Interplay of LHC, LC and PLC in testing the 2HDM (II) for Higgs mass between 200 and 350 GeV

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Outline

- Higgs couplings in 2HDM (II)
- Higgs production at LHC, LC, and PLC
- Interplay of different colliders in testing Higgs boson couplings

2HDM (II)

Higgs boson couplings

We consider light scalar Higgs boson h
in the CP-conserving Two Higgs Doublet Model.

Basic couplings, relative to SM:

$$\chi_x \;=\; g_{\mathcal{H}xx}/g^{SM}_{\mathcal{H}xx} \qquad \mathcal{H} = h, H, A$$

	h	H	A
χ_u	$\frac{\cos\alpha}{\sin\beta}$	$\frac{\sin\alpha}{\sin\beta}$	$-i\,\gamma_5\,\frac{1}{\tan\beta}$
χ_d	$-\frac{\sin\alpha}{\cos\beta}$	$\frac{\cos\alpha}{\cos\beta}$	$-i\,\gamma_5\,\tan\beta$
χ_V	$\sin(\beta-\alpha)$	$\cos(\beta-\alpha)$	0

For charged Higgs boson couplings
(loop contribution to $\Gamma_{\gamma\gamma}$) we set

$$M_{H^\pm} = 800\ GeV \qquad \mu = 0$$

Boson couplings are related by
“patter relation”

$$(\chi_V - \chi_d)(\chi_u - \chi_V) + \chi_V^2 \;=\; 1$$

or

$$(\chi_u + \chi_d)\chi_V \;=\; 1 + \chi_u\chi_d$$

Instead of angles α and β we use couplings χ_V and χ_u to parametrize cross sections and BRs.

2HDM (II)

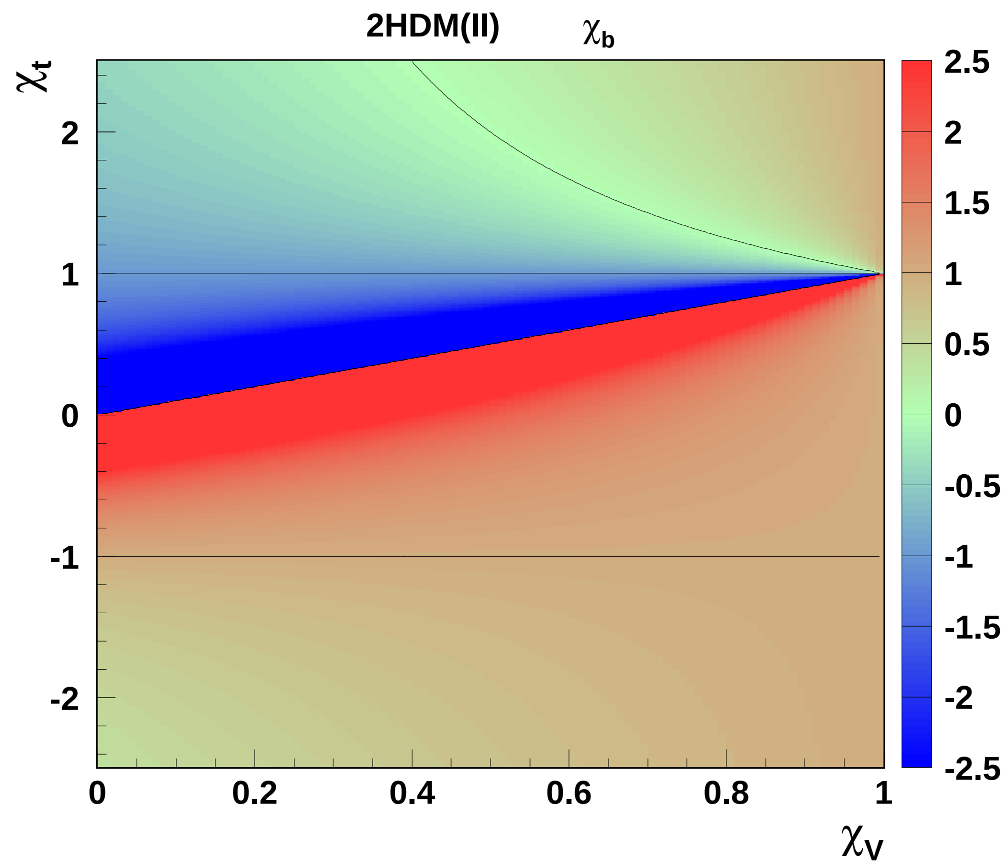
As the overall sign of Higgs couplings does not matter we choose

$$0 \leq \chi_V \leq 1$$

Third basic relative coupling

$$\chi_d = \chi_V + \frac{1-\chi_V^2}{\chi_V - \chi_u}$$

If we neglect H decays to h and A cross sections and BRs calculated for h are also valid for H

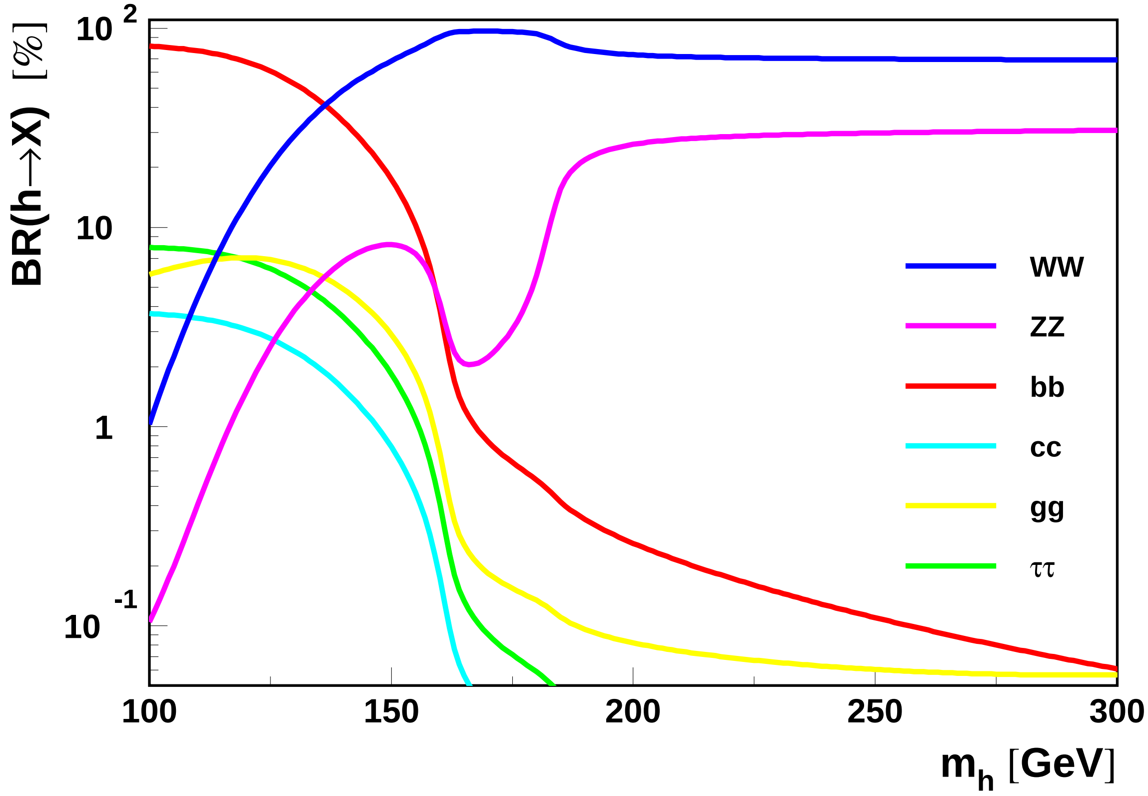


2HDM (II)

We consider Higgs boson production at LHC, LC and PLC, for Higgs boson mass between 200 and 350 GeV.

For SM-like scenarios ($\chi \sim 1$) Higgs boson decays to WW and ZZ dominate.

SM branching ratios



LHC

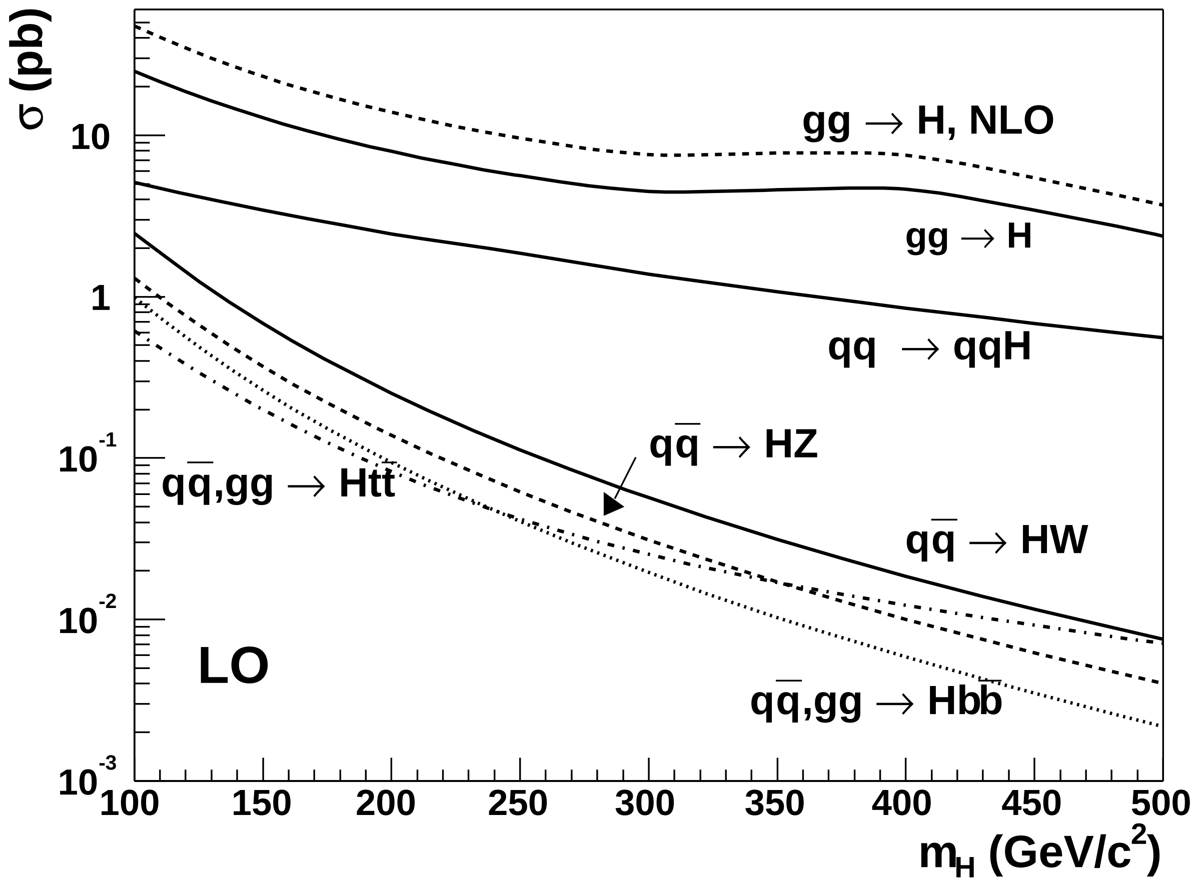
In the considered mass range Higgs boson production at LHC is dominated by the gluon fusion process.

Γ_{hgg} is dominated by the top loop contribution $\Rightarrow$

$$\sigma(gg \to h) \;\sim\; \chi_t^2$$

WW fusion process contributes to about 15% of cross section

$$\sigma(qq \to qqh) \;\sim\; \chi_V^2$$



SM Higgs boson production at LHC

LHC

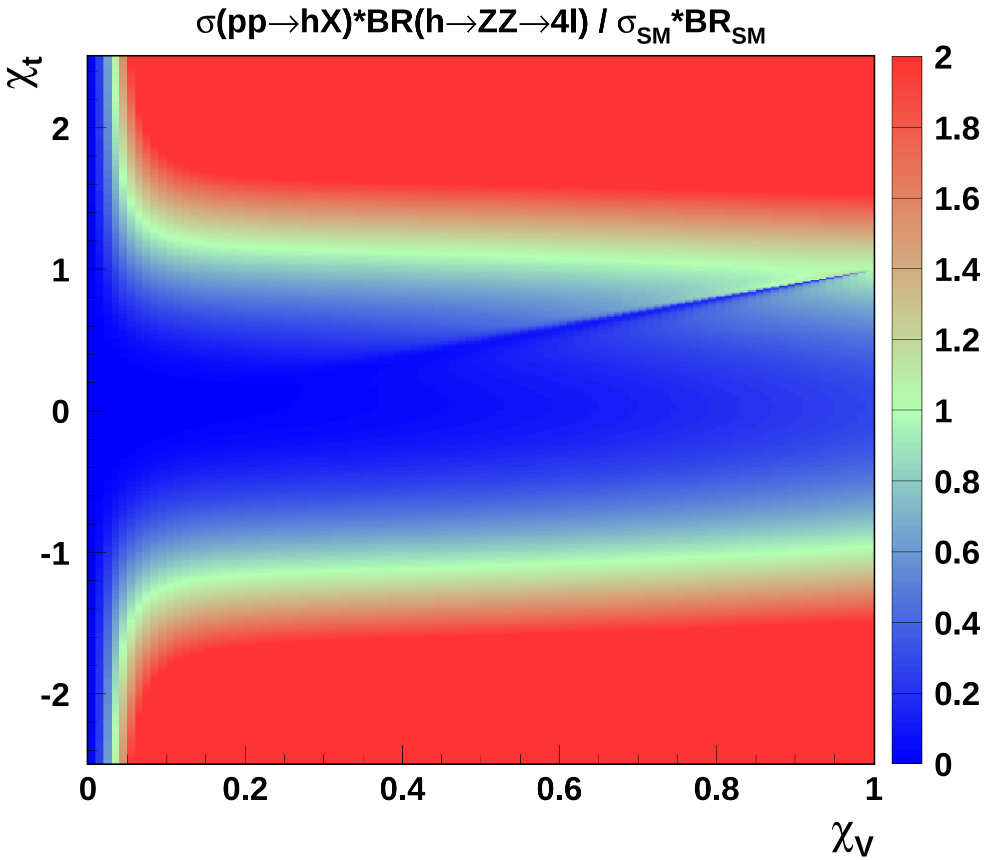
Measurement of the production cross section times branching ratio

$\sigma(pp \to hX) \cdot BR(h \to ZZ \to 4l)$

is possible with precision $\sim$ 15%
(SM-like scenario, 30 fb^{-1})
CMS TN/95-018, CMS CR/2002-020

This will constrain the $|\chi_t|$ value, provided χ_V is not too small.

Cross section relative to SM



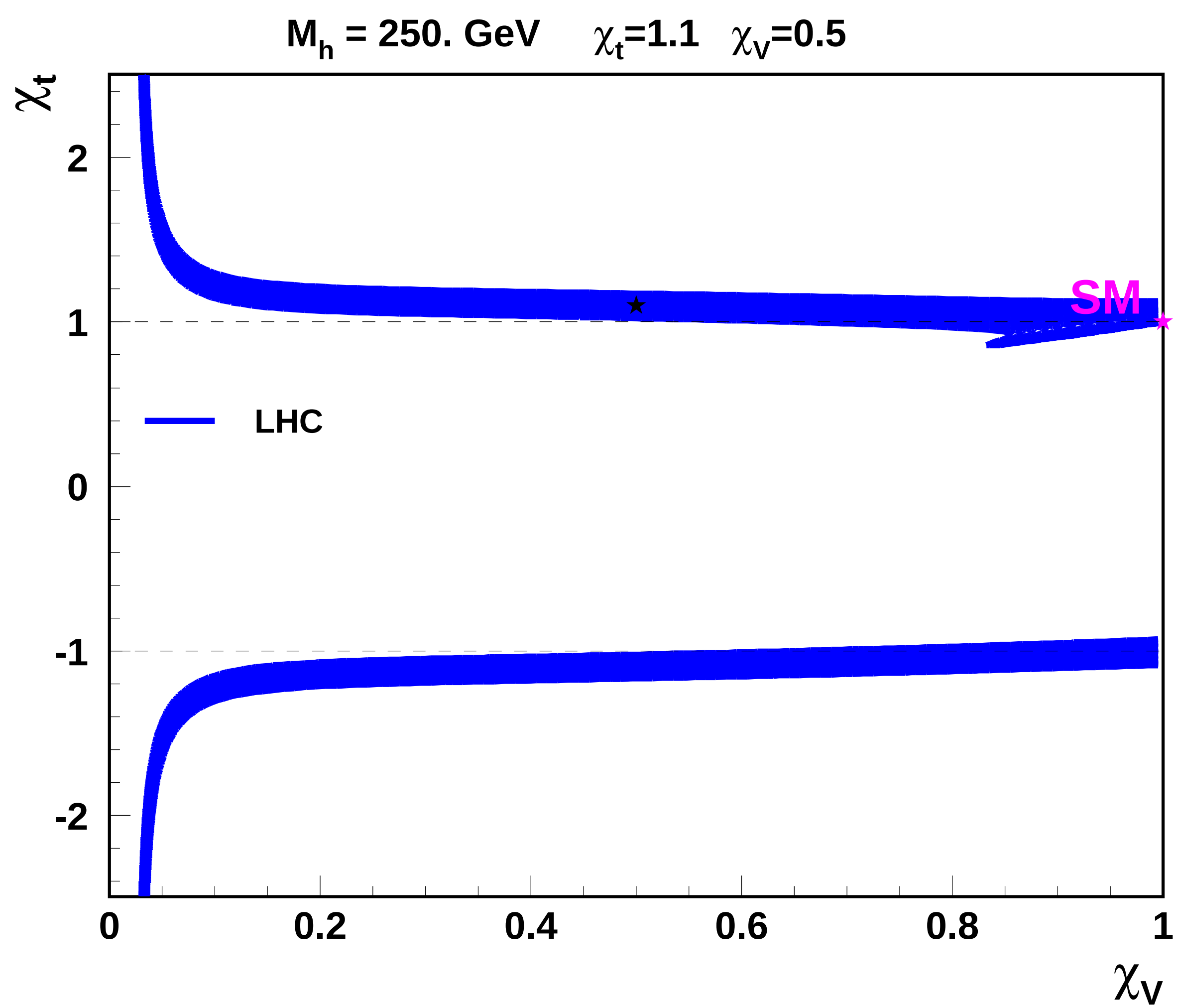
LHC

Allowed coupling values from cross section measurements at LHC

Assumed parameter values:

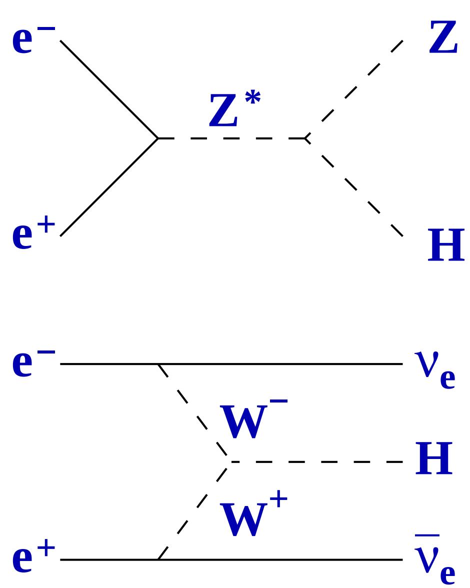
$$M_h = 250\ GeV$$
$$\chi_V = 0.5$$
$$\chi_t = 1.1$$

resulting in the cross section value consistent with SM

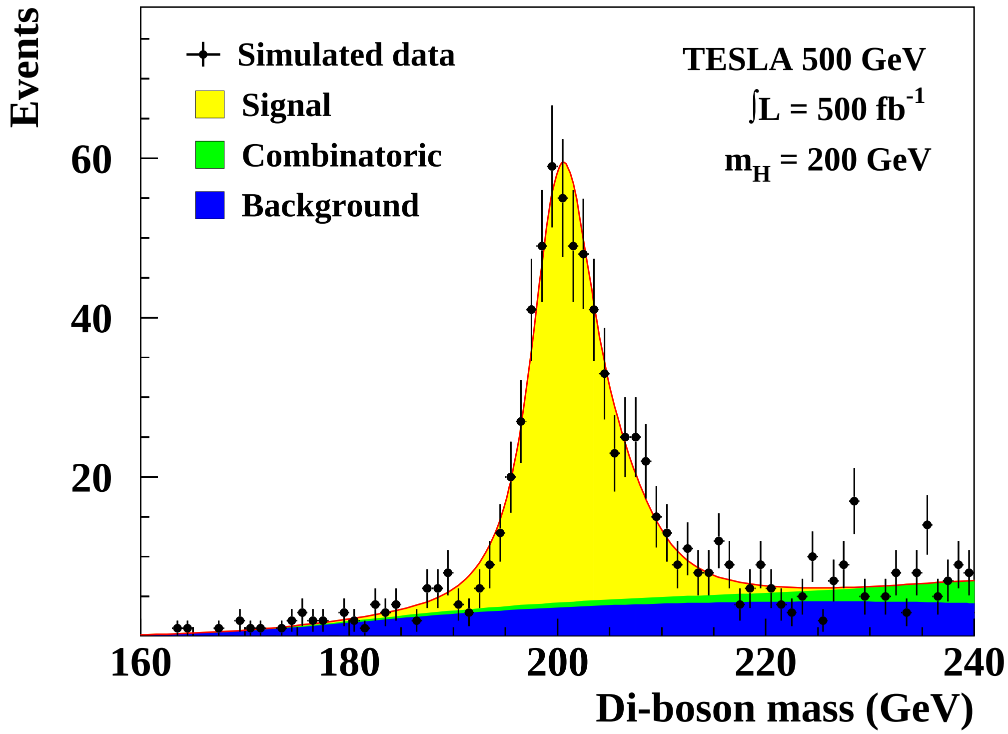


LC

For Higgs boson production at TESLA
($\sqrt{s} = 500\ GeV$, 500 fb^{-1})
two processes are considered



Expected mass distribution (SM)



Production is sensitive only to χ_V

N.Meyer LC-PHSM-2003-066

LC

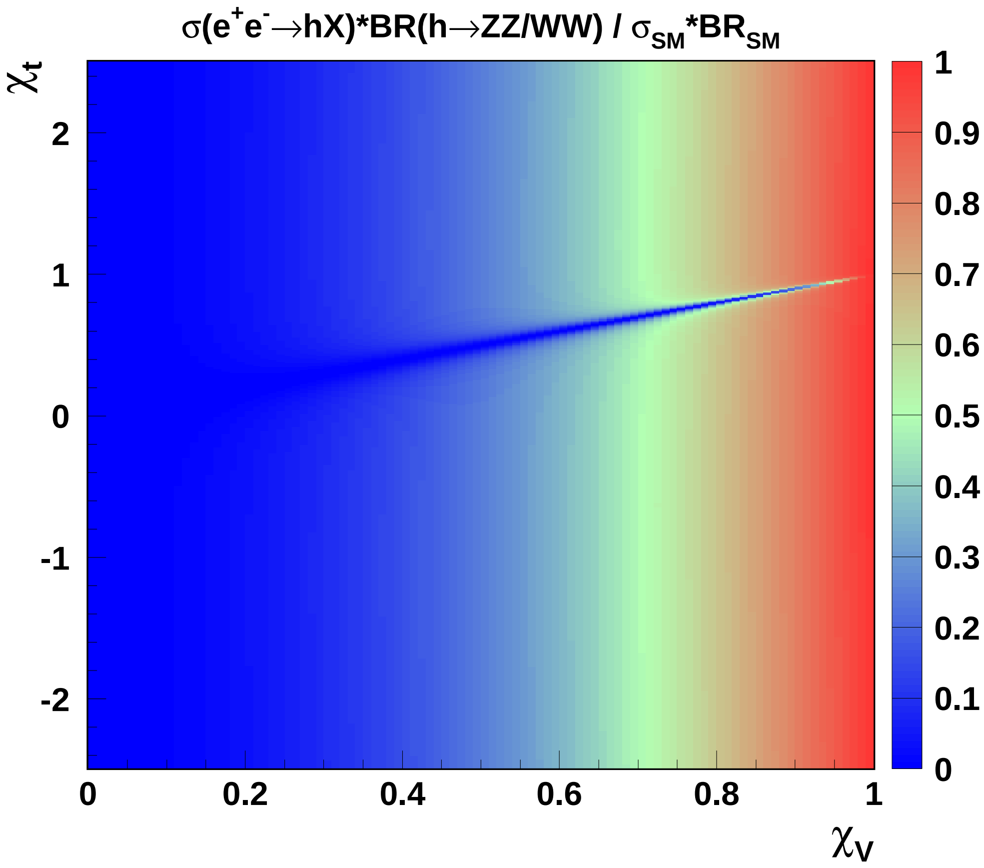
Measurement of the production cross section times branching ratio

$$\sigma(e^+e^- \to hX) \cdot BR(h \to WW/ZZ)$$

is possible with precision $\sim 4-7\%$
(SM-like scenario, 500 fb^{-1})

This will constrain the χ_V value

Cross section relative to SM

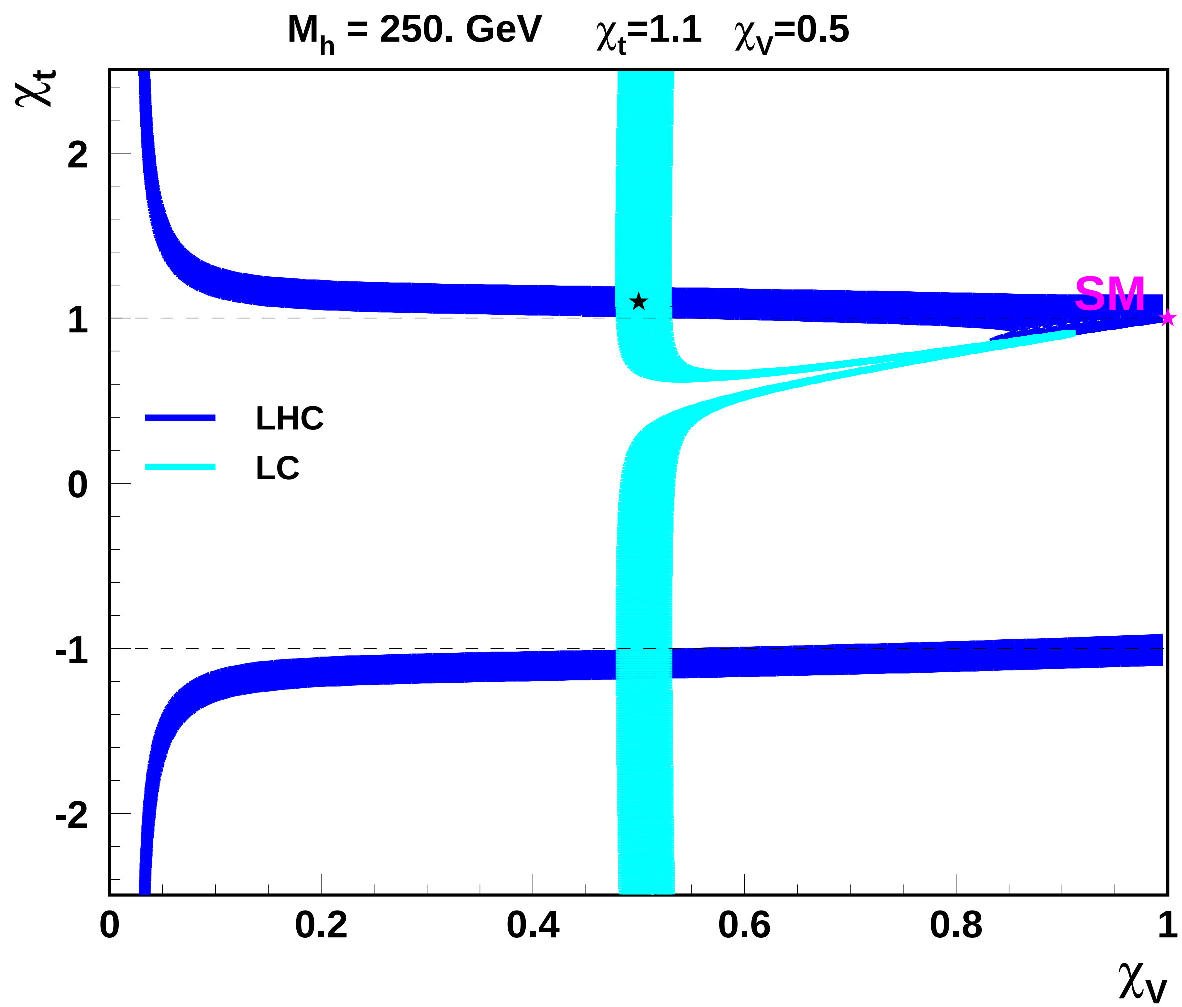


LC

Allowed coupling values from cross section measurements at LHC and LC

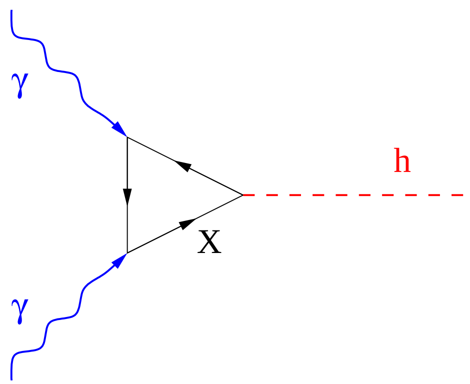
Combining measurements at LHC and LC we can constrain both $|\chi_t|$ and χ_V

However, sign of χ_t (relative to χ_V) can not be determined.



PLC

Cross section for the Higgs boson production at the Photon Collider is proportional to the two-photon width



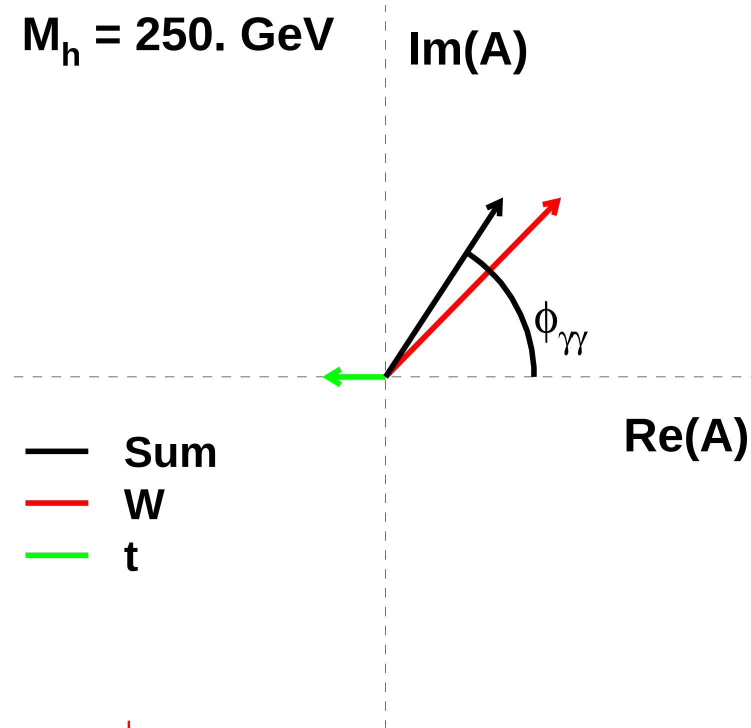
$$\Gamma(h \to \gamma\gamma) = \frac{G_F \alpha^2 M_h^3}{128\sqrt{2}\,\pi^3} \cdot |\mathcal{A}|^2$$

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 !

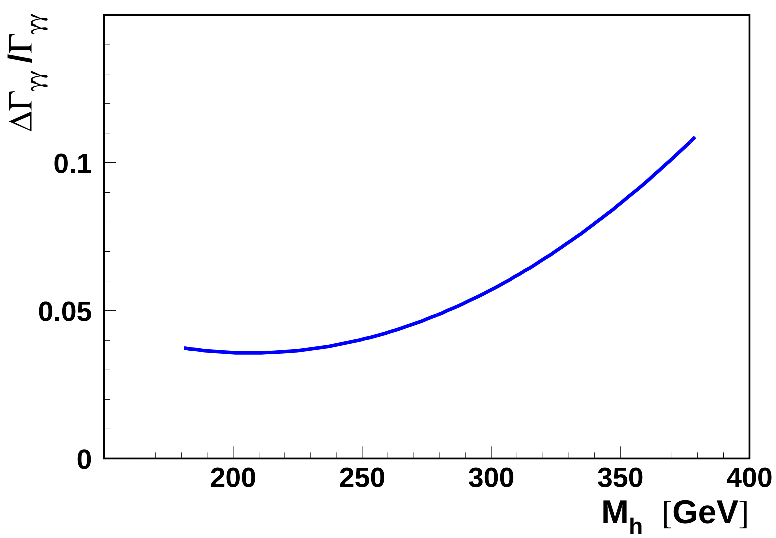
$\Rightarrow$ the phase of the amplitude $\phi_{\gamma\gamma}$ depends on χ_V and χ_t

PLC

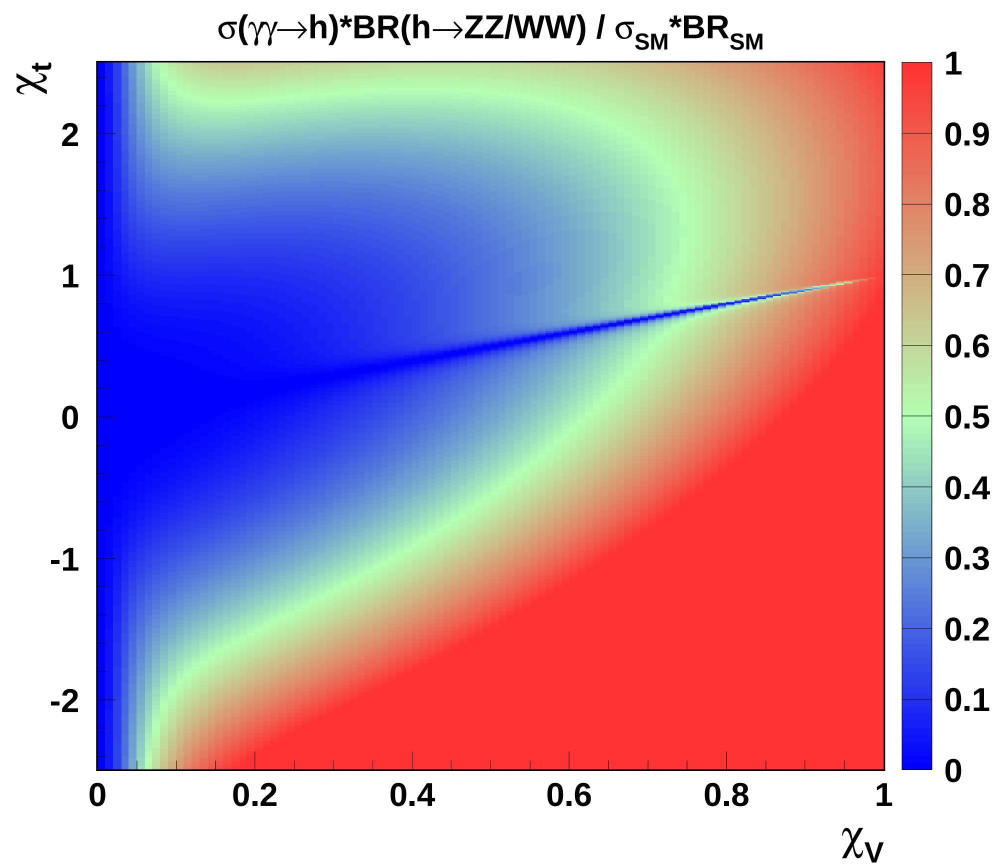
Measurement of the production cross section times branching ratio

$$\sigma(\gamma\gamma \to h) \cdot BR(h \to WW/ZZ)$$

is possible with precision $\sim 4 - 9\%$



Cross section relative to SM



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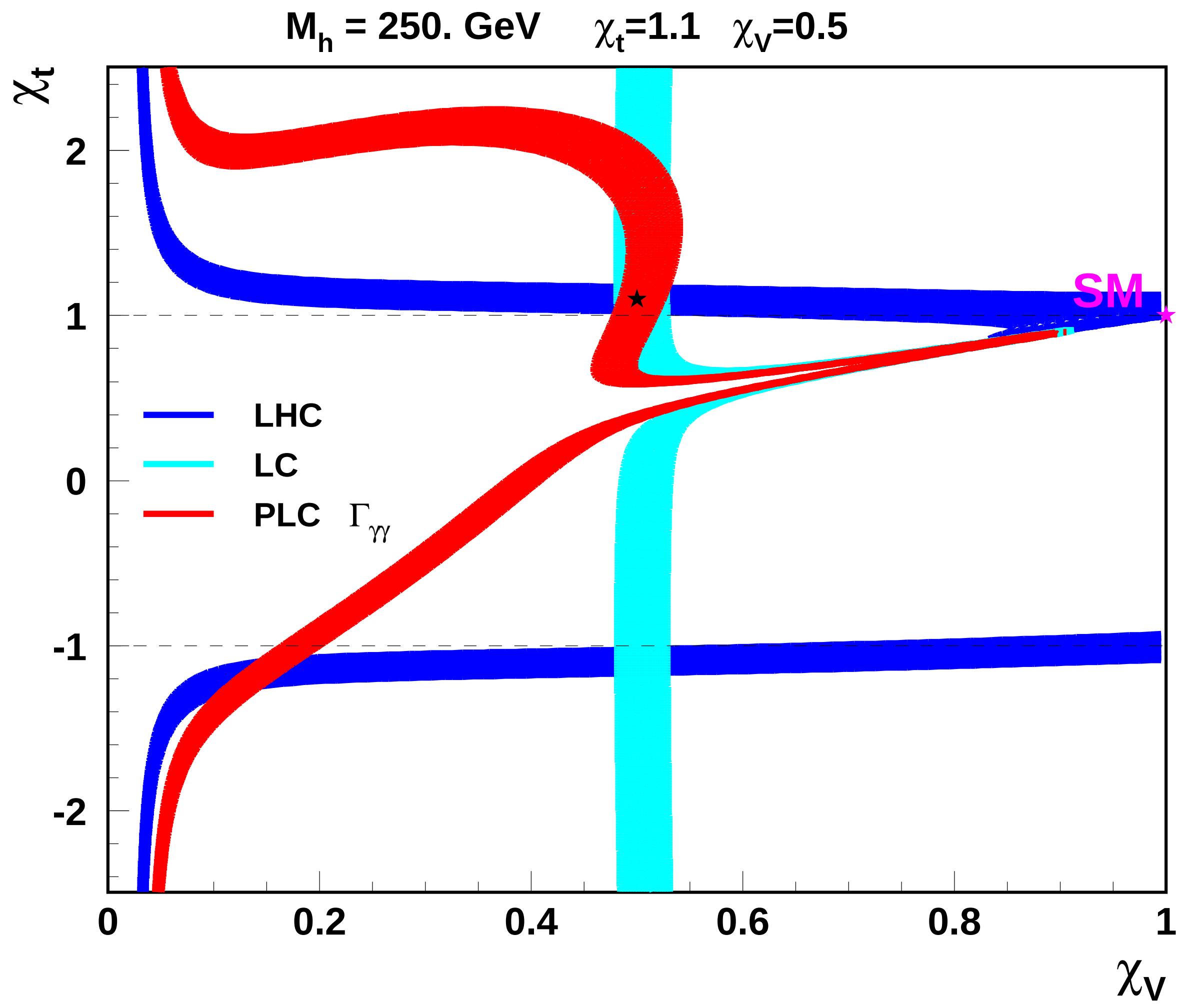
PLC

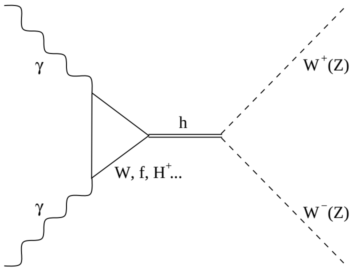
Allowed coupling values from cross section measurements at LHC, LC and PLC

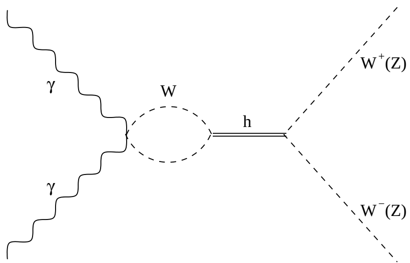
Sign of χ_t can be uniquely determined.



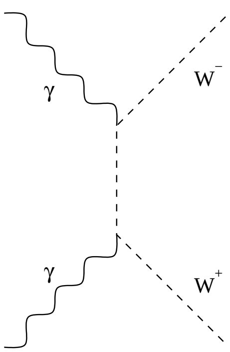
PLC

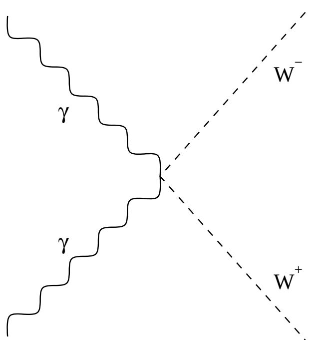
For resonant $\gamma\gamma \to h \to W^+W^-$ signal



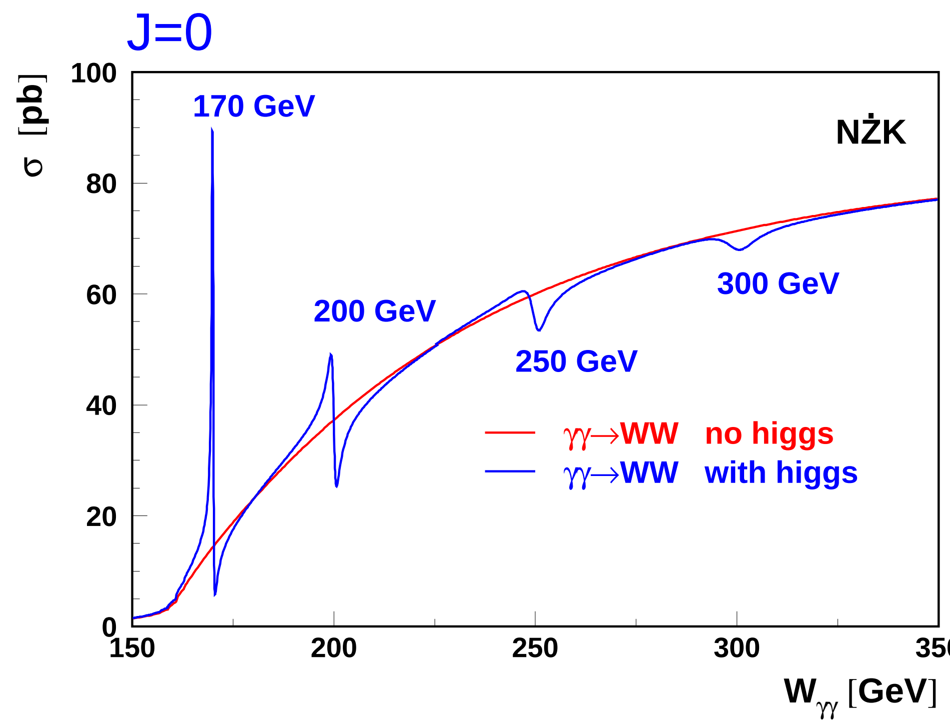


there is a large non-resonant bg.





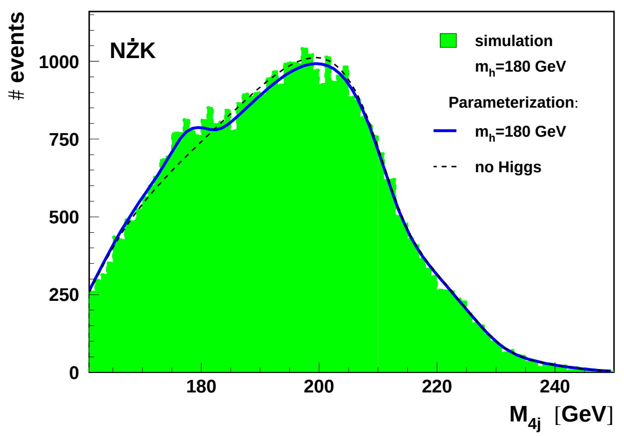
Large interference effects are expected in the considered mass range

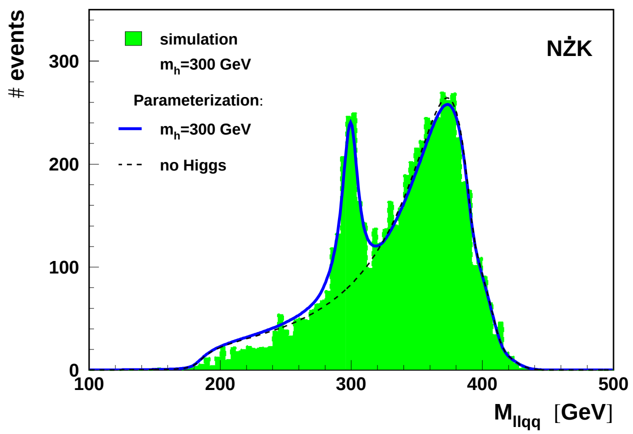


Interference is sensitive to the phase of the two-gamma amplitude

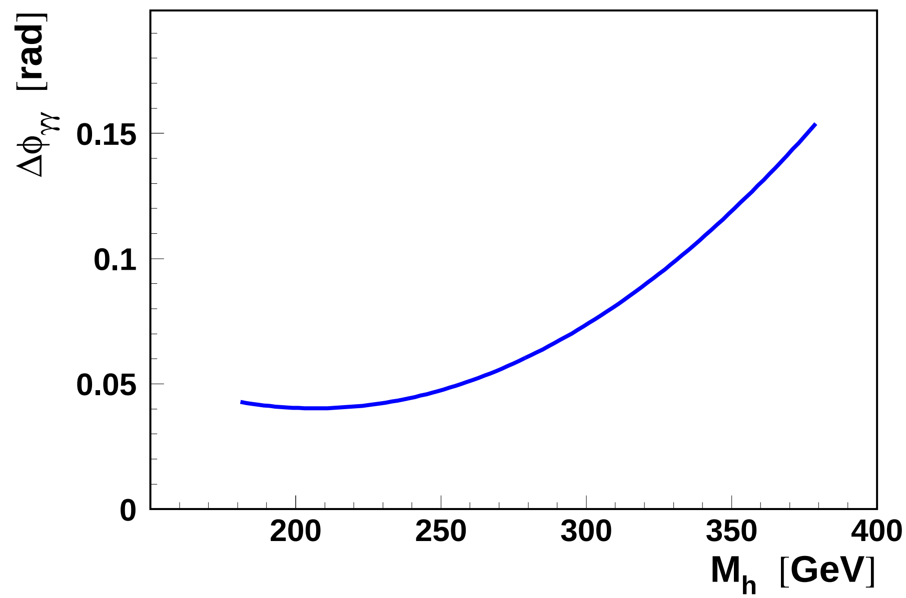
PLC

From the simultaneous fit to the observed W^+W^- and ZZ mass spectra both the two-photon width $\Gamma_{\gamma\gamma}$ and phase $\phi_{\gamma\gamma}$ can be determined.





$\phi_{\gamma\gamma}$ can be measured with precision 40 – 120 mrad



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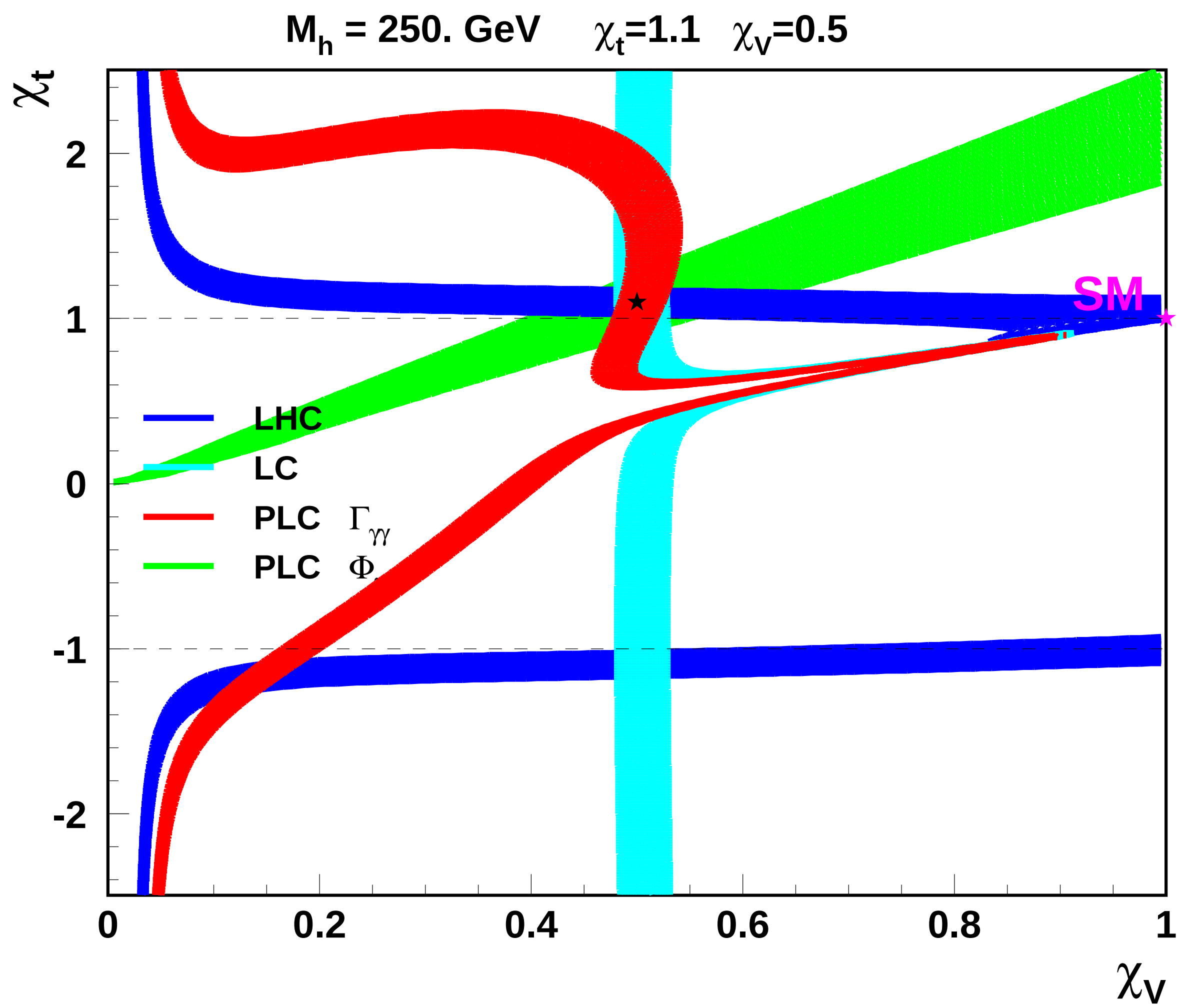
PLC

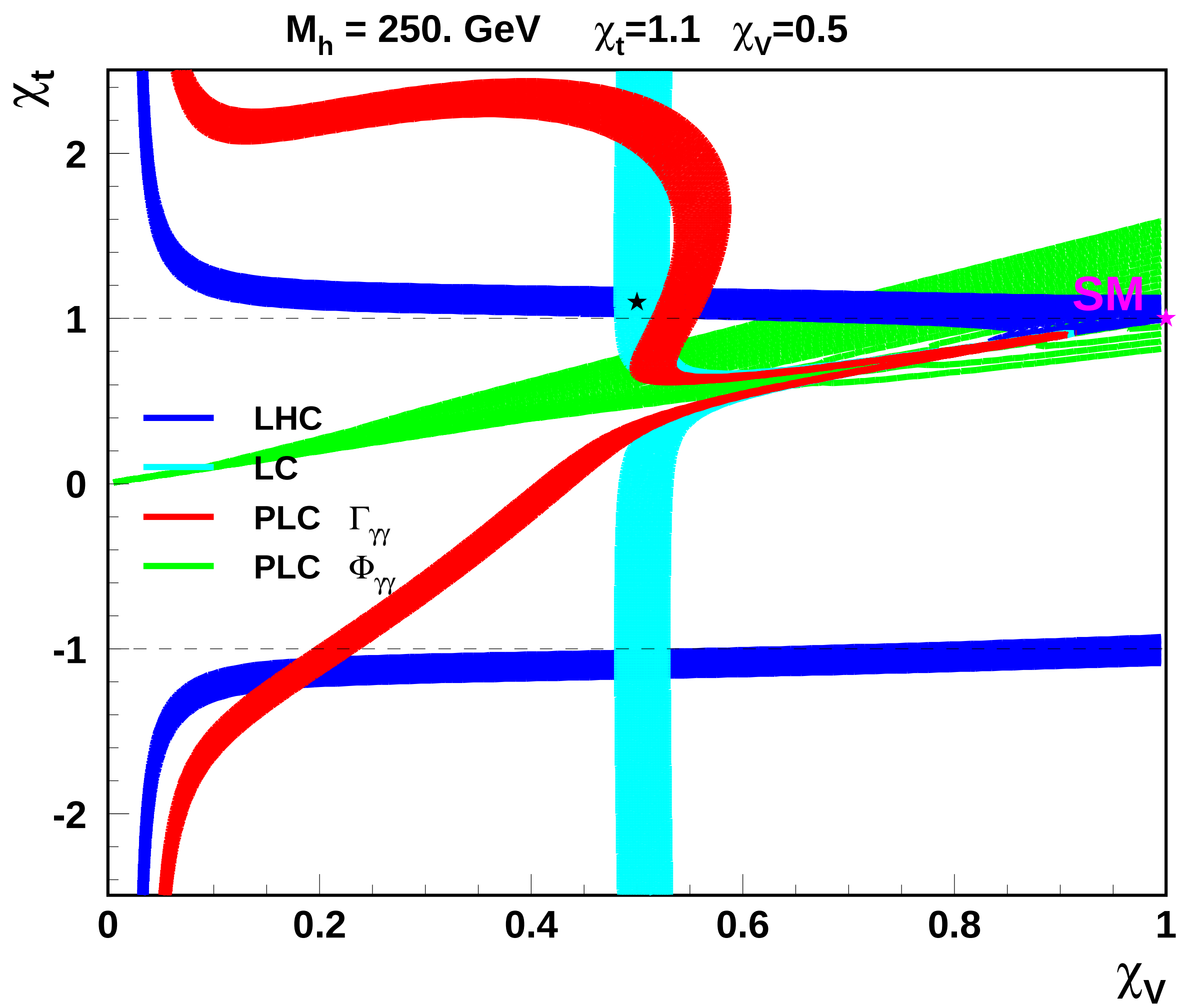
Allowed coupling values from cross section measurements at LHC, LC and PLC, and the phase measurement at PLC.

Consistency of these measurements verifies coupling structure of the model



PLC

Allowed coupling values from cross section measurements at LHC, LC and PLC, and the phase measurement at PLC.



Inconsistency would indicate existence of new heavy particles, contributing to Γ_{gg} and $\Gamma_{\gamma\gamma}$

Results for new charged lepton with mass of 10 TeV $\Rightarrow$

Summary

Measurement of the scalar Higgs boson production at LHC, LC and PLC was studied for CP-conserving 2HDM (II) and Higgs boson mass between 200 and 350 GeV

Cross section measurements at LHC, LC and PLC give complementary constraints on the Higgs boson couplings

By combining all measurements coupling structure and particle contents of the model can be tested.