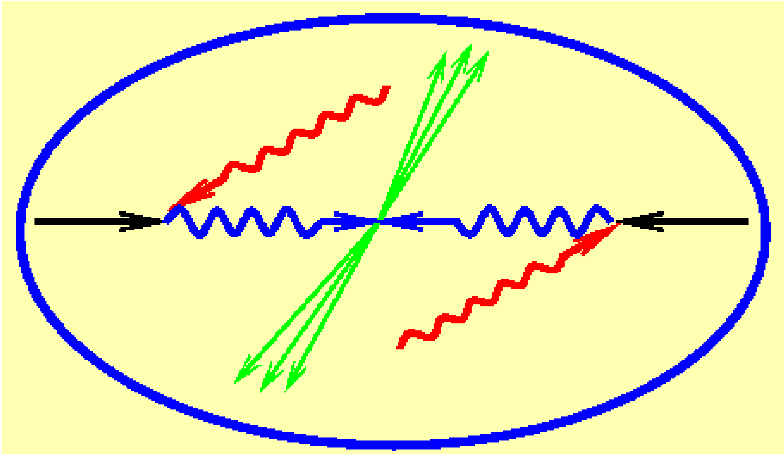


Photon collider Higgs Factories

Valery Telnov

Budker INP and NSU, Novosibirsk

INSTR-2014, BINP, Feb.24, 2014

The discovery of the Higgs boson (and still nothing else) have triggered appearance of many proposals of Higgs factories for precision measurement of the Higgs properties.

Among them are photon colliders (~ 10 projects) without e+e- (in addition to PLC based on e+e- linear colliders ILC, CLIC)

Below is a brief review of ILC-CLIC based and new proposals of photon collider Higgs factories.

Higgs Factories Dreams

Higgs factory colliders

HF2012,
FNAL, Nov.2012

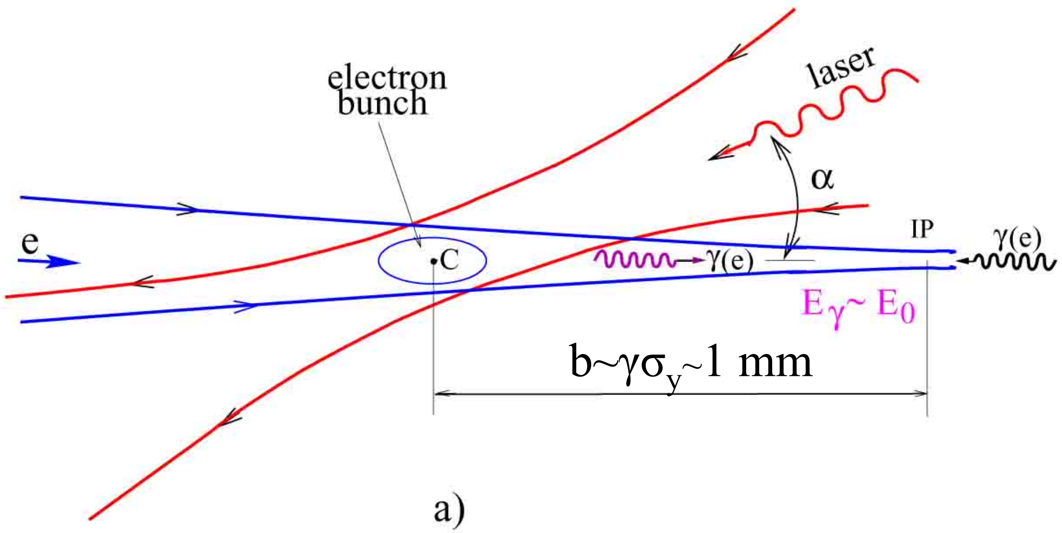
- Linear e+e- collider:
  - ILC
  - CLIC
  - X-band klystron based
- Circular e+e- collider:
  - LEP3
  - TLEP
  - SuperTRISTAN
  - Fermilab site-filler
  - China Higgs Factory (CHF)
  - SLAC/LBNL big ring
- Muon collider
  - Low luminosity, High luminosity
- $\gamma\gamma$ collider:
  - ILC-based
  - CLIC-based
  - Recircul. linac-based SAPPHiRE + HERA,Tevatron rings
  - SLC-type
  - etc

Contents

- Inroduction
- ILC
- CLIC
- SAPPHIRE, HFitt and others
- Super $\gamma\gamma$ factory
- Conclusion

Scheme of $\gamma\gamma$, γe collider

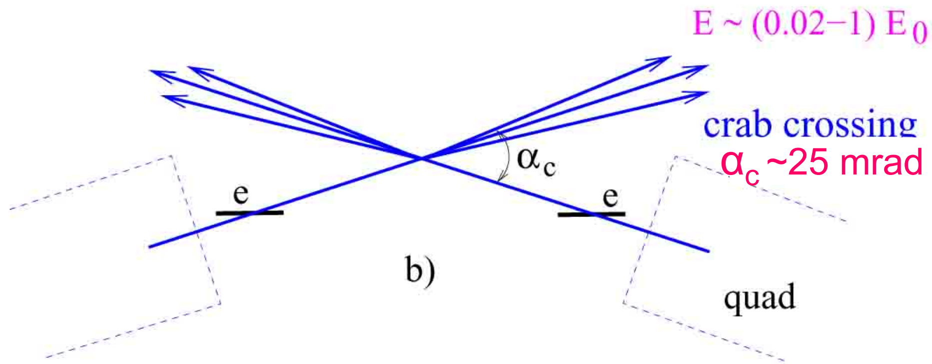
GKST 1981



$$\omega_m = \frac{x}{x+1} E_0$$

$$x \approx \frac{4E_0\omega_0}{m^2c^4} \simeq 15.3 \left[\frac{E_0}{\mathrm{TeV}}\right]\left[\frac{\omega_0}{\mathrm{eV}}\right]$$

$E_0 = 250$ GeV, $\omega_0 = 1.17$ eV ($\lambda = 1.06\ \mu$m) $\Rightarrow$ x=4.5, ω_m=0.82E_0=205 GeV



$x = 4.8$ is the threshold for $\gamma\gamma_L \to e^+e^-$ at conv. reg.

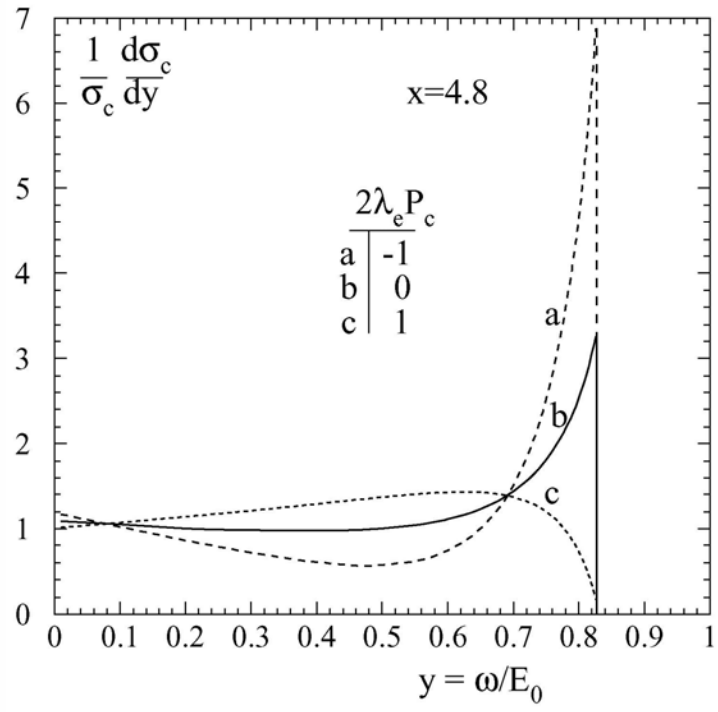
ω_{max}~0.8 E_0

$W_{\gamma\gamma,\ max} \sim 0.8\cdot 2E_0$

$W_{\gamma e,\ max} \sim 0.9\cdot 2E_0$

Electron to Photon Conversion

Spectrum of the Compton scattered photons

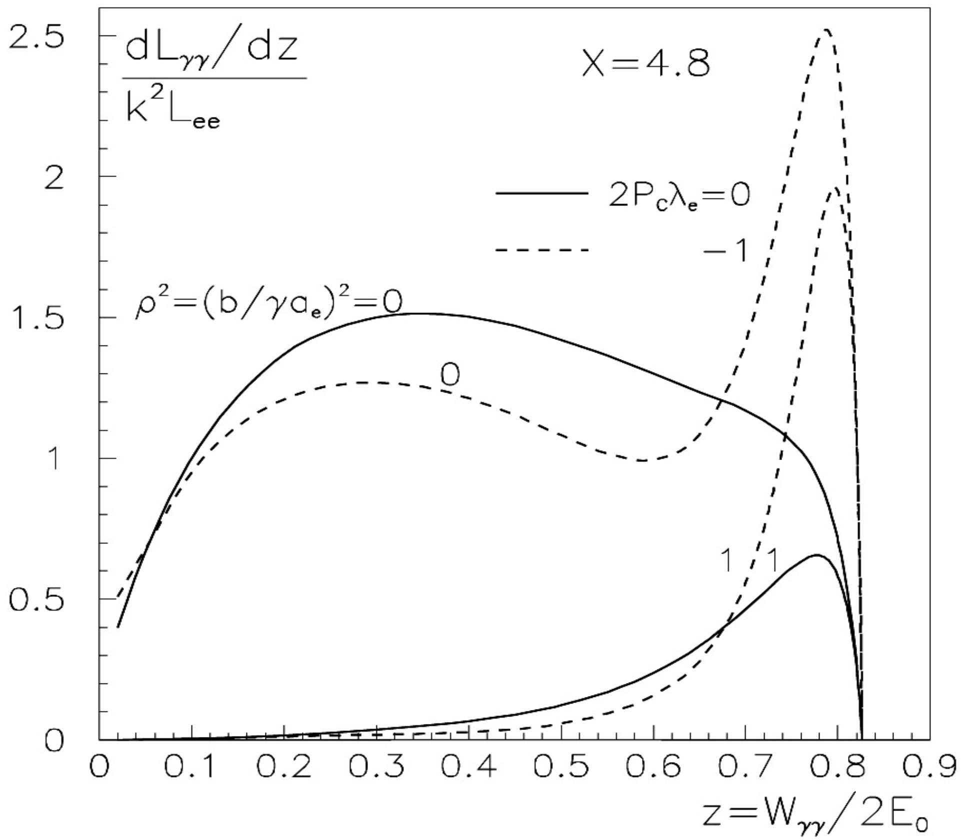


λ_e – electron longitudinal polarization
P_c – helicity of laser photons, $x \approx \frac{4E_0\omega_0}{m^2c^4}$

The electron polarization increases the number of high energy photons nearly by factor of 2).

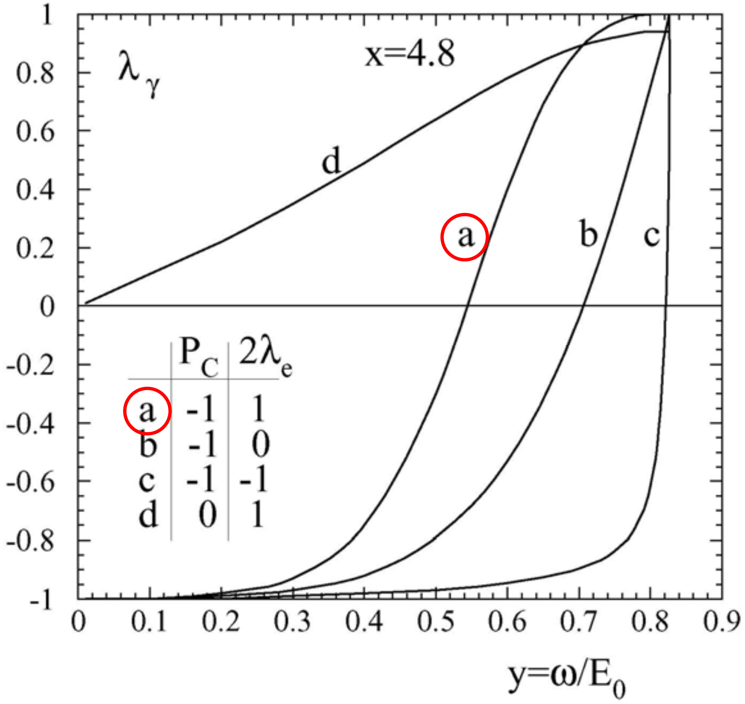
Ideal luminosity distributions, monohromatization

(a_e is the radius of the electron beam at the IP, b is the CP-IP distance)



Electron polarization increases the $\gamma\gamma$ luminosity in the high energy peak up to a factor of ~3 (at large x).

Mean helicity of the scattered photons ($x = 4.8$)



Highest energy scattered photons are polarized even at λ_e=0 (see (b))

(in the case a) photons in the high energy peak have $\lambda_\gamma \approx 1$)

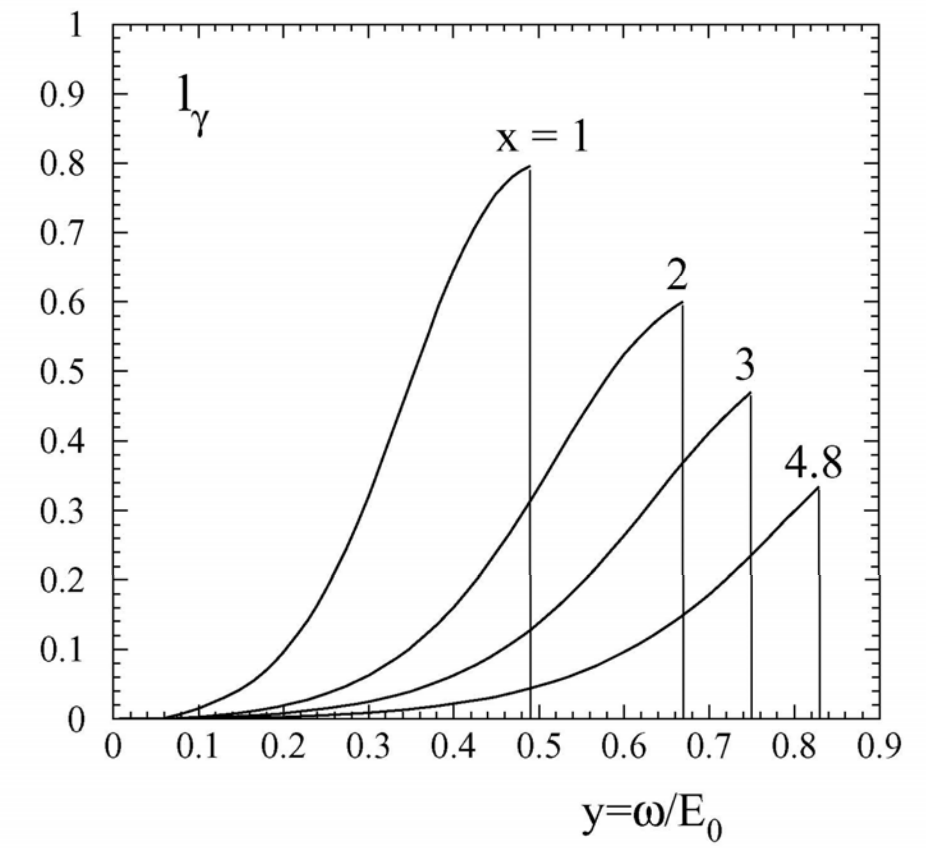
The cross section of the Higgs production

$$\sigma(\gamma\gamma \to h) \propto 1 + \lambda_1\lambda_2$$

The cross section for main backgound

$$\sigma(\gamma\gamma \to b\bar{b}) \propto 1 - \lambda_1\lambda_2$$

Linear polarization of photons



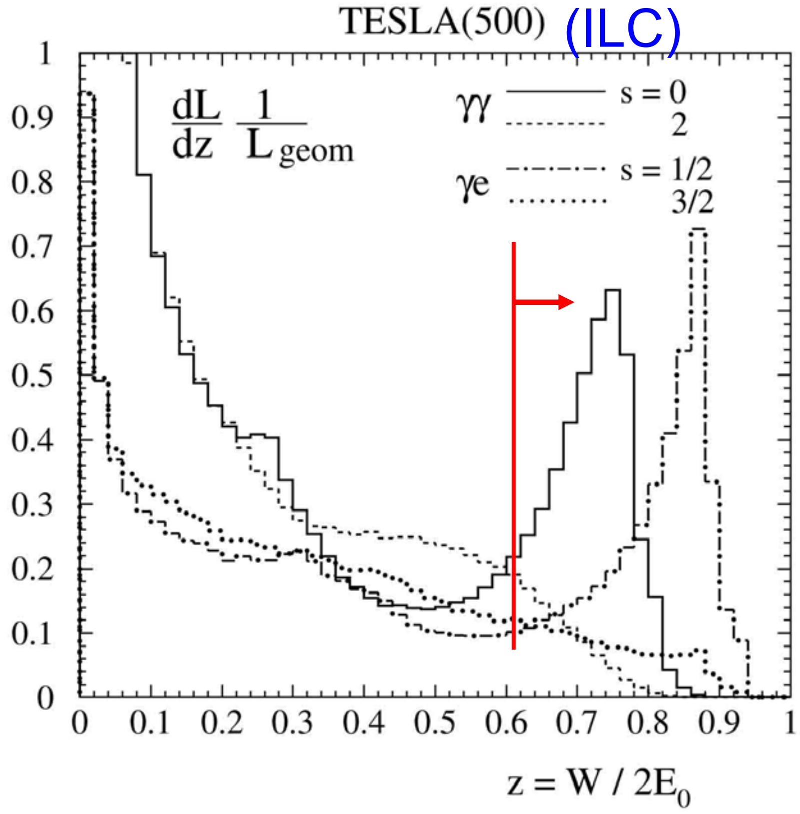
$\sigma \propto 1 \pm l_{\gamma 1} l_{\gamma 2} \cos 2\varphi$ ± for CP=±1

Linear polarization allows to measure Higgs CP mixture and helps to separate SUSY H and A Higgs bosons

Realistic luminosity spectra ($\gamma\gamma$ and γe)

(with account multiple Compton scattering, beamstrahlung photons and beam-beam collision effects)

(decomposed in two states of J_z)



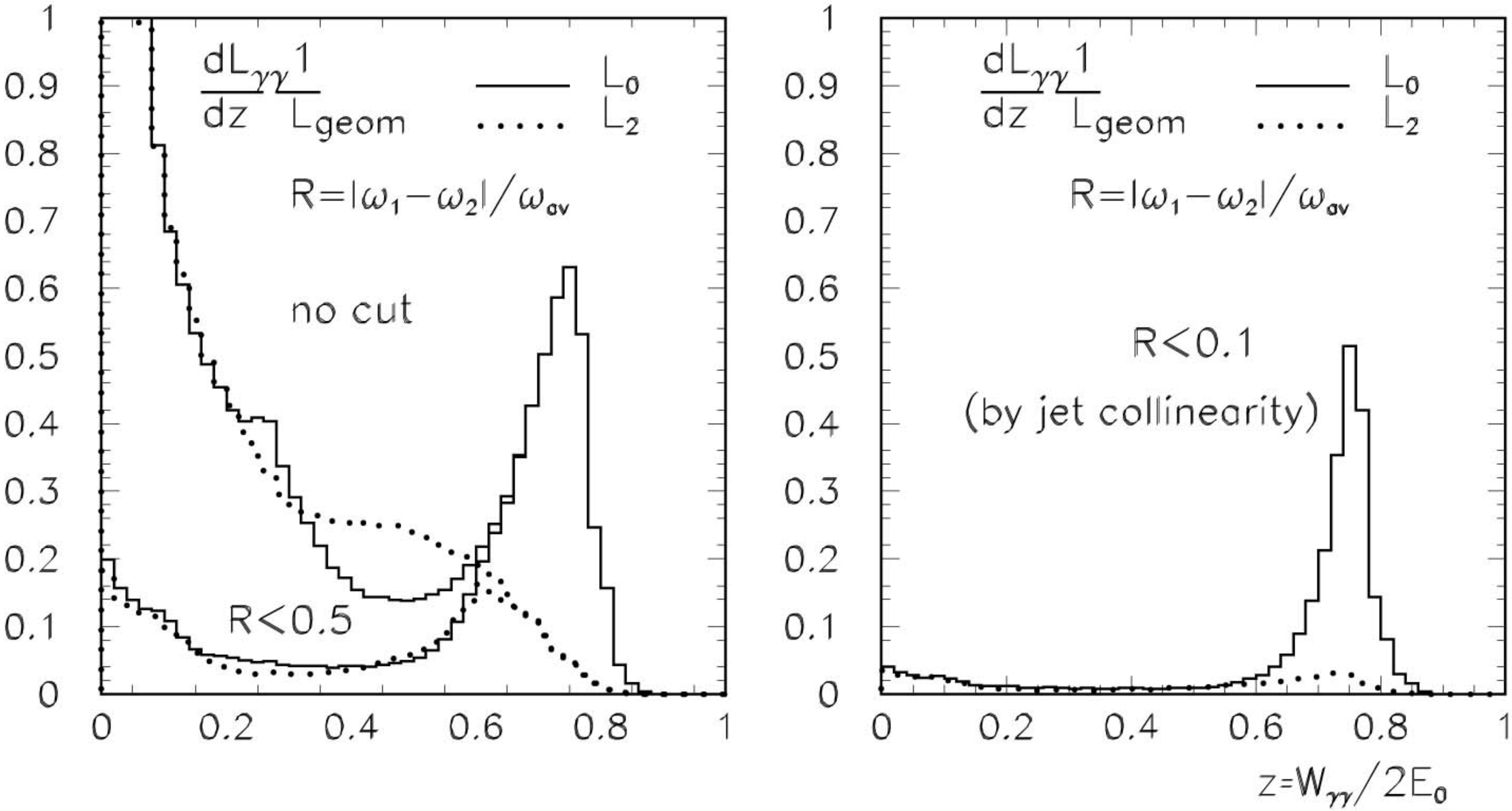
Usually a luminosity at the photon collider is defined as the luminosity in the high energy peak, $z>0.8z_m$.

For ILC conditions

$L_{\gamma\gamma}(z>0.8z_m) \sim 0.1\ L_{e\text{-}e\text{-}}(geom)$

(but cross sections in $\gamma\gamma$ are larger then in e+e- by one order!)

$\gamma\gamma$ luminosity spectra with cuts on the longitudinal momentum

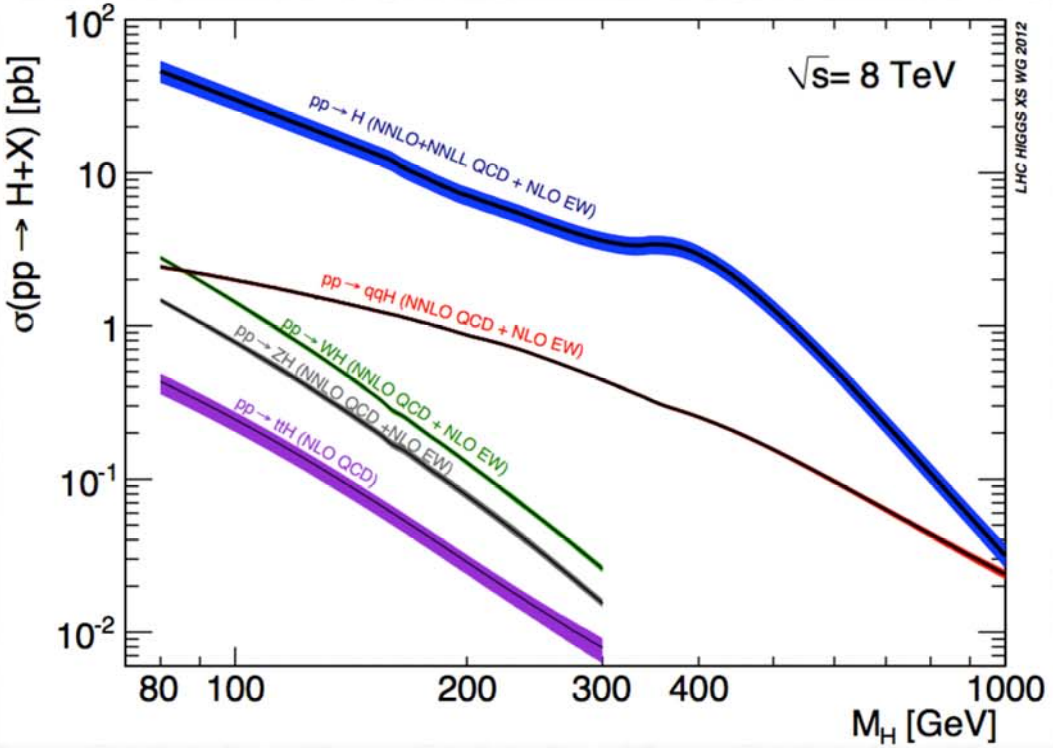


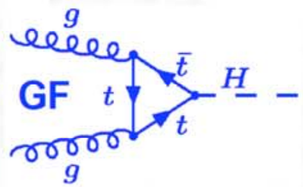
Physics at PLC

Physics at PLC was discussed so many times (>1000 papers), it is difficult to add something essential. Most of examples were connected with production of the Higgs bosons or SUSY (dark matter) particles.

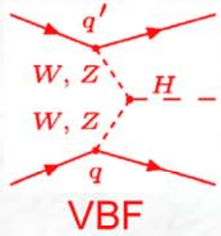
By now, only the light (standard) Higgs boson is discover.

Higgs boson production at LHC

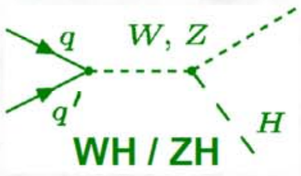




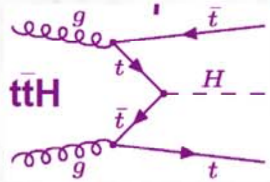
Gluon fusion



Vector boson fusion



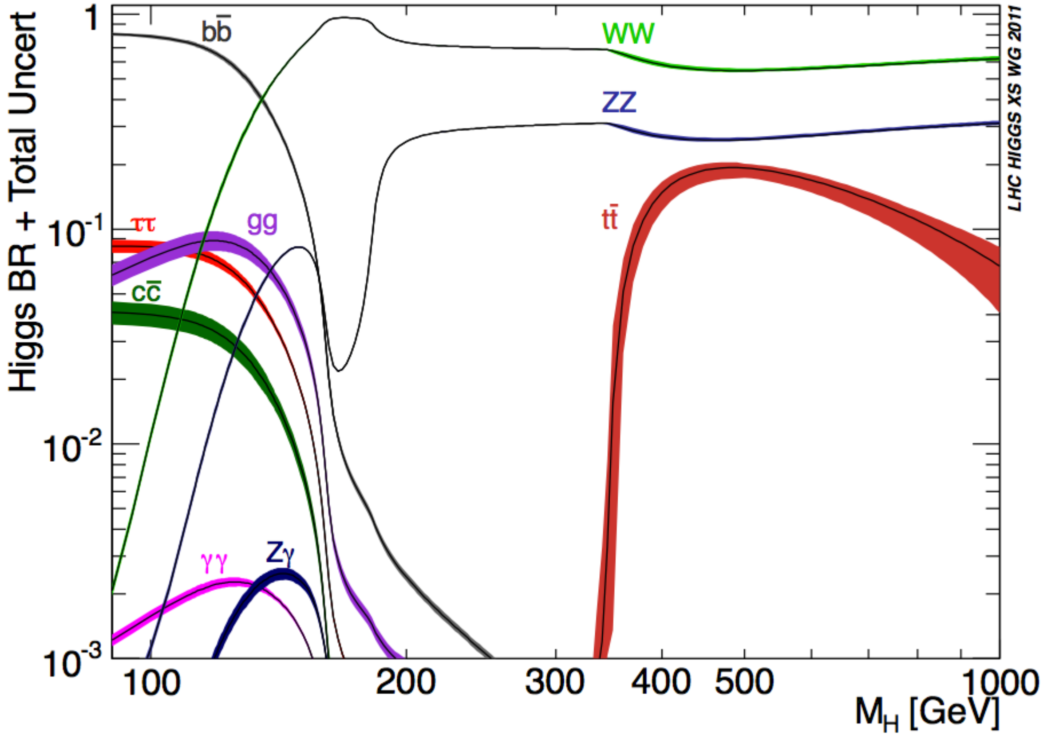
WH/ZH associated production



tt associated production

The total number of Higgs boson produced at LHC (25 fb^{-1}) is $N_H > 10^6$!

Higgs decay branchings

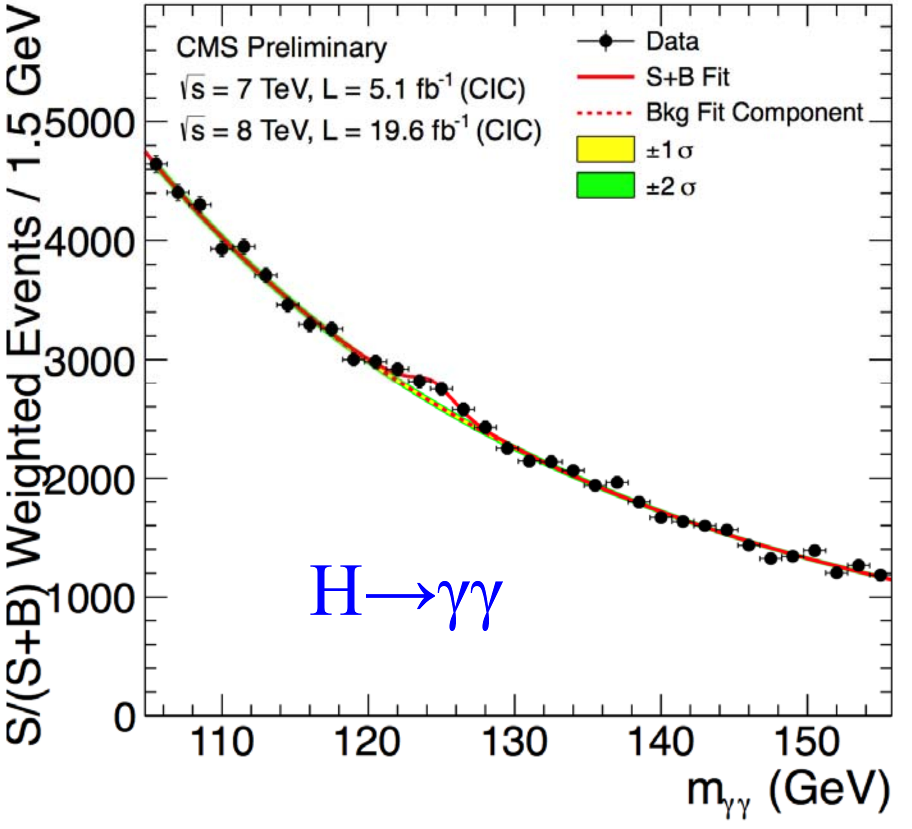


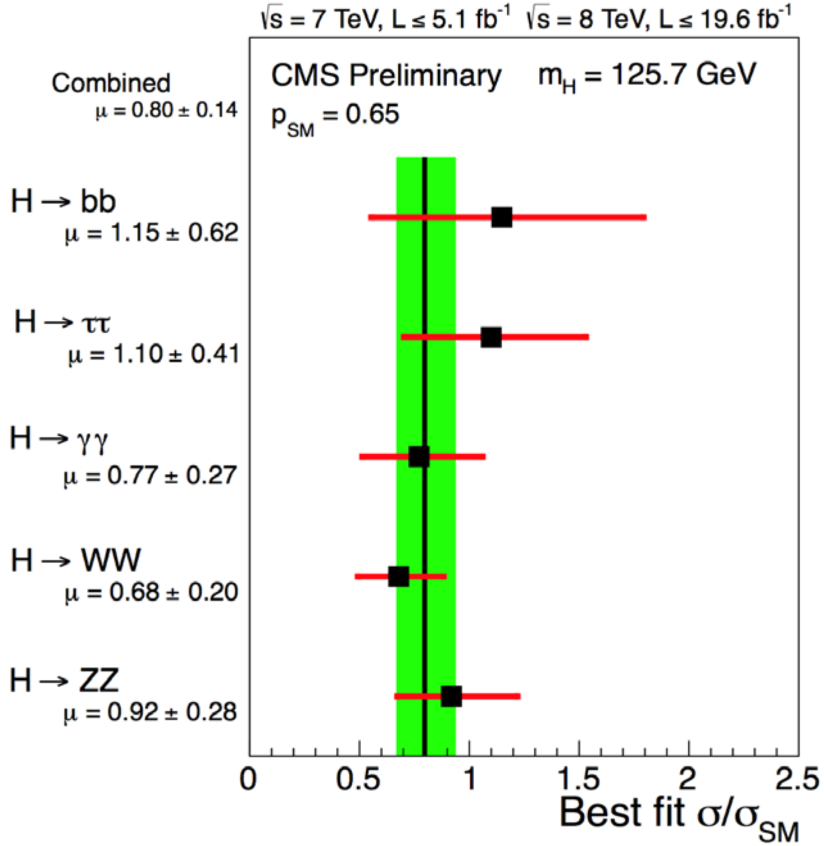
SM predictions (m_H = 125.5 GeV):

BR (H→ WW) = 22.3%	BR (H → bb) = 56.9%
BR (H → ZZ) = 2.8%	BR (H → $\tau\tau$) = 6.2%
BR (H → $\gamma\gamma$) = 0.24%	BR (H →$\mu\mu$) = 0.022%

→ at 125 GeV: only ~11% of decays not observable (gg, cc)

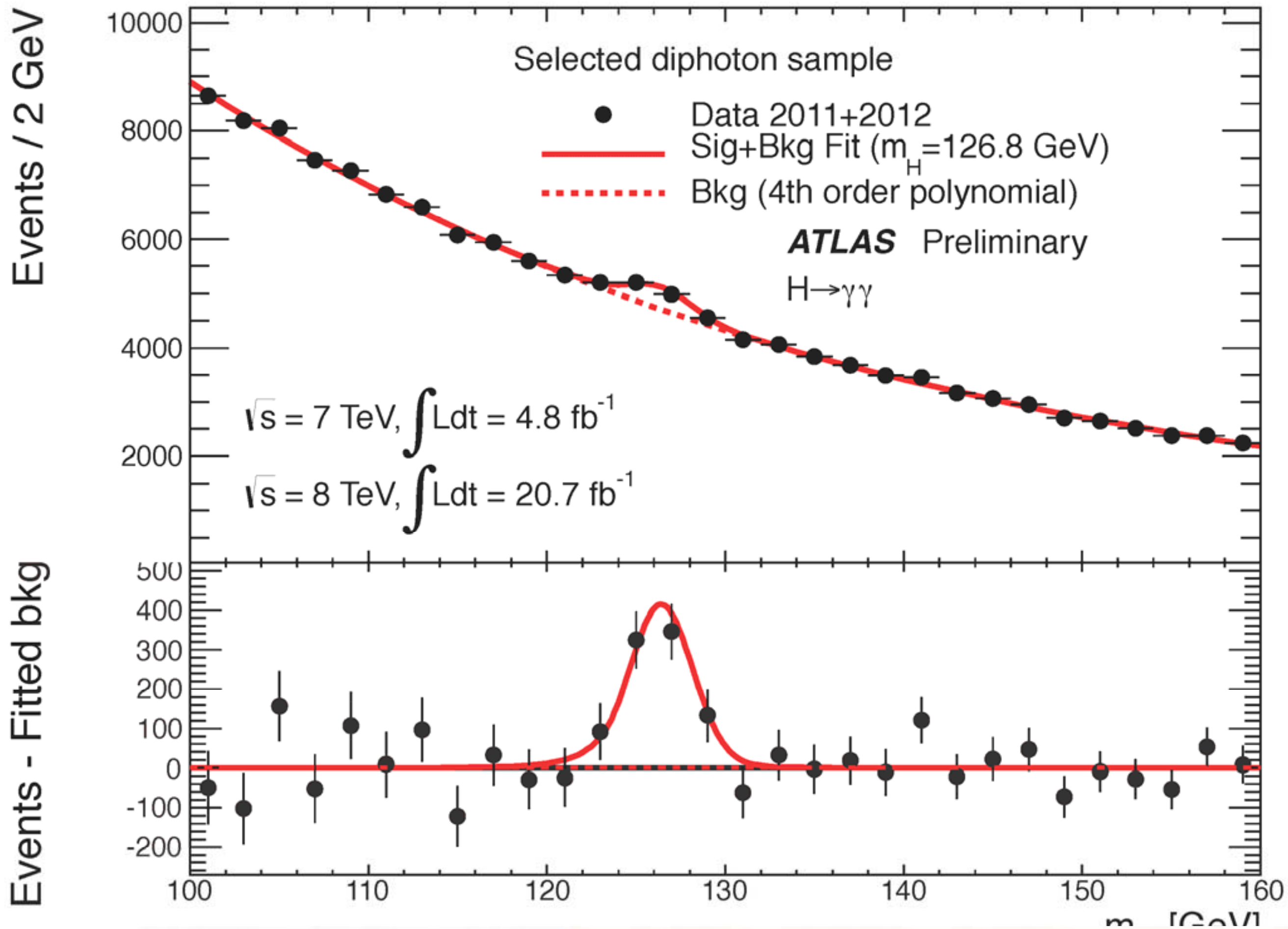
Higgs at CMS





$\mu = \sigma/\sigma_{SM} = 0.77 \pm 0.27$

Full dataset ATLAS-CONF-2013-012

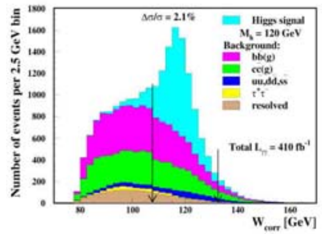


Mass: $m_H = 126.8 \pm 0.2\,(\mathrm{stat}) \pm 0.7\,(\mathrm{syst})$ GeV

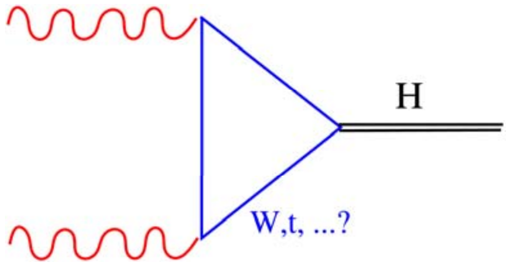
Signal strength: $\mu := \sigma / \sigma_{SM} = 1.57 \pm 0.22(\mathrm{stat})^{+0.24}_{-0.18}(\mathrm{syst})$

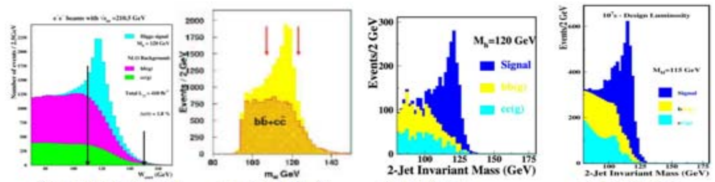
(m_H = 126.8 GeV)

The resonance Higgs production is one of the gold-plated processes for PLC



Very sensitive to high mass particles in the loop





$$\dot{N}_H = L_{ee} \times \frac{dL_{0,\gamma\gamma}}{dW_{\gamma\gamma} L_{ee}} \frac{4\pi^2 \Gamma_{\gamma\gamma}}{M_H^2} (1 + \lambda_1\lambda_2 + CP * l_1 l_2 cos2\varphi) = L_{ee}\sigma$$

$$\sigma = \frac{0.98 \cdot 10^{-35}}{2E_0[\mathrm{GeV}]} \frac{dL_{0,\gamma\gamma}}{dz L_{ee}} (1 + \lambda_1\lambda_2 + CP * l_1 l_2 cos2\varphi), \ \mathrm{cm}$$

For realistic ILC conditions $\sigma(\gamma\gamma\to H)\approx 75$ fb, while $\sigma(e^+e^-\to HZ)\approx 290$ fb

in e+e- $N(H\to\gamma\gamma)\propto L\,\sigma(e^+e^-\to HZ)*Br(H\to\gamma\gamma)$, where $Br(H\to\gamma\gamma)=0.0024$

in $\gamma\gamma$ $N(H\to\gamma\gamma)\propto L\,\sigma(\gamma\gamma\to H)*Br(H\to bb)$, where $Br(H\to bb)=0.57$

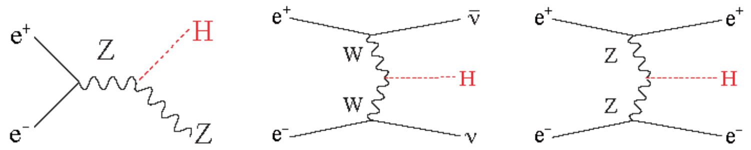
Conclusion: in γγ collisions the $\Gamma(H\to\gamma\gamma)$ width can be measured with statistics (75*0.57)/(290*0.0024)=60 times higher than in e+e- collisions.

That is one of most important argument for the photon collider.

Remark on Photon collider Higgs factories

Photon collider can measure
$\Gamma(H\to\gamma\gamma)$*$Br(H\to bb, ZZ,WW)$, $\Gamma^2(H\to\gamma\gamma)/\Gamma_{tot}$, CP properties (using photon polarizations). In order to get $\Gamma(H\to\gamma\gamma)$ one needs $Br(H\to bb)$ from e+e- (accuracy about 1%). As result the accuracy of $\Gamma(H\to\gamma\gamma)$ is about 1.5-2% after 1 years of operation.

e+e- can also measure $Br(bb, cc, gg, \tau\tau, \mu\mu, \text{invisible})$, Γ_{tot}, less backgrounds due to tagging of Z.



Therefore PLC is nicely motivated in combination with e+e-: parallel work or second stage.

$H \to \gamma\gamma$ from e+e- and LHC

Recently, at Snownass-2013, M.Peskin has noticed that a high luminosity LHC will give a small statistical error for γγ and other branching, but a large systematic error. Measuring precisely only one branching at e+e- collider one can recalculate all Higgs branching obtained at LHC and thus get a small error for all branchings, including γγ.

In this case, the photon collider for measurement of $H \to \gamma\gamma$ is not needed.

Measurement of the Higgs CP-properties

$$\sigma \propto 1 \pm l_{\gamma 1} l_{\gamma 2} \cos 2\phi,$$

where $l_{\gamma i}$ are the degrees of linear polarization and ϕ is the angle between $\vec{l_{\gamma 1}}$ and $\vec{l_{\gamma 2}}$, and the $\pm$ signs correspond to CP$= \pm 1$ scalar particles.

Varying initial state photon polarizations one can measure the Higgs CP value with 5-10% accuracy after one year of operation.

(In e+e- collisons CP-violation can be measured only using particle correlations in final states)

Physics motivation for PLC
(independent on physics scenario)
(shortly)

In $\gamma\gamma$, γe collisions compared to e^+e^-

1. the energy is smaller only by 10-20%
2. the number of events is similar or even higher
3. access to higher particle masses (H,A in $\gamma\gamma$, charged and light neutral SUSY in γe)
4. higher precision for some phenomena ($\Gamma_{\gamma\gamma}$, CP-proper.)
5. different type of reactions (different dependence on theoretical parameters)

It is the unique case when the same collider allows to study new physics in several types of collisions at the cost of rather small additional investments

Some examples of Physics (in addition to H(125))

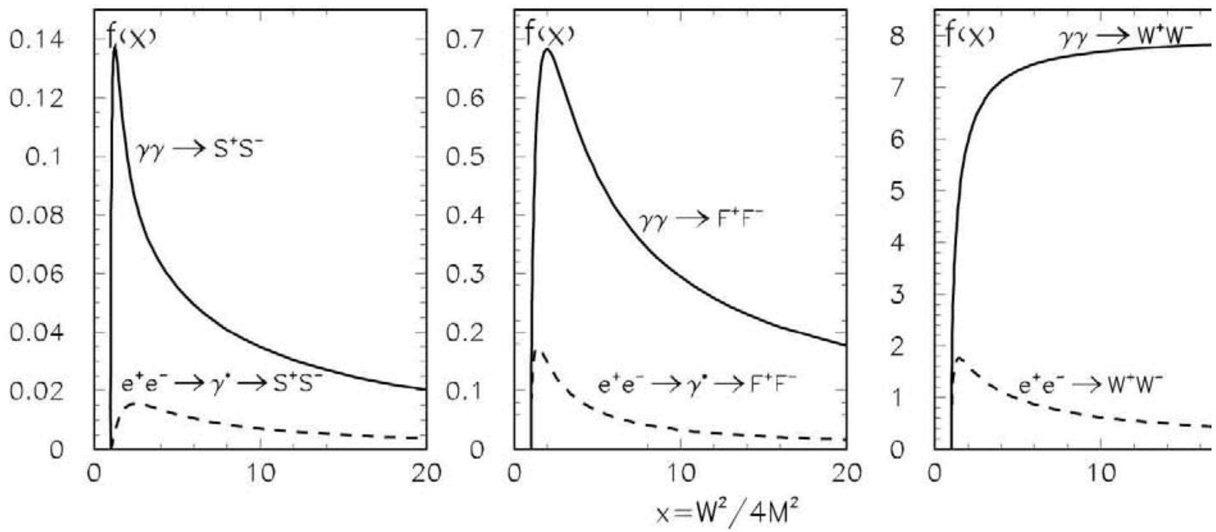
Charged pair production in e^+e^- and $\gamma\gamma$ collisions.

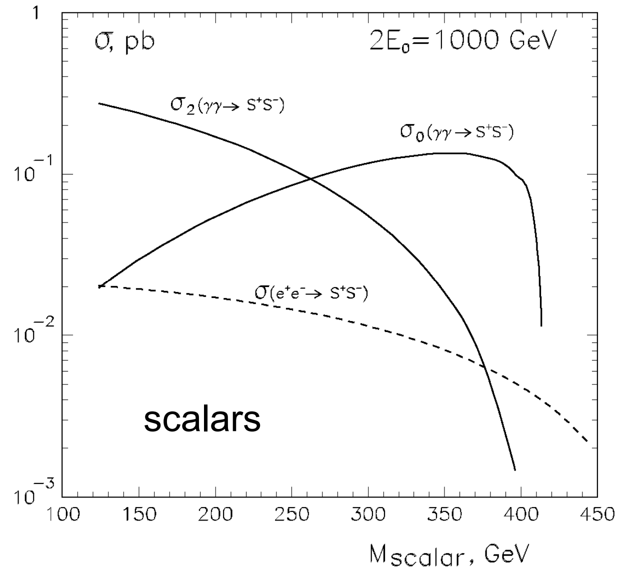
unpolarized beams

S (scalars), F (fermions), W (W-bosons);

$\sigma = (\pi\alpha^2/M^2)f(x)$, beams unpolarized)

polarized beams





So, typical cross sections for charged pair production in $\gamma\gamma$ collisions is larger than in e^+e^- by one order of magnitude (circular polarizations helps)

Supersymmetry in $\gamma\gamma$

In supersymmetric model there are 5 Higgs bosons:

h^0 light, with $m_h < 130$ GeV

H^0, A^0 heavy Higgs bosons;

H^+, H^- charged bosons.

$M_H \approx M_A$, in e^+e^- collisions H and A are produced in pairs (for certain param. region), while in $\gamma\gamma$ as the single resonances, therefore:

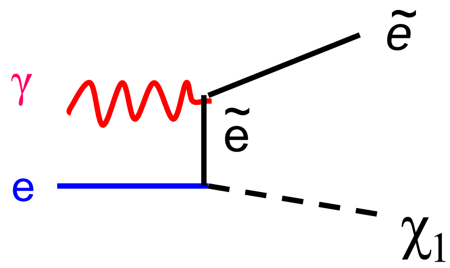
in e^+e^- collisions $M_{H,A}^{max} \sim E_0$ ($e^+e^- \rightarrow H + A$)
in $\gamma\gamma$ collisions $M_{H,A}^{max} \sim 1.6 E_0$ ($\gamma\gamma \rightarrow H(A)$)

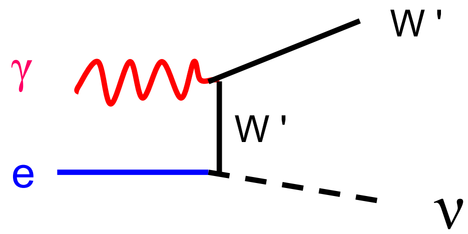
For some SUSY parameters H,A can be seen only in $\gamma\gamma$
(but not in e+e- and LHC)

Supersymmetry in γe

At a γe collider charged particles with masses higher than in e$^+$e$^-$ collisions at the same collider can be produced (a heavy charged particle plus a light neutral one, such as a new W' boson and neutrino or supersymmetric charged particle plus neutralino):

$$m_{\tilde{e}^-} < 0.9 \times 2E_0 - m_{\tilde{\chi}_1^0}$$





Photon collider at ILC

The photon collider at ILC (TESLA) has been developed in detail at conceptual level, all simulated, all reported and published (TESLA TDR (2001), etc.

The conversion region: optimization of conversion, laser scheme.

The interaction region: luminosity spectra and their measurement, optimization of luminosity, stabilization of collisions, removal of disrupted beams, crossing angle, beam dump, backgrounds.

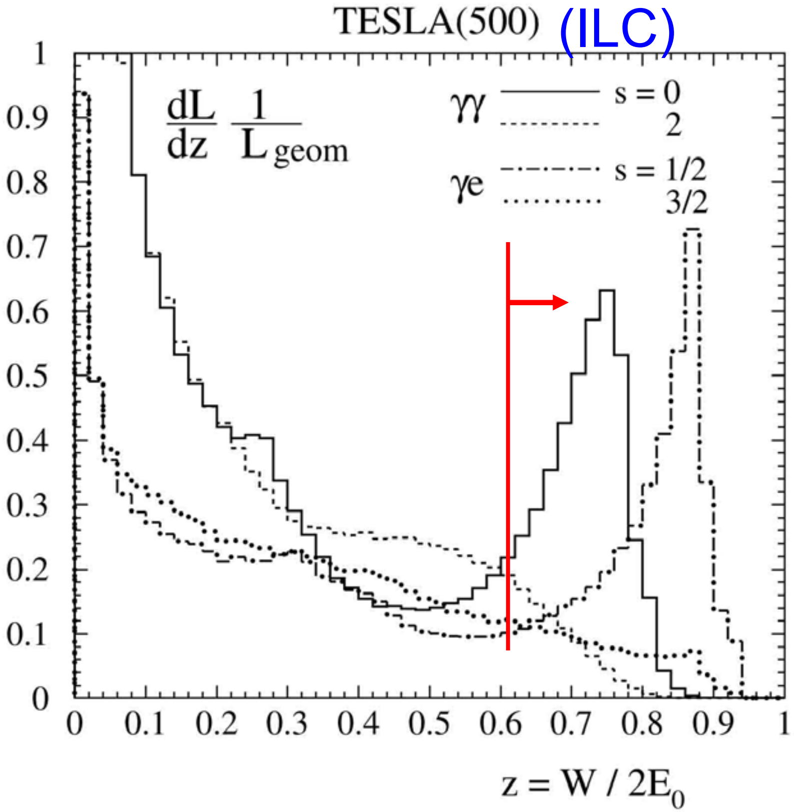
The laser scheme (optical cavity) was considered by experts, there is no stoppers. Required laser technique is developed independently for many other applications based on Compton scattering. Recently LLNL started work on LIFE lasers for thermonuclear plant which seems very attractive (one pass laser).

Further developments need political decisions and finances.

Realistic luminosity spectra ($\gamma\gamma$ and γe)

(with account multiple Compton scattering, beamstrahlung photons and beam-beam collision effects)

(decomposed in two states of J_z)



Usually a luminosity at the photon collider is defined as the luminosity in the high energy peak, $z>0.8z_m$.

For ILC conditions

$L_{\gamma\gamma}(z>0.8z_m) \sim 0.1\ L_{e\text{-}e\text{-}}(geom)$

(but cross sections in $\gamma\gamma$ are larger then in e+e- by one order!)

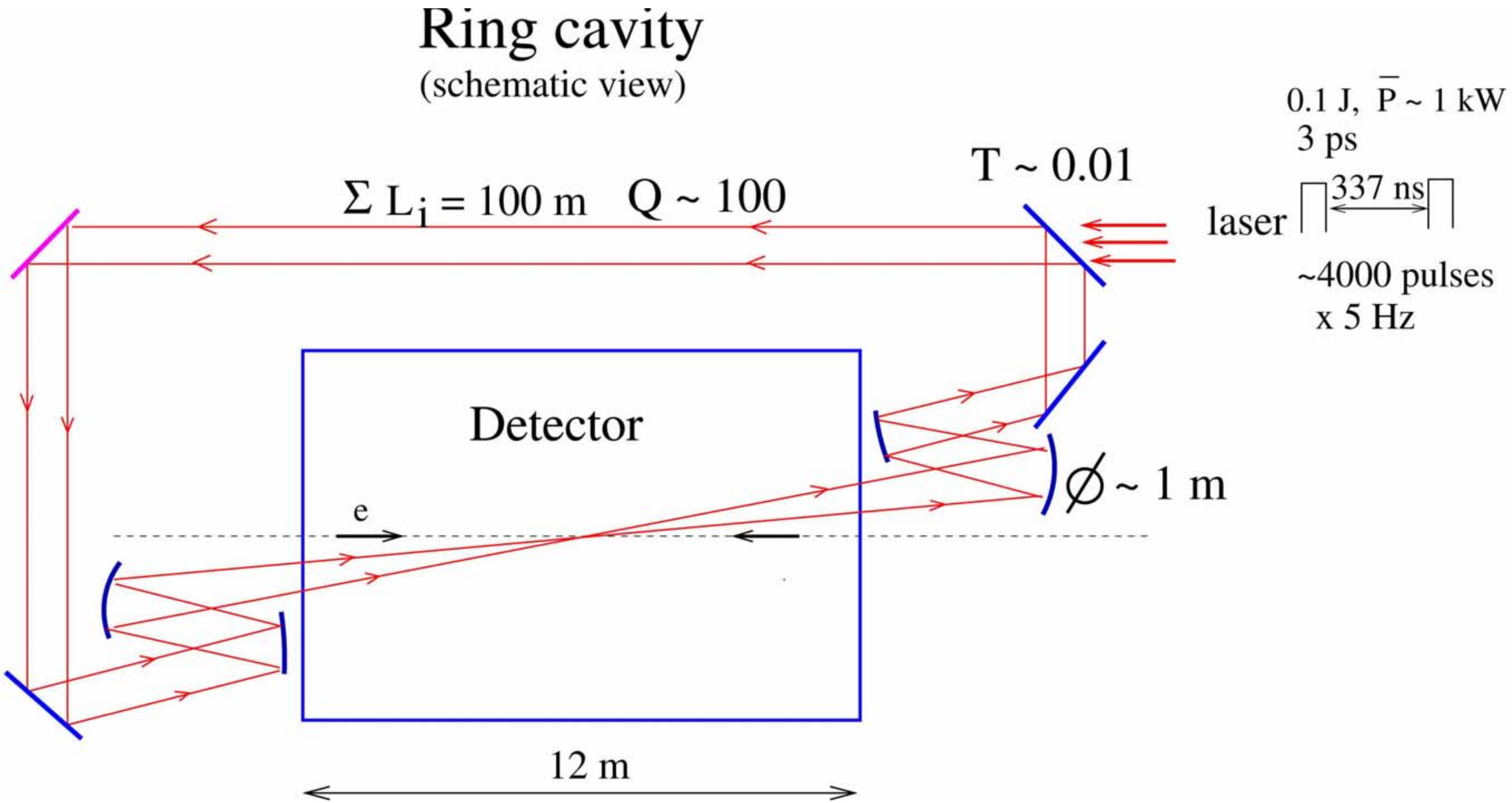
Requirements for laser

- Wavelength ~1 μm (good for 2E<0.8 TeV)
- Time structure Δct~100 m, 3000 bunch/train, 5 Hz
- Flash energy ~5-10 J
- Pulse length ~1-2 ps

If a laser pulse is used only once, the average required power is P~150 kW and the power inside one train is 30 MW! Fortunately, only 10^{-9} part of the laser photons is knocked out in one collision with the electron beam, therefore the laser bunch can be used many times.

The best is the scheme with accumulation of very powerful laser bunch is an external optical cavity. The pulse structure at ILC (3000 bunches in the train with inter-pulse distance ~100 m) is very good for such cavity. It allows to decrease the laser power by a factor of 100-300.

Laser system

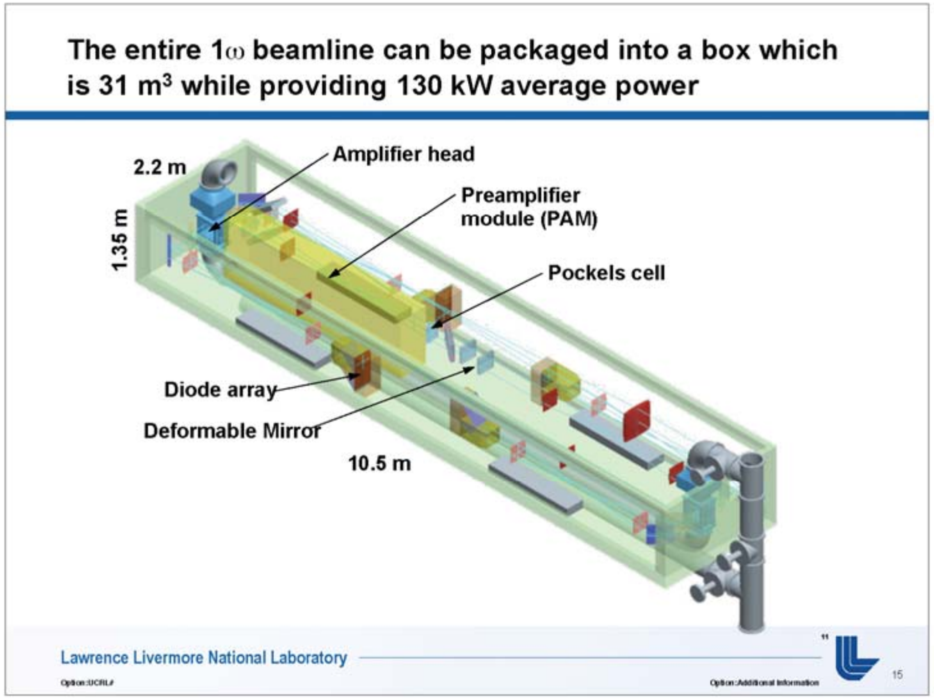


The cavity includes adaptive mirrors and diagnostics. Optimum angular divergence of the laser beam is ±30 mrad, A≈9 J (k=1), $\sigma_t \approx 1.3$ ps, $\sigma_{x,L} \sim 7$ μm

Recently new option has appeared, one pass laser system, based on new laser ignition thermonuclear facility

Project LIFE, LLNL   16 Hz, 8.125 kJ/pulse, 130 kW aver. power

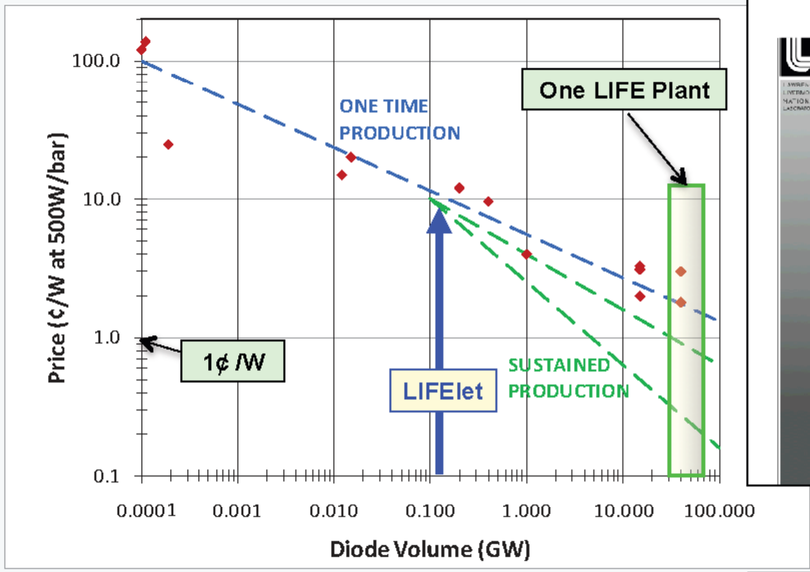
(the pulse can be split into the ILC train)



Laser diodes cost go down at mass production, that makes one pass laser system for PLC at ILC and CLIC realistic!

Diode costs are the main capital cost in the system

- White paper co-authored by 14 key laser diode vendors
- 2009 Industry Consensus: 3¢/W @ 500 W/bar, with no new R&D



LLNL-TR-465931

Semiconductor Laser Diode Pumps for Inertial Fusion Energy Lasers

R. Deri, J. Geske, M. Kanskar, S. Patterson, G. Kim, Q. Hartmann, F. Leibreich, E. Deichsel, J. Ungar, P. Thiagarajan, R. Martinsen, P. Leisher, E. Stephens, J. Harrison, C. Ghosh, O. Rabot, A. Kohl

January 2011

- Power scaling to 850 W/bar provides $0.0176/W (1st plant)
- Sustained production of LIFE plants reduces price to ~$0.007/W
- Diode costs for first plant: $880M
- Diode costs for sustained production: $350M

Diode costs for 1 beamline ~ $2.3M

LIFElet (1st beamline) $0.1/W diodes for 1 beamline $13M

Lawrence Livermore National Laboratory

Option:UCRL#

Option:Additional Information

13

Photon collider at CLIC

Laser system for CLIC

Requirements to a laser system for PLC at CLIC (500)

Laser wavelength	~ 1 μm (5 for 2E=3000 GeV)
Flash energy	A~5 J
Number of bunches in one train	354
Length of the train	177 ns=53 m
Distance between bunches	0.5 nc
Repetition rate	50 Hz

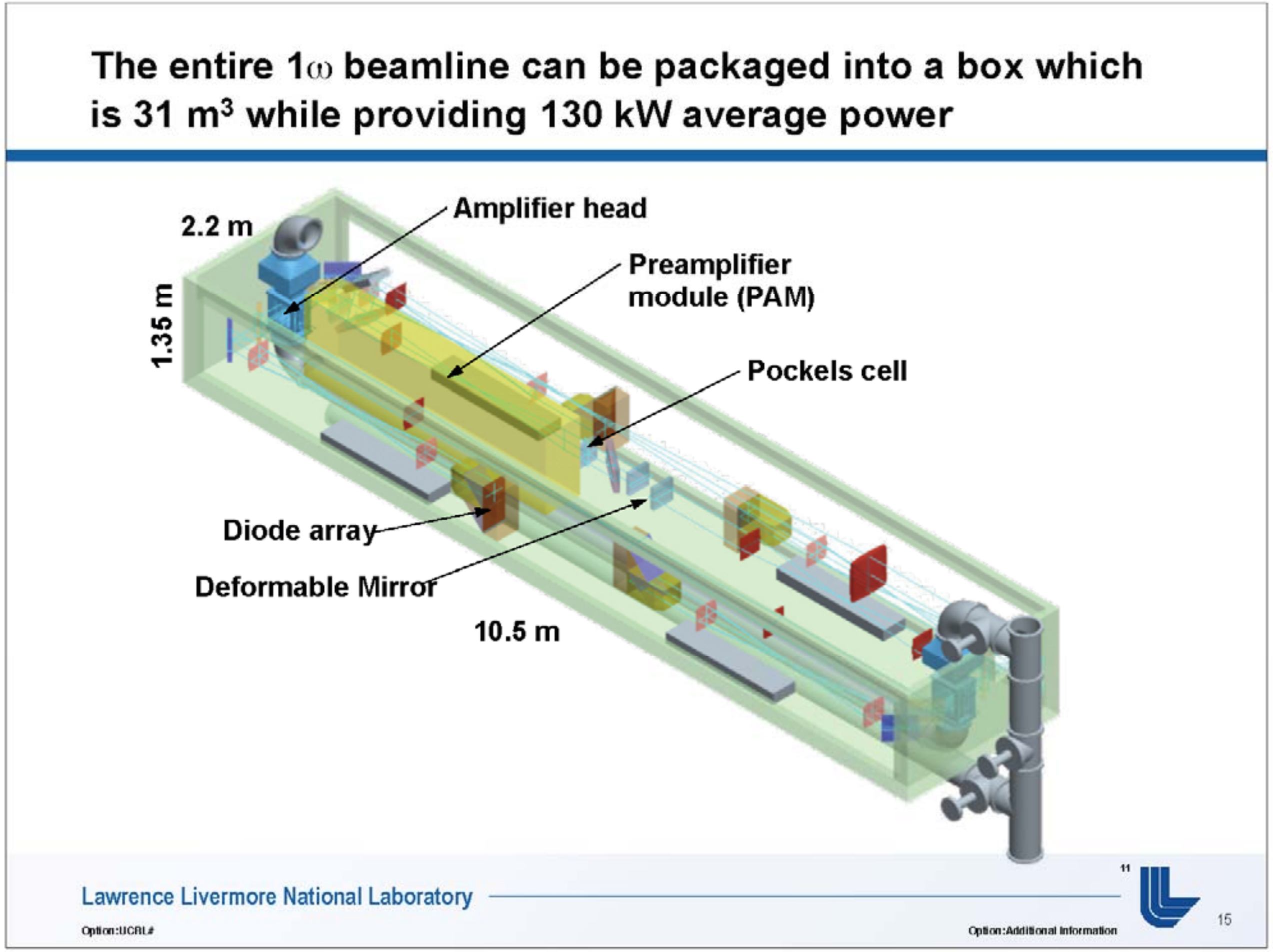
The train is too short for the optical cavity, so one pass laser should be used.

The average power of one laser is 90 kW (two lasers 180 kW).

One pass laser system, developed for LIFE (LLNL) is well suited for CLIC photon collider

Project LIFE, LLNL 16 Hz, 8.125 kJ/pulse, 130 kW aver. power

(the pulse can be split into the CLIC train)



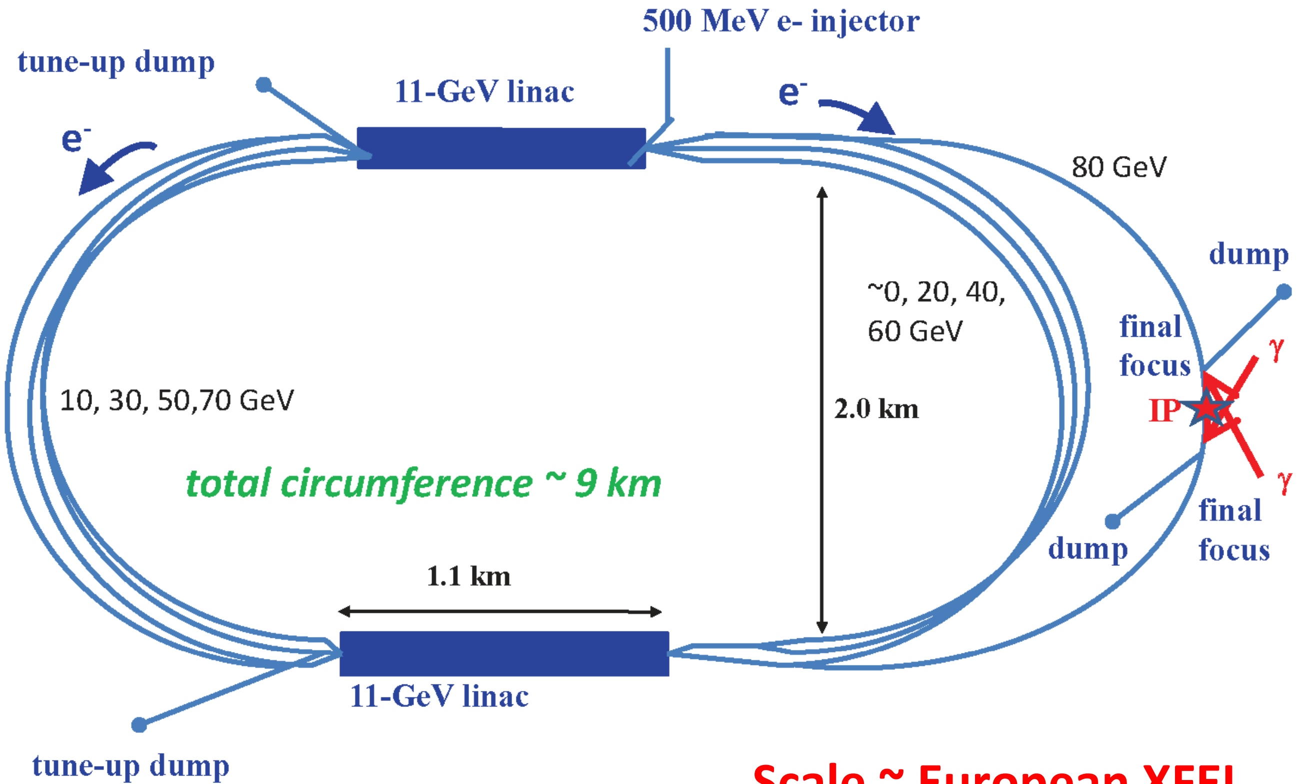
Photon collider Higgs factory SAPPHiRE

Submitted to the European Particle Physics Strategy Preparatory Group

SAPPHiRE: a Small $\gamma\gamma$ Higgs Factory

S. A. Bogacz[1], **J. Ellis**[2,3], **L. Lusito**[4], **D. Schulte**[3], **T. Takahashi**[5], **M. Velasco**[4],
M. Zanetti[6] and **F. Zimmermann**[3]

Aug. 2012



Scale ~ European XFEL
~ 1 Billion ???

Figure 3: *Sketch of a layout for a $\gamma\gamma$ collider based on recirculating superconducting linacs – the SAPPHiRE concept.*

The scheme is based on LHeC electron ring, but shorter bunches and somewhat higher energy, 80 GeV

Some critical remarks on SAPPHIRE

1. The emittance dilution in arcs.
2. Need low emittance polarized electron guns. Several labs are working on low emittance polarized RF guns, there is a good progress and results will appear soon.
3. The length of the ring 9 km (2.2 km linac, 70 km ! arcs). The "usual" warm LC with G=50 MeV/m would have L~4 km total length and can work with smaller emittances and thus can have a higher luminosity. Where is a profit?

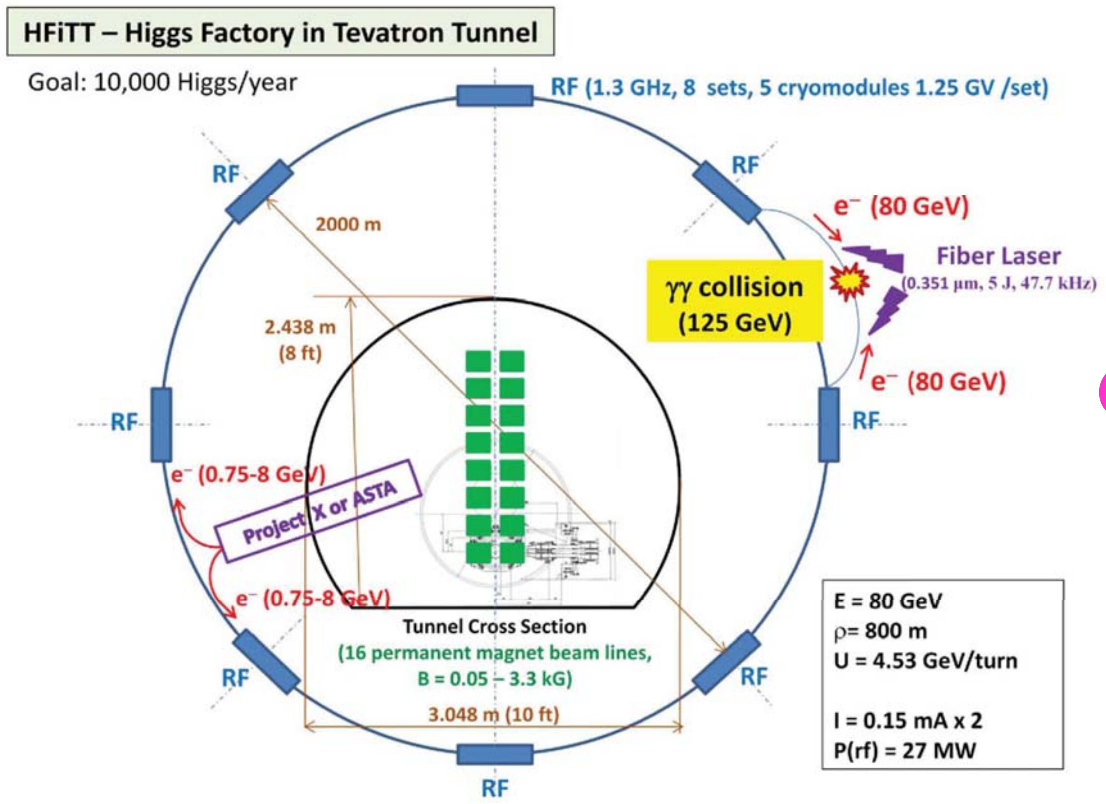
4. The PLC with E=80 GeV and λ=1.06/3 μm (x=4.6) have very low energy final electrons, this courses very large disruption angles. Namely due to this reason for TESLA (ILC) we always considered the Higgs factory with E=110 GeV and λ=1.06 μm (x=2). In addition, at E=110 GeV the product of linear polarizations is 3 times larger (9 times smaller running time for obtai-ning the same accuracy for CP parameter). The energies E>100 GeV are not possible at ring colliders like Sapphire due to unacceptable emittance dilution and the energy spread (the emittance increases is proportional to E^6/R^4)

5. It is obvious that e+e- is better for the Higgs study, there is no chance to get support of physics community, if this collider is instead of e+e-(worse that precursor).

Sapphire has stimulated many other proposals of ring gamma-gamma Higgs factories:

HFiTT – Higgs Factory in Tevatron Tunnel

W. Chou, G. Mourou, N. Solyak, T. Tajima, M. Velasco



C=6 km

The total number of beamlines in the tunnel will be 16, with the total length of approximately 96 km. The eight arcs would be stacked one on top another, so electronswill jump up and down, by up to 1.5 m, 16 times per turn, 128 times in total. The vertical emittance will be certainly destroyed on such “mountains”.

Laser for HFiTT

Fiber Lasers -- Significant breakthrough

Gerard Mourou et al., *“The future is fiber accelerators,” Nature Photonics, vol 7, p.258 (April 2013).*

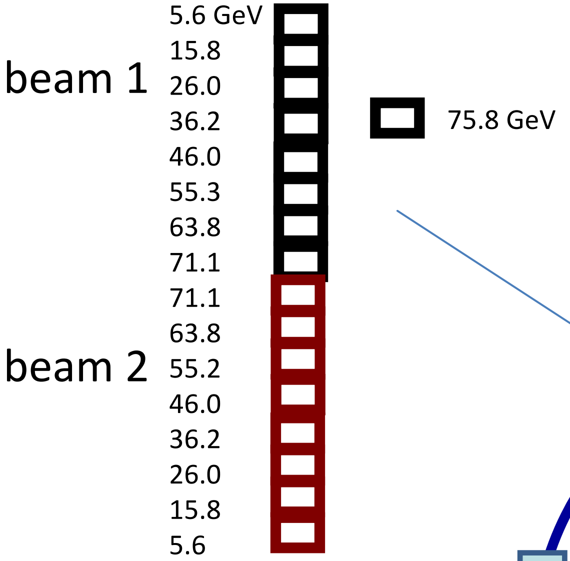
ICAN – International Coherent Amplification Network

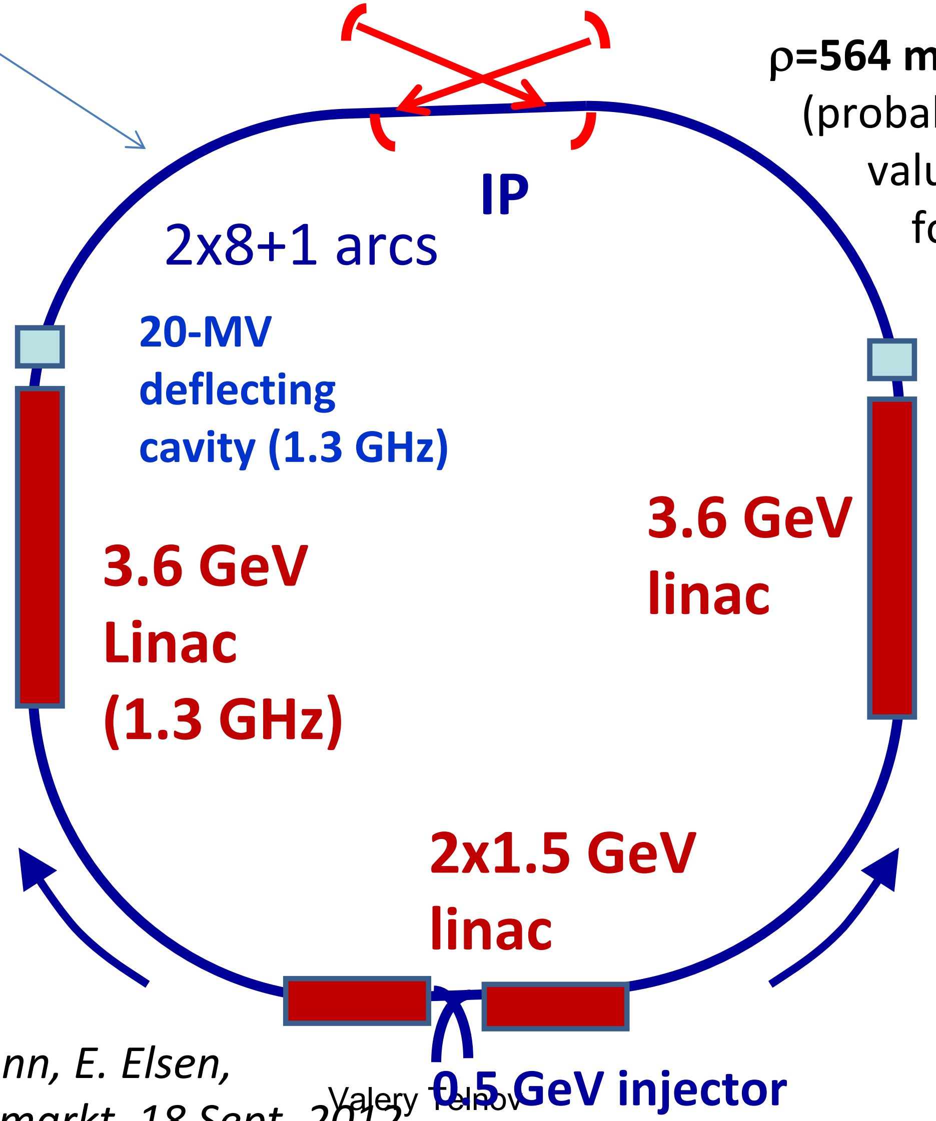
Figure 2: Principle of a coherent amplifier network (CAN) based on fiber laser technology. An initial pulse from a seed laser (1) is stretched (2), and split into many fibre channels (3). Each channel is amplified in several stages, with the final stages producing pulses of ~1 mJ at a high repetition rate (4). All the channels are combined coherently, compressed (5) and focused (6) to produce a pulse with an energy of >10 J at a repetition rate of 10 kHz (7). [3]

HFiTT needs 5 J at ~40kHz!

HERA Tunnel Filler

arc magnets -17 passes!





ρ=**564 m** for arc dipoles (probably pessimistic; value assumed in the following)

real-estate linac Gradient ~ 10 MV/m

total SC RF = 10.2 GV

F. Zimmermann, R. Assmann, E. Elsen, DESY Beschleuniger-Ideenmarkt, 18 Sept. 2012

Edward Nissen

Town Hall meeting Dec 19 2011

Possible Configurations at JLAB

85 GeV Electron energy
γ c.o.m. 141 GeV

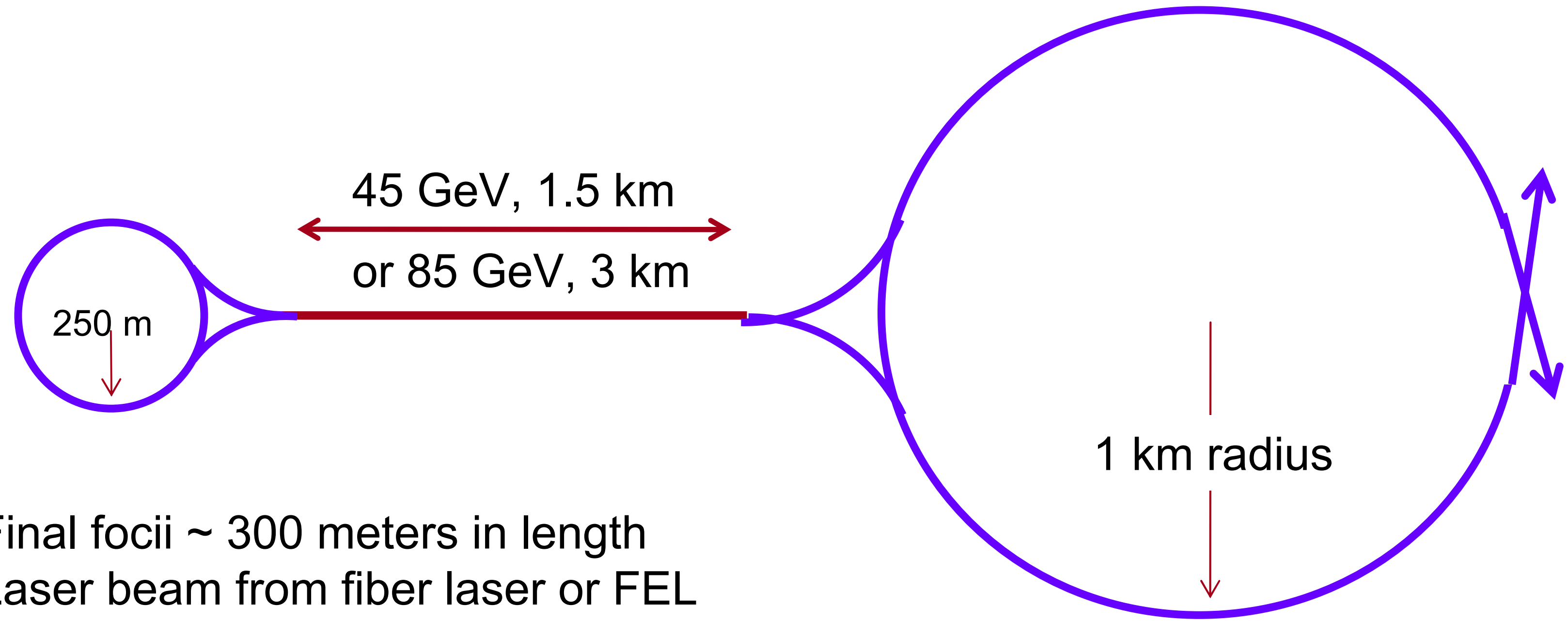
103 GeV Electron energy
γ c.o.m. 170 GeV

SLC-ILC-Style (SILC) Higgs Factor

(T. Raubenheimer)

- Some challenges with 2-pass design!

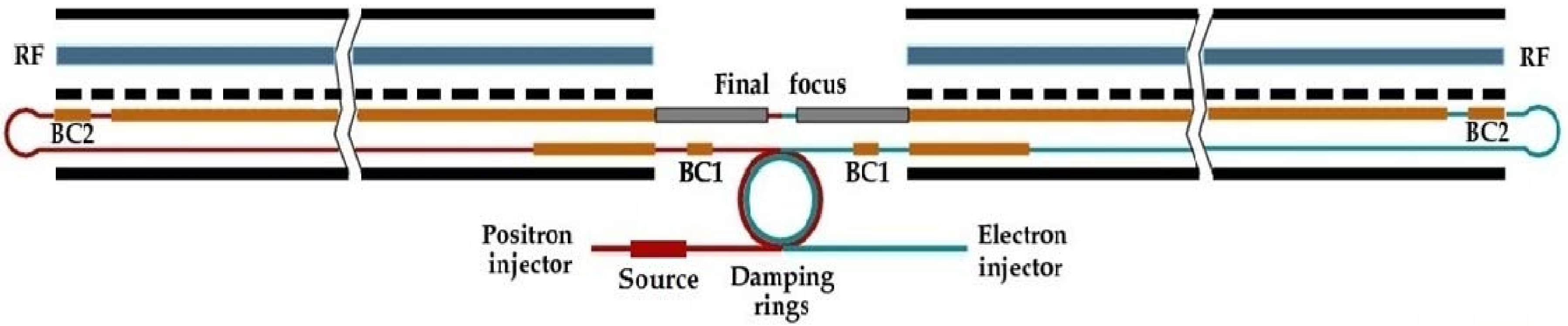
1.6 B$ without laser



Final focii ~ 300 meters in length
Laser beam from fiber laser or FEL
2 x 85 GeV is sufficient for $\gamma\gamma$ collider
Upgrade with plasma afterburners to reach 2 x 120 GeV. Then final ring should have R=3.5 km (to preserve emittance).

KEK the X-band linear collider Higgs factory (e+e-, γγ, γe) with a total length 3.6 km only.

(R. Belusevic and T. Higo)



Why not? With e+e-.

"Higgs" Factory at the Greek-Turkish Border

Serkant Ali CETİN
Doğuş University, Istanbul, Turkey

Evangelos N. GAZIS
National Technical University, Athens, Greece

Bora ISILDAK
OÅNzyeğin University, İstanbul, Turkey

Fatih OÅNmer İLDAY
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onstantinos KORDAS and Chariclia PETRIDOU
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TOBB Economy & Technolgy University, Ankara, Turkey and
ANAS, Institute of Physics, Baku, Azerbaijan

GoÅNkhan UÅNNEL
University of California at Irvine, Irvine, USA

Konstantin ZIOUTAS
University of Patras, Patras, Greece

Photon – Photon Collider Specific

ACCELERATOR

An electron linac with two arcs bending in opposite directi

Simple and cheap option

Two electron linacs facing each other, 80 GeV each

Option with better performance

Both options use the CLIC technology with gradient 100 MV/m, getting electron beam energy 80 GeV in ~1.5 km length (ILC SC technology 35 MV/m)

L=1.6 km !

(SLC type based on CLIC technology)

Plasma people also like photon collders, because acceleration of electron is much easier than positrons

SCHROEDER, ESAREY, GEDDES, BENEDETTI, AND LEEMANS Phys. Rev. ST Accel. Beams **13,** 101301 (2010)

TABLE II. Example parameters for a 0.5 TeV laser-plasma linear $\gamma\gamma$ collider.

Plasma number density, n_0 [cm^{-3}]	10^{17}
Beam energy, γmc^2 [TeV]	0.25
Geometric luminosity, $\mathcal{L}$ [10^{34} s^{-1} cm^{-2}]	2
Number per bunch, N [10^9]	4
Collision frequency, f [kHz]	15
Number of stages (1 linac), N_{stages}	25
Linac length (1 beam), L_{total} [km]	0.05
Total wall-plug power, P_{wall} [MW]	80
Compton scattering laser wavelength [μm]	1
Compton scattering laser energy [J]	6
Compton scattering laser duration [ps]	7
Compton scattering laser Rayleigh range [mm]	1
Compton scattering intensity [10^{18} W/cm^{-2}]	0.27
Gamma beam peak energy [TeV]	0.2
Conversion efficiency [$e \rightarrow \gamma$]	0.65

[8] W. P. Leemans, B. Nagler, A. J. Gonsalves, C. Tóth, K. Nakamura, C. G. R. Geddes, E. Esarey, C. B. Schroeder, and S. M. Hooker, Nature Phys. **2**, 696 (2006).

[9] K. Nakamura, B. Nagler, C. Tóth, C. G. R. Geddes, C. B. Schroeder, E. Esarey, W. P. Leemans, A. J. Gonsalves, and S. M. Hooker, Phys. Plasmas **14**, 056708 (2007).

[10] A. Pukhov and J. Meyer-ter-Vehn, Appl. Phys. B **74**, 355 (2002).

[11] W. Lu, M. Tzoufras, C. Joshi, F. S. Tsung, W. B. Mori, J. Vieira, R. A. Fonseca, and L. O. Silva, Phys. Rev. ST Accel. Beams **10**, 061301 (2007).

[12] N. E. Andreev, L. M. Gorbunov, V. I. Kirsanov, K. Nakajima, and A. Ogata, Phys. Plasmas **4**, 1145 (1997).

[13] K. V. Lotov, Phys. Plasmas **14**, 023101 (2007).

[14] X. Wang, P. Muggli, T. Katsouleas, C. Joshi, W. B. Mori, R. Ischebeck, and M. J. Hogan, Phys. Rev. ST Accel. Beams **12**, 051303 (2009).

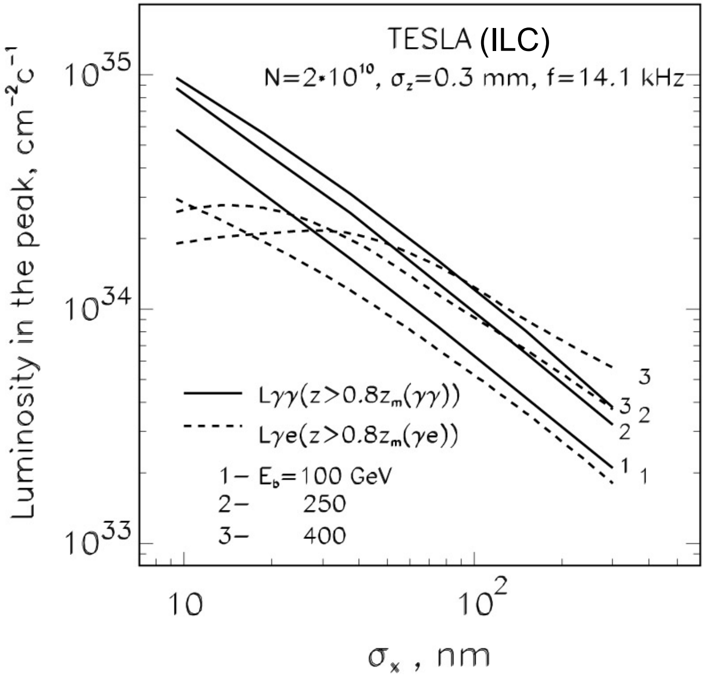
[15] E. Cormier-Michel, E. Esarey, C. G. R. Geddes, C. B. Schroeder, W. P. Leemans, D. L. Bruhwiler, B. Cowan,

My dreams of $\gamma\gamma$ factories

(PLC based on ILC, with very low emittances, without damping rings)

Factors limiting $\gamma\gamma,\gamma e$ luminosities

Telnov,1998



Collision effects:

- Coherent pair creation ($\gamma\gamma$)
- Beamstrahlung (γe)
- Beam-beam repulsion (γe)

On the right figure:
the dependence of $\gamma\gamma$ and γe luminosities in the high energy peak vs the horizontal beam size (σ_y is fixed).

At the ILC nominal parameters of electron beams $\sigma_x \sim 300$ nm is available at $2E_0$=500 GeV,
but PLC can work even with ten times smaller horizontal beam size.

So, one needs: ε_{nx}, ε_{ny} as small as possible and β_x , $\beta_y \sim \sigma_z$

Method based on longitudinal emittances

V.Telnov, LWLC10, CERN

Let us compare longitudinal emittances needed for ILC with those in RF guns.

At the ILC $\sigma_E/E\sim0.3\%$ at the IP (needed for focusing to the IP), the bunch length $\sigma_z\sim0.03$ cm, $E_{min}\sim75$ GeV that gives the required normalized emittance

$$\varepsilon_{nz}\approx(\sigma_E/mc^2)\sigma_z\sim15 \text{ cm}$$

In RF guns $\sigma_z\sim0.1$ cm (example) and $\sigma_E\sim10$ keV, that gives $\varepsilon_{nz}\sim2\cdot10^{-3}$ cm, or 7500 times smaller than required for ILC!

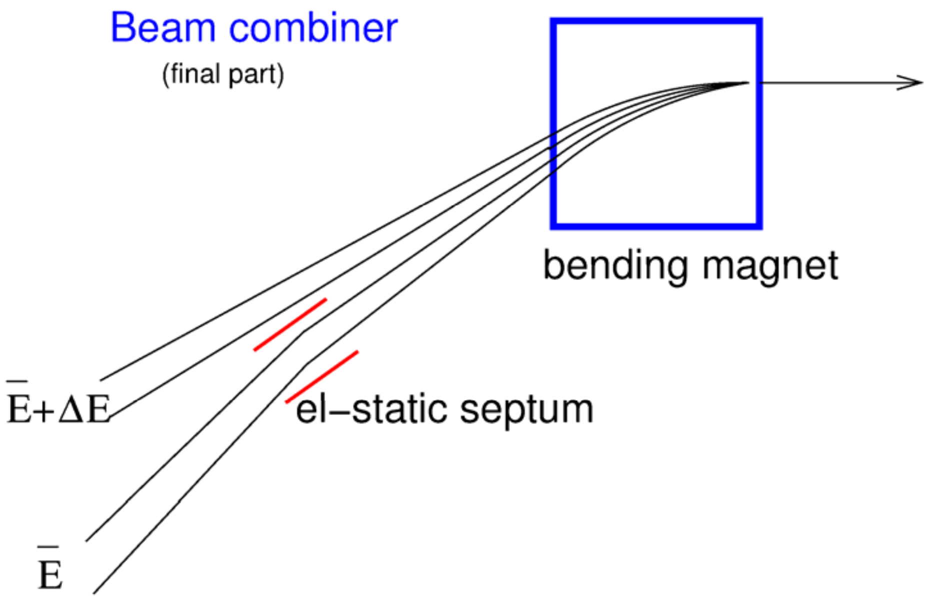
So, photoguns have much smaller longitudinal emittances than it is needed for linear collider (both e+e- or $\gamma\gamma$).

How can we use this fact?

A proposed method

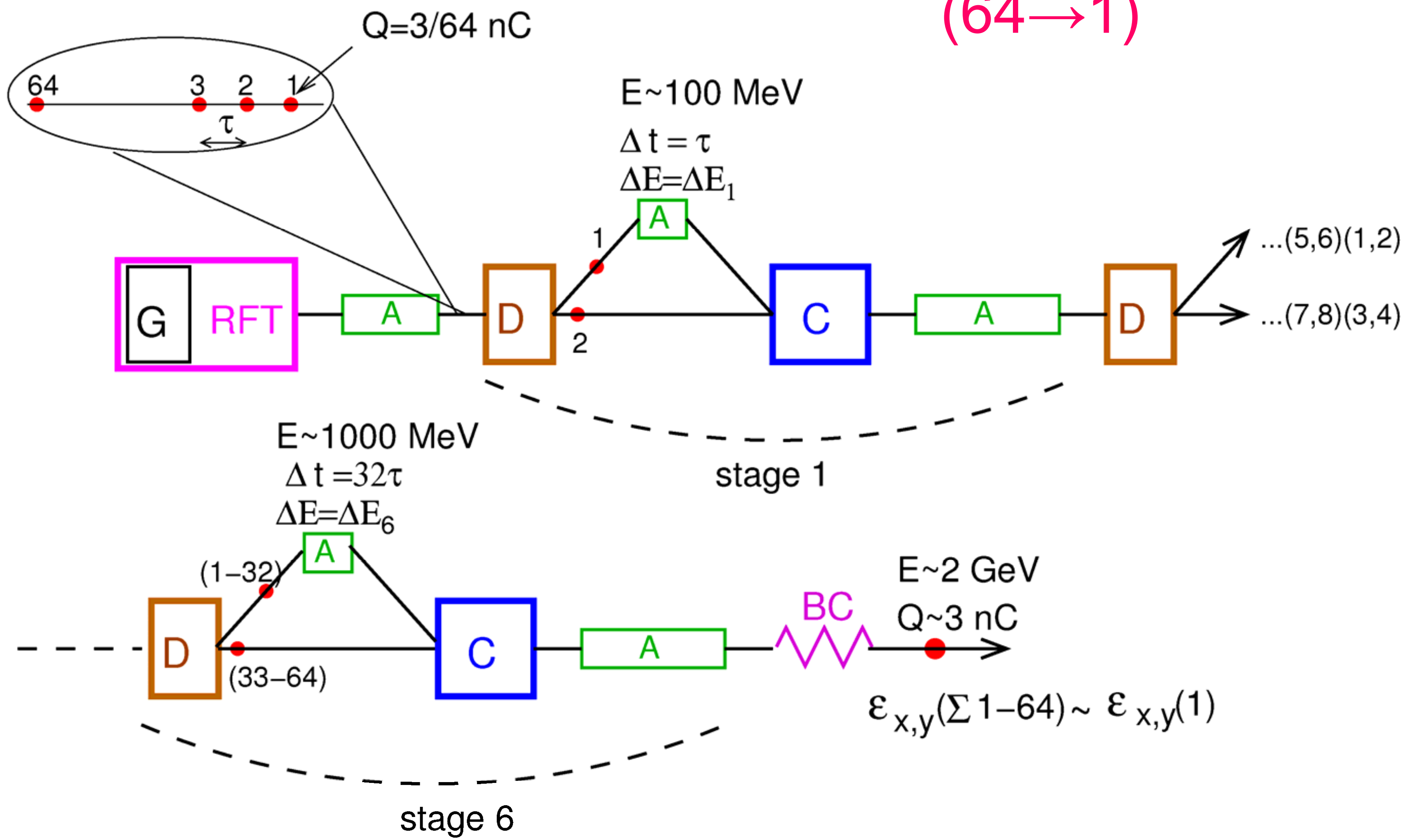
Let us combine many low charge, low emittance beams from photo-guns to one bunch using some differences in their energies. The longitudinal emittance increases approximately proportionally to the number of combined bunches while the transverse emittance (which is most important) remains almost constant.

It is assumed that at the ILC initial micro bunches with small emittances are produced as trains by one photo gun.



Scheme of combining one bunch from the bunch train (for ILC)

(64→1)



G –photogun, A –RF–cavities (accel), RFT –round to flat transformer,

D –deflector, C –beam combiner, BC –bunch compressor

Hopes

Beam parameters: $N=2\cdot10^{10}$ (Q~3 nC), $\sigma_z=0.4$ mm

Damping rings(RDR): $\varepsilon_{nx}=10^{-3}$ cm, $\varepsilon_{ny}=3.6\cdot10^{-6}$ cm, $\beta_x=0.4$ cm, $\beta_y=0.04$ cm,

RF-gun (Q=3/64 nC) $\varepsilon_{nx}\sim10^{-4}$ cm, $\varepsilon_{ny}=10^{-6}$ cm, $\beta_x=0.1$ cm, $\beta_y=0.04$ cm,

The ratio of geometric luminosities

$$L_{RFgun}/L_{DR}=\sim10$$

So, with polarized RF-guns one can get the luminosity ~10 times higher than with DR.

Conclusion

- Photon colliders have sense as a very cost effective addition for e+e- colliders: as the LC second stage or as the second IP (preferable).
- PLC at ILC is conceptually clear, the next step is the design and construction of the laser system prototype. Now, due to LIFE project it seems that one pass scheme becomes very attractive.
- PLC at CLIC is more difficult due to much shorter trains. However LIFE help here as well.
- Ring photon colliders, like SAPPHIRE and HFiTT does not look realistic due to technical problems, restriction on energy and absence of e+e- collisions. All photon colliders for Higgs study without e+e- have not sufficient physics case.
- PLC without damping rings is possible, could have even higher (or much higher) luminosity, needs further study. That could open the way to $\gamma\gamma$ factories, to precision measurement of the Higgs self coupling etc (if there is any new physics in the sub-TeV region).