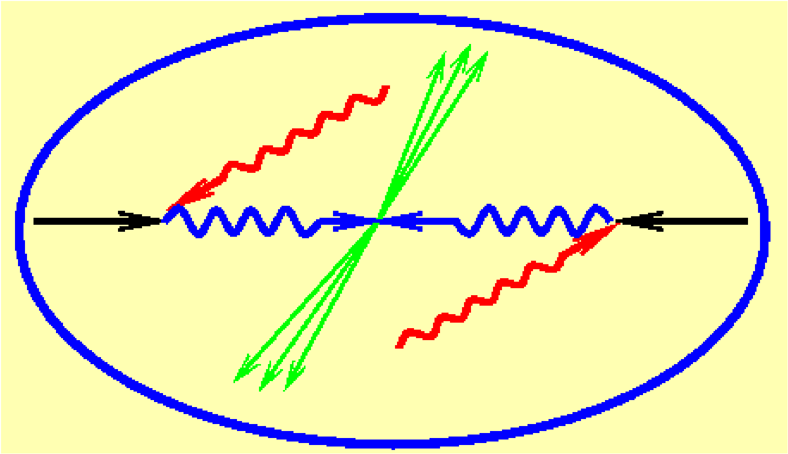

# Layout of the Photon Collider at ILC

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LCWS06, March 9-14, 2006, Bangalore, India

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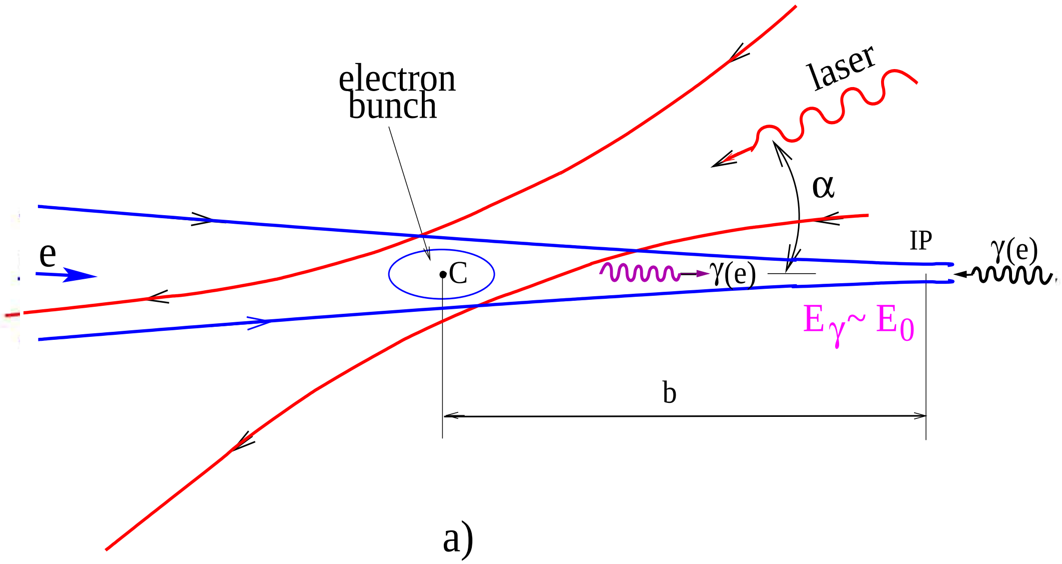
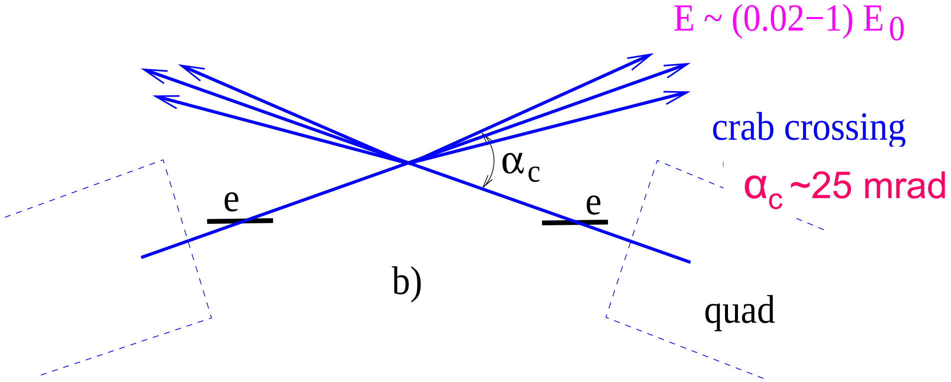
- Crossing angle, IP upgrade.
- Beamdump
- Laser beams path, modification of detector
- Conclusion

# Scheme of $\gamma\gamma$, $\gamma e$ collider



a)



crab crossing

$\alpha_c$ ~25 mrad

b)

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

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

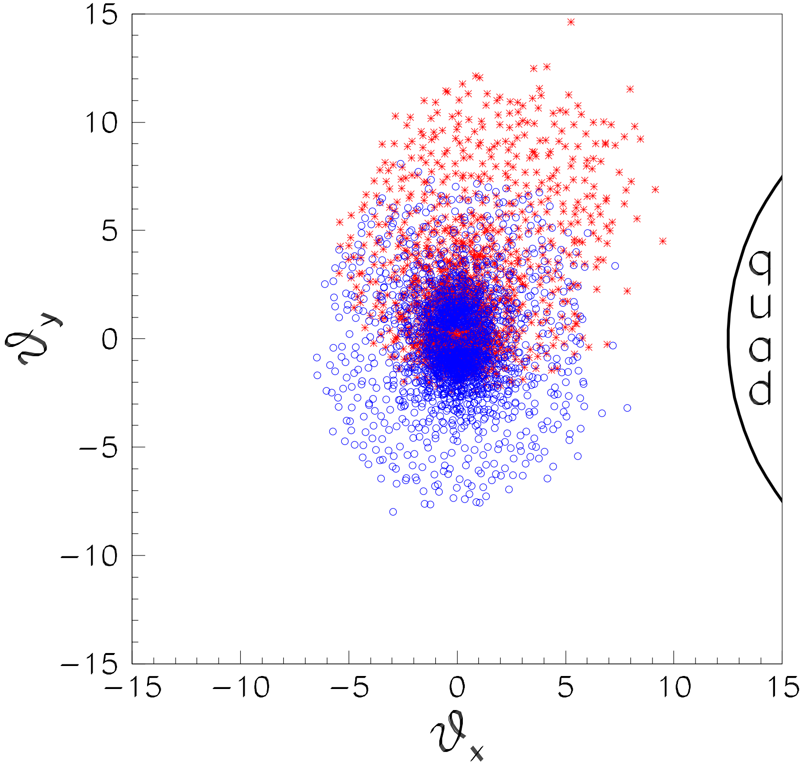
$E_0 = 250$ GeV, $\omega_0 = 1.17$ eV
($\lambda = 1.06$ $\mu$m) $\Rightarrow$
x=4.5, $\omega_m$=0.82$E_0$=205 GeV

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

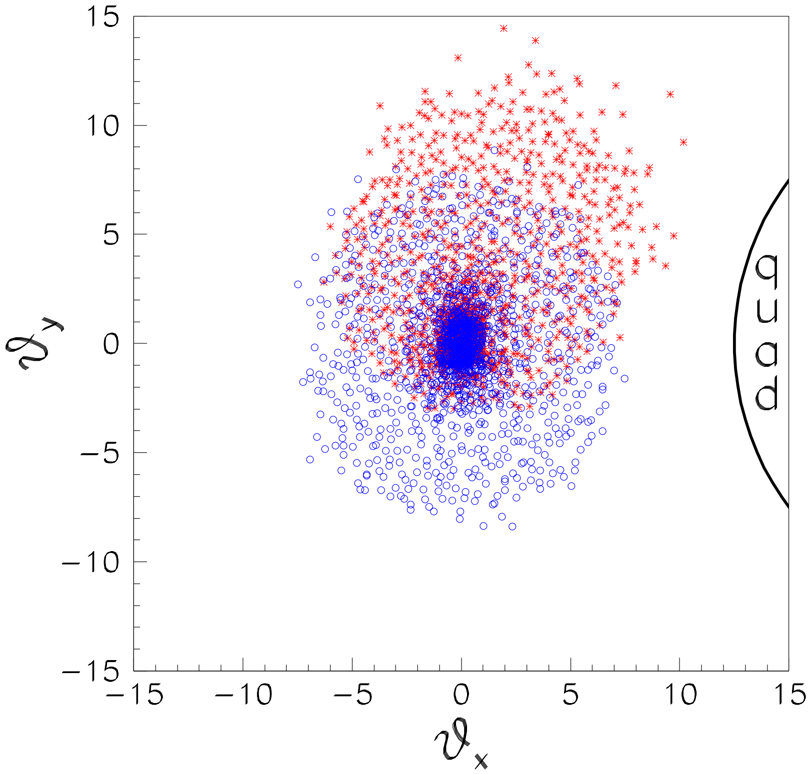
$\omega_{max}$~0.8 $E_0$

$W_{\gamma\gamma,\,max}$ ~ 0.8·2$E_0$
$W_{\gamma e,\,max}$ ~ 0.9·2$E_0$

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



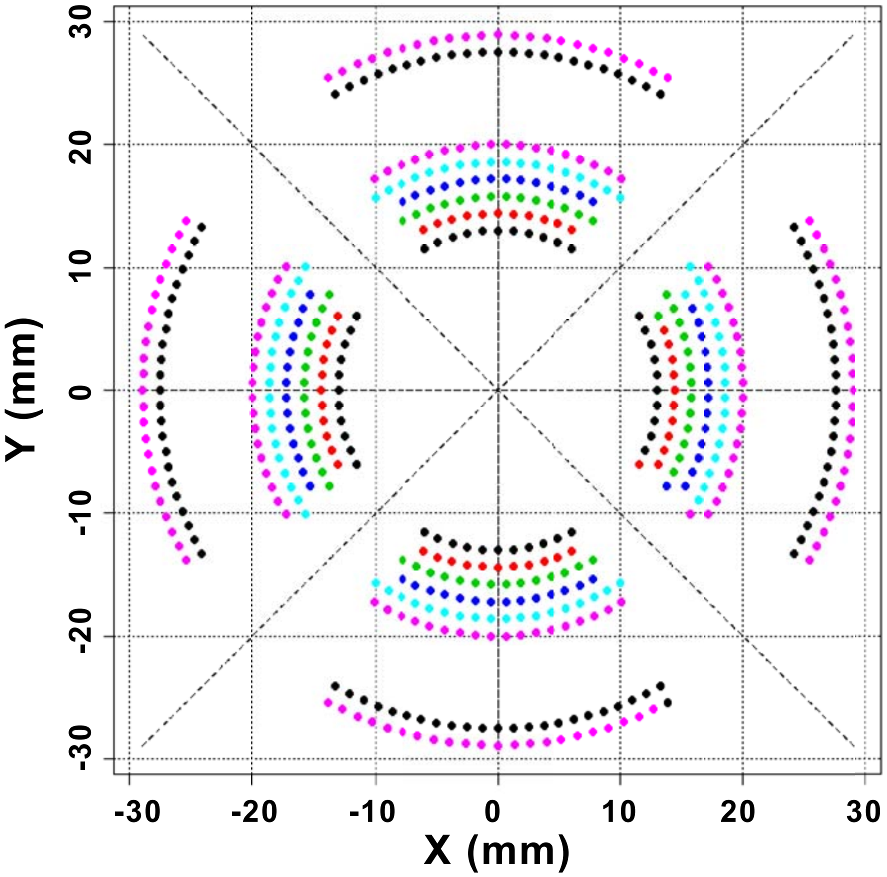
$2E_0$=200 GeV



$2E_0$=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

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

# There are several problem due to crossing angle:

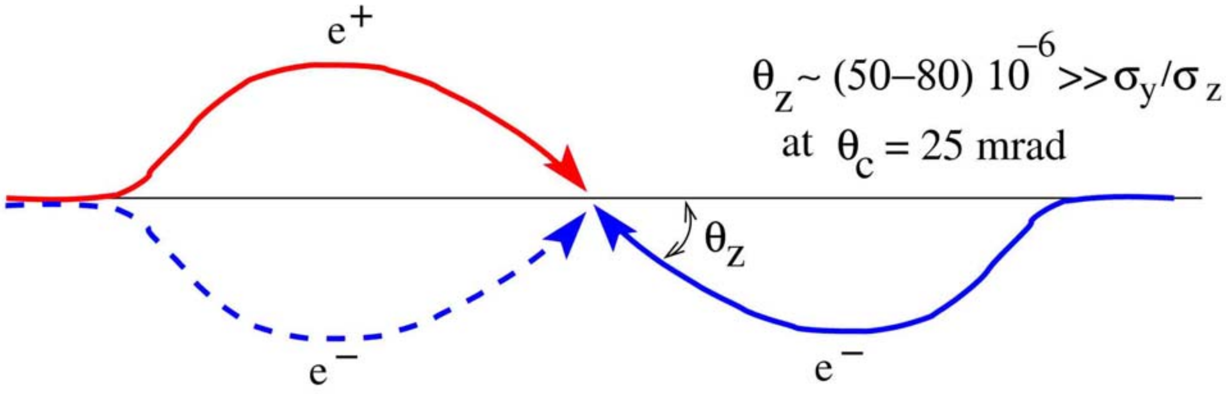
- Due to the detector field $e^-e^-$ beam collide at a non-zero (unacceptably large) vertical collision angle;

- The increase of the vertical beam size due to radiation in the detector field, which depends strongly on $\alpha_c$;

- The “big bend” length depends strongly on the bending angle;

- The additional vertical deflection of low energy particles

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

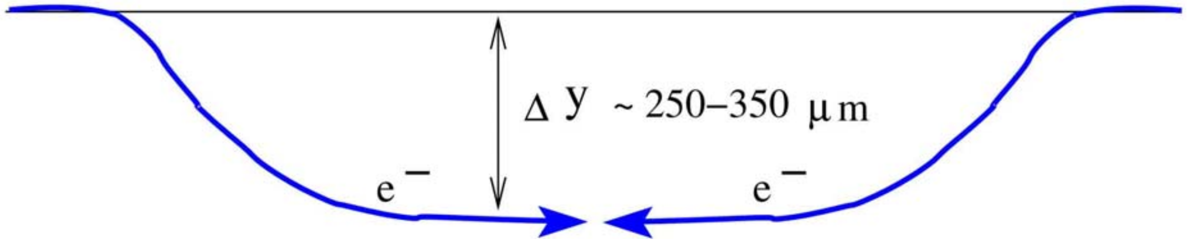


$\theta_z \sim (50\text{–}80)\,10^{-6} \gg \sigma_y/\sigma_z$
at $\theta_c = 25$ mrad

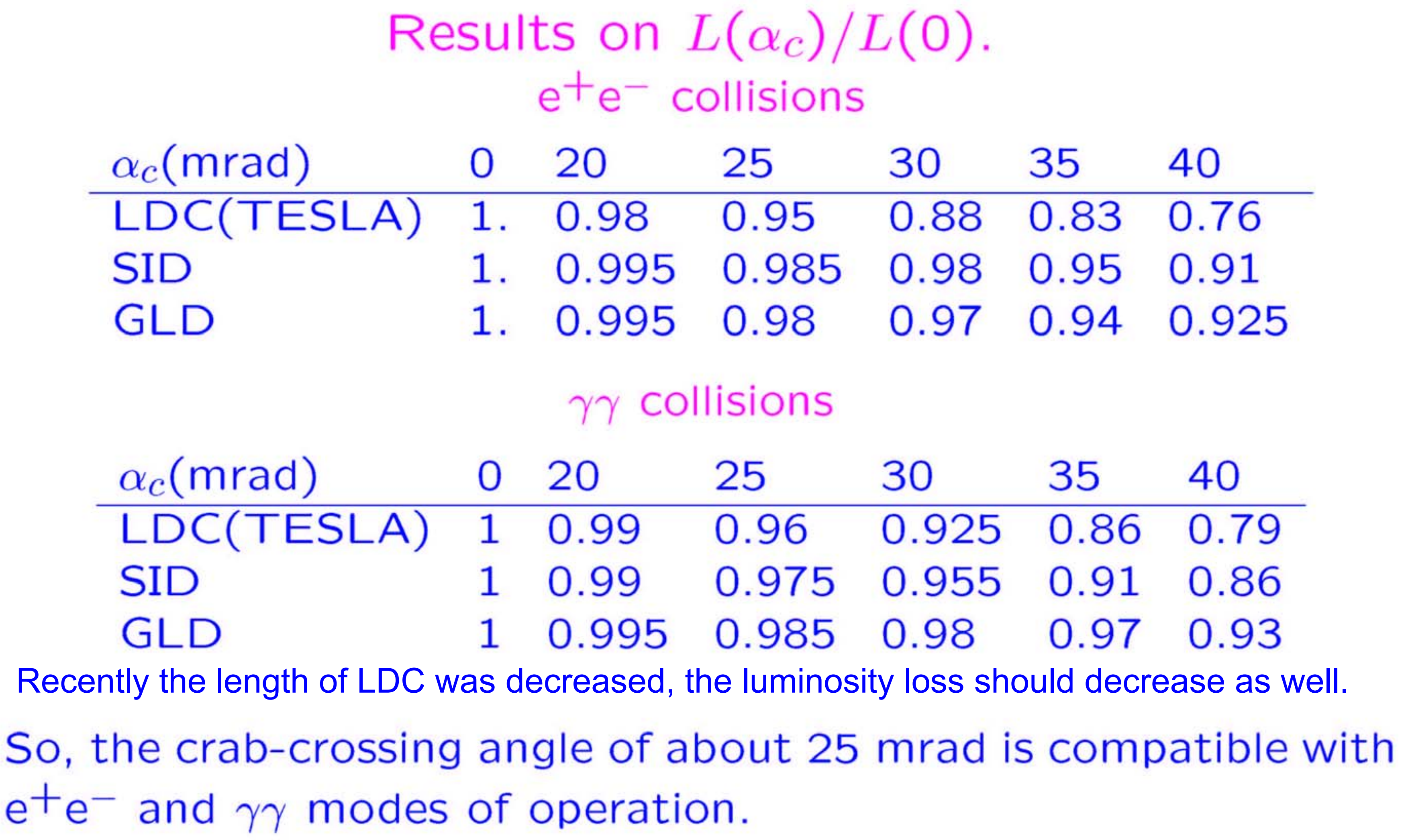
OK for e+e−, but not OK for e−e−(gamma−gamma)

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

(or using correcting dipole coils)



# The increase of the vertical beam size due to SR



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

$e^+e^-$ collisions

| $\alpha_c$(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

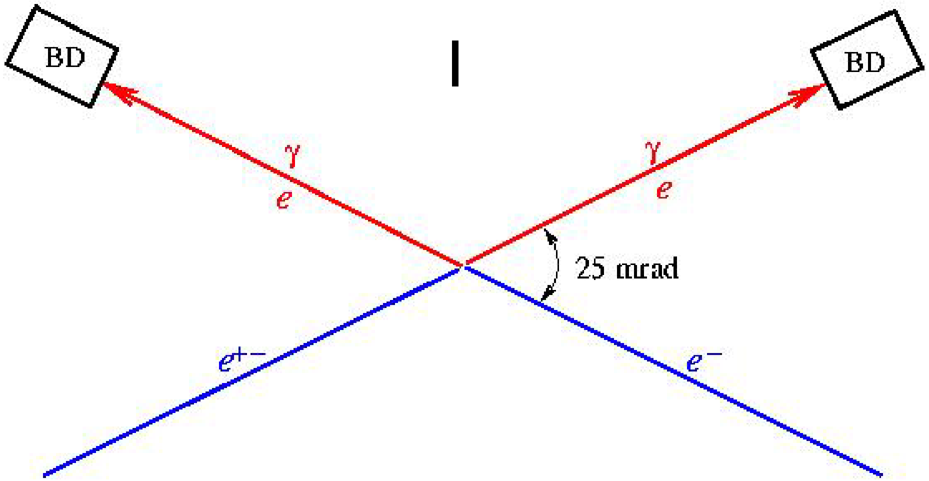
| $\alpha_c$(mrad) | 0 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|
| LDC(TESLA) | 1 | 0.99 | 0.96 | 0.925 | 0.86 | 0.79 |
| SID | 1 | 0.99 | 0.975 | 0.955 | 0.91 | 0.86 |
| GLD | 1 | 0.995 | 0.985 | 0.98 | 0.97 | 0.93 |

Recently the length of LDC was decreased, the luminosity loss should decrease as well.

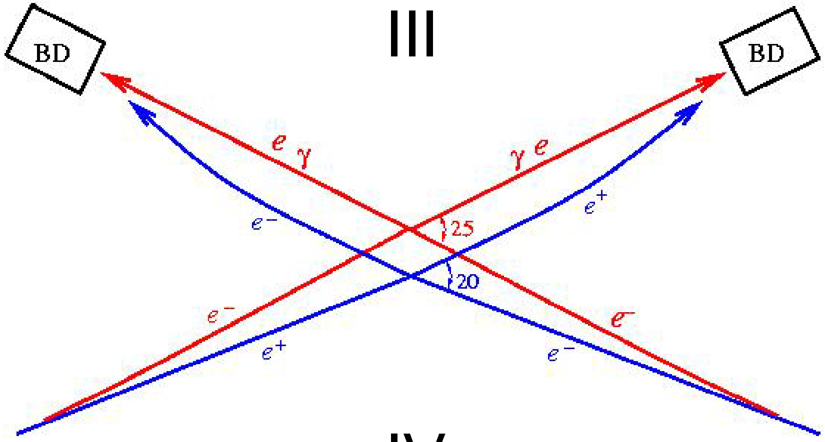
So, the crab-crossing angle of about 25 mrad is compatible with $e^+e^-$ and $\gamma\gamma$ modes of operation.

# IP configurations

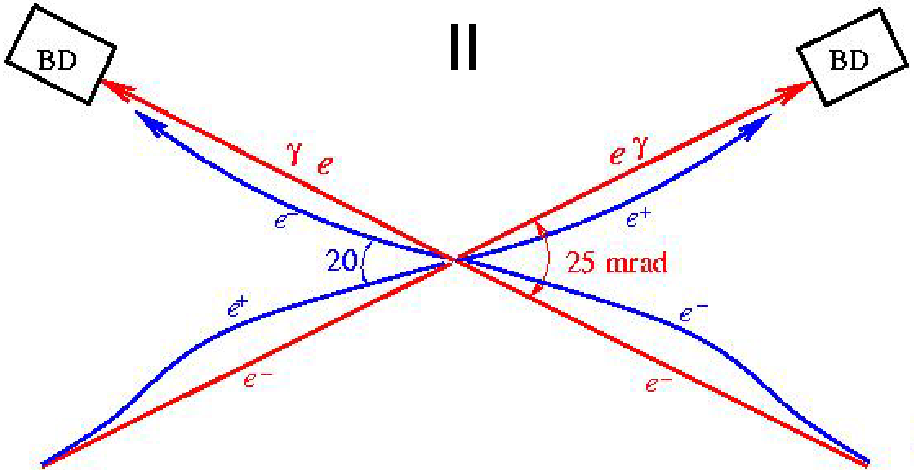
I



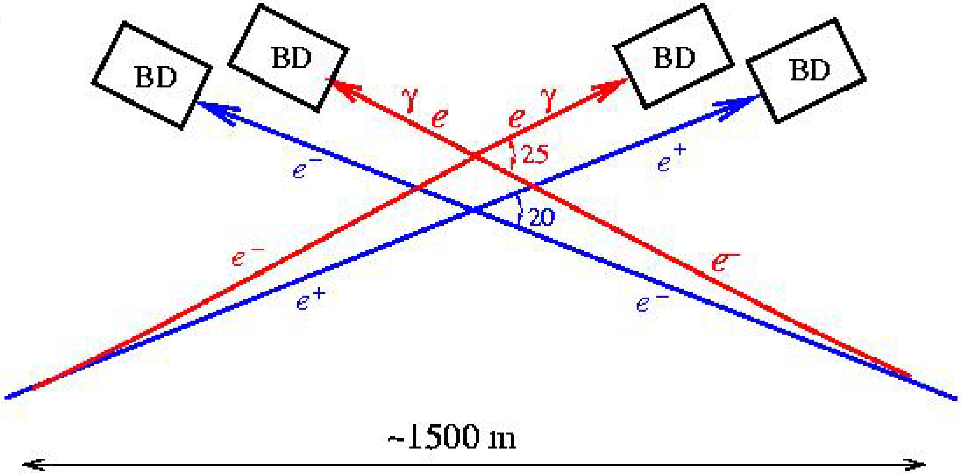
III



II



IV



The scheme 1 is the simplest and cheapest. All the same for e+e- and $\gamma\gamma$ (only smaller $\beta_x$ for $\gamma\gamma$ ). Why not? Because in e+e- there is a special extraction line for measurements of energy and polarization of final particles. Is it really needed? This requirement restrict the parameter space of the ILC. At CLIC such preciscion measurements will be impossible. In the $\gamma\gamma$ extraction line it will be possible to measure only beams profiles. May be it is sufficient for the cross check of the ILC beam parameters and adjustment of simulation?

At present the scheme IV is considered for ILC. Technically it looks OK and reasonable. But the upgrade will take a lot of time and additional resources, is it corrects? Time is especially critical in the case of one IP.

In my opinion, the best would two IPs with one of them for e+e- and $\gamma\gamma$ with minimum modification.

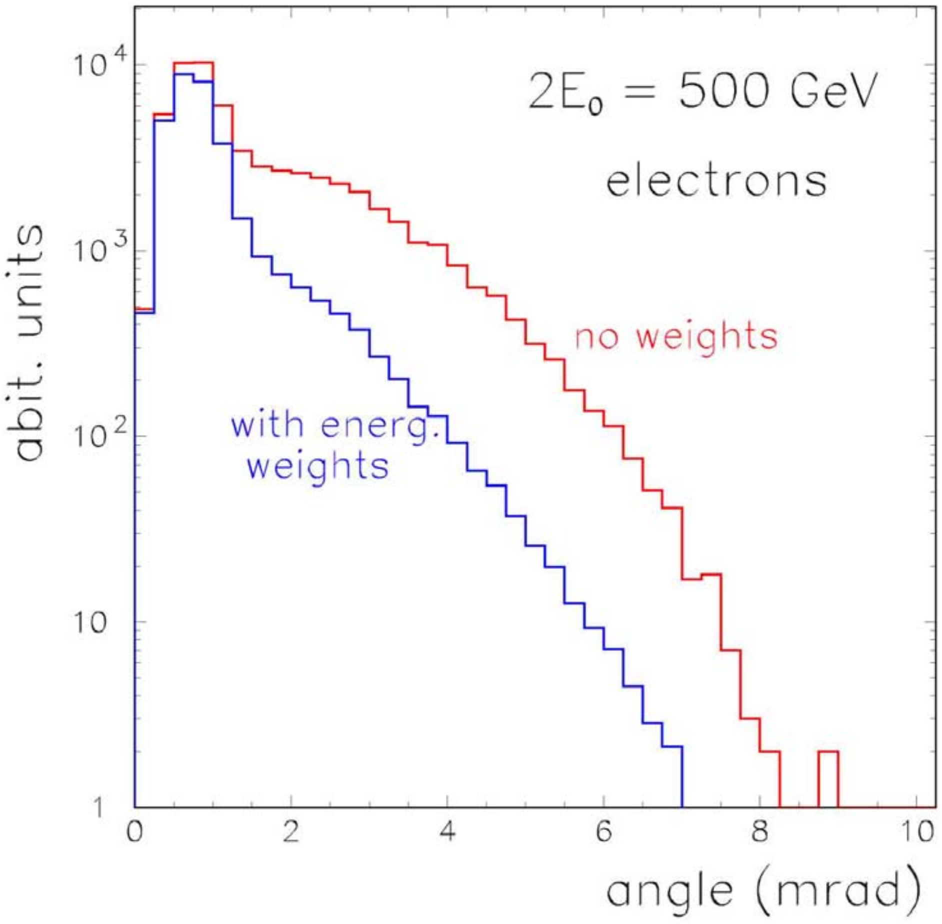
# Beam dump

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.
3. Compton photons with angles $\sigma_{\theta x} \sim 4\cdot10^{-5}$ rad, $\sigma_{\theta y} \sim 1.5\cdot10^{-5}$ rad, that is 1 x 0.35 $\text{cm}^2$ at the distance 250 m.

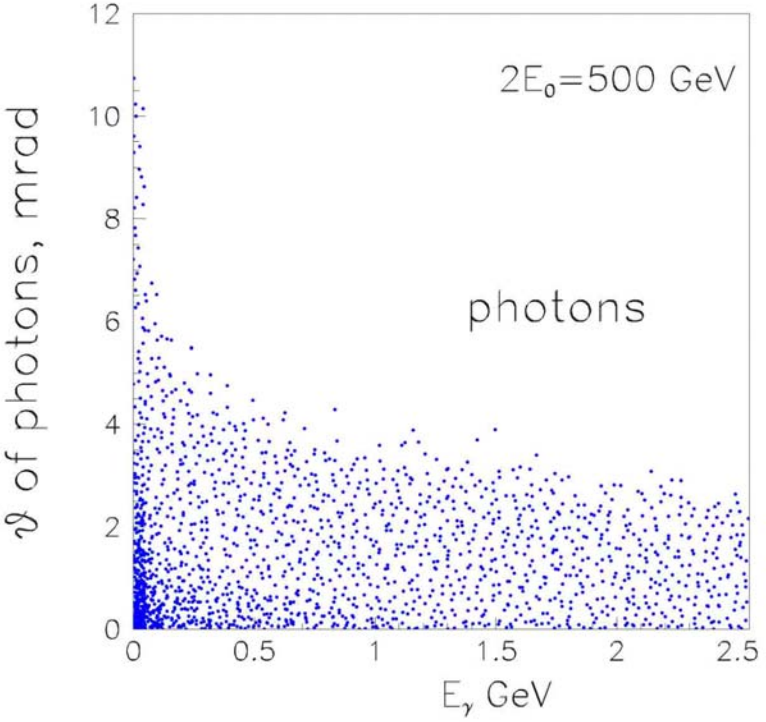
# The angular distribution of electrons

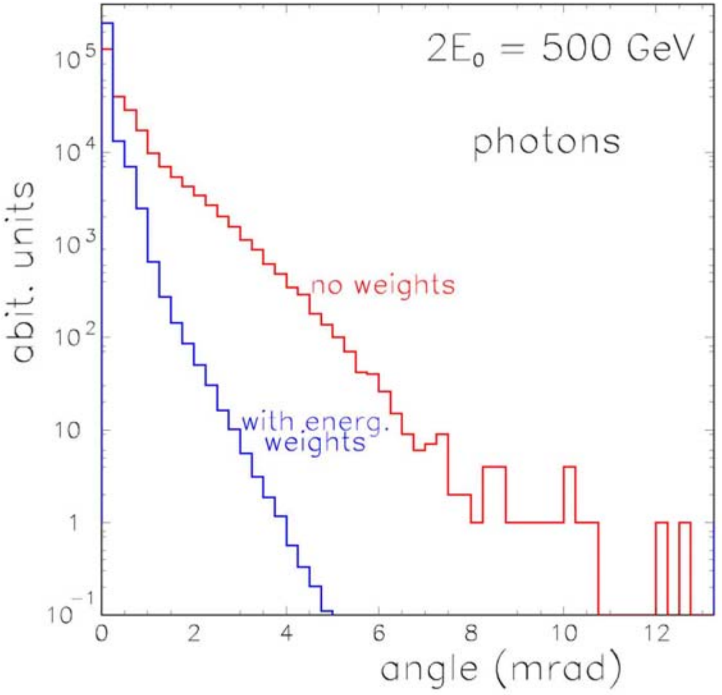


If the beam dump is situated at L=250 m, than for particles with θ=7 mrad r~1.8 m, too much. Some focusing of electrons will be useful in order to decrease the radius of the tube and to reduce the energy deposition (rad. activation on the way to the beam dump).

# Angular distribution of beamstrahlung photons

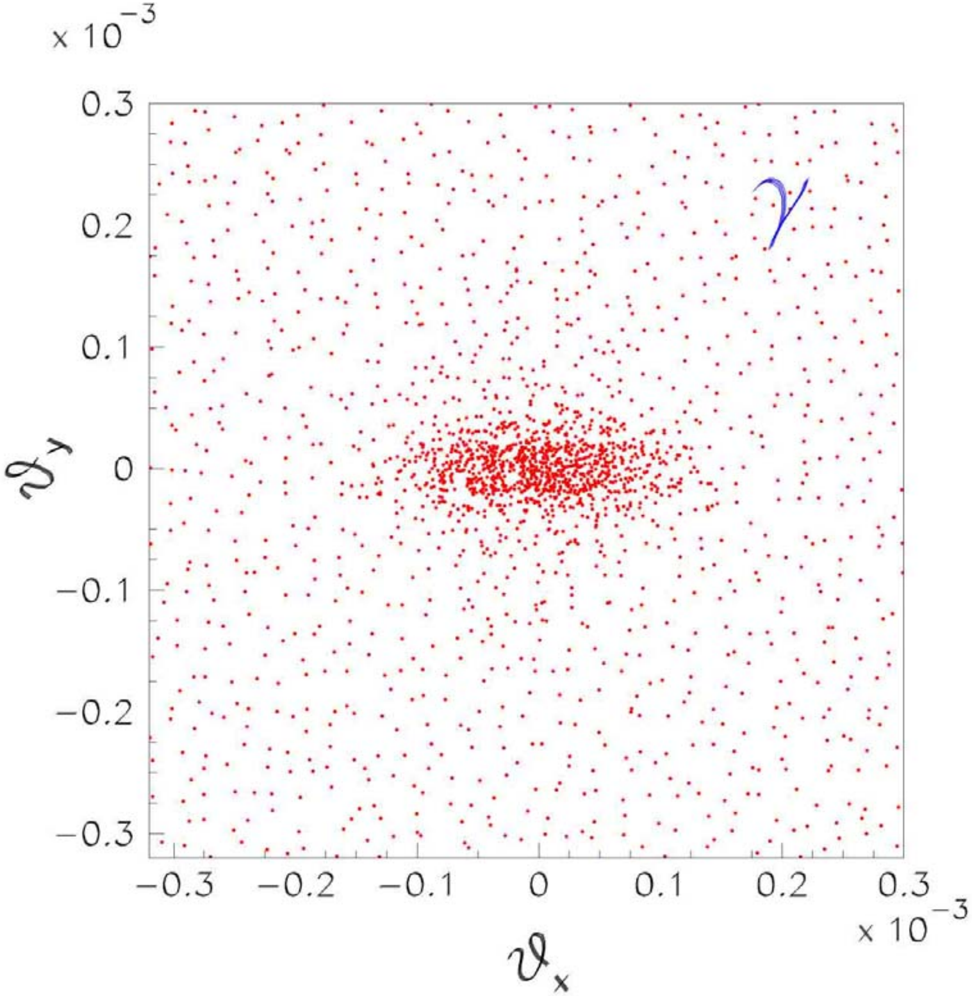
Large angle photons are radiated by low energy electrons, therefore they are soft





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

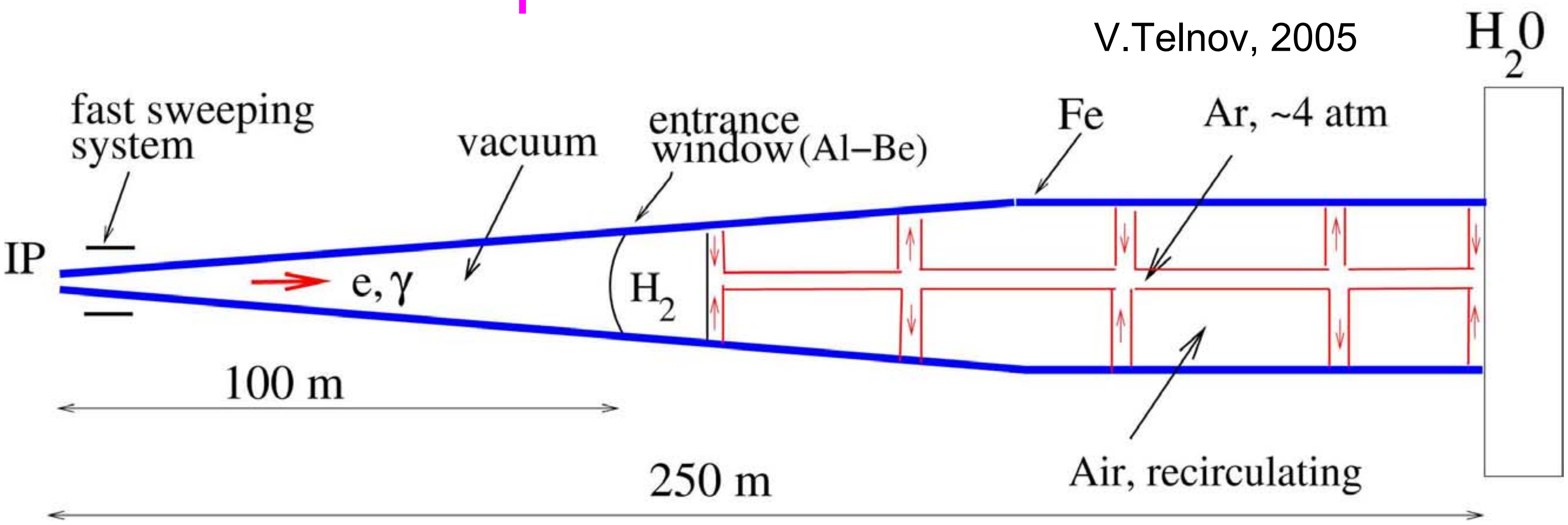
# Compton photons



March 9-14, 2006

# 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.

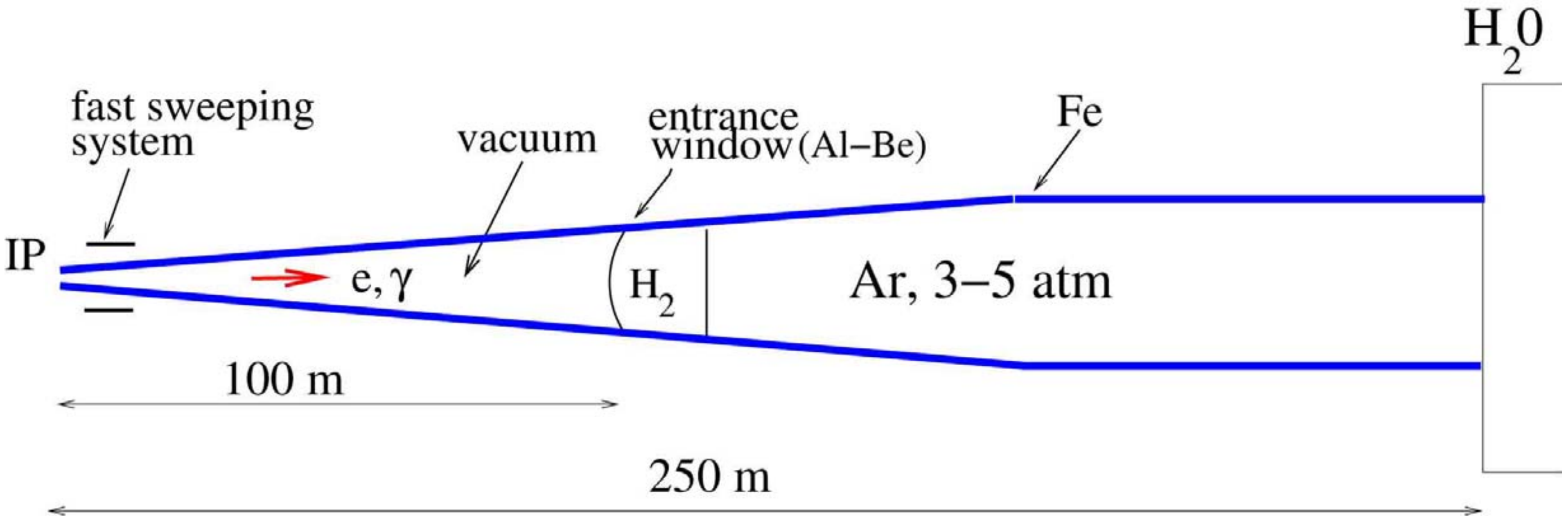
The volume with $H_2$ in front of the gas converter serves for reducing the flux of backward neutrons (simulation gives, at least, factor of 10).

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

Needs detailed technical consideration!

# Previous scheme (simulated)

Telnov, Shekhtman
LCWS04, physics/0411253



Max. ΔT in water after one train at 250 GeV photons is 75,50,25 at Ar pressure 3,4,5 atm. ΔT at entrance window is about 40º C.

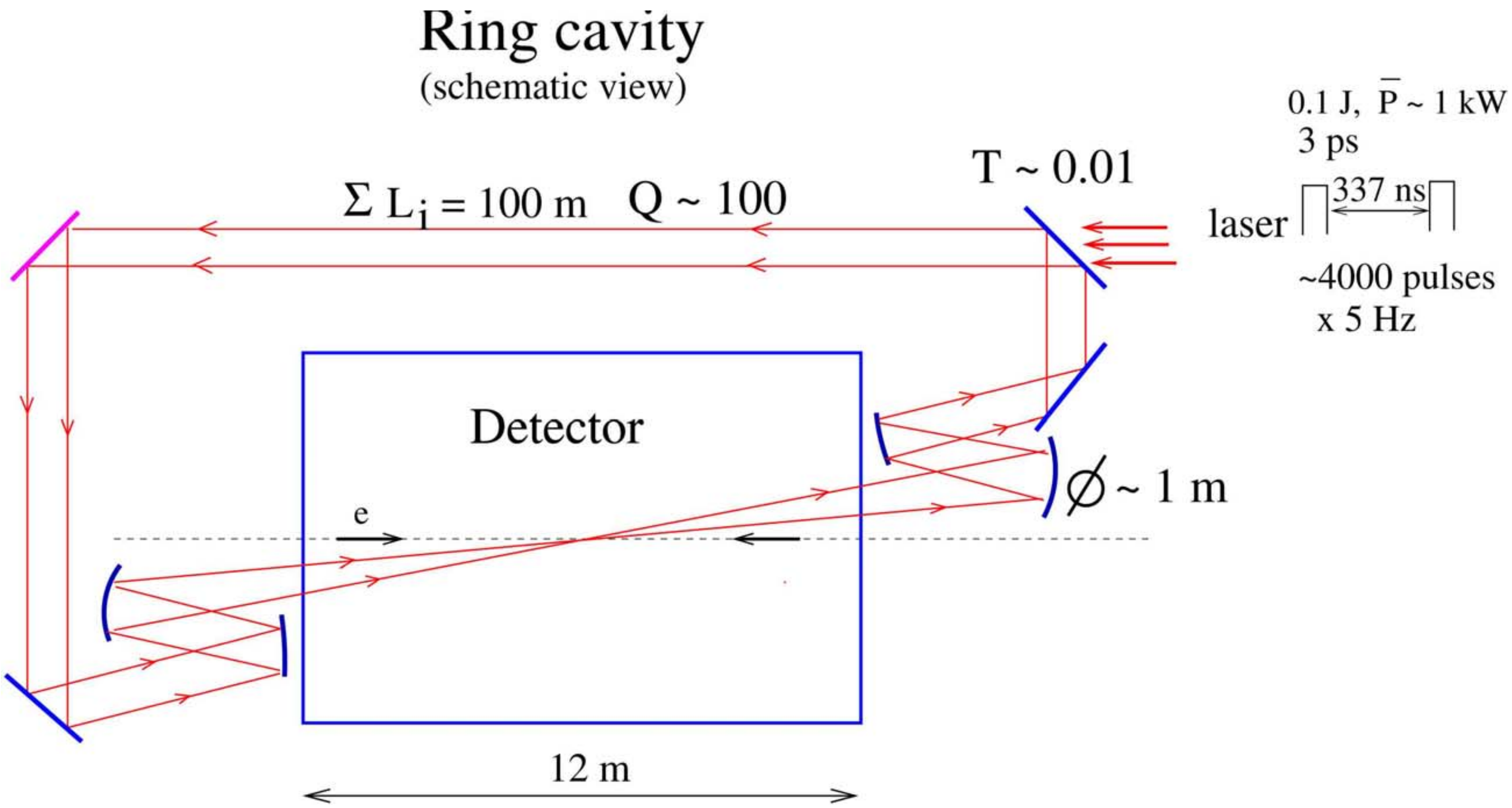
Flux of neutrons at IP is 1.5 $10^{11}$ n for $10^7$ s.
$H_2$ in front reduces the flux at least by a factor of 10!

# 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

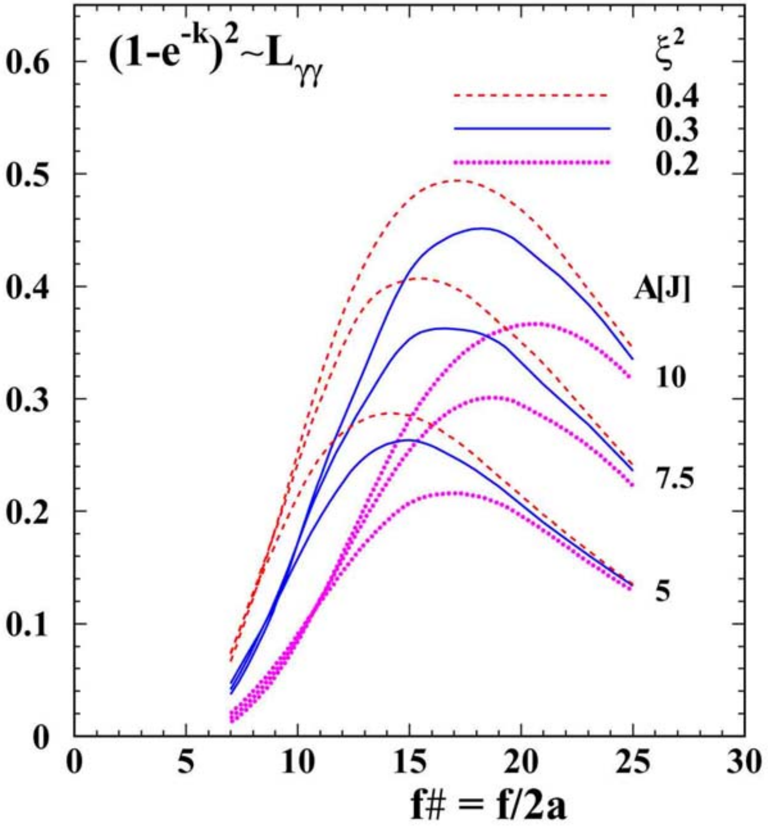


The cavity includes adaptive mirrors and diagnostics. The required tolerances are small, but in gravitation detectors they are $10^9$ times smaller.

# 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.



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

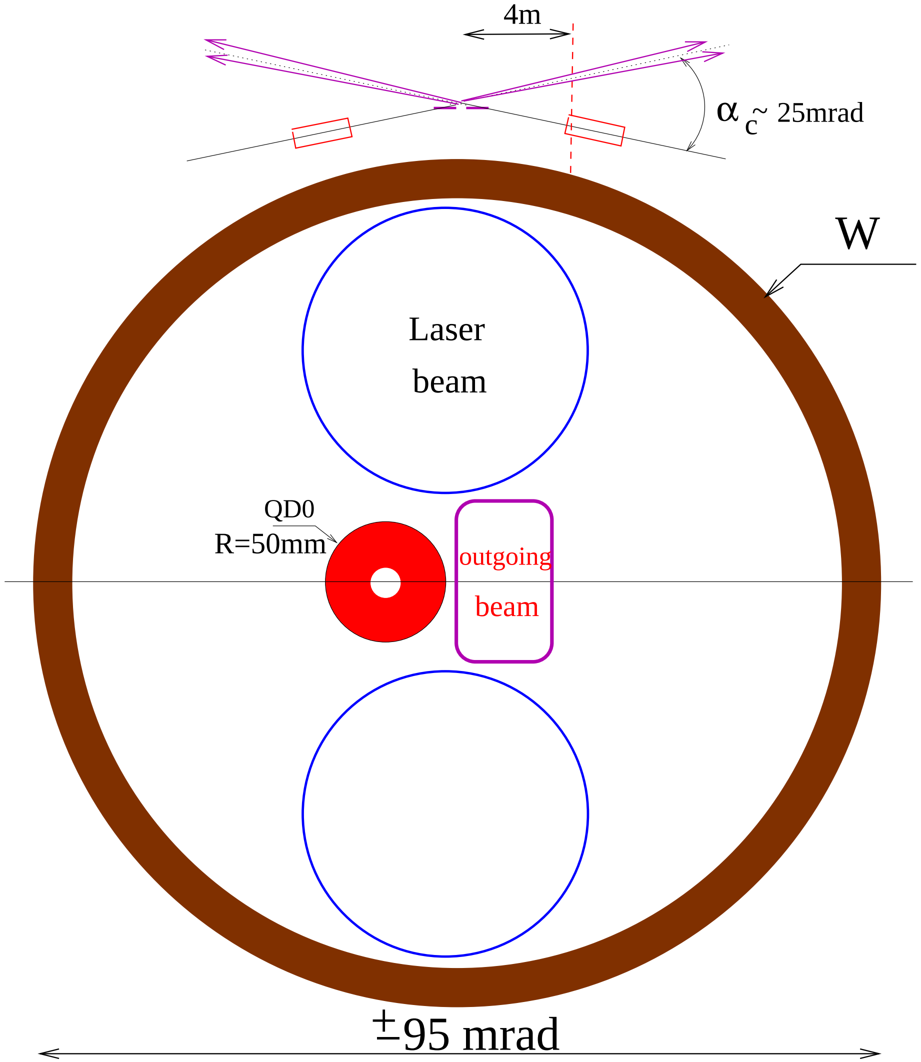
characterizes the probability of Compton scattering on several laser photons simultaneously, it should be kept below 0.2-0.4, depending on the energy (par. x)

For ILC beams, $\alpha_c$=25 mrad, and $\theta_{min}$=17 mrad (see fig. with the quad) the optimum $f_\# \approx 17$, A≈9 J (k=1), $\sigma_t \approx 1.3$ ps, $\sigma_{x,L} \sim 7$ μm.

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

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

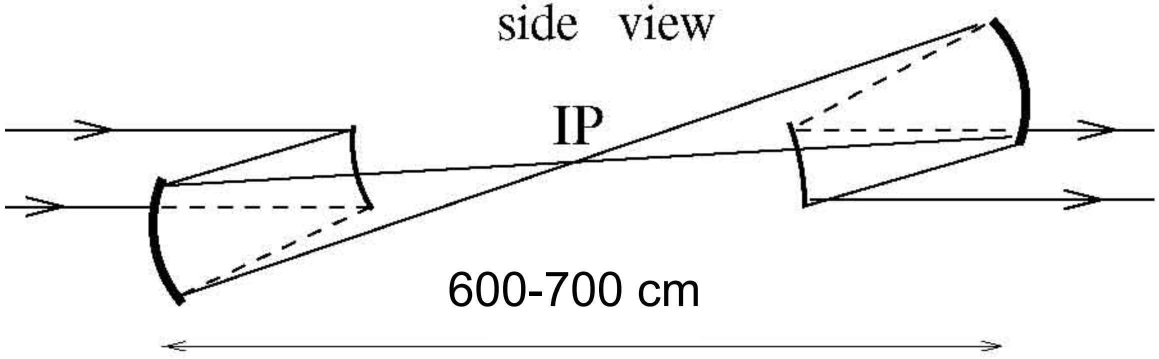
# Layout of the quad, electron and laser beams at the distance 4 m from the interaction point (IP)



# 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.

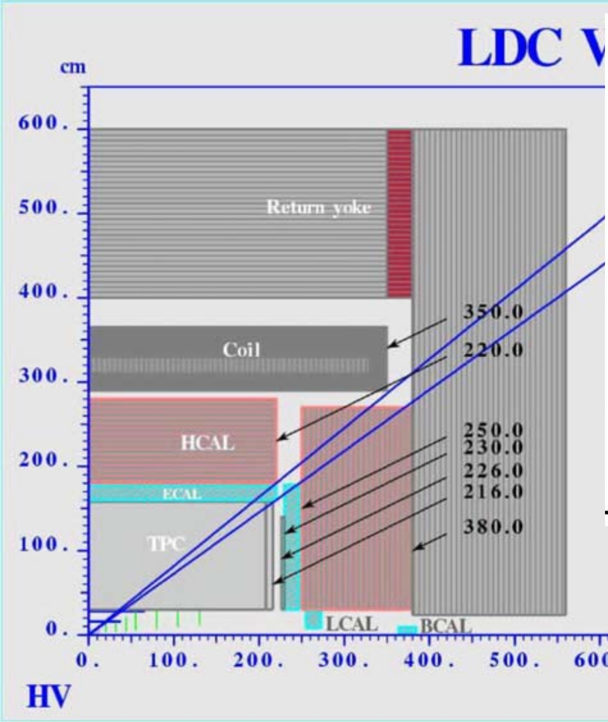
Possible solution: pairs of mirrors inside the detector as was assumed in TESLA TDR



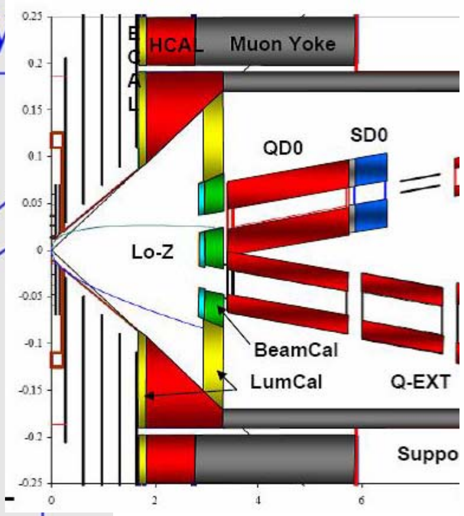
Then the diameter of focusing mirror is about 20 cm and that of the auxiliary mirror about 11 cm. The dead angle for tracking remains as before about ±95 mrad, for calorimetry smaller. The laser density is far from the damage threshold, the average power is the most serious problem.

# Open angle in detectors

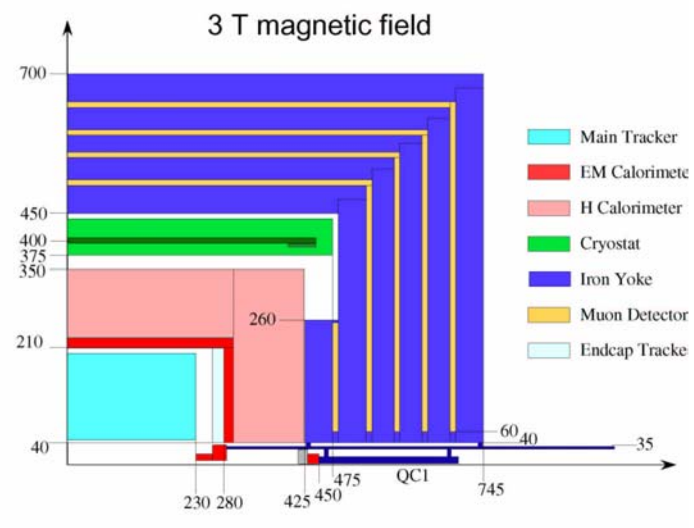
LDC



SID



GLD



θ=±45 mrad

±33 mrad

±50 mrad

# Conclusion

- The photon collider needs the crossing angle about 25 mrad. It is compatible with e+e-.
- Beamdumps for e+e- and $\gamma\gamma$ are very differerent now. In principle, $\gamma\gamma$ beamdump is OK for e+e-, if precision diagnostic is not required. Is it really necessary? A detailed consideration of the $\gamma\gamma$ beamdump is needed.
- Two IP with one of them for e+e- and $\gamma\gamma$ without serious modification would be the best choice. The suggested upgrade pass from 14 or 20 mrad looks technically reasonable, but increases the ILC cost and needs long time for modifications (may be not once).
- The layout of the laser optics in the detector is still under question. It needs consultations with detector people and laser experts.