FeynRules
Status and plans

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

MadGraph Meeting 2011
Fermilab, 05 May 2011

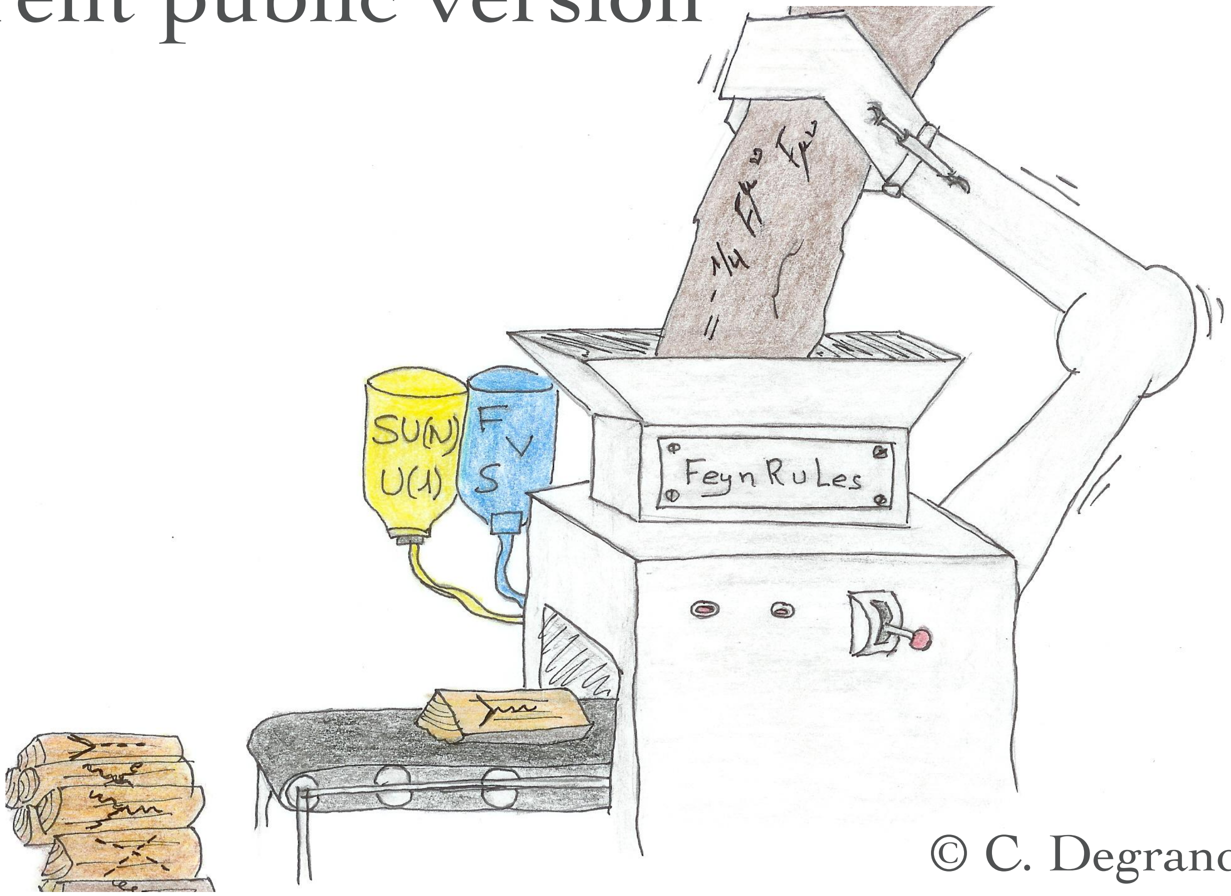
What is FeynRules..?

- 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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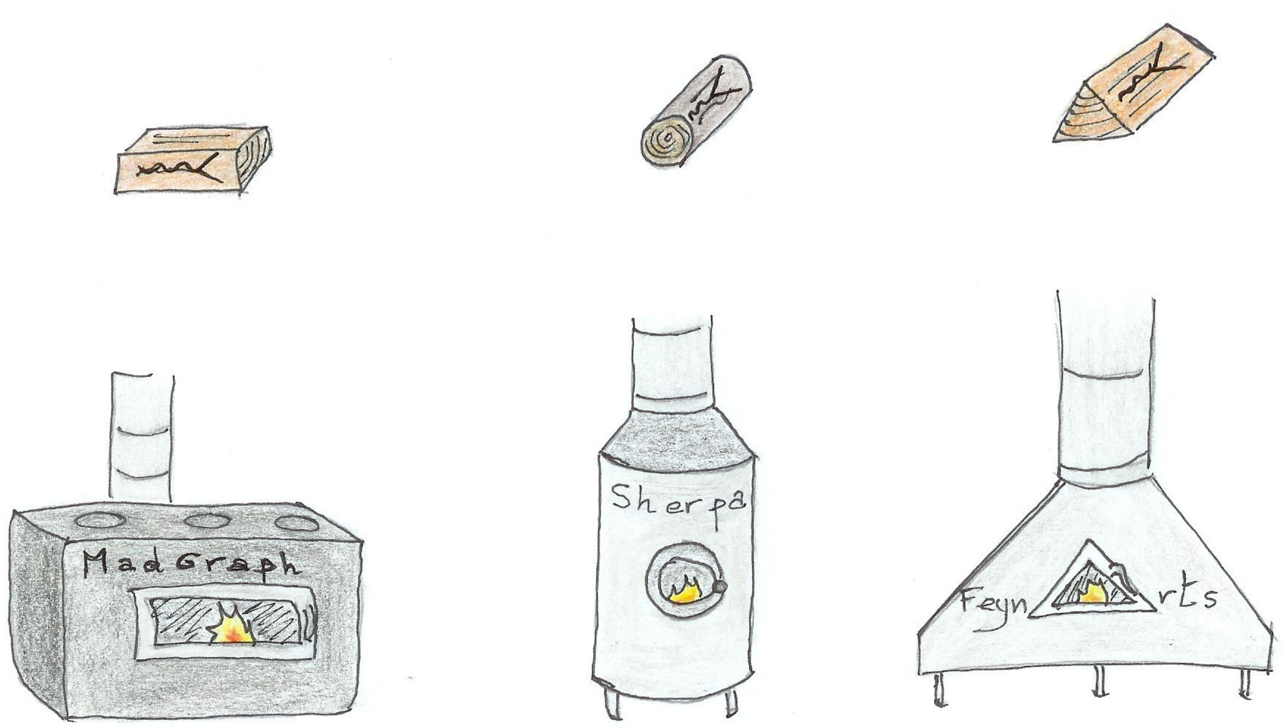

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How to use FeynRules

- 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:

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

```
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:

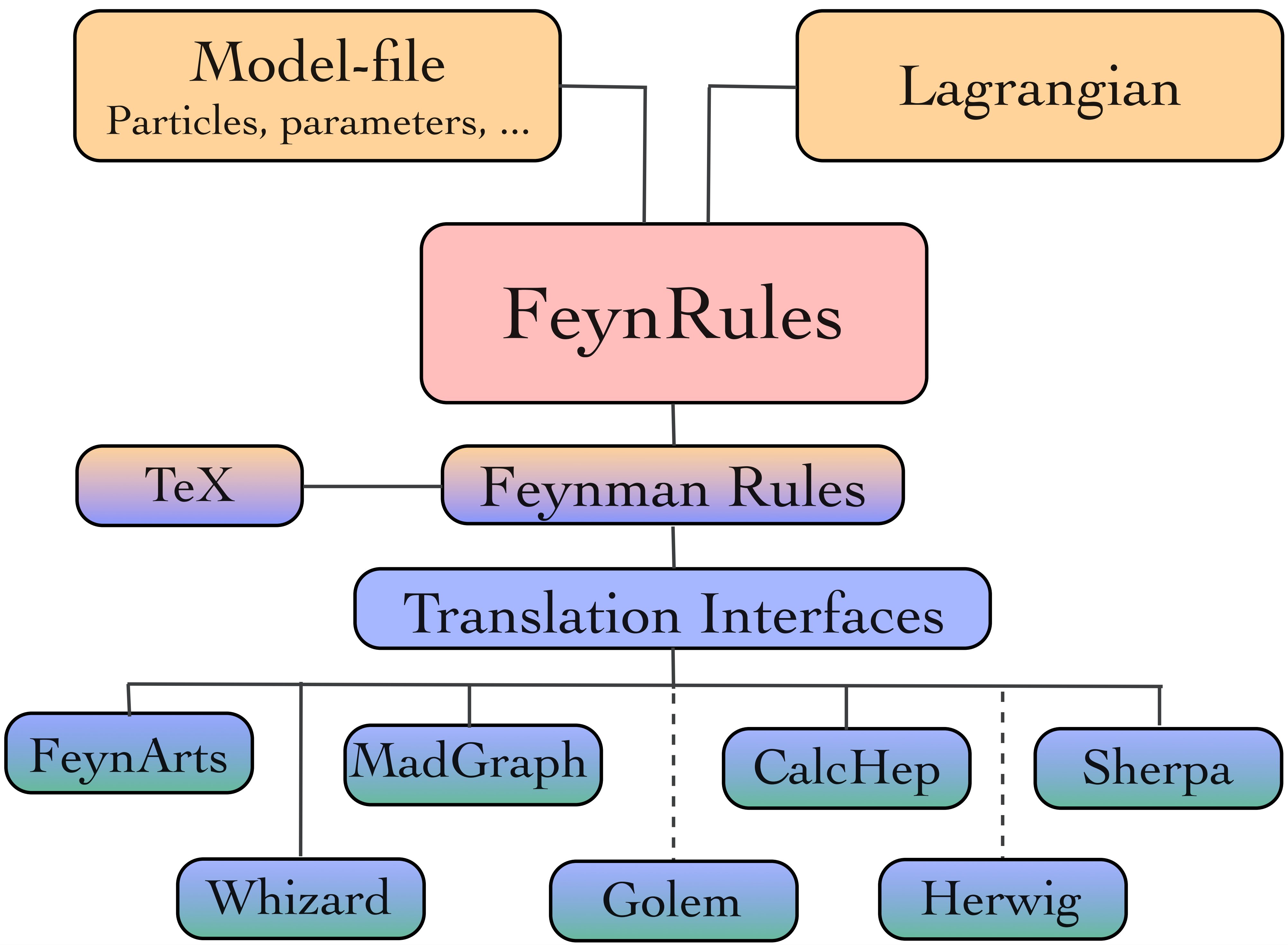
FeynmanRules[L]

- 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

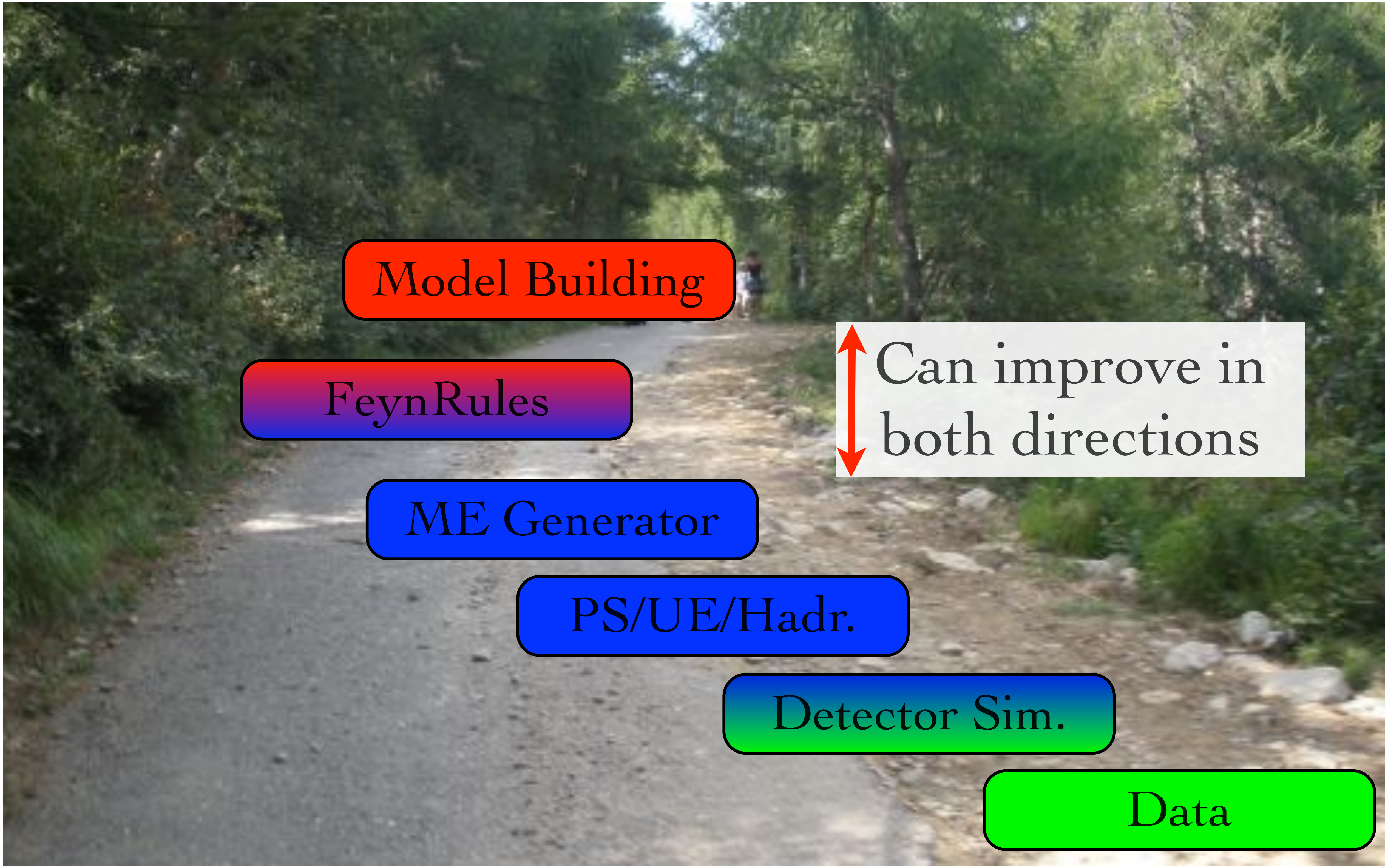
Once upon a time in a land far away...

- ... 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.

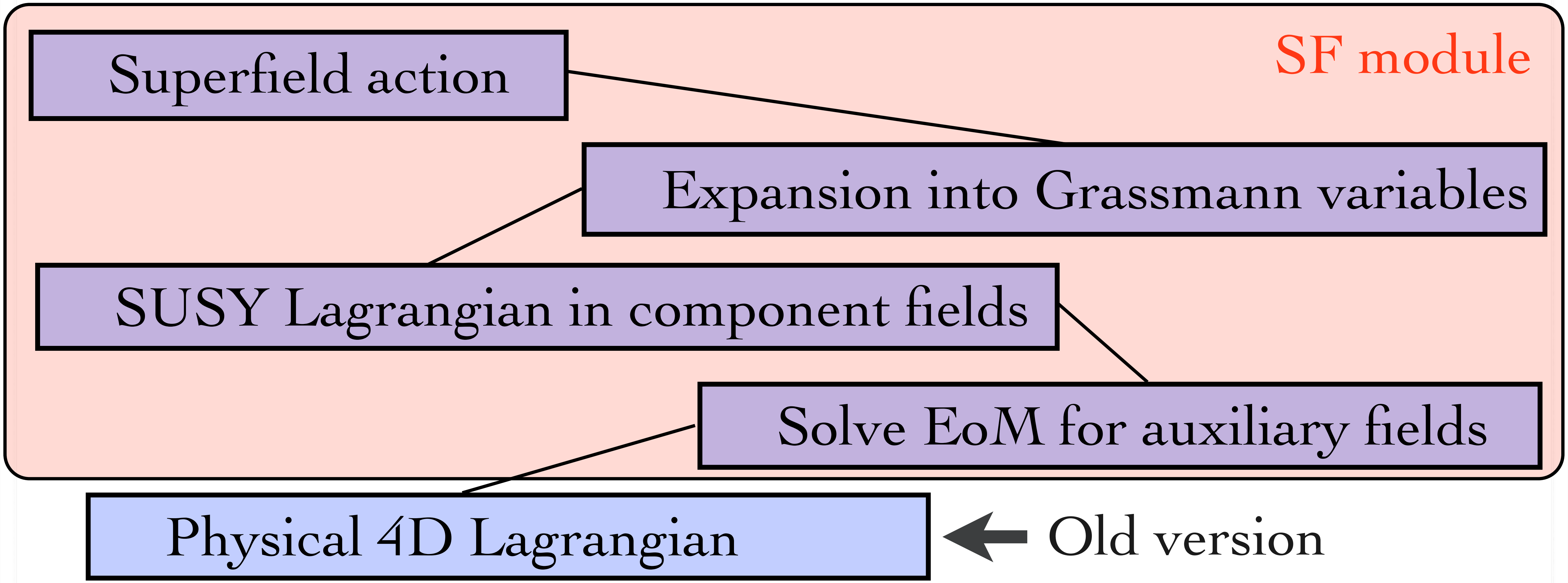
- ... the simulation of non-standard color structures was very hard, if not impossible.

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]
```

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

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(* *)

Vertex 1

Particle 1 : Vector , A

Particle 2 : Majorana , fN

Particle 3 : Real Spin 3/2 , rG

Vertex:

$$2\,\mathrm{gfNrG2}\;\mathrm{p}_1^{\mu 3}\;\gamma^{\mu_1}.\gamma^5{}_{s_2,s_3} - 2\,\mathrm{gfNrG2}\;\eta_{\mu_1,\mu_3}\;\mathrm{SlashedP}(1).\gamma^5{}_{s_2,s_3}$$

(* *)

Sextet color structures

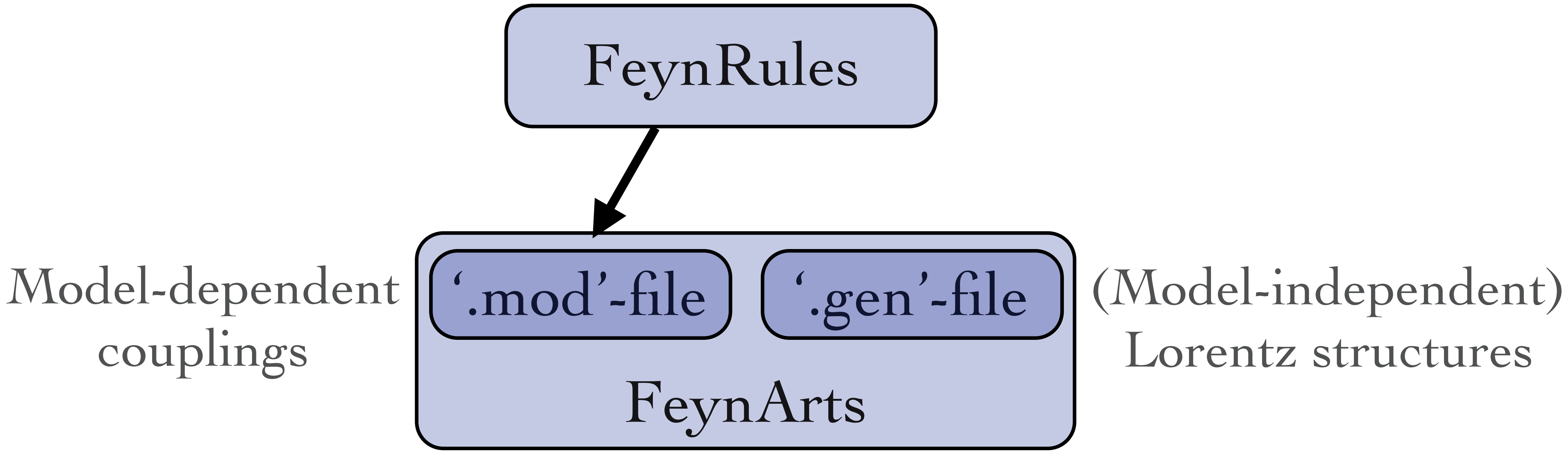
- So far, FeynRules was limited to triplet and octet color structures (mostly because there was no ME generator for higher representations).

- 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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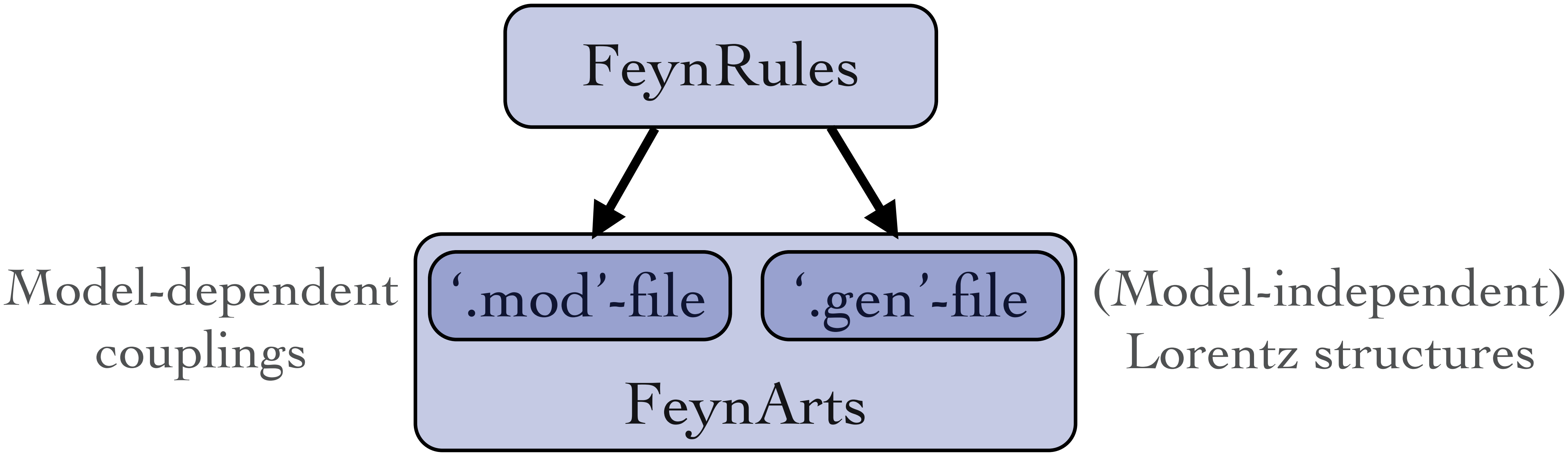


- This development goes along with a new version of FormCalc able to deal with multi-fermion interactions.

The UFO

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

UFO = Universal FeynRules Output

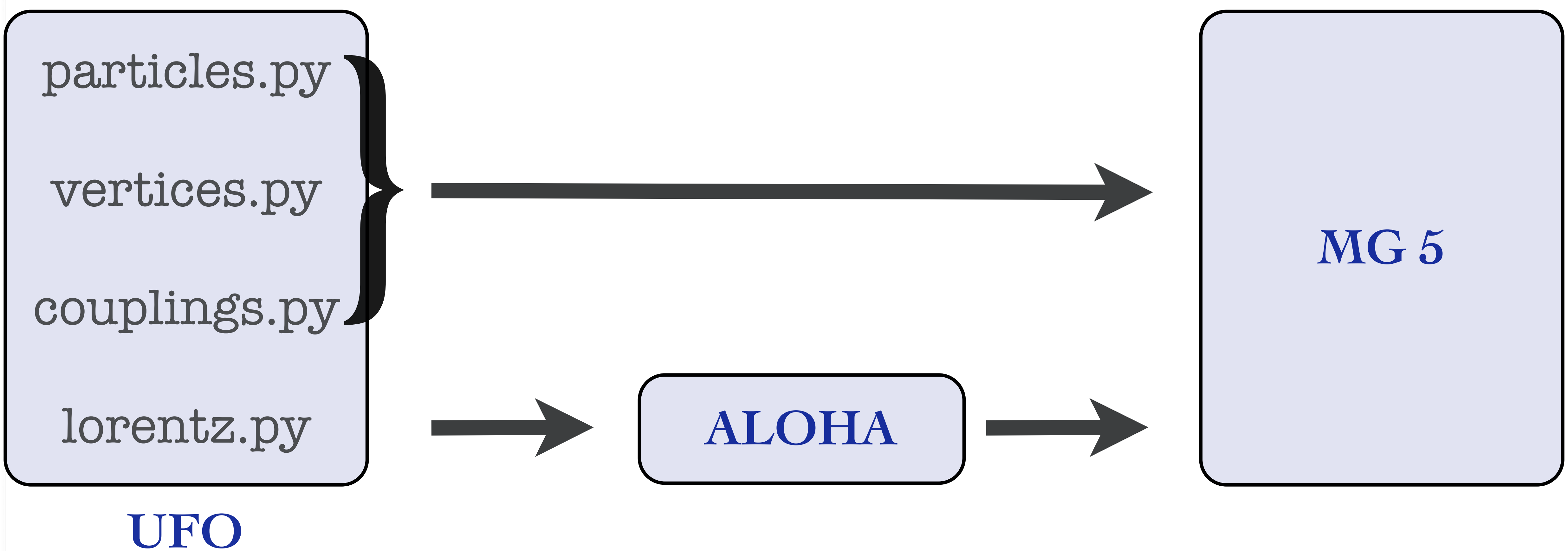
➡ See Olivier's talk

- Idea: Create Python modules that can be linked to other codes and contain all the information on a given model.

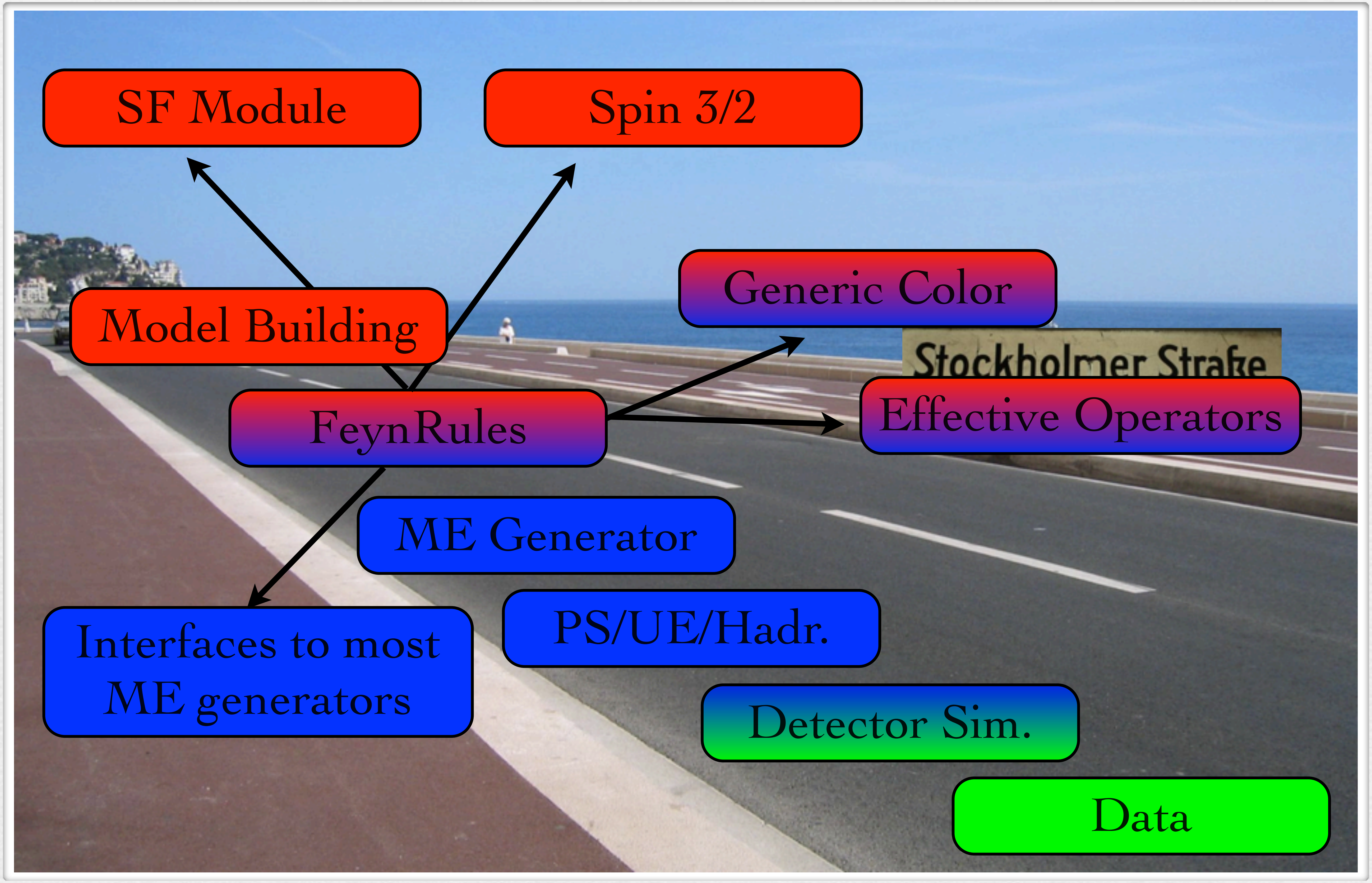
- The UFO is a self-contained Python code, and not tied to a specific matrix element generator.
- The content of the FR model files, together with the vertices, is translated into a library of Python objects, that can be linked to other codes.
- Golem, MadGraph 5 and Herwig++ will use the UFO.
- In particular, 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

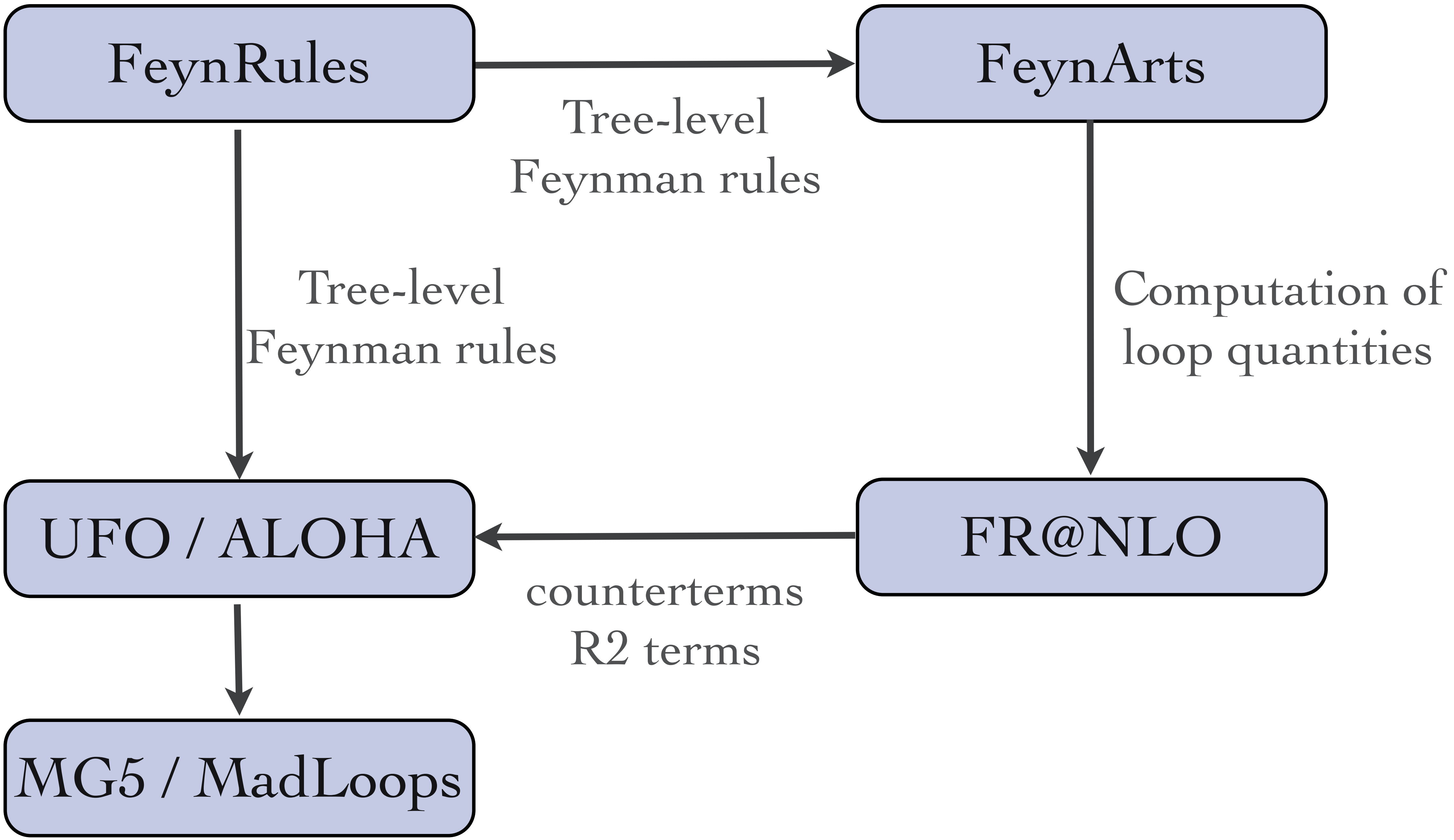


Towards FR@NLO

- 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 se

- 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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- Miscellaneous (0)

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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Standard Model
Simple extensions of the SM (9)
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Strongly coupled and effective field theories (4)
Miscellaneous (0)

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

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- Strongly coupled and effective field theories (4)
- Miscellaneous (0)

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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FeynRules model database, please se

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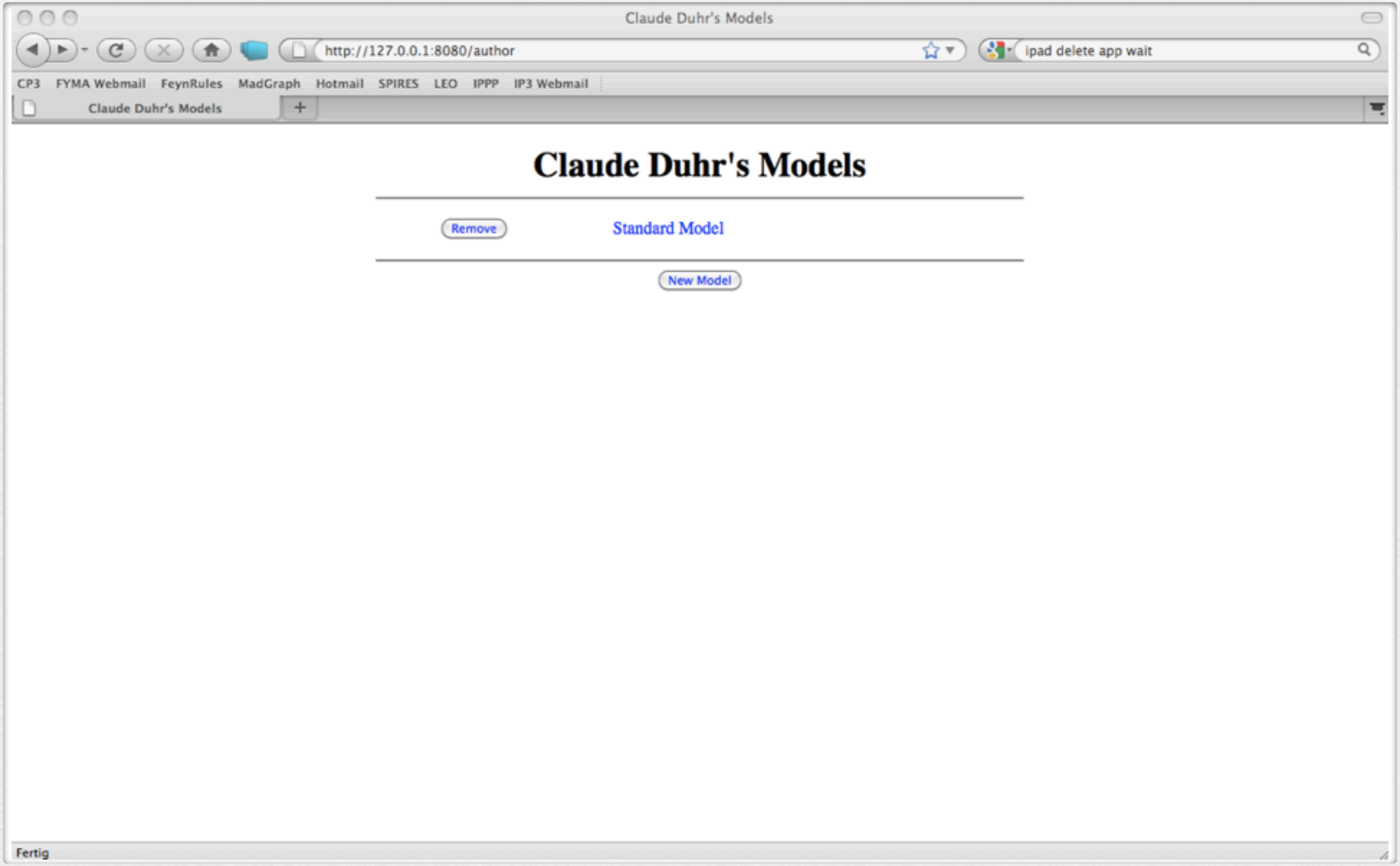
- Simple extensions of the SM (9)
- Supersymmetric Models (4)
- Extra-dimensional Models (4)
- Strongly coupled and effective field theories (4)
- Miscellaneous (0)

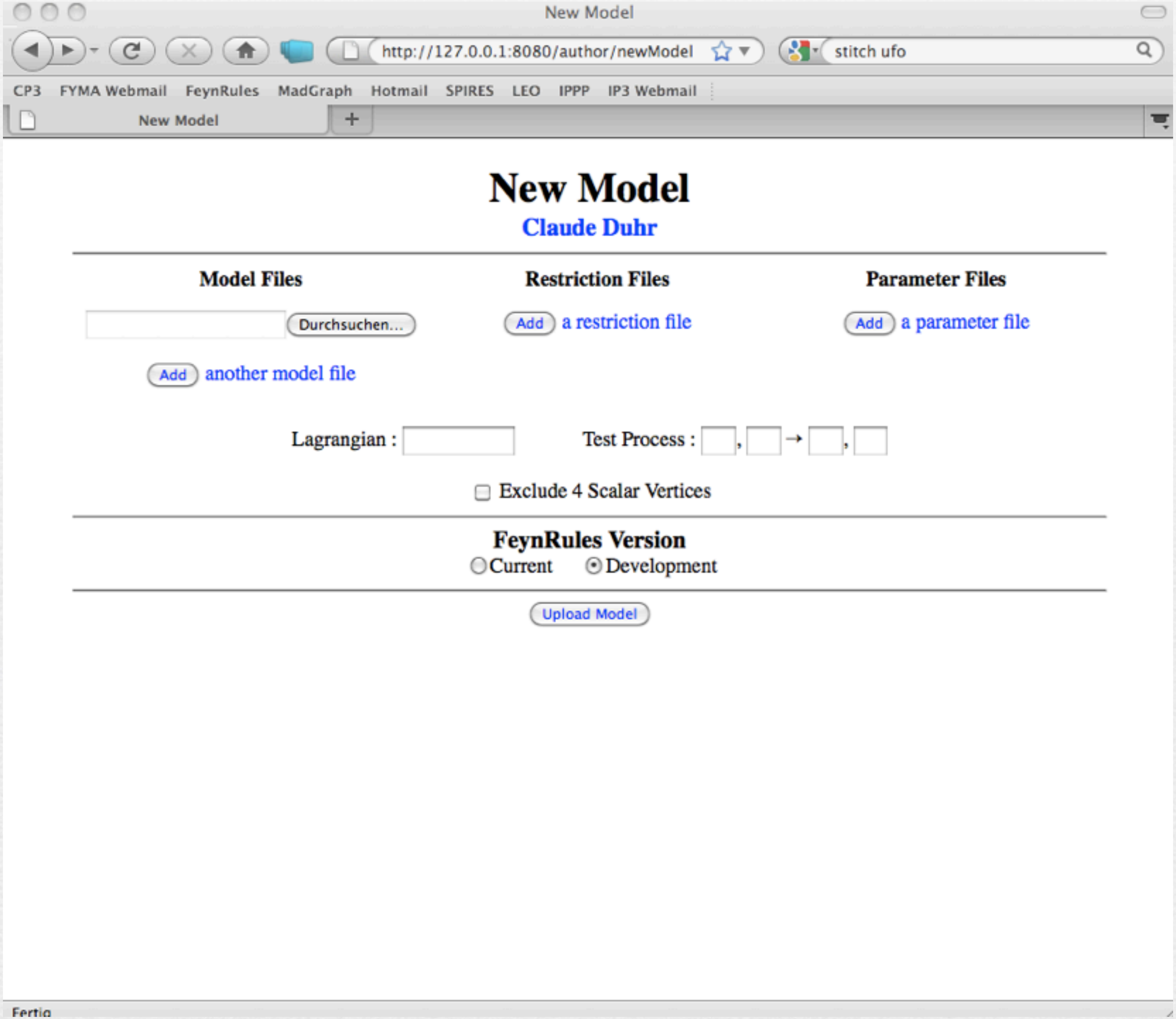
Model	Contact
Mimimal Higgsless Model (3-Site Model)	N. Christensen
Chiral perturbation theory	C. Degrande
Strongly Interacting Light Higgs	C. Degrande
Technicolor	M. Järvinen, T. Hapola, E. Del Nobile, C. Pica

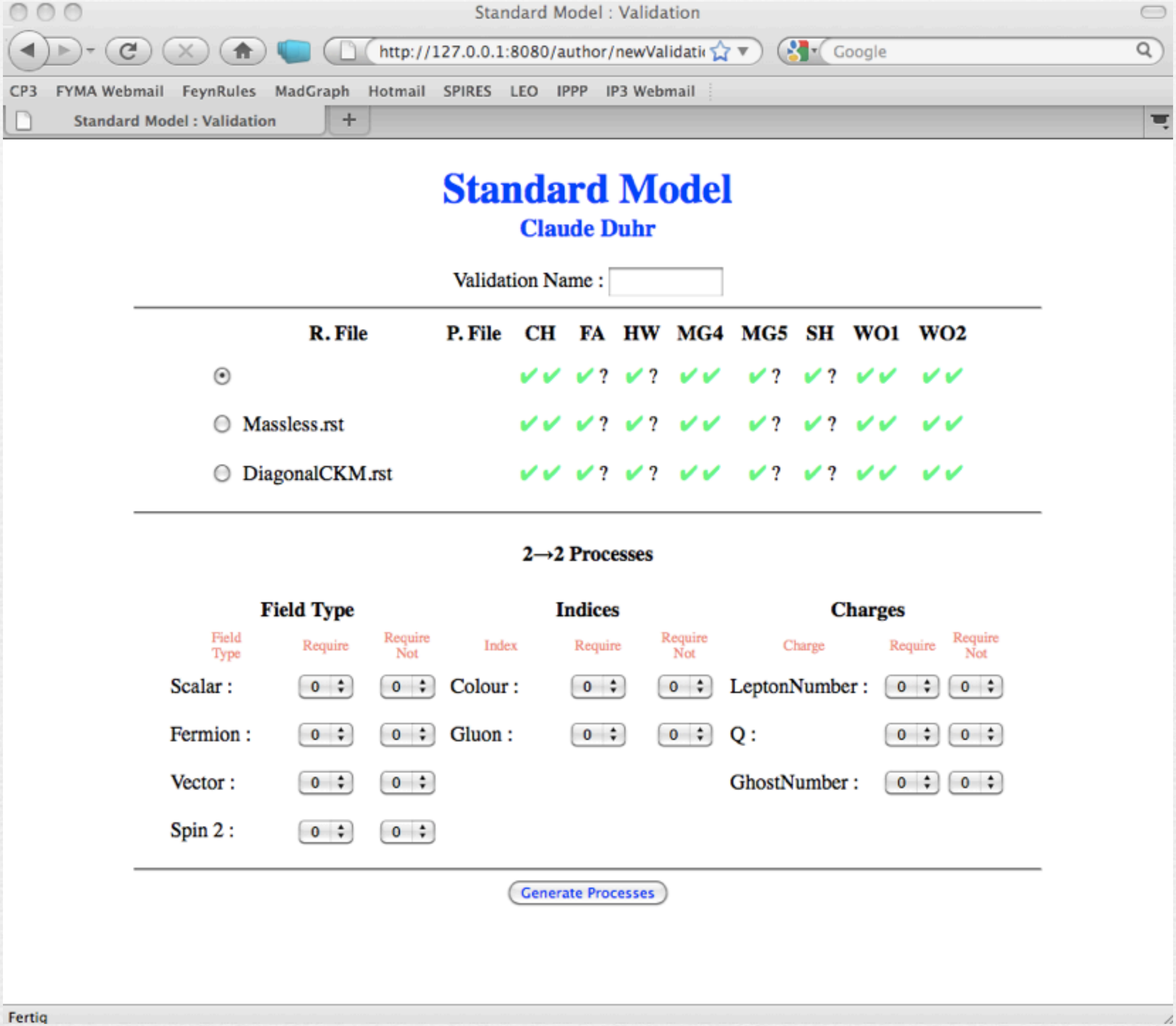
Validation of new models

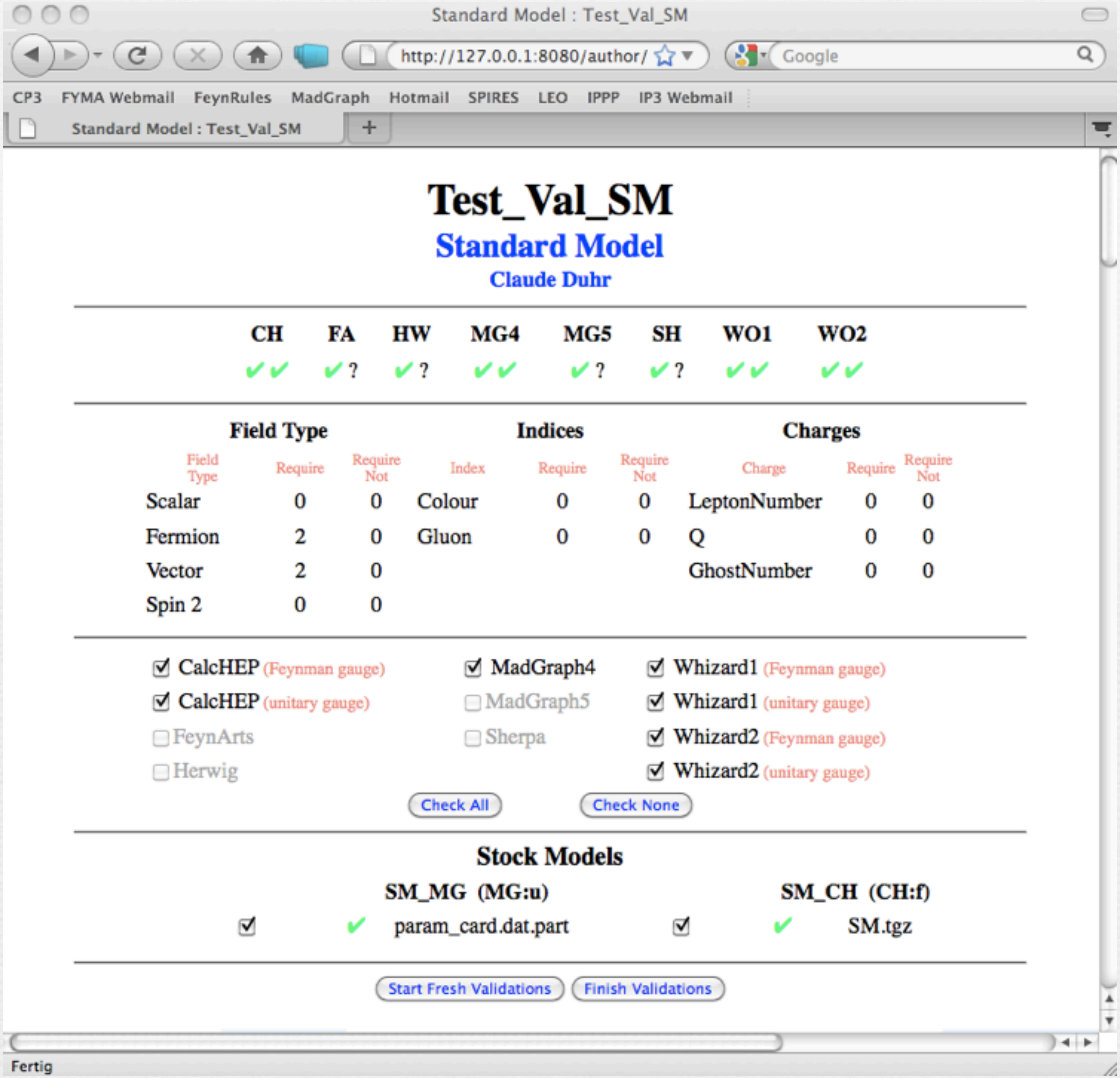
- FeynRules does not only provide the power to develop and validate new models, but also to validate them to an unprecedented level!
- A given model can be output to more than one matrix element generator, and their results can be compared
  - ➡ Different conventions
  - ➡ Different gauges
  - ➡ Different 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
Restriction Files
Parameter Files
Durchsuchen...
Add a restriction file
Add a parameter file
Add another model 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
Indices
Charges
Field Type
Require
Require Not
Index
Require
Require Not
Charge
Require
Require Not
Scalar :
Fermion :
Vector :
Spin 2 :
Colour :
Gluon :
LeptonNumber :
Q :
GhostNumber :
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
Indices
Charges
Field Type Require Require Not
Index Require Require Not
Charge Require Require Not
Scalar 0 0
Fermion 2 0
Vector 2 0
Spin 2 0 0
Colour 0 0
Gluon 0 0
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)
SM_CH (CH:f)
param_card.dat.part
SM.tgz
Start Fresh Validations
Finish Validations
Fertig

Standard Model : Test_Val_SM

http://127.0.0.1:8080/author/validation?v

CP3 FYMA Webmail FeynRules MadGraph Hotmail SPIRES LEO IPPP IP3 Webmail

Standard Model : Test_Val_SM

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%

Fertig

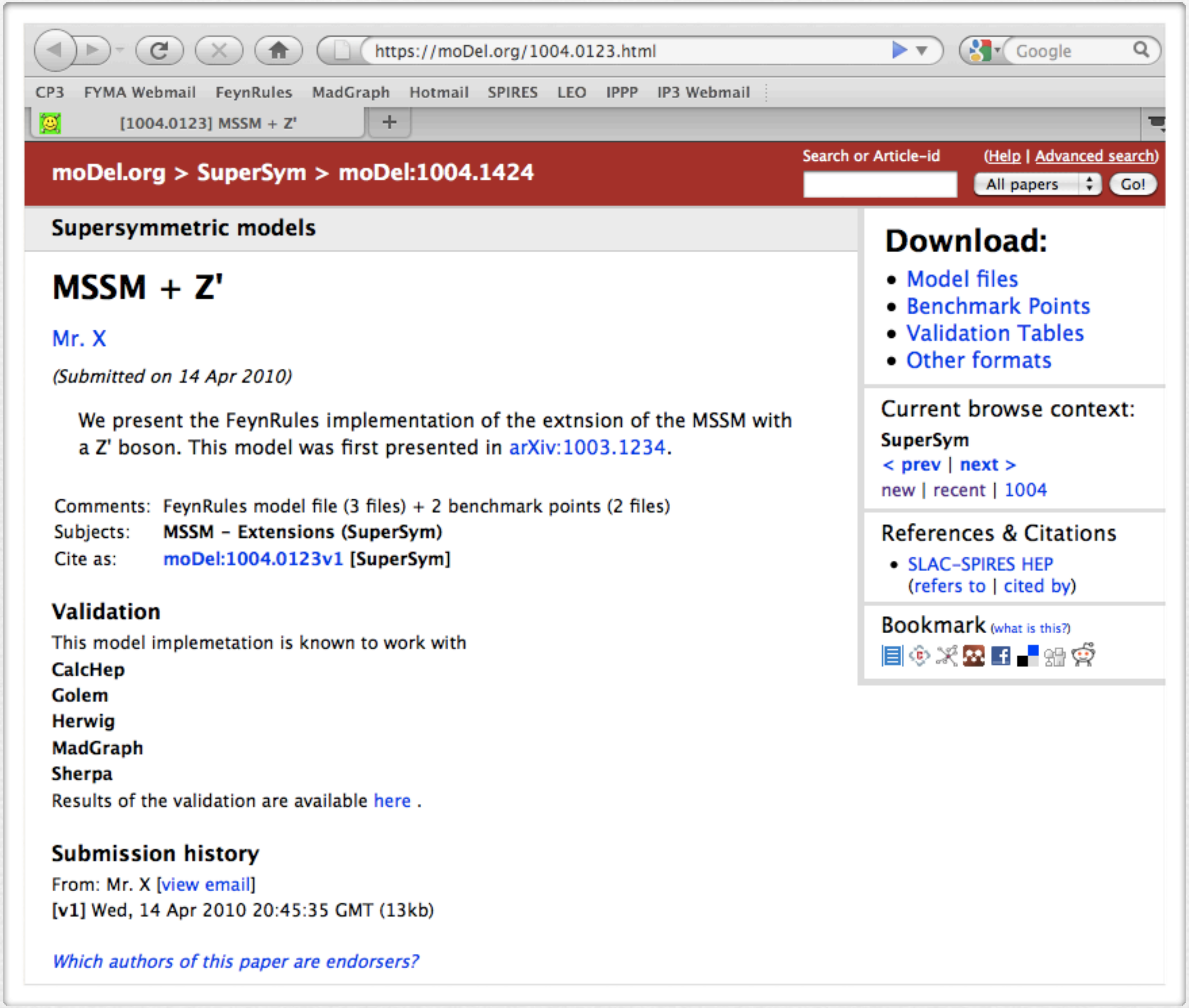
Conclusion

- 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...



https://moDel.org/1004.0123.html

CP3 FYMA Webmail FeynRules MadGraph Hotmail SPIRES LEO IPPP IP3 Webmail

[1004.0123] MSSM + Z'

moDel.org > SuperSym > moDel:1004.1424

Search or Article-id (Help | Advanced search) All papers Go!

Supersymmetric models

MSSM + Z'

Mr. X

(Submitted on 14 Apr 2010)

We present the FeynRules implementation of the extnsion of the MSSM with a Z' boson. This model was first presented in arXiv:1003.1234.

Comments:	FeynRules model file (3 files) + 2 benchmark points (2 files)
Subjects:	**MSSM - Extensions (SuperSym)**
Cite as:	**moDel:1004.0123v1 [SuperSym]**

Validation

This model implemetation is known to work with

CalcHep
Golem
Herwig
MadGraph
Sherpa

Results of the validation are available here .

Submission history

From: Mr. X [view email]
[v1] Wed, 14 Apr 2010 20:45:35 GMT (13kb)

Which authors of this paper are endorsers?

Download:

- Model files
- Benchmark Points
- Validation Tables
- Other formats

Current browse context:
SuperSym
< prev | next >
new | recent | 1004

References & Citations

- SLAC-SPIRES HEP
  (refers to | cited by)

Bookmark (what is this?)