# Higgs studies
# at the TESLA Photon Collider
## *Extended ECFA/DESY Study*


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Warsaw University

# Outline

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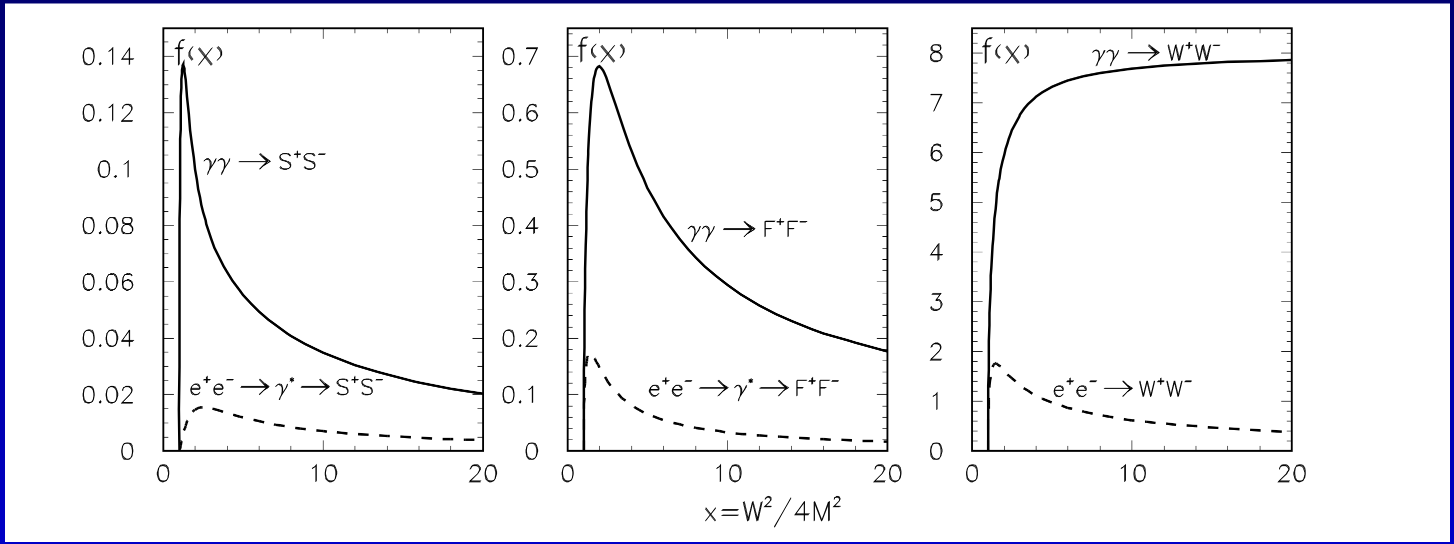

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  resonant Higgs production similar to $Z^\circ$ in $e^+e^-$

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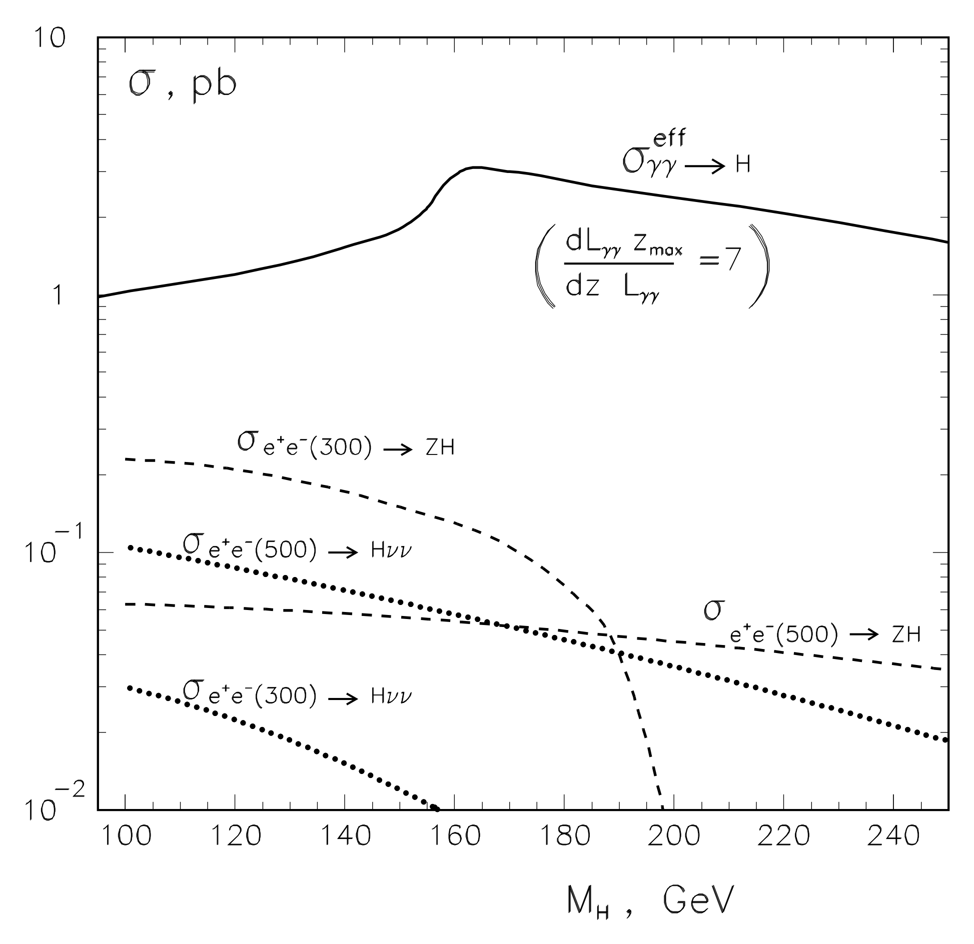
Why do we need Photon Collider ?

Comparison of SM Higgs boson production cross sections:



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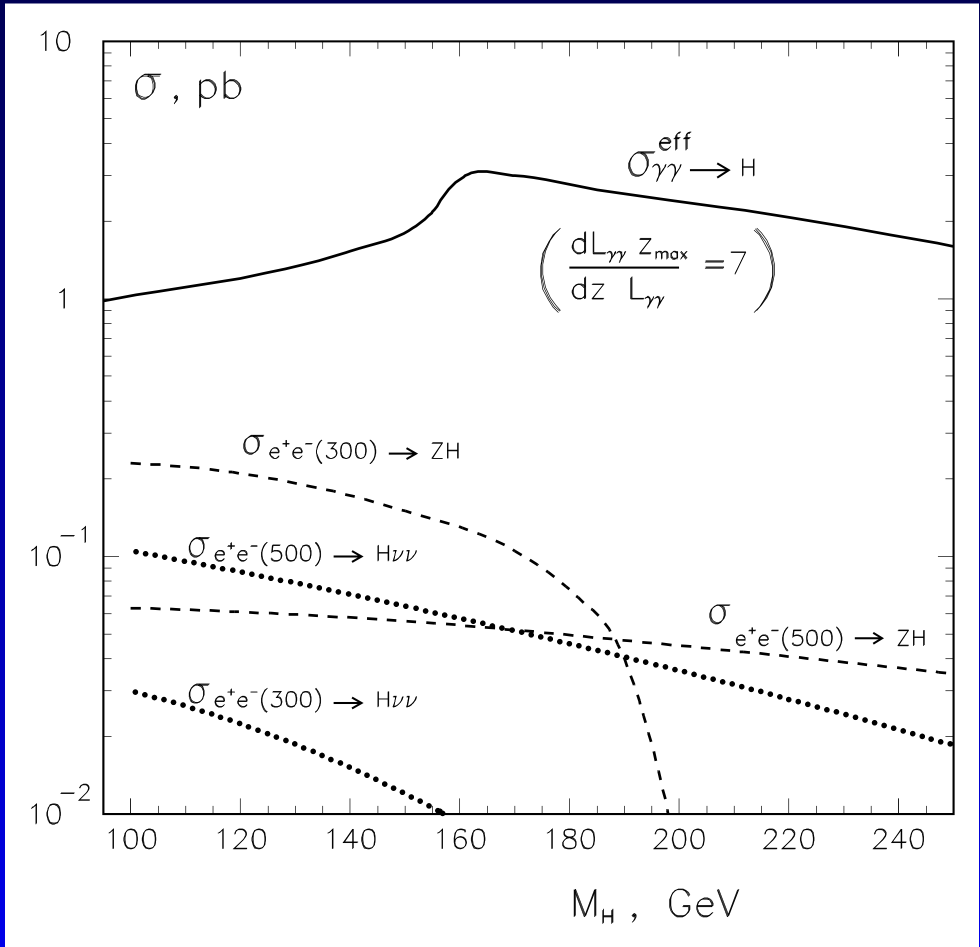


$\gamma\gamma$ cross section order of magnitude higher

$$\sigma = \frac{1}{\mathcal{L}_{\gamma\gamma}} \frac{d\mathcal{L}_{\gamma\gamma}^{J_z=0}}{dW_{\gamma\gamma}} \cdot \frac{4\pi^2 \, \Gamma_{\gamma\gamma}}{M_h^2}$$

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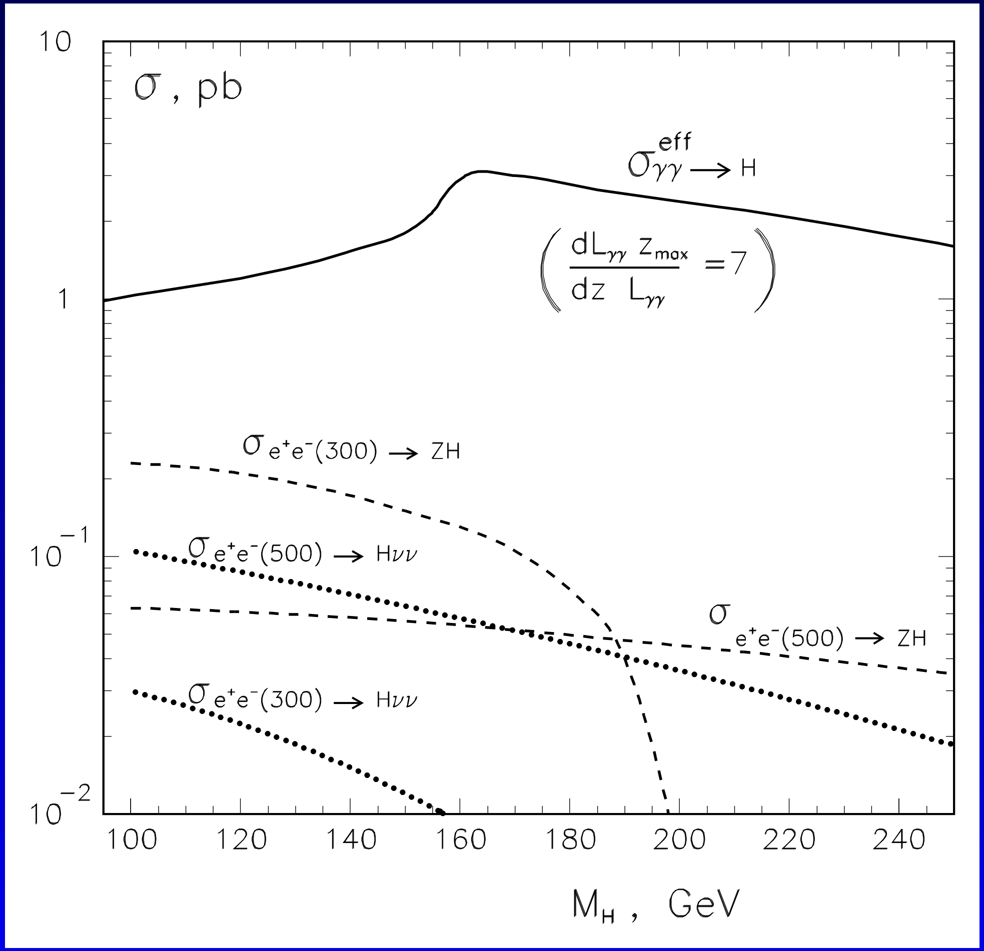


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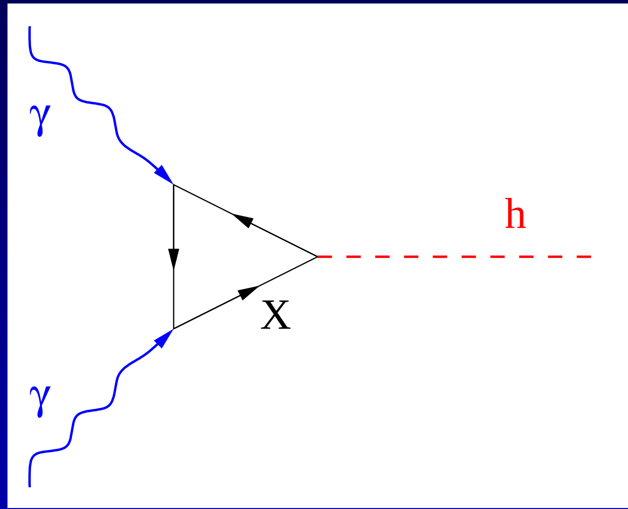
expected $\gamma\gamma$ luminosity similar to $e^+e^-$

# Higgs boson at PC

Two-photon width of the Higgs boson $\Gamma_{\gamma\gamma}$ is sensitive to all massive and charged particles in the loop:

$$\Gamma(h \to \gamma\gamma) \;=\; \frac{G_F \alpha^2 M_h^3}{128\sqrt{2}\,\pi^3} \cdot |\mathcal{A}|^2$$



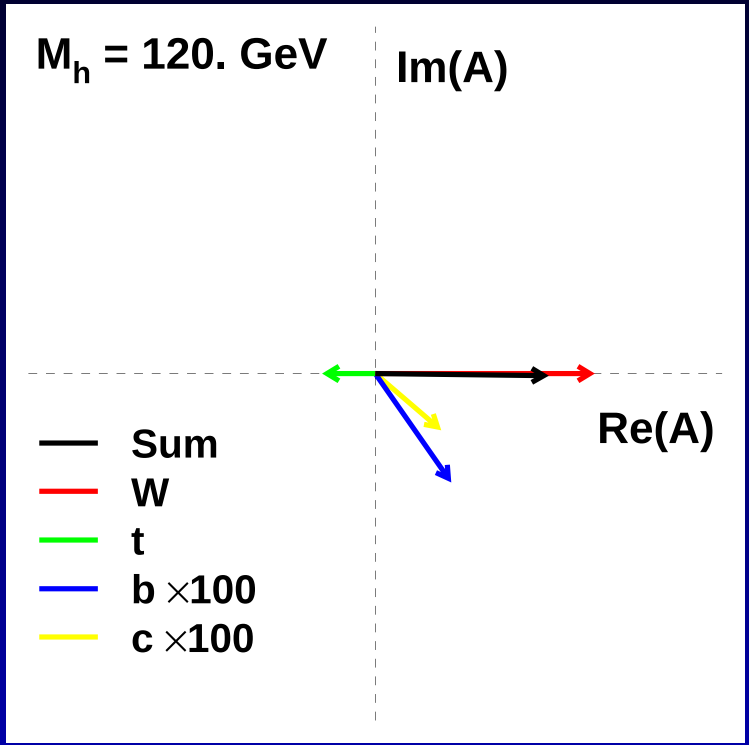

where:

$$\mathcal{A} = A_W(M_W) + \sum_f N_c Q_f^2 A_f(M_f) + \ldots$$

two-photon amplitude

# Phase

- amplitude $\mathcal{A}$ is real
- imaginary contribution from light fermions - very tiny



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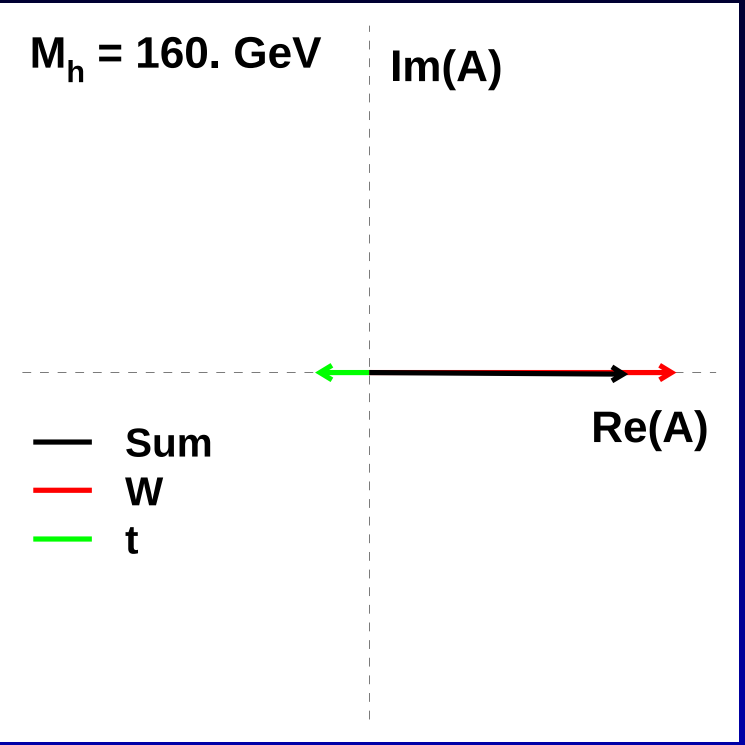

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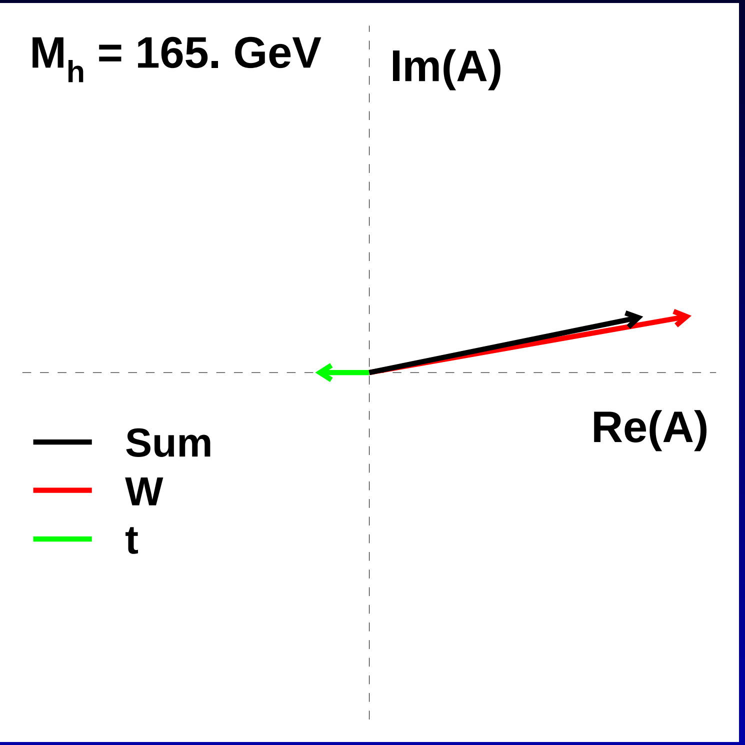

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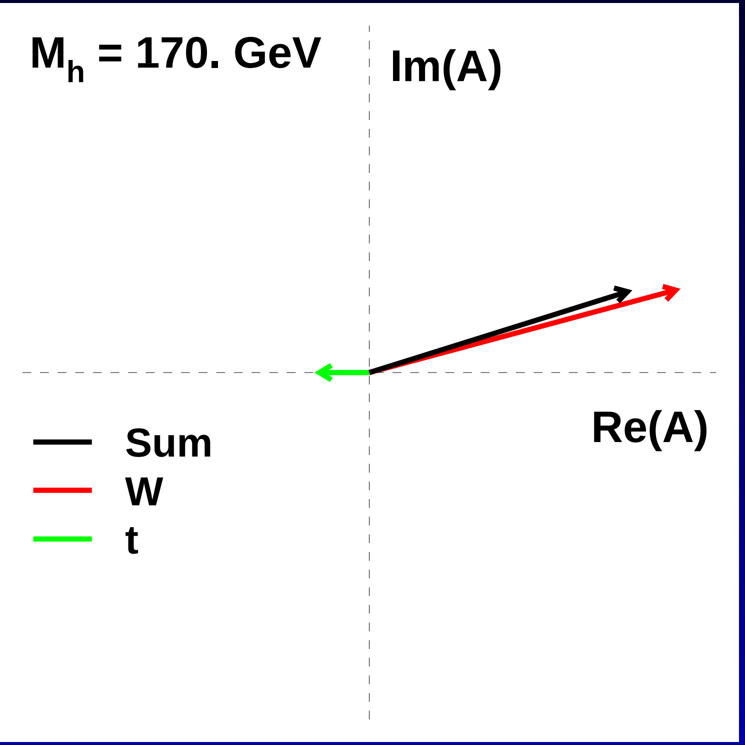

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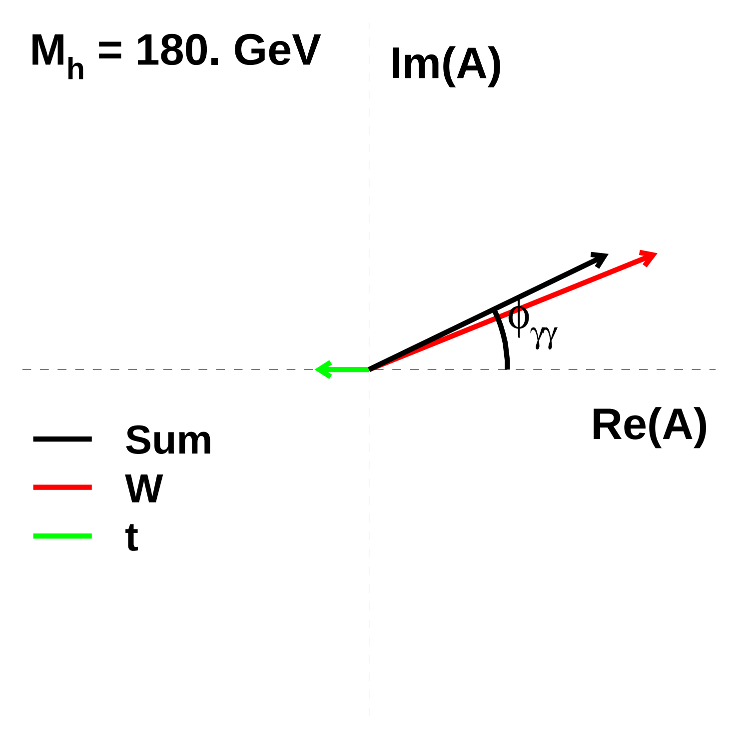
$\Gamma_{\gamma\gamma} \sim Im(\mathcal{A})^2 + Re(\mathcal{A})^2$



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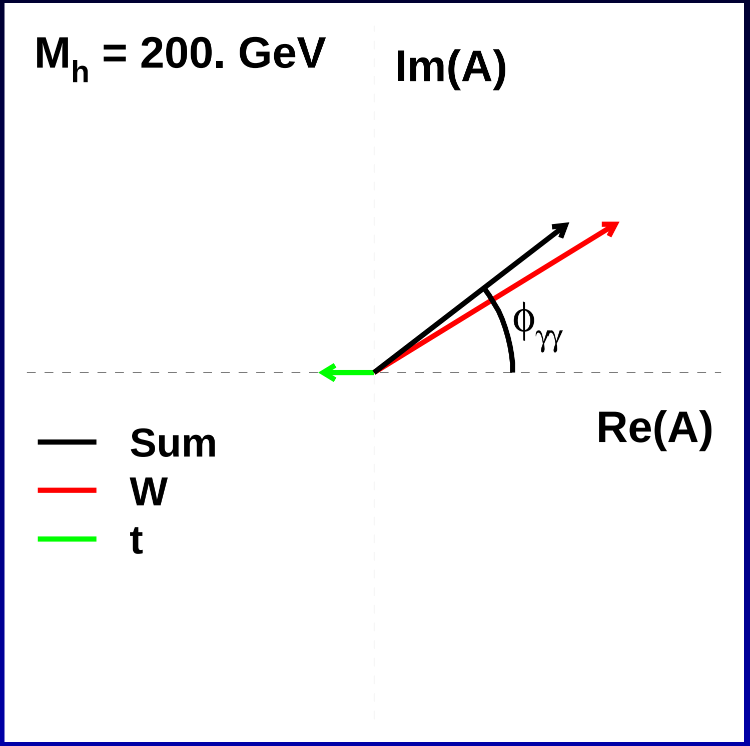

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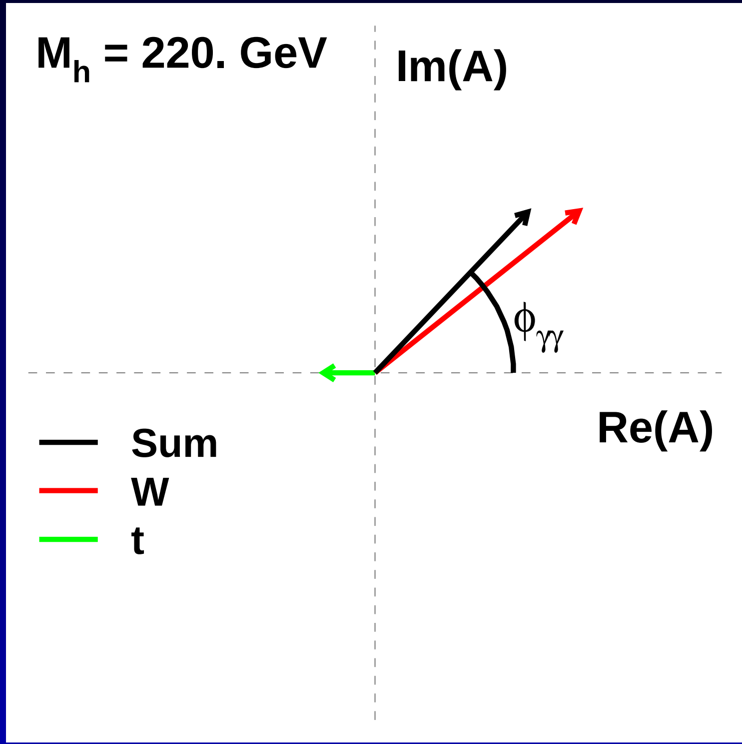

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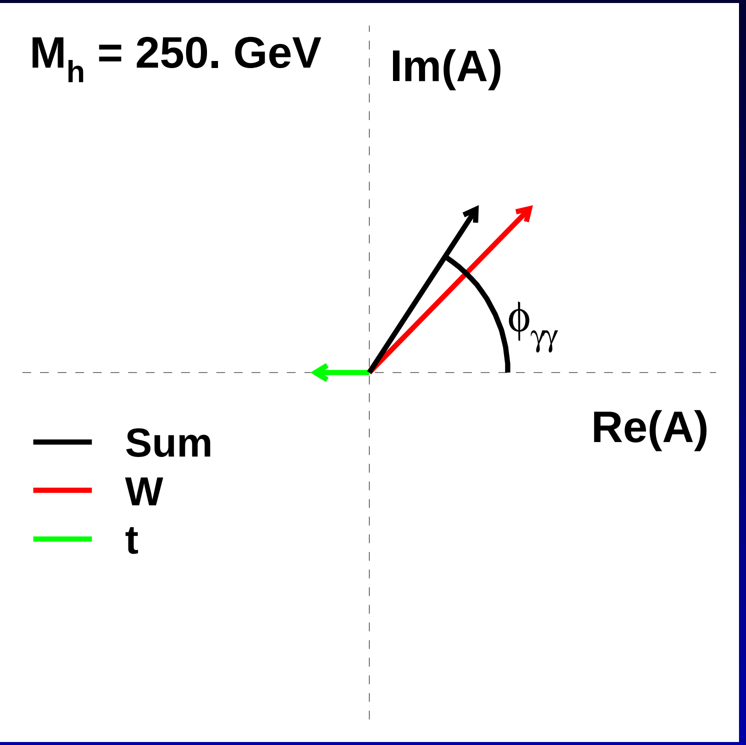

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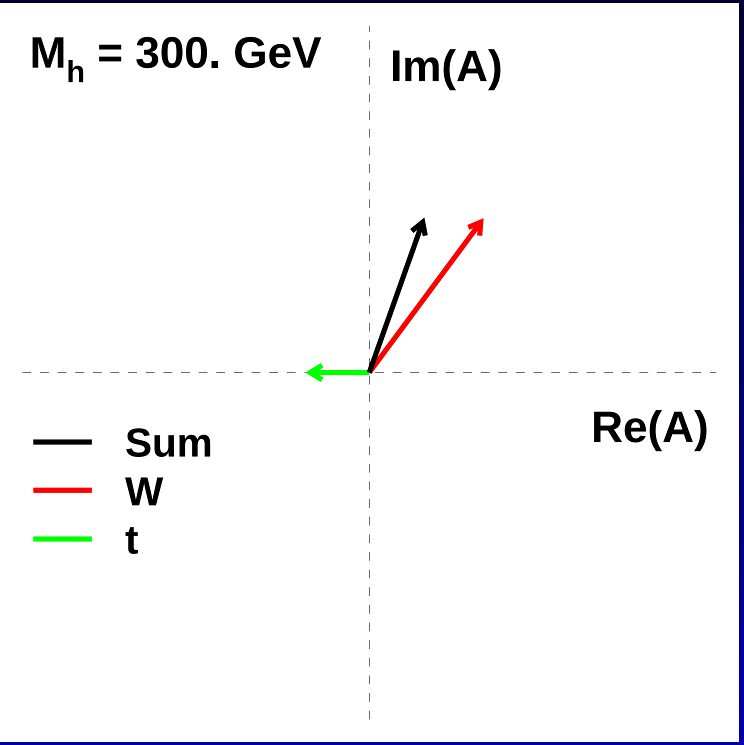

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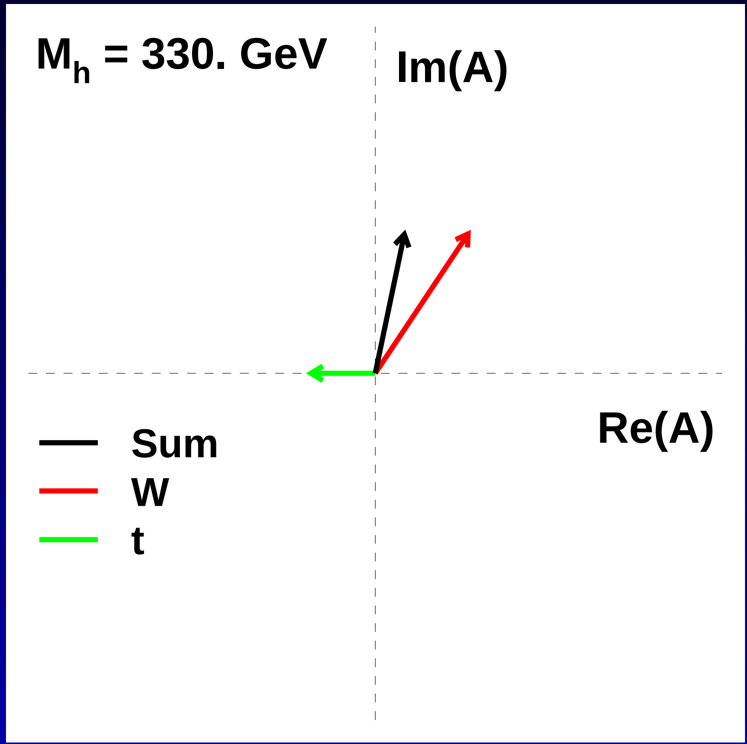

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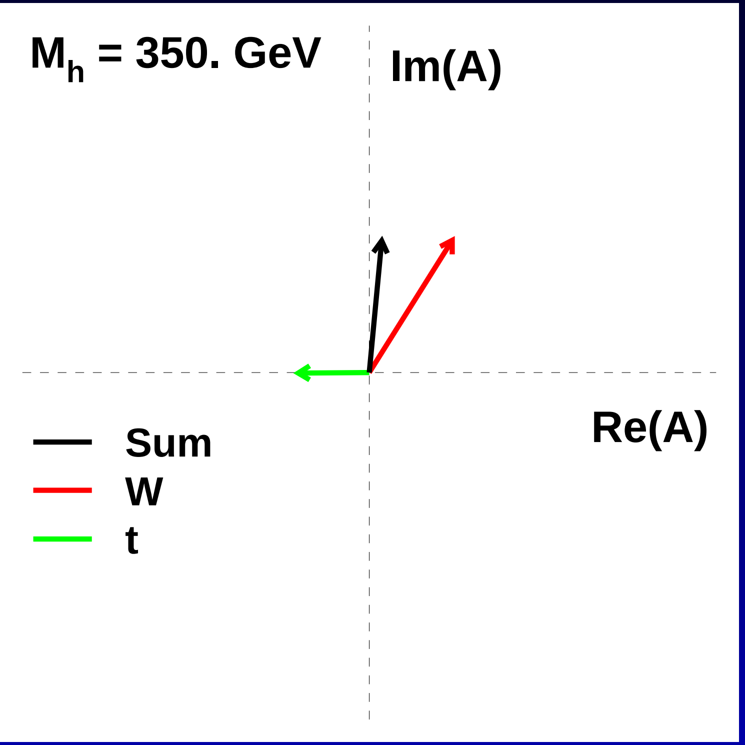

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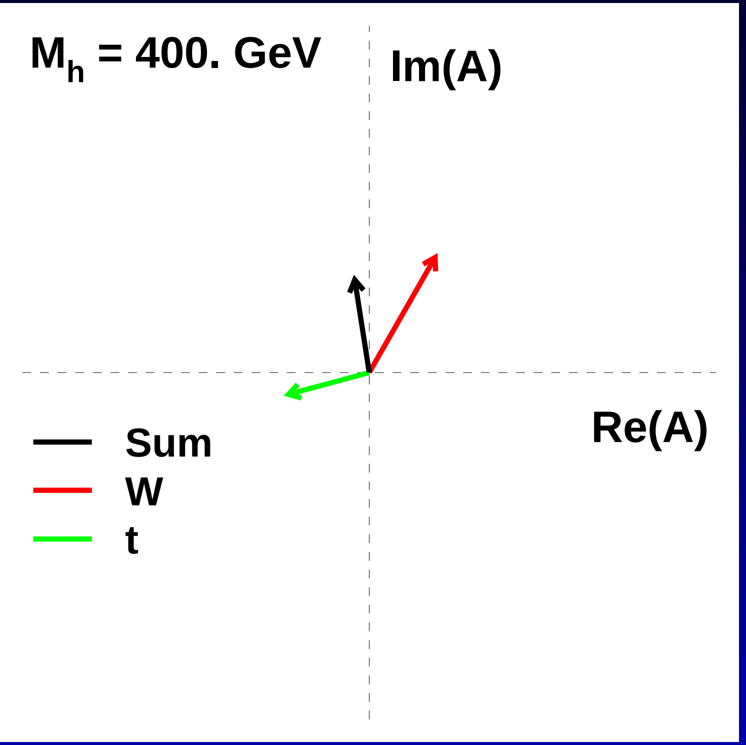

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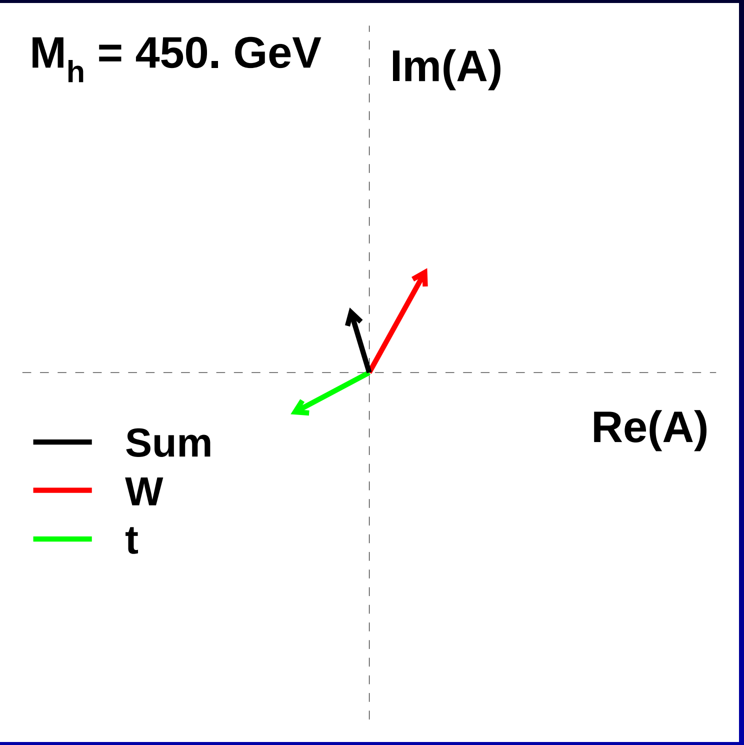

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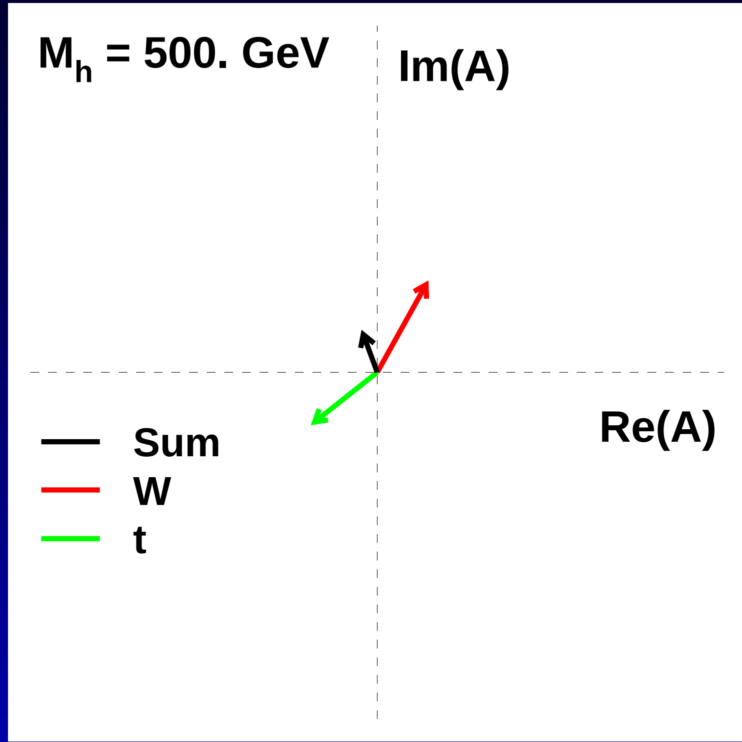


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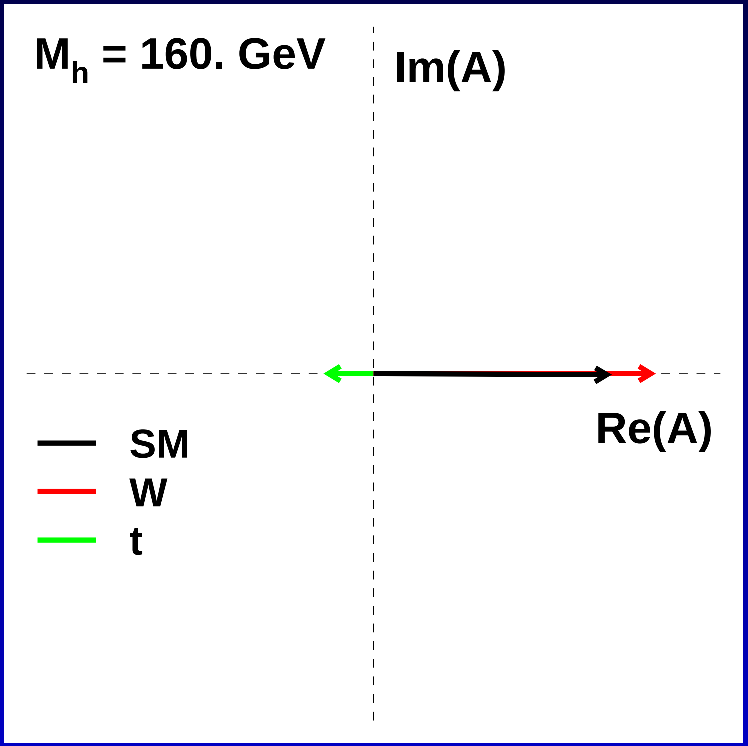

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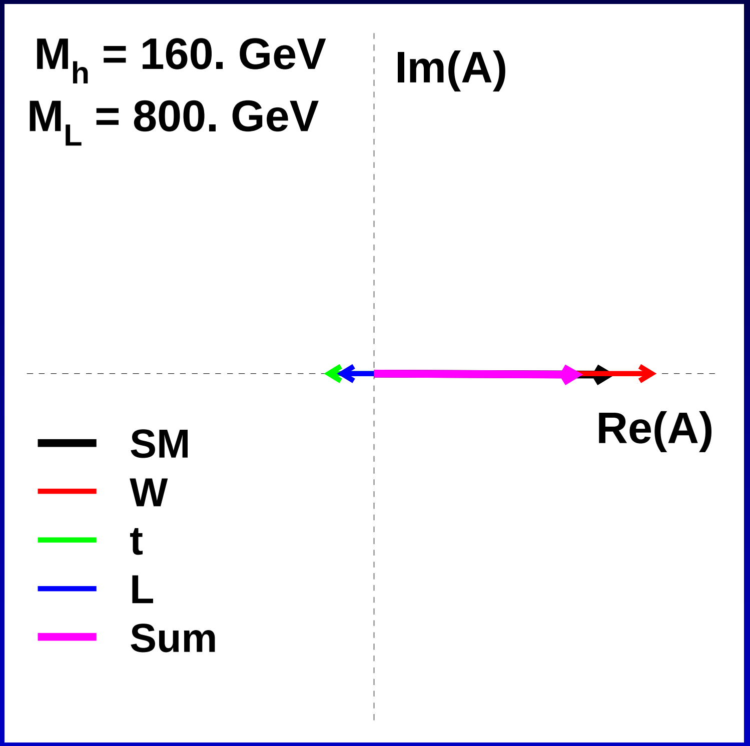

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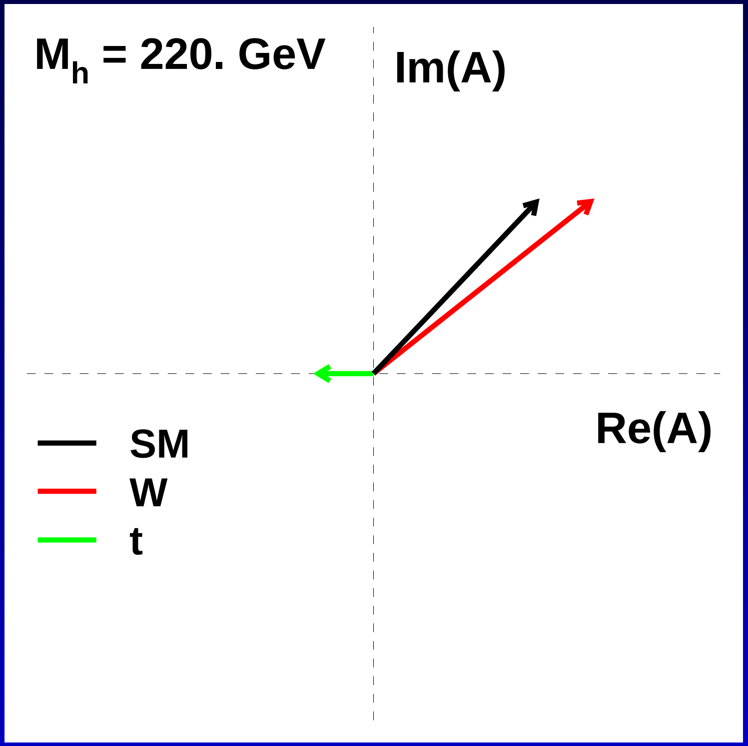

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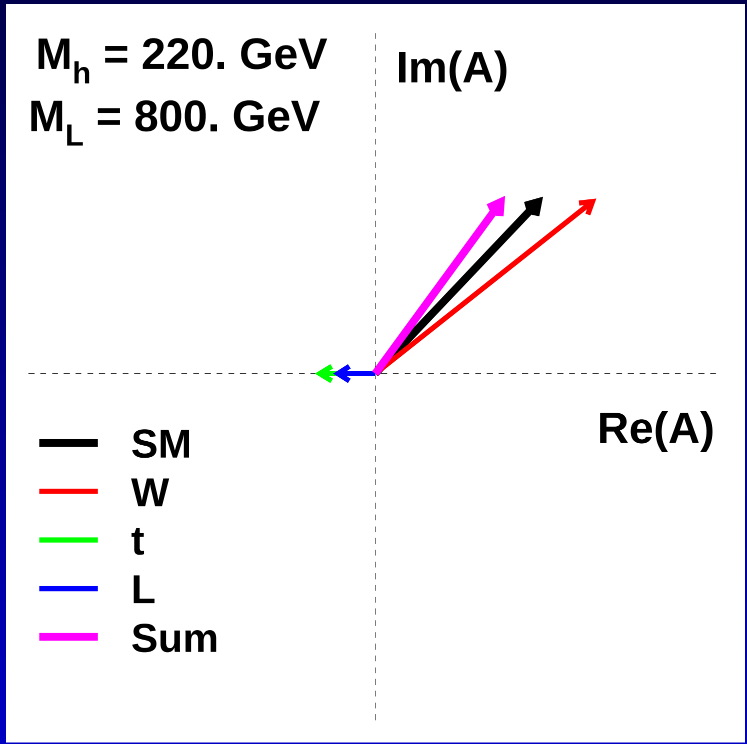

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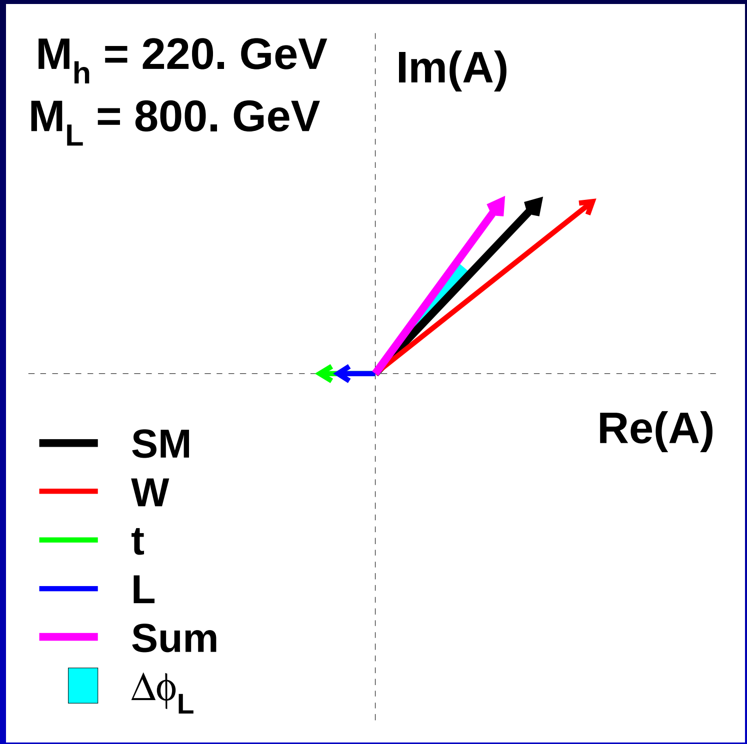

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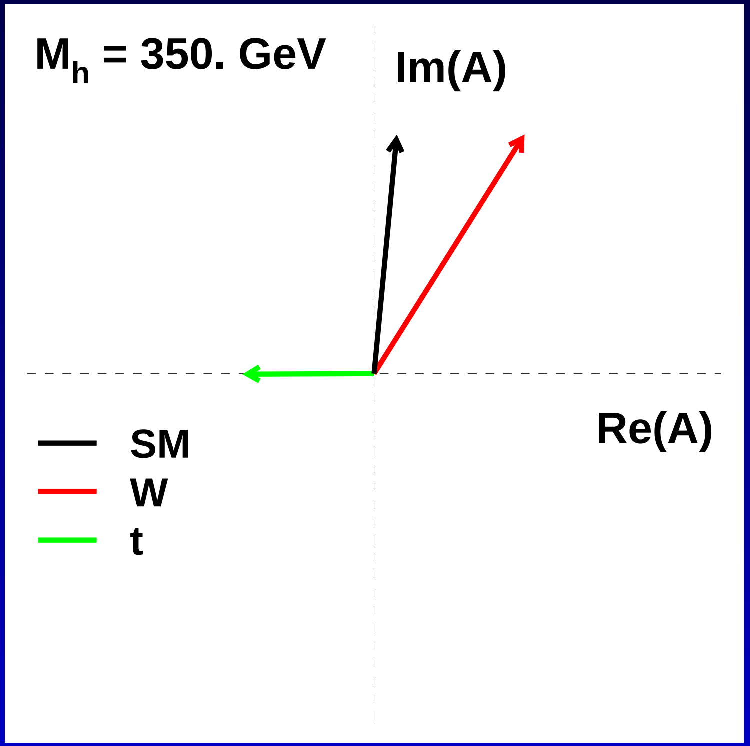


for $M_h$ ~350 GeV
amplitude mostly imaginary:

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TESLA Warszawa

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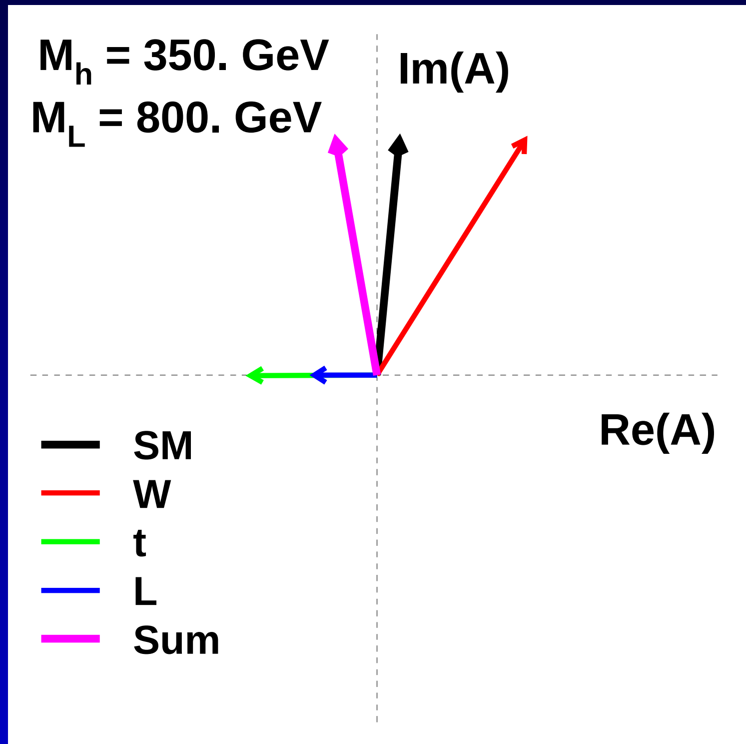


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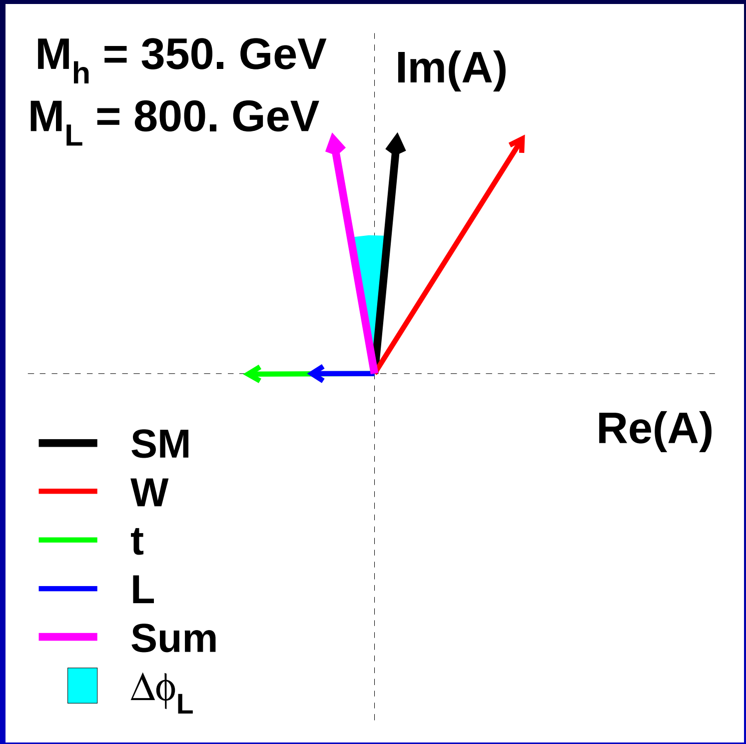


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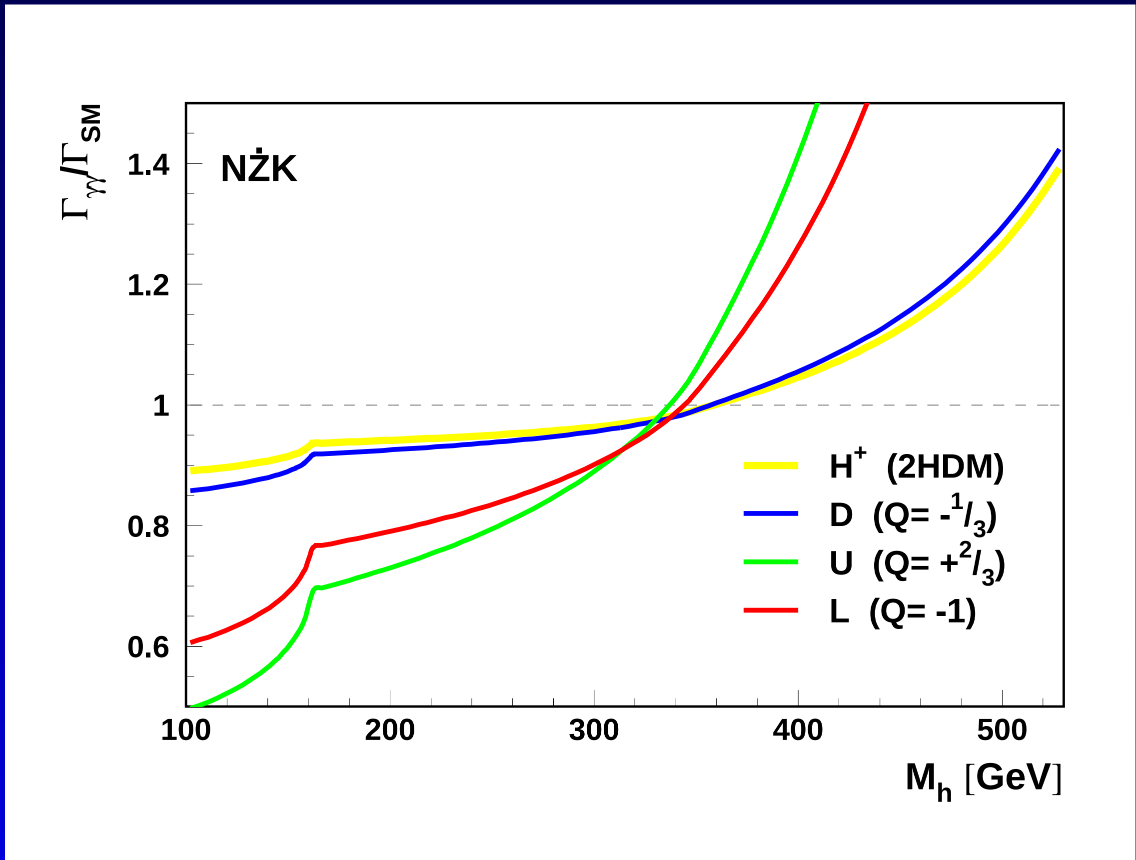
$\Rightarrow$ measure $\phi_{\gamma\gamma}$ ?

# New particles

Contribution to $\Gamma_{\gamma\gamma}$ from new heavy charged particles with mass $\sim$800 GeV




Significant deviations in $\Gamma_{\gamma\gamma}$ for small $M_h$

Small effects for $M_h \sim 350$ GeV

# New particles

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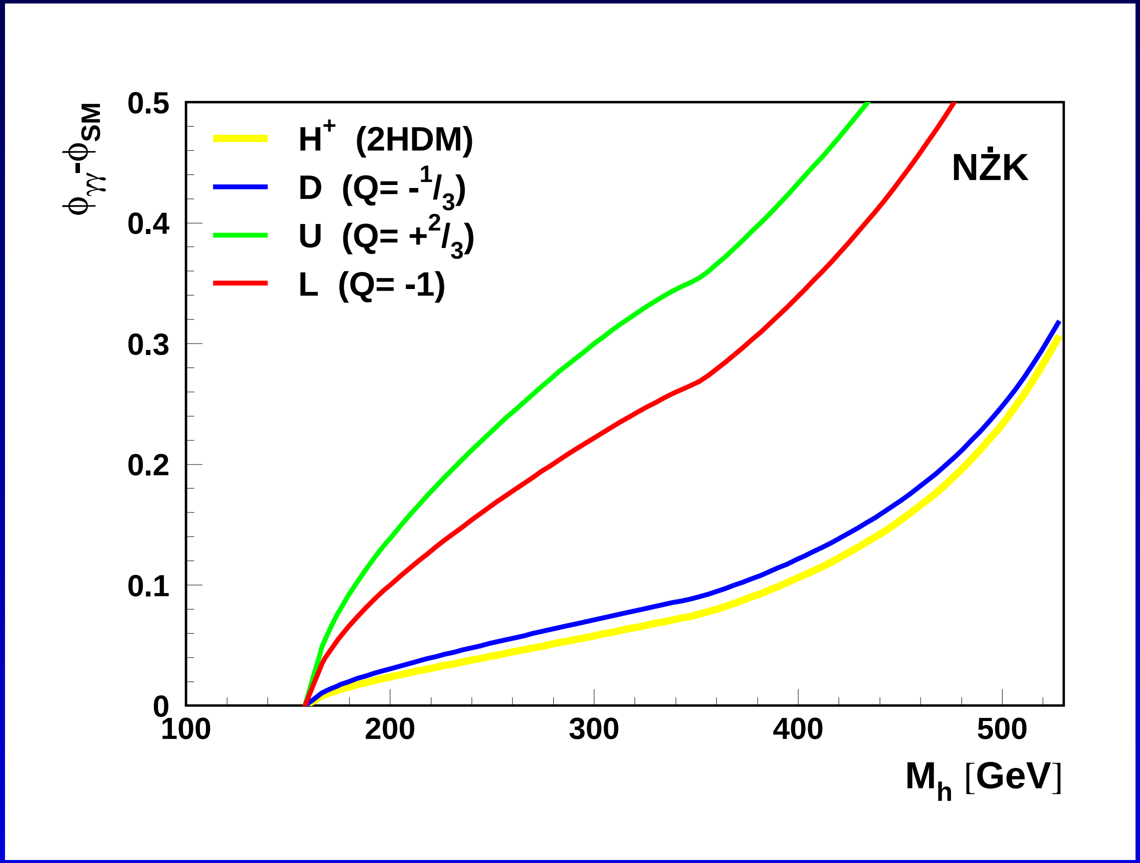
Contribution to $\phi_{\gamma\gamma}$ from new heavy charged particles with mass $\sim$800 GeV

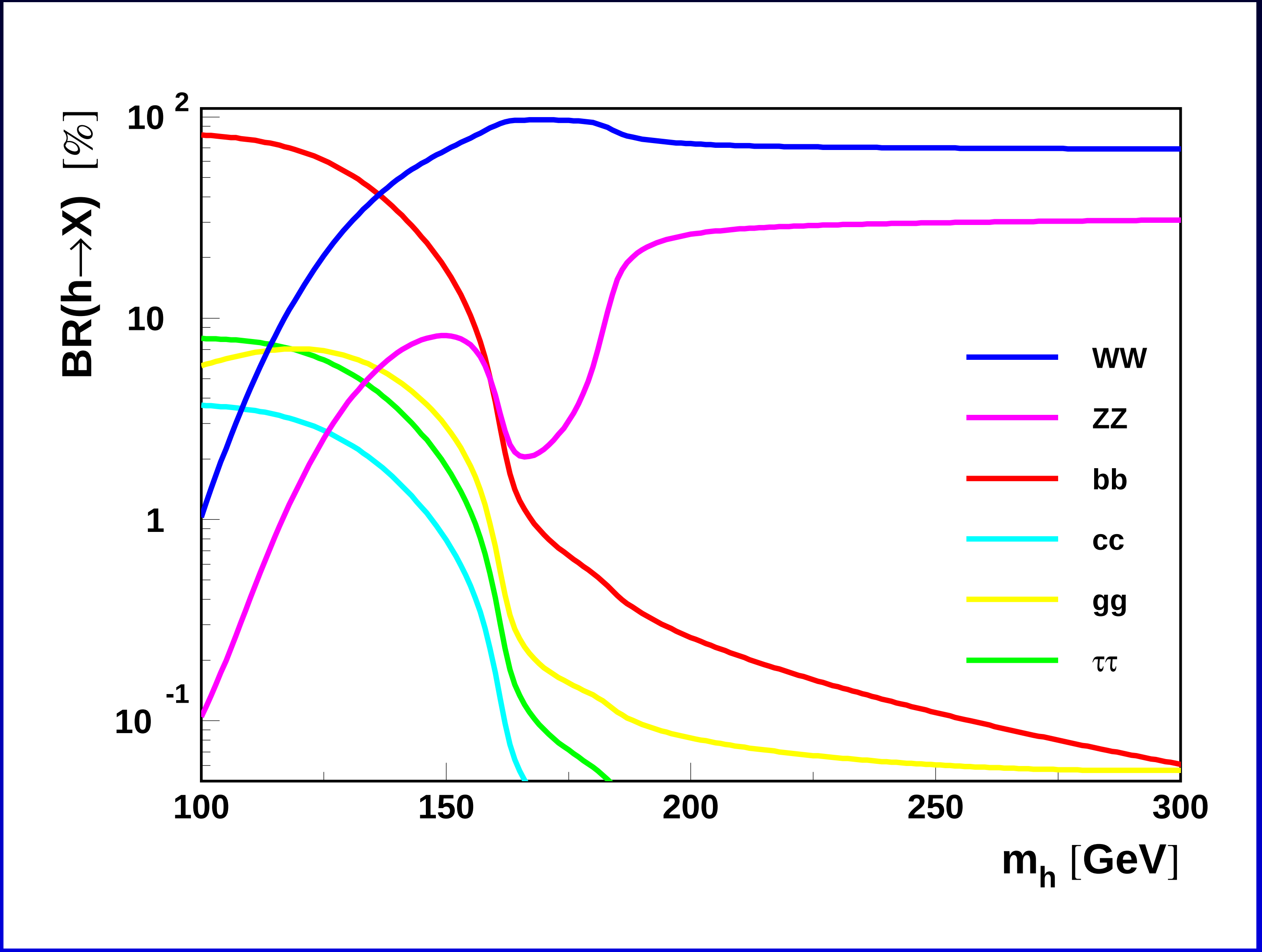



No deviations in $\phi_{\gamma\gamma}$ for light Higgs $M_h < 160$ GeV.

Large effects expected for heavy Higgs

How can we measure it?

# Higgs decays



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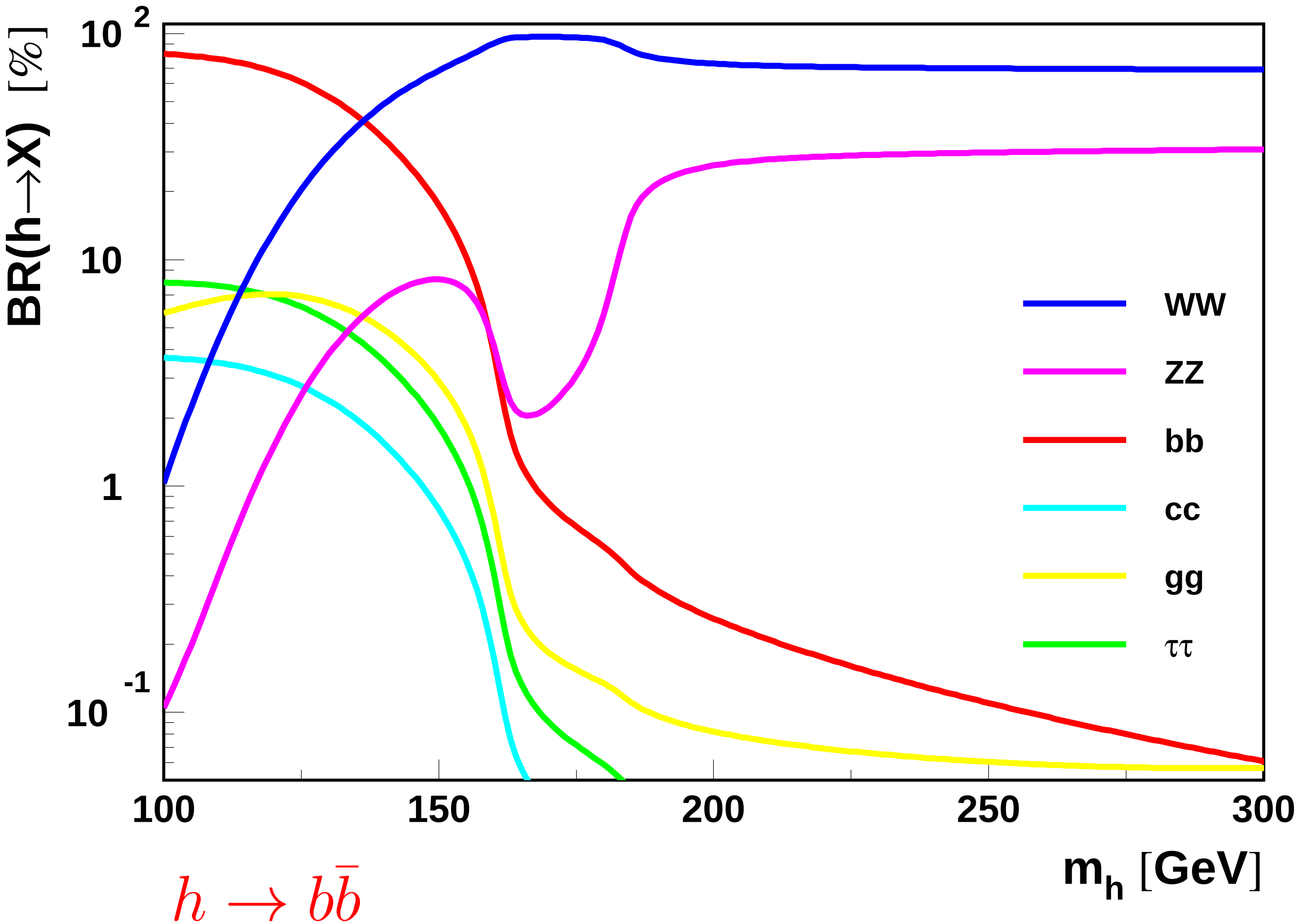
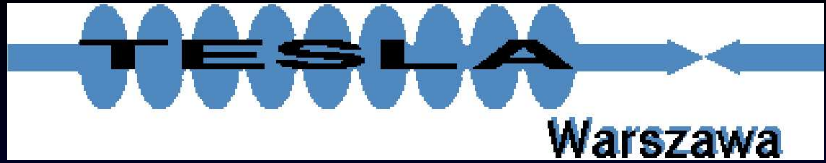
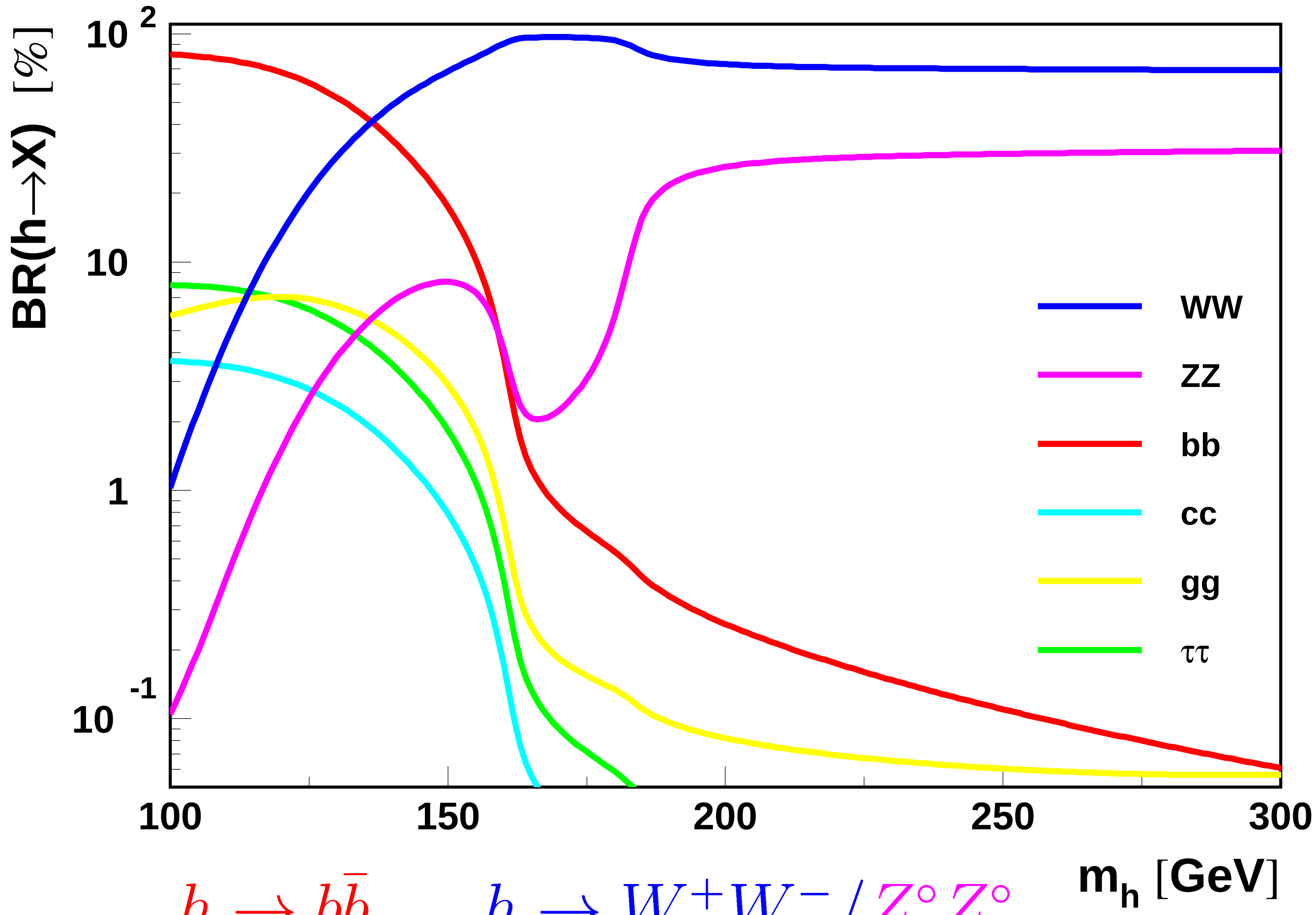



$h \to b\bar{b}$

# Higgs decays

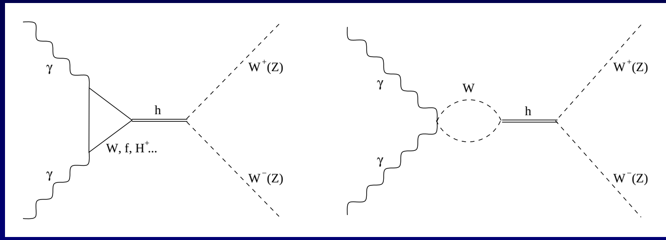


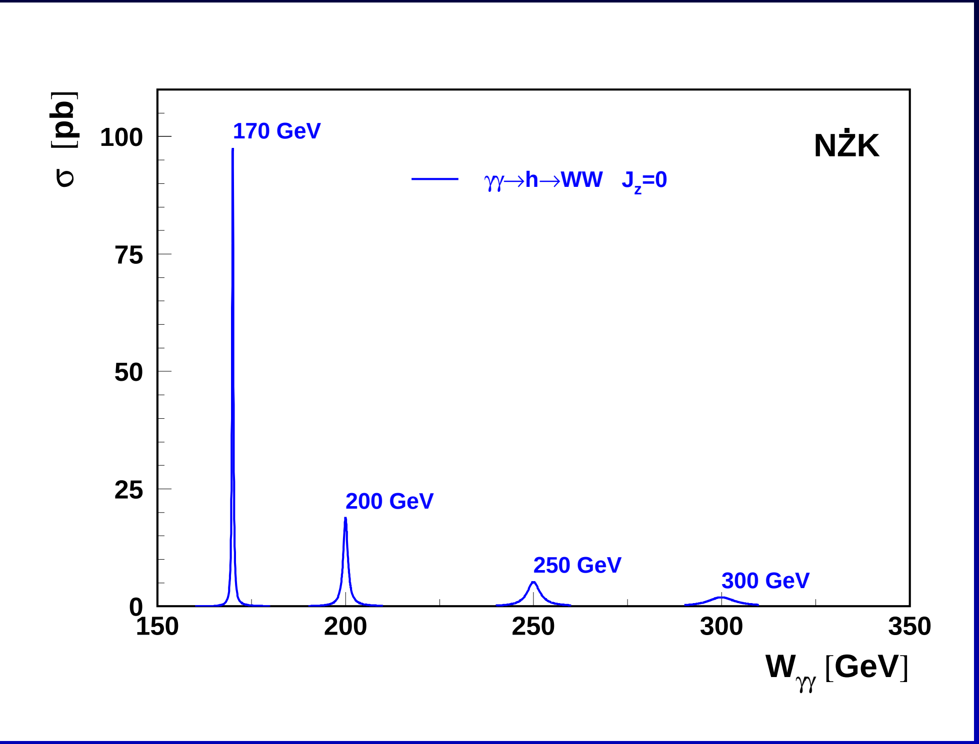




$h \to b\bar{b}$ $h \to W^+W^-/Z^\circ Z^\circ$

# $h \to W^+W^-$

"resonant" signal



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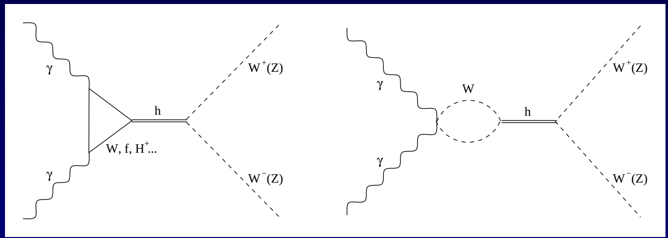
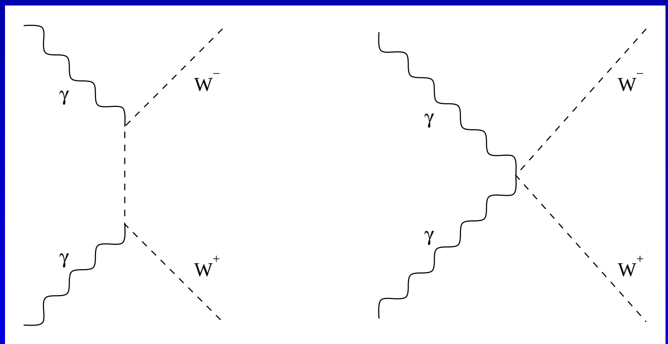
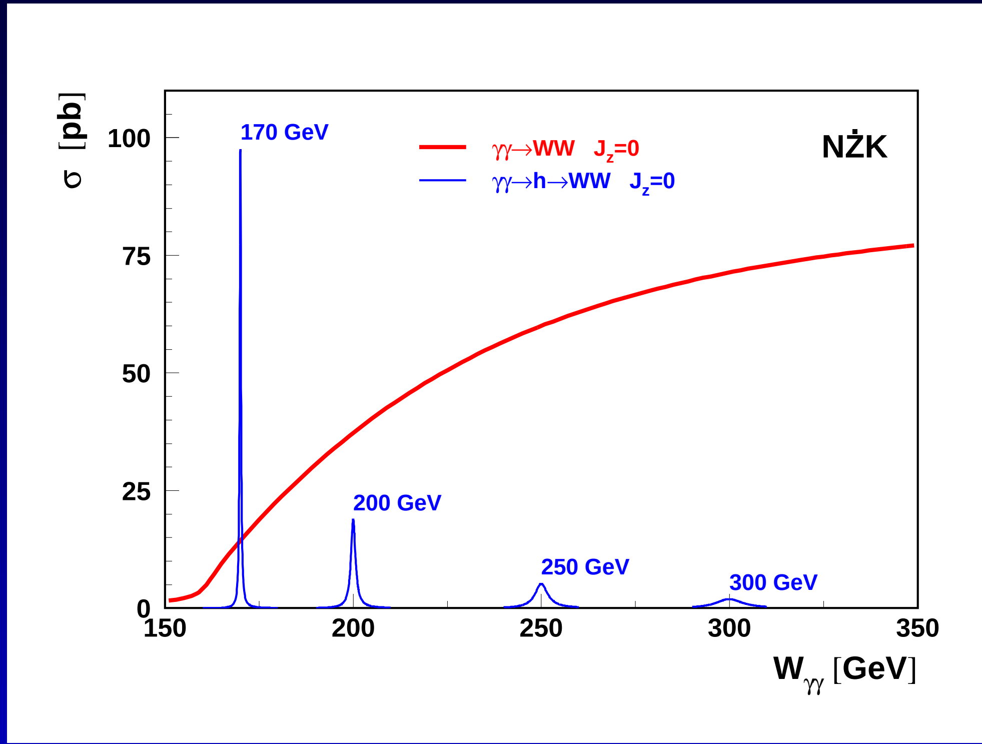



large “direct”, non-resonant bg.



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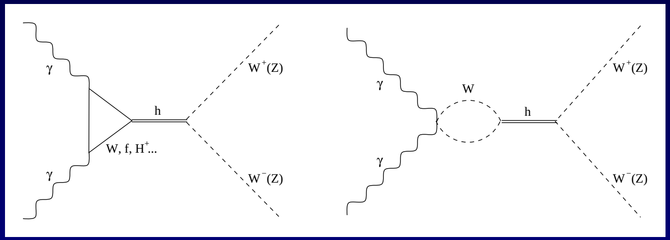


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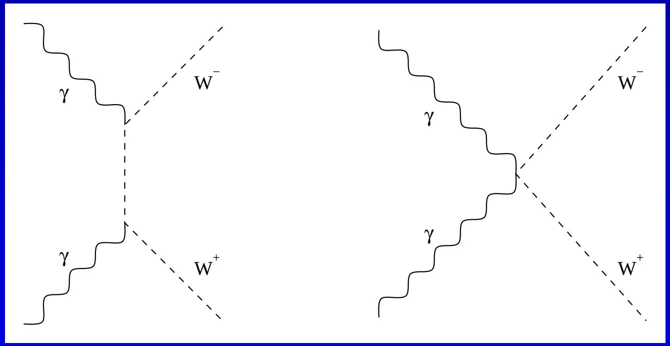
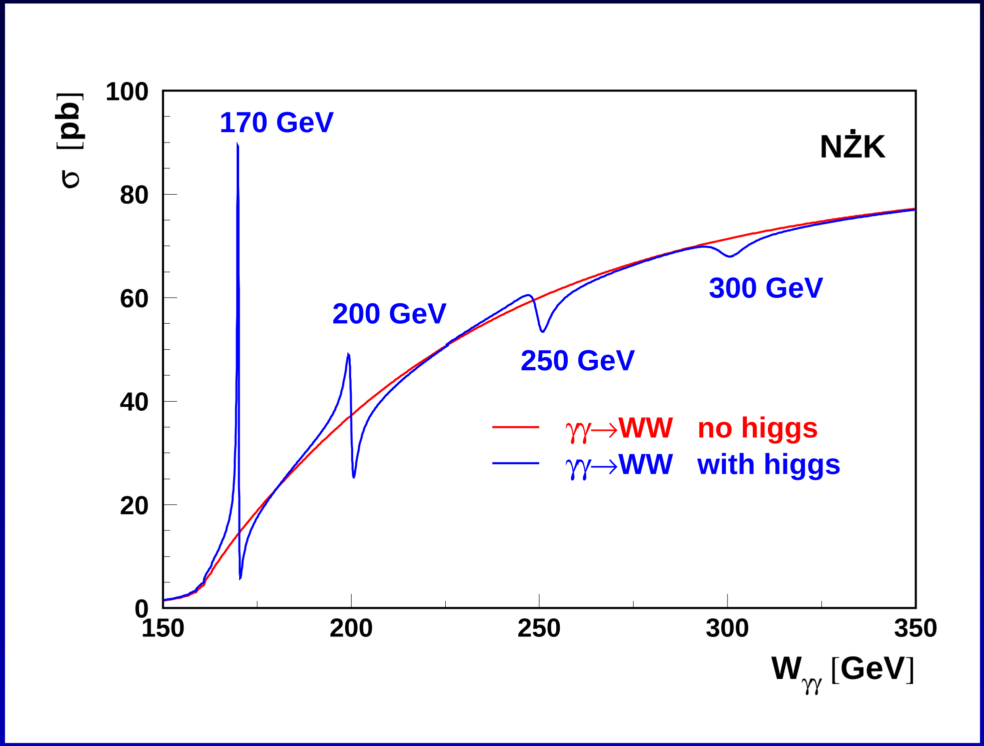
large “direct”,
non-resonant bg.

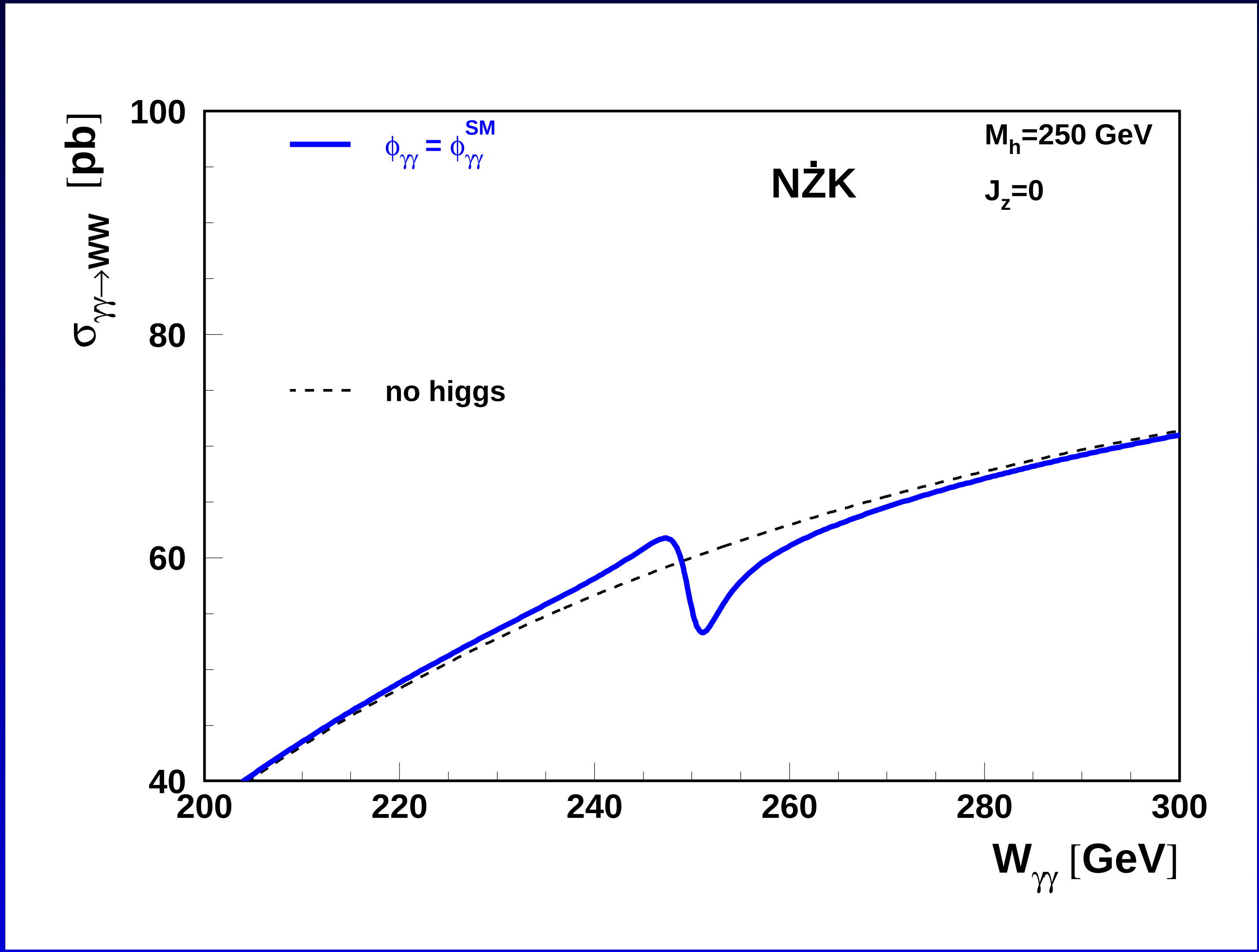



Large interference effects
$\Rightarrow$ destructive interference
dominates above $\sim$ 200 GeV

## $h \to W^+W^-$

$\sigma(\gamma\gamma \to W^+W^-)$ dependence on $\phi_{\gamma\gamma}$



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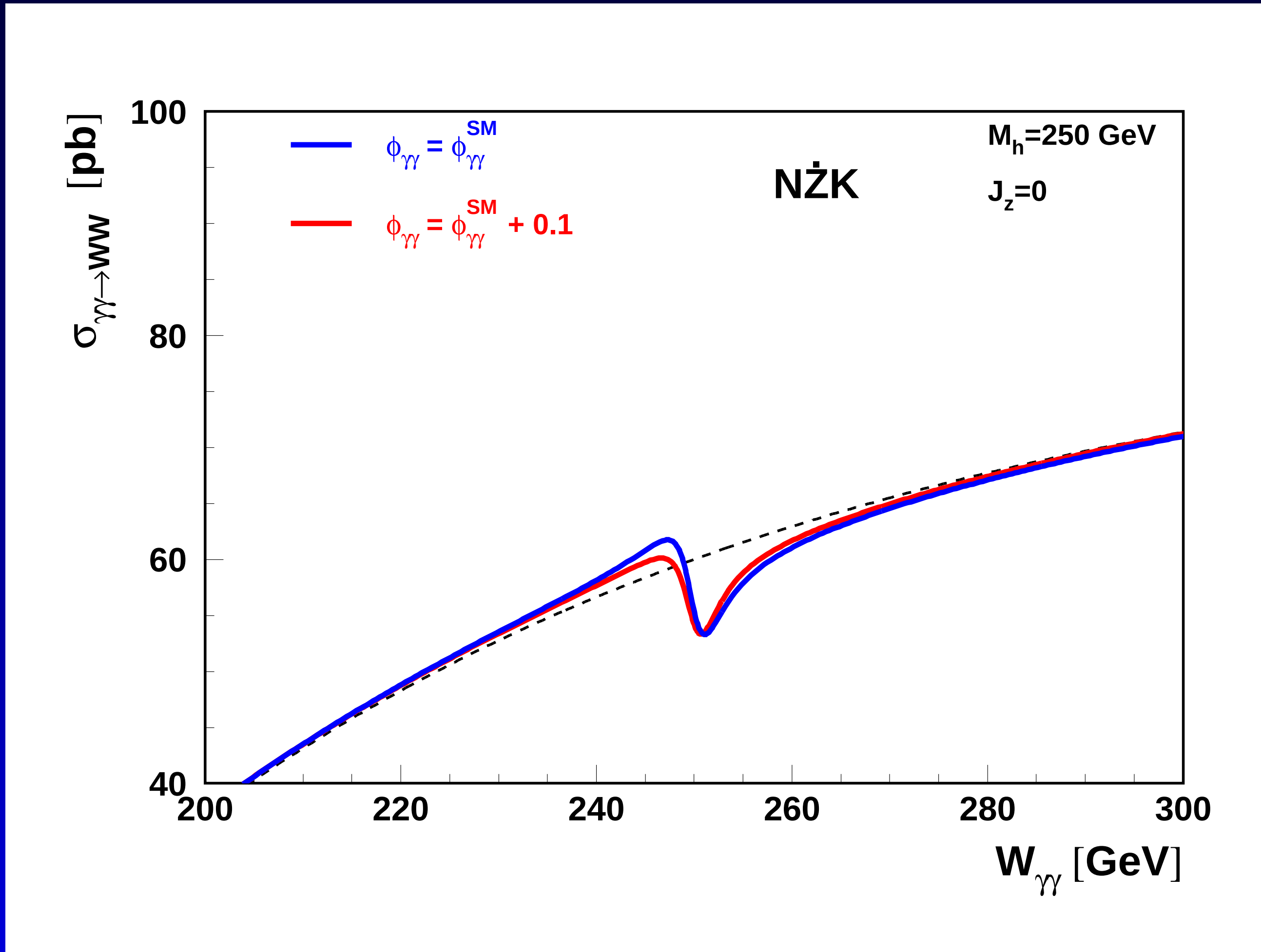

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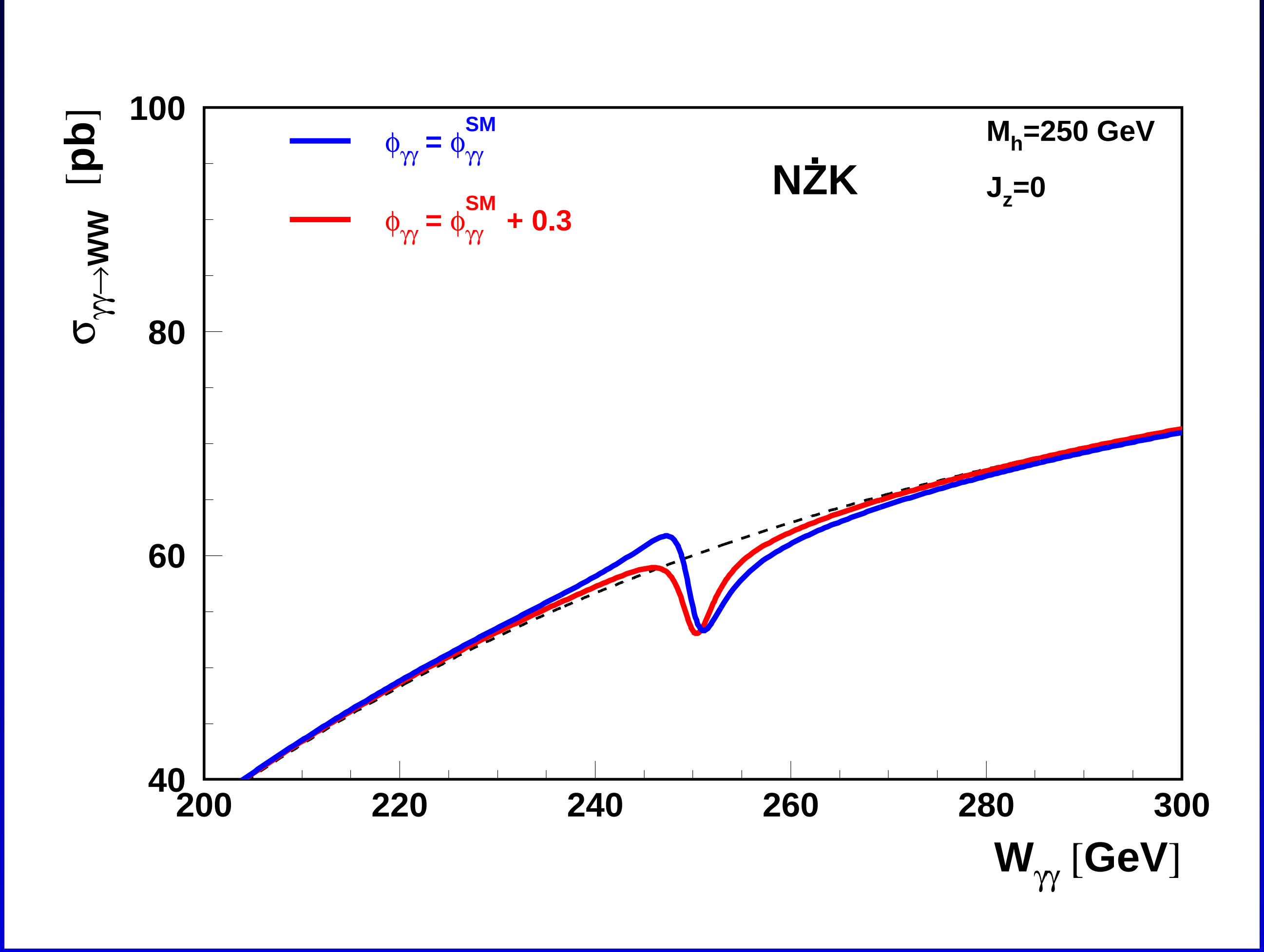

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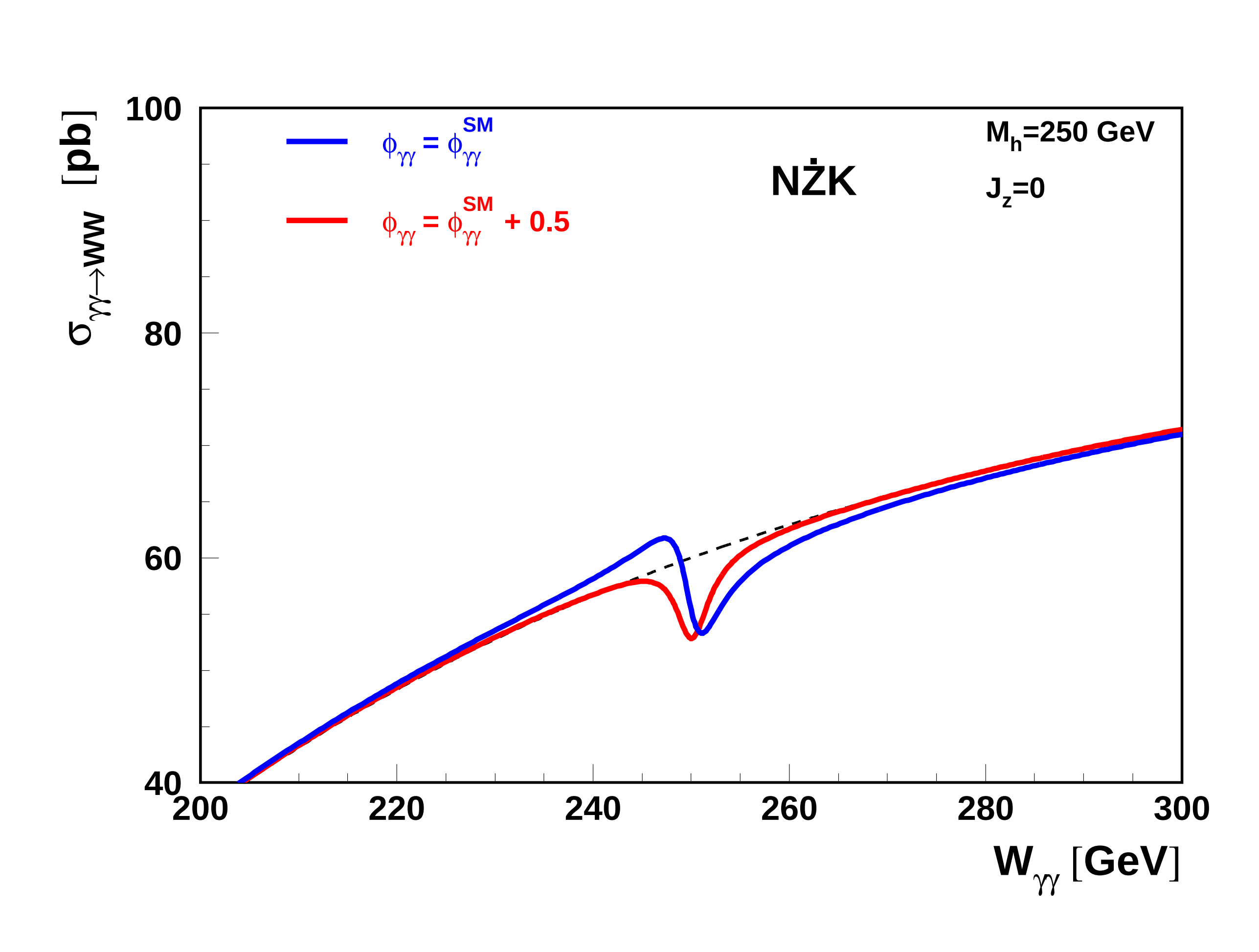

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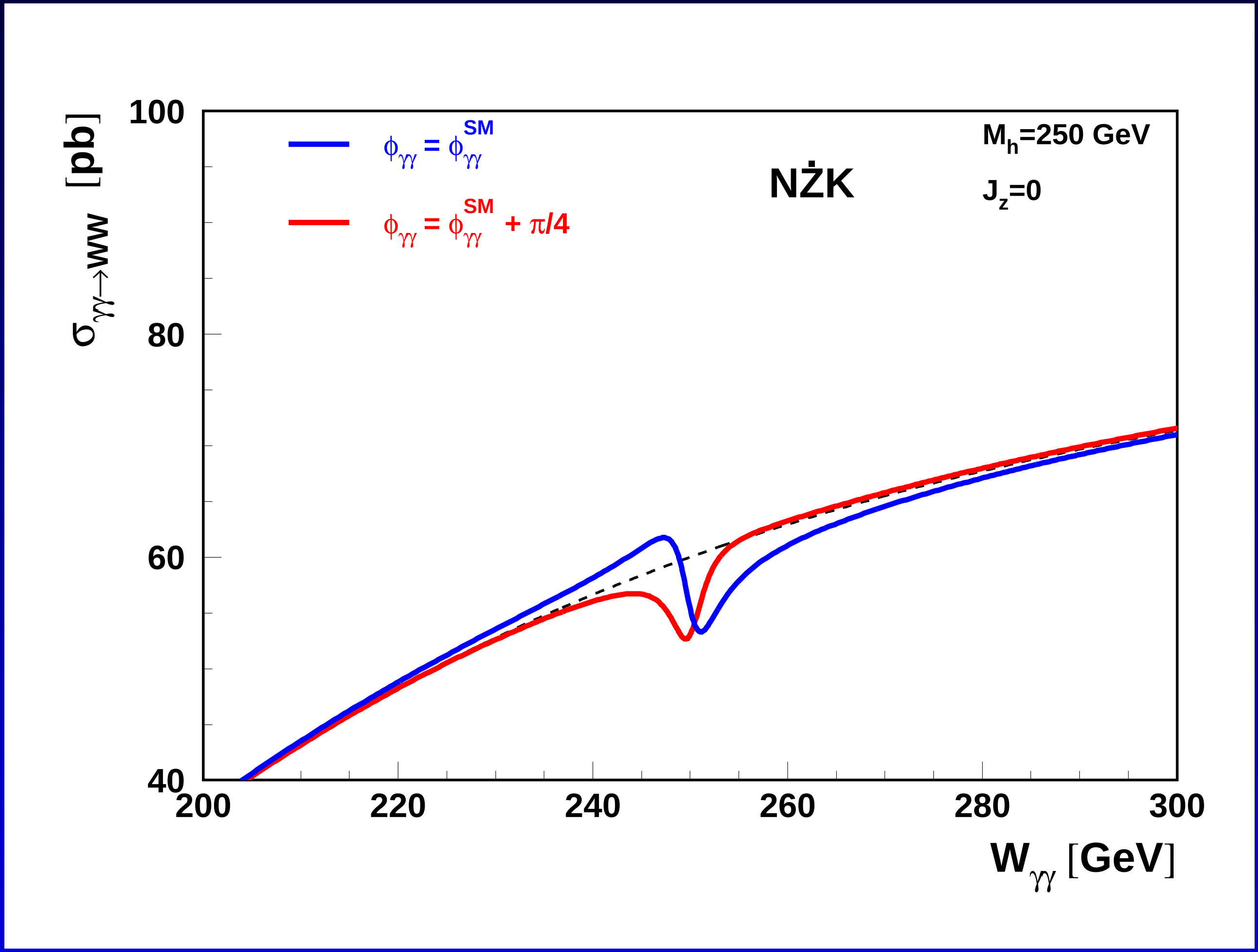

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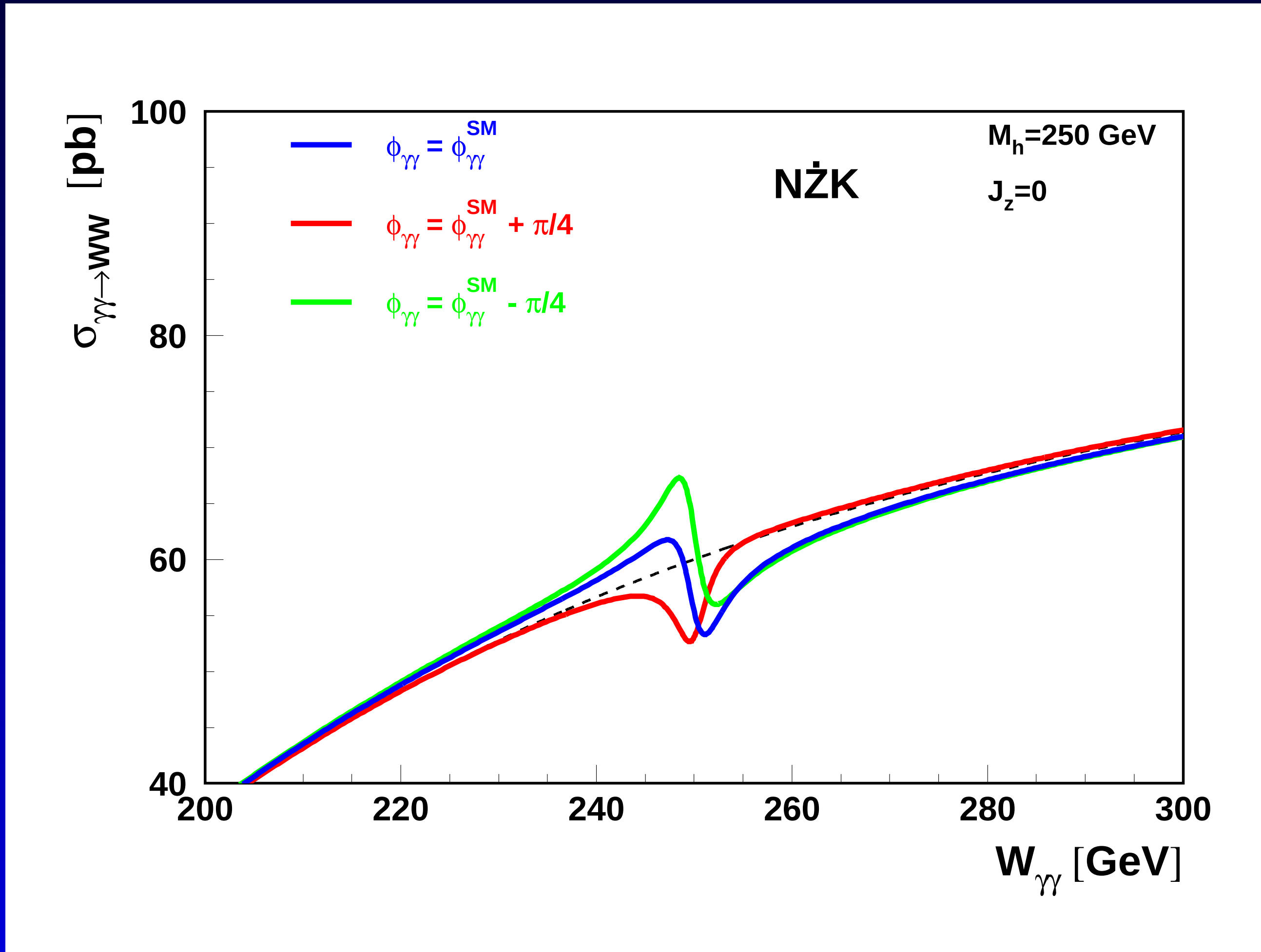
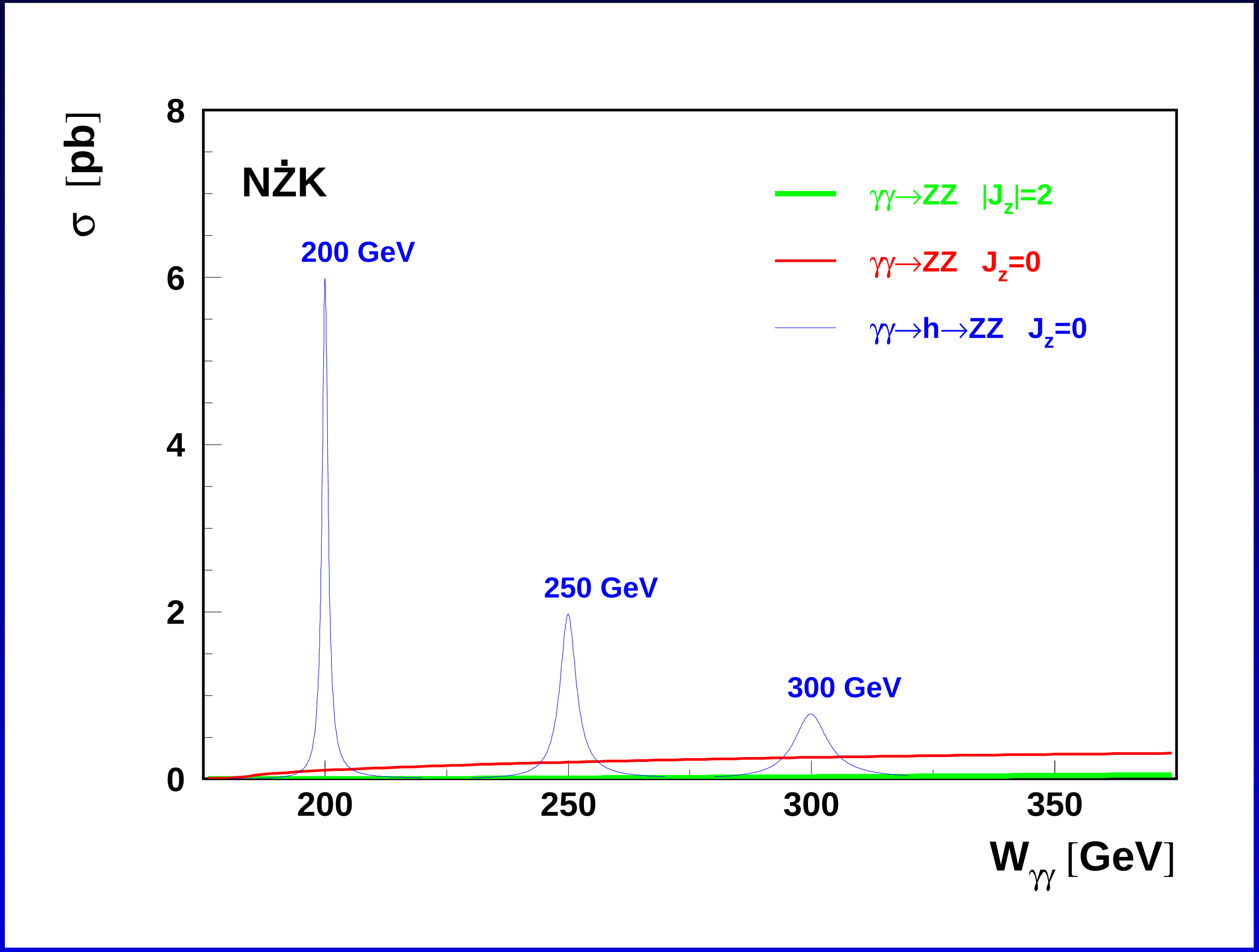



$\Rightarrow$ can be measured !

# $h \to ZZ$

Non-resonant background only at loop level



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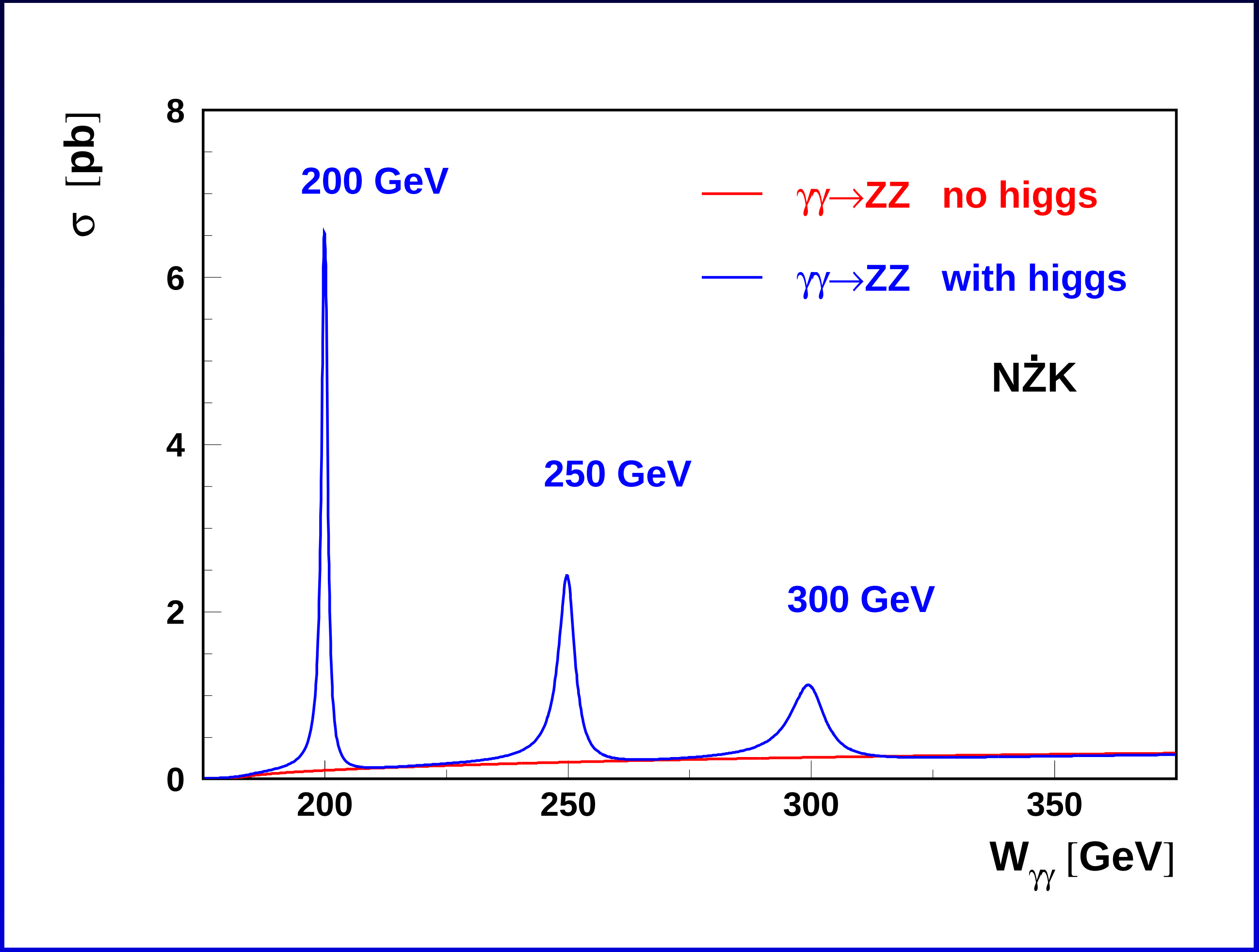

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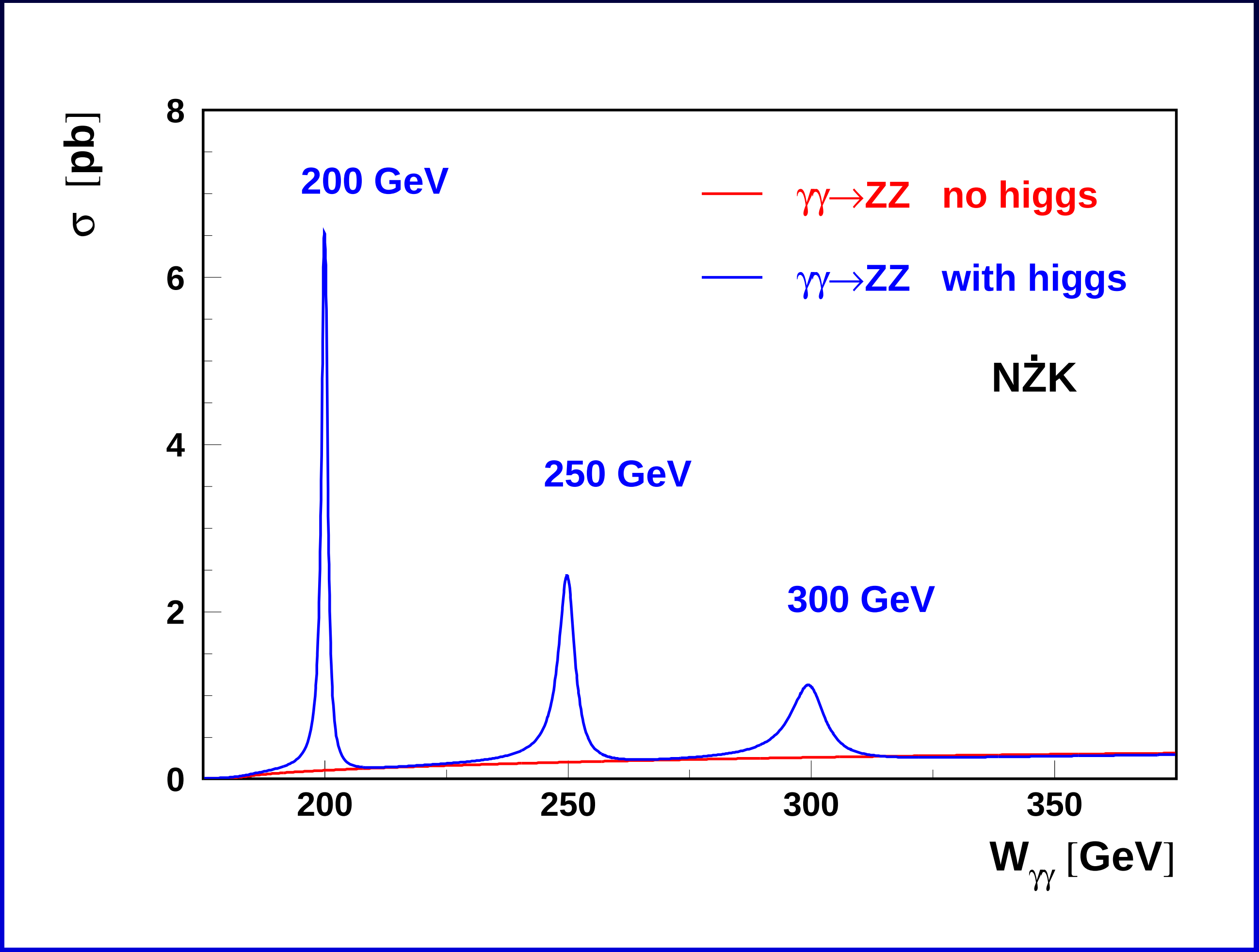
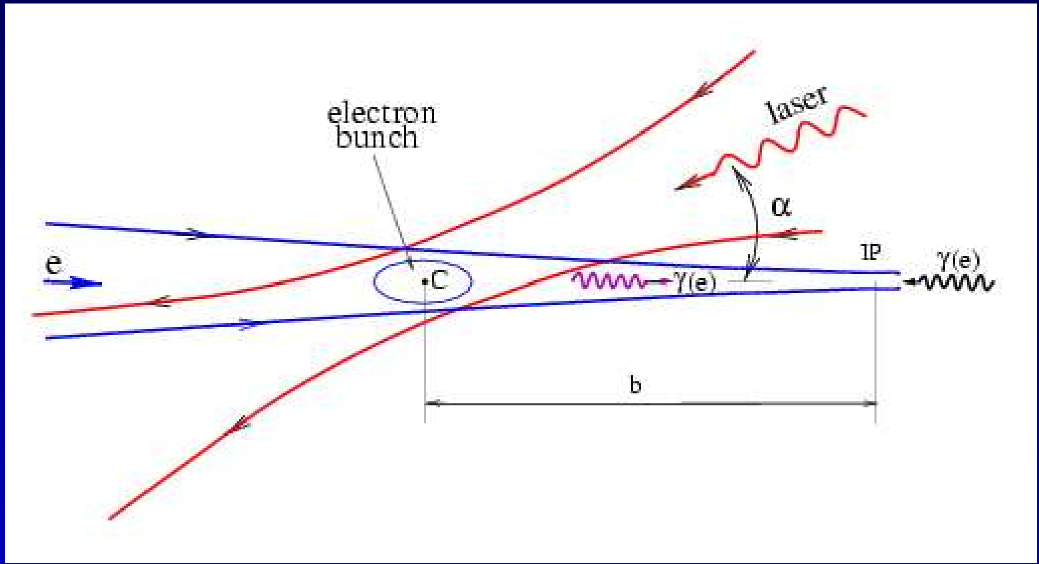


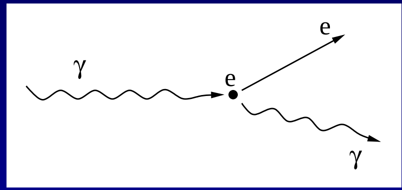

small interference effects $\Rightarrow$ not sensitive to $\phi_{\gamma\gamma}$

# Photon Collider

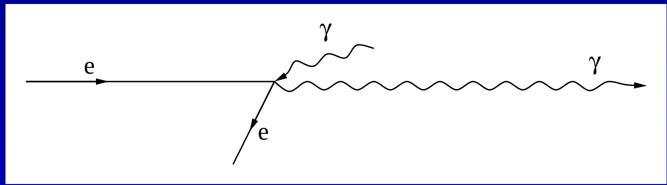
High energy, high intensity photon beam can be obtained using Compton backscattering of laser light off the high energy electrons




Compton scattering:




backscattering:



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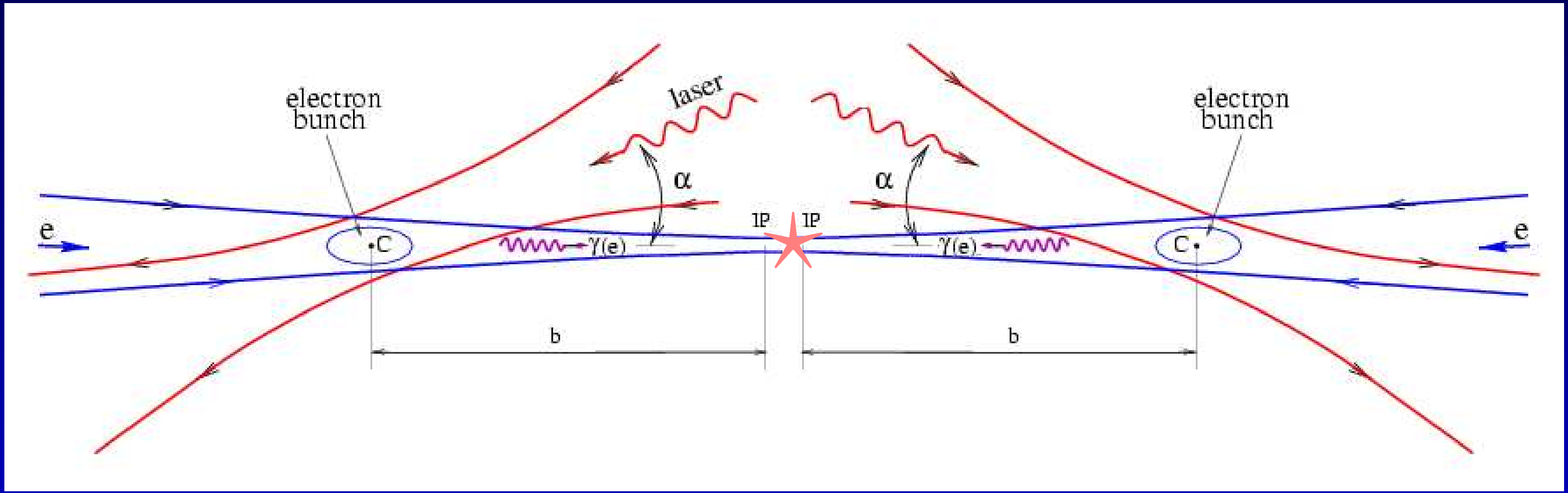


**PC**: natural extension of all $e^+e^-$ linear collider projects including TESLA

# Photon Collider

To get very high $\gamma\gamma$ luminosity we need very powerful lasers and strongly focused electron beams.

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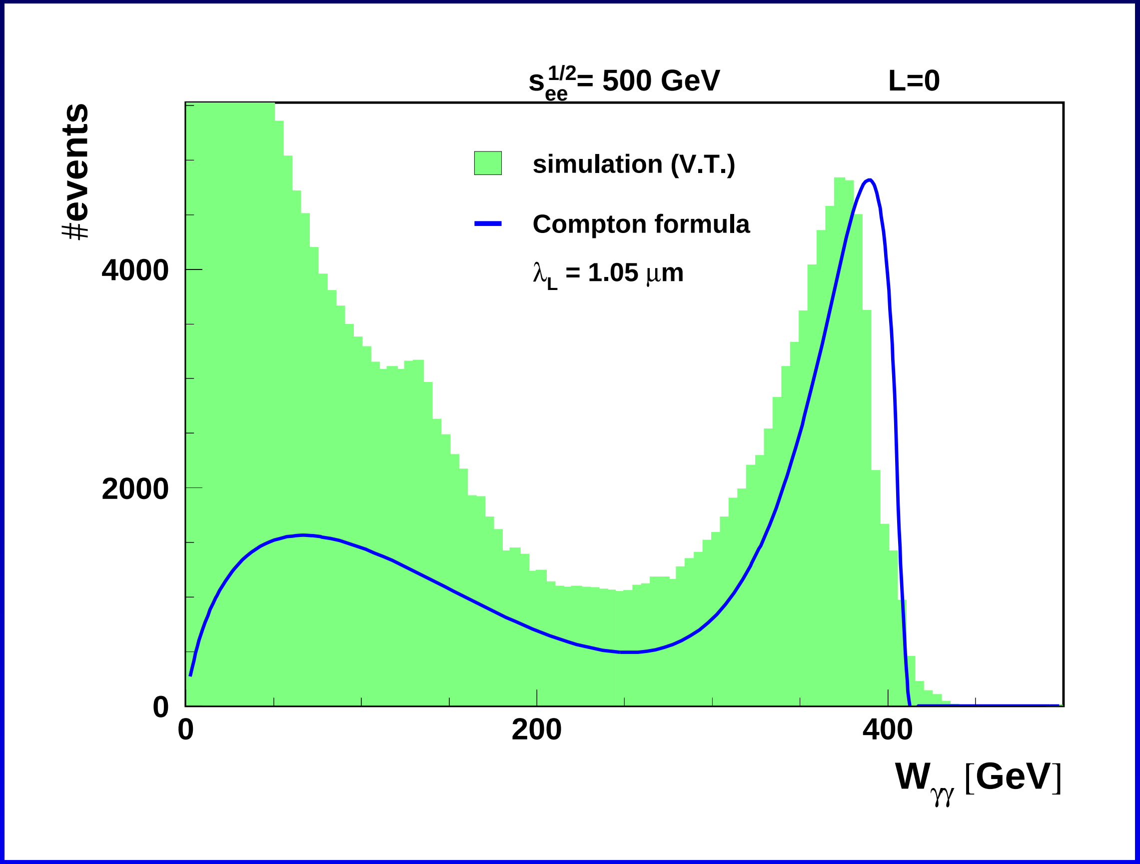
Higher order processes become important.

Compton formula fails to describe the luminosity spectrum

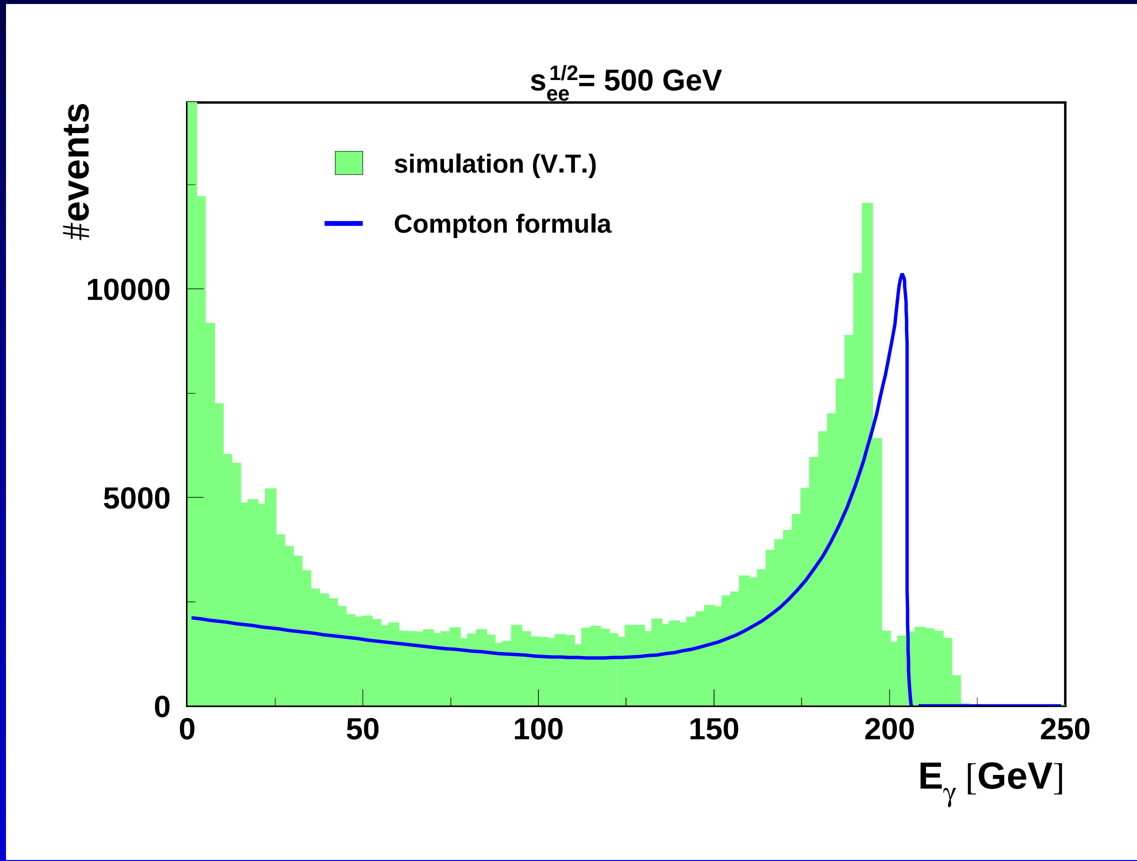


# CompAZ

Parametrization of the photon energy spectrum

Compton formula

corrected for:



# CompAZ

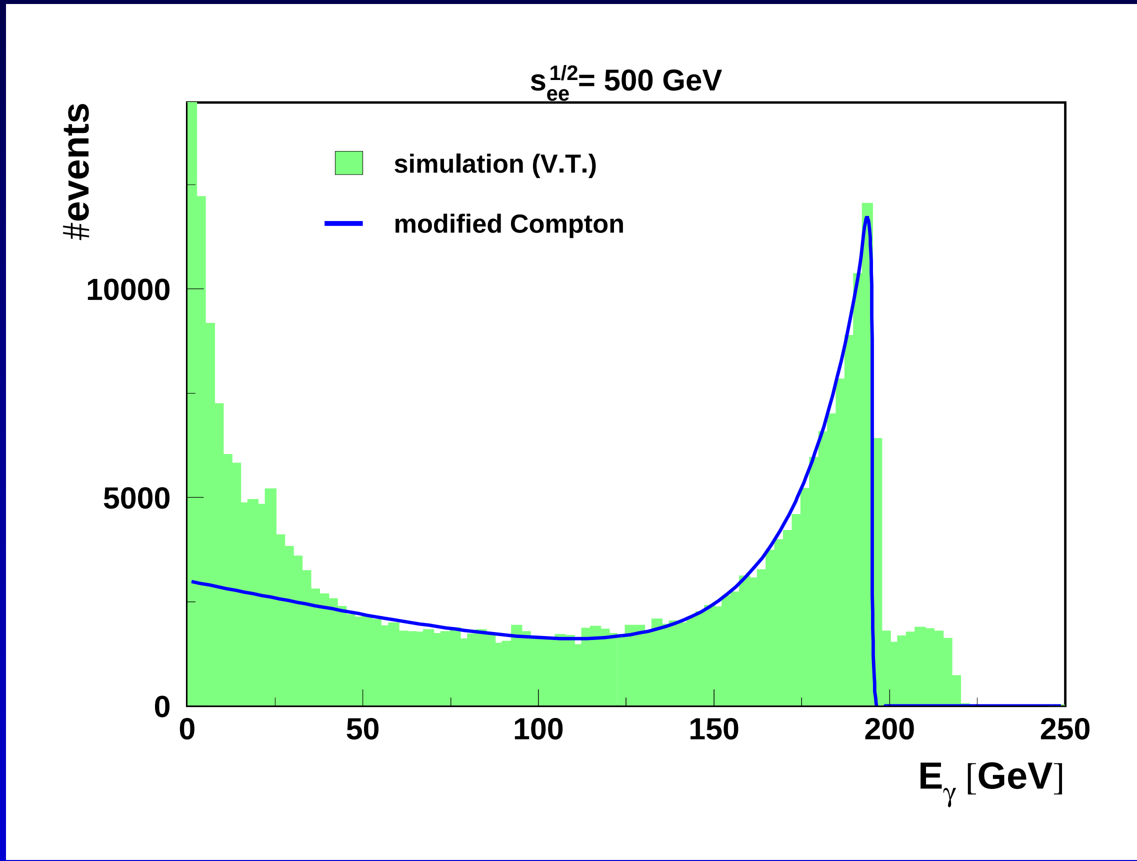
TESLA Warszawa

Parametrization of the photon energy spectrum

Compton formula

corrected for:

- nonlinear effects



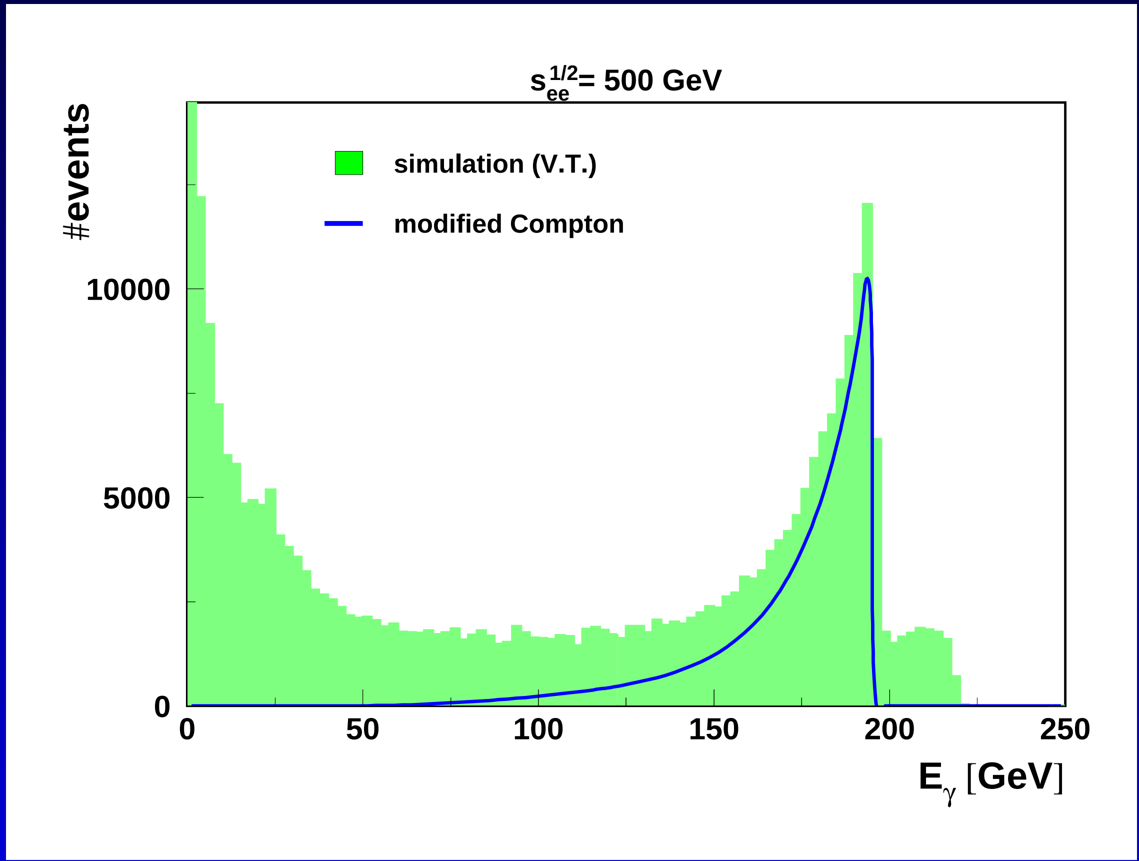
# CompAZ

Parametrization of the photon energy spectrum

Compton formula

corrected for:

- nonlinear effects
- angular correlations



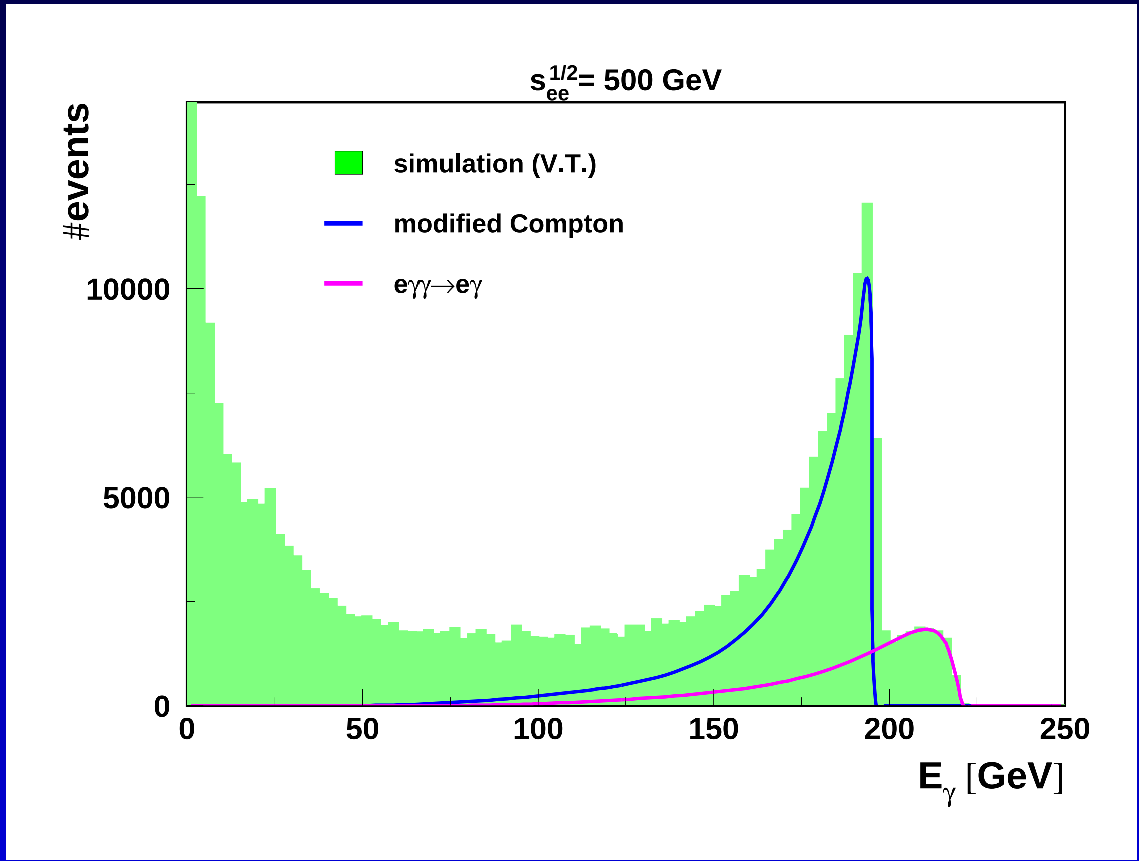
# CompAZ

Parametrization of the photon energy spectrum

Compton formula

corrected for:

- nonlinear effects
- angular correlations
- two photon scattering



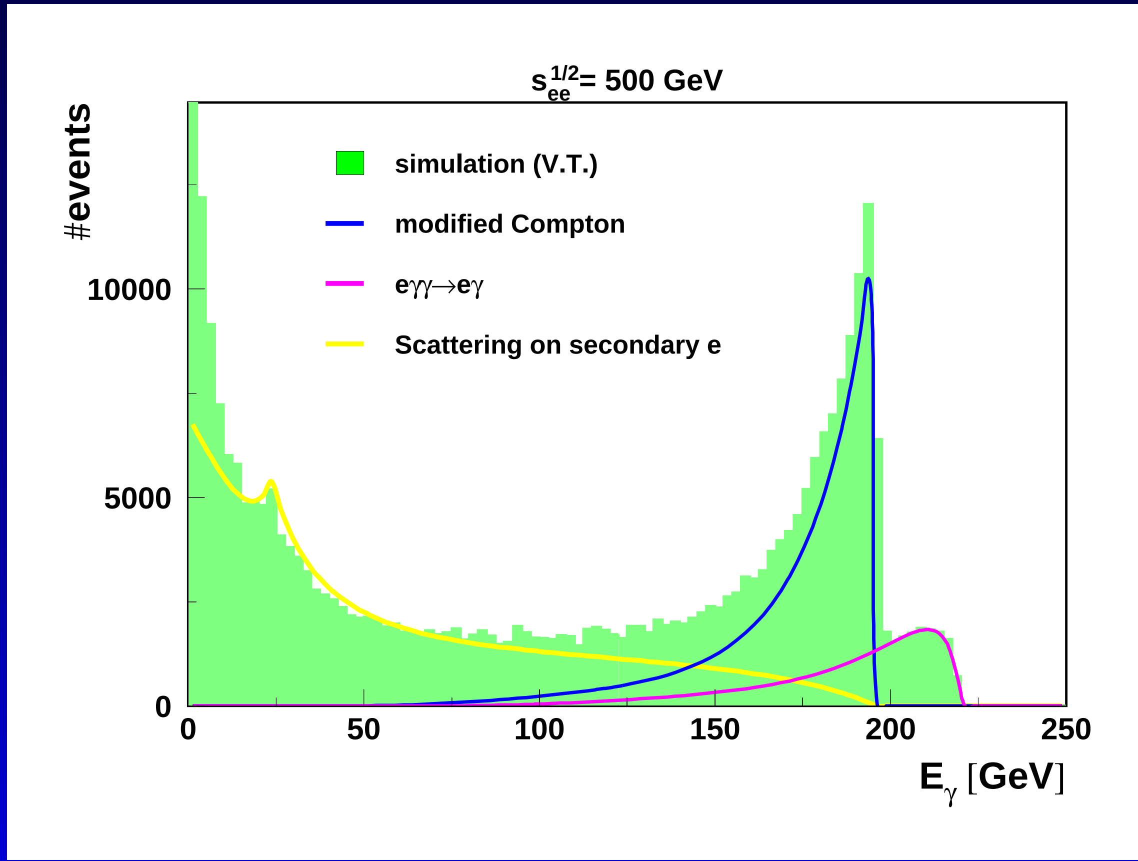
# CompAZ

Parametrization of the photon energy spectrum

Compton formula

corrected for:

- nonlinear effects
- angular correlations
- two photon scattering
- electron rescattering



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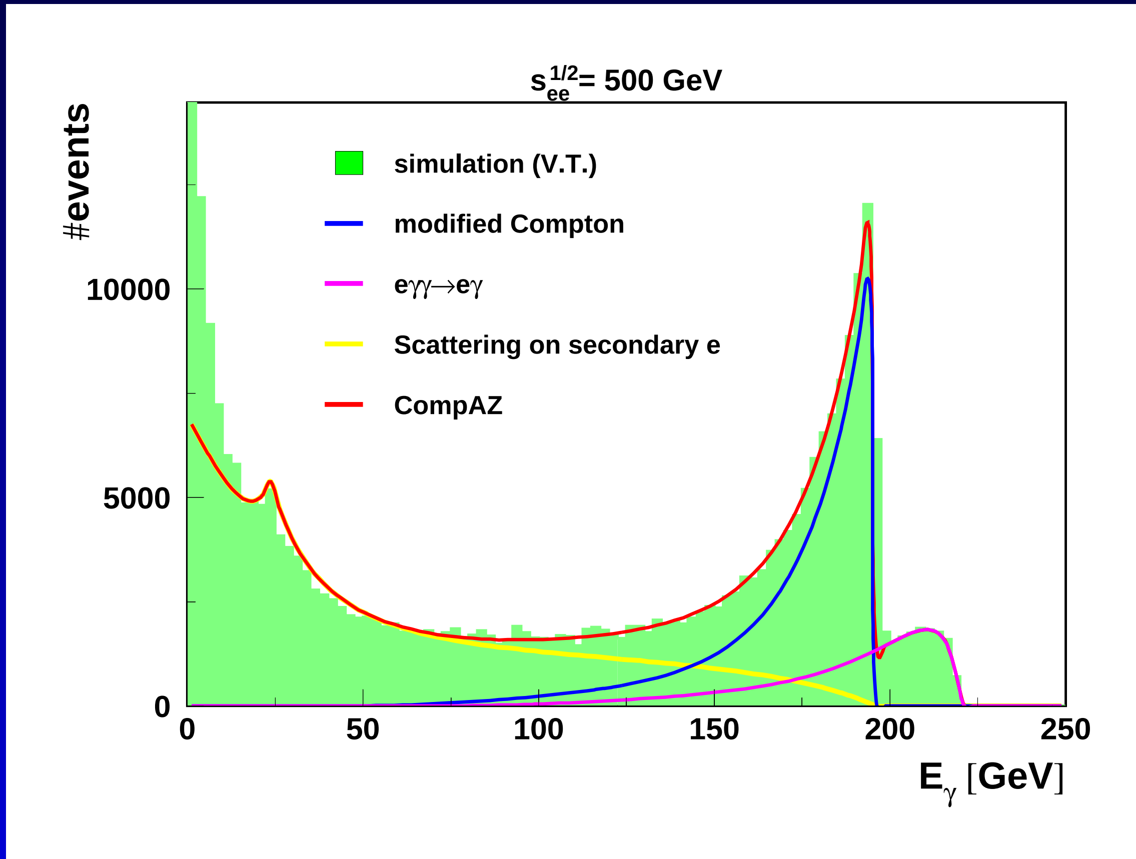


⇒ CompAZ

# CompAZ

TESLA Photon Collider luminosity spectra parametrization
Very good description of the high energy part

$\gamma\gamma$ invariant mass | polarization