The investigation of spin effects in photon production with fermion pair in $\gamma\gamma$-collisions

V. Makarenko

NC PHEP BSU, Minsk, Belarus

K. Mönig

DESY, Zeuthen

T. Shishkina

NC PHEP BSU, Minsk, Belarus

The physics in $\gamma\gamma$ collisions strongly depends on the polarization of interacting photons.

J is the total helicity of $\gamma\gamma$-system.

The luminosity of $J=2$-beams can be measured using the classical QED process $\gamma\gamma \to f\bar{f}$.

On $J=0$-beams the leading term of $\gamma\gamma \to f\bar{f}$ scattering is of order $\alpha/\pi \approx 0.002$.

The opportunity to use exclusive reaction $\gamma\gamma \to f\bar{f}\gamma$ for luminosity measurement on $J=0$-beams.

We analyse the ratio of cross sections of $\gamma\gamma \to f\bar{f}\gamma$ scattering on $J=0$ to $J=2$-beams depending on detector cuts.

$$\sqrt{s} = 120GeV$$

Notations:

Minimum final-stase photon energy: ω_{cut},

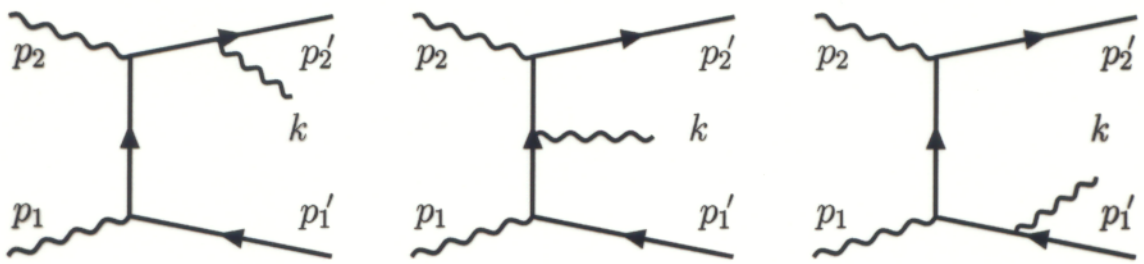
Minimum fermion energy: $E_{f,cut}$,

Minimum angle between any final and any initial particles: Θ_{cut},

Minimum angle between any pair of final particles: φ_{cut}.

$$\gamma(p_1,\lambda_1)+\gamma(p_2,\lambda_2)\to f(p_1{}',e_1{}')+\bar{f}(p_2{}',e_2{}')+\gamma(k,\lambda_3),$$

where λ_i and $e_i{}'$ are photon and fermion helicities.



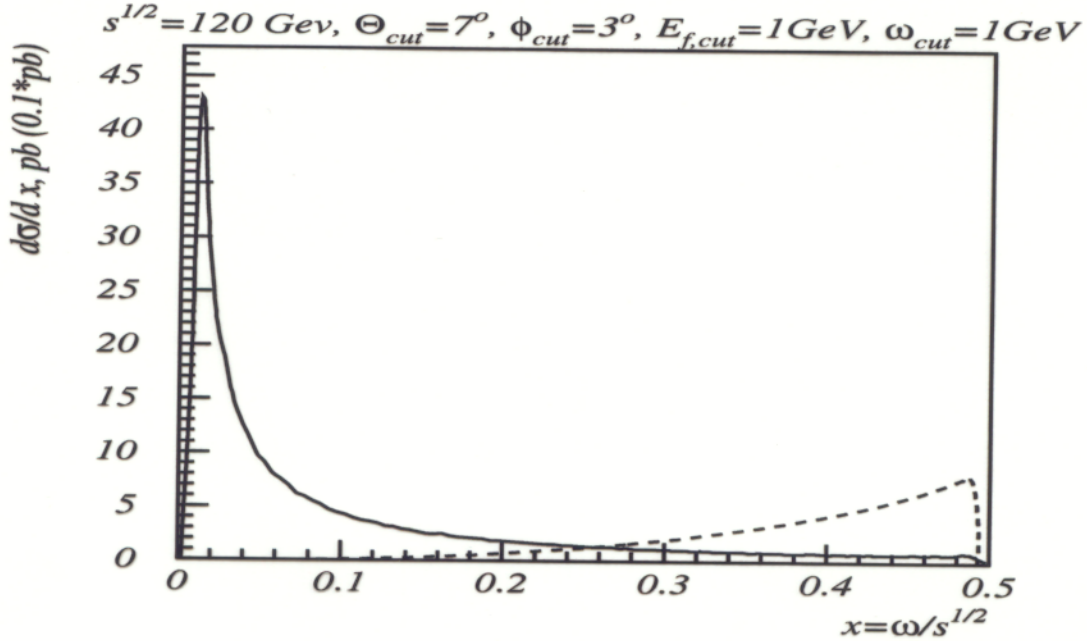
+ crossed graphs $(p_1 \leftrightarrow p_2)$

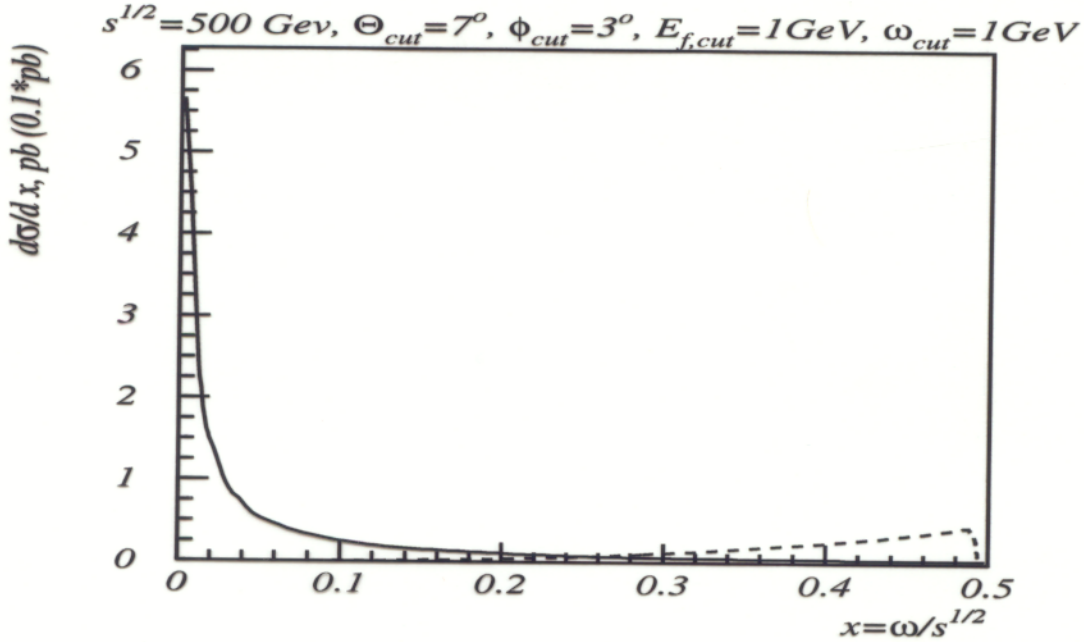
$$|M^{+--++}|^2 = 4e^6 \frac{p_1'\cdot p_2'\ p_2'\cdot p_2{}^2}{p_1'\cdot k\ p_2'\cdot k\ p_1'\cdot p_1\ p_2'\cdot p_1}$$

C + P + Bose + crossing symmetries $\Longrightarrow$

$$\begin{aligned}
d\sigma^{+-+--} &= d\sigma^{+--++}{}_{|1\leftrightarrow 2}, \ (P+Bose)\\
d\sigma^{+-+-+} &= d\sigma^{+--++}{}_{|1'\leftrightarrow 2'}, \ (C)\\
d\sigma^{+--+-} &= d\sigma^{+--++}{}_{|\substack{1\leftrightarrow 2\\ 1'\leftrightarrow 2'}}, \ (CP+Bose)\\
d\sigma^{+++--} &= d\sigma^{+--++}{}_{|\substack{k\leftrightarrow 2\\ 1'\leftrightarrow 2'}}, \ (C+crossing)\\
d\sigma^{++-+-} &= d\sigma^{+++--}{}_{|1'\leftrightarrow 2'}, \ (C)\\
d\sigma^{-\lambda_1,-\lambda_2,-e_1{}',-e_2{}',-\lambda_3} &= d\sigma^{\lambda_1,\lambda_2,e_1{}',e_2{}',\lambda_3}. \ (P)
\end{aligned}$$

Phase space integration is performed numerically using the Monte-Carlo method.

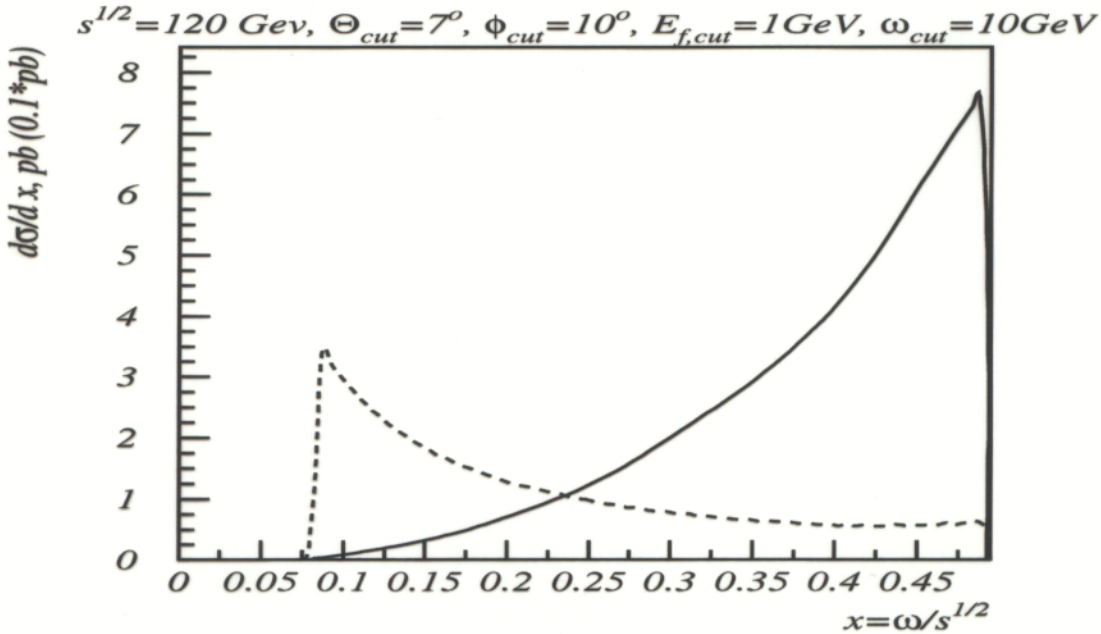


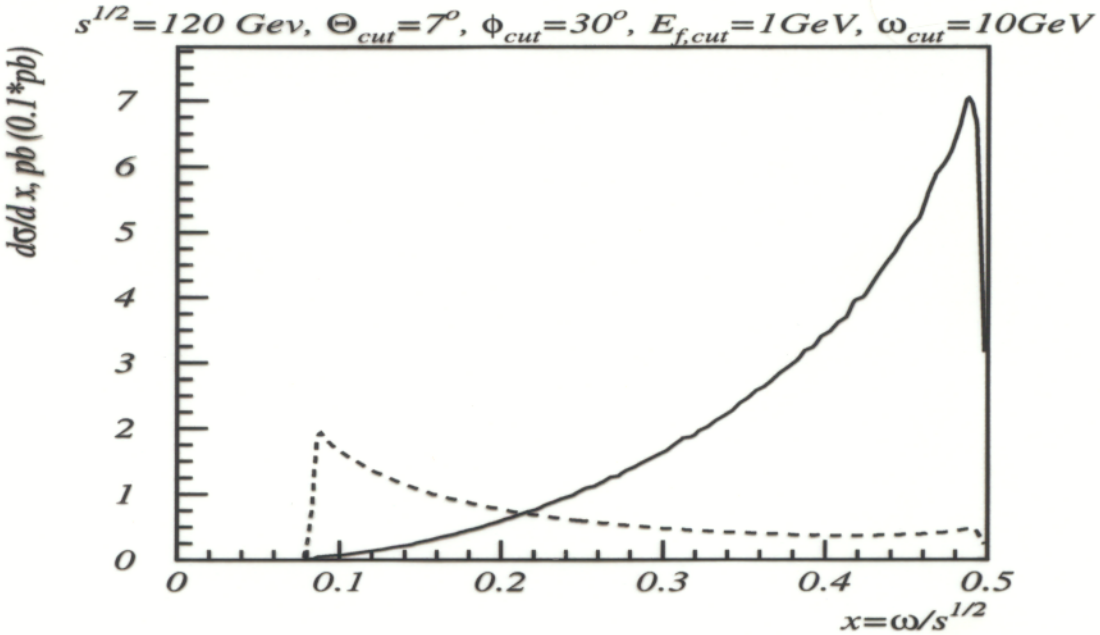


Final-stase photon spectrum: $J=0$ (dotted) and $(J=2)*0.1$ (solid) at $\sqrt{s}=120GeV$ and $\sqrt{s}=500GeV$.

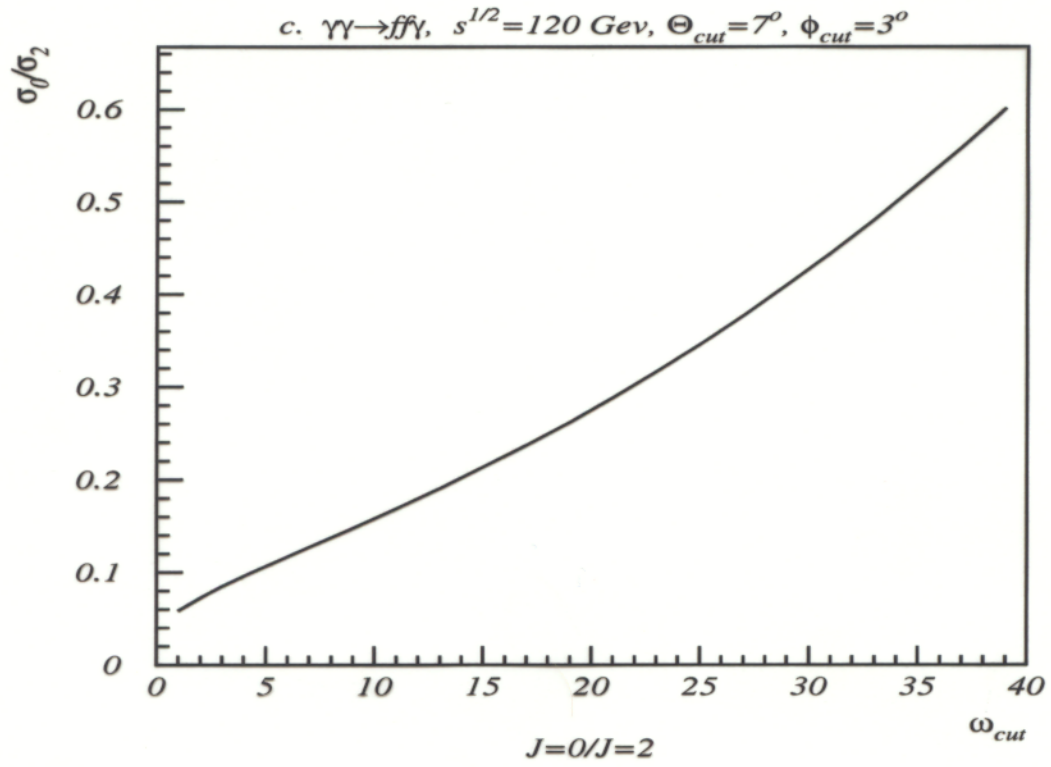
Cuts: $\Theta_{min}=7^o$; $\varphi_{min}=3^o$; $E_{f,min}=1GeV$; $\omega_{min}=1GeV$.

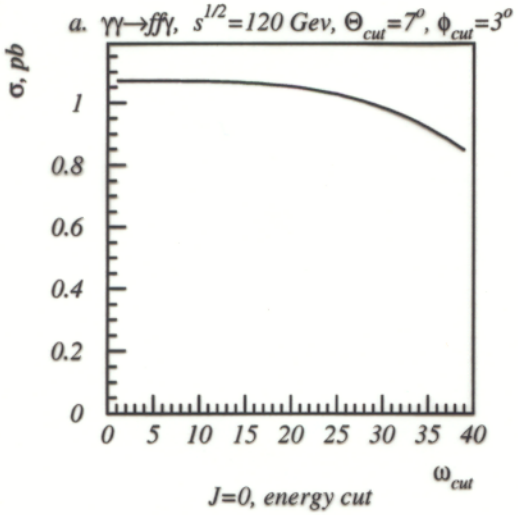
Final-stase photon spectrum: $J=0$ (solid) and $(J=2)*0.1$ (dotted) at $\sqrt{s}=120GeV$.

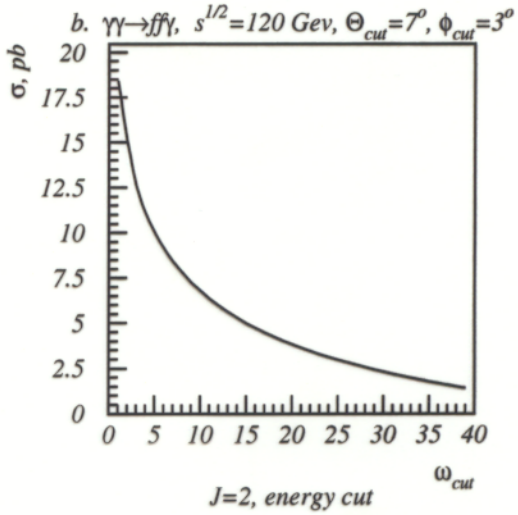




Total cross sections on $J=0$ and $J=2$ beams and their ratio.
Dependence on w_{cut}.

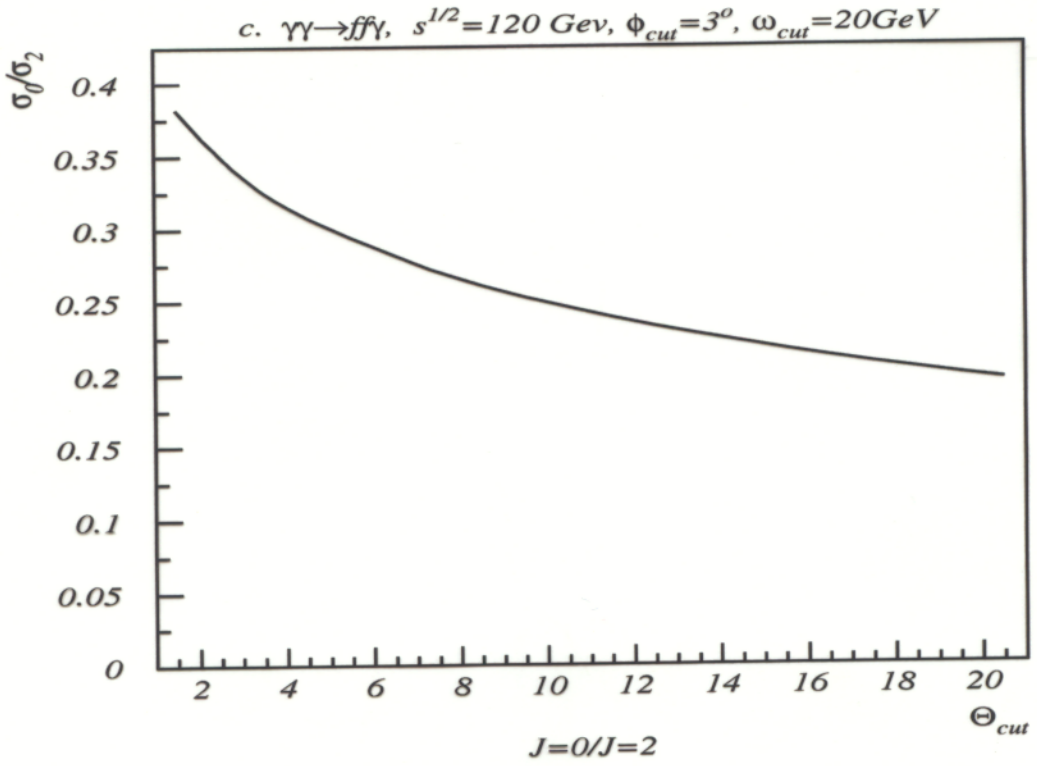


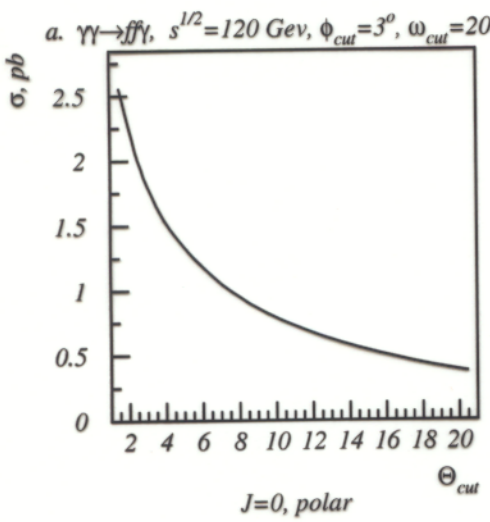


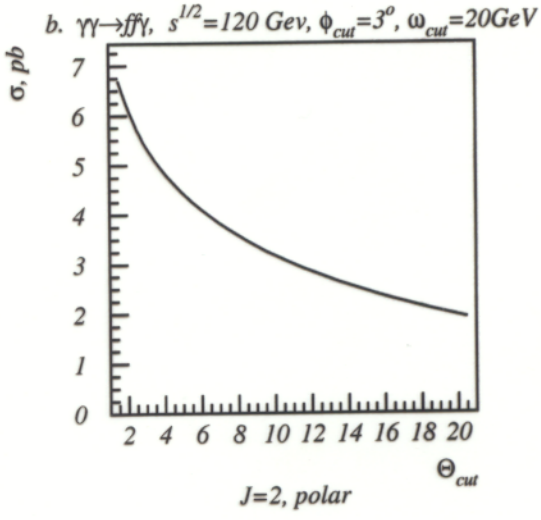


The rise of threshold on the final photon energy greatly restricts the $J=2$-cross section, the $J=0$ reaction is almost unaffected.

Total cross section ratio $J=0/J=2$. Dependence on Θ_{cut}.

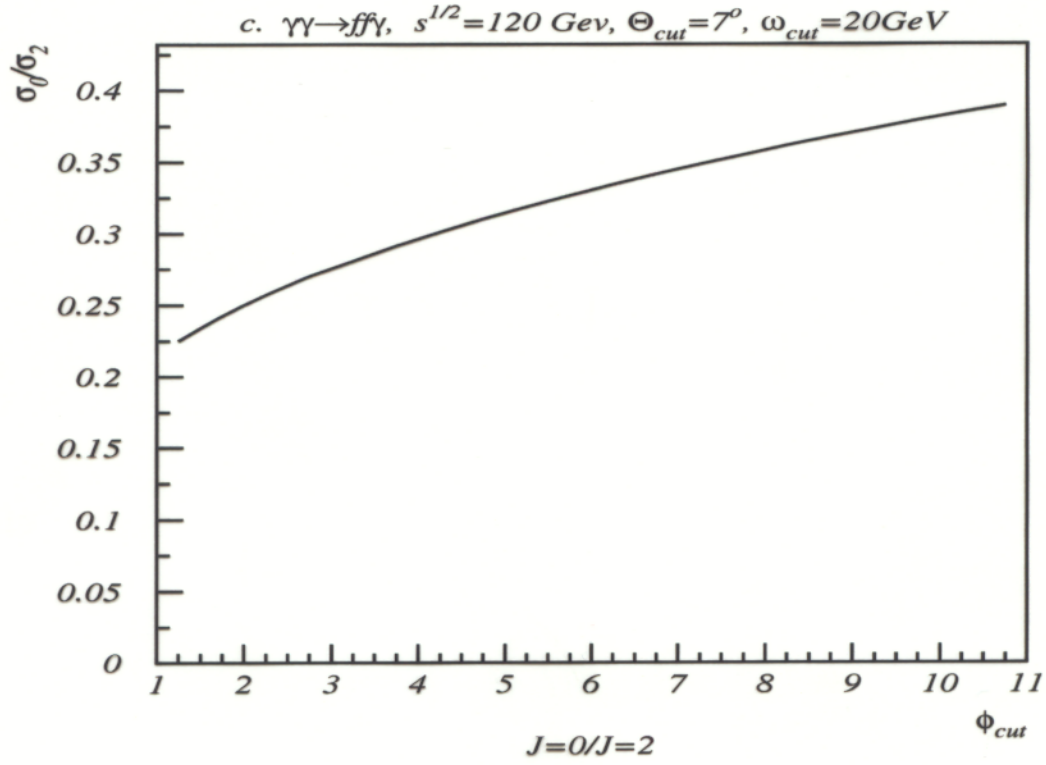


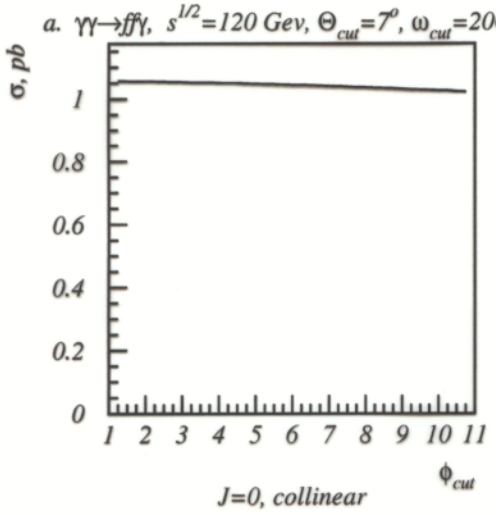


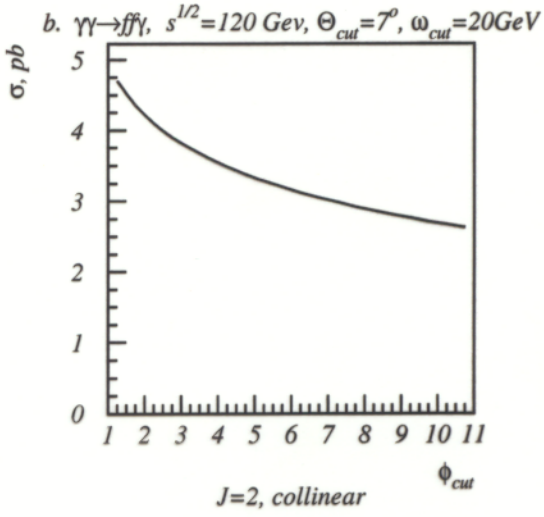


The decrease of threshold on polar angle leads to rise of ratio $J=0/J=2$, increasing both the cross sections.

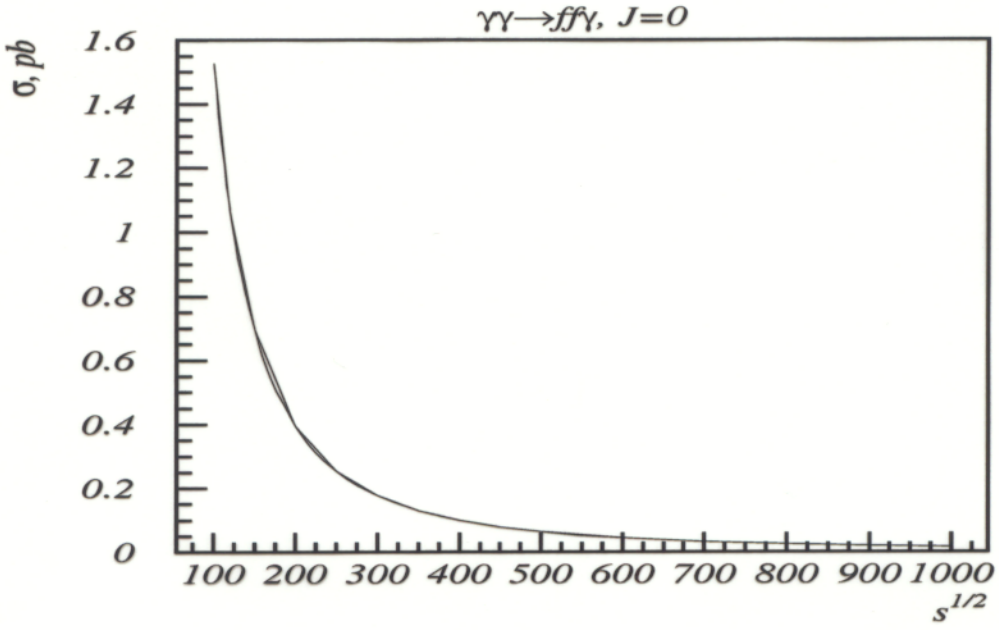
Total cross section ratio $J=0/J=2$. Dependence on φ_{cut}.

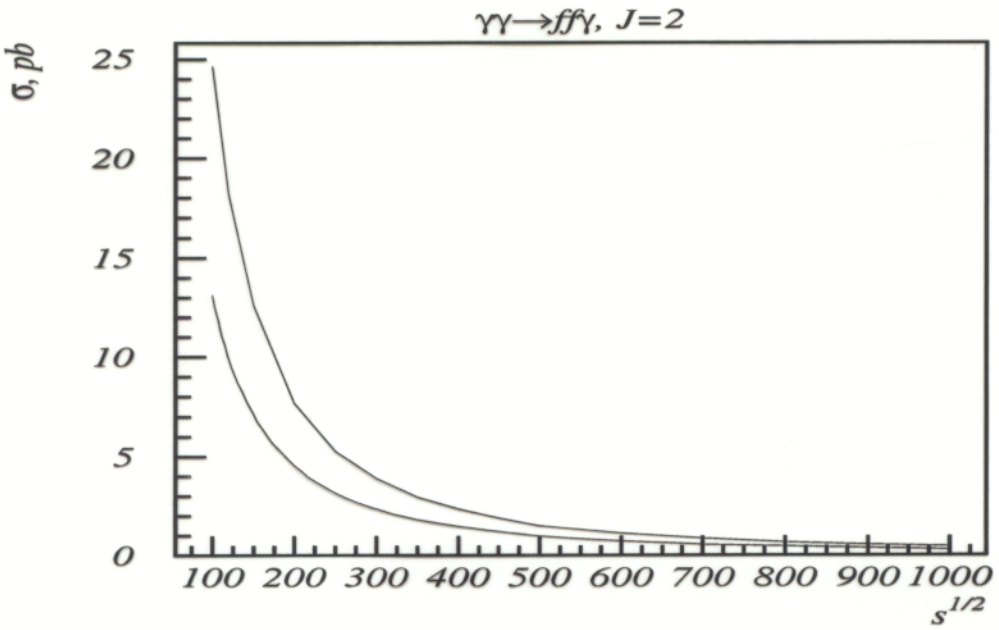






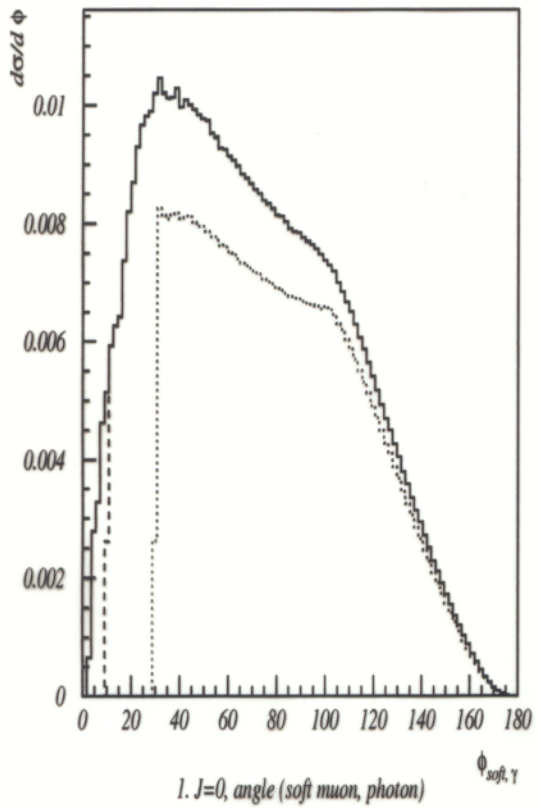
The rise of threshold on angle between final particles restricts the $J=2$-cross section, the $J=0$ reaction is almost unaffected.

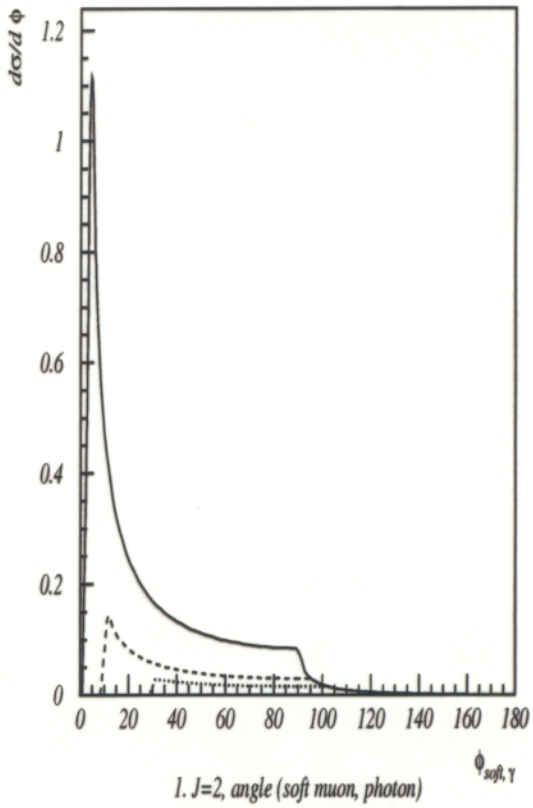




The dependence of total cross section on the c.m.s. energy.

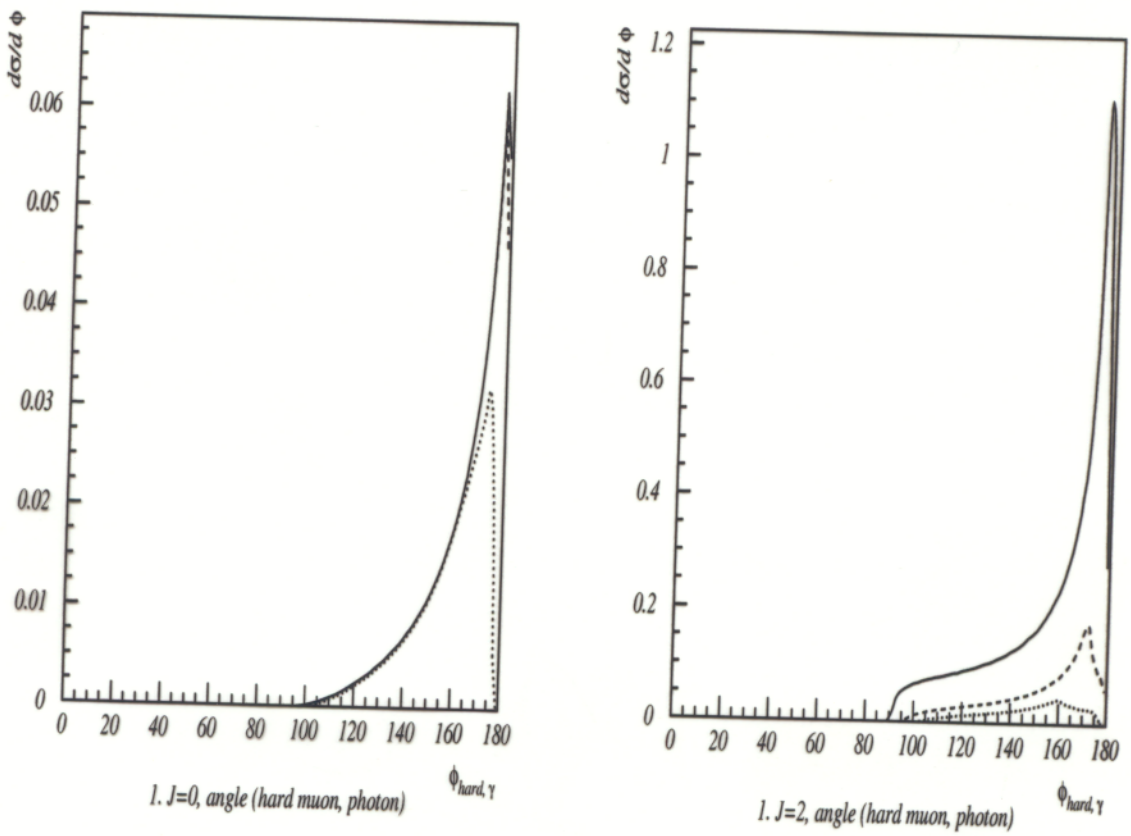
Cuts: $\Theta_{cut} = 7^o$, $\varphi_{cut} = 3^o$, $E_{f,cut} = 1GeV$, $w_{cut} = 1GeV$ (the higher line) and $w_{cut} = 5GeV$ (the lower line).





Angular plots (angle between fermion with lowest energy and final photon) at set of cuts:

1. $\Theta_{min} = 7^o$; $\varphi_{min} = 3^o$; $E_{f,min} = 1GeV$; $\omega_{min} = 1GeV$;
2. $\Theta_{min} = 7^o$; $\varphi_{min} = 10^o$; $E_{f,min} = 1GeV$; $\omega_{min} = 10GeV$;
3. $\Theta_{min} = 7^o$; $\varphi_{min} = 30^o$; $E_{f,min} = 5GeV$; $\omega_{min} = 20GeV$.



Angular plots (angle between fermion with highest energy and final photon) at set of cuts:

1. $\Theta_{min} = 7^o$; $\varphi_{min} = 3^o$; $E_{f,min} = 1GeV$; $\omega_{min} = 1GeV$;
2. $\Theta_{min} = 7^o$; $\varphi_{min} = 10^o$; $E_{f,min} = 1GeV$; $\omega_{min} = 10GeV$;
3. $\Theta_{min} = 7^o$; $\varphi_{min} = 30^o$; $E_{f,min} = 5GeV$; $\omega_{min} = 20GeV$.

Precision of luminosity measurement using the reaction $\gamma\gamma \to f\bar{f}\gamma$.

We choose the set of cuts $E_\mu > 5GeV$, $E_\gamma > 20GeV$, $\Theta_{cut} = 6°$, $\varphi_{cut} = 30°$ and the corresponding cross sections:

$$\begin{aligned} \sigma(J=0) &= 0.82pb \\ \sigma(J=2) &= 1.89pb \end{aligned}$$

TESLA luminosity:

$$\begin{aligned} \mathcal{L}(\sqrt{s'} > 0.8\sqrt{s'_{\max}}) &= 5.3 \cdot 10^{33} cm^{-2} s^{-1} \\ \mathcal{L}(m_H \pm 1GeV) &= 3.8 \cdot 10^{32} cm^{-2} s^{-1} \end{aligned}$$

with $\mathcal{P} \approx 90\%$

$\Rightarrow$ in a 2 years run ($2 \cdot 10^7$s):

$$\begin{aligned} \frac{\Delta\mathcal{L}}{\mathcal{L}}\left(\sqrt{s'} > 0.8\sqrt{s'_{\max}}\right) &= 0.35\% \\ \frac{\Delta\mathcal{L}}{\mathcal{L}}(m_H \pm 1GeV) &= 1.3\% \end{aligned}$$

ω_{cut}, GeV	$E_{f,cut}, GeV$	$\Theta_{cut},^0$	$\varphi_{cut},^0$	$\sigma_{J=0}, pb$	$\sigma_{J=2}, pb$
1	1	5	3	1.368	21.911
1	1	7	3	1.073	18.353
1	1	10	3	0.799	15.713
1	1	7	5	1.066	15.807
1	1	7	10	1.044	12.488
1	1	7	30	0.881	7.150
10	1	7	3	1.070	6.769
10	1	7	10	1.045	4.682
10	1	7	30	0.880	2.842
10	1	5	10	1.314	5.485
10	1	10	10	0.783	3.848
20	1	7	3	1.052	3.820
20	1	7	10	1.026	2.690
20	5	7	3	0.892	3.623
20	5	7	10	0.873	2.559
20	5	5	30	0.898	1.903
20	5	7	30	0.748	1.629
20	5	10	30	0.587	1.327

very useful to measure luminosity of J=0

Total cross sections for $\gamma\gamma \to f\bar{f}\gamma$ for different cuts at $\sqrt{s} = 120GeV$.

Conclusion: Using detector limitations we can greatly restrict the process on $J=2$-beams remaining the process on $J=0$ almost unchanged.