Higgs studies

at the TESLA Photon Collider

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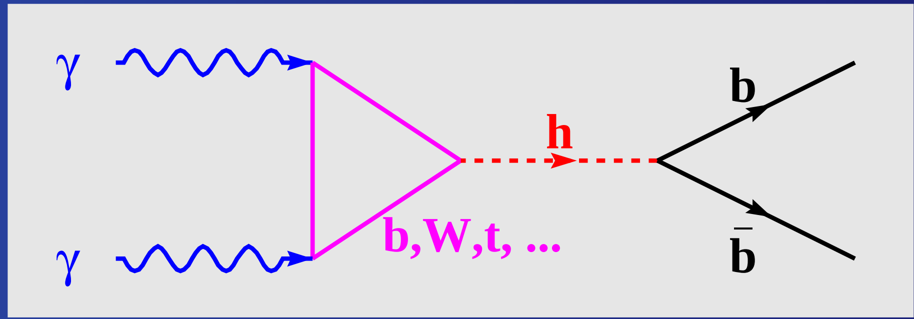
Faculty of Physics

Warsaw University

$m_h \approx 120$ GeV

Process: $\gamma + \gamma \rightarrow h \rightarrow b + \bar{b}$

$$J_z = 0$$



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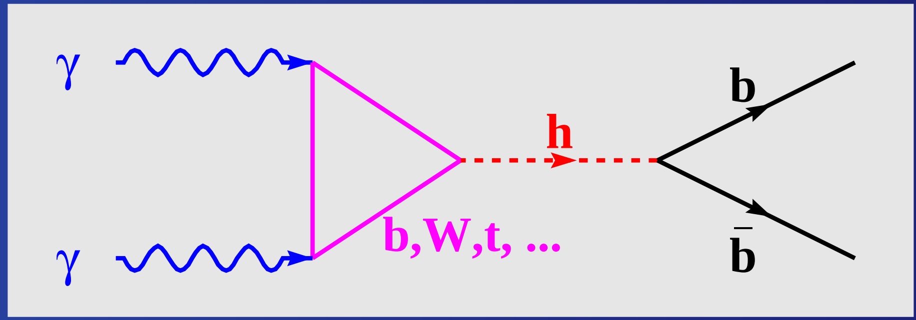
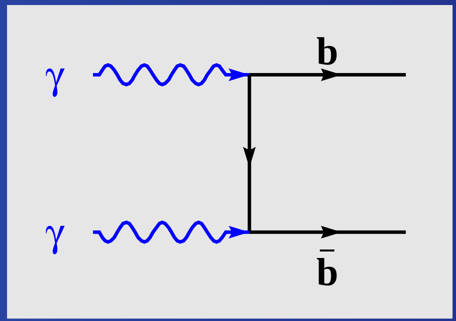


"Hard" background:

- $\gamma + \gamma \to b + \bar{b}$



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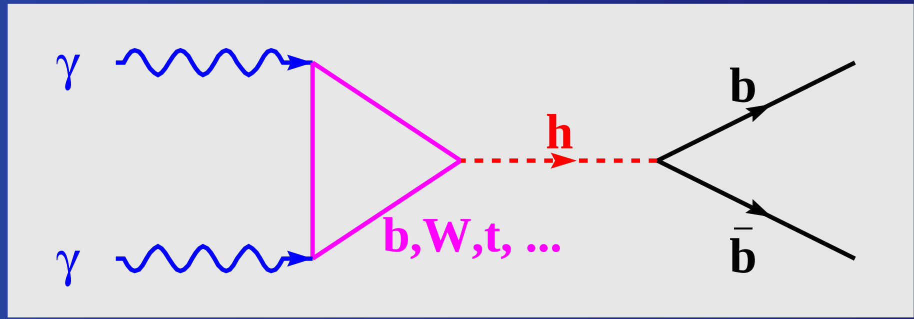
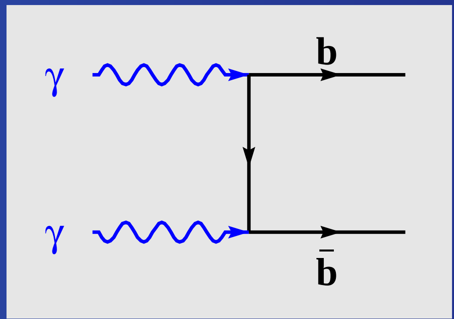


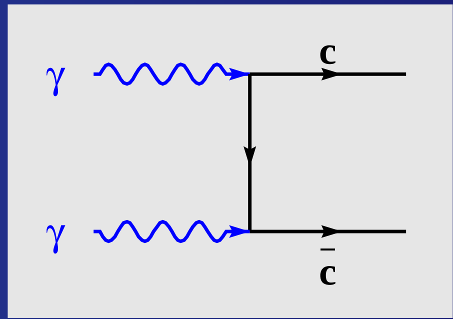
"Hard" background:

- $\gamma + \gamma \to b + \bar{b}$
- $\gamma + \gamma \to c + \bar{c}$

$$\sigma \propto Q_q^4$$

$$\sigma^{LO}(|J_z| = 2) \gg \sigma^{LO}(J_z = 0)$$





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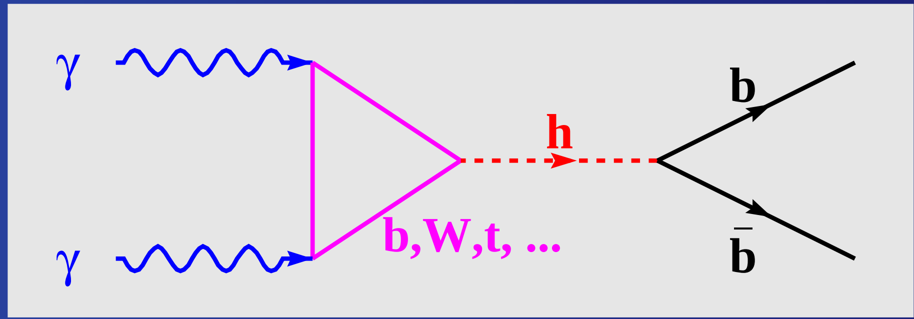

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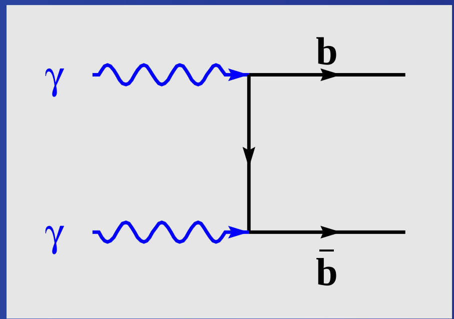

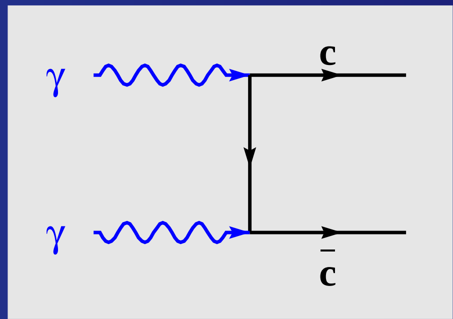

$$\sigma \propto Q_q^4$$

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Other background:

- Resolved photon(s) interactions $\gamma + \gamma \to X + Q + \bar{Q}$

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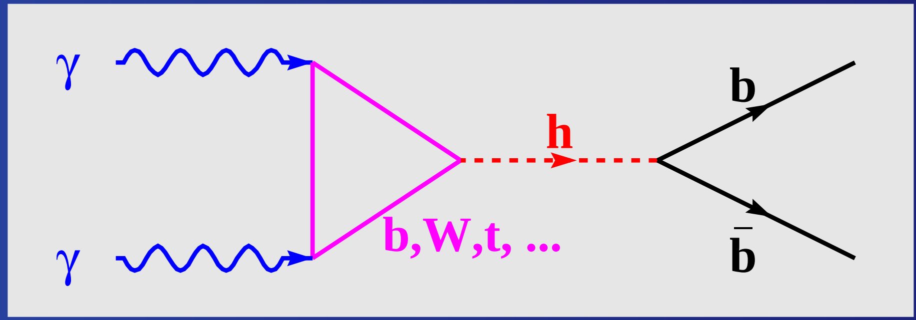

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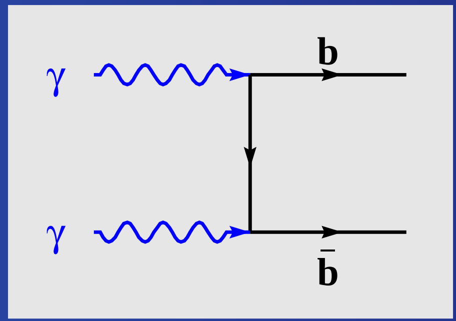

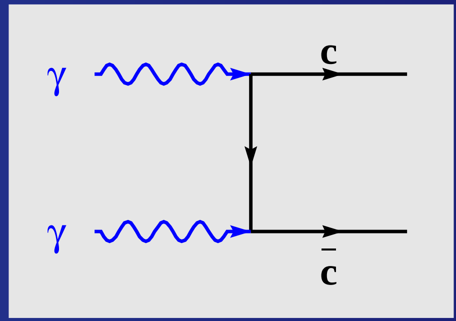

$\sigma \propto Q_q^4$

$\sigma^{LO}(|J_z| = 2) \gg \sigma^{LO}(J_z = 0)$

Other background:

- Resolved photon(s) interactions $\gamma + \gamma \to X + Q + \bar{Q}$
- Overlaying events
  (high intensity of photon-beams in the low-energy part of the spectrum)

$\gamma + \gamma \longrightarrow F + \bar{F}$

- LO cross section for massless fermions

$$\sigma(J_z = 2) \propto \frac{\alpha^2}{s}$$

$$\sigma(J_z = 0) = 0$$

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- LO cross section for massive fermions

$$S_F^\mu = P_F^\mu + \mathcal{O}(\frac{m_F}{E_F})$$

$$\Longrightarrow \sigma(J_z = 2) \propto \frac{\alpha^2}{s}$$

$$\sigma(J_z = 0) \propto \frac{m_F^2}{s}\frac{\alpha^2}{s}$$

$\gamma + \gamma \longrightarrow F + \bar{F}$

- NLO cross section for massless fermions

$$\Longrightarrow \sigma \propto \frac{\alpha^2 \alpha_s}{s}$$

$$\frac{d\sigma}{dE_g}(J_z = 2) \propto \frac{1}{E_g}$$

$$\sigma(J_z = 0) \propto E_g^3$$

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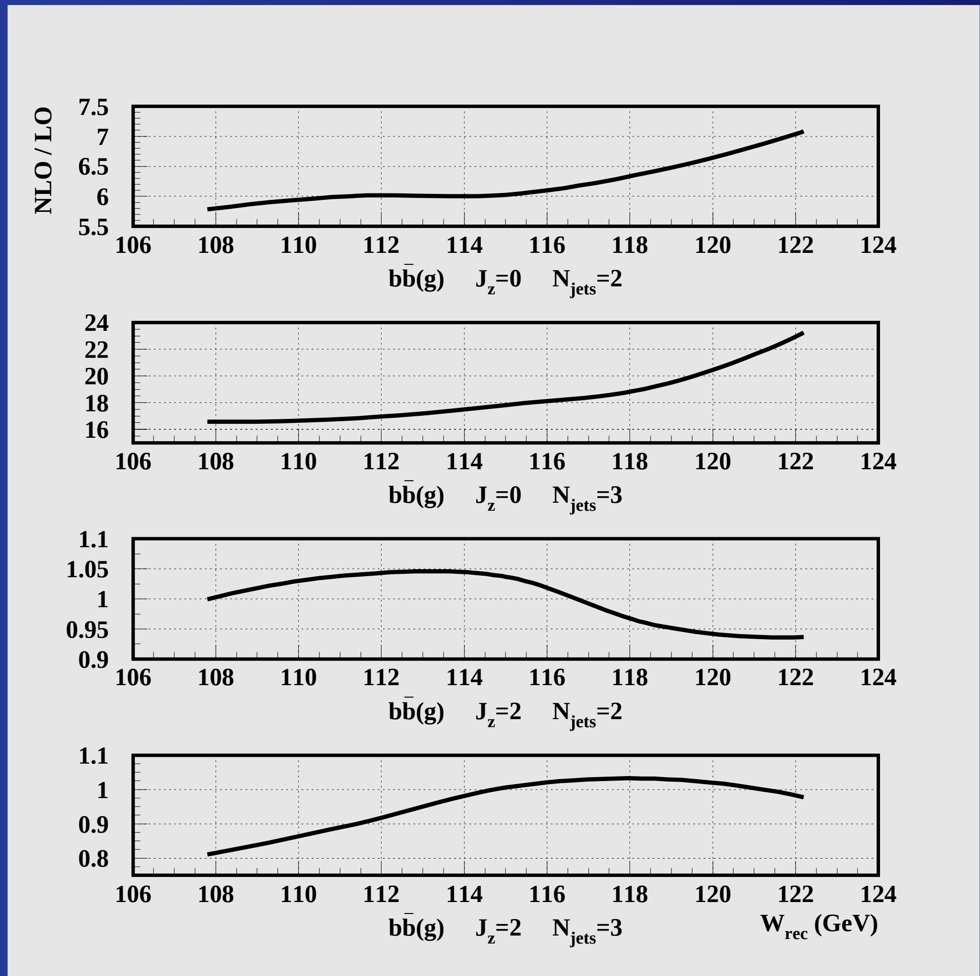
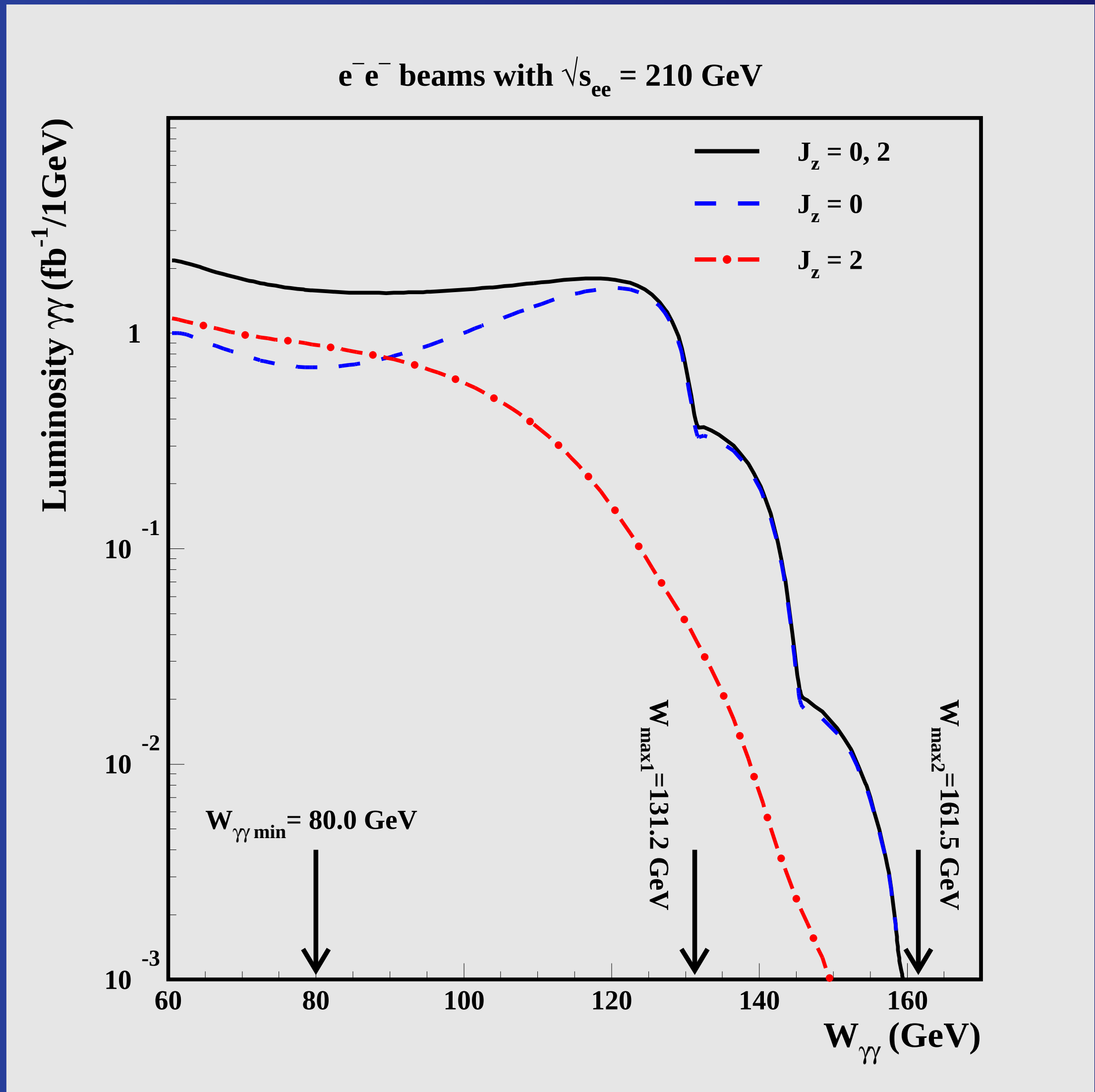


Generation & Simulation. Selection.

Photon-photon spectrum: CompAZ



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Signal: HDECAY, PYTHIA

Background: program by G. Jikia

Fragmentation: Lund in PYTHIA

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Jets: Durham algorithm with $y_{cut} = 0.02$

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Selection of $b\bar{b}$ events:

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- 1) Assumed bb-tagging and mistagging efficiencies: $\varepsilon_{bb} = 70\%$, $\varepsilon_{cc} = 3.5\%$
  2) Using ZVTOP-B-Hadron-Tagger

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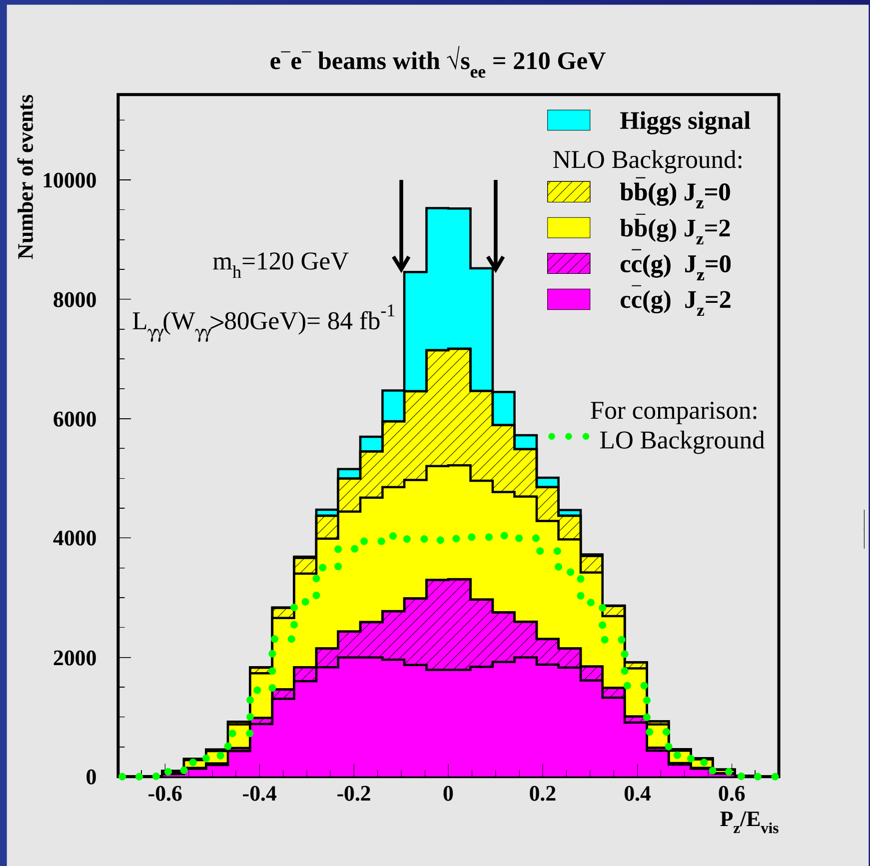
- $|P_z|/E_{vis} < 0.1$



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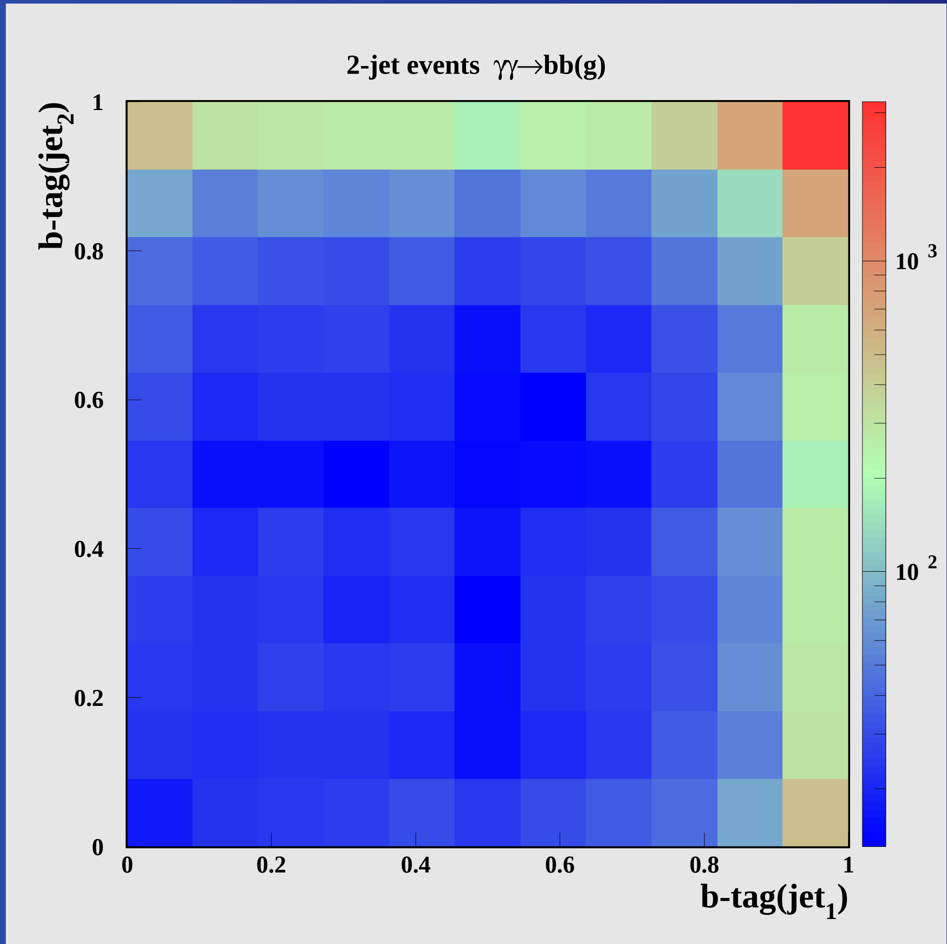
- $E_{vis} > 90$ GeV
- $N_{jets} = 2,\ 3$
- $|P_z|/E_{vis} < 0.1$
- $|\cos\theta_i| < 0.75$ for each jet

B-tagging

ZVTOP-B-Hadron-Tagger



Number of $\gamma + \gamma \to b + \bar{b}$ events per 1 year of collider running

B-tagging

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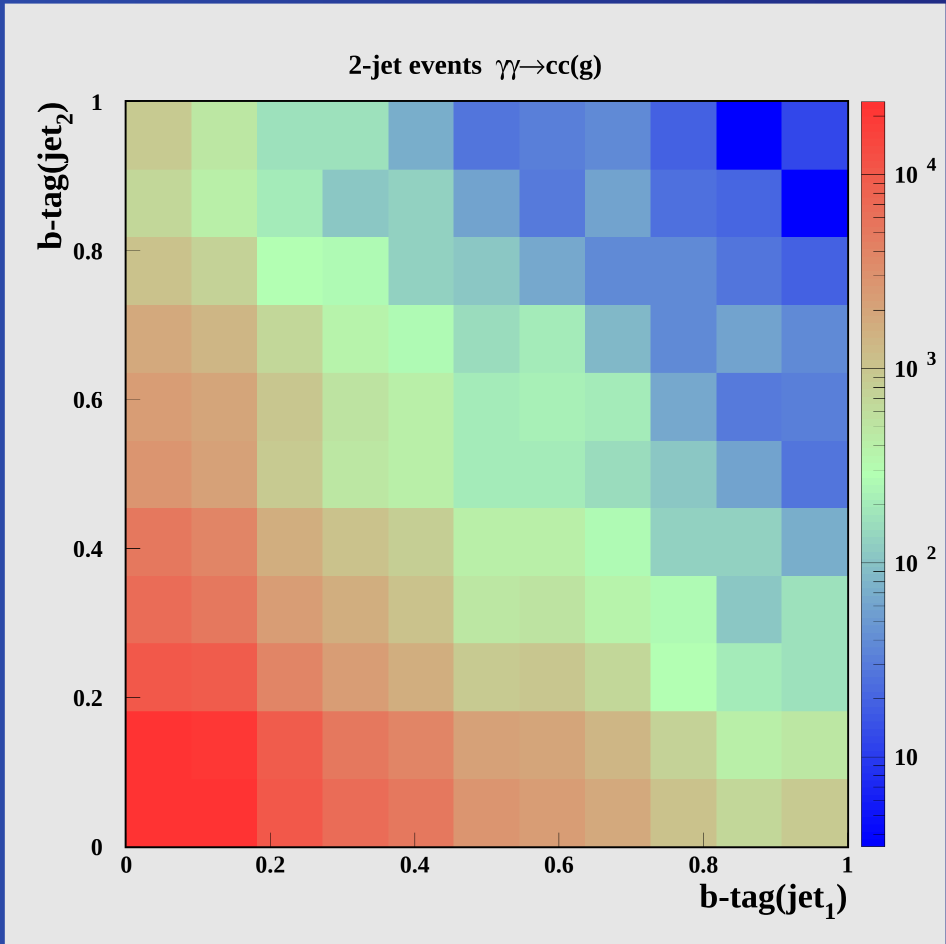

Number of $\gamma + \gamma \to c + \bar{c}$ events per 1 year of collider running

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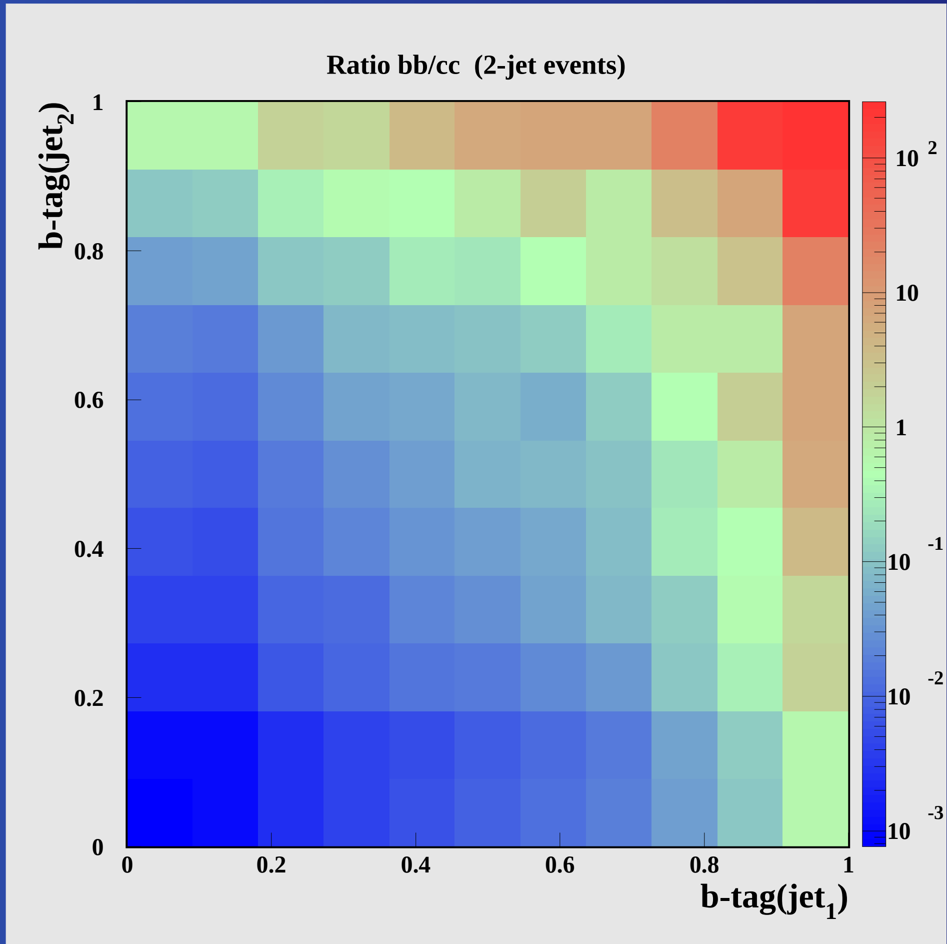
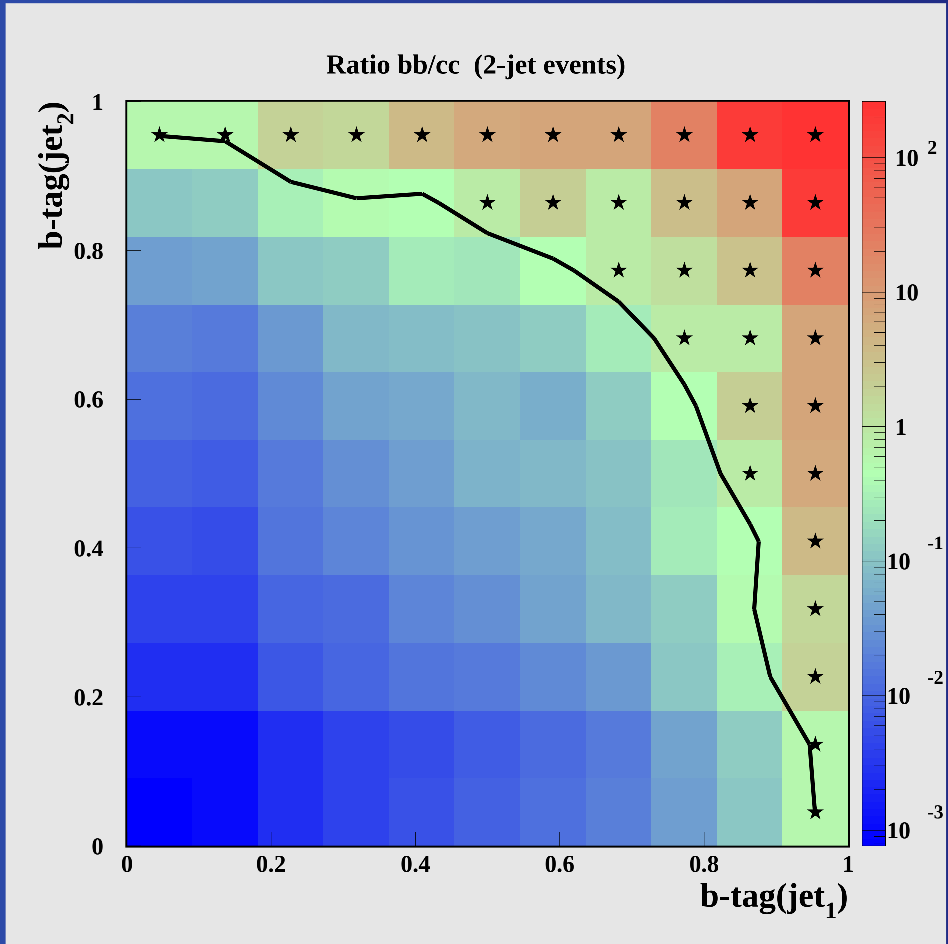


$$\frac{S}{B} = \frac{\#(\gamma\gamma \to b\bar{b})}{\#(\gamma\gamma \to c\bar{c})}$$

B-tagging

ZVTOP-B-Hadron-Tagger



2-jet events: $\varepsilon_{bb} = 81\%$ $\varepsilon_{cc} = 1.8\%$

3-jet events: $\varepsilon_{bb} = 77\%$ $\varepsilon_{cc} = 1.3\%$

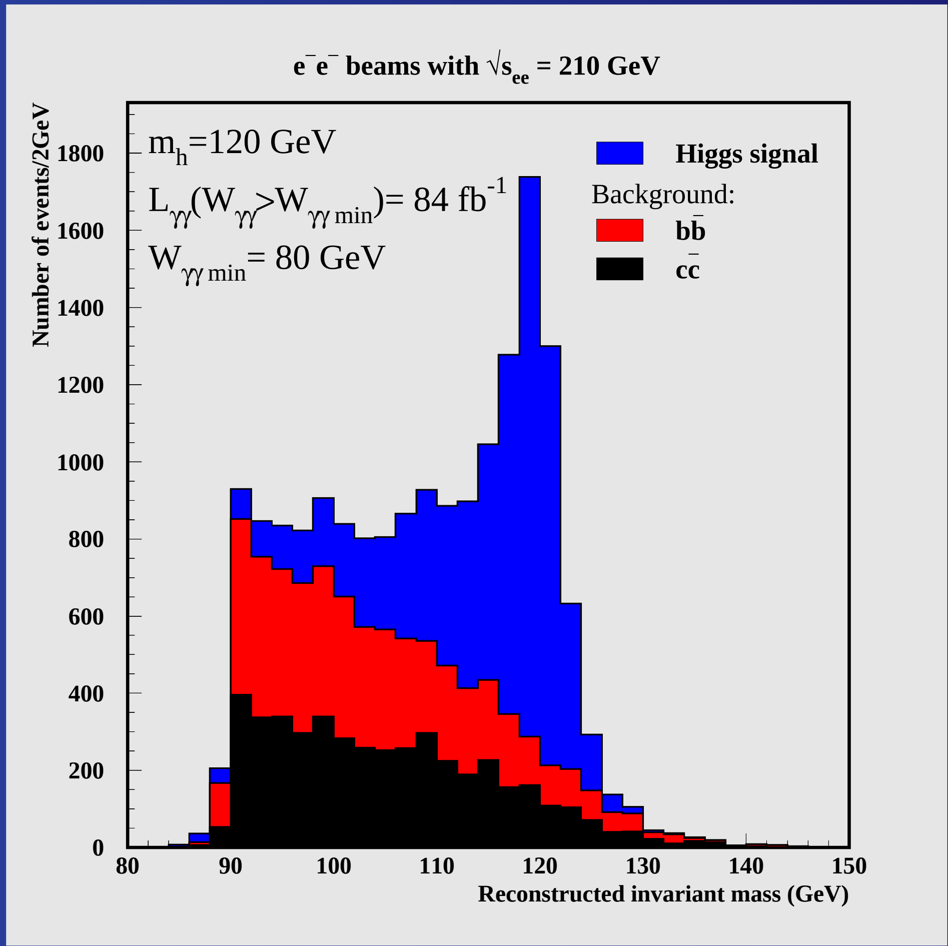
Earlier assumed: $\varepsilon_{bb} = 70\%$ $\varepsilon_{cc} = 3.5\%$

Results

$$\frac{\Delta\left[\Gamma(h\to\gamma\gamma)\mathrm{Br}(h\to b\bar{b})\right]}{\left[\Gamma(h\to\gamma\gamma)\mathrm{Br}(h\to b\bar{b})\right]}=\frac{\sqrt{N_{obs}}}{N_{obs}-N_{bkgd}}$$

Consecutive approaches:

- LO cross section for $\gamma+\gamma\to Q\bar{Q}$. (1.7%)



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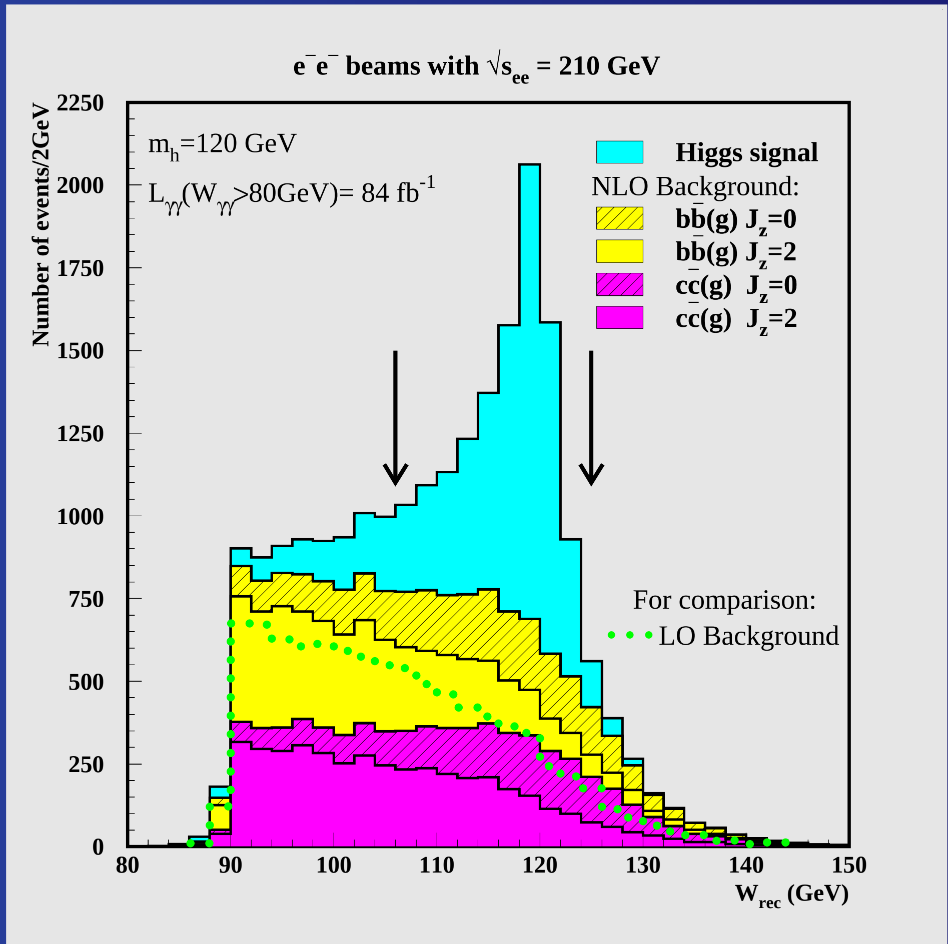
Consecutive approaches:

- LO cross section for $\gamma+\gamma\to Q\bar{Q}$. (1.7%)
- NLO cross section for $\gamma+\gamma\to Q\bar{Q}(g)$. (1.9%)



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$$\frac{\Delta\left[\Gamma(h\to\gamma\gamma)\mathrm{Br}(h\to b\bar{b})\right]}{\left[\Gamma(h\to\gamma\gamma)\mathrm{Br}(h\to b\bar{b})\right]} = \frac{\sqrt{N_{obs}}}{N_{obs}-N_{bkgd}}$$

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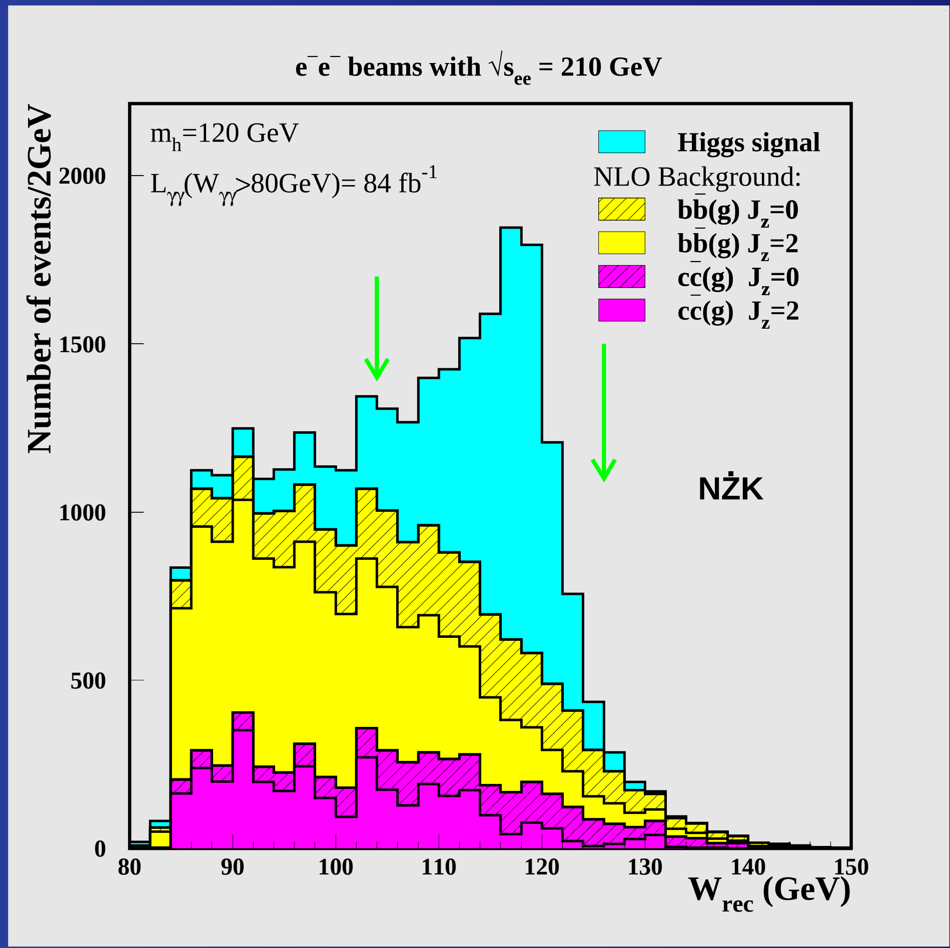
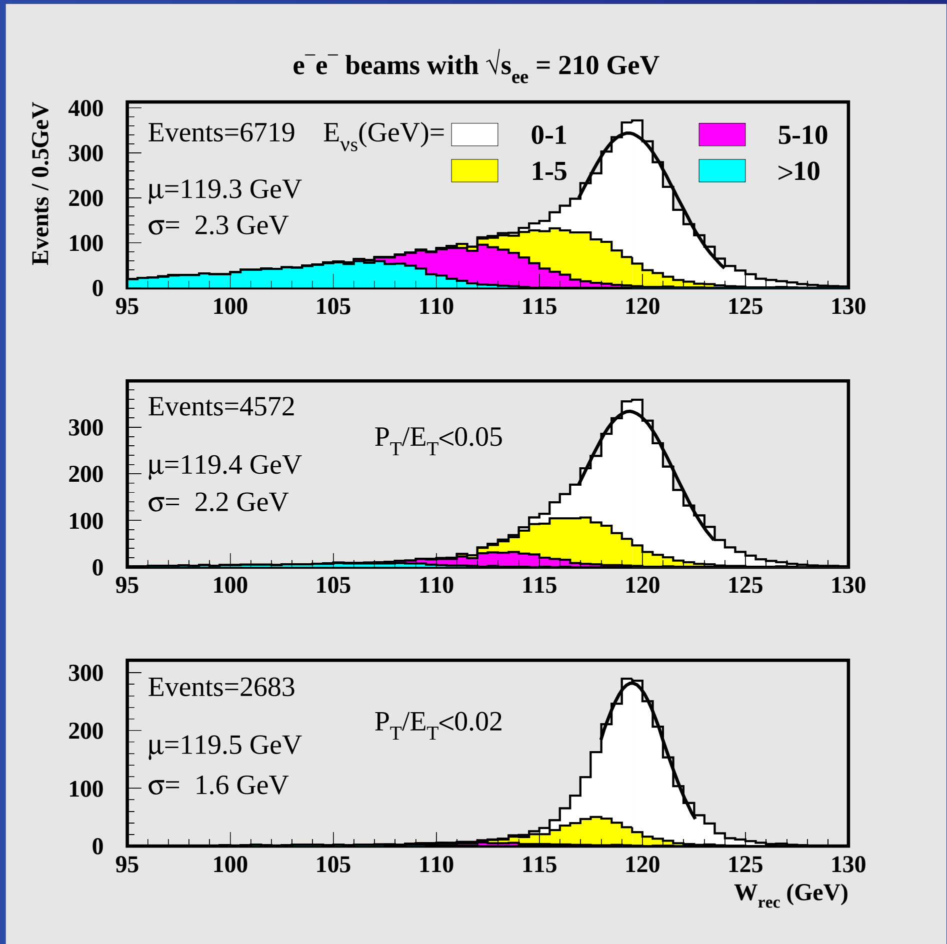


Missing P_T

Neutrinos from semileptonic decays of D- and B-mesons.



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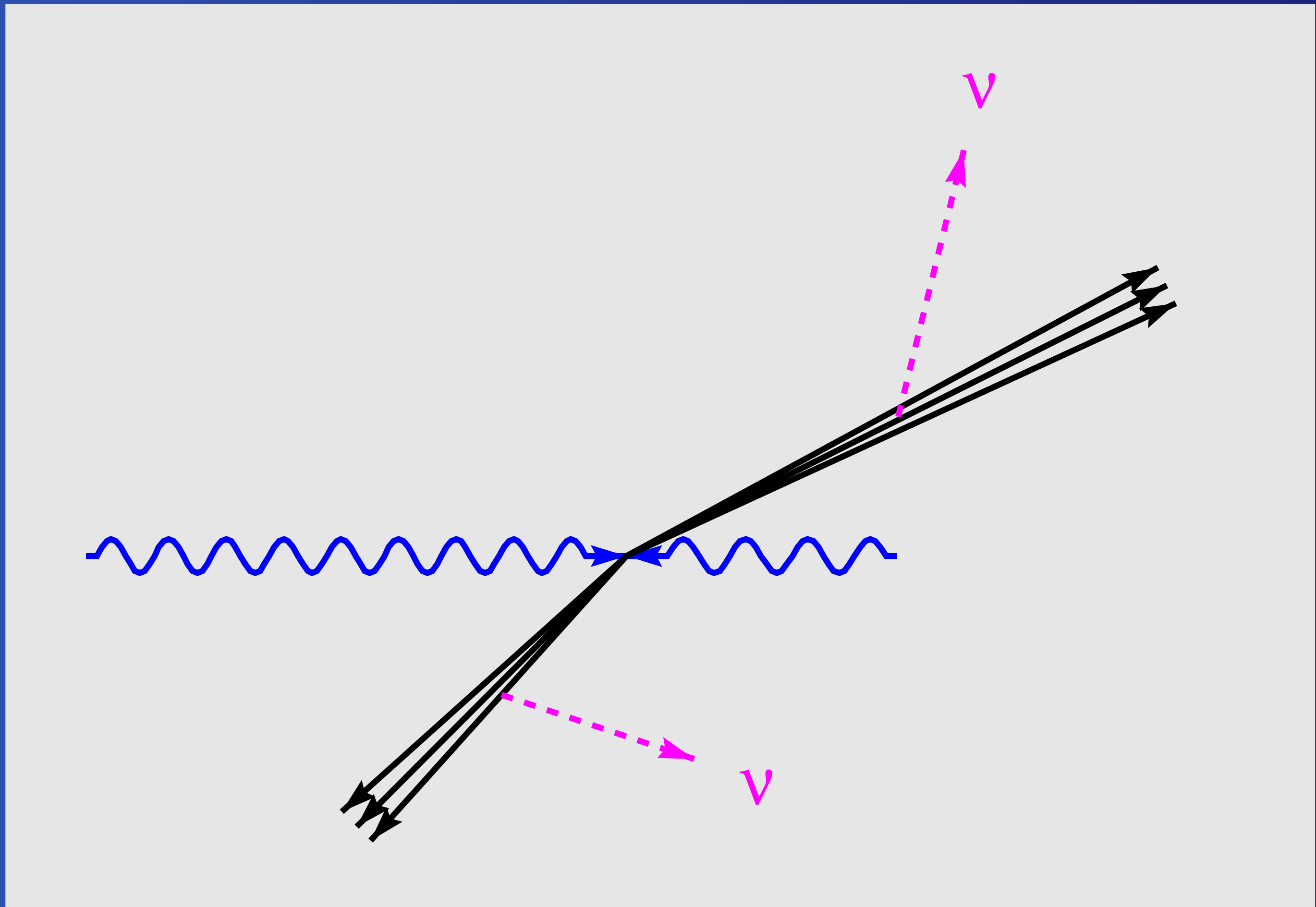

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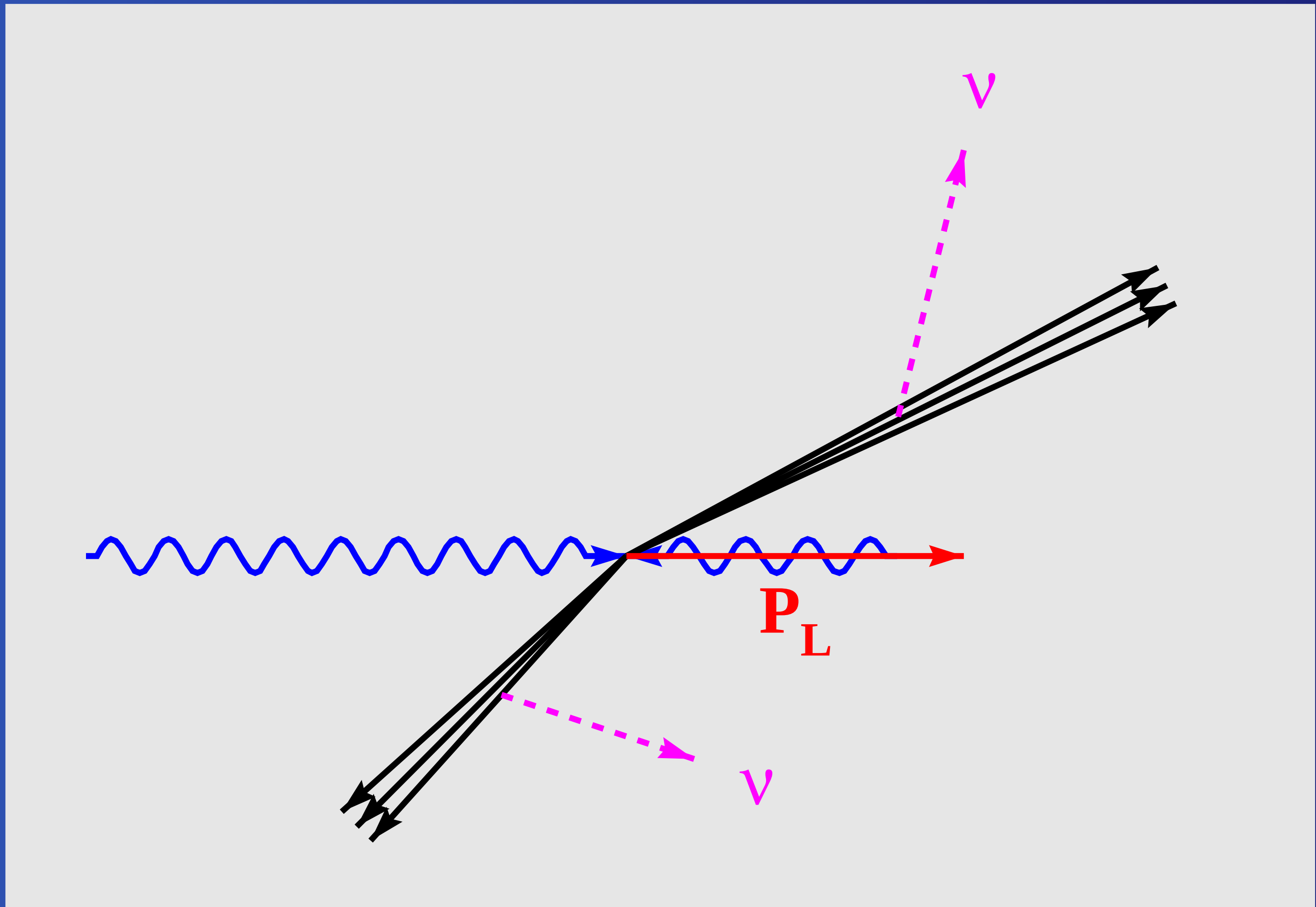

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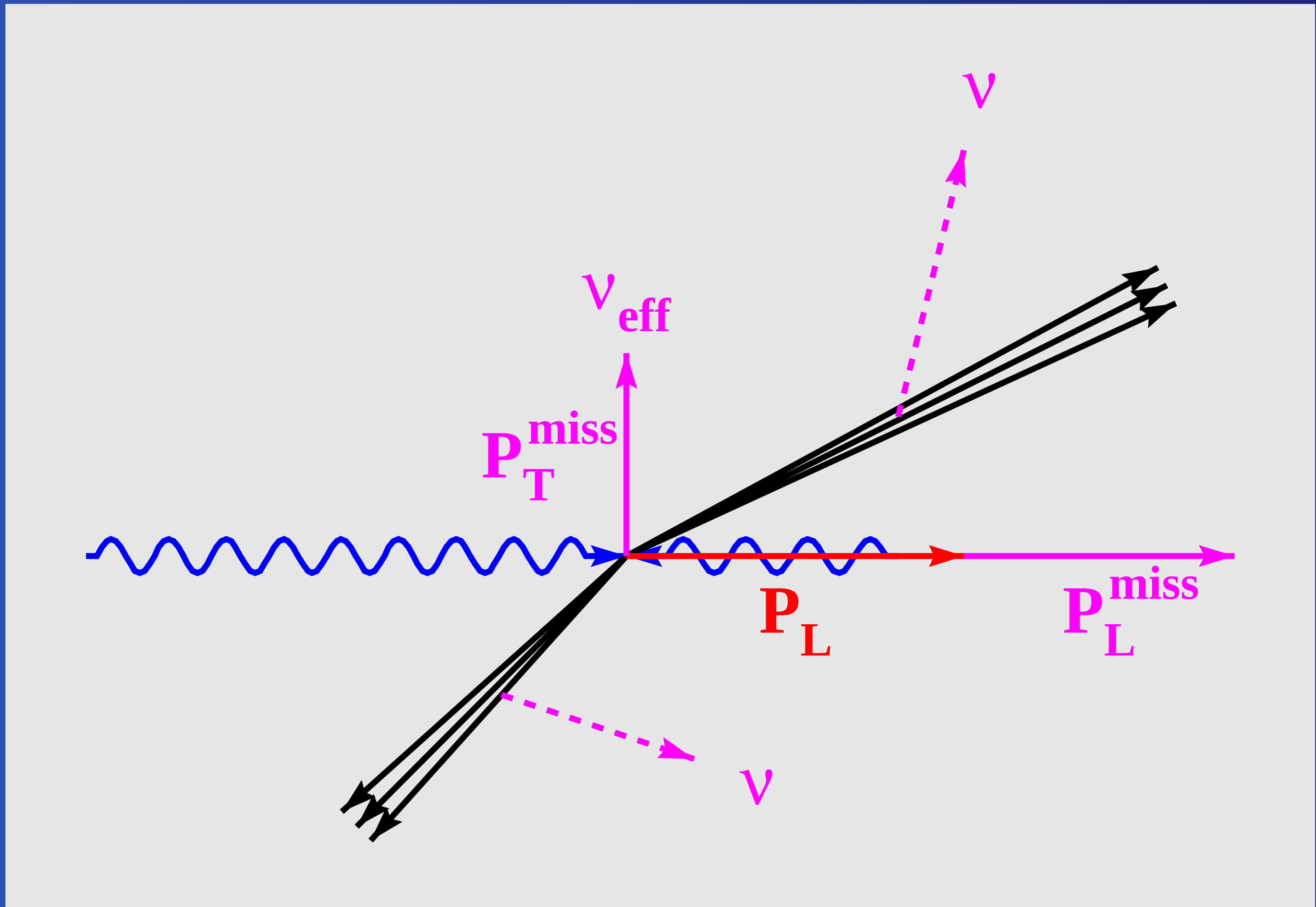
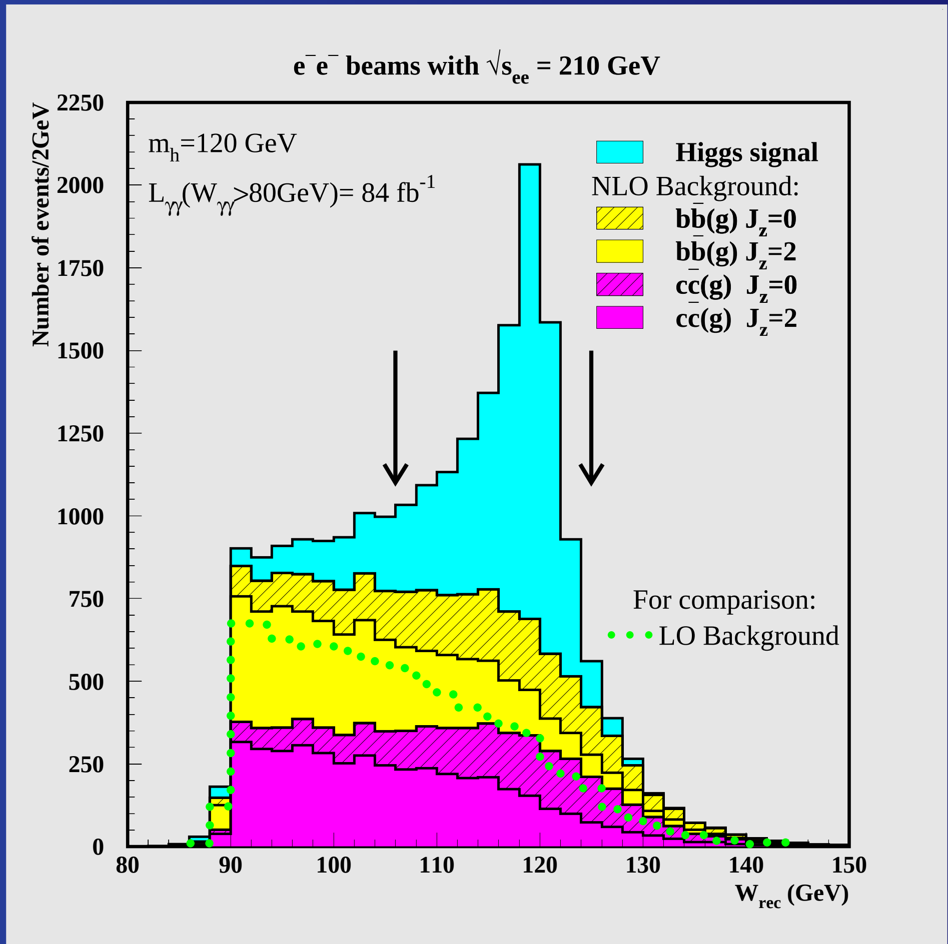


$$W_{corr} \equiv \sqrt{W_{rec}^2 + 2P_T(E_{vis} + P_T)}$$

Final results ($W_{rec} \to W_{corr}$)

$$\frac{\Delta\left[\Gamma(h\to\gamma\gamma)\mathrm{Br}(h\to b\bar{b})\right]}{\left[\Gamma(h\to\gamma\gamma)\mathrm{Br}(h\to b\bar{b})\right]} = \frac{\sqrt{N_{obs}}}{N_{obs}-N_{bkgd}}$$

- NLO cross section for $\gamma+\gamma\to Q\bar{Q}(g)$. (1.9%) - with W_{rec}



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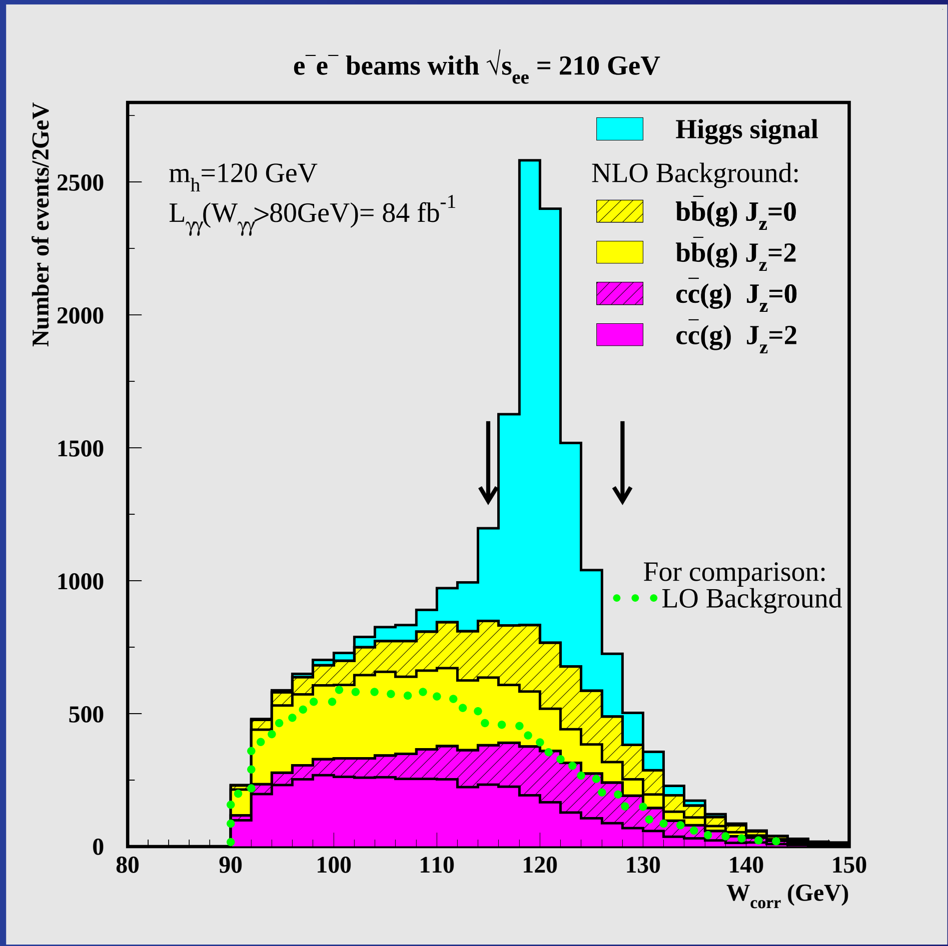

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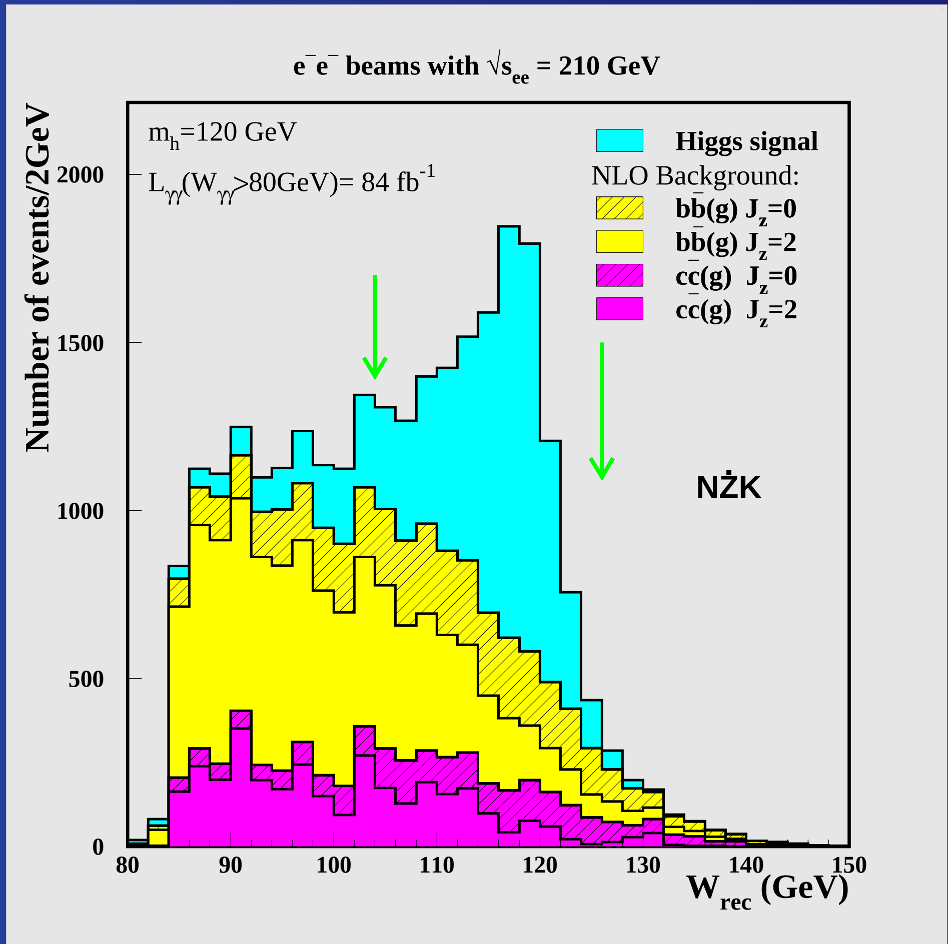
- NLO cross section for $\gamma+\gamma\to Q\bar{Q}(g)$. (1.9%) - with W_{rec} (1.7%) - with W_{corr}
- NLO cross section for $\gamma+\gamma\to Q\bar{Q}(g)$. B-tagging algorithm. (1.8%) - with W_{rec}



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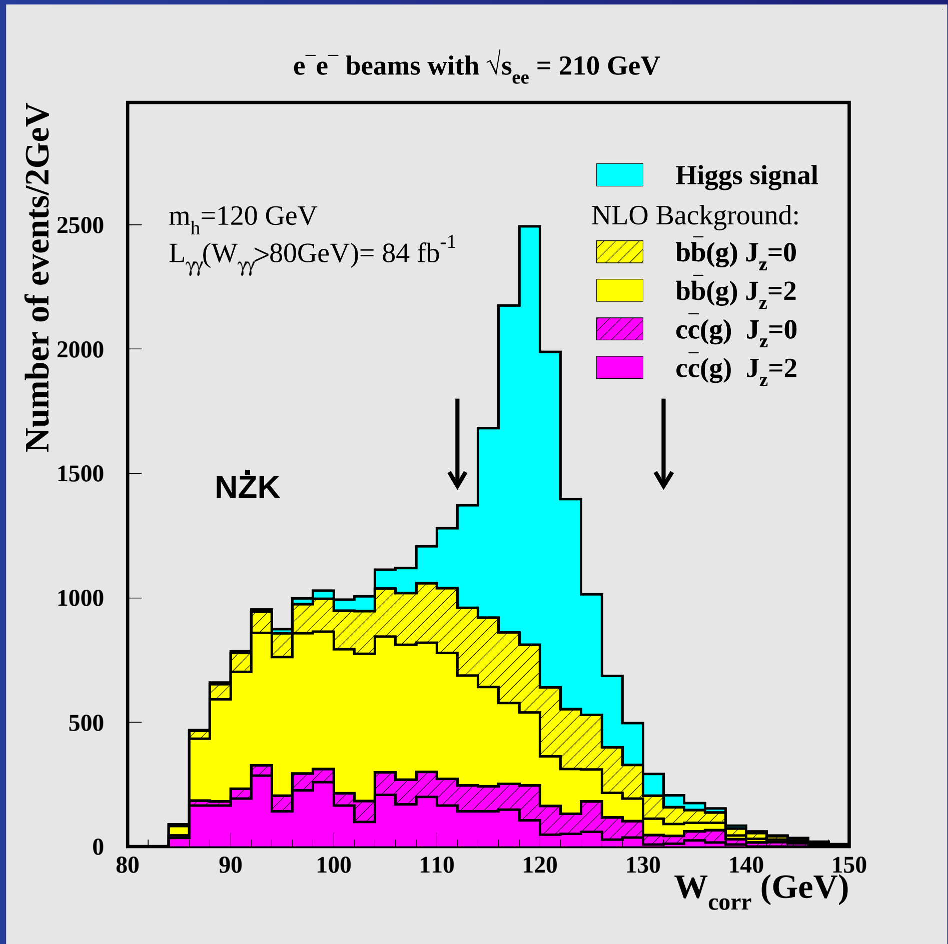

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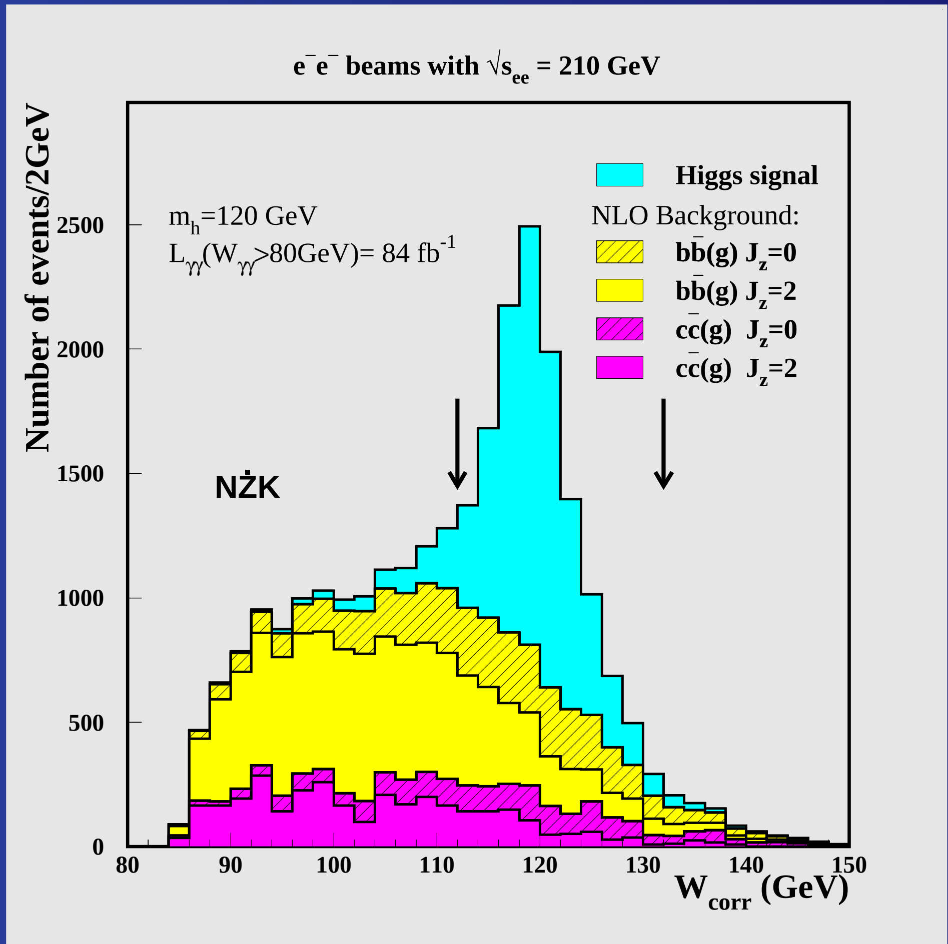
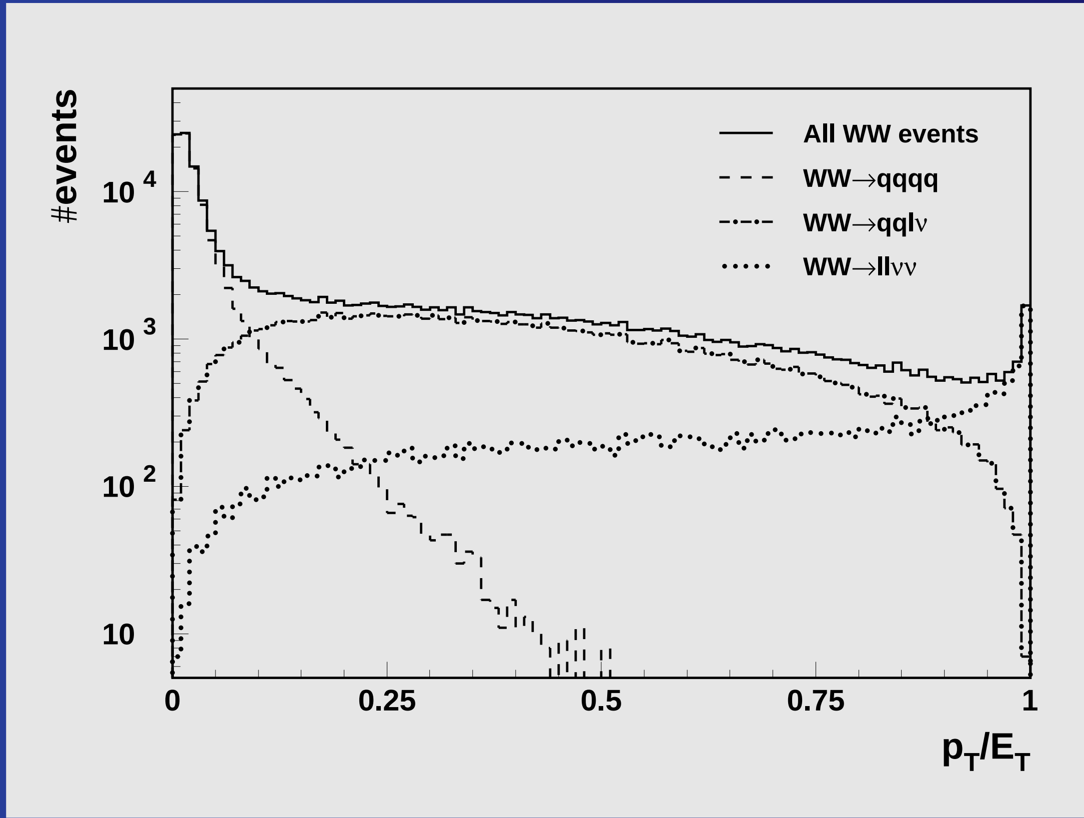


Plans: m_h up to 160 GeV, . . .

$\gamma\gamma \to W^+W^-$

$W^+W^- \to 4\, jets$ event selection:

- balanced transverse momentum:
  $P_T/E_T < 0.1$



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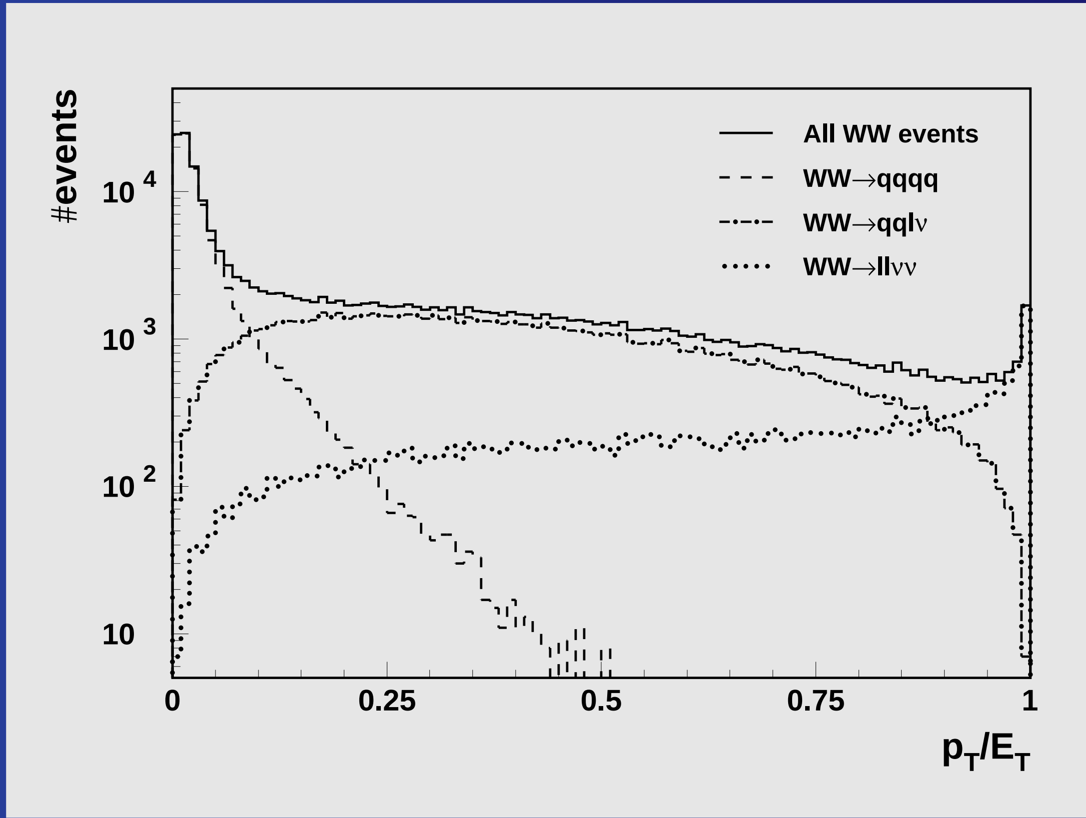

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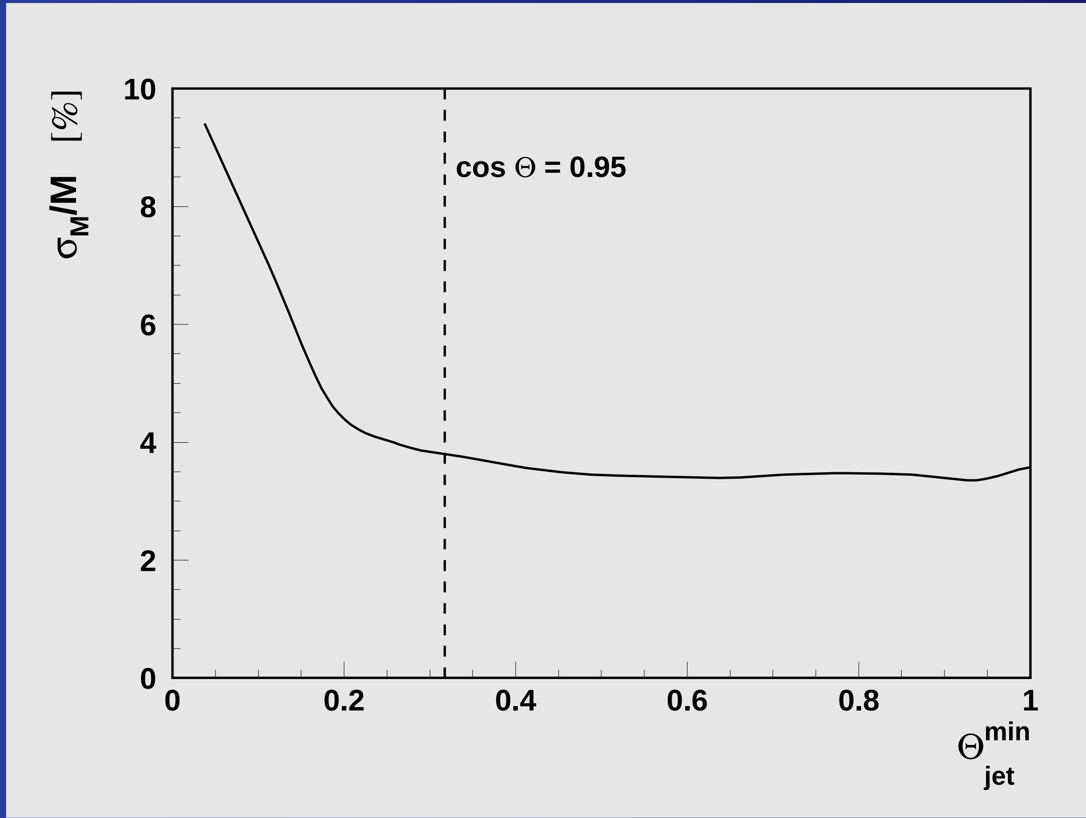

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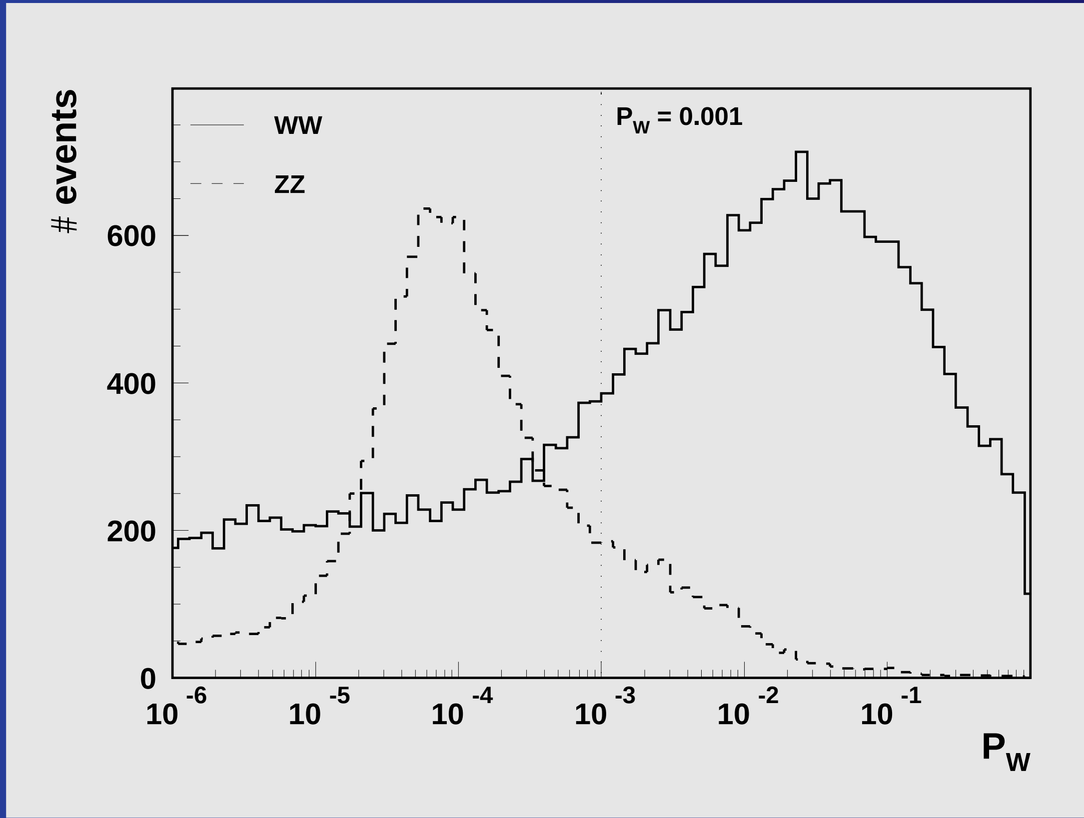
- two $W^\pm$ reconstructed with probability $P_W > 0.001$

$$P_W = \prod_{W_1,W_2} \frac{M_W^2\Gamma_W^2}{\left(m_{jj}^2 - M_W^2\right)^2 + M_W^2\Gamma_W^2}$$



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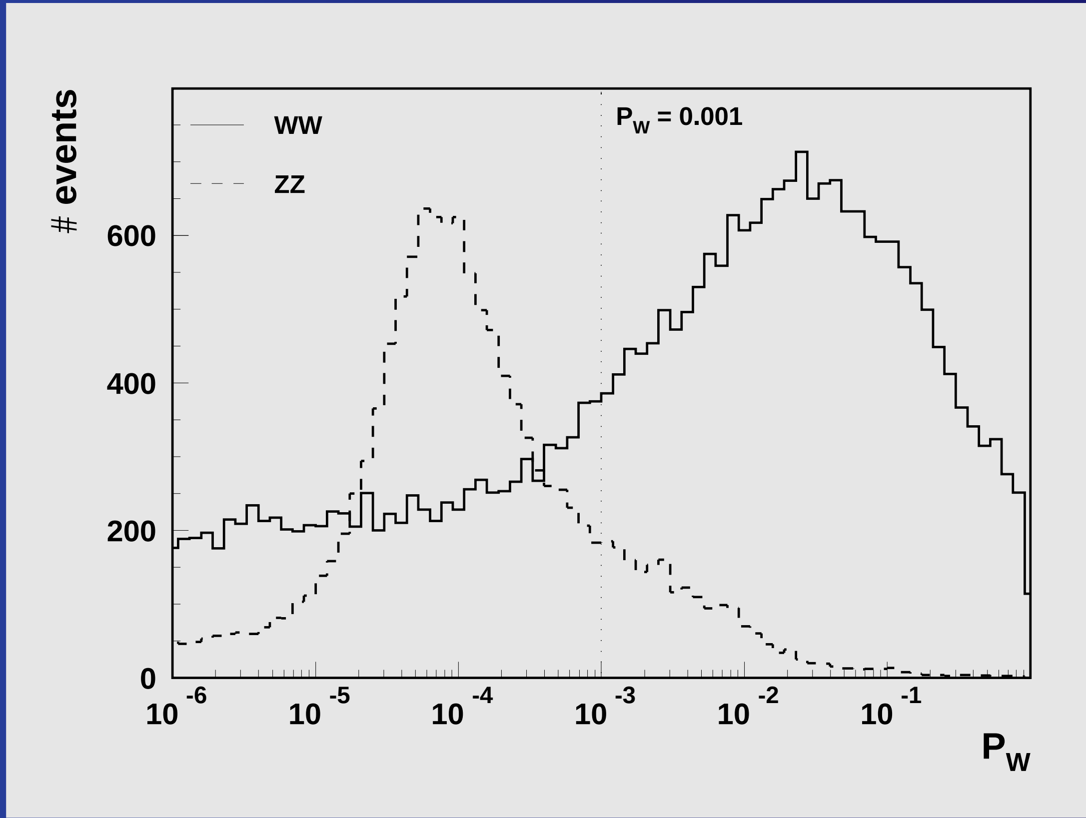


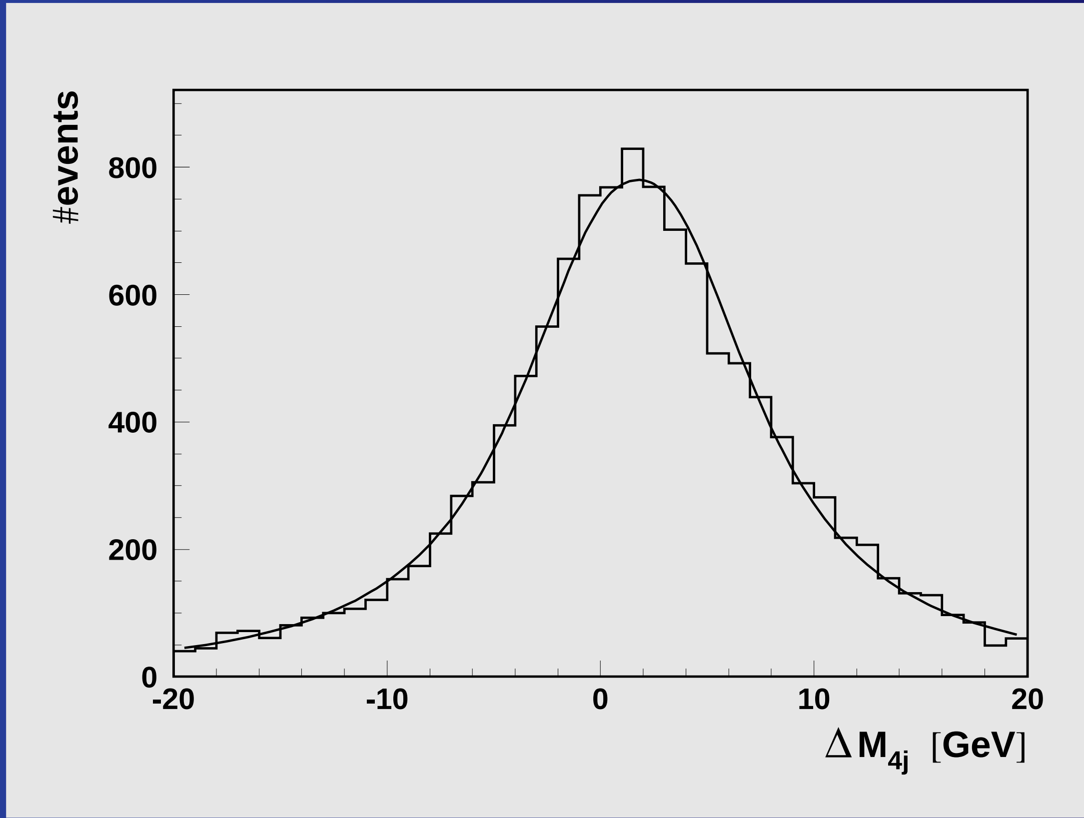
$\Rightarrow$ selection efficiency between 20% for and 16% for ($W_{\gamma\gamma}$ = 200–400 GeV)
probability for both $W^\pm$ to decay into hadrons is $\sim$47%

$\gamma\gamma \to W^+W^-$

$W^+W^- \to 4\,jets$ event selection:

- balanced transverse momentum: $P_T/E_T < 0.1$
- 4 hadronic jets reconstructed (Durham algorithm)
- cut on jet angle $\cos\theta_{jet} < 0.95$ to preserve good mass resolution
- two $W^\pm$ reconstructed with probability $P_W > 0.001$

$$P_W = \prod_{W_1,W_2} \frac{M_W^2\Gamma_W^2}{\left(m_{jj}^2 - M_W^2\right)^2 + M_W^2\Gamma_W^2}$$



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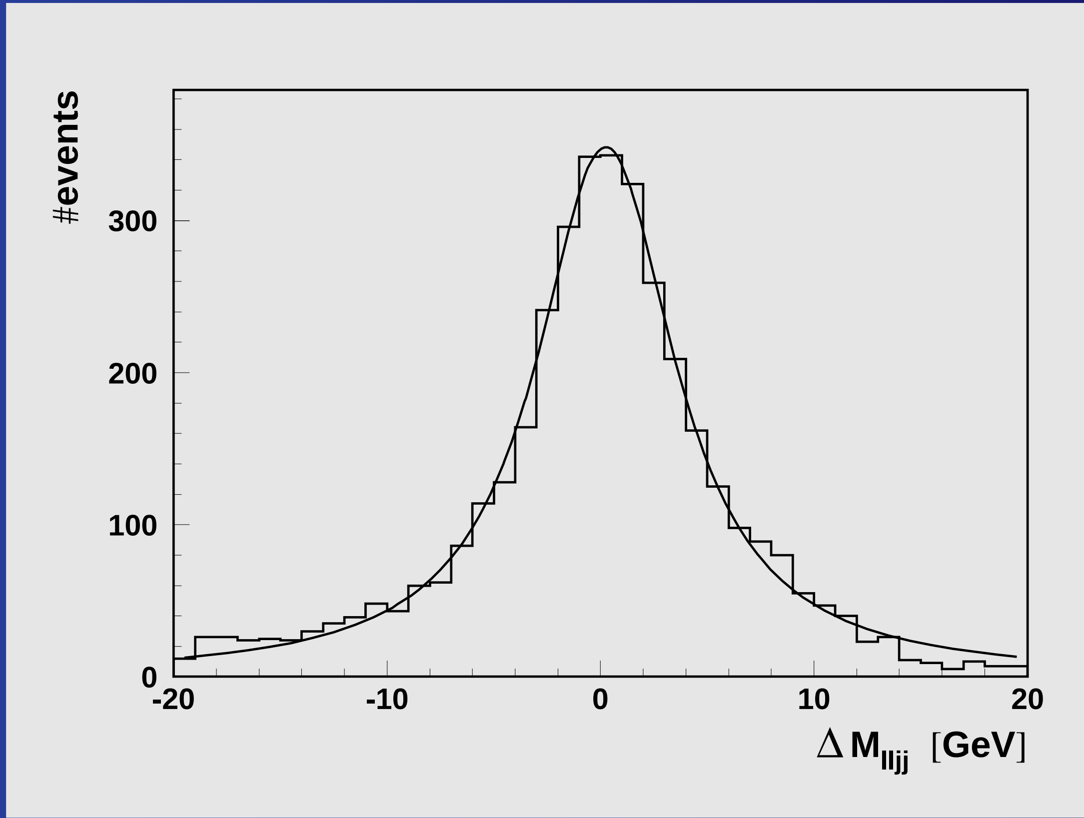
$\Rightarrow$ invariant mass resolution: $\Gamma \sim$ 6.5 – 13 GeV (Breit-Wigner like)

$\gamma\gamma \to ZZ$

$ZZ \to lljj$ selection $(l = e, \mu)$:

- balanced transverse momentum:
  $P_T/E_T < 0.1$
- 2 leptons ($e^{\pm}$ or $\mu^{\pm}$) + 2 hadronic jets reconstructed
  too large background in 4-jet channel
- cut on lepton and jet angle
  $\cos\theta_{jet} < 0.95$
- leptons and jets reconstruct into two Z° with probability $P_Z > 0.001$



$\Rightarrow$ selection efficiency about 5% $(BR(ZZ \to q\bar{q}\, l^+ l^-) \approx 9.4\%)$

$\Rightarrow$ invariant mass resolution: $\Gamma \sim$ 5.5 – 7.5 GeV (Breit-Wigner like)

Parametrization

Invariant mass resolution for selected W^+W^- and ZZ events is parametrized as a function of $W_{\gamma\gamma}$.

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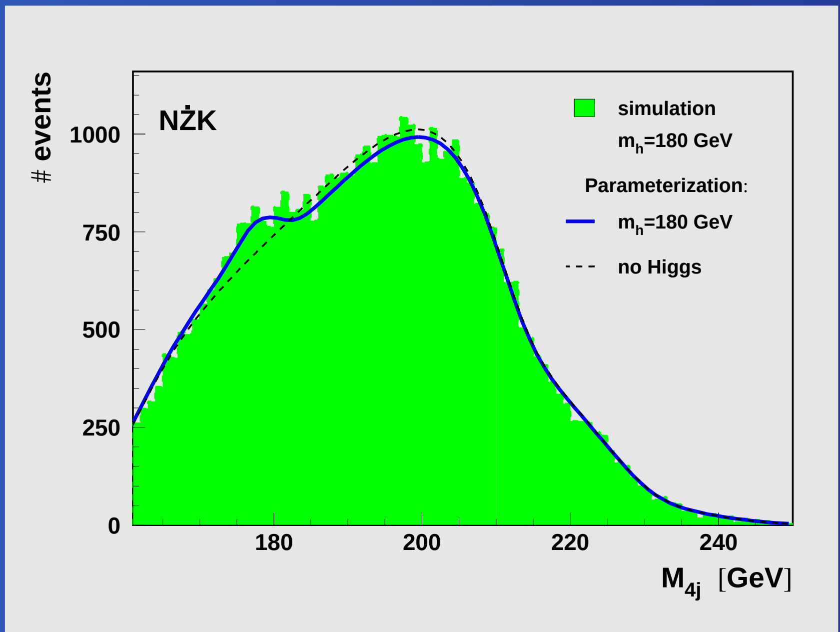
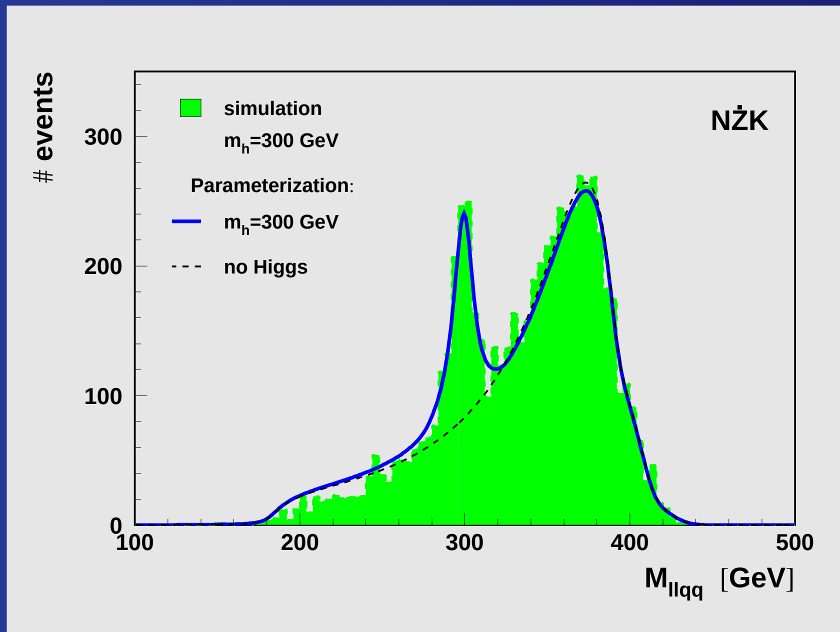


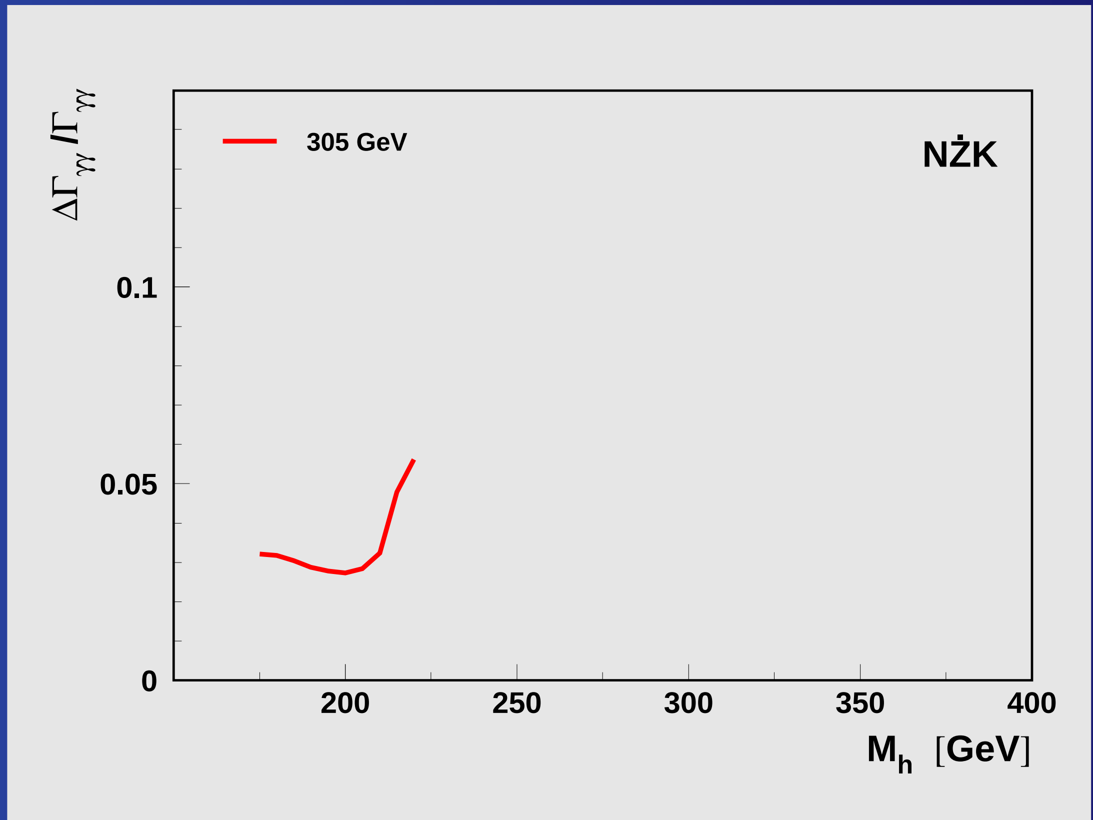


$\Gamma_{\gamma\gamma}$ measurement

Average statistical precision expected after 1 year of PC running

One parameter fit
to invariant mass distribution
for W^+W^- and ZZ events

$\Gamma_{\gamma\gamma}$ only



assuming SM branching ratios

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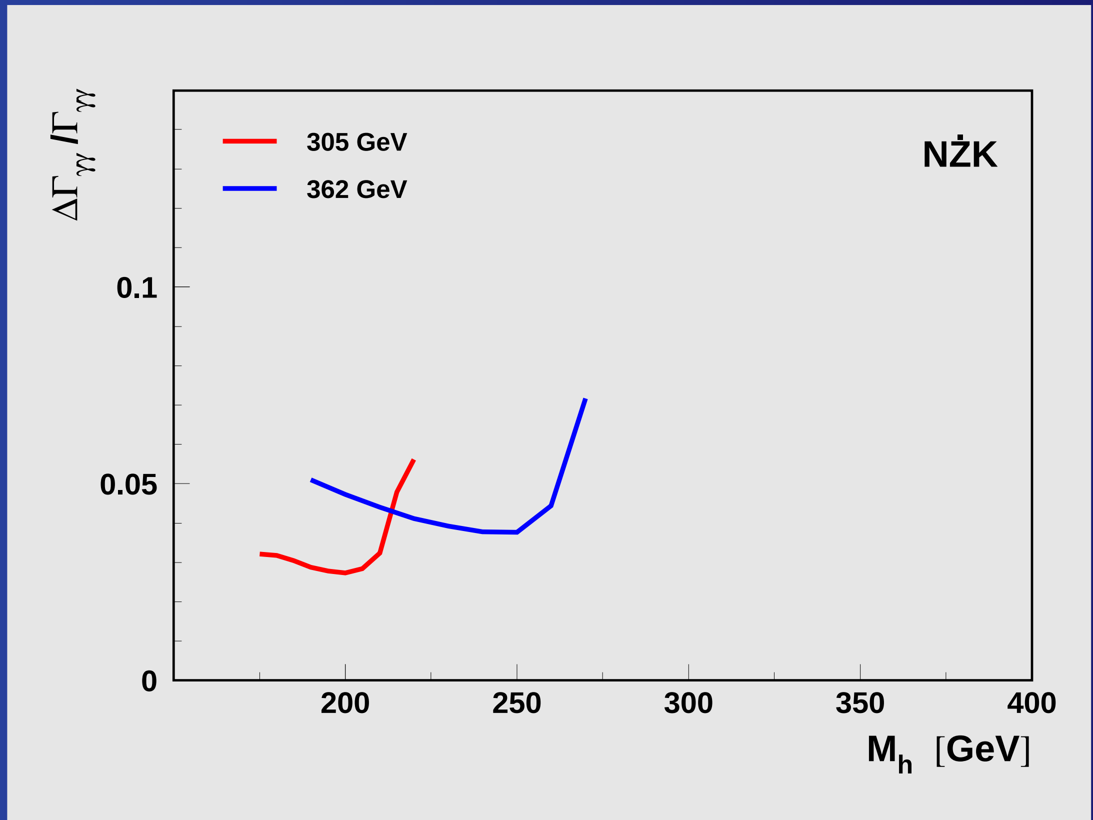

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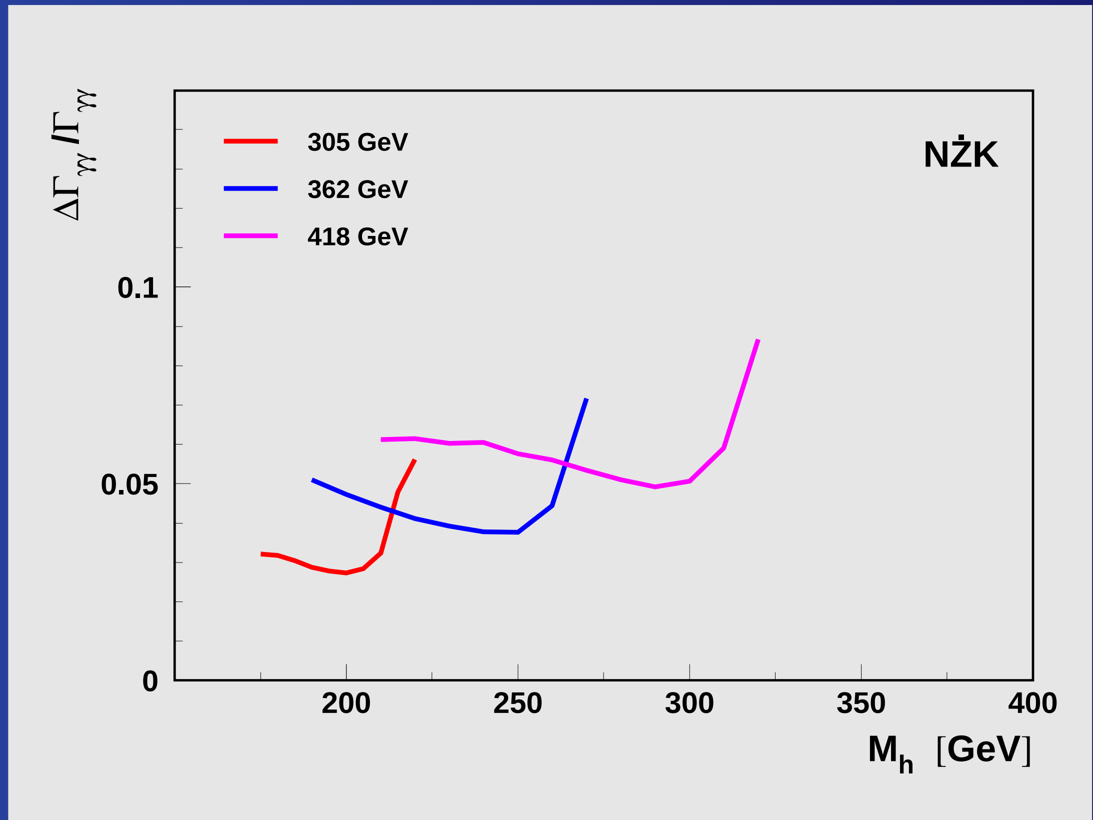

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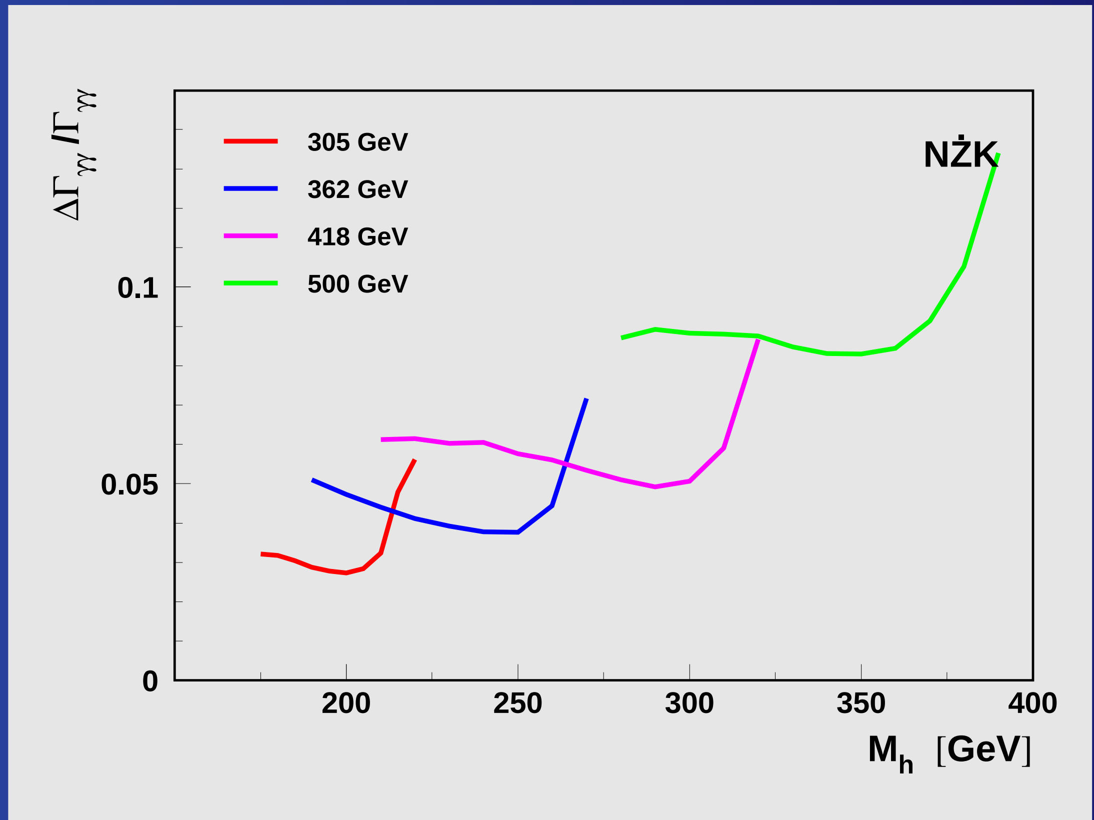

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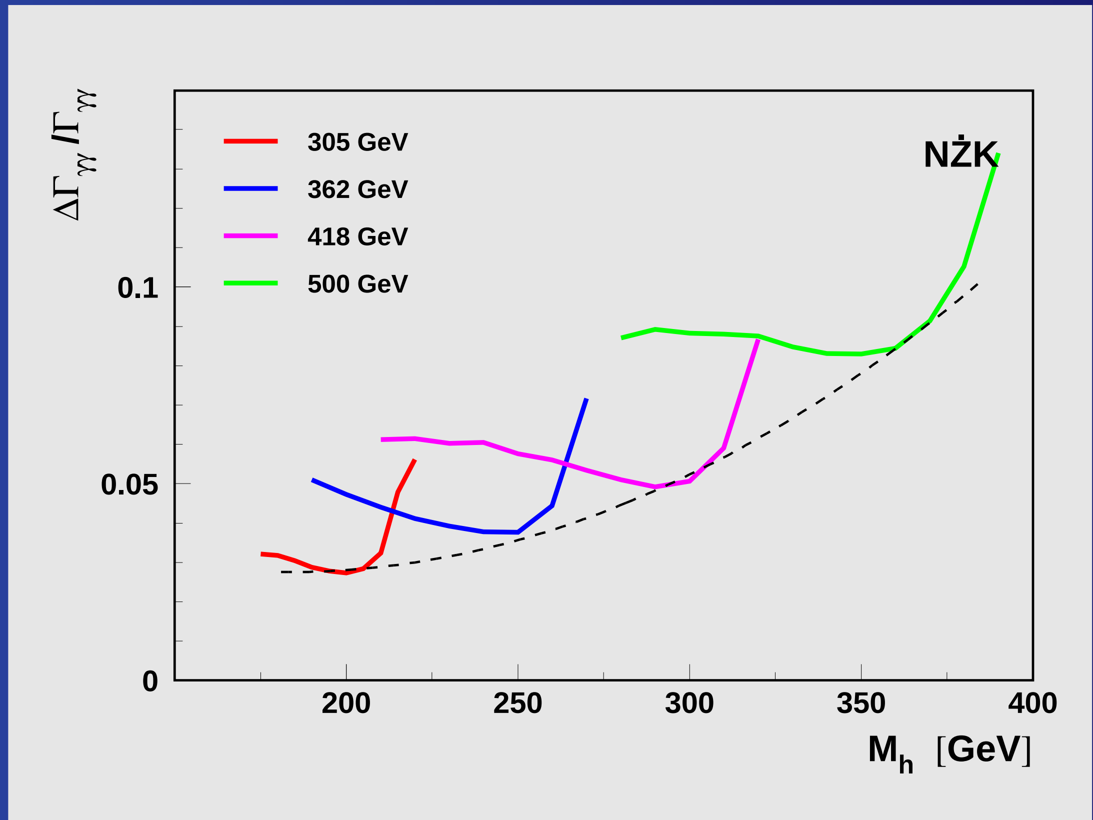

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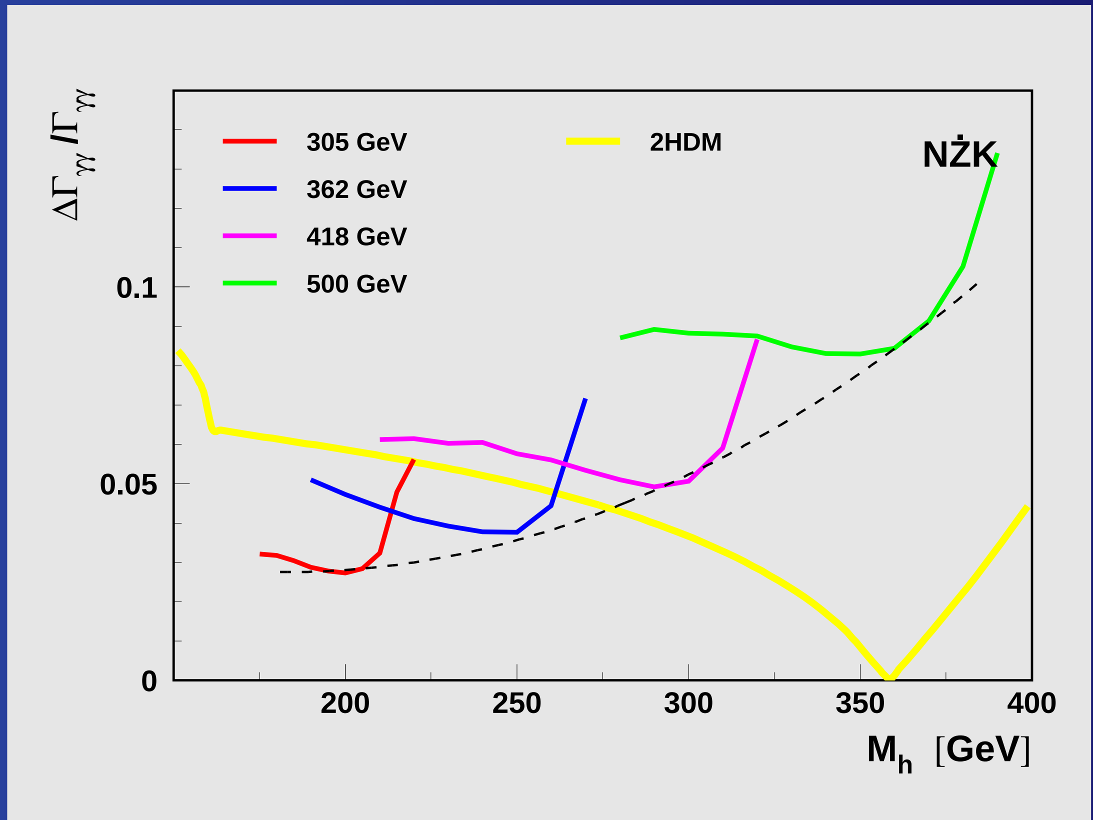
Sensitive to possible "new physics"
only up to $M_h \sim 280$ GeV



assuming SM branching ratios
"new physics" modeled by SM-like 2HDM (II) with $M_{H+} = 800$ GeV

$\Gamma_{\gamma\gamma}$ measurement

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One parameter fit
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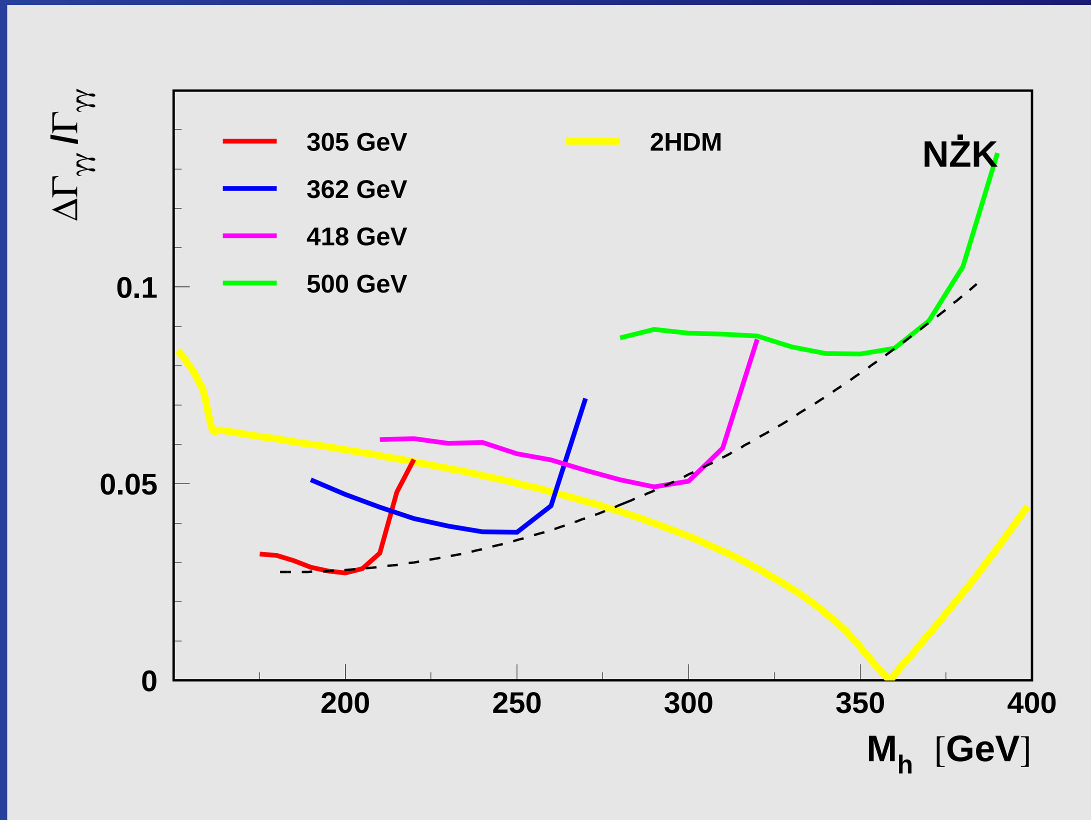
For higher Higgs masses $\Gamma_{\gamma\gamma}$ is little sensitive to contribution of new heavy charged particles !



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$\Gamma_{\gamma\gamma}$ measurement

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Two parameter fit
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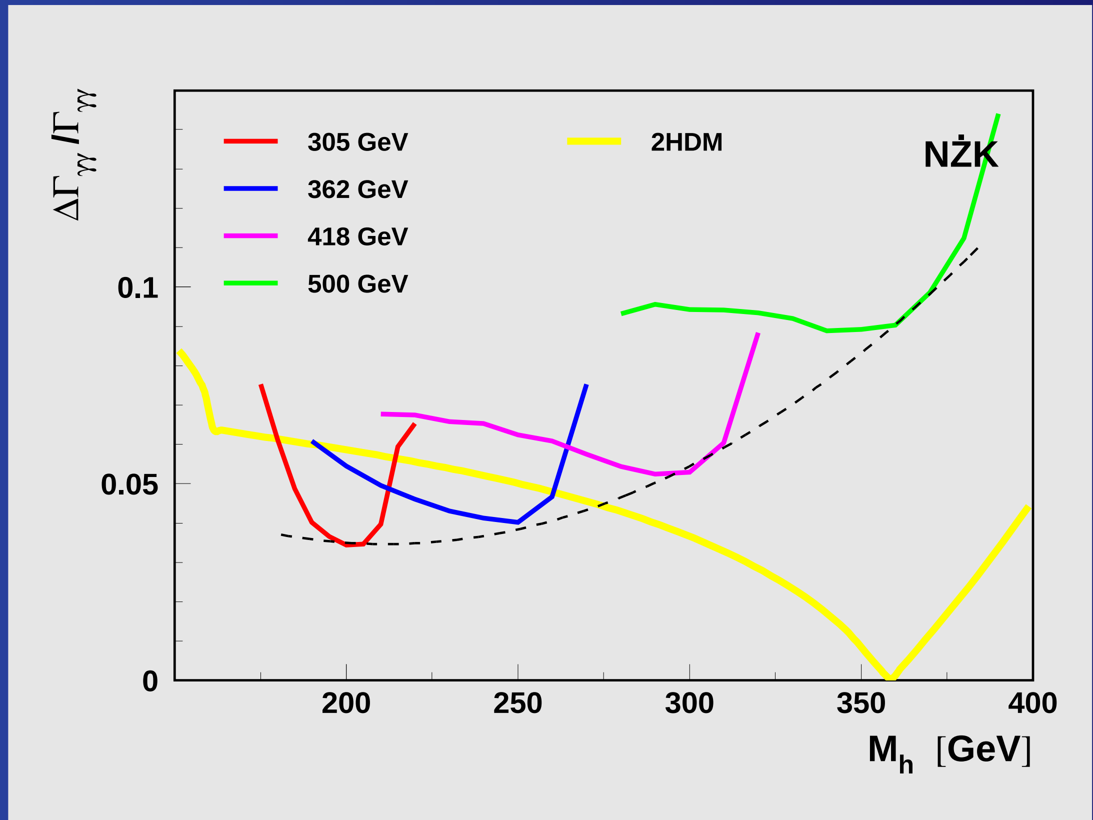
$$\Gamma_{\gamma\gamma} \text{ and } \phi_{\gamma\gamma}$$

Sensitive to possible "new physics" only up to $M_h \sim 280$ GeV

For higher Higgs masses $\Gamma_{\gamma\gamma}$ is little sensitive to contribution of new heavy charged particles !

$\phi_{\gamma\gamma}$ fit increases the error only slightly



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$\phi_{\gamma\gamma}$ measurement

Average statistical precision expected after 1 year of PC running

Two parameter fit
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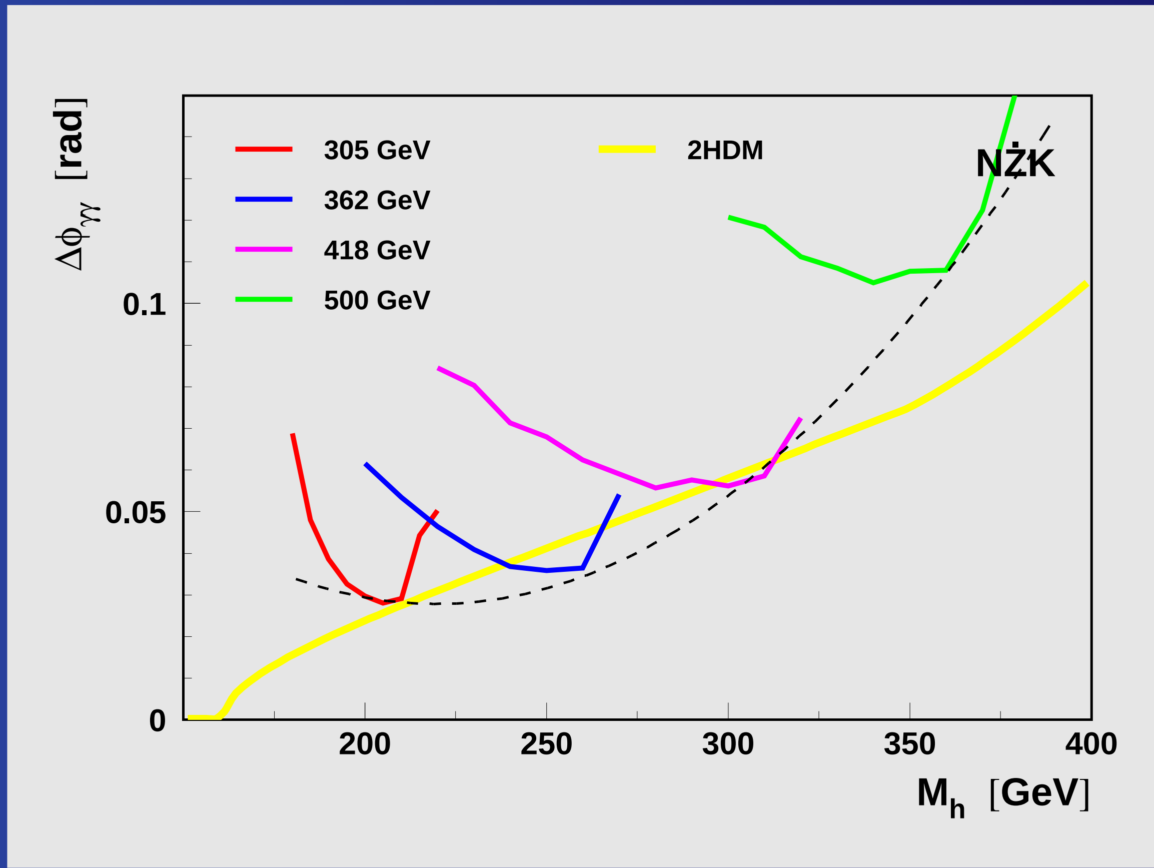
$$\Gamma_{\gamma\gamma} \text{ and } \phi_{\gamma\gamma}$$

Phase measurement significantly improves our sensitivity to new heavy charged particles at large Higgs boson masses



assuming SM branching ratios

Example: heavy charged Higgs boson of the SM-like 2HDM(II) with $M_{H+} = 800$ GeV

$\Gamma_{\gamma\gamma}$ and $\phi_{\gamma\gamma}$ measurement

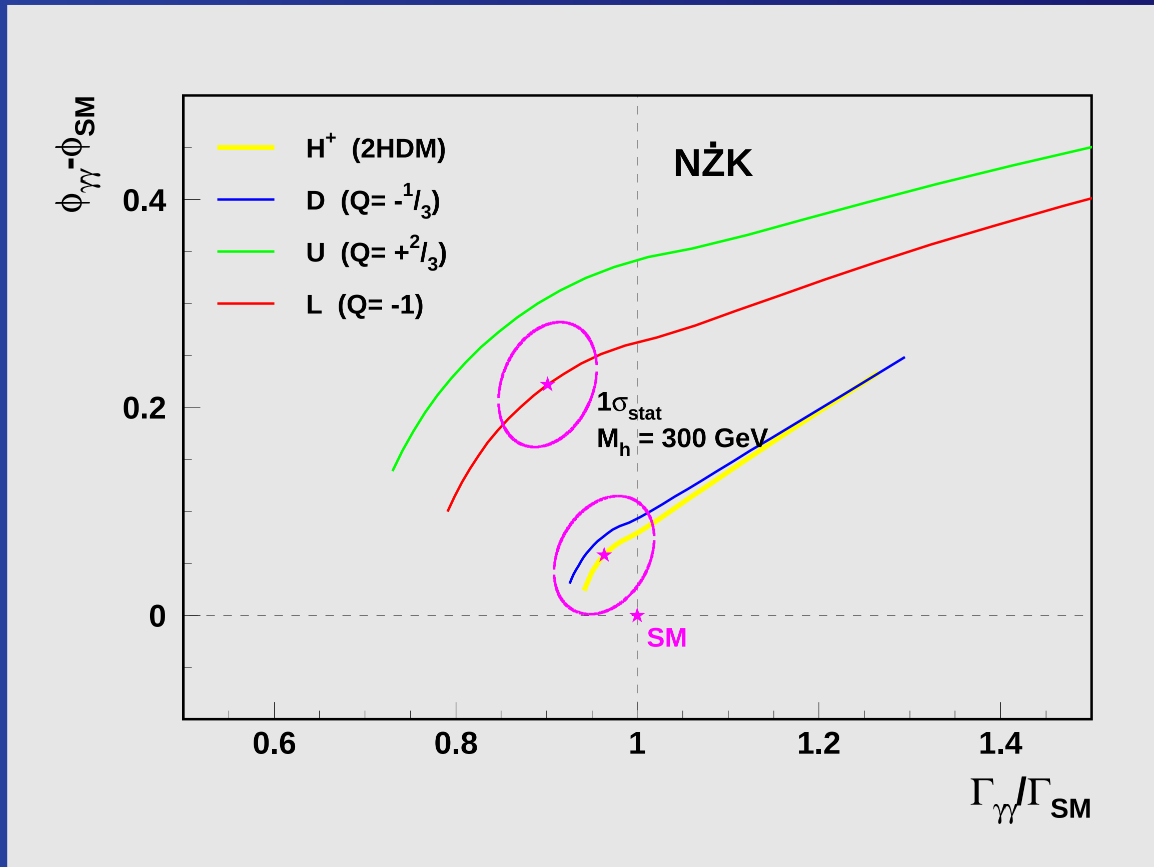
Two parameter fit to W^+W^- and ZZ invariant mass distribution; 1 PC year.
Expected statistical error contours (1σ) in $\phi_{\gamma\gamma}$ - $\Gamma_{\gamma\gamma}$, for $M_h = 300$ GeV:

4^{th} generation lepton

$M_L = 800$ GeV $\Rightarrow$

SM-like 2HDM (II) $\Rightarrow$

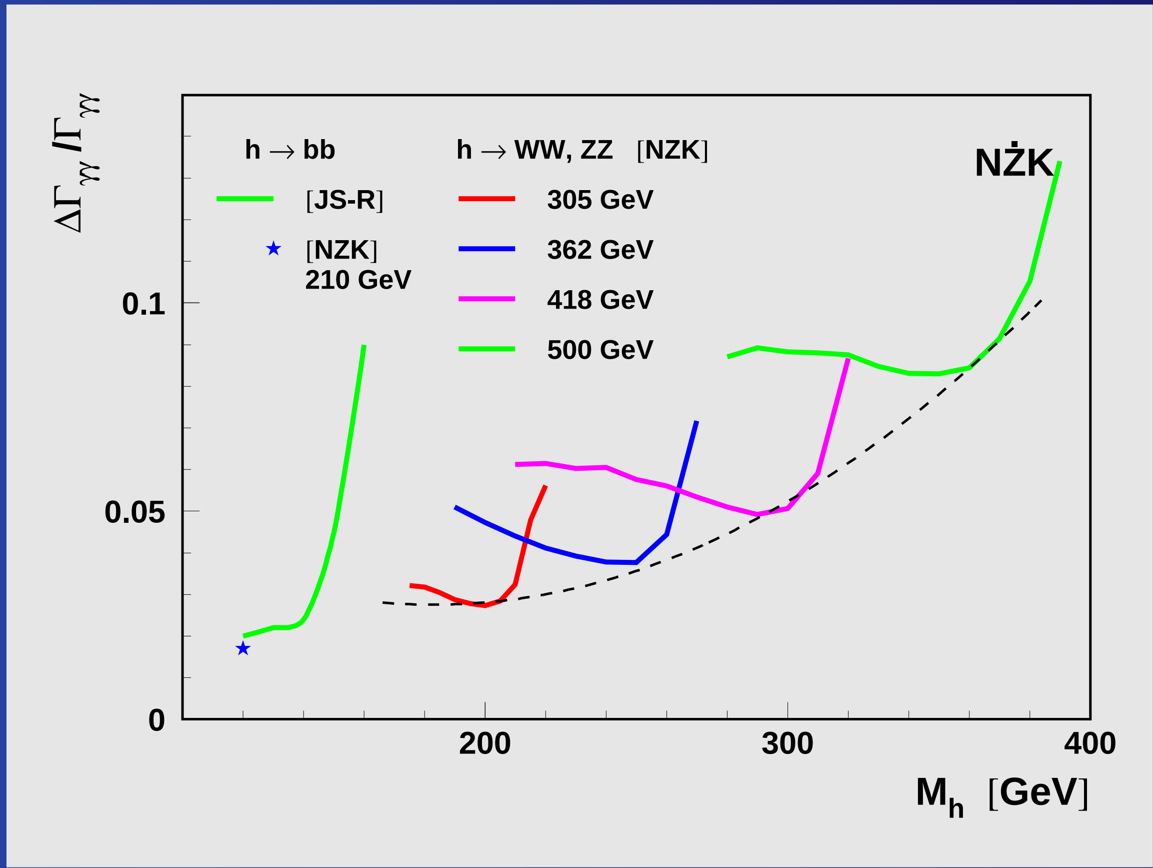
$M_{H^+} = 800$ GeV



separation not possible without phase measurement !

Conclusions

Comparison of $\Gamma_{\gamma\gamma}$ results from different analyses



Our plans:

- $h \rightarrow b\bar{b}$ up to 160 GeV
- $H \rightarrow b\bar{b}$ in MSSM
- CP of h in $h \rightarrow ZZ$
- ...