Durham University

Ip3

FeynRules
Status and plans

Claude Duhr
in collaboration with N. D. Christensen and B. Fuks

MadGraph Meeting 2011
Fermilab, 05 May 2011

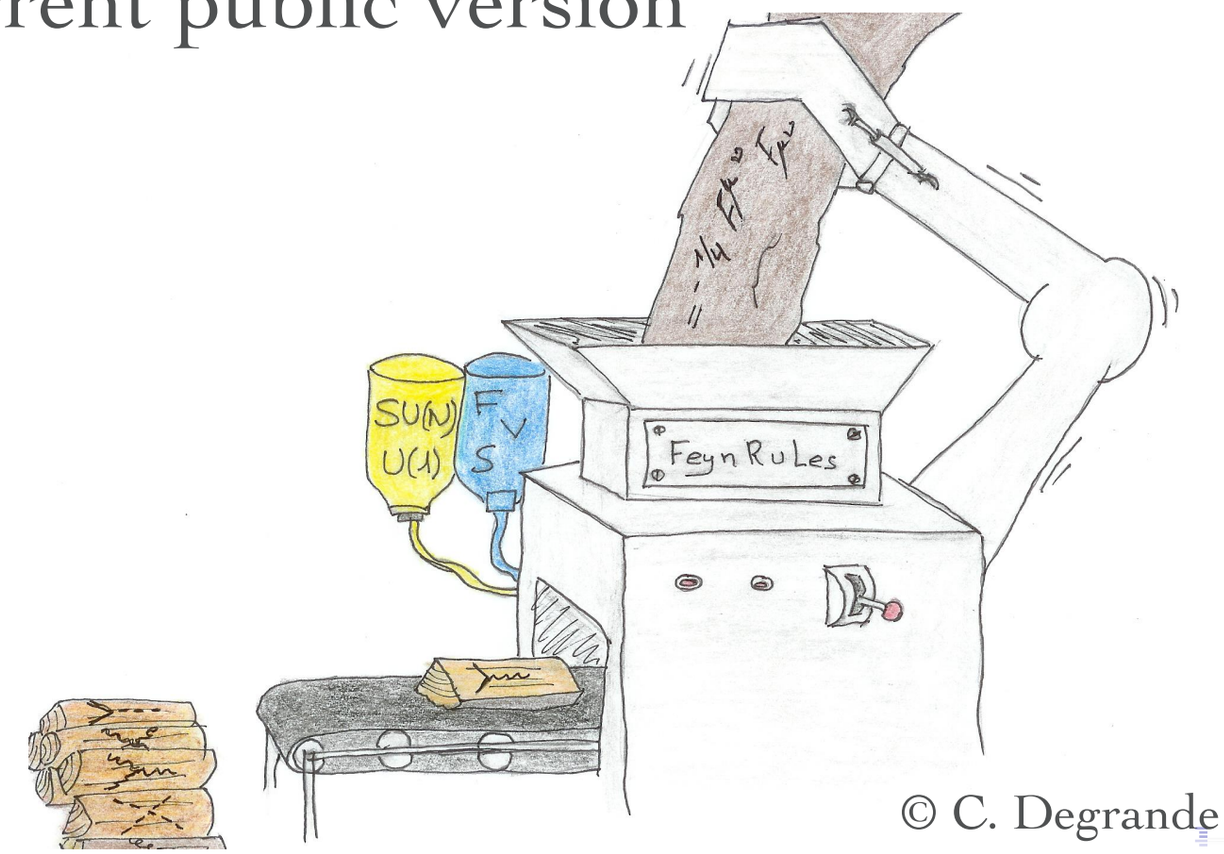
What is FeynRules..?

- FeynRules is a Mathematica package that allows to derive Feynman rules from a Lagrangian.

- The only requirements on the Lagrangian are:
  - ➡ All indices need to be contracted (Lorentz and gauge invariance)
  - ➡ Locality
  - ➡ Supported field types: spin 0, 1/2, 1, 2 & ghosts

What is FeynRules..?

- FeynRules comes with a set of interfaces, that allow to export the Feynman rules to various matrix element generators.
- Interfaces coming with current public version
  - ➡ CalcHep / CompHep
  - ➡ FeynArts / FormCalc
  - ➡ MadGraph 4 & 5
  - ➡ Sherpa
  - ➡ Whizard / Omega



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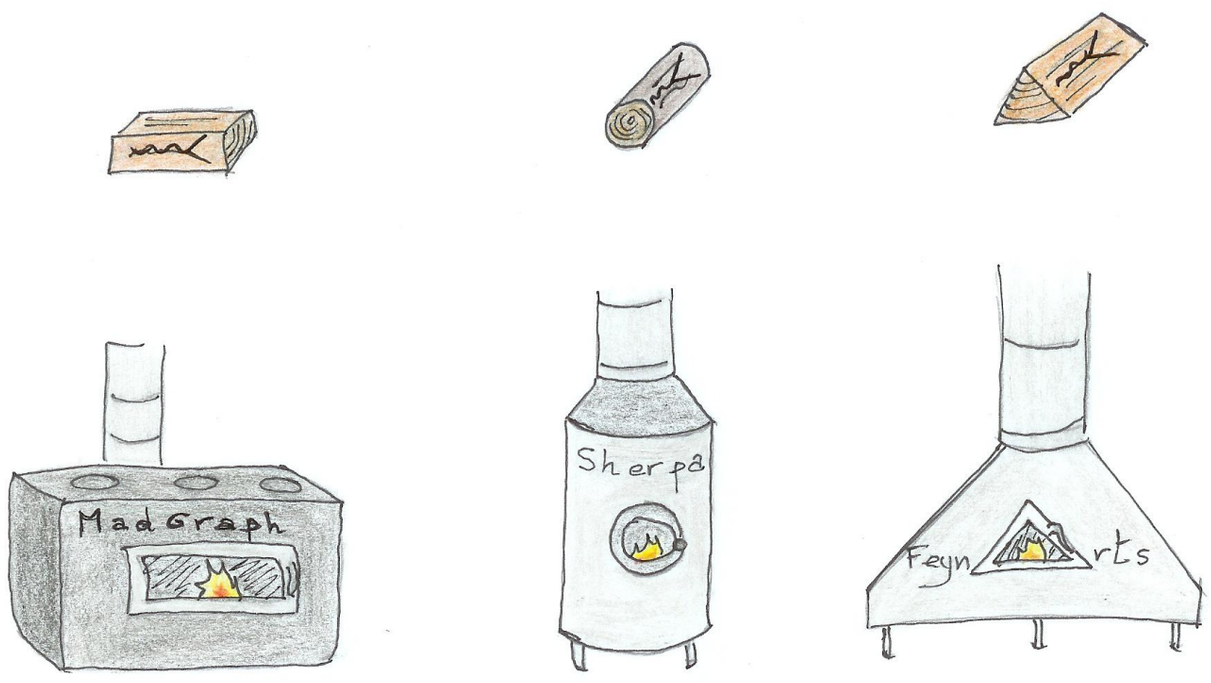


© C. Degrande

How to use FeynRules

- The input requested form the user is twofold.

- The Model File:
  Definitions of particles and parameters (e.g., a quark)

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

- The Lagrangian:

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

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

How to use FeynRules

- Once this information has been provided, FeynRules can be used to compute the Feynman rules for the model:

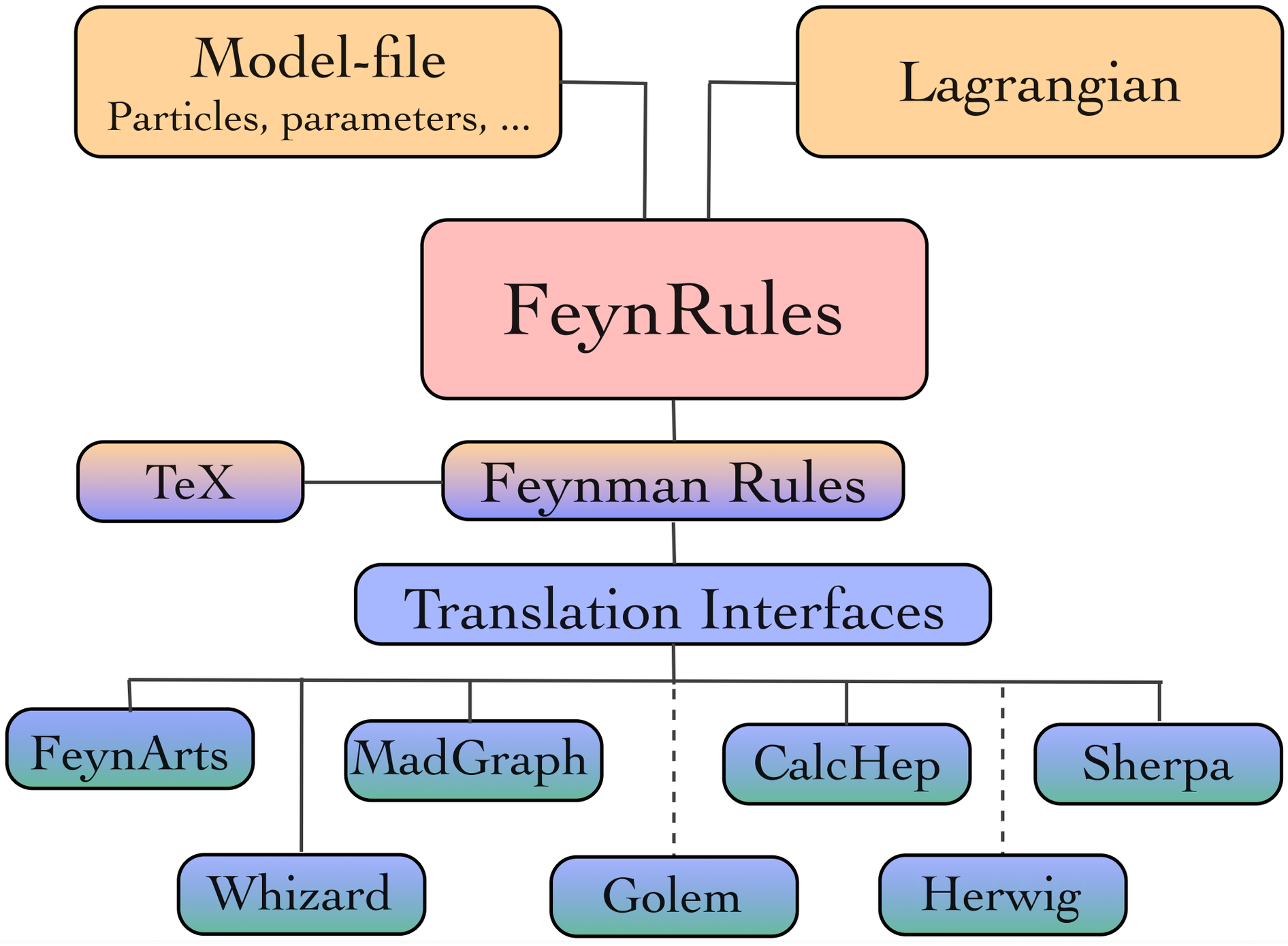
FeynmanRules[L]

- Equivalently, we can export the Feynman rules to a matrix element generator, e.g., for MadGraph 4,

WriteMGOutput[L]

- This produces a set of files that can be directly used in the matrix element generator ("plug 'n' play").

FeynRules


Model-file
Particles, parameters, ...
Lagrangian
FeynRules
TeX
Feynman Rules
Translation Interfaces
FeynArts
MadGraph
CalcHep
Sherpa
Whizard
Golem
Herwig

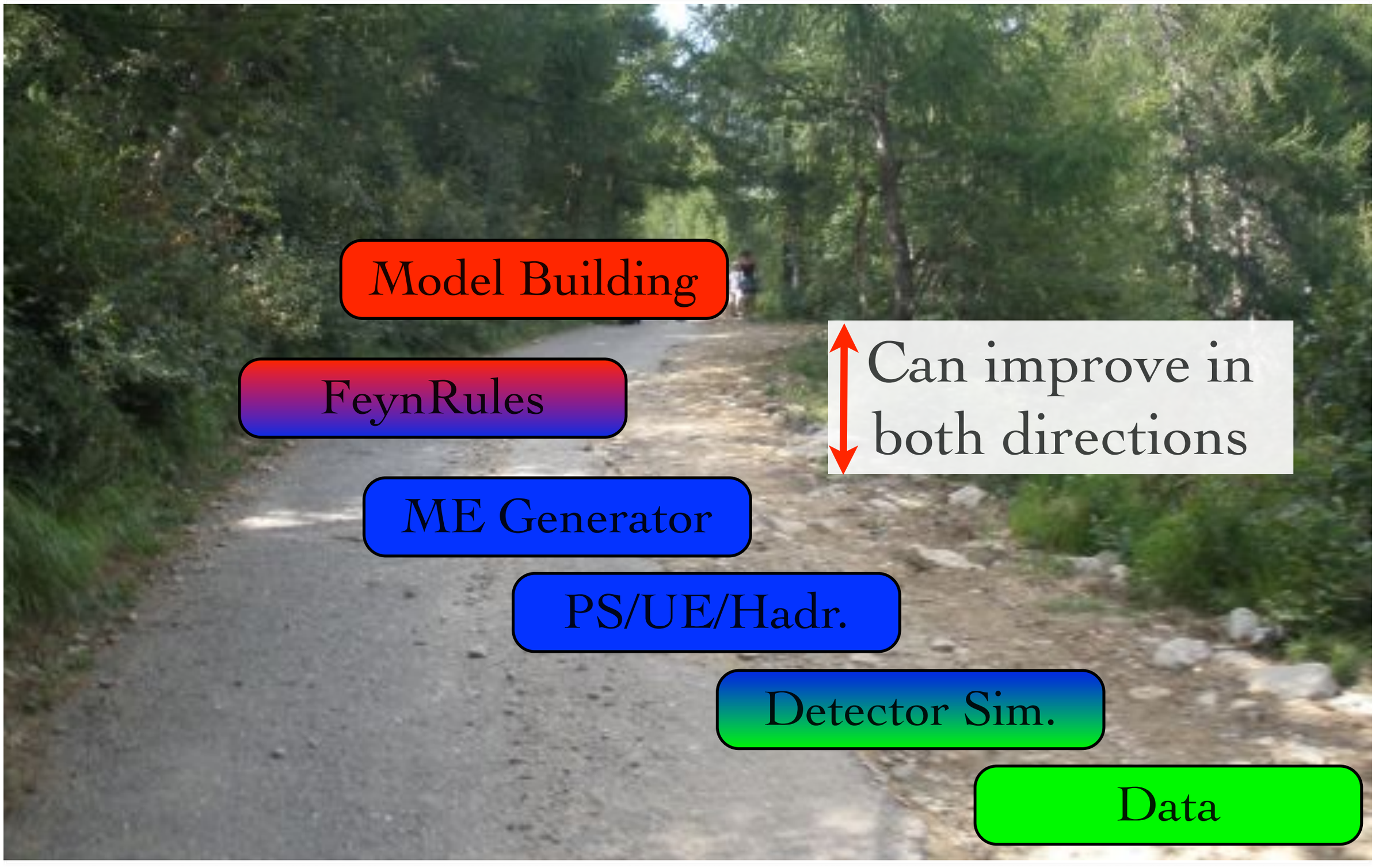
Once upon a time in a land far away...

- ... FeynRules models needed to be implemented in component fields.
  - ➡ Painful especially for SUSY models.

- ... almost all matrix element generators could only handle renormalizable interactions.
  - ➡ Puts enormous restrictions on the models that can be simulated.

- ... the simulation of non-standard color structures was very hard, if not impossible.

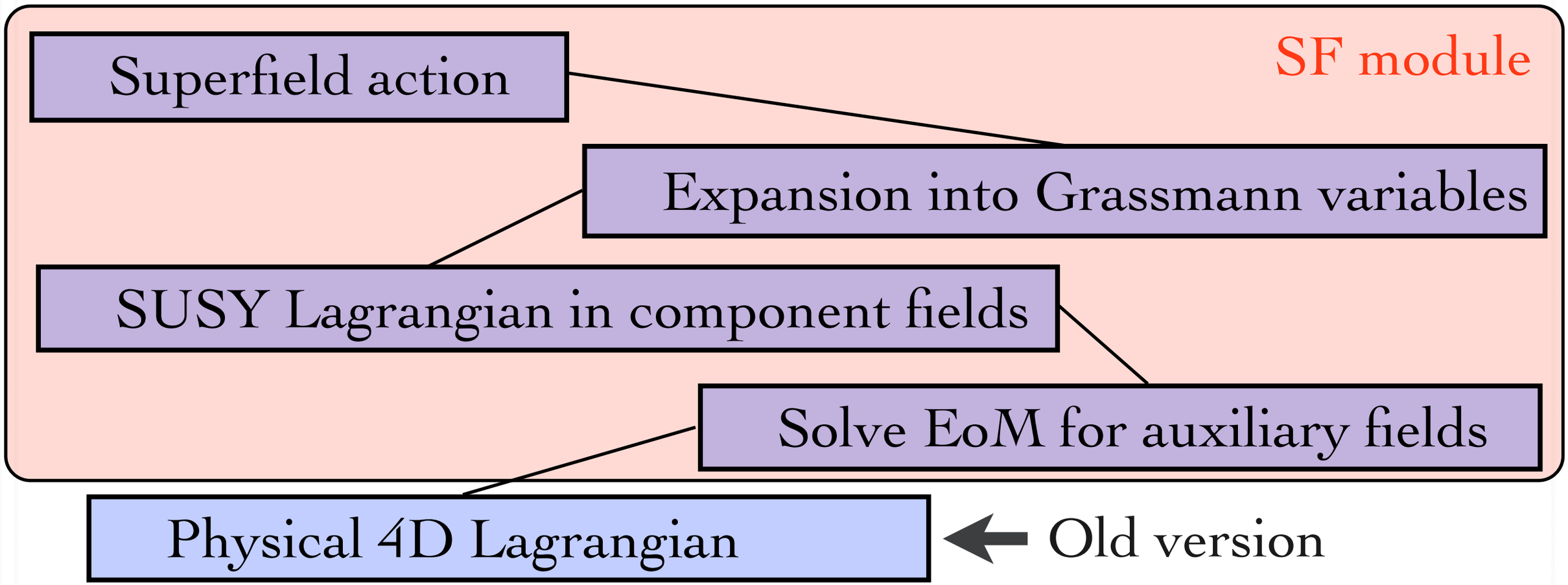
The road to BSM physics



Weyl fermions and superfields

- Full support for two-component fermions.
- Full support for superfields, automatic solving of eq. of motions for auxiliary fields, *etc*.

➡ See Benj's talk



Spin 3/2

- The super-space module opens a completely new way to implement *any* SUSY, with gravitino.
- Spin 3/2 is fully supported (privately), and all vertices have been checked against the literature.

```
R[1] == {
    ClassName -> rG,
    SelfConjugate -> True,
    Mass -> {MrG, 1000},
    Width -> {WrG, 20},
    FullName -> "Spin 3/2 G particle" },
```

```
FA[mu,nu] fNbar[r].(gfNrG1.Ga[mu,r,t]
+gfNrG2.Ga[mu,r,s].Ga[5,s,t]).rG[t,nu]
```

$$(\partial_{\mathrm{nu}}(A_{\mathrm{mu}}) - \partial_{\mathrm{mu}}(A_{\mathrm{nu}}))\,\bar{\mathrm{fN}}_r.\left(\mathrm{gfNrG1}\,\gamma^{\mathrm{mu}}_{r,t} + \mathrm{gfNrG2}\,\gamma^{\mathrm{mu}}.\gamma^{5}{}_{r,t}\right).\mathrm{rG}_{t,\mathrm{nu}}$$

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(* *)

Vertex 1

Particle 1 : Vector , A

Particle 2 : Majorana , fN

Particle 3 : Real Spin 3/2 , rG

Vertex:

$$2\,\mathrm{gfNrG2}\,p_1^{\mu_3}\,\gamma^{\mu_1}.\gamma^5{}_{s_2,s_3} - 2\,\mathrm{gfNrG2}\,\eta_{\mu_1,\mu_3}\,\mathrm{SlashedP}(1).\gamma^5{}_{s_2,s_3}$$

(* *)

Sextet color structures

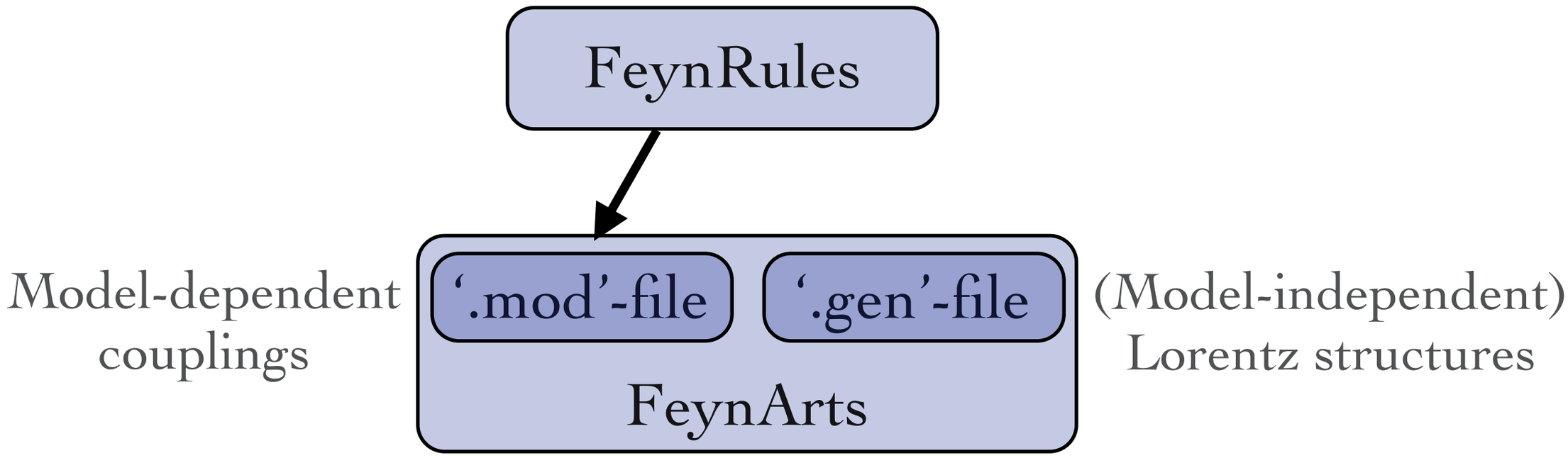
- So far, FeynRules was limited to triplet and octet color structures (mostly because there was no ME generator for higher representations).

- The new FeynRules version allows to include also particles in the sextet representation.

- Together with MG5, this allows to generate for the first time sextet production without having to 'hack' the ME generator.

FeynArts interface (C. Degrande, CD)

- A new interface to FeynArts is being developed that allows to implement arbitrary Lorentz structures.



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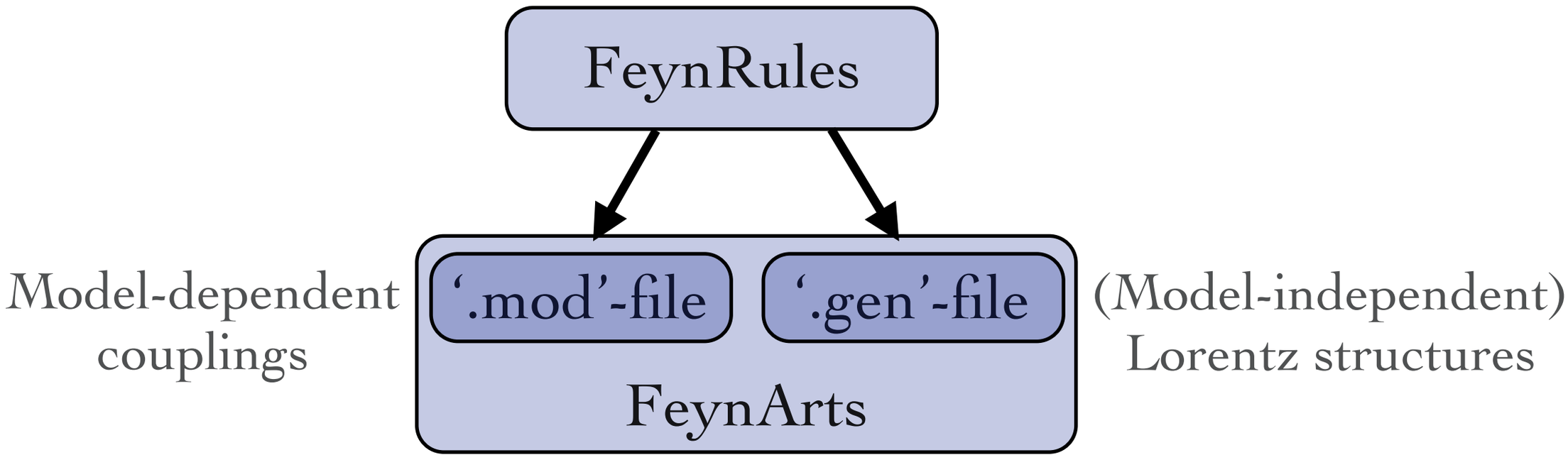


- This development goes along with a new version of FormCalc able to deal with multi-fermion interactions.

The UFO

(C. Degrande, CD, B. Fuks, D. Grellscheid, O. Mattelaer, T. Reiter)

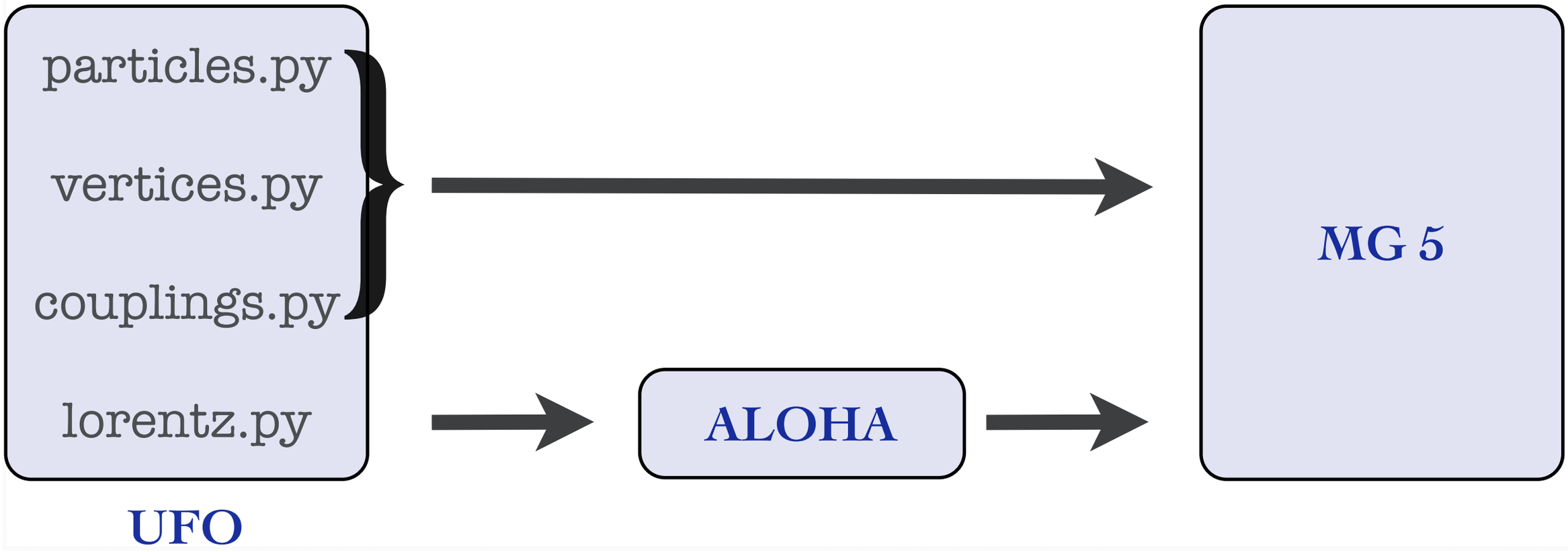
UFO = Universal FeynRules Output

➡ See Olivier's talk

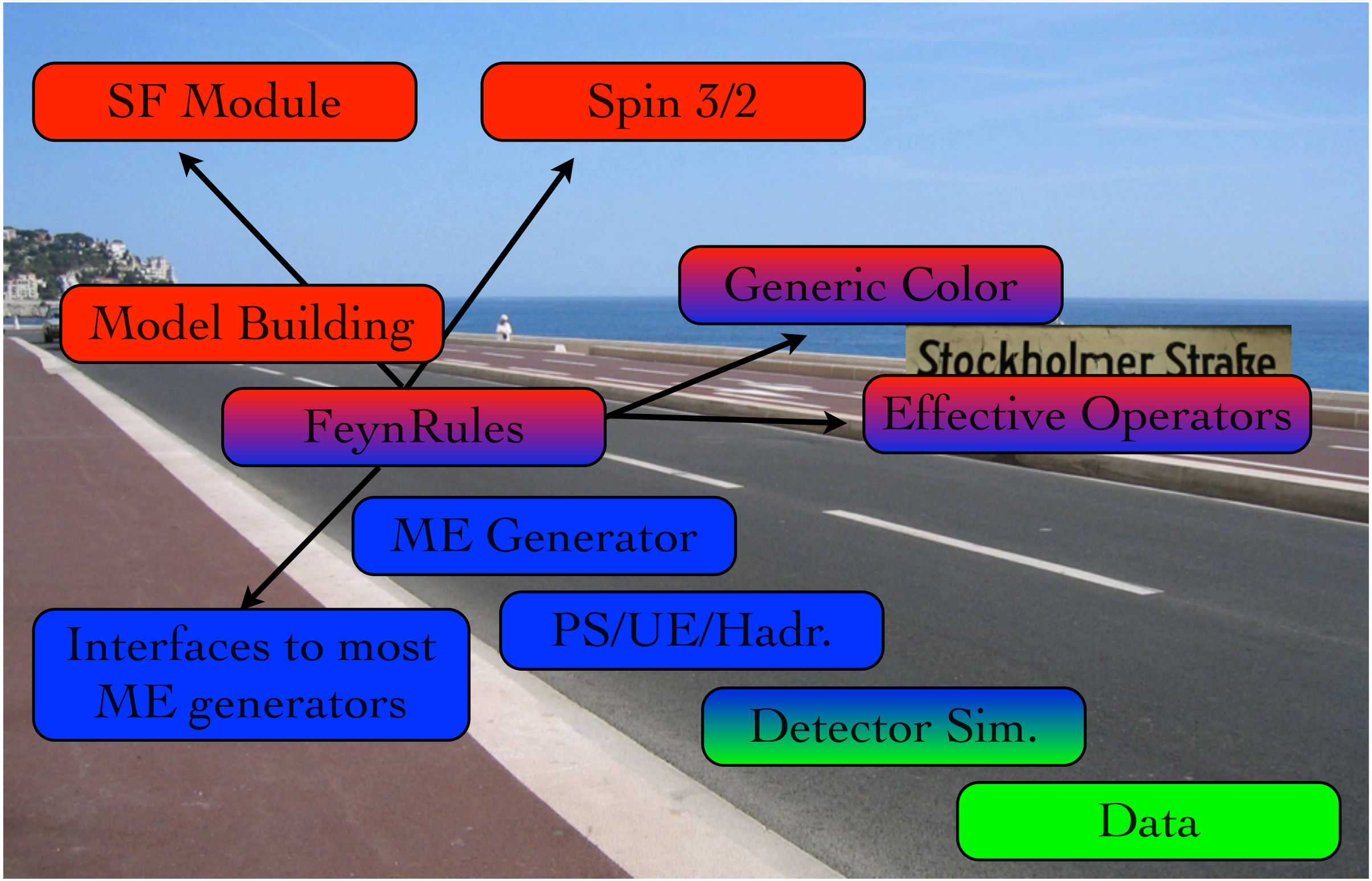
- Idea: Create Python modules that can be linked to other codes and contain all the information on a given model.
- The UFO is a self-contained Python code, and not tied to a specific matrix element generator.
- The content of the FR model files, together with the vertices, is translated into a library of Python objects, that can be linked to other codes.
- Golem, MadGraph 5 and Herwig++ will use the UFO.
- In particular, the UFO is the default model format for MadGraph 5.

The UFO & ALOHA

- The development of the UFO goes hand in hand with the development of ALOHA.
- Idea: ALOHA uses the information contained in the UFO to create the required HELAS routines on the fly!



The road to BSM physics

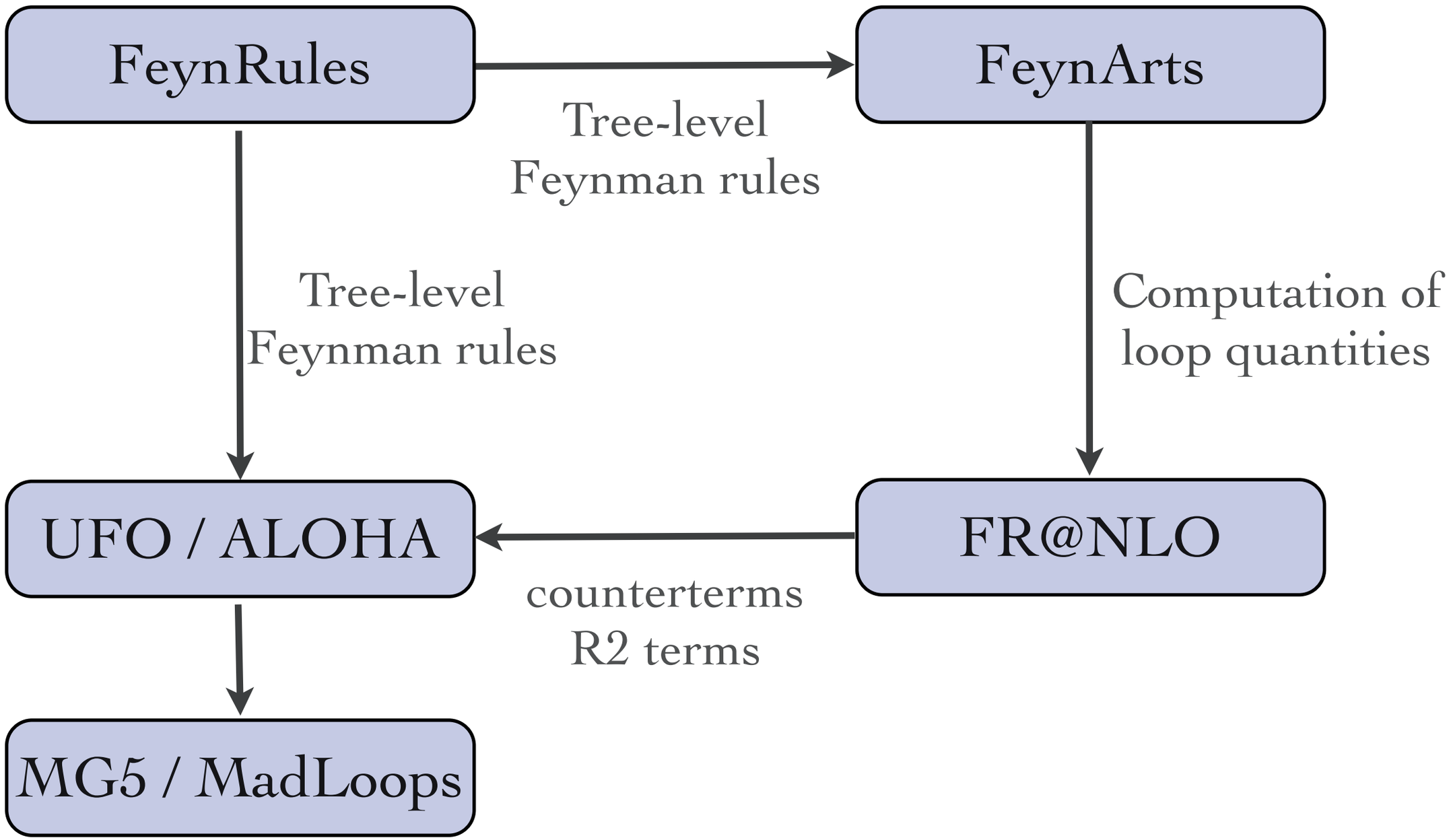


Towards FR@NLO

- In its current version, FeynRules allows already to implement *any* BSM model into tree-level matrix element generators.
- With the release of MadLoops, the bar has been raised, and tree-level Feynman rules are no longer enough.
  - ➡ UV counterterms
  - ➡ Feynman rules for rational (R2) terms.
- Since FeynRules works with the Lagrangian, it has all the information to extract the new NLO building blocks

Towards FR@NLO

- Possible workflow:



Model database

We encourage model builders writing
order to make them useful to a comm
FeynRules model database, please ser

- claude.duhr@durham.ac.uk
- neil@hep.wisc.edu
- fuks@cern.ch

Available models

- Standard Model
- Simple extensions of the SM (9)
- Supersymmetric Models (4)
- Extra-dimensional Models (4)
- Strongly coupled and effective field theories (4)
- Miscellaneous (0)

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Model	Contact
Higgs effective theory	C. Duhr
4th generation model	C. Duhr
Standard model + Scalars	C. Duhr
Hidden Abelian Higgs Model	C. Duhr
Hill Model	P. de Aquino, C. Duhr
The general 2HDM	C. Duhr, M. Herquet
Triplet diquarks	J. Alwall, C. Duhr
Sextet diquarks	J. Alwall, C. Duhr

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MSSM	B. Fuks
NMSSM	B. Fuks
RPV-MSSM	B. Fuks
R-MSSM	B. Fuks

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Model	Contact
Mimimal Higgsless Model (3-Site Model)	N. Christensen
Minimal UED	P. de Aquino
Large Extra Dimensions	P. de Aquino
Compact HEIDI	C. Speckner

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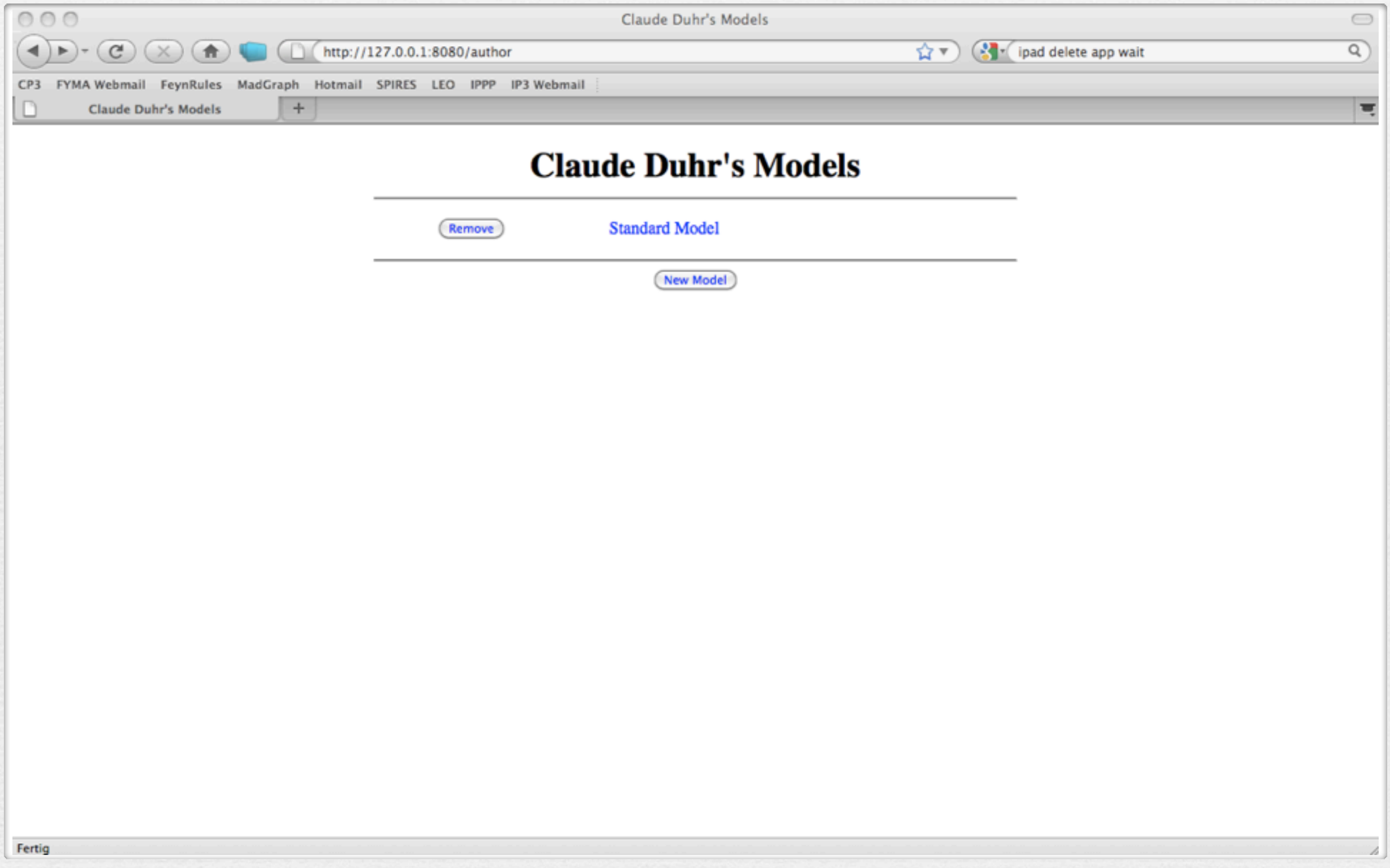
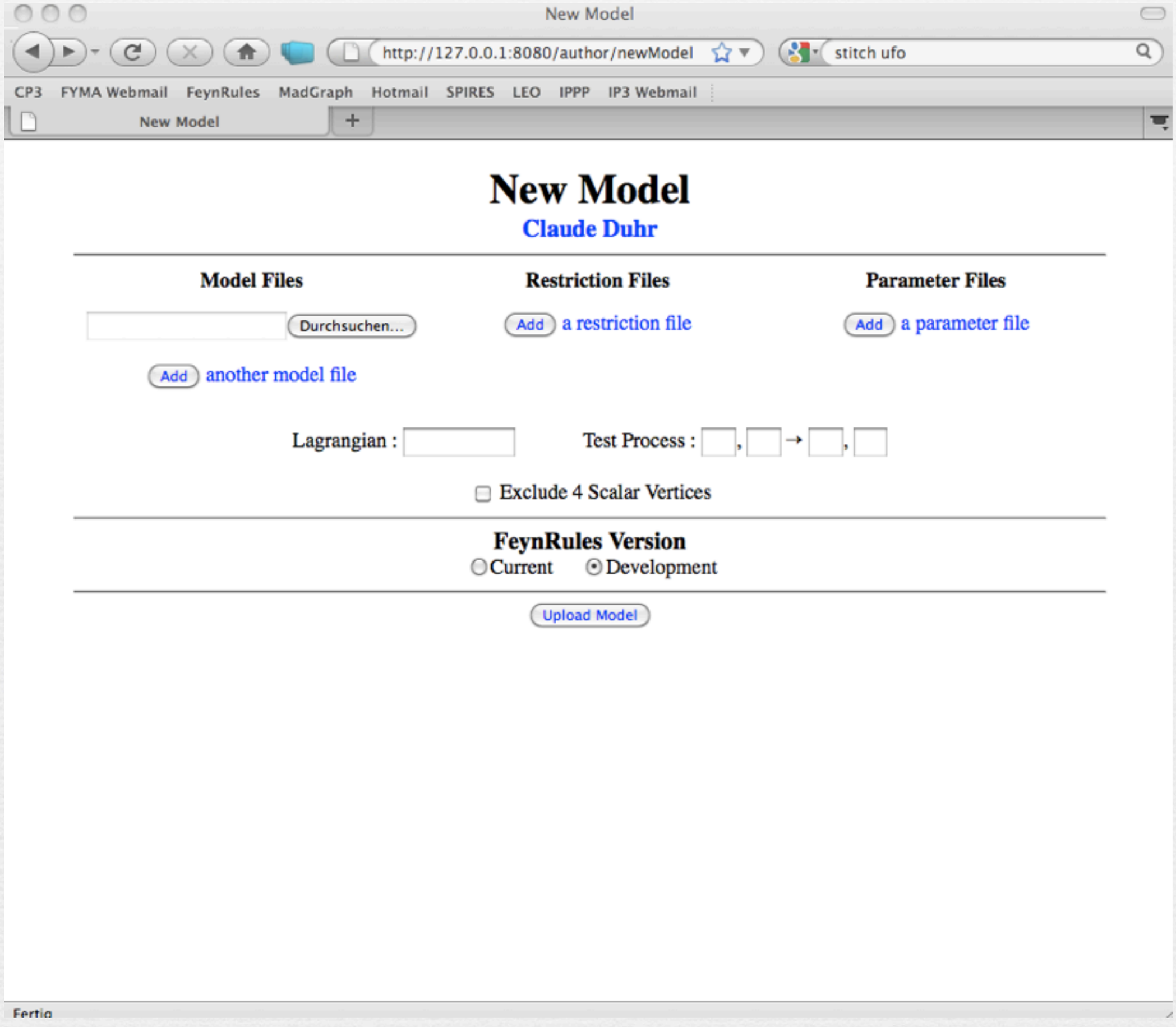
Model	Contact
Mimimal Higgsless Model (3-Site Model)	N. Christensen
Chiral perturbation theory	C. Degrande
Strongly Interacting Light Higgs	C. Degrande
Technicolor	M. Järvinen, T. Hapola, E. Del Nobile, C. Pica

Validation of new models

- FeynRules does not only provide the power to develop and validate new models, but also to validate them to an unprecedented level!
- A given model can be output to more than one matrix element generator, and their results can be compared
  - ➡ Different conventions
  - ➡ Different gauges
  - ➡ Different ways of handling large cancellations.
- This procedure can easily be automatized!

Web validation




New Model
http://127.0.0.1:8080/author/newModel
stitch ufo
CP3
FYMA Webmail
FeynRules
MadGraph
Hotmail
SPIRES
LEO
IPPP
IP3 Webmail
New Model
New Model
Claude Duhr
Model Files
Durchsuchen...
Add another model file
Restriction Files
Add a restriction file
Parameter Files
Add a parameter file
Lagrangian :
Test Process :
Exclude 4 Scalar Vertices
FeynRules Version
Current
Development
Upload Model
Fertig

Standard Model : Validation

http://127.0.0.1:8080/author/newValidati

Google

CP3 FYMA Webmail FeynRules MadGraph Hotmail SPIRES LEO IPPP IP3 Webmail

Standard Model : Validation

Standard Model

Claude Duhr

Validation Name :

	R. File	P. File	CH	FA	HW	MG4	MG5	SH	WO1	WO2
◉			✔✔	✔?	✔?	✔✔	✔?	✔?	✔✔	✔✔
○	Massless.rst		✔✔	✔?	✔?	✔✔	✔?	✔?	✔✔	✔✔
○	DiagonalCKM.rst		✔✔	✔?	✔?	✔✔	✔?	✔?	✔✔	✔✔

2→2 Processes

Field Type

Field Type	Require	Require Not
Scalar :	0	0
Fermion :	0	0
Vector :	0	0
Spin 2 :	0	0

Indices

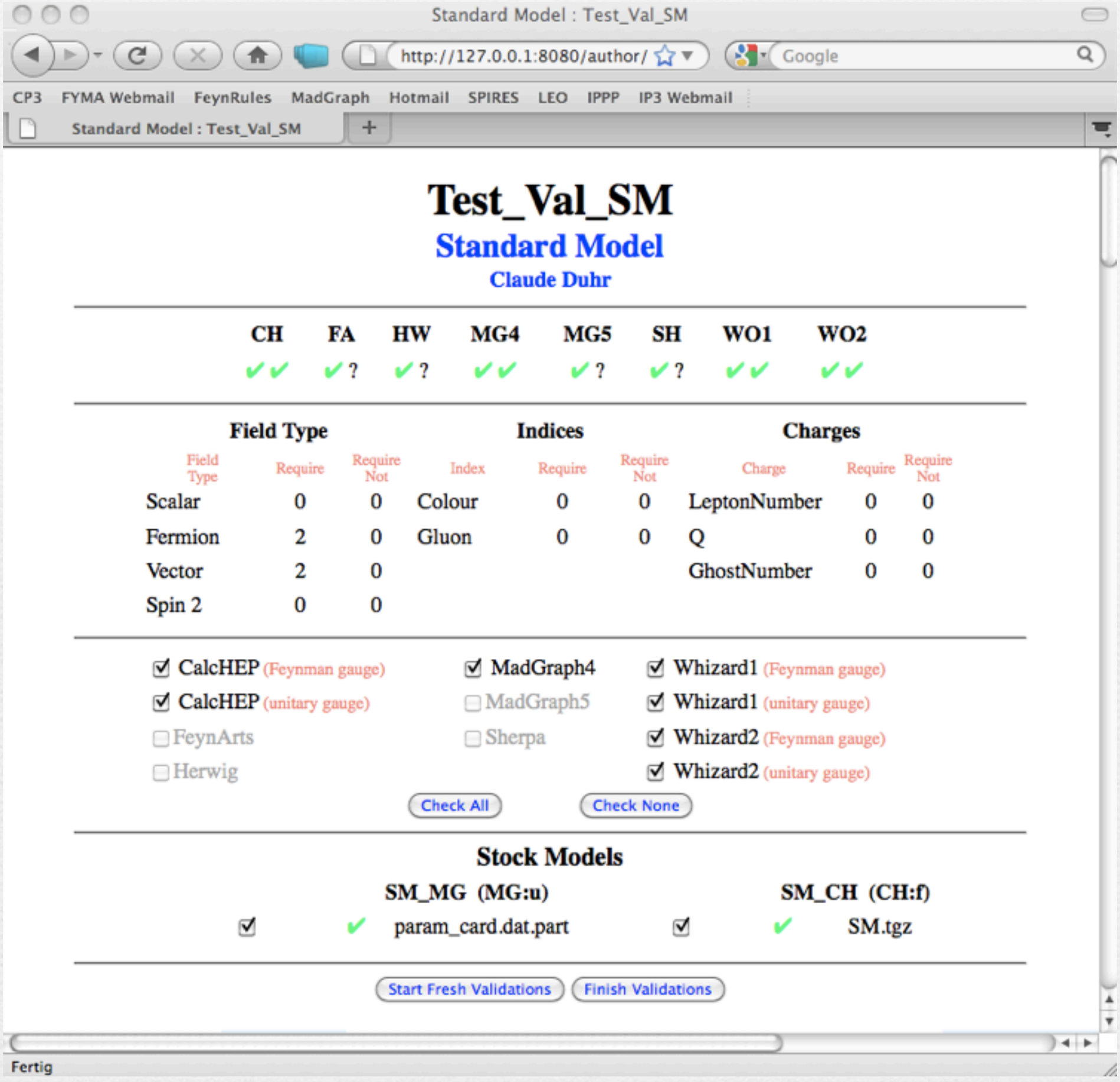
Index	Require	Require Not
Colour :	0	0
Gluon :	0	0

Charges

Charge	Require	Require Not
LeptonNumber :	0	0
Q :	0	0
GhostNumber :	0	0

Generate Processes

Fertig


Standard Model : Test_Val_SM
http://127.0.0.1:8080/author/
Google
CP3
FYMA Webmail
FeynRules
MadGraph
Hotmail
SPIRES
LEO
IPPP
IP3 Webmail
Standard Model : Test_Val_SM
Test_Val_SM
Standard Model
Claude Duhr
CH
FA
HW
MG4
MG5
SH
WO1
WO2
Field Type
Field Type
Require
Require Not
Scalar
0
0
Fermion
2
0
Vector
2
0
Spin 2
0
0
Indices
Index
Require
Require Not
Colour
0
0
Gluon
0
0
Charges
Charge
Require
Require Not
LeptonNumber
0
0
Q
0
0
GhostNumber
0
0
CalcHEP (Feynman gauge)
CalcHEP (unitary gauge)
FeynArts
Herwig
MadGraph4
MadGraph5
Sherpa
Whizard1 (Feynman gauge)
Whizard1 (unitary gauge)
Whizard2 (Feynman gauge)
Whizard2 (unitary gauge)
Check All
Check None
Stock Models
SM_MG (MG:u)
param_card.dat.part
SM_CH (CH:f)
SM.tgz
Start Fresh Validations
Finish Validations
Fertig

ve , ve~ → Z , Z	730.0	182.5	0.49452	0.49452	0.49384	0.494604	0.494622	0.494547	0.494668	0.49351	0.4945	●	0.17%
ve , ve~ → W+ , W-	639.0	159.75	1.0603	1.0603	1.0604	1.06053	1.0604	1.06035	1.06073	1.0665	1.0603	●	0.51%
ve , ve~ → G , G	200.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
ve , vm~ → A , A	200.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
ve , vm~ → A , Z	365.0	91.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
ve , vm~ → Z , Z	730.0	182.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
ve , vm~ → W+ , W-	639.0	159.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
ve , vm~ → G , G	200.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
ve , vt~ → A , A	200.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
ve , vt~ → A , Z	365.0	91.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
ve , vt~ → Z , Z	730.0	182.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
ve , vt~ → W+ , W-	639.0	159.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
ve , vt~ → G , G	200.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
ve , e+ → A , W+	319.0	79.75	2.2219	1.9846	1.9809	1.98496	1.98478	1.98454	1.98491	1.9756	1.9845	✘	10.56%
ve , e+ → Z , W+	684.0	171.0	0.71578	0.54663	0.54717	0.54657	0.546756	0.54641	0.546869	0.54864	0.54661	✘	26.53%
ve , m+ → A , W+	320.0	80.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
ve , m+ → Z , W+	684.0	171.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
ve , tt+ → A , W+	326.0	81.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
ve , tt+ → Z , W+	691.0	172.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
vm , vm~ → A , A	200.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
vm , vm~ → A , Z	365.0	91.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
vm , vm~ → Z , Z	730.0	182.5	0.49452	0.49452	0.49384	0.494505	0.494545	0.494559	0.494447	0.49351	0.4945	●	0.17%
vm , vm~ → W+ , W-	639.0	159.75	1.0603	1.0603	1.0604	1.0604	1.06033	1.06027	1.06006	1.0665	1.0603	●	0.52%
vm , vm~ → G , G	200.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
vm , vt~ → A , A	200.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
vm , vt~ → A , Z	365.0	91.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
vm , vt~ → Z , Z	730.0	182.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
vm , vt~ → W+ , W-	639.0	159.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%

Conclusion

- The new version of FeynRules comes with lots of new features.
  - ➡ Superfields
  - ➡ Spin 3/2 (still private)
  - ➡ Sextets
  - ➡ New FeynArts interface
  - ➡ Interface to UFO, and hence to MadGraph 5
- The chain

  FR → UFO → ALOHA → MG5

  is about to open a completely new era of HE phenomenology!

Towards a database of models...