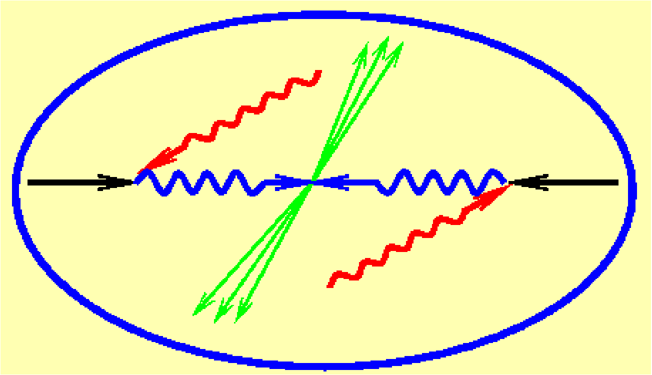

Crossing angle and beamdump at PLC

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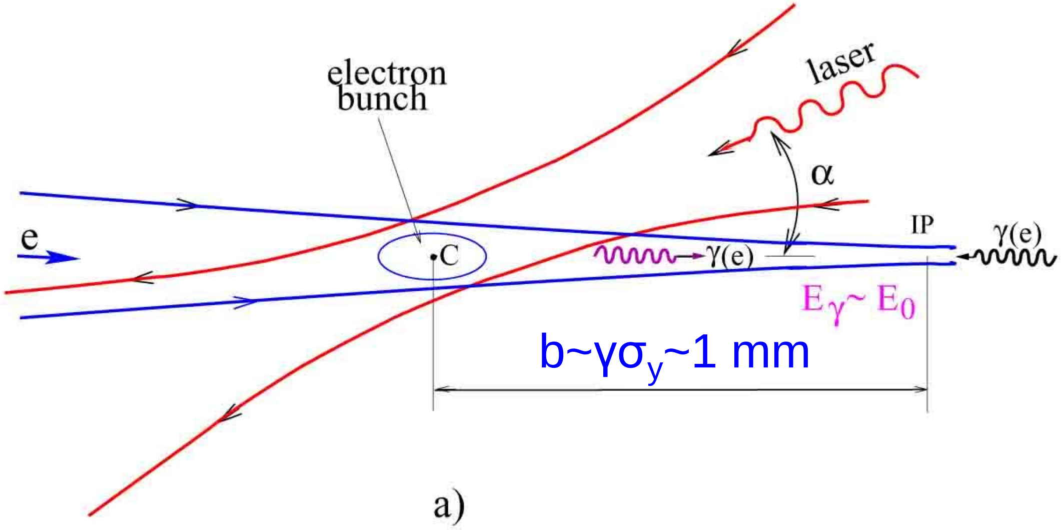
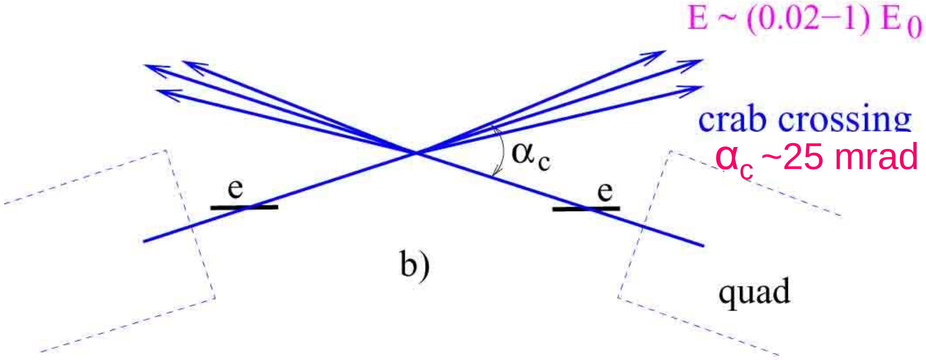
Scheme of $\gamma\gamma$, γe collider





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

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

$E_0 = 250$ GeV, $\omega_0 = 1.17$ eV
($\lambda = 1.06\ \mu$m) ⇒
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

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

PLC requirements to the ILC design

1. For removal of the disrupted beams the crossing angle should be about 25 mrad.

2. The $\gamma\gamma$ luminosity is proportional to the geometric e-e- luminosity, therefore the product of horizontal and vertical emittances and beta-functions at the IP should be as small as possible.

3. Wide disrupted beam should be transported to the beamdump with acceptable losses; the beamdump should withstand absorption of very narrow photon beam after Compton scattering.

4. PLC needs the room near the IP for the laser system and space for the optics around the detector.

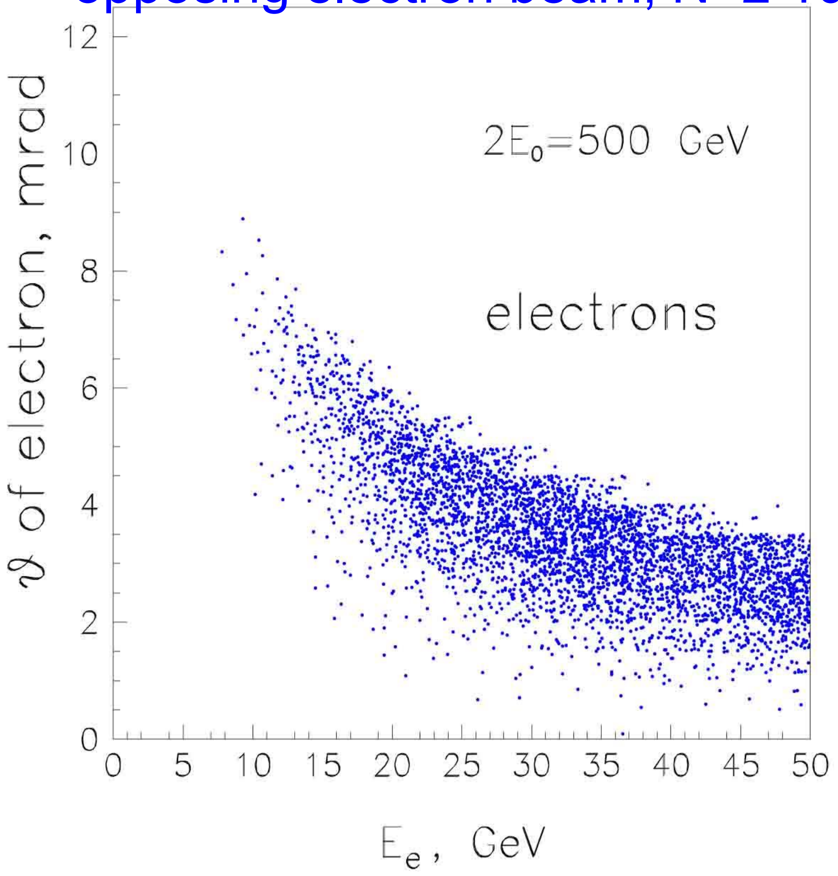
5. The detector design should allow replacement of elements in the forward region (<100 mrad).

Some of these aspects strongly influence the ILC geometry and should be foreseen in ILC design from the very beginning.

Crossing angle

Properties of the beams after CP,IP

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



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

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

An additional deflection ~2-4 mrad (x-y) adds the detector field

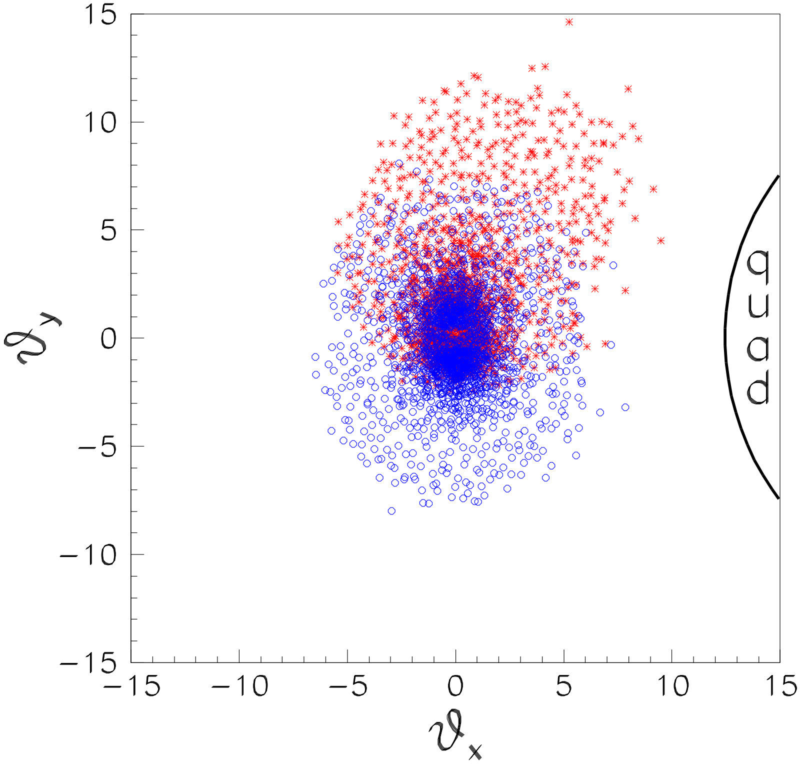
ω_0 – laser photon energy

$E_{min} \sim E_0/(nx+1) \sim m^2/4\omega_0 n$

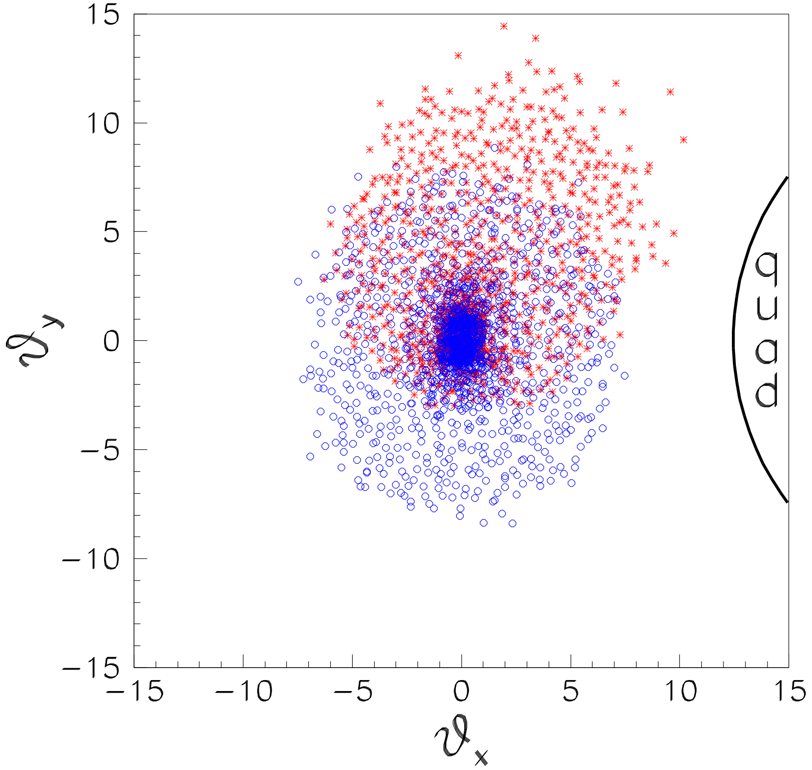
n - number of Compton scattering (up to n~10)

In all considerations we assume λ~1 μm, shorter wavelength – larger disruption angles

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



$2E_0$=200 GeV



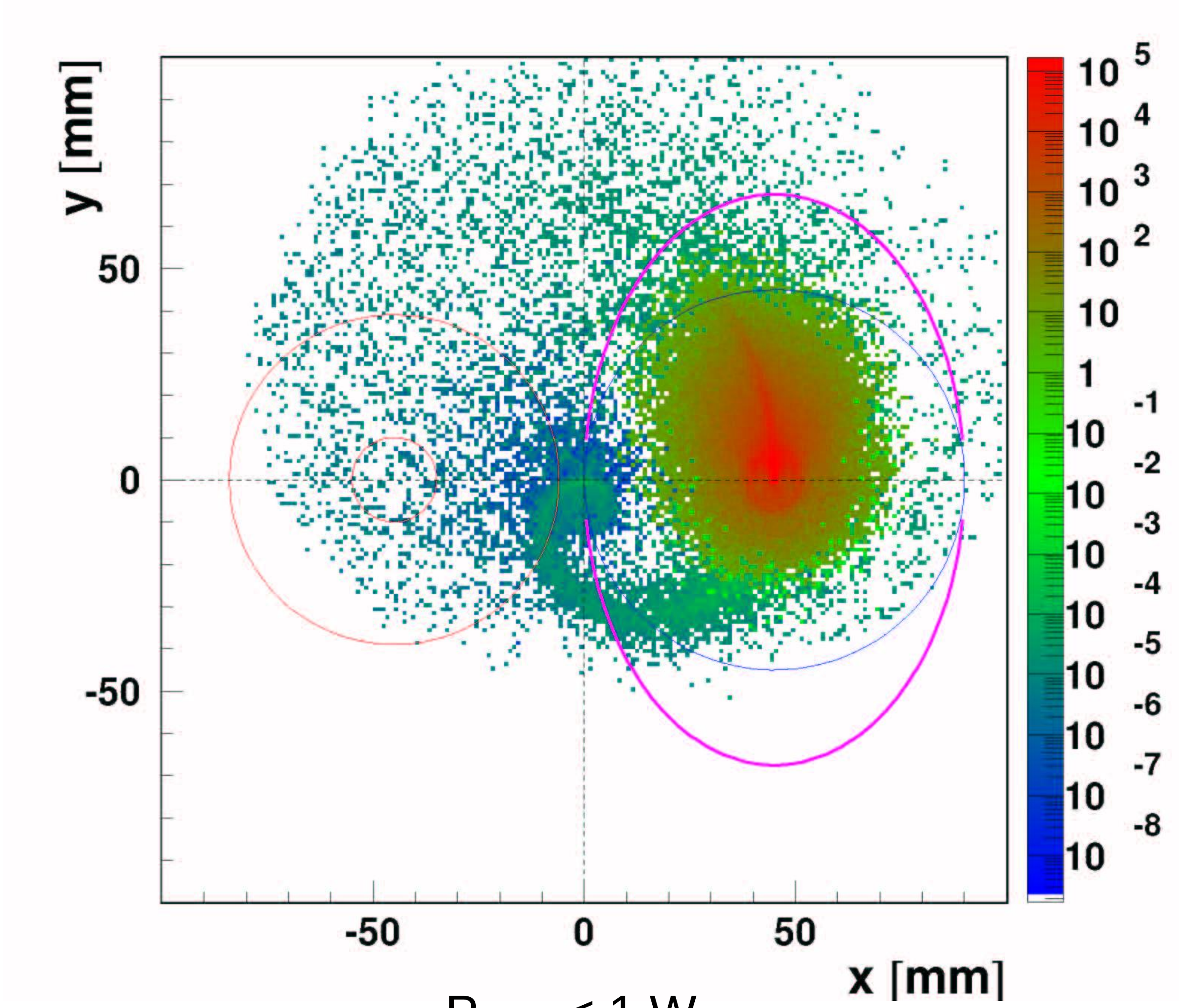
$2E_0$=500 GeV

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

Same with account of secondary e+e- pairs

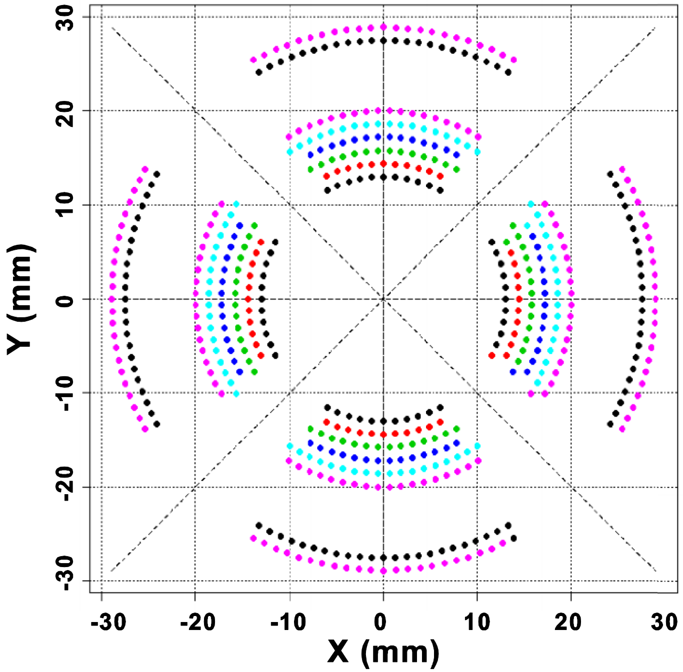
at L=4.5 m

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.



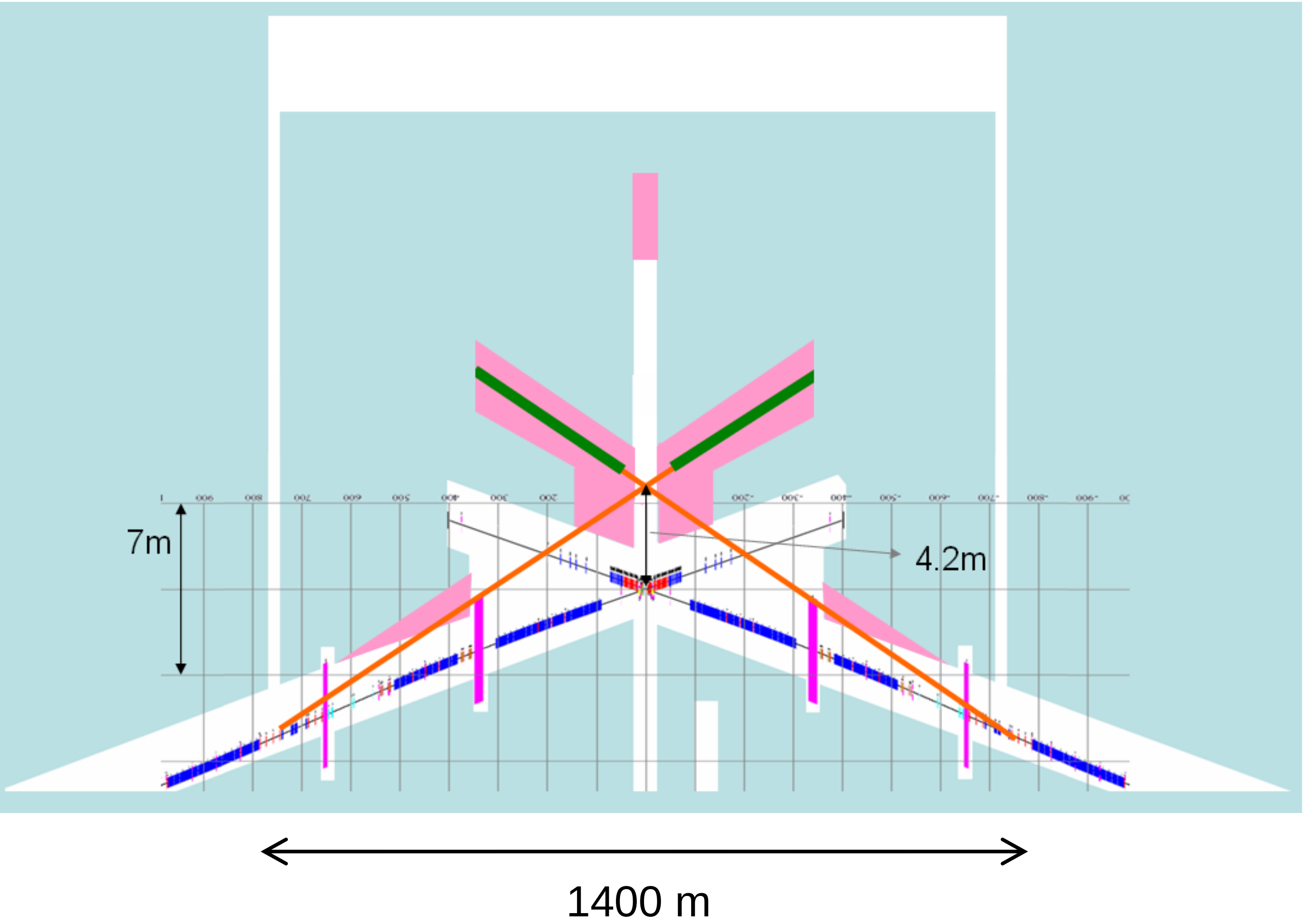
$$\alpha_c = (5/400)*1000(\text{quad}) + 12.5(\text{beam}) \sim 25 \text{ mrad}$$

So, 25 mrad is a very reasonable and justified choice for the PLC.
It is larger than in e+e- case (14 mrad) due to disruption angles and lower energies.

14mr => 25mr

Old scheme

A.Seryi, LCWS06



additional angle is 5.5mrad and detector needs to be moves by about 4.2m and 1.4 km of beamlines + separate beam dump

The above suggestion for PLC was not included to the ILC Reference and Technical Designs just because GDR considered only the baseline e+e- collider.

At present stage one should more seriously consider the ILC design and the problem of the crossing angle.

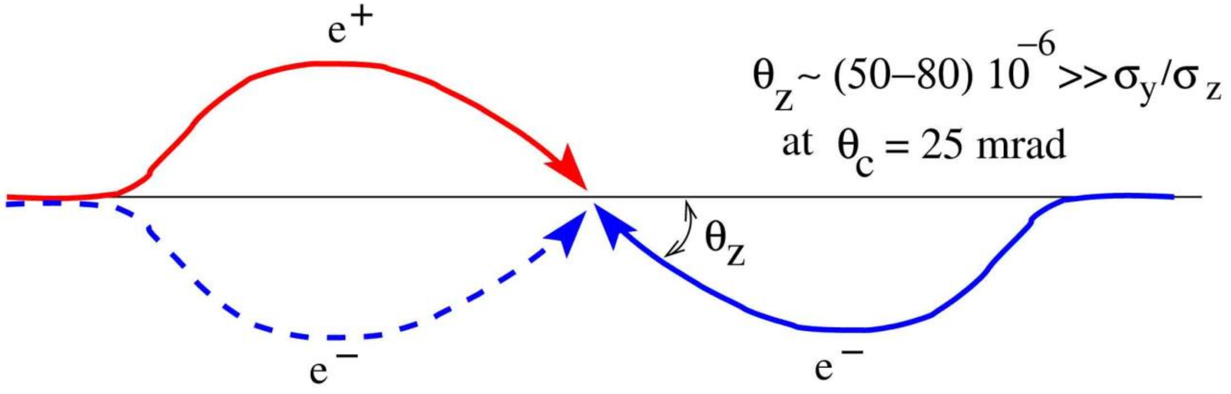
Why 14 mrad? Just because it was the minimum possible angle for the ILC. But CLIC has the crossing angle 20 mrad, it is needed for removal of disrupted beams. It is not excluded that the ILC tunnel will be used later for some more high energy collider.

Can we use the same angle ~ 20-25 mrad both for e+e- and $\gamma\gamma$?
It is a cheapest solution. One has to replace only ~200 m of the beam dump line.

What are limitations on the value of the crossing angle?

Let us consider consequences of the non-zero crossing angle and limitations.

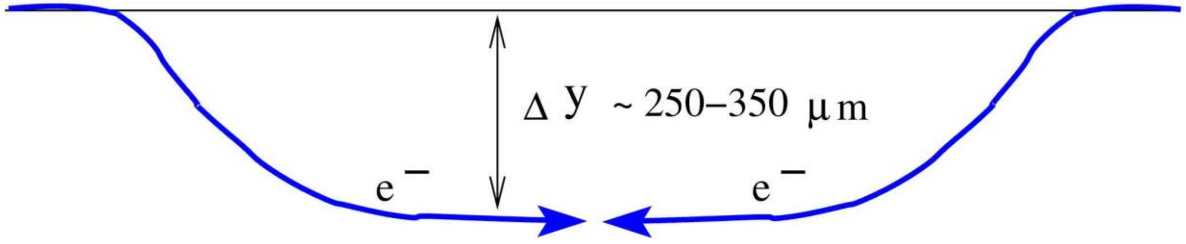
Trajectories in the detector field at $\alpha_c \neq 0$



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

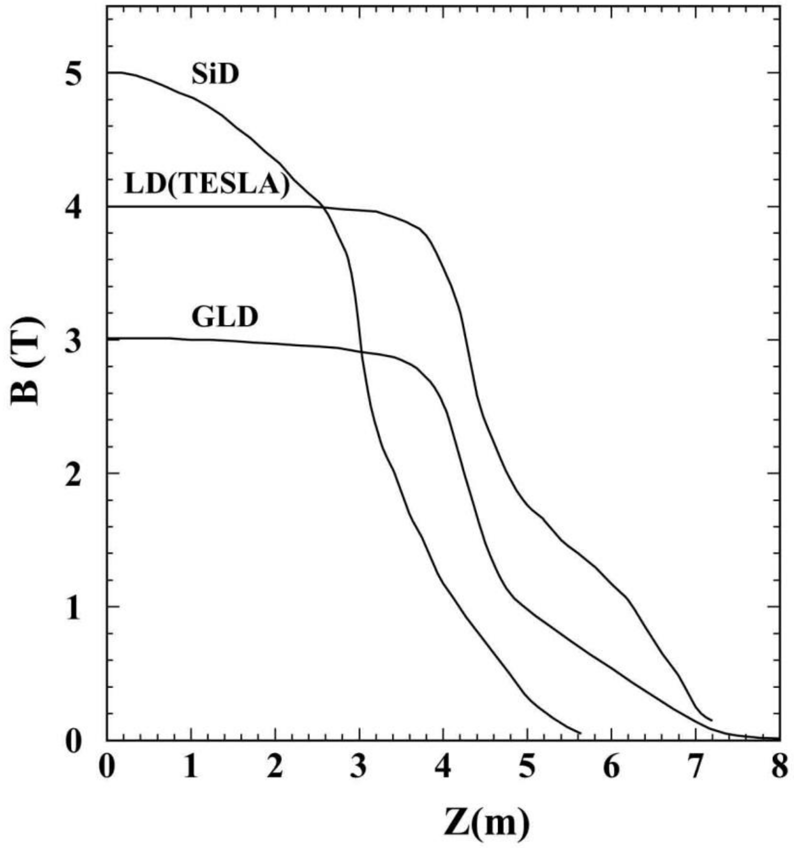
Vertical shifts of final qurds helps for e−e−($\gamma\gamma$)

(or using correcting dipole coils)



Increase of σ_y due to SR

Detector field at the axis



(Field on Jan.2005)

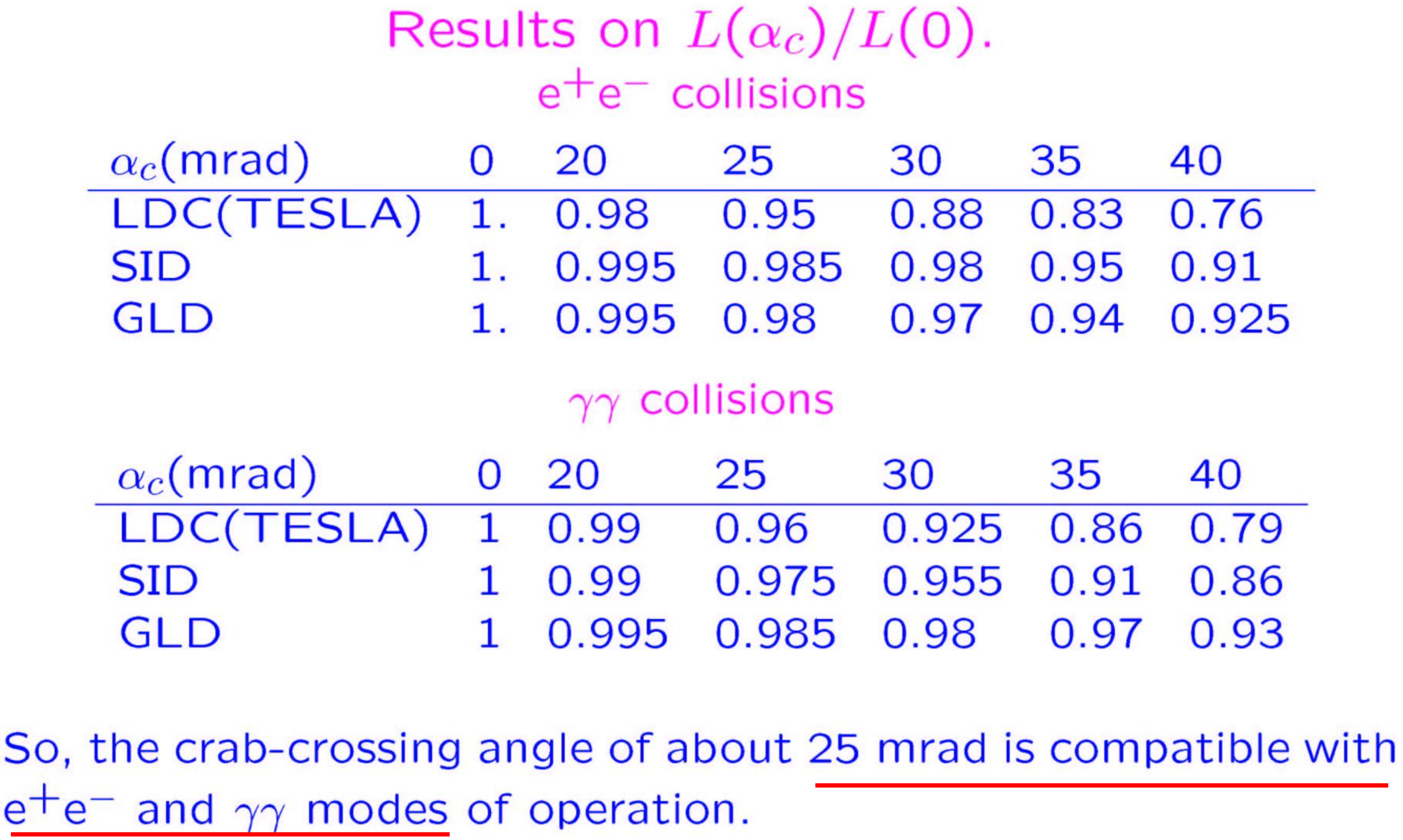
Deflecting force which causes SR

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

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.

The loss of the luminosity is < 5%

Crossing angle, is 20 mrad possible?

Can we adjust PLC parameters for the work with the crossing angle 20 mrad? What is the decrease of the γγ luminosity in this case?

In the case of α_c=25 mrad ½ is determined by quad's sizes and ½ be the disruption angle. So for α_c =20 mrad we have to reduce the disruption angle by 5 mrad or 12.5/7.5=1.67 times.

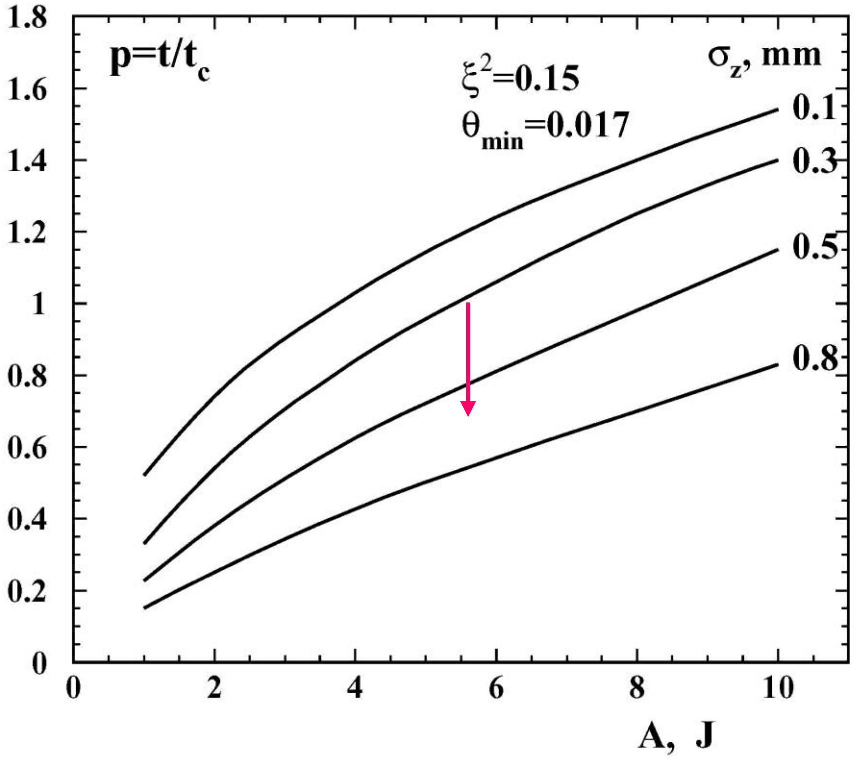
The disruption angle $\vartheta \propto \sqrt{N/\sigma_z E_{min}} \propto \sqrt{Np/\sigma_z}$, where p – the number of collision length in the laser target, the conversion coefficient $k \approx 1 - e^{-p}$. The luminosity $L_{\gamma\gamma} \propto k^2 N^2 f / \sqrt{\sigma_z}$.

Solution 1. Reduce p by a factor of $(1.67)^2$=2.8, from the nominal p=1 to p=0.358 Then the luminosity drops by a factor of 4.4. That is not acceptable.

Solution 2. Make the bunch length 2.8 times longer. But to keep p=const one should increase the laser flash energy by about 2.8 times. Nominally one needs A=5.5 J for E_0=100 GeV, and ξ^2=0.15 (5% shift of max. photon energy), now you need 15.5 J for 2E=200 GeV and 30 J for 2E=500 GeV (smaller σ_c), which are too high flash energies, not acceptable.

Solution 3. Keep the flash energy A=const = 5.5 J and increase the bunch length, then p drops as well.

The dependence of p on σ_z



Taking σ_z=0.6 mm we get p=0.69 (was p=1 for σ_z =0.3 mm), which results in desired 1.7 times decrease of the disruption angle. In this case the luminosity decreases by a factor of 2.3. That is the best we can do.

So, the decrease of the crossing angle from 25 to 20 mrad leads to the decrease of $L_{\gamma\gamma}$ by a factor of 2.3 at best.

Summary:
disadvatages of transition from α_c=25 mrad to 20 mrad

№	A, J	σ_z, mm	p	L, a.u.	
0 (nom)	5.5	0.3	1	1	
1	1.1	0.3	0.36	0.23	
2	15.5	0.84?	1	1	
3	5.5	0.6	0.69	0.43	

So, 20 mrad is too bad for $\gamma\gamma$, may be 23 mrad is a good compromise?

For that we increase σ_z to 0.4 mm and get p=0.9 and the luminosity decrease by a factor of 1.3.

Below I show that 25 mrad is better for e+e- than 20 or 23 mrad.

The main motivation for smallest crossing angle was necessity to detect scattered electrons in two-photon processes in order to suppress background in searches of some SUSY particles. In 2007 the case of 0 and 20 mrad was compared. With 20 mrad there are dead areas due to extra hole for outgoing beam and absence of the detector between two beam pipes (because the free space =350*0.02-1.5-2=3.5 cm is two small for the calorimeter, comparable to Moliere radius r_M~1cm). In the case of 25 mrad the space between beam pipes is already 5.25 cm, which is sufficient for small tagging calorimeter.

Resume: it seems 25 mrad has no obstacles for e+e-.

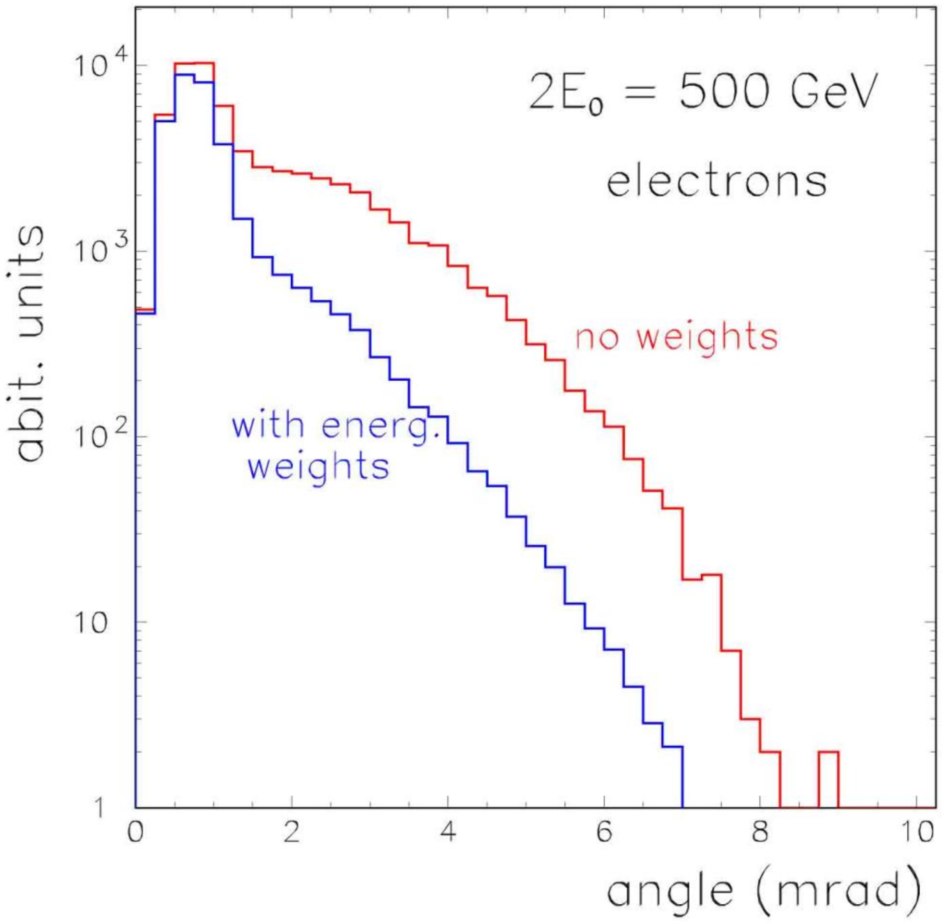
Beam dump

Beam dump

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

- electrons (and few e^+) with the angular spread ~10 mrad (need some focusing or collimation);
- beamstrahlung photons with angles up to 3-4 mrad; R~1 m at L=250 m from the IP.
- 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.

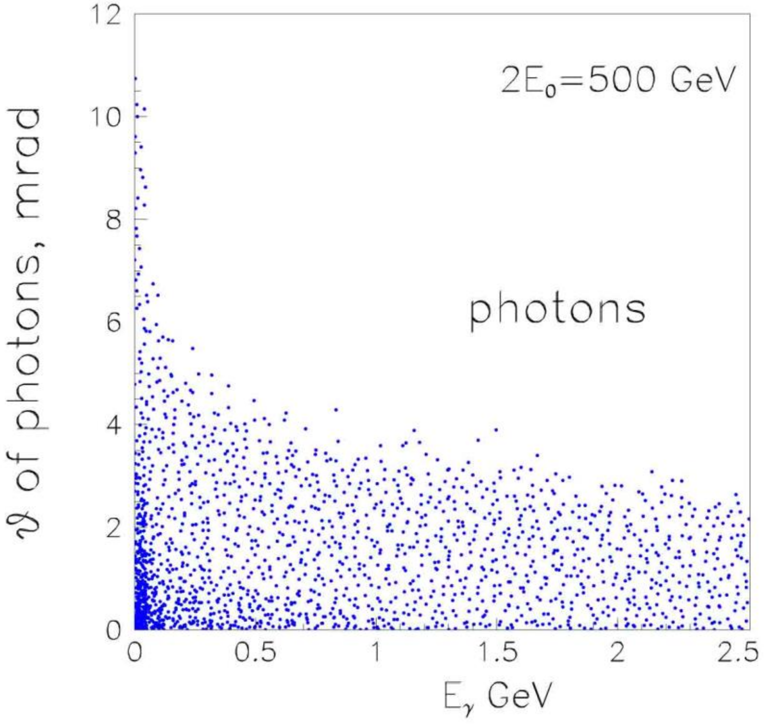
The angular distribution of electrons

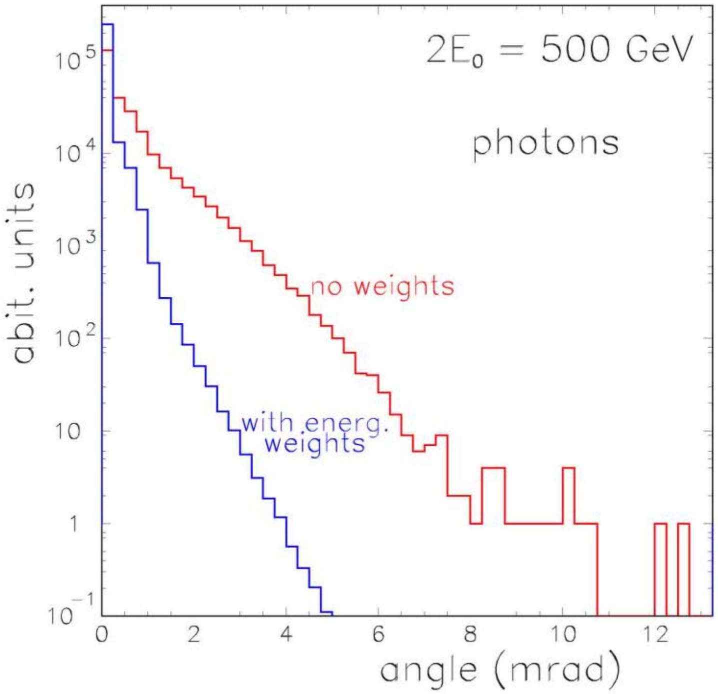


If the beam dump is situated at L=250 m, than for particles with θ=7 mrad r~1.8 m, too much. Some focusing of electrons will be useful in order to decrease the radius of the tube and to reduce the energy deposition (rad. activation on the way to the beam dump).

Angular distribution of photons

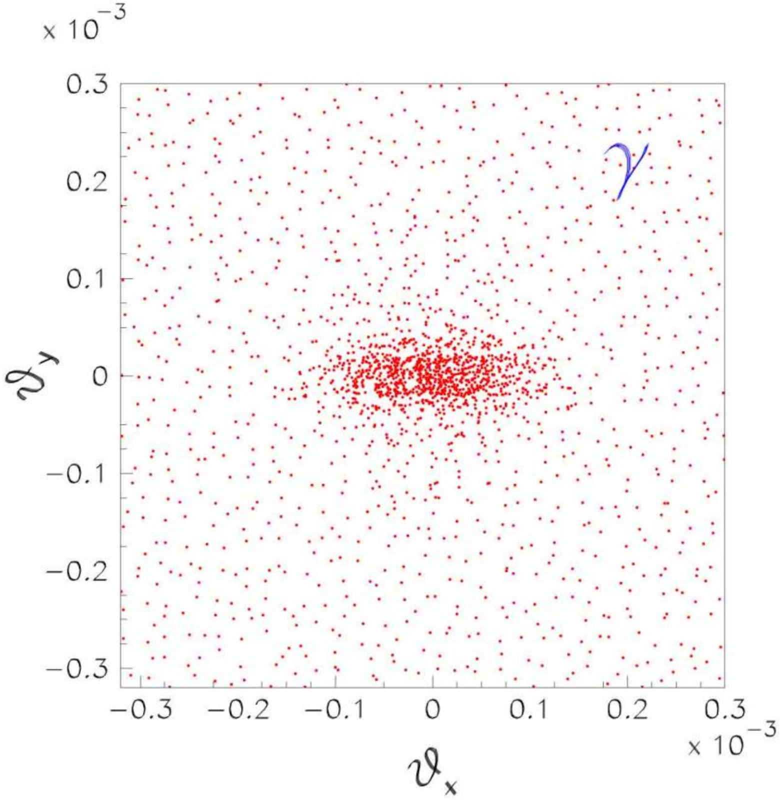
Large angle photons are radiated by low energy electrons, therefore they are soft





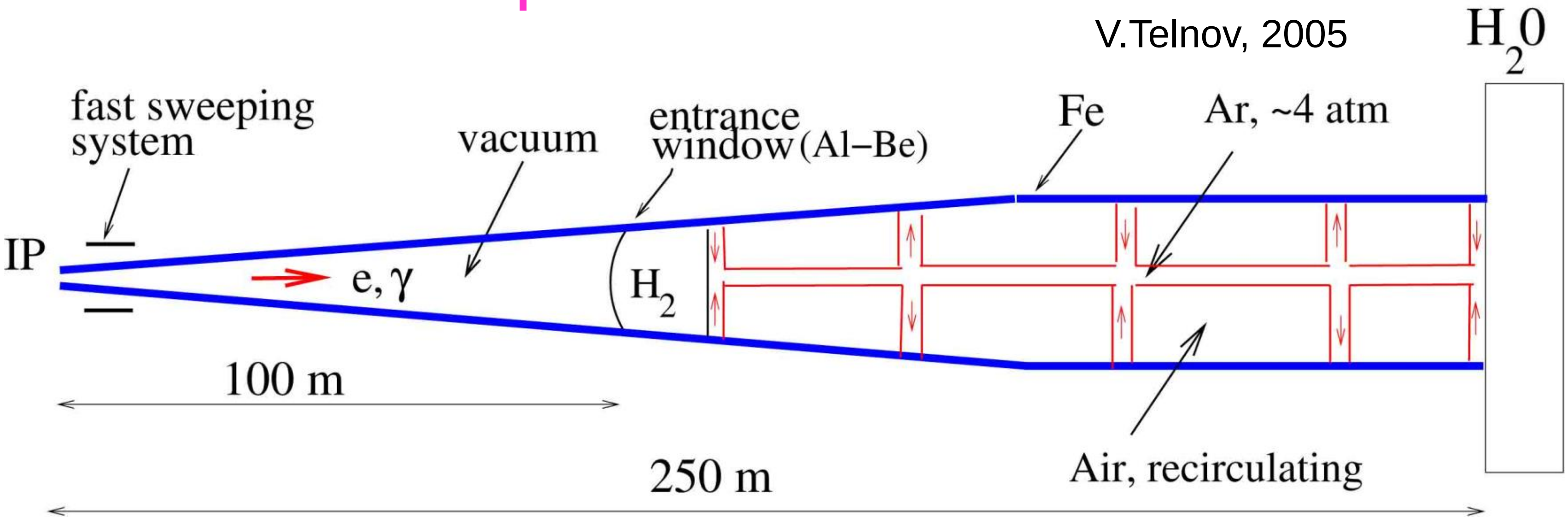
For photons the clear angle about 3 mrad will be sufficient, that is 75 cm at L=250 m.

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. Some people told me that PLC is impossible due to this reason.



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.

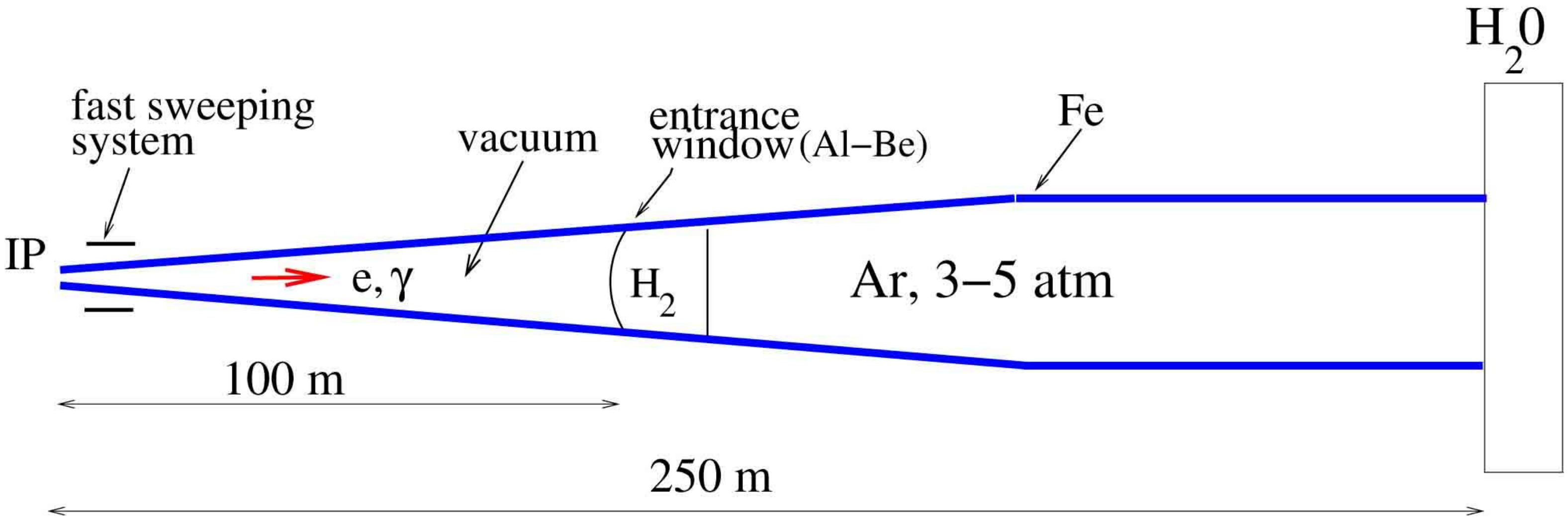
The electron beam without collisions is also very narrow, its density is reduced by the fast sweeping system. As the result, the thermal load is acceptable everywhere.

The volume with H_2 in front of the gas converter serves for reducing the flux of backward neutrons.

In order to reduce angular spread of disrupted electrons some focusing or collimation is necessary.

Simulated scheme

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!

B-D system can contain some simple diagnostics to see the beam profile.

It needs a technical consideration in order to have understanding how to install it instead of e+e- downstream diagnostic beamline and the beam dump.

Conclusion

- 25 mrad is a well justified crossing angle for the PLC. Its reduction down 20 mrad leads to the decrease of $L_{\gamma\gamma}$ by a factor 2.3. The crossing angle 25 mrad is compatible with e+e- and there are no reasons to select the common crossing angle 20 (or 23) mrad. A decision is needed.
- The beamdump for the photon collider is more tricky than for e+e- (due to very narrow γ-beam), but there is a good solution which needs some technical consideration in order to have a plan how to install it in future.
- The IR design should foresee a space for the laser and an optical system which is still unclear, whether a cavity or one-pass laser system. Some clever decision is needed on reservation of the space.