Comparison of photon colliders based on e^-e^- and e^+e^- beams.

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Why e^+e^- beams for $\gamma\gamma$ are under discussion again?

It is always assumed that $\gamma\gamma$ collider is based on e^-e^- beams. The answer to the question "why e^-e^- beams are better than e^+e^-" is know in $\gamma\gamma$ community (V.Telnov, GG2001).

Now designers of the IP region have arisen this question again because some schemes of the final focus do not allow easy switching between e^+e^- and e^-e^- modes.

A short answer:

- study of e^-e^- collisions is a part of physics program and e^-e^- beams are necessary in any case;
- properties of $\gamma\gamma$ collisions based on e^-e^- are much better (larger luminosity, much lower backgrounds), see below.

Luminosity

If damping rings are used, $L_{geom}(\mathrm{e^+e^-}) = L_{geom}(\mathrm{e^-e^-})$. But there is difference in the degree of the polarization: $P_{e^-} = 85\%$, $P_{e^+} \sim 50\%$.

$$\left(\frac{dL}{dW_{\gamma\gamma}}\right)_{peak} \propto \Pi_i \left[x + 1 + \frac{1}{x+1} + \lambda_i \frac{x(x+2)}{(x+1}\right]$$

For $x = 4.8$ one gets

$$\left(\frac{dL}{dW_{\gamma\gamma}}\right)_{\mathrm{e^+e^-}} \sim 0.82 \left(\frac{dL}{dW_{\gamma\gamma}}\right)_{\mathrm{e^-e^-}}$$

0.56 for unpolarized e^+.

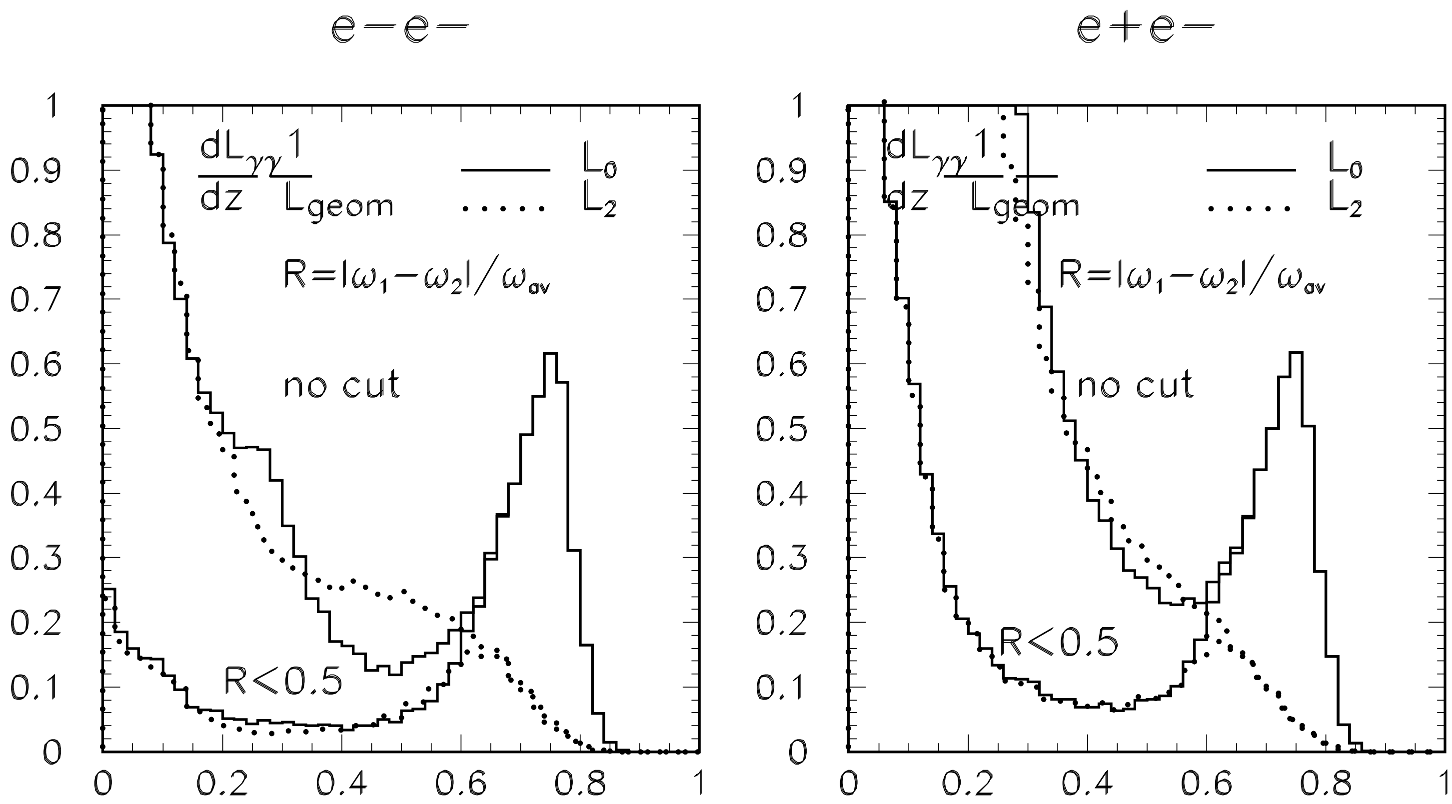
Simulation of photon collider for TESLA beam parameters

	e^-e^-	e^+e^-
$N/10^{10}$	2	2
σ_z,mm	0.3	0.3
σ_x,nm	88	88
σ_y,nm	4.3	4.3
$L_{geom}, 10^{35}$	1.2	1.2
$L_{\gamma\gamma}(z > 0.65)/L_{geom}$	0.1	0.1
$L_{\gamma\gamma}(tot)/L_{geom}$	0.92	5.6
$L_{e^-e^-}/L_{geom}$	0.006	—
$L_{e^+e^-}(z > 0.65)/L_{geom}$	—	0.062
$L_{e^+e^-}(tot)/L_{geom}$	—	0.24

- Total(low energy) $\gamma\gamma$ luminosity with e^+e^- beams is by a factor of 6 larger then with e^-e^-! The number of $\gamma\gamma \to hadr$ events per one beam collision is about 10!
- With e^+e^- beams the $L(e^+e^-)$ and $L(\gamma\gamma)$ in the high energy region are comparable, it will be diffitult to separate e^+e^- and $\gamma\gamma$ reactions

$\gamma\gamma$ luminosity spectra

with cuts on the longitudinal momentum;0,2 are total helicities of photons.



Luminosity measutement

Calibration processes in $\gamma\gamma$ collisions are
$\gamma\gamma \rightarrow e^+e^-$ $(\mu^+\mu^-)$.

Processes $e^+e^- \rightarrow e^+e^-, \mu^+\mu^-$ will give very large contribution. Using anglular distribution one can separate these processes, but this a serious additional problem.

Physical backgrounds

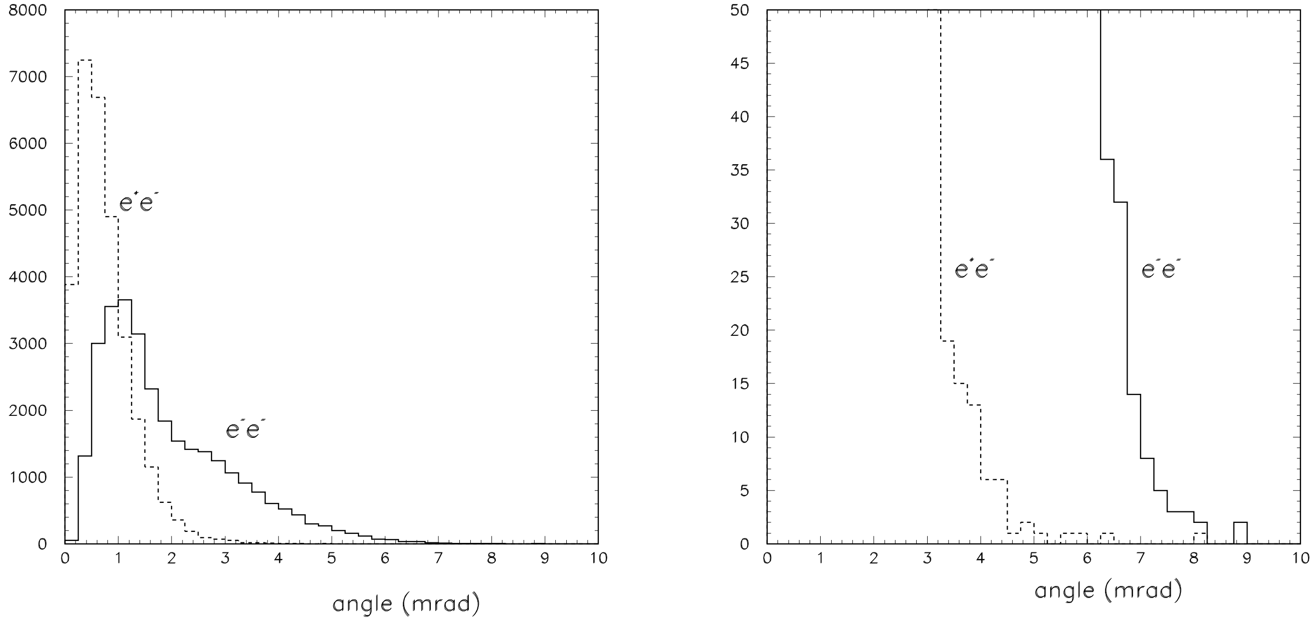
For $\gamma\gamma \to W^+W^-$ background is $e^+e^- \to W^+W^-$
Same problem for any charged pair.

$\gamma\gamma \to H$ main background is QED $\gamma\gamma \to b\bar{b}$ which can be suppressed by choice of proper photon polarization.

However, $e^+e^- \to b\bar{b}$ is not suppressed!
$\sigma_{e^+e^-} \propto (1 - \lambda_e \lambda_{e^+}) \sim (1 - 0.8 \cdot 0.6) \sim 0.5$,
and $\sigma(e^+e^- \to b\bar{b}) > \sigma(\gamma\gamma \to b\bar{b})$,
so $e^+e^- \to b\bar{b}$ gives very large background!

Disrupted beams

The r.m.s. angular spread of the disrupred beam at $2E = 500$ GeV is narrower for e^+e^- colliding beams, but difference in tails is much less.



Moreover, at $E > 250$ GeV and $\lambda(laser) \sim 1$ μm, e^+e^- pairs are produced at the conversion region in collisions of the high energy and laser photons (or at even lower energy due to nonlinear effects), then disruption angles with e^+e^- and e^-e^- and very similar.

Conclusion

For the photon collider e^-e^- beams are much better than e^+e^-.

More stronger: e^-e^- beams are absolutely necessary for the photon collider.