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CalcPHEP group:

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Project "`CalcPHEP`: Calculus for Precision High Energy Physics"

OUTLINE

1. CalcPHEP group and a little bit of history
2. LEP, Precision High Energy Physics and its Future
3. Necessary notion
4. Present Status of the project
5. Branch projects: **`topfit`** and others
6. Plans for nearest two and five years, milestones

1. CalcPHEP group in Sector N^{o}1 NEOFVP LJAP:

- D. Bardin, Dr., project-leader
- L. Kalinovskaya, PhD, deputy-leader, physicists
- P. Christova, PhD, physicists
- A. Andonov, PhD student, computer physicists
- S. Bondarenko, PhD, computer physicists
- G. Nanava, PhD student, physicists
- G. Passarino, Professor, consultant (Torino University)

- `CalcPHEP` – site `brg.jinr.ru` – development in two strategic directions:
  1. creation of a softwear product, capabable to compute pseudo- and realistic observables with one-loop precision for more and more 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 LC.

Aim of this talk:

Next in a series of talks aimed at information of wide scientific community about existence and main goals of the Project.

1. A little bit of history

Two historical sources of `CalcPHEP`:

1. Many codes aimed at a theoretical support of HEP experiments in the past:
    - **1975 – 1986:** Together with A. Akhundov and N. Shumeiko — BCDMS, EMC and NMC, program **`TERAD`**.
    - Together with V. Dokuchaeva — CHARM-I, CDHSW and CHARM-II, programs **`NUDIS2, INVMUD, NUFITTER`**.
    - **1983 – 1989:** The DZRCG – "Dubna–Zeuthen Radiative Correction Group", DB, P. Christova, T. Riemann, S. Riemann, M. Sachwitz, H. Vogt, creation of EW-library **`DIZET`**; together with M. Bilenky, A Chizhov and A. Sazonov, creation of program **`ZBIZON`** – fore-runner of **`ZFITTER`**
    - **1989 – 1997:** Together with A. Akhundov, A. Arbuzov, C. Burdik, J. Blümlein, P. Christova, L. Kalinovskaya T. Riemann – experiments at HERA, program **`HECTOR`**.
    - Together with L. Kalinovskaya – SMC, prorgam $\mu \mathbf{e} la$.
    - **1989 – 2001:** Theoretical support of experiments at LEP, SLC (DELPHI, L3, ALEPH, OPAL and SLD).
2. Together with G. Passarino: "The Standard Model in the Making", OUP 1999. Book-support with $\sim n\cdot 100$ form-codes.

Like `ZFITTER`, `CalcPHEP` is meant as a tool for precision calculations of pseudo- and reasistic observables.

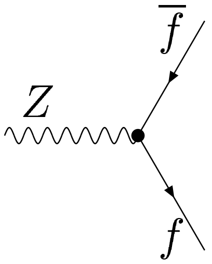
Definition 1 *Realistic Observables — the (differential) cross-sections (more general event distributions) for a reaction, e.g.*

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

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 — 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. they have to be *defined*. At the Born level, we define it as a quantity described by the square one diagram:



2. LEP, Precision High Energy Physics and its Future

- **1989 – 1995** Z resonance:
  - 150 pb^{-1} delivered to each experiment;
  - ~ 17 Z events;
  - unprecedented experimental accuracy $\leq 10^{-3}$.
- **1995 – 2000** work above Z resonance:
  - ≥ 750 pb^{-1} delivered to each experiment;
  - even at high energies accuracy $\leq 1\%$.
- 2/11/2000: the end †

Challenge for theoreticians — to perform calculations with theoretical uncertainty better than experimental errors!

- Efforts of many groups of theoreticians eventually 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 the 12 year LEP-era, which laid the foundation of the Precision High Energy Physics, PHEP.

Future of PHEP

Several Input parameters of the SM need to be improved

- Improvement of the contribution of $\Delta\alpha_h^{(5)}\left(M_Z^2\right)$ to the running e.m. coupling $\alpha(s)$.
  - BES-II, BEPC (Beijing), VEPP2000 (Novossibirsk) $\sigma\left(e^+e^- \to \text{hadrons}\right)$ at cms energies (1-4 GeV);
  - DAFNE – at cms energies around ϕ-meson;
  - muon amm:

$$
\begin{aligned}
a_\mu^{SM} &= a_\mu^{QED} + a_\mu^{Had} + a_\mu^{EW} \\
a_\mu^{QED} &= 116584705.7(2.9) \times 10^{-11} \\
a_\mu^{Had} &= 6739(67) \times 10^{-11} \textit{Davier\&Höcker,1998} \\
a_\mu^{Had} &= 6803(114) \times 10^{-11} \textit{Jegerlerhner, 2000} \\
a_\mu^{EW}(1-loop) &= 195 \times 10^{-11} \\
a_\mu^{EW}(2-loop) &= -43(5) \times 10^{-11} \\
a_\mu^{SM} &= 116591661(114) \times 10^{-11} \\
a_\mu^{EXP}(Average) &= 116592023(151) \\
a_\mu^{EXP} - a_\mu^{SM} &= 362(189) \quad 2\sigma \text{ difference}
\end{aligned}
$$

Exp. error (151) should be improved soon up to $\sim$ (50).

- Improvememt of mass measurements: M_W, m_t:
  - LEP1 indirect – $m_t = 169^{+10}_{-8}$ GeV;
  - LEP1 $\oplus$ TEVATRON constraint – $m_t = 174.5^{+4.4}_{-4.2}$ GeV;
  - LEP2 reached for M_W:

    direct – $M_W = 80.446 \pm 0.040$,

    indirect – $M_W = 80.368 \pm 0.023$;
  - TEVATRON, RUN-I has reached:

    $M_W = 80.452 \pm 0.062$ GeV, $m_t = 174.3 \pm 5.1$ GeV;
  - TEVATRON, RUN-II (recently started) should reach:

    $\Delta M_W \sim 20$MeV, $\Delta m_t \sim 2$ GeV;
  - LHC, like TEVATRON, will be W and t factory;

    however, not so soon ($> 2006?$);

    $\Delta M_W \sim 15$ MeV, $\Delta m_t \sim 1$ GeV;
- Where, when and with which mass Higgs boson might be discovered?
  - TEVATRON has a serious chance up to mass 180 GeV;

    however it will require very high $\int \mathcal{L} \geq 5 fb^{-1}$;
  - LHC, will cover all allowed mass range up to 500 GeV

    (not soon $> 2007?$);

- Electron Linear Colliders: TESLA (DESY) with GigaZ option, i.e. back to Z resonans with statistics 10^9 ($>$ 2011?); CLIC (CERN); JLC (KEK), NLC(SLAC, LNBL, LLNL, FNAL) all that in ten years or more...
  - $\Delta \sin^2 \theta_{eff} \sim 0.00002$
  - $\Delta M_W \sim 6$ MeV, $\Delta m_t \sim 100 - 200$MeV
  - $\Delta M_H \sim 100$ MeV (from $e^+e^- \to ZH$)
  - Detail study of Higgs boson properties;

  2-loop precision level control seems to be absolutely necessary!

- Muon Storage Rings (Higgs Factory):
  - Direct, single-resonance Higgs production!
  - Many advantages over electron LC.

All future colliders – TEVATRON, LHC, electron Linacs (TESLA, NLC, CLIC) and muon factories are, actually, PHEP facilities! They will require a qualitatively new level of both theoretical predictions and principally new computer codes.

A window till 2005 at least. How to use it best?
Try to answer this question within `CalcPHEP` ***project.***

3. Necessary notion, I) Input Parameter Set, IPS

MSM contains big number of Input Parameters

$\longrightarrow 25 =$ 2 interaction constants α and α_S

8 mixing angles (CKM and possible lepton analogs)

15 masses = 12 of fundamental fermions and Z, W, H.

However, the number 25 is *mininal.*

MSM is **unable** to compute its IPS from first principles;

MSM is **able** to compupe *any observable* $O_i^{\rm exp}$ in terms of its IPS:

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

Precision measurements set *constraints* on IPS.

Number of free parameters in fits of Z resonance observables.

Standard LEP1 IPS, 5 parameters:

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

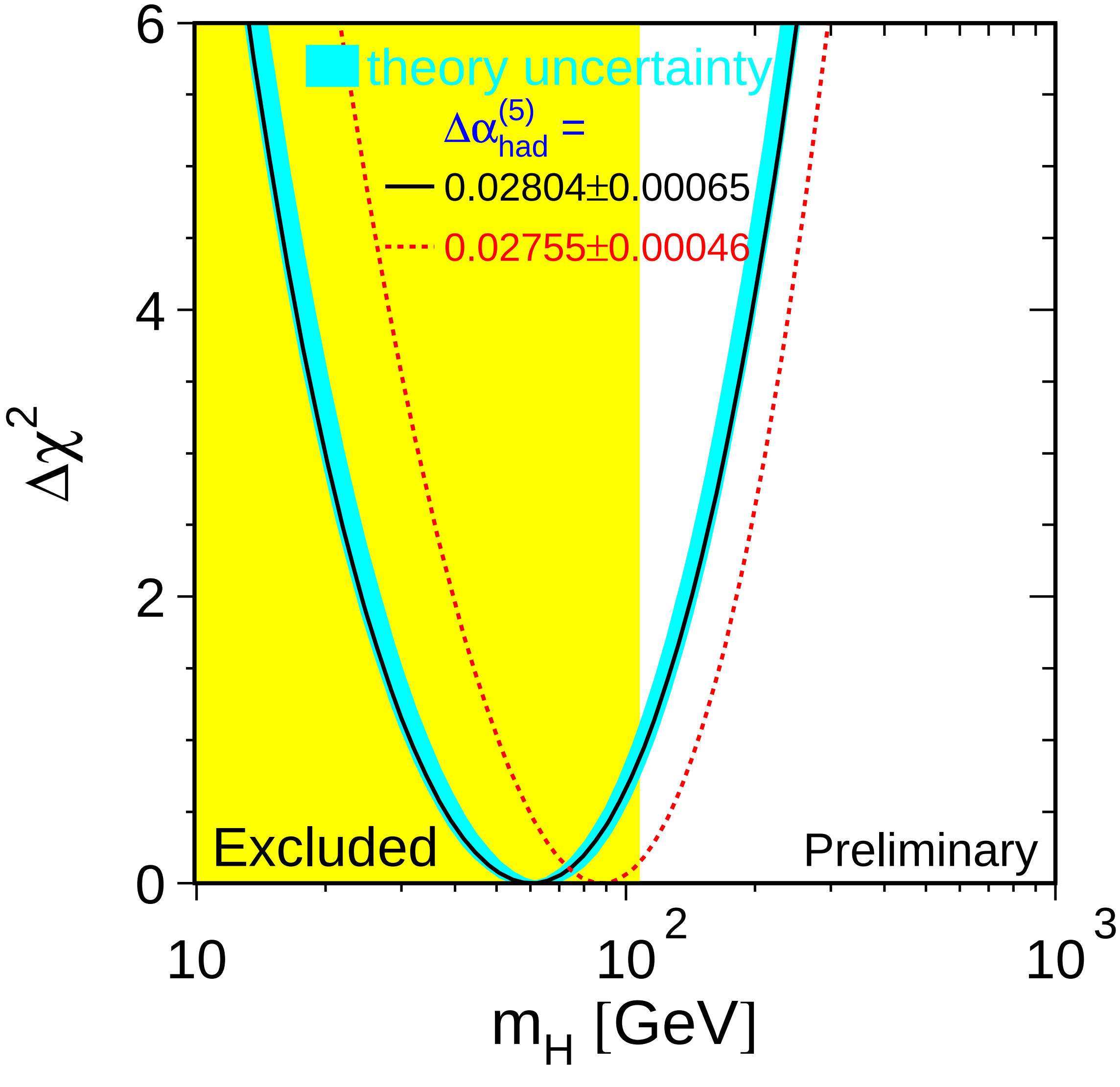
Using M_Z, measured at Z peak itself with the precision $\sim 2\times 10^{-5}$,

and also reach information from the other measurements for:

$$\alpha_S\left(M_Z^2\right), \qquad m_t\,, \qquad M_W$$

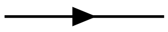
we *approach* one-parameter fit, with Higgs boson mass M_H being the only fitted parameter, *Blue band.*

The Blue Band: ZFITTER and TOPAZ0



3. Necessary notion, II) Quantum Fields of the SM

Three generation of fermions or matter fields:

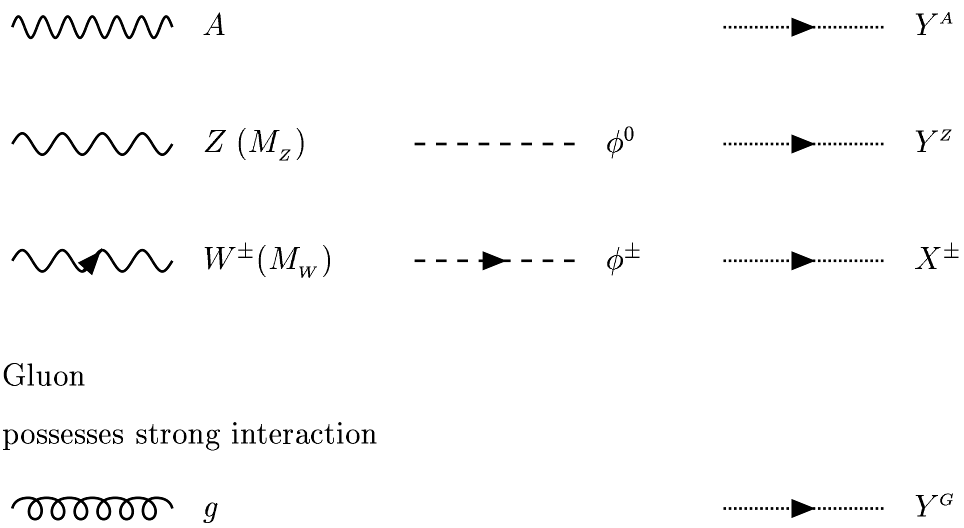


$$f = \begin{cases} \begin{pmatrix} \nu \\ l \end{pmatrix} = \begin{pmatrix} \nu_e \\ e^- \end{pmatrix} \quad \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix} \quad \begin{pmatrix} \nu_\tau \\ \tau \end{pmatrix} \\ \\ \begin{pmatrix} U \\ D \end{pmatrix} = \begin{pmatrix} u \\ d \end{pmatrix} \quad \begin{pmatrix}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

possess masses, m_f, charges, Q_f (in units of positron charge), 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.

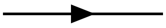
Higgs field:

$H\ (M_H)$ scalar, neutral, massive.

Notion, III) The Lagrangian in R_ξ gauge, Feynman Rules

$$\mathcal{L} = \mathcal{L}(\text{IPS of 25 parameters, fields, } \xi_A,\ \xi_Z,\ \xi)$$

the propagator of a fermion, f:



f

$$\frac{-i\not{p} + m_f}{p^2 + m_f^2}$$

vector boson propagators:

A

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

Z

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

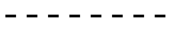
$W^\pm$

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

propagators of unphysical fields:

Y^A

$$\frac{\xi_A}{p^2}$$



ϕ^0

$$\frac{1}{p^2 + \xi_Z^2 M_Z^2},$$

Y^Z

$$\frac{\xi_Z}{p^2 + \xi_Z^2 M_Z^2}$$

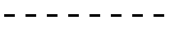
$\phi^\pm$

$$\frac{1}{p^2 + \xi^2 M_W^2},$$

$X^\pm$

$$\frac{\xi}{p^2 + \xi^2 M_W^2}$$

propagator of the physical scalar field, H-boson is

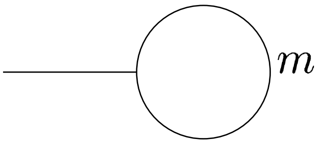


H

$$\frac{1}{p^2 + M_H^2}$$

3. Necessary notion, IV) Passarino–Veltman Functions

One-point integrals, A-functions

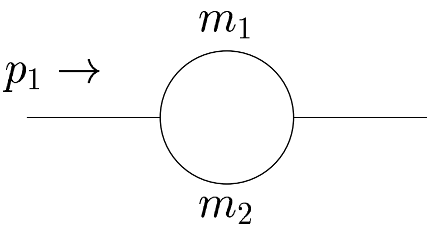


$$i\pi^2\, A_0\,(m) = \mu^{4-n} \int d^n q\, \frac{1}{q^2 + m^2 - i\epsilon}$$

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

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

Two-point integrals, B-functions



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

$$d_0 = q^2 + m_1^2 - i\epsilon, \qquad d_1 = (q + p_1)^2 + m_2^2 - i\epsilon$$

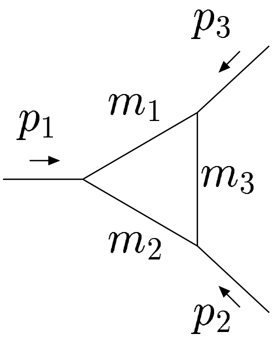
$$B_0\left(p_1^2; m_1, m_2\right) = \frac{1}{\bar{\varepsilon}} - R - \ln \frac{m_1 m_2}{\mu^2} + \frac{m_1^2 - m_2^2}{2 p_1^2} \ln \frac{m_1^2}{m_2^2} + 2$$

$$R = -\frac{\Lambda}{p_1^2} \ln \frac{p_1^2 - i\epsilon + m_1^2 + m_2^2 - \Lambda}{2\, m_1 m_2}$$

$\Lambda^2 = \lambda\left(-p_1^2, m_1^2, m_2^2\right)$

$\lambda\,(x, y, z) = x^2 + y^2 + z^2 - 2xy - 2xz - 2yz$

Three-point integrals, C-functions



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

$$\begin{aligned} d_0 &= q^2 + m_1^2 - i\epsilon, \\ d_1 &= (q+p_1)^2 + m_2^2 - i\epsilon \\ d_2 &= (q+p_1+p_2)^2 + m_3^2 - i\epsilon \end{aligned}$$

$Q^2 = (p_1+p_2)^2$ is one of the Mandelstam variables, $-s, t$ or u.

$$C_0\left(p_1^2, p_2^2, Q^2; m_1, m_2, m_3\right) =$$

$$= \int_0^1 dx \int_0^x dy \left(ax^2 + by^2 + cxy + dx + ey + f\right)^{-1}$$

$$\begin{aligned} a &= -p_2^2, \qquad b = -p_1^2 \\ c &= p_1^2 + p_2^2 - Q^2, \qquad d = p_2^2 + m_2^2 - m_3^2 \\ e &= -p_2^2 + Q^2 + m_1^2 - m_2^2, \qquad f = m_3^2 - i\epsilon \end{aligned}$$

Four-point integrals, D-functions, etc

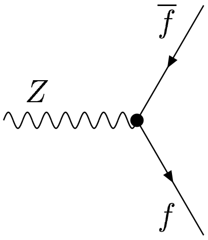
Presently, `CalcPHEP` knows ALL up to third rank tensorial reduction of up to four-point PV-functions and the so-called *special* PV-functions, which are due to special form of photonic propagator in R_ξ gauge.

3. Necessary notion, V) Processes in the SM

- decays $1 \to 2$:
  - $H \to f\overline{f}$ one structures
  - $Z \to f\overline{f}$, $(\gamma \to f\overline{f})$ three structures
  - $W \to f\bar{f}'$, $(t \to W^+b)$ four structures
  - $H \to ZZ,\ W^+W^-$
  - $Z \to W^+W^-$
- processes $2 \to 2$:
  - processes $2f \to 2f$
    - NC: $f\overline{f} \to (\gamma, Z, H) \to f'\overline{f'}$ (4,6) 9 structures
    - CC: $f_1\overline{f}_2 \to (W) \to f_3\overline{f}_4$
  - processes $Vf \to f'V'$
    - Compton-effect: $\gamma e \to \gamma e,\ \ Z \to f\overline{f}\gamma$
    - $e^+e^- \to W^+W^-,\ ZZ,\ Z\gamma, \gamma\gamma$
- decays $1 \to 3$ cross-channels of the previous ones
- processes $2 \to 3$
  - $e^+e^- \to (\gamma, Z, H) \to f\overline{f}\gamma$ and very many others!
- decays $1 \to 4$ cross-channels of the previous ones

3. Necessary notion, VI) Building Blocks, BB

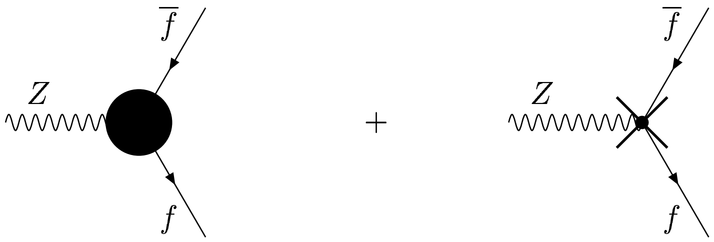
Simplest decay: $Z \to f\overline{f}$



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

Vector, axial coupling constants: $v_f = I_f^{(3)} - 2Q_f s_W^2\,, \quad a_f = I_f^{(3)}$

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

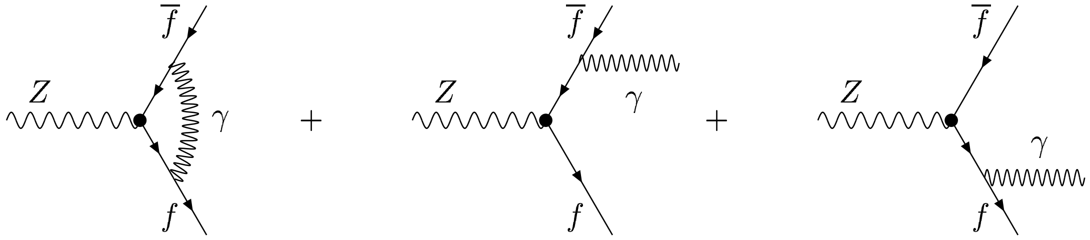


Scalar form factors of one-loop amplitude:

$$V_\mu^{Zf\overline{f}} = (2\pi)^4\, i\, \frac{ig^3}{16\,\pi^2\, 2\, c_W}\, \gamma_\mu \left[I_f^{(3)} F_L \gamma_+ - 2Q_f s_W^2 F_Q \right]$$

Improved Born Approximation – IBA.

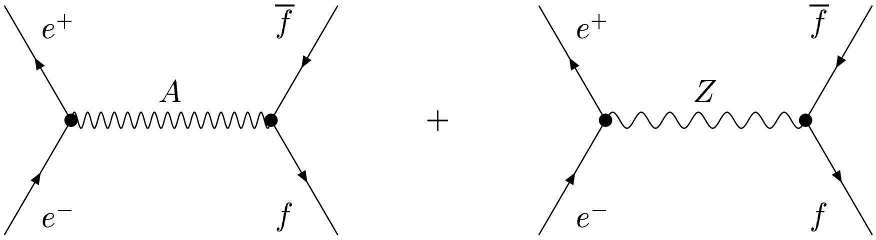
QED diagrams and corrections



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

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

The two tree-level diagrams with γ and Z exchanges:



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

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

$$
\gamma_\mu\left(v_1 + a_1\gamma_5\right) \otimes \gamma_\nu\left(v_2 + a_2\gamma_5\right) =
$$

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

$$
\chi_Z(s) = \frac{1}{s - M_Z^2 + is\Gamma_Z/M_Z}
$$

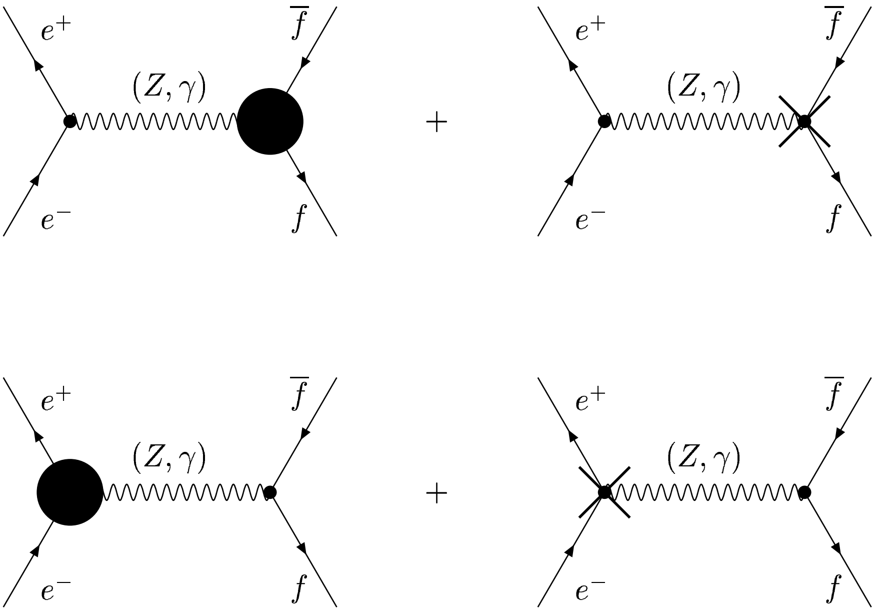
Four structures (massless case):

$$
LL = \gamma_\mu\gamma_+ \otimes \gamma_\mu\gamma_+\,, \qquad LQ = \gamma_\mu\gamma_+ \otimes \gamma_\mu
$$

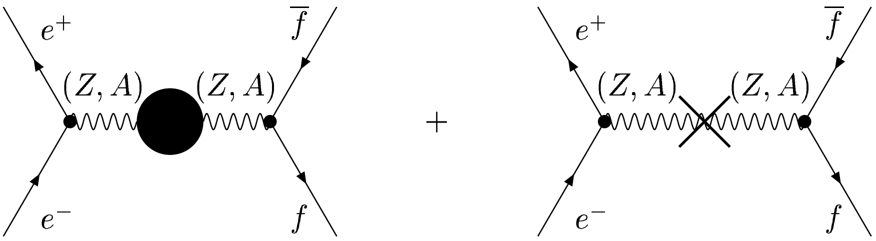
$$
QL = \gamma_\mu \otimes \gamma_\mu\gamma_+\,, \qquad QQ = \gamma_\mu \otimes \gamma_\mu
$$

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

“Dressed” with EWRC γ and Z exchanges may be symbolically depicted as:



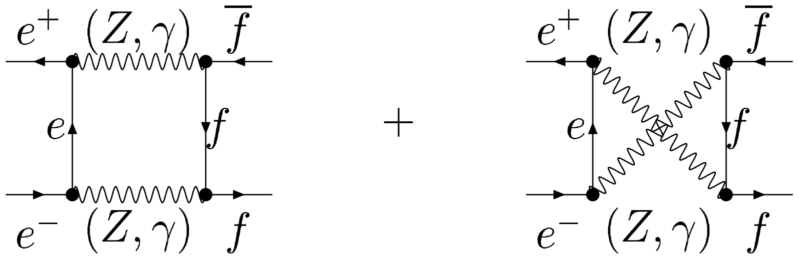
Process $e^+e^- \to (Z,A) \to f\overline{f}$; vertices and counterterms



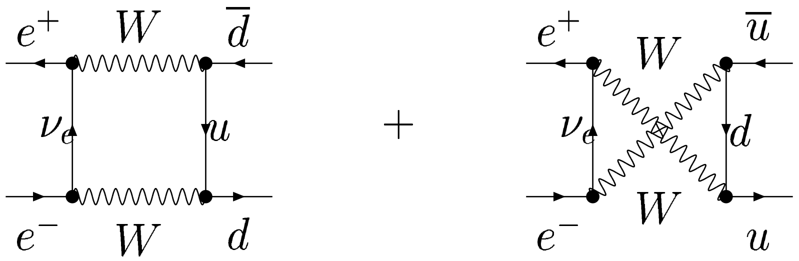
“Dressing” of propagators

Towards realistic observables in $e^+e^- \to f\overline{f}$

Gauge invariant subset of QED diagrams in this case consist of QED vertices and $\gamma\gamma$ and $Z\gamma$ boxes:

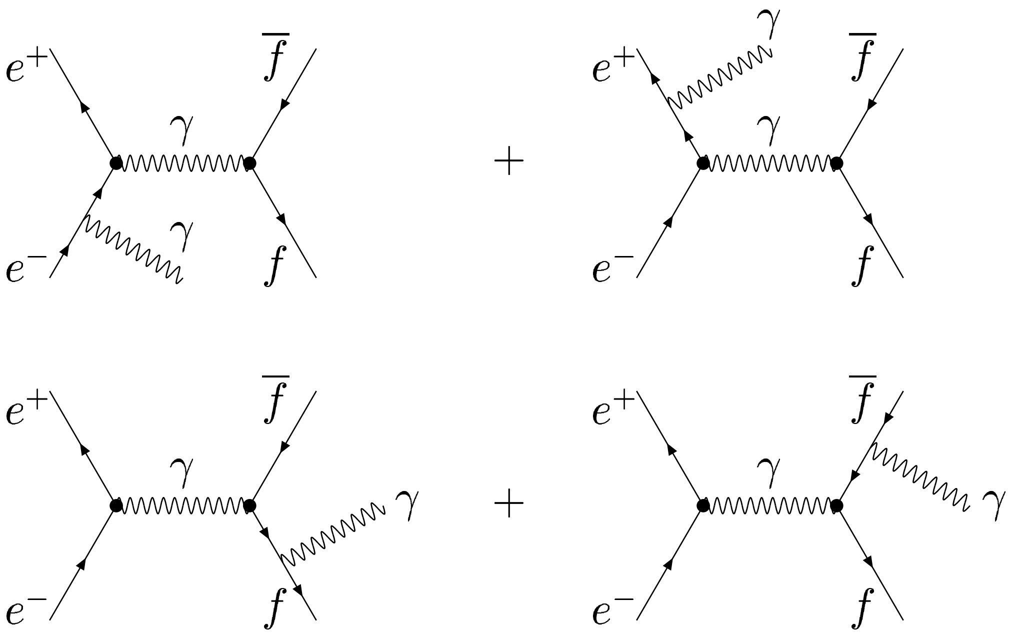


$\gamma\gamma$-, $Z\gamma$-, ZZ-boxes



WW-boxes

Virtual QED one-loop diagrams should be considered together with four QED bremsstrahlung diagrams which form an Infra-Red Divergency free subset:



4. Present Status of the project

Basic information about `CalcPHEP`

- 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.
  - **Internet based;**
  - **Database based,** i.e. a storage of source codes written in several languages, which talk to each other, placed into a homogenious environment written in JAVA;
  - **Intermediate access,** i.e. full chain "from the Lagrangian to realistic distribution" should work out in real time, however, it is supposed to have several "entries", say after each level, or just for accessing its final product.
- Four levels:
  1. From $\mathcal{L}_{SM}$ to the Ultra Violet Free Amplitudes, UVFA (FORM3);
  2. from UVFA to a minimal subset of Helicity Amplitudes, HA (FORM3→ C^{++}, `FORTRAN`);
  3. "infrared rearrangement" of HA → IRRHA;
  4. from IRRHA to realistic distributions (Monte Carlo event generators, C^{++}, `FORTRAN`).

- **Collaboration based**, already supported:
  - HLP – with DESY–Zeuthen (T. Riemann, within `topfit` branch of the project);
  - INTAS – with Universities of Karlsrue (W.Hollik) and Torino (G. Passarino);
  - NATO – with Knoxville–Kracow collaboration (S. Jadach and B. Ward).
  - Collaboration with theorists of INR and IHEP is foreseen.
- Present status:
  - **v0.01** – realises analytic calculations of one-loop UVFA for decays 1 → 2 (level-1);
  - **v0.02** – returns numbers for one-loop decay widths (a temporary bypass of levels 2-4). To be released in July.
  - one has very many almost finished “preparations” for processes 2 → 2 and decays 1 → 3 (one-loop, level 1).

Publications:

[1] D. Bardin and L. Kalinovskaya and G. Nanava, ”An electroweak library for the calculation of EWRC to $e^+e^- \to f\bar{f}$ within the topfit project”, `hep-ph/0012080`.

[2] D. Yu. Bardin and L. V. Kalinovskaya and F. V. Tkachov, ”New algebraic-numeric methods for loop integrals: Some 1-loop experience”, `hep-ph/0012209`, to be published in Tver’2000 Proceedings.

[3] Dmitri Bardin, ”12 years of precision calculations for LEP. What’s next?”, `hep-ph/0101295`, to be published in Sirlin’s Symposium Proceedings.

[4] D. Bardin, P. Christova, L. Kalinovskaya and G. Passarino, “Atomic Parity Violation and Precision Physics”, `hep-ph/0102233`, submitted to EPJC.

Some technical data about `CalcPHEP`

- address *http://brg.jinr.ru/*
- for realization of the site one used:
  - Apache web server under Linux;
  - FORM3 compiler (because the "heritage" was in FORM);
  - mySQL server for relational databases (because of simplicity of syntaxis, reliability and high speed);
- In the current version, user-interface is realized with the use of PHP (hypertext preprocessor);
- 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 homogeniuos environment both for accessing our codes from the database and for offering a possibility for simultaneuos work of several members of the group and external users.

Basis problems to be solved in the second phase

- Automatic generation of Feynman Rules from a Lagrangian;
- Automatic generation of topologies of Feynman diagrams;
- Numerics in very general sence;
- Graphical representation of results.

5. Branch projects: `topfit` and others

6. Plans for nearest two and five years, milestones

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.

Giampiero Passarino,
“Precision Physics Near LEP Shutdown and Evolutionary Developments”
Talk presented at
50 Years of Electroweak Physics
A symposium in honor of Professor
Alberto Sirlin’s 70th Birthday
October 27-28, 2000

5 years – minimum for project of such a kind

`ZFITTER` – *12 years (25 years, together with a preparational period)*

Plans for **two** years, including milestones, are thoroughly elaborated in connection with application for: INTAS, NATO, CRDF. Upon completion of the second phase of the project 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 for two years assume *R&D* for the third phase of the project with duration 3 years (with emphasis to two-loop, however, 1-loop period, most likely, will not be completed in two years).

Program and milestones of the first year

Basically oriented on a common work of theoreticians of the Dubna group and the Knoxville–Krakow collaboration – both known very well in the field of theoretical support of various experiments in HEP, particularly at LEP and SLAC.

United group proposes to realize in 2001-2003 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].

Milestones of first year:

1. realization of the levels 2-4 for the simplest $Z(H,W) \to f\bar{f}$ decays (first level in this case is already accessed);
2. completion of level 1 for the radiative Z decay,
$$Z \to f\bar{f}\gamma,$$
work which is already under way;
3. completion of levels 2-4 for the radiative Z decay.

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[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.