

```

In[*]:= (* F[1, {0}] = electron neutrino,
F[1, {1}] = muon neutrino, F[1, {2}] = tau neutrino,
F[2, {0}] = electron, F[2, {1}] = muon, F[2, {2}] = tau,
F[3, {0}] = up, F[3, {1}] = charm, F[3, {2}] = top,
F[4, {0}] = down, F[4, {1}] = strange, F[4, {2}] = bottom,
V[1] = photon, V[2] = Z, V[3] = W-, S[1] = H *)
$LoadAddOns = {"FeynArts"};
<< FeynCalc`
$FAVerbose = 0;

```

```

MakeBoxes[p1, TraditionalForm] := "\!\(\*SubscriptBox[\(p\), \((1\) )]\)";
MakeBoxes[p2, TraditionalForm] := "\!\(\*SubscriptBox[\(p\), \((2\) )]\)";
MakeBoxes[p3, TraditionalForm] := "\!\(\*SubscriptBox[\(p\), \((3\) )]\)";
MakeBoxes[p4, TraditionalForm] := "\!\(\*SubscriptBox[\(p\), \((4\) )]\)";
topology = CreateTopologies[0, 2 → 2];

```

FeynCalc 10.0.0 (dev version). For help, use the

online documentation, visit the forum and have a look at the supplied examples. The PDF-version of the manual can be downloaded [here](#).

If you use FeynCalc in your research, please

evaluate FeynCalcHowToCite[] to learn how to cite this software.

Please keep in mind that the proper academic attribution

of our work is crucial to ensure the future development of this package!

FeynArts 3.12 (24 May 2024) patched for use with FeynCalc, for documentation see the manual or visit www.feynarts.de.

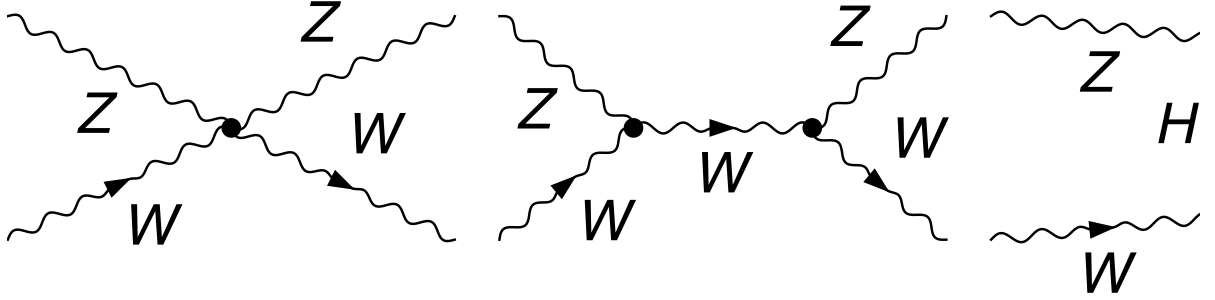
If you use FeynArts in your research, please cite

- T. Hahn, Comput. Phys. Commun., 140, 418–431, 2001, arXiv:hep-ph/0012260

```

In[*]:= (* unpolarised SM: W- Z → W- Z *)
feynman = InsertFields[topology,
{V[2], V[3]} → {V[2], V[3]}, InsertionLevel → {Classes},
Model → {SM, UnitarySM}, GenericModel → {Lorentz, UnitaryLorentz}];
Paint[feynman, Numbering → None, SheetHeader → False,
ColumnsXRows → {4, 1}, ImageSize → {1032, 256}];
amplitude[0] = FCFAConvert[CreateFeynAmp[feynman], IncomingMomenta → {p1, p2},
OutgoingMomenta → {p3, p4}, UndoChiralSplittings → True, ChangeDimension → 4,
DropSumOver → True, List → False, SMP → True, Contract → True]
FCClearScalarProducts[];
SetMandelstam[s, t, u, p1, p2, -p3, -p4,
SMP["m_Z"], SMP["m_W"], SMP["m_Z"], SMP["m_W"]];
squareamplitude[0] = (amplitude[0] (ComplexConjugate[amplitude[0]])) //
DoPolarizationSums[#, p1, ExtraFactor → 1 / 3] & //
DoPolarizationSums[#, p2, ExtraFactor → 1 / 3] & //
DoPolarizationSums[#, p3] & // DoPolarizationSums[#, p4] & // Simplify
(* output = feynman diagrams, amplitude, squared amplitude *)

```



Out[*]=

$$\begin{aligned}
& - \frac{1}{((\overline{p}_3 + \overline{p}_4)^2 - m_W^2) (\sin(\theta_W))^2} \\
& \quad ((2(\overline{p}_3 \cdot \overline{\epsilon}^*(p_4)) + \overline{p}_4 \cdot \overline{\epsilon}^*(p_4)) (-(\overline{p}_2 \cdot \overline{\epsilon}^*(p_3) - \overline{p}_1 \cdot \overline{\epsilon}^*(p_3)) (\overline{\epsilon}(p_1) \cdot \overline{\epsilon}(p_2))) - (\overline{p}_1 \cdot \overline{\epsilon}(p_2) + \overline{p}_3 \cdot \overline{\epsilon}(p_2) + \overline{p}_4 \cdot \overline{\epsilon}(p_2)) \\
& \quad (\overline{\epsilon}(p_1) \cdot \overline{\epsilon}^*(p_3)) - (-\overline{p}_2 \cdot \overline{\epsilon}(p_1) - \overline{p}_3 \cdot \overline{\epsilon}(p_1) - \overline{p}_4 \cdot \overline{\epsilon}(p_1)) (\overline{\epsilon}(p_2) \cdot \overline{\epsilon}^*(p_3))) + \\
& \quad (\overline{p}_3 \cdot \overline{\epsilon}^*(p_3) + 2(\overline{p}_4 \cdot \overline{\epsilon}^*(p_3))) ((\overline{p}_2 \cdot \overline{\epsilon}^*(p_4) - \overline{p}_1 \cdot \overline{\epsilon}^*(p_4)) (\overline{\epsilon}(p_1) \cdot \overline{\epsilon}(p_2)) + (\overline{p}_1 \cdot \overline{\epsilon}(p_2) + \overline{p}_3 \cdot \overline{\epsilon}(p_2) + \overline{p}_4 \cdot \overline{\epsilon}(p_2)) \\
& \quad (\overline{\epsilon}(p_1) \cdot \overline{\epsilon}^*(p_4)) + (-\overline{p}_2 \cdot \overline{\epsilon}(p_1) - \overline{p}_3 \cdot \overline{\epsilon}(p_1) - \overline{p}_4 \cdot \overline{\epsilon}(p_1)) (\overline{\epsilon}(p_2) \cdot \overline{\epsilon}^*(p_4))) + \\
& \quad (\overline{p}_1 \cdot \overline{\epsilon}(p_2)) (\overline{p}_3 \cdot \overline{\epsilon}(p_1) - \overline{p}_4 \cdot \overline{\epsilon}(p_1)) (\overline{\epsilon}^*(p_3) \cdot \overline{\epsilon}^*(p_4)) + (\overline{p}_3 \cdot \overline{\epsilon}(p_2)) (\overline{p}_3 \cdot \overline{\epsilon}(p_1) - \overline{p}_4 \cdot \overline{\epsilon}(p_1)) (\overline{\epsilon}^*(p_3) \cdot \overline{\epsilon}^*(p_4)) - \\
& \quad (\overline{p}_2 \cdot \overline{\epsilon}(p_1)) (\overline{p}_3 \cdot \overline{\epsilon}(p_2) - \overline{p}_4 \cdot \overline{\epsilon}(p_2)) (\overline{\epsilon}^*(p_3) \cdot \overline{\epsilon}^*(p_4)) - (\overline{p}_3 \cdot \overline{\epsilon}(p_1)) (\overline{p}_3 \cdot \overline{\epsilon}(p_2) - \overline{p}_4 \cdot \overline{\epsilon}(p_2)) (\overline{\epsilon}^*(p_3) \cdot \overline{\epsilon}^*(p_4)) - \\
& \quad (\overline{p}_4 \cdot \overline{\epsilon}(p_1)) (\overline{p}_3 \cdot \overline{\epsilon}(p_2) - \overline{p}_4 \cdot \overline{\epsilon}(p_2)) (\overline{\epsilon}^*(p_3) \cdot \overline{\epsilon}^*(p_4)) + (\overline{p}_3 \cdot \overline{\epsilon}(p_1) - \overline{p}_4 \cdot \overline{\epsilon}(p_1)) (\overline{p}_4 \cdot \overline{\epsilon}(p_2)) (\overline{\epsilon}^*(p_3) \cdot \overline{\epsilon}^*(p_4)) + \\
& \quad (-\overline{p}_1 \cdot \overline{p}_3) + \overline{p}_1 \cdot \overline{p}_4 + \overline{p}_2 \cdot \overline{p}_3 - \overline{p}_2 \cdot \overline{p}_4) (\overline{\epsilon}(p_1) \cdot \overline{\epsilon}(p_2)) (\overline{\epsilon}^*(p_3) \cdot \overline{\epsilon}^*(p_4)) (\cos(\theta_W))^2 e^2 + \\
& \quad \frac{1}{((\overline{p}_3 - \overline{p}_2)^2 - m_W^2) (\sin(\theta_W))^2} ((\overline{p}_1 \cdot \overline{\epsilon}^*(p_4)) (-(\overline{p}_2 \cdot \overline{\epsilon}(p_1) - \overline{p}_3 \cdot \overline{\epsilon}(p_1)) (\overline{\epsilon}(p_2) \cdot \overline{\epsilon}^*(p_3)) - \\
& \quad (\overline{p}_2 \cdot \overline{\epsilon}^*(p_4)) (-(\overline{p}_2 \cdot \overline{\epsilon}(p_1) - \overline{p}_3 \cdot \overline{\epsilon}(p_1)) (\overline{\epsilon}(p_2) \cdot \overline{\epsilon}^*(p_3)) + \\
& \quad (\overline{p}_2 \cdot \overline{\epsilon}(p_1)) (-(\overline{p}_2 \cdot \overline{\epsilon}^*(p_4) - \overline{p}_3 \cdot \overline{\epsilon}^*(p_4)) (\overline{\epsilon}(p_2) \cdot \overline{\epsilon}^*(p_3)) - \\
& \quad (\overline{p}_3 \cdot \overline{\epsilon}(p_1)) (-(\overline{p}_2 \cdot \overline{\epsilon}^*(p_4) - \overline{p}_3 \cdot \overline{\epsilon}^*(p_4)) (\overline{\epsilon}(p_2) \cdot \overline{\epsilon}^*(p_3)) + \\
& \quad (-\overline{p}_2 \cdot \overline{\epsilon}(p_1) - \overline{p}_3 \cdot \overline{\epsilon}(p_1)) (\overline{p}_3 \cdot \overline{\epsilon}^*(p_4)) (\overline{\epsilon}(p_2) \cdot \overline{\epsilon}^*(p_3)) + \\
& \quad (-\overline{p}_2 \cdot \overline{\epsilon}^*(p_4) - \overline{p}_3 \cdot \overline{\epsilon}^*(p_4)) (\overline{p}_4 \cdot \overline{\epsilon}(p_1)) (\overline{\epsilon}(p_2) \cdot \overline{\epsilon}^*(p_3)) + \\
& \quad (\overline{p}_1 \cdot \overline{p}_2 + \overline{p}_1 \cdot \overline{p}_3 + \overline{p}_2 \cdot \overline{p}_4 + \overline{p}_3 \cdot \overline{p}_4) (\overline{\epsilon}(p_1) \cdot \overline{\epsilon}^*(p_4)) (\overline{\epsilon}(p_2) \cdot \overline{\epsilon}^*(p_3)) + \\
& \quad (2(\overline{p}_2 \cdot \overline{\epsilon}^*(p_3)) - \overline{p}_3 \cdot \overline{\epsilon}^*(p_3)) ((\overline{p}_1 \cdot \overline{\epsilon}^*(p_4) - \overline{p}_2 \cdot \overline{\epsilon}^*(p_4) + \overline{p}_3 \cdot \overline{\epsilon}^*(p_4)) (\overline{\epsilon}(p_1) \cdot \overline{\epsilon}(p_2)) + \\
& \quad (-\overline{p}_1 \cdot \overline{\epsilon}(p_2) - \overline{p}_4 \cdot \overline{\epsilon}(p_2)) (\overline{\epsilon}(p_1) \cdot \overline{\epsilon}^*(p_4)) + (\overline{p}_2 \cdot \overline{\epsilon}(p_1) - \overline{p}_3 \cdot \overline{\epsilon}(p_1) + \overline{p}_4 \cdot \overline{\epsilon}(p_1)) (\overline{\epsilon}(p_2) \cdot \overline{\epsilon}^*(p_4))) + \\
& \quad (\overline{p}_2 \cdot \overline{\epsilon}(p_2) - 2(\overline{p}_3 \cdot \overline{\epsilon}(p_2))) (-(\overline{p}_1 \cdot \overline{\epsilon}^*(p_4) - \overline{p}_2 \cdot \overline{\epsilon}^*(p_4) + \overline{p}_3 \cdot \overline{\epsilon}^*(p_4)) (\overline{\epsilon}(p_1) \cdot \overline{\epsilon}^*(p_3))) - \\
& \quad (-\overline{p}_1 \cdot \overline{\epsilon}^*(p_3) - \overline{p}_4 \cdot \overline{\epsilon}^*(p_3)) (\overline{\epsilon}(p_1) \cdot \overline{\epsilon}^*(p_4)) - (\overline{p}_2 \cdot \overline{\epsilon}(p_1) - \overline{p}_3 \cdot \overline{\epsilon}(p_1) + \overline{p}_4 \cdot \overline{\epsilon}(p_1)) (\overline{\epsilon}^*(p_3) \cdot \overline{\epsilon}^*(p_4))) \\
& \quad (\cos(\theta_W))^2 e^2 - \frac{(\overline{\epsilon}(p_1) \cdot \overline{\epsilon}^*(p_3)) (\overline{\epsilon}(p_2) \cdot \overline{\epsilon}^*(p_4)) e^2 m_W^2}{((\overline{p}_4 - \overline{p}_2)^2 - m_H^2) (\cos(\theta_W))^2 (\sin(\theta_W))^2} - \\
& \quad i \left(\frac{i (\overline{\epsilon}(p_1) \cdot \overline{\epsilon}^*(p_4)) (\overline{\epsilon}(p_2) \cdot \overline{\epsilon}^*(p_3)) (\cos(\theta_W))^2 e^2}{(\sin(\theta_W))^2} - \frac{2 i (\overline{\epsilon}(p_1) \cdot \overline{\epsilon}^*(p_3)) (\overline{\epsilon}(p_2) \cdot \overline{\epsilon}^*(p_4)) (\cos(\theta_W))^2 e^2}{(\sin(\theta_W))^2} + \right. \\
& \quad \left. \frac{i (\overline{\epsilon}(p_1) \cdot \overline{\epsilon}(p_2)) (\overline{\epsilon}^*(p_3) \cdot \overline{\epsilon}^*(p_4)) (\cos(\theta_W))^2 e^2}{(\sin(\theta_W))^2} \right)
\end{aligned}$$

Out[*]=

$$\begin{aligned}
& \frac{1}{144 (\cos(\theta_W))^4 m_W^4 m_Z^4 (\sin(\theta_W))^4} \\
& e^4 \left(\left(4 m_W^8 - 176 m_Z^2 m_W^6 - 8 s m_W^6 + 40 t m_W^6 - 8 u m_W^6 + 152 m_Z^4 m_W^4 + 8 s^2 m_W^4 + 16 t^2 m_W^4 + 8 u^2 m_W^4 + \right. \right. \\
& \quad 168 s m_Z^2 m_W^4 + 24 t m_Z^2 m_W^4 + 168 u m_Z^2 m_W^4 - 40 s t m_W^4 + 8 s u m_W^4 - 40 t u m_W^4 - 176 m_Z^6 m_W^2 + \\
& \quad 168 s m_Z^4 m_W^2 + 24 t m_Z^4 m_W^2 + 168 u m_Z^4 m_W^2 - 4 s^3 m_W^2 - 16 t^3 m_W^2 - 4 u^3 m_W^2 + 8 s t^2 m_W^2 - \\
& \quad \left. \left. 4 s u^2 m_W^2 + 8 t u^2 m_W^2 - 32 s^2 m_Z^2 m_W^2 + 48 t^2 m_Z^2 m_W^2 - 32 u^2 m_Z^2 m_W^2 - 80 s t m_Z^2 m_W^2 - \right. \right.
\end{aligned}$$

$$\begin{aligned}
& 80 s u m_Z^2 m_W^2 - 80 t u m_Z^2 m_W^2 + 8 s^2 t m_W^2 - 4 s^2 u m_W^2 + 8 t^2 u m_W^2 + 24 s t u m_W^2 + 4 m_Z^8 - \\
& 8 s m_Z^6 + 40 t m_Z^6 - 8 u m_Z^6 + s^4 + 4 t^4 + u^4 + 8 s^2 m_Z^4 + 16 t^2 m_Z^4 + 8 u^2 m_Z^4 - 40 s t m_Z^4 + \\
& 8 s u m_Z^4 - 40 t u m_Z^4 - 4 s^2 t^2 + 2 s^2 u^2 - 4 t^2 u^2 - 4 s^3 m_Z^2 - 16 t^3 m_Z^2 - 4 u^3 m_Z^2 + 8 s t^2 m_Z^2 - \\
& 4 s u^2 m_Z^2 + 8 t u^2 m_Z^2 + 8 s^2 t m_Z^2 - 4 s^2 u m_Z^2 + 8 t^2 u m_Z^2 + 24 s t u m_Z^2 + \frac{1}{(\overline{p_3} + \overline{p_4})^2 - m_W^2} \\
& 2 \left(-2 (88 m_Z^2 + s - 12 t) m_W^8 + (-976 m_Z^4 + 8 (35 s + 13 t + 23 u) m_Z^2 + 5 s^2 + t^2 + 3 u^2 - 56 s t - 12 t u) \right. \\
& \quad m_W^6 - (976 m_Z^6 - 4 (149 s + 72 t + 108 u) m_Z^4 + (77 s^2 + 8 (19 t + 40 u) s - 5 (3 t^2 - 12 u t + u^2))) \\
& \quad m_Z^2 + 3 s^3 + 6 t^3 + 4 u^3 - 7 t u^2 - 7 t^2 u + s^2 (4 u - 33 t) + s (3 t^2 - 24 u t + u^2)) m_W^4 + \\
& \quad (-176 m_Z^8 + 8 (35 s + 13 t + 23 u) m_Z^6 - (77 s^2 + 8 (19 t + 40 u) s - 5 (3 t^2 - 12 u t + u^2))) m_Z^4 + \\
& \quad 2 (3 s^3 + (19 t + 30 u) s^2 + (-5 t^2 + 48 u t + 21 u^2) s - 8 t^3 - 6 u^3 + 5 t u^2 + 5 t^2 u) m_Z^2 + \\
& \quad 2 t^4 + u^4 - 3 t^2 u^2 - s^3 (t - 4 u) - s^2 (5 t^2 + 12 u t + u^2) + s (8 t^3 - 5 u t^2 - 7 u^2 t + 4 u^3)) \\
& \quad m_W^2 - 2 (s - 12 t) m_Z^8 + (5 s^2 - 56 t s + t^2 + 3 u^2 - 12 t u) m_Z^6 - \\
& \quad (3 s^3 + (4 u - 33 t) s^2 + (3 t^2 - 24 u t + u^2) s + 6 t^3 + 4 u^3 - 7 t u^2 - 7 t^2 u) m_Z^4 - \\
& \quad (-2 t^4 + 3 u^2 t^2 - u^4 + s^3 (t - 4 u) + s^2 (5 t^2 + 12 u t + u^2) + s (-8 t^3 + 5 u t^2 + 7 u^2 t - 4 u^3)) m_Z^2 + \\
& \quad s (t^2 - u^2) (s^2 - 2 t^2 + u^2)) + \frac{1}{(\overline{p_3} - \overline{p_2})^2 - m_W^2}^2 \left(-20 m_W^{12} + 2 (-116 m_Z^2 + 7 s + 7 t + 33 u) m_W^{10} + \right. \\
& \quad (1172 m_Z^4 - 2 (65 s + 65 t - 417 u) m_Z^2 + 11 s^2 + 3 t^2 - 70 u^2 - 68 t u - 6 s (t + 10 u)) m_W^8 + \\
& \quad (3792 m_Z^6 - 4 (227 s + 227 t - 367 u) m_Z^4 + 4 (31 s^2 - 22 t s - 28 u s + 15 t^2 - 194 u^2 - 12 t u) m_Z^2 - \\
& \quad 4 s^3 - 4 t^3 + 23 u^3 + 92 t u^2 + s^2 (4 t - 19 u) - 3 t^2 u + s (4 t^2 + 26 u t + 76 u^2)) m_W^6 + \\
& \quad (1172 m_Z^8 - 4 (227 s + 227 t - 367 u) m_Z^6 + 2 (113 s^2 - 82 t s + 12 u s + 185 t^2 - 738 u^2 - 44 t u) \\
& \quad m_Z^4 + (-44 s^3 + (44 t - 97 u) s^2 + (44 t^2 + 62 u t + 316 u^2) s - 44 t^3 + \\
& \quad 165 u^3 + 300 t u^2 - 113 t^2 u) m_Z^2 + s^4 + 8 s^3 u + s^2 (-2 t^2 - 8 u t + 5 u^2) - \\
& \quad 2 s u (4 t^2 + 17 u t + 14 u^2) + t (t^3 + 8 u t^2 - 3 u^2 t - 36 u^3)) m_W^4 + \\
& \quad (-232 m_Z^{10} - 2 (65 s + 65 t - 417 u) m_Z^8 + 4 (31 s^2 - 22 t s - 28 u s + 15 t^2 - 194 u^2 - 12 t u) m_Z^6 + \\
& \quad (-44 s^3 + (44 t - 97 u) s^2 + (44 t^2 + 62 u t + 316 u^2) s - 44 t^3 + 165 u^3 + 300 t u^2 - 113 t^2 u) \\
& \quad m_Z^4 + 2 (5 s^4 + 8 u s^3 + (-10 t^2 - 8 u t + u^2) s^2 - 2 u (4 t^2 + 21 u t + 18 u^2) s + \\
& \quad t (5 t^3 + 8 u t^2 + 9 u^2 t - 28 u^3)) m_Z^2 + u (-2 s^4 - 4 u s^3 + (4 t^2 + 4 u t + 3 u^2) s^2 - \\
& \quad 2 u (-2 t^2 - 7 u t + u^2) s - 2 t^4 + u^4 - 2 t u^3 + 3 t^2 u^2 - 4 t^3 u) m_W^2 + \\
& \quad (u - m_Z^2)^2 (-20 m_Z^8 + 2 (7 s + 7 t + 13 u) m_Z^6 + (11 s^2 - 6 t s - 32 u s + 3 t^2 + 2 u^2 - 40 t u) m_Z^4 + \\
& \quad (-4 s^3 + (4 t + 3 u) s^2 + 2 (2 t^2 + 7 u t - u^2) s - 4 t^3 + u^3 - 2 t u^2 + 3 t^2 u) m_Z^2 + (s^2 - t^2)^2)) + \\
& \quad \frac{1}{(\overline{p_3} + \overline{p_4})^2 - m_W^2}^2 \left(-20 m_W^{12} + 2 (-116 m_Z^2 + 33 s + 7 (t + u)) m_W^{10} - \right. \\
& \quad (-1172 m_Z^4 + (130 (t + u) - 834 s) m_Z^2 + 70 s^2 - 3 t^2 - 11 u^2 + 68 s t + 60 s u + 6 t u) m_W^8 + \\
& \quad (3792 m_Z^6 + 4 (367 s - 227 (t + u)) m_Z^4 - 4 (194 s^2 + 4 (3 t + 7 u) s - 15 t^2 - 31 u^2 + 22 t u) m_Z^2 + \\
& \quad 23 s^3 - 4 (t - u)^2 (t + u) + s^2 (92 t + 76 u) + s (-3 t^2 + 26 u t - 19 u^2)) m_W^6 + \\
& \quad (1172 m_Z^8 + 4 (367 s - 227 (t + u)) m_Z^6 - 2 (738 s^2 + 44 t s - 12 u s - 185 t^2 - 113 u^2 + 82 t u) m_Z^4 + \\
& \quad (165 s^3 + 4 (75 t + 79 u) s^2 + (-113 t^2 + 62 u t - 97 u^2) s - 44 (t - u)^2 (t + u)) m_Z^2 + \\
& \quad (t^2 - u^2)^2 + 8 s (t - u)^2 (t + u) - 4 s^3 (9 t + 7 u) + s^2 (-3 t^2 - 34 u t + 5 u^2)) m_W^4 + \\
& \quad (-232 m_Z^{10} + 2 (417 s - 65 (t + u)) m_Z^8 - 4 (194 s^2 + 4 (3 t + 7 u) s - 15 t^2 - 31 u^2 + 22 t u) m_Z^6 + \\
& \quad (165 s^3 + 4 (75 t + 79 u) s^2 + (-113 t^2 + 62 u t - 97 u^2) s - 44 (t - u)^2 (t + u)) m_Z^4 - \\
& \quad 2 (4 (7 t + 9 u) s^3 - (9 t^2 - 42 u t + u^2) s^2 - 8 (t - u)^2 (t + u) s - 5 (t^2 - u^2)^2) m_Z^2 + \\
& \quad s (s^4 - 2 (t + u) s^3 + (3 t^2 + 14 u t + 3 u^2) s^2 - 4 (t - u)^2 (t + u) s - 2 (t^2 - u^2)^2)) m_W^2 + \\
& \quad (s - m_Z^2)^2 (-20 m_Z^8 + 2 (13 s + 7 (t + u)) m_Z^6 + (2 s^2 - 8 (5 t + 4 u) s + 3 t^2 + 11 u^2 - 6 t u) m_Z^4 + \\
& \quad (s^3 - 2 (t + u) s^2 + (3 t^2 + 14 u t + 3 u^2) s - 4 (t - u)^2 (t + u)) m_Z^2 + (t^2 - u^2)^2)) -
\end{aligned}$$

$$\begin{aligned}
& \frac{1}{(\overline{p_3} - \overline{p_2})^2 - m_W^2} \left(2(2(88 m_Z^2 - 12 t + u) m_W^8 - (-976 m_Z^4 + 8(23 s + 13 t + 35 u) m_Z^2 + \right. \\
& \quad 3 s^2 + t^2 + 5 u^2 - 12 s t - 56 t u) m_W^6 + (976 m_Z^6 - 4(108 s + 72 t + 149 u) m_Z^4 + \\
& \quad (-5 s^2 + 60 t s + 320 u s - 15 t^2 + 77 u^2 + 152 t u) m_Z^2 + 4 s^3 + s^2(u - 7 t) + \\
& \quad s(-7 t^2 - 24 u t + 4 u^2) + 3(2 t^3 + u t^2 - 11 u^2 t + u^3)) m_W^4 - (-176 m_Z^8 + \\
& \quad 8(23 s + 13 t + 35 u) m_Z^6 + (5 s^2 - 20(3 t + 16 u) s + 15 t^2 - 77 u^2 - 152 t u) m_Z^4 + \\
& \quad 2(-6 s^3 + (5 t + 21 u) s^2 + (5 t^2 + 48 u t + 30 u^2) s - 8 t^3 + 3 u^3 + 19 t u^2 - 5 t^2 u) m_Z^2 + \\
& \quad s^4 + 4 s^3 u - s^2(3 t^2 + 7 u t + u^2) + s u(-5 t^2 - 12 u t + 4 u^2) + \\
& \quad t(2 t^3 + 8 u t^2 - 5 u^2 t - u^3)) m_W^2 + (2 u - 24 t) m_Z^8 - (3 s^2 - 12 t s + t^2 + 5 u^2 - 56 t u) \\
& \quad m_Z^6 + (4 s^3 + (u - 7 t) s^2 + (-7 t^2 - 24 u t + 4 u^2) s + 3(2 t^3 + u t^2 - 11 u^2 t + u^3)) m_Z^4 + \\
& \quad (-s^4 - 4 u s^3 + (3 t^2 + 7 u t + u^2) s^2 + u(5 t^2 + 12 u t - 4 u^2) s + t(-2 t^3 - 8 u t^2 + 5 u^2 t + u^3)) \\
& \quad m_Z^2 + (s^2 - t^2) u (s^2 - 2 t^2 + u^2)) + \frac{1}{(\overline{p_3} + \overline{p_4})^2 - m_W^2} \\
& \quad (-32 m_W^{12} + 8(-69 m_Z^2 + 8 s - 6 t + 8 u) m_W^{10} + (-3320 m_Z^4 + 8(70 s + 9 t + 70 u) m_Z^2 - \\
& \quad 24 s^2 + 6 t^2 - 24 u^2 + 58 s t - 146 s u + 58 t u) m_W^8 - 2(3112 m_Z^6 - \\
& \quad 8(37 s + 239 t + 37 u) m_Z^4 - 2(46 s^2 + 3(t - 70 u) s - 111 t^2 + 46 u^2 + 3 t u) m_Z^2 + \\
& \quad 3 s^3 - 6 t^3 + 3 u^3 + 12 t u^2 + s^2(12 t - 37 u) + 7 t^2 u + s(7 t^2 + 26 u t - 37 u^2)) m_W^6 - \\
& \quad (1040 m_Z^8 + 16(48 s - 185 t + 48 u) m_Z^6 + 4(-239 s^2 + 66 t s + 173 u s + 327 t^2 - 239 u^2 + \\
& \quad 66 t u) m_Z^4 + (55 s^3 + (181 t + 45 u) s^2 - 5(19 t^2 + 30 u t - 9 u^2) s - 165 t^3 + \\
& \quad 55 u^3 + 181 t u^2 - 95 t^2 u) m_Z^2 + 2(s^4 - (4 t + 3 u) s^3 + (-6 t^2 - 7 u t + 26 u^2) s^2 + \\
& \quad (3 t^3 - u t^2 - 7 u^2 t - 3 u^3) s + 2 t^4 + u^4 - 4 t u^3 - 6 t^2 u^2 + 3 t^3 u)) m_W^4 + \\
& \quad (376 m_Z^{10} - 48(13 s + 10 t + 13 u) m_Z^8 + 4(152 s^2 + 93 t s + 66 u s - 71 t^2 + 152 u^2 + 93 t u) \\
& \quad m_Z^6 - 2(44 s^3 + (105 t + 134 u) s^2 - 2(17 t^2 + 6 u t - 67 u^2) s - 59 t^3 + 44 u^3 + \\
& \quad 105 t u^2 - 34 t^2 u) m_Z^4 + (-19 s^4 + (33 t + 60 u) s^3 + (19 t^2 + 55 u t + 14 u^2) s^2 + \\
& \quad (-45 t^3 - 26 u t^2 + 55 u^2 t + 60 u^3) s - 4 t^4 - 19 u^4 + 33 t u^3 + 19 t^2 u^2 - 45 t^3 u) \\
& \quad m_Z^2 + 2(u s^4 + (-t^2 - 3 u t + u^2) s^3 + (u^3 - 3 t^2 u) s^2 + \\
& \quad (t^4 + 4 u t^3 - 3 u^2 t^2 - 3 u^3 t + u^4) s + t^2 u(t^2 - u^2)) m_W^2 + 40 m_Z^{12} - \\
& \quad 8(10 s + 7 t + 10 u) m_Z^{10} + 2(34 s^2 + 39 t s + 51 u s - 9 t^2 + 34 u^2 + 39 t u) m_Z^8 - \\
& \quad (27 s^3 + (41 t + 49 u) s^2 + (-11 t^2 + 90 u t + 49 u^2) s - 17 t^3 + 27 u^3 + 41 t u^2 - 11 t^2 u) m_Z^6 - \\
& \quad (s^4 - 13(t + 2 u) s^3 + (-11 t^2 - 37 u t + 22 u^2) s^2 + \\
& \quad (11 t^3 + 24 u t^2 - 37 u^2 t - 26 u^3) s + 4 t^4 + u^4 - 13 t u^3 - 11 t^2 u^2 + 11 t^3 u) m_Z^4 + \\
& \quad (u s^4 + (-2 t^2 - 11 u t + 3 u^2) s^3 + u(-5 t^2 - 6 u t + 3 u^2) s^2 + (2 t^4 + 13 u t^3 - \\
& \quad 5 u^2 t^2 - 11 u^3 t + u^4) s + 2 t^2 u(t^2 - u^2)) m_Z^2 + 2 s(s^2 - t^2) u(t^2 - u^2)) \Big) \\
& (\cos(\theta_W))^8 + \frac{1}{(\overline{p_4} - \overline{p_2})^2 - m_H^2} 2(\cos(\theta_W))^4 m_W^2 \left(-72 m_Z^2 m_W^6 + 12 t m_W^6 + 80 m_Z^4 m_W^4 + \right. \\
& \quad 14 t^2 m_W^4 + \\
& \quad 72 s m_Z^2 m_W^4 - \\
& \quad 28 t m_Z^2 m_W^4 + \\
& \quad 72 u m_Z^2 m_W^4 - \\
& \quad 12 s t m_W^4 - \\
& \quad 12 t u m_W^4 - \\
& \quad 72 m_Z^6 m_W^2 + \\
& \quad 72 s m_Z^4 m_W^2 - \\
& \quad 28 t m_Z^4 m_W^2 + \\
& \quad 72 u m_Z^4 m_W^2 - \\
& \quad 8 t^3 m_W^2 + \\
& \quad 2 s t^2 m_W^2 +
\end{aligned}$$

$$\begin{aligned}
& 2 t u^2 m_W^2 - \\
& 20 s^2 m_Z^2 m_W^2 + \\
& 28 t^2 m_Z^2 m_W^2 - \\
& 20 u^2 m_Z^2 m_W^2 - \\
& 24 s t m_Z^2 m_W^2 - \\
& 32 s u m_Z^2 m_W^2 - \\
& 24 t u m_Z^2 m_W^2 + \\
& 2 s^2 t m_W^2 + \\
& 2 t^2 u m_W^2 + \\
& 8 s t u m_W^2 + \\
& 12 t m_Z^6 + 2 t^4 + \\
& 14 t^2 m_Z^4 - \\
& 12 s t m_Z^4 - \\
& 12 t u m_Z^4 - s^2 t^2 - \\
& t^2 u^2 - 8 t^3 m_Z^2 + \\
& 2 s t^2 m_Z^2 + \\
& 2 t u^2 m_Z^2 + 2 s^2 t m_Z^2 + \\
& 2 t^2 u m_Z^2 + 8 s t u m_Z^2 + \\
& \frac{1}{(\overline{p_3} + \overline{p_4})^2 - m_W^2} \left(8 (t - 6 m_Z^2) m_W^8 + (-336 m_Z^4 + 4 (24 s + 11 t + 9 u) m_Z^2 - 22 s t) m_W^6 + \right. \\
& \quad (-336 m_Z^6 + 8 (24 s + 29 t + 5 u) m_Z^4 - 2 (12 s^2 + 23 t s + 54 u s + 2 t^2 - 6 u^2 + 12 t u) m_Z^2 + \\
& \quad \quad \left. t (13 s^2 - 4 t s + 4 u s - 2 t^2 + 3 u^2 + 3 t u) m_W^4 + \right. \\
& \quad (-48 m_Z^8 + 4 (24 s + 11 t + 9 u) m_Z^6 - 2 (12 s^2 + 23 t s + 54 u s + 2 t^2 - 6 u^2 + 12 t u) m_Z^4 + \\
& \quad \quad 2 (-4 t^3 + u t^2 + u^2 t - 2 u^3 + s^2 (3 t + 10 u) - 2 s (t^2 - 10 u t - 5 u^2)) m_Z^2 + \\
& \quad \quad \left. t (s^3 - 2 (t + 2 u) s^2 + (4 t^2 - u t - 3 u^2) s + t^3 - t u^2) m_W^2 + \right. \\
& \quad \left. t (8 m_Z^8 - 22 s m_Z^6 + (13 s^2 - 4 t s + 4 u s - 2 t^2 + 3 u^2 + 3 t u) m_Z^4 + \right. \\
& \quad \quad \left. (s^3 - 2 (t + 2 u) s^2 + (4 t^2 - u t - 3 u^2) s + t^3 - t u^2) m_Z^2 + s t (u^2 - t^2) \right) + \\
& \frac{1}{(\overline{p_3} - \overline{p_2})^2 - m_W^2} \left(8 (t - 6 m_Z^2) m_W^8 + (-336 m_Z^4 + 4 (9 s + 11 t + 24 u) m_Z^2 - 22 t u) m_W^6 + \right. \\
& \quad (-336 m_Z^6 + 8 (5 s + 29 t + 24 u) m_Z^4 + 2 (6 s^2 - 6 (2 t + 9 u) s - 2 t^2 - 12 u^2 - 23 t u) m_Z^2 + \\
& \quad \quad \left. t (3 s^2 + 3 t s + 4 u s - 2 t^2 + 13 u^2 - 4 t u) m_W^4 + \right. \\
& \quad (-48 m_Z^8 + 4 (9 s + 11 t + 24 u) m_Z^6 + 2 (6 s^2 - 6 (2 t + 9 u) s - 2 t^2 - 12 u^2 - 23 t u) m_Z^4 + \\
& \quad \quad (-4 s^3 + 2 (t + 10 u) s^2 + 2 (t^2 + 20 u t + 10 u^2) s - 2 t (4 t^2 + 2 u t - 3 u^2)) m_Z^2 + \\
& \quad \quad \left. t (t^3 + 4 u t^2 - 2 u^2 t + u^3 - s^2 (t + 3 u) - s u (t + 4 u)) m_W^2 + \right. \\
& \quad \left. t (8 m_Z^8 - 22 u m_Z^6 + (3 s^2 + 3 t s + 4 u s - 2 t^2 + 13 u^2 - 4 t u) m_Z^4 + \right. \\
& \quad \quad \left. (t^3 + 4 u t^2 - 2 u^2 t + u^3 - s^2 (t + 3 u) - s u (t + 4 u)) m_Z^2 + t (s^2 - t^2) u) \right) + \\
& \frac{1}{(\overline{p_4} - \overline{p_2})^2 - m_H^2} \left(m_W^4 (12 m_W^4 - 4 t m_W^2 + t^2) (12 m_Z^4 - 4 t m_Z^2 + \right. \\
& \quad \left. t^2) \right)
\end{aligned}$$

```
In[*]:= Print["\tCPU Time used: ", Round[N[TimeUsed[]], 4], 0.001, " s."];
```

CPU Time used: 76.831 s.

```
In[*]:= FeynCalcHowToCite[]
```

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Out[]=*

Null