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

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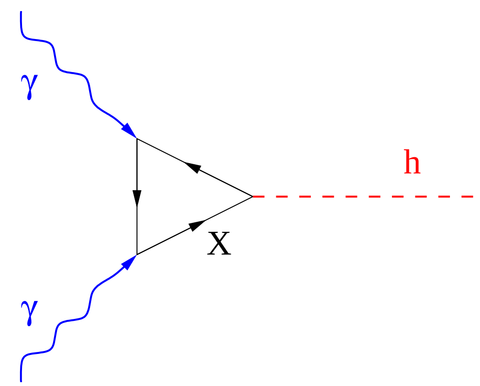
Outline

- 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

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

Higgs boson production at the Photon Collider

Production cross section is proportional to the two-photon width



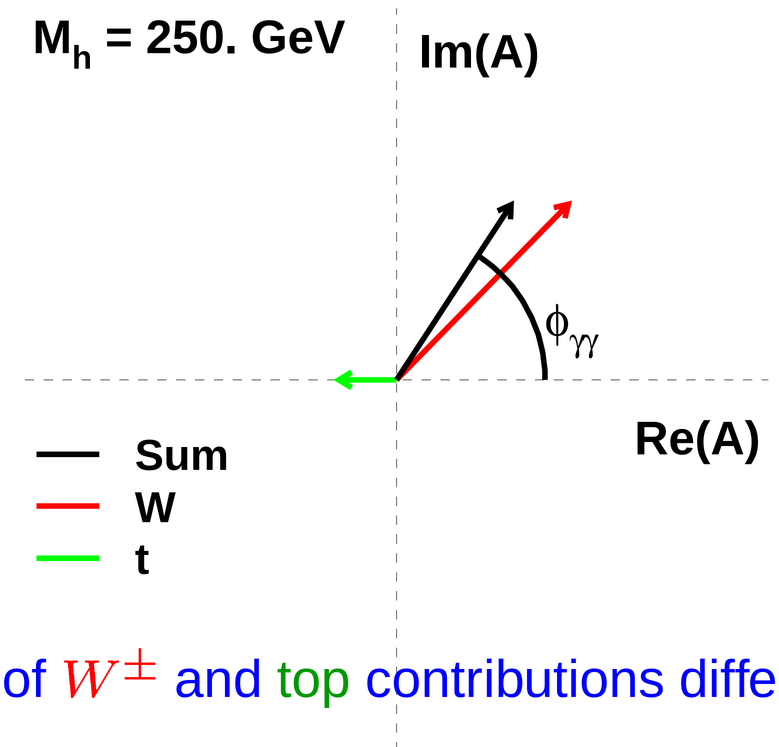
$$\Gamma(h \to \gamma\gamma) \;=\; \frac{G_F \alpha^2 M_h^3}{128\sqrt{2}\,\pi^3} \cdot |\mathcal{A}|^2$$

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.



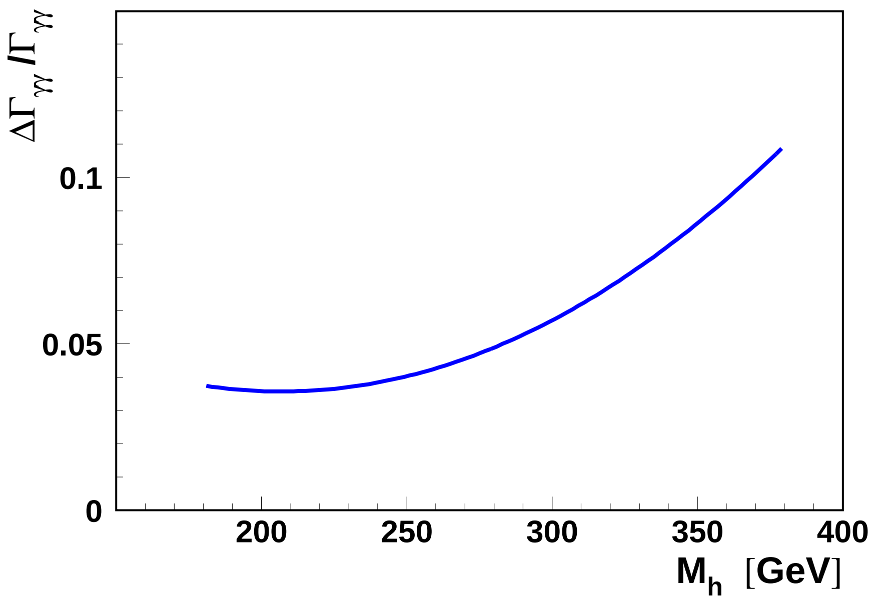
Phases of $W^\pm$ and top contributions differ !

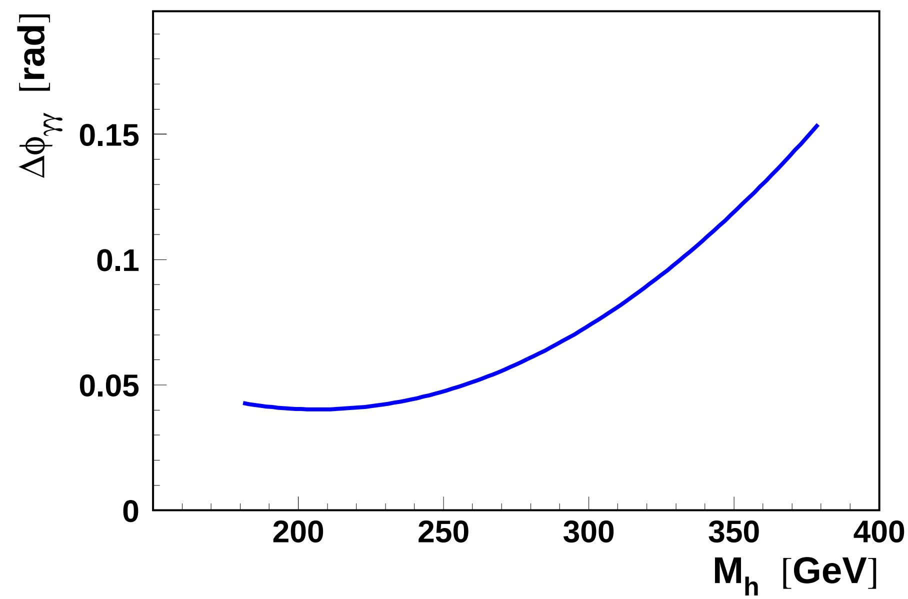
The phase of the amplitude $\phi_{\gamma\gamma}$ depends on Higgs-boson couplings !

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

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.

For SM: $\Gamma_{\gamma\gamma}$ with precision $\sim 4 - 9\%$ $\phi_{\gamma\gamma}$ with precision $40 - 120$ mrad





JHEP 0211 (2002) 034 [hep-ph/0207294]

A.F.Żarnecki, ECFA/DESY workshop, November 2002, Praha (including systematic uncertainties)

2HDM(II)

SM-like 2HDM(II)

We consider SM-like **solution B_h**

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	-1	$-\frac{1}{\tan\beta}$	$-i\,\gamma_5\,\frac{1}{\tan\beta}$
χ_d	$+1$	$-\tan\beta$	$-i\,\gamma_5\,\tan\beta$
χ_V	$\cos(2\beta)$	$-\sin(2\beta)$	0

CP conserving model:

Higgs production ($\Gamma_{\gamma\gamma}$ and $\phi_{\gamma\gamma}$) and decays depend on $\tan\beta$ only.

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

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

CP violation

Mass eigenstates of the neutral Higgs-bosons h_1, h_2 and h_3 do not need to match CP eigen-states h, H and A.

We consider weak CP violation through a small mixing between H and A states:

$$\begin{aligned}
\chi^{h_1}_X &\approx \chi^h_X \\
\chi^{h_2}_X &\approx \chi^H_X \cdot \cos\Phi_{HA} + \chi^A_X \cdot \sin\Phi_{HA} \\
\chi^{h_3}_X &\approx \chi^A_X \cdot \cos\Phi_{HA} - \chi^H_X \cdot \sin\Phi_{HA}
\end{aligned}$$

$\Rightarrow$ additional model parameter:

CP-violating mixing phase Φ_{HA}

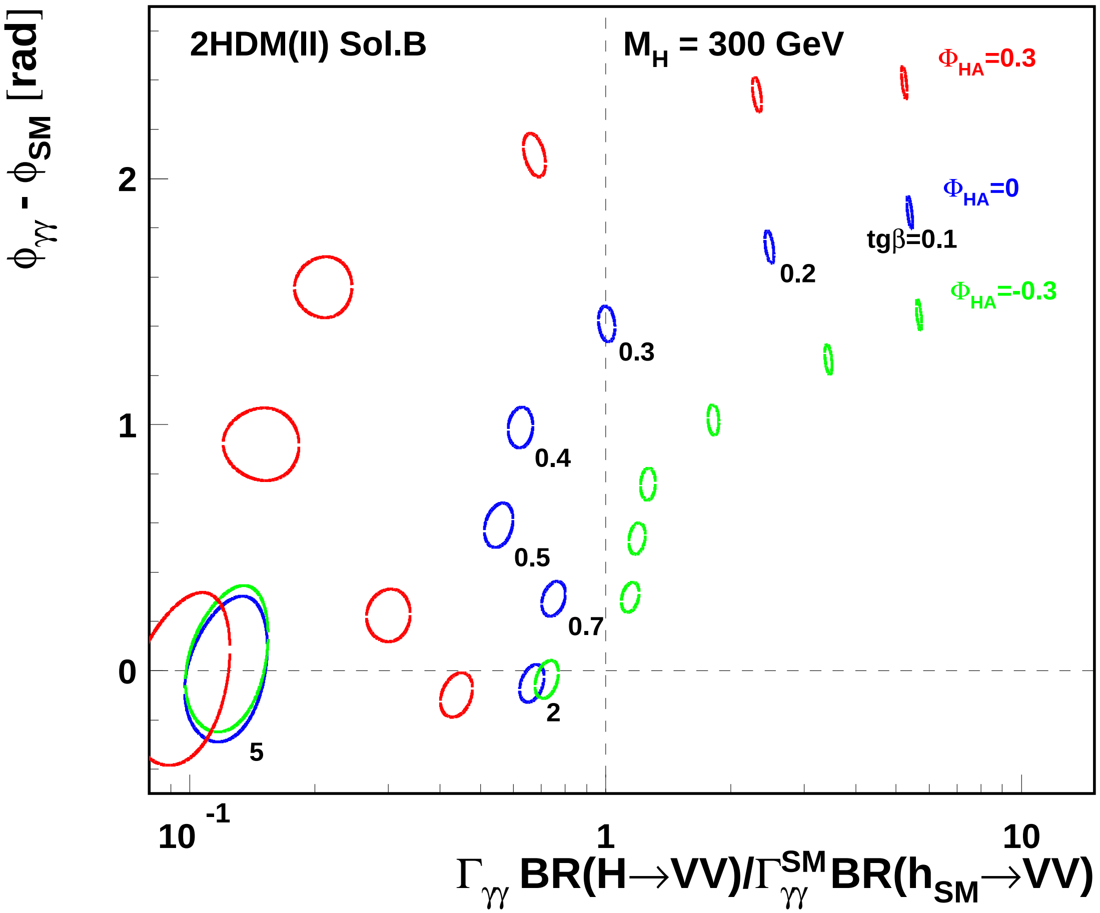
We consider h_2 production and decays

2HDM(II)

Higgs boson h_2

Two-photon width and phase measurement for different $\tan\beta$ and Φ_{HA}

M_{h_2} = 300 GeV



1σ contours for 1 year of PC running

statistical errors only

M_h=120 GeV, M_{H+}=800 GeV

Expected precision at PLC:

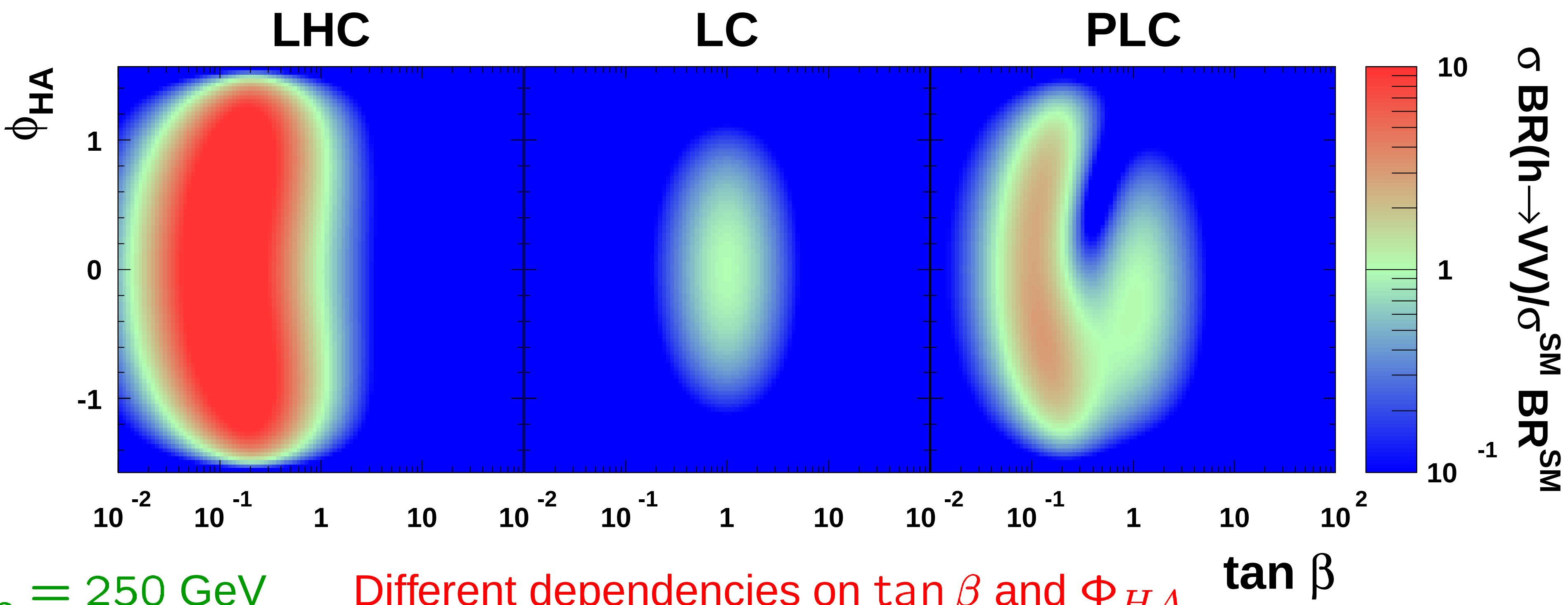
(for small mixing i.e. $\Phi_{HA} \sim 0$)

- $\sim$ 10 % for $\tan\beta$
- $\sim$ 100 mrad for Φ_{HA} (for low $\tan\beta$)

Comparison

Higgs boson h_2 (Solution B_h with weak CP violation)

Expected Higgs-boson production rates times W^+W^-/ZZ branching ratios, relative to SM predictions, as a function of $\tan\beta$ and the CP violating mixing angle Φ_{HA}



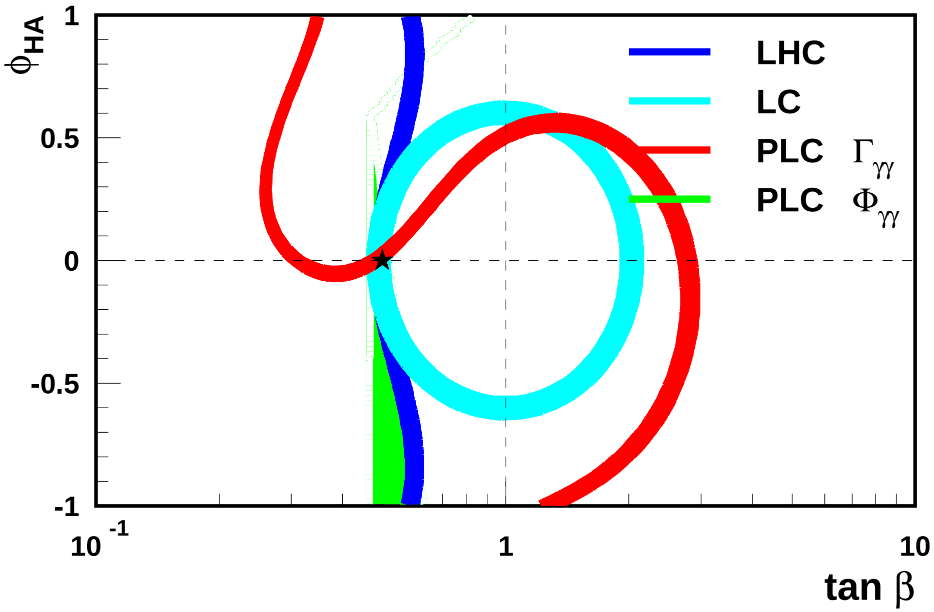
$M_{h_2} = 250$ GeV Different dependencies on $\tan\beta$ and Φ_{HA}

Comparison

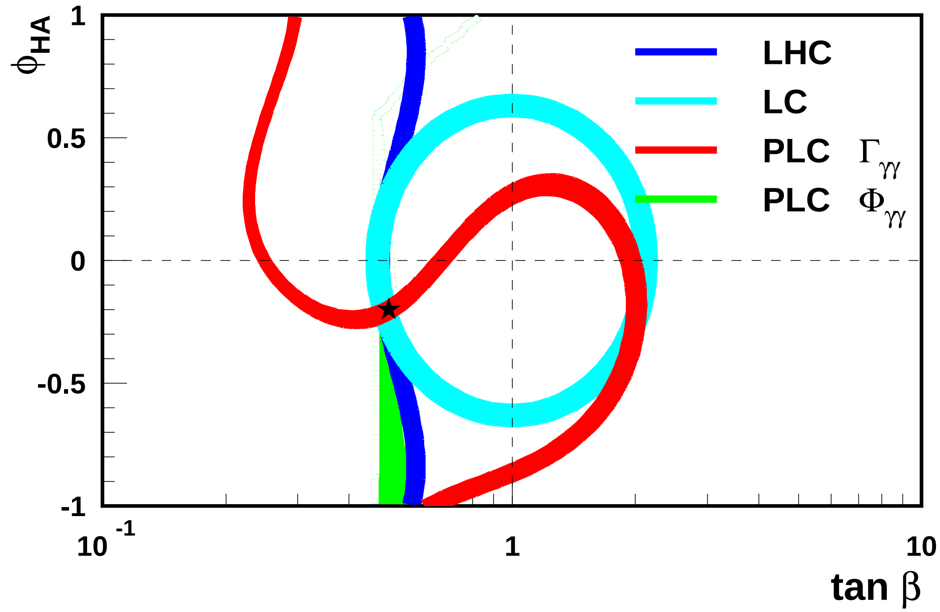
LHC $\oplus$ LC $\oplus$ PLC

Determination of $\tan\beta$ and the CP violating mixing angle Φ_{HA} (1σ contours) for 2HDM (II) solution B_h with CP violation ($M_{h_2} = 250$ GeV, $\tan\beta = 0.5$):

$\Phi_{HA} = 0$



$\Phi_{HA} = -0.2$



CP violating H–A mixing can be precisely measured in SM-like 2HDM (II) solution B_h.

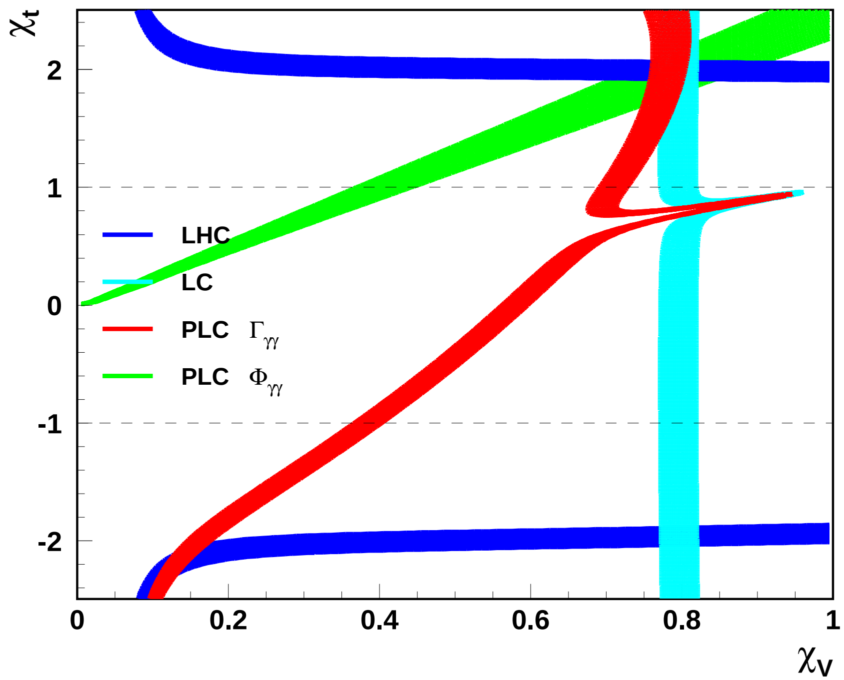
Can we distinguish between solution B_h with CP violation ($\tan\beta$ and Φ_{HA}) **from CP conserving 2HDM (II)** (also with two parameters: $\tan\beta$ and α) **?**

Comparison

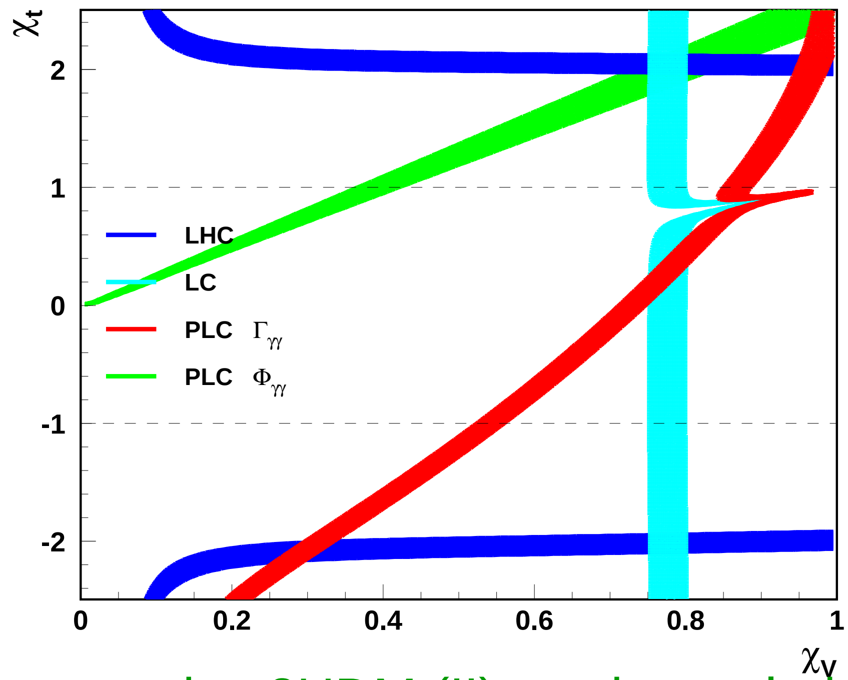
LHC $\oplus$ LC $\oplus$ PLC

2HDM (II) couplings determined (assuming CP conservation) at LHC, LC and PLC
for h_2 (solution B_h) with $M_{h_2} = 250$ GeV and $\tan\beta = 0.5$

$\Phi_{HA} = 0$



$\Phi_{HA} = -0.2$



CP conserving 2HDM (II) can be excluded.

Only from combined analysis of LHC, LC and PLC measurements we can establish CP violation in 2HDM (II)

Summary

Using W^+W^- and ZZ final states both the partial width $\Gamma_{\gamma\gamma}$ and the phase of the $\mathcal{H} \to \gamma\gamma$ amplitude $\phi_{\gamma\gamma}$ can be measured at the Photon Linear Collider.

Both $\tan\beta$ and the CP violating H–A mixing phase Φ_{HA} can be measured at PLC, assuming solution B_h of 2HDM (II).

In general case, combined analysis of LHC, LC and PLC measurements is needed to establish weak CP violation.