FeynRules

arXiv:0806.4194

http://europa.fyma.ucl.ac.be/feynrules

& CalcHEP

http://theory.sinp.msu.ru/~pukhov/calchep.html

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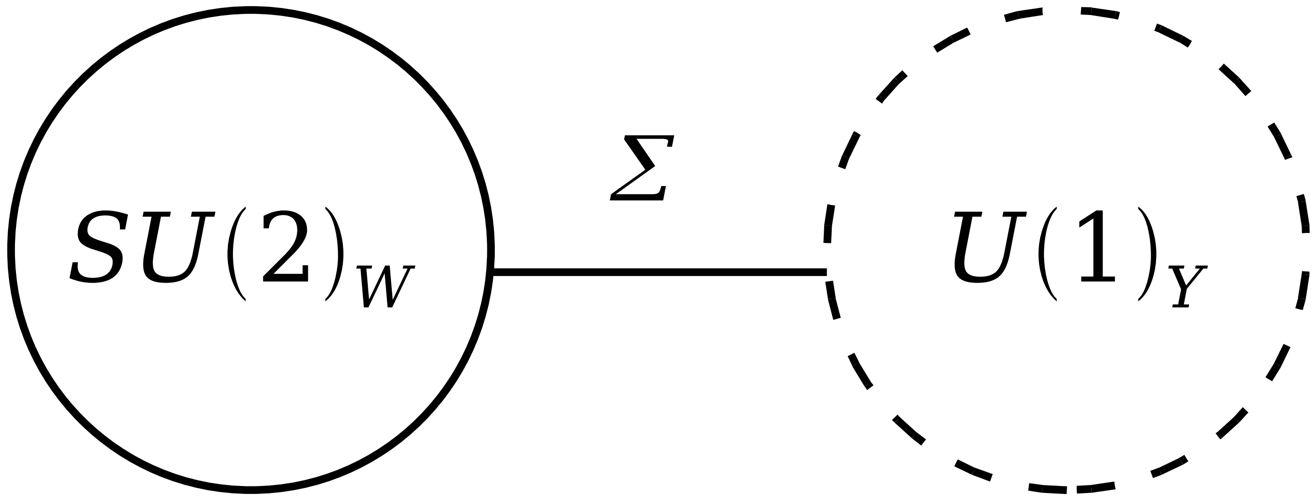
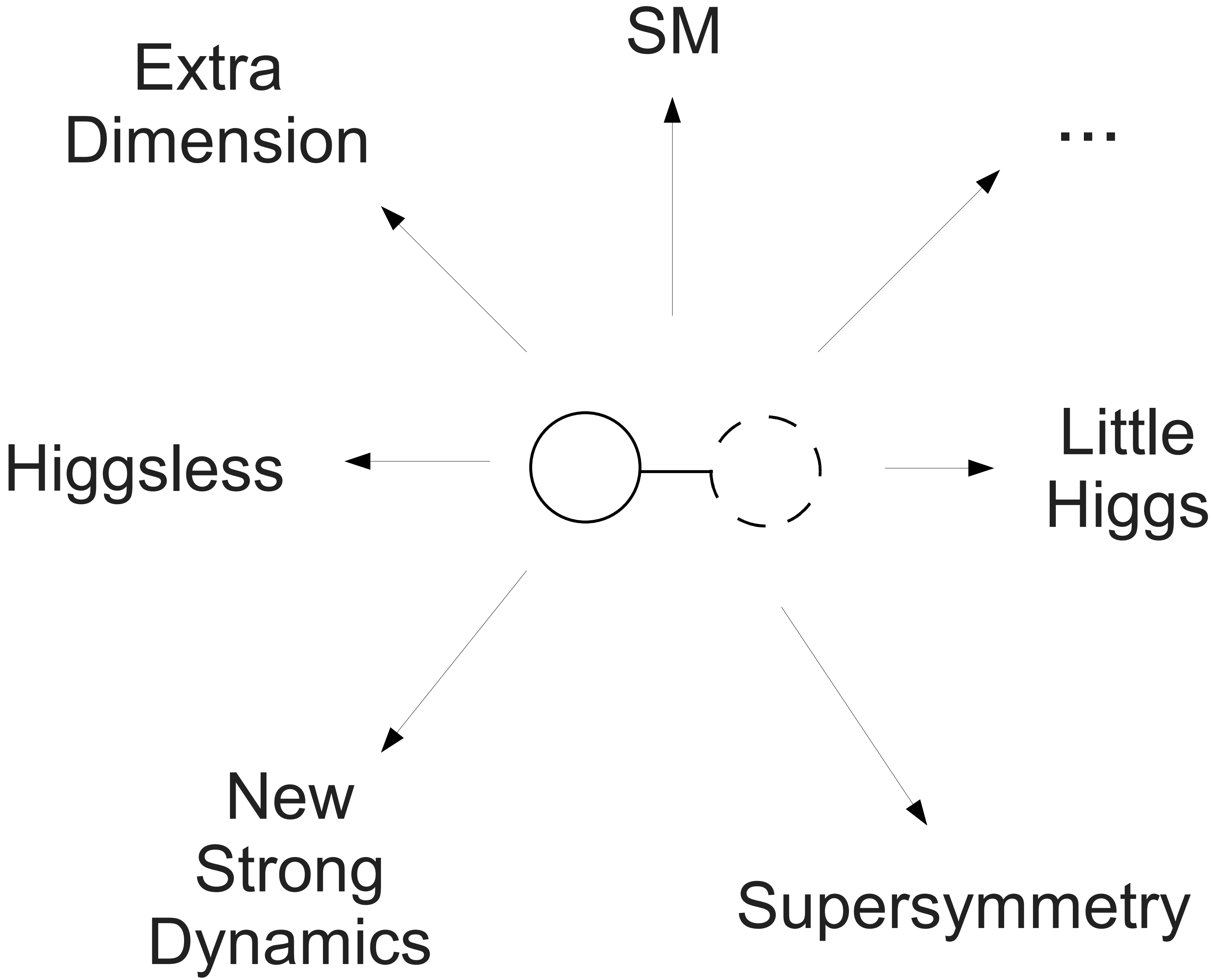
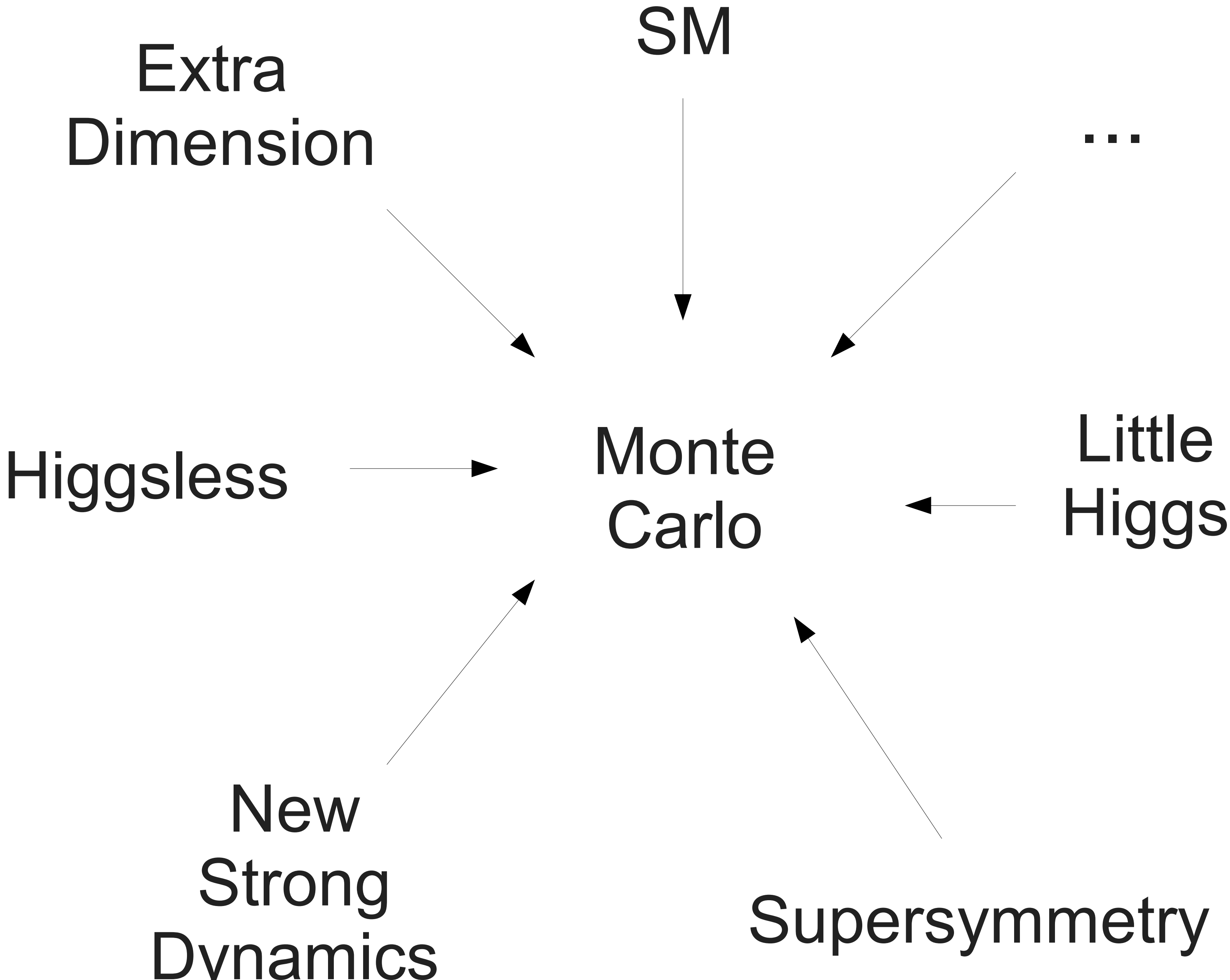
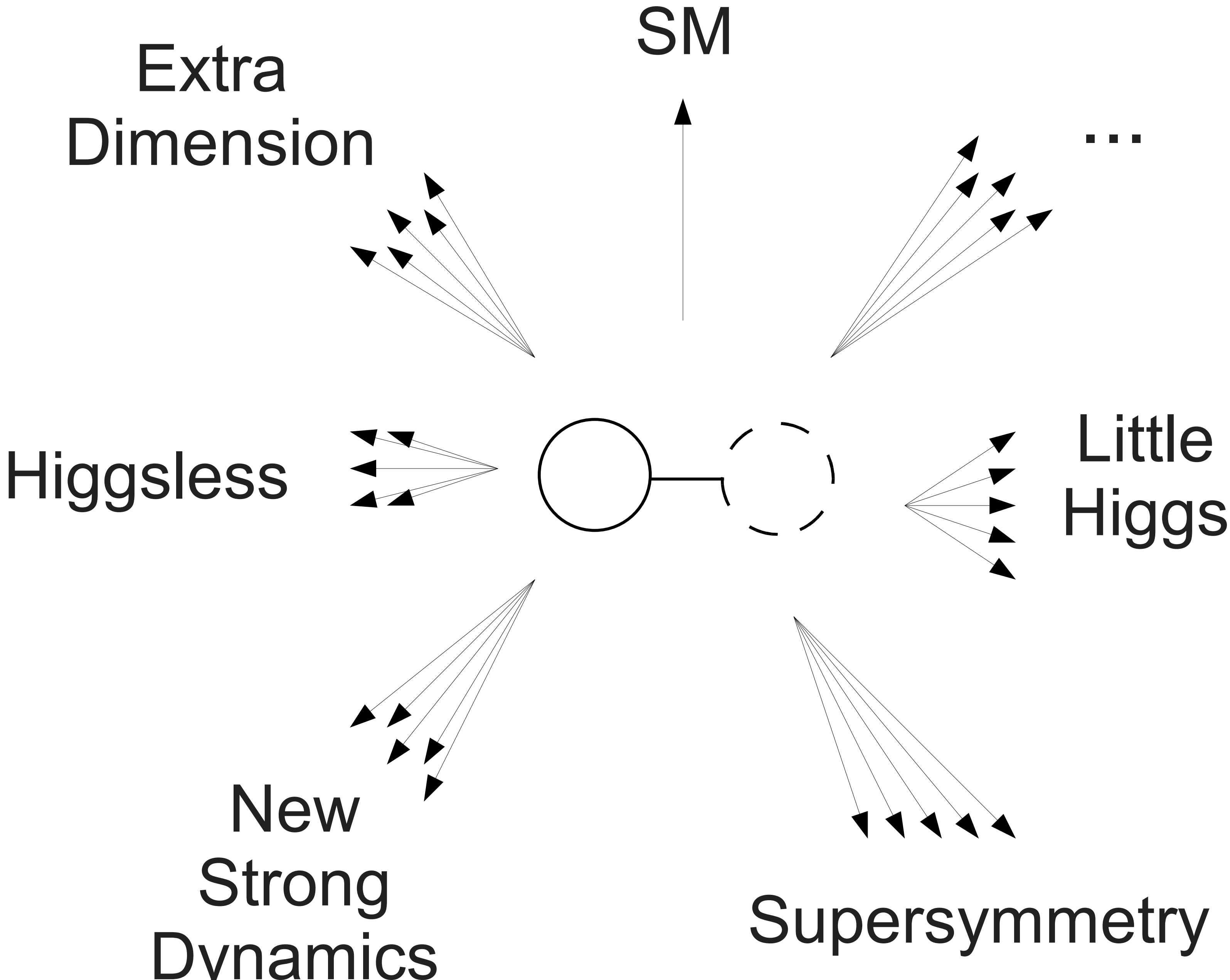
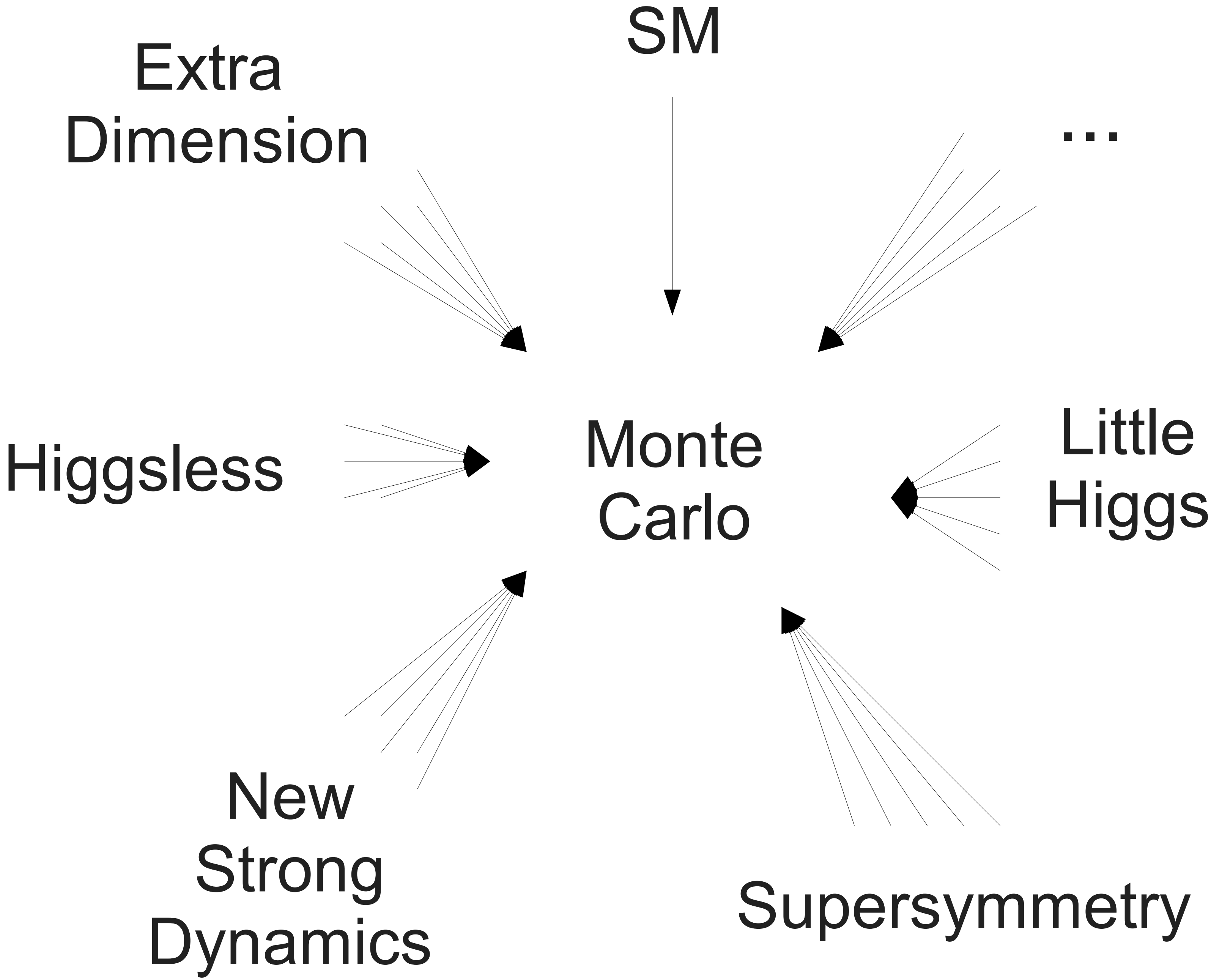
Alexander Belyaev
Southampton

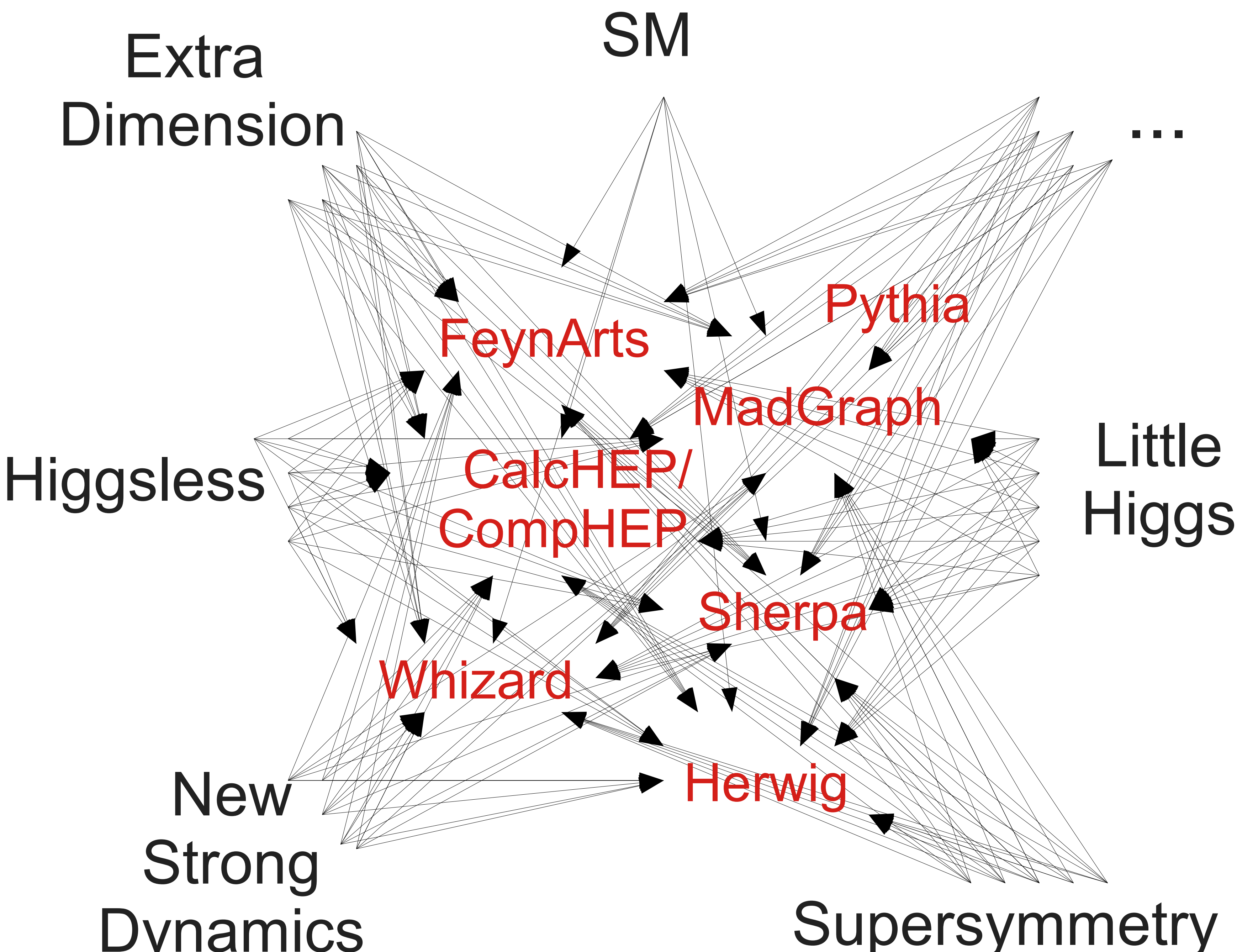

$SU(2)_W$
Σ
$U(1)_Y$

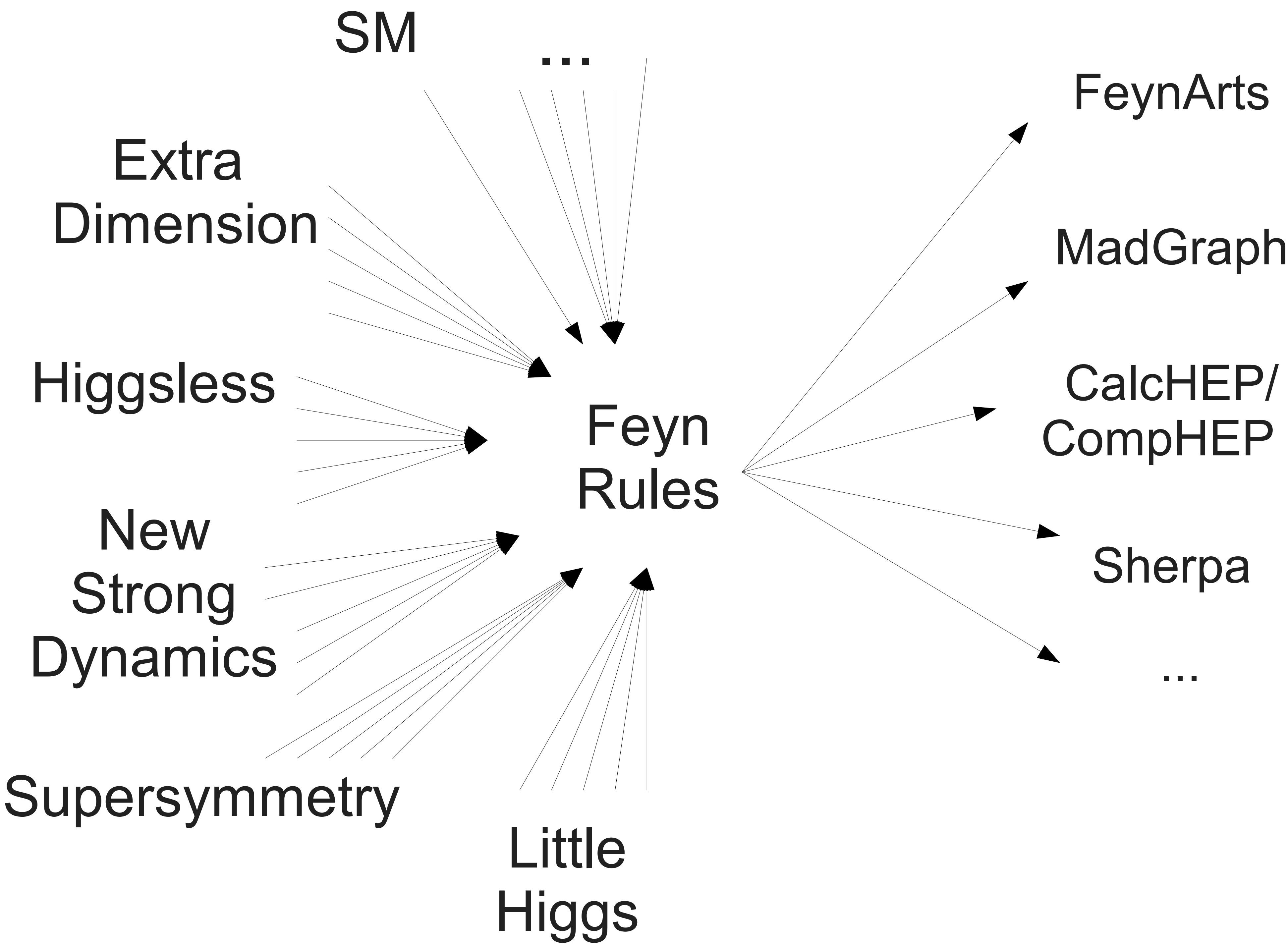

SM
Extra
Dimension
...
Higgsless
Little
Higgs
New
Strong
Dynamics
Supersymmetry

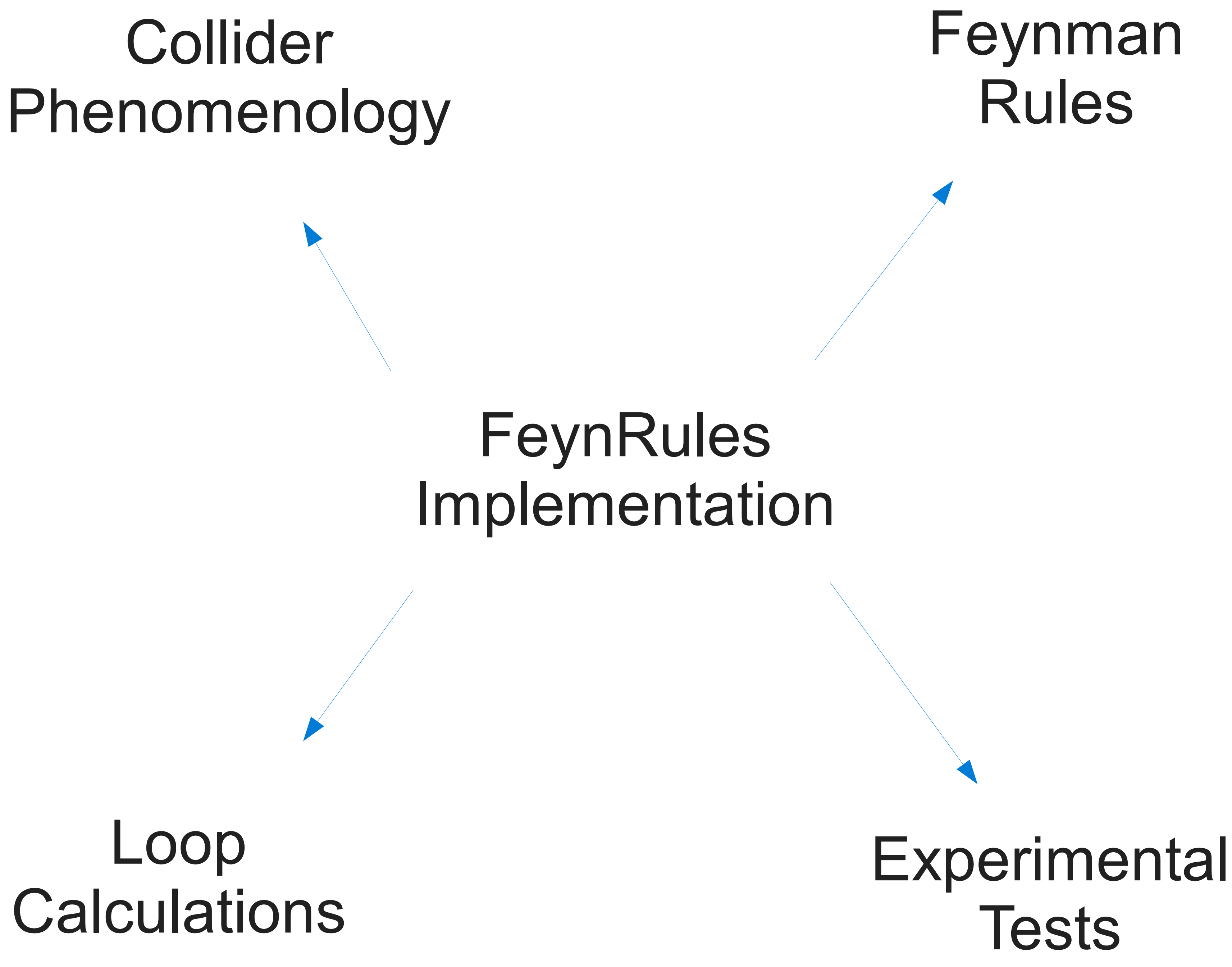

SM
Extra Dimension
...
Higgsless
Monte Carlo
Little Higgs
New Strong Dynamics
Supersymmetry

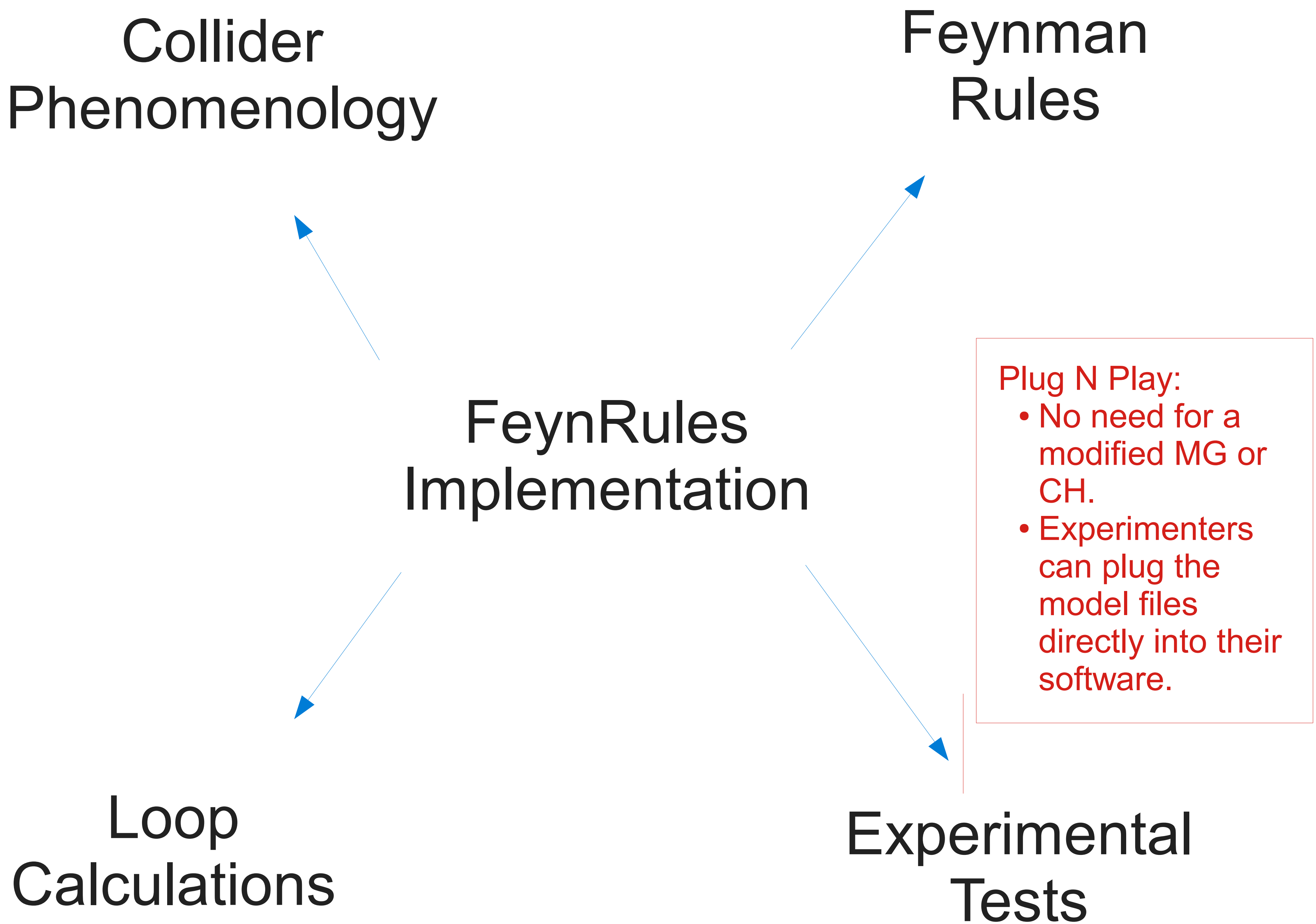

SM
Extra
Dimension
...
Higgsless
Little
Higgs
New
Strong
Dynamics
Supersymmetry

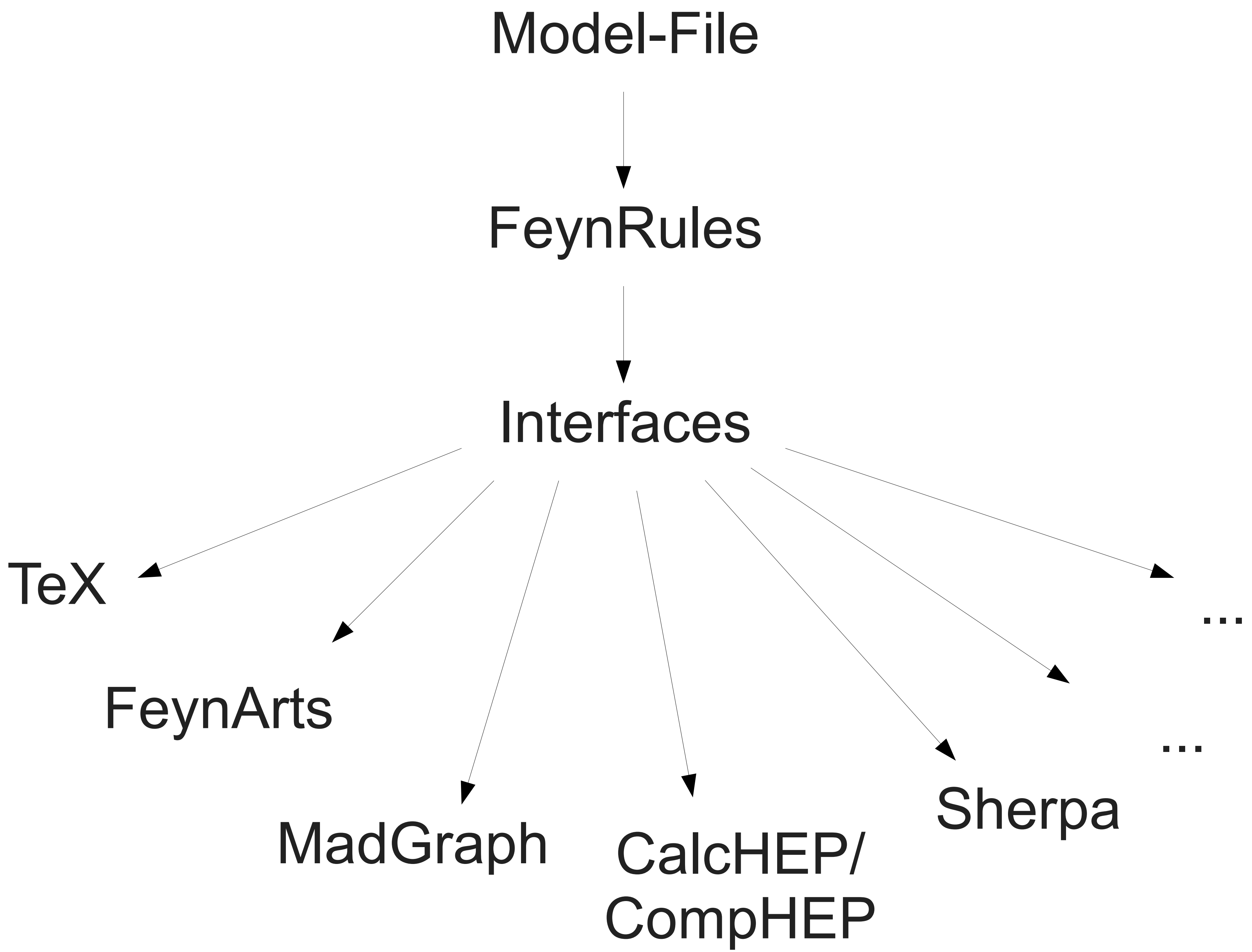

SM
Extra Dimension
...
Higgsless
Monte Carlo
Little Higgs
New Strong Dynamics
Supersymmetry


Extra Dimension
SM
...
FeynArts
Pythia
MadGraph
Higgsless
CalcHEP/ CompHEP
Little Higgs
Sherpa
Whizard
Herwig
New Strong Dynamics
Supersymmetry


SM
...
Extra Dimension
Higgsless
New Strong Dynamics
Supersymmetry
Little Higgs
Feyn Rules
FeynArts
MadGraph
CalcHEP/ CompHEP
Sherpa
...


Collider Phenomenology
Feynman Rules
FeynRules Implementation
Loop Calculations
Experimental Tests


Collider Phenomenology
Feynman Rules
FeynRules Implementation
Plug N Play:
• No need for a modified MG or CH.
• Experimenters can plug the model files directly into their software.
Loop Calculations
Experimental Tests


Model-File
FeynRules
Interfaces
TeX
FeynArts
MadGraph
CalcHEP/
CompHEP
Sherpa
...
...

Model File

Model File

- Model Information
- Gauge Symmetries
- Parameters
- Fields
- Lagrangian

Model File

- Model Information

  M$ModelName = "my new model";

  M$Information = { options };

- Gauge Symmetries
- Parameters
- Fields
- Lagrangian

Model File

- Model Information

```
M$ModelName = "my new model";
M$Information = { options };
```

- Gauge Symmetries
- Parameters
- Fields
- Lagrangian

Options include:
- Authors
- Emails
- Institutions
- References
- Date

Model File

- Model Information
- Gauge Symmetries

```
M$GaugeGroups = {
    gaugegroup1 == { options }     ,
    gaugegroup2 == { options }     ,
    ...                            };
```

- Parameters
- Fields
- Lagrangian

Model File

- Model Information
- Gauge Symmetries

```
M$GaugeGroups = {
    gaugegroup1 == { options }          ,
    gaugegroup2 == { options }          ,
    ...                                 };
```

Options include:
- Abelian
- Boson
- Coupling
- ...

- Parameters
- Fields
- Lagrangian

Model File

- Model Information
- Gauge Symmetries
- **Parameters**

```
M$Parameters = {
    parameter1 == { options }        ,
    parameter2 == { options }        ,
    ...                              };
```

- Fields
- Lagrangian

Model File

- Model Information
- Gauge Symmetries
- **Parameters**

```
M$Parameters = {
    parameter1 == { options }                ,
    parameter2 == { options }                ,
    ...                                      };
```

Options include:
- Type
- Value
- MC Name
- ...

- Fields
- Lagrangian

Model File

- Model Information
- Gauge Symmetries
- Parameters
- **Fields**

```
M$ClassesDescription = {
    field1 == { options }        ,
    field2 == { options }        ,
    ...                          };
```

- Lagrangian

Model File

- Model Information
- Gauge Symmetries
- Parameters
- **Fields**

```
M$ClassesDescription = {
    field1 == { options }      ,
    field2 == { options }      ,
    ...                        };
```

Options include:
- Indices
- Definitions
- Masses
- PDG Codes
- ...

- Lagrangian

Model File

- Model Information
- Gauge Symmetries
- Parameters
- **Fields**

```
M$ClassesDescription = {
    field1 == { options }                              ,
    field2 == { options }                              ,
    ...                                                };
```

- Lagrangian

Can include:
- Gauge eigenstates
- Mass eigenstates

Model File

- Model Information
- Gauge Symmetries
- Parameters
- Fields
- **Lagrangian**

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

Model File

- Model Information
- Gauge Symmetries
- Parameters
- Fields
- Lagrangian

FR symbols:
- FS[...]
- Ga[...]
- del[...]
- ProjP[...]
- ...

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

Model File

- Model Information
- Gauge Symmetries
- Parameters
- Fields
- **Lagrangian**

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

The last line is short for:

+ gs Ga[mu, s, r] T[a, i, j] ubar[s, l] . u[r, j] G[mu, a]
+ gs Ga[mu, s, r] T[a, i, j] cbar[s, l] . c[r, j] G[mu, a]
+ gs Ga[mu, s, r] T[a, i, j] tbar[s, l] . t[r, j] G[mu, a]
+ • • •

Model File

- A lot more details can be found in the manual:

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

Running FeynRules

Running FeynRules

- Load FeynRules
- Load Model
- Feynman Rules
- Translate

Running FeynRules

- Load FeynRules

```
$FeynRulesPath= {path to FeynRules} ;
SetDirectory[ $FeynRulesPath ];
<<FeynRules`
```

- Load Model
- Feynman Rules
- Translate

Running FeynRules

- Load FeynRules
- **Load Model**

```
SetDirectory[ {path to Model} ];
LoadModel[ {file1} , {file2} , ... ];
```

- Feynman Rules
- Translate

Running FeynRules

- Load FeynRules
- Load Model
- **Feynman Rules**

  FeynmanRules[L1 , ... , options];
- Translate

Options include:
- FlavorExpand
- MaxCanonicalDimension
- MaxParticles
- SelectParticles
- ...

Running FeynRules

- Load FeynRules
- Load Model
- Feynman Rules
- Translate

```
WriteFeynArtsOutput[ L1 , L2 , ... , options ];
WriteCHOutput[ L1 , L2 , ... , options ];
WriteMGOutput[ L1 , L2 , ... , options ];
WriteSherpaOutput[ L1 , L2 , ... , options ];
```

Tutorial

- Tutorial later today includes:
  - Extending the SM in FeynRules.
  - Obtaining Feynman rules in FeynRules.
  - Translating the model to MadGraph & CalcHEP.

Validation

Version 1.2
Currently Available

SM validation

31 2→2 processes

Process	CalcHEP Stock	CalcHEP Feynman	CalcHEP Unitary	CompHEP Feynman	MadGraph Stock	MadGraph
gg->gg	116 490.	116 490.	116 490.	116 490.	116 600.	116 510.
$u\bar{u}$->gg	199.95	199.95	199.95	199.94	199.95	200.12
$t\bar{t}$->gg	64.595	64.595	64.595	64.592	64.549	64.652
$e^+e^-\to\mu^+\mu^-$	0.37195	0.37195	0.37195	0.37194	0.3722	0.37187
$e^+e^-\to e^+e^-$	734.15	734.15	734.15	734.16	734.05	734.68
$e^+e^-\to\nu_e\bar{\nu}_e$	49.145	49.145	49.145	49.145	49.104	49.111
$t\bar{t}\to u\bar{u}$	16.018	16.018	16.018	16.018	16.05	16.028
$u\bar{u}\to s\bar{s}$	9.6103	9.6102	9.6103	9.6097	9.6146	9.6284
$u\bar{d}\to c\bar{s}$	0.23864	0.23864	0.23864	0.23864	0.23866	0.23873
$u\bar{s}\to c\bar{d}$	0.018947	0.018947	0.018947	0.018947	0.018956	0.01895
$t\bar{t}\to W^+W^-$	17.265	17.265	17.265	17.265	17.237	17.199
$t\bar{t}\to ZZ$	1.2686	1.2686	1.2686	1.2686	1.2722	1.2704
$t\bar{t}\to Z\gamma$	1.3119	1.3119	1.3119	1.312	1.3109	1.31
$t\bar{t}\to\gamma\gamma$	0.088486	0.088486	0.088486	0.088485	0.088385	0.088379
$u\bar{u}\to W^+W^-$	2.0465	2.0465	2.0465	2.0465	2.0438	2.0441
$u\bar{u}\to ZZ$	0.21123	0.21123	0.21123	0.21123	0.21172	0.21147
$u\bar{u}\to Z\gamma$	0.33812	0.33812	0.33812	0.33811	0.33789	0.33803
$u\bar{u}\to\gamma\gamma$	0.18322	0.18322	0.18322	0.18323	0.18321	0.18332
$\tau^+\tau^-\to W^+W^-$	6.1871	6.187	6.187	6.187	6.1842	6.1884
$\tau^+\tau^-\to ZZ$	0.34765	0.34765	0.34765	0.34765	0.34841	0.34884
$\tau^+\tau^-\to Z\gamma$	2.0057	2.0057	2.0057	2.0057	2.0032	2.0108
$\tau^+\tau^-\to\gamma\gamma$	2.7791	2.7791	2.7791	2.779	2.7799	2.7825
$u\bar{d}\to W^+W^+W^-$	0.016192	0.016192	–	0.016175	0.016115	0.016162
$u\bar{d}\to ZZW^+$	0.004209	0.0042089	–	0.0042012	0.0042088	0.0042131
$u\bar{d}\to\gamma ZW^+$	0.0085385	0.0085385	–	0.0085216	0.0085062	0.0085409
$u\bar{d}\to\gamma\gamma W^+$	0.0033698	0.0033698	–	0.00338	0.003365	0.0033772
ZZ->ZZ	1.9672	1.9672	1.9672	1.9672	1.9685	1.9666
$W^+W^-\to ZZ$	290.85	290.85	290.85	290.85	291.15	290.67
hh->hh	1.94	1.94	1.94	1.94	–	1.9399
hh->ZZ	65.801	65.801	65.801	65.801	65.947	65.927
$hh\to W^+W^-$	100.49	100.49	100.49	100.49	100.81	100.8

3-Site Model Validation

191 2→2 processes

Phys.Rev.D74:075011,2006
Chivukula, Coleppa, Di Chiara, Simmons, He, Kurachi, Tanabashi

Phys.Rev.D78:031701,2008
Belyaev, Chivukula, Christensen, He, Kuang, Qi, Simmons, Zhang

	Lanhep CalcHEP Feynman	Lanhep CalcHEP Unitary	FeynRules CalcHEP Feynman	FeynRules CalcHEP Unitary	FeynRules CompHEP Feynman	FeynRules CompHEP Unitary
uū->gg	170.5	170.5	170.5	170.5	170.49	-
u'ū->gg	0	0	0	0	0	-
u'ū'->gg	0.098763	0.098763	0.098763	0.098763	0.098761	-
tt̄->gg	55.906	55.906	55.906	55.906	55.903	-
t't̄->gg	0	0	0	0	0	-
t't̄'->gg	0.098774	0.098774	0.098774	0.098774	0.098771	-
uū->γγ	0.15862	0.15862	0.15862	0.15862	0.15862	-
u'ū->γγ	0	0	3.6538×10^{-37}	3.6538×10^{-37}	3.6539×10^{-37}	-
u'ū'->γγ	0.00027859	0.00027859	0.00027859	0.00027859	0.00027859	-
tt̄->γγ	0.075034	0.075034	0.075034	0.075034	0.075035	-
t't̄->γγ	0	0	1.6984×10^{-34}	1.6984×10^{-34}	1.6981×10^{-34}	-
t't̄'->γγ	0.0002815	0.0002815	0.0002815	0.0002815	0.0002815	-
uū->γZ	0.30828	0.30828	0.30828	0.30828	0.30829	-
uū->γZ'	0.00055876	0.00055876	0.00055876	0.00055876	0.0005587	-
u'ū->γZ	0.031561	0.031561	0.031561	0.031561	0.031563	-
u'ū'->γZ	0.0019654	0.0019654	0.0019654	0.0019654	0.0019654	-
u'ū->γZ'	0.035049	0.035049	0.035049	0.035049	0.035053	-
u'ū'->γZ'	0.014649	0.014649	0.014649	0.014649	0.014649	-
tt̄->γZ	1.1233	1.1233	1.1233	1.1233	1.1233	-
tt̄->γZ'	0.00016576	0.00016576	0.00016576	0.00016576	0.00016576	-
t't̄->γZ	0.033204	0.033204	0.033204	0.033204	0.033204	-
t't̄'->γZ	0.0049275	0.0049275	0.0049275	0.0049275	0.0049276	-
t't̄->γZ'	0.042476	0.042476	0.042476	0.042476	0.042473	-
t't̄'->γZ'	0.012657	0.012657	0.012657	0.012657	0.012657	-
uū->ZZ	0.19694	0.19694	0.19694	0.19694	0.19694	-
uū->ZZ'	0.00017633	0.00017633	0.00017633	0.00017633	0.00017633	-
u'ū'->ZZ	0.65643	0.65643	0.65643	0.65643	0.65643	-
uū->Z'Z'	0.000017411	0.000017411	0.000017411	0.000017411	0.000017411	-
u'ū'->ZZ'	1.429	1.429	1.429	1.429	1.429	-
u'ū->Z'Z'	5.7578	5.7578	5.7577	5.7577	5.7576	-
u'ū'->Z'Z'	0.9318	0.9318	0.9318	0.9318	0.9318	-
tt̄->ZZ	3.722	3.722	3.722	3.722	3.722	-
tt̄->ZZ'	0.0030041	0.0030041	0.0030041	0.0030041	0.0030041	-
t't̄->ZZ	7.1013	7.1013	7.1013	7.1013	7.1013	-
t't̄'->ZZ	1.5706	1.5706	1.5706	1.5706	1.5706	-
t't̄->ZZ'	18.994	18.994	18.994	18.994	18.995	-
tt̄->Z'Z'	0.00081748	0.00081748	0.00081748	0.00081748	0.00081747	-
t't̄'->ZZ'	0.31826	0.31826	0.31826	0.31826	0.31826	-
t't̄'->Z'Z'	1.887	1.887	1.887	1.887	1.887	-
ud̄->γW⁺	0.40404	0.40404	0.40404	0.40404	0.40414	-
ud̄->γW⁺'	0	0	3.5597×10^{-34}	3.6326×10^{-34}	3.5599×10^{-34}	-
u'd̄->γW⁺	0.013331	0.013331	0.013331	0.013331	0.013333	-
u'd̄'->γW⁺	0.00058105	0.00058105	0.00058105	0.00058105	0.00058105	-
u'd̄->γW⁺'	0.015262	0.015262	0.015262	0.015262	0.015262	-
u'd̄'->γW⁺'	0.0038294	0.0038294	0.0038294	0.0038294	0.0038295	-
tb̄->γW⁺	0.48358	0.48358	0.48358	0.48358	0.48358	-
tb̄->γW⁺'	2.661×10^{-6}	2.661×10^{-6}	2.661×10^{-6}	2.661×10^{-6}	2.661×10^{-6}	-
t'b̄->γW⁺	0.011891	0.011891	0.011891	0.011891	0.011891	-
t'b̄'->γW⁺	0.00091791	0.00091791	0.00091791	0.00091791	0.00091792	-
t'b̄->γW⁺'	0.015651	0.015651	0.015651	0.015651	0.015652	-
t'b̄'->γW⁺'	0.0033961	0.0033961	0.0033961	0.0033961	0.0033961	-
ud̄->ZW⁺	1.1175	1.1175	1.1175	1.1175	1.1175	-
ud̄->ZW⁺'	0.093081	0.093081	0.093081	0.093081	0.093081	-
ud̄->Z'W⁺	0.091217	0.091217	0.091217	0.091217	0.091217	-
u'd̄'->ZW⁺	2.0768	2.0768	2.0768	2.0768	2.0769	-
u'd̄'->Z'W⁺	2.8699	2.8699	2.8699	2.8699	2.8699	-
u'd̄'->ZW⁺'	2.9439	2.9439	2.9439	2.9439	2.9439	-
u'd̄'->Z'W⁺'	2.6562	2.6562	2.6562	2.6562	2.6562	-
tb̄->ZW⁺	3.2078	3.2078	3.2078	3.2078	3.2076	-
tb̄->ZW⁺'	1.5603	1.5603	1.5603	1.5603	1.5604	-
t'b̄'->ZW⁺	3.1463	3.1463	3.1463	3.1463	3.1463	-
t'b̄'->Z'W⁺	2.0864	2.0864	2.0864	2.0864	2.0864	-
t'b̄'->ZW⁺'	2.1612	2.1612	2.1612	2.1612	2.1612	-
t'b̄'->Z'W⁺'	4.0253	4.0253	4.0253	4.0253	4.0253	-
uū->W⁺W⁻	1.6964	1.6964	1.6964	1.6964	1.6964	-
uū->W⁺W⁻'	0.048112	0.048112	0.048112	0.048112	0.048112	-
u'ū'->W⁺W⁻	2.2967	2.2967	2.2967	2.2967	2.2967	-
u'ū->W⁺W⁻'	10.53	10.53	10.53	10.53	10.53	-
uū->W⁺'W⁻'	0.026073	0.026073	0.026073	0.026073	0.026073	-
u'ū'->W⁺W⁻'	2.8898	2.8898	2.8898	2.8898	2.8898	-
u'ū->W⁺'W⁻'	11.989	11.989	11.989	11.989	11.989	-
u'ū'->W⁺'W⁻'	3.2639	3.2639	3.2639	3.2639	3.2639	-
tt̄->W⁺W⁻	28.473	28.473	28.473	28.473	28.473	-
t't̄->W⁺W⁻	15.349	15.349	15.349	15.349	15.348	-
t't̄'->W⁺W⁻	3.2841	3.2841	3.2841	3.2841	3.2841	-
t't̄->W⁺W⁻'	17.737	17.737	17.737	17.737	17.737	-
tt̄->W⁺'W⁻'	0.043117	0.043117	0.043117	0.043117	0.043117	-
t't̄'->W⁺W⁻'	1.9339	1.9339	1.9339	1.9339	1.9339	-
t't̄->W⁺'W⁻'	17.947	17.947	17.947	17.947	17.947	-
t't̄'->W⁺'W⁻'	4.4655	4.4655	4.4655	4.4655	4.4655	-
eē->eē	736.83	736.83	736.83	736.83	736.81	-
eē->e'ē	0.093127	0.093127	0.093127	0.093127	0.093127	-
e'ē->e'ē	745.94	745.94	745.94	745.94	746.04	-
e'ē->e'ē'	0.99477	0.99477	0.99477	0.99477	0.99478	-
e'ē'->e'ē'	1366.2	1366.2	1366.2	1366.2	1366.2	-
eē->μμ̄	0.32623	0.32623	0.32623	0.32623	0.32623	-
eē->μ'μ̄	2.9705×10^{-6}	2.9705×10^{-6}	2.9705×10^{-6}	2.9705×10^{-6}	2.9705×10^{-6}	-
e'ē->μ'μ̄	0.78676	0.78676	0.78676	0.78676	0.78676	-
eē->μ'μ̄'	0.00048778	0.00048778	0.00048778	0.00048778	0.00048779	-
e'ē'->μμ̄	0.0015054	0.0015054	0.0015054	0.0015054	0.0015054	-
e'ē->μ'μ̄'	0.075312	0.075312	0.075312	0.075312	0.075312	-
e'ē'->μ'μ̄	0.16051	0.16051	0.16051	0.16051	0.16051	-
e'ē'->μ'μ̄'	0.22706	0.22706	0.22706	0.22706	0.22707	-
eē->ττ̄	0.32623	0.32623	0.32623	0.32623	0.32623	-
eē->τ'τ̄	2.9707×10^{-6}	2.9707×10^{-6}	2.9707×10^{-6}	2.9707×10^{-6}	2.9708×10^{-6}	-
e'ē->τ'τ̄	0.78675	0.78675	0.78675	0.78675	0.78676	-
eē->τ'τ̄'	0.00048778	0.00048778	0.00048778	0.00048778	0.00048779	-
e'ē'->ττ̄	0.0015069	0.0015069	0.0015069	0.0015069	0.0015069	-
e'ē->τ'τ̄'	0.075311	0.075311	0.075311	0.075311	0.075311	-
e'ē'->τ'τ̄	0.16051	0.16051	0.16051	0.16051	0.16051	-
e'ē'->τ'τ̄'	0.22706	0.22706	0.22706	0.22706	0.22707	-
eē->uū	0.53039	0.53039	0.53039	0.53039	0.53039	-
eē->u'ū	8.9114×10^{-6}	8.9114×10^{-6}	8.9114×10^{-6}	8.9114×10^{-6}	8.9115×10^{-6}	-
e'ē->u'ū	2.3603	2.3603	2.3603	2.3603	2.3603	-
eē->u'ū'	0.00063592	0.00063592	0.00063592	0.00063592	0.00063593	-
e'ē'->uū	0.0024538	0.0024538	0.0024538	0.0024538	0.0024538	-
e'ē->u'ū'	0.22594	0.22594	0.22594	0.22594	0.22594	-
e'ē'->u'ū	0.48152	0.48152	0.48152	0.48152	0.48152	-
e'ē'->u'ū'	0.65627	0.65627	0.65627	0.65627	0.65628	-
eē->tt̄	0.44504	0.44504	0.44504	0.44504	0.44504	-
eē->t't̄	0.000016904	0.000016904	0.000016904	0.000016904	0.000016904	-
e'ē->t't̄	2.2672	2.2672	2.2672	2.2672	2.2672	-
eē->t't̄'	0.00061549	0.00061549	0.00061549	0.00061549	0.0006155	-
e'ē'->tt̄	0.047158	0.047158	0.047158	0.047158	0.047158	-
e'ē->t't̄'	0.19818	0.19818	0.19818	0.19818	0.19818	-
e'ē'->t't̄	0.47047	0.47047	0.47047	0.47047	0.47048	-
e'ē'->t't̄'	0.61743	0.61743	0.61743	0.61743	0.61743	-
e'$\bar\nu_e$->e'$\overline{\nu_e'}$	0.53737	0.53737	0.53737	0.53737	0.53737	-
e'$\overline{\nu_e'}$->e'$\bar\nu_e$	1.1455	1.1455	1.1455	1.1455	1.1455	-
e'$\overline{\nu_e'}$->e'$\overline{\nu_e'}$	179.49	179.49	179.49	179.49	179.48	-
e$\bar\nu_e$->μ$\bar\nu_\mu$	0.36221	0.36221	0.36221	0.36221	0.36221	-
e$\bar\nu_e$->μ'$\bar\nu_\mu$	0.000011865	0.000011865	0.000011865	0.000011865	0.000011865	-
e'$\bar\nu_e$->μ'$\bar\nu_\mu$	3.147	3.147	3.147	3.147	3.147	-
e$\bar\nu_e$->μ'$\overline{\nu_\mu'}$	0.0005618	0.0005618	0.0005618	0.0005618	0.00056181	-
e'$\overline{\nu_e'}$->μ$\bar\nu_\mu$	0.0017338	0.0017338	0.0017338	0.0017338	0.0017338	-
e'$\bar\nu_e$->μ'$\overline{\nu_\mu'}$	0.30125	0.30125	0.30125	0.30125	0.30125	-
e'$\overline{\nu_e'}$->μ'$\bar\nu_\mu$	0.64203	0.64203	0.64203	0.64203	0.64203	-
e'$\overline{\nu_e'}$->μ'$\overline{\nu_\mu'}$	0.85872	0.85872	0.85872	0.85872	0.85872	-
e$\bar\nu_e$->τ$\bar\nu_\tau$	0.36221	0.36221	0.36221	0.36221	0.36221	-
e$\bar\nu_e$->τ'$\bar\nu_\tau$	0.000011865	0.000011865	0.000011865	0.000011865	0.000011865	-
e'$\bar\nu_e$->τ'$\bar\nu_\tau$	3.147	3.147	3.147	3.147	3.147	-
e$\bar\nu_e$->τ'$\overline{\nu_\tau'}$	0.0005618	0.0005618	0.0005618	0.0005618	0.00056181	-
e'$\overline{\nu_e'}$->τ$\bar\nu_\tau$	0.0017368	0.0017368	0.0017368	0.0017368	0.0017368	-
e'$\bar\nu_e$->τ'$\overline{\nu_\tau'}$	0.30125	0.30125	0.30125	0.30125	0.30125	-
e'$\overline{\nu_e'}$->τ'$\bar\nu_\tau$	0.64202	0.64202	0.64202	0.64202	0.64203	-
e'$\overline{\nu_e'}$->τ'$\overline{\nu_\tau'}$	0.85871	0.85871	0.85871	0.85871	0.85872	-
e$\bar\nu_e$->dū	1.0866	1.0866	1.0866	1.0866	1.0866	-
e$\bar\nu_e$->d'ū	0.000035595	0.000035595	0.000035595	0.000035595	0.000035596	-
e'$\bar\nu_e$->d'ū	9.4411	9.4411	9.4411	9.4411	9.4411	-
e$\bar\nu_e$->d'ū'	0.0016854	0.0016854	0.0016854	0.0016854	0.0016854	-
e'$\overline{\nu_e'}$->dū	0.0052014	0.0052014	0.0052014	0.0052014	0.0052015	-
e'$\bar\nu_e$->d'ū'	0.90374	0.90374	0.90374	0.90374	0.90375	-
e'$\overline{\nu_e'}$->d'ū	1.9261	1.9261	1.9261	1.9261	1.9261	-
e'$\overline{\nu_e'}$->d'ū'	2.5761	2.5761	2.5761	2.5761	2.5762	-
e$\bar\nu_e$->bt̄	0.95043	0.95043	0.95043	0.95043	0.95042	-
e$\bar\nu_e$->b't̄	0.00006507	0.00006507	0.00006507	0.00006507	0.00006507	-
e'$\bar\nu_e$->b't̄	9.4972	9.4972	9.4972	9.4972	9.4973	-
e$\bar\nu_e$->b't̄'	0.0016343	0.0016343	0.0016343	0.0016343	0.0016343	-
e'$\overline{\nu_e'}$->bt̄	0.091549	0.091549	0.091549	0.091549	0.09155	-
e'$\bar\nu_e$->b't̄'	0.8467	0.8467	0.8467	0.8467	0.84671	-
e'$\overline{\nu_e'}$->b't̄	1.9708	1.9708	1.9708	1.9708	1.9708	-
e'$\overline{\nu_e'}$->b't̄'	2.4975	2.4975	2.4975	2.4975	2.4975	-
gg->gg	114310.	114310.	114310.	114310.	114310.	-
ZZ->ZZ	0	0	0	0	0	-
ZZ->ZZ'	0	0	0	0	0	-
ZZ->Z'Z'	0	0	0	0	0	-
ZZ'->ZZ'	0	0	0	0	0	-
ZZ'->Z'Z'	0	0	0	0	0	-
Z'Z'->Z'Z'	0	0	0	0	0	-
W⁺W⁻->γγ	20.343	20.343	20.343	20.343	20.343	-
W⁺'W⁻'->γγ	1.0446	1.0446	1.0446	1.0446	1.0446	-
W⁺W⁻->γZ	164.95	164.95	164.95	164.95	164.95	-
W⁺W⁻->γZ'	6.4818	6.4818	6.4818	6.4818	6.4816	-
W⁺W⁻'->γZ	8.329	8.329	8.329	8.329	8.3288	-
W⁺W⁻'->γZ'	38.273	38.273	38.273	38.273	38.273	-
W⁺'W⁻'->γZ	1.198	1.198	1.198	1.198	1.198	-
W⁺'W⁻'->γZ'	70.338	70.338	70.338	70.338	70.339	-
W⁺W⁻->ZZ	365.67	365.67	365.67	365.67	365.67	-
W⁺W⁻->ZZ'	27.087	27.087	27.087	27.087	27.089	-
W⁺W⁻'->ZZ	20.1	20.1	20.1	20.1	20.1	-
W⁺W⁻->Z'Z'	13.183	13.183	13.183	13.183	13.183	-
W⁺'W⁻'->ZZ	42.717	42.717	42.717	42.717	42.716	-
W⁺'W⁻'->ZZ'	33.195	33.195	33.195	33.195	33.195	-
W⁺W⁻'->Z'Z'	17.905	17.905	17.905	17.905	17.905	-
W⁺'W⁻'->Z'Z'	1943.	1943.	1943.	1943.	1943.	-
W⁺W⁻->W⁺W⁻	1408.6	1408.6	1408.6	1408.6	1408.6	-
W⁺W⁻->W⁺W⁻'	12.176	12.176	12.176	12.176	12.177	-
W⁺W⁻'->W⁺W⁻	18.05	18.05	18.05	18.05	18.05	-
W⁺W⁻->W⁺'W⁻'	11.245	11.245	11.245	11.245	11.245	-
W⁺W⁻'->W⁺W⁻'	1249.6	1249.6	1249.6	1249.6	1249.5	-
W⁺'W⁻'->W⁺W⁻	36.264	36.264	36.264	36.264	36.264	-
W⁺'W⁻'->W⁺W⁻'	23.265	23.265	23.265	23.265	23.266	-
W⁺W⁻'->W⁺'W⁻'	10.55	10.55	10.55	10.55	10.55	-
W⁺'W⁻'->W⁺'W⁻'	2721.9	2721.9	2721.9	2721.9	2721.9	-

3-Site Model Validation

191 2→2 subprocesses

	Lanhep CalcHEP Feynman	Lanhep CalcHEP Unitary	FeynRules CalcHEP Feynman	FeynRules CalcHEP Unitary	FeynRules CompHEP Feynman
$u\bar{u} \to gg$	170.5	170.5	170.5	170.5	170.49
$u'\bar{u} \to gg$	0	0	0	0	0
$t\bar{t} \to gg$	55.906	55.906	55.906	55.906	55.903
$t'\bar{t} \to gg$	0	0	0	0	0
$u\bar{u} \to \gamma\gamma$	0.15862	0.15862	0.15862	0.15862	0.15862
$u'\bar{u} \to \gamma\gamma$	0	0	3.6538×10^{-37}	3.6538×10^{-37}	3.6539×10^{-37}
$t\bar{t} \to \gamma Z'$	0.00016576	0.00016576	0.00016576	0.00016576	0.00016576
$t'\bar{t} \to \gamma Z$	0.033204	0.033204	0.033204	0.033204	0.033204
$t'\overline{t'} \to \gamma Z$	0.0049275	0.0049275	0.0049275	0.0049275	0.0049276
$t'\bar{t} \to \gamma Z'$	0.042476	0.042476	0.042476	0.042476	0.042473
$t'\overline{t'} \to \gamma Z'$	0.012657	0.012657	0.012657	0.012657	0.012657

Validation

Version 1.4
Available Soon

3-Site Model Validation

224 2→2 processes

Process	MG-FR	CH-FR	CH-Stock	Result
e1,E1>e1,E1	7.5297×10^{2}	7.5325×10^{2}	7.5276×10^{2}	OK: 0.0650726%
e1,E1>~e1,E1	9.2959×10^{-2}	9.3187×10^{-2}	9.3127×10^{-2}	OK: 0.244969%
~e1,E1>~e1,E1	7.4668×10^{2}	7.4643×10^{2}	7.4594×10^{2}	OK: 0.0991545%
~e1,E1>~e1,~E1	9.9398×10^{-1}	9.9571×10^{-1}	9.9506×10^{-1}	OK: 0.173896%
e1,E1>e2,E2	1.1508×10^{-3}	1.1495×10^{-3}	1.1488×10^{-3}	OK: 0.173943%
e1,E1>~e2,E2	2.9709×10^{-6}	2.9724×10^{-6}	2.9705×10^{-6}	OK: 0.0639418%
~e1,E1>~e2,E2	7.8648×10^{-1}	7.8727×10^{-1}	7.8676×10^{-1}	OK: 0.100397%
e1,E1>~e2,~E2	4.889×10^{-4}	4.8812×10^{-4}	4.878×10^{-4}	OK: 0.225248%
~e1,~E1>e2,E2	1.5044×10^{-3}	1.5064×10^{-3}	1.5054×10^{-3}	OK: 0.132855%
~e1,E1>~e2,~E2	7.531×10^{-2}	7.5364×10^{-2}	7.5315×10^{-2}	OK: 0.0716779%
~e1,~E1>~e2,E2	1.6019×10^{-1}	1.6061×10^{-1}	1.6051×10^{-1}	OK: 0.261845%
~e1,~E1>~e2,~E2	2.2723×10^{-1}	2.2722×10^{-1}	2.2707×10^{-1}	OK: 0.070438%
e1,E1>e3,E3	1.1494×10^{-3}	1.1495×10^{-3}	1.1488×10^{-3}	OK: 0.0609146%
e1,E1>~e3,E3	2.972×10^{-6}	2.9727×10^{-6}	2.9707×10^{-6}	OK: 0.0673015%
~e1,E1>~e3,E3	7.8513×10^{-1}	7.8727×10^{-1}	7.8675×10^{-1}	OK: 0.272195%
e1,E1>~e3,~E3	4.8854×10^{-4}	4.8812×10^{-4}	4.878×10^{-4}	OK: 0.151587%
~e1,~E1>e3,E3	1.5036×10^{-3}	1.5079×10^{-3}	1.5069×10^{-3}	OK: 0.285572%
~e1,E1>~e3,~E3	7.5366×10^{-2}	7.5363×10^{-2}	7.5314×10^{-2}	OK: 0.0690204%
~e1,~E1>~e3,E3	1.6051×10^{-1}	1.6061×10^{-1}	1.6051×10^{-1}	OK: 0.062282%
~e1,~E1>~e3,~E3	2.2698×10^{-1}	2.2722×10^{-1}	2.2707×10^{-1}	OK: 0.10568%
e1,E1>u1,U1	1.872×10^{-3}	1.8679×10^{-3}	1.8666×10^{-3}	OK: 0.288878%
e1,E1>~u1,U1	8.9133×10^{-6}	8.9172×10^{-6}	8.9114×10^{-6}	OK: 0.065064%
~e1,E1>~u1,U1	2.3601	2.3618	2.3603	OK: 0.0720049%
e1,E1>~u1,~U1	6.3623×10^{-4}	6.3636×10^{-4}	6.3595×10^{-4}	OK: 0.0644497%
~e1,~E1>u1,U1	2.4565×10^{-3}	2.4554×10^{-3}	2.4538×10^{-3}	OK: 0.109973%
~e1,E1>~u1,~U1	2.2601×10^{-1}	2.2609×10^{-1}	2.2594×10^{-1}	OK: 0.0663673%
~e1,~E1>~u1,U1	4.8124×10^{-1}	4.8183×10^{-1}	4.8152×10^{-1}	OK: 0.122525%
~e1,~E1>~u1,~U1	6.5637×10^{-1}	6.5672×10^{-1}	6.563×10^{-1}	OK: 0.0639747%
e1,E1>u3,U3	1.8471×10^{-3}	1.8498×10^{-3}	1.8486×10^{-3}	OK: 0.146068%
e1,E1>~u3,U3	1.6911×10^{-5}	1.6915×10^{-5}	1.6904×10^{-5}	OK: 0.0650522%
~e1,E1>~u3,U3	2.2679	2.2687	2.2672	OK: 0.066139%
e1,E1>~u3,~U3	6.1769×10^{-4}	6.1592×10^{-4}	6.1552×10^{-4}	OK: 0.351927%
~e1,~E1>u3,U3	4.7048×10^{-2}	4.7189×10^{-2}	4.7158×10^{-2}	OK: 0.299246%
~e1,E1>~u3,~U3	1.981×10^{-1}	1.9832×10^{-1}	1.9819×10^{-1}	OK: 0.110993%
~e1,~E1>~u3,U3	4.7045×10^{-1}	4.7078×10^{-1}	4.7048×10^{-1}	OK: 0.070121%

MSSM Validation

456 key 2→2 processes from hep-ph/0512260
used to compare Sherpa, Whizard and MadGraph
Benjamin Fuks

Process	MG-FR	MG-Stock	CH-FR	CH-Stock	Result
Z,a>mu+,mu-	3.5558×10^{-1}	3.5568×10^{-1}	3.5551×10^{-1}	3.5551×10^{-1}	OK: 0.0478072%
Z,a>e+,e-	3.5539×10^{-1}	3.5555×10^{-1}	3.5551×10^{-1}	3.5551×10^{-1}	OK: 0.0450108%
Z,a>tau+,tau-	3.5512×10^{-1}	3.5588×10^{-1}	3.5542×10^{-1}	3.5542×10^{-1}	OK: 0.213783%
Z,a>u,u~	5.385×10^{-1}	5.393×10^{-1}	5.3908×10^{-1}	5.3909×10^{-1}	OK: 0.148451%
Z,a>t,t~	2.	2.002	2.0023	2.0023	OK: 0.114934%
Z,a>d,d~	1.7388×10^{-1}	1.7391×10^{-1}	1.7393×10^{-1}	1.7394×10^{-1}	OK: 0.0345006%
Z,a>b,b~	1.7335×10^{-1}	1.7324×10^{-1}	1.7326×10^{-1}	1.7326×10^{-1}	OK: 0.0634756%
Z,a>W+,W-	2.3846×10^{2}	2.3684×10^{2}	2.3829×10^{2}	2.3829×10^{2}	OK: 0.681675%
Z,a>sl1-,sl1+	1.2075×10^{-2}	1.207×10^{-2}	1.2073×10^{-2}	1.2072×10^{-2}	OK: 0.0414164%
Z,a>sl2-,sl2+	1.7109×10^{-2}	1.7096×10^{-2}	1.7123×10^{-2}	1.7122×10^{-2}	OK: 0.157807%
Z,a>sl3-,sl3+	1.7098×10^{-2}	1.7111×10^{-2}	1.7123×10^{-2}	1.7122×10^{-2}	OK: 0.146109%
Z,a>sl4-,sl4+	1.883×10^{-2}	1.8826×10^{-2}	1.8829×10^{-2}	1.8829×10^{-2}	OK: 0.021245%
Z,a>sl5-,sl5+	1.8788×10^{-2}	1.8789×10^{-2}	1.8829×10^{-2}	1.8829×10^{-2}	OK: 0.217987%
Z,a>sl6-,sl6+	1.3431×10^{-2}	1.3435×10^{-2}	1.345×10^{-2}	1.345×10^{-2}	OK: 0.141364%
Z,a>sl1-,sl6+	6.2754×10^{-3}	6.2714×10^{-3}	6.2715×10^{-3}	6.2715×10^{-3}	OK: 0.0637613%
Z,a>su1,su1~	1.3139×10^{-6}	1.3113×10^{-6}	1.3117×10^{-6}	1.3104×10^{-6}	OK: 0.266738%
Z,a>su2,su2~	4.0727×10^{-3}	4.0721×10^{-3}	4.0734×10^{-3}	4.0734×10^{-3}	OK: 0.0319195%
Z,a>su3,su3~	4.0752×10^{-3}	4.0768×10^{-3}	4.0734×10^{-3}	4.0734×10^{-3}	OK: 0.0834335%
Z,a>su4,su4~	1.8383×10^{-2}	1.8375×10^{-2}	1.8384×10^{-2}	1.8384×10^{-2}	OK: 0.0489676%
Z,a>su5,su5~	1.8371×10^{-2}	1.8379×10^{-2}	1.8384×10^{-2}	1.8384×10^{-2}	OK: 0.0707387%
Z,a>su6,su6~	3.844×10^{-3}	3.843×10^{-3}	3.8422×10^{-3}	3.8423×10^{-3}	OK: 0.0468372%
Z,a>su1,su6~	3.2889×10^{-2}	3.2864×10^{-2}	3.2862×10^{-2}	3.2862×10^{-2}	OK: 0.082128%
Z,a>sd1,sd1~	6.2093×10^{-3}	6.2098×10^{-3}	6.2113×10^{-3}	6.2114×10^{-3}	OK: 0.0338145%
Z,a>sd2,sd2~	1.4741×10^{-5}	1.4737×10^{-5}	1.4742×10^{-5}	1.4741×10^{-5}	OK: 0.0339225%
Z,a>sd3,sd3~	2.5967×10^{-4}	2.5975×10^{-4}	2.5983×10^{-4}	2.5982×10^{-4}	OK: 0.0615977%
Z,a>sd4,sd4~	2.5982×10^{-4}	2.5983×10^{-4}	2.5983×10^{-4}	2.5982×10^{-4}	OK: 0.00384874%
Z,a>sd5,sd5~	6.4416×10^{-3}	6.4402×10^{-3}	6.4401×10^{-3}	6.4401×10^{-3}	OK: 0.0232889%
Z,a>sd6,sd6~	6.4391×10^{-3}	6.4427×10^{-3}	6.4401×10^{-3}	6.4401×10^{-3}	OK: 0.0558928%
Z,a>sd1,sd2~	1.2389×10^{-3}	1.2381×10^{-3}	1.2388×10^{-3}	1.2388×10^{-3}	OK: 0.0645943%
Z,a>H+,H-	1.124×10^{-2}	1.1255×10^{-2}	1.124×10^{-2}	1.124×10^{-2}	OK: 0.133363%

MSSM Validation

2708 2→3 processes (MG stock vs FR MG)
100 phase space points tested
Benjamin Fuks

Process	Result
e+e->sl5-,sv3~,h+	OK: 0.00231897%
e+e->sl2-,sv3~,h+	OK: 0.00206813%
e+e->sl5-,sv3~,h+	OK: 0.00231897%
e+e->sl4-,sv2~,h+	OK: 0.00212638%
e+e->sl1-,sv1~,h+	OK: 0.00131054%
e+e->sl6-,sv1~,h+	OK: 0.00449663%
e+e->sl5+,sv3,h-	OK: 0.00244297%
e+e->sl2+,sv3,h-	OK: 0.00210734%
e+e->sl5+,sv3,h-	OK: 0.00244297%
e+e->sl4+,sv2,h-	OK: 0.00212638%
e+e->sl1+,sv1,h-	OK: 0.00131054%
e+e->sl6+,sv1,h-	OK: 0.00449663%
e+e->su5,sd5~,h-	OK: 0.00211725%
e+e->su4,sd6~,h-	OK: 0.00211725%
e+e->su1,sd1~,h-	OK: 0.00116314%
e+e->su6,sd2~,h-	OK: 0.00123555%
e+e->su6,sd1~,h-	OK: 0.0012443%
e+e->su1,sd2~,h-	OK: 0.00122908%
e+e->su5~,sd5,h+	OK: 0.00211725%
e+e->su4~,sd6,h+	OK: 0.00211725%
e+e->su1~,sd1,h+	OK: 0.00116314%
e+e->su6~,sd2,h+	OK: 0.00123555%
e+e->su6~,sd1,h+	OK: 0.0012443%
e+e->su1~,sd2,h+	OK: 0.00122908%

MSSM validation

320 key decays

Benjamin Fuks

Process	MG-FR	MG-Stock	Result
h2>h1,h1	9.9641×10^{-3}	9.9641×10^{-3}	OK: 0.%
su1>n1,t	3.9006×10^{-1}	3.9006×10^{-1}	OK: 0.%
su1>n2,t	2.3748×10^{-1}	2.3748×10^{-1}	OK: 0.%
su1>x1+,b	1.3661	1.3661	OK: 0.%
su1>x2+,b	2.797×10^{-2}	2.797×10^{-2}	OK: 0.%
su2>n1,u	1.1373	1.1373	OK: 0.%
su2>n2,u	9.7615×10^{-3}	9.7615×10^{-3}	OK: 0.%
su2>n3,u	1.4285×10^{-3}	1.4285×10^{-3}	OK: 0.%
su2>n4,u	4.5165×10^{-3}	4.5165×10^{-3}	OK: 0.%
su3>n1,c	1.1373	1.1373	OK: 0.%
su3>n2,c	9.7615×10^{-3}	9.7615×10^{-3}	OK: 0.%
su3>n3,c	1.4285×10^{-3}	1.4285×10^{-3}	OK: 0.%
su3>n4,c	4.5165×10^{-3}	4.5165×10^{-3}	OK: 0.%
su4>n1,c	3.6437×10^{-2}	3.6437×10^{-2}	OK: 0.%
su4>n2,c	1.7475	1.7475	OK: 0.%
su4>n3,c	4.6278×10^{-3}	4.6278×10^{-3}	OK: 0.%
su4>n4,c	5.6681×10^{-2}	5.6681×10^{-2}	OK: 0.%
su4>x1+,s	3.5574	3.5574	OK: 0.%
su4>x2+,s	7.4507×10^{-2}	7.4507×10^{-2}	OK: 0.%
su5>n1,u	3.6437×10^{-2}	3.6437×10^{-2}	OK: 0.%
su5>n2,u	1.7475	1.7475	OK: 0.%
su5>n3,u	4.6278×10^{-3}	4.6278×10^{-3}	OK: 0.%
su5>n4,u	5.6681×10^{-2}	5.6681×10^{-2}	OK: 0.%
su5>x1+,d	3.5574	3.5574	OK: 0.%
su5>x2+,d	7.4507×10^{-2}	7.4507×10^{-2}	OK: 0.%
su6>n1,t	2.1885×10^{-1}	2.1885×10^{-1}	OK: 0.%
su6>n2,t	6.4001×10^{-1}	6.4001×10^{-1}	OK: 0.%
su6>n3,t	3.085×10^{-1}	3.085×10^{-1}	OK: 0.%
su6>n4,t	1.4251	1.4251	OK: 0.%
su6>x1+,b	1.6194	1.6194	OK: 0.%
su6>x2+,b	1.4909	1.4909	OK: 0.%
su6>su1,z	1.4002	1.4002	OK: 0.%
su6>su1,h1	2.7015×10^{-1}	2.7015×10^{-1}	OK: 0.%
su1~>n1,t~	3.9006×10^{-1}	3.9006×10^{-1}	OK: 0.%
su1~>n2,t~	2.3748×10^{-1}	2.3748×10^{-1}	OK: 0.%
su1~>x1-,b~	1.3661	1.3661	OK: 0.%
su1~>x2-,b~	2.797×10^{-2}	2.797×10^{-2}	OK: 0.%
su2~>n1,u~	1.1373	1.1373	OK: 0.%
su2~>n2,u~	9.7615×10^{-3}	9.7615×10^{-3}	OK: 0.%

MSSM validation

Benjamin Fuks

Several 2->2 processes calculated by hand and compared with FeynRules implementation in FeynArts/FormCalc.

MUED validation

Priscila de Aquino

118 2->2 processes

compared to Datta, Kong, Matchev implementation

JHEP 0601:038,2006, PRD72:096006,2005, ...

Process	MG-FR	CH-FR	CH-Stock	Result
e1R-,e1R+>d,d~	3.277×10^{-2}	3.2795×10^{-2}	3.2795×10^{-2}	OK: 0.0762602%
e1R-,e1R+>A,A	2.0803×10^{-1}	2.0788×10^{-1}	2.0788×10^{-1}	OK: 0.072131%
e1L-,e1L+>e-,e+	2.5×10^{-1}	2.4978×10^{-1}	2.4978×10^{-1}	OK: 0.0880387%
e1L-,n11>e-,n1	1.0519	1.0519	1.0519	OK: 0.%
B1,B1>d,d~	6.1392×10^{-3}	6.1347×10^{-3}	6.1347×10^{-3}	OK: 0.0733263%
Z1,Z1>W-,W+	2.8571×10^{1}	2.8573×10^{1}	2.8573×10^{1}	OK: 0.00699986%
W1+,W1->Z,Z	8.4226	8.4161	8.4161	OK: 0.0772031%
G1,B1>u,u~	3.6894×10^{-1}	3.7095×10^{-1}	3.7103×10^{-1}	OK: 0.564888%
Du1,Du1>u,u	9.1353	9.1361	9.1392	OK: 0.0426824%
Dd1,Dd1~>d,d~	7.9776	7.984	7.9871	OK: 0.119013%
Su1,Su1>u,u	7.153	7.1468	7.1495	OK: 0.0867145%
Sd1,Sd1>d,d	5.8596	5.8576	5.86	OK: 0.040964%
Su1,Su1~>u,u~	8.3667	8.3857	8.3888	OK: 0.263794%
Sd1,Sd1~>d,d~	9.1003	9.1	9.1032	OK: 0.0351587%
t1R-,t1R+>u,u~	1.1102×10^{-1}	1.1094×10^{-1}	1.1094×10^{-1}	OK: 0.0720851%
t1R-,t1R+>d,d~	3.2697×10^{-2}	3.2795×10^{-2}	3.2795×10^{-2}	OK: 0.299273%
t1R-,t1R+>tt-,tt+	2.5568×10^{-1}	2.5537×10^{-1}	2.5537×10^{-1}	OK: 0.121319%
t1R-,t1R+>A,A	2.0837×10^{-1}	2.0788×10^{-1}	2.0788×10^{-1}	OK: 0.235435%
t1R-,m1R->tt-,m-	6.58×10^{-1}	6.5818×10^{-1}	6.5818×10^{-1}	OK: 0.0273519%
Z1,Z1>W-,W+	2.8542×10^{1}	2.8573×10^{1}	2.8573×10^{1}	OK: 0.108553%
Sb1,Sb1~>b,b~	9.0986	9.1005	9.1037	OK: 0.0560369%
Z1,A>W+,W1-	2.0182×10^{2}	2.0162×10^{2}	2.0162×10^{2}	OK: 0.0991473%
Z,A>W1+,W1-	3.1895	3.1925	3.1925	OK: 0.0940144%
W1+,W1->W+,W-	8.6923	8.7236	1.3988×10^{5}	Discrepancy: 199.975%
W1+,W1->A,A	7.6591×10^{-1}	7.6562×10^{-1}	7.6563×10^{-1}	OK: 0.0378706%

FeynRules

- Much, much easier to implement new models in mc packages.
- Implement the vertices in a form similar to how you write the Lagrangian on paper.
- Interfaces for new models to:
  - TeX
  - FeynArts
  - CalcHEP/CompHEP
  - MadGraph
  - Sherpa (very soon)
  - ...
- Tested:
  - SM
  - 3-Site Model
  - MSSM
  - MUED
  - Further testing planned for the future.
- New features planned for the future.

CalcHEP 2.5

http://theory.sinp.msu.ru/~pukhov/calchep.html

CalcHEP 2.5

- Event Mixer
- Batch File
- Parallelization
- Process Library
- HTML Progress
- HTML Help Files

CalcHEP 2.5

- Event Mixer

  Combines CH event files and connects production and decays.

  Produces new event file in LSHA format.

  Contains Qnumbers, Widths, Brs, etc.

  Ready to be run through Pythia or analyzed directly.

- Batch File
- Parallelization
- Process Library
- HTML Progress
- HTML Help Files

CalcHEP 2.5

- Event Mixer
- Batch File

    Key phrases to specify details of run:

        Process : p,p->t,t~,h1

        Decay : h1->b,b~

        Composite : p=u,u~,d,d~,G

        ...

- Parallelization
- Process Library
- HTML Progress
- HTML Help Files

CalcHEP 2.5

- Event Mixer
- Batch File
- **Parallelization**

  Local Machine:

  Dual core: 2 cpus at once.

  Dual quad core: 8 cpus at once.

  PBS cluster:

  I have had as many as 100 cpus working at once!

  Depends on cluster and process involved.
- Process Library
- HTML Progress
- HTML Help Files

CalcHEP 2.5

- Event Mixer
- Batch File
- Parallelization
- **Process Library**

  Stores symbolic calculation and compilation.

  Next time, it is used from the library rather than redone.
- HTML Progress
- HTML Help Files

CalcHEP 2.5

- Event Mixer
- Batch File
- Parallelization
- Process Library
- HTML Progress

  Progress of batch is written to linked html files.

- HTML Help Files

CalcHEP 2.5

- Event Mixer
- Batch File
- Parallelization
- Process Library
- HTML Progress
- HTML Help Files

Help files are included in the html.

Tutorial

- Tutorial later today includes:
  - Importing FeynRules generated model file in CH.
  - Generating events in CalcHEP using the batch.

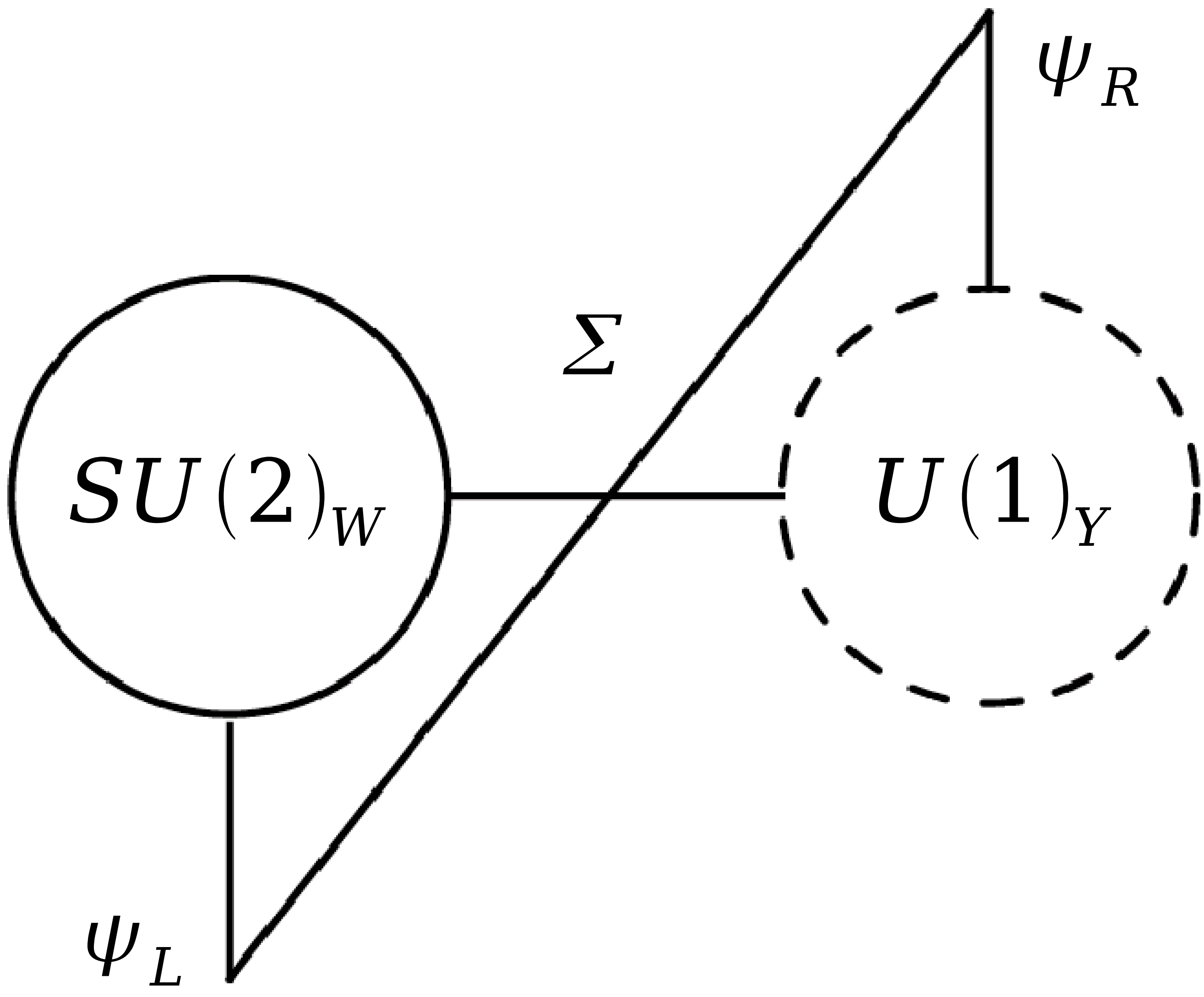
FeynRules

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

CalcHEP

http://theory.sinp.msu.ru/~pukhov/calchep.html

Appendix



ψ_R
Σ
$SU(2)_W$
$U(1)_Y$
ψ_L

Other validation

Celine Degrande

A one loop mixing in an effective non-linear sigma model was compared with a hand done calculation.