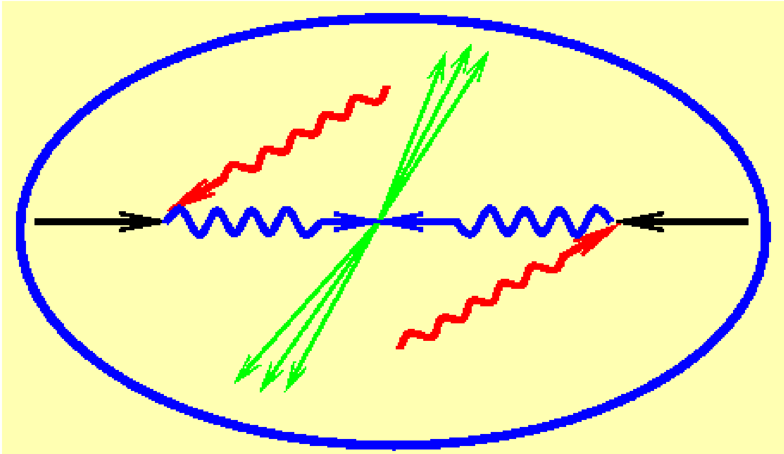


The Photon Collider at ILC: technical problems

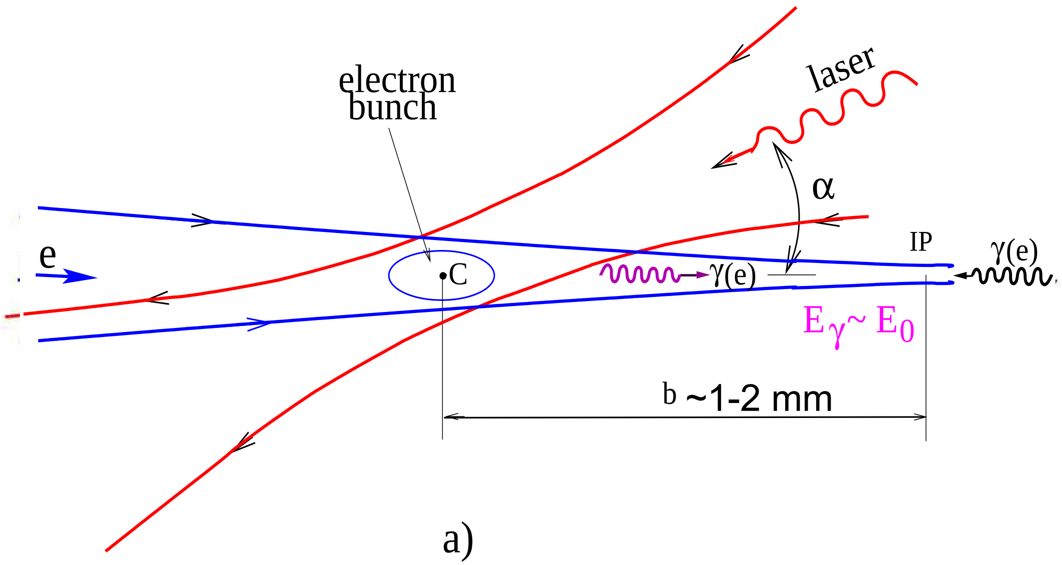
Valery Telnov

ECFA-ILC, November 10, 2006, Valencia

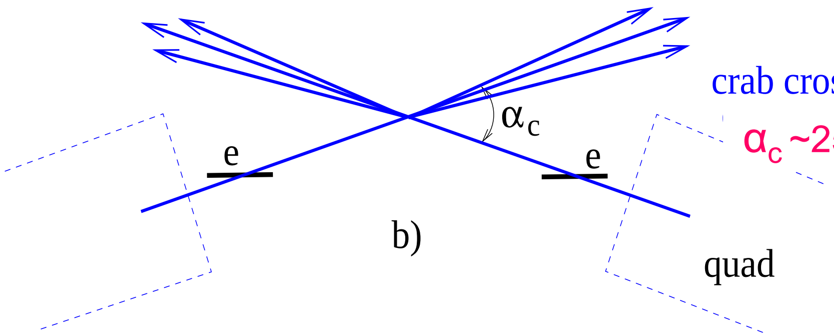
Contents

- Introduction
- Crossing angle, layout
- Luminosity
- Lasers, optics, detector
- Org. questions

Scheme of $\gamma\gamma$, γe collider



a)



b)

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

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

$E_0 = 250$ GeV, $\omega_0 = 1.17$ eV ($\lambda = 1.06\ \mu$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.

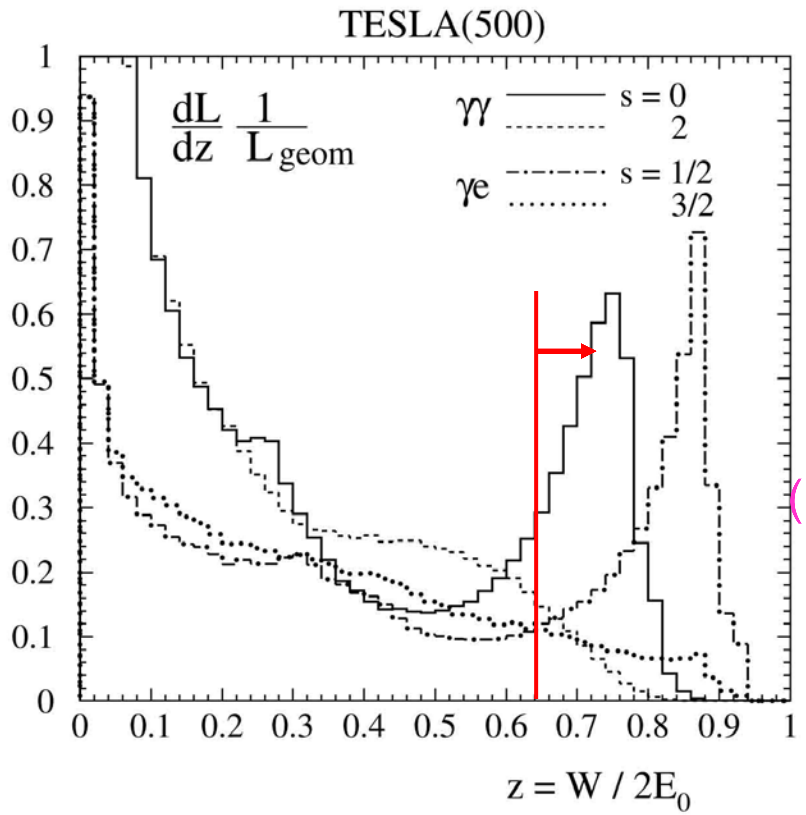
$\omega_{max} \sim 0.8\ E_0$

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

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

Luminosity spectra

(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

$L_{\gamma\gamma}(z>z_m)$ ~(0.17-??) L_{e+e-}(nom)

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

First number - nominal beam emittances
Second - can be ~3 times larger
(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.

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
   (H,A in $\gamma\gamma$, charged and light neutral SUSY in γe)
4. higher precision for some phenomena
5. different type of reactions
   (different dependence on theoretical parameters)

One example: $2E_0$=500 GeV and no energy upgrade.

For e+e- $M_{H,A}$(max)~250 GeV (H,A are produced in pairs)

For $\gamma\gamma$ ~400 GeV (single resonance)

Important now.

It is important to make design decisions in the baseline project which are not prohibitive or unnecessarily difficult for the photon collider, allow to reach its ultimate performance and rather easy transition between modes:

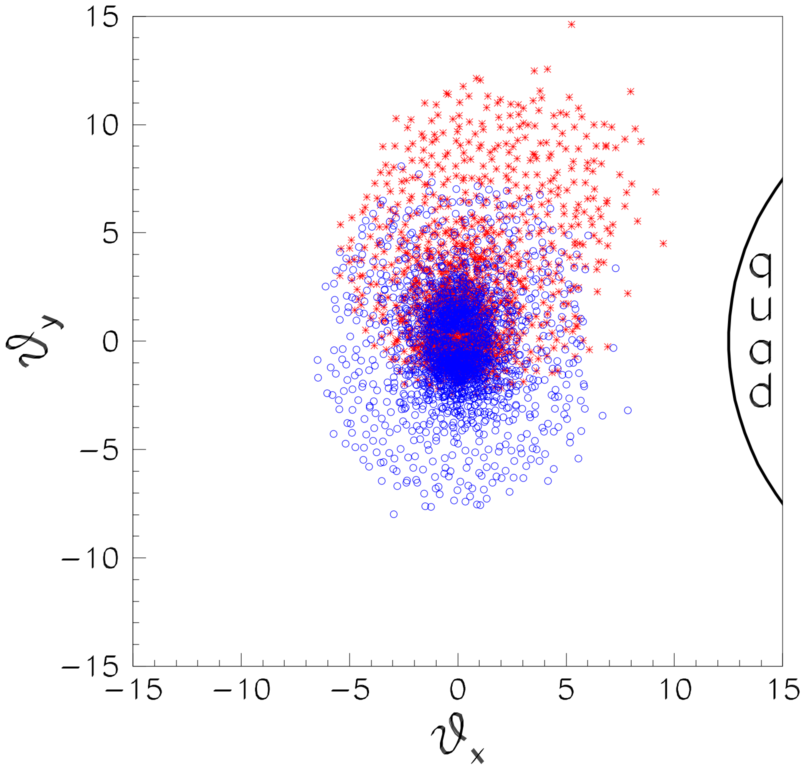
- crossing angle ~ 25 mrad;
- small as possible beam emittances;
- place for beam dump and laser;
- laser scheme;
- scheme of detector modification.

Crossing angle

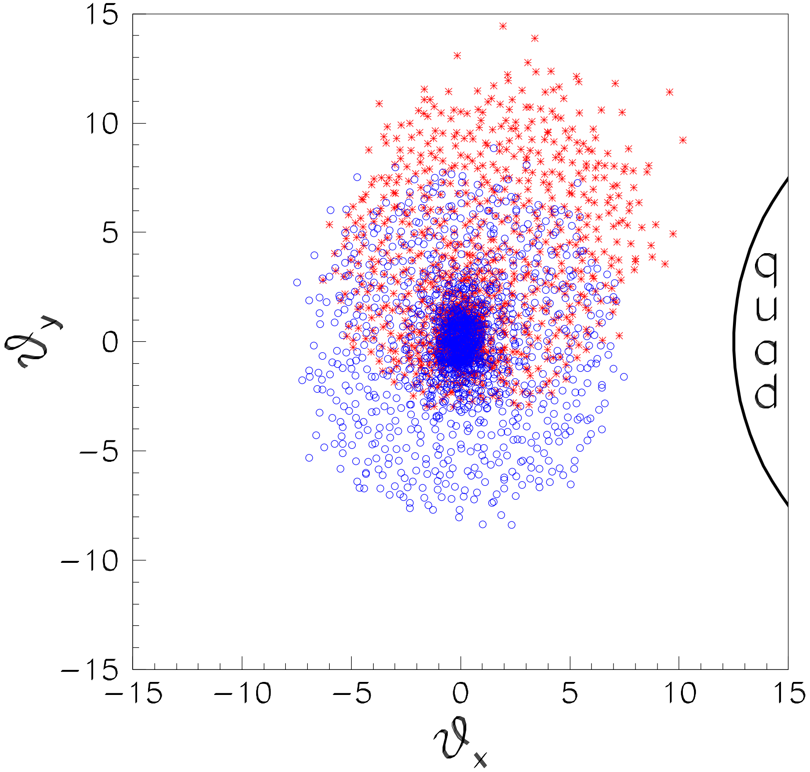
Disrupted beam with account of the detector field (at the front of the quad)

L=4m, B=4T

Telnov, Snowmass2005



$2E_0$=200 GeV

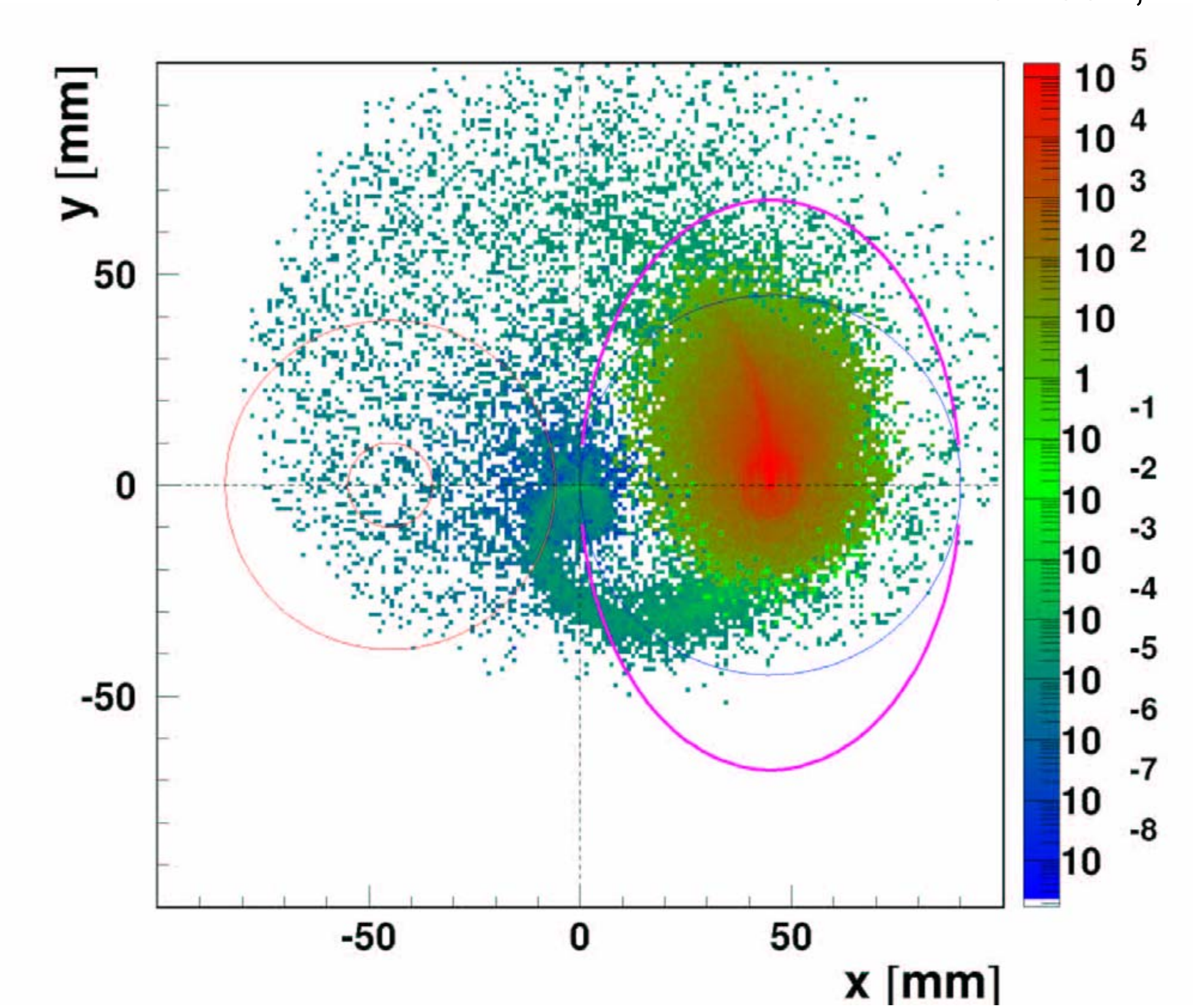


$2E_0$=500 GeV

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

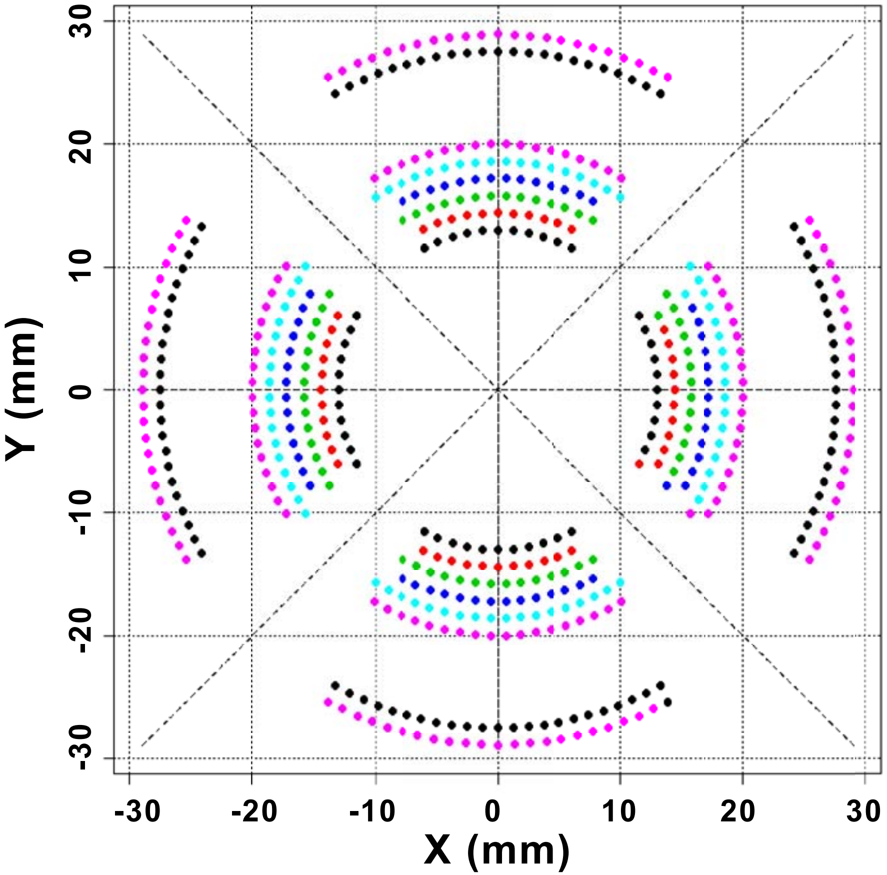
at L=4.5 m

A.F.Zarnecki, LCWS06



$P_{quad} < 1$ W

The radius of the quad with the cryostat is about 5 cm.
(B.Parker, Snowmass 2005)



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

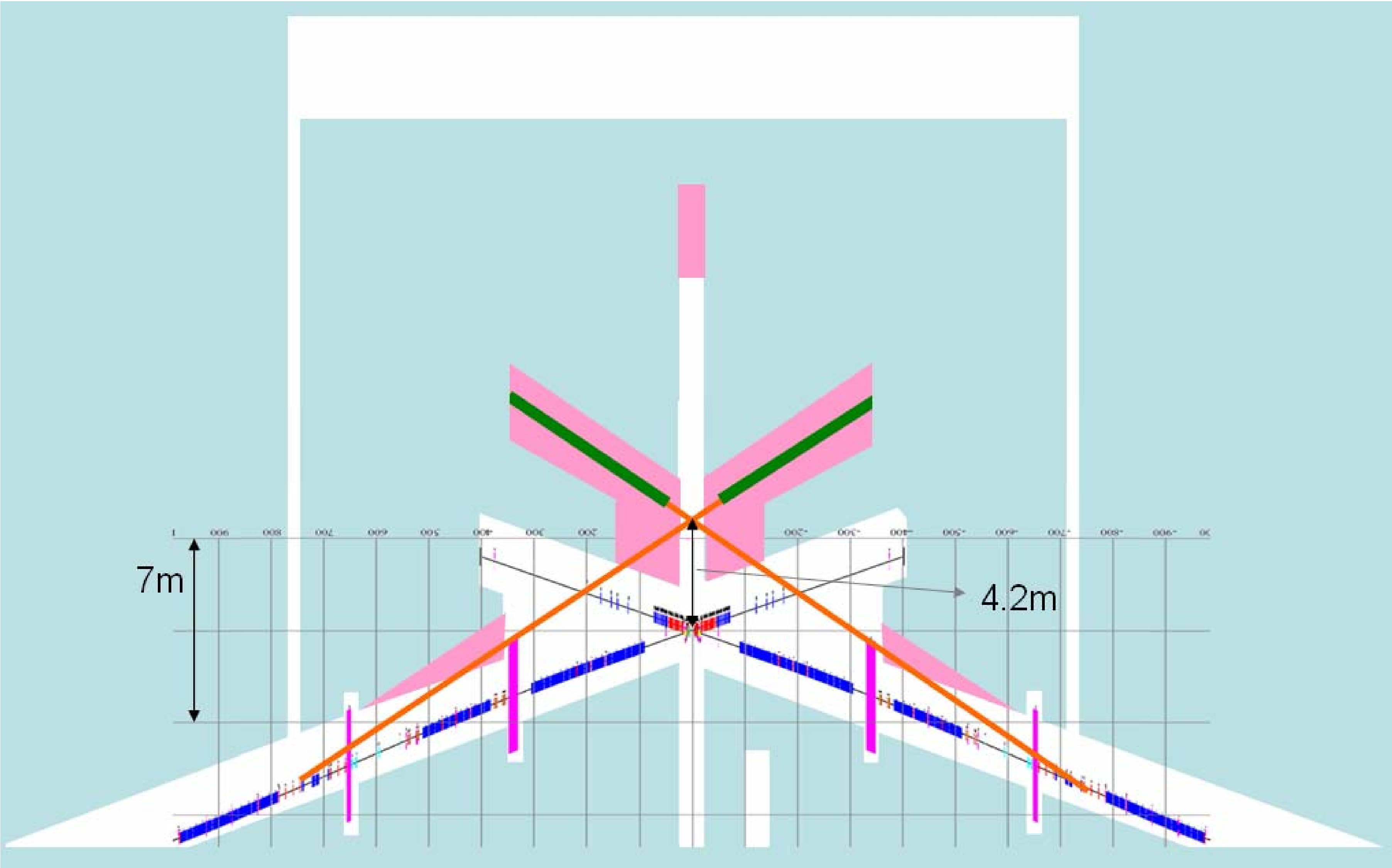
L_{mag} = 2.200 m

L_{coil} = 2.228 m

$\alpha_c = (5/400)*1000 + 12.5 \sim 25$ mrad

14mr => 25mr

A.Seryi, LCWS06



- additional angle is 5.5mrad and detector need to move by about 4.2m

Upgrade of 14 mr(e+e-) to 25 mr($\gamma\gamma$)

- Tunnel in FF area may need to be wider
- For transition from e+e- to $\gamma\gamma$ one should shift the detector and about 700 m long upstream FF system. May be it is not so difficult, if beamline elements are situated on long movable platforms.
- The same angle, 25 mrad, for e+e- and $\gamma\gamma$ is also possible, but e+e- people want special extraction line with beam diagnostic (energy, spectrum, polarization), while $\gamma\gamma$ needs clear way to the beam dump.

  Replacements will be difficult due to induced radioactivity. So, different crossing angles are even more preferable.

$\gamma\gamma$ can not work in parallel with e+e- in pull-push mode

If one IP, $\gamma\gamma$ can start only after completion of e+e-experiments.

Luminosity

In $\gamma\gamma$ collisions the luminosity (in ILC case) is just proportional to the geometric e-e- luminosity.
So, one needs smallest product of beam emittances and smaller, than in e+e-, β_x .

Comparison of $L_{\gamma\gamma}$ and L_{e+e-}

At the nominal ILC parameters $L_{e+e-}=2\cdot 10^{34}$ cm^{-2}c^{-1}. For same parameters, CP-IP distance b=1 mm and $t/\lambda_c=1$ $L_{\gamma\gamma}(z>0.8z_m)=3.4\cdot 10^{33}$ or

$$L_{\gamma\gamma} / L_{e+e-} = 0.17$$

If one reduces somewhat emittances:

$\varepsilon_{nx}=10^{-5} \rightarrow 0.5\cdot 10^{-5}$; $\varepsilon_{ny}=4\ 10^{-8} \rightarrow 3\cdot 10^{-8}$ and $\beta_x=5 \rightarrow 3.7$ mm

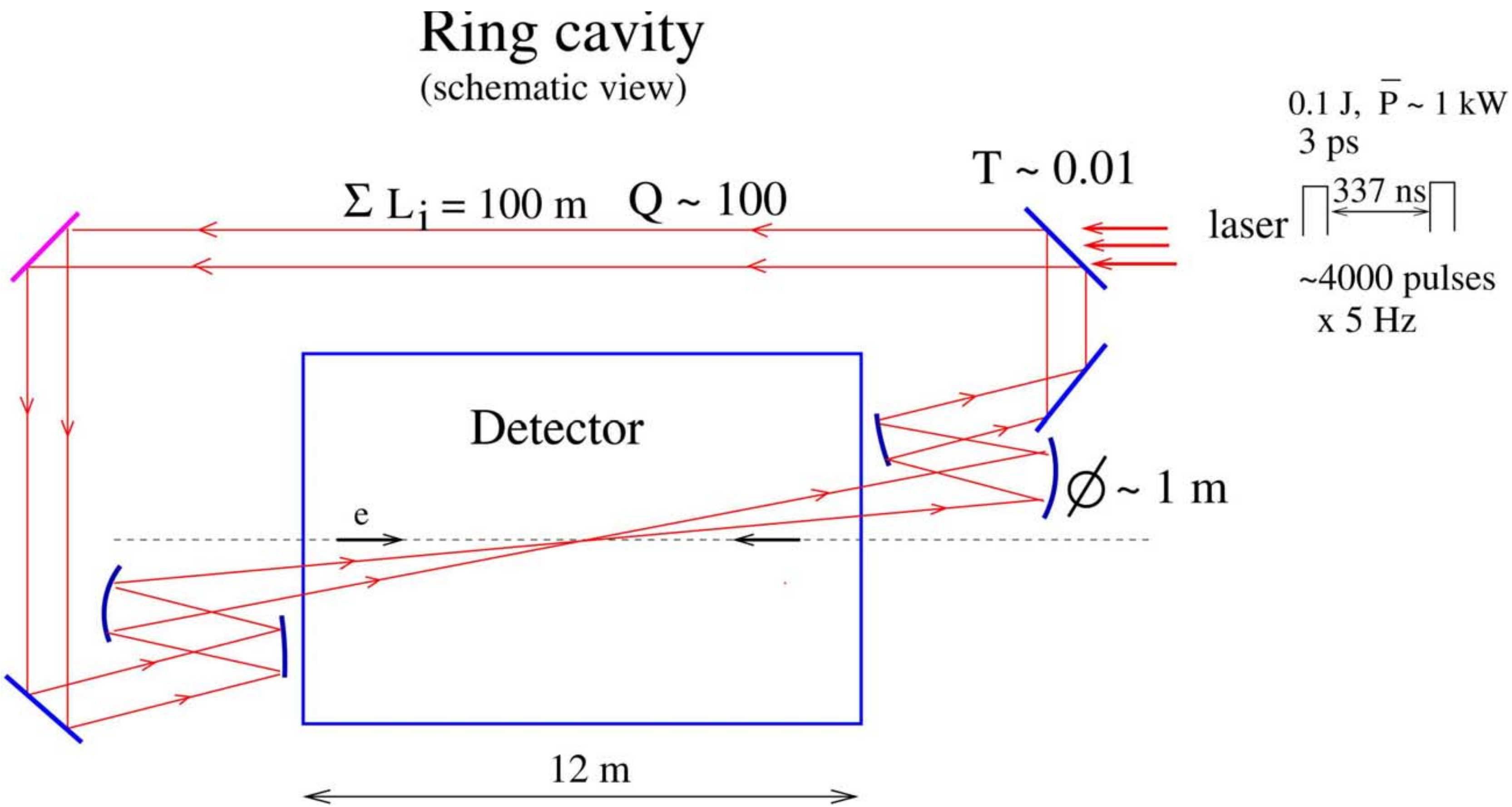
then $L_{\gamma\gamma} / L_{e+e-} = 0.32$ (0.3 in TESLA TDR).

Optimistically, $\varepsilon_{nx}=10^{-5} \rightarrow 0.25\cdot 10^{-5}$ ($\beta_x=5 \rightarrow 2.2$ mm)

then $L_{\gamma\gamma} / L_{e+e-} = 0.59$

Note, cross sections in $\gamma\gamma$ are larger than in e+e- by a factor of 10. So, even in the worst (nominal) case the number of events in $\gamma\gamma$ collisions is larger than in e+e-, but the increase of the $\gamma\gamma$ luminosity by an additional factor 2 – 3 is quite possible by optimizing damping ring (more wigglers). For cost-performance optimization it is interesting to know cost = $f(\varepsilon_x \varepsilon_y)$. Unfortunately, DR people “are busy with the baseline DR” (already many years).

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, $\sigma_{x,L}$~7 μm

Meeting with UK laser experts attracted by D.Miller

Background to Daresbury Meeting

January 10, 2006

"THE PHOTON COLLIDER AT TESLA", V.Telnov et. al

↓

" Design study of an optical cavity for a future photon-collider at ILC "

G. Klemz , K. Moenig , I. Will

↓

"Thoughts on R+D for Gamma Gamma Optical System" Josef Frisch

"Additional comments on R+D for Gamma Gamma Optical System "

Ken Strain

"Optical cavity for ILC g-g collider: feasibility and development "Mark Oxborrow

"Photon Linear Collider Laser Cavity Requirements. "

Andrea Freise

Jan 10th Meeting to discuss all the above…

Meeting to Discuss Laser Cavity Design for Photon Linear Collider - Daresbury, UK Jan 10th 2006

Present +on-line

Mark Oxborrow *National Physical Laboratory*

Graeme Hirst *Central Laser Facility RAL*

Guido Klemz *DESY/Zeuthen*

Klaus Moenig *LAL-Orsay/DESY-Zeuthen*

Andrew Rollanson *Keele University*

Ken Strain *Glasgow University*
Valery Telnov *Novosibirsk*
David Walker *Zeeko Ltd.*
David Miller *UCL*
Aleksander Filip Zarneki *Warsaw*
Alexander Finch *Lancaster University*
Steve Maxfield *Liverpool University*

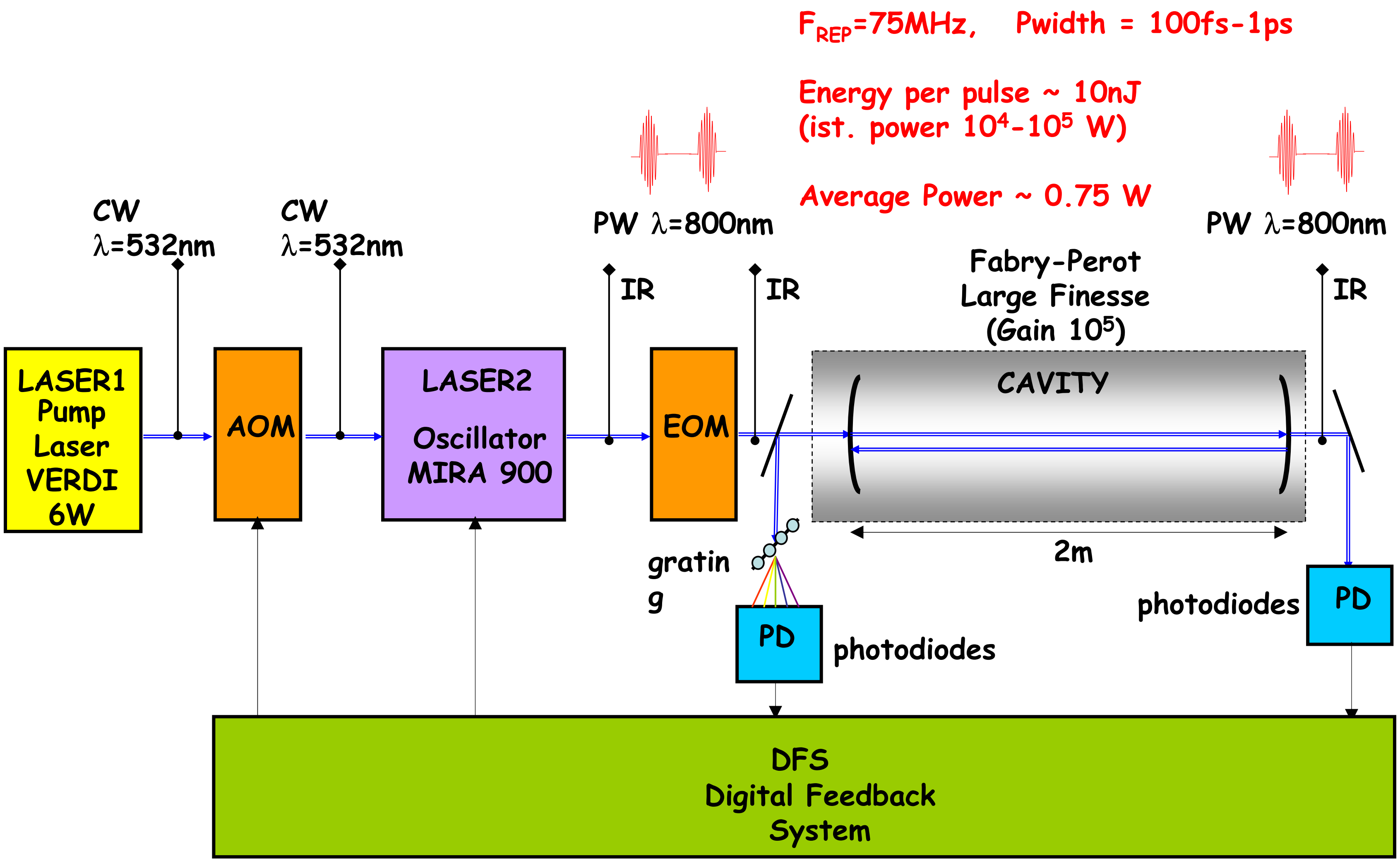
Conclusion of the meeting

There is no **known** effect at present that would prevent it working at all.

Way Forward for the Laser Cavity…

- Continue **networking**!
- Need an **"End to End" simulation** of the dynamics of the design. This will help to identify which are the critical elements. Codes exist in Astronomy community.
- Study the **locking** issue further.
- Need to **investigate damage threshold** issues further using rapidly pulsed lasers, may need R+D if no-one else has studied it.
- Alternative designs need to be looked at in at least as much detail.
- Learn as much as possible from **other related projects** such as the work done for the polarimeter, the laser wire and the positron source. See **other related projects** below.

LAL-Orsay (A.Variola et al.)
A Fabry-Perot cavity for FLC polarimetry



The ILC Compton Scheme

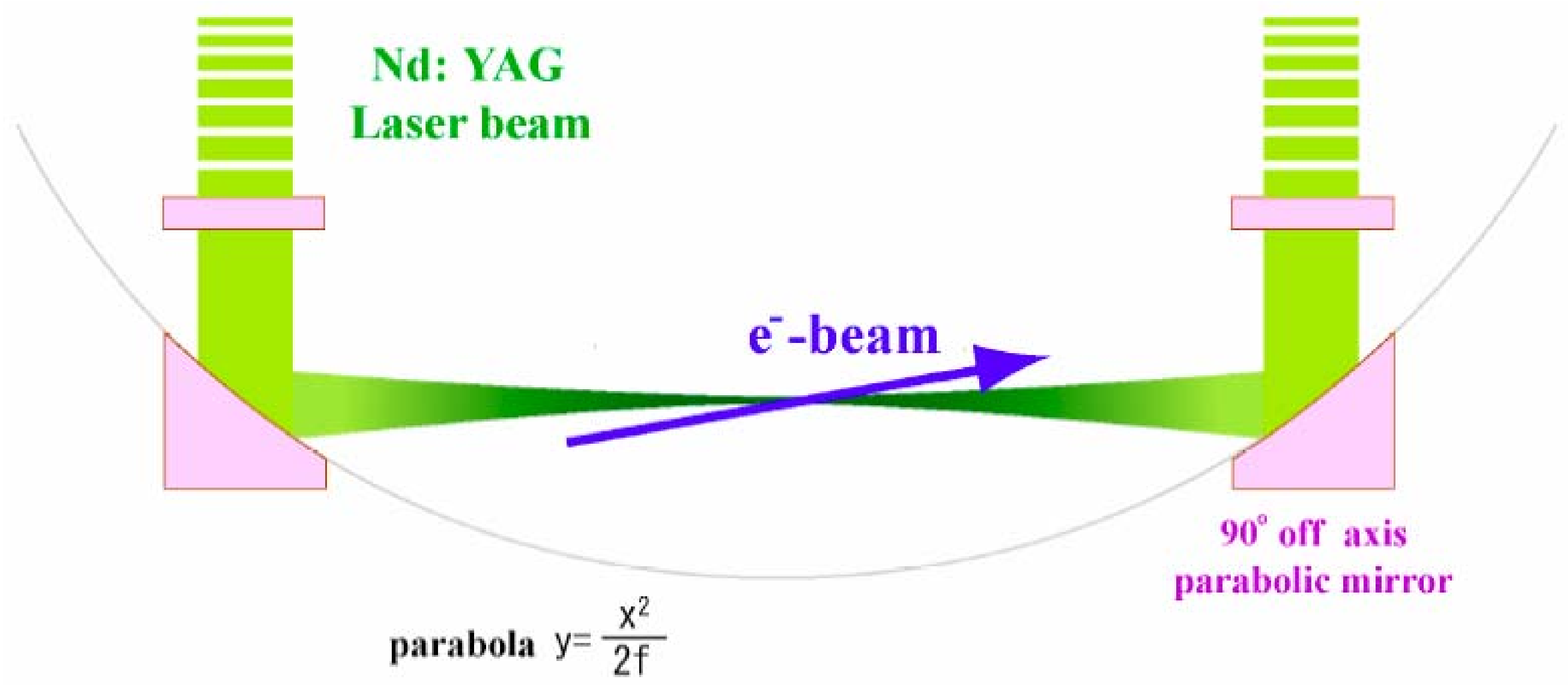
Junji Urakawa, KEK

Laser Pulse Stacking Cavity

Fabry-perot Resonator

Input laser (YAGlaser)
- Energy 0.75 mJ/bunch
- 3.077 nsec laser pulse spacing
- train length = 50 μsec

Cavity
Enhancement Factor =3000



Laser pulse in cavity
- 2250 mJ/bunch
- single bunch in a cavity

30 IP will be reduced to 10 IP.

CLIC scheme of polarized e+ source based on laser Compton scattering

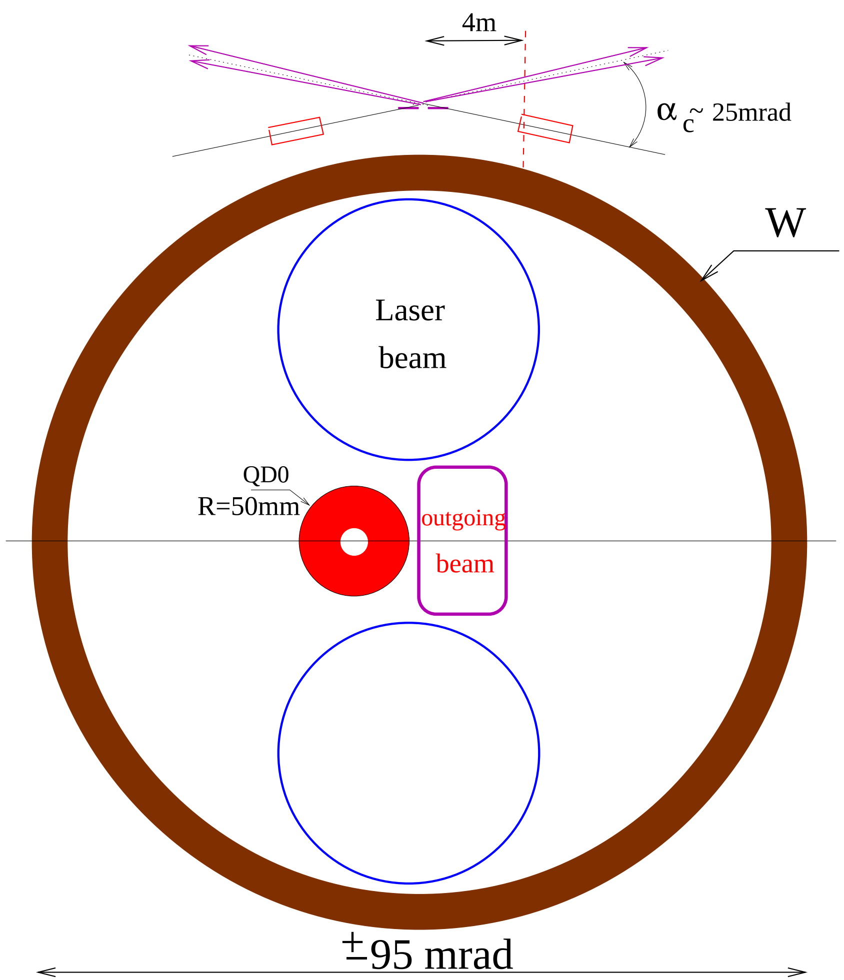
Frank Zimmermann

POSIPOL2006, CERN, 26. April 2006

Thanks to
Eugene Bulyak, Peter Gladkikh,
Masao Kuriki, Klaus Moenig,
Tsunehiko Omori, Junji Urakawa,
Alessandro Variola

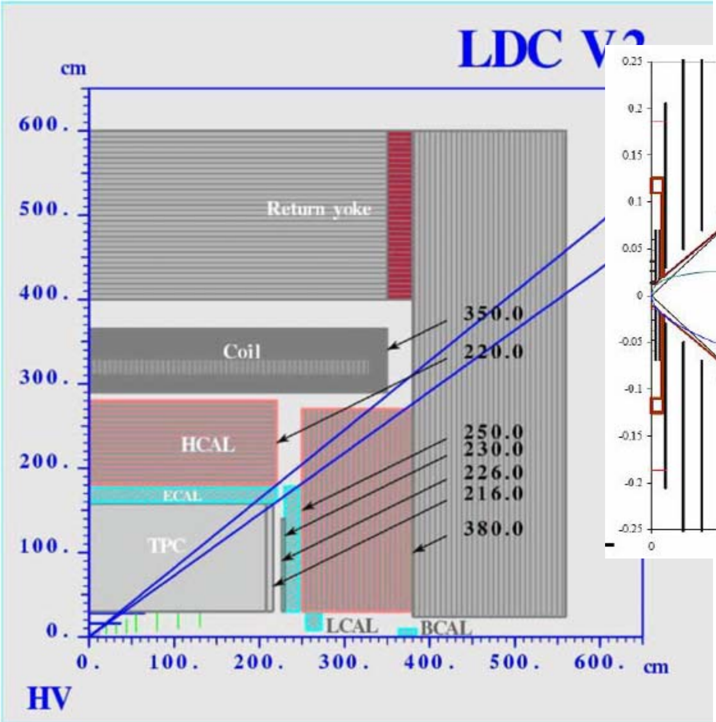
Interference of laser optics with detector

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

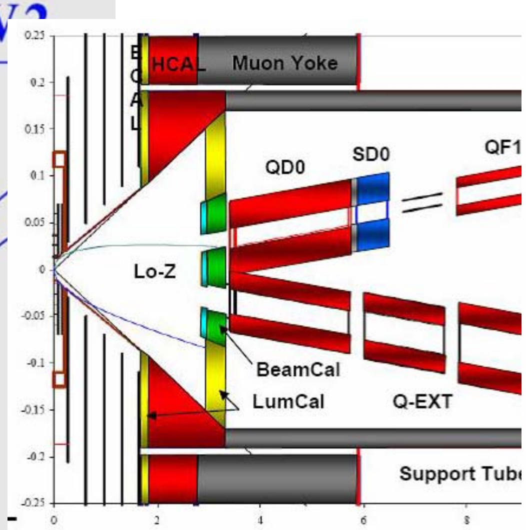


Open angle in detectors

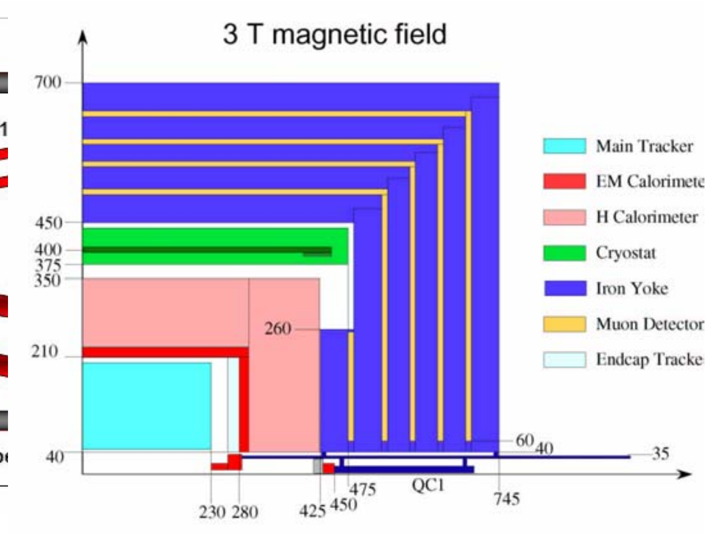
LDC



SID



GLD

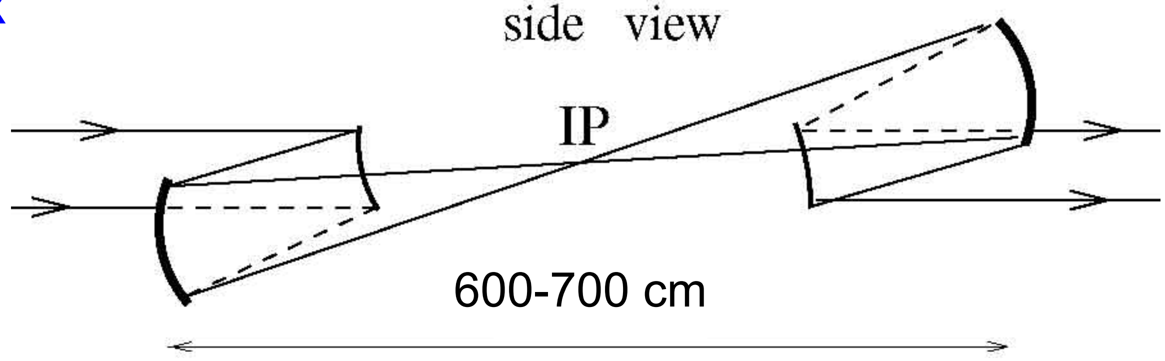


θ=±45 mrad ±33 mrad ±50 mrad

Some problems with laser optics

- If the final mirror is outside the detector at the distance ~15 m from the center, its diameter is about d~90 cm, very large.
- Detectors have holes in forward direction ±33-50 mrad (see next slide) while the photon collider needs ±95 mrad, so there should be special removable parts in ECAL, HCAL and the yoke.

Possible solution: pairs of mirrors inside the detector as was assumed in TESLA TDR



Then the diameter of focusing mirror is about 20 cm and that of the auxiliary mirror about 11 cm. The dead angle for tracking remains as before about ±95 mrad, for calorimetry smaller. The laser density is far from the damage threshold, the average power is the most serious problem.

Organization questions

Linear colliders provide a unique opportunity to study $\gamma\gamma,\gamma e$ interaction at high energies and luminosities. About 20-25% of all publications on LC physics are related to this subject.

PLC considerably influence baseline ILC design and detector, joint work with many groups is needed.

However, it is difficult to do anything when hear every time that it is not in baseline.

- There is no one PLC representatives in GDE and other ILC committees, there is no such group in the ILC structure.
- Photon collider is not mentioned in the BCD, RDR, DCR(3 lines) e.t.c.
- In absence of political and financial support further progress is problematic.

Some people suggest “keep open (and do nothing) until very strong physics case appears”.

That is wrong. The photon collider can not appear "tomorrow", when physics will be clear. It needs many years for development and construction of the laser system, many special features should be foreseen in basic designs of the ILC and detectors.

These problems were discussed with top ILC management, editors of the scope document and there is hope that situation will be corrected in some way.