Durham University

FeynRules Status and Plans

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+ O. Mattelaer, C. Speckner, S. Schumann, M. Wiebusch

MadGraph Week 2010, VUB
Bruxelles, October 6th 2010

Outline

- A Roadmap for BSM physics

- Status:
  - ➡ What is FeynRules..?
  - ➡ Status of the current public version (1.4.10)

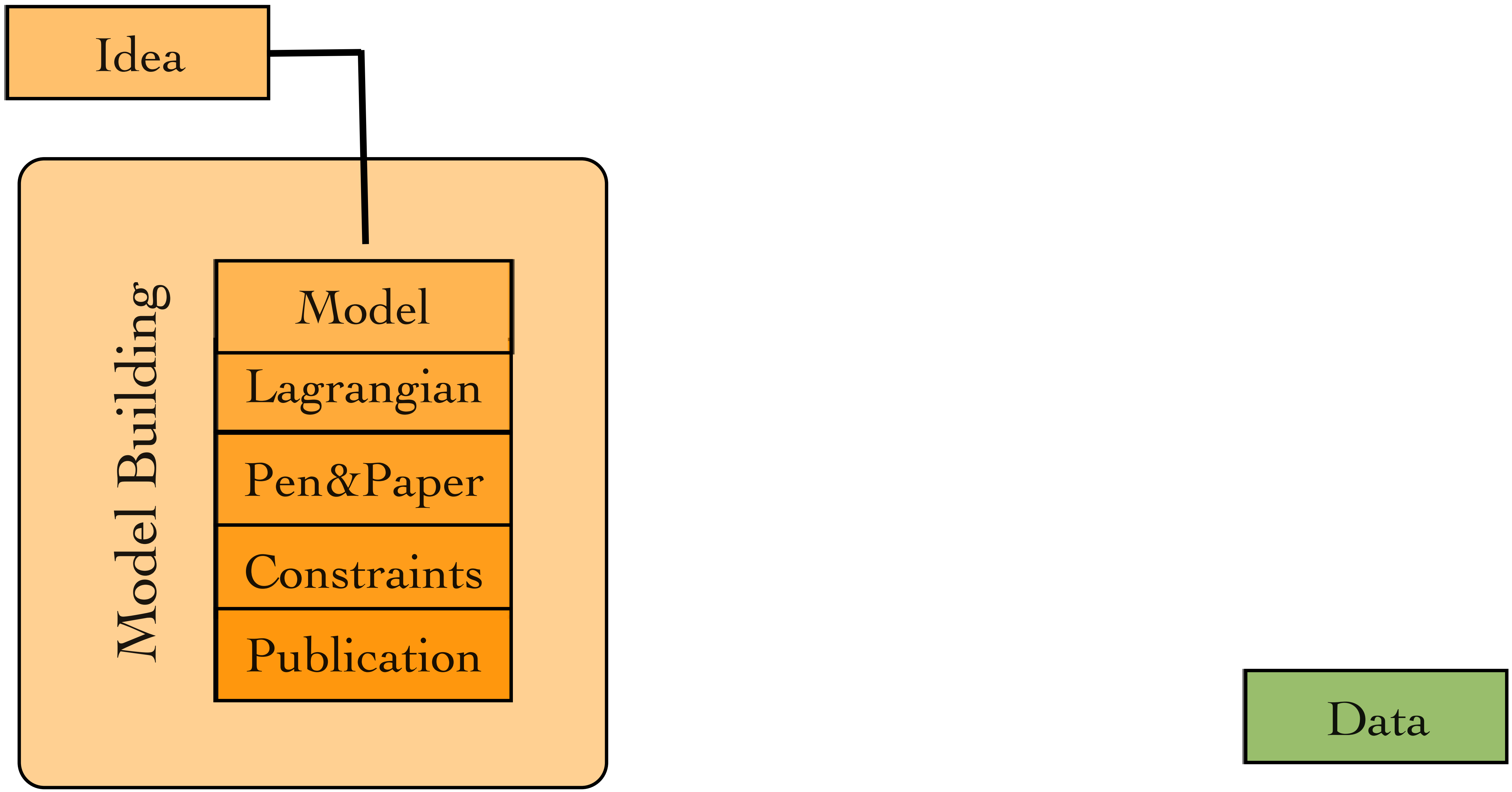
- Plans:
  - ➡ New interfaces
  - ➡ Superfields
  - ➡ Mass diagonalisation
  - ➡ Web validation interface

A Roadmap for BSM @ the LHC

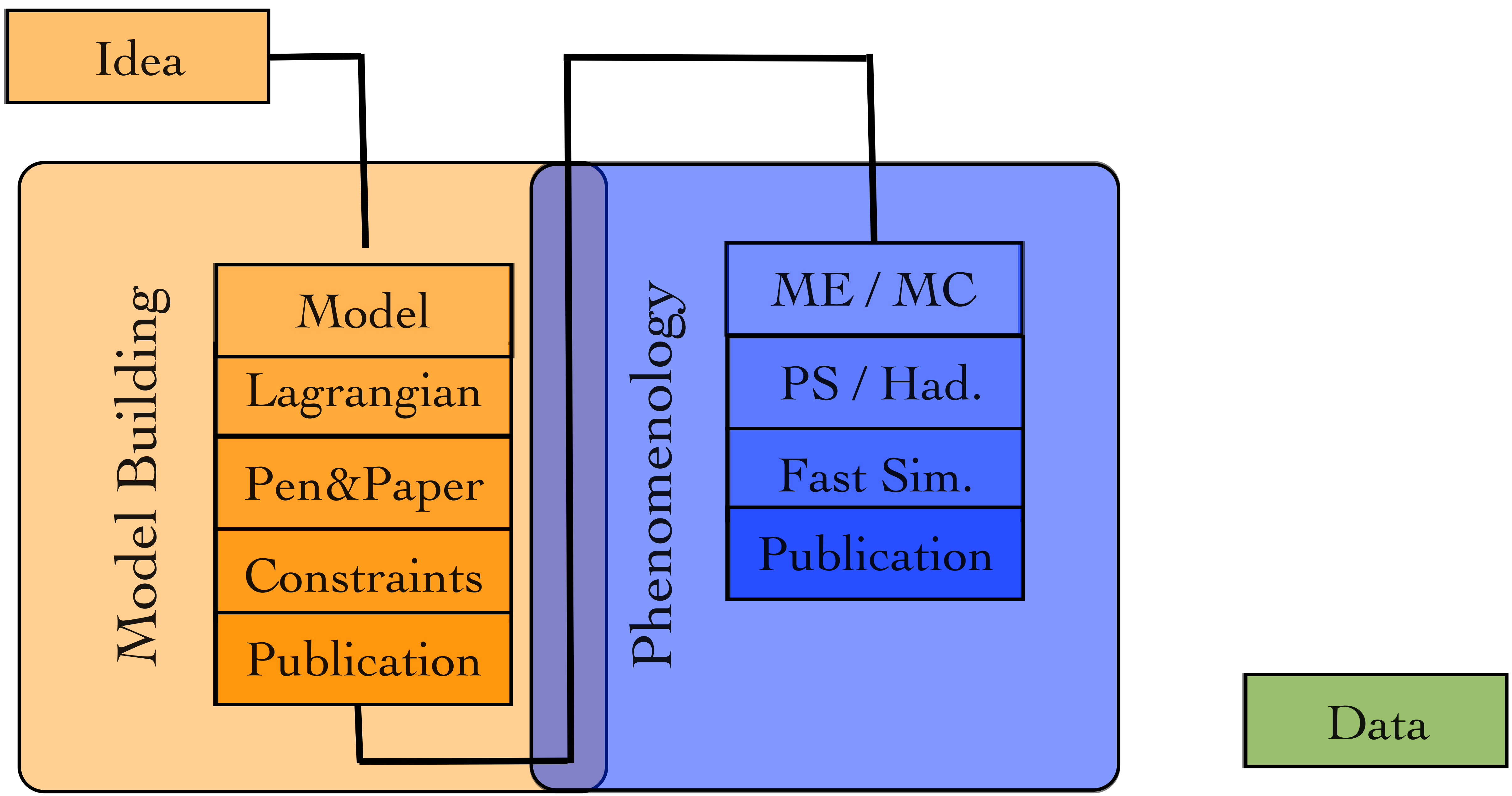
Idea

Data

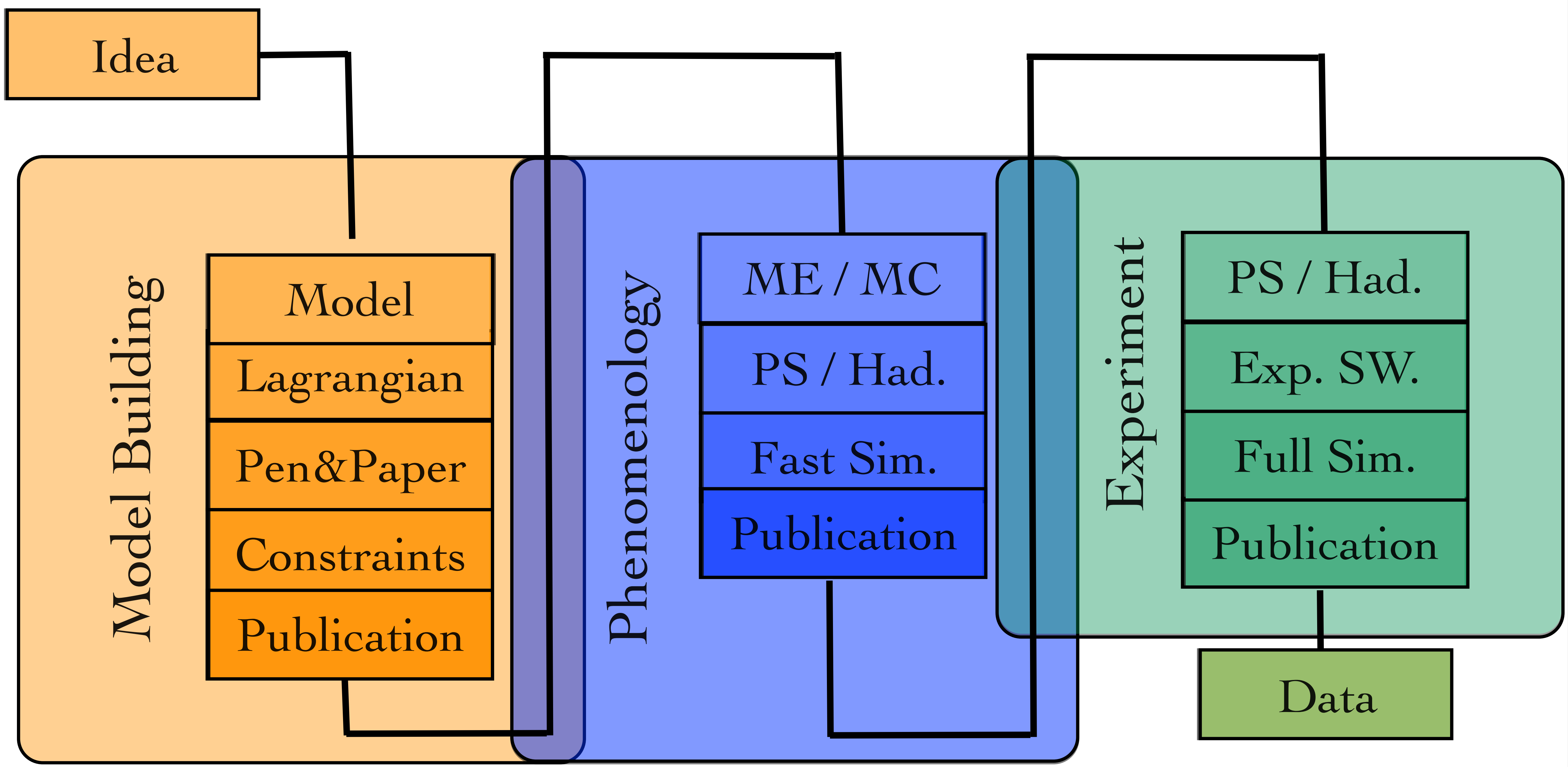
A Roadmap for BSM @ the LHC



A Roadmap for BSM @ the LHC



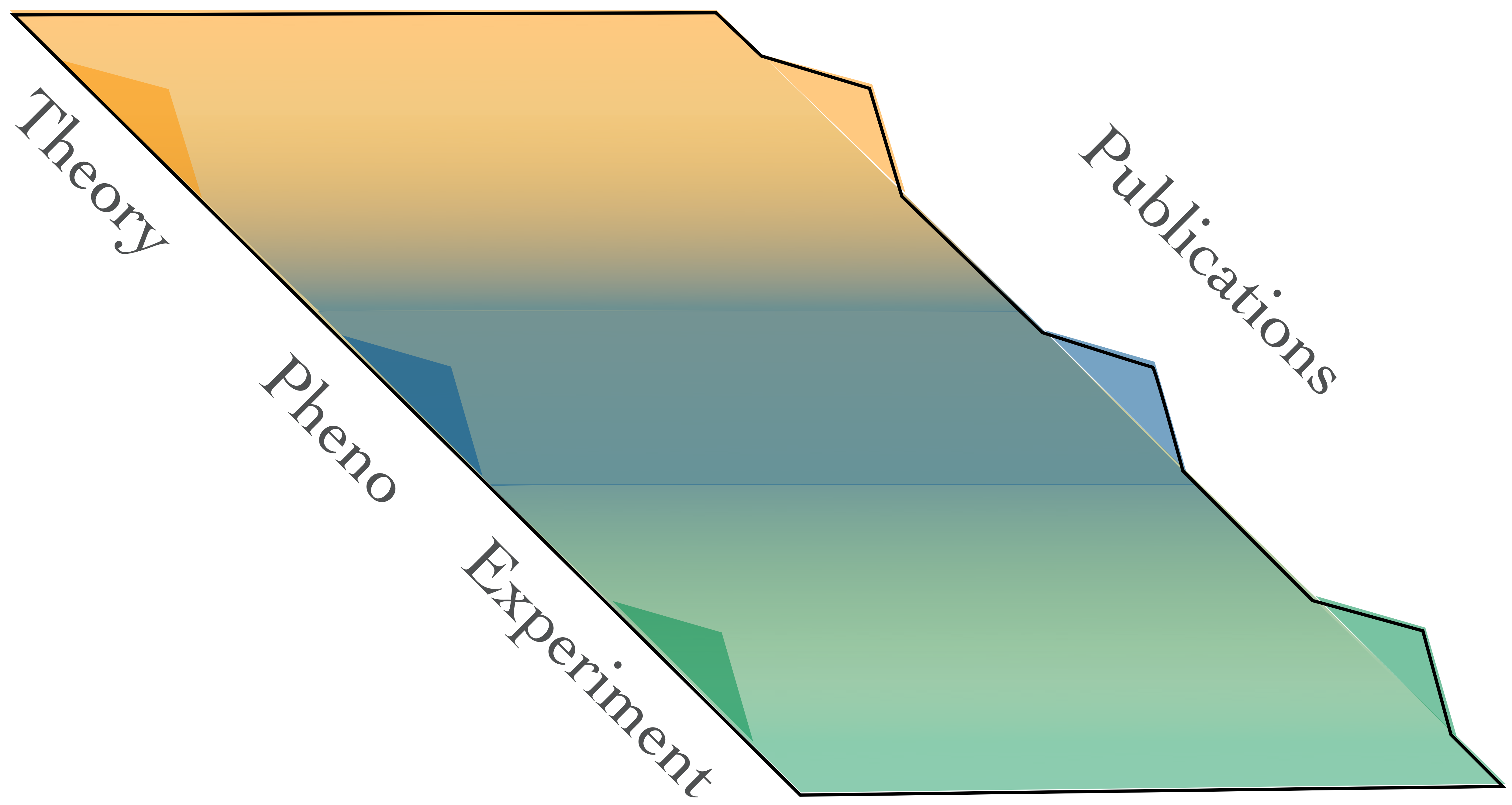
A Roadmap for BSM @ the LHC



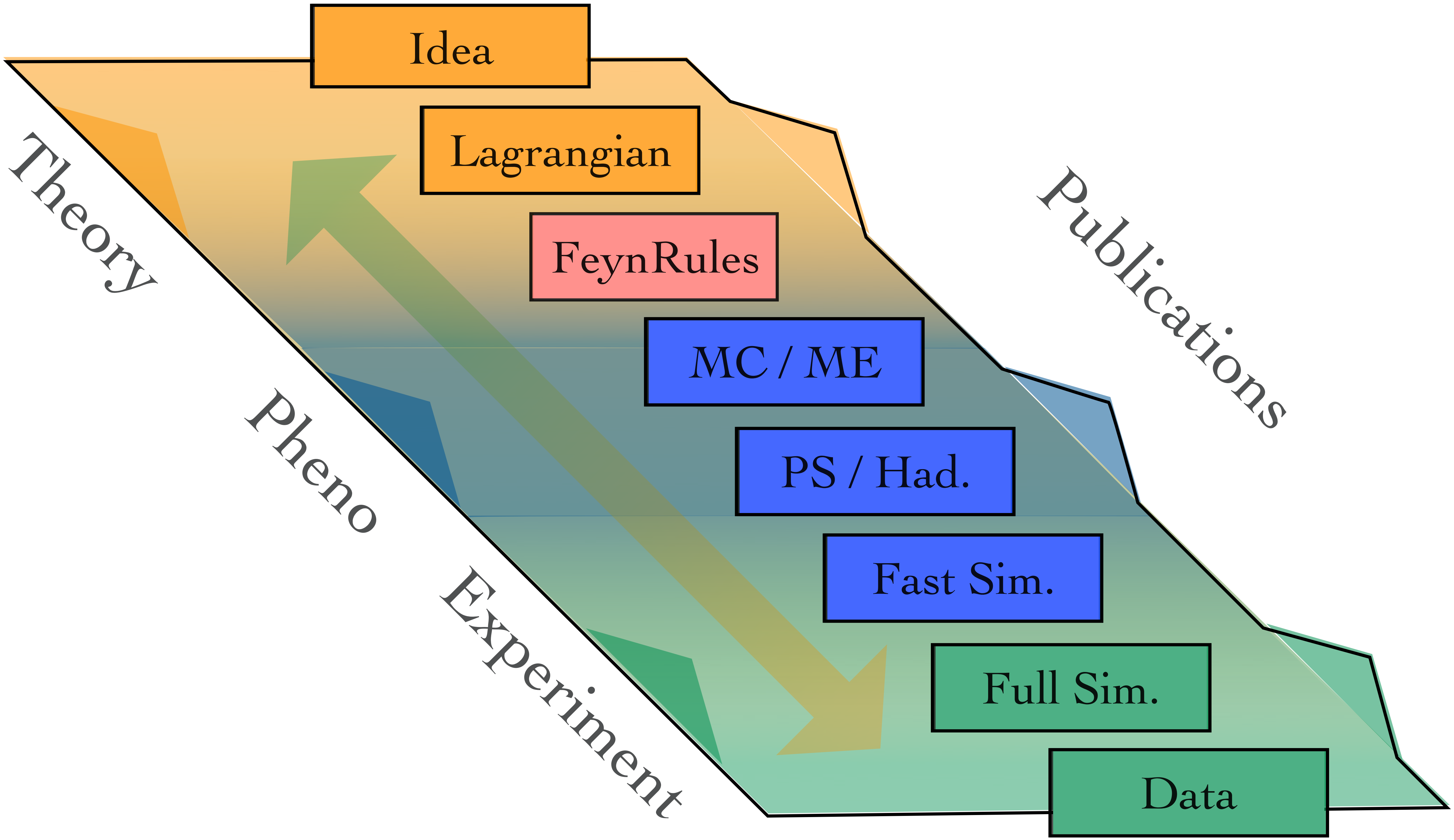
A Roadmap for BSM @ the LHC

- Workload is tripled, due to disconnected fields of expertise.
- Error-prone, painful validation at each step.
- Proliferation of private MC's/Pythia tunings:
  - ➡ No clear documentation.
  - ➡ Not traceable.
- We need more than just papers to communicate between theorists and experimentalists!

A Roadmap for BSM @ the LHC



A Roadmap for BSM @ the LHC



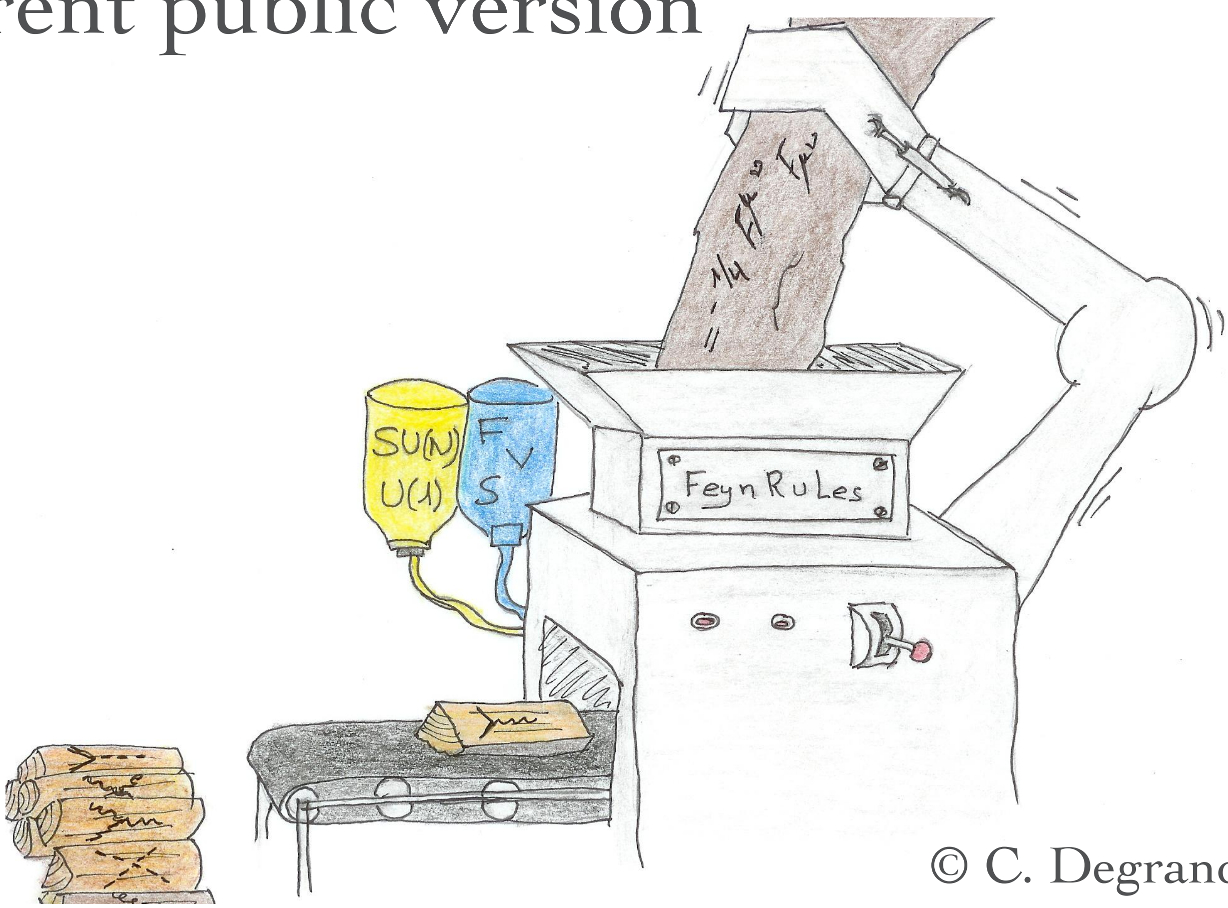
FeynRules in a nutshell

- FeynRules is a Mathematica package that allows to derive Feynman rules from a Lagrangian.
- Current public version: 1.4.10, available from

  http://feynrules.phys.ucl.ac.be
- 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

FeynRules in a nutshell

- 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
  - ➡ Sherpa
  - ➡ Whizard / Omega



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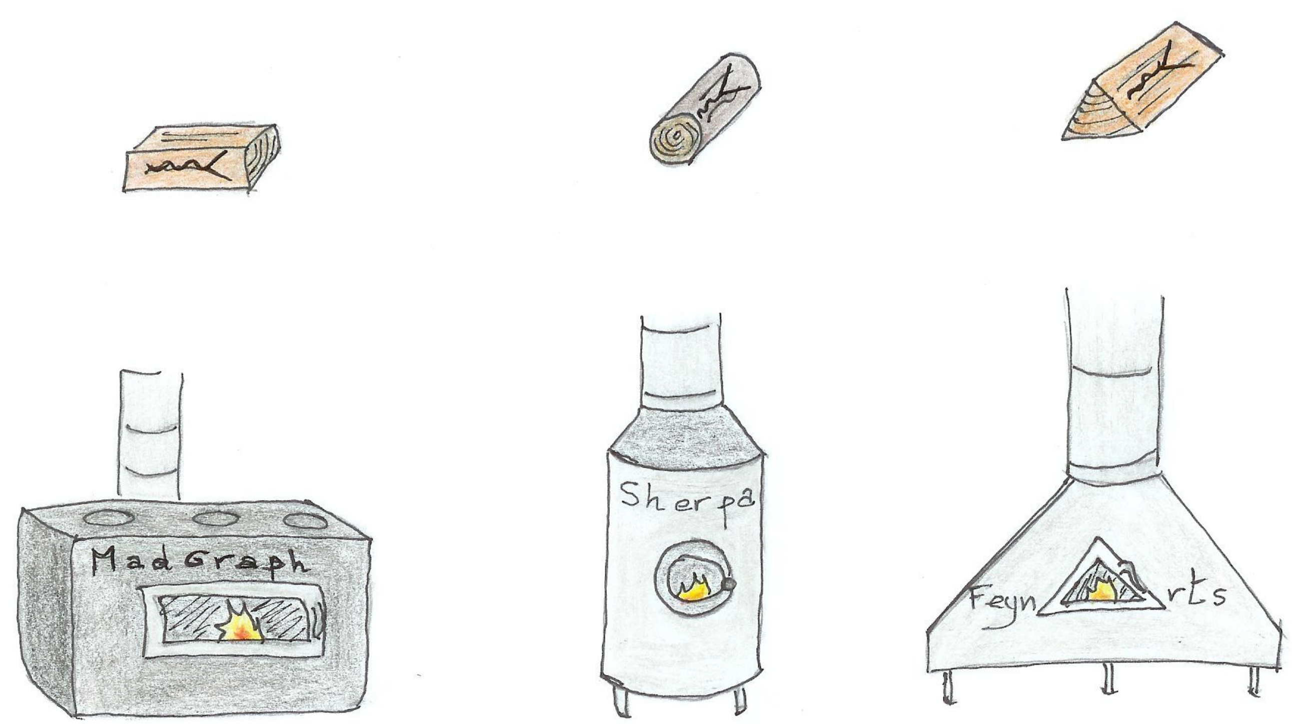


FeynRules in a nutshell

- 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
```

FeynRules in a nutshell

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

```
FeynmanRules[ L ]
```

FeynRules in a nutshell

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

FeynmanRules[L]

Vertex 1

Particle 1 : Vector , G

Particle 2 : Dirac , $q^\dagger$

Particle 3 : Dirac , q

Vertex:

$$i\, \mathrm{gs}\, \gamma^{\mu_1}{}_{s_2,s_3}\, \delta_{f_2,f_3}\, T^{a_1}{}_{i_2,i_3}$$

FeynRules in a nutshell

- 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").

interactions.dat

```
  q  q G      GG         QCD
  G G G      MGVX1  QCD
G G G G      MGVX2  QCD QCD
```

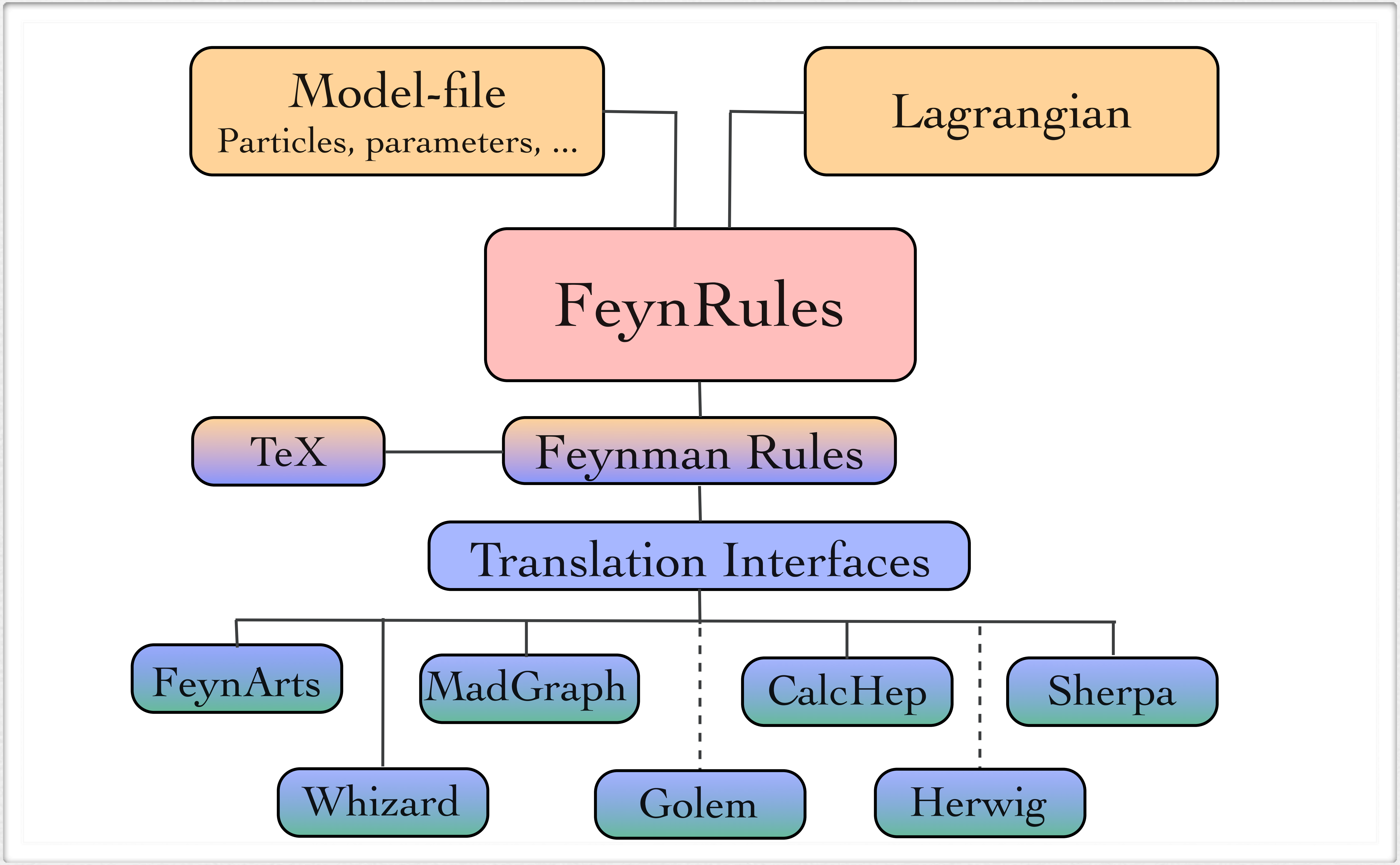
particles.dat

```
q   q~  F   S   ZERO ZERO T   d   1
G   G    V  C   ZERO ZERO O   G  21
```

couplings.dat

```
GG(1)   =  -G
GG(1)   =  -G
MGVX1 = G
MGVX2 = G^2
```

FeynRules



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

Implemented models

	CalcHep	Herwig	MadGraph	Sherpa	Whizard
SM	✓	✓	✓	✓	✓
cMSSM	✓	✓	✓	✓	✓
MSSM	✓			✓	✓
NMSSM					✓
2HDM			✓		
UED	✓				✓
ADD				✓	
Technicolor					

Implemented models

	CalcHep	Herwig	MadGraph	Sherpa	Whizard
SM	✓	✓	✓	✓	✓
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NMSSM	✓	✓	✓	✓	✓
2HDM	✓	✓	✓	✓	✓
UED	✓	✓	✓	✓	✓
ADD				✓	
Technicolor					

Implemented models

- Standard Model* (CD, N. Christensen)
- Most general two Higgs doublet model* (CD, M. Herquet)
- Minimal Higgsless Model* (N. Christensen)

  * available at http://feynrules.phys.ucl.ac.be

- Validation of the models:

Process	MG-FR	MG-ST	CH-FR	CH-ST	SH-FR	SH-ST	WO-FR	WO-ST	Comparison
e+,e->sd1,sd1~	2.85002×10^{-3}	2.85011×10^{-3}	2.8501×10^{-3}	2.8501×10^{-3}	2.85007×10^{-3}	2.85007×10^{-3}	2.85013×10^{-3}	2.85013×10^{-3}	$\delta = 0.00394796$ %
e+,e->sd2,sd2~	4.34049×10^{-4}	4.34207×10^{-4}	4.3415×10^{-4}	4.3415×10^{-4}	4.34145×10^{-4}	4.34145×10^{-4}	4.34155×10^{-4}	4.34155×10^{-4}	$\delta = 0.0364994$ %
e+,e->sd1,sd2~	2.85795×10^{-4}	2.85759×10^{-4}	2.8578×10^{-4}	2.8579×10^{-4}	2.85825×10^{-4}	2.85825×10^{-4}	2.8579×10^{-4}	2.8579×10^{-4}	$\delta = 0.0229397$ %
e+,e->n1,n1	7.45909×10^{-2}	7.45813×10^{-2}	7.4637×10^{-2}	7.4637×10^{-2}	7.46268×10^{-2}	7.46266×10^{-2}	7.463×10^{-2}	7.46338×10^{-2}	$\delta = 0.0746855$ %
e+,e->n1,n2	2.5541×10^{-2}	2.55366×10^{-2}	2.5555×10^{-2}	2.5555×10^{-2}	2.55523×10^{-2}	2.55516×10^{-2}	2.55521×10^{-2}	2.55535×10^{-2}	$\delta = 0.0719985$ %
e+,e->n1,n3	2.08218×10^{-3}	2.08034×10^{-3}	2.081×10^{-3}	2.081×10^{-3}	2.08093×10^{-3}	2.08089×10^{-3}	2.0811×10^{-3}	2.081×10^{-3}	$\delta = 0.0880299$ %
e+,e->n1,n4	3.73046×10^{-3}	3.73254×10^{-3}	3.7325×10^{-3}	3.7325×10^{-3}	3.73208×10^{-3}	3.7321×10^{-3}	3.73223×10^{-3}	3.73238×10^{-3}	$\delta = 0.0555803$ %

Implemented models: (Susy)

- Full MSSM* (B. Fuks)
- NMSSM (B. Fuks)
- R-symmetric MSSM (B. Fuks)
- RPV MSSM (B. Fuks)

* available at http://feynrules.phys.ucl.ac.be

Implemented models: (ED)

- Universal Extra Dimensions* (P. de Aquino)
- Large extra dimensions* (P. de Aquino)
- Randall-Sundrum I (P. de Aquino)

* available at http://feynrules.phys.ucl.ac.be

Implemented models: (Effective)

- Strongly interacting Little Higgs (C. Degrande)
- Composite Top model (C. Degrande)
- Chiral perturbation theory (C. Degrande)

* available at http://feynrules.phys.ucl.ac.be

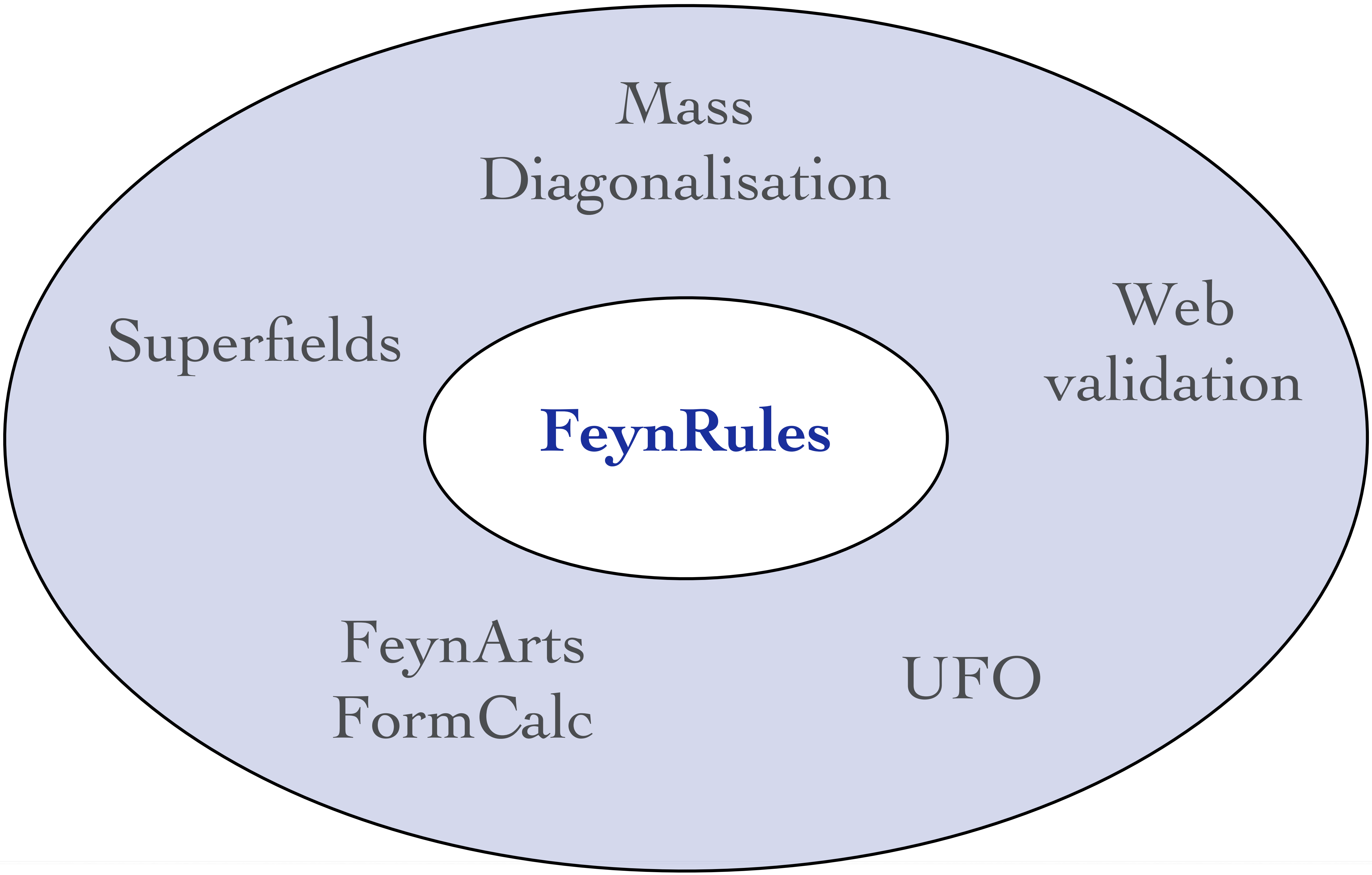
Improvements for the future

- FeynRules can handle mixing of particles, however the mass matrices must be diagonalized manually by the user.
- SUSY models have to be implemented in component fields.
- Many interfaces are running, but matrix element generators can only handle a very limited set of color/ Lorentz structures.

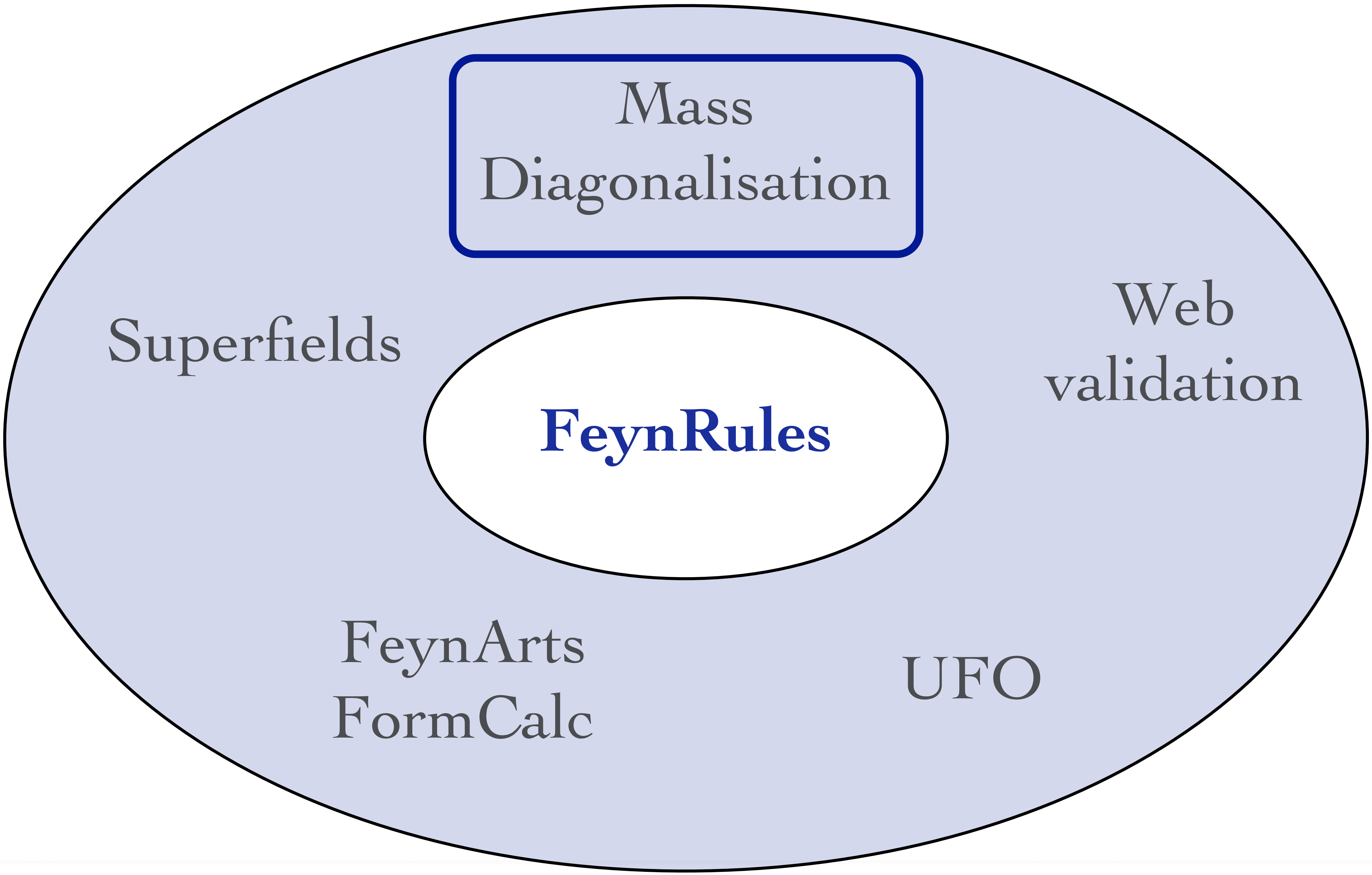
New Developments

- In spring 2010, we locked up 13 experts in a room in a nice monastry for 5 days, and let them gather new ideas...
- As a result, many new projects got started (in fact too many to review them all here...)

New Developments



New Developments



Mass Matrix diagonalization (N. Christensen, M. Wiebusch)

- In the future, FeynRules will perform the diagonalization automatically.

Input 1: Lagrangian

qLbar[s1,l1,f1,i].uR[s1,f2,i] Yu[f1,f2] Eps[l1,l2] Phibar[l2]

Input 2: Mixing relations

uq[s, #, o] == CKMU.uqp[s, #, o]

Output 1: Mass matrix to be diagonalized

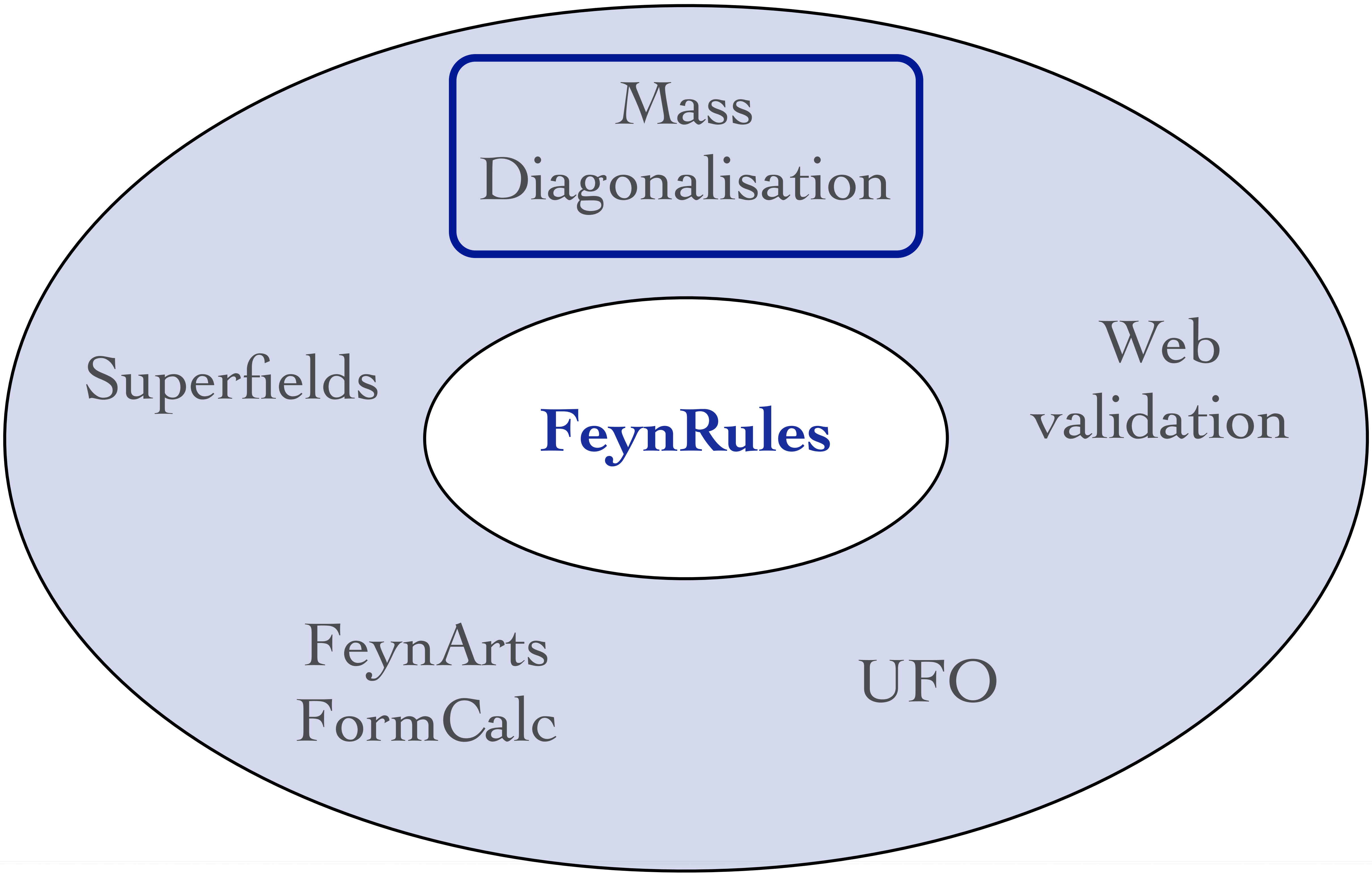
$$\text{Diagonalization}(\text{HEigensystem}, \text{CKMU}, \{m_u, m_c, m_t\}) \to \begin{pmatrix} -\frac{v\,\text{Yu}_{1,1}}{2\sqrt{2}} & -\frac{v\,\text{Yu}_{1,2}}{2\sqrt{2}} & -\frac{v\,\text{Yu}_{1,3}}{2\sqrt{2}} \\ -\frac{v\,\text{Yu}_{2,1}}{2\sqrt{2}} & -\frac{v\,\text{Yu}_{2,2}}{2\sqrt{2}} & -\frac{v\,\text{Yu}_{2,3}}{2\sqrt{2}} \\ -\frac{v\,\text{Yu}_{3,1}}{2\sqrt{2}} & -\frac{v\,\text{Yu}_{3,2}}{2\sqrt{2}} & -\frac{v\,\text{Yu}_{3,3}}{2\sqrt{2}} \end{pmatrix}$$

Output 2: 'Rotation rules'

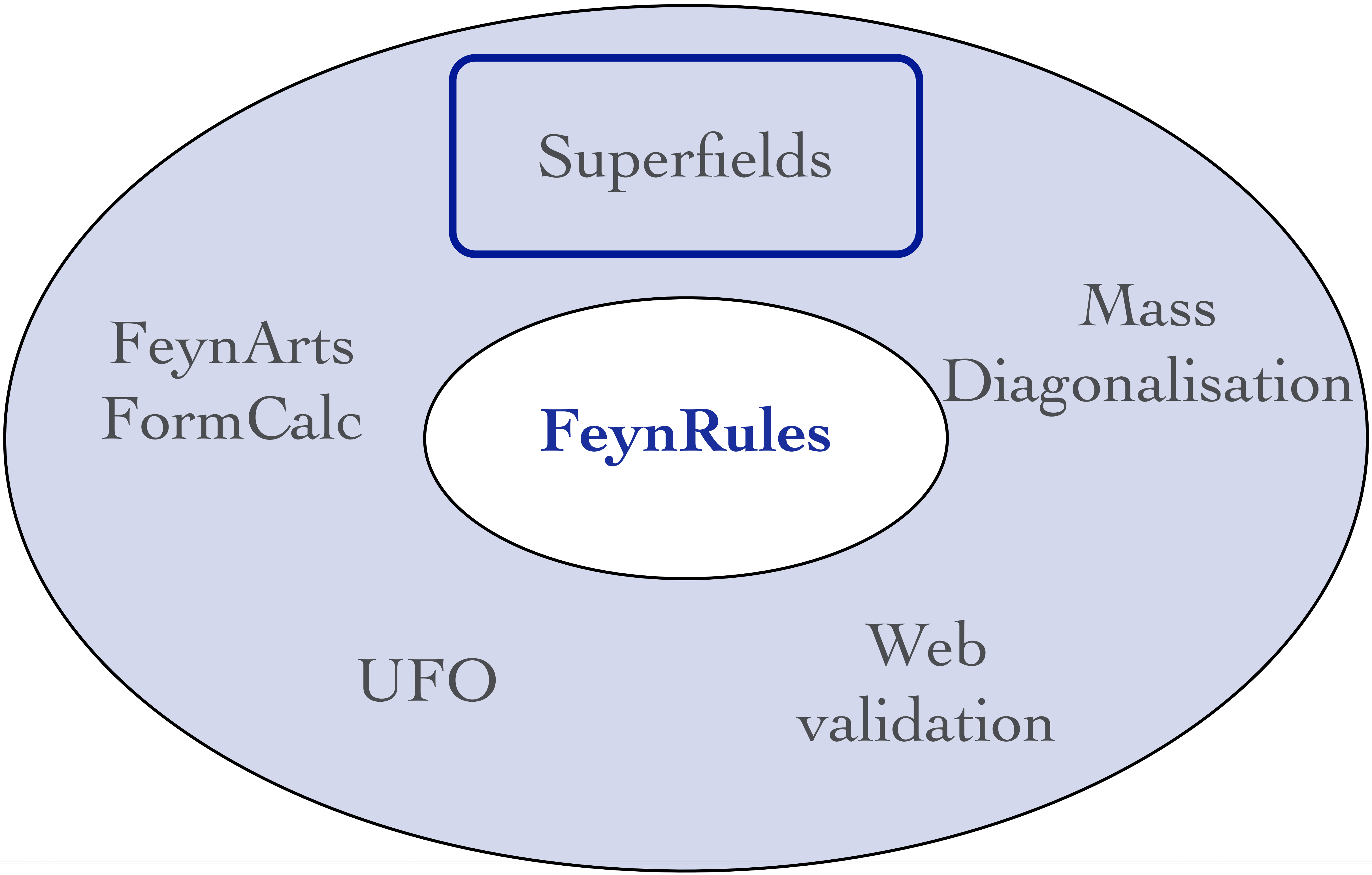
$$(P_+)_{s1,s}\left(\text{CKMU}(1,1)^* \,\text{uq}_{s,1,o} + \text{CKMU}(2,1)^* \,\text{uq}_{s,2,o} + \text{CKMU}(3,1)^* \,\text{uq}_{s,3,o}\right)$$

- To be done: numerical code for the diagonalization.

New Developments



New Developments



Superfields (B. Fuks)

- In the future, FeynRules will allow the use of superfields.
- Example: Superpotential for left-handed quarks

$$\mathcal{W} = a_i Q_{Li} + M_{ij} Q_{Li} Q_{Lj} + \frac{1}{6} \lambda_{ijk} Q_{Li} Q_{Lj} Q_{Lk}$$

```
W = a[i] QL[i] + 1/2*M[i, j] QL[i] QL[j] + 1/6*l[i, j, k] QL[i] QL[j] QL[k]
```

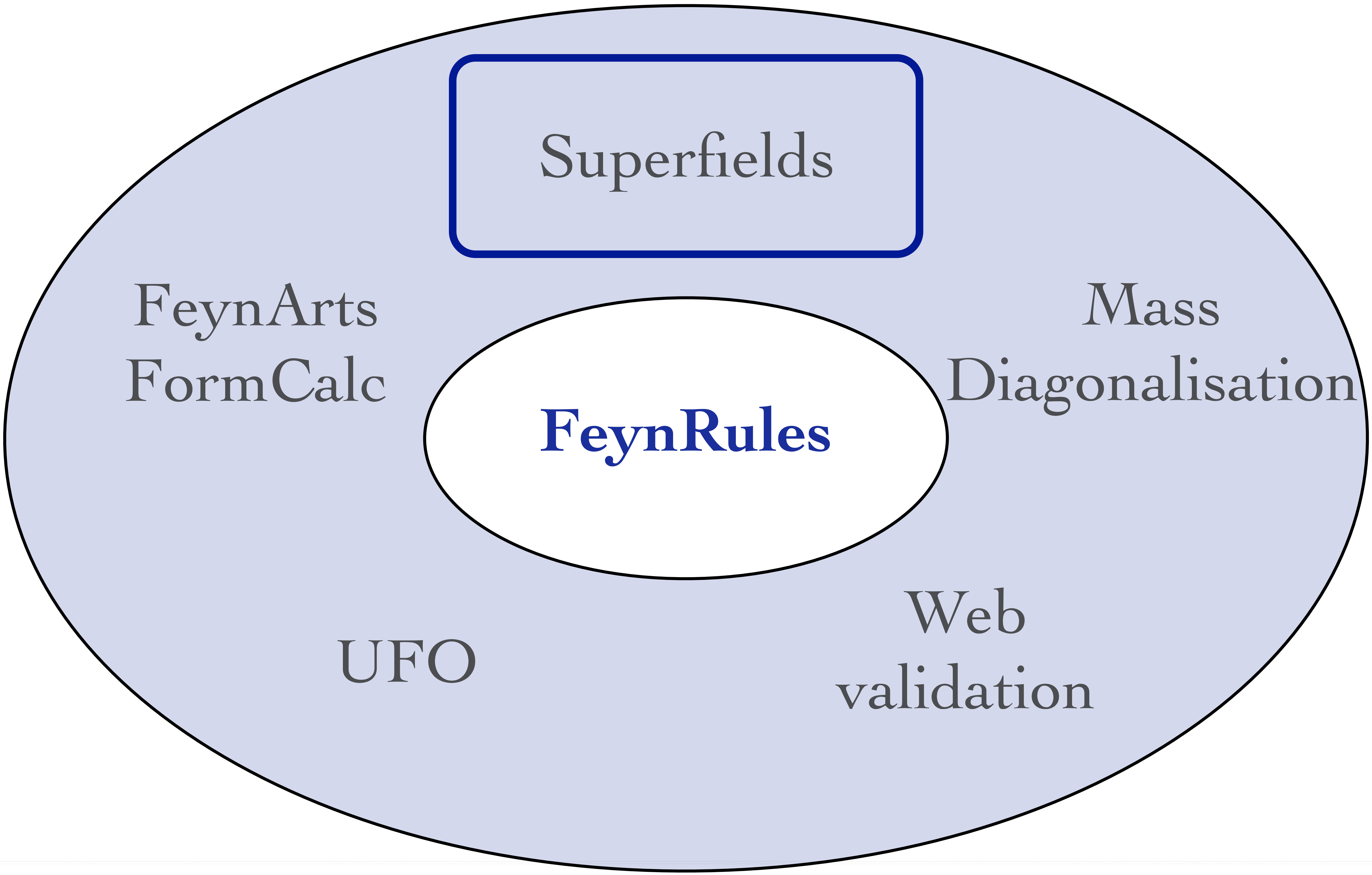
- FeynRules then converts the superfields into component fields:

```
SF2Components[ W ]
```

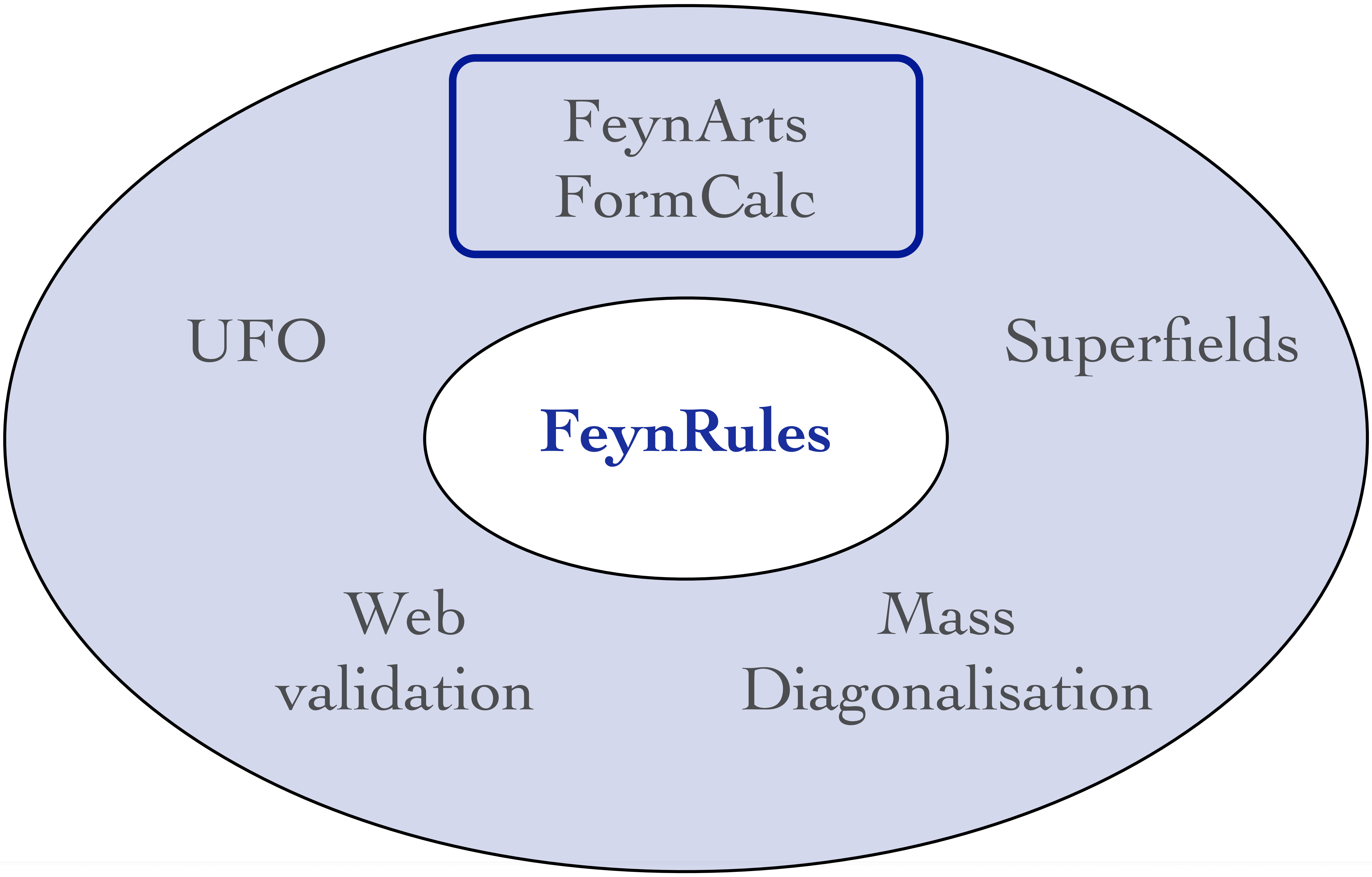
$$-\frac{1}{6}\,\mathrm{FTerm3}_i\,\mathrm{sqL}_j\,\mathrm{sqL}_k\,l_{i,j,k} - \frac{1}{6}\,\mathrm{FTerm3}_k\,\mathrm{sqL}_i\,\mathrm{sqL}_j\,l_{i,j,k} - \frac{1}{6}\,\mathrm{FTerm3}_j\,\mathrm{sqL}_i\,\mathrm{sqL}_k\,l_{i,j,k}$$

$$- \frac{1}{6}\,\mathrm{sqL}_j\,l_{i,j,k}\,\mathrm{qL}_{\mathrm{sp\$2},i}.\mathrm{qL}_{\mathrm{sp\$2},k} - \frac{1}{6}\,\mathrm{sqL}_i\,l_{i,j,k}\,\mathrm{qL}_{\mathrm{sp\$2},j}.\mathrm{qL}_{\mathrm{sp\$2},k} - \frac{1}{2}\,M_{i,j}\,\mathrm{qL}_{\mathrm{sp\$2},i}.\mathrm{qL}_{\mathrm{sp\$2},j}$$

New Developments



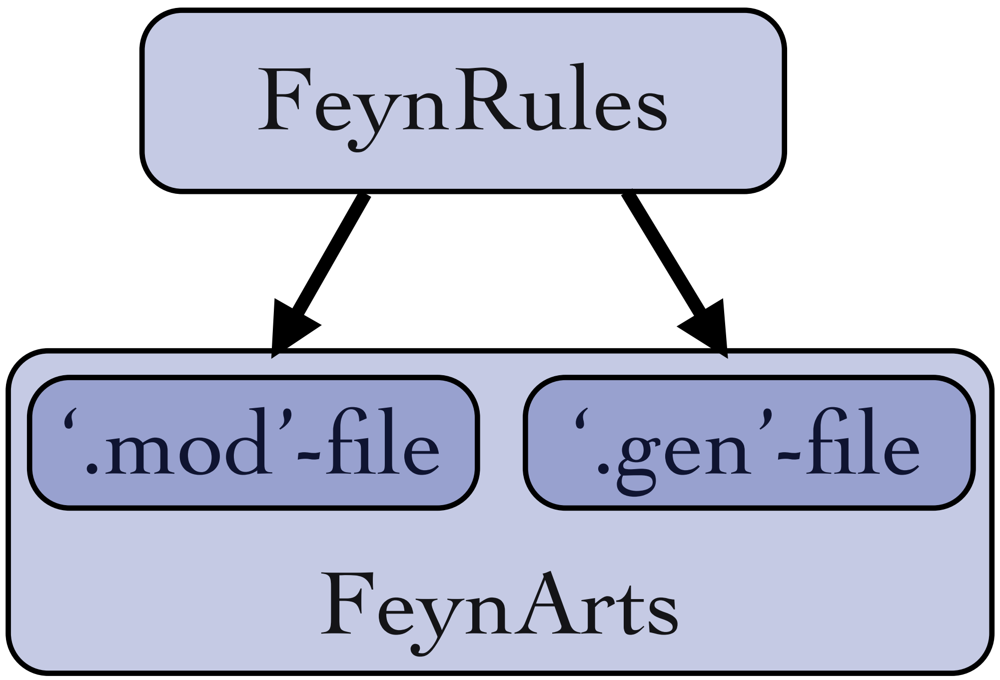
New Developments



FeynArts interface (C. Degrande, CD)

- A new interface to FeynArts has been developed that allows to implement arbitrary Lorentz structures.

Model-dependent couplings (cf. couplings.f and interactions.dat)



(Model-independent) Lorentz structures (cf. HELAS)

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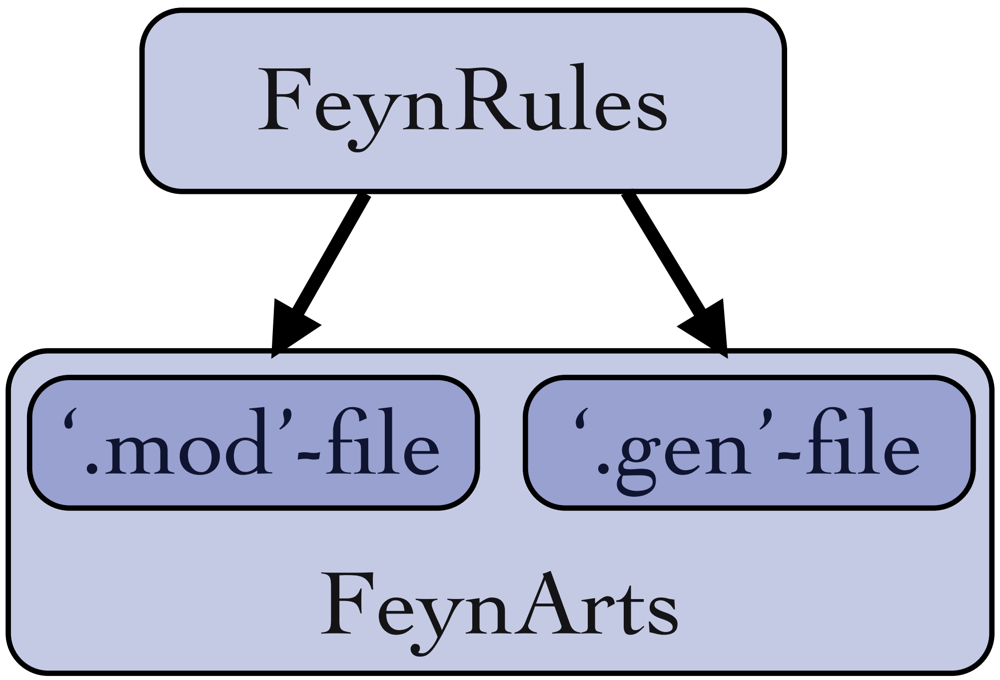

(Model-independent) Lorentz structures (cf. HELAS)

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

FeynArts interface (C. Degrande, CD)

- Example:

$$\mathcal{L} = g_1 \, \Phi \, \bar{Q}_L \sigma^{\mu\nu} T^a t_R \, G^a_{\mu\nu}$$

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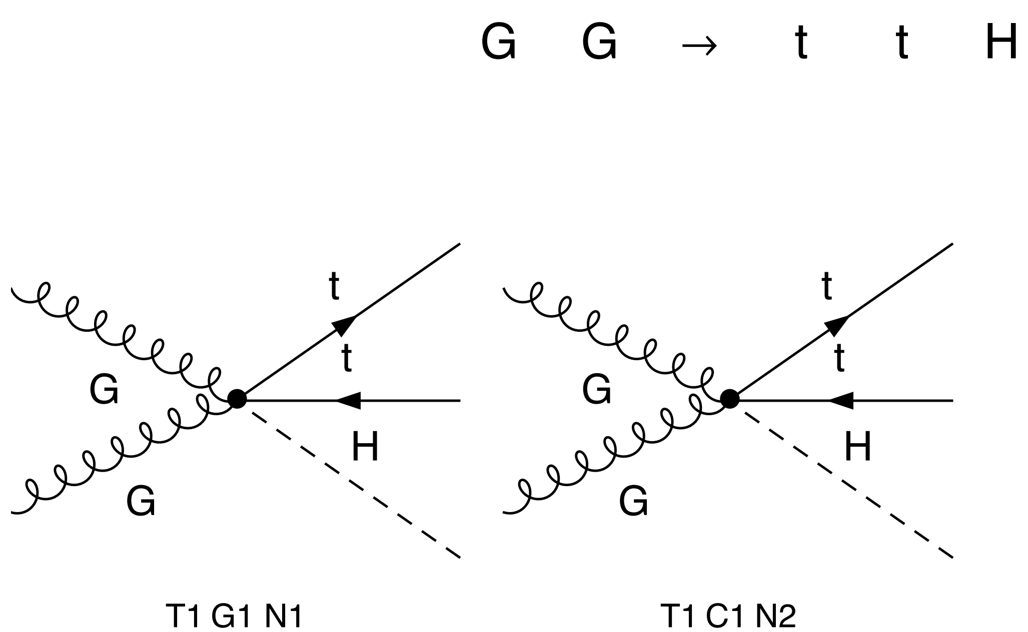
- FeynArts output:



FeynArts interface (C. Degrande, CD)

- Example:

$$\mathcal{L} = g_1 \, \Phi \, \bar{Q}_L \sigma^{\mu\nu} T^a t_R \, G^a_{\mu\nu}$$

- 'Classes coupling':

```
C[ -F[9, {i}] , F[9, {j}] , V[4, {a}] , V[4, {b}] , S[1] ] ==
        {{I*gc78*Conjugate[G1]*(SUNT[a, b, i, j] - SUNT[b, a, i, j])},
        {I*G1*gc78*(SUNT[a, b, i, j] - SUNT[b, a, i, j])},
        {(-I)*gc78*Conjugate[G1]*(SUNT[a, b, i, j] - SUNT[b, a, i, j])},
        {(-I)*G1*gc78*(SUNT[a, b, i, j] - SUNT[b, a, i, j])}}
```

FeynArts interface (C. Degrande, CD)

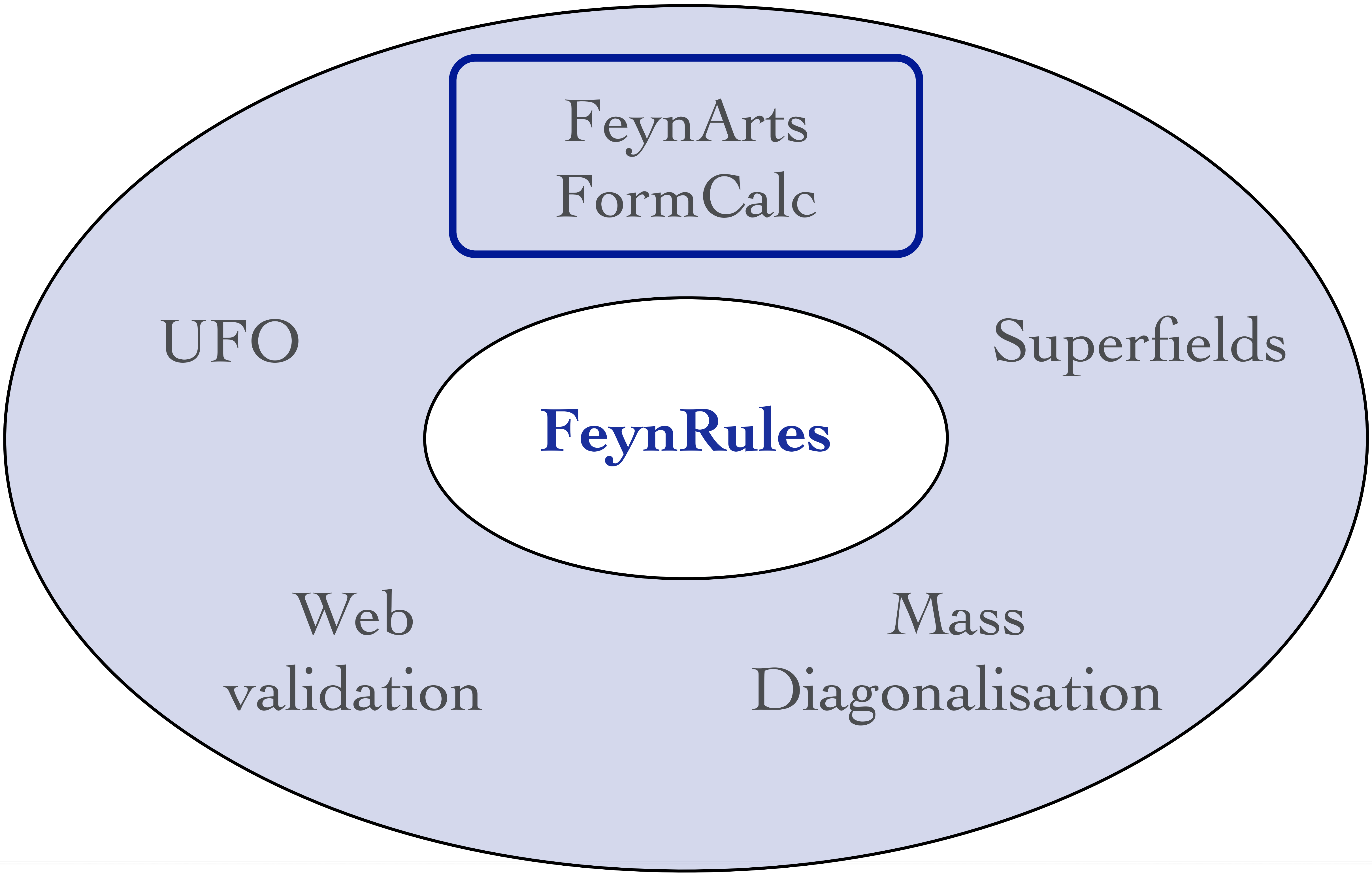
- Example:

$$\mathcal{L} = g_1\, \Phi\, \bar{Q}_L \sigma^{\mu\nu} T^a t_R\, G^a_{\mu\nu}$$

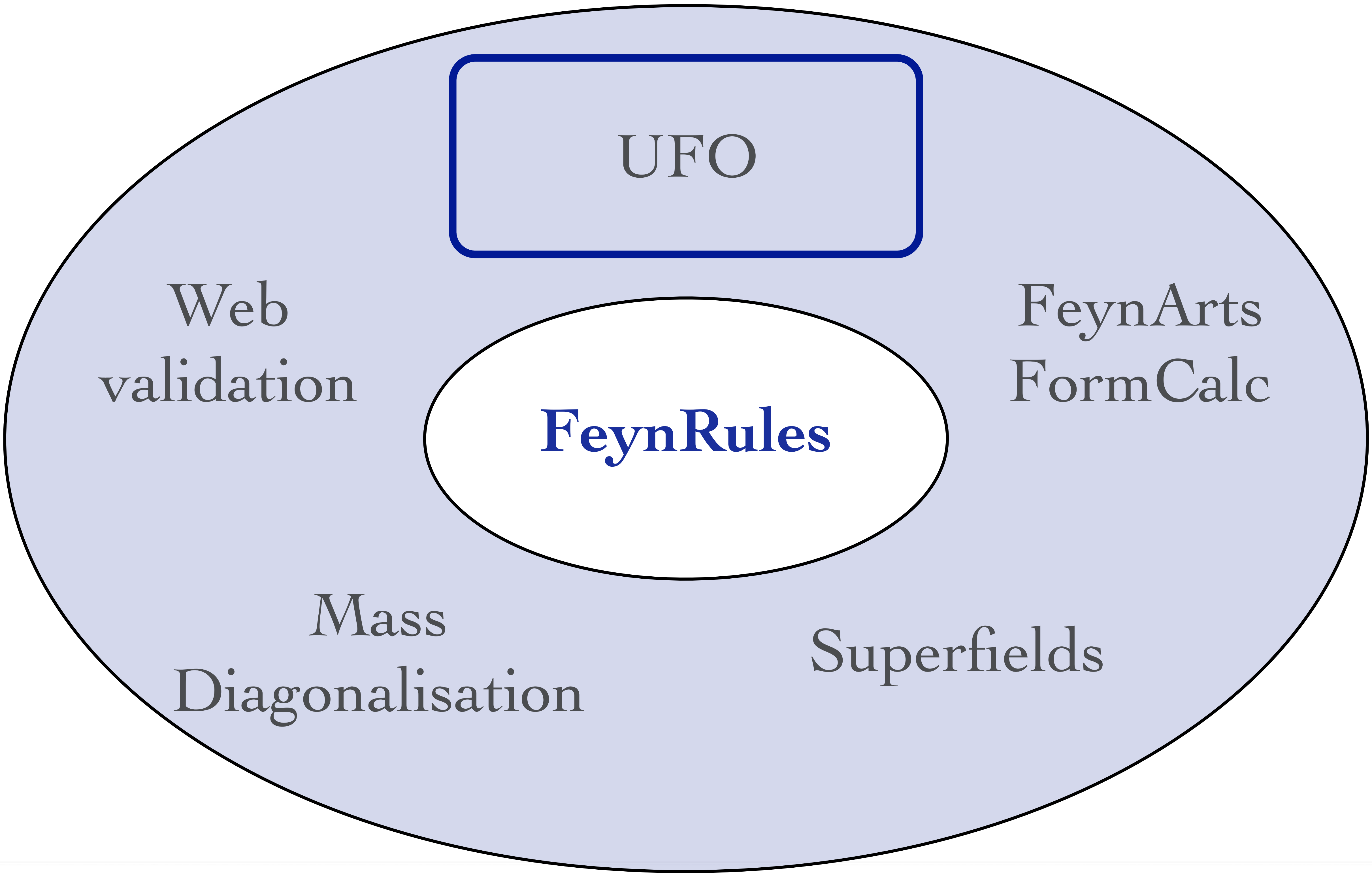
- 'Generic coupling':

```
AnalyticalCoupling[s1 F[j1, mom1], s2 F[j2, mom2],
    s3 V[j3, mom3, {li3}], s4 V[j4, mom4, {li4}], s5 S[j5, mom5] ] ==
   G[+1][s1 F[j1], s2 F[j2], s3 V[j3], s4 V[j4], s5 S[j5]].
  {MetricTensor[li3,li4]NonCommutative[ChiralityProjector[-1]],
   MetricTensor[li3,li4]NonCommutative[ChiralityProjector[+1]],
   NonCommutative[DiracMatrix[li3], DiracMatrix[li4],
   ChiralityProjector[-1] ], NonCommutative[DiracMatrix[li3],
   DiracMatrix[li4], ChiralityProjector[+1] ]},
```

New Developments



New Developments



The UFO

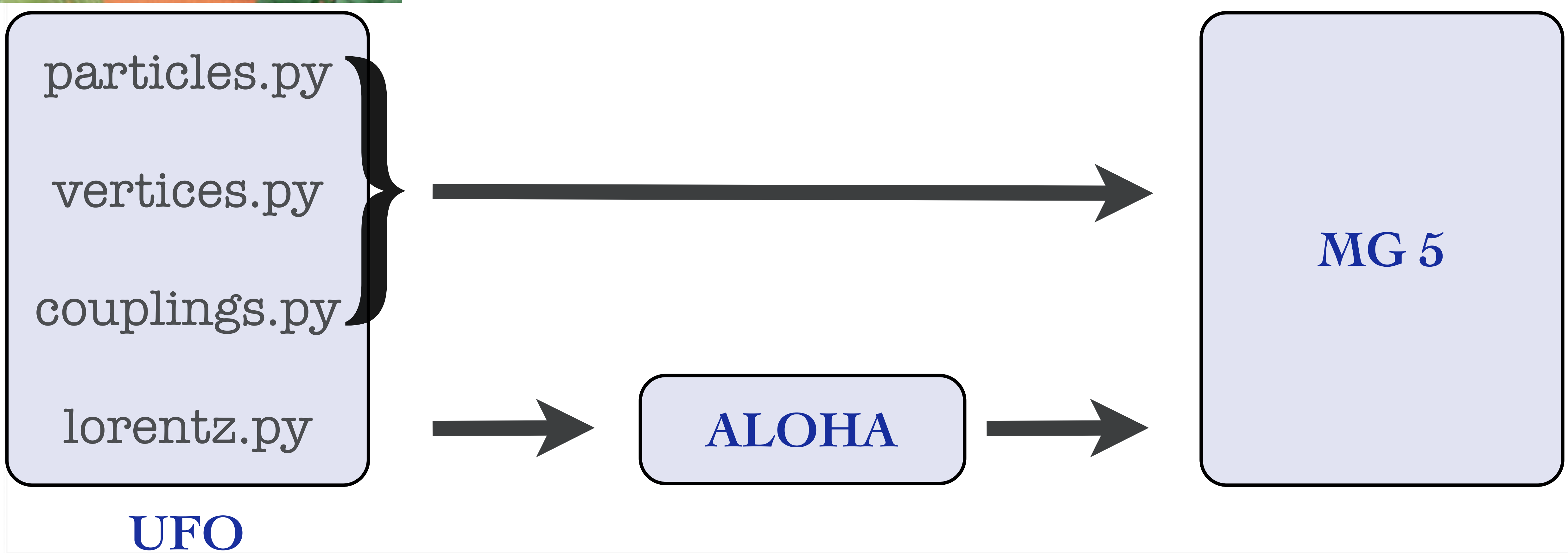
(P. de Aquino, CD, D. Grellscheid, W. Link, O. Mattelaer)

UFO = Universal FeynRules Output

- 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.

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 UFO & ALOHA

- Example: t t~ H reloaded!

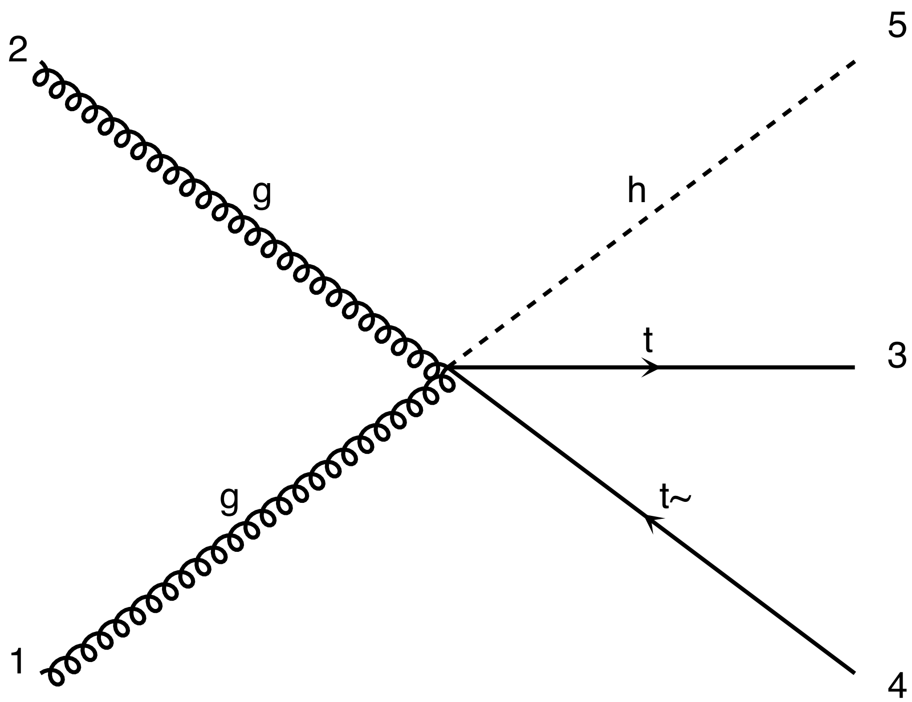
mg5>import model dim6
    models.import_ufo: load particles
    models.import_ufo: load vertices

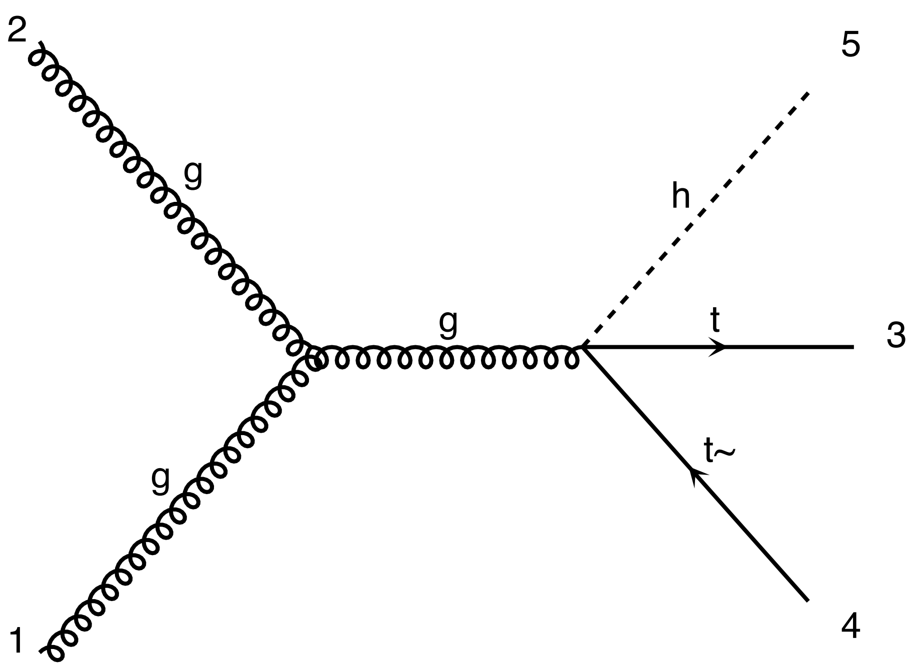
mg5>generate g g > t t~ H
    INFO: Process has 16 diagrams

mg5>output dim6
    INFO: Generating Helas calls for process: g g > t t~ h
    INFO: Processing color information for process: g g > t t~ h
    Export UFO model to MG4 format
    ALOHA: aloha creates FFV8 routines
    ALOHA: aloha creates FFVV8 routines
    ALOHA: aloha creates FFVS2 routines
    ALOHA: aloha creates FFVVS2 routines

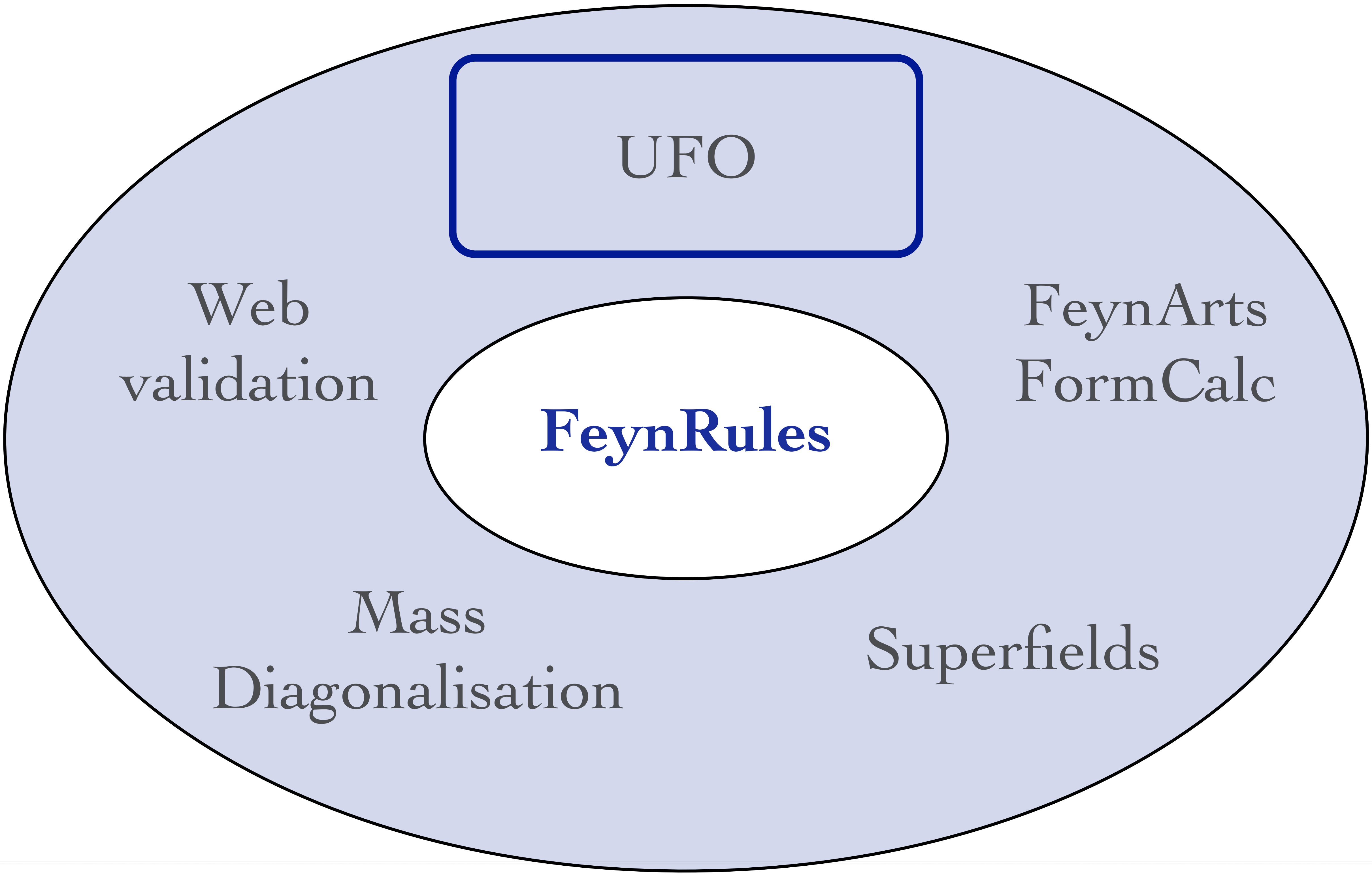
The UFO & ALOHA

- Example: t t~ H reloaded!

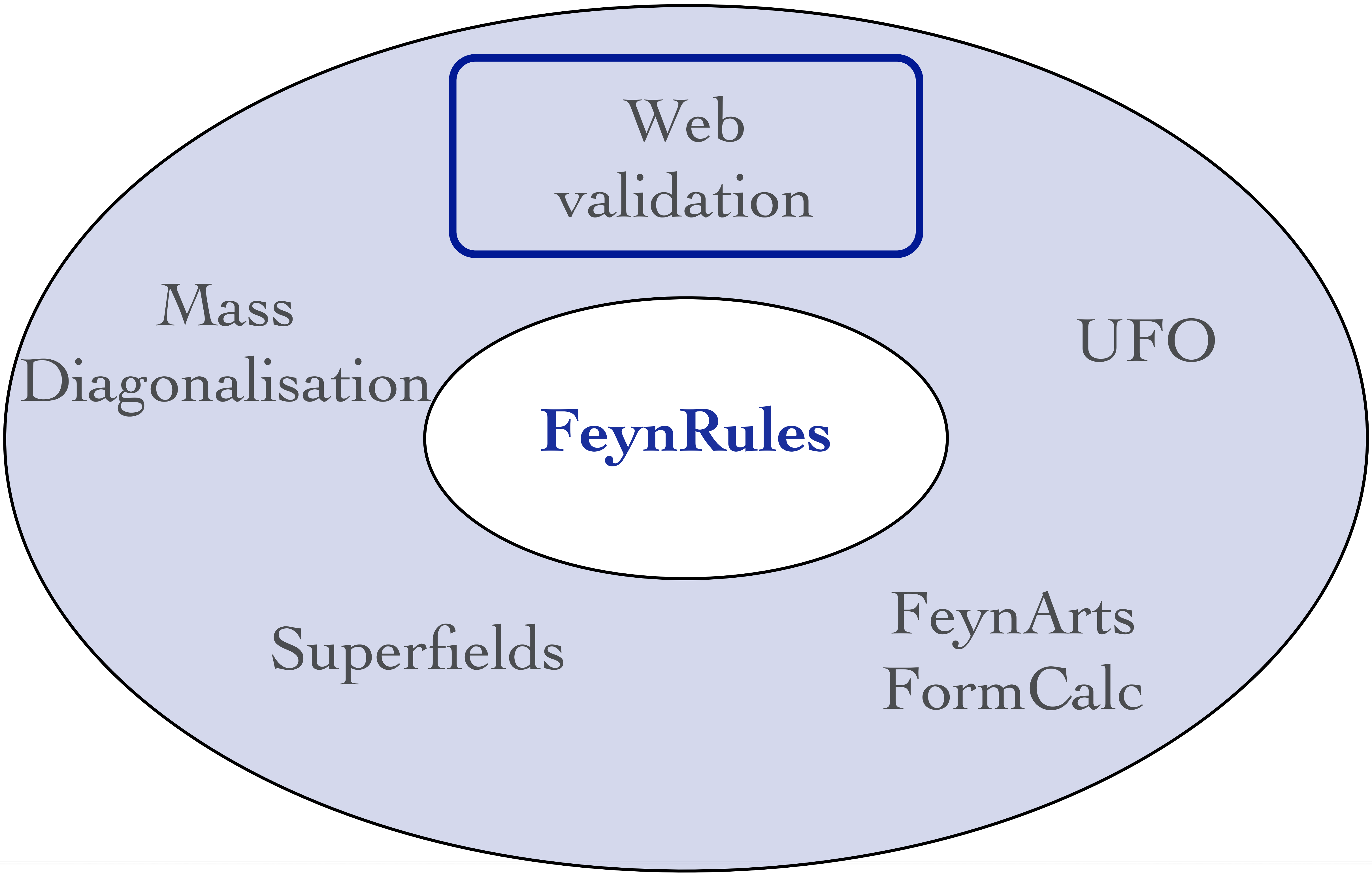




New Developments



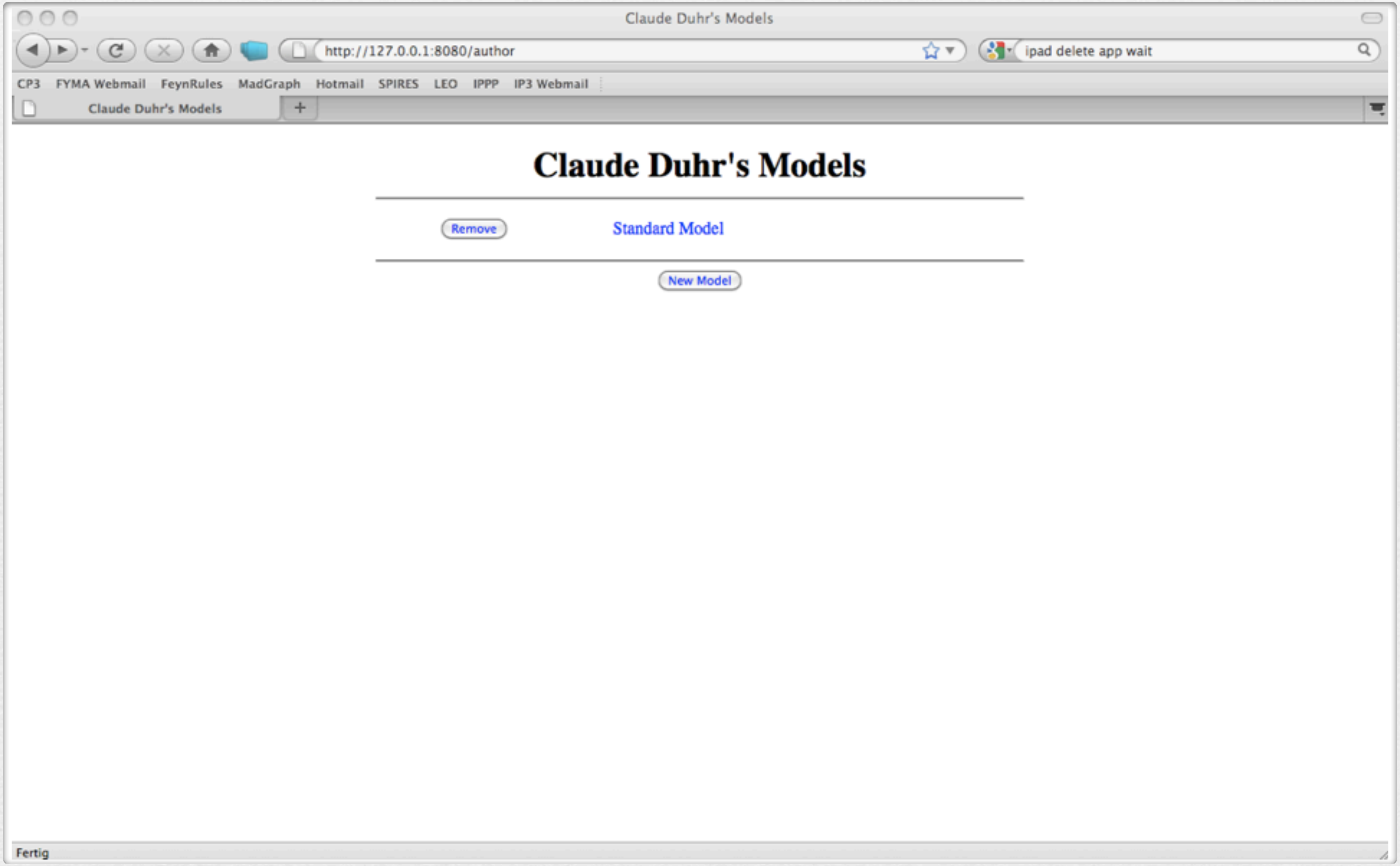
New Developments

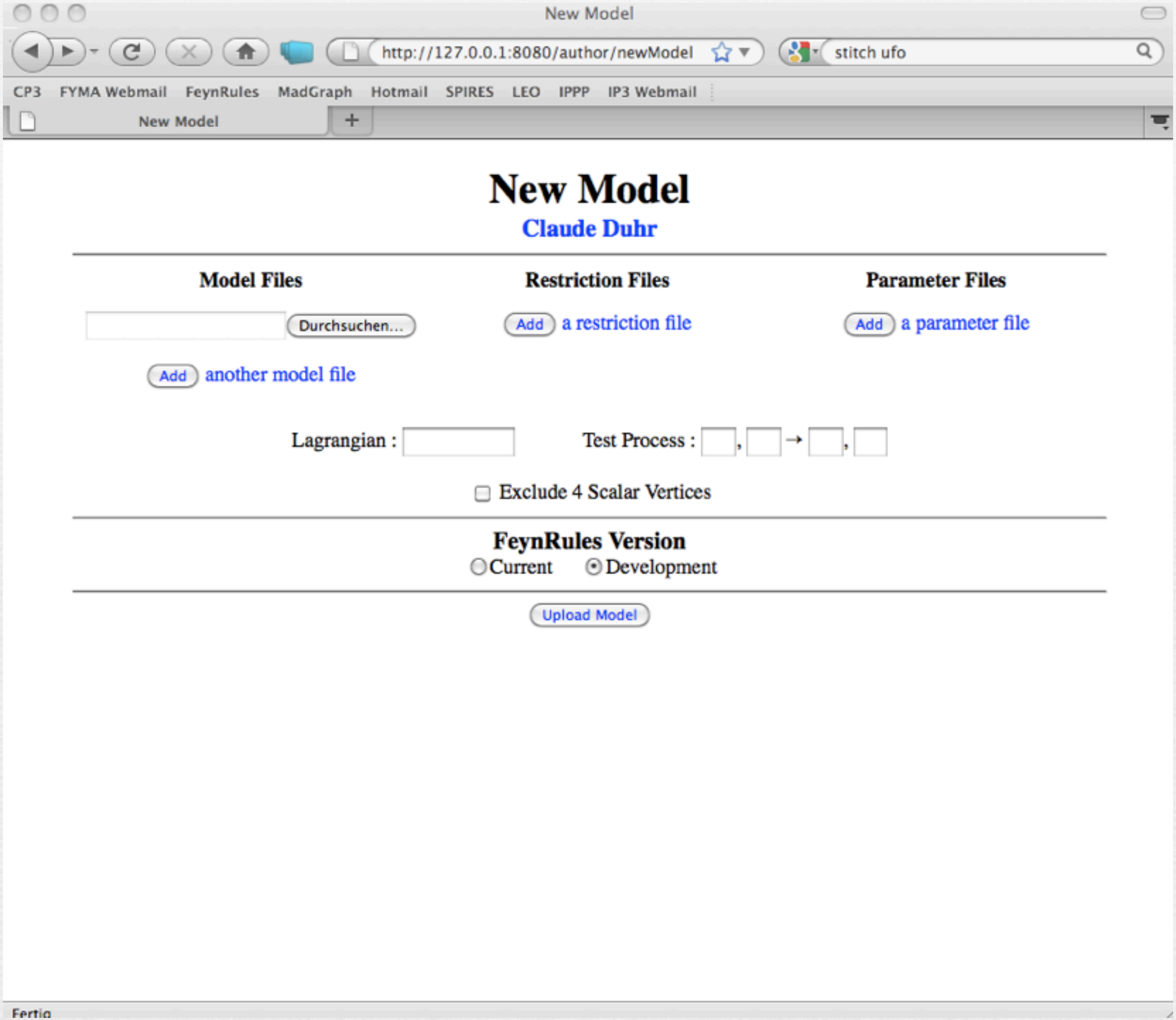


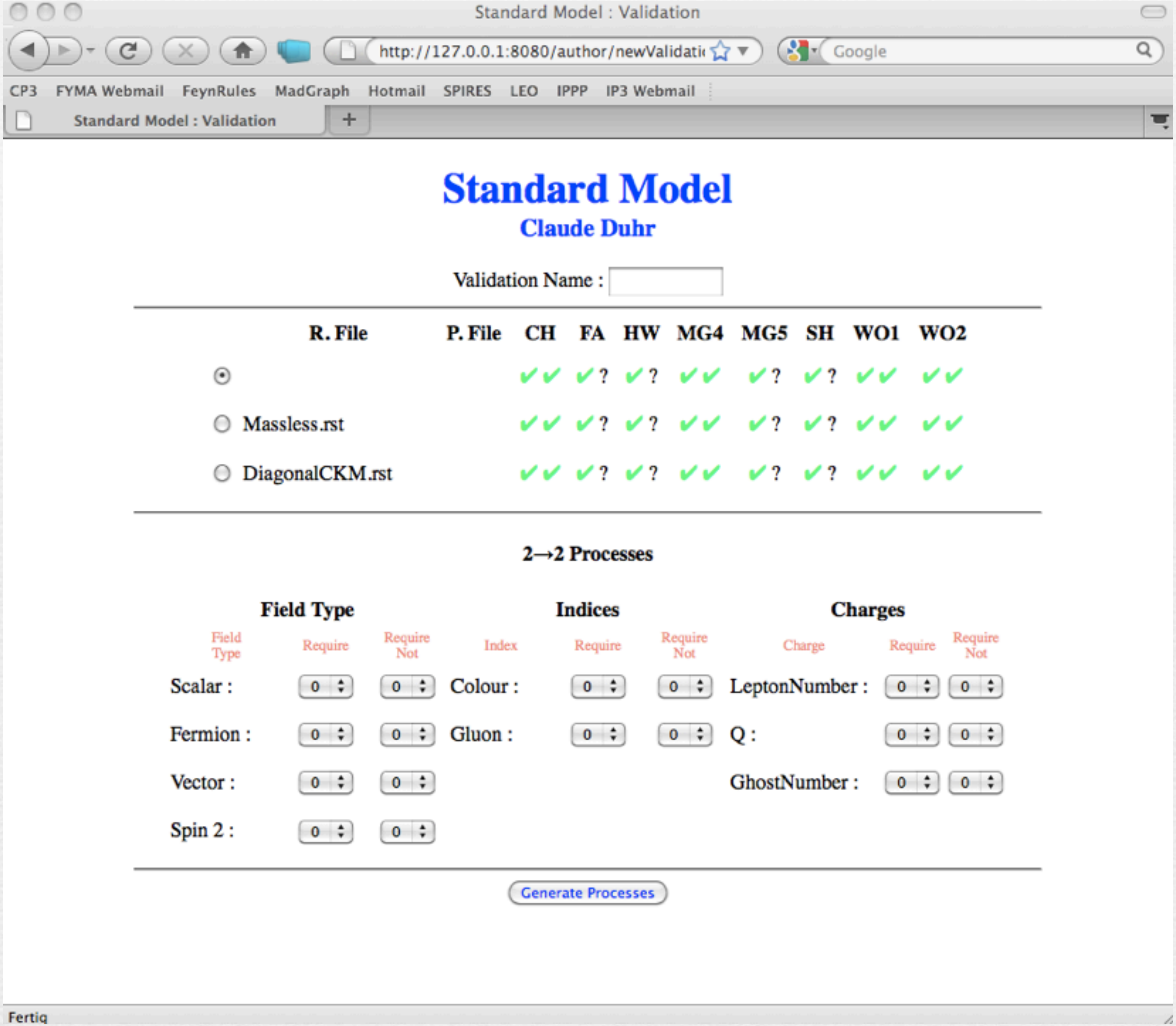
Validation of new models

- FeynRules does not only provide the power to develop and validate new models, but also to validate them to an unprecendented 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 : 0 0
Fermion : 0 0
Vector : 0 0
Spin 2 : 0 0
Colour : 0 0
Gluon : 0 0
LeptonNumber : 0 0
Q : 0 0
GhostNumber : 0 0
Generate Processes
Fertig

Standard Model : Test_Val_SM

http://127.0.0.1:8080/author/

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	Colour	0	0	LeptonNumber	0	0
Fermion	2	0	Gluon	0	0	Q	0	0
Vector	2	0				GhostNumber	0	0
Spin 2	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

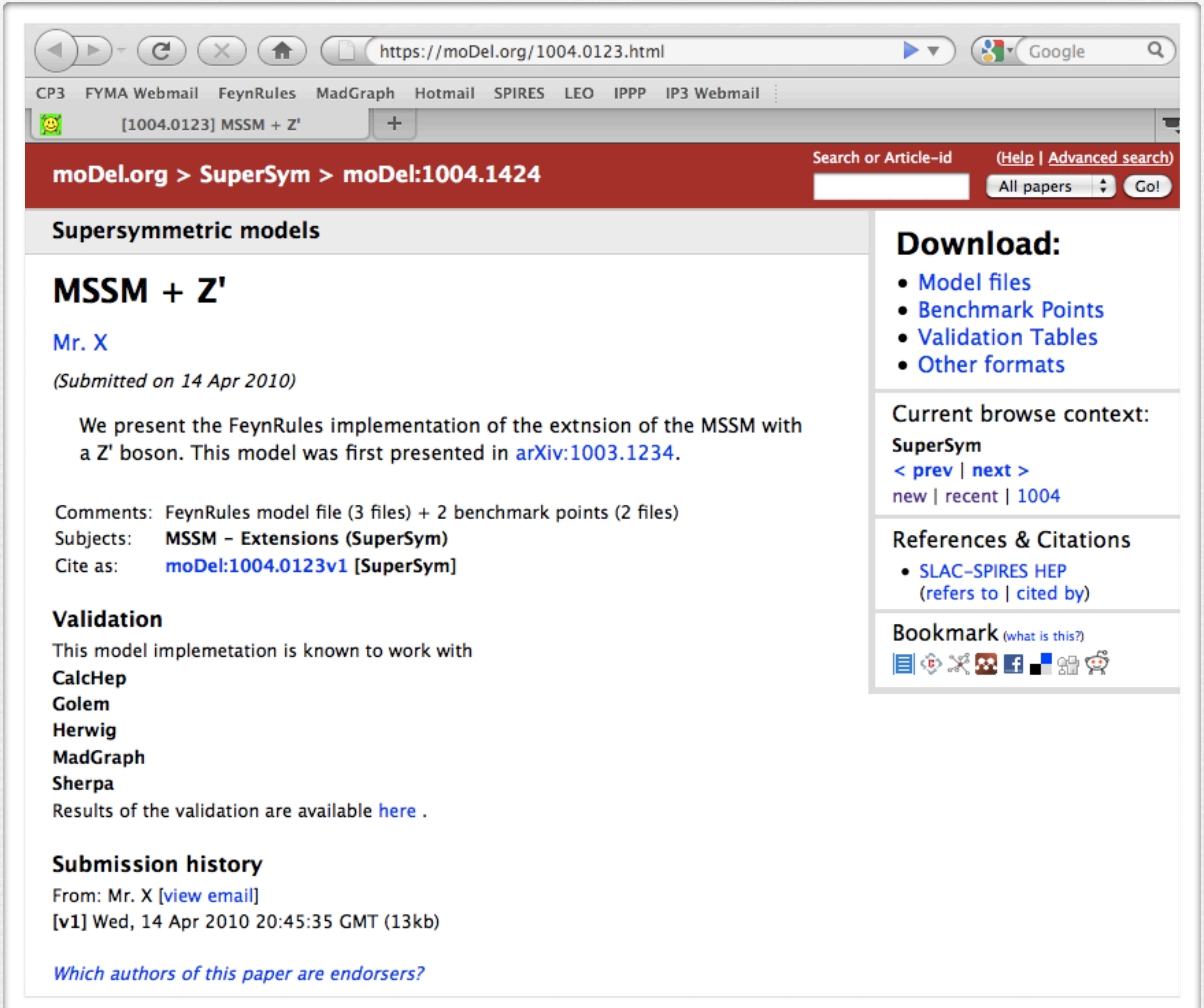
ve , ve~ → Z , Z	730.0	182.5	0.49452	0.49452	0.49384	0.494604	0.494622	0.494547	0.494668	0.49351	0.4945	●	0.17%
ve , ve~ → W+ , W-	639.0	159.75	1.0603	1.0603	1.0604	1.06053	1.0604	1.06035	1.06073	1.0665	1.0603	●	0.51%
ve , ve~ → G , G	200.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	✔	0%
ve , vm~ → A , 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

A look into the future...

- The future release of FeynRules will allow even more to
  - ➡ develop new models.
  - ➡ study the phenomenology of new models.
  - ➡ validate new implementations.
- However we still need to communicate the models to the experimentalists...
- Idea:
  - ➡ Theory paper on the arXiv are not enough to communicate new ideas.
  - ➡ so why not getting the model implementations directly instead?

Towards a database of models...



Conclusion

- The LHC is running, and we have to stay tuned!
- FeynRules is ready to cope with a large variety of models, ranging from model building, over phenomenology to experimental analysis.
- In particular, the chain UFO -> ALOHA -> MG5 is working flowlessly so far, making MG5 the probably most flexible BSM tool on the market.