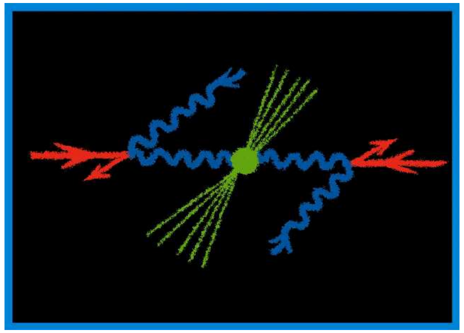


Remarks on PHOTON-PHOTON PHYSICS OR PHYSICS AT PHOTON LINEAR COLLIDER

Maria Krawczyk, Warsaw U.

Higgs Physics at Future Colliders, January 2005


Picasso

STANDARD MODEL

Symmetry $\longrightarrow$ basic idea of modern particle physics

STANDARD MODEL

$$\text{SM=SU(2)}_{I_{weak}}\text{xU(1)}_{Y_{weak}}\text{xSU(3)}_{color}$$

Origin of masses of elementary particles :
$\longrightarrow$ spontaneous symmetry breaking

Higgs mechanism in SM and beyond (MSSM, 2HDM,...) : Higgs Particle (s) predicted

Higgs sector- a clue to further understanding of matter

PHOTON COLLIDER as a unique machine

Physics at a Gamma-Gamma/Electron-Gamma Collider

A Photon Collider based on laser beams back-scattered from high energy electrons allows

detailed studies of various high energy gamma-gamma and electron-gamma processes for definite polarizations

$\Longrightarrow$ It offers a unique opprtunity to study resonant production of the Higgs bosons in the process

$$\gamma\gamma \rightarrow \mathrm{H}$$

This process is sensitive to all charged fundamental particles of the theory!

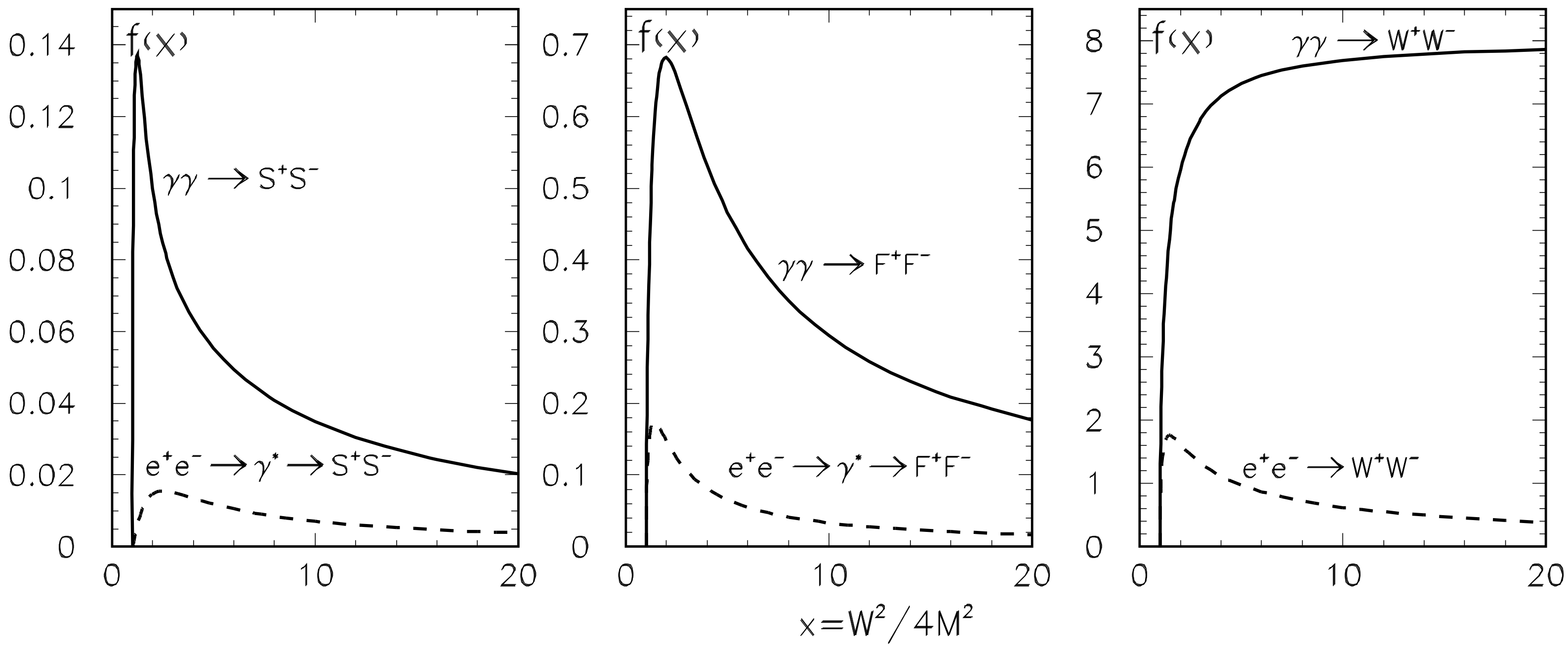
The photon-photon collider and processes

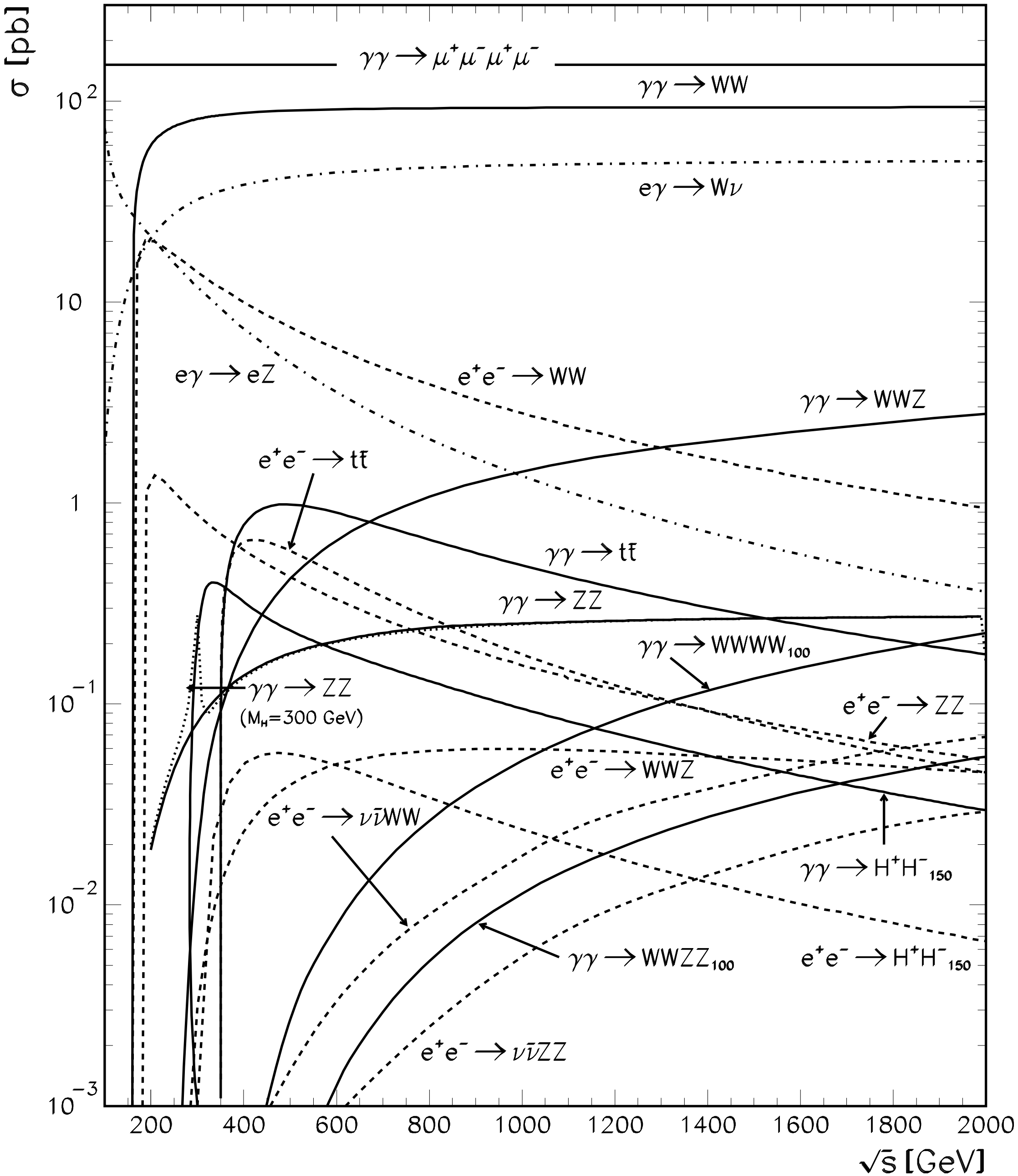
Uniqueness of the photon-photon collider:

- Variable energy and degree of polarizations (both circular and transverse)
- Clean or dirty collider? Hadronic interaction of (component of) photon important - “hadronic type of collider”

Uniqueness of photon-photon processes:

- Formation of neutral resonance with other quantum numbers than in $e+e-$, (spin 1 is forbidden for system of two real photons!), among other neutral Higgs particles (scalars and pseudoscalars, or mixture) (loop)
- The $\gamma\gamma higgs$ loop - sensitive to all charged fundamental particles of the theory - NON-DECOUPLING
- Pair production of charged scalars, fermions, vectors (direct)
- Pair production of neutral scalars, fermions, vectors (loop), among other $\gamma\gamma \to \gamma\gamma$
- Measurement of parton densities of really REAL photons (in $e\gamma$ F_2 for real photons!)


f(x)
γγ → S⁺S⁻
e⁺e⁻ → γ* → S⁺S⁻
γγ → F⁺F⁻
e⁺e⁻ → γ* → F⁺F⁻
γγ → W⁺W⁻
e⁺e⁻ → W⁺W⁻
x=W²/4M²


σ [pb]
γγ → μ⁺μ⁻μ⁺μ⁻
γγ → WW
eγ → Wν
eγ → eZ
e⁺e⁻ → WW
γγ → WWZ
e⁺e⁻ → tt̄
γγ → tt̄
γγ → ZZ
γγ → WWWW100
γγ → ZZ
(MH=300 GeV)
e⁺e⁻ → ZZ
e⁺e⁻ → WWZ
e⁺e⁻ → νν̄WW
γγ → H⁺H⁻150
γγ → WWZZ100
e⁺e⁻ → H⁺H⁻150
e⁺e⁻ → νν̄ZZ
10²
10
1
10⁻¹
10⁻²
10⁻³
200
400
600
800
1000
1200
1400
1600
1800
2000
√s [GeV]

Higgs study

- Precise measurement of the properties of Higgs resonance

- Distinquishing SM-like scenarios (CP consv.): $\gamma\gamma h(H)$ (non-decoupling of H^+)
- Establishing CP properties of Higgs bosons,

among other “SM-like” h ($\sim h_1$) and HA mixing (h_2, h_3)
- Heavy Higgs production

Different channels

SM Higgs to bb

Detailed studies of $\gamma\gamma$ and eγ modes at the TESLA collider were performed based on realistic photon spectra.

Several NLO analyses of the light SM Higgs production decaying into $b\bar{b}$ final state were made with a simulation of the detector

$\Longrightarrow$ the two-photon width can be measured with high accuracy:

SM HIGGS to WW

Production of a heavy SM Higgs boson with masses above 150 GeV for the WW final state

the important interference effects between signal and background

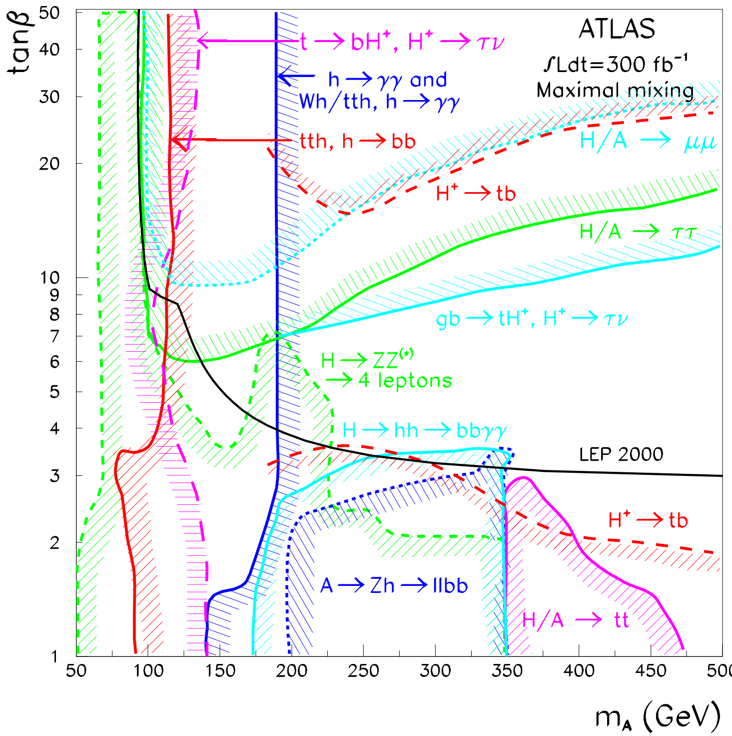
MSSM HIGGS: A and H

The heavy MSSM Higgs bosons A and H in the mass range above 200 GeV and with $\tan\beta$ between 6 and 15 $\rightarrow$ too heavy to be produced in the e^+e^- mode

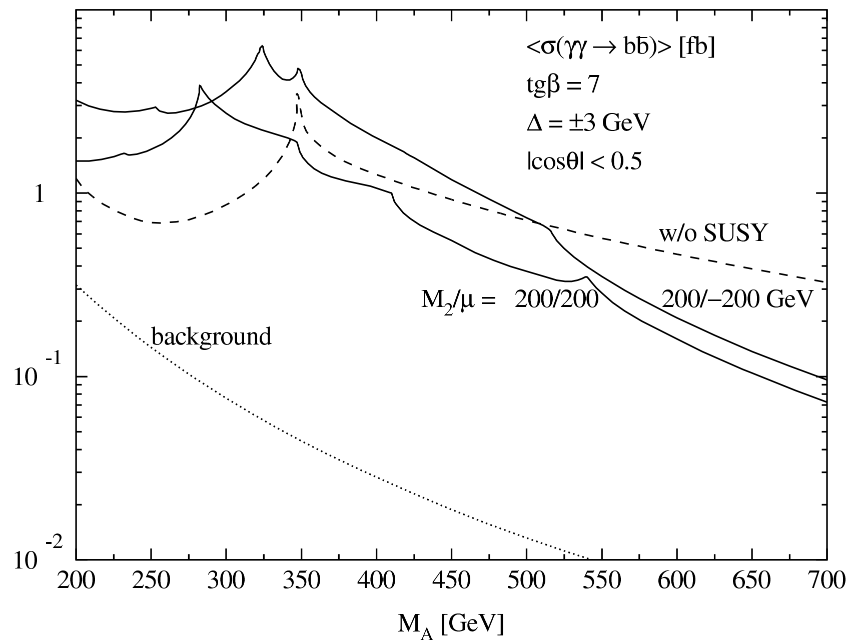
=> would escape discovery at the LHC.

=> could be discovered with the photon collider option

An study of the $b\bar{b}$ final state has been performed for this scenario (NZK)



Kraemer,Mulleitner, Spira, Zerwas



WHAT PLC CAN AND CANNOT DO (A .deRoeck

Reaction	Remarks
$\to H, h \to b\bar{b}$	SM/MSSM Higgs, $M_{H,h} < 160$ GeV
$\to H \to WW(^*)$	SM Higgs, 140$< M_H < 190$ GeV
$\to H \to ZZ(^*)$	SM Higgs, 180$< M_H < 350$ GeV
$\to H \to \gamma\gamma$	SM Higgs, 120$< M_H < 160$ GeV
$\to H \to t\bar{t}$	SM Higgs, $M_H > 350$ GeV
$\to H, A \to b\bar{b}$	MSSM heavy Higgs, interm. $\tan\beta$
$\to \tilde{f}\bar{\tilde{f}},\ \tilde{\chi}_i^+\tilde{\chi}_i^-$	large cross sections
$\to \tilde{g}\tilde{g}$	measurable cross sections
$\to H^+H^-$	large cross sections
$\to S[\tilde{t}\bar{\tilde{t}}]$	$\tilde{t}\bar{\tilde{t}}$ stoponium
$\to \tilde{e}^-\tilde{\chi}_1^0$	$M_{\tilde{e}^-} < 0.9 \times 2E_0 - M_{\tilde{\chi}_1^0}$
$\gamma\gamma \to \gamma\gamma$	non-commutative theories
$e\gamma \to eG$	extra dimensions
$\gamma\gamma \to \phi$	Radions
$e\gamma \to \tilde{e}\tilde{G}$	superlight gravitions
$\to W^+W^-$	anom. W inter., extra dimensions
$\to W^-\nu_e$	anom.W couplings
$\to 4W/(Z)$	WW scatt., quartic anom. W,Z
$\to t\bar{t}$	anomalous top quark interactions
$\to \bar{t}b$	anomalous Wtb coupling

If LHC and e^+e^- Linear Colliders

Standard-Model-like scenario (GKO):

- One Higgs boson will be discovered with mass $M_h > 115$ GeV. Either the SM Higgs boson OR one Higgs boson from two: h and H ($M_h < M_H$) of the 2HDM
- The measured decay widths (or coupling constants squared) to quarks, charged leptons, EW gauge bosons and gluons in agreement with their SM values $\Gamma_i^{\rm SM}$ within the experimental precision

$$\left|\frac{\Gamma_j^{\rm exp}}{\Gamma_j^{\rm SM}} - 1\right| = \left|\left(\frac{g_j}{g_j^{\rm SM}}\right)^2 - 1\right| \lesssim \delta_j \ll 1, \text{ where } j = u, d, V.$$

- No other Higgs boson will be discovered.

Either they are weakly coupled with the Z boson, gluons and quarks, or they are sufficiently heavy (above O (800 GeV) to escape observation.
- All other new particles are heavier than the discovery limits of LHC and the e^+e^- Linear Collider.

SM-like scenarios

χ_j differ by ϵ from ± 1, with $|\epsilon_i| \le \delta_i$. Additional constraints on these ϵ_i follow from the pattern relation.

The loop-induced transition rate $h \to \gamma\gamma$ and $h \to Z\gamma$ will differ from the SM prediction due to the charged Higgs boson contribution, proportional to the trilinear Higgs coupling hH^+H^-:

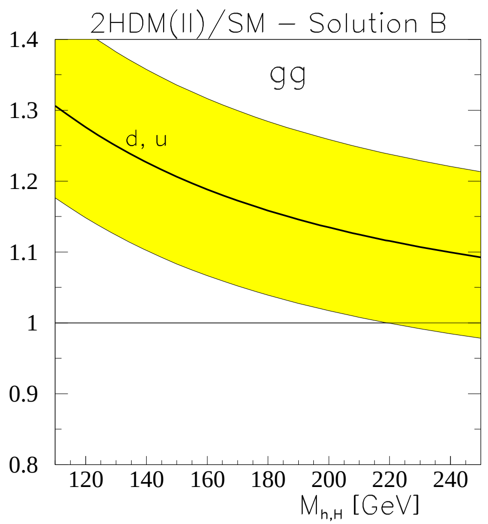
$$\chi^h_{H^\pm} \equiv -\frac{v g_{hH^+H^-}}{2M^2_{H^\pm}} = \left(1 - \frac{M_h^2}{2M^2_{H^\pm}}\right)\chi^h_V + \frac{M_h^2 - \mu^2}{2M^2_{H^\pm}}(\chi^h_u + \chi^h_d)$$

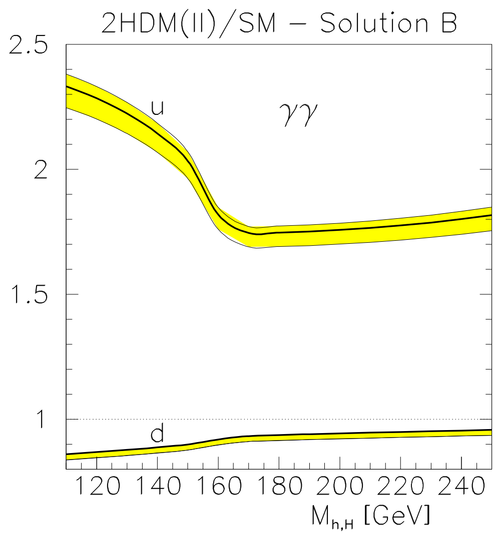
Two different types of realizations of a SM-like limit of the 2HDM II:

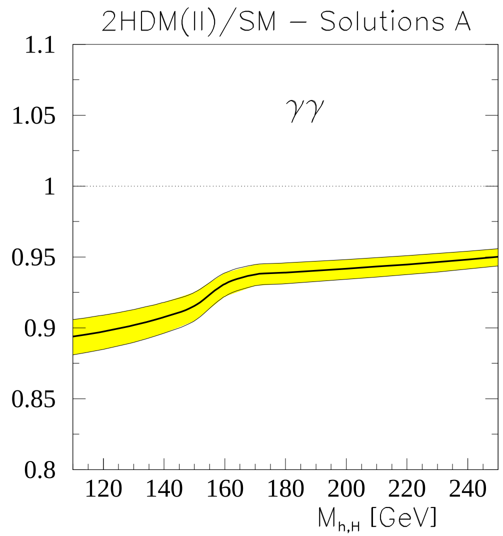
- solutions A all basic (relative) couplings are close to 1 or all are close to -1
- solutions B, one basic coupling, χ_u or χ_d, has opposite sign to the other two

solution	basic couplings	$\lvert\chi_{gg}\rvert^2$	$\lvert\chi_{\gamma\gamma}\rvert^2$	$\lvert\chi_{Z\gamma}\rvert^2$
$A_{h\pm}$	$\chi_V \approx \chi_d \approx \chi_u \approx \pm 1$	1.00	0.90	0.96
$B_{h\pm d}$	$\chi_V \approx -\chi_d \approx \chi_u \approx \pm 1$	1.28	0.87	0.96
$B_{h\pm u}$	$\chi_V \approx \chi_d \approx -\chi_u \approx \pm 1$	1.28	2.28	1.21

The two-gluon decay-width and two-photon decay-width







The shaded bands reflecting experimental uncertainties

Note, that

$$|\chi_{\gamma\gamma}|^2 = 1 + \left(\frac{M_h^2}{2M_{H+}^2}\right) - \left(\frac{\mu^2}{M_{H+}^2}\right).$$

Determination of CP violating H-A mixing from $h_2 \to WW,\ ZZ$ decays in 2HDM: PLC and comparison with LHC and LC.

A.F. Żarnecki, Warsaw University

with P. Nieżurawski and M. Krawczyk

NŻK

ECFA Study
SUSY/Higgs working group meeting
CERN, March 18-19, 2004
LCWS 2004, Paris

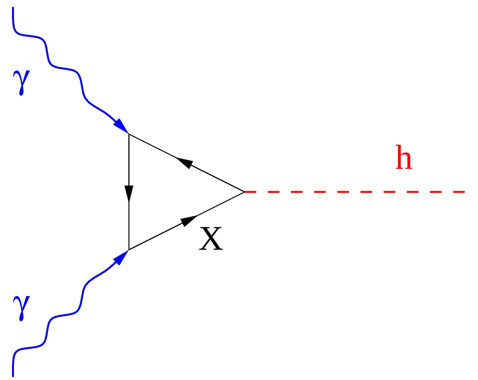
Outline

- Higgs boson production and decays to WW and ZZ at PLC JHEP 0211 (2002) 034 [hep-ph/0207294]
- Weak CP violation in SM-like 2HDM (II) at PLC hep-ph/0307175; hep-ph/0403138
- Comparison with LHC and LC in LHC/LC WG, hep-ph/0404024

$$\gamma\gamma \to \mathcal{H} \to WW,\ ZZ$$

Higgs boson production at the Photon Collider

Production cross section is proportional to the two-photon width



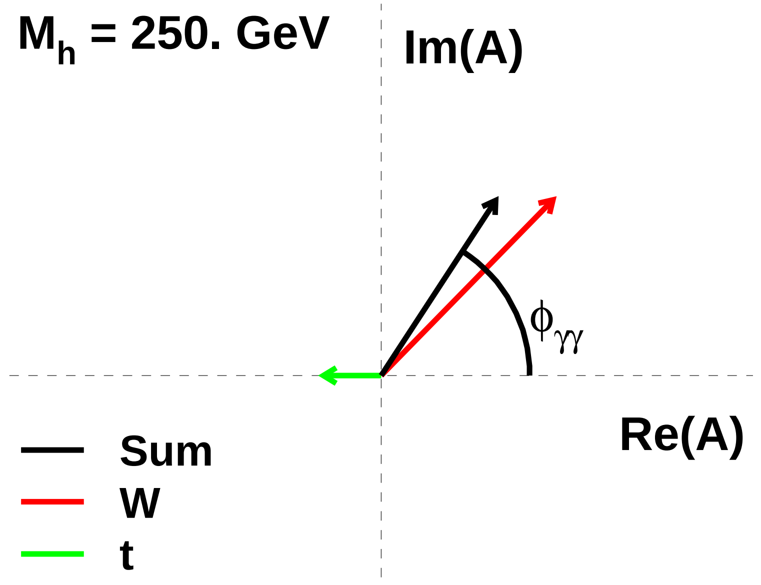
$$\Gamma(h \to \gamma\gamma) = \frac{G_F \alpha^2 M_h^3}{128\sqrt{2}\,\pi^3} \cdot |\mathcal{A}|^2$$

where:

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

two-photon amplitude

In SM, dominant contributions to two-photon amplitude $\mathcal{A}$ are due to $W^{\pm}$ and top loops.



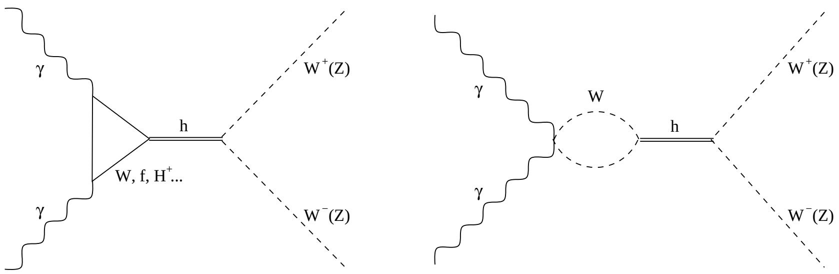
Phases of $W^{\pm}$ and top contributions differ !

The phase of the amplitude $\phi_{\gamma\gamma}$ depends on Higgs-boson couplings !

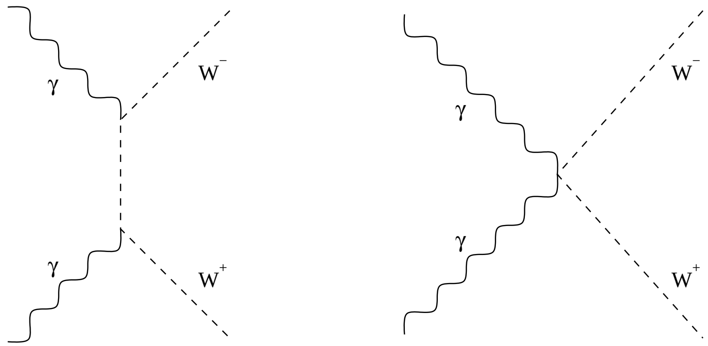
$\gamma\gamma \to \mathcal{H} \to WW,\ ZZ$

We consider Higgs boson production and decays to WW/ZZ, for masses 200–350 GeV.

For resonant $\gamma\gamma \to h \to W^+W^-$ signal

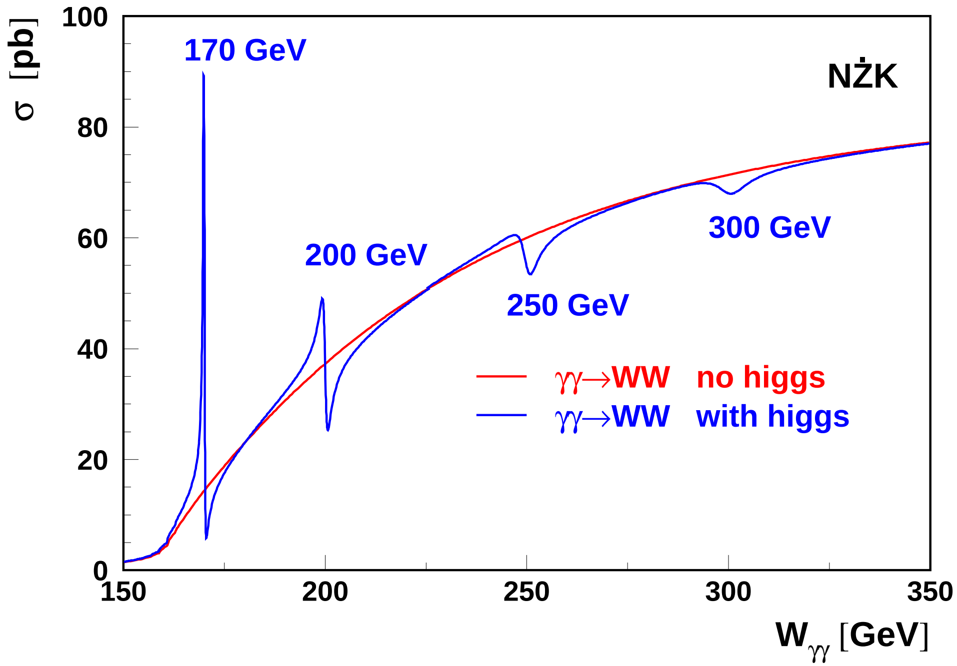


there is a large non-resonant bg.



Large interference effects are expected in the considered mass range (Morris,Ginzburg,..)

J=0



Interference is sensitive to the phase of the two-gamma amplitude

Partial Summary

SM-like scenario can be realized at the LHC and e^+e^- Linear Colliders. An anticipated uncertainties in future measurements of the basic couplings of the Higgs boson (in SM case) are known.

Goal: to establish how one can discriminate models, the SM and the 2HDM (II), for a Higgs boson with mass 110–250 GeV (which can be either one of two scalars of the 2HDM, h or H).

Method : as basic quatities we use ratios of measurable couplings of the Higgs boson with quarks and electroweak gauge bosons to their SM values. We obtain a useful pattern relation among them. To establish deviation from SM we study the $\gamma\gamma$ and $Z\gamma$ (also $gluon - gluon$) partial widths.

Types of SM-like scenarios in 2HDM: the pattern relation allows for two types of SM-like solutions:

A - all basic couplings are close to their SM values.
B - some of basic couplings are close to their SM values while others differ in sign from the SM values.

Conclusion: with anticipated high accuracy of measuring $\gamma\gamma$ width at a Photon Collider, this measurement could in general resolve the 2HDM (II) and the SM.

On NZK results $\longrightarrow$ next semester!