LanHEP - a package for automatic generation of Feynman rules from the Lagrangian. Updated version 3.2

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Abstract

We present a new version 3.2 of the LanHEP software package. New features include UFO output, color sextet particles and new substitution techniques which allow to define new routines.

Introduction

The LanHEP program [1] is developed for Feynman rules generation from the Lagrangian. It reads the Lagrangian written in a compact form, close to the one used in publications. It means that Lagrangian terms can be written with summation over indices of broken symmetries and using special symbols for complicated expressions, such as covariant derivative and strength tensor for gauge fields. Supersymmetric theories can be described using the superpotential formalism and the 2-component fermion notation. The output is Feynman rules in terms of physical fields and independent parameters in the form of CompHEP [2] or CalcHEP [3] model files, which allows one to start calculations of processes in the new physical model. Alternatively, Feynman rules can be generated in FeynArts [4] format or as LaTeX table. The program can also generate one-loop counterterms in the FeynArts format.

New version of the package can also generate Feynman rules in UFO [5] format. Use command line option -ufo to select this format.

The package can be downloaded from http://theory.sinp.msu.ru/~semenov/lanhep.html

1 Color sextets

One can use now particles belonging to 6-dimensional representation of the color SU(3) group, color sextets. LanHEP name for this representation is color c6 (and color c6b for anti-sextets), it can be used in the particle definition like:

scalar s6/S6:('some sextet', mass M6=100, color c6).
There are matrices for interaction of color sextets with triplets: \( k_{c6} \) with two antitriplet indices and one with sextet index, conjugated matrix \( k_{c6b} \) with two triplet and one antisextet indices, and the matrix for interaction of sextets with gluon \( l_{c6} \) with sextet, antisextet, and octet indices. So one can write the covariant derivative \( \partial^{\mu} \delta_{ab} + ig \lambda^c_{ab} G^{\mu}_c \) as \( \text{deriv}^\mu \delta_\text{color} \) + \( i \times g \times l_{c6} \times G^\mu \).

Now color sextets are supported only for CalcHEP output.

2 Coefficients in the vertices

A new feature in LanHEP allows to extract the expression from any generated vertex. This can be used to implement the different contributions to the loop-induced \( H\gamma\gamma \) and \( Hgg \) vertices. The function which allows to extract a specific coupling is \( \text{CoefVrt(} [\text{particles}] , [\text{options}] \) \), where \text{particles} is the comma-separated list of particles in the vertex, and \text{options} specifies the tensor structure of the required coefficient as well as other options. The only tensor structure that can be extracted are 1, \( \gamma^\mu \), \( \gamma^5 \), \( \gamma^\mu \gamma^5 \), \( p^\mu \) and the function \( \text{CoefVrt} \) must be called separately for each tensor structure. The second list can contain the following symbols in any order:

- \text{gamma} corresponds to only \( \gamma^\mu \) matrices in the vertex, \text{gamma5} to only \( \gamma^5 \) matrices and \text{gamma, gamma5} to product of \( \gamma^\mu \gamma^5 \) matrices. If none of these symbols are listed, then only terms which do not include \( \gamma \)-matrices will be extracted;
- \text{moment(} P \) where \( P \) is a particle name selects the terms depending on this particle momentum, note that vertices corresponding to higher order operators and containing the product of several momenta cannot be handled;
- \text{re, im} - take real or imaginary part of the expression. It can be combined with options above.
- \text{abbr} - use abbreviations in the returned expressions, this option is useful for long expressions.

For example, we can obtain expressions from the vertices of the Higgs boson interaction with sleptons (divided by the square of the slepton mass), which contribute into \( H\gamma\gamma \) vertex:

\[
_\text{p}=[\text{eL}, \text{eR}, \text{mL}, \text{mR}, 11, 12] \text{ in parameter } \text{AhS}_\text{p}=\text{CoefVrt(}[\text{anti(}_\text{p}), _\text{p}, \text{h}] )/(\text{mass } _\text{p})^2/2/2.
\]

3 Aliases

Aliases allow to define substitution rules which are applied to all subsequent LanHEP statements. For example, the statement \text{alias} \( \mu=\text{mue} \) allows to rename the parameter \( \mu \) in the entire model. This statement must be placed before the declaration of this parameter.

Aliases can have arguments, for example one can define electric charge for quarks:
alias Q(u)=2/3, Q(c)=2/3, Q(t)=2/3, Q(d)=-1/3, Q(s)=-1/3, Q(b)=-1/3.

If a symbol appears on both the left-hand and the right-hand side of '=' sign in the definition of an alias, then it denotes any term in the actual expression. For example,

alias declScalar(name/antiname, massValue) =
(scalar name/antiname:('scalar 'name, mass Mname=massValue)).

will declare a scalar particle named name with mass $M_{name}$ equal to massValue. Here # sign means concatenation of the symbols to the left-hand and right-hand side. If the symbol on the left-hand side of '=' sign begins with '_' character, it denotes any term. For example, alias Q(x)=0. will define charge equal to zero for all particles. Since aliases are applied to the expressions in the same order as they were defined, more general definitions must follow more specific ones. On the other hand, if a symbol which appears on both the left-hand and the right-hand side of '=' sign, must denote only itself, it has to come on the left-hand side with unary plus operator: +symbol. Also unary plus in the rest of the model prevents its argument from being processed by aliases.

As it was shown, aliases can define new statements to be used in the model. An alias can be defined for a list of statements:

alias newStat= [(Stat1), (Stat2) ...].

In these statements new symbols (names for particles, parameters) can be generated by means of in operator or by # sign from the arguments of newStat. New symbols can also be defined in the separate local statement which creates temporary aliases used in the block of statements:

alias declScalar(name/aname, massValue) = [
  (local sMass=M#name),
  (scalar name/aname:('scalar 'name, mass sMass=massValue))
].

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References

[1] A. Semenov, Comput.Phys.Commun. 180:431-454,2009. e-Print: arXiv:0805.0555 [hep-ph].
[2] E. Boos et al., Nucl.Instrum.Meth. A534:250-259,2004. e-Print: hep-ph/0403113
[3] A. Pukhov. e-print hep-ph/0412191.
[4] J. Küblbeck, M. Böhm, and A. Denner, *Comp. Phys. Commun.* 60 (1990) 165;
   H. Eck and J. Küblbeck, *Guide to FeynArts 1.0* (Würzburg, 1992);
   H. Eck, *Guide to FeynArts 2.0* (Würzburg, 1995);
   T. Hahn, *Comp. Phys. Commun.* 140 (2001) 418; [arXiv:hep-ph/0012260].

[5] Céline Degrande, Claude Duhr, Benjamin Fuks, David Grellscheid, Olivier Mattelaer,
   Thomas Reiter *Comput.Phys.Commun.* 183 (2012) 1201-1214

[6] A. Perez-Lorenzana, *An introduction to extra dimensions*, *J.Phys. Conf. Ser* 18
   (2005) 224–269, [hep-ph/0503177].