Precision Higgs boson mass determination at photon-photon colliders

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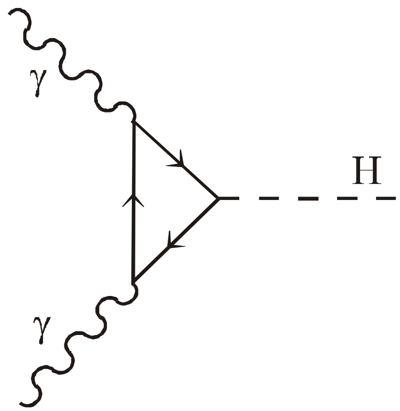
Introduction

- **Higgs boson at photon-photon colliders**

$\gamma\gamma \to h$



$m_h < 2m_w$

$b\bar{b}, c\bar{c}, \tau^+\tau^-, gg, WW^*$

- Search

Broad energy distribution of luminosity

D.L.Borden et al. SLAC-PUB-5715

- Precision measurement $\Gamma_{\gamma\gamma} B(h \to b\bar{b})$ within 6,7%

D.L.Borden et al. Phys. Rev. D48, 4018 (1993)

T.Ohgaki et al. Phys. Rev. D56, 1723 (1997)

Time table

Discovery Run

LHC, LC → Light Higgs boson
Heavy Higgs bosons, SUSY particles

(LC option) γγ Collider

Precision Run

LC → Light Higgs boson

Cross-section for $e^+e^- \to Zh$

$B(h\to\tau^+\tau^-)/B(h\to b\bar{b}), B(h\to c\bar{c}+gg)/B(h\to b\bar{b})$

$\Delta m_h = 180\ \mathrm{MeV}, L = 50\,\mathrm{fb}^{-1}, m_{hSM} = 100\ \mathrm{GeV}$

$\Delta m_h = 60\ \mathrm{MeV}, L = 100\,\mathrm{fb}^{-1}$ in threshold region

LHC $gg \to h \to \gamma\gamma \quad \Delta m_h = 200\ \mathrm{MeV}, L = 300\,\mathrm{fb}^{-1}$

γγ Collider $\Gamma_{\gamma\gamma} B(h \to b\bar{b}), \quad \Delta m_h = ?$

Determination of m_h and Γ_h

- mass and width

  SM Higgs boson --- mass undetermined by the theory

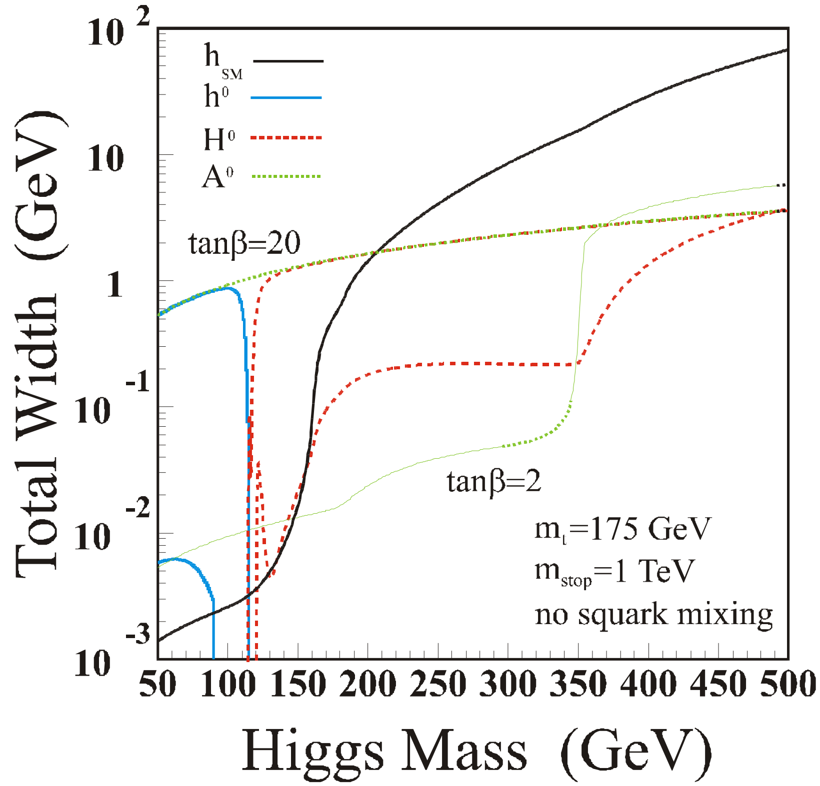
  --- Couplings to fermions and vector bosons are completely determined

  SUSY Higgs boson

  $\Delta m_{h^0} \Rightarrow$

  constraints

  $m_{A^0}, \tan\beta, m_t, m_{\rm stop}$



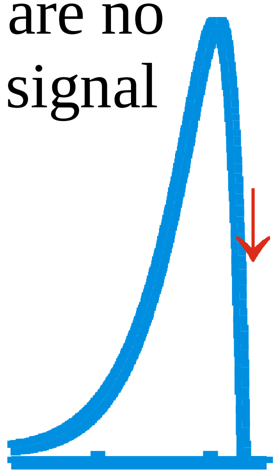
How can we determine the Higgs boson mass?

- Measurement of single point using large luminosity

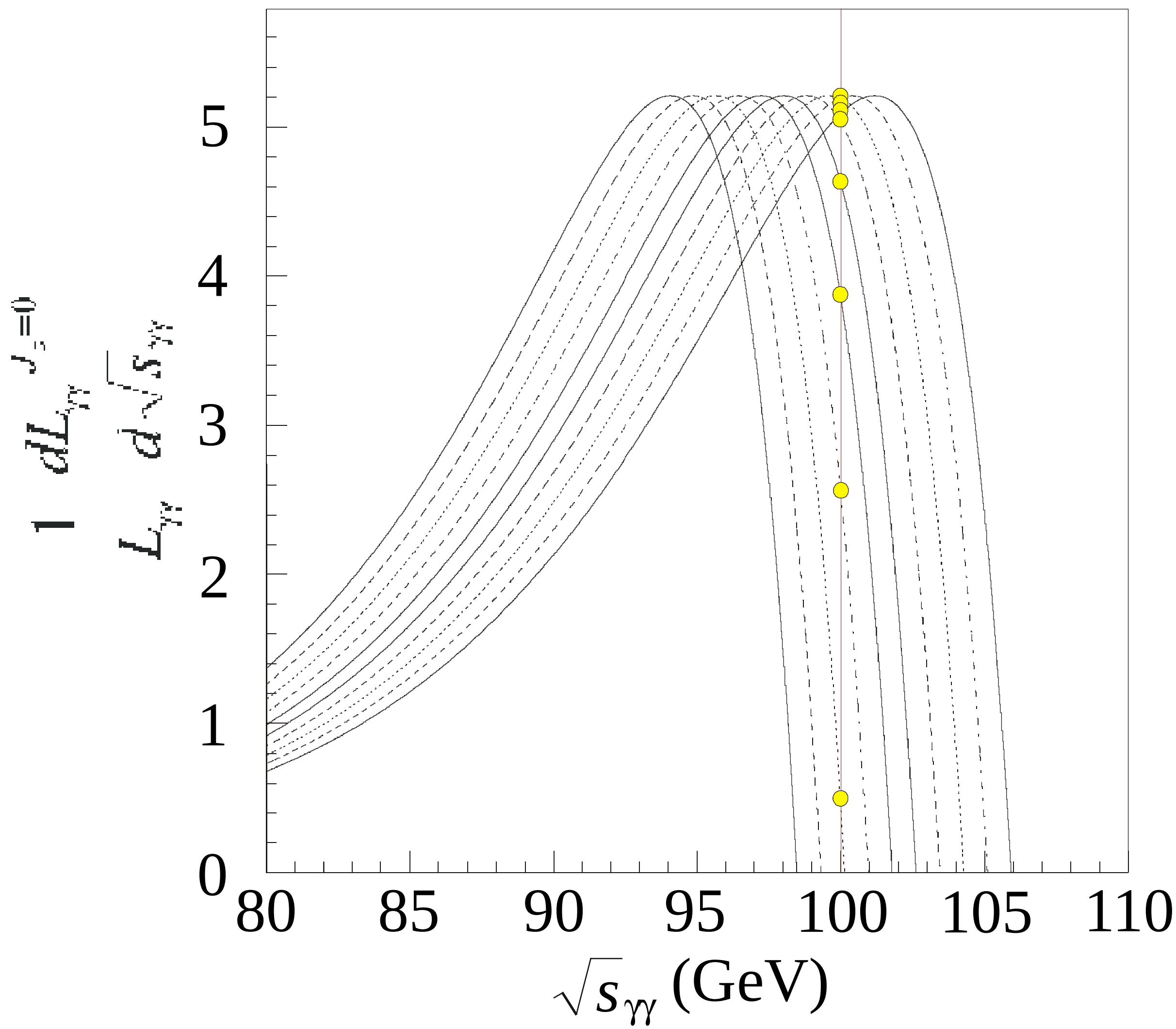
Luminosity peak of $\gamma\gamma$ Collider has the FWHM 10 ~ 15%
Therefore the large backgrounds are included in the region.

- Measurement of multiple points with small luminosity by the method of energy scanning

Using the high-energy edge of the photon spectrum, there are no backgrounds in the high-energy region and the number of signal event is decreasing, but S/N is increasing.



Differential Luminosity



Tunable Laser Case

x=4.8
m_h=100 GeV

Scanning 10 points
Electron Energy
from 119 to 128 GeV

Laser Photon Energy
from 2.63 to 2.45 eV

Calculated Events and Event Selection

- **Events**

Signal $\gamma\gamma \to h \to b\bar{b}$ $m_h < 2m_W$

Background $\gamma\gamma \to b\bar{b}(g), c\bar{c}(g)$ G.Jikia et al. Phys.Rev.D54, 2030 (1996)

- **Event Selection**

$|\cos\theta| < 0.95$

$95 < M_{jj} < 105\,\mathrm{GeV}$

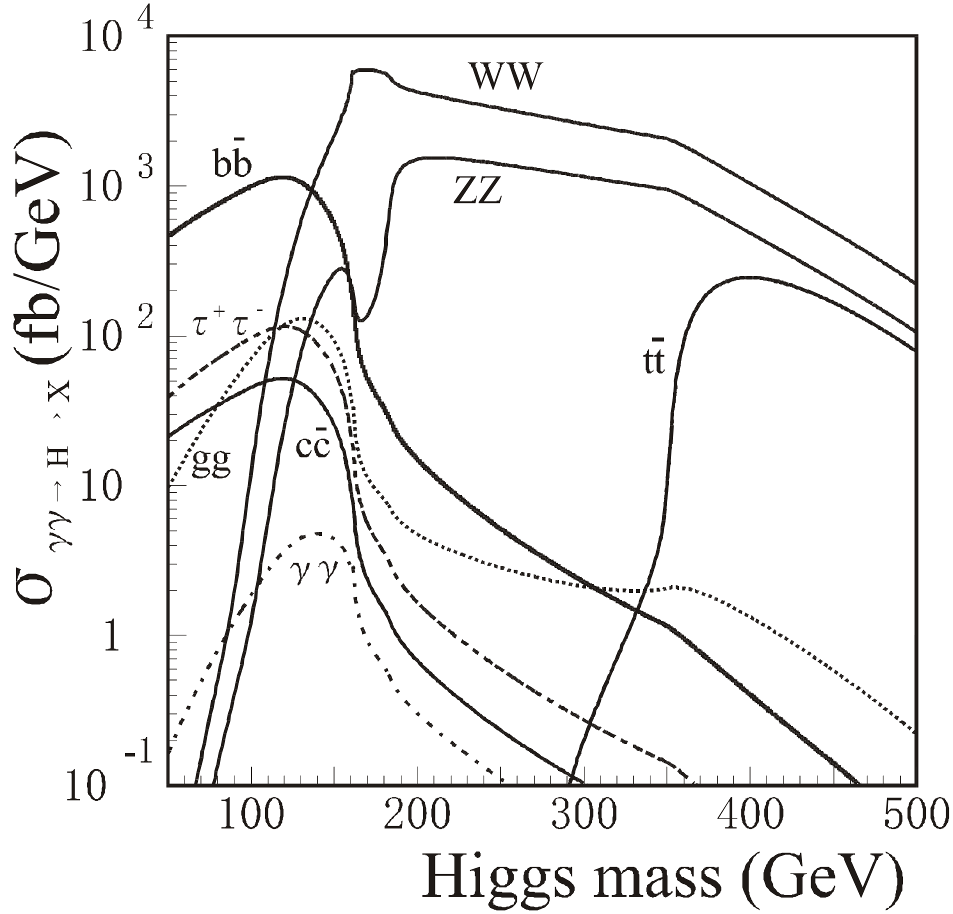
$b\bar{b}$ tagging (Topological Vertexing)

$b\bar{b}$ 49.0%

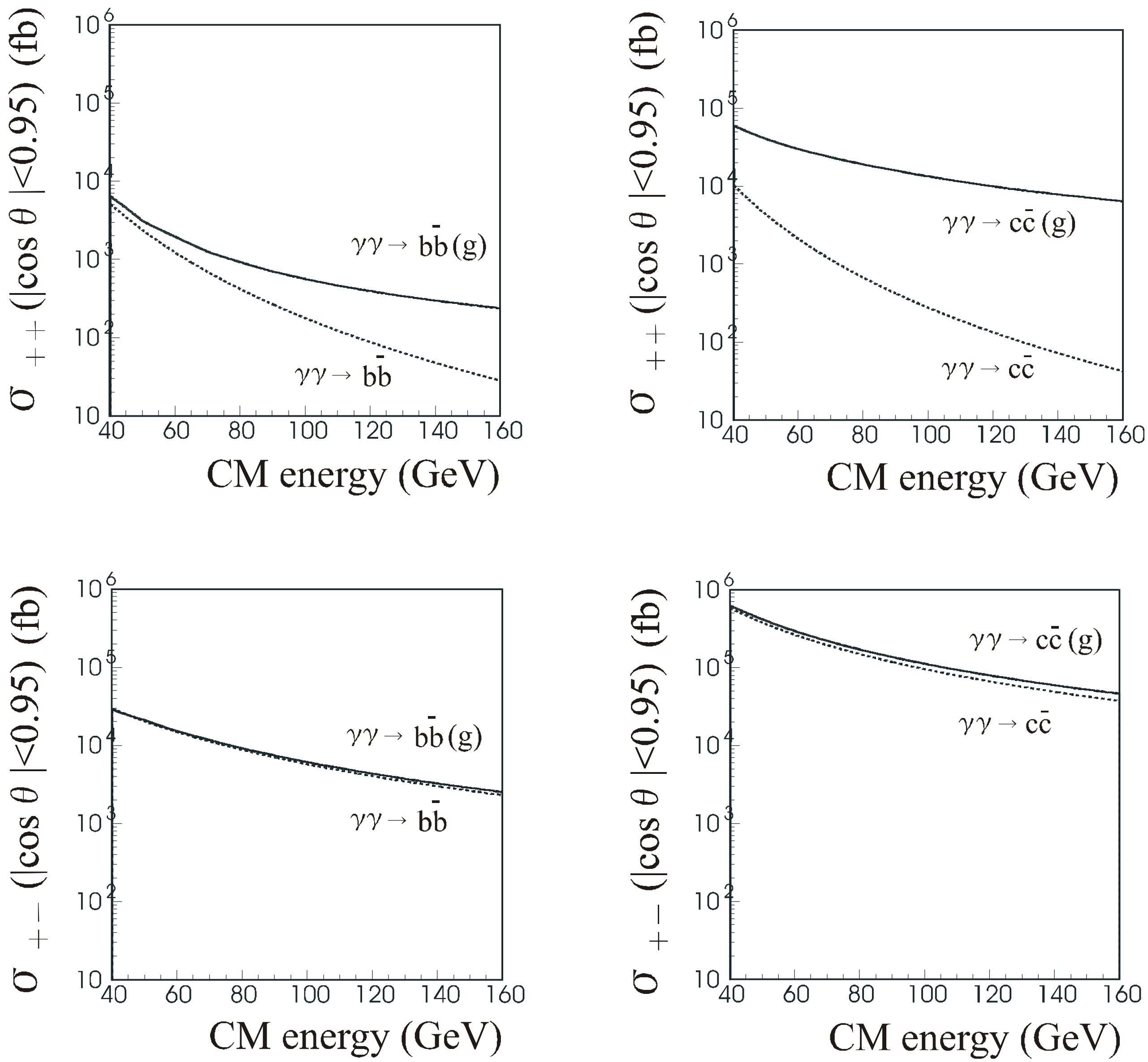
$c\bar{c}$ 0.005%

Signal

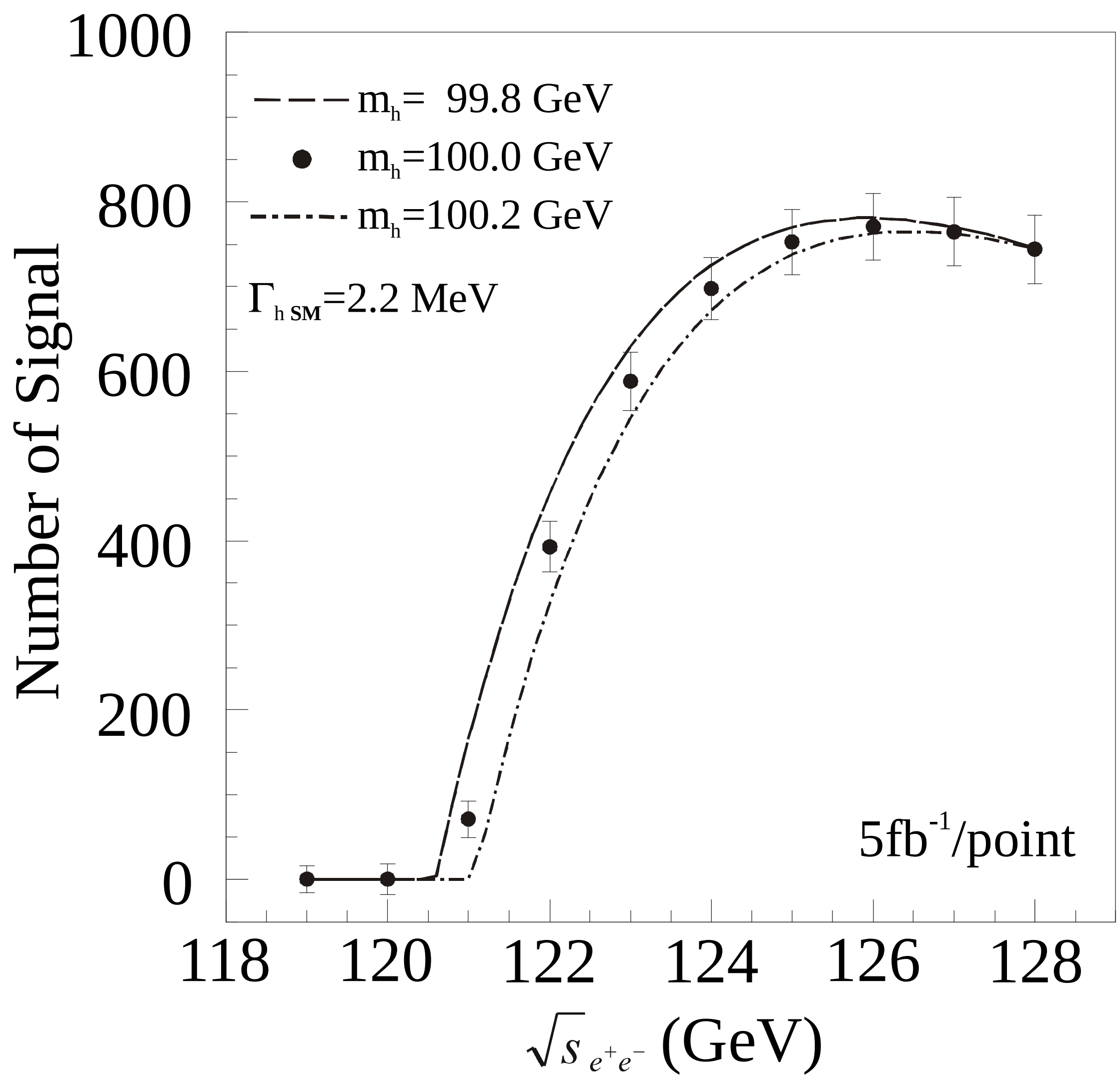
$$\sigma_{\gamma\gamma\to h\to X} = \frac{8\pi^2\Gamma(h\to\gamma\gamma)B(h\to X)}{M_h^{\ 2}}$$



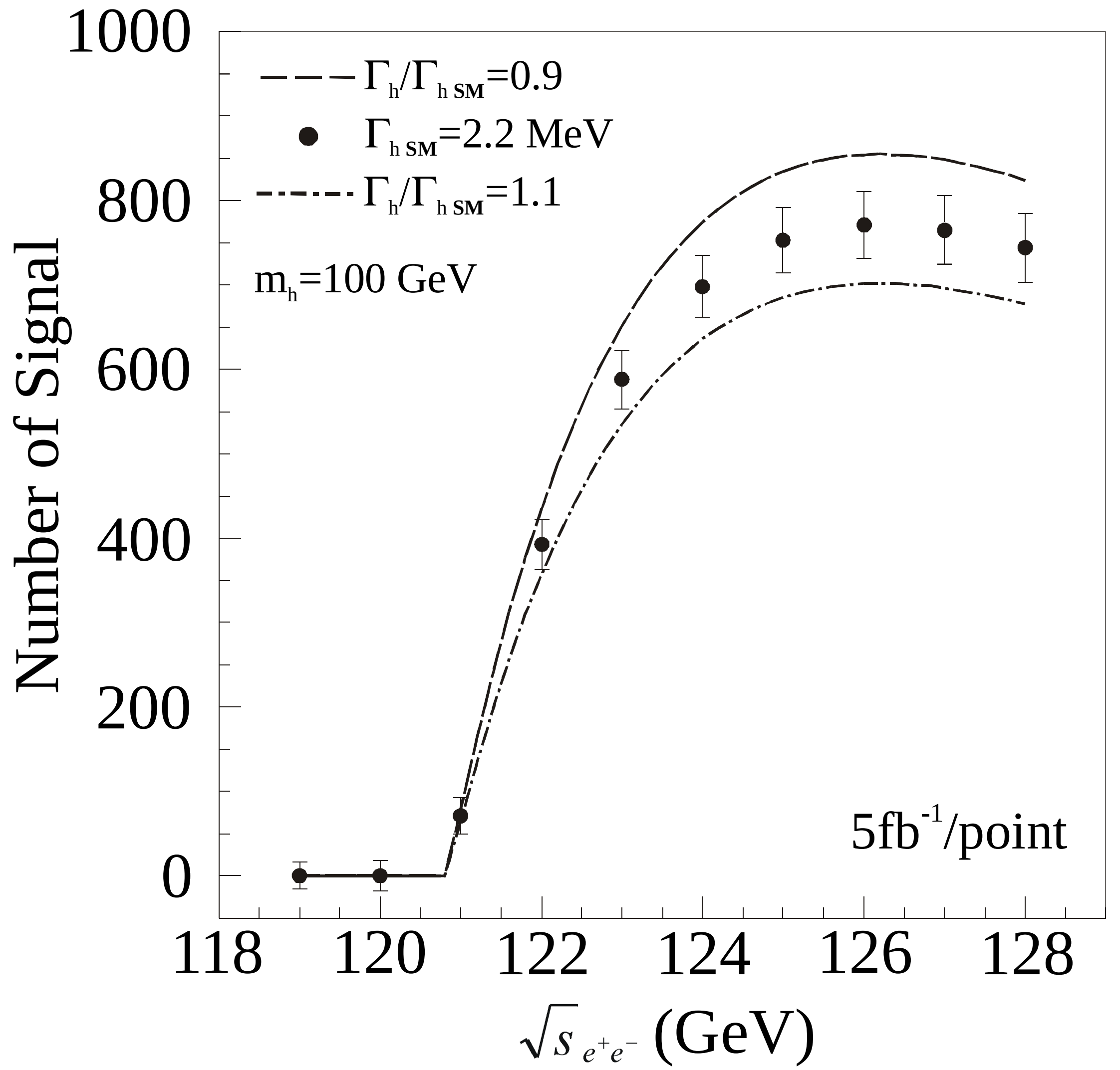
Backgrounds



Determining m_h



Determining Γ_h



Statistical errors of m_h and Γ_h of the SM Higgs Bosons

$\Delta m_{h\ SM}$ (MeV)

$m_{h\ SM}$ (GeV)	*80*	*90*	*100*	*110*	*120*	*140*
Tunable	140	120	100	140	170	210
Fixed	140	120	100	170	200	210

$\Delta\Gamma_h/\Gamma_{h\ SM}$

$m_{h\ SM}$ (GeV)	*80*	*90*	*100*	*110*	*120*	*140*
Tunable	0.078	0.067	0.060	0.057	0.057	0.074
Fixed	0.085	0.073	0.066	0.062	0.063	0.081

Tagging efficiency $b\bar{b}$ 60%, $c\bar{c}$ 2%

m_h=100 GeV, $\Delta m_{h\ SM}$=120 MeV, $\Delta\Gamma_h/\Gamma_{h\ SM}$=0.067

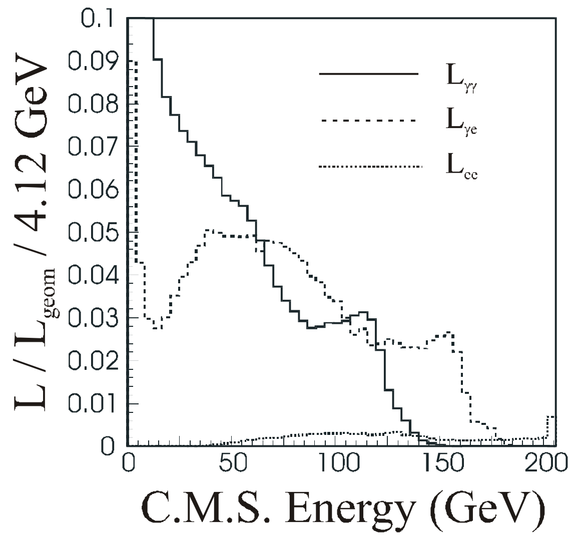
Tunable:Tunable laser energy, **Fixed**:Fixed laser energy

Problems

- We need to include the nonlinear effects in conversion region. The high-energy edge of the luminosity is softer. We need to calculate the polarization of the photons taking account of the nonlinear effects.

- The measurement of the luminosity distribution at the high-energy edge is important.

KEK Report 97-17,I.Watanabe et al.
$\gamma\gamma \to e^+e^-, \gamma\gamma \to WW$



Summary and Conclusions

- We have calculated the statistical errors of mass and total width of the Higgs boson.

- Single Compton scattering
  m_h=100 GeV, L=50fb^{-1}
  $\Delta m_{h\ SM}$=100 MeV, $\Delta\Gamma_h/\Gamma_{h\ SM}$=0.066

- We need to take into account Nonlinear Compton scattering with polarization of the photons and the measurement of the luminosity distribution at the high-energy edge.