$\Gamma_{\gamma\gamma}$ and phase measurement from the SM Higgs decays into WW and ZZ at the Photon Collider

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Outline

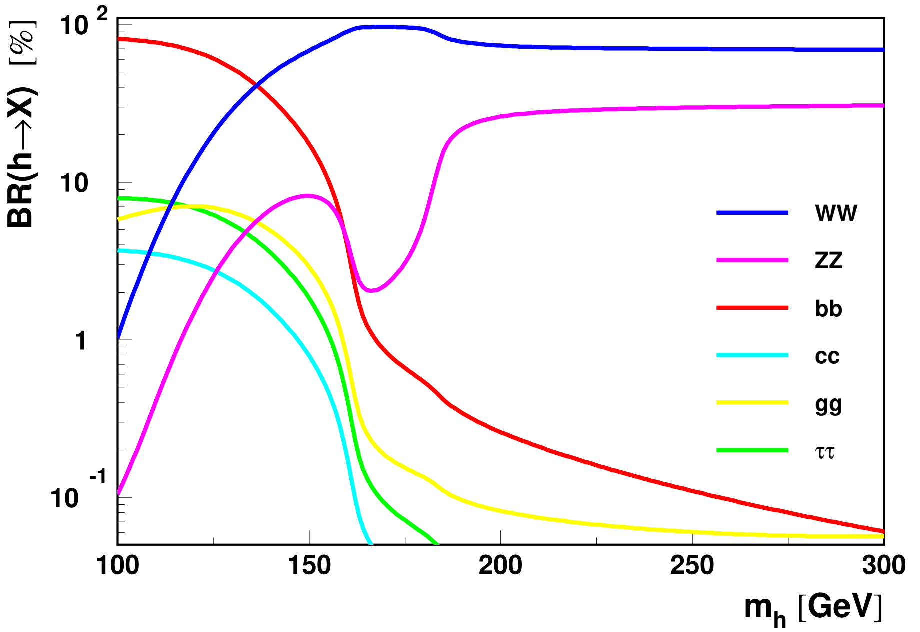
- Signal and background
  interference effects
- Analysis
  simulation, event selection, parametrization
- Results
  measurement of $\Gamma_{\gamma\gamma}$ and $\phi_{\gamma\gamma}$

hep-ph/0207294, hep-ex/0207021

International Workshop on Linear Colliders
August 26-30, 2002, Jeju Island, Korea

$\Gamma_{\gamma\gamma}$ measurement

SM Higgs decay modes



BR($h \to b\bar{b}$) decreases fast above $m_h \sim 150$ GeV.

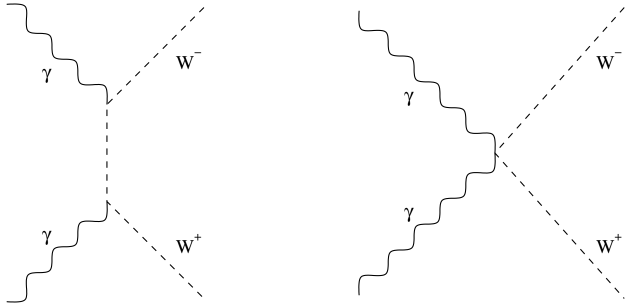
Decay to W^+W^- starts to dominate

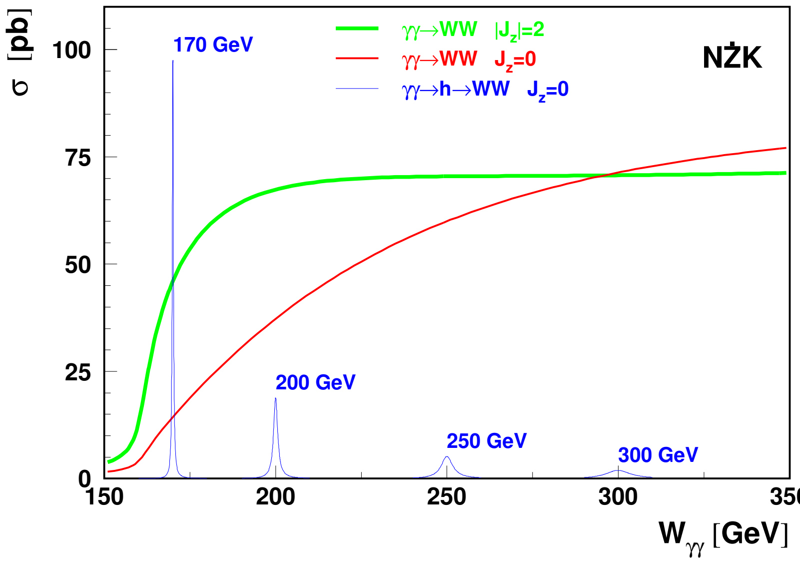
How well can we measure it ?

$h \to Z^\circ Z^\circ$ also sizable...

$h \to W^+W^-$

Large background from direct production

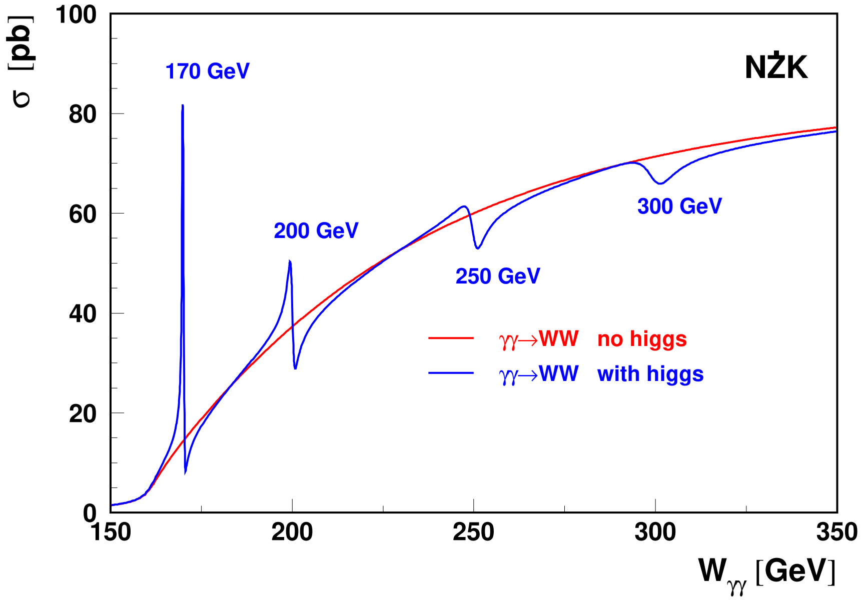




$h \to W^+W^-$

Interference

Large effects in $\gamma\gamma \to W^+W^-$



Destructive interference dominates above $\sim$ 200 GeV

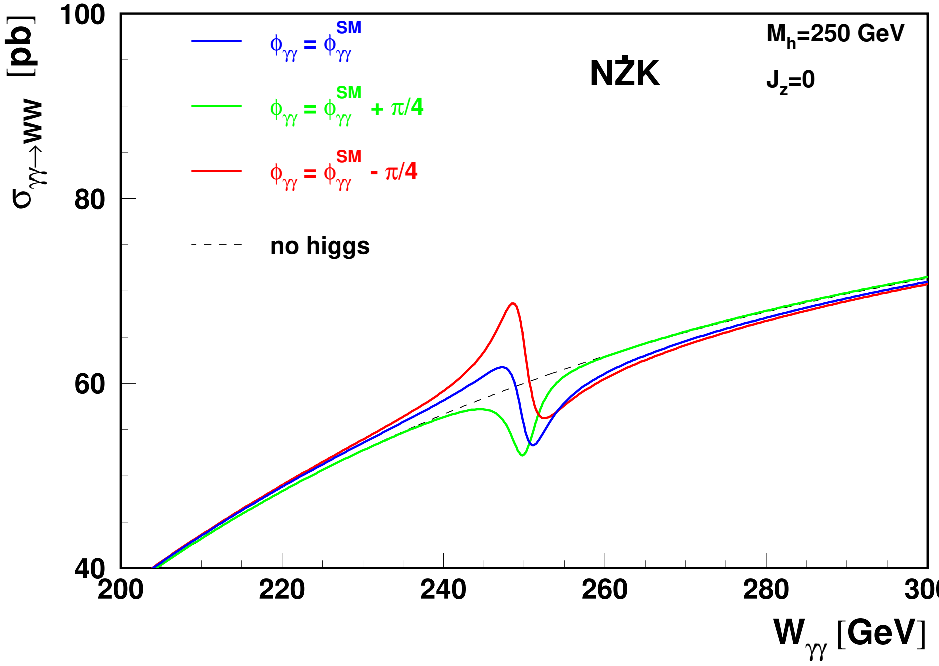
Background from direct $\gamma\gamma \to ZZ$ small (loop)

Interference with $\gamma\gamma \to h \to ZZ$ still visible

Phase measurement

Interference term is sensitive to the phase $\phi_{\gamma\gamma}$ of the $\gamma\gamma \to h$ amplitude

$\sigma(\gamma\gamma \to W^+W^-)$ for m_h = 250 GeV

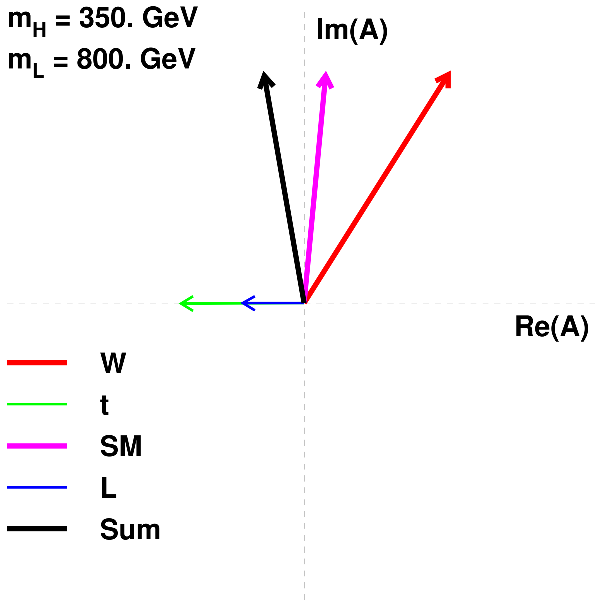


$\Rightarrow$ can be measured !

$h\gamma\gamma$ phase

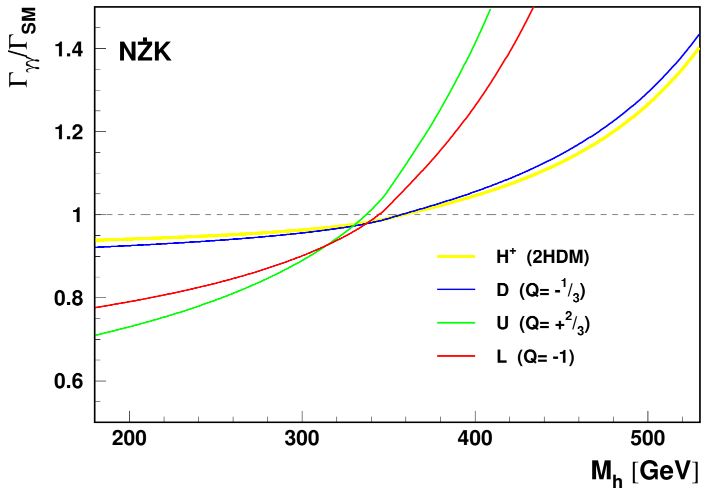
For Higgs-boson masses arround 350 GeV, $h \to \gamma\gamma$ amplitude is mostly imaginary.

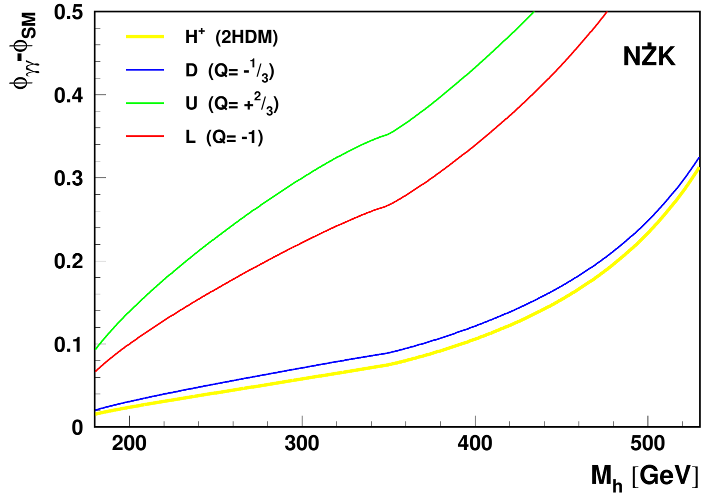
4^{th} generation heavy charged lepton:



New heavy charged particles hardly change $\Gamma_{\gamma\gamma}$, but do affect the phase of the amplitude!

Expected $\Gamma_{\gamma\gamma}$ and $\phi_{\gamma\gamma}$ deviations for SM with fourth-generation fermions and SM-like 2HDM (II)





Analysis

Simulation

$\gamma\gamma$ spectra from **CompAZ**

$\gamma\gamma \rightarrow W^+W^-,\ ZZ$ events
generated with PYTHIA 6.152

events reweighted to take into account:

- beam polarization
- Higgs production and interference

detector simulation with SIMDET v. 3.01

total $\gamma\gamma$ luminosity: 600 – 1000 fb^{-1}

High $W_{\gamma\gamma}$ peak: 75 – 115 fb^{-1}

for $\sqrt{s_{ee}}$ = 305 – 500 GeV

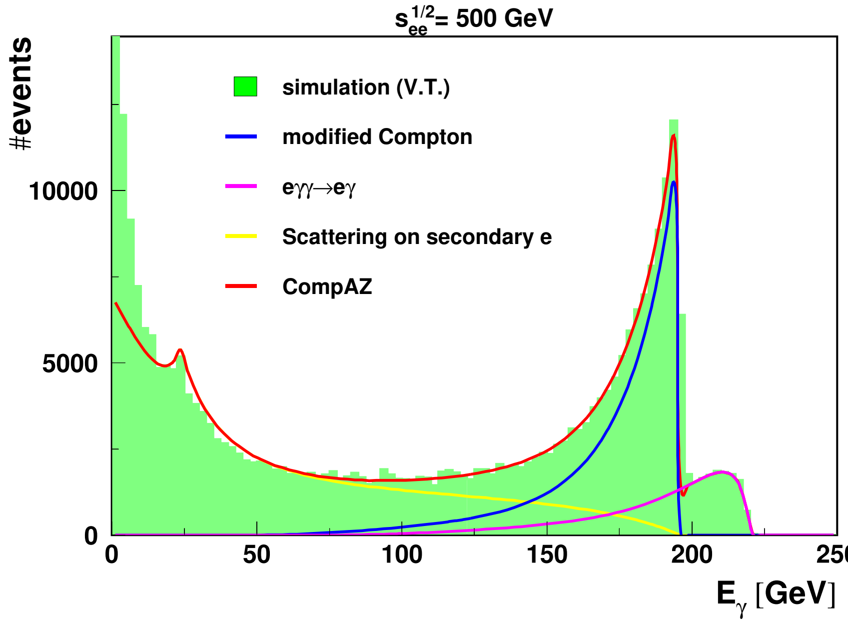
CompAZ

Parametrization of the Photon Collider luminosity spectra ⇒ hep-ex/0207021

Based on the detailed simulation by V.Telnov
NIM A355(1995)3, NIM A472(2001)267

Higher order QED effect taken into account.

Comparison with detailed simulation:



Analysis

Event selection

W^+W^-

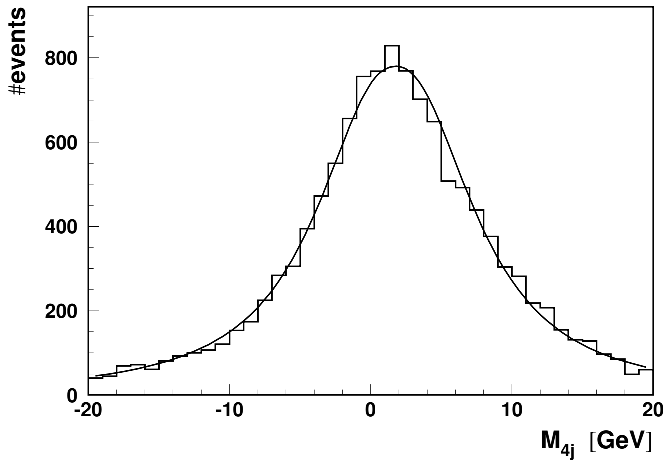
- balanced transverse momentum:
  $P_T/E_T < 0.1$
- 4 hadronic jets reconstructed
  (Durham algorithm)
- cut on jet angle $\cos\theta_{jet} < 0.95$
  to preserve good mass resolution
- two $W^\pm$ can be reconstructed
  with probability $P_W > 0.001$

ZZ

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

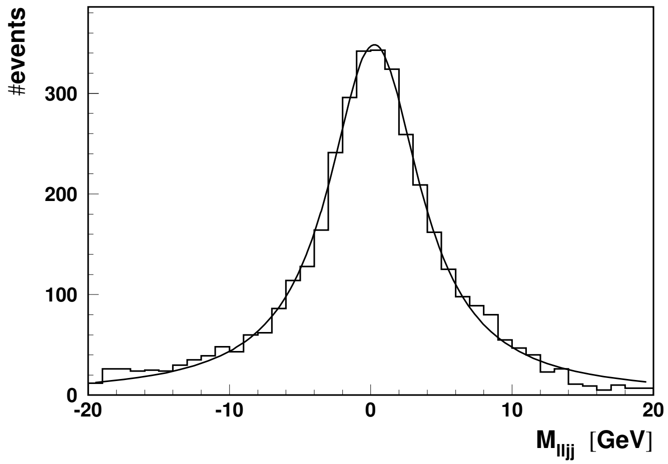
Mass resolution

$\gamma\gamma \to W^+W^- \to$ 4 jets



$\Gamma \sim$ 6.5 – 13 GeV

$\gamma\gamma \to ZZ \to l^+l^-$ + 2 jets



$\Gamma \sim$ 5.5 – 7.5 GeV

for

$W_{\gamma\gamma}$=200–400 GeV

Analysis

Parametrization

“Measured” invariant mass distribution for selected W^+W^- and ZZ events is described by convolution of:

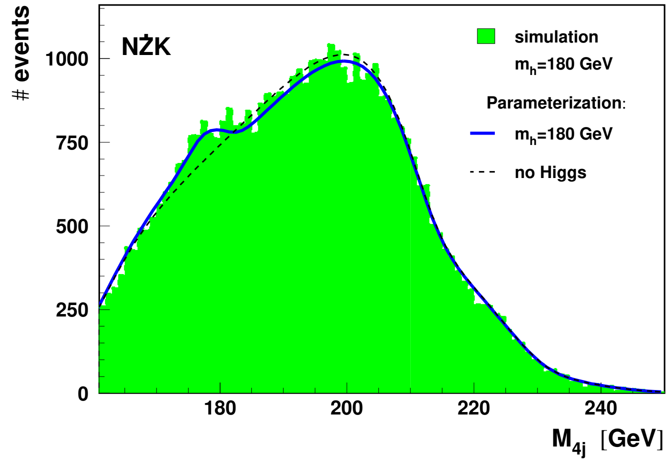
- Analytical luminosity Spectra **CompAZ**
- Cross section formula
  for signal + background + interf.
- Invariant mass resolution
  parametrized as a function of $W_{\gamma\gamma}$

$\Rightarrow$ mass spectra can be calculated for any $\sqrt{s_{ee}}$ and m_h without time-consuming MC simulation

$\Rightarrow$ can be used for fast simulation and fitting

Comparison with full simulation:

W^+W^-



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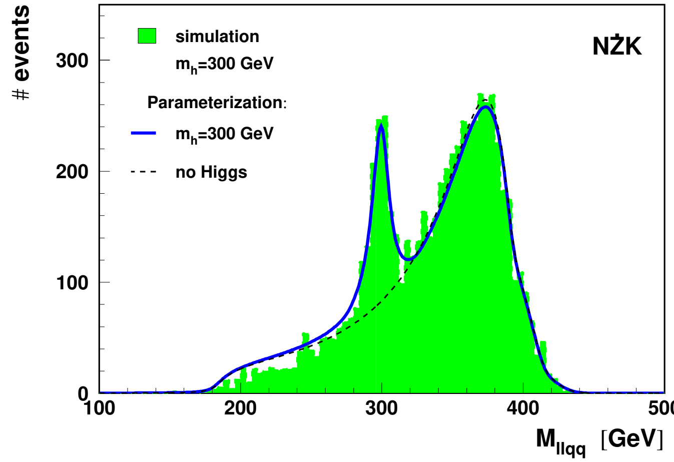
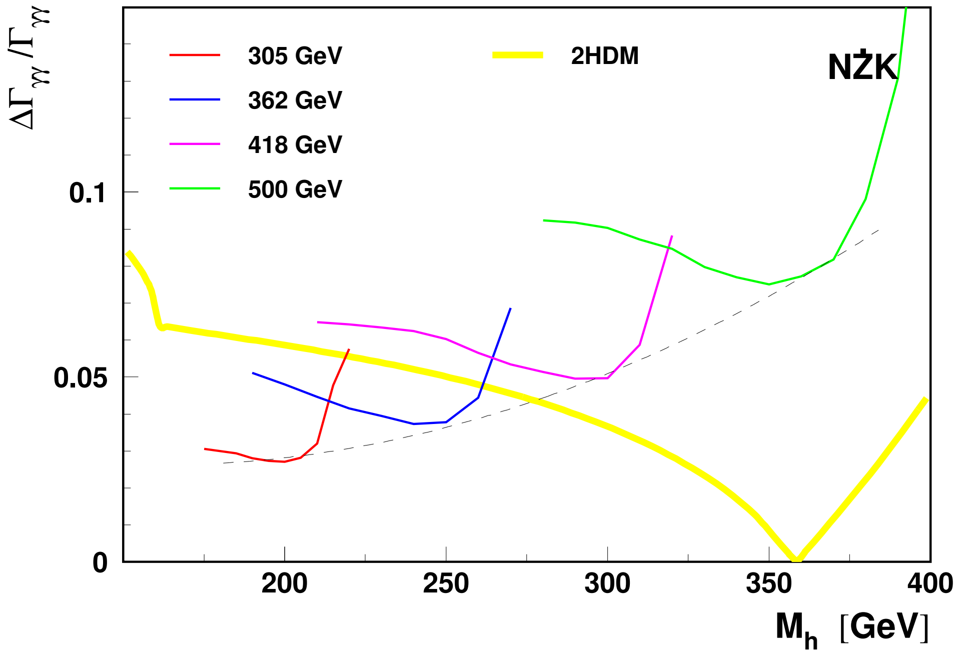


Results

$\Gamma_{\gamma\gamma}$ measurement

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

$\Rightarrow$ Average statistical precision (1 PC year):



assuming SM branching ratios

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 !

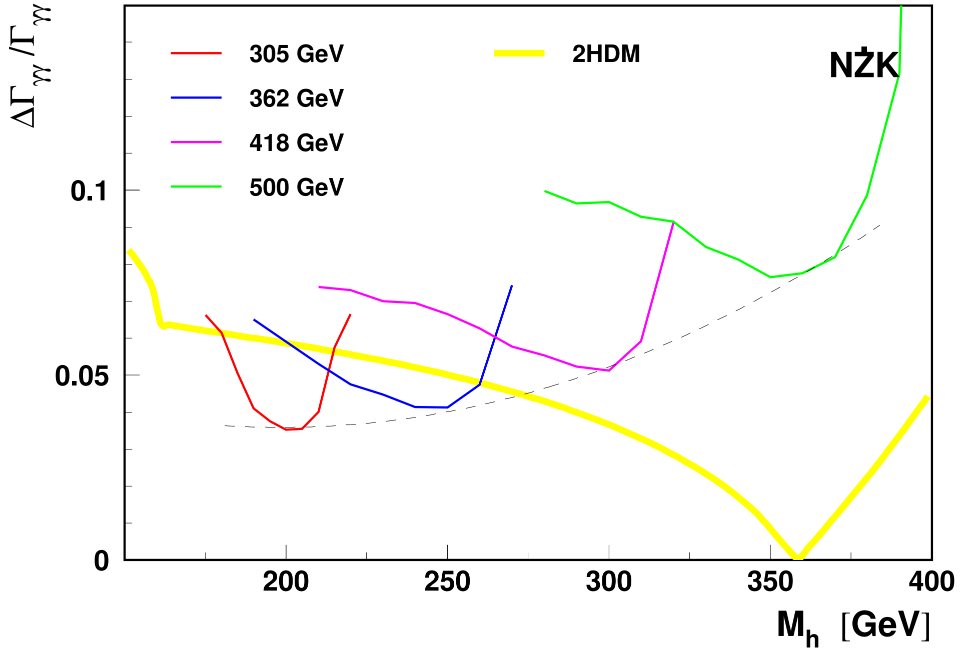
"new physics" modeled by SM-like 2HDM (II) with $m_{H^+} = 800$ GeV

Results

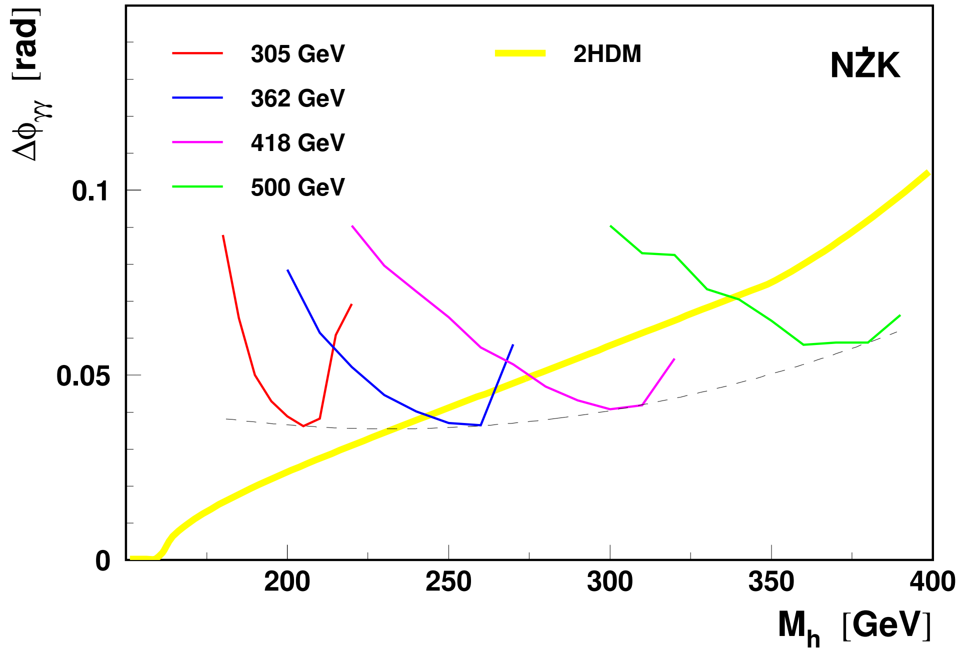
Two parameter fit to W^+W^- and ZZ invariant mass distribution

Expected statistical precision,   assuming SM branching ratios

$\Gamma_{\gamma\gamma}$



$\phi_{\gamma\gamma}$



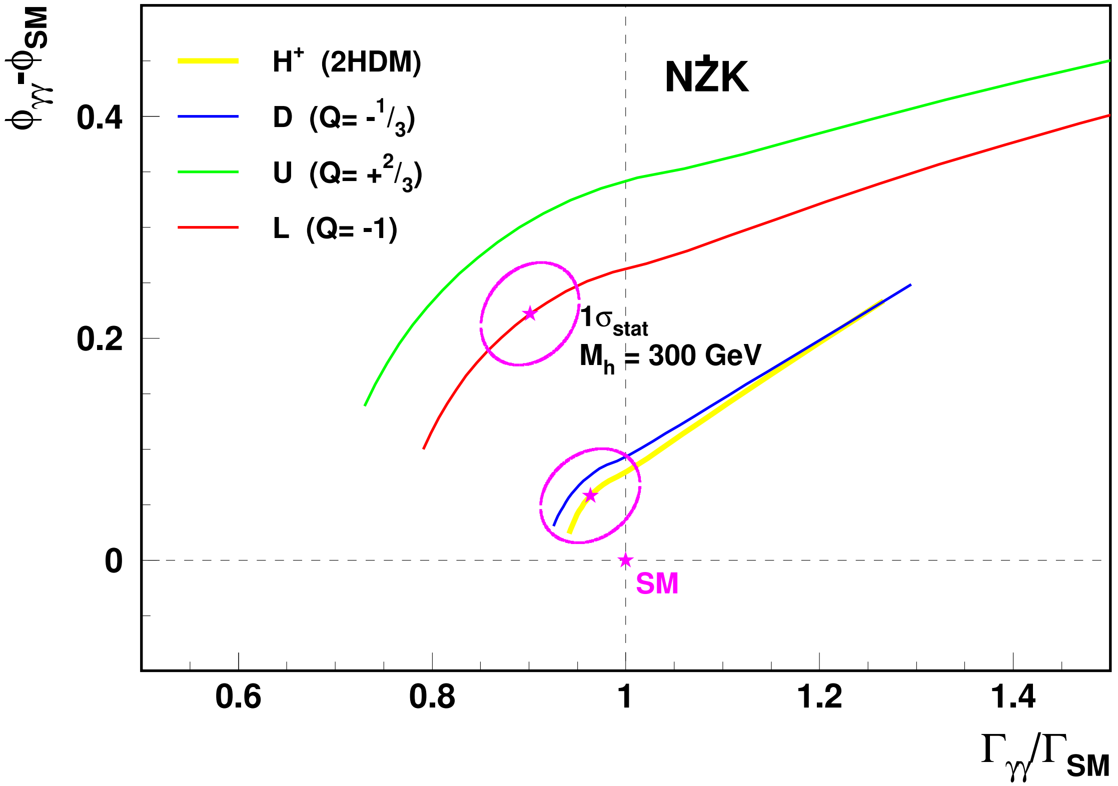
Phase measurement extends our sensitivity to new heavy charged particles
e.g. heavy charged Higgs boson of the SM-like 2HDM(II) with $m_{H+} = 800$ GeV
to large Higgs boson masses

Results

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



$\Rightarrow$ separation not possible without phase measurement !

Two parameter fit to W^+W^- and ZZ invariant mass distribution; one year of Photon Collider running.

Summary

Production of the SM Higgs-boson in $\gamma\gamma \rightarrow h$ studied for masses above 150 GeV

Large interference effects are expected in the W^+W^- decay channel

Using W^+W^- and ZZ final states both the partial width $\Gamma_{\gamma\gamma}$
and the phase of the $h \rightarrow \gamma\gamma$ amplitude $\phi_{\gamma\gamma}$ can be measured.

For masses around 300 – 400 GeV the amplitude phase $\phi_{\gamma\gamma}$
can be more sensitive to the contributions of new particles than the $\Gamma_{\gamma\gamma}$

Measurements of phase $\phi_{\gamma\gamma}$
$\Rightarrow$ window for the precise measurements
and searches of “new physics”

For more details see hep-ph/0207294