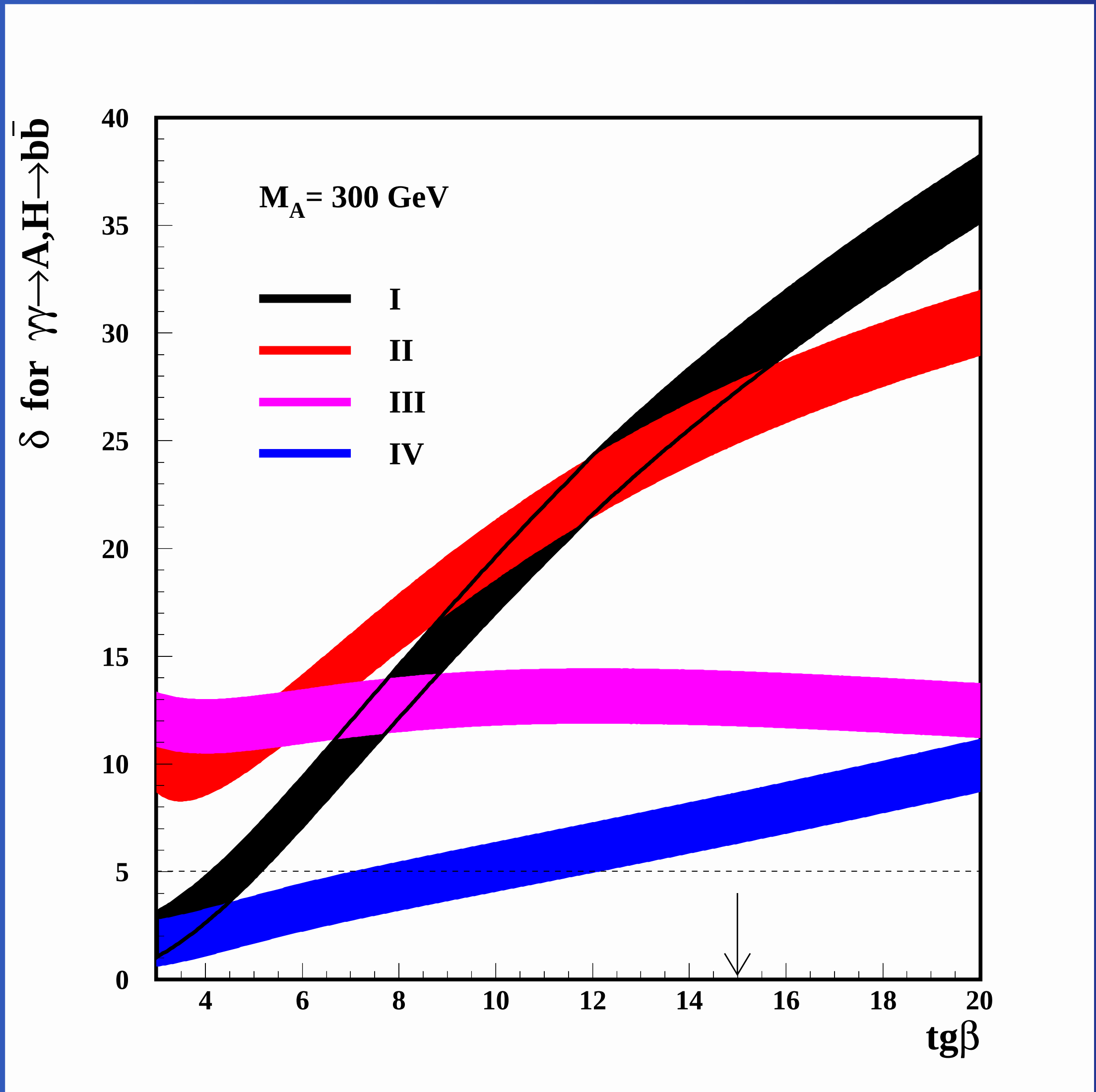

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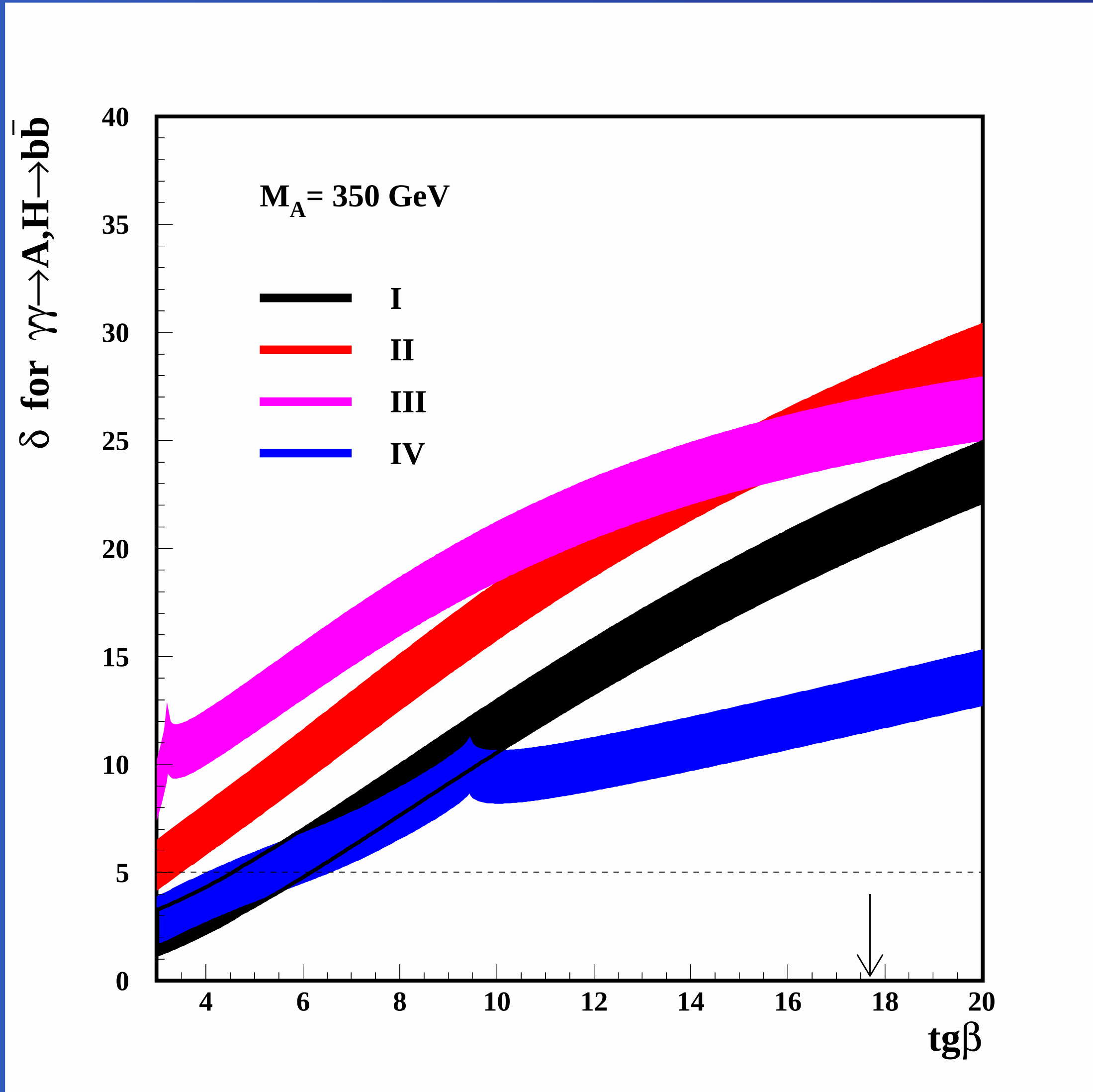

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The band widths indicate the level of possible statistical fluctuations

Arrow – lower limit of the LHC discovery region.

Conclusions

- All important theoretical and experimental aspects of the measurement taken into account.
- Optimal cuts per mass point.
- *higgs*-tagging: cut on the ratio of $\gamma\gamma \to A, H \to b\bar{b}$ to $\gamma\gamma \to b\bar{b}(g), c\bar{c}(g), q\bar{q}$ ($q = u, d, s$) events.
- Four MSSM parameter sets, $\tan\beta =$ 3–20.
- Precision between 11% and 21% for $M_A =$ 200–350 GeV, $\tan\beta =$ 7, and parameter set I, after one year.
- Significance compared to LHC estimates.
- For $M_A \gtrsim 300$ GeV the Photon Collider can discover MSSM Higgs bosons for much lower values of $\tan\beta$ than LHC.