A FORTRAN code for $\gamma\gamma \to ZZ$ in SM and MSSM

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Based on the publications:

- **Th. Diakonidis , GJG, J. Layssac, hep-ph/0610085**
- **GJG, P. Porfyriadis, F.M. Renard, Eur. Phys. J. C19:57 (2001), hep-ph/0010006.**
- **GJG, P. Porfyriadis, J. Layssac, F.M. Renard, Eur. Phys. J. C13:79(2000), hep-ph/9909243.**

•The whole code is contained in the file gamgamZZ.tar.gz downloaded from

http://users.auth.gr/~gounaris/FORTRANcodes/

It contains 4 sub-codes called, sm1, mssm1, sm2 and mssm2.
A Readme.dat file explains everything.
Real SM and MSSM parameters are assumed.

The $\gamma(\lambda_1)\,\gamma(\lambda_2) \to Z(\lambda_3)\,Z(\lambda_4)$ helicity amplitudes

λ_j=helicities

Helicity amplitudes $\Rightarrow$ $F_{\lambda_1\lambda_2\lambda_3\lambda_4}(\beta_Z, t, u)$, $s = s_{\gamma\gamma} = \dfrac{4m_Z^2}{1-\beta_Z^2}$

Bose $\Rightarrow$ $F_{\lambda_1\lambda_2\lambda_3\lambda_4}(\beta_Z, t, u) = F_{\lambda_2\lambda_1\lambda_4\lambda_3}(\beta_Z, t, u)(-1)^{\lambda_3-\lambda_4}$

$$F_{\lambda_1\lambda_2\lambda_3\lambda_4}(\beta_Z, t, u) = F_{\lambda_2\lambda_1\lambda_3\lambda_4}(\beta_Z, u, t)(-1)^{\lambda_3-\lambda_4}$$

$$F_{\lambda_1\lambda_2\lambda_3\lambda_4}(\beta_Z, t, u) = F_{\lambda_1\lambda_2\lambda_4\lambda_3}(\beta_Z, u, t)$$

CP $\Rightarrow$ $F_{\lambda_1\lambda_2\lambda_3\lambda_4}(\beta_Z, t, u) = F_{-\lambda_1,-\lambda_2,-\lambda_3,-\lambda_4}(\beta_Z, t, u)(-1)^{\lambda_3-\lambda_4}$

Thus, the 10 independent helicity amplitudes are:

F_{++++} , F_{+-+-} , F_{+-00}

F_{+++-} , F_{+-++} , F_{++00}

F_{+++0} , F_{++--} , F_{++-0}

F_{+-+0}

Codes sm1 and mssm1 calculate these amplitudes for SM and MSSM respectively.

The three **magenta** amplitudes respect the asymptotic **Helicity Conservation** (**HC**) rule

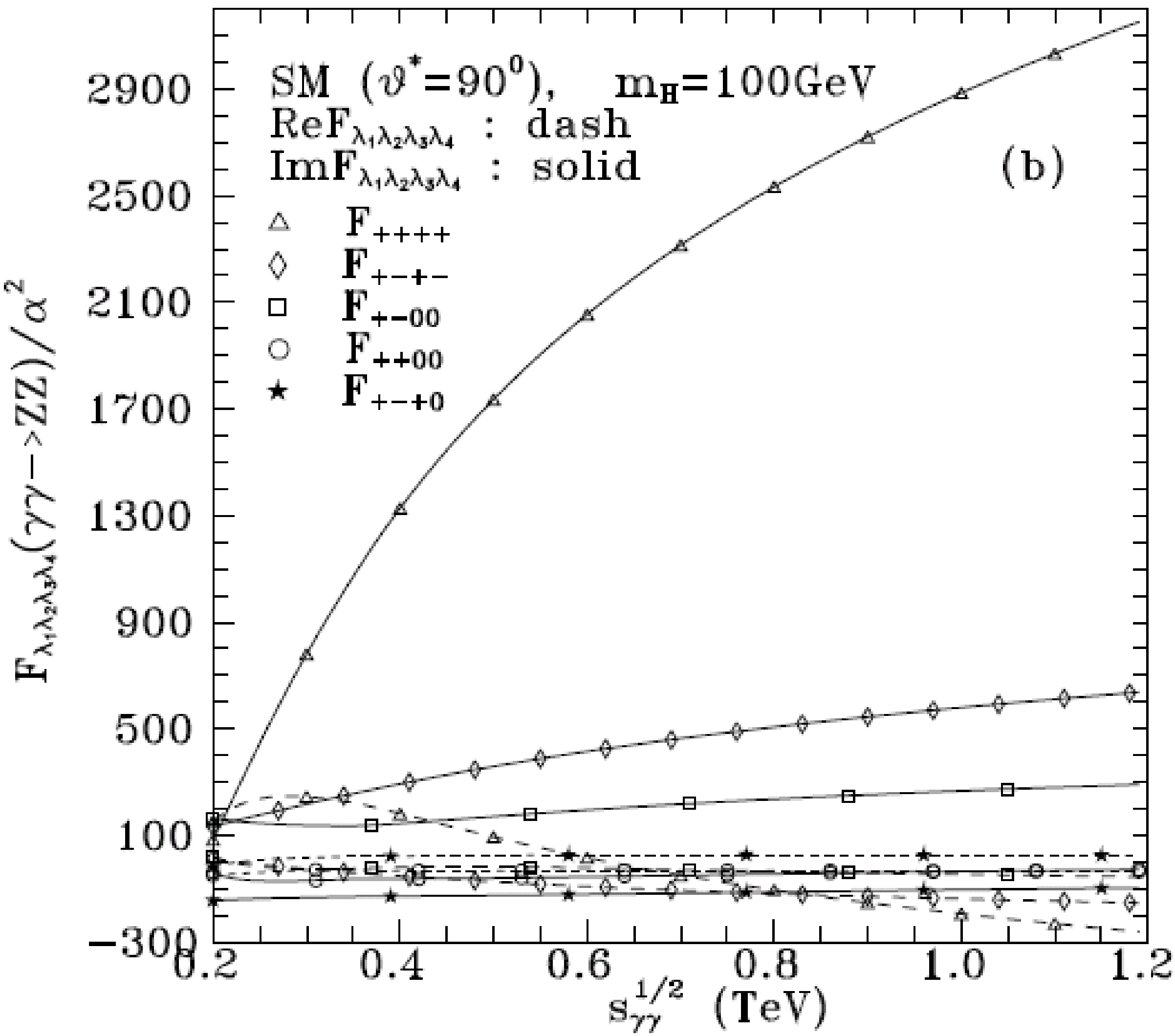
$$\lambda_1 + \lambda_2 = \lambda_3 + \lambda_4$$

They are the largest ones, and **mostly imaginary**.

The rest of these amplitudes violate **HC** and they are very small above 200GeV.

HC: Renard + G, hep-ph/0501046, hep-ph/0604041

Example…



Imaginary and real parts of the helicity amplitudes in SM at 90^0.

HC respecting amplitudes mostly imaginary.
HC violating amplitudes very small at high (s, t)

Cross sections for unpolarized Z's, given by the codes **sm2** and **mssm2** for SM and MSSM respectively.
These are:

$$\frac{d\sigma_0(\gamma\gamma \to ZZ)}{d\cos\theta} = \left(\frac{\beta_Z}{128\pi\hat{s}}\right)\sum_{\lambda_3\lambda_4}[|F_{++\lambda_3\lambda_4}|^2 + |F_{+-\lambda_3\lambda_4}|^2] ,$$

$$\frac{d\sigma_{22}(\gamma\gamma \to ZZ)}{d\cos\theta} = \left(\frac{\beta_Z}{128\pi\hat{s}}\right)\sum_{\lambda_3\lambda_4}[|F_{++\lambda_3\lambda_4}|^2 - |F_{+-\lambda_3\lambda_4}|^2] ,$$

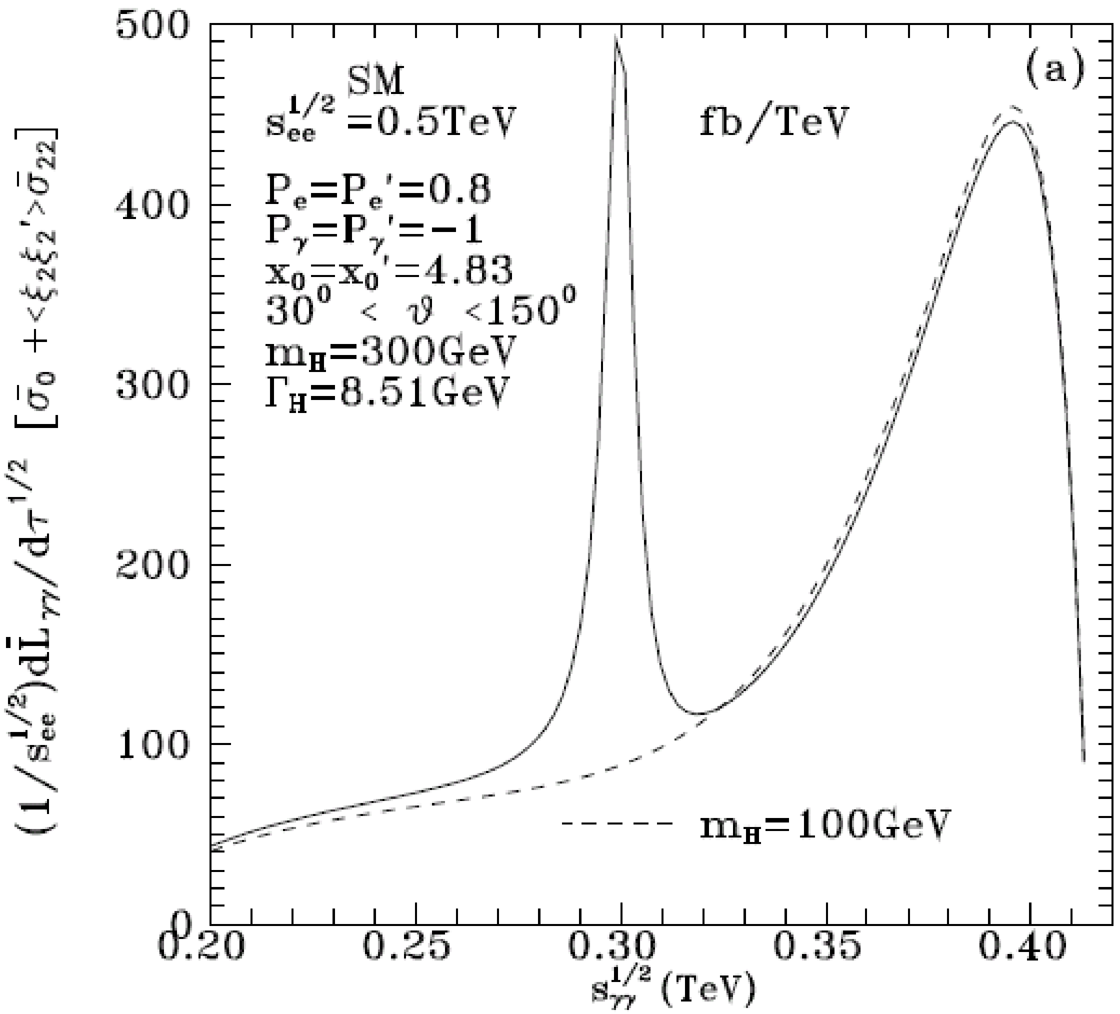
$$\frac{d\sigma_3(\gamma\gamma \to ZZ)}{d\cos\theta} = \left(\frac{-\beta_Z}{64\pi\hat{s}}\right)\sum_{\lambda_3\lambda_4} Re[F_{++\lambda_3\lambda_4}F^*_{-+\lambda_3\lambda_4}] ,$$

$$\frac{d\sigma_{33}(\gamma\gamma \to ZZ)}{d\cos\theta} = \left(\frac{\beta_Z}{128\pi\hat{s}}\right)\sum_{\lambda_3\lambda_4} Re[F_{+-\lambda_3\lambda_4}F^*_{-+\lambda_3\lambda_4}] ,$$

$$\frac{d\sigma'_{33}(\gamma\gamma \to ZZ)}{d\cos\theta} = \left(\frac{\beta_Z}{128\pi\hat{s}}\right)\sum_{\lambda_3\lambda_4} Re[F_{++\lambda_3\lambda_4}F^*_{--\lambda_3\lambda_4}] ,$$

$$\frac{d\sigma_{23}(\gamma\gamma \to ZZ)}{d\cos\theta} = \left(\frac{\beta_Z}{64\pi\hat{s}}\right)\sum_{\lambda_3\lambda_4} Im[F_{++\lambda_3\lambda_4}F^*_{+-\lambda_3\lambda_4}]$$

Cross sections for polarized e$^{\pm}$ beams, integrated over the azimuthal angles in SM



$$\bar{\sigma}_j \equiv \sigma_j$$

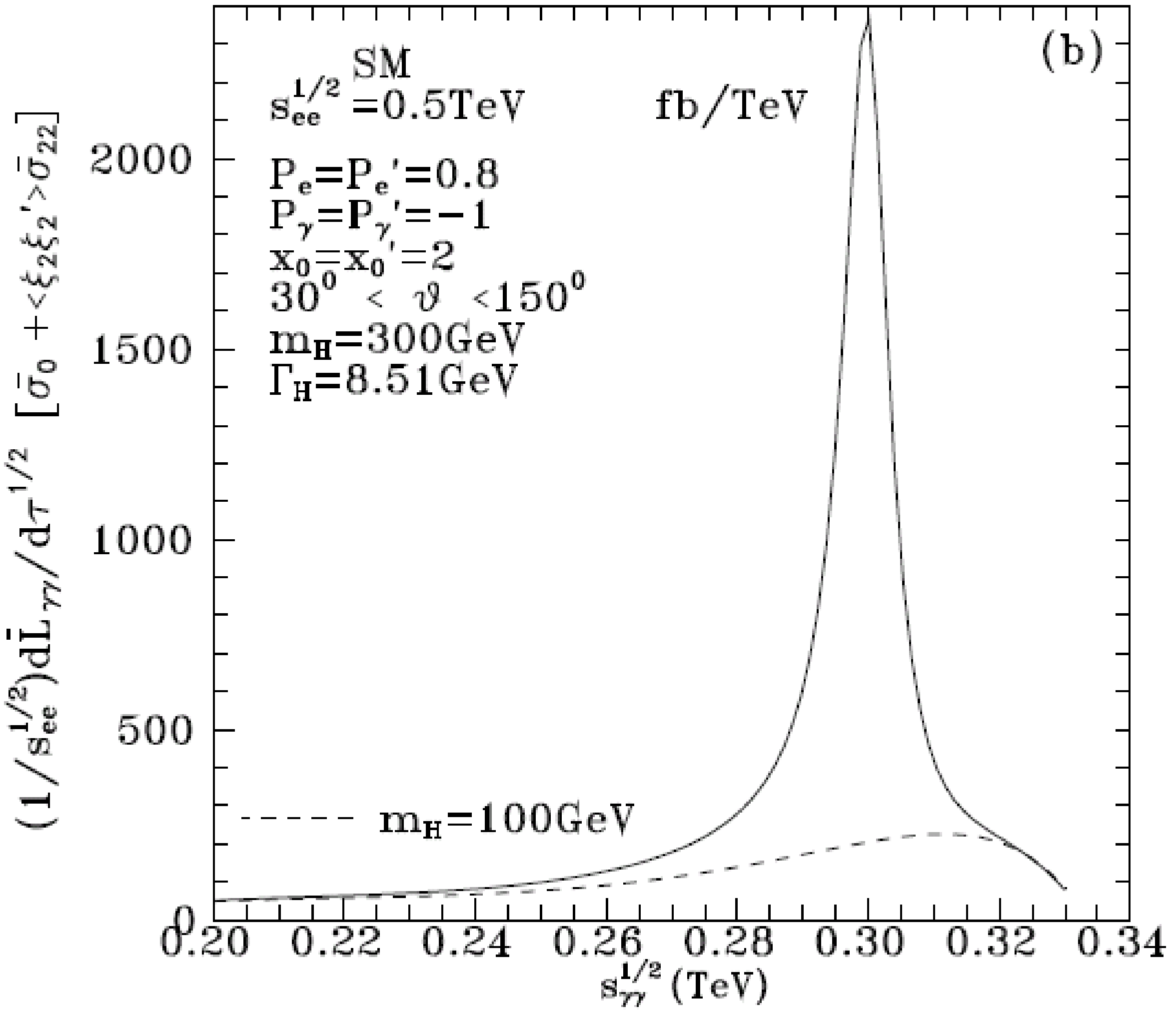
$$\tau = \frac{s_{\gamma\gamma}}{4E_e^2}$$

$$x_0 = \frac{4E_e\omega_{\text{lazer}}}{m_e^2}$$

E_e =energy of the e$^{\pm}$ beams.

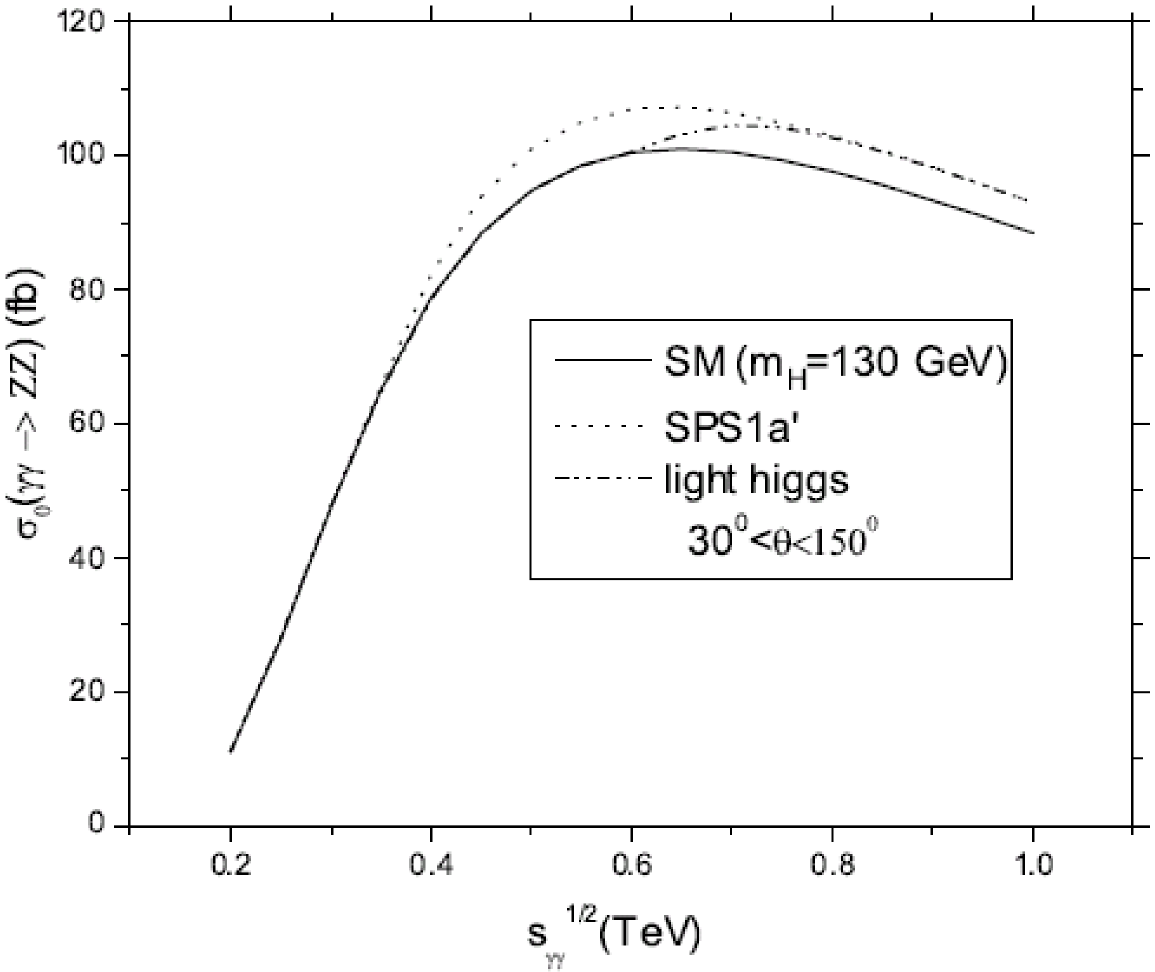
A Higgs peak may be visible in SM, if m_H large.

Cross sections for polarized $e^{\pm}$ beams, integrated over the azimuthal angles in SM



Effect stronger for smaller x_0.

σ_0 cross sections in MSSM and SM

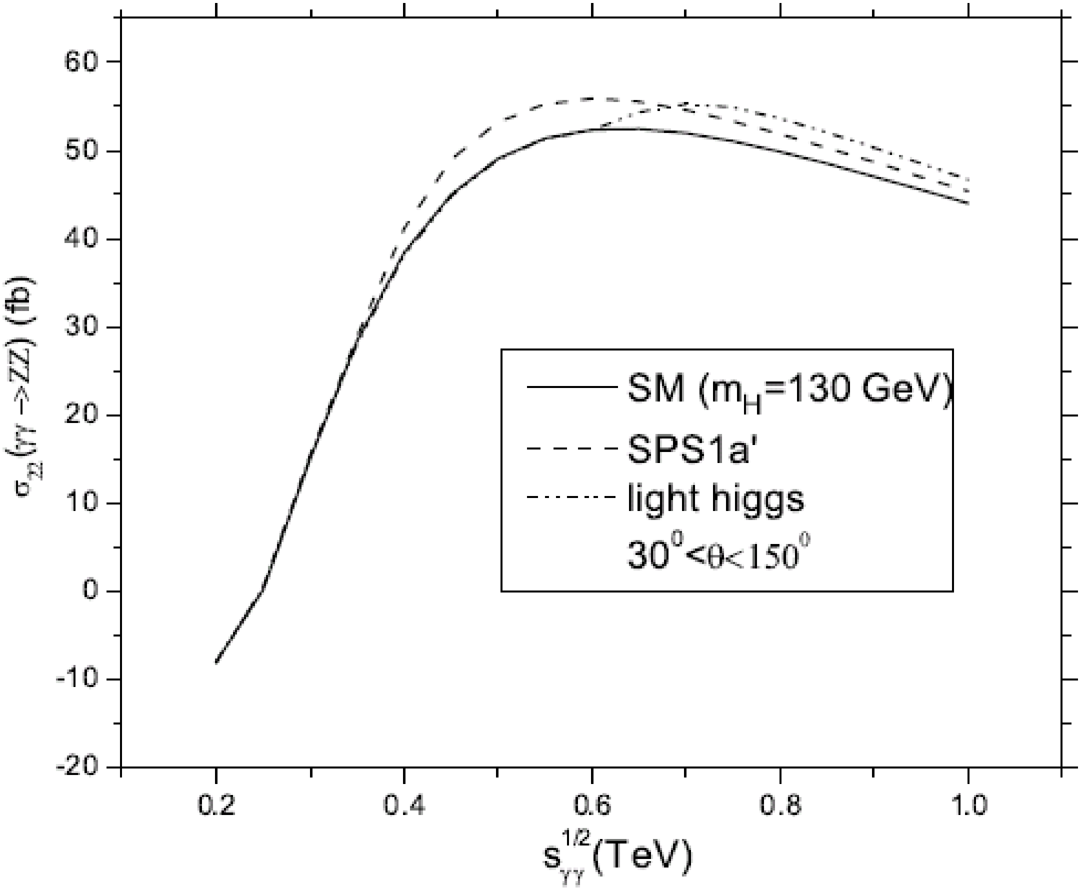


SPS1a'
m_0=70GeV,
$m_{1/2}$=250GeV,
A_0=-300GeV,
$\tan\beta$=10, μ>0

Here H^0 lies at 424GeV, but it couples so weakly, and its width is so large, that no peak is visible in σ_0, (integrated over the indicated angular range).

"light higgs" is an MSSM model from hep-ph/0609079, where H^0 is below the ZZ threshold.

σ_{22} cross sections in MSSM and SM



Again, no H^0 peak is visible in σ_{22}, in SPS1a'.

Nevertheless, there exist MSSM examples, where H^0 peaks may be visible in both, σ_0 and σ_{22}.

Summary

The purpose of this talk is to inform the community that a code called gamgamZZ.tar.gz exists in

http://users.auth.gr/~gounaris/FORTRANcodes/

which calculates:

- **All helicity amplitudes for $\gamma(\lambda_1)\,\gamma(\lambda_2) \rightarrow Z(\lambda_3)\,Z(\lambda_4)$.**
This should be useful in cases where Z-polarization effects must be studied.

- **All cross sections where Z-polarizations are summed over. These give all physical observables, in case Z-polarization is not looked at.**

- **MSSM parameters are assumed real.**

- **Please send me suggestions for improvements…**