



Feasibility study of Higgs pair creation in gamma-gamma collider

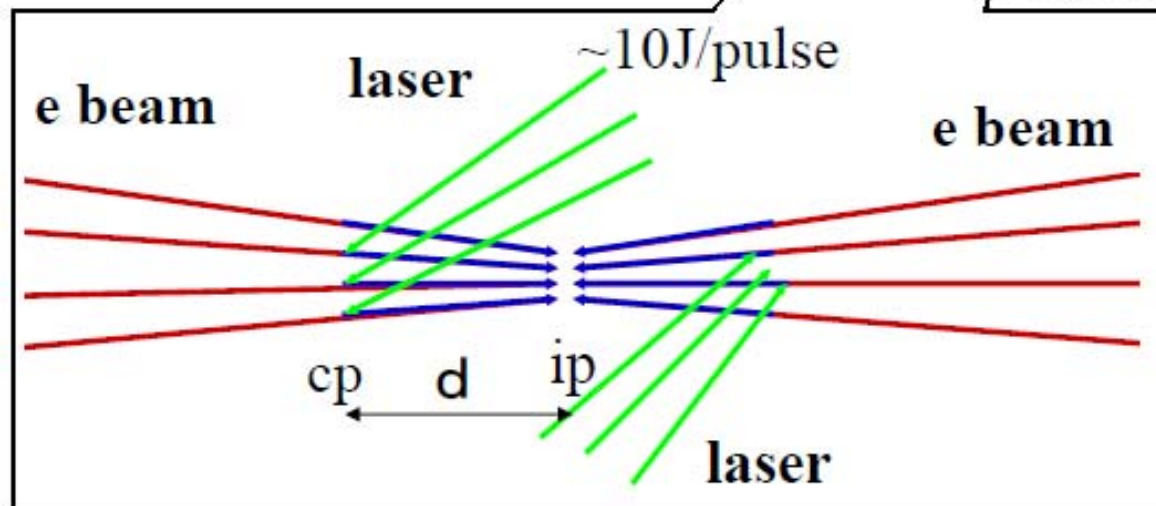
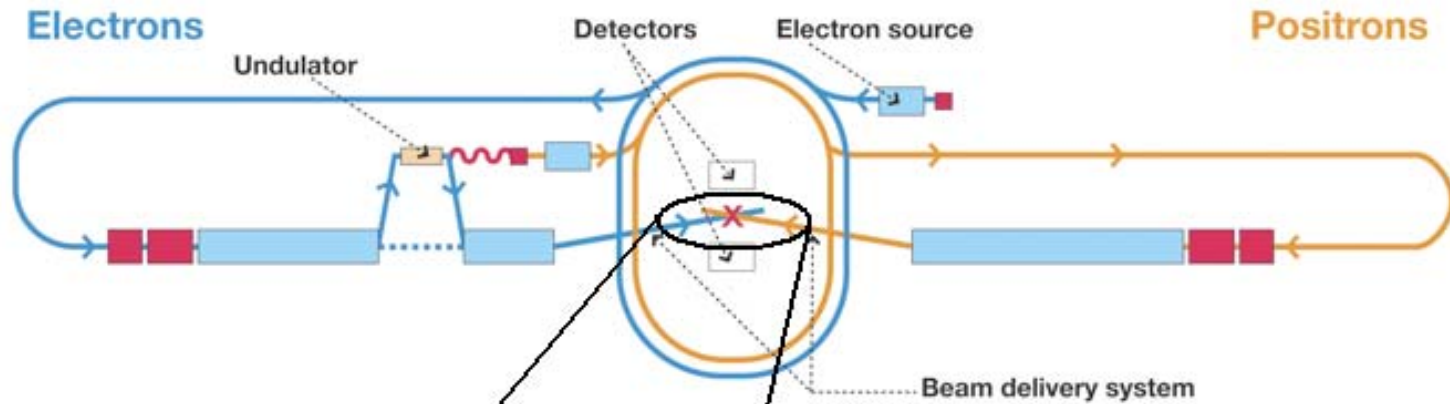
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19.April 2009

PLC in ILC



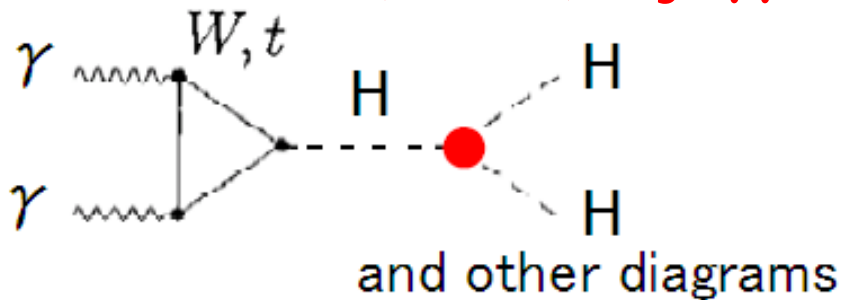
Photon Linear Collider (PLC) is gamma-gamma collision option in ILC.

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

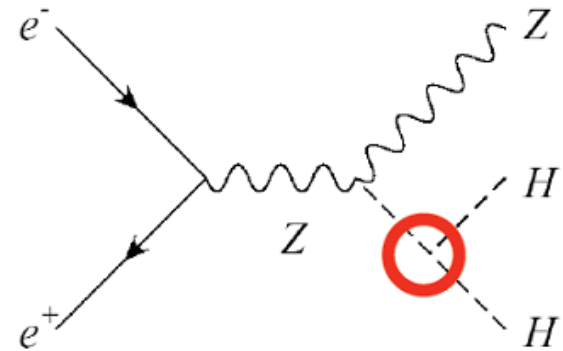
We study feasibility of measurement of rare process at PLC.

$\gamma\gamma \rightarrow HH$

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



final state is 2 particles
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 ?

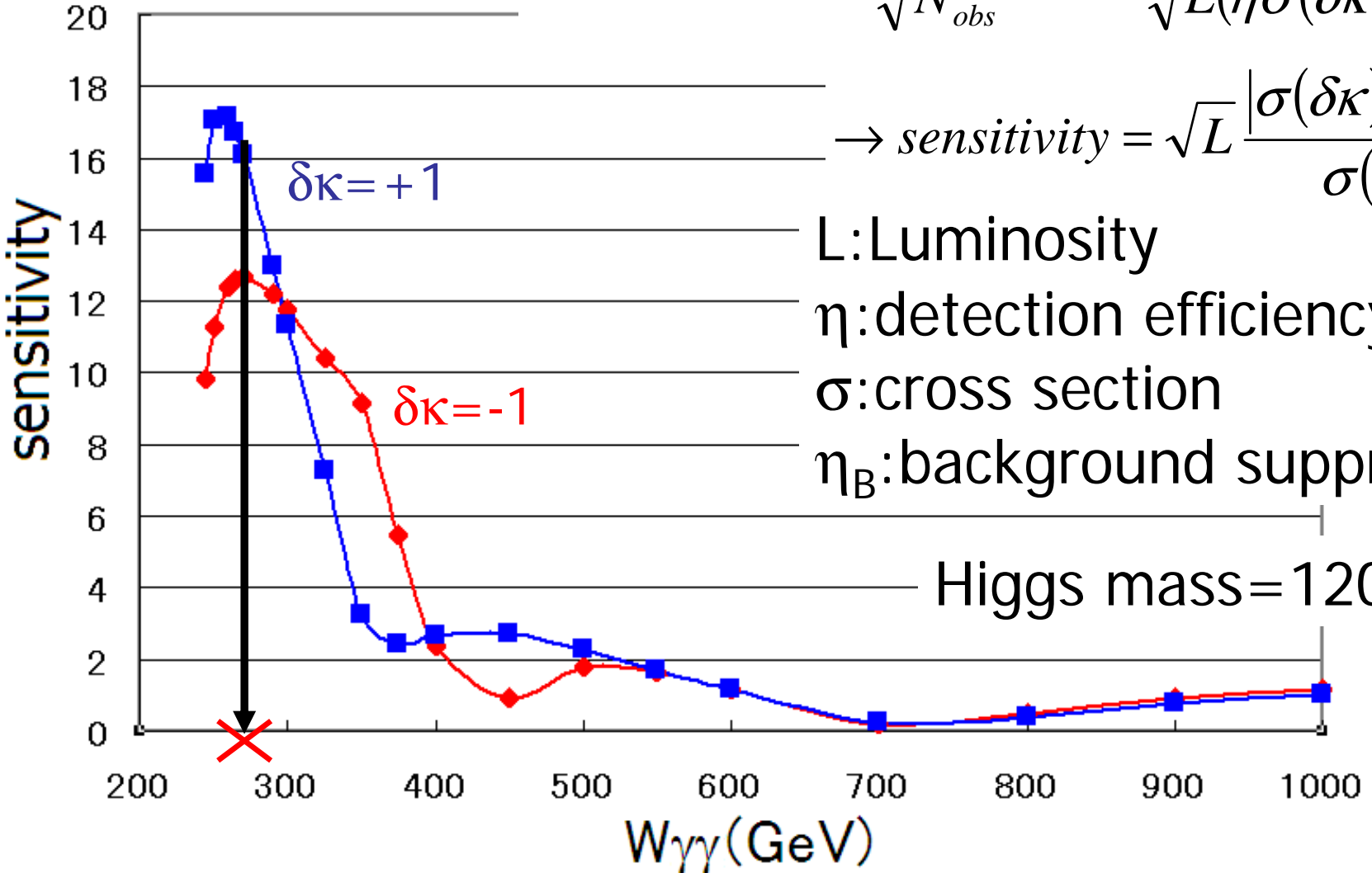
Energy optimization

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

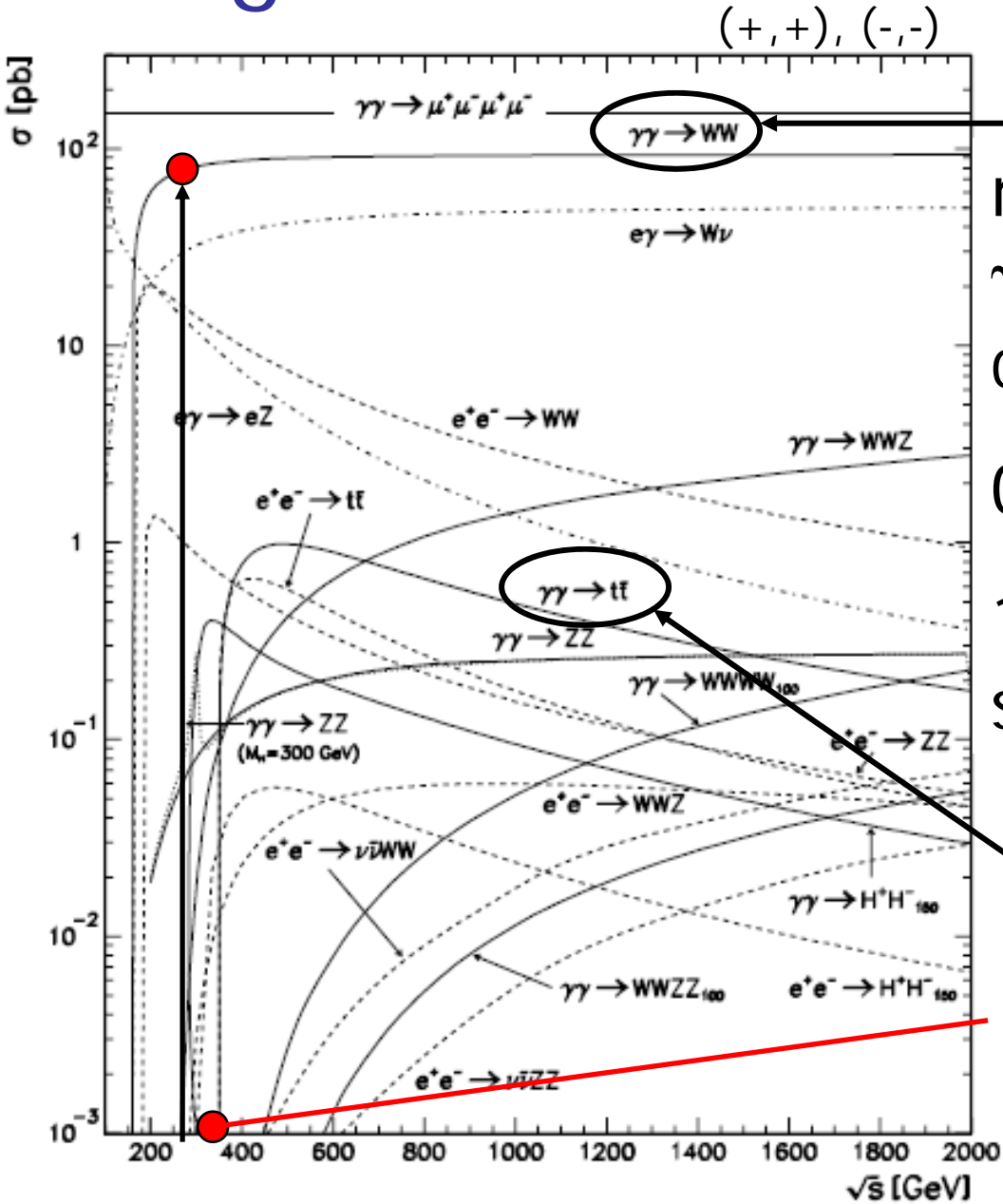
$$\rightarrow sensitivity = \sqrt{L} \frac{|\sigma(\delta\kappa) - \sigma_{SM}|}{\sigma(\delta\kappa)}$$

- L: Luminosity
- η : detection efficiency
- σ : cross section
- η_B : background suppression

Higgs mass = 120 GeV



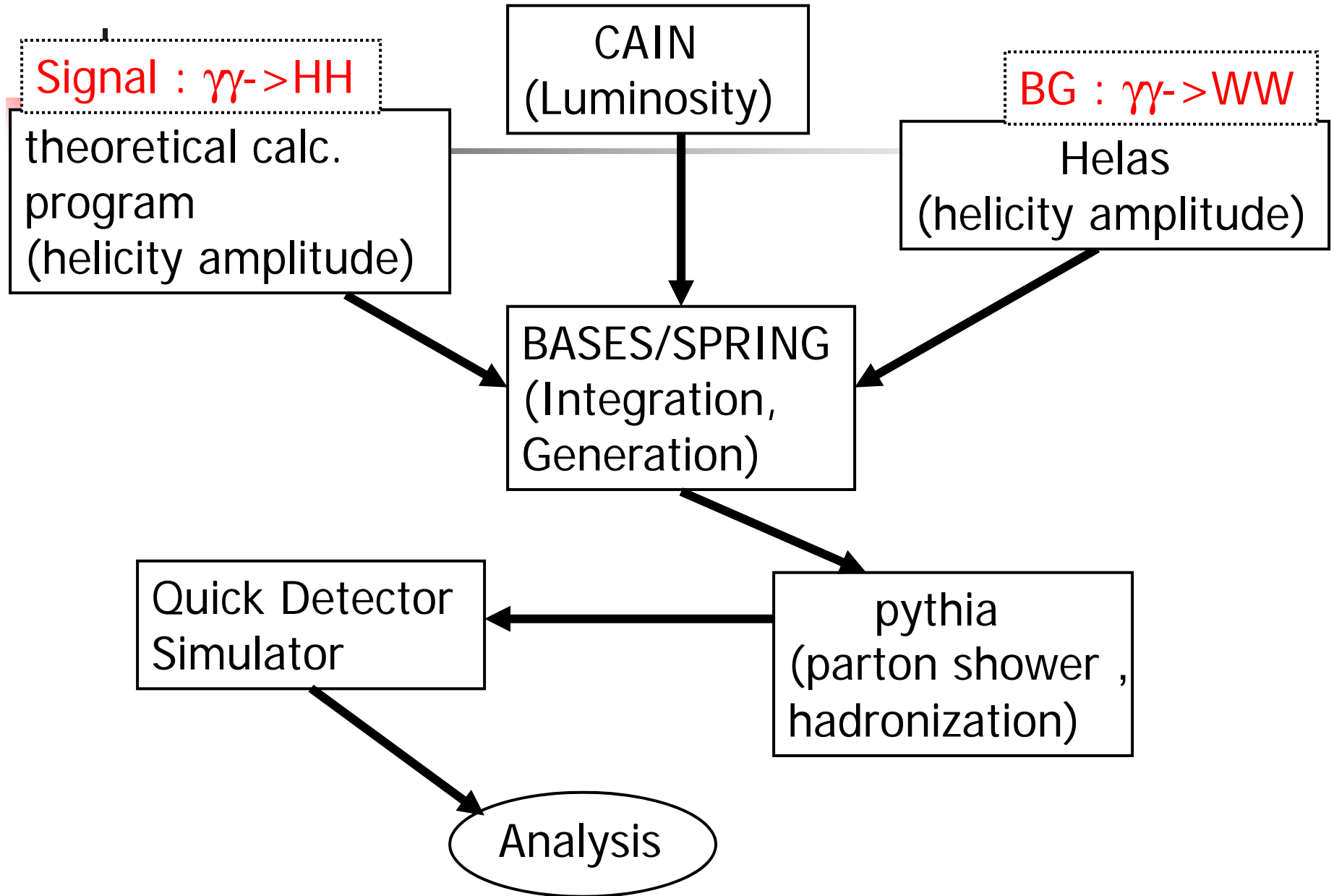
Background



(+,+), (-,-)

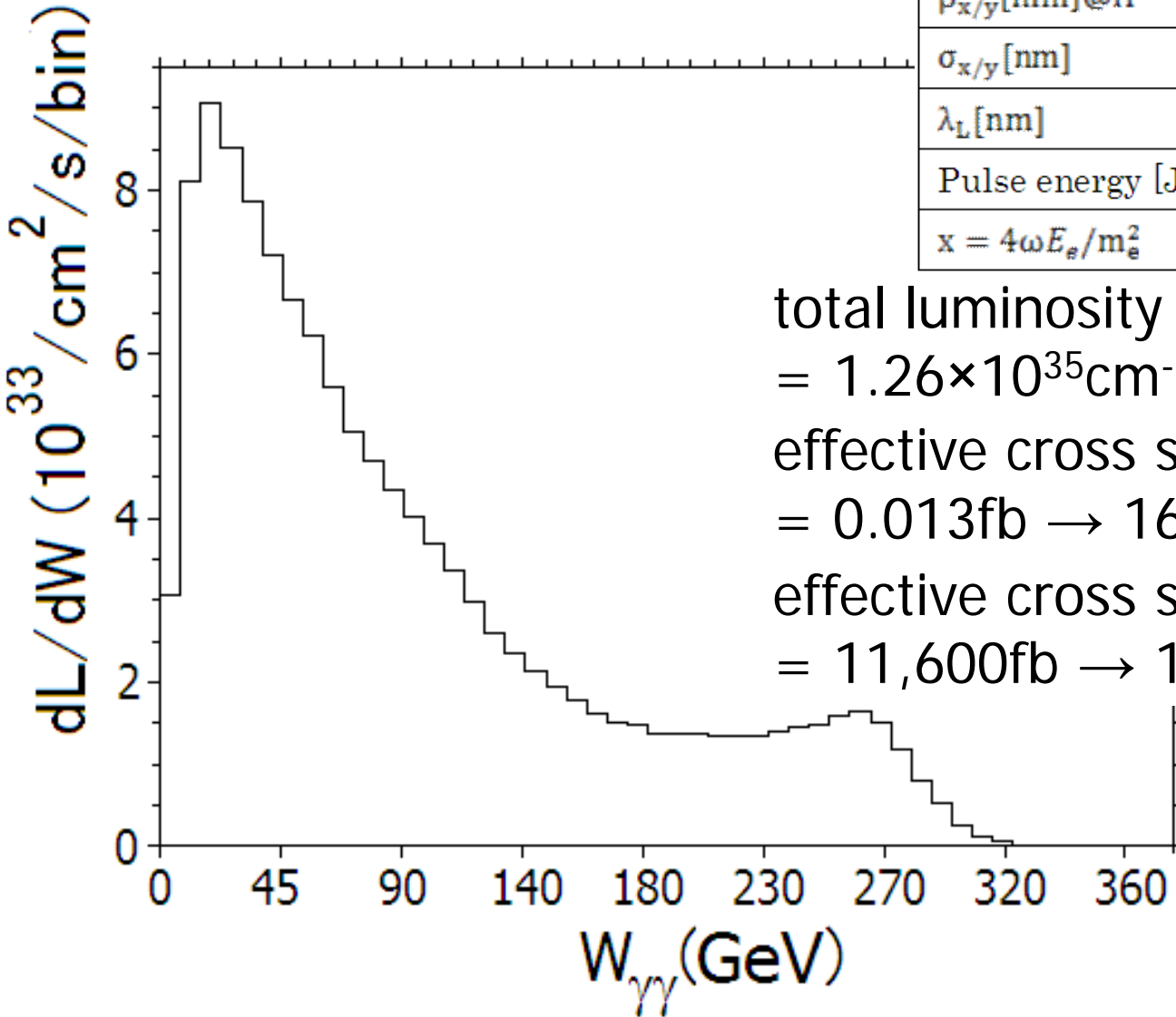
main background is $\gamma\gamma \rightarrow WW$ ($\sigma_B \sim 90\text{pb}$)
 cf.) Signal: $\sigma = 0.044\text{fb}$
 $0.044\text{fb}/90\text{pb} = 4.9 \times 10^{-7}$
 10^{-7} background suppression is necessary.
 $\gamma\gamma \rightarrow t\bar{t}$ does not occur.
 Optimum energy is below $t\bar{t}$ threshold.

Simulation Framework



Luminosity spectrum

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



total luminosity of photon collision
 $= 1.26 \times 10^{35} \text{cm}^{-2} \text{s}^{-1}$

effective cross section(Signal)
 $= 0.013 \text{fb} \rightarrow 16 \text{event/year}$

effective cross section(BG)
 $= 11,600 \text{fb} \rightarrow 1.467 \times 10^7 \text{event/year}$

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



Analysis

- Signal : $\gamma\gamma \rightarrow HH$
H \rightarrow **bB** or WW^* or gg
- Background : $\gamma\gamma \rightarrow WW$
W \rightarrow **ud** or **cs** or ev

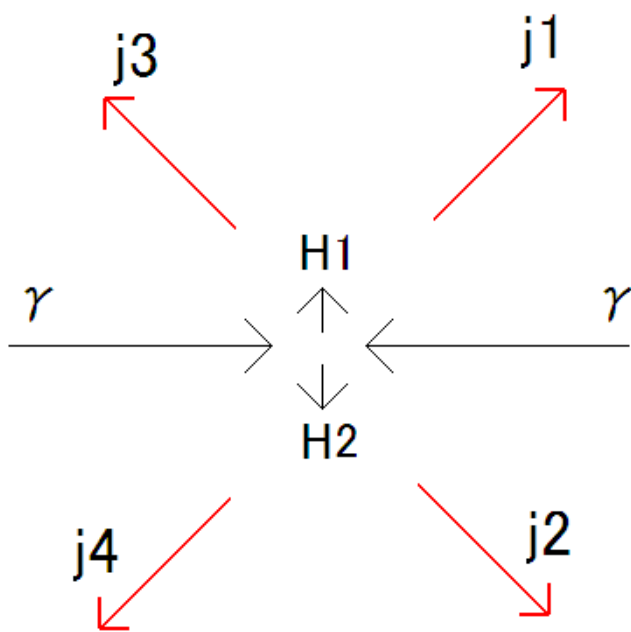
choose **HH \rightarrow 4b** (Branching ratio = 0.43).

background: **WW \rightarrow 4quark**

\rightarrow 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 .

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

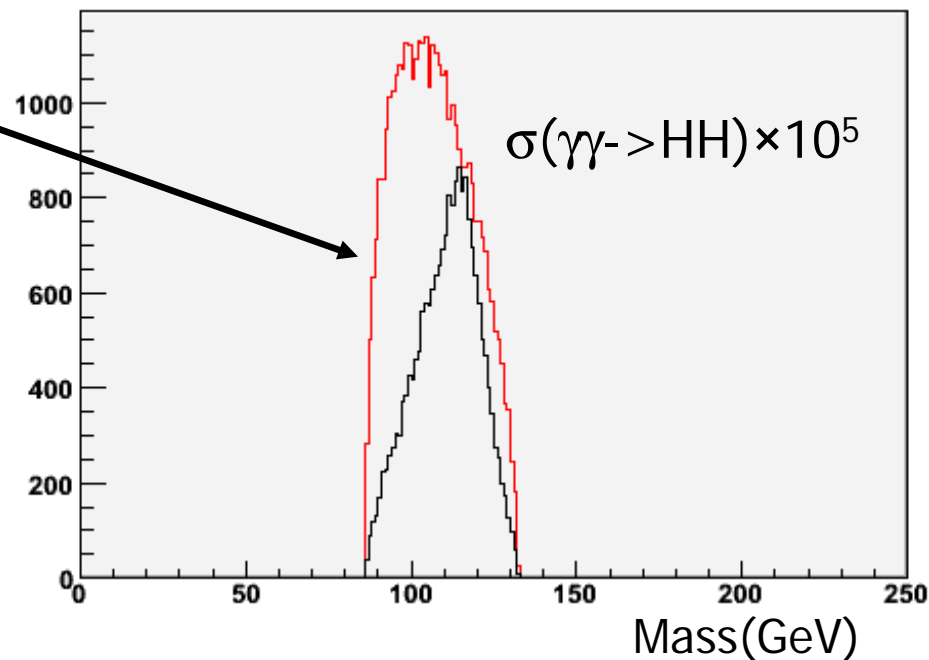
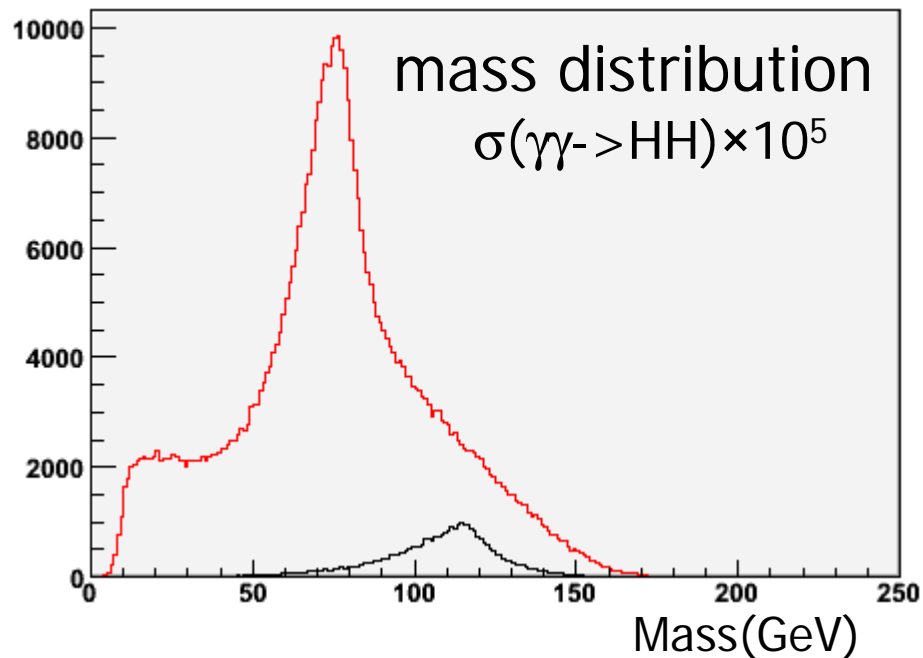
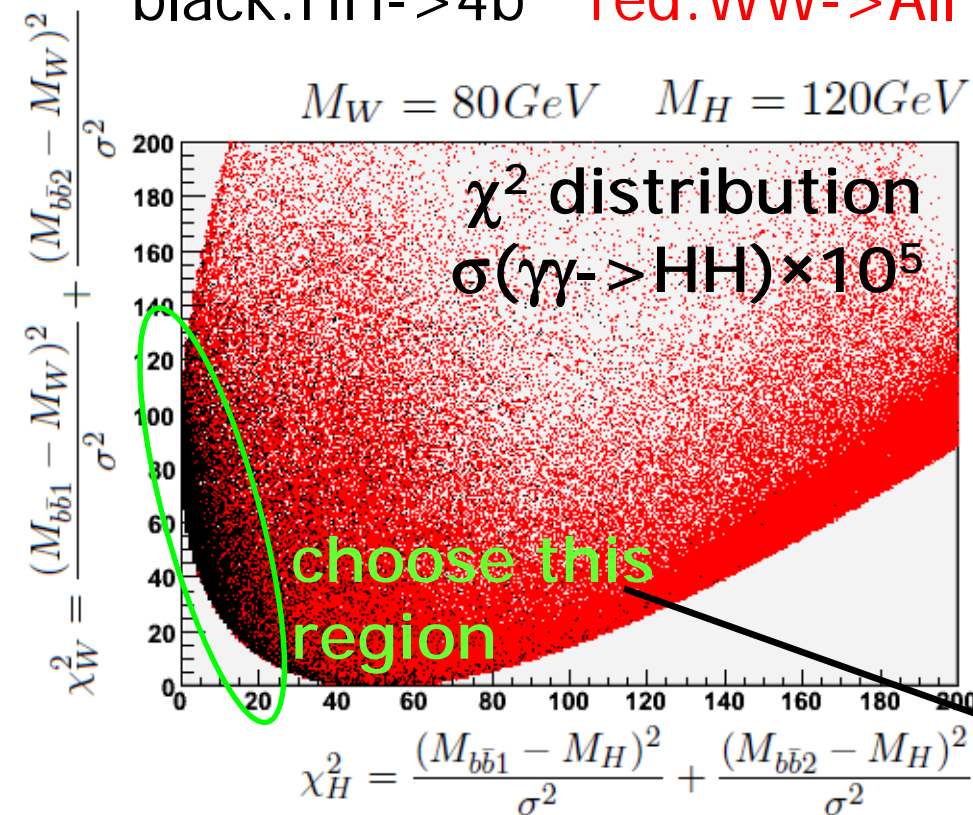
M_1, M_2 = reconstructed particle mass

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

χ^2 distribution

black: $HH \rightarrow 4b$ red: $WW \rightarrow \text{All}$

$$M_W = 80 \text{ GeV} \quad M_H = 120 \text{ GeV}$$

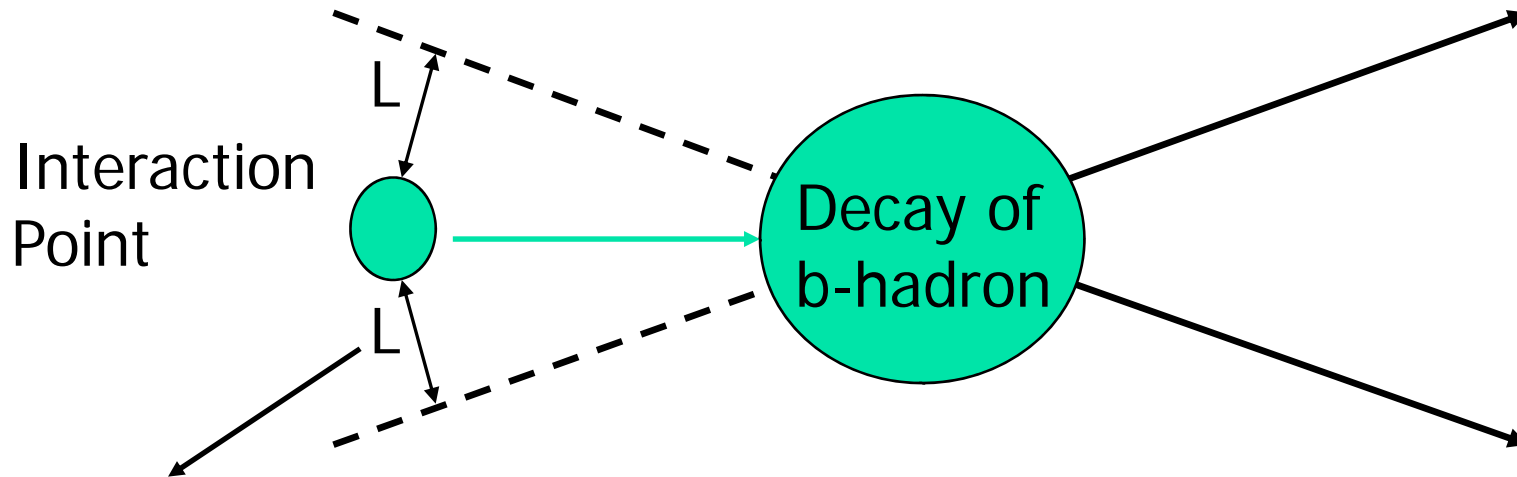


Selection by χ^2 is not enough
to suppress background.

→ b-tagging is necessary.

b-tagging by simulation

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



$nsig = L/\sigma_L$ (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 : $n_{\text{sig}} = 3, n_{\text{offv}} = 1$

tight b-tag : $n_{\text{sig}} = 3, n_{\text{offv}} = 2$

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
$\chi^2(H) < 18$	12	1.03E+04
$\chi^2(W) > 5$	2	9.15E+03
maximum charged particle energy $\geq 2\text{GeV}$	0	6.60E+03

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

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

If RLIC runs for 10 years...
 $\epsilon_{\text{Signal}} = 0.132$

$16\text{events/year} \times 10\text{years} \times 0.132 = 21\text{events} \rightarrow 4.6\sigma$



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 $\gamma\gamma \rightarrow WW$.
- $\gamma\gamma \rightarrow HH$ can be observed with 4.6σ in 10 years.
- Next plan, consider $HH \rightarrow bBWW^*$ (B.R.=0.18).



Thank you for your attention.


backup

b-tagging by simulation

loose : nsig=3, noffv=1
of b-tagged jets = 4,
 $\eta_{\text{BG}} = 9.23 \times 10^{-5}$ η_{Signal}
= 0.324

tight : nsig=3, noffv=2
of b-tagged jets = 4,
 $\eta_{\text{BG}} = 1.50 \times 10^{-6}$ η_{Signal}
= 0.161

Event selection



of loose b-tagged jets = 4
of tight b-tagged jets ≥ 3

$\eta_B = 1.4e-5$
 $\eta_{\text{Signal}} = 0.27$

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

$\eta_B = 1.2e-6$
 $\eta_{\text{Signal}} = 0.17$

of loose b-tagged jets = 4
of tight b-tagged jets ≥ 3
 $\chi^2(\text{H}) < 18$
 $\chi^2(\text{W}) > 5$

$\eta_B = 2.0e-7$
 $\eta_{\text{Signal}} = 0.18$

b-tagging by simulation

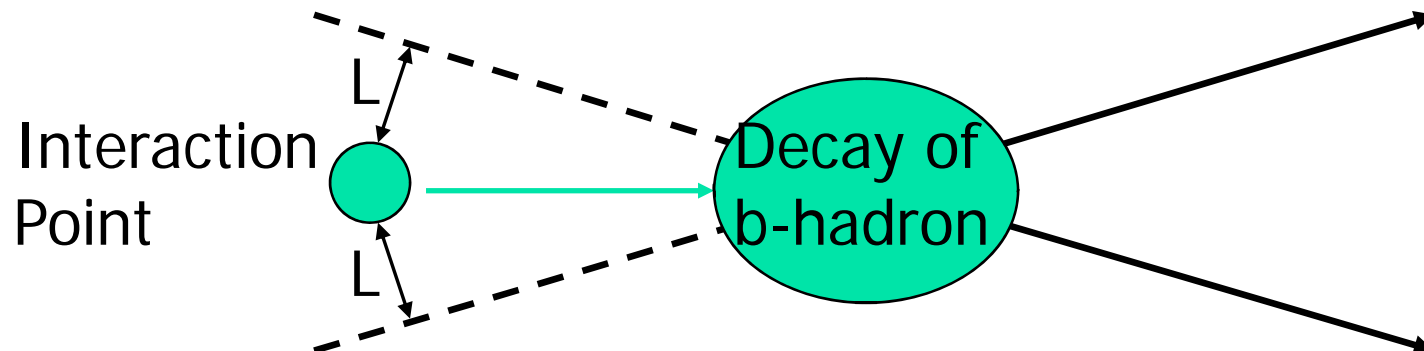
We tried to b-tagging by simulation.
nsig method was used.

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.