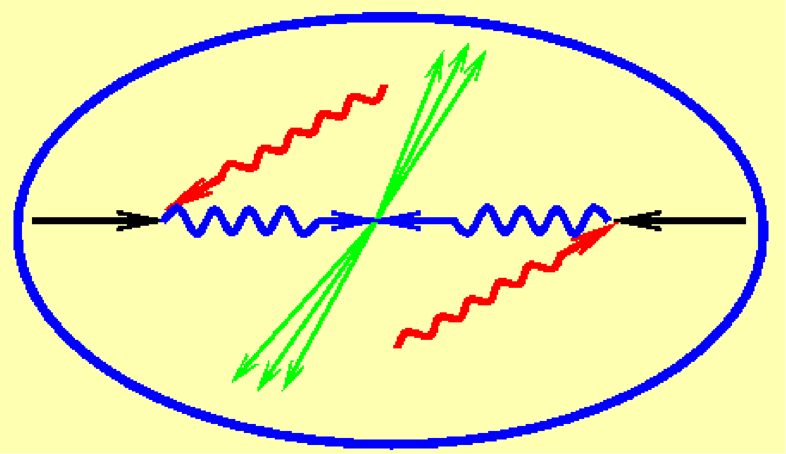


The Photon Collider at ILC: technical problems

Valery Telnov

ECFA, November 17, 2005, Vienna

Last events related to the photon collider

- Snowmass 2005: the 2nd accelerator workshop on ILC
Global group 6 (Options): Parameters and configurational aspects of $\gamma\gamma$, γe, e^-e^-, GigaZ, fixed target,
Conveners: V.Telnov, B.Parker, T.Omori

- Photon2005, Warsaw, Sept. 2005 +
- PLC2005, Kazimierz, Poland (M.Krawczyk)

In ECFA Study: Conveners on $\gamma\gamma$ technology:
V.Telnov, K.Moenig → D.Miller

The David's choice is a recognition that the photon collider is one of the most exciting fields in the ECFA study.

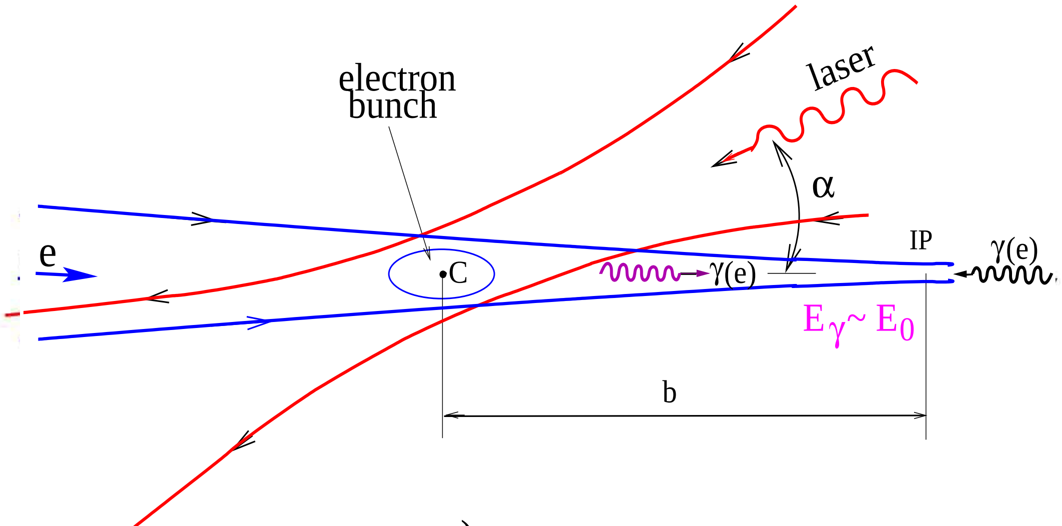
Conributions on γγ-technology at Vienna

- V.Telnov, Luminosity stabilization at the photon collider.
- Crossing angle for the photon collider at ILC.
- A. Zarnecki, Results from beam simulation with CAIN.
- A.Finch, Progress on the Cavity Laser

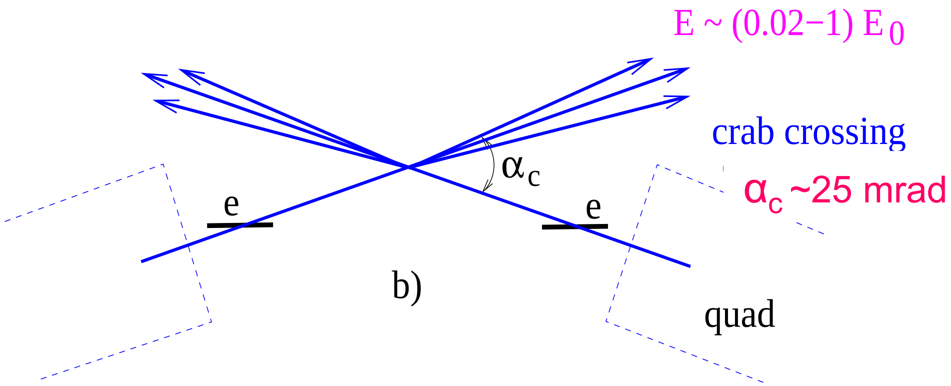
Contents

- Introduction
- Crossing angle
- Beam dump
- Lasers, optics
- Conclusion

Scheme of $\gamma\gamma$, γe collider



a)



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

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

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

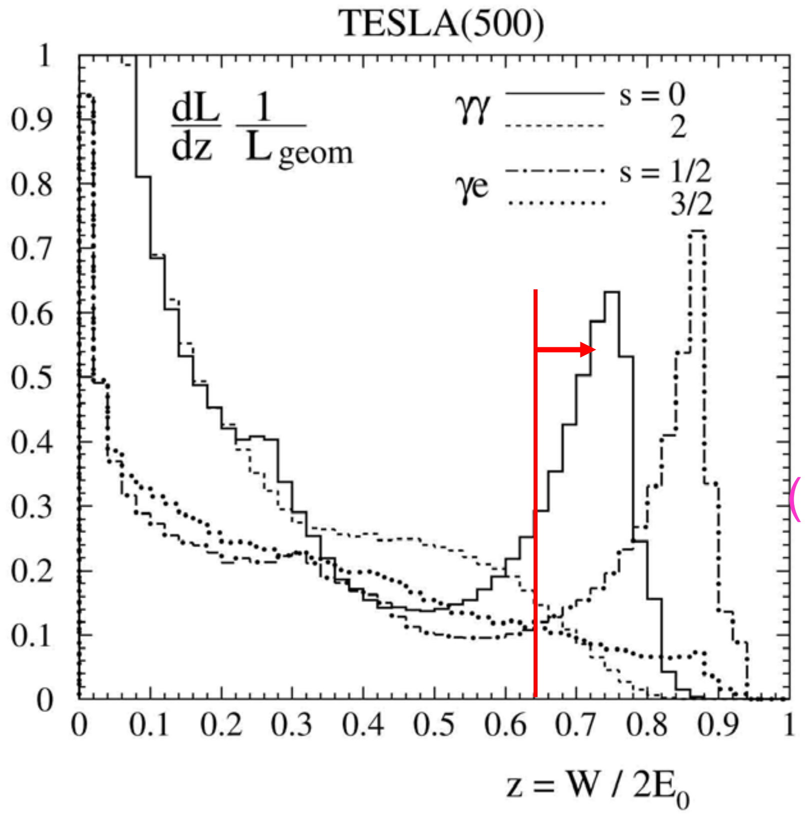
$x = 4.8$ is the threshold for
$\gamma\gamma_L \to e^+e^-$ at conv. reg.

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

$W_{\gamma\gamma,\ max} \sim 0.8\cdot 2E_0$
$W_{\gamma e,\ max} \sim 0.9\cdot 2E_0$

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

$L_{\gamma\gamma}(z>z_m) \sim (0.17\text{-}0.55)\ L_{e+e-}(\text{nom})$

(but cross sections in γγ are larger by one order!)

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

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.

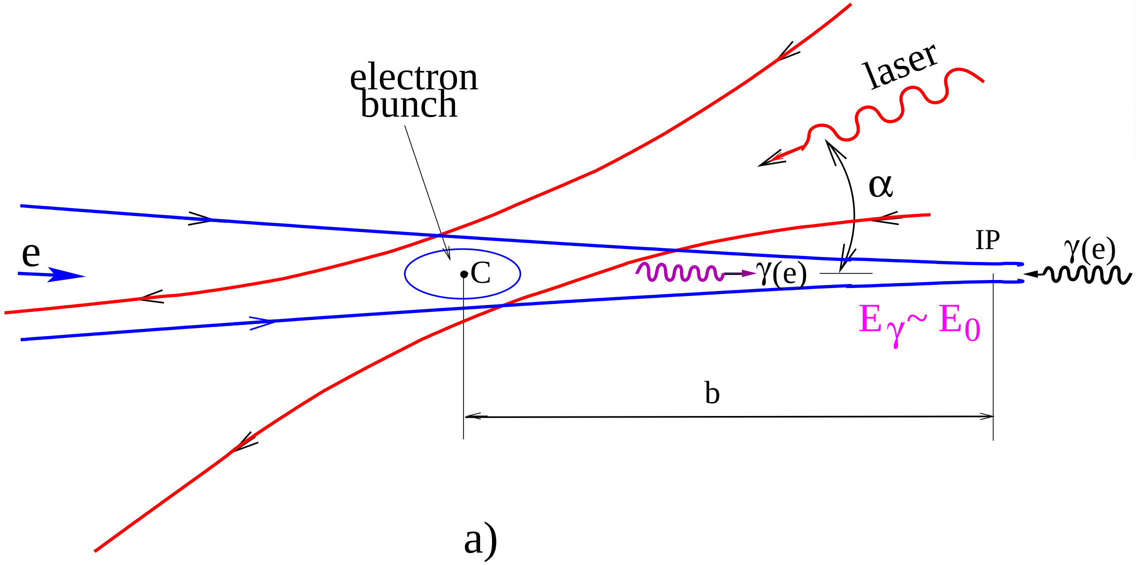
Physics motivation: summary

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

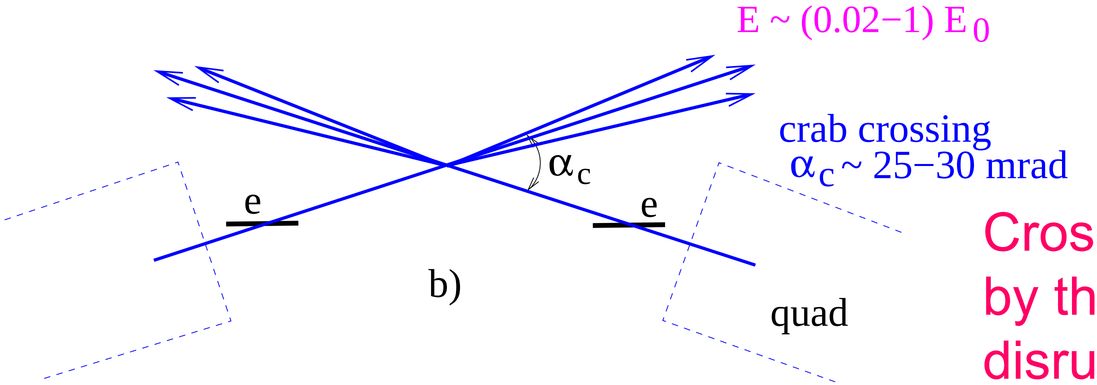
1. the energy is smaller only by 10-20%
2. the number of events is similar or even higher
3. access to higher particle masses
   (H,A in $\gamma\gamma$, charged SUSY in γe)
4. higher precision for some phenomena
5. different type of reactions
   (different dependence on theoretical parameters)

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

Crab-crossing angle



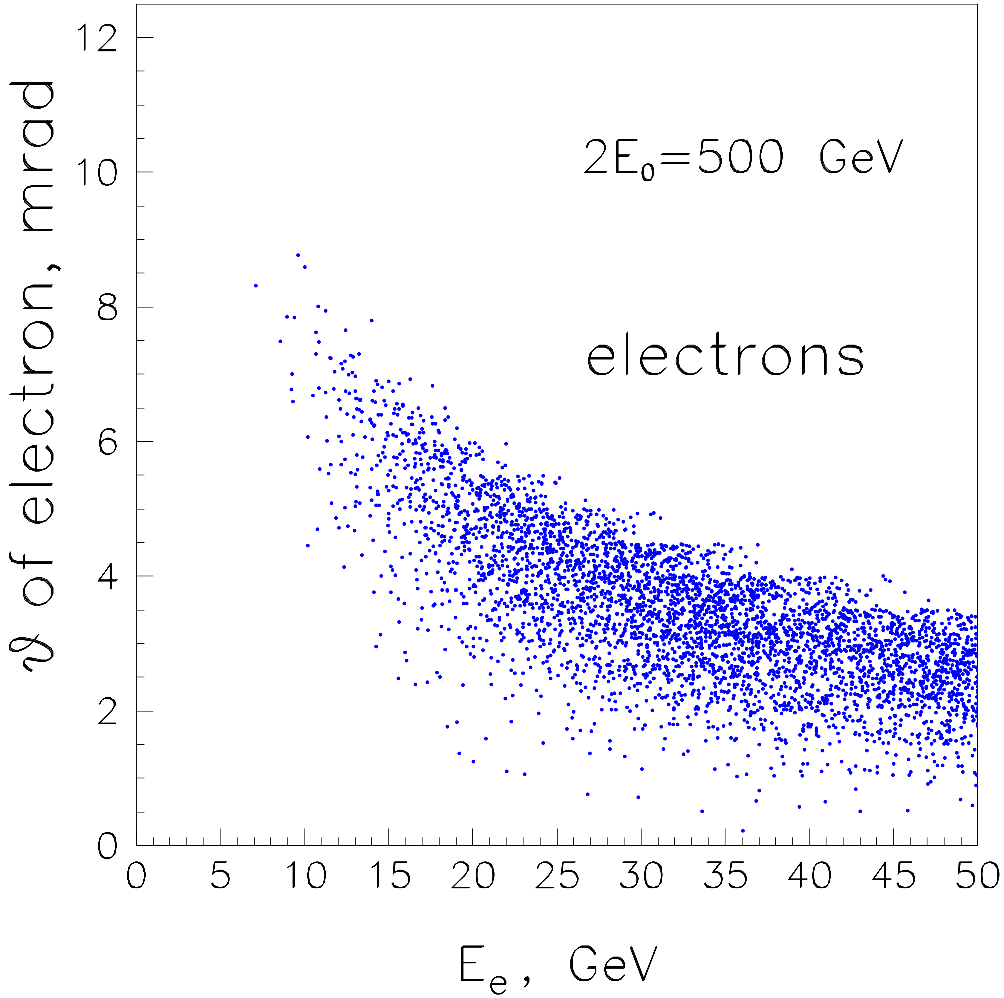
a)



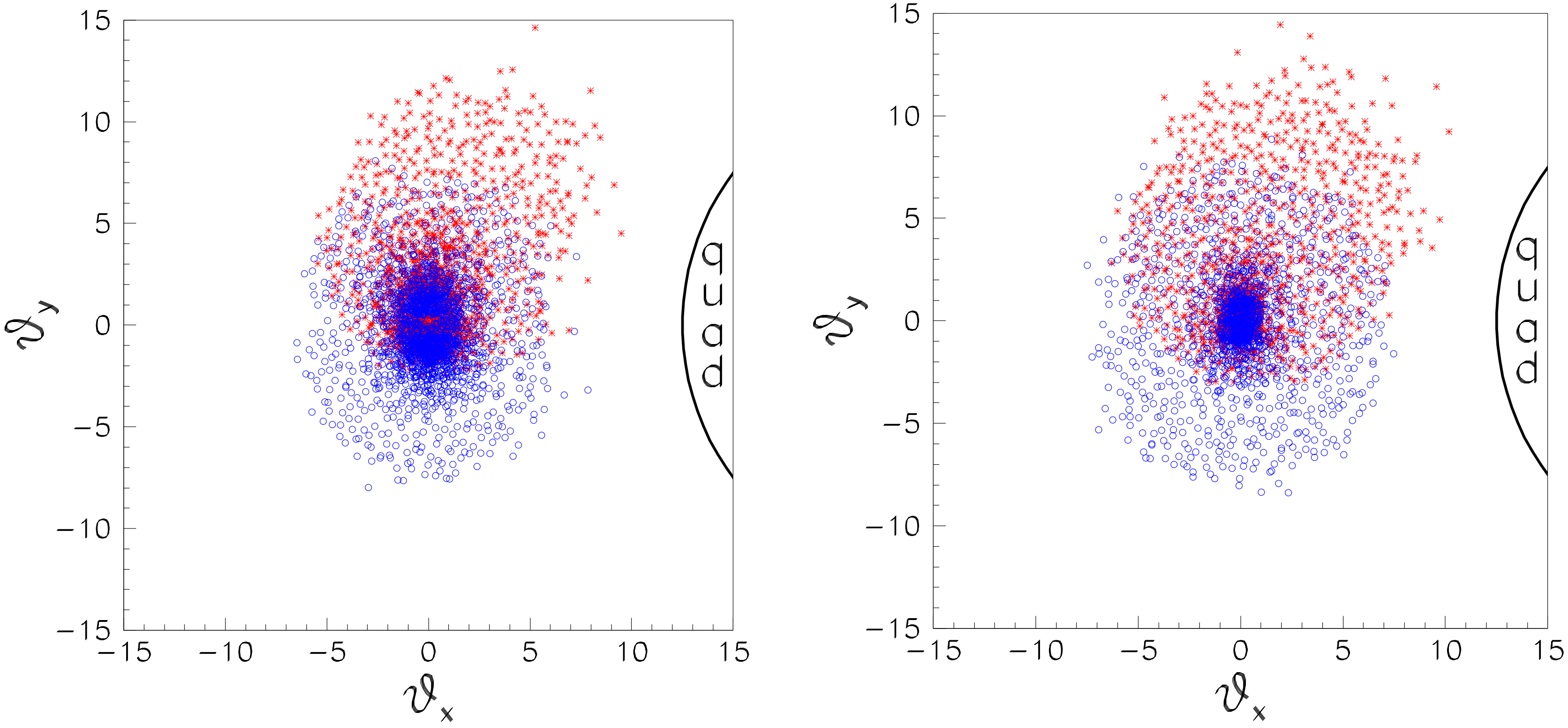
b)

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

Angles of disrupted electrons after Compton scattering and interaction with opposing electron beam; $N=2\cdot10^{10}$, σ_z =0.3 mm



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

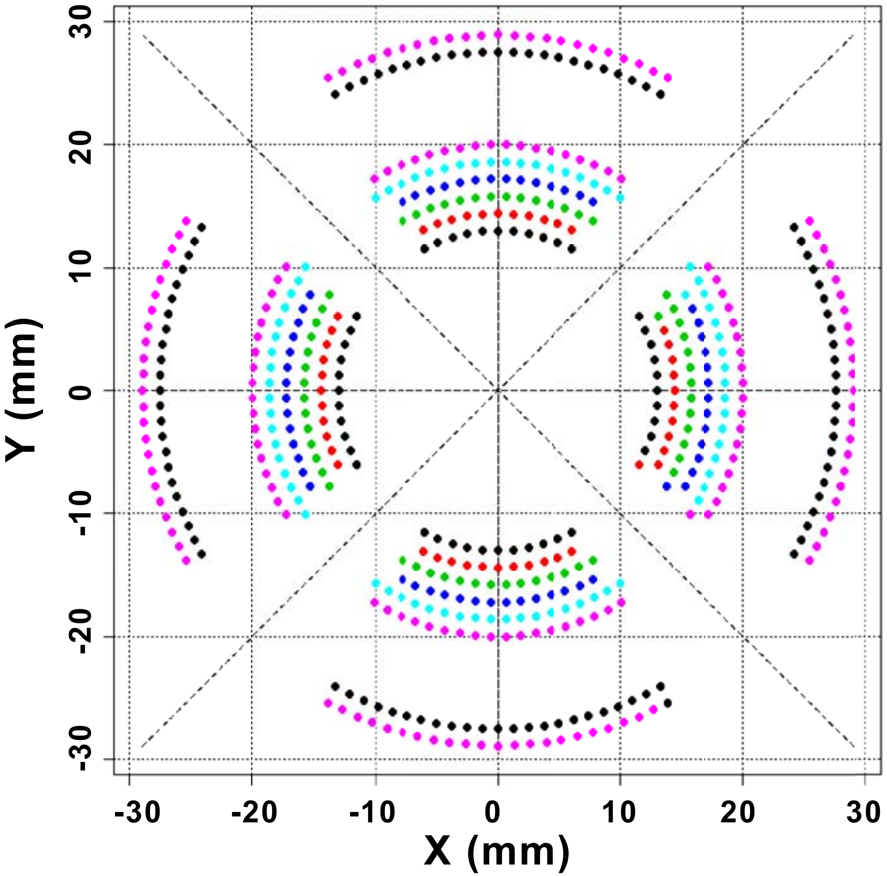


$2E_0$=200 GeV

$2E_0$=500 GeV

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

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

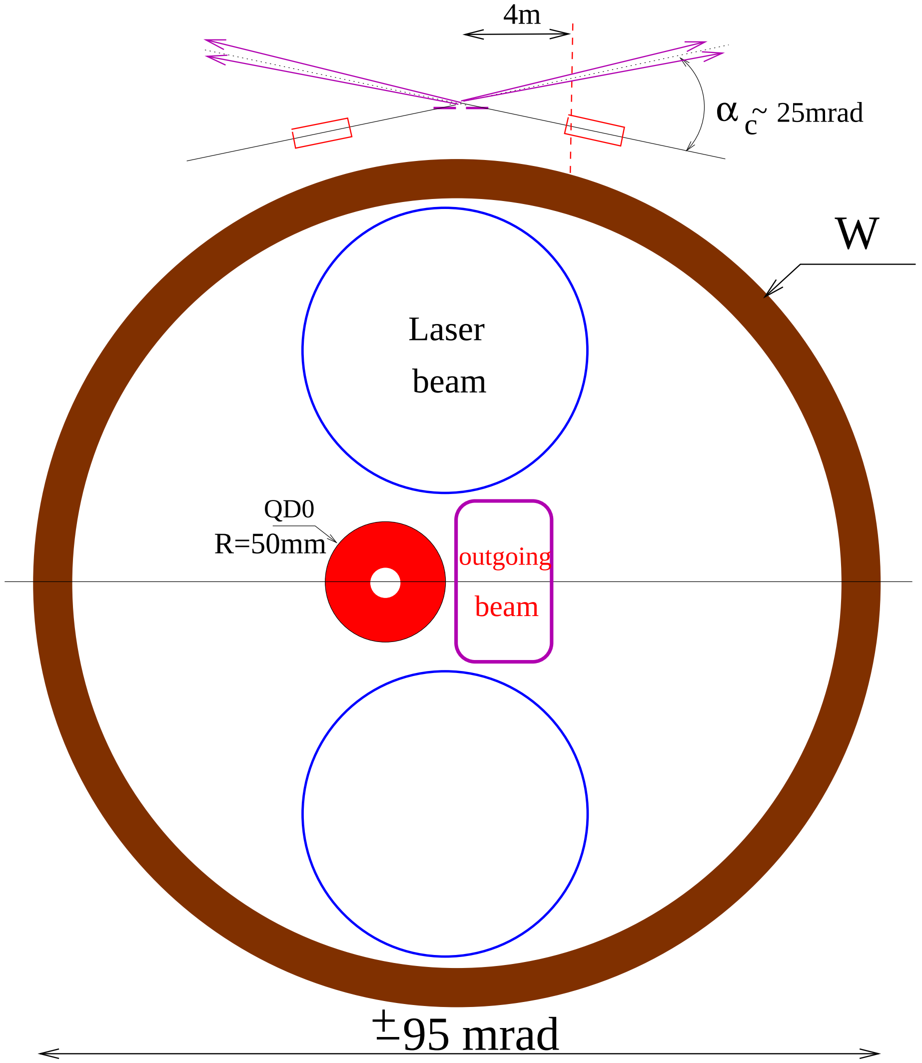
for G_{eff} = 140 T/m

L_{mag} = 2.200 m

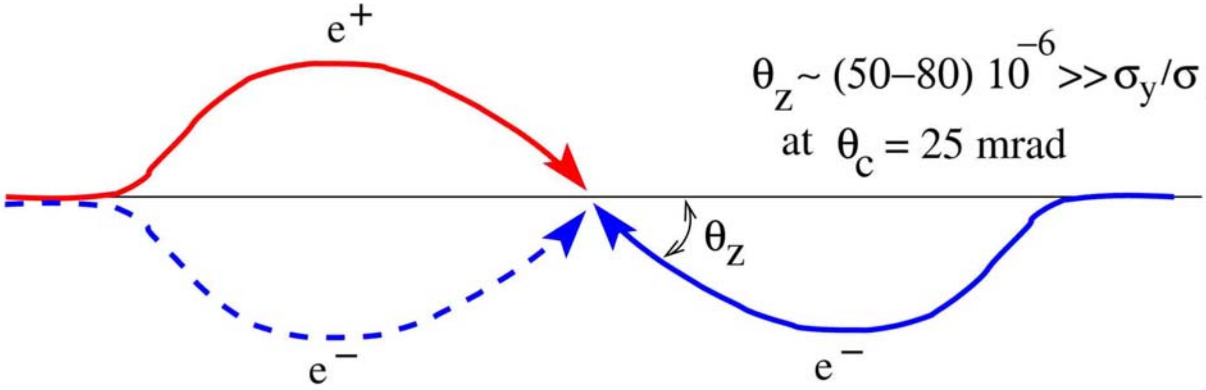
L_{coil} = 2.228 m

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

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



Trajectories in the detector field at $\alpha_c \neq 0$



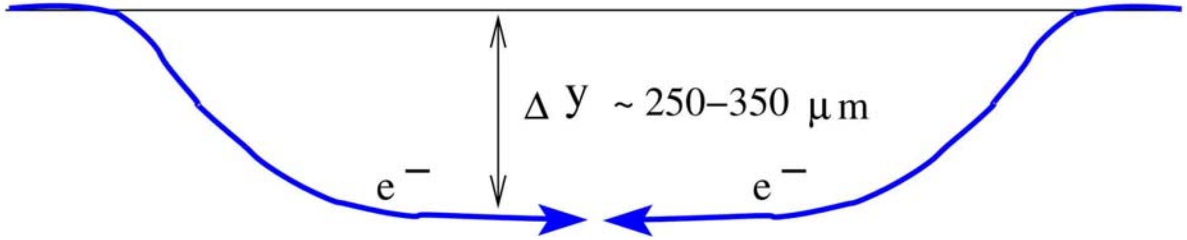
$\theta_z \sim (50\text{–}80)\ 10^{-6} >> \sigma_y/\sigma_z$

at $\theta_c = 25$ mrad

OK for e+e−, but not OK for e−e−(gamma−gamma)

Vertical shifts of final qurds helps for e−e−($\gamma\gamma$)

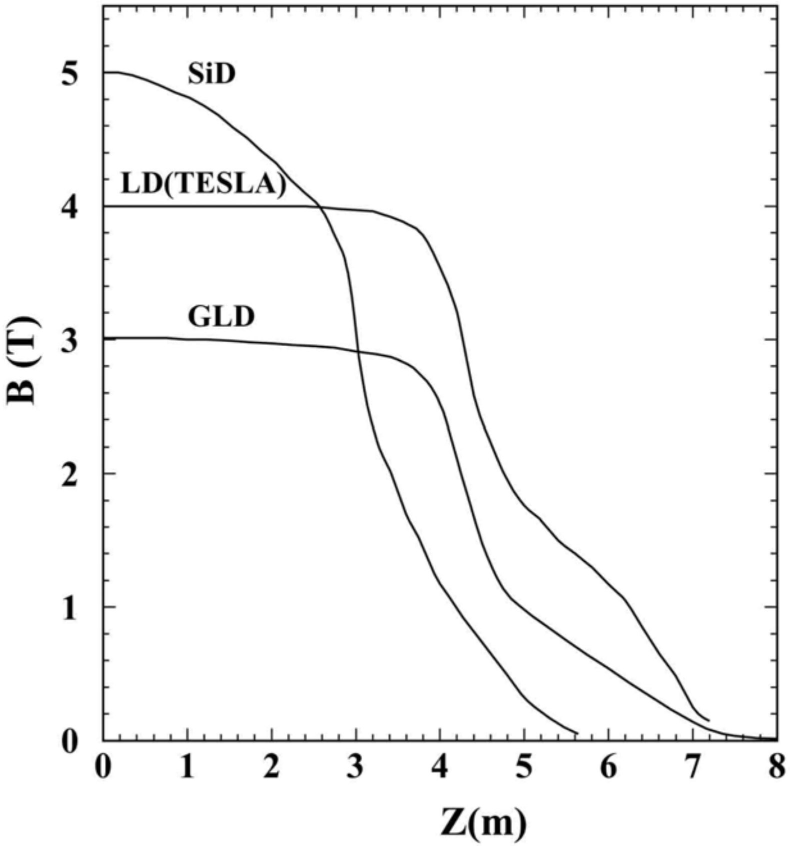
(or using correcting dipole coils)



$\Delta y \sim 250\text{–}350\ \mu m$

Increase of σ_y due to SR

Detector field at the axis



(Field on Jan.2005)

Deflecting force which causes SR

$$F_y = e\frac{v}{c}(-B_z\,\theta_0 + B_r) = -e\frac{v}{c}\,\theta_0\left(B_z + \frac{\partial B_z}{\partial z}\frac{z}{2}\right).$$

where $\theta_0 = \alpha_c/2$

Influence of SR on luminosity was found by full simulation

(V.Telnov, physics/0507134)

Results on $L(\alpha_c)/L(0)$.

e^+e^- collisions

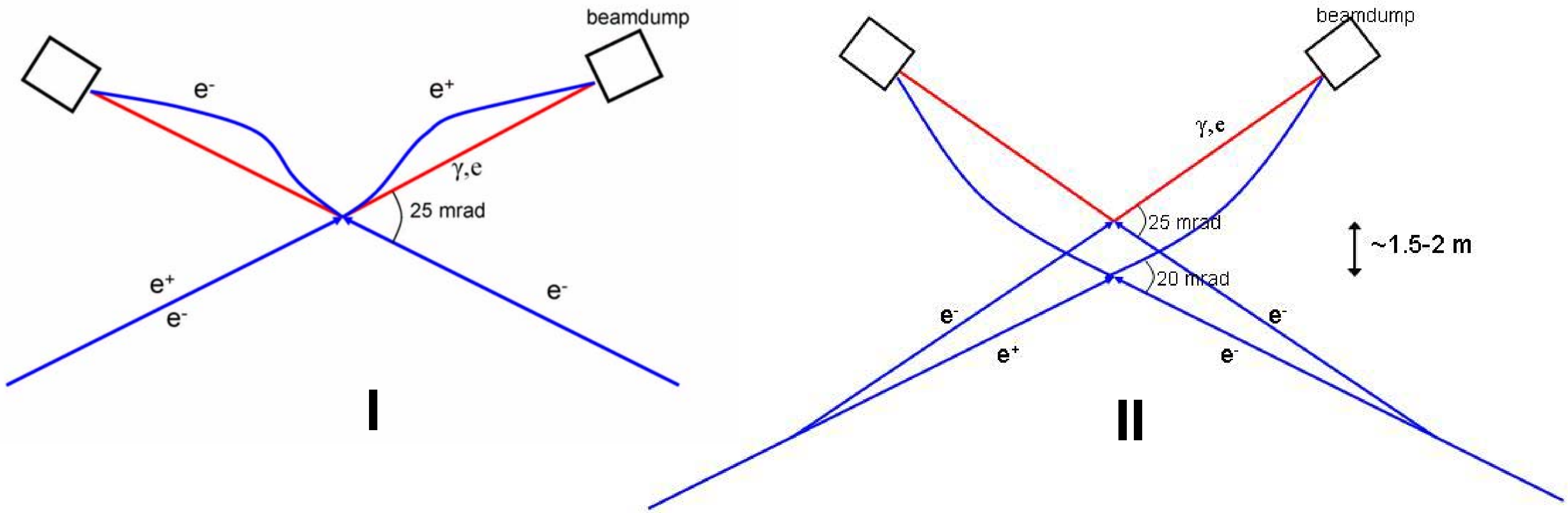
α_c(mrad)	0	20	25	30	35	40
LDC(TESLA)	1.	0.98	0.95	0.88	0.83	0.76
SID	1.	0.995	0.985	0.98	0.95	0.91
GLD	1.	0.995	0.98	0.97	0.94	0.925

$\gamma\gamma$ collisions

α_c(mrad)	0	20	25	30	35	40
LDC(TESLA)	1	0.99	0.96	0.925	0.86	0.79
SID	1	0.99	0.975	0.955	0.91	0.86
GLD	1	0.995	0.985	0.98	0.97	0.93

So, the crab-crossing angle of about 25 mrad is compatible with e^+e^- and $\gamma\gamma$ modes of operation.

Possible configurations of the IP



The scheme II looks attractive. The angle for e^+e^- and $\gamma\gamma$ are different. The required shift of the detector is not a problem (the beam dump is the same). The bend before the beam dump in the e^+e^- case is good for suppression of backward (shielding between the beam dump and the IP is not shown).

The scheme without the shift of the detector is also possible but needs an extra space for bends of beams before the IP.

Beam dump

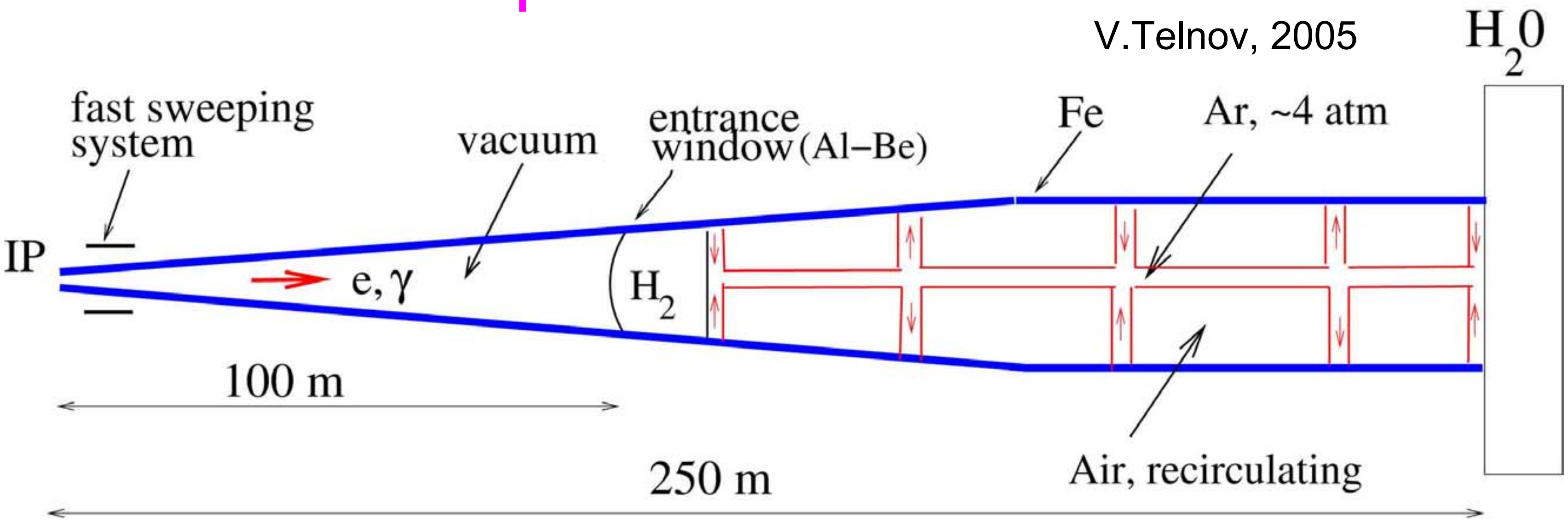
The disrupted beam at the photon collider has 3 components, two wide and one narrow:

1. e^+,e^- with the angular spread ~10-12 mrad (need some focusing);
2. beamstrahlung photons with angles up to 3-4 mrad;

   R~1 m at L=250 m from the IP.
1. Compton photons with angles $\sigma_{\theta x} \sim 4 \cdot 10^{-5}$ rad, $\sigma_{\theta x} \sim 1.5 \cdot 10^{-5}$ rad, that is 1 x 0.35 cm^2 at the distance 250 m.

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.

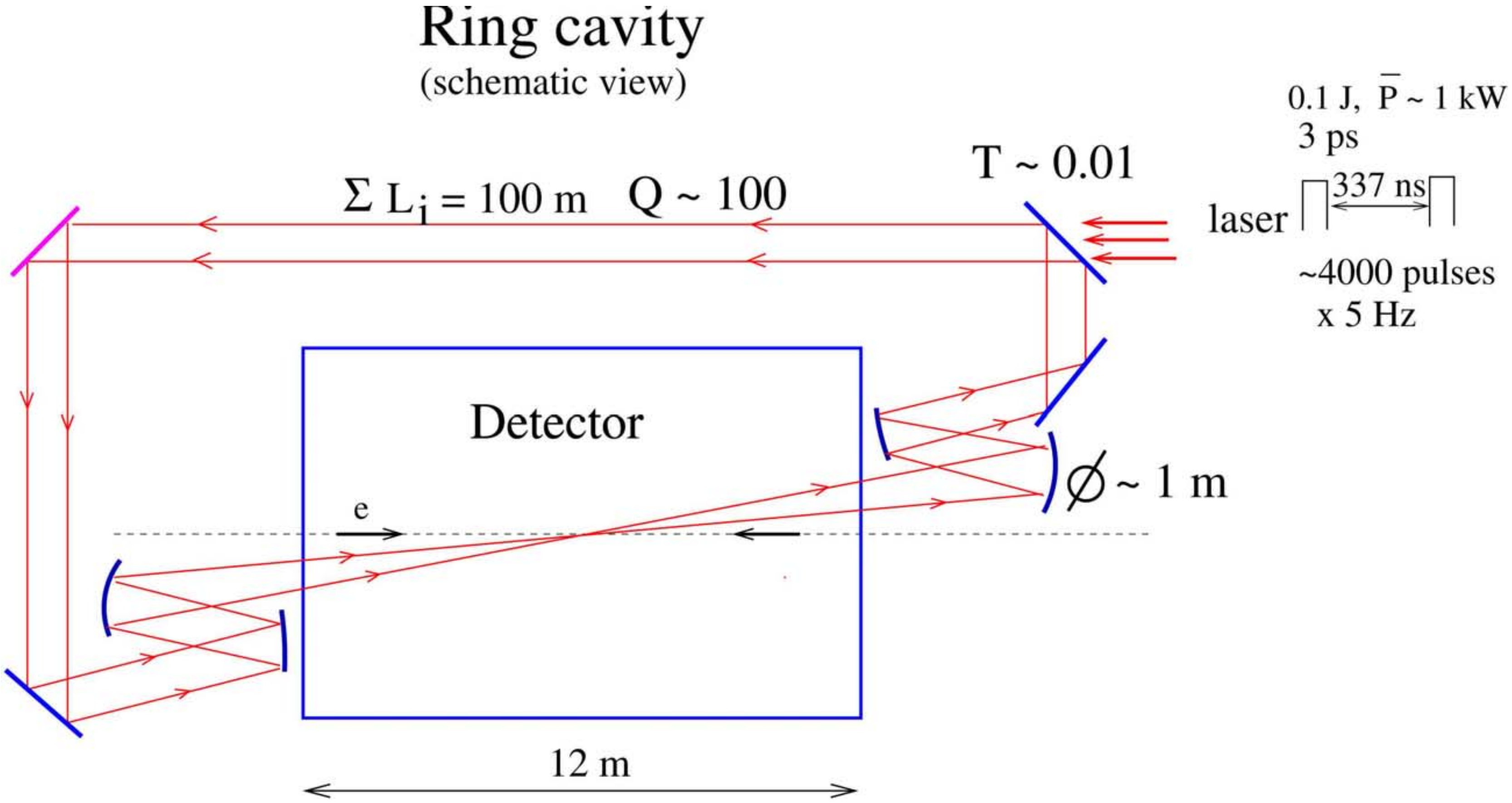
Needs detailed technical consideration!

Requirements for the laser

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

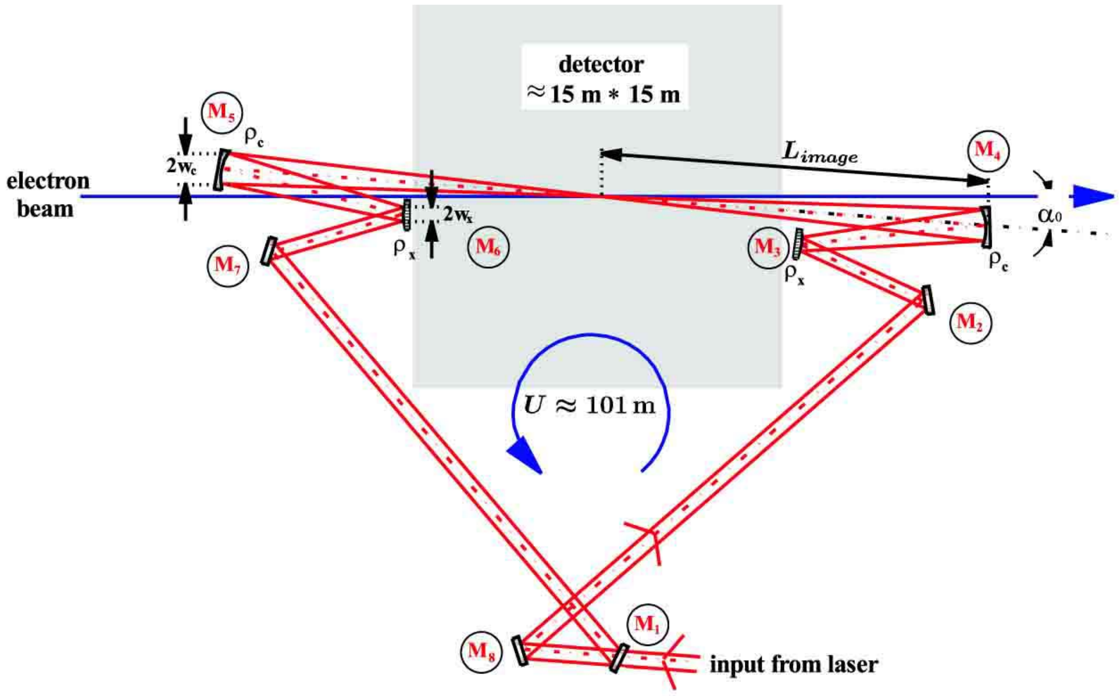
The best is the scheme with accumulation of very powerful laser bunch is an external optical cavity. It allows to decrease the laser power by a factor of Q~100, but even in this case the pumping laser should be very powerful. According to LLNL estimates the cost of the laser is about 10M$ each, photon 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

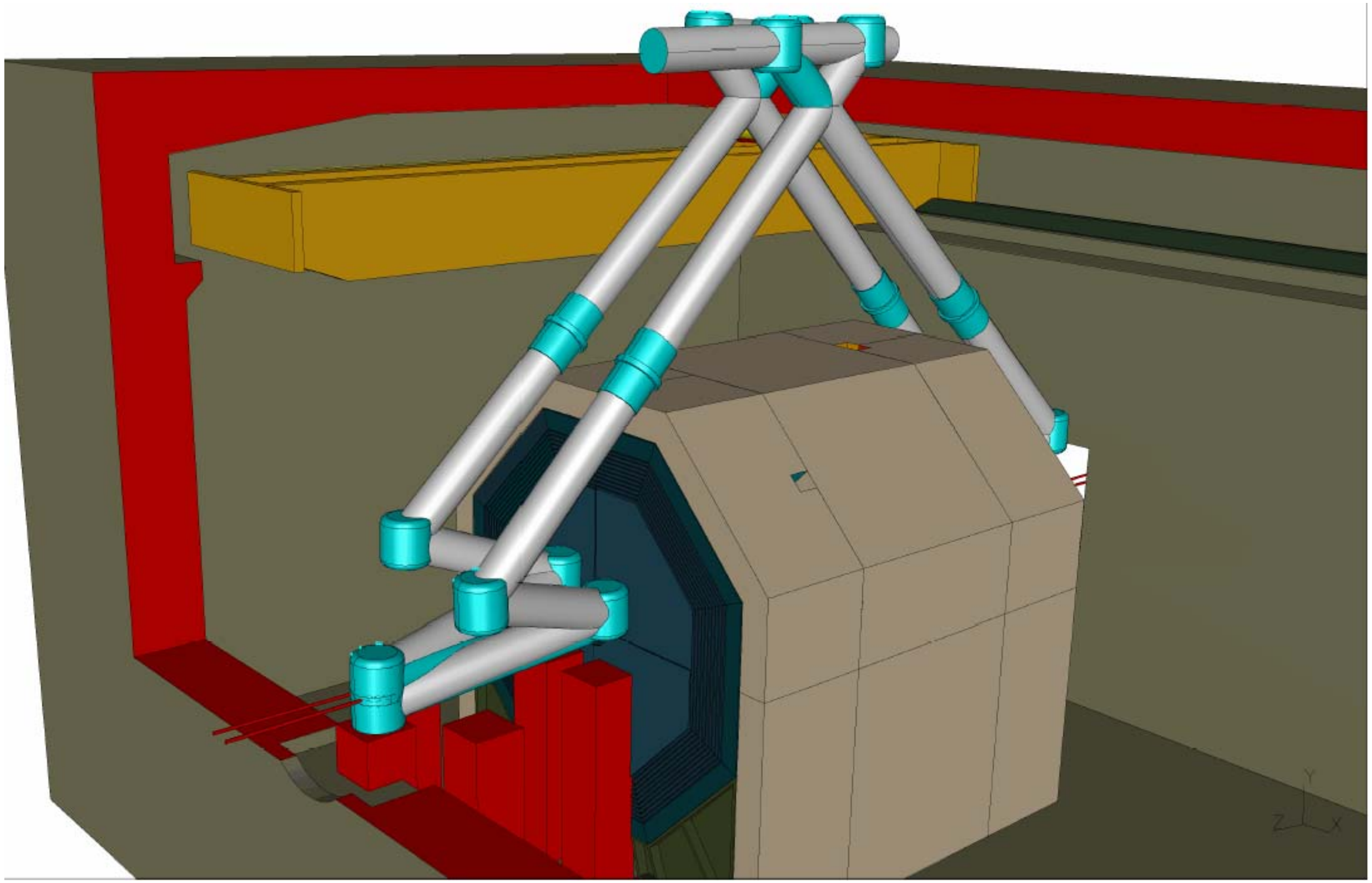
At DESY-Zeuthen optimization was done at the wave level. The cavity was pumped by a truncated Gaussian beam with account of diffraction losses (which are negligibly small).



The next step is a detailed technical consideration of the optical cavity together with laser cavity experts. Desirable to finish a first round by the end of this year.

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

Progress on the Cavity Laser

(A.Finch, Vienna)

D.Miller has found laser experts in UK and planned meeting on 26th October which was postponed. Nevertheless, there is the response:
Mark Oxborrow (National Physical Laboratory,UK) and Ken Strain (Glasgow/LIGO) have given detailed analysis based on Joe Frisch's (SLAC) technical remarks on the optical cavity for the photon collider:
“the optical cavity, per se, would appear to be feasible through the scaling up and refining of existing optical/mechanical technologies”.

There is plan to organize a meeting in the UK to gather laser experts together for a brainstorming meeting.

Next steps on ILC

Baseline Configuration Document: the end of 2005

Reference Design Report, including costs estimates: end of 2006.

All this needs hard work on:

- Accelerator and interaction region aspects of PLC;
- Laser and laser optics;
- Detector aspects (<100 mrad);
- Physics