```
filename: detailed-ZFitterBosonPart.cxx
commented printout of gfitter/GSM/ZFitterBosonPart.cxx, J. Haller, 2011-03-03
"All 6 functions calculated here are not quoted, but copied from zfitter/dizet "
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Correct references:

D. Bardin, G. Passarino, "The Standard Model in the Making", Oxford University Press, 1999

D. Bardin, P. Christova, O. Fedorenko,
"ON THE LOWEST ORDER ELECTROWEAK CORRECTIONS TO SPIN-1/2 FERMION SCATTERING,
(II). The one-loop amplitudes", Nucl. Phys. B197 (1982) 1-44

D. Bardin, M. Bilenky, S. Riemann, T. Riemann et al.,hep-ph/9709229, "Electroweak Working Group Report"
section 4.4: ZFITTER basics, p. 86-91

D. Bardin, M. Bilenky, P. Christova, M. Jack, L. Kalinovskaya, A. Olchevski,
S. Riemann, T. Riemann, hep-ph/9908433,
"ZFITTER v.6.21 A Semi-Analytical Program for Fermion Pair Production in e+e- Annihilation",
CPC 133 (2001) 229–395
==================================================================================================
original file begins here, with insertions from zfitter and coments from zfitter group
==================================================================================================

/*****************************************************************************
***
 * Project: GSM - Electroweak fitting package                                *
 * Package: GSM                                                              *
 * Class  : ZFitterBosonPart                                                 *
 *                                                                           *
 * Description:                                                              *
 *      Auxiliary Theory for bosonic part of self energies                   *
 *      one loop core of ZFitter option                                      *
 *                                                                           *
 * Papers:                                                                   *
 *      The Standard Model in the Making                                     *
 *      Nucl. Phys. B197 (1982) 1-44 / first summary of one loop core        *
 *      hep-ph/9709299, hep-ph/9908433                                       *
 *                                                                           *
 *                                                                           *
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 *                                                                           *
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 *                                                                           *
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 * (http://mva.sourceforge.net/license.txt)                                  *
 *                                                                           *
 * File and Version Information:                                             *
 * $Id: ZFitterBosonPart.cxx,v 1.9 2008/05/18 15:51:12 mgoebel Exp $
 *****************************************************************************/
#include <math.h>

#include "TMath.h"

#include "Gfitter/GMath.h"
#include "Gfitter/GConstants.h"
#include "Gfitter/GTheory.h"
#include "Gfitter/GTheoryRef.h"
#include "Gfitter/GParameterRef.h"
#include "Gfitter/GReference.h"
#include "Gfitter/GVariable.h"
#include "Gfitter/GStore.h"

#include "GSM/ZFitterBosonPart.h"
#include "GSM/GSMMath.h"
#include "GSM/MH.h"

using std::complex;
```

```
using namespace Gfitter;

GSM::ZFitterBosonPart::ZFitterBosonPart()
   : Gfitter::GAuxTheory(),
     m_isUpToDate_Update( kFALSE )
{

   SetTheoryName( GetName() );
   SetExistDerivative( kFALSE );

   const TString& logMH = gStore()->GetVariable( "GSMFlags::logMH" )->GetStringValue();
   m_logger << kINFO << "Using logMH: \"" << logMH << "\"" << GEndl;

   if      (logMH == "Yes" ) m_logMH  = kTRUE;
   else if (logMH == "No" )  m_logMH  = kFALSE;
   else {
      m_logger << kFATAL << "unknown value for \"GSMFlags::logMH\": \"" << logMH << "\""
               << ". Possible are: \"Yes\" and \"No\"\""
               << GEndl;
   }

   BookParameter( "MZ"      , & p_MZ );
   BookTheory   ( "GSM::MW" , & t_MW );
   BookTheory   ( "GSM::MH" , & t_MH );
}

void GSM::ZFitterBosonPart::UpdateLocalFlags( GReference& /* ref */ )
{
   m_isUpToDate_Update = kFALSE;
}

void GSM::ZFitterBosonPart::Update()
{
   if (m_isUpToDate_Update) return;

   // now, it is uptodate (I mean... it will be)
   m_isUpToDate_Update = kTRUE;

   Double_t MH      = GetMH().GetValue(); //p_MH;
   if( m_logMH ) MH = TMath::Exp(GetMH().GetValue() ); //p_MH );

   Double_t MZ2 = p_MZ*p_MZ;
   Double_t MW2 = GMath::IPow( GetMW(), 2 );
   Double_t MH2 = MH*MH;

   m_R         = MW2/MZ2;
   m_rw        = MH2/MW2;
   m_rz        = MH2/MZ2;

   // Get L and J functions
   m_L0 = GSMMath::L( -MZ2, MW2, MW2 )/MZ2;
   m_L1 = GSMMath::L( -MW2, MH2, MW2 )/MW2;
   m_L2 = GSMMath::L( -MW2, MW2, MZ2 )/MW2;
   m_L3 = GSMMath::L( -MZ2, MH2, MZ2 )/MW2;
   m_L4 = GSMMath::L( -MZ2, MW2, MW2 )/MW2;
   m_J1 = GSMMath::J( -MW2, MH2, MW2 )*MH2;
   m_J3 = GSMMath::J( -MZ2, MH2, MZ2 )*MH2/m_R;

   SetUpToDate();
}

// see to all equation for a deeper understanding
// The Standard Model in the Making page 192-195
// hep-ph/9908433v3 page 152-155 and entire Appendix A
// Nucl. Phys. B197 (1982) 1-44

// eq.(259) of  hep-ph/9709229v1
// Z boson self energy at MZ
```

```
complex<Double_t> GSM::ZFitterBosonPart::GetZbAtMZ()
{
   Update();
   return ( 35.0/(18.0*m_R) + 35.0/18.0 - 34.0/3.0*m_R - 8.0*m_R*m_R - m_rw/2.0
            + m_rw*m_rw*m_R/12.0 + m_rw*(-3.0/4.0 + m_rz/4.0 - m_rz*m_rz/24.0)*TMath::Log(m_rz)
            + 5.0/(6.0*m_R)*TMath::Log(m_R) + (0.5 -m_rz/6.0 + m_rz*m_rz/24.0)*m_L3
            + (1.0/24.0 + 2.0/3.0*m_R -17/6.0*m_R*m_R - 2.0*m_R*m_R*m_R)*m_L4 );
}
"-----------------------------------------------------------------------------------------------------"
"compare to zfitter/dizet6_42.f  lines 1977 ff: [even the linebreaks agree]"

     XZM1=35.D0/18.D0/R+35.D0/18.D0-34.D0/3.D0*R-8.D0*R2-RW/2.D0
     *    +RW2*R/12.D0+RW*(-3.D0/4.D0+RZ/4.D0-RZ2/24.D0)*ALRZ
     *    +5.D0/6.D0/R*ALR+(0.5D0-RZ/6.D0+RZ2/24.D0)*XL3
     *    +(1.D0/24.D0+2.D0/3.D0*R-17.D0/6.D0*R2-2.D0*R3)*XL4

 comment: eq.(259) Z_b(M_Z^2) of  hep-ph/9709229v1
 looks different because was 'optimized' by us for printing.
See: ZFitterBosonPart-working-group-report-9709229v1.pdf
"-----------------------------------------------------------------------------------------------------
-------"

// eq.(260) of  hep-ph/9709229v1
// derivative of Z boson self energy at MZ
complex<Double_t> GSM::ZFitterBosonPart::GetZbFAtMZ()
{
   Update();
   return ( -4.0*m_R*m_R + 17.0/3.0*m_R - 23.0/9.0 + 5.0/(18.0*m_R) - m_rw/2
            + m_rw*m_rz/6.0 - TMath::Log(m_R)/(12.0*m_R)
            + m_rw*(-3.0/4.0 + 3.0/8.0*m_rz - m_rz*m_rz/12.0)*TMath::Log(m_rz) +
            0.5/m_R*TMath::Log(m_rz)
            + (-m_R*m_R*m_R + 7.0/6.0*m_R*m_R - 17.0/12.0*m_R - 1.0/8.0)*m_L4
            + (0.5 -5.0/24.0*m_rz + 1.0/12.0*m_rz*m_rz)*m_L3 + 0.5*m_J3 );
}
"-------------------------------------------------------------------"
"compare to zfitter/dizet6_42.f  lines 1983 ff: [even the linebreaks agree]"

      XZFM1=-4.D0*R2+17.D0/3.D0*R-23.D0/9.D0+5.D0/18.D0/R-RW/2.D0
     *     +RW*RZ/6.D0-ALR/12.D0/R
     *     +RW*(-3.D0/4.D0+3.D0/8.D0*RZ-RZ2/12.D0)*ALRZ+0.5D0/R*ALRZ
     *     +(-R*R2+7.D0/6.D0*R2-17.D0/12.D0*R-1.D0/8.D0)*XL4
     *     +(0.5D0-5.D0/24.D0*RZ+1.D0/12.D0*RZ2)*XL3+0.5D0*XJ3

 comment: eq.(260) Z_b^F(M_Z^2) of  hep-ph/9709229v1
 looks different because was 'optimized' by us for printing.
See: ZFitterBosonPart-working-group-report-9709229v1.pdf
"-----------------------------------------------------------------------------------------------------
------------------"


// eq.(257) of  hep-ph/9709229v1
// W boson self ennergy at 0 GeV
complex<Double_t> GSM::ZFitterBosonPart::GetWbAt0()
{
   Update();
   return ( 5.0/(8.0*m_R) - 17.0/4.0 + 5.0/8.0*m_R*(1.0+m_R) - m_rw/8.0
            + 3.0/4.0*m_rw/(1-m_rw)*TMath::Log(m_rw) + (3.0/(4.0*m_R) + 9.0/4.0 - 3.0/(1-
            m_R))*TMath::Log(m_R) );
}
"-----------------------------------------------------------------------------------------------------
-"
"compare to zfitter/dizet6_42.f  lines 1969 ff: [even the linebreaks agree]

     W0=5.D0/8.D0/R-17.D0/4.D0+5.D0/8.D0*R*(1.D0+R)-RW/8.D0
     *  +3.D0/4.D0*RW/RW1*ALRW+(3.D0/4.D0/R+9.D0/4.D0-3.D0/R1)*ALR

 comment: eq.(257) W_b(0) of  hep-ph/9709229v1
 looks [a bit] different because was 'optimized' by us for printing.
See: ZFitterBosonPart-working-group-report-9709229v1.pdf
"-----------------------------------------------------------------------------------------------------
--"
```

```
// eq.(258) of  hep-ph/9709229v1
// W boson self ennergy at MW
complex<Double_t> GSM::ZFitterBosonPart::GetWbAtMW()
{
   Update();
   return ( 1.0/(12.0*m_R*m_R) + 23.0/(12.0*m_R) - 157.0/9.0 - m_rw/2.0 + m_rw*m_rw/12.0
            - m_rw*(3.0/4.0 - m_rw/4.0 + m_rw*m_rw/24.0)*TMath::Log(m_rw)
            + (1.0/(24.0*m_R*m_R*m_R) + 7.0/(12.0*m_R*m_R) - 7.0/(2.0*m_R))*TMath::Log(m_R)
            + (0.5 -m_rw/6.0 + m_rw*m_rw/24.0)*m_L1
            + (1.0/(24.0*m_R*m_R) + 2.0/(3.0*m_R) - 17.0/6.0 - 2.0*m_R)*m_L2 );
}
"-----------------------------------------------------------------------------------------------------------
-"
"compare to zfitter/dizet6_42.f  lines 1972 ff: [even the linebreaks agree]

      XWM1=1.D0/12.D0/R2+23.D0/12.D0/R-157.D0/9.D0-RW/2.D0+RW2/12.D0
     *    -RW*(3.D0/4.D0-RW/4.D0+RW2/24.D0)*ALRW
     *    +(1.D0/24.D0/R3+7.D0/12.D0/R2-7.D0/2.D0/R)*ALR
     *    +(0.5D0-RW/6.D0+RW2/24.D0)*XL1
     *    +(1.D0/24.D0/R2+2.D0/3.D0/R-17.D0/6.D0-2.D0*R)*XL2

 comment: eq.(258) W_b(M_W^2) of  hep-ph/9709229v1
 looks different because was 'optimized' by us for printing.
See: ZFitterBosonPart-working-group-report-9709229v1.pdf
"-----------------------------------------------------------------------------------------------------------
-"

// eq.(A.7) of Nucl. Phys. B197 (1982)
// fermionic and bosonic part were added together in that eq.
// photon Z mixing function
complex<Double_t> GSM::ZFitterBosonPart::GetMbPhoZAtMZ()
{
   Update();
   return ( 2.0/(9.0*m_R) + 35.0/18.0 - 34.0/3.0*m_R - 8.0*m_R*m_R
            + (1.0/24.0 + 2.0/3.0*m_R - 17.0/6.0*m_R*m_R - 2.0*m_R*m_R*m_R)*m_L4 );
}
"-----------------------------------------------------------------------------------------------------------
-"
"compare to zfitter/dizet6_42.f  lines 1988 ff: [even the linebreaks agree]

     XAMM1=2.D0/9.D0/R+35.D0/18.D0-34.D0/3.D0*R-8.D0*R2
     *     +(1.D0/24.D0+2.D0/3.D0*R-17.D0/6.D0*R2-2.D0*R*R2)*XL4

NPB197, p. 29, eq. (A7): A(q^2/M_W^2), it is a similar, but quite different notations,
is evidently not the origin of MbPhoZAtMZ.
See: ZFitterBosonPart-bardin-christo-fedor-NPB197-1982.pdf
"-----------------------------------------------------------------------------------------------------------
-"
"
// eq.(A.3) of Nucl. Phys. B197 (1982)
// fermionic and bosonic part were added together in that eq.
// derivative of W boson self energy at MW
complex<Double_t> GSM::ZFitterBosonPart::GetWbFAtMW()
{
   Update();
   return ( m_R - 34/9.0 + 2/m_R + 1/(6.0*m_R*m_R) - m_rw/2.0 + m_rw*m_rw/6.0
            + (3.0*m_R + 5/2.0 - 17/(4.0*m_R) + 7/(8.0*m_R*m_R) + 1/(12.0*m_R*m_R*m_R))*TMath::Log(m_R)
            + (0.5 - 3.0*m_rw/4.0 + 3.0*m_rw*m_rw/8.0 - GMath::IPow(m_rw,3)/12.0)*TMath::Log(m_rw)
            + (-m_R/2.0 - 2.0 + 25/(24.0*m_R) + 1/(12.0*m_R*m_R))*m_L2
            + (0.5 - 5*m_rw/24.0 + m_rw*m_rw/12.0)*m_L1 + 0.5*m_J1 );
}
"-------------------------------------------------------------------------------"
"compare to zfitter/dizet6_42.f  lines 1990 ff: [even the linebreaks agree]"

     XWFM1=R-34.D0/9.D0+2.D0/R+1.D0/6.D0/R2-RW/2.D0+RW**2/6.D0
     *     +(3.D0*R+5.D0/2.D0-17.D0/4.D0/R+7.D0/8.D0/R2+1.D0/12.D0/R3)
     *     *ALR+(0.5D0-3.D0*RW/4.D0+3.D0*RW2/8.D0-RW**3/12.D0)*ALRW
     *     +(-R/2.D0-2.D0+25.D0/24.D0/R+1.D0/12.D0/R2)*XL2
     *     +(0.5D0-5.D0*RW/24.D0+RW2/12.D0)*XL1+0.5D0*XJ1

NPB197, p. 28, eq. (A3): W_F(-1), it is a similar, but quite different notations,
is evidently not the origin of WbFAtMW; contains several terms not appearing here.
See: ZFitterBosonPart-bardin-christo-fedor-NPB197-1982.pdf
```

```
"-----------------------
```