

# Higgs Boson Production in $\gamma\gamma$ Collisions via Resolved Photon Contributions

M. Doncheski, S. Godfrey & S. Zhu

Phys Rev D67, 073021 (2003) hep-ph/0105070

Phys Rev D68, 053001 (2003) hep-ph/0306126

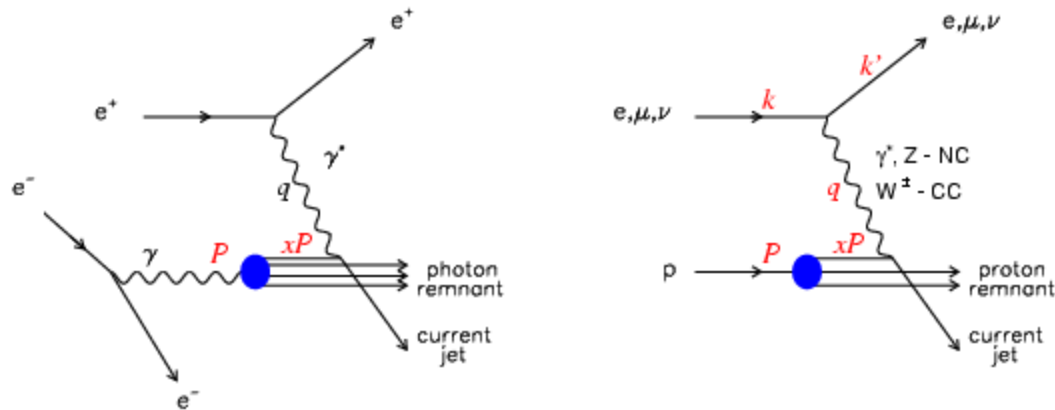
- Resolved Photons
- Higgs Boson Production
- Measuring  $\tan\beta$  in associated  $t$ - $H^{+/-}$  production
- Summary



# Can view photon as consisting of quarks and gluons

Internal structure similar to that of hadrons except with probability  $\alpha \sim 1/137$

Study structure of photon via DIS



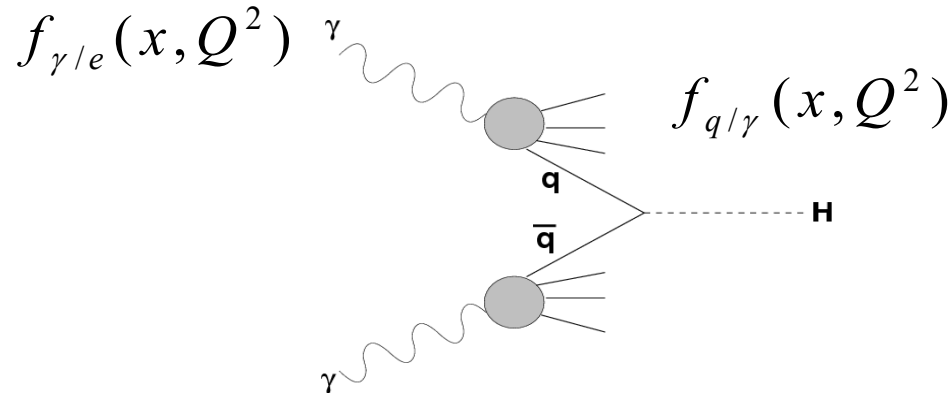
Obtain quark and gluon distributions in photons analogous to those of hadrons:  $f_{q/\gamma}(x, Q^2)$ ,  $f_{g/\gamma}(x, Q^2)$

Take advantage:

- Leptoquark production
- W' searches
- etc

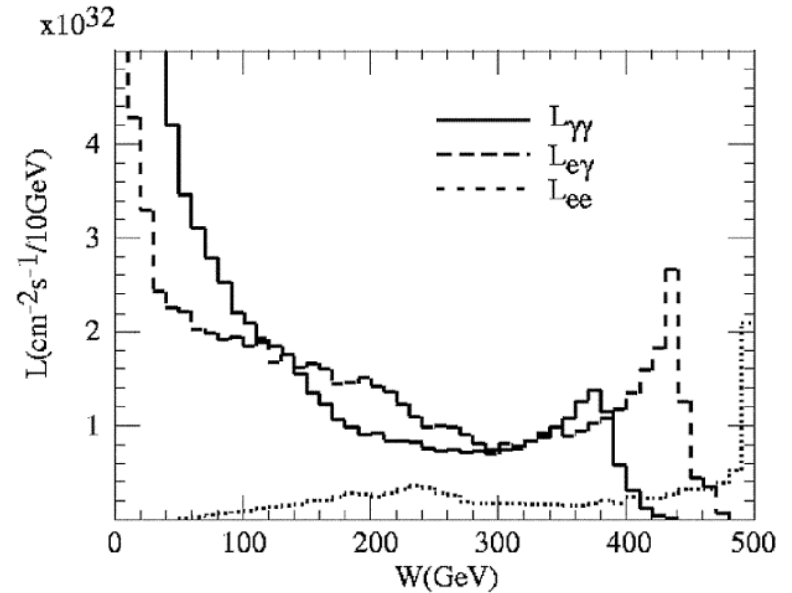
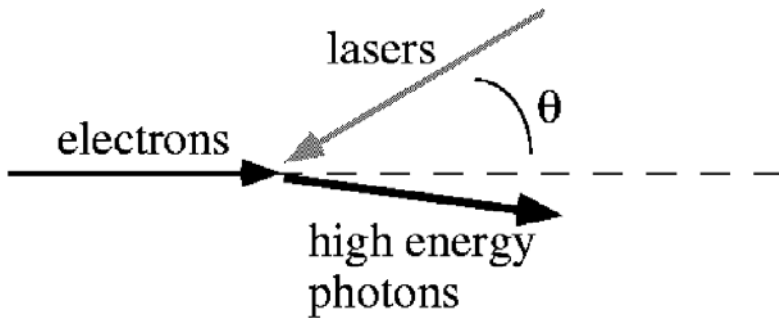


Convolute parton distributions and photon distributions with parton level cross section:



$$\sigma = \int dx_1 dx_2 dx_3 dx_4 f_{\gamma/e}(x_1, Q^2) f_{\gamma/e}(x_2, Q^2) f_{p_i/\gamma}(x_3, Q^2) f_{p_j/\gamma}(x_4, Q^2) \hat{\sigma}(\hat{s})$$

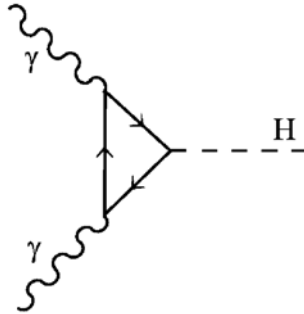
Compton Photon Collider (CPC):



# Higgs Production:

"Compton Collider" advocated for precision Higgs measurements

- $2\gamma$  proceeds via loops so is sensitive to new particles in loop



- Can distinguish between SM and lightest scalar of MSSM in decoupling limit
- Need to understand all SM contributions



## Assumptions:

- Only consider tree-level contributions
- Do not include branching ratios (well known)
- Detector efficiencies
- Backgrounds
- Adopt TESLA TDR criteria of 20 events/1 ab<sup>-1</sup> of Luminosity

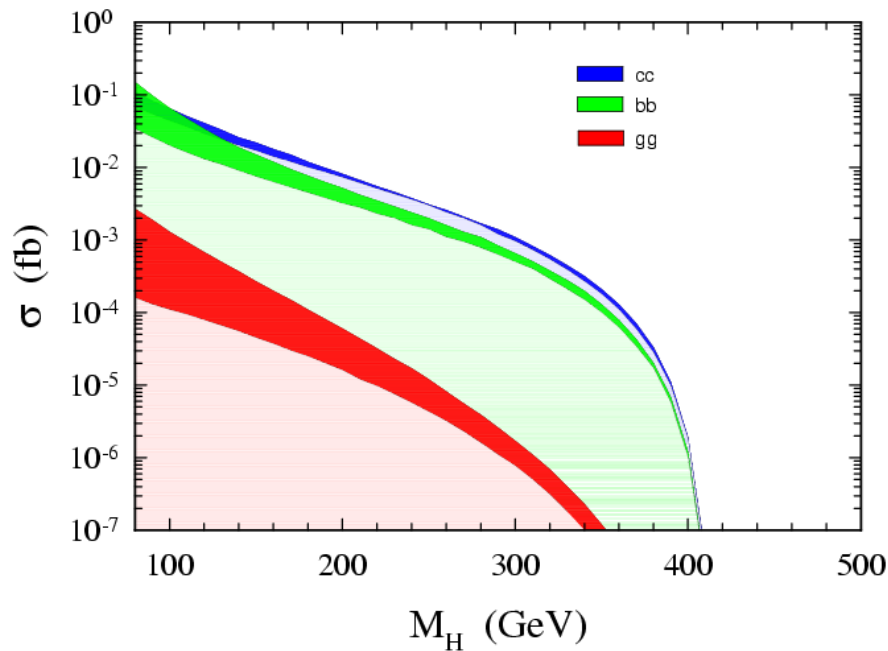
- Acknowledge that this is crude preliminary study
- Just want to gauge how important these contributions are

**Subprocess cross section:** (generic for all processes)

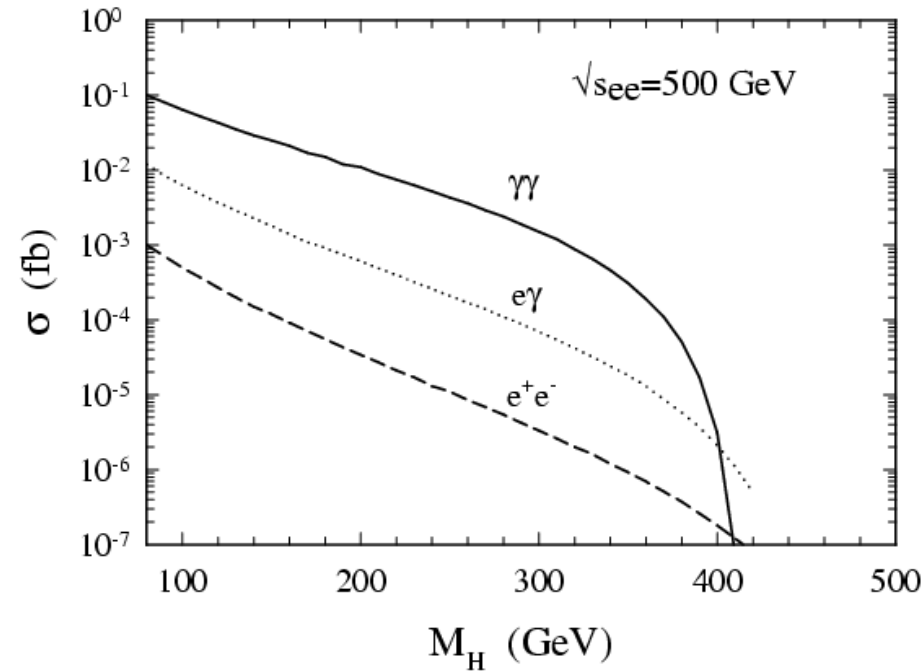
$$\sigma(q\bar{q} \rightarrow H) = \frac{G_F \pi}{3\sqrt{2}} m_f^2 (1 - 4m_f^2 / M_h^2)^{1/2} \delta(M_h^2 - \hat{s})$$



## Variation due to different parton distributions

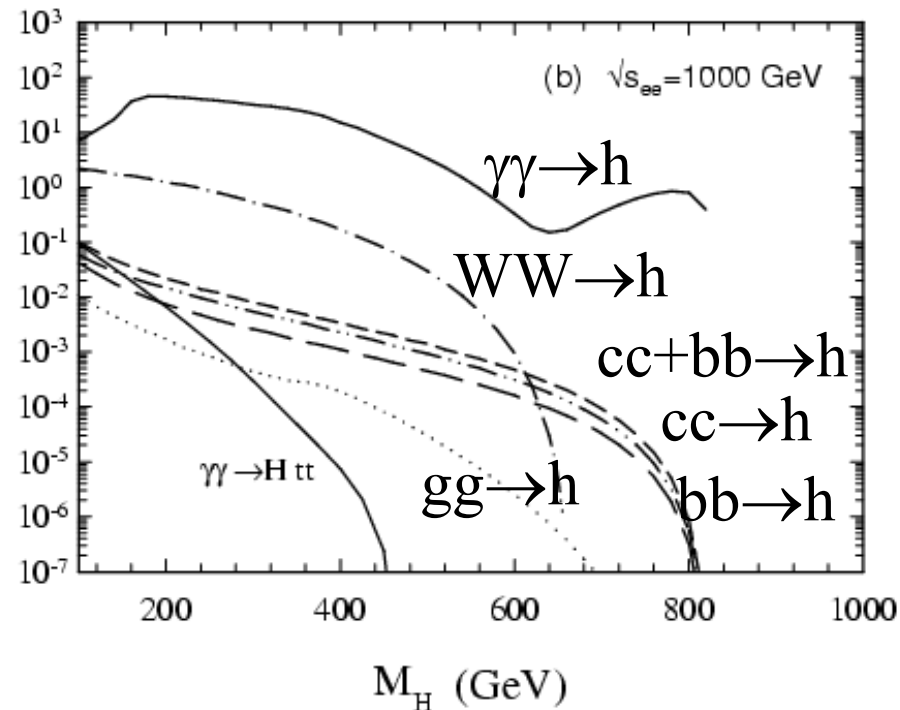
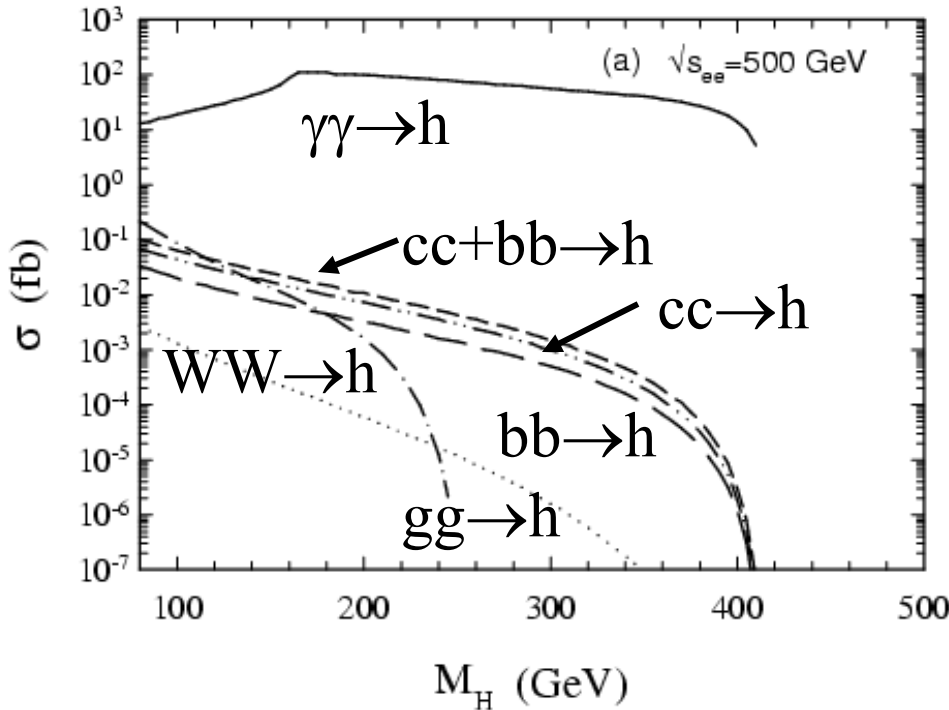


## Variation due to different photon distributions



# SM Higgs Production:

c-quark contributions are largest due to charge in  $f_{c/\gamma}(x, Q^2)$



- For light Higgs contributes  $\sim\%$  level so may not be negligible
- Many different contributions to Higgs production
  - very rich physics content



# Heavy Neutral MSSM Higgs Boson Production:

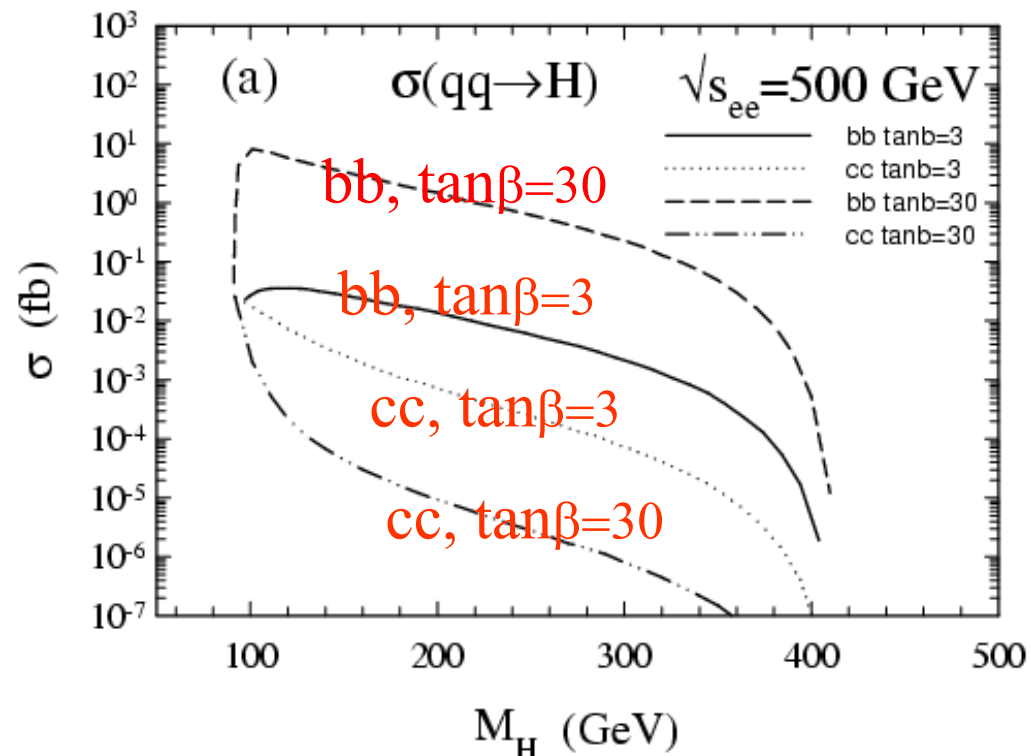
- With 2 doublets exist 3 neutral Higgs bosons:  $h^0, H^0, A^0$
- MSSM neutral Higgs can be produced in  $\gamma\gamma$   
But resolved photon process has different  $\tan\beta$  dependence
- Take tree level MSSM relationships to fix parameters
- $\tan\beta$  and  $M_A$  as input

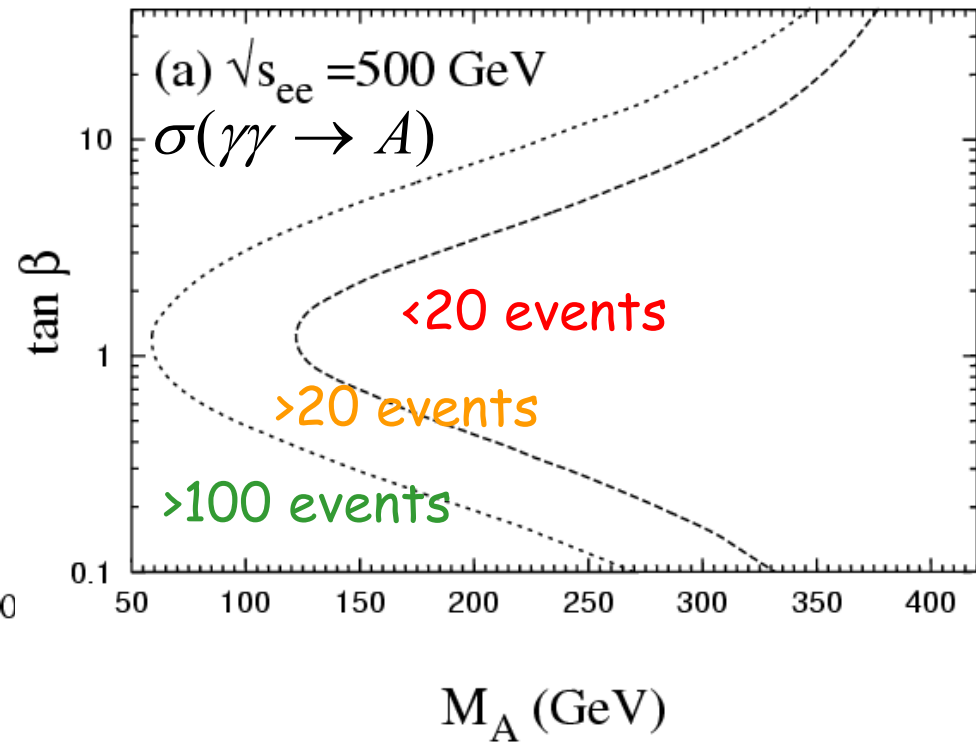
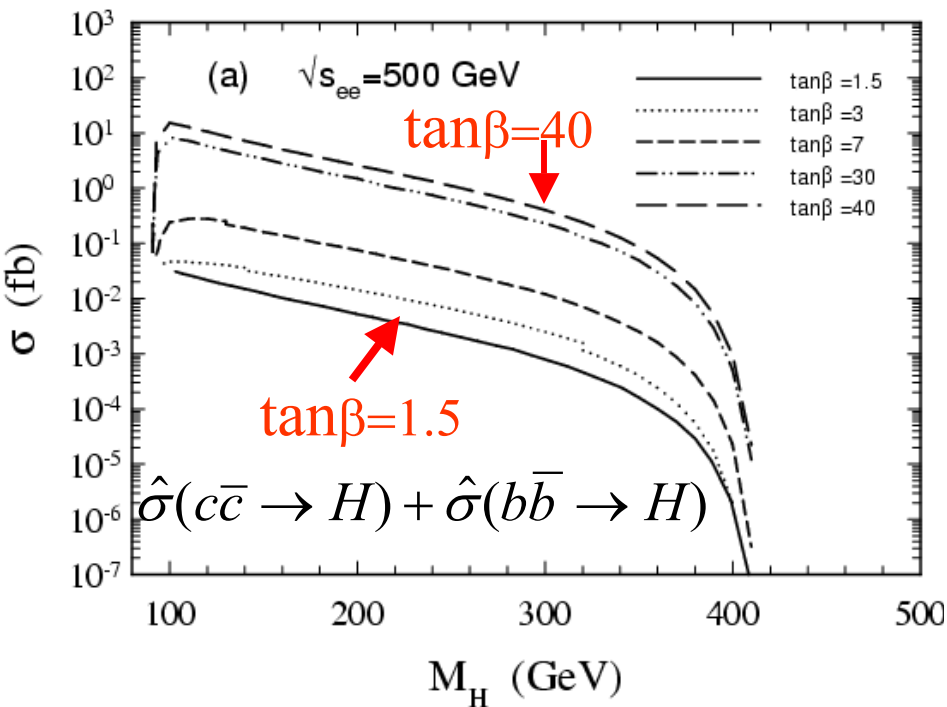
$$\sigma(c\bar{c} \rightarrow H^0) = \frac{G_F \pi}{3\sqrt{2}} m_b^2 \frac{\sin^2 \alpha}{\sin^2 \beta} \delta(M_H^2 - \hat{s})$$

$$\sigma(b\bar{b} \rightarrow H^0) = \frac{G_F \pi}{3\sqrt{2}} m_b^2 \frac{\cos^2 \alpha}{\cos^2 \beta} \delta(M_H^2 - \hat{s})$$

$$\sigma(c\bar{c} \rightarrow A^0) = \frac{G_F \pi}{3\sqrt{2}} m_c^2 \cot^2 \beta \delta(M_A^2 - \hat{s})$$

$$\sigma(b\bar{b} \rightarrow A^0) = \frac{G_F \pi}{3\sqrt{2}} m_b^2 \tan^2 \beta \delta(M_A^2 - \hat{s})$$





- For large  $\tan\beta$  both  $H$  and  $A$  will be produced for  $M > \sqrt{s}/2$  so  $H$  and  $A$  with relatively high mass should be observed
- In contrast to  $SM$  where at best non-negligible contribution
- Maybe use cross section to constrain  $\tan\beta$

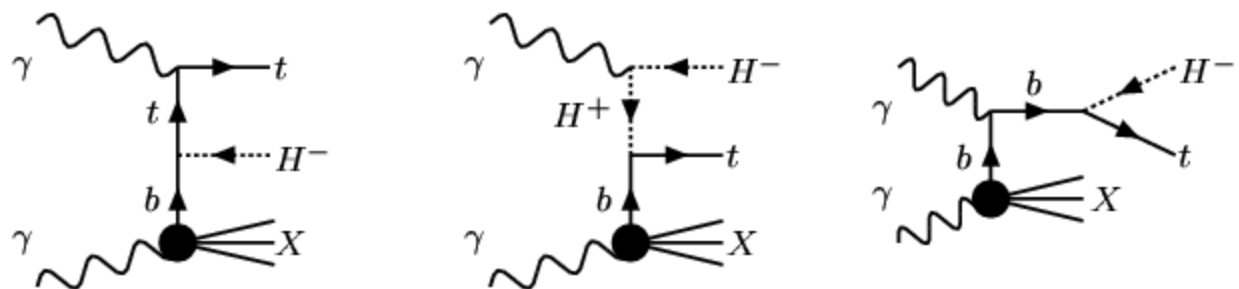


# Measurement of $\tan\beta$ in $t$ - $H^{\pm}$ production

- $\tan\beta$  is a key parameter of 2HDM
- Measurements of  $H^{\pm}$  BR's allow determination of  $\tan\beta$  for low  $\tan\beta$
- Propose to use  $b\gamma \rightarrow H^{\pm}t$  in  $\gamma\gamma \rightarrow H^{\pm}t + X$
- Interaction given by:

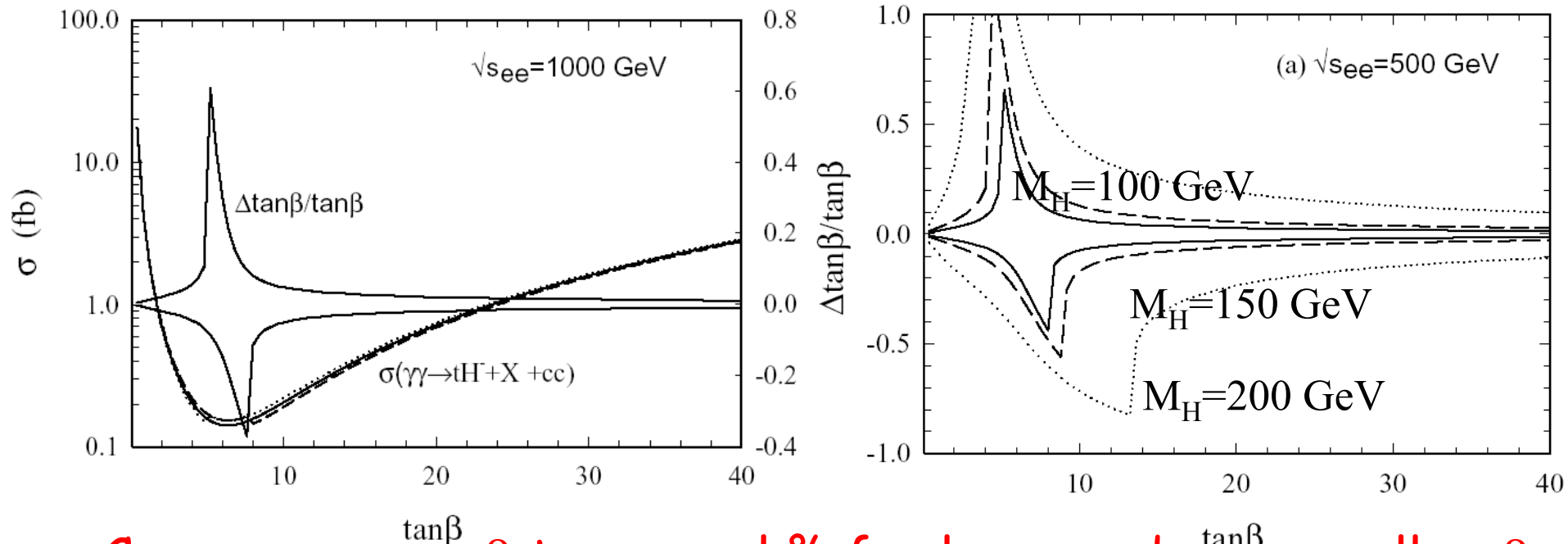
$$i \frac{V_{tb}}{\sqrt{2}v} [m_b \tan\beta(1 + \gamma_5) + m_t \cot\beta(1 - \gamma_5)]$$

• Process is:



$$\sum |M(b\gamma \rightarrow tH^{\pm})|^2 \propto 8\sqrt{2}G_F\pi\alpha(m_b^2 \tan^2\beta + m_t^2 / \tan^2\beta)$$

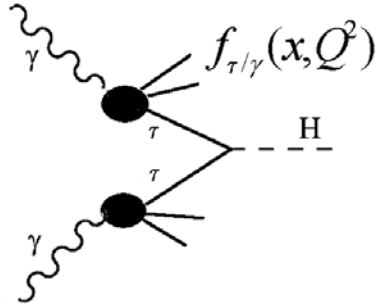
- Backgrounds are:  $\gamma\gamma \rightarrow t\bar{t}$ ,  $\gamma\gamma \rightarrow t\bar{b} + \bar{t}b$ ,  $\gamma\gamma \rightarrow t\bar{b} + W^-$
- To distinguish from signal need to reconstruct final state
- b-tagging is crucial (or  $\tau$  tagging depending on  $M_H$ )
- Tagging efficiencies a tradeoff of efficiency vs purity  
show curves for different  $\varepsilon$  and let expt decide value



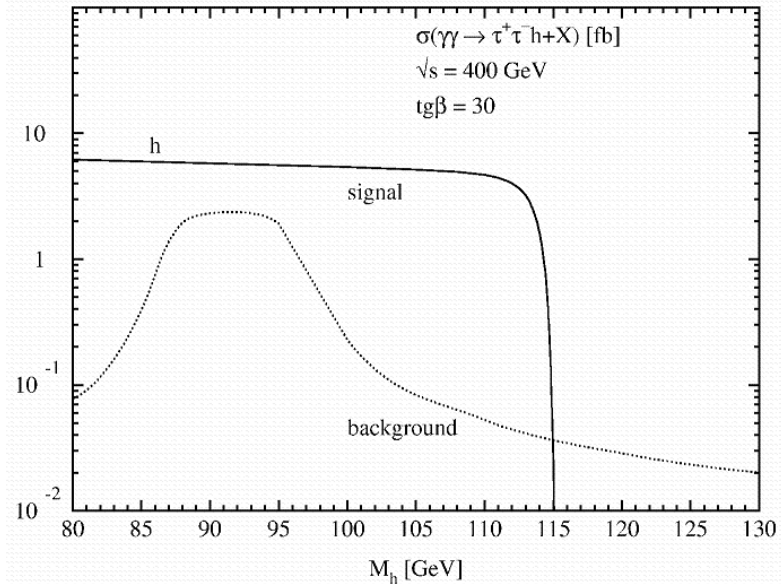
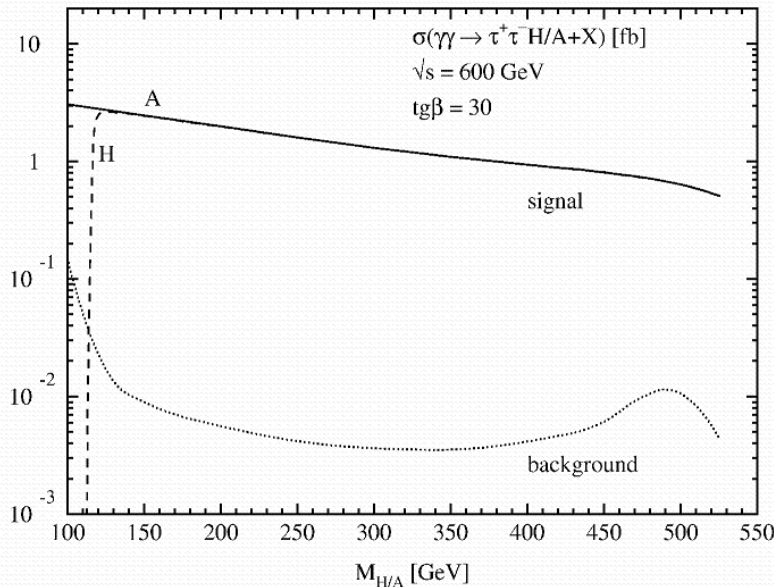
- Can measure  $\tan\beta$  to several % for large and very small  $\tan\beta$
- Complements other processes for certain regions of parameter space  $\Rightarrow$  provides an additional tool



# $\tau\tau \rightarrow$ Higgs boson in **resolved photon** processes



S. Choi et.al, hep-ph/0404119



- $\Delta\tan\beta \sim 0.9$  to  $1.3$  uniform in  $\tan\beta$  for all  $M_A$  up to kinematical limit.



# Summary

1. Hadron content of photon more than a test of perturbative QCD
2. Contributions non-negligible for precision Higgs measurements
3. Important for  $H^0$ ,  $A^0$  production for large  $\tan\beta$
4. Associated  $t$ - $H^{+/-}$  production in  $\gamma\gamma$  collisions a useful tool for measuring  $\tan\beta$

