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 $e^+ e^- \rightarrow \mu^+ \mu^- \gamma$ 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 11-069  “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 colleagues 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-07-69** Author: J. Fleischer, J. Gluza, K. Kajda, T. Riemann Title: PENTAGON DIAGRAMS OF BHBHA SCATTERING APP [18]

**SFB/CPP-07-70** Author: S. Actis, M. Czakon, J. Gluza, T. Riemann Title: FERMIONIC NNLO CONTRIBUTIONS TO BHBHA 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]

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

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

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

$$d = 4 - 2\epsilon$$

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

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

\[
\frac{1}{D_1^{n_1}D_2^{n_2} \ldots D_N^{n_N}} = \frac{\Gamma(n_1 + \ldots + n_N)}{\Gamma(n_1) \ldots \Gamma(n_N)} \int_0^1 dx_1 \ldots \int_0^1 dx_N \frac{x_1^{n_1-1} \ldots x_N^{n_N-1} \delta(1 - x_1 - \ldots - x_m)}{(x_1D_1 + \ldots + x_ND_N)^{N_\nu}}
\]

\[N_\nu = n_1 + \ldots + n_N\]
Starting point of AMBRE

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

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

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.

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/](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 ...

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

\[
I_{n}^{\mu_{1} \cdots \mu_{R}} = \int \frac{d^{d}k}{i\pi^{d/2}} \frac{\prod_{r=1}^{R} k^{\mu_{r}}}{\prod_{j=1}^{n} c_{j}^{\nu_{j}}},
\]

\( d = 4 - 2\varepsilon \) and denominators \( c_{j} \) have indices \( \nu_{j} \) 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
  - $\textbf{new:} \cdots$ killed all inverse pentagon Gram determinants
  - $\cdots$ treatment of full kinematics, also with small sub-diagram Gram determinants
  - $\textbf{new:} \cdots$ multiple sums over tensor coefficients made efficient by $\textbf{contracting with external momenta}$
  - $\textbf{new:} \cdots$ higher $n$ point functions, $n \geq 6$
History of the Approach - not a complete list of references


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

[33] Tarasov 1996: Dimensional recurrence relations

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


   See also Diakonidis et al. [37]

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

   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]

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

\[
I_\mu^n = \int^d k^\mu \prod_{r=1}^n c_r^{-1} = -\sum_{i=1}^n q^\mu_i I_{n,i}^{[d+]} \\
I^\mu_\nu^n = \int^d k^\mu k^\nu \prod_{r=1}^n c_r^{-1} = \sum_{i,j=1}^n q^\mu_i q^\nu_j n_{ij} I_{n,ij}^{[d+]} - \frac{1}{2} g^{\mu\nu} I_n^{[d+]} \\
I^\mu_\nu^\lambda^n = \int^d k^\mu k^\nu k^\lambda \prod_{r=1}^n c_r^{-1} = -\sum_{i,j,k=1}^n q^\mu_i q^\nu_j q^\lambda_k n_{ijk} I_{n,ijk}^{[d+]} + \frac{1}{2} \sum_{i=1}^n g^{[\mu\nu} q^\lambda_i I_{n,i}^{[d+]}^2 \\
I^\mu_\nu^\lambda^\rho^n = \int^d k^\mu k^\nu k^\lambda k^\rho \prod_{r=1}^n c_r^{-1} = \sum_{i,j,k,l=1}^n q^\mu_i q^\nu_j q^\lambda_k q^\rho_l n_{ijkl} I_{n,ijkl}^{[d+]}^4 - \frac{1}{2} \sum_{i,j=1}^n g^{[\mu\nu} q^\lambda_i q^\rho_j n_{ij} I_{n,ij}^{[d+]}^3 + \frac{1}{4} g^{[\mu\nu} g^{\lambda\rho]} I_n^{[d+]}^2
\]

(1)
Dimensional shifts and recurrence relations for pentagons

Direct approach – just perform Tarasov’s dimensional recurrences

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:

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

shift dimension:

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

also:

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

where the operators $i^\pm, j^\pm, k^\pm$ act by shifting the indices $\nu_i, \nu_j, \nu_k$ by $\pm 1$.  

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

\[ I_{4}^{\mu \nu \lambda \rho} = \int d^{4} k \prod_{r=1}^{4} c_{r}^{-1} = \sum_{i,j,k,l=1}^{n} q_{i}^{\mu} q_{j}^{\nu} q_{k}^{\lambda} q_{l}^{\rho} n_{ijkl} I_{4,ijkl}^{[d+]} \]

\[ -\frac{1}{2} \sum_{i,j=1}^{4} g[\mu \nu q_{i}^{\lambda} q_{j}^{\rho}] n_{ij} I_{4,ij}^{[d+]} + \frac{1}{4} g[\mu \nu g^{\lambda \rho}] I_{4}^{[d+]^{2}} \]

(5)

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

\[ I_{4,222}^{[d+]^{3}} = D_{111} \]

(6)

Similarly:

\[ I_{4,2222}^{[d+]^{4}} = D_{1111} \]

(7)
Example: $E_{3333}$ coefficient in small Gram region ($x \to 0$) [from V.Y. Valencia 2011 [42]]
From [5]. On left: Muon pair distributions including 5-point functions at KLOE calculated with \texttt{PJFry} (bottom: absolute error estimate). On right: the same calculated without dedicated routines to avoid small Gram determinants. Approximately $4 \cdot 10^{10}$ ($10^9$) events have been generated.
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 is the “etalon” software for the $Z$-boson resonance studied for many years at LEP 1 and at LEP 2.

Among main results of LEP are:

Review of Particle Properties, 2012 [46]

\[
\begin{align*}
M_Z &= 91.1876 \pm 0.0021 \text{ GeV}, \quad (8) \\
\Gamma_Z &= 2.4952 \pm 0.0023 \text{ GeV}, \quad (9) \\
\sin^2 \theta_{\text{weak}} &= 0.22296 \pm 0.00028, \quad (10) \\
\sin^2 \theta_{\text{eff}}^{\text{lept}} &= 0.23146 \pm 0.00012, \quad (11) \\
\sin^2 \theta_{Z}^{\text{MS}} &= 0.23116 \pm 0.00012, \quad (12) \\
N_{\nu} &= 2.989 \pm 0.007. \quad (13)
\end{align*}
\]

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://fh.desy.de/projekte/gfitter01/Gfitter01.htm (June 2013, Prof.Mnich)
http://zfitter-gfitter.desy.de/ (March 2014, Helmut Dosch and Christian Scherf)

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:

\[
\begin{align*}
  m_H [\text{GeV}] &= 118 + 203 - 64 \quad \text{only LEP} \\
  m_H [\text{GeV}] &= 122 + 59 - 41 \quad \text{plus m-top} \\
  m_H [\text{GeV}] &= 148 + 237 - 81 \quad \text{plus m-w and gamma-w} \\
  m_H [\text{GeV}] &= 94 + 29 - 24 \quad \text{plus m-top and m-w and gamma-w}
\end{align*}
\]

**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 → QED corrections
550,000 Euro → 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.
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 $\rho$-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]
Guten Abend Tord,

ich arbeite an der Messung von Fermion paar-Asymmetrien (zunächst nur Muonpaare) bei Belle (sqrt(s)=10.58GeV). Ich hoffe Du hast Zeit und Lust mir bei einigen Fragen/Problemen zu helfen. Ich möchte 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-rahe" 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 einige Fragen und hoffe auf Deinen Rat:

...
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:

\[
\frac{d\sigma}{d \cos \theta} = \frac{\pi \alpha^2}{2s} \frac{c_t \beta}{2} 2\Re \left[ (u^2 + t^2 + 2m_{\mu}^2s) \left( \bar{F}_{111}^{11, B^*} + \bar{F}_{11}^{51, B^*} \right) + (u^2 + t^2 - 2m_{\mu}^2s) \left( \bar{F}_{151}^{15, B^*} + \bar{F}_{15}^{55, B^*} \right) + (u^2 - t^2) \left( \bar{F}_{155}^{55, B^*} + \bar{F}_{15}^{15, B^*} + \bar{F}_{1}^{51, B^*} + \bar{F}_{1}^{11, B^*} \right) \right] + 2m_{\mu} (tu - m_{\mu}^4) \left( \bar{F}_{3}^{111, B^*} + \bar{F}_{3}^{51, B^*} \right),
\]

(14)
Compare two predictions of weak corrections, no QED

\[ e^+e^- \to \tau^+\tau^- \quad \sqrt{s} = 500 \text{ GeV} \]

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</table>

Table from SFB/CPP-03-13, [45].

Differential cross-sections for selected scattering angles for \( \tau \)-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.
### Introduction

AMBRE, PJFry, OLEC, ZFITTER, TOPFIT, MUFIT

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**topfit and Grace, 2002, Comparison with QED**

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

<table>
<thead>
<tr>
<th>cos θ</th>
<th>ω / √s</th>
<th>[dσ/d cos θ]_Born</th>
<th>[dσ/d cos θ]_QED</th>
<th>[dσ/d cos θ]_SM</th>
<th>[dσ/d cos θ]_tot</th>
</tr>
</thead>
<tbody>
<tr>
<td>−0.9</td>
<td>T : 0.1</td>
<td>0.108839194075</td>
<td>+0.098664253</td>
<td>+0.11408410</td>
<td>0.13144</td>
</tr>
<tr>
<td></td>
<td>G : 0.00001</td>
<td>0.108839194075</td>
<td>−0.017474702</td>
<td>−0.002054858</td>
<td>0.13209</td>
</tr>
<tr>
<td>−0.5</td>
<td>T : 0.1</td>
<td>0.14227506932</td>
<td>+0.12850790</td>
<td>+0.14308121</td>
<td>0.15973</td>
</tr>
<tr>
<td></td>
<td>G : 0.00001</td>
<td>0.14227506932</td>
<td>−0.029702340</td>
<td>−0.015129038</td>
<td>0.16029</td>
</tr>
<tr>
<td>+0.0</td>
<td>T : 0.1</td>
<td>0.225470464033</td>
<td>+0.20239167</td>
<td>+0.21718801</td>
<td>0.23638</td>
</tr>
<tr>
<td></td>
<td>G : 0.00001</td>
<td>0.225470464033</td>
<td>−0.058010508</td>
<td>−0.043214169</td>
<td>0.23476</td>
</tr>
<tr>
<td>+0.5</td>
<td>T : 0.1</td>
<td>0.354666470332</td>
<td>+0.31511723</td>
<td>+0.32933727</td>
<td>0.35651</td>
</tr>
<tr>
<td></td>
<td>G : 0.00001</td>
<td>0.354666470332</td>
<td>−0.109721291</td>
<td>−0.095501257</td>
<td>0.35104</td>
</tr>
<tr>
<td>+0.9</td>
<td>T : 0.1</td>
<td>0.491143715767</td>
<td>+0.43071437</td>
<td>+0.44290816</td>
<td>0.48796</td>
</tr>
<tr>
<td></td>
<td>G : 0.00001</td>
<td>0.491143715767</td>
<td>−0.179672655</td>
<td>−0.16747886</td>
<td>0.47709</td>
</tr>
</tbody>
</table>

Various differential cross sections. The upper and lower numbers correspond to the topfit (T) and GRACE (G) approach, respectively, √s = 500 GeV.
From Fleischer, Fujimoto, Ishikawa, TR et al. [55]

\[
\begin{array}{|c|c|c|c|c|c|c|}
\hline
\sqrt{s} & \sigma_{tot}^0 & A_{FB}^0 & \sigma_{SM, tot} & \sigma_{SM, FB} & \sigma_{tot} & A_{FB} \\
\hline
500 & T : 0.5122744 & 0.4146039 & -0.1198972 & -0.0855551 & 0.526337 & 0.362929 \\
    & G : 0.5122751 & 0.4146042 & -0.1198973 & -0.0855551 & 0.526371 & 0.363140 \\
1000 & T : 0.1559185 & 0.5641706 & -0.0683693 & -0.0522582 & 0.171916 & 0.488869 \\
    & G : 0.1559187 & 0.5641710 & -0.0683695 & -0.0522582 & 0.171931 & 0.488872 \\
\hline
\end{array}
\]

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

\[
\sigma_{tot}^0 \quad \text{Born}
\]
\[
\sigma_{SM, tot} \quad \text{elastic (with soft photons, } \omega/\sqrt{s} = 0.00001\text{)}
\]
\[
\sigma_{tot} \quad \text{also hard photons}
\]
Dissemination of Results

The fate of ZFITTER software raised serious questions.
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: 

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


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


References II


[16] J. Gluza, K. Kajda, T. Riemann, AMBRE - a Mathematica package for the construction of Mellin-Barnes representations for Feynman integrals,

http://pos.sissa.it/archive/conferences/050/081/ACAT_081.pdf.


References III


References IV


[45] T. Hahn, W. Hollik, A. Lorca, T. Riemann, A. Werthenbach, \( o(\alpha) \) electroweak corrections to the processes \( e^+ e^- \rightarrow \tau^+ \tau^- , \bar{c}c, \bar{b}b, \bar{t}\bar{t} \): A comparison. 


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“

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
Backup: Z0ZFitter.cxx (2007), an annotation

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

AMBRE

Backup: Z0ZFitter.cxx (2)

https://docs.google.com/file/d/0B2sxXddQaKKIb0tSME/edit
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/0B2sxXddQaKKIX1REWFrUnNwQ0U/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 a large 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/0B2sxXddQaKKI0yd3ZlN2lBTtk/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/0B2sxXddQaKKlb0tSMEZaTGE1YmM/edit