New Progress on FDC project
- Automatic deduction renormalization counter term

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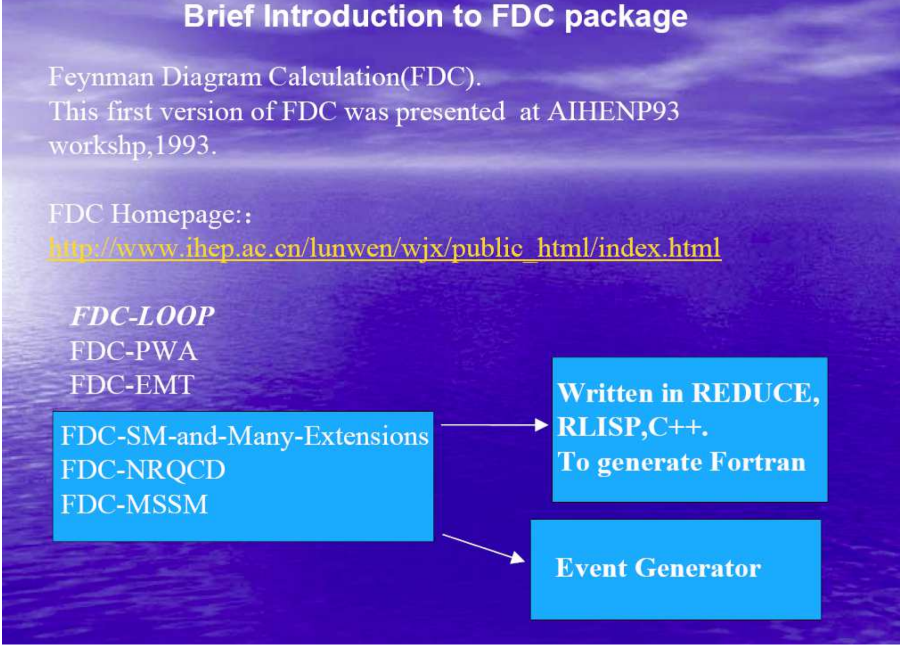
Introduction

- It is well known that precision theoretical description on high energy phenomonolgy must be achieved.
- Therefore, higher-order perturbative calculations in QFT for SM are required for signal and background.
- FDC project is aimed at automatic calculation on these calculation and already can do next-leading-order(NLO) calculation automatically.
- Based on FDC, there are already many hard works been achieved in last 8 years.
- Recent progress for FDC project will be introduced in this talk.

Brief Introduction to FDC package



Feynman Diagram Calculation(FDC).
This first version of FDC was presented at AIHENP93 workshp,1993.

FDC Homepage::
http://www.ihep.ac.cn/lunwen/wjx/public_html/index.html

FDC-LOOP
FDC-PWA
FDC-EMT

FDC-SM-and-Many-Extensions
FDC-NRQCD
FDC-MSSM

Written in REDUCE, RLISP,C++.
To generate Fortran

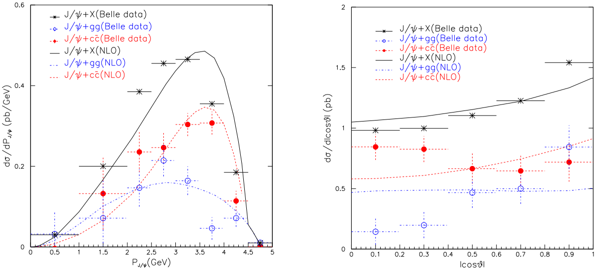
Event Generator

Introduction

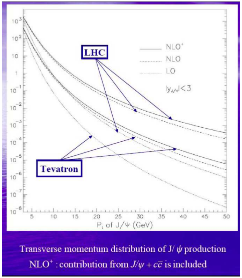
- The results are obtained analytically.
- Two ways to generate square of amplitude:
- Automatically phase space treatment
- To automatically construct the Lagrangian and deduce the Feynman rules for SM, MSSM
- First version of "FDC-LOOP" was completed by the end of 2007, used and improved since then.
- Many work on QCD correction are finished and published.
- First version of FDC-PWA was completed on 2001 and improved 2003, used by BES experimental group for partial-wave analysis

The calculations by using FDC-loop in last 8 years

- Our work concentrate on QCD correction to heavy quarkonium production and polarization in B-factory, z boson decay, Υ decay, HERA, Tevatron, LHC.
- It is found that that QCD corrections to these processes are very important.

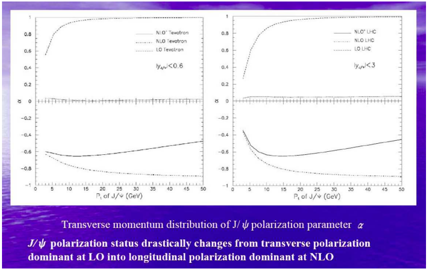


Momentum distribution of J/ψ for $e^+e^- \to J/\psi + gg$ at QCD NLO. PRL102, (2009) B. Gong and J. X. Wang



Transverse momentum distribution of J/ ψ production

NLO$^+$: contribution from $J/\psi + c\bar{c}$ is included



Transverse momentum distribution of J/ ψ polarization parameter α

J/ψ polarization status drastically changes from transverse polarization dominant at LO into longitudinal polarization dominant at NLO

P_t distribution of J/ψ polarization at QCD NLO. PRL100,232001 (2008), B. Gong and J. X. Wang

QCD Correction to prompt $J/\psi({}^3S_1^1,\ {}^1S_0^8,\ {}^3S_1^8,\ {}^3P_J^8)$ polarization

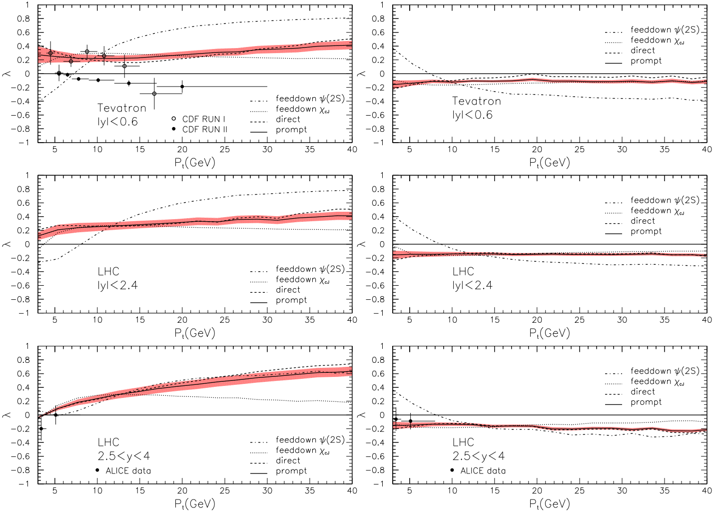
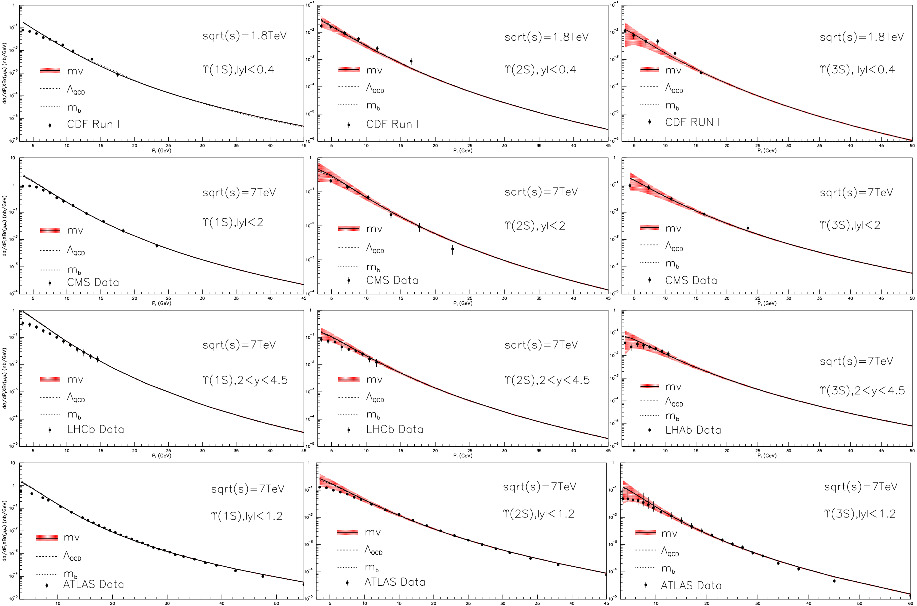


Figure: Polarization parameter λ of prompt J/ψ hadroproduction in helicity(left) and CS(right) frames.

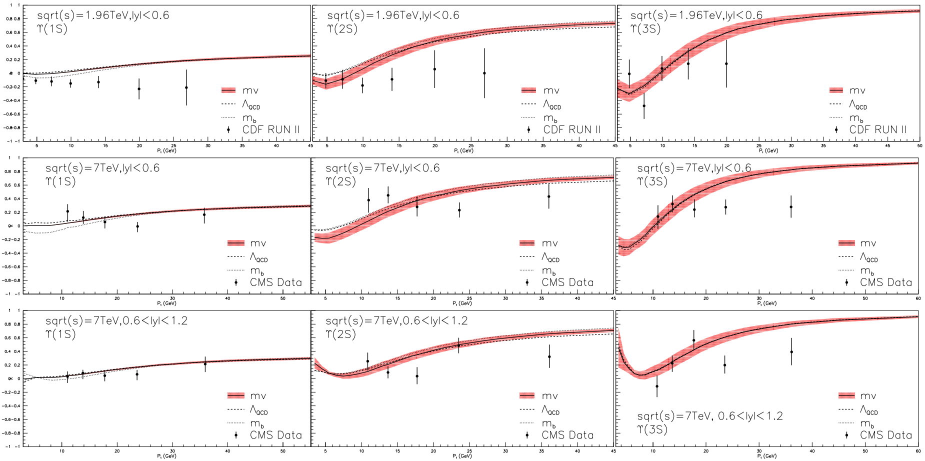
PRL110, 042002, 2013, Bin Gong, Lu-Ping Wan, Jian-Xiong Wang and Hong-Fei Zhang

QCD Correction to $\Upsilon(1S, 2S, 3S)$ production



PRL 112, 032001, 2014, by Bin Gong, Lu-Ping Wan, Jian-Xiong Wang and Hong-Fei Zhang

QCD Correction to $\Upsilon(1S, 2S, 3S)$ polarization



PRL 112, 032001, 2014, by Bin Gong, Lu-Ping Wan, Jian-Xiong Wang and Hong-Fei Zhang

Figure: Polarization parameter λ of prompt $\Upsilon(1S, 2S, 3S)$ hadroproduction in helicity frame

Recent Progress in FDC project

- New algorithm to construct and triangulate convex polyhedral cone and it's application in higher order perturbative QFT calculation (I presented the talk on High1-2016 workshop)
- automatic counter terms generation , automatic calculation of renormalization constant (This talk on High1-2017 workshop)

Tree-level Lagrangian construction and Feynman rules generation

- 1994, Standard Model, 3 gauge group, 3 generation quark and leptons, more than 100 interaction vertices
- 2000, MSSM, 3 gauge group and suppersymmetry, 3 generation quark and leptons with their supper partners, more than 5000 interaction vertices
- 2008, QCD one-loop counter term input by hand.

One-loop counter terms generation in last year

To construct counter terms and calculatioin all the renormalization constats for QCD or eletro-weak one-loop renormalization.

- Very simple description input for first principle model with $SU(n)$ gauge symmetry, such as the Standard Model, two-higgs doublet model, ...
- Easy to add different matter fields
- Different gauge can be easiy choosed, such as unitary gauge, Feynman-tohoft gauge, R-ksi Gauge, Landau gauge, ...
- Different renormalization scheme, such as Keyto-scheme, European-scheme, On-shell or MS-bar scheme for QCD renormalization choice.
- For MSSM one-loop renormalization is still under construction.
- Two-loop counter terms generation are under construction

European scheme(gauge-symmetric scheme)

The on-shell subtraction conditions

1. $R_e\hat{\Sigma}(M_w^2) = R_e\hat{\Sigma}^{zz}(M_z^2) = R_e\hat{\Sigma}^f(\not{p} = m_f) = 0$
2. $\hat{\Gamma}_\mu^{\gamma ee}(k^2 = 0, \not{p} = \not{q} = m_e) = ie\gamma_\mu$
3. $\hat{\Gamma}^{\gamma z}(0) = 0$
4. $\frac{\partial\hat{\Gamma}^{\gamma\gamma}}{\partial k^2}(0) = 0$
5. $\lim\limits_{\not{k} \to m_-} \frac{1}{\not{k} - m_-}\hat{\Gamma}^f(k)\mu_-(k) = 0$ (if μ_- is the wave function for $I_3 = -1/2$ particle.)

The last condition is formated for charged leptons and quarks with $I_3 = -1/2$.Thus we could drived the renormalization constant Z_L and Z_R^-.In the same time,the Z_L also determines the $I_3 = +1/2$ (in this scheme,we keep the Su(2) gauge symmetry,so for Su(2) doulet we must have same renormalization constant). For above case the residue of $I_3 = +1/2$ quark and nertrino propagator is not equal to 1.

European scheme(gauge-symmetric scheme)

So the γ_μ term and $\gamma_\mu\gamma_5$ term in $S_F^f(k)$ is

$$S_{\gamma_\mu}^f(k) = \frac{i}{\not{k}-m_f}\not{k}\Gamma_V^f(k^2)\frac{i}{\not{k}-m_f}$$

$$S_{\gamma_5}^f(k) = \frac{i}{\not{k}-m_f}\not{k}\gamma_5\Gamma_A^f(k^2)\frac{i}{\not{k}-m_f}$$

We write them in a siplifying form i.e.

$$S_{\gamma_5}^f(k) = \frac{1}{(k^2-m_f^2)^2}(k^2 - m_f^2)\not{k}\Gamma_A^f(k^2)$$

$$S_{\gamma_\mu}^f(k) = \frac{1}{(k^2-m_f^2)^2}(\not{k} + m_f)(\not{k} + m_f)\not{k}\gamma_5\Gamma_V^f(k^2)$$

Compare the two equation we find that $S_5^f(k)$ there is a $k^2 - m_f^2$ factor.

That's why we say the taylor expansion at $k^2 = m^2$ of γ_5 term has no zero order term,it begin with one order.

The renormalization of mixing fields in electroweak

It would be different for mixing fields when we do renormalization.

for example:

$$\begin{pmatrix} Z_\mu \\ A_\mu \end{pmatrix} = \begin{pmatrix} cos\theta_w & -sin\theta_w \\ sin\theta_w & cos\theta_w \end{pmatrix} \begin{pmatrix} W_\mu^3 \\ B_\mu \end{pmatrix} \tag{1}$$

We do renromalization as follow:

$$\begin{pmatrix} Z_\mu \\ A_\mu \end{pmatrix}_0 = \begin{pmatrix} 1+\frac{1}{2}\delta Z_Z Z & \frac{1}{2}\delta Z_Z A \\ \frac{1}{2}\delta Z_A Z & 1+\frac{1}{2}\delta Z_A A \end{pmatrix} \begin{pmatrix} Z_\mu \\ A_\mu \end{pmatrix} \tag{2}$$

Inverting the matrix, we obtain the renormalized propagator as

$$\begin{aligned}
&(i\hat{D}_{WA}(q^2))_{\mu\nu} \\
= \; & -g_{\mu\nu} \begin{pmatrix} \frac{1}{q^2-M_Z^2-\hat{\Pi}_{ZZ}} & \frac{1}{q^2-m_\gamma^2} \frac{\hat{\Pi}_{AZ}}{q^2-M_Z^2-iIm\hat{\Pi}_{ZZ}} \\ \frac{1}{q^2-m_\gamma^2} \frac{\hat{\Pi}_{AZ}}{q^2-M_Z^2-iIm\hat{\Pi}_{ZZ}} & \frac{1}{q^2-m_\gamma^2-\hat{\Pi}_{AA}} \end{pmatrix} \\
& -i\frac{q_\mu q_\nu}{q^2} \begin{pmatrix} \frac{1}{q^2-M_Z^2-\hat{\Pi}_{ZZ}} \frac{q^2(\xi_Z-1)+\xi_Z\hat{\Pi}^L_{ZZ}}{q^2-\xi_Z M_Z^2-\xi_Z(\hat{\Pi}^L_{ZZ}+\hat{\Pi}_{ZZ})} & \frac{1}{q^2-m_\gamma^2} \frac{\hat{\Pi}^L_{AZ}}{q^2-M_Z^2-iIm\hat{\Pi}_{ZZ}} \\ \frac{1}{q^2-m_\gamma^2} \frac{\hat{\Pi}^L_{AZ}}{q^2-M_Z^2-iIm\hat{\Pi}_{ZZ}} & \frac{1}{q^2-m_\gamma^2} \frac{q^2(\xi_\gamma-1)+\xi_\gamma\hat{\Pi}^L_{AA}}{q^2-\xi_\gamma m_\gamma^2-\xi_\gamma(\hat{\Pi}^L_{AA}+\hat{\Pi}_{AA})} \end{pmatrix},
\end{aligned} \tag{c.12}$$

which becomes to one-loop order

$$\begin{aligned}
&(i\hat{D}_{WA}(q^2))_{\mu\nu} \\
= \; & -ig_{\mu\nu} \begin{pmatrix} \frac{1}{q^2-M_Z^2} & 0 \\ 0 & \frac{1}{q^2-m_\gamma^2} \end{pmatrix} \\
& -iq_\mu q_\nu \begin{pmatrix} \frac{\xi_Z-1}{(q^2-M_Z^2)(q^2-\xi_Z M_Z^2)} & 0 \\ 0 & \frac{\xi_\gamma-1}{(q^2-m_\gamma^2)(q^2-\xi_\gamma m_\gamma^2)} \end{pmatrix} \\
& -ig_{\mu\nu} \begin{pmatrix} \frac{1}{q^2-M_Z^2}\hat{\Pi}_{ZZ}\frac{1}{q^2-M_Z^2} & \frac{1}{q^2-m_\gamma^2}\hat{\Pi}_{AZ}\frac{1}{q^2-M_Z^2} \\ \frac{1}{q^2-m_\gamma^2}\hat{\Pi}_{AZ}\frac{1}{q^2-M_Z^2} & \frac{1}{q^2-m_\gamma^2}\hat{\Pi}_{AA}\frac{1}{q^2-m_\gamma^2} \end{pmatrix} \\
& -i\frac{q_\mu q_\nu}{q^2} \begin{pmatrix} C_{ZZ}\hat{\Pi}_{ZZ} + \xi_Z^2\frac{\hat{\Pi}^L_{ZZ}}{(q^2-\xi_Z M_Z^2)^2} & \frac{1}{q^2-m_\gamma^2}\hat{\Pi}^L_{AZ}\frac{1}{q^2-M_Z^2} \\ \frac{1}{q^2-m_\gamma^2}\hat{\Pi}^L_{AZ}\frac{1}{q^2-M_Z^2} & C_{\gamma\gamma}\hat{\Pi}_{AA} + \xi_\gamma^2\frac{\hat{\Pi}^L_{AA}}{(q^2-\xi_\gamma m_\gamma^2)^2} \end{pmatrix},
\end{aligned} \tag{c.13}$$

Input file for Standard Model at electroweak NLO

```
%------------------------ Gauge fields ------------------------
gaugefields:=
%No.  Name  SU(n)   notation  couping      breaking
  '((1    u         1          b         g1               yes  )
    (2    su        2          a         g                yes  )
    (3    su        3          gs        g3               no    ))$
%----------------------- Matter fields -------------------------
matterinput:={{name,  2*spin,  chiral,      1,      2,    3},
               { hig,        0  ,     rl  ,        1,     2,    0},
               { el ,         1,         l  ,       -1,     2,    0},
               { er ,          1,         r  ,      -2,     0,    0},
               { q1l ,        1,         l  ,       1/3,    2,    3},
               { q1dr,        1,         r  ,      -2/3,    0,    3},
               { q1ur,        1,         r  ,       4/3,    0,    3}}$
gauge_boson_redefine:={
               a(1,~v) => (w(1,v)+w(-1,v))/2**0.5,
               a(2,~v) => (w(-1,v)-w(1,v))/2**0.5/i,
               a(3,~v) => z(0,v), b(~v)   => p(0,v) };
vancumexpectation:='((hig v0));

%        name  n_group   1_componet  2_componet  ...
 mdefl:={  {hig,   2,          xx2   , (v0+h0-i*xx3)/2**0.5},
           {el ,    2,          nue   ,               ef             },
           {er ,    2,          ef                                    },
           {q1l ,  2,          qu   ,                qd             },
           {q1dr, 2,          qd                                    },
           {q1ur, 2,          qu                                  }}$
```

```
realfamily:='(  (q1l q2l q3l)    (q1dr q2dr q3dr)
 (q1ur q2ur q3ur)    (qu qc qt)    (qd qs qb) (el mul taul
(er mur taur)  (ef mu tau)  (nue numu nut));

phymass:={{w, wm}, {z, zm}, {p, 0}, {h0, hm},
{ef, fme}, {nue, 0},{mu, fmmu},{numu, 0},{tau, fmtau},
{nut, 0},{qd, fmd}, {qu, fmu},{qs, fms}, {qc, fmc},
{qb, fmb}, {qt, fmt}}$

phyinput:={g3,g,theta,wm, hm,fme, fmmu,fmtau,fmd,
 fmu,fms, fmc,fmb, fmt}$

construles:={ g1=>g*sin(theta)/cos(theta)};

expriment_easy_list:={
{g,         replaceby,  ge,  -i*ge*gg(l,v), {p,ef,ef}},
{theta,   replaceby,  zm}  };

charge_def:=tp(2,3)+tp(1,1)/2;

renormalization:=‘before_broken;   %European schem
%renormalization:=‘after_broken;   %Kyoto scheme

%ms_list:='(g3 );

symbolic(rform:='(1 2 ));
symbolic(rloop:='((g . 2)));
```

Generatetd File: “gauge_fix_term” Can be used to choose different Gague

```
fyl:={
{p, ksi1,  sin(theta)*pd(a(3,v),v)+cos(theta)*pd(b(v),v),sin(theta)*(mutiplet(-1,2,hig,2,xx2(-1),
(h0(0)+xx3(0)*i)/sqrt(2))*tp(1,2,2,3)*mutiplet(1,2,hig,2,0,v0/sqrt(2))*g*i-mutiplet(1,2,hig,2,0,v0
/sqrt(2))*tp(1,2,2,3)*mutiplet(1,2,hig,2,xx2(1),(h0(0)-xx3(0)*i)/sqrt(2))*g*i)/
2+cos(theta)*(mutiplet(-1,2,hig,2,xx2(-1),(h0(0)+xx3(0)*i)/sqrt(2))*mutiplet(1,2,hig,2,0,v0/
sqrt(2))*g1*i-mutiplet(-1,2,hig,2,0,
v0/sqrt(2))*mutiplet(1,2,hig,2,xx2(1),(h0(0)-xx3(0)*i)/sqrt(2))*g1*i)/2,
gh(-1,2,3)*sin(theta)+gh(-1,1)*cos(theta)},

{z,  ksi2, cos(theta)*pd(a(3,v),v)+(-sin(theta))*pd(b(v),v),cos(theta)*(mutiplet(-1,2,hig,2,xx2(-1),
(h0(0)
+xx3(0)*i)/sqrt(2))*tp(1,2,2,3)*mutiplet(1,2,hig,2,0,v0/sqrt(2))*g*i-mutiplet(-1,2,hig,2,0,v0/sqrt(2))*
tp(1,2,2,3)*mutiplet(1,2,hig,2,xx2(1),(h0(0)-xx3(0)*i)/sqrt(2))*g*i)/2+(-sin(theta))*(mutiplet(-1,2,hig,
2,xx2(-1),(h0(0)+xx3(0)*i)/sqrt(2))*mutiplet(1,2,hig,2,0,v0/sqrt(2))*g1*i-mutiplet(-1,2,hig,2,0,v0
/sqrt(2))*mutiplet(1,2,hig,2,xx2(1),(h0(0)-xx3(0)*i)/sqrt(2))*g1*i)/2,
gh(-1,2,3)*cos(theta)-gh(-1,1)*sin(theta)},

{a(1),  ksi3,  pd(a(1,v),v),(mutiplet(-1,2,hig,2,xx2(-1),(h0(0)+xx3(0)*i)/sqrt(2))*tp(1,2,2,1)*
mutiplet(1,2,hig,2,0,v0/sqrt(2))*g*i-mutiplet(-1,2,hig,2,0,v0/sqrt(2))*tp(1,2,2,1)*mutiplet(1,2,hig,2,
xx2(1),(h0(0)-xx3(0)*i)/sqrt(2))*g*i)/2,  gh(-1,2,1)},

{a(2),  ksi3,  pd(a(2,v),v),(mutiplet(-1,2,hig,2,xx2(-1),(h0(0)+xx3(0)*i)/
sqrt(2))*tp(1,2,2,2)*mutiplet(1,2,
hig,2,0,v0/sqrt(2))*g*i-mutiplet(-1,2,hig,2,0,v0/sqrt(2))*tp(1,2,2,2)*mutiplet(1,2,hig,2,xx2(1),
(h0(0)-xx3(0)*i)/sqrt(2))*g*i)/2,    gh(-1,2,2)},

{gs(ic10),   ksi4   ,pd(gs(ic10,v),v),0,   gsg(-1,ic10)}}$

r_ksi_value:='(  (ksi1 . 1)     (ksi2 . 1)     (ksi3 . 1)    (ksi4 . 1))$    %Default Feynman-tohoft  gaige
```

Generatetd File: “gauge_fix_term” Can be used to choose different Gague

```
fyl:={
{p, ksi1,  sin(theta)*pd(a(3,v),v)+cos(theta)*pd(b(v),v),sin(theta)*(mutiplet(-1,2,hig,2,xx2(-1),
(h0(0)+xx3(0)*i)/sqrt(2))*tp(1,2,2,3)*mutiplet(1,2,hig,2,0,v0/sqrt(2))*g*i-mutiplet(1,2,hig,2,0,v0
/sqrt(2))*tp(1,2,2,3)*mutiplet(1,2,hig,2,xx2(1),(h0(0)-xx3(0)*i)/sqrt(2))*g*i)/
2+cos(theta)*(mutiplet(-1,2,hig,2,xx2(-1),(h0(0)+xx3(0)*i)/sqrt(2))*mutiplet(1,2,hig,2,0,v0/
sqrt(2))*g1*i-mutiplet(-1,2,hig,2,0,
v0/sqrt(2))*mutiplet(1,2,hig,2,xx2(1),(h0(0)-xx3(0)*i)/sqrt(2))*g1*i)/2,
gh(-1,2,3)*sin(theta)+gh(-1,1)*cos(theta)},

{z,  ksi2, cos(theta)*pd(a(3,v),v)+(-sin(theta))*pd(b(v),v),cos(theta)*(mutiplet(-1,2,hig,2,xx2(-1),
(h0(0)
+xx3(0)*i)/sqrt(2))*tp(1,2,2,3)*mutiplet(1,2,hig,2,0,v0/sqrt(2))*g*i-mutiplet(-1,2,hig,2,0,v0/sqrt(2))*
tp(1,2,2,3)*mutiplet(1,2,hig,2,xx2(1),(h0(0)-xx3(0)*i)/sqrt(2))*g*i)/2+(-sin(theta))*(mutiplet(-1,2,hig,
2,xx2(-1),(h0(0)+xx3(0)*i)/sqrt(2))*mutiplet(1,2,hig,2,0,v0/sqrt(2))*g1*i-mutiplet(-1,2,hig,2,0,v0
/sqrt(2))*mutiplet(1,2,hig,2,xx2(1),(h0(0)-xx3(0)*i)/sqrt(2))*g1*i)/2,
gh(-1,2,3)*cos(theta)-gh(-1,1)*sin(theta)},

{a(1),  ksi3,  pd(a(1,v),v),(mutiplet(-1,2,hig,2,xx2(-1),(h0(0)+xx3(0)*i)/sqrt(2))*tp(1,2,2,1)*
mutiplet(1,2,hig,2,0,v0/sqrt(2))*g*i-mutiplet(-1,2,hig,2,0,v0/sqrt(2))*tp(1,2,2,1)*mutiplet(1,2,hig,2,
xx2(1),(h0(0)-xx3(0)*i)/sqrt(2))*g*i)/2,  gh(-1,2,1)},

{a(2),  ksi3,  pd(a(2,v),v),(mutiplet(-1,2,hig,2,xx2(-1),(h0(0)+xx3(0)*i)/
sqrt(2))*tp(1,2,2,2)*mutiplet(1,2,
hig,2,0,v0/sqrt(2))*g*i-mutiplet(-1,2,hig,2,0,v0/sqrt(2))*tp(1,2,2,2)*mutiplet(1,2,hig,2,xx2(1),
(h0(0)-xx3(0)*i)/sqrt(2))*g*i)/2,    gh(-1,2,2)},

{gs(ic10),   ksi4   ,pd(gs(ic10,v),v),0,   gsg(-1,ic10)}}$

r_ksi_value:='(  (ksi1 . infinit)    (ksi2 . infinit)    (ksi3 . infinit)    (ksi4 . 1))$    %Unitary Gauge
```

Input file for Standard Model at QCD NLO by using onshell scheme

```
%------------------------ Gauge fields ------------------------
gaugefields:=
%No.  Name  SU(n)   notation  couping     breaking
  '((1    u        1         b        g1              yes  )
    (2    su       2         a        g               yes  )
    (3    su       3         gs       g3              no    ))$
%----------------------- Matter fields -------------------------
matterinput:={{name,  2*spin,  chiral,     1,     2,    3},
              { hig,        0 ,     rl  ,       1,     2,    0},
              { el ,         1,       l  ,      -1,     2,    0},
              { er ,          1,       r  ,      -2,     0,    0},
              { q1l ,        1,       l  ,      1/3,    2,    3},
              { q1dr,        1,       r  ,     -2/3,    0,    3},
              { q1ur,        1,       r  ,      4/3,    0,    3}}$
gauge_boson_redefine:={
               a(1,~v) => (w(1,v)+w(-1,v))/2**0.5,
               a(2,~v) => (w(-1,v)-w(1,v))/2**0.5/i,
               a(3,~v) => z(0,v), b(~v)   => p(0,v) };
vancumexpectation:='((hig v0));

%        name  n_group   1_componet  2_componet ...
 mdefl:={  {hig,   2,          xx2   , (v0+h0-i*xx3)/2**0.5},
           {el ,    2,          nue   ,                 ef             },
           {er ,    2,          ef                                     },
           {q1l ,  2,          qu   ,                  qd             },
           {q1dr, 2,          qd                                     },
           {q1ur, 2,          qu                                    }}$
```

```
realfamily:='(  (q1l q2l q3l)    (q1dr q2dr q3dr)
 (q1ur q2ur q3ur)    (qu qc qt)    (qd qs qb) (el mul taul
(er mur taur)  (ef mu tau)  (nue numu nut));

phymass:={{w, wm}, {z, zm}, {p, 0}, {h0, hm},
{ef, fme}, {nue, 0},{mu, fmmu},{numu, 0},{tau, fmtau},
{nut, 0},{qd, fmd}, {qu, fmu},{qs, fms}, {qc, fmc},
{qb, fmb}, {qt, fmt}}$

phyinput:={g3,g,theta,wm, hm,fme, fmmu,fmtau,fmd,
 fmu,fms, fmc,fmb, fmt}$

construles:={ g1=>g*sin(theta)/cos(theta)};

expriment_easy_list:={
{g,        replaceby,  ge,  -i*ge*gg(l,v), {p,ef,ef}},
{theta,   replaceby,  zm}  };

charge_def:=tp(2,3)+tp(1,1)/2;

renormalization:='before_broken;   %European schem
%renormalization:='after_broken;   %Kyoto scheme

ms_list:='(g3 );

symbolic(rform:='(3));
symbolic(rloop:='((g3 . 2)));
```

Input file for Standard Model at QCD NLO by using MS_bar scheme

```
%------------------------ Gauge fields ------------------------
gaugefields:=
%No.  Name  SU(n)   notation  couping     breaking
  '((1    u        1          b         g1              yes  )
    (2    su       2          a         g               yes  )
    (3    su       3          gs        g3              no    ))$
%----------------------- Matter fields -------------------------
matterinput:={{name,  2*spin,  chiral,     1,     2,    3},
              { hig,        0  ,      rl  ,       1,     2,    0},
              { el ,          1,         l  ,      -1,     2,    0},
              { er ,           1,        r  ,      -2,     0,    0},
              { q1l ,        1,         l  ,      1/3,    2,    3},
              { q1dr,       1,         r  ,     -2/3,    0,    3},
              { q1ur,       1,         r  ,      4/3,    0,    3}}$
gauge_boson_redefine:={
              a(1,~v) => (w(1,v)+w(-1,v))/2**0.5,
              a(2,~v) => (w(-1,v)-w(1,v))/2**0.5/i,
              a(3,~v) => z(0,v), b(~v)   => p(0,v) };
vancumexpectation:='((hig v0));

%       name  n_group   1_componet  2_componet  ...
 mdefl:={  {hig,   2,          xx2   , (v0+h0-i*xx3)/2**0.5},
           {el ,    2,          nue   ,                ef            },
           {er ,    2,          ef                                    },
           {q1l ,  2,          qu    ,                qd            },
           {q1dr, 2,          qd                                    },
           {q1ur, 2,          qu                                   }}$
```

```
realfamily:='(  (q1l q2l q3l)    (q1dr q2dr q3dr)
 (q1ur q2ur q3ur)    (qu qc qt)    (qd qs qb) (el mul taul
(er mur taur)  (ef mu tau)  (nue numu nut));

phymass:={{w, wm}, {z, zm}, {p, 0}, {h0, hm},
{ef, fme}, {nue, 0},{mu, fmmu},{numu, 0},{tau, fmtau},
{nut, 0},{qd, fmd}, {qu, fmu},{qs, fms}, {qc, fmc},
{qb, fmb}, {qt, fmt}}$

phyinput:={g3,g,theta,wm, hm,fme, fmmu,fmtau,fmd,
 fmu,fms, fmc,fmb, fmt}$

construles:={ g1=>g*sin(theta)/cos(theta)};

expriment_easy_list:={
{g,        replaceby,  ge,  -i*ge*gg(l,v), {p,ef,ef}},
{theta,   replaceby,  zm}  };

charge_def:=tp(2,3)+tp(1,1)/2;

renormalization:='before_broken;   %European schem
%renormalization:='after_broken;   %Kyoto scheme

ms_list:='(g3  gs  qu qb qt qs qd qc);

symbolic(rform:='(3));
symbolic(rloop:='((g3 . 2)));
```

Summary

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Thanks for your attention!