Feasibility study of Higgs pair creation in gamma-gamma collider

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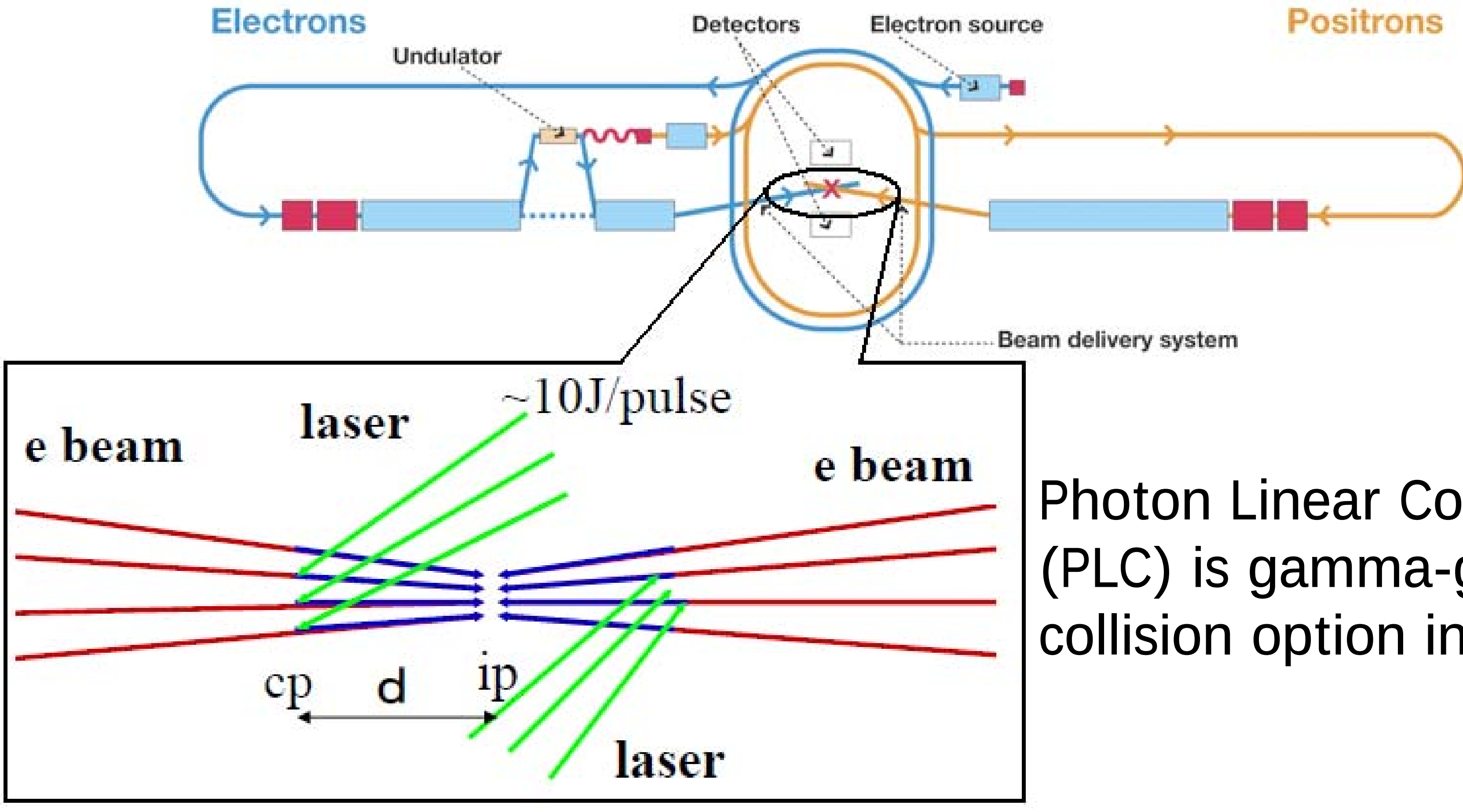
PLC in ILC



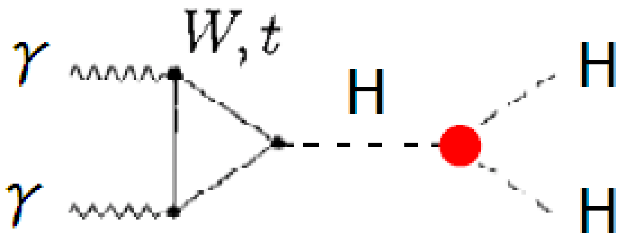
Photon Linear Collider (PLC) is gamma-gamma collision option in ILC.

Measurement of basic physical quantity of Higgs at PLC has been studied. e.g.)the two photon decay width of Higgs.

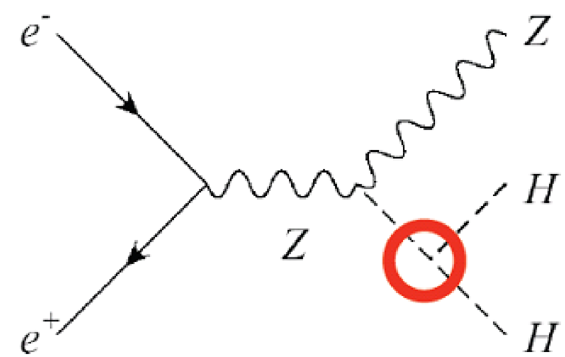
We study feasibility of mesurement of rare process at PLC.

γγ->HH

Measurement of Higgs self-coupling constant $\lambda=\lambda^{SM}(1+\delta\kappa)$ by γγ->HH



and other diagrams



final state is 2particles
include loop diagram

1. This process occurs at low energy(than e^+e^-).
2. λ contribution to cross section is different.

→Can PLC measure Higgs self-coupling constant λ?

Energy optimization

$$sensitivity = \frac{\left|N(\delta\kappa) - N_{SM}\right|}{\sqrt{N_{obs}}} = \frac{L\left|\eta\sigma(\delta\kappa) - \eta\sigma_{SM}\right|}{\sqrt{L(\eta\sigma(\delta\kappa) + \eta_B\sigma_B)}}$$

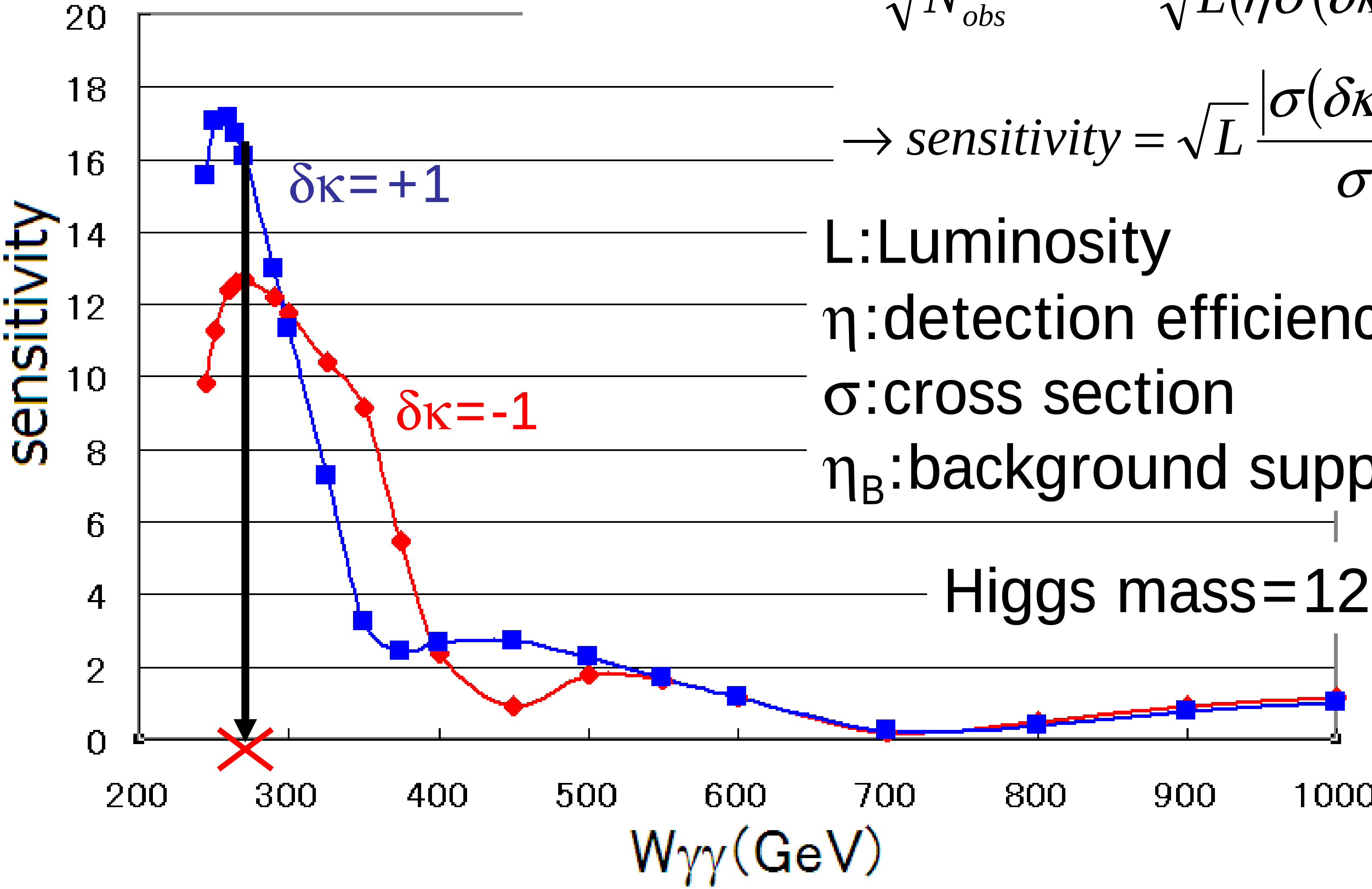
$$\rightarrow sensitivity = \sqrt{L}\,\frac{\left|\sigma(\delta\kappa) - \sigma_{SM}\right|}{\sigma(\delta\kappa)}$$

L:Luminosity

η:detection efficiency

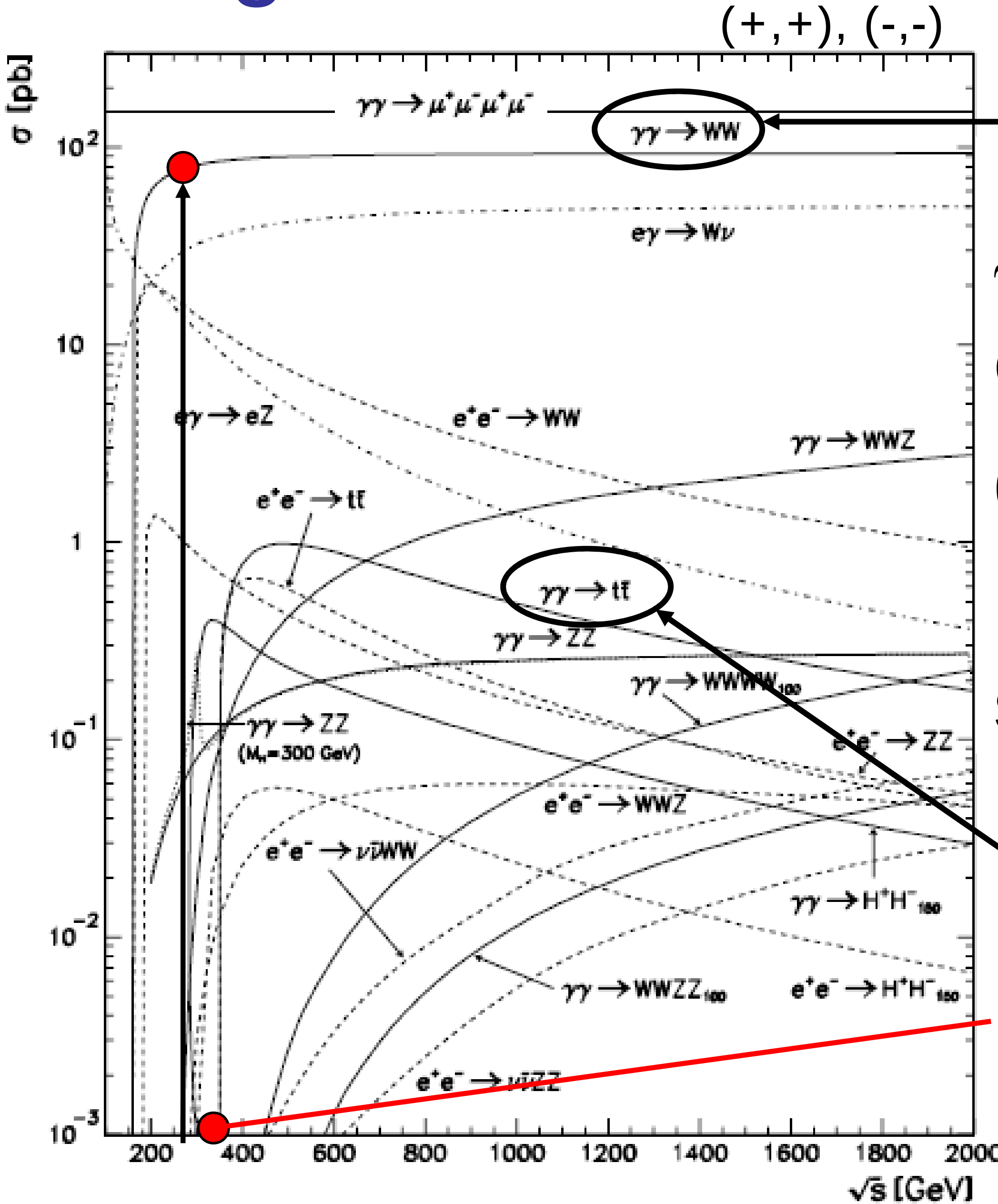
σ:cross section

η_B:background suppression



Higgs mass=120GeV

Background



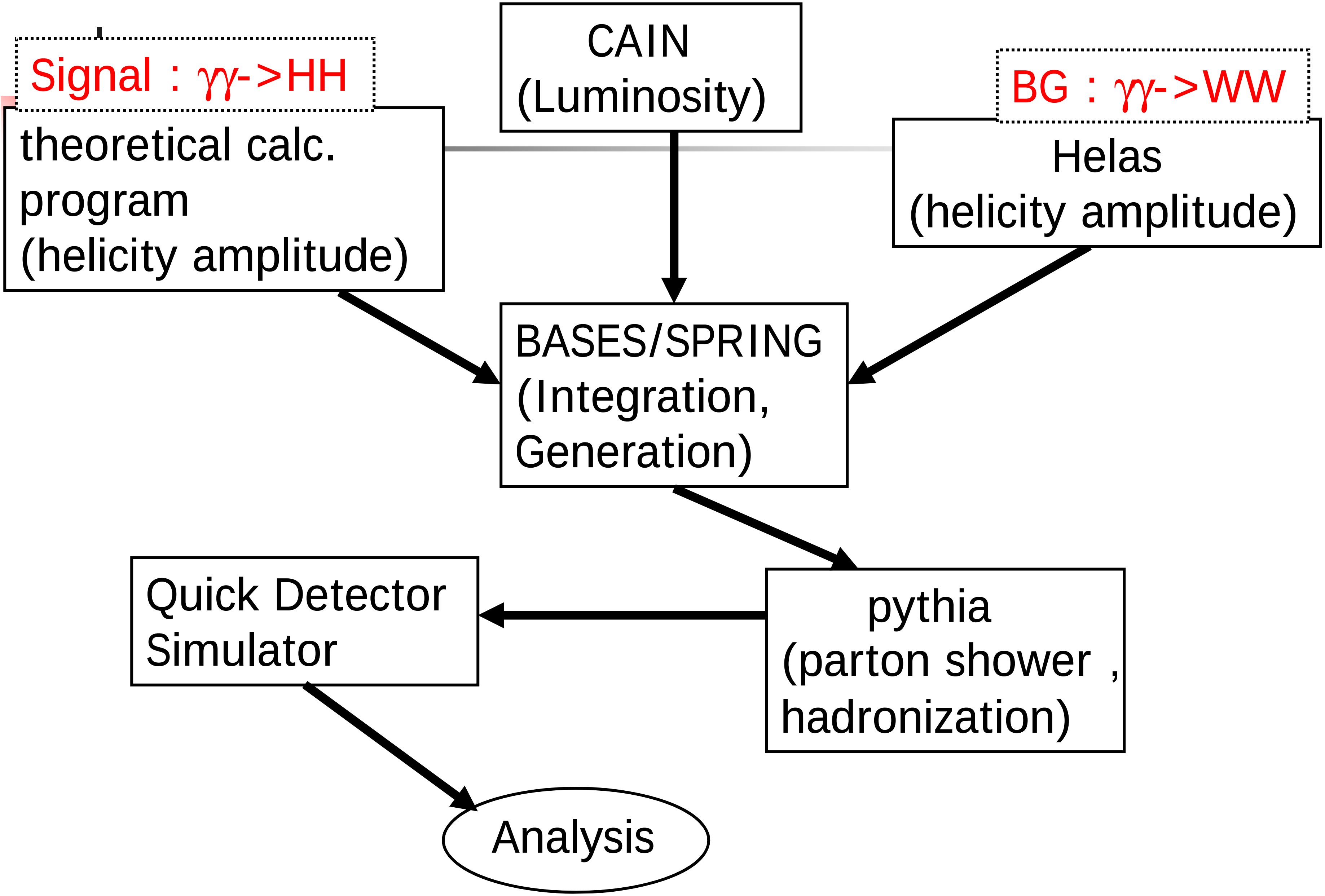
main background is $\gamma\gamma$->WW ($\sigma_B \sim$ 90pb)
cf.) Signal:σ = 0.044fb

0.044fb/90pb = 4.9×10^{-7}

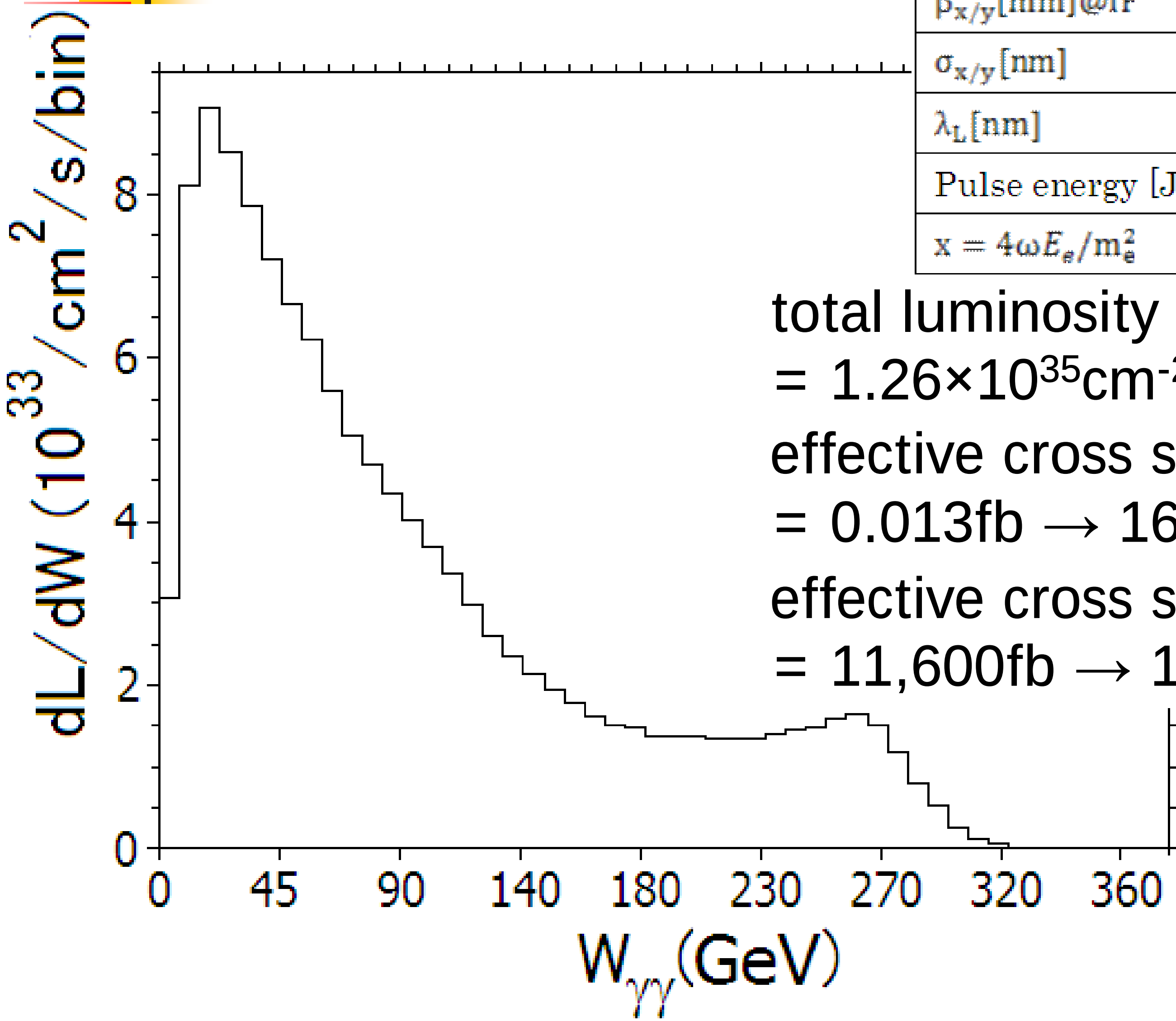
10^{-7} background supression is necessary.

$\gamma\gamma$->tT does not occur.
Optimum energy is below tT threshold.

Simulation Framework



Luminosity spectrum



Ee[GeV]	190
$N/10^{10}$	2
σ_z[mm]	0.35
$\gamma\varepsilon_{x/y}/10^{-6}$[m rad]	2.5/0.03
$\beta_{x/y}$[mm]@IF	1.5/0.3
$\sigma_{x/y}$[nm]	96/4.7
λ_L[nm]	1054
Pulse energy [J]	10
$x = 4\omega E_e/m_e^2$	3.76

total luminosity of photon collision
= 1.26×10^{35}cm^{-2}s^{-1}
effective cross section(Signal)
= 0.013fb → 16event/year
effective cross section(BG)
= 11,600fb → 1.467×10^{7}event/year

$\eta_B<10^{-6}$ is required.

Analysis

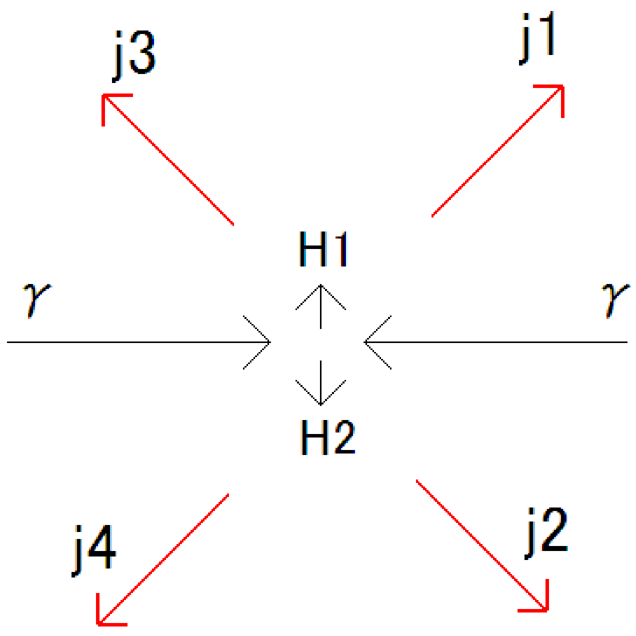
- Signal : $\gamma\gamma$->HH
  H -> bB or WW* or gg
- Background : $\gamma\gamma$->WW
  W -> ud or cs or eν

choose HH->4b(Branching ratio = 0.43).

background:WW->4quark

→reconstruct particles, and try to distinguish them.

Event reconstruction



choose 2jets from 4jets, and reconstruct Higgs(or W-boson) from this 2jets.

→ 3 combinations for 1event.

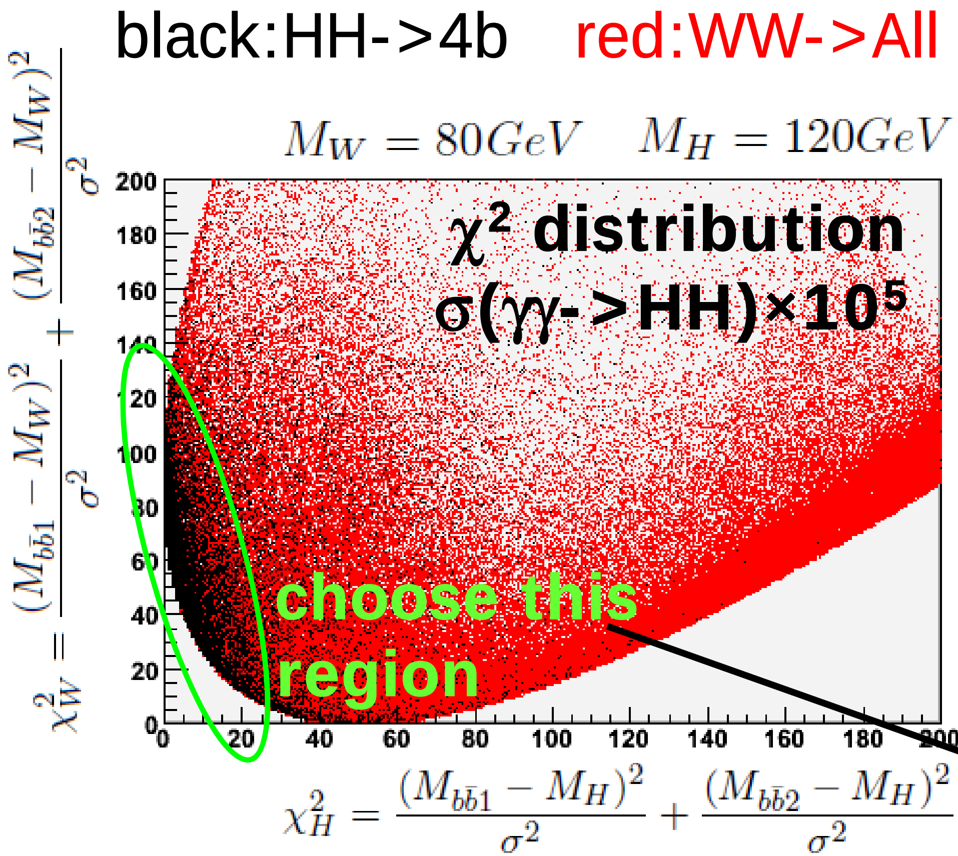
→ choose a combination that has the smallest χ^2.

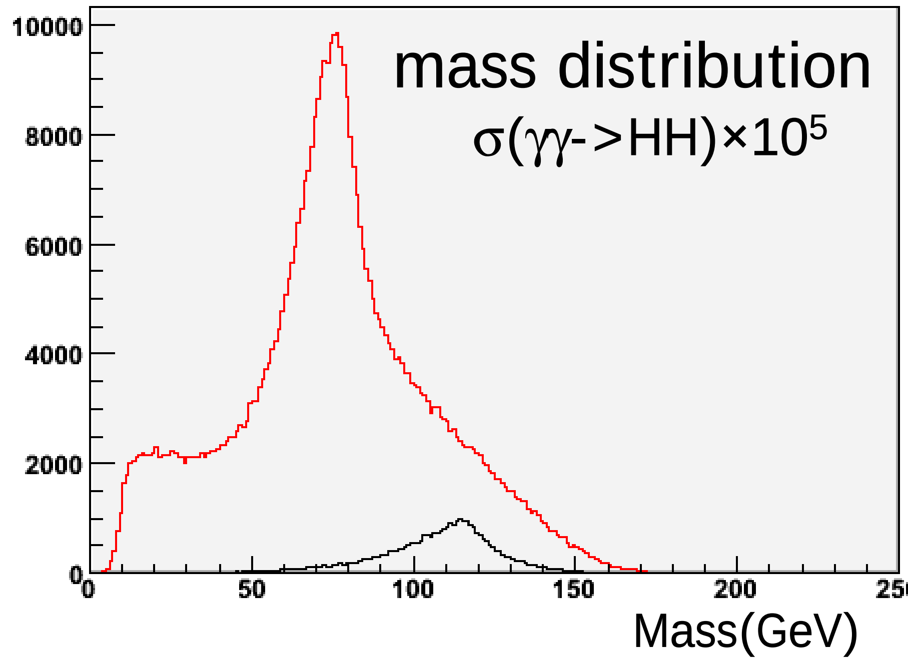
$$\chi^2 = \frac{(M_1 - M)^2}{\sigma_{2j}^2} + \frac{(M_2 - M)^2}{\sigma_{2j}^2}$$

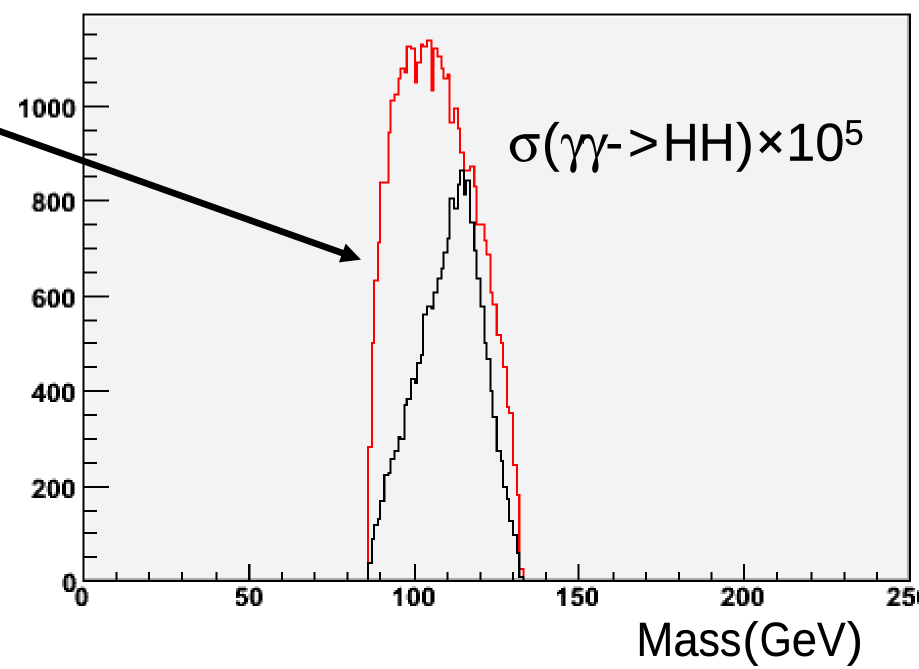
M_1, M_2 = reconstructed particle mass

$M = M_H$ or M_W σ_{2j} = 2jets mass resolution

χ^2 distribution





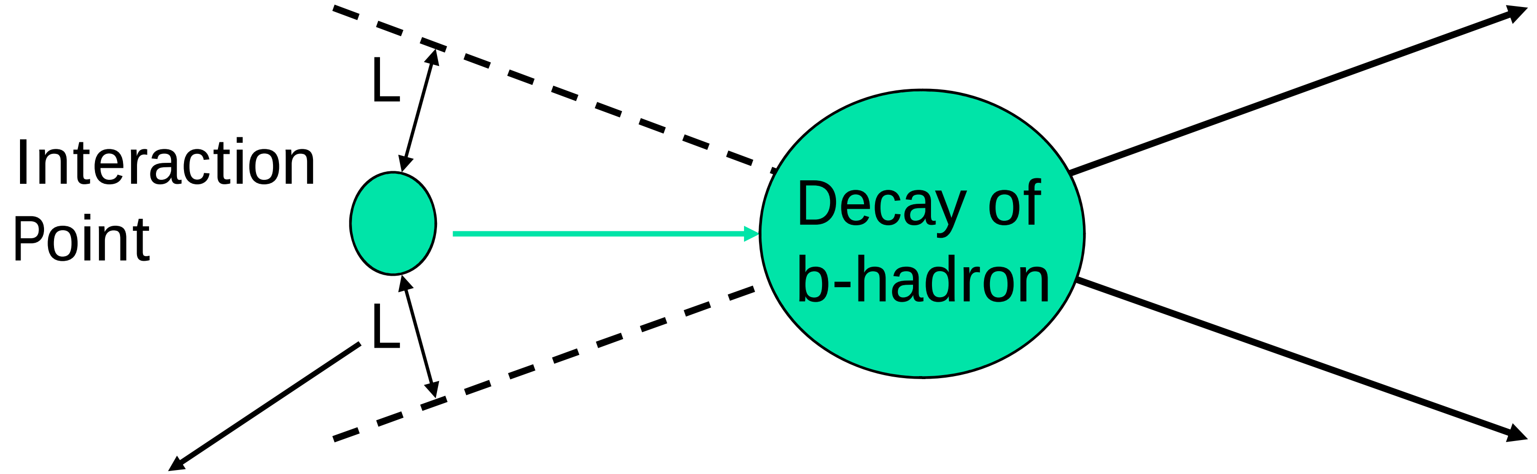


Selection by χ^2 is not enough to suppress background.

→b-tagging is necessary.

b-tagging by simulation

We tried to b-tagging by simulation.
nsig method was used.



nsig = L/σ_L (σ_L : measurement error)

noffv = # of tracks that has a certain nsig.

→define the jet that has a certain noffv as b-jet.

b-tagging by simulation

Definition

loose b-tag : nsig = 3, noffv = 1
tight b-tag : nsig = 3, noffv = 2

Event selection

condition	# of BG	# of Signal
nocut	10,000,000	50,000
# of jets = 4	8.09E+06	4.97E+04
# of loose b-tagged jets = 4	923	1.62E+04
# of tight b-tagged jets ≧ 3	135	1.33E+04
χ2(H) < 18	12	1.03E+04
χ2(W) > 5	2	9.15E+03
maximum charged particle energy ≧ 2GeV	0	6.60E+03

→ Background : 10,000,000event -> 0event

Signal : 50,000event -> 6,607event

(m_{Signal}=0.132)

If PLC runs for 10 years…

16events/year×10years×0.132 = 21events → 4.6σ

Summary

- We study feasibility of measurement of Higgs self-coupling constant λ at PLC.
- If Higgs mass = 120GeV, optimized photon collision energy is 270GeV.
- No. of Signal event is expected 16events/year with PLC parameter(TESLA optimistic).
- Selection by b-tagging and kinematics parameters can suppress almost $\gamma\gamma$->WW.
- $\gamma\gamma$->HH can be observed with 4.6σ in 10 years.
- Next plan, consider HH->bBWW*(B.R.=0.18).

Thank you for your attention.

backup

b-tagging by simulation

loose : nsig=3, noffv=1
# of b-tagged jets = 4,
η_{BG} = 9.23×10^{-5} η_{Signal} = 0.324

tight : nsig=3, noffv=2
# of b-tagged jets = 4,
η_{BG} = 1.50×10^{-6} η_{Signal} = 0.161

Event selection

of loose b-tagged jets = 4
# of tight b-tagged jets ≧ 3

→ η_B = 1.4e-5
η_{Signal} = 0.27

# of loose b-tagged jets = 4
# of tight b-tagged jets ≧ 3
particle mass > 80GeV
maximum charged particle mass > 2GeV
Visible energy > 200

→ η_B = 1.2e-6
η_{Signal} = 0.17

# of loose b-tagged jets = 4
# of tight b-tagged jets ≧ 3
$\chi^2(H) < 18$
$\chi^2(W) > 5$

→ η_B = 2.0e-7
η_{Signal} = 0.18

b-tagging by simulation

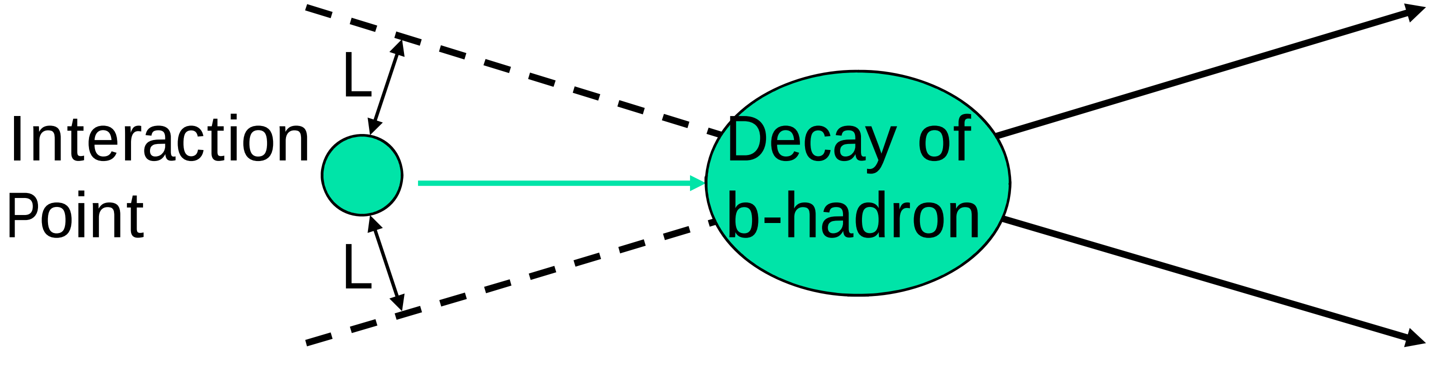
We tried to b-tagging by simulation.
nsig method was used.

nsig method

assuming the distance between tracks and IP, L
and the measurement error, σ_L

define the track as “off vertex track” if L/σ_L is over a certain value(nsig).

define the jet as b-jet if the number of “off vertex tracks” in a jet is over a certain value(noffv).



Probability of miss identify for charm quark is the highest in b-tagging.