Sonderforschungsbereich/Transregio 9 of DFG
"Advances in Computational Particle Physics"

Project Group B "Predictions for High Energy Reactions"

Project B1 "Precision Predictions for Massive Particle Production (20011-14)"

Project Leaders

Johannes Blümlein (2003-2010)
Fred Jegerlehner (2003-2006)
Tord Riemann (2003-2014) **2011-2014: this talk**
Sven-Olaf Moch (2007-2014) **2011-14: see talk by M. Dowling**
Michal Czakon (2011-14) **see talk by M. Czakon**

T. Riemann, Talk at Final Meeting

https://indico.desy.de/conferenceDisplay.py?confId=10306

Publications 2011-2014

2014:

SFB/CPP 14-048 "Summary of the ACAT Round Table Discussion: Open-source, knowledge sharing and scientific collaboration" [1, 2]
SFB/CPP 14-046 "The ZFITTER project" [3]
SFB/CPP 14-042 "Non-planar Feynman integrals, Mellin-Barnes representations, multiple sums" [4]

2013:

SFB/CPP 13-108 "Complete QED NLO contributions to the reaction $e^+e^- \to \mu^+\mu^-\gamma$ and their implementation in the event generator PHOKHARA" [5]
SFB/CPP 14-044 "Some Remarks on Non-planar Feynman Diagrams" [6]
SFB/CPP 14-045 "Reductions and Contractions of 1-loop Tensor Feynman Integrals" [7]

2012

SFB/CPP 14-072 "Theoretical Improvements for Luminosity Monitoring at Low Energies" [8]
SFB/CPP 14-049 "New developments in PJFry" [9]
SFB/CPP 14-047 "Efficient contraction of 1-loop N-point tensor integrals" [10]

2011

SFB/CPP 11-076 "One-Loop Tensor Feynman Integral Reduction with Signed Minors" [11]
SFB/CPP 11-069 "A solution for tensor reduction of one-loop N-point functions with $N \geq 6$ [12]
SFB/CPP 11-066 "Simplifying 5-point tensor reduction" [13]
SFB/CPP 11-026 "NNLO leptonic and hadronic corrections to Bhabha scattering and luminosity monitoring at meson factories" [14]
SFB/CPP 11-025 "Calculating contracted tensor Feynman integrals" [15]

Outline of projects since 2011 I

1. Introduction
2. AMBRE and applications
3. PJFry, OLEC and applications
4. ZFITTER, TOPFIT, MUFIT and applications
5. Dissemination of scientific results - software aspects
6. Conclusions
7. References
8. Backup

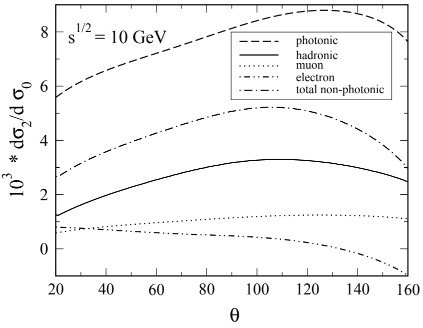
AMBRE, 2-loop Bhabha Scattering and Electroweak Physics

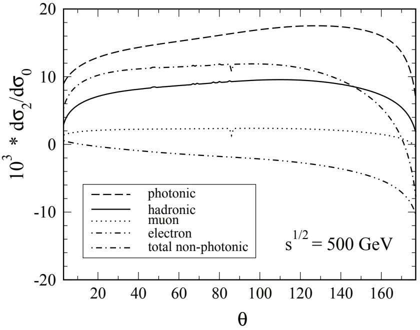
- AMBRE
  is a Mathematica software tool for the representation of L-loop, n-point, rank R Feynman integrals by Mellin-Barnes representations
- Applications
  – By many collegues for their research
  Our group: NNLO massive multi-scale corrections to the Bhabha cross-section
  – At a Linear Collider
  – And at meson factories (BabaYaga)
  Work in progress
  Our group: Massive electroweak 2-loop corrections
- Publications in 2011 - 2014
  SFB/CPP 14-042,14-044,11-026 [4, 6, 14]

SFB papers related to AMBRE, 2003-2010

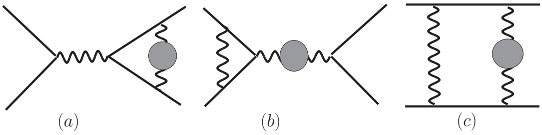
SFB/CPP-07-14 Author: J. Gluza, K. Kajda, T. Riemann Title: *AMBRE - a Mathematica package for the construction of Mellin-Barnes representations for Feynman integrals* **Comput. Phys. Commun. [16]**
SFB/CPP-07-39 Author: J. Gluza, F. Haas, K. Kajda, T. Riemann Title: Automatic derivation of Mellin-Barnes representations for Feynman integrals
ACAT2007 PoS [17]
SFB/CPP-07-69 Author: J. Fleischer, J. Gluza, K. Kajda, T. Riemann Title: PENTAGON DIAGRAMS OF BHABHA SCATTERING APP [18]
SFB/CPP-07-70 Author: S. Actis, M. Czakon, J. Gluza, T. Riemann Title: FERMIONIC NNLO CONTRIBUTIONS TO BHABHA SCATTERING APP [19]
SFB/CPP-07-15 Author: S. Actis, M. Czakon, J. Gluza, T. Riemann Title: Two-Loop Fermionic Corrections to Massive Bhabha Scattering NPB [20]
SFB/CPP-07-86 Author: J. Gluza and T. Riemann Title: New results for 5-point functions LCWS [21]
SFB/CPP-06-17 Author: M. Czakon, J. Gluza, T. Riemann Title: *The planar four-point master integrals for massive two-loop Bhabha scattering* **Nucl. Phys. B [22]**
SFB/CPP-08-93 Author: Stefano Actis, Michal Czakon, Janusz Gluza, Tord Riemann Title: *Virtual Hadronic and Heavy-Fermion $O(alpha^2)$ Corrections to Bhabha Scattering* **Phys. Rev. Lett. [23]**
SFB/CPP-09-53 Author: S. Actis, A. Arbuzov, G. Balossini, C. Bignamini, R. Bonciani, C.M. Carloni Calame, M. Czakon, H. Czyz, A. Denig, A. Ferroglia, J. Gluza, A. Hafner, P. Mastrolia, G. Montagna, F. Nguyen, O. Nicrosini, A. Penin, F. Piccinini, E. Remiddi, T. Riemann, A. Sibidanov, L. Trentadue, J. J. van der Bij, P. Wang, and M. Worek Title: Quest for understanding hadrons at low energies: Monte Carlo tools vs. experimental data. Section: Luminosity EPJC [24]

Figures 2 and 3 from SFB/CPP-07-81 PRL [23]





The massive corrections (with scales s, t, m_e, m_{heavy}) or with hadronic insertion amount to few per mil.



Some definitions

L–loop n–point functions

Consider an arbitrary L–loop integral $G(X)$ with loop momenta k_l , with E external legs with momenta p_e and with N internal lines with masses m_i and propagators $1/D_i$

L–loop n–point function

$$G(X) = \frac{1}{(i\pi^{d/2})^L} \int \frac{d^d k_1 \ldots d^d k_L \, X(k_1, \ldots, k_L)}{D_1^{n_1} \ldots D_i^{n_i} \ldots D_N^{n_N}}$$

$$d = 4 - 2\epsilon$$

$$D_i = q_i^2 - m_i^2 = \left[\sum_{l=1}^{L} c_i^l k_l + \sum_{e=1}^{M} d_i^e p_e \right] - m_i^2$$

$X(k_1, \ldots, k_L)$ stands for tensors in the loop momenta.

Feynman parameter representation

$$\frac{1}{D_1^{n_1} D_2^{n_2} \ldots D_N^{n_N}} = \frac{\Gamma(n_1 + \ldots + n_N)}{\Gamma(n_1) \ldots \Gamma(n_N)} \int_0^1 dx_1 \ldots \int_0^1 dx_N \frac{x_1^{n_1-1} \ldots x_N^{n_N-1} \delta(1 - x_1 - \ldots - x_m)}{(x_1 D_1 + \ldots + x_N D_N)^{N_\nu}}$$

$N_\nu = n_1 + \ldots + n_N$

Starting point of AMBRE

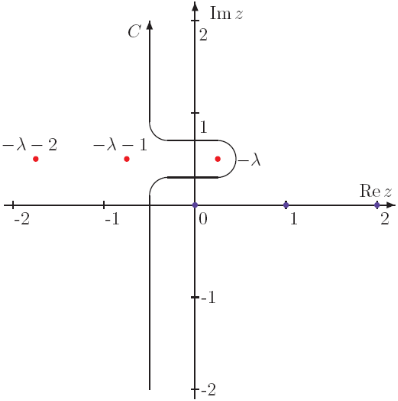
After performing the momentum integrations, the x-parameters are left

$$G(X) = \frac{(-1)^{N_\nu}\Gamma\left(N_\nu - \frac{d}{2}L\right)}{\prod_{i=1}^{N}\Gamma(n_i)} \int \prod_{j=1}^{N} dx_j\, x_j^{n_j-1}\delta(1-\sum_{i=1}^{N} x_i)\frac{U(x)^{N_\nu - d(L+1)/2}}{F(x)^{N_\nu - dL/2}}$$

The functions U and F are called graph or Symanzik polynomials.

The Mellin-Barnes relation (not shown) can be multiply applied to polynomials U and F

$$\frac{1}{(A_1+\ldots+A_n)^\lambda} = \frac{1}{\Gamma(\lambda)}\frac{1}{(2\pi i)^{n-1}}\int_{-i\infty}^{i\infty} dz_1\ldots dz_{n-1}$$
$$\times \prod_{i=1}^{n-1} A_i^{z_i}\, A_n^{-\lambda-z_1-\ldots-z_{n-1}} \prod_{i=1}^{n-1}\Gamma(-z_i)\,\Gamma(\lambda+z_1+\ldots+z_{n-1})$$



The integration paths in the multi-dimensional complex domain have to be chosen properly and to be closed to the left or to the right at infinity.

J. Gluza and T. Riemann, *Simple Feynman diagrams and simple sums*, RISC-DESY Meeting, May 2012, Linz [25]

$\longrightarrow$

It would be wonderful to have an algorithm for automatic analytical evaluation of all the scalar (and tensor) integrals by infinite multiple sums!

For not too involved classes of functions, typical of massless problems, see the packages:
– Summer, at http://www.nikhef.nl/ t68/
– XSUMMER [26].

We are exploring the potential of using the package SIGMA (Carsten Schneider, Linz) [27, 28].

For automation we have to ...

1. Know about topology – planarity or non-planarity see hep-ph/1312.5603, [6]
2. Construct MB representations New: non-planar case (I. Dubovyk et al.)
3. Change them into nested sums MBsums package (M. Ochman et al., unpubl., see talk at LL2014)
4. Try to perform the multiple sums analytically
   see talks at LL2014 by J. Gluza (LL2014_052.pdf, [4]) and C. Raab (LL2014_020.pdf, [29])
5. Accept Minkowskian kinematics

Certainly, there are limitations:

- Number of loops: One-loop, two-loop,...?
- Number of scales: Massive, off-shell?
- Number of legs: 2-,3-,.... point functions?
- ... and the complexity, e.g. due to non-planarity

PJFry, OLEC and $\mu^+\mu^-\gamma$ production at a Linear Collider and meson factories

- PJFry and OLEC
  - Are C++ software tools
  - Result of long-term theoretical research
  - For the calculation of 1-loop, n-point, rank R Feynman integrals
  - With a stable handling of small inverse Gram determinants.
- LHC studies - Use by third parties
- PHOKHARA and BabaYaga@NLO - Update of the Fortran codes by new higher order contributions
- SFB/CPP 14-049,066,069,076 [9, 13, 12, 11],
  SFB/CPP 14-025,045,047 [15, 7, 10],
  SFB/CPP 13-108 [5]
  SFB/CPP 14-072 [8]

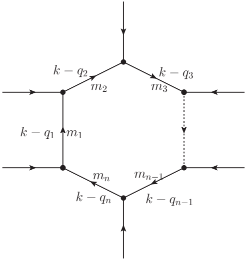
Definitions

n-point tensor integrals of rank R: (n,R)-integrals

$$I_n^{\mu_1\cdots\mu_R} = \int \frac{d^dk}{i\pi^{d/2}} \frac{\prod_{r=1}^{R} k^{\mu_r}}{\prod_{j=1}^{n} c_j^{\nu_j}},$$

$d = 4 - 2\epsilon$ and denominators c_j have *indices* ν_j and *chords* q_j

$$c_j = (k - q_j)^2 - m_j^2 + i\varepsilon$$



tensor integrals due to, e.g.:

- fermion propagators
- three-gauge boson couplings

Efficient reduction formulae in the algebraic Davydychev-Tarasov-Fleischer-Jegerlehner-TR approach

in d dimensions. .

- Get $n > 4$ tensor reduction with $\cdots$:
- $\cdots$ arbitrary masses
- **new:** $\cdots$ killed all inverse pentagon Gram determinants
- $\cdots$ treatment of full kinematics, also with small sub-diagram Gram determinants
- **new:** $\cdots$ multiple sums over tensor coefficients made efficient by **contracting with external momenta**

  Fleischer, TR [15] PLB 701(2011)646
- **new:** $\cdots$ higher n point functions, $n \geq 6$

  Fleischer, TR [12] PLB 707(2012)375

History of the Approach - not a complete list of references

[30] Melrose 1965: Reduction of Feynman diagrams and Cayley determinants

[31] Davydychev 1991: Integrals in different space-time dimension.

See also Bern et al. (1993) [32]

[33] Tarasov 1996: Dimensional recurrence relations

[34] Fleischer,Jegerlehner,Tarasov 2000: 1-loop reductons and signed minors.

[35] Binoth,Guillet,Heinrich,Pilon,Schubert, 2005: Algebraic/numerical formalism for one-loop multi-leg amplitudes

[36] Fleischer and T.Riemann (since 2007) 2011: Complete reduction of 1-loop tensors.

See also Diakonidis et al. [37]

[38] Yundin's package PJFry 2010; https://github.com/Vayu/PJFry.

See also Fleischer,TR,Yundin [39, 40]

[15] Fleischer and T.Riemann 2011: Contracted tensor Feynman integrals.

See also Diakonidis et al. [41]

[12] Fleischer and T.Riemann 2012: A solution for tensor reduction of one-loop n-point functions with $n \geq 6$

Tensor integrals expressed in terms of scalar integrals in higher dimensions $D = d + 2l \;=\; 4 - 2\epsilon,\; 6 - 2\epsilon, \cdots$ [Davydychev:1991] , also [Fleischer et al.:2000]

$n_{ij} = \nu_{ij} = 1 + \delta_{ij}, n_{ijk} = \nu_{ij}\nu_{ijk}, \nu_{ijk} = 1 + \delta_{ik} + \delta_{jk}$

$$
\begin{aligned}
I_n^{\mu} &= \int^d k^{\mu} \prod_{r=1}^{n} c_r^{-1} = -\sum_{i=1}^{n} q_i^{\mu}\, I_{n,i}^{[d+]} \\
I_n^{\mu\,\nu} &= \int^d k^{\mu}\, k^{\nu} \prod_{r=1}^{n} c_r^{-1} = \sum_{i,j=1}^{n} q_i^{\mu}\, q_j^{\nu}\, n_{ij}\, I_{n,ij}^{[d+]^2} - \frac{1}{2}\, g^{\mu\nu}\, I_n^{[d+]} \\
I_n^{\mu\,\nu\,\lambda} &= \int^d k^{\mu}\, k^{\nu}\, k^{\lambda} \prod_{r=1}^{n} c_r^{-1} = -\sum_{i,j,k=1}^{n} q_i^{\mu}\, q_j^{\nu}\, q_k^{\lambda}\, n_{ijk}\, I_{n,ijk}^{[d+]^3} + \frac{1}{2}\sum_{i=1}^{n} g^{[\mu\nu} q_i^{\lambda]} I_{n,i}^{[d+]^2} \\
I_n^{\mu\,\nu\,\lambda\,\rho} &= \int^d k^{\mu}\, k^{\nu}\, k^{\lambda}\, k^{\rho} \prod_{r=1}^{n} c_r^{-1} = \sum_{i,j,k,l=1}^{n} q_i^{\mu}\, q_j^{\nu}\, q_k^{\lambda}\, q_l^{\rho}\, n_{ijkl}\, I_{n,ijkl}^{[d+]^4} \\
&\quad - \frac{1}{2}\sum_{i,j=1}^{n} g^{[\mu\nu} q_i^{\lambda} q_j^{\rho]}\, n_{ij} I_{n,ij}^{[d+]^3} + \frac{1}{4} g^{[\mu\nu} g^{\lambda\rho]} I_n^{[d+]^2}
\end{aligned}
\tag{1}
$$

Dimensional shifts and recurrence relations for pentagons

Direct approach – just perform Tarasov's dimensional recurrences

Following [Tarasov:1996,Fleischer:1999 [33, 34]]
apply recurrence relations, relating scalar integrals of different dimensions, in order to get rid of the dimensionalities $[d+]^l = 4 - 2\epsilon + 2l$:

shift dimension + index:

$$\nu_j(\mathbf{j}^+ I_5^{[d+]}) = \frac{1}{(\text{Gram})_5}\left[-\binom{j}{0}_5 + \sum_{k=1}^{5}\binom{j}{k}_5 \mathbf{k}^-\right] I_5 \tag{2}$$

shift dimension:

$$(d - \sum_{i=1}^{5}\nu_i + 1) I_5^{[d+]} = \frac{1}{(\text{Gram})_5}\left[\binom{0}{0}_5 - \sum_{k=1}^{5}\binom{0}{k}_5 \mathbf{k}^-\right] I_5, \tag{3}$$

also:

$$\nu_j \mathbf{j}^+ I_5 = \frac{1}{\binom{0}{0}_5}\sum_{k=1}^{5}\binom{0j}{0k}_5\left[d - \sum_{i=1}^{5}\nu_i(\mathbf{k}^-\mathbf{i}^+ + 1)\right] I_5 \tag{4}$$

where the operators $\mathbf{i}^\pm, \mathbf{j}^\pm, \mathbf{k}^\pm$ act by shifting the indices ν_i, ν_j, ν_k by ± 1.

Example: Getting a 4-point function from a six-point function

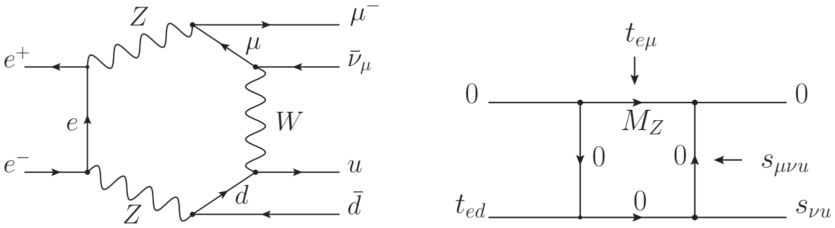


Figure 1 : A six-point topology (a) leading to four-point functions (b) with realistically vanishing Gram determinants.

Following Davydychev [31], one gets

$$I_4^{\mu\,\nu\,\lambda\,\rho} = \int^d k^\mu\, k^\nu\, k^\lambda\, k^\rho \prod_{r=1}^{4} c_r^{-1} = \sum_{i,j,k,l=1}^{n} q_i^\mu\, q_j^\nu\, q_k^\lambda\, q_l^\rho\, n_{ijkl}\, I_{4,ijkl}^{[d+]^4}$$
$$- \frac{1}{2} \sum_{i,j=1}^{4} g^{[\mu\nu} q_i^\lambda q_j^{\rho]}\, n_{ij} I_{4,ij}^{[d+]^3} + \frac{1}{4} g^{[\mu\nu} g^{\lambda\rho]} I_4^{[d+]^2} \quad (5)$$

We identify the tensor coefficients $D_{11\ldots}$ a la LoopTools, e.g.:

$$I_{4,222}^{[d+]^3} = D_{111} \quad (6)$$

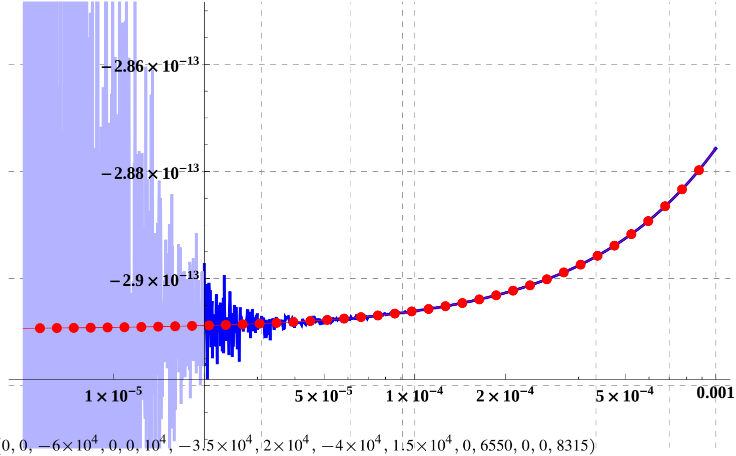
Similarly:

$$I_{4,2222}^{[d+]^4} = D_{1111} \quad (7)$$

PJFry — small Gram region example

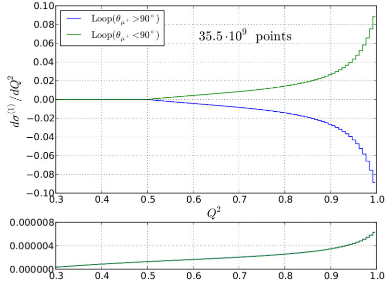
Example: E_{3333} coefficient in small Gram region $(x \to 0)$ [from V.Y. Valencia 2011 [42]]

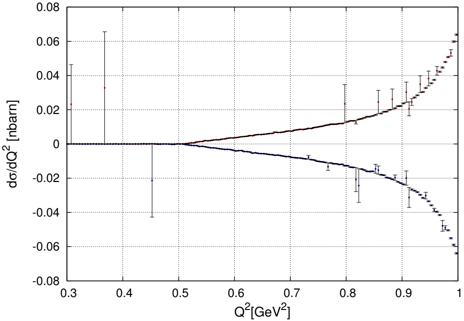
Comparison of Regular and Expansion formulae:



x=0: $E_{3333}(0, 0, -6\times10^4, 0, 0, 10^4, -3.5\times10^4, 2\times10^4, -4\times10^4, 1.5\times10^4, 0, 6550, 0, 0, 8315)$

PHOKHARA - NNLO terms from 5-point functions I





From [5]. On left: Muon pair distributions including 5-point functions at KLOE calculated with `PJFry` (bottom: absolute error estimate). On right: the same calculated without decicated routines to avoid small Gram determinants. Approximately $4 \cdot 10^{10}$ (10^9) events have been generated.

PHOKHARA - NNLO terms from 5-point functions II

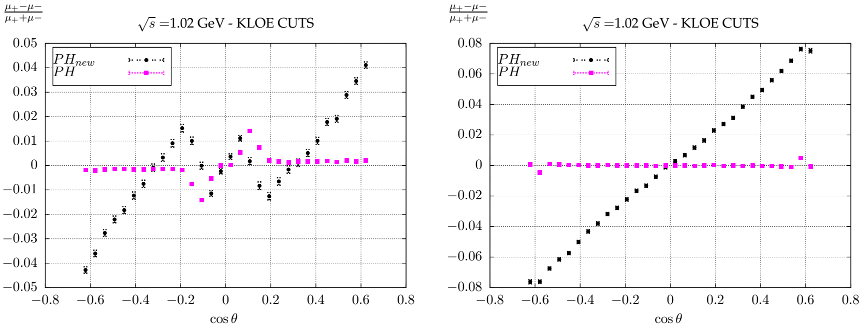


Figure 2 : The asymmetries given by PHOKHARA7.0 (denoted as PH) and PHOKHARA9.0 (denoted as PH_{new}). $q^2 \in (0.54, 0.55)$ - left plot; $q^2 \in (0.94, 0.95)$ - right plot.

ZFITTER, TOPFIT, MUFIT

- ZFITTER
  Since 1989 the unique Standard Model software for the Z resonance, Z boson mass measurement, predictions for top-quark and Higgs-boson masses from radiative corrections in the Standard Model
  Project documentation, support, development and description:
  SFB/CPP 14-046 [3], see also SFB/CPP-05-022 [43]
- TOPFIT
  Software for semi-analytic treatment of electroweak fermion pair production in e^+e^--annihilation
  - With exact mass handling
  - With hard QED bremsstrahlung
  SFB/CPP-03-02 and SFB/CPP-03-13 [44, 45])
- MUFIT
  Work in progress for the Belle II experiment, based on TOPFIT

ZFITTER

ZFITTER is the “etalon” software for the Z-boson resonce studied for many years at LEP 1 und at LEP 2.

Among main results of LEP are:

Review of Particle Properties, 2012 [46]

$$M_Z = 91.1876 \pm 0.0021 \;\; \mathrm{GeV}, \quad (8)$$

$$\Gamma_Z = 2.4952 \pm 0.0023 \;\; \mathrm{GeV}, \quad (9)$$

$$\sin^2\theta_{\mathrm{weak}} = 0.22296 \pm 0.00028, \quad (10)$$

$$\sin^2\theta_{\mathrm{lept}}^{\mathrm{eff}} = 0.23146 \pm 0.00012, \quad (11)$$

$$\sin^2\theta_Z^{\mathrm{MS}} = 0.23116 \pm 0.00012, \quad (12)$$

$$N_\nu = 2.989 \pm 0.007. \quad (13)$$

From ALEPH, DELPHI, L3, OPAL, LEPEWWG, 2013, arXiv:1302.3415 [47]:

Finally, all measurements are used to infer constraints on the Higgs boson of the minimal SM. This analysis updates our previous analysis [4]. **Similar analyses of this type are presented in References [178, 272], obtaining equivalent results** *when accounting for the different sets of measurements considered.*

ref. [178] = PDG 2010 [48]

ref. [272] = Gfitter EPJC 2009 [49]

The Gfitter reference [272] uses ZFITTER's Standard Model library without saying this.
See:
http://zfitter.com/gfitter-publications.html (August 2011, ZFITTER)
http://fh.desy.de/projekte/gfitter01/Gfitter01.htm (June 2013, Prof.Mnich)
http://zfitter-gfitter.desy.de/ (March 2014, Helmut Dosch and Christian Scherf)

From ALEPH, DELPHI, L3, OPAL, LEPEWWG, 2013, arXiv:1302.3415 [47]:

...
ZFITTER ... For a consistent treatment, the complete two-loop calculation for the partial Z decay widths should be calculated.

... obtain the constraint $m_t = 178 + 11 - 8$ *GeV, in good agreement with the much more precise direct measurement of* $m_t = 173.2 \pm 0.9$ *GeV.*
determined with ZFITTER:

mH [GeV] = 118+203-64 only LEP
mH [GeV] = 122+59-41 plus m-top
mH [GeV] = 148+237-81 plus m-w and gamma-w
mH [GeV] = 94+29-24 plus m-top and m-w and gamma-w

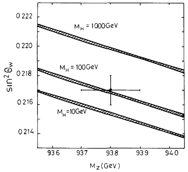
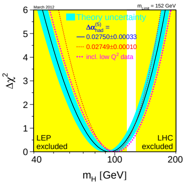


Fig 1 Graph of $\sin^2\theta_W$ versus M_Z, influenced by M_H through radiative corrections The thickness corresponds to the range 30 GeV ⩽ m_t ⩽ 40 GeV, the error bars indicate the accuracy expected at Z boson factories.



Left: *The first ever plotted LEP observables' dependence on the Higgs mass in the Standard Model (reprinted from Physics Letters, A. Akhundov, D. Bardin, and T. Riemann, "Hunting the hidden standard Higgs", volume B166, p. 111, Copyright (1986) [50], with permission from Elsevier.)*

Right: *Blue-band plot of the LEPEWWG [51] with a Standard Model Higgs boson mass prediction based on combined world data from precision electroweak measurements.*

From “THE ZFITTER PROJECT”, 2014, [3]:

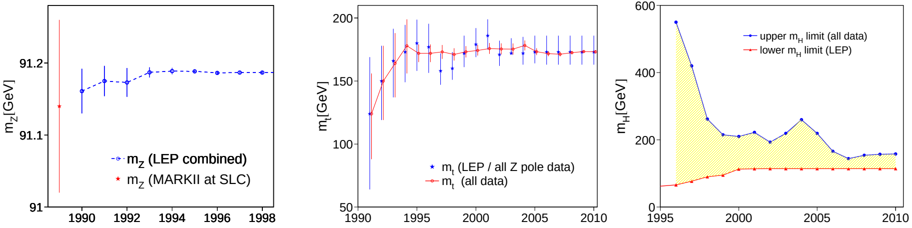


Figure 3 : **Left:** *Z boson mass measurements at LEP. Earlier measurements are from UA1, UA2 at SPS (CERN) (see text, not shown in plot) and from MARKII at SLC (SLAC).*
Middle: *Top quark mass measurements.*
Right: *Higgs boson mass measurements. The upper limits and the fit values for M_H derive from a combination of virtual corrections to LEP and similar data, top and W mass measurements, performed by the LEPEWWG. The lower mass limit is due to LEP direct searches. The lower limits from data combinations are not shown.*

Human investment into ZFITTER

2.2 million Euro
derived from 30 years FTE (staff researcher full time equivalent with 74,000 Euro per FTE)

1.1 million Euro
1/2 of the amount for project management, publications, numerical tests, user support etc.

550,000 Euro $\rightarrow$ QED corrections
550,000 Euro $\rightarrow$ Standard Model library
1/2 of the amount for Software = QED corrections + Standard Model library

Gfitter project: just “port” secretly the Standard Model library of ZFITTER to C++

You might invest 50,000 Euro instead of 550,000 Euro
The profit rate of “porting” is here about 1000 %.

We consider to distribute only *executables* of new software *on request*.

Belle II and ZFITTER, TOPFIT, MUFIT

The Belle experiment at KEK in Japan

- Belle II will measure about $10^9 \mu^+\mu^-$ pairs at $\sqrt{s} = 10.58$ GeV
- Need a theoretical precision of about 10^{-3} or even better
- With account of muon mass: $\frac{m_\mu^2}{s} \approx 10^{-4}$
- Opens the opportunity to measure at $\sqrt{s} \approx 10$ GeV the weak ρ-parameter
  NOT accessible: the weak mixing angle
- Observable: Forward-backward asymmetry $A_{FB}(\mu^+\mu^-)$

Some references:

- Section 5.14 “Electroweak physics” in “Physics at Super B Factory” [52]
- Report at 15th meeting of the Working Group on Rad. Corrections and MC Generators for Low Energies [53]
- “Report from Belle and Belle II” to 77th DESY PRC Meeting, 24 April 2014 [54]

30 January 2014, Email from Belle group at DESY/Hamburg

```
...
Guten Abend Tord,

ich arbeite an der Messung von Fermionpaar-Asymetrien (zunaechst nur
Muonpaare) bei Belle (sqrt(s)=10.58GeV). Ich hoffe Du hast Zeit und Lust
mir bei einigen Fragen/Problemen zu helfen. Ich moechte gerne ZFITTER
verwenden um

1) einen unabhaengigen Vergleich zu unserem MC (KKMC) zu haben was die
hoeheren Ordnungen QEQ+weak Korrekturen angeht (weitere Vergleiche mit
KORALZ, KORALB und analytischen Rechnungen wie z.B. Dein aus Deinem
Artikel Acta Phys. Polonica B18, 1887)

2) um schnell (=schneller als fuer jeden Parametersatz >10^9 events mit
KKMC zu erzeugen) fuer "experiment-nahe" Cuts (auf Acollinearitaet und
Acceptance) Werte fuer AFB zu erhalten

3) Um die "improved Born" diff. cross section zu berechnen mit denen wir
die Daten auf QED-Effekte korrigieren.

Ich habe
...
```

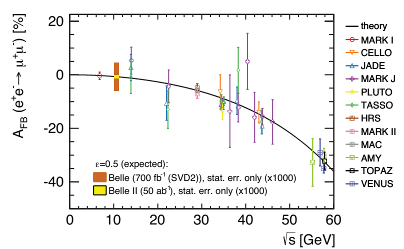


Figure from [53]

Figure 2.3.1: Measurements of $\mathcal{A}_{FB}(e^+e^- \to \mu^+\mu^-)$ at different energies $\sqrt{s}$ corrected

From TOPFIT to MUFIT

For Belle, **ZFITTER** can be used without any changes

- QED: take it as-is
- But: might need exact higher orders. Do theory predictions exist?
- Take Standard Model library *without* the 2-loop corrections - they are made for the Z peak, not for $\sqrt{s}$ = 10 GeV

At Belle, do we need precise muon mass handling?

For a fine-tuning of exact, complete massive one-loop electroweak corrections:
TOPFIT - Software for electroweak fermion pair production with exact mass handling based on SFB/CPP-03-02 and SFB/CPP-03-13 [44, 45])

TOPFIT was never used so far outside ILC workshops
The software is not made public and got nearly forgotten.

The cross-section formula depends on six form factors. But at small energies, only one of them contributes to the forward-backward asymmetry:

$$
\begin{aligned}
\frac{d\sigma}{d\cos\theta} \quad = \quad & \frac{\pi\alpha^2}{2s}\, c_t\, \beta\, 2\Re e\Big[(u^2+t^2+2m_\mu^2 s)\left(\bar{F}_1^{11}\bar{F}_1^{11,B*}+\bar{F}_1^{51}\bar{F}_1^{51,B*}\right) \\
& + (u^2+t^2-2m_\mu^2 s)\left(\bar{F}_1^{15}\bar{F}_1^{15,B*}+\bar{F}_1^{55}\bar{F}_1^{55,B*}\right) \\
& + (u^2-t^2)\left(\bar{F}_1^{55}\bar{F}_1^{11,B*}+\bar{F}_1^{15}\bar{F}_1^{15,B*}+\bar{F}_1^{51}\bar{F}_1^{51,B*}+\bar{F}_1^{11}\bar{F}_1^{55,B*}\right) \\
& + 2m_\mu(tu-m_\mu^4)\left(\bar{F}_3^{11}\bar{F}_1^{11,B*}+\bar{F}_3^{51}\bar{F}_1^{51,B*}\right)\Big], \qquad (14)
\end{aligned}
$$

Compare two predictions of weak corrrections, no QED

$e^+e^- \to \tau^+\tau^- \qquad \sqrt{s} = 500$ GeV				
$\cos\theta$	$\left[\frac{d\sigma}{d\cos\theta}\right]_{\rm Born}$ /pb	$\left[\frac{d\sigma}{d\cos\theta}\right]_{\rm B+weak}$ /pb	$\left[\frac{d\sigma}{d\cos\theta}\right]_{\rm B+w+QED+soft}$ /pb	Program
-0.9	$0.94591\ 02171\ 86329 \cdot 10^{-1}$	$0.10860\ 60371\ 92303$	$0.92419\ 02671\ 14061 \cdot 10^{-1}$	TOPFIT
-0.9	$0.94591\ 02171\ 86327 \cdot 10^{-1}$	$0.10860\ 60371\ 93233$	$0.92419\ 02671\ 18656 \cdot 10^{-1}$	FA/FC
-0.5	$0.89298\ 53117\ 79858 \cdot 10^{-1}$	$0.10025\ 68354\ 16001$	$0.86699\ 48248\ 65248 \cdot 10^{-1}$	TOPFIT
-0.5	$0.89298\ 53117\ 79856 \cdot 10^{-1}$	$0.10025\ 68354\ 16428$	$0.86699\ 48248\ 69477 \cdot 10^{-1}$	FA/FC
0.0	$0.15032\ 16827\ 75192$	$0.16418\ 09556\ 08258$	$0.14359\ 79492\ 08648$	TOPFIT
0.0	$0.15032\ 16827\ 75192$	$0.16418\ 09556\ 07903$	$0.14359\ 79492\ 08618$	FA/FC
0.5	$0.28649\ 90174\ 53525$	$0.31504\ 05045\ 07441$	$0.28258\ 86777\ 59811$	TOPFIT
0.5	$0.28649\ 90174\ 53525$	$0.31504\ 05045\ 06135$	$0.28258\ 86777\ 59161$	FA/FC
0.9	$0.44955\ 18970\ 14604$	$0.50904\ 21673\ 78790$	$0.47648\ 29191\ 20038$	TOPFIT
0.9	$0.44955\ 18970\ 14604$	$0.50904\ 21673\ 76612$	$0.47648\ 29191\ 19623$	FA/FC

Table from SFB/CPP-03-13, [45].
Differential cross-sections for selected scattering angles for τ-production at $\sqrt{s} = 500$ GeV. The three columns contain the Born cross-section, Born including only the weak $O(\alpha)$ corrections, and Born including the weak and photonic $O(\alpha)$ corrections. For each angle, the first row represents the TOPFIT result of the Zeuthen group while the second stands for the Feynaarts/Feyncalc calculation of the Munich group.

topfit and Grace, 2002, Comparison with QED

From [Fleischer, Fujimoto, Ishikawa, TR et al. [55]]

$\cos\theta$	$\omega/\sqrt{s}$	$\left[\frac{d\sigma}{d\cos\theta}\right]_{Born}$	$\left[\frac{d\sigma}{d\cos\theta}\right]_{QED}$	$\left[\frac{d\sigma}{d\cos\theta}\right]_{SM}$	$\left[\frac{d\sigma}{d\cos\theta}\right]_{tot}$
−0.9	T : 0.1	0.108839194075	+0.098664253	+0.11408410	0.13144
	T : 0.00001	0.108839194075	−0.017474702	−0.002054858	0.13229
	G : 0.00001	0.108839194076		−0.002054859	0.13206(12)
−0.5	T : 0.1	0.142275069392	+0.12850790	+0.14308121	0.15973
	T : 0.00001	0.142275069392	−0.029702340	−0.015129038	0.16029
	G : 0.00001	0.142275069393		−0.015129039	0.16013(13)
+0.0	T : 0.1	0.225470464033	+0.20239167	+0.21718801	0.23638
	T : 0.00001	0.225470464033	−0.058010508	−0.043214169	0.23476
	G : 0.00001	0.225470464033		−0.043214168	0.23513(14)
+0.5	T : 0.1	0.354666470332	+0.31511723	+0.32933727	0.35651
	T : 0.00001	0.354666470332	−0.109721291	−0.095501257	0.35062
	G : 0.00001	0.354666470332		−0.095501252	0.35104(17)
+0.9	T : 0.1	0.491143715767	+0.43071437	+0.44290816	0.48796
	T : 0.00001	0.491143715767	−0.179672655	−0.16747886	0.47768
	G : 0.00001	0.491143715767		−0.16747886	0.47709(21)

Various differential cross sections. The upper and lower numbers correspond to the `topfit` (T) and GRACE (G) approach, respectively, $\sqrt{s}$ = 500 GeV.

topfit and Grace, 2002, QED integrated

From Fleischer, Fujimoto, Ishikawa, TR et al. [55]

$\sqrt{s}$	σ^0_{tot}	A^0_{FB}	$\sigma_{\mathrm{SM,tot}}$	$\sigma_{\mathrm{SM,FB}}$	σ_{tot}	A_{FB}
500	T : 0.5122744	0.4146039	−0.1198972	−0.0855551	0.526337	0.362929
	G : 0.5122751	0.4146042	−0.1198973		0.526371	0.363140
1000	T : 0.1559185	0.5641706	−0.0683693	−0.0522582	0.171916	0.488869
	G : 0.1559187	0.5641710	−0.0683695		0.171931	0.488872

Total cross sections (in pbarn) and forward-backward asymmetries.

σ^0_{tot} – Born
$\sigma_{\mathrm{SM,tot}}$ – elastic (with soft photons, $\omega/\sqrt{s} = 0.00001$)
σ_{tot} – also hard photons

Dissemination of Results

The fate of ZFITTER software raised serious questions.

DFG: Ombudsman for Science in Germany, 11/2011 to 07/2012 I

The ombuds expertise of the Ombudsman for Science in Germany Prof. Löwer of 3 July 2012 is no more confidential.
Reason: It was not realized for more than 12 months.
https://docs.google.com/file/d/0B2sxXddQaKKILXhxRUFrYmwxdTQ/...

Professional English translation by Intertext GmbH:

http://zfitter.com/Schiedsspruch_prof_loewer-EN-06Jul2012.pdf

From Prof. Löwer's Schiedsspruch [expertise]:

"Die sachgesetzliche richtige Erfassung von solcher Software im Spannungsfeld von Regeln guter wissenschaftlicher Praxis ist bis jetzt nicht Gegenstand der Regelbildung gewesen (wenn ich das recht sehe), so dass es an klaren Fixpunkten fehlt, die die Vorwerfbarkeit erheblichen Fehlverhaltens rechtfertigen würde."
Bonn, am 3. Juli 2012 Prof. Dr. Wolfgang Löwer

Similar statements by the Editor-in-Chief of EPJC, see Backup Slides.
So we organized a ...
... Round Table Discussion at the Conference ACAT 2013 in Beijing, China, on software sharing
Study of ethical, legal and licence aspects of open-source software in knowledge sharing and scientific collaboration

Questions related to software sharing:

- Attribution is essential element of ethics in academic basic research
- Legal aspects (different national laws)
- Copyright aspects
- Licences – formalized conditions of use ($\rightarrow$ **essentially diverse!**)
- Practical side: Authors guaranty support, have responsibility and rights

Round Table Discussion at the Conference ACAT 2013 on software sharing
Preparation and Write-up:
Federico Carminati (CERN), Denis Perret-Gallix (LAPP), T.R. (DESY)
J. Phys. Conf. Series 523, Red Report DESY 14-079 [1, 2]

Why to write software for the public?, or: Dissemination of Scientific Results I

Question from the Department of Energy, Office of Science, Office of the Director, to the Chair of HEPAP, Feb 25, 2011, answered by
Junescience.energy.gov/ /media/hep/hepap/pdf/Dissemination_Report.pdf
"Report of the HEPAP Sub-Committee on the Dissemination of Research Results", June 3, 2011, Lance Dixon et al.

Dissemination of Theoretical Research Results – Digital Data

Although not technically "digital data", it's important to note that some theoretical research produces results besides the published articles. Examples include simulation programs (e.g. lattice gauge theory simulations like USQCD or MILC and Monte Carlo simulation programs like PYTHIA, HERWIG, SHERPA, or ALPGEN), computation programs (e.g. MCFM or MadGraph), and global fits to a large corpus of data (e.g. CTEQ, **ZFITTER***, or CKMFITTER). Typically the computer code itself is disseminated in an open access manner via the internet. The release of the computer code is usually accompanied by a publication in a peer reviewed journal describing the functionality of the code and, if relevant, specific results obtained using the code. Since these endeavors usually involve a larger collaboration of theorists (and sometimes experimentalists too), the criteria for dissemination typically include some set of cross-checks that verify the validity of the computer code and/or the results being released.* **The Version of Record is taken to be the latest version available from the relevant URL***, which also provides additional functionality by providing versioning, documenting the relevant differences among versions, producing a User's Manual, and referencing the related articles in peer reviewed journals and/or posted on the arXiv.* **The long-term stewardship of these results is provided by the collaborations themselves via their web pages.** *It's worth noting that the HepForge () project offers a common repository for many of these computer codes.*

Conclusions

- SFB/TR 9 is truly important, also for scientists at DESY, a Helmholtz Zentrum
- SFB/TR 9 supports both
  - Research
  - Education (Ph.D. students, School on Computer Algebra CAPP)
- Our SFB/TR 9 is devoted to
  - Theoretical research
  - Application to experimental questions

  and
  - Dissemination of software
- I see a need of more support, by DFG, of our authors' rights against misuse by third parties

I remember thankful the cooperation with

Prof. Dr. Jochem Burkhard Fleischer
17 December 1937 - 1 April 2013

http://www-zeuthen.desy.de/ riemann/FleischerJ

References I

[1] F. Carminati, D. Perret-Gallix, T. Riemann, Summary of the ACAT Round Table Discussion: Open-source, knowledge sharing and scientific collaboration, J. Phys. Conf. Ser. 523 (2014) 012066.
doi:10.1088/1742-6596/523/1/012066.

[2] F. Carminati, D. Perret-Gallix, T. Riemann, Summary of the ACAT Round Table Discussion: Open-source, knowledge sharing and scientific collaboration. Red report DESY 14-079.
arXiv:1407.0540.

[3] A. Akhundov, A. Arbuzov, S. Riemann, T. Riemann, The ZFITTER project, Phys. Part. Nucl. 45 (3) (2014) 529–549.
arXiv:1302.1395, doi:10.1134/S1063779614030022.

[4] J. Blümlein, I. Dubovyk, J. Gluza, M. Ochman, C. G. Raab, T. Riemann, C. Schneider, Non-planar Feynman integrals, Mellin-Barnes representations, multiple sums, PoS(LL2014)052.
http://pos.sissa.it/archive/conferences/211/052/LL2014_052.pdf.
arXiv:1407.7832.

[5] F. Campanario, H. Czyż, J. Gluza, M. Gunia, T. Riemann, G. Rodrigo, V. Yundin, Complete QED NLO contributions to the reaction $e^+e^- \to \mu^+\mu^-\gamma$ and their implementation in the event generator PHOKHARA, JHEP 1402 (2014) 114.
arXiv:1312.3610, doi:10.1007/JHEP02(2014)114.

[6] K. Bielas, I. Dubovyk, J. Gluza, T. Riemann, Some Remarks on Non-planar Feynman Diagrams, Acta Phys. Polon. B44 (11) (2013) 2249–2255.
arXiv:1312.5603, doi:10.5506/APhysPolB.44.2249.

[7] I. Dubovyk, J. Gluza, T. Riemann, A. A. Almasy, Reductions and Contractions of 1-loop Tensor Feynman Integrals, Acta Phys. Polon. B44 (11) (2013) 2241–2247.
arXiv:1311.2267, doi:10.5506/APhysPolB.44.2241.

[8] J. Gluza, M. Gunia, T. Riemann, M. Worek, Theoretical Improvements for Luminosity Monitoring at Low Energies, PoS RADCOR2011 (2011) 034,
http://pos.sissa.it/archive/conferences/145/034/RADCOR2011_034.pdf.
arXiv:1201.0968.

[9] J. Fleischer, T. Riemann, V. Yundin, New developments in PJFry, PoS LL2012 (2012) 020,
http://pos.sissa.it/archive/conferences/151/020/LL2012_020.pdf.
arXiv:1210.4095.

References II

[10] J. Fleischer, J. Gluza, M. Gluza, T. Riemann, R. Sevillano, Efficient contraction of 1-loop N-point tensor integrals, PoS LL2012 (2012) 051, http://pos.sissa.it/archive/conferences/151/051/LL2012_051.pdf. arXiv:1211.3921.

[11] J. Fleischer, T. Riemann, V. Yundin, One-Loop Tensor Feynman Integral Reduction with Signed Minors, J. Phys. Conf. Ser. 368 (2012) 012057. arXiv:1112.0500, doi:10.1088/1742-6596/368/1/012057.

[12] J. Fleischer, T. Riemann, A solution for tensor reduction of one-loop N-point functions with $N \geq 6$, Phys. Lett. B707 (2012) 375–380. arXiv:1111.5821, doi:10.1016/j.physletb.2011.12.060.

[13] J. Fleischer, T. Riemann, Simplifying 5-point tensor reduction, Acta Phys. Polon. B42 (2011) 2371–2378. arXiv:1111.4153, doi:10.5506/APhysPolB.42.2371.

[14] C. Carloni Calame, H. Czyz, J. Gluza, M. Gunia, G. Montagna, O. Nicrosini, F. Piccinini, T. Riemann, M. Worek, NNLO leptonic and hadronic corrections to Bhabha scattering and luminosity monitoring at meson factories, JHEP 1107 (2011) 126. arXiv:1106.3178, doi:10.1007/JHEP07(2011)126.

[15] J. Fleischer, T. Riemann, Calculating contracted tensor Feynman integrals, Phys. Lett. B701 (2011) 646–653. arXiv:1104.4067, doi:10.1016/j.physletb.2011.06.033.

[16] J. Gluza, K. Kajda, T. Riemann, AMBRE - a Mathematica package for the construction of Mellin-Barnes representations for Feynman integrals, Comput. Phys. Commun. 177 (2007) 879–893. arXiv:0704.2423, doi:10.1016/j.cpc.2007.07.001.

[17] J. Gluza, F. Haas, K. Kajda, T. Riemann, Automatizing the application of Mellin-Barnes representations for Feynman integrals, PoS ACAT2007 (2007) 081, http://pos.sissa.it/archive/conferences/050/081/ACAT_081.pdf. arXiv:0707.3567.

[18] J. Fleischer, J. Gluza, K. Kajda, T. Riemann, Pentagon diagrams of Bhabha scattering, Acta Phys. Polon. B38 (2007) 3529–3536, http://www.actaphys.uj.edu.pl/_cur/store/vol38/pdf/v38p3529.pdf. arXiv:0710.5100.

[19] S. Actis, M. Czakon, J. Gluza, T. Riemann, Fermionic NNLO contributions to Bhabha scattering, Acta Phys. Polon. B38 (2007) 3517–3528, http://www.actaphys.uj.edu.pl/_cur/store/vol38/pdf/v38p3517.pdf. arXiv:0710.5111[hep-ph].

References III

[20] S. Actis, M. Czakon, J. Gluza, T. Riemann, Two-Loop Fermionic Corrections to Massive Bhabha Scattering, Nucl. Phys. B786 (2007) 26–51. arXiv:0704.2400v2, doi:10.1016/j.nuclphysb.2007.06.023.

[21] J. Gluza, T. Riemann, New results for 5-point functions, Proc. LCWS, HamburgSee also at http://www-zeuthen.desy.de/∼riemanns/LCWS07-Loops.htm. arXiv:0712.2969[hep-ph].

[22] M. Czakon, J. Gluza, T. Riemann, The Planar four-point master integrals for massive two-loop Bhabha scattering, Nucl. Phys. B751 (2006) 1–17. arXiv:hep-ph/0604101, doi:10.1016/j.nuclphysb.2006.05.033.

[23] S. Actis, M. Czakon, J. Gluza, T. Riemann, Virtual hadronic and leptonic contributions to Bhabha scattering, Phys. Rev. Lett. 100 (2008) 131602. arXiv:0711.3847, doi:10.1103/PhysRevLett.100.131602.

[24] S. Actis, et al., Quest for precision in hadronic cross sections at low energy: Monte Carlo tools vs. experimental data, Eur. Phys. J. C66 (2010) 585–686. arXiv:0912.0749, doi:10.1140/epjc/s10052-010-1251-4.

[25] J. Gluza and T. Riemann, *Simple Feynman diagrams and simple sums*, Talk held at RISC - DESY *Workshop on Advanced Summation Techniques and their Applications in Quantum Field Theory* on the occasion of the 5th year jubilee of the RISC-DESY cooperation, May 7-8, 2012, RISC Institute, Castle of Hagenberg, Linz, Austria. Conference link: http://www.risc.jku.at/conferences/RISCDESY12/, talk link: http://www-zeuthen.desy.de/ riemann/Talks/riemann-Linz-2012-05.pdf .

[26] S. Moch, P. Uwer, XSummer: Transcendental functions and symbolic summation in form, Comput. Phys. Commun. 174 (2006) 759–770. arXiv:math-ph/0508008, doi:10.1016/j.cpc.2005.12.014.

[27] C. Schneider, Symbolic summation assists combinatorics, Sém. Lothar. Combin. 56 (2007) 1–36, Article B56b, http://www.emis.de/journals/SLC/wpapers/s56.html.

[28] C. Schneider, Simplifying multiple sums in difference fields, in: C. Schneider, J. Blümlein (Eds.), Computer Algebra in Quantum Field Theory: Integration, Summation and Special Functions, Texts and Monographs in Symbolic Computation, Springer, 2013, pp. 325–360. arXiv:arXiv:1304.4134.

[29] J. Ablinger, J. Blümlein, C. G. Raab, C. Schneider, Nested (inverse) binomial sums and new iterated integrals for massive Feynman diagrams, PoS(LL2014). arXiv:1407.4721.

References IV

[30] D. B. Melrose, Reduction of Feynman diagrams, Nuovo Cim. 40 (1965) 181–213.
doi:10.1007/BF028329.

[31] A. I. Davydychev, A simple formula for reducing Feynman diagrams to scalar integrals, Phys. Lett. B263 (1991) 107–111.
doi:10.1016/0370-2693(91)91715-8.

[32] Z. Bern, L. J. Dixon, D. A. Kosower, Dimensionally Regulated One-Loop Integrals, Phys. Lett. B302 (1993) 299–308 [Erratum–ibid. B **318** (1993) 649].
arXiv:hep-ph/9212308, doi:10.1016/0370-2693(93)90400-C.

[33] O. Tarasov, Connection between Feynman integrals having different values of the space-time dimension, Phys. Rev. D54 (1996) 6479–6490.
arXiv:hep-th/9606018, doi:10.1103/PhysRevD.54.6479.

[34] J. Fleischer, F. Jegerlehner, O. Tarasov, Algebraic reduction of one-loop Feynman graph amplitudes, Nucl. Phys. B566 (2000) 423–440.
arXiv:hep-ph/9907327, doi:10.1016/S0550-3213(99)00678-1.

[35] T. Binoth, J. P. Guillet, G. Heinrich, E. Pilon, T. Reiter, Golem95: a numerical program to calculate one-loop tensor integrals with up to six external legs, Comput. Phys. Commun. 180 (2009) 2317–2330.
arXiv:0810.0992, doi:10.1016/j.cpc.2009.06.024.

[36] J. Fleischer, T. Riemann, Complete algebraic reduction of one-loop tensor Feynman integrals, Phys. Rev. D83 (2011) 073004.
arXiv:1009.4436, doi:10.1103/PhysRevD.83.073004.

[37] T. Diakonidis, J. Fleischer, J. Gluza, K. Kajda, T. Riemann, J. Tausk, A complete reduction of one-loop tensor 5- and 6-point integrals, Phys. Rev. D80 (2009) 036003.
arXiv:0812.2134, doi:10.1103/PhysRevD.80.036003.

[38] J. Alcaraz Maestre, et al., The SM and NLO Multileg and SM MC Working Groups: Summary Report.
arXiv:1203.6803.

[39] V. Yundin, Massive loop corrections for collider physics, PhD thesis, Humboldt-Universität zu Berlin, 2012, see http://edoc.hu-berlin.de/docviews/abstract.php?id=39163 and urn:nbn:de:kobv:11-100199626.

[40] J. Fleischer, T. Riemann, V. Yundin, PJFry: A C++ package for tensor reduction of one-loop Feynman integrals. In: [38], preprint DESY 11-252 (2011).
http://www-library.desy.de/cgi-bin/showprep.pl?desy11-252.

References V

[41] T. Diakonidis, J. Fleischer, T. Riemann, J. B. Tausk, A recursive reduction of tensor Feynman integrals, Phys. Lett. B683 (2010) 69–74.
arXiv:0907.2115, doi:10.1016/j.physletb.2009.11.049.

[42] V. Yundin, Talk at Kick-off meeting of the LHCPhenoNet Initial Training Network, Jan/Feb 2011, Valencia, Spain.

[43] A. Arbuzov, M. Awramik, M. Czakon, A. Freitas, M. Grünewald, K. Mönig, S. Riemann, T. Riemann, ZFITTER: A Semi-analytical program for fermion pair production in e^+e^- annihilation, from version 6.21 to version 6.42, Comput. Phys. Commun. 174 (2006) 728–758.
arXiv:hep-ph/0507146, doi:10.1016/j.cpc.2005.12.009.

[44] J. Fleischer, A. Leike, T. Riemann, A. Werthenbach, Electroweak one loop corrections for e^+e^- annihilation into $t\bar{t}$ including hard bremsstrahlung, Eur. Phys. J. C31 (2003) 37–56.
arXiv:hep-ph/0302259, doi:10.1140/epjc/s2003-01263-8.

[45] T. Hahn, W. Hollik, A. Lorca, T. Riemann, A. Werthenbach, $o(\alpha)$ electroweak corrections to the processes $e^+e^- \rightarrow \tau^-\tau^+, c\bar{c}, b\bar{b}, t\bar{t}$: A comparison.
http://www-flc.desy.de/lcnotes/notes/LC-TH-2003-083.pdf.
arXiv:hep-ph/0307132.

[46] J. Beringer, et al., Review of Particle Physics (RPP), Phys. Rev. D86 (2012) 010001.
doi:10.1103/PhysRevD.86.010001.

[47] S. Schael, et al., Electroweak Measurements in Electron-Positron Collisions at W-Boson-Pair Energies at LEP, Phys. Rept. 532 (2013) 119–244.
arXiv:1302.3415, doi:10.1016/j.physrep.2013.07.004.

[48] K. Nakamura, et al., Review of particle physics, J. Phys. G37 (2010) 075021.
doi:10.1088/0954-3899/37/7A/075021.

[49] H. Flacher, M. Goebel, J. Haller, A. Hocker, K. Monig, et al., Revisiting the Global Electroweak Fit of the Standard Model and Beyond with Gfitter, Eur. Phys. J. C60 (2009) 543–583.
arXiv:0811.0009v1, doi:10.1140/epjc/s10052-009-0966-6, 10.1140/epjc/s10052-011-1718-y.

[50] A. Akhundov, D. Bardin, T. Riemann, Hunting the hidden standard Higgs, Phys. Lett. B166 (1986) 111.
doi:10.1016/0370-2693(86)91166-4.

[51] LEP Electroweak Working Group (LEPEWWG), webpage http://lepewwg.web.cern.ch/LEPEWWG/.

References VI

[52] T. Aushev, W. Bartel, A. Bondar, J. Brodzicka, T. Browder, et al., Physics at Super B Factory.
arXiv:1002.5012.

[53] J. van der Bij, H. Czyż, S. Eidelman, G. Fedotovich, T. Ferber, et al., Mini-Proceedings, 15th meeting of the Working Group on Rad. Corrections and MC Generators for Low Energies.
arXiv:1406.4639.

[54] S. Yashchenko, report to 77^{th} DESY PRC Meeting, *Report from Belle and Belle II*, 24 April 2014.
https://indico.desy.de/getFile.py/access?contribId=7&resId=0&materialId=slides&confId=10000.

[55] J. Fleischer, J. Fujimoto, T. Ishikawa, A. Leike, T. Riemann, Y. Shimizu, A. Werthenbach, One loop corrections to the process $e^+e^- \to t\bar{t}$ including hard bremsstrahlung, in: Y. Kurihara (ed.), Second Symposium on Computational Particle Physics (CPP, Tokyo, 28–30 Nov 2001), KEK Proceedings 2002-11 (2002), p. 153.
arXiv:hep-ph/0203220.

Backup: Licence Problems

We made some bad experiences in recent years concerning fair quotations of source-open software.

See e.g.:
http://zfitter.com (ZFITTER collab. 2011)
http://zfitter.education (ZFITTER collab. 2014)
A review is [3].

See also:
http://fh.desy.de/projekte/gfitter01/Gfitter01.htm (DESY General Director 2013)
http://zfitter-gfitter.desy.de (DESY Research Director 2014)

The generally accepted rules for using software in high energy physics were discussed at the round table discussion at ACAT 2013, see the summary:
F. Carminati, D. Perret-Gallix, T. Riemann:
“Summary of the ACAT Round Table Discussion: Open-source, knowledge sharing and scientific collaboration“
hep-ph/1407.0540, DESY-14-079, J. Phys. Conf. Ser. 523 (2014) 012066 [1, 2]

We consider to distribute only *executables* of new software *on request*.

Backup: Z0ZFitter.cxx (2014) A software comparison example

From Helmut Dosch's and Christian Scherf's DESY webpage:
http://zfitter-gfitter.desy.de/sites2009/site_zfitter-gfitter/content/e170987/infoboxContent170999/2014-03-17Quellcode_Z0ZFitter.cxx.pdf

Backup: Z0ZFitter.cxx (2014) A software comparison example I

E… …nparison example II

```
// see dizet6_42.f line 3226
Double_t DkTBCor = 3.0*TopCon*ZMath::TbQCD( alphasTop, mt*mt, MZ*MZ, (1.0-m_R) );

// see dizet6_42.f line 3051
m_Renorm        = GMath::Sqrt2()*p_GF*MZ*MZ*(1.0-m_R)*m_R/(pi*GConstants::alphaQED());
// see dizet6_42.f line 3053
m_KapCorr       = ( GConstants::alphaQED()/(4*pi)*WZCorr + Scale
                  + 0.75*GConstants::alphaQED()/(4*pi*(1.0-m_R)*(1.0-m_R))*mt*mt/(MZ*MZ) );

// see dizet6_42.f line 3054
m_RhoTop        = 0.75*GConstants::alphaQED()/(4*pi*m_R*(1.0-m_R))*mt*mt/(MZ*MZ);
// see dizet6_42.f line 3067
m_TBCorL        = -GConstants::alphaQED()/(4*pi)*alphasTop/pi*mt*mt/(MW*MW*(1.0-m_R))*(0.5+pi*pi/6.0);

// see dizet6_42.f line 3071-3072
m_RhoRemAdd     = -1.0 - m_TBCorL +  (1.0-m_R)/m_R*m_KapCorr - m_RhoTop;
m_KapRemAdd     = -1.0 - m_R/(1.0-m_R)*(m_TBCorL + m_RhoTop) + m_KapCorr + DkTBCor;

// see hep-ph/9908433 page 77, DROBAR
// see dizet6_42.f line 2300
m_DRhoBar       = ( TBCor0 - (GConstants::alphaQED()/(4*pi)*WZCorr + Scale)
                  *GMath::Sqrt2()*p_GF*MZ*MZ*GMath::IPow( 1-m_R , 2 )/pi*1/GConstants::alphaQED()
                  + GetEW2Loop().GetDrho2L() );
// see hep-ph/9908433 page 77, DROBLO
// see dizet6_42.f line 2302
m_DRhoBarLO     = (  - (GConstants::alphaQED()/(4*pi)*WZCorr + Scale)
                  *GMath::Sqrt2()*p_GF*MZ*MZ*GMath::IPow( 1-m_R , 2 )/pi*1/GConstants::alphaQED() );


// eq. (2.4.23) of hep-ph/9908433
// bosonic reminder term
// see dizet6_42.f line 2176-2178 ||~ bzw. line 2021-2025 / 2252???
m_DrRem         =  ( GConstants::alphaQED()/(4*pi)
                  *(-2.0/3.0 + 1.0/(1.0-m_R)
                   *(real( GetBosonPart().GetWbAt0() ) - real( GetBosonPart().GetWbAtMW() )
                    - 5.0/8.0*m_R*(1.0+m_R) + 11.0/2.0 + 9.0/4.0*m_R/(1.0-m_R)*TMath::Log(m_R)))
                  - GConstants::alphaQED()/(4*pi*(1.0-m_R))*(1.0/6.0 + 7.0*m_R)*TMath::Log(m_R) );
// fermionic reminder term
m_DrRem         += ( GConstants::alphaQED()/(4*pi*(1.0-m_R))
                  *( real( GetFermionPart().GetWfAt0() ) - real( GetFermionPart().GetWfAtMW() ) )
                  + GConstants::alphaQED()/(pi*(1.0-m_R))*TMath::Log(m_R) );
```

```
3225  * Here TBQCDR is called for FOKAPP
3226          DKTB3R=3*TOPX2*TBQCDR(CALST,AMT2,AMZ2,SW2)
3227         ENDIF

3062          TBQCD0=-TOPX2*CALXI/PI*2D0*(1D0+PI2/3D0)
3063           ELSE
3064          TBQCD0=3*TOPX2*AFMT3(CALST,AMT2,AMZ2,SW2)
3065  * Here TBQCDR has to be called!!! ROKAPP - 3
3066         ENDIF
3067       TBQCDL=-AL4PI*ALST/PI*AMT2/AMW2/R1*(.5D0+PI2/6D0)
3068      ENDIF
3069      ROFACL=1/(1-DRHOT4-TBQCD0)
3070      AKFACL=(1+R/SW2*(DRHOT4+TBQCD0)-CORKAP*RENORM)
3071      ROFACR=ROFACI       -DRHOT-TBQCDL        -1
3072      AKFACR=AKFACI-R/SW2*(DRHOT+TBQCDL)+CORKAP-1
3073     ENDIF

2300      DROBAR=3D0*AXF*TBQCD0-(AL4PI*DWZ1AL+SCALE)
2301    &        *SQRT(2D0)*GMU*AMZ2*R1**2/PI*ALFAI+DRHOD
2302      DROBLO=                -(AL4PI*DWZ1AL+SCALE)
2303    &        *SQRT(2D0)*GMU*AMZ2*R1**2/PI*ALFAI

2175  * See p.18 of PCWG-notebook
2176        DRREMF= DR1FER+R/SW2*DRHO1-DALFA1+TBQCD3+CORRDR
2177        DRREMB= DR1BOS-DRHIG1
2178        DRREM = DRREMF+DRREMB
2179        DRBIG=1-(1+R/SW2*DRIRR-DRHIGS)*(1D0-DALFA)

2020  DWZ1AL=R/R1*DREAL(XWZ1R1+XDWZ1F)
2021  RXX=-2D0/3D0+4D0/3D0*(SL2+SQ2)+DWZ1AL
2022 *   +(W0AL-WM1AL-5D0/8D0*R2-5D0/8D0*R+11D0/2D0+9D0/4D0*R/R1*ALR)/R1
2023  RXXFER=4D0/3D0*(SL2+SQ2)+R/R1*DREAL(XDWZ1F)+(W0F-DREAL(XWM1F))/R1
2024  RXXBOS=-2D0/3D0+R/R1*DREAL(XWZ1R1)+(W0
2025 &   -DREAL(XWM1)-5D0/8D0*R2-5D0/8D0*R+11D0/2D0+9D0/4D0*R/R1*ALR)/R1
2026  AMH=SQRT(AMH2)
2027  AMW=SQRT(AMW2)

2252        SCALEB = AL4PI/R1*(1D0/6D0+7D0*R)*ALR
```

Ende Match 3

```
// corrections for Z->bb
// there isn't a full two loop calculation
// see dizet6_42.f line 3789-3804||~ bzw. line 3798-3804
Double_t xt       = GConstants::GF()*mt*mt/(8*GMath::Sqrt2()*pi*pi);||~line 3798
m_taub1           = -2.0*xt*( 1.0 - pi/3.0*alphasTop ); ||~line 3800
m_taub2           = -2.0*xt*( xt*ZMath::BarbMb( MH/mt ) );

// see dizet6_42.f line 3069-3070
m_RhoCL           = 1/( 1.0 - RhoTop4 - TBCor0 );
m_KapCL           = ( 1.0 + m_R/(1.0-m_R)*(RhoTop4 + TBCor0) - m_KapCorr*m_Renorm );

// see dizet6_42.f line 2972
m_CorrBB          = GConstants::alphaQED()/(8.0*pi*(1.0-m_R))*mt*mt/(MW*MW);

// for Z decay
// see dizet6_42.f line 3167
m_kapmix          = ( 1/pi*GConstants::alphaQED()
                  *alphasMZ/(24.0*(1-m_R)*(1-m_R))*(2.0*(1-m_R)-1.0) );


  SetUpToDate();
}

// effective weak mixing angle
// see also class Sin2ThetaF.h
Double_t GSM::Z0ZFitter::GetSin2Eff( GTypes::Particle ParticleType )
{
  Double_t sineff = 0;

  sineff = GetSinEffF().GetSin2ThetaF( ParticleType );
```

Match 4

Match 5

Match 6

```
3786  IF(IBARB.EQ.0.OR.IBARB.EQ.-1) THEN
3787   AMT4B=(27-PI2)/3
3788    ELSEIF(IBARB.EQ.1) THEN
3789   RBTH=AMT2/AMH2
3790   ALRB=LOG(RBTH)
3791   AMT4B=1D0/144*(311D0+24*PI2+282*ALRB+90*ALRB**2
3792 &      -4D0*RBTH*(40D0+ 6*PI2+ 15*ALRB+18*ALRB**2)
3793 &      +3D0*RBTH**2*(242.09D0-60*PI2-454.2D0*ALRB-180*ALRB**2))
3794    ELSEIF(IBARB.EQ.2) THEN
3795   RBARB=SQRT(AMH2/AMT2)
3796   AMT4B=FBARBB(RBARB)
3797  ENDIF
3798  TOPX2 = GMU*AMT2/DSQRT(2.D0)/8.D0/PI2
3799  IF(IFTJR.EQ.1) THEN
3800    TAUBB1=-2*TOPX2*(1-PI/3*CALST)
3801  ELSE
3802    TAUBB1=-2*TOPX2
3803  ENDIF
3804  TAUBB2=-2*TOPX2*TOPX2*AMT4B*V_TB**2

3069        ROFACL=1/(1-DRHOT4-TBQCD0)
3070        AKFACL=(1+R/SW2*(DRHOT4+TBQCD0)-CORKAP*RENORM)
3071        ROFACR=ROFACI       -DRHOT-TBQCDL        -1
3072        AKFACR=AKFACI-R/SW2*(DRHOT+TBQCDL)+CORKAP-1

2971       TAUBB2=-2*TOPX2*(TOPX2*AMT4B)*V_TB**2
2972       CORBB =+AL1PI/8/SW2*AMT2/AMW2*V_TB**2

3167       AKMIX=AL1PI*ALSZ/8D0/3D0/SW2**2*(2D0*SW2-1D0)
3168       AR1IM=DIMAG(XRO1)
3169       AK1IM=DIMAG(XAK1)+AKMIX
```

Backup: Z0ZFitter.cxx (2007), an annotation

https://docs.google.com/file/d/0B2sxXddQaKKIb0tSMEZaTGE1YmM/edit

Backup: Z0ZFitter.cxx (2007), an annotation I

Backup: Z0ZFitter.cxx (2

https://docs.google.com/file/d/0B2sxXddQaKKIb0tSME

```
                          * Authors (alphabetical):                                                   *
                          *      Martin Goebel   <martin.goebel@desy.de>  - DESY, Germany              *
                          *      Andreas Hoecker <Andreas.Hocker@cern.ch> - CERN, Switzerland          *
                          *                                                                           *
                          * Copyright (c) 2006:                                                       *
                          *      CERN, Switzerland,                                                   *
                          *                                                                           *
                          * Redistribution and use in source and binary forms, with or without        *
                          * modification, are permitted according to the terms listed in LICENSE     *
                          * (http://mva.sourceforge.net/license.txt)                                  *
                          *                                                                           *
                          * File and Version Information:                                             *
1.37  ! mgoebel           * $Id: Z0ZFitter.cxx,v 1.36 2007/10/25 13:07:28 haller Exp $
1.2     mgoebel          **********************************************************************************/
1.1     hoecker          #include "TMath.h"

                         #include "Gfitter/GMath.h"
                         #include "Gfitter/GConstants.h"
                         #include "Gfitter/GTheory.h"
1.3     mgoebel          #include "Gfitter/GTheoryRef.h"
1.1     hoecker          #include "Gfitter/GParameterRef.h"
                         #include "Gfitter/GReference.h"
1.18    mgoebel          #include "Gfitter/GVariable.h"
                         #include "Gfitter/GStore.h"
1.1     hoecker
1.9     mgoebel          #include "GSM/GSMMath.h"
1.1     hoecker          #include "GSM/Z0ZFitter.h"
                         #include "GSM/ZFitterQCDCorrections.h"
                         #include "GSM/Sin2ThetaF.h"
                         #include "GSM/RadiatorFunctions.h"
1.34    haller           #include "GSM/RunningAlphaQCD.h"
1.7     mgoebel          #include "GSM/ZFitterFermionPart.h"
                         #include "GSM/ZFitterBosonPart.h"
1.9     mgoebel          #include "GSM/Vertex.h"
1.15    mgoebel          #include "GSM/DAlphaQED.h"
1.18    mgoebel          #include "GSM/EW2Loop.h"
1.28    mgoebel          #include "GSM/RadiatorFunctions.h"
                         #include "GSM/Sin2ThetaF.h"
                         #include "GSM/DAlphaQED.h"
1.1     hoecker
                         using namespace Gfitter;
                         using std::complex;
1.36    haller           using namespace Gfitter::GTypes;
1.1     hoecker
                         ClassImp(GSM::Z0ZFitter)

                         GSM::Z0ZFitter::Z0ZFitter()
                           : Z0Base(),
1.9     mgoebel              m_isUpToDate_Update( kFALSE )
1.1     hoecker          {
1.23    hoecker             SetTheoryName( GetName() );
                           SetExistDerivative( kFALSE );
1.1     hoecker
1.32    hoecker             const TString& OMSType = gStore()->GetVariable( "GSMFlags::OMSType" )->GetStringValue();
1.29    hoecker             m_logger << kINFO << "Using OMs type: \"" << OMSType << "\"" << GEndl;
1.18    mgoebel
1.23    hoecker             if      (OMSType == "OMS1" )  m_OMSType  = OMS1;
                           else if (OMSType == "OMS1_2") m_OMSType  = OMS1_2;
                           else if (OMSType == "OMS2")   m_OMSType  = OMS2;
                           else {
1.32    hoecker                m_logger << kFATAL << "unknown value for \"GSMFlags::OMStype\": \"" << OMSType << "\""
1.23    hoecker                         << ". Possible are: \"OMS1\", \"OMS1-2\" \"OMS2\""
```

Backup: Editor-in-Chief von EPJC, 01/2012 I

The compliance rules of EPJC, “Springer’s Policy on Publishing”:
http://www.springer.com/cda/content/document/cda_downloaddocument/Policy_on_Publishing_Integrity2010.pdf?SGWID=0-0-45-784498-0

The official complaint to EPJC vom 23.12.2011 and part of the following correspondence:
https://docs.google.com/file/d/0B2sxXddQaKKIUTVEUzNXcUs2S0k/edit (23.12.11, to Editor-in-Chief)

https://docs.google.com/file/d/0B2sxXddQaKKIX1REWFFrUnNwQ0U/edit (26.1.12, answer from Editor-in-Chief)
“We note that in EPJC60,543 the relevant references (refs 5 and 6) to the original ZFITTER publications in CPC are cited at various places: in the introduction and, more specifically, in Appendix A3. In an erratum to EPJC60,543, namely in EPJC71,1718, the reference to usage and - specifically - the implementation of ZFITTER code into Gfitter GSM is made more explicit. In the view of EPJC, the requirement of proper referencing is therefore fulfilled, and is in accordance with the CPC license.”
“We note that a subtlety may remain in the question as of what "scientific usage of the code" includes in the broader sense, namely if it is restricted to using the code as-is, or if copying and altering the original code is also permitted. Here we refer to the common practice of e.g. using Monte Carlo generator code by alarge number of scientists who, as we observe, not only run that original code, but alter and copy parts of it according to their specific (scientific) needs. Such Monte Carlo codes exist, in a wide variety, under similar or identical license terms, as Open Source software, and we are not aware of any case where ”usage“ or implementation of (parts of) such code, with proper references, has ever led to the accusation of plagiarism.”
“Equations, once published, are of course meant to be used and reproduced by other authors, whereby proper reference to the original work proposing these equations should be given wherever appropriate (there are basic and commonly known equations where such referencing is not possible or not necessary). According to our view, there is no intellectual achievement nor property in the actual LaTeX coding of such equations. We do not see that this fulfills the common understanding of plagiarism in any way.
”Both parties, whether or not this is now “undone” a posteriori, had at the time also at least one joint member.“

https://docs.google.com/file/d/0B2sxXddQaKKIZ0oyd3ZIN2lBTkk/edit (2.2.12 second letter to Editor-in-Chief and to the Gfitter collaboration)

Z0ZFitter.cxx (2007), an annotation:

https://docs.google.com/file/d/0B2sxXddQaKKIb0tSMEZaTGE1YmM/edit