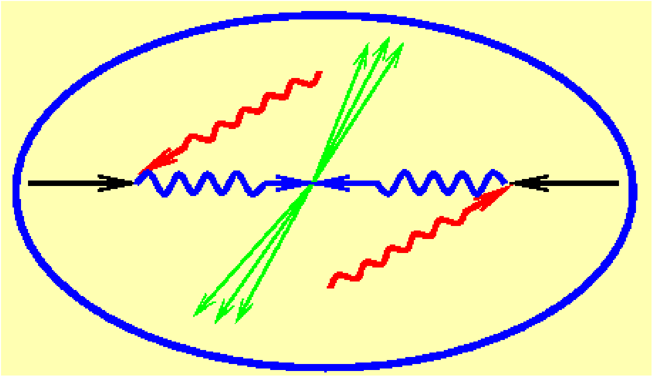


Introduction to the Photon Linear Collider

Valery Telnov

PHOTON 2007,
Paris, July 12, 2007

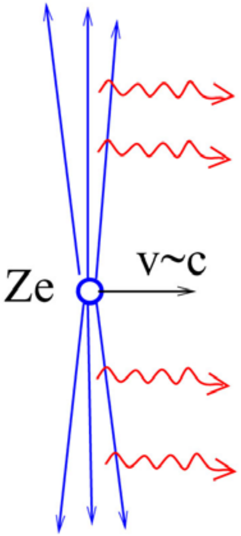
Contents

- Basic principles and properties the $\gamma\gamma$, γe collider
- Conversion and Interaction regions issues
- Lasers, optics
- Physics motivation
- The Photon collider at ILC, current status
- Conclusion

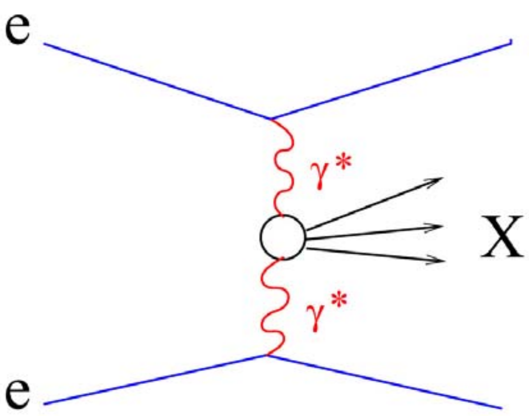
Colliding $\gamma^*\gamma^*$ photons

The idea to study some physics in photon-photon collisions is about 75 years old. The problem: a source of high energy photons.

In 30-th, Fermi-Weizsacker-Williams noticed that the field of a charged particle can be treated as the flux of almost real photons.



Landau-Lifshitz process



(e^+e^-, ….)

Such two-photon processes have been discovered and studied at e^+e^- storage rings

1970 $e^+e^- \to e^+e^-e^+e^-$ Novosibirsk
1972 $e^+e^- \to e^+e^-\mu^+\mu^-$ Frascati
1979 $e^+e^- \to e^+e^- \to \eta'$ SLAC
and later many processes in all e+e- experiments

Physics in $\gamma^*\gamma^*$ is quite interesting, though it is difficult to compete with e^+e^- collisions because the number of equivalent photons is rather small and their spectrum soft

$$dn_\gamma \approx \frac{2\alpha}{\pi}\frac{dy}{y}\left(1-y+\frac{1}{2}y^2\right)\ln\frac{E}{m_e} \sim 0.035\,\frac{d\omega}{\omega};$$

$L_{\gamma\gamma}(z>0.1) \sim 10^{-2}\, L_{e+e-}$

$z=W_{\gamma\gamma}/2E_0$

$L_{\gamma\gamma}(z>0.5) \sim 0.4\cdot 10^{-3}\, L_{e+e-}$

Idea of the photon collider

The idea of the high energy photon collider is based on the fact that at linear e+e- colliders electron beams are used only once which makes possible to convert electron beam to high energy photons just before the interaction point (it is not possible at storage ring where bunches are used many times).

The conversion can be done placing some target just before the interaction point, in the best way is the Compton scattering of the laser light off the high energy electrons (laser target). Thus one can get the energy and luminosity in $\gamma\gamma$ collisions close to those in e+e- collisions:

$$E_\gamma \sim E_e \;; \qquad L_{\gamma\gamma} \sim L_{e+e-}$$

First publications

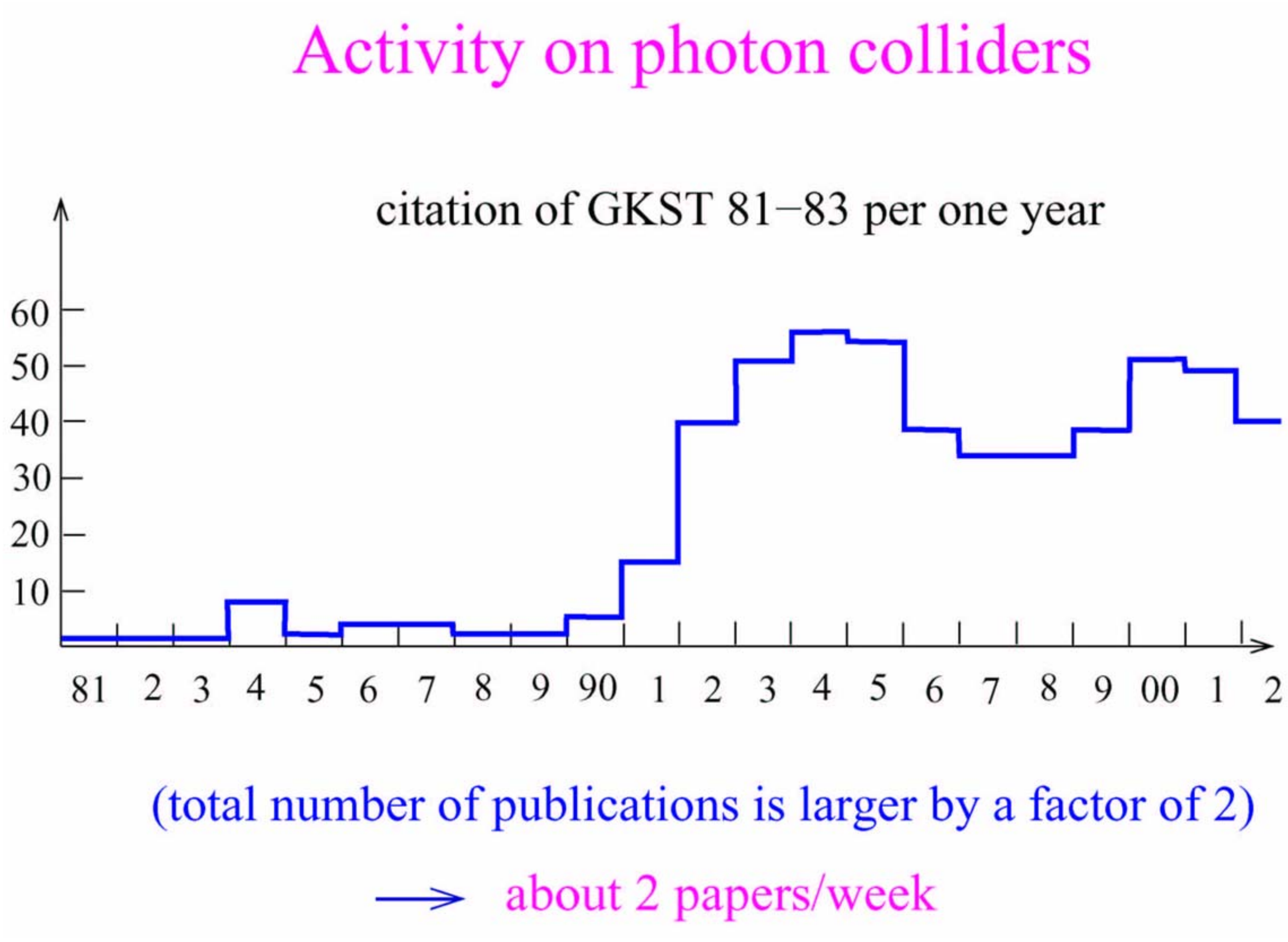
1. I.Ginzburg, G.Kotkin, V.Serbo, V.Telnov, On posibility of obtaining gamma-gamma, gamma-electron beams with high energy and luminosity, Preprint INP 81-50, Feb.1981, Pizma ZhETF 34 (1981) 514; JETP Lett. 34 (1982) 91(191citations)
2. I.Ginzburg, G.Kotkin, V.Serbo, V.Telnov, Nucl.Insr.and Meth 205(1983) 47; (548c)
3. I.Ginzburg, G.Kotkin, S.Panfil, V.Serbo, V.Telnov, Nucl.Insr.&Meth A219 (1984) 5; (479c) (2 and 3 – detailed description of PLC principles: kinematics, polarization effects, luminosity spectra e.t.c.)

Very important

1. V.Telnov, Problems of obtaining $\gamma\gamma,\gamma e$ at lin.coll., Nucl.Insr.&Meth A294 (1990) 72; (283c) (Removal of beams (crab crossing), beam collision effects)
2. V.Telnov, Status of gamma gamma, gamma electron colliders (PHOTON99, May1999) Nucl.Phys.Proc.Suppl.82:359-366,2000. ("External" optical cavity for PLC at TESLA has been suggested)

Most full description of the PLC up to now

Badelek et al., Photon collider at TESLA (TESLA TDR), Int.J.Mod.Phys.A19: 5097-5186, 2004 (121c).



Activity on photon colliders

citation of GKST 81−83 per one year

(total number of publications is larger by a factor of 2)

→ about 2 papers/week

About 20% of all publications on physics at LC are devoted to physics at photon colliders

Laser e→γ conversion

The method of the Compton scattering of laser light off high energy electrons was known since 1964 (Arutyunian, Tumanian, Milburn) and was used since 1966 at SLAC and other labs with $k=n_\gamma/n_e \sim 10^{-6}$.

For the photon collider one needs k~1 !

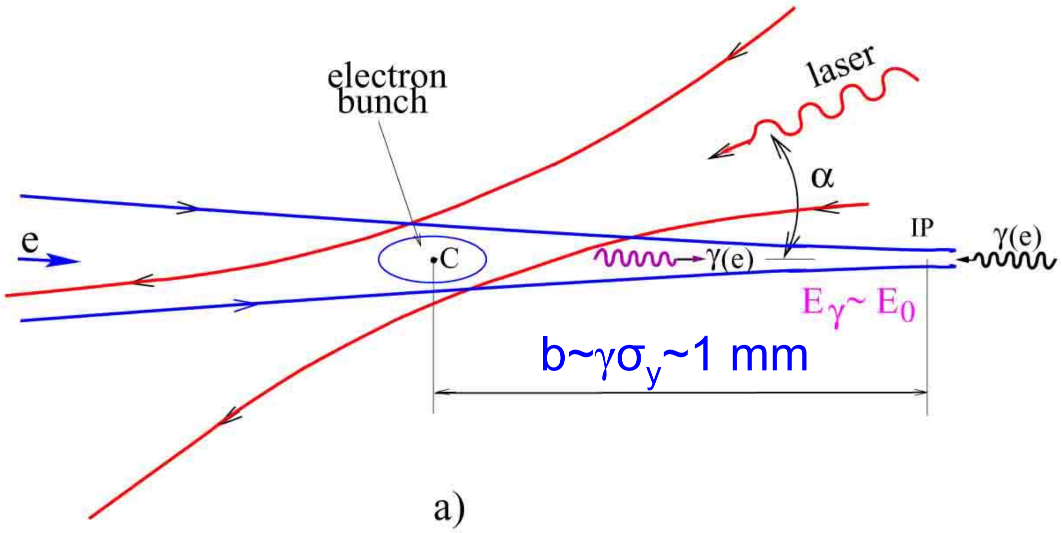
The required laser flash energy is about 1-10 J and ~1-3 ps durations and rep.rate similar to the linear collider (~10 kHz).

In 1981 we believed that it will be possible just extrapolating the progress in the laser technique (beside rep.rate was only 10-100 Hz).

In 1985 D.Strickland and G.Mourou invented the chirped pulse technique which made the photon collider realistic.

For the supercondicting ILC one can use the external optical cavity which considerably decreases the required laser power and together with other modern laser techniques (diode pumping, adaptive optics, multilayer mirrors) makes the photon collider really technically feasible.

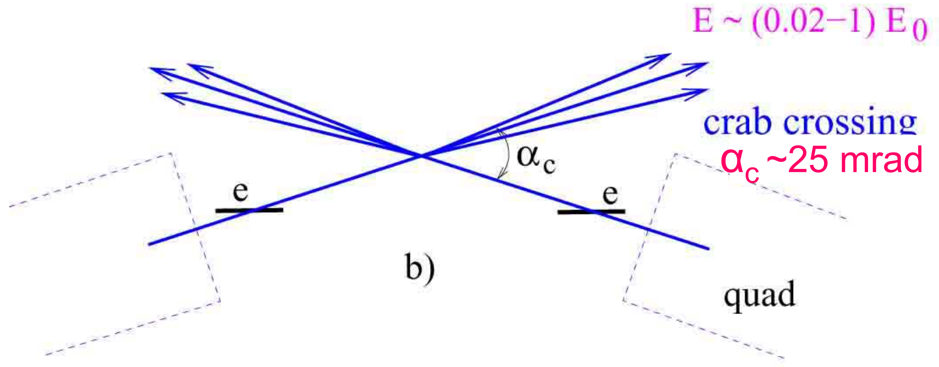
Scheme of $\gamma\gamma$, γe collider



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

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

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



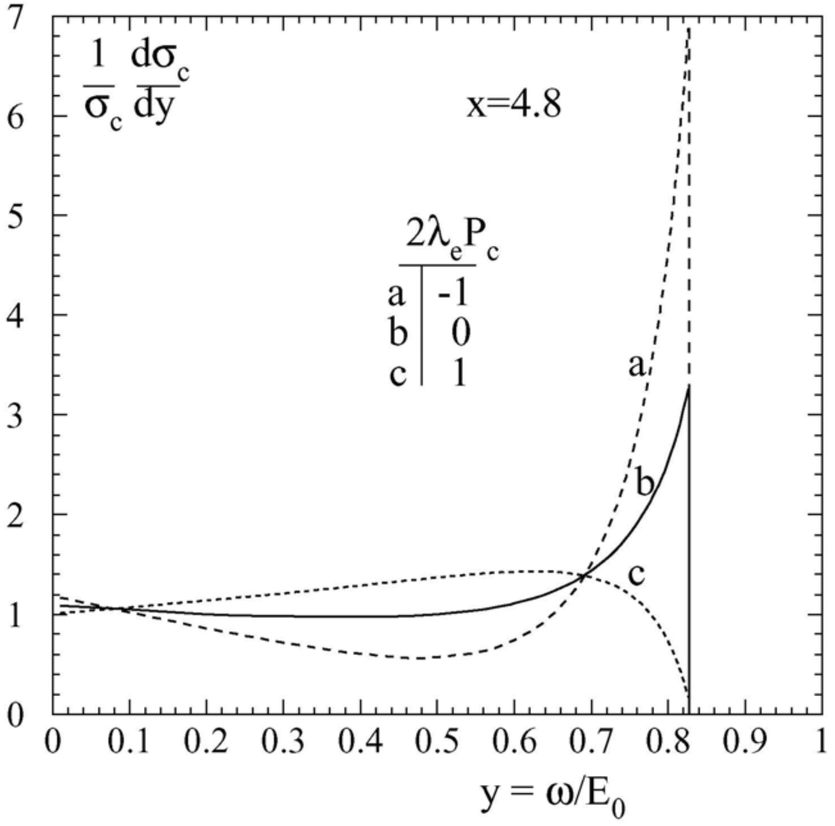
$x = 4.8$ is the threshold for $\gamma\gamma_L \to e^+e^-$ at conv. reg.

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

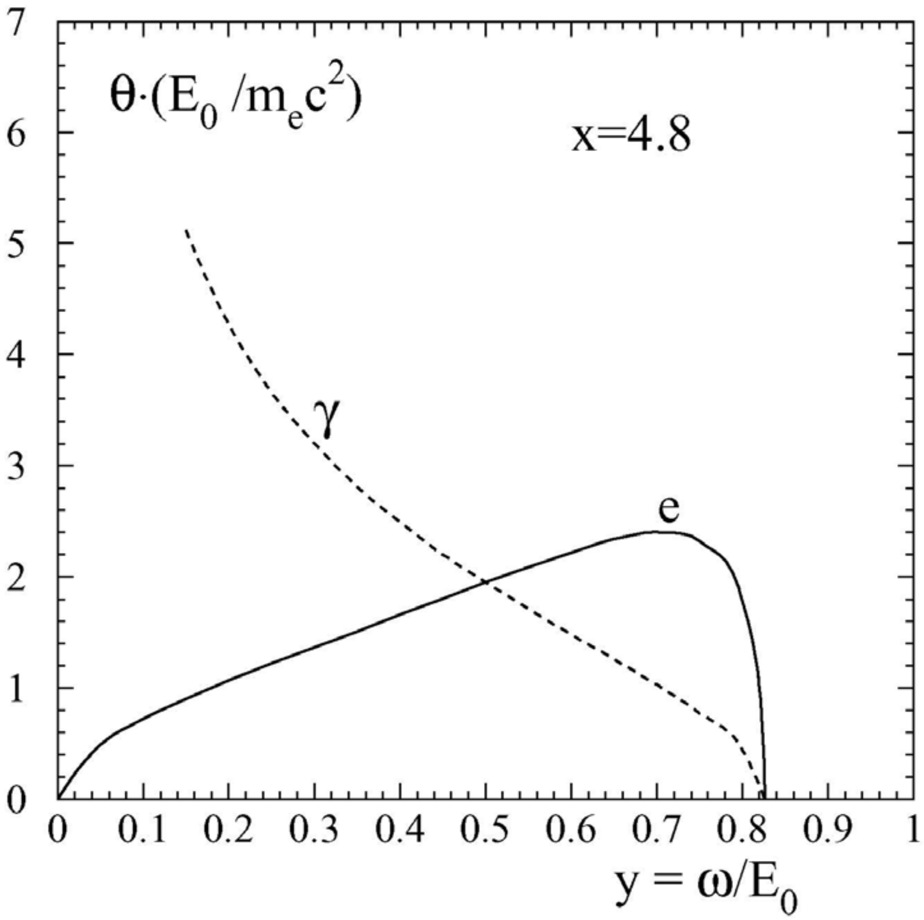
Spectrum of the Compton scattered photons



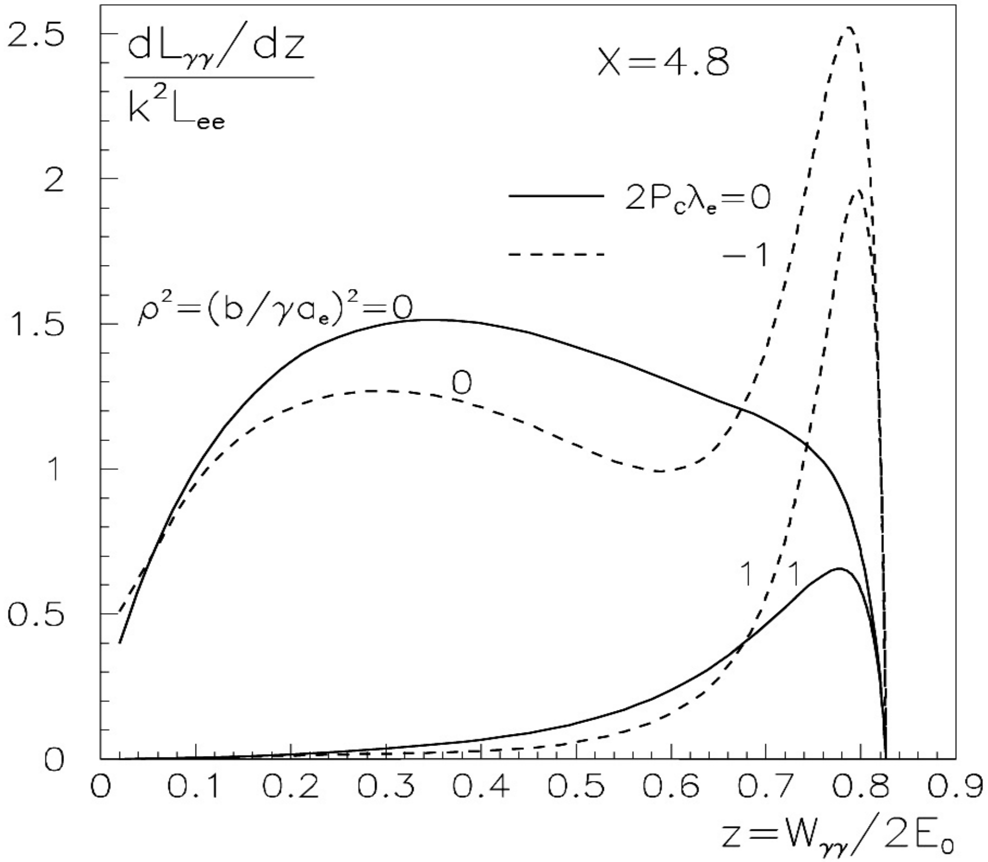
λ_e – electron longitudinal polarization

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

Angle-energy correlation for photons

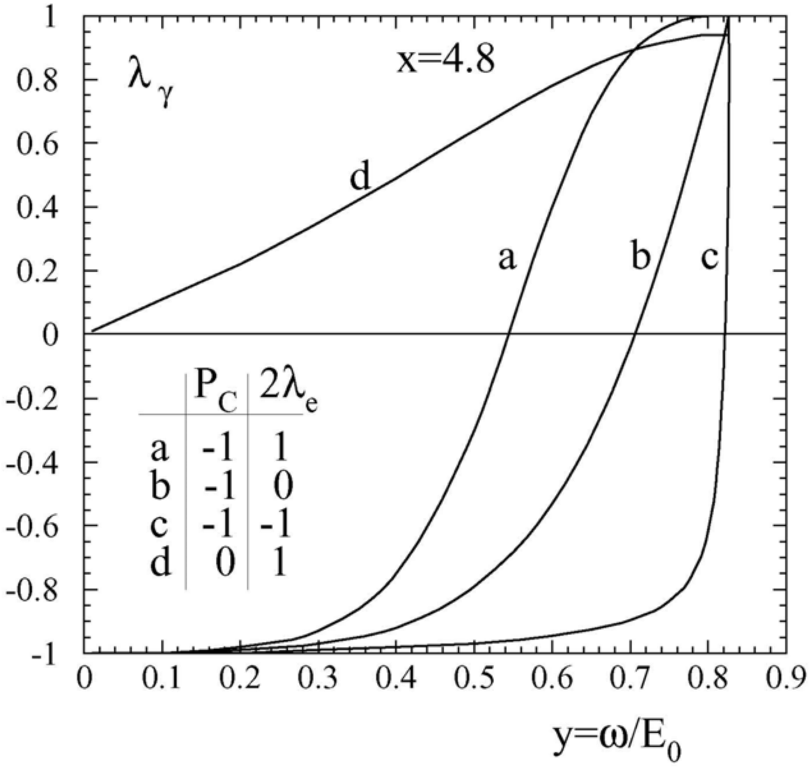


Ideal luminosity distributions, monohromatization



Due to angle-energy correlation high energy photons collide at smaller spot size, providing monohromatization of $\gamma\gamma$ collisions. This happends at $b/\gamma > a_e$.

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



	P_C	$2\lambda_e$
a	-1	1
b	-1	0
c	-1	-1
d	0	1

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

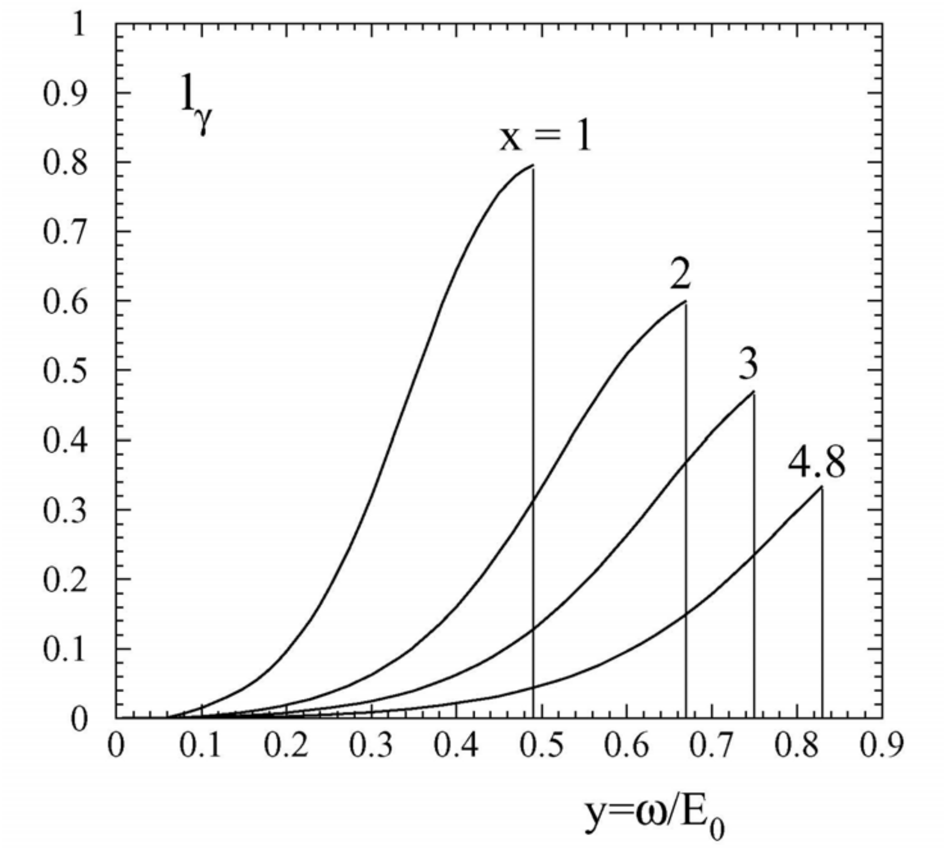
The cross section of the Higgs production

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

The cross section for main backgound

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

Linear polarization of photons

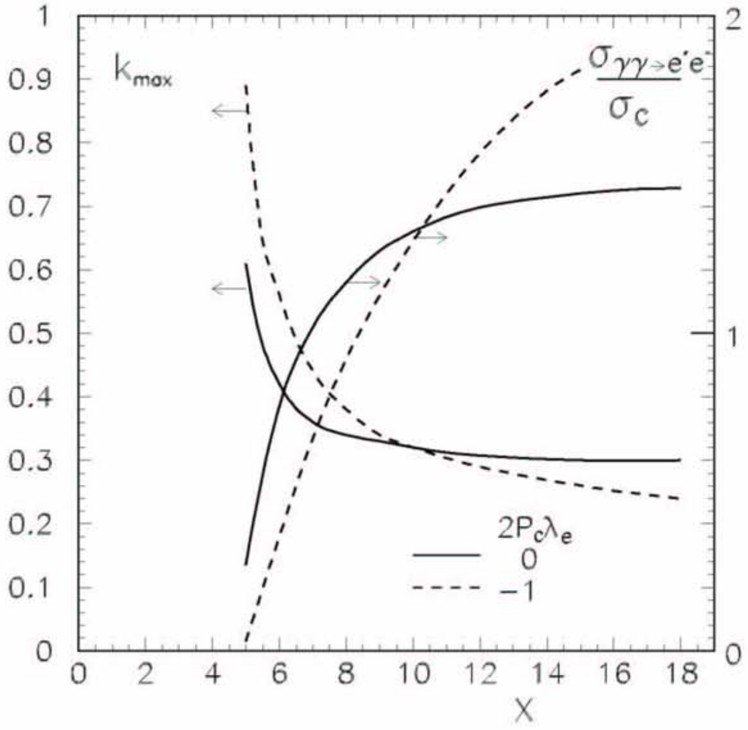


$\sigma \propto 1 \pm l_{\gamma 1} l_{\gamma 2} \cos 2\varphi$ ± for CP=±1

Linear polarization helps to separate H and A Higgs bosons

e^+e^- pair creation

in the collisions of laser and high energy photons



The threshold of e^+e^- creation: $x = 4.8$, the optimum value.

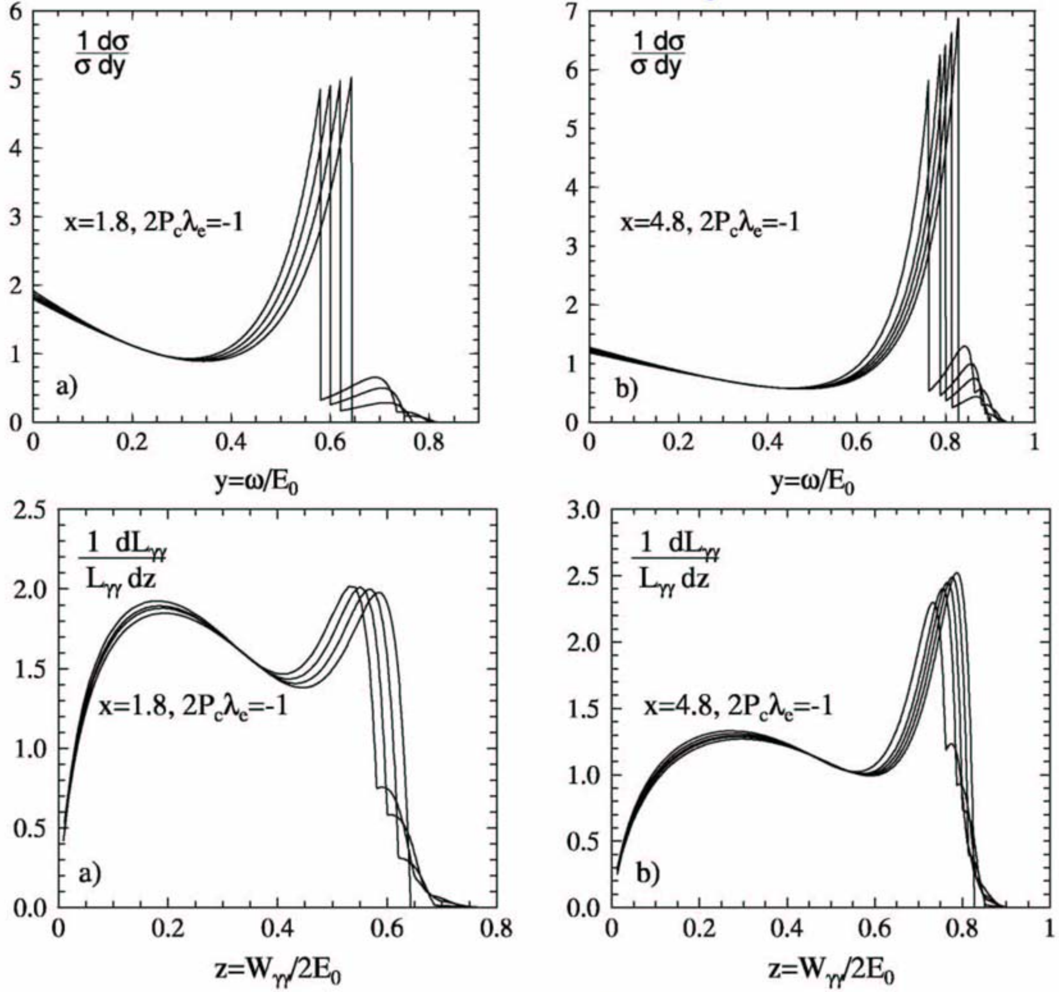
Corrsponding wavelength $\lambda = 4.2 E_0[\text{TeV}]\,\mu\text{m}$.

Due to nonlinear effects at $x = 4.8 \implies 4.8(1+\xi^2)$

At $2E_0 = 800$ GeV, $x = 7.17$ (at $\lambda = 1.06\ \mu$m), but for $\xi^2 \sim 0.4$ e^+e^- production is neglegible.

Nonlinear effects in Compton scattering

$$\xi^2 = \frac{e^2 \bar{F}^2 \hbar^2}{m^2 c^2 \omega_0^2} = \frac{2 n_\gamma r_e^2 \lambda}{\alpha}$$



Photon spectra

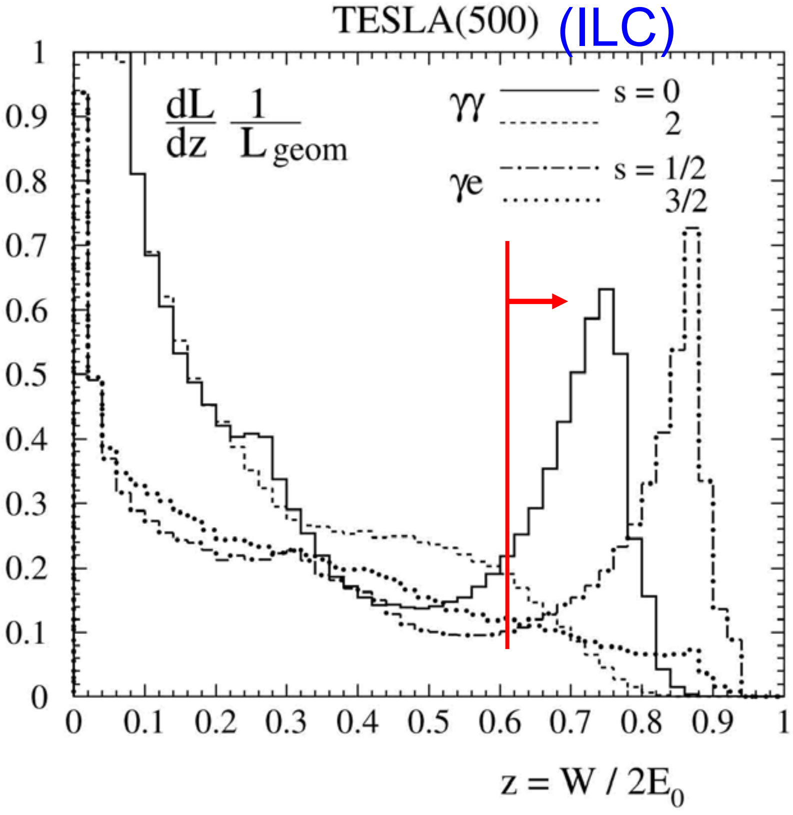
$\gamma\gamma$ luminosity spectra

(Curves from right to left: $\xi^2 = 0, 0.1, 0.2, 0.3, 0.5$)

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

$L_{\gamma\gamma}(z>0.8z_m) \sim (0.17\text{-}0.55)\ L_{e+e-}(\text{nom})$
$\sim (0.35\text{-}1)\cdot 10^{34}\ \text{cm}^{-2}\ \text{s}^{-1}$

(but cross sections in $\gamma\gamma$ are larger by one order!)

First number - nominal beam emittances
Second - optimistic emittances
(possible, needs optimization of DR for $\gamma\gamma$)

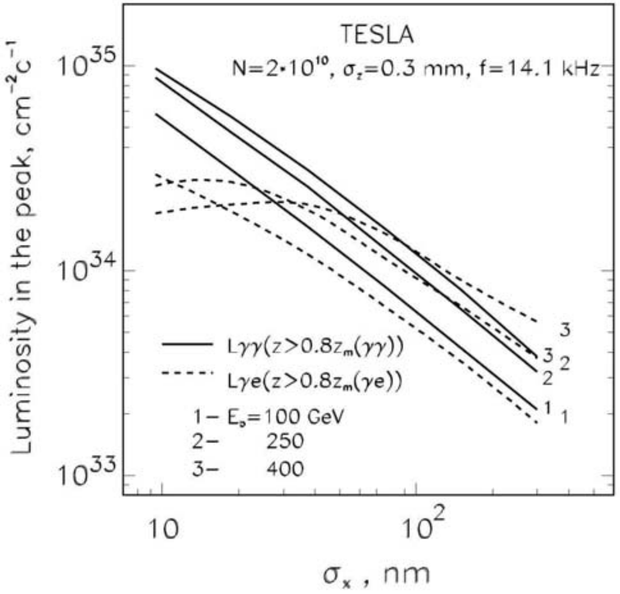
For γe it is better to convert only one electron beam, in this case it will be easier to identify γe reactions and the γe luminosity will be larger.

Factors limiting $\gamma\gamma$,γe luminosities

Collisions effects:

- Coherent pair creation
- Beamstrahlung
- Beam-beam repulsion

On the right: dependence of $\gamma\gamma$ and γe luminosities in the high energy peak on the horizontal beam size:



For the TESLA electron beams $\sigma_x \sim 100$ nm at $2E_0 = 500$. Having beams with smaller emittances one could have by one order higher $\gamma\gamma$ luminosity.

γe luminosity in the high energy peak is limited due to the beam repulsion and beamstrahlung

At e^+e^- the luminosity is limitted by collision effects (beamstrahlung, instability), while in $\gamma\gamma$ collsions only by available beam sizes or geometric e^-e^- luminosity (for at $2E_0$<1 TeV).

Some interaction region issues (shortly)

1. For removal of the disrupted beams the crossing angle at one of the interaction regions should be about 25 mrad (the exact number depends on the final quad design).

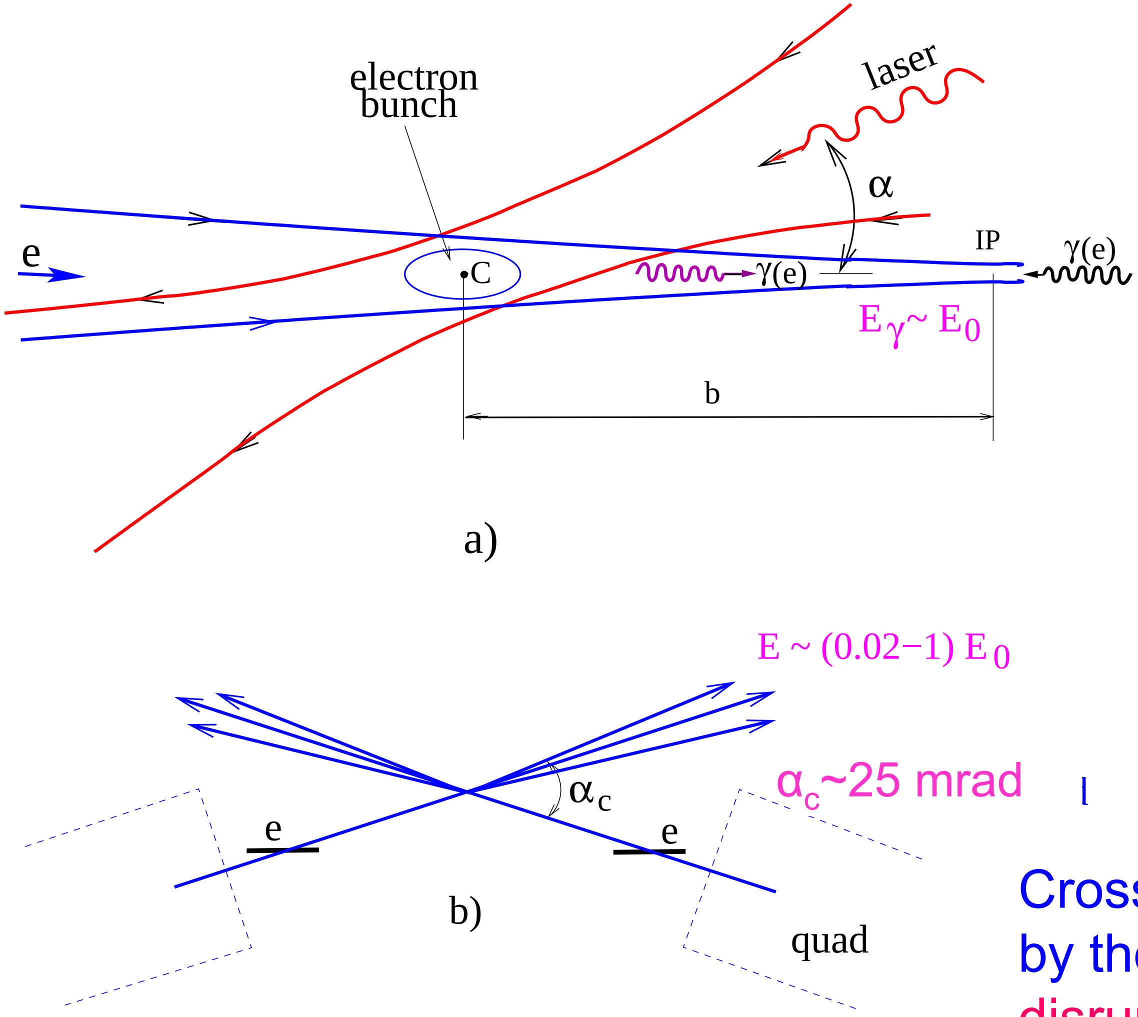
2. The $\gamma\gamma$ luminosity is almost proportional to the geometric e-e- luminosity, therefore the product of horizontal and vertical emittances should be as small as possible (requirements to damping rings and beam transport lines);

3. The final focus system should provide a spot size at the interaction point as small as possible (the horizontal β-functions can be smaller by one order of magnitude than that in the e+e- case);

4. Very wide disrupted beam should be transported to the beam dump with acceptable losses; the beam dump should withstand absorption of very narrow photon beam after Compton scattering;

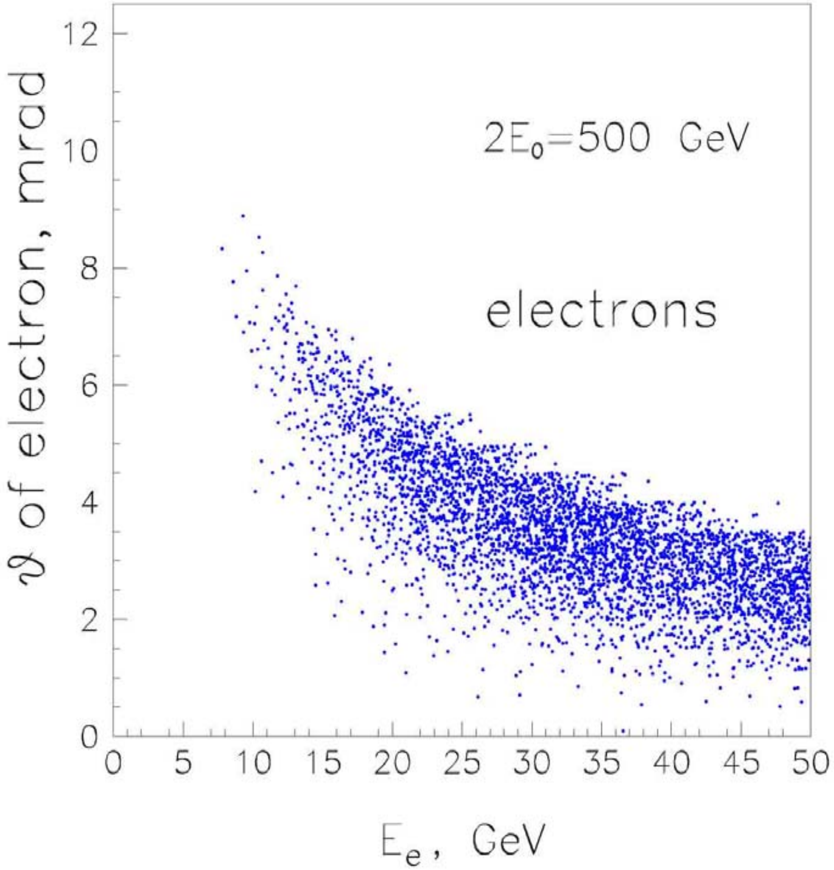
5. The detector design should allow replacement of elements in the forward region (<100 mrad);

Crab-crossing angle



Crossing angle is determined by the angular spread in the disrupted beam and the radius of the first quad

Properties of the beams after CP,IP



Electrons:

E_{min}~6 GeV,
$\theta_{x\ max}$~8 mrad
$\theta_{y\ max}$~10 mrad

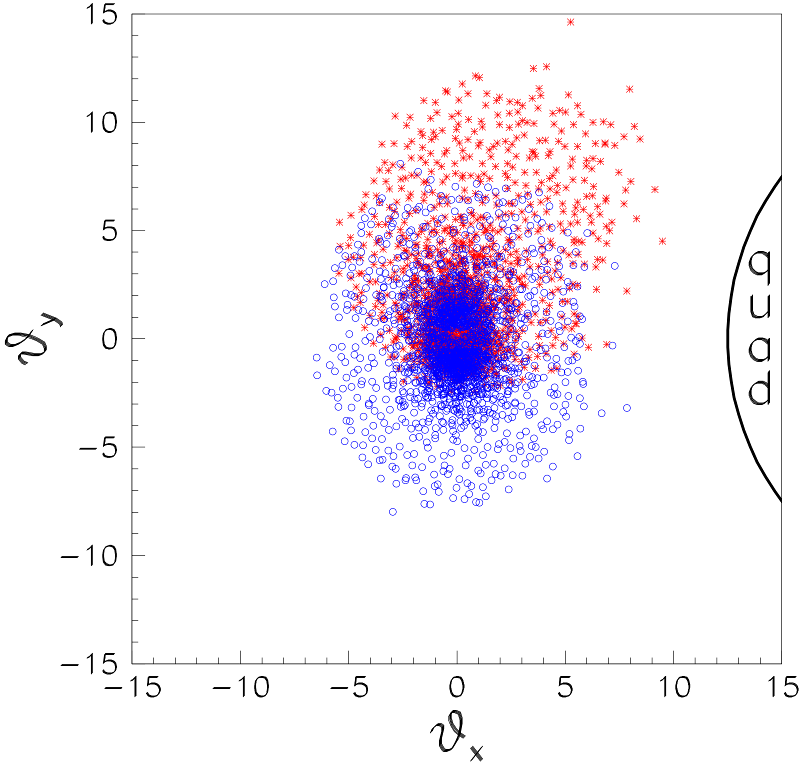
practically same for
E_0=100 and 250 GeV

For low energy particles the deflection in the field of opposing beam

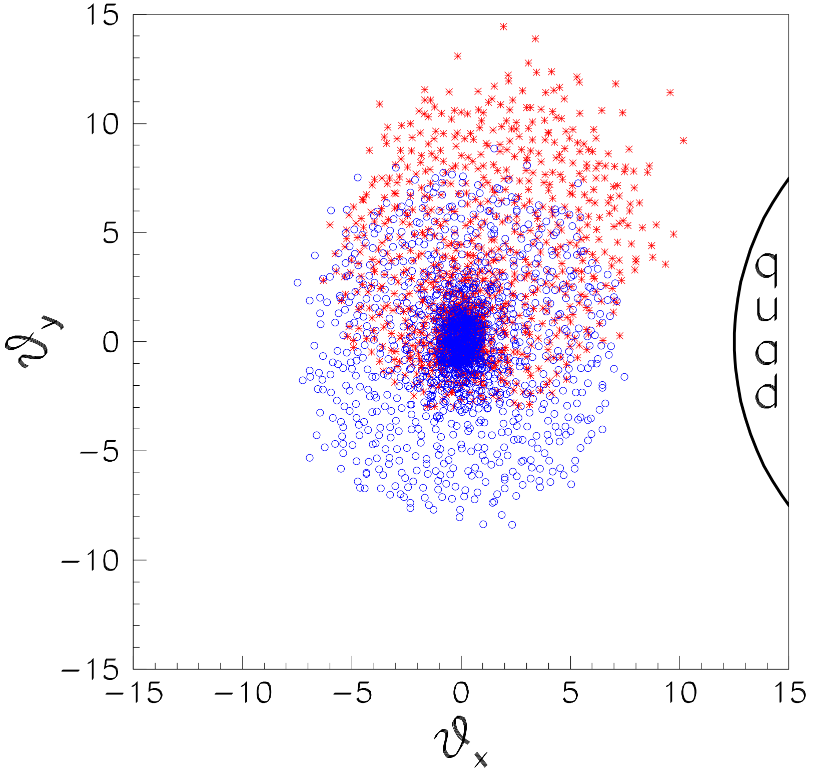
$$\vartheta \propto 1/\sqrt{E\sigma_z}$$

An additional vertical deflection, about ±4 mrad, adds the detector field

Disrupted beam with account of the detector field (at the front of the first quad, L~4 m)



$2E_0$=200 GeV



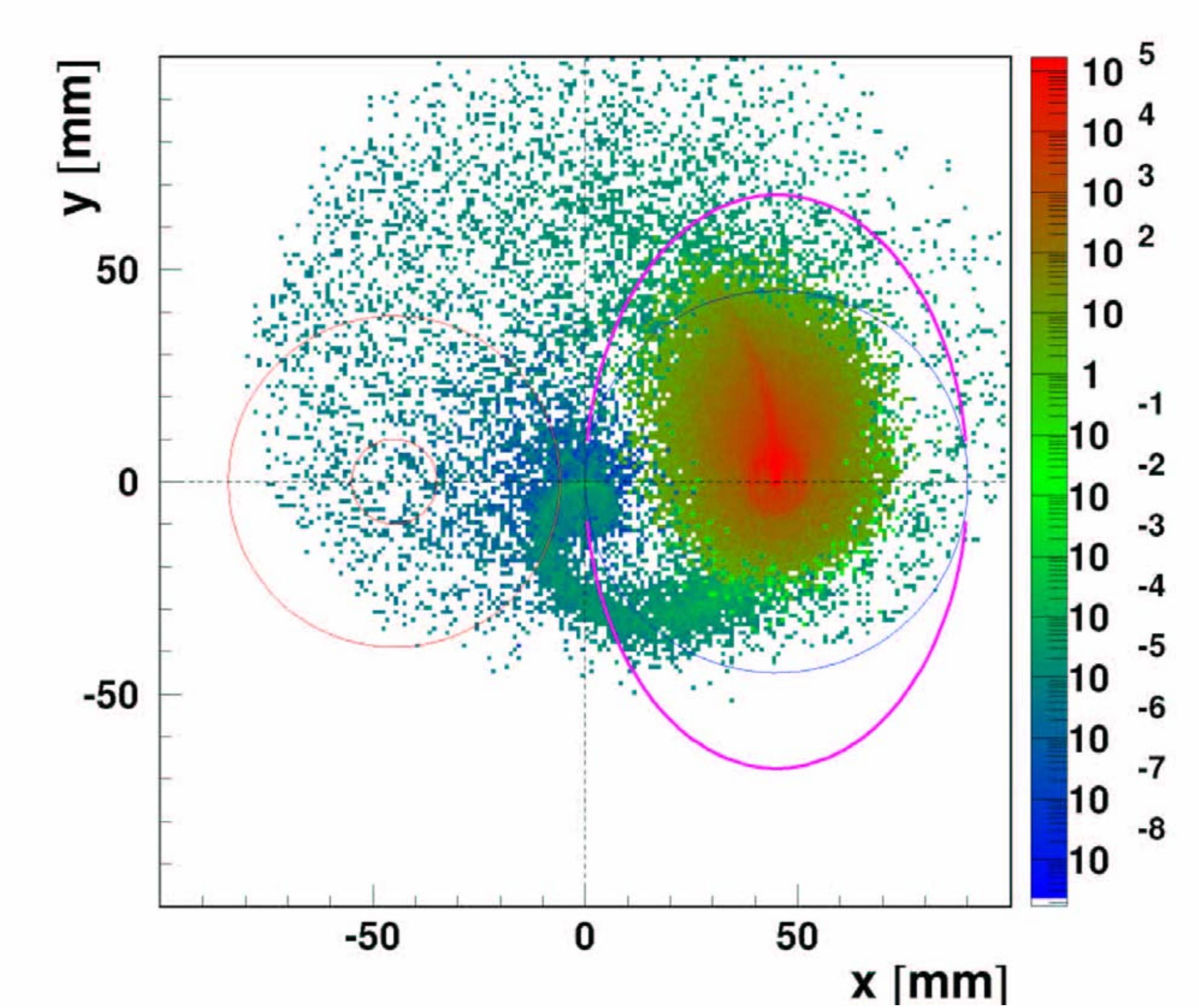
$2E_0$=500 GeV

With account of tails the save beam sizes are larger by about 20 %.

Same with account of secondary e+e- pairs

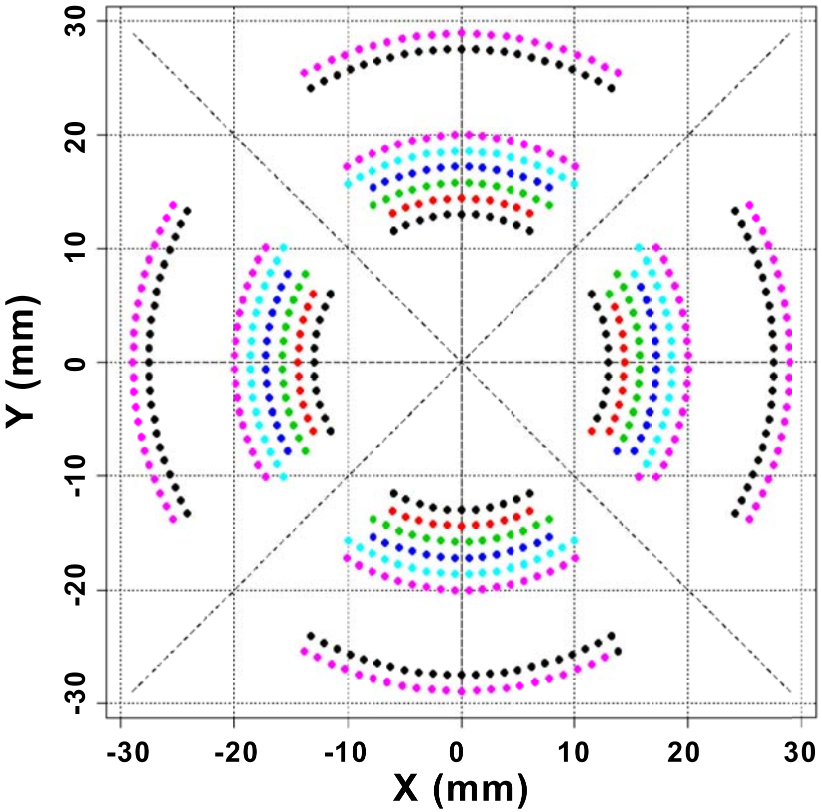
at L=4.5 m

A.F.Zarnecki, LCWS06



$P_{quad} < 1$ W

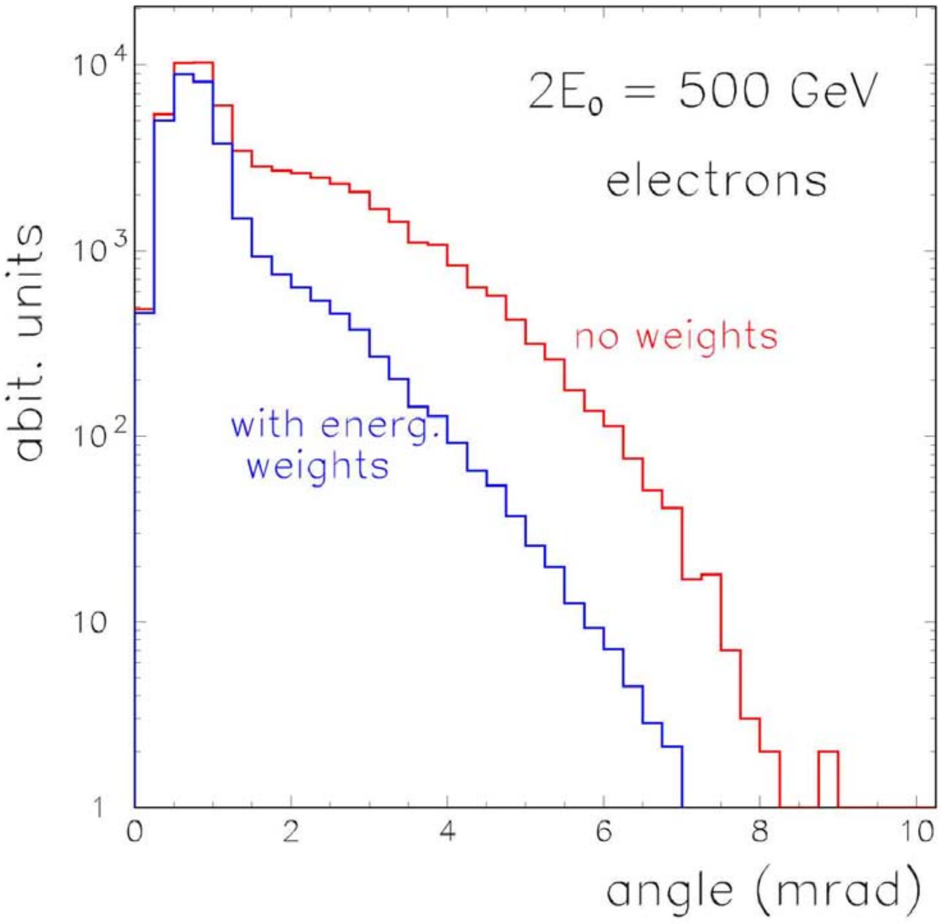
Principle design of the superconducting quad (B.Parker), only coils are shown (two quads with opposite direction of the field inside each other). The radius of the quad with the cryostat is about 5 cm.
The residual field outside the quad is negligibly small.



For compensation
G_{in} = 160 T/m
at I_o = 767 A
G_{out} = -20 T/m
at I_o = 517 A
for G_{eff} = 140 T/m
L_{mag} = 2.200 m
L_{coil} = 2.228 m

$$\alpha_c = (5/400)*1000(\text{quad}) + 12.5(\text{beam}) \sim 25 \text{ mrad}$$

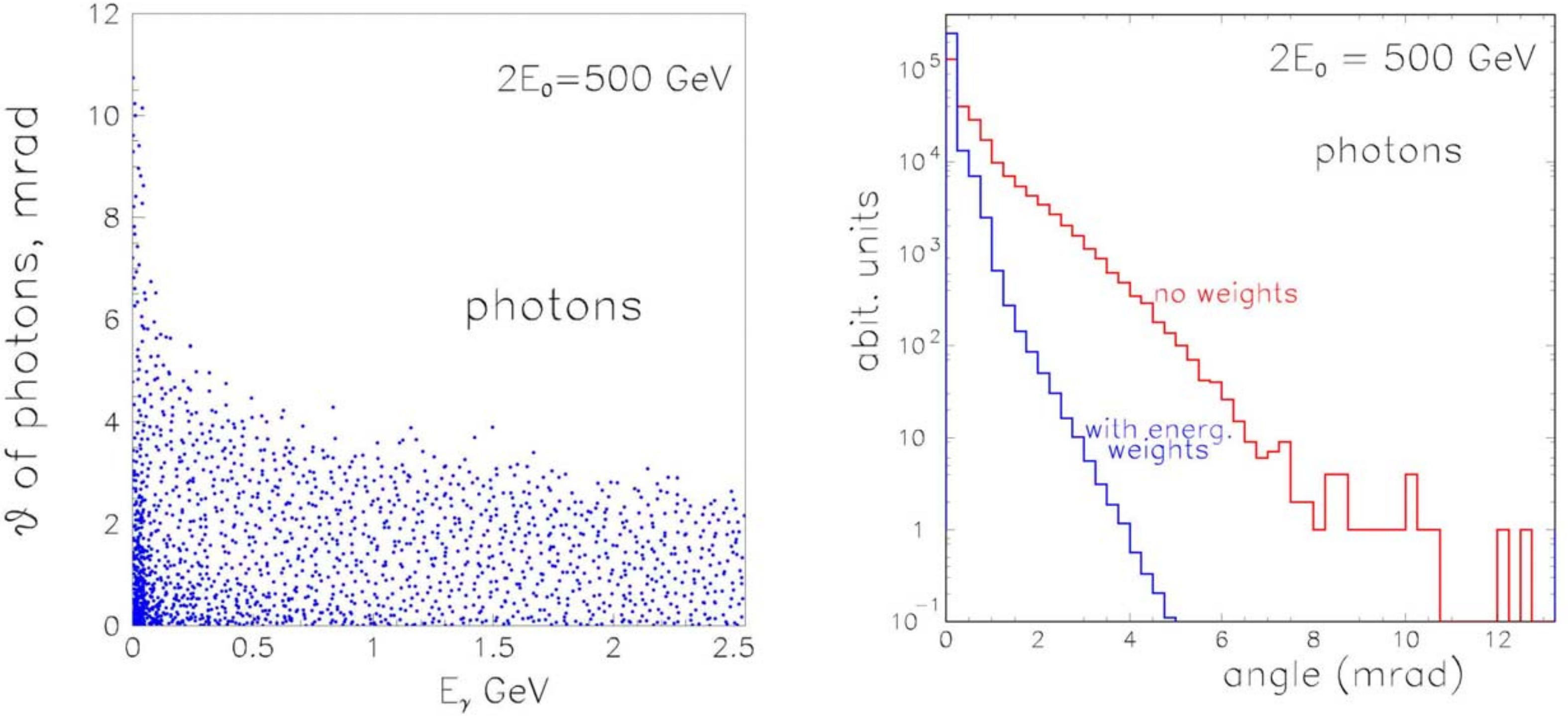
The angular distribution of electrons



If the beam dump is situated at L=250 m, than for particles with θ=7 mrad r~1.8 m, too much. Some focusing of electrons will be useful in order to decrease the radius of the tube and to reduce the energy deposition (rad. activation on the way to the beam dump).

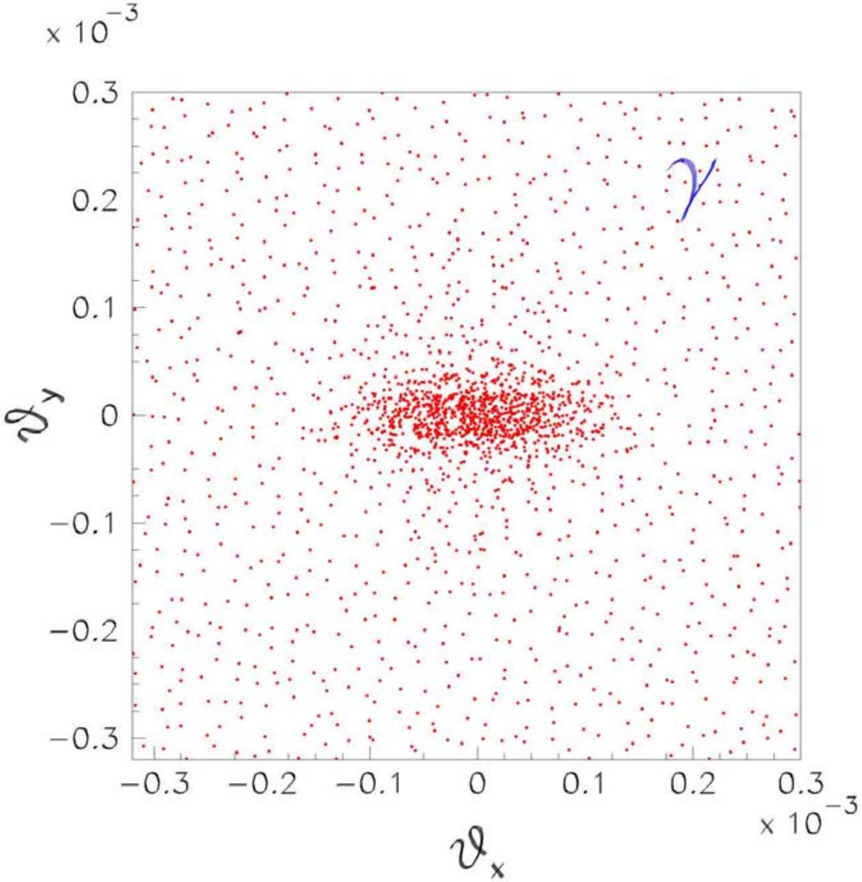
Angular distribution of photons

Large angle photons are radiated by low energy electrons, therefore they are soft



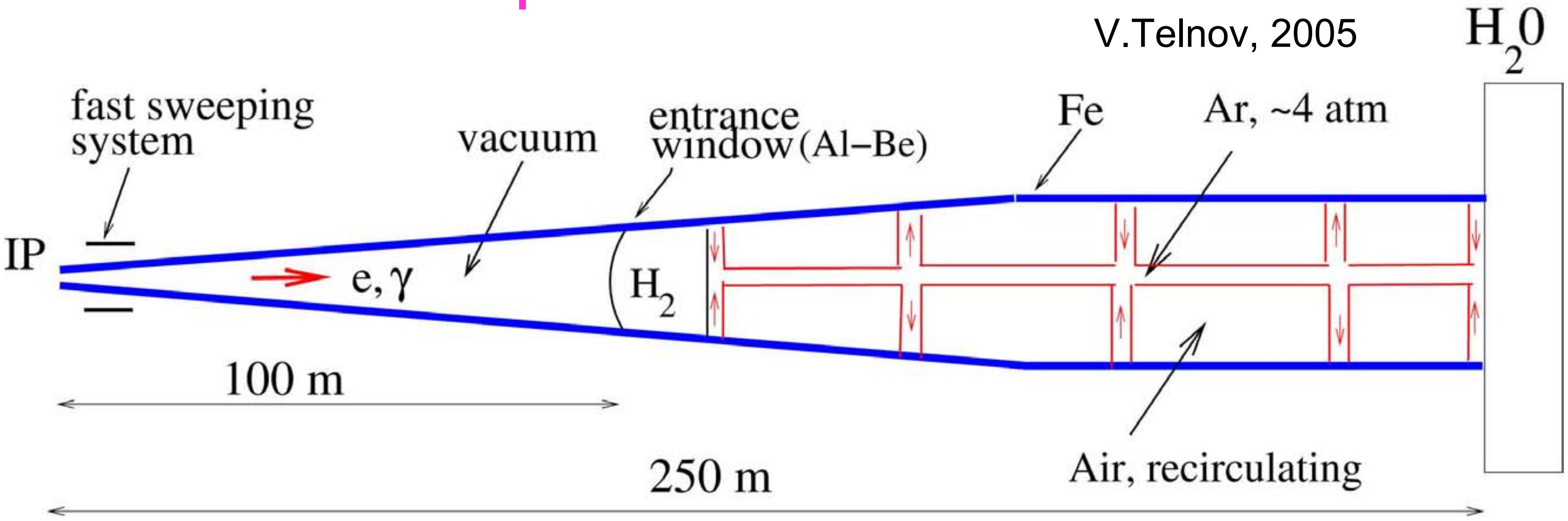
For photons the clear angle about 3 mrad will be sufficient, that is 75 cm at L=250 m.

On the contrary, the angular distribution of photons after Compton scattering is very narrow, equal to the angular divergence of electron beams at the IP: $\sigma_{\theta x} \sim 4 \cdot 10^{-5}$ rad, $\sigma_{\theta y} \sim 1.5 \cdot 10^{-5}$ rad, that is 1 x 0.35 cm^2 and beam power about 10 MW at the beam dump. No one material can withstand with such average power and energy of one ILC train.



Possible scheme of the beam dump for the photon collider

V.Telnov, 2005



The photon beam produces a shower in the long gas (Ar) target and its density at the beam dump becomes acceptable.

The electron beam without collisions is also very narrow, its density is reduced by the fast sweeping system. As the result, the thermal load is acceptable everywhere.

The volume with H_2 in front of the gas converter serves for reducing the flux of backward neutrons (simulation gives, at least, factor of 10).

In order to reduce angular spread of disrupted electrons some focusing after the exit from the detector is necessary.

Needs detailed technical consideration!

Requirements for laser

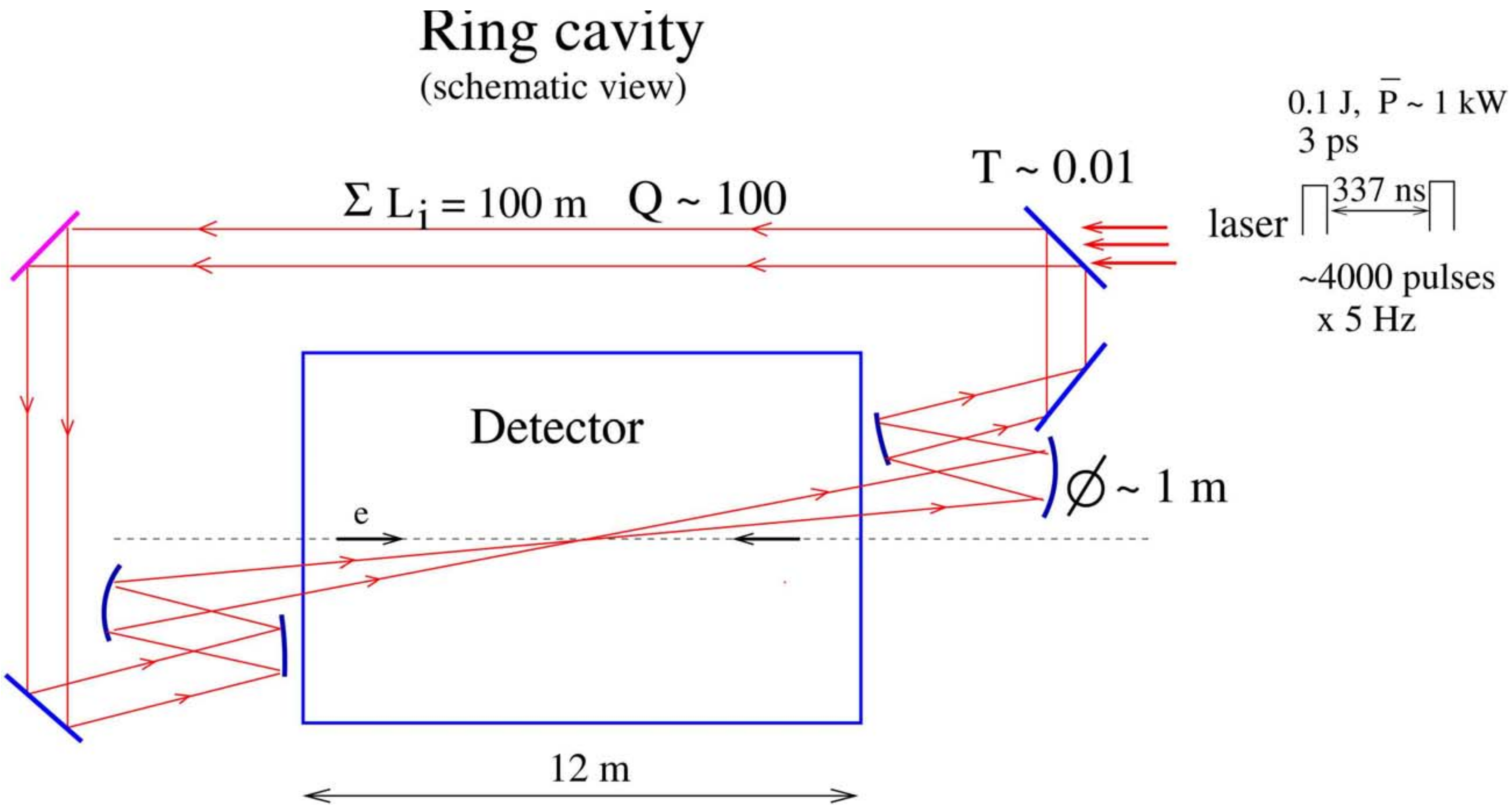
Wavelength	~1 μm (good for 2E<0.8 TeV)
Time structure	Δct~100 m, 3000 bunch/train, 5 Hz
Flash energy	~5-10 J
Pulse length	~1-2 ps

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 (V.T. 1999). 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 100-200, but even in this case the pumping laser should be very powerful.

According to LLNL estimates the cost of the laser is about 10M$ each, photon collider needs 2+(1-2 spare) lasers.

Laser system

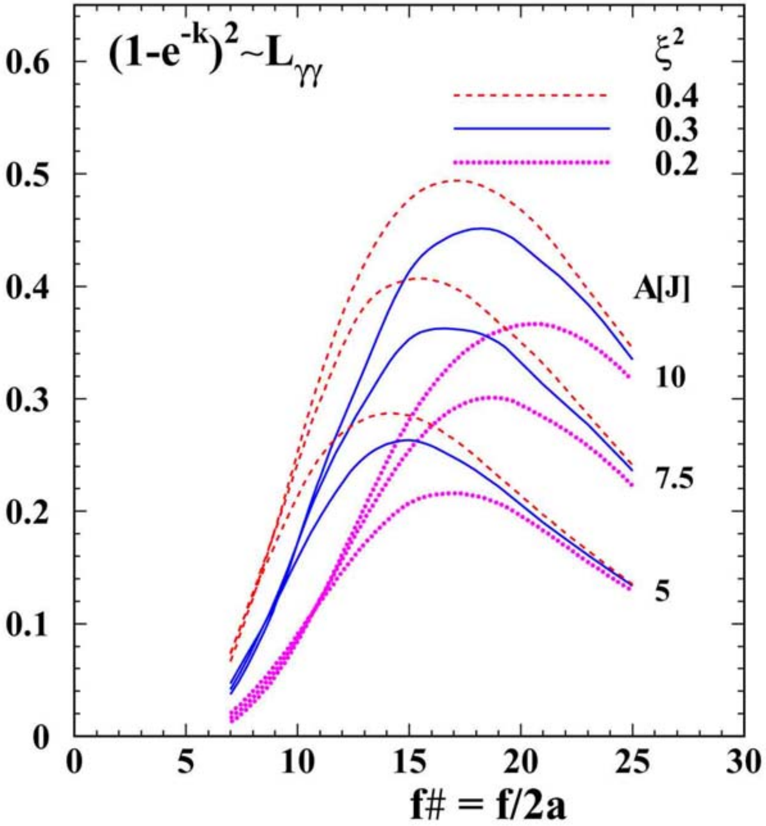


The cavity includes adaptive mirrors and diagnostics. Optimum angular divergence of the laser beam is ±30 mrad, A≈9 J (k=1), $\sigma_t \approx$ 1.3 ps, $\sigma_{x,L} \sim 7$ μm

Parameters of the laser system

The figure shows how the conversion efficiency depends on the f# of the laser focusing system for flat top beams in radial and Gaussian in the longitudinal directions

T.V.



f- focal distance
a – mirror radius

The parameter $\xi^2 = \frac{e^2F^2}{m^2c^2\omega^2} = \frac{2n_\gamma r_e^2\lambda}{\alpha}$

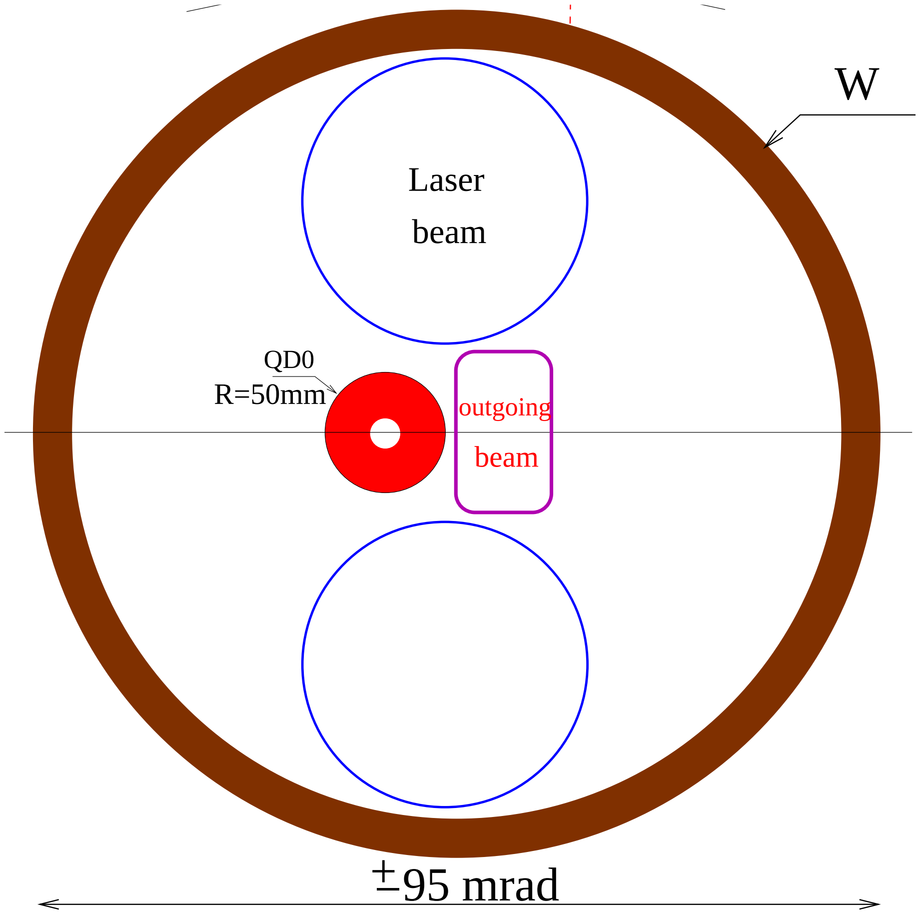
characterizes the probability of Compton scattering on several laser photons simultaneously, it should be kept below 0.2-0.4, depending on the par. x)

For ILC beams, α_c=25 mrad, and θ_{min}=17 mrad (see fig. with the quad) the optimum $f_\#$ =f/2a ≈ 17, A≈9 J (k=1), σ_t ≈ 1.3 ps, $\sigma_{x,L}$~7 µm.

So, the angle of the laser beam is ±1/2$f_\#$ = ±30 mrad,

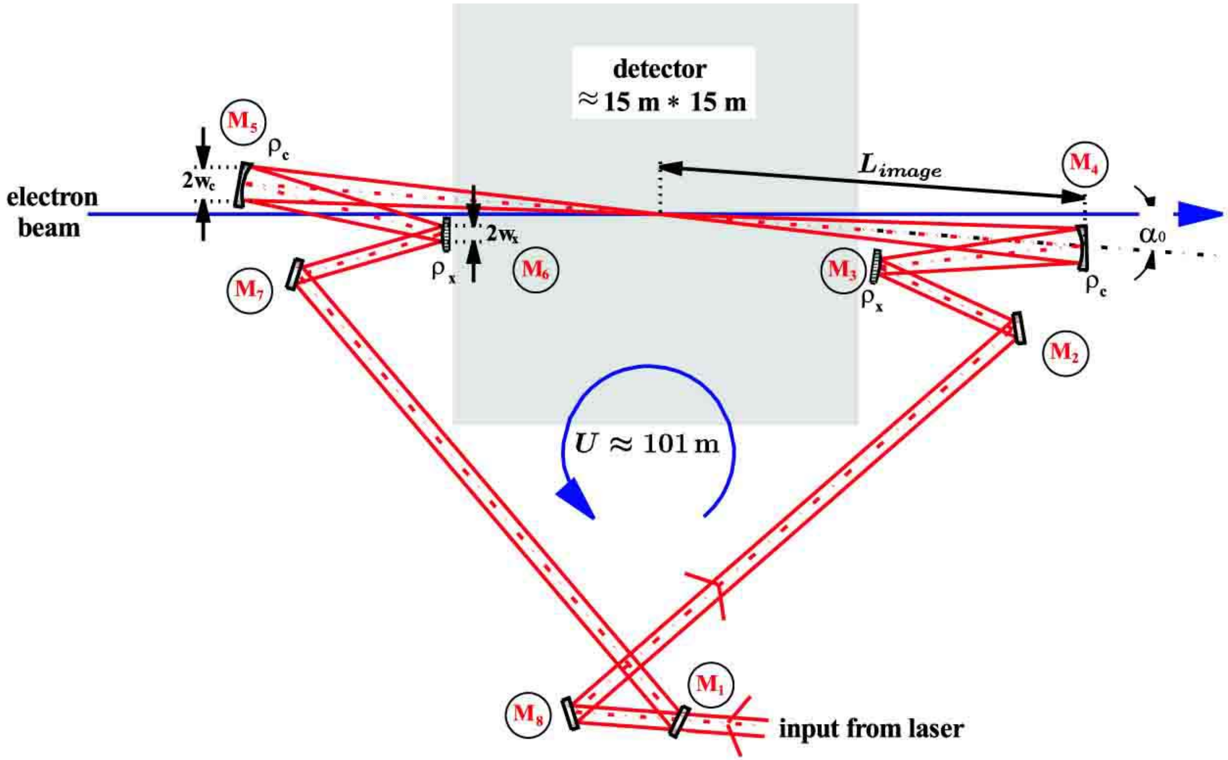
The diameter of the focusing mirror at L=15 m from the IP is about 90 cm.

Layout of the quad, electron and laser beams at the distance 4 m from the interaction point (IP)



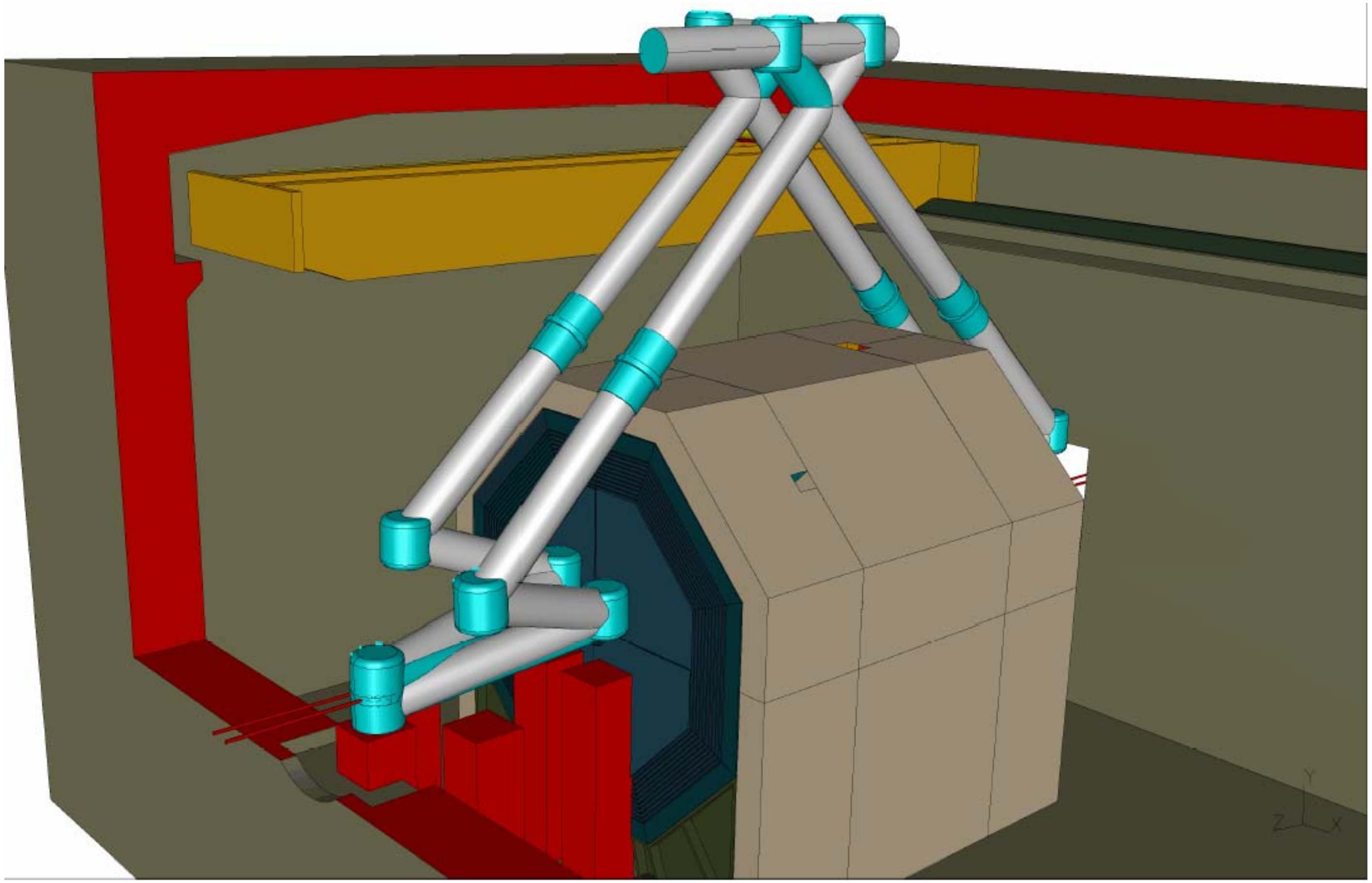
Simulation of the ring optical cavity in DESY-Zeuthen

Optimization was done at the wave level. The cavity was pumped by a truncated Gaussian beam with account of diffraction losses (which are negligibly small). Obtained numbers are close to that for flat-top beams (shown above).



View of the detector with the laser system

(the pumping laser is in the building at the surface)



For easier manipulation with bridge crane and smaller vibrations it may be better to hide the laser tubes under the detector

Laser experts (meeting in Daresbury, January 2006) critically considered requirements to the optical cavity for the photon collider and have not revealed any stoppers.

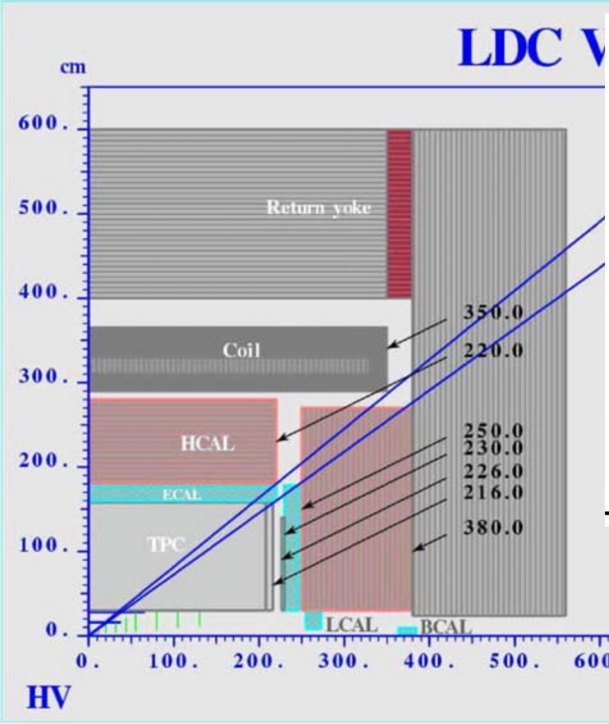
At present there is very big activity on development of the laser pulse stacking cavities at Orsay, KEK, CERN, BNL, LLNL for

ILC polarimetry
Laser wire
Laser source of polarized positrons(ILC,CLIC,Super-B)
X-ray sources

All these developments are very helpful for the photon collider.

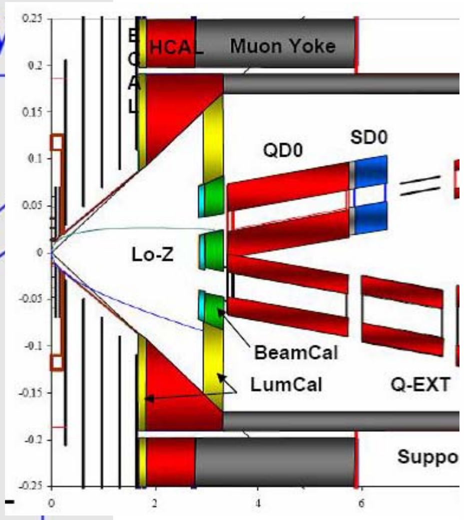
Clear angle in detectors

LDC



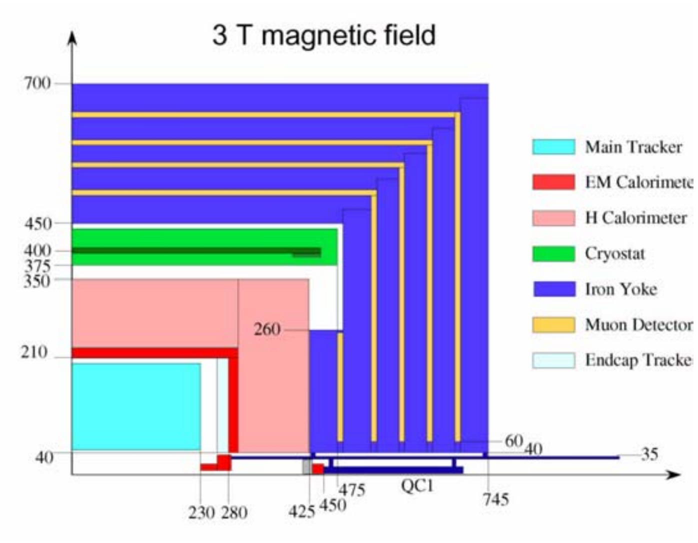
θ=±45 mrad

SID



±33 mrad

GLD

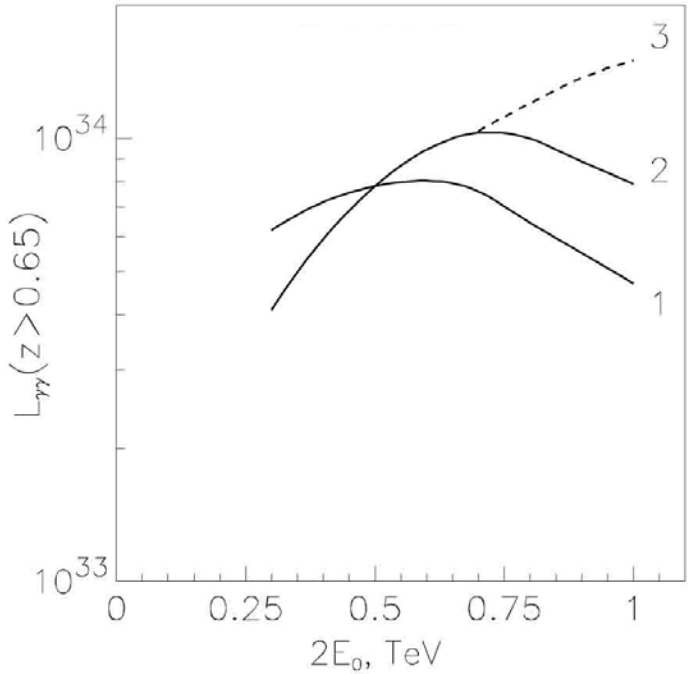


±50 mrad

For the PLC laser system the clear angle θ=±90-95 mrad is needed. It should be foreseen in the detector design.

Dependence of the γγ luminosity on the energy due to laser parameters

V.Telnov, LCWS04, physics/0411252



1- k=0.64 at 2E=500, A = const, ξ^2 = const, λ = 1.05 μm

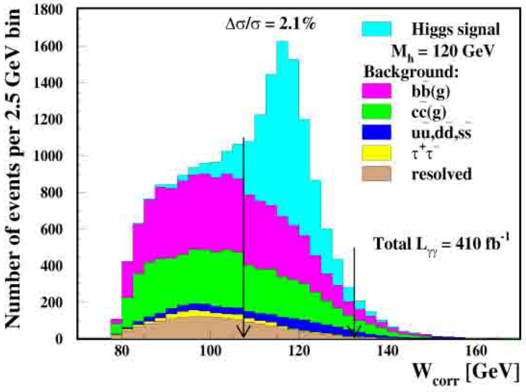
2- k=0.64 at all energies, $\xi^2 \propto$ A, λ =1.05 μm

3- k=0.64 at all energies, $\xi^2 \propto$ A, λ =1.47 μm (to avoid pair creation)

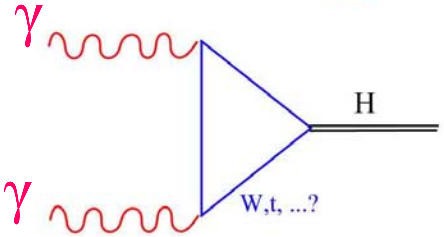
If the laser wave length is fixed, the Compton cross section decreases with increasing the energy, consequently the conversion coefficient decreases. Moreover for $x > 4.8$, the e^+e^- pair creation in the conversion region is possible which leads to large decrease of the conversion coefficient at large x. Laser with $\lambda \sim 1.05$ μm (most developed powerful lasers) can be used up to the energy of about $2E_0 = 750 - 800$ GeV. For $2E_0 = 1$ TeV it is desirable to use lasers with $\lambda \sim 1.5$ μm.

Examples of physics at PLC

realistic simulation P.Niezurawski et al

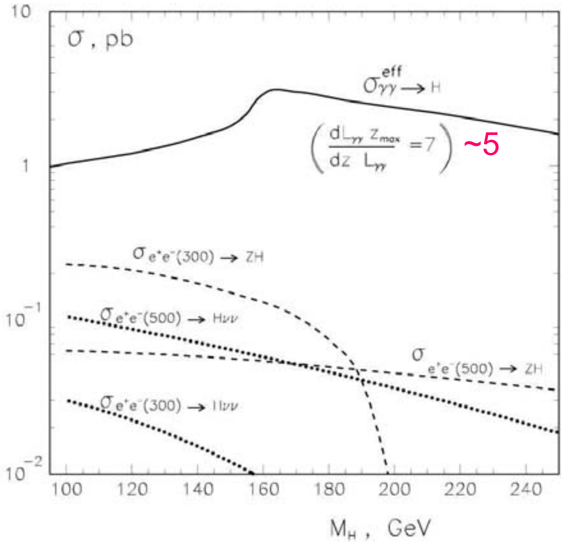


Higgs boson



Very sensitive to heavy charge particles in the loop.

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



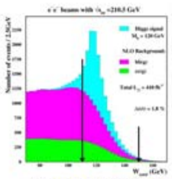
$$\dot N_{\gamma\gamma\to H} = L_{\gamma\gamma}\times\frac{dL_{\gamma\gamma}M_H}{dW_{\gamma\gamma}L_{\gamma\gamma}}\frac{4\pi^2\Gamma_{\gamma\gamma}(1+\lambda_1\lambda_2)}{M_H^3}$$

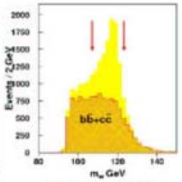
At ILC

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

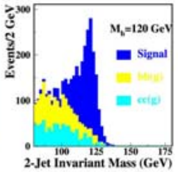
For M_H=115-250 GeV

(previous analyses)

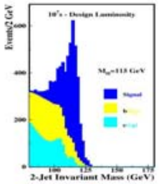

Niezurawski(TESLA)



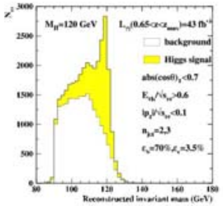
Rosca(TESLA)



Asner(NLC)



Asner(Cliche)

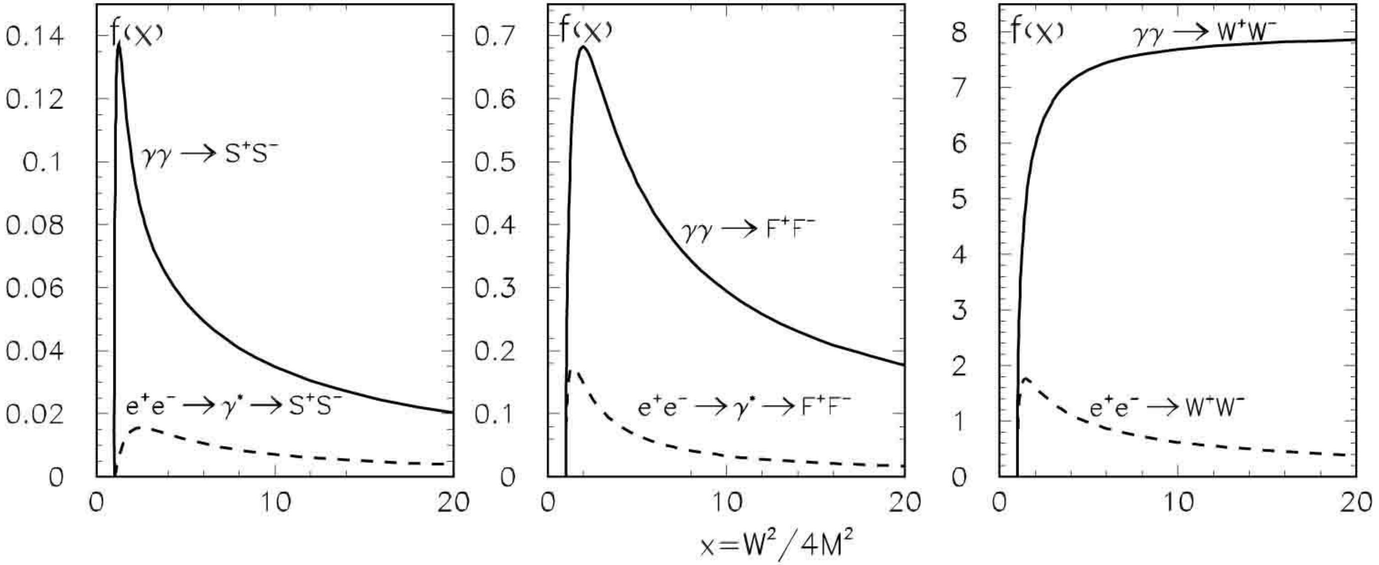


S.Soldner-Rembold

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

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

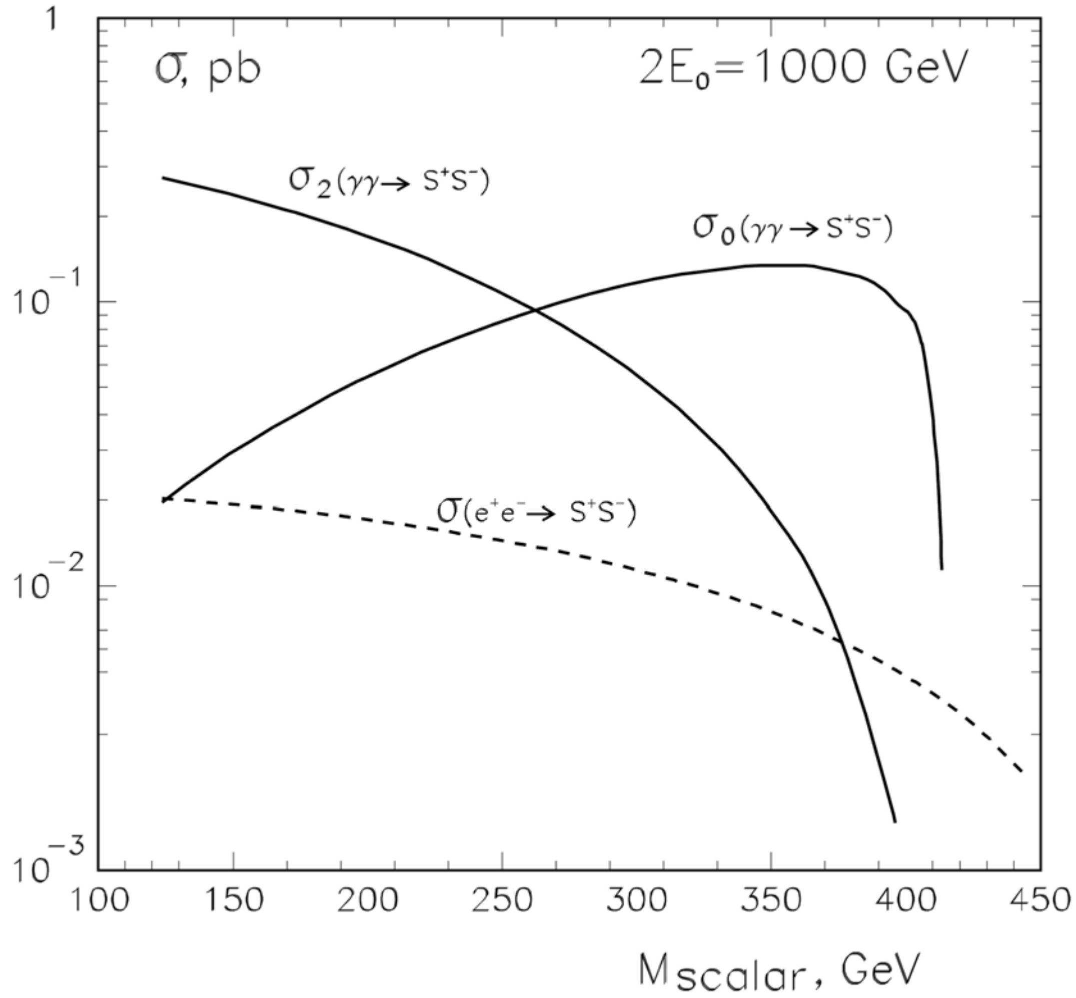
$\sigma = (\pi\alpha^2/M^2)f(x)$, beams unpolarized)



unpolarized
beams

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

With polarized photon beams the difference is even larger.
The cross section for scalars has sharp threshold behavior.



Supersymmetry in $\gamma\gamma$

In supersymmetric model there are 5 Higgs bosons:

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

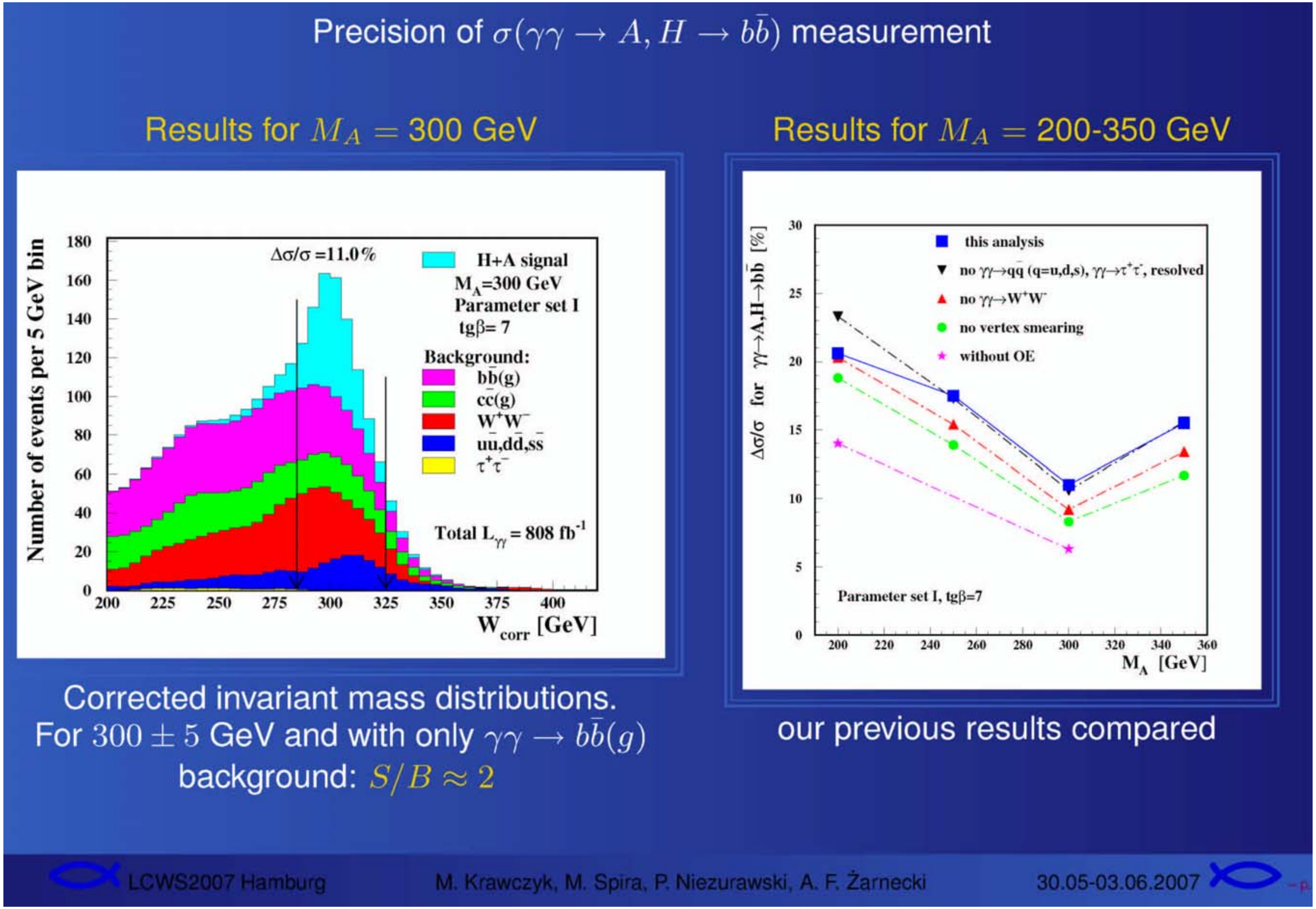
H^0, A^0 heavy Higgs bosons;

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 $M_{H,A}^{max} \sim 1.6E_0$ ($\gamma\gamma$ $\rightarrow H(A)$)

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



Precision of $\sigma(\gamma\gamma \to A, H \to b\bar{b})$ measurement

Results for $M_A = 300$ GeV

Results for $M_A = 200$-350 GeV

Corrected invariant mass distributions.
For 300 ± 5 GeV and with only $\gamma\gamma \to b\bar{b}(g)$
background: $S/B \approx 2$

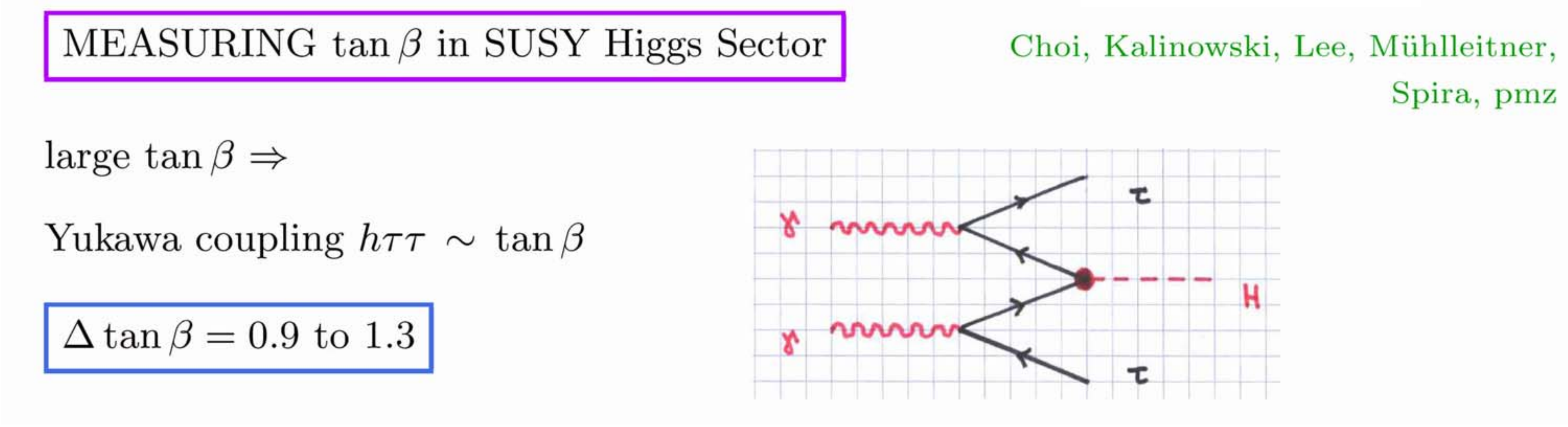
our previous results compared

LCWS2007 Hamburg M. Krawczyk, M. Spira, P. Niezurawski, A. F. Żarnecki 30.05-03.06.2007

In addition, linear polarized photons at the PLC allow to distinguish A and H (though not easy, ZNK at LCWS07).

Measuring tan β in SUSY

P.Zerwas, PLC05



MEASURING tan β in SUSY Higgs Sector

Choi, Kalinowski, Lee, Mühlleitner, Spira, pmz

large tan $\beta \Rightarrow$

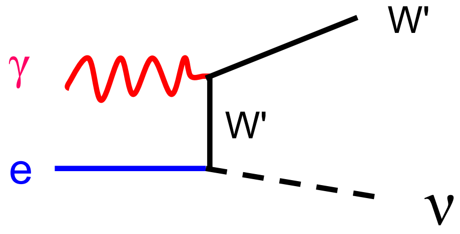
Yukawa coupling $h\tau\tau \sim \tan\beta$

$\Delta \tan\beta = 0.9$ to 1.3

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):

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



Sneutrino production

P.Zerwas, PLC05

- sneutrino production : $e^+e^- \to \tilde{\nu}\tilde{\nu}$ invisible for light ν [*cf.* $\mathcal{SPS}$1a′]

exploit $\tilde{\chi}^\pm$ decays in pairs : $\tilde{\chi}_1^\pm \to \ell^\pm\tilde{\nu}_\ell$ / difficult bkgds

alternative channel : $e\gamma \to \tilde{\nu}_e\tilde{\chi}_1^\pm$

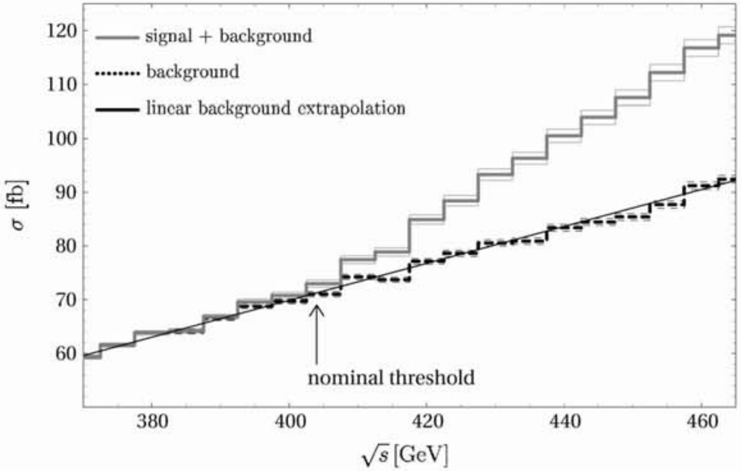
$\to \tilde{\nu}_e\tilde{\nu}_\mu\,\mu$

$\sigma \sim \beta$: sharp onset ⇒

F: Freitas, Porod, pmz

threshold scan : $\sqrt{s}_{\gamma e} \geq m_{\tilde{\nu}} + m_{\tilde{\chi}}$

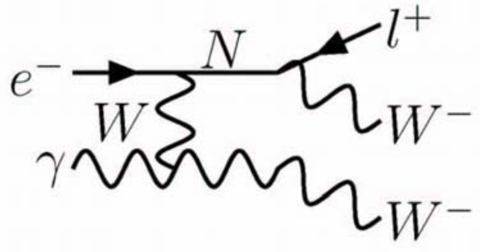
$$\boxed{m_{\tilde{\nu}_e} = 169.8 \pm 3.2 \text{ GeV}}$$



MAJORANA NEUTRINOS

P.Zerwas, PLC05

PROCESS: $e^- \gamma \to e^+ W^- W^-$



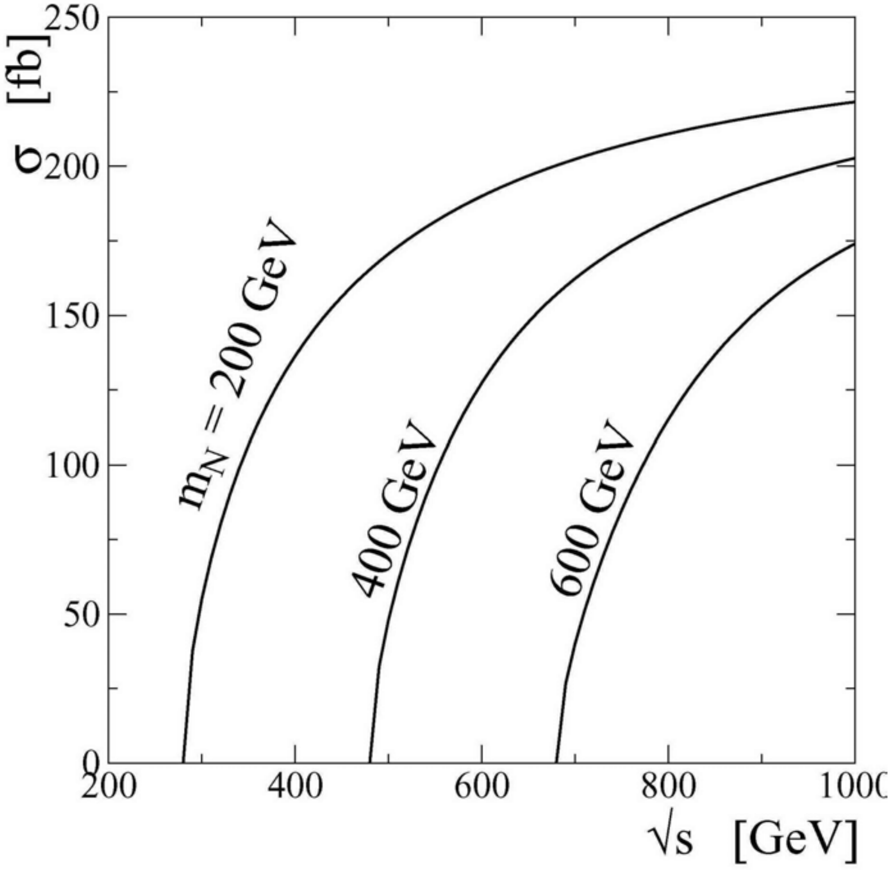
(a)

specific *Majorana N* signal /

sizable cross section for $X_{eN} = 0.07$ ⇒

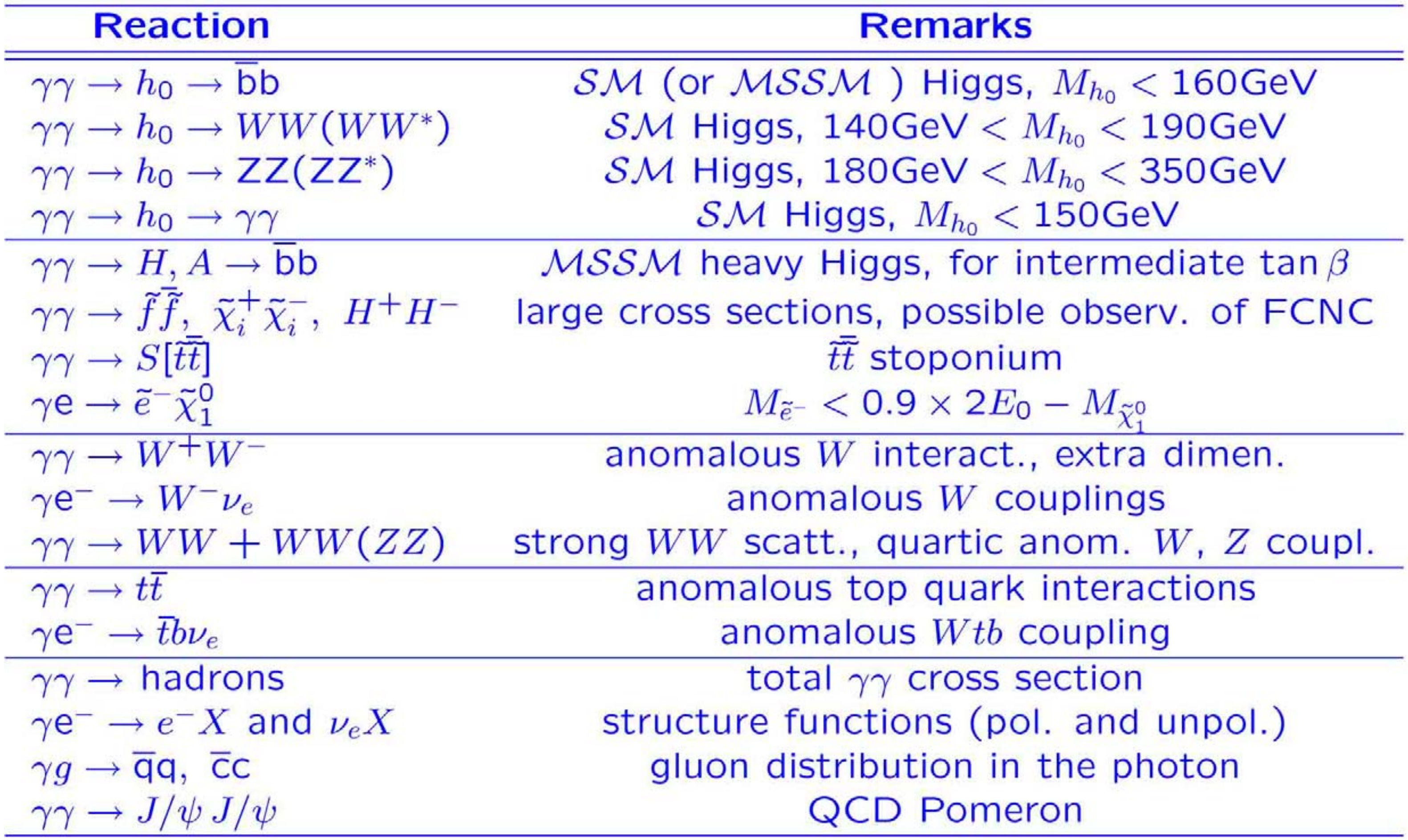
little SM bkgd: CC $e^- \gamma \to \nu_e W^- W^- W^+$

[Bray, Lee, Pilaftsis]



Gold-plated processes at photon colliders

(PLC in TESLA TDR, 2001)



Reaction	Remarks
$\gamma\gamma \to h_0 \to \mathrm{b\bar{b}}$	$\mathcal{SM}$ (or $\mathcal{MSSM}$) Higgs, $M_{h_0} < 160\mathrm{GeV}$
$\gamma\gamma \to h_0 \to WW(WW^*)$	$\mathcal{SM}$ Higgs, $140\mathrm{GeV} < M_{h_0} < 190\mathrm{GeV}$
$\gamma\gamma \to h_0 \to \mathrm{ZZ}(\mathrm{ZZ}^*)$	$\mathcal{SM}$ Higgs, $180\mathrm{GeV} < M_{h_0} < 350\mathrm{GeV}$
$\gamma\gamma \to h_0 \to \gamma\gamma$	$\mathcal{SM}$ Higgs, $M_{h_0} < 150\mathrm{GeV}$
$\gamma\gamma \to H, A \to \mathrm{b\bar{b}}$	$\mathcal{MSSM}$ heavy Higgs, for intermediate $\tan\beta$
$\gamma\gamma \to \tilde{f}\bar{\tilde{f}},\ \tilde{\chi}_i^+\tilde{\chi}_i^-,\ H^+H^-$	large cross sections, possible observ. of FCNC
$\gamma\gamma \to S[\tilde{t}\bar{\tilde{t}}]$	$\tilde{t}\bar{\tilde{t}}$ stoponium
$\gamma\mathrm{e} \to \tilde{e}^-\tilde{\chi}_1^0$	$M_{\tilde{e}^-} < 0.9 \times 2E_0 - M_{\tilde{\chi}_1^0}$
$\gamma\gamma \to W^+W^-$	anomalous W interact., extra dimen.
$\gamma\mathrm{e}^- \to W^-\nu_e$	anomalous W couplings
$\gamma\gamma \to WW + WW(ZZ)$	strong WW scatt., quartic anom. W, Z coupl.
$\gamma\gamma \to t\bar{t}$	anomalous top quark interactions
$\gamma\mathrm{e}^- \to \bar{t}b\nu_e$	anomalous Wtb coupling
$\gamma\gamma \to$ hadrons	total $\gamma\gamma$ cross section
$\gamma\mathrm{e}^- \to e^-X$ and $\nu_e X$	structure functions (pol. and unpol.)
$\gamma g \to \mathrm{\bar{q}q},\ \mathrm{\bar{c}c}$	gluon distribution in the photon
$\gamma\gamma \to J/\psi\, J/\psi$	QCD Pomeron

+ practically many others

Physics motivation: summary

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
4. higher precision for some phenomena
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

Status of the ILC

International linear collider ILC is not approved yet, main problem is a high cost, ~6.5B$ in minimum configuration (only e+e- 2E=500 GeV, one IP).

Plans:

2007-RDR -reference design report

2007-2010-EDR engineering DR

2010-2012 site, first results from LHC

2012-2019 construction (optimistic plan)

2019-2025? e+e- experiments

2025 – options (incl. $\gamma\gamma,\gamma e$)

Status of the photon collider at ILC

The PLC is “the option” at ILC (all except e+e-(500) are options)
However, it is important to make design decisions on the baseline project not prohibitive or unnecessarily difficult for the photon collider, which allow to reach its ultimate performance and rather easy transition between e^+e^- and $\gamma\gamma$, γe modes.

The PLC needs (now):

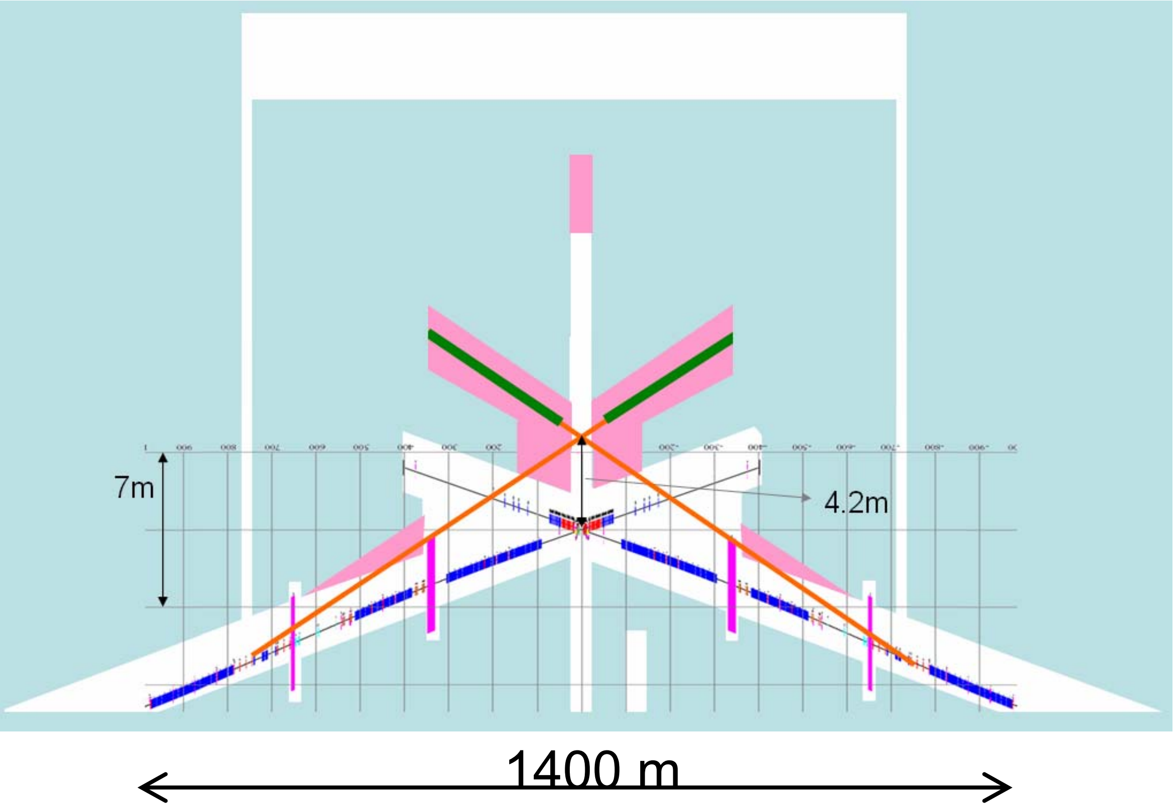
- the IP with the crossing angle ~ 25 mrad (the upgrades should not require new excavation);
- place for the beam dump and the laser system;
- R&D on the laser system;
- detector, which can be easily modified for $\gamma\gamma$ mode;
- DR with as small as possible beam emittances.

PLC needs crossing angle ~25 mrad, e+e- can work with >14 mrad

In 2006, GDE considered two IP with crossing angle 14 mrad with further upgrade of one IP to ~25 mrad

14mr => 25mr

A.Seryi, LCWS06



- additional angle is 5.5mrad and shift of detector by about 4.2m

Unfortunately, in the RDR (2007) only one IP with 14 mrad crossing angle is assumed with two detectors working in pull-push mode.

$\gamma\gamma$ can not work in parallel with e+e- in pull-push mode (because needs larger angle and different beam dump).

Moreover, in the RDR the photon collider is not considered at all!

There is only one comment to this decision

(B.Barish's (head of GDE) response to my letter to the LCWS07 program committee) :

"Valery ….

You certainly have every right to disagree with the ILC baseline, but it has resulted from an unprecedented worldwide process. A photon collider is one of the alternatives or options to that baseline and **yes, in the present version it will require excavation** to carry out that option. **Why is that so bad?** …Let me assure you for the n-th time that we will be considering both technical and scientific alternatives as we move forward."

Barry

Note, physics community (ILC scope document) clearly required the ILC with two IP (one compatible with gamma-gamma) and several options: PLC,e^-e^-,e^+polarization,GigaZ, fix target, 2E=1000 GeV.

What is now:

1) 2E=500 GeV (1 TeV needs excavation);
2) One IP with two pull-push detectors;
3) No PLC, no e-e-, no fix target experiments, e.t.c.

(Very likely that at the end only one detector will be left)

Clearly, these decisions decrease only the initial ILC cost but considerably increase the total cost and complicate the life. Nobody can imaging excavation around the IP in several meters from beamlines and detectors.

Such strange decisions can be understood only as a tactical step in order to get approval (in DOE?) of the ILC at the cost of many cuts (all options).

In my mind, the ILC is very expensive machine, therefore it should have ultimate performance and get maximum results for a reasonable total cost. Solution of such problem as the origin of masses and nature of the dark matter in the Universe will be a great success of all mankind and will give excitement for several generation of people, 10 ± $O(10)$ B$ would be a negligible price for the that.

There is no doubt that, if e+e- linear collider is built, the photon collider should be build as well. I hope that this will happen sometime and

$$e^+e^-, e^-e^-, \gamma\gamma, \gamma e$$

collider will help to understand better our world!