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New QCD and QED Phenomena for CLIC

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Abstract

- **1- QCD: quark colour dissipation, instability of motion and stabilization by Higgs-boson; order-chaos transition; squeezed and entangled states in jets; QCD - instantons**

- **2- QED: luminosity for photon colliders (γe – and γγ collisions) taking into account the nonlinear contributions in the inverse Compton scattering, polarization of colliding electrons and photon of laser wave; parameters of beams for effective boson Higgs investigation; modernization of generator o'mega by the advantages of diagonal spin bases in which spin 4-vectors of fermions are expressed via their 4-momenta**

- **3- SM: multi W-bosons interactions. Higgs production at CLIC**

- **4- Technique proposal: RF-cavities, optical alignment systems (for accelerator) slow control system (for accelerator and detector), mechanics, experience in production of plates for ATLAS at Minsk's plant**

1- QCD New nonperturbative QCD phenomena

V. Kuvshinov

1).Colour Dissipation by Propagation Through QCD Vacuum

- -- For colour particles moving through QCD stochastic vacuum Wilson loop tends to zero exponentially when composition RT tends to infinity with
- string tension
- $$\sigma_{fund} = \frac{g^2}{2} l_{corr}^2 F^2$$ =confinement (Simonov et al)
-
-
- -- Stochastic vacuum is environment with colour density matrix (Kuvshinov , Buividovich)

$$\rho(loop, \gamma\bar{\gamma}) = N_c^{-1} + (|\phi_{in}\rangle\langle_{in}\phi| - N_c^{-1}) W_{adj}(loop, \gamma\bar{\gamma})$$

. $$P = N_c^{-1} + (1 - N_c^{-1}) \exp(-2\sigma_{fund} G_{adj} G_{fund}^{-1} RT)$$

- --We have decoherence, colour dissipation.
- -When T or R tends to 0, purity P corresponds to pure state.
- -When composition RT tends to infinity purity corresponds to the white mixture state

- --Information about colour states lost as a result of interaction with the QCD stochastic vacuum
-
- --“Grey” particles? White mixtures - “prehadrons” ? How to measure?

2). Confinement and instability of colour particle motion

- --Fidelity describes the stability of quantum motion (Peres) and it's definition is similar to Wilson loop definition in QCD (Kuvshinov, Kuzmin).
- The expression for the fidelity of the colour particle moving in the stochastic vacuum Wilson loop goes to zero is

$$f = \exp\left(-\frac{1}{2}g^2 l_{corr}^2 F^2 S_\gamma\right)$$

-
- --Fidelity for colour particle decays exponentially. The decay rate is equal to the string tension in confinement regime. Decreasing of fidelity means that the motion of colour charges become more and more instable.

- -- Cconnection between confinement and instability of colour particle motion

- Connection with entanglement as a probe of confinement. Entanglement increases in the confinement region (Kuvshinov, Buividovich; Nashioka; Klebanov)

Critical energy for order-chaos transition

- --The increasing of instability of motion in the confinement region is also connected with existence of chaotic solutions of Yang-Mills field and possible chaos onset (Savvidy; Kuvshinov ,Kuzmin)

- --Higgs bosons, quantum corrections regularize inherently chaotic dynamics of (classical) Yang-Mills field below critical energy density and lead the emergence of order-chaos transition (Matinian, Savvidy; Kuvshinov, Petrov)

m - mass, λ - coupling constant of Higgs boson,

$$E_{cr} \sim \frac{g^2 m^4}{\lambda^2}, \qquad |\Phi_0| = \sqrt{\frac{m^2}{4\lambda}}$$

g - coupling constant for YM - field

$$E_C = \frac{3\mu^4}{32\pi^2} \exp\left(2\alpha_w - \frac{2\lambda}{g^4}\beta_w\right)\left(1 + \frac{1}{2\cos^4\theta_w}\right)\left(1 - 7e^{-2}\right)$$

- s
- $$\alpha_w = \frac{2\ln\cos\theta_w}{1+2\cos^4\theta_w}; \quad \beta_w = \frac{32\pi^2\cos^4\theta_w}{9\left(1+2\cos^4\theta_w\right)}$$

$$\frac{\lambda}{g^4} > \frac{2}{\beta_w}$$

Quantum Chaos Criterium

- As it was shown V.I. Kuvshinov, A.V. Kuzmin, Phys. Lett. A, vol. 296 (2002) pp.82-86
- The behavior of Green function is important

$$G_{ik}(x,y) = -\frac{\delta^2 W[\vec{J}]}{\delta J_i(x)\delta J_k(y)}\bigg|_{\vec{J}=0}$$

- --Quantum chaos exists if the Green function goes to zero exponentially (or faster
- -- Order exists if Green function oscilates or decreases slowly
- when $|x - y| \to \infty$, $(x - y)2>0$, $(x0 - y0) > 0$

- It is suitable as for quarks , gluon and for pions

- -- Correspondence to classical chaos criterion: when $\tau_q \ll \Delta t_{cl}$
- (dynamical localization)

$$G_i(t_1 - t_2) = \frac{i}{2}\mathrm{Re}\left(\frac{\exp\{-\lambda_i(t_1 - t_2)\}}{\lambda_i}\right), \quad t_1 > t_2$$

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3). Experimental search for squeezed and entangled states inside jets

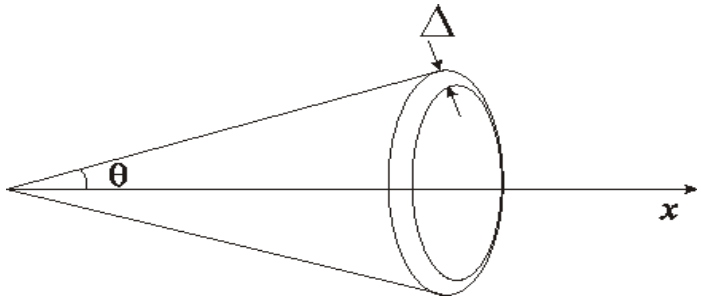
V.Kuvshinov, V. Shaparau

--Both perturbative and non-perturbative stages of the jet evolution are important with sub-Poissonian MD at NPB stage (Kokoulina, Kuvshinov)

--Gluon multiplicity distribution at the end of the perturbative cascade in the range of the small transverse momenta (thin ring of jet) is Poissonian (Lupia, Ochs, Wosiek). MD for the whole jet at the end of the perturbative cascade can be represented as a combination of Poissonian distributions (coherent states)

--Gluon coherent states under the influence of the nonlinearities of QCD Hamiltonian transform into the squeezed and entangled states with sub-Poissonian MD (Kuvshinov, Shaparau)

--In the thin jet ring we obtain gluon two-mode squeezed and entangled states



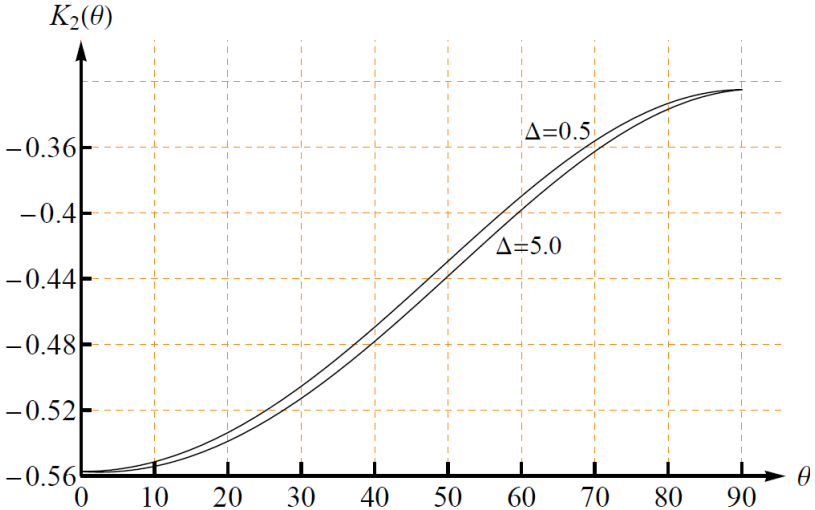
--The emergence of such states becomes is possible due to the four-gluon self-interaction, the three-gluon self-interaction does not lead to squeezing effect

--Two-mode gluon squeezed and entangled states with two different colours can lead to quark-antiquark-entangled states, role of which could be important for of the confinement phenomenon.

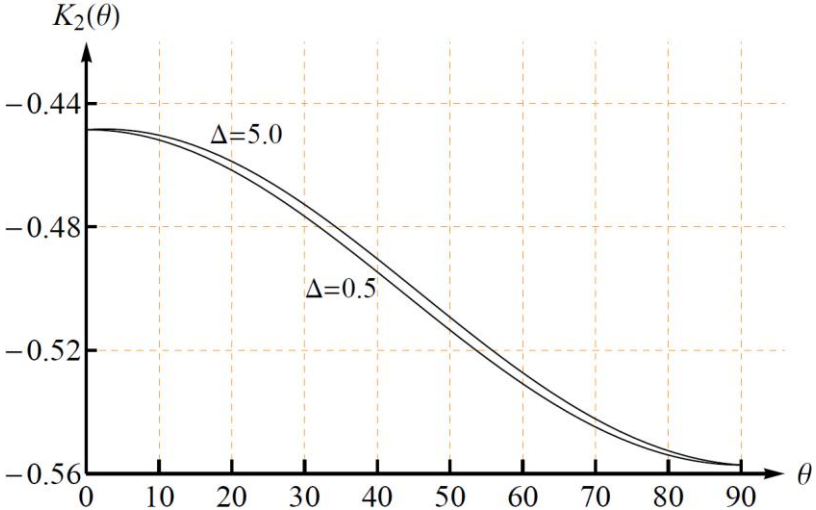
--Within local parton-hadron duality we estimate nonperturbative contribution of the gluon squeezed states to the pion correlation functions in the jet narrow ring (Kuvshinov, Shaparau)

$$K_{(2)}(\theta, \Delta) = \frac{C_{(2)}(\theta, \theta - \Delta)}{\rho_1(\theta)\rho_1(\theta - \Delta)}$$

$$K_{(2)}(\theta,\Delta) = -\sum_{l=1}^{3}\sum_{b=1}^{8}\omega_l^b\, M_1(\theta,\Delta) \Big/ \left\{\sum_{l=1}^{3}\sum_{b=1}^{8}\omega_l^b \mid \alpha_l^b \mid^4 - 2\sum_{l=1}^{3}\sum_{b=1}^{8}\omega_l^b \mid \alpha_l^b \mid^2 M_1(\theta,\Delta) + \sum_{l=1}^{3}\sum_{b=1}^{8}\omega_l^b M_2(\theta,\Delta)\right\}$$



Effect of the pion antibunching with corresponding sub-poissonian distribution



Effect of the pion bunching with corresponding super-poissonian distribution

Proposal: Modernization of Monte-Carlo generators (in particular, PYTHIA) taking into account new non-perturbative (squeezed and entangled) states of gluons and quarks

Search of experimental signals (in particular, specific behaviour of correlation functions and moments) characteristic for the new hadron states (pions) in jet events

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4). QCD instantons

V.Kuvshinov, R.Shulyakovsky, V. Kashkan

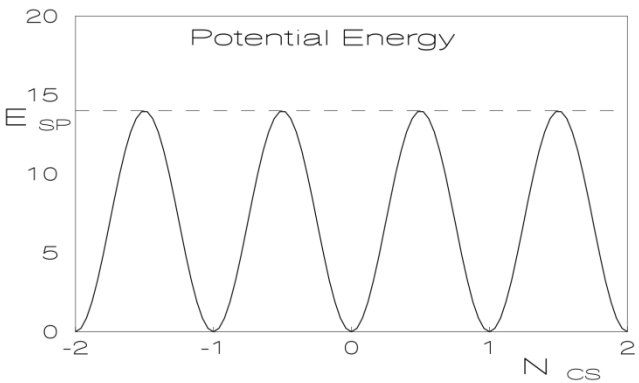
PROPOSAL: QCD - INSTANTONS SEARCH AT THE CLIC

(Experimental search of QCD instantons in quark-gluon subproceses of e+e- or γγ colliders.) (Ringwald,V.I.Kuvshinov, Shulyakovsky, Kashkan, A.V.Kuzmin, R.G., V.A.Petrov)

...when instanton effects are important, the calculational tools do not work; when they work, the instanton effects are unobservable. In this, the instantons resemble that mythical animal, the basilisk, whose sight was supposed to cause the death of the beholder.

F. Ynduráin, The Theory of Quark and Gluon Interactions

Non-trivial structure of QCD vacuum:



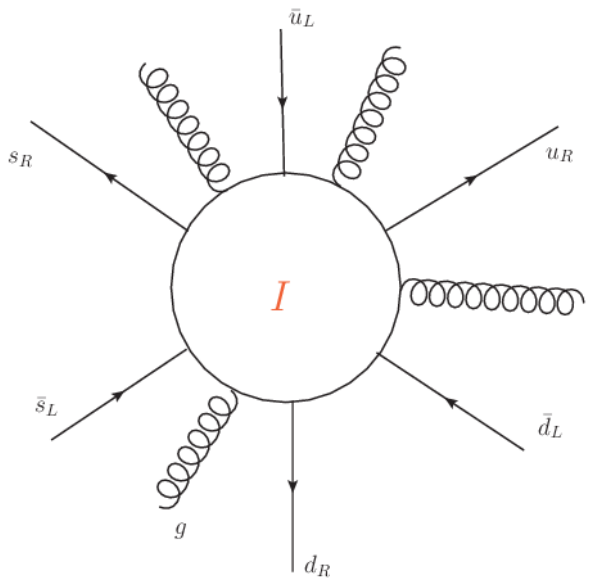
$$N_{cs} = \frac{g^2}{16\pi^2} \int d^3x \varepsilon_{ijk} \left(A_i^a \partial_j A_k^a + \frac{g}{3} \varepsilon^{abc} A_i^a A_j^b A_k^c \right)$$

Quantum tunneling between vacua with different N_{cs}

The larger energy scale the more is the tunneling rate
DIS at 0.9 TeV (DESY) vs. e^+e^- at 3 TeV (CLIC)

Can different vacuums be physically distinguished? Yes, by axial charge!

Chirality violating QCD-instanton subprocess

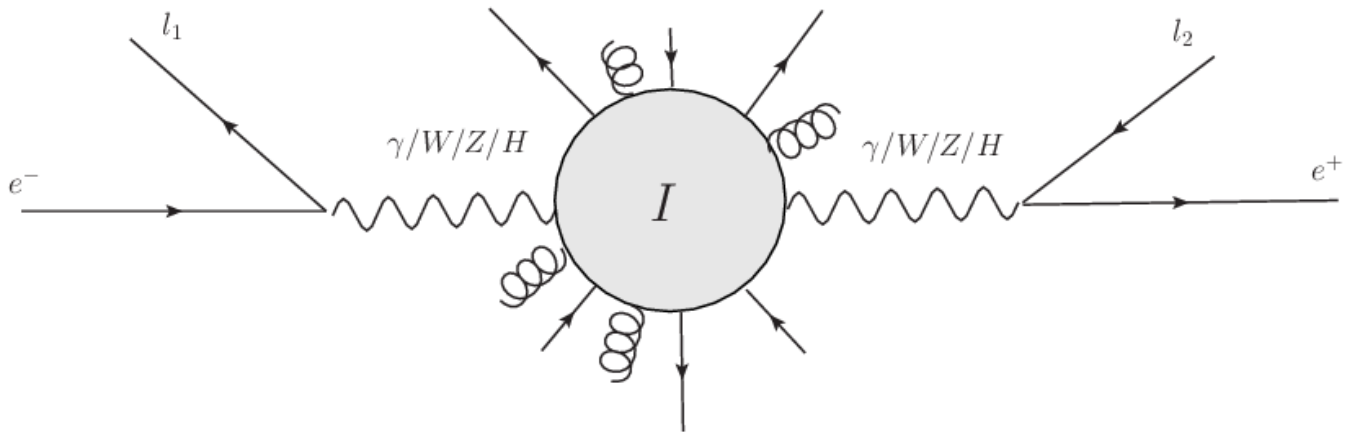


$$\Delta Q_5 = 2n_f(N_L - N_R)$$

Key features in hard scattering:

- Factorisation
- Can be calculated from QCD-instanton perturbation theory (Ringwald, Schrempp)
- There is a dynamic cutoff for instanton size $\rho < Q^{-1}$, where Q is the hard scattering scale.

QCD-instanton induced process at CLIC



Chirality violating subprocess $\gamma^* + \gamma^* \to 2\, n_f (q_R + \bar{q}_R) + n_g g$

Key differences of QCD-Instanton induced final states in comparison to pQCD final states

- **Flavour democratic**
- **Isotropic**
- **High average multiplicity**
- **Poisson distribution of gluons**
- **Specific correlation moments**
- **Others non-investigated yet**

Confront these final states with pQCD predictions to find QCD-instanton enhanced regions

The QCD-instanton induced events were modelled by the Monte Carlo generator QCDINS (Chekanov)

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2-QED. Luminosity. Pairs, Higgs boson production

M.Galynskii

- 1. **Luminosity** for photon colliders (γe – and γγ collisions) taking into account
- - the nonlinear contributions in the inverse Compton scattering,
- - polarization of colliding electrons
- - polarization of photon of laser wave.
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- 2. Parameters of beams for effective **Higgs boson** investigation.
-
- 3. **Modernization of generator o'mega** by the advantages of diagonal spin bases in
- which spin 4-vectors of fermions are expressed via their 4-momenta.
-

The backward Compton scattering (BCS)

- --Basic process at future higher energy photon colliders.
- --To obtain a high probability of e-gamma conversion the density of laser photons in the conversion region should be so high that simultaneous interaction of one electron with several laser photons is possible (nonlinear BCS).
- --Energy spectra, helicities of final photons and electrons in nonlinear backward Compton scattering of circularly polarized laser photons is given. Distributions of gamma gamma luminosities with total helicities 0 and 2 are investigated
- --Very high intensity of laser wave leads to broadening of the energy (luminosity) spectra and shift to lower energies (invariant masses)
- -- General formulae for energy spectrum and polarization of backscattered photons are given for arbitrary and relatively small nonlinear parameter ξ^2.
- --All this is necessary for optimization of the conversion region at photon colliders and study of physics processes, where a sharp edge of the luminosity spectrum and monochromaticity of collisions are important

In the case of head-on collision ultrarelativistic electrons with photons of circularly polarized laser wave, the energy dependence of the differential cross section of process BCS as a function of $y = \omega / \varepsilon$ (where ε is the electron energy) has the form (The polarization states of all particles involved in reaction are helicity ones), $J_n, J_{n\pm1}$ are the Bessel functions various order.

$$\frac{d\sigma_c}{dy}(\lambda, \lambda_e, \lambda', \lambda'_e) = \frac{\pi\alpha^2}{2xm^2\xi^2} \sum_{n=1}^{\infty} \{ (1 + \lambda_e\lambda'_e) F_{1n} + \lambda(\lambda_e + \lambda'_e) F_{2n} + \lambda'(\lambda F_{3n} + \lambda_e F_{4n}) + \lambda_e\lambda'_e F_{5n} \} ,$$

$$F_{1n} = -4\ J_n^2 + \xi^2 \left(1 - y + \frac{1}{1-y}\right) (J_{n-1}^2 + J_{n+1}^2 - 2J_n^2) ,$$

$$F_{2n} = \xi^2 \left(-1 + y + \frac{1}{1-y}\right) \left(1 - 2\frac{y}{y_n}\frac{(1-y_n)}{(1-y)}\right) (J_{n-1}^2 - J_{n+1}^2) ,$$

$$F_{3n} = \xi^2 \left(1 - y + \frac{1}{1-y}\right) \left(1 - 2\frac{y}{y_n}\frac{(1-y_n)}{(1-y)}\right) (J_{n-1}^2 - J_{n+1}^2) ,$$

$$F_{4n} = -4y\ J_n^2 + \xi^2 \left(-1 + y + \frac{1}{1-y}\right) (J_{n-1}^2 + J_{n+1}^2 - 2J_n^2) ,$$

$$F_{5n} = 4J_n^2 \left(1 + y - \frac{1}{1-y}\right) ,$$

$$z_n = \frac{2n\xi}{\sqrt{1+\xi^2}} \sqrt{\alpha_n} , \ \alpha_n = r_n(1 - r_n) = \frac{y}{y_n}\left(1 - \frac{y}{y_n}\right)\frac{(1-y_n)}{(1-y)^2} ,$$

$$y_n = \frac{u_n}{1+u_n} , \ r_n = \frac{y}{u_n(1-y)} , \ u_n = \frac{nx}{1+\xi^2} , \ x = \frac{2k_0 p}{m^2} = \frac{4\omega_0\varepsilon}{m^2} ,$$

The photon energy spectra f(x,y) are defined through the differential cross section $d\sigma_c(\lambda,\lambda_e)/dy$

In the case when hard γ-quanta colliding just after Compton conversion, the distribution of the spectral luminosity $\gamma\gamma$ collisions $L_{\gamma\gamma}$ over the invariant mass of colliding photons is expressed through the energy spectra of the photons

$$\frac{1}{L_{\gamma\gamma}}\frac{dL_{\gamma\gamma}}{dz} = 2z \int_{-\eta_m}^{+\eta_m} f(x, ze^{+\eta})\, f(x, ze^{-\eta})\, d\eta\,, \quad \eta \equiv \ln\sqrt{y_1/y_2}$$

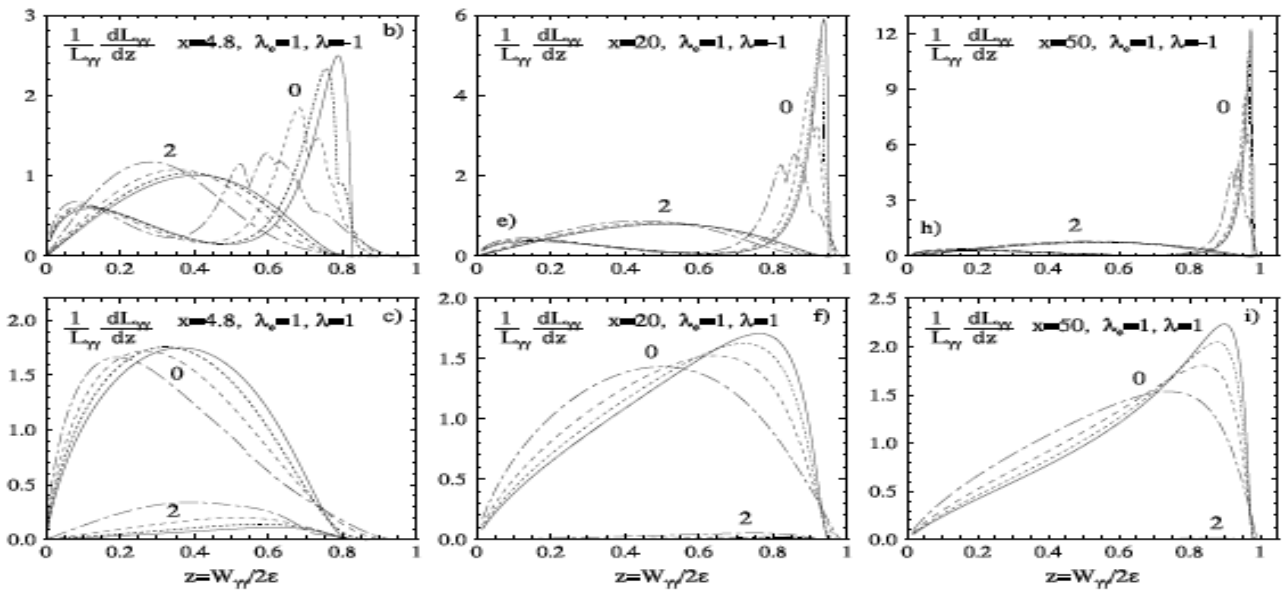

Fig. 5. The distribution of spectral luminosities dL_0/dz and dL_2/dz of the $\gamma\gamma$ system over the invariant mass of photons $z = W_{\gamma\gamma}/2\varepsilon$. Corresponding curves are labelled by numbers 0 and 2 (for spin 0 and 2). The left, central, and right panels correspond to $x = 4.8$, 20, and 50, respectively. Fig.(a,d,g), (b,e,h), and (c,f,i) were built for $\lambda\lambda_e = 0$, $\lambda\lambda_e = -1$, and $\lambda\lambda_e = 1$, respectively. The solid, dotted, dashed, and dash-dotted curves correspond to the intensity parameter $\xi^2 = 0.0, 0.3, 1.0$, and 3.0, respectively.

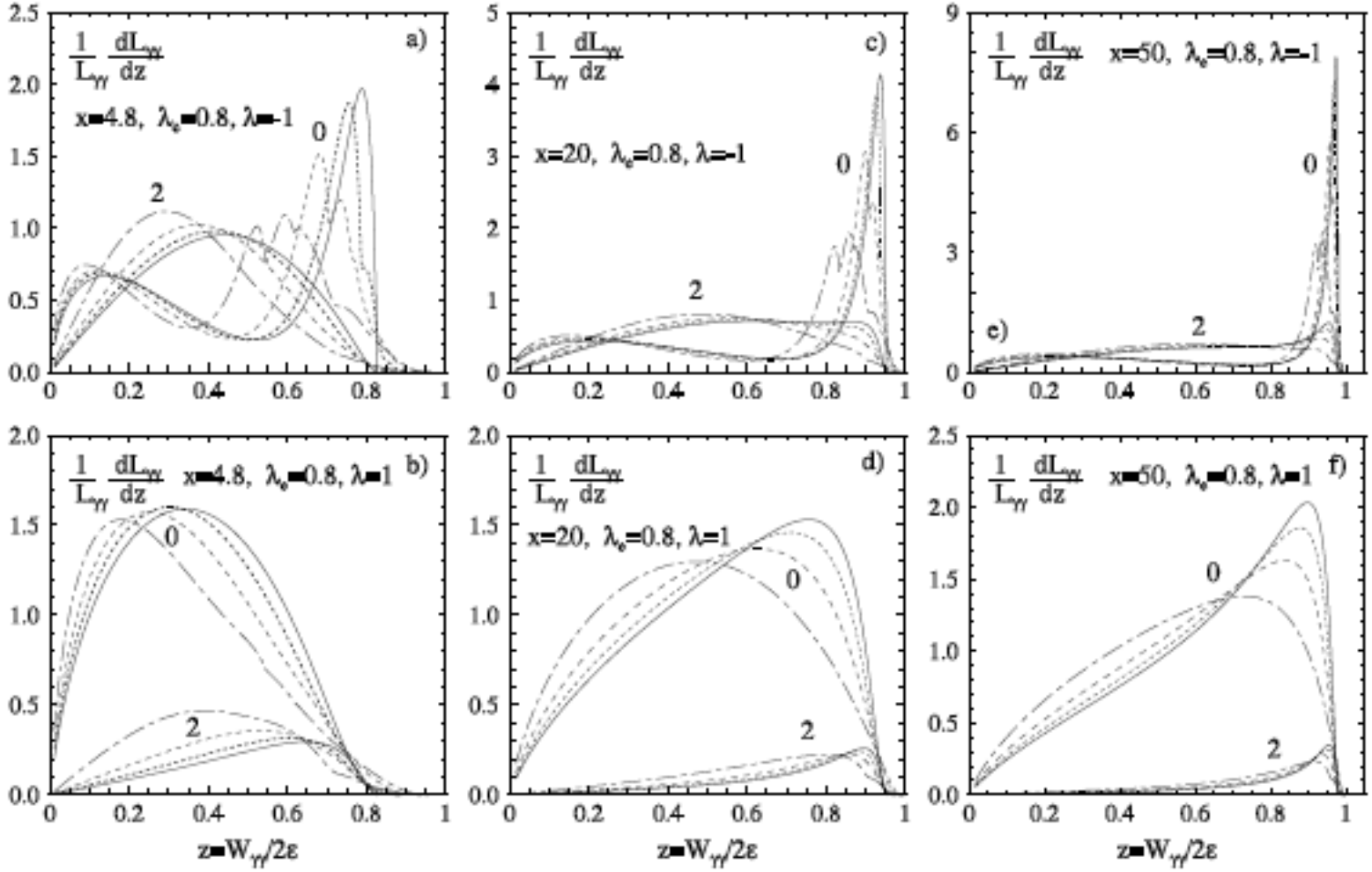

Fig. 6. The distribution of spectral luminosities dL_0/dz and dL_2/dz of the $\gamma\gamma$ system over $z = W_{\gamma\gamma}/2\varepsilon$. Corresponding curves are labelled by numbers 0 and 2. The left, central, and right panels correspond to $x = 4.8$, 20 and 50, respectively. Fig.(a,c,e) and (b,d,f) stand for $\lambda\lambda_e = -0.8$ and $\lambda\lambda_e = +0.8$, respectively. The solid, dotted, dashed, and dash-dotted curves correspond to the intensity parameter $\xi^2 = 0.0, 0.3, 1.0$, and 3.0, respectively.

The process of BCS will be the main method to produce high energy photons in future PLC. As we have just seen nonlinear effects in BCS lead to increase of the energy of scattered photons. However, when the intensity of laser wave grows the monochromaticity of $\gamma\gamma$ collisions becomes to be worse because of the increase of the spectral luminosity in the region of low and intermediate invariant masses. The reason for this increase consists in the fact that only photons of the first harmonic can be emitted along the direction of the initial electron beam. Such a behavior is not permitted for photons of higher order harmonics because of the helicity conservation for the particle system $e + n\gamma_0$ before interaction and $e + \gamma$ after interaction [22]. This leads to widening the angular distribution of the higher order harmonics and in its turn decreases the monochromaticity of $\gamma\gamma$ collisions.

As has already been shown the helicity of final photon at large $x = 20, 50$ in the case when $\lambda\lambda_e = 1$ is most insensitive to nonlinear effects. In the range of $\xi^2 \leq 1$ it is practically equal to one in all region $0 < z < z_m$. As a consequence, the contribution of the spin 2 state to the total luminosity zeroizes and the total luminosity is equal to dL_0/dz. This fact offers new possibilities for search of Higgs bozon.

Diagonal spin basis and calculation of processes involving polarized particles

- --New techniques for calculation of matrix elements in QED -"Diagonal Spin Basis" (DSB)
- --Calculation of differential cross sections of processes when polarization of particles is to be taken into account
- --Spin 4-vectors of in-and out-fermions are expressed just in terms of their 4-momenta
- Little Lorentz group, common for the initial and final states
- Spin operators of in-and out-particles coincidence, allowing to separate the spin-flip and non spin-flip interactions
- -In contrast to methods of CALKUL-group etc, it is valid both for massive and for masslessfermions Formalism is applied to the following processes:
- 1) Möller's and Bhabha's bremsstrahlung (e ± e − → e ± e − γ)
- in the ultrarelativistic (massless) limit when initial particles and photon are helicity polarized;
- 2) back Compton scattering of photons of intensive circularly polarized laser wave focused on a beam
- of longitudinally polarized ultrarelativistic electrons (e + nγ_0 → e + γ); 3) e + e − -pair production
- by a hard photon in simultaneous collision with several laser beam photons (γ + nγ_0 → e + + e −);
- 4) Bethe-Heitler process in the case of a linearly polarized photon emission by an electron with
- account for proton recoil and form factors; 5) the reaction ep → epγ with proton polarizability being
- taken into account in a kinematics when proton bremsstrahlung dominates; 6) orthopositronium 3-photon annihilation (e + e − → 3γ).
- --Efficiency for calculation of multiparticle processes when polarization is to be taken into account

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3.-SM. Multi-boson interactions. Higgs production at CLIC

V. Gilewsky

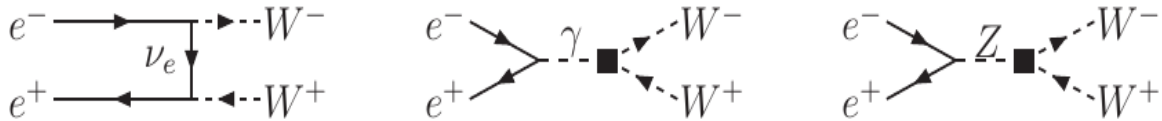
- --At CLIC energies σ(WW) is large then σ(ff) and σ(HZ) =>
  (7.5 pb vs 0.45 pb and 0.06 pb).
  We have to pay a great attention to ee->WW reaction
- --The simplest way to modify is to include form-factors in 3-boson vertex
- Standard Model vertex is

$$\mathcal{L}^{(3)}_{SM} = ig\Big\{(W^-_{\mu\alpha}W^+_\mu - W^-_\nu W^+_{\nu\alpha})W^3_\alpha + W^-_\mu W^+_\nu W^3_{\mu\nu}\Big\} =$$
$$= \sum_{V=\gamma,Z} ig_{WWV}\Big\{(W^-_{\mu\alpha}W^+_\mu - W^-_\nu W^+_{\nu\alpha})V_\alpha + W^-_\mu W^+_\nu V_{\mu\nu}\Big\},$$

- HPZH modification is

$$\mathcal{L}^{(3)}_{HPZH} = g_{WWV}\Big\{ig^V_1(W^-_{\mu\nu}W^+_\mu - W^-_\mu W^+_{\mu\nu})V_\nu + ik_V W^-_\mu W^+_\nu V_{\mu\nu} + \frac{i\lambda_V}{m^2_W}W^-_{\rho\mu}W^+_{\mu\nu}V_{\nu\rho}$$
$$-g^V_4 W^-_\mu W^+_\nu(\partial_\mu V_\nu + \partial_\nu V_\mu) + g^V_5\epsilon_{\mu\nu\rho\sigma}(W^-_\mu \overleftrightarrow{\partial}_\rho W^+_\nu)V_\sigma +$$
$$+i\tilde{k}_V W^-_\mu W^+_\nu \tilde{V}_{\mu\nu} + \frac{i\tilde{\lambda}_V}{m^2_W}W^-_{\rho\mu}W^+_{\mu\nu}\tilde{V}_{\nu\rho}\Big\},$$

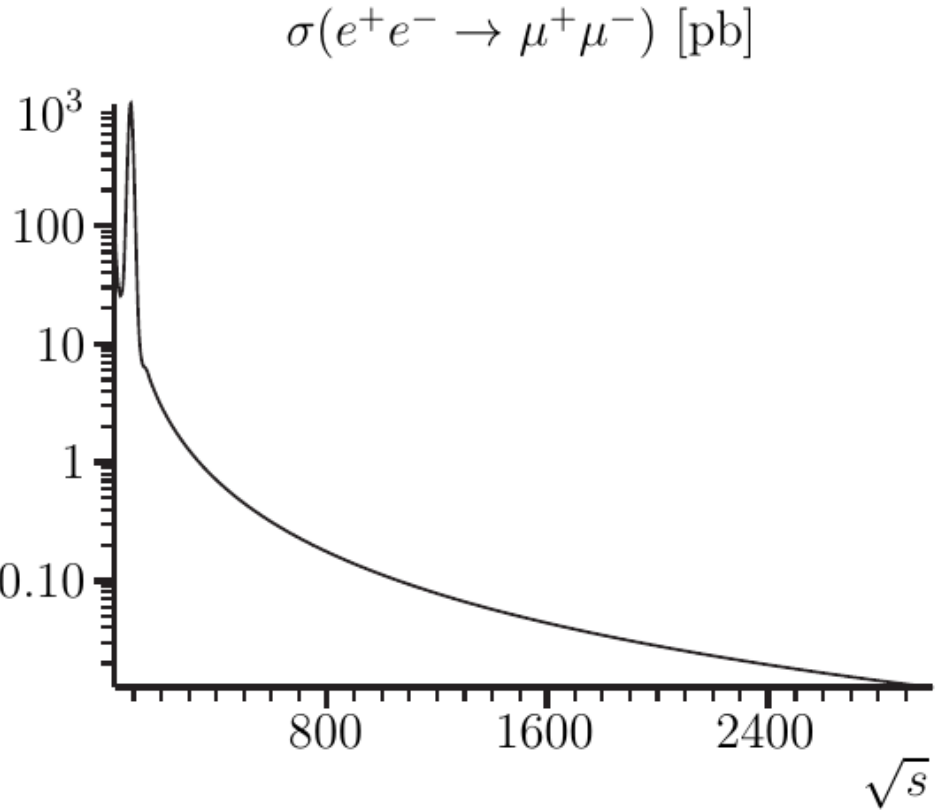
Possible 3-boson vertex modification

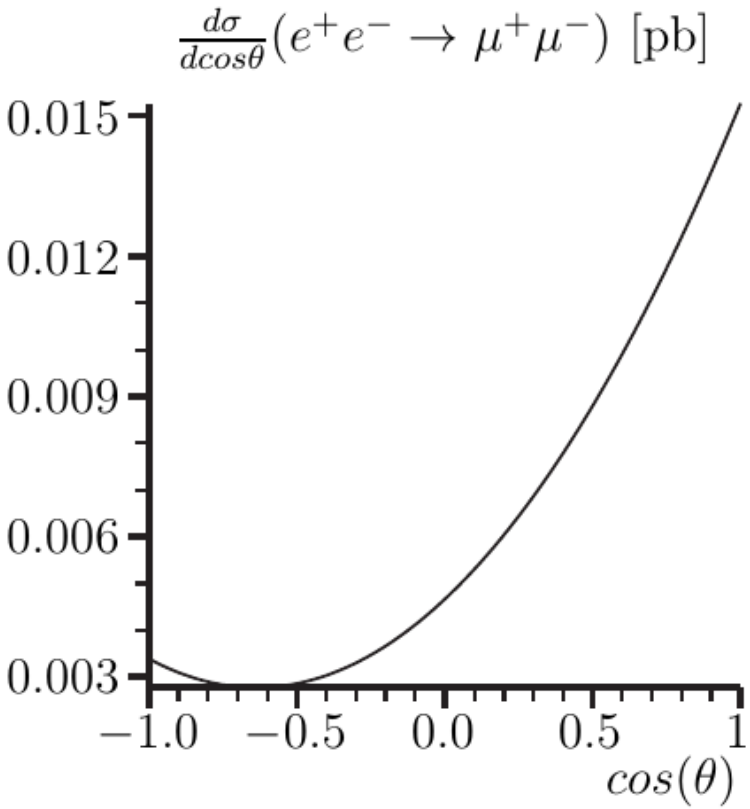


$\nu-$exchange $\gamma-$exchange Z^0-exchange

$$
\begin{aligned}
\mathcal{L}(G_1) &= ieG_1V_\alpha[W_\nu^+\partial_\alpha W_\nu - (\partial_\alpha W_\nu^+)W_\nu], \\
\mathcal{L}(G_2) &= ieG_2V_\alpha[W_\nu^+\partial_\nu W_\alpha - (\partial_\nu W_\alpha^+)W_\nu], \\
\mathcal{L}(G_3) &= ie\frac{G_3}{M^2}V_\alpha[(\partial_\alpha\partial_\nu W_\mu^+)(\partial_\mu W_\nu) - (\partial_\nu W_\mu^+)(\partial_\alpha\partial_\mu W_\nu)], \\
\mathcal{L}(G_4) &= -e\frac{G_4}{M^2}V_\alpha\{\partial_\sigma\partial_\sigma[(\partial_\mu W_\alpha^+)W_\mu + W_\mu^+(\partial_\mu W_\alpha)] - 2\partial_\alpha[(\partial_\nu W_\mu^+)(\partial_\mu W_\nu)]\}, \\
\mathcal{L}(G_5) &= ie\frac{G_5}{M^2}V_\alpha(\partial_\sigma\partial_\sigma\delta_{\alpha\beta} - \partial_\alpha\partial_\beta)\epsilon_{\beta\mu\nu\lambda}[(\partial_\lambda W_\mu^+)W_\nu - W_\mu^+(\partial_\lambda W_\nu)], \\
\mathcal{L}(G_6) &= eG_6V_\alpha\epsilon_{\alpha\mu\nu\lambda}\partial_\lambda(W_\mu^+W_\nu), \\
\mathcal{L}(G_7) &= -e\frac{G_7}{M^2}V_\alpha\epsilon_{\beta\mu\nu\lambda} \times \partial_\beta[(\partial_\alpha\partial_\lambda W_\mu^+)W_\nu - (\partial_\alpha W_\mu^+)(\partial_\lambda W_\nu) \\
&\quad -(\partial_\lambda W_\mu^+)(\partial_\alpha W_\nu) + W_\mu^+(\partial_\alpha\partial_\lambda W_\nu)],
\end{aligned}
$$

$e^+e^- \to W^+W^-$


$\sigma(e^+e^- \to \mu^+\mu^-)$ [pb]
10^3
100
10
1
0.10
800
1600
2400
$\sqrt{s}$


$\frac{d\sigma}{dcos\theta}(e^+e^- \to \mu^+\mu^-)$ [pb]
0.015
0.012
0.009
0.006
0.003
−1.0
−0.5
0.0
0.5
1
$cos(\theta)$

Differential cross-section

$$\frac{d\sigma}{dt} = \frac{d\sigma_t}{dt} + \frac{d\sigma_{st}}{dt} + \frac{d\sigma_s}{dt},$$

$$\begin{aligned}
\frac{d\sigma_t}{dt} &= \frac{\pi\alpha^2}{2s^2}\frac{g^4}{4e^4}\Big\{2\frac{s}{M^2} + 2\frac{ut - M^4}{s^2}\Big[\frac{s^2}{t^2} + \frac{s^2}{4M^4}\Big]\Big\}, \qquad (13)\\
\frac{d\sigma_{st}}{dt} &= \frac{\pi\alpha^2}{2s^2}\frac{g^2}{4e^2}\Big\{f_1\frac{ut - M^4}{s^2}(4\frac{s}{t} + 2\frac{s}{M^2} + \frac{s^2}{M^4}) + f_2[\frac{ut - M^4}{s^2} - 4 + 2\frac{s}{M^2} + 4\frac{M^2}{t}]\\
&\quad + f_3\frac{ut - M^4}{\mathrm{sM}^2}[-2\frac{s}{t} - \frac{s^2}{2M^4}] + f_5[4\frac{ut - M^4}{tM^2}(1 - 2\frac{s}{M^2}) + 8\frac{s}{M^2} - 2\frac{s^2}{M^4}]\Big\},\\
\frac{d\sigma_s}{dt} &= \frac{\pi\alpha^2}{2s^2}\Big\{4\frac{ut - M^4}{s^2}\Big[F_1(3 - \frac{s}{M^2} + \frac{s^2}{4M^4}) + F_2\frac{s(s - 2M^2)}{4M^4} + F_{12}\frac{s(s - 2M^2)}{2M^4} +\\
&\quad + F_3\frac{s^4}{16M^8}V^2 + F_{13}\frac{s^2(s - 2M^2)}{4M^6}(-V^2) + F_{23}(-\frac{s^3}{4M^6}V^2) +\\
&\quad + F_6(-\frac{s}{2M^2}) + F_7 2\frac{s^2}{M^4}V^2 + F_{67}(-4\frac{s}{M^2}) + F_4(-\frac{s^3}{2M^6}) + F_5(-\frac{s^3V^2}{2M^6})\Big]\\
&\quad + F_2\frac{s}{M^2}V^2 + F_4\frac{s^3}{M^6}V^2 + F_5\frac{s^3}{M^6}V^4 + F_6\frac{s}{M^2} +\\
&\quad + 4\frac{s^2}{M^4}\frac{t - M^2 + s/2}{s}[\tilde{F}_{25}V^2 + \tilde{F}_{46}]\Big\},
\end{aligned}$$

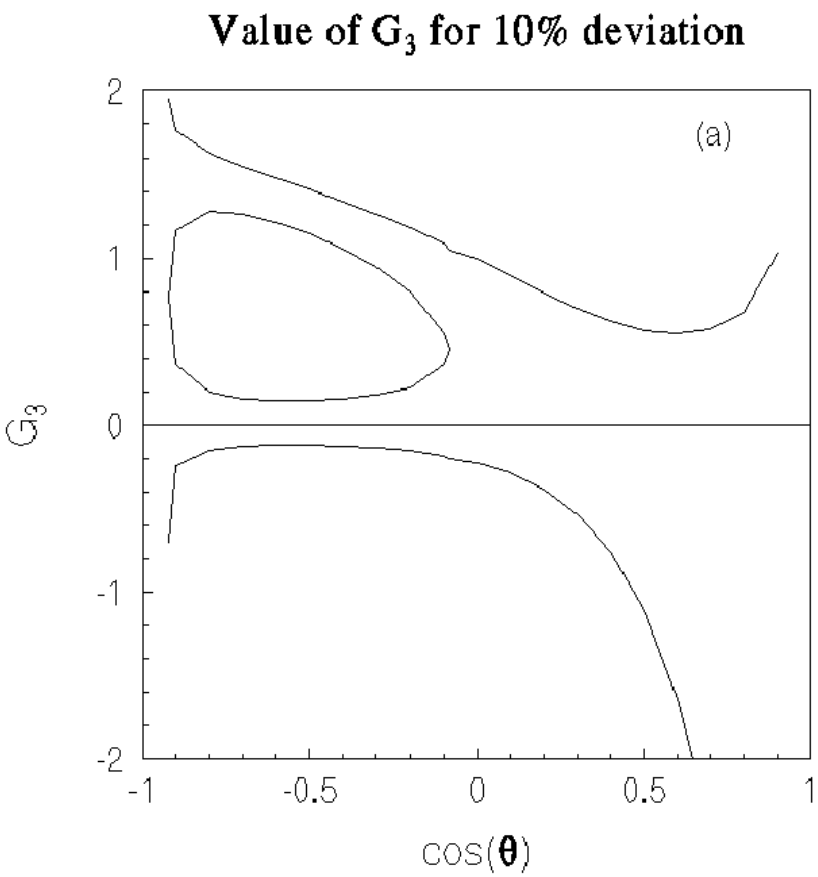
Total cross-section

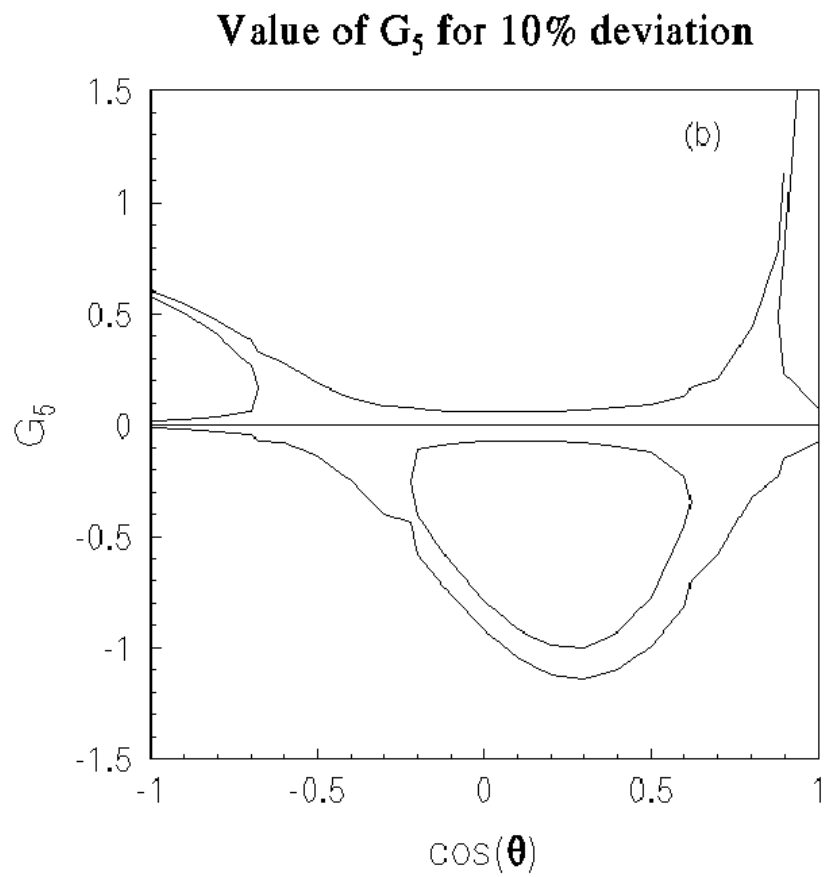
$$
\begin{aligned}
f_i &= Q_e Q_w G_i^\gamma + (1+\eta_e)\chi G_i^z; \\
F_{ij} &= Q_e^2 Q_w^2 G_i^\gamma G_j^\gamma + Q_e Q_w \eta_e \chi (G_i^\gamma G_j^z + G_i^z G_j^\gamma) + (1+\eta_e^2)\chi^2 G_i^z G_j^z, \qquad F_i = F_{ii}, \\
\tilde{F}_{ij} &= Q_e Q_w \chi (G_i^\gamma G_j^z + G_i^z G_j^\gamma) + 2\eta_e \chi^2 G_i^z G_j^z,
\end{aligned}
$$

$$\sigma = \sigma_t + \sigma_{st} + \sigma_s.$$

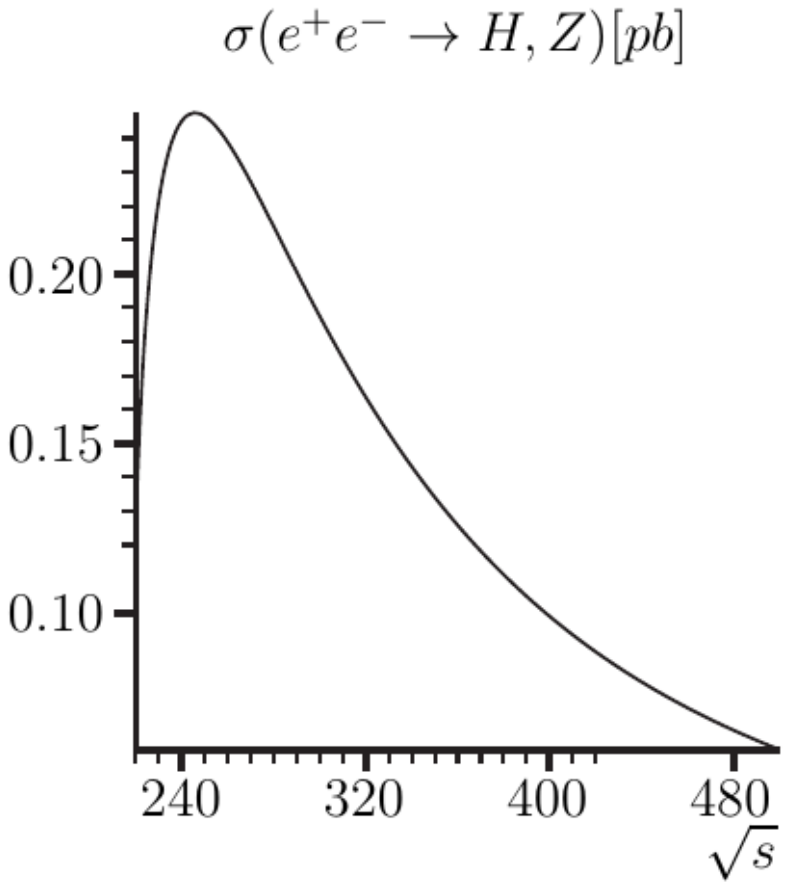
$$
\begin{aligned}
\sigma_t &= \frac{\pi\alpha^2 V}{2s}\frac{g^4}{4e^4}\Big\{-4 + \frac{20}{3}y + \frac{4}{3}y^2 + 4\frac{2y-1}{2y}L\Big\}, \qquad (16) \\
\sigma_{st} &= \frac{\pi\alpha^2 V}{2s}\frac{g^2}{4e^2}\Big\{f_1(\frac{1}{y} - \frac{10}{3} - \frac{4}{3}y + \frac{8}{3}y^2 + \frac{1}{2y}2L) + f_2(-4 + \frac{16}{3}y + \frac{8}{3}y^2 - \frac{2}{y}L) \\
&\quad + f_3(-2 + 4y + \frac{16}{3}y^2 - \frac{16}{3}y^3 - \frac{1}{y}L) + f_5(4 + 8y - 2\frac{4y-1}{y}L)\Big\}, \\
\sigma_s &= \frac{\pi\alpha^2 V}{2s}\Big\{F_1\frac{2}{3}V^2(3 - 4y + 4y^2) + F_2\frac{8}{3}V^2 y(y+1) + F_{12}\frac{8}{3}V^2 y(2y-1) \\
&\quad + F_3\frac{32}{3}V^6 y^4 + F_{13}(-\frac{16}{3}V^4 y^2(2y-1)) + F_{23}(-\frac{32}{3}V^4 y^3) \\
&\quad + F_4\frac{128}{3}V^2 y^3 + F_5\frac{128}{3}V^4 y^3 + F_6\frac{4}{3}(2y+1) + F_7\frac{64}{3}V^4 y^2 + F_{67}(-\frac{32}{3}V^2 y)\Big\}.
\end{aligned}
$$

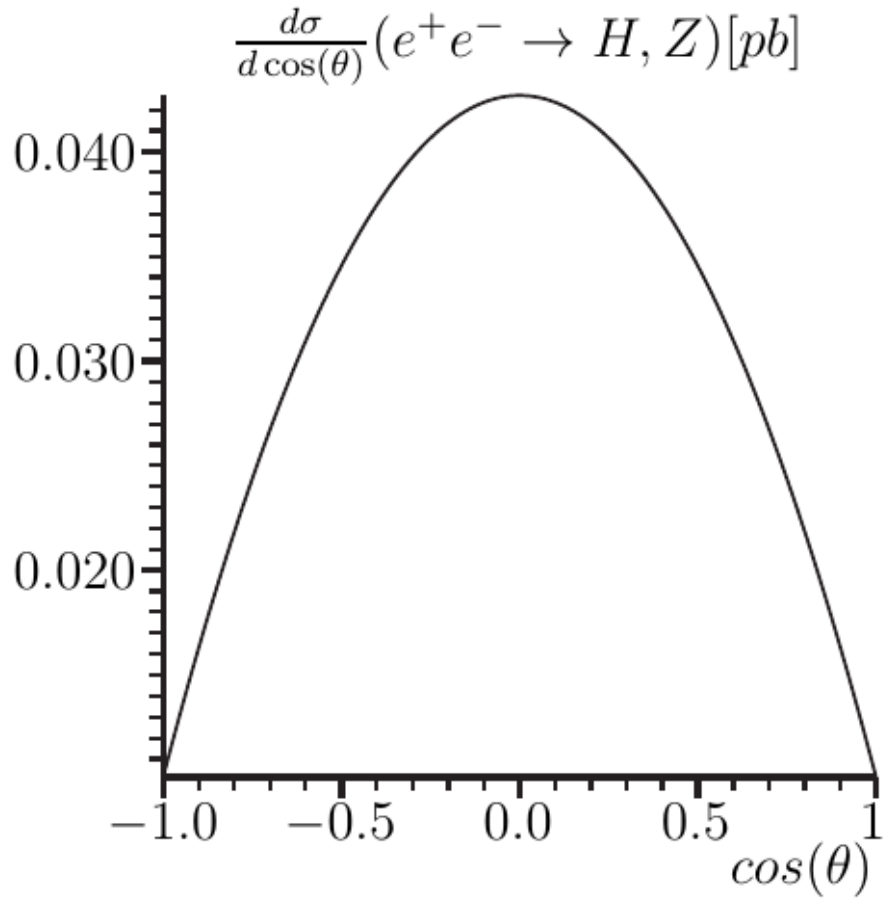
Differential cross-section sensitivity to G3 and G5





HZ production to compare





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- V. V. Gilewsky and I. S. Satsunkevich, Some estimations for influence of the intermediate vector boson CP-invariant formfactors in the electron-positron annihilation reaction, preprint, Institute of Physics, Minsk 1987, No.473.
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4- Technique proposal for CLIC
V. Gilewsky

-RF-cavities,

optical alignment systems (for accelerator)

slow control system (for accelerator and detector),

mechanics

There is an experience in production of support structures for toroidal magnets, plates for TileCal at some Minsk plants and LVPS for ATLAS.

Conclusion

- **QCD:**
- **- colour dissipation,**
- **-instability of motion and stabilization by Higgs-boson; order-chaos transition;**
- **-squeezed and entangled states in jets;**
- **QCD - instantons**

- **QED:**
- **-luminosity for photon colliders (γe – and γγ collisions) taking into account the nonlinear contributions in the inverse Compton scattering, polarization of colliding electrons and photon of laser wave;**
- **-parameters of beams for effective boson Higgs investigation;**
- **- modernization of generator o'mega by the advantages of diagonal spin bases in which spin 4-vectors of fermions are expressed via their 4-momenta**

- **SM:**
- **- multi W-bosons interactions**

- **Technique proposal:**
- **-RF-cavities, optical alignment systems (for accelerator) slow control system (for accelerator and detector), mechanics, experience in production of plates for ATLAS at Minsk's plant**

Thank you for the attention!