Studying Higgs bosons by Top pair production at Photon colliders

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1. Introduction
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3. Complex phase of $\gamma\gamma\phi$ vertex
4. Summary

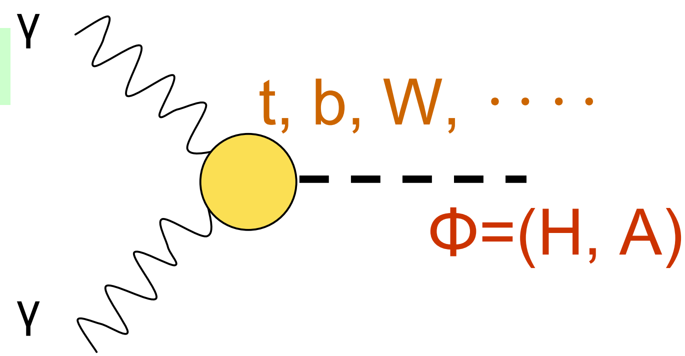
Based on E.A. and Hagiwara
EPJ**C31**,351 (2003)

1. Introduction

- Photon colliders   An option of e^+e^- LC

  Polarization (circular and linear)

  Higgs production in s-channel

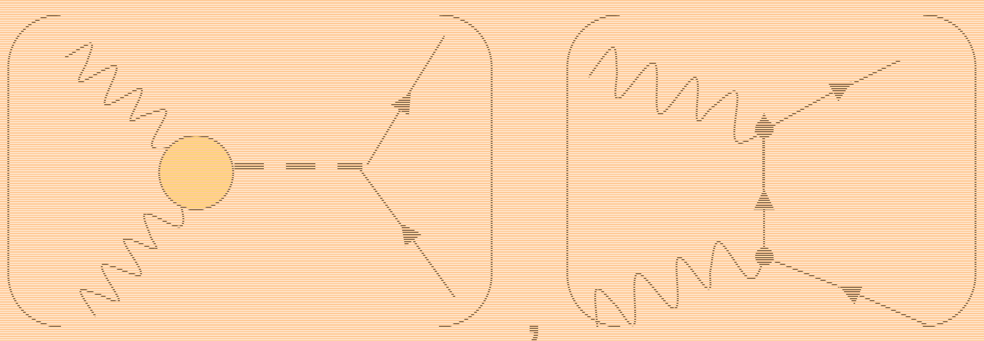


- Top pair production

  Polarization measurable

  Large coupling to φ

Large interference effects !



Comparable around the resonance

Interference effects are sensitive to ***phase of γγφ vertex***

$\gamma\gamma\phi$ vertex

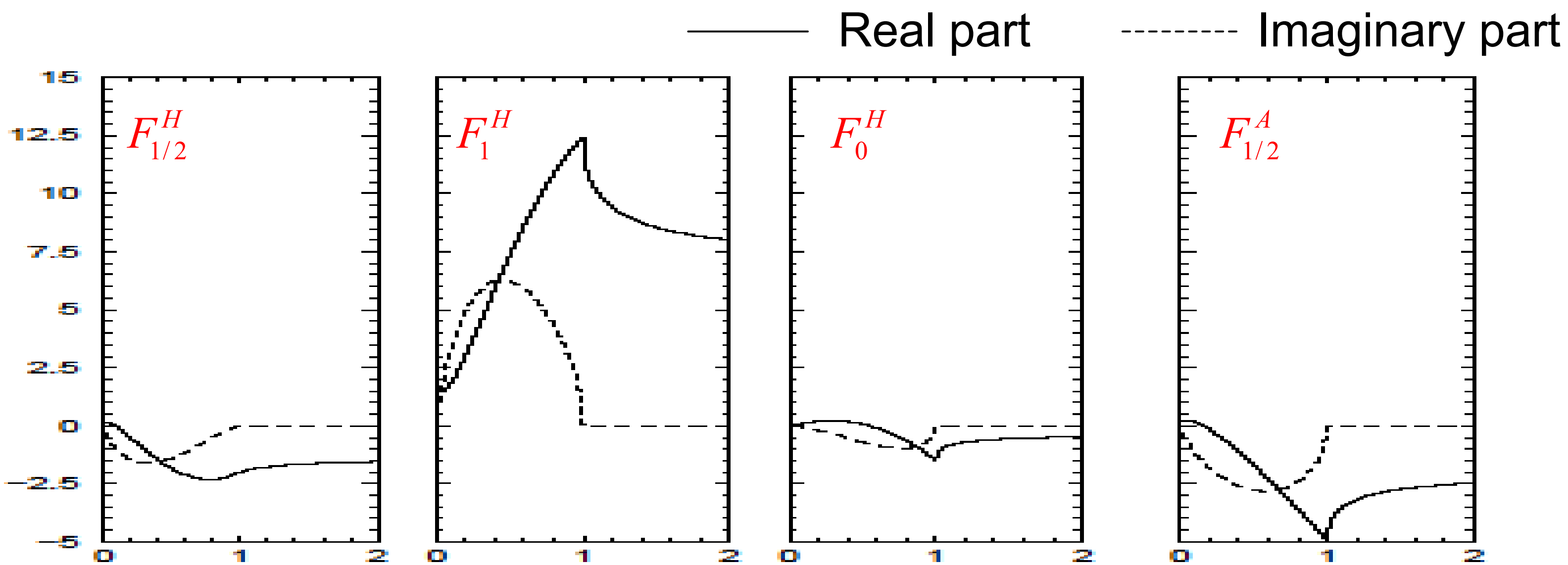
The contributions from HEAVY particles is NOT decoupled.
⇒ sensitive to existence of new charged particles

magnitude of the vertex ⟸ $\Gamma(\varphi \to \gamma\gamma)$

phase of the vertex ⟸ Observables from interference effects

for $\gamma\gamma \to WW/ZZ$ *case*
Niezurawski, Zarnecki, Krawczyk
JHEP 2002

$$\gamma\gamma\phi\ vertex \propto \sum_i e_i^2 \cdot g(\phi i i\ \ vertex) \cdot g F_i^{\phi}$$



$$\tau = \frac{4m_i^2}{m_\phi^2}$$

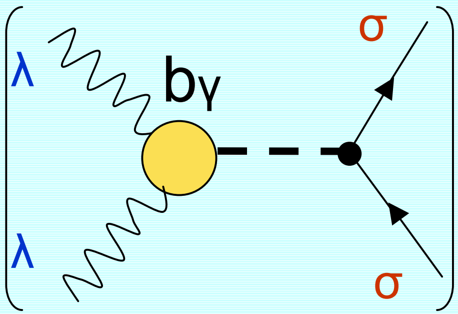
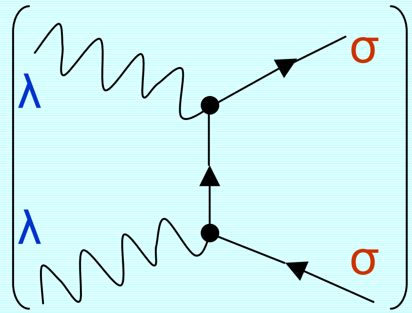
The phase is variant, as m_i / m_ϕ changes.

The phase as well as magnitude depends on models.

2. Observables in $\gamma\gamma \to t\bar{t}$

- Helicity amplitudes

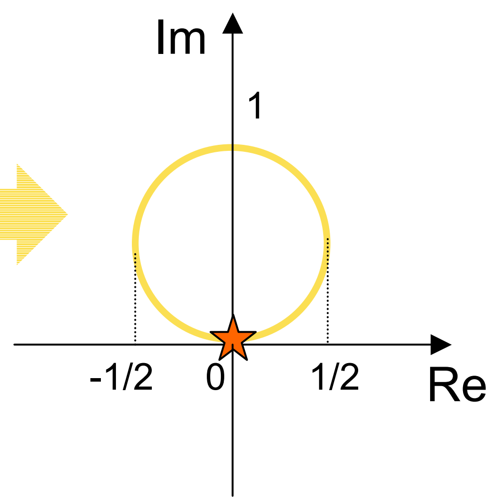
We consider the process $\gamma(\lambda)\,\gamma(\lambda) \to t(\sigma)\bar{t}(\sigma)$.

$M^{\sigma\sigma}_{\lambda\lambda} =$  +  $= [M_\phi]^{\sigma\sigma}_{\lambda\lambda} + [M_{cont}]^{\sigma\sigma}_{\lambda\lambda}$

bγ : γγφ coupling

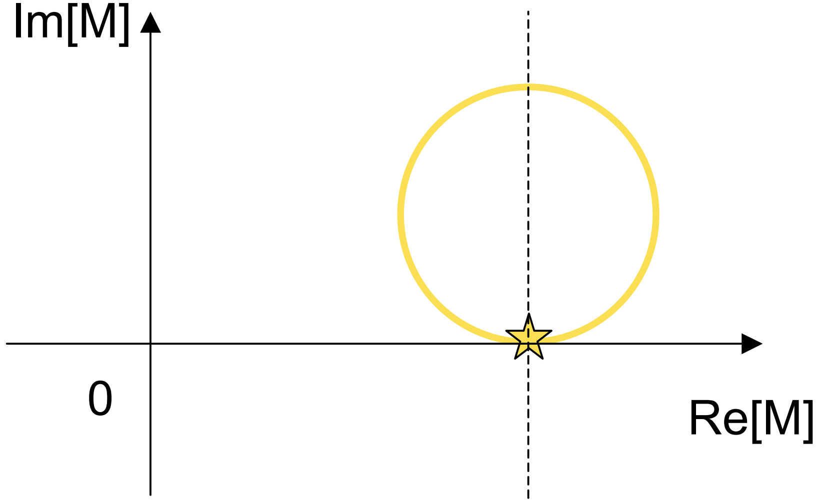
$$L_{\phi\gamma\gamma} = \frac{1}{m_\phi}\left(b_\gamma^H A_{\mu\nu}A^{\mu\nu}H + b_\gamma^A \tilde{A}_{\mu\nu}A^{\mu\nu}A\right)$$

$$[M_\phi]^{\sigma\sigma}_{\lambda\lambda} \propto b_\gamma \cdot i\left[1+\exp\left(2i\tan^{-1}\frac{s-m_\phi^2}{m_\phi\Gamma_\phi}\right)\right]$$

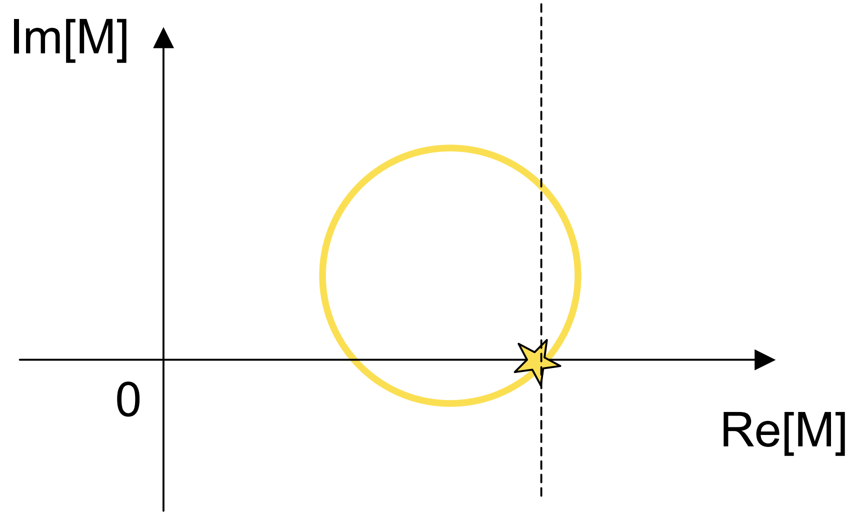


$$[M_{cont}]^{\sigma\sigma}_{\lambda\lambda} = \frac{8\pi\alpha Q_t^2}{1-\beta^2\cos^2\Theta}\,\frac{\beta\sigma+\lambda}{\gamma} \approx real$$

$$\arg\left(b_\gamma\right) = 0^\circ$$



$$\arg\left(b_\gamma\right) = 45^\circ$$



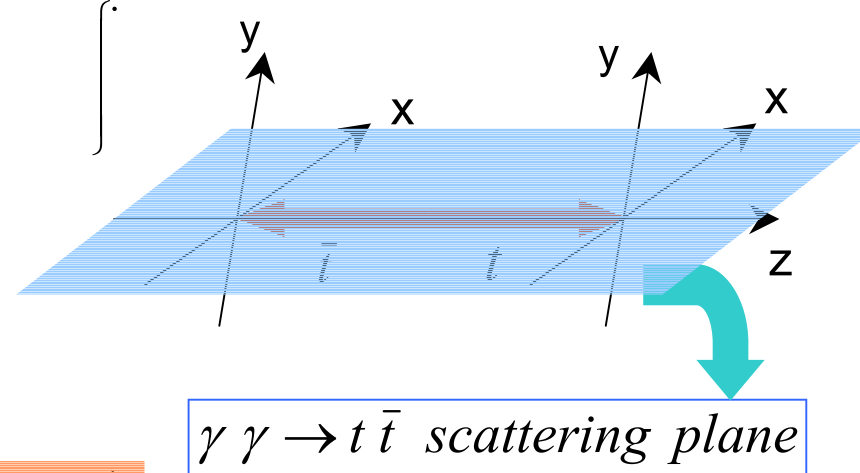
Angular correlation of top decay

We can obtain the 4 observables by considering the angular distribution of top decays $t \to bW$;

$$\frac{d\hat{\sigma}_{\lambda\lambda}}{d\cos\theta\, d\cos\bar{\theta}\, d\phi\, d\bar{\phi}} = \frac{3\beta}{32\pi s}\times$$

$$\begin{array}{ll} S_1 & \left\{ \left|M^{RR}_{\lambda\lambda}\right|^2 \left[\left(a + b\cos\theta\cos\bar{\theta}\right) + c\left(\cos\theta + \cos\bar{\theta}\right)\right] \right. \\ S_2 & + \left|M^{LL}_{\lambda\lambda}\right|^2 \left[\left(a + b\cos\theta\cos\bar{\theta}\right) - c\left(\cos\theta + \cos\bar{\theta}\right)\right] \\ S_3 & + 2\Re\left[M^{RR}_{\lambda\lambda}\left(M^{LL}_{\lambda\lambda}\right)^*\right]\left[d\sin\theta\sin\bar{\theta}\cos\left(\phi - \bar{\phi}\right)\right] \\ S_4 & \left. + 2\Im\left[M^{RR}_{\lambda\lambda}\left(M^{LL}_{\lambda\lambda}\right)^*\right]\left[-d\sin\theta\sin\bar{\theta}\sin\left(\phi - \bar{\phi}\right)\right] \right\}. \end{array}$$

$\theta,\ \phi\ (\bar{\theta}, \bar{\phi})$: *polar and azimuthal angles of* $W^+\ (W^-)$ *in* $t\ (\bar{t})$ *rest frame*



$\Sigma_1 - \Sigma_4$ are shown instead of $S_1 - S_4$

$$\Sigma_i\left(\sqrt{s_{\gamma\gamma}}\right) \equiv \sum_{\lambda_1,\lambda_2}\left(\frac{1}{L_{0.8}}\frac{dL^{\lambda_1\lambda_2}}{d\sqrt{s_{\gamma\gamma}}}\right) S_i^{\lambda_1\lambda_2}\left(\sqrt{s_{\gamma\gamma}}\right)$$

for $\sqrt{s_{ee}} = 500\ GeV, \quad x = 4.8$

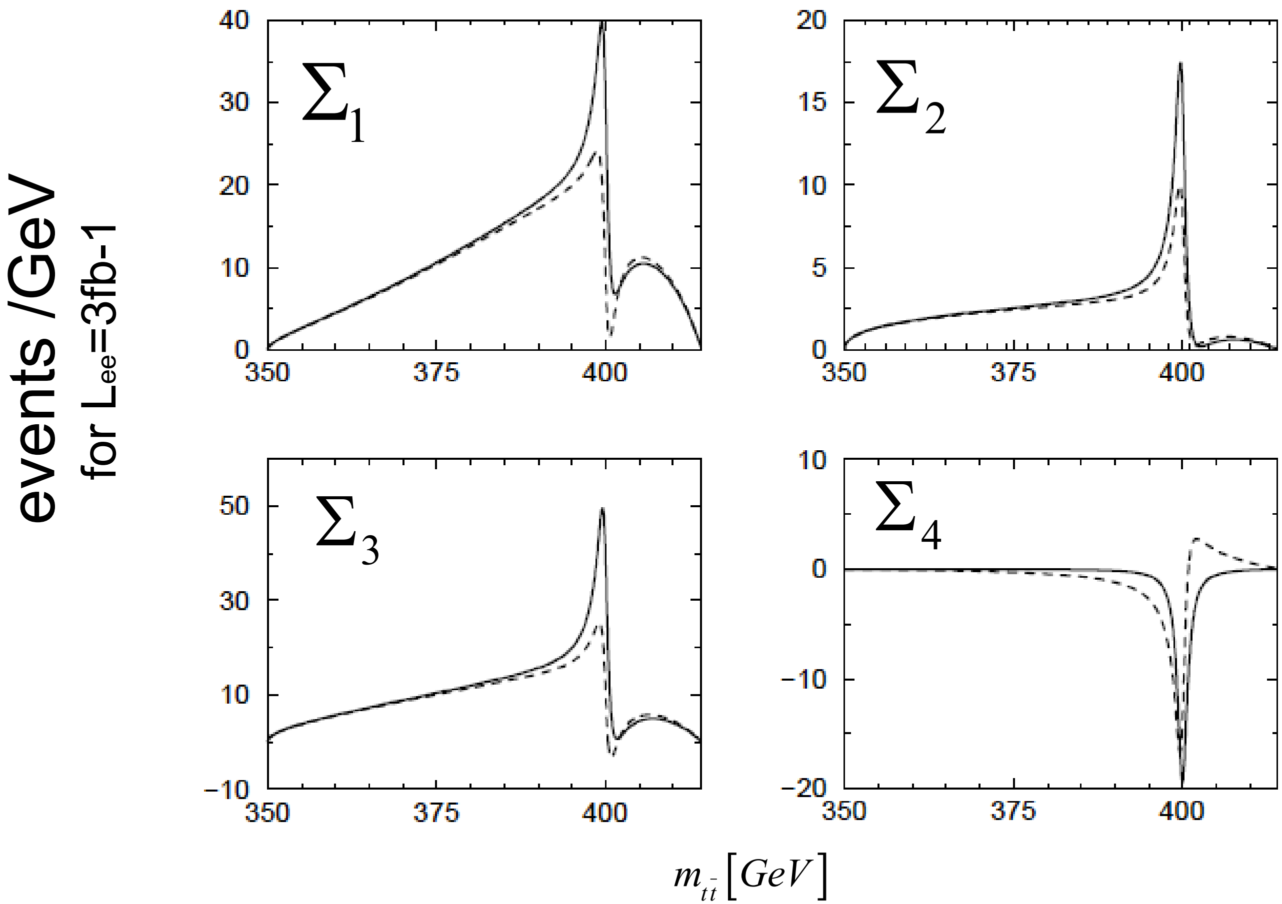
3. Complex phase of $\gamma\gamma\phi$ vertex

As an example, let us fix the magnitude of M_ϕ with based on CP-odd Higgs in the MSSM.

$M_A = 400\ GeV$
$\tan\beta = 3$

are selected. SUSY parameters are fixed as $\begin{cases} m_{\tilde{f}} = 1\ TeV \\ M_2 = 500\ GeV \\ \mu = -500\ GeV \end{cases}$

A + QED



——— $\arg(b_A) = 0^o$

- - - - $\arg(b_A) = 45^o$

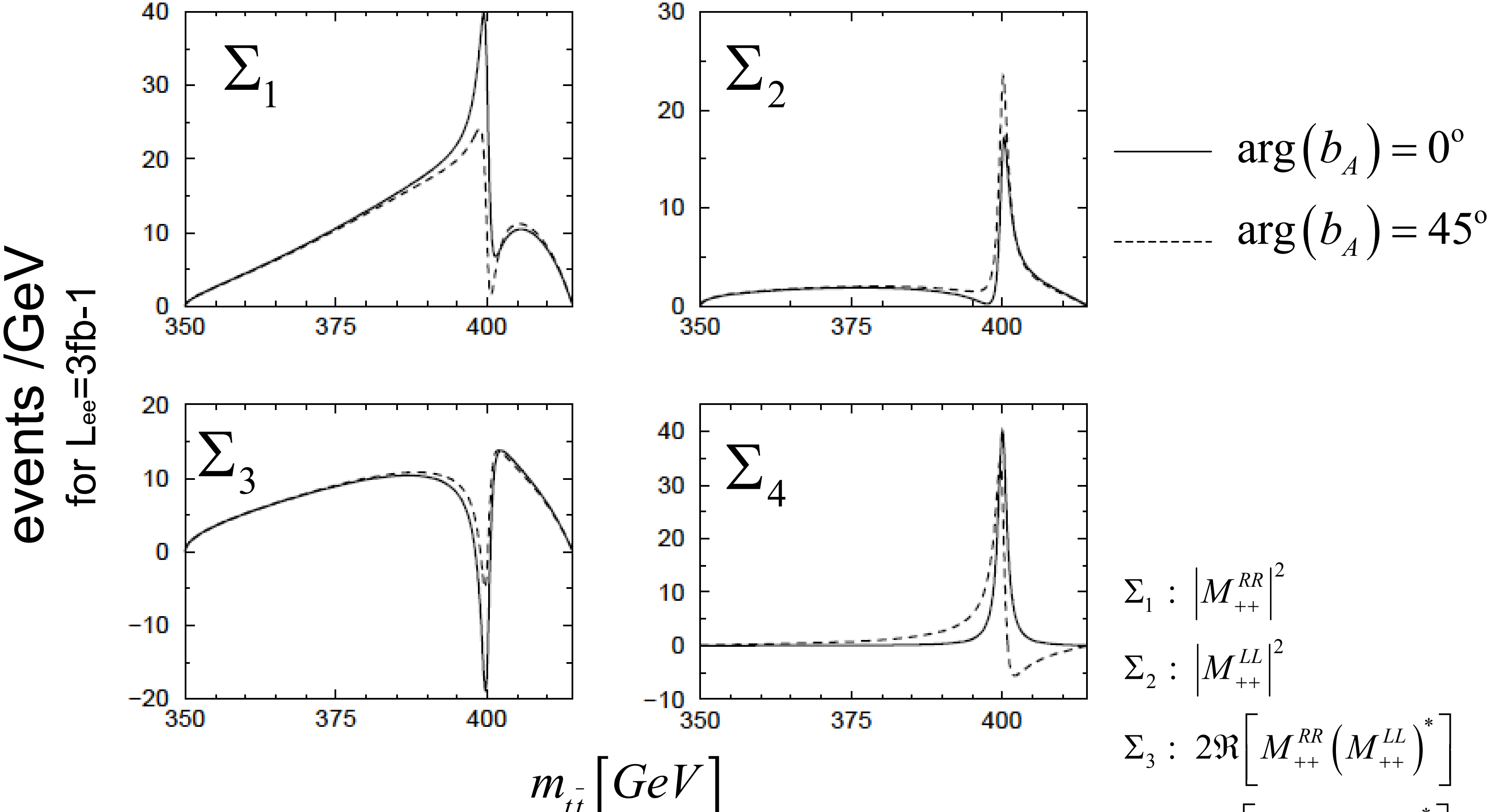
$\Sigma_1 : \left|M_{++}^{RR}\right|^2$

$\Sigma_2 : \left|M_{++}^{LL}\right|^2$

$\Sigma_3 : 2\Re\left[M_{++}^{RR}\left(M_{++}^{LL}\right)^*\right]$

$\Sigma_4 : 2\Im\left[M_{++}^{RR}\left(M_{++}^{LL}\right)^*\right]$

H + QED



$\Sigma_1 : \left|M_{++}^{RR}\right|^2$

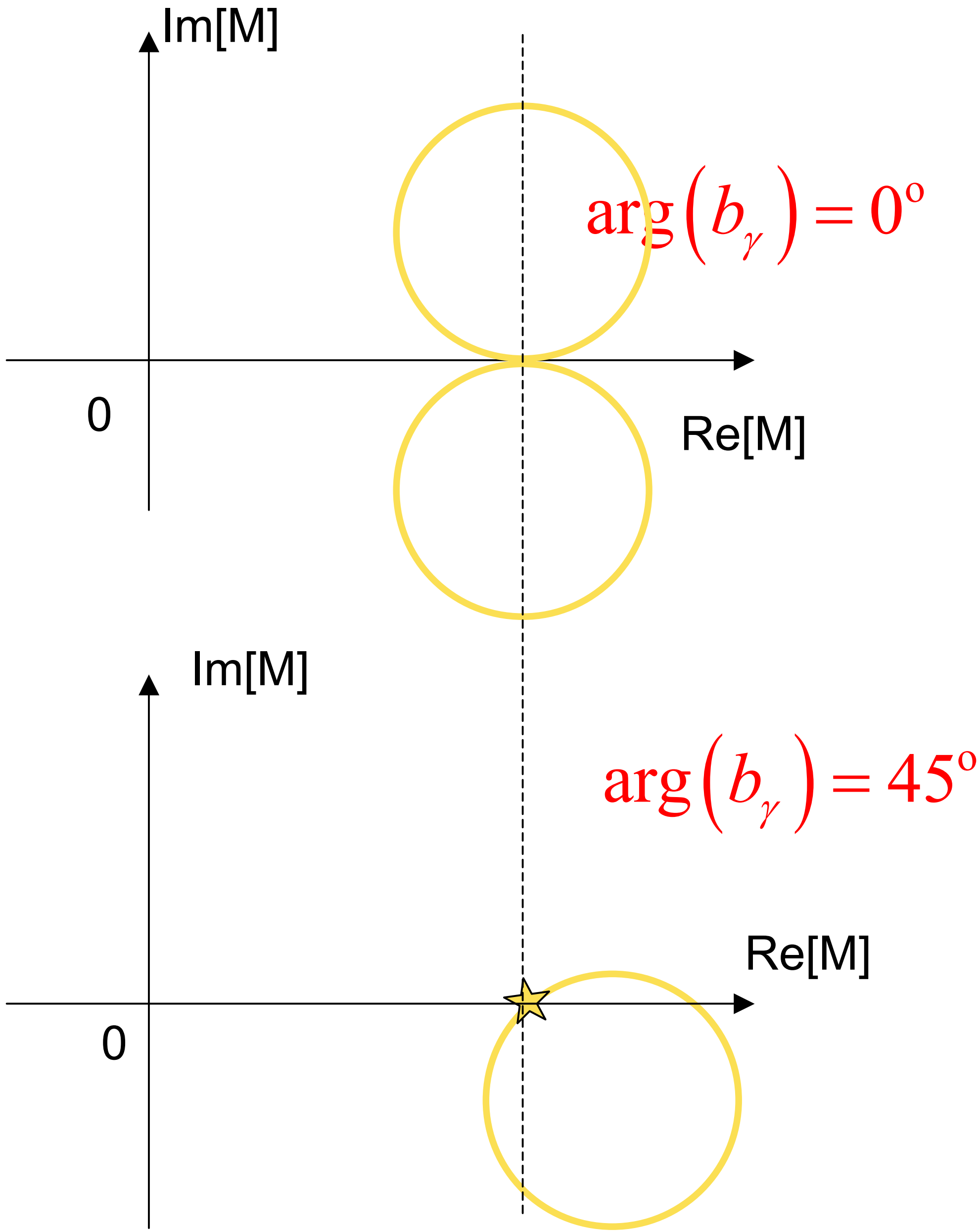
$\Sigma_2 : \left|M_{++}^{LL}\right|^2$

$\Sigma_3 : 2\Re\left[M_{++}^{RR}\left(M_{++}^{LL}\right)^*\right]$

$\Sigma_4 : 2\Im\left[M_{++}^{RR}\left(M_{++}^{LL}\right)^*\right]$

For H production

σσ \ λλ	RR	LL
++	M_H M_A	$-M_H$ M_A



	$M_A = 400\ GeV,\ \tan\beta = 3$		$M_A = 600\ GeV,\ \tan\beta = 4$	
	$b_\gamma^A \times 10^4$	$b_\gamma^H \times 10^4$	$b_\gamma^A \times 10^4$	$b_\gamma^H \times 10^4$
Total	14 +12 i	11 +1.3 i	2.7 +13 i	6.3 +7.9 i
Phase	40.6°	6.7°	78.3°	51.4°
t	15 +12 I	12 +3.3 i	4.1 +12 i	6.6 +8.7 i
W	0.0	-1.0 -1.7 i	0.0	-0.33-0.54i
$\tilde{\chi}_1^+$ 469GeV	-1.1	- 1.2	-2.0	-1.9
$\tilde{\chi}_2^+$ 541GeV	0.51	1.0	1.0	1.5
b	-0.19 +0.15i	0.18 -0.15i	-0.21+0.15i	0.20-0.15i

$$m_{\tilde{f}} = 1\ TeV$$

$$M_2 = 500\ GeV$$

$$\mu = -500\ GeV$$

Observed phase from interference effects

and

Predictied phase from known particles

agree

Model confirmation

disagree

<u>agree in imaginary part</u>

New particles !

<u>disagree in imaginary part</u>

Need to reexamine known particles

Might miss $\tau < 1$ particles

or

misunderstand the property?

4. Summary

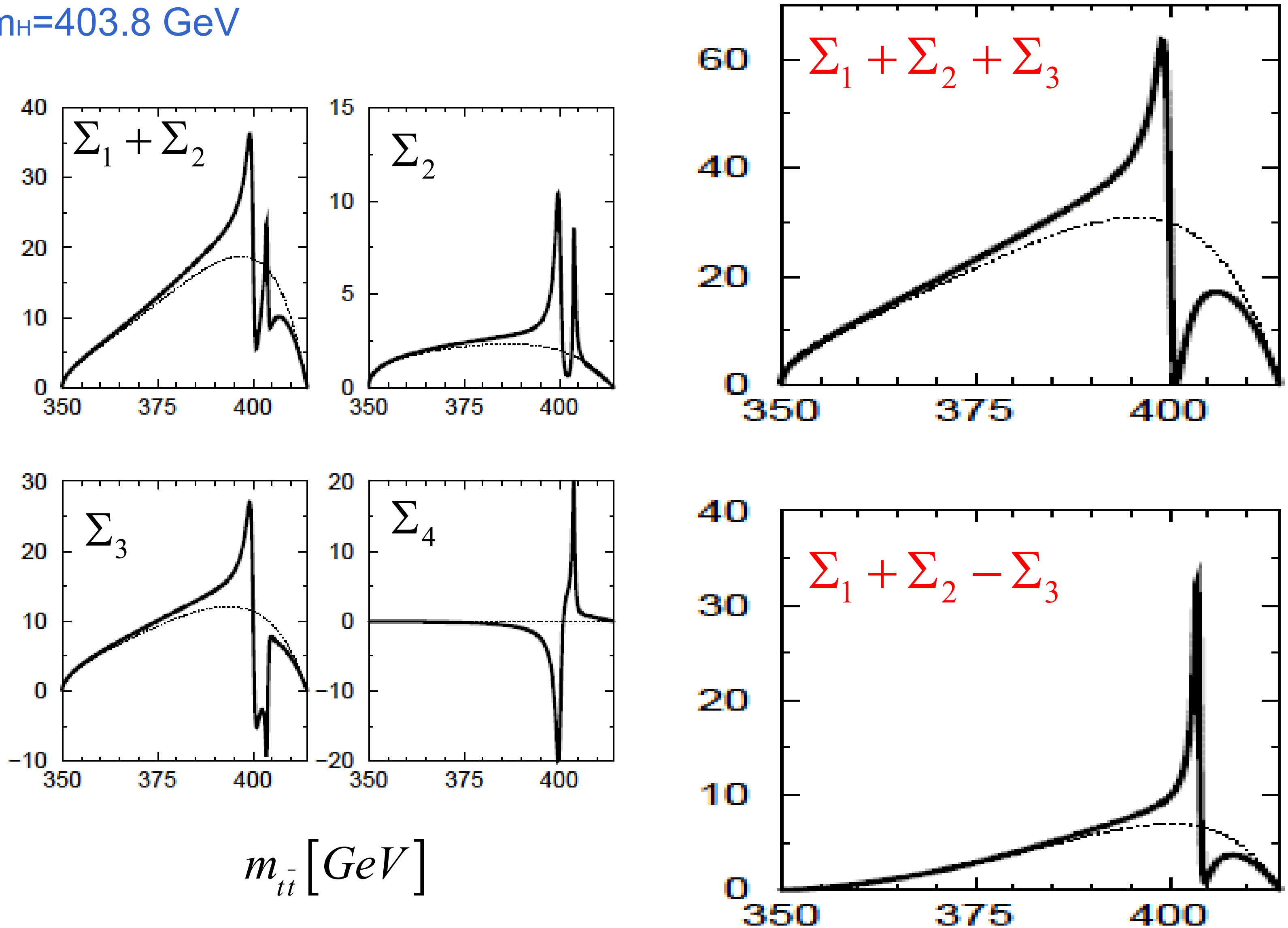
The phase of $\gamma\gamma\phi$ vertex depends on models.

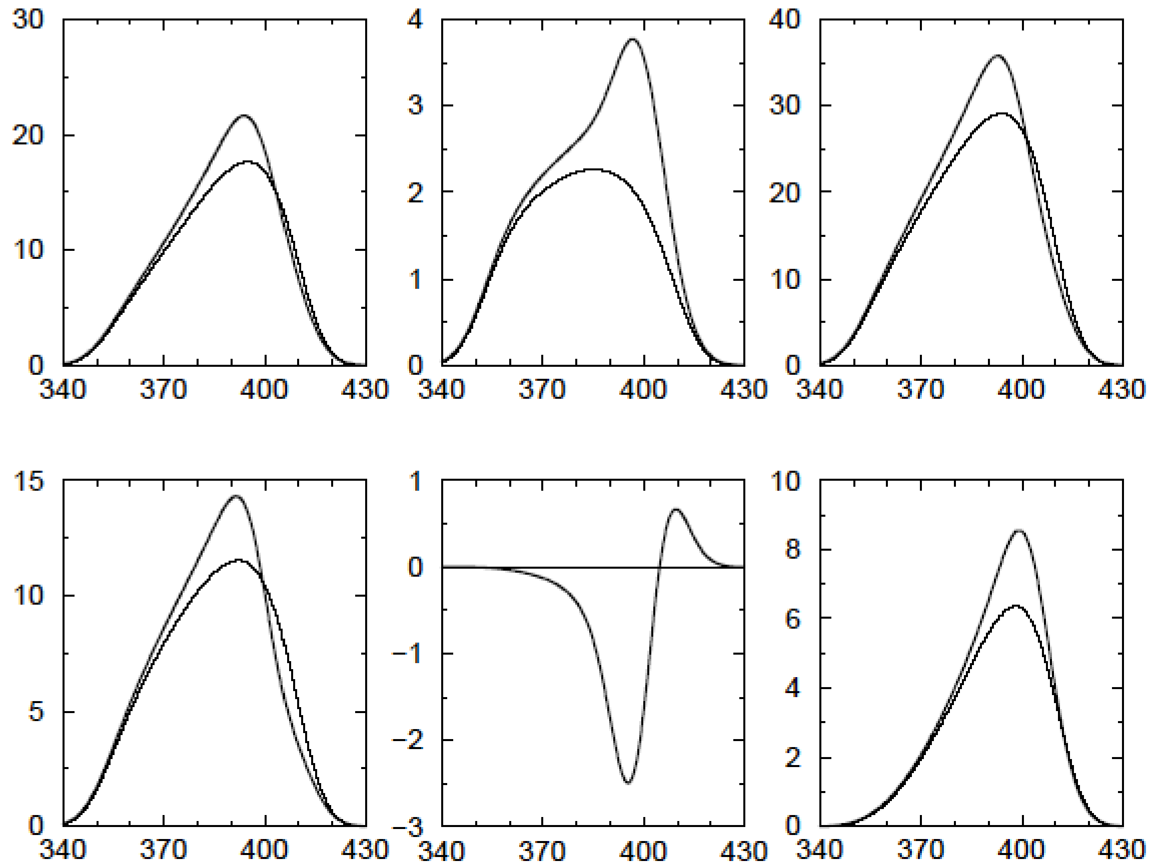
We have discussed

how the phase of $\gamma\gamma\phi$ vertex contributes
to the observables in $\gamma\gamma \to t\,\bar{t}$ process.

The observables are helpful
to search new particles / constrain models.

MSSM (tanβ=3)
m_A=400.0 GeV
m_H=403.8 GeV





30
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−3
340
370
400
430
10
8
6
4
2
0
340
370
400
430

$$\arg\left(b_{\gamma}\right) = 0^{o}$$

$$\arg\left(b_{\gamma}\right) = 90^{o}$$