Project "CalcPHEP: Calculus for Precision High Energy Physics"

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1 Introduction

The `CalcPHEP` collaboration joins the efforts of several groups of theorists known very well in the field of theoretical support of various experiments in HEP, particularly at SLAC and LEP, (see, for instance [1], [2] and [3]). The first phase of the `CalcPHEP` system was realized in the site *http://brg.jinr.ru/* in 2000–2001. It is written mostly in `FORM3`, [4]. In this talk, we will describe the present status and our plans for the realization of next phases of the `CalcPHEP` project aimed at the theoretical support of experiments at modern and future accelerators: TEVATRON, LHC, electron Linear Colliders (LC's) i.e. TESLA, NLC, CLIC, and muon factories. Within this project, we are creating a four-level computer system which eventually must automatically calculate pseudo- and realistic observables for more and more complicated processes of elementary particle interactions, using the principle of knowledge storing. Upon completion of the second phase of the project, started January 2002 with duration of about three years, we plan to have a complete set of computer codes, accessible via an Internet-based environment and realizing the complete chain of calculations "from the Lagrangian to the realistic distributions" at the one-loop level precision including all $1 \to 2$ decays, $2 \to 2$ processes and certain classes of $2 \to 3$ processes.

1.1 CalcPHEP group

The `CalcPHEP` group was formed in 2001 in sector N°1 NEOVP LJAP.

During the first phase of the project in 2000–2001, the `CalcPHEP` group created the site `brg.jinr.ru`, where the development in two strategic directions is foreseen:

1. Creation of a softwear product, capable to compute HEP observables with one-loop precision for complicated processes of elementary particle interactions, using the principle of knowledge storing. Application: LHC.
2. Works towards two-loop precision level control of simple processes: $1 \to 2$, $1 \to 3$ and $2 \to 2$. Application: GigaZ option of electron LC's.

1.2 A little bit of history

There are two historical **sources** of `CalcPHEP` project:
1. From one side it roots back to many codes written by Dubna group aimed at a theoretical support of HEP experiments in the past:
1975 – 1986: support of CERN DIS experiments (BCDMS, EMC, NMC), creation of program `TERAD`; support of CERN neutrino experiments (CHARM-I, CDHSW and CHARM-II), creation of programs `NUDIS, INVMUD, NUFITTER`.
1983 – 1989: Foundation of the DZRCG — "Dubna–Zeuthen Radiative Correction Group", creation of EW library `DIZET`; creation of the program `ZBIZON` — the fore-runner of `ZFITTER` [5].
1989 – 1997: support of the DIS experiments at HERA, creation of the program `HECTOR`; participation in SMC experiment at CERN with the program μ**e**la.
1989 – 2001: Theoretical support of experiments at LEP, SLC (DELPHI, L3, ALEPH, OPAL and SLD).
2. From the other side, a monograph "The Standard Model in the Making" was written [6]. While working on the book, the authors wrote hundreds of "book-supporting" form-codes, which comprised the proto-type of future `CalcPHEP` system.

Like well known codes of LEP era: `TOPAZ0` [7], `ZFITTER` [5], $\mathcal{KK}$MC [8], `CalcPHEP` is supposed to be a tool for precision calculations of pseudo- and realistic observables. Let's remind these definitions that arose in depth of LEP community:

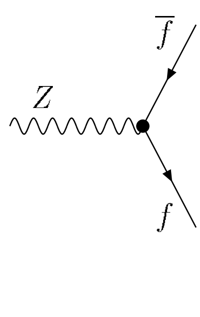
Definition 1 *Realistic Observables are the (differential) cross-sections (more general event distributions) for a reaction, e.g.*

$$e^+e^- \to (\gamma, Z) \to f\overline{f}(n\gamma)$$

calculated with all available in the literature higher order corrections (QCD, EW), including real and virtual QED photonic corrections, possibly accounting for kinematical cuts.

Definition 2 *Pseudo-Observables are related to measured quantities by some de-convolution or unfolding procedure (e.g. undressing of QED corrections). The concept itself of pseudo-observability is rather difficult to define. One way say that the experiments measure some primordial distributions which are then reduced to secondary quantities under some set of specific assumptions (definitions).*

Z decay partial width represents typical example of pseudo-observables, i.e. it has to be *defined*. At the tree level, we define it as a quantity described by the square of one diagram:



2 LEP, Precision High Energy Physics and its Future

One may say that during recent years a new physical discipline was born. We call it PHEP, Precision High Energy Physics. Experimentally, it finally shaped in the result of glorious 12 year LEP era: measurements at Z resonance in **1989 – 1995**, and reaching an unprecedented experimental accuracy $\leq 10^{-3}$, and measurements above Z resonance in **1995 – 2000**, at higher energies, where high enough experimental accuracy was also reached $\leq 1\%$. By 2/11/2000 LEP2 possibly saw hints of "God blessed" particle — Higgs boson, but was stopped, unfortunately, mainly due to lack of financing.

For the first time huge HEP facility challenged for theoreticians to perform calculations with uncertainty better than experimental errors of $\mathcal{O}\left(10^{-3}\right)$ and, eventually, efforts of many groups of theoreticians allowed the achievement of the theoretical precision of the order $2.5 \cdot 10^{-4}$ at the Z resonance and $2-3 \cdot 10^{-4}$ at LEP2 energies.

This, in turn, greatly contributed to the success of precision tests of the SM, the main result of LEP era, which laid the foundation of the Precision High Energy Physics. This is why our project got this suffix `PHEP`.

2.1 Future of PHEP

PHEP has good perspectives and after the end of LEP. Several Input parameters of the Standard Model (SM) are expected to be improved in near future.

Recent discrepancy in the muon amm:

$$\begin{aligned} a_\mu^{SM} &= 116591661(114) \times 10^{-11} \\ a_\mu^{EXP}(Average) &= 116592023(151) \\ a_\mu^{EXP} - a_\mu^{SM} &= 362(189) \quad 2\sigma \text{ difference} \\ & \quad \text{exp. error (151) should be improved soon up to} \sim (50), \end{aligned} \tag{1}$$

necessitates an improvement of the knowledge of the hadronic contribution of $\Delta\alpha_h^{(5)}\left(M_Z^2\right)$ to the running e.m. coupling. An experimental input for $\sigma\left(e^+e^- \to \text{hadrons}\right)$ at cms energies (1-4 GeV) is expected from BES-II, BEPC (Beijing), VEPP2000 (Novossibirsk) and DAFNE at cms energies around ϕ-meson.

Very important should be projected improvements of mass measurements: M_W, m_t.

LEP1 finished with *indirect* result for the top mass: $m_t = 169^{+10}_{-8}$ GeV; while LEP1 $\oplus$ TEVATRON constraint yielded: $m_t = 174.5^{+4.4}_{-4.2}$ GeV.

LEP2 reached for W mass M_W: $M_W = 80.450 \pm 0.039$, in the *direct* measurements and $M_W = 80.373 \pm 0.023$ as *indirect* result.

TEVATRON in RUN-I reached: $M_W = 80.454 \pm 0.060$ GeV, $m_t = 174.3 \pm 5.1$ GeV.

Much better precision tags are expected to be reached at TEVATRON, RUN-II (recently started): $\Delta M_W \sim 20$MeV, $\Delta m_t \sim 2$ GeV; and later at LHC (not so sooner than in 2006, however): $\Delta M_W \sim 15$ MeV, $\Delta m_t \sim 1$ GeV.

Where, when and with which mass Higgs boson might be discovered?
– TEVATRON has a serious chance to see Higgs up to mass 180 GeV; however it will require very high integrated luminosity: $\int \mathcal{L} \geq 5 fb^{-1}$;
– LHC, will cover all allowed mass range up to 500 GeV (not so soon, after 2007);
– LC's and muon factories (after 2010–2012).

New horizon of PHEP will be opened with experiments at electron LC's: TESLA (DESY) particularly with GigaZ option, i.e. coming back to Z resonance with statistics 10^9; CLIC (CERN); JLC (KEK), NLC(SLAC, LNBL, LLNL, FNAL) and Muon Storage Rings (Higgs Factory) — all that more than in ten years from now.

One expects fantastic precision tags there in:
– $\Delta \sin^2\theta_{eff} \sim 0.00002$;
– $\Delta M_W \sim 6$ MeV, $\Delta m_t \sim 100 - 200$MeV;
– $\Delta M_H \sim 100$ MeV (from $e^+e^- \to ZH$);
– and detail study of Higgs boson properties.

Given our LEP1 experience one should definitely state that ***2-loop precision level control will be absolutely necessary for the analysis of these data!***

One may conclude that PHEP has a bright future: all future colliders — TEVATRON, LHC, electron LC's (TESLA, NLC, CLIC) and muon factories will be, actually, PHEP facilities! For data analysis, they will surely require qualitatively new level of both theoretical predictions and principally new computer codes.

3 Necessary notion

In order to understand the language of `CalcPHEP` one has to introduce many notions and notations.

3.1 Input Parameter Set, IPS

The Minimal Standard Model (MSM), contains large number of Input Parameters:
$25 = 2$ interaction constants α and α_S
$\oplus$ 8 mixing angles (CKM and possible lepton analogs)
$\oplus$ 15 masses (12 fundamental fermions and 3 fundamental bosons Z, W, H).

However, the number 25 is *minimal*. MSM is **unable** to compute its IPS from first principles; MSM is **able** to compute *any observable* $O_i^{\rm exp}$ in terms of its IPS:

$$O_i^{\rm exp}\,(\text{measured}) \quad \leftrightarrow \quad O_i^{\rm theor}\,(\text{calculated, as a function of IPS})\,. \tag{2}$$

This is the way how precision measurements set *constraints* on IPS.

3.1.1 Number of free parameters in fits of Z resonance observables

At Z resonance, not all 25 parameters matter. Actually only 5 parameters:

$$\Delta\alpha_h^{(5)}\left(M_Z^2\right), \qquad \alpha_S\left(M_Z^2\right), \qquad m_t\,, \qquad M_Z\,, \qquad M_H\,, \tag{3}$$

which we call the Standard LEP1 IPS, matter.

Using M_Z, measured at Z peak itself with the precision $\sim 2\times 10^{-5}$, and also reach information from the other measurements for:

$$\alpha_S\left(M_Z^2\right), \qquad m_t\,, \qquad M_W\,, \tag{4}$$

we *approach* one-parameter fit, with Higgs boson mass M_H being the only fitted parameter. The result of such a fit was shown in the *Blue band* figure, the most celebrated LEP era figure, derived with the aid of `TOPAZ0` [7] and `ZFITTER` [6] codes.

3.2 Quantum Fields of the SM

Here we sketch all fundamental quantum fields of the SM in one of the most general gauges — R_ξ, with three arbitrary gauge parameters ξ_A, ξ_Z, ξ.

Three generation of fermions or matter fields:

$$f = \begin{cases} \begin{pmatrix} \nu \\ l \end{pmatrix} = \begin{pmatrix} \nu_e \\ e^- \end{pmatrix} \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix} \begin{pmatrix} \nu_\tau \\ \tau \end{pmatrix} \\ \begin{pmatrix} U \\ D \end{pmatrix} = \begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix} \begin{pmatrix} t \\ b \end{pmatrix} \end{cases}$$

possess masses, m_f, charges, Q_f, and third projections of weak isospin, $I_f^{(3)}$:

$$m_f, \quad Q_f = \begin{pmatrix} \nu & l & U & D \\ 0 & -1 & +\frac{2}{3} & -\frac{1}{3} \end{pmatrix}, \quad I_f^{(3)} = \begin{pmatrix} \nu & l & U & D \\ +\frac{1}{2} & -\frac{1}{2} & +\frac{1}{2} & -\frac{1}{2} \end{pmatrix}.$$

Gauge fields:

Vector bosons	Unphysical scalars	Faddeev–Popov ghosts
A		Y^A
$Z\,(M_Z)$	ϕ^0	Y^Z
$W^\pm(M_W)$	$\phi^\pm$	$X^\pm$

Gluon
possesses strong interaction

g		Y^G

possess physical charges and physical masses

possess physical charges and unphysical masses

and unphysical charges.

Higgs field:

$H\,(M_H)$ is a scalar, neutral, massive field.

3.2.1 The Lagrangian in R_ξ gauge, Feynman Rules

At the ground level of `CalcPHEP` system one has this Lagrangian

$$\mathcal{L} = \mathcal{L}(\text{IPS of 25 parameters, 17 fields, 3 gauge parameters}), \tag{5}$$

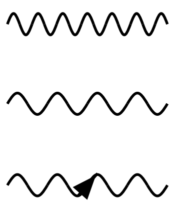
from which one derives *primary Feynman rules for vertices.*

3.2.2 Propagators in R_ξ gauge

Here we list propagators in R_ξ gauge, the other important bricks of `CalcPHEP` system.
Propagator of a fermion, f:


f $\quad \dfrac{-i\not{p}+m_f}{p^2+m_f^2}$

Vector boson propagators:



A $\quad \dfrac{1}{p^2}\left\{\delta_{\mu\nu}+\left(\xi_A^2-1\right)\dfrac{p_\mu p_\nu}{p^2}\right\}$

Z $\quad \dfrac{1}{p^2+M_Z^2}\left\{\delta_{\mu\nu}+\left(\xi_Z^2-1\right)\dfrac{p_\mu p_\nu}{p^2+\xi_Z^2 M_Z^2}\right\}$

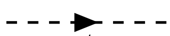
$W^\pm$ $\quad \dfrac{1}{p^2+M_W^2}\left\{\delta_{\mu\nu}+\left(\xi^2-1\right)\dfrac{p_\mu p_\nu}{p^2+\xi^2 M_W^2}\right\}$

Propagators of unphysical fields:


Y^A $\quad \dfrac{\xi_A}{p^2}$

ϕ^0 $\quad \dfrac{1}{p^2+\xi_Z^2 M_Z^2}\,,$


Y^Z $\quad \dfrac{\xi_Z}{p^2+\xi_Z^2 M_Z^2}$


$\phi^\pm$ $\quad \dfrac{1}{p^2+\xi^2 M_W^2}\,,$

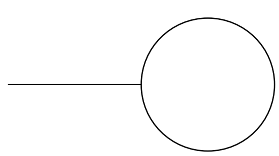

$X^\pm$ $\quad \dfrac{\xi}{p^2+\xi^2 M_W^2}$

Propagator of the physical scalar field, H-boson

H $\quad \dfrac{1}{p^2+M_H^2}$

3.3 Scalar A_0, B_0, etc functions

For calculation of one-loop integrals `CalcPHEP` uses the standard scalar A_0, B_0, C_0 and D_0 functions [6].
One-point integrals or A_0 functions, are met in tadpoles diagrams:



We give its defining expression:

$$i\pi^2 A_0(m) = \mu^{4-n}\int d^n q\,\frac{1}{q^2+m^2-i\epsilon}\,, \tag{6}$$

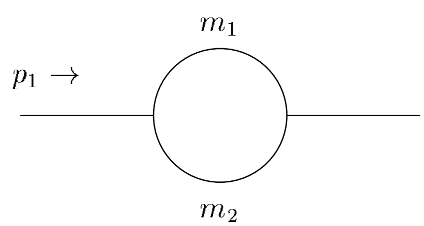
and the answer in the *dimensional regularization*:

$$A_0(m) = m^2\left(-\frac{1}{\bar{\varepsilon}}-1+\ln\frac{m^2}{\mu^2}\right)+\mathcal{O}(\varepsilon)\ , \tag{7}$$

where the ultraviolet pole is:

$$\frac{1}{\bar{\varepsilon}} = \frac{2}{\varepsilon} - \gamma - \ln \pi \,, \qquad n = 4 - \varepsilon \,. \tag{8}$$

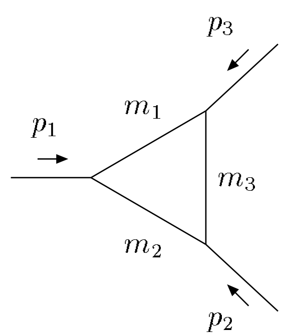
Two-point integrals or B_0-functions are met in self-energy diagrams:



We limit ourselves by giving its defining expression:

$$i\pi^2 B_0 \left(p_1^2; m_1, m_2\right) = \mu^{4-n} \int d^n q \frac{1}{d_0 d_1} \,,$$
$$d_0 = q^2 + m_1^2 - i\epsilon, \qquad d_1 = (q + p_1)^2 + m_2^2 - i\epsilon \,. \tag{9}$$

Three-point integrals, C functions, are met in vertices:



Its defining expression reads:

$$i\pi^2 C_0 \left(p_1^2, p_2^2, Q^2; m_1, m_2, m_3\right) = \mu^{4-n} \int d^n q \frac{1}{d_0 d_1 d_2} \,, \tag{10}$$

$$d_0 = q^2 + m_1^2 - i\epsilon, \quad d_1 = (q + p_1)^2 + m_2^2 - i\epsilon, \quad d_2 = (q + p_1 + p_2)^2 + m_3^2 - i\epsilon, \tag{11}$$

where $Q^2 = (p_1 + p_2)^2$ is one of the Mandelstamm variables: s, t or u.
Four-point integrals, D-functions, are met in boxes.

Presently, `CalcPHEP` knows ALL about reduction of up to four-point functions up to third rank tensors and of the so-called *special* functions, which are due to peculiar form of the photonic propagator in the R_ξ gauge, see [6].

3.4 Processes in the SM

One should be aware of a hierarchical classification of processes accepted in `CalcPHEP` and of a relevant notion of *independent structures*, or *independent amplitude form factors*, which number is deeply related to the number of *independent helicity amplitudes* by which a process may be described (below we present these numbers for unpolarized cases).

3.4.1 Decays $1 \to 2$

There are $B \to f\overline{f}$ and $3B$ decays:

- $H \to f\overline{f}$ (one structure)
- $Z \to f\overline{f}$, $(\gamma \to f\overline{f})$ (three structures)
- $W \to f\bar{f}'$, $(t \to W^+ b)$ (four structures)
- $H \to ZZ,\ W^+W^-$
- $Z \to W^+W^-$

3.4.2 Processes $2 \to 2$

There are $2f \to 2f$ processes, which in turn are subdivided into Neutral Current (NC) and Charged Current (CC) ones:

- NC: $f\overline{f} \to (\gamma, Z, H) \to f'\overline{f'}$ (4,6) 10 structures depending on whether initial and final state fermion masses are ignored
- CC: $f_1\overline{f}_2 \to (W) \to f_3\overline{f}_4$

Next, there are many processes of a kind $Vf \to f'V'$, in particular

- compton-effect: $\gamma e \to \gamma e,\ \ Z \to f\overline{f}\gamma$
- $e^+e^- \to W^+W^-,\ ZZ,\ Z\gamma, \gamma\gamma$

Decays $1 \to 3$ are cross-channels of the previous processes and their one-loop description in terms of independent objects, mentioned above, one gets for free. Present level of `CalcPHEP` has a lot of preparations for all above processes, but far not all is put into the working areas of the site `brg.jinr.ru`.

3.4.3 Processes $2 \to 3$

They comprise a very reach family, for instance:

- $e^+e^- \to (\gamma, Z, H) \to f\overline{f}\gamma$.

Their implementation is one of main goals of the second phase of `CalcPHEP` project. Corresponding decays $1 \to 4$ are again cross-channels of the previous processes and need not be studied separately.

3.4.4 Processes $2 \to 4$

To this family belongs 4 fermion processes of LEP2. Their study is not foreseen at the second phase of `CalcPHEP` project, but might be a subject of its third phase.

4 Building Blocks and knowledge storing

4.1 Simplest decay: $Z \to f\overline{f}$

4.1.1 Amplitude of $Z \to f\overline{f}$ decay at tree level

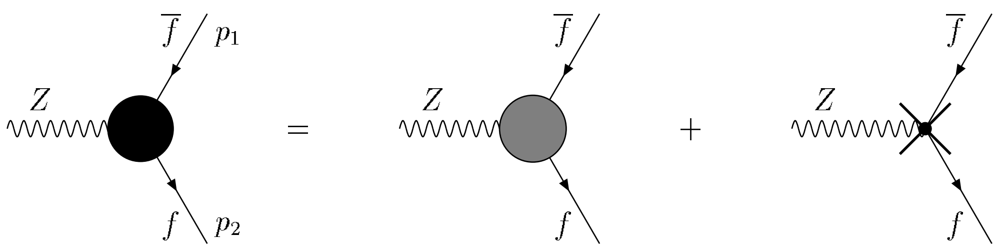
Its tree level diagram was already presented at the end of Section 1.2; the corresponding amplitude reads:

$$V_\mu^{Zf\overline{f}} = (2\pi)^4\, i\, \frac{ig}{2\, c_W}\, \gamma_\mu \left[I_f^{(3)}(1+\gamma_5) - 2Q_f s_W^2 \right], \tag{12}$$

with vector and axial coupling constants: $v_f = I_f^{(3)} - 2Q_f s_W^2$, $a_f = I_f^{(3)}$. Note appearance of the two structures in Eq. (12), which might be termed as L and Q structures, correspondingly. Note also, that Eq. (12) as well as all below, are written in Pauli metrics that is used by `CalcPHEP`.

4.1.2 Amplitude of $Z \to f\overline{f}$ decay with loop corrections

It might be schematically depicted as a sum of one-loop vertices and counter terms:



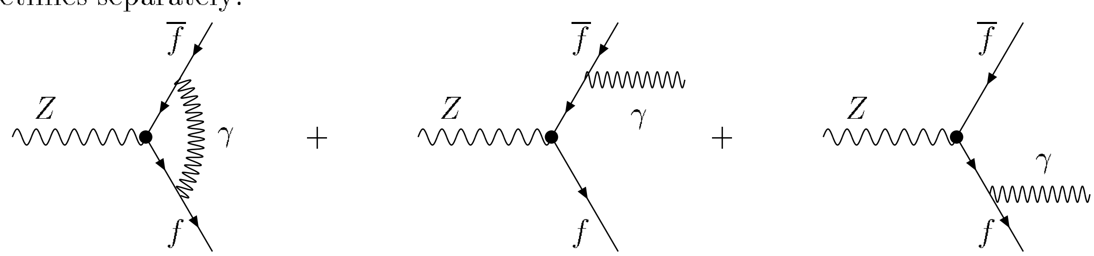
In the most general case (but for unpolarized study) the one-loop amplitude may be parameterized by the three *scalar form factors*:

$$V_\mu^{Zf\overline{f}} = (2\pi)^4\, i\, \frac{g^3}{16\,\pi^2\, 2\, c_W}\, \gamma_\mu \left[i I_f^{(3)} F_L \gamma_+ - 2iQ_f s_W^2 F_Q + m_f\,(p_1 - p_2)\, F_D \right]. \tag{13}$$

Given similarity of Eqs. (12) and (13), the latter is called sometimes Improved Born Approximation (IBA) amplitude.

4.1.3 QED diagrams and corrections

The QED diagrams comprise gauge invariant subsets, this is why they are considered sometimes separately:



Their contribution to the partial Z widths, in the case when no photon cuts are imposed, reads:

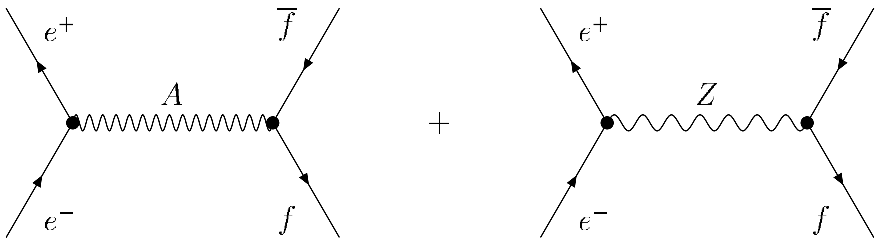
$$\Gamma_f^{\rm QED} = \Gamma_f \left(1 + \frac{3\alpha}{4\pi} Q_f^2 \right). \tag{14}$$

4.2 Process $e^+e^- \to f\overline{f}$

Coming to a more complicated case of a $2f \to 2f$ process, we will illustrate how building blocks, derived for a study of a lower level process, might be use at a higher level.

4.2.1 Tree-level diagrams and amplitudes of $e^+e^- \to f\overline{f}$

Consider first the two tree-level diagrams with γ and Z exchanges in order to introduce basis of relevant structures.



$$\begin{aligned}
\mathcal{A}^{\rm Born}_{\gamma} &= \frac{e^2 Q_e Q_f}{s}\gamma_\mu \otimes \gamma_\mu\,, \\
\mathcal{A}^{\rm Born}_{Z} &= \frac{e^2}{4 s^2_{W} c^2_{W}}\chi_Z(s)\,\gamma_\mu(v_e + a_e\gamma_5)\otimes\gamma_\mu(v_f + a_f\gamma_5) \\
&= \frac{e^2}{4 s^2_{W} c^2_{W}}\chi_Z(s)\,\gamma_\mu\left[I^{(3)}_e\gamma_+ - 2Q_e s^2_{W}\right]\otimes\gamma_\mu\left[I^{(3)}_f\gamma_+ - 2Q_f s^2_{W}\right], \qquad (15)
\end{aligned}$$

where $\gamma_\pm = 1 \pm \gamma_5$ and symbol $\otimes$ stands for a short-hand notation

$$\gamma_\mu\left(v_1 + a_1\gamma_5\right)\otimes\gamma_\nu\left(v_2 + a_2\gamma_5\right) = \bar{v}\left(p_+\right)\gamma_\mu\left(v_1 + a_1\gamma_5\right)u\left(p_-\right)\bar{u}\left(q_-\right)\gamma_\nu\left(v_2 + a_2\gamma_5\right)v\left(q_+\right)$$

and

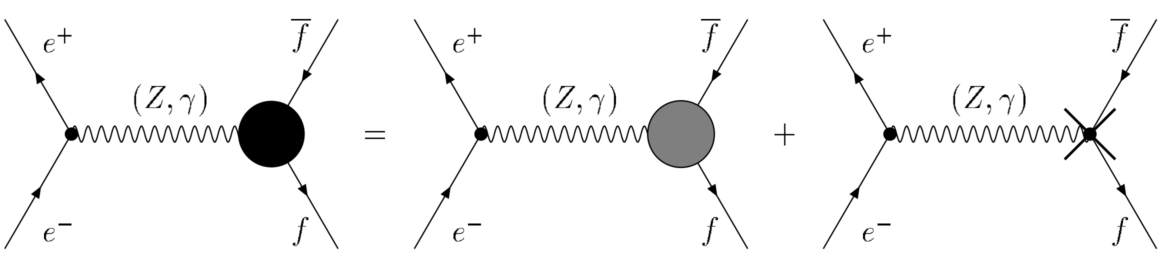
$$\chi_Z(s) = \frac{1}{s - M^2_Z + is\Gamma_Z/M_Z}\,. \qquad (16)$$

This amplitude is characterized by four structures:

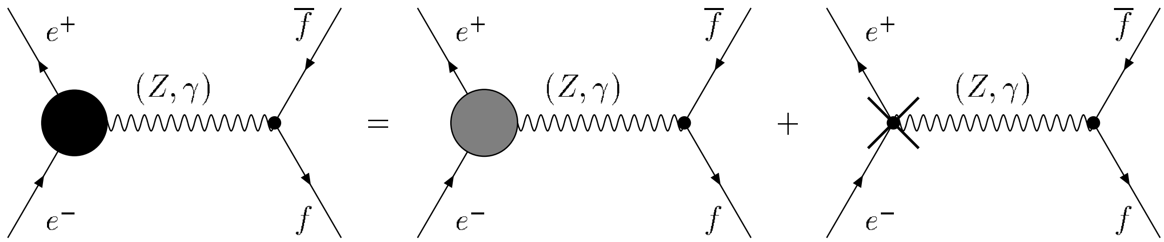
$$LL = \gamma_\mu\gamma_+\otimes\gamma_\mu\gamma_+\,,\quad LQ = \gamma_\mu\gamma_+\otimes\gamma_\mu\,,\quad QL = \gamma_\mu\otimes\gamma_\mu\gamma_+\,,\quad QQ = \gamma_\mu\otimes\gamma_\mu\,. \qquad (17)$$

4.2.2 One-loop amplitude for $e^+e^- \to f\overline{f}$

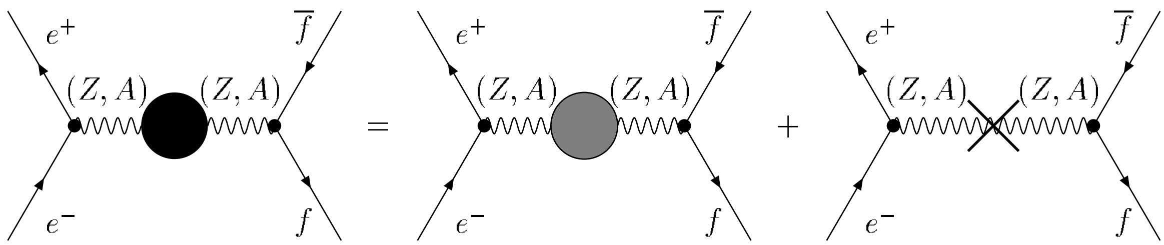
"Dressed" with one-loop vertices and counterterms, the γ and Z exchanges may be symbolically depicted as:



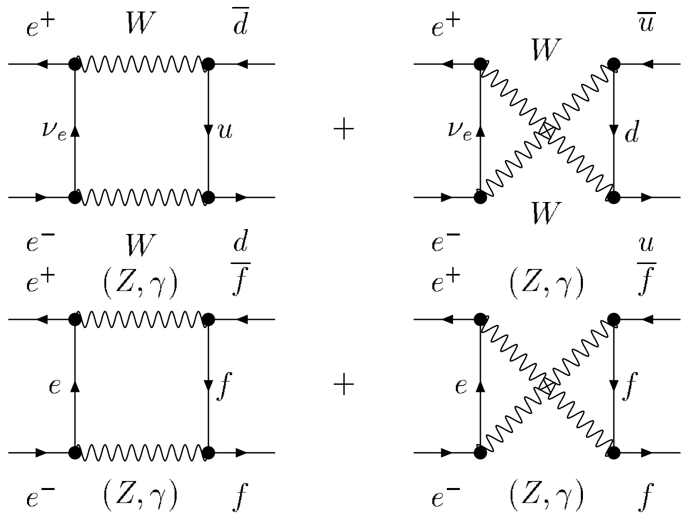
And similarly for the initial state vertex:



Where one can easily recognize building blocks already known from the calculation of one-loop radiative corrections for Z decay, however, now we need to dress $\gamma \to f\overline{f}$ vertex too and add into consideration "dressing" of propagators:



To complete calculations of one-loop EWRC for the process $e^+e^- \to f\overline{f}$ one should add WW and ZZ boxes:



ZZ, $\gamma\gamma$ and $Z\gamma$ boxes comprise gauge invariant subset of diagrams. Moreover, $\gamma\gamma$ and $Z\gamma$ boxes QED, vertices and QED bremsstrahlung for NC $2f \to 2f$ processes often are separated into a gauge invariant QED subset of diagrams.

Virtual QED one-loop diagrams together with four QED bremsstrahlung diagrams form an Infra-Red Divergence (IRD) free subset.

This example clearly shows how the principle of knowledge storing is implemented within `CalcPHEP` project: one starts from the simplest decays and collects all relevant building blocks, BB's (off-shell with respect to boson mass). Then one moves to next level of complexity where all BB's computed at the previous level are requested, but on top one needs more complicated objects (here boxes).

This strategy was realized in our recent calculations of the EWRC to the $e^+e^- \to f\bar{f}$ process, which are completely done with the aid of `CalcPHEP` system [9]. There is another study accomplished with `CalcPHEP` [10].

5 Status of the project

Before discussing what is already available at the site `brg.jinr.ru`, we present some general information about `CalcPHEP` system.

5.1 Basic information about `CalcPHEP`, keywords

`CalcPHEP` is **four-level computer system** for automatic calculation of pseudo- and realistic observables (decay rates, event distributions) for more and more complicated processes of elementary particle interactions, using the principle of knowledge storing.

At each of the four levels there are:

1. Codes (written in FORM3), realizing full chain of analytic calculations from the SM Lagrangian $\mathcal{L}_{SM}$ to the Ultra Violet Free Amplitudes, UVFA, parameterized by a minimal set of scalar form factors;
2. Codes (written in FORM3), realizing analytic calculations of a minimal subset of Helicity Amplitudes, HA's, followed by an automatic procedure of generation of codes for numerical calculations of HA's (presently `FORTRAN` codes, and in a near perspective C^{++} codes).
3. Codes, realizing the so-called "infrared rearrangement" of HA's. This is needed if the multiple photon emission is being exponentiated at the amplitude level. Currently, bremsstrahlung photons are added in the lowest order and the third level is skipped.
4. Codes, that use HA's derived at the second (or third) level together with tree-level HA's for one-photon (or multiple-photon) emission, within a Monte Carlo event generator, which is supposed to compute realistic distributions (presently `FORTRAN` codes, and in a near perspective C^{++} codes.)

It is an **Internet based** and **Database based** system. The latter means that there is a storage of source codes written in different languages, which talk to each other. They are placed into a homogeneous environment written in JAVA.

It follows **Intermediate access principle** i.e. full chain "from the Lagrangian to realistic distribution" should work out completely in real time, if someone requests this, however, it is supposed to have several "entries", say after each level, or just providing the user with its final product — a Monte Carlo event generator.

5.2 Some technical data about `CalcPHEP`

1. Address *http://brg.jinr.ru/*
2. For realization of the site one used:
   - Apache web server under Linux,
   - `form3` compiler,
   - mySQL server for relational databases.
3. In the current version, user-interface is realized with the use of PHP.
4. Nowadays, everything is being rewritten in JAVA in order to reach better "interactivity" and to use reach possibilities of already written in this language libraries. **Main goal of this rewriting is to create a homogeneous environment both for accessing our codes from the database and for offering a possibility for simultaneous work of several members of the group and external users.**

5.3 Present and nearest versions of CalcPHEP system

In 2001, we released two test-versions of CalcPHEP:

1. **v0.01 from March'01** realizes analytic calculations of one-loop UVFA for decays $1 \to 2$ (level-1).
2. **v0.02 from September'01** returns numbers for one-loop decay widths (levels-1,2) via temporary bypass of level 4. It realizes also levels-1,2 for $2f \to 2f$ NC process.
3. One has very many almost finished "preparations" for the other processes $2 \to 2$ and decays $1 \to 3$ (level-1). All this should comprise **v0.03** of Summer 2002.
4. An active work is being realized on implementation of level-4 for decays $1 \to 2$, this should complete full chain "from the SM Lagrangian to pseudo-observables" for the simplest decays.
5. There are many problems to be solved at the second or later phases of the project. Among them one should mention:
   – automatic generation of Feynman Rules from a Lagrangian,
   – automatic generation of topologies of Feynman diagrams,
   – graphical representation of the results.

6 Conclusion

At a Symposium in honor of Professor Alberto Sirlin's 70th Birthday was said: *A new frontier is as the horizon: most likely it is goodbye to the one man show. Running a new Radiative Correction project will be a little like running an experiment [11].*

Indeed, projects of such a kind as CalcPHEP are definitely long term projects. Remember, that ZFITTER took about 12 years, about the same time exists already FeynArts [12].

Our nearest goal is the realization of the second phase of the project upon completion of which we plan to have a complete software product, accessible via an Internet-based environment, and realizing the chain of calculations "from the Lagrangian to the realistic distributions" at the one-loop level precision including some processes $2 \to 3$ and decays $1 \to 4$. Plans also assume to perform an $R\&D$ for the third phase of the project (see also [13]–[16]) which should begin in 2004.

Second phase is basically oriented on a common work of theoreticians of the Dubna group and the Knoxville–Krakow collaboration [8].

United group proposes to realize in 2002-2004 an important phase of CalcPHEP project: oriented toward a merger of analytic results to be produced by Dubna team with MC event generators to be developed by Knoxville–Krakow collaboration[1].

Among most important milestones of first year, one should mention: realization of the levels 2-4 for the simplest $Z(H,W) \to f\bar{f}$ decays; completion of level 1 for the radiative Z decay, $Z \to f\bar{f}\gamma$, work on which is already under way; completion of levels 2-4 for the radiative Z decay.

[1]In this connection it is necessary to emphasize that any future code aimed at a comparison of experimental data with theory predictions should be a MC generator, since the processes at very high energies will have multi-particle final states that make impossible a semi-analytic approach used at LEP within ZFITTER project.

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