*FeynArts*绘制费曼图
以及*FeynCalc*计算振幅、截面

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目录

FeynArts is a Mathematica package for the generation and visualization of Feynman diagrams and amplitudes.

FeynArts-3.11

FeynCalc is a Mathematica package for algebraic calculations in QFT and semi-automatic evaluation of Feynman diagrams.

FeynCalc-9.3.1

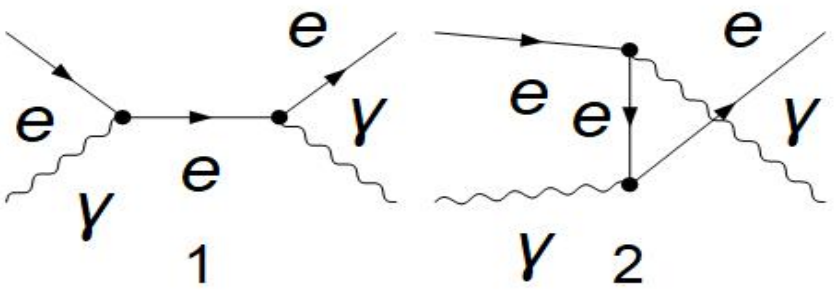
```
Quit[];
退出内核

SetDirectory[NotebookDirectory[]];
设置目录          当前笔记本的目录
$LoadFeynArts = True;
                真

<< FeynCalc`;
```

F[1]	中微子	V[1]	γ	S[1]	H
F[2]	轻子	V[2]	Z	S[2]	G^0
F[3]	u c t	V[3]	W^-	S[3]	G^-
F[4]	d s b				

```
top = InsertFields[CreateTopologies[0, 2 → 2], {F[2, {1}], V[1]} → {F[2, {1}], V[1]},
   InsertionLevel → {Classes}, Model -> "SM", Restrictions → QEDOnly];
Paint[top, ColumnsXRows → {2, 1}, Numbering → Simple, SheetHeader → None,
                                                        无
  ImageSize → {400, 400}];
  图像尺寸
```



$$-\frac{e^2\left(\varphi\left(\overline{p'},m_e\right)\right).(\overline{\gamma}\cdot\overline{\varepsilon}(k)).\left(\overline{\gamma}\cdot\left(\overline{p'}-\overline{k}\right)+m_e\right).(\overline{\gamma}\cdot\overline{\varepsilon}^*(k')).(\varphi\left(\overline{p},m_e\right))}{\left(\overline{k}-\overline{p'}\right)^2-m_e^2}-$$

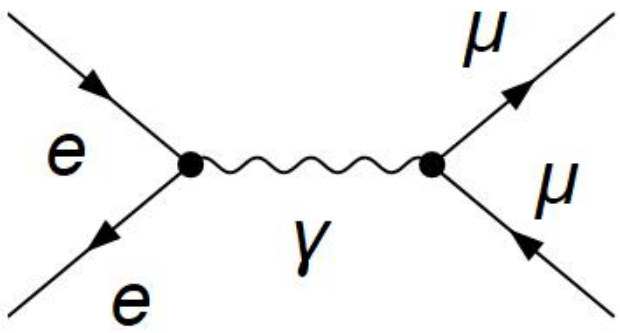
$$\frac{e^2\left(\varphi\left(\overline{p'},m_e\right)\right).(\overline{\gamma}\cdot\overline{\varepsilon}^*(k')).\left(\overline{\gamma}\cdot\left(\overline{k'}+\overline{p'}\right)+m_e\right).(\overline{\gamma}\cdot\overline{\varepsilon}(k)).(\varphi\left(\overline{p},m_e\right))}{\left(-\overline{k'}-\overline{p'}\right)^2-m_e^2}$$

```
amp = FCFAConvert[CreateFeynAmp[top], IncomingMomenta → {p, k}, OutgoingMomenta → {p', k'},
    UndoChiralSplittings → True, ChangeDimension → 4, List → False, SMP → True] // Contract
                                  真                  列表     假              真
```

```
top = InsertFields[CreateTopologies[0, 2 → 2],
    {F[2, {1}], -F[2, {1}]} → {F[2, {2}], -F[2, {2}]}, InsertionLevel → {Classes},
    Model -> "SM", Restrictions → QEDOnly];
Paint[top, ColumnsXRows → {1, 1}, Numbering → Simple, SheetHeader → None,

   ImageSize → {200, 200}];
```

Antiparticles are denoted by a minus sign in front of the field.



$$-\frac{e^2\left(\varphi\left(-\overline{p'},m_e\right)\right).\overline{\gamma}^{\text{Lor1}}.\left(\varphi\left(\overline{p},m_e\right)\right)\left(\varphi\left(\overline{k},m_\mu\right)\right).\overline{\gamma}^{\text{Lor1}}.\left(\varphi\left(-\overline{k'},m_\mu\right)\right)}{\left(\overline{k}+\overline{k'}\right)^2}$$

```
amp = FCFAConvert[CreateFeynAmp[top], IncomingMomenta → {p, p'},
    OutgoingMomenta → {k, k'}, UndoChiralSplittings → True, ChangeDimension → 4,
                                                          真
    List → False, SMP → True] // Contract
    列表    假              真
```

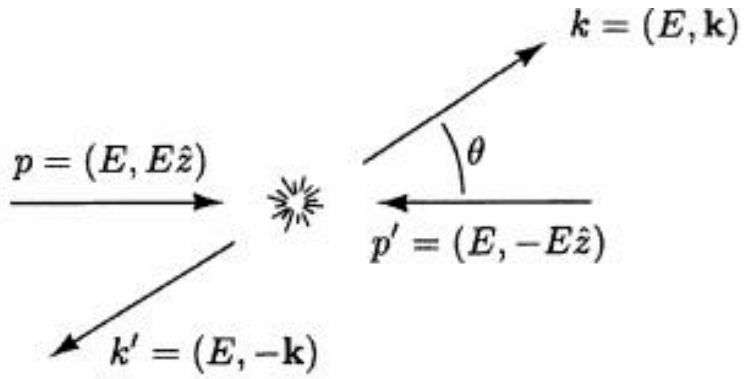
```
SetMandelstam[s, t, u, p, p', -k, -k', 0, 0, SMP["m_mu"], SMP["m_mu"]];
sqAmp =
 (amp * (ComplexConjugate[amp] // FCRenameDummyIndices)) //
      PropagatorDenominatorExplicit // FermionSpinSum[#, ExtraFactor → 1 / 2^2] & //
    ReplaceAll[#, {SMP["m_e"] → 0, DiracTrace -> Tr}] & // Contract // Simplify
     全部替换                                          迹                    化简
```

$$\frac{2\,\mathrm{e}^4\left(2\,m_\mu^4+2\,m_\mu^2\,(s-t-u)+t^2+u^2\right)}{s^2}$$

$$s=(p+p')^2=(k+k')^2$$

$$t=(k-p)^2=(k'-p')^2$$

$$u=(k'-p)^2=(k-p')^2$$



$$\frac{16\,\pi^2\,\alpha^2\left(4\,m_\mu^2 - 4\,m_\mu^2\cos^2(\text{th}) + s\cos^2(\text{th}) + s\right)}{s}$$

```
sqAmp0 =
 Factor[sqAmp /. {t → SMP["m_mu"]^2 - (s / 2 - Sqrt[s^2 / 4 - SMP["m_mu"]^2 * s] * Cos[th]),
   u → SMP["m_mu"]^2 - (s / 2 + Sqrt[s^2 / 4 - SMP["m_mu"]^2 * s] * Cos[th]),
   SMP["e"]^4 → (4 * Pi * SMP["alpha_fs"])^2}]
```

因式分解 平方根 余弦 平方根 余弦

$$\left(\frac{d\sigma}{d\Omega}\right)_{\mathrm{CM}} = \frac{1}{2E_A 2E_B \left|v_A - v_B\right|} \frac{|\mathbf{p}_1|}{(2\pi)^2 \, 4E_{\mathrm{cm}}} \left|\mathcal{M}(p_A, p_B \to p_1, p_2)\right|^2$$

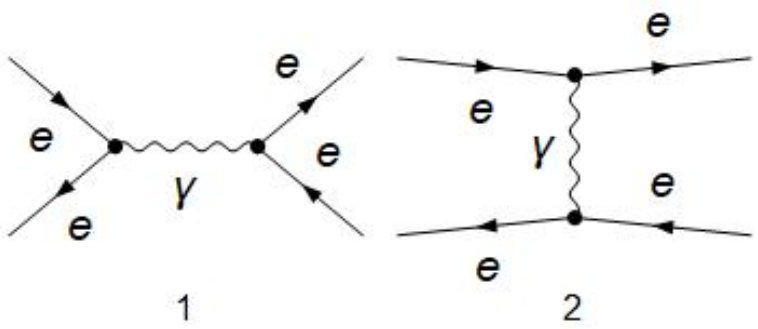
```
prefac = Sqrt[s / 4 - SMP["m_mu"]^2] / (32 Pi^2 * s * Sqrt[s]);
         |平方根                      |圆周率    |平方根
diffXSection0 = prefac * sqAmp0;
crossSectionTotal0 = 2 Pi * Integrate[diffXSection0 * Sin[th], {th, 0, Pi}]
```

$$\frac{4\pi\alpha^2 \sqrt{s - 4m_\mu^2}\,(2m_\mu^2 + s)}{3s^{5/2}}$$

```
diffXSection1 = diffXSection0 /. SMP["m_mu"] -> 0 // Apart;
                                                  |分解分式
crossSectionTotal1 = 2 Pi * Integrate[diffXSection1 * Sin[th], {th, 0, Pi}]
```

$$\frac{4\pi\alpha^2}{3s}$$

```
top = InsertFields[CreateTopologies[0, 2 → 2],
    {F[2, {1}], -F[2, {1}]} → {F[2, {1}], -F[2, {1}]}, InsertionLevel → {Classes},
    Model -> "SM", Restrictions → QEDOnly];
Paint[top, ColumnsXRows → {2, 1}, Numbering → Simple, SheetHeader → None,
                                                                    无
  ImageSize → {200, 100}];
```



$$\frac{e^2\left(\varphi\left(\bar{k},m_e\right)\right).\bar{\gamma}^{\mathrm{Lor2}}.\left(\varphi\left(\bar{p},m_e\right)\right)\left(\varphi\left(-\bar{p}',m_e\right)\right).\bar{\gamma}^{\mathrm{Lor2}}.\left(\varphi\left(-\bar{k}',m_e\right)\right)}{\left(\bar{k}'-\bar{p}'\right)^2} -$$

$$\frac{e^2\left(\varphi\left(\bar{k},m_e\right)\right).\bar{\gamma}^{\mathrm{Lor1}}.\left(\varphi\left(-\bar{k}',m_e\right)\right)\left(\varphi\left(-\bar{p}',m_e\right)\right).\bar{\gamma}^{\mathrm{Lor1}}.\left(\varphi\left(\bar{p},m_e\right)\right)}{\left(\bar{k}+\bar{k}'\right)^2}$$

```
amp = FCFAConvert[CreateFeynAmp[top], IncomingMomenta → {p, p'},
    OutgoingMomenta → {k, k'}, UndoChiralSplittings → True, ChangeDimension → 4,
    List → False, SMP → True] // Contract
```

```
SetMandelstam[s, t, u, p, p', -k, -k', SMP["m_e"], SMP["m_e"], SMP["m_e"], SMP["m_e"]];
sqAmp =
 (amp * (ComplexConjugate[amp] // FCRenameDummyIndices)) // PropagatorDenominatorExplicit //
     FermionSpinSum[#, ExtraFactor → 1 / 2^2] & // ReplaceAll[#, {DiracTrace -> Tr}] & //
                                                全部替换                    迹
   Contract // Simplify
```

$$\frac{2\,e^4\left(8\,m_e^4\left(s^2+s\,t+t^2\right)-4\,m_e^2\left(s^3+s^2\,(u-2\,t)+s\,t\,(3\,u-2\,t)+t^2\,(t+u)\right)+s^4+s^2\,u^2+2\,s\,t\,u^2+t^4+t^2\,u^2\right)}{s^2\,t^2}$$

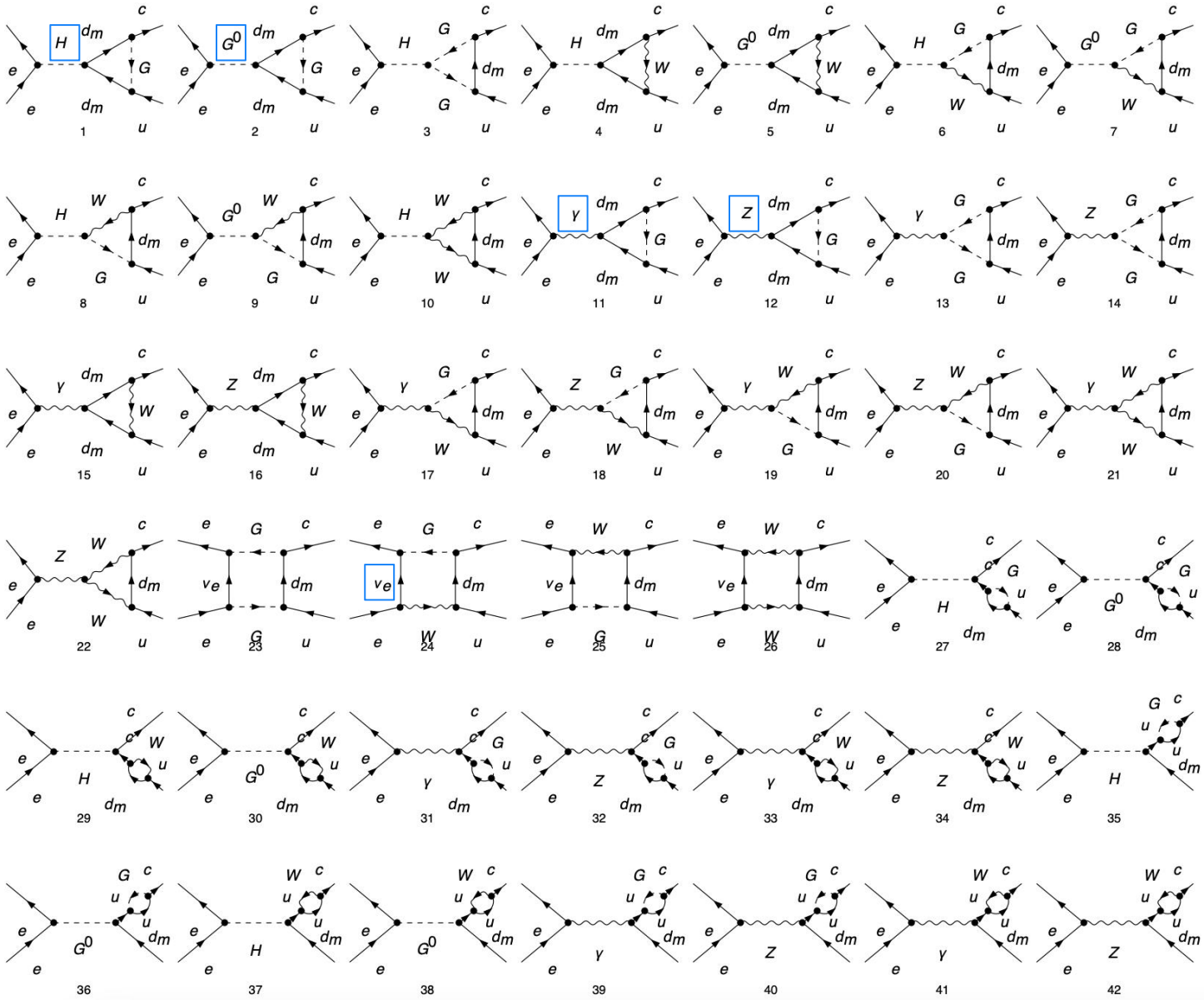
```
sqAmp0 = Factor[sqAmp /. {SMP["e"]^4 → (4 * Pi * SMP["alpha_fs"])^2}];
         因式分解                      圆周率
prefac = Sqrt[s / 4 - SMP["m_e"]^2] / (32 Pi^2 * s * Sqrt[s]);
         平方根                      圆周率      平方根
diffXSection0 = prefac * sqAmp0 /. SMP["m_e"] → 0
```

$$\frac{\alpha^2\left(s^4+s^2\,u^2+2\,s\,t\,u^2+t^4+t^2\,u^2\right)}{2\,s^3\,t^2}$$

```
$CKM = True;
```
真

```
top = InsertFields[CreateTopologies[1, 2 → 2],
    {-F[2, {1}], F[2, {1}]} → {F[3, {2}], -F[3, {1}]}, InsertionLevel → {Classes}
    (*,GenericModel → "Lorentz"*), Model → "SM"];
Paint[top, ColumnsXRows → {7, 6}, Numbering → Simple, SheetHeader → None,
```
无

```
  ImageSize → {310, 270}];
```



InsertFields[]

ExcludeParticles -> {S[1], S[2], F[1]}

γ、Z

ExcludeParticles -> {S[1], S[2], V[2], F[1]}

γ

恳请各位老师同学
批评指正