Gamma-ray polarization

Tom Blackburn
Department of Physics, University of Gothenburg

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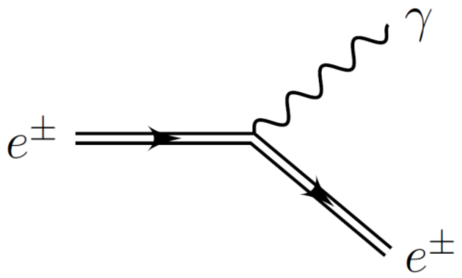
LUXE SAS

Overview

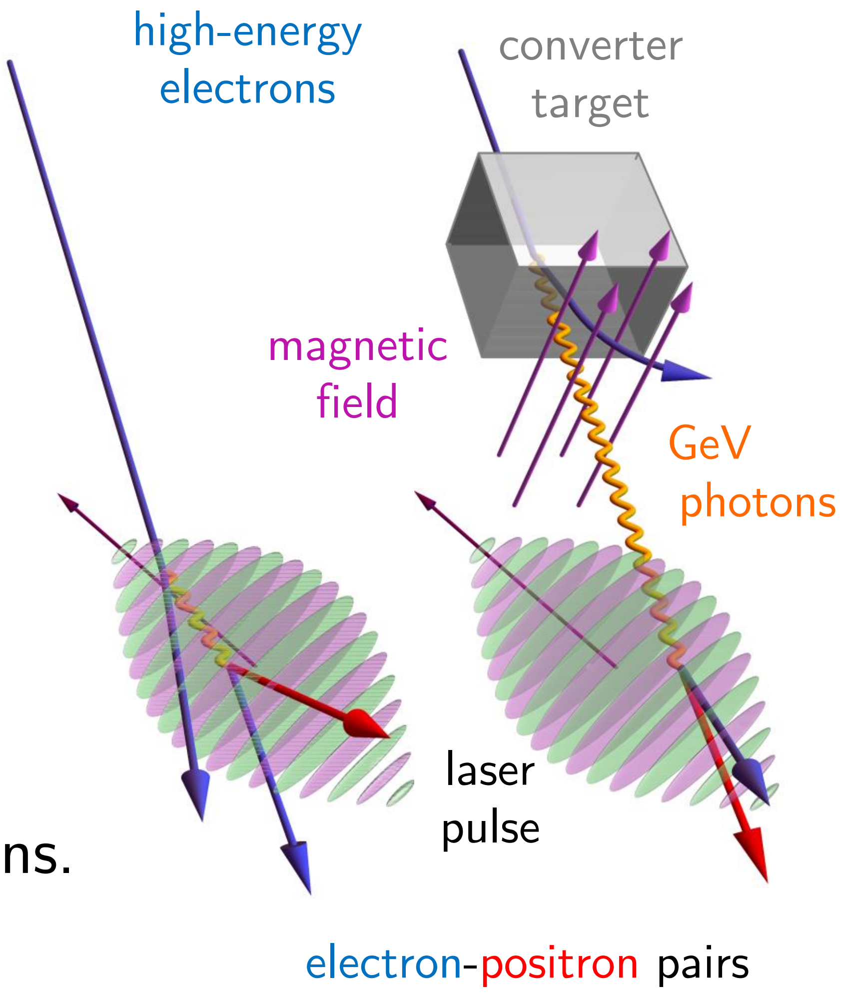
- All previous simulation results based on spin-averaged/summed rates.
- Ptarmigan now resolves gamma-ray polarization dependence in photon emission and electron-positron pair creation.
- Most significant for electron + LP laser collisions.
- Positron yield reduced by 20% when the polarization of the intermediate gamma ray is taken into account.

LUXE modes



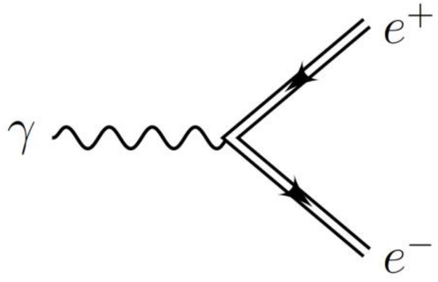
Electron-laser collisions:

- Nonlinear Compton scattering of multi-GeV photons
- "Mass shift" of the electrons.
- Trident electron-positron pair creation



Photon-laser collisions:

- Electron bunch directed onto foil, bremsstrahlung photons collide with the laser downstream
- Nonlinear Breit-Wheeler pair creation



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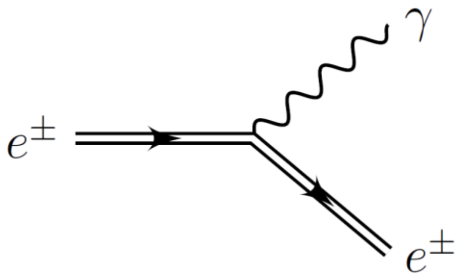

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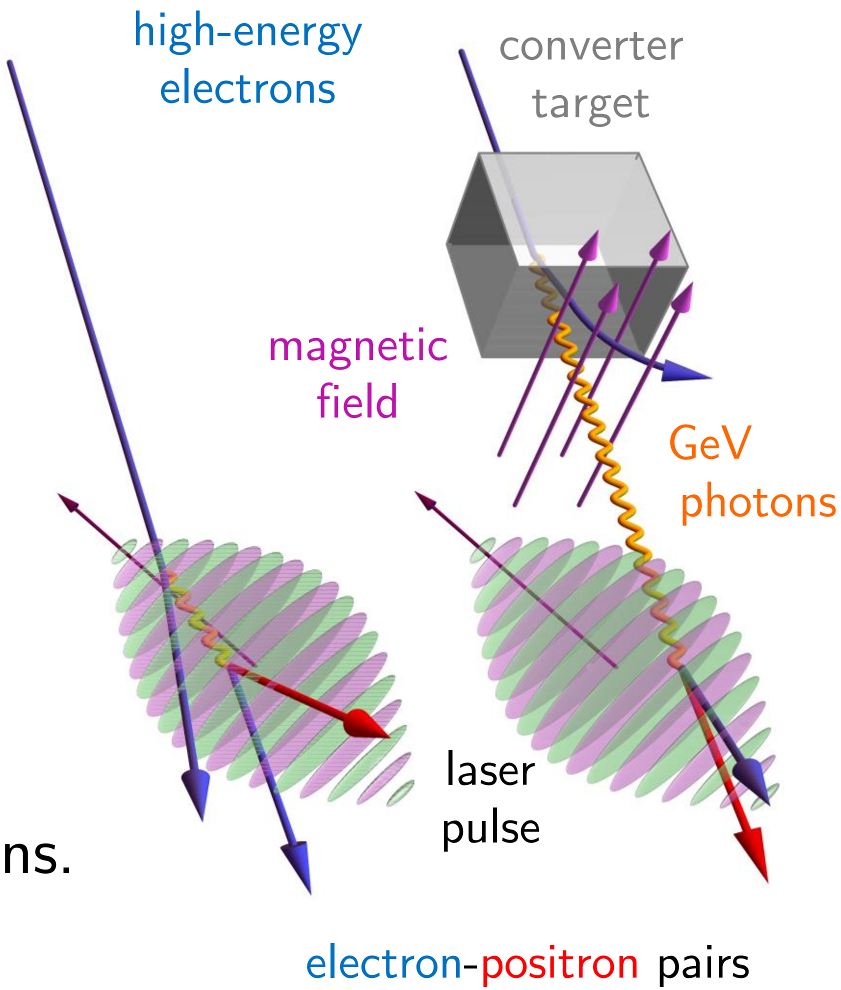

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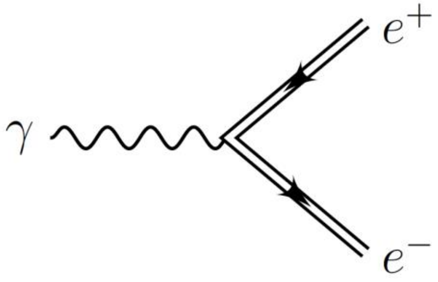
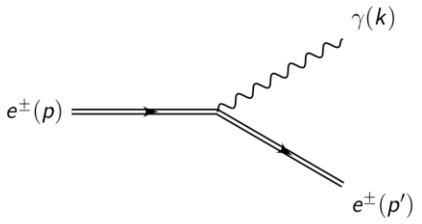


Required processes

Electron + laser

Nonlinear Compton scattering



Signals:

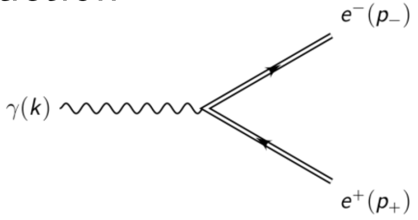
- Intensity dependence of Compton edges
- γ-photon angular profile

Needed:

- Photon emission rate (LMA, LP/CP)

Bremsstrahlung γ + laser

Nonlinear Breit-Wheeler pair production



Signals:

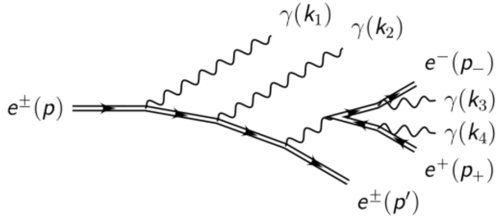
- Intensity dependence of positron yield

Needed:

- Pair creation rate (LMA, LP/CP), unpolarized γ photons

Electron + laser

Nonlinear trident pair creation



Signals:

- Intensity dependence of positron yield

Needed:

- Photon emission rate (LMA, LP/CP), γ-pol resolved
- Pair creation rate (LMA, LP/CP), γ-pol resolved

Simulation framework

Required processes

Electron + laser	Bremsstrahlung γ + laser	Electron + laser

Electron + laser

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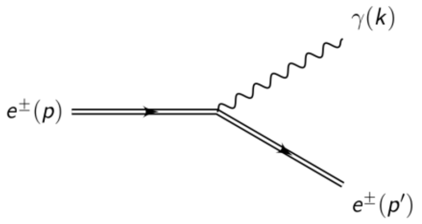

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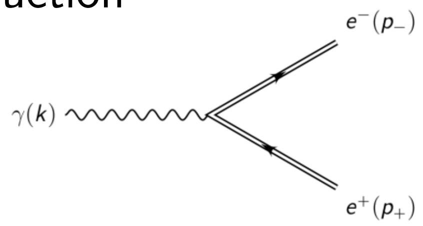

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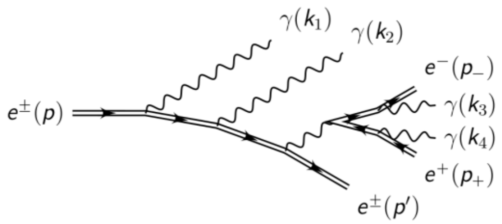

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Needed:
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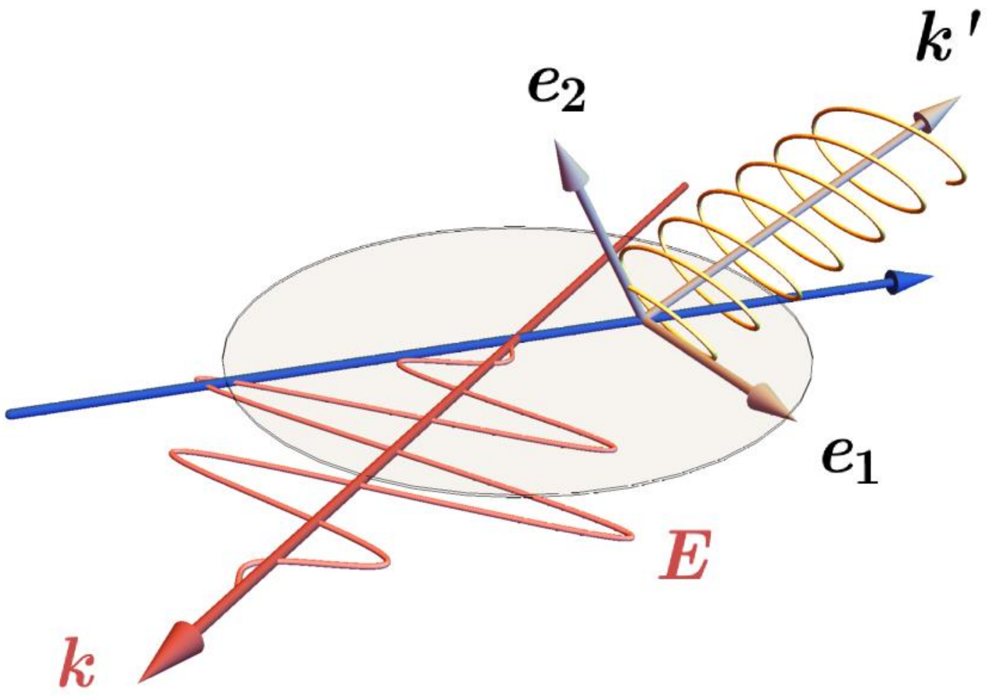
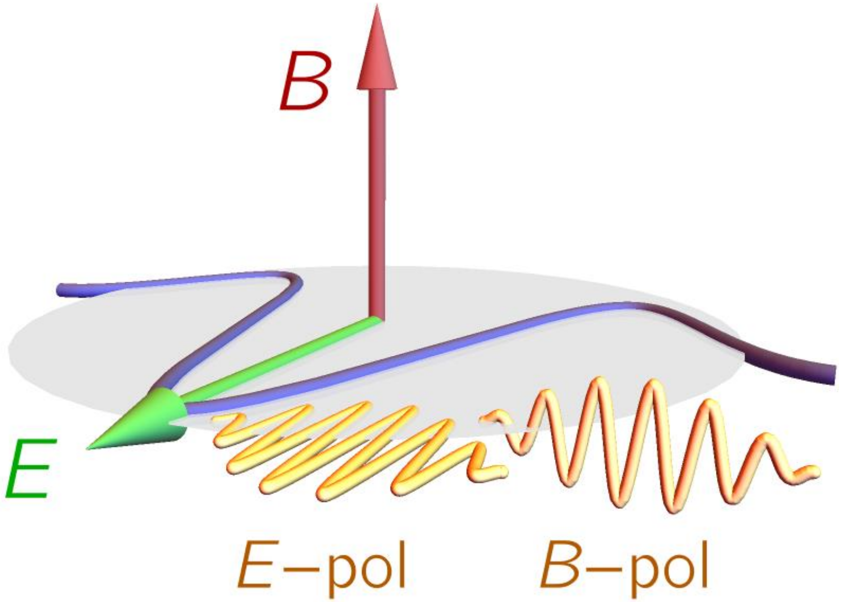
- Pair creation rate (LMA, LP/CP), γ-pol resolved

Description of polarization

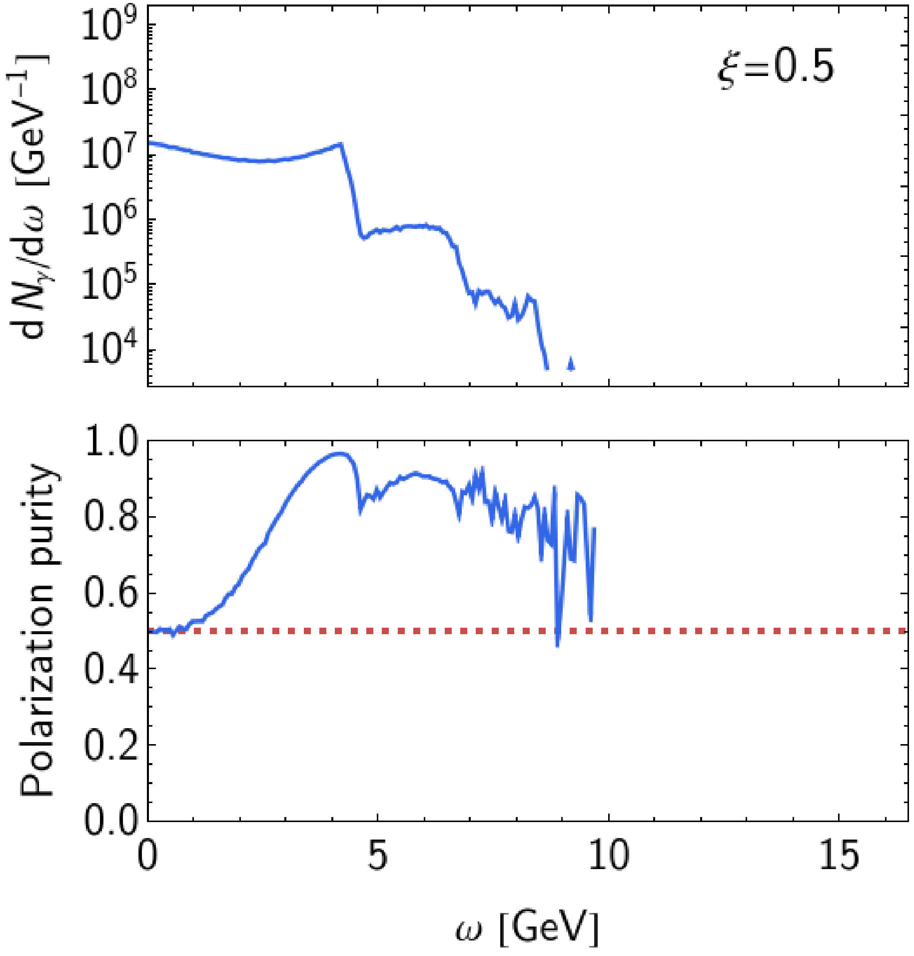


- Photon polarization state described by three Stokes parameters S_1, S_2, S_3.
- (S_0: Always 1.)
- S_1: linear pol. along $\boldsymbol{e_1}$ and $\boldsymbol{e_2}$.
- S_2: linear pol. along $(\boldsymbol{e_1} \pm \boldsymbol{e_2})/\sqrt{2}$.
- S_3: circular polarization.
- Unpolarized? $S_1 = S_2 = S_3 = 0$.

Radiation is polarized



Electron-laser, LP, phase 0:



- Radiation is predominantly *E*-polarized i.e. in the plane of the electron trajectory...

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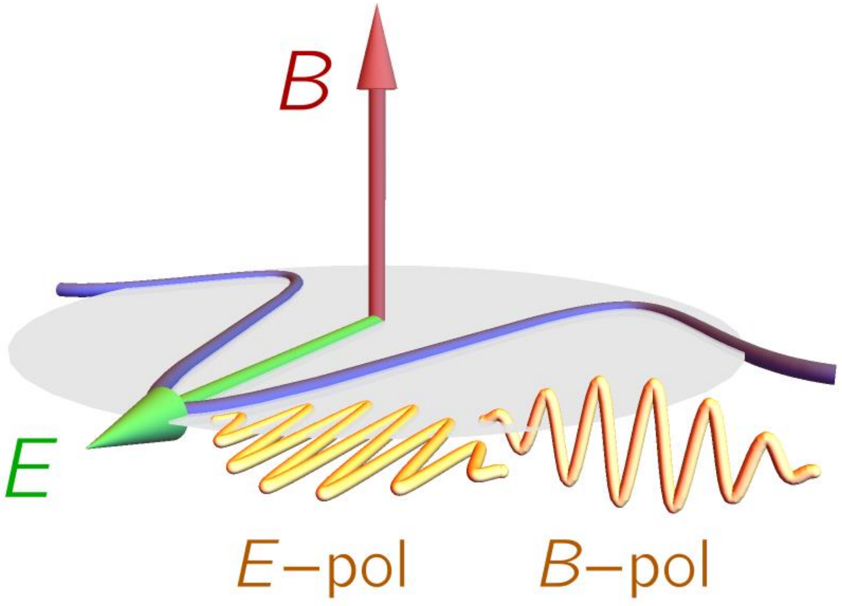

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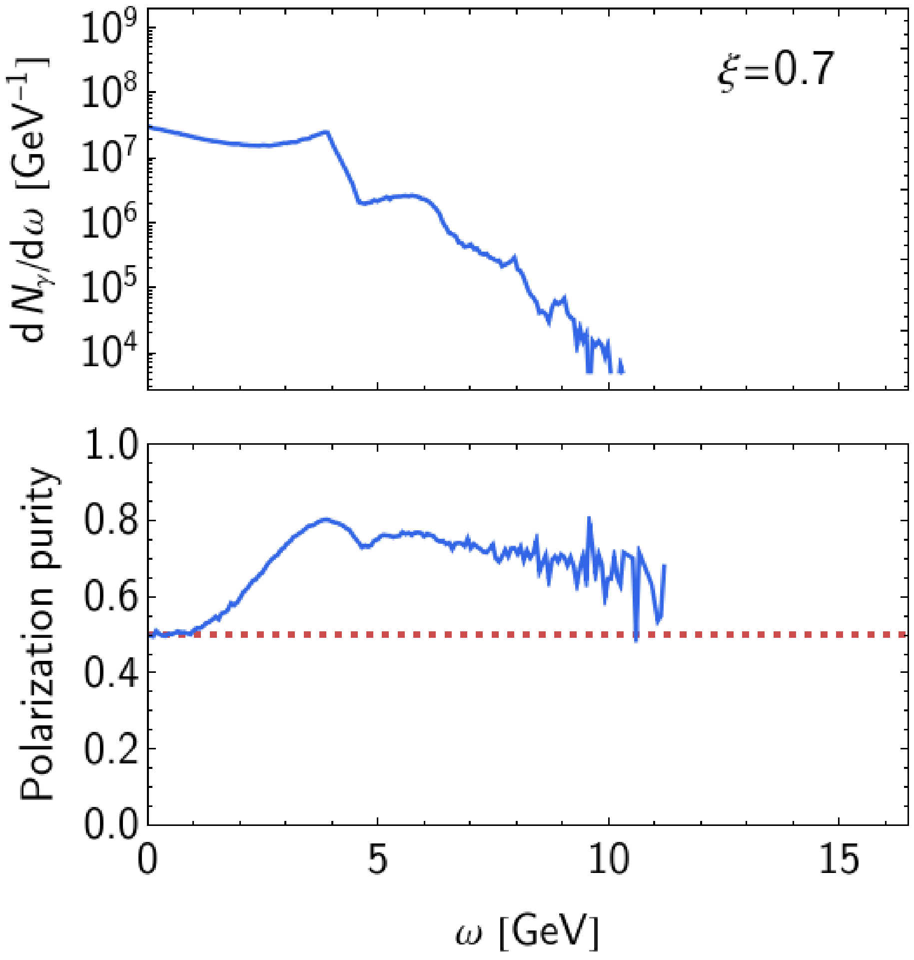

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Nonlinear Compton

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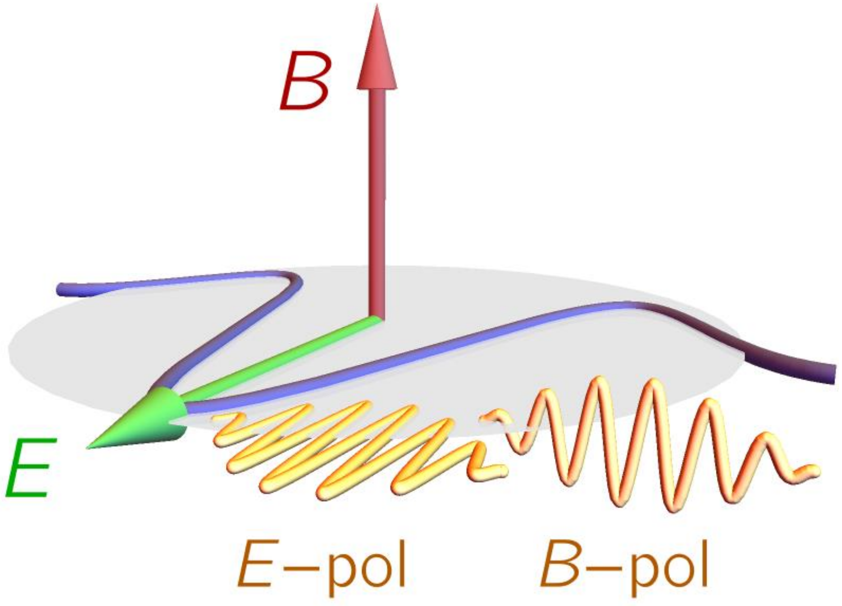

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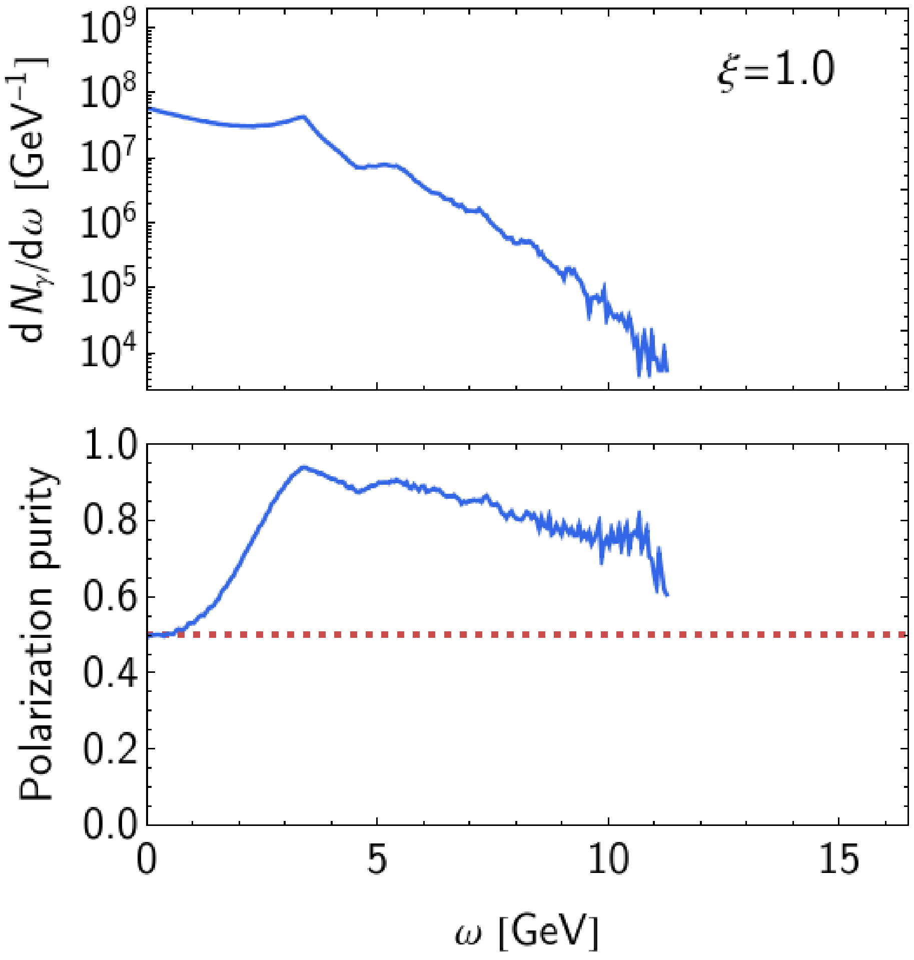

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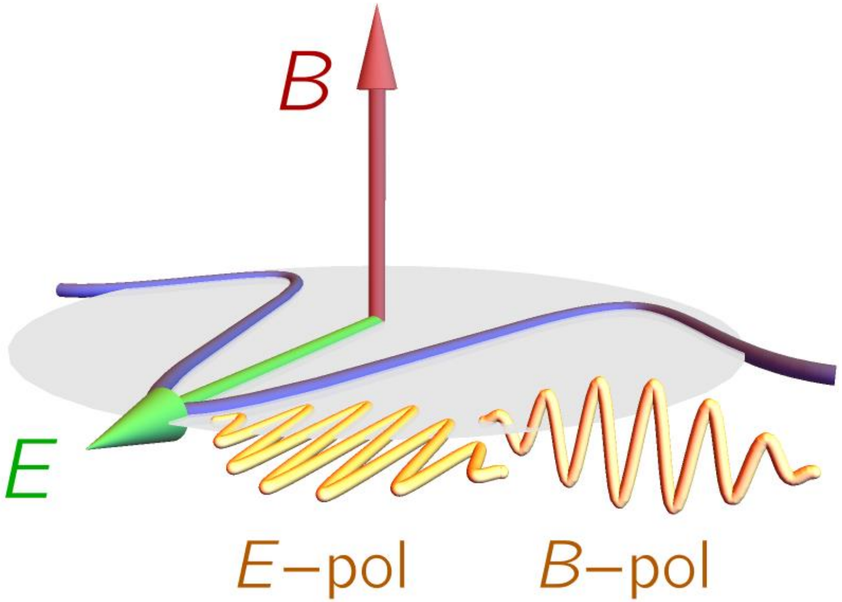

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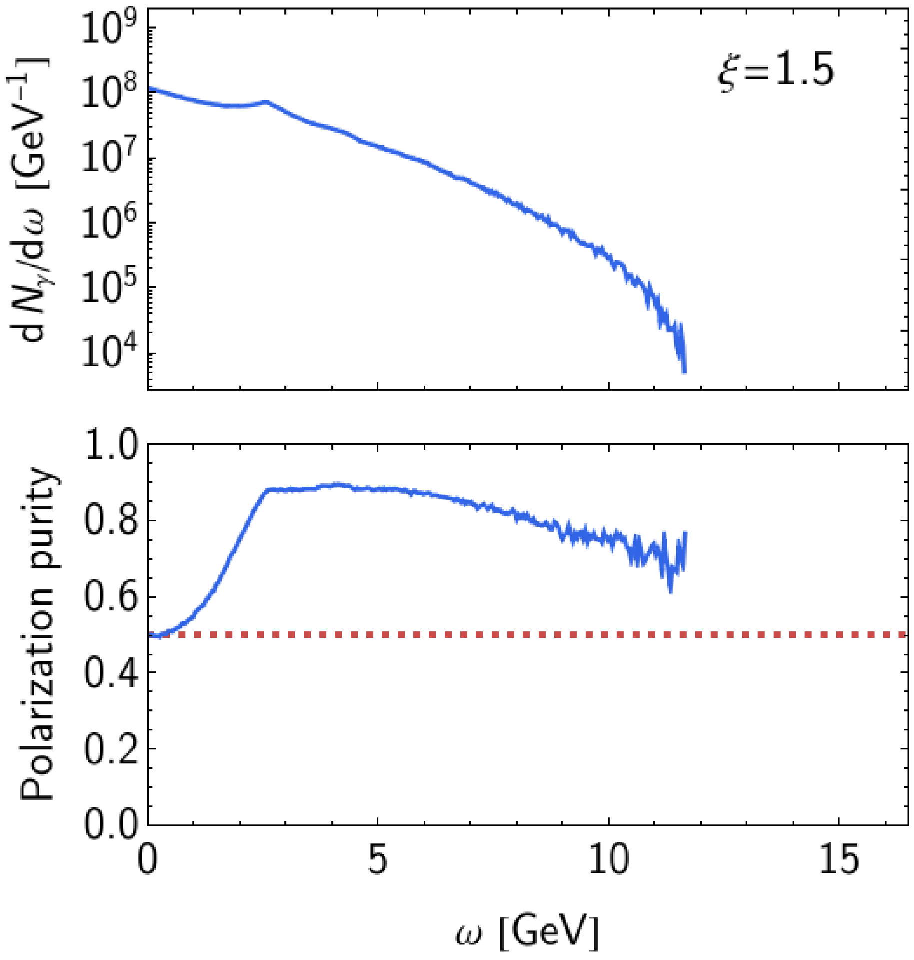

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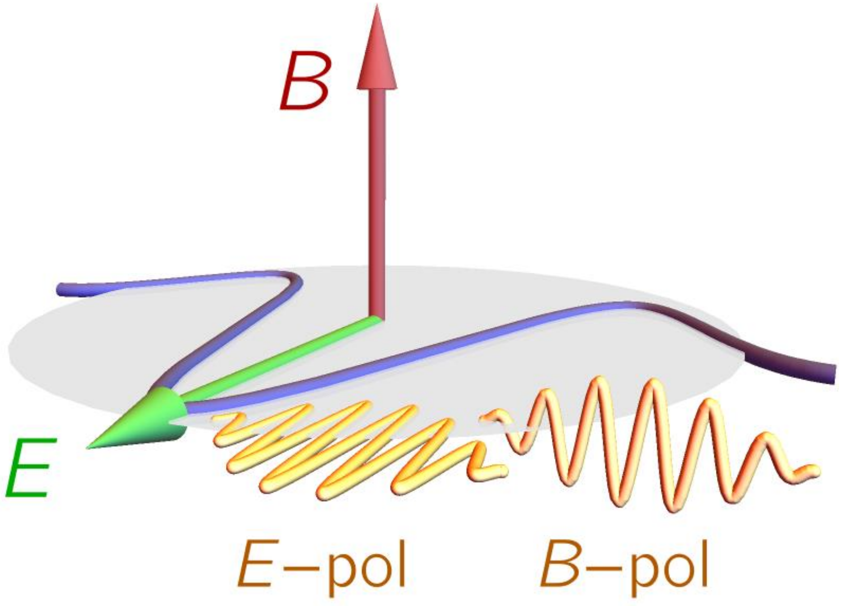

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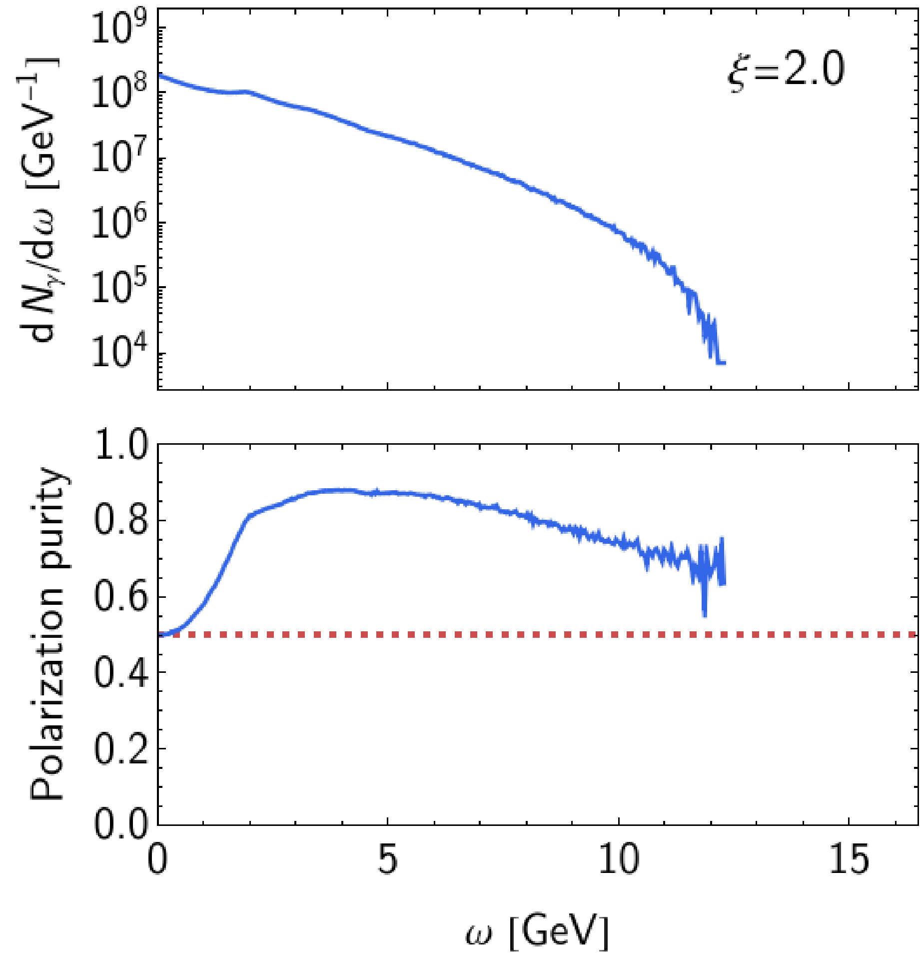

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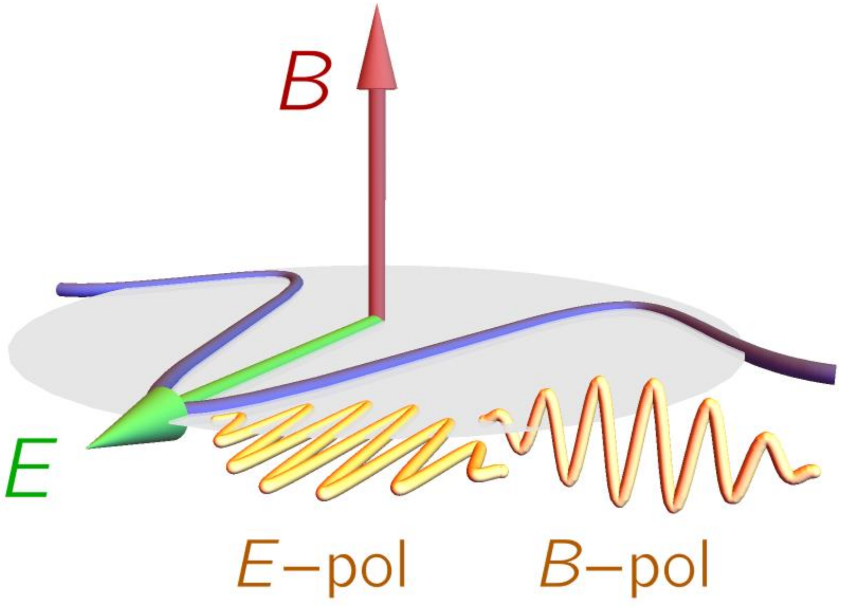

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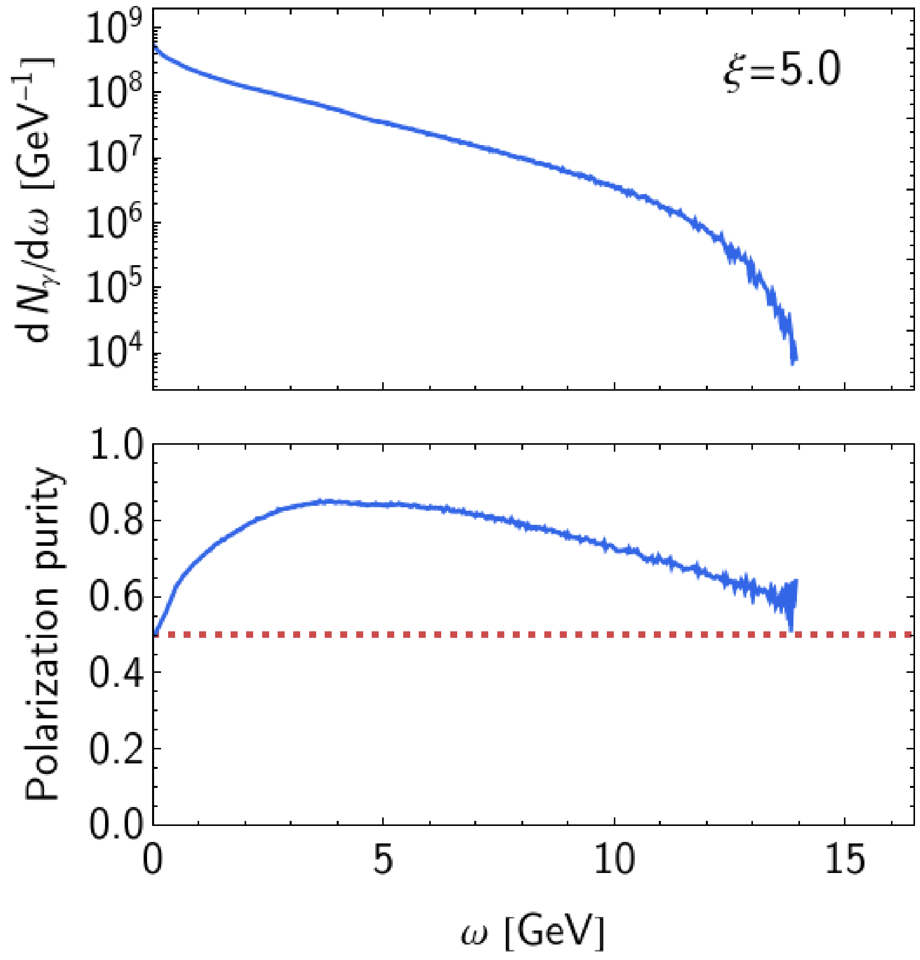

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Nonlinear Compton

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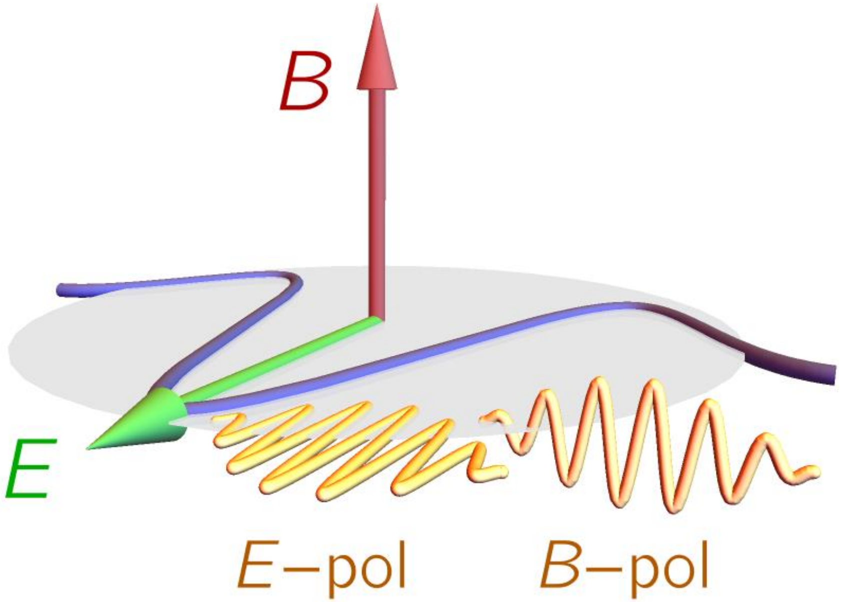

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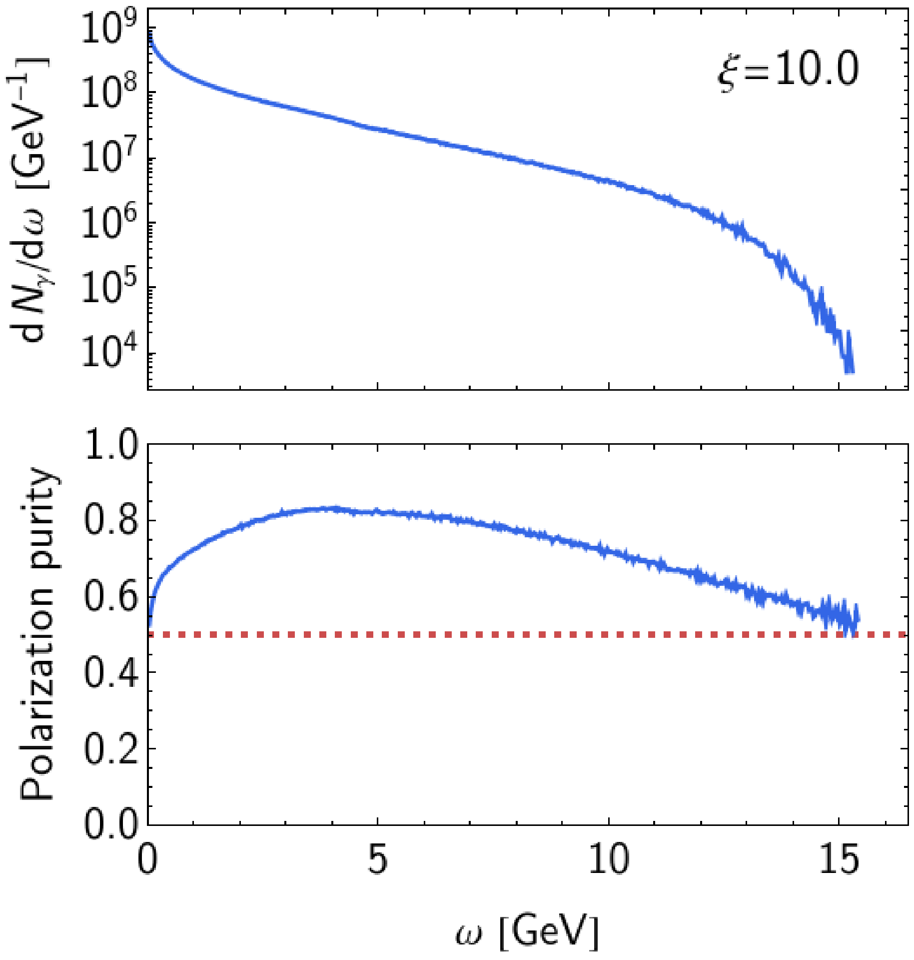

Pair creation is polarization-dependent

Polarization-resolved pair creation rate (LCFA):

$$\frac{dW_\pm}{df} = \frac{\alpha m^2}{\sqrt{3}\pi\omega'}\left[\left(\frac{f}{1-f} + \frac{1-f}{f} - S_1\right) K_{2/3}(\xi) - \int_\xi^\infty K_{1/3}(y)\,dy\right]$$

$$\xi = \frac{2}{3\chi f(1-f)}$$

Single and double-differential rates depend only on S_1;
triple-differential depends on all three.

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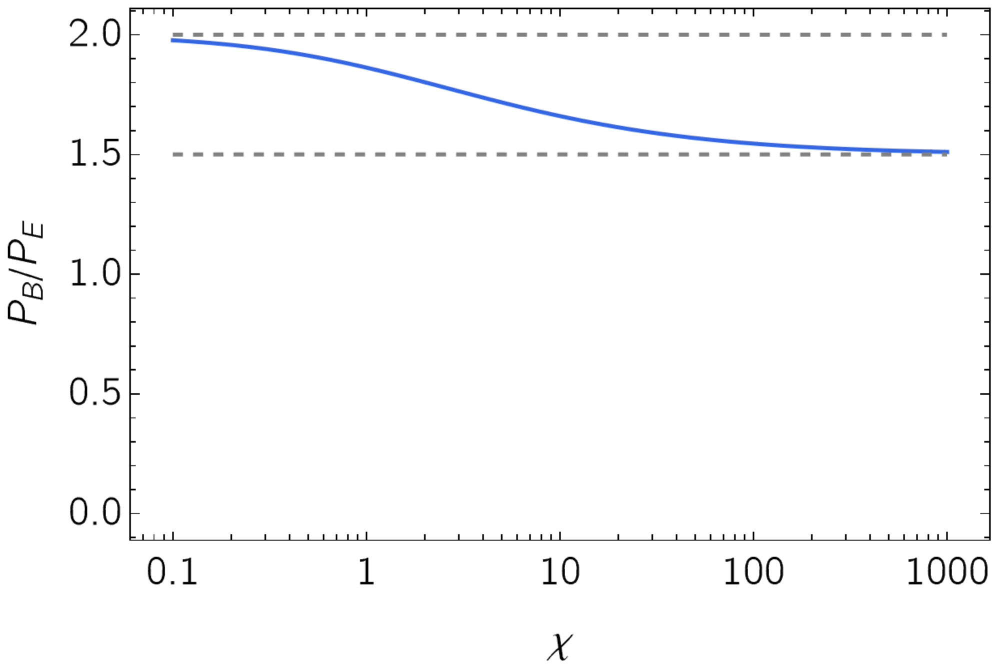
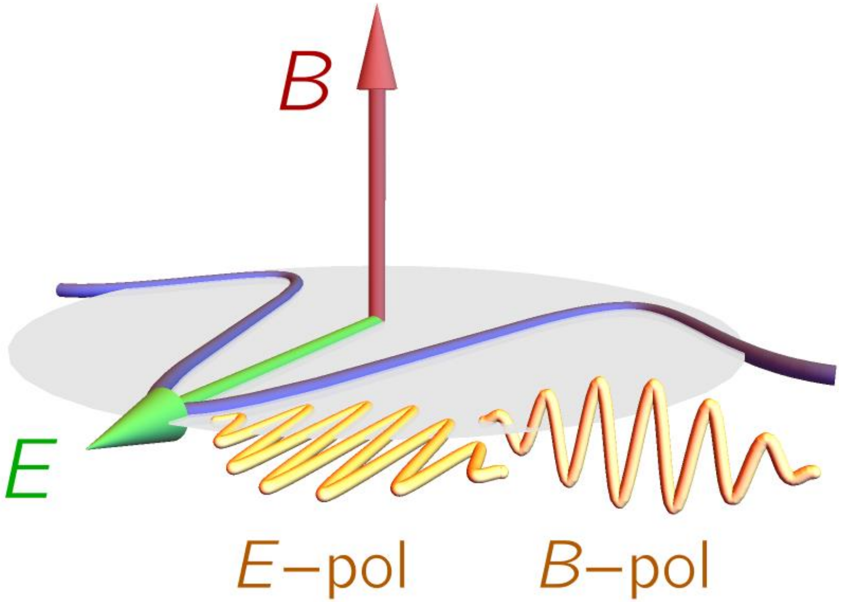
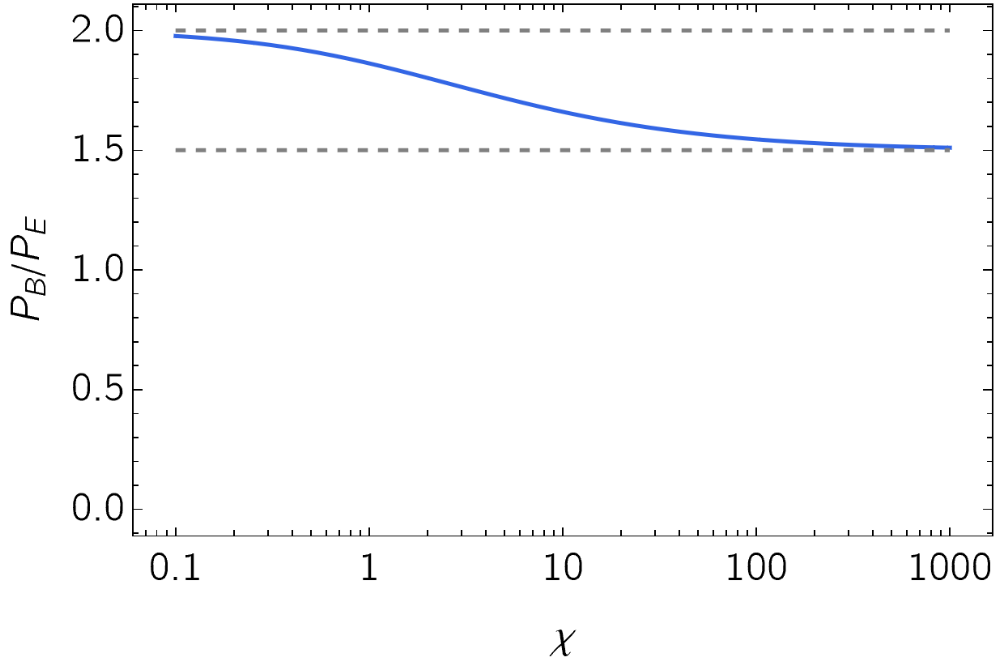


- *B*-polarized photons are more likely to create electron-positron pairs.

Positron yield is overestimated





- Radiation is predominantly *E*-polarized i.e. in the plane of the electron trajectory...
- ... but *B*-polarized photons are more likely to create electron-positron pairs.

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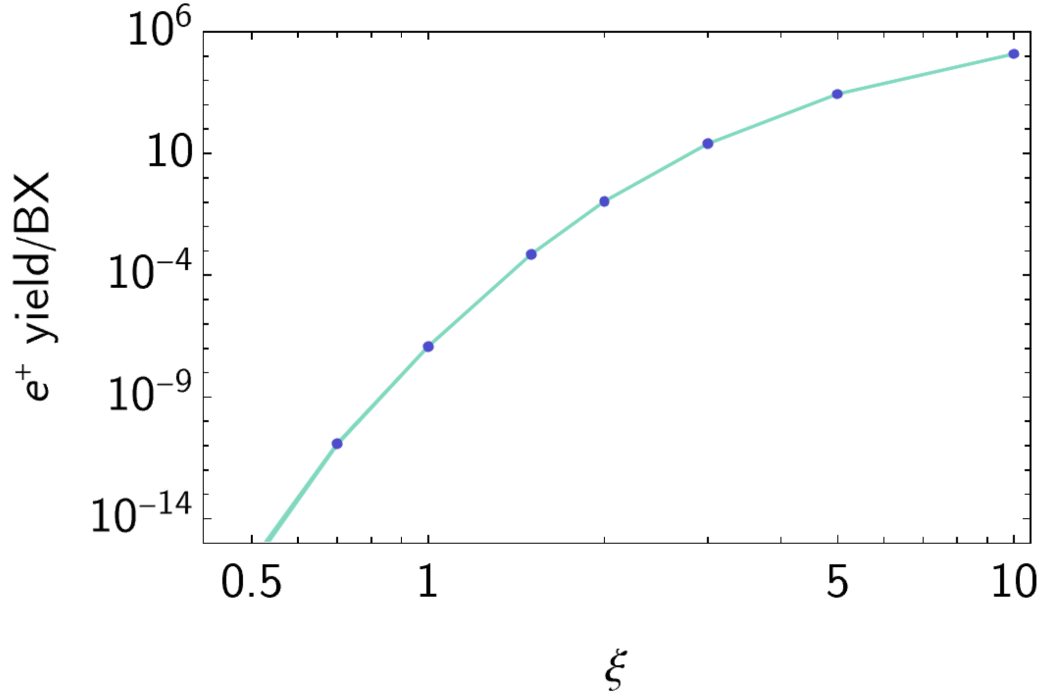
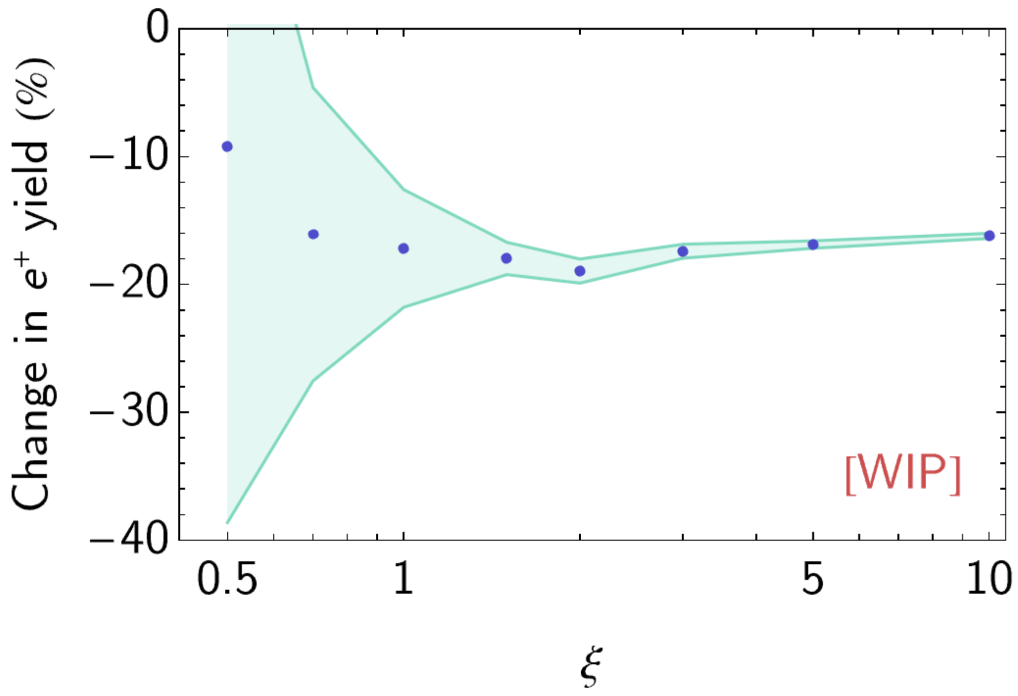
Conclusion

Positron yield is overestimated





- Standard electron beam parameters
- Phase-0 laser (40 TW), linearly polarized

- Positron yield reduced by 20%.
- Expected to be almost independent of ξ, according to theory.

Overview

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- Ptarmigan now resolves gamma-ray polarization dependence in photon emission and electron-positron pair creation.
- Most significant for electron + LP laser collisions.
- Positron yield reduced by 20% when the polarization of the intermediate gamma ray is taken into account.
- What about ICS-laser?