Study of the ISR-FSR interference in radiative return measurements in e^+e^- -annihilation.

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ISR (initial- state radiation)-FSR (final- state radiation) interference

The FSR events

-represent unavoidable background to RRM by large-angle radiative photon.

-in process $e^+(p_2)+e^-(p_1)\rightarrow\gamma(k\ )+\pi^+(p_+)+\pi^-(p_-)$ (1)

give a non- negligible value in hadronic contribution to the muon anomalous magnetic moment,

- carries very useful information about electromagnetic interaction of hadrons and their structure.

That is why ISR-FSR interference effects at last estimated.

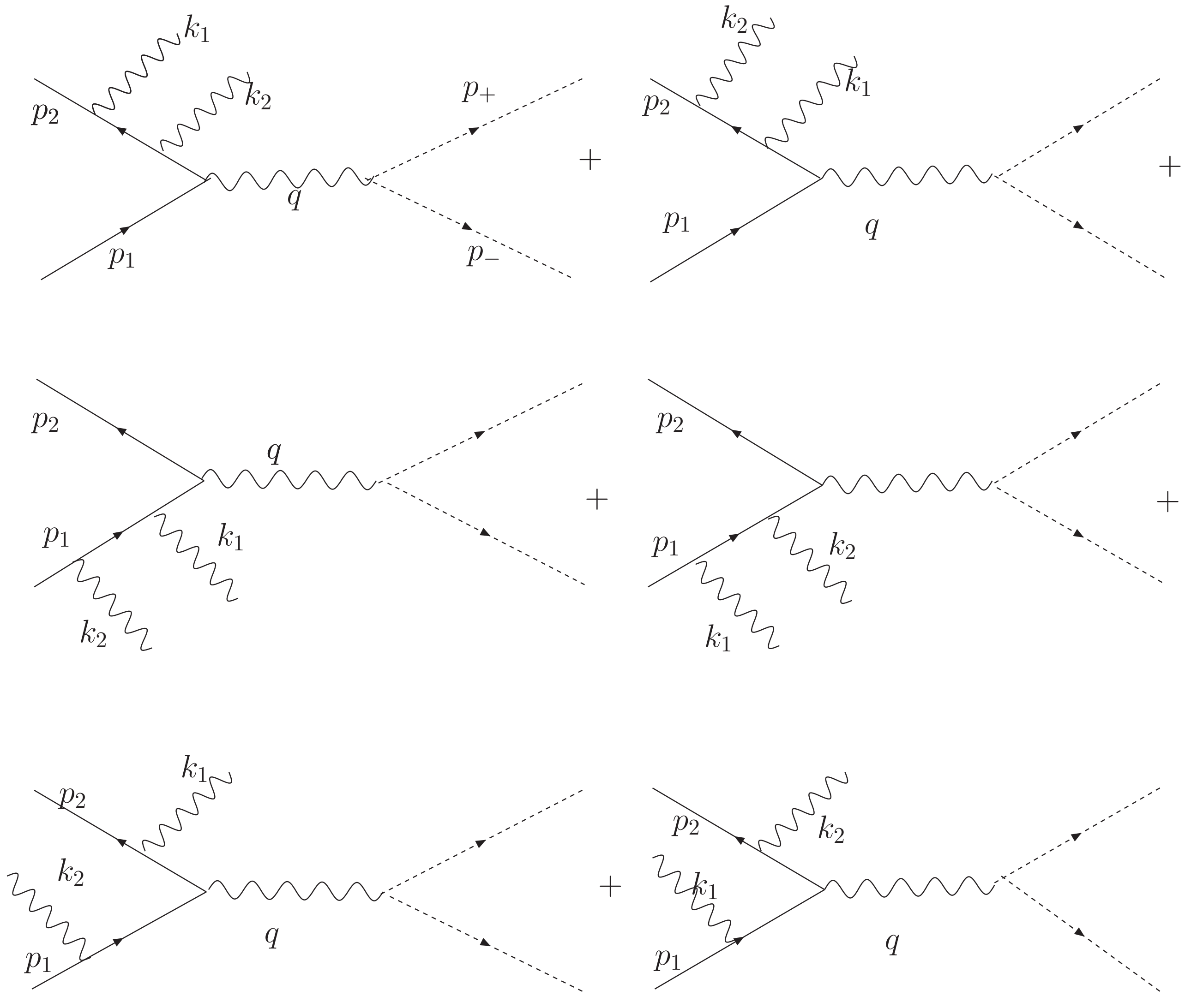
We try to investigate just effects due to ISR-FSR interference in double photon events in

$$e^+(p_2) + e^-(p_1) \to \gamma(k_1) + \gamma(k_2) + \pi^+(p_+) + \pi^-(p_-) \,. \qquad (2)$$

The RRM supposes that we have at least one hard photon radiated from initial state.

We must consider events where there are

- either two ISR photon or
- one is ISR and another is FSR.



k_1
k_2
p_2
p_+
q
p_1
p_-
+
k_2
k_1
p_2
p_1
q
+
p_2
q
p_1
k_1
k_2
+
p_2
p_1
k_2
k_1
+
k_1
p_2
k_2
p_1
q
+
p_2
k_2
k_1
p_1
q

Fig.1 a)

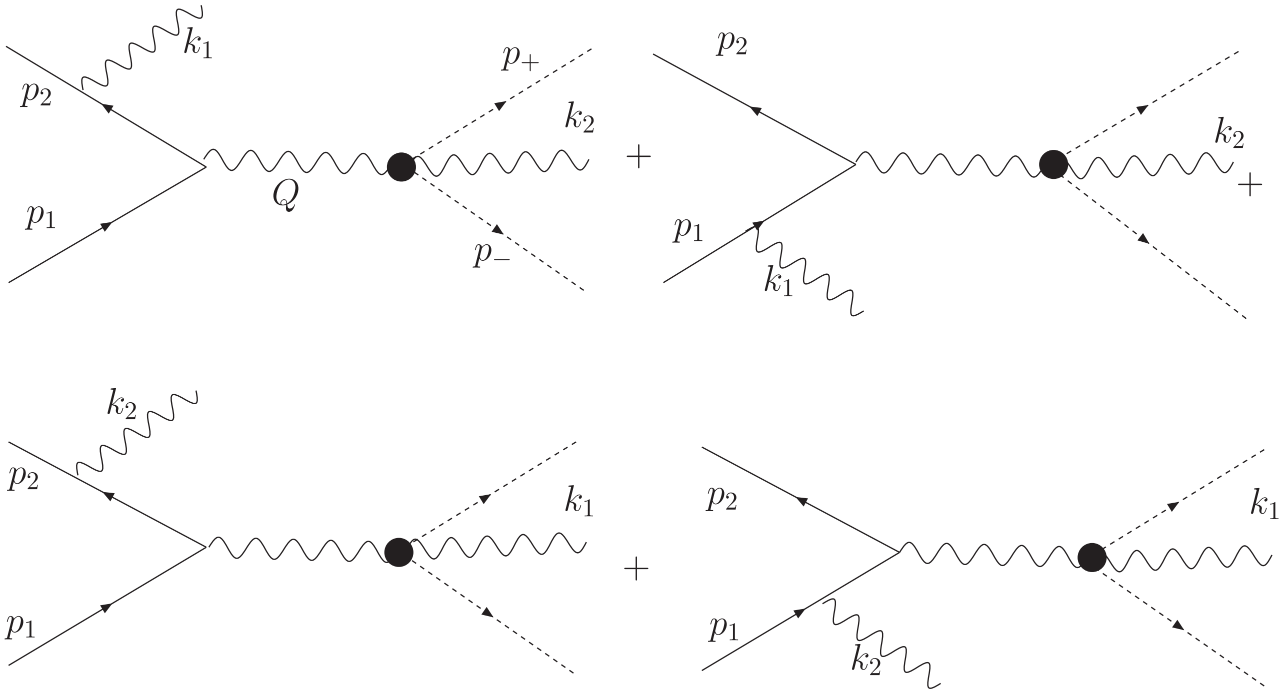


Fig.1 b)

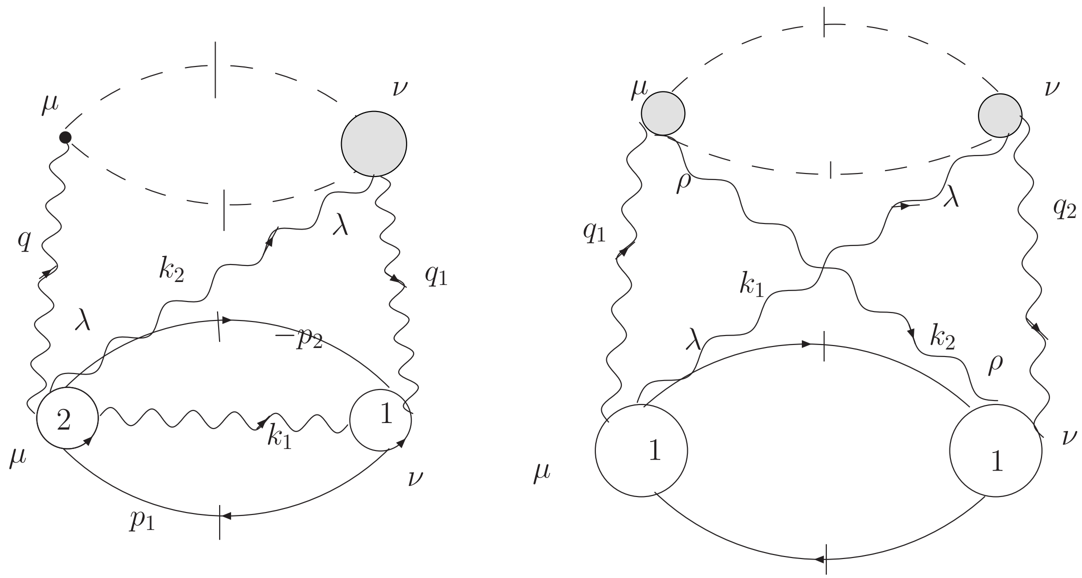
Leptonic blocks can be written by QED rules and are universal.

The hadronic part is model-dependent and changes for different hadronic states and chosen models.

There are two types of interferences effect:

1. the first one is caused by interference of diagrams 1a) and 1b);

2. the second one arises due interference of the two diagrams 1b) with interchanged photon momentum k_1 and k_2.



a) b)

Fig.2.

1. $$M_a = \frac{1}{q^2}\frac{1}{q_1^2} L_{\mu\lambda;\nu} H_{\mu;\lambda\nu} + (1 \leftrightarrow 2),\qquad (3)$$

where

$$q = p_1 + p_2 - k_1 - k_2, \qquad q_1^{\;2} = (p_1 + p_2 - k_1)^2,\ q_2^{\;2} = (p_1 + p_2 - k_2)^2.$$

Leptonic tensor $L_{\mu\lambda;\nu}$ depends on four 4-momenta: p_1, p_2, k_1, k_2 and on six invariants.. It satisfies conditions

$$q_\mu L_{\mu\lambda;\nu} = q_{1\nu} L_{\mu\lambda;\nu} = k_{2\lambda} L_{\mu\lambda;\nu} = 0 \qquad (4)$$

Hadronic tensor $H_{\mu;\lambda\nu}$ [1] depends on three momenta p_+, p_-, k_2 and on three invariants.

$$H_{\mu;\lambda\nu} = K_{\lambda\nu}(p_+, p_-, k_2) J_\mu(p_+, p_-) \qquad (5)$$

Tensor $L_{\mu\lambda;\nu}$ is expressed in terms of 36 independent Lorentz structures constructed from 4-vectors

1. S.Dubinsky at al. Eur.Phys.J.C40,41-54(2005).

$$\tilde{p}_{1\mu} = p_{1\mu} - \frac{p_1 q}{q^2} q_\mu; \quad \tilde{p}_{2\mu} = p_{2\mu} - \frac{p_2 q}{q^2} q_\mu; \quad \tilde{k}_{1\mu} = k_{1\mu} - \frac{k_1 q}{q^2} q_\mu; \quad \tilde{k}_{2\mu} = k_{2\mu} - \frac{k_2 q}{q^2} q_\mu; \quad (6a)$$

$$\tilde{p}_{1\nu} = p_{1\nu} - \frac{p_1 q_1}{q_1^2} q_{1\nu}; \quad \tilde{p}_{2\nu} = p_{2\nu} - \frac{p_2 q_2}{q_2^2} q_{2\nu}; \quad \tilde{k}_{1\nu} = k_{1\nu} - \frac{k_1 q_1}{q_1^2} q_{1\nu}; \quad \tilde{k}_{2\nu} = k_{2\nu} - \frac{k_2 q_1}{q_1^2} q_{1\nu}; \quad (6b)$$

$$-p_{1\lambda} + \frac{k_2 p_1}{k_2 p_2} p_{2\lambda}; \quad -k_{1\lambda} + \frac{k_1 k_2}{k_2 p_1} p_{1\lambda}; \quad k_{2\lambda}, \qquad (7)$$

and the second rank tensors

$$\tilde{g}_{\lambda\mu} = g_{\lambda\mu} - \frac{k_{2\mu} q_\lambda}{k_2 q}; \quad \tilde{g}_{\lambda\nu} = g_{\lambda\nu} - \frac{k_{2\nu} q_{1\lambda}}{k_2 q_1}; \quad \tilde{g}_{\nu\mu} = g_{\nu\mu} - \frac{q_{1\mu} q_\nu}{q_1 q}; \qquad (8)$$

One test for obtained result. The sets (6a), (6b), (7), (8) satisfied (4).

The second test is the calculation of collinear limit

$$\vec{k}_1 \parallel \vec{p}_1, \quad \omega_1 = (1-x)E, \qquad t_1 = -2k_1 p_1$$

Contributions terms t_1^{-1} , $m^2 t_1^{-2}$ proportional $-\frac{1}{x(1-x)}(\frac{1+x^2}{t_1}-\frac{2xm^2}{t_1^2})$

$$\int L_{\mu\lambda;\nu}(p_1,p_2,k_2,k_1,\vec{k}_1 \parallel \vec{p}_1)\frac{d^3k_1}{(2\pi)^3 2\omega_1}=\frac{\alpha}{2\pi}(\frac{1+x^2}{1-x}L_0-\frac{2x}{1-x})L_{\mu\lambda;\nu}(xp_1,p_2,k_2), \quad L_0=\ln\frac{E^2\theta_0^2}{m^2}.$$

Six structures in the contraction of leptonic and hadronic tensors

$$F_\pi(q^2)f_1^*(p_+,p_-,k_2), \quad F_\pi(q^2)f_2^*(p_+,p_-,k_2), \quad F_\pi(q^2)f_3^*(p_+,p_-,k_2),$$
$$F_\pi(q^2)f_1^*(p_+,p_-,k_1), \quad F_\pi(q^2)f_2^*(p_+,p_-,k_1), \quad F_\pi(q^2)f_3^*(p_+,p_-,k_1)$$

Coefficient at $F_\pi(q^2)f_1^*(p_+,p_-,k_2)$ for illustration

$$\frac{4\,(\text{p2pm}-\text{p2pp})}{\text{t1 t2}}$$

$$\Bigg(\frac{1}{\text{v1 v2}}\Big(\text{q1}^2\left(\text{v1}^3+3\,(2\,\text{s}+\text{t1}+\text{t2})\,\text{v1 v2}+\text{v2}^3+\text{s}\,(\text{t2 v1}+\text{t1 v2})+(\text{t1}-\text{t2})\left(\text{v1}^2-\text{v2}^2\right)\right)+$$

$$\text{s}\left(2\,\text{k2q}\left(2\,\text{k2q}+\text{q1}^2\right)\right)(\text{v1}+\text{v2})+$$

$$2\,\text{k2q}\left(\text{q1}^2\left((\text{v1}-\text{v2})^2\right)+\left(\text{t1}^2+\text{t2}^2\right)(\text{v1}+\text{v2})+\text{s}\left(\text{v1}^2+\text{v2}^2\right)\right)\Big)+$$

$$-\text{q1}^2\Bigg(\frac{\left(\text{t1}\left((\text{s}+\text{t2})\,\text{v1}+\text{s t1}+\text{v2}^2\right)-\text{v1}^2\,(\text{t2}+\text{v1})+\text{q1}^2\,(\text{t1}+\text{v1})\,\text{v2}\right)}{\text{v1}\,\Delta\text{m}^2}+$$

$$\frac{\left(\text{t2}\left(\text{v1}^2+\text{t1 v2}+\text{s}\,(\text{t2}+\text{v2})\right)+\text{q1}^2\,\text{v1}\,(\text{t2}+\text{v2})+-\text{v2}^2\,(\text{t1}+\text{v2})\right)}{\text{v2}\,\Sigma\text{m}^2}\Bigg)\Bigg)+$$

$$\text{k21}$$

$$\Bigg(\frac{4}{\text{t1 t2 v1 v2}}\Big(4\,\text{k2q}^2\,\text{s v1}+\text{s}^3\,(\text{v1}-\text{v2})+\left(\text{t1}^2+\text{t2}^2\right)(\text{t2 v1}-\text{t1 v2})+(\text{t1}-\text{t2})\,\text{t2}\left(\text{v1}^2-\text{v2}^2\right)+$$

$$(\text{t1}+\text{t2})\,(2\,\text{t1}+\text{t2})\,\text{v1 v2}+\text{v1}^2\,(\text{t2 v1}-\text{t1 v2})+\text{t2 v2}^2\,(\text{v1}+\text{v2})+$$

$$\text{s q1}^2\,(4\,\text{t2 v1}+3\,(-\text{t1}+\text{v1})\,\text{v2})+$$

$$\text{s}\left(2\,\text{t1 t2}\,(-\text{v1}+\text{v2})+\text{v1}\left(\text{v1}^2-\text{v1 v2}+\text{v2}^2\right)+-\text{t2}\left(\text{v1}^2-3\,\text{v1 v2}-\text{v2}^2\right)\right)+$$

$$2\,\text{k2q}\left(-\text{s t2 v1}+(2\,\text{s}+\text{t2})\,\text{v1}^2+(\text{s}+\text{t1})^2\,\text{v2}+\text{t2}\,(\text{s}+\text{t2})\,\text{v2}+-\text{q1}^2\,\text{v1 v2}+\text{t2 v2}^2\right)\Big)+$$

$$-\frac{4\,\text{q1}^2}{\text{t1 t2}}\Bigg(\frac{(\text{s}+\text{t2}+\text{v2})\left(\text{t1 q2}^2+\text{q1}^2\,\text{v1}-2\,\text{t1 v1}\right)}{\text{v1}\,\Delta\text{m}^2}-$$

$$\frac{\left((\text{s}+\text{t1})^2\,\text{v2}+\text{s t2}\,(\text{s}+\text{t1}+\text{v1})+-\text{t2}\,(\text{s}+\text{v1})\,(\text{t2}+\text{v2})-\text{t1 t2 v2}+\text{v2}^2\,(\text{t1}+\text{v2})\right)}{\text{v2}\,\Sigma\text{m}^2}\Bigg)\Bigg)+$$

$$\text{k11}$$

$$\Bigg(\frac{1}{\text{t1 t2 v1 v2}}\,4$$

$$\Big(4\,\text{k2q}^2\,\text{s v1}-2\,\text{k2q}\left(\text{q1}^2\,(\text{s}\,(\text{v1}-2\,\text{v2})+\text{v1 v2})+-(\text{s}+\text{t2})\left(\text{v1}^2+\text{v2}^2\right)+-\left(\text{t1}^2+\text{t2}^2\right)\text{v2}\right)+$$

$$\text{q1}^2\left(\text{s t2 v1}+-\text{v1}^2\,(\text{s}+\text{t2}-\text{v2})+3\,(\text{s}+\text{t1})\,\text{v1 v2}+\text{v2}^2\,(\text{s}+\text{t2}-\text{v1}+\text{v2})\right)\Big)+$$

$$-\frac{4\,\text{q1}^2}{\text{t1 t2}}\left(\frac{(\text{s}+\text{t2}+\text{v2})\left(-\text{v1}^2+\text{t1 v2}\right)}{\text{v1}\,\Delta\text{m}^2}+\frac{\left((\text{s}+\text{v1}+\text{v2}-2\,\text{v2})\left(\text{t2}^2+\text{v2}^2\right)+\text{q1}^2\,(\text{t2}+\text{v1})\,\text{v2}\right)}{\text{v2}\,\Sigma\text{m}^2}\right)\Bigg)+$$

$$\Bigg(\frac{8\,(\text{p2pm}-\text{p2pp})}{\text{t1 t2}}$$

$$\Bigg(-\left(\frac{1}{\text{t1 t2 v1 v2}}\right)$$

$$\Big(+2\,\text{k2q}\left(2\,\text{t1 t2}\,(\text{t1 v1}+\text{t2 v2})+\text{q1}^2\,(\text{t2}\,(-3\,\text{t1}+\text{t2})\,\text{v1}+\text{t1}\,(\text{t1}-3\,\text{t2})\,\text{v2})-\right.$$

$$\left.2\,(\text{t1}+\text{t2})^2\,\text{v1 v2}\right)+-\text{t1 t2}\left(\text{t1}^2+\text{t2}^2\right)(\text{v1}+\text{v2})+$$

$$(\text{t1}+\text{t2})\left(3\,\text{t1}^2-4\,\text{t1 t2}+3\,\text{t2}^2\right)\text{v1 v2}+$$

$$\text{s}\left(\text{t1 t2}\,(\text{t1}+\text{t2})\,(\text{v1}+\text{v2})+-2\,\text{t1 t2}\,(\text{v1}+\text{v2})^2+3\,(\text{t1}+\text{t2})^2\,\text{v1 v2}\right)\Big)+$$

$$\frac{1}{\text{t1 v1}\,\Delta\text{m}^2}\Big(\text{t1}^2\left(\text{s t1}-\text{t1}^2+\text{s t2}-\text{t2}^2\right)+\text{t1}^2\,(3\,\text{t1}+\text{t2})\,(-\text{v1}+\text{v2})+$$

$$\text{q1}^2\,(\text{t1 t2}\,(\text{v1}+\text{v2})+\text{v1}\,(-2\,\text{t1 v1}+\text{t2 v2}))+\text{t1}\,(-\text{s}+\text{t1}+3\,\text{t2})\,\text{v1 v2}+$$

$$\text{t1}^2\left(-(\text{v1}+\text{v2})\,(\text{s}+\text{v1}+\text{v2})-(\text{v1}-\text{v2})^2\right)\Big)+\frac{1}{\text{t2 v2}\,\Sigma\text{m}^2}\Big(\text{t2}^2\,((\text{s}-\text{t1})\,\text{t1}+(\text{s}-\text{t2})\,\text{t2})+$$

$$\Big(\big((t1-t2)\,t2\,(v1+v2)+(t1-t2)\,v1\,v2-2\,t2\,v2^2\big)\,q1^2+$$

$$2\,t2\,\big(t2\,(t1+t2)\,v1+t2^2\,(v1-v2)+(2\,t1+t2)\,v1\,v2-t2\,(v1^2+v2^2)\big)\Big)\Big)\Big)+$$

$$k1l$$

$$\Bigg(-\frac{4}{t1\,t2^2\,v1\,v2}$$

$$\Big(-t2\,\big(t1\,t2\,(-v1+v2)+2\,t2^2\,(v1+v2)+(t1-2\,t2)\,v1^2+(t1+t2)\,v1\,v2+$$

$$(2\,t1-t2)\,v2^2+v1\,(v1-v2)\,v2-2\,s\,(2\,t1\,v1+t1\,v2-t2\,v2+v1\,v2-2\,v2^2)\big)+$$

$$6\,t1\,(s+t1)\,v1\,v2+4\,k2q^2\,t2\,(v1-v2)+$$

$$2\,k2q\,\big(2\,q1^2\,(-2\,t2\,v1+t1\,v2)+(t1-2\,t2)\,t2\,v1+t2\,(-2\,s+t2)\,v2+$$

$$-4\,(t1+t2)\,v1\,v2\big)\Big)+$$

$$\frac{4\,(t1-v2)\,\big(2\,t1\,(s+v2)-2\,t2\,q1^2+4\,(s+t1+t2)\,v1+t1\,(t2-v1)+(t2+v1)\,v2\big)}{t1\,t2\,v1\,\Delta m^2}+$$

$$\frac{1}{t1\,t2^2\,v2\,\Sigma m^2}\,4\,\Big((t1-2\,t2)\,t2^3+2\,t1\,t2\,(t2\,v1+t1\,v2)+$$

$$t2^2\,(4\,t2\,v1-4\,t1\,v2-9\,t2\,v2)+t2\,\big(-2\,t2\,v1^2+t1\,(v1^2-4\,v2^2)\big)+$$

$$2\,\big((t1+t2)^2+t2^2\big)\,v1\,v2+t2\,v1^2\,v2+8\,t2\,v2\,(t1\,v1-t2\,v2)+$$

$$2\,s\,\big(t2\,(-3\,t2+v1-2\,v2)\,v2+t1\,(2\,t2^2+t2\,v2+v1\,v2)\big)\Big)\Bigg)+$$

$$k2l$$

$$\Bigg(\frac{1}{t1^2\,t2^2\,v1\,v2}\,4\,\Big(t2\,\big((t1-2\,t2)\,(t1+t2)^2-t1\,t2\,(4\,t1+t2)\big)\,v1+$$

$$-2\,t1\,t2\,(t1+t2)\,v1^2+t1\,\big((t1+t2)^2\,(2\,t1+t2)+t1^2\,t2\big)\,v2-4\,t1^3\,v1\,v2+$$

$$2\,(t1-t2)\,t2^2\,v1\,v2+2\,t1\,t2\,(t1+t2)\,v2^2+5\,t1\,t2\,v1\,(v1-v2)\,v2+$$

$$4\,v1\,v2\,(t1^2\,v1-t2^2\,v2)+$$

$$2\,s\,\big(2\,(t1+t2)^2\,(-t2\,v1+t1\,v2)+-t1\,t2^2\,(v1+v2)+t1\,t2\,(v1+v2)^2-$$

$$t1\,(t1+t2)\,v1\,v2+-(t1+t2)^2\,v1\,v2\big)+2\,s^2\,(t1+t2)\,(-t2\,v1+t1\,v2)+$$

$$2\,k2q\,t1\,\big(t2\,(6\,s+7\,t2)\,v1-2\,t1\,(s+t1+t2)\,v2+t2\,(-t1+2\,t2)\,v2+$$

$$4\,(t1+t2)\,v1\,v2+t2\,(-v1^2+v2^2)\big)+4\,k2q^2\,t1\,t2\,(-v1+v2)\Big)+$$

$$-\frac{1}{t1\,t2^2\,v2\,\Sigma m^2}\,4\,\Big(2\,s^2\,(t1+t2)\,(t2+v2)+t2^2\,(3\,t1^2+2\,t1\,t2+2\,t2^2)+$$

$$t2\,(t1^2-4\,t2^2)\,v1+2\,\big((t1+t2)^3+t2^2\,(t1+2\,t2)\big)\,v2+$$

$$t2\,\big(2\,t1\,v2\,(-3\,v1+v2)+t2\,(4\,v1^2+5\,v2^2)\big)+t2\,v1\,v2^2+$$

$$2\,s\,\Big(t1\,t2\,(t1+2\,t2)+2\,\big(t1\,(t1+2\,t2)\,v2+t2^2\,(v1+v2)\big)+t2\,v2\,(2\,v1+v2)\Big)\Big)+$$

$$\frac{1}{t1^2\,t2\,v1\,\Delta m^2}\,4\,\Big(2\,s^2\,(t1+t2)\,(t1+v1)+t1^2\,t2\,(2\,t1+t2)+8\,t1\,t2\,(t1+t2)\,v1+$$

$$2\,(t2^3\,v1+t1^3\,v2)+t1\,t2\,(4\,t1+3\,t2)\,v2+$$

$$v1\,\big(2\,t2^2\,v2-t1^2\,v1+-2\,t1\,(t1+t2)\,(v1-v2)\big)+t1\,v1^2\,v2+$$

$$2\,s\,\Big(t1\,\big((t1+t2)^2+t1\,t2\big)+(t1^2+5\,t1\,t2+2\,t2^2)\,v1+t1\,(t1+t2)\,v2-$$

$$t1\,v1^2+(t1+t2)\,v1\,v2\Big)\Big)\Bigg)\,m[e]^2-$$

$$\frac{32\,(t1+t2)}{t1^2\,t2^2\,v1\,v2\,\Delta m^2\,\Sigma m^2}$$

$$\Big((p2pm-p2pp)\,\big(t1\,(t2-v1)\,v1\,(t2+v2)\,\Delta m^2+t2\,(t1+v1)\,(t1-v2)\,v2\,\Sigma m^2+$$

$$-\Delta m^2\,\Sigma m^2\,(2\,t1\,v1\,v2+2\,t2\,v1\,v2+t2\,v1\,\Delta m^2+t1\,v2\,\Sigma m^2)\big)+$$

$$2\,k2q\,\Delta m^2\,\big(k1l\,t1\,(t2\,v1+v2\,(v1+\Sigma m^2))+k2l\,v1\,(t2\,(t1+\Sigma m^2)+t1\,v2)\big)\Big)\,m[e]^4;$$

There

$\Delta m^2 = (p_1 - k_1 - k_2)^2 - m^2, \quad \Sigma m^2 = (p_2 - k_1 - k_2)^2 - m^2,$

$v_{1,2} = -2k_2 p_{1,2}, t_{1,2} = -2k_1 p_{1,2}, k1l = k_1 l, k2l = k_2 l, l = p_+ - p_-, pp -> p_+, pm -> p_-$.

2. The diagram 2b) corresponds

$$M_b = \frac{1}{q_1^{\ 2}} \frac{1}{q_2^2} L_{\mu\lambda;\nu\rho}(p_1, p_2, k_1, k_2) K_{\mu\rho}(p_+, p_-, k_2) K_{\nu\lambda}(p_+, p_-, k_1) \qquad (12)$$

We can write tensor $L_{\mu\lambda;\nu\rho}$ in terms of 4-vectors

$$\tilde{x}_\mu^{(i)} = x_\mu^{(1)} - \frac{x^{(i)} q_1}{q_1^2} q_{1\mu}, \quad \tilde{x}_\nu^{(i)} = x_\nu^{(1)} - \frac{x^{(i)} q_2}{q_2^2} q_{2\nu}, \quad x_\mu^{(i)} = p_{1\mu}, p_{2\mu}, k_{1\mu}, k_{2\mu} \qquad (13)$$

and second rank tensor

$$\tilde{g}_{\rho\mu} = g_{\rho\mu} - \frac{k_{2\mu} q_{1\rho}}{k_2 q_1}; \quad \tilde{g}_{\lambda\mu} = g_{\lambda\mu} - \frac{k_{1\mu} q_{1\lambda}}{k_1 q_1}; \quad \tilde{g}_{\rho\nu} = g_{\rho\nu} - \frac{k_{2\nu} q_{2\rho}}{k_2 q_2};$$

$$\tilde{g}_{\lambda\nu} = g_{\lambda\nu} - \frac{k_{1\nu} q_{2\lambda}}{k_1 q_2}; \quad \tilde{g}_{\mu\nu} = g_{\mu\nu} - \frac{q_{2\mu} q_{1\nu}}{q_1 q_2}. \qquad (14)$$

In collinear limit diagram 2b) does not contribute.

We calculate the distribution over the pion invariant mass q^2.

The reduced phase space can be written as

$$\frac{d^3k_1}{2\omega_1}\frac{d^3k_2}{2\omega_2}\frac{d^3p_+}{2E_+}\frac{d^3p_-}{2E_-}\delta^4(p_1+p_2-k_1-k_2-p_+-p_-)=$$

$$\frac{\pi}{32s}dq^2 d\cos\theta d\varphi\, ds_3 ds_4 |\vec{p}_-|^2 \frac{d\cos\theta\_d\phi\_}{|\vec{p}_-|(2E-\omega_1-\omega_2)+E_-(\omega_1 c_{1-}+\omega_2 c_{2-})} \qquad (15)$$

where θ - is angle between $\vec{p}_1$ and $\vec{k}_1, \varphi$ angle between planes $(\vec{p}_1, \vec{k}_1)$ and $(\vec{k}_1, \vec{k}_2)$, θ_-, ϕ_- - polar and azimuthal angles of negative pion with 4- momentum p_-. Invariants s_3, s_4 define the energy of radiated photons

$$\omega_1 = \frac{s-s_3}{2\sqrt{s}}; \quad \omega_2 = \frac{s-s_4}{2\sqrt{s}},$$

and

$$c_{1-} = \frac{(\vec{k}_1\vec{p}_-)}{|\vec{k}_1||\vec{p}_-|}, c_{2-} = \frac{(\vec{k}_2\vec{p}_-)}{|\vec{k}_2||\vec{p}_-|},$$

The energy of pion can be derived from conservation laws [2]

$$q^2 - 2E_-(2E - \omega_1 - \omega_2) - 2|\vec{p}_-|(\omega_1 c_{1-} + \omega_2 c_{2-}) = 0$$

The angular region in (15) covers the whole space, and the integration region over variables s_3, s_4 at fixed value of q^2 was obtained in [3].

$$q^2 + \varepsilon s < s_3 < (1-\varepsilon)s \qquad \frac{sq^2}{s_3} < s_4 < s + q^2 - s_3$$

$$q^2(1+\varepsilon) < s_3 < q^2 + \varepsilon s \qquad \frac{sq^2}{s_3} < s_4 < (1-\varepsilon)s$$

2. V.A.Khose at al. Eur,Phys.J.C25,199-213(2002).
3. F.A.Berends at al. Nucl.Phys,B297(1988)429.

Summary

1. We obtained the analytical expressions for matrix element squared of interferences processes (2).

2. The advantages of the used approach in this case are:

- the applied hadronic tensor $K_{\lambda\nu}$ has general form based on Lorentz and gauge invariance.

-The obtained results may be used

- for verification of results obtained with Monte Carlo generators,

- in calculation of charge–odd asymmetry.

3. For complete numerical result we must to take in account the emission of soft photon ant loop corrections.