Implement new effective operators in FeynRules

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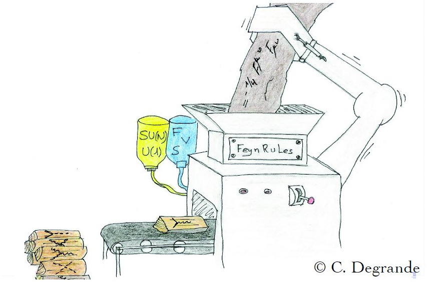
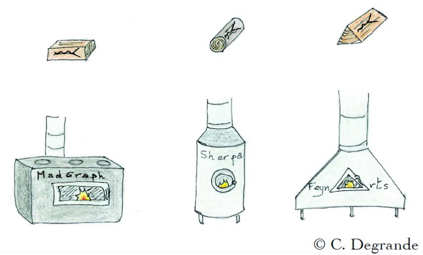
FeynRules

FeynRules: a Mathematica-based package which addresses the implementation of particle physics models, which are given in the form of a list of fields, parameters and a Lagrangian, into high-energy physics tools. [A. Alloul, N. D. Christensen, C. Degrande, C. Duhr, B. Fuks]

Website: `http://feynrules.irmp.ucl.ac.be`

FeynRules 2.0 manual: arXiv:1310.1921





Interfaces to matrix element generators:

- CalcHEP/CompHEP
- FeynArts/FormCalc
- UFO (MadGraph, future GoSam and Herwig++)
- Sherpa
- Whizard/Omega

The requirements on the Lagrangian:

- Lorentz and gauge invariance (all indices need to be contracted)
- Hermiticity and CPT invariance
- Locality
- Supported field types: spin 0, 1/2, 1, 3/2, 2 & ghosts

Inputs requested from the user

Definitions of Gauge groups

```
SU3C == {
Abelian -> False,
CouplingConstant -> gs,
GaugeBoson -> G,
StructureConstant -> f,
Representations -> {T,Colour},
SymmetricTensor -> dSUN }
```

Definitions of particles

```
F[1] ==
{ClassName -> q,
SelfConjugate -> False,
Indices -> {Index[Colour]},
Mass -> {MQ, 200},
Width -> {WQ, 5} }
```

Definitions of parameters

```
gs == {
ParameterType -> Internal,
Value -> Sqrt[4 Pi aS],
InteractionOrder -> {QCD,1},
TeX -> Subscript[g,s],
ParameterName -> G }
```

Definition of the Lagrangian

```
L = -1/4 FS[G,mu,nu,a]
FS[G,mu,nu,a]
+ I qbar.Ga[mu].DC[q,mu]
- MQ qbar.q
```

$$\mathcal{L} = -\frac{1}{4} G^a_{\mu\nu} G^{a\mu\nu} + i\bar{q}\gamma^\mu D_\mu q - M_q \bar{q} q$$

Checking the implementation of the model

In FeynRules

Test if the Lagrangian L is hermitian:

```
CheckHermiticity[L]
```

Test if the mass terms in the Lagrangian L are correctly diagonalized and if their values corresponds to the numerical values given in the model file:

```
CheckMassSpectrum[L]
```

Check if the kinetic terms in the Lagrangian L are correctly diagonalized and normalized:

```
CheckKineticTermNormalisation[L]
```

In MadGraph

Check if the process is gauge and Lorentz invariant:

```
mg5> check gauge p p > u u
mg5> check lorentz_invariance p p > u u
```

Example 1: $hgtt$ effective interaction

SM Lagrangian supplemented by a chromomagnetic dipole term

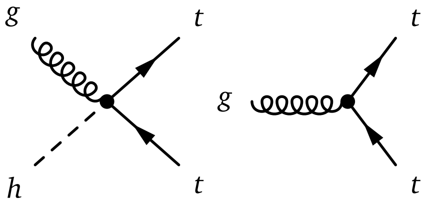
$$\mathcal{L}_{hgt} = \frac{c_{hgt}}{\Lambda^2} \varepsilon^{ij} \bar{Q}_{iL} \Phi_j^\dagger \sigma^{\mu\nu} T^a t_R G^a_{\mu\nu} + \text{h.c.}$$

[Bramante *et al.*, arXiv:1402.5985]

In the unitarity gauge, $\Phi \to \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ v + h \end{pmatrix}$

New parameters: c_{hgt}, Λ

Relevant process: $pp \to t\bar{t}h$



Example 2: dark matter effective interaction

SM Lagrangian supplemented by WIMP-quark axial vector interaction

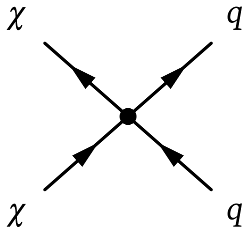
$$\mathcal{L}_{\text{WIMP}} = i\bar{\chi}\gamma^\mu\partial_\mu\chi - m_\chi\bar{\chi}\chi + \frac{1}{\Lambda^2}\sum_q \bar{\chi}\gamma^\mu\gamma_5\chi\bar{q}\gamma_\mu\gamma_5 q$$

[Goodman *et al.*, arXiv:1008.1783]

New field: Dirac fermionic WIMP χ

New parameters: m_χ, Λ

Relevant process: $pp \to \chi\bar{\chi}j$



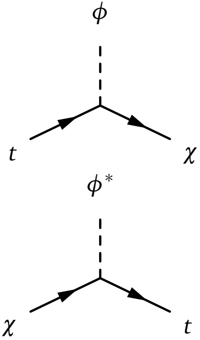
Example 3: dark matter interaction mediated by a scalar

Top portal dark matter Model

$$\mathcal{L}_{\text{WIMP}} = i\bar{\chi}\gamma^{\mu}\partial_{\mu}\chi - m_{\chi}\bar{\chi}\chi + (D_{\mu}\phi)^{\dagger}D_{\mu}\phi - m_{\phi}^{2}\phi^{*}\phi + g_{\text{DM}}(\phi^{*}\bar{\chi}t_R + \phi\bar{t}_R\chi)$$

[Gómez *et al.*, arXiv:1404.1918]

$$D_{\mu}\phi = \left(\partial_{\mu} - ig_s G_{\mu}^{a}T^{a} - i\frac{2}{3}eA_{\mu} + \frac{2ies_W}{3c_W}Z_{\mu}\right)\phi$$



New fields: Dirac fermionic WIMP χ
Colored scalar mediator ϕ

New parameters: m_{χ}, m_{ϕ}, g_{DM}

Relevant process: $pp \to \phi\phi^{*} \to t\bar{t}\chi\bar{\chi}$

FeynRules model database

Link:

http://feynrules.irmp.ucl.ac.be/wiki/ModelDatabaseMainPage

Available models

Standard Model	The SM implementation of FeynRules, included into the distribution of the FeynRules package.
Simple extensions of the SM (18)	Several models based on the SM that include one or more additional particles, like a 4th generation, a second Higgs doublet or additional colored scalars.
Supersymmetric Models (5)	Various supersymmetric extensions of the SM, including the MSSM, the NMSSM and many more.
Extra-dimensional Models (4)	Extensions of the SM including KK excitations of the SM particles.
Strongly coupled and effective field theories (8)	Including Technicolor, Little Higgs, as well as SM higher-dimensional operators, vector-like quarks.
Miscellaneous (0)	

New features in FeynRules 2.0

New features relative to FeynRules 1.0:

- Support for two-component Weyl fermion notation.
- Support for spin-3/2 and spin-2 fields.
- Support for superspace notation and calculations.
- Automatic calculation of $1 \to 2$ decays.
- Automatic mass diagonalization (ASperGe).
- Automatic generation of FeynArts generic files.
- New Universal FeynRules Output (UFO) interface.
- New Whizard interface.
- Speed and efficiency improvements.

Thanks for your attentions!