New Developments in FEYNRULES arxiv:1310.1921

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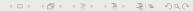
October 28-30, 2013



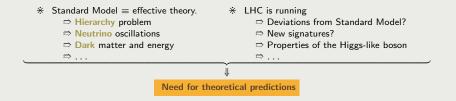
Basic features of FEYNRULES

2 New developments in version 2.0





Need for automatization



- * Develop new models
 - ⇒ Write Lagrangian
 - ➡ Compute several quantities (decay widths, mass and mixing matrices . . .)
- * Implement in Monte Carlo (MC) tools
 - ⇒ Many available tools (CALCHEP, MADGRAPH, PYTHIA, SHERPA...)
 - Every tool has its dedicated file format
 - Every tool has its advantages / disadvantages

Starting from a model, $\rm FEYNRULES$ provides all the necessary ingredients to generate the model file for the beloved MC tool(s)

A simple example: The Higgs Effective Lagrangian

[AA, B. Fuks, V. Sanz arXiv:1310.5150]

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Model implementation

 $\ensuremath{\overset{\,\,{}_{\scriptstyle{\scriptstyle{\scriptstyle{\scriptstyle{\scriptstyle{\scriptstyle{\scriptstyle{\scriptstyle}}}}}}}}}$ Consider the dimension-six $\mathcal{CP}\text{-conserving coupling}$

$$ig_1 rac{ar{c}_{HB}}{M_W^2} B_{\mu
u} D^\mu \Phi^\dagger D^
u \Phi$$

➡ First declare the gauge symmetries M\$GaugeGroups = {U1Y == {...}, SU2L == {...}}

➡ The fields M\$ClassesDescription = {V[1] == {....}, S[1] == {....}}

⇒ Other types of fields supported U, F, W, CSF, VSF, R, RW

➤ The parameters M\$Parameters = {cHB == {...}, g1 == {...}, MW == {...}}

* Finally, the Lagrangian

Lagr = I cHB g1/ MW^2 FS[B,mu,nu] DC[Phibar[ii],mu] DC[Phi[ii],nu]

⇒ Several commands to compute (non-)supersymmetric Lagrangians.

A simple example: The Higgs Effective Lagrangian

[AA, B. Fuks, V. Sanz arXiv:1310.5150]

Passing the information to Monte Carlo tools

- * Several interfaces to pass the information
 - CALCHEP FEYNARTS MADGRAPH SHERPA WHIZARD
- ✤ "Home-made" interface
 - ▷ PYTHON based
 - ➢ No restrictions with respect to Lorentz/Colour structure
 - ➡ Supported by Aloha, MADANALYSIS 5 AND MADGRAPH 5
 - ⇒ Will be used in the future by GOSAM AND HERWIG++

WriteUF0[lagr]

For further details

- 🛤 FeynRules Feynman rules made easy, Christensen, Duhr, CPC'09
- Main A superspace module for the FeynRules package, Duhr, Fuks, CPC'11

A Comprehensive approach to new physics simulations, Christensen, de Aquino, Degrande, Duhr, Fuks, Herquet, Maltoni, Schumann, E.P.J C71 '11

🛤 UFO - The Universal FeynRules Output, Degrande, Duhr, Fuks, Grellscheid, Mattelaer, Reiter, CPC '12

Introducing an interface between WHIZARD and FeynRules, Christensen, Duhr, Fuks, Reuter, Speckner, E.P.J. C72 '12

Beyond the Minimal Supersymmetric Standard Model: from theory to phenomenology, Fuks, Int.J.Mod.Phys. A27 '12

Spin-3/2 particles at colliders, Christensen, de Aquino, Deutschmann, Duhr, Fuks, Garcia-Cely, Mattelaer, Mawatari, Oexl, Takaesu, Eur. Phys. J. C73 (2013) 2580

🟁 New developments in FeynRules, AA, Christensen, Degrande, Duhr, Fuks, arXiv:1309.7806

FeynRules 2.0 - A complete toolbox for tree-level phenomenology, AA, Christensen, Degrande, Duhr, Fuks, arXiv:1310.1921







New developments in version 2.0



Conclusion



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Spin-3/2 Rarita-Schwinger fields

Implementing the field

- ✤ Spin-3/2 fields
 - ⇒ Described first by Rarita & Schwinger in 1941.
 - ⇒ Appears in some BSM theories (Gravitino in SUSY, e.g)

* In FEYNRULES { Lagrangian's dimensionality unrestricted. Complete superspace module. } Everything is there !

- * Two new classes for field decalaration
 - \Rightarrow For two-component fermions RW
 - \Rightarrow For four-component fermions R

In the case of supersymmetry

- * Goldstino / Gravitino
 - \Rightarrow Spontaneous supersymmetry breaking \Rightarrow massless fermion.
 - \Rightarrow Its interactions given by supercurrent $\epsilon \cdot J^{\mu} + \bar{\epsilon} \cdot \bar{J}^{\mu} = \frac{\partial \mathcal{L}}{\partial (\partial_{\mu} X)} \delta_{\epsilon} X K^{\mu}$
 - ➡ FEYNRULES dedicated command Supercurrent[lc,lv,lw,sp,mu]

1c: Chiral Lagrangian, 1v: Vector Lagrangian, 1w: Superpotential, sp,mu: Spin & Lorentz indices.

 \times UFO and CALCHEP interfaces adapted

Simulating spin-3/2 particle production at colliders,

Christensen, de Aquino, Deutschmann, Duhr, Fuks, Garcia-Cely, Mattelaer, Mawatari, Oexl, Takaesu, Eur. Phys. J. C73 (2013) 2580

Decays package

- * Tree-Level two-body decay widths
 - Are now automatically computed for any model verts = FeynmanRules[LQCD]; results = ComputeWidths[verts];
 - ⇒ Everything is analytical
- * Phase-space closed channels included
 - ⇒ No information on the (numerical values of the) spectrum at this level
 - Benchmark scenario independent
- * Information passed to the UFO WriteUFO[LQCD, AddDecays -> True]
 - ⇒ Flexible: closed formulas (NLO, n-body) can be included.
- ✤ MadGraph 5¹
 - ⇒ checks numerically open channels.
 - ⇒ compute automatically n-body decay widths

Computing decay rates for new physics theories with FEYNRULES and MADGRAPH, Alwall, Duhr, Fuks, Mattelaer, Oeztürk, In preparation

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Spectrum generator

Problem

- * After generating the model file for the MC-generator, we need
 - To calculate the mass matrices: Lengthy and error-prone
 - Diagonalize them: No analytical solution for matrices bigger than 4 × 4
 - Dupdate the model file: Lengthy (several scenarios) and error-prone

Solution

- ✤ FeynRules will
 - ⇒ extract automatically analytical expressions for mass matrices
 - ⇒ generate automatically a numerical code for the diagonalization
- * The numerical code:
 - ⇒ produces a SLHA-like output

Mass matrices generation with $\operatorname{FeynRules}$

Model file simplified

- * Two new global variables M\$MixingDescription, M\$vevs
- * Mass matrices, mixing matrices declared automatically as complex

Commands available in $\operatorname{FeynRules}$

- * Compute mass matrices: ComputeMassMatrix[lagr]
- * Summary of all results MixingSummary[]
- * ...

Towards a numerical code

- * Write the C++ package: WriteASperGe[Lagrangian]
- * Run the package and import results: RunASperGe[]

Block MASS
<pre># pdg code mass particle</pre>
22 0.000000e+00 # A
23 9.180401e+01 # Z

Mutomated mass spectrum generation for new physics,

AA, D'Hondt, De Causmaecker, Fuks, Rausch de Traubenberg, E.P.J C73 '13

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Conclusion

Features of $\operatorname{FeynRules}$ 2.0

- * Model implementation minimal
- * Superspace package
- * Many interfaces to Monte Carlo tools
- * Universal FeynRules Output
- * Spectrum generator (with ASPERGE).
- ★ Decay package for $1 \rightarrow 2$ processes.
- * Rarita-Schwinger spin-3/2 field implemented.
- * LATEX interface
- * Major speed improvement and bug corrections.

feynrules.irmp.ucl.ac.be

Thank you for your attention

WriteLaTeXOutput[L1, L2, ... , V1, V2, ...]

L1, L2,... are Lagrangians V1, V2,... are list of vertices

* The output

- title.tex: Contains the title.
- abstract.tex: Contains the abstract.
- introduction.tex: Contains the introduction.
- symmetries.tex: Contains information about the gauge symmetries and indices.
- fields.tex: Contains information about the fields.
- ➡ lagrangians.tex: Contains the Lagrangians.
- **parameters.tex**: Contains information about the parameters.
- vertices.tex: Contains the vertices.
- bibliography.tex: Contains the bibliography.

$$\left(egin{array}{cc} \gamma & 1 \ \phi^{++} & 2 \ \phi^{--} & 3 \end{array}
ight) \qquad 2ie(p_2{}^{\mu_1}-p_3{}^{\mu_1})$$