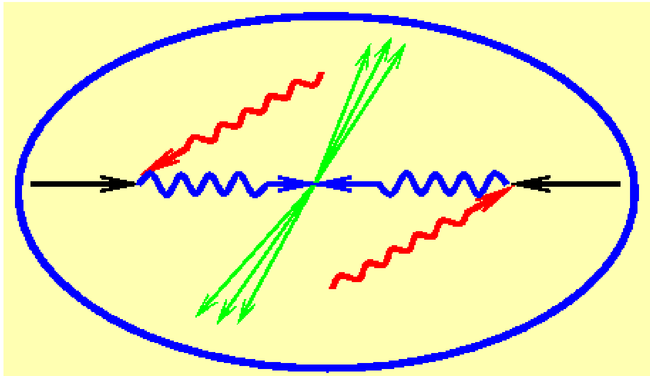

Introduction to the discussion on Physics case of the PLC as the first stage of ILC

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- History of the question, simple arguments for the low energy PLC as the first stage of LC (I do not share)
- Requirements to PLC for H(120) study (DR,polarization).
- Comparison of Higgs physics in $\gamma\gamma$ and e^+e^-.
- How to reduce the LC cost? Is it necessary to reduce too much?
- Conclusion, what kind of minimum LC is reasonable.

History of the question

The photon collider ($\gamma\gamma,\gamma e$) is usually considered as a natural supplement to e^+e^-,e^-e^- linear collider which allows to study new physics in different types of collisions at the cost of rather small additional investments.

Usually we assumed that LC starts with e^+e^- and comes to $\gamma\gamma,\gamma e$ several years later, even in the case of two IP.

However, already many times people suggested to build the photon collider before e+e-(or even without e+e-), just because it is simpler (no e+, may be no damping rings) and somewhat lower beam energy is needed to produce the intermediate mass Higgs boson.

Several such suggestions (not all):

1) V.Balakin, I. Ginzburg, LCWS93; V.Balakin, A.Seryi, GG-col, LBL,1994 (2x100,VLEPP based)
2) D.Asner et al, 2001, CLICHE (based on CLIC 1 with E_b=70 GeV)
3) H.Sugawara, Photon-photon collider Higgs factory as a precursor to ILC, ILCSC, 2008.
4) T. Barklow, J.Gronberg, M.Peskin, A.Seryi, Photon-photon collider Higgs factory as a precursor to ILC (Physics panel was asked by S.Yamada to consider physics case of Sugawara's suggestion)

Beam energies for the Higgs production

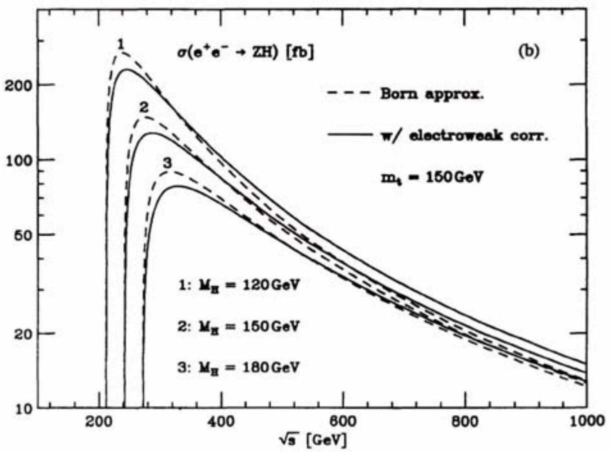
Indeed, the maximum energy of photons is $E_\gamma = \dfrac{x}{x+1+\xi^2} E_0 \qquad x = \dfrac{4E_0\omega_0}{m^2c^4}$

$E_\gamma \sim 0.8\ E_0$ (at $x \leq 4.8$). ($\xi^2 \sim 0.15$ – due to nonlinear effects in Compton scattering)

In $\gamma\gamma$ collisions in order to produce single h(120) one needs $2E_0 = 120/0.8 = 150$ GeV +10%(for scanning)=165 GeV.

Due to the problem of removal low energy electrons (after multiple Compton scattering) the minimum energy should be higher: > 180 GeV

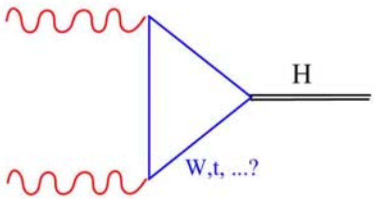
In $e^+e^- \to Z\,h$, one needs $2E_0 \sim 235$ GeV, or higher by a factor of 1.3-1.4.



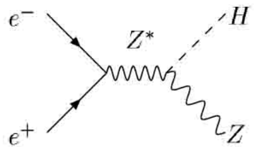
Properties of the photon collider for the Higgs study:

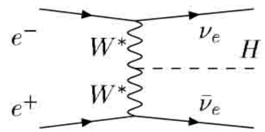
Luminosity

$\gamma\gamma$ $\quad\quad\quad\quad$ e^+e^-

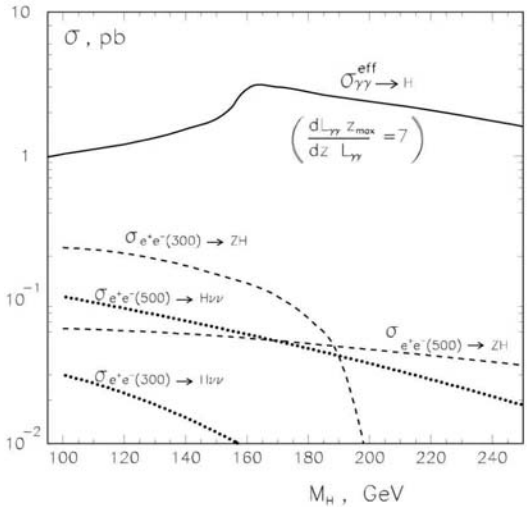


Very sensitive to heavy charge particles in the loop.





Cross sections of the Higgs boson in $\gamma\gamma$ and e^+e^- collisions



$$\dot{N}_{\gamma\gamma\to H} = L_{\gamma\gamma}\times\frac{dL_{\gamma\gamma}M_H}{dW_{\gamma\gamma}L_{\gamma\gamma}}\frac{4\pi^2\Gamma_{\gamma\gamma}(1+\lambda_1\lambda_2)}{M_H^3}$$

At TESLA

$$\frac{N(\gamma\gamma\to H)}{N(e^+e^-\to H+X)}\sim 1-10$$

for $M_H = 100 - 250$ GeV.

The effective cross section $\gamma\gamma\to h(120)$ (with account of the energy spread) is about 1 pb, while that of $e^+e^-\to Z\,h$ it is 0.2 pb (see previous slide)

For the same beams $L_{\gamma\gamma}\sim 0.2L_{e+e-}$, so the number of events will be similar.

Properties of the photon collider for the Higgs study:

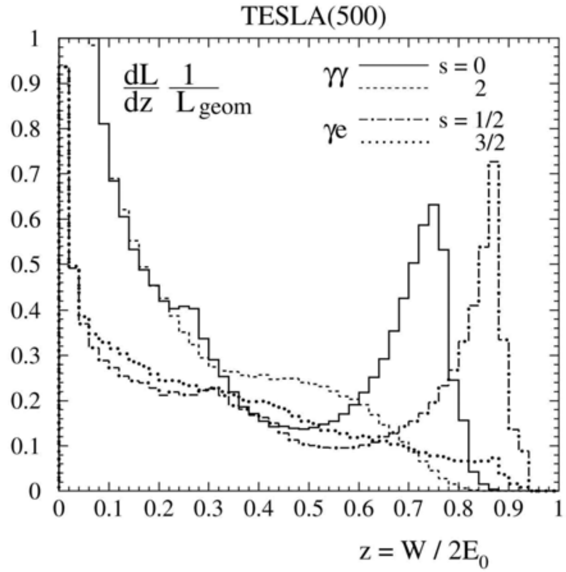
Polarization

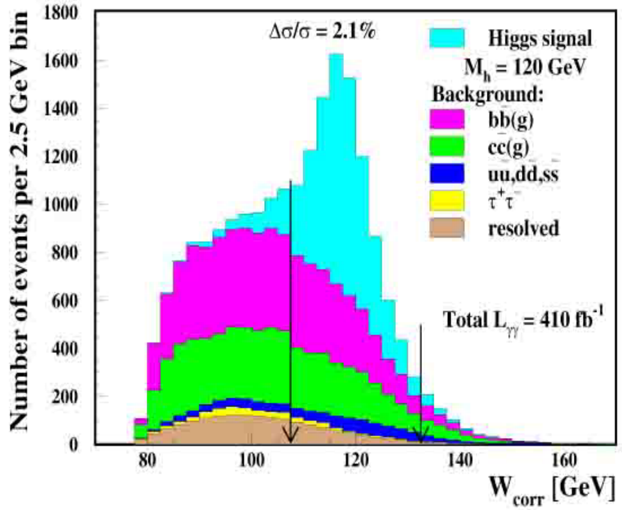
Higgs is produced by two photons in helicity state 0.

Main background, QED process $\gamma\gamma \to cc$, bb, is produced by photons with helicity 2.

Luminosity spectra for 85% polarized electrons and 100% laser photons

At the high energy edge L_0/L_2~10





The high photon polarization is crucial for suppression backgrounds.

If laser photons are polarized but electrons are unpolarized then L_0/L_2~1.5 and the Higgs boson will be invisible. In addition the absence of electron polarization leads to the decrease of the luminosity in the peak by a factor of 3.

Presence of a high electron polarization is obligatory!

Damping rings

Existing DC photo-guns produce highly polarized electron beams but with large normalize emittances. Without cooling in damping rings the luminosity will be smaller by a factor of 100!

RF polarized sources with small emittances do no exist.

So, the damping ring is mandatory for the photon collider for the Higgs study!

The only element which absence in the photon collider is the positron source, but in addition it has the laser system.

Resume: technically the photon collider for h(120) is not easier and may be somewhat cheaper only due to lower energy.

Higgs study in e^+e^- and $\gamma\gamma$ collisions

The goal is not just the Higgs production but investigation of its properties, coupling to different particles.

The channel $e^+e^- \to Zh$ is very unique, detecting $Z \to \mu\mu$ one can reconstruct the recoil mass and thus to "see" even invisible Higgs decays. This channel allows to measure different branching ($h \to bb, cc, \tau\tau, gg, WW, \gamma\gamma$) and the Higgs spin, namely this is required for demonstration that this particles is the Higgs boson.

The photon collider (at this Higgs mass) can measure first of all $\Gamma_{\gamma\gamma}(h) \cdot Br(h \to bb)$ and $\Gamma_{\gamma\gamma}(h) \cdot Br(h \to \gamma\gamma)$ (+may be WW, ZZ).
The value $\Gamma_{\gamma\gamma}(h) \cdot$is very important quantity, it can be measured at the photon collider with much better accuracy but for this one needs to know $Br(h \to bb)$, which can be measured only at e^+e^-.
Other channels, $h(120) \to cc, \tau\tau, gg$ can not be extracted at the photon collider due to large SM backgrounds ($\tau\tau$ may be possible to see but with very small statistics due to cuts.)

So, the minimum e^+e^- collider will be somewhat more expensive than the PLC but much more powerful for study of the Higgs boson.

From BGPS

γγ

Higgs boson observables from PLC assuming

M_H=120 GeV and 60 fb^{-1} of total $\gamma\gamma$ luminosity

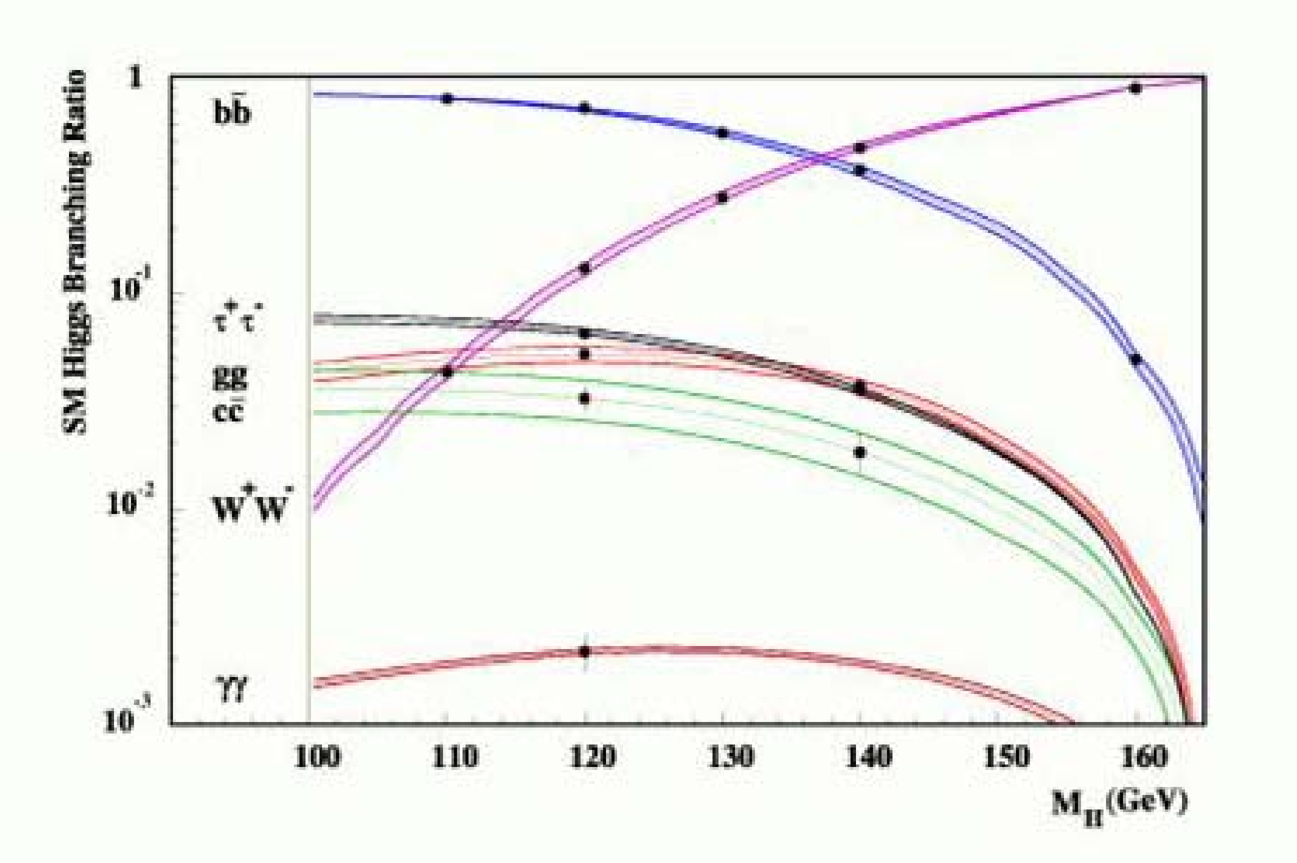
(Two years at stage 1 & two years at stage 2 or 3)

observable	relative error	
$\sigma(\gamma\gamma)\cdot BR(b\bar{b})$	4%	
$\sigma(\gamma\gamma)\cdot BR(WW)$	9%	?
$\sigma(\gamma\gamma)\cdot BR(ZZ)$	20%	?
$\sigma(\gamma\gamma)\cdot BR(\gamma\gamma)$	40%	

e+e- (230)

observable	relative error
$\mathrm{BR}(b\bar{b})$	2%
$\mathrm{BR}(WW)$	5%
$\mathrm{BR}(gg)$	6%
$\mathrm{BR}(\gamma\gamma)$	23%
$\mathrm{BR}(c\bar{c})$	8%
$\mathrm{BR}(\tau^+\tau^-)$	5%
$\sigma(e^+e^-\to ZH)$	3%

Higgs branching accuracy expected in e+e- collisions



If e^+e^- is much better for the Higgs study, why we need the photon collider at all?

The reasons are the following (independent of physics scenarios):

1. It is the unique case when the same collider can study new physics in several types of collisions at the cost of rather small additional investments
2. In $\gamma\gamma$, γe collisions compared to e^+e^- the energy is smaller only by 10-20%;
3. The number of events is similar or even higher;
4. Access to higher particle masses (H,A in $\gamma\gamma$, charged and light neutral SUSY in γe);
5. Higher precision for some phenomena;
6. Different type of reactions (different dependence on theoretical parameters);

One example: detection of the heavy SUSY Higgs boson. Let $2E_0$=500 GeV.
in e+e- $M_{H,A}$(max)~250 GeV (H,A are produced in pairs);
in $\gamma\gamma$ $M_{H,A}$(max)~400 GeV (a single resonance).

We don't know what physics expects us in a new energy region (LHC will see not all). The photon collider can add new information and even can observe physics and particles not accessible for e^+e^- (at fixed energy).

But, if we want to built a low energy linear collider for study of the "standard) h(120) we certainly need e^+e^- for justification of the multi-B$ facility, the minimum LC energy is determined by the reaction $e^+e^- \to Z\, h$!

The cost problem

The ILC(500) is too expensive (for politicians). What to do?
One can reduce the energy for the first stage, 2E=235 GeV, for example.
But the ILC(500) linac contributes 60% to the total cost, so the decrease of the energy down to 235 GeV reduces the cost only by 30%.

More radical is a change of a ILC technology. The warm linac will be certainly cheaper and the DR will be smaller due to shorter trains.

What are possibilities:
S-band (klystrons), as SLAC (also SBLC, DESY project)
C-band (KEK)
X-band (NLC,JLC)
X-band (CLIC, two beams)

Many year ago G.Voss tried to convince the LC community that the S-band technology is practically optimum for the LC cost. Beside this technology is well developed. Why not? For PLC S-band technology is also OK.

But the best would be SC ILC for 2E<0.5-1 TeV and CLIC up maximum energy (3-5 TeV).

Understanding the nature of masses and direct production and understanding dark matter is very strong motivation to give HEP physicists requested money for ILC!

The cost problem (continue)

Construction of the low energy PLC before e+e- does not save money at all, only increase, because we need e+e in any case!

If we are not able to get money for constraction of ILC with the initial energy 2E=230 GeV, better not to start the construction at all.

Conclusion

- The photon collider is a very natural part of the linear collider (two additional type of collisions for very small incremental cost).

  Though I advocate its construction but, in my opinion, the first photon collider should be constructed as a supplement for e+e- (second stage).
- In order to make the LC cost acceptable for politicians it worth to start from lower energy, say 2E=~1.1(M_h +M_Z), if the Higgs exists, with possibility of upgrade up to tt quark threshold 2E=350 GeV.