Chiral amplitudes for two jets processes in quasi-peripheral kinematics

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Outlook

- Introduction - ILC
- Quasipheripheral kinematics
- Impact factors
- Radiative corrections
- Conclusions

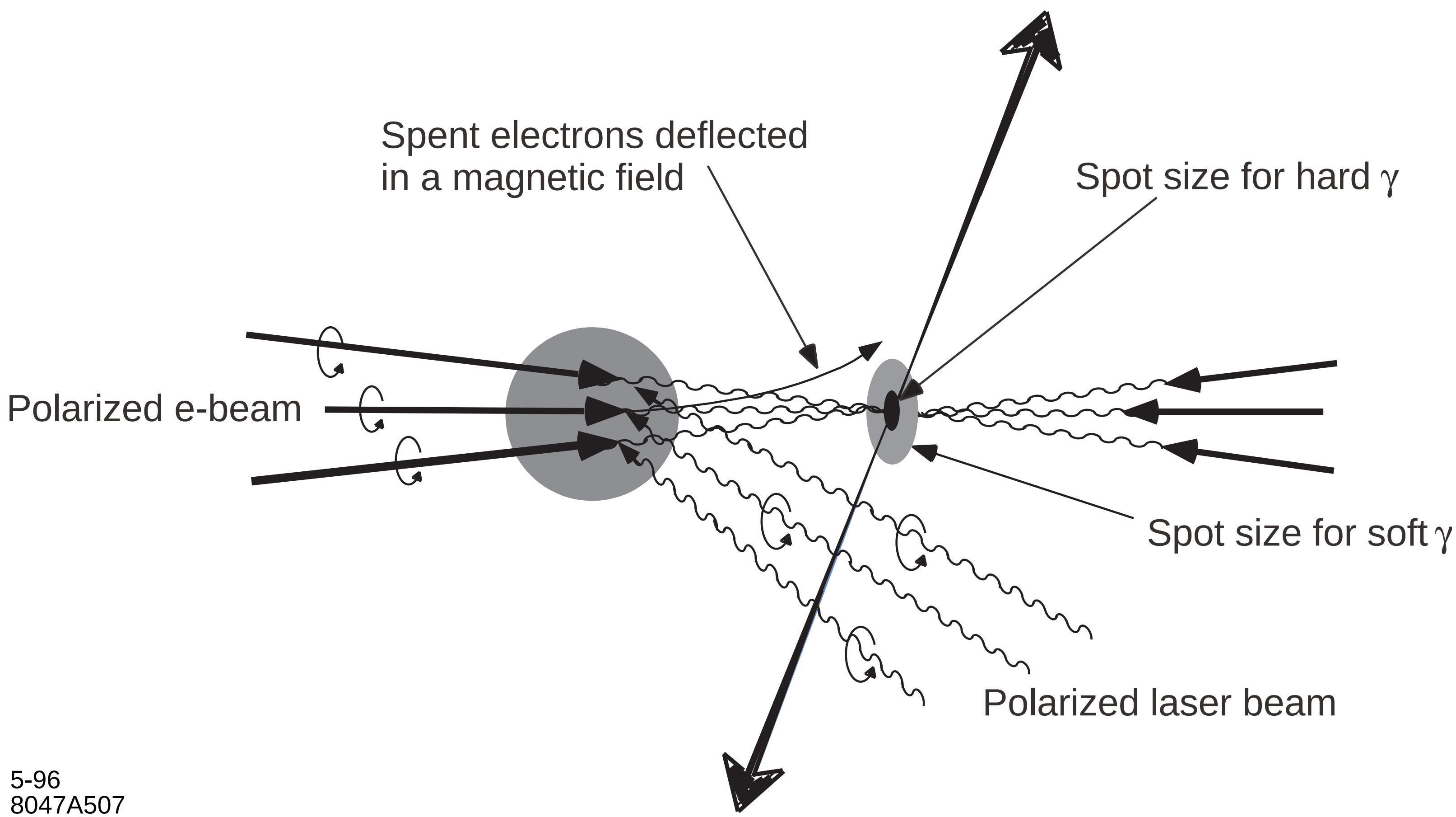
Relevant Works

- V. Bytev, E. Bartos, M. V. Galynskii and E. A. Kuraev,
  "Radiative corrections to chiral amplitudes in quasiperipheral kinematics,"
  J. Exp. Theor. Phys. 103, 224 (2006).

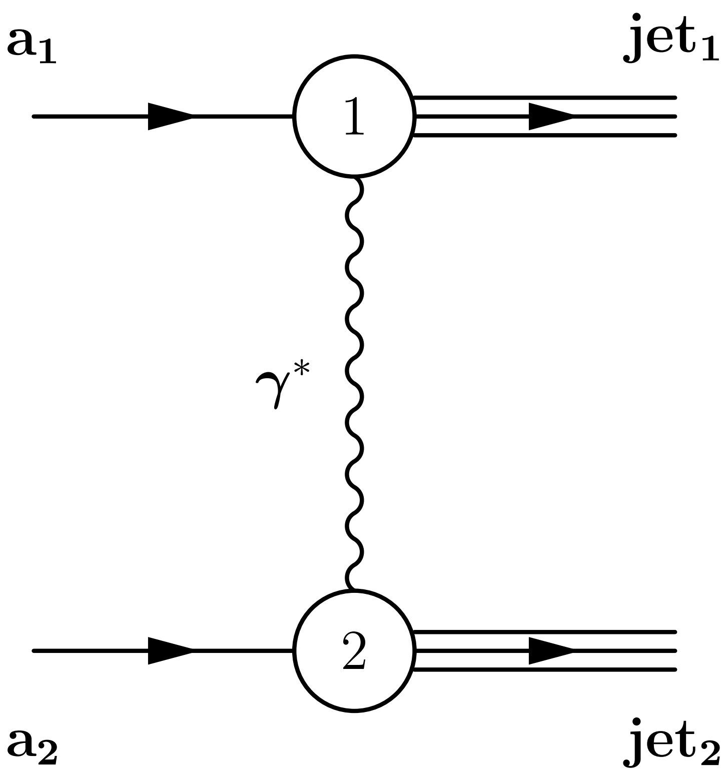
- E. Bartos, M. V. Galynsky, S. R. Gevorkian and E. A. Kuraev,
  "QED calibration processes for polarized gamma–gamma and gamma–e- colliders,"
  Phys. Part. Nucl. 35, S90 (2004).

- E. Bartos, A. Z. Dubnickova, M. V. Galynskii and E. A. Kuraev,
  "Calibration processes for photon–photon colliders,"
  Nucl. Phys. B 676, 481 (2004).

International Linear Collider



Considered QED processes



$$a_1(p_1,\delta_1) + a_2(p_2,\delta_2) \rightarrow$$
$$\rightarrow \mathrm{jet}_1^{(\lambda_1)} + \mathrm{jet}_2^{(\lambda_2)}$$

$$a_{1,2} = e^{\pm}, \gamma,$$
$$(p_1+p_2)^2 = s \gg m_i^2,$$

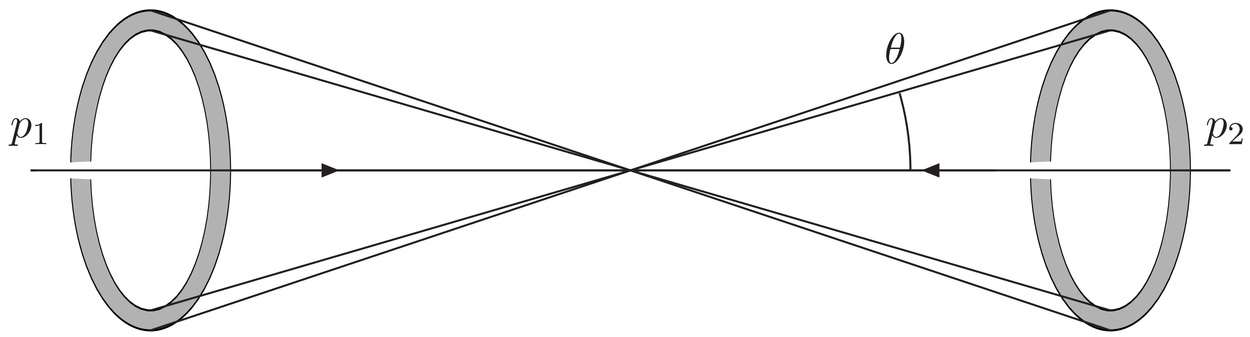
- Processes could be studied at high energy collisions of initial particles in **peripheral kinematics**, i.e. small angles θ of emission of jet particles to the direction of its parent particle

- **Significant property** of processes: their differential and total crossing sections do not decrease with c.m.s. total energy $\sqrt{s}$

- Corresponding cross sections of the relevant QED processes are **large numerically** $\Rightarrow$ essential background in studying of weak and strong interactions. Moreover, could serve for monitoring and calibration purposes.

- Unfortunately, small θ-s are very **hard measurable**.

Quasipheripheral (QP) kinematics



- $\frac{2m_i}{\sqrt{s}} \ll \theta_i \ll 1$ – provides the independence on energy of differential cross sections but have an accuracy of order of θ^2, so comparable with the accuracy of peripheral kinematics contribution.

- independence of spin states of a_1-jet_1 and a_2-jet_2 blocks of process (we can put $\delta_{1,2} = +1$) $\rightarrow$ consequence of Gribov's decomposition of metric tensor

Generalized form of the amplitude

$$M^{(12)} = \mathrm{i}s\frac{8\pi\alpha}{\boldsymbol{q}^2}\Phi_1\Phi_2,$$

$$\Phi_1 = \frac{1}{s}J^{1,\mu}p_{2\mu}, \qquad \Phi_2 = \frac{1}{s}J^{2,\nu}p_{1\nu}.$$

J^i – currents for blocks 1,2

Φ_i – their light-cone projections: $\Phi_{1,2}(\boldsymbol{q}) \to 0$ if $|\boldsymbol{q}| \to 0$

We used Sudakov's parametrization of 4-momenta

$$p_{i1} = \alpha_i p_2 + x_i p_1 + p_{\perp i1}, \qquad p_{j2} = y_j p_2 + \beta_j p_1 + p_{\perp j2},$$

$$q = \alpha p_2 + \beta p_1 + q_\perp, \qquad q^2 \approx -\boldsymbol{q}^2$$

The differential cross section written in terms of impact factors

$$\int \mathrm{d}\sigma^{(12)} = \frac{\alpha^2}{\pi^2}\frac{\mathrm{d}^2\boldsymbol{q}}{(\boldsymbol{q}^2)^2}\int d\tau_1^{\lambda_1}\int d\tau_2^{\lambda_2},$$

$$\int \mathrm{d}\tau_i^{(\lambda_i)} = \int |\Phi_i^{(\lambda_i)}(q)|^2 \mathrm{d}\Gamma_i, \quad i = 1, 2.$$

Impact factors $\int \mathrm{d}\tau_i$ do not depend on s.

Helicity states

- F. A. Berends, R. Kleiss, P. De Causmaecker, R. Gastmans, W. Troost and T. T. Wu,
  "Multiple Bremsstrahlung In Gauge Theories At High-Energies. 2. Single Bremsstrahlung,"
  Nucl. Phys. B **206** (1982) 61.

- F. A. Berends, R. Kleiss, P. De Causmaecker, R. Gastmans and T. T. Wu,
  "Single Bremsstrahlung Processes In Gauge Theories,"
  Phys. Lett. B **103** (1981) 124.

Conversion of the initial photon with momentum p_1 and helicity λ

$$\gamma^*(q) + \gamma(p_1, \lambda) \to \mathrm{e}^+(q_+) + \mathrm{e}^-(q_-, \sigma)$$

$$\hat{\varepsilon}^\lambda(p_1) = N_\gamma(\hat{q}_-\hat{q}_+\hat{p}_1\omega_{-\lambda} - \hat{p}_1\hat{q}_-\hat{q}_+\omega_\lambda),$$

$$(\varepsilon^\lambda)^2 = 0, \quad (\varepsilon^\lambda\varepsilon^{-\lambda}) = -1, \quad \omega_\sigma = \frac{1+\sigma\gamma_5}{2}, \quad \sigma = \pm 1.$$

Helicity states of fermions are defined as $u^\sigma = \omega_{-\sigma}u$, $v^\sigma = \omega_\sigma v$.

$$\Phi_B^{\gamma,++} \sim \bar{u}(q_-)\omega_-\hat{q}_+\hat{q}\frac{\hat{p}_2}{s}\omega_+ v(q_+) \to \int \mathrm{d}\tau_B^{\gamma,++} = \frac{\alpha}{\pi}\int \frac{d^2q_-dx_-}{x_+x_-}\frac{\boldsymbol{q}^2x_+^2}{\chi_+\chi_-}$$

Other subprocesses in Born approximation

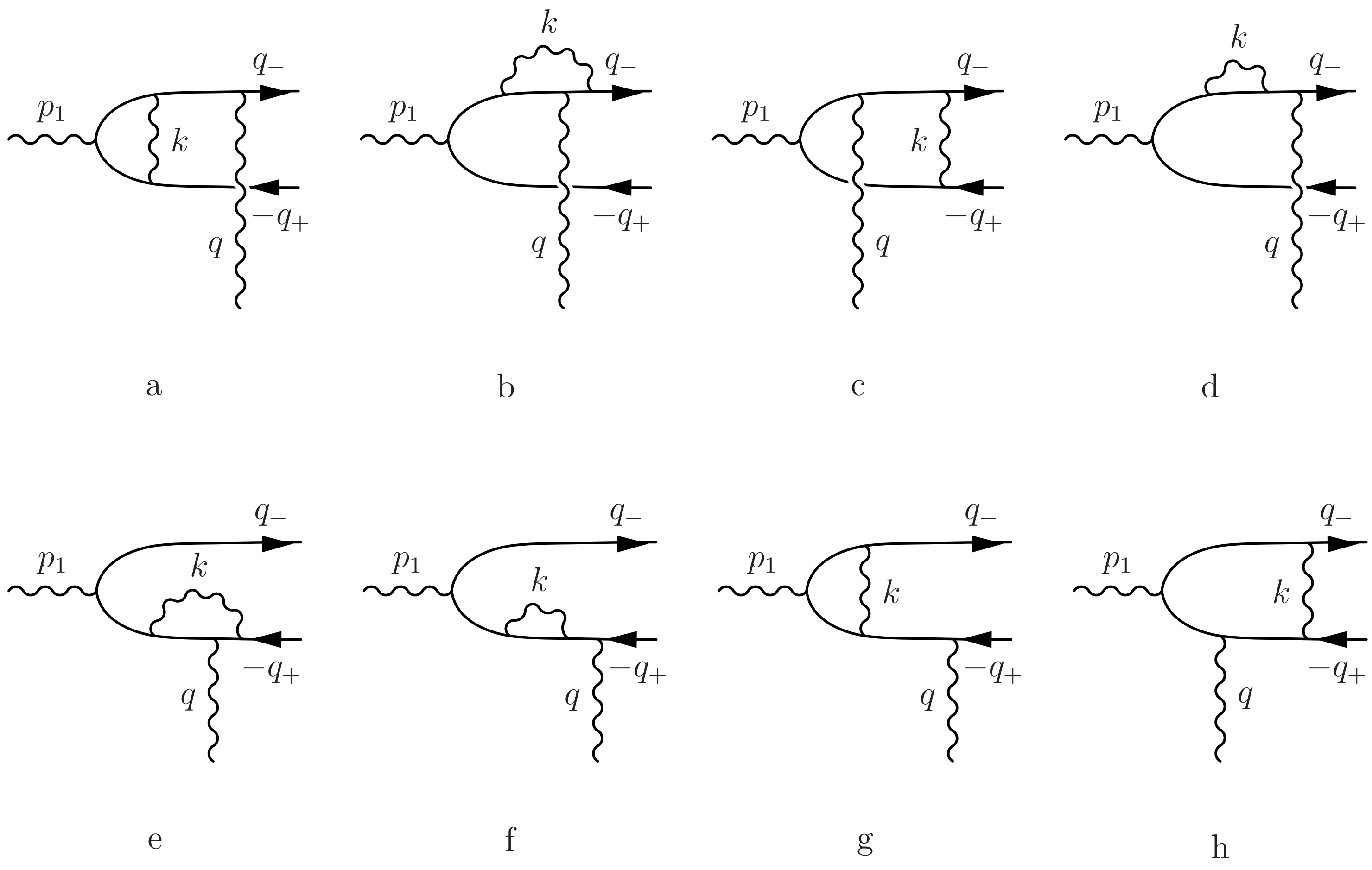
$$\gamma(p_1, \lambda = +) + \mathrm{e}^-(p_2, \eta) \to \mathrm{e}^+(q_+, \mp) + \mathrm{e}^-(q_-, \pm) + \mathrm{e}^-(p_2', \eta)$$

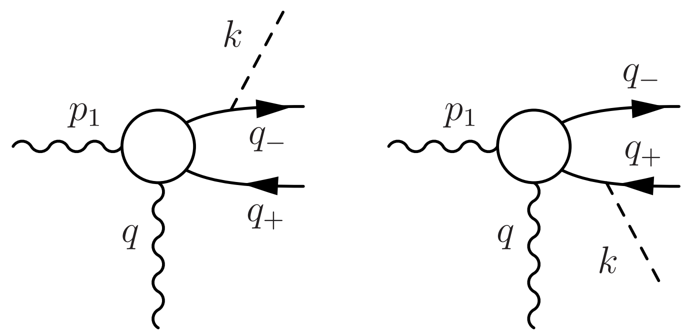
$$\frac{\mathrm{d}\sigma_\eta^{\gamma,++}}{\mathrm{d}\Gamma} = \frac{\mathrm{d}\sigma_\eta^{\gamma,--}}{\mathrm{d}\Gamma} = \frac{2x_+^2\alpha^3}{\pi^2\boldsymbol{q}^2\chi_+\chi_-},$$
$$\frac{\mathrm{d}\sigma_\eta^{\gamma,+-}}{\mathrm{d}\Gamma} = \frac{\mathrm{d}\sigma_\eta^{\gamma,-+}}{\mathrm{d}\Gamma} = \frac{2x_-^2\alpha^3}{\pi^2\boldsymbol{q}^2\chi_+\chi_-}, \quad \mathrm{d}\Gamma = \frac{\mathrm{d}^2q\mathrm{d}^2q_-\mathrm{d}x_-}{x_+x_-}.$$

Similarly for the process

$$\mathrm{e}^-(p_2, \eta) + \mathrm{e}^-(p_1, \sigma = +) \to \mathrm{e}^-(p_1', +) + \gamma(k_1, \lambda = \pm) + \mathrm{e}^-(p_2', \eta)$$

Photon impact factor



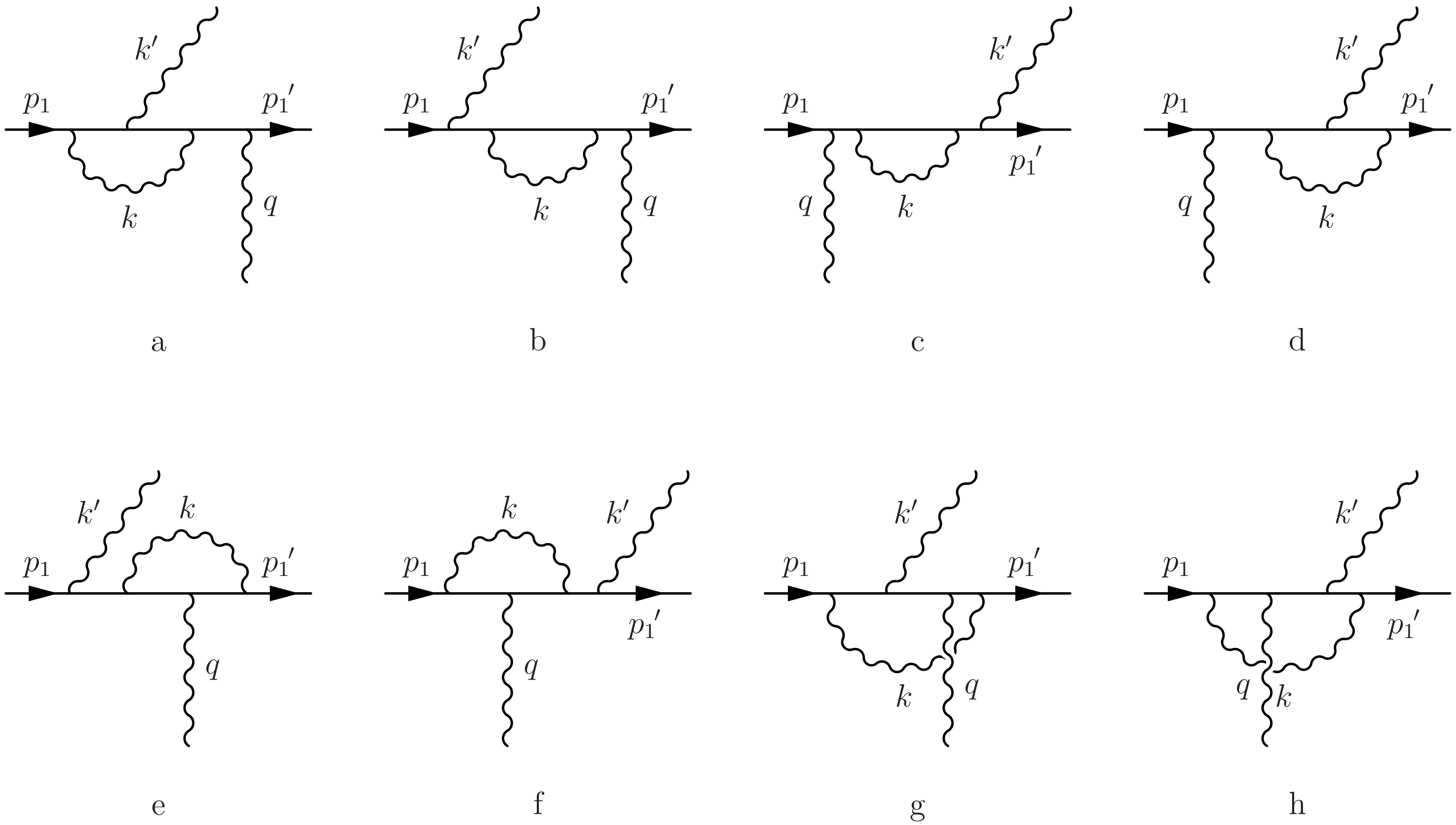


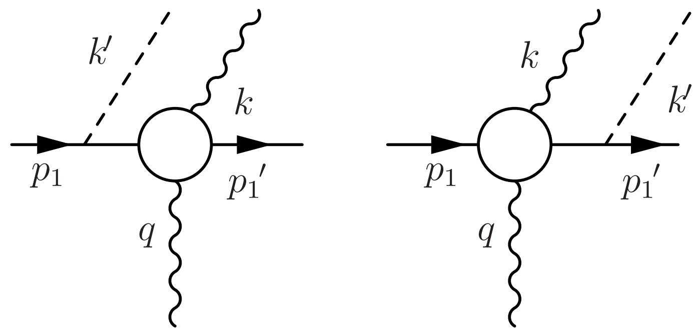
$$
\begin{aligned}
d\sigma^{\gamma} &= 2[d\tau^{\gamma,+\pm}_{\pm,\mathrm{box}} + d\tau^{\gamma,+\pm}_{\mp,\Sigma V} + d\tau^{\gamma,+\pm}_{\mp,V}] + d\tau^{\gamma,+\pm}_{\mathrm{soft}} \\
&= \frac{\alpha}{2\pi} d\tau^{\gamma\pm}_{B}[(l_s - 1)(\ln\Delta + 3 - 2\ln(x_+ x_-)) + K^{\gamma,\pm}_{SV}], \\
&\quad \Delta = \Delta\epsilon/\epsilon_{\gamma}, \quad l_s = \ln(s_1/m^2)
\end{aligned}
$$

– K factor – next-to-leading terms

– r.h.s. $\rightarrow 0$ if $\boldsymbol{q}^2 \rightarrow 0$ (check of calculation)

Electron impact factor





$$
\begin{aligned}
\mathrm{d}\sigma^{\mathrm{e}} &= 2[\mathrm{d}\tau^{\mathrm{e},+\pm}_{i,V} + \mathrm{d}\tau^{\mathrm{e},+\pm}_{i,\Sigma} + \mathrm{d}\tau^{\mathrm{e},+\pm}_{i,V} + \mathrm{d}\tau^{\mathrm{e},+\pm}_{i,box}] + \mathrm{d}\tau^{+\pm}_{\mathrm{e,soft}} \\
&= \mathrm{d}\tau^{\mathrm{e},+\pm}_{B}\frac{\alpha}{2\pi}[(l_u - 1)(4\ln\Delta + 3 - 2\ln\chi') + K^{\mathrm{e},+\pm}_{SV}], \\
l_{\chi'} &= \ln(\chi'/m^2) - i\pi^2
\end{aligned}
$$

– K factor – next-to-leading terms

Contribution of hard photon emission

$$\text{parameter } \theta_0 \ (\theta_0 \ll 1) \begin{cases} \theta < \theta_0, & \textbf{collinear} \text{ kinematics} \\ & \text{CALCUL collaboration,} \\ \theta > \theta_0, & \textbf{noncollinear} \text{ kinematics} \\ & \text{quasi-real electron method} \end{cases}$$

- total sum is independent on the parameter θ_0
- next-to-leading terms depend on experimental setup (included in K-factors)
- K-factors are free of infrared and collinear divergences (are independent of λ, Δ and θ_0)

Results

γ impact factor

$$\mathrm{d}\tau^{\gamma,\lambda\sigma}(q_-,q_+) = \int\limits_{x_-}^{1} \frac{\mathrm{d}z_-}{z_-} \int\limits_{x_+}^{1} \frac{\mathrm{d}z_+}{z_+} D(\frac{x_-}{z_-}, l_s) D(\frac{x_+}{z_+}, l_s) \mathrm{d}\tau_B^{\gamma,\lambda\sigma}(\frac{q_-}{z_-}, \frac{q_+}{z_+})$$

$$\times\ (1 + \frac{\alpha}{\pi}[K_{SV}^{\gamma,\lambda\sigma} + K_{\mathrm{coll}}^{-,\gamma} + K_{\mathrm{coll}}^{+,\gamma} + K_{\mathrm{ncol}}^{\gamma}]),$$

D – non-singlet structure function of fermion

$$D(z,l) = \delta(z-1) + \frac{\alpha}{2\pi}(l-1)P^{(1)}(z) + \ldots$$

$$P^{(1)}(z) = \Big(\delta(1-z)(2\ln\Delta + \frac{3}{2}) + \theta(1-z-\Delta)\frac{1+z^2}{1-z}\Big)_{\Delta\to 0}$$

electron impact factor

$$d\tau^{e,\sigma\lambda}(p_1,p_1') = \int\limits_0^1 dz_1 \int\limits_{x'}^1 \frac{dz_2}{z_2} D(z_1,l_u) D(\frac{x'}{z_2},l_u) d\tau_B^{e,\sigma\lambda}(z_1 p_1, \frac{p_1'}{z_2})$$

$$\times (1 + \frac{\alpha}{\pi}[K_{SV}^{e,\sigma\lambda} + K_{coll}^{i,e} + K_{coll}^{f,e} + K_{ncoll}^{e}]),$$

D – non-singlet structure function of fermion

$$D(z,l) = \delta(z-1) + \frac{\alpha}{2\pi}(l-1)P^{(1)}(z) + \dots$$

$$P^{(1)}(z) = \left(\delta(1-z)(2\ln\Delta + \frac{3}{2}) + \theta(1-z-\Delta)\frac{1+z^2}{1-z}\right)_{\Delta\to 0}$$

Conclusions

- We calculated **helicity amplitudes** for two–jet processes **in quasiperipheral kinematics** at Born and 1-loop correction levels.
- Contributions of the emission of virtual, soft and hard real additional photons were taken into account in construction of e, γ **impact factors** in the leading logarithmic approximation.
- The relevant **cross sections** were introduced in terms of structure functions for any helicity states of initial and final particles.
- We've presented K–factors (next-to-leading terms) in analytic form.
- Results were **validated** by gauge-invariance check.

Thank You for attention