Higgs production in $e\gamma$ collider

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Outline

- Introduction and motivations
  - Higgs transition form factor
- Higgs production in e and real γ collision in SM
- Numerical analysis
- Summary

Introduction

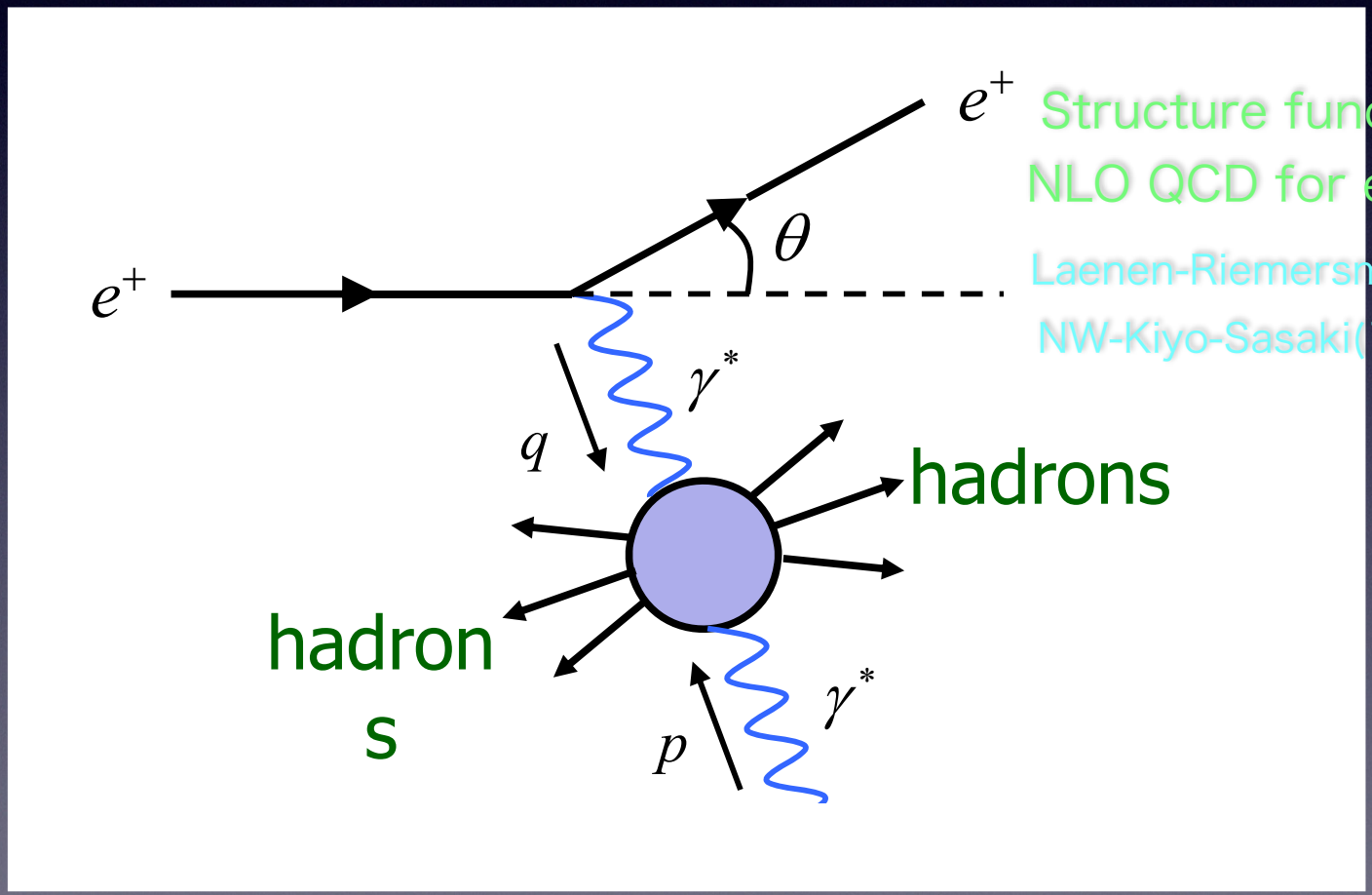
- A Higgs particle was found at the LHC
  - Is it the SM Higgs, a SUSY Higgs, a Higgs of different model ?
- Future linear collider: ILC
  - e^+e^- collider: $\sqrt{s}$ =250GeV～
  - It may be constructed in Japan.
- Before e+ beams are ready, other options are possible
  - $e^-e^-/e^-\gamma/\gamma\gamma$ option:
    using one beam to produce high energy photon

Physics @eγ collider

- DIS of the real photon
  - Real photon structure functions,…
- Single top production
  - Direct measure CKM,…
- Doubly charged particles
  - Higgs triplet model etc,…
- Higgs production
  - Transition form factor,…
- etc…

Physics @eγ collider

- DIS of the real photon
  - Real photon structure functions,…



Structure funcs. are calculated NLO QCD for each helicity state

Laenen-Riemersma-Smith-VanVeerven(94)

NW-Kiyo-Sasaki(13)

Physics @eγ collider

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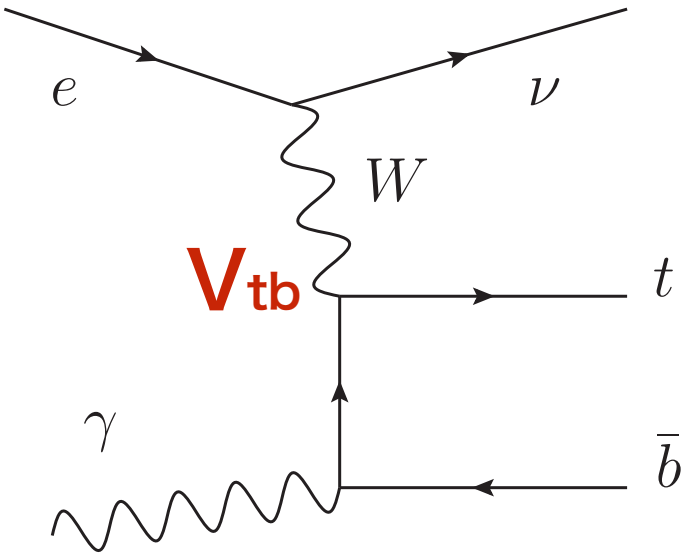
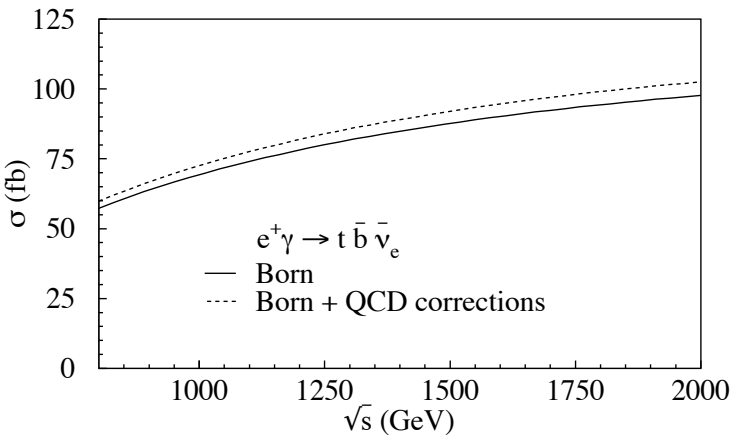


Kuhn-Strum-Uwer(03)



Physics @eγ collider

- DIS of the real photon
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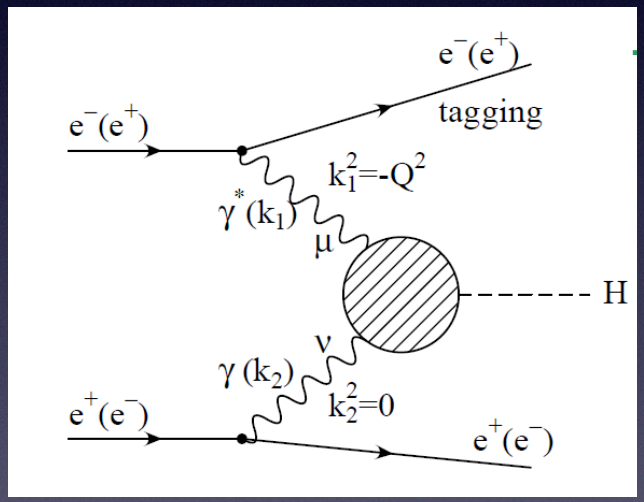
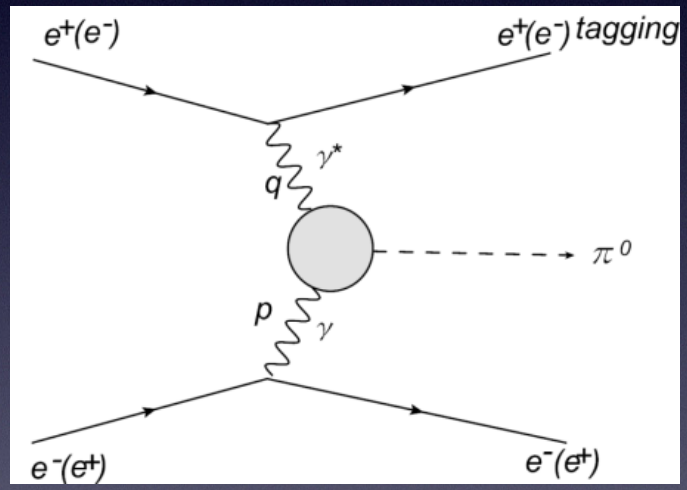
  - Transition form factor,…
- etc…

Higgs transition factor

- We evaluate the transition form factor of Higgs and its Q^2 dependence just like a transition form factor of π^0



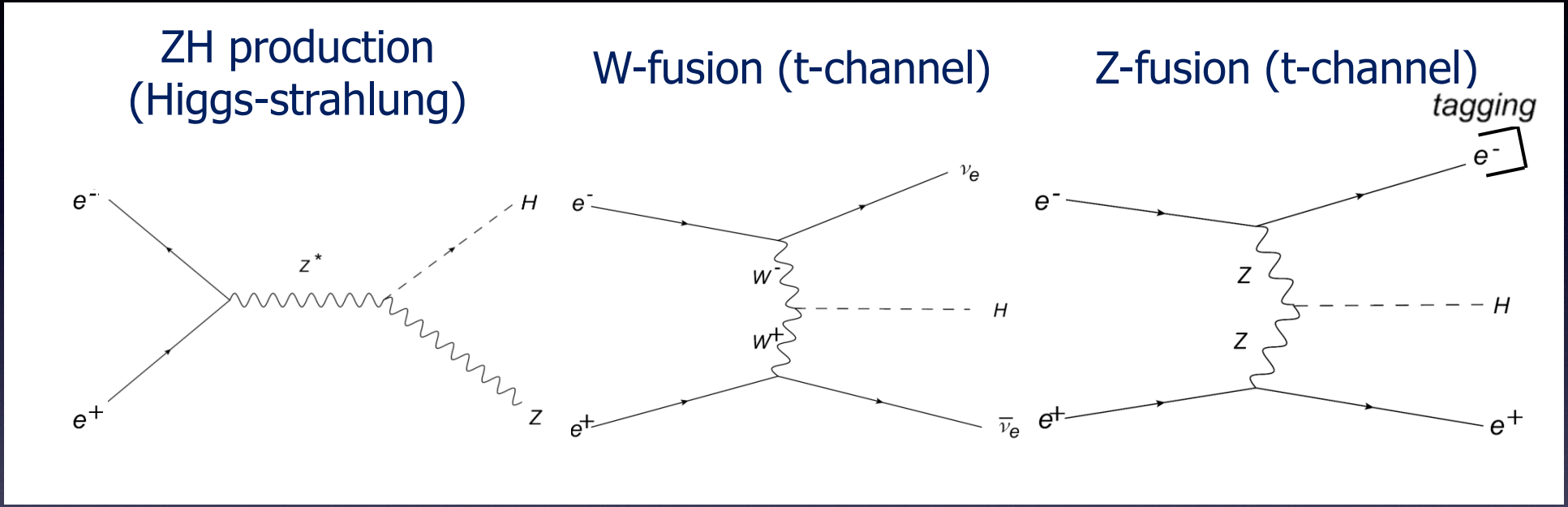
analogy



Lapage-Brodsky(1980)

- These give us the good information Higgs is elementary particle(SM) or not

Tree diagrams for Higgs production in e^+e^- collision



Single tagging of scattered electrons

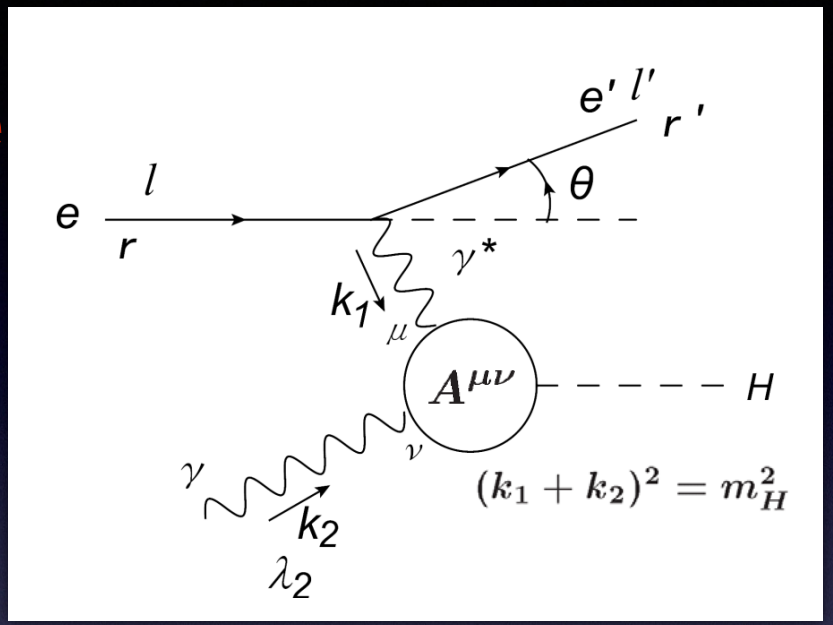
The Z-fusion is the tree-level for ee→eeH

We consider $e\gamma$ collision to avoid Z-fusion

Higgs production in 2γ process

One photon is virtual while other photon is real

DIS of real photon

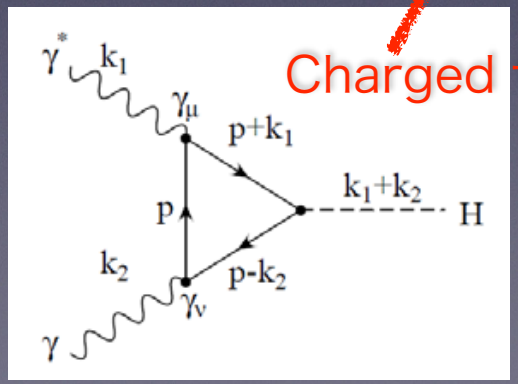


Scattering amplitude

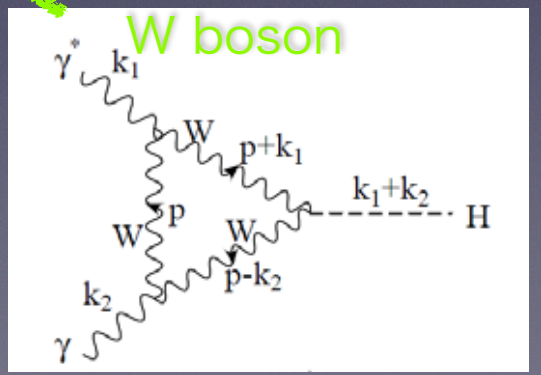
$$M \equiv \langle H|T|\gamma^*(k_1)\gamma(k_2)\rangle = \epsilon^{\mu}(k_1)\epsilon^{\nu}(k_2)\ A_{\mu\nu}(k_1,k_2)$$

$$= [g^{\mu\nu}(k_1\cdot k_2) - k_2^{\mu}k_1^{\nu}]\, S_1(m^2,Q^2,m_H^2)\epsilon_{\mu}(k_1)\epsilon_{\nu}(k_2)$$

Charged fermion



W boson



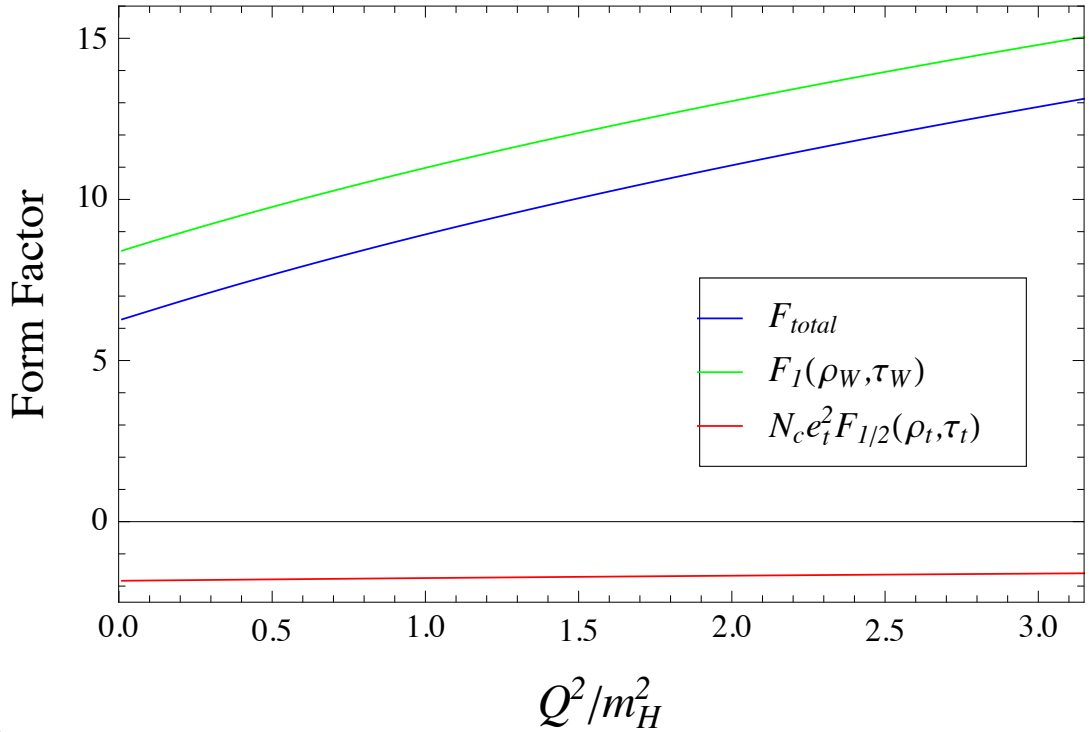
Transition form factor of Higgs

- We define the transition form factor as

$$S_1(m^2, Q^2, m_H^2)/\left(\frac{ge^2}{(4\pi)^2}\frac{1}{m_W}\right) = F_{\rm total}(Q^2, m_H^2) = \sum_f N_c e_f^2 F_{1/2}(\rho_f, \tau_f) + F_1(\rho_W, \tau_W)$$

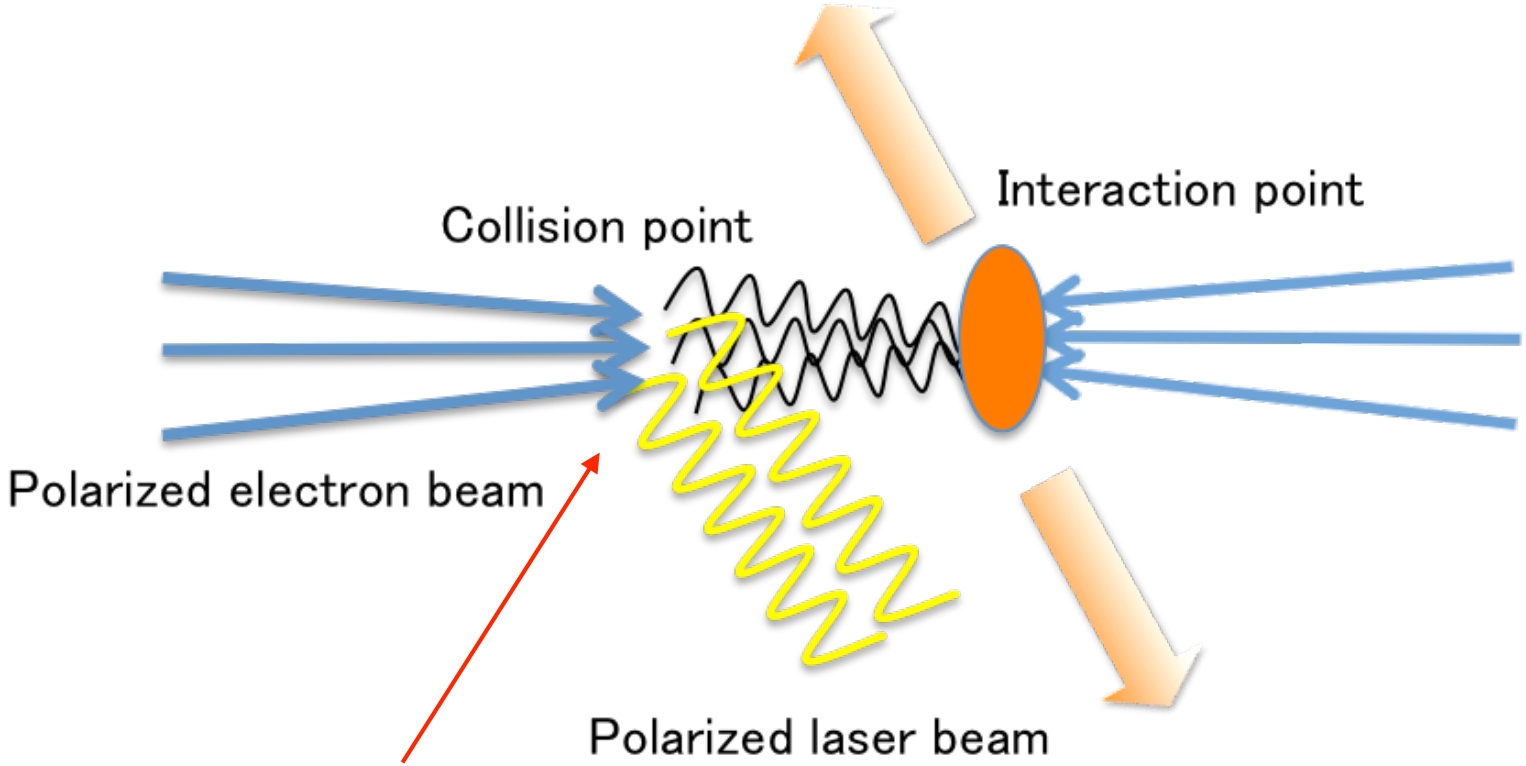
Charged fermion W boson

NW-Kurihara-Sasaki-Uematsu(13)



This behaviour is important to check SM Higgs

eγ collider



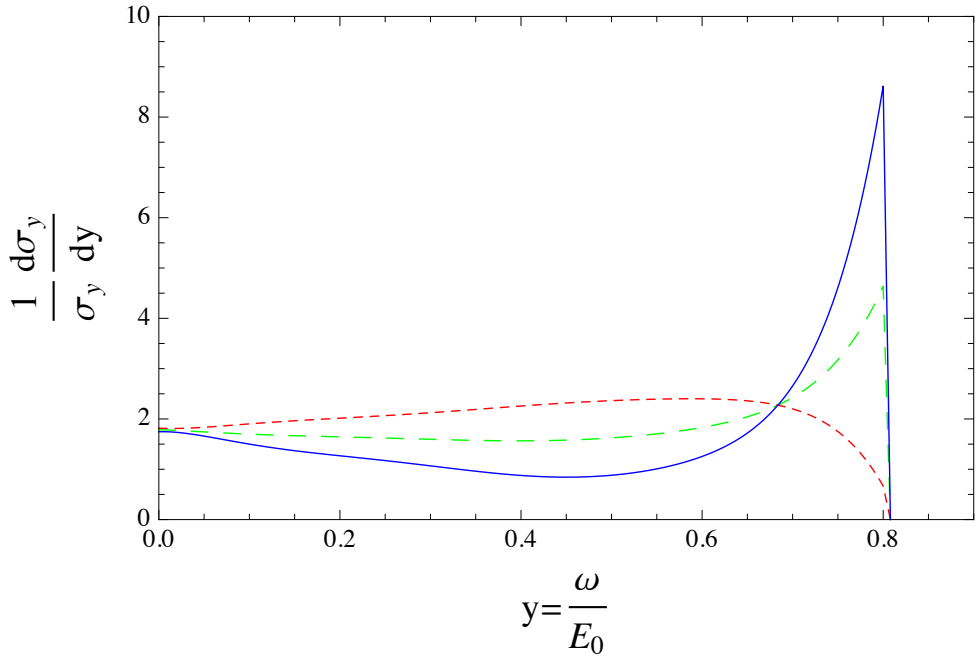
Backward Compton

$e^- \gamma_{\mathrm{Laser}} \rightarrow e^- \gamma$

high energy γ beam can be produced

eγ collider

Energy transfer of Compton scattering



unpol.

different helicity

same helicity

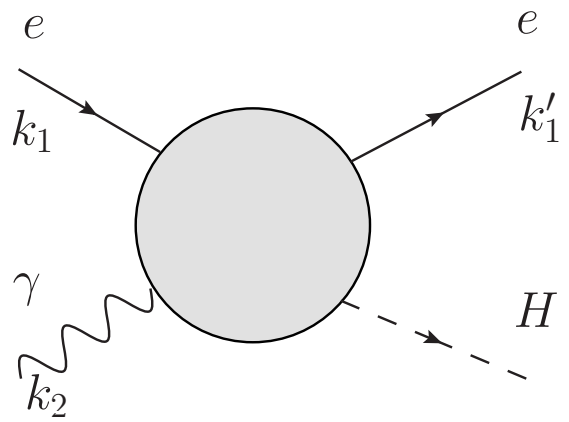
$E_{\mathrm{Laser}} = 2.33GeV$

$e^-\gamma_{\mathrm{Laser}} \rightarrow e^-\gamma$ can transfer 80% of energy to γ

cross section $\sigma_{e^-\gamma_{\mathrm{Laser}}} = \int \frac{d\omega}{\omega} N(\omega)\sigma_{\mathrm{part.}}(\omega)$

Higgs production in eγ collider

- Higgs can be produced in $\gamma\gamma$/eγ collider
  - Higgs physics in $\gamma\gamma$ collider are studied Ginzburg-Krawczyk(2013)
- Here we investigate Higgs production in eγ collider
  - We can measure the variable dependence



kinematics

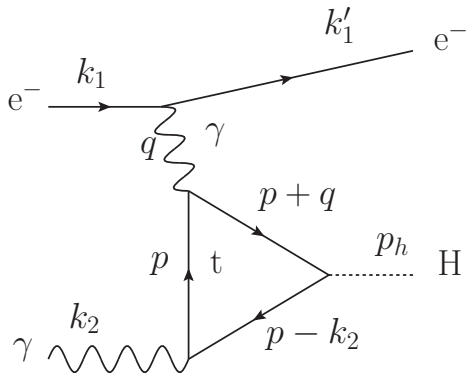
$$s = (k_1 + k_2)^2 = 2k_1 \cdot k_2$$
$$t = (k_1 - k_1')^2 = -2k_1 \cdot k_1' = -Q^2$$
$$u = (k_1 - p_h)^2 = -2k_1' \cdot k_2$$
$$s + t + u = m_h^2$$

Higgs production in $e\gamma$ collider

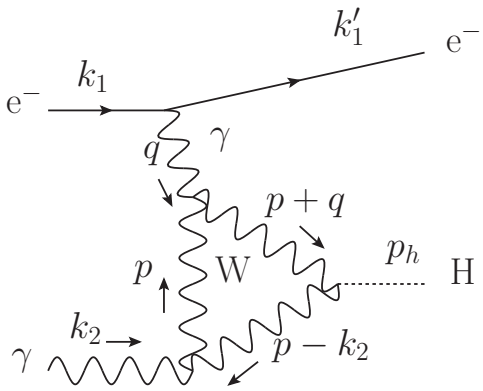
- Higgs are produced by loop diagrams
  - Calculation is done in unitary gauge
  - Amplitudes are expressed in analytical form
- Feynman diagrams at one-loop level
  - photon-photon/photon-Z fusion diagrams
  - Other diagrams

Higgs production in eγ collider

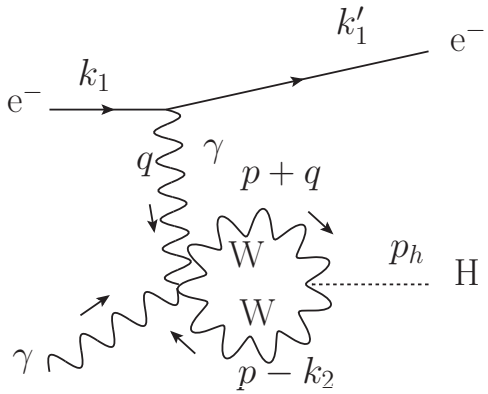
- Fusion diagrams: $\gamma\,\gamma$ fusion



Top-quark loop



W boson loop

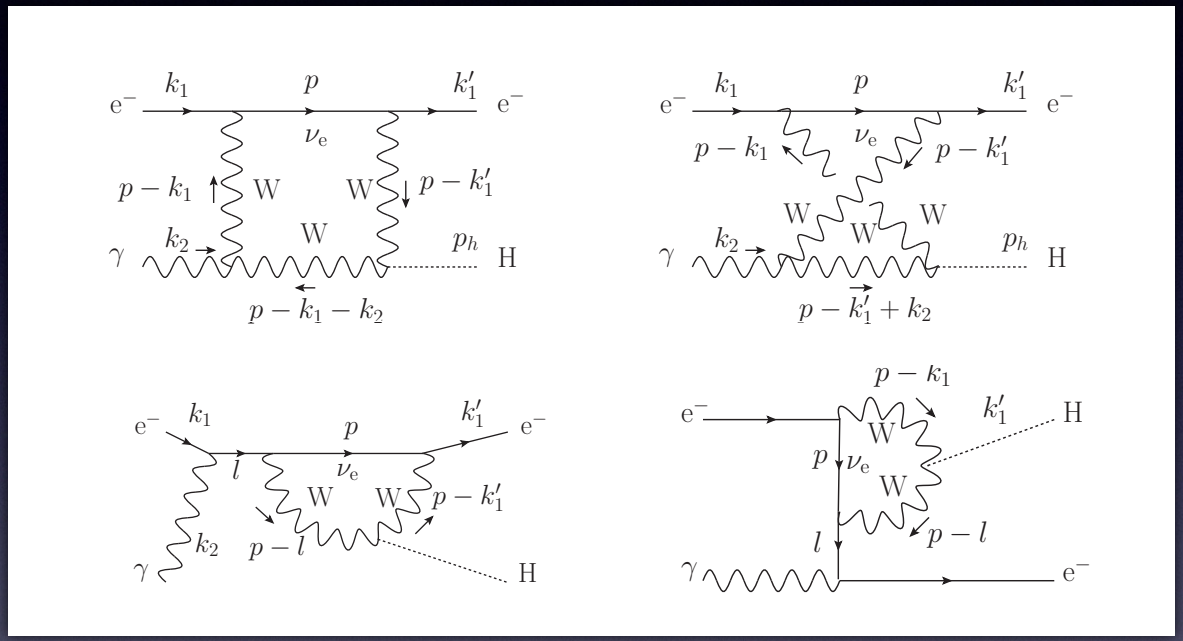


  - γZ fusion: photon propagator⇒Z propagator

- Form factor can be defined in fusion diagrams

Higgs production in eγ collider

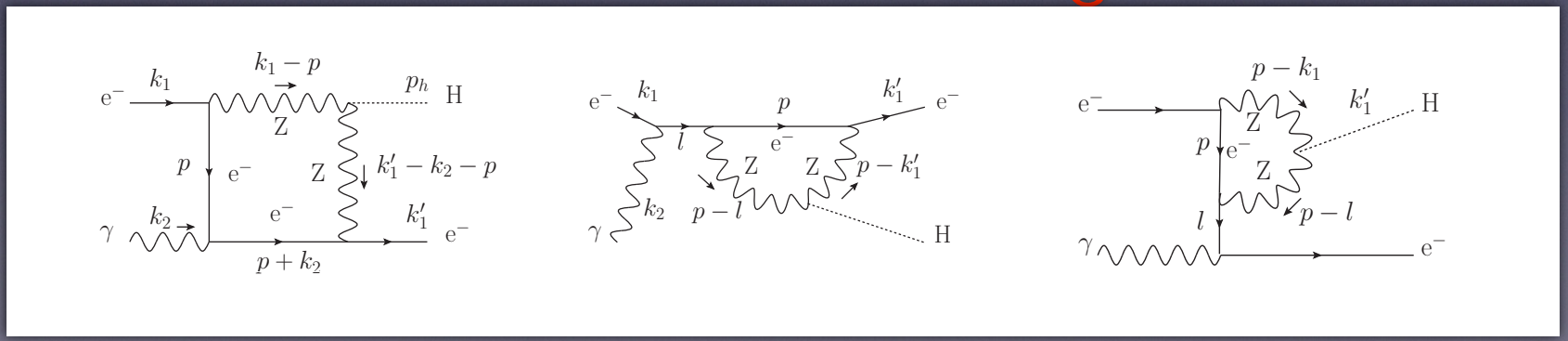
- Other diagrams W-related diagrams



Polarized beam

Zero

Z-related diagrams

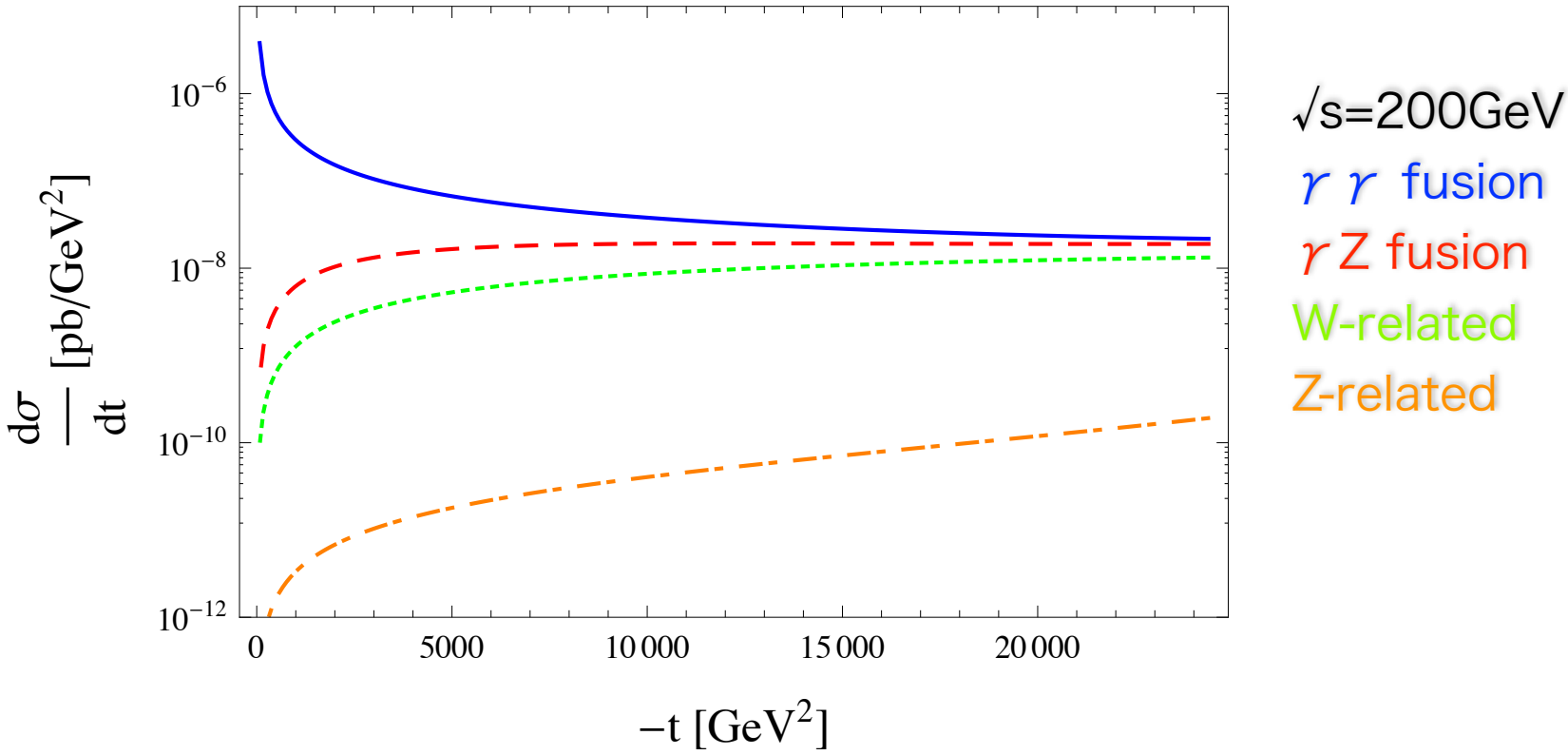


Numerical analysis

Parameters

$m_h = 125\ \mathrm{GeV}$ $m_t = 173\ \mathrm{GeV}$ $m_Z = 91\ \mathrm{GeV}$ $m_W = 80\ \mathrm{GeV}$

t dependence of each topology



√s=200GeV

$\gamma\gamma$ fusion

γZ fusion

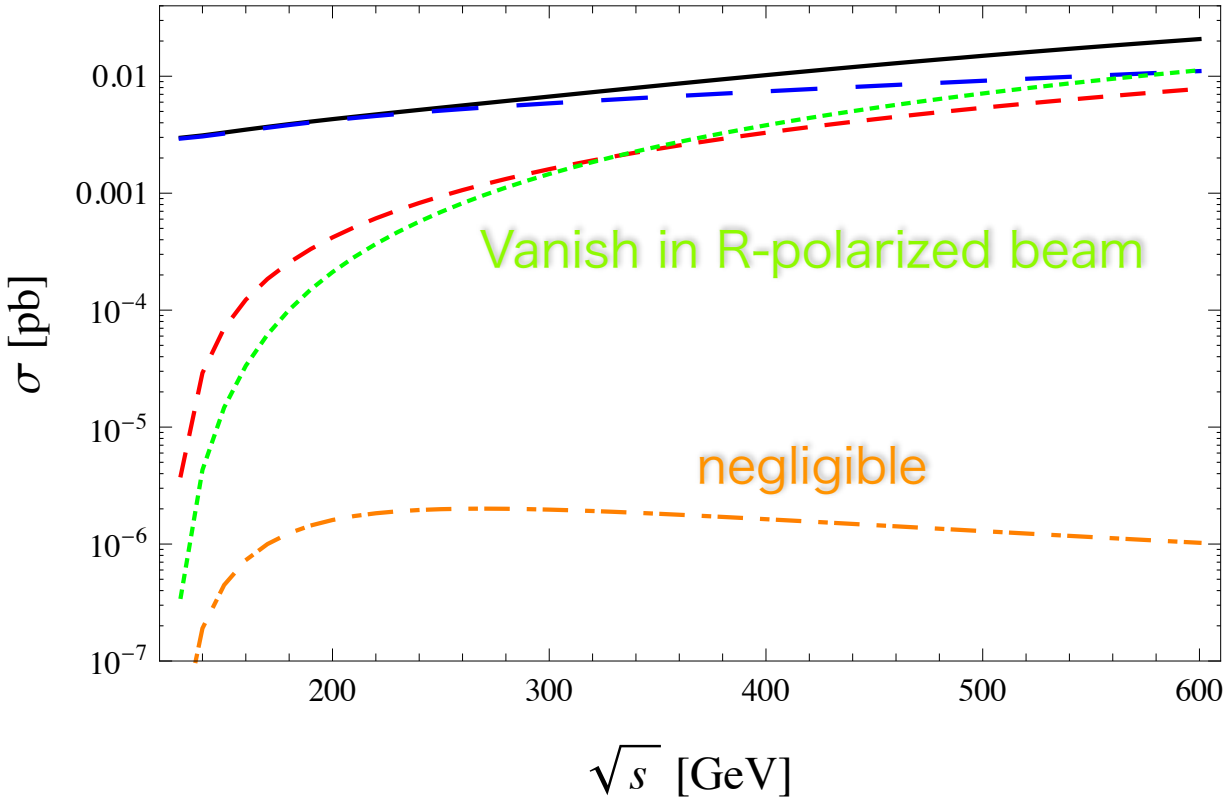
W-related

Z-related

$\gamma\gamma$ fusion is dominant in forwardly region

Numerical analysis

Contribution of each topology



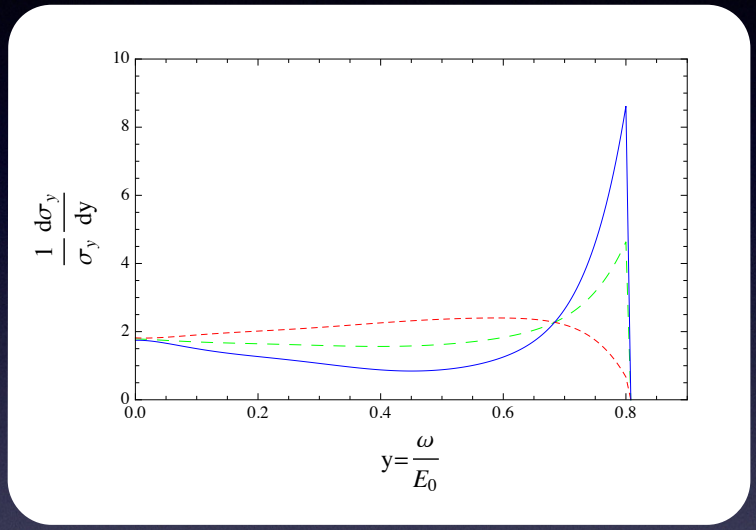
$\gamma\gamma$ fusion is dominant below √s=400GeV

Numerical analysis

- Initial photon has a energy band

Convolution like PDF

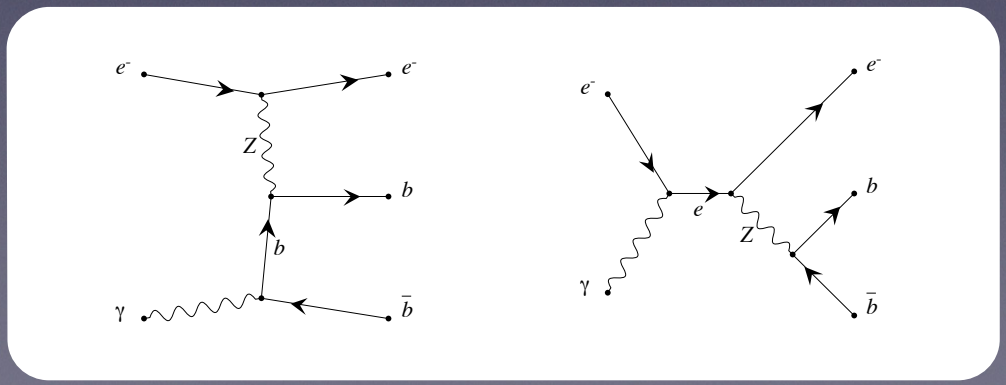
$\sigma = 3.6\mathrm{fb}/9.8\mathrm{fb} \quad @\sqrt{s} = 250\mathrm{GeV}/500\mathrm{GeV}$



- Feasibility to find Higgs in b-decay channel

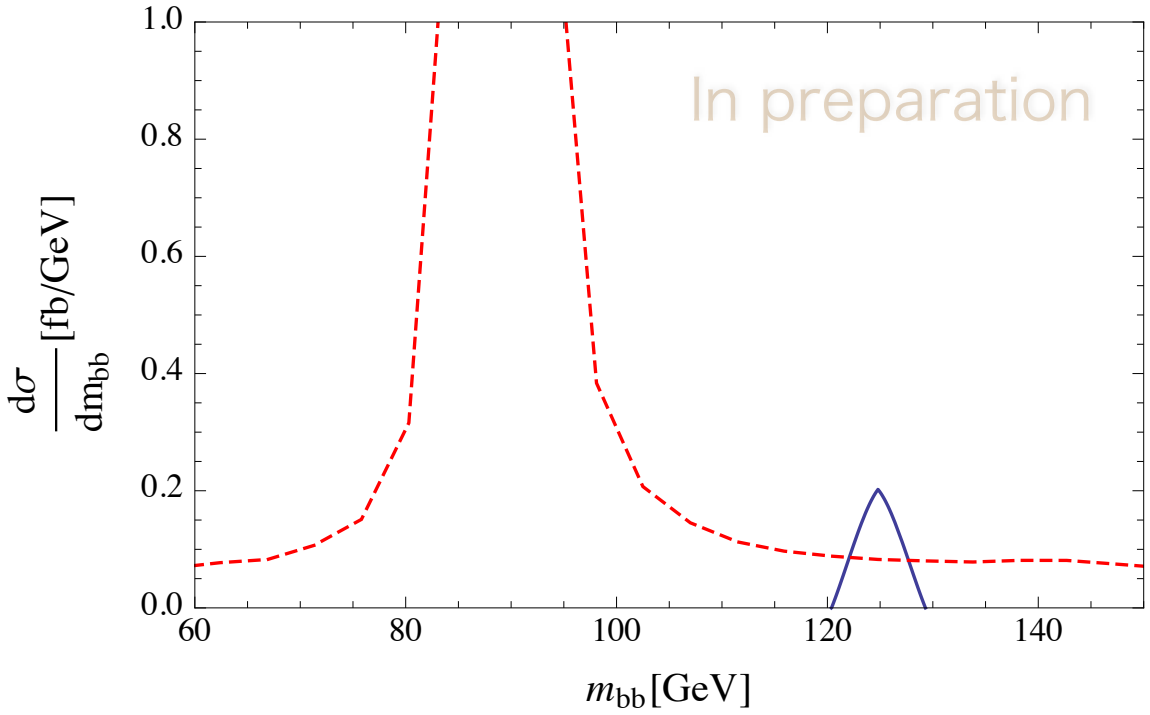
$e + \gamma \to e + H \to e + b + \bar{b}$

- Background exists at tree level



Numerical analysis

- Higgs can be measured by mbb if using appropriate kinematical cut



example

$\sqrt{s} = 500\mathrm{GeV}$

$10^\circ < \theta_e < 170^\circ$

$40^\circ < \theta_b < 170^\circ$

$\mathcal{L} = 250\mathrm{fb}^{-1}$

$$S_{\mathrm{ideal}} = \frac{N_{Sig}}{\sqrt{N_{Back}}} = 16.9$$

Summary

- We studied the transition form factor of Higgs particle
- Higgs production in eγ collision was investigated in SM
  - Fusion diagrams ⇒ form factor
  - Other diagrams: W-related⇒polarized beam
    Z-related ⇒negligible
- Numerical analysis was performed
  - The feasibility to find Higgs in eγ collision in b decay channel

Thanks for your attentions

We hope $\gamma\gamma$/eγ collider are realized